

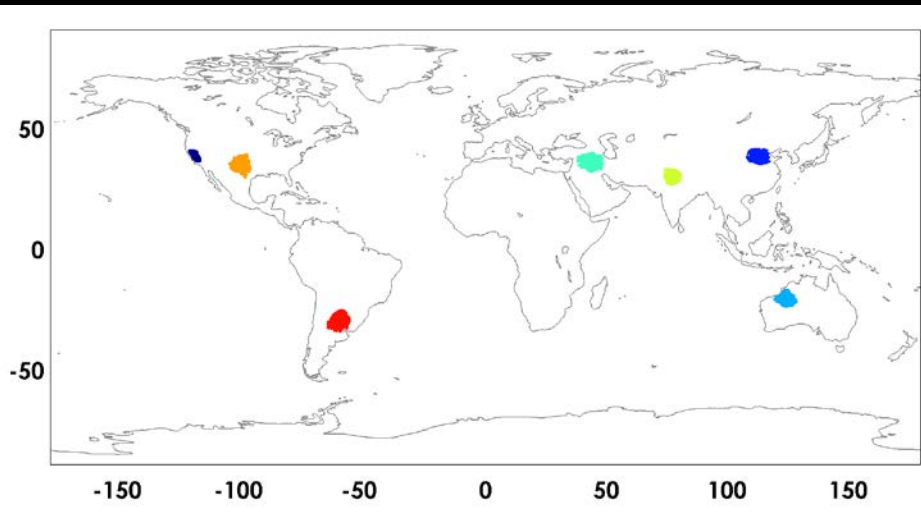
THE CONTRASTING IMPACTS OF CLIMATE CHANGE ON GROUNDWATER IN MID-LATITUDE AQUIFERS

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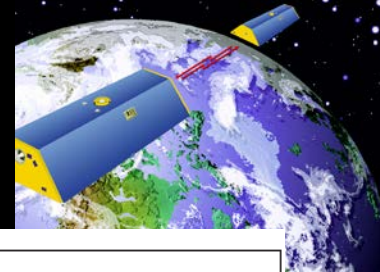
2016/10/03-05 @ 1st I-GEM Workshop, Paris



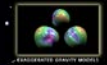
Groundwater crisis

Measuring Earth's Gravity from Space

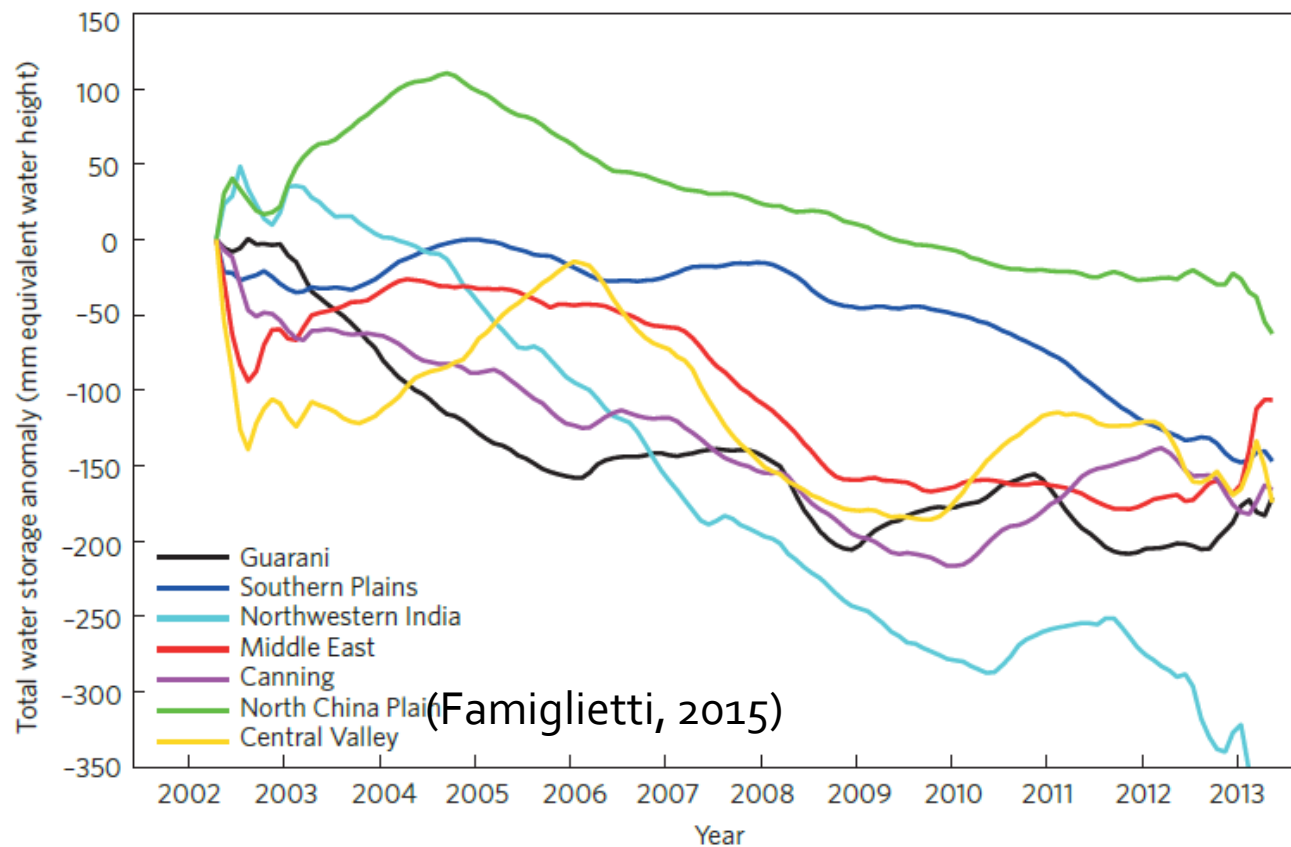
GRACE
Gravity Recovery and Climate Experiment



