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20. Earth System Science related Earth Observation

Michael E. Schaepman, Brigitte Buchmann, Alain Geiger

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20.1
Alpine vegetation biomass mapping from imaging spectrometer data

Fatehi Parviz[1], Damm Alexander[1], Kneubühler Mathias[1] & Schaepman Michael[1]

[1] *Remote Sensing Laboratories, Department of Geography, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich (parviz.fatehi@geo.uzh.ch)*

Aboveground biomass (AGB) of terrestrial ecosystems is an important input to global change and productivity models and is needed to assess carbon stocks and the contribution of vegetation to the global carbon cycle. In the present study, the suitability of imaging spectrometer (IS) data for estimating aboveground biomass of an alpine ecosystem was investigated. The approach of Continuous Fields Mapping (CFM) is a promising alternative to discrete mapping approaches for representing the spatial and temporal distribution of terrestrial ecosystem biomass since it overcomes the limitations of "hard" classes boundaries. In this contribution, a dedicated methodological framework for deriving continuous fields of an alpine ecosystem's biomass is presented.

First, abundance mapping of predominant land surface types was performed using linear spectral mixture (LSM) analysis. Then, linear regression models which are based on measured field data and vegetation indices derived from APEX (Airborne Prism Experiment) IS data were used to generate quantitative maps of aboveground biomass of vegetated areas, Continuous fields of biomass were eventually complied by combining LSM derived abundance maps of land surface types and corresponding biomass from linear regression modelling.

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20.2

Extending Global Monitoring of Essential Climate Variables Through the GCOS Cooperation Mechanism

König Sebastian J.[1], Fontana Fabio[1], Seiz Gabriela[1] & Foppa Nando[1]

[1] *Federal Office of Meteorology and Climatology MeteoSwiss, Swiss GCOS Office (sebastian.koenig@meteoswiss.ch)*

High-quality climate observations are vital for the international community to take the most appropriate action to detect, adapt to, and mitigate climate change in line with the objectives of the UN Framework Convention on Climate Change UNFCCC. Switzerland has a long tradition in climate observation, ranging from temperature and precipitation series of more than 150 years to glacier measurements since the end of the 19th century. The Swiss GCOS Office at the Federal Office of Meteorology and Climatology MeteoSwiss ensures among others the continuation of such climate relevant measurements in Switzerland. These measurements contribute to the systematic monitoring of Essential Climate Variables (ECV) within the National Climate Observing System GCOS Switzerland.

(Satellite) Earth observation encompasses the monitoring of coupled systems at a global level. Whereas Switzerland features an established network of climate and environmental data, globally, data is highly limited in certain areas. In the framework of the GCOS Cooperation Mechanism the Swiss GCOS Office coordinates an international project to improve climate observation in developing countries where climate (atmospheric domain) and environmental data (terrestrial domain) is sparse. This capacity building project promotes among others in situ glacier mass-balance monitoring in Central Asia and atmospheric measurements in South East Asia supported by Swiss partner institutions. The data obtained will be submitted to the International Data Centers and will be valuable for a wide range of applications, e.g., regional climate modelling, monitoring of climate change, or validation of satellite derived products.

We report on GCOS activities on monitoring atmospheric and terrestrial components through means of an international project in the framework of the GCOS Cooperation Mechanism. The outcomes will contribute to the global network of Earth observation, by extending monitoring of ECVs, such as glaciers and atmospheric composition, and will ultimately establish a sound scientific data basis to improve policy decisions in those countries and at an international level.

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20.3

Feasibility study on snow property extraction based on differential SAR interferometry

Leinß Silvan[1], Hajnsek Irena[1,2]

[1] *Institute of Environmental Engineering (IfU), ETH Zürich, 8093 Zürich, Switzerland (leinss@ifu.baug.ethz.ch)*
[2] *Microwaves and Radar Institute, German Aerospace Center (DLR), Germany*

Currently the determination of snow water equivalent (SWE) and other snow parameters rely on a network of weather stations, and air- and space borne missions with resolutions on the km-scale. High resolution weather and precipitation models will depend on high resolution input data. Active radar systems, especially SAR-systems can provide high resolution datasets independent of daylight. For a sufficient interaction of microwave radiation with the snow cover, high radar frequencies are needed. The satellite formation TerraSAR-X and TanDEM-X build for the generation of a high resolution globe-covering digital elevation model (DEM) (Krieger 2007) provides X-band data at 9.65 GHz with a resolution on the meter scale. Every time, flying over a certain area two acquisitions are taken which allow a DEM-generation for each pass (single pass interferometry). Further differential interferometry (D-InSAR) is possible between acquisitions of different passes. Here, feasibility studies and results for snow height and snow water equivalent determination by using differential SAR interferometry of multi-pass and single-pass acquisitions will be presented.

