



中国科学院 青藏高原研究所

Institute of Tibetan Plateau Research
Chinese Academy of Sciences



TPDC

国家青藏高原科学数据中心
National Tibetan Plateau/Third Pole Environment Data Center

Introduction to the Distributed multi-sphere hydrological model (WEB-DHM)

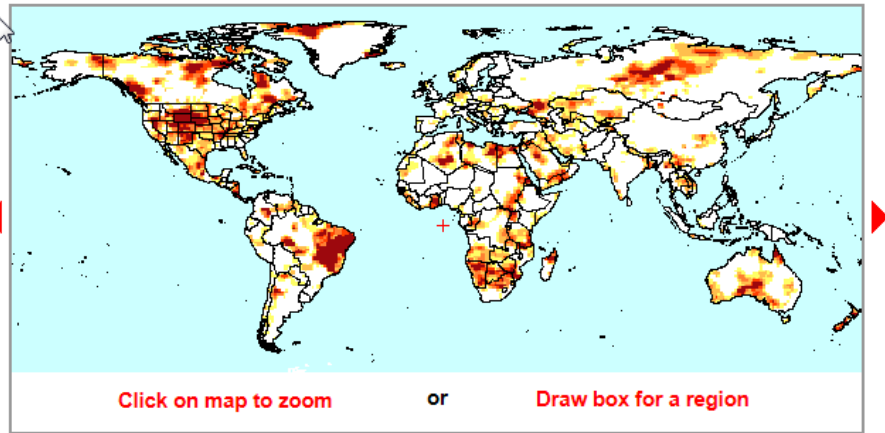
Baohong Ding, Lei Wang, Jing Zhou
dingbh@itpcas.ac.cn

13 May 2026

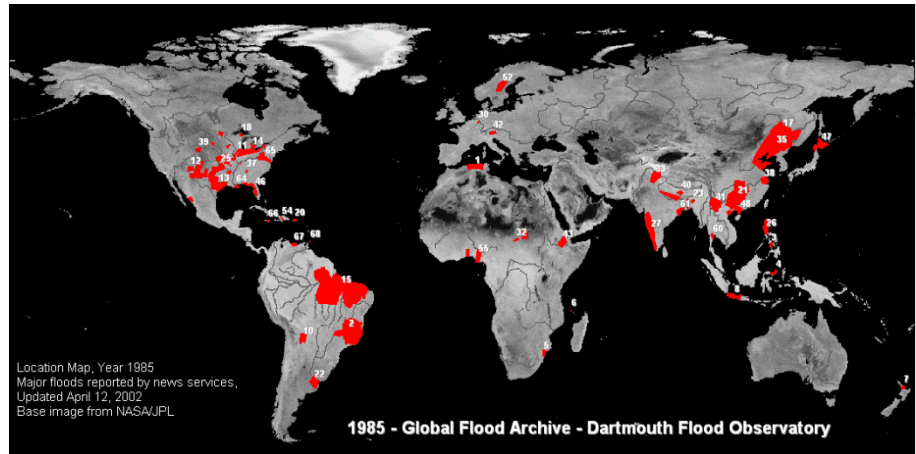
WEB-DHM Training Course

1. Model introduction
2. Input data preparing: landuse, vegetation (LAI/FPAR)
3. Forcing data preparing: TPMFD, CMFD
4. Running Model.

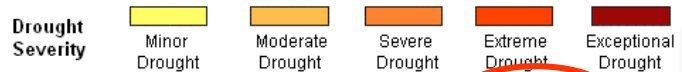
Global drought monitoring (2023)



Global flood distribution (1985-2006)



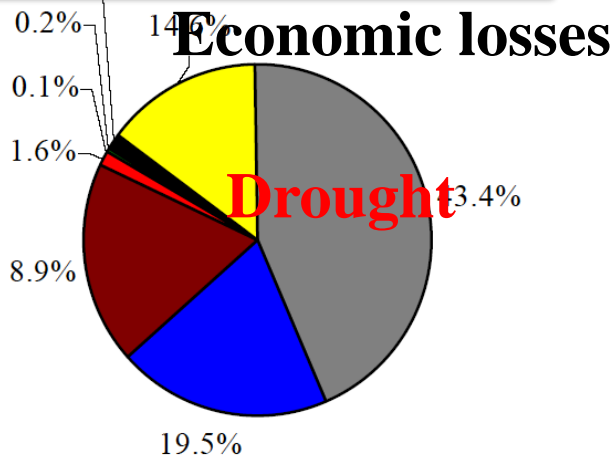
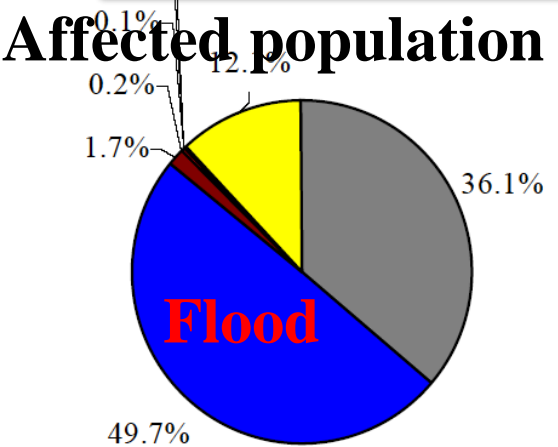
0 9200 18400 27600 36800 km



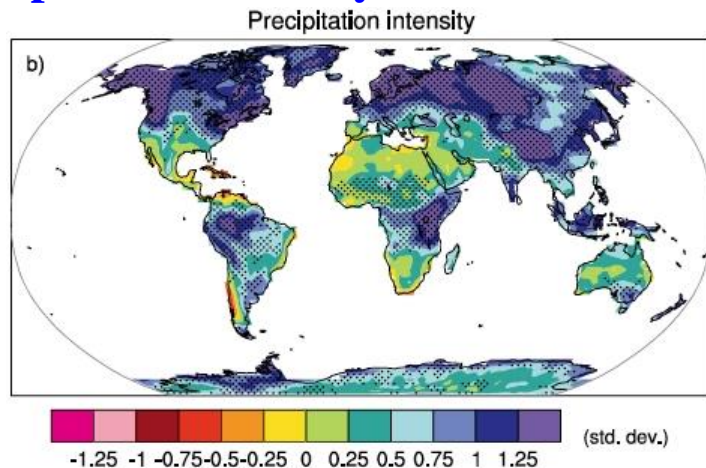
Population in the current view under exceptional drought: **161,684,000**

Global losses due to disasters (In the past 28 years)

- Drought
- Floods
- Earthquake
- Extreme-temperature
- Slide
- Volcano
- Wild-fire
- Windstorm



Precipitation intensity



IPCC fifth report

Heavy precipitation events will likely become more frequent.

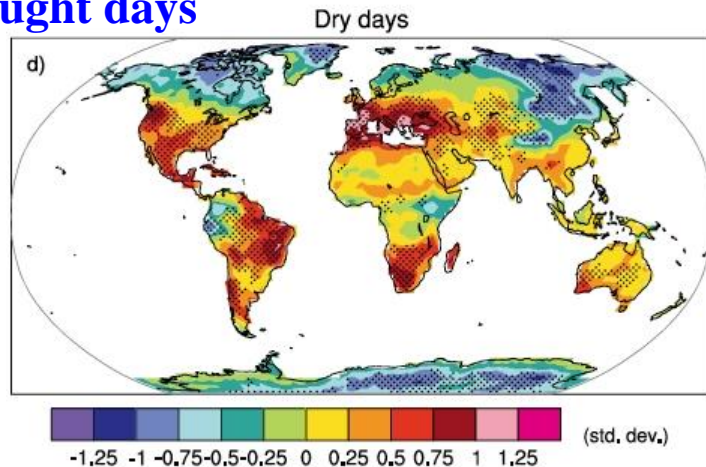
> 90%

Predict the change in climate extreme events

The area affected by the drought will increase.

> 67%

Drought days



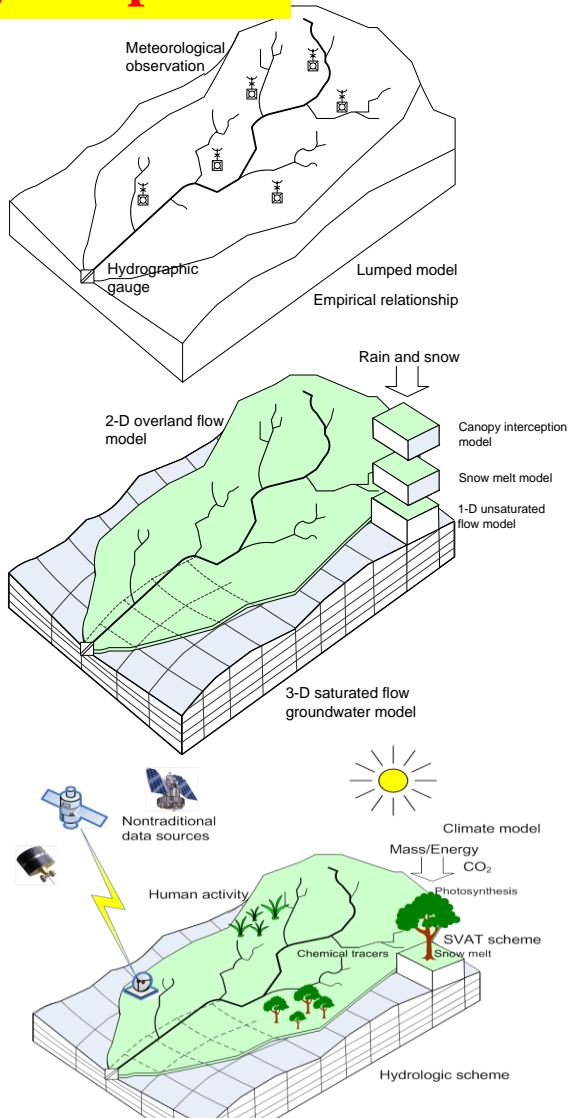
Scientific question: How to improve the forecast of extreme events and reduce disaster losses?

Solution: Improve meteorological forecasts &

Improve hydrological modeling

Hydrological model development: Improving hydrological simulation

Hydrosphere



1960s–1970s: First lumped hydrological model

Advantage: Describe the rules of rainfall-runoff.

Disadvantage: Ignore the influence of the spatial variations of topography and vegetation on runoff.

1980s–1990: Second distributed hydrological model

Advantage: Considering the spatial variations of watersheds based on physical processes.

Disadvantage: Water and heat exchanges between land and atmosphere is not carefully considered

Recent 20 years: Distributed biosphere hydrological model

- Considering water and heat exchange between land and atmosphere
- Improve vegetation physiology
- Hydrosphere-Atmosphere-Biosphere coupling simulation

Multi-sphere

Multi-sphere hydrological model development

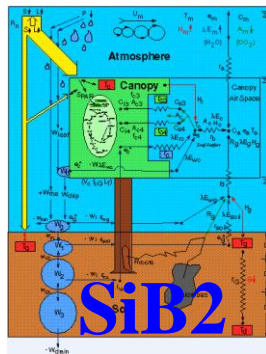
Distributed biosphere hydrological model development

Development idea: Improve the mechanism of distributed hydrological models using the advanced biosphere LSM energy balance and biophysical mechanisms.

