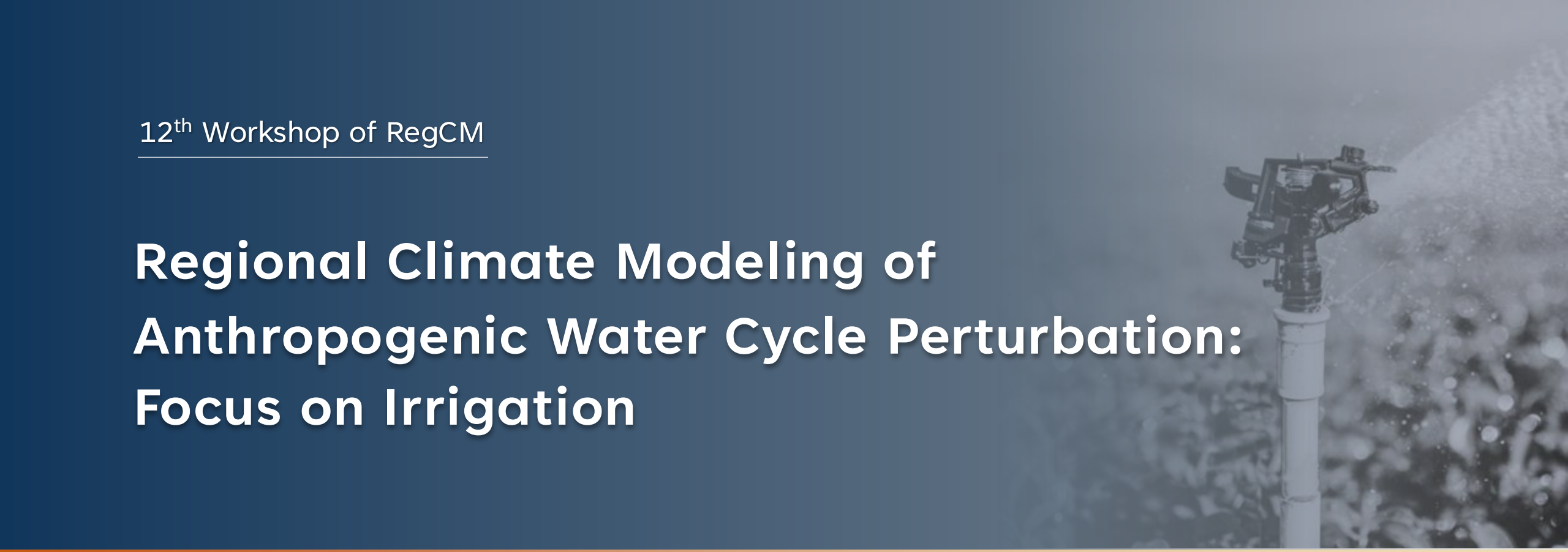
12th Workshop of RegCM



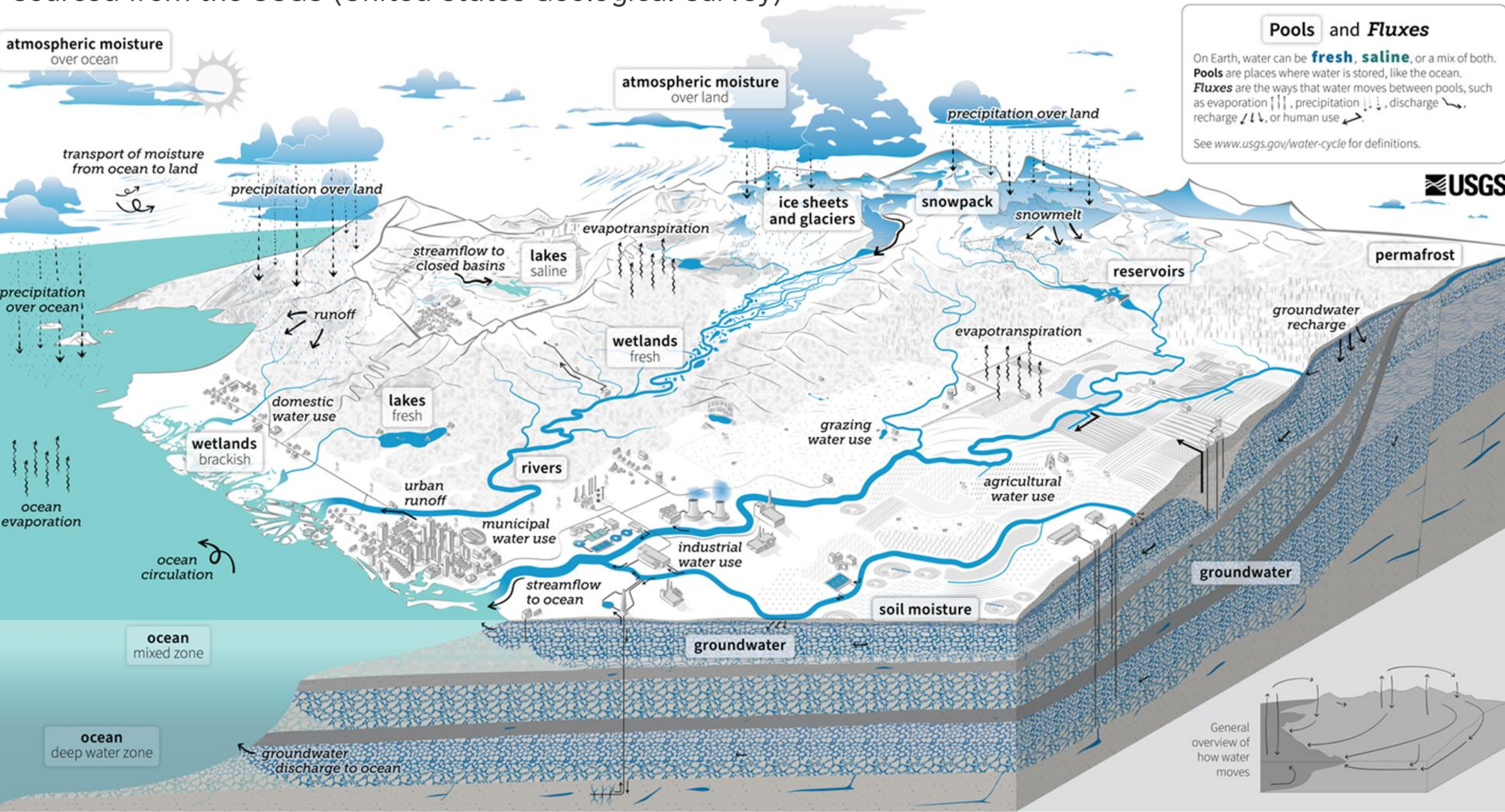
Regional Climate Modeling of Anthropogenic Water Cycle Perturbation: Focus on Irrigation

Presenter: Eun-Soon Im, Yuwen Fan (Wendy)

Affiliation: The Hong Kong University of Science and Technology

Date: Aug 29th 2025

Sourced from the USGS (United States Geological Survey)



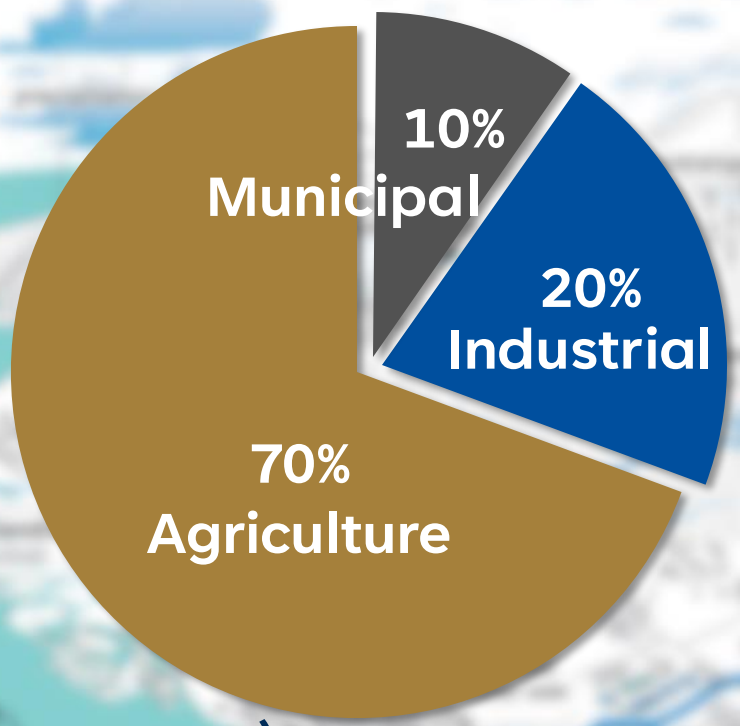
Municipal

Industrial

Municipal

Industrial

Agricultural



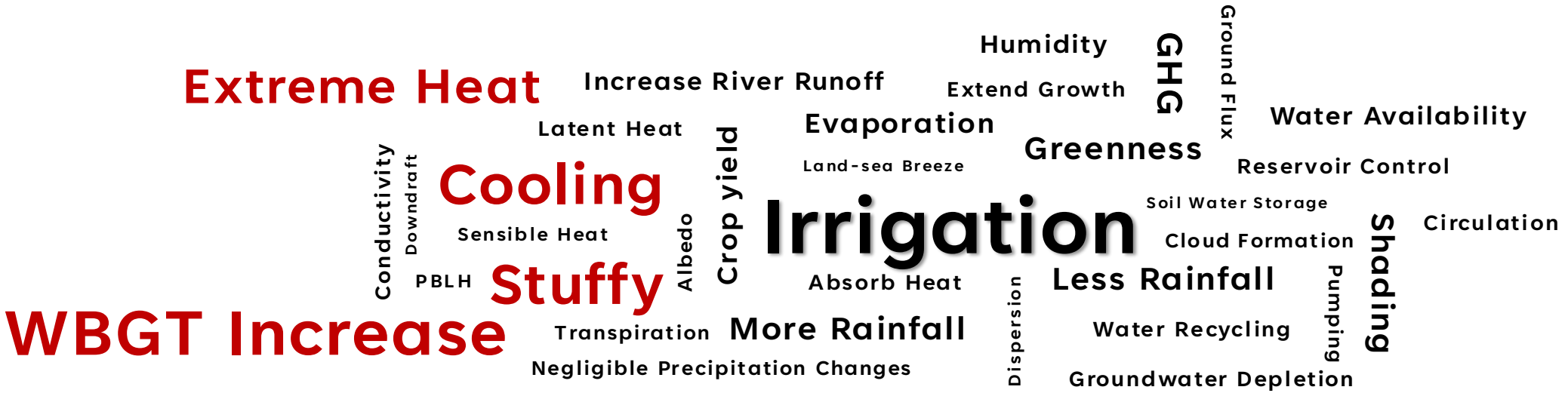
(FAO, 2000)

Today, agriculture accounts for about **70%** of the global freshwater withdrawal,

