# BACI

## Newsletter

# Detecting Changes in Essential Ecosystem and Biodiversity Properties: Towards a Biosphere Atmosphere Change Index

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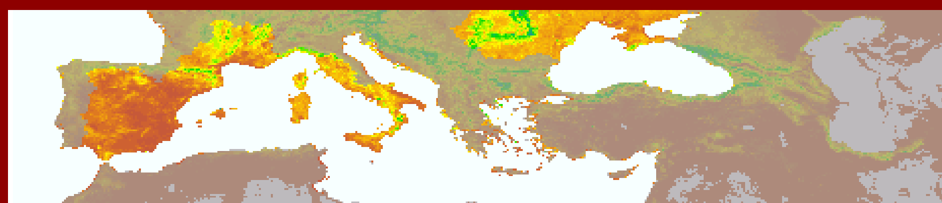


## Welcome to BACI

Dear colleagues and friends,

Welcome to the first issue of the BACI newsletter! Through this biannual publication we will keep you informed about the work progress, main achievements and upcoming events and activities related to the project. We aim to reach biodiversity scientists and ecologists as well as experts from land system science, experts of co-design and co-production of knowledge, land managers and practitioners to establish a data user network. We hope you find it interesting.

If you have any questions, suggestions, feedback or comments you would like to address to the consortium or to the project coordination, please e-mail us.

Thank you for joining us!

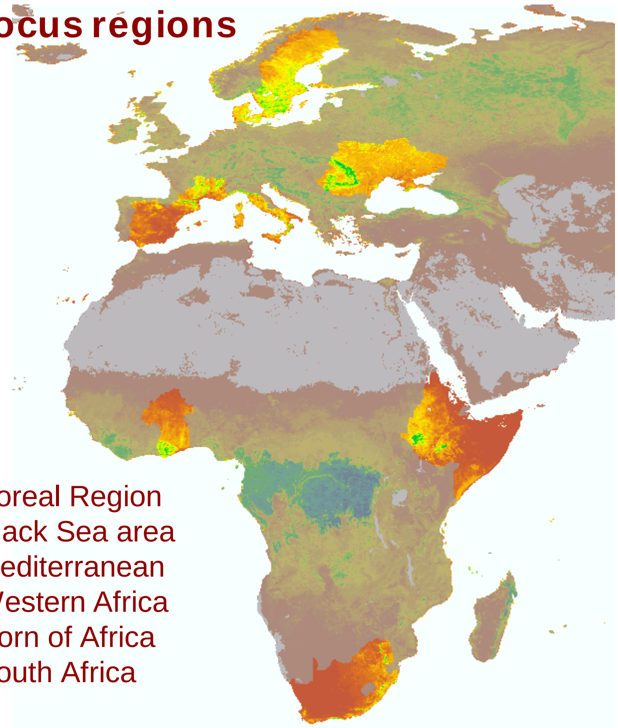
Miguel Mahecha
Project Coordinator


This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 640176.

# BACI in a nutshell

Space data offer multiple opportunities for monitoring ecosystems and their transformations, e.g., in response to human interventions or climate extremes. Today, these data are available in unprecedented spatial, spectral, and temporal resolutions. This development is complemented with the increasing availability of a wide range of ground data on diverse aspects of ecosystem functioning and ecosystem structure, and other parameters relevant to fully describe the functional biogeography of ecosystems. In this broad context, the BACI project aims to tap into the yet-to-be realized potential of existing and scheduled space-borne Earth observation (EOs) in conjunction with ground data to derive new "Essential Ecosystem Variables" and detect changes in ecosystem functioning. The specific objective is to derive novel downstream data products by integrating Earth observations and in-situ data with machine learning methods. A second component of BACI consists of building a system that automatically detects critical transitions in ecosystems and attributes these to transitions and the societal system.