Biosphere land model

Distributed hydrological model

Typical representative

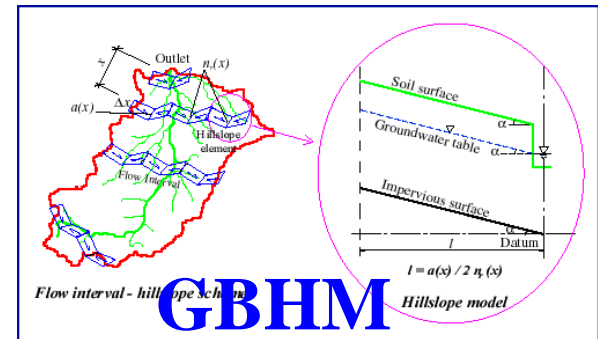


SiB2

Sellers et al., 1996, J. Climate
Sellers et al., 1997, Science

GBHM

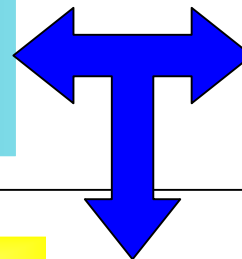
Yang et al., 2000, Hydrol. Process.
Yang et al., 2004, Hydrol. Process.



Advantage

- Describes the water-heat cycle between Soil-Vegetation-Atmosphere
- Vegetation physiology

Couple



- Describes spatial variation of watershed
- Calculate slope runoff and river routing
- Considering groundwater

Disadvantage

1-d model, not considered:

- Sub-grid variation of terrain
- Lateral outflow of soil
- Groundwater module

Remove

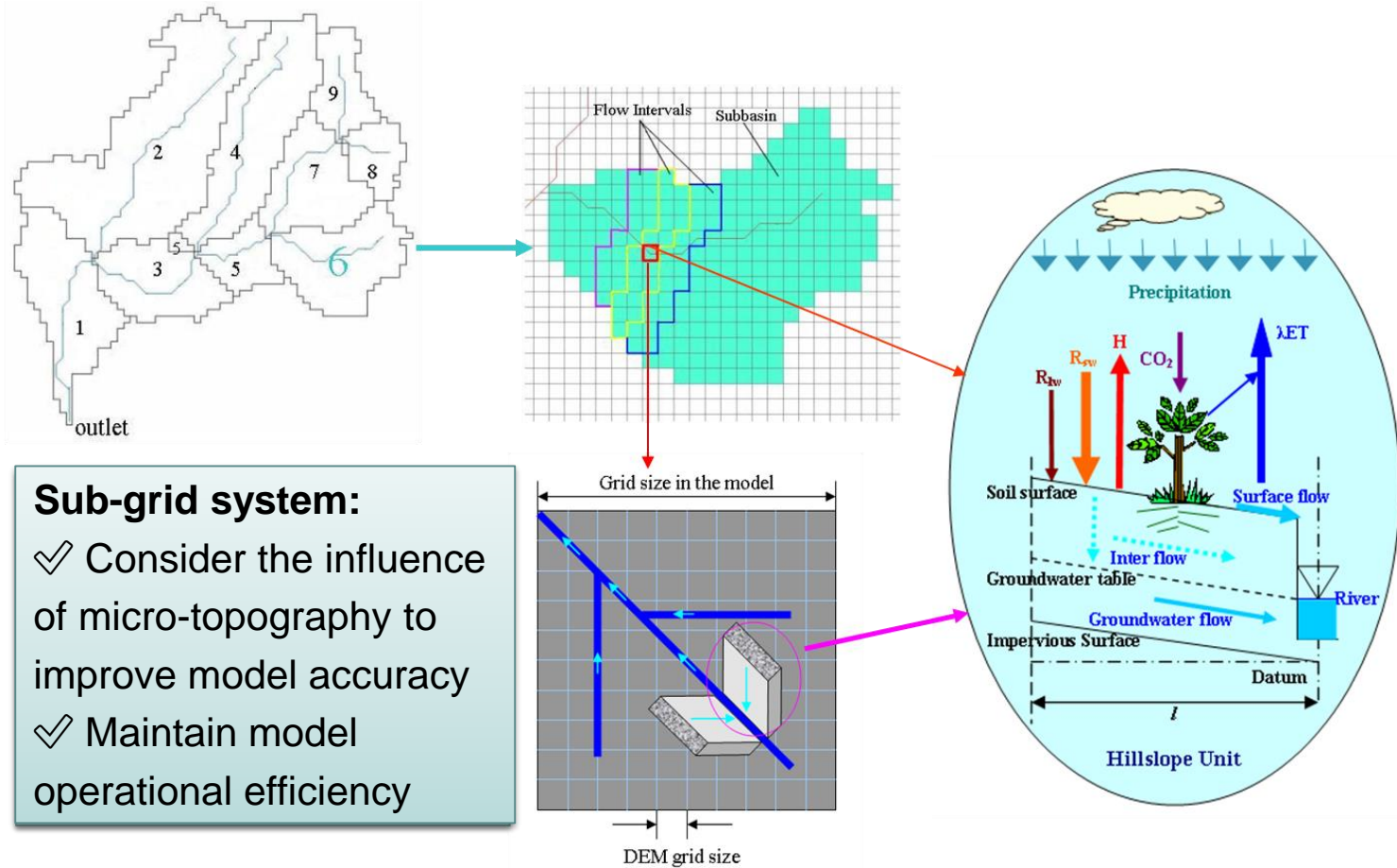


Empirical description of land surface processes, the following variables calculation have large uncertainty:

- **ET**
- **Soil moisture content**

Distributed biosphere hydrological model: WEB-DHM

Wang, 2007 PhD thesis & Wang* et al., 2009 JGR



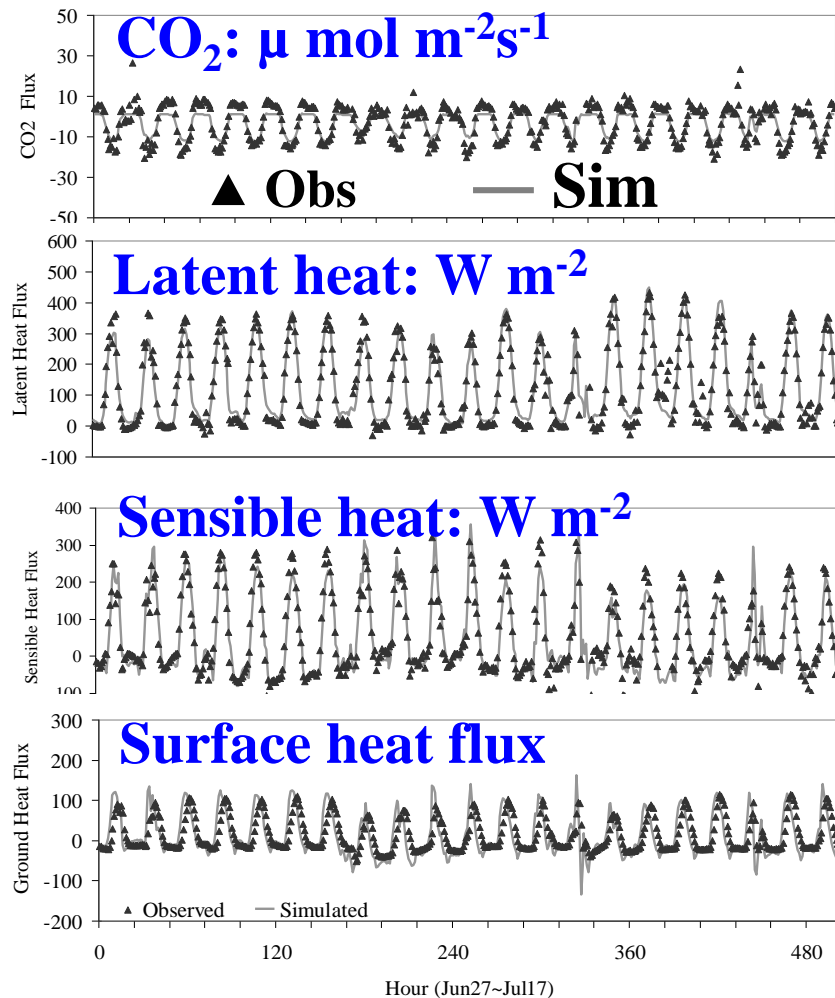
基于水和能量平衡的分布式水文模型

WEB-DHM: Water and Energy Budget-based Distributed Hydrological Model

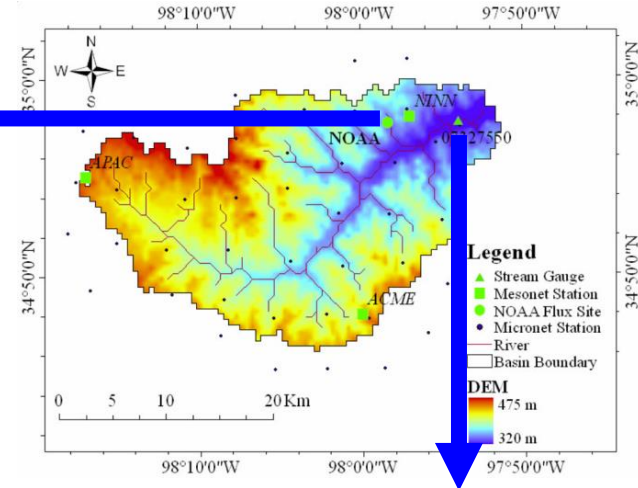
Almost achieved a comprehensive simulation of hydrosphere-atmosphere-biosphere within watershed

Wang* et al., 2009, J. Geophys. Res.

