The 9th GEWEX OPEN SCIENCE CONFERENCE

Groundwater table depth changes driven by climate change in China

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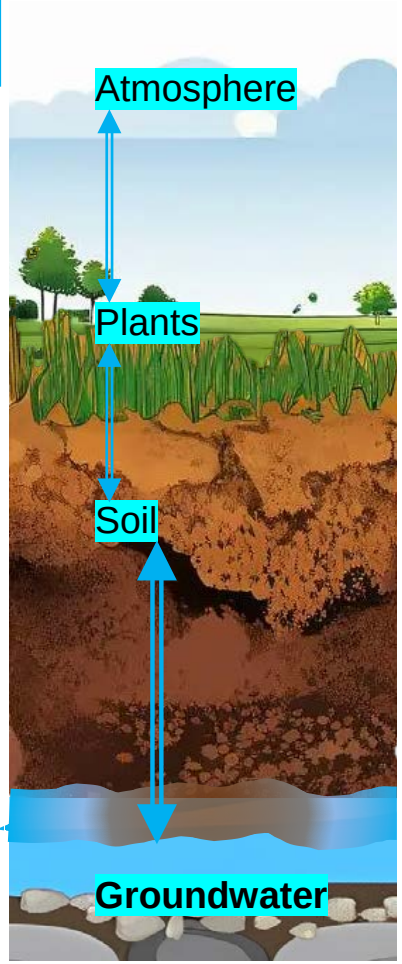
Motivation



- **Groundwater** plays an important role in regional climate and available water for agriculture，ecosystems，and our everyday lives.
- **We want to know:**
  - To what extent climate change affected groundwater during the past four decades.
  - How the groundwater changes affected land surface water and energy balances.

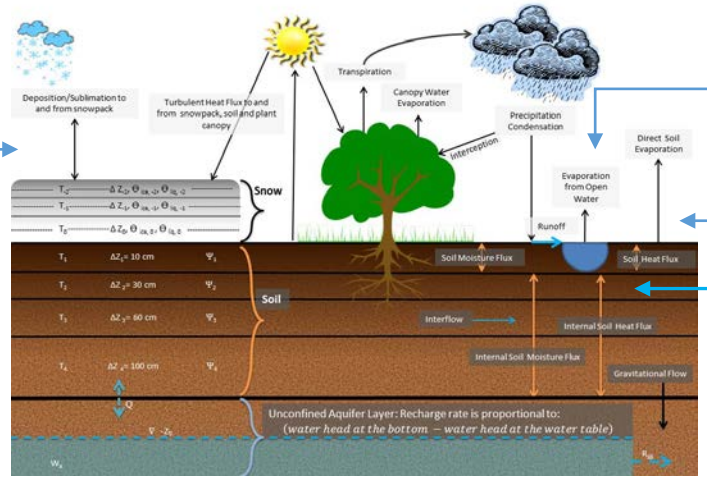
Methods: Model and Data

Off-line mode: NoahMP Land model + ERA5 forcings

Climate forcings

0.25˚×0.25˚
1 hr

Land model, **Noah-MP**



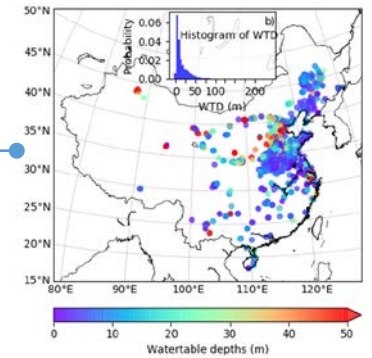
Parts of land data in China derived from:
Common Land Model
Dai, et al., 2013; 2019; Shangguan , et al., 2014; 2017

Groundwater-related processes:

8 representations.
free drainage- lateral flow

Test

Observed water levels



Land surface model, Noah-MP

Groundwater-related processes:

