清華大學
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Water resource monitoring, modeling, and information systems in China: Implications to water resource management in cold and dry regions

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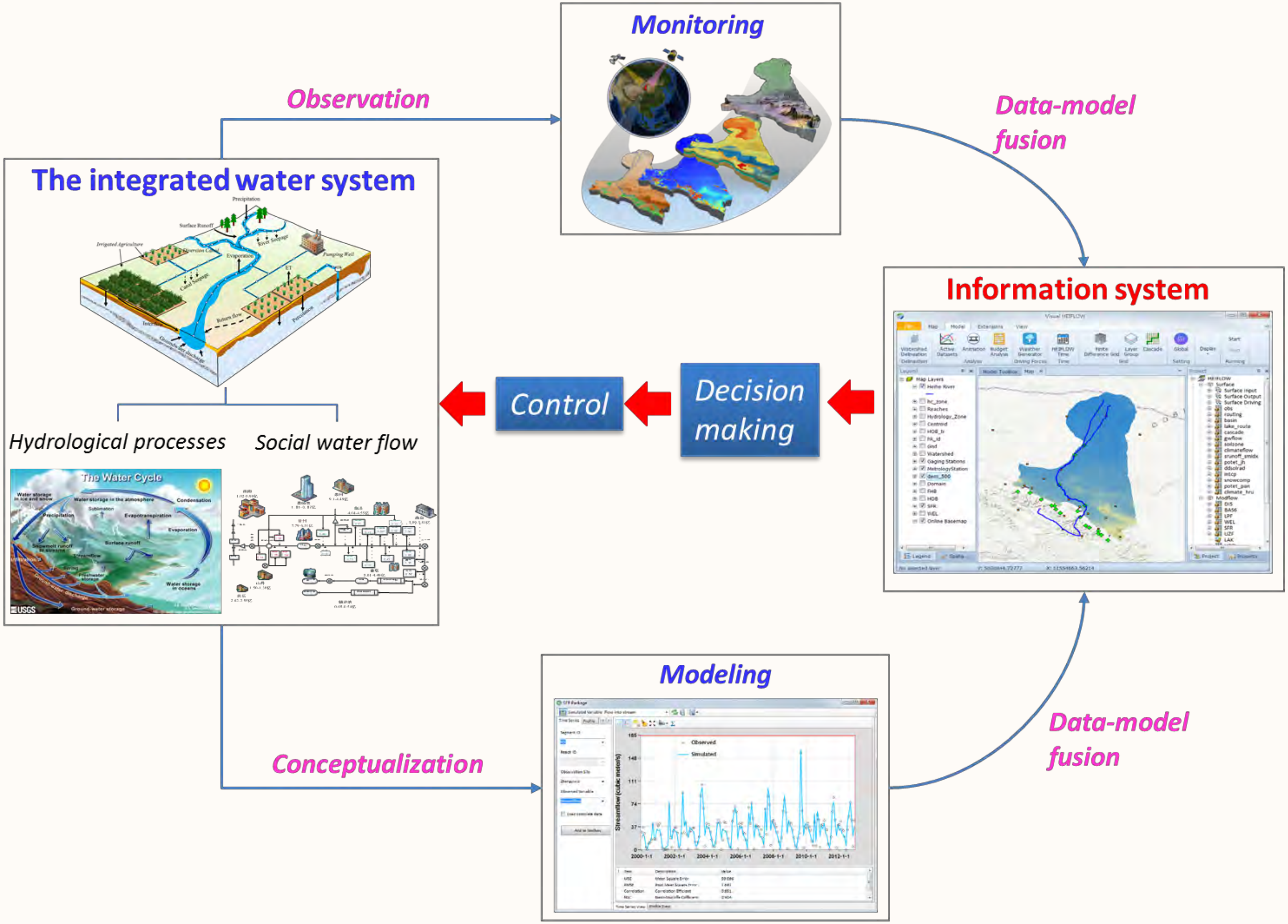
- Background
- Ground monitoring networks in China
- Space monitoring of water resources in China
- Regional modeling and information systems: Cold regions
- Regional modeling and information systems: Arid regions

1. Background

Monitoring, modeling, and information systems

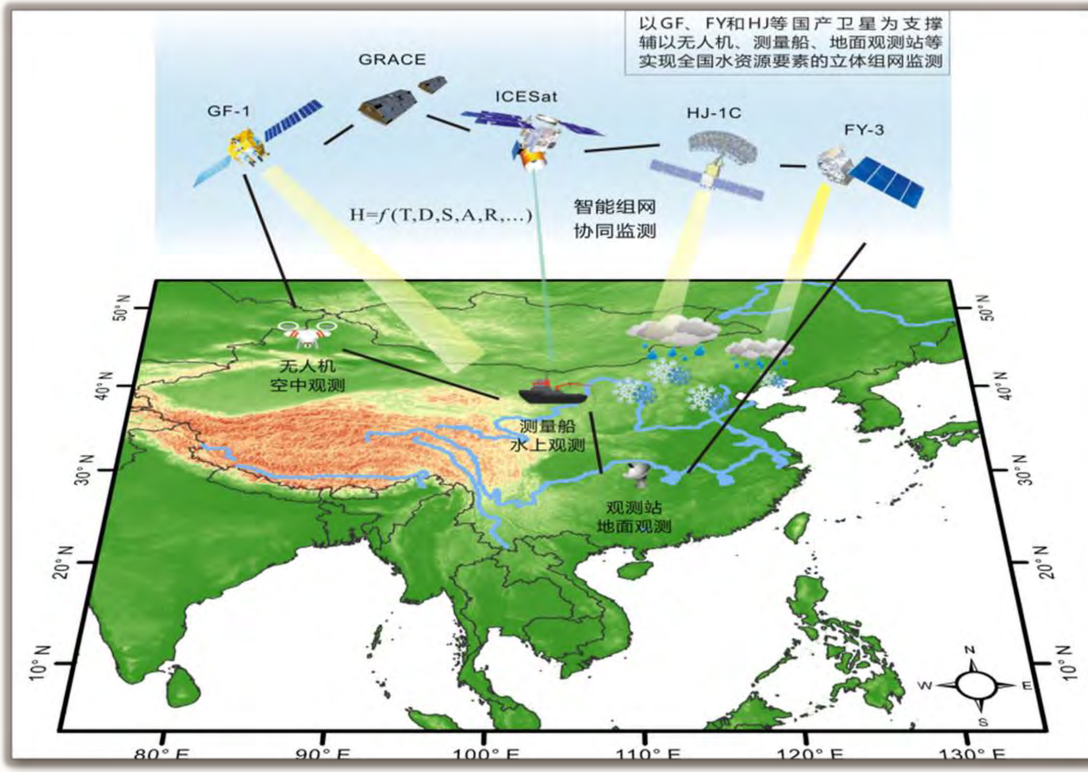


1. Background

A national water resource stereoscopic monitoring system

- A new system of national water resource stereoscopic monitoring

- Stereoscopic: Ground, airborne and spaceborne
- Hydrological elements: P, ET, R, SW, SM, GW, etc.



Objectives: Based on the development of the global Earth observation system and the needs for water resource management, a new national water resource stereoscopic monitoring system is being developed

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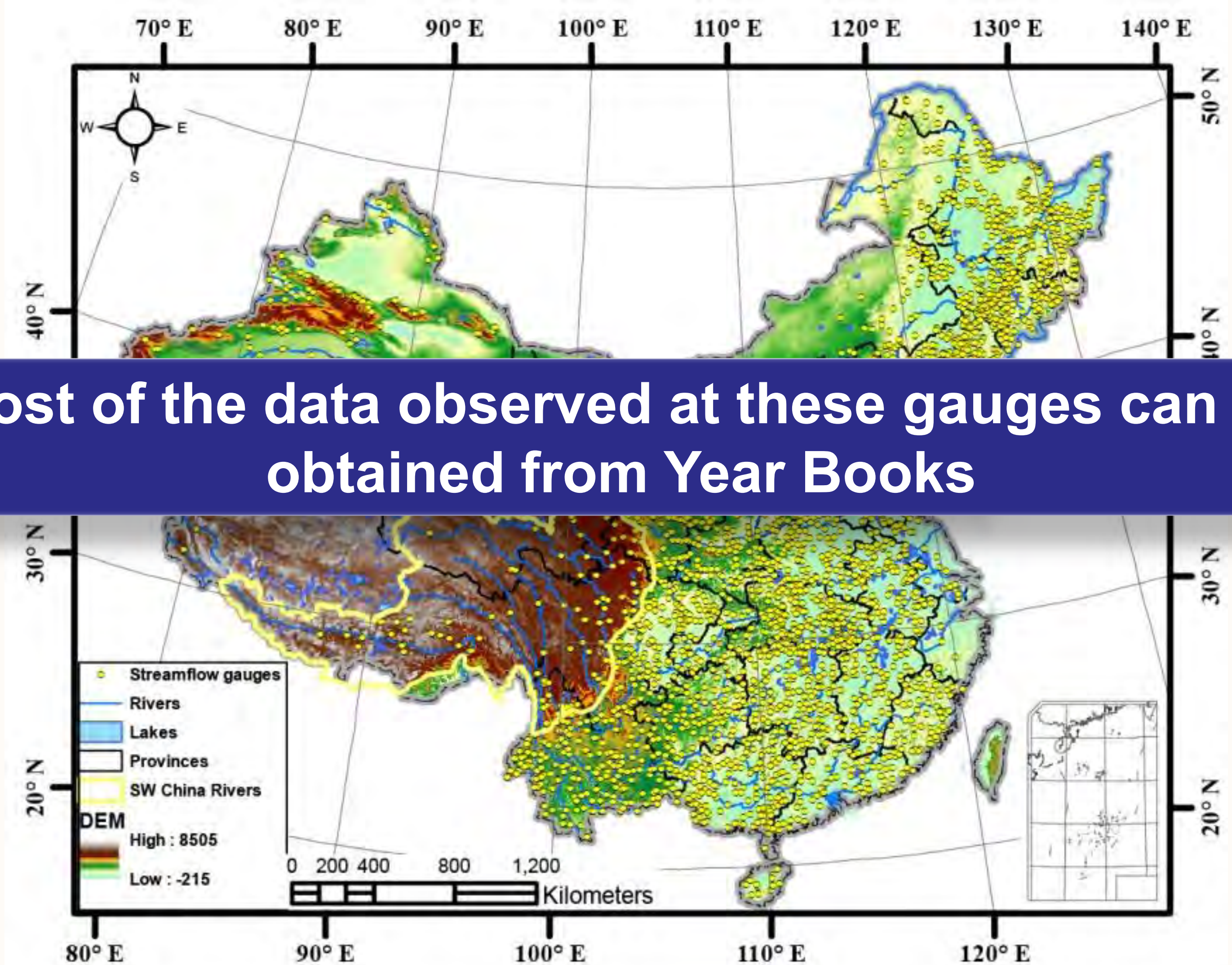
Streamflow gauges: 3283