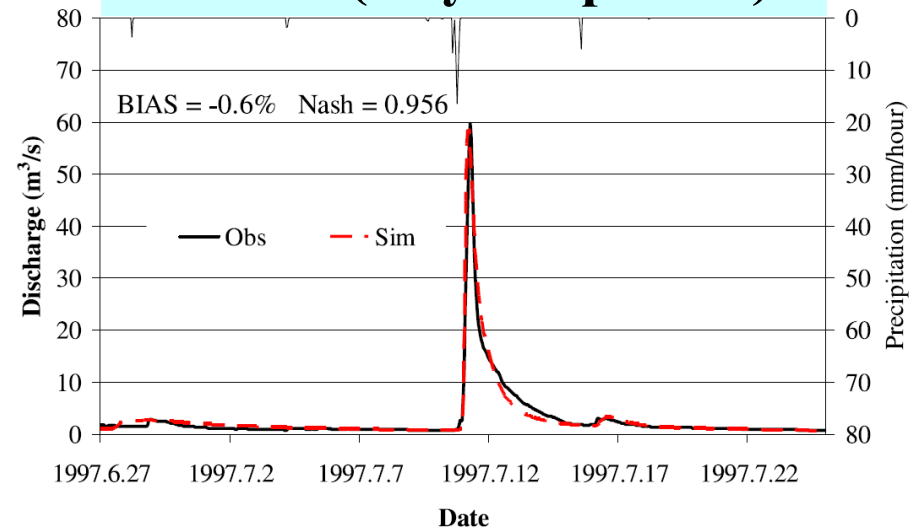
Flux (“Atmosphere-Biosphere”)



LittleWashita watershed in USA



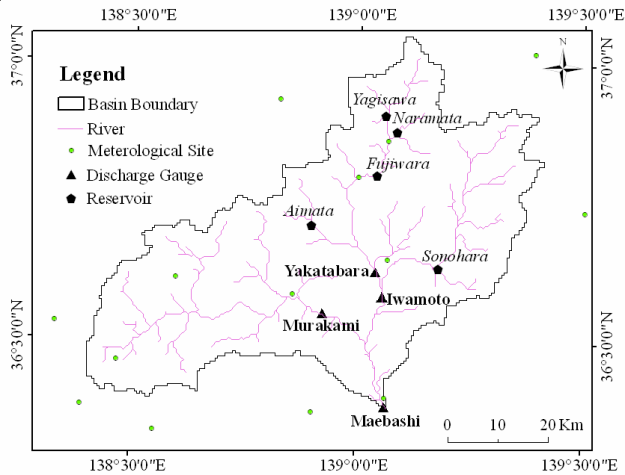
Runoff (“Hydrosphere”)



Global satellite data are available to validate model

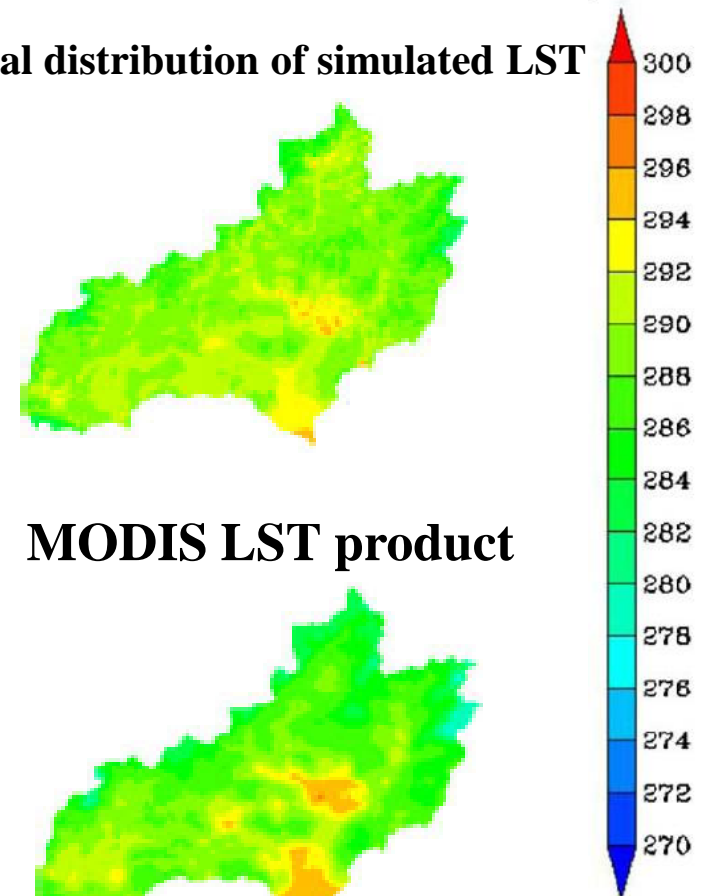
Wang* et al., 2009, J. Hydrol.

Upper Tone river basin in Japan

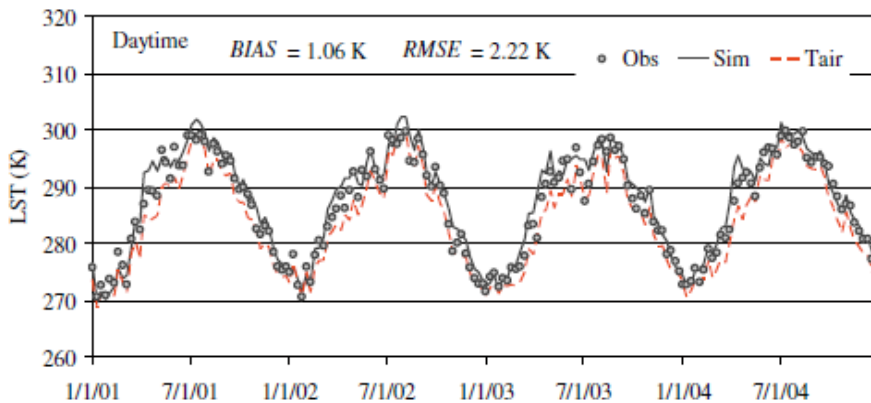


LST simulation

Spatial distribution of simulated LST



Time series comparison



unit: K

Improve long-term runoff simulation, and more accurately calculate flood peak (Wang* et al., 2009, J. Hydrol.)

Annual peak flow (hour by hour)

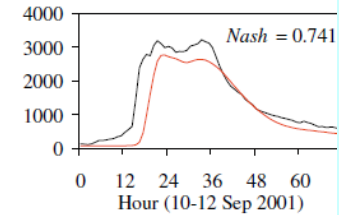
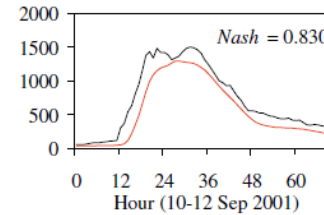
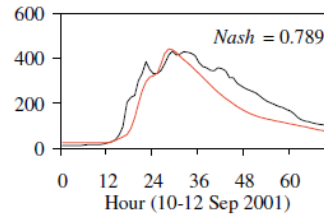
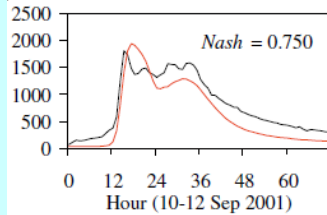
(a) Murakami

(b) Yakatabara

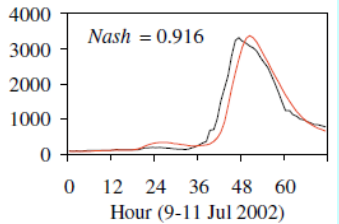
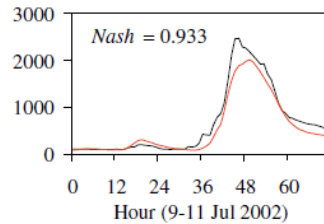
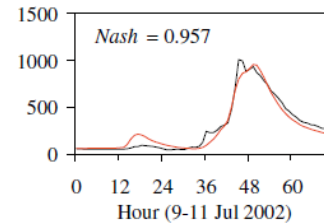
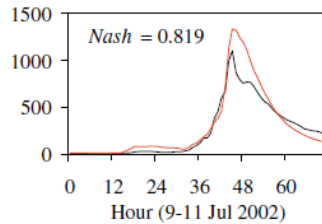
(c) Iwamoto

(d) Maebashi

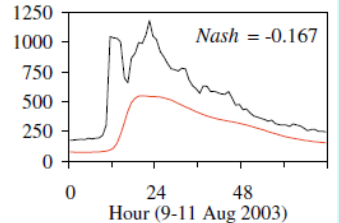
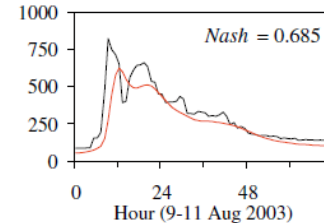
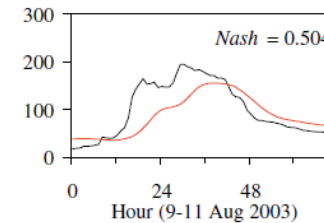
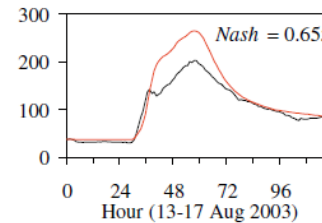
2001



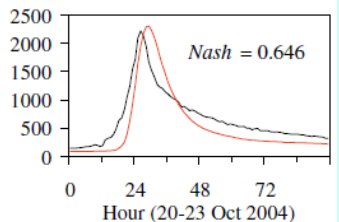
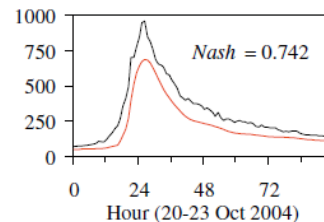
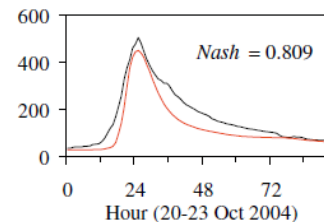
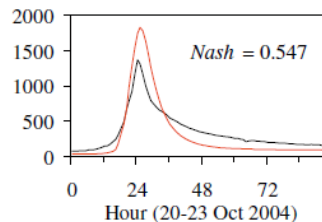
2002



2003



2004



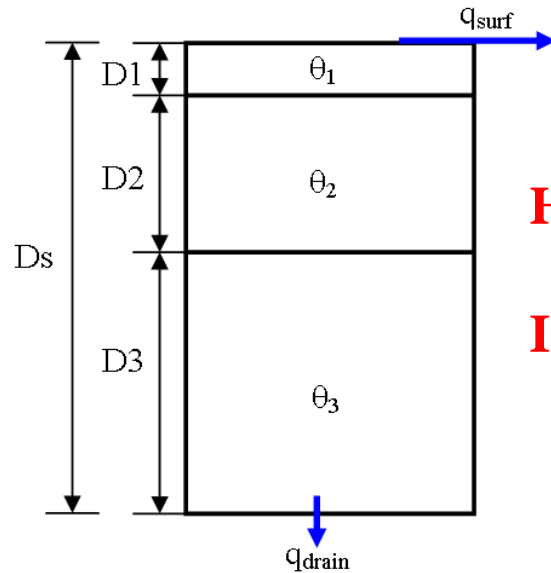
— Simulated

— Observed

Hydrological improvements relative to LSM

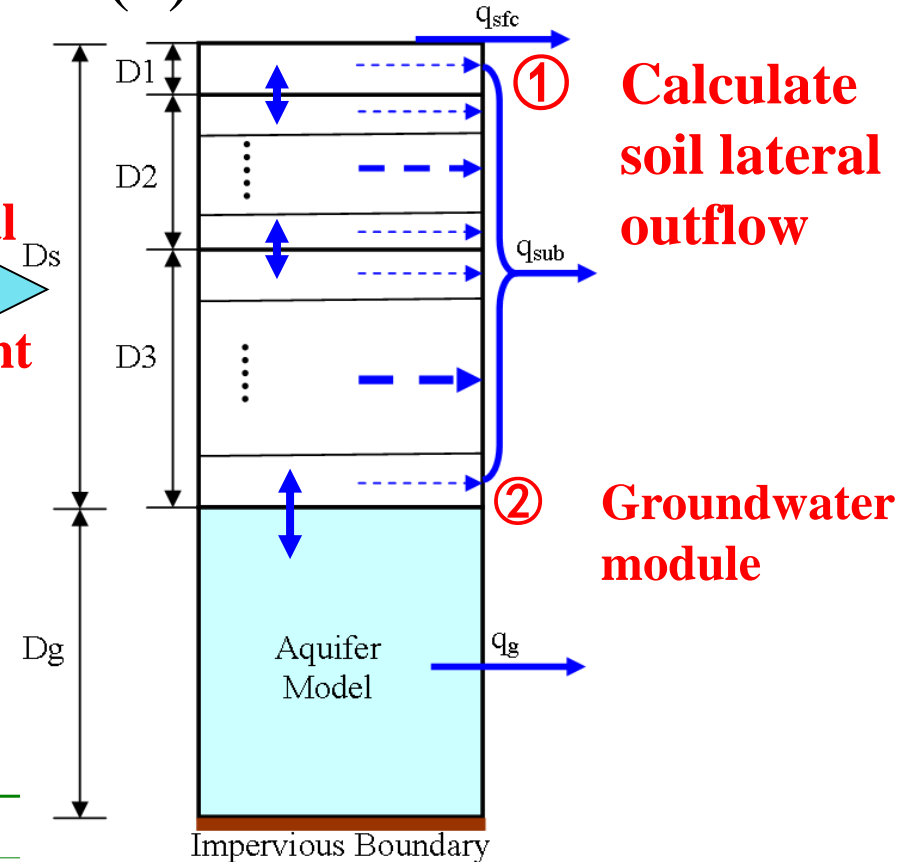
Wang* et al., 2009, Hydrolog. Sci. J.