and most of the water is consumed by **Irrigation**

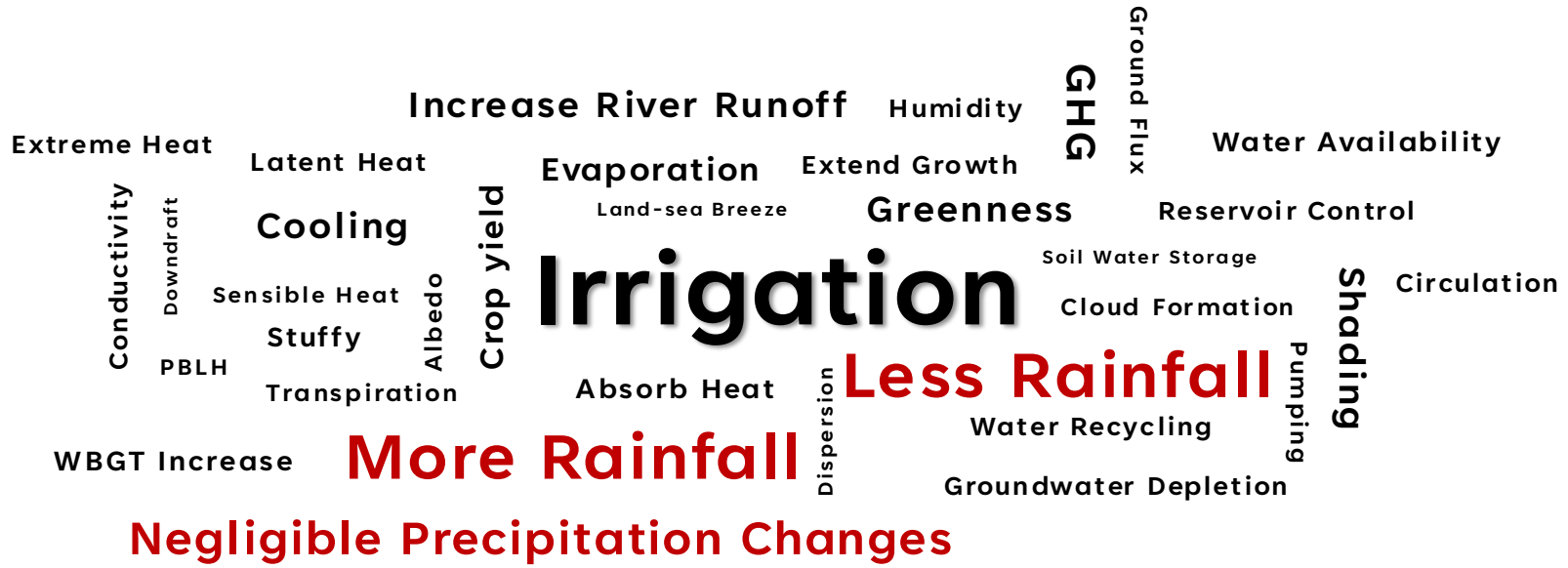
Topic: Irrigation Impact

Topic: Irrigation Impact



Heat Comfort

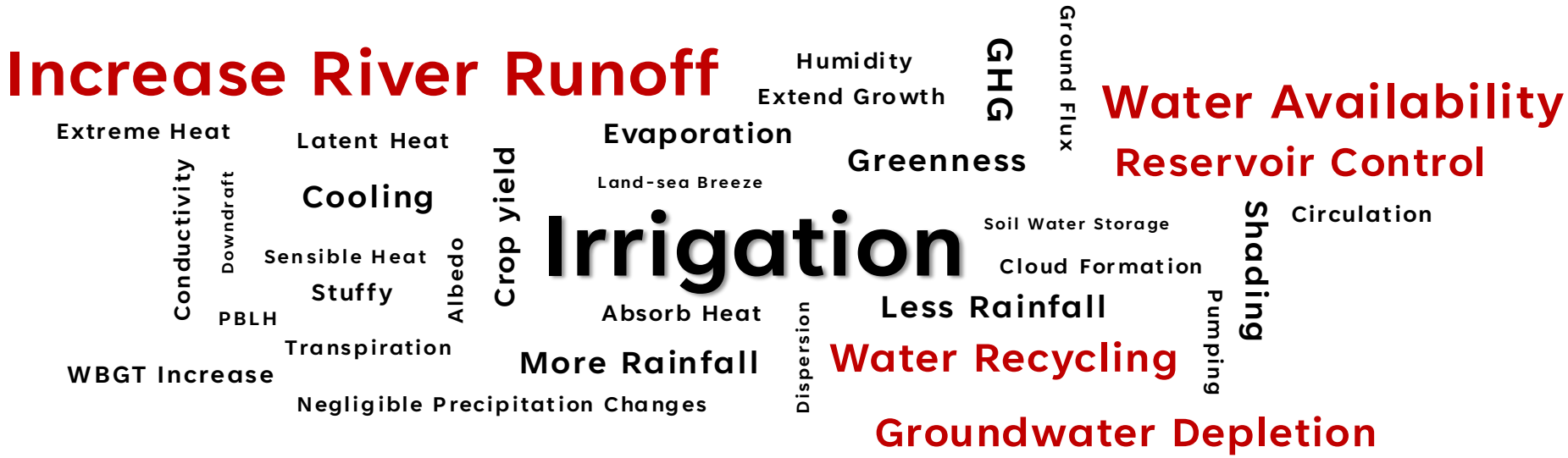
Topic: Irrigation Impact



Heat Comfort

Precipitation

Topic: Irrigation Impact



Heat Comfort

Precipitation

Water Resource

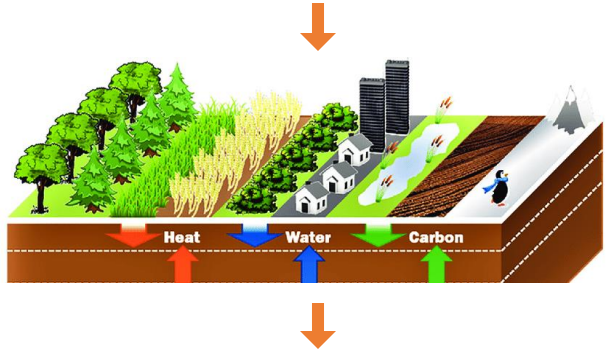
Method: Climate Models

Field Study

Not Feasible for large-scale

Offline Model

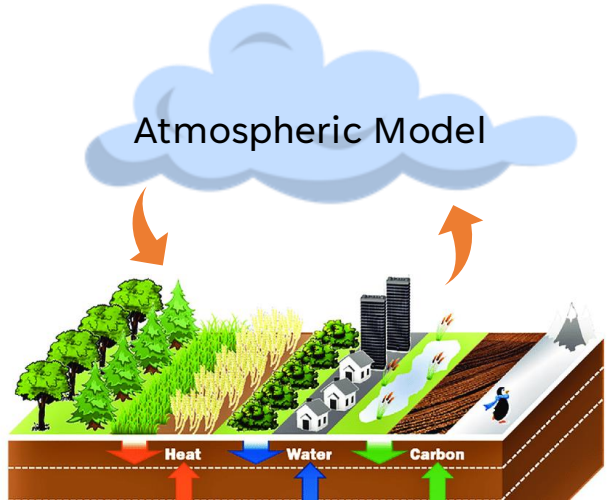
Temperature, Precipitation, Radiation …



Heat, Evaporation, Vegetation …

Not Interactive

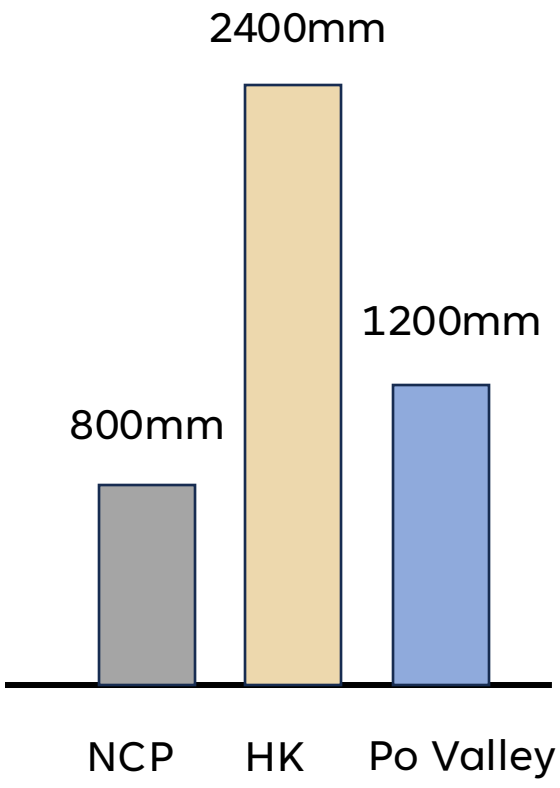
Coupled Climate Model



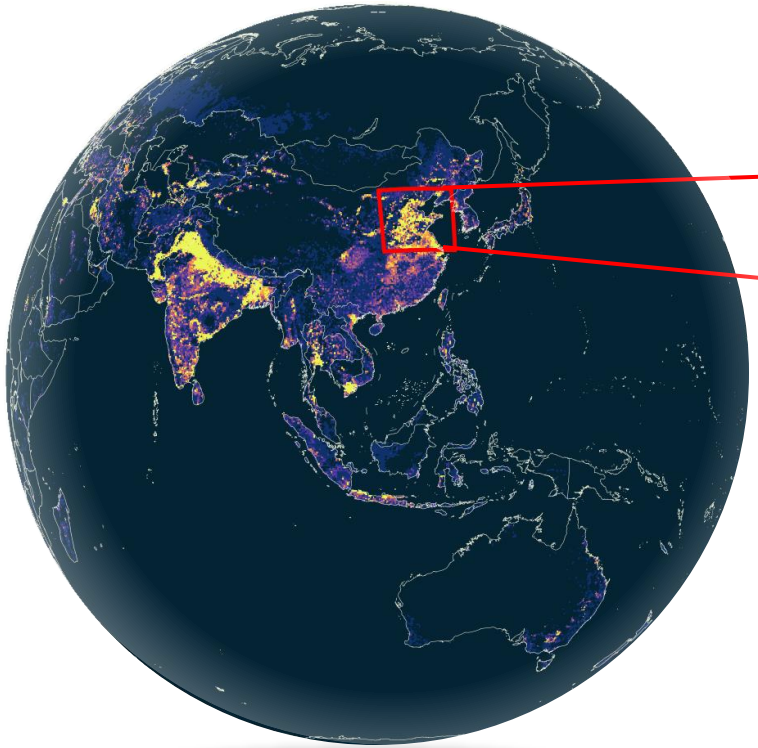
Large-scale & Interactive

Domain: North China Plain

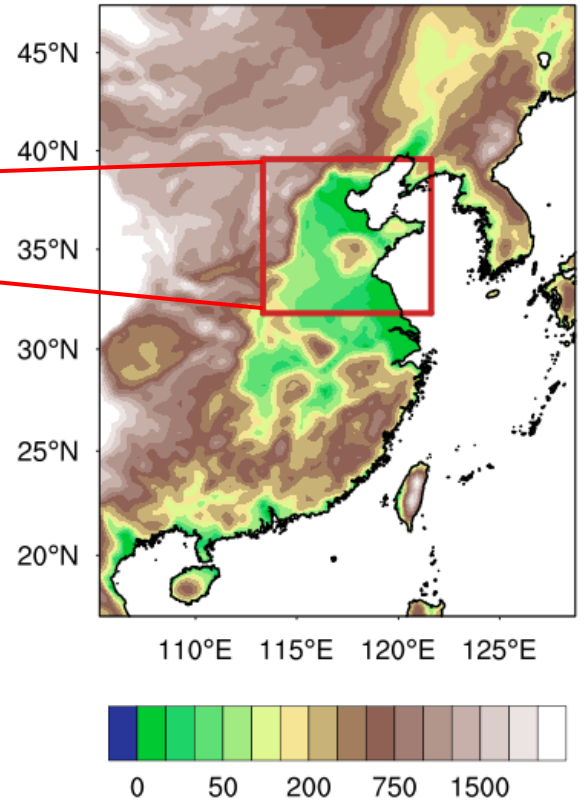
Annual Precipitation



Irrigation Intensity



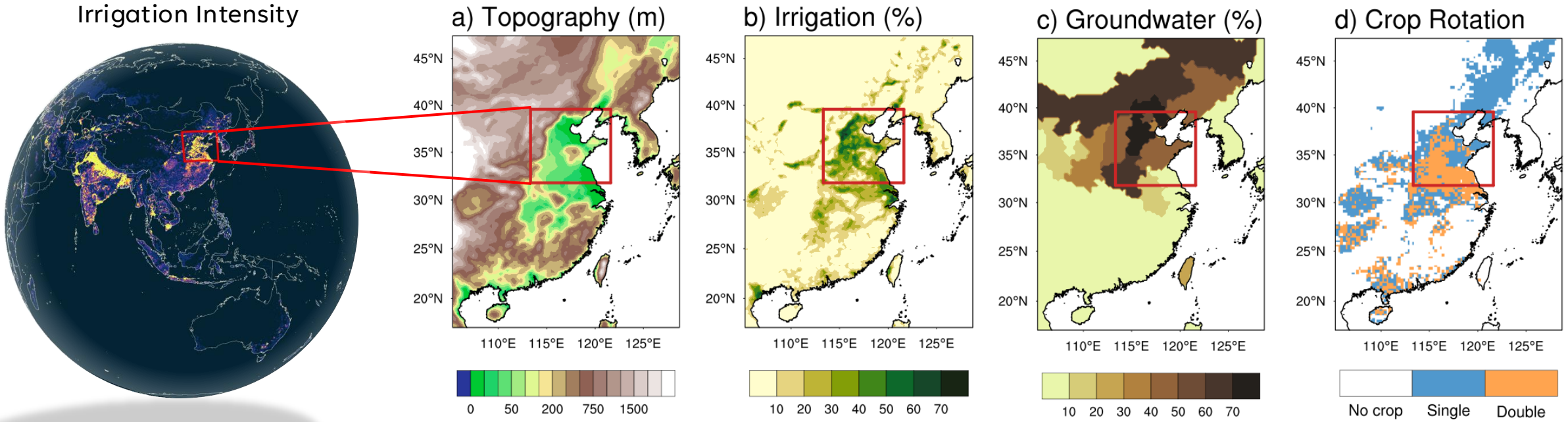
Topography



Domain: North China Plain

- Intense irrigation
- Heavily rely on groundwater
- Double-season crop rotation

} **Complex Irrigation System**



Research Gap

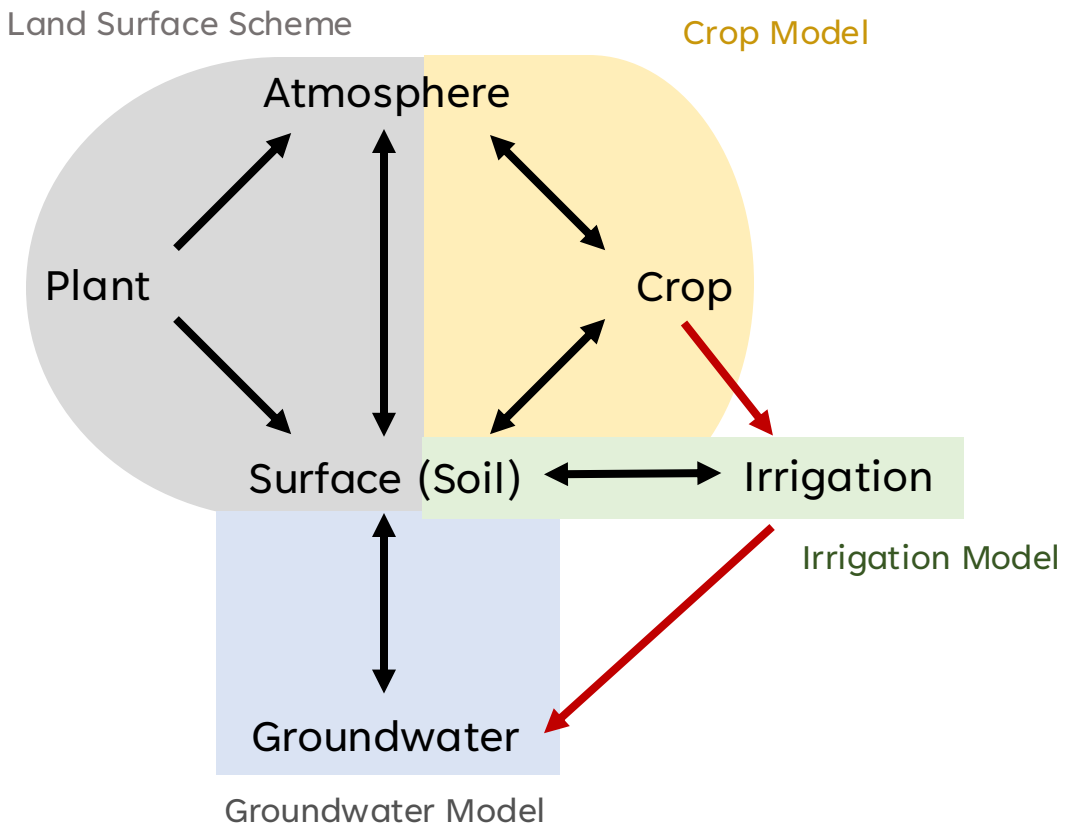
Integration

This “Complex Irrigation System” is NOT well considered.

Research Gap

Integration

This "Complex Irrigation System" is NOT well considered.



Why is Joint Crop-Irrigation-Groundwater System not included yet?

Research Gap

Integration

Regionalization

Why is Joint Crop-Irrigation-Groundwater System not included yet?

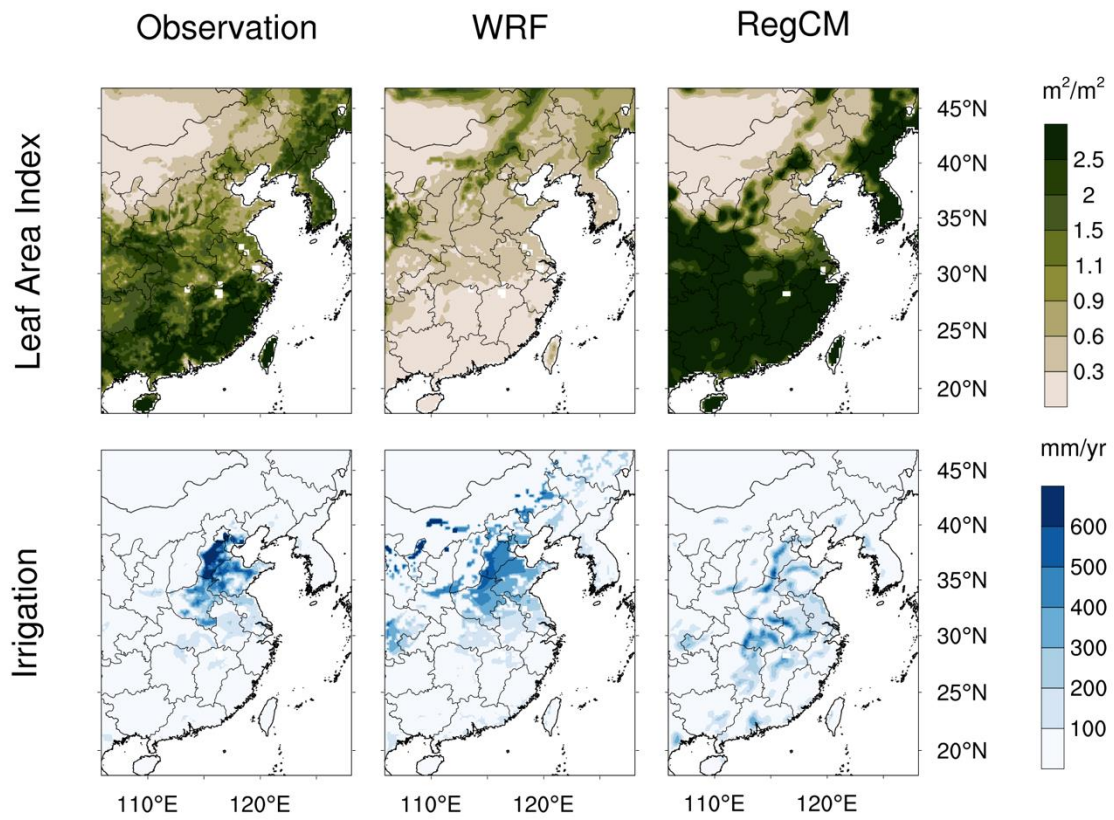
Current related models are NOT appropriate in the NCP region.

Research Gap

Integration

Regionalization

Current related models are NOT appropriate in the NCP region.



Implement regional-specific functions and parameters.

Research Gap

- Integration
- Regionalization
- Model-dependency

Previous results have heavy dependence on models.

Research Gap

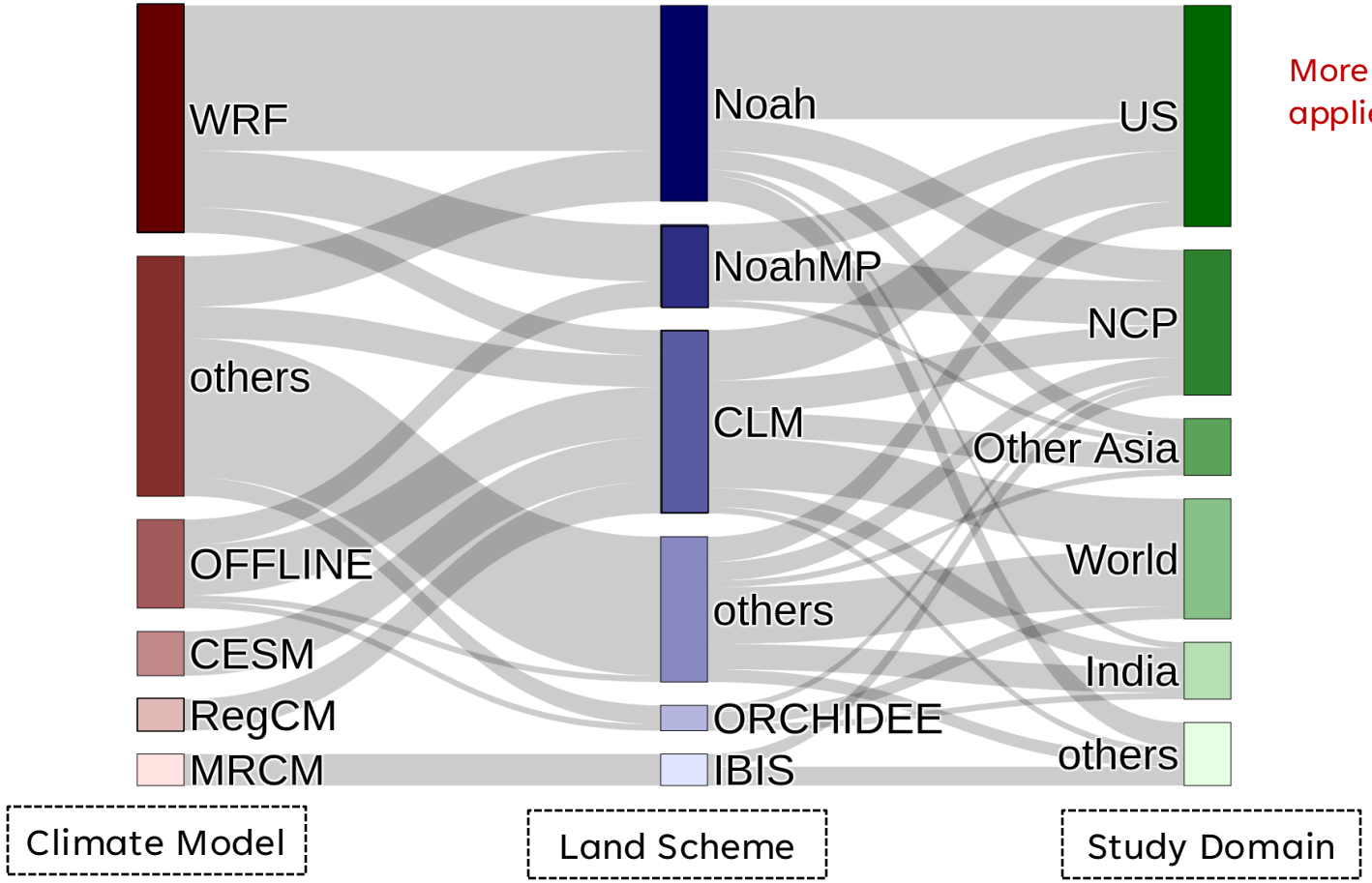
Integration

Regionalization

Model-dependency

Previous results have heavy dependence on models.

Model Statistics for studies on temperature/precipitation/radiations until 2024



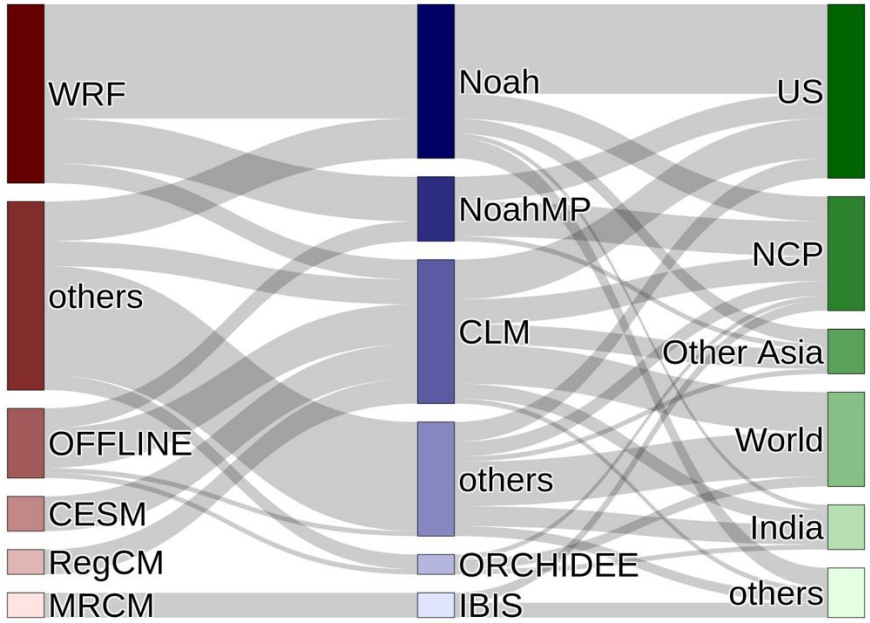
(land sector in climate models)

More than half applied Noah+WRF

Research Gap

- Integration
- Regionalization
- Model-dependency

Previous results have heavy dependence on models.



RegCM ⚯ CLM

WRF ⚯ NoahMP

Comparison

↓

Reliability

Uncertainty

Research Gap

Integration

Regionalization

Model-dependency

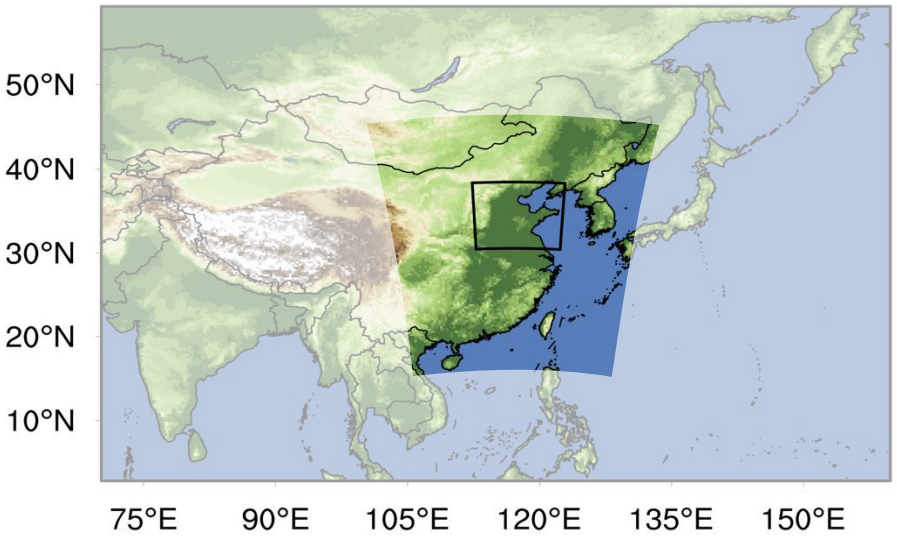
Model Design

Model-dependency

Title: Regional Climate Modeling of Anthropogenic Water Cycle Perturbation: Focus on Irrigation

Integration

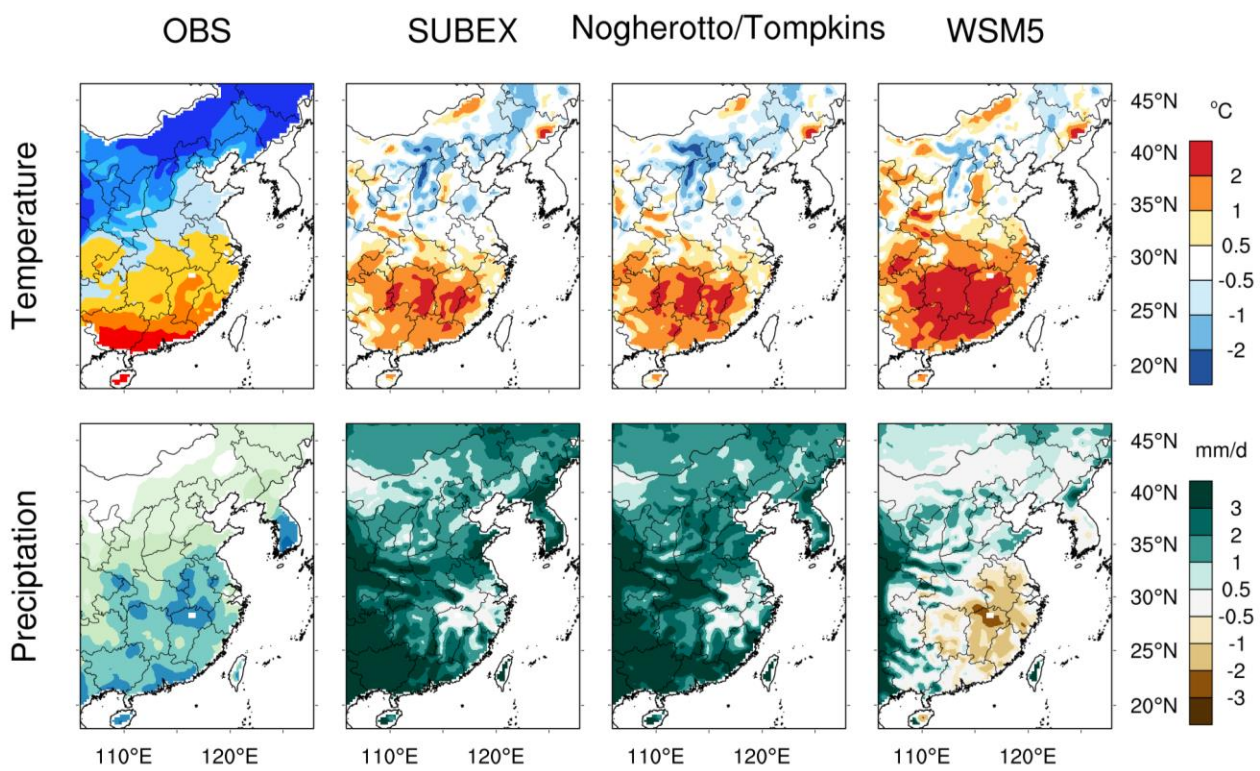
Regionalization

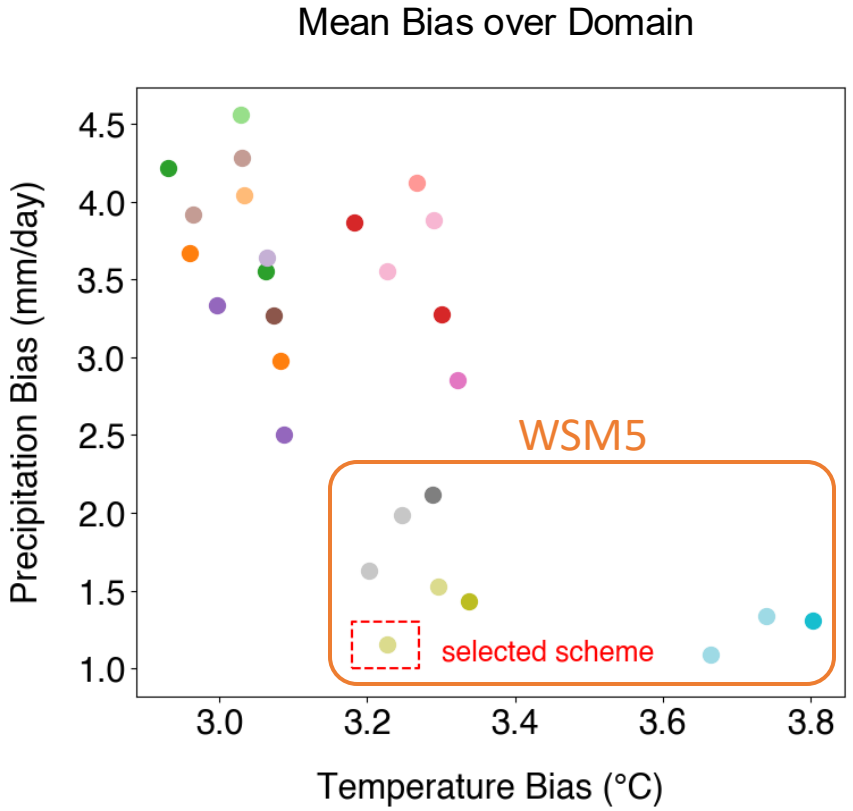


Model 1	RegCM5 + CLM4.5-**CN-CROP**
Model 2	WRF4.5 + Noah-MP5
Resolution	27km
Timespan	2005-2014 (2004 spin-up)

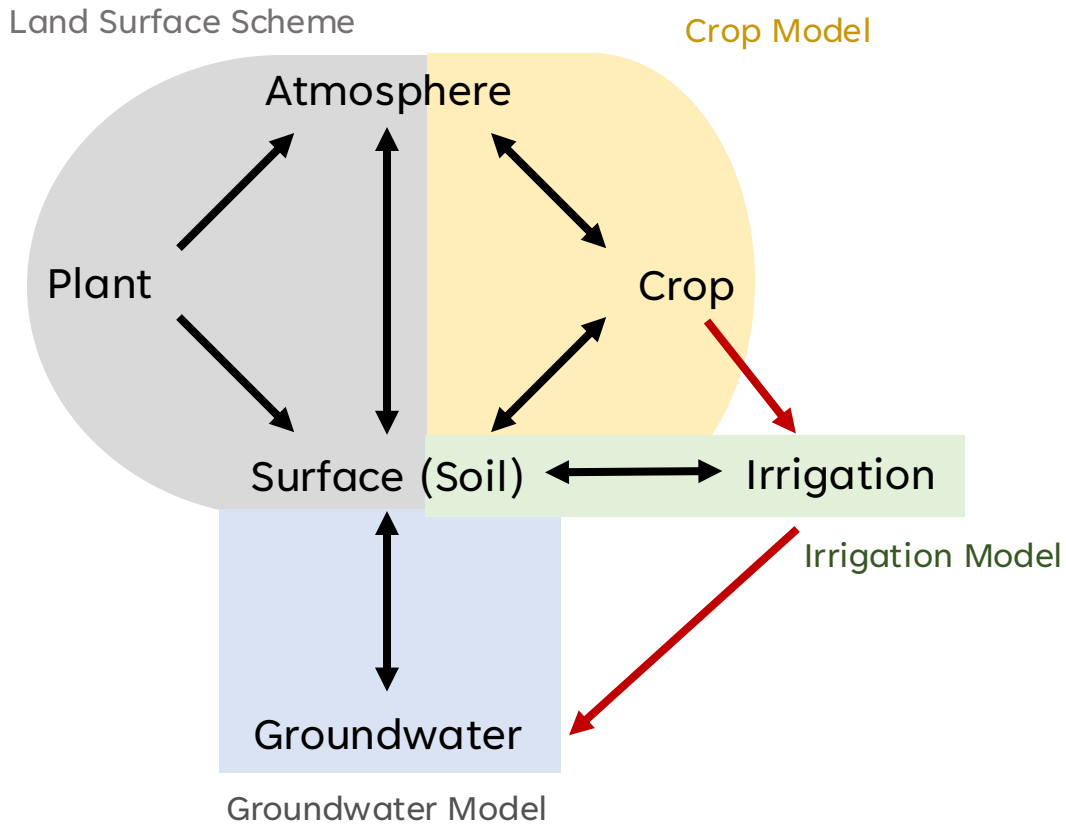
Scheme Selection

Greater hot bias, less dry bias. WSM5 group performs generally better.