D-InSAR is a known method to detect height changes (Gabriel, 1989) on the wavelength-scale (l = 3 cm) by comparing the measured phase with a reference, here a synthetically calculated phase, based on the best available digital elevation model (DEM). Atmospheric disturbances cancel out in single-pass interferograms, but remain visible as long-range phase patterns in multi-pass interferograms. Still, they cannot explain small scale phase patterns, which correlate with local topographic features. These phase patterns are caused by the changing penetration depth of microwaves but also height deformations, both resulting in different location of scattering centers. Various properties of the cryosphere change over time and affect the location of scattering centers. Soil freezing, water content of snow, snow height and snow water equivalent but also vegetation cover are discussed to explain the detected phase patterns. Further, the interferometric coherence, which measures changes between two acquisitions, allows the detection of snowfall and melting periods.

In single pass interferometry, due to zero temporal difference between the two acquisitions, the bistatic mode of the TanDEM-X formation provides a very high coherence and phase accuracy. Therefore, elevation changes on the sub-meter scale can be detected, by comparing two obtained DEMs. This might not work in early winter when the snow layer is very cold (not conducting) and thin, but with some content of liquid water in the snow, a height difference should be possible to detect.

For validation, ground measurements are essential and have been acquired. The test sites Sodankylae in northern Finland and Churchill in Canada, MB, have been chosen as already intensive ground measurements were done there within the framework of the CoreH_2O mission (Rott, 2010). Snow height, snow water equivalent, air temperature, soil moisture, wind speed and even snow profile data are available. For both test-sites exists a set of 20 - 25 TerraSAR-X multi-pass acquisitions and 6, resp. 8 single-pass TanDEM-X acquisitions during the winter 2011/2012.

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20.4

High resolution retrieval of forest canopy structure using multi-temporal airborne laser scanning

Leiterer, Reik[1]; Morsdorf, Felix[1] & Schaepman, Michael E.[1]

[1] *Remote Sensing Laboratories, Department of Geography, University of Zurich, Winterthurerstrasse 190, CH-8057 Zürich (reik.leiterer@geo.uzh.ch)*

Forests play a pivotal role in the global biogeochemical and -physical cycles between atmosphere and the land surface (Toda et al. 2011). Particularly the complex three-dimensional distribution of geometric objects and their topology within forests canopies, here termed forest canopy structure, influences the fluxes of energy and matter between the atmosphere and forests (Xue et al. 2011). Assessing forest canopy structure is difficult: conventional fieldwork is time-consuming and mostly limited in its spatial extent, whereas traditional remote sensing methods are lacking information in the vertical dimension (Jones et al. 2012). Airborne laser scanning (ALS) systems have been shown to be suitable for providing not only horizontal information on the forest canopy structure, but also explicit vertical information due to the canopy penetration of the emitted signal (Leeuwen & Nieuwenhuis 2010). However, existing approaches to derive forest canopy structure using ALS data mostly include manual processing steps or need additional data about stand characteristics. Therefore, an automated and transferable method is basically needed to provide a more efficient monitoring of forest canopy structure as well as to improve the robustness and reliability of derived forest canopy structure information.

In this study, we used full-waveform ALS data under leaf-on and leaf-off canopy conditions in a mainly semi-natural, deciduous-dominated forest stand in Laegeren (Swiss Jura – 47°28’N, 8°21’E). The forest stand is characterized by a high diversity concerning species, age, and diameter distribution. Based on the specific characteristics of the ALS derived point cloud we developed a new adaptive multi-scale algorithm to calculate the digital terrain model (DTM) and the belonging digital surface model (DSM). A canopy height model (CHM) was calculated from the difference between DSM and DTM. Finally, for each point of the point cloud we determined the height above ground as well as the according DTM, DSM and CHM values. Based on the full point cloud, we applied a segmentation algorithm to enable the characterization of the canopy structure on the individual tree/ crown level. As input for the segmentation a set of seed points is necessary, representing the positions of the individual trees. To determine this seed points, we used an iterative, three-dimensional grayscale dilation based on an ellipsoid-shaped structuring element. Accordingly, the resulting points were utilized as initial points for a hierarchical k-means clustering approach. For each obtained cluster, we calculated the alpha shape to derive additional crown specific variables such as crown volume or crown diameter. Based on the crown specific variation in the point distribution between leaf-on and leaf-off acquisition (e.g. percentage distribution in vertical extent), we distinguished deciduous from coniferous trees. The extracted forest canopy structure variables can be used for a complete three-dimensional representation of the forest area (Figure 1).