(a) LSM SiB2



Hydrological Improvement

(b) WEB-DHM



③ Update soil hydraulic function

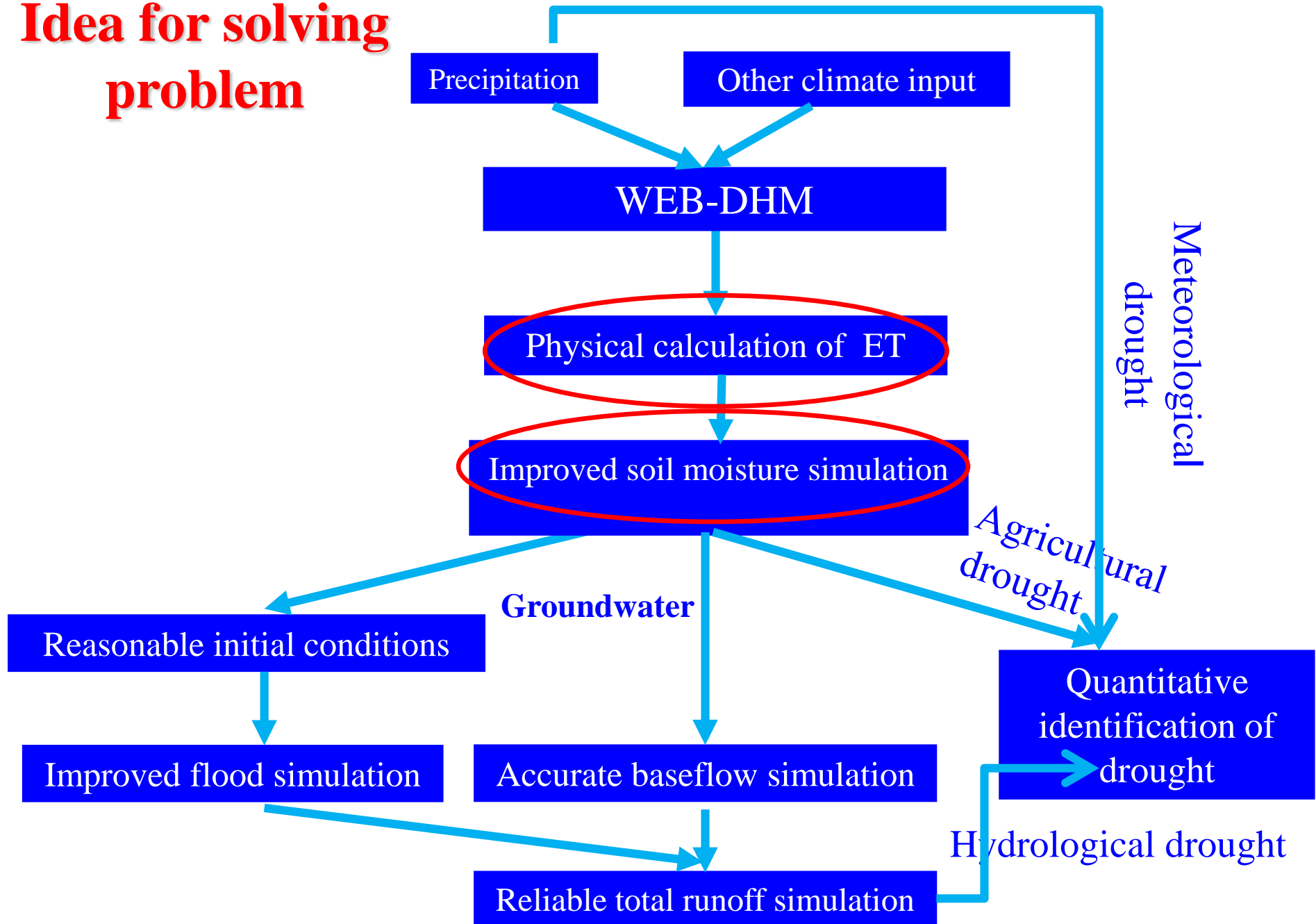
Table 1. Soil hydraulic functions used in SiB2 and HydroSiB2

Source	$\psi(\theta)$	$K(\theta)/K_s$
<u>Campbell (1974)</u>	$\psi_s \left(\frac{\theta}{\theta_s} \right)^{-b}$	$\left(\frac{\theta}{\theta_s} \right)^{2b+3}$
<u>van Genuchten (1980)</u>	$\frac{1}{\alpha} \left[(S)^{-1/m} - 1 \right]^n$	$S^{1/2} \left[1 - (1 - S^{-1/m})^m \right]^2$

SiB2

WEB-DHM

Idea for solving problem



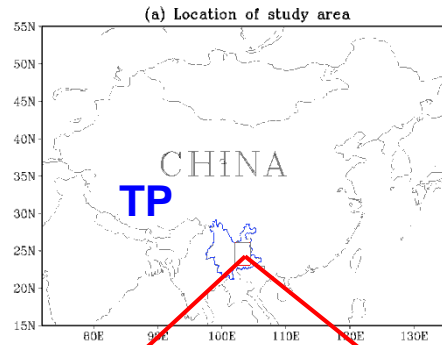
Use hydrological model to solve practical problems such as flood and drought

(a) Short-term flood forecast (Wang* et al., 2012, J. Meteorol. Soc. Jpn.)

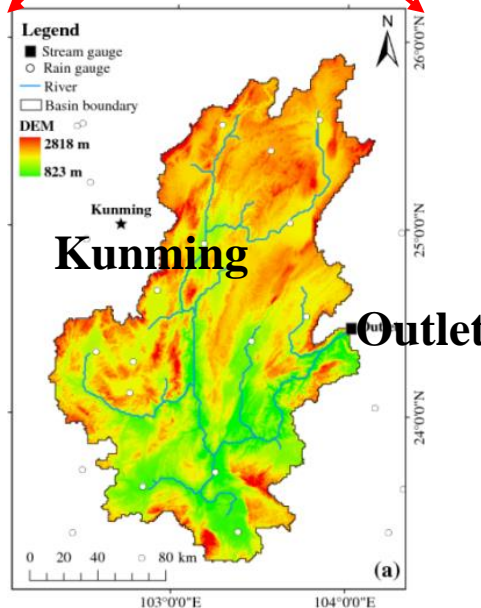
July 1-2, 2008
Kunming, Yunnan



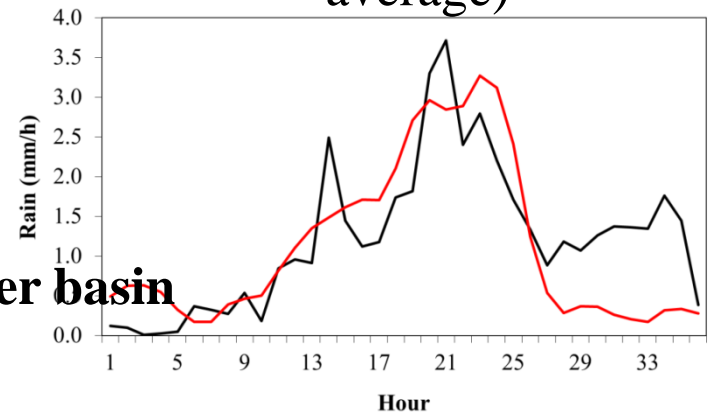
Storm: 117mm/d



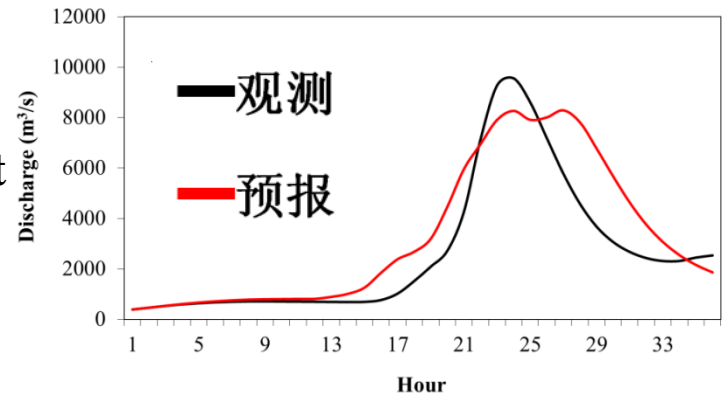
Nanpanjiang river basin



Precipitation forecast (basin-average)



Runoff prediction (outlet)