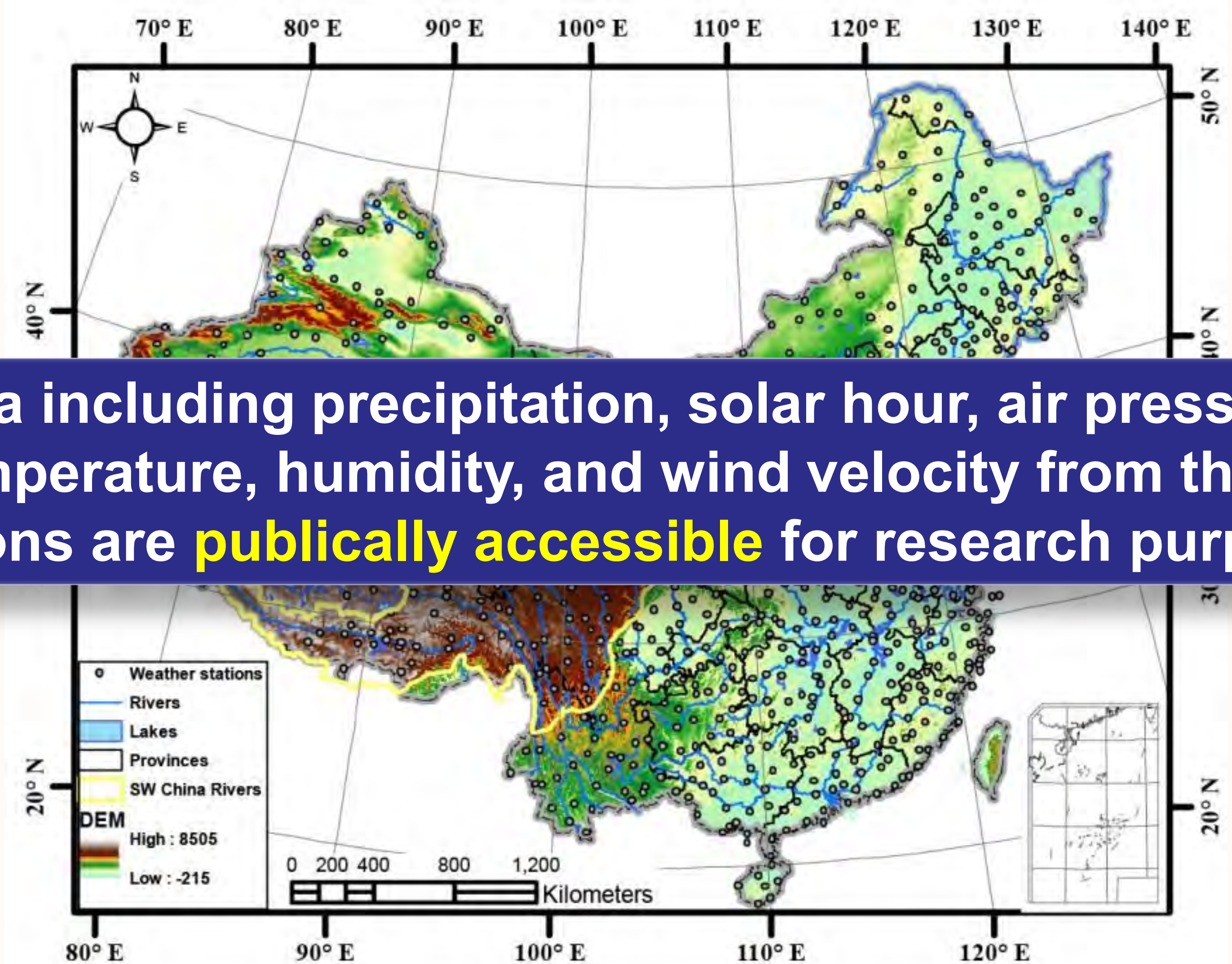


Most of the data observed at these gauges can be obtained from Year Books

Data sources are from the Ministry of Water Resources in China

2. Ground monitoring networks in China

Basic meteorological stations: ~756

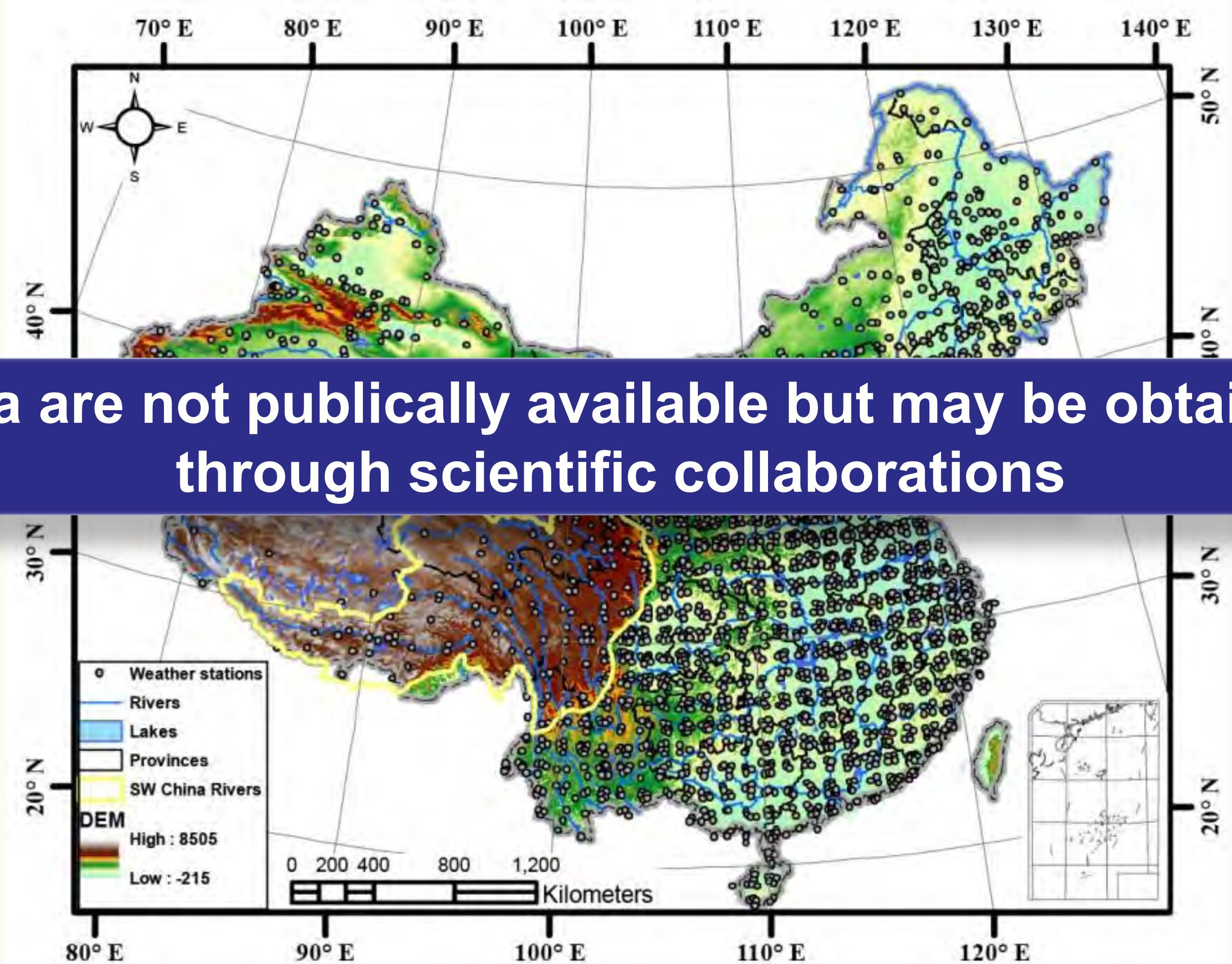


Data including precipitation, solar hour, air pressure, temperature, humidity, and wind velocity from these stations are publically accessible for research purposes

Data sources are from the China Meteorological Data Service Center

2. Ground monitoring networks in China

Basic meteorological stations: ~2477



Data are not publically available but may be obtained through scientific collaborations

Data sources are from the China Meteorological Data Service Center

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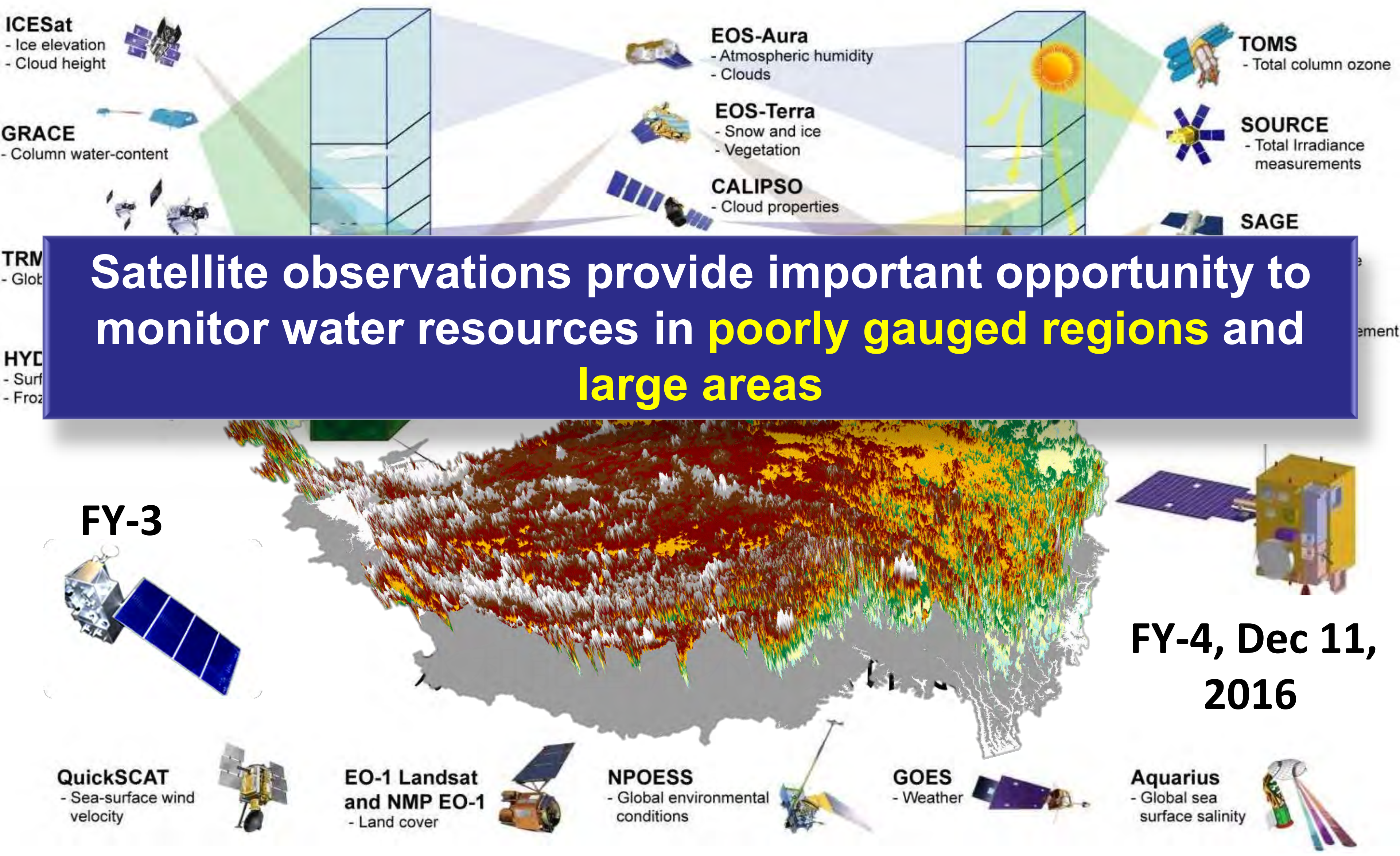
3. Space monitoring of water resources in China

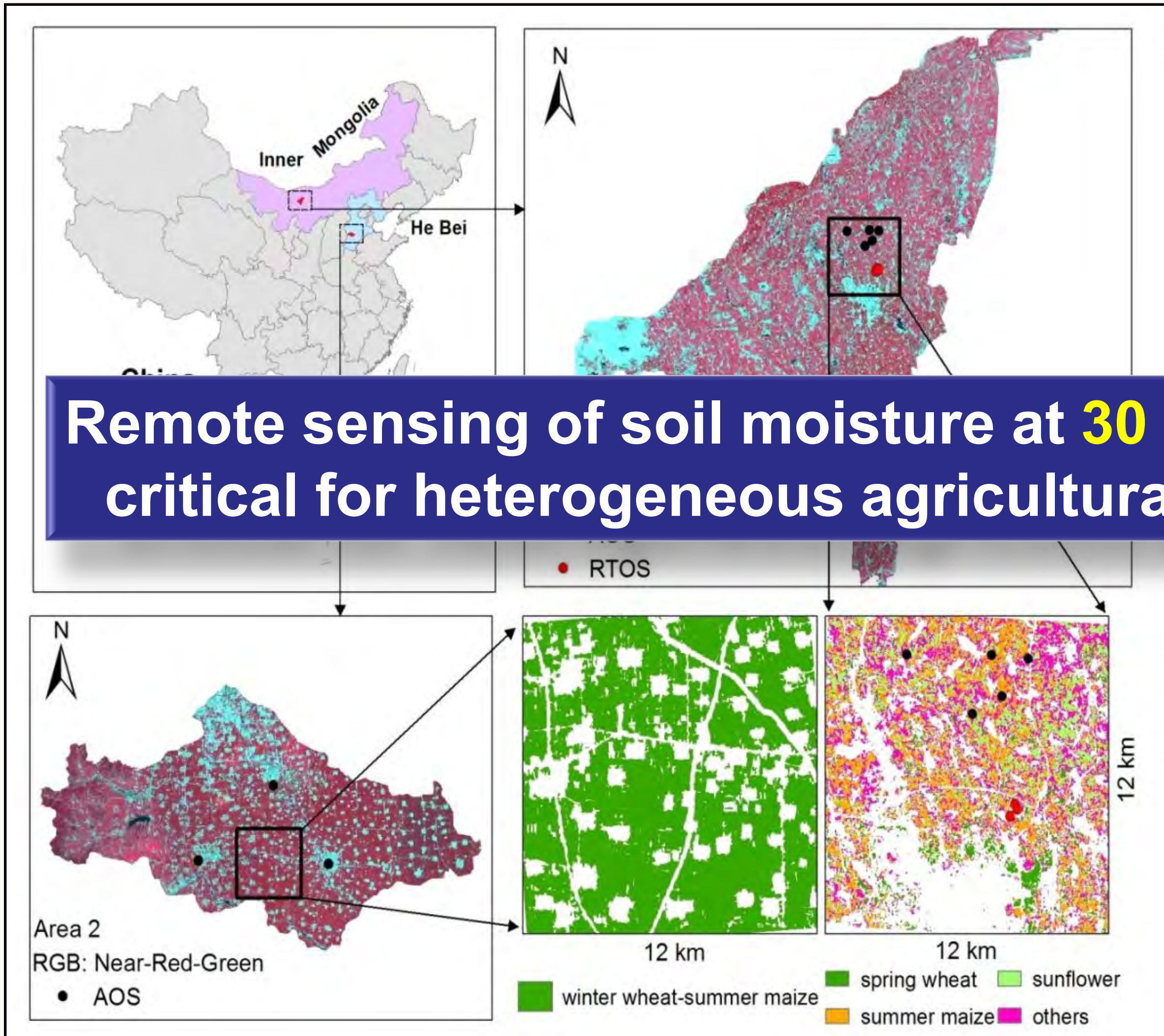
International and China's satellite missions



Satellite observations provide important opportunity to monitor water resources in poorly gauged regions and large areas

3. Space monitoring of water resources in China

Application 1: Soil surface temperature and moisture



- Area 1
- Hetao Irrigation District with heterogeneous agriculture lands
- Main crops: Spring wheat, spring maize, and sunflower
- Irrigation water: Depending

Remote sensing of soil moisture at 30 m spatial resolution is critical for heterogeneous agricultural land in North China

- South of Hebei Province in the NCP with homogeneous agricultural land
- Main crops: Winter wheat-summer maize rotation system
- Irrigation water: Depending mostly on groundwater

Two pilot agricultural districts, North China

Bai and *Long, in revision

3. Space monitoring of water resources in China

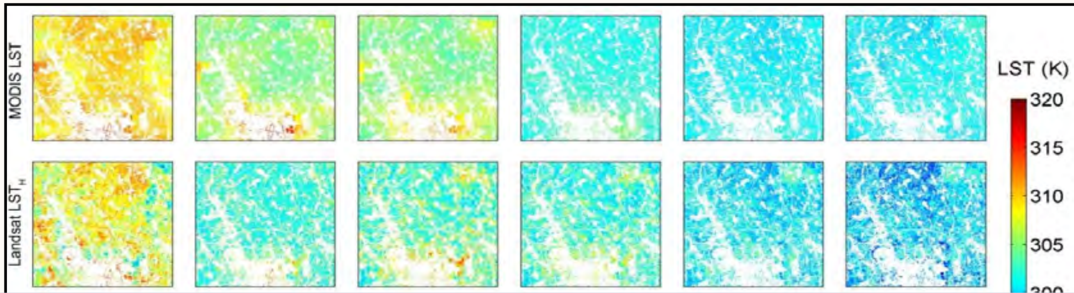
Application 1: Soil surface temperature and moisture

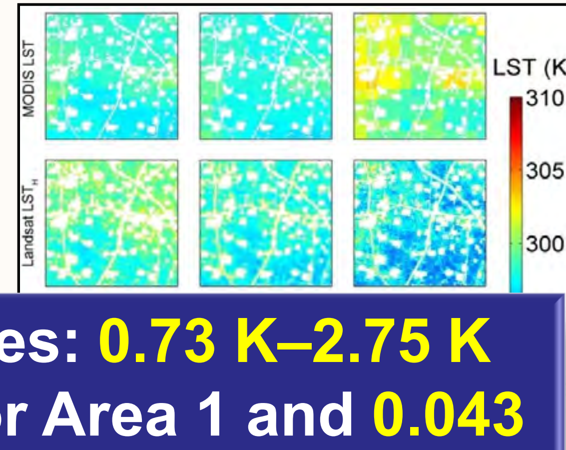
Input data → HUT and ESTARFM models → Output data

Landsat 7, 8, and MODIS | Spatial downscaling and data fusion | 30 m LST

1 km MODIS

30-100 m Landsat





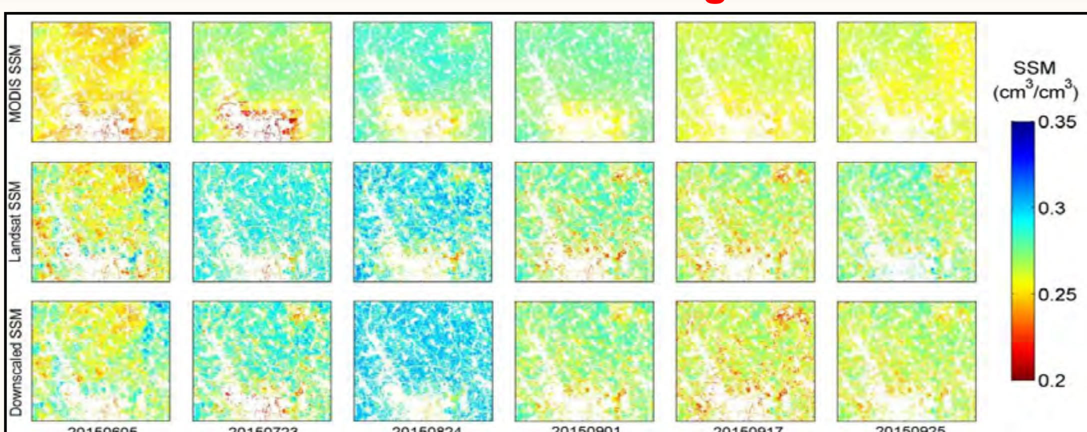
RMSE of surface soil temperature estimates: 0.73 K–2.75 K
RMSE of SSM estimates: 0.038 cm^3/cm^3 for Area 1 and 0.043 cm^3/cm^3 for Area 2

