A Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

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Italian Hydrological Society

GH2MF2

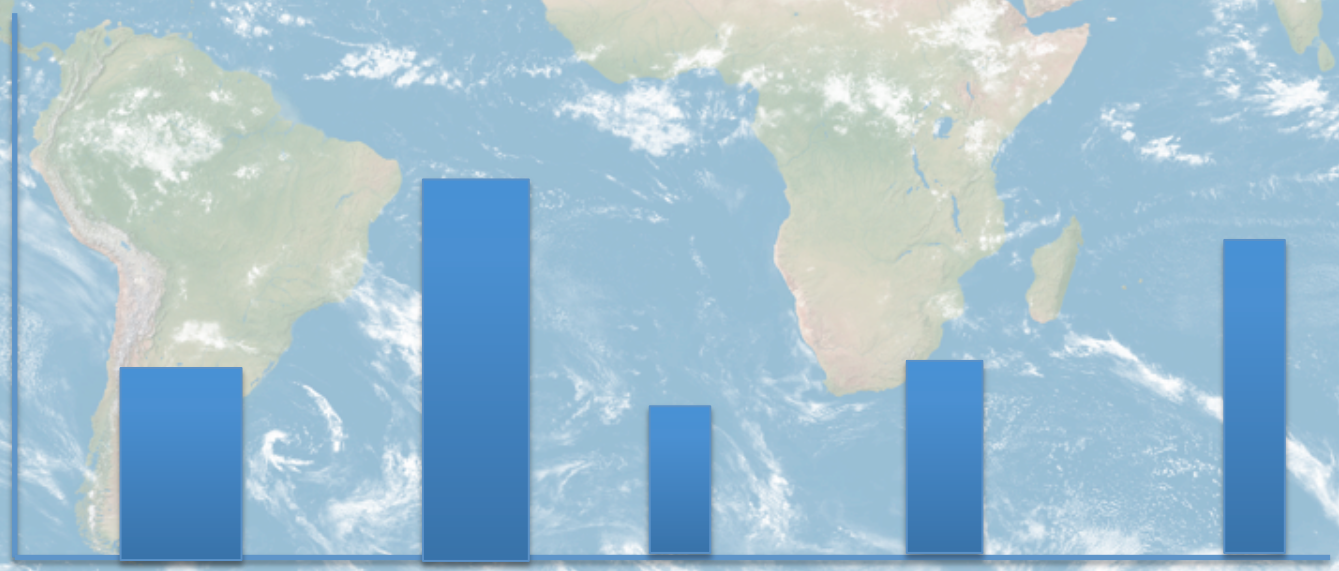
1/T
ONCE UPON A TIME ……

Meteorologists on one side
and
Hydrologist on the other side
had peculiar ideas on what
was leaving their
domain of interest

Hydrologists considered “evapo-transpiration” as LOSSES, although evapo-transpiration accounts from 40% to 60 % of the entire water budget.

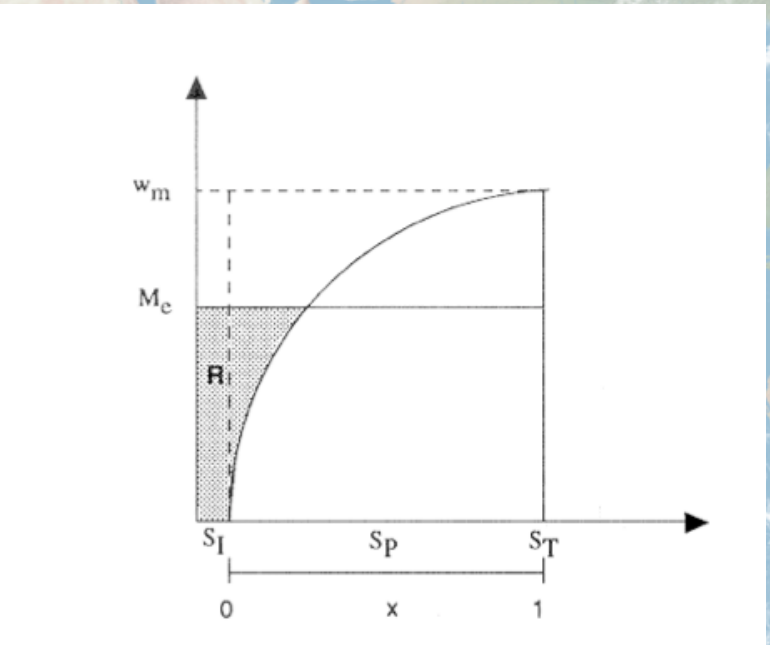
Meteorologists and Climatologists considered “surface runoff” as LOSSES, although surface runoff accounts from 20% to 40 % of the entire water budget.

In particular Meteorologists and Climatologists considered the soil effect as a BUCKET (the Manabe Bucket, 1969) which used to produce the following type of river flow:

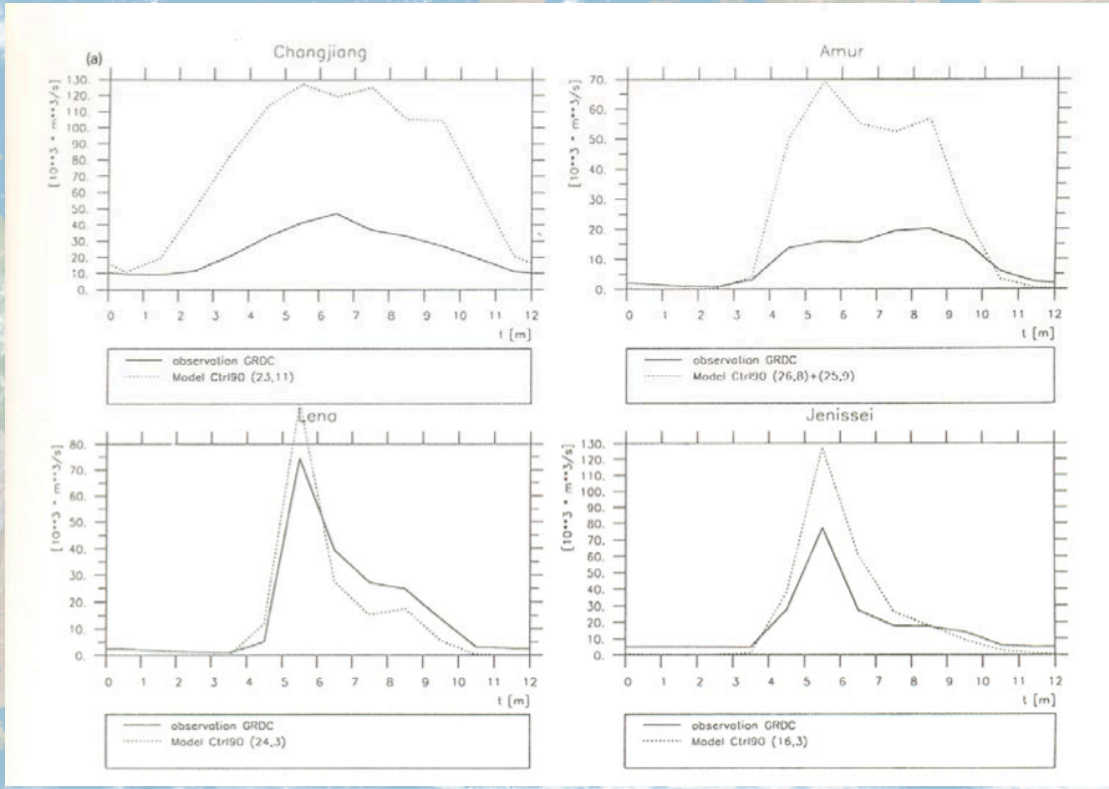


At the end of the eighties I collaborated with Lydia Dümenil, a climatologist from the Hamburg Max-Plank institute, who asked me if I could provide her with a very simple scheme as an alternative to the Manabe Bucket.

