MAR CHINA

GROUNDWATER RESOURCES MODELLING IN NORTH CHINA PLAIN

- MANAGED AQUIFER RECHARGE SCENARIOS

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Based on work by and collaboration with:
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OUTLINE

- MAR-CHINA PROJECT
- CASE-STUDY: NORTH CHINA PLAIN
- MODELLING FRAMEWORK
- CALIBRATION STRATEGY
- MAR SCENARIOS

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MAR-CHINA PROJECT

- Funded by DANIDA 2018-2022

- SUSTECH, Uni. Jinan, BWSTI, IWHR, GEUS, Nordiq

- The project aims at three outcomes:
  - Assess the quantitative aspects of the large-scale potential of MAR as a tool for water scarcity alleviation
  - Assess the water qualitative aspects of MAR in NCP
  - Increase the knowledge on MAR among stakeholders, practitioners and policy makers
- The aims of the object are linked to three work packages:
  - WP1: Integrated hydrological modelling of coupled surface-water and groundwater systems
  - WP2: Water quality improvements through managed aquifer recharge in the North China Plain
  - WP3: Dissemination of results

CASE STUDY: NORTH CHINA PLAIN

- Agricultural intensive
  - Irrigation: 70 % of water consumption
- High population density
  - Beijing-Tianjin-Baoding agglomeration of >35 mio ppl
- Inter-basin transfers for supply augmentation (SNWT)
- **Groundwater deficit: ~5.5 km^3/year** (1)

(1) Shen, H., Leblanc, M., Tweed, S., & Liu, W. (2015). Groundwater depletion in the Hai River Basin, China, from *in situ* and GRACE observations. *Hydrological Sciences Journal*, *60*(4), 671–687.

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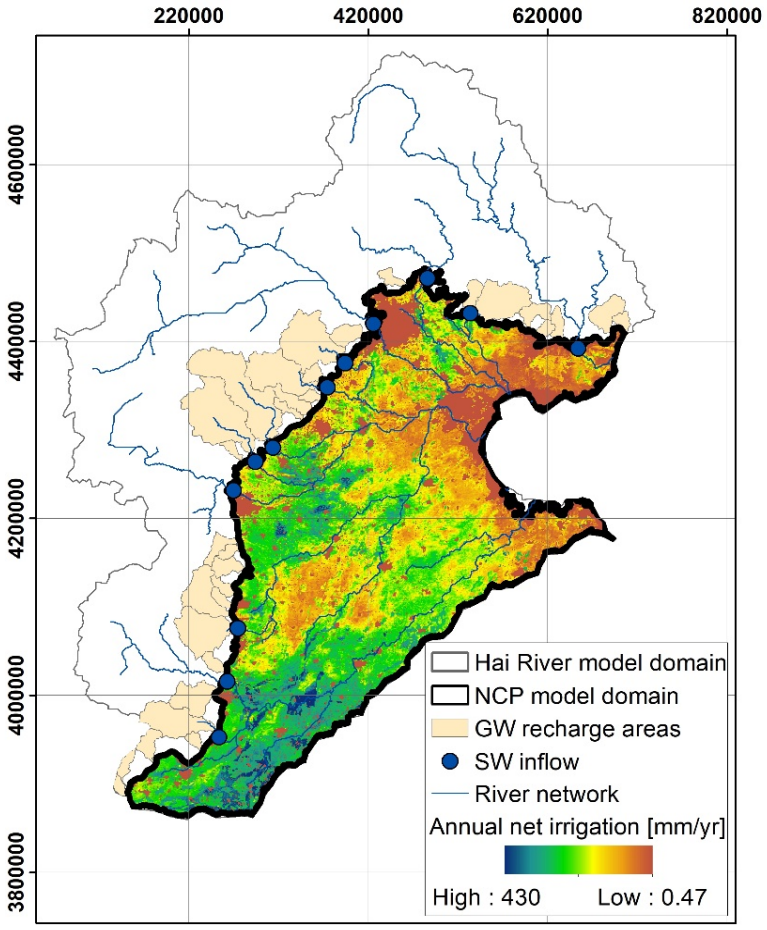
MODELLING FRAMEWORK



- For scenario analysis of large-scale MAR potential
- Based on existing groundwater models for NCP(2)
- Identified four major potentials for model improvements

1. Improved boundary condition
2. Spatially distributed quantification of Irrigation
3. Spatially distributed water demands
4. Multi-objective model calibration and uncertainty assessment

