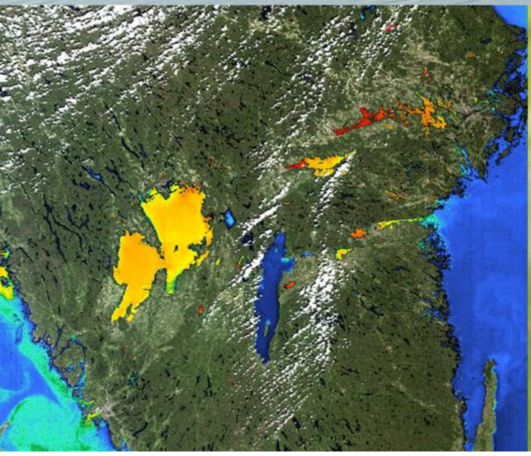


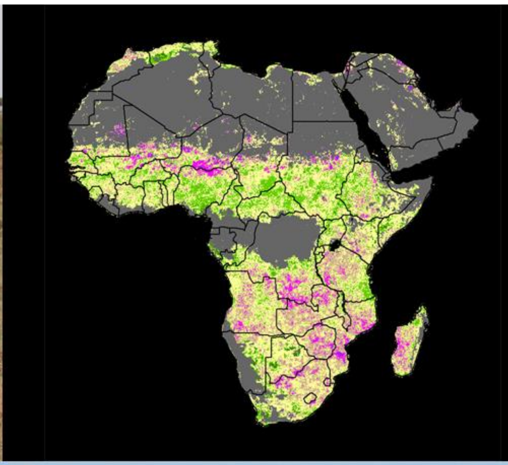
diversity
drylands

diversity
inland waters

DIVERSITY II

Supporting the Convention on Biological Diversity

A project of the European Space Agency – Data User Element

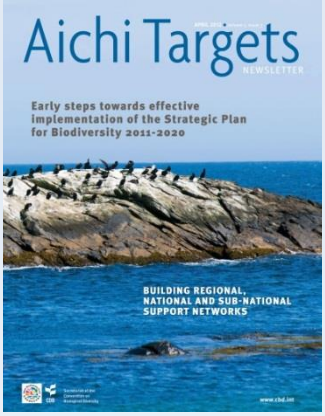


Diversity II Executive Summary

Motivation

The Convention on Biological Diversity and the Aichi Biodiversity Targets

Biological diversity (biodiversity) provides resources and ecosystem services upon which mankind is dependent. Since long, it is on the decline globally. The ongoing loss of biodiversity is a threat to human well-being, security and economic growth. Reversing these trends is a major environmental challenge facing the global community. The first global step to accept this challenge was the Convention on Biological Diversity (CBD). It was opened for signature at the UN Conference on Environment and Development in Rio de Janeiro in 1992 and entered into force in 1993. Since then, biodiversity conservation has developed into a key political issue and the CBD has become a major instrument for the conservation of biodiversity, both at national and international levels. At present, the Convention has 193 Parties, including the European Union.



Aichi Targets
NEWSLETTER

Early steps towards effective implementation of the Strategic Plan for Biodiversity 2011-2020

BUILDING REGIONAL, NATIONAL AND SUB-NATIONAL SUPPORT NETWORKS

www.cbd.int

The objectives of the CBD are “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources”. The Convention translates these objectives into binding commitments in a number of substantive provisions.

In 2010 the 10th Conference of Parties contributing to the CBD adopted a Strategic Plan for Biodiversity for the 2011-2020 period. This Plan is now the overarching framework on biodiversity for the UN, other international organizations and national governments. The plan is constructed around 20 headline targets, also called the Aichi Biodiversity Targets.

One of the 5 strategic goals of the CBD is to “Enhance implementation through participatory planning, knowledge management and capacity building“. This is addressed by target 17: “By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of loss, are improved, widely shared and transferred, and applied.” The European Space Agency, through its Data User Element and together with key users from the CBD, has seen the potential role of Earth Observations (EO) to meet this target, particularly in regards to status and trends of biodiversity. Two ecosystems, drylands and inland waters, were identified which are of critical importance as expressed in target 11: “By 2020, at least 17 per cent of terrestrial and inland water … especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed … protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.”

Project Objectives

In order to contribute to the assessment and monitoring of the Aichi 2020 Biodiversity Targets of the CBD, the objectives of the Diversity II Project are to provide for selected key parameters, status maps, associated change maps, status indicators and trend indicators aggregated at different administrative and biome level. These key parameters are:

For Inland Waters

- Availability of freshwater through water extent and water level
- Quality of freshwater, reflected by its water constituents such as chlorophyll-α and/or suspended matter concentration, as well as by its temperature

The parameters were compiled for 350 large lakes worldwide, using the full ENVISAT data archive acquired between 2002 and 2012.

For Drylands and Sub-Humid Lands

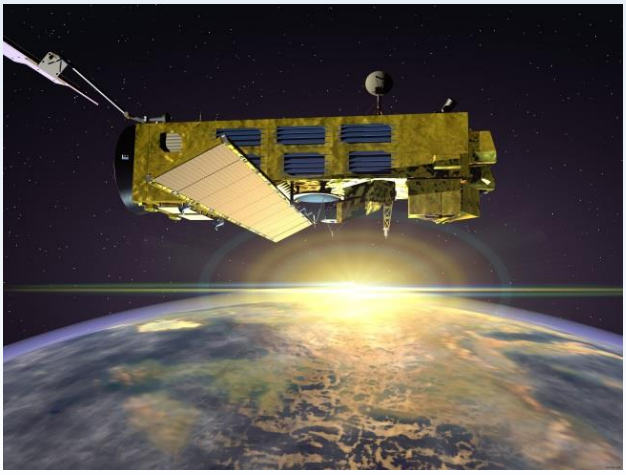
- Net Primary Productivity (NPP), through the fraction of absorbed photosynthetically available radiation (fAPAR) and the Normalized Difference Vegetation Index (NDVI) as indices on the vegetative/ biomass productivity
- Rain use efficiency (RUE) as an index for the land/ vegetation conditions (status and degradation)

The parameters were compiled for 22 large dryland areas worldwide, using the full ENVISAT data archive acquired between 2002 and 2012.

Earth Observation Technology

The primary data sources for the Diversity II Project are Earth Observation data from the ESA ENVISAT satellite, specifically from the MERIS, AATSR, RA-2 and ASAR instruments. Among these, the MERIS Full Resolution (300 m) data were the most important dataset in view of the abovementioned water quality and terrestrial vegetation parameters.

Diversity II also assessed and verified how Earth observation can support the CBD Strategic Plan throughout the next decades, by adapting the selected approaches to long-term available Sentinel data and data by other Earth observation satellites.



Project Plan

The Diversity II project started in September 2012 and lasted 3 years. The first phase was dedicated to a requirements consolidation, algorithm selection and development phase. The second phase was focused on product generation and biodiversity indicator demonstration. The project has been organized along the following key activities:

Linking Biodiversity Users and EO Experts

Professor Per Wramner has been leading the Diversity User Bureau (DUB). The DUB coordinated the Diversity User Group, a cross cutting activity which was running in parallel to the technical tasks and focussed on all user interactions in one place. Based on his long term involvement in the CBD process and – on the other hand – his technical expertise, Per facilitated the dialogue between the biodiversity users and the EO experts of the team, making sure that the most suitable indicators were generated, and keeping the users closely attached to the project.

Selection of Best Algorithms

Inland waters are subject to complex and geographically highly heterogeneous optical properties, especially with regard to the phytoplankton pigments present in waters of different trophic state. A variety of algorithms were developed in the past years to deal with these optical properties. Diversity II was the first initiative to provide inland water quality products from remote sensing at global scale, and thus to identify the most suitable algorithms. This selection was carried out with in situ monitoring measurements in 45 lakes as reference, and included more than 100 combinations of algorithms that are publicly available. A dual approach using different methods for oligotrophic and eutrophic waters was finally applied, in combination with an optical water type classification as basis for selection.