## Focus regions

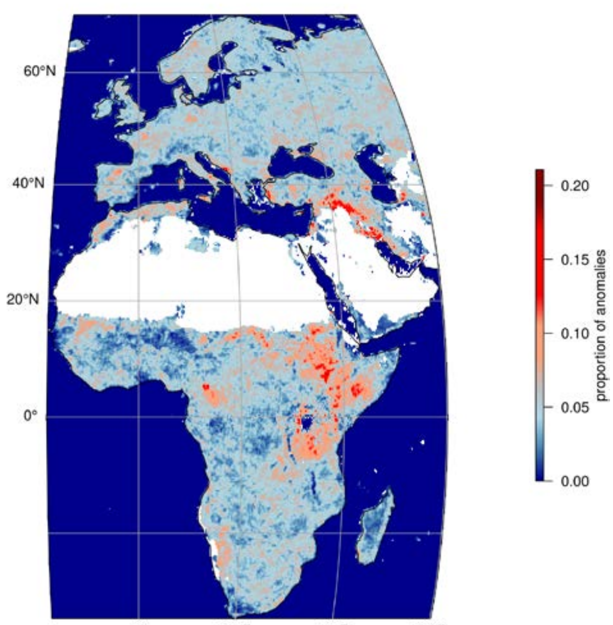


- Boreal Region
- Black Sea area
- Mediterranean
- Western Africa
- Horn of Africa
- South Africa

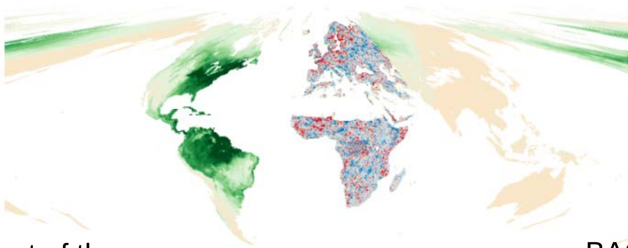
One of the goals is identifying hotspots of change within selected key regions in Europe and Africa, all of which are undergoing different societal-ecological transformations that might itself be attributable to environmental change.

## Overarching goals

- To **trace transient/abrupt changes** in biodiversity and ecosystem states.
- To **co-interpret the index** of change based on state-of-the-art machine learning.
- To **attribute hotspots of change** to climate drivers, bio-physical variation of the land-surface, and socio-ecological transformations.
- To **develop a biodiversity early warning system** that combines observations of ecosystem change with an assessment of biodiversity vulnerability.



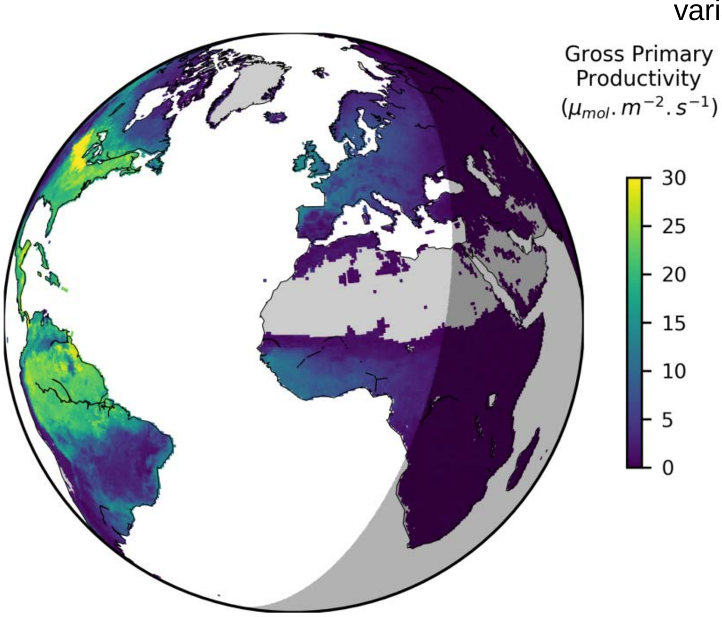
**Decoding multiple data streams to a general index of change**



**Encoding local information towards upscaled "Essential Ecosystem Variables"**

The most exploratory part of the BACI project is developing a novelty index of change to detect (in near real-time) abrupt changes relevant to "Essential Ecosystem Variables" (EEVs). We want to find transitions relevant to the functioning of terrestrial ecosystems, biosphere-atmosphere exchanges of matter and energy, and biodiversity related properties. The index is based on modern machine learning tools and will also detect major extreme events in our data streams.