Next 36 hours forecast

(b) Drought study: Quantitative identification of drought and areas

Sanchez* & Wang et al., 2011, WRR

Drought period identification

Drought areas identification

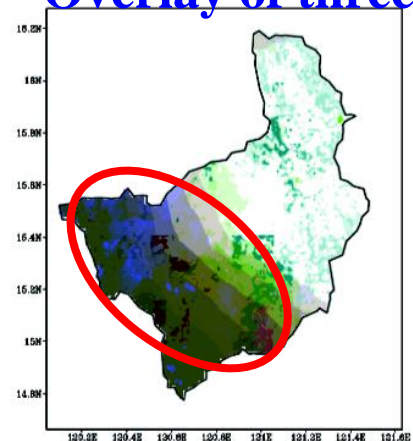
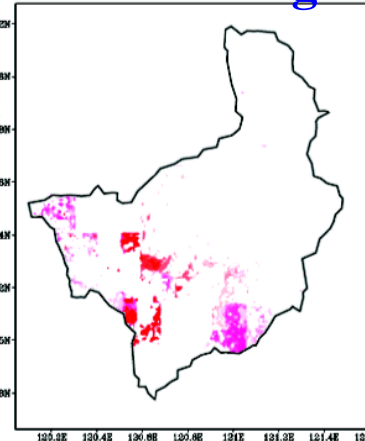
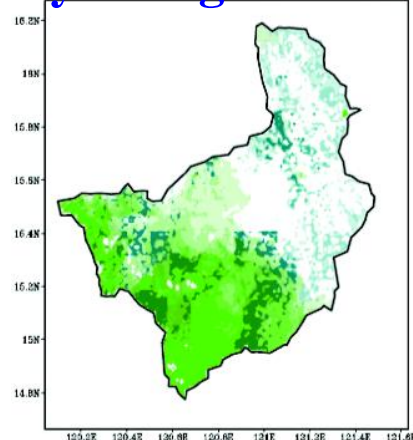
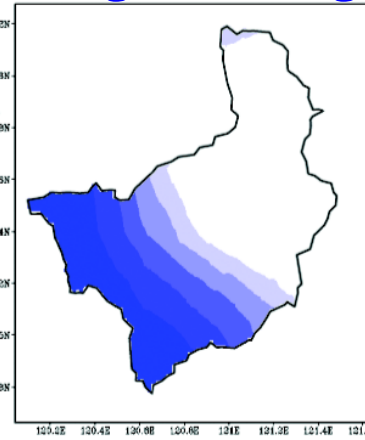
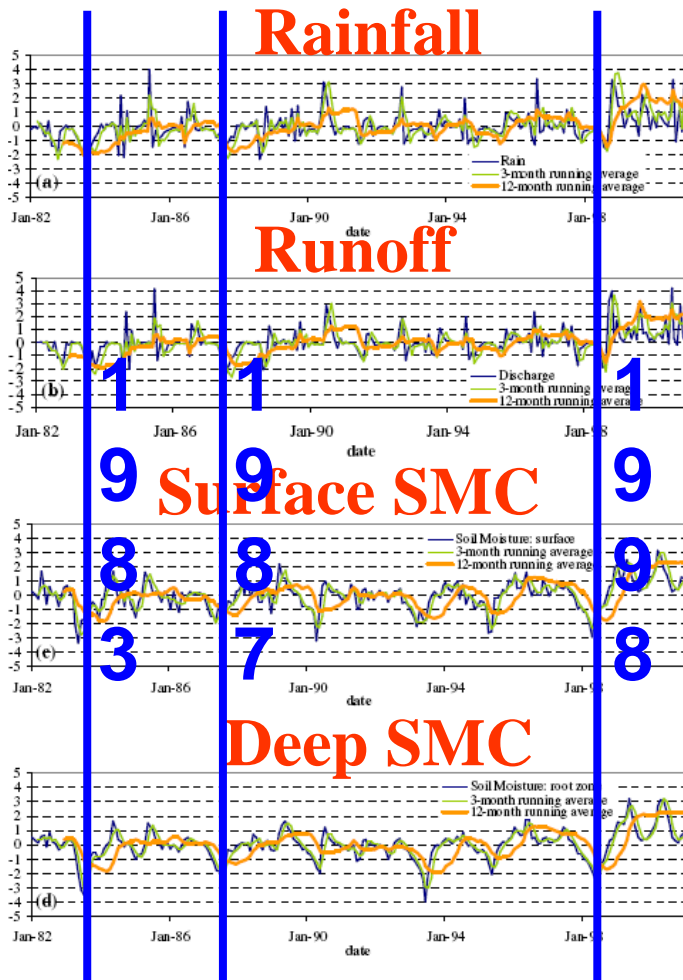
Meteorological drought

Hydrological drought

Agriculture drought

Overlay of three

Standardized Anomaly (SA)



Pampanga River Basin of Philippines

The Cryosphere description of WEB-DHM was preliminarily improved

Background

- Cryosphere significantly affects Third Pole region
- The interaction of multi-spheres need in-depth study

Cryosphere description

- Improved frozen soil simulation in WEB-DHM
- Improved snow simulation in WEB-DHM

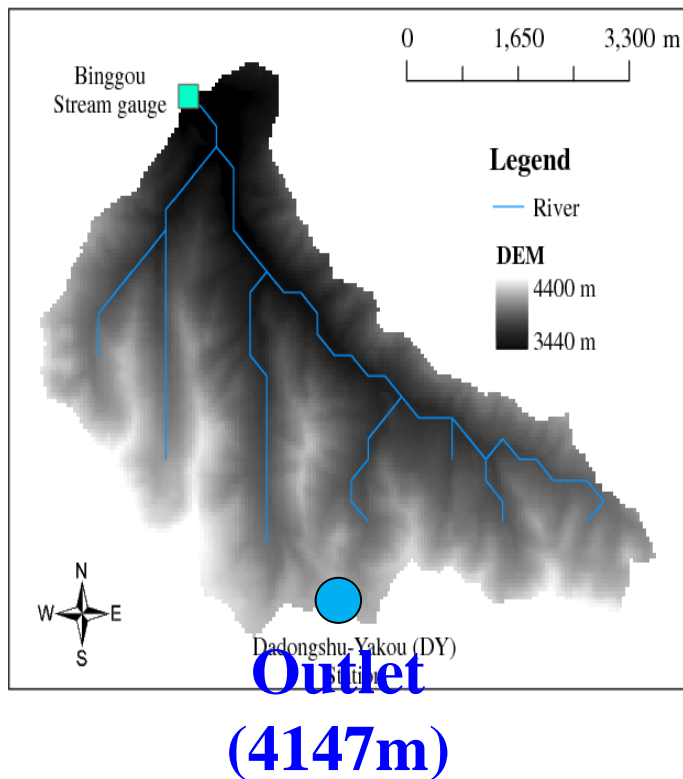
Applications in third pole

- Applications in cryosphere hydrology study (**such as:** Dudhkoshi watershed of Nepal, Naqu watershed, Upper yellow river basin, Puna Tsang watershed of Bhutan)

Improved frozen soil simulation of WEB-DHM

Wang* et al., 2010, Hydrol. Earth Syst. Sc.

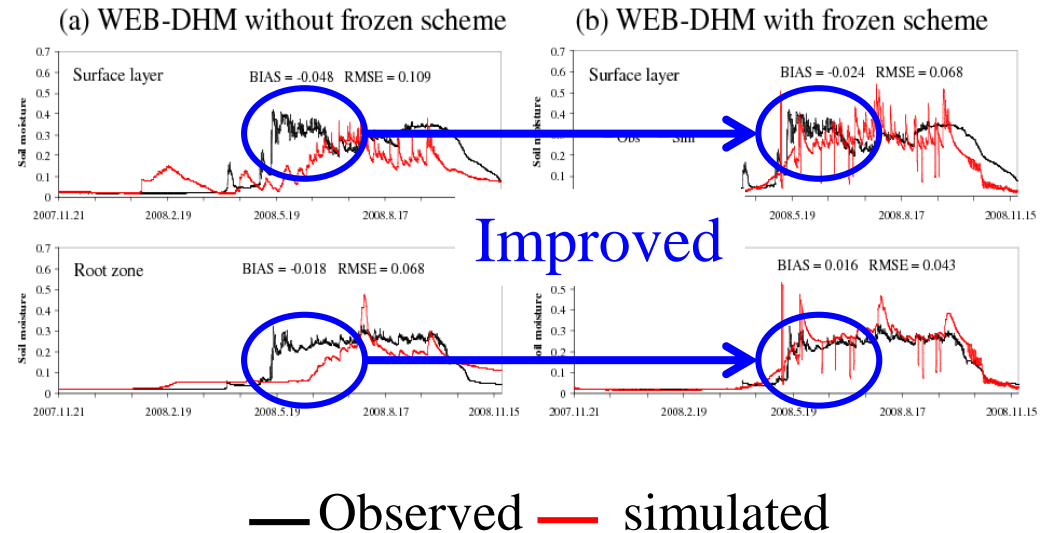
Upper Heihe River Basin (Bingou watershed)



Soil water content

without frozen soil

with frozen soil

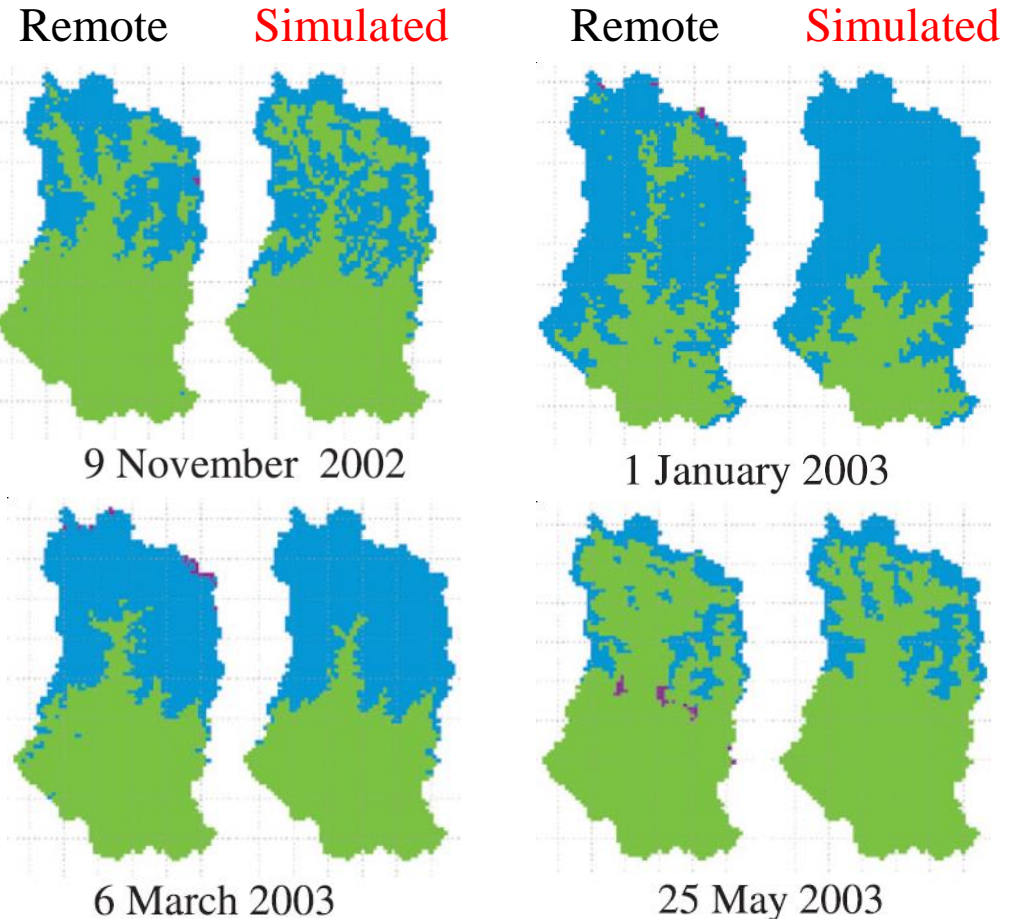
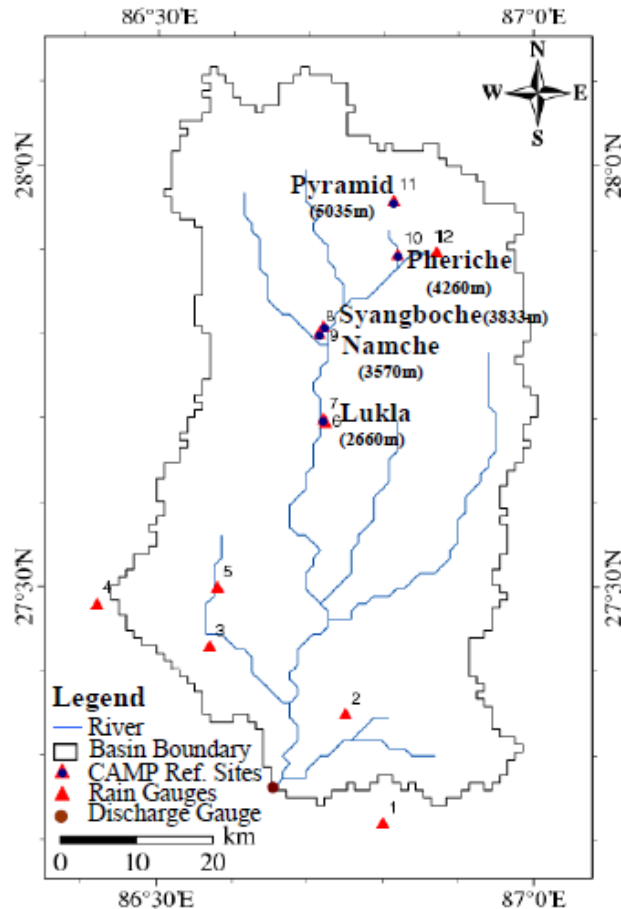