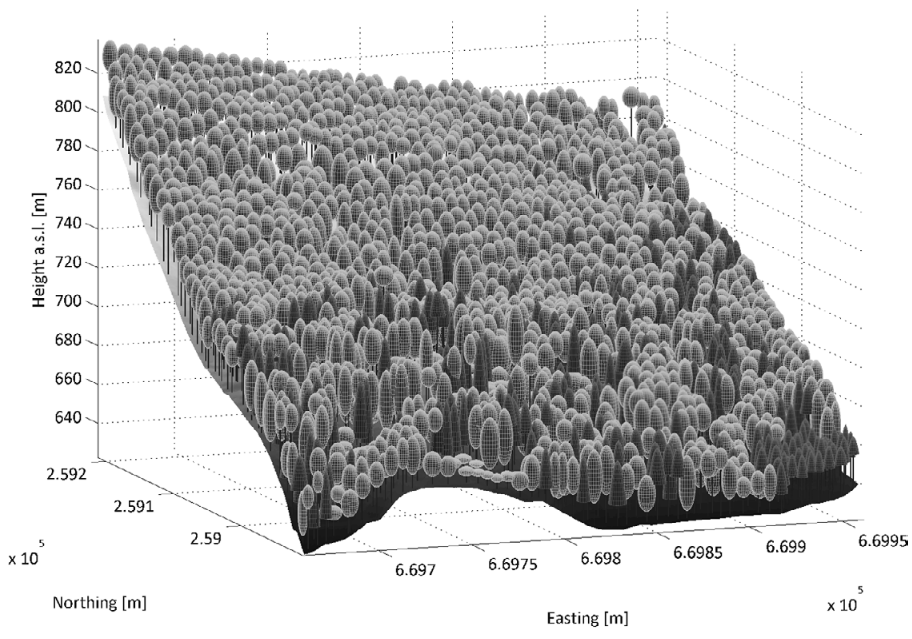

Figure 1. Simplified visualization of the reconstructed forest scene.

The tree detection accuracy and the delineation of crown variables were assessed based on a stratified random sampling approach using ortho-images, terrestrial laser scanning (TLS) and forest inventory data. The commission and omission errors for the tree detection are 5.2 % and 13.1 %, respectively. The classification of the tree species (coniferous, deciduous) results in an overall accuracy of 89.7 % with a kappa coefficient of 0.74. The crown dimension variables were validated within the TLS plots and results in a mean error of ± 2.8 m. The derived foliage distribution information and bio-physical variables could not be validated yet directly. For this purpose a dense vertical sampling of the full canopy is necessary, which will be carried out in future studies.

We conclude that it is possible to extract forest canopy structure variables on the tree level to a certain extent without any previous knowledge about stand specific characteristics. The validation/evaluation shows that the determination of canopy structure variables was performed with high accuracy, whereas the quantitative validation of specific horizontal crown variables (e.g. crown projection area, crown diameter) and bio-physical variables (e.g. leaf area density) is still difficult, particularly for a dense deciduous dominated forest.

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20.5

Precipitation in extratropical cyclones: the role of warm conveyor belts

Madonna Erica[1], Wernli Heini[1], Joos Hanna[1], Olivia Martius[2] & Maxi Böttcher[1]

[1]Institute for Atmospheric and Climate science, ETH Zürich. Universitätstrasse 16, CH- 8092 Zürich (erica.madonna@env.ethz.ch)
[2]Oeschger-Zentrum für Klimaforschung, University of Bern, Zähringerstrasse 25, CH-3012 Bern

Extratropical cyclones are everyday phenomena and are an important component of the atmospheric general circulation since they transfer energy, moisture and momentum poleward. They can cause adverse weather, trigger torrential rains, strong winds, thunderstorms, squall lines and hail and significantly impact our climate.

During their intensification and in the mature stage, extratropical cyclones are typically associated with three coherent major airstreams – the dry intrusion, the cold conveyor belt and the warm conveyor belt (WCB), respectively (Browning 1990).