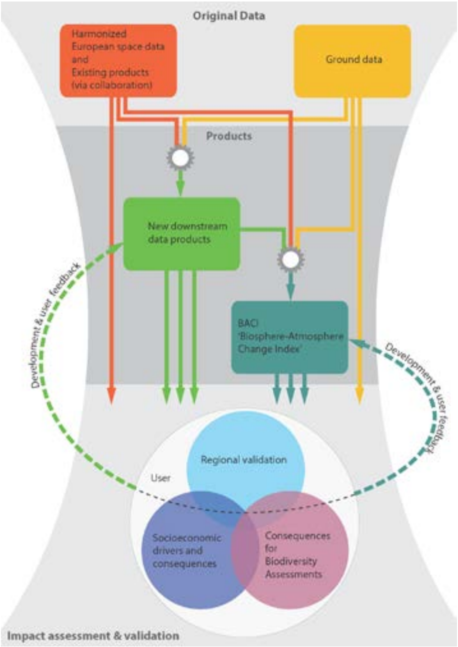
BACI focusses on deriving "Essential Ecosystem Variables" (EEVs). These are variables essential to the monitoring of the fundamental feedbacks in the Earth System. Of particular interest to BACI are interactions between the biosphere and atmosphere. Specific objectives include integrating Earth observations and in-situ data with machine learning methods to resolve the diurnal patterns of gross primary production, latent heat fluxes, or the spatial prediction of tree ring variability.



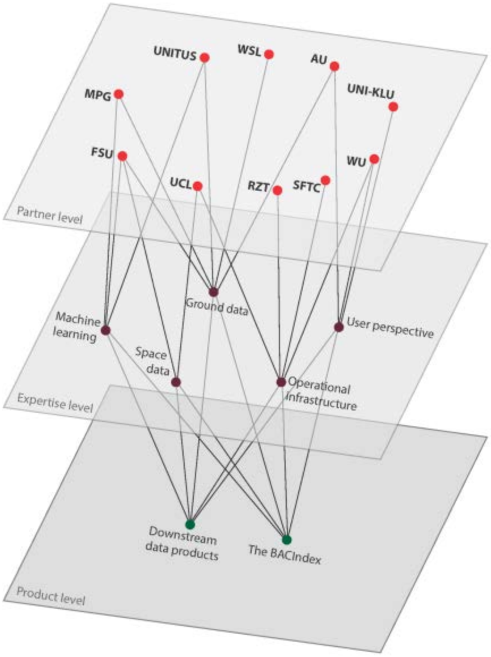

GPP globe map: The total uptake of $CO_2$ via photosynthesis ("Gross Primary Production, GPP") can only be observed from eddy covariance towers. However, using modern machine learning methods and high-resolution ancillary data (e.g. from satellites or meteorology), we were able to estimate GPP at half-hourly intervals at the global scale. In this figure, we see how the day-night transition in GPP occurs.

# Approach

The BACI project is a cascading workflow separated into seven work packages. The integration of ground and space observations leads to a series of new downstream products (light green) that can be either directly interpreted by the user community, or ingested to a statistical system that translate these variables to a general index of change (BACIndex). The novel data products will be evaluated against independent data. We selected regional study areas (Focus regions), as well as fast track sites for which regional evaluations are foreseen.
Partners and tasks covering various aspects of land-use of change, regional attributions, socio-ecological transformations, and biodiversity monitoring aspects are key elements of the project and constantly seeking the interaction with a broader user community.




# Partners and expertise




The consortium is a composite of experts in the field of terrestrial remote sensing ecosystem and biodiversity ground observations of different types, machine learning big data processing, and applications of innovative methods in biogeochemistry, terrestrial ecosystem modelling, biodiversity monitoring and modelling, and socio-ecological change assessments.