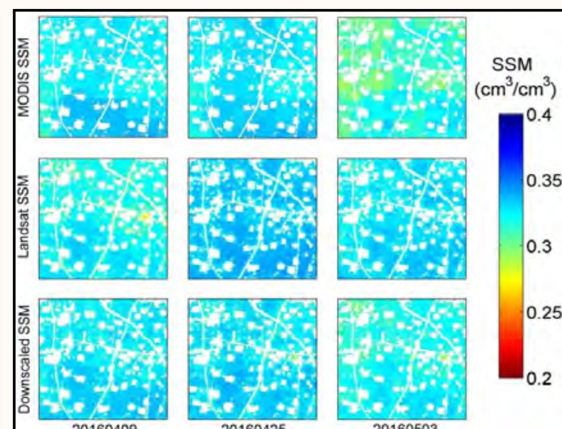
30 m LST | LST and vegetation index based | 30 m SSM

1 km MODIS

30-100 m Landsat

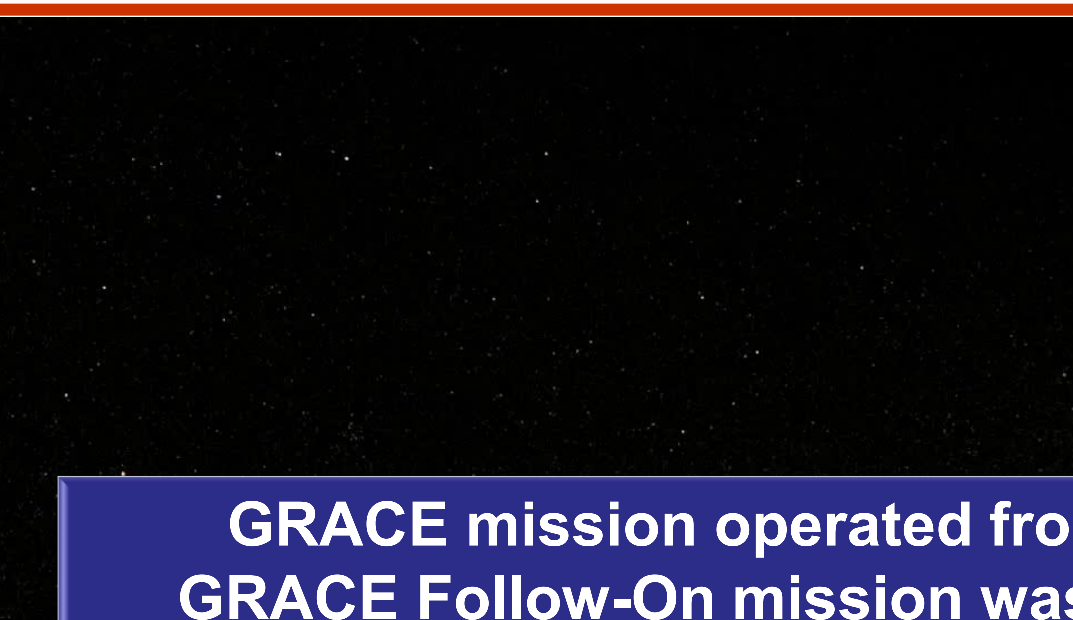
30 m





3. Space monitoring of water resources in China

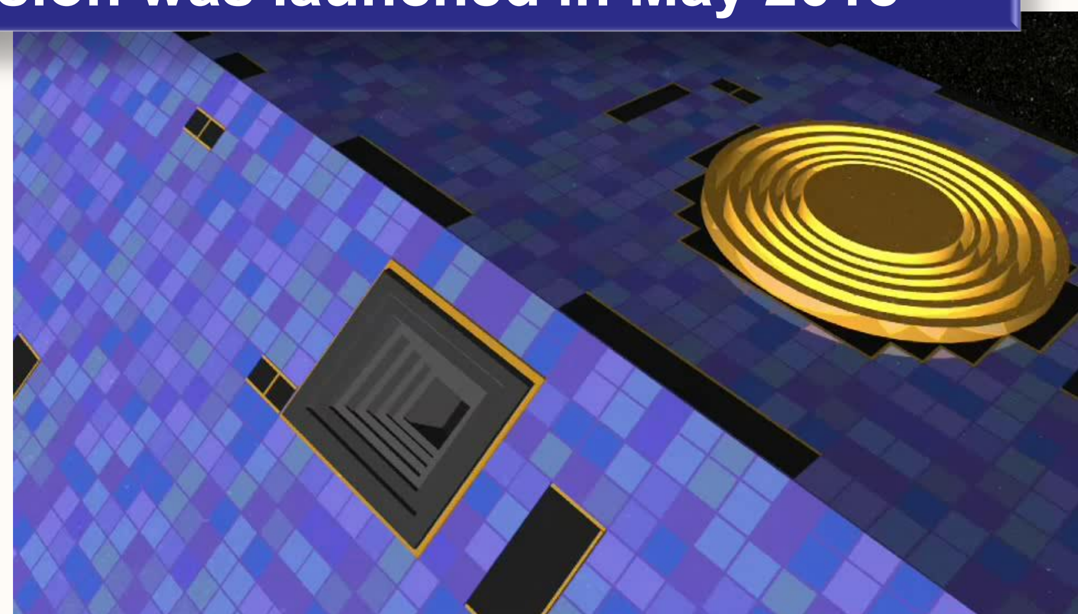
Application 2: Groundwater monitoring using GRACE



- GRACE can detect variations in the Earth's gravity field which reflects TWS changes

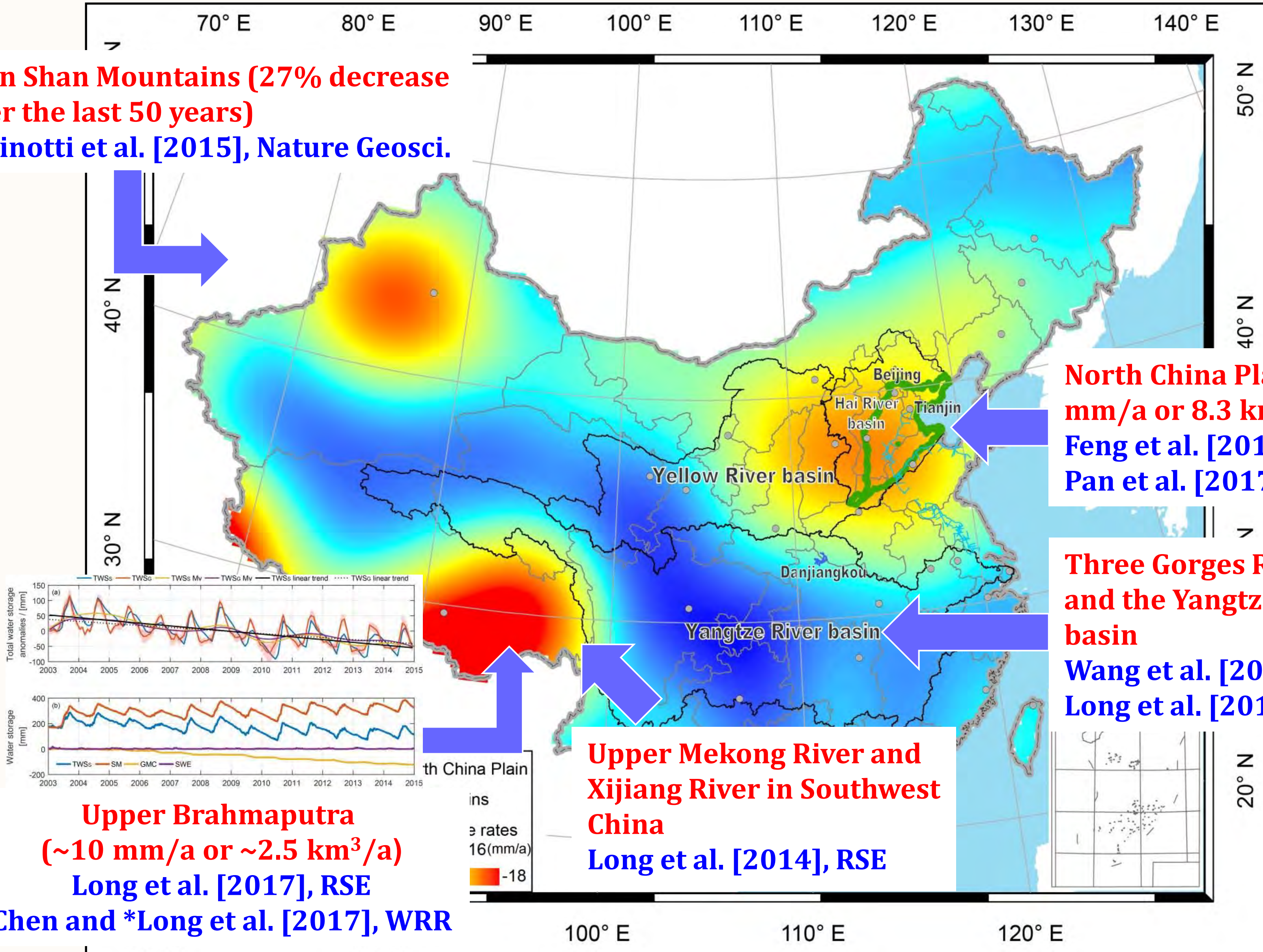
GRACE mission operated from Apr 2002–Jan 2017
GRACE Follow-On mission was launched in May 2018

- The GRACE mission has two identical spacecrafts flying ~200 km apart in a polar orbit ~500 km above the Earth. The animations are from the US NASA website.



1. Background

Water storage changes across China (2002–2016)



Tien Shan Mountains (27% decrease over the last 50 years)
Farinotti et al. [2015], Nature Geosci.

North China Plain (~22 mm/a or 8.3 km³/a)
Feng et al. [2012], WRR;
Pan et al. [2017], GRL

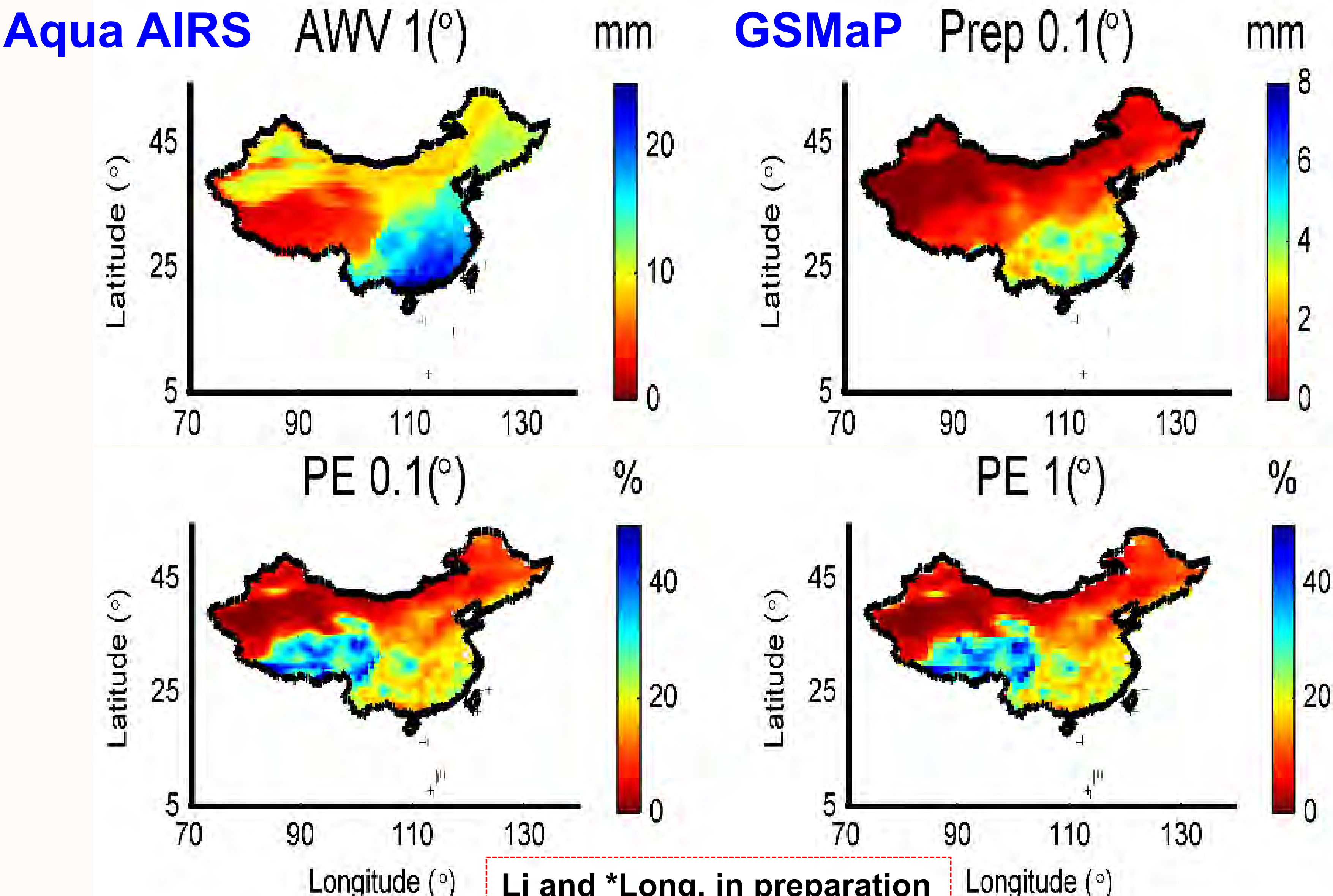
Three Gorges Reservoir and the Yangtze River basin
Wang et al. [2011], WRR;
Long et al. [2015], RSE

Upper Mekong River and Xijiang River in Southwest China
Long et al. [2014], RSE

Upper Brahmaputra (~10 mm/a or ~2.5 km³/a)
Long et al. [2017], RSE
Chen and *Long et al. [2017], WRR

3. Space monitoring of water resources in China

Application 3: Atmospheric water vapor (AWV), precipitation (Prep) and precipitation efficiency (PE) across China (2007–2012)



