The background of the slide is a dark, moody photograph of water. In the upper center, a single water droplet is suspended in mid-air, just before it hits a surface. Below it, a large splash of water is captured, with many smaller droplets rising and falling. The lighting creates highlights on the water's surface and within the droplets, giving a sense of movement and texture. The overall tone is scientific and naturalistic.

Integrating remote sensing and models for water resources management



Walter Immerzeel
20 May 2009

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Introduction: <http://www.futurewater.nl>



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FutureWater:
Research and consultancy
for a sustainable future
of our water resources

The **uniqueness** of water is that
you can neither create nor
destroy it.

The **problem** with water is that
some parts of the world have too
much, others too little.

The **challenge** of water is to
manage it properly to ensure a
sustainable future.

Welcome to FutureWater

FutureWater is a research and consulting organization that works
throughout the world to combine scientific research with
practical solutions for water management.

We work at both global and national levels with partners on
projects addressing water for food, water excess, water shortage,
climate change, river basin management, and irrigation.

Our key expertise lies in the areas of quantitative methods, often
based on simulation models, geographic information systems and
satellite observations.

News

[FutureWater assesses requirements for ESA satellite missions for
water resource management](#)

[NWO-Casimir grant for Monsoon research](#)

[Evaluation of usability of rainradar for waterboard Rivierenland](#)

[Further extension China activities](#)

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Methods

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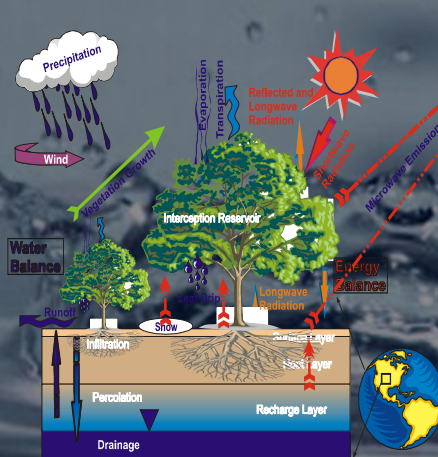
Introduction



