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Detecting changes in essential ecosystem and biodiversity properties- towards a Biosphere Atmosphere Change Index: BACI

<u>Deliverable 6.2:</u> Product comparison and validation report

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Abbreviations

BACI	Biosphere Atmosphere Change Index
ESA	European Space Agency
ESDC	Earth System Data Cube
GPP	Gross Primary Productivity
HYDE	History Database of the Global Environment
LE	Latent Energy
LST	Land Surface Temperature
LUE	Light Use Efficiency
MODIS	Moderate-resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NEE	Net Ecosystem Exchange
NUTS	Nomenclature des unités territoriales statistiques
PUE	Precipitation Use Efficiency
SH	Sensible Heat
TER	Terrestrial Ecosystem Respiration
WUE	Water Use Efficiency

1. Summary

Deliverable 6.2 presents the validation of the first generation BACIndex (WP5) and the BACI downstream products (WP4). We first conducted a descriptive analysis of the datasets, before we validated the BACI products following the BACI validation framework (Deliverable 6.1). Additional methods used here and not described in the validation framework report, were discussed and consolidated during the annual BACI progress and review meeting in November 2017. The framework enabled the validation of a large variety of extreme events in terms of spatial, temporal and thematic accuracy. In total, 120 events were validated; 80 events as a sampled subset of the *detected events* were used for evaluating the commission error. 40 *known extreme events* (from experts and literature) were used for assessing the omission error. The independent validation was supported by expert feedback provided by 15 experts from different countries in Europe and Africa. Regional expert feedback showed similar patterns compared to the results of the independent validation indicating the robustness of the validation results. Additionally, we compare long-term socio-economic changes with results of the BACIndex and reflect on challenges on how to use socio-economic data to validate change products of high temporal and spatial detail.

The key findings are:

- Clear seasonal patterns of detected extreme events following the major growing seasons and phenological active time periods were found.
- The highest correlation between the ESDC (Earth System Data Cube) input data for the detected extreme events was found for GPP (Gross Primary Productivity) and NEE (Net Ecosystem Exchange), followed by GPP and TER (Terrestrial Ecosystem Respiration). Other input variables show weaker correlations.

- Average accuracy scores were found in the spatial, temporal and thematic domain, with a significant part of the *detected extreme events* not being derived accurately.
- Regional expert feedback confirms the results for the *detected extreme events*
- Poor accuracy scores were found for *known extreme events* when compared to the *detected extreme events*. Most of the *known extreme events* were omitted by the BACIndex.
- Larger *detected extreme events* were more likely to have a higher accuracy in the thematic and temporal domain.
- Amongst *the known extreme* events floods and droughts indicated the best accuracy, showing improved precision with increasing temporal and spatial extent of extreme events. Storms and cold / heat waves were poorly detected.
- The sensitivity of the BACI index to uncover socio-economic anomalies seems low. *Detected extreme events* do not necessarily correspond with high socio-economic impacts. Major *known events*, such as heavy storms were not detected although they repeatedly had major repercussions on the socio-ecological system.
- The event based validation of the downstream products showed that a reasonable part of the *detected* and *known extreme events* co-occur with significant changes in the annual downstream products, but it is unclear if these events caused the significant change or other events.

In summary, the BACI validation framework was successfully implemented and allowed the validation of the BACIndex and the BACI downstream products. Based on the findings of the validation exercise we provide a list of key recommendations to improve the BACIndex and lead the way to a near real-time version. It should be noted that the assessed BACIndex is the first generation version with limited set of input data and methods. The results presented here should not be interpreted as an overall limit of the BACI framework, but rather an intermediate step to point at potentials and limitations that will need to be addressed in the next version using more and better quality input data respectively more advanced methods.

2. Introduction

2.1 Objectives

Deliverable 6.2 presents the product comparison and validation report. Following the BACI validation framework (Deliverable 6.1; Chapter 2.1), the BACIndex (WP5) and the BACI downstream products (WP4) are validated. The objectives of the validation exercise are:

1. Characterization of detected events for further assessment
2. Independent assessment of characterized events against reference data in terms of spatial and temporal quality
3. Identify recommendations for further internal improvement of the BACI products
4. Stimulate feedback and engagement with regional experts and potential users

The validation exercise is a crucial step in the communication of the BACI results to potential user communities. We will identify recommendations for further internal improvement of the BACI products and stimulate feedback and engagement with regional experts and potential users. Ultimately, the validation exercise aims to create international awareness and confidence in the BACI results and their adoption by a number of potential user communities (e.g. modellers).

2.2 BACI validation framework

The BACI validation framework applied here has been developed and presented in Deliverable 6.1. Based on lessons learnt from MS5 and MS12 a two-step validation framework was proposed to characterise and independently assess relevant regional events detected in the new downstream data products generated in WP4 and the generic BACIndex developed in WP5. A two-step approach is essential, since the BACI product as an “index” cannot be directly validated but should rather be first characterized (in terms of the types and causes of events), before it can be quantitatively compared to appropriate reference data reflecting the types and causes of regional events, and before it can be assessed by independent experts.

Key elements of the validation framework are summarized in Figure 1. A detailed description is provided Deliverable 6.1.

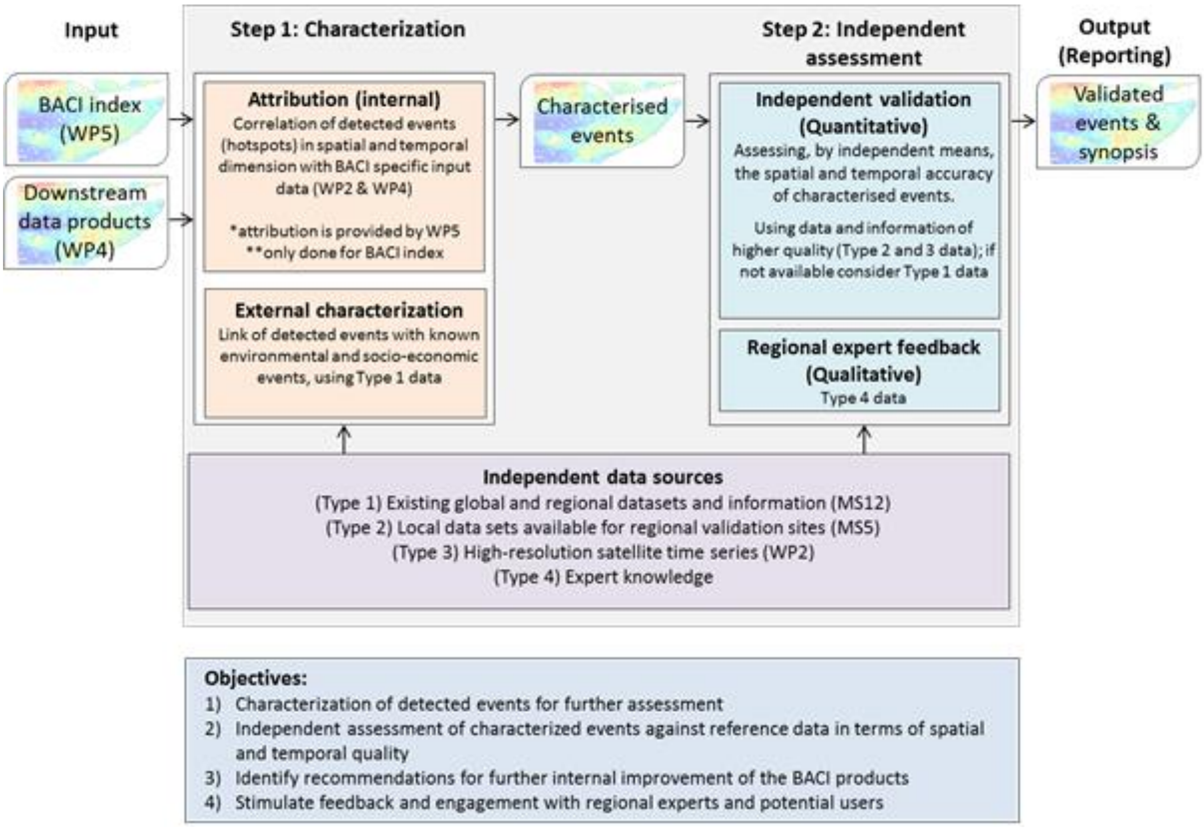

Figure 1: Validation framework for BACI products.

2.3 Document structure

Chapter 3 provides an overview of the validated BACI products, including the BACIndex (WP5) and downstream products (WP4). Methods used for the validation are described in Chapter 4. Validation results for the BACIndex and the downstream products are presented in Chapter 5 and Chapter 6, respectively. Chapter 7 gives a synthesis of the results and recommendations for further developments.

3. BACI products

Table 1 provides an overview of the BACI products that are validated, including the BACIndex and downstream products.

Table 1: Overview of the BACI products.

Product	Version / Deliverable	Spatial coverage	Spatial resolution	Temporal coverage	Temporal resolution
BACIndex	v1, 2017-09-19 (D5.3)	Europe & Africa	0.25 degree	2001 - 2011	8 days
Bowen Ratio	D4.2	Global	0.5 degree	2001 - 2014	Annual
Light Use Efficiency	D4.2	Global	0.5 degree	2001 - 2014	Annual
Water Use Efficiency	D4.2	Global	0.5 degree	2001 - 2014	Annual
Precipitation Use Efficiency	D4.2	Global	0.5 degree	2001 - 2014	Annual
Tree-ring widths	D4.3	Europe	0.5 degree	1901 - 2010	Annual

3.1 BACIndex

The BACIndex version 1 (v1, 2017-09-19) covering Europe and Africa was validated here (Table 1). Five biosphere variables spanning 11 years starting from 2001 to 2011 provided by the Earth System Data Cube (ESDC) were used as input data to detect extreme events:

- Gross Primary Productivity (GPP)
- Latent Energy (LE)
- Net Ecosystem Exchange (NEE)
- Sensible Heat (SH)
- Terrestrial Ecosystem Respiration (TER)

The BACIndex has a temporal resolution of 8 days and a spatial resolution of 0.25 degrees. The method used for calculating the BACIndex is described in Deliverable 5.3. The BACIndex defines four classes: (1) no data available (seas and deserts), (2) no change, (3) possible anomaly and (4) intense anomaly. Here, events classified as “intense anomaly” were validated. In total 9973 single extreme events were detected by the BACIndex.

3.2 Downstream products

The validated downstream products consist of two data types:

- Fluxnet derived ecosystem functional properties (Deliverable 4.2)
    - Bowen Ratio
    - Light Use Efficiency (LUE)
    - Water Use Efficiency (WUE)
    - Precipitation Use Efficiency (PUE)
- Tree-ring widths (D4.3)

The Fluxnet derived ecosystem functional properties are global products and have an annual temporal resolution. The spatial resolution is 0.5 degrees (Table 1) covering the time period of 2001 - 2011.
The Tree-ring widths were present for Europe from 1901 - 2010 for six different genus of trees based on a yearly temporal resolution and a spatial resolution of 0.5 degrees (Table 1).

4. Methods

4.1 Validation part 1 - BACIndex

4.1.1 Descriptive analysis

A descriptive analysis of the events detected by the BACIndex was conducted. Several statistics were calculated for each event, including area, centre longitude and latitude. We also calculated the z-scores (Peters et al. 2002) for each of the five input variables, comparing the BACIndex extreme event (pixel distribution) with the multi-year normal. The multi-year normal is defined as all pixels covering the detected area and time period (+/- 2 timestamps around the date of the extreme event) of the extreme event for all years (2001-2011). Excluded from this multi-year normal are (i) the year of the detected event itself, and (ii) all pixel of the remaining time period that were classified as “anomaly” within the BACIndex.

4.1.2 Sampling

The validation of the extreme events detected by the BACIndex was carried out for (i) a representative selection of the *detected events* and (ii) *known events* of the BACI focus regions. Validating the *detected events* will allow an estimation of the commission error, while the validation of the *known events* will allow an estimation of the omission error.

<u>*Detected extreme events*</u>: We selected 80 detected BACI extreme events, including the 20 largest events (area size) and 60 randomly selected events (Figure 2). The minimum mapping unit of the sampled events was 4 pixels. The location of the selected events is shown in Figure 3A.

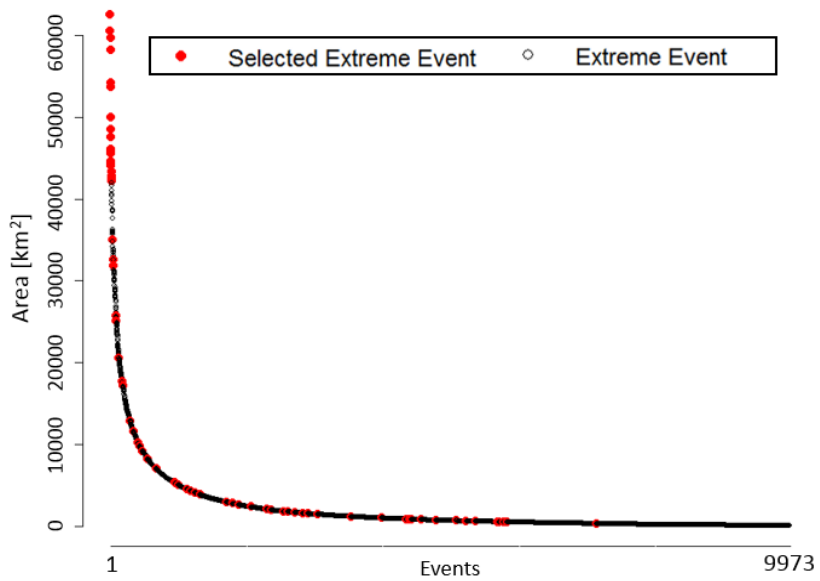

Figure 2: Detected BACIndex events ordered by area size (n = 9973), and the 80 sampled events in red.

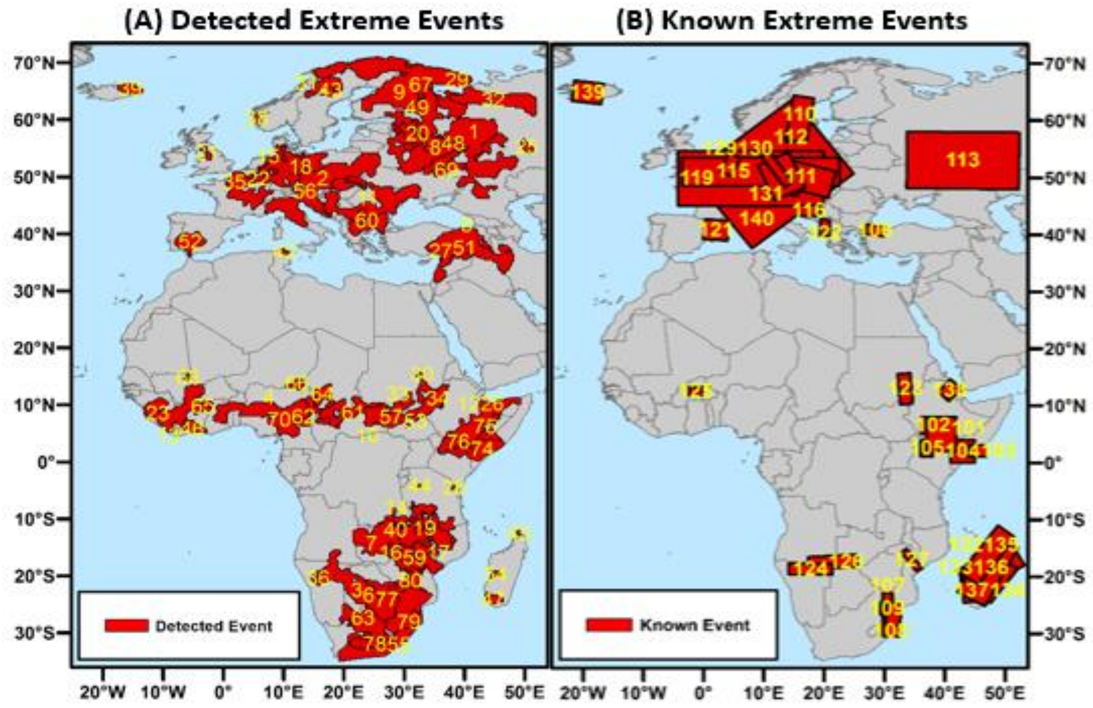

Figure 3: Location of the detected extreme events (A) and of the known extreme events (B).

<u>*Known extreme events*:</u> A list of 40 *known extreme events* covering the period of 2001 - 2011 was created based on literature research. These events included: floods, fires, droughts, heat and cold waves, tree cover losses, storms, cyclones, and volcanic eruptions. The events are equally distributed over the BACI focus areas (Figure 3B). A detailed overview of the known extreme events is provided in Annex 5.

4.1.2 Validation

We followed the BACI validation framework (see chapter 2.1, Deliverable 6.1) to evaluate the accuracy of the BACIndex and the BACI downstream products. This framework consists of two major steps: (i) characterisation (internal attribution and external characterization) and (ii) independent assessment (independent validation and regional expert feedback). Standardized templates were used for the validation of the individual events (Annex 2 & 3).

<u>Step 1: Characterisation</u>
Internal attribution: Several statistics were calculated for each event, including area, centre longitude and latitude, date of maximum extent and duration of the event. We also calculated the z-scores for each of the five input variables, comparing the extreme event (pixel distribution) with the multi-year normal. The calculation of the z-score was similar to the method used for the descriptive analysis (Chapter 4.1.1), but the actual duration of the extreme event was calculated and considered.

External characterization: We considered the additional 15 environmental variables available in the ESDC, which were not used for the calculation of the BACIndex, for the external characterization: air temperature in 2 m height, maximal air temperature, minimal air temperature, bare soil evaporation, burnt area, evaporation, fraction of absorbed photosynthetic active radiation, interception loss, potential evaporation, precipitation, relative humidity, soil moisture, surface moisture, transpiration, and vapour pressure deficit. We calculated the z-scores for each of the 15 variables, comparing the extreme event with the multi-year normal.

Step 2: Independent assessment

Independent validation: The independent validation consisted of literature/internet recherché of various natural disaster databases; GIS analysis of existing environmental and socio-economic datasets, and time series analysis in GoogleEarthEngine (Bartholome et al. 2002; Copernicus Programme 2014; ESA 2017; FAO 2017a; FAO 2017b; Hansen et al. 2013; Woodcock et al. 2008). See Deliverable 6.1 for more details. The large diversity of events, drivers and relevant reference data did not allow to assess the accuracy using a conventional approach.

To evaluate the accuracy in a standardized manner across all events, we assessed the thematic (type of extreme event), spatial, and temporal accuracy using scores ranging from 1 (not accurate) to 3 (accurate). Table 2 provides a definition of the scores. For *known extreme events* the thematic accuracy was not evaluated as the type of event is known.

Using long term socio-economic data for validating the BACIndex is particularly intricate, because such changes can be influenced by not only a single, but several extreme events detected in the BACIndex and time-lags are to be considered as well. As an update of Deliverable 7.2 in WP7 and for Deliverable 7.3 a spatially explicit data set on annual changes of human appropriation of NPP (HANPP) between 2000-2014, including a data set on biomass harvest is currently developed (upcoming Deliverable 7.3), which can be tested here on the identified BACI-events in Europe. HANPP has been developed and used as an indicator for the pressure exerted on natural ecosystems through land use and the respective withdrawal of NPP (Haberl et al. 2007; Haberl et al. 2014). HANPP consists of the components a) biomass harvest and b) NPP changes due to land use/-cover changes. Harvested biomass (HANPPharv) was calculated for the four main land-use types croplands, grasslands, woodlands and build-up areas as part of WP7 (upcoming Deliverable 7.3). Harvested biomass on croplands is defined as the sum of primary harvest and used-as well as unused crop residues and grassland harvest is defined as the amount of grazed biomass, using livestock statistics and applying a grazing gap calculation. Forest harvest is calculated as the sum of fuelwood and roundwood harvest including used and unused residues and harvest on build-up areas is defined as biomass harvested on urban recreational areas (gardening, maintenance of parks, etc.). Important data-sources were the FAO statistical database for harvested biomass (FAO 2017b), as well as the HYDE 3.2 database (which is calibrated using ESA CCI land cover information (ESA 2016) to convert land cover data into land-use data) for downscaling of biomass harvest to the grid (Goldewijk 2016). For a full representation of methodological details refer to the upcoming deliverable Deliverable 7.3 (or to Deliverable 7.2 for the historic time-period which is based on similar methods). The sampled subset of 23 European detected BACI-events co-occurrence with abnormal high or low biomass harvest (HANPPharv) was tested. Using the spatial extent of the *detected BACI-events*, the amount of HANPPharv on croplands, grazing lands and forest lands was extracted from the gridded HANPP time-series for the period 2000-2011. Next, z-scores were calculated, where a z-score above 1 was defined to indicate HANPPharv anomalies.

Table 2: Accuracy scores definition

Accuracy Score	Definition
1 - not accurate	No evidence of an extreme event visible in neither external characterization nor independent assessment
2 - average	Clear evidence of an extreme event visible in either external characterization or independent assessment
3 - accurate	Clear evidence of an extreme event visible in external characterization and independent assessment

Regional expert feedback: A total number of 15 regional experts were consulted to provide independent feedback on the detected extreme events. Annex 1 provides an overview of the regional experts and the evaluated events. Each of the regional experts received a template describing the extreme event (Date of maximum extent, location, extent and duration of the event). Regional experts were expected to provide scores (thematic, spatial, and temporal) as used for the validation (Table 2), and to provide a short description and interpretation of the extreme event respectively a justification of their accuracy scores.

4.2 Validation part 2 - Downstream products

4.2.1 Descriptive analysis

A descriptive analysis of the downstream products was conducted. This was done individually for each detected extreme event. We analysed if the different BACI downstream products (annual) represent the individual BACIndex extreme events. For each detected BACI event, we calculated the t-test (incl. p-value) comparing the extreme event and the multi-year normal. We used the p-value to test the statistical significance.

4.2.2 Validation

For the 80 *detected extreme events* and the 40 *known extreme events* (Chapter 4.1.2), an event-based validation was conducted comparing z-scores (Chapter 4.2.1) with event statistics and accuracy scores from the validation of the individual events (Chapter 4.1.2).

5. Validation Results 1 – BACIndex

5.1 Descriptive analysis

Seasonal patterns of detected extreme events: Figure 4 shows the monthly accumulated extreme events detected for the time period of 2001 to 2011. A clear seasonal pattern is visible following the major growing season with extreme events mainly detected in vegetated regions and phenologically active time periods. The majority of the extreme events are located in the northern hemisphere (boreal forests), the Sahel zone, and in scattered regions in Southern Africa.

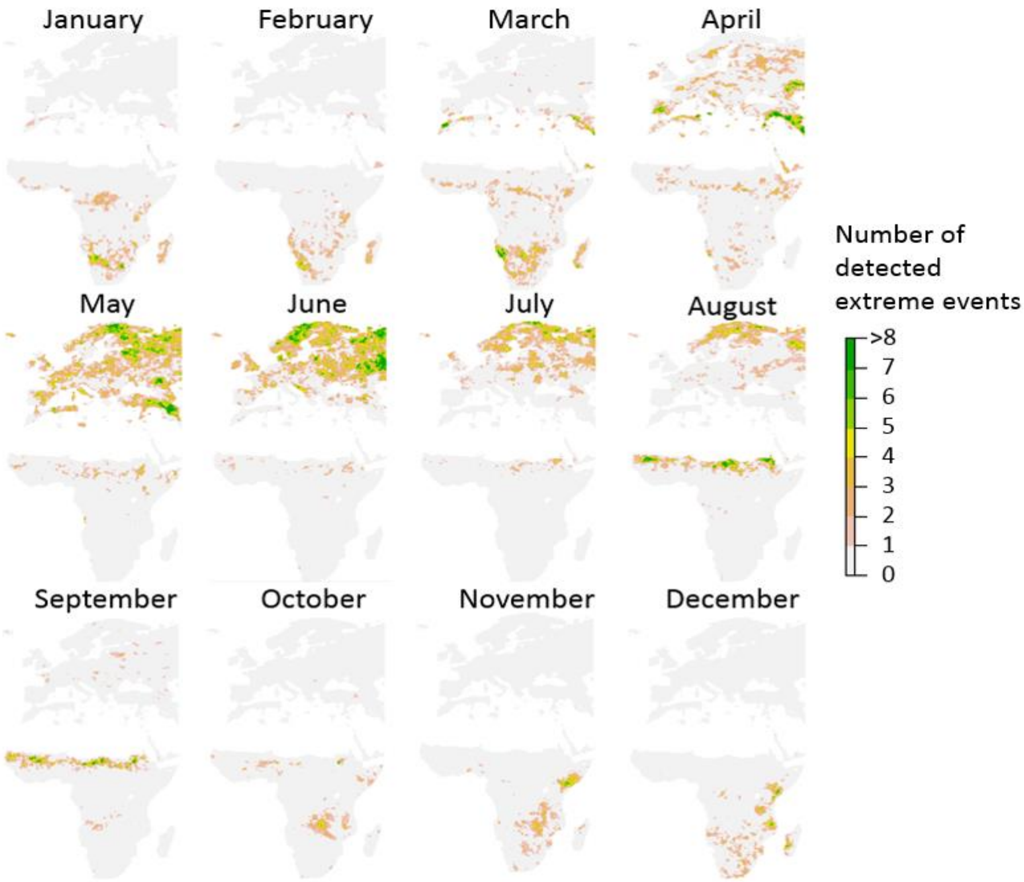

Figure 4: Monthly accumulated extreme events detected by the BACIndex for the time period of 2001 to 2011.

Correlation of ESDC input variables: Figure 5 shows scatterplot matrices of the z-scores of all ESDC input variables, their correlation coefficient and linear regression. The highest correlation was found for GPP and NEE (R = -0.81), indicating a strong negative relationship. The second highest correlation was evident between GPP and TER. Overall the lowest correlation is visible for Sensible Heat regardless of the other variable.

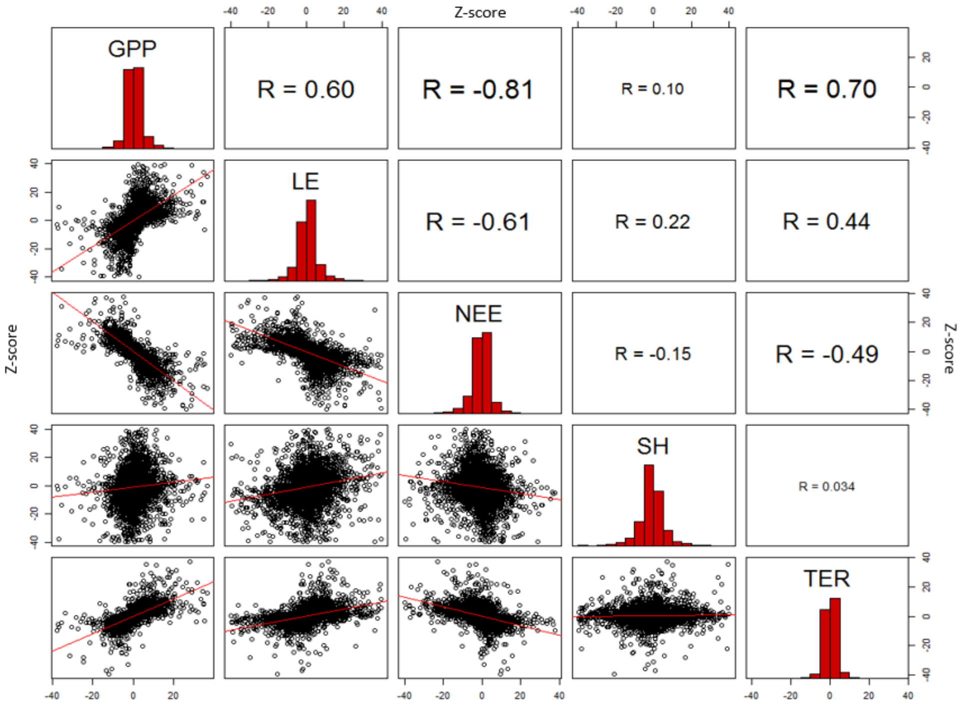

Figure 5: Scatterplot matrices of the z-scores of all ESDC input variables, their correlation coefficient and linear regression.

Latitude dependency: Figure 6 depicts density plots of all of the z-scores of detected extreme events against the latitude, separately for the five ESDC input variables. The majority of extreme events are located between a latitude of 5 - 20 degrees north. These very high values are linked to photosynthetic active regions, whereas the region between 20 - 25 degrees north is mostly covered by the African desert. A high density of z-scores in the range between -5 to 5 were found (i) around 20 degrees south, (ii) 5 - 20 degrees north and (iii) 40 - 65 degrees north. All ESDC input variables show similar spatial patterns with a major cluster in the tropical/sub-tropical area. The only difference is visible in northern latitudes, where temperature related input variables (Latent Energy, Sensible Heat) show a significant different behaviour.

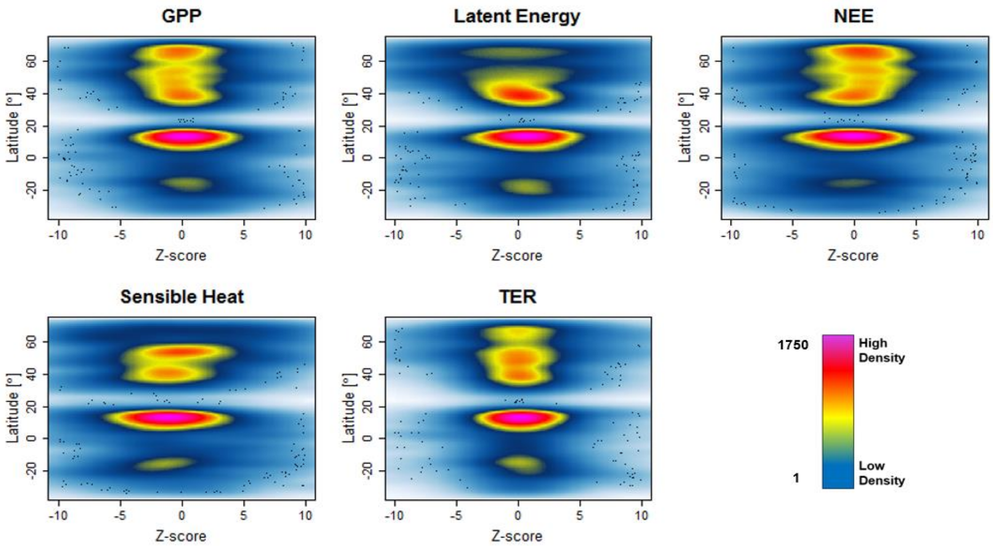

Figure 6: Density plots of the ESDC data z-scores based on all BACIndex detected extreme events against the latitude.

Effect of area size: Figure 7 shows boxplots of the absolute z-scores of all detected extreme events for four area groups, separately for each ESDC input variable. Results indicate decreasing z-scores for increasing area size. In theory, small events often occur to have a larger impact on the location (e.g. forest cover loss), while large-scale events are climate driven (e.g. droughts) affecting land-cover in a lesser manner, but can have high implications on parameters such as plant productivity at the regional scale, thus potentially affecting e.g. the amount of harvested biomass.

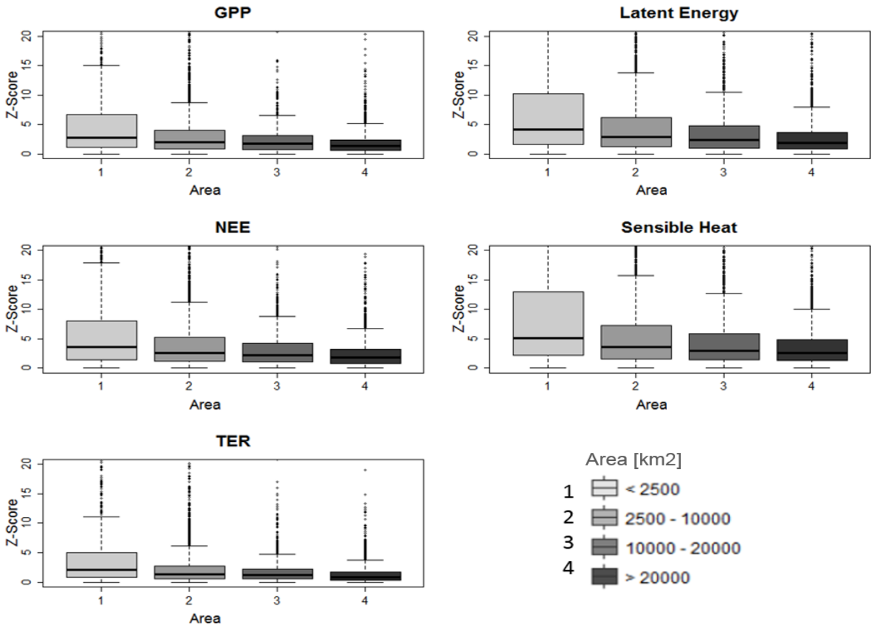

Figure 7: Boxplot of absolute z-scores of all detected extreme events for four area groups, separately for each ESDC input variable.

5.2 Detected extreme events

Figure 8 depicts the percentages of thematic, spatial and temporal accuracy scores of the *detected extreme events* for (A) the independent validation and (B) regional expert feedback. All validation templates with results from the independent validation and the regional expert feedback are listed in the supplementary material. Examples for a precise *detected extreme event* and a commission error are shown in Annex 2 & 3. The results can be summarized as follow.

Independent validation: The mean score for the thematic, spatial and temporal accuracy was found to be 2.18, 1.83 and 2, respectively (Figure 8A). The mean of all scores across all categories was 2, showing good agreement in general. However, only 2.5% of the *detected extreme events* showed an accuracy score of 3 in all categories. In comparison 50% events showed accuracy scores of 2 or less in all categories and 15% indicated an accuracy score of 1 in all three categories. These results indicate a high number of committed extreme events or extreme events that poorly represent the true events on the ground.

Regional expert feedback: In total 46 of the 80 *detected events* were assessed by regional experts. A table of all accuracy scores as results of the independent assessment and the regional feedback is given in Annex 4. The mean score for the thematic, spatial and temporal accuracy was 1.78, 1.71 and 1.86, respectively (Figure 8B). The mean of all scores across all categories was 1.78 showing an average agreement in general. Only 4.3% of the assessed extreme events showed an accuracy score of 3 in all categories. In comparison, 69.6% of the events showed accuracy scores of 2 or less, and 9 of the 46 (19.6%) events indicated an accuracy score of 1 in all three categories. When comparing the results of the regional expert feedback (Figure 8B) with results of the independent validation (Figure 8A), similar patterns were found for the spatial and temporal accuracy with slightly higher accuracy scores in the independent validation. Different patterns were found for the thematic accuracy. Results of the regional expert feedback confirm the results of the independent validation, meaning a high number of committed extreme events or extreme events that poorly represent the true events on the ground.

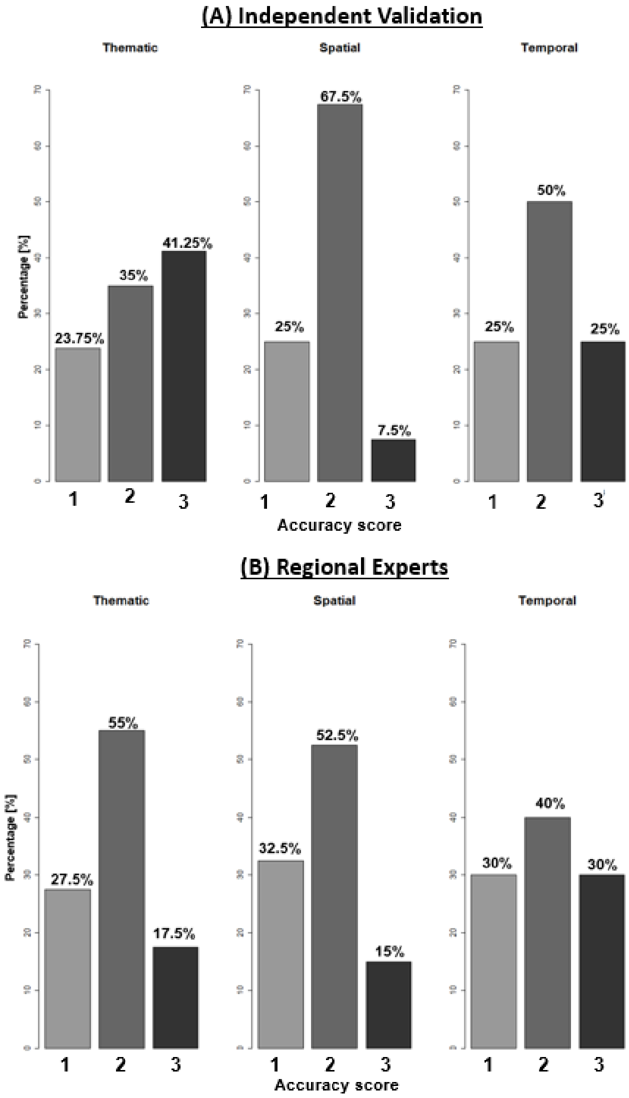

Figure 8: Percentages of thematic, spatial and temporal accuracy scores of the *detected extreme events* for (A) the independent validation and (B) regional expert feedback.

<u>Effect of the area size:</u> Figure 9 depicts the independent validation and regional expert based accuracy scores versus the size of the extreme events. Results suggest that large (10.000 - 20.000 km²) and very large events (> 20.000 km²) show better accuracy scores when compared to mid-size (2.500 - 10.000 km²) and small events (< 2.500 km²). This supports the previous finding that the BACIndex performs better for larger scale extreme event.

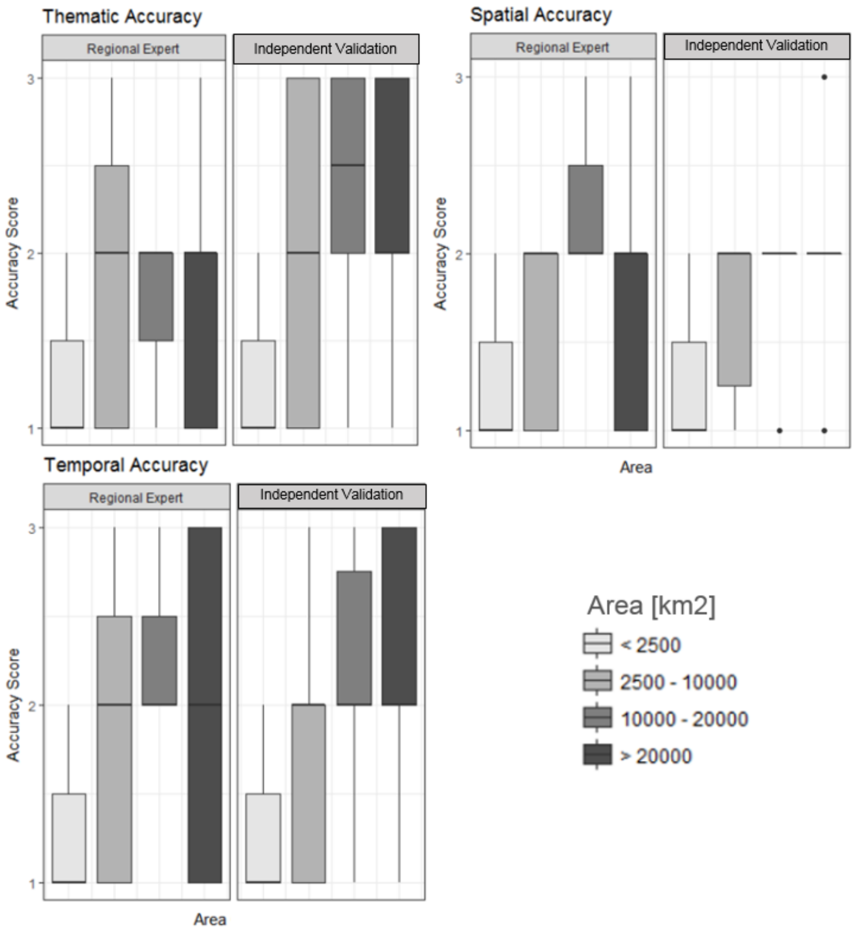

Figure 9: Independent validation and regional expert based accuracy scores versus the size of the extreme events

<u>BACI-related to long-term socio-economic changes:</u>

Evaluating the co-occurrence of the *detected extreme events* with abnormal high or low biomass harvest (HANPPharv) showed that for the 23 detected European BACI events, six events matched with HANPPharv z-scores above 1. The characteristics of these events are listed in Table 3 and the HANPPharv time series for the exact event-location on an annual basis are shown in Figure 10 (black rectangles indicate the year of the extreme event). This indicates a relatively good match of biomass harvest anomalies with occurrence of BACI-events for only around one quarter of European events. No, or only moderate relation to biomass harvest anomalies can be found for roughly 75 % of the tested BACI events. Furthermore even in the six cases of good agreement, the year of the most extreme harvest anomaly, was missed by the BACIndex (i.e. refer to events ID2, ID8, or ID15, see Figure 14).

Table 3: Description of the type, date, duration, extent and location of the BACI-events, for which the year of the event matched the year of anomaly high or low gridded HANPPharv (biomass harvest).

Event ID	Type of extreme event	Time/ Duration	Extent [km²]	Location
2	Heavy rainfalls, long wet period	20.05.2008/ 20.05.2008 – 28.05.2008	605748.4	Eastern to Southern Europe
8	Above average temperatures, humid conditions	27.04.2001/ 27.04.2001 – 05.05.2001	485062.7	Western Russia, Eastern Belarus, Northern Ukraine
15	European extreme heat wave	09.08.2003/ 09.08.2003 – 25.08.2003	440595.3	Central Europe
21	Above average temperatures, high MODIS NDVI levels	14.06.2003/ 14.06.2003 – 14.06.2003	15801.5	Western UK
32	Cold-wave in European Russia	20.05.2008/ 20.05.2008 – 13.06.2008	177002.1	North-western Russia
39	Anomaly wet conditions and heavy winds	06.06.2003/ 06.06.2003 – 14.06.2003	27698.0	Iceland

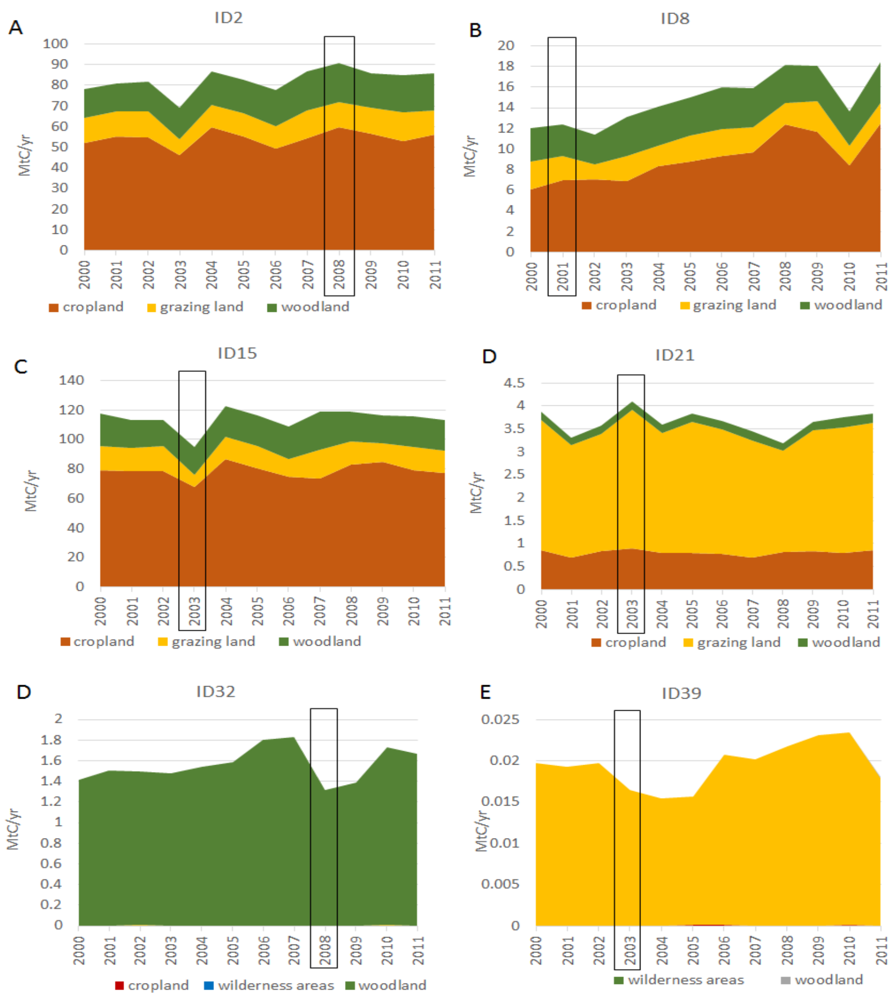

Figure 10: Biomass harvest (HANPPharv) on croplands, woodlands, grazing land and build-up areas for the 2000-2011 period. Black rectangles show the year of the BACI-event.

5.3 Known extreme events

The results for the *known extreme events* are shown in Figure 11 and are summarised below. All the scores of the k*nown extreme events* are given in Annex 5. Figure 12 shows examples of *known extreme events* well detected by the BACIndex (A) and omitted by the BACIndex (B). Example 1 (Figure 12A) shows a well detected cyclone event in Madagascar occurring in the period between 01-03-2004 to the 18-03-2004. Example 2 (Figure 12B) shows an omitted large-scale drought event on the coast of Somalia occurring in the period between 29-01-2008 to 08-08-2008.

Independent validation: The mean score for the spatial and temporal accuracy was found to be 1.58 and 1.55, respectively. Only 5% of the assessed extreme events showed an accuracy score of 3 in all categories. In comparison, 75% of the events indicated accuracy scores of 2 or less, and 52.5% resulted in an accuracy score of 1 in all three categories. These results indicate a high number of omitted extreme events or extreme events that poorly represented by the BACI index.

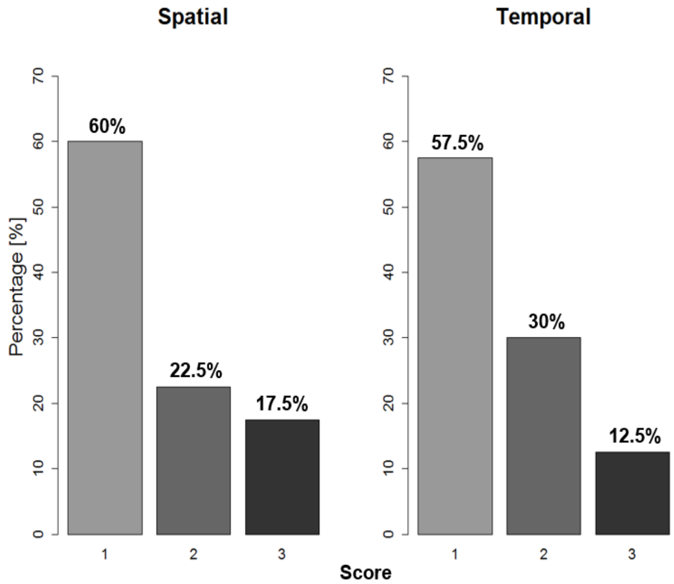

Figure 11: Accuracy scores for the known extreme events

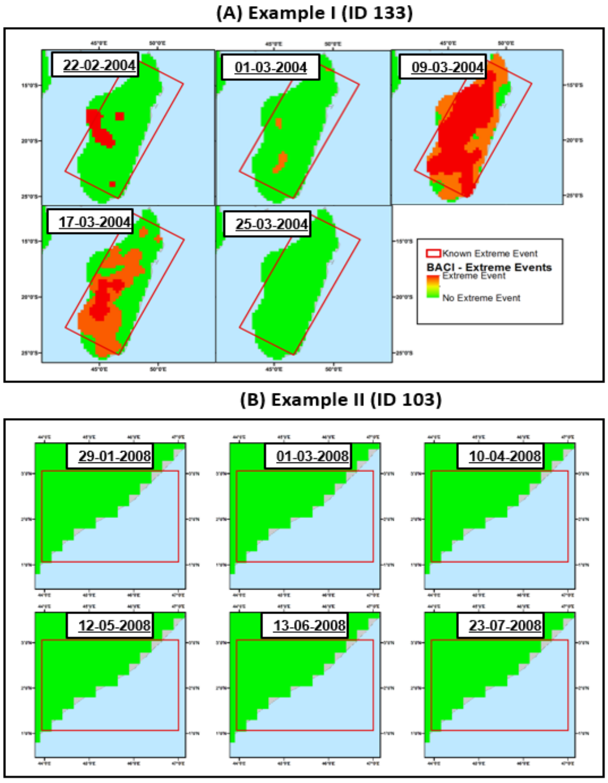

Figure 12: Known extreme events well detected by the BACIndex (A) and omitted by the BACIndex (B).

Effect of area size and the type of event: Figure 13 shows boxplots of the accuracy scores for different types of *known extreme events* and different area size. Best performance of *known extreme events* was achieved for floods (Spatial: Score - 2; Temporal: Score - 2), droughts (Spatial: Score - 2; Temporal: Score - 1), and storms (Spatial: Score - 1; Temporal: Score - 1.5) (Table 4.2). All remaining types of extreme events resulted in scores of 1 for both spatial and temporal accuracy. Large droughts and storms tend to be more accurate than smaller anomalies, whereas cold and heat waves and floods showed higher accuracies with decreasing size (Figure 13). In general, it was visible that smaller cold and heat waves and floods tend to be more precise with decreasing size and droughts and storms with increasing size.

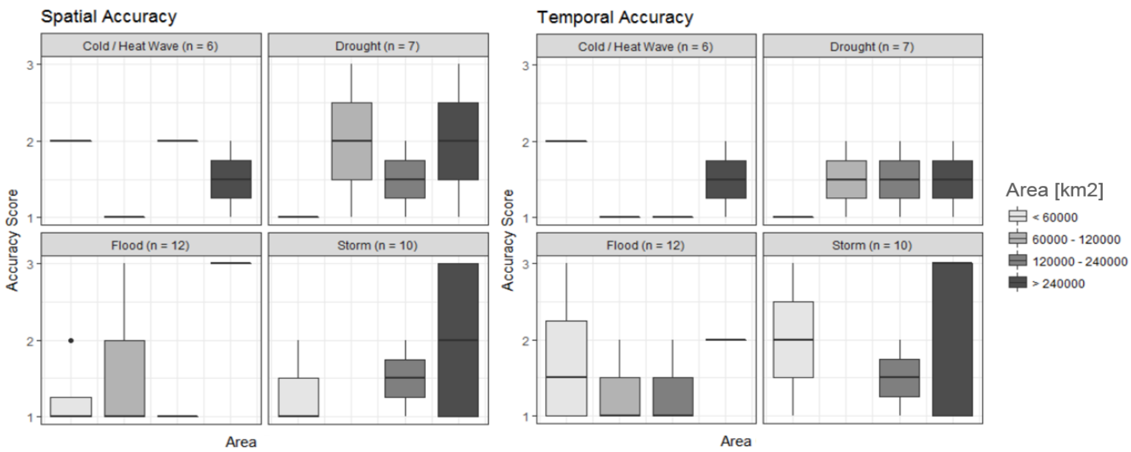

Figure 13: Boxplots of the accuracy scores for different types of known extreme events versus the area size

6. Validation Results 2 - Downstream products

6.1 Descriptive analysis

Latitude dependency: Figure 14 depicts density plots of all of the t-value scores of detected extreme events against the latitude, separately for the different downstream products. The majority of extreme events are located between a latitude of 5 - 20 degrees north. These very high values are linked to photosynthetic active regions, whereas the region between 20 - 25 degrees north is mostly covered by the African desert (no biosphere). A high density of low respectively medium t-value scores in the ranges of (i) around 20 degrees south, (ii) 5 - 20 degrees north and (iii) 40 - 65 degrees north. Similar patterns were found for all downstream products, except for PUE, which indicated slightly higher values for the Sahel zone.

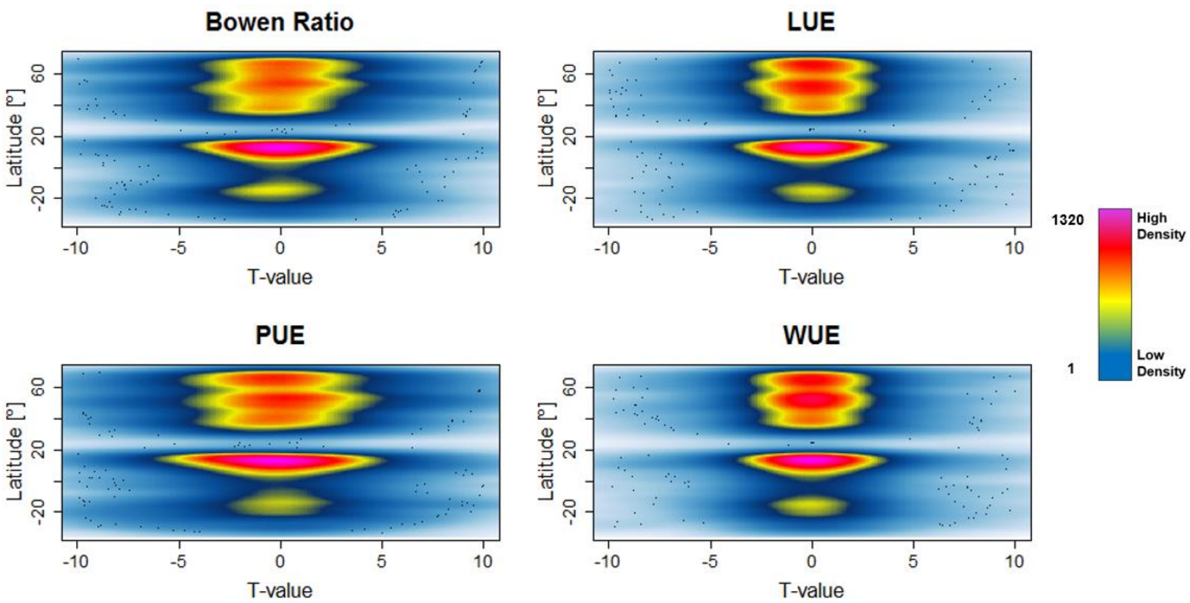

Figure 14: Density plots of all of the z-scores for the annual downstream products against the latitude of the respective extreme event.

Effect of area size: Figure 15 depicts the boxplot of absolute z-scores of all detected extreme events in area groups for each annual downstream product. Larger detected extreme events indicate smaller t-values, which can be linked to local events showing extreme impact on a small scale (e.g. land use change). However, both the Bowen Ratio and PUE indicated higher t-values for the largest area group and do not stay in agreement with the ESDC and LUE respectively WUE.

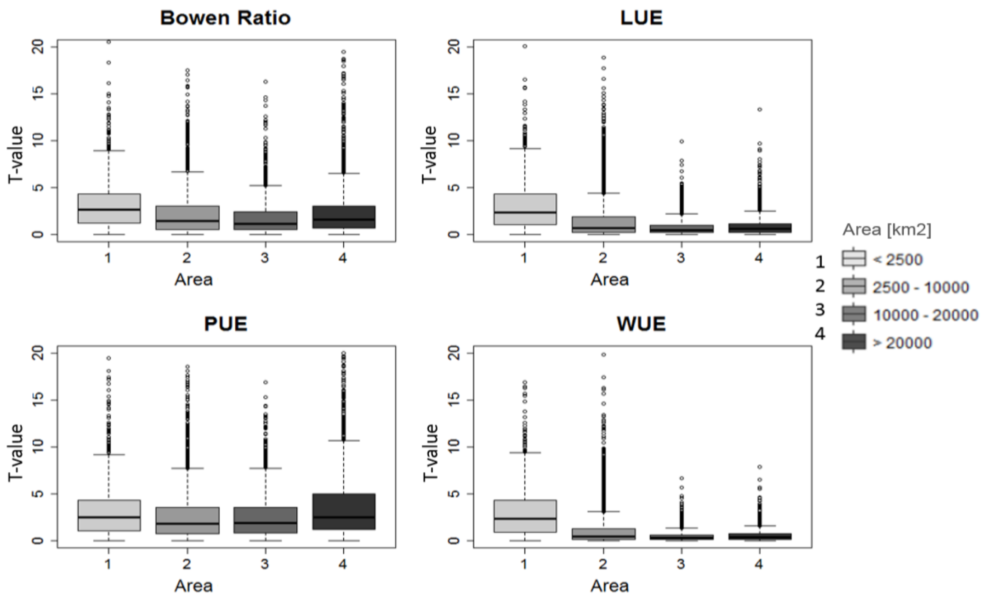

Figure 15: Boxplot of absolute T-values of all detected extreme events in area groups for each annual downstream product.

6.2 Validation

For the event based validation of the downstream products, we identified extreme events co-occurring with a significant change in the annual downstream products. The highest number of *detected extreme events* co-occurring with a significant change in the annual downstream products was found for the Precipitation Use Efficiency, which represents 46 significant t-values of 80 extreme events, followed by Bowen Ratio (26), Light Use efficiency (7) and Water Use efficiency (3). Similar results are found for the *known extreme events*. The highest number of *known extreme* events co-occurring with a significant change in the annual downstream products was found for the Precipitation Use Efficiency representing a noticeable number of significant t-values (24; 60%), followed by Bowen Ratio (13; 32.5%), Light Use efficiency (7; 17.5%) and Water Use efficiency (0; 0%). Figure 16 shows an extreme event in South Africa of extreme high values of precipitation and WUE on the 02.03 - 18.03.2011, were all downstream products show significant values.

For tree ring increments, 56 of the 63 detected extreme events covering Europe showed significant t-values. Figure 17 shows a heat wave in central Europe occurred between the 02.03 - 18.03.2011, were the majority of species of the tree ring increment products show significant values.

While we can identify *detected extreme events* to co-occur with significant changes in the annual downstream products, it is unclear if this is caused by the BACIndex detected extreme events or other events.

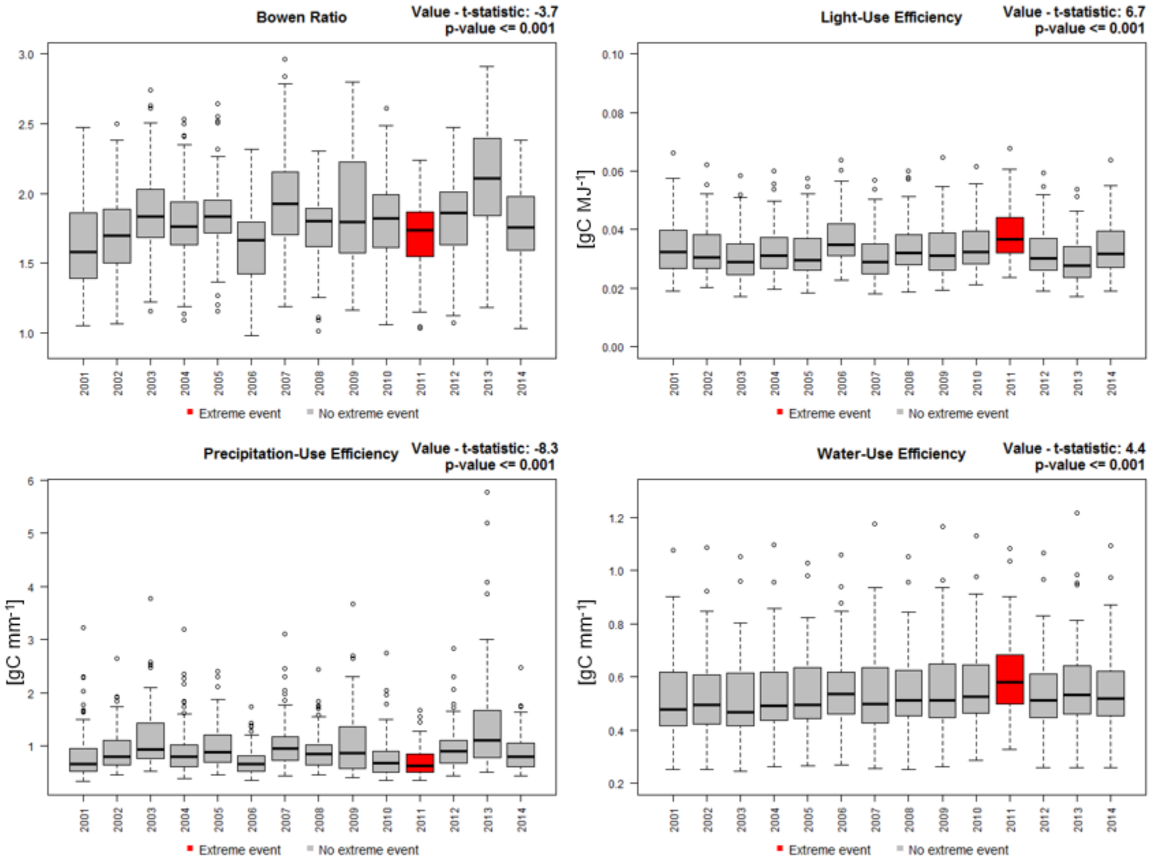

Figure 16: Example for the downstream product validation of an extreme event of high precipitation occurring on the 02.03.2011 - 18.03.2011.

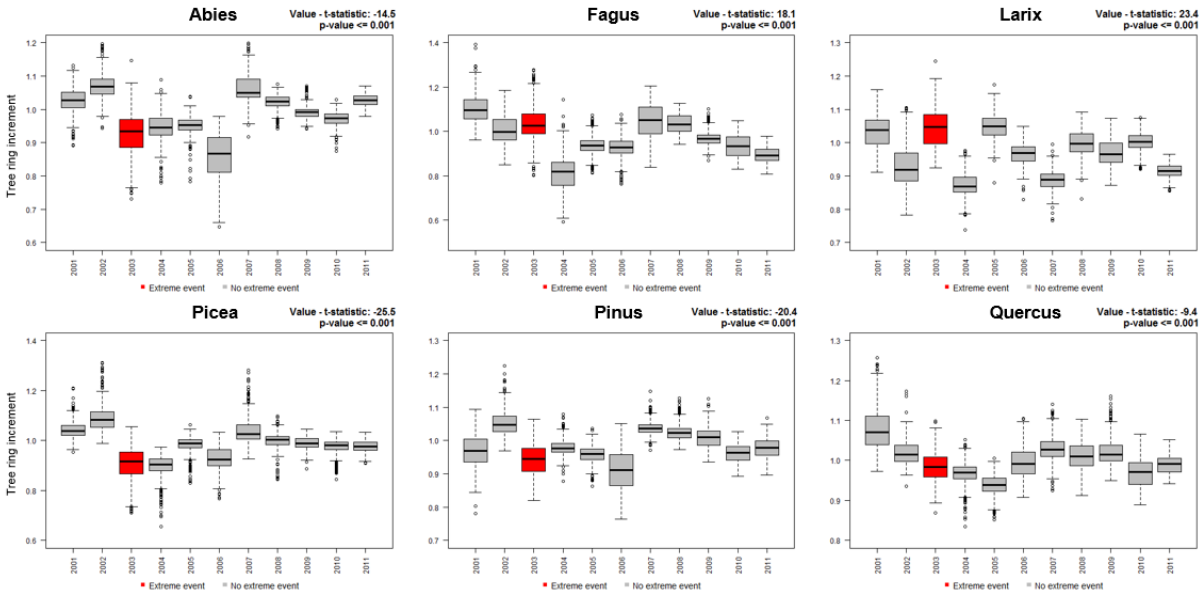

Figure 17: Example for the tree ring width validation of an extreme event of high temperatures occurring on the 09.08.2003 - 25.08.2003 in central Europe.

7. Synthesis and recommendations

Deliverable 6.2 presents the validation of the first generation BACIndex (WP5) and the BACI downstream products (WP4). We first conducted a descriptive analysis of all 9973 events to gain a general understanding of the datasets, before we validated the BACI products following the BACI validation framework (Deliverable 6.1). The BACI validation framework was successfully implemented and allowed validating the BACIndex and the BACI downstream products. The framework enabled the validation of a large variety of extreme events, in terms of the spatial, temporal and thematic accuracy. In total, 120 events were validated; 80 events were used for evaluating the commission error, and 40 *known extreme events* were used for investigating the omission error. The validation was supported by expert feedback provided by 15 experts from different countries in Europe and Africa. Results of the regional expert feedback showed similar patterns compared with results of the independent validation indicating the robustness of the results. We put particular emphasis on the capacity to detect socio-economic changes and reflected on challenges on how to use socio-economic data to validate change products of high temporal and spatial detail.

The key findings of the descriptive analysis are:

- Clear seasonal patterns of detected extreme events following the major growing seasons and phenological active time periods were found for the majority of the extreme events in the northern hemisphere detected between April - August and in the southern hemisphere between September - March (Figure 4).
- Analysing the correlation between the ESDC input data for the detected extreme events the highest correlation was visible for GPP and NEE (R = -0.81), followed by GPP and TER (R = 0.7) (Figure 5). Other input variables showed weaker correlations. SH indicated consistently weak correlation with other input variables.
- Analysing the effect of areas size showed that small-scale extreme events resulted in a higher z-score when compared to larger events (Figure 7). The same was evident for the t-values of WUE and LUE, whereas the Bowen Ratio and PUE showed high values for both small and large detected extreme events (Figure 15)
- Comparing the downstream products and the ESDC input data for the BACIndex detected extremes indicates the same spatial distribution and pattern with hotspots in Europe, Sahel Zone and South Africa (Figure 14).

The key results of the validation are:

- Average accuracy scores were found in the spatial, temporal and thematic domain, with a significant part of the of the *detected extreme events* not being detected accurately. Only 2.5% (2 of 80) extreme events showed a high accuracy score in the spatial, temporal and thematic domain. About 40 % of the validated extreme events indicated a poor accuracy in either temporal, spatial or thematic domain (Figure. 8).
- Regional expert feedback confirms the weak results for the *detected extreme events*
- Lower accuracy scores were found for *known extreme events* when compared to the *detected extreme events*. Most of the *known extreme events* were omitted by the BACIndex. The majority of the *known extreme events* (~60%) showed poor temporal and spatial accuracy.
- Larger *detected extreme events* were more likely to have a higher accuracy in the thematic and temporal domain (Figure 9). No area dependency was found for the spatial accuracy.

- Floods and droughts indicated the best accuracy, showing improved precision with increasing temporal and spatial extent of extreme events. Storms and cold / heat waves were poorly detected (Figure 13).
- The BACIndex, as it is implemented now, potentially detects socio-economic events that are a direct effect of climatic/meteorological extreme events (e.g. floods and droughts). However, the sensitivity uncovering socio-economic anomalies that potentially occur as a consequence of multiple extreme events over a certain time period is relatively weak, since such events are prone to time-lags that can span several weeks to months.
- *Detected extreme events* do not necessarily correspond with high socio-economic impacts. Major *known events*, such as heavy storms were not detected although they repeatedly had major repercussions on the socio-ecological system (high disaster costs, dramatic increases of wood harvest, etc.). Prominent examples include the storms Gudrun in 2003 and Kyrill in 2007 that led to tremendous socio-economic costs, including extensive areas prone to wind-falls in Northern Europe.
- The event based validation of the downstream products showed that a reasonable part of the detected and known extreme events co-occur with significant changes in the annual downstream products. Hereby, PUE showed to be most sensitive, followed by Bowen Ratio, LUE and WUE (Figure 16). The same was evident for the Tree-ring width product (Figure 17). While we can identify detected extreme events to co-occur with significant changes in the annual downstream product, it is unclear if this event is caused by the detected significant change or other events. Moreover, using mainly biophysical parameters for detecting the BACIndex (V1) might cause the missing sensitivity of LUE and WUE for the detected extreme events.

The key finding for the validation of socio-economic changes that play out at longer temporal scales exemplified for the case of biomass harvest trends was a relatively low agreement with BACI extreme events (Figure 10). Reasons for this could be amongst the following:

- Mismatch of spatial-temporal resolutions: Biomass harvest data is reported at the end of a harvest period on an annual basis for national to sub-national units (i.e. national to provincial data, such as Nomenclature des unités territoriales statistiques 2 (NUTS2) or NUTS3 regions in Europe, instead of gridded information in BACI), which are downscaled to the grid using remote sensing information and model-assumptions. Hence, biomass harvested at the end of a growing period has likely been subject to a number of BA-changes/anomalies/extreme events within the preceding growing period. Considering cumulative anomalies of the BACIndex within longer periods of time, i.e. vegetation periods, instead of focusing on single events might be a way forward to enhance agreement.
- Time-lags between a BACI event and biomass harvest. For instance, a potentially detected drought or cold wave by BACI in the early growing season, likely turns out in form of low biomass harvest at the end of the growing season.
- The focus on relative anomalies of underlying downstream indicators rather than on their temporal length in the current definition of extreme events in the BACIndex. This is related to the resilience of plant growth to biosphere-atmosphere extreme events, particularly if they occur within short time-periods. Hence, the BACIndex is probably not able to detect changes of biomass harvest amounts, due to the ability of ecosystems to buffer BA-disturbances. Land management certainly can increase this resilience and even buffer effects of BACI-events that occurred within longer time-

periods, i.e. for example a longer drought-period can be buffered with cropland irrigation.

- Data uncertainties either in the biomass harvest data, or the BACIndex. In the case of biomass harvest, allocation of national to sub-national statistical harvest data to the grid is a potential source of uncertainty. Here, the History Database of the Global Environment (HYDE-database) that is based on European Space Agency (ESA) land cover maps combined with model assumptions was used for the gridding of biomass harvest, which could be a source of uncertainty. Vice versa, downstream products used to calculate the BACIndex, as well as methods used to characterize extreme events could be another source of uncertainty. For instance, GPP is based on plot measurements that are upscale to the regional/continental level.

Based on the finding of the validation the following recommendations arise:

- Consider also atmospheric ESDC variables and/or other variables that were not utilized for deriving the current version of the BACIndex (v1). This may increase the sensitivity towards other change types and decrease the number of committed changes.
- In addition to the ESDC variables, consider the temporally dense state-vector derived from the high spatial resolution optical and radar remote sensing data (Sentinel-1 and MODIS). This will also increase the spatial and temporal resolution of the product and increase sensitivity to smaller events.
- Analyse the driver (data, method or real changes) of the clear seasonal pattern found for the detected extreme events, and if needed adapt the processing chain.
- Derive downstream products at a sub-annual scale to be able to better capture extreme event.
- Assess the near real-time performance of the BACIndex to accommodate the needs of users to access such information in a timely manner. We suggest to emulate a near real-time scenario first using existing historical data and put particular emphasis on the trade-off between spatial and temporal accuracy inherent for near real-time change monitoring (see Milestone 16).

Central recommendation for increasing the agreement between the BACIndex and long-term socio-economic changes, such as biomass harvest, are:

- Provide more weight to the temporal length of events, particularly if they affect larger areas in the index.
- Focus on cumulative anomalies within longer periods instead of one single events that might play a minor role for long-term socio-economic changes.

Updating the current BACIndex based on these findings could also increase the suitability of the BACIndex to be used as an early warning system to land-use practitioners, such as farmers.

In summary, the BACI validation framework was successfully implemented and allowed the validation of the BACIndex and the BACI downstream products. Based on the findings of the validation exercise we provide a list of key recommendations to improve the BACIndex and lead the way to a near real-time version. It should be noted that the assessed BACIndex is the first generation version with limited set of input data and methods. The results presented here should not be interpreted as an overall limit of the BACI framework but rather an intermediate step to point at potentials and limitations that will need to be addressed in the next version using more and better quality input data and more advanced methods.

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Annex 1: Overview of the consulted regional experts

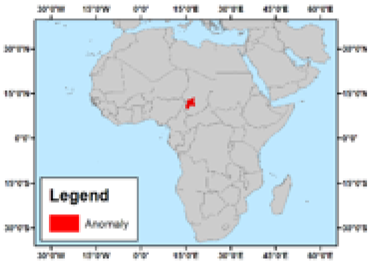
Name	Job	Affiliation	Sent Events	Validated Events
Jascha Muller	Assistant General Manager / GIS & EO Analyst	Centre for Geographical Analysis, Stellenbosch (South Africa)	3, 6, 7, 14, 16, 17, 19, 37, 40, 41, 55, 58, 59, 63, 77, 78, 79, 80	3, 6, 37, 41, 55, 63, 77, 78, 79, 80
Victor Oyango Odipo	PhD Student	Friedrich-Schiller University, Jena (Germany)	12, 74, 75, 76	12, 74, 75, 76
Elias B. Gebremeskel	Research assistant	Addis Ababa University, Addis Ababa (Ethiopia)	10, 12, 26, 30, 33, 34, 53, 57, 61, 74, 75, 76	12, 26, 30, 33, 34, 75, 76
Ralph Adewoye	Post Doc	Remote Sensing/tropical Biodiversity Group. Forestry Research Institute of Nigeria. Ibadan, Nigeria	4, 62, 64, 66, 70	4, 62, 64, 66, 70
Jesse Owino	PhD Student	International Livestock Research Institute, Nairobi (Kenya)	10, 12, 24, 26, 30, 34, 53, 74, 75, 76	10, 12, 24, 26, 30, 34, 53, 74, 75, 76
Steven Okoth Owuor	Post Doc	International Livestock Research Institute, Nairobi (Kenya)	10, 12, 24, 26, 30, 34, 53, 74, 75, 76	10, 12, 24, 26, 30, 34, 53, 74, 75, 76
Edmund Githoro	Student and field scientist	International Livestock Research Institute, Nairobi (Kenya)	14, 17, 19, 28, 44	14, 17, 19, 28, 44
Daniel Müller	Researcher, Lecturer	Leibniz Institute of Agricultural Development in Transition Economies (IAMO); Germany	1, 2, 8, 20, 25, 32, 48, 69, 71	/
Alexander Prishchepov		Department of Geosciences and Natural Resource Management (IGN), University of Copenhagen, Denmark; Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Germany; Institute of Environmental Sciences, Kazan Federal University, Russia	1, 2, 8, 20, 25, 32, 48, 69, 71	/
Claire Lorel	PhD Student	Université Paris Sud (Paris XI); Museum National d'Histoire Naturelle; CESCO (UMR7204)	15, 18, 22, 29, 31, 38, 43, 49, 52, 67, 73, 15, 22, 35	15, 18, 22, 29, 31, 38, 43, 49, 52, 67, 73, 15, 22, 35
Maud Mouchet	Researcher	Département Écologie et Gestion de la Biodiversité, Muséum National d'Histoire Naturelle	15, 22, 35	/
Angheluta Vadineanu	Professor, researcher	Research Centre in Systems ecology and Sustainability, University of Bucharest	11, 60, 73	/
Constantin Cazacu	Post-Doc researcher	Department of Systems Ecology and Sustainable Development, University of Bucharest	11, 60, 73	11, 60, 73
Rupert Seidl	Assoc. Prof., senior researcher	Institute of Silviculture (WALDBAU); University of Natural Resources and Life Sciences, Vienna	8, 15, 18, 22, 29, 31, 38, 43, 49, 52, 67, 73, 1, 2, 8, 20, 25, 32, 48, 69, 71	2, 8, 15, 18, 22, 29, 31, 38, 43, 49, 52, 67, 73
Hans Verkerk	senior researcher	European Forest Institute;	9, 29, 31, 38, 49, 67	/

Annex 2: Template of a committed extreme event

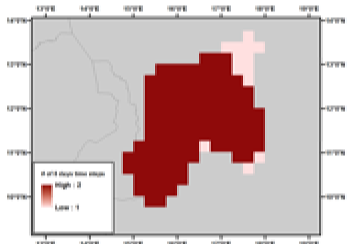
Event ID 64:

1. Attribution (internal)

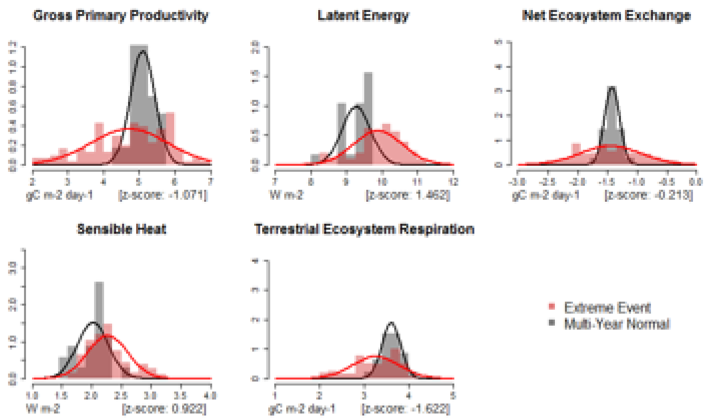
Type: Extreme event
Location: Chad
Area: 91385.1 km²
Time: 25.08.2011
Duration: 17.08.2011 – 25.08.2011



Extent of the event

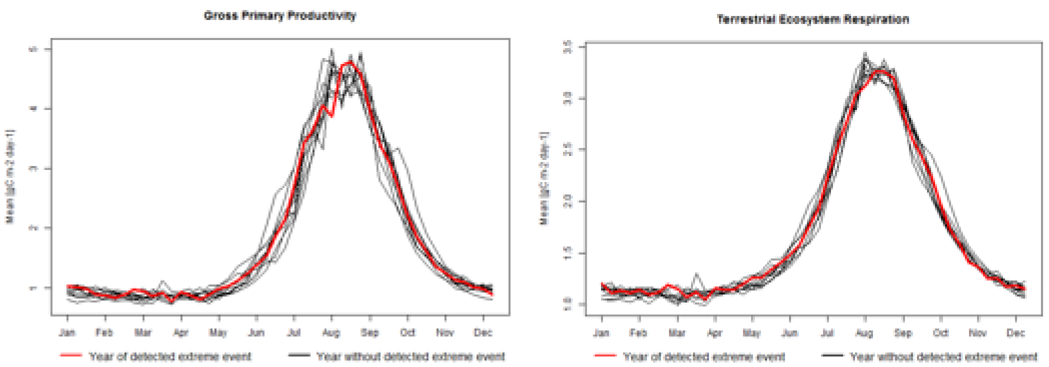


# of 8 day time steps for which the event was detected



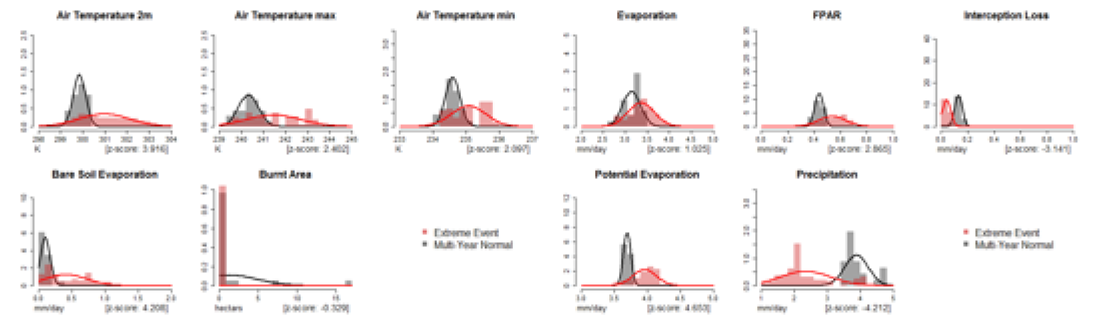
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



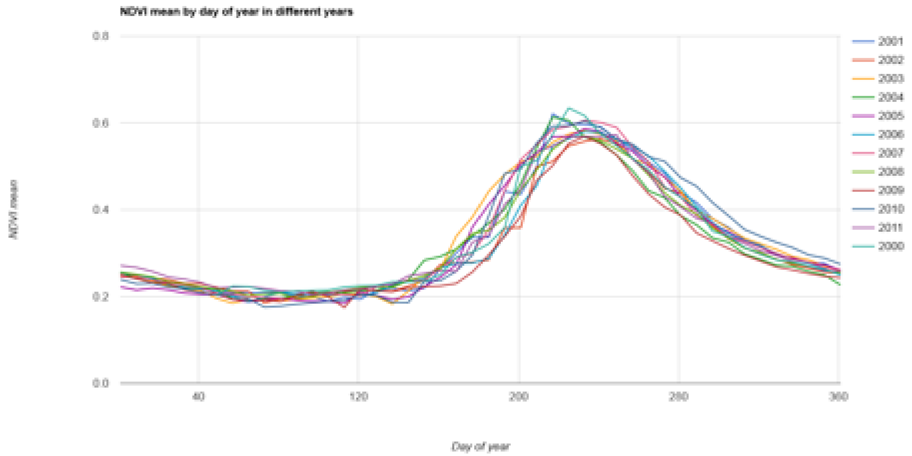
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed:
  - Significantly lower values for both GPP and TER, whereas LE showed higher values comparing the detected extreme event and the multi-year normal
  - Lower values of GPP and TER are visible for a short period of time in the time series plots respectively

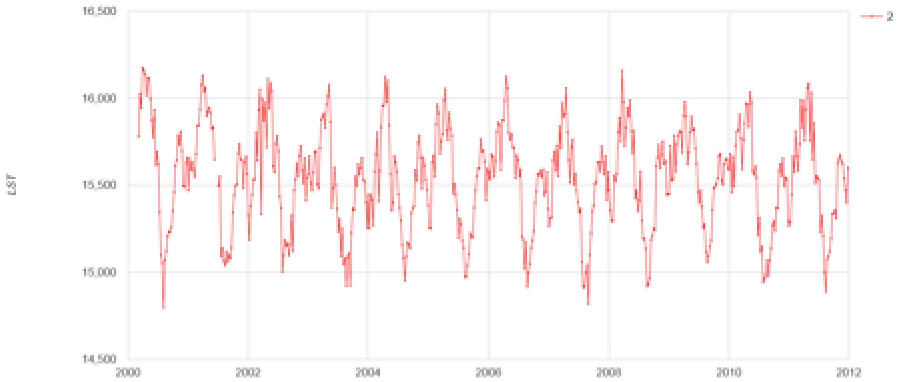
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - considerable higher values for temperature, evaporation, FPAR, bare soil evaporation and potential evaporation, whereas precipitation was significantly lower than what was expected for that period of time compared to the multi-year normal
  - The behaviour of FPAR and GPP are hereby in contrast to one another, which may can be linked to less cloud cover (higher FPAR) and at the same time higher temperatures (worse growing conditions for plants) --> still Latent Energy, which was one driver of the detection of this extreme event seems to be not really reasonable

3. Independent validation & regional expert feedback





- **MODIS NDVI and LST analysis showed for the independent analysis that:**
  - MODIS NDVI shows not significant differences of the investigated time period compared to the other years and stays therefore in disagreement with the BACIndex respectively the MODIS analysis
  - However, LST may show some higher values but do not seem to be as high as proposed by the CABLAB data

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

Annex 3: Template of a high precision detected extreme event

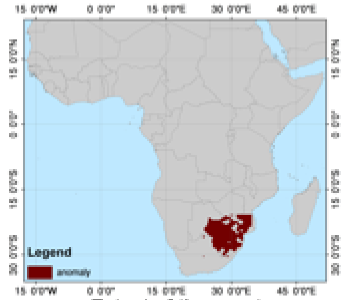
Event ID 77:

1. Attribution (internal)

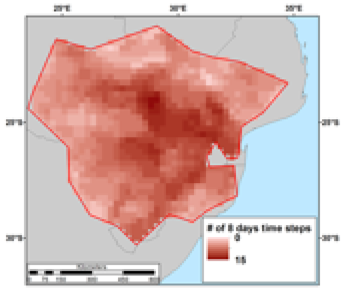
Type: Extreme event
Location: South Africa

Area: 695801.8 km²

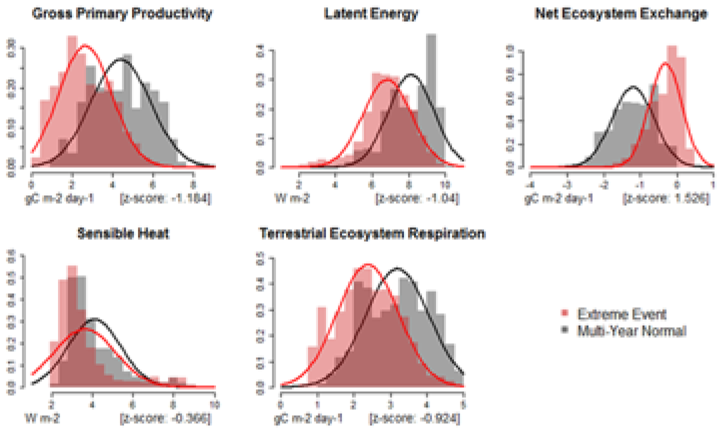
Time: 2004/01/21
Duration: 2003/11/29 – 2004/04/10



Extent of the event

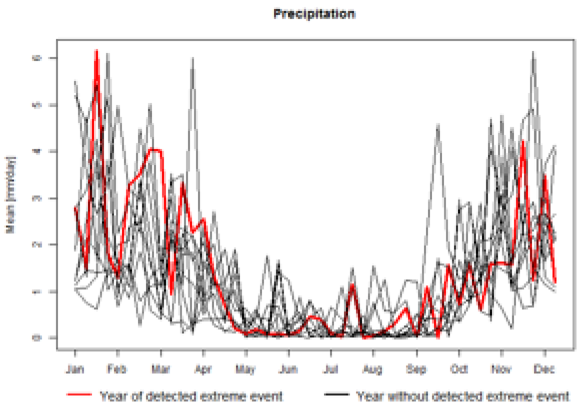


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

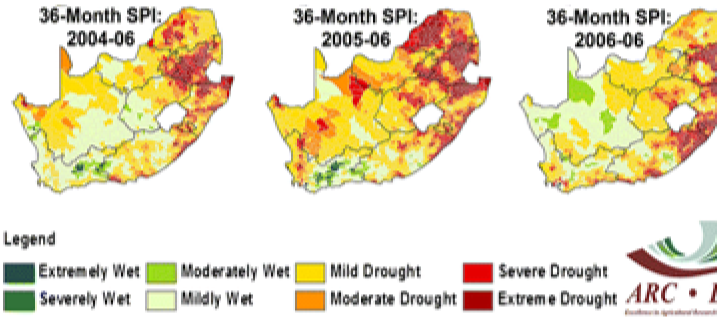


Annual time series of precipitation for the year of detected extreme event (red) and all other years

2. External characterisation

<u>Drought event in South Africa 2003 / 2004</u>

- *"Drought remains a major disaster causing huge damages to humanity, the environment and the economy, despite making considerable progress on monitoring, forecasting and mitigation of droughts across the world."* (Masih et al. 2004:3636)
- Between 1990-2013, Africa is facing the majority of drought events (up to 300) during this time period, when compared on continental scale (Masih et al. 2004)
- The ENSO phenomenon (El Niño / Southern Oscillation), which is driven by periodic fluctuations of ocean temperatures in the equatorial Pacific, is following regular repetition pattern over time (Singels & Potgieter 1997) and is negatively correlated with the amount of rainfall during the summer season in southern Africa (Malherbe et al. 2016).
- However, Reason & Phaladi (2005) found that the drought event 2003/2004 seem not to be caused by an El Niño event. Moreover, this drought is followed by large precipitation events end of January 2004 – which agrees with the precipitation plot in Point 1 (Attribution) and explanations in Point 3 (Independent Validation)
- Comparing the detected extreme event of the BACIndex with the findings from Malherbe et al. (2016), high agreement are found (see Figure below lower left)



Most extensive droughts events (severe to extreme) since 1920 observed at the 36-month SPI* time scale (figure changed Malherbe et al. 2016).

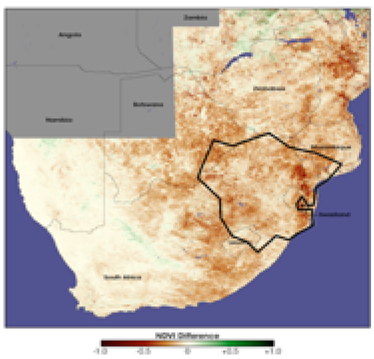
**The SPI is based on the probability of precipitation for a given time period. Technically, the SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable." (Rouault & Richard 2003:491)*

3. Independent validation & regional expert feedback

NDVI Difference in 2004 (Base Period: 2001-2003):

(Source: https://earthobservatory.nasa.gov/IOTD/view.php?id=4226&eocn=related_to&eoci=related_image)

- Food shortage in Southern Africa due to dry soils in late 2003 and early 2004
- Less than 50 % of rainfall in north-eastern South Africa, Lesotho, and Swaziland
- Increase of vulnerability to drought as it was the third season of below-average rainfall
- up to 700K people requires food aid this year
- MODIS NDVI shows the extent of the drought events (see figure below)
- heavy rain in late January induced better conditions for some regions, but it may have also damaged crops
- for most regions rain came too late as many farmers could not plant due to water scarcity
- resulting in shorter growing season, which reduces size of crops

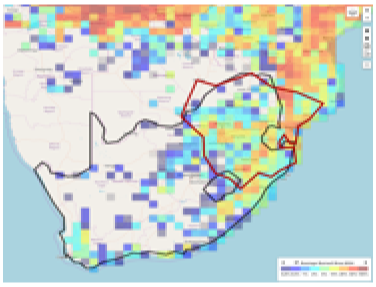


Comparison of amount of vegetation during the first sixteen days of January 2004 (Base Period: first 16 days in 2001, 2002, and 2003). (Extreme Event in black). (Source: https://earthobservatory.nasa.gov/IOTD/view.php?id=4226&eocn=related_to&eoci=related_image)

Fire Affected Area in the year of drought event 2004:

(Source: http://www.globalfiredata.org/analysis.html)

- Burned area statistics are showing increasing amount of fire affected areas in the year of drought event in 2004
- Fire events might be cause due to dry vegetation, etc.
- the extent of the burned areas and detected extreme event from the BACIndex shows good agreement



Average burned area in % for the year of drought in 2004. (Extreme Event in red). (Source: http://www.globalfiredata.org/analysis.html)

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision			X

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision			X

Short event description by the regional expert: Drought -
It seems like there was a drought in the northern regions of south Africa in this time.
https://open.uct.ac.za/bitstream/item/17523/article_2005_reason_c_j_c_phaladi_r_f.pdf?sequence=1

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Malherbe, J.; Dieppois, B.; Maluleke, P.; Van Staden, M.; Pillay, D. L. South African droughts and decadal variability. Nat. Hazards 2016, 80, 657–681, doi:10.1007/s11069-015-1989-y.

Masih, I., Maskey, S., Mussá, F. E. F., and Trambauer, P.: A review of droughts on the African continent: a geospatial and long-term perspective, Hydrol. Earth Syst. Sci., 18, 3635-3649, https://doi.org/10.5194/hess-18-3635-2014, 2014.

Reason, C. J. C.; Phaladi, R. F. Evolution of the 2002-2004 drought over northern South Africa and potential forcing mechanisms. S. Afr. J. Sci. 2005, 101, 544–552.

Rouault, M.; Richard, Y. Intensity and spatial extension of drought in South Africa at different time scales. 2003, 29.

Singels, A.; Potgieter, A. B. A technique to evaluate ENSO-based maize production strategies. South African J. Plant Soil 1997, 14, doi:10.1080/02571862.1997.10635088.