Li and *Long, in preparation

- Background
- Ground monitoring networks in China
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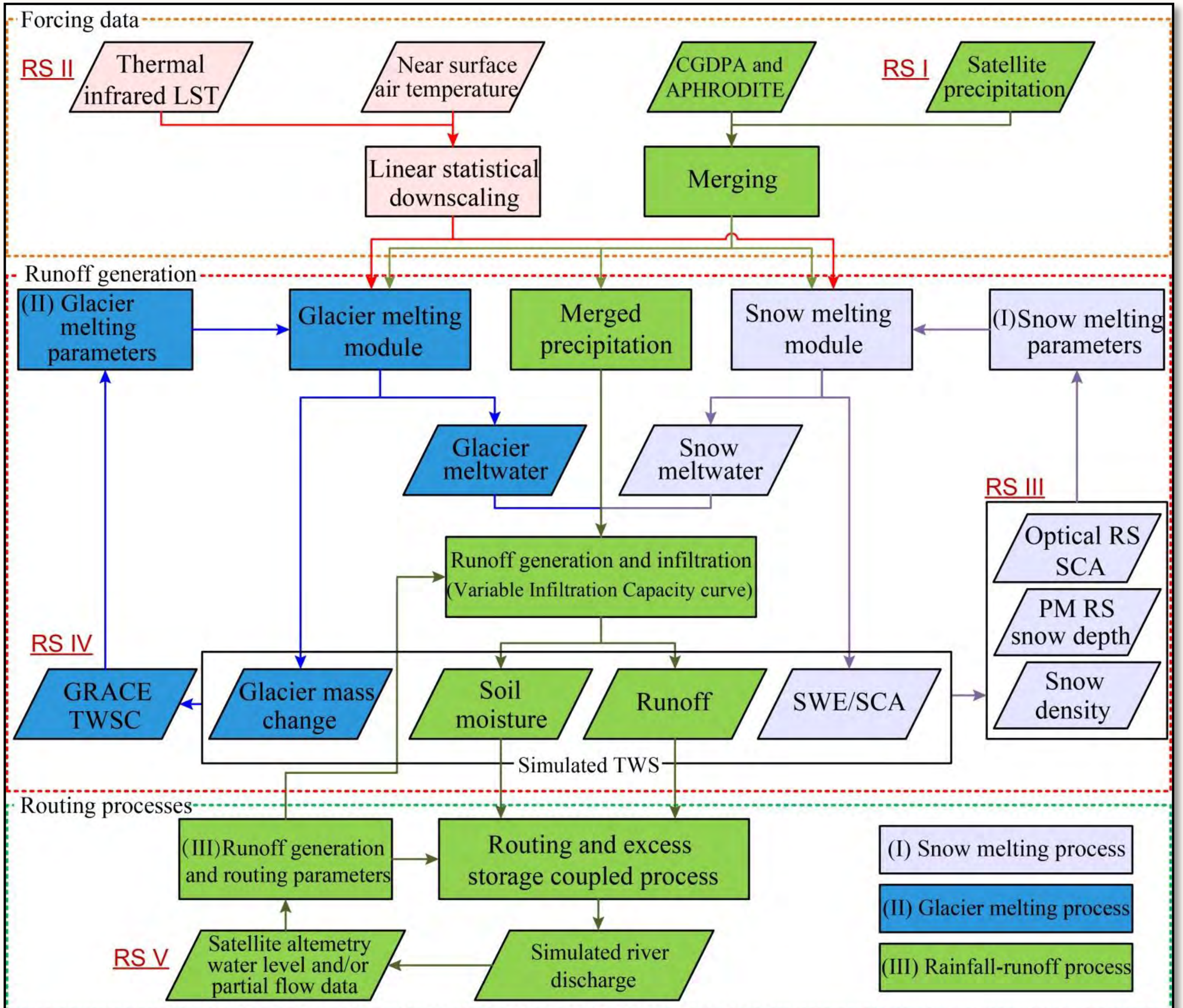
4. Regional modeling and information systems: Cold regions

Flowchart of the developed model: CREST-RS



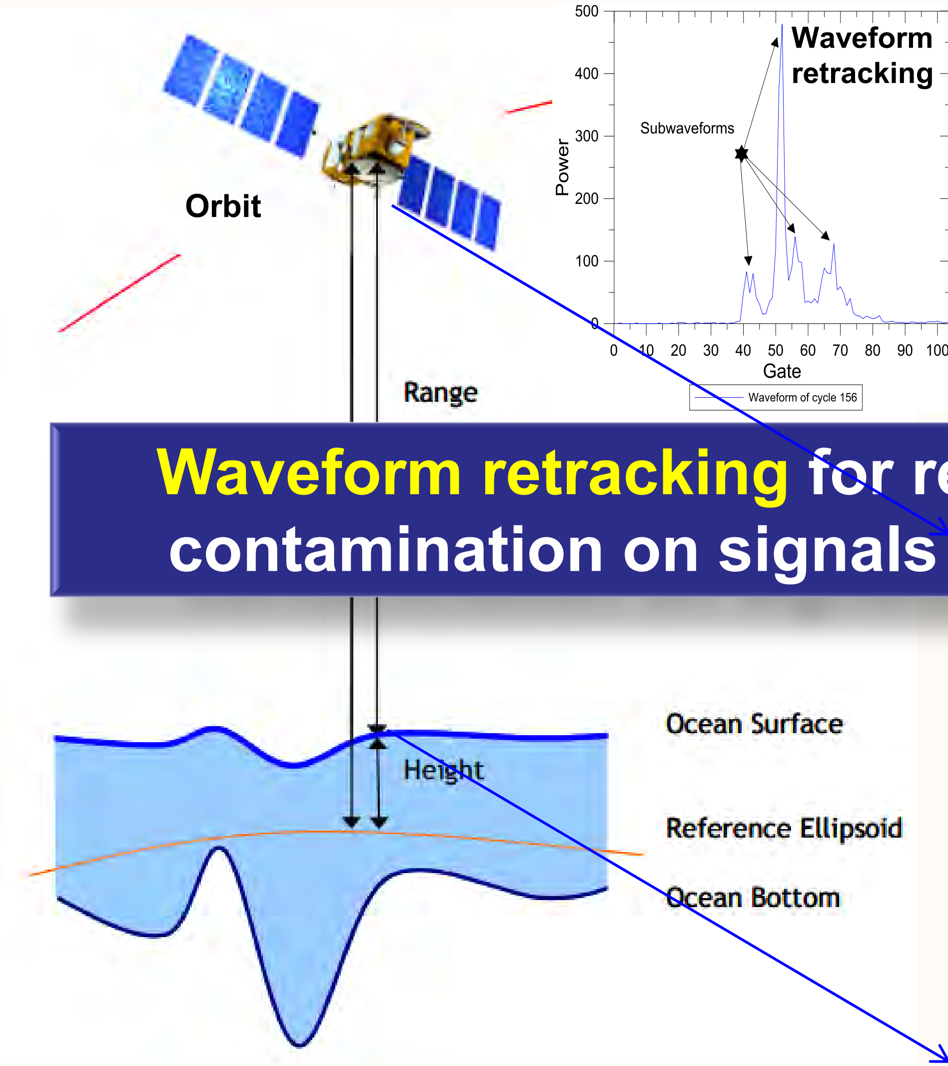
- **RS I**: Satellite-based precipitation
- **RS II**: Thermal infrared LST
- **RS III**: Optical RS-based SCA and passive microwave RS-based snow depth
- **RS IV**: GRACE-derived total water storage changes
- **RS V**: Satellite altimetry-based water levels

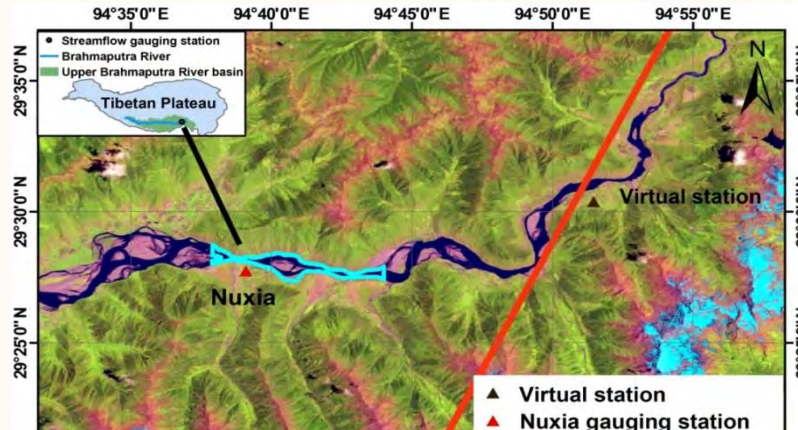
Chen and *Long et al., 2017, WRR

Long et al., 2018, under review

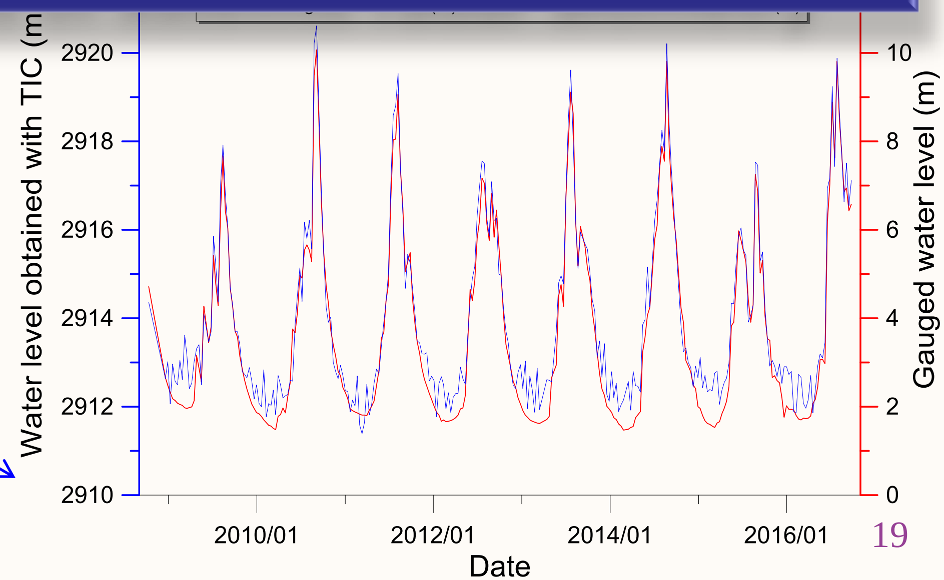
4. Regional modeling and information systems: Cold regions

Satellite altimetry (Jason 2)-based river water levels





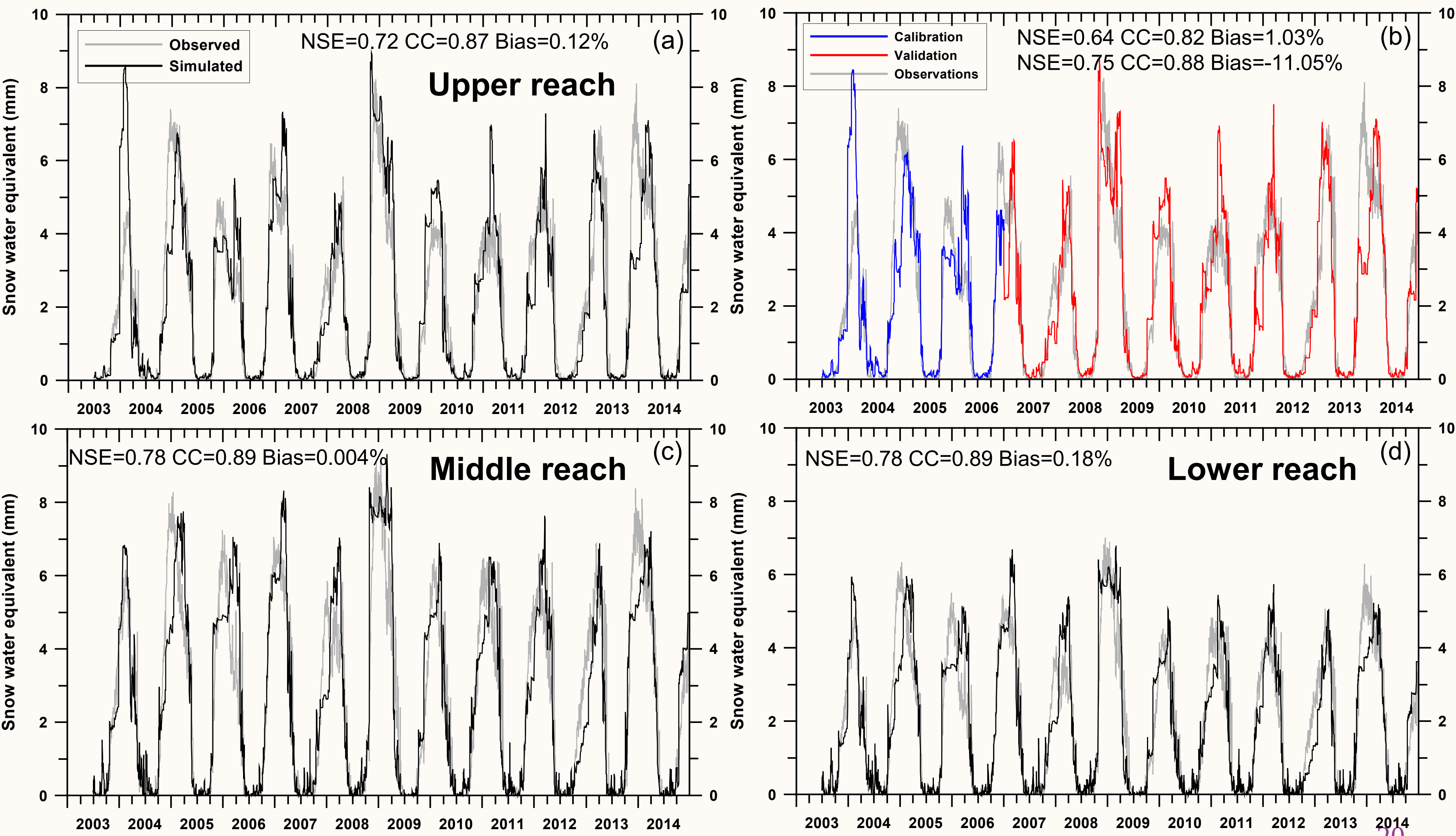
Waveform retracking for reducing the impact of land contamination on signals of satellite radar altimetry