8 representations. From free drainage to lateral flow

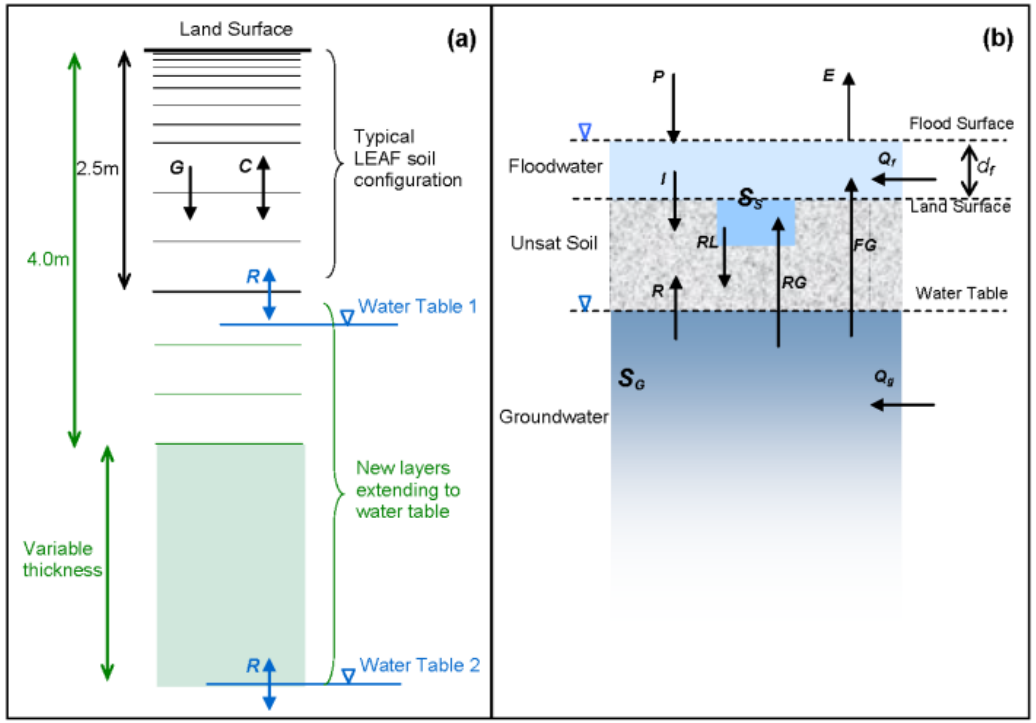
Eight parameterizations for runoff- and groundwater-related terrestrial water balances:

1. TOPMODEL with groundwater (**SIMGM**, Niu et al. 2007)
2. TOPMODEL with an equilibrium water table (**SIMTOP,** Niu et al. 2005)
3. Original surface and subsurface runoff (**free drainage**)
4. BATS surface and subsurface runoff (**free drainage**)
5. **Miguez-Macho&Fan groundwater scheme (LEAF-Hydro, Miguez-Macho et al. 2007 Fan et al. 2007)**

6. Variable Infiltration Capacity Model surface runoff scheme (Wood et al., 1992, JGR)
7. Xiananjiang Infiltration and surface runoff scheme ((Jayawardena and Zhou, 2000)
8. Dynamic VIC surface runoff scheme (Liang and Xie, 2001)

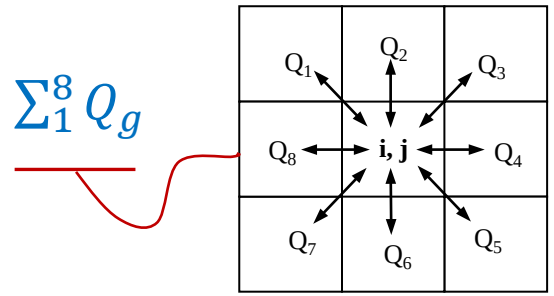
Land surface model, Noah-MP

5. LEAF-Hydro groundwater scheme has a representation of lateral water flow



Water balance processes:

$$\frac{dS_G}{dt} = \Delta x \Delta y(-R - FG) - RG + \sum_1^8 Q_g$$



$\boldsymbol{S_G}$ groundwater storage,

$\boldsymbol{R}$ soil-aquifer water exchanges,

$\boldsymbol{FG}$ flooding area-aquifer water exchanges (not included in this study),

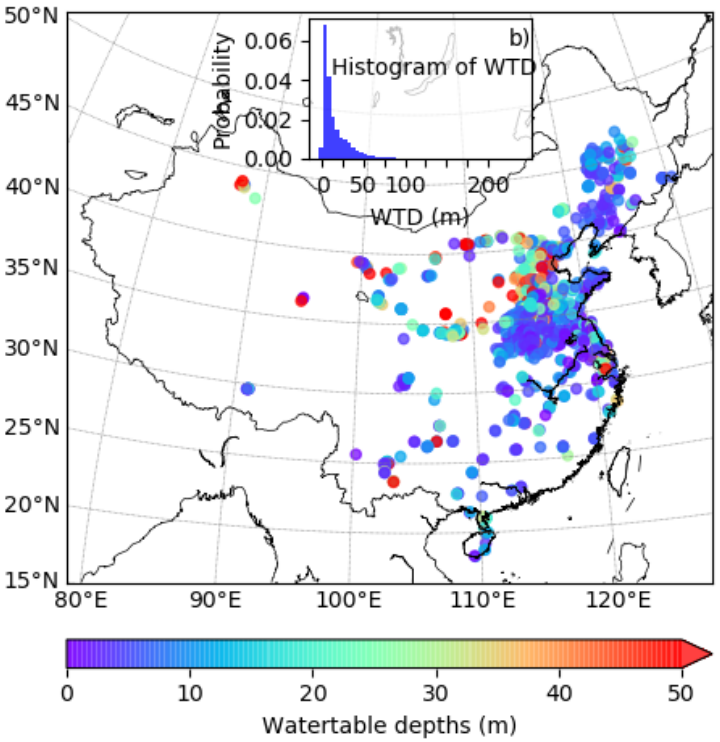
$\boldsymbol{RG}$ river channel-aquifer water exchanges,

