Earth Observation integrated modeling tool for the description of water balance and run-off production of Tibetan Plateau

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Abstract

Quantifying the spatial and temporal relationships between the different water balance terms for the entire Tibetan Plateau is a key-focus of the CEOP-AEGIS project funded by the 7th framework programme of the European commission. One of the products of this project will be a prototype water balance observation system for the Tibetan plateau, built as an integrated platform between Earth Observation products and a distributed water balance and run-off model. The prototype package will provide a quantification of the water yield being supplied to the downstream areas and it will be also used to evaluate the effects of climate change in the water yield of the plateau.

As a requirement, it will rely on an existing and expanding network of observatories and on space-borne observing systems for which data continuity is guaranteed. Earth Observation-based input will include evapotranspiration fluxes, precipitation, snow-melt and top soil moisture.

Following a comparative analysis among different modelling approaches, the raster-based modelling environment PC-Raster, developed at Utrecht University has been chosen to develop the prototype. The model PCR-GLOBWB of Tibetan Plateau will be applied to an area of over 1.2 million square kilometres, between 27.20 and 36.70 degrees latitude and 78.20 and 99.10 degrees longitude and borders India, Nepal and Bhutan.

For a preliminary validation of PCR-GLOBWB, daily stream-flow data for 2009 in a section of the Upper Yellow river have been considered, with actual evapotranspiration derived from MODIS and precipitation from TRMM.

Introduction

Estimates of the Plateau water balance and water yield rely on sparse and scarce observations that cannot provide the required accuracy, spatial density and temporal frequency. However, during recent years, the development of methodologies for analysing Earth Observation data has made available new tools to support water resources management. In this context, one of the goals of the CEOP-AEGIS project ("*Coordinated Asia-European long-term Observing system of Qinghai–Tibet Plateau hydro-meteorological processes and the Asian-monsoon systEm with Ground satellite Image data and numerical Simulations*"), financed by the European Commission under Framework P7 topic ENV.2007.4.1.4.2 "Improving observing systems for water resource management", is to develop a distributed hydrological model of the Tibetan plateau based on observing systems to determine and monitor water balance and water yield.

A preliminary version of the model, named PCR-GLOBWB has been developed and applied to the Tibetan plateau. The area interest covers 1.2 million square kilometres, ranging between 27.20 and 36.70 degrees latitude and 78.20 and 99.10 degrees longitude. Elevations vary from 700 meter above sea level in the south-east to the summit of Mt. Everest at 8848 m.a.s.l, with an average elevation over 4000 m.a.s.l.

The integration of observations into the distributed water balance model PCR-GLOBWB will contribute to clarify the role of Plateau hydrology in the onset and intensity of the Asian Monsoon and in intense precipitation. The time-series of hydrological satellite data products will be used to demonstrate an Early Warning system on droughts and one on floods.

Modeling approach

EO products can be integrated in hydrological modelling in different ways. In CEOP-AEGIS priority will be given to the use of EO products in model forcing (Droogers and Bastiaanssen, 2002; Kite and Pietroniro, 1996) and validation (Schuurmans et al., 2003; Immerzeel and Droogers, 2007).

In the case of PCR-GLOBWB, the EO forcing variables will consist of direct inputs into the model such as precipitation, evapotranspiration, snow and ice dynamics; additional parameters related to vegetation and land cover will be also considered as input data. E.O. products will be generated within different work-packages of the CEOP-AEGIS project. In particular, a continuous set of precipitation maps with a high temporal and spatial resolution will be made available by integrating the Doppler radar network on the Tibetan plateau, satellite data and ground rain gauge data. Low resolution maps of all components of the energy balance based for the entire Tibetan plateau with a target frequency of one week. The latent heat flux, specifically, will be used subsequently to force the hydrological model after conversion to actual evaporation rates. Fig.1 depicts in a conceptual way the integration of E.O. products (from different CEOP-AEGIS work-packages) into the model.

In PCR-GLOBWB, the dimension of the simulation grid-cells, 5 x5 km, has been chosen by taking into consideration the resolution of the different RS products and the level of detail of water balance estimates. The grid for the basin of the Tibetan plateau will cover an area of approximately 700 x 400 cells.

Within each cell, precipitation in the form of rain or snow either falls on soil or in open water surface. The soil is divided in three compartments (two upper soil stores plus groundwater), each one of them generating different drainage components, respectively: direct runoff, interflow and base flow. Snow is accumulated when the temperature is sufficiently low, otherwise it melts and adds to the liquid precipitation that reaches the soil as rain or through-fall. A part of the liquid precipitation is transformed in direct or surface runoff, whereas the remainder infiltrates into the soil. The resulting soil moisture is subject to soil evaporation when the surface is bare and to transpiration when vegetated; the remainder contributes in the long-term to river discharge by means of slow drainage which is subdivided into subsurface storm flow from the soil and base flow from the groundwater reservoir.

The total runoff from the land surface feeds without any delay into the river network and is lumped with the changes due to consumptive water use, net precipitation and ice formation from the total open water volume prior to routing (Zhao, 1992). Discharge is calculated from the kinematic wave approximation of the Saint-Venant Equation, by using a numerical solution available as an internal function in PCRaster. Reservoirs, lakes and permafrost conditions are considered in the modelling scheme.

As shown in Fig.1, two different sources of information will be used to calibrate and validate the model. In first instance, data on river discharges will be used to refine model parameterization in selected key-areas. A cal/val procedure will be implemented for the distributed water balance output by using top soil moisture derived in CEOP-AEGIS. This variable will be derived by combining passive and active microwave sensor and the Chinese geostationary satellite Fengyun.