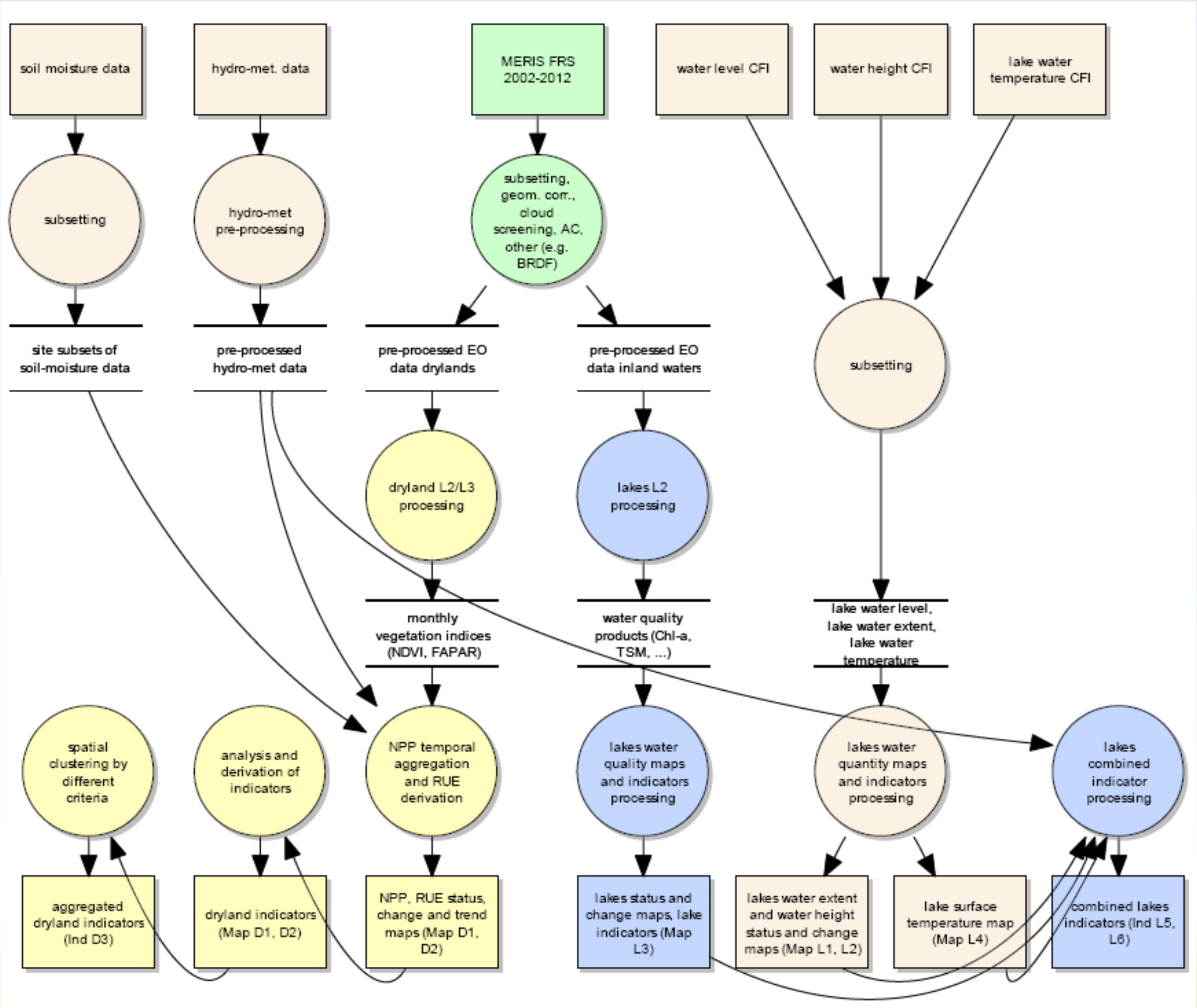
Approaches for the assessment of dryland conditions and biodiversity based on Earth observation depend strongly on the geographic scale and related ground information. Global and continental assessments often analyse time series data of above ground green biomass, which are estimated for fixed increments of time (most typically decades, months, years) using EO derived vegetation indices or bio-physical indices. Most commonly, the NDVI is used as a proxy for NPP. The project referred to NDVI based heritage methods with regard to monitoring continuity, but the main work was based on an advanced index, the fAPAR. In addition, efficiency indices such as Rain Use Efficiency served to relate NPP indices to the major driving forces.

Software and Production

The software to generate the Diversity II products is complex and has to work on very large amounts of data efficiently. The processing chain includes steps from child product generation, merging of data from different sensors and sources, cloud screening, atmospheric correction, bio-optical inversions, indices calculation, spatial and temporal integration, change detection, indicator calculation, up to the final map generation. The production involves processing of more than 100 terabytes of input data. Most applied algorithms were developed for the ESA BEAM toolbox and the ERDAS Spatial Modeler.

Production comprised of the following steps:

- Step 1) Prototype products for 4 lakes and 3 drylands, generated with different algorithms for algorithm intercomparison
- Step 2) Prototype products for 10 lakes and 5 drylands, generated with the finally selected proposed algorithms
- Step 3) Qualified products for 10 lakes and 5 drylands, generated with the final algorithms, for qualification of the production system
- Step 4) All products (350 lakes and 22 drylands) for assessment by users



Validation

Validation is a key to acceptance of the products by the users, and was done at two levels in order to ensure the validity of the basic parameters, as well as the biodiversity relevance of all derivatives. The basic EO parameters, i.e. for land the surface reflectance and the vegetation indices, and for water the water leaving reflectance, IOPs, Chlorophyll-α concentration, Total Suspended Matter (TSM) and Coloured Dissolved Organic Matter (CDOM) concentration, turbidity and Secchi depth, were validated using in-situ data and international validation standards, such as the MAVT protocol. Subsequently, a detailed validation of the final products compared to biodiversity reference data was performed by using multi-scale species database.

Communication and Product Dissemination

The WebPortal (www.diversity2.info) provides more detailed project information, all public project deliverables and access to the final inland waters and drylands products. A WebGIS interface was implemented for browsing product previews, and handbooks are provided that include tutorials for working with the Diversity products. In addition, biodiversity stories and booklets are available that provide detailed material about on value of the EO products for specific sites.

Preparing the Future

The potential of new sensors to continue the ENVISAT based Diversity II work was assessed, including Sentinel-2 MSI, Sentinel-3 OLCI, and Landsat-8 OLI for inland waters, as well as SPOT Vegetation I/II and Proba-V for drylands. All these sensors have a potential to support the continuation of the ENVISAT time series, in particular Sentinel-3 that provides full continuity for MERIS and other ENVISAT instruments. The results of the study are documented in the Sentinel/Proba-V Adequacy Analysis report, one of the Diversity II deliveries.

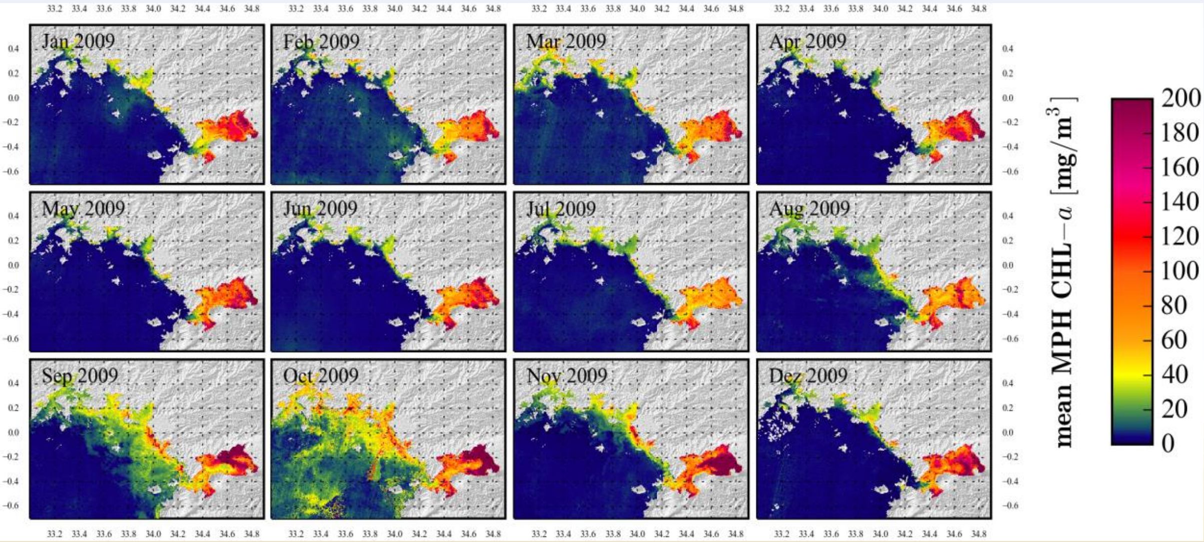
Diversity II Inland Water Products

The monthly, yearly and 9-year water quality products comprise of several indicators for eutrophication, physical disturbance and ecosystem state. Chlorophyll-a, TSM, CDOM, turbidity, and cyanobacteria and floating matter presence are provided in 300 m resolution map format for all 350 lakes. For 298 lakes, Lake Surface Water Temperature (LSWT, adopted from the ARC Lake project) is included at a reduced spatial resolution of 0.05°, and water level (adopted from LEGOS Hydroweb) time series are given in separate tables for 103 lakes. Supplemented with meta datasets and Python scripts for post processing, the package aims to provide users with maximum information content and a basis for custom analyses.