Huang and *Long et al., 2018, RSE

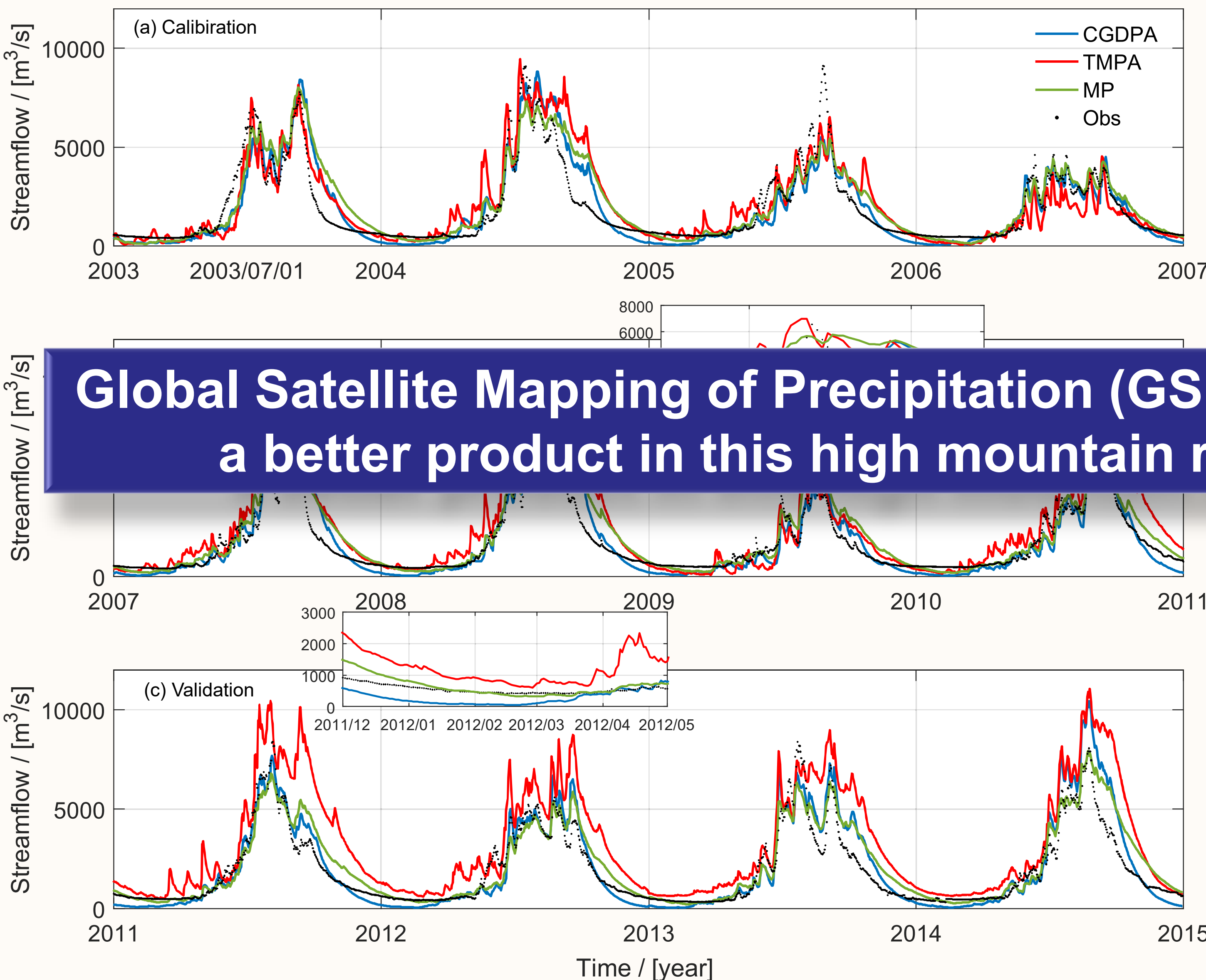
4. Regional modeling and information systems: Cold regions

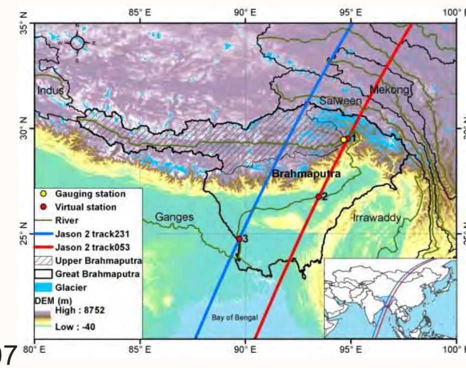
Snow water equivalent observations and modeling



4. Regional modeling and information systems: Cold regions

Streamflow simulations using different precipitation





Global Satellite Mapping of Precipitation (GSMaP) can be a better product in this high mountain region!

Three P forcings:

)

(Ground)

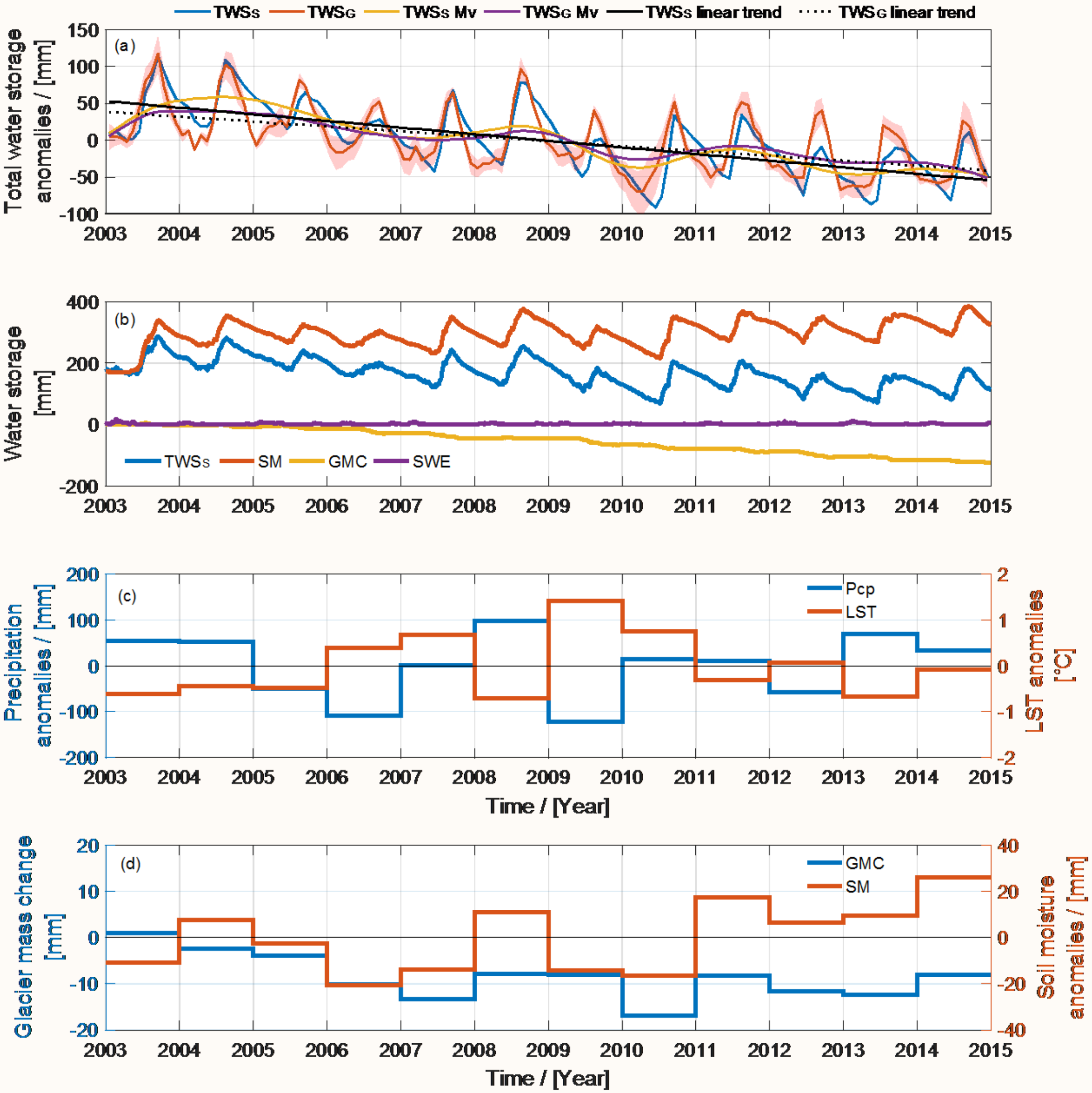
- **MP** (Merged in our study)

Performance:

- Calibration: Obj_Q=0.79;
- Validation: Obj_Q=0.85

4. Regional modeling and information systems: Cold regions

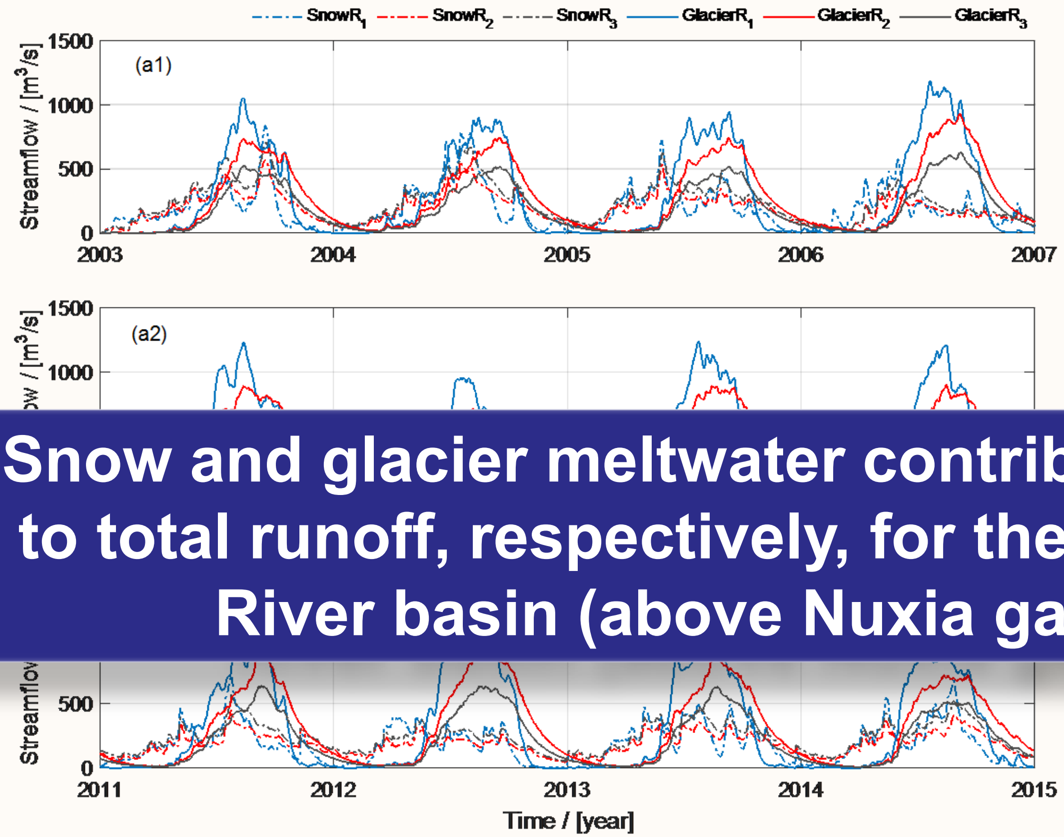
GMC dominates TWS changes (upper reach)

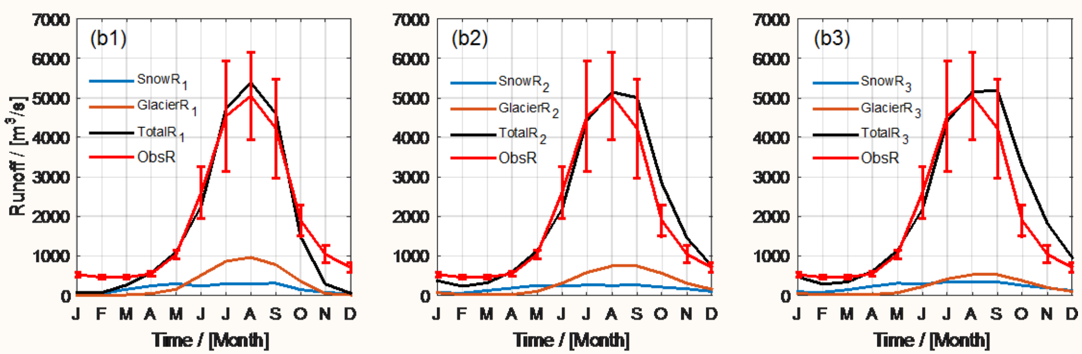


- Simulated TWS changes are consistent with GRACE-observed ones
- Compared with SWE, GMC shows more significant depletion, found to be the primary contributor of TWS depletion
- Depletion in glacier mass is mainly contributed by both **rising temperatures** and **decreasing P**

4. Regional modeling and information systems: Cold regions

Snow and glacier melt flooding simulation and prediction

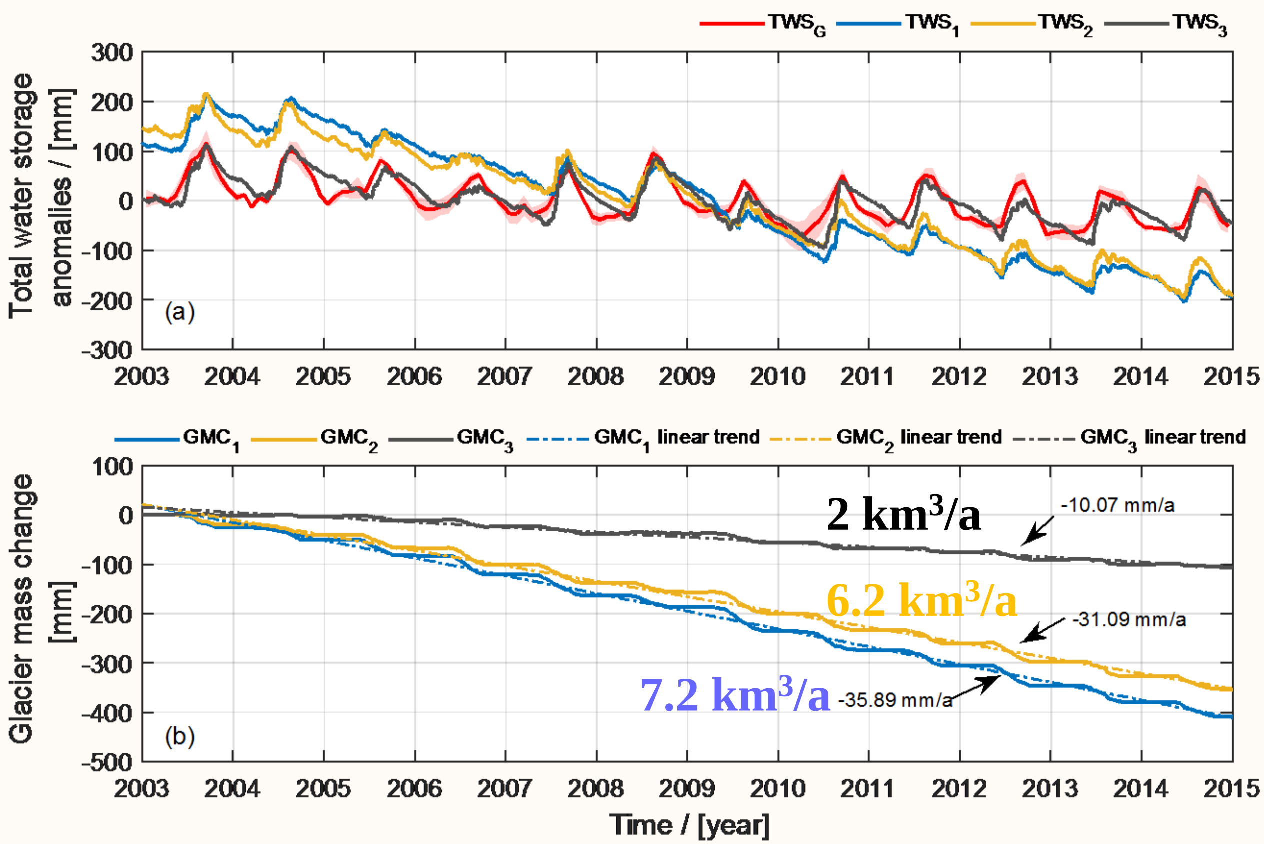




Snow and glacier meltwater contributes ~11% and ~10% to total runoff, respectively, for the Upper Brahmaputra River basin (above Nuxia gauging station)

- Snowmelt runoff and glacier runoff under:
  - Scenario (I): CGDPA P+Q calibration
  - Scenario (II): Merged
  - developed
- Climatology of runoff components for three scenarios :
  - (b1): Scenario (I)
  - (b2): Scenario (II)
  - (b3): Scenario (III)