$\boldsymbol{Q_g}$ inter-grid water flow。

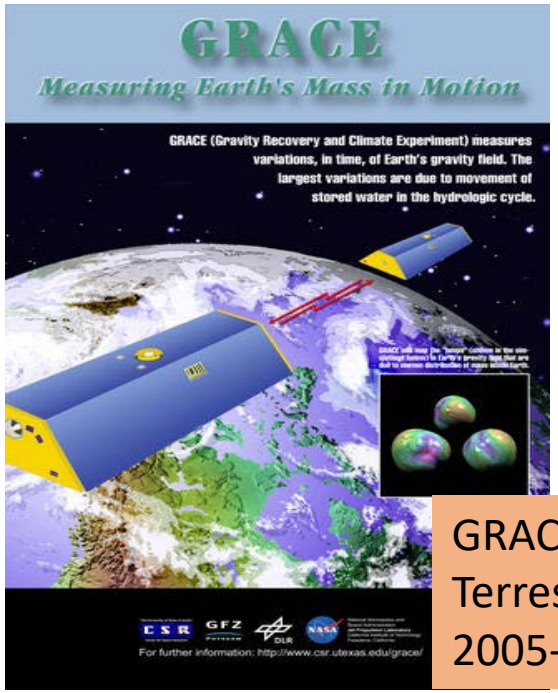
Fan et al. 2007; Miguez-Macho and Fan 2012

Observational data for validation

Groundwater table depths measured in wells across China from 2005-2016



980 wells monthly 2005-2016

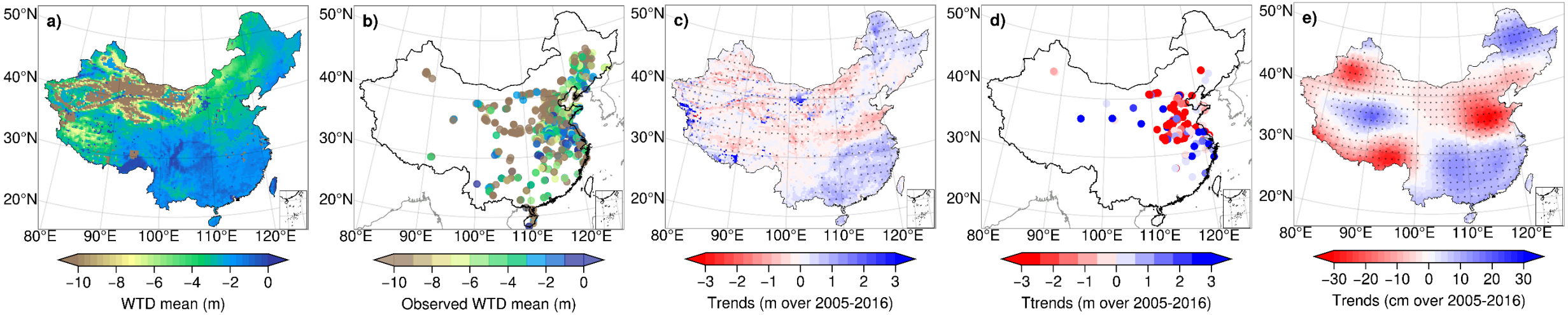


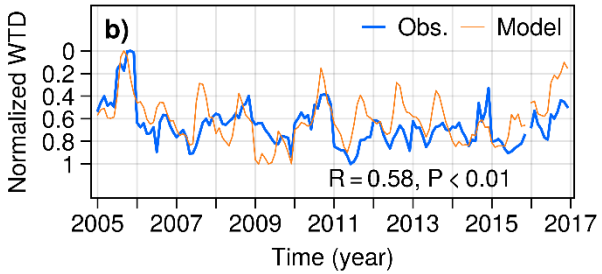
GRACE TWS from UT-CSR Terrestrial water storage 2005-2016 used