I had recently modified the Xinanjiang model (Zhao, 1977) by introducing infiltration and percolation losses, and produced a new lumped model, the Arno Model. The Xinanjiang/Arno saturated area vs soil moisture volume function was then introducedin the Hamburg ECHAM GCM.



Using ECHAM with the new hydrological model we were able of comparing the GCM results with the flow of the large riversin the world, which data were made available by the Koblenz Global Runoff Data Centre.



The results showed that only few rivers could be correctly reproduced and this was mainly due to two reasons.

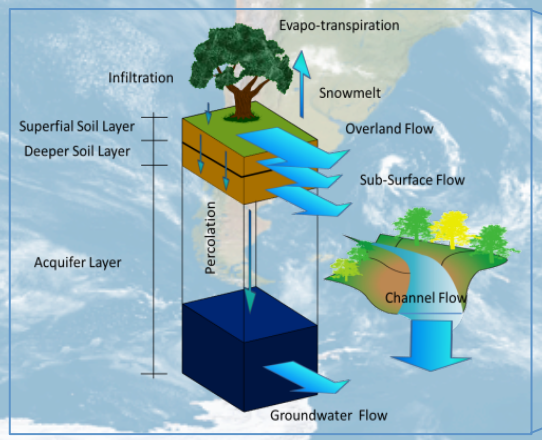
1) The lack of a good routing component

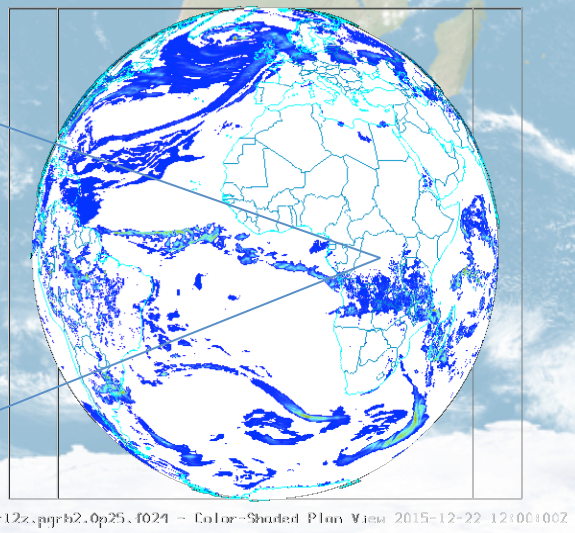
2) The lack of physically meaningful parameters in the hydrologic model to be estimated on the basis of available maps

This raised the idea of developing a physically meaningful model which parameters could be estimated from maps.

Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

This project presented at the EGU 2016 born of solidarity and the need to dignify the most disadvantaged people living in the poorest countries (Africa, South America and Asia), which are continually exposed to changes in the hydrologic cycle suffering events of large floods and/or long periods of droughts.





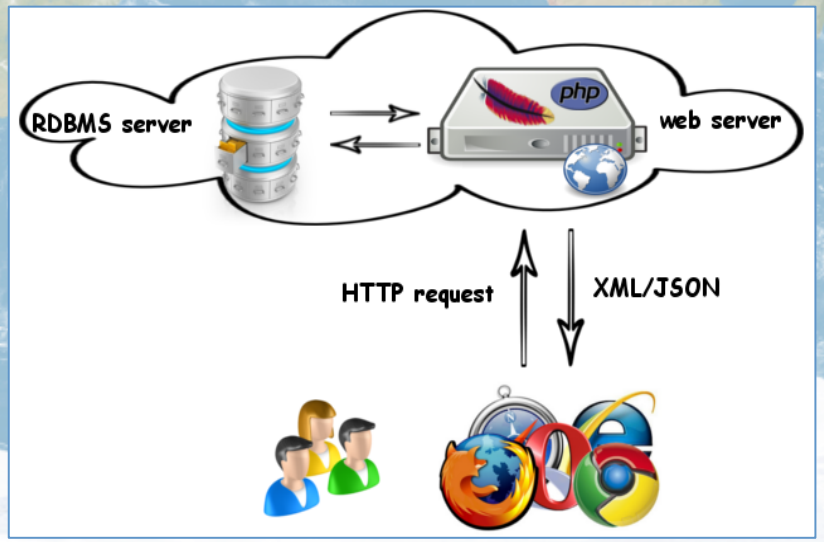
Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

The project called: *A Global High-resolution Hydrological Model for Flood Monitoring and Forecasting* (**GH^{2}MF^2**) is Non-Profit and aims to provide at global high resolution (**1x1 km^2**) hydrological monitoring and forecasting in real time and continuously coupling Weather Forecast of **GFS-0.25°** (Deterministic and Ensembles Run) forcing a physically based distributed hydrological model **TOPKAPI-eXtended**. Finally using the **MCP** approach for the proper use of ensembles for Predictive Uncertainty assessment.

Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

THE PLATFORM

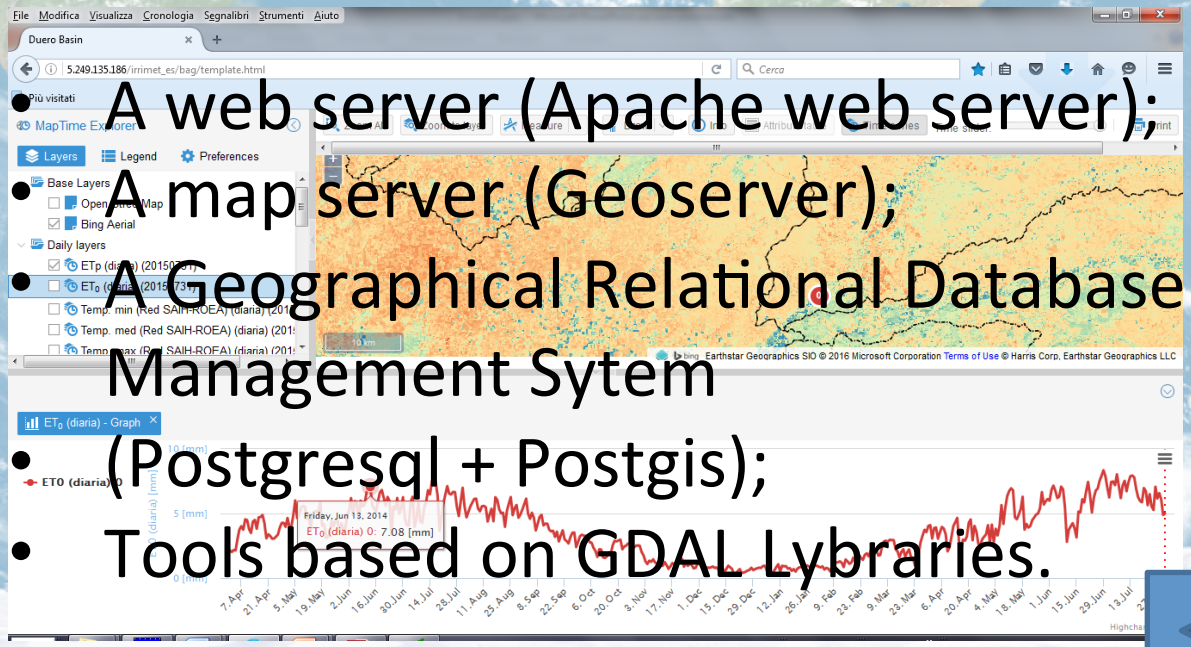
The system will be integrated into a Decision Support System (DSS) platform, based on geographical data. The DSS is a classical client-server web application (for Pcs, Tablets, Mobile phones) not requiring installation (a web browser and an internet connection only) or updating (all upgrading being deployed on the remote server).