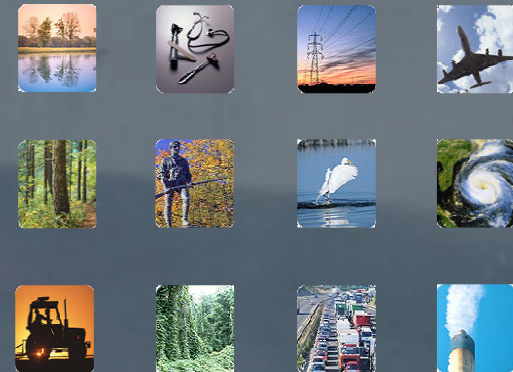
Remote sensing



Hydrological modelling



Applications

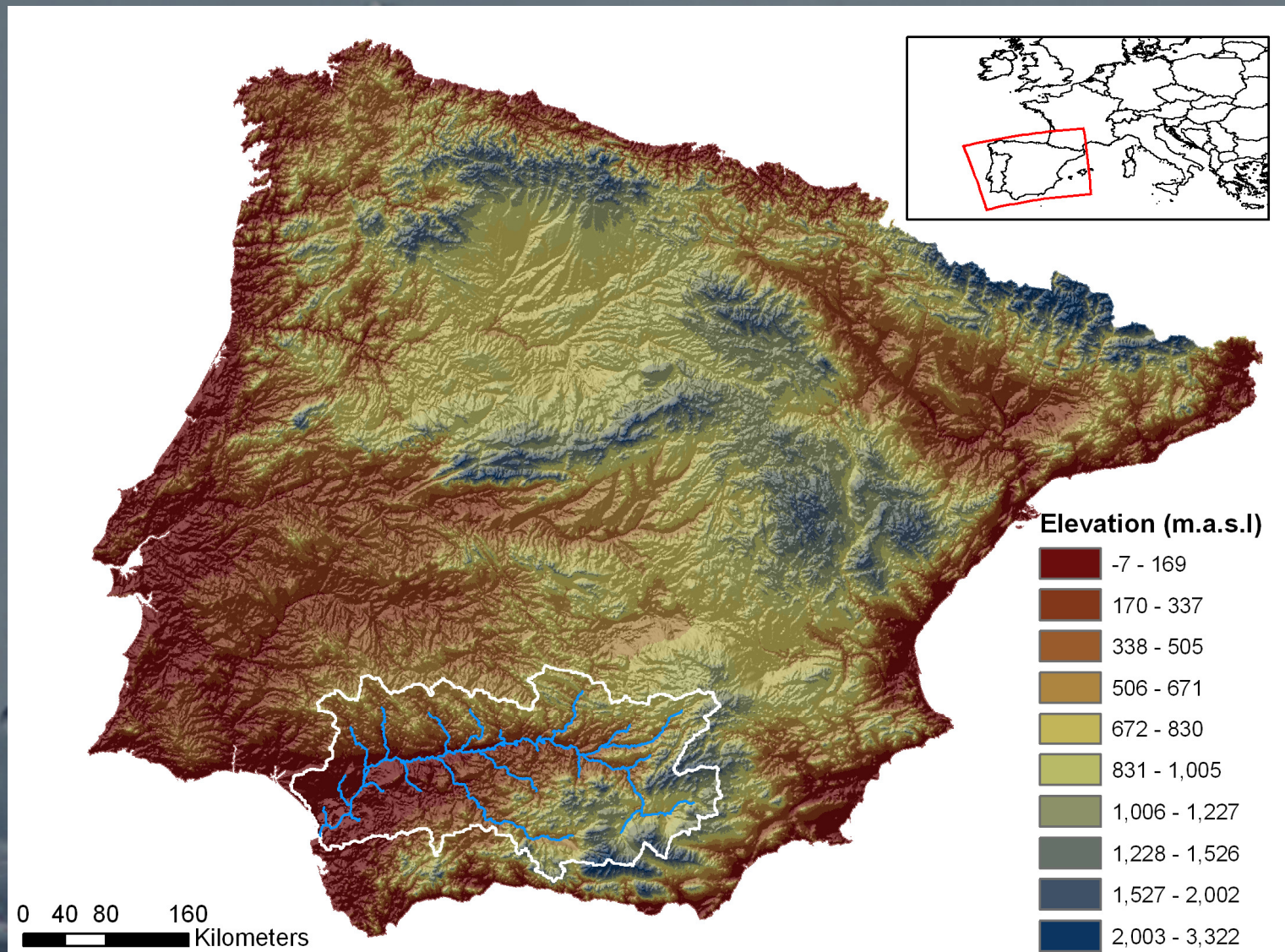


Remotely sensed ET and model calibration

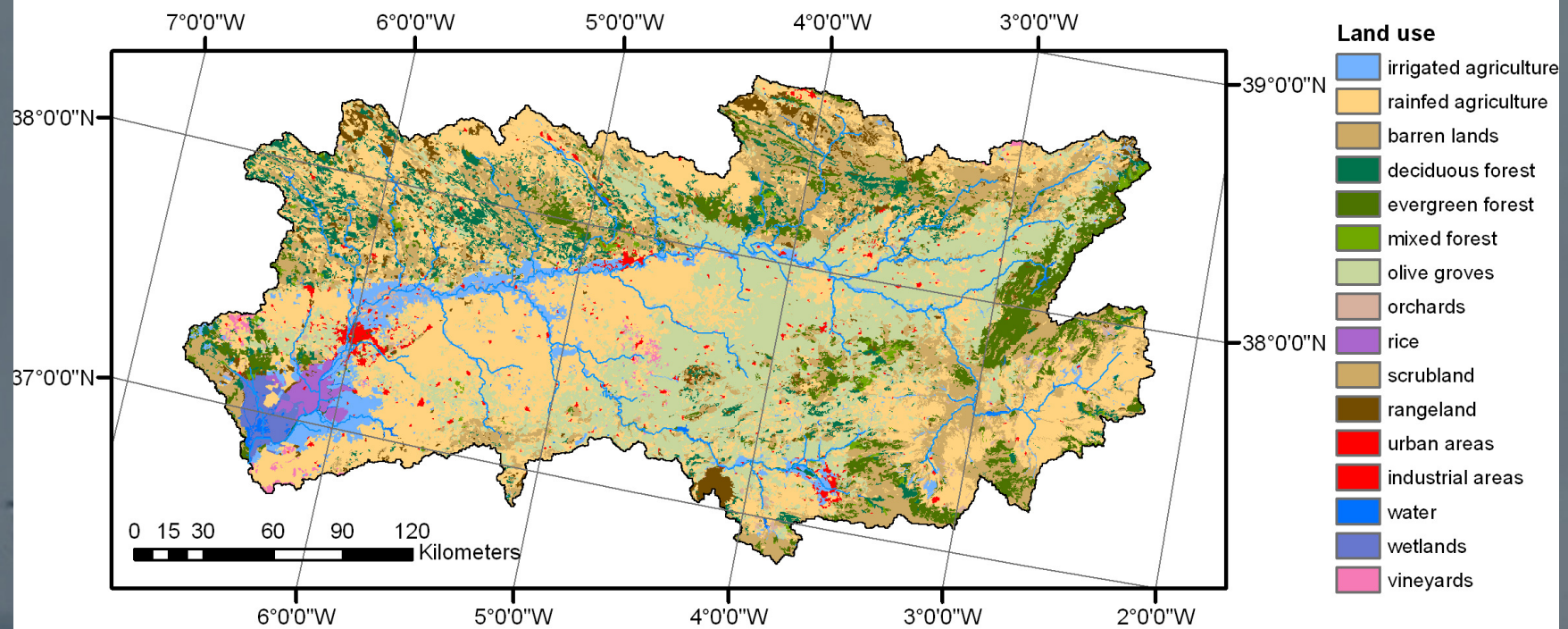


- Problem:
 - Poor data availability in many countries
 - Absence of natural flow
 - Equifinality
 - Basin water balance vs. local water balance
- Scale and field of application
 - Medium to large scale river basins
 - Semi-arid and heterogeneous land use
 - Regulated basins
- Clients:
 - World Bank
 - River basin authorities
- Applications:
 - Hai basin in China
 - Rio Bravo basin in Mexico
 - Krishna basin in India
 - Guadalquivir basin in Spain

Remotely sensed ET and model calibration



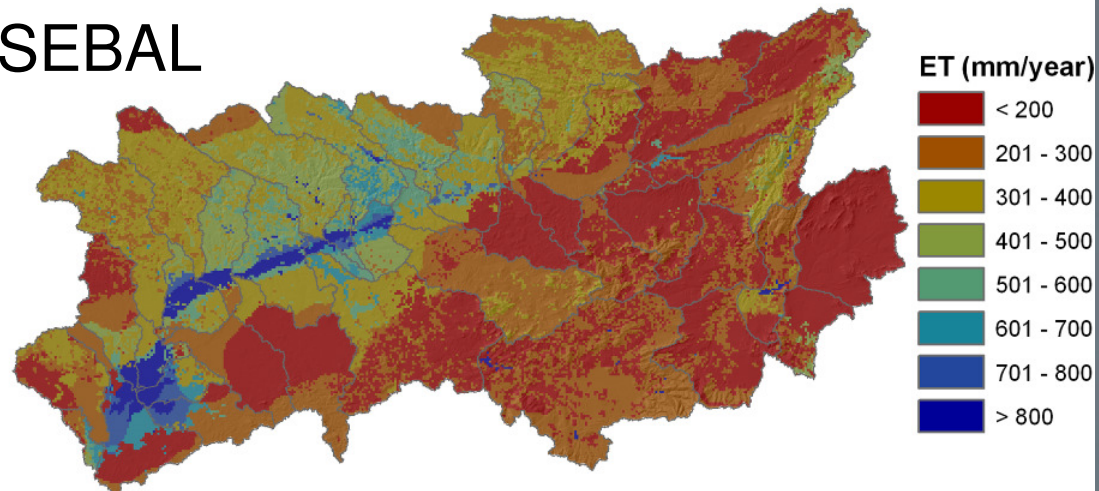
Remotely sensed ET and model calibration