Noah-MP WTD compared to observations

Model water table depth (WTD) compared to observations from 2005-2016

Noah-MP WTD | **Observed WTD** | **Linear trends** | **Observed trends** | **GRACE trends**

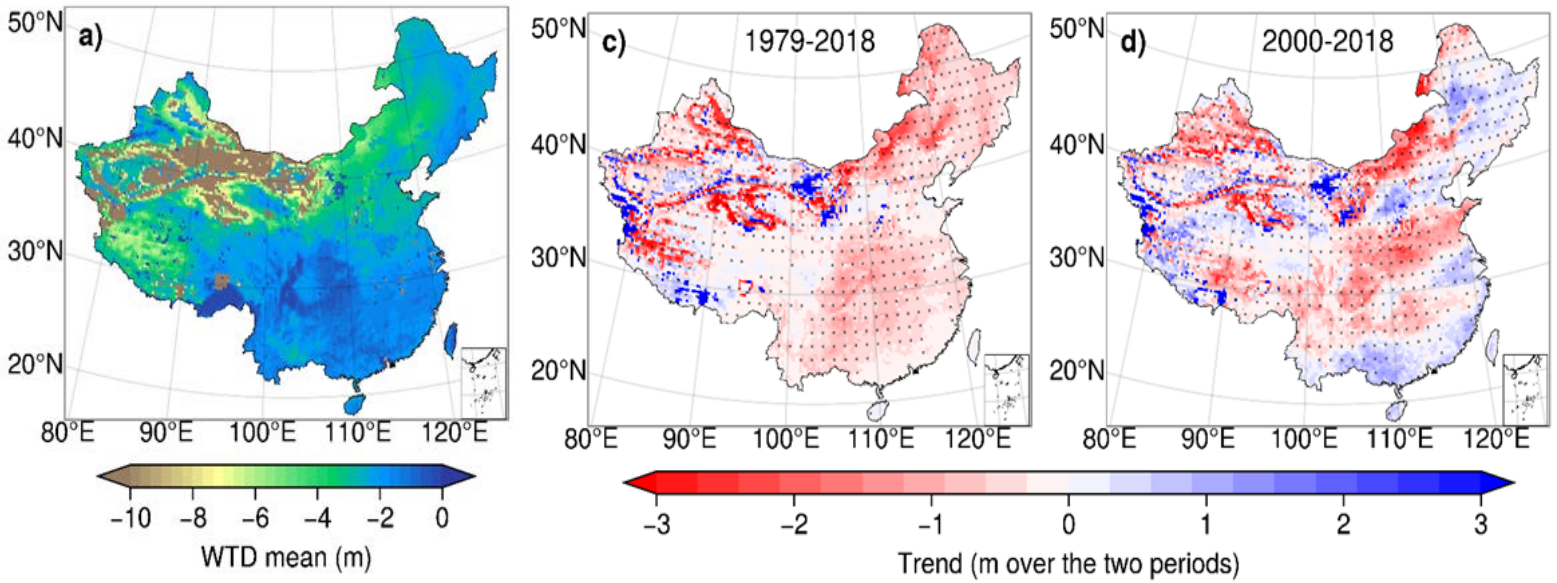


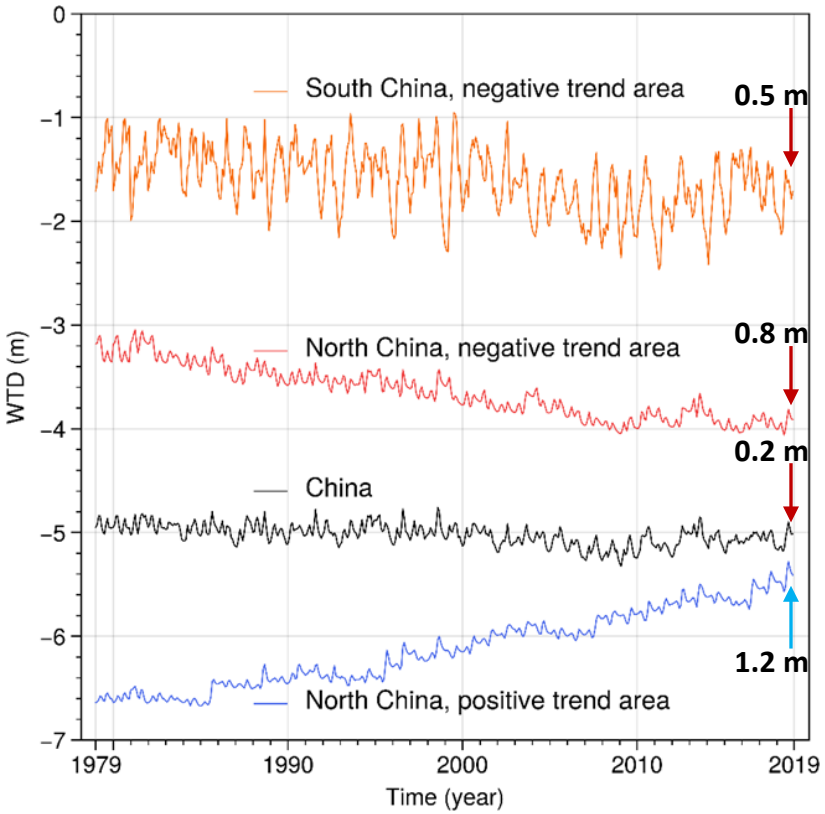


Regionally averaged WTD series compared with observations: R=0.58， p<0.01

WTD changes driven by climate change