Water Quality Maps

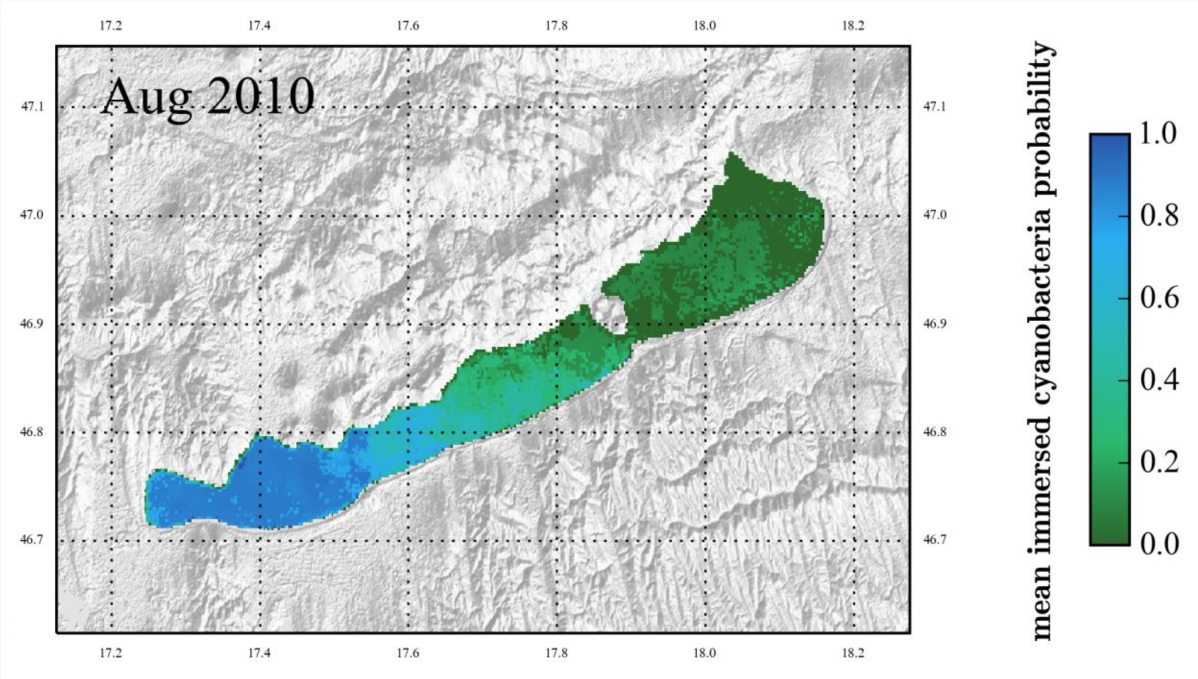
The Diversity II Inland Water products comprise several water quality parameters, such as chlorophyll-*a,* a widely used indicator for eutrophication, which refers to the increase in primary productivity in aquatic ecosystems due to increasing availability of nutrients, mainly phosphates. Originating from detergents, fertilizer or untreated sewage, increasing phosphate levels are a widespread issue in densely populated or intensively cultivated areas. Eutrophication affects the abundance and composition of phytoplankton directly, and can lead to reoccurring and potentially toxic cyanobacteria blooms. Indirect consequences include decreasing transparency and corresponding implications for benthic habitats, modifications of the food chain and higher-level species composition. The Diversity II products provide an unparalleled amount of spatio-temporal information on chlorophyll-*a* variations worldwide, indicating eutrophication hot spots as well as minor implications that are hard to identify with conventional sampling techniques. In addition, relative observation frequencies of cyanobacteria or floating matter are provided, as additional ecosystem indicators for lakes at intermediate to high trophic levels.

At advanced stages, eutrophication can cause deep water oxygen depletion and hypoxia. Vertical mixing processes are vital to prevent hypoxia and sustain deep water oxygen renewal, but in mid latitudes they depend on sufficient cooling and wind forcing during the winter months. Lake Surface Water Temperature (LSWT) can be used as a proxy to monitor winter cooling, and thus to identify years where vertical circulation and oxygen renewal are insufficient. For example in the case of Lake Biwa, the Diversity II products' highest winter LSWT in 2007 coincides with a large fish kill observed later in the year.

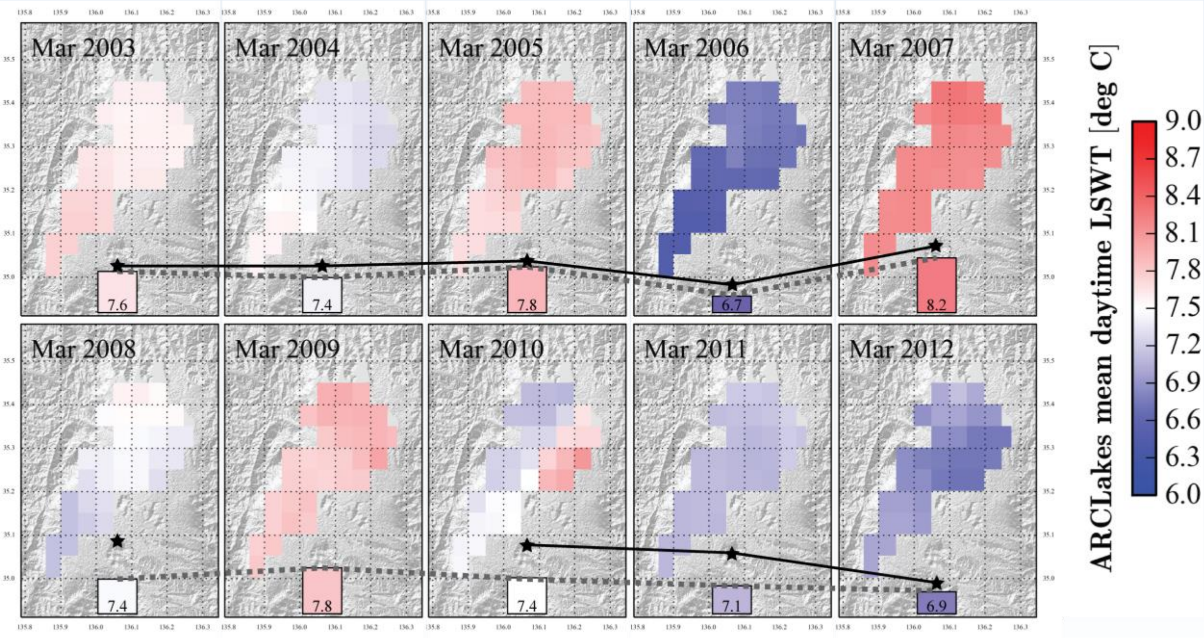


The annual course of monthly Chlorophyll-a in the north-east of Lake Victoria in 2009 depicts the Winam Gulf in the very east, which receives most of the terrestrial inflow into the lake, and increased productivity even in pelagic areas in

September and October (example from the Lake Victoria biodiversity story, available at www.diversity2.info).



Cyanobacteria dominance observed in Lake Balaton, Hungary, in August 2010. The dominance is identified by using optical features in individual observations, the probability represented by the Diversity II products corresponds to the relative number of positive observations per aggregation period (e.g. month).



Minimum monthly mean Lake Surface Water Temperatures in Lake Biwa, Japan. Labelled bars and the dotted line indicate spatial LSWT averages, the solid line represents in situ temperature measurements at 1 m depth by the Univ. Tsukuba (example from the Lake Biwa biodiversity story, available at www.diversity2.info).

Full list of water quality parameters available from Diversity II

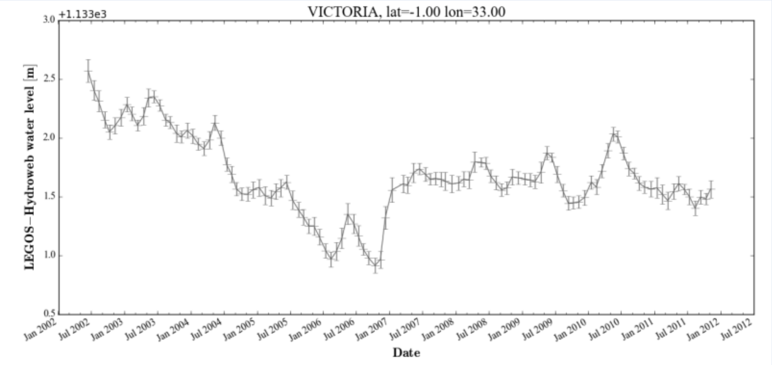
Parameter	Content
Eutrophication indicators	
Chlorophyll-α (MPH) chl_mph_mean, chl_mph_sigma	Average and standard deviation of the chlorophyll-α concentration [mg/m^3]. **Recommended for eutrophic and turbid lakes, see "optical water types" below.**
Chlorophyll-α (FUB) chl_fub_mean, chl_fub_sigma	Average and standard deviation of the chlorophyll-α concentration [mg/m^3]. **Recommended for clear and absorbing waters, see "optical water types" below.**
Lake surface water temperature lswt_d_mean, lswt_d_sigma, lswt_n _mean, lswt_n_sigma	Day- and night-time acquired, DINEOF-interpolated lake surface water temperatures, from ARC Lake v.3 dataset. In the yearly and 9-year bins, the bands are included as *_mean and *_sigma
Physical disturbance and contamination indicators	
Total suspended matter tsm_cc_mean, tsm_cc_sigma	Average and standard deviation of the total suspended matter concentration [g/m^3].
Turbidity turbidity_cc_mean, turbidity_cc_sigma	Average and standard deviation of the turbidity [FNU]
Coloured dissolved organic matter cdom_fub_mean, cdom_fub_sigma	Average and standard deviation of the absorption by coloured dissolved organic matter at 443 nm [m-1].
Ecosystem indicators	
Immersed cyanobacteria dominated water immersed_cyanobacteria_mean	The portion of observations where the water's optical properties are dominated by immersed cyanobacteria, using an arithmetic classification scheme.
Floating cyanobacteria dominated water floating_cyanobacteria_mean	The portion of observations where the water's optical properties are dominated by floating cyanobacteria, using an arithmetic classification scheme.
Floating vegetation dominated water floating_vegetation_mean	The portion of observations where the water's optical properties are dominated by floating vegetation, using an arithmetic classification scheme.
Metadata layers	
Number of observations num_obs	Number of aggregated MERIS observations for each binning period. Empty records correspond to data gaps, ice coverage or cloudiness. Mathematically, each yearly product is the average of 12 monthly products, not of the individual observations quantified here. The same applies for 9-year products, which are averages of the 9 individual years.
Optical water type owt_dominant_class_cc_majority_class	A classification in 7 optical water types defined specifically for inland waters. Class 1-3 represent clear to absorption-dominated waters, class 4-5 represent highly productive waters, and class 6-7 are for high levels of turbidity. It is recommended to use Chlorophyll-*a* [FUB] products for classes 1-3, and Chlorophyll-*a* [MPH] for classes 4-7.
Shallow shallow	A binary mask of areas where significant benthic reflectance is expected due to constantly high signals in visible wavelengths.
Extent extent	A binary mask of the lake's maximum extent between June 2002 and April 2011.