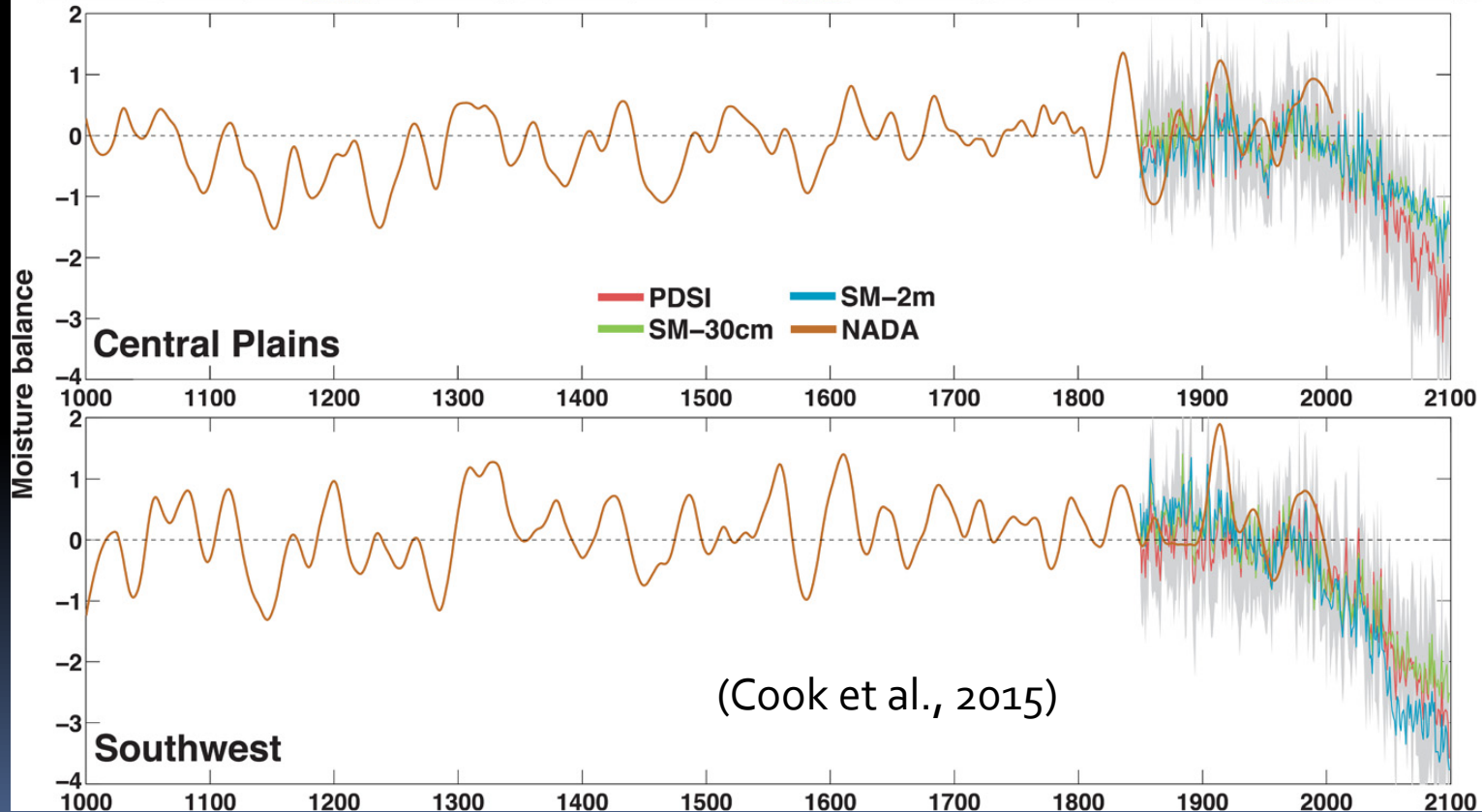
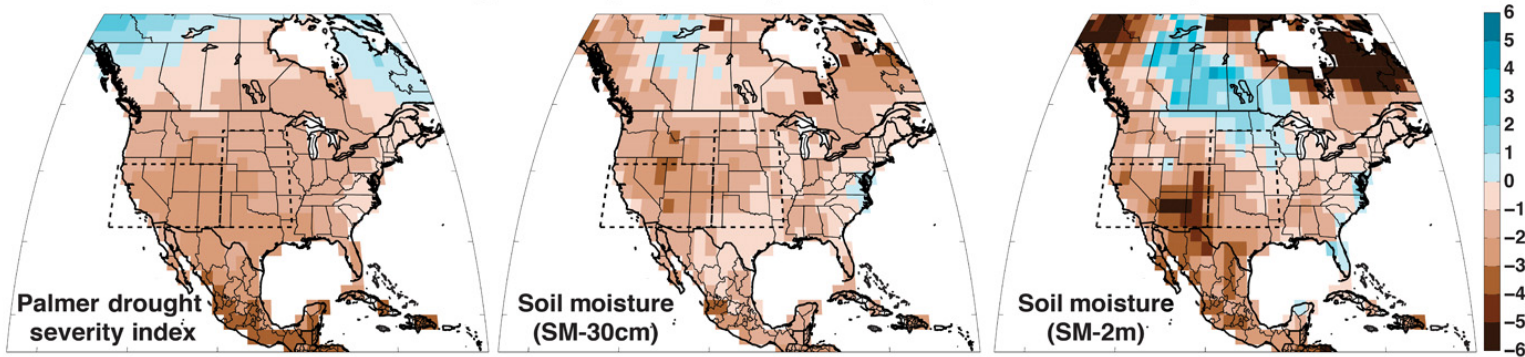
The Gravity Recovery and Climate Experiment (GRACE) is a joint mission between NASA and the German Aerospace Establishment (DLR). It consists of two identical satellites, which orbit the Earth in tandem, measuring the Earth's gravity field by tracking the distance between them. This data is used to monitor changes in the Earth's mass distribution, such as the melting of ice sheets and the depletion of groundwater resources.



