EGU25-7692

Assessing the Irrigation Impact in North China Plain Using Regional Climate Models with Dynamic Vegetation and Groundwater Pumping

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OSPP Poster

Background: Complex Irrigation Impact

Intensive irrigation in the North China Plain (NCP) poses significant environmental challenges, yet its effects on regional climate—including thermal comfort, precipitation, and groundwater depletion—remain **inconsistent across studies**.

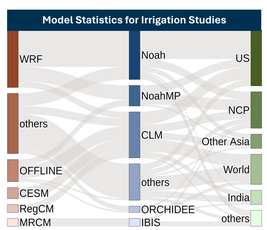
Evaporative/Shading Cooling	*vs*	GHG Warming / Heat Discomfort
More water vapor and more rain	*vs*	Cooling stabilization and less rain

These inconsistencies likely arise from **current models' inability** to fully resolve the complex interactions between irrigation and climate.

Methodology: Coupled Regional Climate Model

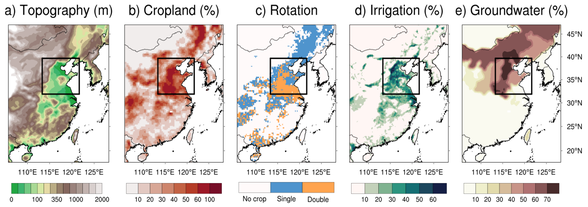
To address this gap, we leverage two widely used regional climate models (RCMs) for the NCP, WRF and RegCM, by integrating their land surface modules with atmospheric components to **explicitly simulate irrigation-climate feedbacks**.

Configuration for the two selected models	
Model1	Model2
WRF4.5	RegCM5
Noah-MP	CLM4.5
Horizontal resolution: **27km**	
Period: **2005-2014** (spin-up in 2004)	
Double cropping: summer corn + winter wheat Single cropping: spring corn	
Dominant type only (Single land/crop type per grid)	Mosaic sub-grids (multiple types per grid)
Groundwater (with lateral flow)	No Lateral flow



The NCP's **unique irrigation regime** is characterized by:

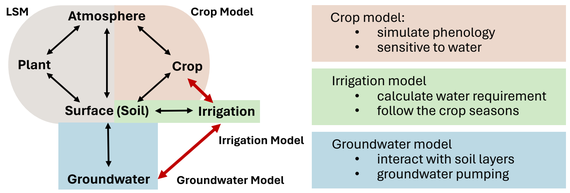
- High-density croplands with rapid crop rotation
- Spatially heterogeneous irrigation intensity
- Overexploitation of groundwater resources



However, these surface properties are NOT captured by current RCMs.

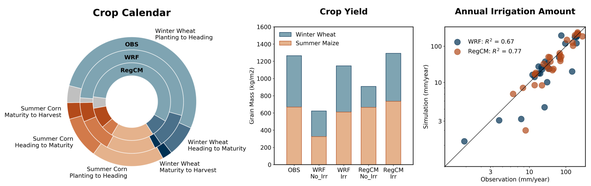
Model Development: Performance Evaluation

1. Fully couple crop growth, irrigation, and groundwater processes:

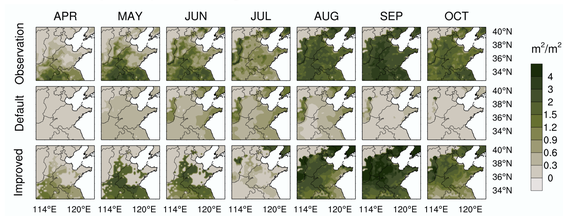


2. Implement double-cropping, recalibrated using station data:

- Crop calendar: Planting -> Heading -> Maturity -> Harvest
- Crop yield: Irrigation increases yield typically for winter wheat
- Irrigation amount: Province-level annual irrigation totals



3. Validate spatial patterns against satellite observations:

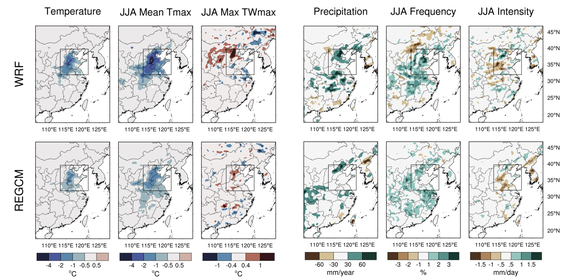


Now, improved models BETTER capture NCP's irrigation dynamics.

