CEOP-AEGIS

Hydrology and Climatology of the Tibetan Plateau

Toward an observing system of the Plateau

Headwater of rivers that flow down to 1.4 billion people, the Tibetan Plateau, with an average altitude of 4,700 meters and an extent of 2.5 million square kilometers, plays a determinant role on both hydrology and climate of Southeast Asia.

The dynamic and thermodynamic effects of the Plateau on the atmospheric circulation also influence downstream river flow. Surface topography and surface radiative and convective fluxes within the Atmospheric Boundary Layer not only determine the water balance of the Tibetan Plateau, but also exert a profound influence of the onset, maintenance and withdrawal of the Southeast Asian Monsoon. A good understanding of the linkage of land processes on the Plateau with monsoon onset and precipitation is of major relevance from both societal and environmental points of view for many Asian countries, in particular in terms of flood and drought, but also in terms of food security in a changing environment.

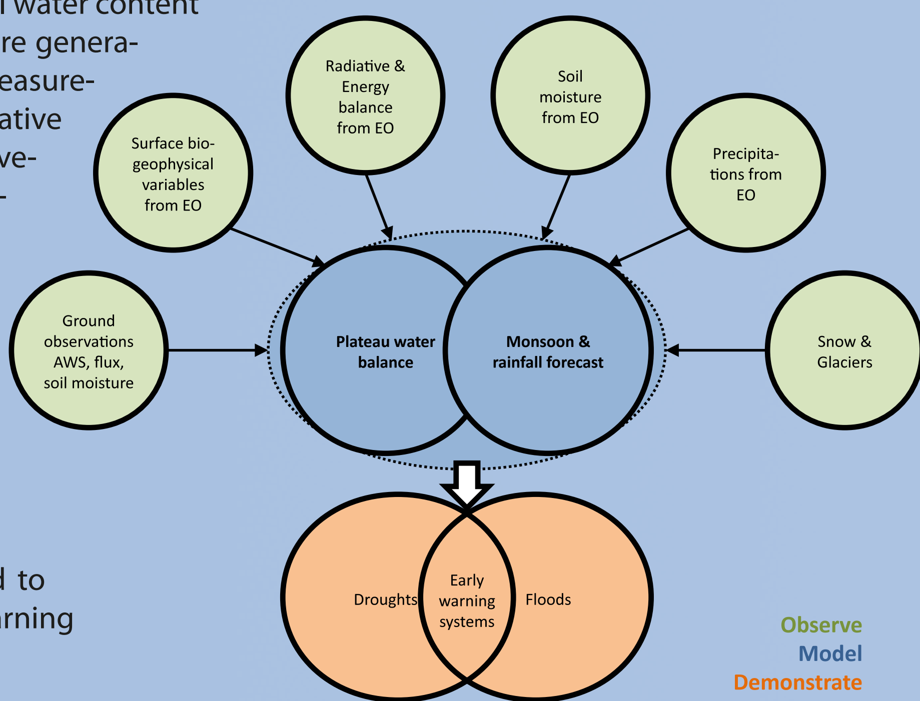
Improving water management and predicting changes in water resources in Southeast Asia cannot only rely on existing ground observation network, whose spatial density could never be sufficient for such a challenge. Therefore, there is an urgent need for reliable, long-term observations from space. Observing systems onboard current and future satellites provide regular and global coverage of surface and atmospheric properties. Imaging spectro-radiometers, radars, microwave radiometers and backscatter lidar provide a very comprehensive suite of measurements over a wide range of wavelengths, time frequencies and spatial resolutions. The challenge is to devise new ways to merge efficiently every available observations rather than focusing on each instrument separately.

Initiated in 2008, the CEOP-AEGIS project aims at building such a long-term observing system for the Tibetan Plateau to monitor surface bio-geophysical properties, energy and water balance, and to improve the modelling of the Asian monsoon and of extreme meteorological events. Three main elements are foreseen:

A) Observations of the terms of the water balance: precipitation, meltwater from snow and glaciers, changes in soil water content and evaporation for a period of three years are generated by integrating ground and satellite measurements on weekly and monthly basis. Radiative transfer models and algorithms are under development for different regions of the electromagnetic spectrum.