The BACI consortium is formed by 10 institutions from 7 European Countries:

- **MPG**: Max Planck Institute for Biogeochemistry representing the Max Planck Society, Jena Germany.
- **UNITUS**: Università degli Studi della Tuscia, Italy.
- **WSL**: Eidgenoessische Forschungsanstalt, Switzerland.
- **FSU**: Friedrich-Schiller-Universität Jena, Germany.
- **WU**: Wageningen University, The Netherlands.
- **UCL**: University College London, UK.
- **UNI-KLU**: Alpen-Adria Universität Klagenfurt-Vienna-Graz, Austria.
- **AU**: Aarhus University, Denmark.
- **RZT**: Rezatec Limited, UK.
- **STFC**: Science and Technology Facilities Council, UK.

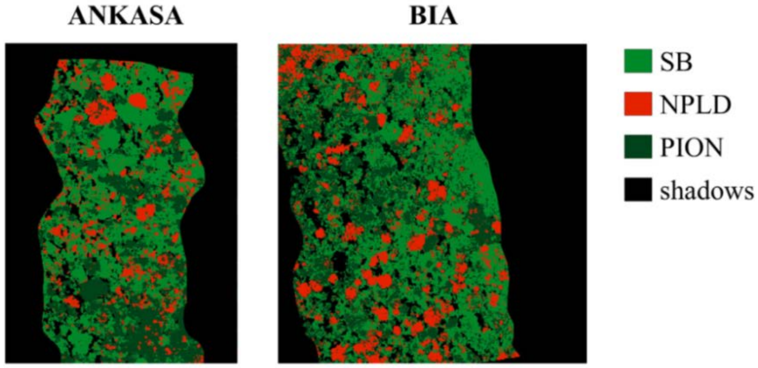
# Mapping tropical tree functional groups from space

The BACI outcomes are validated in different sites, and among them there is a biodiversity hotspot in West Africa: the remaining forest fragments of the Upper Guinean Forest Belt, that once covered the entire West African coastal region. Today these forests – encompassing wet, moist and dry tropical types- survive mostly in protected areas and host hundreds of species, including rare and endemic trees and wildlife. The west coast is a region of fast changes due to multiple drivers, including climate, with recurrent droughts, raised temperatures, and desertification increase, and rapid population and infrastructures growth. Forest types and tree species monitoring is very important here, providing information on how forests respond and adapt to changes, and delivering data useful for biodiversity conservation and management. Each tree species has an optimal growth range: when the environmental conditions (e.g. temperature, canopy closure) change beyond certain thresholds, the composition of tree species also changes in the forest, as well as the biodiversity of the whole ecosystem. When hundreds of tree species are present, such as in tropical forests, is not feasible to monitor each one and species are aggregated into groups that show similarities in functional behavior.

Using advanced Earth Observation hyperspectral data, collected through an airborne survey in two Ghana National Parks (Ankasa and Bia), we were able to discriminate among different tree functional groups on the basis of the characteristics of their leaves and crowns, which are adapted to different solar illumination and other environmental conditions.

We classified three main groups: the Shadow Bearer (SB) tree species, which optimally growth in the lower and shadowed sub-canopy level; the Pioneer (PION) species, which need direct sunlight and are the first to occupy open gaps in the forest; and the Non-Pioneer Light Demanding (NPLD) species, a group intermediate between the other two. The balance of these groups changes according to forest type and degradation level.

We then demonstrated that the new ESA Sentinel-2 satellites, which repeatedly acquire images with freely distributed data, can also accurately map these groups, being a useful tool to monitor the functional groups and their changes along time as a response to impacts. We propose the functional guilds mapping as an innovative approach to: (i) monitor compositional changes, especially with respect to the effects of global climate change on forests, and particularly in the tropical biome where the occurrence of hundreds of species prevents mapping activities at species level; (ii) improve the precision of forest inventories, for instance supporting the initial stratification of the inventory or using functional information coupled with field data as input in inferential models.