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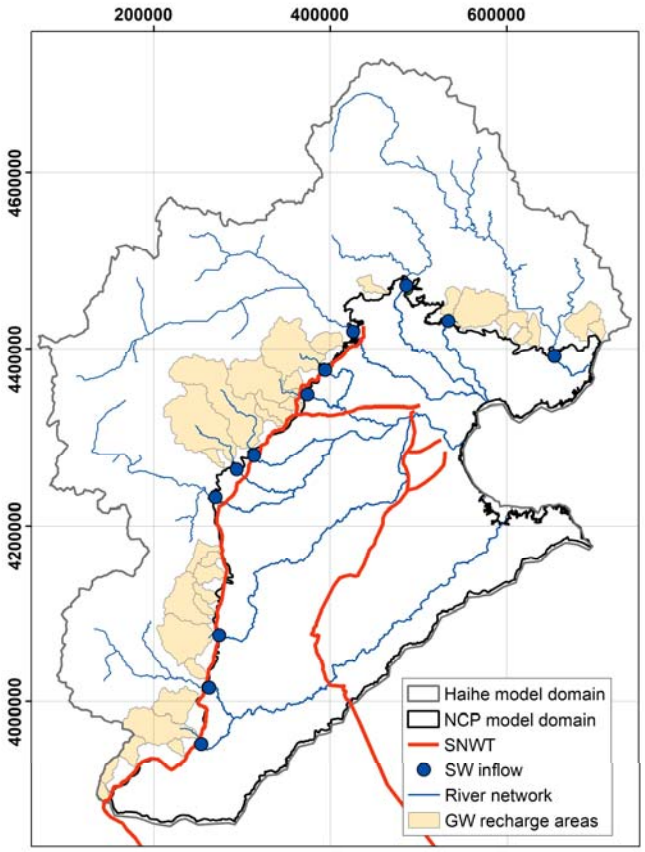
(2) Qin et al. (2019). Analysis of Water Management Scenarios Using Coupled Hydrological and System Dynamics Modeling. *Water Resources Management*, 33:4849–4863.

MODELLING FRAMEWORK



- Fully distributed MIKE SHE model for NCP and Baoding Plain
- Larger scale Haihe model[3] in mHM as boundary for
  - Lateral GW inflow
  - SW runoff into model domain
  - NSWT inflows

3) Koch J, Zhang W, Martinsen G, He X, Stisen S (2020) Estimating net irrigation across the North China Plain through dual modelling of evapotranspiration. Water Resources Research

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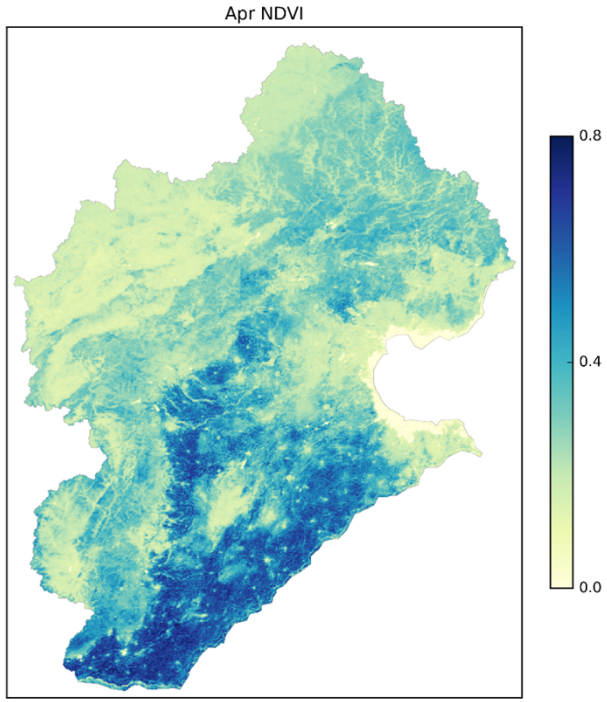
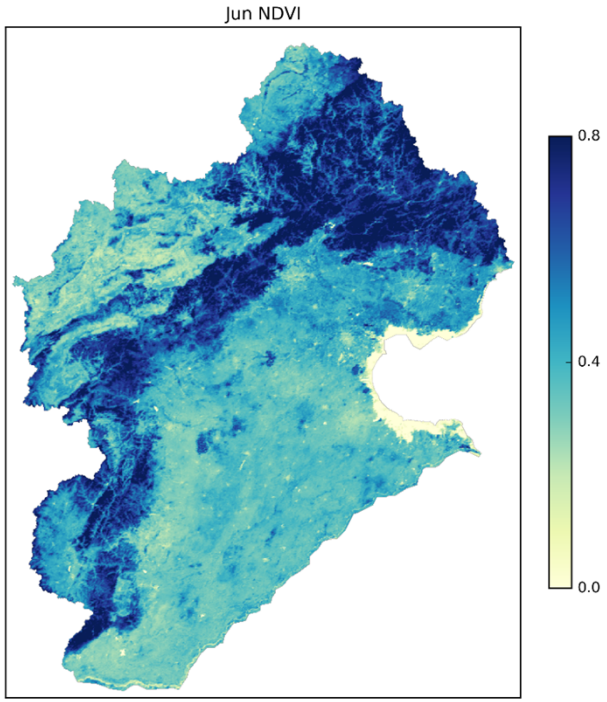
IRRIGATION QUANTIFICATION