Global System for Hydrological Monitoring and Forecasting in Real Time at High Resolution

THE PLATFORM

DSS is a classical client – server application. The client side is an HTML 5 – CSS 3 application, it runs in one of the most common browser (Mozilla Firefox, Google Chorme, Safari). The server side consist in:



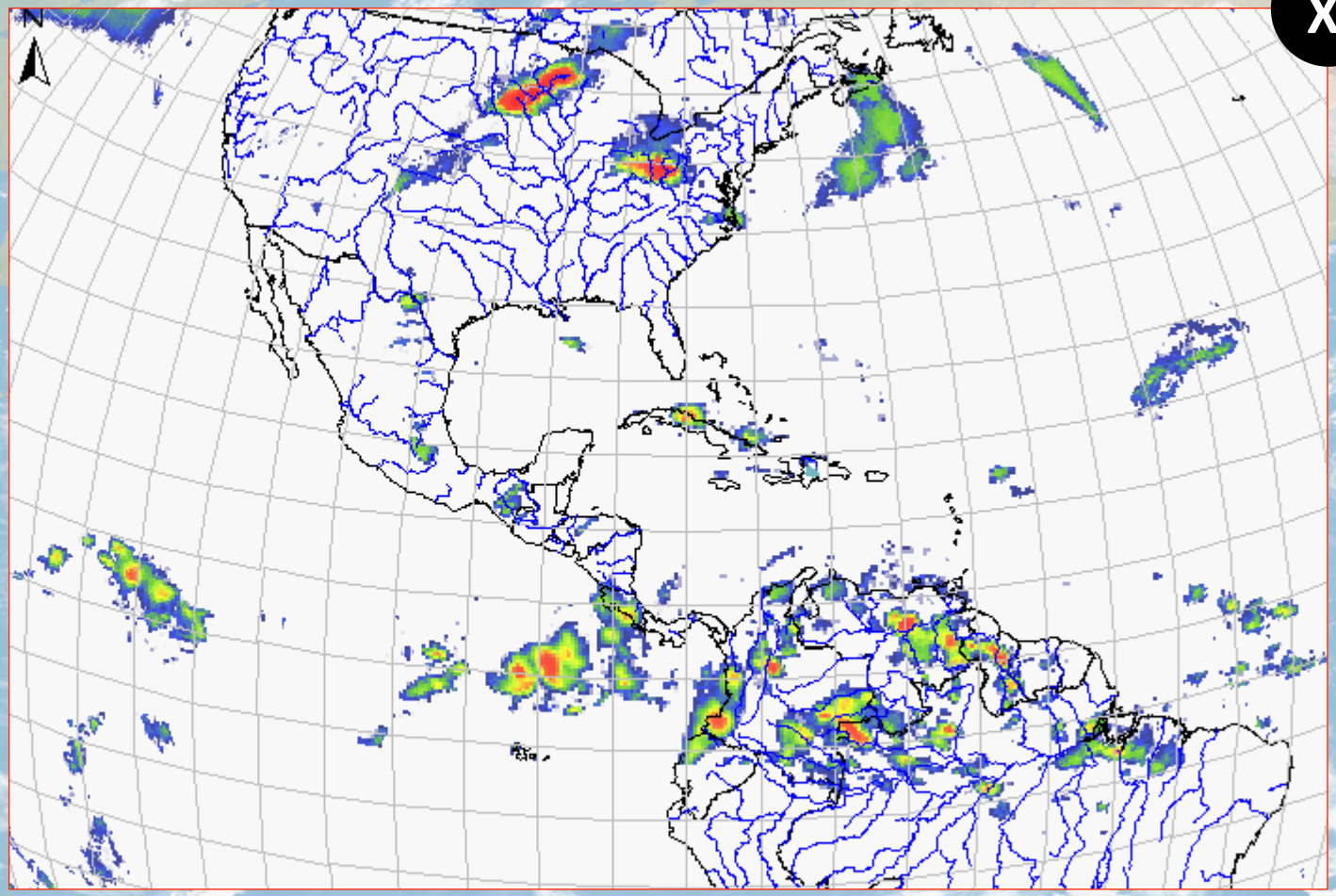
- A web server (Apache web server);
- A map server (Geoserver);
- A Geographical Relational Database Management Sytem (Postgresql + Postgis);
- Tools based on GDAL Lybraries.

Global System for Hydrological Monitoring and Forecasting in Real Time at High Resolution

- The proposed platform is meant to be participative and interactive. To meet this objective, all information used in the system must be freely accessible to users, including the hydrological models, and allowed to set-up the models for the benefit of the community.

- The novel aspect of the proposed project and its platform is that any user will be allowed set-up, calibrate and validate hydrological models, by downloading from the platform the base maps (DEM, Flow Directions, Flow Accumulation, Soil Types and Land Use) and the hydro-meteorological forcing data.

Assimilation of remote sensing observed rainfall NASA product TRMM 3B42RT into platform



X

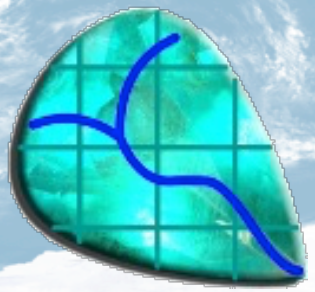
Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

- Validated models (according to provided standards) will be then uploaded on the platform to be part of the daily run of the system and to be available to other users, who can view and interrogate the platform for forecasts in all basins.

- The hydrological simulations will also be processed by the platform for visualization, diffusion and dissemination of warnings, alerts and alarms.

Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

The proposed project is based on a much more computationally powerful hydrological model TOPKAPI-eXtended whose physically based parameters allow an easy settung-up using world-wide availablebase maps. TOPKAPI-X has already accumulated a long history in the literature as well in operation all over the world. The simulations are meant to be performed at hourly temporal resolution on spatial scales of 1x1 km2.

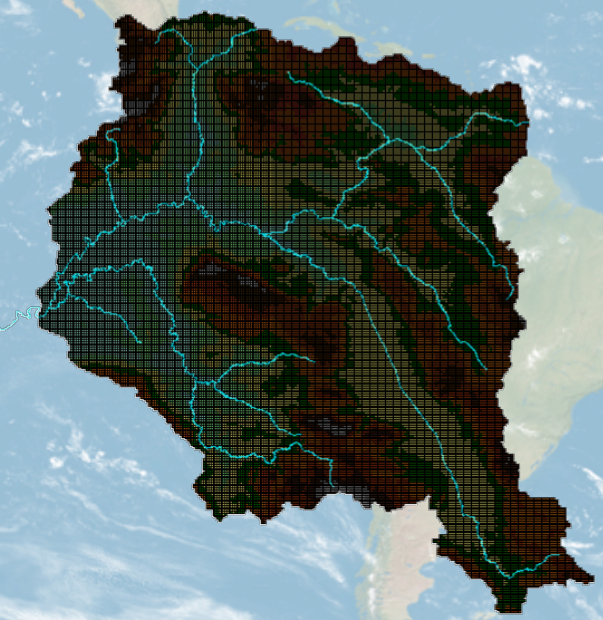


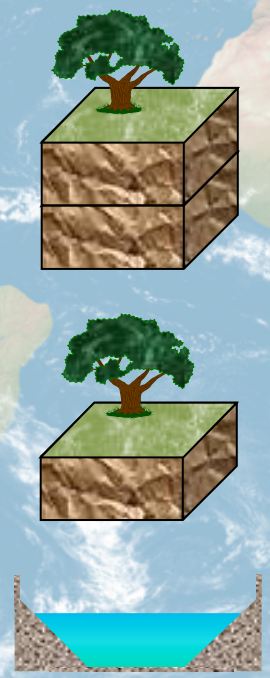
Continue for Presentation

Click for exploring TOPKAPI-X Model

KINEMATIC APPROACH HYPOTHESIS IN TOPKAPI-X

TOPKAPI-X is based on the hypothesis that sub-surface flow (Two Layers), overland flow and channel flow can be approximated using a **Kinematic wave approach.**