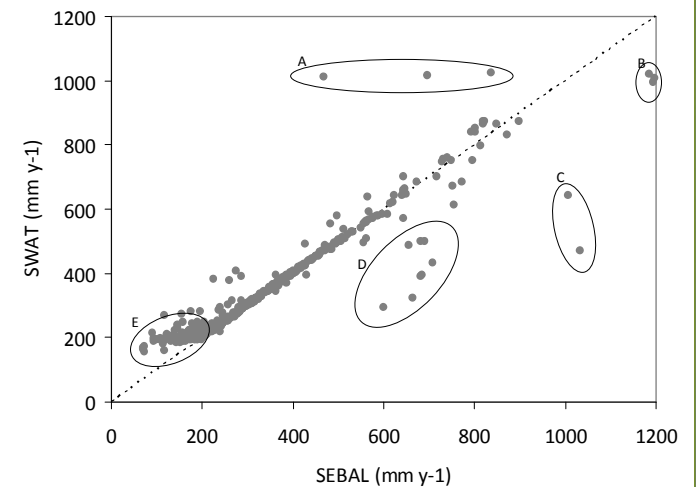
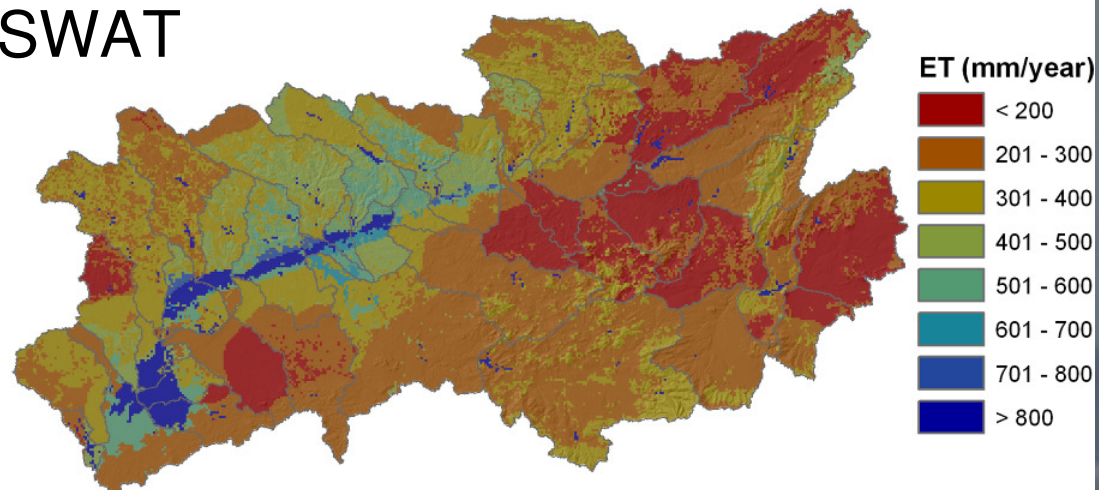
Remotely sensed ET and model calibration



SEBAL



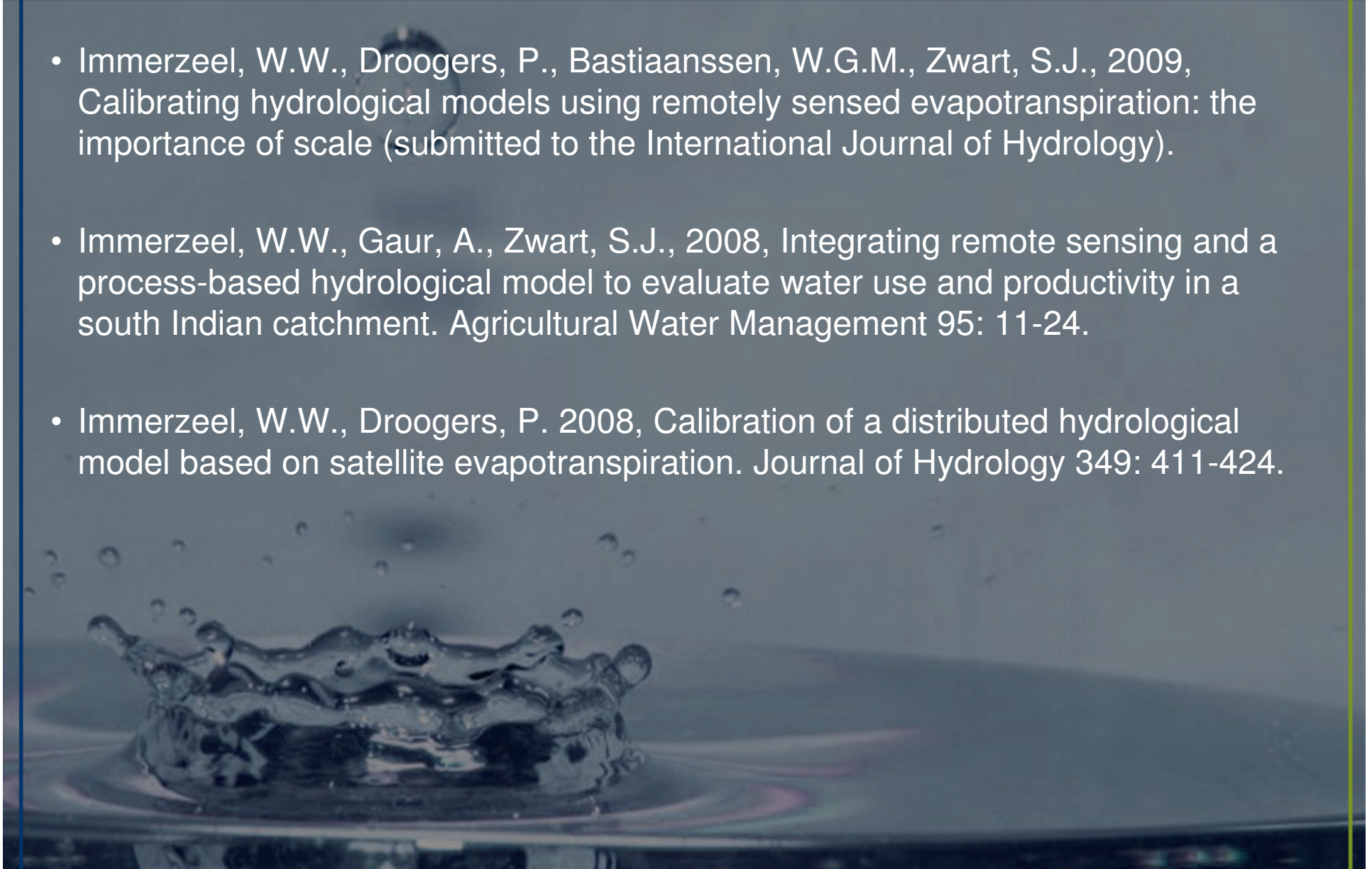
SWAT



Remotely sensed ET and model calibration



- Immerzeel, W.W., Droogers, P., Bastiaanssen, W.G.M., Zwart, S.J., 2009, Calibrating hydrological models using remotely sensed evapotranspiration: the importance of scale (submitted to the International Journal of Hydrology).
- Immerzeel, W.W., Gaur, A., Zwart, S.J., 2008, Integrating remote sensing and a process-based hydrological model to evaluate water use and productivity in a south Indian catchment. Agricultural Water Management 95: 11-24.
- Immerzeel, W.W., Droogers, P. 2008, Calibration of a distributed hydrological model based on satellite evapotranspiration. Journal of Hydrology 349: 411-424.