Annex 4: Scores of the independent assessment and regional expert feedback

ID	Independent Assessment			Regional Expert Feedback		
	Thematic	Spatial	Temporal	Thematic	Spatial	Temporal
1	3	2	2	NA	NA	NA
2	3	2	2	1	1	1
3	3	1	2	1	1	1
4	3	3	2	2	2	2
5	2	2	2	NA	NA	NA
6	2	2	3	2	2	2
7	1	1	1	NA	NA	NA
8	3	2	3	1	1	1
9	3	2	3	NA	NA	NA
10	3	3	3	3	3	3
11	3	2	2	1	1	1
12	3	2	3	3	3	3
13	3	2	2	NA	NA	NA
14	3	2	2	2	2	2
15	3	2	3	2	2	2
16	2	1	1	NA	NA	NA
17	2	2	3	2	2	2
18	3	2	2	2	2	2
19	2	2	3	2	2	2
20	3	2	2	NA	NA	NA
21	3	2	3	NA	NA	NA

22	2	2	2	2	2	3
23	2	2	2	NA	NA	NA
24	3	2	2	3	2	3
25	3	2	2	NA	NA	NA
26	3	2	2	3	2	3
27	1	2	2	NA	NA	NA
28	3	2	1	NA	NA	NA
29	1	1	1	1	1	1
30	2	2	3	2	2	2
31	2	2	2	1	1	1
32	3	2	2	NA	NA	NA
33	3	2	1	1	1	1
34	3	2	3	1	1	1
35	3	2	3	1	2	3
36	1	1	1	NA	NA	NA
37	1	1	1	2	1	1
38	1	1	1	1	1	1
39	2	2	2	NA	NA	NA
40	3	2	3	NA	NA	NA
41	1	1	1	1	1	1
42	1	1	1	NA	NA	NA
43	2	2	2	1	1	1
44	1	2	2	3	2	2
45	1	1	1	NA	NA	NA
46	2	2	1	NA	NA	NA

47	2	2	2	NA	NA	NA
48	2	2	2	NA	NA	NA
49	2	2	2	1	1	1
50	3	2	2	NA	NA	NA
51	3	2	3	NA	NA	NA
52	3	2	3	1	1	1
53	2	2	2	2	3	2
54	1	1	1	NA	NA	NA
55	1	1	2	1	2	1
56	2	2	2	NA	NA	NA
57	2	1	1	NA	NA	NA
58	1	1	1	NA	NA	NA
59	2	2	3	NA	NA	NA
60	2	2	1	2	2	3
61	1	1	2	NA	NA	NA
62	1	1	2	2	1	2
63	2	2	2	2	2	2
64	1	1	1	1	1	1
65	3	2	3	NA	NA	NA
66	1	1	1	1	1	1
67	2	2	2	2	2	2
68	1	1	2	NA	NA	NA
69	3	2	3	NA	NA	NA
70	2	2	2	2	2	2
71	2	2	2	NA	NA	NA

72	2	3	3	NA	NA	NA
73	1	2	1	2	1	1
74	3	3	2	2	2	3
75	2	3	2	2	3	3
76	3	2	2	3	3	3
77	3	3	3	3	3	3
78	2	1	1	2	2	2
79	3	2	2	2	1	3
80	2	2	2	2	2	2
Overall	**2.175**	**1.8**	**2**	**1.78**	**1.72**	**1.87**

Annex 5: Scores for the selected known extreme events

ID	Type	Location	Score	
			Spatial	Temporal
101	Drought	East Africa	2	1
102	Drought	East Africa	1	1
103	Drought	East Africa	1	1
104	Drought	East Africa	2	1
105	Drought	East Africa	2	2
106	Flood	Turkey	2	2
107	Fire	South Africa	1	1
108	Flood	South Africa	3	2
109	Drought	South Africa	1	1
110	Cold Wave	Sweden	1	1
111	Flood	Central Europe	2	2
112	Tree cover loss	North Europe	1	1
113	Drought	Russia	3	2
114	Tree cover loss	North Europe	1	1
115	Cyclon Kyrill	West-East Europe	1	1
116	Heat wave	South-East Europe	1	1
117	Tree cover loss	Central Europe	1	1
118	Tree cover loss	Central Europe	1	1
119	Heat wave	Central Europe	3	2
120	Tree cover loss	Central Europe	1	1
121	Cold wave Catalunya	Southern Europe	1	1

122	Heat wave	South-East Europe	1	1
123	Flash flood	Sudan	1	2
124	Flood	Namibia	2	3
125	Flood	Western Africa	1	1
126	Flood	Angola, Namibia and Zambia	1	2
127	Flood	Mozambique	3	2
128	Flood	Southern Africa	3	2
129	Flood	North Sea	1	1
130	Flood	Central Europe	1	1
131	Flood	Central/Eastern Europe	2	3
132	Cyclone Bondo	Madagascar	1	2
133	Cyclone Gafilo	Madagascar	3	3
134	Cyclone Hary	Madagascar	1	1
135	Cyclone Indlala	Madagascar	2	3
136	Cyclone Ivan	Madagascar	2	2
137	Cyclone Japhet	Madagascar	3	3
138	Nabro Eruption	Eritrea	1	1
139	Eyjafjallajökull Eruption	Iceland	1	1
140	Cold wave	Mainland Europe	1	1
Overall			**1,575**	**1,55**

Detecting changes in essential ecosystem and biodiversity properties- towards a Biosphere Atmosphere Change Index: BACI

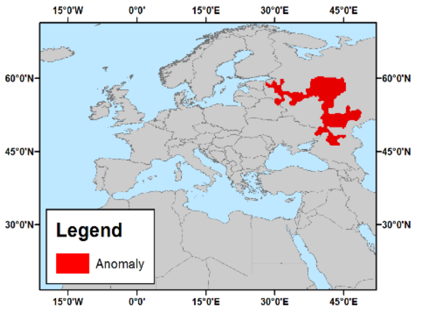
Deliverable 6.2: Product comparison and validation report Supplementary

Project title:	Detecting changes in essential ecosystem and biodiversity properties- towards a Biosphere Atmosphere Change Index
Project Acronym:	BACI
Grant Agreement number:	640176
Main pillar:	Industrial Leadership
Topic:	EO- 1- 2014: New ideas for Earth-relevant space applications
Start date of the project:	1st April 2015
Duration of the project:	48 months
Dissemination level:	Public
Responsible of the deliverable	WU
Date of submission:	31/03/2018

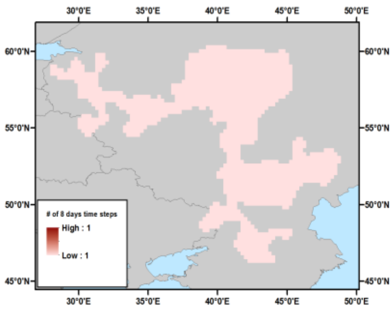
Event ID 01:

1. Attribution (internal)

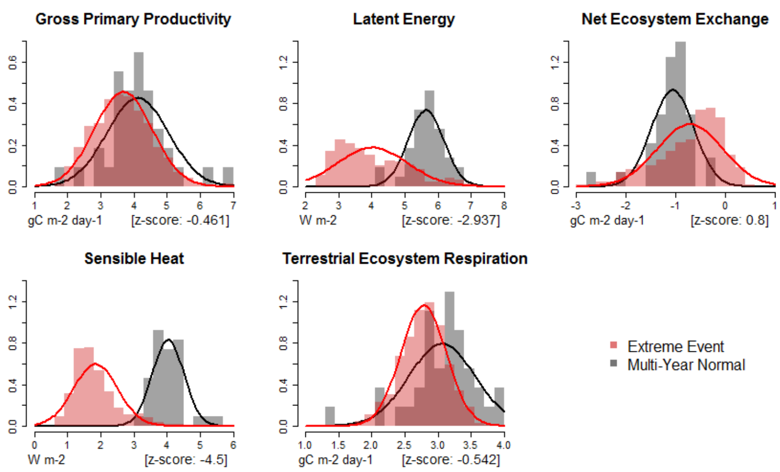
Type: Extreme event
Location: West Russia/North Ukraine
Area: 625034.4 km²
Time: 29.05.2001
Duration: 29.05.2001 – 29.05.2001



Extent of the event



# of 8 day time steps for which the event was detected

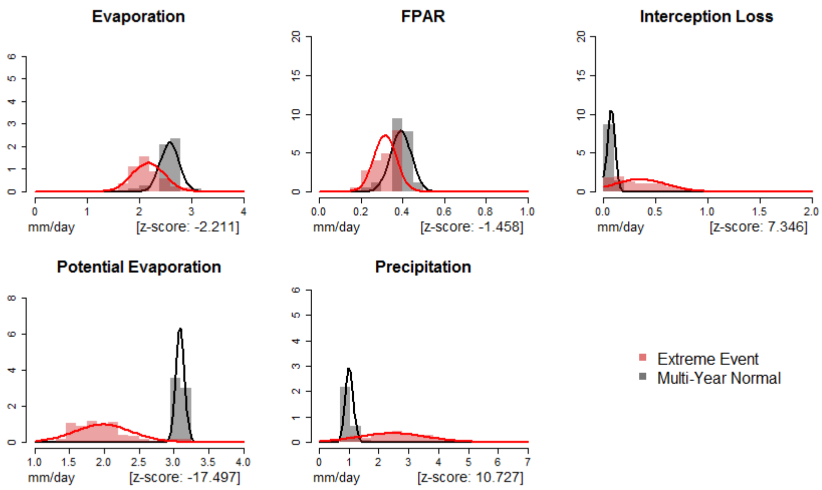


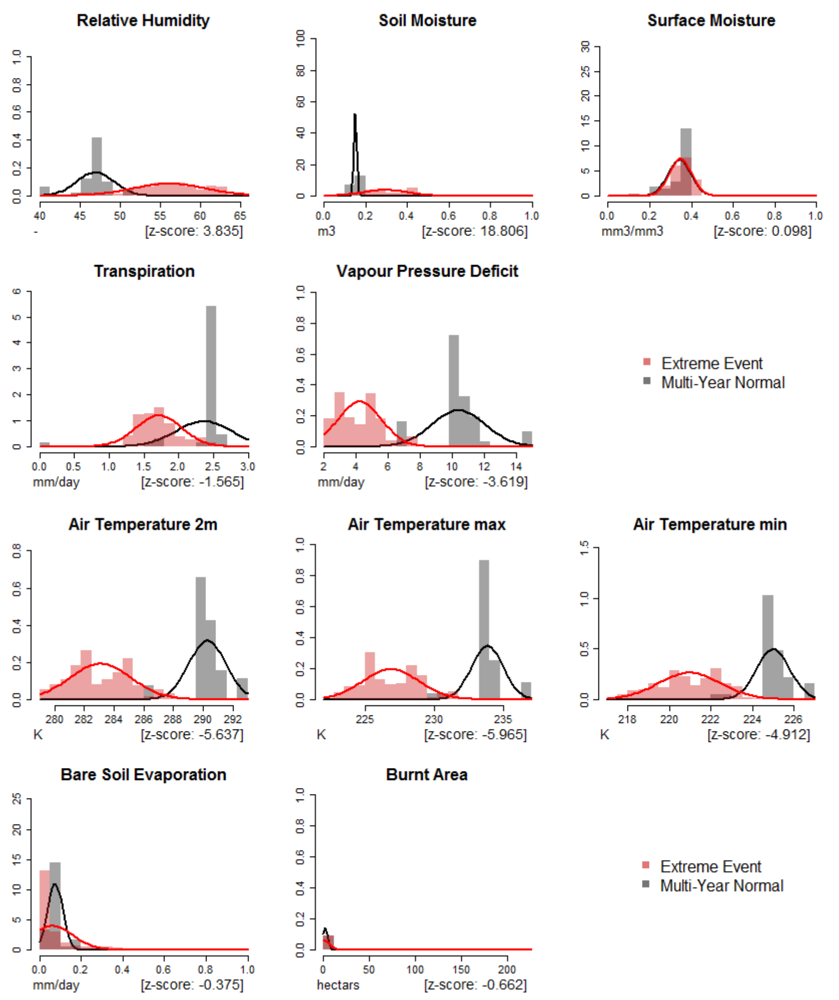
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterization hints to exceptionally low temperatures, low evapotranspiration and thus to generally unsuitable growing conditions, which supports the results of internal attribution.





3. Independent validation & regional expert feedback

Internet recherché

The international disaster database (EM-DAT) reports a cold wave for Russia in 2001. This corresponds well with the z-scores of the downstream products that reveal exceptionally low sensible and latent heat in May 2001. However, the duration and geographic extent of the reported cold wave are unclear.

Thematic precision 3: Cold wave reported in Literature and supported by external characterization

Spatial precision 2: Supported only by ext. charact.

Temporal precision 2: Supported only by ext. charact.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			3
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

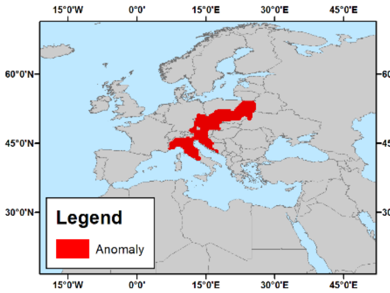
References

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

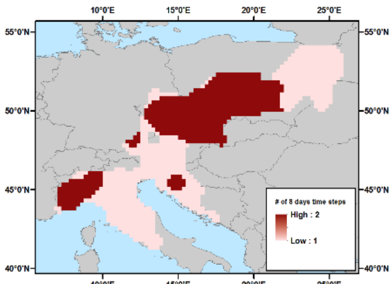
Event ID 02:

1. Attribution (internal)

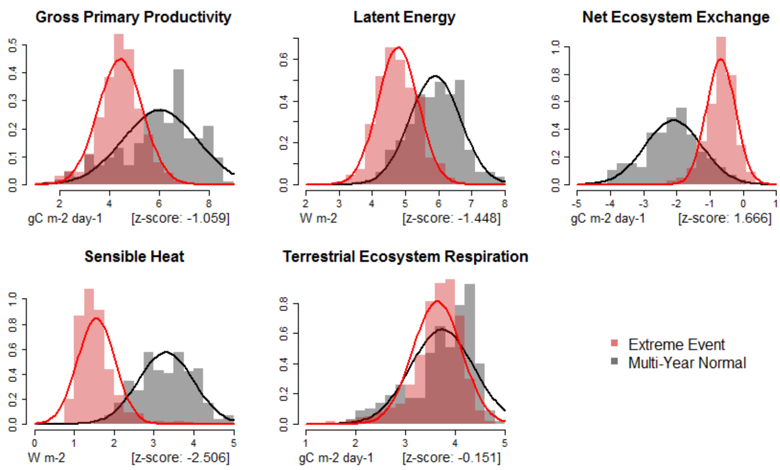
Type: Extreme event
Location: Eastern to Southern Europe
Area: 605748.4 km²
Time: 20.05.2008
Duration: 20.05.2008 – 28.05.2008



Extent of the event



# of 8 day time steps for which the event was detected

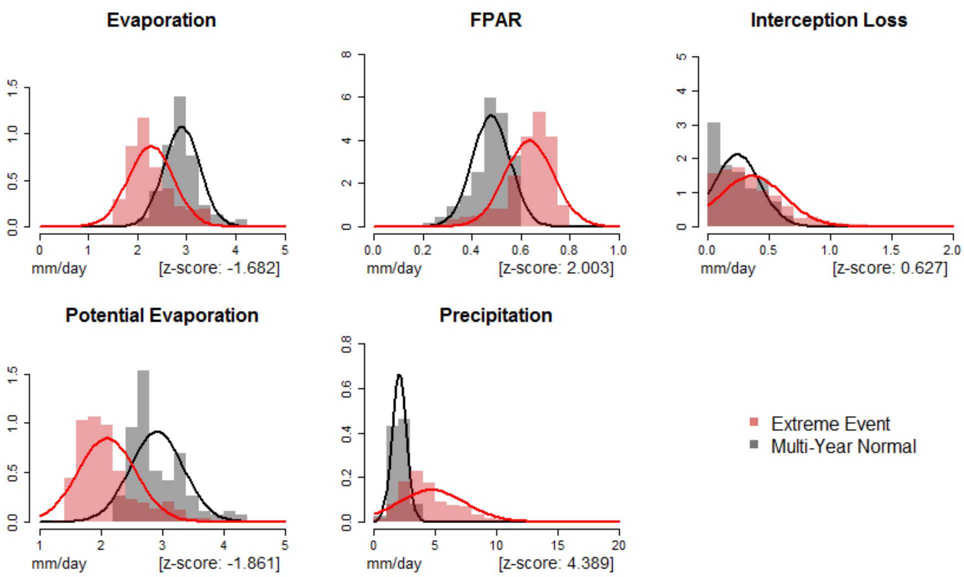


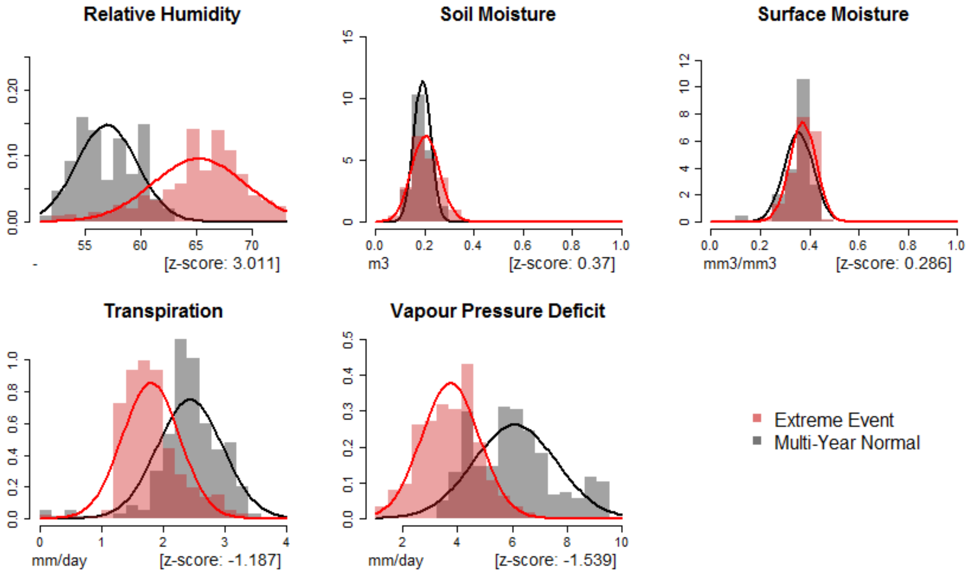
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Indication of very high humidity/precipitation, high photosynthetic activity (FPAR) and low transpiration hints to a long wet period. Interestingly FPAR was high too.





3. Independent validation & regional expert feedback

Heavy rainfalls end of May (Wiegland et al., year??) starting at 23.5.2008 and continuing for days; floods in Alpine regions of Southern Switzerland and Northern Italy; Lago Maggiore rose by 10cm in 24 hours. This is also supported by the European Severe Weather Database, which reports several events of heavy rainfall in the affected area, with several events of hail storm and even one tornado located in the Czech Republic (ESWD, 2013).

MODIS NDVI trends do not show very low vegetation activity around day 141, which contradicts attribution findings of low GPP (Figure 1)

Gridded harvest data (WP 7.3 upcoming report) shows a relatively good year of biomass harvest in 2008, probably as a result of higher precipitation (Figure 2).

Apparently, socio-economic effects of the BACI-event were mixed, including positive (higher harvest) and negative (floods, landslides) feedbacks to the socio-economic system.

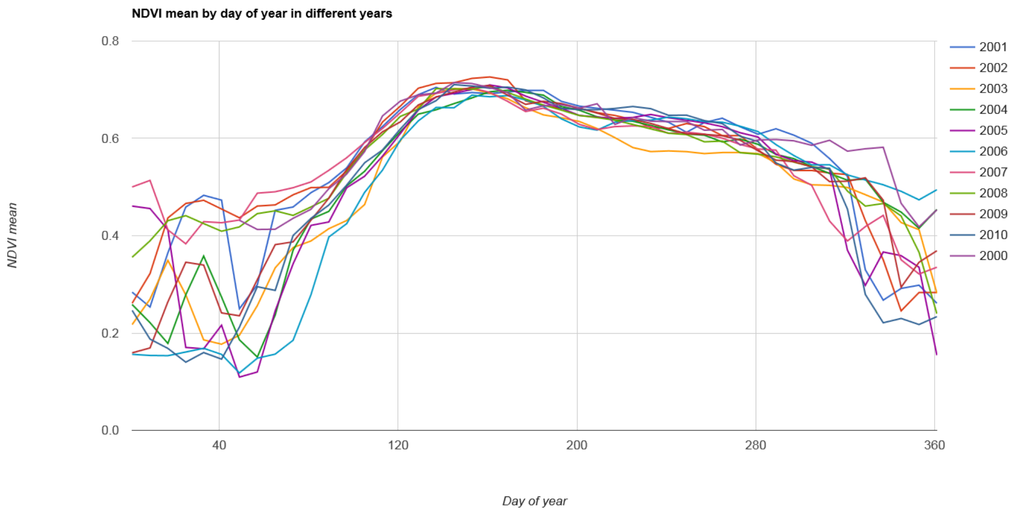


Figure 1: MODIS NDVI trends

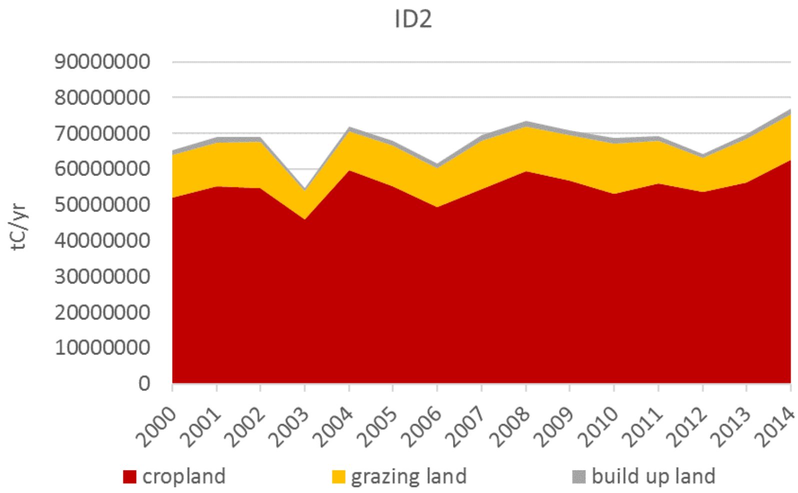


Figure 2: Time-line results on biomass harvest in the extreme event (refer to WP 7.3., upcoming report). Note that temporal resolution is one year.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

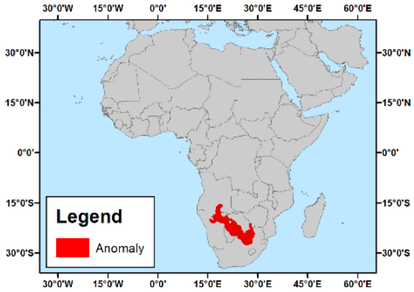
Wiegland et al.: An unusual Saharan dust outbreak into central Europe and heavy precipitation at the southern side of the Alps in May 2008: A TIGGE case study

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

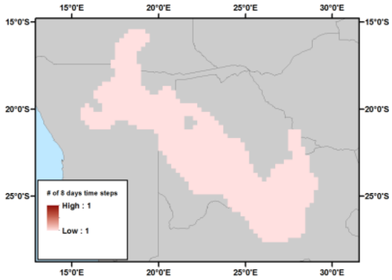
Event ID 03:

1. Attribution (internal)

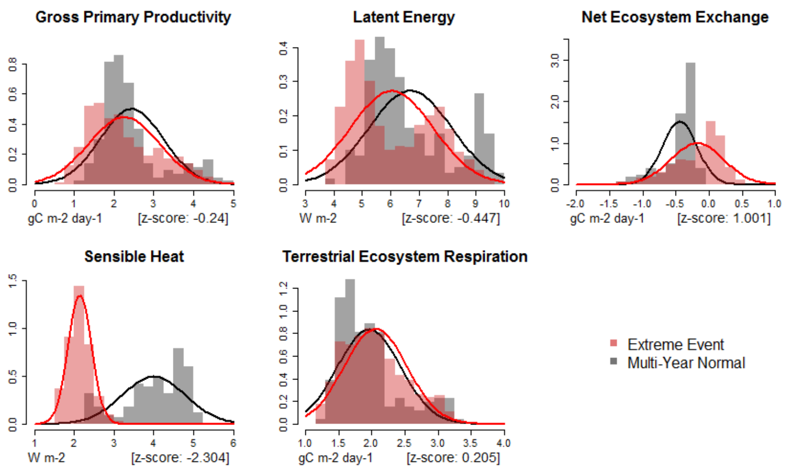
Type: Extreme event
Location: southern Africa
Area: 596916.4 km²
Time: 17.03.2008
Duration: 17.03.2008 – 17.03.2008



Extent of the event



# of 8 day time steps for which the event was detected



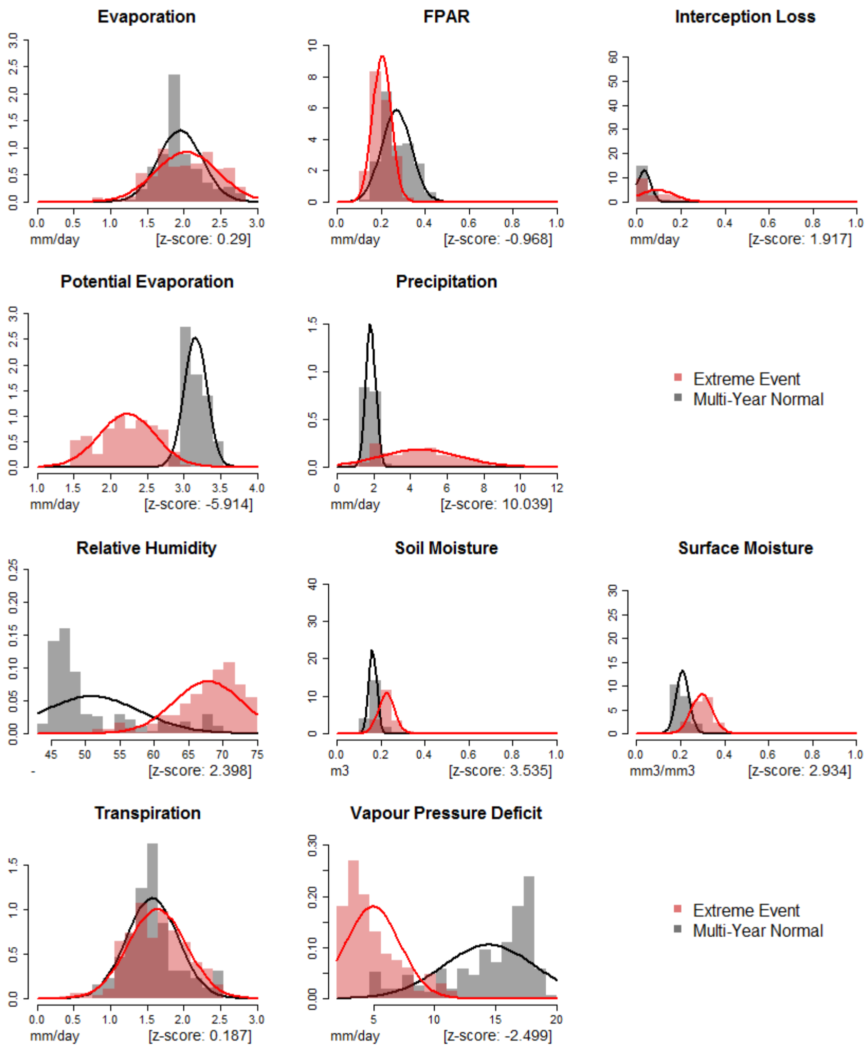
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Potential Flood Event:

- parameters such as potential evaporation, relative humidity, soil moisture and vapour pressure deficit show significant anomaly for this time step



3. Independent validation & regional expert feedback

Intense Seasonal Floods in Southern Africa
(Source: https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19501)

- increasing rainfall in beginning of 2008 (Figure 1)
- 120.000 people displaced by due to flooding event

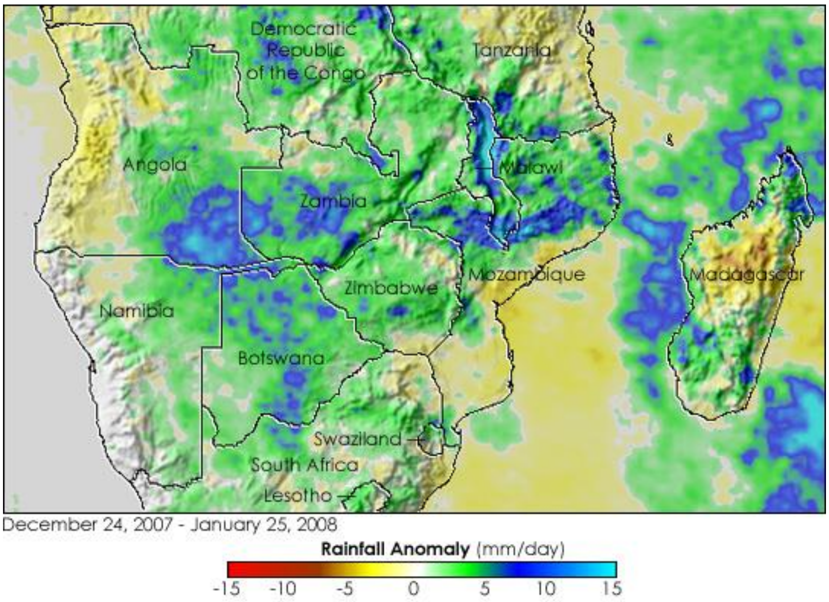


Figure 1. Difference of total rainfall measured between December 24, 2007, and January 25, 2008.
(Source: https://eoimages.gsfc.nasa.gov/images/imagerecords/19000/19501/SouthernAfrica_TRM_2008025.jpg)

Floods in Namibia
(Source: https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19691

- Effects in Namibia due to intense rainfall early 2008
- In Namibia, the flood started early February 2008 (Figure 2)

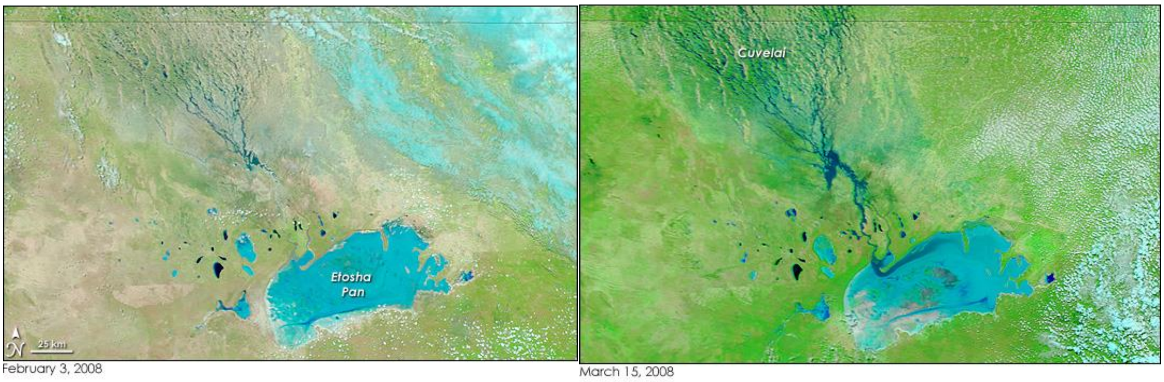


Figure 2. Water Level of Cuvelai between February and March 2008.
(Source: https://eoimages.gsfc.nasa.gov/images/imagerecords/19000/19691/Namibia_TMO_2008075.jpg)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision	**X**		
Temporal precision		**X**	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

References

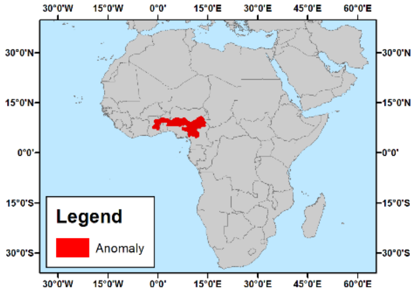
https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19501

https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19691

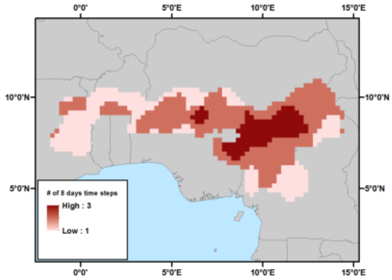
Event ID 04:

1. Attribution (internal)

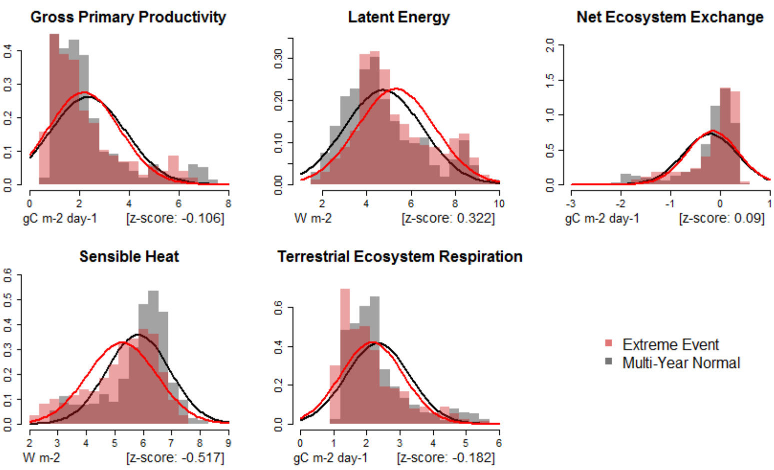
Type: Extreme event
Location: Western Africa
Area: 581908.6 km²
Time: 18.03.2010
Duration: 18.03.2010 – 03.04.2010



Extent of the event

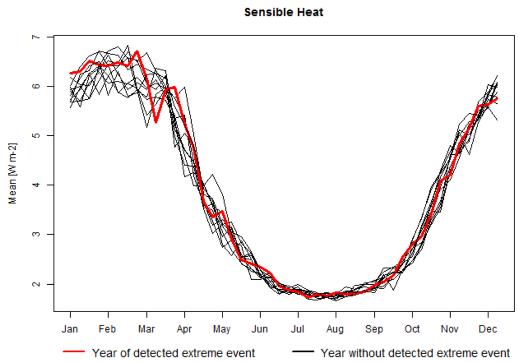


# of 8 day time steps for which the event was detected

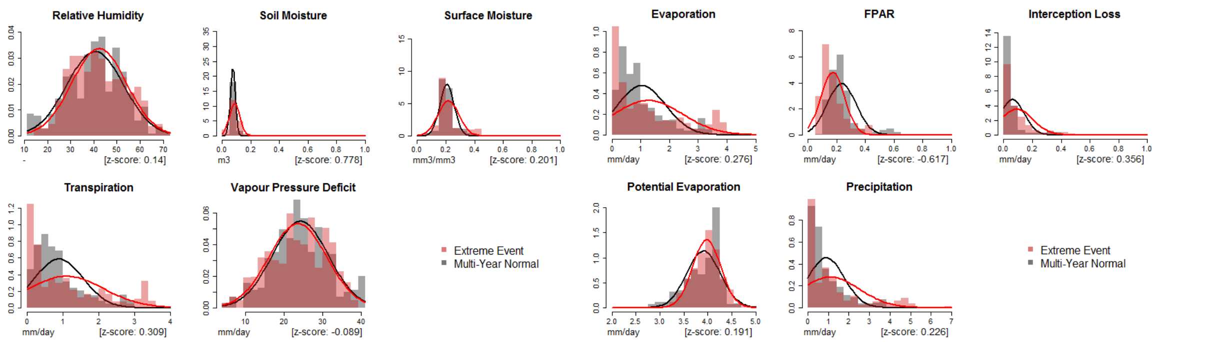


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



2. External characterisation



- CABLAB data shows higher amounts of soil moisture, surface moisture and relative humidity compared to the expected amounts during that time
- Additionally the potential evaporation, precipitation are higher, whereas FPAR is lower indicating too much water respectively more rain during that time period

3. Independent validation & regional expert feedback

- In Nigeria, displacement of people following heavy rains. (Internal displacement monitoring centre 2011)
- Floods across Niger which left over 111,000 people homeless in 2010. (Anonymous 2010)
  - highest levels in 80 years
- The floods along the River Niger (Nigeria, Ghana, Burkina Faso, Togo and Benin) (Figure below) (Anonymous 2017)

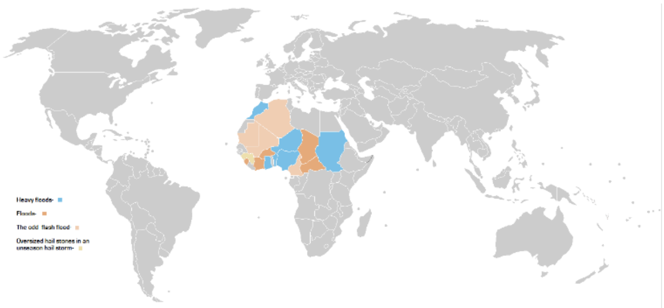


Figure 1 2010 African floods (Anonymous 2017)

- flooding caused damages and inundation resulting in loss of lives and properties (Nigerian Meterological Agency 2011:29)
- Very high temperatures in the north and high precipitation in the south caused a massive water and humidity (Nigerian Meterological Agency 2011:25)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	

	Temporal precision	**X**	

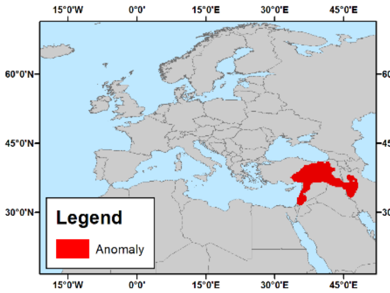
References

- Internal displacement monitoring centre (2011): Displacement due to natural hazard-induced disasters. NRC, Geneva (Switzerland).
- Anonymous (2010): Thousands left homeless in Niger. Last access (15.03.2018). Standing (29.08.2010). <http://www.aljazeera.com/news/africa/2010/08/2010824133834821879.html>
- Anonymous (2017): 2010 West African floods. Last access (15.03.2018). Standing (13.11.2017). <https://en.wikipedia.org/wiki/2010_West_African_floods#cite_note-1>
- Nigerian Meterological Agency (2011): Nigeria Climate Review Bulletin 2010, Maitama-Abuja (Nigeria).

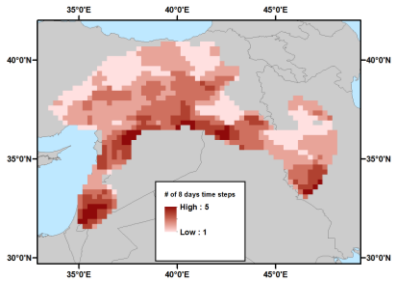
Event ID 05:

1. Attribution (internal)

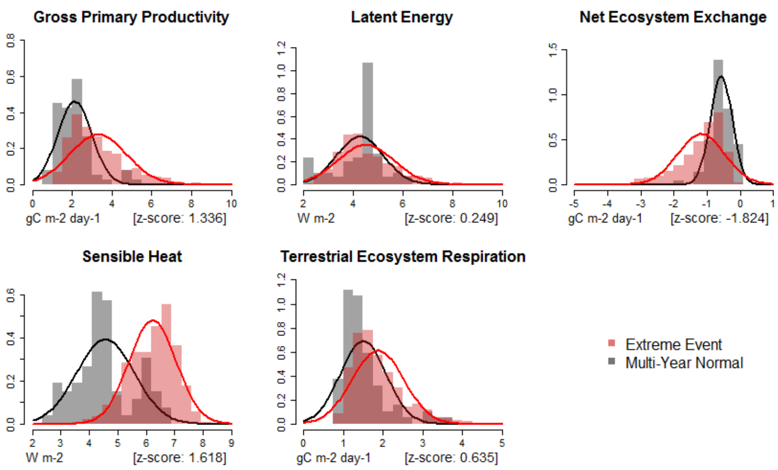
Type: Extreme event
Location: East Turkey/ Levante
Area: 542527.1 km²
Time: 05.05.2003
Duration: 03.04.2003 – 05.05.2003



Extent of the event



# of 8 day time steps for which the event was detected



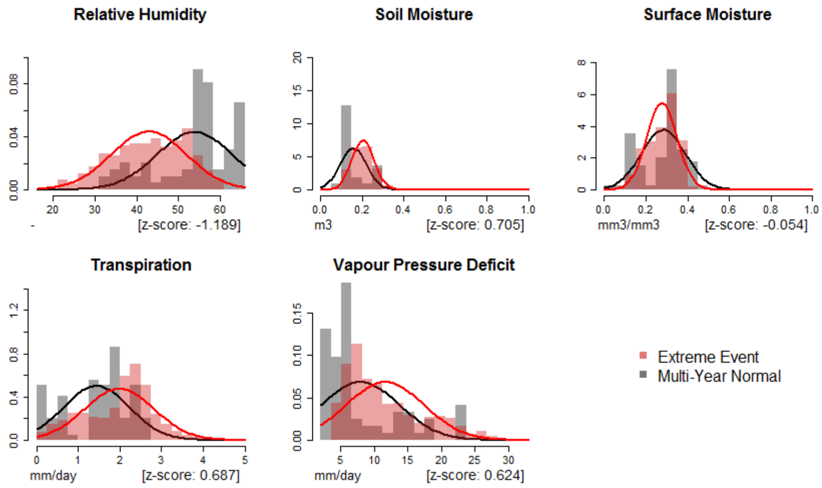
Extreme event vs. multi-year normal distribution of BACIndex input parameters

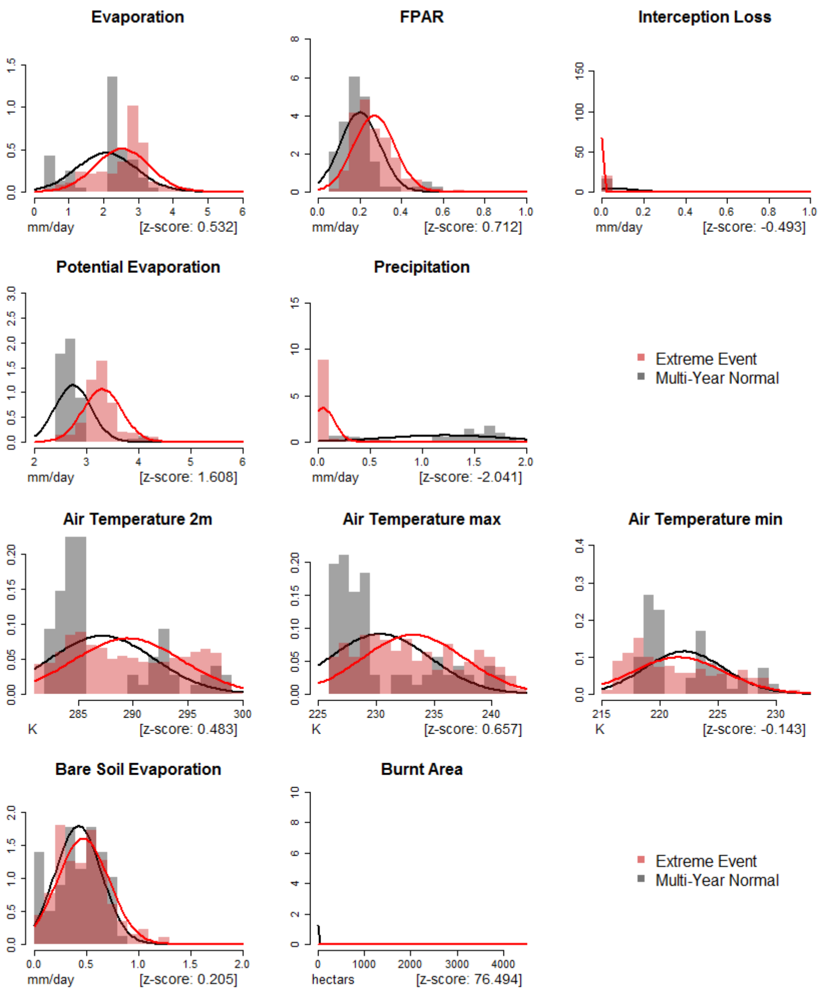
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

2. External characterisation

The external characterisation indicates high soil moisture and above average FPAR, which supports the internal attribution, which records above average GPP. Results on Temperature, however, do not correspond with high sensible heat in the internal attribution.





3. Independent validation & regional expert feedback

The literature does not mention any extreme event in terms of socio-economic feedbacks in this period. However, the MODIS NDVI time series supports a peak in plant growth, while annual harvest in the area was normal.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**x**	
Spatial precision		**x**	
Temporal precision		**x**	

Regional expert based evaluation

	1	2	3

of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**	
	Spatial precision	
	Temporal precision	

References

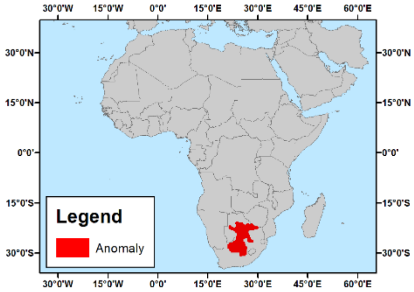
EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

European Forest Fire Information System (EFFIS). Applications. Fire History. http://effis.jrc.ec.europa.eu/applications/fire-history/ (accessed 06.02.2018)

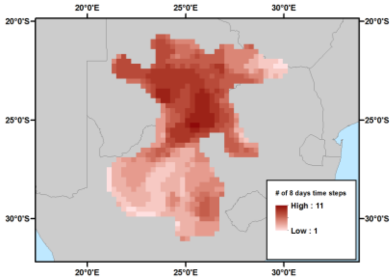
Event ID 06:

1. Attribution (internal)

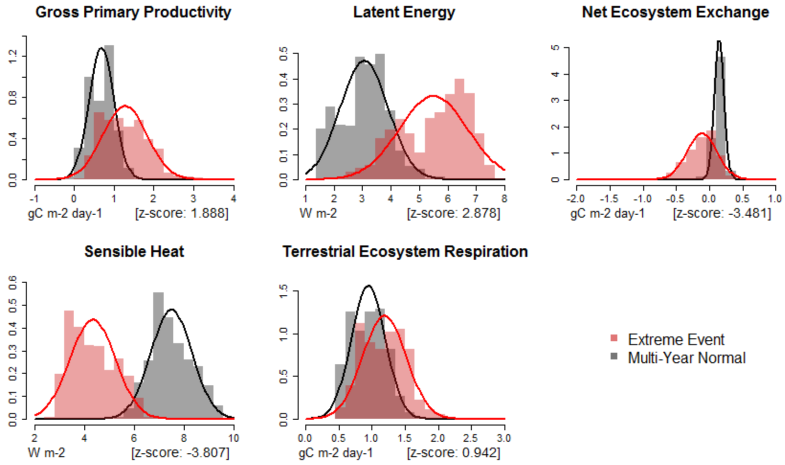
Type: Extreme event
Location: southern Africa
Area: 536752.9 km²
Time: 13.11.2001
Duration: 28.10.2001 – 13.01.2002



Extent of the event



# of 8 day time steps for which the event was detected



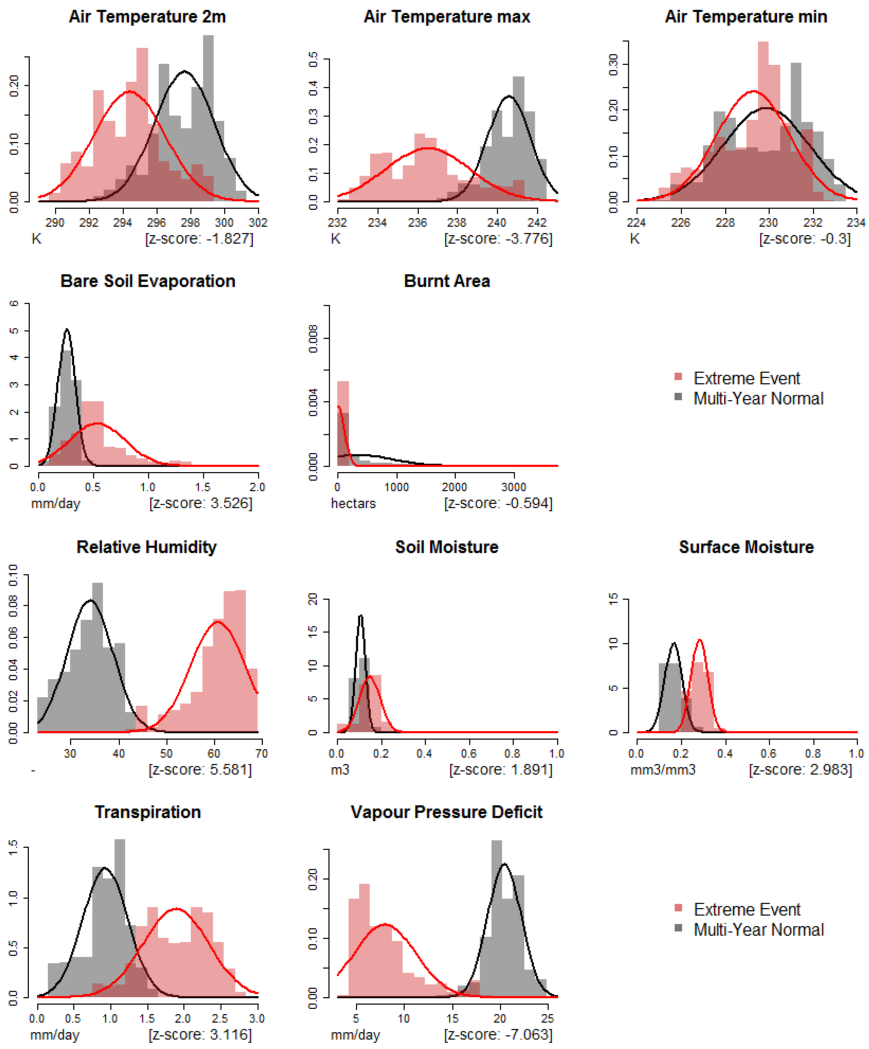
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Unknown Event:

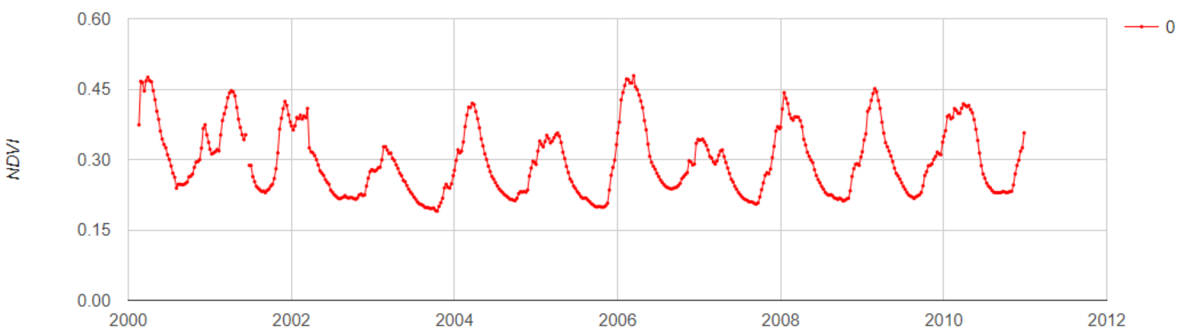
- parameters such as air temperature, humidity, transpiration and vapour pressure deficit show significant anomaly for this time step



3. Independent validation & regional expert feedback

Unknown Event:

- LST and NDVI show depression in time period of detected anomaly (Figure 1)



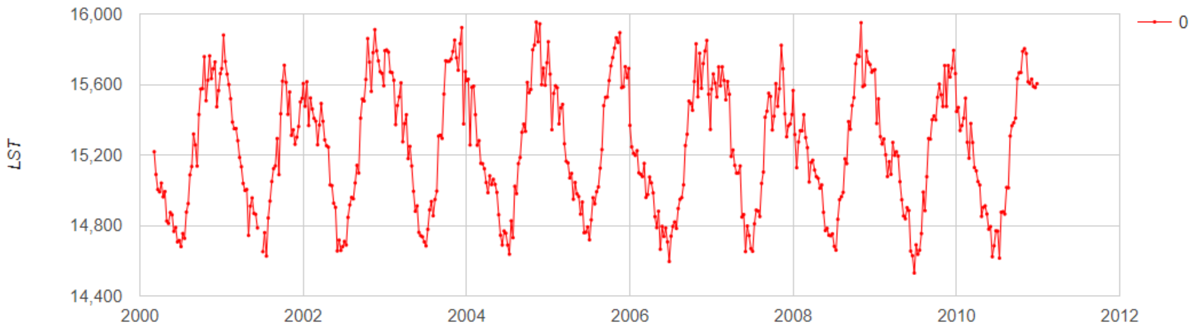


Figure 1. NDVI and LST temporal profile of anomaly region.
(Source: Google Earth Engine)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision			X

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

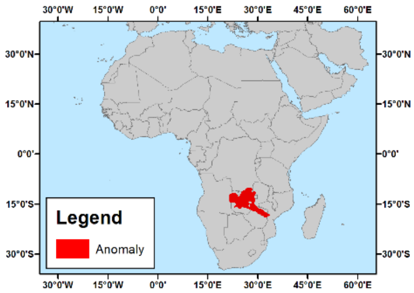
	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

References

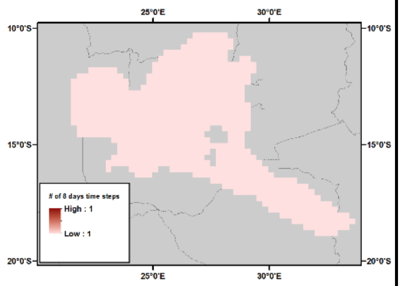
Event ID 07:

1. Attribution (internal)

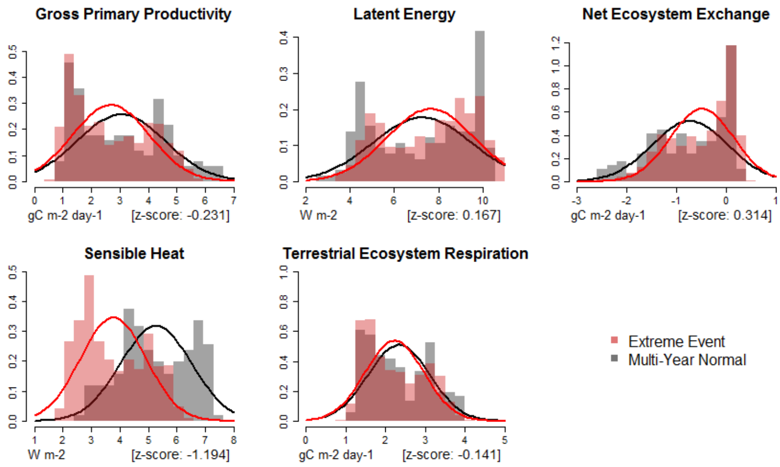
Type: Extreme event
Location: southern Africa
Area: 500429.0 km²
Time: 28.10.2002
Duration: 28.10.2002 – 28.10.2002



Extent of the event



# of 8 day time steps for which the event was detected

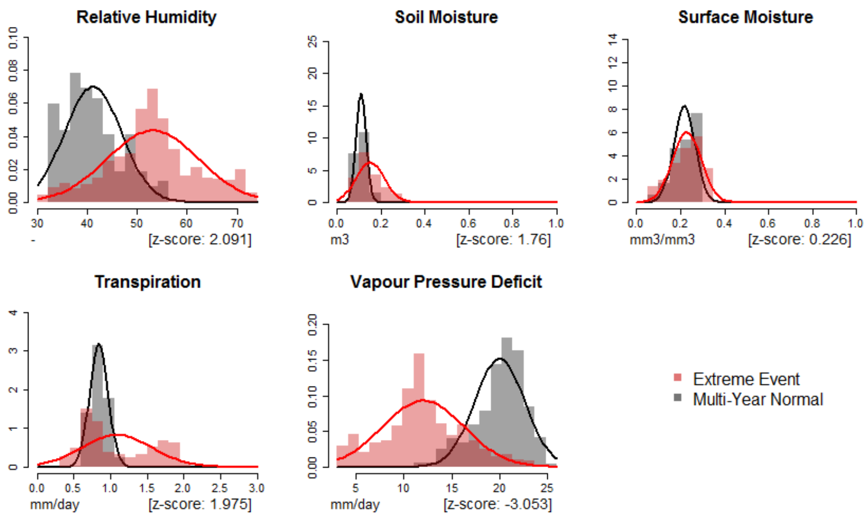


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.



3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		
Temporal precision	x		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

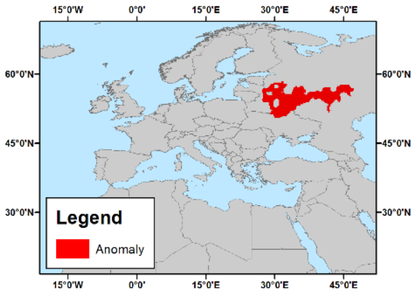
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

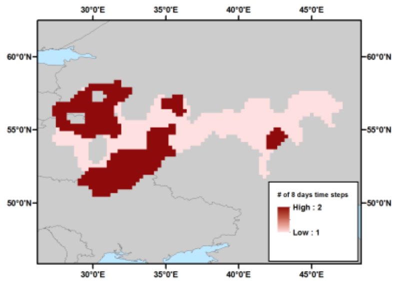
Event ID 08:

1. Attribution (internal)

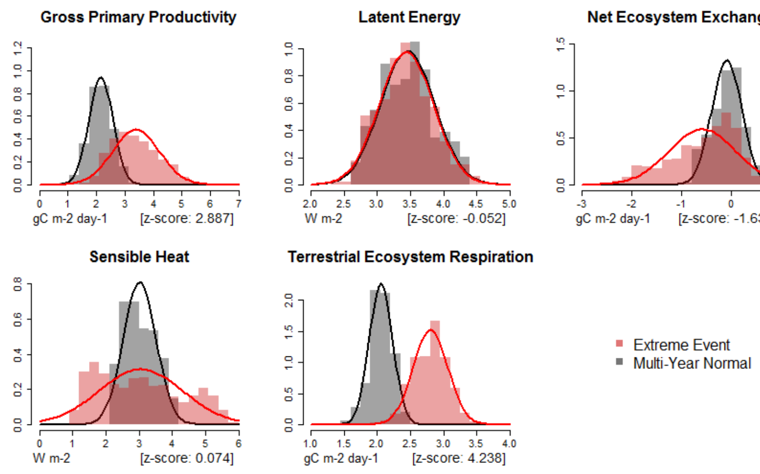
Type: Extreme event
Location: Western Russia, Eastern Belarus, Northern Ukraine
Area: 485062.7 km²
Time: 27.04.2001
Duration: 27.04.2001 – 05.05.2001



Extent of the event



# of 8 day time steps for which the event was detected

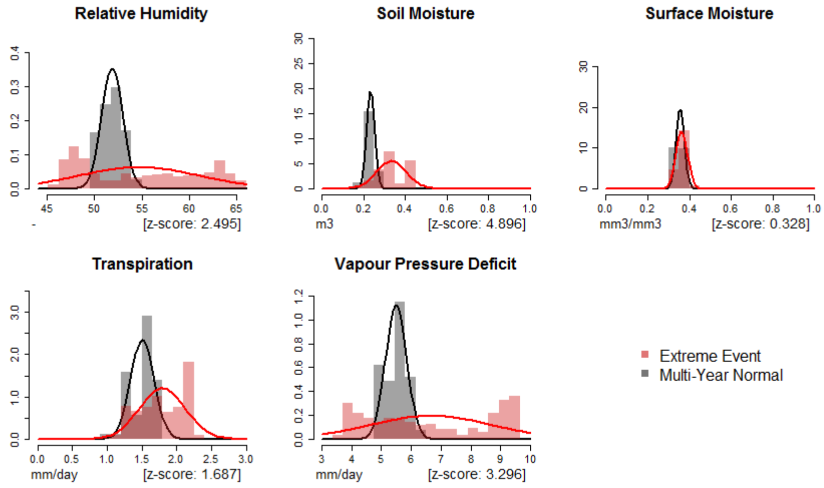


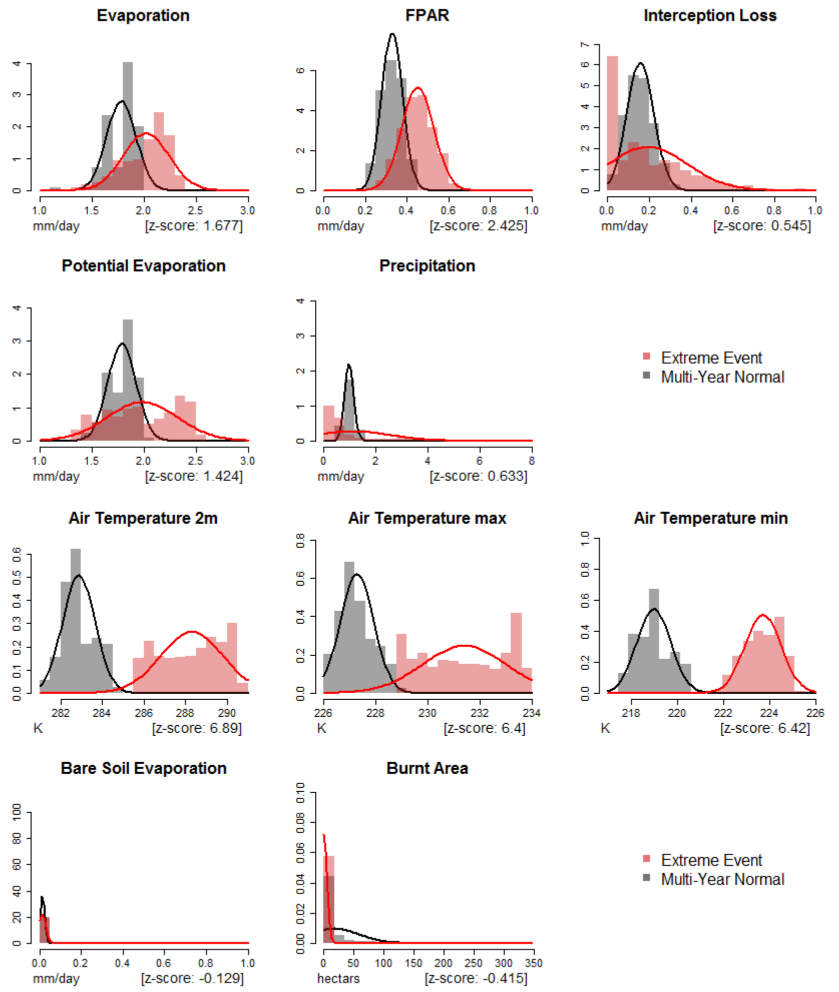
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation supports findings of high GPP and TER by indicating humid conditions, high evapotranspiration and above average temperatures and FPAR, which promotes plant growth.





3. Independent validation & regional expert feedback

No external validation for extreme conditions for the given time frame could be found, but weather archives confirm above average temperatures for the region.

Apparently, the good weather conditions led to a relatively good year of biomass harvest in 2001 compared to 2000 and 2002 (Figure 1)

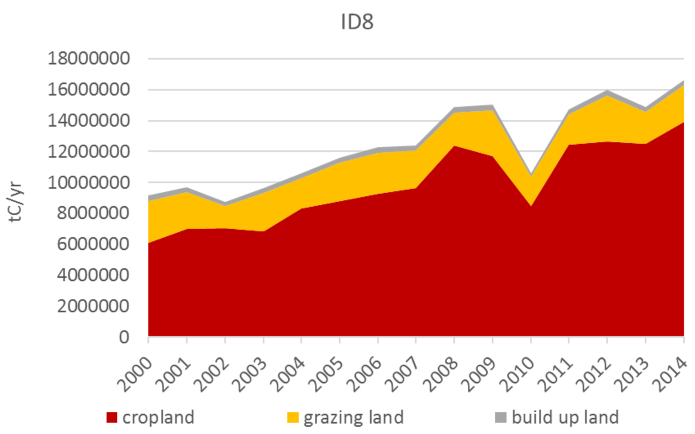


Figure 1: Annual biomass harvest in the extreme event. Results from WP7.3. (upcoming report)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**x**
Spatial precision		**x**	
Temporal precision			**x**

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

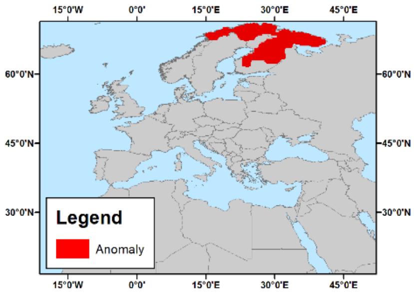
References

Weather Underground. History for Vitebsk. https://www.wunderground.com/history/airport/UMII/2001/5/1/DailyHistory.html?req_city=Wizebsk&req_state=VI&req_statename=Belarus&reqdb.zip=00000&reqdb.magic=1&reqdb.wmo=26666 (accessed 05.02.2018)

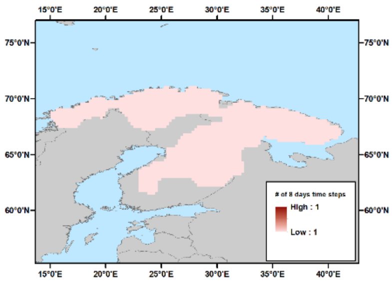
Event ID 09:

1. Attribution (internal)

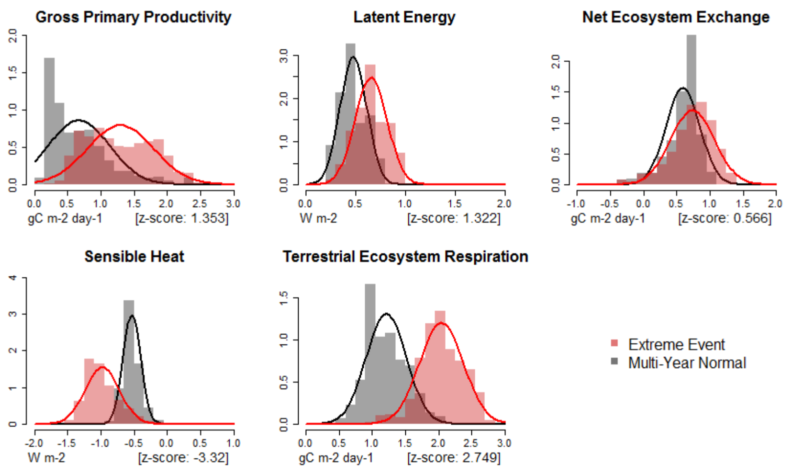
Type: Extreme event
Location: Northern Scandinavia, North-western Russia
Area: 476099.7 km²
Time: 12.10.2005
Duration: 12.10.2005 – 12.10.2005



Extent of the event



\# of 8 day time steps for which the event was detected

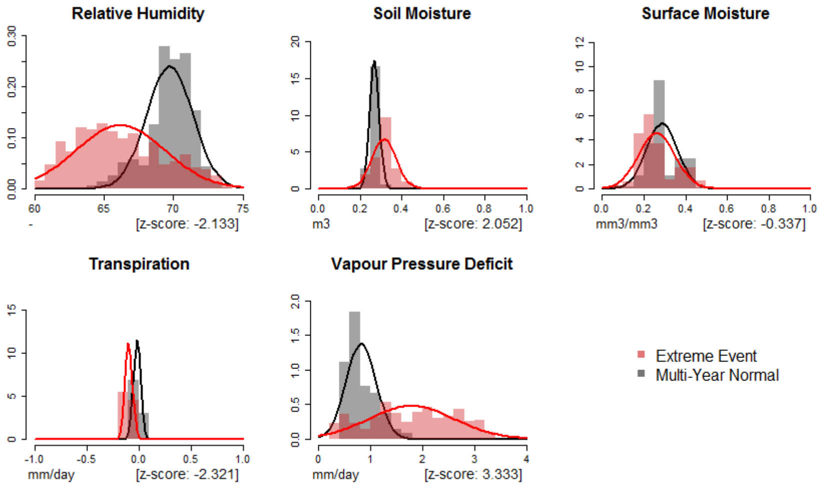


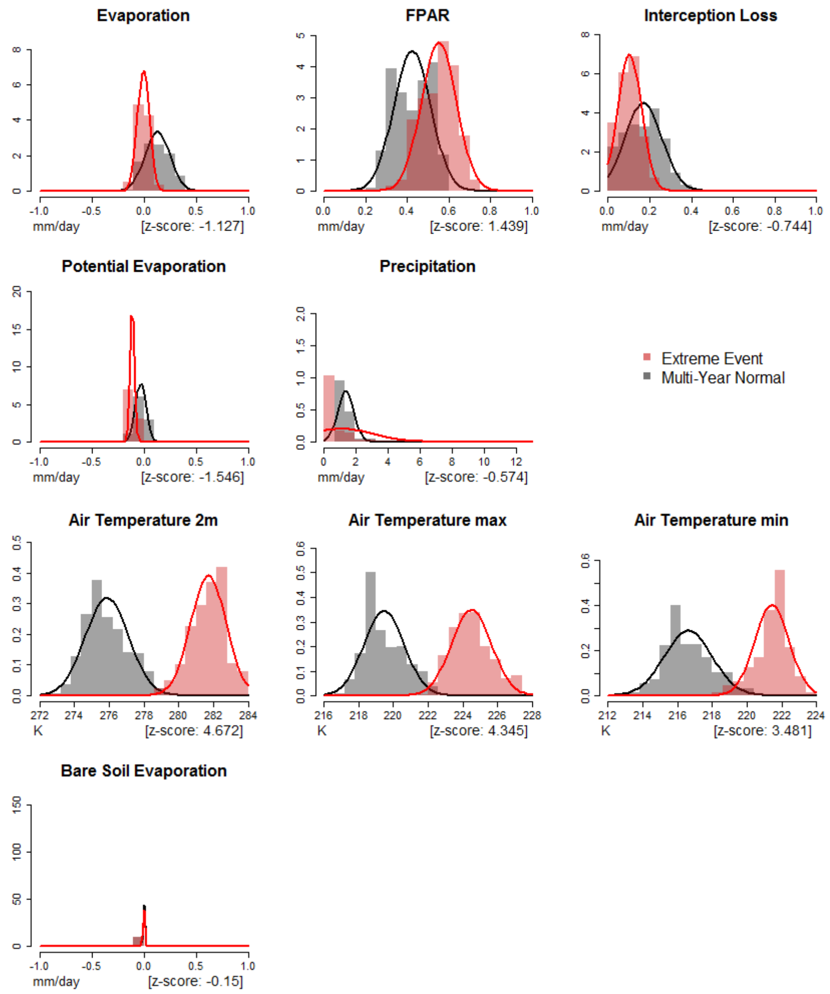
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation suggests above average temperatures, low evapotranspiration and high soil moisture and FPAR, hinting to good growing conditions, which confirms the results of the internal attribution.





3. Independent validation & regional expert feedback

Autumn 2005 presented record-breaking warm temperatures in the North of Europe. On October 11th several Norwegian weather stations reported temperatures well above 20°C during the day. Overall, 2005 is ranked as the 5th to 8th warmest year since regular measurements began in many Nordic countries.
Russia also experienced very warm conditions in 2005 in general with autumn 2005 being the hottest autumn on record for Russia. However, the given region is not amongst those exhibiting the biggest anomalies (figure 1) (Shein 2006).

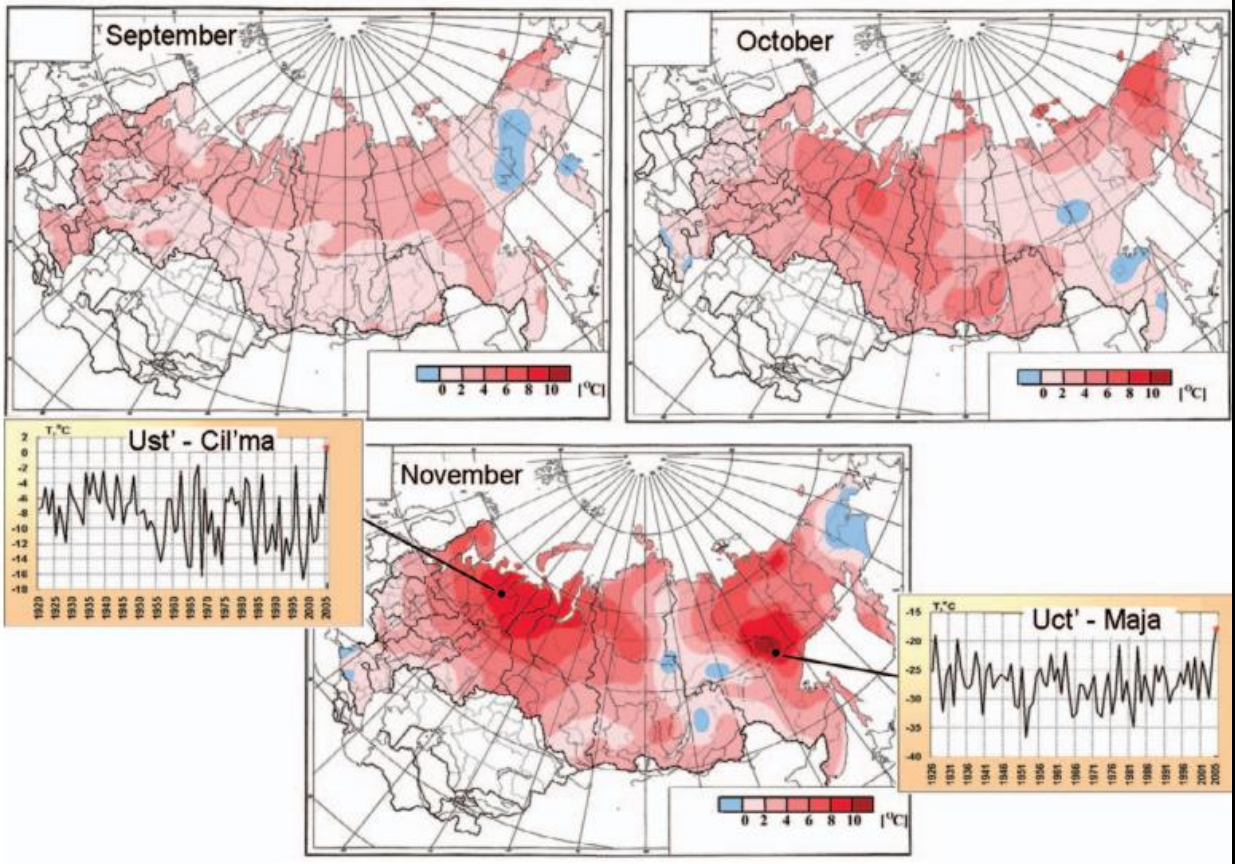


Figure 1: Russian air temperature anomalies (°C) in autumn 2005. The figure is taken from Shein (2006).

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision			x

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

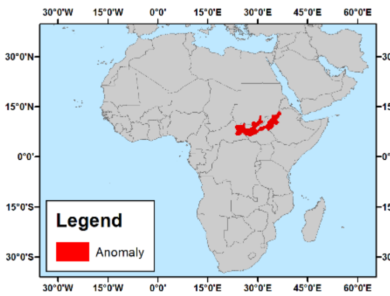
References

Shein, K.A. (Ed.), 2006: State of the Climate in 2005. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-87-6-shein (accessed 07.02.2018)

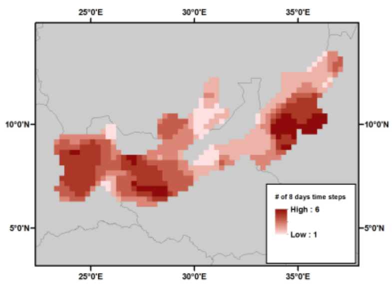
Event ID 10:

1. Attribution (internal)

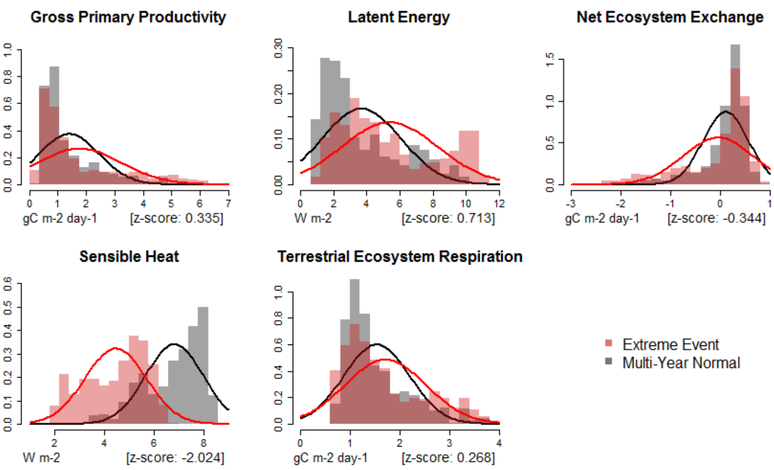
Type: Extreme event
Location: Eastern Africa
Area: 460551.7 km²
Time: 10.04.2008
Duration: 02.04.2008 – 20.05.2008



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

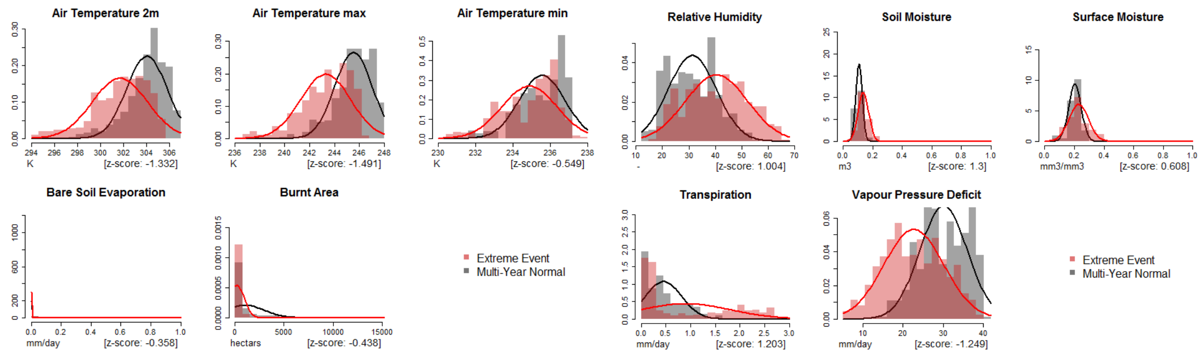


Figure 1 Additional CABLAB data not used for calculating the BACIndex

- The external characterization of additional CABLAB data not used for calculating the BACIndex showed lower temperatures in general (figure 1) and considerable higher relative humidity, soil moisture and surface moisture indicating better environmental conditions for plants to grow compared to the usual time period.

3. Independent validation & regional expert feedback

- Usually high temperatures were considerable lower compared to other years resulting in better growing conditions for vegetation (Anonymous 2009)
- Analysis of MODIS NDVI time series from 2001 to 2010 carried out via Google EarthEngine indicate

better growing conditions of vegetation by higher NDVI values during that time period in 2008 (Figure 2)

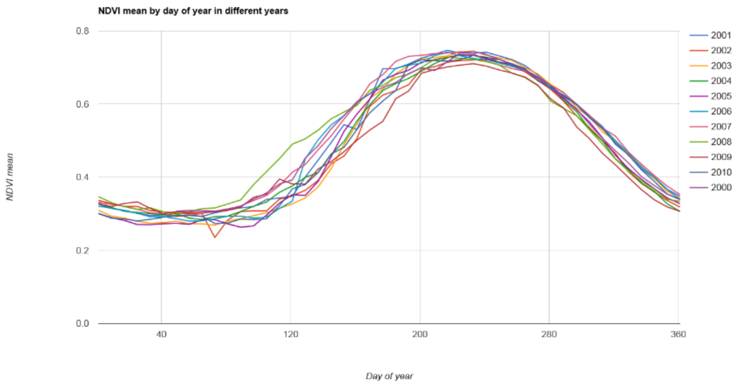


Figure 2 MODIS NDVI trend analysis for each year of 2000 to 2010

- This trend is also visible by a study evaluating yield growing patterns in Ethiopia for 2008, where agricultural fields in the south-western part of the country delivering very good yields for that year (figure 3) (ADDS 2008)

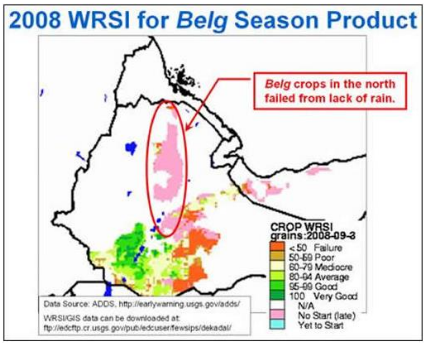


Figure 3: WRSI for Belg Season Product 2008 (ADDS 2008)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision			X

Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision		X	

Regional expert based evaluation

	1	2	3

(2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision			**X**

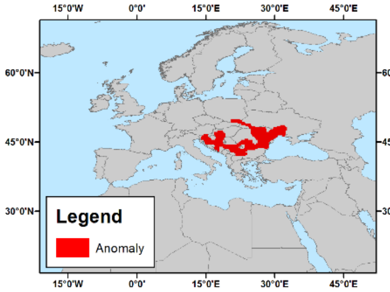
References

1. Anonymous (2009):Climate – South Sudan. Last Asscess (15.03.2018). Standing (16.09.2009).https://www.climatestotravel.com/climate/south-sudan.
2. ADDS (2008): Early Warning and Environmental Monitoring Program. Last Asscess (15.03.2018). Standing (28.06.2016). <htttp://earlywarning.usgs.gov/adds>.

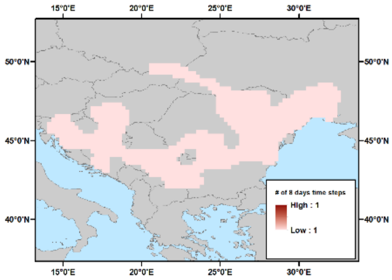
Event ID 11:

1. Attribution (internal)

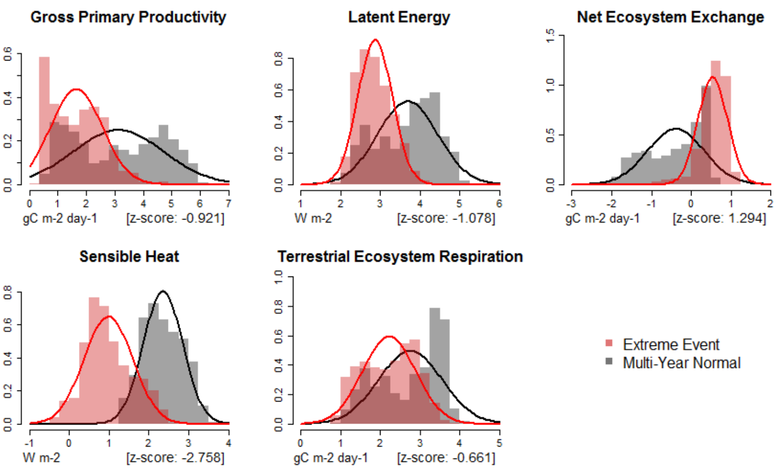
Type: Extreme event
Location: South-eastern Europe
Area: 460379.2 km²
Time: 17.09.2008
Duration: 17.09.2008 – 17.09.2008



Extent of the event



# of 8 day time steps for which the event was detected

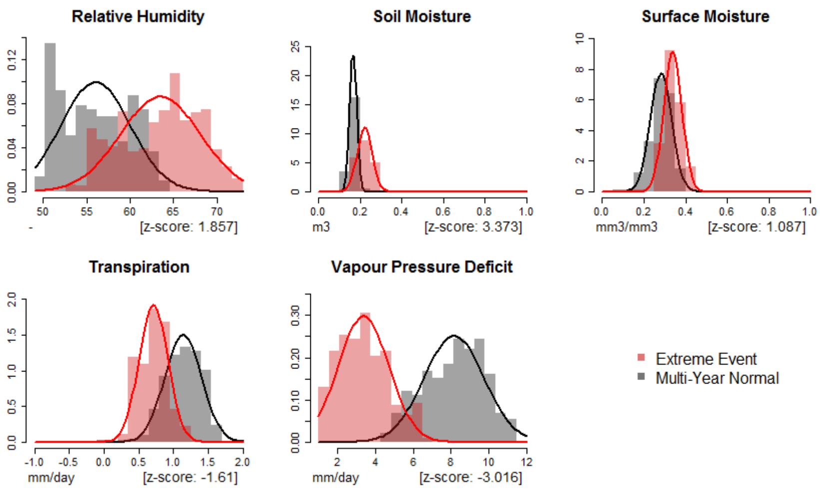


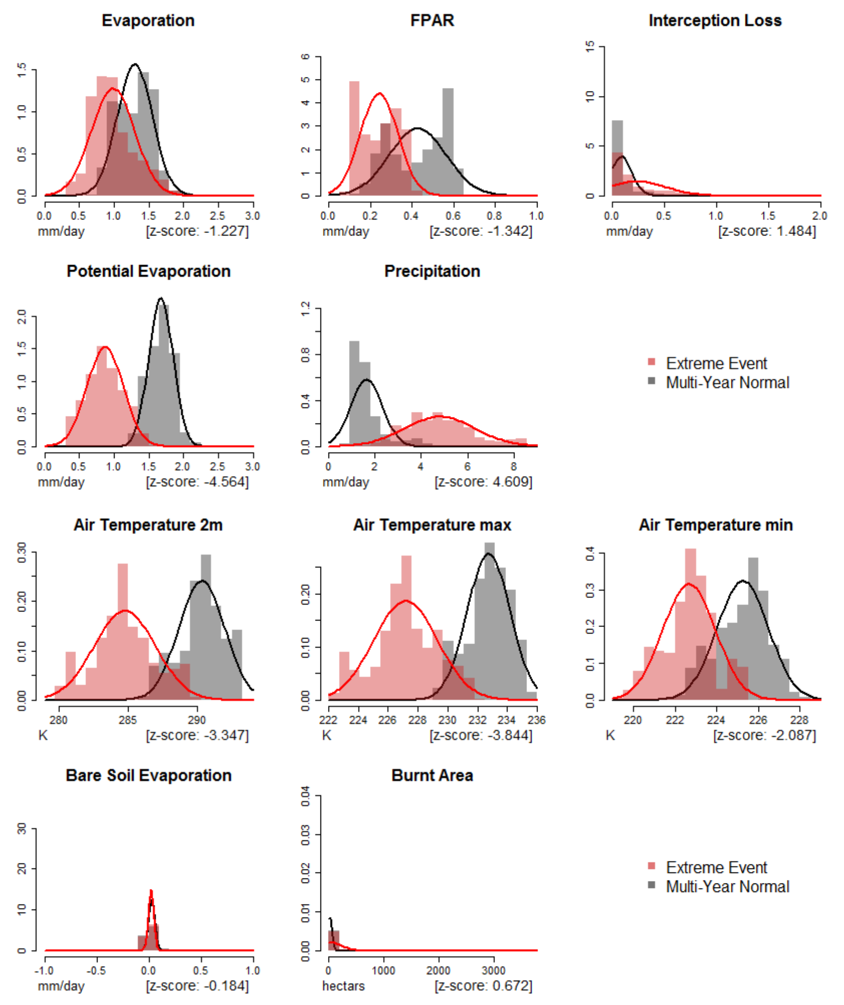
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Indications of low temperatures, low evapotranspiration and therefore unsuitable growing conditions support the findings of the internal attribution.





3. Independent validation & regional expert feedback

For many areas of South-eastern Europe September was the only month of 2008 that was cooler than average. Serbia experienced a heat wave at the beginning of the month but then had cooler conditions in the second half of September (Peterson and Baringer 2009)

September was exceptionally wet in Bulgaria (Peterson and Baringer 2009), with a hailstorm reported for September 18th in Bulgaria (ESWD 2013).

MODIS-NDVI time series support a drop in plant activity in the respective period (Figure 1).