**Original publication**

Vaglio Laurin, G. V., Puletti, N., Hawthorne, W., Liesenberg, V., Corona, P., Papale, D., ... & Valentini, R. (2016). Discrimination of tropical forest types, dominant species, and mapping of functional guilds by hyperspectral and simulated multispectral Sentinel-2 data. *Remote Sensing of Environment*, *176*, 163-176. doi:10.1016/j.rse.2016.01.017.

# Older and more diverse forests are more stable in taking up carbon dioxide

Plants take up carbon dioxide ($CO_2$) from the atmosphere through photosynthesis. This “natural $CO_2$ pump” is the largest flux in the global carbon cycle and its intensity shapes the atmospheric concentrations of the greenhouse gas. The photosynthetic capacity of forests is highly dynamic as influenced by climate variability. A BACI study led by the Max Planck Institute for Biogeochemistry in Jena (Germany) and recently published in Nature Ecology and Evolution, gives new insights into the main mechanisms controlling the photosynthetic capacity of forest year-to-year.

The study compiled data from 50 forests globally distributed across different climatic regions and combined a variety of different data sources, including ecosystem-atmosphere $CO_2$ fluxes from a global network of measurement sites, climate data, biodiversity information, nutrient availability, forest age, and other properties derived from satellite data, such as forest height and tree cover. The scientists then tried to identify the main factors that buffer the annual variations of photosynthetic capacity.

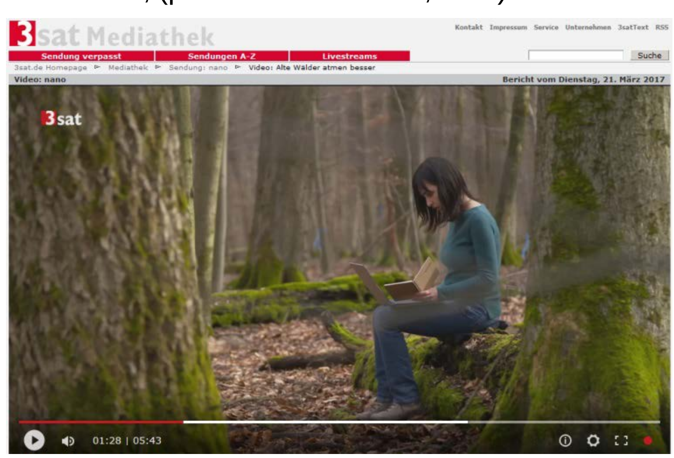
“*The year to year variability is driven by climate but the magnitude of the year to year variability decreases in older and more diverse forests. We conclude that the stability of photosynthetic capacity is mostly controlled by forest age and species richness*”, says Talie Musavi leader of the research team. This finding can be read as a scientific call to preserving old forests and their species diversity in order to stabilize their functionality.

Old forest in Hessen, Germany
(Picture by Achim Lueckemeyer/pixelio.de)

**Original publication**

Talie Musavi, Mirco Migliavacca, Markus Reichstein, Jens Kattge, Christian Wirth, T. Andrew Black, Ivan Janssens, Alexander Knohl, Denis Loustau, Olivier Roupsard, Andrej Varlagin, Serge Rambal, Alessandro Cescatti, Damiano Gianelle, Hiroaki Kondo, Rijan Tamrakar and Miguel D. Mahecha. (2017). Stand age and species richness dampen interannual variation of ecosystem-level photosynthetic capacity. Nature Ecology & Evolution. doi:10.1038/s41559-016-0048

**TV:** 3sat-nano: **Alte Wälder atmen besser**, short film with Talie Musavi on older and diverse forests and climate variability, Link to 3sat mediathek, (published March 21,2017)



# Water as the underlying driver of the Earth's carbon cycle

Extreme dry periods alternating with rainy seasons characterize the savanna ecosystems. Savanna in East Africa. (Copyright Ulla Trampert / pixelio.de)