These airstreams are important for the dynamics of the cyclone evolution, and potentially also for the rapid long-range transport of atmospheric constituents as ozone and pollutants. They are key features for the meridional and vertical transport of water vapor and heat, linking the atmospheric boundary layer and the tropopause region.

WCBs are moist airstreams which originate in the moist subtropical marine boundary layer and ascend polewards ahead of the cold front. They are characterized by a rapid ascent, within about two days, to the upper troposphere (Wernli and Davies 1997; Eckhardt et al. 2004). Moreover, WCBs are the primary cloud-producing flows and are responsible for the major part of precipitation in the extratropics (Browning 1990). In IR- and WV-satellite images, they are visible as slightly S-shaped bright frontal cloud bands (Figure 1).

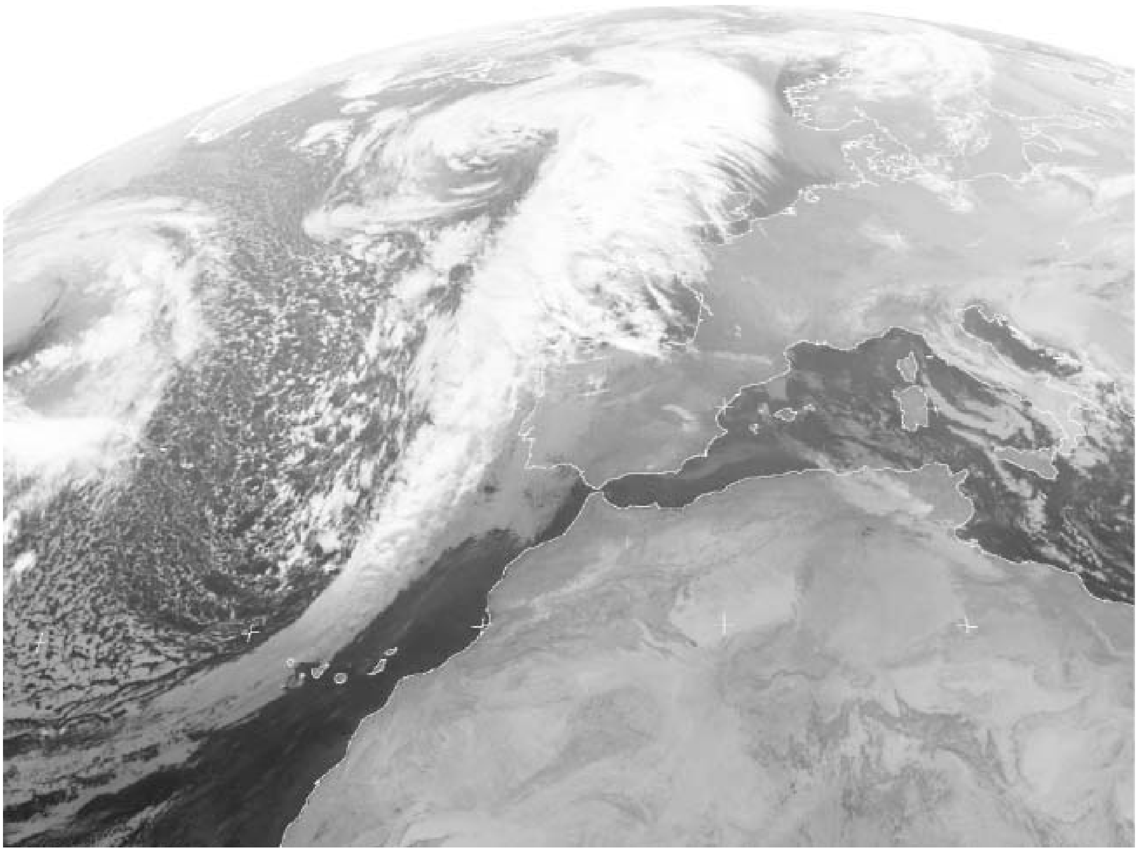

Figure 1. Meteosat SEVIRI infrared satellite image (0600 UTC 30 January 2009 from http://www.neodaas.ac.uk/) showing a WCB.

Furthermore, from a dynamical point of view, WCBs are important for the evolution of the cyclone and can amplify upper-level Rossby waves leading to the formation of PV streamers. These in turn can act as precursors of extreme weather events.

WCBs will be considered from a climatological point of view, using 32-years of the ERAinterim reanalysis data set (1979-2010). WCBs are identified from comprehensive trajectory calculations that select air parcels in the vicinity of cyclones with a minimum ascent of 600 hPa in 48 hours.