Result: Consistent Irrigation Impact

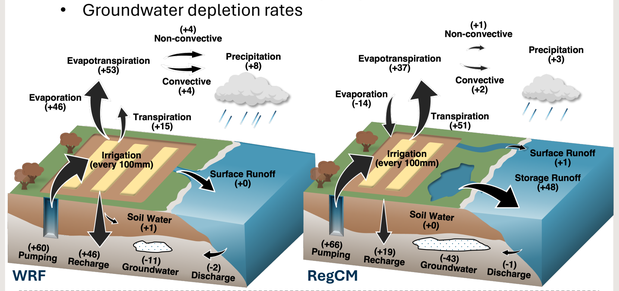
Both simulations consistently show:

- Thermal regulation:
  - Reduced annual and daytime maximum temperatures;
  - Higher wet-bulb temperatures (northern NCP, +humidity).
- Precipitation shifts:
  - Increased annual totals (northern NCP);
  - Summer rainfall becomes more frequent but less intense.



Water-cycle partitioning remains inconsistent across models:

- Evaporation vs. transpiration ratios
- Convective vs. non-convective precipitation
- Groundwater depletion rates



Total precipitation changes are SIMILAR with different land responses.

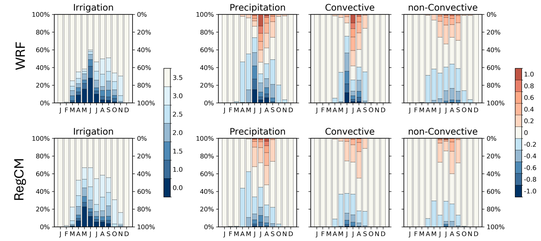
Discussion: Inconsistent Irrigation Impact

Inconsistent partition between evaporation and transpiration:

- WRF: Uniformly water across the grid → more bare soil evaporation
- RegCM: Restricts irrigation to cropland (fixed land fraction as input) → underrepresented vegetation fraction changes.

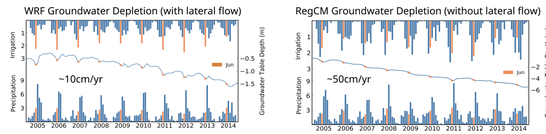
Inconsistent partition between convective and non-convective:

- Both models show precipitation changes driven by convection.
- June: Less convection in RegCM due to less irrigation.
- July: Weaker suppression on non-convective rainfall in RegCM (RegCM is more sensitive to orographic uplift)



Inconsistent groundwater depletion rates:

- WRF depletion peaks in June (aligned with peak irrigation).
- RegCM delays depletion to July due to inefficient recharge (summer rainfall lost as runoff, and no lateral flow).



Discussion: Inconsistent Irrigation Impact

Limitation and Future work

- Input uncertainty: Quantify by sensitivity tests.
- Model dependency: Expand comparison (multi-model/multi-scheme).

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New consensus from improved regional climate models WRF & RegCM:

WATERING CROPS, SEEDING CLOUDS !

Publications for this project:

Fan, Y., Im, E.-S.*, Lan, C.-W., & Lo, M.-H. (2023). An increase in precipitation driven by irrigation over the North China Plain based on RegCM and WRF simulations. *Journal of Hydrometeorology.* https://doi.org/10.1175/JHM-D-22-0131.1

Fan, Y.*, Yang, Z., Lo, M.-H., Hur, J., & Im, E.-S.* (2024). Applying double cropping and interactive irrigation in the North China Plain using WRF4.5. *Geoscientific Model Development*, 17(18), 6929–6947. https://doi.org/10.5194/gmd-17-6929-2024

Fan, Y.*, Yang, Z., Lo, M.-H., Hur, J., & Im, E.-S.* (Accepted). Deciphering the Capricious Precipitation Response: Irrigation Impact in the North China Plain. *npj Climate and Atmospheric Science*.

Fan, Y.*, and Im, E.-S. (In revision). The Role of Vegetation Dynamics in Assessing Irrigation Impacts. *Geophysical Research Letters*.

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