Water Level Time Series

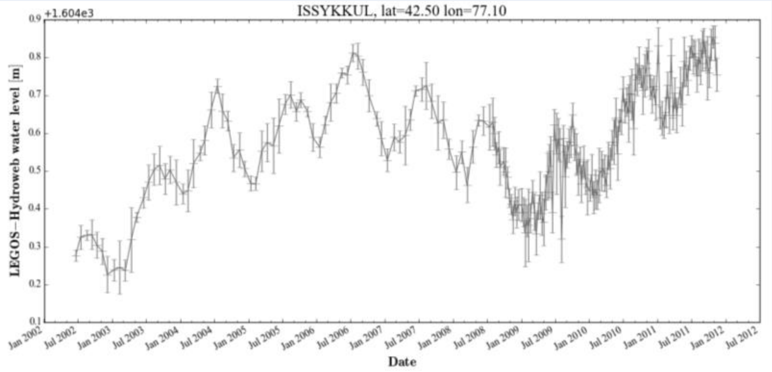
Water level variations occur at various temporal scales. Short-term increases can be related to extraordinary precipitation events, and correspondingly increased runoff and nutrient loads, and can cause severe implications such as in Winam Gulf, Lake Victoria, 2007. Like for previous ENSO related rainfalls, surface erosion during the rainfalls is considered to have caused a severe water hyacinth proliferation event in subsequent months.

At longer intervals, trends in water level or its seasonal course are related to climatic changes, changes in water management and in particular water diversion, which are serious threats to sustainable ecosystem maintenance especially in endorheic lakes like Lake Issykkul.

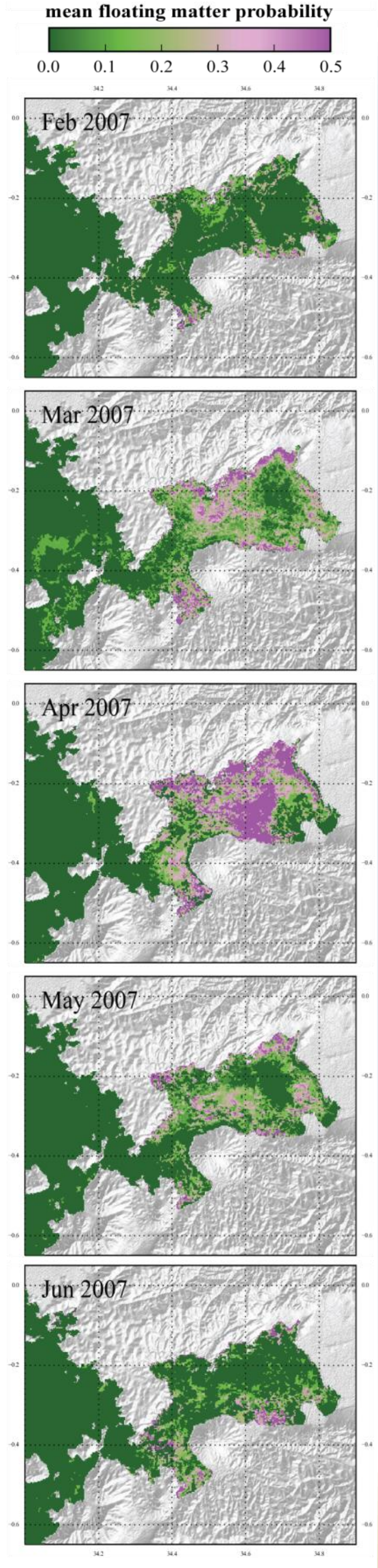
Radar altimetry derived water level variations from the LEGOS Hydroweb database complement the Diversity II water quality parameters with quantity variations. Water level is provided as individual observations in tables and time series plots.



Water level variations in Lake Victoria, 2002-2012.



Water level variations in Lake Issykkul (Kyrgyzstan), 2002-2012.

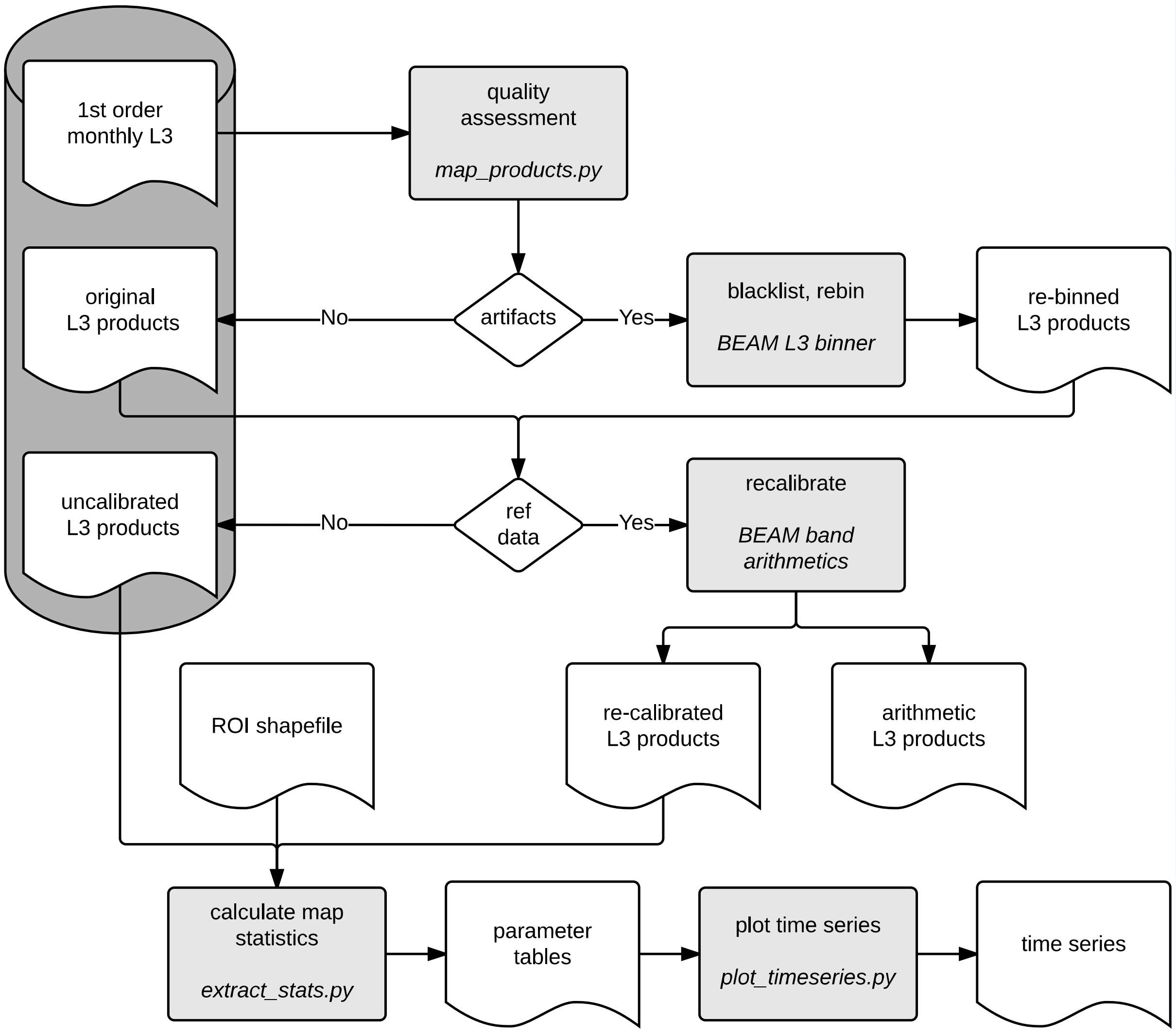


Water hyacinth observations in Winam Gulf, Lake Victoria, spring 2007.