The global geographical distribution of WCB starting regions and their tracks will be presented for different seasons. The importance of these airstreams for precipitation in the extratropics will be pointed out as well as their importance for the climate system.

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20.6

Co-location in space and its impact on the geodetic reference frame for Earth observation

Männel Benjamin[1], Rothacher Markus[1]

[*] Institue for Geodesy and Photogrammetry, ETH Zürich, Schafmattstr. 34, 8093

The realization of a unique terrestrial reference frame (TRF) that is accurate enough to allow the monitoring of the Earth's system is limited on the one hand by individual error sources of the contributing space techniques and on the other hand by the quality of the links between them. In conjunction with the "Global Geodetic Observing System" the accuracy and stability level of the desired TRF were defined to be at 1 mm and 0.1 mm/yr resp. To achieve these requirements, investigations in both limiting factors are necessary. Based on a small number of existing scientific and navigation satellites equipped with sensors of two or more techniques and reasonably known offset vectors, co-location in space can be investigated. The data from GPS and DORIS receivers onboard LEOs and SLR measurements to GNSS satellites and LEOs are available for this purpose. The use of VLBI would become possible as well if a VLBI signal is transmitted by a satellite and received on Earth by radio telescopes.

For our investigations we chose observations from the satellite mission OSTM/Jason-2 because of the high-quality sensor data and the relatively high satellite altitude of 1336 km. In addition to the real GPS and SLR data we simulated satellite-based VLBI observations as mentioned above. After a single-technique processing for all three data types we combined these results on the normal equation level and estimated station coordinates, orbital parameters and other relevant unknowns. We will present first results of this co-location in space and its impact on the accuracy of the TRF.

20.7

Toward a satellite-based climatology (1989–2011) of lake surface water temperature from AVHRR 1-km for European water bodies

Riffler Michael[1,2], Schulze Sebastian[2], Wunderle Stefan[2]

[1] Oeschger Centre, University of Bern, Zähringerstrasse 25, CH-3012 Bern (michael.riffler@oeschger.unibe.ch)
[2] Geographisches Institut, University of Bern, Hallerstrasse 12, CH-3012 Bern

The Swiss Global Climate Observing System (GCOS) office has initiated a project to generate a satellite-based lake surface water temperature (LSWT) climatology for the pre-alpine water bodies in Switzerland. In contrast to in situ observations, satellite imagery offers the possibility to derive spatial patterns of LSWT variability. Moreover, the temperature of many lakes in Switzerland is monitored on a non-regular basis. Hence, the extensive Advanced Very High Resolution Radiometer (AVHRR) 1-km data record (1985– 2011) of the Remote Sensing Research Group at the University of Bern (RSGB) will offer new insights into the temperature evolution of lakes over the past three decades.

The time series is compiled from the AVHRR/2 (NOAA-11, -14) and AVHRR/3 (NOAA-16, -17, -18, -19 and Metop-A) instruments on board the National Oceanic and Atmospheric Administration (NOAA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) platforms. Especially NOAA-16 and prior satellites were prone to unwanted noise, e.g., due to transmission errors or fluctuations in the instrument's thermal state. This has resulted in partly corrupted thermal calibration data and may cause errors of up to several Kelvin in the final brightness temperatures. Therefore, a multistage correction scheme has been applied to the data, in order to minimize these artefacts in the satellite observations.

For the LSWT retrieval, we compared three different methods. First, we applied the operational NOAA NESDIS and NOAA Pathfinder global SST algorithms to our data set. In addition, we developed an optimized simulation-based scheme making use of the Radiative Transfer for TOVS (RTTOV) Version 10 together with operational analysis and reanalysis data from the European Centre for Medium Range Weather Forecasts (ECMWF). All methods were validated extensively using in situ measurements from lakes with various sizes between 14 (Lake Sempach) and 580 km2 (Lake Geneva). The simulation-based algorithm helped to reduce the RMSE and Bias for the lakes in the study region of Switzerland compared to the global SST algorithms and even small lakes yield good results.

As a next step the model-based LSWT retrieval shall be expanded to all European lakes, which are covered and recorded by the AVHRR data retrieval station at the RSGB.