$$\frac{\partial \eta}{\partial t} = a - b\eta^c$$

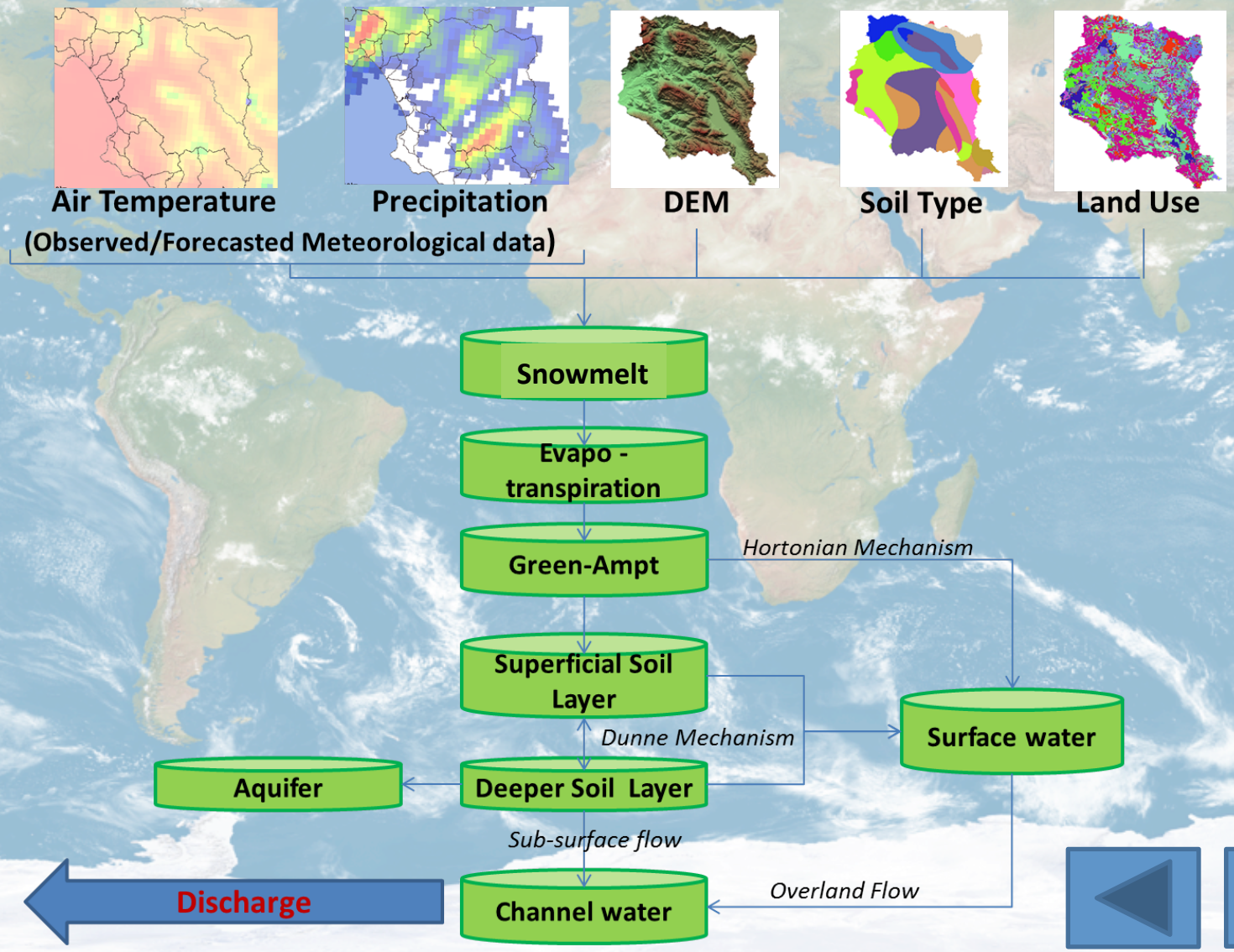
The integration in space of the non-linear Kinematic wave equations representing subsurface flow, overland flow and channel flow results in **FOUR** 'structurally-similar' non-linear reservoir equations.

MAIN MODIFICATIONS IN TOPKAPI - eXtended

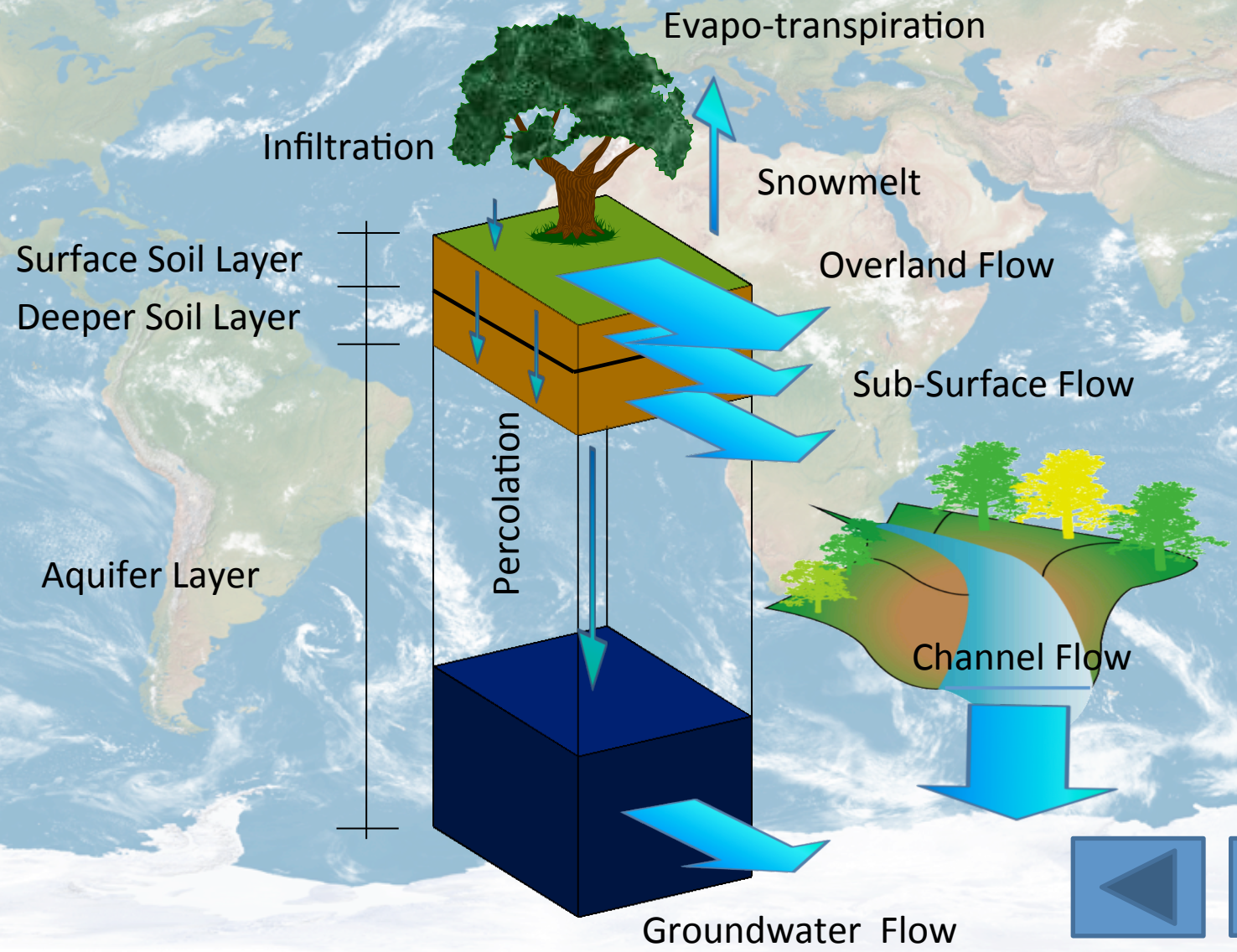
1. Introduction of an 8-DIRECTIONS drainage network
2. ADDITIONAL SOIL RESPONSE in order to reproduce different hydrological situations. Two soil layers
3. Addition of an infiltration module based on the GREEN-AMPT MODEL, to reproduce hortonian processes
4. Introduction of two coefficients to take into account the sun height with respect to the cell aspect for the RADIATION ASSESSMENT and ALBEDO
5. Addition of a GROUNDWATER MODEL based on the cellular automa
6. Addition of a RESERVOIR/LAKES MANAGEMENT MODE