Model Development



Model Development

Irrigation

Groundwater

Crop

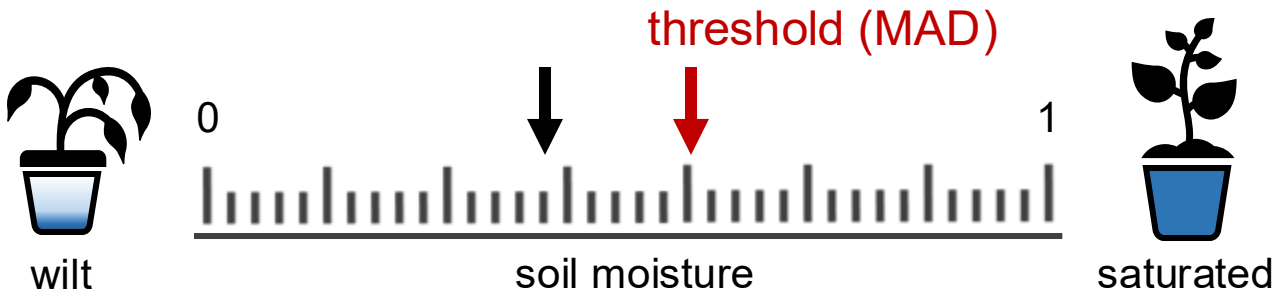
Model Development

Irrigation

- Amount

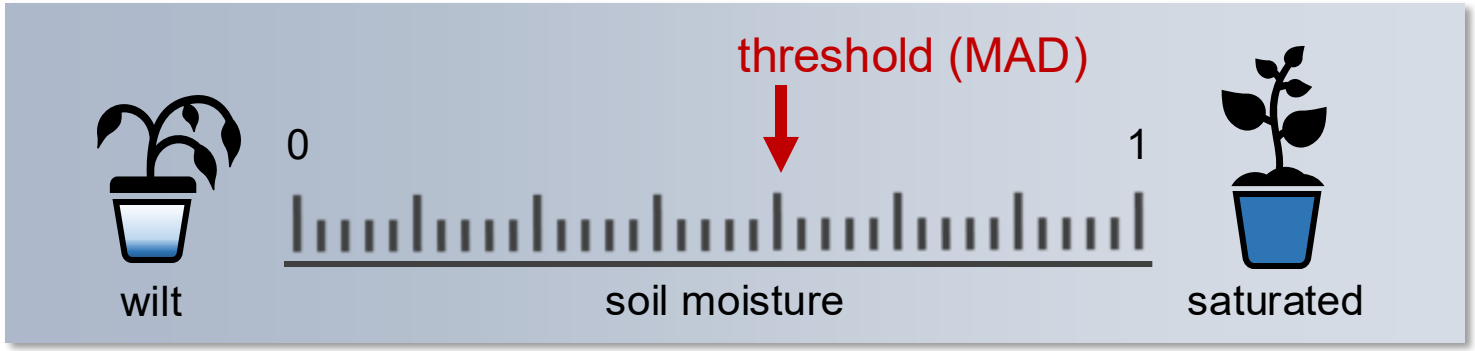
Groundwater

Crop

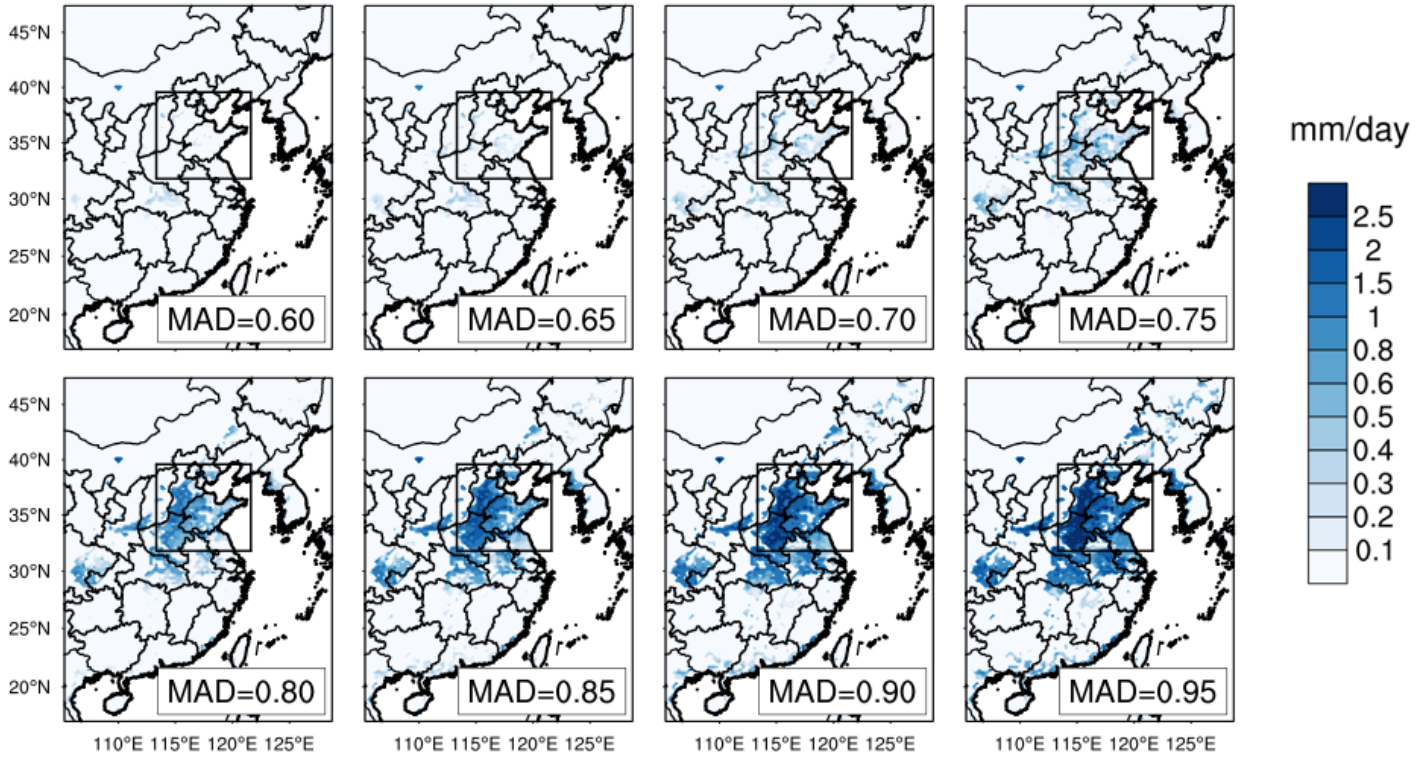


Model Development

- Irrigation
  - Amount
- Groundwater
- Crop



Averaged irrigation amount using default model



Model Development

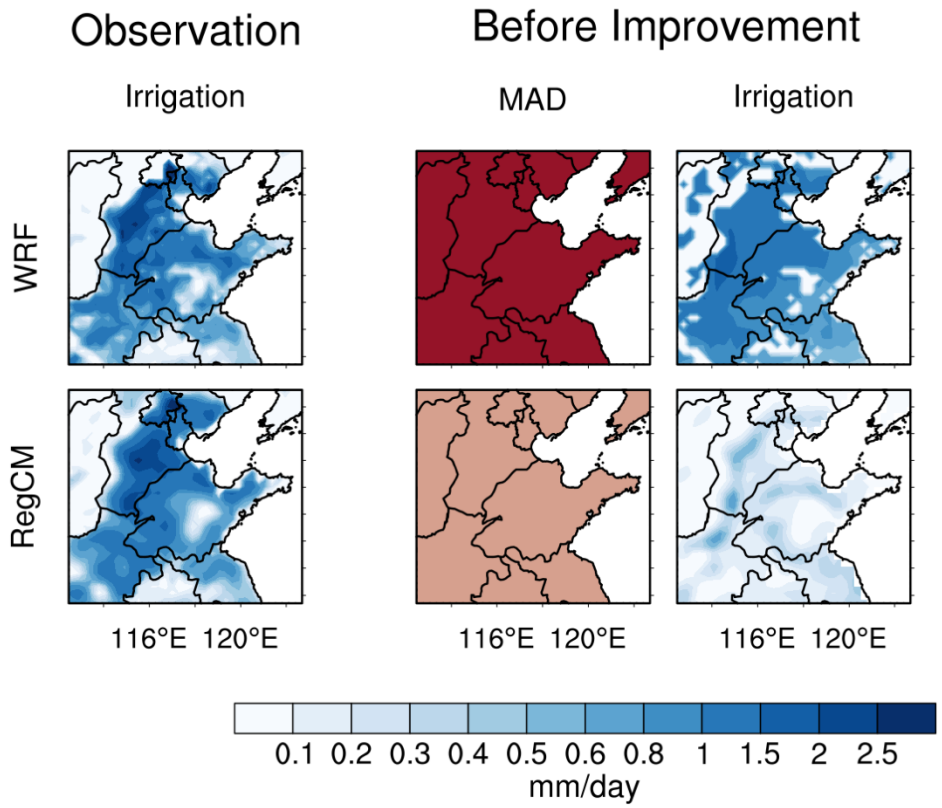
Irrigation

- Amount

Groundwater

Crop

Default model adopts spatially uniformed threshold (MAD).
Regional heterogeneity might not be well captured.



Model Development

Irrigation

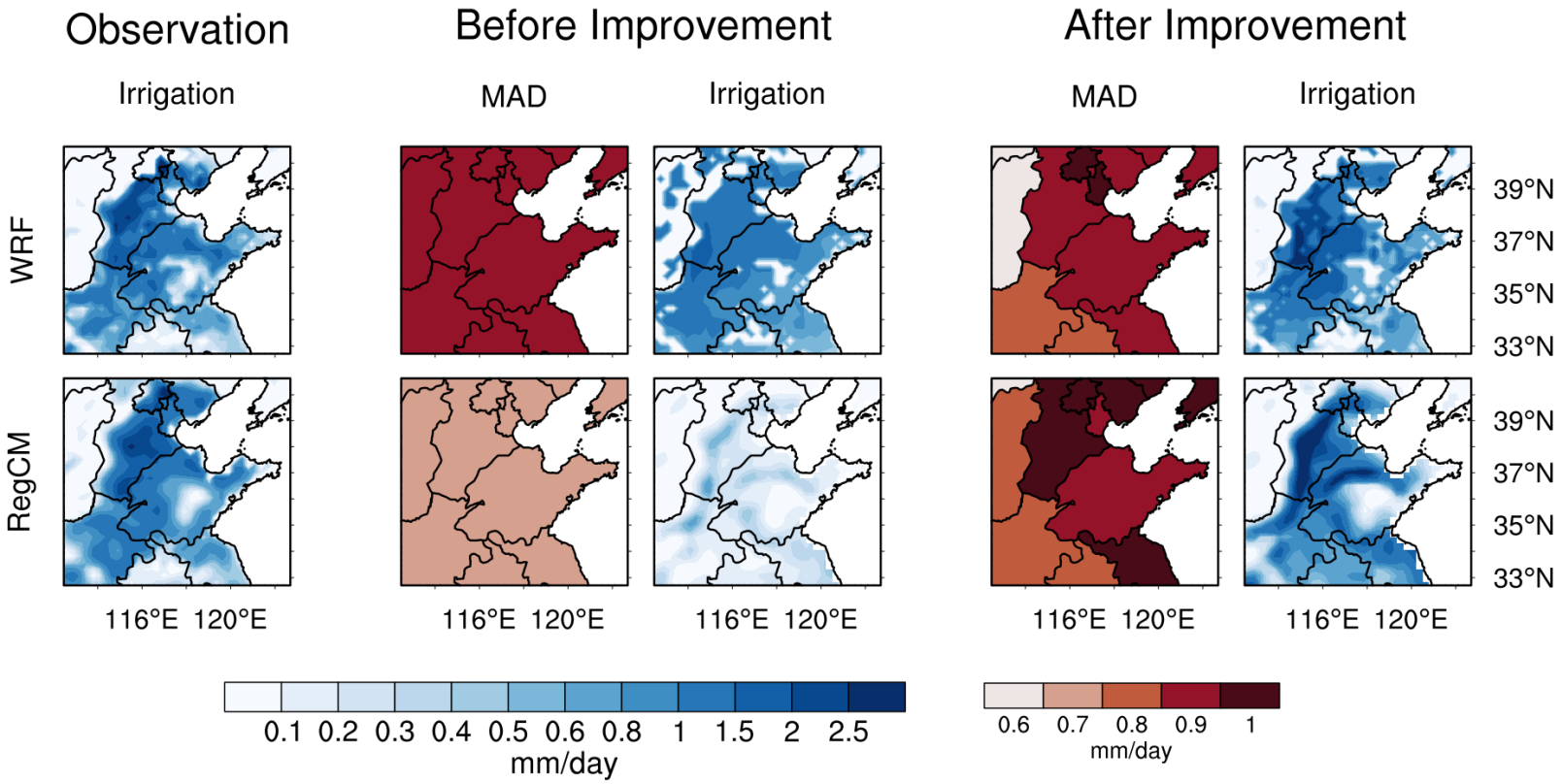
└ Amount

Groundwater

Crop

Default model adopts spatially uniformed threshold (MAD).
Regional heterogeneity might not be well captured.

⇒ **Calibrate the irrigation amount on provincial basis.**

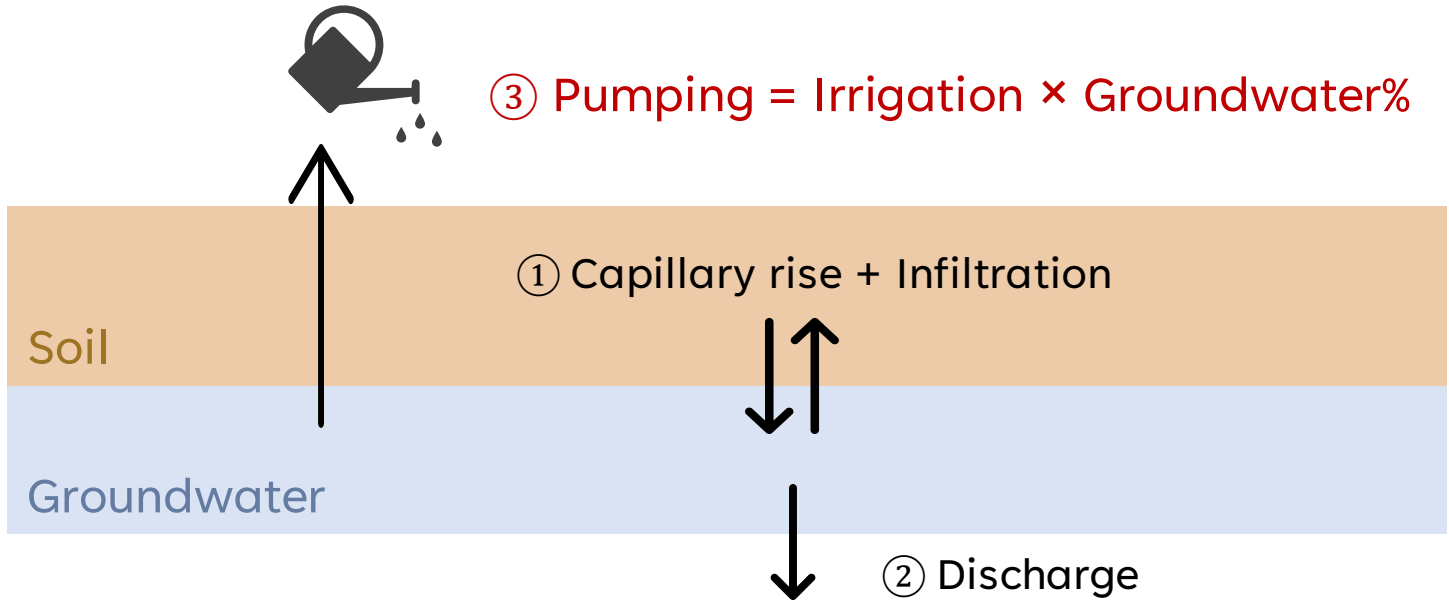


Model Development

Irrigation
- Amount

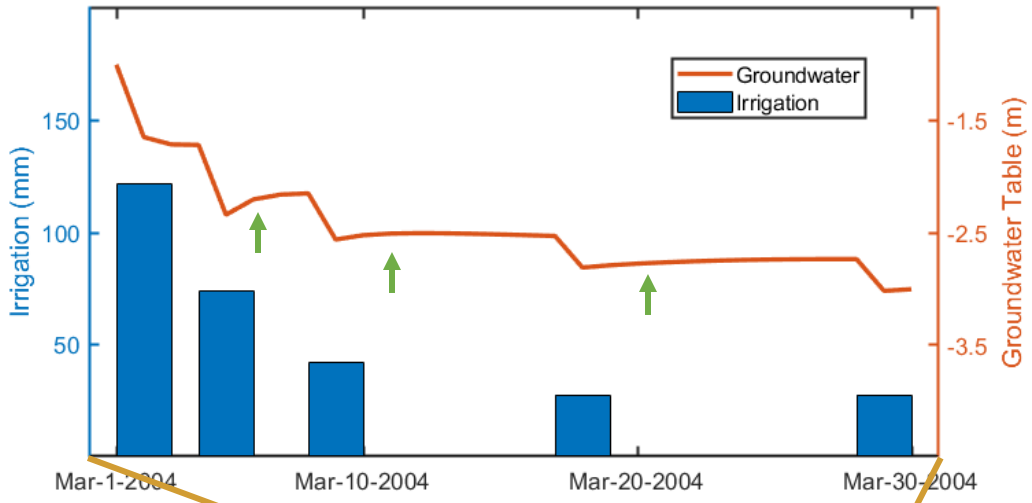
Groundwater
- Pumping

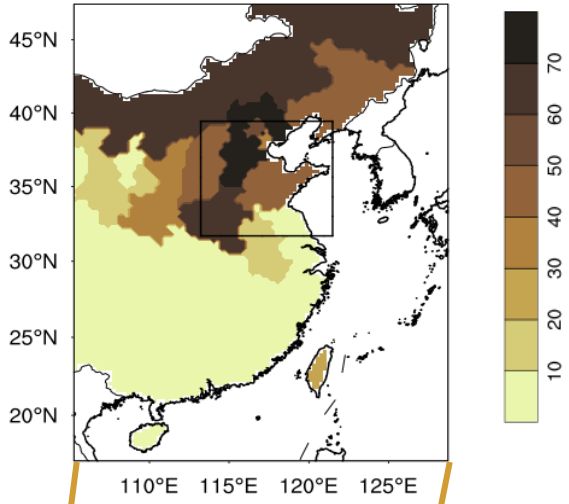
Crop



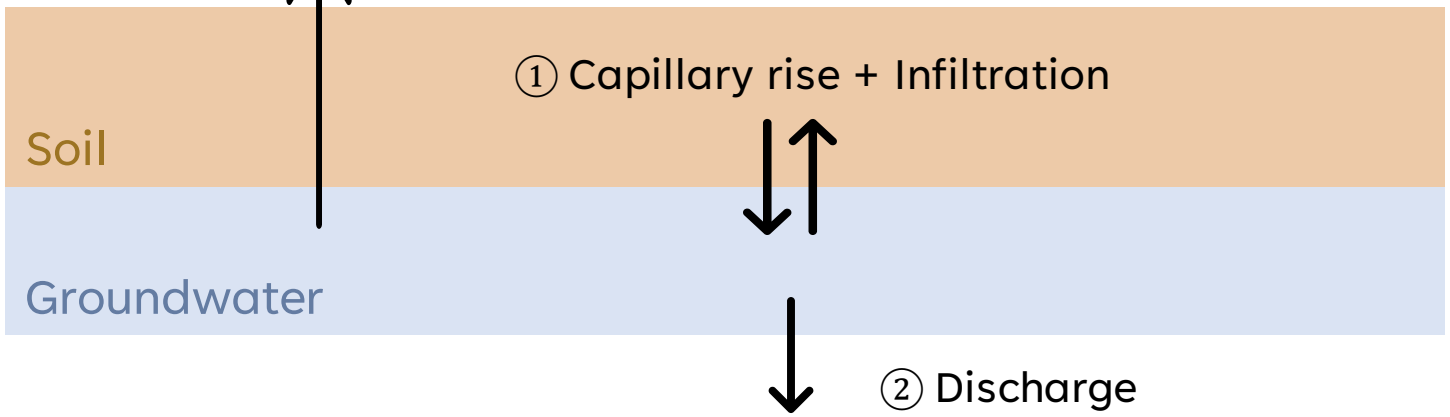
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop



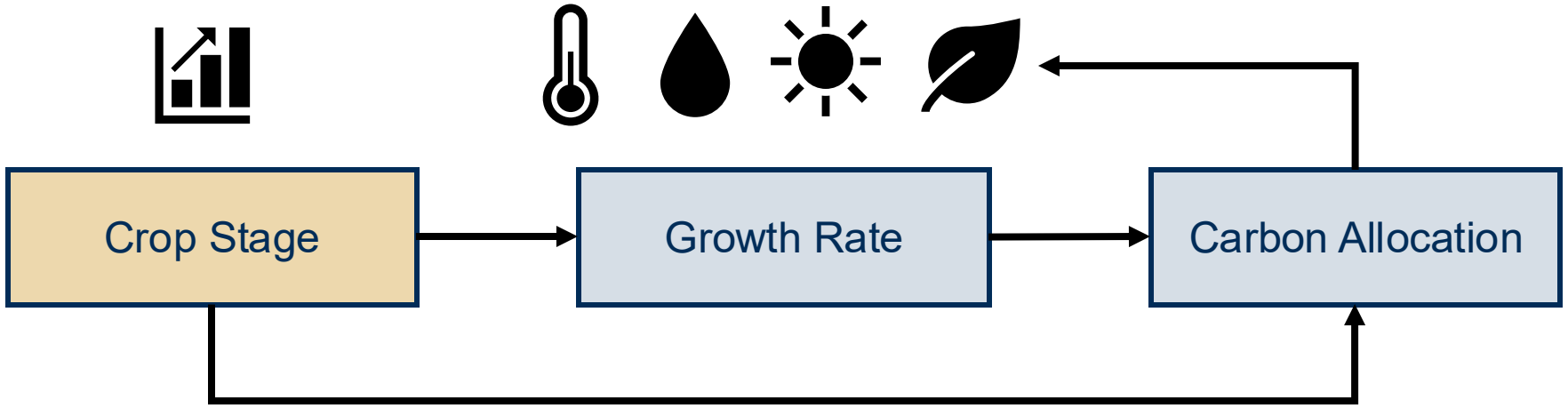


③ Pumping = Irrigation × Groundwater%



Model Development

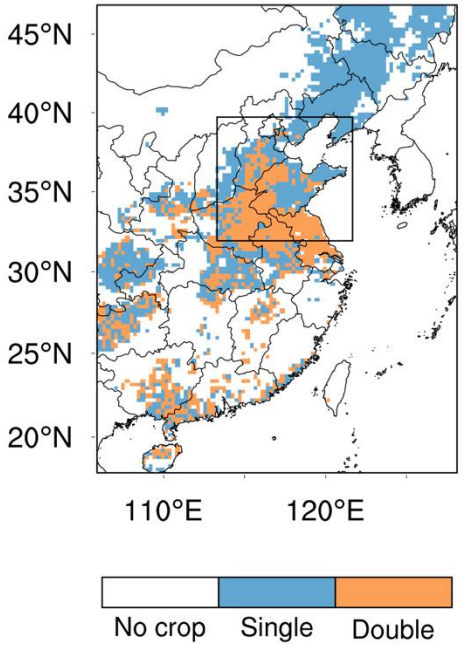
- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar



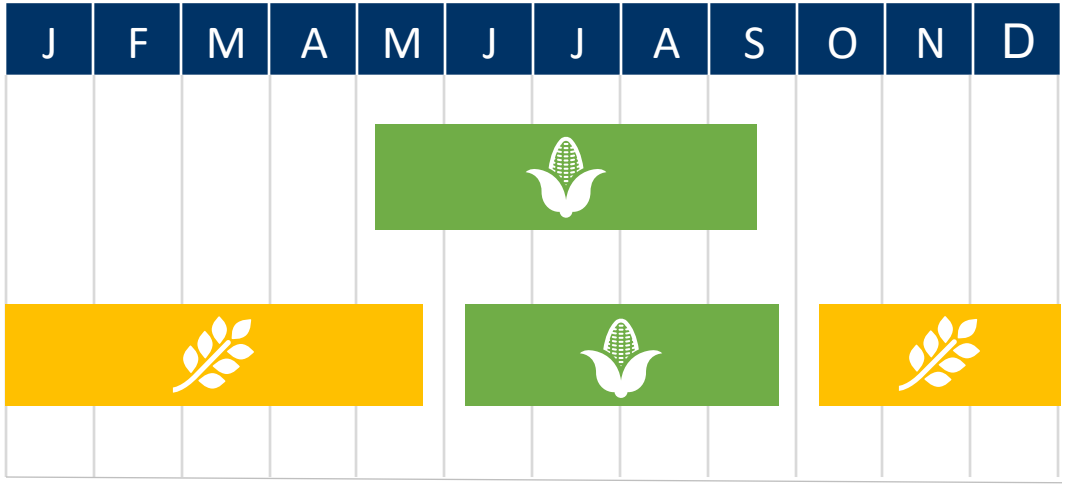
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar

Crop Rotation



Crop Calendar

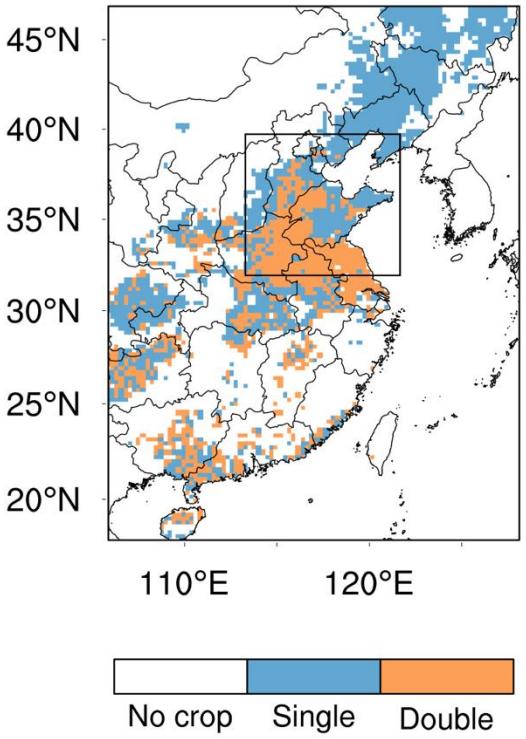


Satellite data comes from ChinaCropPhen1km (Luo et al., 2020)

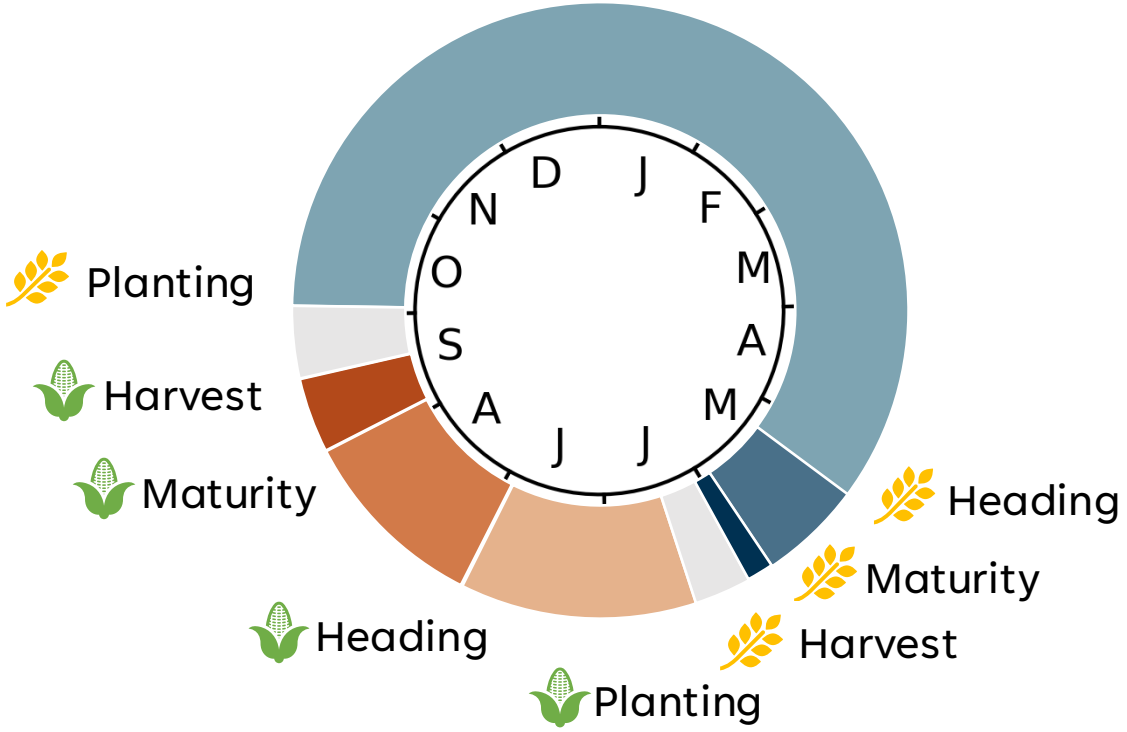
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar

Crop Rotation



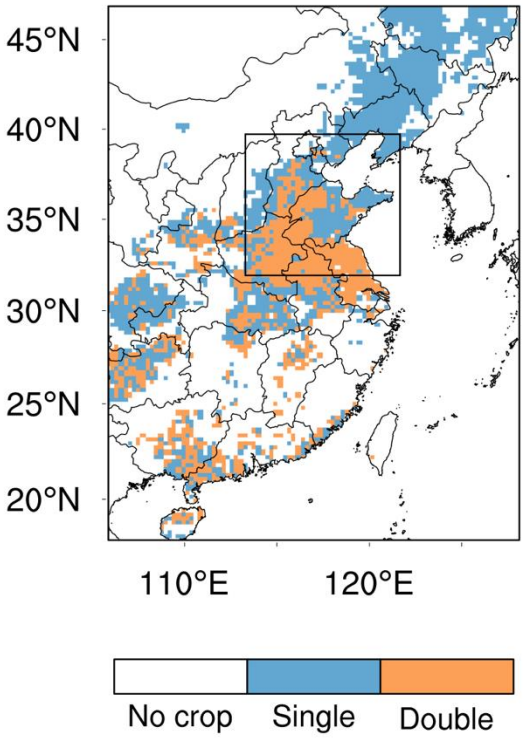
Crop Calendar



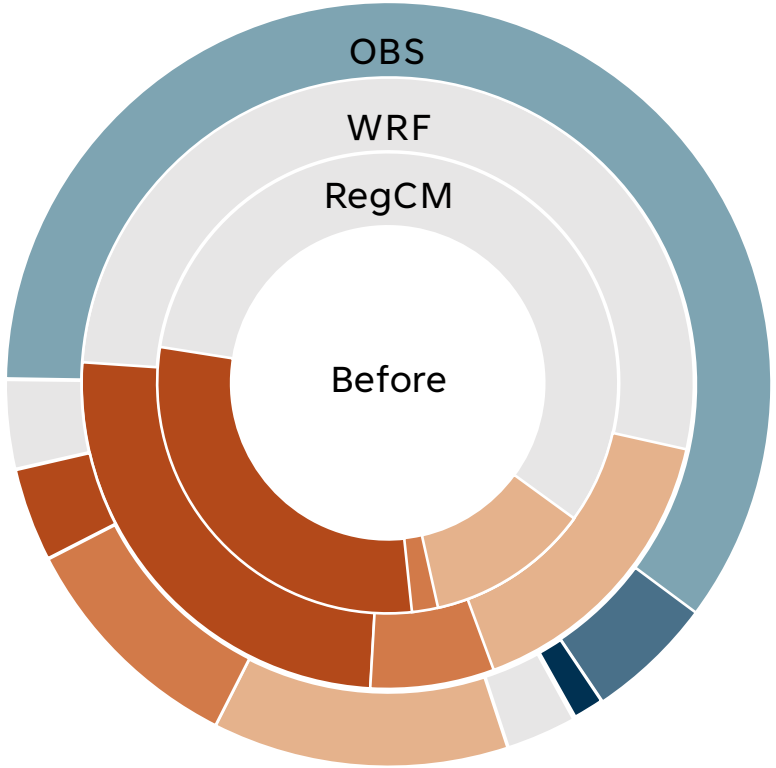
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar

Crop Rotation



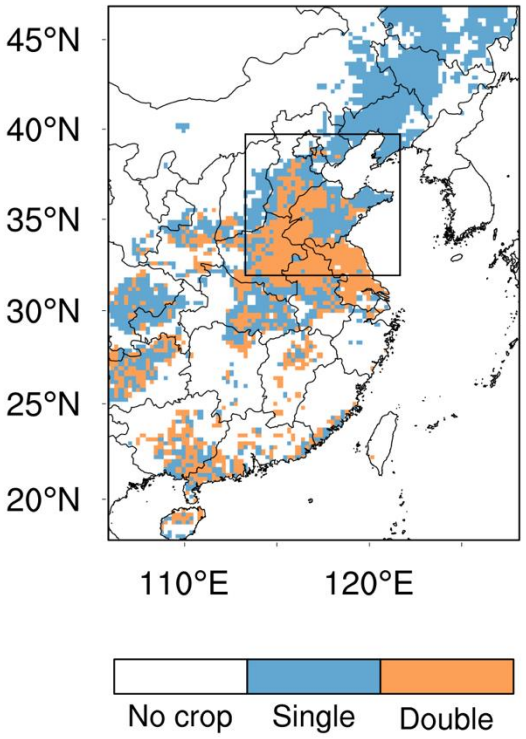
Crop Calendar Validation



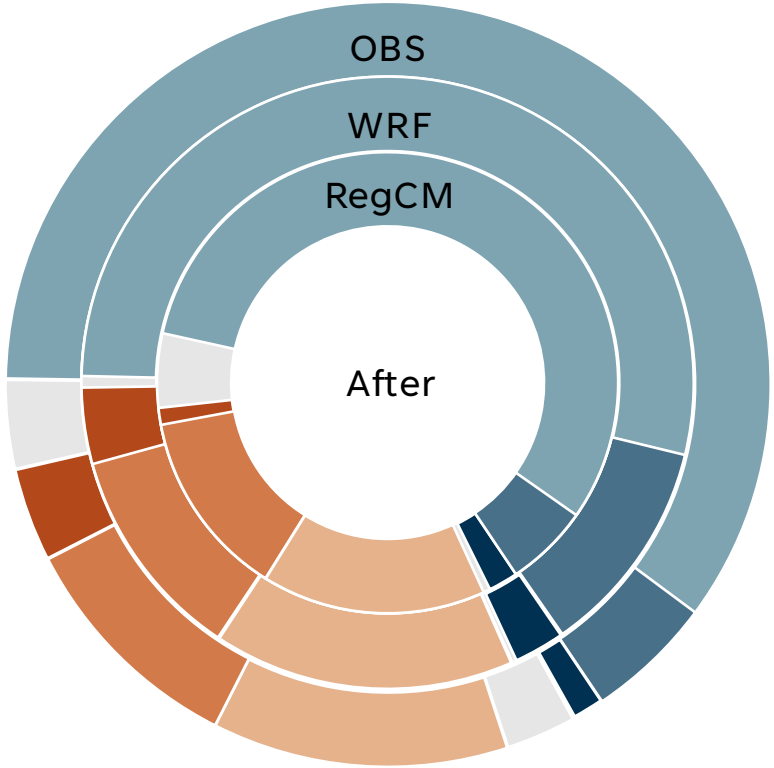
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar

Crop Rotation



Crop Calendar Validation



Model Development

- Irrigation
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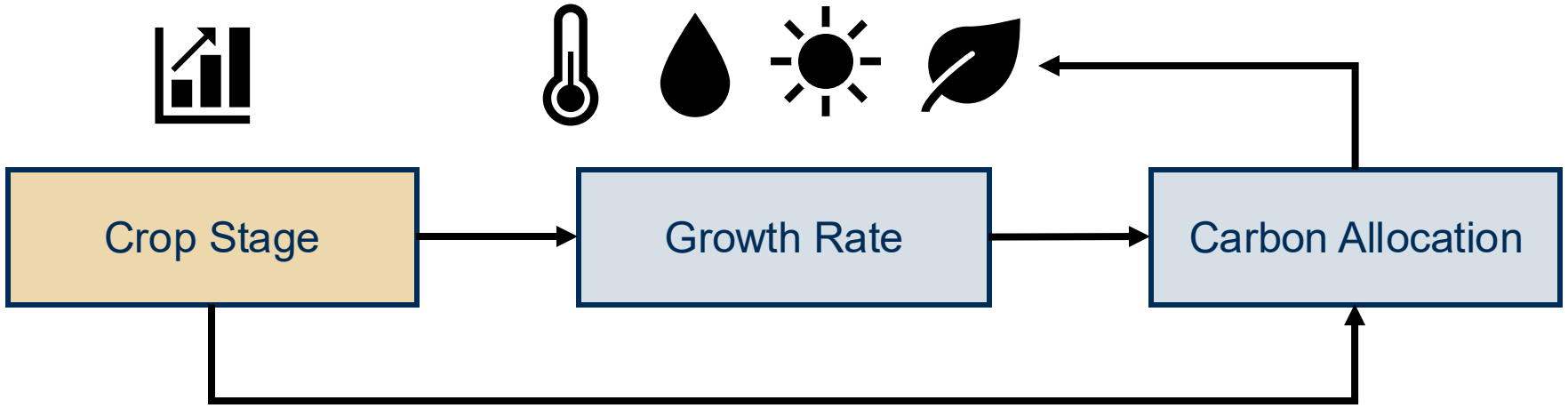
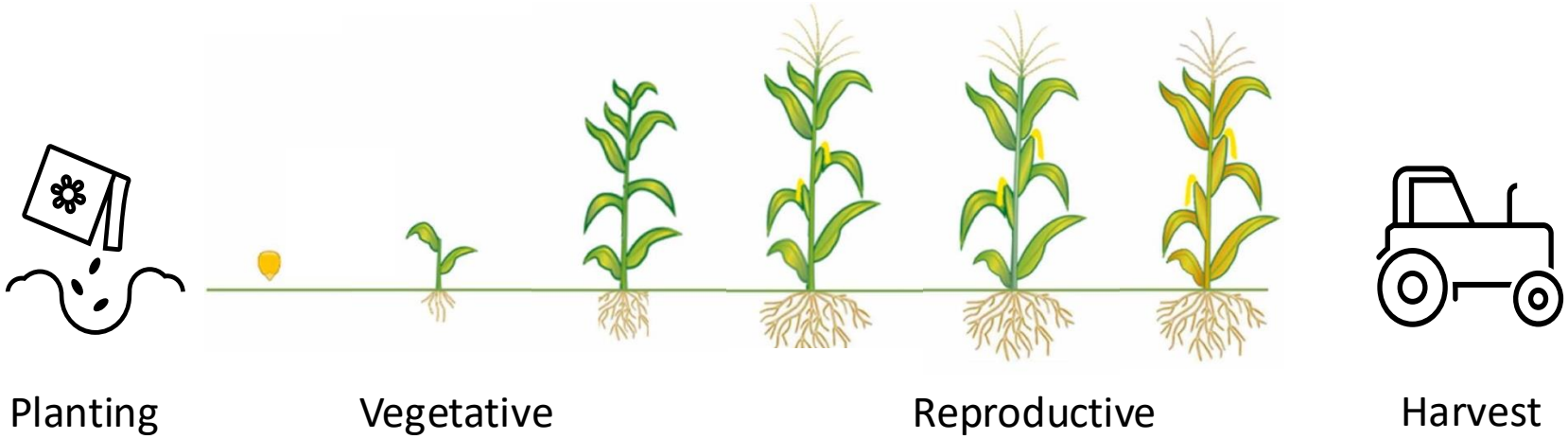
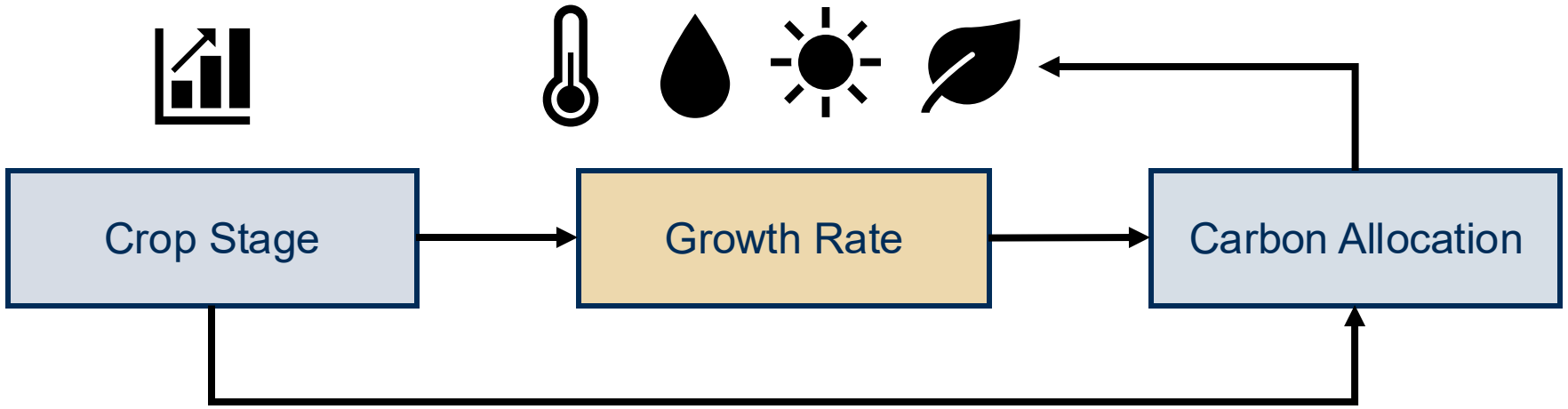
- Crop
  - Calendar