Mean WTD | **Linear trends 1979-2018** | **Linear trends 2000-2018**



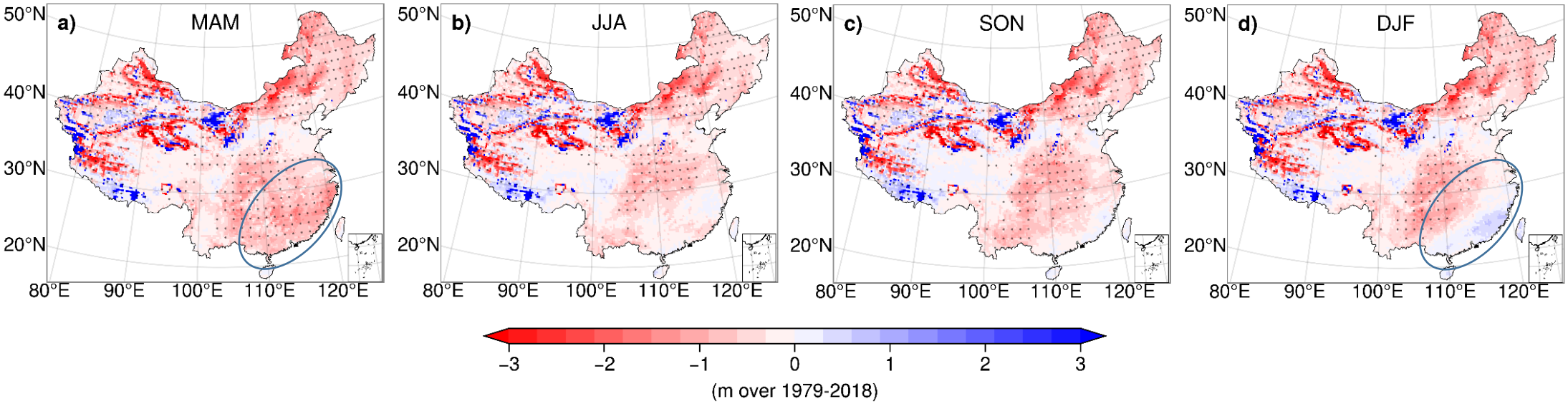


WTD are deep in arid and mountainous regions, but shallow in humid east.

Long-term trends show significant dropping water tables nationwide, reaching 0.2 m on average and exceeding 3 m in the dry northwest China, although a 1.2 m increase on average in northern China.