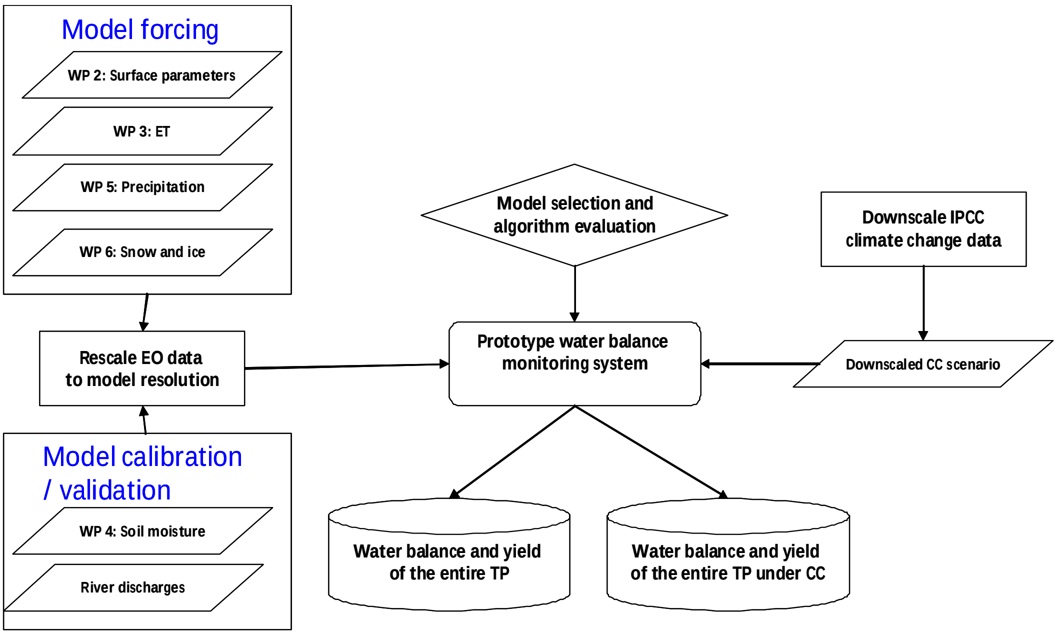

Figure 1: Schematic representation of the development of the water balance monitoring system in the CEOP-AEGIS project and integration with E.O. products (model forcing and cal/val procedures)

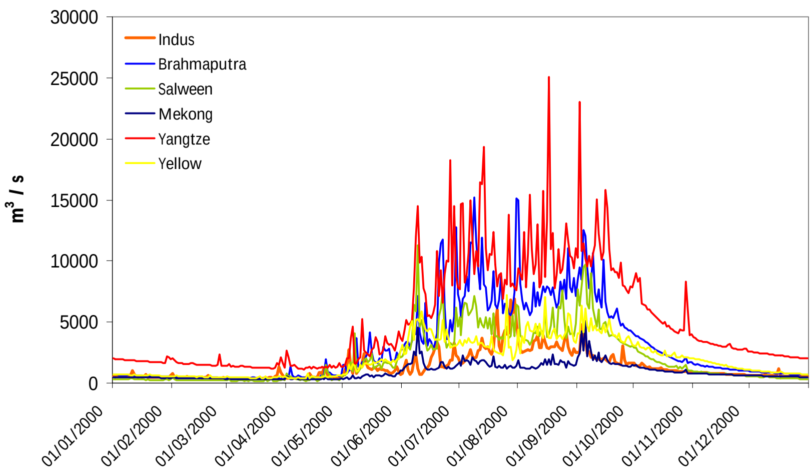

Figure 2: Simulated discharge (year 2000) at selected section of main rivers generating from Tibetan plateau.

Preliminary results - i.e. streamsflow discharge on selected points of main rivers for the year 2000 - are consistent with currently available information (Fig.2). The complete set-up of E.O. input data will only be available in a later stage of project development. However, a preliminary procedure of calibration and validation is being carried out on the sub-basin of Upper Yellow River, covering a total area of 143451 km^2. TRMM daily precipitation maps (Fig.3) are input to the model together with actual evapotranspiration maps (WaterWatch-ETlook product). TRMM maps have been corrected by using 6 ground-based meteorological stations in the Upper Yellow River Basin (Fig.2). Air temperature data from ground station are used for partitioning precipitation between rainfall and snow. Daily streamflow discharges at the Tangnaihai station are used for the calibration of input parameters. The results confirm the reliability of the modelling approach in simulating the temporal variability of streamflow at the considered observation station.

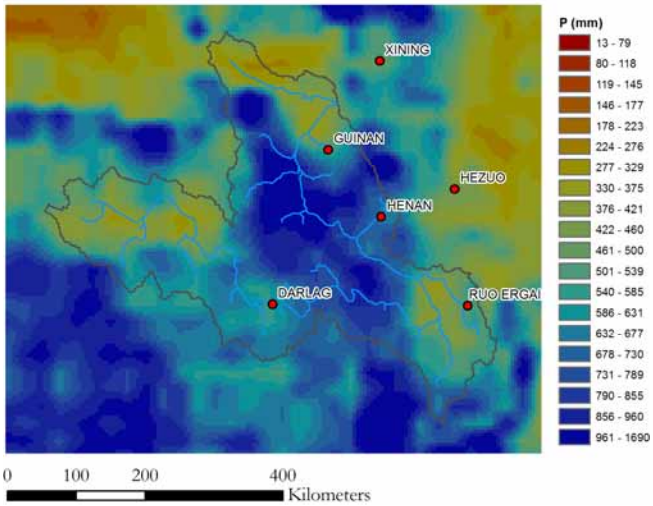

Figure 3: Corrected precipitation data from TRMM; cumulative values for the year 2009 and location of ground based meteorological stations.

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