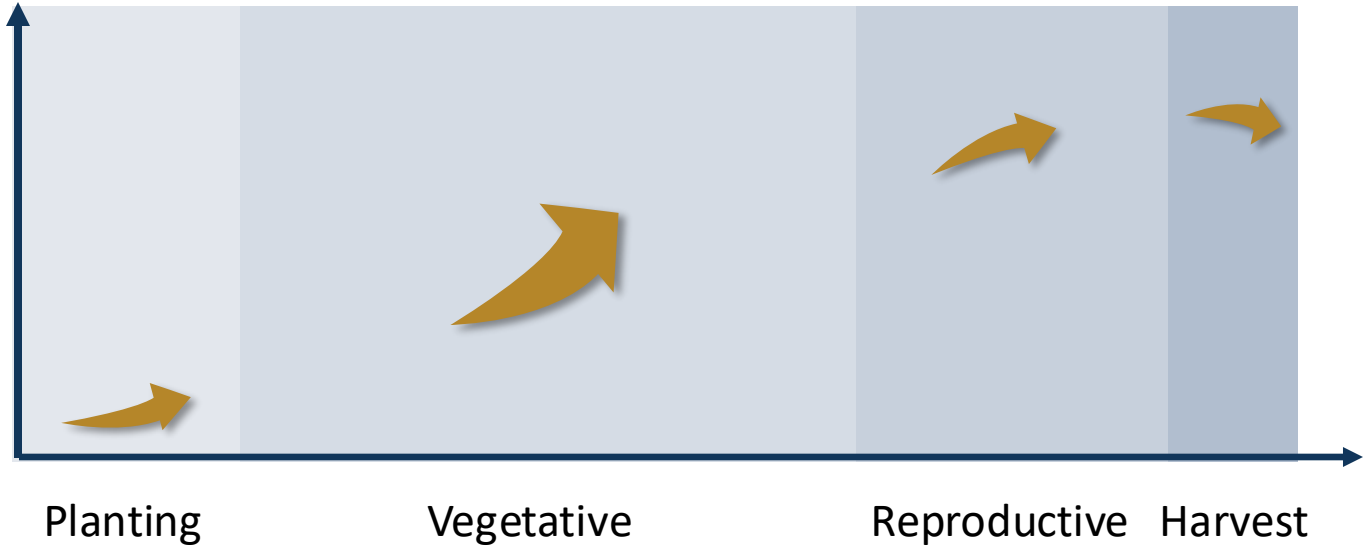




Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar
  - Biomass





Model Development

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  - Amount
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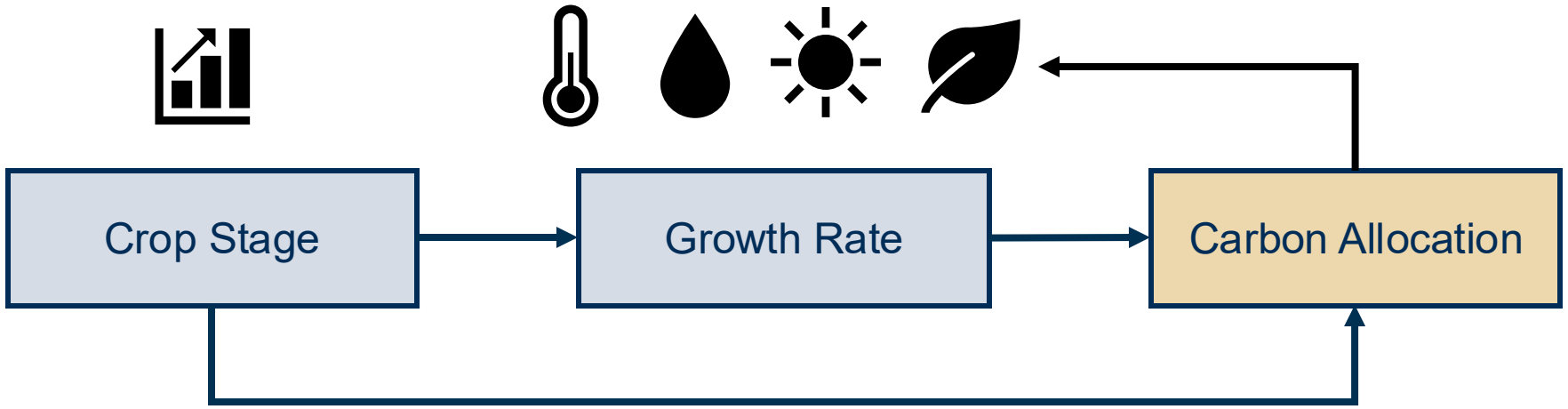
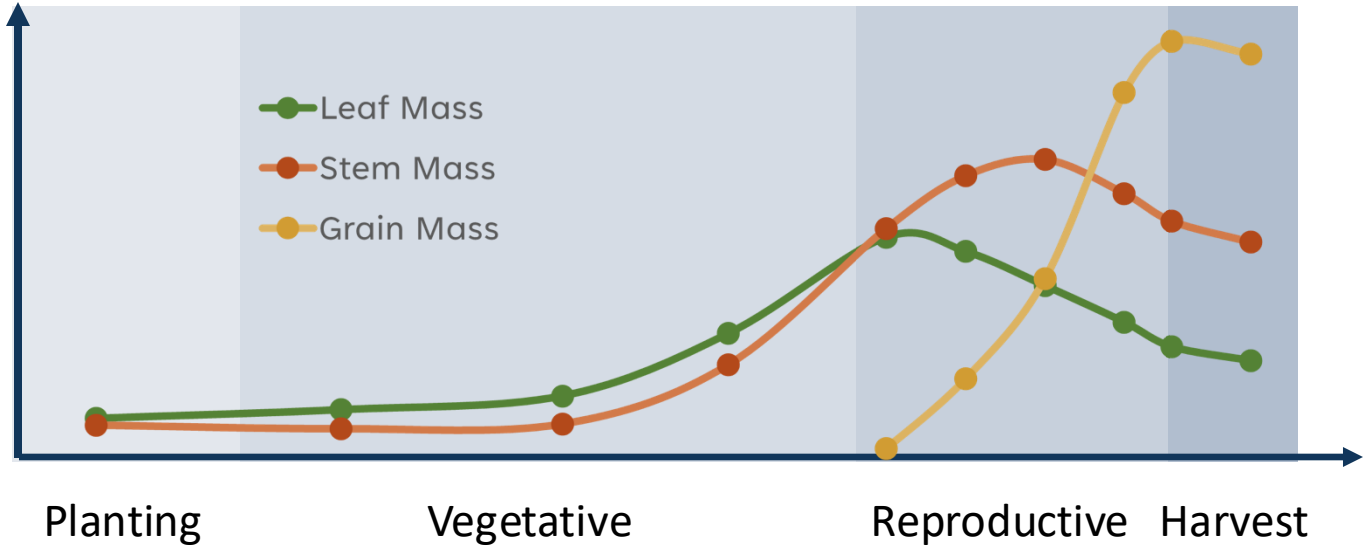
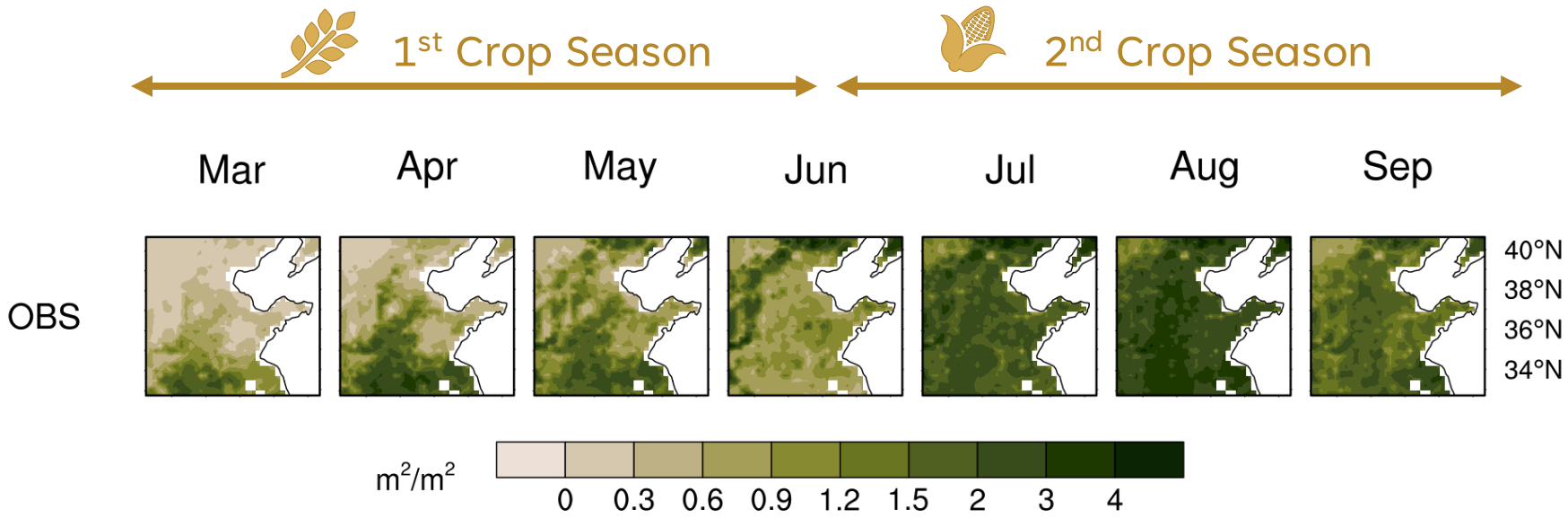




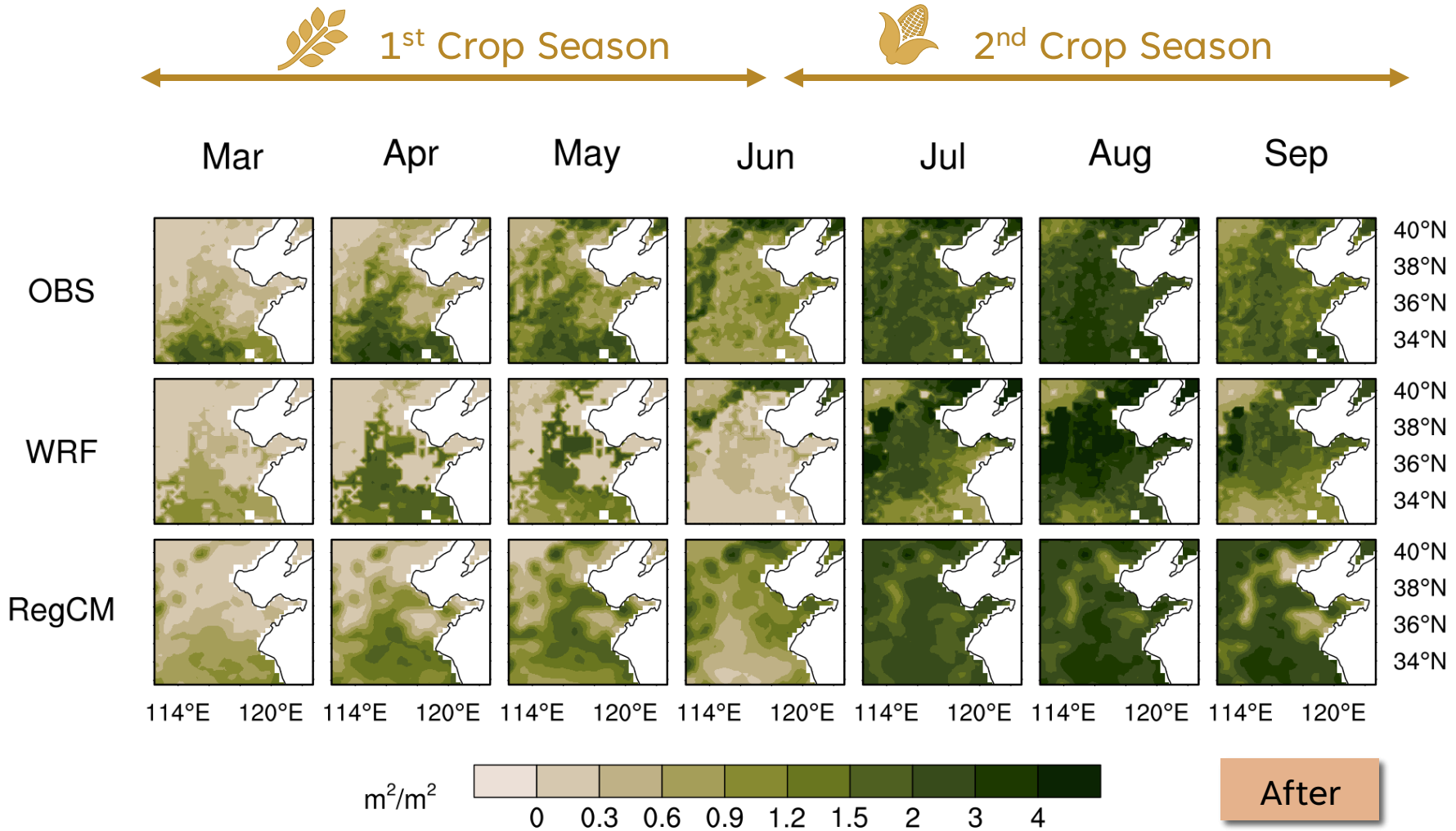
Model Development

- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar
  - Biomass
  - Leaf Area Index

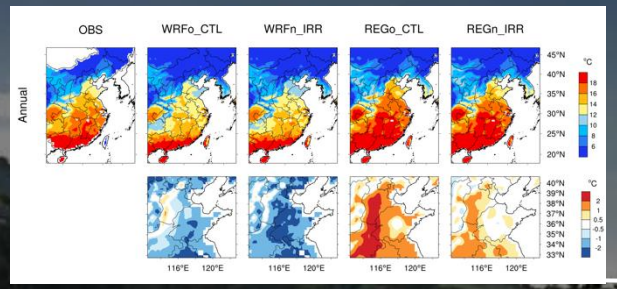


Model Development

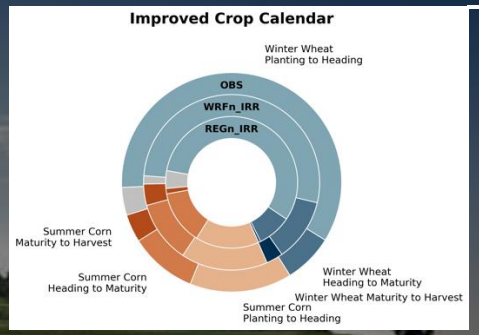
- Irrigation
  - Amount
- Groundwater
  - Pumping
- Crop
  - Calendar
  - Biomass
  - Leaf Area Index