WTD changes driven by climate change

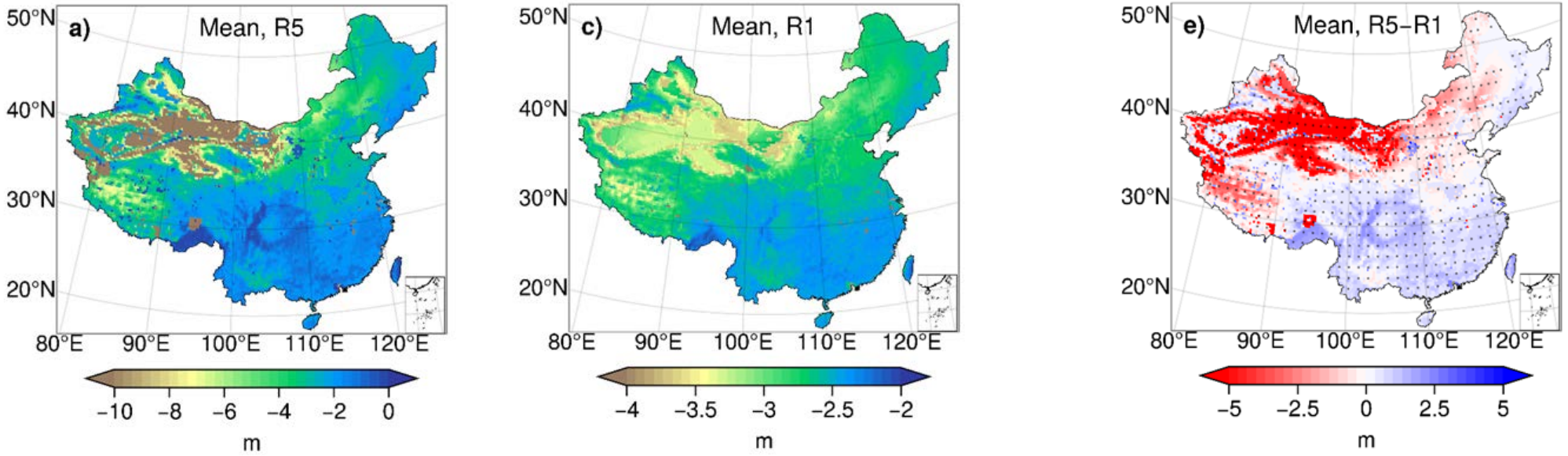
Seasonal trends in WTD from 1979-2018



In southeast China, where WTDs are shallow and both annual total precipitation and its seasonal changes are large, seasonal changes in WTD can be seen more clearly.
Meanwhile, seasonal changes are not clear in the regions with deep WTD climatology in the Northwest.

Effects of lateral flow process on WTD simulation

With lateral flow — **Without** lateral flow = Lateral flow **effects**



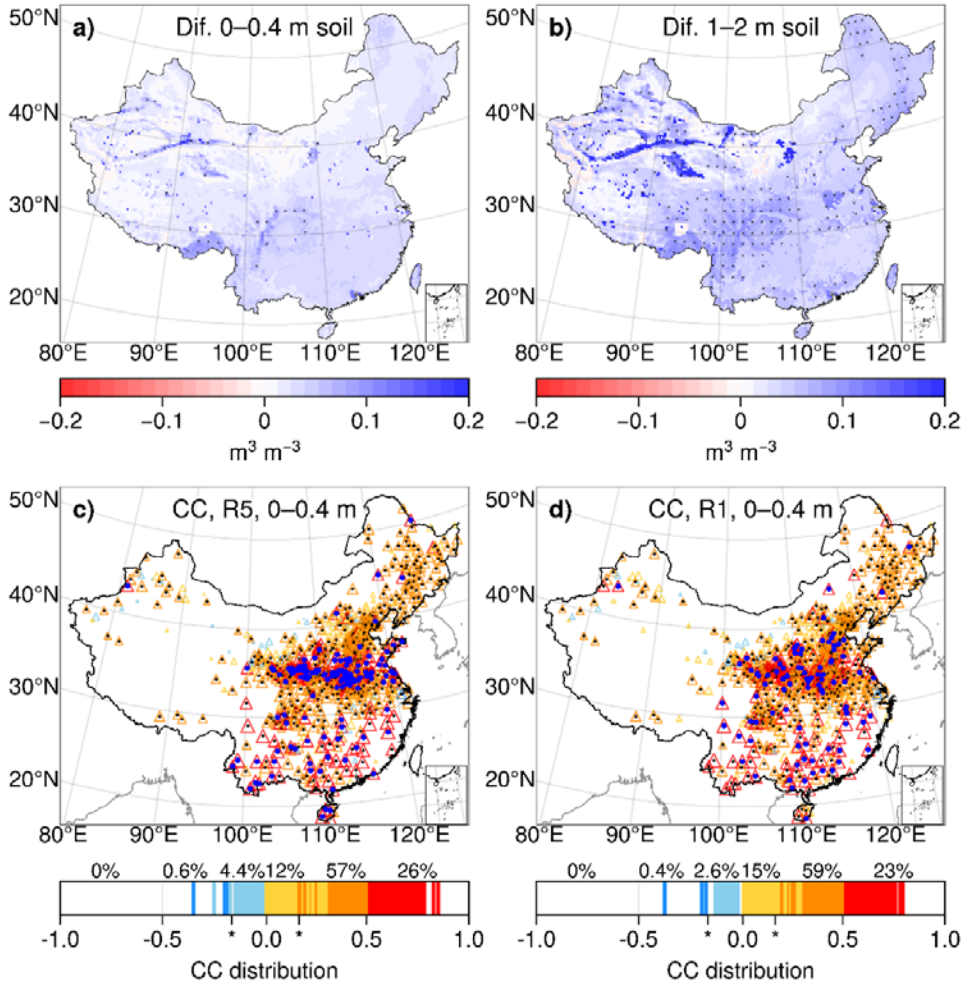
Adding lateral flow processes makes the WTD deeper in northern China, due to the topographical driving. In Contrast, in southeastern China, the lateral flow processes help WTDs stay at shallower levels, which improved WTD simulation, according to previous comparisons with observations.