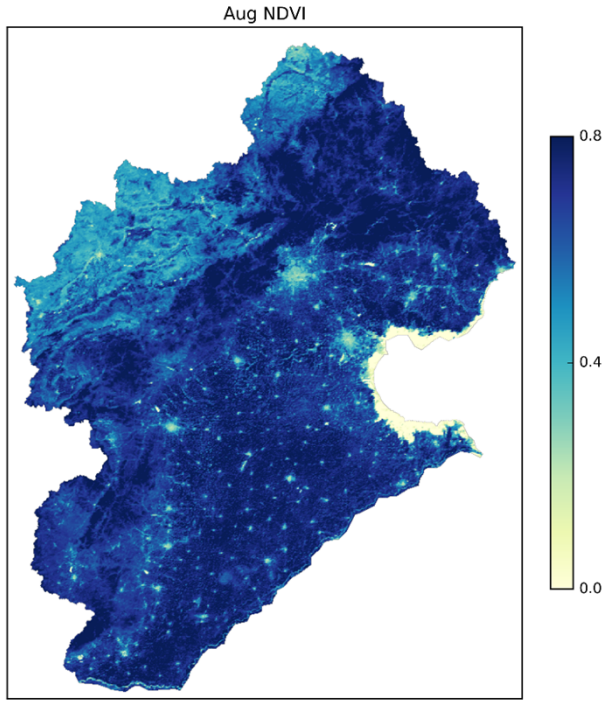
- Vegetation Pattern: normalized difference vegetation index (NDVI)
  - Haihe River Basin (320k km^2) North China Plain (140k m^2)



peak of winter wheat



winter wheat harvested



peak of summer maize

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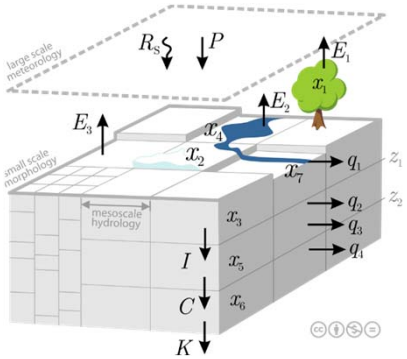
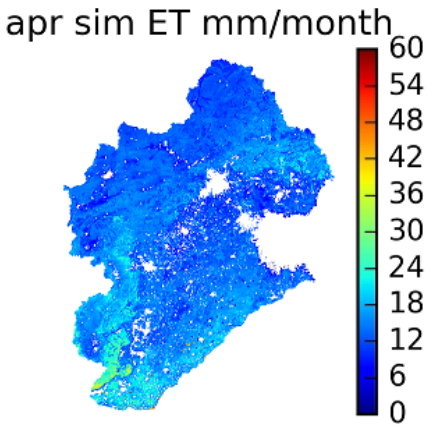
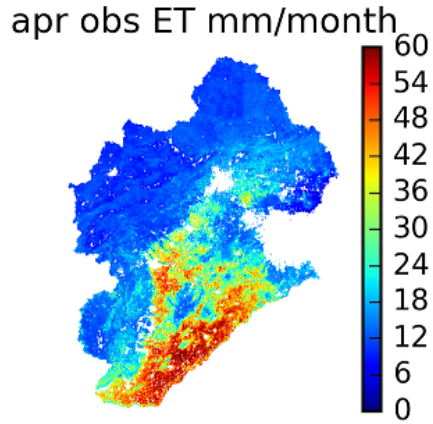
DUAL MODELLING OF EVAPOTRANSPIRATION

Hydrological Model
mHM

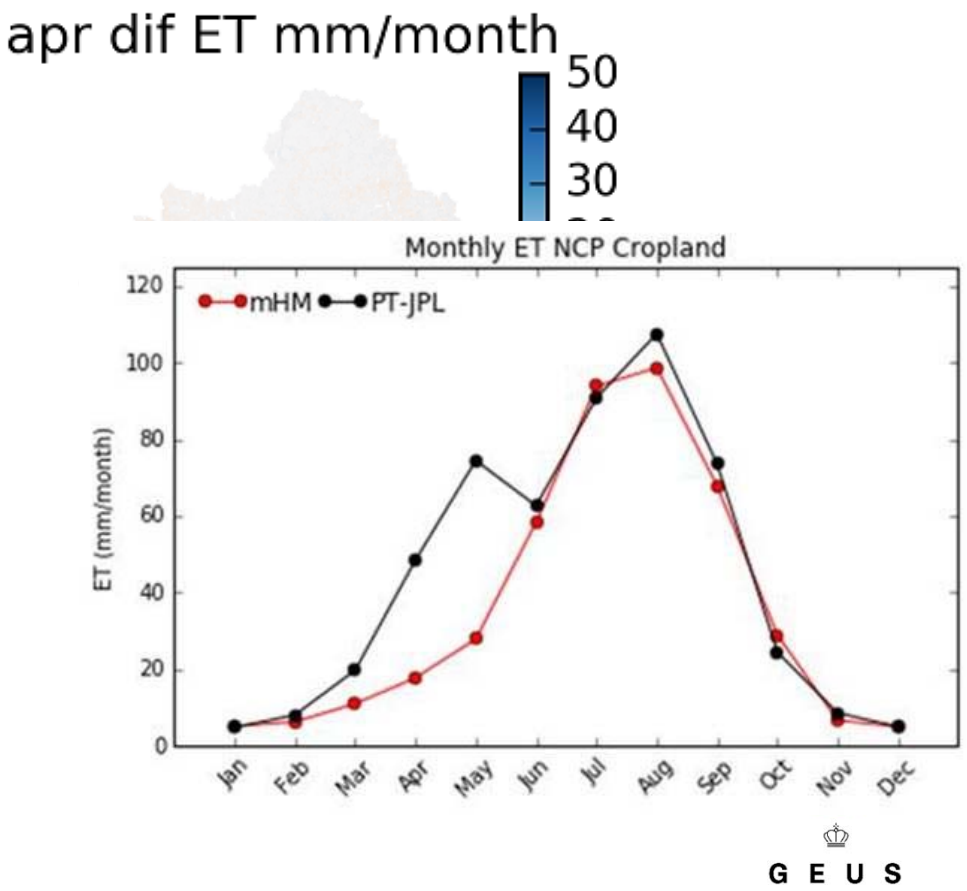


Remote sensing method
PT-JPL





Difference: Irrigation loss



Water Resources Research

RESEARCH ARTICLE
10.1029/2020WR027413

Special Section:
Advancing Process Representation in Hydrologic Models: Integrating New Concepts, Knowledge, and Data