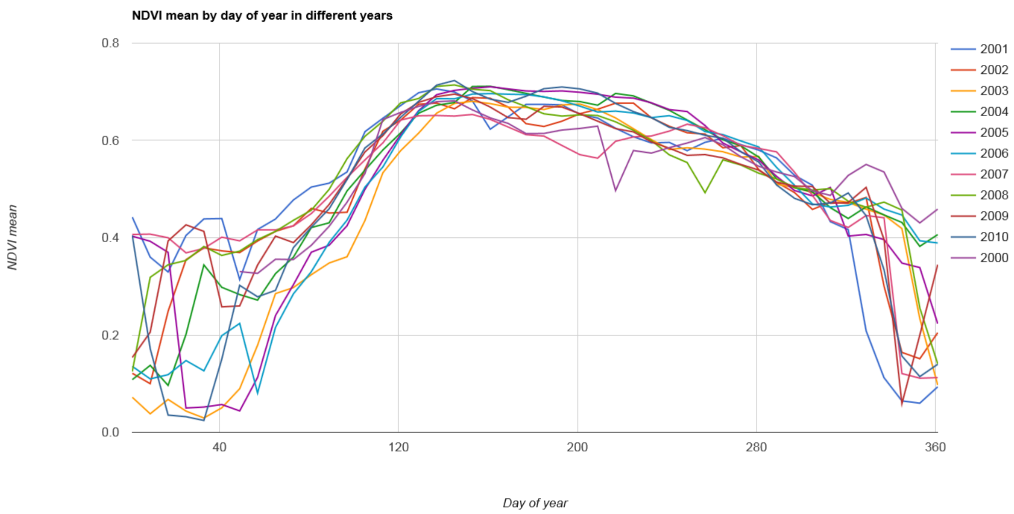


Figure 1: MODIS-NDVI time series in the BACI-event calculated as mean by day compared between the years.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

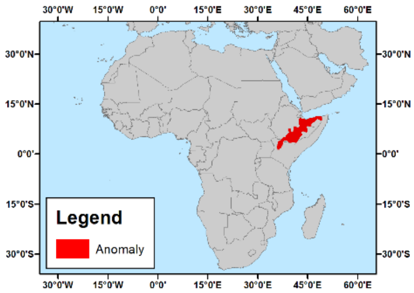
European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

Peterson, T.C., Baringer M.O. (Eds.), 2009: State of the Climate in 2008. Special Supplement to the Bulletin of the American Meteorological Society. Vol. 90, No. 8, August 2009. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-90-8-StateoftheClimate (accessed 07.02.2018)

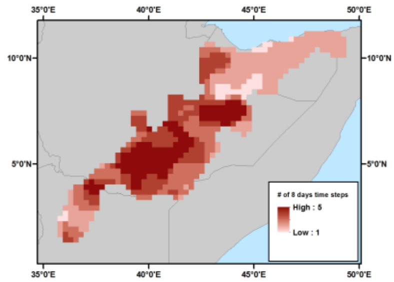
Event ID 12:

1. Attribution (internal)

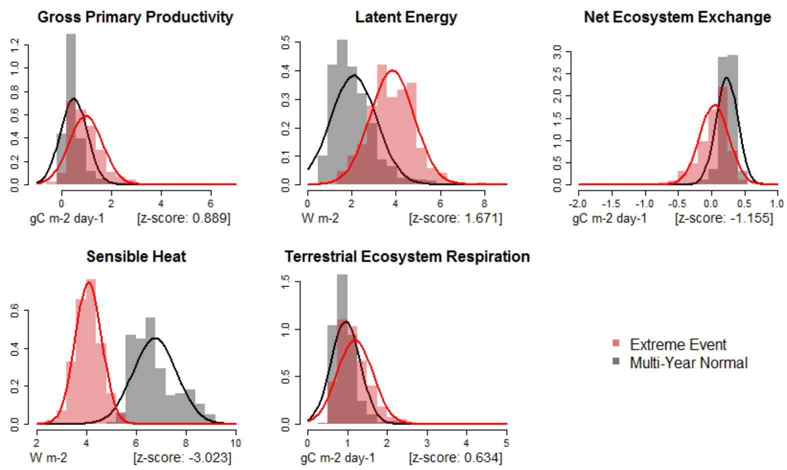
Type: Extreme event
Location: Eastern Africa
Area: 455282.7 km²
Time: 02.03.2010
Duration: 02.03.2010 – 03.04.2010



Extent of the event



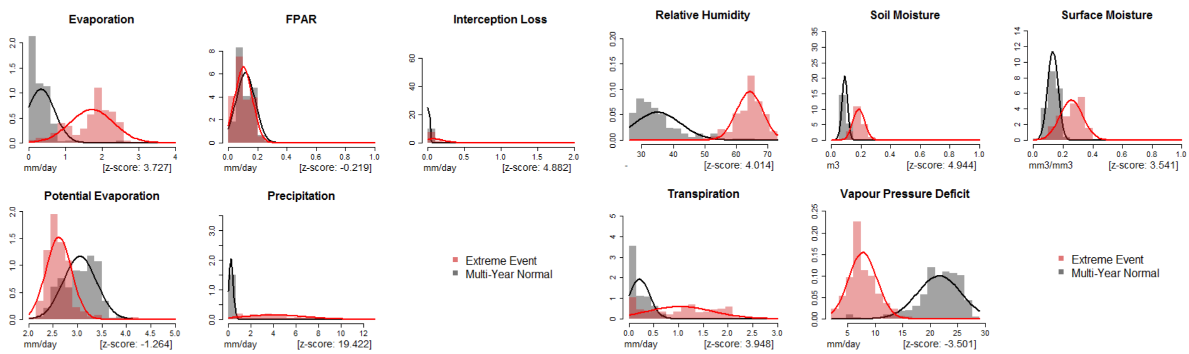
# of 8 day time steps for which the event was detected

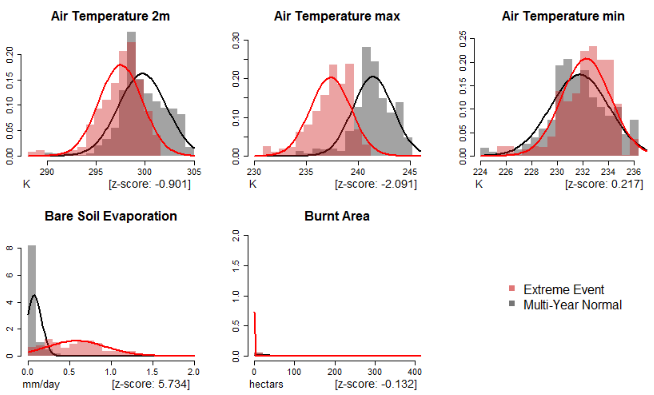


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

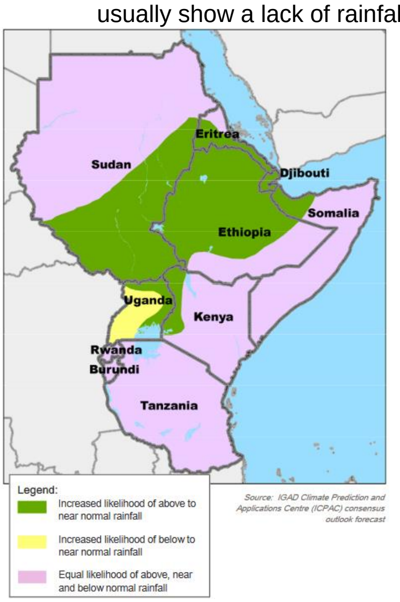




- Better growing conditions for natural growing plants and crops are also visible in the analysis of additional CABLAB data, which was not used for calculating the BACIndex.
- Hereby, temperatures are lower than usual and especially precipitation is significantly higher than usual during that time period indicated by an z-score of 19.4 (figure).
- This in return is leading to better growing condition in these otherwise ungrateful regions for plant growth, resulting in higher GPP and FPAR

3. Independent validation & regional expert feedback

- The most complete data is available from the 2010-2011 La Niña event, which followed on from the 2009-2010 El Niño event (considered to have been only 'moderate' in intensity) (United Nations Office for the Coordination of Humanitarian Affairs 2016)
- During that time period higher precipitation and therefore better plant growth have been noticed for Southern Sudan and Ethiopia which is in favour with the findings of the BACIndex, since these regions usually show a lack of rainfall. (FSNWG 2010)



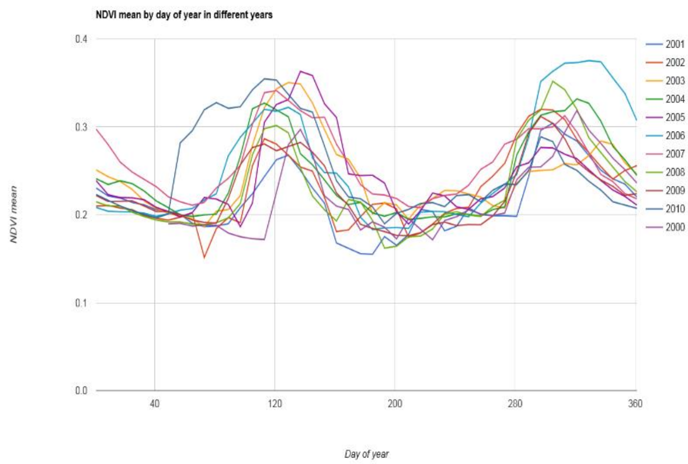


Figure Rainfall patterns for 2010 (FSNWG (2010): Food Security & nutrition Working Group. Central & Eastern Africa) & results of the MODIS NDVI Time series analysis for 2000 - 2010

- All findings are also backed by the analysis of NDVI MODIS time series resulting in much higher NDVI values for March and April of 2010 showing higher photosynthetic activity respectively healthier or more vegetation (Figure)
- However, the figure indicates a much broader extent than what was detected by the BACIndex.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	

	Temporal precision			X
Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		1	2	3
	Thematic precision			X
	Spatial precision			X
	Temporal precision		X	
Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		1	2	3
	Thematic precision			X
	Spatial precision			X
	Temporal precision			X
Regional expert based evaluation (3) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		1	2	3
	Thematic precision			X
	Spatial precision			X
	Temporal precision			X
Regional expert based evaluation (4) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		1	2	3
	Thematic precision			X
	Spatial precision		X	
	Temporal precision			X

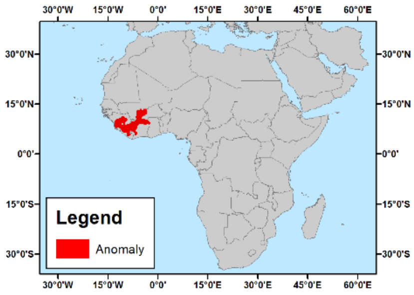
References

1. United Nations Office for the Coordination of Humanitarian Affairs (2016): LEARNING FROM THE IMPACT OF PAST LA NIÑA EVENTS.
2. FSNWG (2010): Food Security & nutrition Working Group. Central & Eastern Africa.

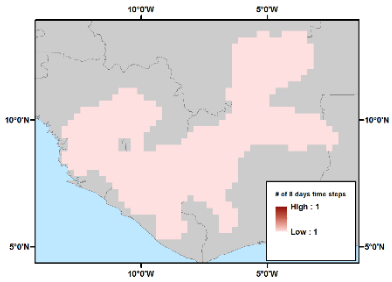
Event ID 13:

1. Attribution (internal)

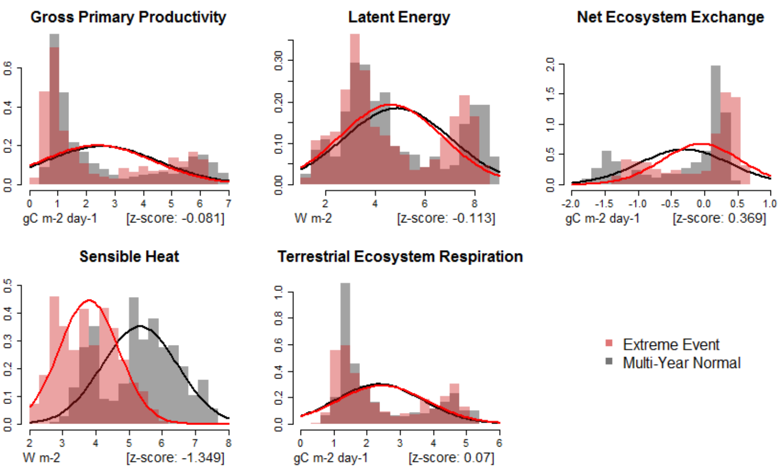
Type: Extreme event
Location: Western Africa
Area: 445916.2 km²
Time: 21.01.2003
Duration: 21.01.2003 – 21.01.2003



Extent of the event



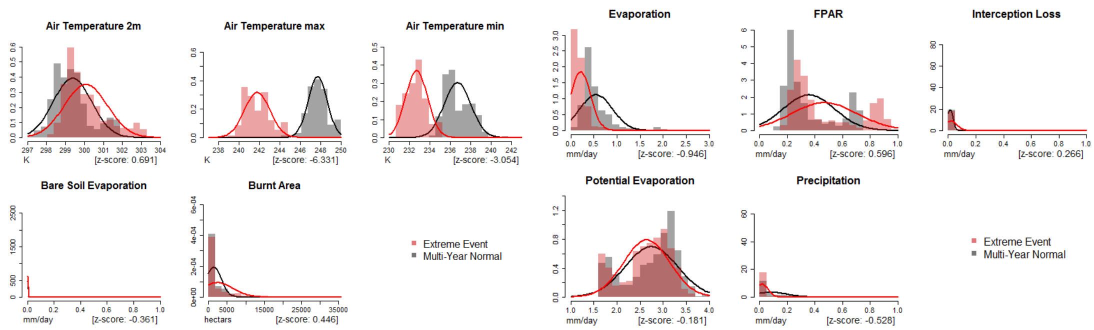
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation



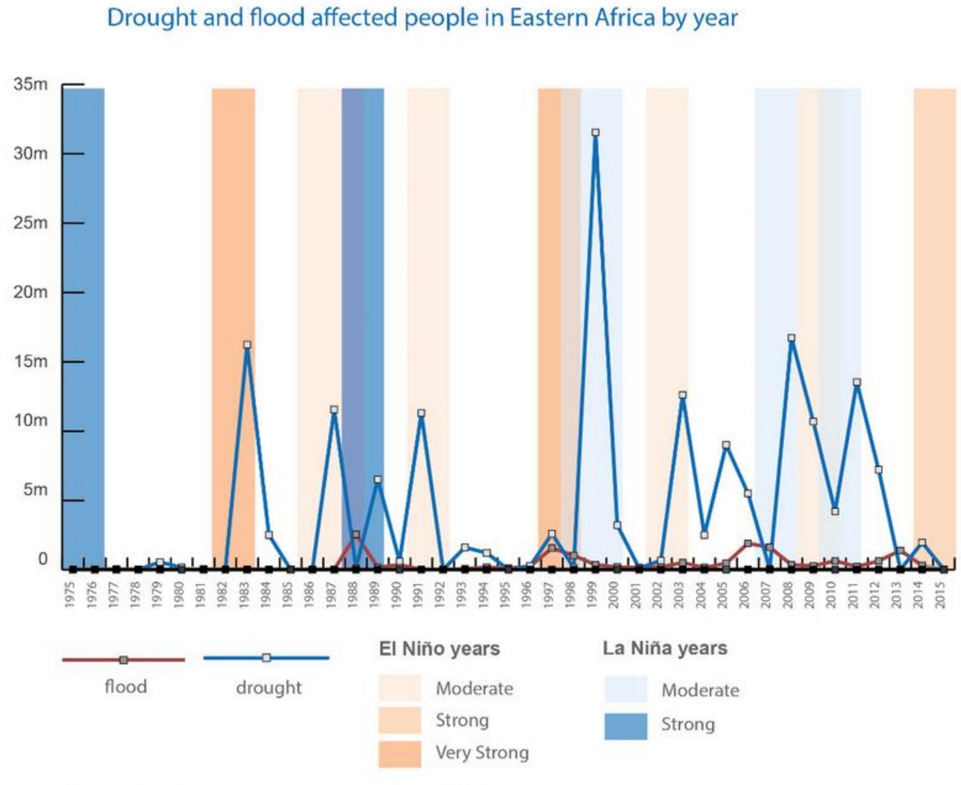
- The additional CABLAB data shows lower minimal and maximal temperatures respectively and at the same time lower evaporation and potential evaporation. Thus, seen in the initial and used CABLAB data lower sensible heat values are reasonable and may be linked to lower temperatures in general.
- In contrast to the GPP, which was close to the usual expected value, FPAR (giving the photosynthetic activity of plants) showing slightly higher values showing better conditions for plants.

3. Independent validation & regional expert feedback

- Findings of the internal and external characterization can be validated by the indepentend validation showing EL nino appearance.
- Cooler than average temperatures occurred over far western half of Russia, much of West

Africa and the eastern U.S. (NOAA 2003)

- Caused by a moderate El nino condition during the beginning of the year (Anonymous 2018)



Source: http://ggweather.com/enso/oni.htm, EMDAT

- In 2003, the humanitarian situation in Côte d'Ivoire was adversely affected not only by the political crisis that dates back to September 2002, but also by the security situation in eastern Liberia. (UNHCR – The UN Refugee Agency 2003:232)
- However, even though the temporal accuracy seems to be too short taking into account that only one time stamp was detected as the event, the spatial extent is also too small, since mostly the whole western part of Africa was affected by el Nino.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

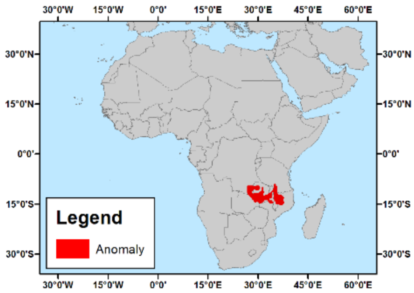
References

1. NOAA (2003): Global Climate Report. June 2003. <https://www.ncdc.noaa.gov/sotc/global/200306>
2. Anonymous (2018): **El Niño and La Niña Years and Intensities** Last Access: 15.02.2018. Standing: 01.02.2018. <htttp://ggweather.com/enso/oni.htm>
3. UNHCR – The UN Refugee Agency (2003): Global Report - Côte d'Ivoire.

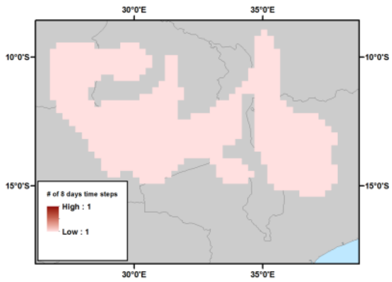
Event ID 14:

1. Attribution (internal)

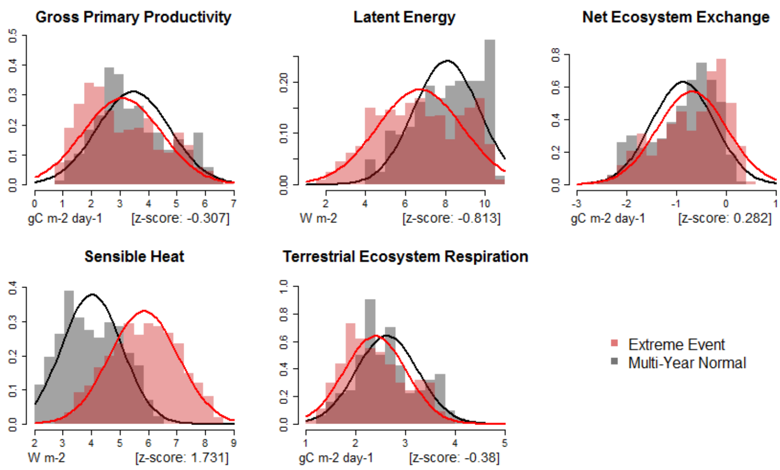
Type: Extreme event
Location: south-east Africa
Area: 443679.2 km²
Time: 21.11.2005
Duration: 21.11.2005 – 21.11.2005



Extent of the event



# of 8 day time steps for which the event was detected



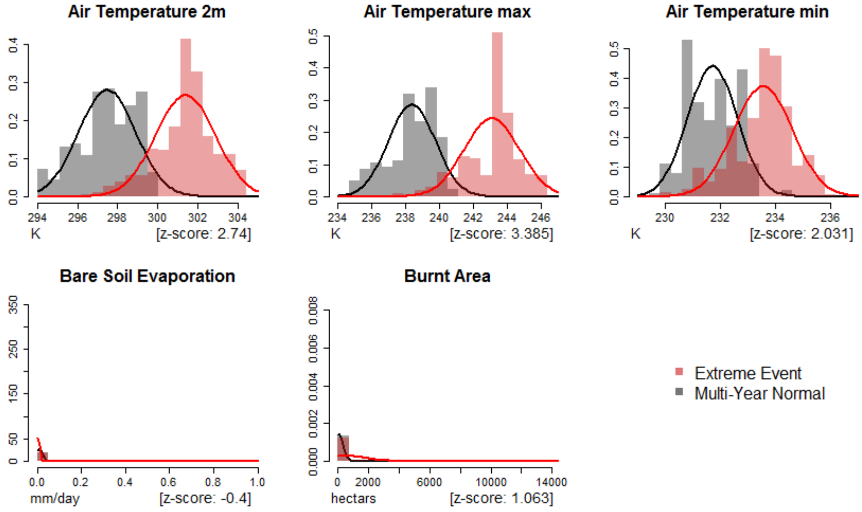
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Potential Drought Event:

- air temperature show significant anomaly for this time step



3. Independent validation & regional expert feedback

Potential Drought Event:

- LST above other average compared to 10 year time period (Figure 1)

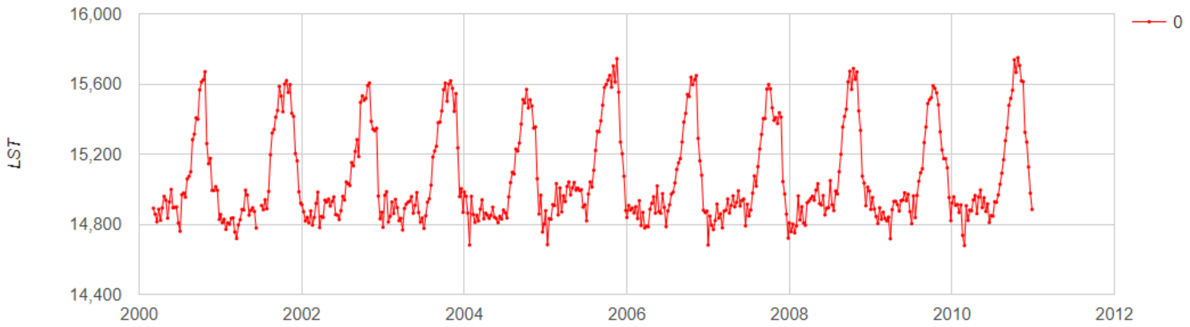


Figure 1. LST temporal profile of anomaly region.
(Source: Google Earth Engine)

Lekprichakul (2008):

- Lekprichakul (2008) shows impact of drought in Zambia to agriculture production (Figure 2)

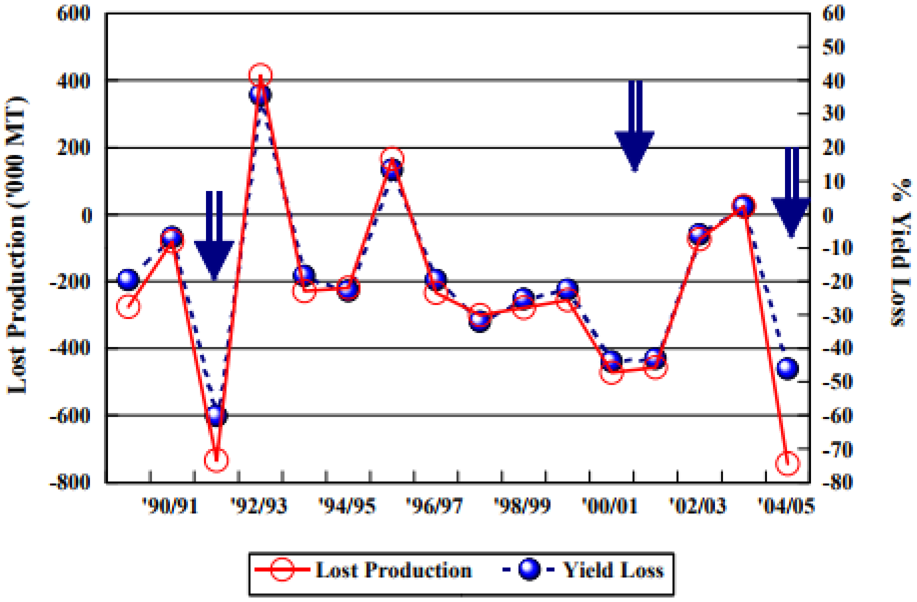


Figure 2. Maize Production Losses and Yield Losses, 1989/1990-2004/2005.
(Source: Lekprichkul 2008)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

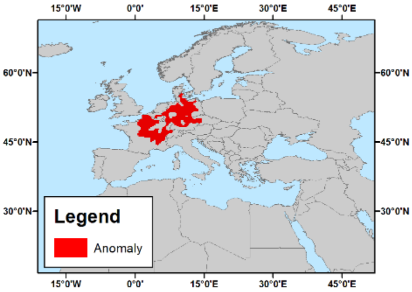
References

Lekprichakul, T. Vulnerability and Resilience of Social-Ecological Systems Impact of 2004/2005 Drought on Zambia's Agricultural Production: Preliminary Results. 2008.

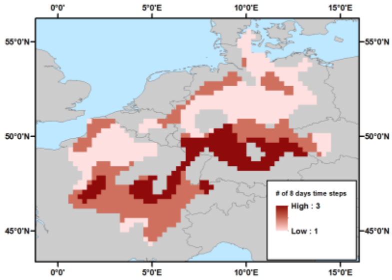
Event ID 15:

1. Attribution (internal)

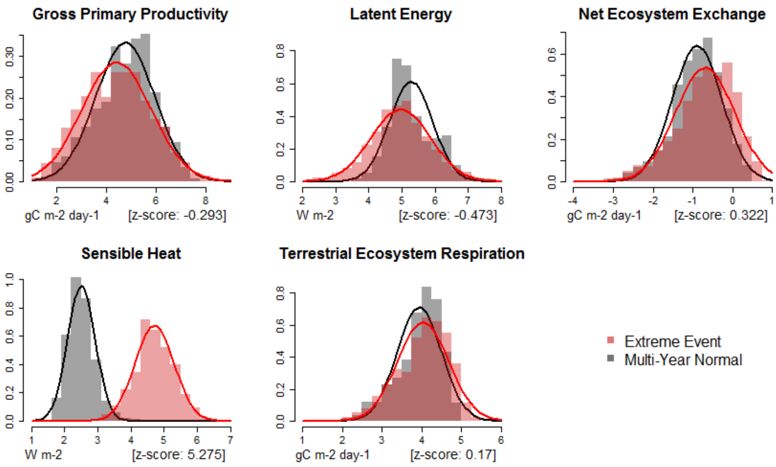
Type: Extreme event
Location: ??????
Area: 440595.3 km²
Time: 09.08.2003
Duration: 09.08.2003 – 25.08.2003



Extent of the event



# of 8 day time steps for which the event was detected

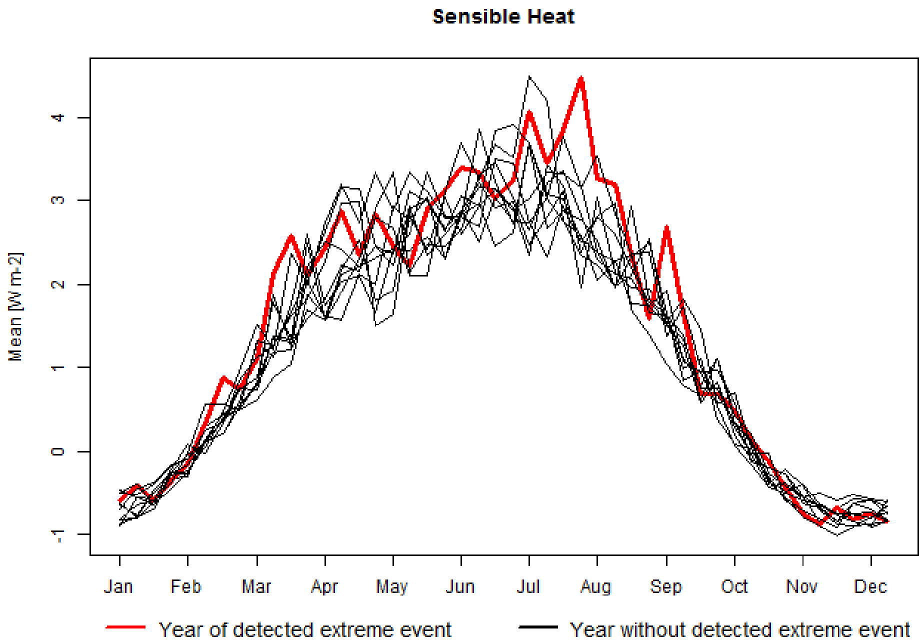


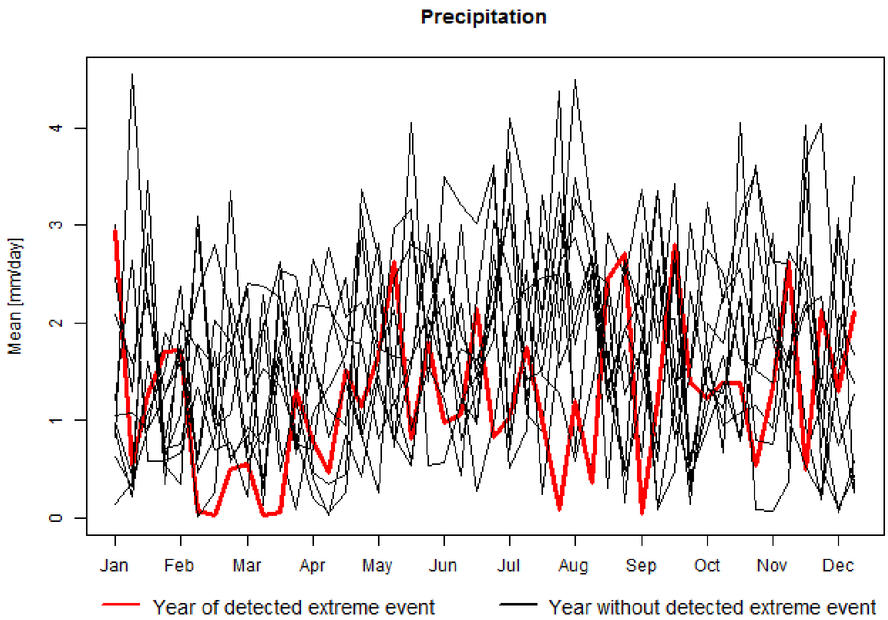
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External characterization hints at a temperature peak and very low precipitation, supporting internal attribution results and indicating a heat wave in Europe.





3. Independent validation and regional expert feedback

European heat wave

- Europe experienced probably the hottest summer since 1500 AD in 2003 (Stott et al. 2004). The heat wave commenced in mud-June and continued until mid-August and affected large parts over central and southern Europe (De Bono et al. 2004).

- Temperatures were up to 30% higher than the long-term average over large parts of Europe (De Bono et al. 2004; Stott et al. 2004). Figure 1 shows the deviation in 2003 from the long-term average.
- A large precipitation deficit combined with early vegetation green-up and extreme radiative anomalies in the month before contributed to an early and rapid loss of soil moisture. This is also supported by the internal attribution that revealed very low precipitation in the respective period compared to periods without anomalies.
- Low soil moisture was responsible for reduced latent heat fluxes and high sensible heat fluxes (Fischer et al. 2007). This is also supported by the internal attribution that reveals abnormal sensible heat fluxes for the 2003-event.
- Human activities have at least doubled the risk of observed temperature anomalies (Stott et al. 2004)
- Social, ecological and economic losses were devastating and include the following (De Bono et al. 2004):
    - Heat related health incidences peaked
    - Estimated 30,000 – 70,000 (also refer to Robine et al. 2008) heat related death in Europe: Deadliest natural disaster of the past 50 years.
    - Agricultural losses: cereal yields historic low; in Europe 10% less biomass was harvested than in the 2002
    - Livestock sector: Suffered extremely in the following winter due to fodder deficits of 30% and 60% in Germany and France (COGECA 2003)
    - Glacier melting: Loss of 5-10% of total ice volume on European glaciers
    - Forest fires: More than 25 000 fires were recorded in Portugal, Spain, Italy, France, Austria, Finland, Denmark and Ireland. The estimation of forest areas destroyed reached 647 069 hectares.
    - Total economic losses amount to 13 billion euros

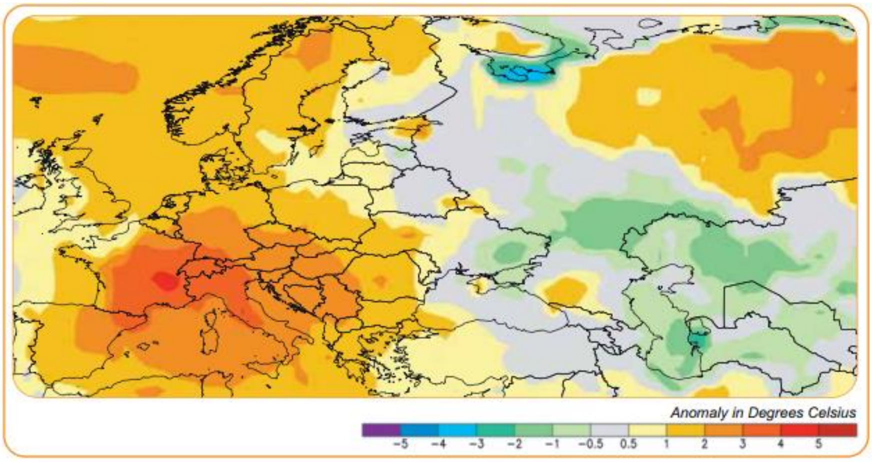


Figure 1: Temperature deviations from June to August 2003 compared to the base period 1988-2003 for the same month. Difference exceeds 4°C in several regions. The Figure is taken from de Bono (2004).

Cereal yields 2003

Agricultural yields are directly related to precipitation and temperature distributions of the growing season. Hence, unsurprisingly the detected 2003 heat event is reflected in agricultural yields of the respective year. According to FAOSTAT (FAO 2017), cropland yields were historically in Germany and France, where particularly cereal yields were blow the long-term average (Figure 2).

Low yields were particularly related to an early start of the growing season and the related low soil moisture during spring 2003, as well as to an abnormally hot and dry summer-growing season (Loew et al. 2009).

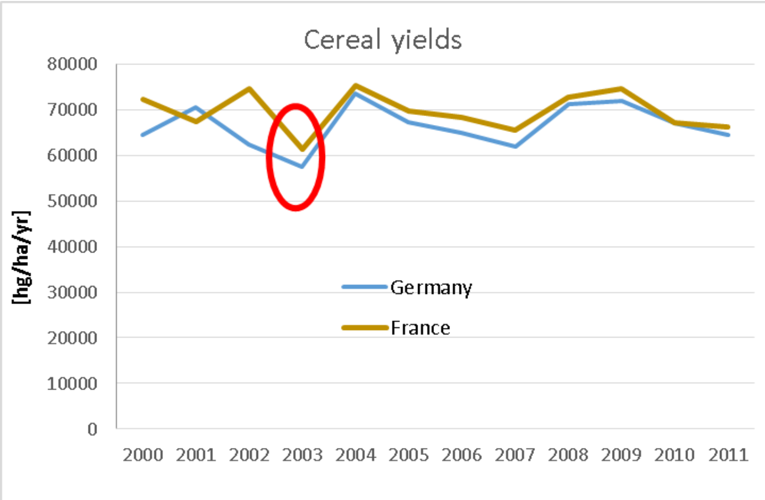


Figure 2: Cereal yields in Germany and France according to FAOSTAT data

Ecosystem productivity based on vegetation indices:

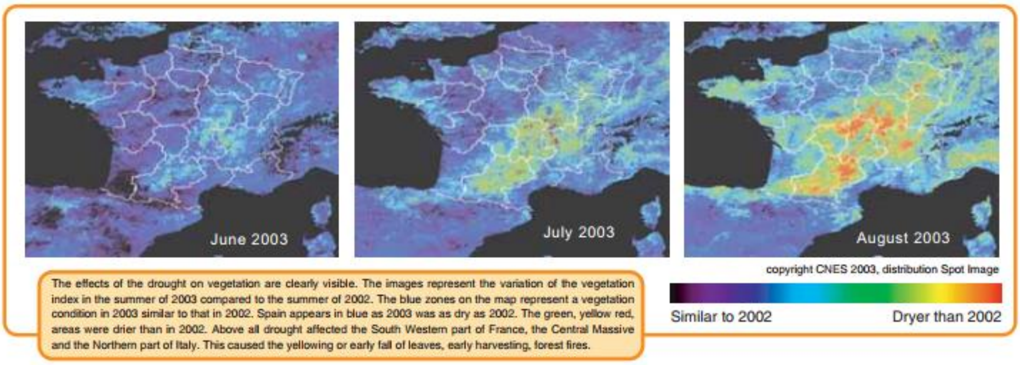


Figure 3: Variation of vegetation index from June to August from the 2002-level. The Figure is taken from de Bono (2004).

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision	x		
Temporal precision		x	

Regional expert feedback 2

Short event description

This event seems to be in good congruence with the European heat wave of 2003. This event affected large parts of Central and Western Europe, and was characterized by considerably warmer than average temperatures (>+3°C) paired with strongly reduced growing season precipitation (> -100mm/month), see Reichstein et al. (2007).

Spatial delineation: The climatic anomaly did affect a larger area than the one delineated here, but the ecosystem consequences varied strongly with elevation (see Jolly et al. 2005), which is why it makes sense that the BACI-algorithm doesn't include the Alps in the event.

Temporal delineation: The climatic anomaly actually started considerably earlier in the year, so based on a meteorological definition that start date was estimated too late. However, as the effects of drought during a vegetation period are cumulative, many ecosystem impacts only became apparent late in the growing season (e.g., early leaf off in trees), so in this regard the estimated timing appears ok.

References

Reichstein et al. (2007, doi: 10.1111/j.1365-2486.2006.01224.x)
Jolly et al. (2005, doi:10.1029/2005GL023252)

Side note: Both references I've given in the context of validation are based on remote sensing data. So it is quite self-evident that BACI (also being based on remote sensing data) agrees with these studies. In other words: Such a comparison does not constitute a true evaluation against independent data sensu strictu. How the consortium wants to deal with this issue (which I'm sure will come up multiple times) is up to you, I just wanted to bring it to your attention! Rupert Seidl

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy		x	
Spatial accuracy		x	
Temporal accuracy		x	

References

COGECA, C., 2003: Assessment of the impact of the heat wave and drought of the summer 2003 on agriculture and forestry. Comm. Agric. Organ. Eur. Union Gen. Comm. Agric. Coop. Eur. Union Bruss., 15.

De Bono, A., P. Peduzzi, S. Kluser, and G. Giuliani, 2004: Impacts of Summer 2003 Heat Wave in Europe. https://archive-ouverte.unige.ch/unige:32255 (Accessed November 8, 2017)..

Fischer, E. M., S. I. Seneviratne, P. L. Vidale, D. Lüthi, and C. Schär, 2007: Soil moisture–atmosphere interactions during the 2003 European summer heat wave. J. Clim., 20, 5081–5099.

Robine, J.-M., S. L. K. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, J.-P. Michel, and F. R. Herrmann, 2008: Death toll exceeded 70,000 in Europe during the summer of 2003. C. R. Biol., 331, 171–178, doi:10.1016/j.crvi.2007.12.001.

Stott, P. A., D. A. Stone, and M. R. Allen, 2004: Human contribution to the European heatwave of 2003. Nature, 432, 610–614.

De Bono, A., P. Peduzzi, S. Kluser, and G. Giuliani, 2004: Impacts of Summer 2003 Heat Wave in Europe. https://archive-ouverte.unige.ch/unige:32255 (Accessed November 8, 2017).

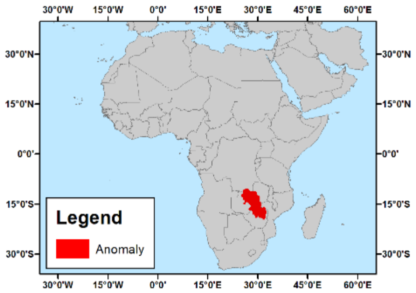
FAO, 2017: FAOSTAT: Statistical Database of the United Nations Food and Agricultural Organization. http://faostat.fao.org/,

Loew, A., T. Holmes, and R. de Jeu, 2009: The European heat wave 2003: Early indicators from multisensoral microwave remote sensing? J. Geophys. Res. Atmospheres, 114, D05103, doi:10.1029/2008JD010533.

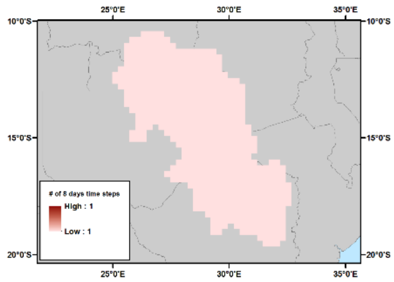
Event ID 16:

1. Attribution (internal)

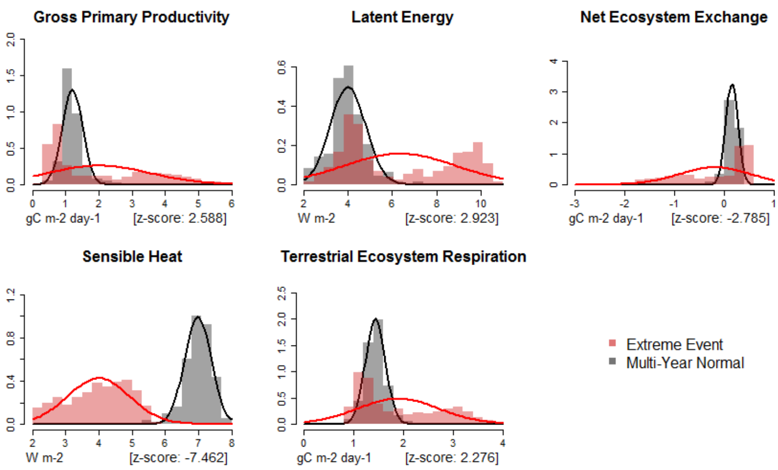
Type: Extreme event
Location: southern Africa
Area: 433177.6 km²
Time: 20.10.2003
Duration: 20.10.2003 – 20.10.2003



Extent of the event



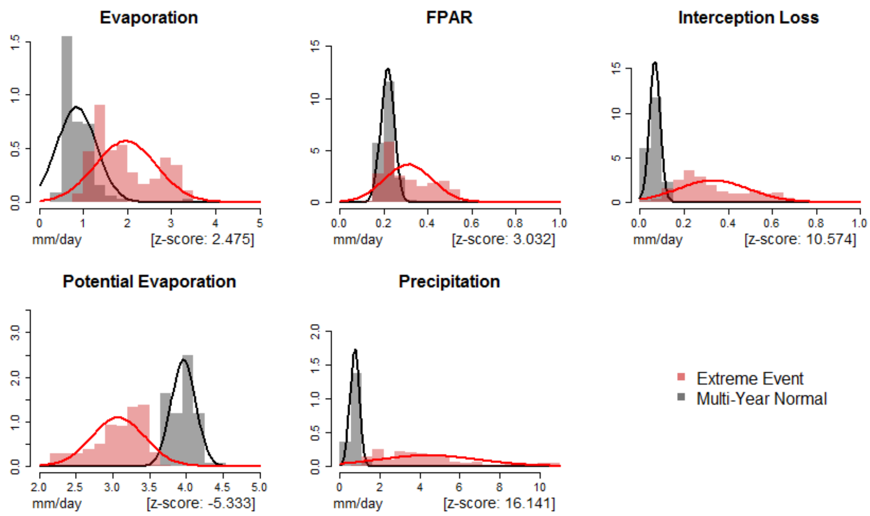
# of 8 day time steps for which the event was detected

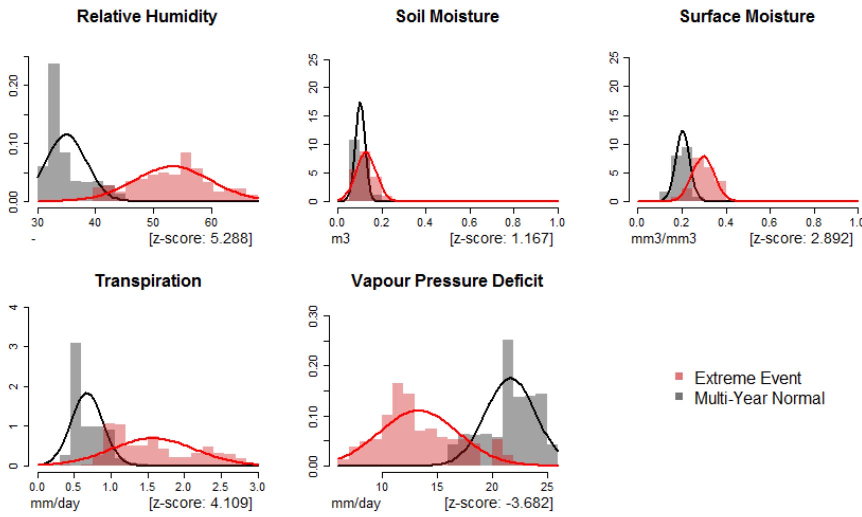


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation





3. Independent validation & regional expert feedback

Decreasing amount of Rainfall in Southern Africa:
(Source: SARPN 2004)

- "In particular, large areas in Swaziland, southern Mozambique, and eastern Zimbabwe, have received less than half of their normal rainfall (dark orange colors) since November 2003. This will mean severe water shortages for irrigation, livestock, and domestic use, as well as crop stress and crop failure in many of these areas." (SARPN 2004) (Figure 1)

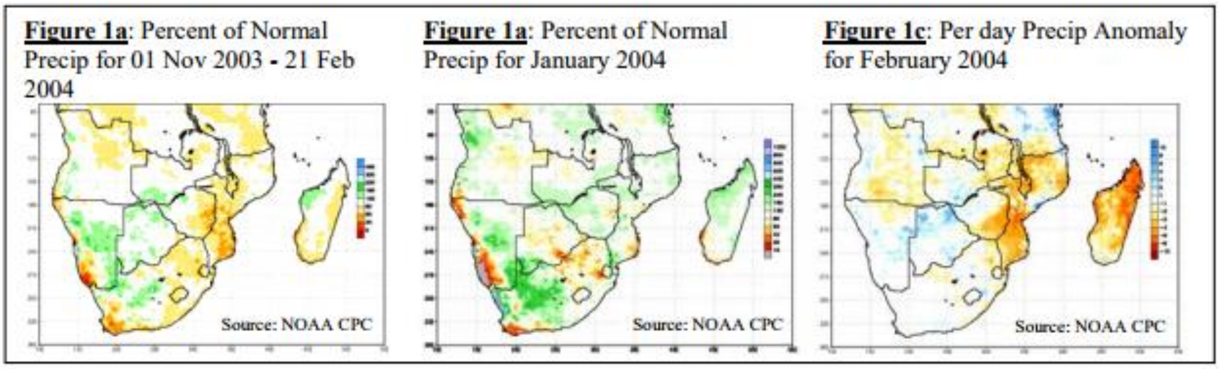


Figure 1. Percent of normal Precipitation.
(Source: SARPN 2004)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision	x		
Temporal precision	x		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	<table><tr><th></th><th>1</th><th>2</th><th>3</th></tr><tr><td>**Thematic precision**</td><td></td><td></td><td></td></tr><tr><td>**Spatial precision**</td><td></td><td></td><td></td></tr><tr><td>**Temporal precision**</td><td></td><td></td><td></td></tr></table>

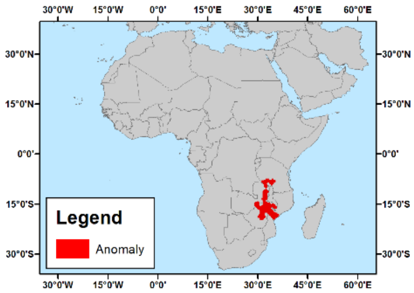
References

SARPN *Famine Early Warning Systems Network*; 2004; https://sarpn.org/documents/d0000741/P838-FEWSNET_2004_02.pdf

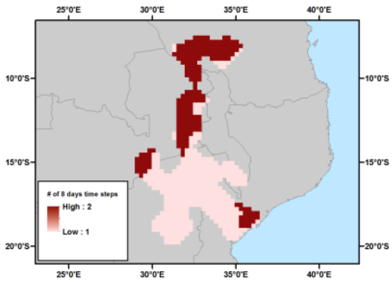
Event ID 17:

1. Attribution (internal)

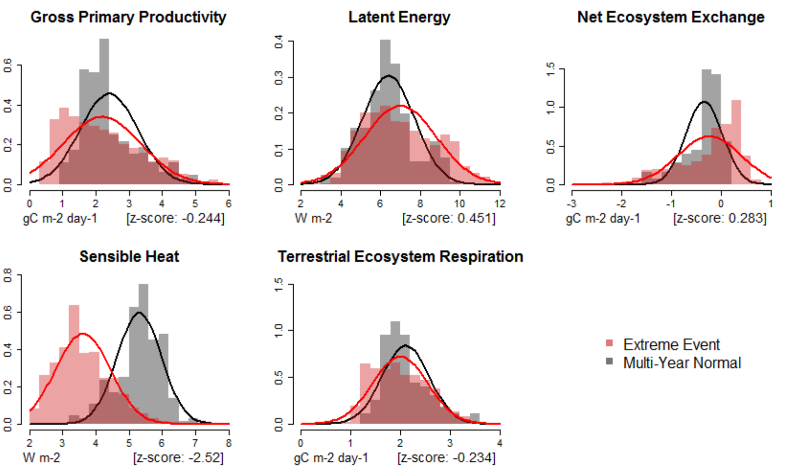
Type: Extreme event
Location: southern Africa
Area: 427822.0 km²
Time: 21.11.2009
Duration: 13.11.2009 – 21.11.2009



Extent of the event



# of 8 day time steps for which the event was detected



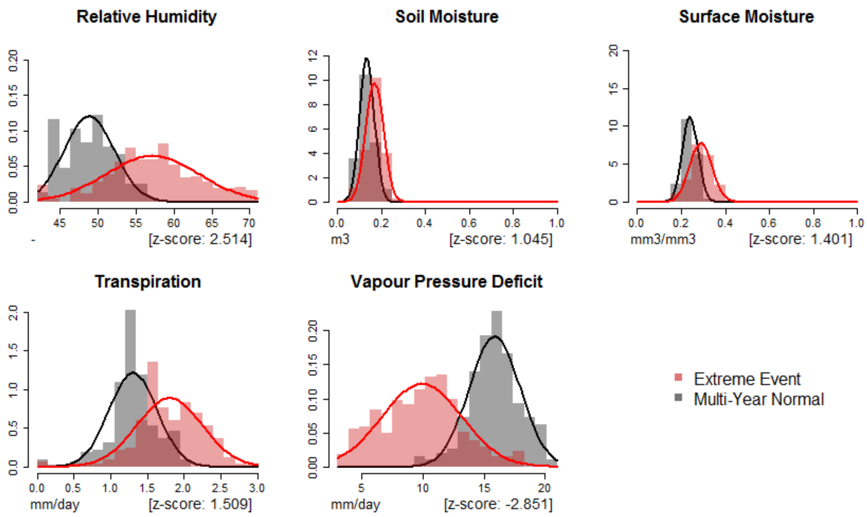
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

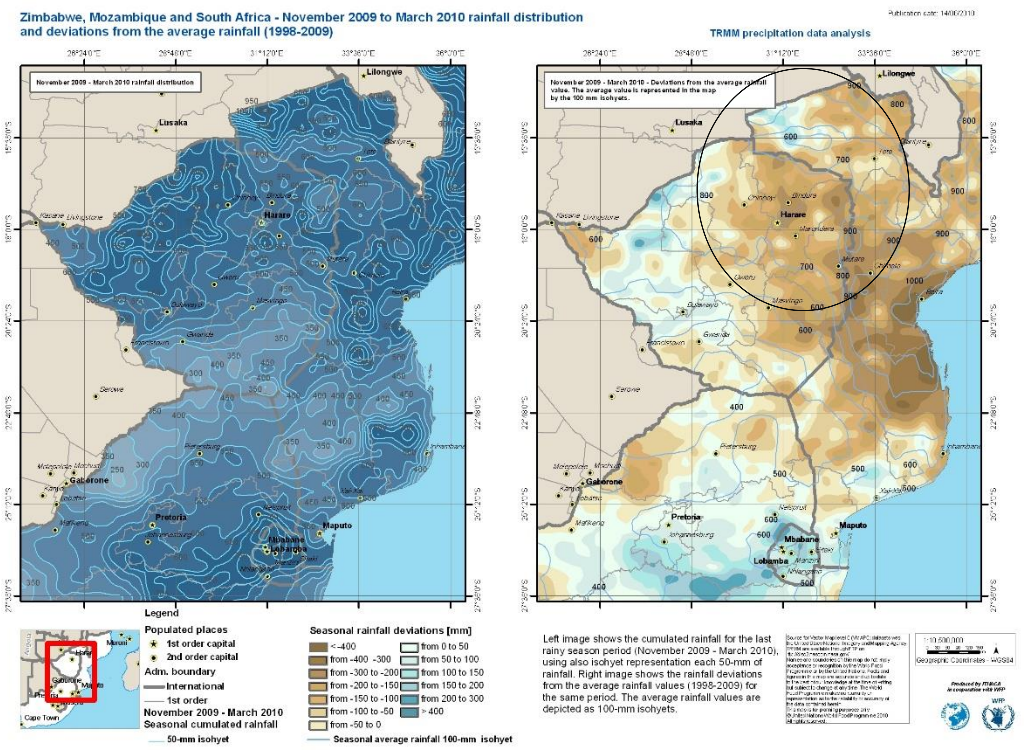
Event: Change in Amount of Precipitation:

- parameters such as soil moisture and surface moisture only show slight significant anomaly for this time step



3. Independent validation & regional expert feedback

Decrease in Amount of Precipitation during rainfall season:
(Source: http://www.ithacaweb.org/maps/zimbabwe/)



Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision			X

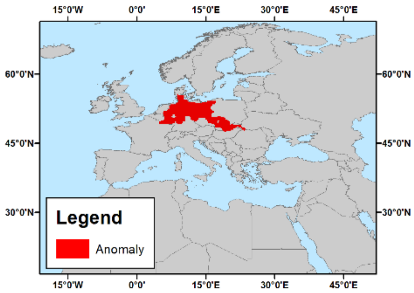
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1**	**2**	**3**
	Thematic precision		X	
	Spatial precision		X	
	Temporal precision		X	

References

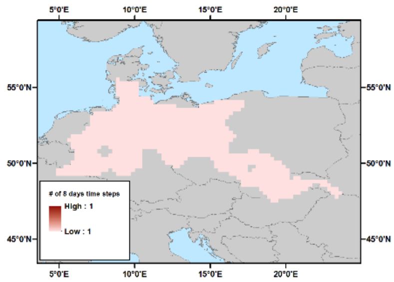
Event ID 18:

1. Attribution (internal)

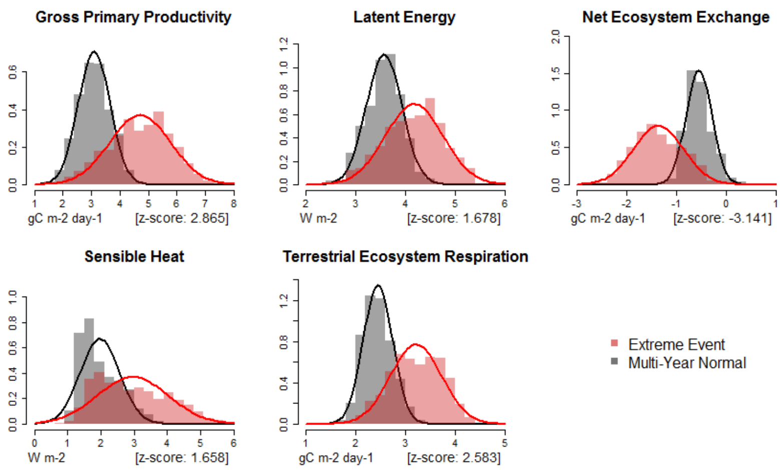
Type: Extreme event
Location: Germany, Central Europe
Area: 424331.0 km²
Time: 11.04.2009
Duration: 11.04.2009 – 11.04.2009



Extent of the event



# of 8 day time steps for which the event was detected

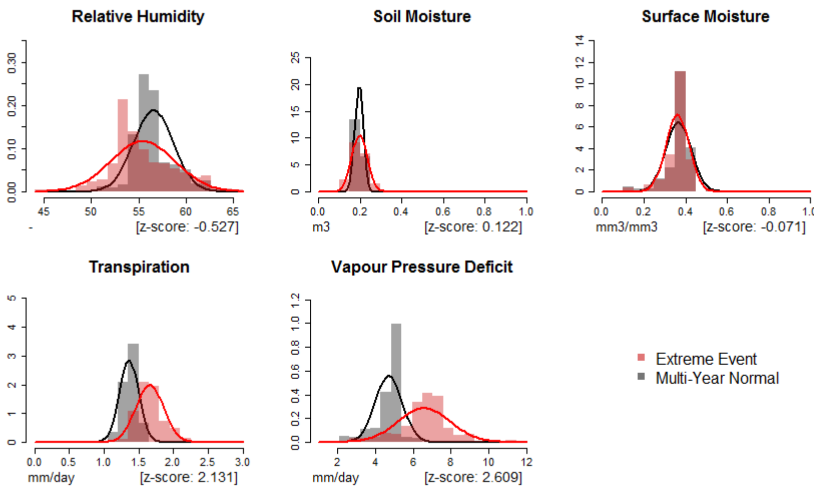


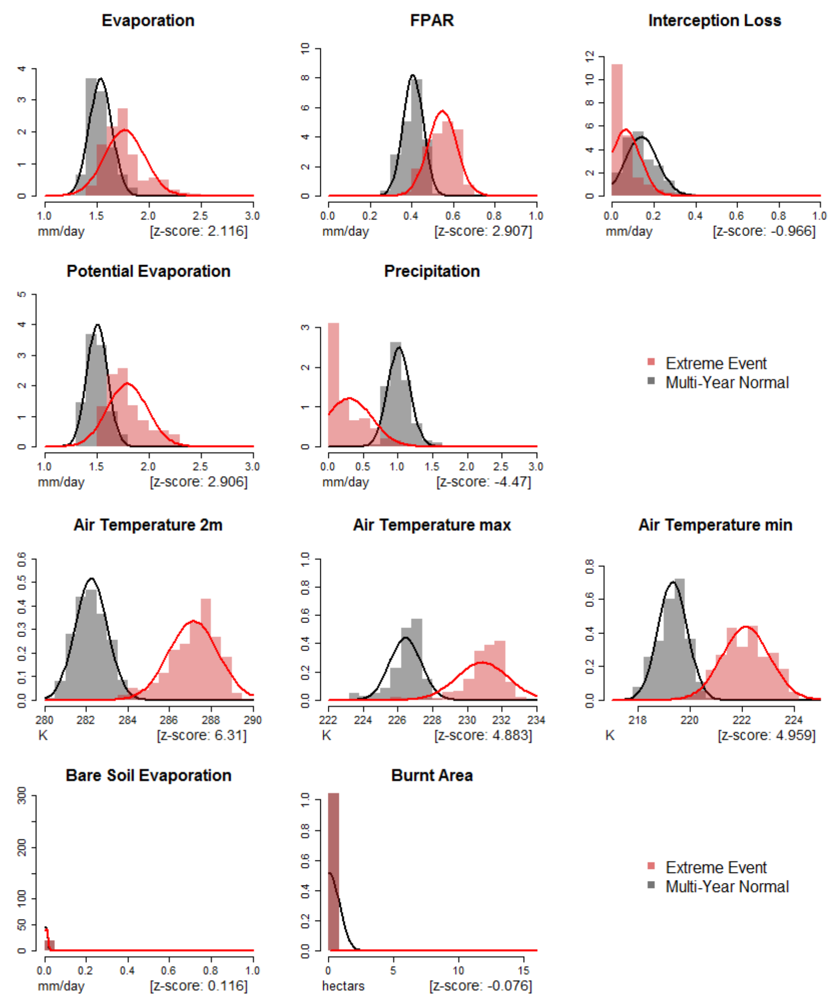
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same sson.

2. External characterisation

External indications of high temperatures, high evapotranspiration and above average FPAR are consistent with internal attribution .





3. Independent validation & regional expert feedback

April temperatures were well above average in all of Central Europe (figure 1), with new national records for mean anomalies in Hungary (+4,2°C) and Germany (Arndt et al. 2010). In many parts of Germany temperatures in April 2009 were the highest ever recorded for that month up until then. Average temperatures ranged from 11°C to 14°C, which was 4°C to 5°C above the long-term average. Maximum temperatures above 25°C were reported around April 12th in North-eastern Germany (wetteronline 2009).

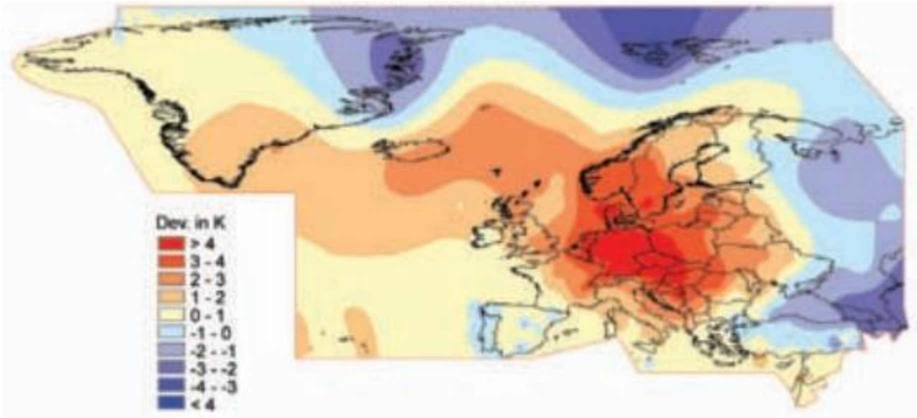


Figure 2: Mean anomalies of surface air temperature in April 2009 (1961 – 90 base period) based on CLIMAT and ship observations. The figure is taken from Arndt et al. (2010)

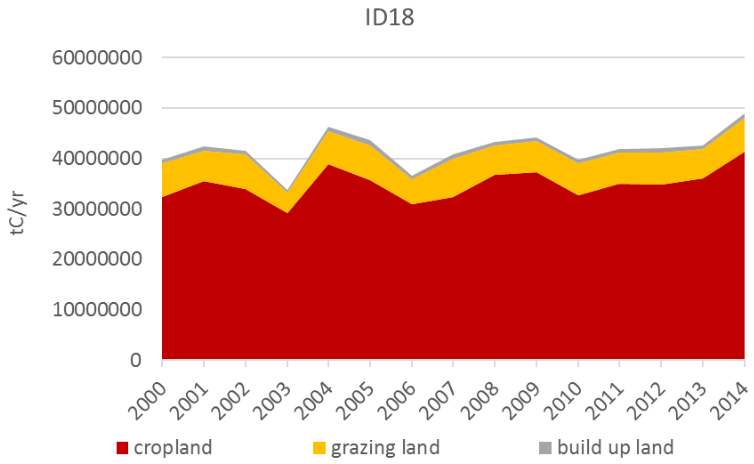


Figure 2: Time-line results on biomass harvest in the extreme event (refer to WP 7.3., upcoming report). Note that temporal resolution is one year.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert feedback 1

April of 2009 was a particularly warm month, with temperature deviations in the order of >3°C in Central Europe (while March was +/- average, and May was only moderately warmer than average), so a phenological event (i.e., large-scale shift to earlier bud-burst due to warm weather conditions) is plausible. A phenological shift would also be in congruence with the large footprint of the event identified by BACI, as well as with elevated GPP and R activity. The temporal identification of the event is ok, but the temporal duration (a single day) estimated by BACI is unrealistic.

Short event description

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy		x	
Spatial accuracy		x	
Temporal accuracy	x		

Regional expert feedback 2

Short event description
Heavy rain ?

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy	x		
Spatial accuracy		x	
Temporal accuracy		x	

References

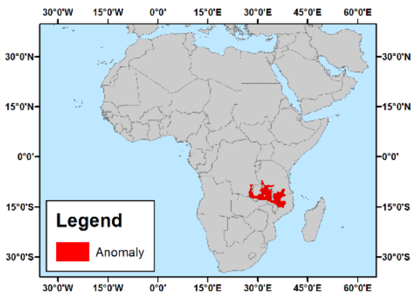
Arndt, D.S., Baringer, M.O., Johnson, M.R. (Eds.), 2010: State of the Climate in 2009. Special Supplement to the Bulletin of the American Meteorological Society. Vol91, No7, July 2010. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-91-7-StateoftheClimate (accessed 08.02.2.2018)

wetteronline, 2009: Wetterrückblick. Rückblick April 2009. Vielerorts neuer Rekordmonat. https://www.wetteronline.de/wetterrueckblick/2009-04-29-ah (accessed 05.02.2018)

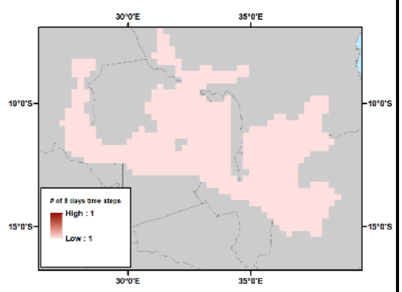
Event ID 19:

1. Attribution (internal)

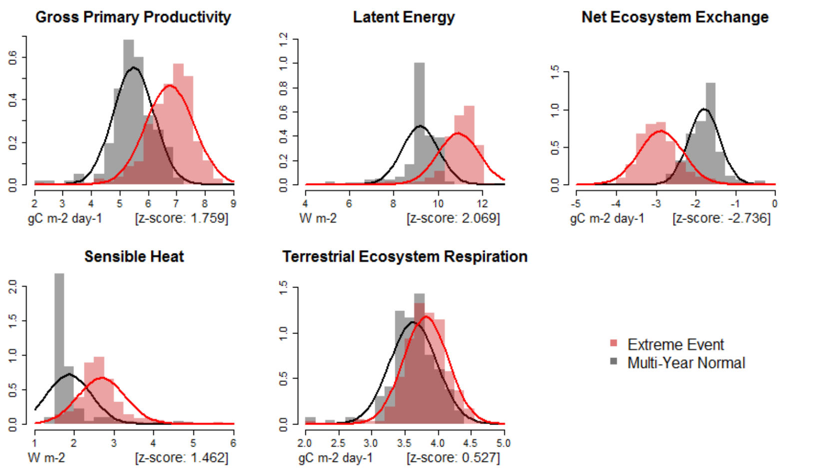
Type: Extreme event
Location: central Africa
Area: 421769.9 km²
Time: 02.03.2003
Duration: 02.03.2003 – 02.03.2003



Extent of the event



# of 8 day time steps for which the event was detected



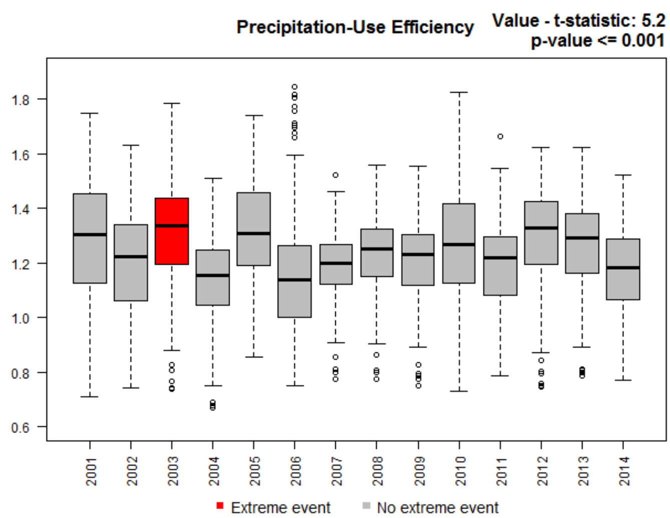
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Potential Flood Event:

- Precipitation use efficiency significant higher than multi-annual average



3. Independent validation & regional expert feedback

Risk of Flood
(Source: SADC 2003)

- heavy rains increase the risk of serious flooding (Figure 1)

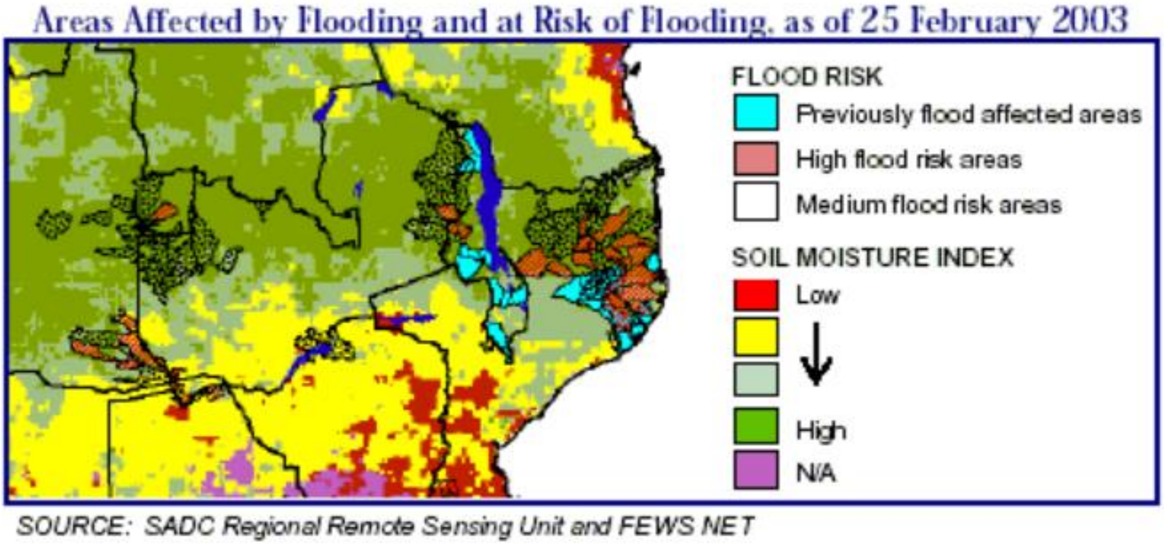


Figure 1. Areas Affected by Flooding or at Risk of Flooding.
(Source: https://reliefweb.int/report/angola/sadc-food-security-ministerial-brief-28-feb-2003)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision			X

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

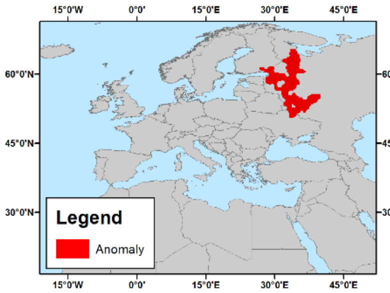
References

SADC (Southern African Development Community) SADC Food Security Ministerial Brief: 28 Feb 2003 Available online: https://reliefweb.int/report/angola/sadc-food-security-ministerial-brief-28-feb-2003 (accessed on Jan 23, 2018).

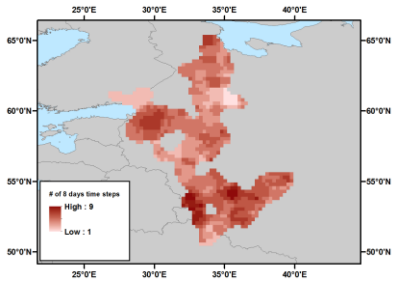
Event ID 20:

1. Attribution (internal)

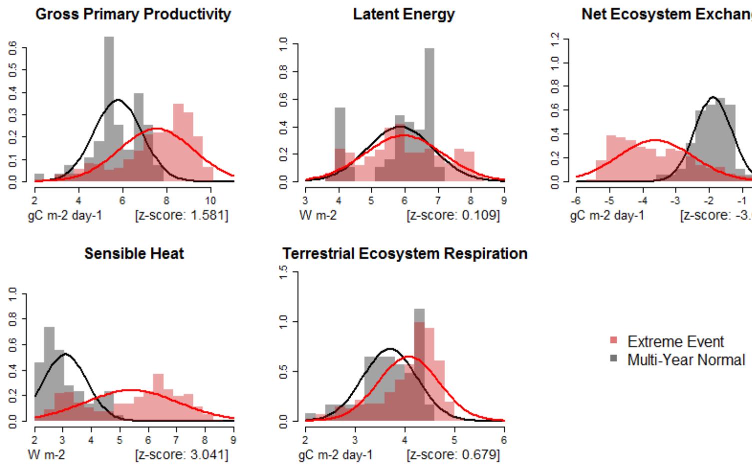
Type: Extreme event
Location: Western Russia
Area: 421693.1 km²
Time: 29.05.2009
Duration: 05.05.2009 – 24.07.2009



Extent of the event



# of 8 day time steps for which the event was detected

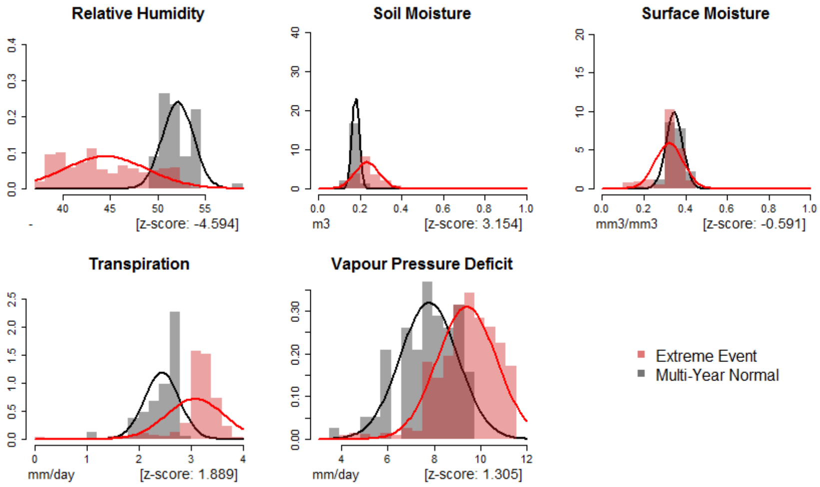


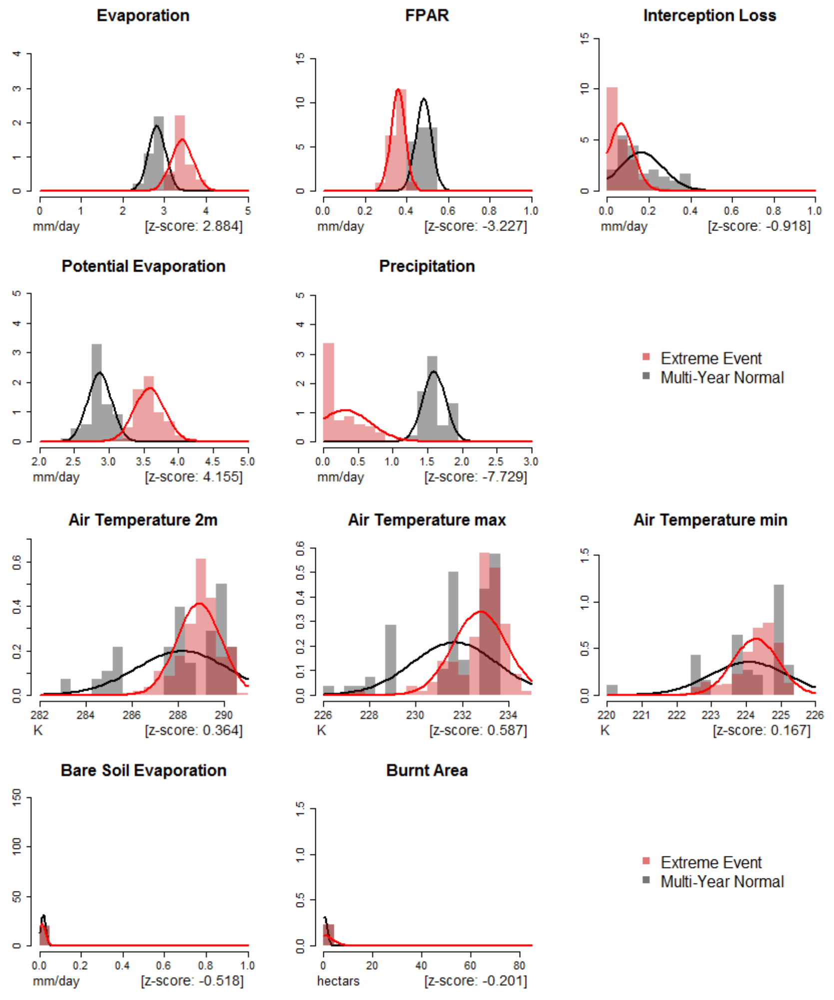
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External characterization hints at very low precipitation and humidity. Low FPAR contradicts findings of high GPP in the internal attribution.





3. Independent validation & regional expert feedback

Biomass harvest in the respective year supports the findings above. Apparently, the long and warm early growing period had positive effects on plant growth (WP7.3, upcoming report). MODIS-NDVI time series support a high plant growth (Figure 2).

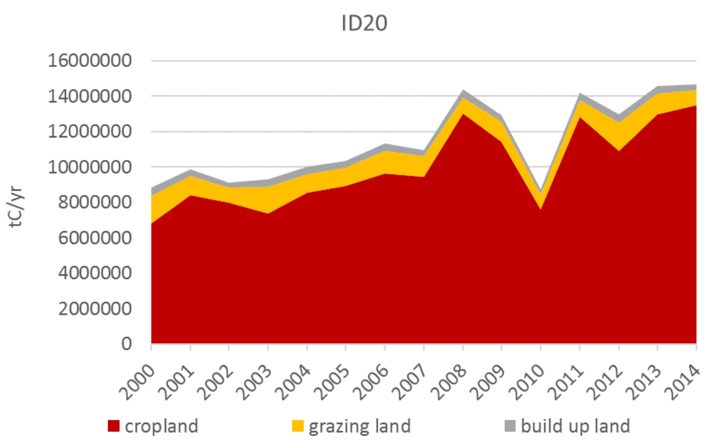


Figure 2: Time-line results on biomass harvest in the extreme event (refer to WP 7.3., upcoming report). Note that temporal resolution is one year.

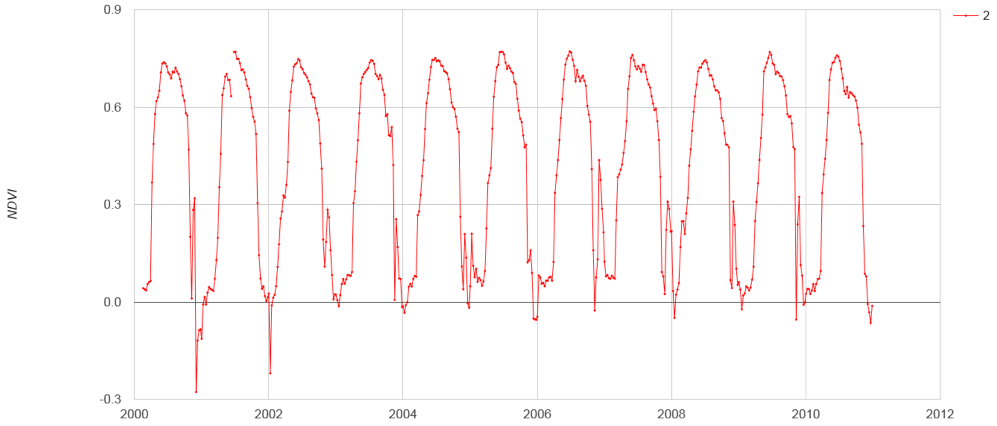


Figure 2: MODIS-NDVI time series

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

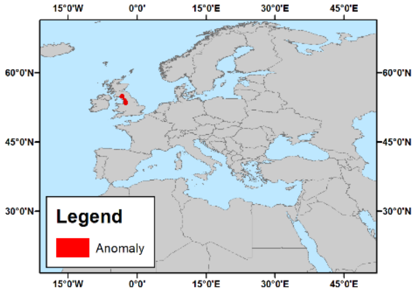
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

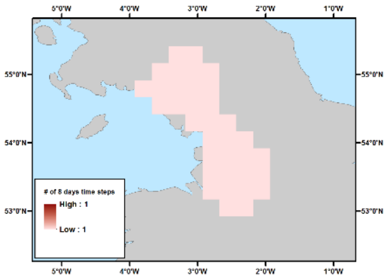
Event ID 21:

1. Attribution (internal)

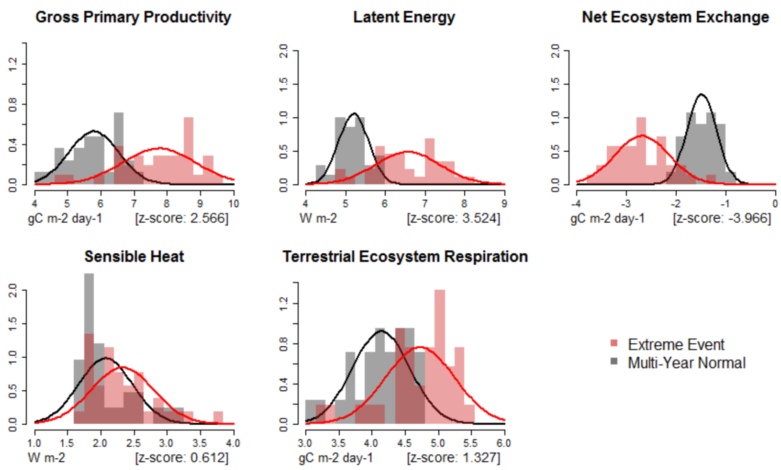
Type: Extreme event
Location: Western UK
Area: 15801.5 km²
Time: 14.06.2003
Duration: 14.06.2003 – 14.06.2003



Extent of the event



# of 8 day time steps for which the event was detected

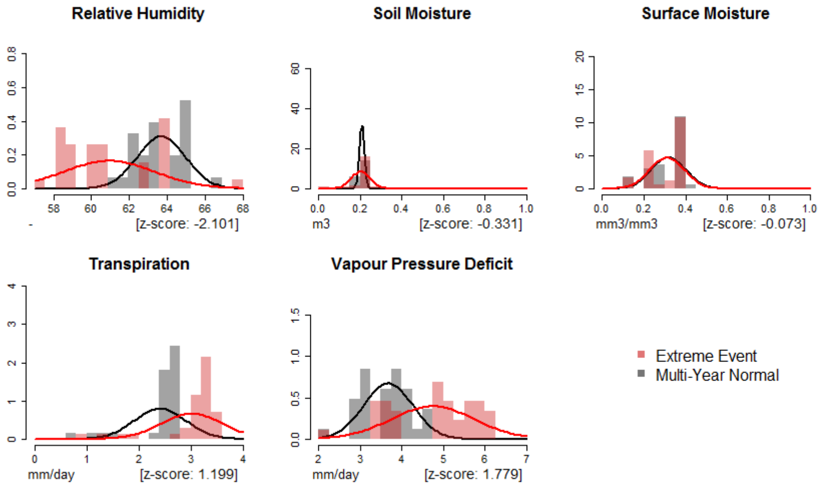


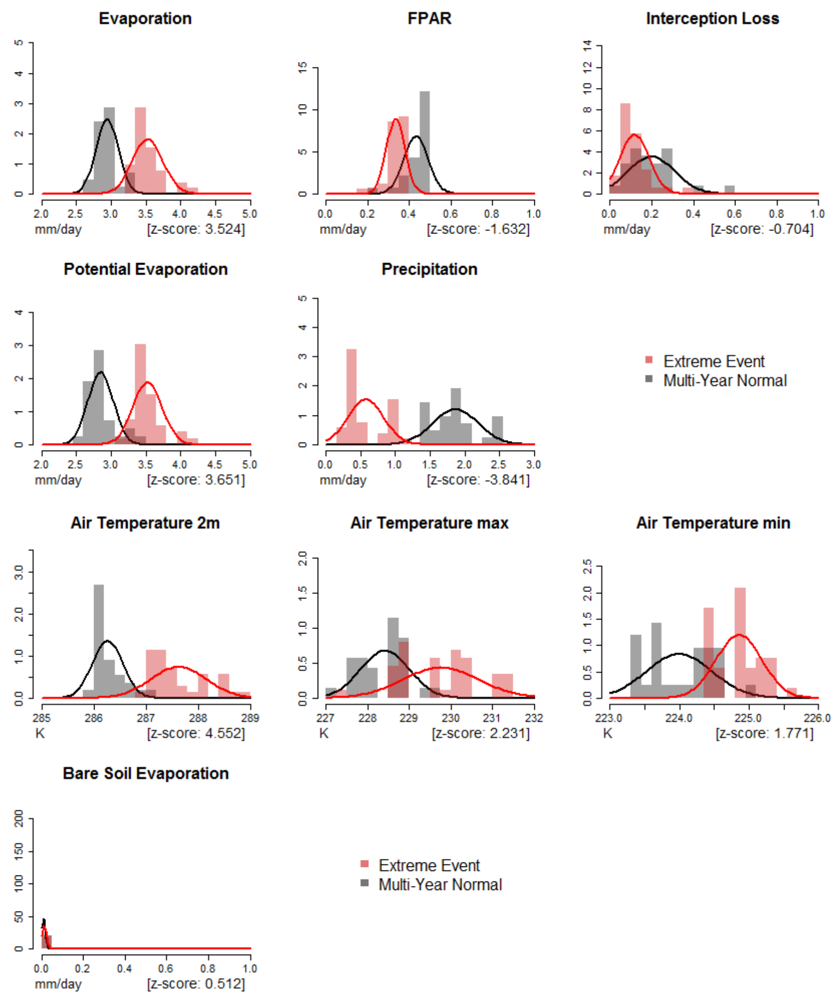
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Indications of above average temperatures and low FPAR as well as low precipitation differ slightly from internal findings of average sensible heat and high GPP.





3. Independent validation & regional expert feedback

MODIS-NDVI time series support a high plant growth (Figure 1).

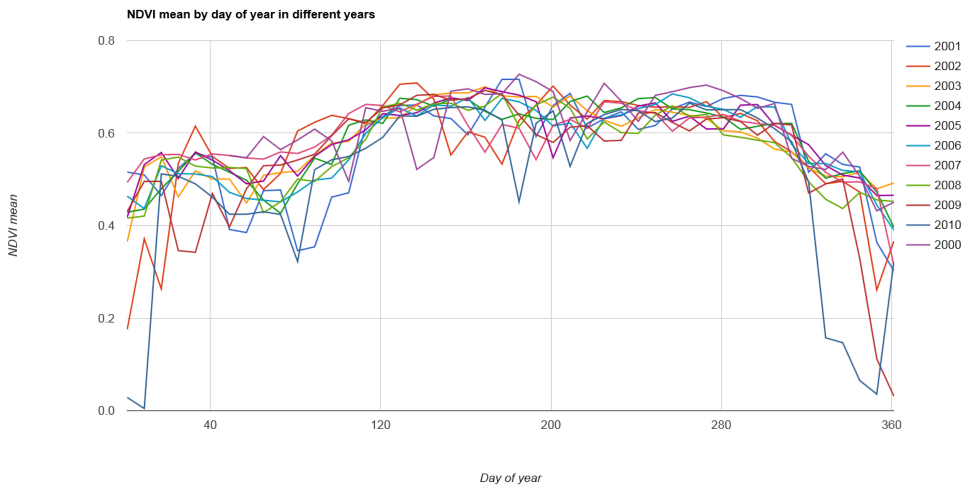


Figure 1: MODIS-NDVI time series, shown as daily mean of each year in the time series.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision			x

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

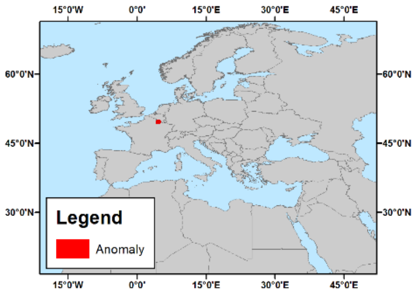
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

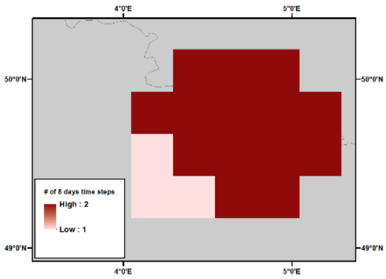
Event ID 22:

1. Attribution (internal)

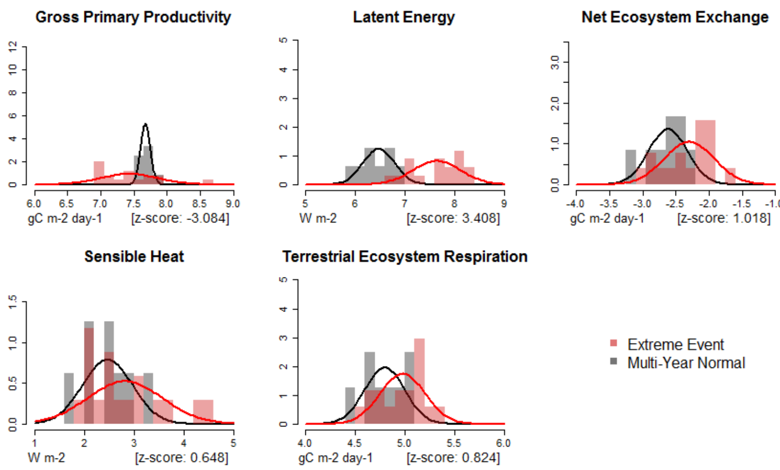
Type: Extreme event
Location: Northern France, Southern Belgium
Area: 8482.7 km²
Time: 06.06.2011
Duration: 29.05.2011 – 06.06.2011



Extent of the event



# of 8 day time steps for which the event was detected

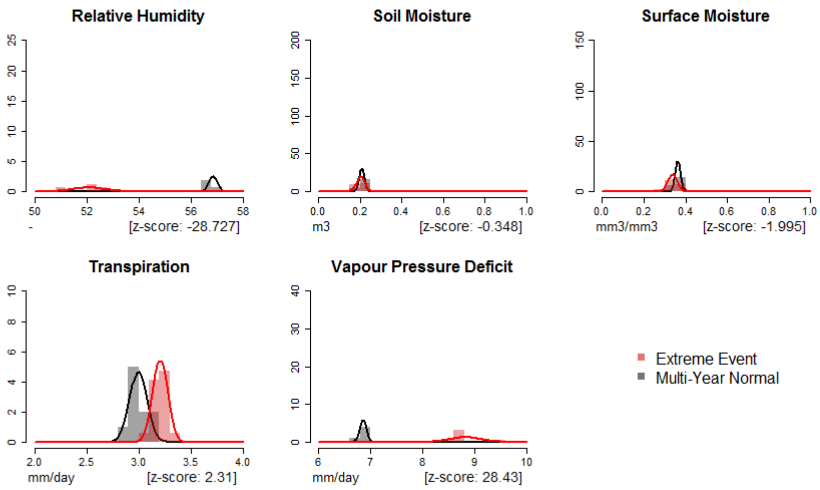


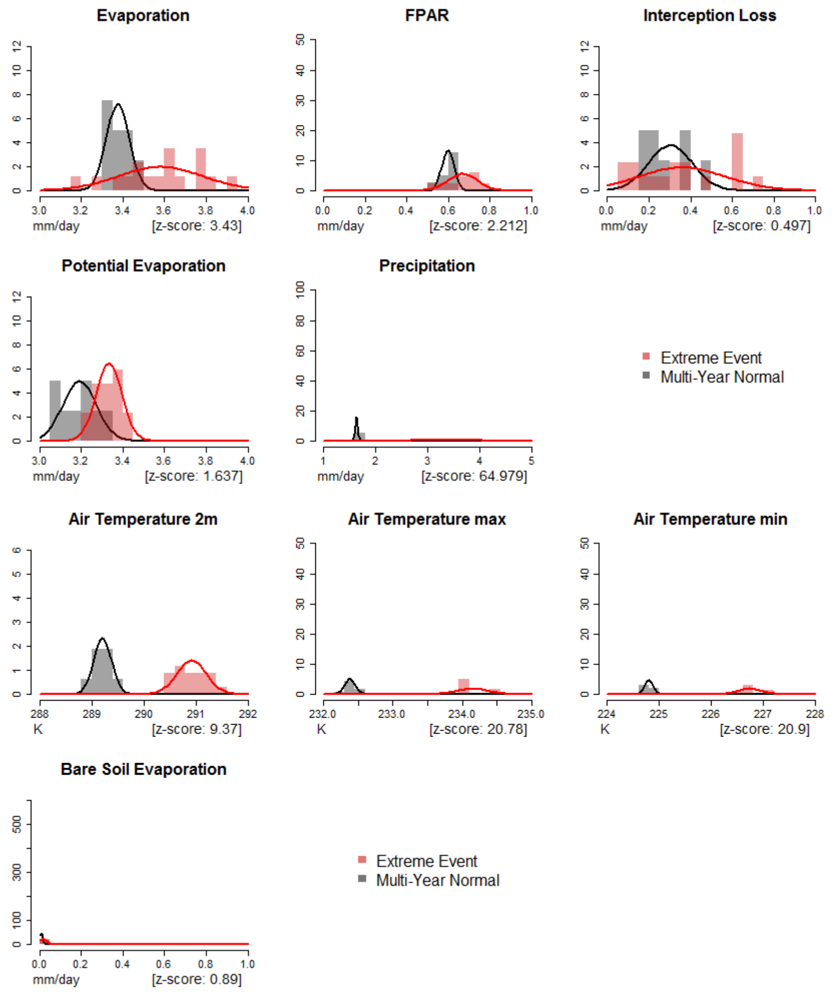
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation suggests extremely high temperatures and heavy rainfalls with high evapotranspiration and FPAR.





3. Independent validation & regional expert feedback

Temperatures in the region were slightly above average during the summer in general (Blunden and Arndt 2012) and at the given time period (www.wunderground.com). One incident of heavy rain (ESWD 2013) was reported for the given region and time period during a summer that was overall wetter than normal due to prevailing cyclonic conditions (Blunden and Arndt 2012). This supports external characterization, which also shows above-average precipitation.