Long-term trends in snow and glacier meltwater



- (a) GRACE-derived TWS changes and simulated TWS changes under scenarios (I) – (III)
- (b) Glacier mass changes under scenarios (I) – (III) and their linear trends

Traditional calibration using Q only significantly overestimated glacier mass depletion (6.2 km^3/a or 7.2 km^3/a) for the Upper Brahmaputra River basin, relative to the newly estimated rate of **2 km^3/a** in our study

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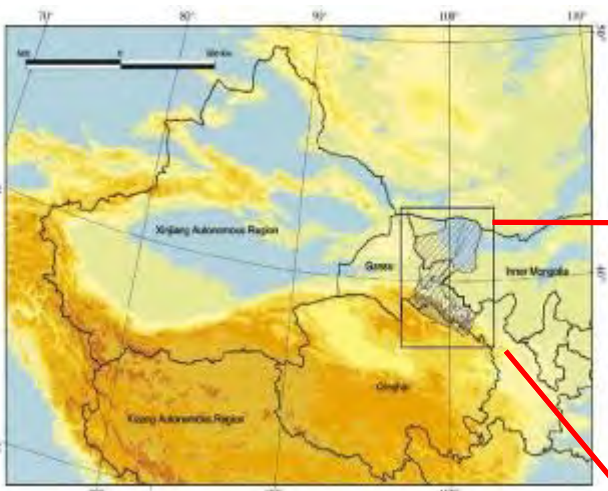
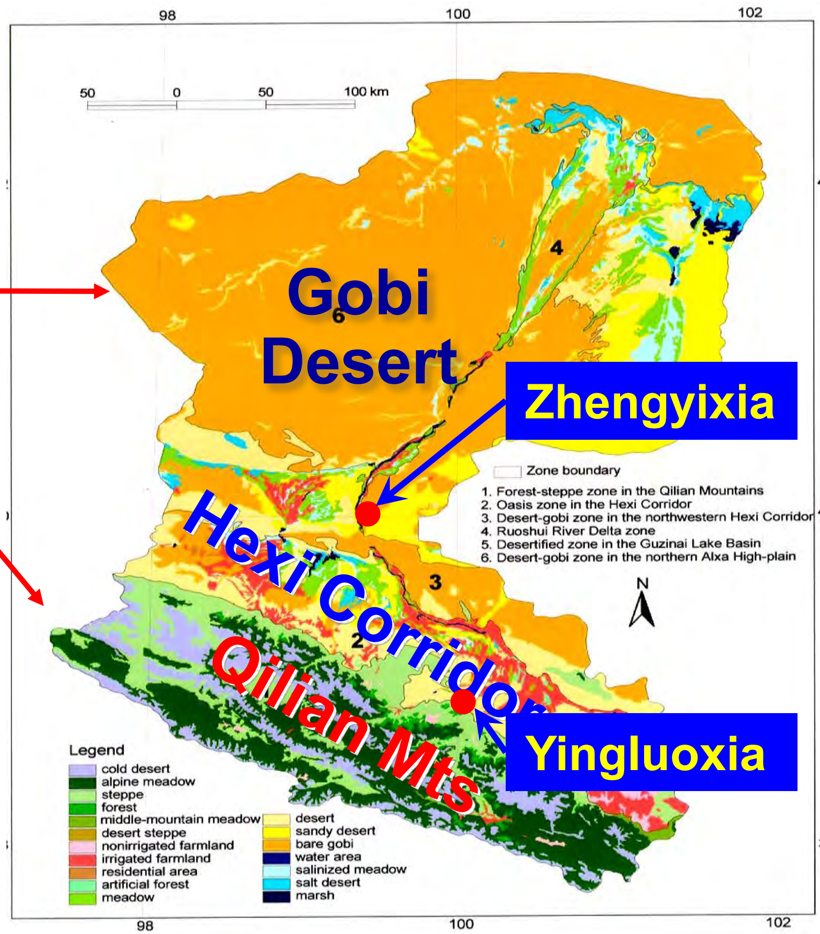
Heihe River basin in Northwest China

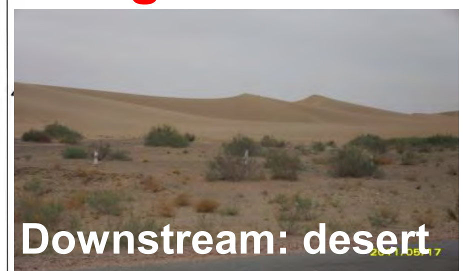
- The 2nd largest inland river basin in China (~130,000 km^2)
- A steep mountain-oasis-desert ecological gradient, typical in western China

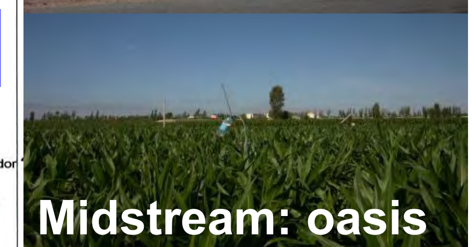




Yingluoxia: Upstream-midstream dividing point
Zhengyixia: Midstream-downstream dividing point

Steep ecological gradient





5. Regional modeling and information systems: Arid regions

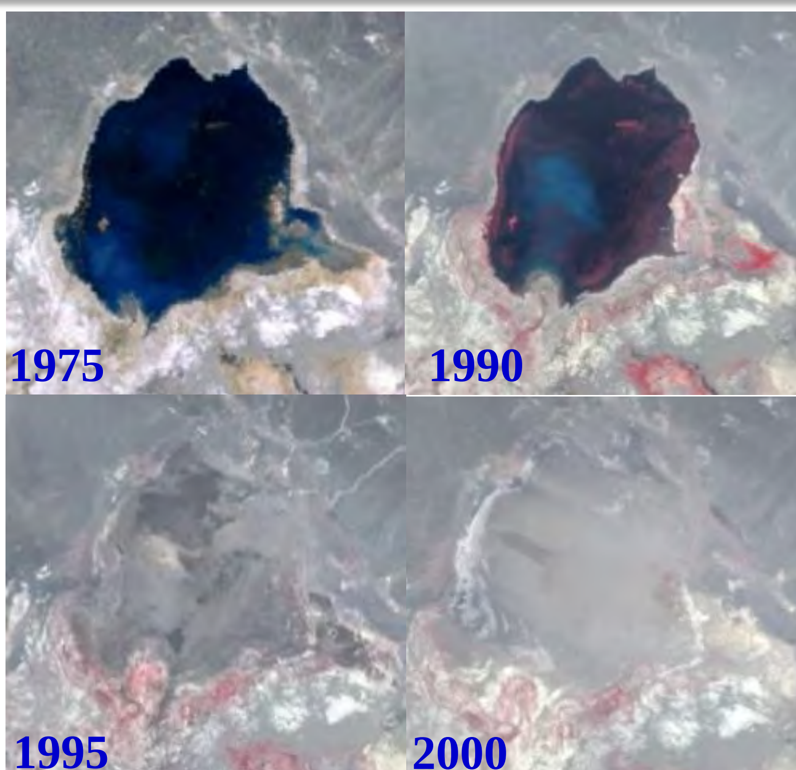
Heihe River basin in Northwest China

5. Regional modeling and information systems: Arid regions

Water conflicts in the Heihe River basin

- From 1970’s to 2000, excessive river flow diversion for irrigation in the middle HRB had caused vegetation degradation in the lower HRB and drying up of the terminal lake
- Two conflicts: Human vs. ecosystem, midstream vs. downstream

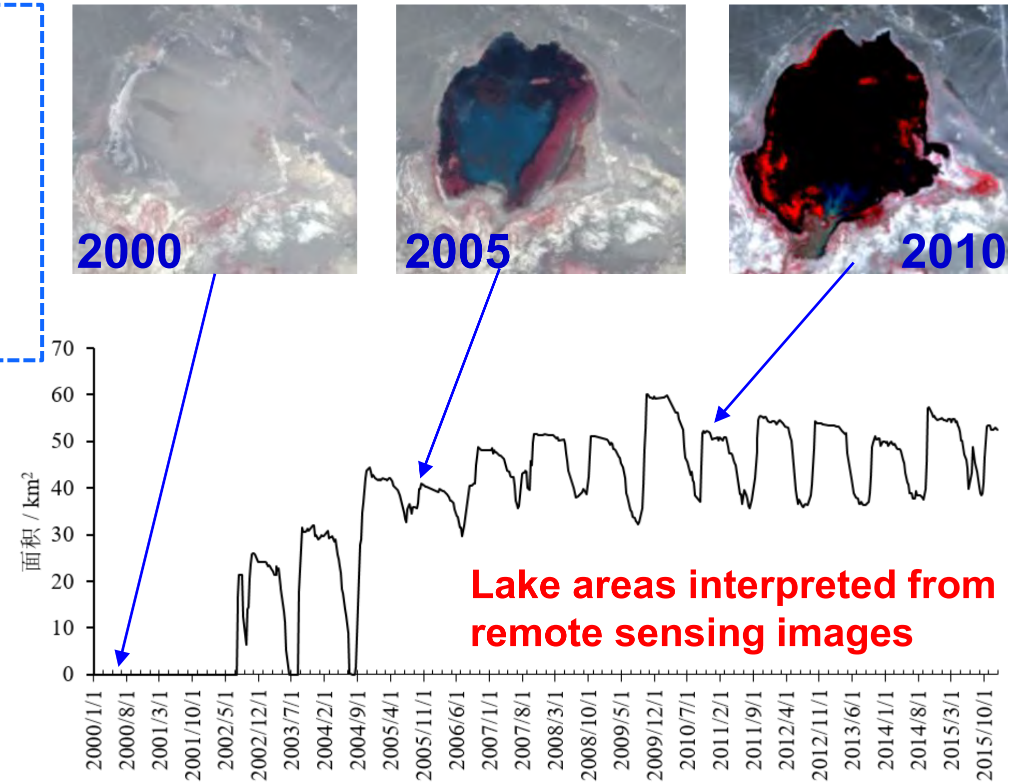
Remote sensing images of the East Juyan Lake



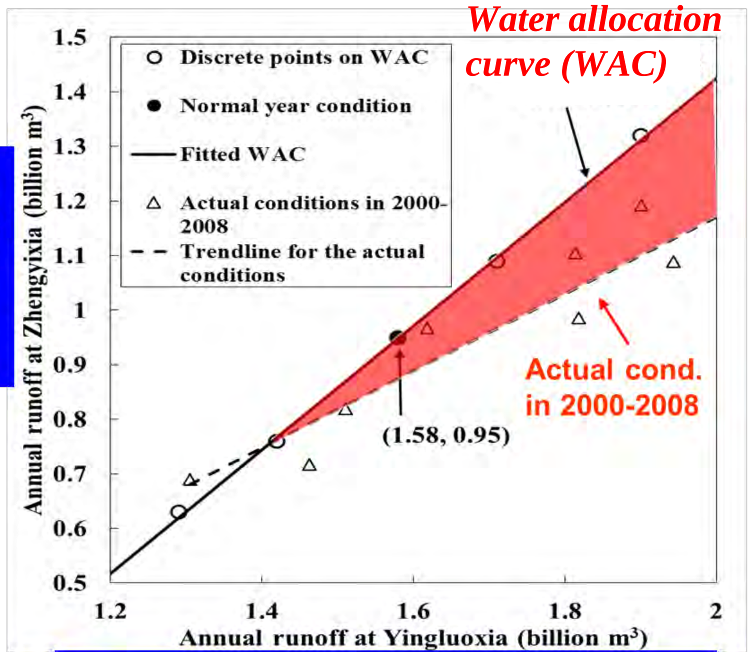
5. Regional modeling and information systems: Arid regions

Rejuvenation of the East Juyan Lake

- Since 2000, a water allocation plan has been enforced by the central government to protect the ecological flow towards the downstream



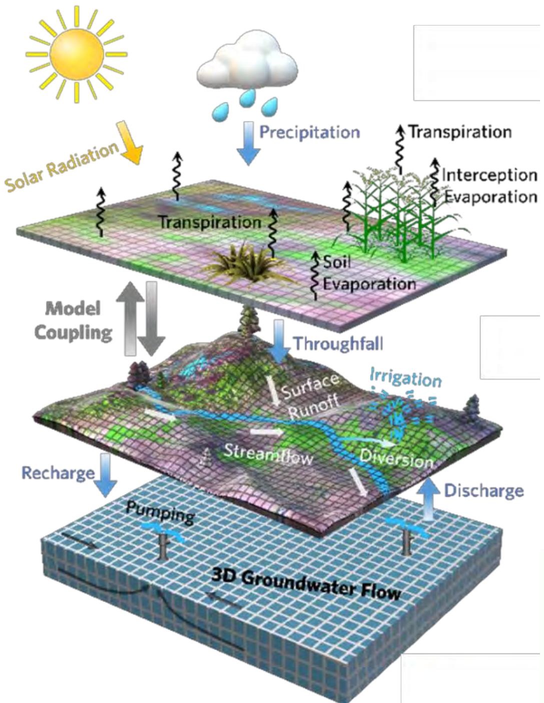
Flow to the lower Gobi area



Inflow from the upper mountain area

5. Regional modeling and information systems: Arid regions

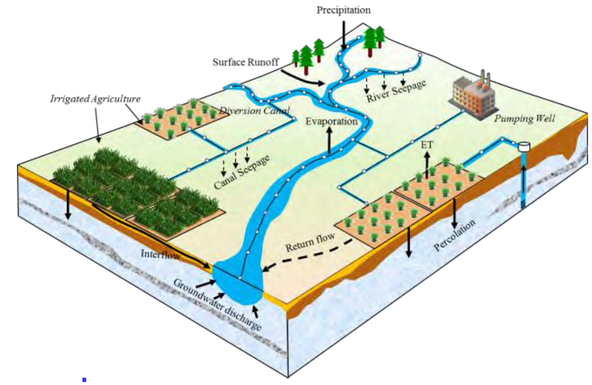
An integrated ecohydrological model for inland river basins



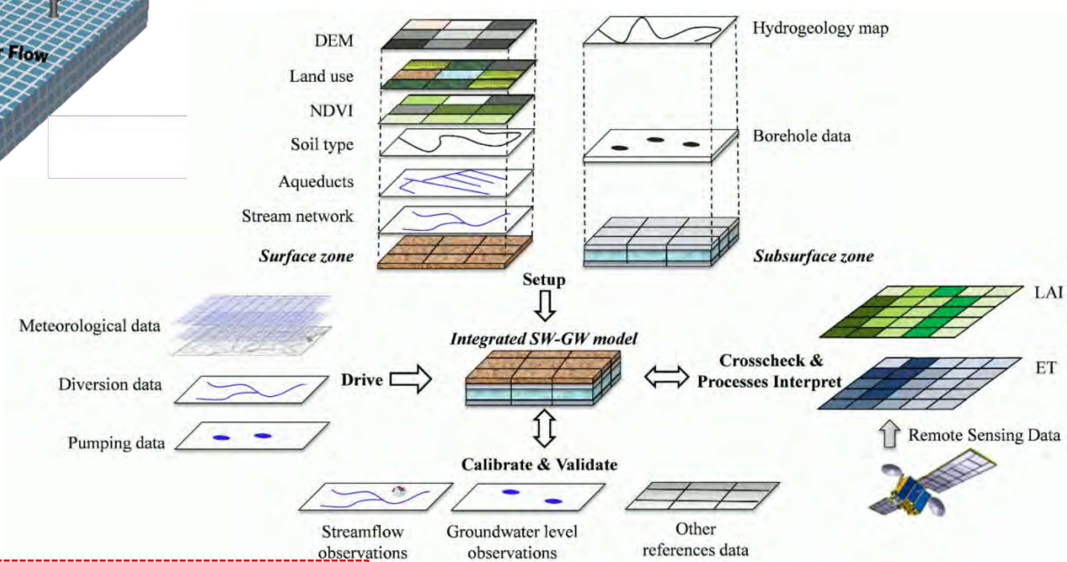
Concept

Natural processes + **Human activities**

Natural processes	Human activities
Vegetation	Flow diversion
Surface water	Groundwater pumping
Groundwater	Irrigation