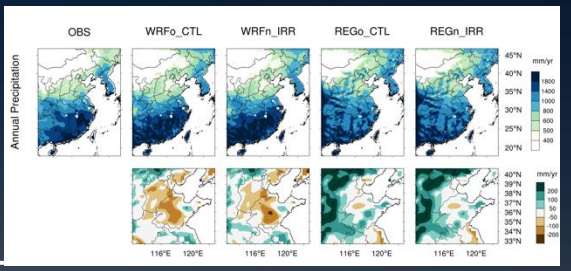
Model Performance



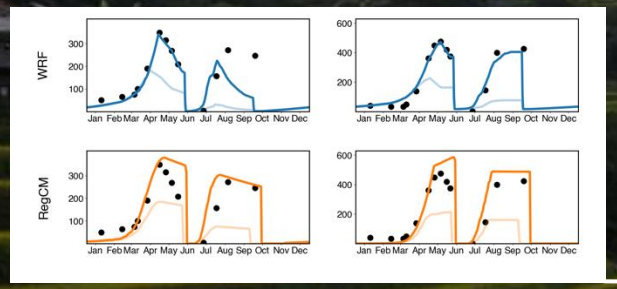
Temperature



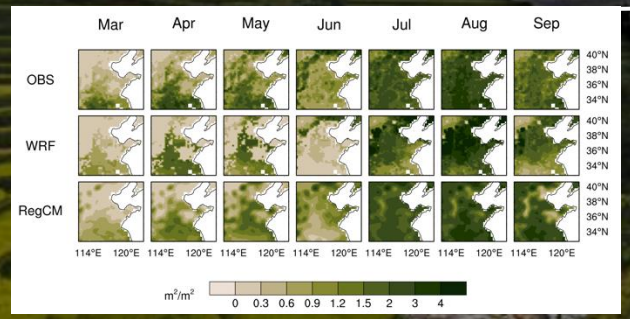
Calendar



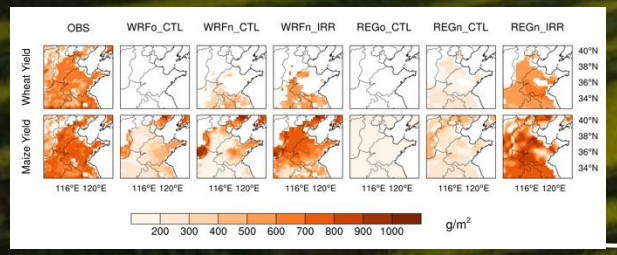
Precipitation



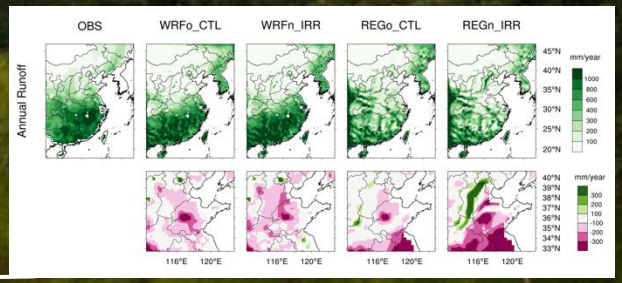
Biomass



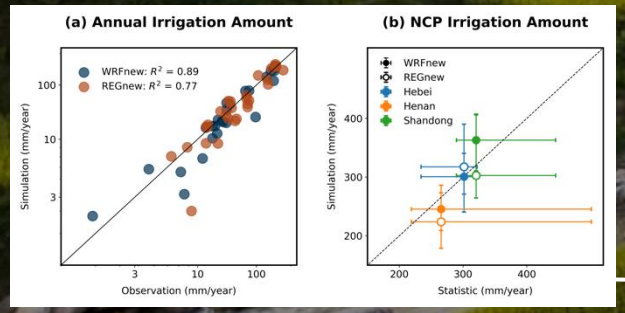
Leaf Area Index



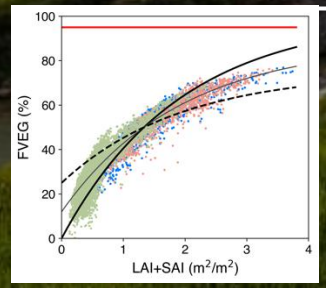
Crop Yield



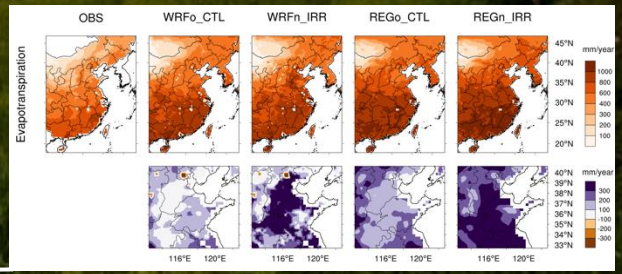
Runoff



Irrigation



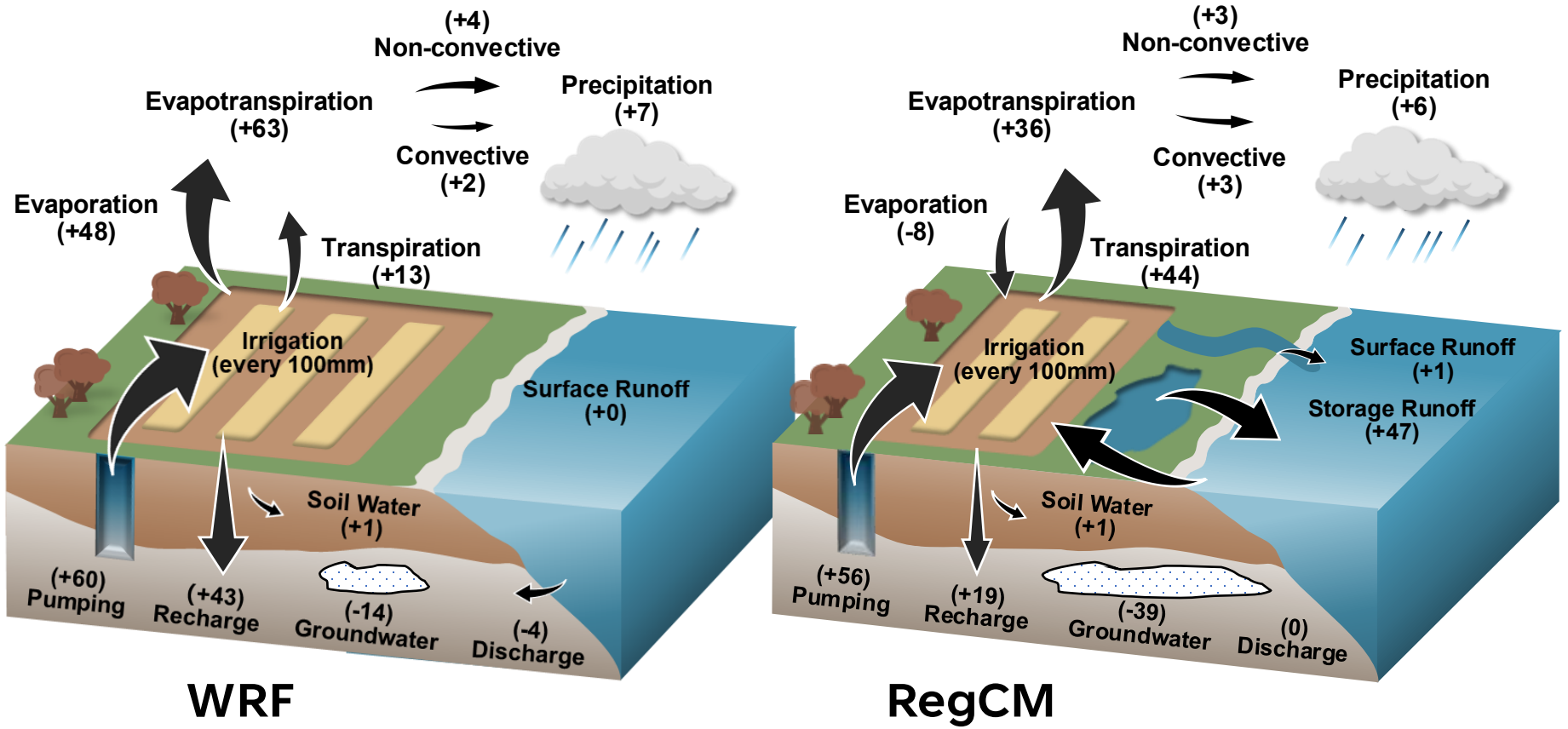
Greeness



Evapotranspiration

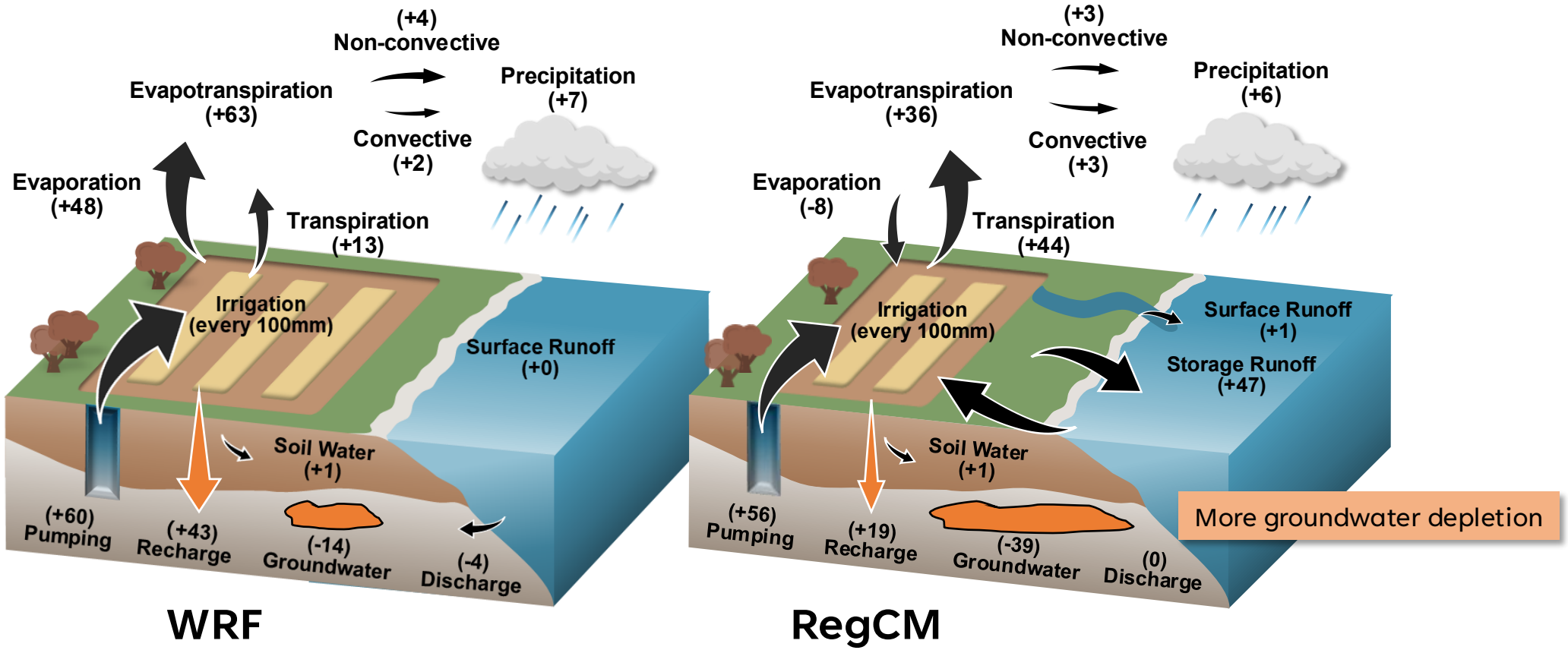
Impact: Water Cycle

RegCM has more runoff loss from water body storage.



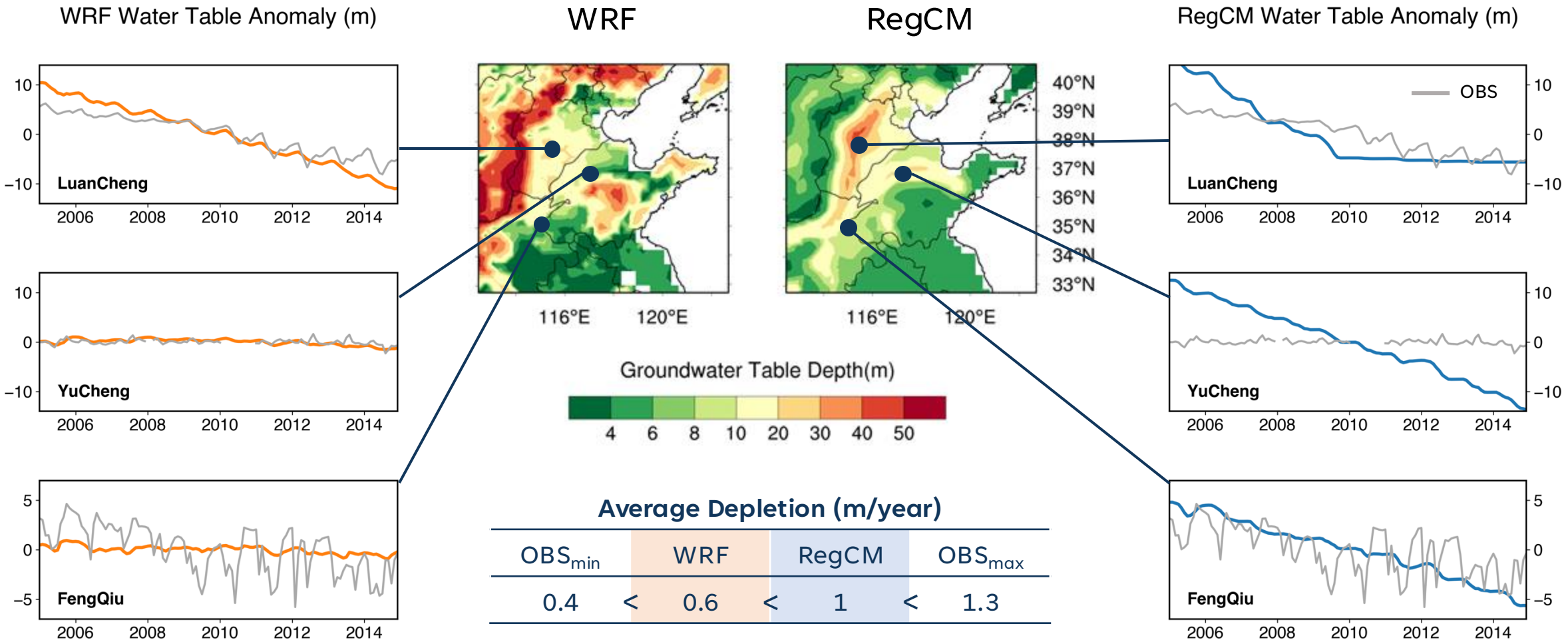
Impact: Water Cycle

Both model shows groundwater depletion, but more serious in RegCM.



Impact: Groundwater

More groundwater depletion

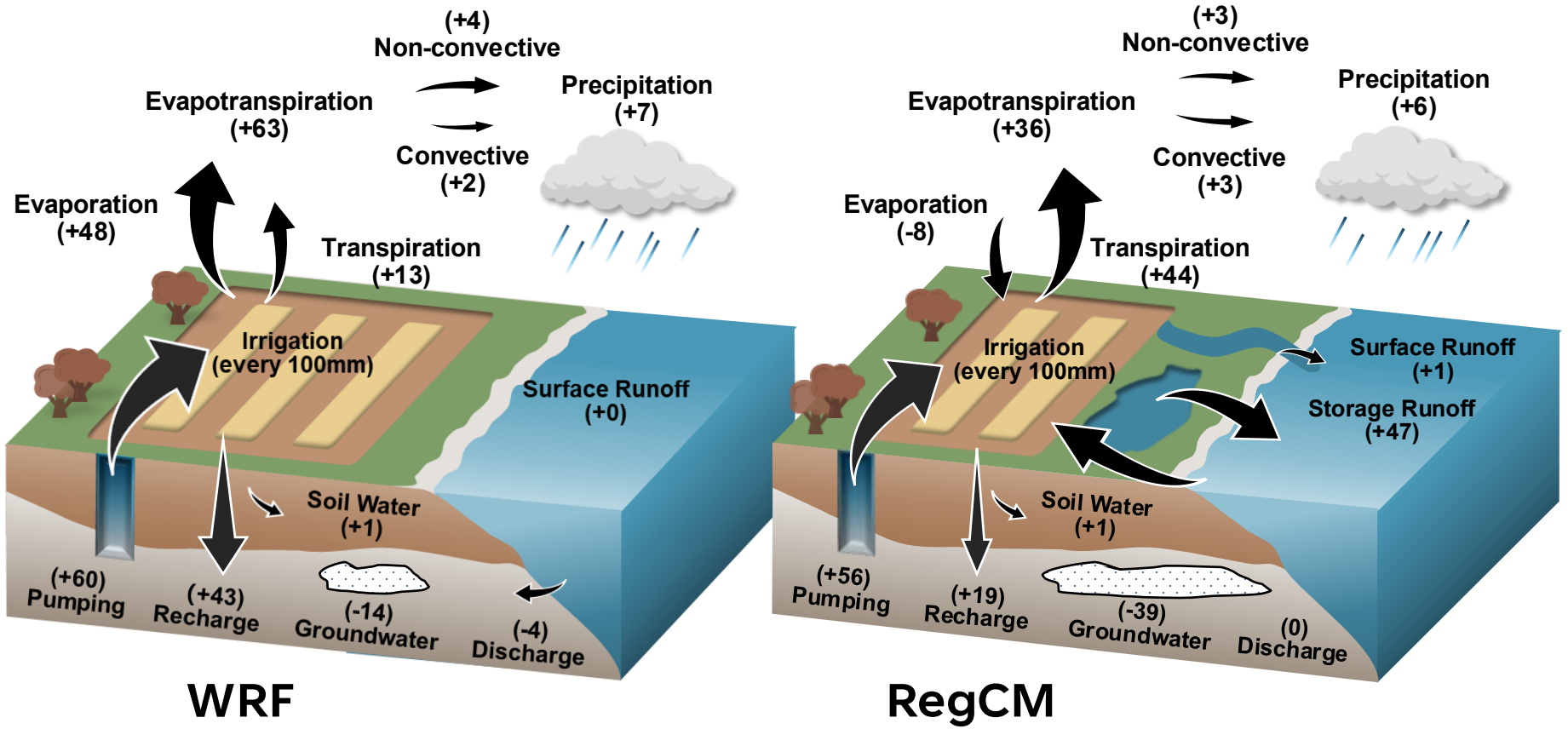


Average Depletion (m/year)

OBS_{min}		WRF		RegCM		OBS_{max}
0.4	<	0.6	<	1	<	1.3

Impact: Water Cycle

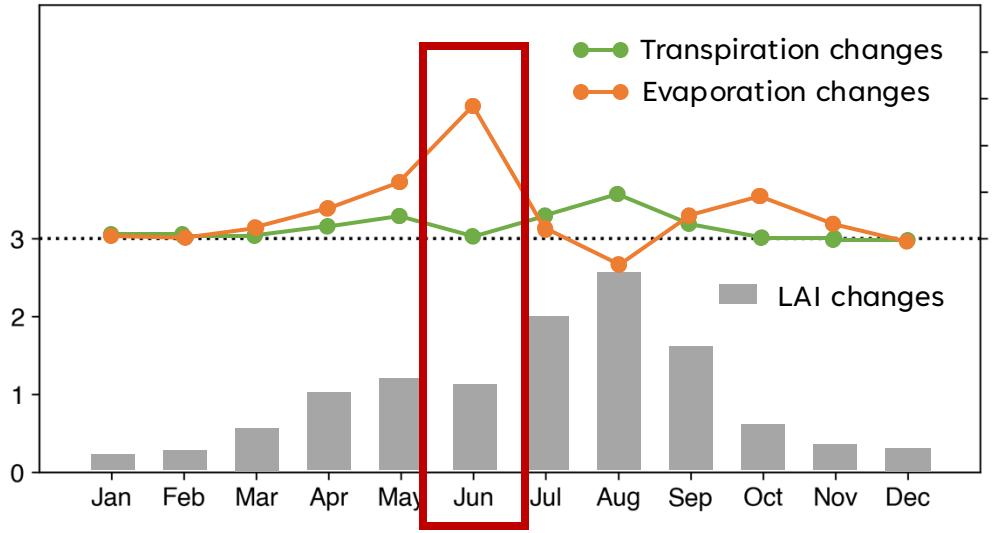
ET increases, but WRF and RegCM has different ET partition.



Impact: ET Partition

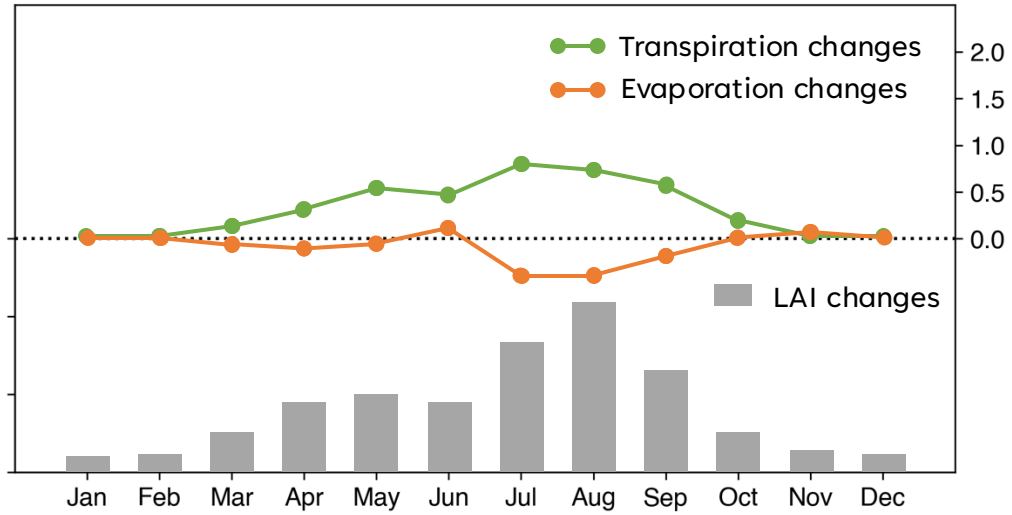
Transpiration ↑ during vegetated period

Evaporation ↑ during rotation period (more bareland)



Transpiration ↑ during vegetated period

Evaporation even ↓ due to regional cooling



Impact: ET Partition

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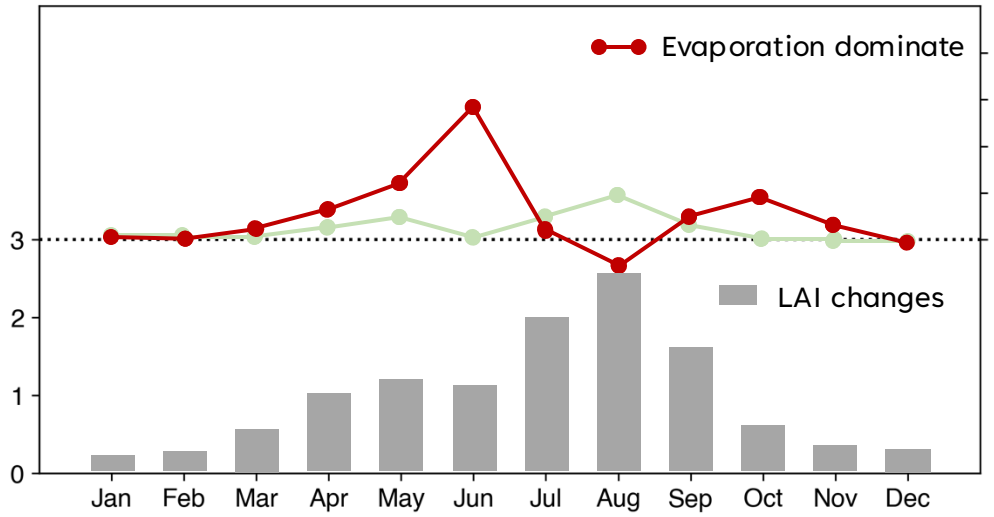

Transpiration ↑ during vegetated period

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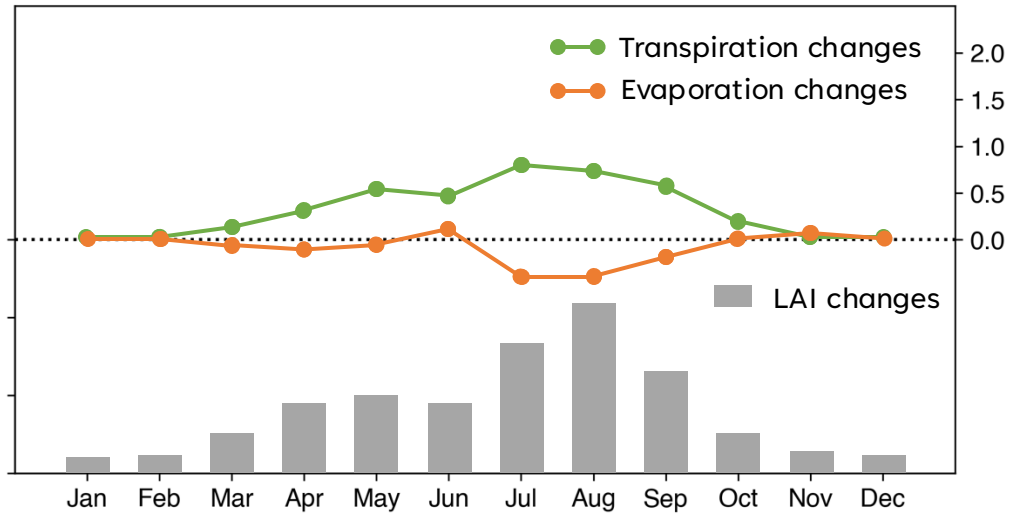
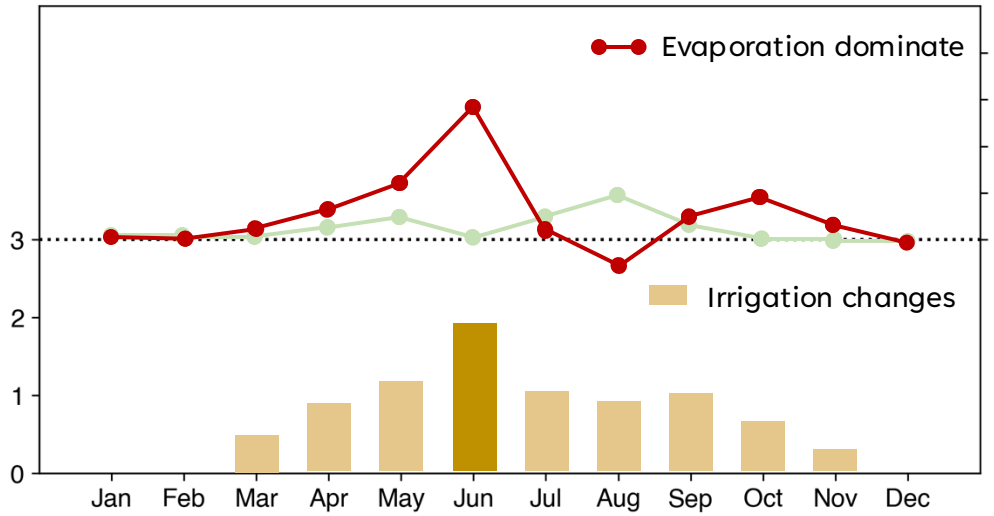


Impact: ET Partition

Transpiration ↑ during vegetated period

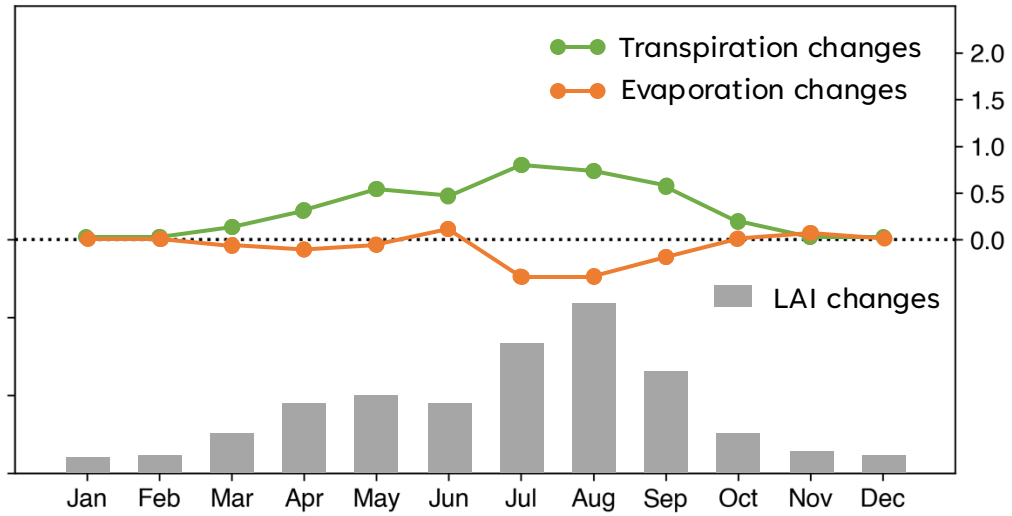
Evaporation ↑ during rotation period (more bareland)