B) The water balance of the Plateau is calculated with a distributed hydrological model. Interactions of land surface hydrology with convective activity and the Asian Monsoon are being investigated by using a meso-scale atmospheric model.

C) Time-series of image data are being used to demonstrate a Drought and a Flood Early Warning Systems.

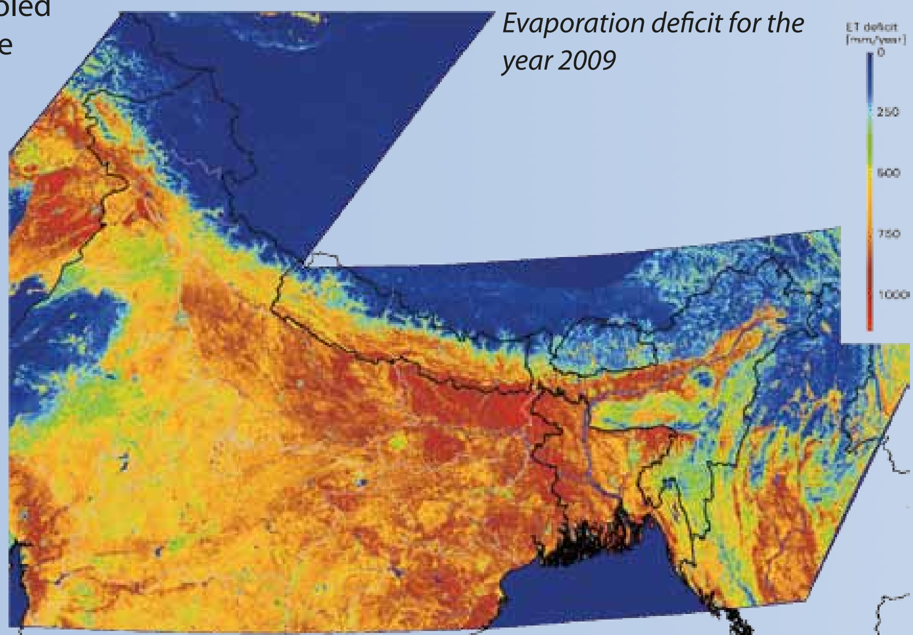


Multi-sensors bio-geophycial surface parameters

Ground observations are a key component of the project to provide reference data, in particular for the validation of Earth Observation based variables at both regional and continental scales. Although the landscape over the Tibetan Plateau is very heterogeneous, observation sites of the TORP, GAME/Tibet and CAMP/ Tibet cover almost every type of land surfaces over the Tibetan Plateau. Beside standard weather station sensors, these sites also include radiative and energy balance terms measurements to monitor the seasonal and inter-annual time scale of surface heat flux, momentum flux, water vapour flux, surface and soil moisture over the different land surfaces of the Tibetan Plateau. Tethered balloons, radio-sondes, wind profilers and PBL towers data provide key variables to monitor the structure and characteristics of the surface and atmospheric boundary layer.

All these ground observations are invaluable sources of information to develop and validate generic algorithms designed to characterize the physical state of the land surface from satellites.

Any multi-spectral imaging radiometer is a potential source of data to retrieve these variables, but relying on a single satellite or sensor system severely reduces the frequency of useful (cloud-free) observations. On the other hand, there is a broad family of multi-spectral, multi-angular imaging radiometers, many developed and operated by China and India, which could guarantee the required spatial and temporal coverage if pooled together. The latter requires going beyond the traditional single-sensor approach to retrieval by inversion of Top Of Atmosphere radiometric data. One of the main tasks conducted within CEOP-AEGIS is to develop a data acquisition and processing system to use effectively these multiple data sources, following a virtual satellite constellation concept, by relying on the current and growing Earth Observation capabilities of newly industrialized countries such as India and China, particularly for South and East Asia.