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P 20.1

MSG SEVIRI-based solar energy mapping over complex terrain

Reto Stöckli[1], Rebekka Posselt[1], Christian Steger[1], Mark Liniger[1]

[1]*Federal Office of Meteorology and Climatology MeteoSwiss, Krähbühlstrasse 58, 8044 Zürich, Switzerland*

Global radiation is an essential climate variable highly relevant for applications such as solar energy, agriculture or climate monitoring. Global radiation retrieved from geostationary satellites has continuous spatial and temporal coverage of high resolution and complements station-based estimates. The Meteosat Second Generation (MSG) based global radiation dataset presented here explicitly treats clouds over snow and accounts for terrain shadowing. Validation results suggest a monthly averaged accuracy of <5 W m-2 over flat and <10 W m-2 over Alpine terrain.

The algorithm (Stöckli, in prep) employs the MSG SEVIRI High Resolution Visible (HRV) channel in combination with 4 near-infrared and infrared chan- nels. The clear sky compositing is based on a probabilistic cloud mask (Khlopenkov and Trishchenko, 2007) and a parametric fit of the diurnal course of clear sky reflectance and brightness temperature. Since snow can be brighter than clouds, an infrared-based cloud index is applied over bright surfaces. Spatially distributed maximum cloud reflectances are calculated with a cloud angular distribution model. Clear sky radiation is calculated with the gnu-MAGIC (Müller et al., 2009) radiative transfer model driven by 6-hourly ECMWF water vapor and ozone and by a monthly aerosol climatology. A SRTM-based digital elevation model is used to calculate the effects of terrain shading and sky view on the direct and diffuse radiation components (Figure 1).

We present validation and inter-comparison results, followed by several examples of how this dataset is currently employed in applied climate research and for solar energy applications.

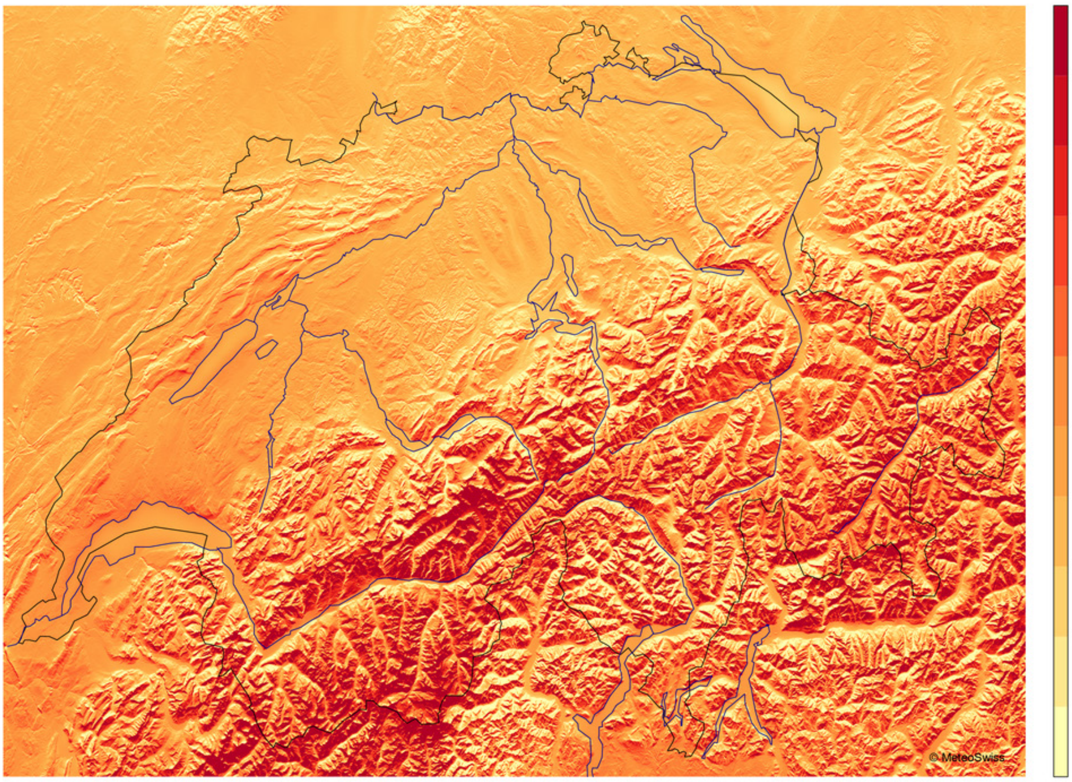

Figure 1. Mean global radiation (W m-2) for Switzerland (2004-2011) projected on effective area of inclined terrain surfaces of a 100 m elevation dataset.

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