An integrated model is also a platform to fuse multi-source data

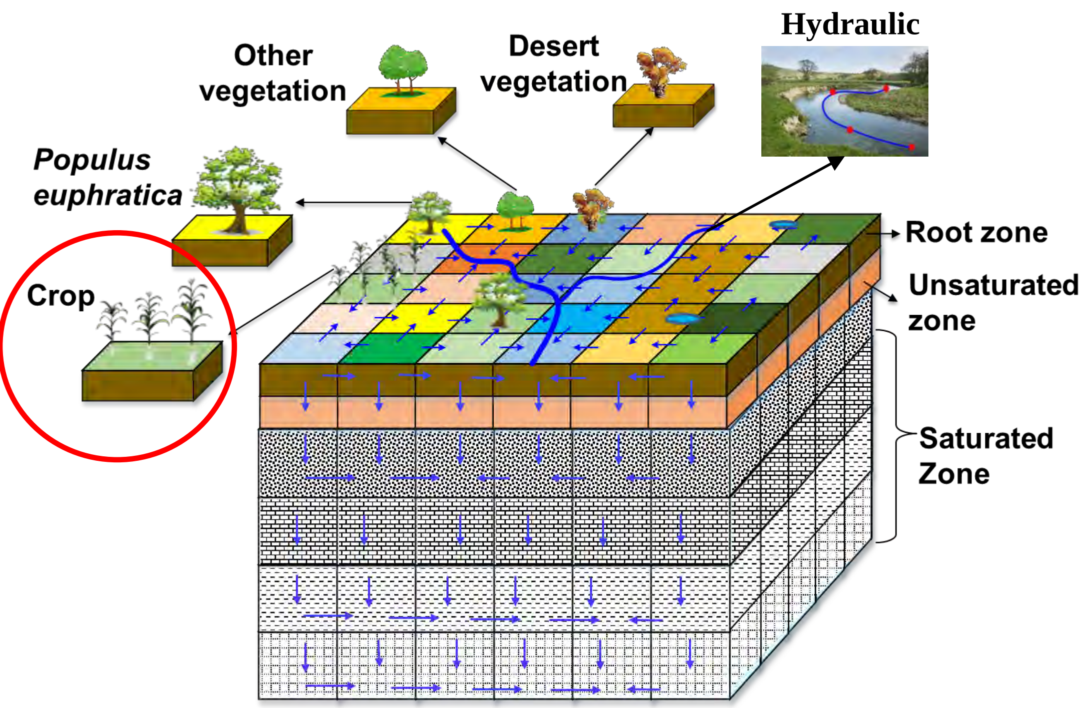


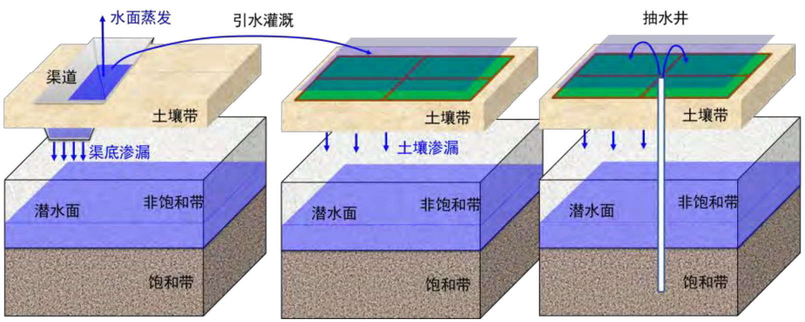
Tian and *Zheng et al., 2015, *WRR*

5. Regional modeling and information systems: Arid regions

HEIFLOW–Hydrological-Ecological Integrated watershed-scale FLOW model

- Specifically designed for inland river basins with substantial surface water-groundwater interactions and agricultural irrigation
- Developed from GSFLOW (a USGS model)
- An advanced hydraulic module embedded, explicitly accounting for water diversion, pumping and irrigation
- Multiple eco-hydrological modules coupled





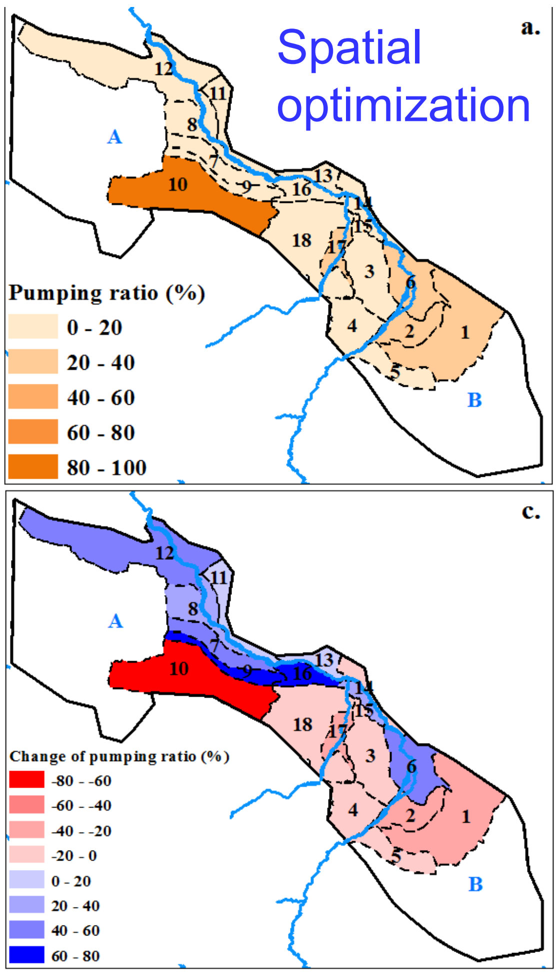
Tian and *Zheng et al., 2015, *EMS*

5. Regional modeling and information systems: Arid regions

An integrated ecohydrological model for inland river basins

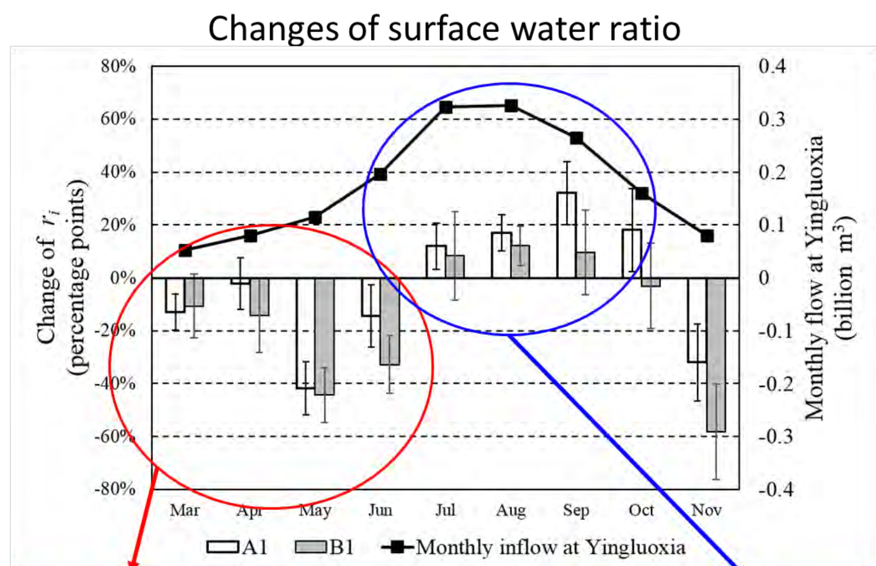
- Modeling-based optimization of the conjunctive use of surface water and groundwater in the midstream

Spatial optimization



Temporal optimization

Changes of surface water ratio



Use more groundwater in the dry season

Groundwater reservoir!

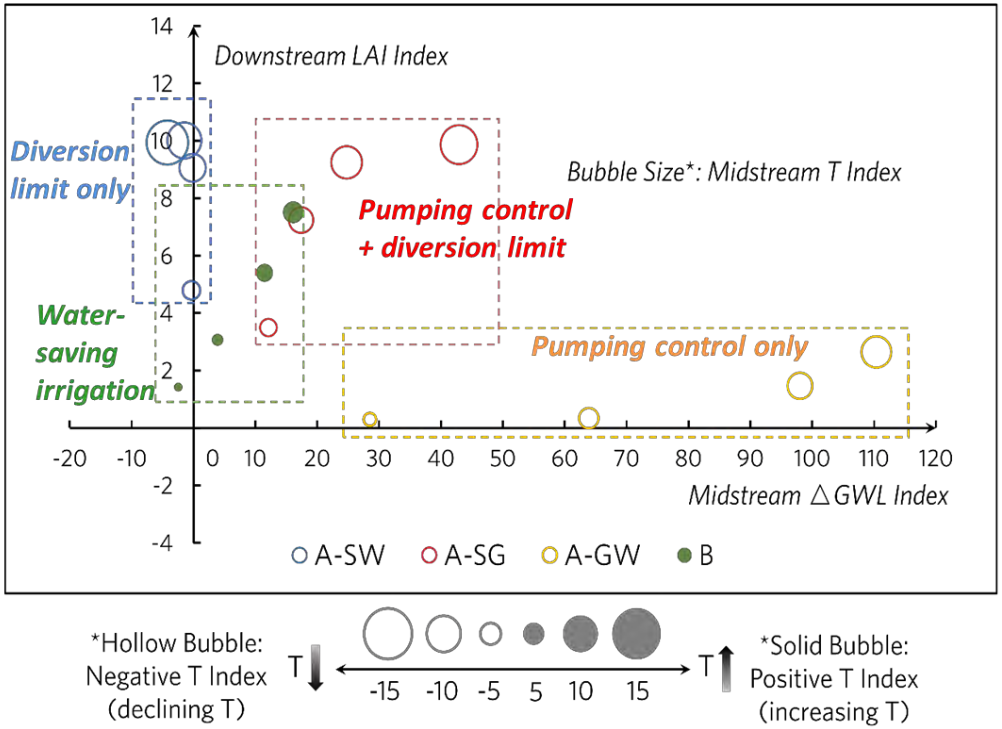
Use more surface water during the flood season

Wu and *Zheng et al., 2015, *WRR*
Wu and *Zheng et al., 2016, *AWM*

5. Regional modeling and information systems: Arid regions

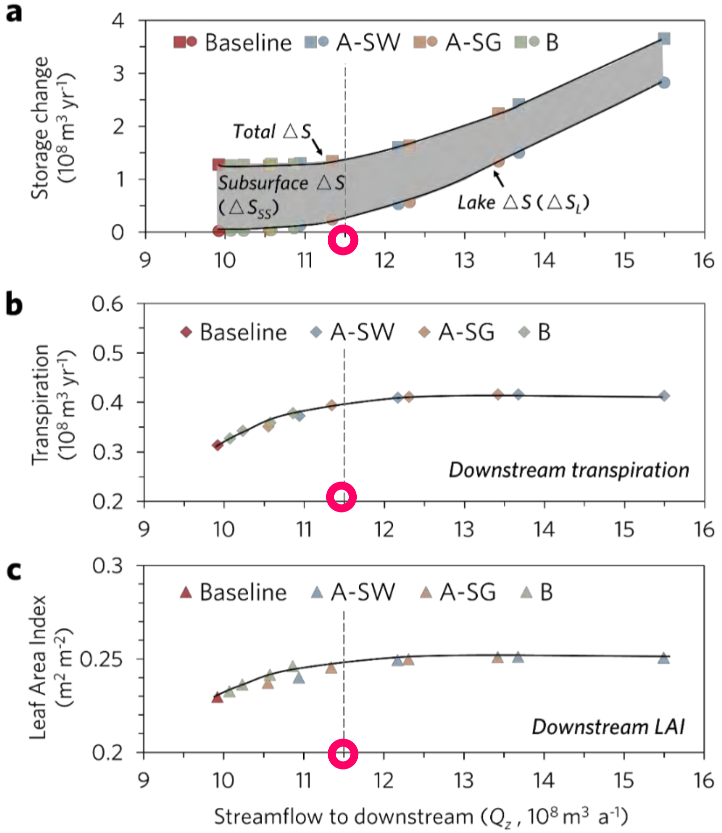
Analysis of the water-ecosystem-food (WEF) nexus in HRB

Coevolution of the groundwater storage, food production and ecosystem health in different management regimes



Sun and *Zheng et al., under review

Identification of the "tipping point" for the ecological flow regulation

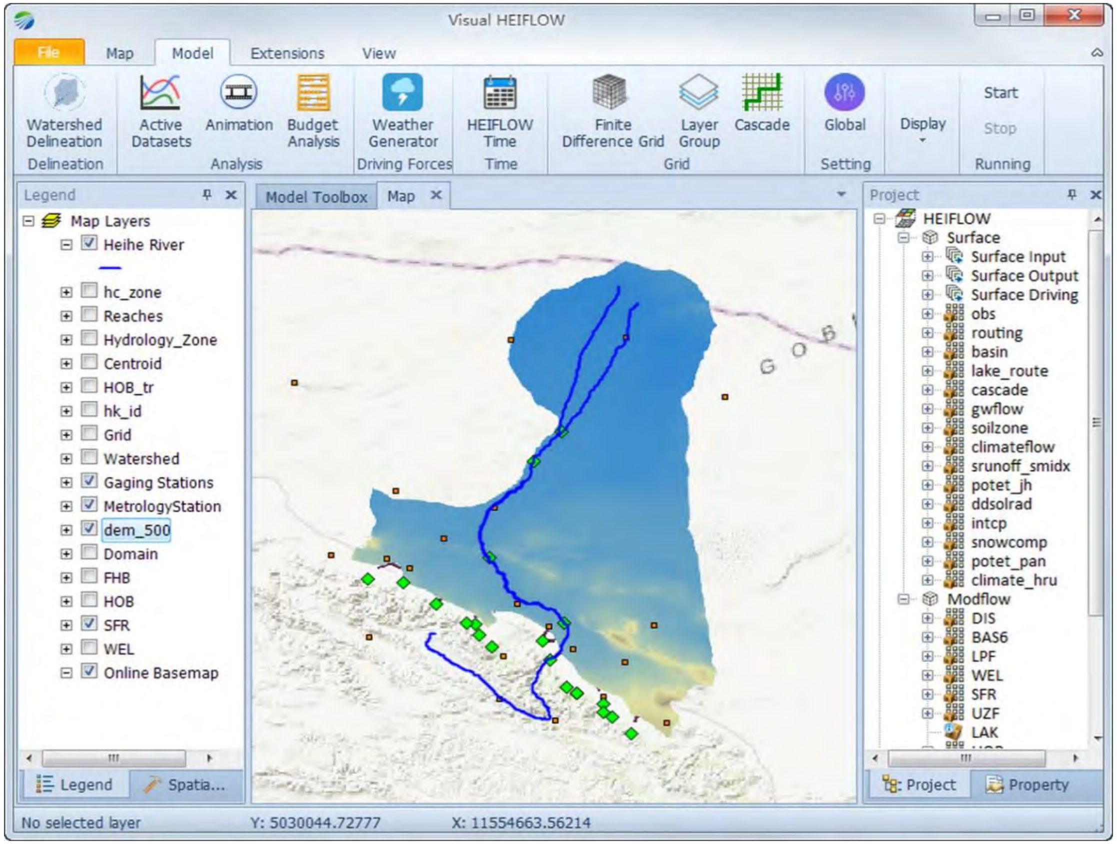


5. Regional modeling and information systems: Arid regions

Visual HEIFLOW (VHF)

- A comprehensive system for supporting integrated watershed management in arid inland regions

- Originally designed for HEIFLOW, but can be easily extended to accommodate other integrated models
- It streamlines the entire modeling procedure, from data preparation to visualization and analysis of modeling results, in a uniform environment.