Product Customization

The 350 inland waters considered in Diversity II differ widely in altitude, latitude, depth or catchment morphology and land use to name just a few. Accordingly heterogeneous is the relevance of the provided water quality and quantity parameters. Against this background, and following corresponding user recommendations collected in the course of the project, it was decided to provide the basic temporally aggregated products, and thus the maximum information content, but leave further aggregation towards higher level indicators to the data users.

Several Python scripts and workflow descriptions are provided that shall help the users in executing generic post processing tasks and simplify the creation of higher level indicators. They facilitate map representations for custom perimeters and using different base maps, re-binning of annual and 9-year products, calibration with in situ measurements, the extraction of spatial statistics and time series plots.



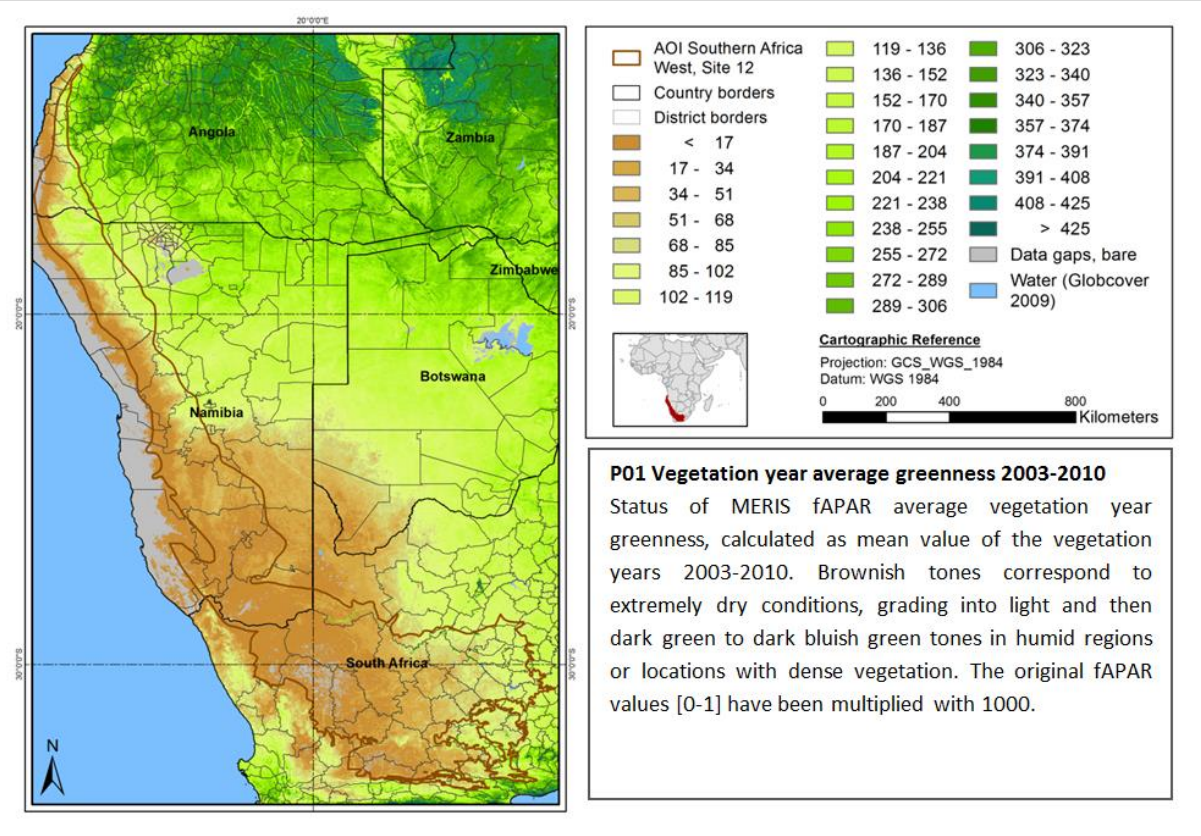
Example workflow combining all provided scripts and workflows to derive quality controlled and lake-specifically calibrated products and time series from the original Diversity II products. Please refer to the Product User Handbook for Inland Waters at http://www.diversity2.info/products/documents/ for more details.

Diversity II Drylands Products

A total of 43 first order, seven second order and three phenology products was generated per test site, amounting to 1166 map products overall. The second order indicators are derivatives of the first order indicators and show status, changes and trends of the most essential first order indicators, such as NPP (proxy) trends versus rainfall trends. All products are thematic maps with worldwide uniform discrete classes and thus directly comparable across the regions.

Drylands First Order Indicators

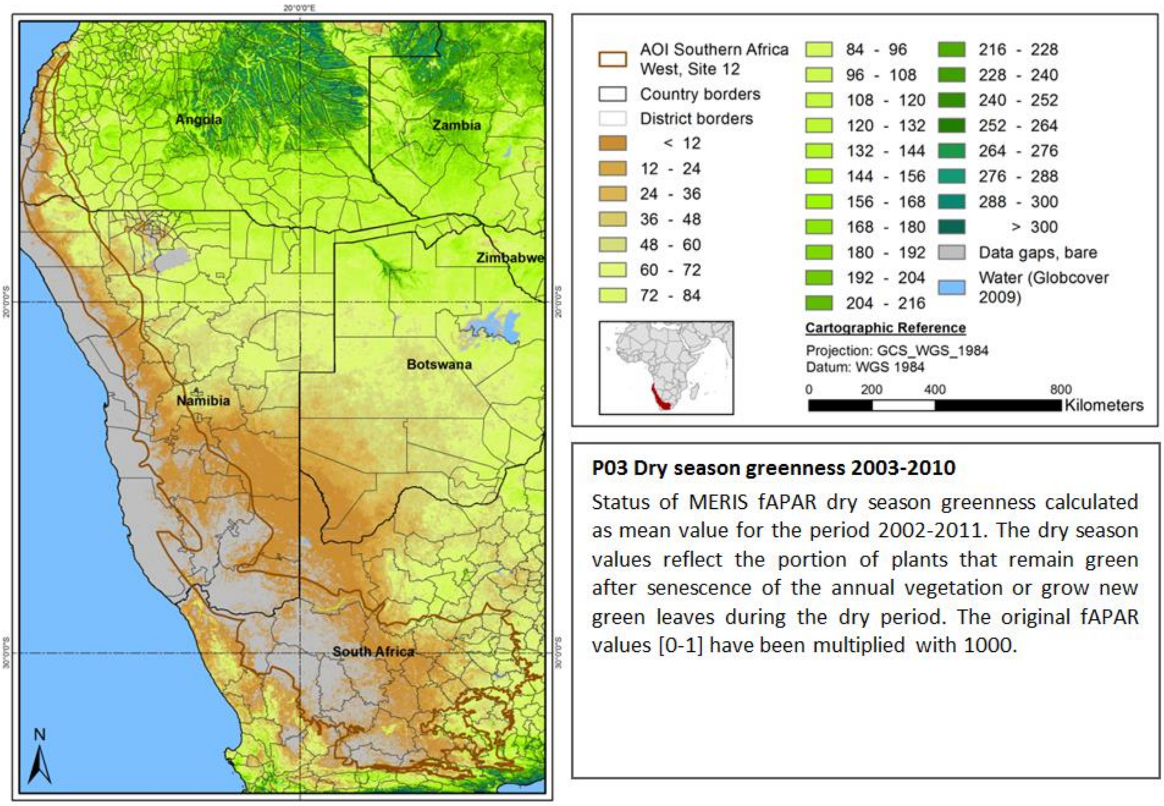
The first order indicators show averages, changes and trends for vegetation greenness, rainfall, soil moisture, Rain Use Efficiency (RUE), and Soil Moisture Use Efficiency (SMUE). They reflect the vegetation productivity – both standing biomass and the yearly increase during the wet seasons, vegetation decline/increase and potential degradation, and show the high variability and trends of vegetation greenness.



P01 Vegetation year average greenness 2003-2010

Status of MERIS fAPAR average vegetation year greenness, calculated as mean value of the vegetation years 2003-2010. Brownish tones correspond to extremely dry conditions, grading into light and then dark green to dark bluish green tones in humid regions or locations with dense vegetation. The original fAPAR values [0-1] have been multiplied with 1000.