Current climate change is characterized by rising atmospheric carbon dioxide ($CO_2$) concentrations and concomitant atmospheric warming. However, the annual growth rate of $CO_2$ which has been measured in the atmosphere for several decades varies largely from year to year. These variations originate primarily from fluctuations in carbon uptake by land ecosystem, rather than by oceans or from alterations in anthropogenic emissions. How this carbon sink is controlled and will develop in the future is uncertain. Discussions on whether temperature or water availability is driving the strength of the land carbon sink, and thus its variations, have been highly controversial. According to current knowledge, the year to year changes of the carbon balance seem to be related to tropical temperature when looking at the global scale. However, other studies find that the largest carbon balance variability is seen in wide-spread water-limited regions.

New clues on how the land carbon sink is regulated have been now revealed by researchers led by the Max Plank Institute for Biogeochemistry in Jena, Germany.

In a systematic modelling approach, Martin Jung and his collages applied empirical and process-based models, to analyse from small areas up to the global surface the effect of temperature and water availability variations on carbon exchange between the atmosphere and the terrestrial biosphere. The results, published in the journal *Nature*, explain now this apparent discrepancy.

At local scales, water availability is the dominant cause of the year to year variability of both $CO_2$ uptake in plants by photosynthesis, measured as gross primary productivity (GPP), and $CO_2$ release from plants and microbes, measured as terrestrial ecosystem respiration (TER).

In sum, the net ecosystem exchange of $CO_2$ between the atmosphere and the terrestrial biosphere, termed NEE, is also determined by water availability. However, at the global scale, variability in the temporal net exchange is mostly driven by temperature fluctuations. These apparent contradictory results can be explained by looking at the different spatial and temporal variations of the biosphere-atmosphere interactions.

“There are two compensatory effects of water availability: firstly, at the local scale, temporal water driven GPP and TER variations compensate each other. E.g., very dry weather conditions lead to diminished water availability and concomitantly reduced photosynthetic $CO_2$ fixation, but also to reduced amounts of respired $CO_2$ . In sum, the effects partially compensate each other. “Secondly, on a global scale, anomalies of water availability also compensate in space. If it is very dray in one part of the world, it is often very wet in another region, thus globally water-controlled anomalies in net carbon exchange outweigh in space.

**Original publication**

Jung et *al*., (2017). Compensatory water effects link yearly global land $CO_2$ sink changes to temperature. Nature, 541, 516-520. doi:10.1038/nature20780.

# Vegetation greening in Europe

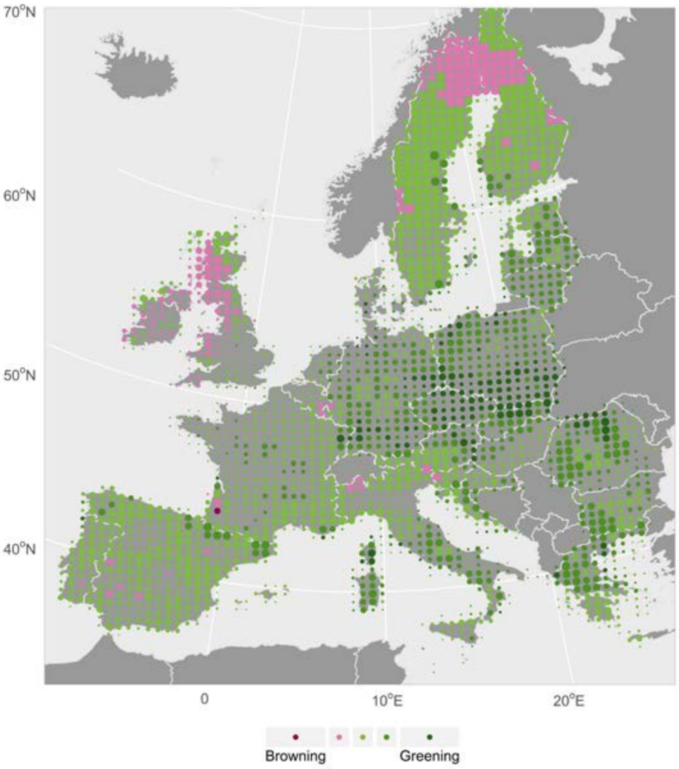
Robert Buitenwerf, Signe Normand, Anne Mimet, Brody Sandel and Jens-Christian Svenning
Aarhus University