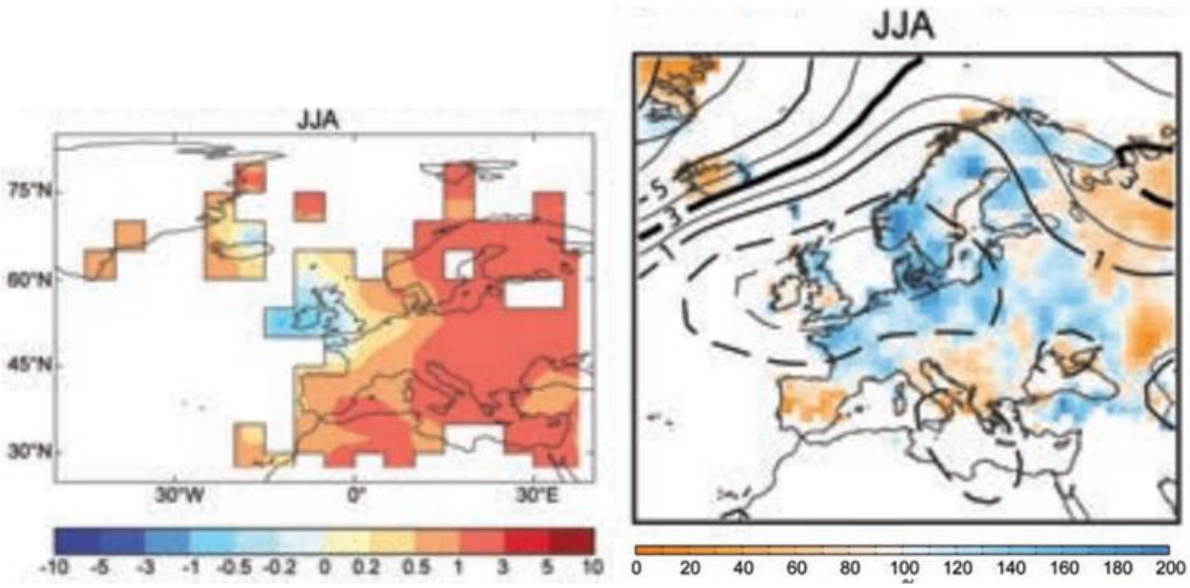


Figure 3: Surface temperature anomalies (°C, 1961-1990 base period) (left) and percentage of seasonal mean precipitation (1961-1990 base period) (right) for June to August 2011. The figures were adapted from Blunden and Arndt (2012)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Regional expert feedback 1

Short event description

The event is fairly localized, and is likely an episode of intensified tree harvesting in conifer plantations in the area, based on a clearly visible pattern in historical aerial photos available in Google Earth. In these images it is clear that the signal is harvesting (and not natural disturbances of forests) as the canopy removal follows a clear delineation of stand polygons, and focuses on the clearly distinguishable portion of the land that holds conifer plantations

Harvesting would be consistent with a generally decreased GPP and increased NEE and R observed by BACI. Also the generally larger variation in the BACI distributions makes sense, given that only a portion of the cell areas are actually affected by the harvesting event. As for the timing the year seems to have been correctly predicted by BACI, but I cannot speak to the timing within the year.

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy		x	
Spatial accuracy		x	
Temporal accuracy		x	

Regional expert feedback 2

A low

Short event description

Violent storms in PACA regions following low in the northern part of France
Duration: 1-06-2011 – 5-06-2011.

After a hot and dry month of May, a depression in northern France spawned a southwesterly flow over the country, bringing a hot and unstable air mass in which many storms formed. During these 5 days of violent storms burst on the Paca region accompanied by torrents of water. At the same time following an episode of "return from east" abundant rains fall on the Queyras. In French, it’s « Retour d’Est », I don’t have the exact translation but here is a definition: It is a contribution of moisture from the East via a flow coming from the same direction. This is an uncommon phenomenon because in France the general atmospheric circulation is from west to east in the majority of cases. This flow of continental origin can then cause a stall of low anomalies in our direction and awaken cyclogenesis in the Mediterranean. The disturbed flow, instead of being oriented as usual to the west, then turns to the East where this expression of return of East.
When these returns from the east occur outside of winter, it sometimes results in significant accumulations of precipitation in the coastal regions and more particularly in Languedoc-Roussillon where the rains are blocked on the Pyrenees reliefs.

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy	X		
Spatial accuracy		X	
Temporal accuracy			X

References:

Blunden, J., Arndt, D.S. (Eds.), 2012: State of the Climate in 2011. Bull. Amer. Meteor.Soc., 93 (7). https://journals.ametsoc.org/doi/pdf/10.1175/2012BAMSStateoftheClimate.1 (accessed 07.02.2018)

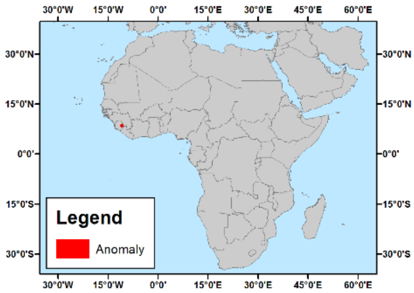
European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

Weather Underground. History for Mons. https://www.wunderground.com/history/airport/EBCV/2011/5/29/DailyHistory.html?req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo= (accessed 07.02.2018)

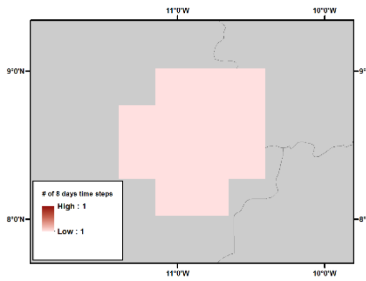
Event ID 23:

1. Attribution (internal)

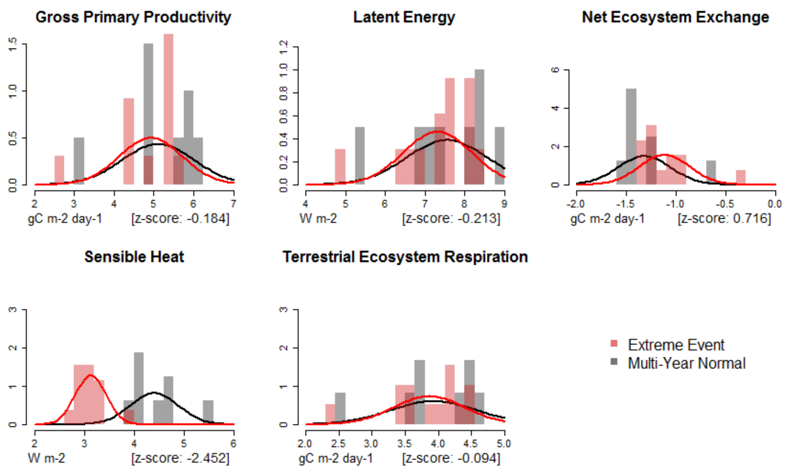
Type: Extreme event
Location: Sierra Leone
Area: 9834.3 km²
Time: 13.01.2002
Duration: 13.01.2002 – 13.01.2002



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

- Especially the sensible heat shows an unexpected behaviour for the detected extreme event.
  - With -2.452 is considerably lower than it would be during that time for 2000 to 2011
  - Therefore the detected extreme event can be linked to most likely lower temperatures
  - Thus GPP, LE and TER are also a bit lower than usually indicating lower vegetation activity

2. External characterisation

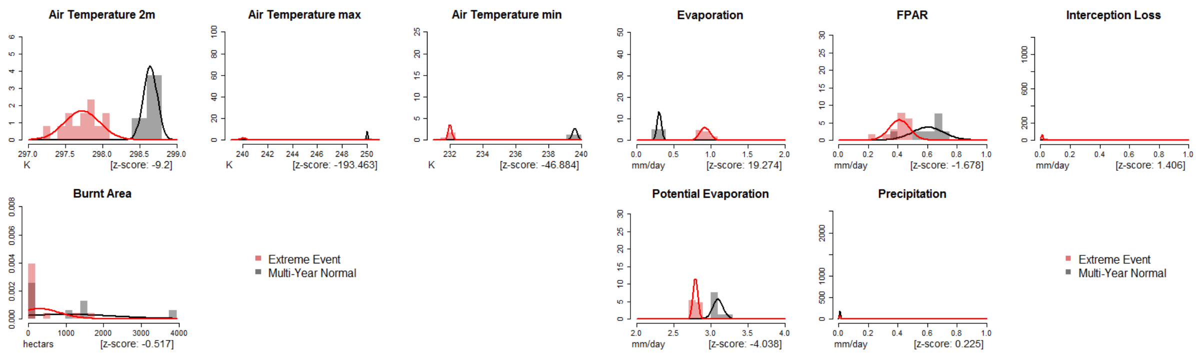
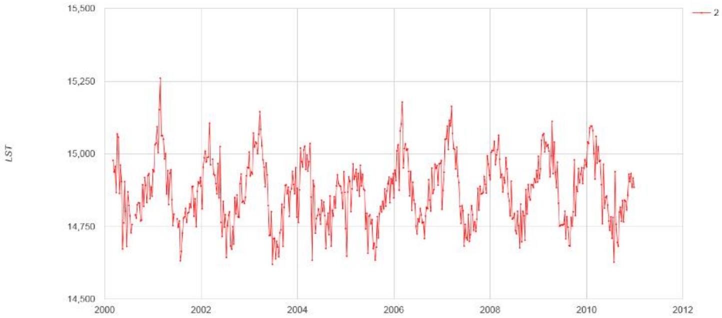


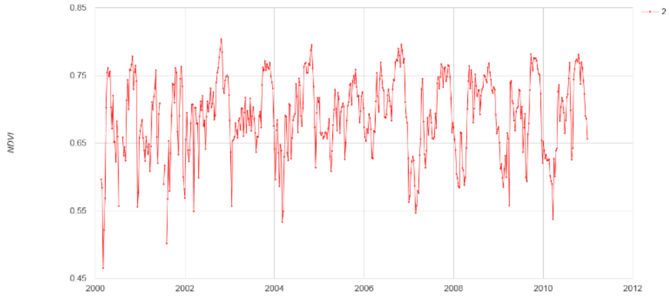
Figure 3 Additional CABLAB data not used for calculating the BACIndex

- The additional CAPLAP data not used for calculating the BACIndex show considerable lower air temperatures during the detected time period of the event (Figure)
- Also FPAR values (z-score of -1.678) shows reduced photosynthetic activity during that time and can be

linked to bad growing conditions (lower temperatures)

3. Independent validation & regional expert feedback





- LST and NDVI MODIS indicate the same behaviour as detected by the CABLAB data. Lower temperatures during the incident and also lower NDVI, as seen by lower FPAR and GPP (lower vegetation activity)
- So far it looks like it was abnormally cold during that time, which resulted in unusual vegetation activity
- However time period of lower NDVI and LST seems to be a bit longer than what detected by the BACIndex

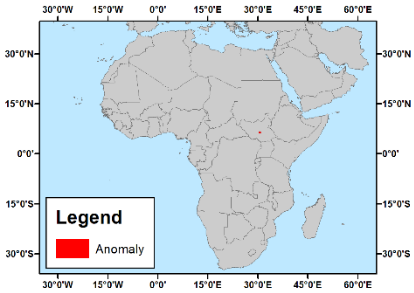
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

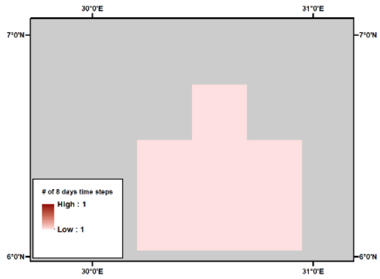
Event ID 24:

1. Attribution (internal)

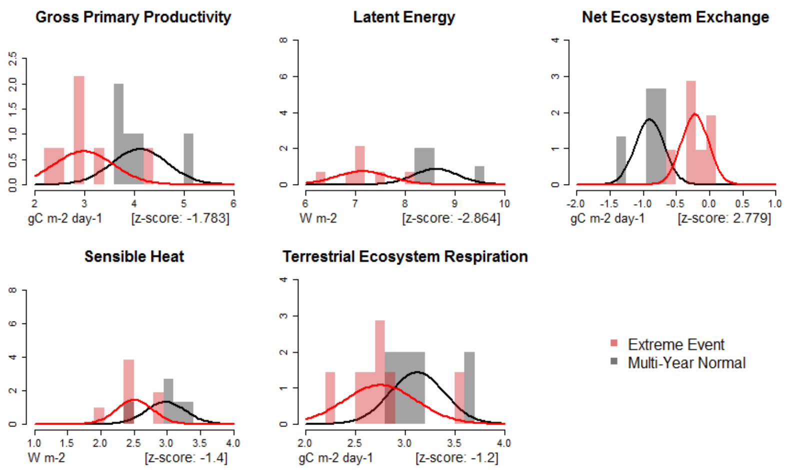
Type: Extreme event
Location: South Sudan
Area: 5321.6 km²
Time: 28.05.2004
Duration: 28.05.2004 – 28.05.2004



Extent of the event

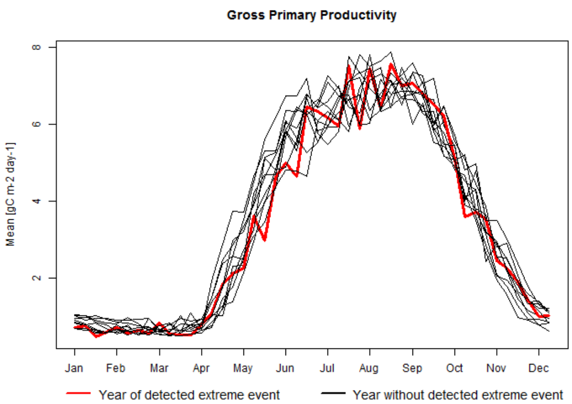


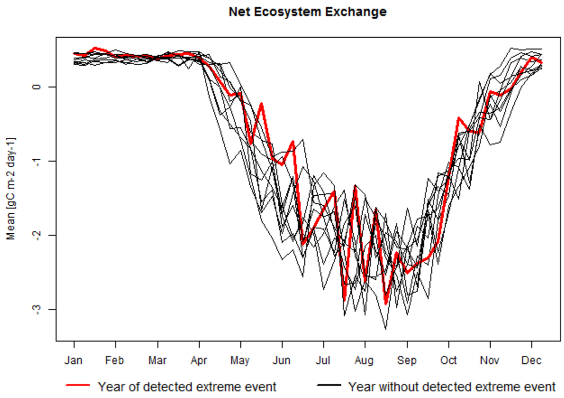
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

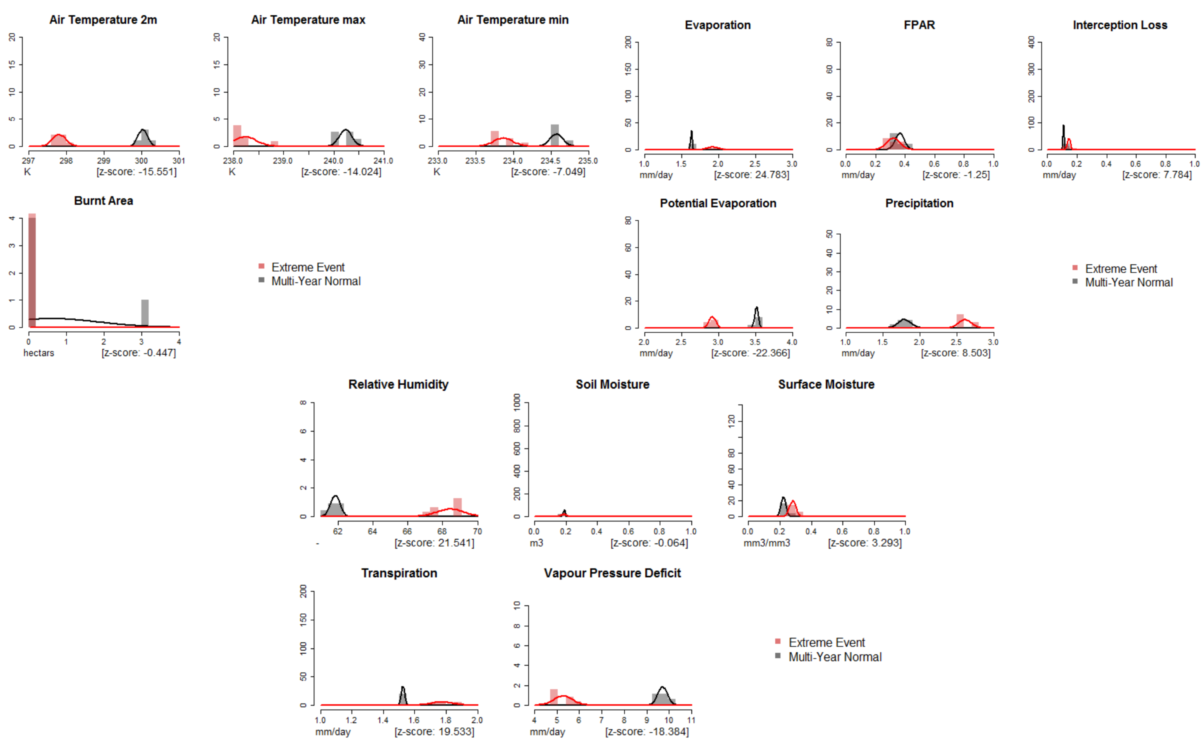
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





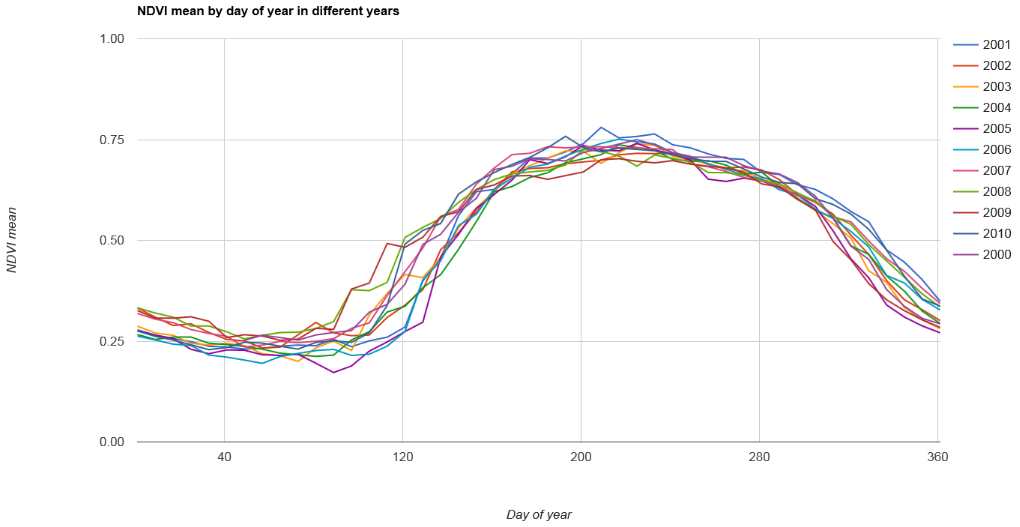
- Lower GPP, Latent Energy, Sensible Heat and Terrestrial Ecosystem Respiration with an z-score between -1.2 to -2.864
  - Considerably lower than the expected photosynthetic activity respectively energy going out of the ecosystem
- On the other hand Net ecosystem exchange shows abnormal high values with an z-score of 2.779, indicating release of CO_2 out of the ecosystem and therefore lower photosynthetic activities
- These findings may be linked to lower temperatures and are visible in the time series of GPP and NEE for the end of May in 2004 with lower respectively lower values

2. External characterisation



- Same trends are visible in the analysis of the additional CABLAB data showing
  - Lower temperatures in general with an z-score ranging between -15.5 to -7.1
  - Lower rates of FPAR (therefore lower photosynthetic activity) with an z-score of -1.25 and extremely high values of precipitation (8.503)
  - High values of relative humidity compared to the expected values and the same is valid for surface moisture

3. Independent validation & regional expert feedback



- MODIS NDVI analysis showed very low values for May 2004 compared to the rest of the years supporting the findings of the internal and external characterization
- Therefore an anomaly was present in form of lower temperatures and higher precipitation resulting in bad conditions of plant growth respectively lower photosynthetic activity

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision	X		
Temporal precision		X	

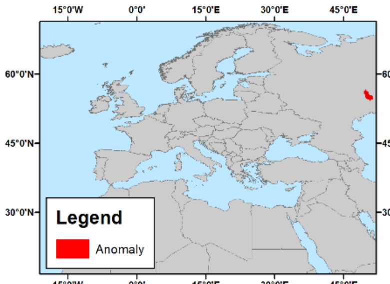
Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision			X

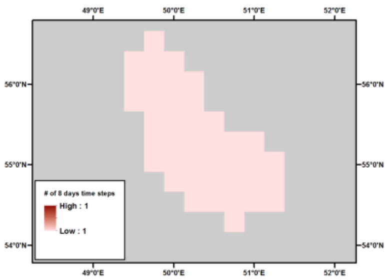
Event ID 25:

1. Attribution (internal)

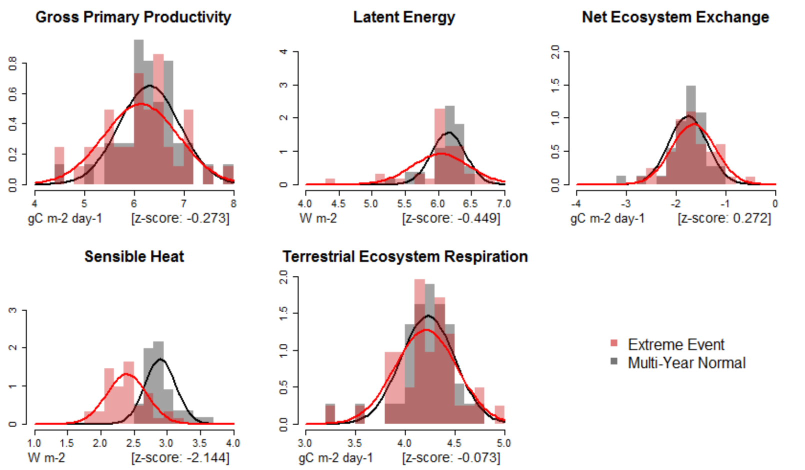
Type: Extreme event
Location: Russia, Kazakhstan
Area: 18009.0 km²
Time: 16.07.2002
Duration: 16.07.2002 – 16.07.2002



Extent of the event



# of 8 day time steps for which the event was detected

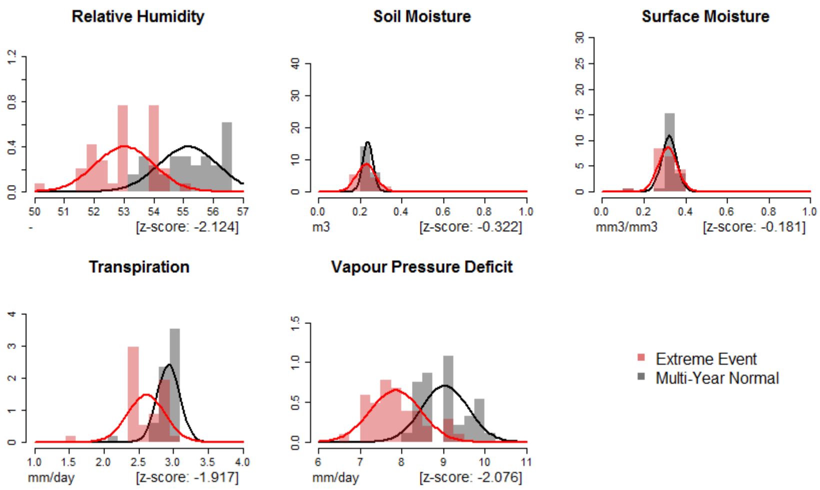


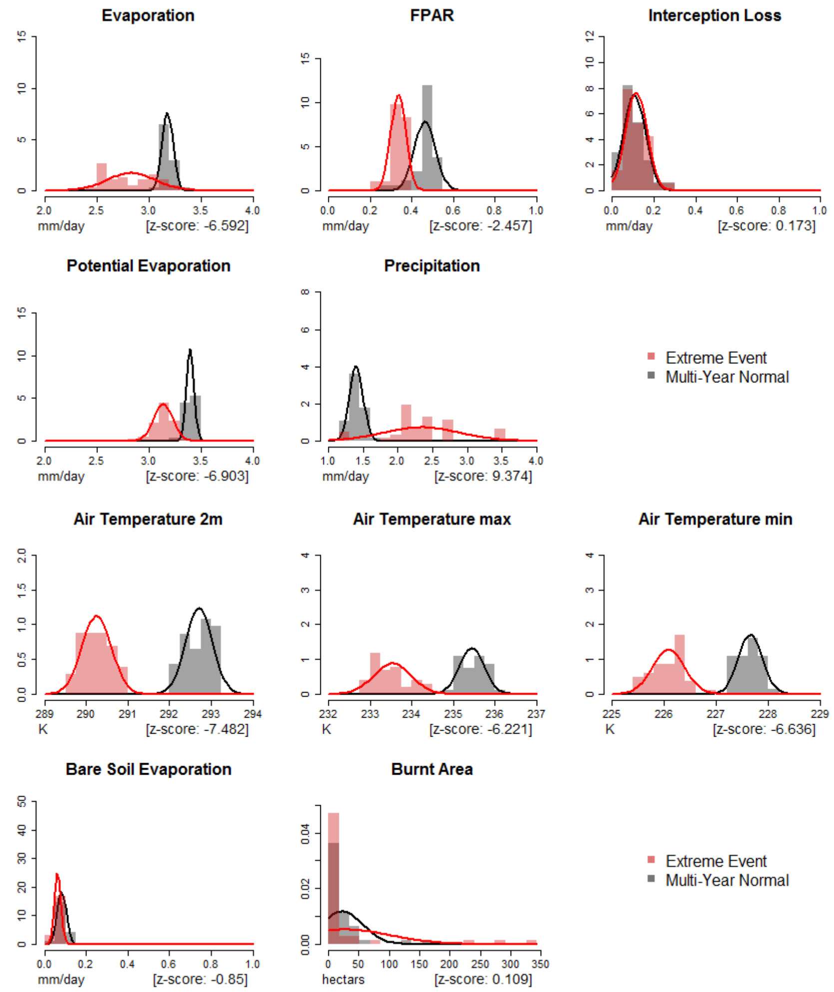
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External indication hints at above normal precipitation, low evapotranspiration and FPAR and low temperatures which is in line with the low sensible heat found in the internal attribution.





3. Independent validation & regional expert feedback

Heavy rainfalls

One instance of heavy rain on July 11th in the given region is reported (ESWD 2013) but no other independent validation of extreme conditions for this area was found.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1** **2** **3**
	Thematic precision	
	Spatial precision	
	Temporal precision	

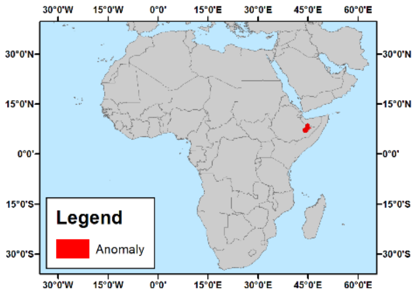
References

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

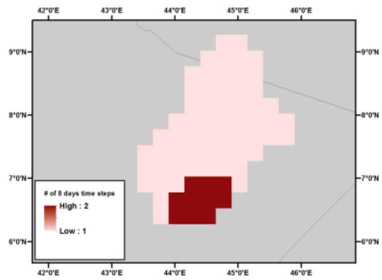
Event ID 26:

1. Attribution (internal)

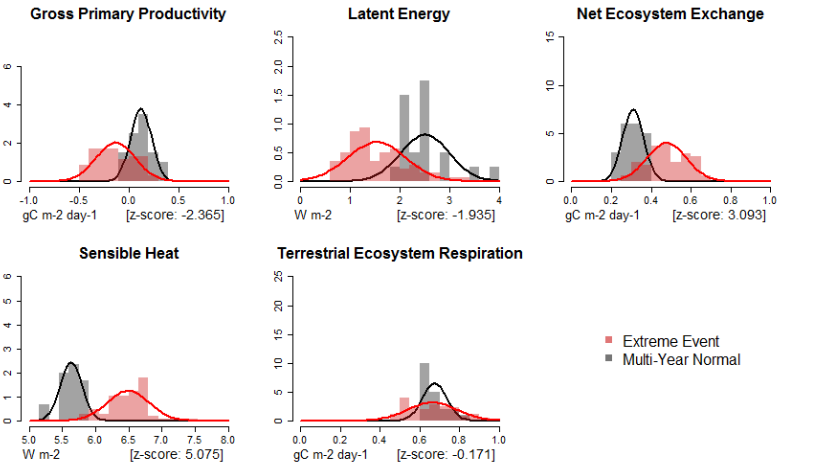
Type: Extreme event
Location: Ethiopia
Area: 53064.1 km²
Time: 19.04.2011
Duration: 19.04.2011 – 27.04.2011



Extent of the event

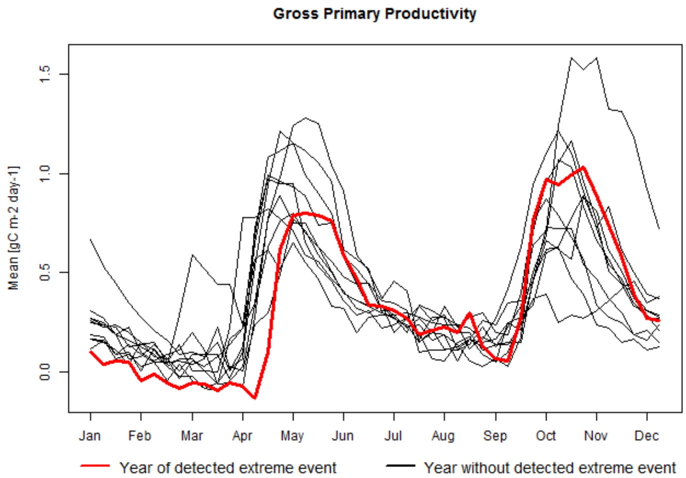


# of 8 day time steps for which the event was detected



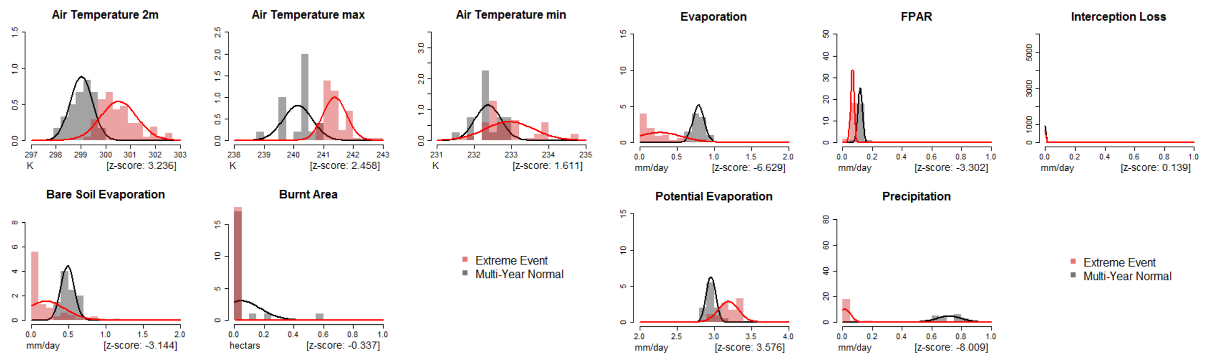
Extreme event vs. multi-year normal distribution of Basined input parameters

Distribution of extreme event versus multi-year normal for the Basined input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



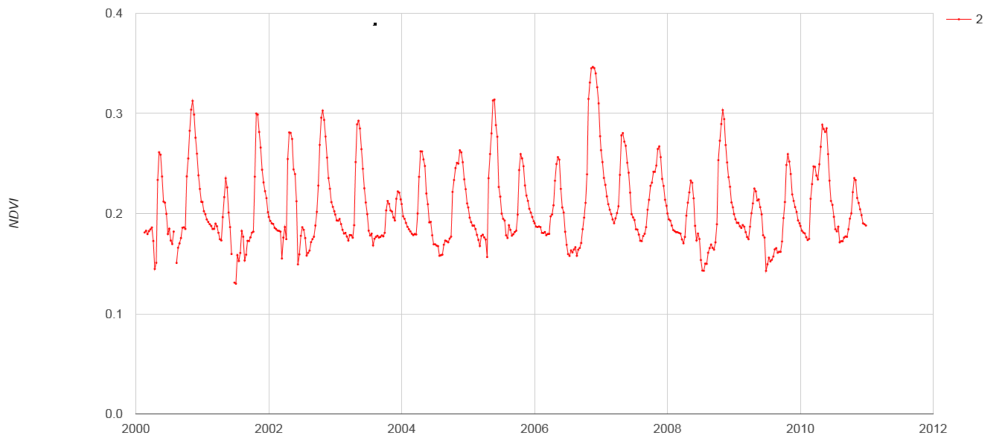
- The used CABLAB data indicate that there was a drought or temperature related stress for vegetation indicated by low GPP (z-score: -2.365) and high sensible heat (z-score: 5.075)
- Additionally the time series of the GPP coming from the CABLAB data shows considerable lower values for 2011 starting in April and lasting until the middle of May

2. External characterisation



- As indicated by the internal characterization Air temperatures were significantly higher. Thus, z-scores ranged between 1.6 to 3.236
- Linking to these findings FPAR (z-score: -3.3) and precipitation (z-score: -8) were lower and potential evaporation was higher (z-score: 3.576)

3. Independent validation & regional expert feedback



- These findings were also visible in the MODIS NDVI time series showing significantly lower values for April and May 2011

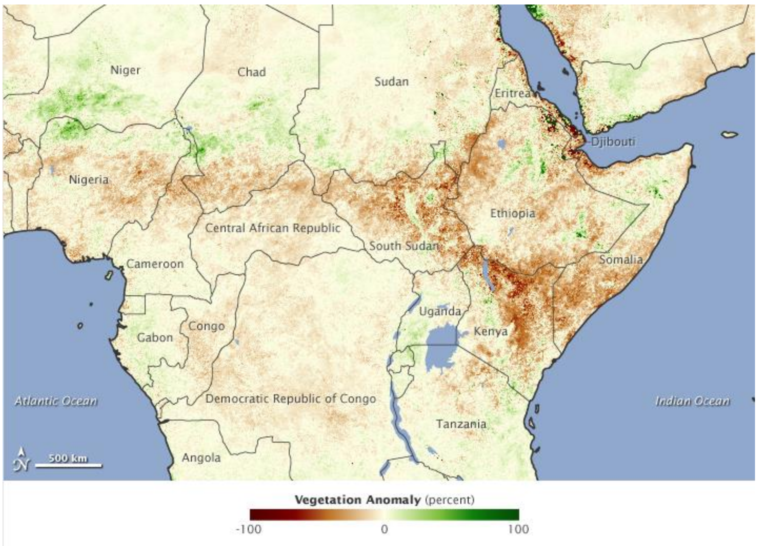


Figure Vegetation Anomaly based on AVHRR analysis(Earth Observatory 2011)

- Due that time the great east Africa drought was beginning resulting in the biggest drought in 60 years in the region of the Horn of Africa (figure)
- However, studies showed that the spatial and temporal extent of the extreme event were significantly larger respectively longer than detected by the Basined

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision		**X**	

Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision			**X**
Temporal precision			**X**

Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision		**X**	

Regional expert based evaluation (3) of the thematic, spatial and temporal precision of the event. 1 =

	1	2	3
Thematic precision		**X**	

		1	2	3
not precise, 2 = average, 3 = precise.	**Spatial precision**		X	
	Temporal precision		X	
Regional expert based evaluation (4) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1**	**2**	**3**
	Thematic precision		X	
	Spatial precision		X	
	Temporal precision			X

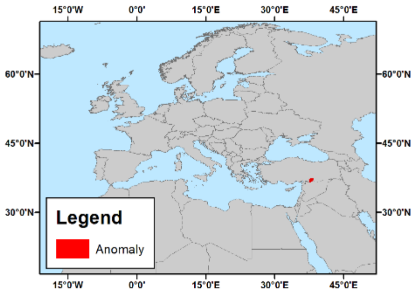
References

1. Earth Observatory (2011): Severe Drought causes Famine in East Arica. <https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=51411>

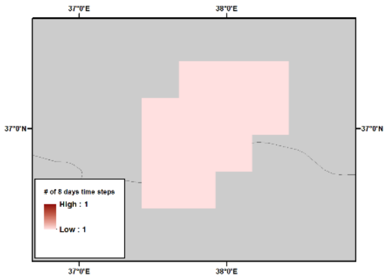
Event ID 27:

1. Attribution (internal)

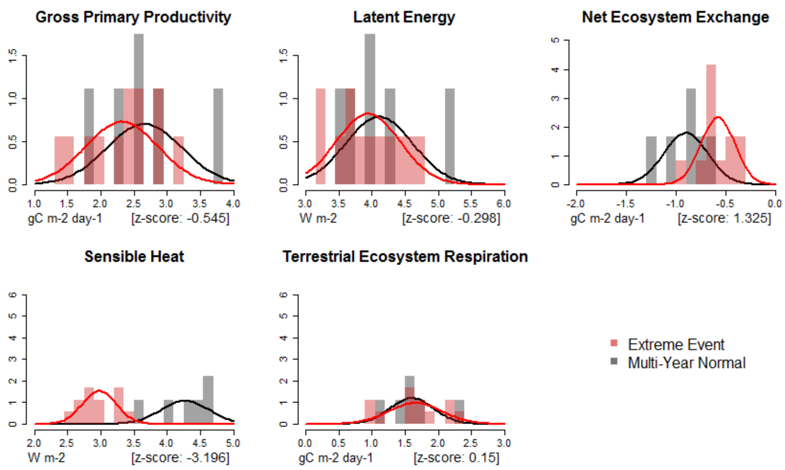
Type: Extreme event
Location: Turkish/Syrian Border
Area: 7365.1 km²
Time: 03.04.2006
Duration: 03.04.2006 – 03.04.2006



Extent of the event



# of 8 day time steps for which the event was detected

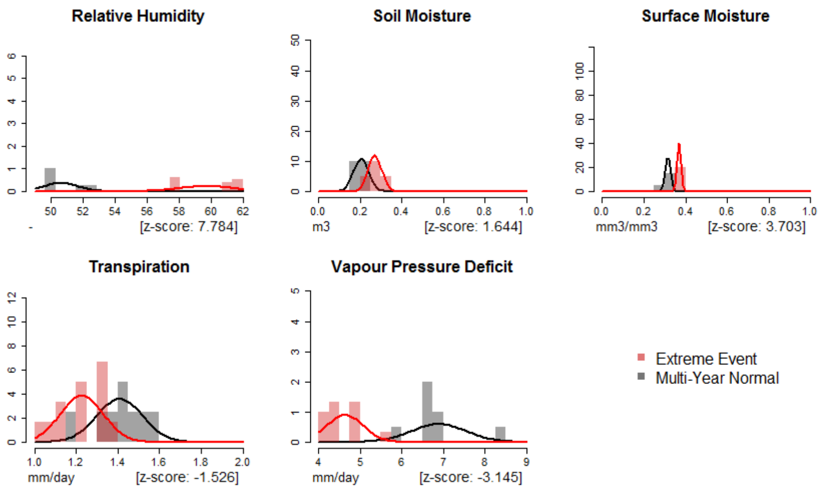


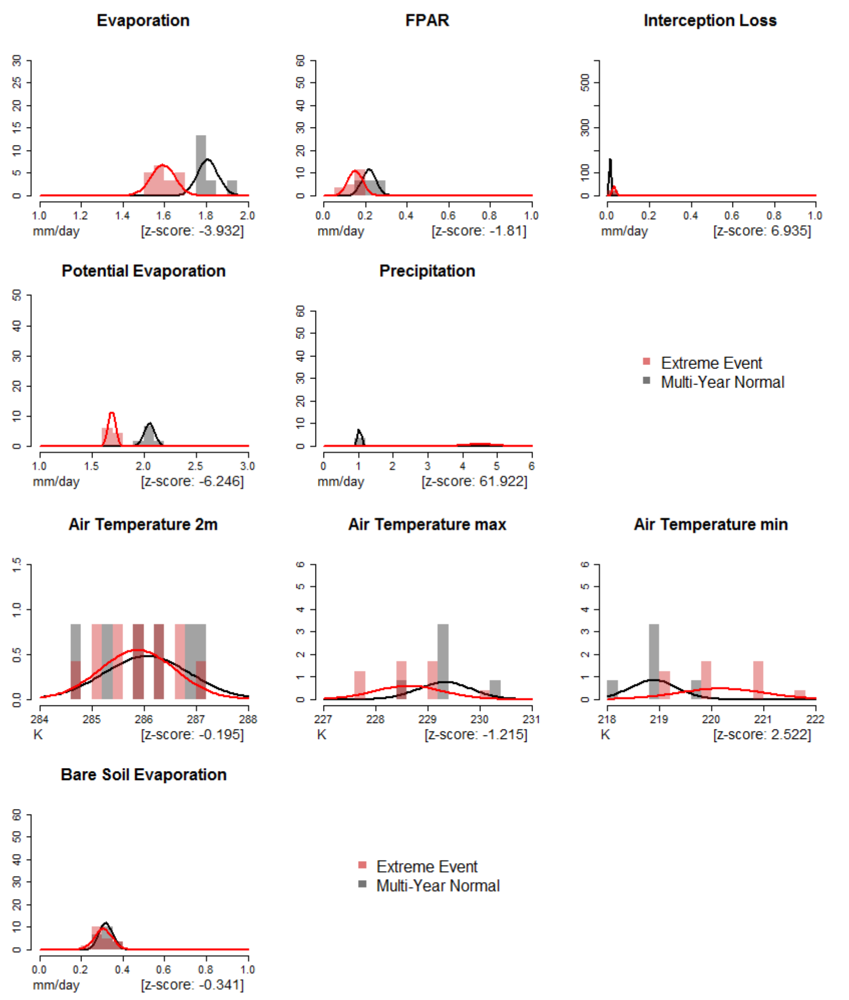
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation suggests above average precipitation and very humid conditions in general with low evapotranspiration which is in line with moist soils and surfaces and low sensible heat as put forward by the internal attribution.





3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Neither the OFDA/CRED International Disaster Database (EM-DAT) nor the European Severe Weather Database (ESWD) record any extreme weather or rainfall events for the given time period and region.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			

	Temporal precision		

References

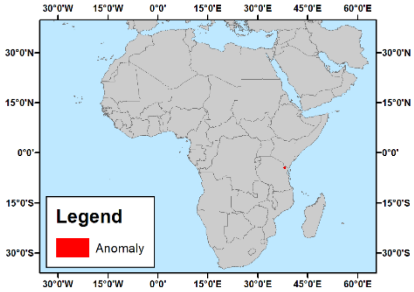
EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

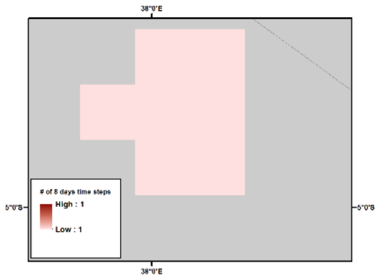
Event ID 28:

1. Attribution (internal)

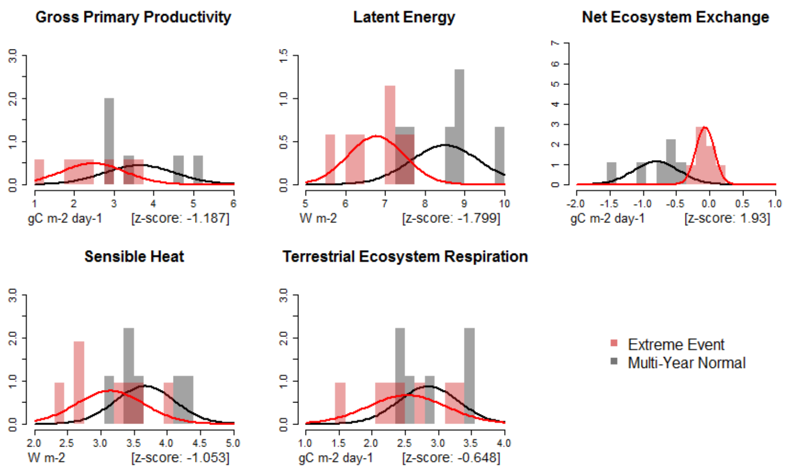
Type: Extreme event
Location: Tanzania
Area: 5336.8 km²
Time: 02.03.2006
Duration: 02.03.2006 – 02.03.2006



Extent of the event

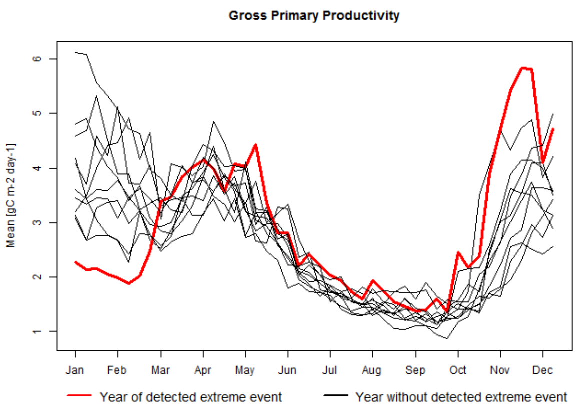


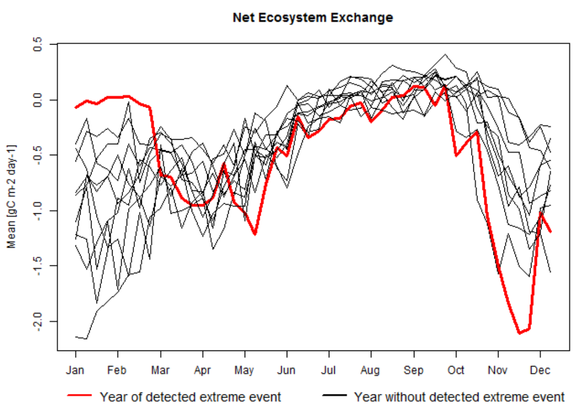
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

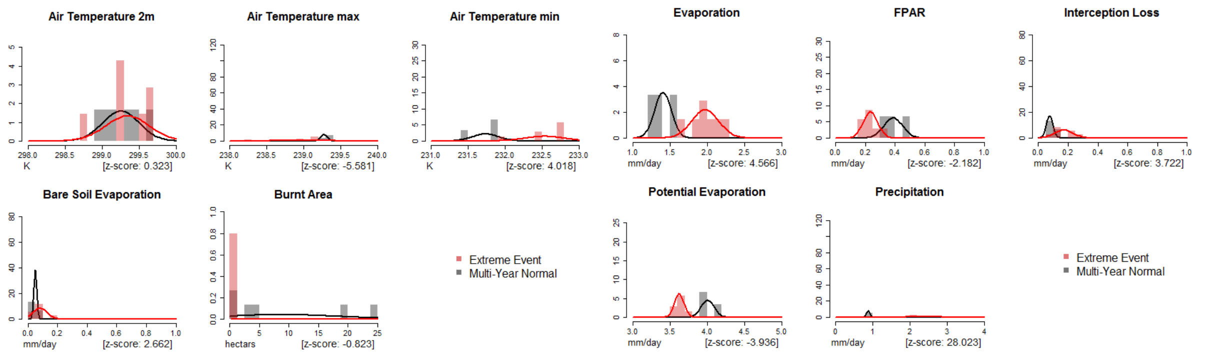
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





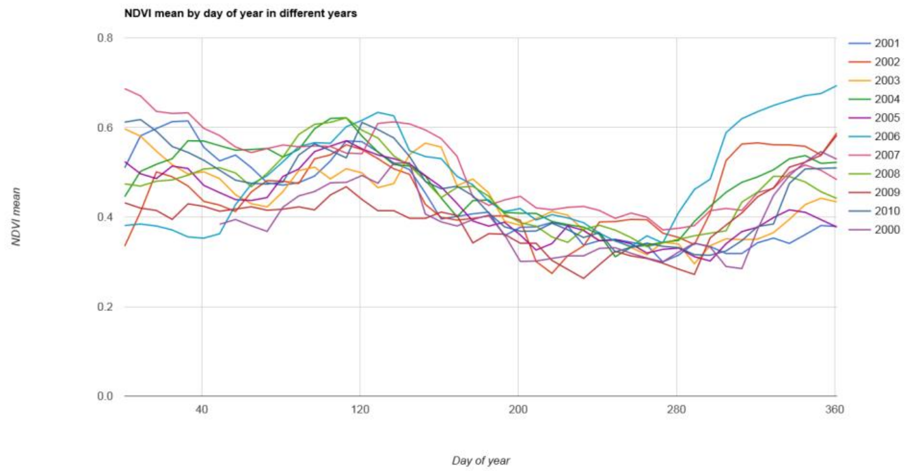
- GPP, LE, SH and TER are lower compared to the mean values of the respective variable during that time
- In contrast to that NEE values are very high
- These two trends of lower GPP and higher NEE in early March of 2006 are also visible in the time series analysis
    - But it's also visible that this trend started even earlier than the duration of the event – January of that year

2. External characterisation



- Linked to the findings of the internal characterization both the minimal air temperature was higher (z-score: 4.02) and the maximal air temperature was lower (z-score: -5.58) indicating setteled weather conditions for plant growth or activity
- That can be linked to the higher evaporation (z-score: 4.6), becvause of the higher amount of precipitation (z-score: 28) during that time underlying the worse conditions visible in reduced FPAR values (z-score: -2.2)

3. Independent validation & regional expert feedback



- MODIS NDVI indicates lower values for the detected time period, but also shows that NDVI values were significantly lower even before

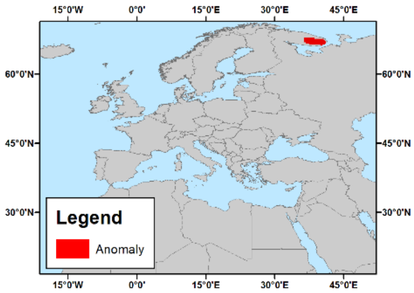
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision	X		

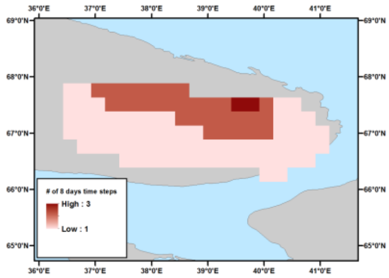
Event ID 29:

1. Attribution (internal)

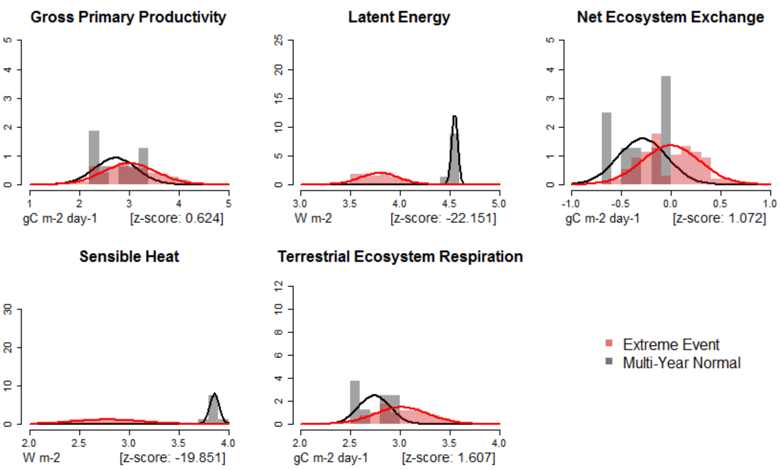
Type: Extreme event
Location: North-western Russia
Area: 29220.6 km²
Time: 30.06.2002
Duration: 14.06.2002 – 30.06.2002



Extent of the event



# of 8 day time steps for which the event was detected

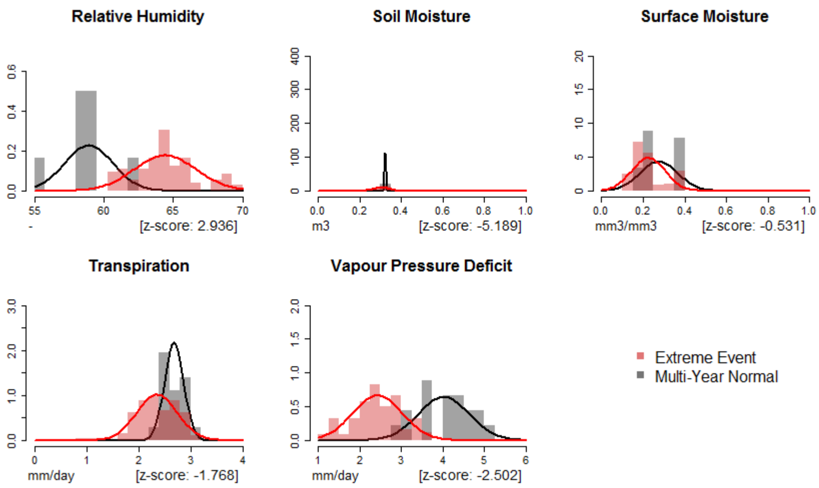


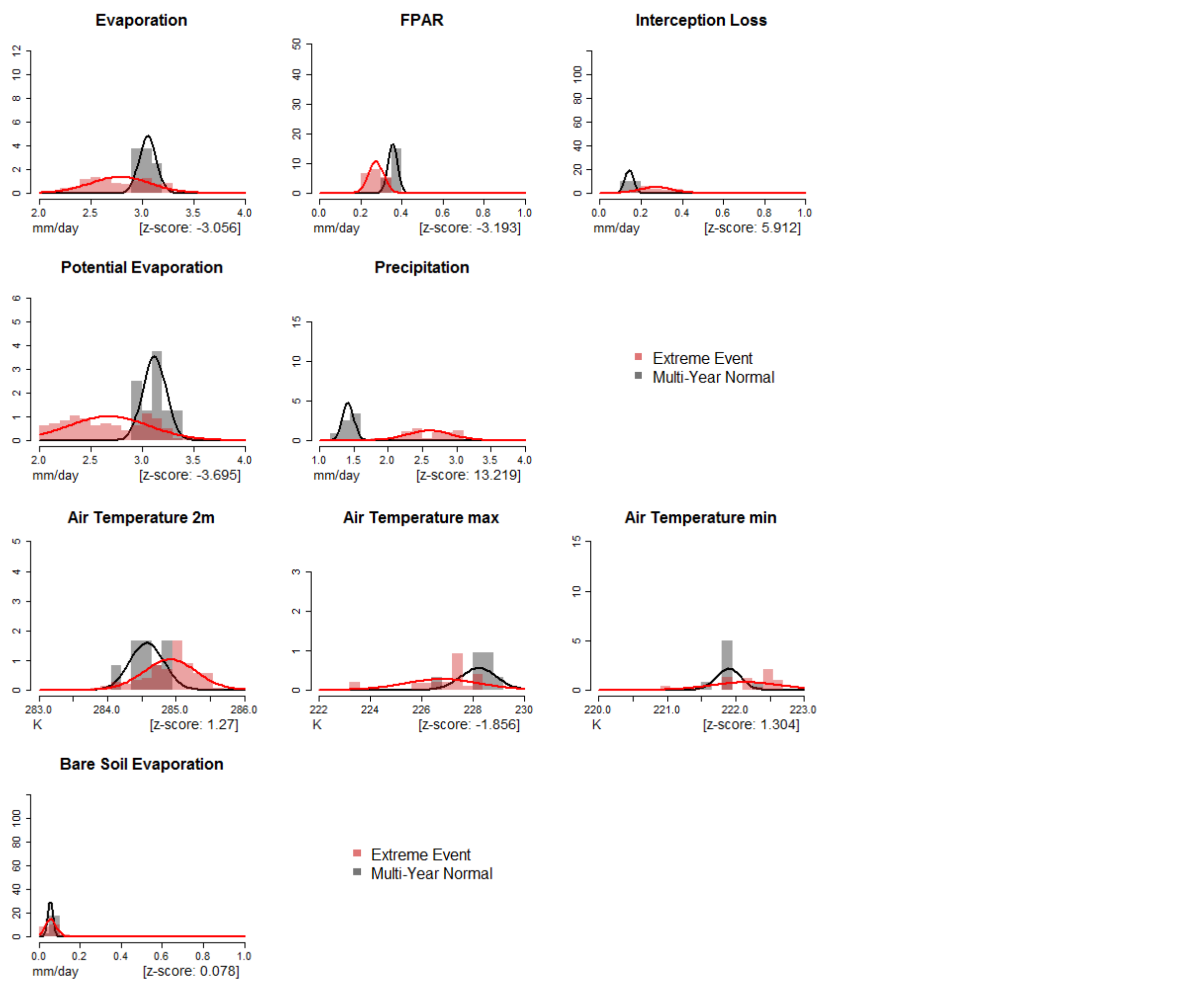
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation highlights above normal precipitation and humidity





3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

No extreme weather conditions were reported for the given time period and region (ESWD 2013; EM-DAT).

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		
Temporal precision	x		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			

	Temporal precision		

References

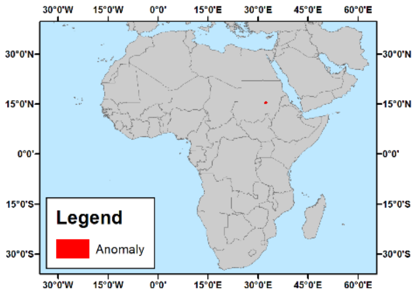
EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

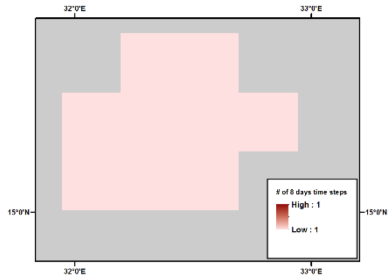
Event ID 30:

1. Attribution (internal)

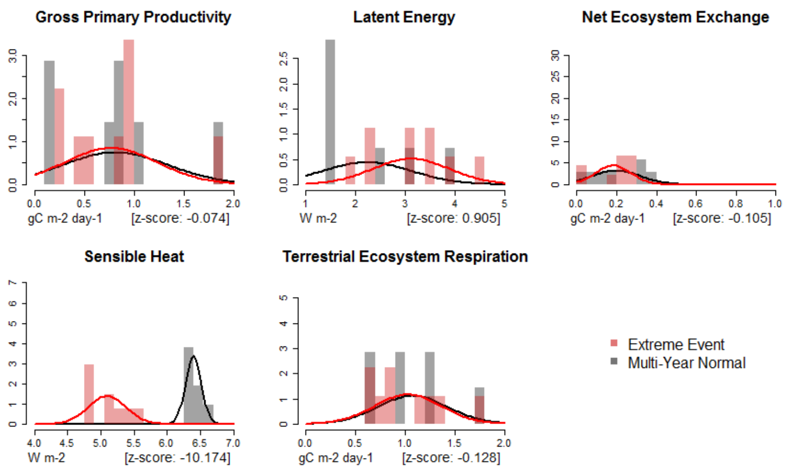
Type: Extreme event
Location: Sudan
Area: 6643.5 km²
Time: 30.06.2003
Duration: 30.06.2003 – 30.06.2003



Extent of the event

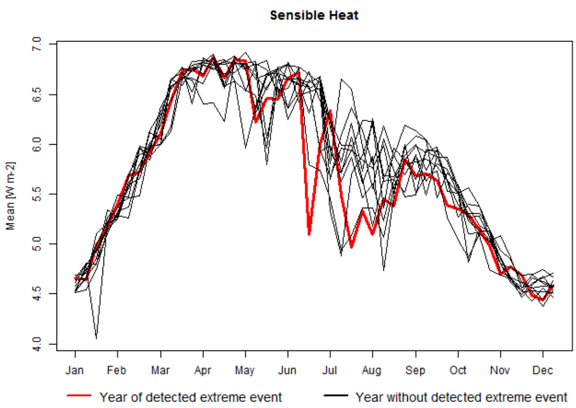


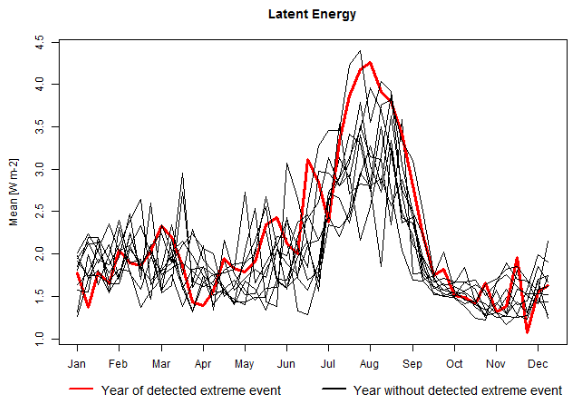
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

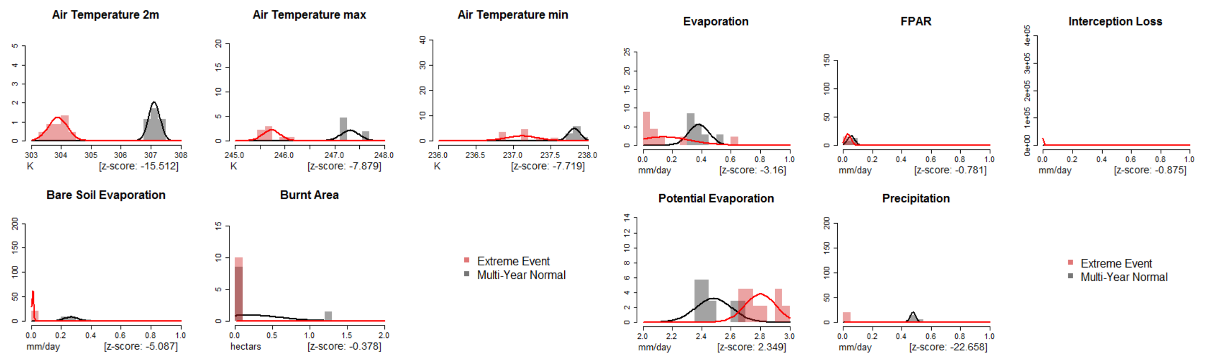
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





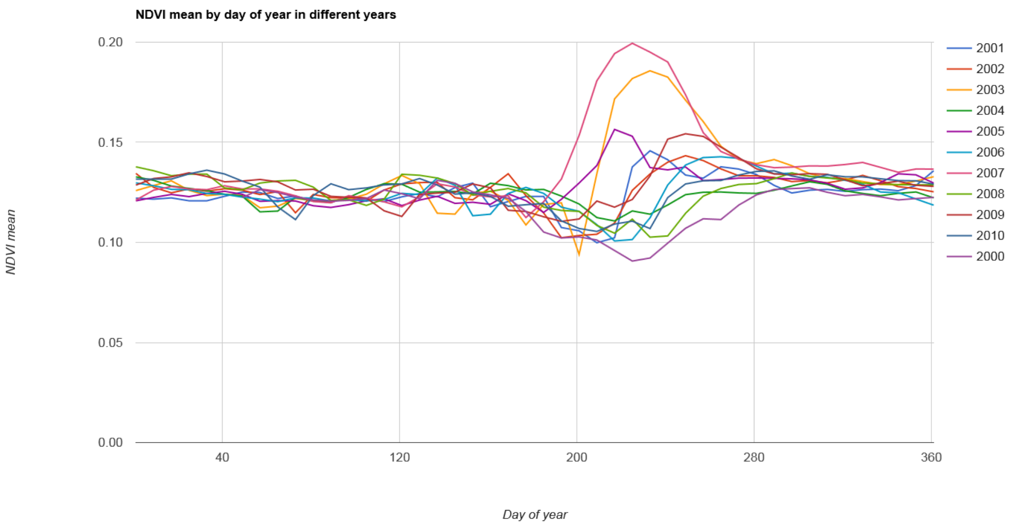
- Latent Energy indicated higher values compared to the multi-year normal with an z-score of 0.9 indicating more energy saved in the environment
- In contrast sensible heat showed with an z-score of -10.2 significantly lower values than expected indicating either low temperatures or in general less energy released by a system
    - These trends are also clearly visible in the time series of both parameters
- All other used CABLAB data parameters did not show any significant differences compared to the multi-year normal

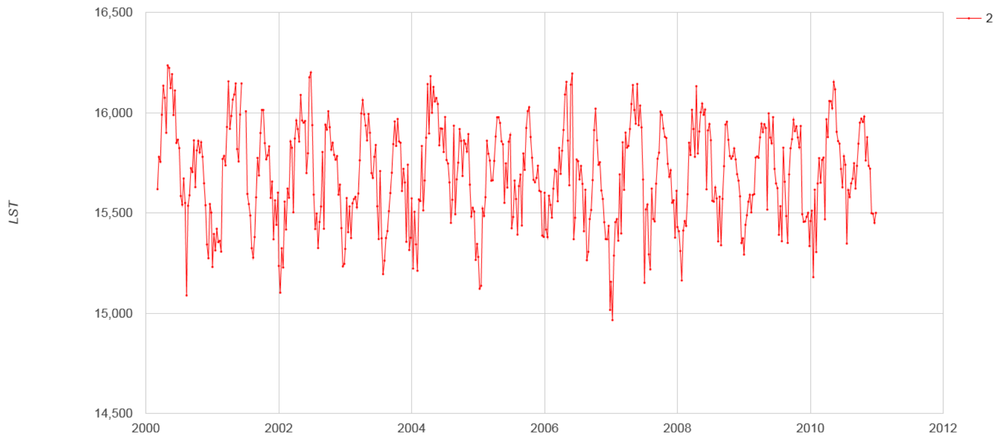
2. External characterisation



- The analysis of the additional CABLAB data showed similar and reasonable results indicating lower temperatures with z-scores ranging between -15.5 to -7.7 explaining the low values of the sensible heat
  - Therefore this event can be described as unusual low temperatures for that period resulting in less GPP and FPAR (z-score: -0.8) respectively photosynthetic activity

3. Independent validation & regional expert feedback





- The lower Temperatures and lower photosynthetic activity were also present while conducting the MODIS LST & NDVI analysis indicating lower values for both variable
  - Especially the temporal accuracy is very similar for the NDVI analysis
  - However, the impact on the NDVI is much larger than what was visible in the CABLAB data for either GPP or FPAR

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision			X

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision		X	
Temporal precision	X		

Regional expert based evaluation

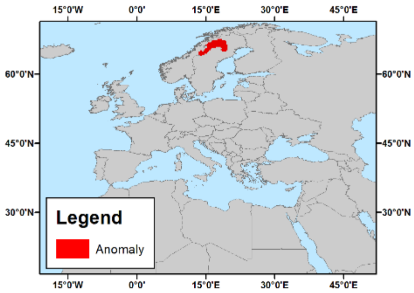
	1	2	3

of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**		**X**		
	Spatial precision			**X**	
	Temporal precision			**X**	

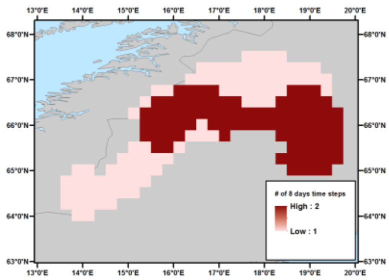
Event ID 31:

1. Attribution (internal)

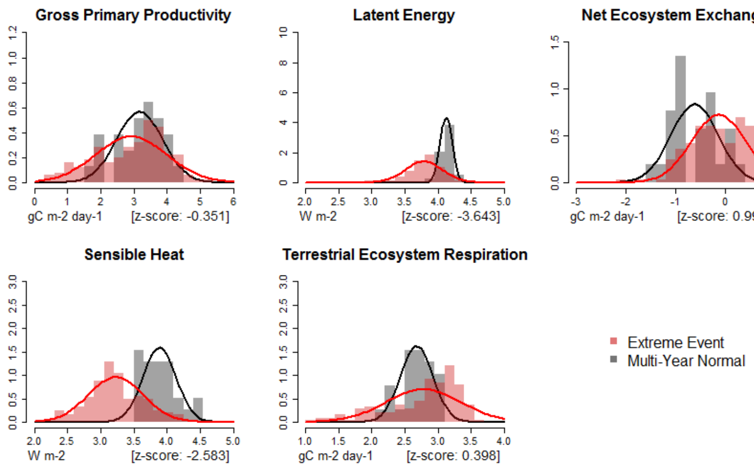
Type: Extreme event
Location: Sweden
Area: 52222.3 km²
Time: 30.06.2007
Duration: 30.06.2007 – 08.07.2007



Extent of the event



# of 8 day time steps for which the event was detected

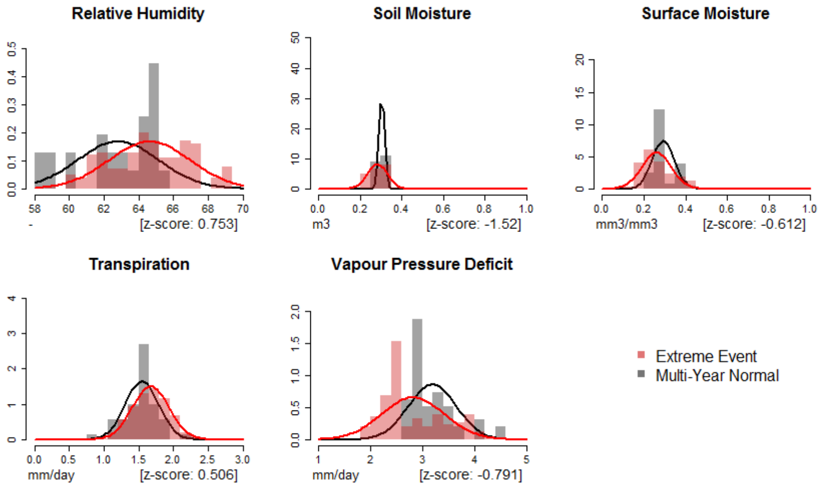


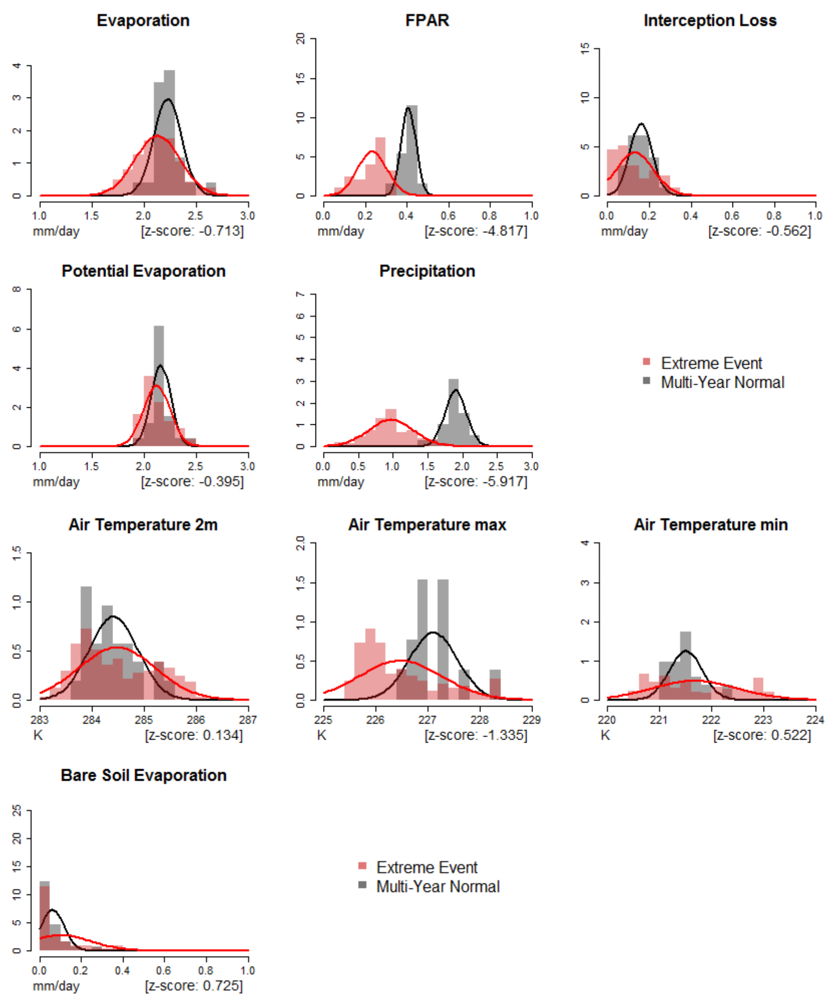
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External indication of low precipitation and FPAR and low maximum air temperature partly supports findings of internal attribution.





3. Independent validation & regional expert feedback

Dry and cold weather conditions

Sweden experienced a very warm and sunny first half of June followed by unsettled weather for the rest of the summer. Precipitation in the given region was slightly below average for June - August (see figure 1) (Levinson and Lawrimore 2008), which supports external characterization.

No other extreme weather conditions were reported for the given time period and region (ESWD 2013; EM-DAT).

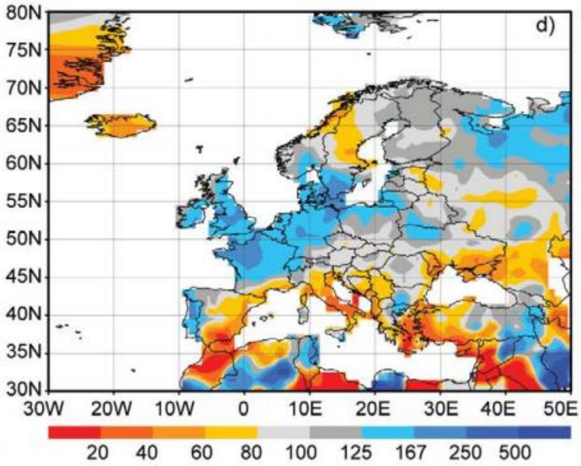


Figure 4: European precipitation total (% of normal, 1961-1990 base) for June to August 2007. The figure was taken from Levinson and Lawrimore (2008).

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Regional expert feedback

Short event description
Heat wave ?

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy	x		
Spatial accuracy	x		
Temporal accuracy		x	

References

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

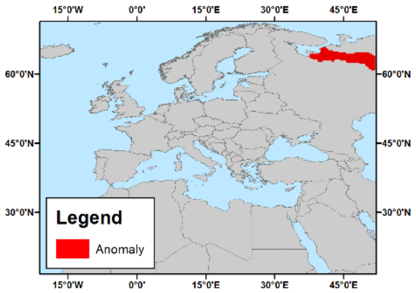
European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

Levinson, D.H., Lawrimore, J.H. (Eds.), 2008: State of the Climate in 2007. Special Supplement to the Bulletin of the American Meteorological Society. Vol. 89, No7, July 2008. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-89-7-StateoftheClimate (accessed 07.02.2018)

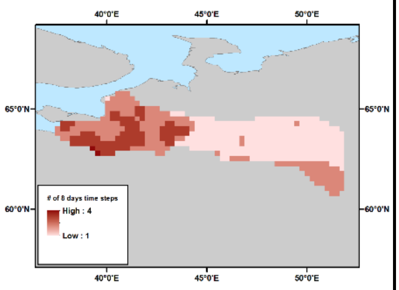
Event ID 32:

1. Attribution (internal)

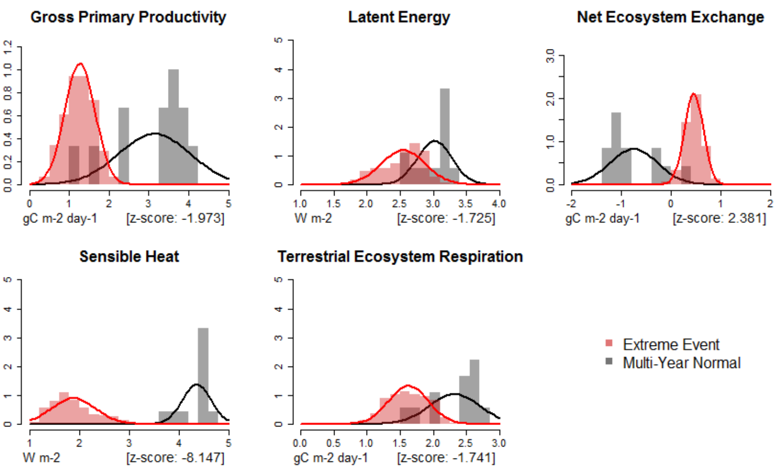
Type: Extreme event
Location: North-western Russia
Area: 177002.1 km²
Time: 20.05.2008
Duration: 20.05.2008 – 13.06.2008



Extent of the event



# of 8 day time steps for which the event was detected

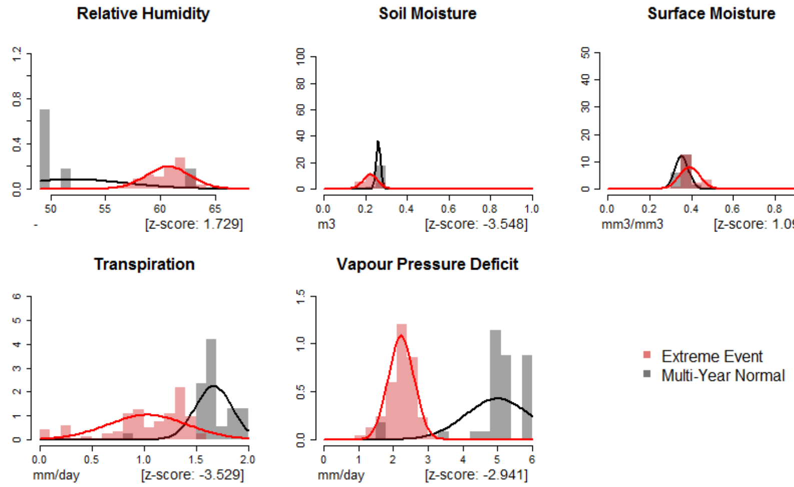


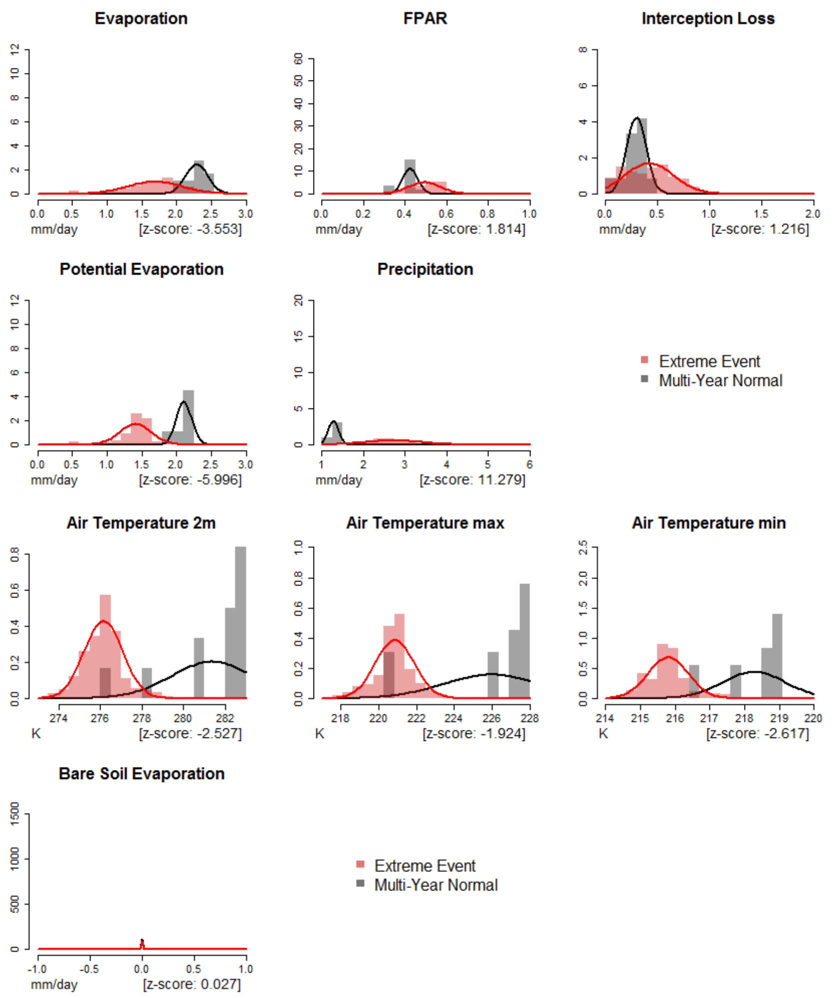
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The external characterisation indicates high precipitation and FPAR, but low evapotranspiration and low temperatures, which supports findings of low GPP and sensible heat of the internal attribution.





3. Independent validation & regional expert feedback

Cold-wave in European Russia:

Although 2008 was very warm over Russia, European Russia experienced below normal temperatures in May with record breaking daily minima in some regions. Negative temperature anomalies continued into June, where ground and air frosts were recorded in the first 10 days of June in most locations (Peterson and Baringer 2009).
MODIS-NDVI time series results support very low GPP levels in the given time period.