GRACE to assess changes in terrestrial water storage



- Problem:
 - Large scale groundwater information lacking
- Scale and field of application
 - Large scale river basins
- Clients:
 - World Bank
 - River basin authorities
- Applications:
 - GMEP project China
 - World Bank project Saudi Arabia



Groundwater Management Exploration Package

[Conference](#) [Background](#) [GMEP-tools](#) [Yellow River Basin](#) [Shiyang River Basin](#) [Publications](#) [Links](#) [Contact](#)

GMEP Northern China

The GMEP-project will demonstrate that advanced observations and planning tools can assist decision makers. The package will be demonstrated for two river basins:

- The large Yellow River Basin
- The relatively small Shiyang River Basin

GMEP is based on:

- Satellite Monitoring by GRACE
- Water Allocation by WEAP

NEW: The [GMEP Google Maps Tool](#) for monitoring and a planning in the Yellow River Basin.

State of the Art Report from February 2008 can be downloaded [here](#). A draft-version of the scenario analyses report can be downloaded [here](#).

Conference

FutureWater has successfully organised a conference on "Advanced tools in water resources management" from May 26 to May 27, 2008. Further details and the conference proceedings can be found [here](#).

GMEP

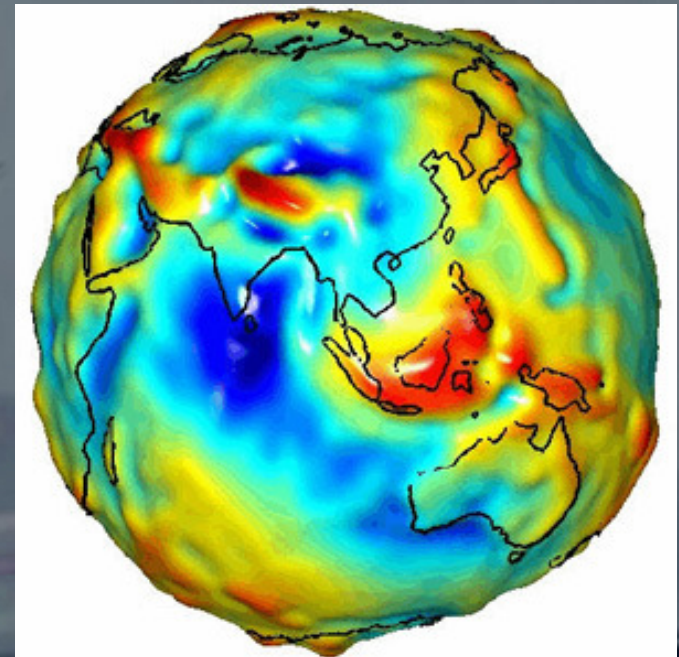
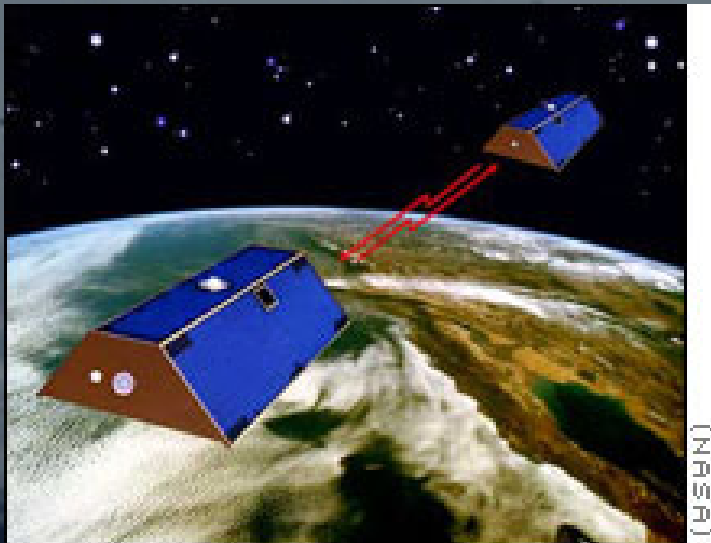
- [Conference](#)
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- ▶ [Shiyang River Basin](#)
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www.futurewater.nl/gmep

Satellite observations: groundwater (GRACE)



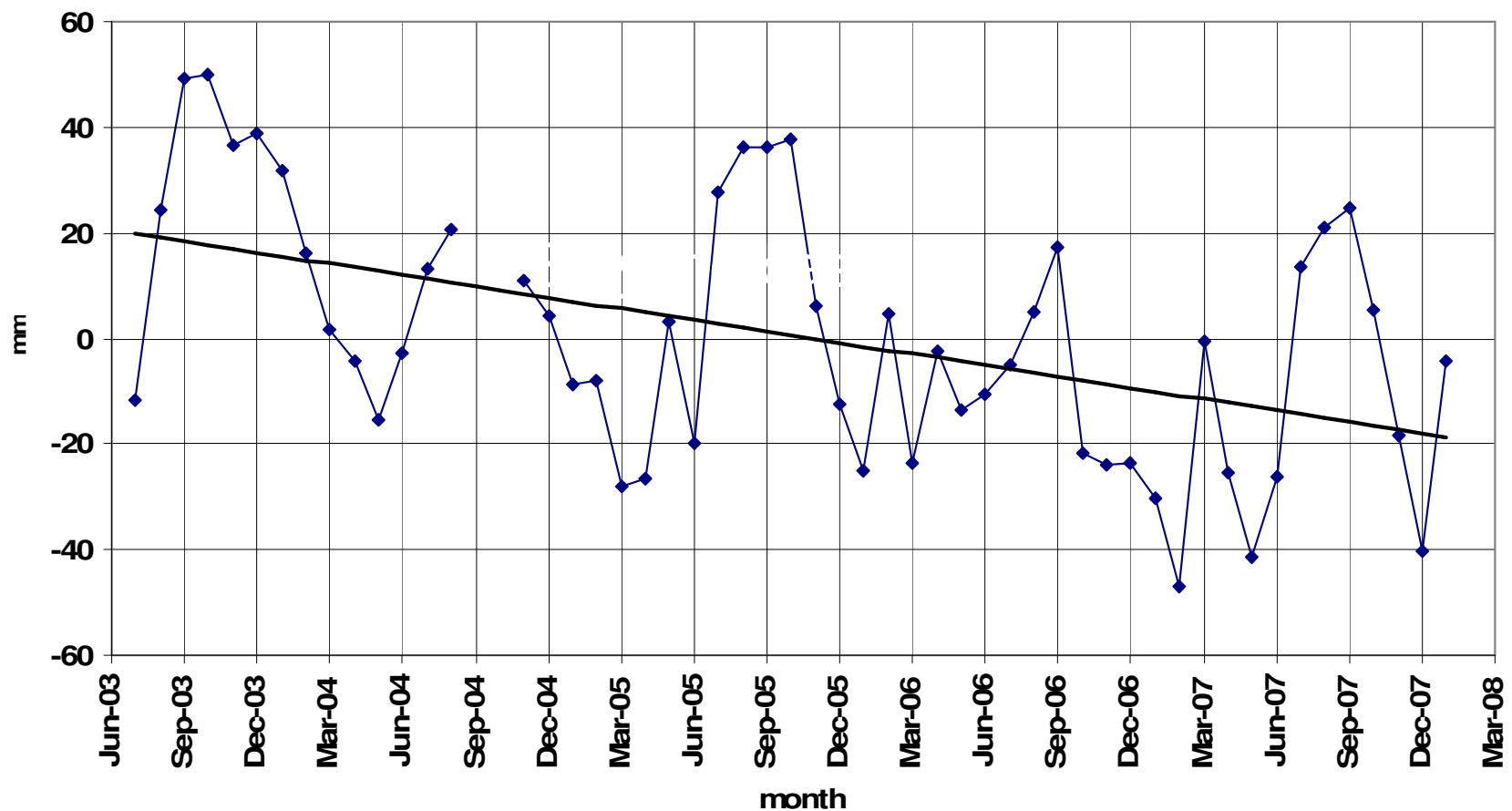
- GRACE: Gravity Recovery and Climate Experiment
 - NASA satellite
 - Two satellites, co-orbiting at 300-500 km altitude
 - Separated along track by 220 km
 - Launched March 2002