Recent study in the Third pole: Dudhkoshi watershed of Nepal

Shrestha* & Wang et al., 2012, J. Hydrometeorol.

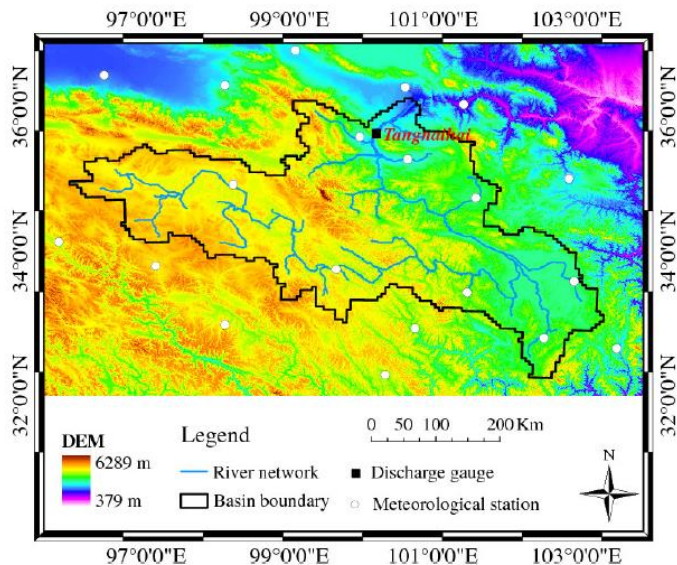
Spatial distribution of snow cover in different seasons

Dudhkoshi watershed

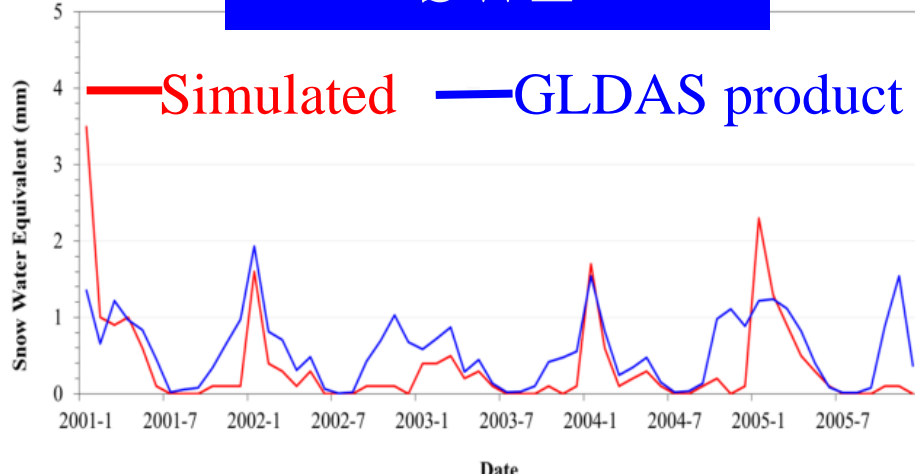


Legend: Land, Snow, Cloud

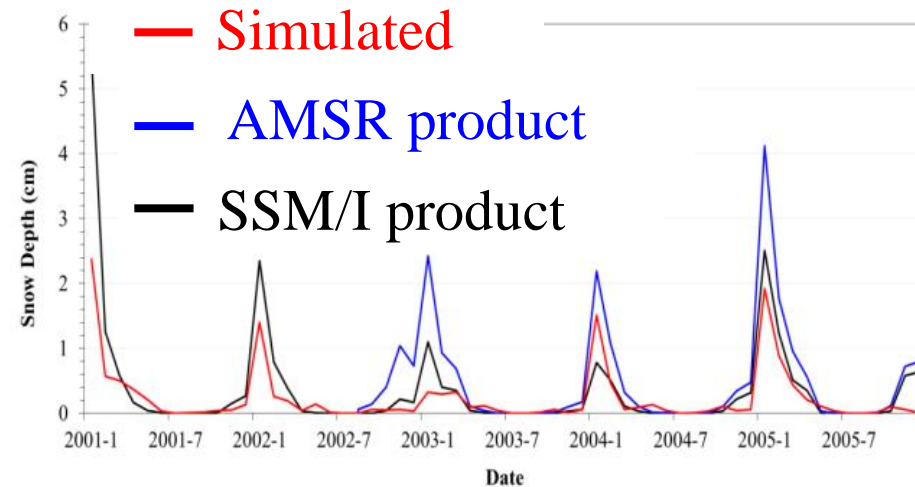
Recent study in the Third pole: Upper Yellow River Basin



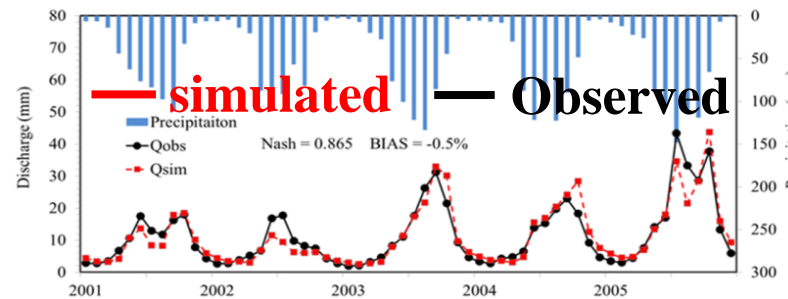
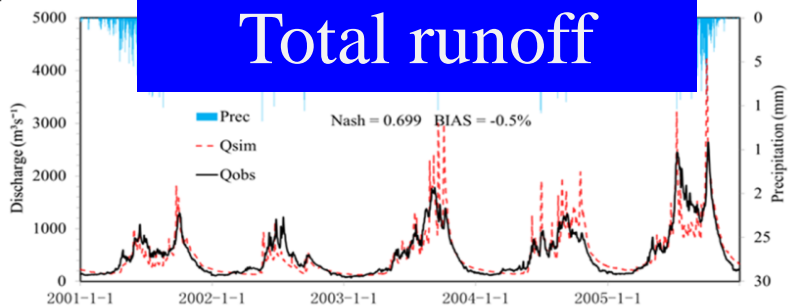
SWE



Snow depth

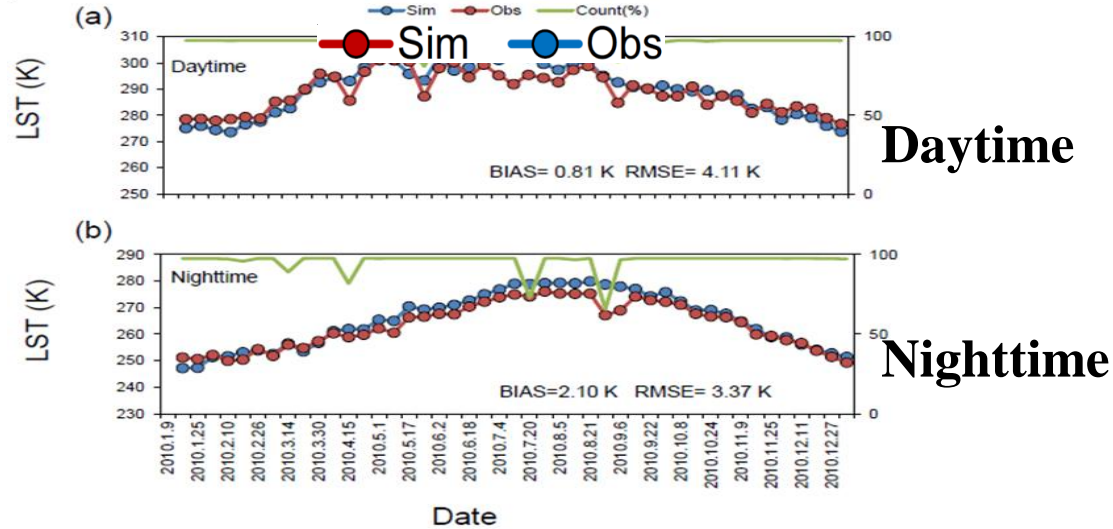
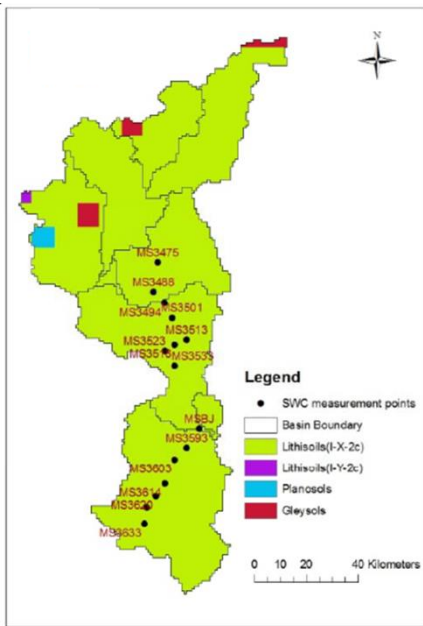
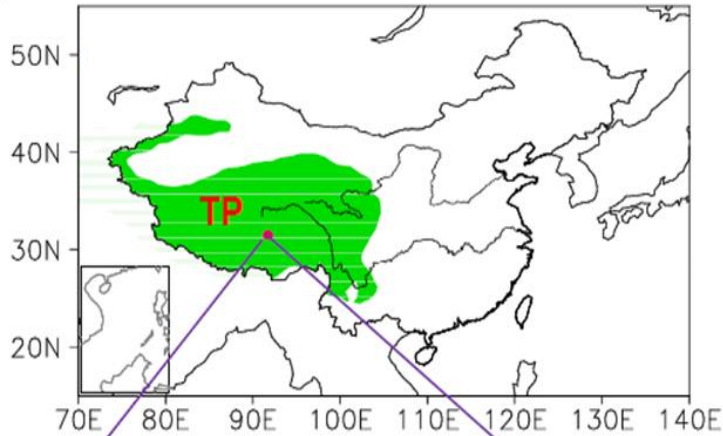