NEW version of the model: TOPKAPI-eXtended

CONCEPTUAL SCHEME TOPKAPI - eXtended

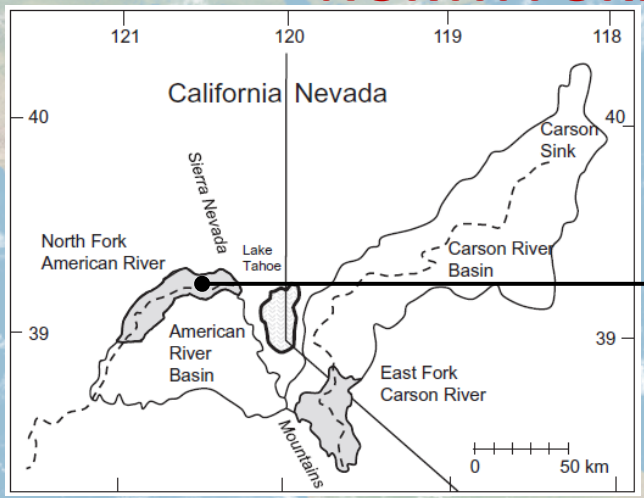


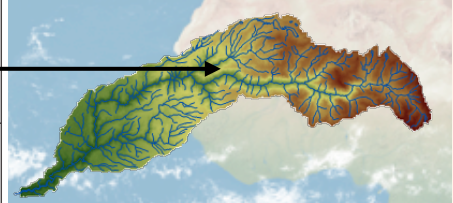
CONCEPTUAL SCHEME TOPKAPI - eXtended

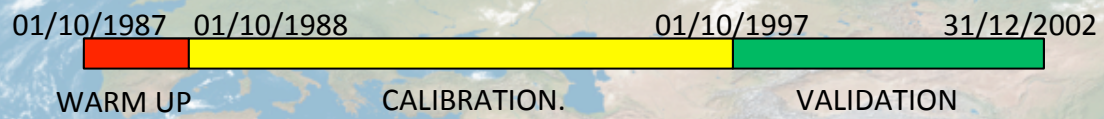


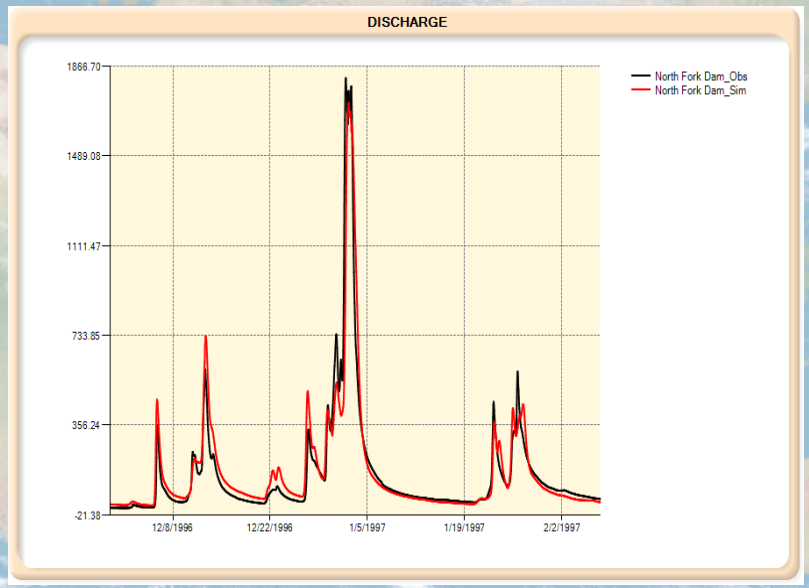
NEW version of the model: TOPKAPI-eXtended

2nd PHASE of Distributed Model Intercomparison Project, Phase 2
NORTH FORK AMERICAN RIVER BASIN, CA, USA





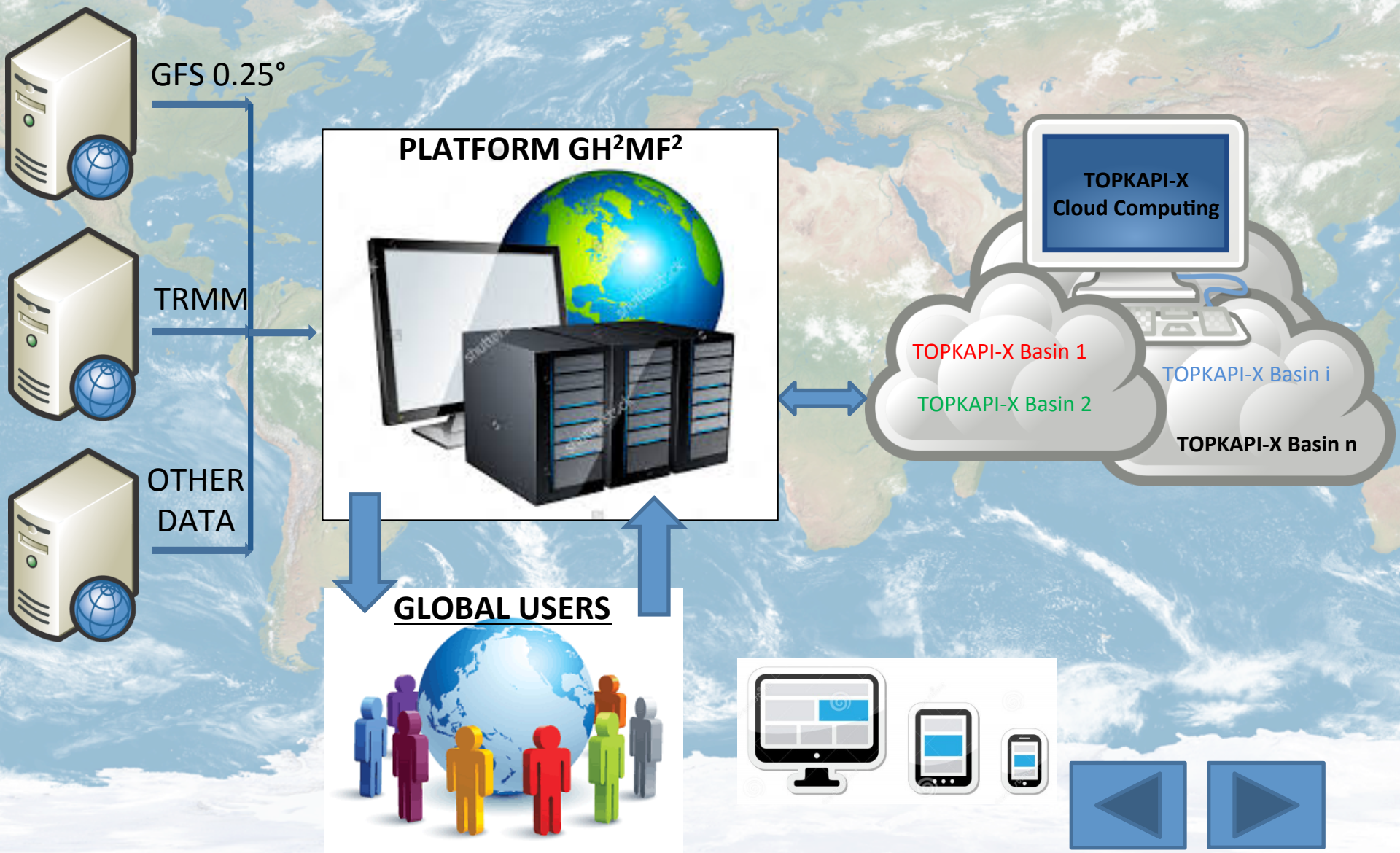




In the application of American River Basin (*inside the project DMIP-2/NWS*) the **TOPKAPI-X** has generated the best simulation during the calibration period *(Smith et al., 2013)*. The new conceptualization of the two soil layers plus Green and Ampt has allowed a correct reproduction of peak floods, the base flow and recession curves. Thanks to the model of infiltration even small summer events are simulated correctly. The evaluation indices confirm the good behavior of the model, which returned a Nash-Sutcliffe coefficient equal to 0.90 calculated over 9 years of simulation with hourly time step.