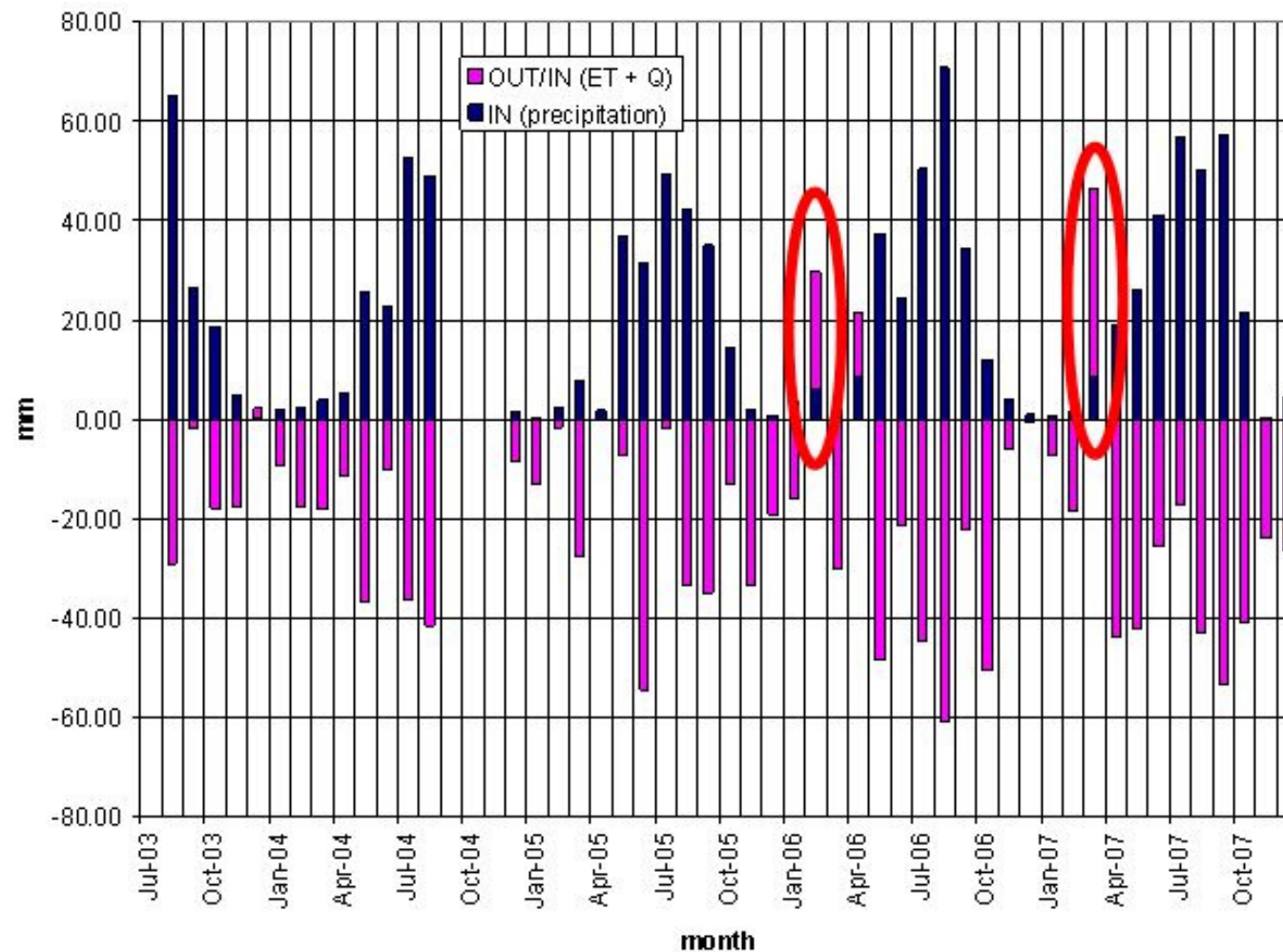
Shiyang River Basin: GRACE results



Storage change with respect to the long term average