How the land surface water and energy balances respond to the effects of lateral flow?

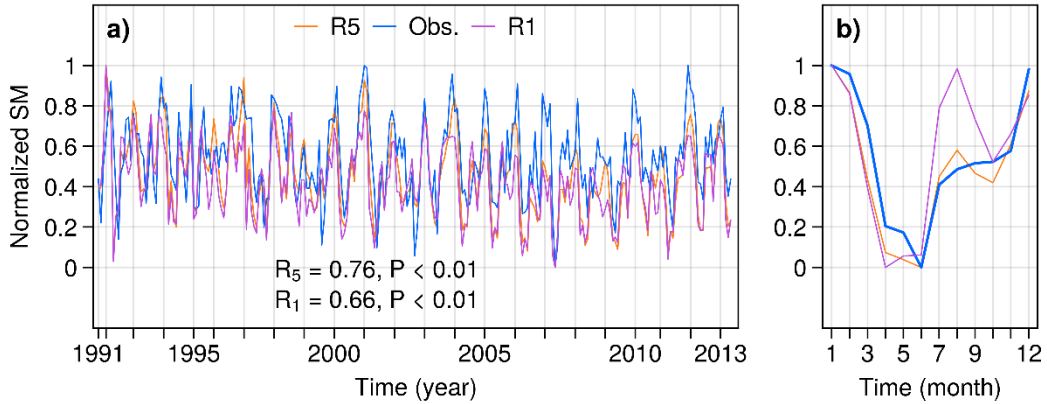
Effects of WTD changes on soil moisture

Upper layer

Lower layer



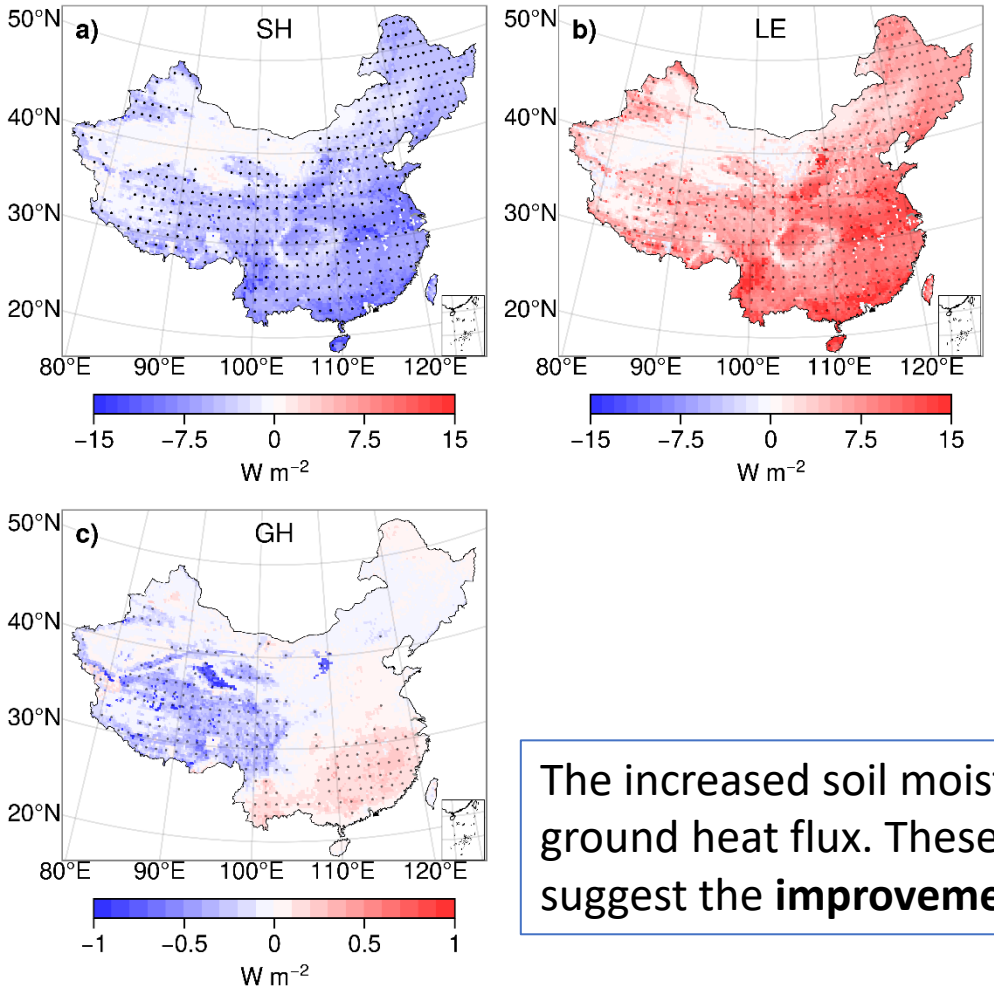
Difference between Soil moisture simulated with and without Lateral flow schemes