For our study we were interested in "greening" of the land surface, which has been detected throughout the northern hemisphere since at least the 1980s. The greening is caused by an accumulation of vegetation, which in turn has been attributed to human impacts on the global environment. For example, the emission of carbon dioxide ($CO_2$) has caused global warming, which stimulates plant growth in colder regions. In addition to warming, $CO_2$ also directly stimulates plant growth. During the process of photosynthesis, plants use light energy to convert $CO_2$ into sugar molecules, which form the building blocks of plant tissue. Although warming and $CO_2$ explain an important part of the observed greening, in some areas the greening signal is larger than expected based on just these variables. This is the case in Europe.

To understand the additional processes that cause greening, we used new satellite data with a finer resolution than previous studies. The fine resolution allowed us to very precisely pinpoint areas that had greened significantly since the year 2000. Our results indicate substantial greening throughout most parts of Europe, regardless of the type of vegetation. This means that greening is not restricted to forest areas, but also occurs in more open habitat such as shrubland and grassland. Increases in grassland are particularly interesting, because it suggests that woody plants are invading grassland.

The explanation for this observation becomes clear when we looked at the spatial pattern of greening. We noticed particularly high rates in parts of Eastern Europe and in mountainous regions of southern Europe. These areas have seen large tracts of farmland being abandoned since the 1990s, after the Soviet Union collapsed (Eastern Europe) and the EU reformed agricultural subsidies, forcing less productive (mountainous and dry) regions out of production. The abandonment of farmland has started the process of natural succession, where plant species are gradually being replaced by more competitive species. The consequence is that cropland and grazing land become overgrown by woody shrubs and eventually return to forest.

The woody encroachment observed throughout Europe is likely to affect biodiversity, for example by suppressing species that thrive in (partly) open landscapes. In a follow-up study within BACI we will look into the consequences of environmental change on biodiversity, but also into the role of biodiversity in buffering the response of ecosystems to environmental shocks.




Vegetation "greening" in Europe since 2000. The size of the dots is proportional to the area of semi-natural vegetation in a location.

# libmaxdiv: Maximally Divergent Intervals for Anomaly Detection

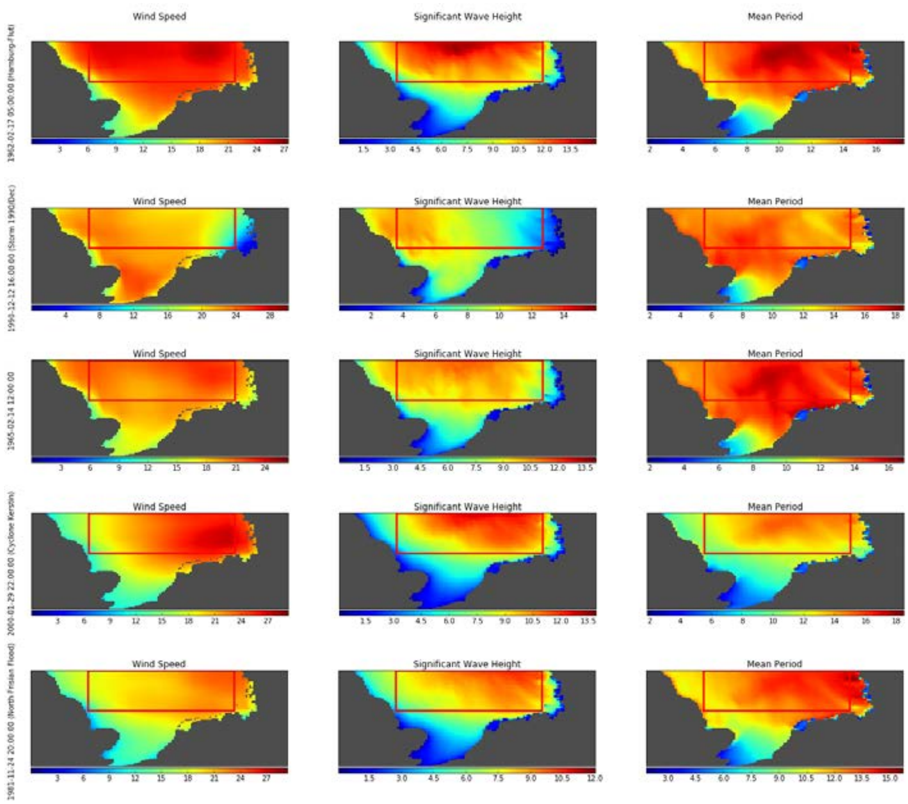
The detection of abnormal events in any kind of data can help us to understand the system and the relations between the variables involved. Automated methods for anomaly detection are specially important nowadays, where huge amounts of data are available in several domains like environmental applications.