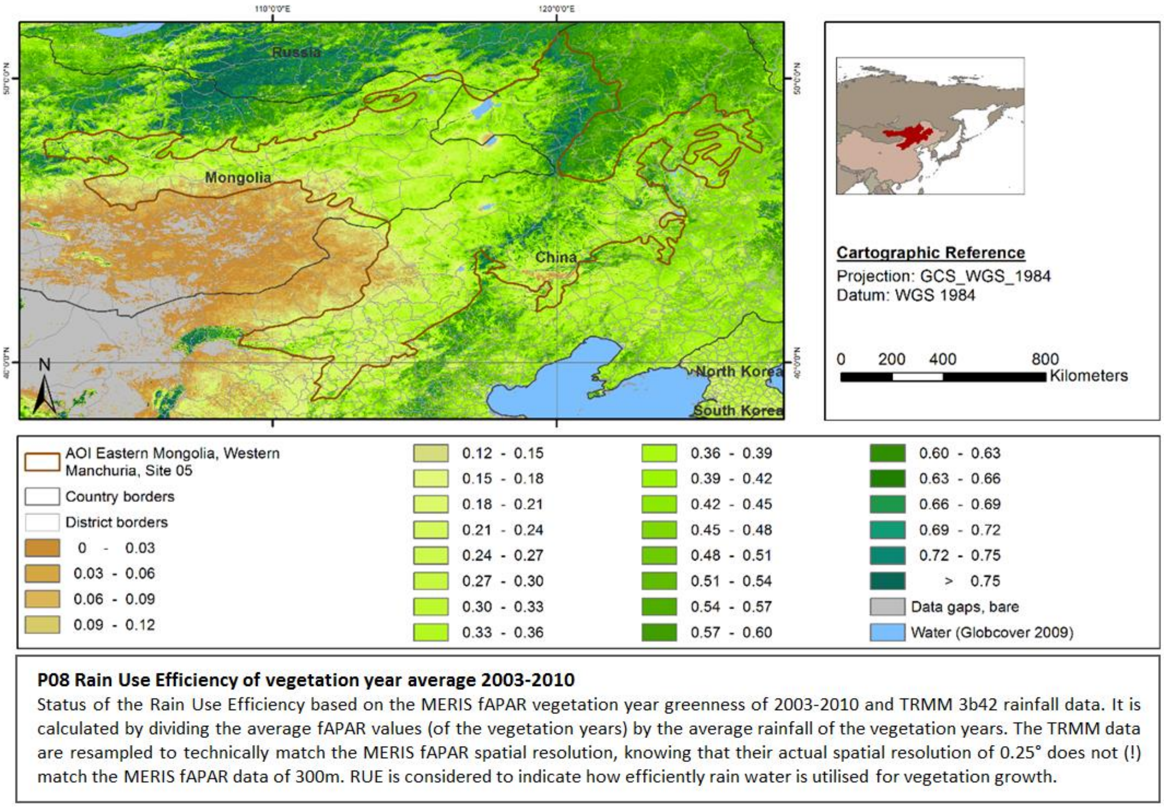
First order indicator example for the site Southern Africa West depicting the average vegetation year greenness in 2003-2010.



P03 Dry season greenness 2003-2010

Status of MERIS fAPAR dry season greenness calculated as mean value for the period 2002-2011. The dry season values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period. The original fAPAR values [0-1] have been multiplied with 1000.

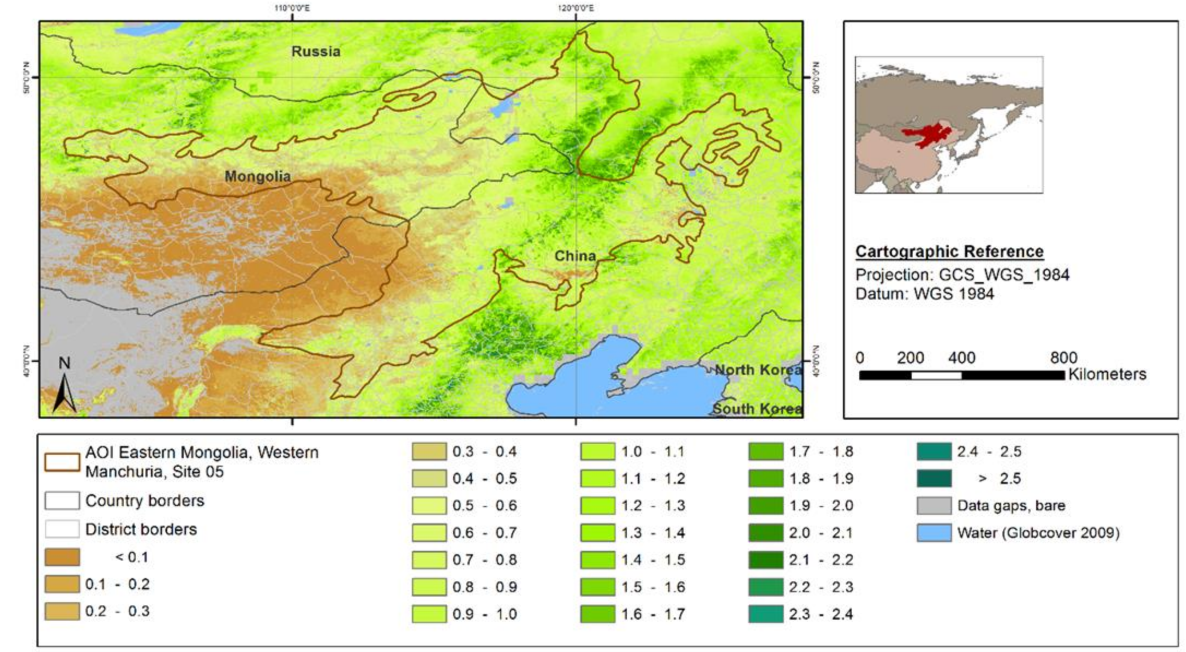
First order indicator example for the site Southern Africa West depicting the average dry season greenness in 2003-2010.



P08 Rain Use Efficiency of vegetation year average 2003-2010

Status of the Rain Use Efficiency based on the MERIS fAPAR vegetation year greenness of 2003-2010 and TRMM 3b42 rainfall data. It is calculated by dividing the average fAPAR values (of the vegetation years) by the average rainfall of the vegetation years. The TRMM data are resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the MERIS fAPAR data of 300m. RUE is considered to indicate how efficiently rain water is utilised for vegetation growth.

First order indicator example for the site Eastern Mongolia/Western Manchuria, depicting average rain use efficiency for the vegetation years 2003-2010.



P17 Soil Moisture Use Efficiency of vegetation year average 2003-2010

Status of the Soil Moisture Use Efficiency based on the MERIS fAPAR vegetation year greenness of 2003-2010 and CCI soil moisture data. It is calculated by dividing the average fAPAR values (of the vegetation years) by the average soil moisture of the vegetation years. The SM data are resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the MERIS fAPAR data of 300m. SMUE is considered to indicate how efficiently soil moisture is utilised for vegetation growth. The original SM values reach from 0 to 1 and have been stretched from 0 to 1000.

First order indicator example for the site Eastern Mongolia/Western Manchuria, depicting average rain use efficiency for the vegetation years 2003-2010.

Summary table of dryland first order indicators

Phenological integration period	[Numbers] and Types of Indicators
Parameter: MERIS fAPAR	
Vegetation Year Full vegetation cycle starting at the local Start of Season and ending after the dry season	- [P1] Average of the mean fAPAR of the vegetation years 2003-2010 - [P4] Coefficient of variation in [%] of the yearly averages - [P33] Theil-Sen trend slope (p 0.1)
Cyclic Fraction The period of the green peaks of the vegetation cycles	- [P2] Average of the sum fAPAR of the vegetation years 2003-2010 - [P5] Coefficient of variation in [%] of the yearly sums - [P34] Theil-Sen trend slope (p 0.1)
Dry Season Season between the rainy seasons, in drylands usually with little or no vegetation growth	- [P3] Average of the mean fAPAR of the vegetation years 2003-2010 - [P6] Coefficient of variation in [%] of the yearly averages - [P35] Theil-Sen trend slope (p 0.1)
Parameter: RUE (Rain Use Efficiency) based on MERIS fAPAR and TRMM rainfall	
Vegetation Year Full vegetation cycle starting at the local Start of Season and ending after the dry season	- [P8] Average of the mean fAPAR of the vegetation years 2003-2010 - [P9] Coefficient of variation in [%] of the yearly averages - [P36] Theil-Sen trend slope (p 0.1)
Cyclic Fraction The period of the green peaks of the vegetation cycles	- [P10] Average of the sum fAPAR of the vegetation years 2003-2010 - [P11] Coefficient of variation in [%] of the yearly sums - [P37] Theil-Sen trend slope (p 0.1)
Dry Season Season between the rainy seasons, in drylands usually with little or no vegetation growth	- [P14] Average of the mean fAPAR of the vegetation years 2003-2010 - [P15] Coefficient of variation in [%] of the yearly averages - [P38] Theil-Sen trend slope (p 0.1)

Parameter: SMUE (Soil moisture use efficiency) based on MERIS fAPAR and CCI soil moisture	
Vegetation Year Full vegetation cycle starting at the local Start of Season and ending after the dry season	- [P17] Average of the mean fAPAR of the vegetation years 2003-2010 - [P18] Coefficient of variation in [%] of the yearly averages - [P39] Theil-Sen trend slope (p 0.1)
Cyclic Fraction The period of the green peaks of the vegetation cycles	- [P20] Average of the sum fAPAR of the vegetation years 2003-2010 - [P21] Coefficient of variation in [%] of the yearly sums - [P40] Theil-Sen trend slope (p 0.1)
Dry Season Season between the rainy seasons, in drylands usually with little or no vegetation growth	- [P23] Average of the mean fAPAR of the vegetation years 2003-2010 - [P24] Coefficient of variation in [%] of the yearly averages - [P41] Theil-Sen trend slope (p 0.1)
Parameter: TRMM Rainfall	
Vegetation Year Full vegetation cycle starting at the local Start of Season and ending after the dry season	- [P25] Average rainfall sum 2003-2010 - [P26] Coefficient of variation [%] of the yearly sums - [P42] Theil-Sen trend slope (p 0.1) - [P46] Epochal change 2003-2006 vs 2007-2010
Cyclic Fraction The period of the green peaks of the vegetation cycles	- [P27] Average rainfall sum 2003-2010 - [P28] Coefficient of variation [%] of the yearly sums - [P43] Theil-Sen trend slope (p 0.1) - [P47] Epochal change 2003-2006 vs 2007-2010
Parameter: CCI Soil Moisture	
Vegetation Year Full vegetation cycle starting at the local Start of Season and ending after the dry season	- [P29] Average soil moisture 2003-2010 - [P30] Coefficient of variation [%] of the yearly averages - [P44] Theil-Sen trend slope (p 0.1) - [P48] Epochal change 2003-2006 vs 2007-2010
Cyclic Fraction The period of the green peaks of the vegetation cycles	- [P31] Average soil moisture 2003-2010 - [P32] Coefficient of variation [%] of the yearly averages - [P45] Theil-Sen trend slope (p 0.1) - [P49] Epochal change 2003-2006 vs 2007-2010