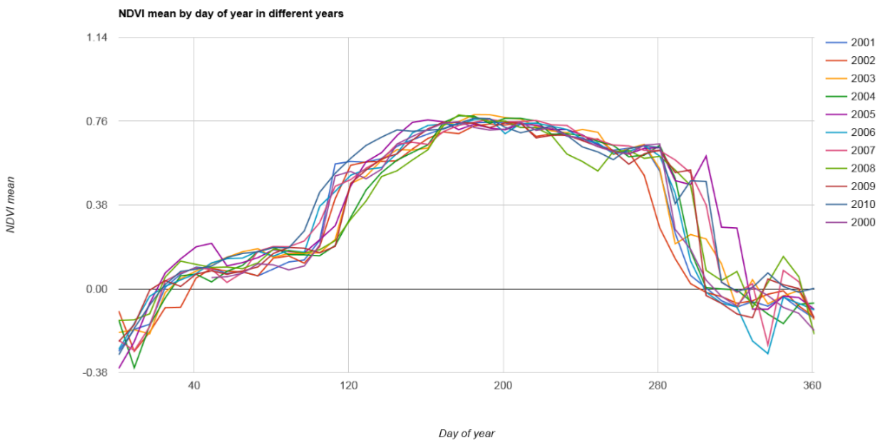


Figure 1: MODIS NDVI daily averages inter-compared between each years in the 2000-2010 time period.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

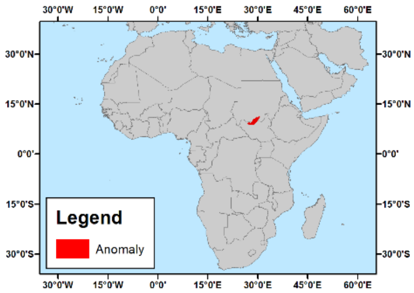
References

Peterson, T.C., Baringer M.O. (Eds.), 2009: State of the Climate in 2008. Special Supplement to the Bulletin of the American Meteorological Society. Vol. 90, No. 8, August 2009. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-90-8-StateoftheClimate (accessed 07.02.2018)

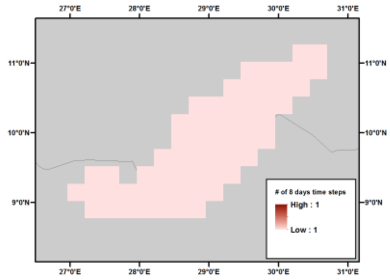
Event ID 33:

1. Attribution (internal)

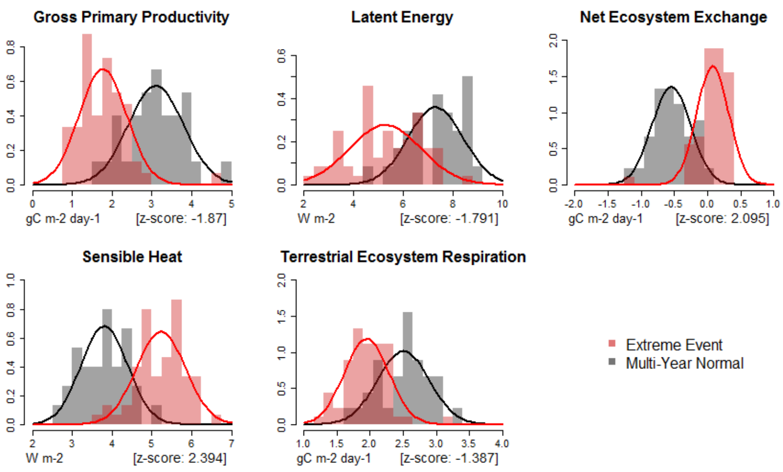
Type: Extreme event
Location: Sudan / South Sudan
Area: 45226.3 km²
Time: 14.06.2009
Duration: 14.06.2009 – 14.06.2009



Extent of the event

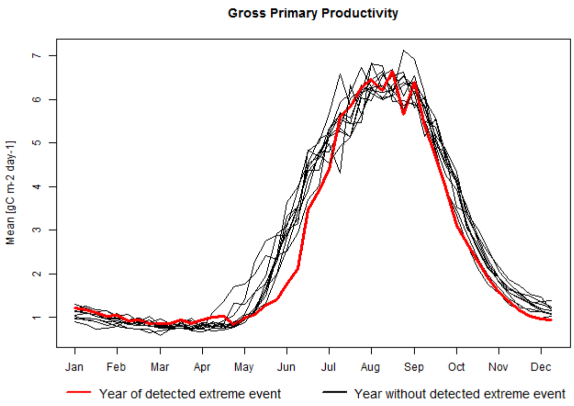


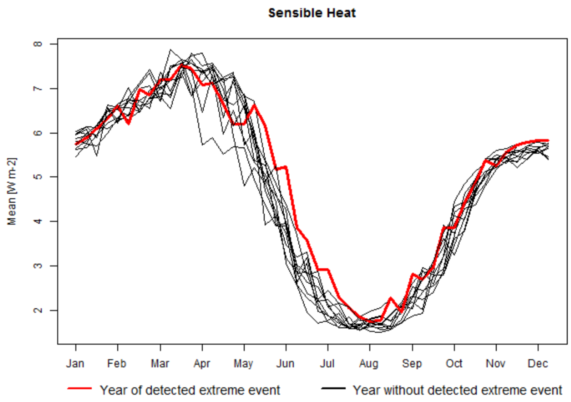
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

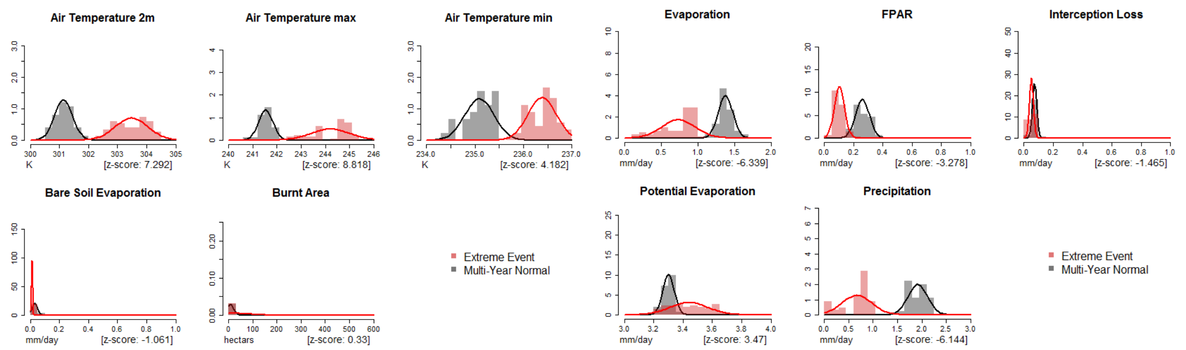
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





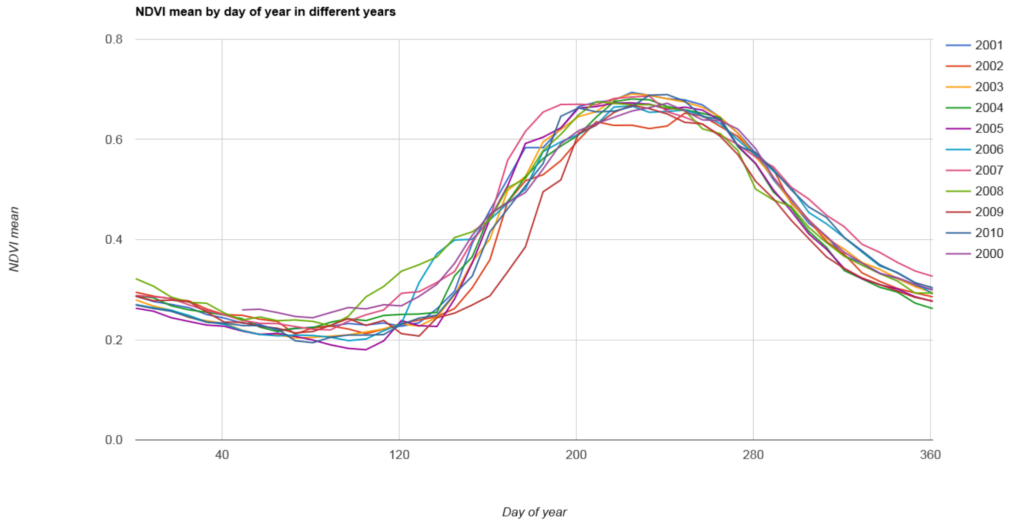
- The internal characterization resulted in revealing of a drought as the event represented by lower values for GPP, LE and TER
- In contrast the SE and NEE were considerably higher than the multi-year normal
- This was also visible for the detected time period for GPP and SE

2. External characterisation



- The findings of the internal characterization are covered by the analysis of additional CABLAB data showing higher temperatures (figure) and reduced FPAR, precipitation and evaporation (figure)

3. Independent validation & regional expert feedback



- The MODIS NDVI analysis showed similar results in reduced photosynthetic activity mopst likley caused by a drought for 2009
  - However, it is noticeable that the time period of these reduced NDVI values is much longer than what was detected as an extreme event by the BACIndex

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision	**X**		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 =

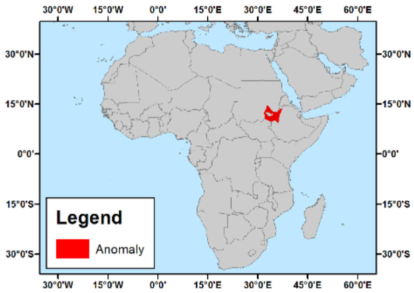
	1	2	3
Thematic precision	**X**		

not precise, 2 = average, 3 = precise.	**Spatial precision**	**X**	
	Temporal precision	**X**	

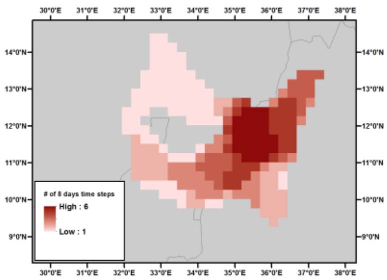
Event ID 34:

1. Attribution (internal)

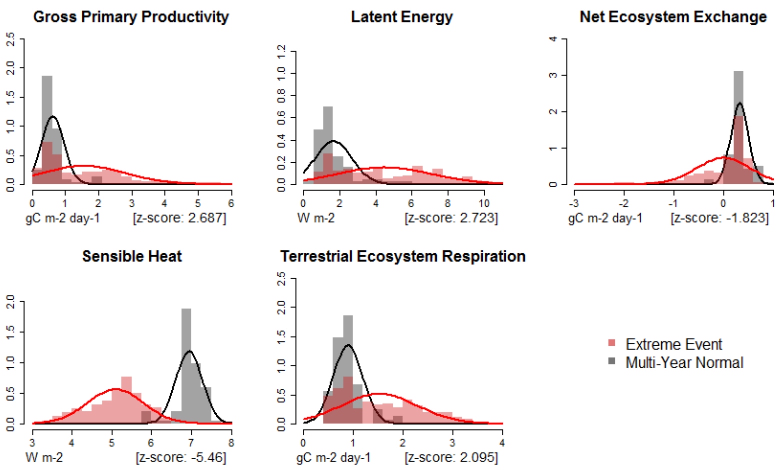
Type: Extreme event
Location: Horn of Africa
Area: 171560.5 km²
Time: 13.05.2006
Duration: 05.05.2006 – 14.06.2006



Extent of the event



\# of 8 day time steps for which the event was detected

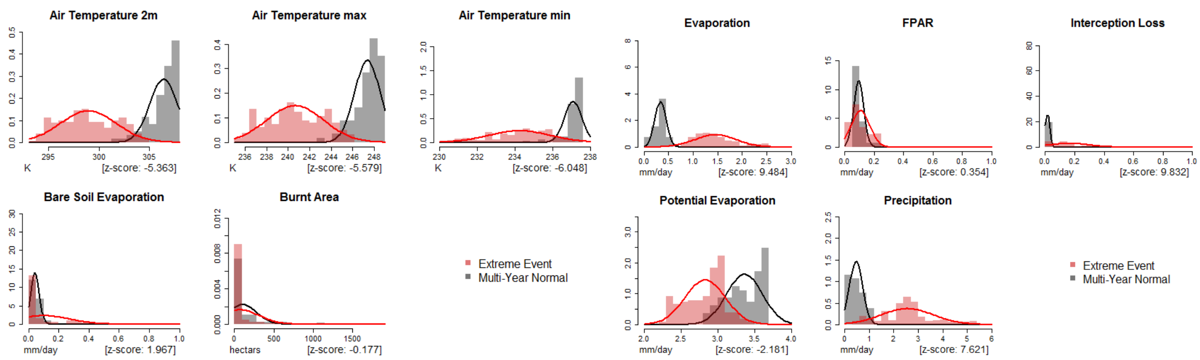


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

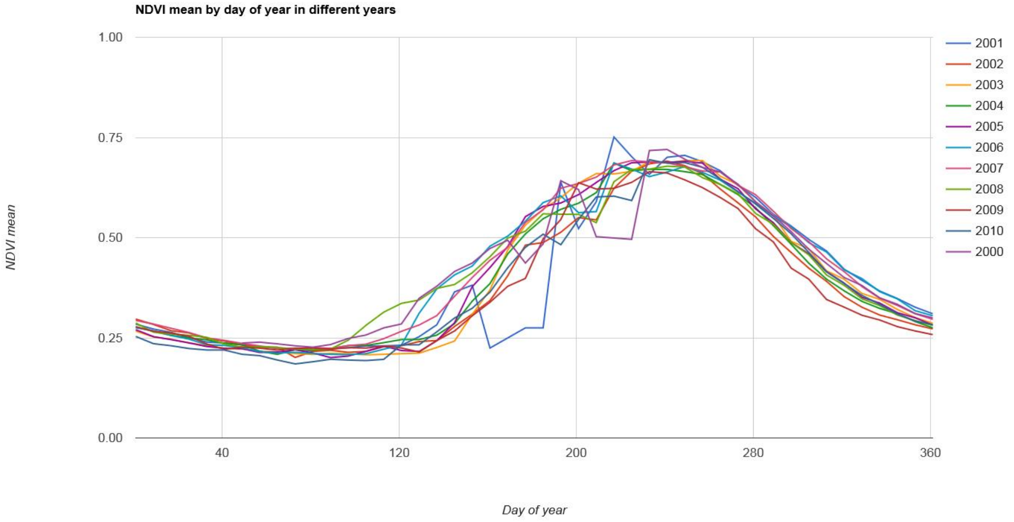
- The used CABLAB data showed significantly higher GPP, LE and TER, whereas SH and NEE were much lower than the multi-year normal
- This in return means more plant activity and lower temperatures, since GPP ist higher and SH is lower than expected

2. External characterisation



- The additional CABLAB data not used for the calculation of the BACIndex showed resonable results taking the internal characterization into account (figure)
    - Lower temperatures
    - Higher evaporation
    - Higher precipitation
- These findings stay in good agreement with better conditions for plants to grow and better potential photosynthetic activity

3. Independent validation & regional expert feedback



- The analysis of MODIS NDVI values for the years 2000 – 2010 showed good agreement with the findings by the internal and external characterization
    - NDVI values were higher for the detected duration of the event

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision			X

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

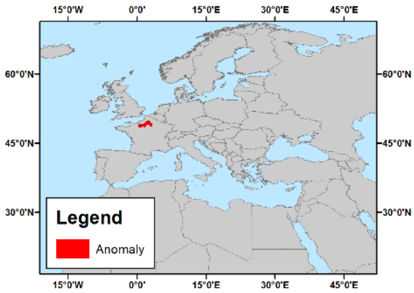
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	

	1	2	3
Thematic precision		X	
Spatial precision			X
Temporal precision		X	

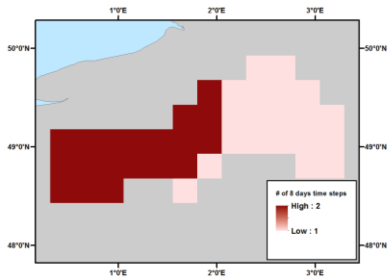
Event ID 35:

1. Attribution (internal)

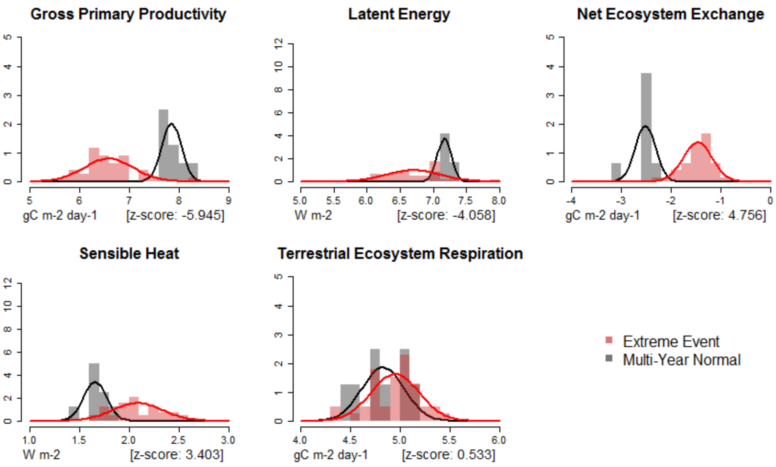
Type: Extreme event
Location: Northern France
Area: 19681.7 km²
Time: 06.06.2011
Duration: 29.05.2011 – 06.06.2011



Extent of the event



# of 8 day time steps for which the event was detected

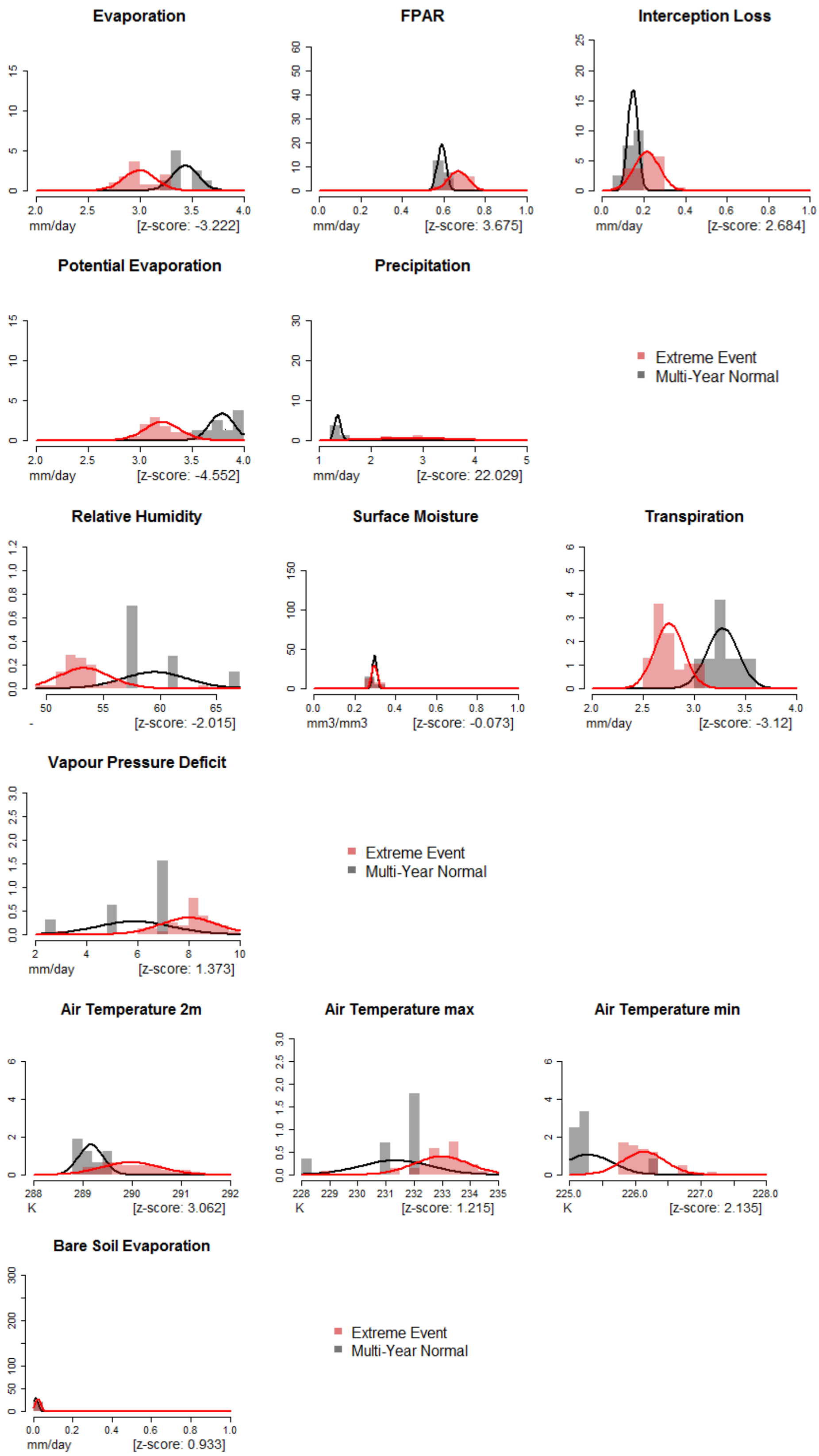


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

The BACI hotspot corresponds with very high temperatures and low relative humidity, low evaporation and transpiration, which indicate low plant productivity. This supports the attribution results, i.e. low GPP and high sensible heat. Apparently, precipitation was extremely high, probably indicating heavy rainfalls.



3. Independent validation & regional expert feedback

Heavy rainfalls and local floods in Northern France, Paris area

The European Severe Weather Database (ESWD, 2013) reports heavy rainfalls and local floods in two areas within the hotspot: Région Picardie and Région Centre on the 7.6. and 4.6.2011. Information is based on eye-witness reports.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			x
Spatial precision		x	
Temporal precision			x

Regional expert feedback

A low

Short event description

Violent storms in PACA regions following low in the northern part of France
Duration: 1-06-2011 – 5-06-2011.

After a hot and dry month of May, a depression in northern France spawned a southwesterly flow over the country, bringing a hot and unstable air mass in which many storms formed. During these 5 days of violent storms burst on the Paca region accompanied by torrents of water. At the same time following an episode of "return from east" abundant rains fall on the Queyras. In French, it's « Retour d'Est », I don't have the exact translation but here is a definition: It is a contribution of moisture from the East via a flow coming from the same direction. This is an uncommon phenomenon because in France the general atmospheric circulation is from west to east in the majority of cases. This flow of continental origin can then cause a stall of low anomalies in our direction and awaken cyclogenesis in the Mediterranean. The disturbed flow, instead of being oriented as usual to the west, then turns to the East where this expression of return of East.
When these returns from the east occur outside of winter, it sometimes results in significant accumulations of precipitation in the coastal regions and more particularly in Languedoc-Roussillon where the rains are blocked on the Pyrenees reliefs.

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

	1	2	3
Thematic accuracy	X		
Spatial accuracy		X	
Temporal accuracy			X

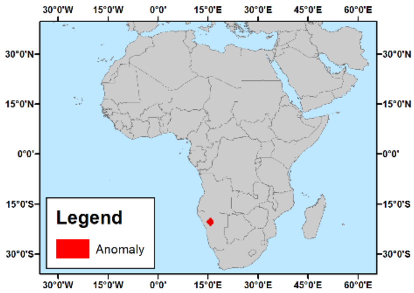
References

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

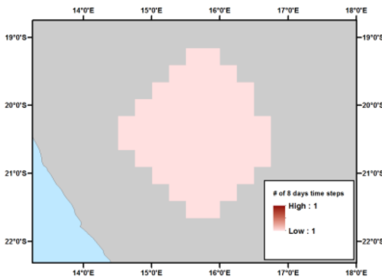
Event ID 36:

1. Attribution (internal)

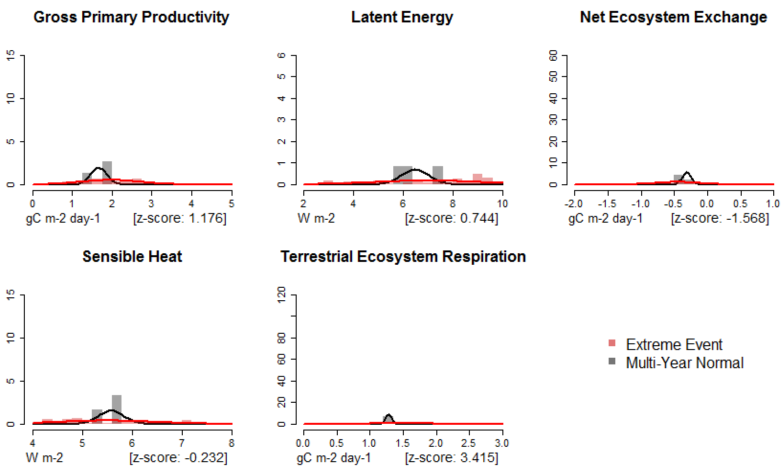
Type: Extreme event
Location: southern Africa
Area: 40918.4 km²
Time: 06.02.2003
Duration: 06.02.2003 – 06.02.2003



Extent of the event



# of 8 day time steps for which the event was detected



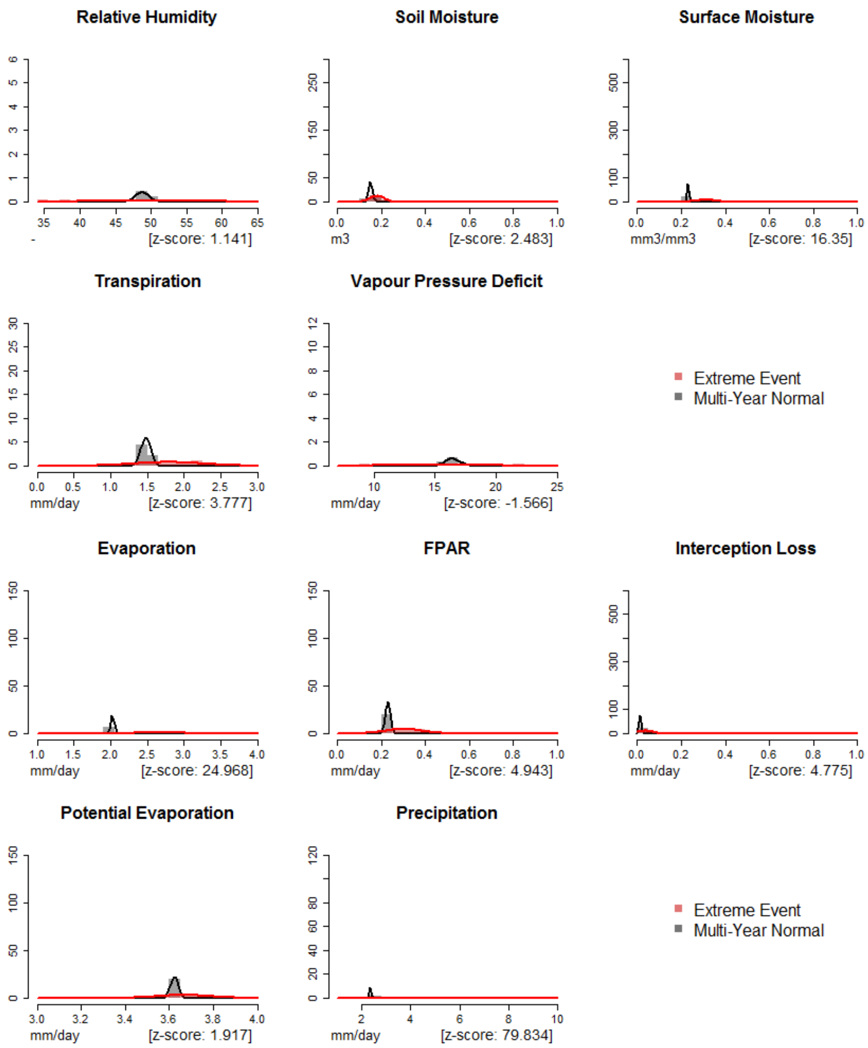
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Potential Flood Event:

- parameters such as surface moisture and precipitation show significant anomaly for this time step



3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based **1** **2** **3**

evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

Thematic precision	**x**		
Spatial precision	**x**		
Temporal precision	**x**		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

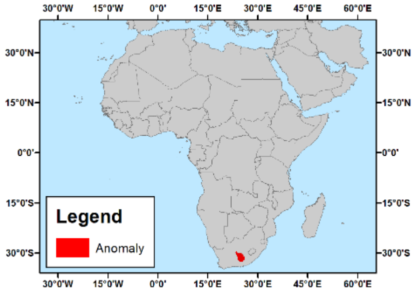
	1	**2**	**3**
Thematic precision			
Spatial precision			
Temporal precision			

References

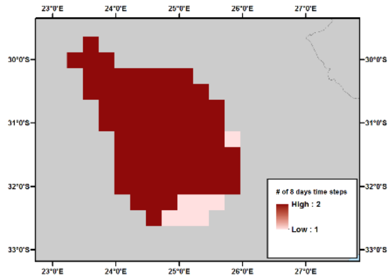
Event ID 37:

1. Attribution (internal)

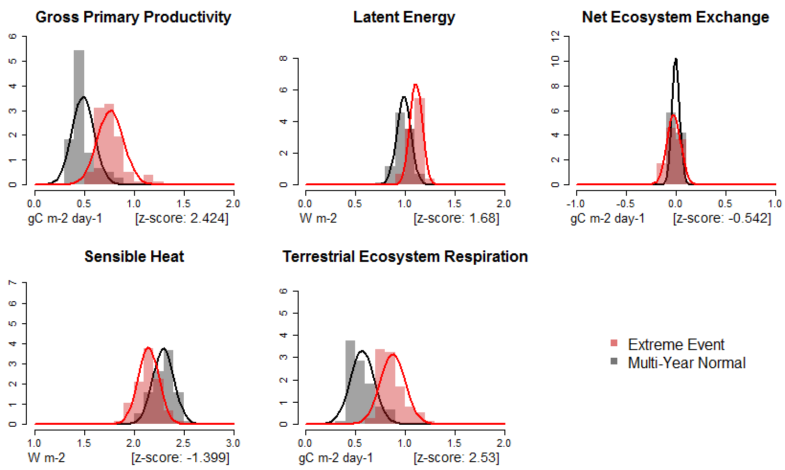
Type: Extreme event
Location: ??????
Area: 50525.3 km²
Time: 30.06.2001
Duration: 30.06.2001 – 08.07.2001



Extent of the event



# of 8 day time steps for which the event was detected



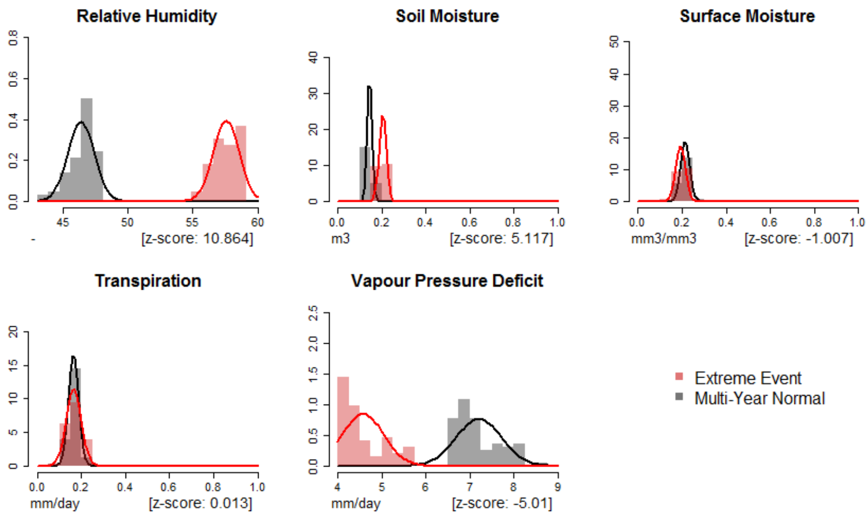
Extreme event vs. multi-year normal distribution of BACIndex input parameters

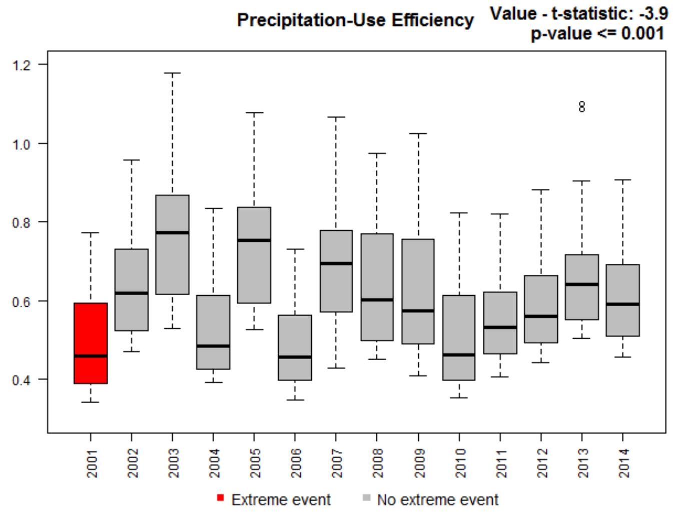
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Unknown Event:

- relative humidity show significant anomaly for this time step





3. Independent validation & regional expert feedback

Unknown Event:

- LST is high above multi-annual average in time period of detected anomaly (Figure 1)

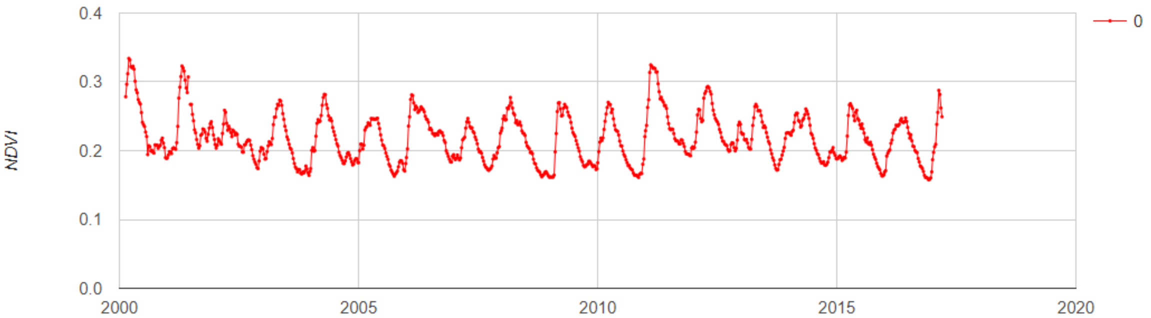


Figure 1. NDVI temporal profile of anomaly region.
(Source: Google Earth Engine)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation

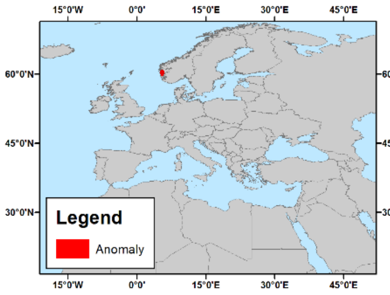
	1	2	3

of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**	**X**
	Spatial precision	**X**
	Temporal precision	**X**
References		

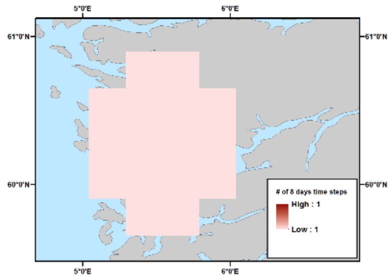
Event ID 38:

1. Attribution (internal)

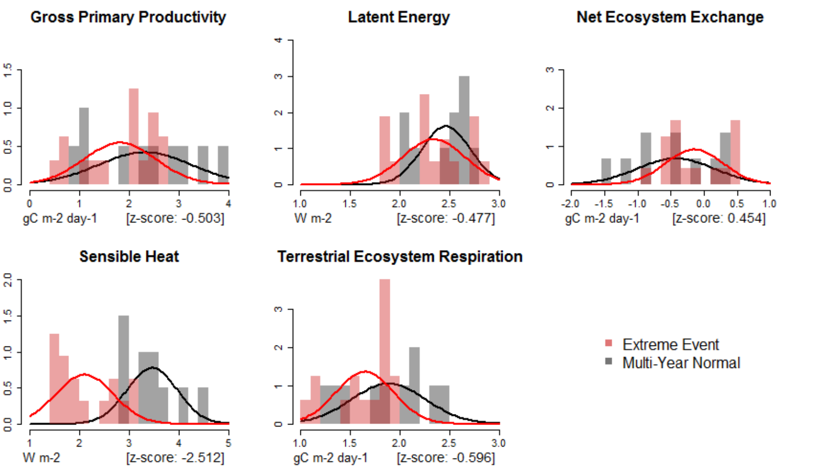
Type: Extreme event
Location: Southern Norway
Area: 6128.6 km²
Time: 05.05.2003
Duration: 05.05.2003 – 05.05.2003



Extent of the event



# of 8 day time steps for which the event was detected

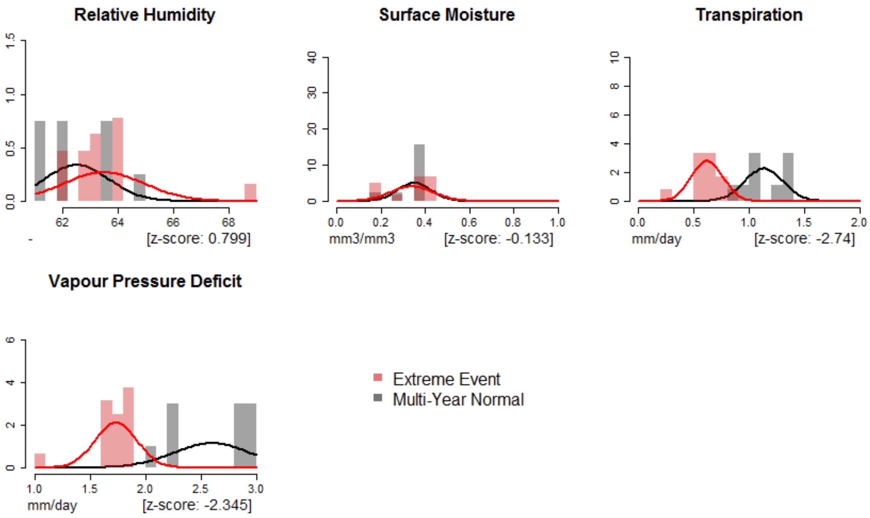


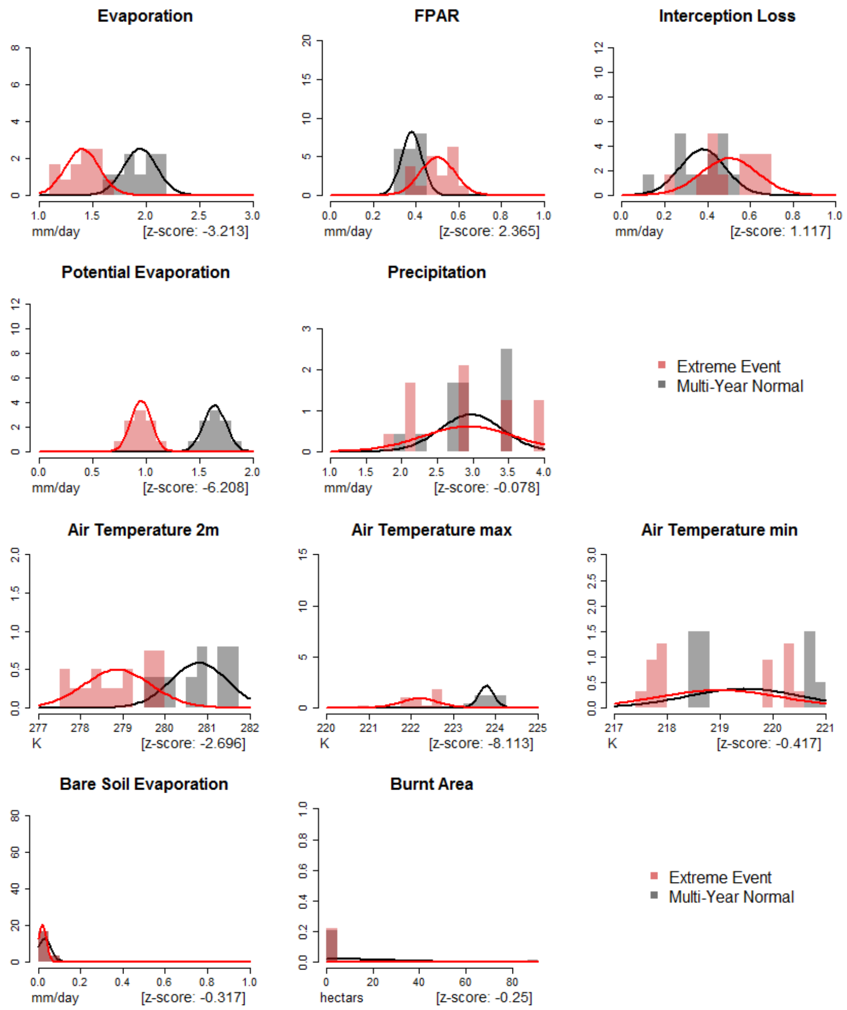
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External characterization hints to low evaporation and transpiration and low air temperatures, supporting low sensible heat in the internal attribution.





3. Independent validation & regional expert feedback

No information could be found in neither the European Severe Weather Database (ESWD, 2013), nor the in the EM-DAT, or in any other source

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**x**		
Spatial precision	**x**		
Temporal precision	**x**		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		1	2	3
	Thematic precision			
	Spatial precision			
	Temporal precision			

References

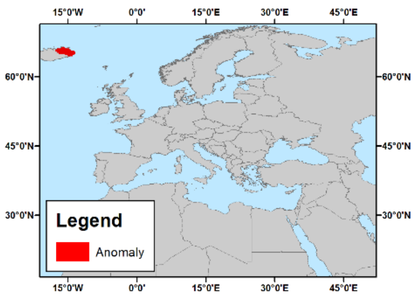
European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (accessed 06.02.2018)

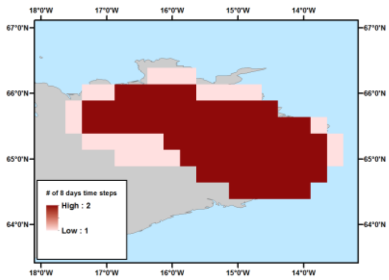
Event ID 39:

1. Attribution (internal)

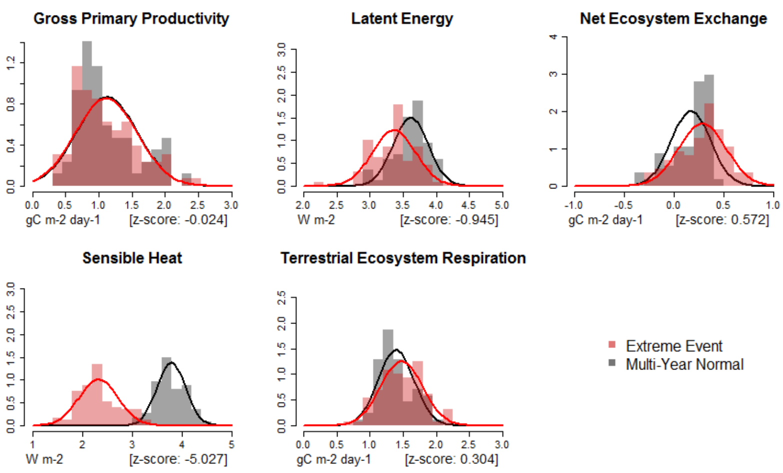
Type: Extreme event
Location: Iceland
Area: 27698.0 km²
Time: 06.06.2003
Duration: 06.06.2003 – 14.06.2003



Extent of the event



# of 8 day time steps for which the event was detected

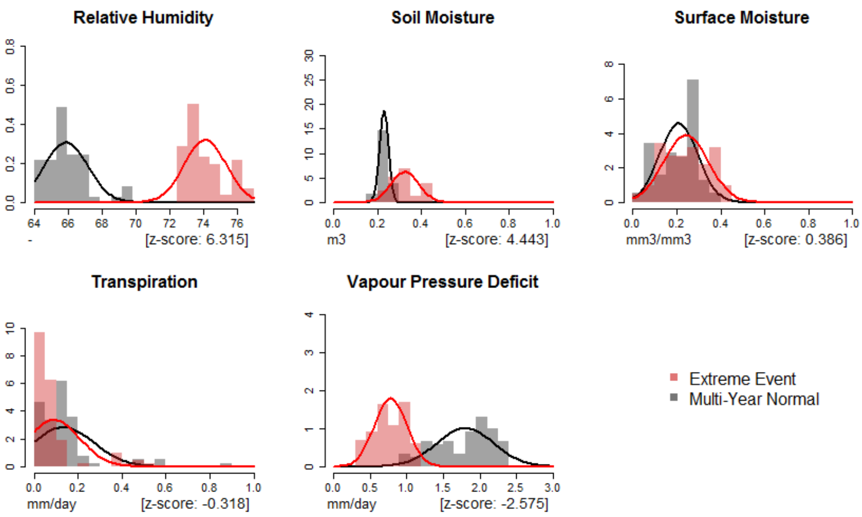


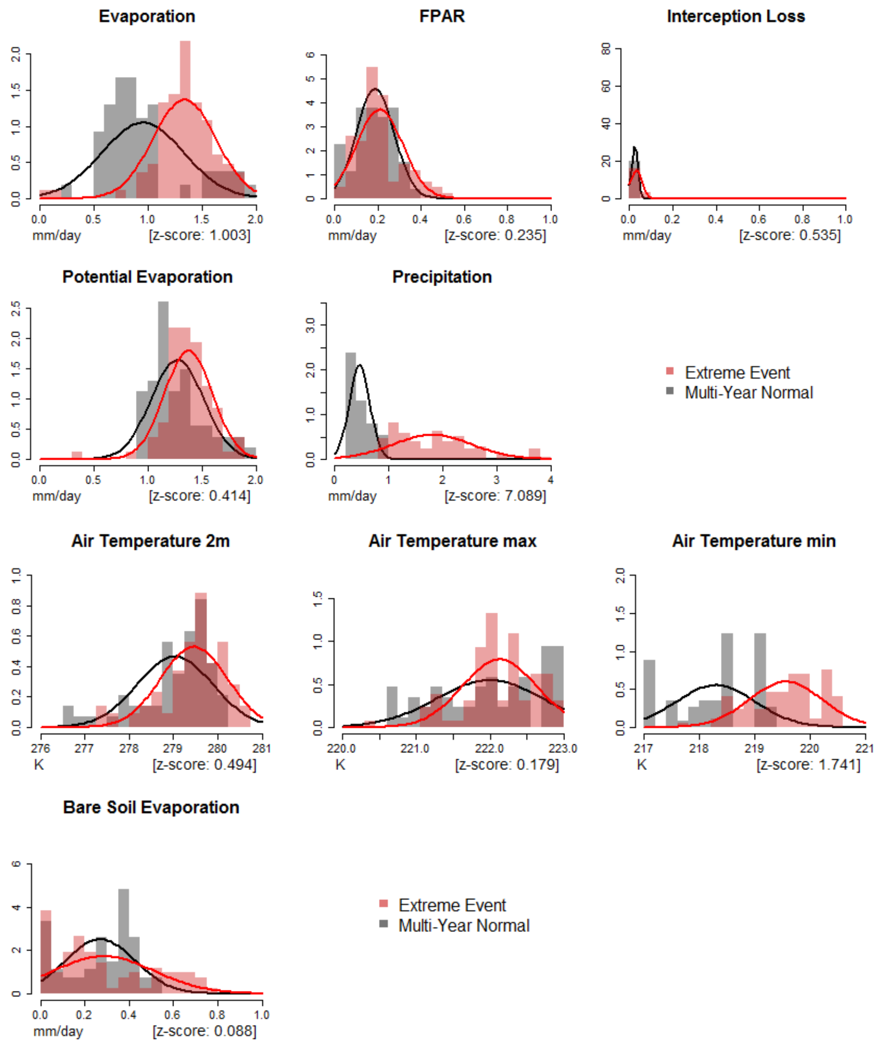
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

External characterization hints to heavy precipitation and anomaly wet conditions (high relative humidity).





3. Independent validation & regional expert feedback

Heavy winds in Iceland:

The European Severe Weather Database (ESWD, 2013) reports heavy winds in the affected area and given time period (end of May to early June), which supports findings of very low sensible heat. No other information could be found.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			

Temporal precision	

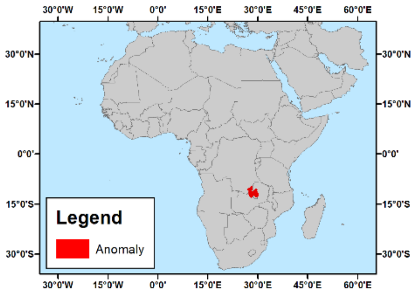
References

European Severe Weather Database (ESWD). Version4.2.2. (2013). http://www.eswd.eu/cgi-bin/eswd.cgi (accessed 06.02.2018)

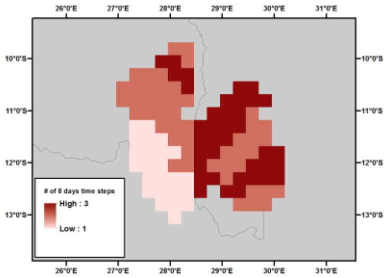
Event ID 40:

1. Attribution (internal)

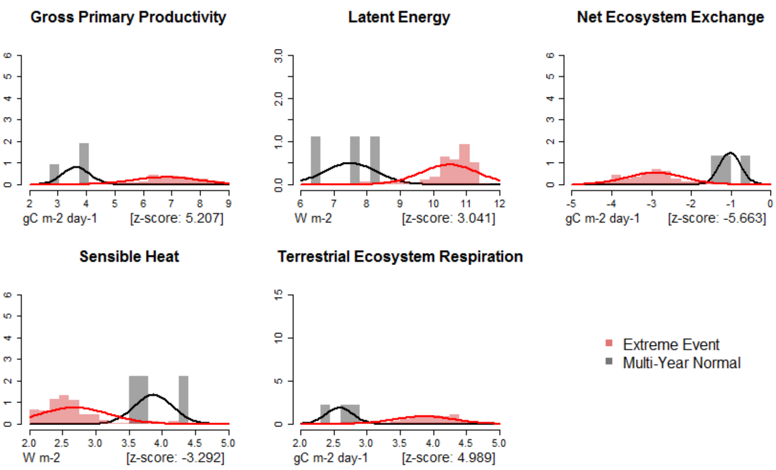
Type: Extreme event
Location: southern Africa
Area: 82457.1 km²
Time: 15.12.2010
Duration: 15.12.2010 – 05.01.2011



Extent of the event



# of 8 day time steps for which the event was detected



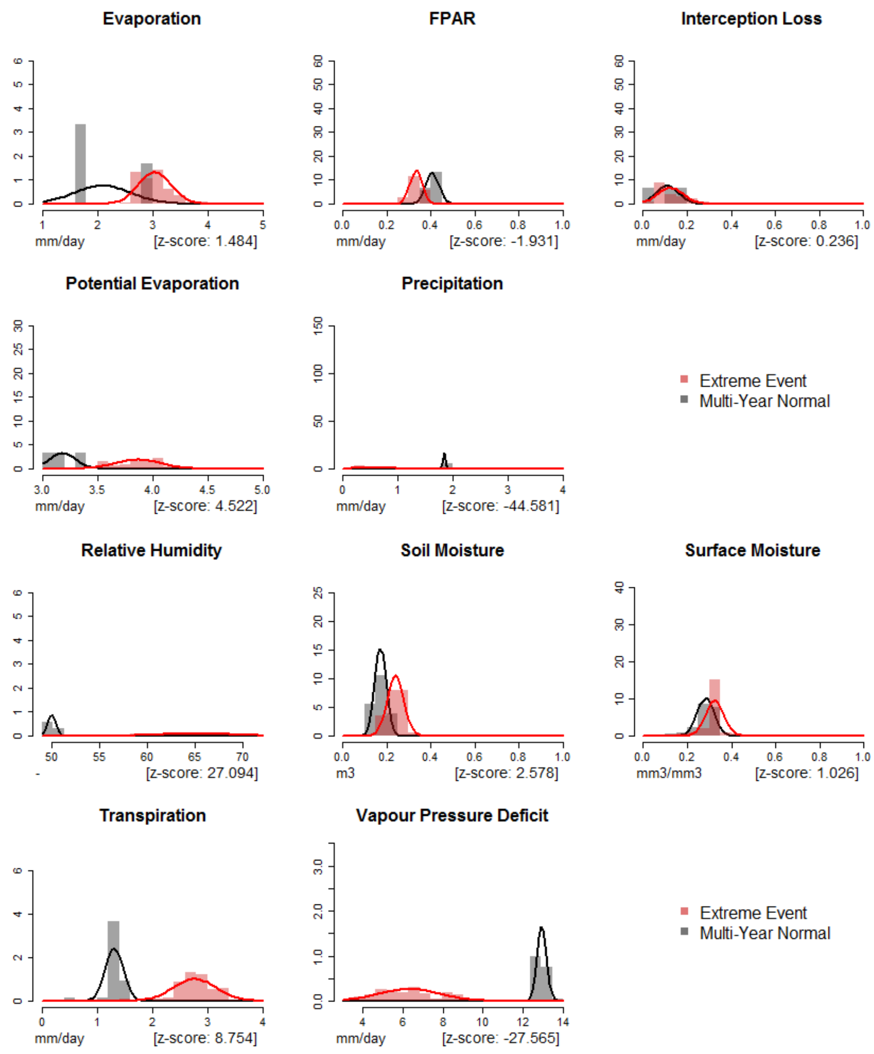
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Flood Event:

- parameters such as precipitation and soil moisture show significant anomaly for this time step



3. Independent validation & regional expert feedback

Flood Event:

- Large amount of rainfall during rain season (DJF) 2010 in Zambia (Brigadier et al. 2010 (Figure 1)

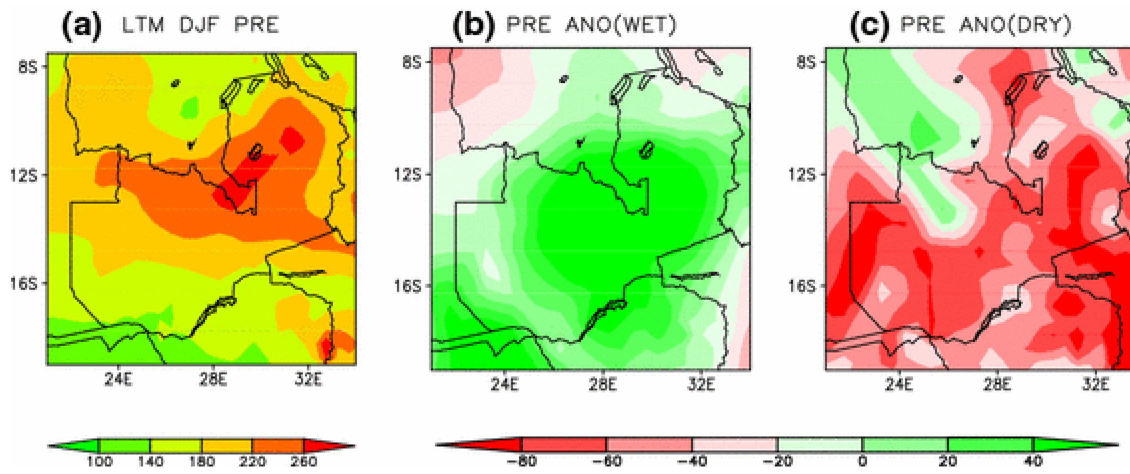


Figure 1. a Climatology of the mean DJF rainfall (mm) based on the period 1981–2010. b Mean rainfall anomaly during wet year (2010). c Mean rainfall anomaly during dry year (1992).
(Source: Brigadier et al. 2010)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision			**X**

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

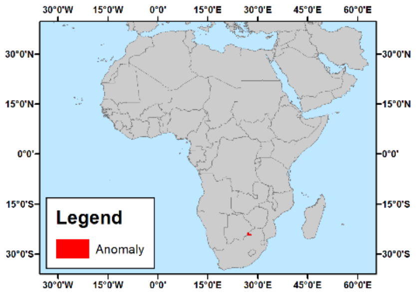
References

Brigadier, L.; Ogwang, B. A.; Ongoma, V.; Ngonga, C.; Nyasa, L. Diagnosis of the 2010 DJF flood over Zambia. Nat. Hazards 2016, 81, 189–201, doi:10.1007/s11069-015-2069-z.

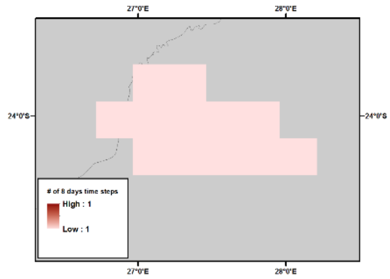
Event ID 41:

1. Attribution (internal)

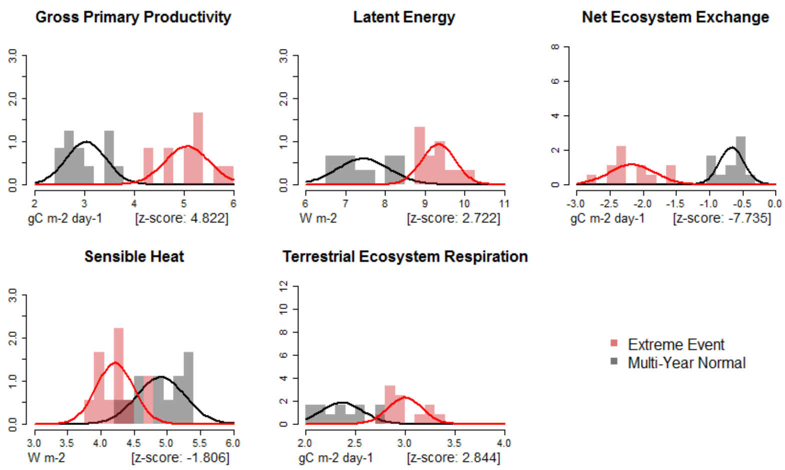
Type: Extreme event
Location: ??????
Area: 8396.8 km²
Time: 22.12.2008
Duration: 22.12.2008 – 22.12.2008



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

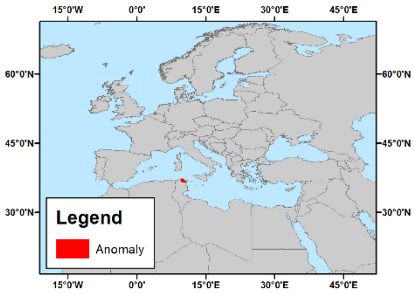
	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

References

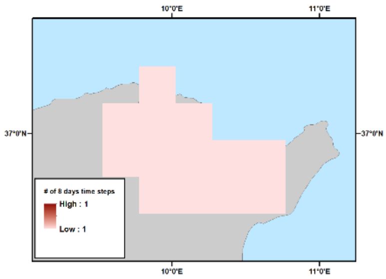
Event ID 42:

1. Attribution (internal)

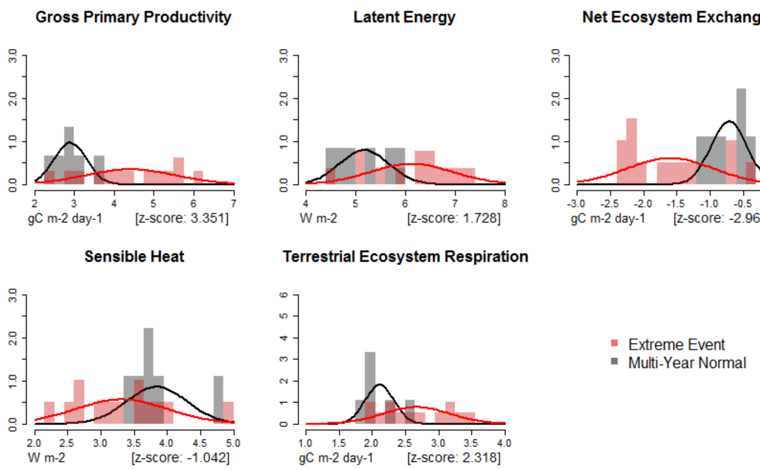
Type: Extreme event
Location: Tunisia
Area: 7994.0 km²
Time: 19.04.2005
Duration: 19.04.2005 – 19.04.2005



Extent of the event



# of 8 day time steps for which the event was detected

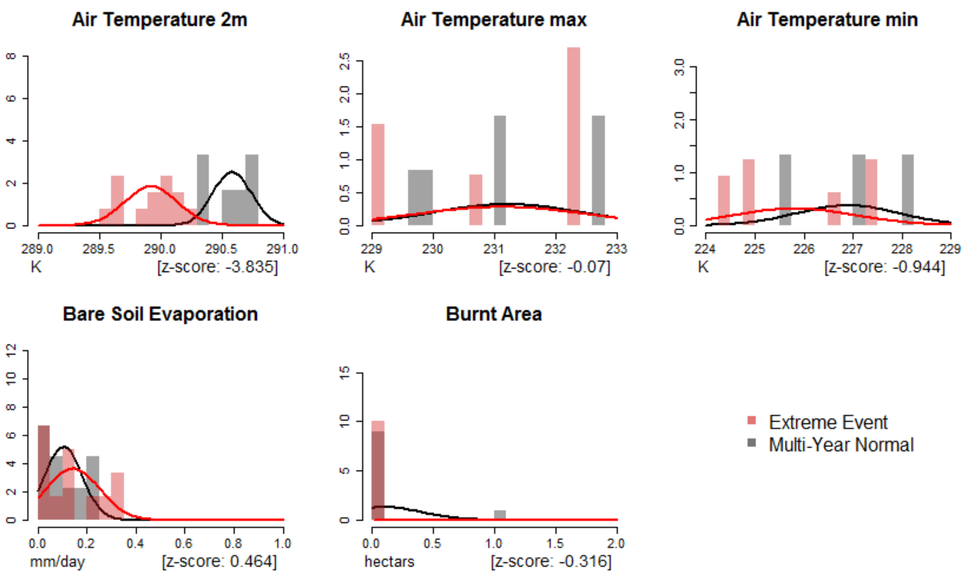


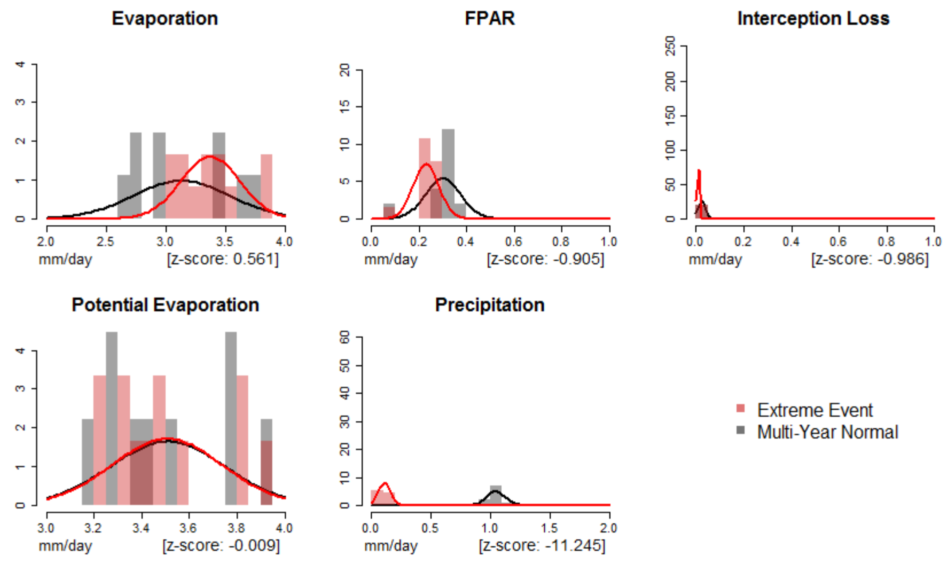
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Low air-temperatures and low precipitation contradict the findings of internal attribution





3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		
Temporal precision	x		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

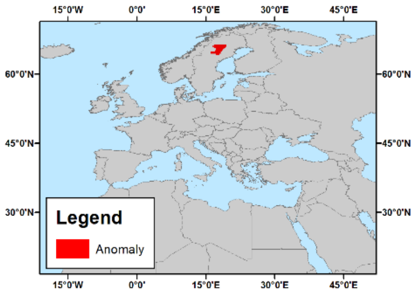
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

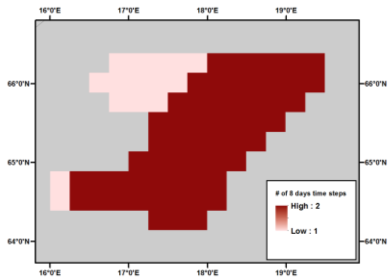
Event ID 43:

1. Attribution (internal)

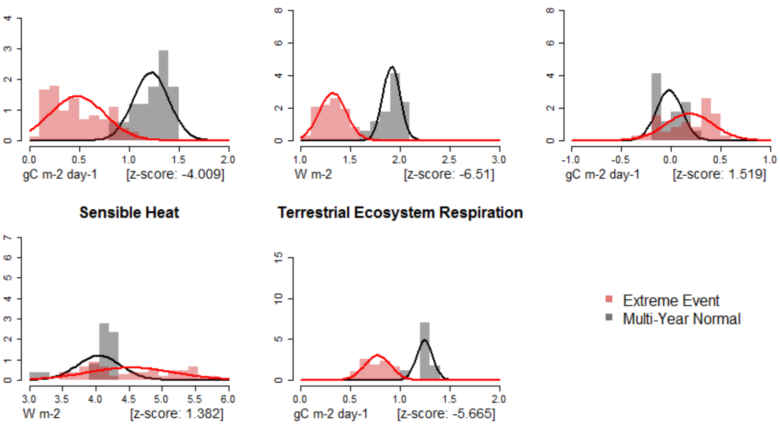
Type: Extreme event
Location: Northern Sweden
Area: 23484.9 km²
Time: 05.05.2010
Duration: 05.05.2010 – 13.05.2010



Extent of the event



# of 8 day time steps for which the event was detected

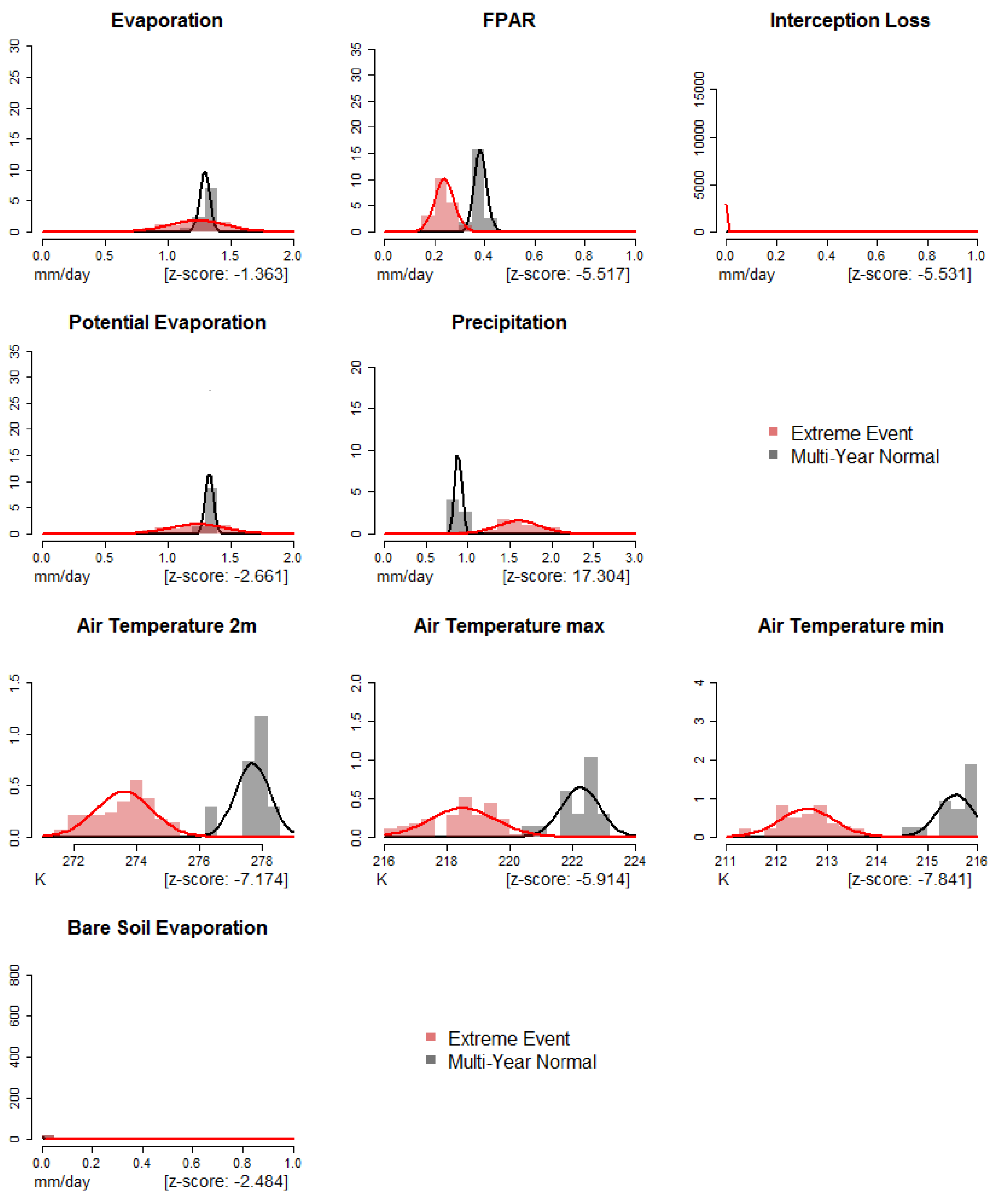


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Results of indicators show very low temperatures combined with high precipitation and low FPAR. This would support findings of attribution, i.e. anomaly low GPP and latent energy and low TER.



3. Independent validation & regional expert feedback

Literature recherché did not show any anomalies.
MODIS NDVI time series do not show any anomalies.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Coolest year ?

Regional expert based evaluation of the thematic, spatial and temporal accuracy of the event. 1 = not accurate, 2 = average, 3 = accurate.

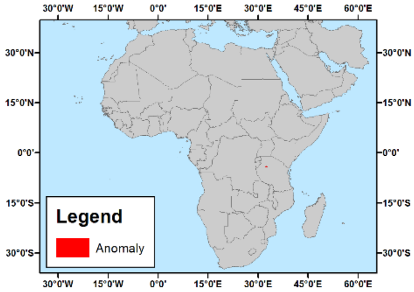
	1	2	3
Thematic accuracy	x		
Spatial accuracy	x		
Temporal accuracy		x	

References

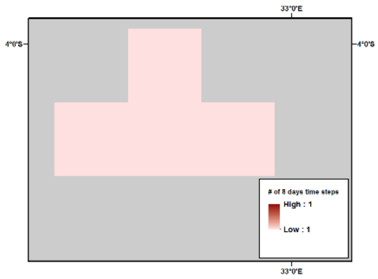
Event ID 44:

1. Attribution (internal)

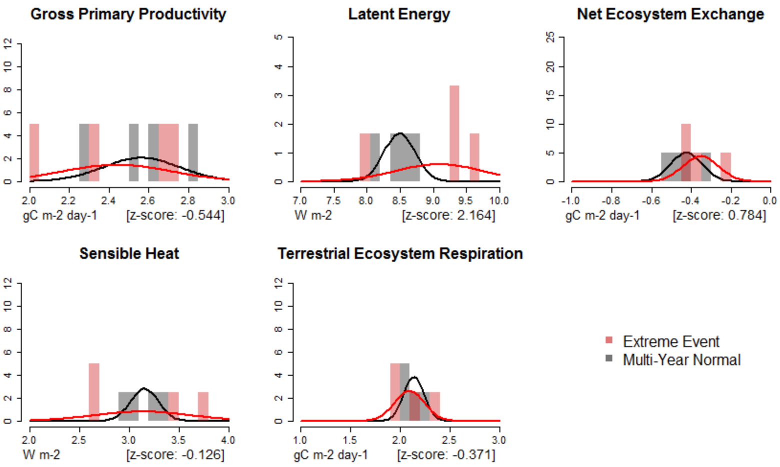
Type: Extreme event
Location: Tanzania
Area: 3050.9 km²
Time: 29.11.2003
Duration: 29.11.2003 – 29.11.2003



Extent of the event



# of 8 day time steps for which the event was detected

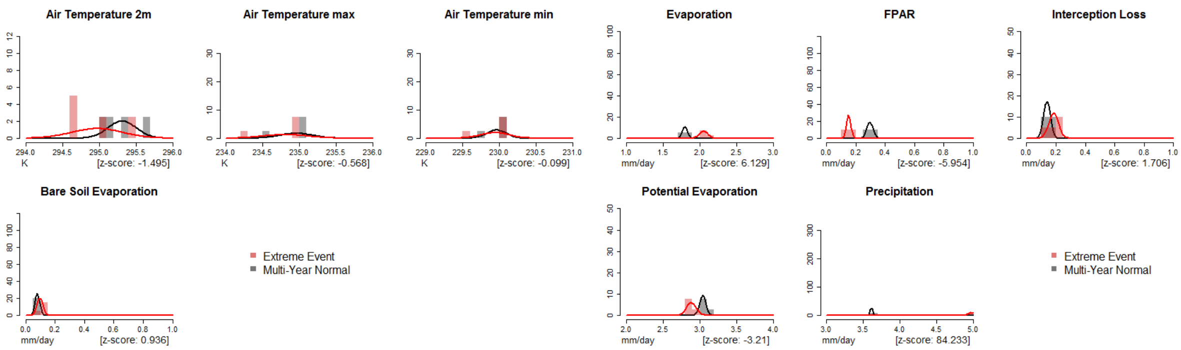


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

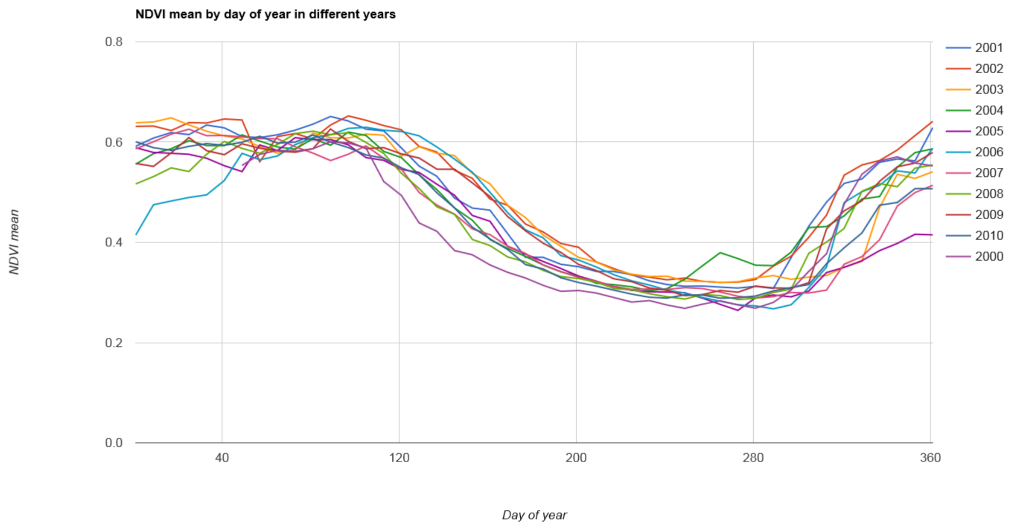
- The internal characterization showed: (figure)
  - Higher values of LE and NEE in the detected temporal extent of the extreme event
  - Also GPP values were lower than expected

2. External characterisation



- The external characterization of additional CABLAB data not used for the calculation of the BACIndex showed:
  - Slightly lower values for the temperatures (Figure)
  - Moreover, Evaporation was significantly higher, whereas FPAR showed distinct low values compared to the multi-year normal

3. Independent validation & regional expert feedback



- The analysis of MODIS NDVI time series showed slightly lower values for the detected time period (Figure)
  - These findings can be linked to the internal and external characterization
  - However, the impact on the NDVI is not as large as the internal and especially the external characterization (FPAR) showed

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision		X	
Temporal precision		X	

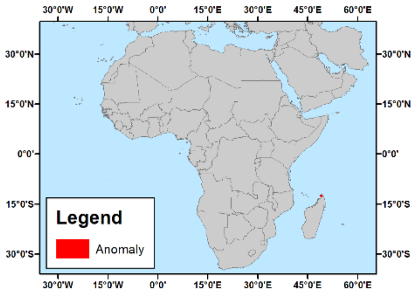
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

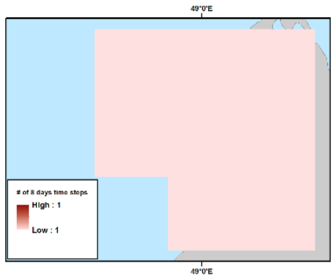
Event ID 45:

1. Attribution (internal)

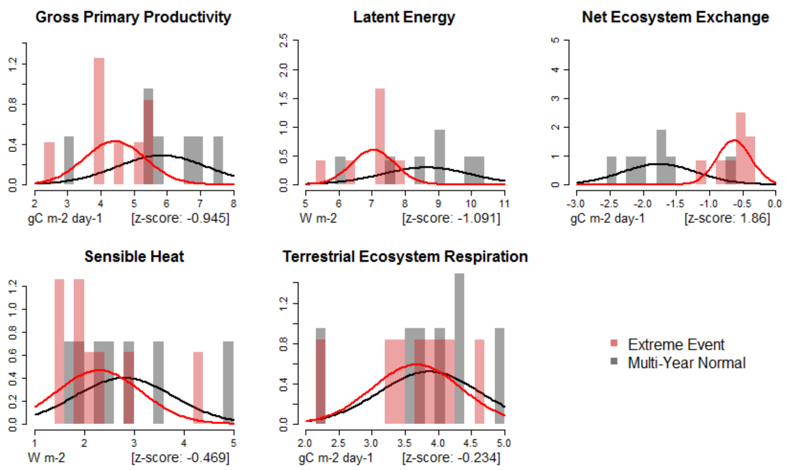
Type: Extreme event
Location: ??????
Area: 5976.4 km²
Time: 02.03.2006
Duration: 02.03.2006 – 02.03.2006



Extent of the event



# of 8 day time steps for which the event was detected



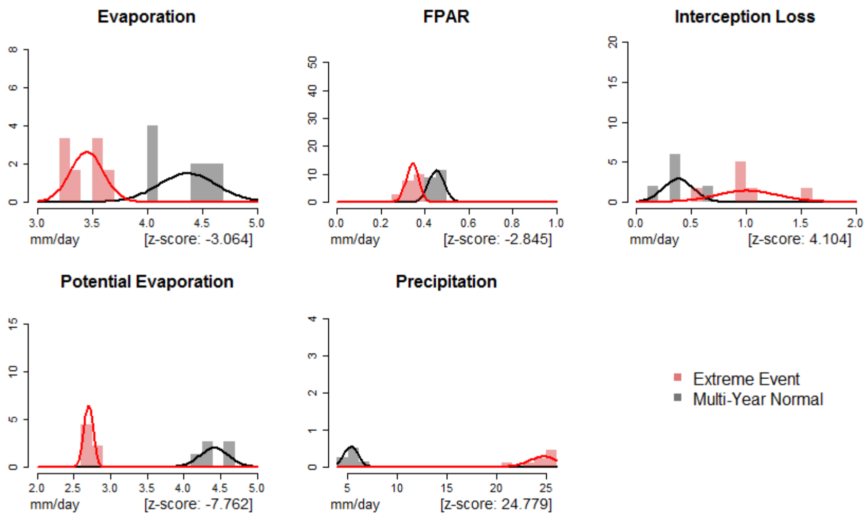
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Unknown Event:

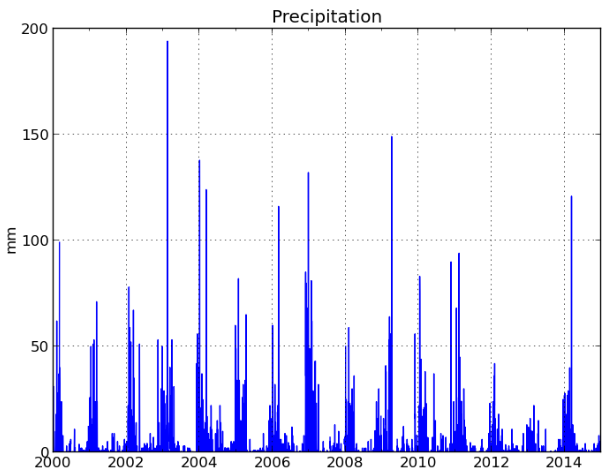
- precipitation show significant anomaly for this time step



3. Independent validation & regional expert feedback

Unknown Event:

- no precipitation anomaly was found at this time based on information from climate station in this area (Figure 1)



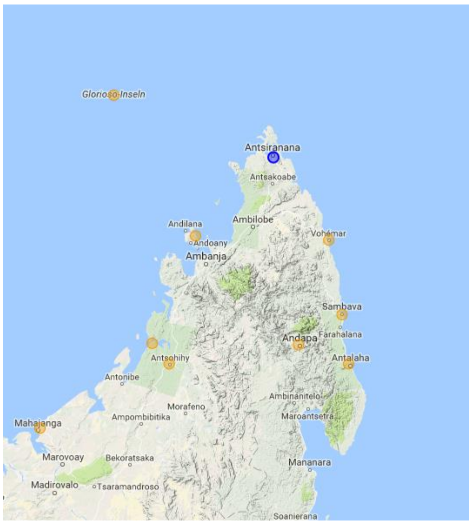


Figure 1. Precipitation time series from climate station (Global Surface Summary if the day).

(Source: Earth Observation Monitor - http://earth-observation-monitor.net)**Remote sensing expert based evaluation** of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

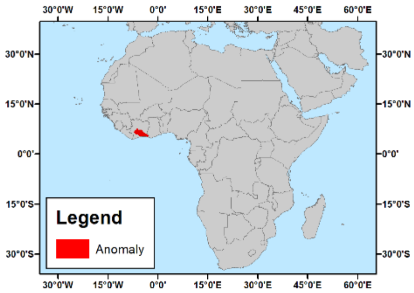
	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	<table><tr><th></th><th>1</th><th>2</th><th>3</th></tr><tr><td>**Thematic precision**</td><td></td><td></td><td></td></tr><tr><td>**Spatial precision**</td><td></td><td></td><td></td></tr><tr><td>**Temporal precision**</td><td></td><td></td><td></td></tr></table>
References	

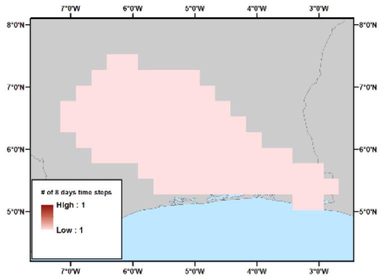
Event ID 46:

1. Attribution (internal)

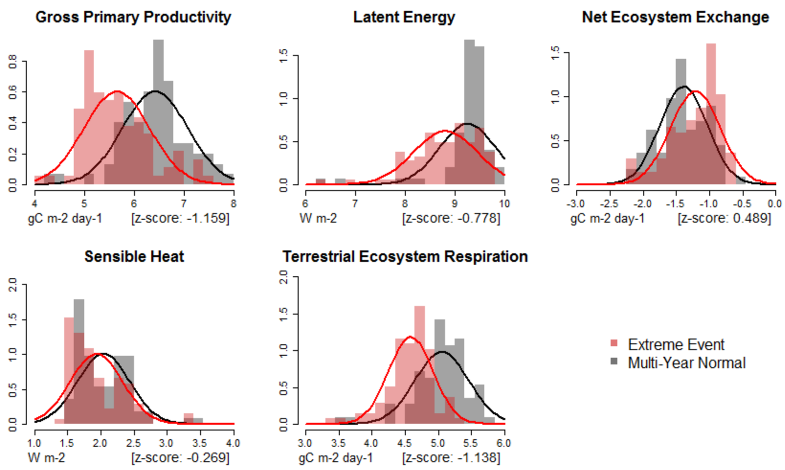
Type: Extreme event
Location: Côte d'Ivoire
Area: 69954.5 km²
Time: 27.04.2005
Duration: 27.04.2005 – 27.04.2005



Extent of the event

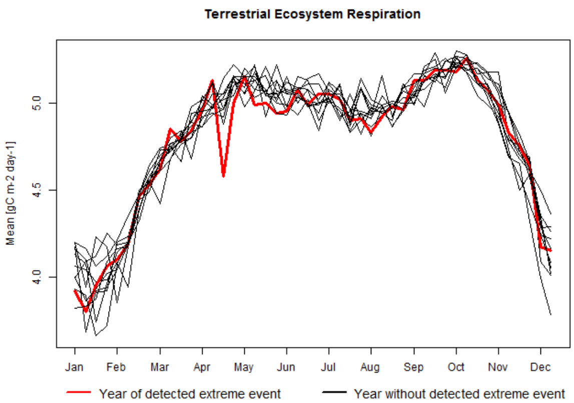


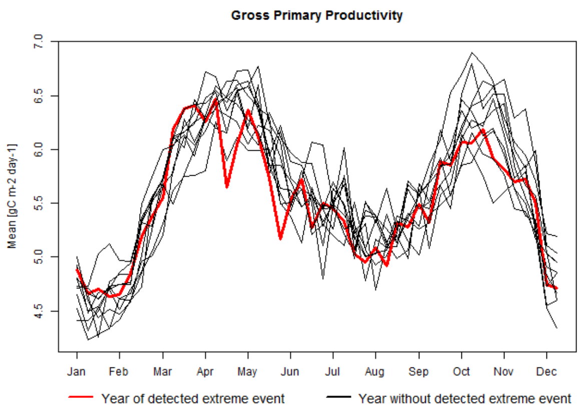
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

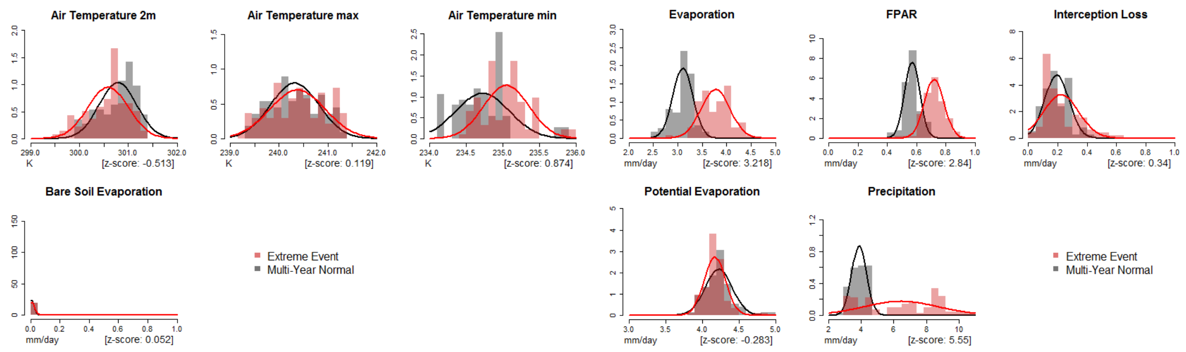
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





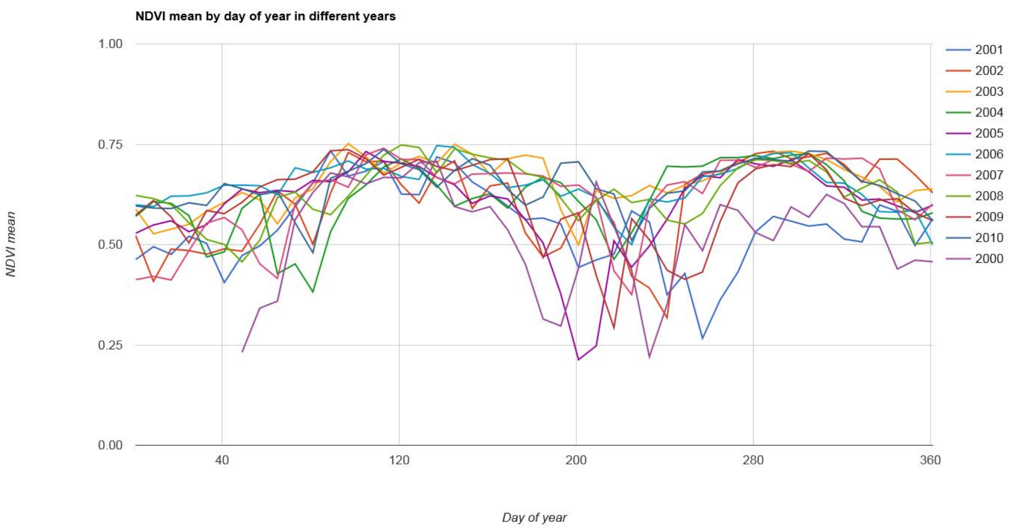
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Especially low values for GPP and TER, which were also visible in the time series of the respective parameter (Figure)

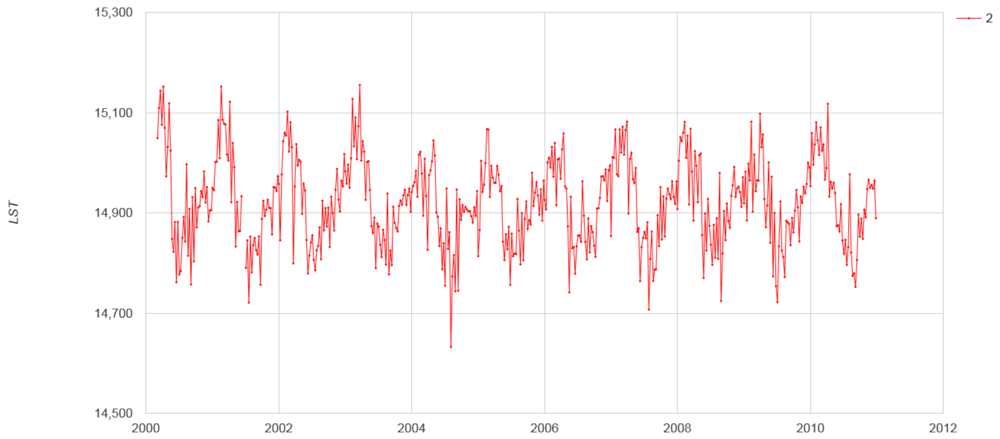
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - slightly higher minimal and maximal temperatures compared to the multi-year normal (figure)
  - significantly higher FPAR, evaporation values and precipitation (figure)
  - hereby, higher FPAR values stay in contrast to the findings of lower GPP

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - The start of decreasing NDVI values. So it seems like there actual anomaly is longer than what was detected by the BACIndex
  - Really low temperatures for the year 2005
  - So therefore the reduced photosynthetic activities last longer than expected and are more intense

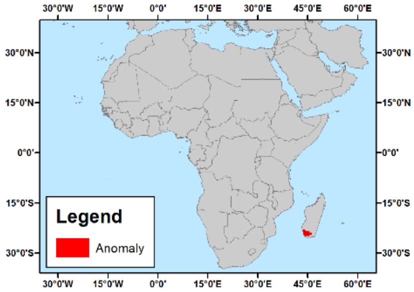
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision	X		

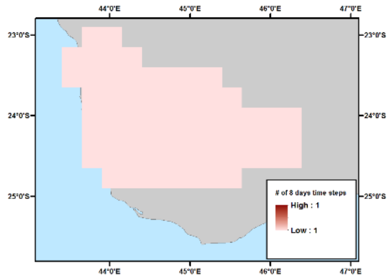
Event ID 47:

1. Attribution (internal)

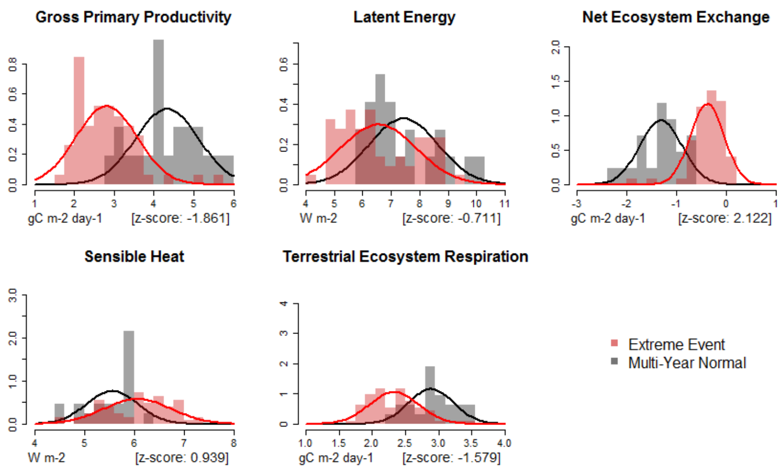
Type: Extreme event
Location: Madagascar
Area: 43389.3 km²
Time: 06.02.2010
Duration: 06.02.2010 – 06.02.2010



Extent of the event



# of 8 day time steps for which the event was detected



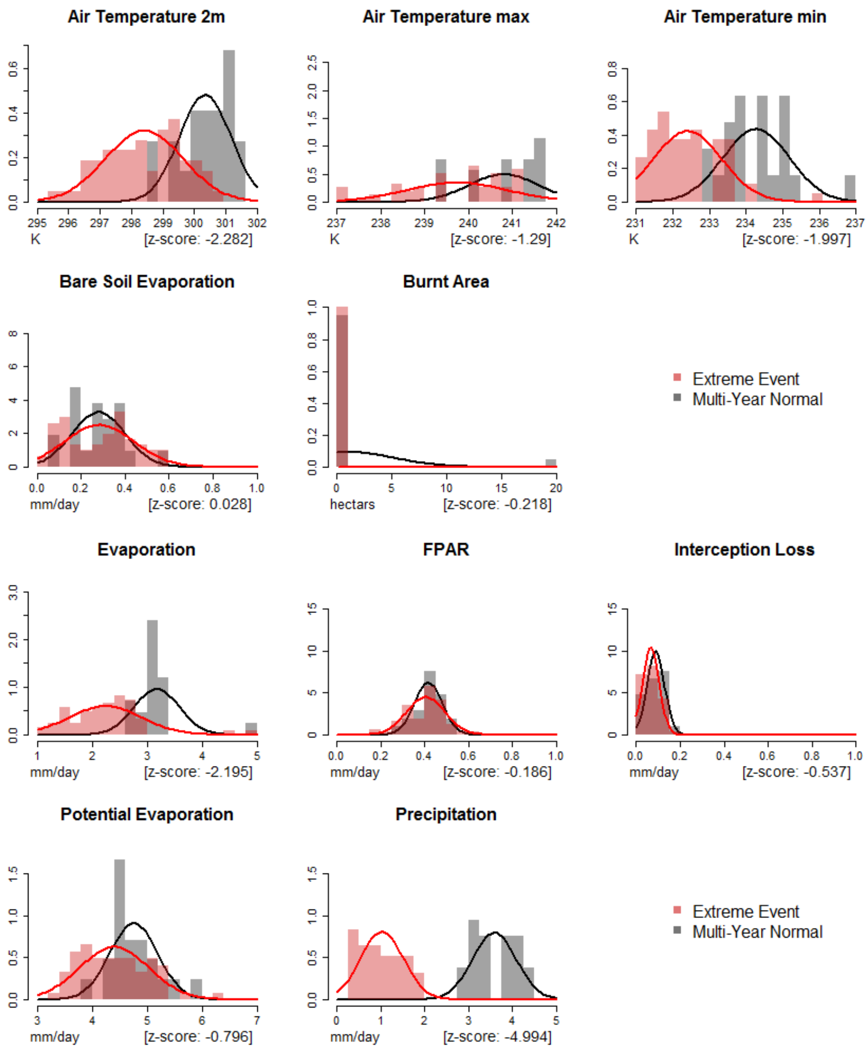
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Unknown Event:

- parameters such as air temperature and precipitation show significant anomaly for this time step



3. Independent validation & regional expert feedback

Unknown Event:

- NDVI show depression in time period of detected anomaly (Figure 1)

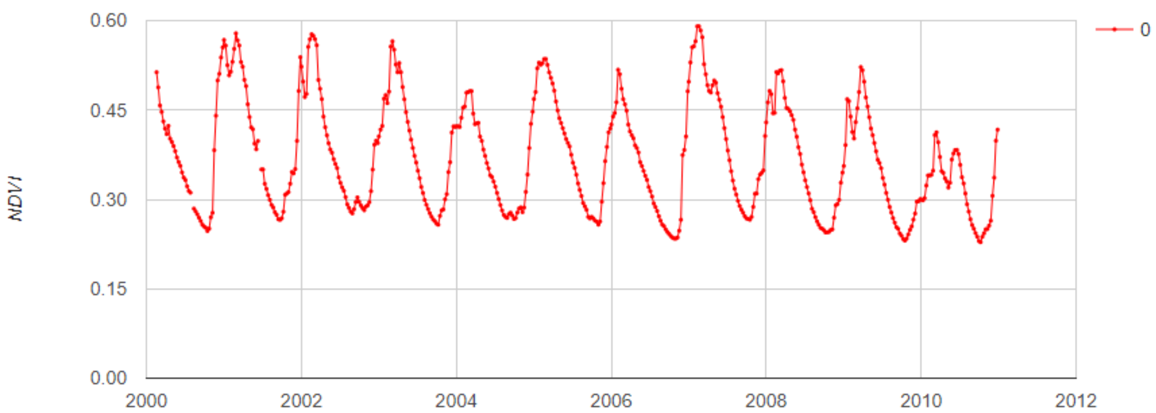


Figure 1. NDVI temporal profile of anomaly region.

(Source: Google Earth Engine)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

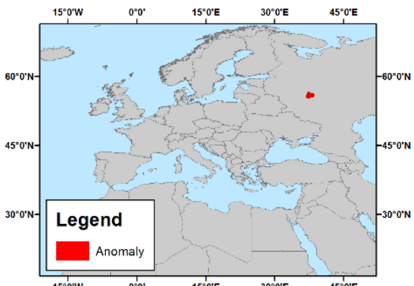
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

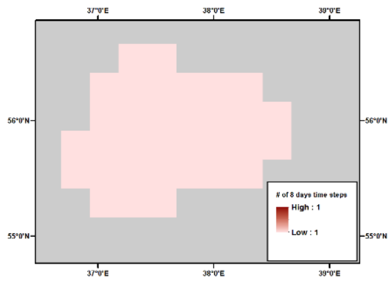
Event ID 48:

1. Attribution (internal)

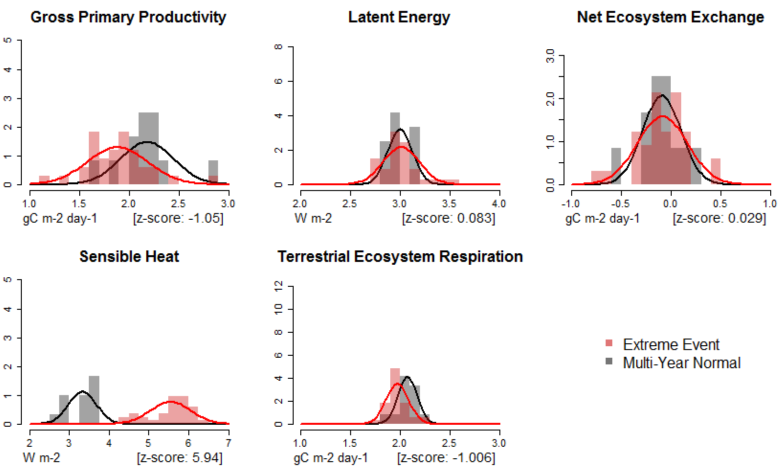
Type: Extreme event
Location: Western Russia
Area: 14287.8 km²
Time: 27.04.2011
Duration: 27.04.2011 – 27.04.2011



Extent of the event



# of 8 day time steps for which the event was detected

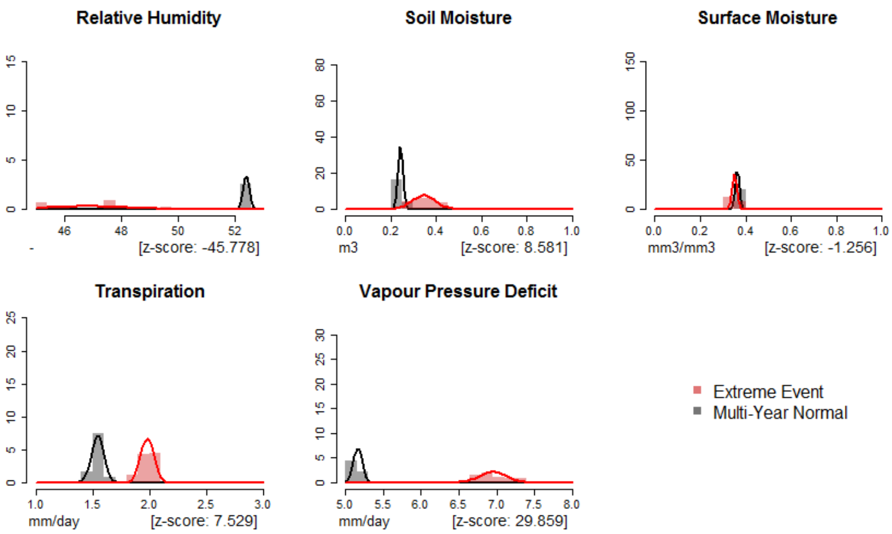


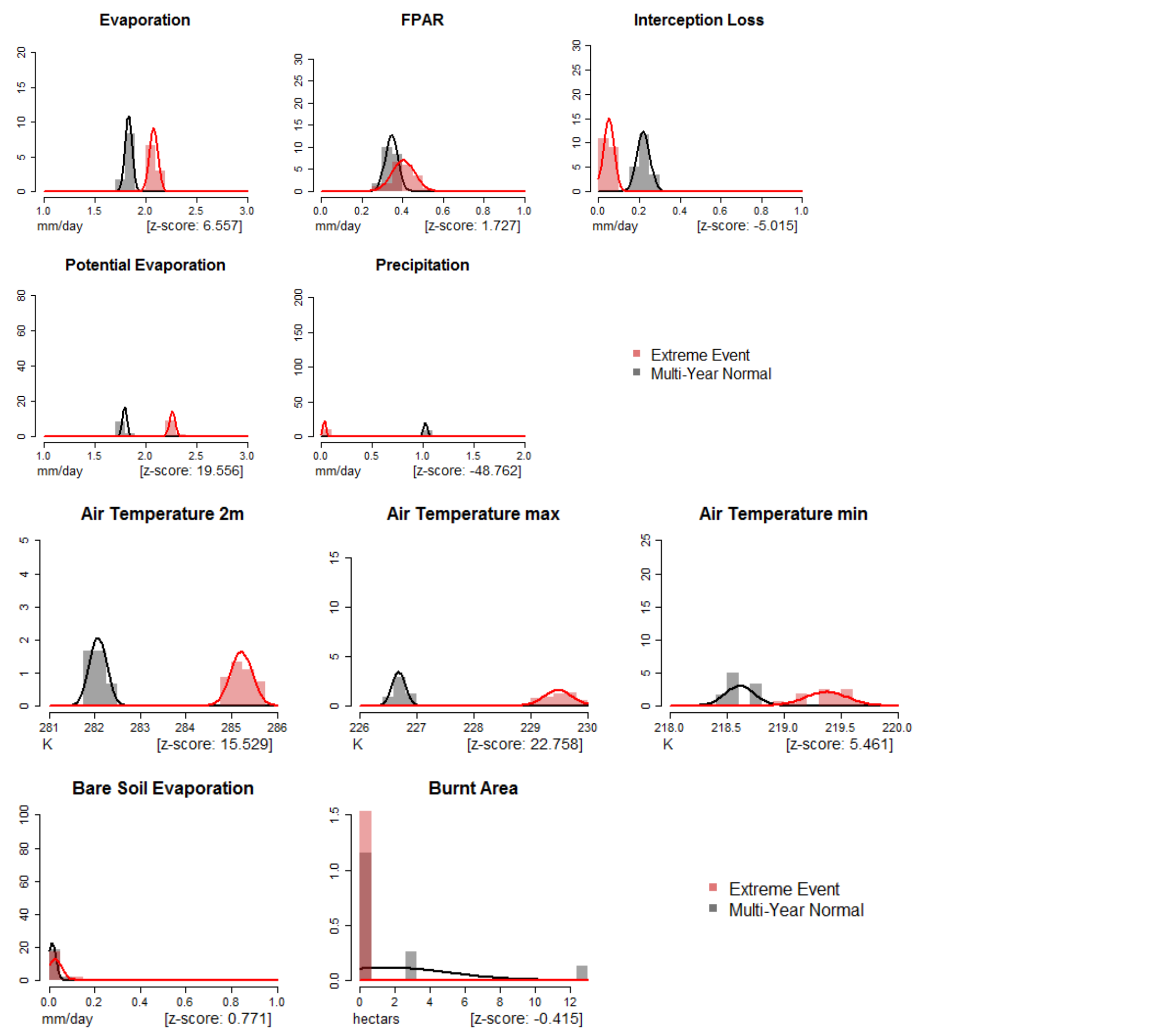
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Results indicate very high temperature and extremely low humidity and precipitation, supporting the results of attribution. Evaporation and transpiration were at the same time high, while GPP was slightly below average, which indicates plant stress most likely due to heat and water deficits.