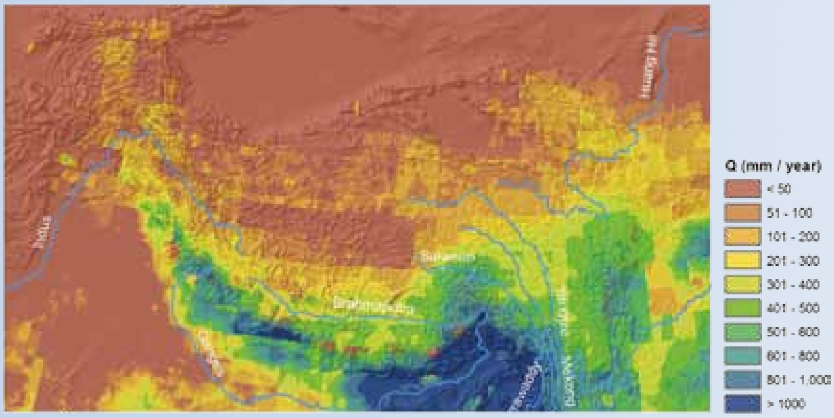


Evaporation deficit for the year 2009

The core of this system is a family of generic algorithms able to use any set of multi-spectral, multi-angular radiometric data to retrieve with the required spatial density and temporal frequency the same set of land surface properties, i.e. snow and vegetation cover, surface albedo and temperature.
Many other satellite sensors are also used to extend the panel of key eco-hydrological products. Among others, passive microwave emission radiometers at low frequencies provide useful measurements of surface soil moisture. The recent SMOS (Soil Moisture and Ocean Salinity) mission is particularly interesting in this respect. The GRACE and GOCE missions are also used to estimate changes in the total water stock of the Plateau, as well as data collected by the Geoscience Laser Altimeter System (GLAS) onboard the Ice, Cloud and land Elevation Satellite (ICESat), used to estimate the mass balance of glaciers and snow-packs.

All these sources of observation are merged in a single Earth Observation System to provide a three-year dataset of bio-geophysical variables at a target frequency of ten days and a spatial resolution ranging from 1 to 5 kilometres. These observations are then used as forcing or validation data for hydrological models, and as knowledge base to improve existing Numerical Weather Prediction Models.

Hydrological modeling and monsoon studies



Preliminary result of specific runoff for the year 2000

The integration of spatial information from Earth Observation into a distributed hydrological model can lead to a prototype water balance monitoring system of the whole Tibetan Plateau.

The panoply of ground based and satellite based product is either used for forcing or calibration /validation. Forcing consists of direct inputs of timely remotely sensed observations, such as precipitation, evaporation, snow, ice and vegetation cover. Snow and ice coverage derived from observations from polar satellites, expressed both in terms of surface and water equivalent, are also ingested as forcing variables. Vegetation cover, surface albedo and leaf area index maps are provided to follow land surface changes on a bi-monthly basis. A set of Surface Energy Balance algorithms provides time series of turbulent fluxes, and in particular the surface evaporation all over the Plateau.

All these observations are integrated using a GIS-based hydrological model to provide a complete hydrological balance of the entire Plateau. The water balance model developed to monitor the water yield of the Tibetan Plateau, called TibWatMod, is based on PCRGLOB-WB model. It is designed to allow the use of downscaled IPCC Global Climate Change data to implement scenarios of hydrological response of the Plateau in the coming decades.