<http://www.nasa.gov/mission/grace/>



CMIP5 Drought Projections (RCP 8.5, 2050-2099 CE)



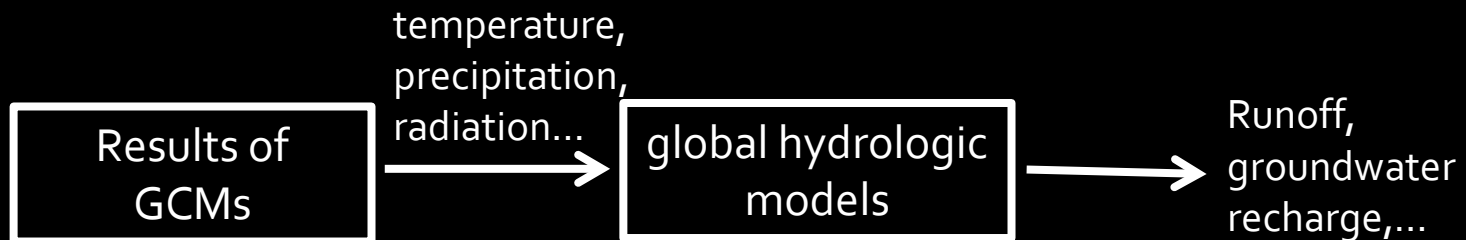


How about future groundwater
changes?