Simth M. et al., 2013. The Distributed Model Intercomparison Project - Phase 2: Experiment Design and Summary Results of the Western Basin Experiments, Journal of Hydrology 507 (Dec. 2013) 300–329.
http://dx.doi.org/10.1016/j.jhydrol.2013.08.040

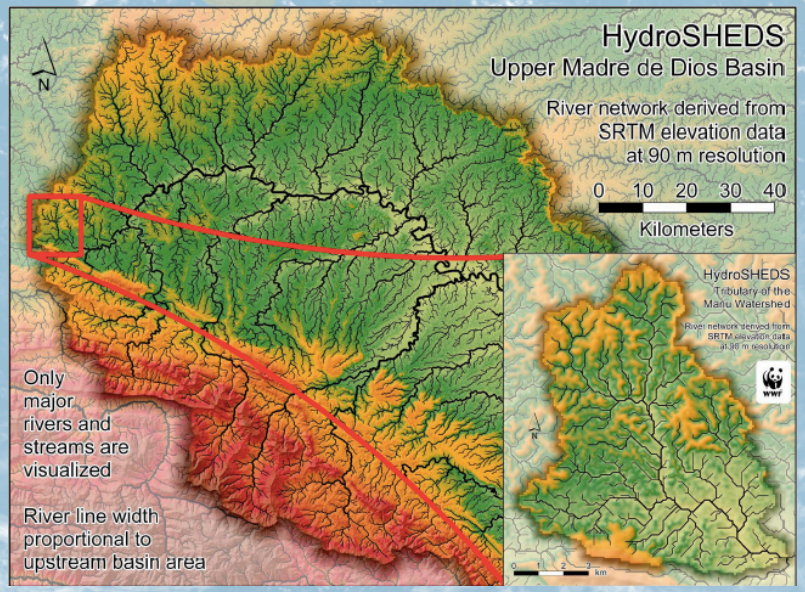
Global High-resolution Hydrological Model for Monitoring and Forecasting



Global High-resolution Hydrological Model for Monitoring and Forecasting

Common Database GIS layers for topological processing of hydrologic models with TOPKAPI-X

HydroSHEDS 30 arc-sec

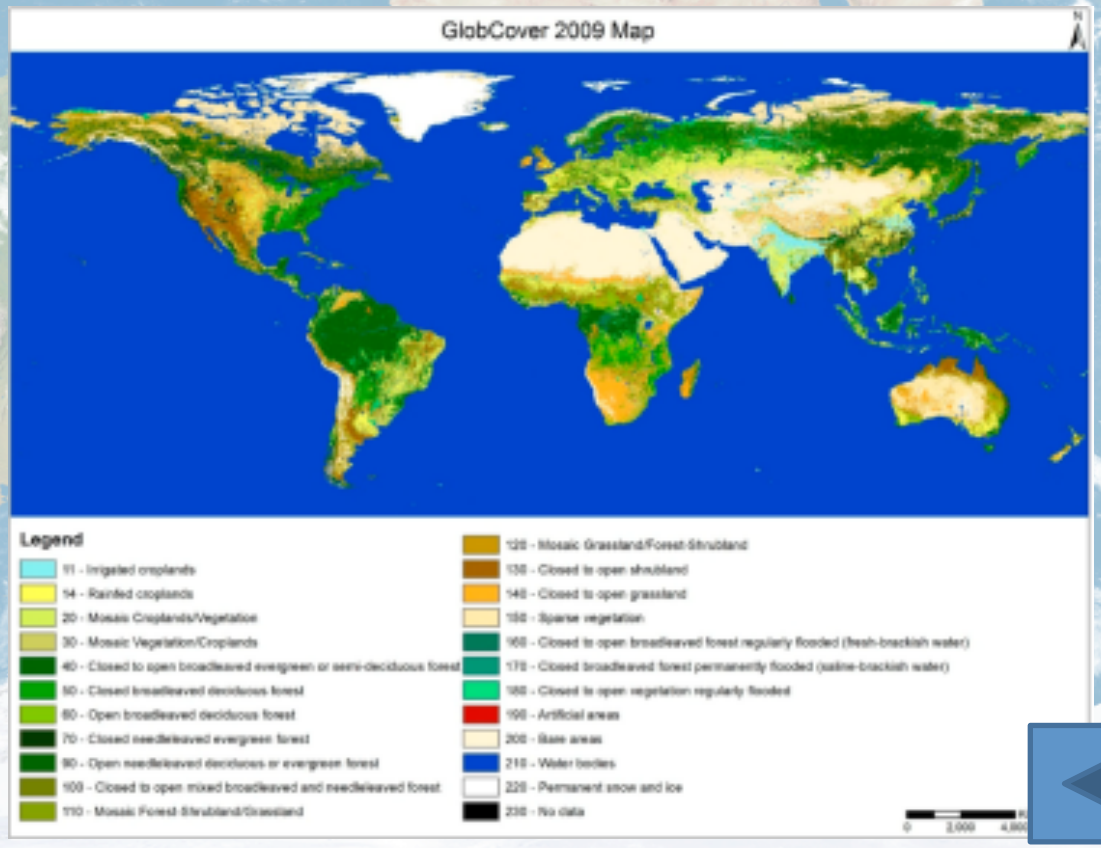


Identifier	Types of data
DEM	Digital elevation model (void-filled)
CON	Hydrologically conditioned elevation
DIR	Drainage directions
ACC	Flow accumulation (number of cells)
RIV	River network (stream lines)
BAS	Drainage basins (watershed boundaries)

Global High-resolution Hydrological Model for Monitoring and Forecasting

Common Database GIS layers for topological processing of hydrologic models with TOPKAPI-X