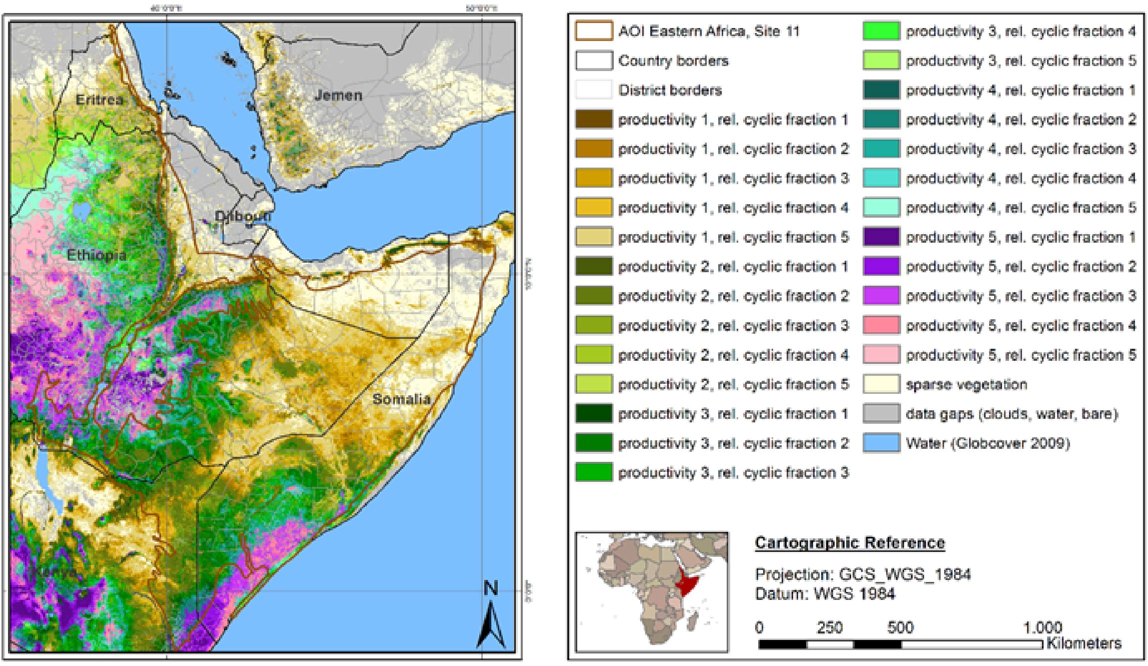
Drylands Second Order Indicators

Three types of second order products were generated, namely ecosystem functional types (called “Functional Classes”), seasonal trend relations, and the synoptic presentation of NPP proxy and rainfall trends.

“Functional Classes” [P50] combines yearly vegetation productivity and the quotient of cyclic vegetation and yearly vegetation. This indicator represents a functional classification of vegetation productivity and basic type: perennial versus annual/seasonal/ephemeral vegetation. The respective map is closely related to land use/cover patterns and also to soil type and terrain structures. The change indicator (Functional Differences [P51]) displays epochal (2003-2006 versus 2007-2010) changes between the respective epochal indicators.

“Seasonal Trend Relations” [P52] combines the trends in vegetation year, cyclic vegetation and dry season greenness. This indicator shows the dynamics of the different basic vegetation types in relation to each other during the observation period. Developments such as bush encroachment or the extension of crop area may be captured by this indicator, the first by a relative increase of the dry season greenness, the latter by a relative increase of the cyclic vegetation productivity in relation to that of the dry season.

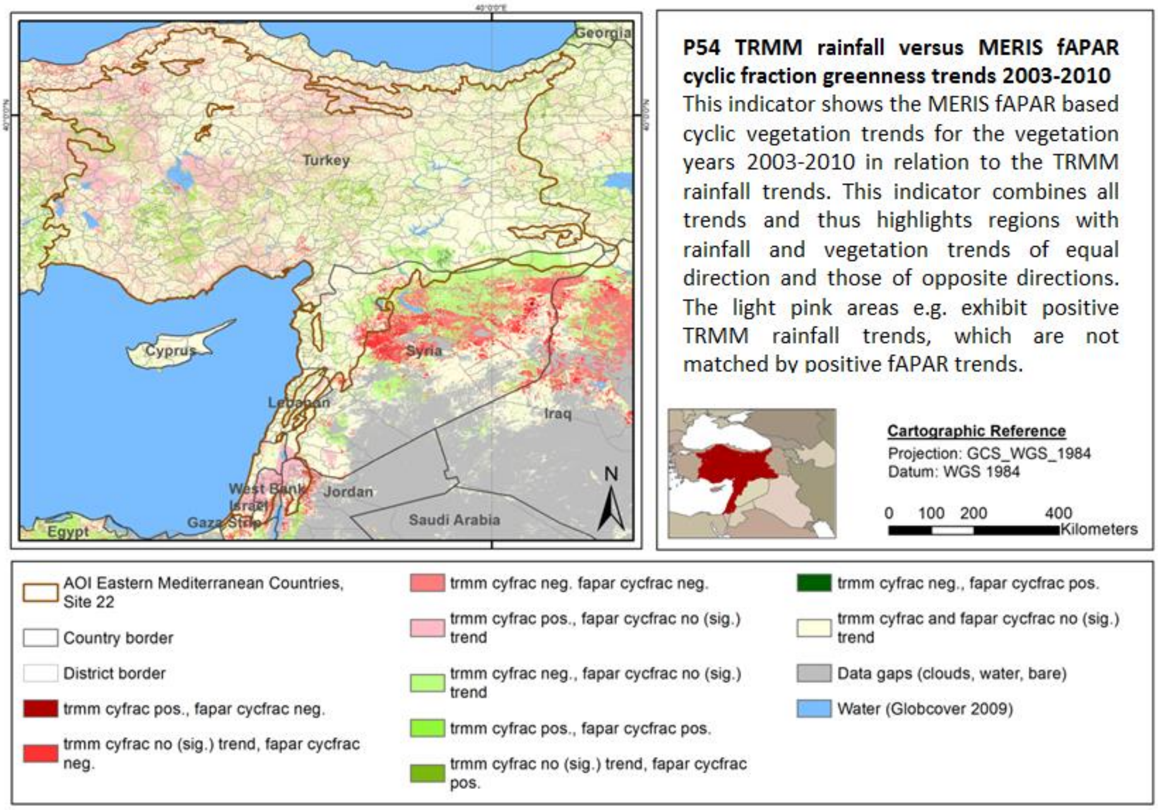
As an alternative to RUE/SMUE trends, synoptic relation indicators between rainfall and NPP trends were generated. Indicators were prepared for the relation between rainfall and vegetation year greenness, cyclic vegetation, and respectively dry season greenness [P53, P54, P55]. The same indicator was derived for a time span prior to MERIS (1981-2002), using GPCP rainfall data and NOAA GIMMS NDVI data [P56]. This group of indicators contrasts rainfall trends and NPP proxy trends and reveals areas where the two parameters exhibit diverging trends, which may point to land cover changes or human induced degradation processes.



P50 Functional classes

The functional classes originate from a combined classification of vegetation productivity and the percentage of cyclic vegetation of the yearly vegetation. The numbers in the legend increase with increasing values of these parameters. The lighter the tone, the higher is the percentage of the cyclic vegetation and the lower probably the share of woody evergreen vegetation. The respective map is closely related to land use/cover patterns and to soil and terrain type and structures.

Second order indicator example for the site Eastern Africa, depicting functional classes.



P54 TRMM rainfall versus MERIS fAPAR cyclic fraction greenness trends 2003-2010

This indicator shows the MERIS fAPAR based cyclic vegetation trends for the vegetation years 2003-2010 in relation to the TRMM rainfall trends. This indicator combines all trends and thus highlights regions with rainfall and vegetation trends of equal direction and those of opposite directions. The light pink areas e.g. exhibit positive TRMM rainfall trends, which are not matched by positive fAPAR trends.