3. Independent validation & regional expert feedback

A Literature recherché did not yield any results.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 =

	1	2	3
Thematic precision			

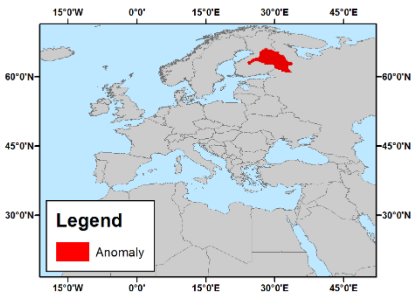
not precise, 2 = average, 3 = precise.	**Spatial precision**		
	Temporal precision		

References

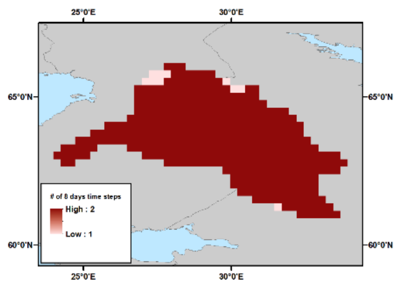
Event ID 49:

1. Attribution (internal)

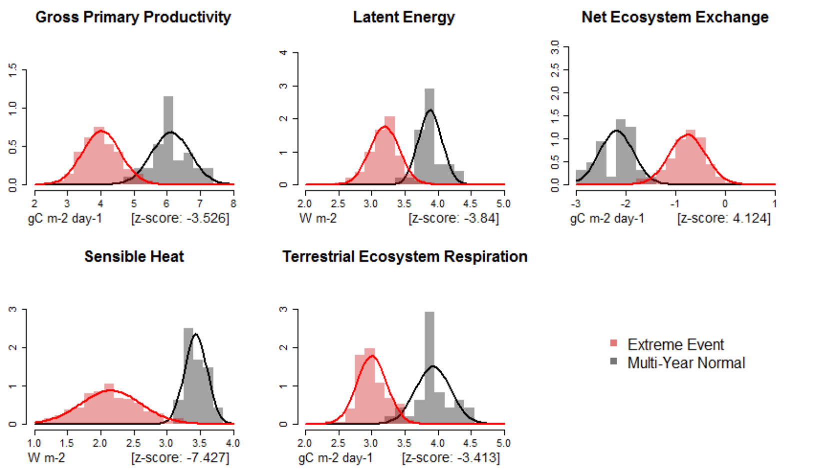
Type: Extreme event
Location: Finland/ Northwest Russia
Area: 128267.8 km²
Time: 08.08.2008
Duration: 08.08.2008 – 16.08.2008



Extent of the event



# of 8 day time steps for which the event was detected



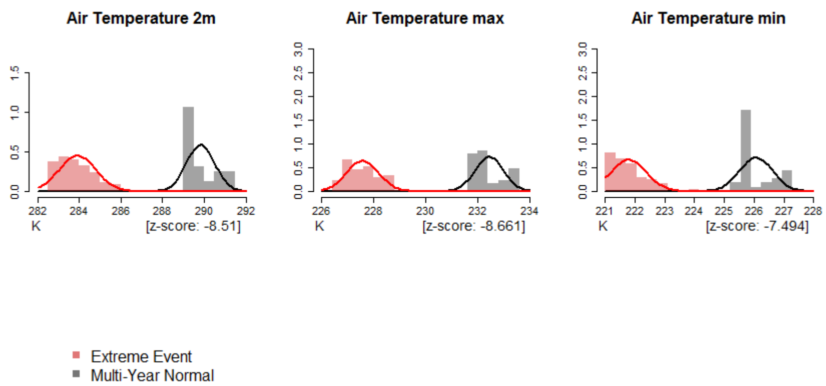
Extreme event vs. multi-year normal distribution of BACIndex input parameters

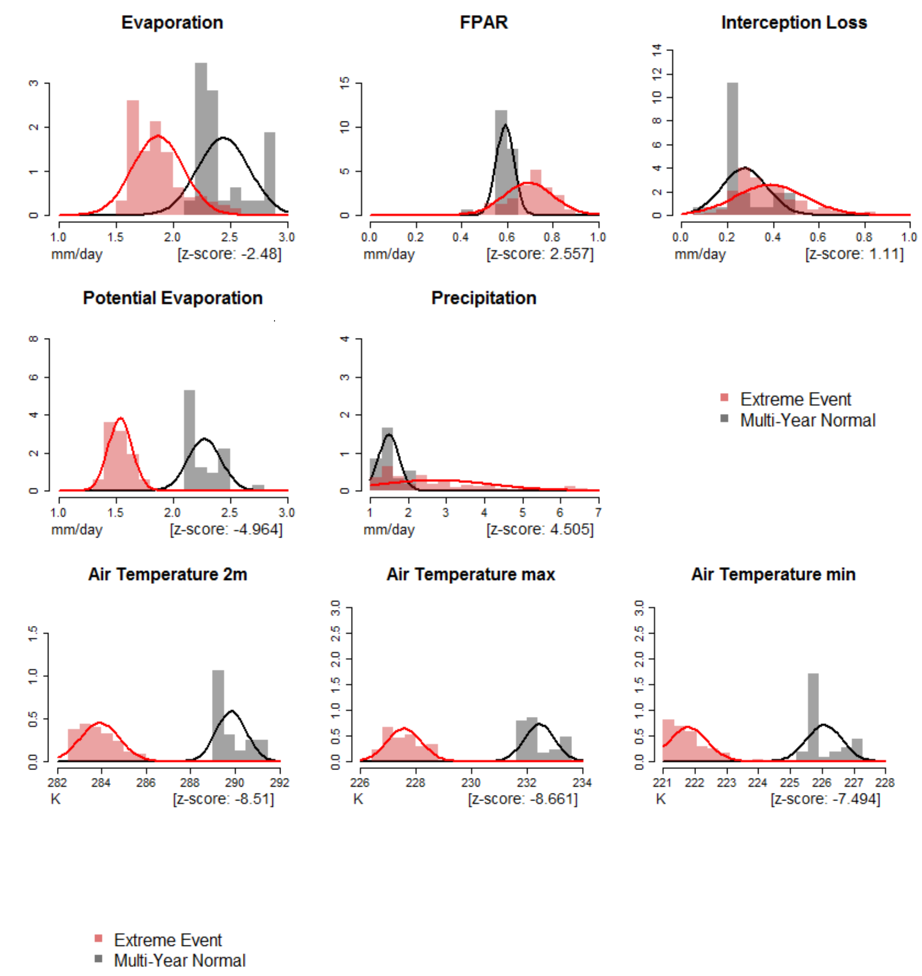
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Potential Cold wave with high precipitation in August:

Results point to very low temperatures but very high precipitation, supporting results of below-average GPP, latent energy and sensible heat.





3. Independent validation & regional expert feedback

Literature recherché did not yield any results that would allow for a definite characterization of the event. Furthermore, the Finnish meteorological institute did not report a similar cold-wave, or very high precipitation in the same period (http://en.ilmatieteenlaitos.fi/maps-from-1961-onwards) :

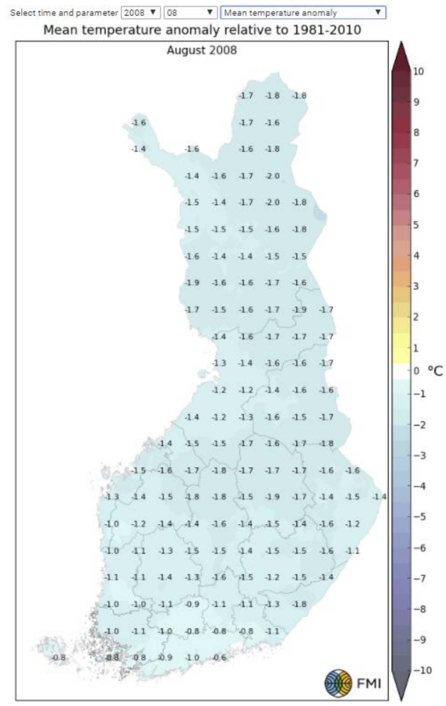


Figure 1: Temperature anomalies in August 2008

However, MODIS NDVI time series support very low vegetation activity and thus support the results of attribution.

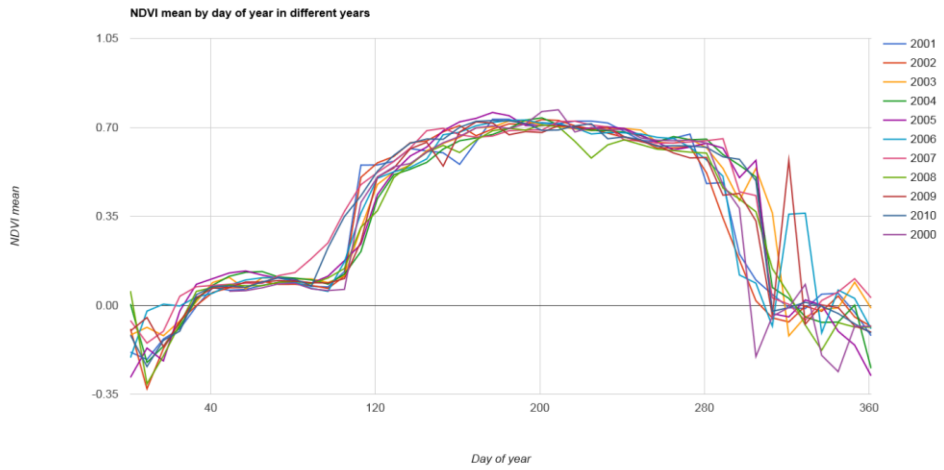


Figure 2: MODIS-NDVI time series results shown as daily averages compared between the years in the 2000-2010 time span.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

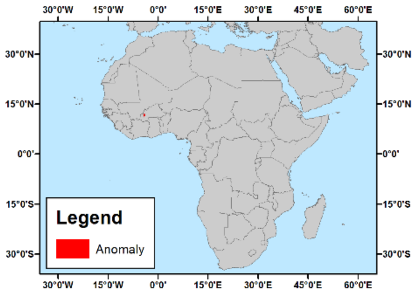
References

http://en.ilmatieteenlaitos.fi/maps-from-1961-onwards

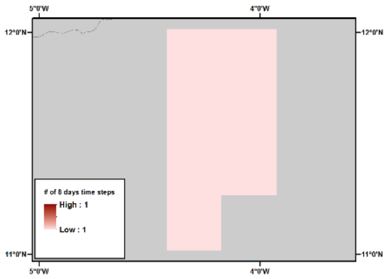
Event ID 50:

1. Attribution (internal)

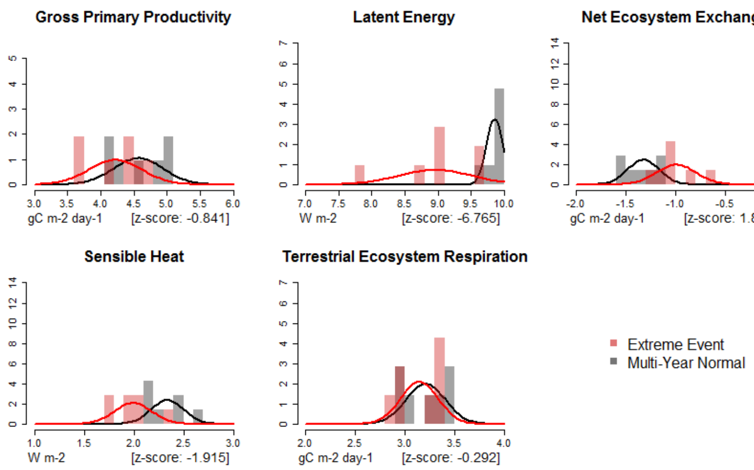
Type: Extreme event
Location: Burkina Faso
Area: 5247.4 km²
Time: 17.09.2008
Duration: 17.09.2008 – 17.09.2008



Extent of the event

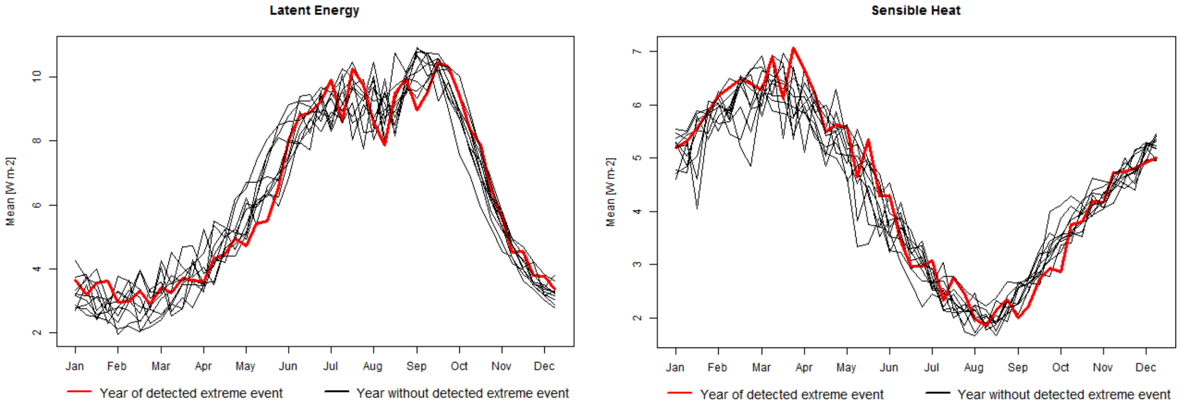


# of 8 day time steps for which the event was detected



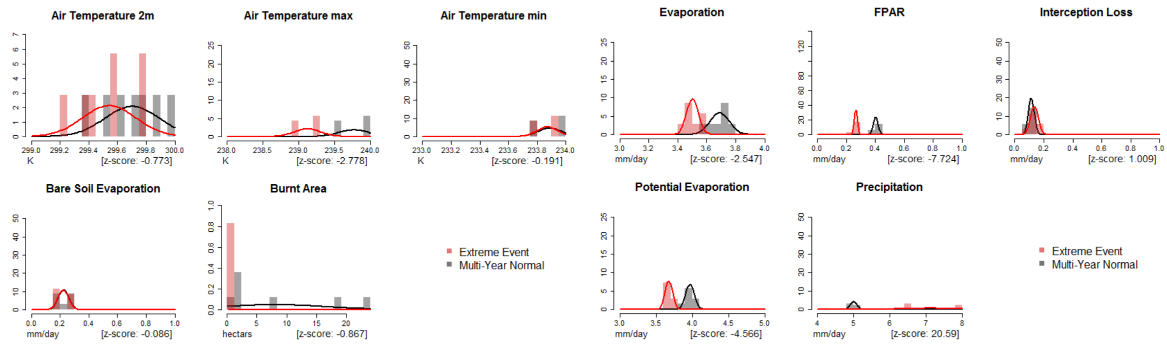
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



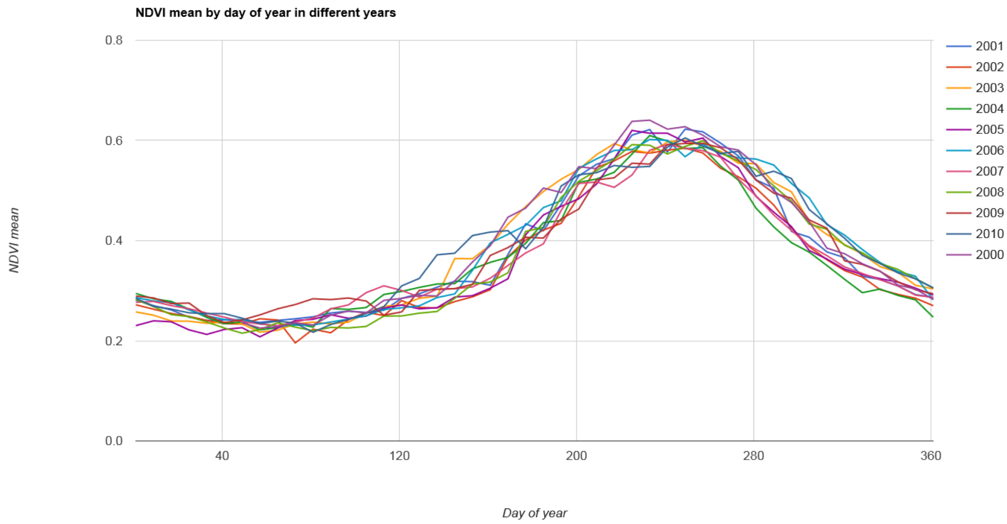
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
    - Significantly lower values of both Latent Energy and Sensible Heat compared to the multi-year normal
        - These negative peaks were also visible in the time series analysis of respectively Latent Energy and Sensible Heat
    - However, NEE showed significantly higher values than expected
    - Therefore the extreme event can be linked to cold temperatures, thus less photosynthetic activity and more CO_2 contribution into the atmosphere than usual (lower GPP and higher NEE)

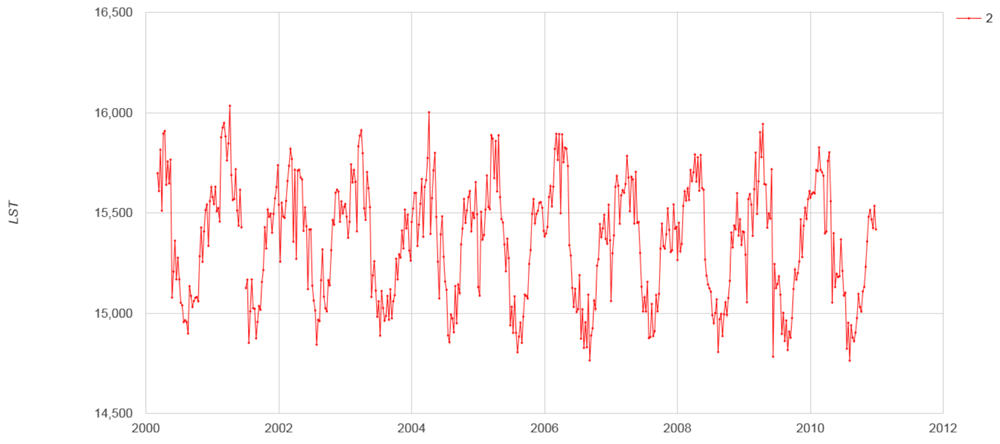
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - lower temperatures as expected by interpreting the internal characterization (figure)
  - lower evaporation and FPAR, because of lower temperatures and at the same time higher precipitation resulting in rather unideal growing conditions and less photosynthetic activity (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values in 2008 were lower than usual for September indicating reduced photosynthetic activity (figure)
    - However, as seen in the figure this reduced activity lasted longer than only 8 days
  - MODIS LST showed slightly lower temperatures and are therefore in agreement with the findings in the internal characterization and external characterization

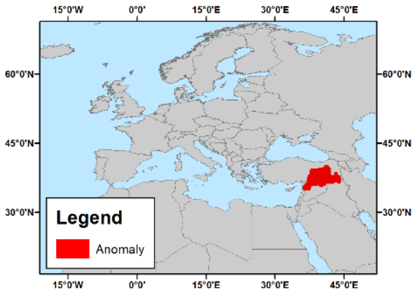
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

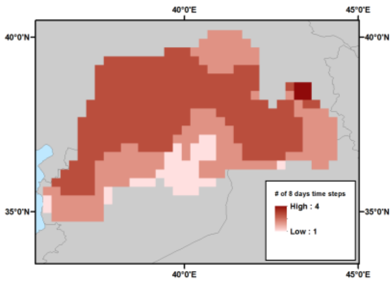
Event ID 51:

1. Attribution (internal)

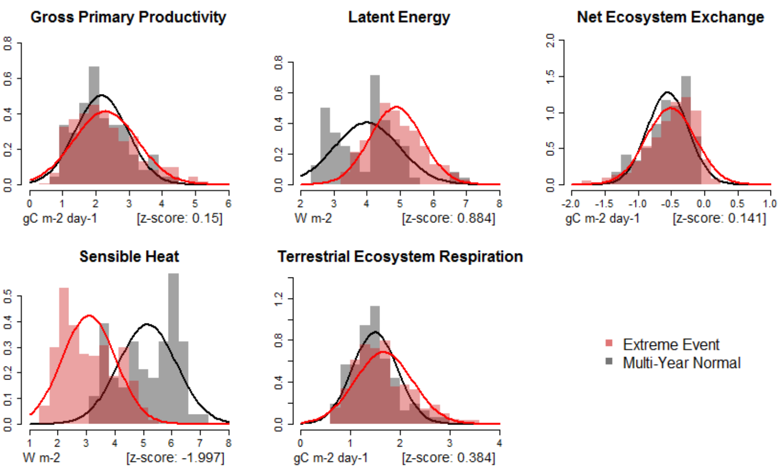
Type: Extreme event
Location: Middle East
Area: 256818.8 km²
Time: 05.05.2001
Duration: 05.05.2001 – 06.06.2001



Extent of the event

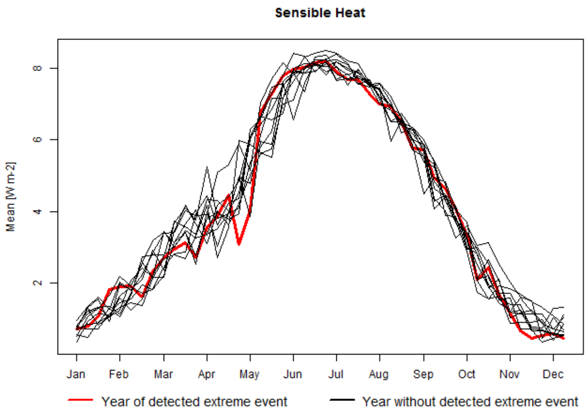


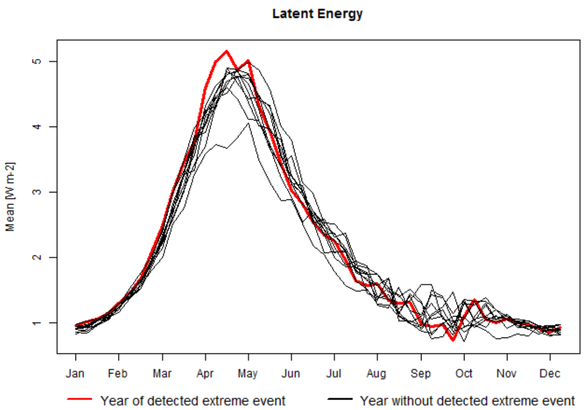
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

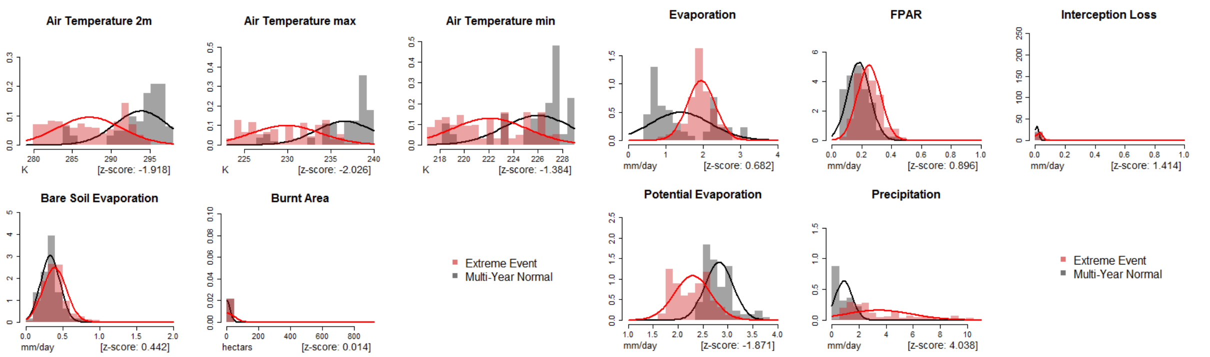
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





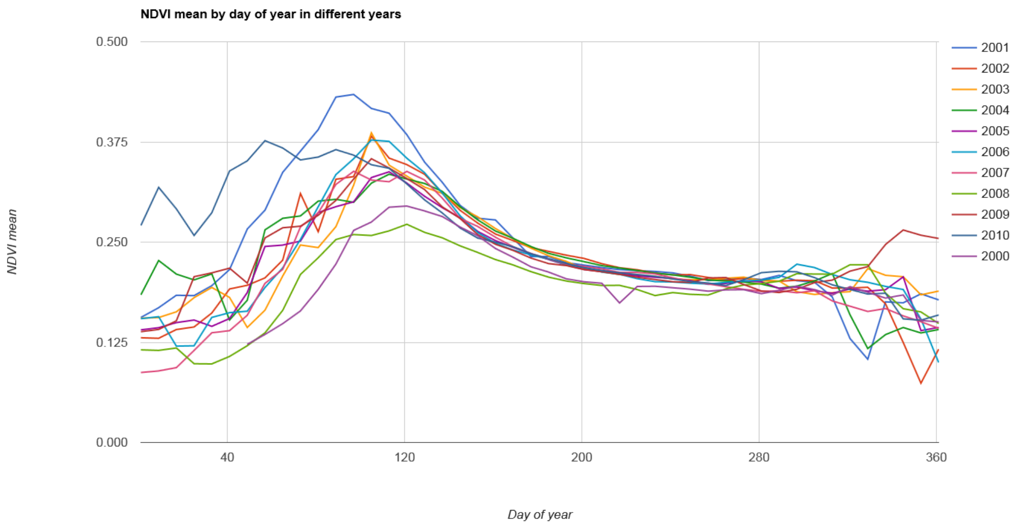
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly higher values of the parameter Sensible Heat (figure)
  - At the same time lower values compared to the multi-year normal (figure)
  - Both anomalies are clearly visible in the time series plots of the respective parameter (figure)
  - This could be a response to higher temperatures and or changes in precipitation

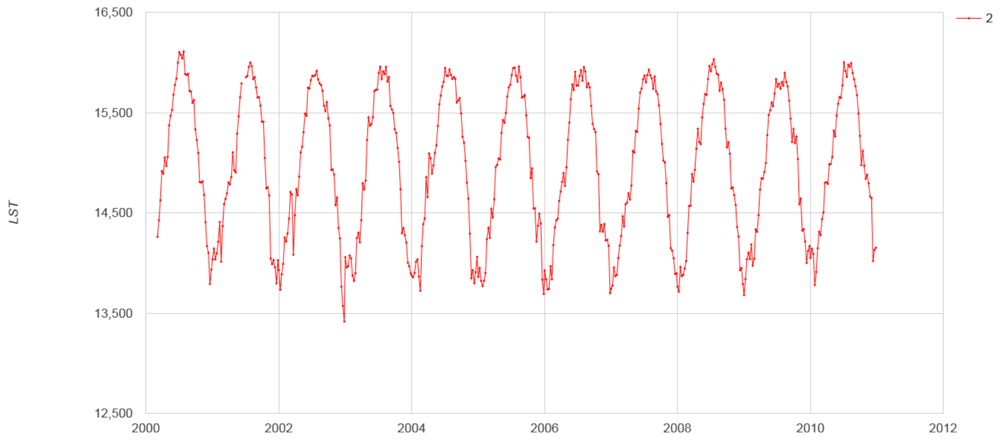
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - As already stated in the internal characterization this behaviour results from lower temperatures (figure) and at the same time more precipitation (figure)
    - This results in higher sensible heat and at the same time lower latent heat

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values show a little positive peak for the investigated period of time underlaying the findings of the internal and external characterization (higher GPP and higher FPAR) (Figure)
  - The same is valid for MODIS LST, which shows unusually low values for that very time (figure)

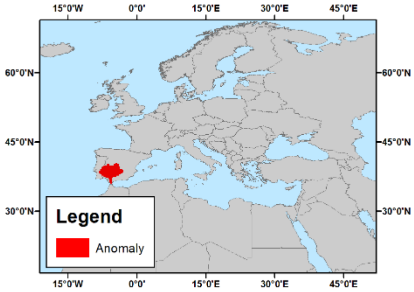
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision			X

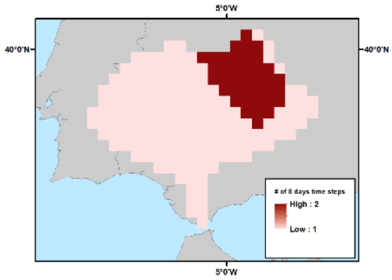
Event ID 52:

1. Attribution (internal)

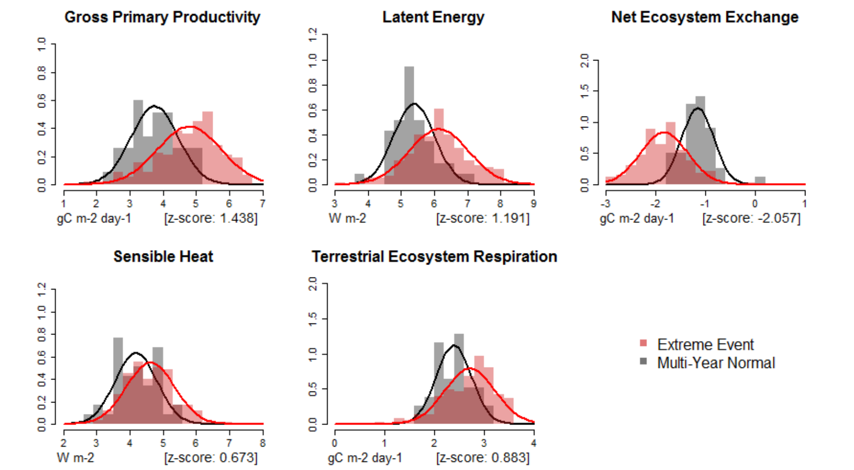
Type: Extreme event
Location: Spain
Area: 115316.8 km²
Time: 19.04.2002
Duration: 03.04.2002 – 19.04.2002



Extent of the event

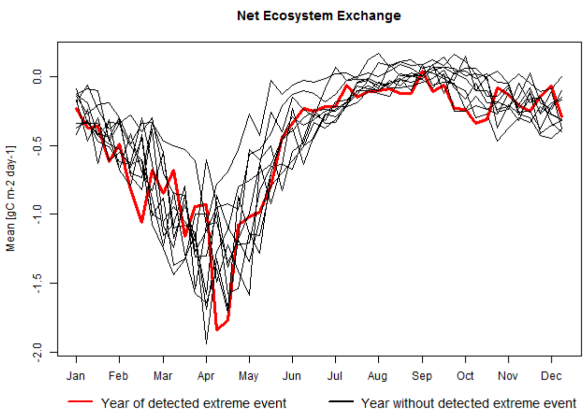


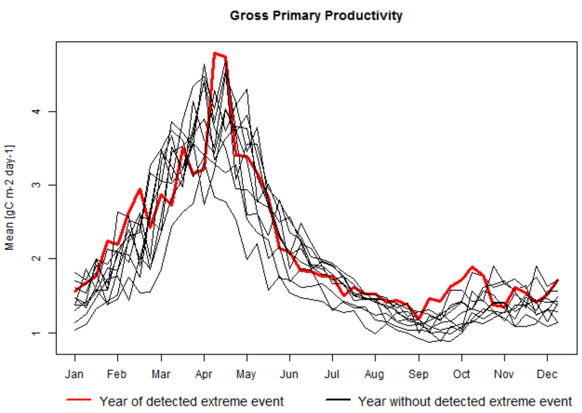
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

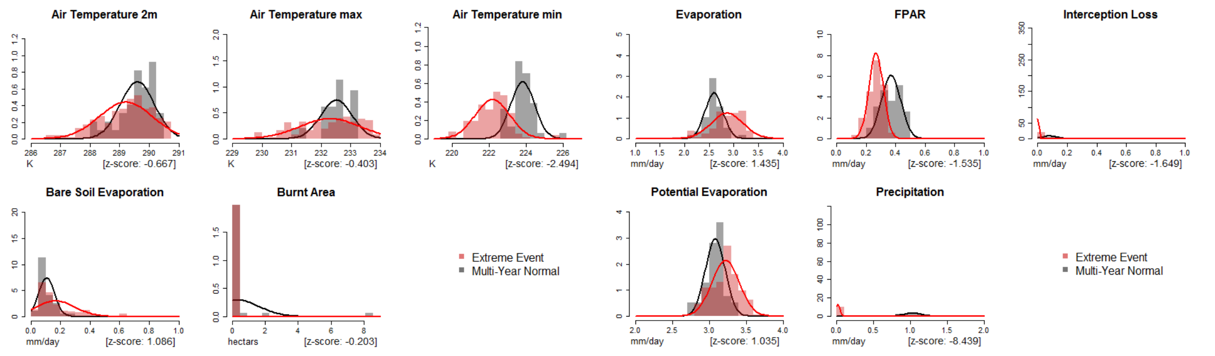
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





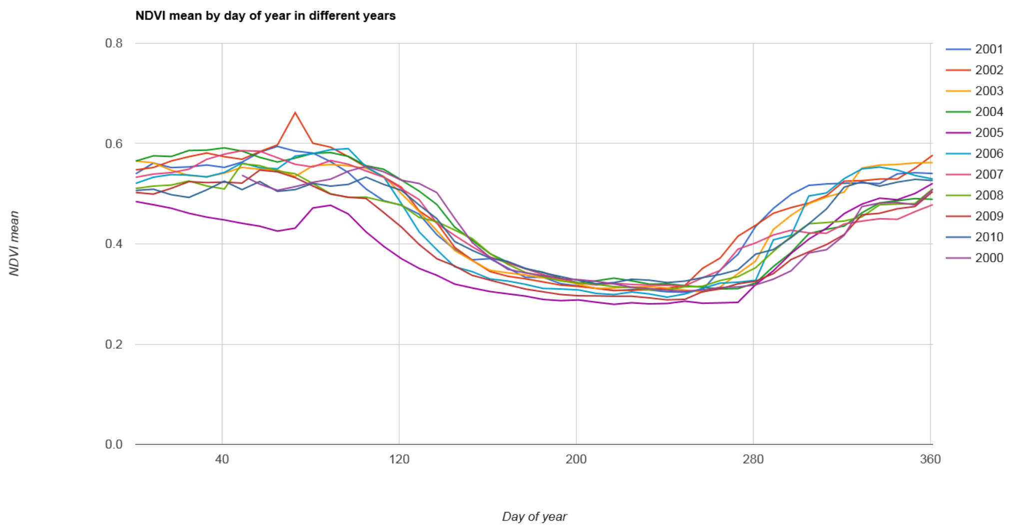
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Considerably higher GPP and LE values for the detected extreme event, whereas NEE was significantly lower than the expected values (figure)
  - The time series plots of NEE and GPP show this abnormal behaviour in a good manner (figure)
  - Since this happened in Spain, lower temperatures or more rainfall can be linked to that extreme event causing better conditions for plants to grow during spring

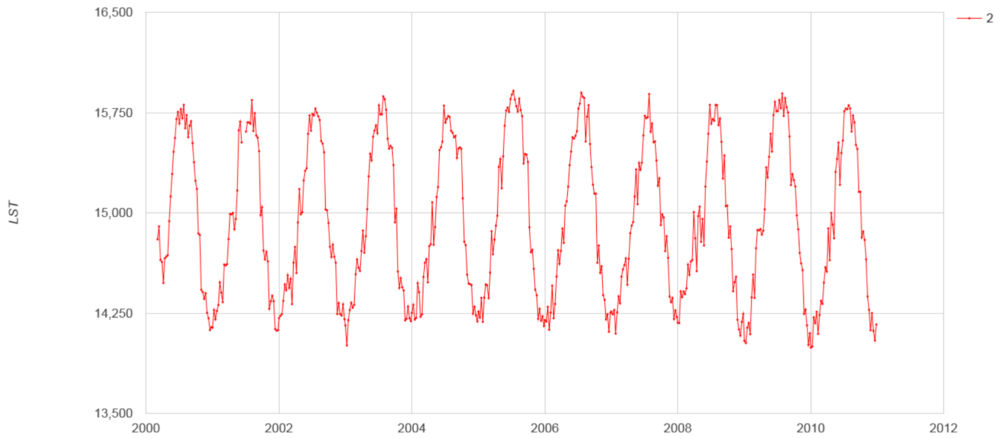
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - Temperatures were considerably lower than expected, whereas evaporation and potential evaporation were lower (figure)
    - But as stated above these lower temperatures lead to better conditions for plants to grow, even with less precipitation in that region (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - MODIS NDVI does not show any significant differences for the detected time period compared to the rest of the years (figure)
  - However, in the time series plot of MODIS LST there is an anomaly visible indicating lower temperatures staying in good agreement with the findings of the BACIndex (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision			**X**

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

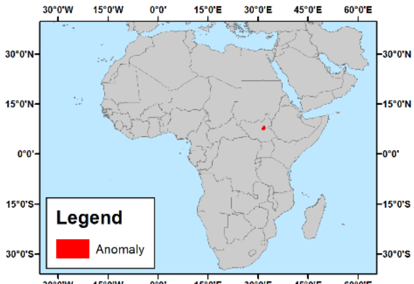
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision		**X**	
Temporal precision		**X**	

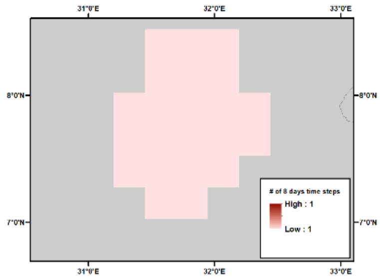
Event ID 53:

1. Attribution (internal)

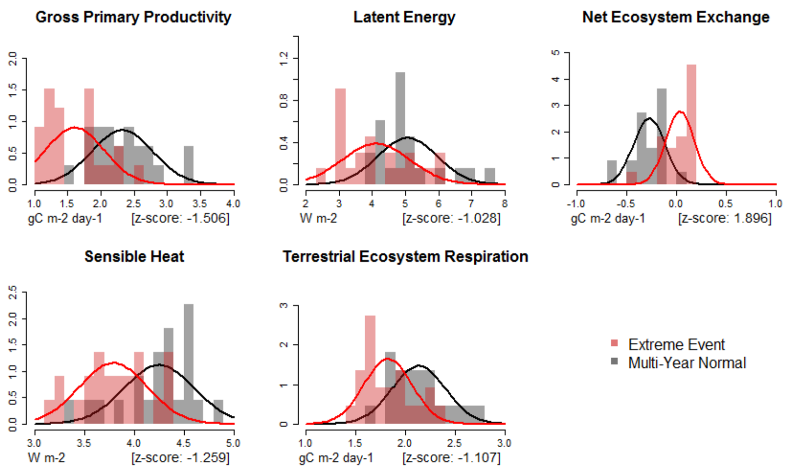
Type: Extreme event
Location: South Sudan
Area: 16673.6 km²
Time: 28.05.2004
Duration: 28.05.2004 – 28.05.2004



Extent of the event

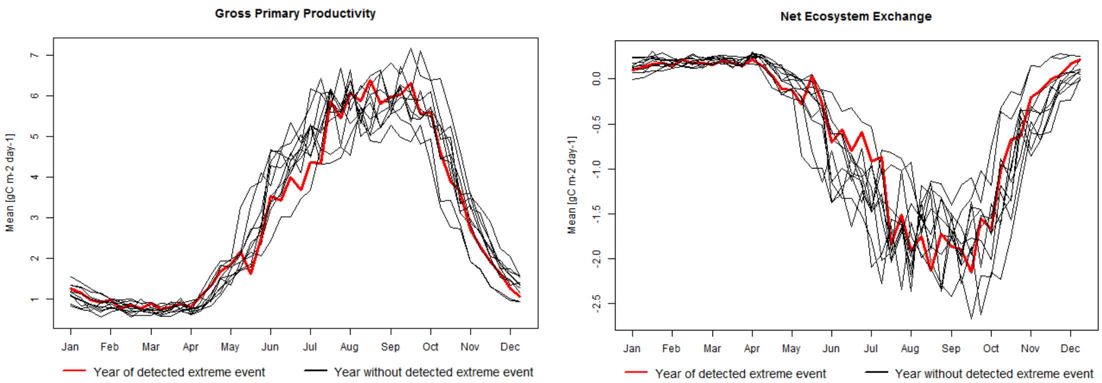


# of 8 day time steps for which the event was detected



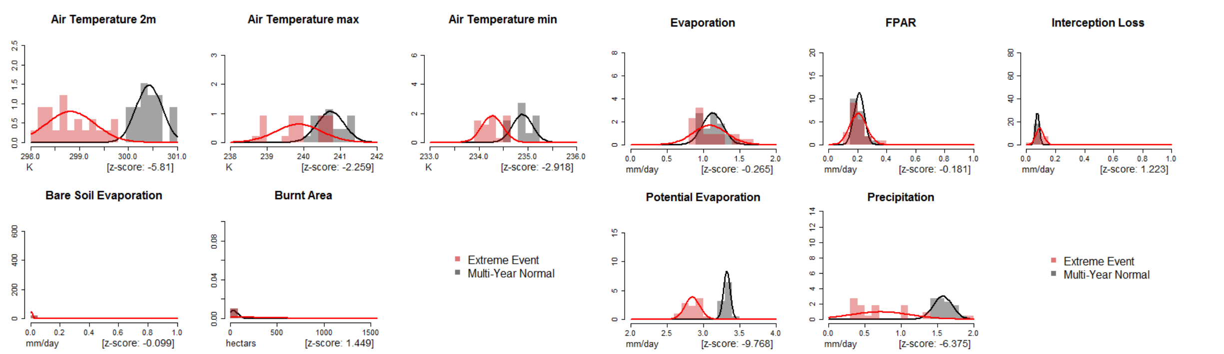
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



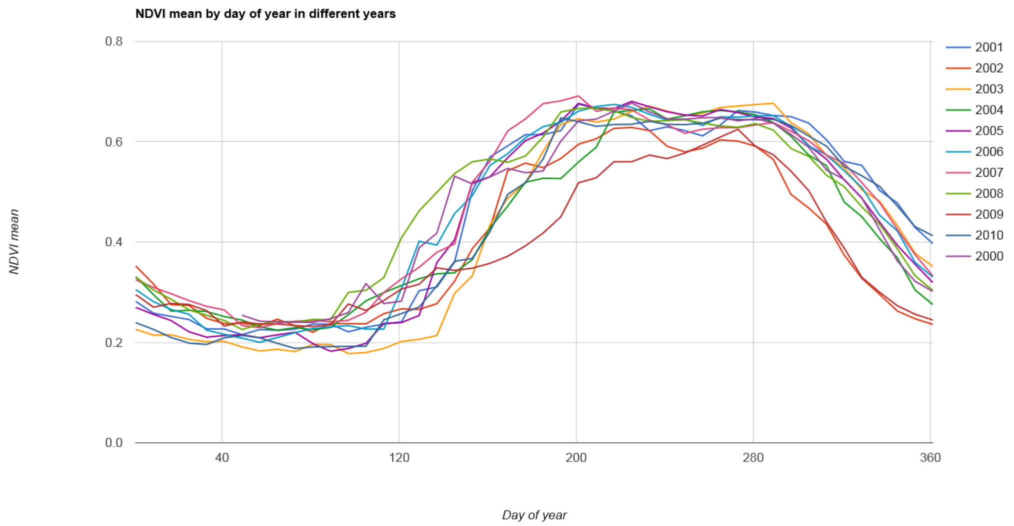
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
    - Significantlly low values of GPP, LE, SH and TER comparing the extreme event with the multi-year normal (figure)
    - In contrast to that NEE showed much higher values (figure)
    - These trends are also visible in the time series of GPP and NEE (figure)
    - Since GPP and TER are lower than expected and NEE is higher than usually CABLAB data shows reduced plant activity due to most likely lower temperatures

2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - lower temperatures which stay in good agreement of the findings of the internal characterization (figure)
  - additionally potential evaporation and precipitation are significantly lower than the expected values explaining low values of sensible heat and latent heat (figure)

3. Independent validation & regional expert feedback



- MODIS NDVI analysis showed for the independent analysis that (figure):
  - NDVI values are lower than the expected, but not as much as indicated by the BACIndex respectively the CABLAB data
  - Also the duration seems to be longer than the detected 8 days detected by the BACIndex

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation

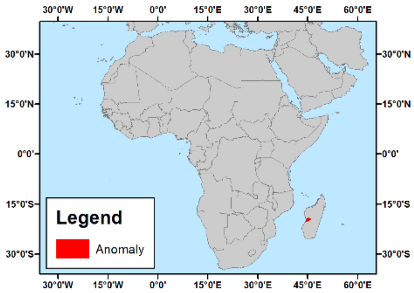
	1	2	3

(1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**	**X**		
	Spatial precision		**X**	
	Temporal precision	**X**		
Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1**	**2**	**3**
	Thematic precision		**X**	
	Spatial precision			**X**
	Temporal precision		**X**	

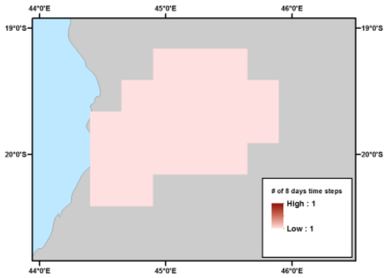
Event ID 54:

1. Attribution (internal)

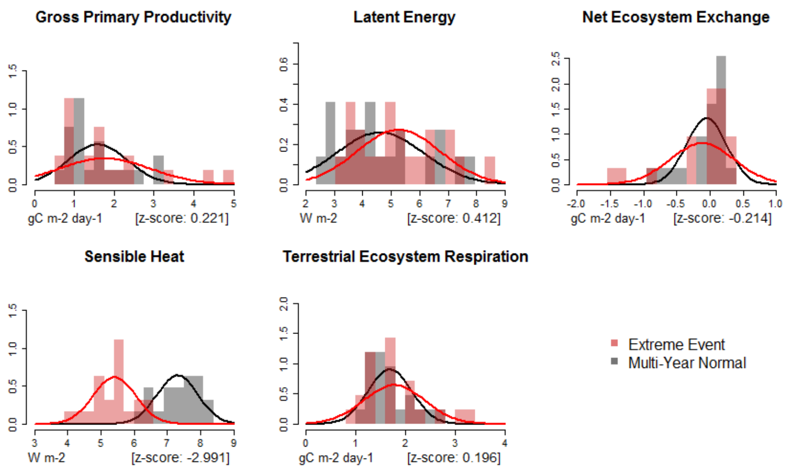
Type: Extreme event
Location: Madagascar
Area: 15137.3 km²
Time: 28.10.2001
Duration: 28.10.2001 – 28.10.2001



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		

	Temporal precision	x

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

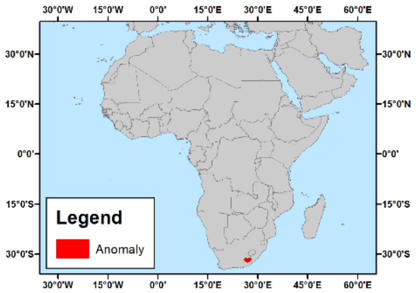
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

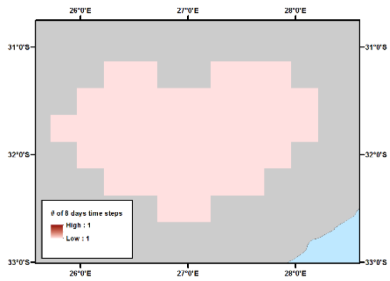
Event ID 55:

1. Attribution (internal)

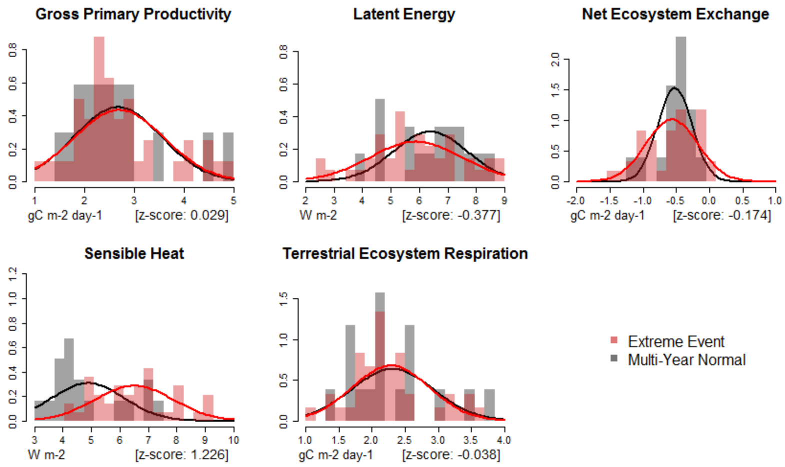
Type: Extreme event
Location: South Africa
Area: 26095.1 km²
Time: 06.02.2010
Duration: 06.02.2010 – 06.02.2010



Extent of the event



# of 8 day time steps for which the event was detected



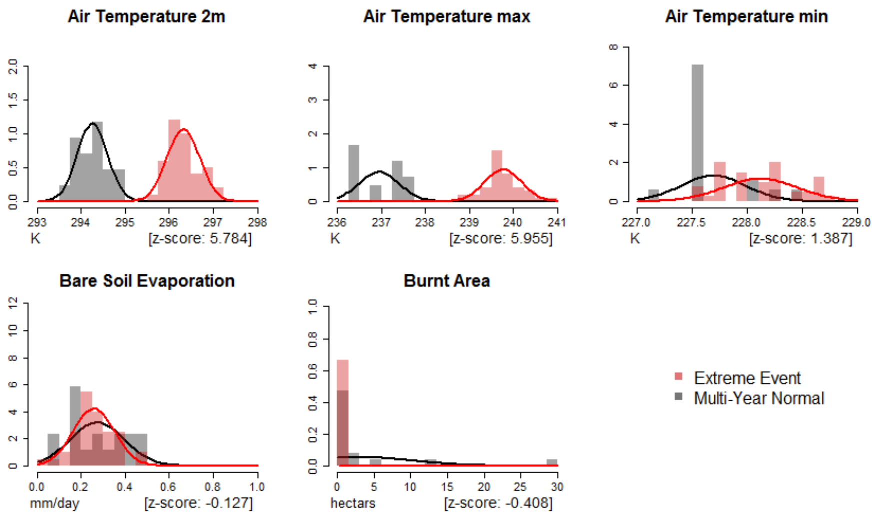
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Unknown Event:

- parameters such as air temperature (at 2m and max) show significant anomaly for this time step



3. Independent validation & regional expert feedback

Unknown Event:

- NDVI show depression in time period of detected anomaly (Figure 1)

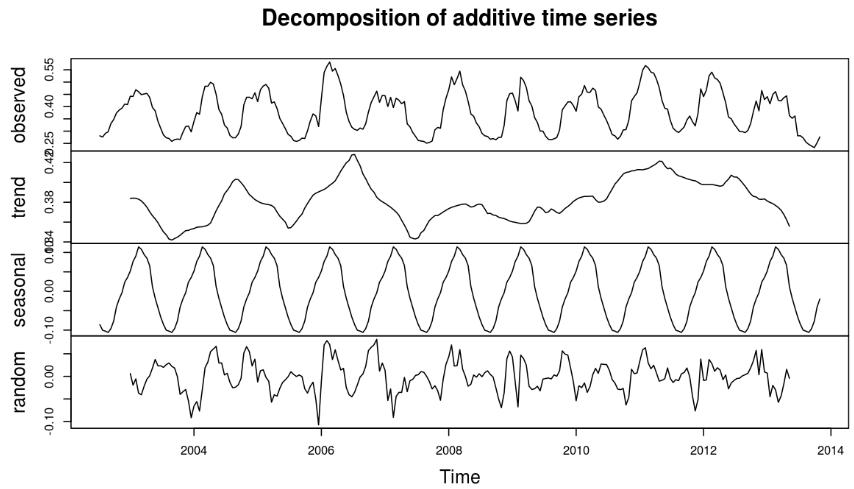


Figure 1. NDVI temporal profile of anomaly region.
(Source: EOM – Earth Observation Monitor - http://earth-observation-monitor.net

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		
Temporal precision		x	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

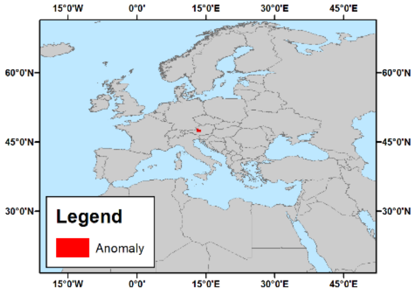
	1	2	3
Thematic precision	x		
Spatial precision		x	
Temporal precision	x		

References

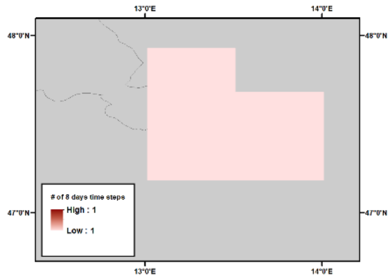
Event ID 56:

1. Attribution (internal)

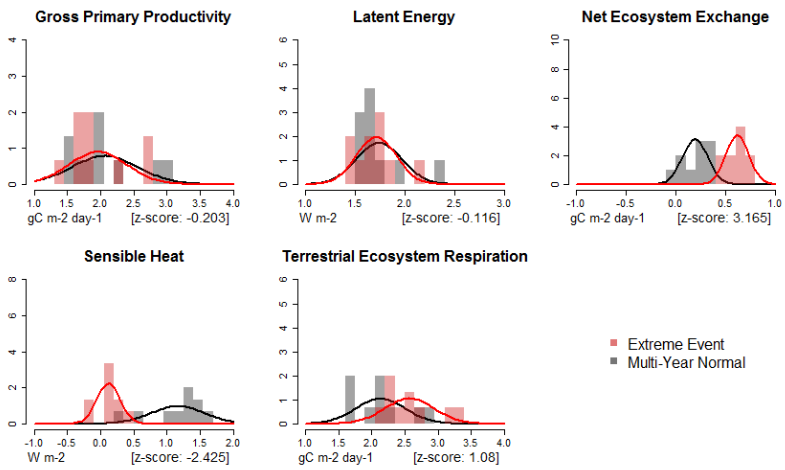
Type: Extreme event
Location: Central Europe
Area: 5203.9 km²
Time: 20.10.2007
Duration: 20.10.2007 – 20.10.2007



Extent of the event

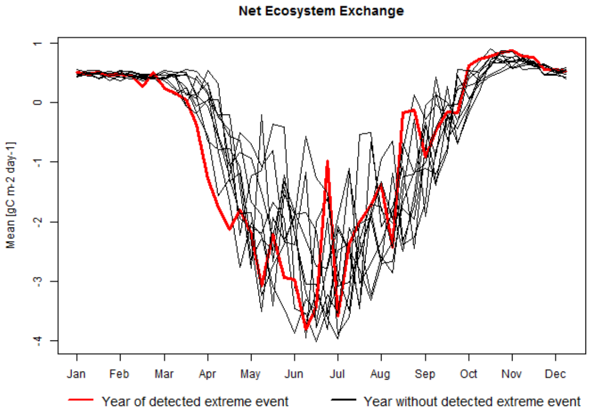


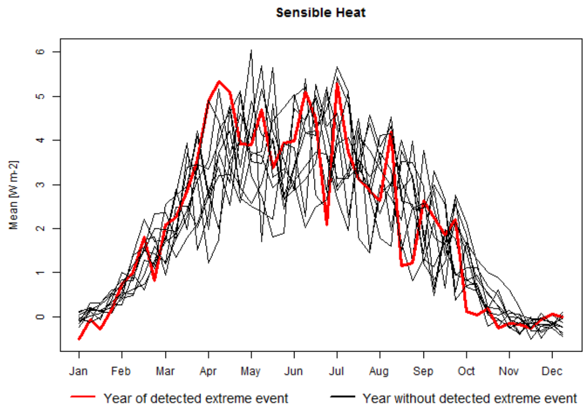
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

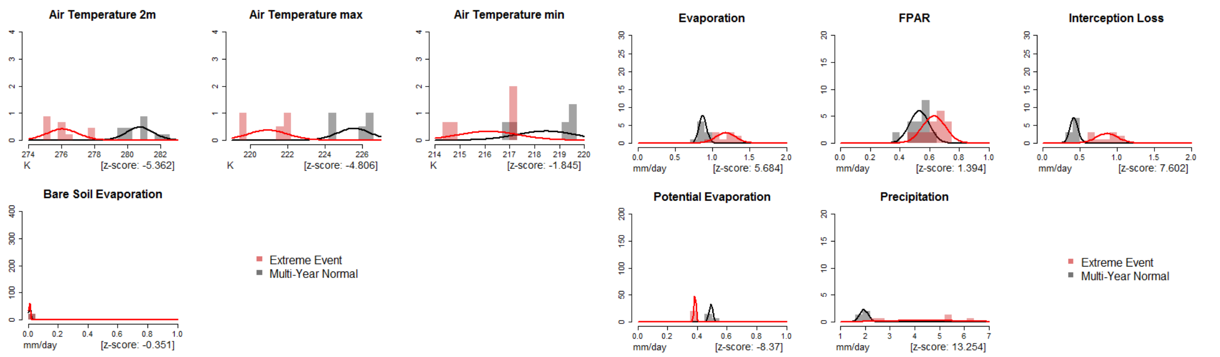
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





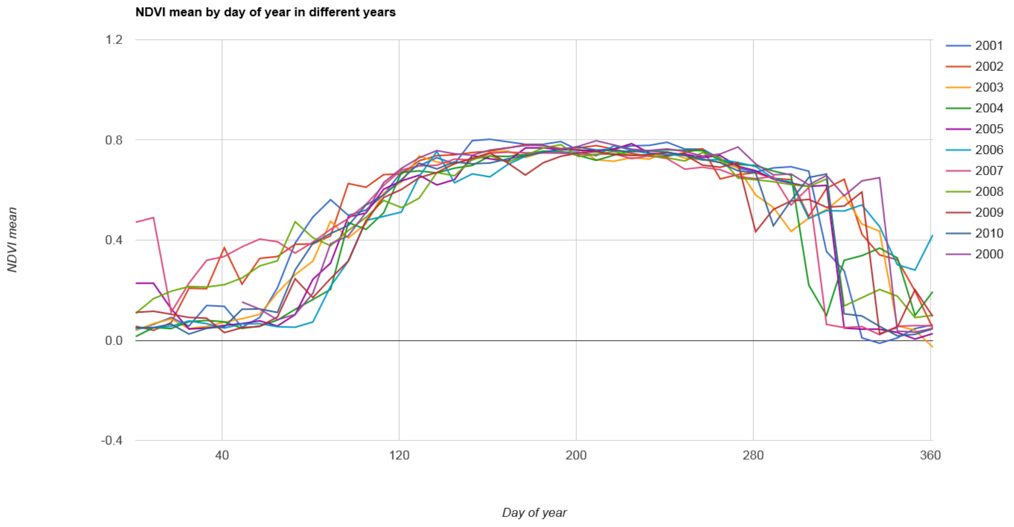
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly higher values of NEE and TER (figure), which is clearly visible for the NEE time series (figure)
  - At the same time the parameter sensible heat indicated lower values (figure), which was again visible in the time series plot (figure)
  - This behaviour could be based on lower temperatures and therefore worse conditions for plants to grow, therefore more NEE and lower SH

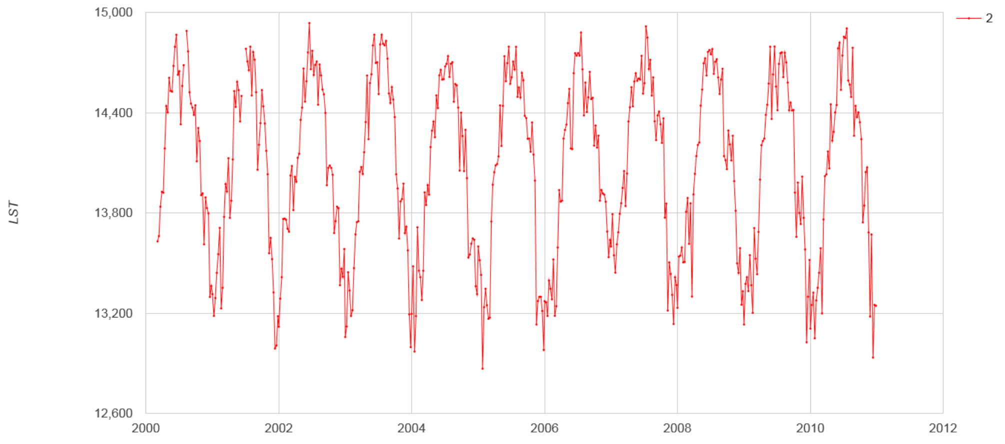
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - As stated above lower temperatures might cause this behaviour, which is valid depending on additional BACI data (figure)
    - Moreover precipitation was higher, but since temperatures were this low most of the energy exchanges were in the atmosphere and not in the biosphere (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values were not significant lower but indicated slightly lower values in the detected time period (figure)
  - The same was visible for MODIS LST values (figure)

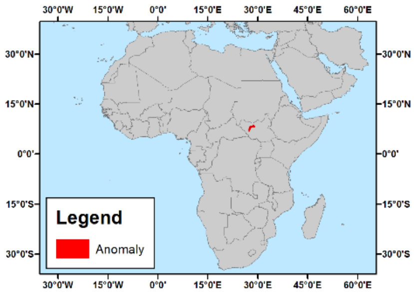
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

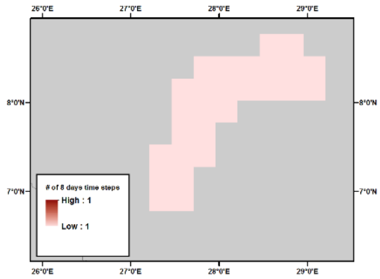
Event ID 57:

1. Attribution (internal)

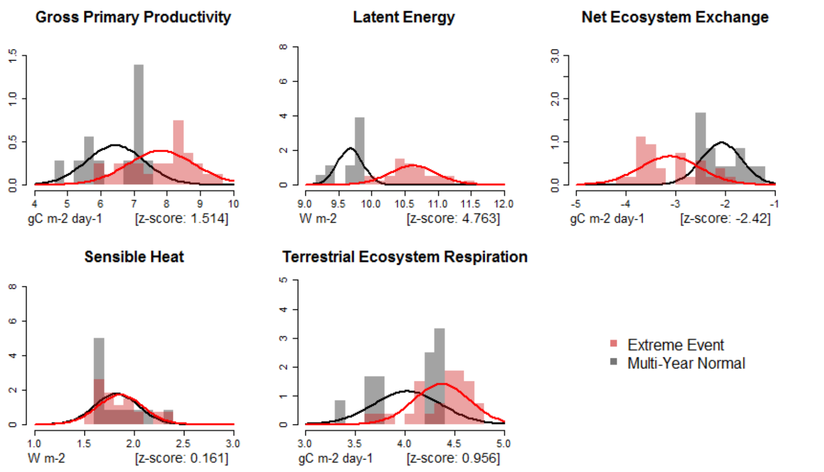
Type: Extreme event
Location: South Sudan
Area: 20455.9 km²
Time: 09.08.2005
Duration: 09.08.2005 – 09.08.2005



Extent of the event

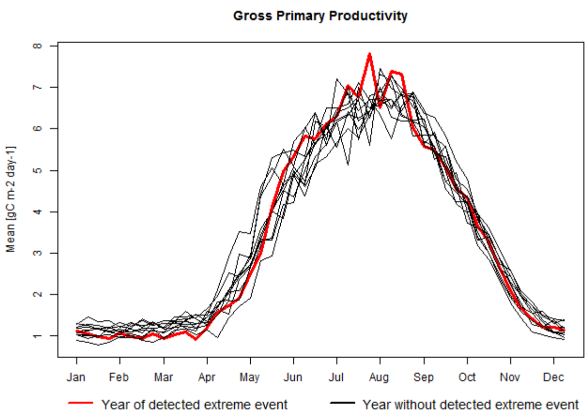


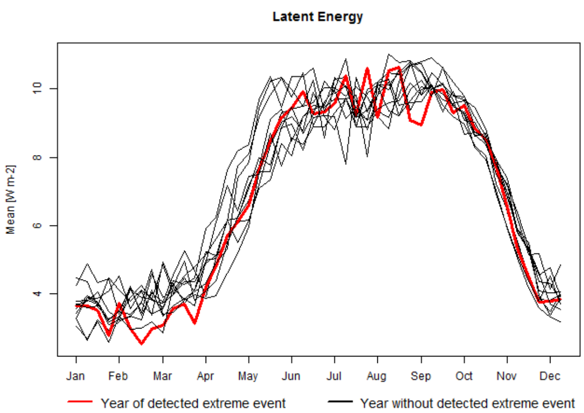
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

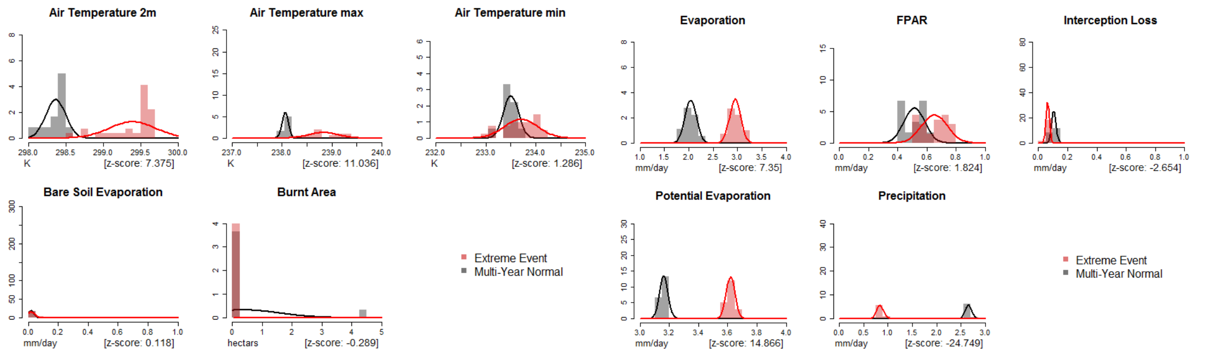
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





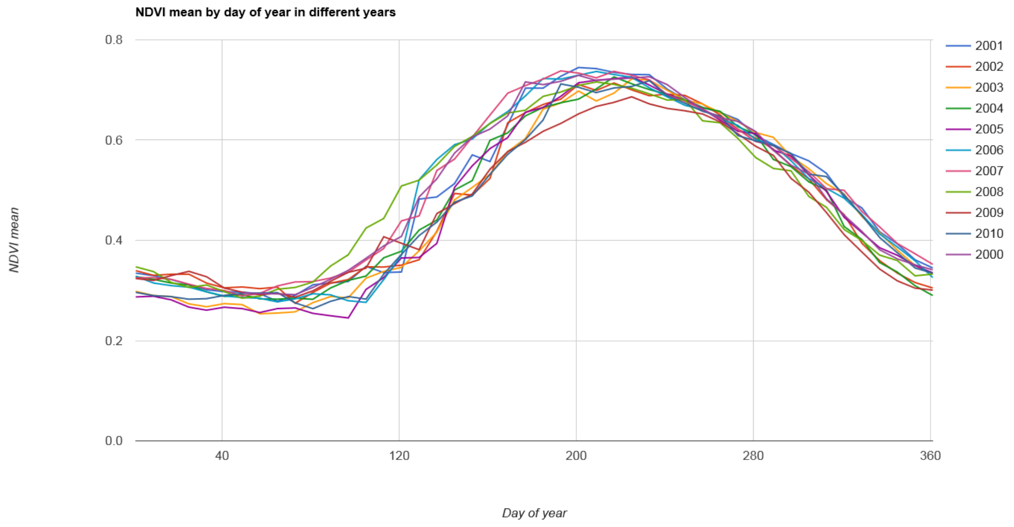
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly higher values for GPP and LE, whereas NEE showed lower values indicating plant growth and therefore more saved Carbon in the plants, because of more ideal conditions than usual (figure)
  - The same trend is visible for GPP and LE showing peaks of values in the time series (figure)

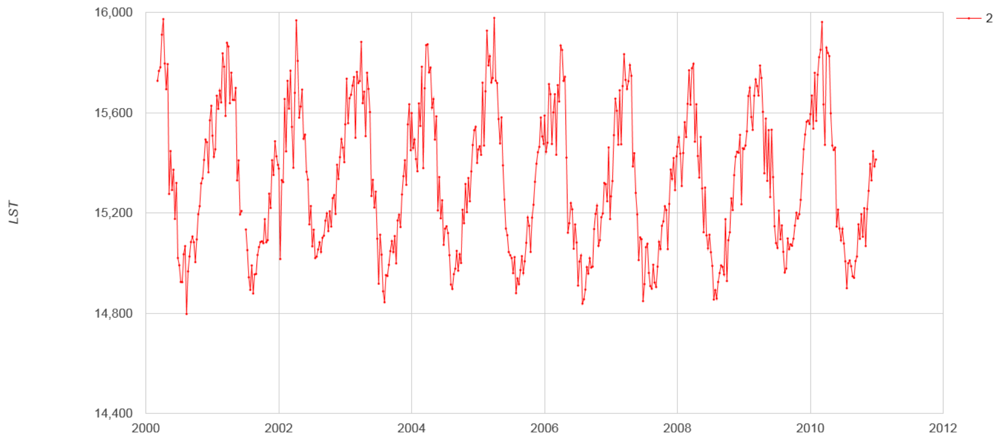
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - higher values for all temperatures (2m, max and min), whereas precipitation were significantly lower than usual (figure)
    - on the other hand evaporation (because of higher temperatures and lower precipitation) showed a much higher value (figure)
    - the findings of higher GPP in the internal characterization are also visible for FPAR showing better growing conditions due to most likely higher temperatures and less interception loss (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - Neither of the findings of the internal nor external characterization and be validated by the analysis of MODIS NDVI and LST, since they show a “normal” or expected behaviour for the detected extreme event (figure)
  - Even though there is a small peak of NDVI values for 2005 it does not show a good agreement with the massive difference showed in the internal and external characterization

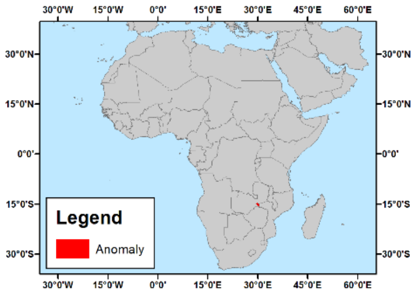
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision	X		
Temporal precision	X		

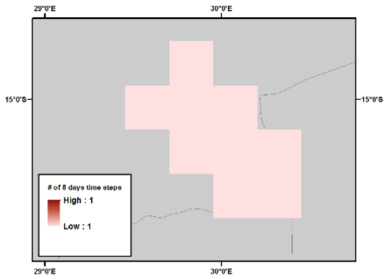
Event ID 58:

1. Attribution (internal)

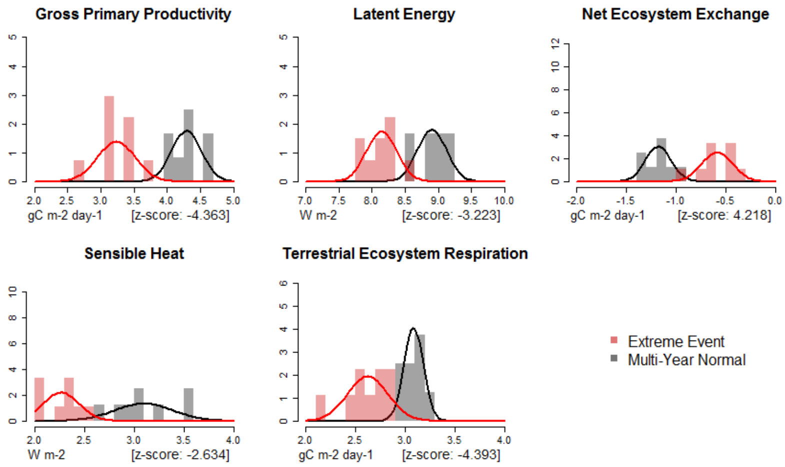
Type: Extreme event
Location: southern Africa
Area: 6647.8 km²
Time: 07.12.2010
Duration: 07.12.2010 – 07.12.2010



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

3. Independent validation & regional expert feedback

It was not able to validate this extreme event as the existence of an anomaly could not be found, even after an intensive literature and web recherché.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	x		
Spatial precision	x		
Temporal precision	x		

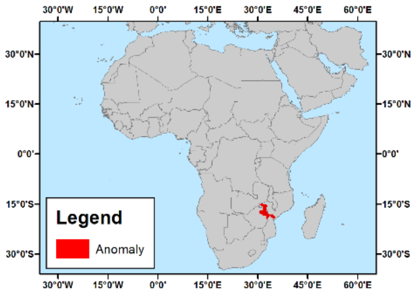
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	<table><tr><th></th><th>1</th><th>2</th><th>3</th></tr><tr><td>**Thematic precision**</td><td></td><td></td><td></td></tr><tr><td>**Spatial precision**</td><td></td><td></td><td></td></tr><tr><td>**Temporal precision**</td><td></td><td></td><td></td></tr></table>

References

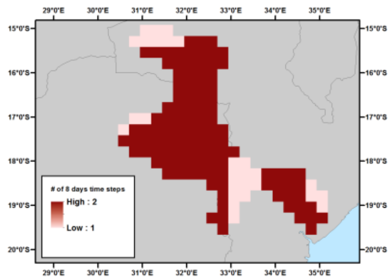
Event ID 59:

1. Attribution (internal)

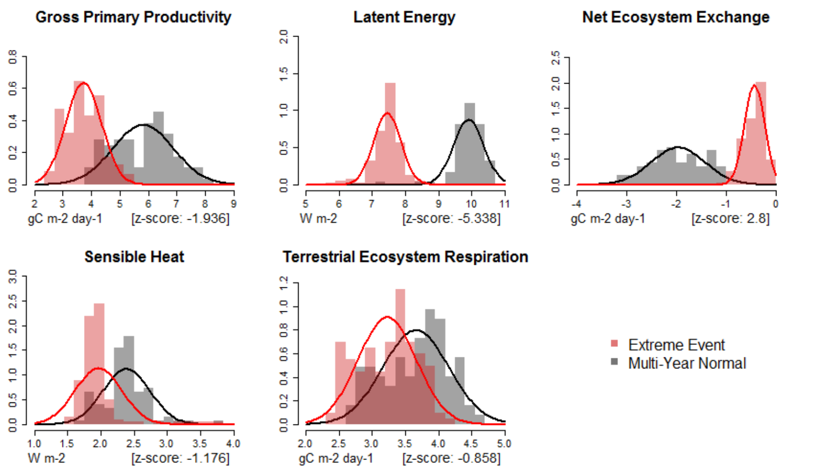
Type: Extreme event
Location: southern Africa
Area: 97877.3 km²
Time: 14.02.2001
Duration: 14.02.2001 – 22.02.2001



Extent of the event



# of 8 day time steps for which the event was detected



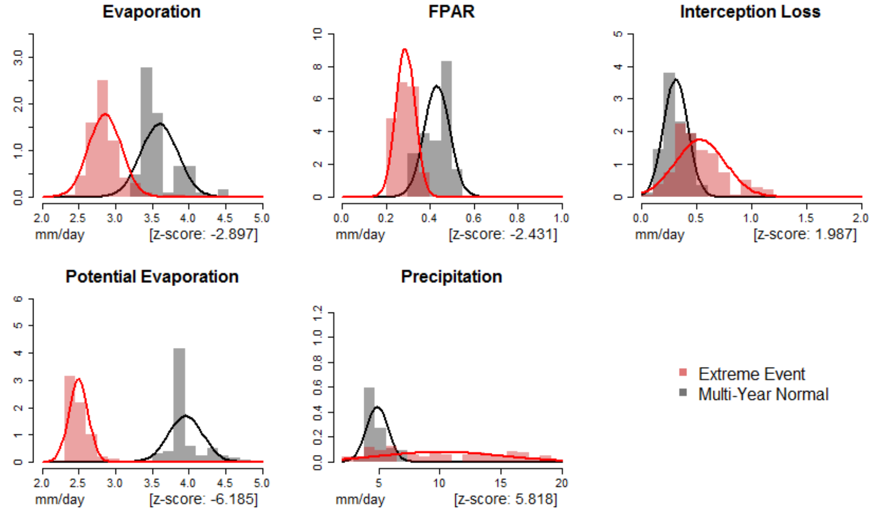
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Vegetation Loss Event:

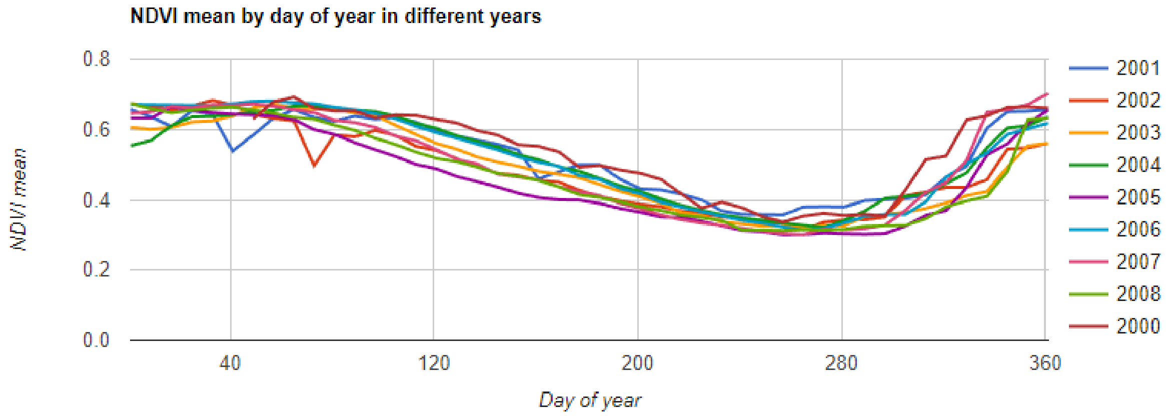
- parameters such as FPAR, evaporation and pot. Evaporation show significant anomaly for this time step



3. Independent validation & regional expert feedback

Vegetation Loss Event:

- NDVI show depression in time period of detected anomaly (Figure 1)
- comparing between the years, a clear drop of NDVI values can be found for this time period (blue line in Figure 1)



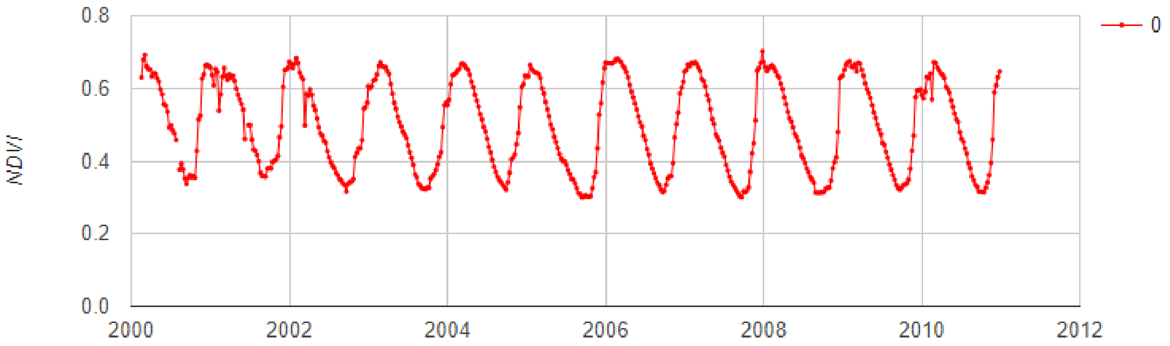


Figure 1. NDVI temporal profile of anomaly region (temporal mean of each year (above), time series for entire period (below).
(Source: EOM – Earth Observation Monitor - http://earth-observation-monitor.net)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		x	
Spatial precision		x	
Temporal precision			x

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

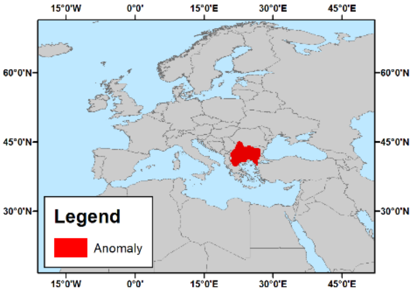
	1	2	3
Thematic precision			
Spatial precision			
Temporal precision			

References

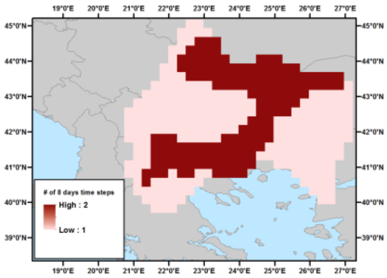
Event ID 60:

1. Attribution (internal)

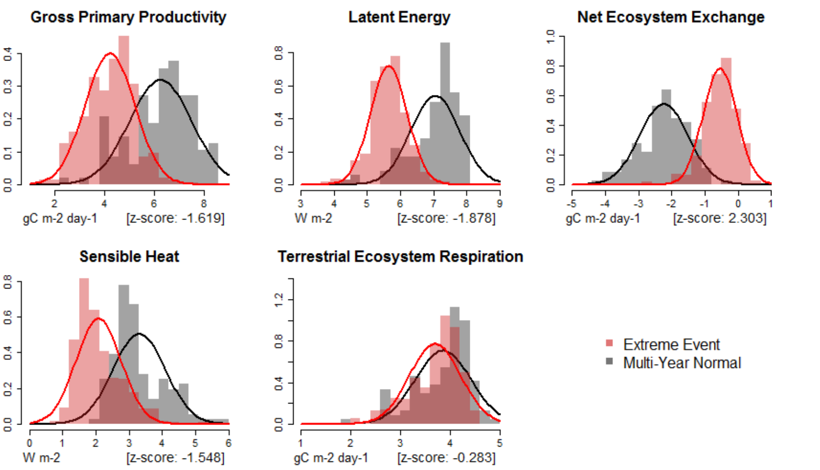
Type: Extreme event
Location: South-eastern Europe
Area: 205476.1 km²
Time: 21.05.2007
Duration: 21.05.2007 – 29.05.2007



Extent of the event

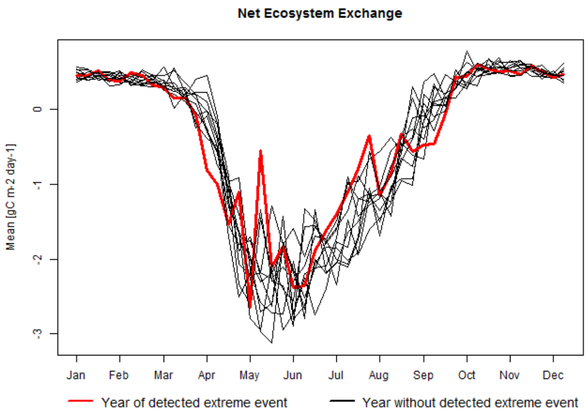


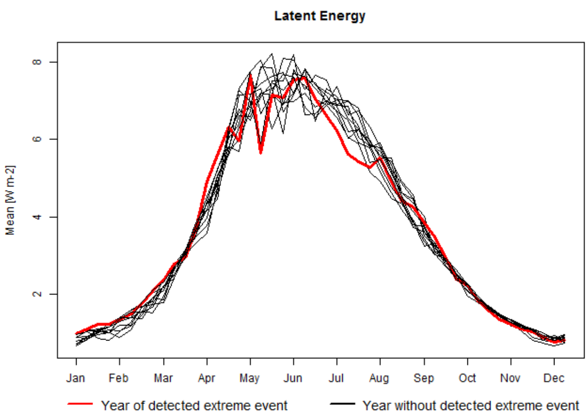
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

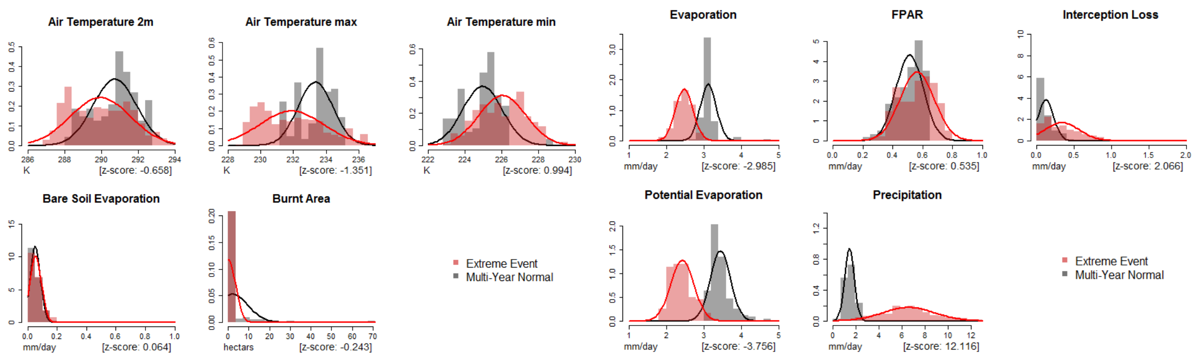
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





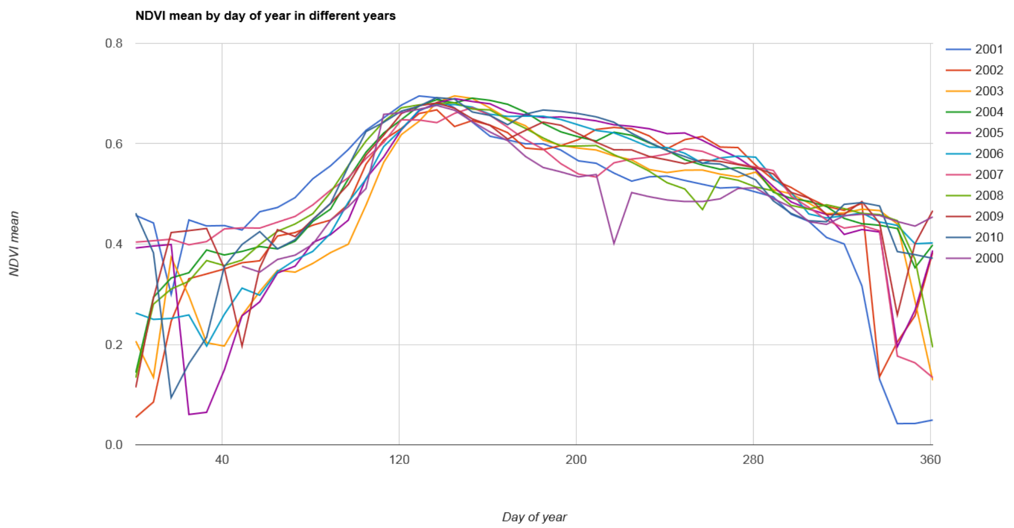
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly lower values of GPP, LE and SH of the detected time period compared to the multi-year normal (figure)
  - On the other hand NEE indicated very high values (figure), which were present in the time series (figure)

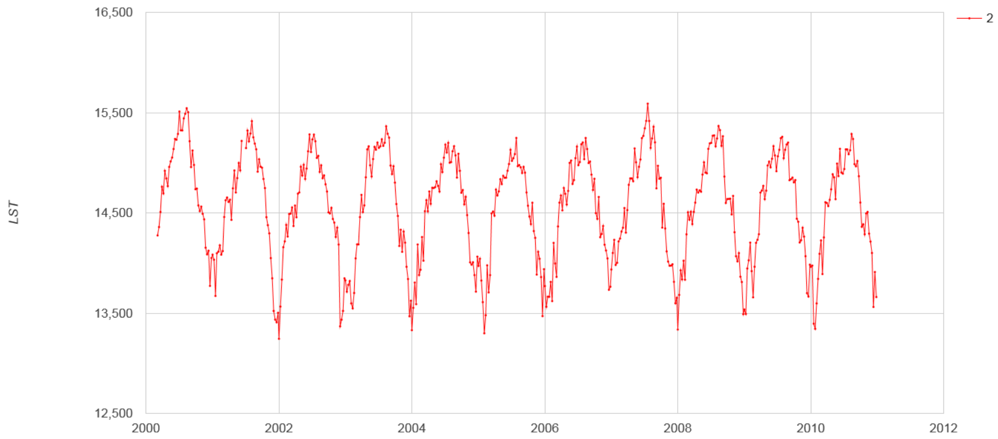
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - overall temperatures were more moderate compared to the expected values, since maximal temperature was lower, whereas the minimal temperature was higher (figure)
    - these, on paper, improved growing conditions were violated by too much rain, causing more NEE respectively more energy exchange in the atmosphere ergo less photosynthetic activity (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI showed these trends due to lower values as well, but indicated a longer duration of the extreme event (figure)
  - No anomalies were visible in the MODIS LST plot (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision	X		