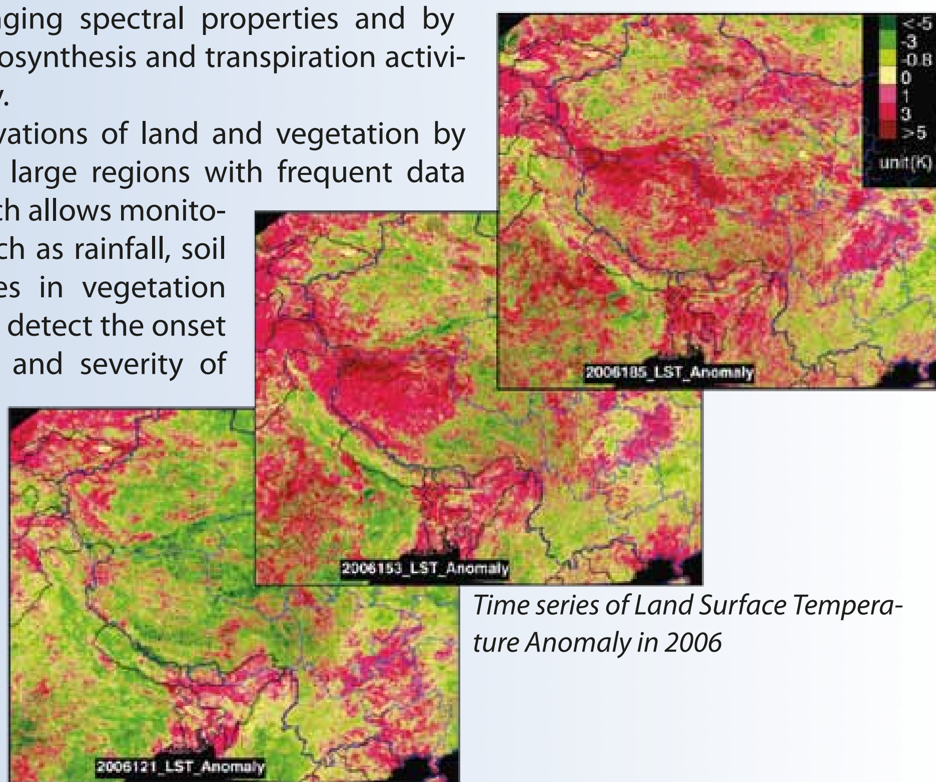
The use of the high resolution non-hydrostatic Numerical Weather Prediction model GRAPES helps to investigate the role of fine scale heterogeneity in underlying surface on initiation of meso-scale convections associated with heavy rainfall around the Plateau area, the purpose being to understand the land-atmosphere interaction processes in influencing the monsoon precipitation events, and to help improving the heavy rainfall forecast skill of meso-scale numerical models over the Plateau and surrounding regions.

Early warning on drought and flood

Vegetation responds to drought by changing spectral properties and by increasing thermal emission since the photosynthesis and transpiration activities are reduced by insufficient water supply.