Estimating Net Irrigation Across the North China Plain Through Dual Modeling of Evapotranspiration

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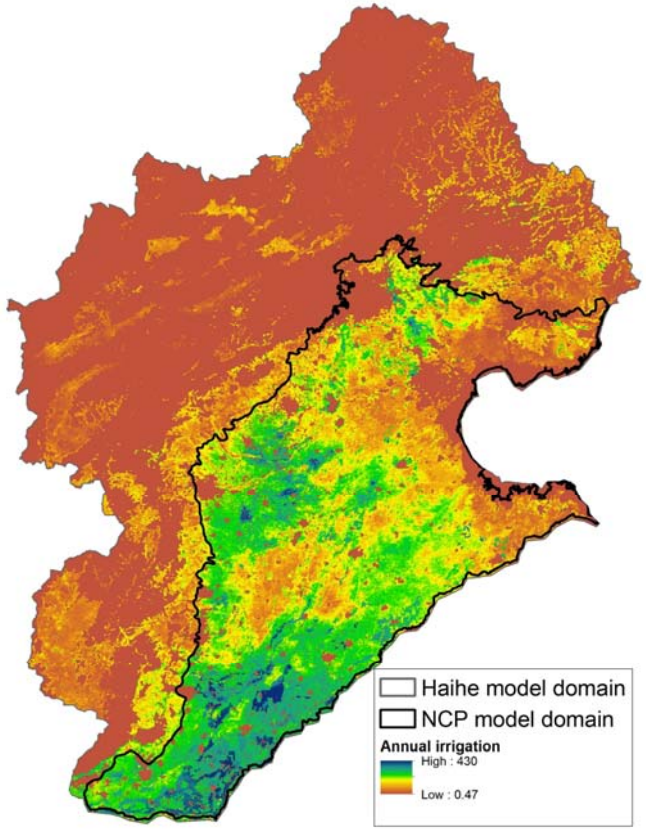
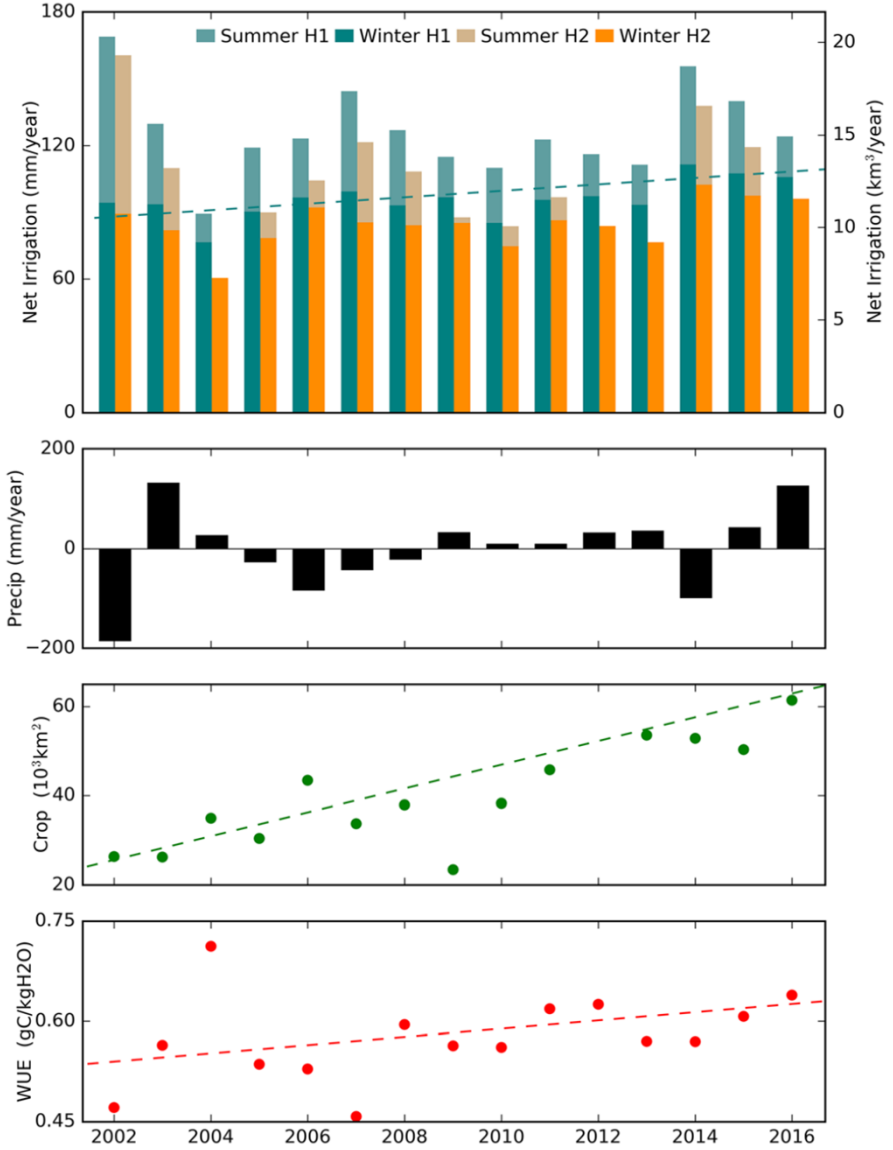
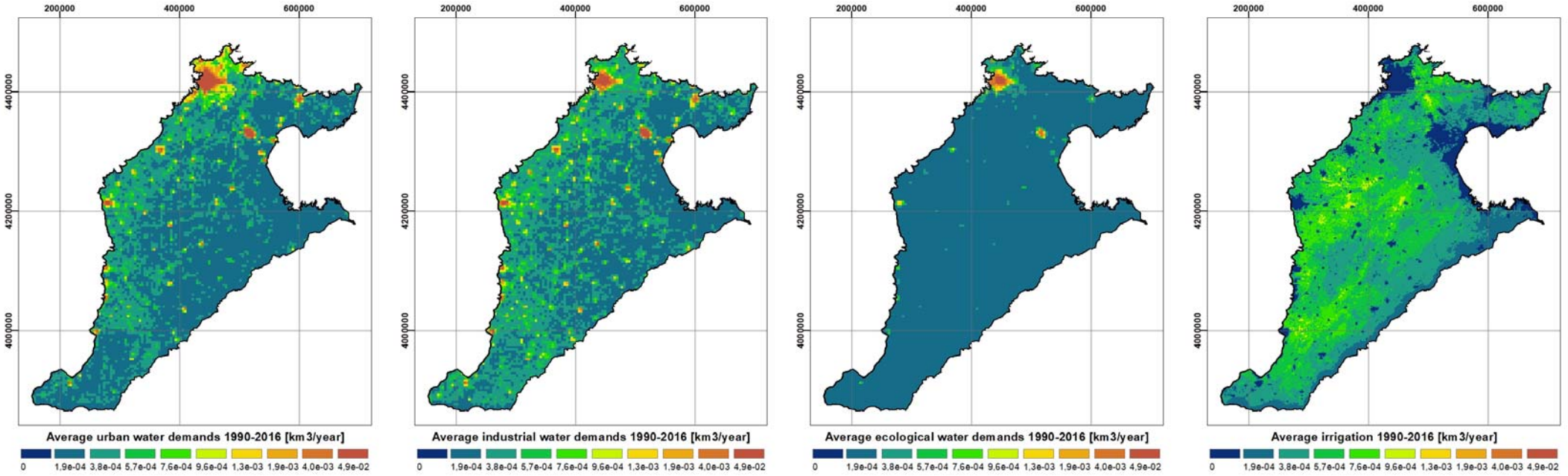
https://doi.pangaea.de/10.1594/PANGAEA.914113