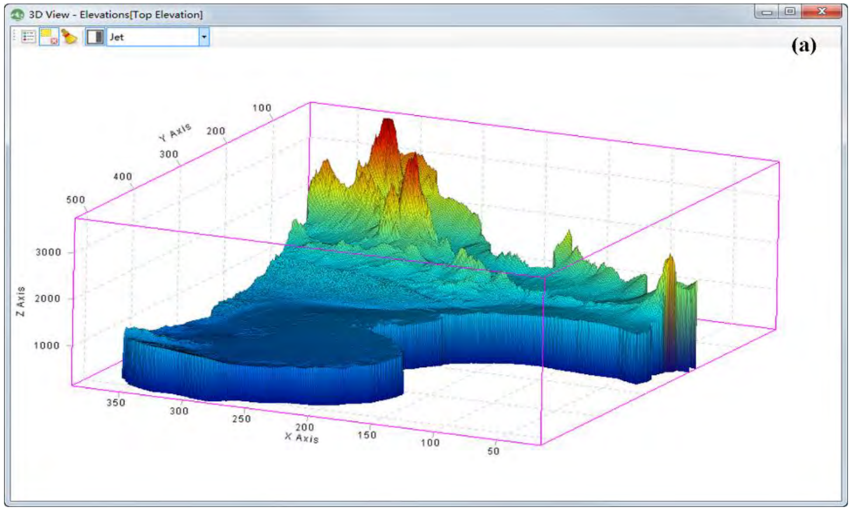


Tian and *Zheng et al., in revision

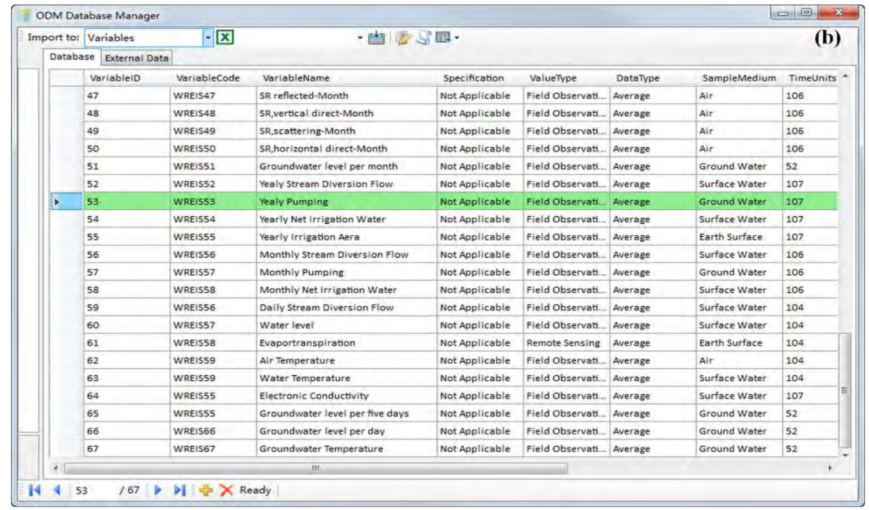
5. Regional modeling and information systems: Arid regions

Some key tools in Visual HEIFLOW

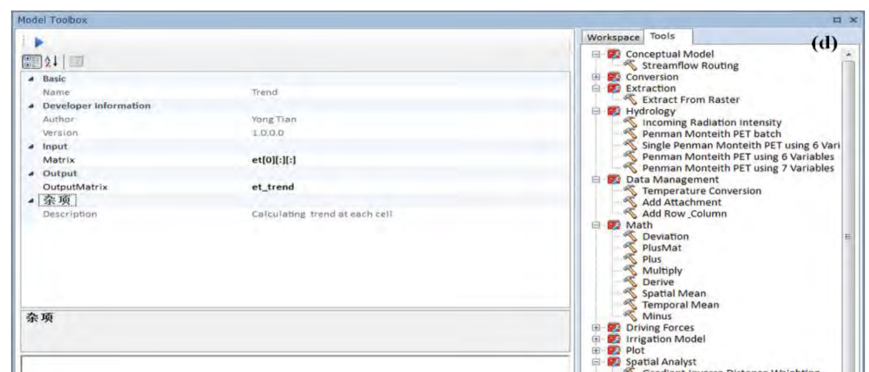
3D view tool



ODM database manager



Spatial toolbox

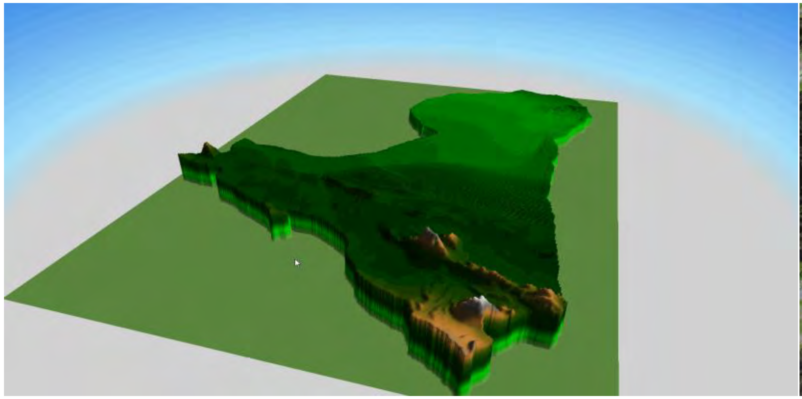


Model toolbox

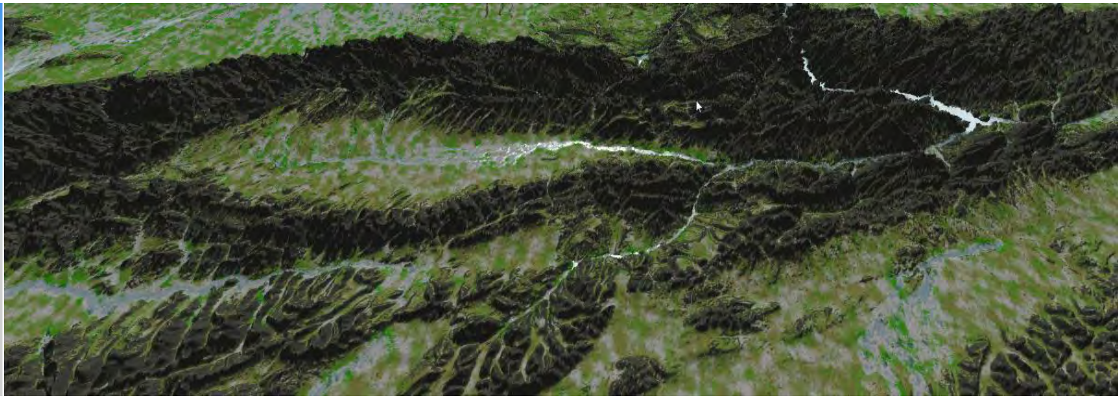
5. Regional modeling and information systems: Arid regions

Visualization

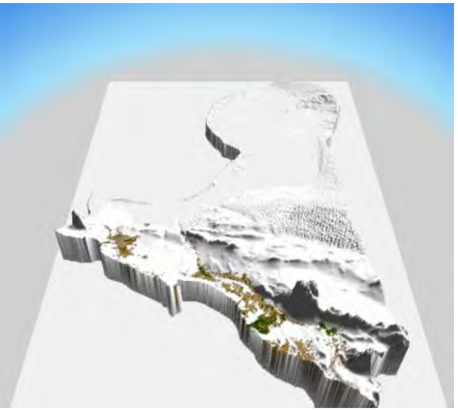
Hydrogeological features



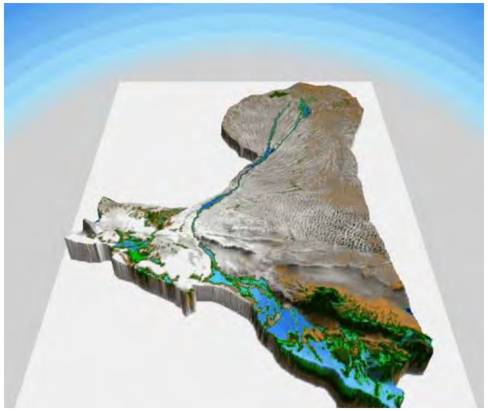
Topography and river network



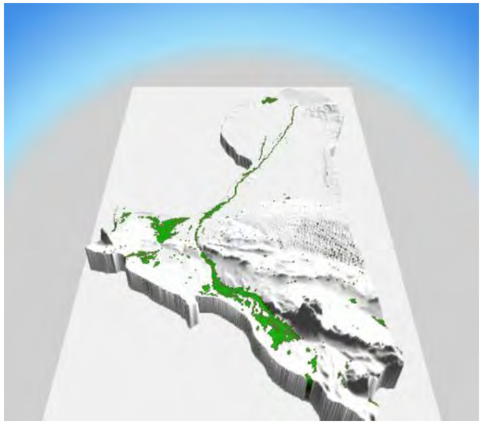
Leaf Area Index



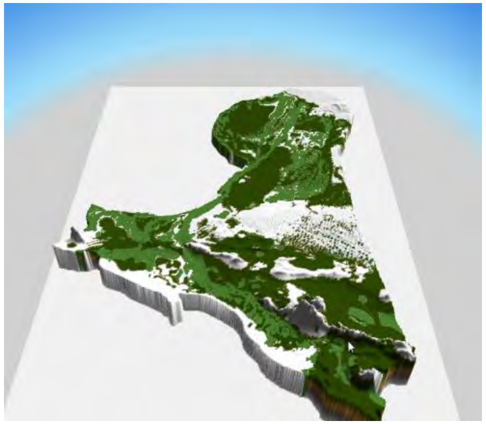
Evapotranspiration



GW recharge



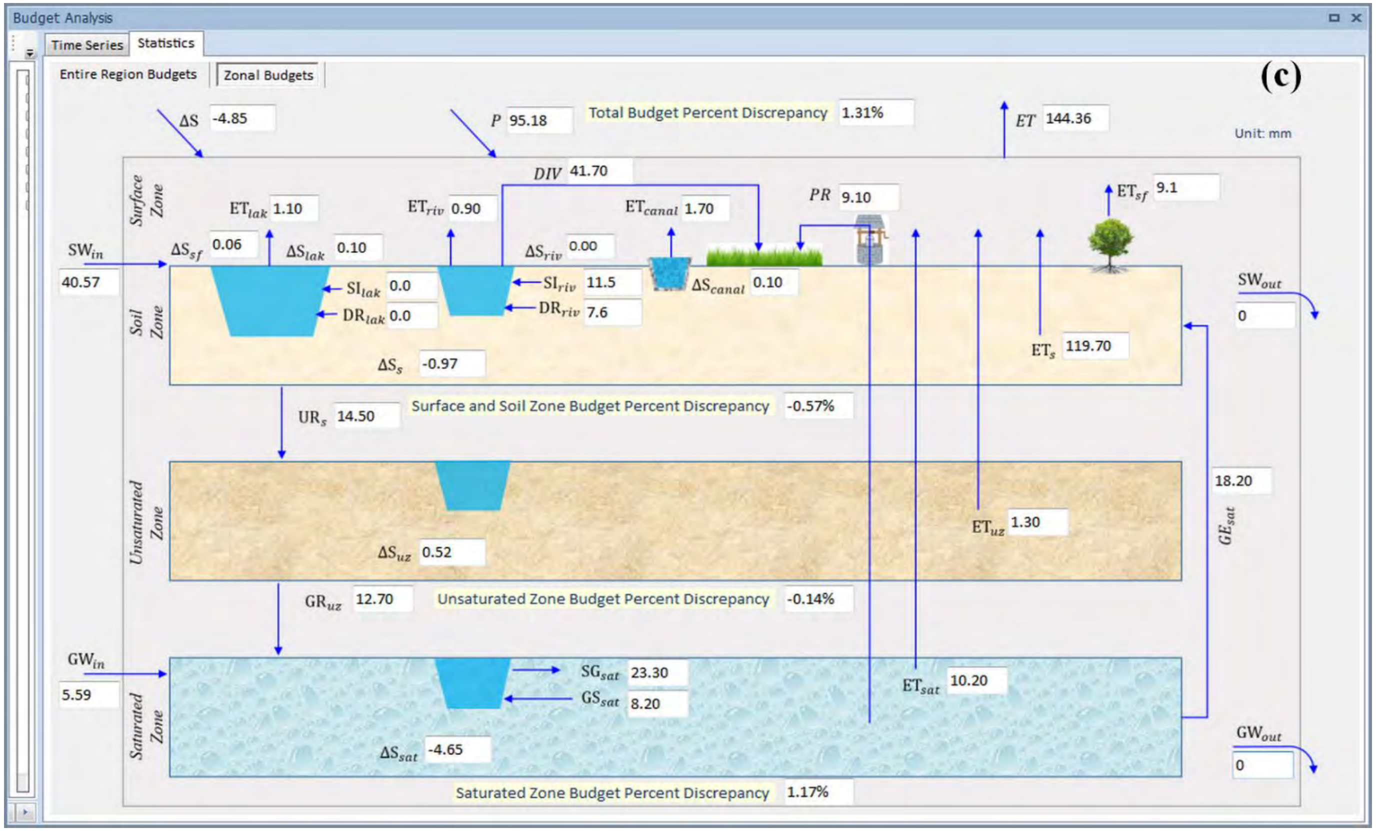
GWS



5. Regional modeling and information systems: Arid regions

Supporting management

- The budget analysis tool computes the water balance for pre-specified periods.
- The graphical presentation helps the user easily understand the complicated hydrological processes and compare different management scenarios.



Concluding remarks

- We call for enhancing ground monitoring of water resources and developing a transparent data sharing mechanism in China
- Satellite observations of the hydrological cycle (i.e., soil moisture, groundwater, atmospheric water vapor) play an increasingly important role in water resource monitoring and management (e.g., at a spatial resolution of 30 m by 30 m)
- Satellite observations provide critical information on hydrological modeling in poorly gauged cryospheric regions, highly valuable for snow and ice melt and flooding monitoring and prediction, and understanding impacts of climate change on water resources
- An integrated ecohydrological model (HEIFLOW) and an information system (Visual HEIFLOW) have been developed in the arid Heihe River basin, which greatly helps improve our understanding of hydrological and ecological processes, and facilitates decision making for water allocation in arid regions in China

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