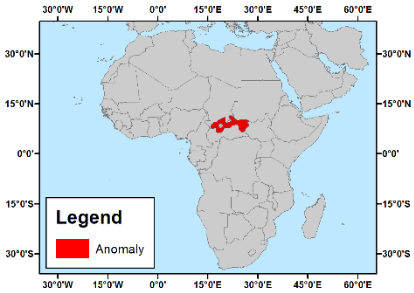
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision			X

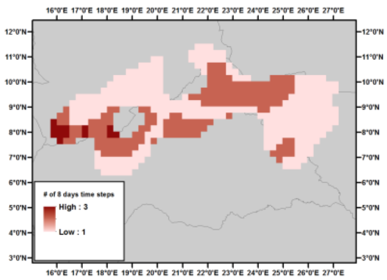
Event ID 61:

1. Attribution (internal)

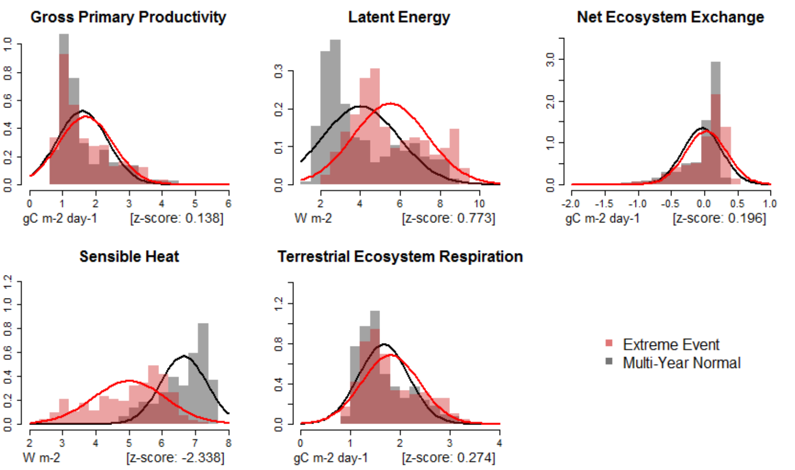
Type: Extreme event
Location: Central Africa
Area: 349952.8 km²
Time: 18.03.2010
Duration: 18.03.2010 – 03.04.2010



Extent of the event

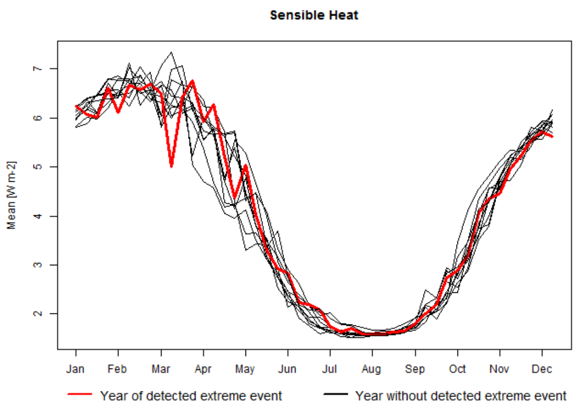


# of 8 day time steps for which the event was detected



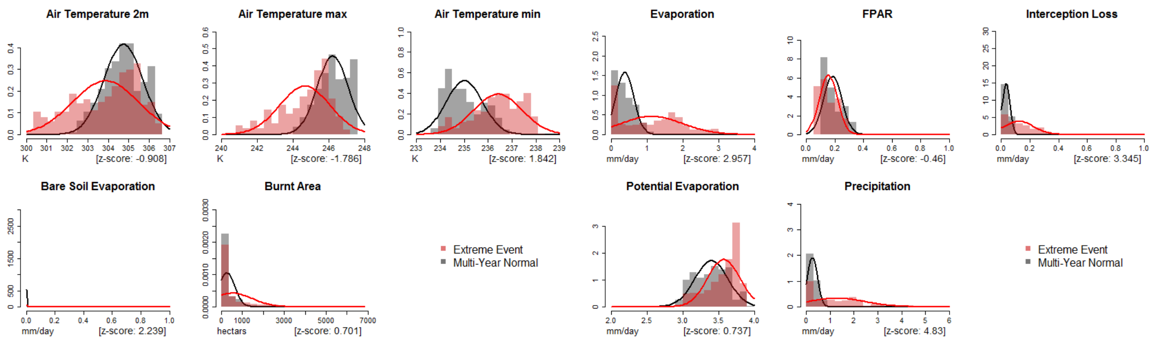
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



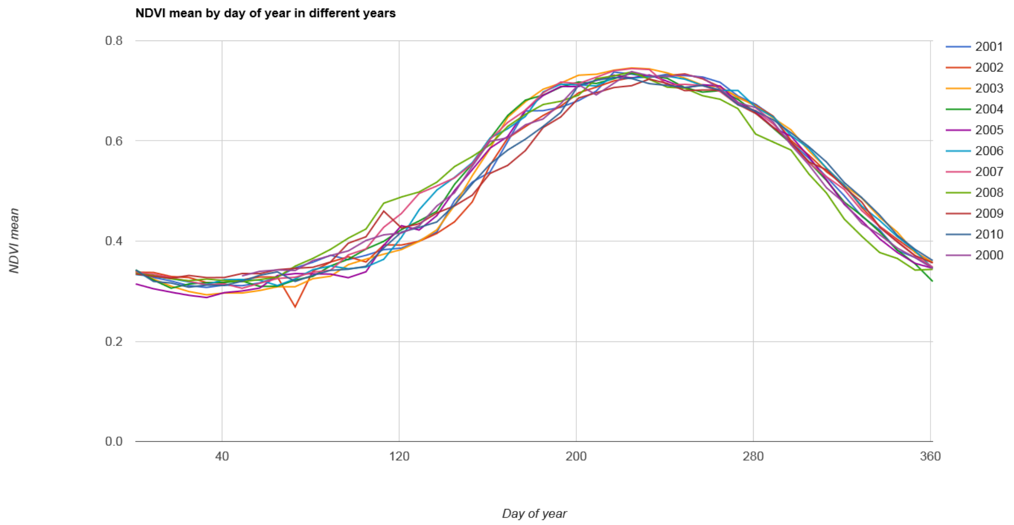
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly lower sensible heat indicating lower temperatures than expected by the multi-year normal
  - This behaviour is also visible in a massive drop of values regarding the time series analysis of sensible heat (figure)
  - All other input parameters showed no significantly anomalies

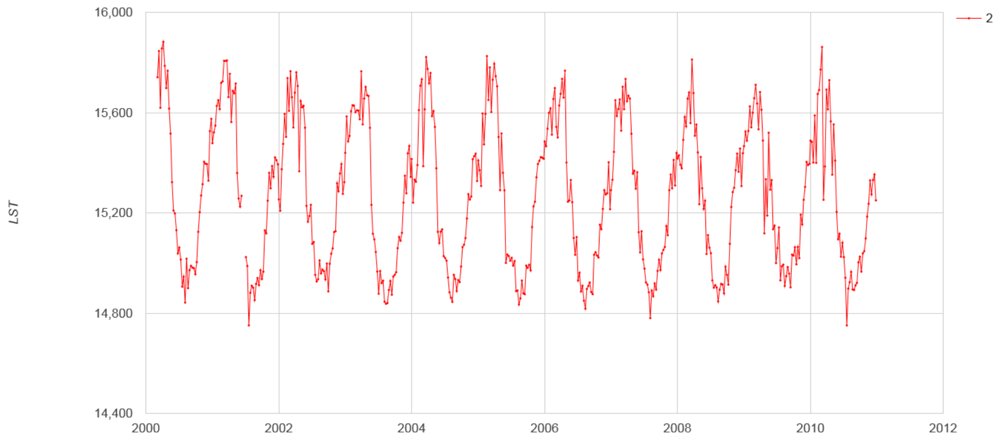
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - lower maximal temperatures, whereas minimal temperatures were higher than the multi-year normal (figure)
    - at the same time evaporation and precipitation were higher than expected (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values showed no significant anomalies compared to the other inspected years (figure)
  - LST showed actually slightly higher values than the other years and stay therefore in disagreement with the findings provided by the CABLAB data (figure)

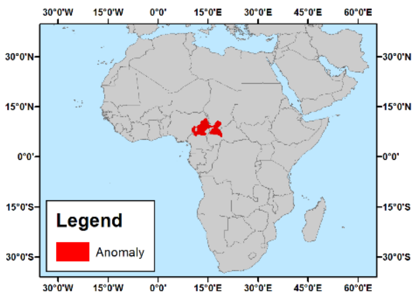
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision		**X**	

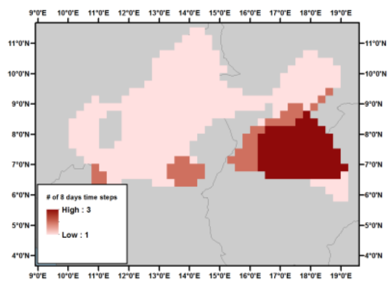
Event ID 62:

1. Attribution (internal)

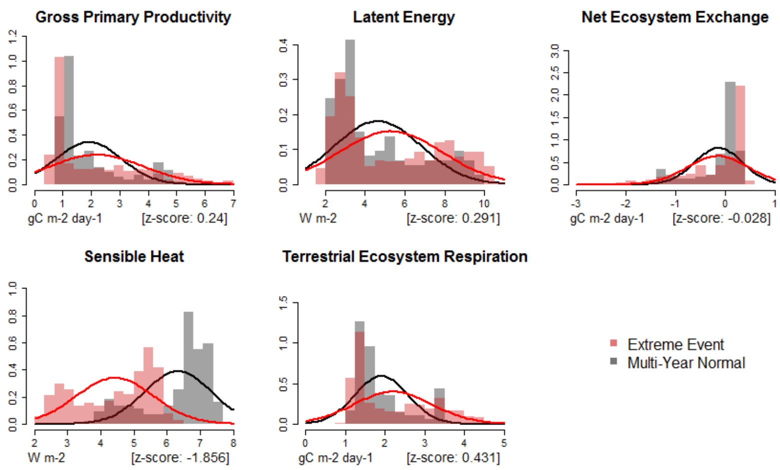
Type: Extreme event
Location: Central Africa
Area: 326130.8 km²
Time: 02.04.2008
Duration: 02.04.2008 – 18.04.2008



Extent of the event

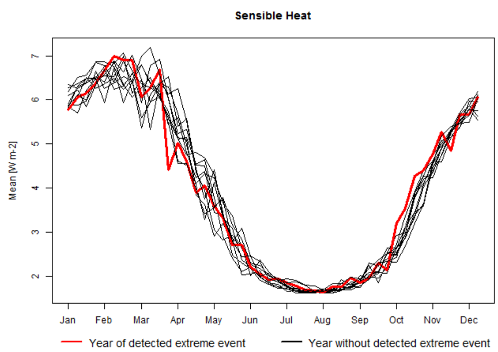


# of 8 day time steps for which the event was detected



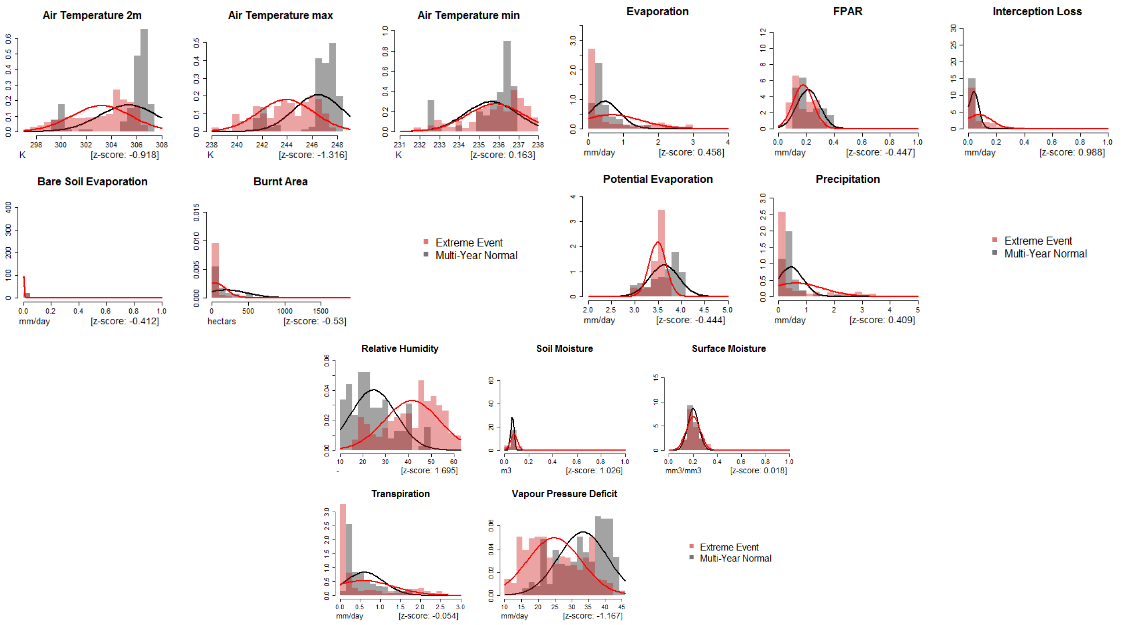
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



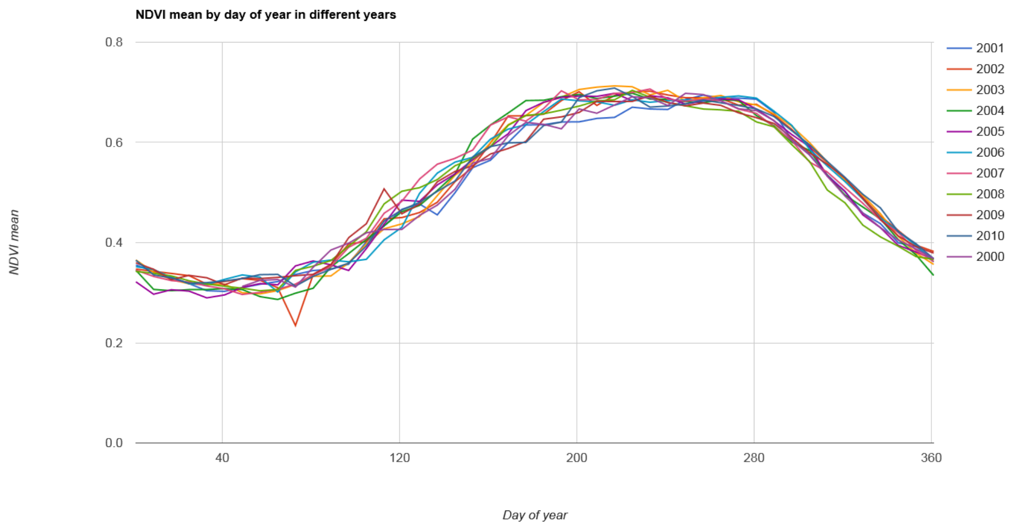
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
    - Significantly lower values of the input parameter sensible heat with an z-score of -1.856 (figure), which was also clearly visible in the time series analysis of the sensible heat indicated by a drop during the detected time (figure)

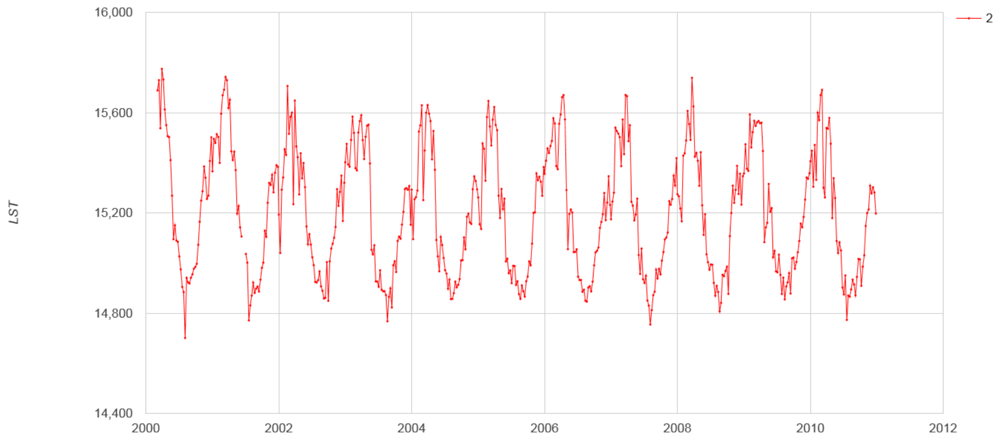
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - the only significant difference was visible for maximal temperature, which was considerable lower than expected, whereas relative humidity was also much higher and vapour pressure deficit was lower (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - Neither any noticeable difference between the years for the detected period of time compared to all other years (figure)
  - However, slightly lower maximal temperatures are visible but only later that year (figure)
- Floods were detected in the northern part of Cameroon and central part during the same time, which influences were not present in the CABALAB data apart from the relative humidity (Bang 2016:111f)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision	X		
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision	X		
Temporal precision		X	

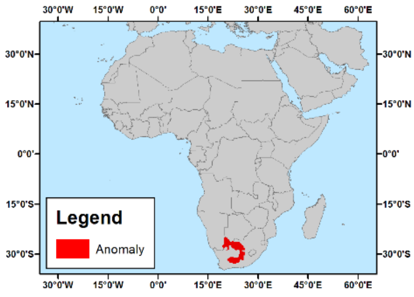
References

1. Bang, H. N. (2016): 30 Years After the Lake Nyos Diaster: Waht Prospects for Rehabilitation in the Region? BookVenture Publishing LLC. Ishpeming.

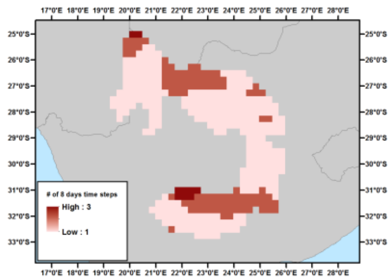
Event ID 63:

1. Attribution (internal)

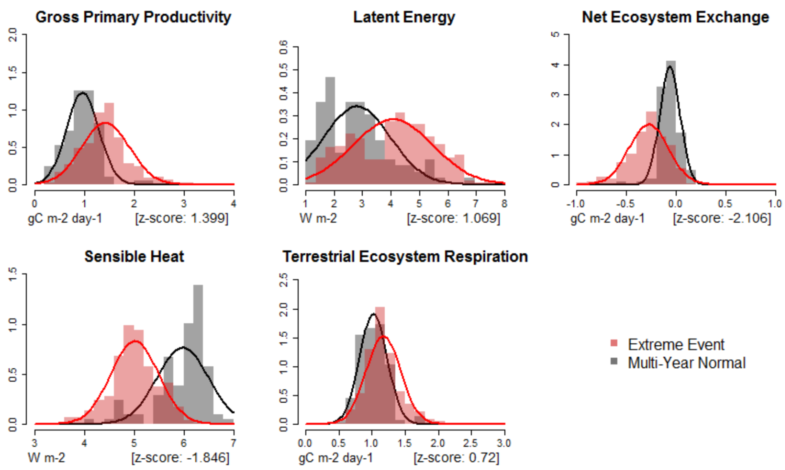
Type: Extreme event
Location: ??????
Area: 251004.5 km²
Time: 02.03.2011
Duration: 02.03.2011 – 18.03.2011



Extent of the event

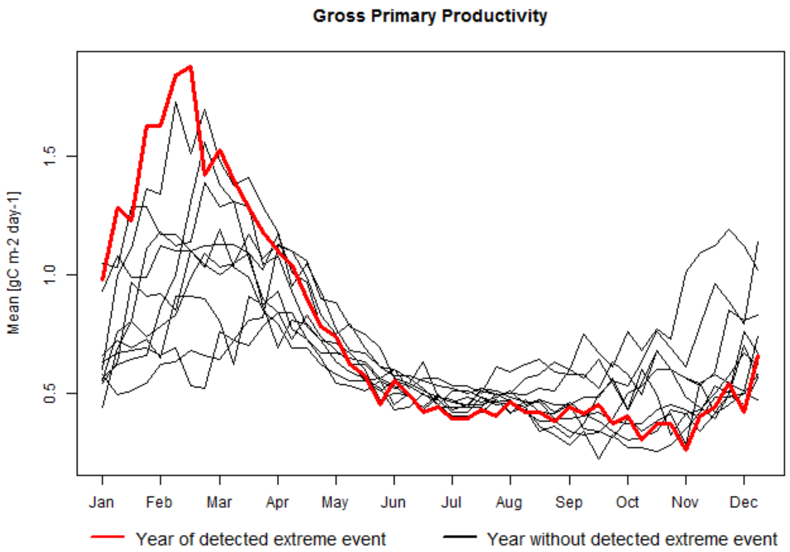


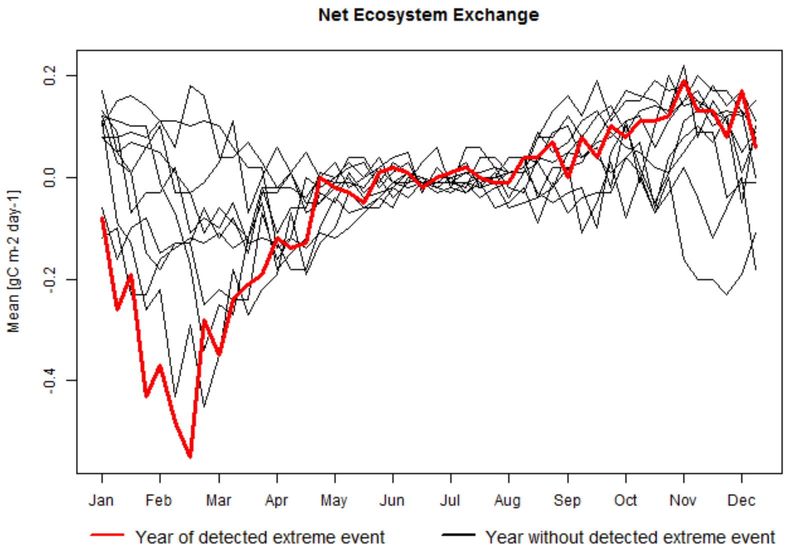
# of 8 day time steps for which the event was detected

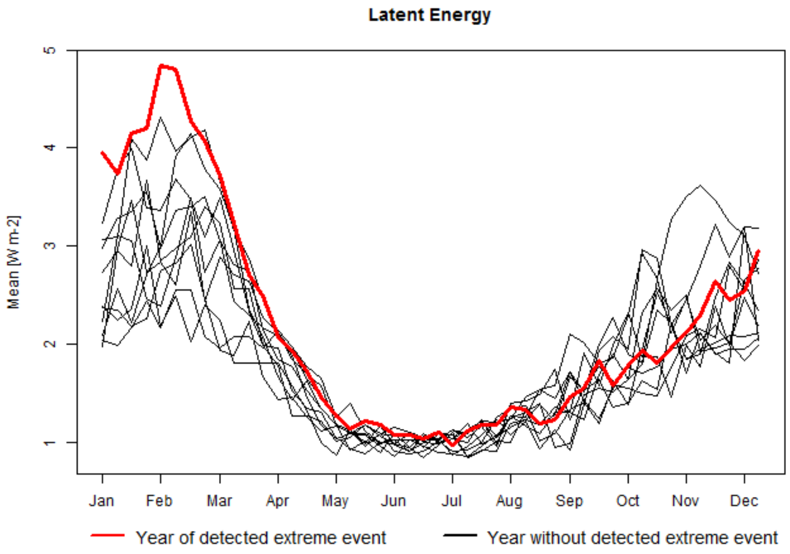


Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





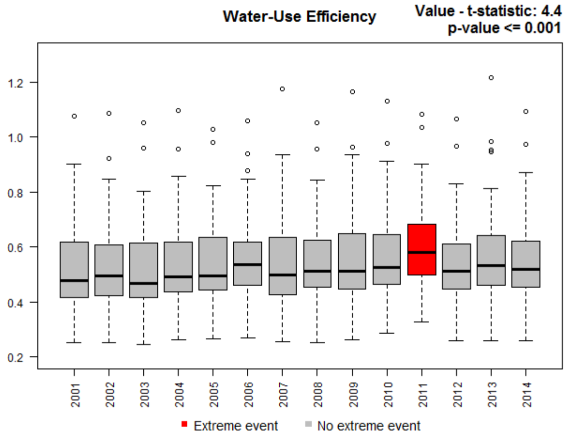


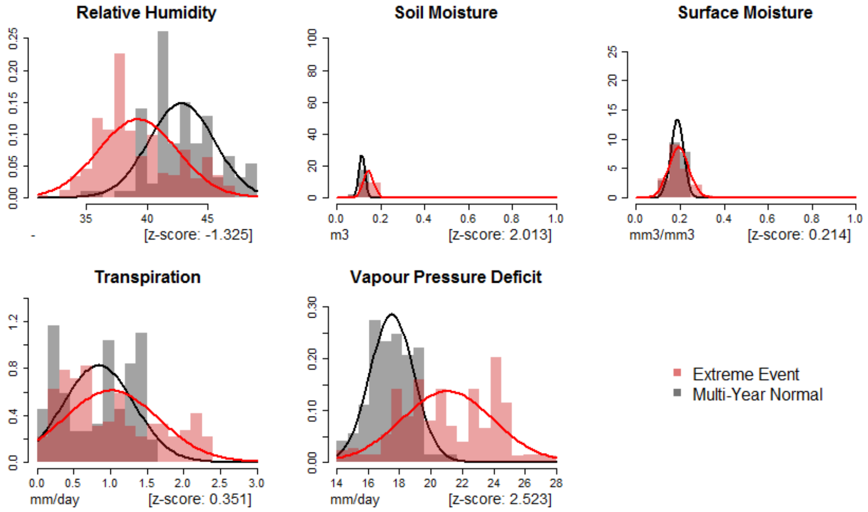
- Anomaly in GPP (depends on chlorophyll content), Net Ecosystem Exchange and Latent Energy

2. External characterisation

Unknown Event:

- Water use efficiency (on top) and soil moisture (below) show significant anomaly for this time step





3. Independent validation & regional expert feedback

Unknown Event:

- NDVI show high values in time period of detected anomaly (Figure 1)
- Refer to increase in GPP

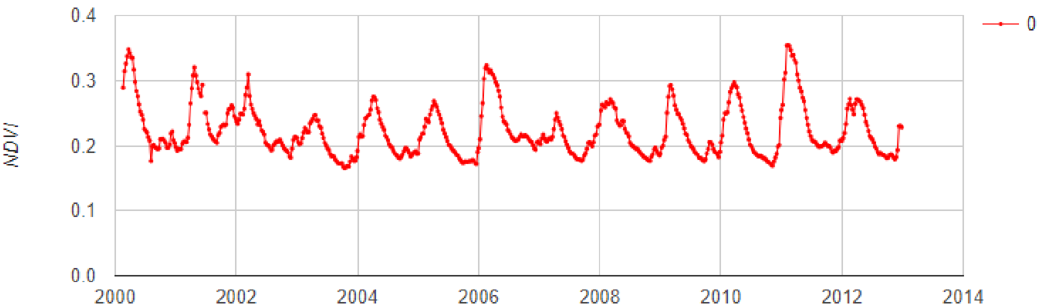


Figure 1. NDVI temporal profile of anomaly region.
(Source: Google Earth Engine)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

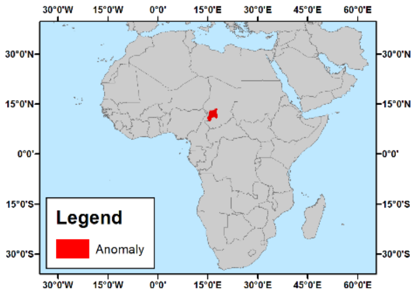
	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

References

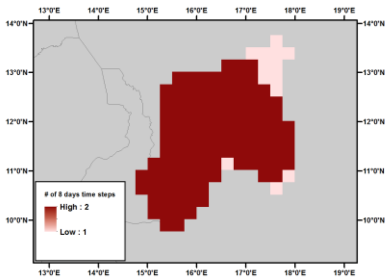
Event ID 64:

1. Attribution (internal)

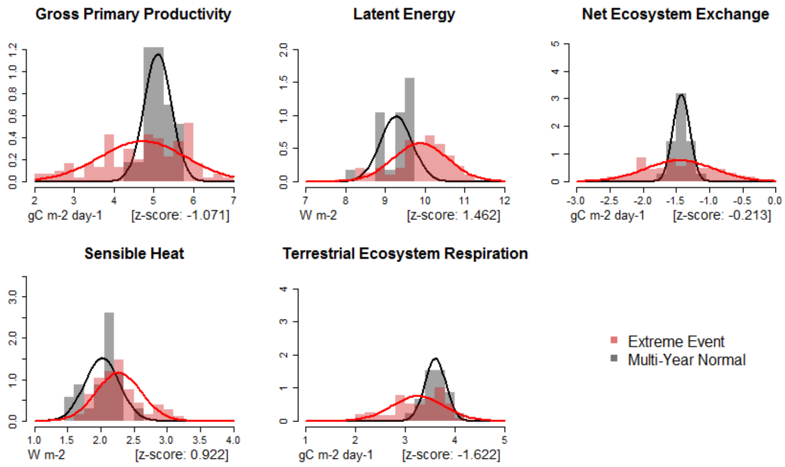
Type: Extreme event
Location: Chad
Area: 91385.1 km²
Time: 25.08.2011
Duration: 17.08.2011 – 25.08.2011



Extent of the event

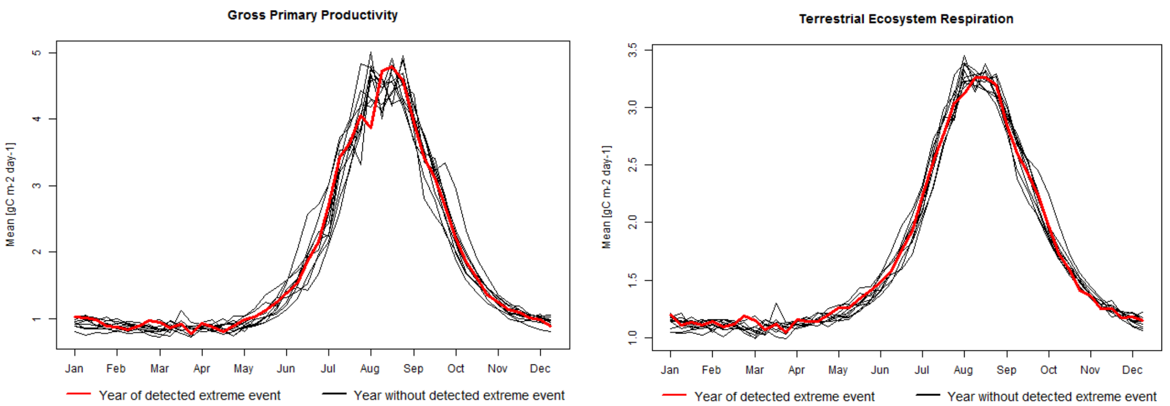


# of 8 day time steps for which the event was detected



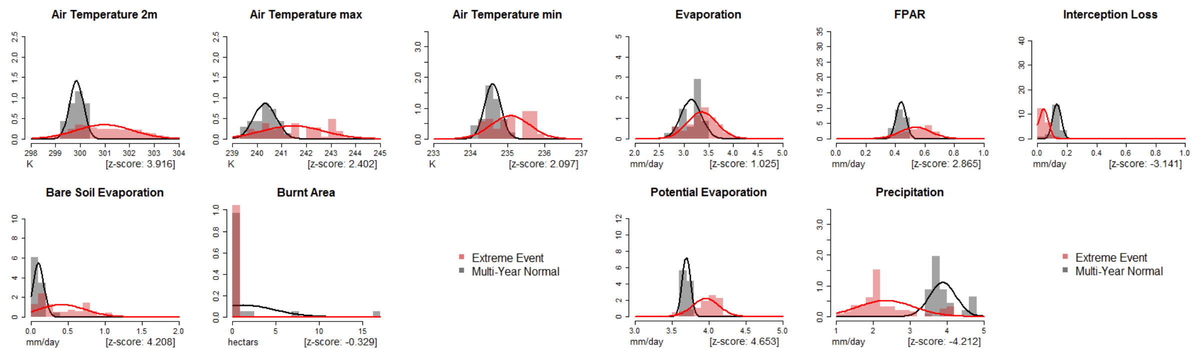
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



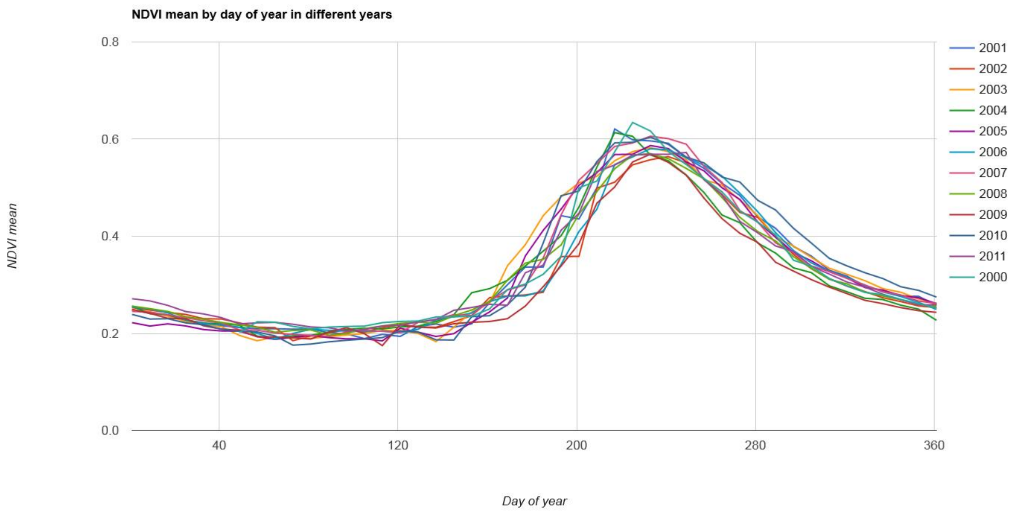
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Significantly lower values for both GPP and TER (figure), whereas LE showed higher values comparing the detected extreme event and the multi-year normal (figure)
  - Lower values of GPP and TER are visible for a short period of time in the time series plots respectively (Figure)

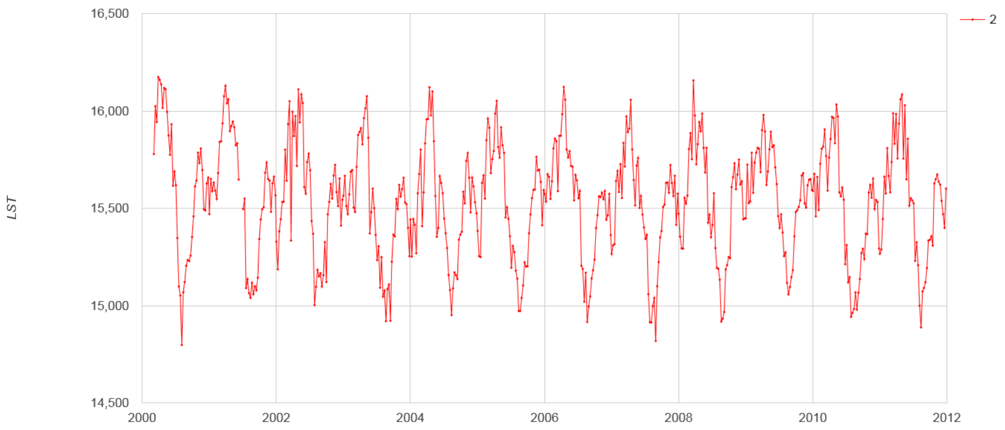
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - considerable higher values for temperature, evaporation, FPAR, bare soil evaporation and potential evaporation, whereas precipitation was significantly lower than what was expected for that period of time compared to the multi-year normal (figure)
  - The behaviour of FPAR and GPP are hereby in contrast to one another, which may can be linked to less cloud cover (higher FPAR) and at the same time higher temperatures (worse growing conditions for plants) --> still Latent Energy, which was one driver of the detection of this extreme event seems to be not really reasonable (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
    - MODIS NDVI shows not significant differences of the investigated time period compared to the other years and stays therefore in disagreement with the BACIndex respectively the MODIS analysis (figure)
    - However, LST may show some higher values but do not seem to be as high as proposed by the CABLAB data (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

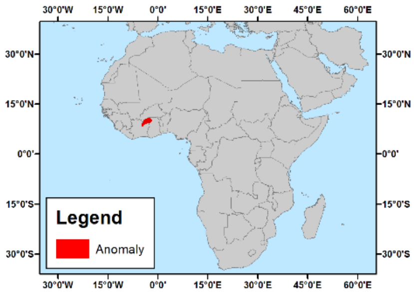
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

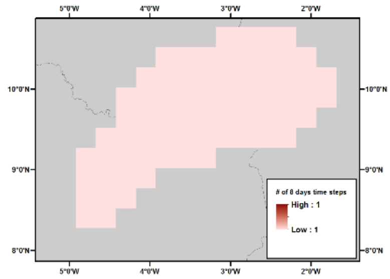
Event ID 65:

1. Attribution (internal)

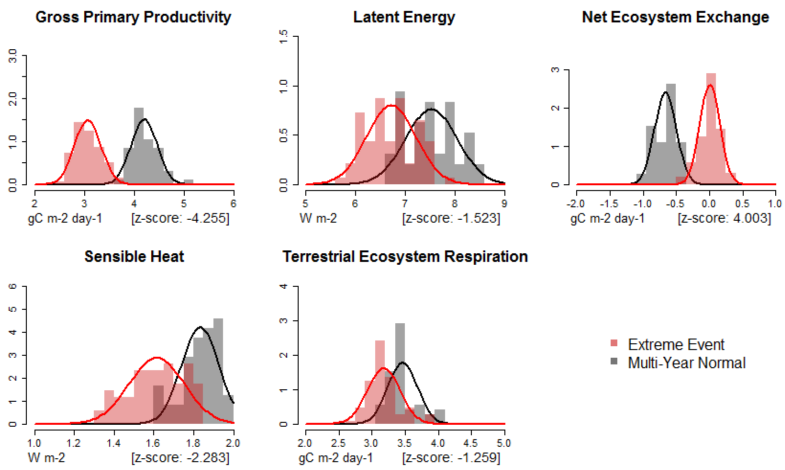
Type: Extreme event
Location: West Africa
Area: 52033.2 km²
Time: 17.08.2001
Duration: 17.08.2001 – 17.08.2001



Extent of the event

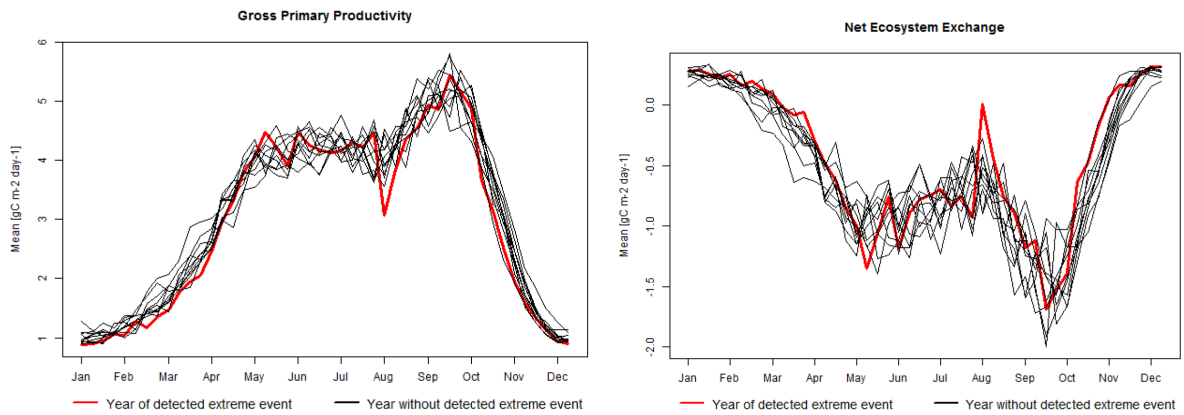


# of 8 day time steps for which the event was detected



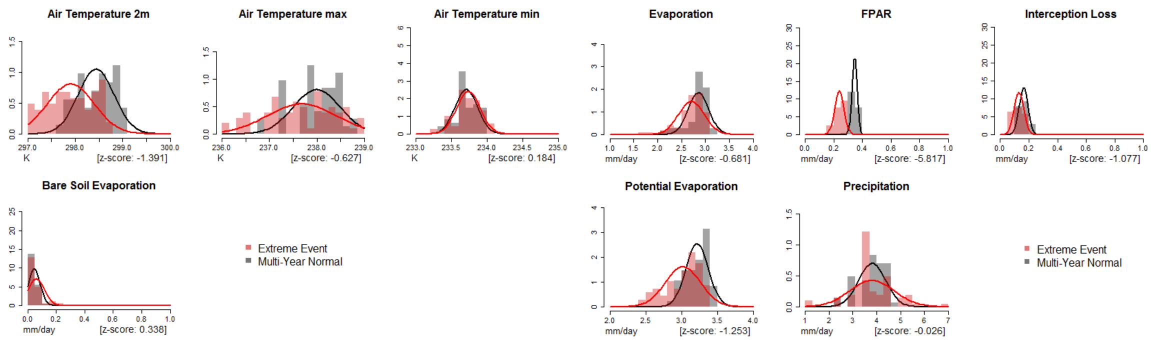
Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



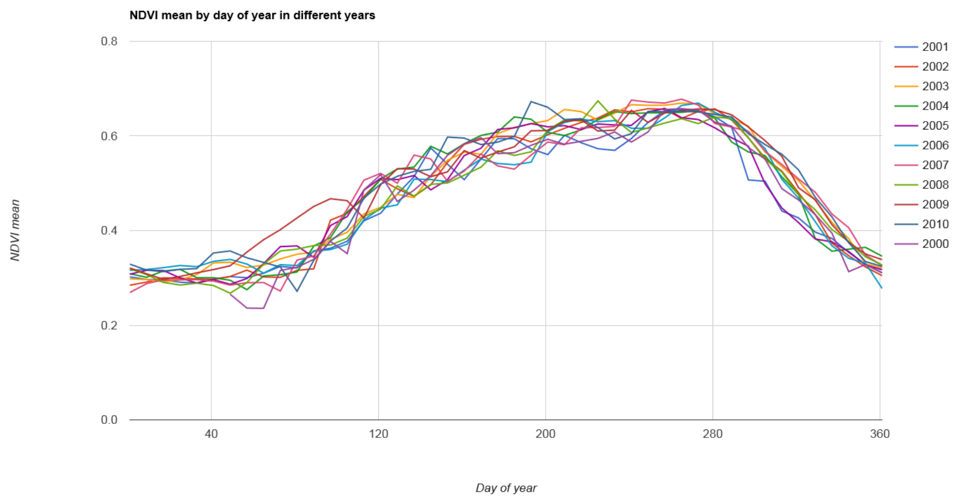
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - GPP, LE, SH and TER were significantlly lower compared to the multi-year normal, whereas NEE was considerably higher than the expected value (figure)
    - This is expected due to lower temperatures and/or lower precipitation than normal
  - Especially the low GPP is visible in the time series (figure), as well as the high NEE (figure)

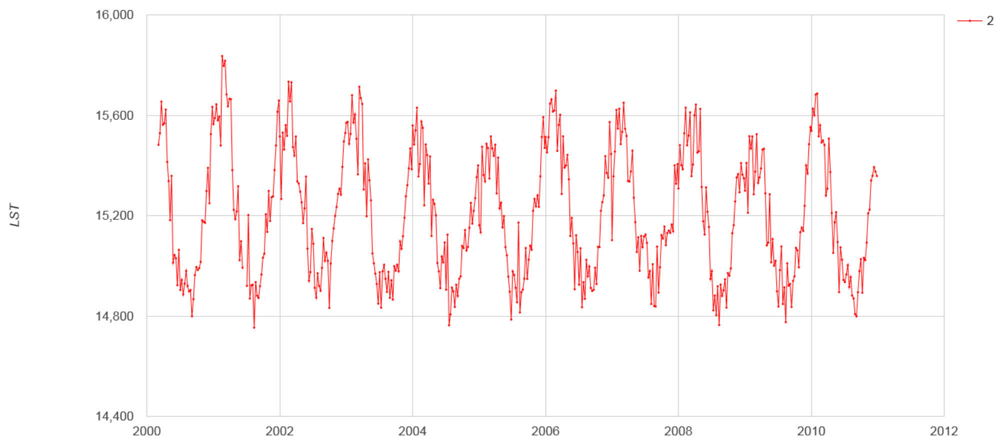
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - lower temperatures stay in good agreement with the findings of the internal characterization (figure)
    - in addition lower FPAR values underline the findings too, which are most likley caused by higher temperatures, because precipitation was very similar to the expected values (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values were considerably lower during the detected duration of the event (figure)
  - LST values of the detected time were very similar to those of the other years (figure)

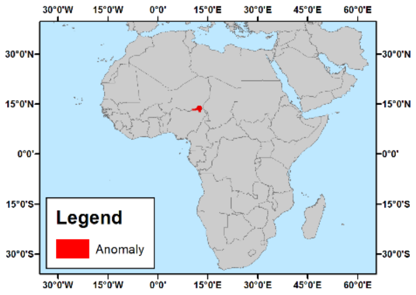
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision			**X**

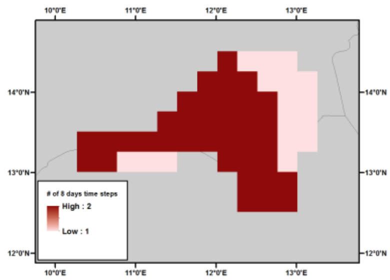
Event ID 66:

1. Attribution (internal)

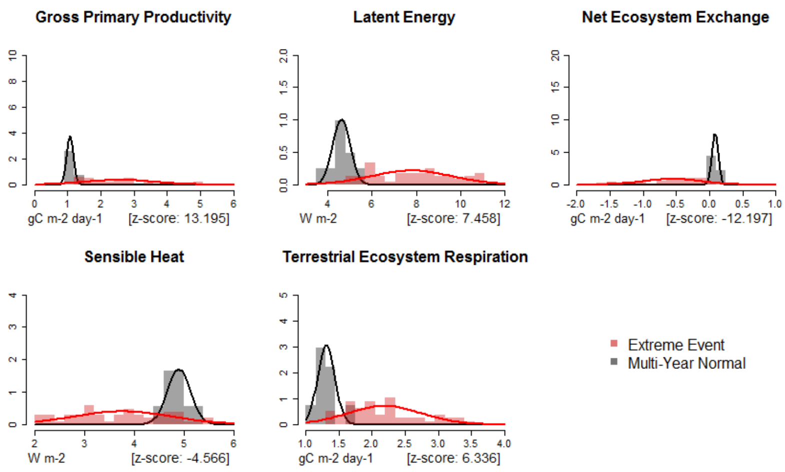
Type: Extreme event
Location: Central Africa
Area: 38689.9 km²
Time: 02.09.2006
Duration: 25.08.2006 – 02.09.2006



Extent of the event

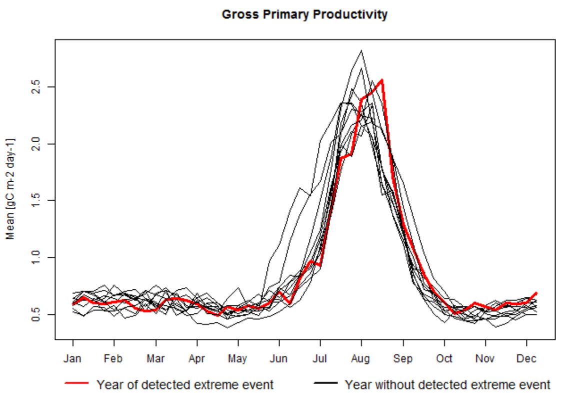


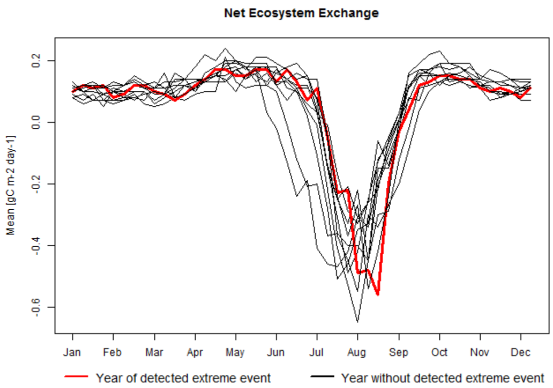
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

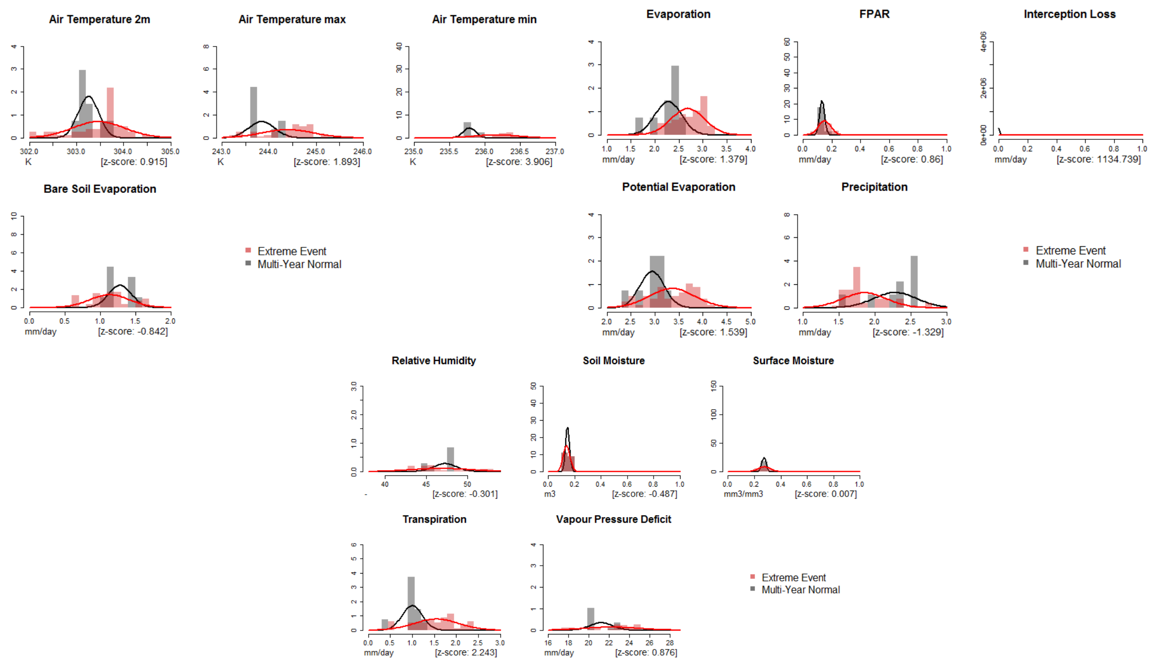
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





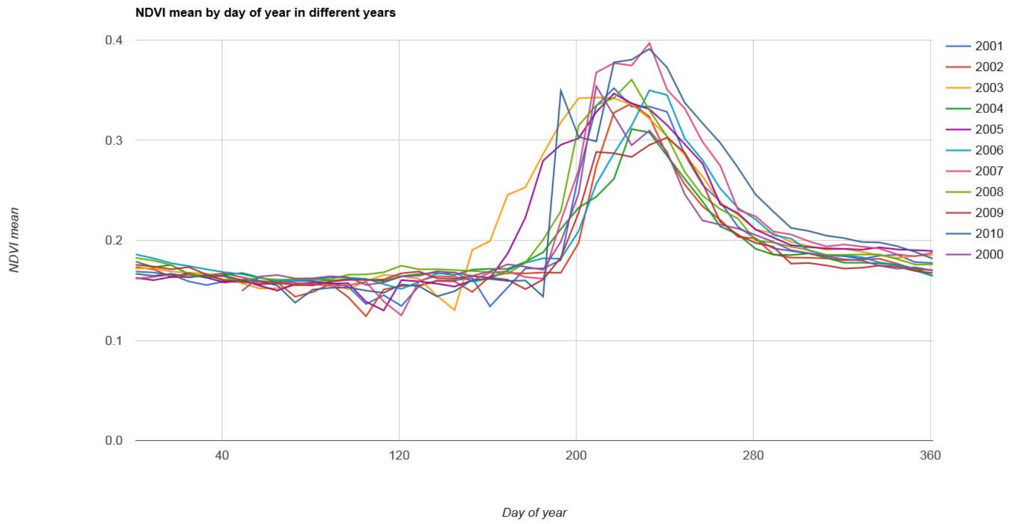
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - All of the input parameters were significantly different compared to the multi-year normal with:
    - Lower sensible heat and net ecosystem exchange
    - Higher GPP, LE and TER
  - Therefore lower temperatures are expected and/or higher precipitation during that period of time (figure)

2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - in contrast to the findings of the internal characterization temperatures were higher and precipitation considerably lower, which does not show a good agreement with the findings of the CABLAB data (figure)
  - also a flooding is not reasonable, since soil and surface moisture were very similar to the multi-year normal

3. Independent validation & regional expert feedback



- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI and LST were not different to those of the other years resulting in similar values for the detect time period (figure)

Remote sensing expert based	**1**	**2**	**3**

evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

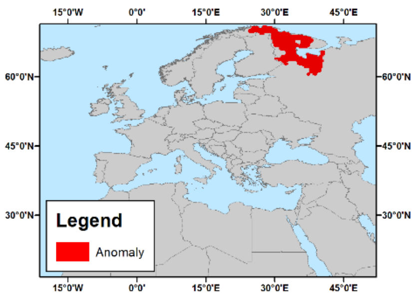
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	**2**	**3**
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision	**X**		

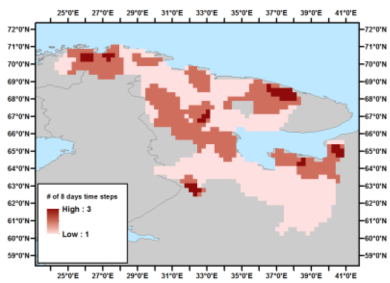
Event ID 67:

1. Attribution (internal)

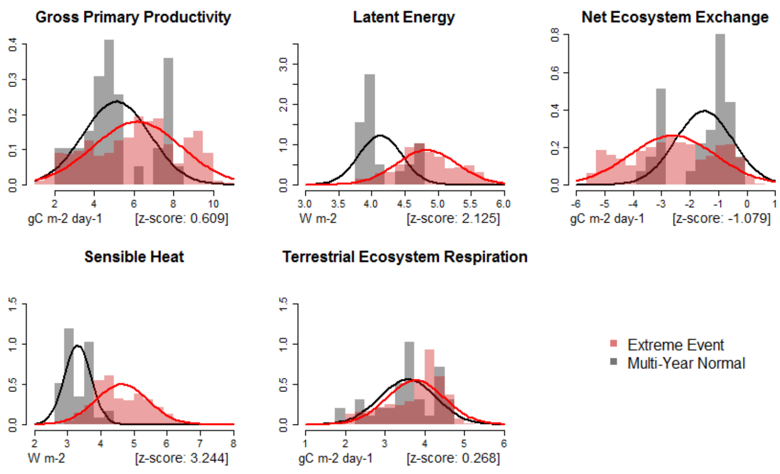
Type: Extreme event
Location: Scandinavia / Russia
Area: 318839.5 km²
Time: 23.07.2004
Duration: 23.07.2004 – 08.08.2004



Extent of the event

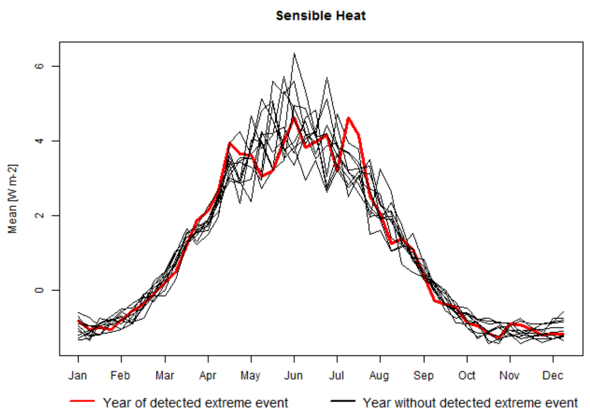


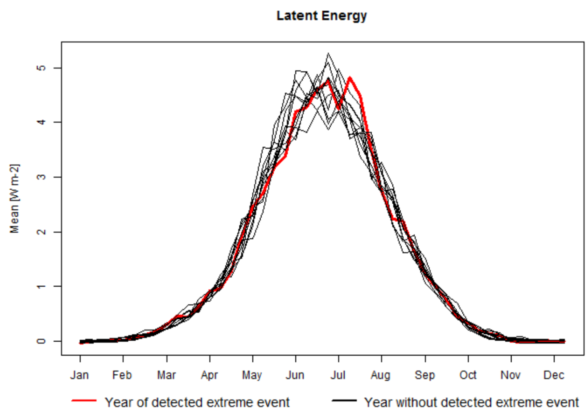
\# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

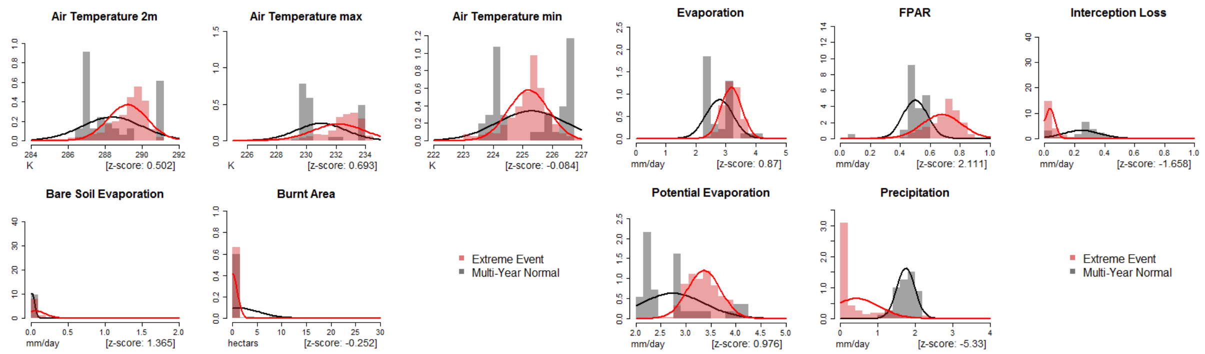
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





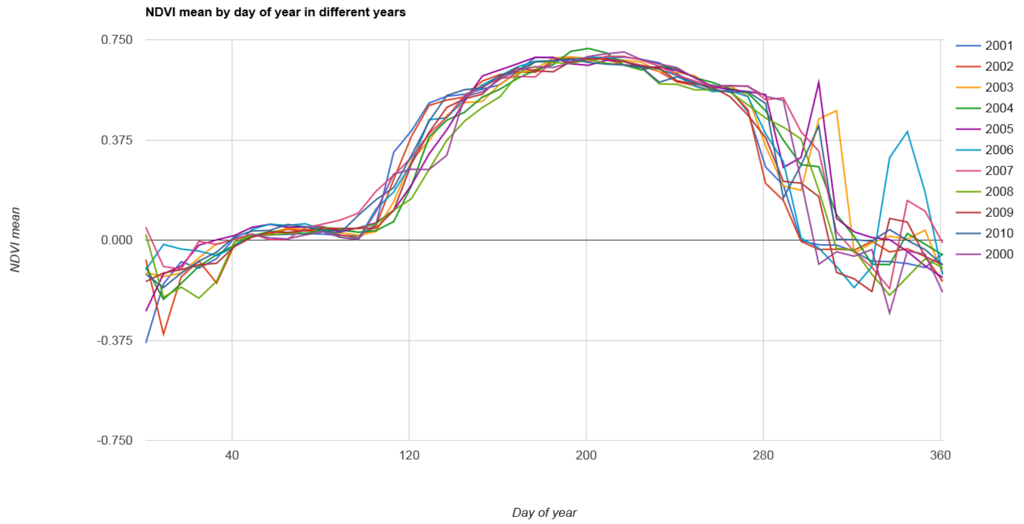
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
    - Significantly higher values of Latent Energy and Sensible Heat (figure), whereas Net Ecosystem Exchange showed considerably lower values for the detected period of time (figure)
    - These trends for Sensible Heat and Latent Energy are also visible in the time series plots indicating an abnormal behaviour during the event (figure)
    - Since the energy fluxes or heat are more present in both biosphere and atmosphere at the same time it can be expected that it was caused by either higher temperatures and/or more precipitation (figure)

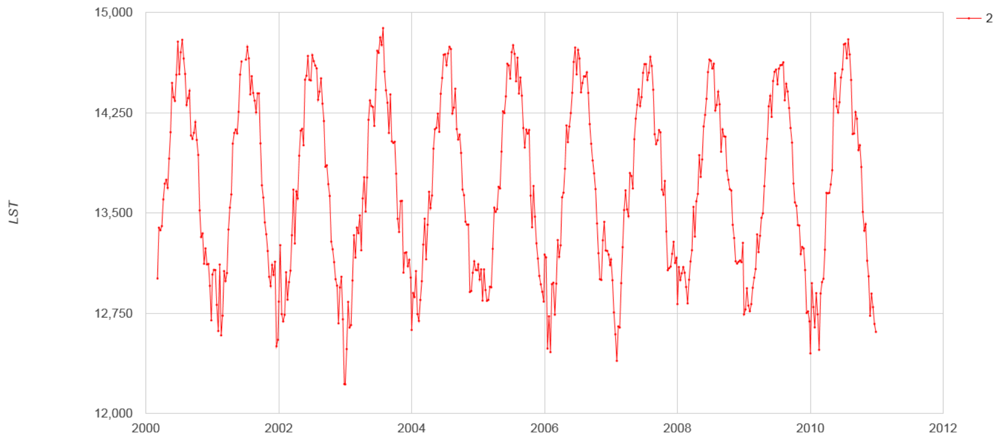
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - higher values for FPAR and at the same time lower values of precipitation and interception loss (figure)
  - the later ones can be linked to a stable GPP (figure)
  - Higher FPAR indicate more sunlight and therefore more energy in both, biosphere and atmosphere
  - Thus the extreme event is caused by unusual higher amounts of sunlight and less precipitation at the same time causing more energy respectively more sensible heat (even though air temperatures stayed similar)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI was lower compared to what was visible in GPP and FPAR coming from the CABLAB data (figure)
  - MODIS LST did not show any significant differences in the detected time period when compared to other years (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

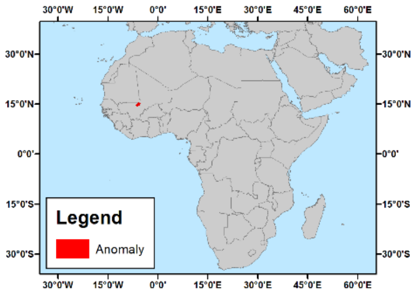
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

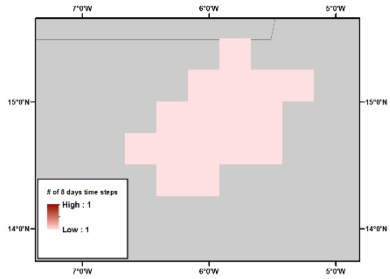
Event ID 68:

1. Attribution (internal)

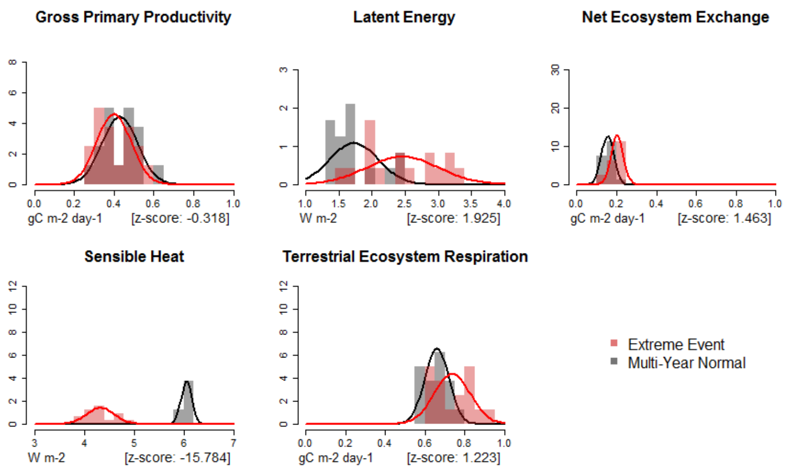
Type: Extreme event
Location: Mali
Area: 11838.6 km²
Time: 02.03.2005
Duration: 02.03.2005 – 02.03.2005



Extent of the event

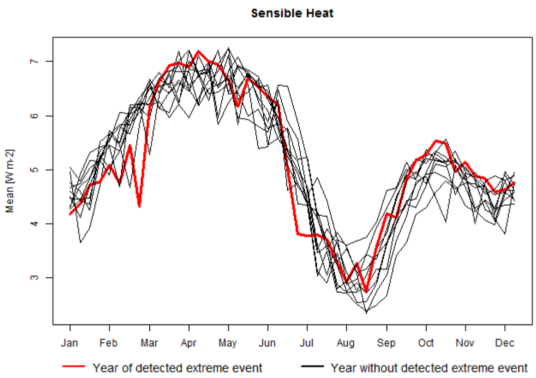


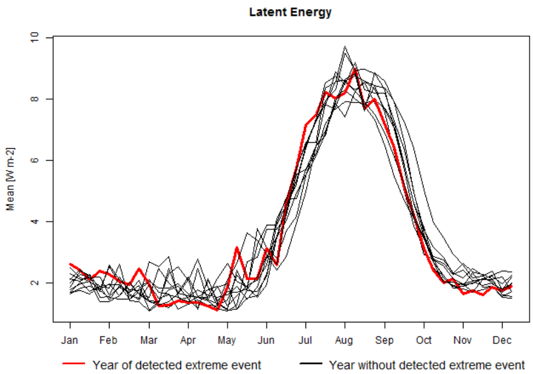
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

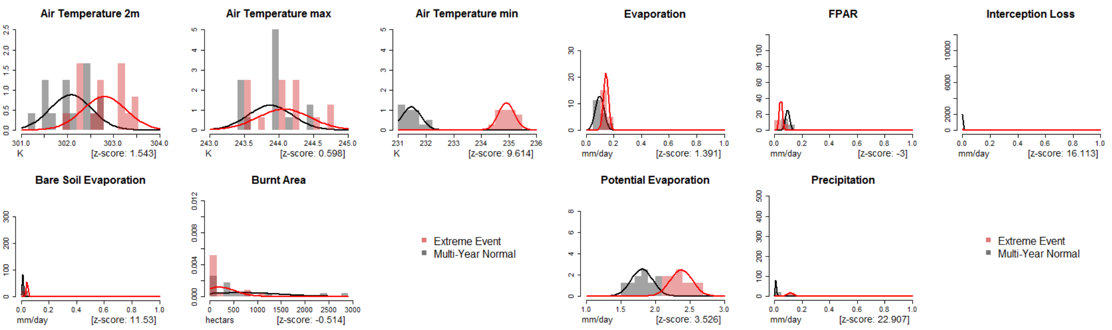
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





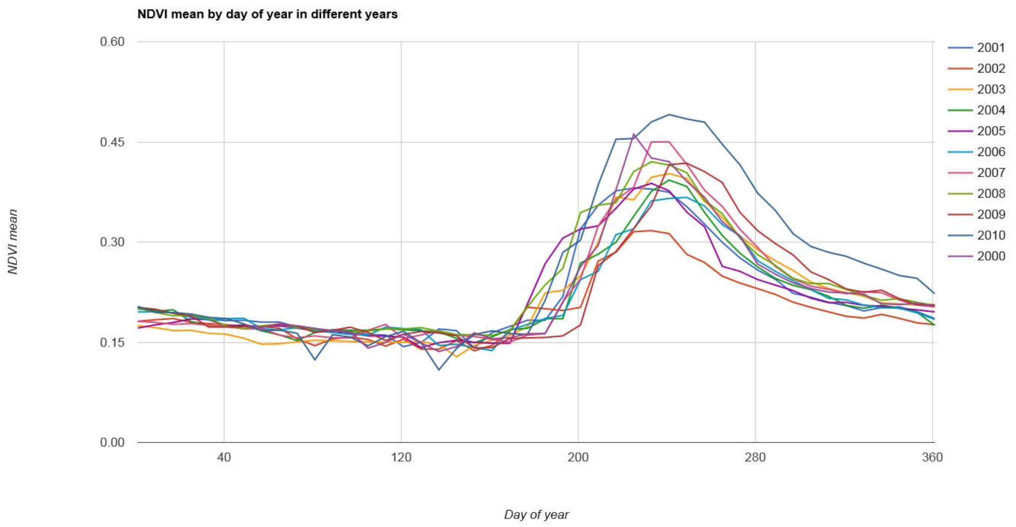
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Higher values for the variables Latent Energy, Net Ecosystem Exchange and Terrestrial Ecosystem Respiration (Figure)
    - This means that the vegetation or ecosystem caused a release of Carbon (higher Net Ecosystem Exchange), with more activity coming from the terrestrial vegetation
  - At the same time values of the Sensible Heat were considerably lower than the ones of the multi-year normal (figure)
    - The reason for that could have been lower temperatures

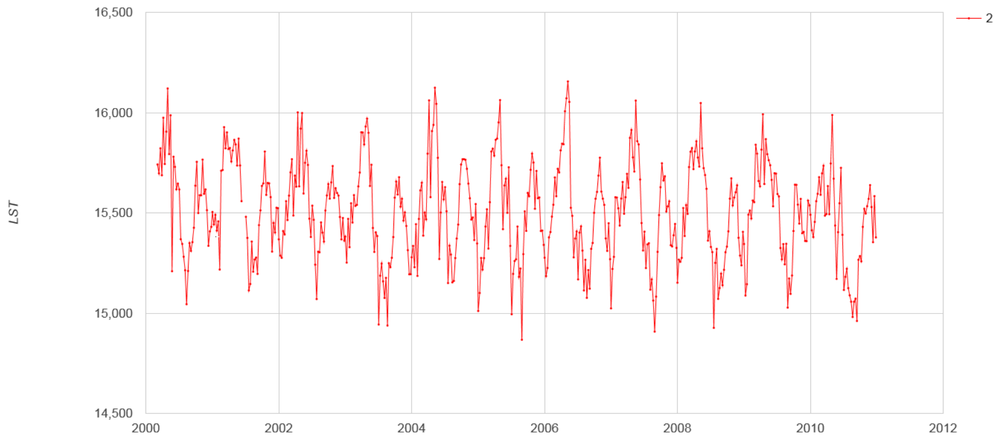
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - considerably higher temperatures with show a disagreement to the findings of the internal characterization (figure)
  - also evaporation, bare soil evaporation and potential evaporation are significantly higher than the expected values, whereas FPAR show lower values (figure)
  - One reason for this otherwise abnormal behaviour of the variables could be the influence of the higher precipitation causing lower sensible heat by higher temperatures and lower photosynthetic activity (caused by clouds?)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - The NDVI values were not considerable different to those of the other years (figure)
  - LST indicated slightly higher values compared to the rest of the years

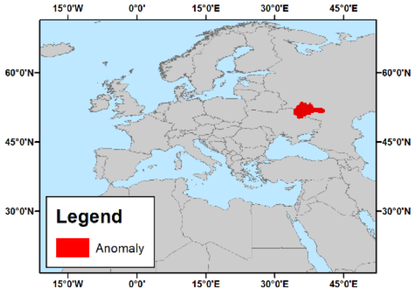
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	**X**		
Spatial precision	**X**		
Temporal precision		**X**	

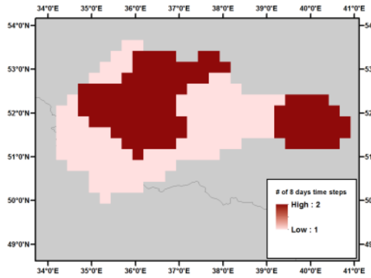
Event ID 69:

1. Attribution (internal)

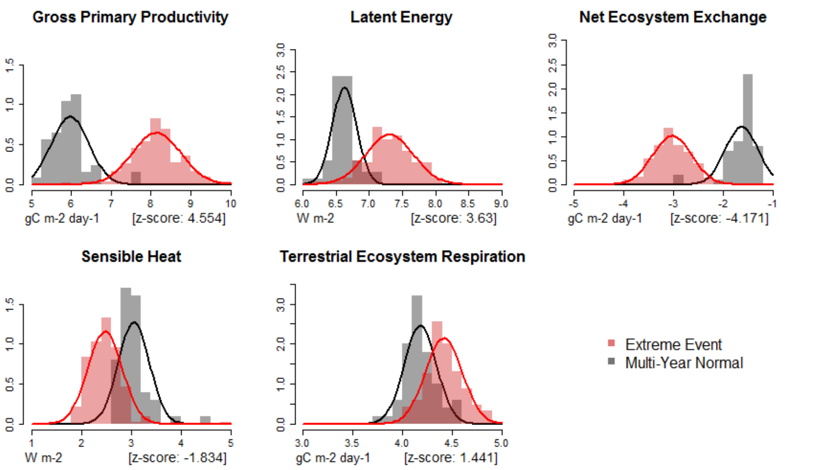
Type: Extreme event
Location: Russia
Area: 101880.9 km²
Time: 30.06.2005
Duration: 22.06.2005 – 30.06.2005



Extent of the event

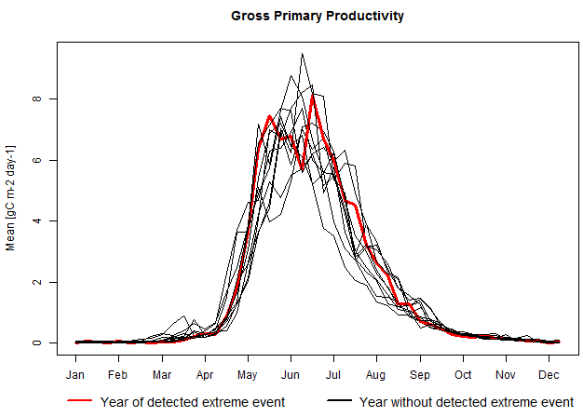


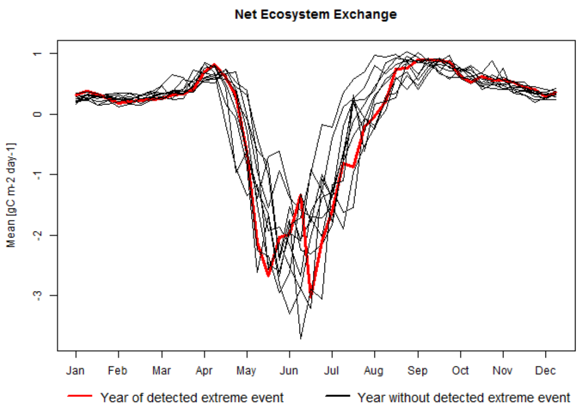
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

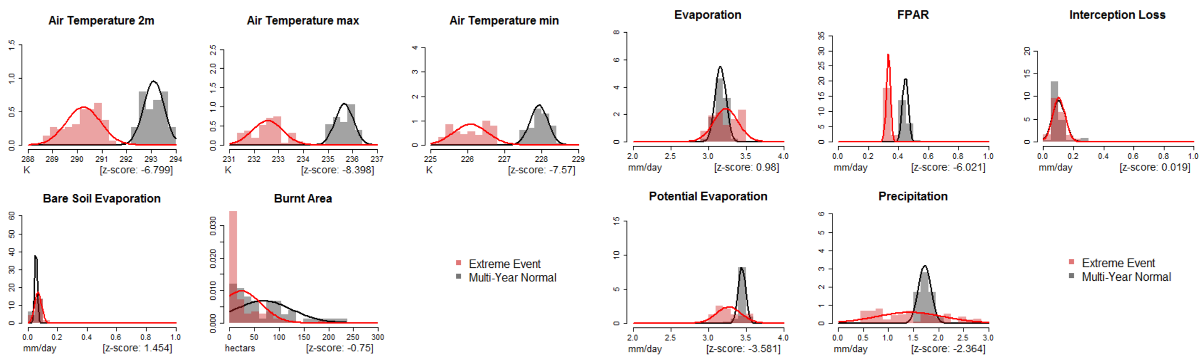
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





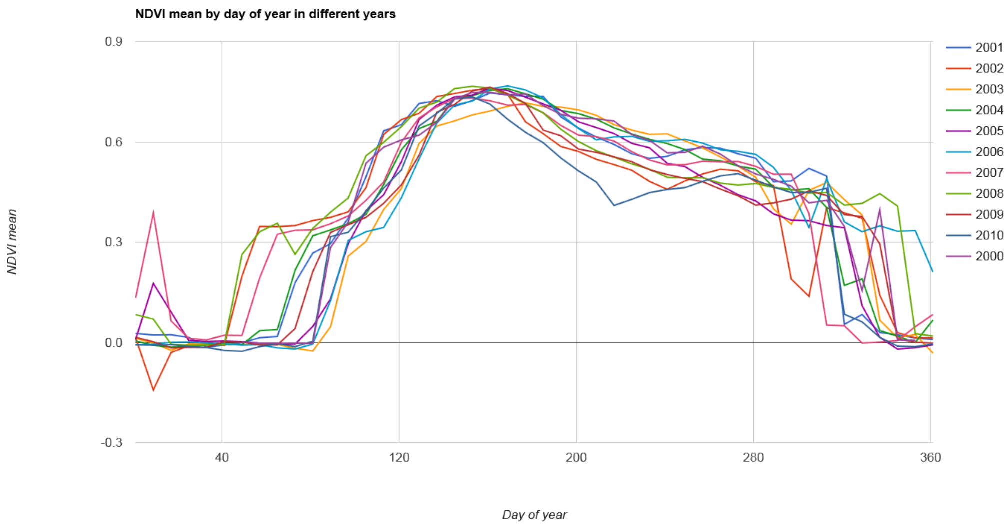
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Higher GPP, LH and TER values for the detected time period compared to the multi-year normal (figure)
  - At the same time lower values of NEE and SH were detected (figure)
  - This behaviour was also visible of the time series of GPP and NEE and might be caused by lower temperatures and/or more precipitation during the detected time (figure) resulting in better climate conditions for plants to grow

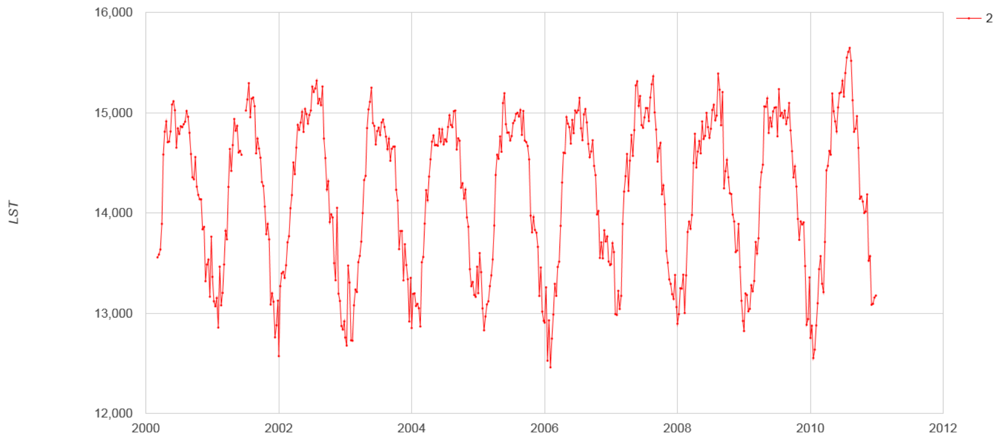
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - As already described in the internal characterization temperatures were significantly lower than the multi-year normal causing better growing conditions in the otherwise hot summer (figure)
  - At the same time precipitation were lower, but not as focused and more frequent supporting the mentioned climatic conditions (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI values were not as high as expected (figure)
  - MODIS LST values however showed significantly lower values during the extreme event showing a good agreement to the detected event (figure)

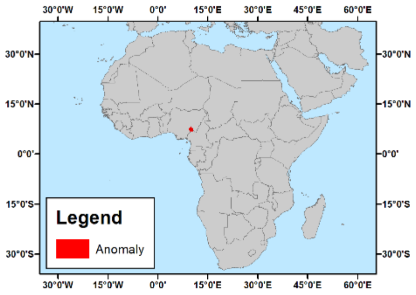
Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision		**X**	
Temporal precision			**X**

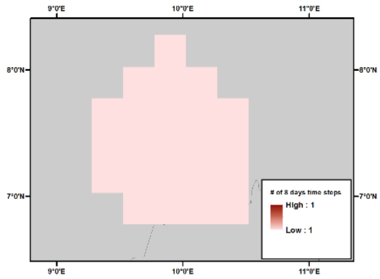
Event ID 70:

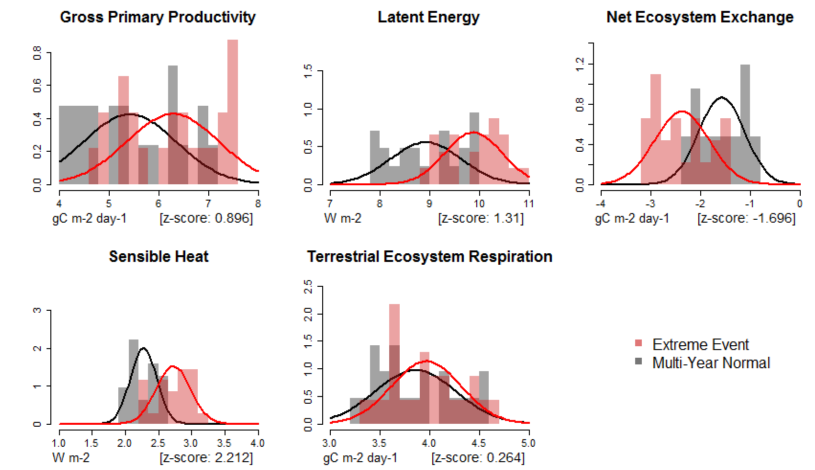
1. Attribution (internal)

Type: Extreme event
Location: Nigeria
Area: 17446.3 km²
Time: 12.10.2010
Duration: 12.10.2010 – 12.10.2010



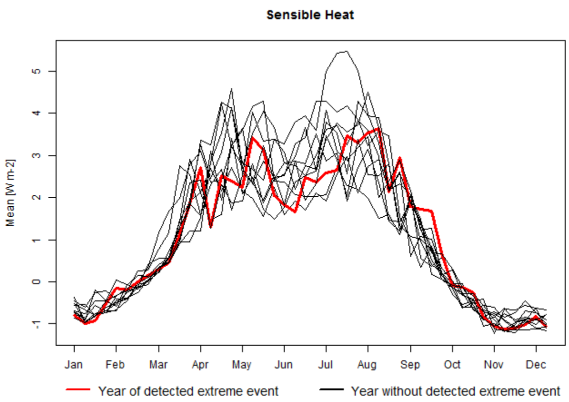
Extent of the event

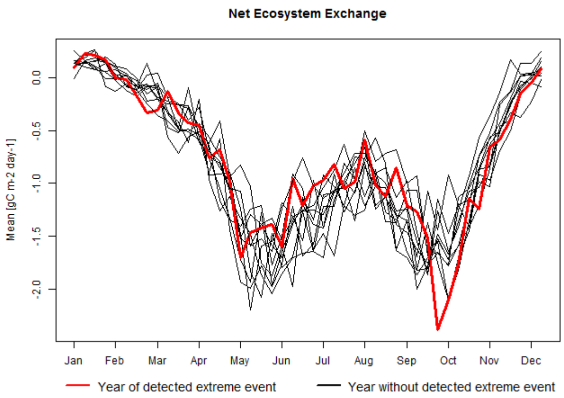

# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

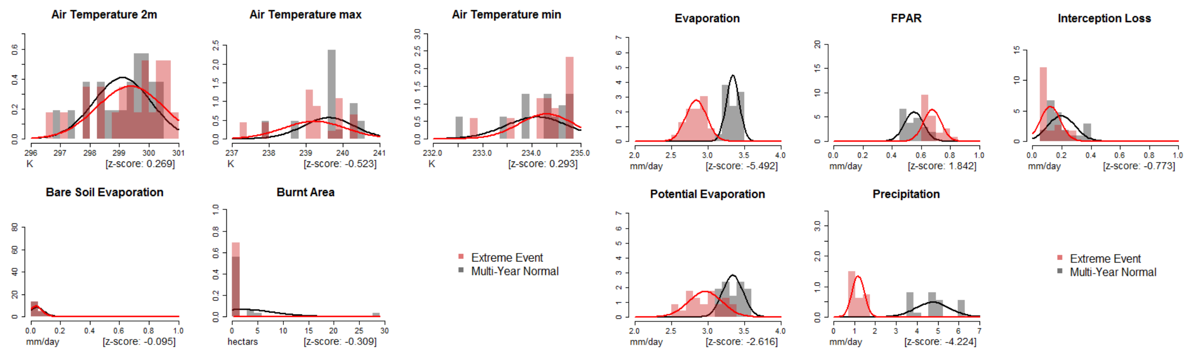
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





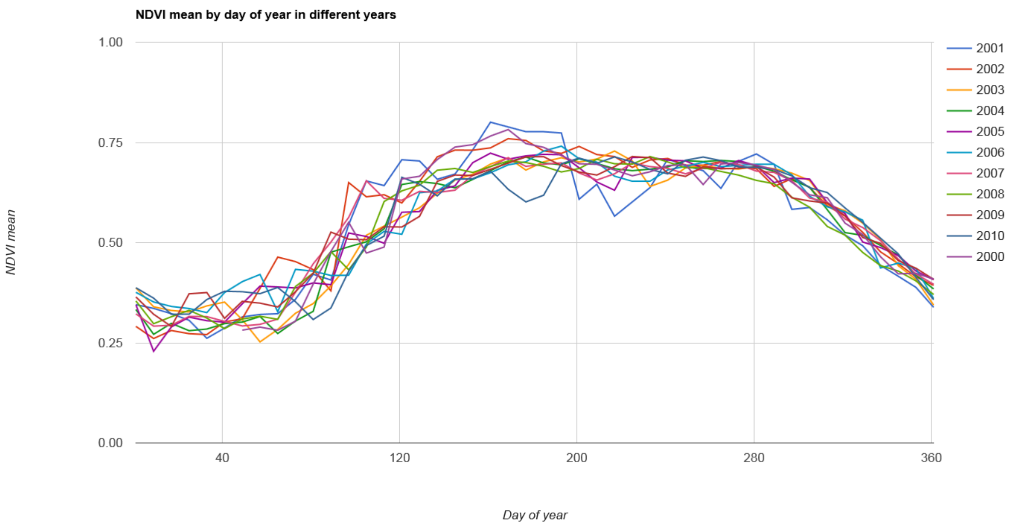
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - Higher values for Sensible Heat and Latent Energy compared to the multi-year normal (figure)
  - Lower values for the Net Ecosystem Exchange (figure)
    - These trends for sensible heat and net ecosystem exchange were also clearly visible in the time series for both parameters (figure)
  - So more energy was saved or stored in the terrestrial ecosystem by higher sensible heat --> better growing conditions due to higher temperatures?