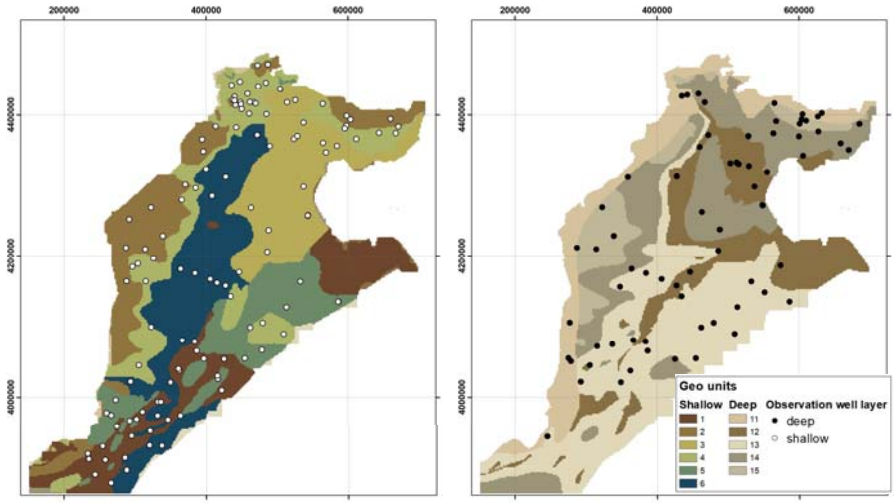


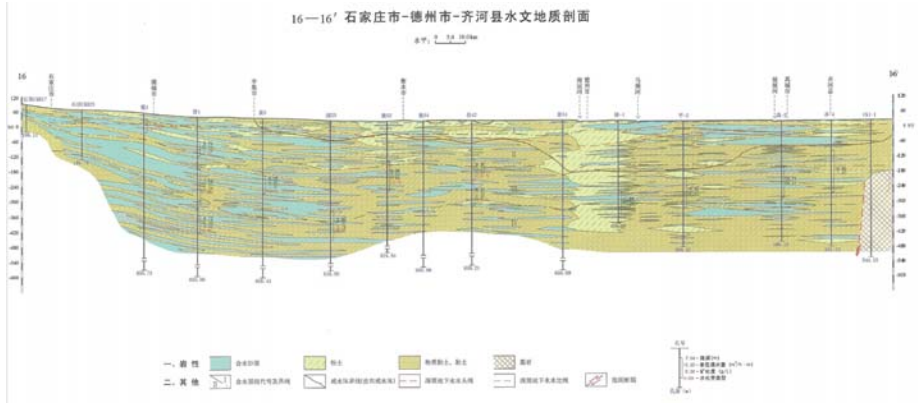
DISTRIBUTED WATER DEMANDS

- Scaled to population density
- GW pumping
  - GW supply + SW supply
- Inter-basin transfers
  - South-to-North Water Transfers: Subtracted from population density scaled estimates