Affected by evaporation, irrigation peaks in June



Transpiration ↑ during vegetated period

Evaporation even ↓ due to regional cooling



Impact: ET Partition

Transpiration ↑ during vegetated period

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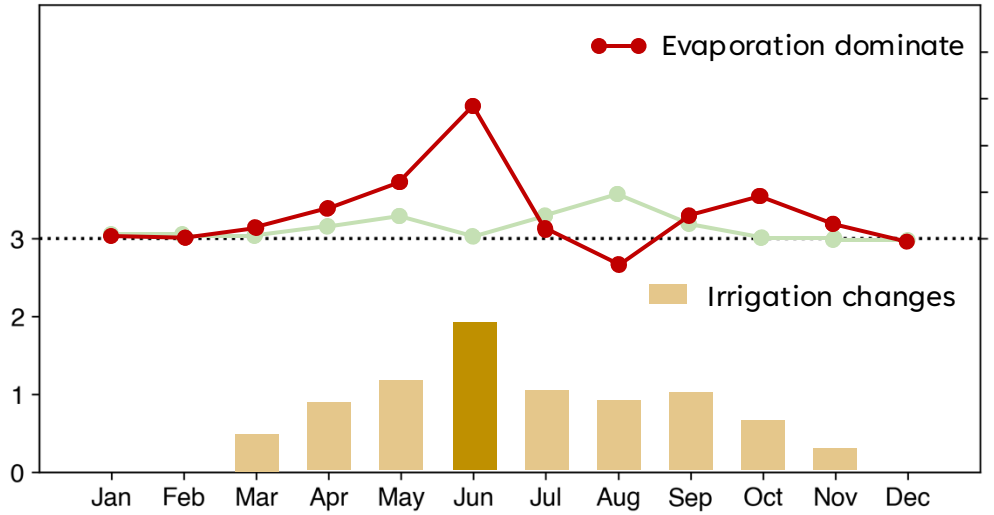
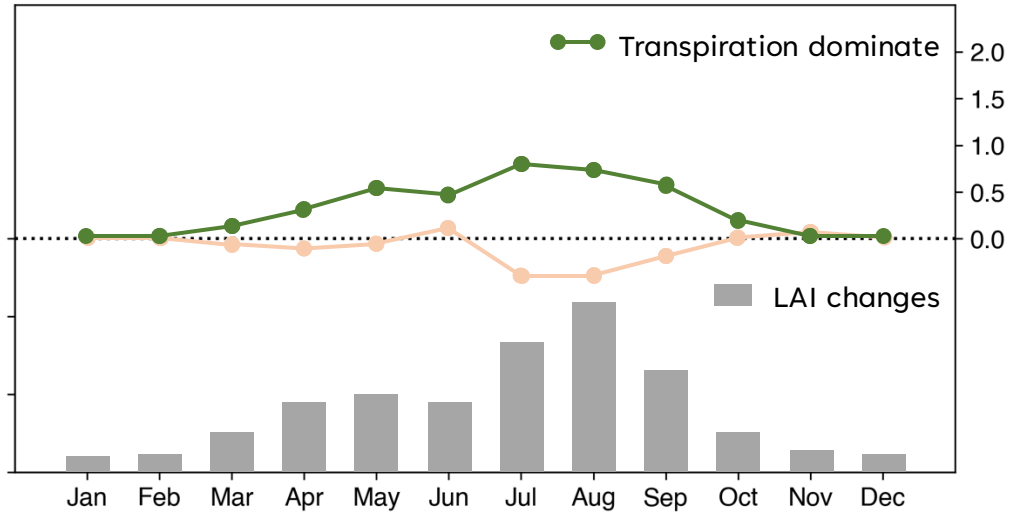
Affected by evaporation, irrigation peaks in June



Transpiration ↑ during vegetated period

Evaporation even ↓ due to regional cooling

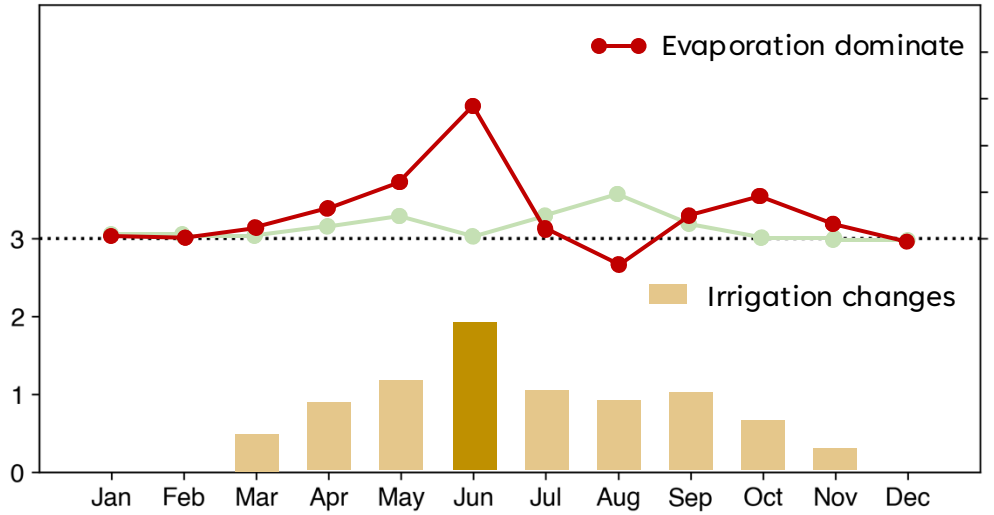


Impact: ET Partition

Transpiration ↑ during vegetated period

Evaporation ↑ during rotation period (more bareland)

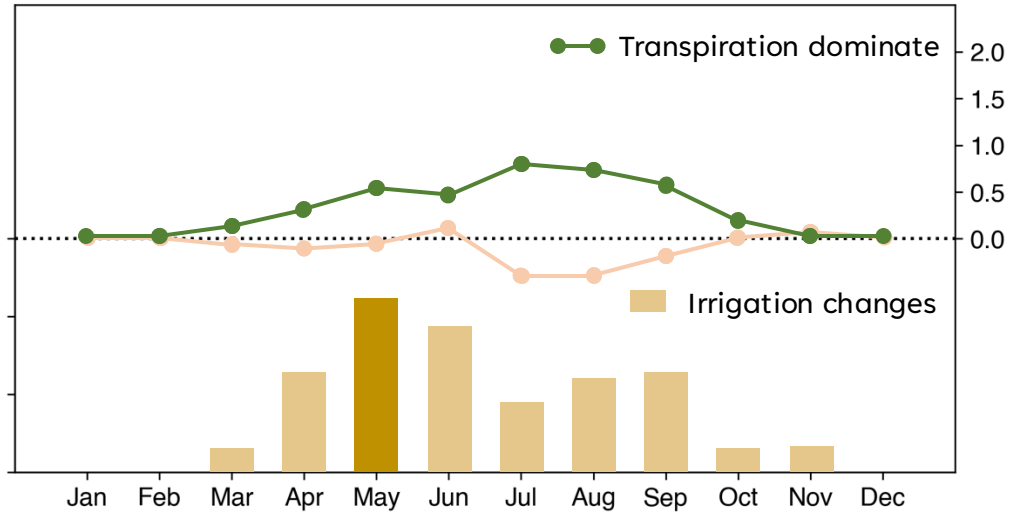
Affected by evaporation, irrigation peaks in June



Transpiration ↑ during vegetated period

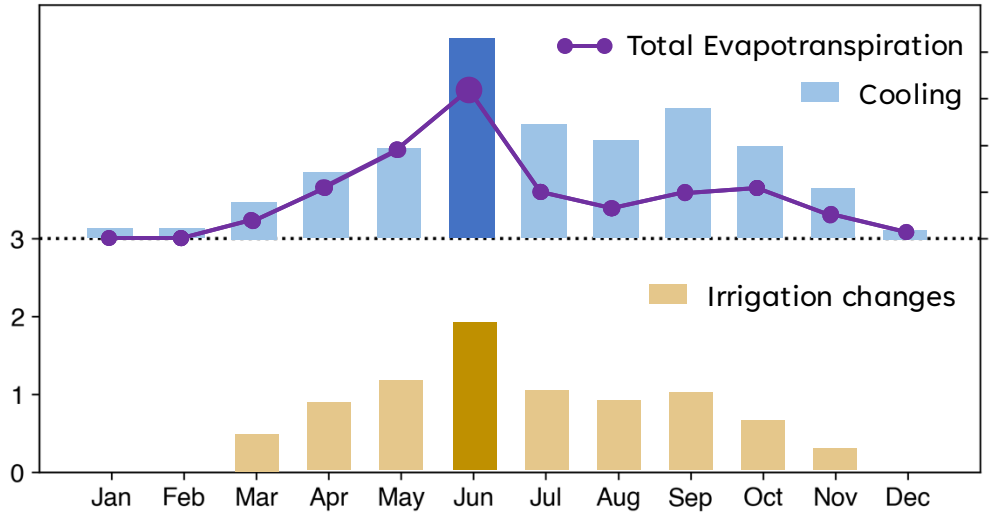
Evaporation even ↓ due to regional cooling

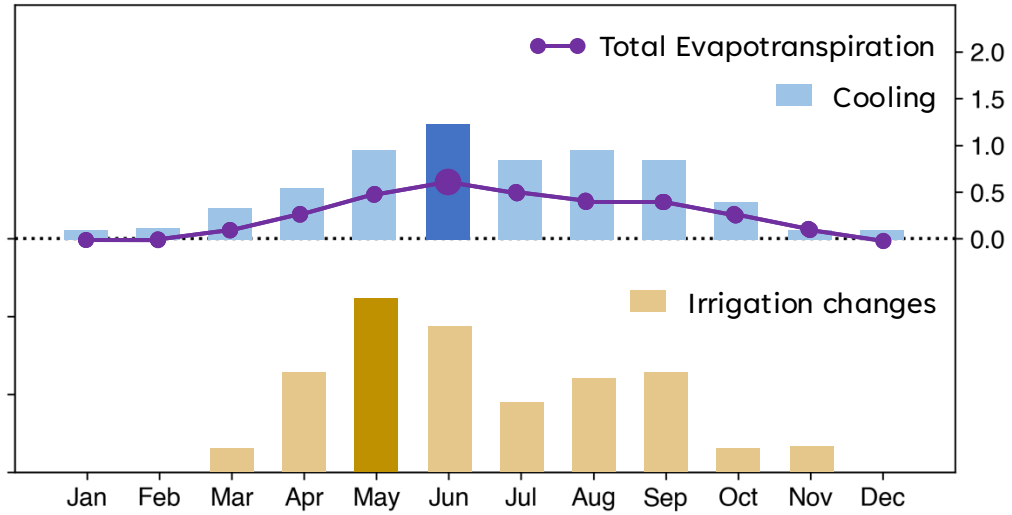
Affected by transpiration, irrigation peaks in May



Impact: ET Partition

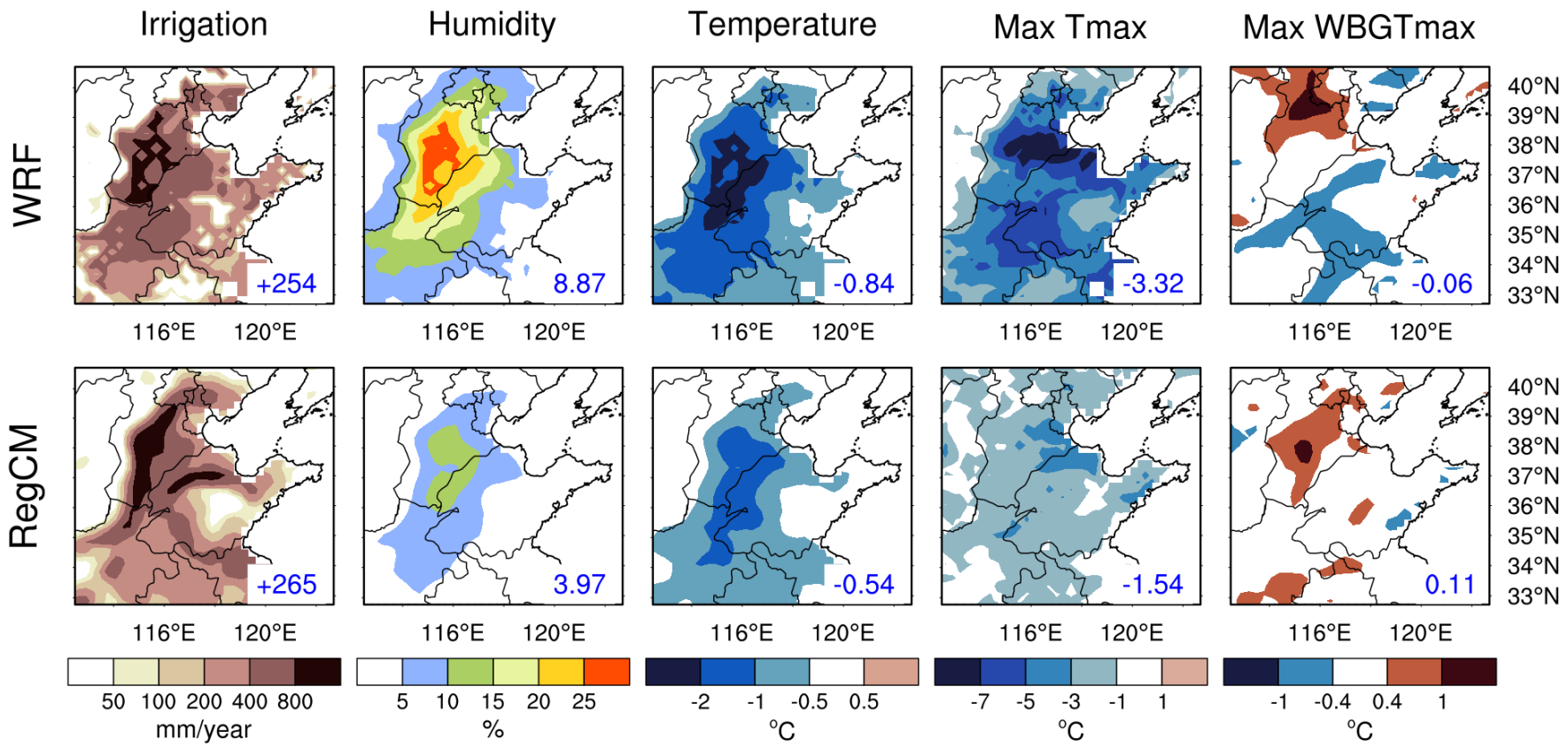
Even though seasonal pattern of irrigation are different,
the seasonal pattern of cooling are consistent.





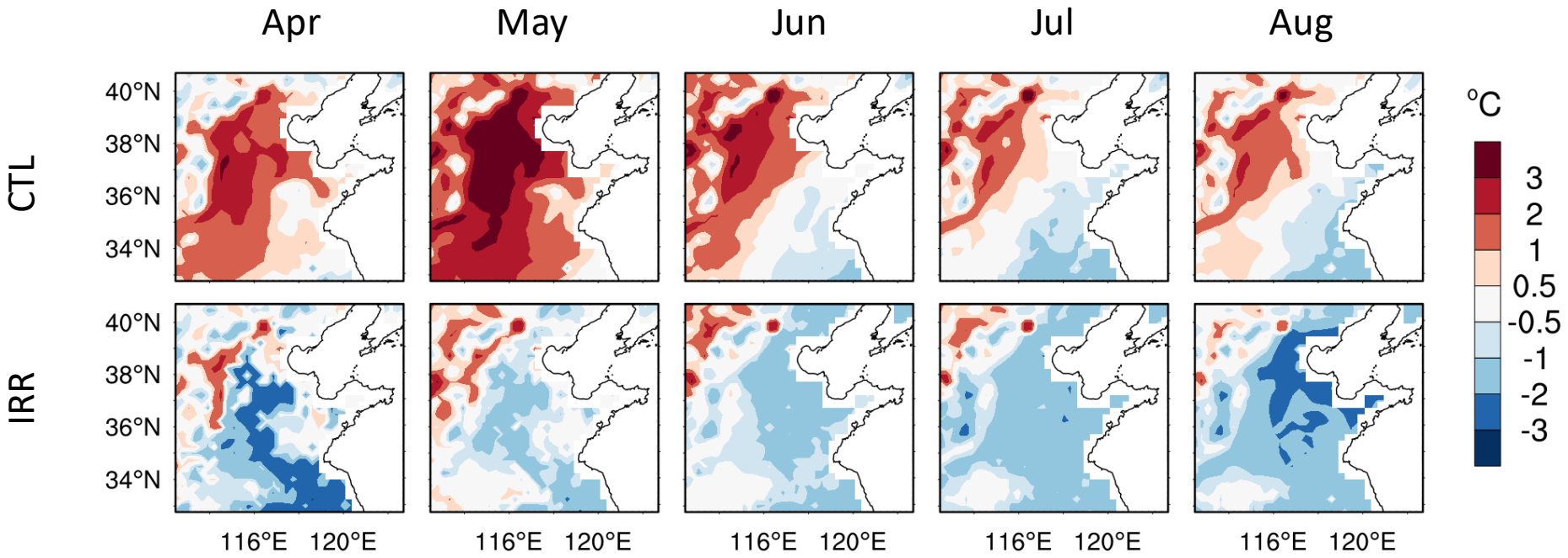
Impact: Cooling

Irrigation causes a general cooling.
Extreme heat may become intensified when considering humidity.



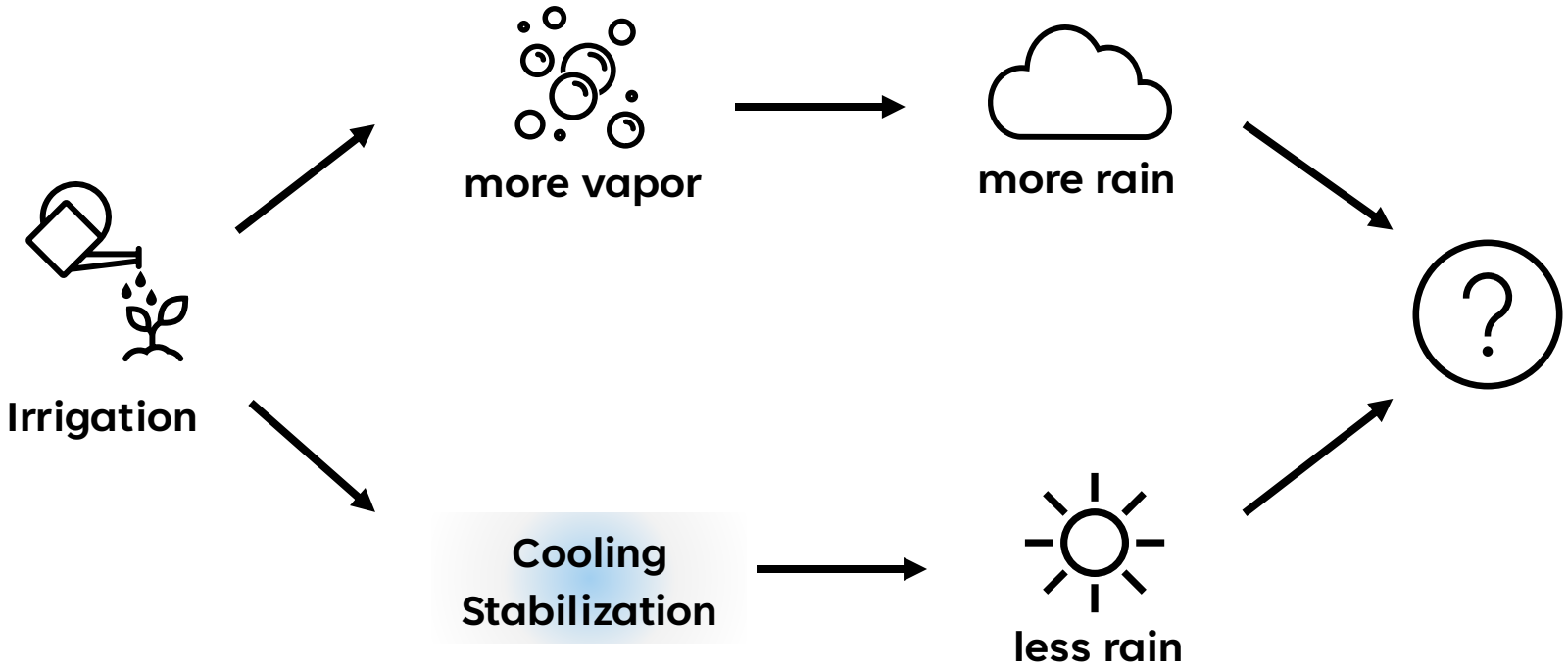
Impact: Cooling

Irrigation causes a general cooling.
This helps to reduce the original warm bias.



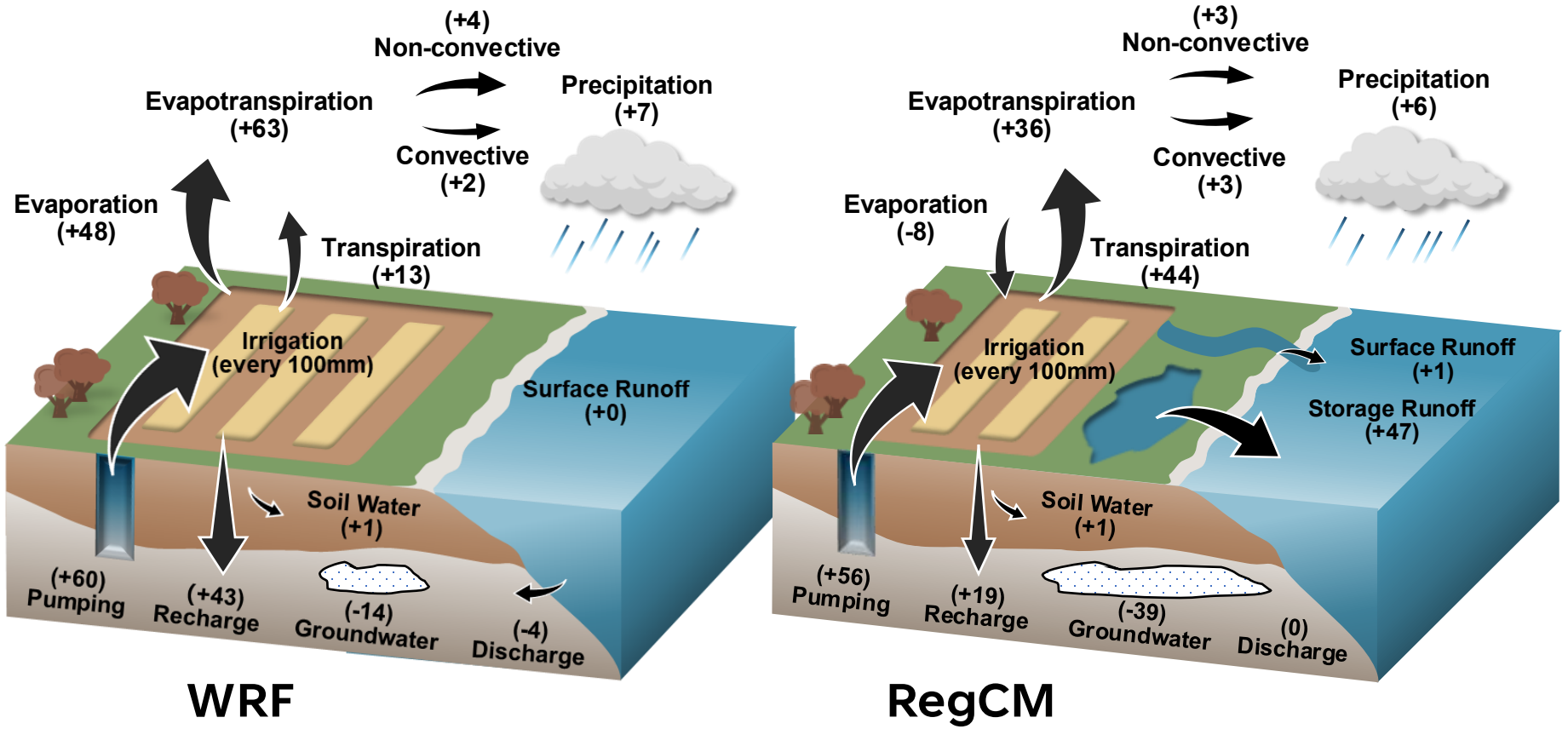
Complex Precipitation

Irrigation has a non-linear impact on precipitation.