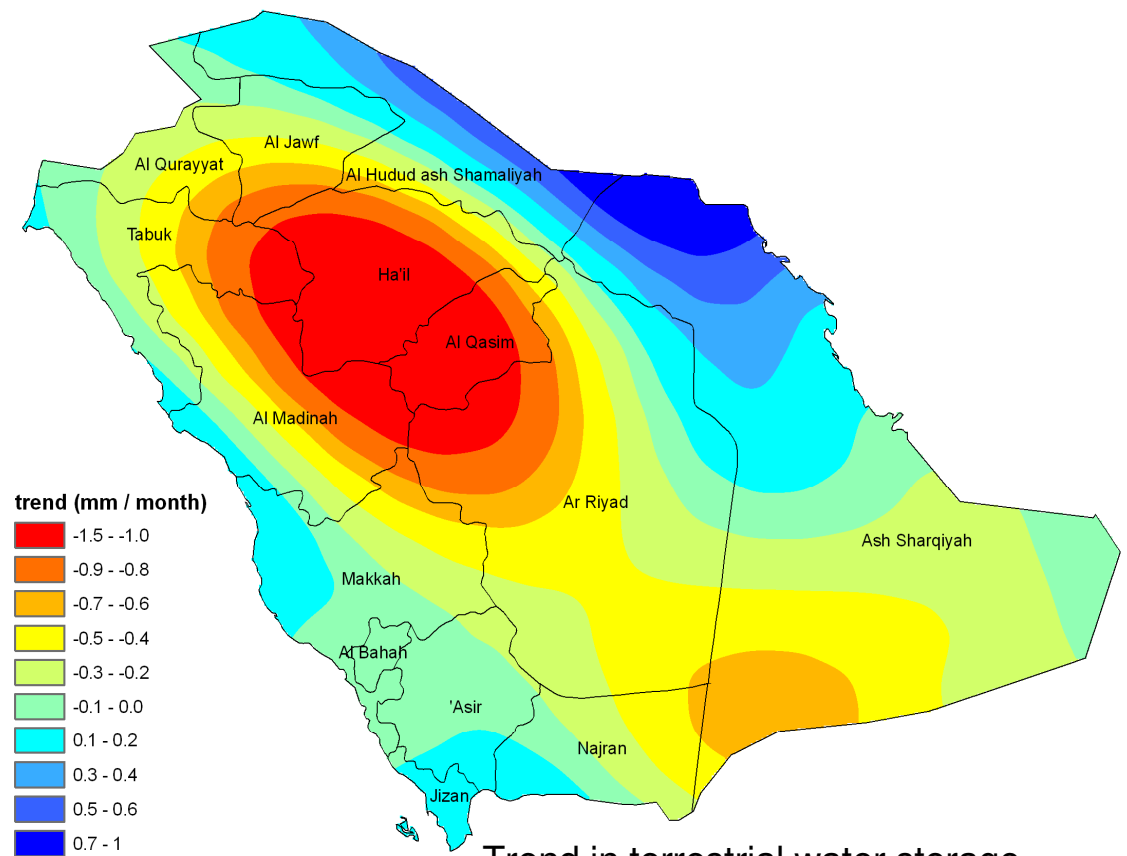
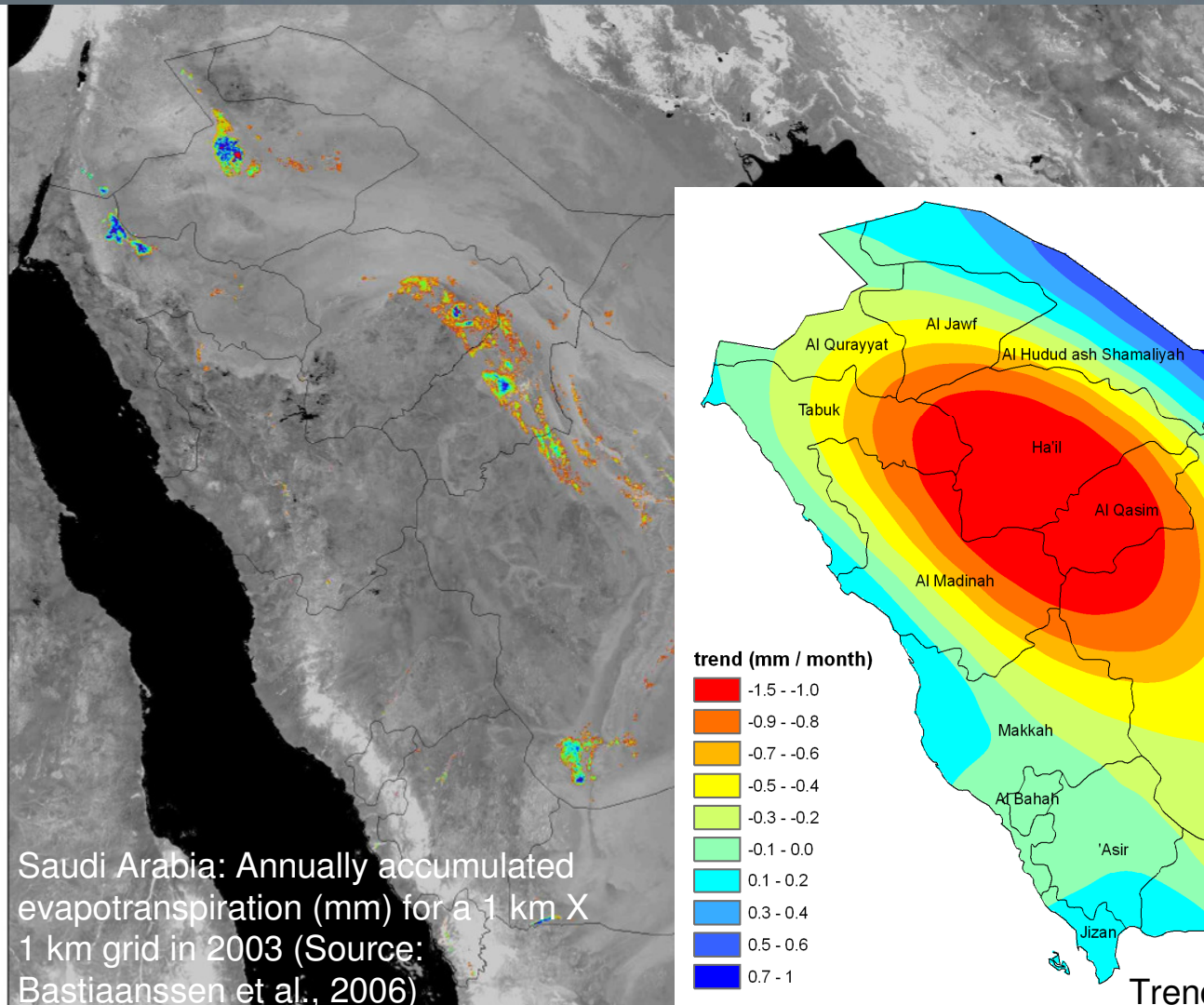


Shiyang River Basin: GRACE results



Source: Brian Gunter (TU Delft)