Total runoff

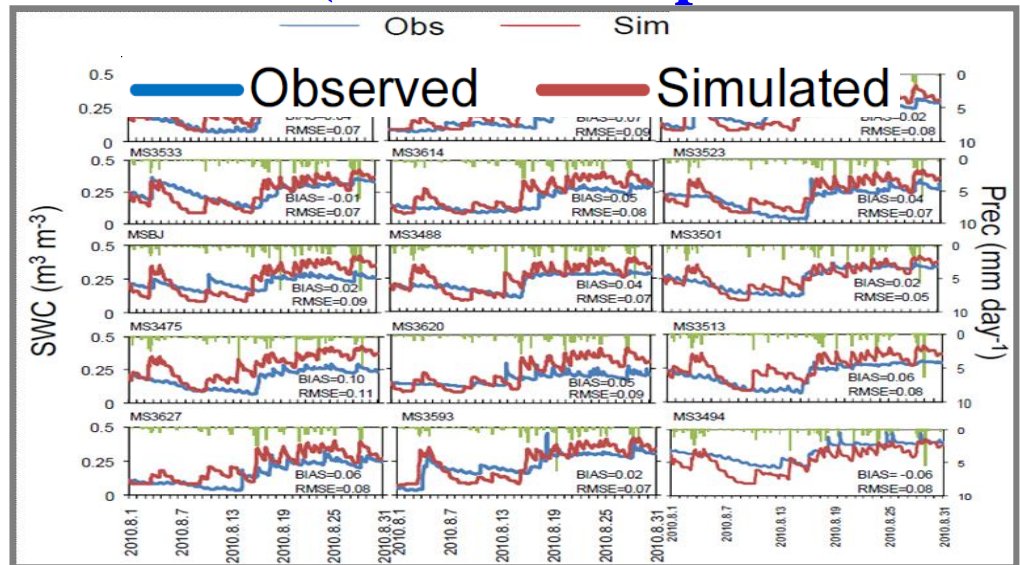


Recent study in the Third pole: Naqu watershed (central TP)

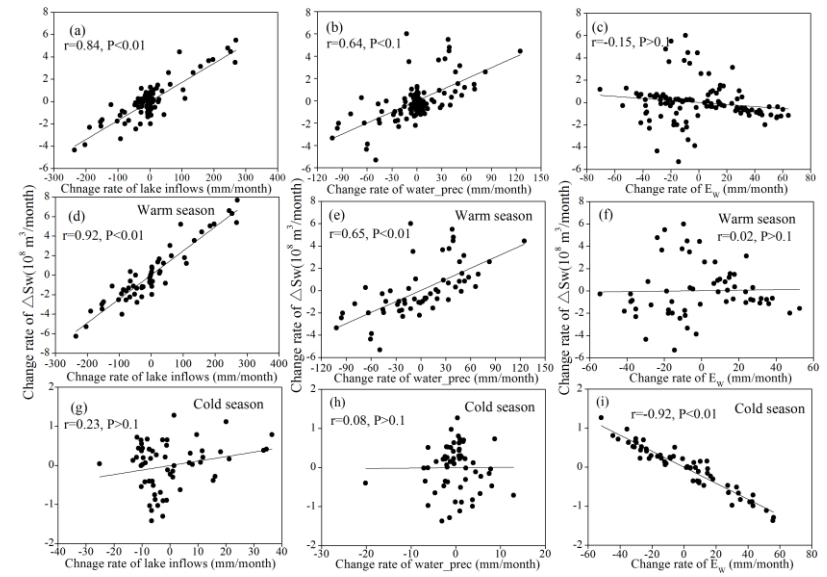
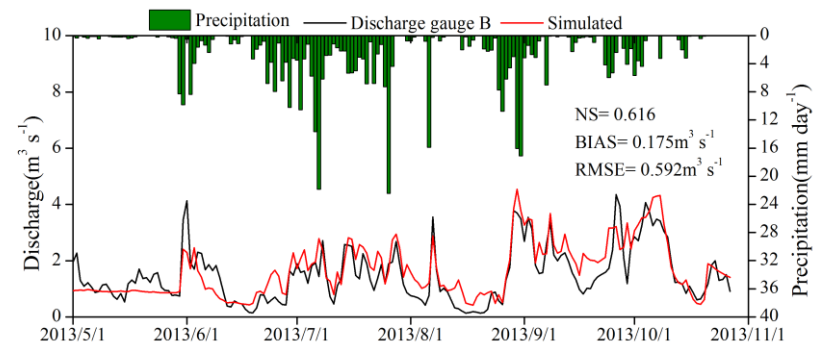
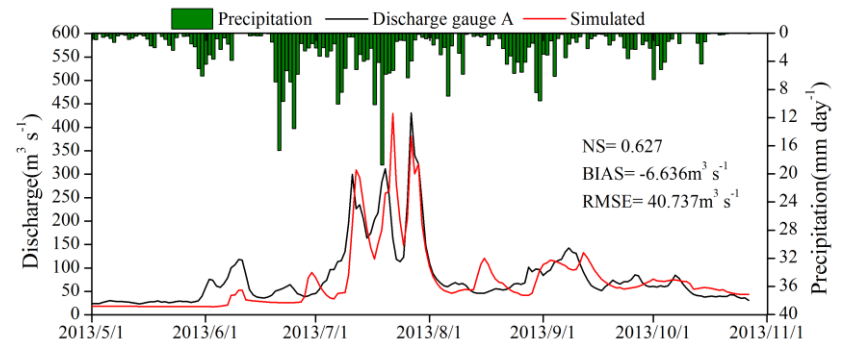
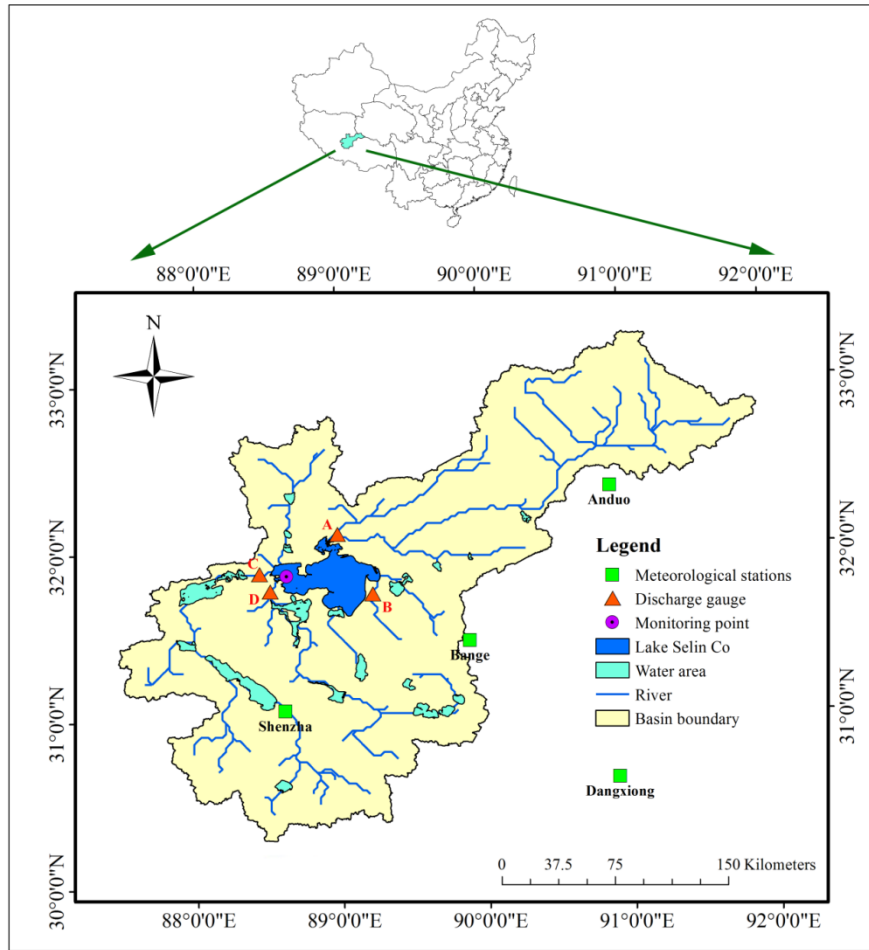
LST (simulated \leftrightarrow satellite)



Soil moisture (simulated \leftrightarrow point observed)



Recent study in the Third pole: Lake SelinCo Basin



Exploring the main driving factors of lake expansion for the largest TP lake (SelinCo)

Model Input

- DEM, river networks, sub-catchments with geomorphology
- Soil map
- Land use map
- FPAR & LAI (satellite data)
- Surface meteorological forcing data
(Precipitation, Shortwave and longwave radiation, wind speed, humidity, air pressure, air temperature, cloud fraction)

DEM

SRTM (90m / 30m)

ASTER GDEM (30m)

Copernicus DEM (30m / 90m)

TPDC:

Tibet Plateau SRTM Digital Elevation Model Dataset (2000)

<https://data.tpdc.ac.cn/zh-hans/data/b918d825-da34-458b-a2f0-1ce6e0e37d22> (30 m)

River networks, sub-catchments with geomorphology derived from DEM

Soil map

**Food and Agriculture Organization of the United Nations (FAO):
Harmonized World Soil Database v 1.2**

<https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/harmonized-world-soil-database-v12/en/>

TPDC:

Soil Dataset Based on the Harmonized World Soil Database (FAO-HWSD)

<https://data.tpdc.ac.cn/zh-hans/data/844010ba-d359-4020-bf76-2b58806f9205>

Data processing method (in Chinese) can be referenced at :