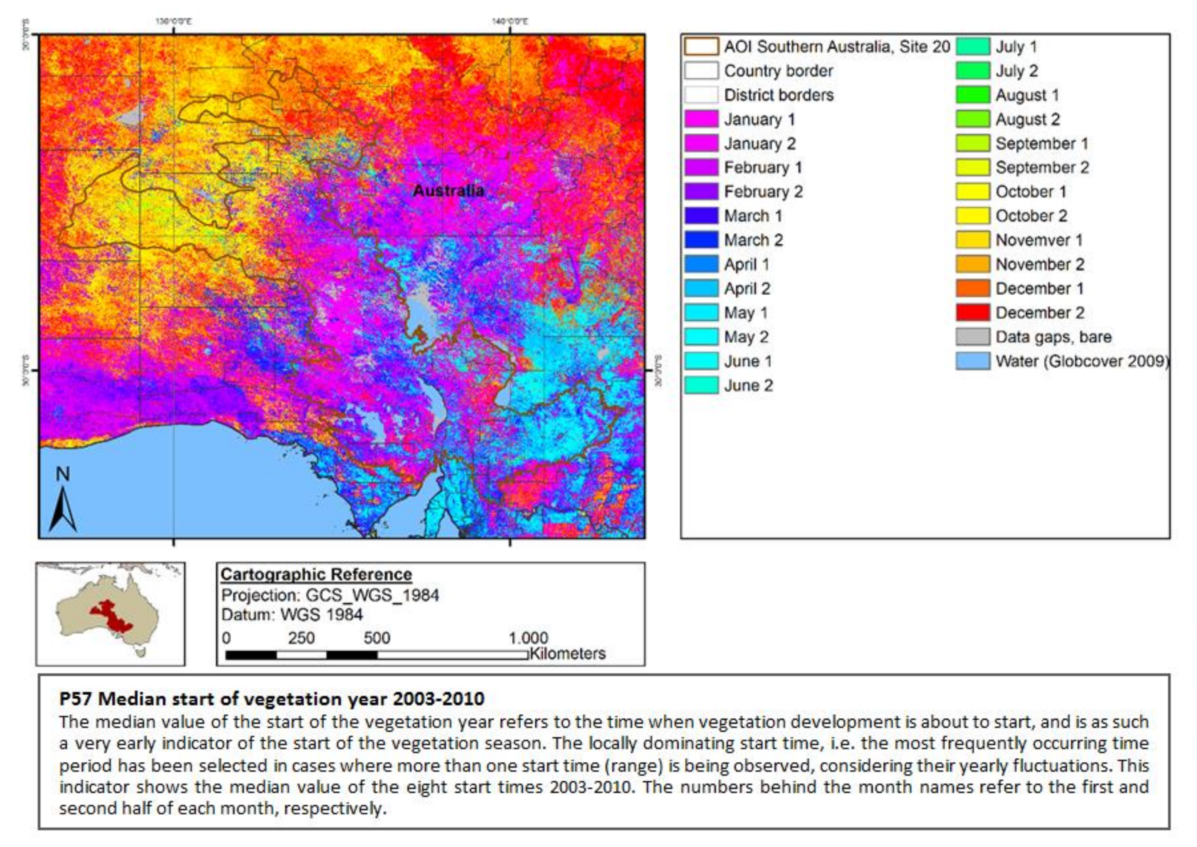
Second order indicator example for the site Eastern Mediterranean Countries, depicting the TRMM rainfall versus cyclic fraction greenness trends.

Summary table of dryland second order indicators

Input first Order Indicators	Second Order Indicators and [numbers]	Types of Indicators
Parameter: MERIS fAPAR		
- Vegetation year average greenness 2003-2010 - Mean percent of cyclic vegetation of vegetation year greenness* 2003-2010	**Functional classes [P50]** - Relation between vegetation year greenness classes and the classified percentage of the cyclic vegetation of the yearly vegetation 2003-2010	**Status indicator** - 2003-2010
- Epochal Vegetation year average greenness 2003-2006 and 2007-2010 - Epochal percent of cyclic vegetation of vegetation year greenness 2003-2006 and 2007-2010	**Functional differences [P51]** - Epochal (2003-2006/2007-2010) difference map of the relation between vegetation year greenness classes and the classified percentage of the cyclic vegetation of the yearly vegetation	**Epochal difference indicator** - 2003-2006 versus 2007-2010
Parameter: MERIS fAPAR		
- Trendslope of vegetation year greenness 2003-2010 - Trendslope of cyclic fraction greenness 2003-2010 - Trendslope of dry season greenness 2003-2010	**Seasonal Trend Relations [P52]** - Relation between vegetation year greenness trends and seasonal greenness trends 2003-2010	**Combined trend indicator** - 2003-2010
Parameter: fAPAR and rainfall		
- Trendslope of vegetation year greenness 2003-2010 - Trendslope of vegetation year TRMM rainfall 2003-2010	**Trend Relation of fAPAR and rainfall [P53]** - TRMM Rainfall versus MERIS fAPAR vegetation year greenness trend	**Combined trend indicator** - 2003-2010
- Trendslope of cyclic fraction greenness 2003-2010 - Trendslope of cyclic fraction TRMM rainfall 2003-2010	**Trend Relation of fAPAR and rainfall [P54]** - TRMM Rainfall versus MERIS fAPAR cyclic fraction greenness trend	**Combined trend indicator** - 2003-2010
- Trendslope of dry season greenness 2003-2010 - Trendslope of vegetation year TRMM rainfall 2003-2010	**Trend Relation of fAPAR and rainfall [P55]** - TRMM Rainfall versus MERIS fAPAR dry season greenness trend	**Combined trend indicator** - 2003-2010
Parameter: NOAA AVHRR GIMMS NDVI and GPCP rainfall		
- Trendslope of GIMMS NDVI 1981-2002 - Trendslope of GPCP rainfall 1981-2002	**Trend Relation of NDVI and rainfall [P56]** - GPCP Rainfall versus GIMMS NDVI vegetation year greenness trend	**Combined trend indicator** - 1981-2002

Dryland Phenology Indicators

In addition to the first and second order products, which are all based on phenological and productivity parameters, explicit phenology indicator maps were generated in order to characterize the average conditions of major phenological properties of the test sites. While the start of the vegetation year [P57] is situated at the very start of the vegetation signal rise directly at the end of the dry season, the start time of the vegetation season [59] is defined to be marked by the time when the vegetation rise has surpassed the baseline, i.e. the threshold between the (approximately) upper dry season level and the cyclic vegetation. In addition to these two, a length of vegetation season indicators [P58] is provided, which includes the time period between the start of the vegetation season [P59] and the end of the vegetation season, when the vegetation time series curve falls under the baseline.



P57 Median start of vegetation year 2003-2010

The median value of the start of the vegetation year refers to the time when vegetation development is about to start, and is as such a very early indicator of the start of the vegetation season. The locally dominating start time, i.e. the most frequently occurring time period has been selected in cases where more than one start time (range) is being observed, considering their yearly fluctuations. This indicator shows the median value of the eight start times 2003-2010. The numbers behind the month names refer to the first and second half of each month, respectively.

Phenology indicator example for the site Southern Australia, depicting the median start of vegetation years in 2003-2010.

Phenology Indicators and [numbers]		
Parameter: MERIS fAPAR		
	-	Median of the start times of the vegetation year 2003-2010, expressed as half month number of the calendar year [P57]
	-	Mean of the lengths of the vegetation seasons 2003-2010 in half-months [P58]
	-	Average start time of the vegetation seasons (cyclic vegetation) 2003-2010, , expressed as half month number of the calendar year [P59]

Geographical Coverage

The final selection of the Diversity II demonstration sites includes 350 large perennial inland waters globally with a total surface of 1.4 million km^2 and 22 dryland areas with a total surface of 15.7 million km^2.

Distribution of the 350 lakes considered in Diversity II, selected by relevance, size and global distribution. The selection includes all LakeNet Biodiversity Priority sites and Ramsar sites with a contiguous open water area above 50 km^2.

Perimeters of the 22 Dryland demonstration sites. The test sites have been selected based on WWF ecoregions, using criteria including the UNEP Aridity Index, the representativeness of the drylands ecosystems, and the presence of *biodiversity hotspots in several cases.*

Team

European Space Agency

Project requirement definition; user interface; EO data provision; project control

Brockmann Consult GmbH, Germany

Prime contractor; project management; algorithms for preprocessing including atmospheric correction over land and lakes; software and production

GeoVille, Austria

Drylands requirements analysis; algorithms for drylands; software and production

Brockmann Geomatics AB, Sweden

Biodiversity and user interface; algorithms for in-water retrieval and lake indicators; website, web GIS, communication and outreach

Research Centre in Biodiversity and Genetic Resources CIBIO, Portugal

Requirements engineering, validation

Group of Consultants

Dr. Sampsa Koponen (Finnish Environmental Institute SYKE) - remote sensing of inland waters in boreal areas; Dr. Kai Sorensen (NIVA) - Norwegian and African Lakes expert. Dr. Steven Greb (chair of the GEO Inland and Near Coastal Water Working Group) - lake remote sensing in North and South America. Prof. Rasmus Fensholt (Uni Copenhagen) - Earth Observation ecology studies of terrestrial dryland ecosystems. Dr. Kurt Günther (DLR) - Soil-Vegetation-Atmosphere-Transfer (SVAT) modelling and validation.

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