GEOLOGICAL MODEL





- Geological interpretation based on China Geological Survey report
- Geology aggregated into major hydrogeological units
- Sparse groundwater level observation data
  - 620 km^2/observation well

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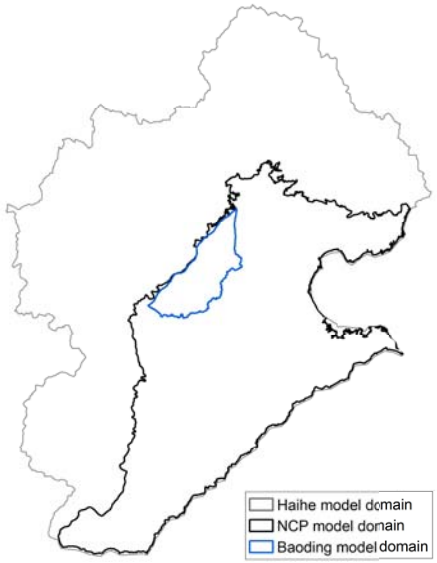
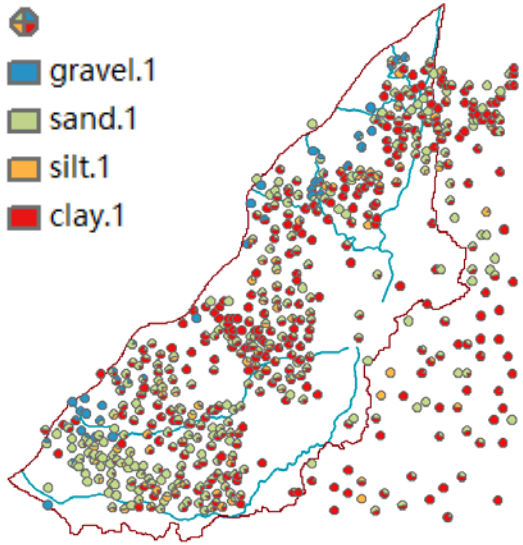
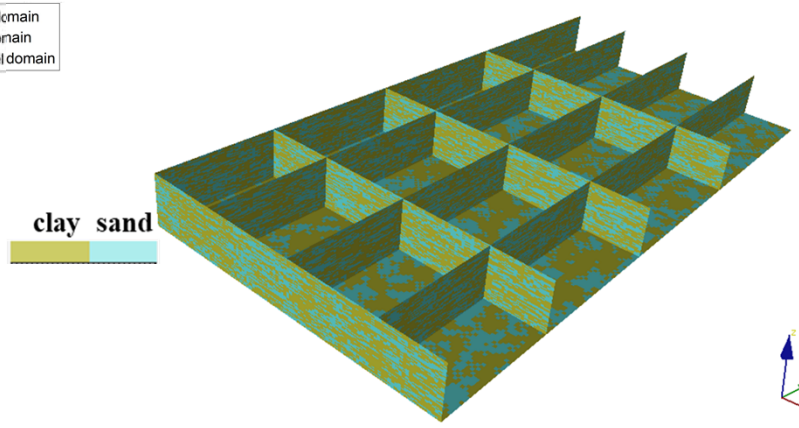
GEOLOGICAL MODEL

- Baoding Plain model
- Transition Probability Geostatistical Software (TPROGS)
- Stochastic high resolution Hydrostratigraphic model
- Denser groundwater level observation data
  - 170 km^2/observation well







CALIBRATION STRATEGY

Groundwater heads

Bias

- Squared sum of the ME in each geounit

Trend

- RMSE of trends in each geounit

Amplitude

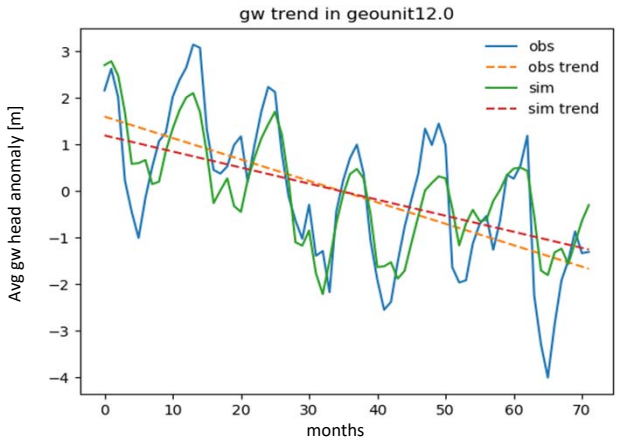
- RMSE of median amplitude differences in each geounit