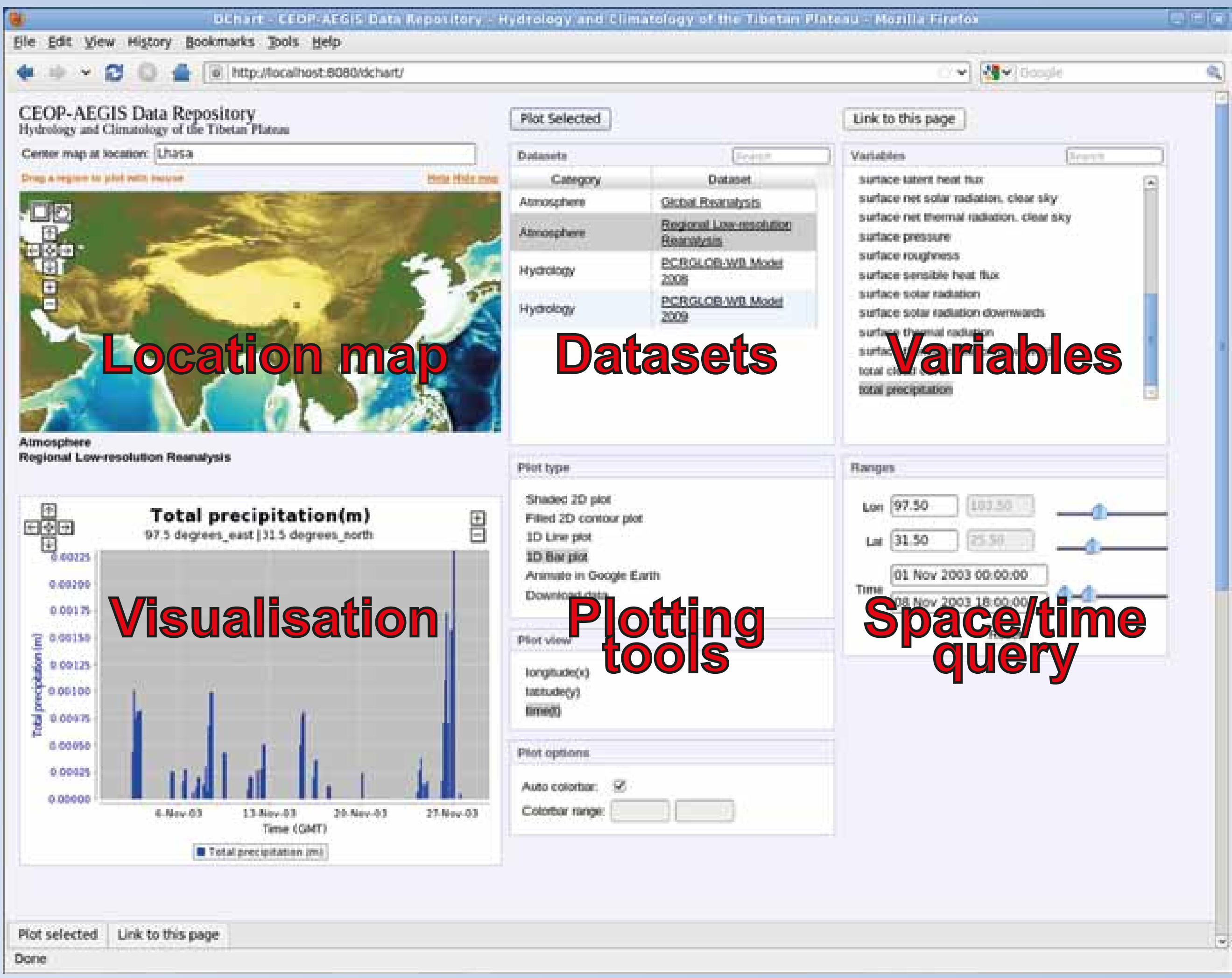
In data-scarce environments, direct observations of land and vegetation by satellites have the advantage of covering large regions with frequent data acquisition and high spatial resolution, which allows monitoring dynamic environmental conditions such as rainfall, soil moisture, thermal properties and changes in vegetation growth condition. Such data can be used to detect the onset of drought and to monitor the duration and severity of drought.

A drought monitoring and prediction technique is being developed by time series analysis of anomalies in multiple indicators based on precipitation, solar radiation, Land Surface Temperature (LST) and vegetation response represented by fAPAR (fraction of Absorbed Photosynthetically Active Radiation) and Vegetation Index (VI).



Time series of Land Surface Temperature Anomaly in 2006

Contributing to GEOSS



With 18 European and Asia research organizations and about a hundred participating scientists, the CEOP-AEGIS project contributes to the creation of highly innovative datasets on the hydrology and climatology of the Tibetan plateau. To get the most out of these datasets, an efficient and user-friendly data-sharing platform has been established to help scientists exchange ground-based and satellite-based data and information.

On a broader perspective, the CEOP-AEGIS project constitutes an important contribution to the Global Earth Observation System of Systems (GEOSS) 10-year implementation plan and contributes to several GEOSS societal benefit areas including water resources, climate, weather and disasters themes. It also contributes to the Group on Earth Observation (GEO) Architecture and Data Committee and GEO Capacity Building Committee, including such aspects as precipitation, water storage measured from space, networks of super sites, data access and data sharing, as well as capacity building.

The infrastructure presented as a new "CEOP-AEGIS Data Portal" is clearly dedicated to the "data access and data sharing" commitment. The prototype of data service designed at the University of Strasbourg consists in a complete processing chain from the data producers to the end-users, to allow the access to project information, documentation and data catalogue. The data management backend follows international standards for data storage, data model and meta-data semantic, and rely on open-source solutions. The Institute for Tibetan Plateau Research hosts the hardware infrastructure in Beijing. After validation, the presented prototype will be transferred to ITP Beijing to provide a new data access service for the community.

Project participants

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SEVENTH FRAMEWORK PROGRAMME