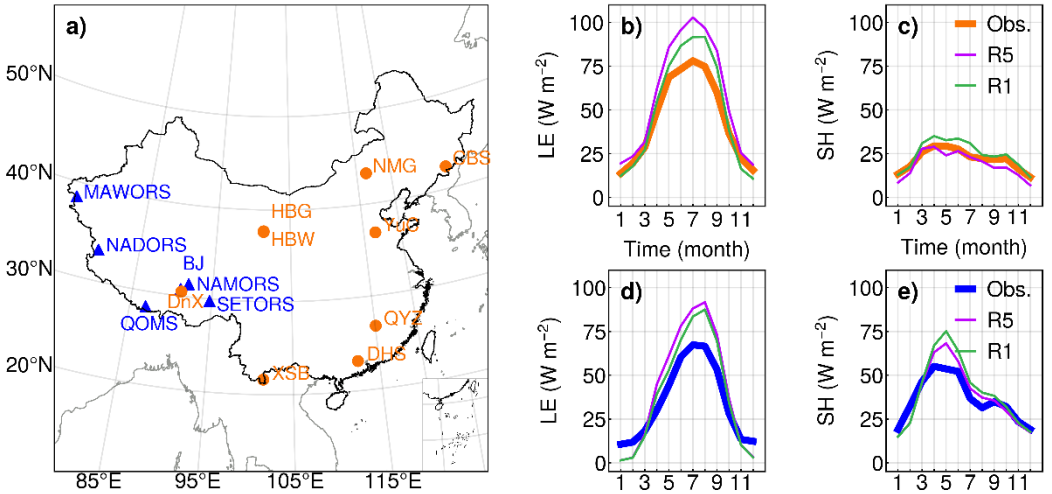
With shallowing water tables, soil moisture increases, especially in lower soil layer, and the correlations with observations get stronger.

The timing of the annual driest soil moisture moves toward that of observations.

Effects of WTD changes on heat flux partitioning

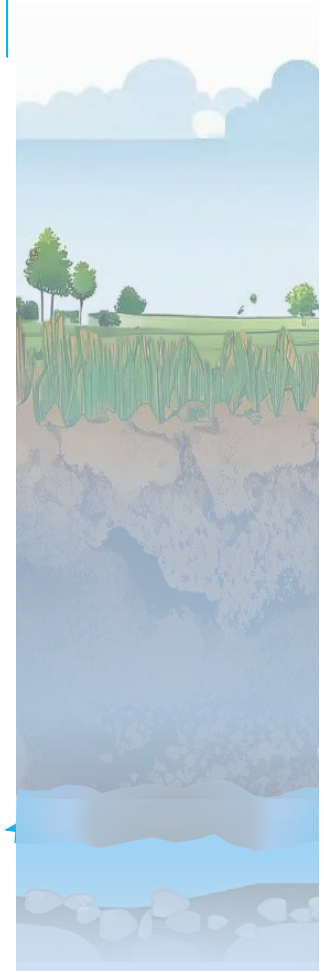


Difference between sensible and latent heat fluxes simulated with and without Lateral flow schemes



The increased soil moisture leads to increases in LE but decreases in SH, and changes ground heat flux. These heat fluxes' changes, compared to in situ observations, suggest the **improvement of the summer energy balance simulations**.

Conclusions



We investigated WTD changes in an offline mode. The results showed that:

- Climate change has significant impacts on groundwater changes in China

  WTD decreased 0.2 m on average, and decreases in semiarid regions exceeded 3 m during 1979-2018

- WTD Changes significantly affect land surface water and energy balances

Limitations:

- Without explicit consideration of water withdrawing/irrigating processes
- Mean WTDs are much shallower than the observations

Future study:

- Getting a comparable WTD climatology with observations
- How groundwater changes affect land-atmospheric interactions

Li, et al. (2022). J. Hydrology. Doi. 10.1016/j.jhydrol.2022.127551

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TANKS FOR YOUR ATTENTION

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