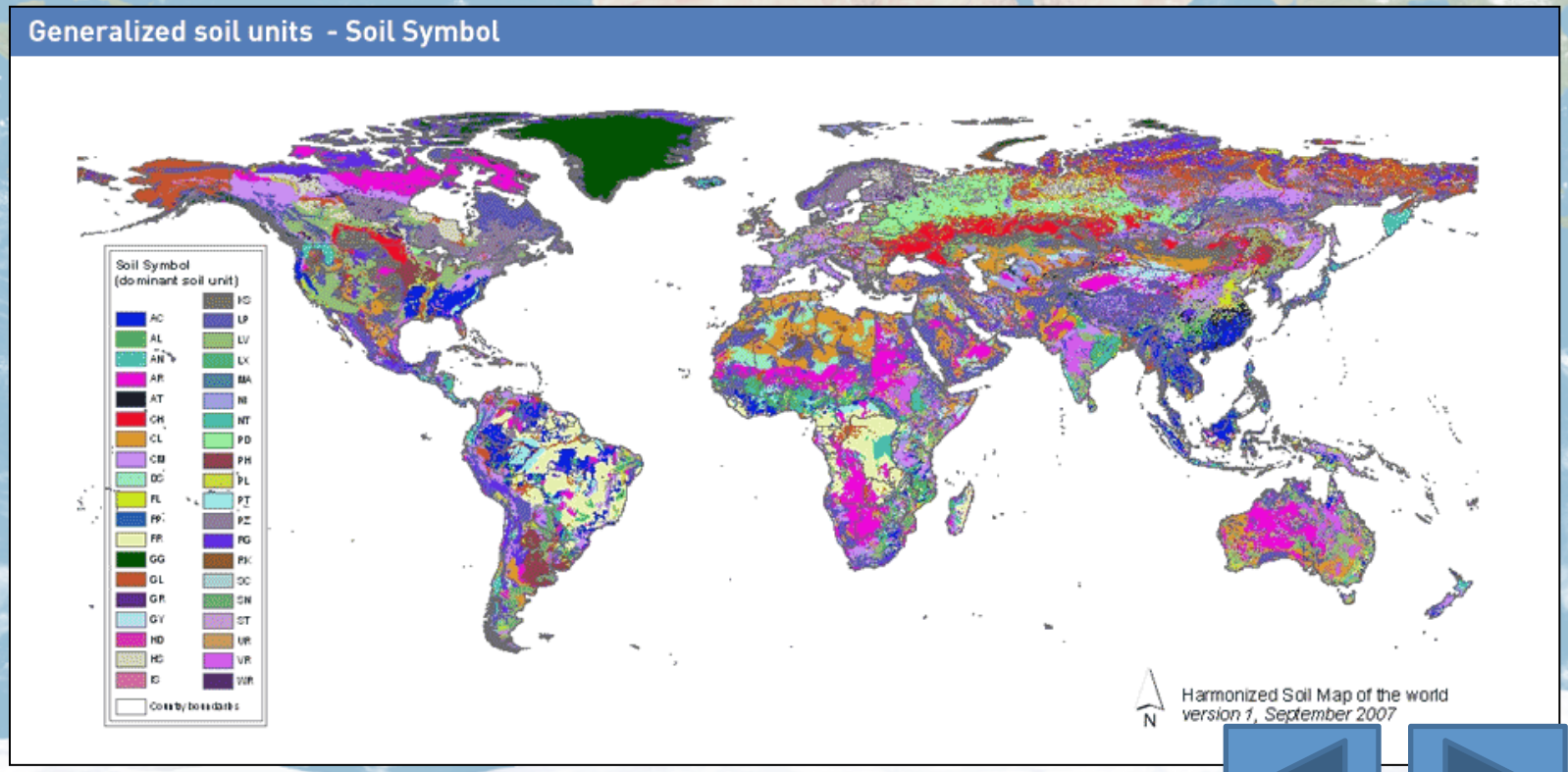
Global Land Cover



Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

Common Database GIS layers for topological processing of hydrologic models with TOPKAPI-X

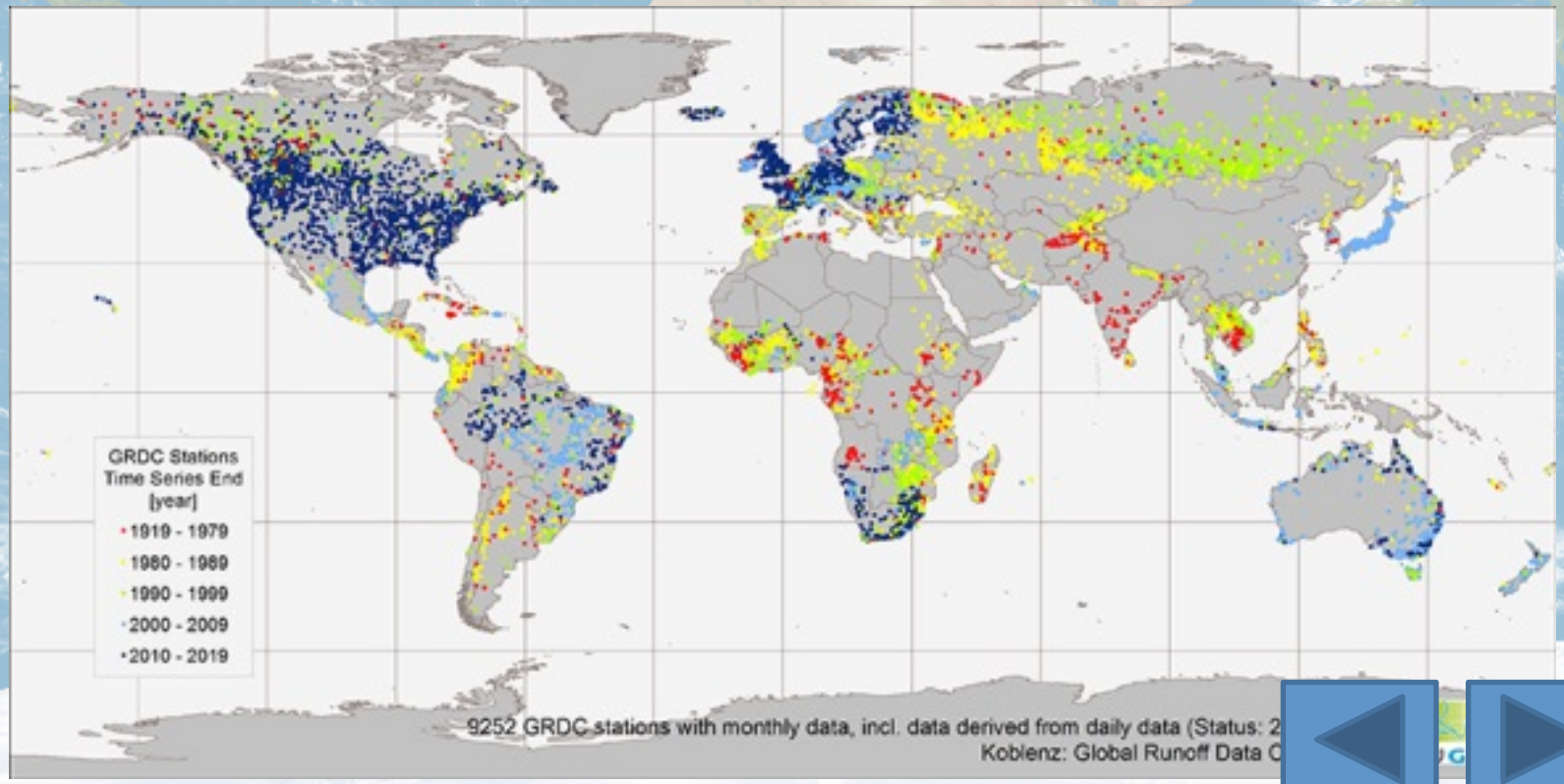
Soil Type Harmonized World Soil Database (HWSD)



Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

Common Database for calibrate/validate of hydrologic models with TOPKAPI-X

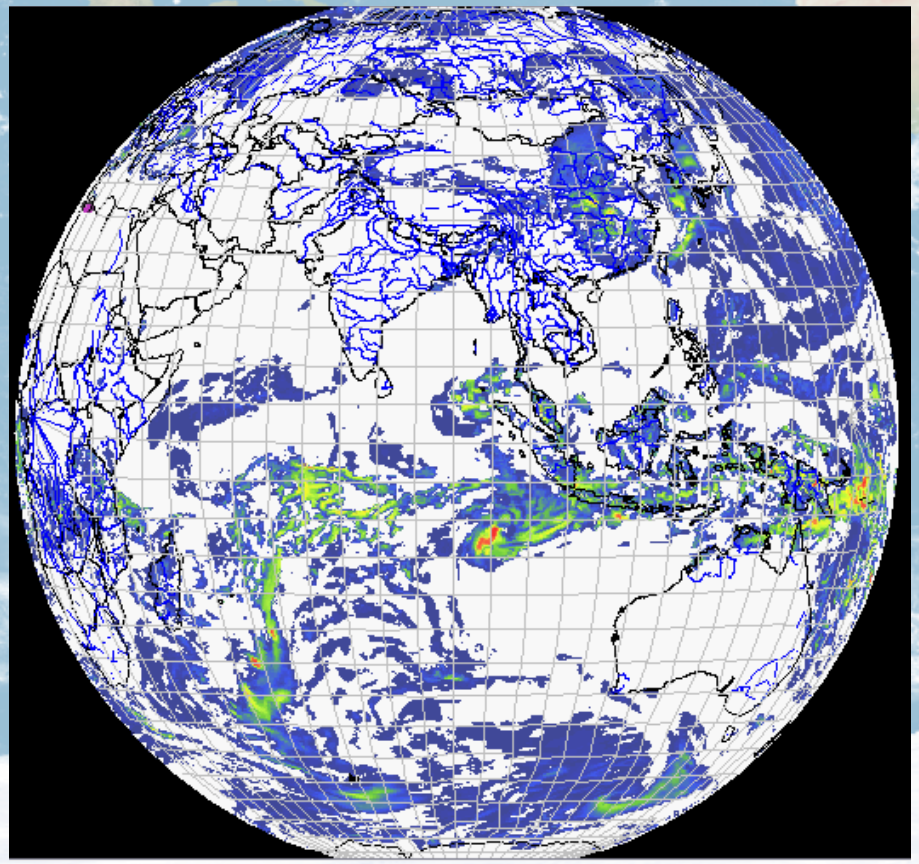
Discharge: Global Runoff Data Centre and others as well as data from institutions who want to participate

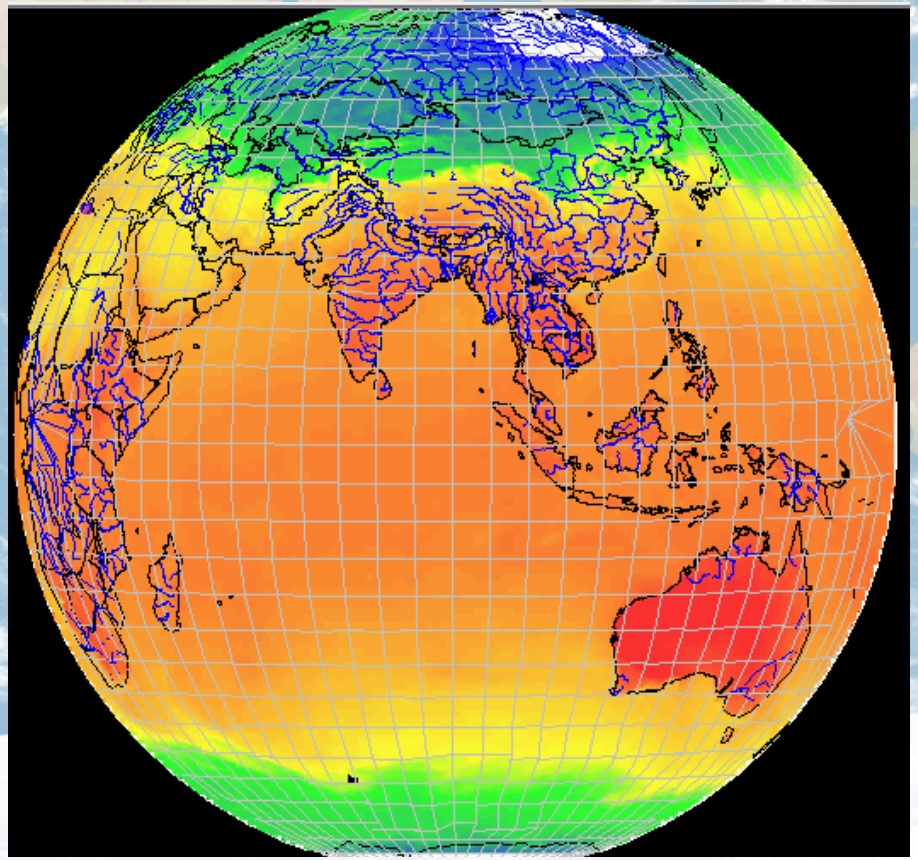


Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

Common Meteorological DataSets for calibrate/validate hydrologic models with TOPKAPI-X

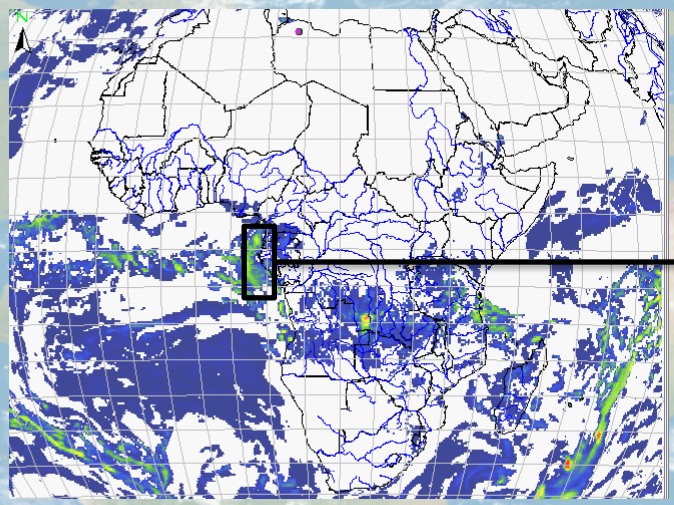
ERA-Interim|ECMWF and Others

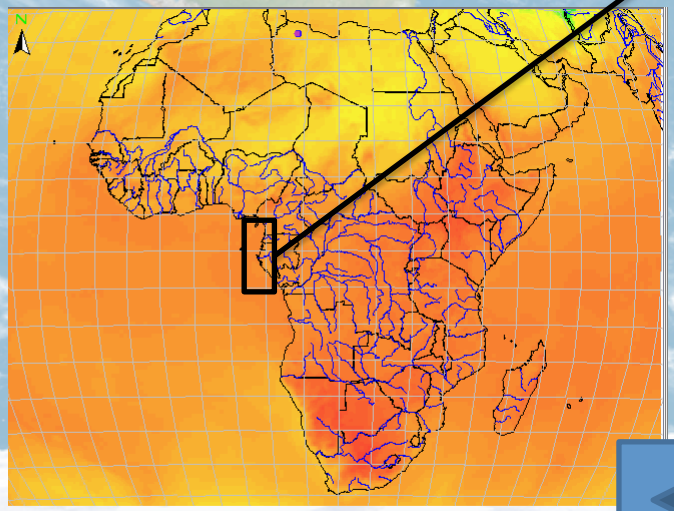


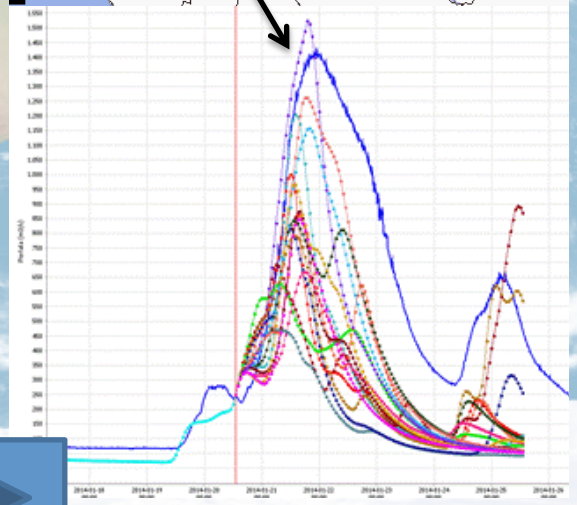


Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

GFS 0.25° Forcing
TOPKAPI-X







DISCHARGE FORECAST AT PIXEL
SCALE 1x1 km² TOPKAPI-X

Global High-resolution Hydrological Model for Monitoring and Flood Forecasting

This project received the unanimous approval and support from the Council of the Italian Hydrological Society (SII-IHS)

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CROWDFUNDING

https://es.ulule.com/global-high-resolution-system-for-hydrological-mon/