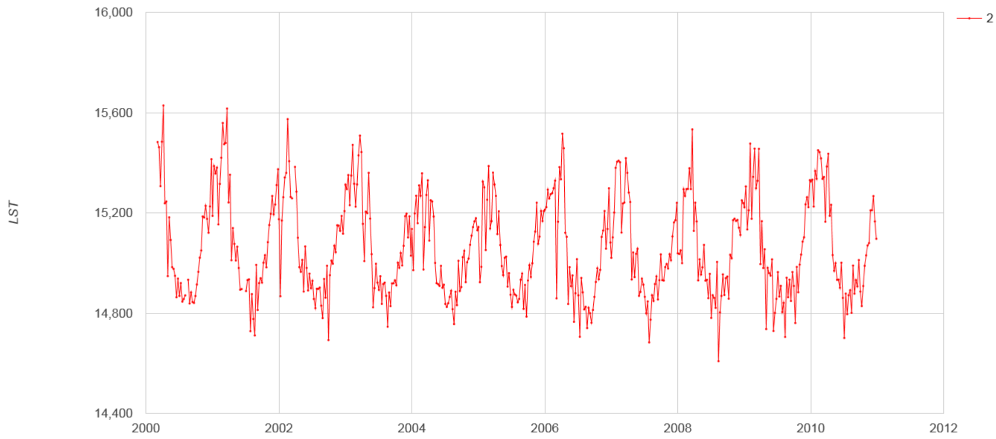
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
    - the initial explanation in the internal characterization has to be withdrawn, since temperatures were stable or as expected for that period in the year (figure)
    - the missing precipitation can been seen as the root for this detection, since sensible heat is linked to the amount of precipitation or humidity in the air, which was lower due to missing precipitation (figure)
    - therefore FPAR was higher, since the cloud coverage was not as high --> missing rain (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI showed slightly lower values for the detected period of time and spatial extent (figure), whereas LST behaviour was not different to the other years (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

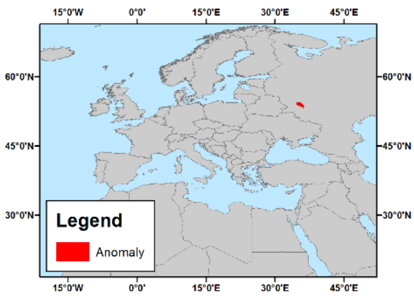
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

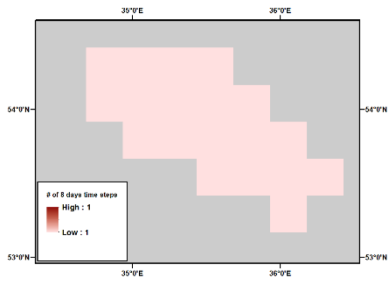
Event ID 71:

1. Attribution (internal)

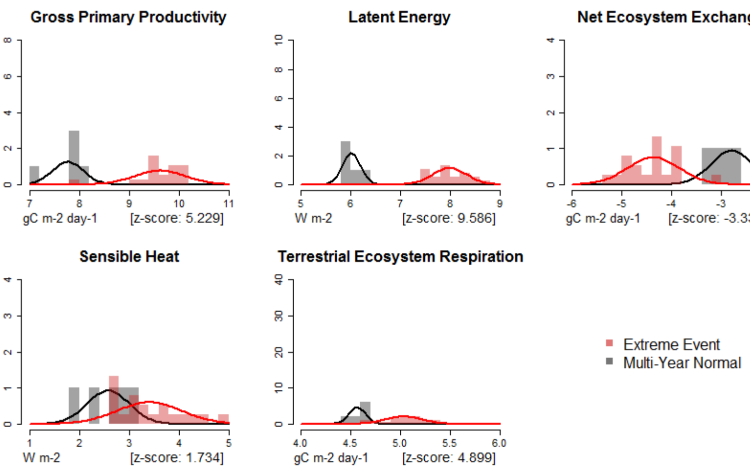
Type: Extreme event
Location: Russia
Area: 8640.0 km²
Time: 06.06.2011
Duration: 06.06.2011 – 06.06.2011



Extent of the event

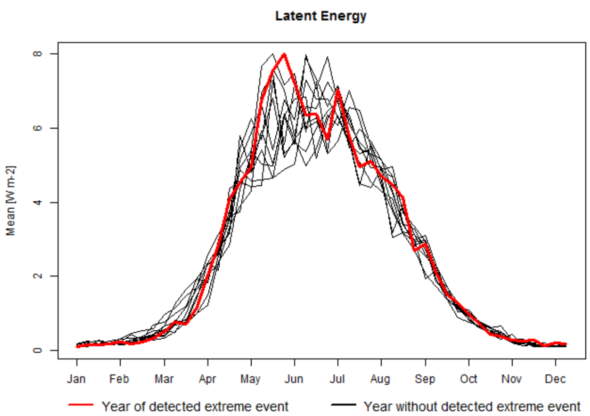


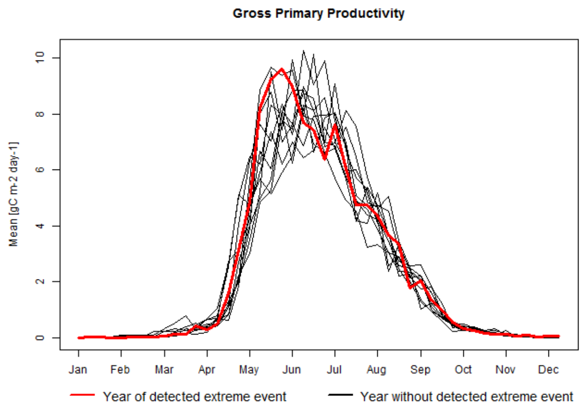
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

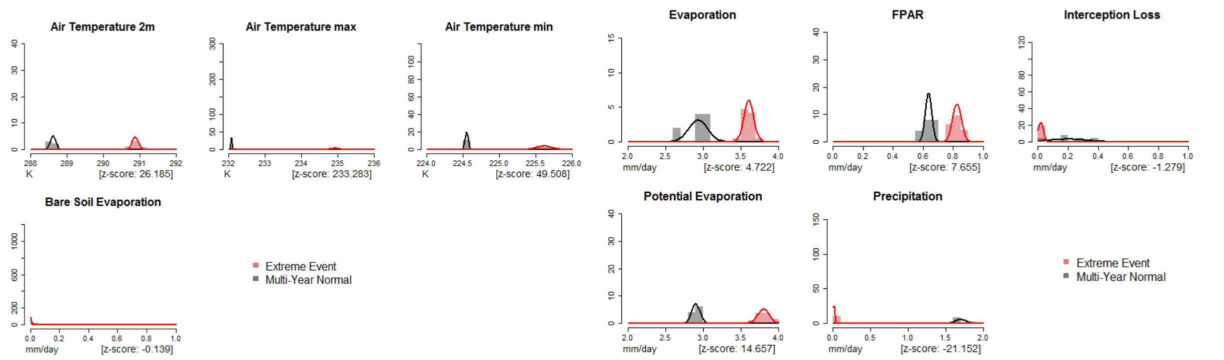
Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





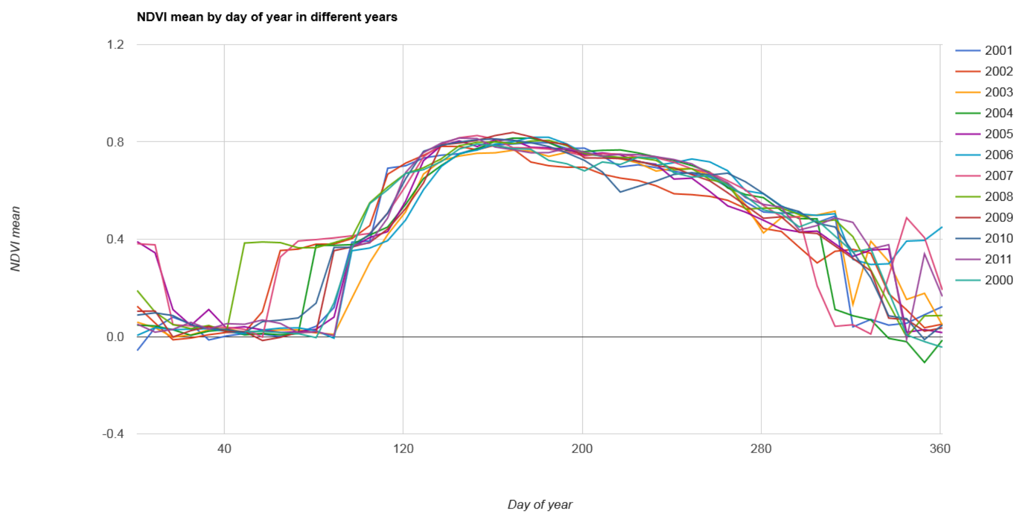
- Internal characterization based on the used CABLAB data used for calculating the BACIndex showed (Figure):
  - GPP, LE, SH and TER were all significantly higher compared to the multi-year normal (figure)
  - NEE showed lower values when compared (figure)
  - The major differences for LE and GPP were also visible in the respective time series plot (figure)
  - This could be explained by both: more moderate temperatures and more precipitation during the detected event

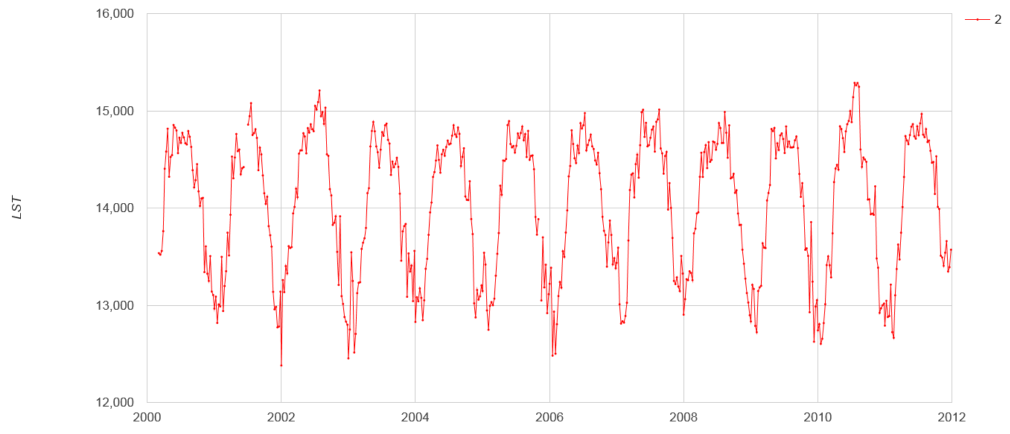
2. External characterisation



- external characterization based on the additional CABLAB data not used for calculating the BACIndex showed:
  - Temperatures were a lot higher than the excepted values , whereas FPAR and Evaporation showed significantly higher values (figure)
  - At the same time precipitation was considerably lower than the multi-year normal (figure)

3. Independent validation & regional expert feedback





- MODIS NDVI and LST analysis showed for the independent analysis that:
  - NDVI did not show any deviations from the normal behaviour (figure)
  - For the MODIS LST there was a very high peak visible supporting the findings of very hot temperatures (figure)

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

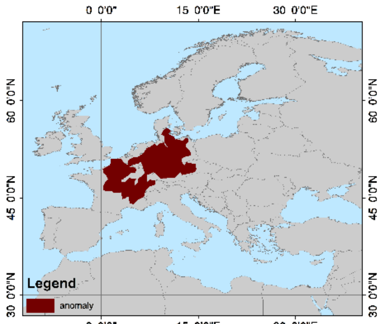
	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

Event ID 72:

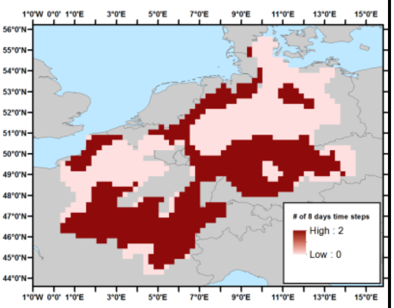
1. Attribution (internal)

Type: Extreme event
Location: central Europe
Area: 562397.9 km²

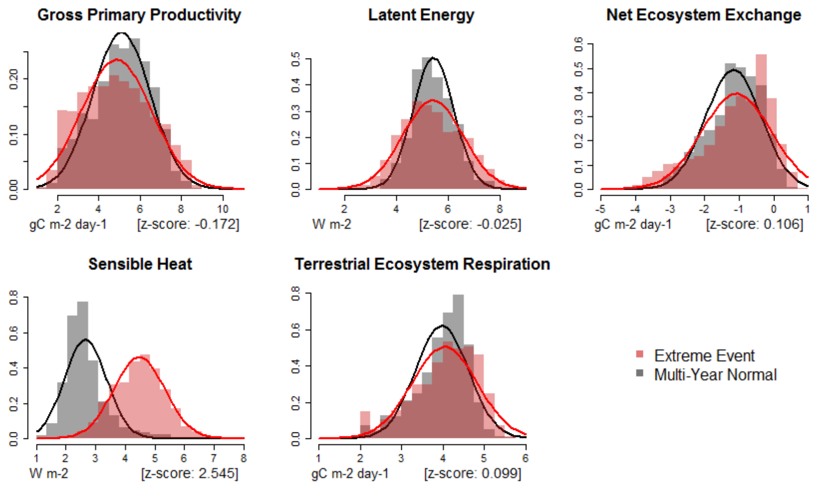
Time: 2003/08/09
Duration: 2003/08/09– 2003/17/08



Extent of the event

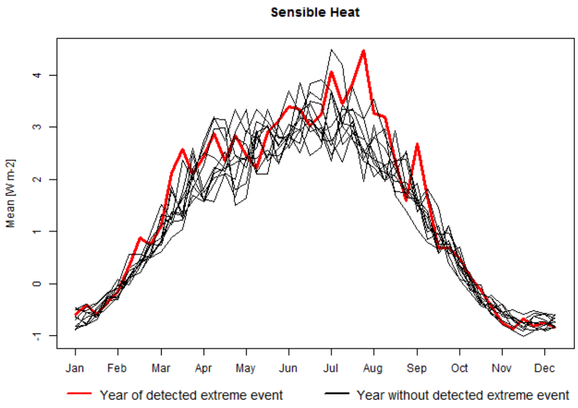


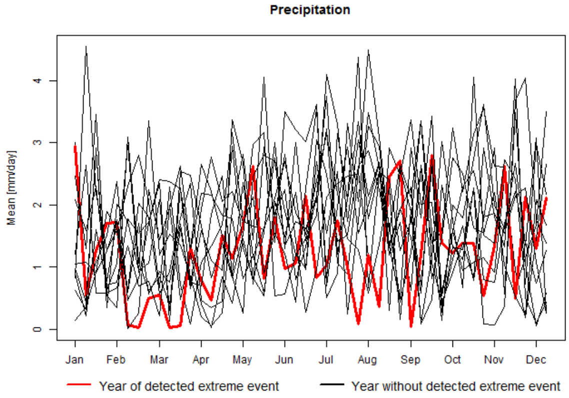
# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.





2. External characterisation

European heat wave

- Europe experienced probably the hottest summer since 1500 AD in 2003 (Stott et al. 2004). The heat wave commenced in mud-June and continued until mid-August and affected large parts over central and southern Europe (De Bono et al. 2004).
- Temperatures were up to 30% higher than the long-term average over large parts of Europe (De Bono et al. 2004; Stott et al. 2004). Figure 1 shows the deviation in 2003 from the long-term average.
- A large precipitation deficit combined with early vegetation green-up and extreme radiative anomalies in the month before contributed to an early and rapid loss of soil moisture. This is also supported by the internal attribution that revealed very low precipitation in the respective period compared to periods without anomalies.
- Low soil moisture was responsible for reduced latent heat fluxes and high sensible heat fluxes (Fischer et al. 2007). This is also supported by the internal attribution that reveals abnormal sensible heat fluxes for the 2003-event.
- Human activities have at least doubled the risk of observed temperature anomalies (Stott et al. 2004)
- Social, ecological and economic losses were devastating and include the following (De Bono et al. 2004):
    - Heat related health incidences peaked
    - Estimated 30,000 – 70,000 (also refer to Robine et al. 2008) heat related death in Europe: Deadliest natural disaster of the past 50 years.
    - Agricultural losses: cereal yields historic low; in Europe 10% less biomass was harvested than in the 2002
    - Livestock sector: Suffered extremely in the following winter due to fodder deficits of 30% and 60% in Germany and France (COGECA 2003)
    - Glacier melting: Loss of 5-10% of total ice volume on European glaciers
    - Forest fires: More than 25 000 fires were recorded in Portugal, Spain, Italy, France, Austria, Finland, Denmark and Ireland. The estimation of forest areas destroyed reached 647 069 hectares.
    - Total economic losses amount to 13 billion euros

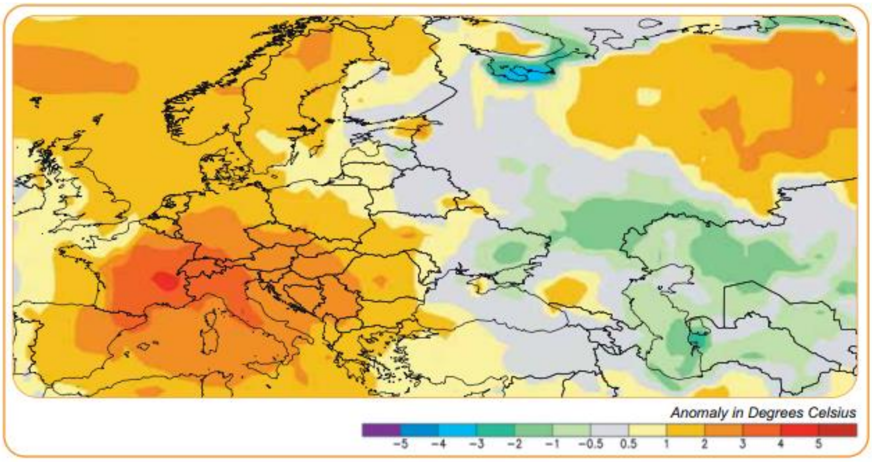


Figure 1: Temperature deviations from June to August 2003 compared to the base period 1988-2003 for the same month. Difference exceeds 4°C in several regions. The Figure is taken from de Bono (2004).

References

COGECA, C., 2003: Assessment of the impact of the heat wave and drought of the summer 2003 on agriculture and forestry. *Comm. Agric. Organ. Eur. Union Gen. Comm. Agric. Coop. Eur. Union Bruss.*, **15**.

De Bono, A., P. Peduzzi, S. Kluser, and G. Giuliani, 2004: Impacts of Summer 2003 Heat Wave in Europe. https://archive-ouverte.unige.ch/unige:32255 (Accessed November 8, 2017)..

Fischer, E. M., S. I. Seneviratne, P. L. Vidale, D. Lüthi, and C. Schär, 2007: Soil moisture–atmosphere interactions during the 2003 European summer heat wave. *J. Clim.*, **20**, 5081–5099.

Robine, J.-M., S. L. K. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, J.-P. Michel, and F. R. Herrmann, 2008: Death toll exceeded 70,000 in Europe during the summer of 2003. *C. R. Biol.*, **331**, 171–178, doi:10.1016/j.crvi.2007.12.001.

Stott, P. A., D. A. Stone, and M. R. Allen, 2004: Human contribution to the European heatwave of 2003. *Nature*, **432**, 610–614.

3. Independent validation & regional expert feedback

Land use in the affected area

According to results from WP7 of the BACI-project (refer to report as of task 7.2), the detected event consists of 35% cropland, 35% forests and woodlands, 15% grazing lands, 2% sealed areas and 13% other land. The event covers mostly areas of high HANPP levels, indicating high land use intensity as is typical for central European croplands, particularly in northern France and Germany (Figure 1). Hence, the extreme event had major impacts on agricultural production in central Europe.

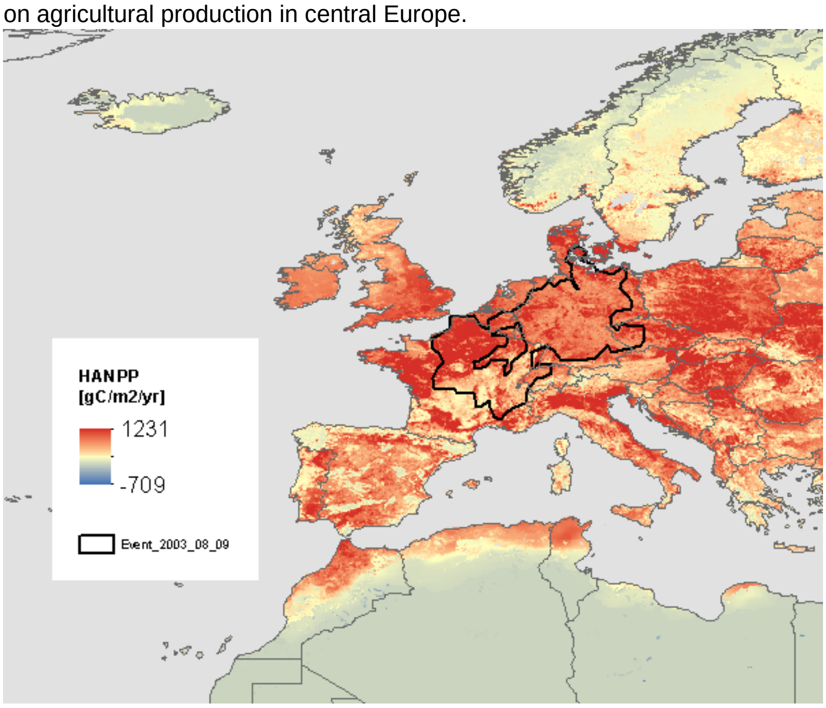


Figure 1: HANPP levels in gC/m2/yr witin the detected BACI extreme event (refer to task 7.2 of the BACI project)

Cereal yields 2003

Agricultural yields are directly related to precipitation and temperature distributions of the growing season. Hence, unsurprisingly the detected 2003 heat event is reflected in agricultural yields of the respective year. According to FAOSTAT (FAO 2017), cropland yields were historically in Germany and France, where particularly cereal yields were blow the long-term average (Figure 2).

Low yields were particularly related to an early start of the growing season and the related low soil moisture during spring 2003, as well as to an abnormally hot and dry summer-growing season (Loew et al. 2009).

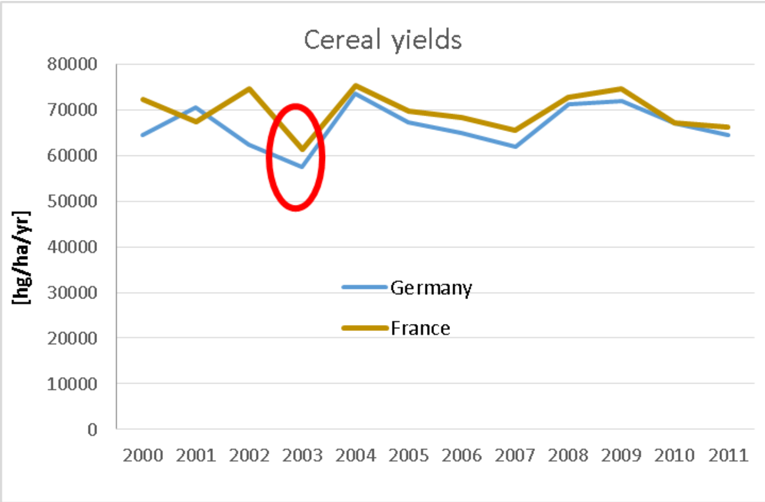


Figure 2: Cereal yields in Germany and France according to FAOSTAT data

Ecosystem productivity based on vegetation indices:

Compared to the previous year, 2003 experienced low

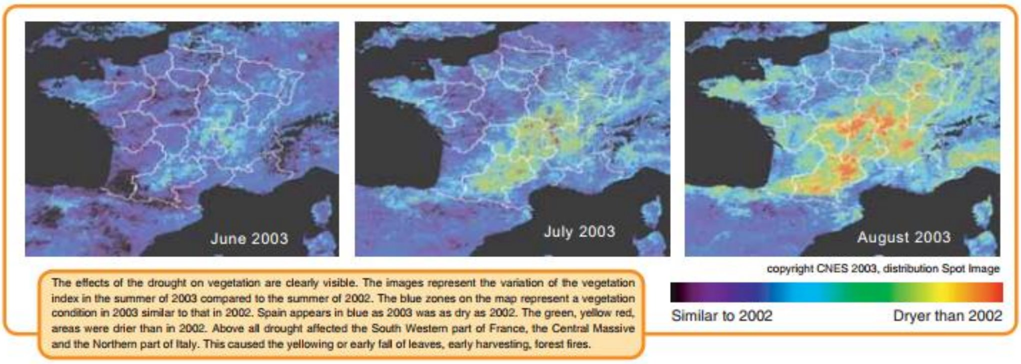


Figure 3: Variation of vegetation index from June to August from the 2002-level. The Figure is taken from de Bono (2004).

NDVI decomposition time-series based on MODIS NDVI data (https://modis.gsfc.nasa.gov/data/dataprod/mod13.php) for two selected areas in Germany and France support the findings above. Particularly the NDVI trend points to a low vegetation activity in the respective year.

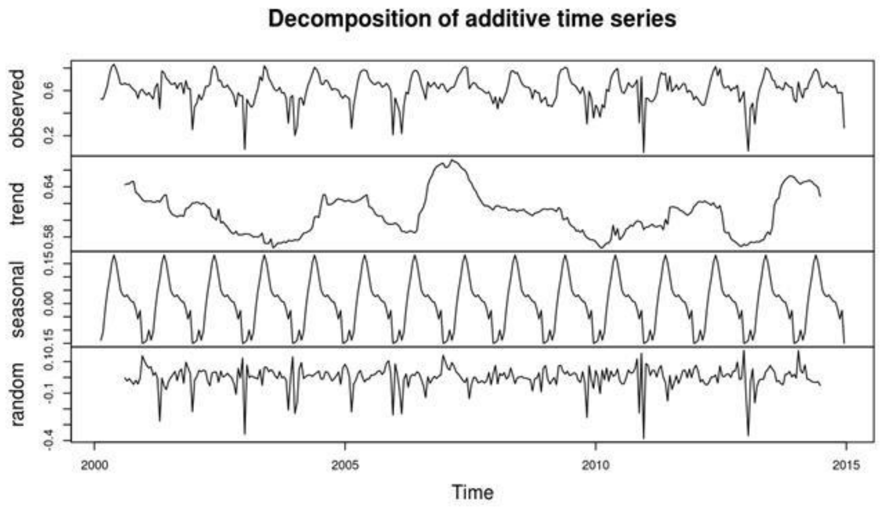


Figure 4: NDVI decomposition 2000-2015 for a selected area in Germany

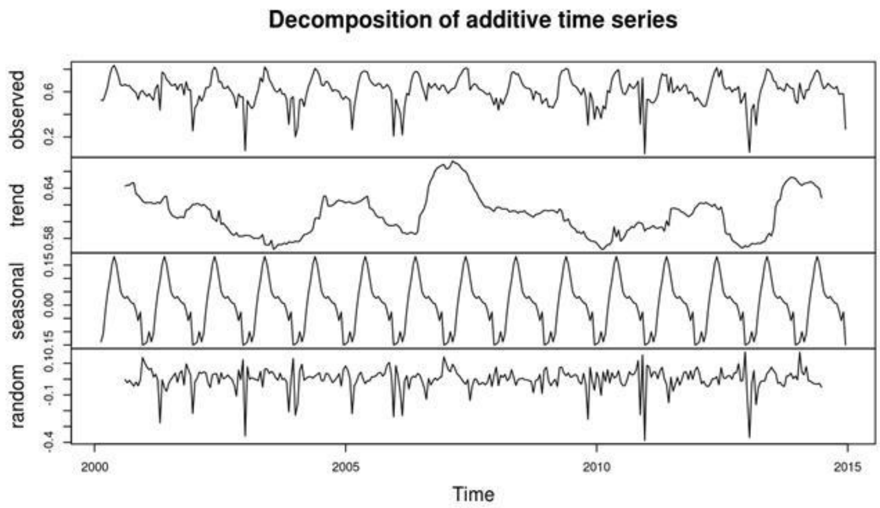


Figure 5: NDVI decomposition 2000-2015 for a selected area in France

References

1. De Bono, A., P. Peduzzi, S. Kluser, and G. Giuliani, 2004: Impacts of Summer 2003 Heat Wave in Europe. https://archive-ouverte.unige.ch/unige:32255 (Accessed November 8, 2017).
2. FAO, 2017: FAOSTAT: Statistical Database of the United Nations Food and Agricultural Organization. http://faostat.fao.org/,
3. Loew, A., T. Holmes, and R. de Jeu, 2009: The European heat wave 2003: Early indicators from multisensoral microwave remote sensing? J. Geophys. Res. Atmospheres, 114, D05103, doi:10.1029/2008JD010533.

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

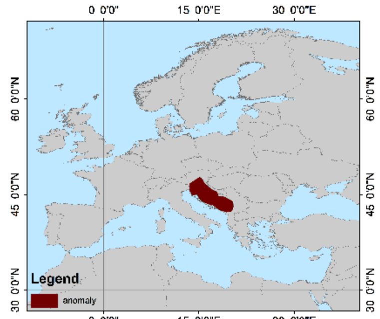
	1	2	3
Thematic precision		X	
Spatial precision			X
Temporal precision			X

Event ID 73:

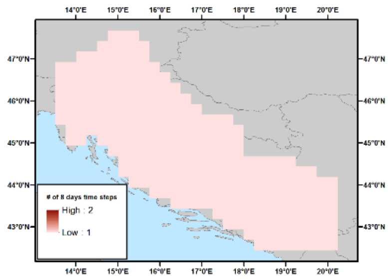
1. Attribution (internal)

Type: Extreme event
Location: South-eastern Europe
Area: 149167.7 km²

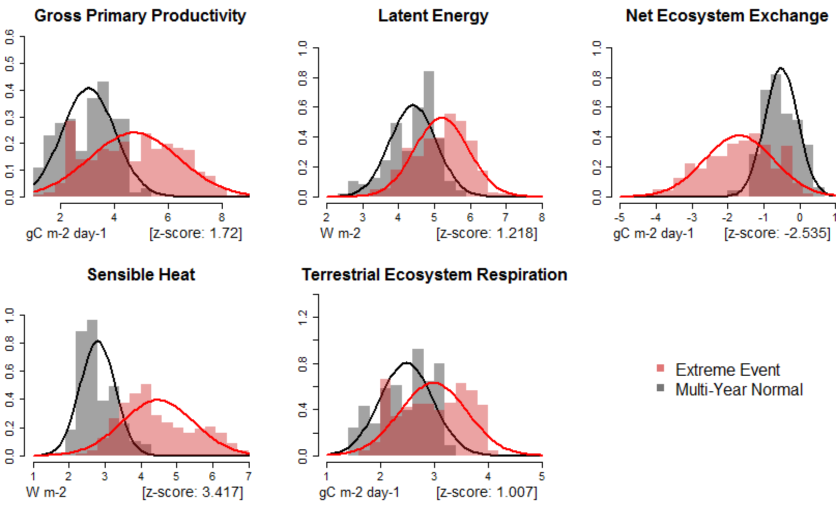
Time: 06.06.2011
Duration: 06.06.2011 – 06.06.2011



Extent of the event

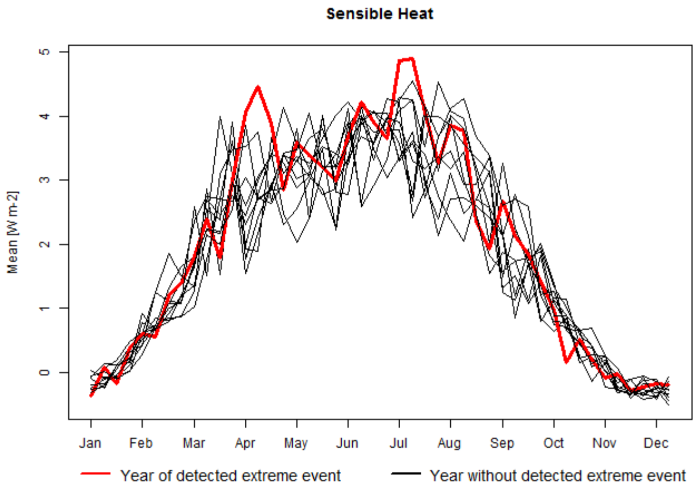


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



2. External characterisation

Heat wave former Yugoslavia spring-summer 2007

Bosnia and Herzegovina

- Due to the unusually strong heatwaves and the missing rain in summer 2007 in former Yugoslavia, Bosnia and Herzegovina had problems with their water supply. The situation was most critical in a few municipalities in the eastern Herzegovina. The local authorities tried to meet the needs of the population and provided free water cisterns, but the inhabitants of the areas who were in need, were expected to pay for their transport and they could not afford that. So there were some social conflicts discontent on the site of the locals. (https://reliefweb.int/report/bosnia-and-herzegovina/bosnia-and-herzegovina-heatwave-dref-operation-no-mdrba001-final)
- In the end of July, Bosnia and Herzegovina, Montenegro, Serbia, the former Yugoslav Republic of Macedonia and Albania were victims of forest burnings. (https://reliefweb.int/map/bosnia-and-herzegovina/eastern-europe-satellite-image-fires-burning-southern-europe-27-jul-2007
- There is a reduction in the sector of agriculturally used area, the number of the actual workers in agriculture and the quote of agriculture in the gross value added between the years 2005 and 2010. The extreme heatwave in that area in 2007 probably contributed to this trend. (https://wko.at/statistik/laenderprofile/lp-bosnien.pdf)

Croatia

- Because of the extreme heatwave in 2007, the energy providers noted a record of power consumption in Croatia.
- Furthermore, the water supply was endangered, just like in Bosnia and Herzegovina.
- In some regions, the farmers could not provide enough water for their animals, which had a very bad influence on the production of milk and meat.
- The harvest in general was bad.
- In Rijeka, the emergency calls had increased about 15% during the hot period.

(https://mkelava.wordpress.com/tag/hitzewelle-kroatien/)

Serbia

- Due to the high temperatures, the lunchtime breaks for authorities were extended to 6 hours a day so that they would not have to work during the extremely hot hours in the noon.

- Tempertures above 40 degree were first measured in 2007.
- At least two people died in the flames of a burning forest. 300 more had to be threatened at the hospital due to smoke inhalation.
- It's not clear how many people really died due to the heat, especially in the affected areas in the south and east of the country, numerous villages are literally cut off from any modern medical care. Due to the extreme poverty, going to hospitals and to the next doctor is unaffordable for many people
- https://www.wsws.org/de/articles/2007/07/hitz-j27.html

3. Independent validation & regional expert feedback

Land use in the affected area

According to results from WP7 of the BACI-project (refer to report as of task 7.2), the detected event consists of 35% cropland, 35% forests and woodlands, 15% grazing lands, 2% sealed areas and 13% other land. The event covers mostly areas of high HANPP levels, indicating high land use intensity as is typical for central European croplands, particularly in northern France and Germany (Figure 1). Hence, the extreme event had major impacts on agricultural production in central Europe.

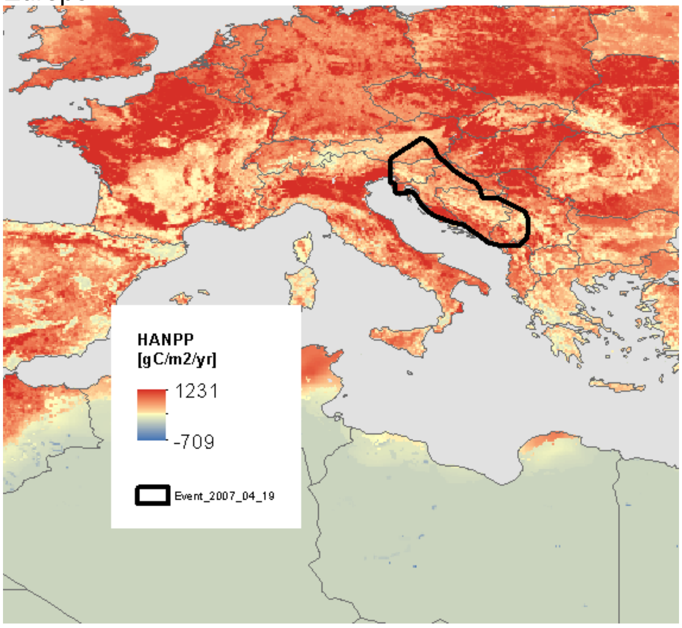


Figure 1: HANPP levels in gC/m2/yr witin the detected BACI extreme event (refer to task 7.2 of the BACI project)

Cereal yields 2007

According to the trends of cereal yields in South-Eastern Europe, particularly in the former Yugoslavian countries (Bosnia and Herzegovina, Serbia and Croatia), cereal yields were below the decadal average in the year 2007.

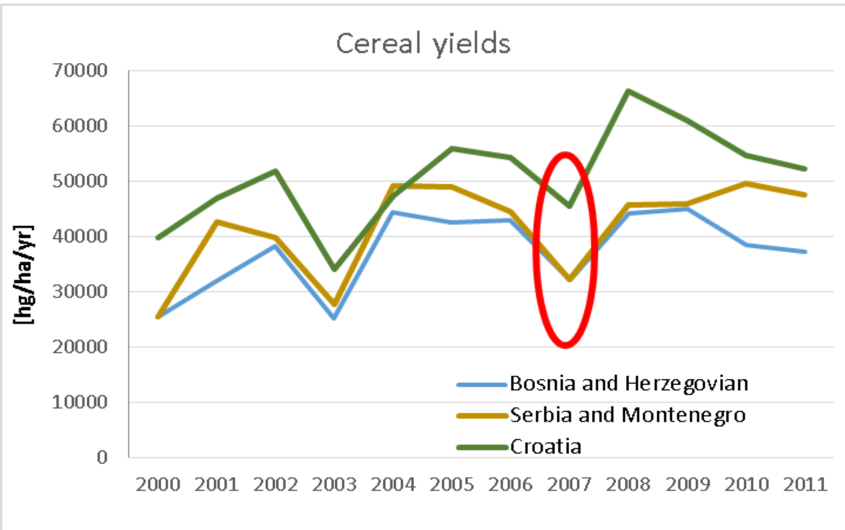


Figure 1: Cereal yields in selected southeast European countries according to FAOSTAT data

Remote sensing expert based	1 2 3

evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	Thematic precision	X		
	Spatial precision		X	
	Temporal precision	X		

		1	2	3
Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	Thematic precision	X		
	Spatial precision	X		
	Temporal precision	X		

		1	2	3
Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	Thematic precision			X
	Spatial precision		X	
	Temporal precision	X		

References

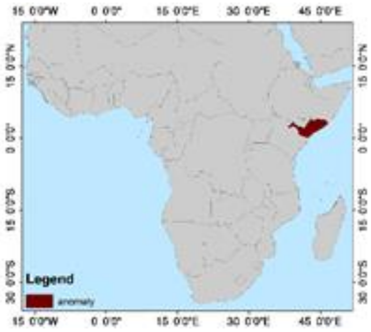
4. FAO, 2017: FAOSTAT: Statistical Database of the United Nations Food and Agricultural Organization. *http://faostat.fao.org/*,

Event ID 74:

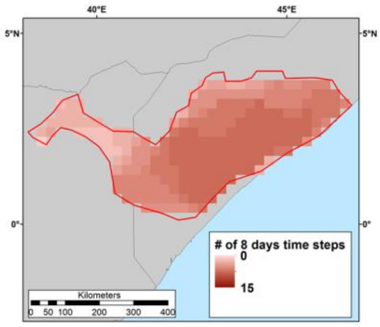
1. Attribution (internal)

Type: Extreme event
Location: South Somalia
Area: 183835.9 km²

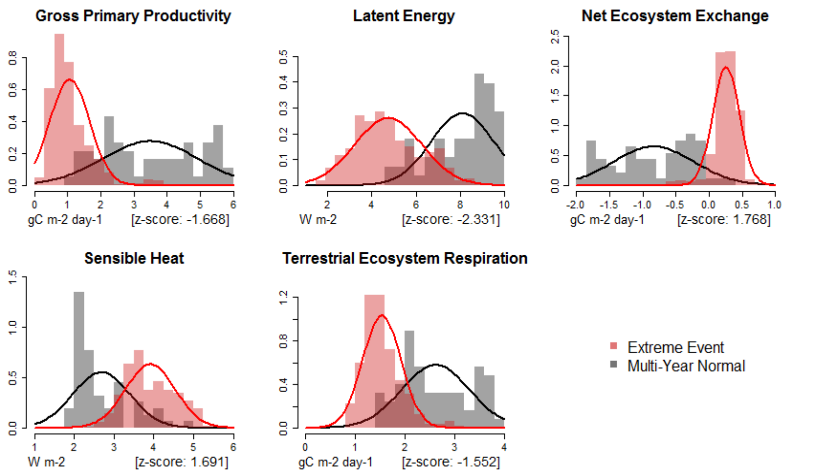
Time: 2010/11/21
Duration: 2010/10/29 – 2010/12/23



Extent of the event

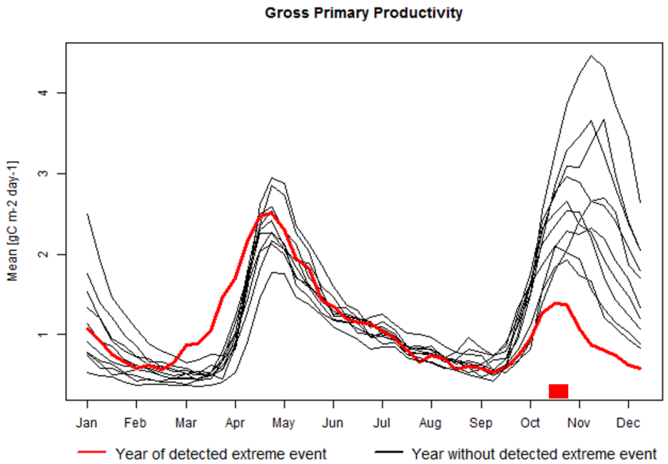


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



Annual time series of Gross Primary Production for the year of detected extreme event (red) and all other years

2. External characterisation

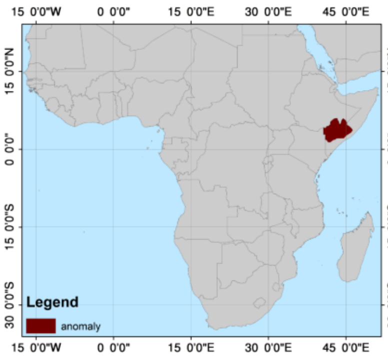
3. Independent validation & regional expert feedback

		1	2	3
Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**			X
	Spatial precision			X
	Temporal precision		X	
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**	X		
	Spatial precision		X	
	Temporal precision	X		
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**		X	
	Spatial precision			X
	Temporal precision			X
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.	**Thematic precision**			X
	Spatial precision		X	
	Temporal precision			X

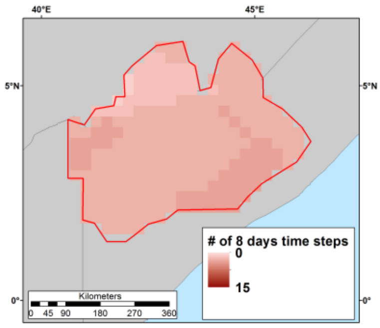
Event ID 75: East Africa 2

1. Attribution (internal)

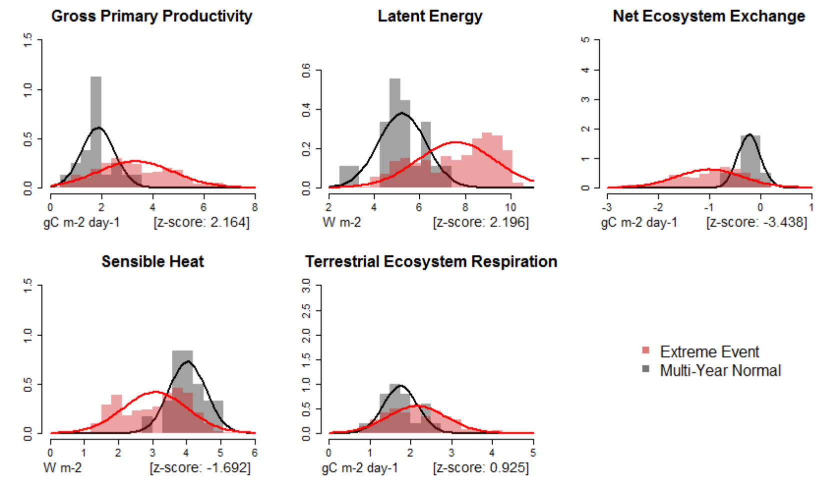
Type: Extreme event
Location: South Somalia
Area: 200245 km²
Time: 2004/11/28
Duration: 2004/11/12 – 2004/12/06



Extent of the event

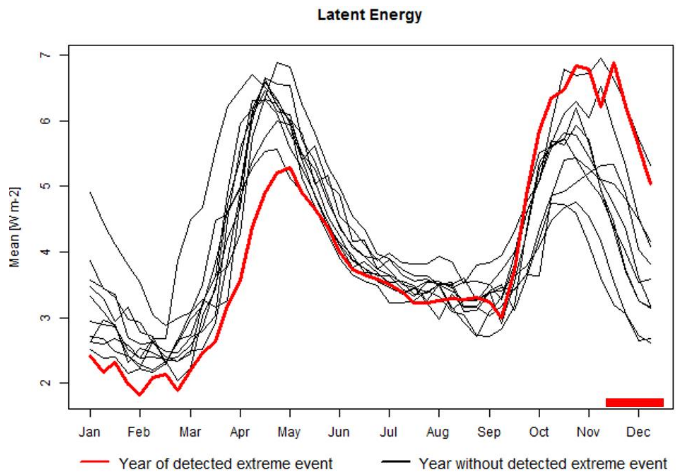


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



Annual time series of Latent heat for the year of detected extreme event (red) and all other years

2. External characterisation

- Dry seasons are usually found to be followed by periods of above normal rainfall, so happened in 2004 [1]
- Responsible is a weak El Nino during that time [2]
- Resulted in higher NDVI values than usual and more GPP [1]

- Additionally in December the tsunami from the megathrust earthquake near Sumatra hit the East African Coast of Somalia and caused severe damages [3]

3. Independent validation & regional expert feedback

- As investigated by Alwesabi et al in 2012 Somalia showed higher NDVI values in the second half of 2004 which stays in good agreement with the detected extreme event of more GPP etc.

year	season	Hergisa	Garoowe	Hudur	Jamame	Gedo	Amino	Garrisa
	first season	-1	1	1	-1	-1	1	-1
2000	second s.		1	-1	-1	-1	-1	-1
	first season				1		-1	
2001	second s.			-1		-1	-1	1
	first season	1	1	-1				1
2002	second s.			1	1		1	
	first season		-1	1	1		1	1
2003	second s.		-1	-1			-1	1
	first season	-1	-1		1		-1	
2004	second s.	-1	1	1	1	1	1	1
	first season	1	1	1			1	
2005	second s.	1	1	-1	-1	-1	-1	-1
	first season		1					-1
2006	second s.	1	1	1	1	1	1	1
	first season	1		1	1	1	1	1
2007	second s.	1	-1	1		1	1	1
	first season		-1	-1	1	1	-1	
2008	second s.			1	-1	-1	1	-1
	first season	-1	-1	-1	-1	-1	-1	
2009	second s.	-1		1	1	1	-1	1
	first season	1	1	1		1	-1	1
2010	second s.		-1	-1	-1	-1	-1	-1
2011	first season		-1	-1	-1	-1	-1	-1

Figure: Plus one indicates above average NDVI and minus one indicates below average NDVI while without number is equal or close to the average. [1:32]

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision			X
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 =

	1	2	3
Thematic precision			X

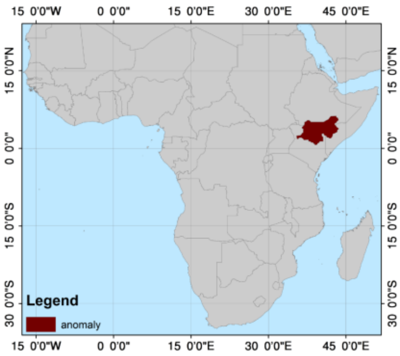
not precise, 2 = average, 3 = precise.	**Spatial precision**			**X**
	Temporal precision			**X**
Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1**	**2**	**3**
	Thematic precision			**X**
	Spatial precision		**X**	
	Temporal precision			**X**

Event ID 76:

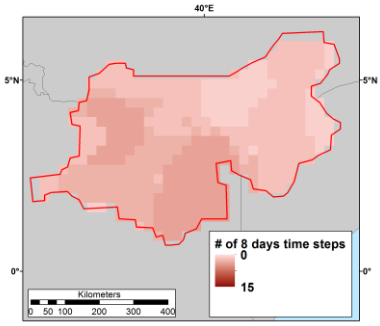
1. Attribution (internal)

Type: Extreme event
Location: South Somalia
Area: 303219.7 km²

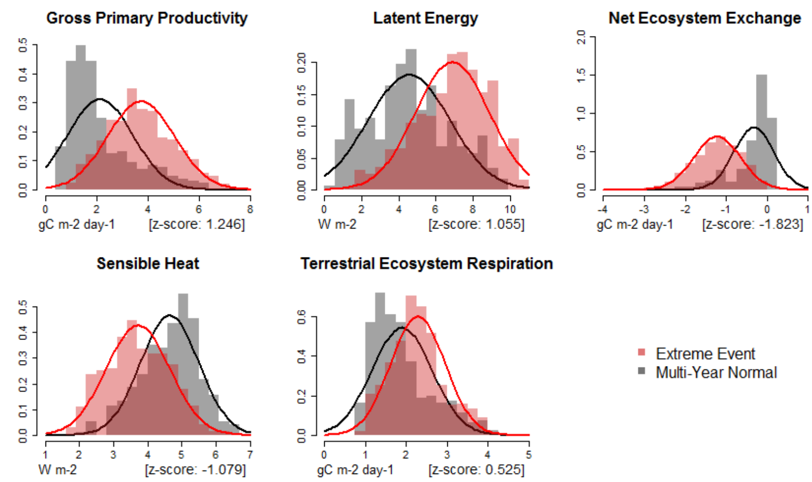
Time: 2011/12/07
Duration: 2011/11/29 – 2011/12/23



Extent of the event

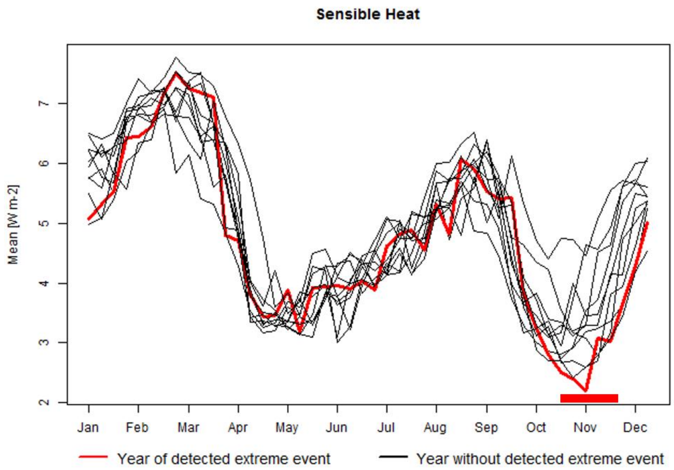


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



Annual time series of Gross Primary Production for the year of detected extreme event (red) and all other years

2. External characterisation

- Between July 2011 and mid-2012 entire eastern Africa experienced a severe drought [1]
- Since spring and fall rainfalls are especially crucial for agricultural use and therefore secure food supplies in the saharan respectively sub-saharan missing those in 2011 was the reason for the "worst drought in 60 years" [2]
- Especially the southern parts of Somalia (Bakool and Lower Shabelle) were affected by this drought [3]

- Due to that many refugees fled to neighbouring Kenya and Ethiopia and the food crisis resulted in 9.5 millionen threatened livelihoods in eastern Africa [4]

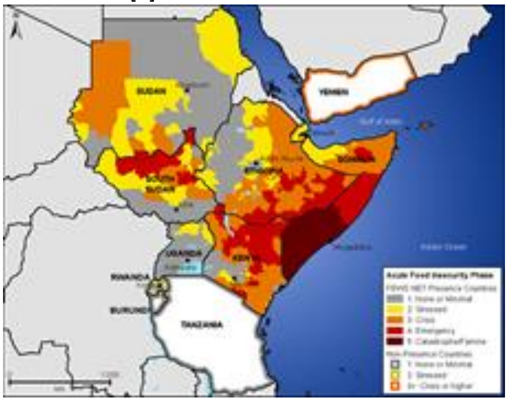


Figure: Food security projection for East Africa at the height of the drought (Famine Early Warning Systems Network)

3. Independent validation & regional expert feedback

- See Jan verbesselt above
- Additionally EOM Analysis are also valid for this extreme event

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation (1) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation (2) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision	X		
Spatial precision			X
Temporal precision			X

Regional expert based evaluation (3) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision			X

	Temporal precision			**X**
Regional expert based evaluation (4) of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.		**1**	**2**	**3**
	Thematic precision			**X**
	Spatial precision		**X**	
	Temporal precision			**X**

References

[1] [1] OCHA (UN Office for the Coordination of Humanitarian Affairs) (2011). "Eastern Africa Drought Humanitarian Report No. 3".

[2] NOAA: Measuring Somalia https://www.nnvl.noaa.gov/MediaDetail.php?MediaID=799&MediaTypeID=1&MediaFileID=213, stand: 08.08.2011, last access: 14.11.2017

[3] UN. Office for the Coordination of Humanitarian Affairs (2011) :Humanitarian Requirements for the Horn of Africa Drought 2011. <https://reliefweb.int/sites/reliefweb.int/files/resources/Humanitarian%20Requirements%20for%20the%20Horn%20of%20Africa%20Drought%20%28reduced%20file%20size%29.pdf>

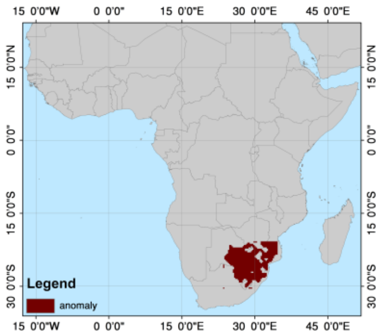
[4] "UN: Somali famine is over, but action still needed". Thejournal.ie. Retrieved 7 August 2012.

Event ID 77:

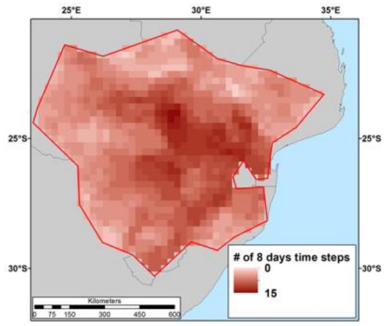
1. Attribution (internal)

Type: Extreme event
Location: South Africa
Area: 695801.8 km²

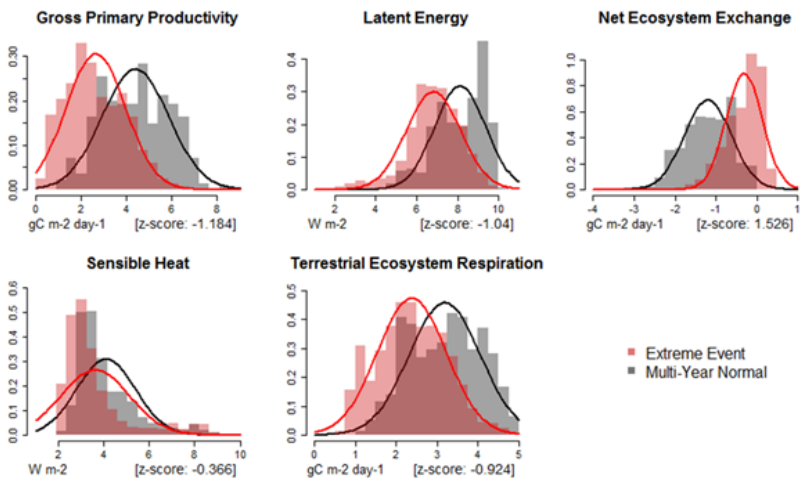
Time: 2004/01/21
Duration: 2003/11/29 – 2004/04/10



Extent of the event

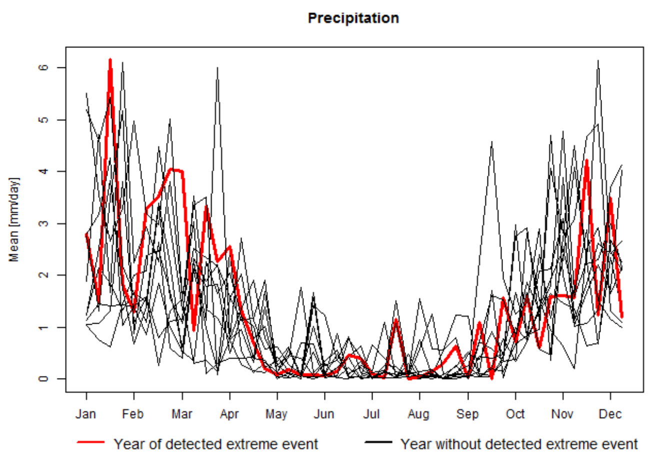


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

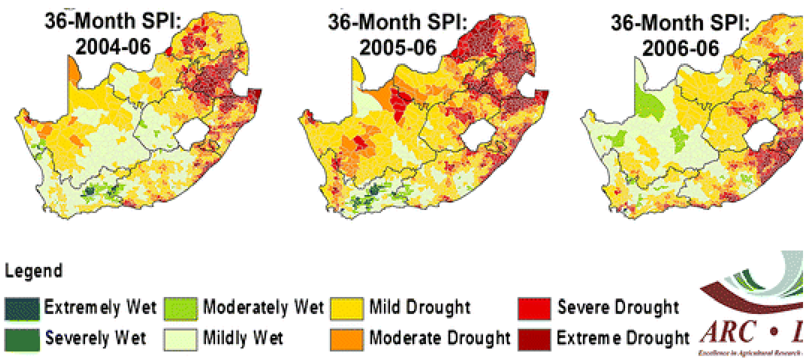


Annual time series of precipitation for the year of detected extreme event (red) and all other years

2. External characterisation

Drought event in South Africa 2003 / 2004

- *"Drought remains a major disaster causing huge damages to humanity, the environment and the economy, despite making considerable progress on monitoring, forecasting and mitigation of droughts across the world."* (Masih et al. 2004:3636)
- Between 1990-2013, Africa is facing the majority of drought events (up to 300) during this time period, when compared on continental scale (Masih et al. 2004)
- The ENSO phenomenon (El Niño / Southern Oscillation), which is driven by periodic fluctuations of ocean temperatures in the equatorial Pacific, is following regular repetition pattern over time (Singels & Potgieter 1997) and is negatively correlated with the amount of rainfall during the summer season in southern Africa (Malherbe et al. 2016).
- However, Reason & Phaladi (2005) found that the drought event 2003/2004 seem not to be caused by an El Niño event. Moreover, this drought is followed by large precipitation events end of January 2004 – which agrees with the precipitation plot in Point 1 (Attribution) and explanations in Point 3 (Independent Validation)
- Comparing the detected extreme event of the BACIndex with the findings from Malherbe et al. (2016), high agreement are found (see Figure below lower left)



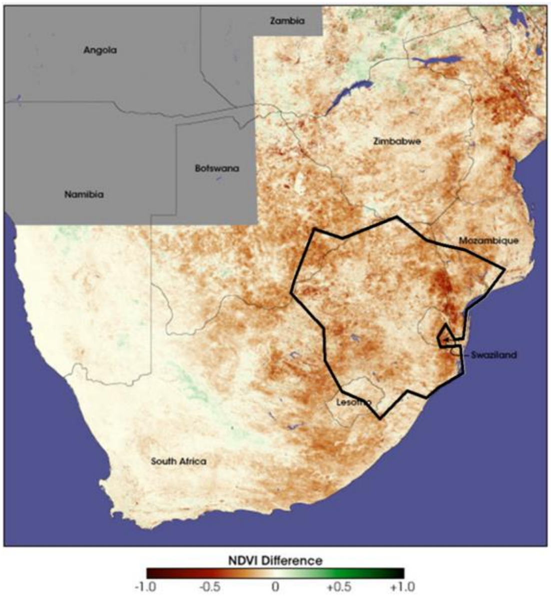
Most extensive droughts events (severe to extreme) since 1920 observed at the 36-month SPI* time scale (figure changed Malherbe et al. 2016).

**"The SPI is based on the probability of precipitation for a given time period. Technically, the SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable." (Rouault & Richard 2003:491)*

3. Independent validation & regional expert feedback

NDVI Difference in 2004 (Base Period: 2001-2003):
(Source: https://earthobservatory.nasa.gov/IOTD/view.php?id=4226&eocn=related_to&eoci=related_image)

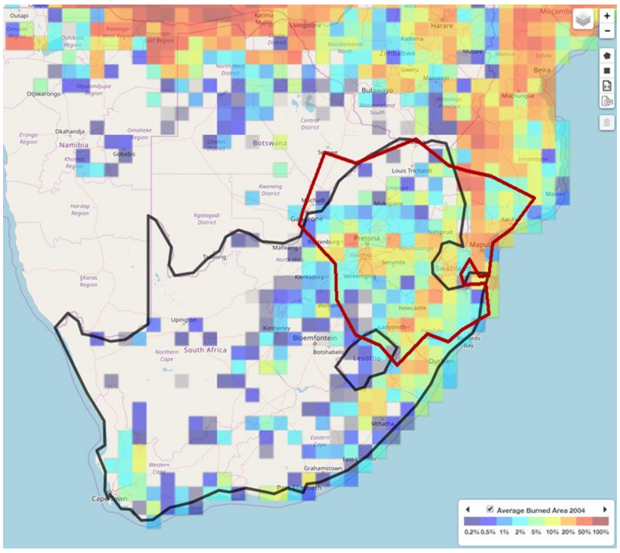
- Food shortage in Southern Africa due to dry soils in late 2003 and early 2004
- Less than 50 % of rainfall in north-eastern South Africa, Lesotho, and Swaziland
- Increase of vulnerability to drought as it was the third season of below-average rainfall
- up to 700K people requires food aid this year
- MODIS NDVI shows the extent of the drought events (see figure below)
- heavy rain in late January induced better conditions for some regions, but it may have also damaged crops
- for most regions rain came too late as many farmers could not plant due to water scarcity
- resulting in shorter growing season, which reduces size of crops



Comparison of amount of vegetation during the first sixteen days of January 2004 (Base Period: first 16 days in 2001, 2002, and 2003). (Extreme Event in black). (Source: https://earthobservatory.nasa.gov/IOTD/view.php?id=4226&eocn=related_to&eoci=related_image)

<u>Fire Affected Area in the year of drought event 2004:</u>
(Source: http://www.globalfiredata.org/analysis.html)

- Burned area statistics are showing increasing amount of fire affected areas in the year of drought event in 2004
- Fire events might be cause due to dry vegetation, etc.
- the extent of the burned areas and detected extreme event from the BACIndex shows good agreement



Average burned area in % for the year of drought in 2004. (Extreme Event in red). (Source: http://www.globalfiredata.org/analysis.html)

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			**X**
Spatial precision			**X**
Temporal precision			**X**

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision			X
Temporal precision			X

References

Malherbe, J.; Dieppois, B.; Maluleke, P.; Van Staden, M.; Pillay, D. L. South African droughts and decadal variability. Nat. Hazards 2016, 80, 657–681, doi:10.1007/s11069-015-1989-y.

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Reason, C. J. C.; Phaladi, R. F. Evolution of the 2002-2004 drought over northern South Africa and potential forcing mechanisms. S. Afr. J. Sci. 2005, 101, 544–552.

Rouault, M.; Richard, Y. Intensity and spatial extension of drought in South Africa at different time scales. 2003, 29.

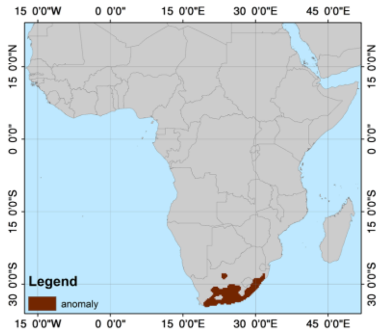
Singels, A.; Potgieter, A. B. A technique to evaluate ENSO-based maize production strategies. South African J. Plant Soil 1997, 14, doi:10.1080/02571862.1997.10635088.

Event ID 78:

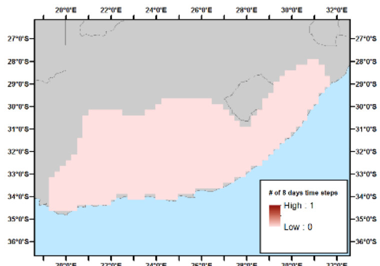
1. Attribution (internal)

Type: Extreme event
Location: South Africa
Area: 470516.8 km²

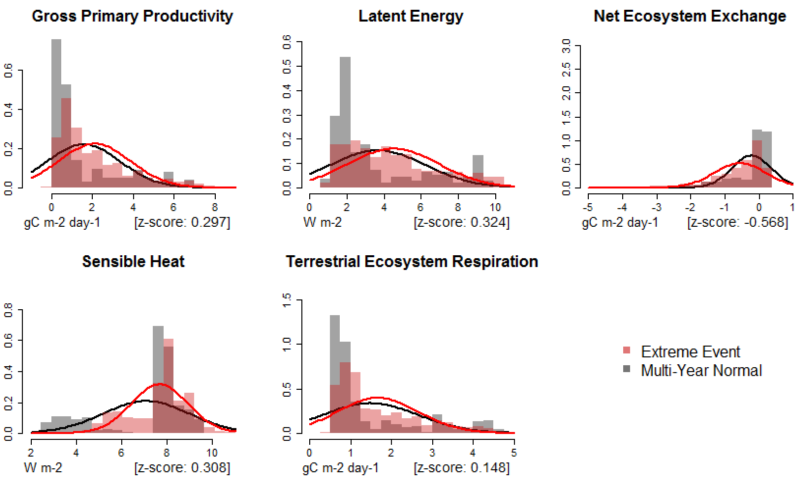
Time: 2007/12/31
Duration: 2007/12/31 – 2007/12/31



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

<u>Fire event in South Africa 2007/12/31</u>

- Higher number of fires compared to average of 2003 - 2013 (Syndrom & Savage 2016)
- warm La Niña year 2006 may led to increasing fire frequencies in 2007, but not driven by air-temperature, which was on average in 2007 (Syndrom & Savage 2016)
- La Niña usually results in increased rainfall which may have led to increased vegetation growth and higher fire frequencies (Syndrom & Savage 2016)
-

<u>Fire Affected Area in 2007 (Davies et al. 2004 & Giglio et al. 2003):</u>
<u>(Source: https://lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi?period=2007361-2008005)</u>

Figure. Active Fire hot Spots between 27-12-2007 and 05-01-2008. (Extreme Event in red line).
(Source: https://lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi?period=2007361-2008005)

Fire Affected Area in 2007:
(Source: http://www.globalfiredata.org/analysis.html)

- Burned area statistics are showing increasing amount of fire affected areas in the year 2007
- the extent of the burned areas and detected extreme event from the BACIndex shows good agreement

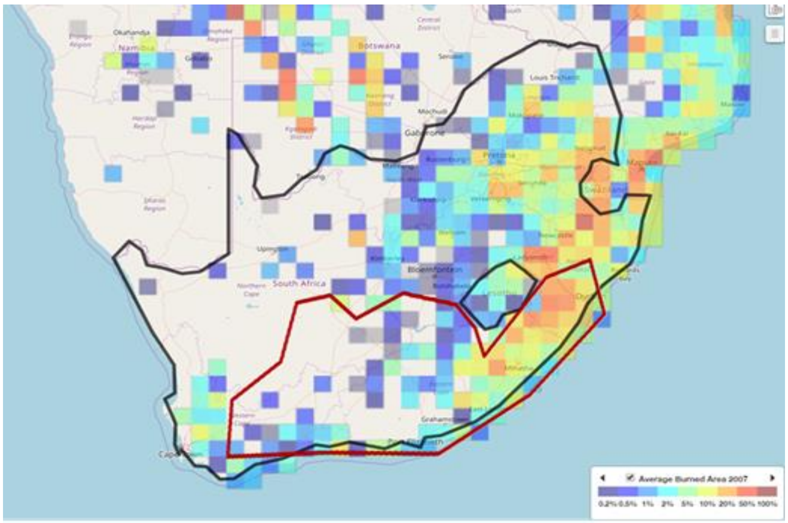


Figure. Average burned area in % for the year in 2007. (Extreme Event in red).
(Source: http://www.globalfiredata.org/analysis.html)

3. Independent validation & regional expert feedback

Forest loss in 2007 from Hansen et al. (2013):
(Source: https://earthobservatory.nasa.gov/IOTD/view.php?id=4226&eocn=related_to&eoci=related_image)

- loss of forest area are found in both extreme events, which have been found in 2007
- Nevertheless, the agreement between the extreme events and loss of forest area is very low as only small proportion of the area (Figure below)

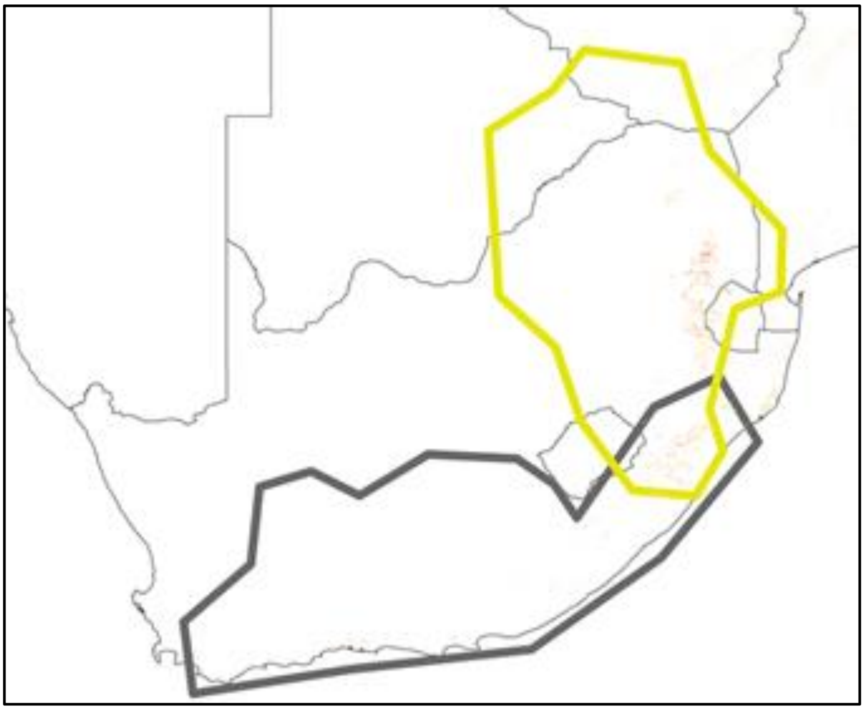


Figure. Forest loss in 2007 (red areas) from Hansen et al. 2013. (extreme event from 31-12-2007 in grey – additional extreme fire event from 04-10-2007 in yellow).
(Source: http://earthenginepartners.appspot.com/science-2013-global-forest)

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision	X		
Temporal precision	X		

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision		X	
Temporal precision		X	

References

Strydom S, Savage MJ. A spatio-temporal analysis of fires in South Africa. S Afr J Sci. 2016;112(11/12), Art. #2015-0489, 8 pages. http://dx.doi.org/10.17159/ sajs.2016/20150489

Giglio, L., J. Descloitres, C. O. Justice, and Y. J. Kaufman. 2003. An enhanced contextual fire detection algorithm for MODIS. Remote Sensing of Environment, 87:273-282

Davies, D., Kumar, S., and Descloitres, J. (2004). Global fire monitoring using MODIS near-real-time satellite data. GIM International, 18(4):41-43

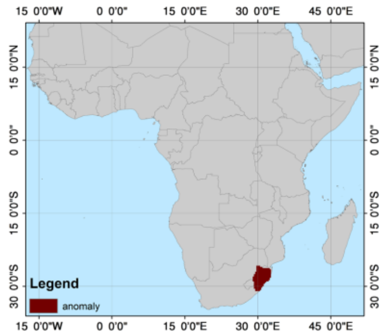
Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

Event ID 79:

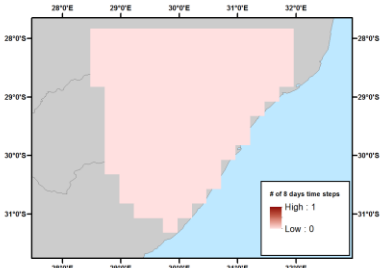
1. Attribution (internal)

Type: Extreme event
Location: South Africa
Area: 195874.2 km²

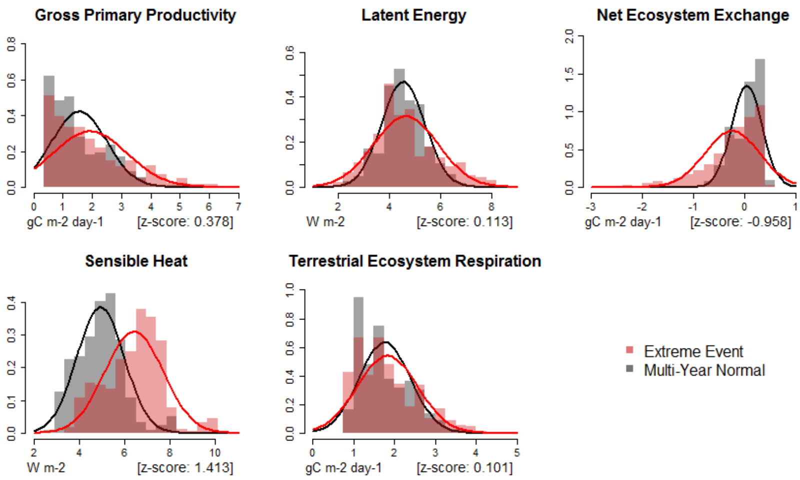
Time: 2011/10/12
Duration: 2011/10/12 – 2011/10/12



Extent of the event



# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.

2. External characterisation

Floods in 2011/10/12:

In South Africa more than 6,000 people have been displaced and 70 known to have been killed due to the floods.[4][7] This number is expected to rise as police continue to search for an unknown number of missing persons.[8] Eight of the country's nine provinces have been declared disaster areas, allowing for national funds to be distributed.[4][5] Preliminary estimates placed crop damage at R1 billion ($145 million US$).[9] Property damage was also estimated at $52 million.[4] An estimated 20,000 hectares (49,000 acres) of agricultural land has been affected by the floods

In Lesotho, infrastructure was destroyed as heavy rains fell between December 2010 and March 2011. In total, 672 houses in seven districts were destroyed, and the most impact was felt in the districts situated in the northern part of the country. Safety was threatened and households lost most of their belongings, including livestock. The sanitation situation was severely compromised, creating a health hazard. (IFRC, 22 Dec 2011)

South Africa received above normal rainfall and flooding in early 2011. The floods caused unprecedented destruction, resulting in disruption in service delivery, displacement of people and loss of lives and livelihoods. Over 200,000 people were reportedly affected by floods and 40 deaths were reported. A *national state of disaster was declared in 28 district municipalities in eight provinces. (IFRC, 22 Dec 2011).*

Most parts of the region remain food secure following three consecutive years of average to above-average crop harvests. Consequently, staple food prices have stabilized, and are declining, particularly in surplus-producing areas. The situation is expected to remain stable across the region until the start of the lean season in October/November. However, reduced harvests in areas affected by floods and/ or prolonged mid-season dry spells have resulted in pockets of food insecurity in localized areas where food access has become problematic for affected households.

• Food prices in markets located in surplus-producing areas continue to follow normal post-harvest seasonal trends (stabilization and/or decline), while those in grain deficient and/or high consumption areas depict anomalous price increases. Price levels and trends are also being influenced by other factors including national government policies on trade (trade bans, import duties and others), and the efficiency with which food is moved internally or across borders from surplus to deficit areas.

• The 2011 national VAC assessment findings released in July point to varying food insecurity levels across countries; a few have recorded higher levels of food insecurity, while most are more food secure compared to the two previous seasons and the past five-year average. Higher levels of food insecurity are reported in Lesotho, and are expected in Namibia, the two countries where the impact of excessive rains and floods on crop production and livelihoods was most severe and more widespread. Malawi, Mozambique and Namibia are yet to complete and release their assessment results.

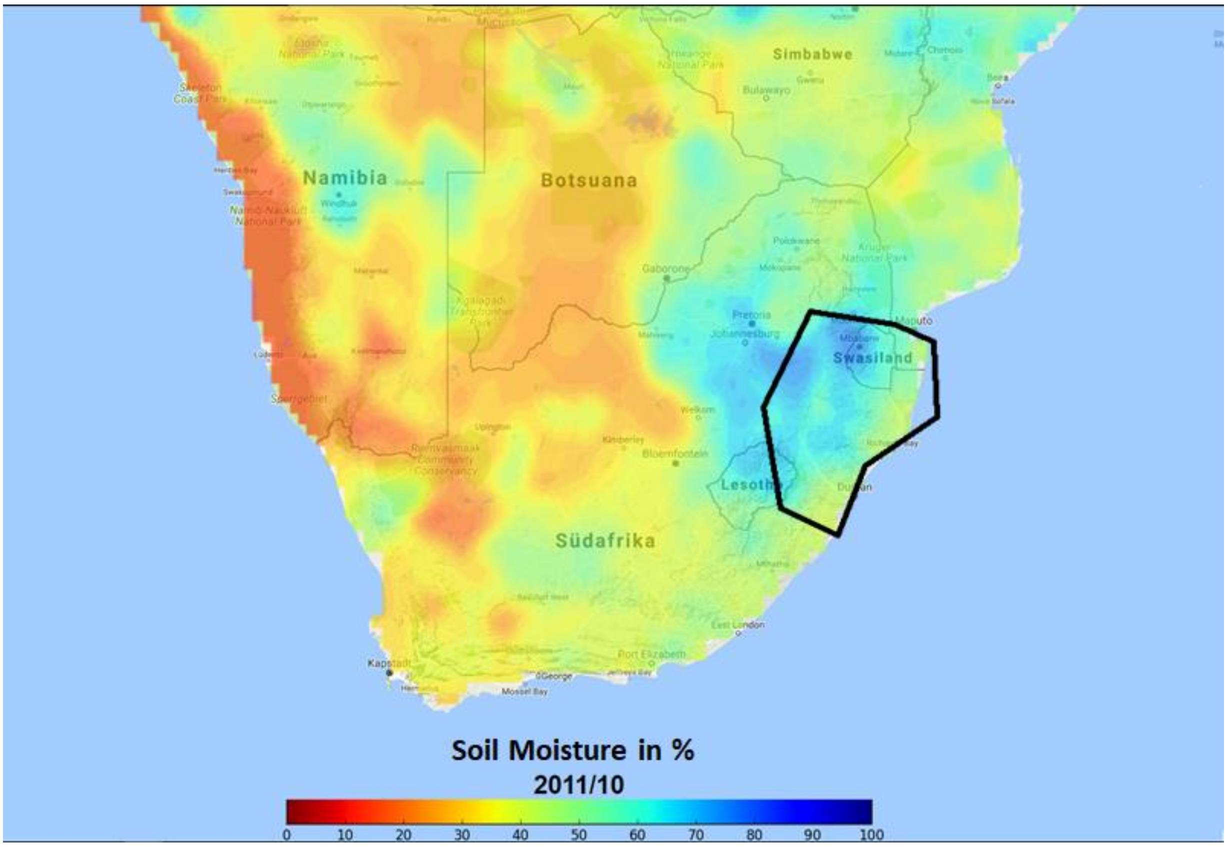


Figure. Soil Moisture in % (extreme event from 12-10-2011 in black).
(http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en)

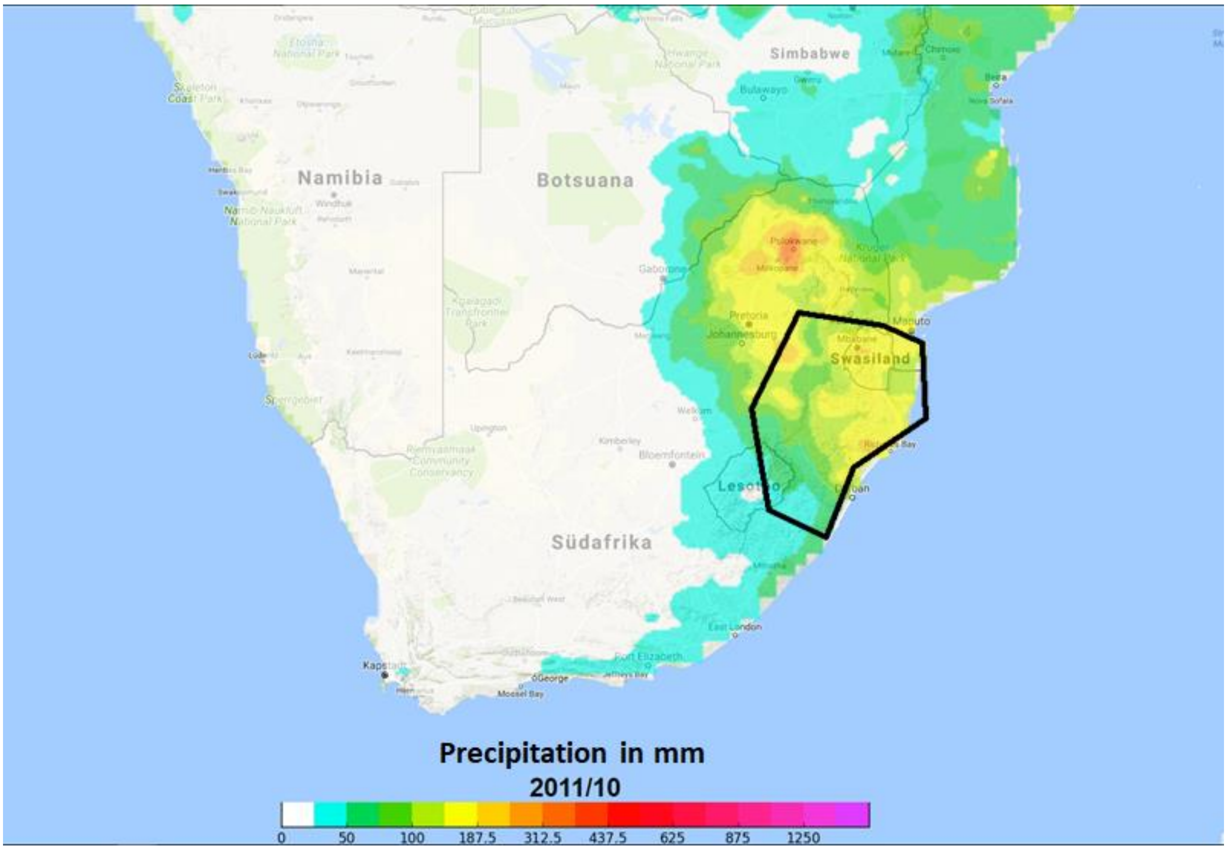


Figure. Precipitation in mm (extreme event from 12-10-2011 in black).
(http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en)

3. Independent validation & regional expert feedback

Expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision			X
Spatial precision		X	
Temporal precision		X	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		X	
Spatial precision	X		
Temporal precision			X

References

Source: http://www.globalfiredata.org/analysis.html

http://www.sajs.co.za/sites/default/files/publications/pdf/SAJS-112-11-12-Savage_ResearchArticle.pdf

Giglio, L., J. Descloitres, C. O. Justice, and Y. J. Kaufman. 2003. An enhanced contextual fire detection algorithm for MODIS. Remote Sensing of Environment, 87:273-282

Davies, D., Kumar, S., and Descloitres, J. (2004). Global fire monitoring using MODIS near-real-time satellite data. GIM International, 18(4):41-43

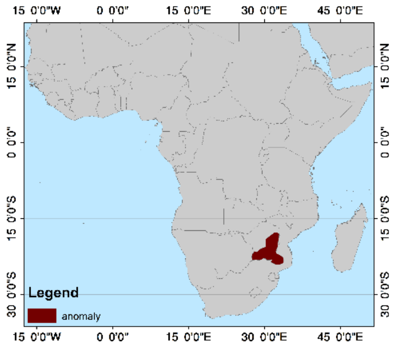
Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

Event ID 80:

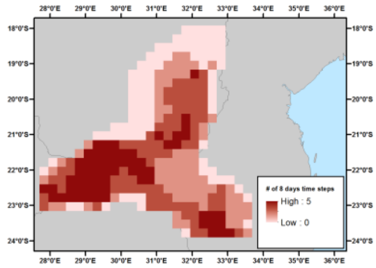
1. Attribution (internal)

Type: Extreme event
Location: South Africa
Area: 224382.8 km²

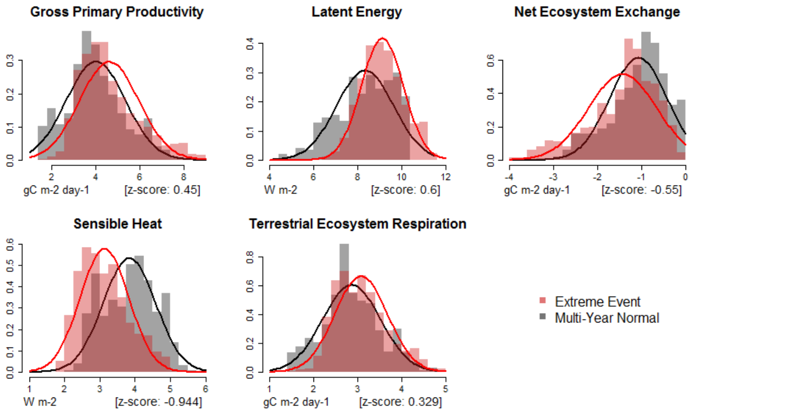
Time: 06.06.2011
Duration: 2007-12-23 to 2008-01-21



Extent of the event

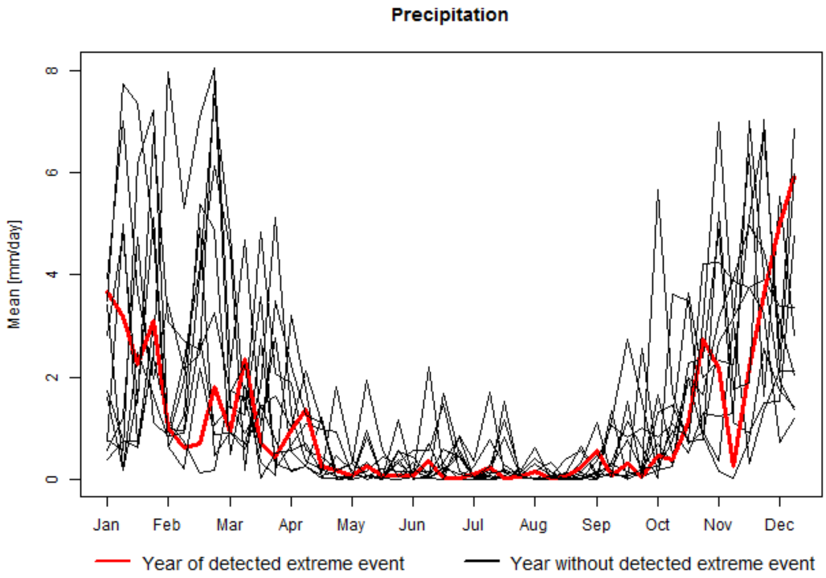


# of 8 day time steps for which the event was detected



Extreme event vs. multi-year normal distribution of BACIndex input parameters

Distribution of extreme event versus multi-year normal for the BACIndex input parameters. Histograms are shown with fitted normal distribution curve and z-scores. Multi-year normal distribution are derived with images from the same season.



2. External characterisation

Climate-related famine in Zimbabwe

- Heavy rainfalls at the beginning of the year combined with drought periods afterwards led to severe harvest failures
- Below-average sensible heat supports high rainfalls
- Interestingly, precipitation patterns appear relatively normal
- Dought as such was mild in 2008, but together with the heavy rainfalls resulted in high impacts on crop production
- Maize harvest in 2008 was 60% below the long-term average
- Not only climate, but also hyper-inflation and related lack of fertilizers, seeds, and tillage power was responsible for the historic low harvests.
- Almost half of the population was threatened by starvation in the same year, because food imports did not meet domestic demands (http://www.nytimes.com/2008/12/22/world/africa/22zimbabwe.html).
- a third of the population was chronically malnourished and many families fled to neighboring countries. (https://www.theguardian.com/world/2008/jul/21/zimbabwe.unitednations)
- Still, President Mugabe told aid organizations to stop handing out food and medicines. (http://www.telegraph.co.uk/news/worldnews/africaandindianocean/zimbabwe/2089601/Zimbabwe-faces-worst-harvest-on-record-as-Robert-Mugabe-stops-charity-food-handouts.html)
- In some parts heavy floods occurred: Officially 3 people in Zimbabwe died because of the flood. (http://www.abc.net.au/news/2008-01-14/50-dead-in-mozambique-floods/1010930)
- The agriculture value-added growth in Zimbabwe declined by an average of about 18 percent in 2007 and 2008 following the drought.

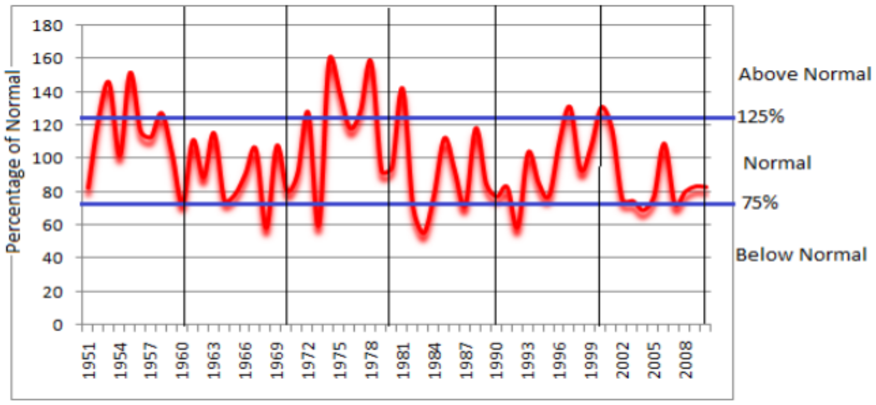


Fig 1: Time series showing the extreme rainfall years in Zimbabwe

Figure source: http://www.droughtmanagement.info/literature/UNW-DPC_NDMP_Country_Report_Zimbabwe_2014.pdf

3. Independent validation & regional expert feedback

Land use in the affected area

According to results from WP7 of the BACI-project (refer to report as of task 7.2), the detected event covers areas of rather low land-use intensity, particularly when compared to the neighbouring country South Africa, that is (partly) dominated by much higher HANPP levels. This is typical for extensive grasslands and shrublands, but also for low-intensive agriculture (Figure 1). In the case of many Sub-Saharan African countries, such as Zimbabwe, crop yields are low and climatic extreme events have major impacts on yields and food security.

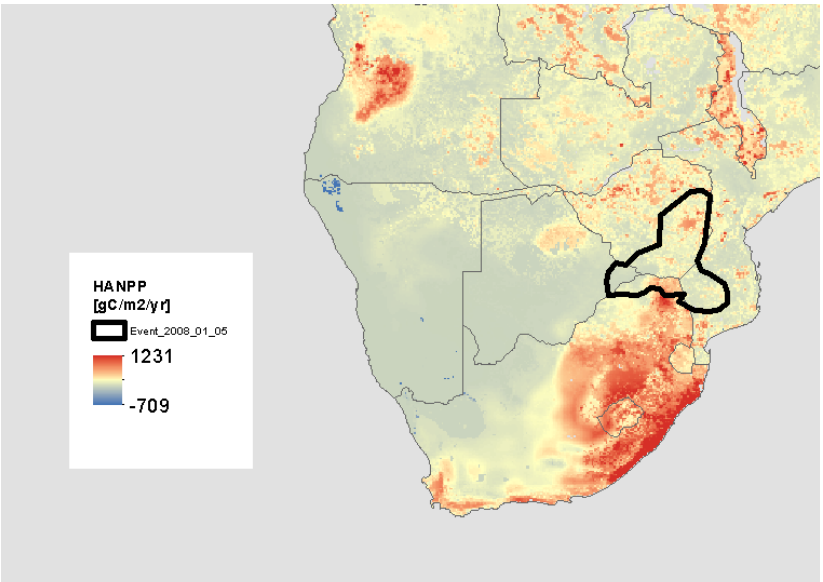


Figure 1: HANPP levels in gC/m2/yr witin the detected BACI extreme event (refer to task 7.2 of the BACI project)

Cereal yields 2008

The year 2008 was marked by the lowest cereal yields within the 2000-2011 time period according to FAOSTAT data (Figure 1). Losses occurred particularly in the Southern part, where the BACI hotspot is located.

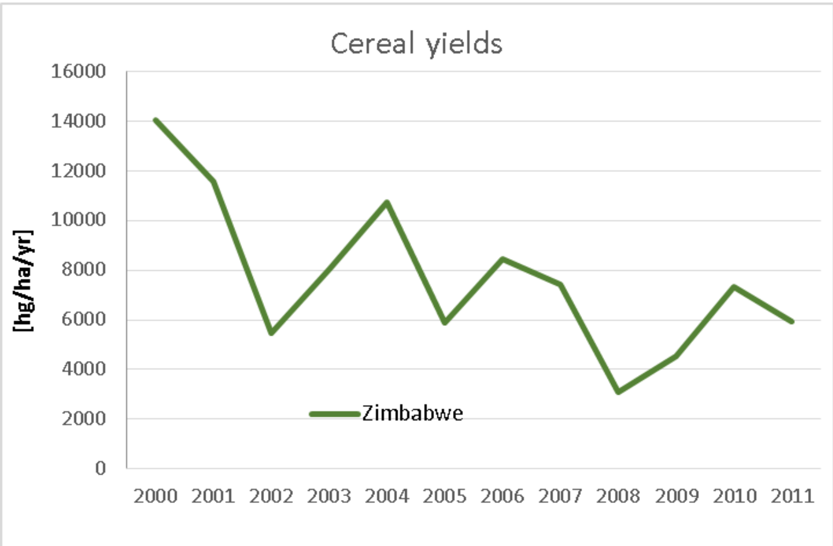


Figure 1: Cereal yields in Zimbabwe according to FAOSTAT data

Remote sensing expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

Regional expert based evaluation of the thematic, spatial and temporal precision of the event. 1 = not precise, 2 = average, 3 = precise.

	1	2	3
Thematic precision		**X**	
Spatial precision		**X**	
Temporal precision		**X**	

References

5. FAO, 2017: FAOSTAT: Statistical Database of the United Nations Food and Agricultural Organization. *http://faostat.fao.org/*,