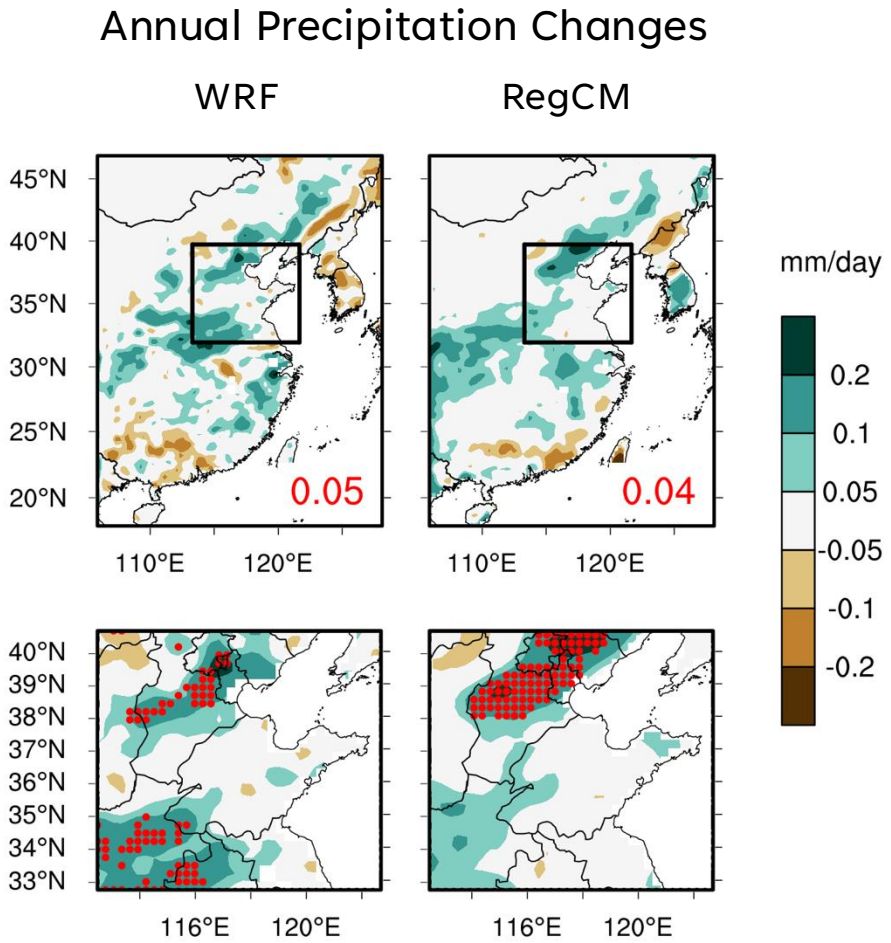
Impact: Water Cycle

Consistent precipitation increases although land processes are different.



Impact: Precipitation

Consistent Annual Precipitation Pattern

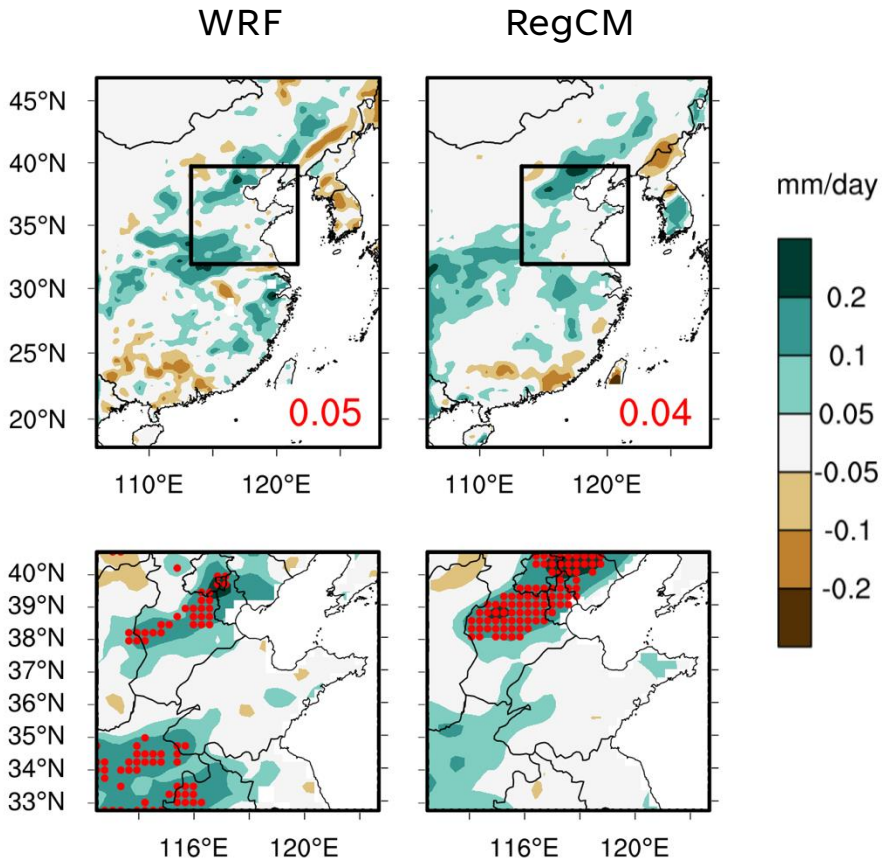


Red dots:
(1) p<0.05
(2) >30mm/year
(3) >5% increase
(4) ≥7 years

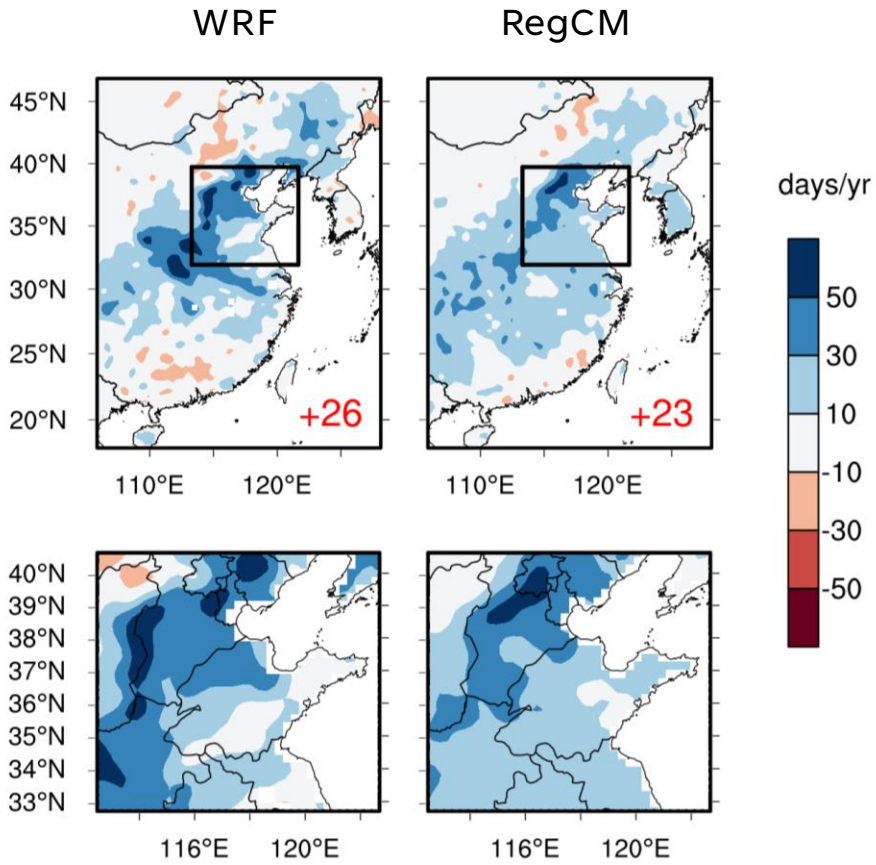
Impact: Precipitation

Irrigation promoting precipitation by increasing frequency.

Annual Precipitation Changes



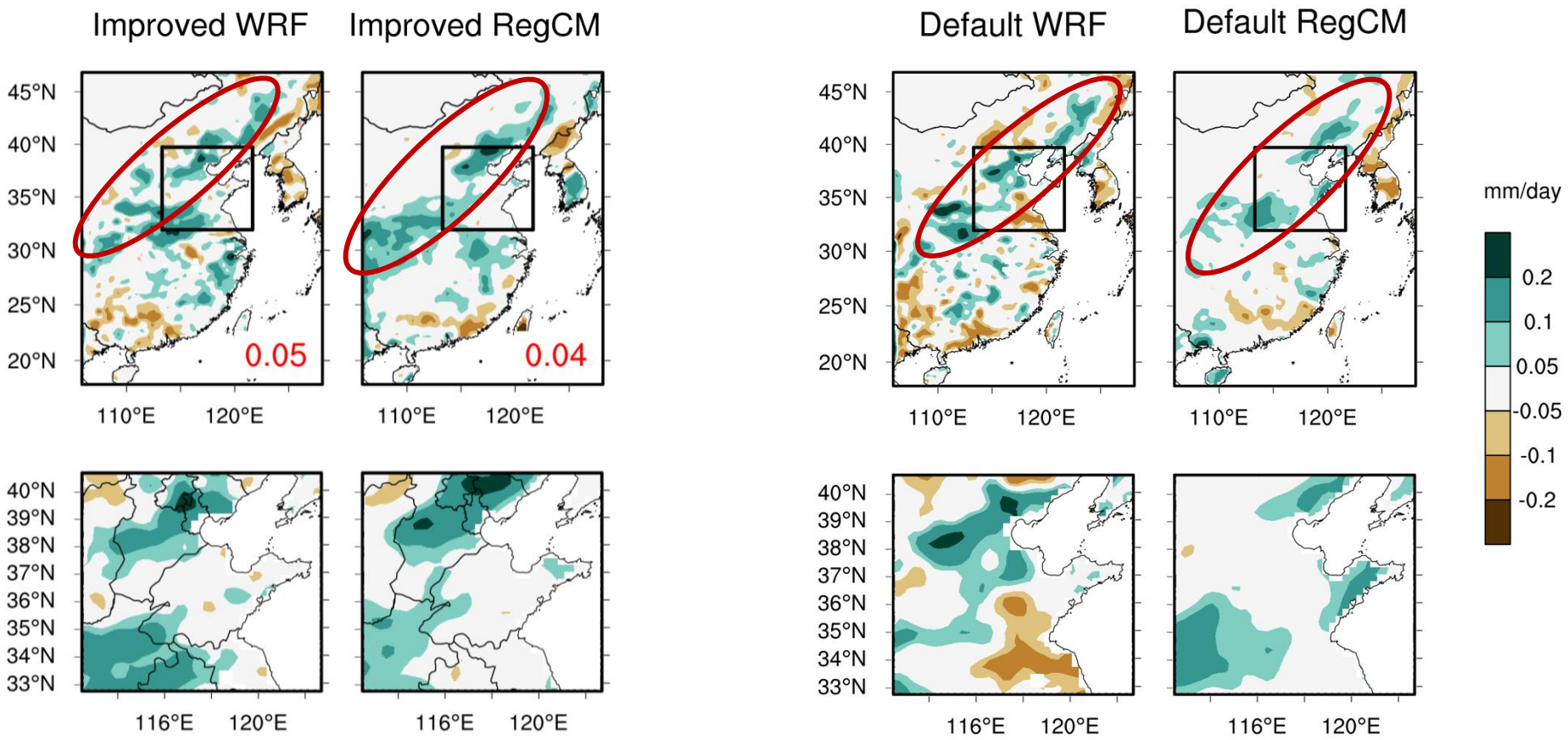
Frequency Changes (days >1mm)



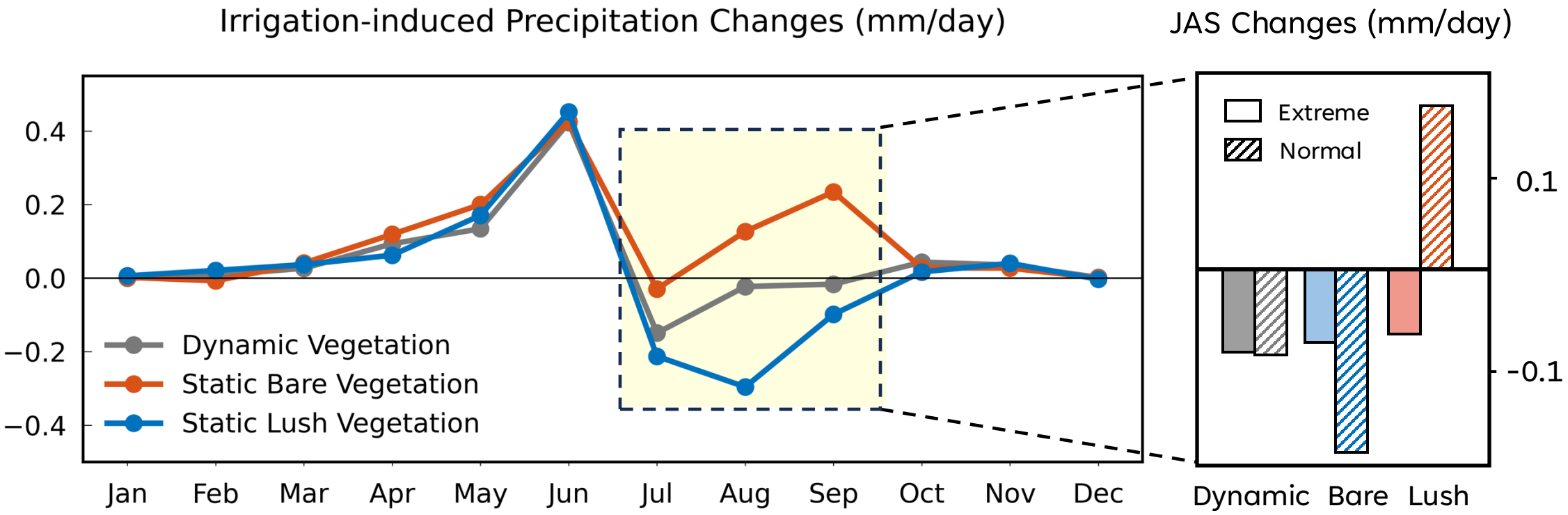
Red dots:
(1) p<0.05
(2) >30mm/year
(3) >5% increase
(4) ≥7 years

Significance

Better irrigation representation can increase model consistency.



Significance of Vegetation



Model deficiency may cause great uncertainty in irrigation impact.

Conclusion

Model-dependency

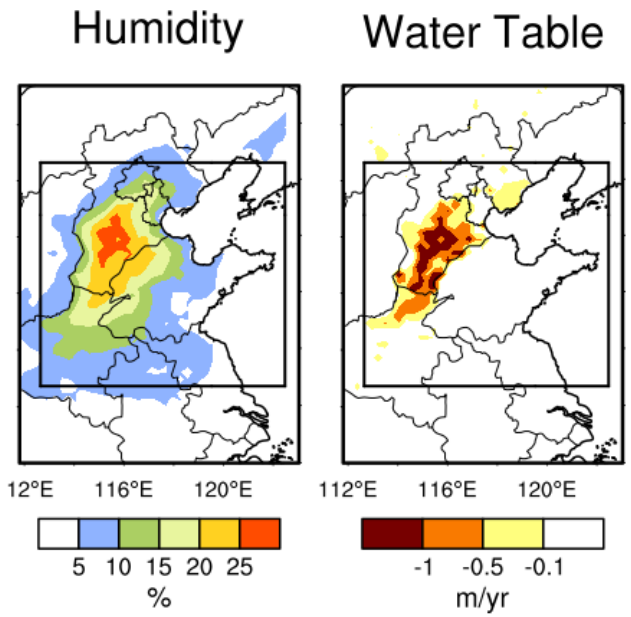
Title: Regional Climate Modeling of Anthropogenic Water Cycle Perturbation: Focus on Irrigation

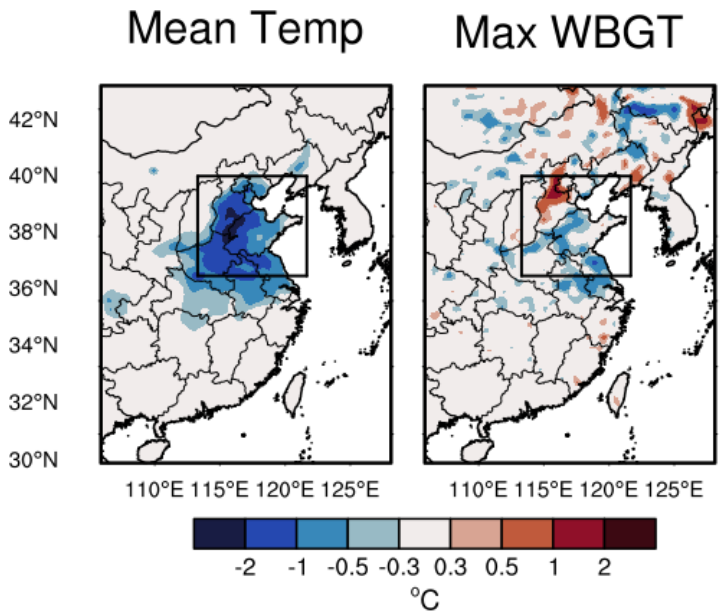
Integration

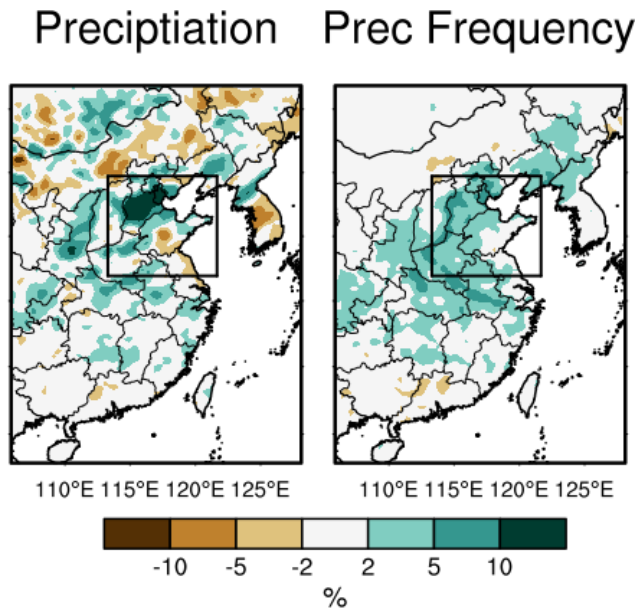
Regionalization

Model Development	Significant Study	Irrigation Impact
VALIDATED	PROVED	ASSESSED

Consistent Findings







Water Cycle:

Humidity upto **+25/+10%**

GW depletion **-0.6/-1 m/yr**

Extreme Heat:

Temperature **-0.8/-0.5°C**

$WBGT_{max}$ **+1°C** in northern part

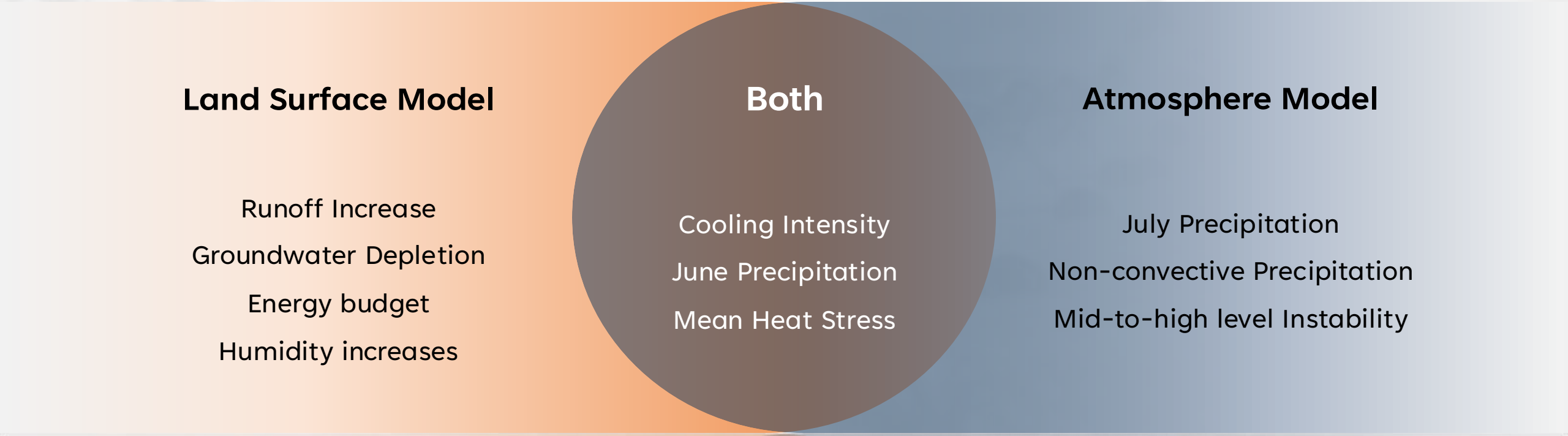
Precipitation Pattern:

Annually up to **+10%**

More frequent **drizzles**

Inconsistency Identification

Necessity of better land representations and multi-model comparison



Publication

2022

Journal of Hydrometeorology

Irrigation impact with current models
Recognize the modelling deficiency

WRF Development

Geoscientific Model Development

npj Climate and Atmospheric Science

Irrigation impact with improved model

Significance assessment of model improvement

Geophysical Research Letters

In preparation

RegCM Development

2025

Inter-model Comparison

In preparation

Fan, Y., and Im, E.-S. (2025). The Role of Vegetation Dynamics in Assessing Irrigation Impacts. Geophysical Research Letters.

Fan, Y., Yang, Z., Lo, M.-H., Hur, J., & Im, E.-S. (2025). Deciphering the Capricious Precipitation Response: Irrigation Impact in the North China Plain. npj Climate and Atmospheric Science.

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.

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.