Saudi Arabia



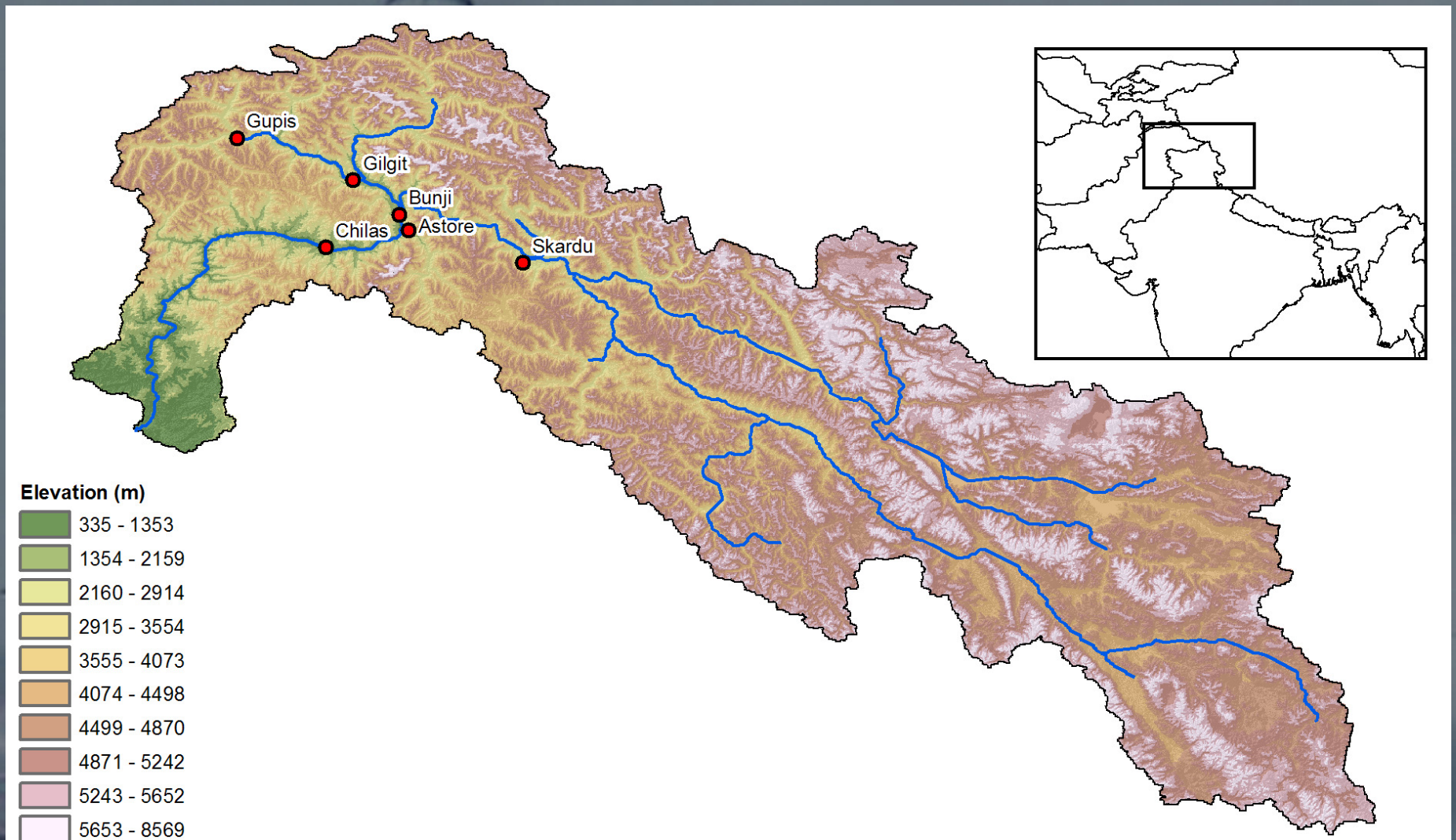
Trend in terrestrial water storage (2003-2008) based on GRACE data (based on 100 x 100 km²).

Remote sensing and snow melt runoff modelling



- Problem:
 - Mountains are black boxes
- Scale and field of application
 - Medium to large scale river basins
- Clients:
 - NWO
 - EU FP7
 - ICIMOD
 - River basin authorities
- Applications:
 - CASIMIR
 - CEOP-AEGIS

Study area





Datasets



MODIS 8-day snow cover at 0.05° resolution (MOD10C2 product)

- Normalized Difference Snow Index:

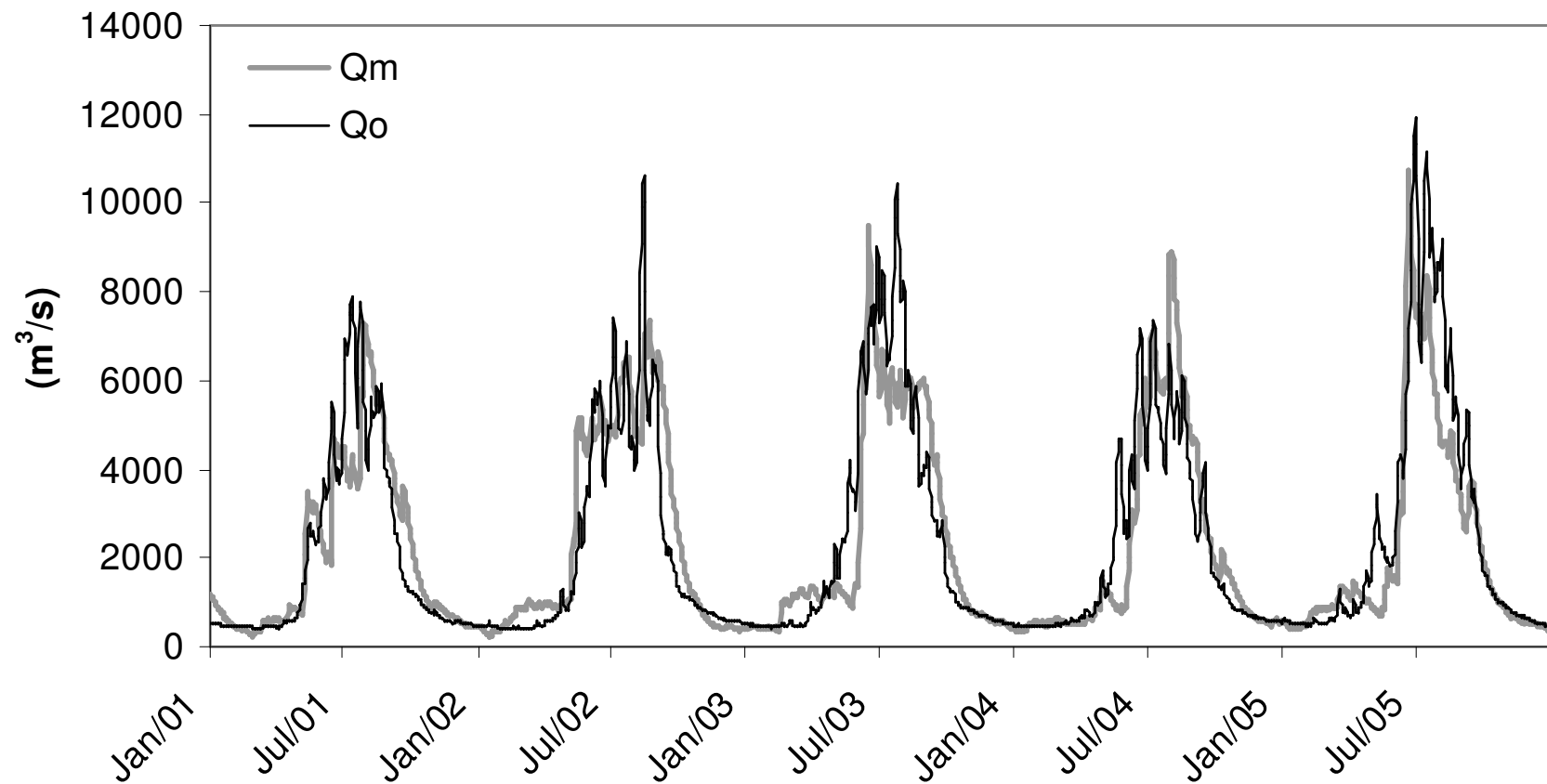
$$\text{NDSI} = (\text{GREEN} - \text{NIR}) / (\text{GREEN} + \text{NIR})$$