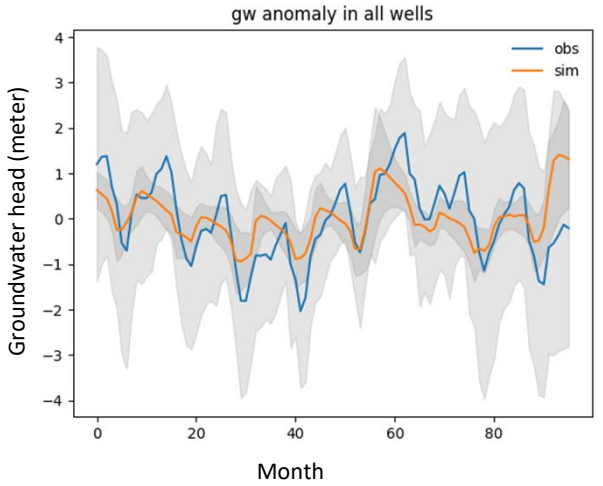
Spatial Efficiency

- SPAEF on long-term simulated and observed patterns of ET

Discharge 2Sea

- Fractions of outflow versus inflow compared to long-term average observations





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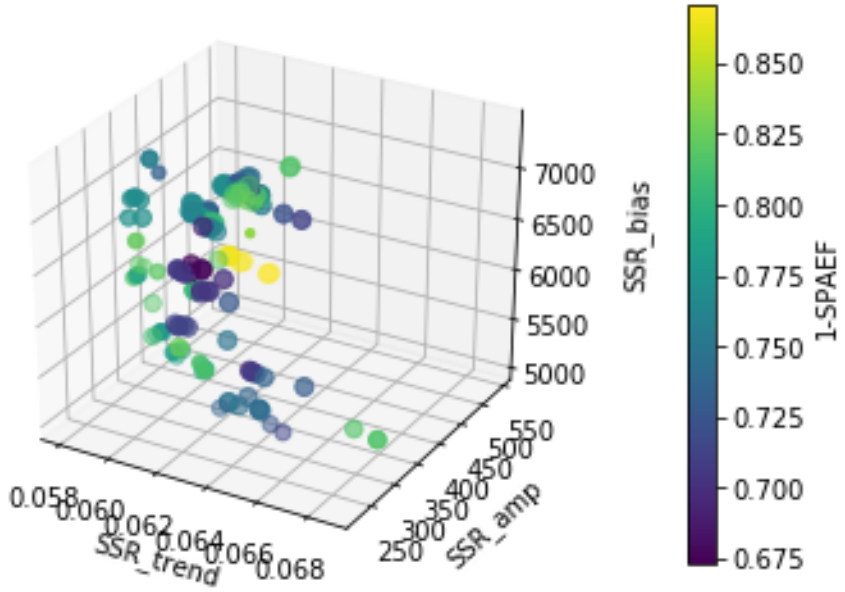
MULTI-OBJECTIVE CALIBATION

- Use of multi-objective optimization *without* the use of weights
  - PADDS Stochastic global optimization algorithm
- Facilitates an uncertainty approach to model application based on multiple parameter sets from non-dominated solutions
- Subsequent scenarios are analyzed using multiple plausible parameter sets



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SCENARIOS

Baseline

- Water management in the period 2000-2013

MAR scenario

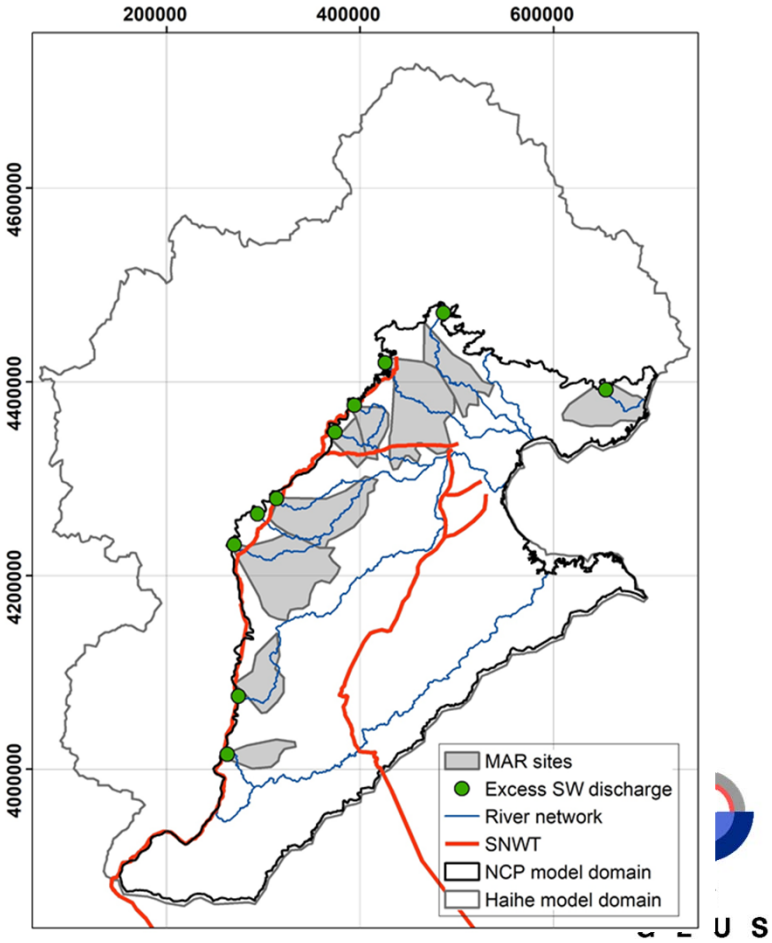
- Excess peak discharge at 10 major surface water reservoirs
- Riverbank infiltration in MAR sites