Within this framework we have developed an algorithm to detect abnormal intervals within multivariate time series. This algorithm, based on a divergence criteria, allow us to detect those intervals that differ most from the rest of the time series.

libmaxdiv is a library implemented in c++ but that can be run from any other programming language. The library can handle non-spatial time series and also spatio-temporal data.

For non-spatial, purely temporal time series, we have developed a graphical user interface (GUI) that facilitates the experimentation with any kind of data without having to write a single line of code.

We have tested the algorithm with very different kind of data, ranging from environmental data to videos or even text passages. In the plot below, there are shown the Top 5 events detected in wind and wave parameters (significant wave height, wind speed and mean period) at the North Sea, where four of them correspond to historical storms recorded. More information about the library, the codes as well as a detailed installation and user guide can be found at: https://cvjena.github.io/libmaxdiv/.




**Original publication**

Rodner, E., Barz, B., Guanche, Y., Flach, M., Mahecha, M. D., Bodesheim, P., Reichstein, M., Denzler, J. (2016). Maximally divergent intervals for anomaly detection. In ICML 2016 Anomaly Detection Workshop. doi:10.17871/BACI_ICML2016_Rodner.

# News and upcomming events

## BACI Workshop on regional validation and socio-economic dimension

The 20 and 21 March 2017 in Vienna, Austria, the BACI project organized a special workshop on regional validation and socio-economic dimension. *More information on our website*.

## "BACI: Essential Ecosystem Variables and ecosystem functional properties" at the KOSMOS Workshop

On the 30th-31st of March 2017, the Geomatics Lab hosted the Workshop "Remote Sensing of Ecosystem Functioning", bringing together a group of researchers from GEO BON (Group on Earth Observations Biodiversity Observation Network) Ecosystem Function Working Group. M. Mahecha presented for BACI: Essential Ecosystem Variables and ecosystem functional properties. *More information on our website*.


## European Geosciences Union General Assembly 2017

Relevant BACI contributions to the EGU General Assembly 23 – 28 April 2017, Vienna, Austria:

- Upscaling diurnal cycles of carbon fluxes. P. Bodesheim et *al., More info here*
- Detecting Biosphere anomalies hotspots. Y. Guanche-Garcia et *al., More info here*
- The magnitude of interannual variability of ecosystem photosynthetic capacity is controled by stand age and biodiversity. T.Musavi et *al., More info here*


## BACI Workshop on Environmental Informatic Challenges

The BACI Workshop on Environmental Informatic Challenges will take place from 19 to 21 June in Jena, Germany. The overall aim of the event is to bring together experts from environmental sciences and from computer science to identify the challenges of combining both disciplines.

During 3 days we will combine key note talks with break-out sessions. Additionally we will dedicate the last day specifically to BACI-related questions and issues therefore we encourage all the partners from the consortium to come to Jena. The opportunity of physically meeting during three days will be certainly helpful to organize our next review meeting in autumn and also the near future deliverables. *More information on our website*.