Green = 0.545–0.565 μm

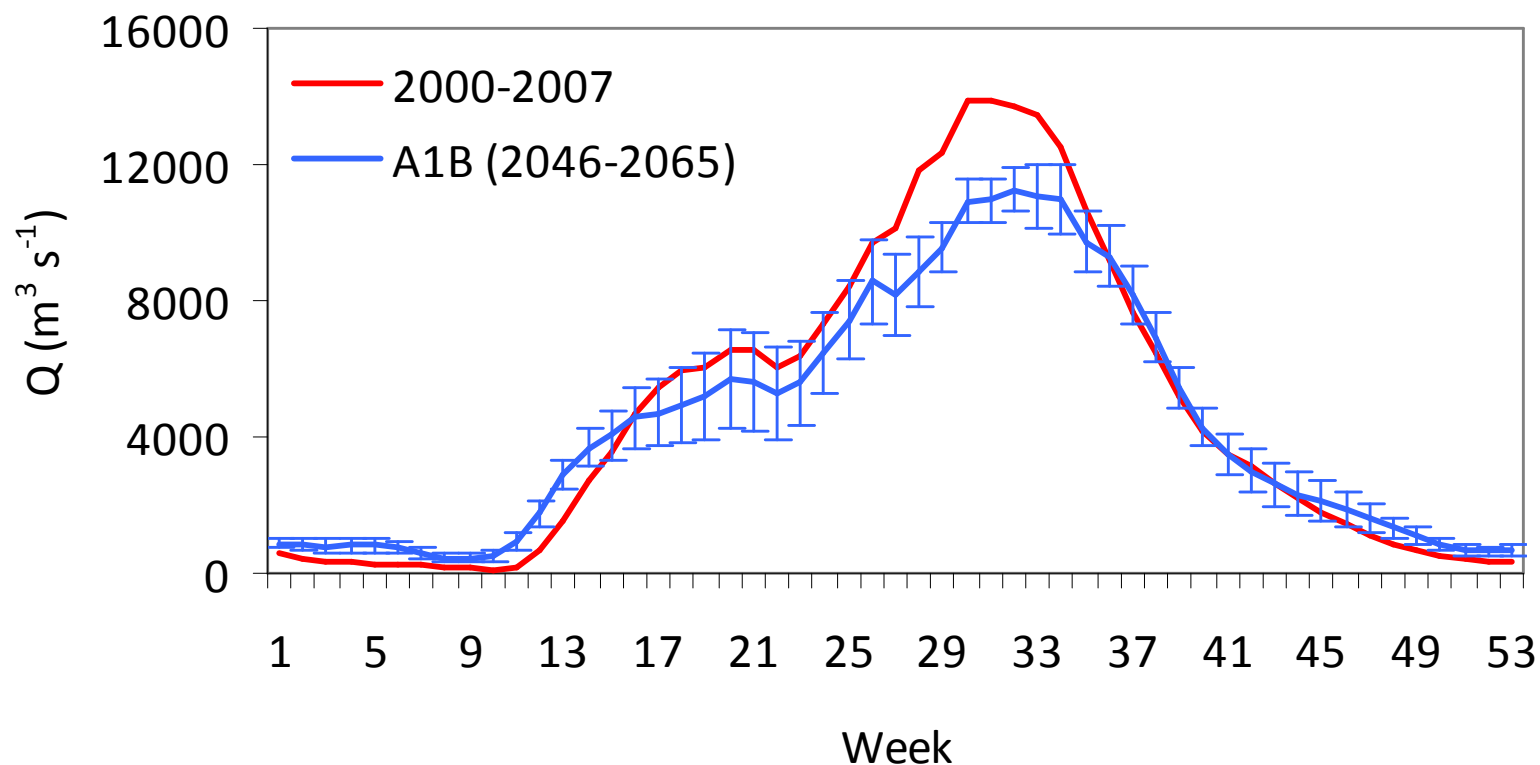
NIR = 1.628–1.652 μm

- TRMM precipitation
 - 3B43 monthly blended multi-satellite and gauge corrected precipitation estimates at 0.25° resolution
- Daily precipitation and temperature data from 6 different stations

Snowmelt Runoff Model



Snowmelt Runoff Model



Immerzeel, W.W., Droogers, P., de Jong, S.M., Bierkens, M.F.P., 2009, Large-scale monitoring of snow cover and runoff simulation in Himalayan river basins using remote sensing Remote Sensing of Environment 113: 40-49.

Conclusions



- The water balance is closing!
- Unique (Dutch) expertise in the coupling between remote sensing and models has been developed over the last years!
- Further commercialize this expertise both in the national and international markets!