SNWT scenario

- Substitute groundwater pumping with SNWT water allocations
- Consider return flow from SNWT water use

Irrigation scenario

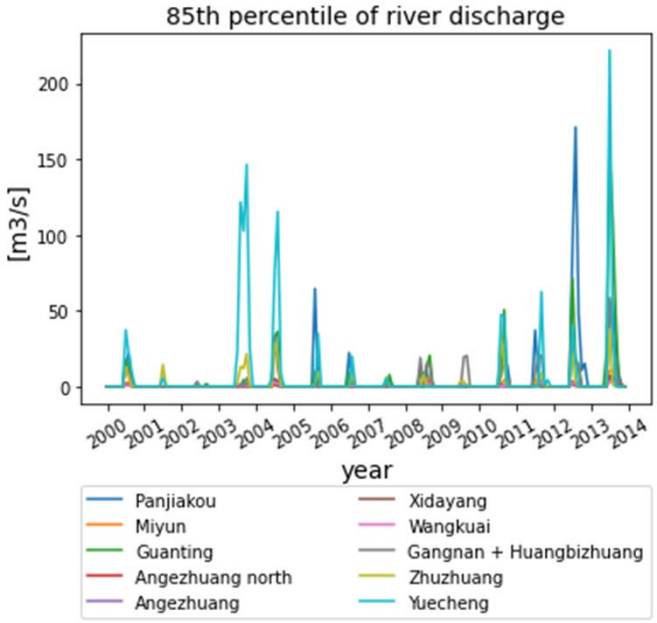
- Curtail winter wheat irrigation by 10, 20 and 30 %



SCENARIOS

MAR scenario

- Excess peak discharge at the 85 percentile
- 5, 10 and 15% of yearly peak discharge for MAR



SNWT scenario

- Full utilization of SNWT middle route allocations
  - Present utilization (anno 2017)
  - Full utilization (anno 2035)

Scenario	Water availability	
	[亿方/年]	[km³/yr]
MAR 5%	3.4	0.34
MAR 10%	6.7	0.67
MAR 15%	10	1.0
SNWT 2017 年	45	4.5
SNWT 2035 年	57	5.7

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KEY MESSAGES

- Improved water budget for the NCP groundwater flow model
- High resolution Irrigation quantification
- Scenario modelling in an uncertainty framework
- Model capable of analyzing a range of large-scale MAR and water management scenarios
- Scenario results are work in progress

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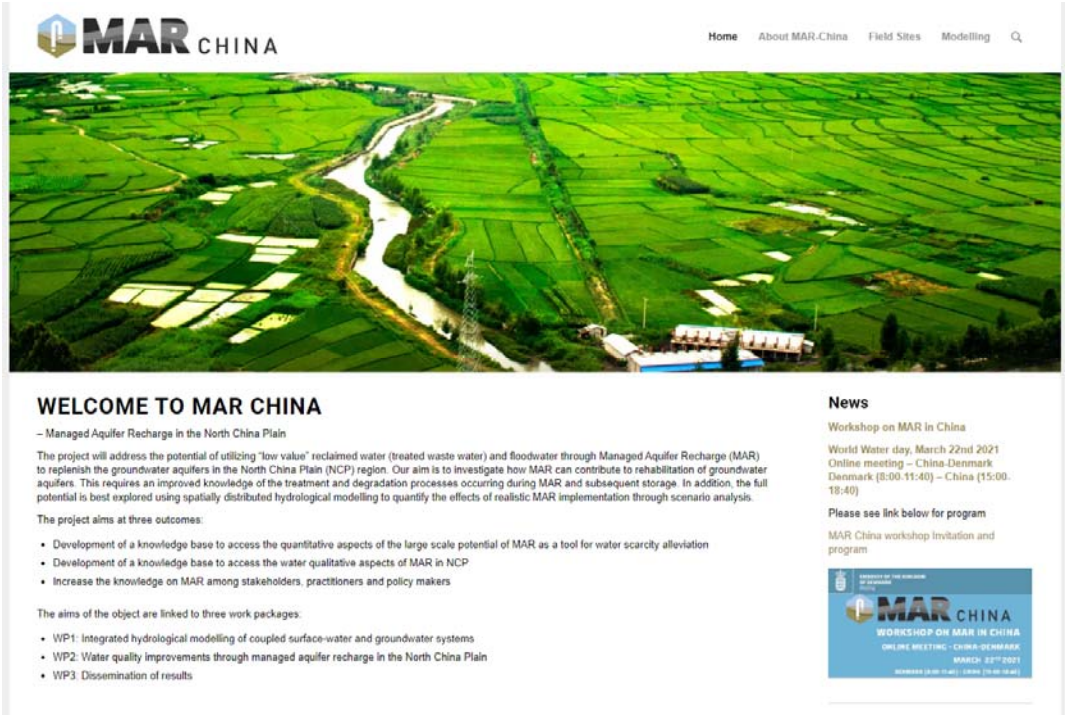
https://www.mar-china.geus.dk/



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