<https://zhuanlan.zhihu.com/p/477677143>

Model Input

- DEM, river networks, sub-catchments with geomorphology
- Soil map
- Land use map
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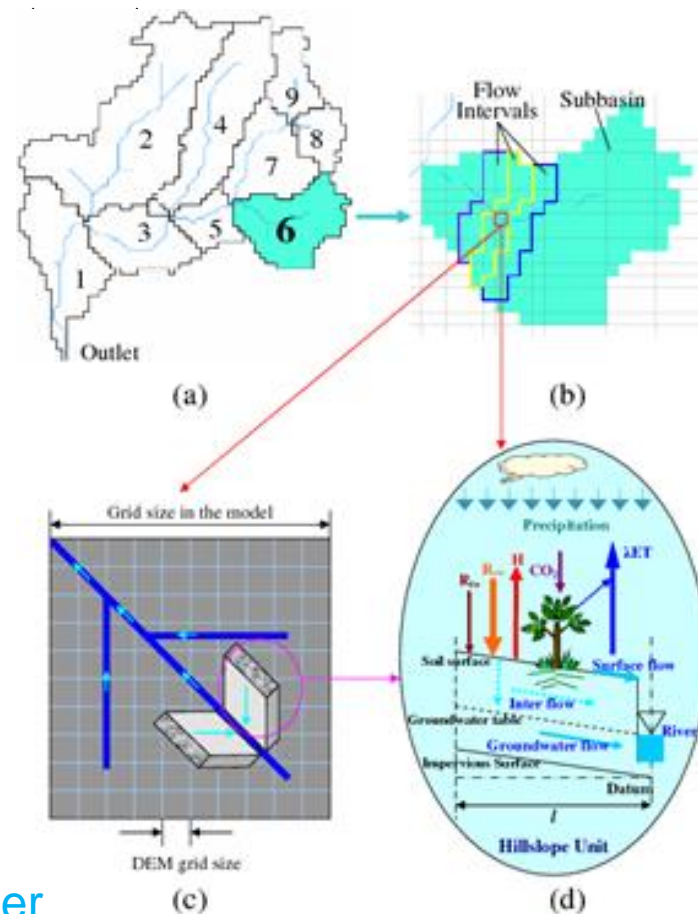
Land use and glacier data

USGS 1km global land use/land cover data

<https://doi.org/10.5066/F7GB230D>

Land Use Classification Table

Value	Description
1	Broadleaf Evergreen Trees
2	Broadleaf Deciduous Trees
3	Broadleaf and Needleleaf Trees
4	Needleleaf Evergreen Trees
5	Needleleaf Deciduous Trees
6	Short Vegetation/C4 Grassland
7	Shrubs with Bare Soil
8	Dwarf Trees and Shrubs
9	Agriculture or C3 Grassland
10	Water, Wetlands
11	Ice



glacier

TPDC:

Land Use Data on the Qinghai-Tibet Plateau (1992, 2005, and 2015)

<https://data.tpdc.ac.cn/zh-hans/data/e0d78831-ac3d-493c-af62-6a1248de4ead>

First Step: Use GIS software to convert the land use map to UTM projection, resample it to the watershed grid, and clip to the watershed extent.

1. Convert img file to grid file

Arc:imagegrid easib22.bil land

2. Define the projection of the grid file

Arc: projectdefine grid land

Project: projection lambert_azimuth

Project: units meters

Project: parameters

radius of the sphere of reference [0.00000]: 6370997

longitude of center of projection [0 0 0.000]: 100 0 0

latitude of center of projection [0 0 0.000]: 45 0 0

false easting (meters) [0.00000]: 0

false northing (meters) [0.00000]: 0

3. Clip grid file to extent

Grid: disp 9999 ! Open graphics window

Grid: mape land

Grid: grids land ! Display raster data

Grid: setwindow * ! Select watershed extent with mouse

Grid: land1 = land ! Name the land within watershed extent as land1

Grid: q ! Quit grid

4. Convert to UTM projection

Arc: project grid land1 land_prj lambert2UTM.prj

5. Resample to watershed grid and export

Grid: land_prj_5km = resample(land_prj, 5000, nearest)

Grid: setwindow wsheds

Grid: setmask wsheds ! Clip data by wsheds extent

Grid: land_use = land_prj_5km

Grid: land_use.asc = gridascii(land_use)

Second Step: Using the generated land_use.asc file, extract glacier data. Assign a value of 1 to glacier grid cells and 0 to other grid cells.

Run “Processing Glacier Input Data” part in the “WEBDHM_Data_Process.ipynb” file

Randolph Glacier Inventory:

[GLIMS: Global Land Ice Measurements from Space \(http://www.glims.org/RGI/\)](http://www.glims.org/RGI/)

ICIMOD:

<http://rds.icimod.org/Home/Data?any=GLACIER&Category=datasets&&hemekey=Glacier&&page=3&&themekey=HKH>

TPDC:

The Second Chinese Glacier Inventory Dataset (V1.0) (2006-2011):

<https://data.tpdc.ac.cn/zh-hans/data/f92a4346-a33f-497d-9470-2b357ccb4246>

名称	修改日期	类型	大小
 10_rgi60_NorthAsia.zip	2017/7/9 1:25	压缩(zippped)文件...	5,446 KB
 13_rgi60_CentralAsia.zip	2017/7/9 1:27	压缩(zippped)文件...	64,125 KB
 14_rgi60_SouthAsiaWest.zip	2017/7/9 1:28	压缩(zippped)文件...	45,337 KB
 15_rgi60_SouthAsiaEast.zip	2017/7/9 1:28	压缩(zippped)文件...	15,546 KB
 Clean Ice and Debris covered glacier...	2021/1/25 12:31	压缩(zippped)文件...	77,868 KB
 hybas lake as lev01-12_v1c.rar	2023/7/25 16:54	RAR 文件	306,593 KB
 The Second Chinese Glacier Inventor...	2026/5/6 4:55	压缩(zippped)文件...	23,154 KB

RGI

ICIMOD

**The Second Chinese 27
Glacier Inventory Dataset**

Python Environment Setup: Anaconda + Jupyter Notebook

1. Create Python environment:

`conda create -p env-path python=3.9` (version) Create virtual environment in a folder

`conda remove -p env-path` Delete virtual environment in a folder

`conda activate env-path` Activate virtual environment

2. Install Python packages:

`numpy, xarray, pandas, pyhdf, matplotlib`

`conda install packagename`

`pip install packagename`

`conda install -c conda-forge pyhdf`

<https://www.anaconda.com/>

3. Install Jupyter Notebook extensions:

`pip install jupyter_contrib_nbextensions`

`conda install -c conda-forge notebook=6 jupyter_contrib_nbextensions`

`jupyter_nbextensions_configurator -y`

`jupyter contrib nbextension install --user`

`jupyter nbextensions_configurator enable --user`

Vegetation Data Processing

Dynamic Vegetation Input Data for the WEB-DHM Model:

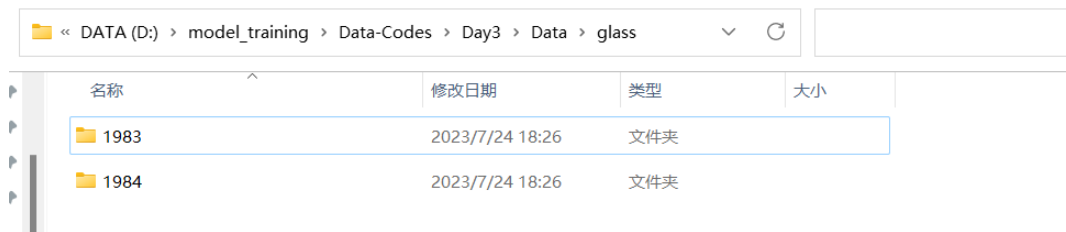
Leaf Area Index (LAI): The ratio of the total one-sided leaf area per unit ground area.

Fraction of Photosynthetically Active Radiation (Fpar): The fraction of photosynthetically active radiation absorbed by vegetation, referring to the incident photosynthetically active radiation above the crop canopy。

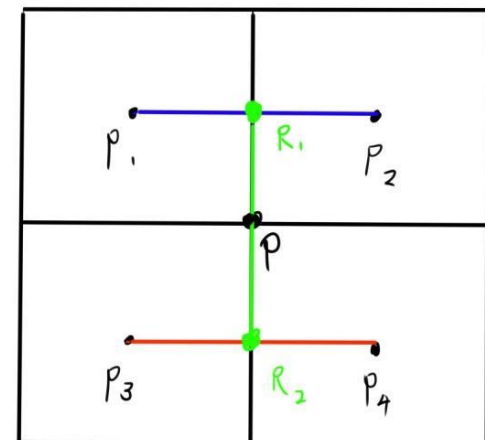
Global Land Surface Satellite (GLASS) Products: 0.05° , 8 Days

<http://www.glass.umd.edu/Download.html>

Method: Bilinear Interpolation



名称	修改日期	类型	大小
1983	2023/7/24 18:26	文件夹	
1984	2023/7/24 18:26	文件夹	



Generate Watershed Longitude and Latitude

Reference document: readme - Generate watershed longitude/latitude file

名称	修改日期	类型	大小
Codes	2026/5/6 6:21	文件夹	
Data	2026/4/25 18:40	文件夹	
readme- Generating Watershed LongitudeLatitude Files (in Chinese).docx	2023/7/27 10:38	Microsoft Word ...	233 KB

1. Run calculatexy.f code

Generate: pointxy.txt

2. Run outputlonlat.f code

Generate: latgrid.txt, longrid.txt

The longitude (longrid.txt) and latitude (latgrid.txt) of each grid point, for subsequent modeling or interpolation.

Processing Approach:

1. Read multi-dimensional raw data (hdf, netcdf, etc.);
2. For each grid point within the watershed, identify the four nearest raw data grid points and calculate the weights for bilinear interpolation of the four raw data grid points;
3. Perform bilinear interpolation for each time step of the raw data onto the grid points within the watershed;
4. Output and save the results in a file format readable by Fortran (e.g., txt, direct).

Run the “Processing vegetation input data” in the

[“WEBDHM_Data_Process.ipynb”](#) file.

The meteorological input data required by the

WEBDHM model are as follows:

- Air temperature (K)
- Precipitation (mm/h)
- Downward shortwave radiation (W/m^2)
- Downward longwave radiation (W/m^2)
- Wind speed (m/s)
- Air pressure (Pa)
- Specific humidity (kg/kg)

Example datasets used in this training:

1. Third Pole Meteorological Forcing Dataset (TPMFD)

A long-term (1979–2020) high-resolution ($1/30^\circ$, ~ 3 km) near-surface meteorological forcing dataset for the Third Pole region, with monthly, daily, and hourly temporal resolutions. Available from the National Tibetan Plateau Data Center (TPDC). <https://data.tpdc.ac.cn/zh-hans/data/44a449ce-e660-44c3-bbf2-31ef7d716ec7>

2. China Meteorological Forcing Dataset v2.0 (CMFD 2.0)

A meteorological forcing dataset for China (1950–2024) with a 3-hour temporal resolution and 0.1° horizontal spatial resolution. Available from TPDC. <https://data.tpdc.ac.cn/zh-hans/data/e60dfd96-5fd8-493f-beae-e8e5d24dece4>

3. Other precipitation data sources:

- **ERA5**: Reanalysis precipitation data from the Copernicus Climate Change Service (<https://cds.climate.copernicus.eu/>)
- **GLDAS**: Global Land Data Assimilation System precipitation data from NASA (<https://www.earthdata.nasa.gov/>)

Run the “Meteorological data processing” in the “WEBDHM_Data_Process.ipynb” file.

04. Model Configuration and Execution

1. Model Data Preparation:

Static parameter files: Domain extent, topography, river network, soil, land use type, glacier distribution;

Dynamic forcing files: Vegetation, meteorology

2. Modify the input.txt file. Refer to Initialization setting_WEBDHM2.0.pdf

3. Modify the model configuration. Refer to the document "Model Setup (1)_Zhong Xiaoyang.docx"

Thank you!



Note: Please install **Jupyter** and **Fortran** before the training course.