Previous Studies

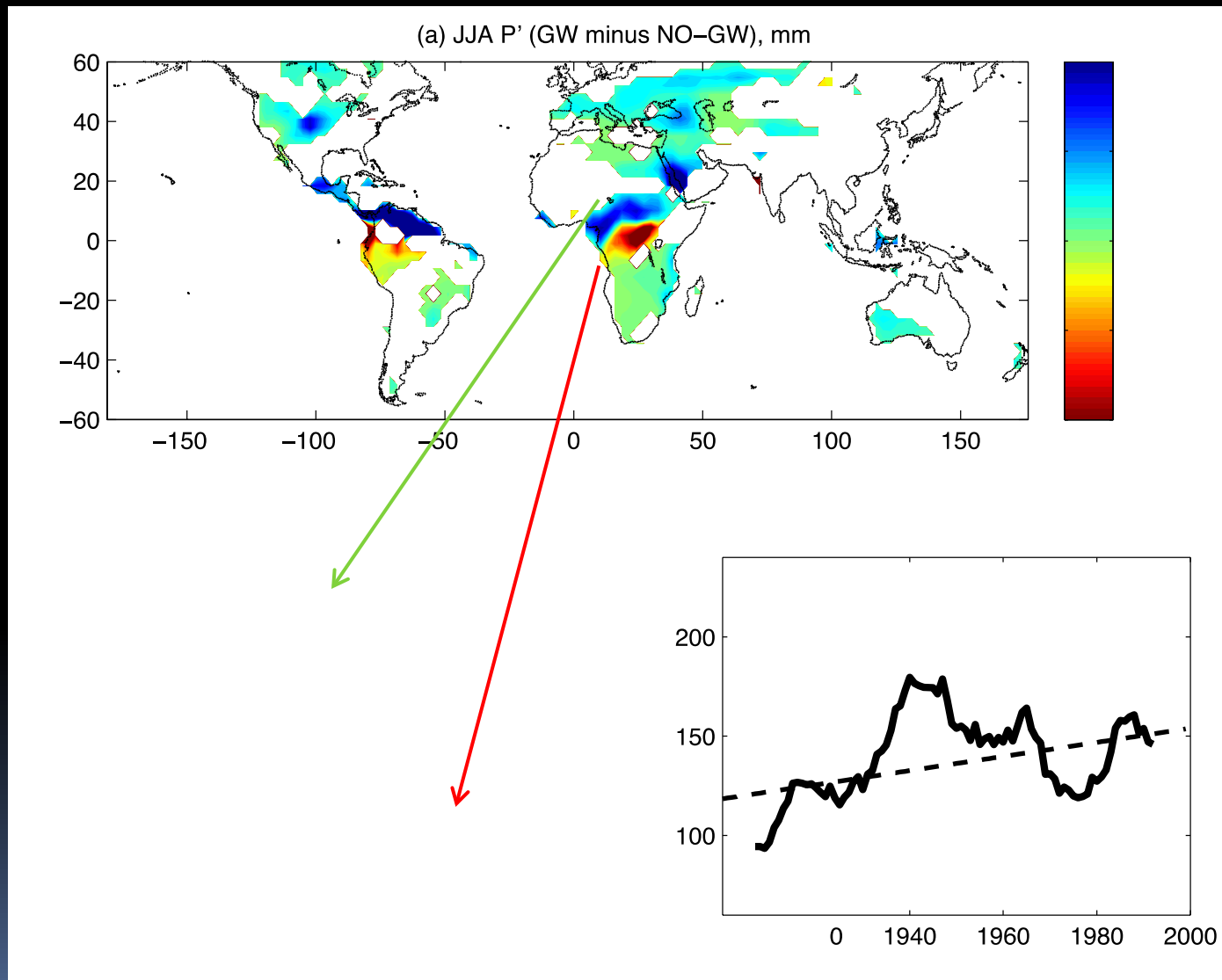
- Estimation of changes in large-scale groundwater relied on models.
- Some studies have already used the results of GCMs to drive **offline** land hydrologic models (Wada et al., 2012; Portmann et al., 2013;...).



- However, the studies using offline models, **uncertainties can be** from multiple sources (downscaling of data from lower resolution of GCMs to higher or different resolution of hydrologic models, and inputs from different GCMs...).

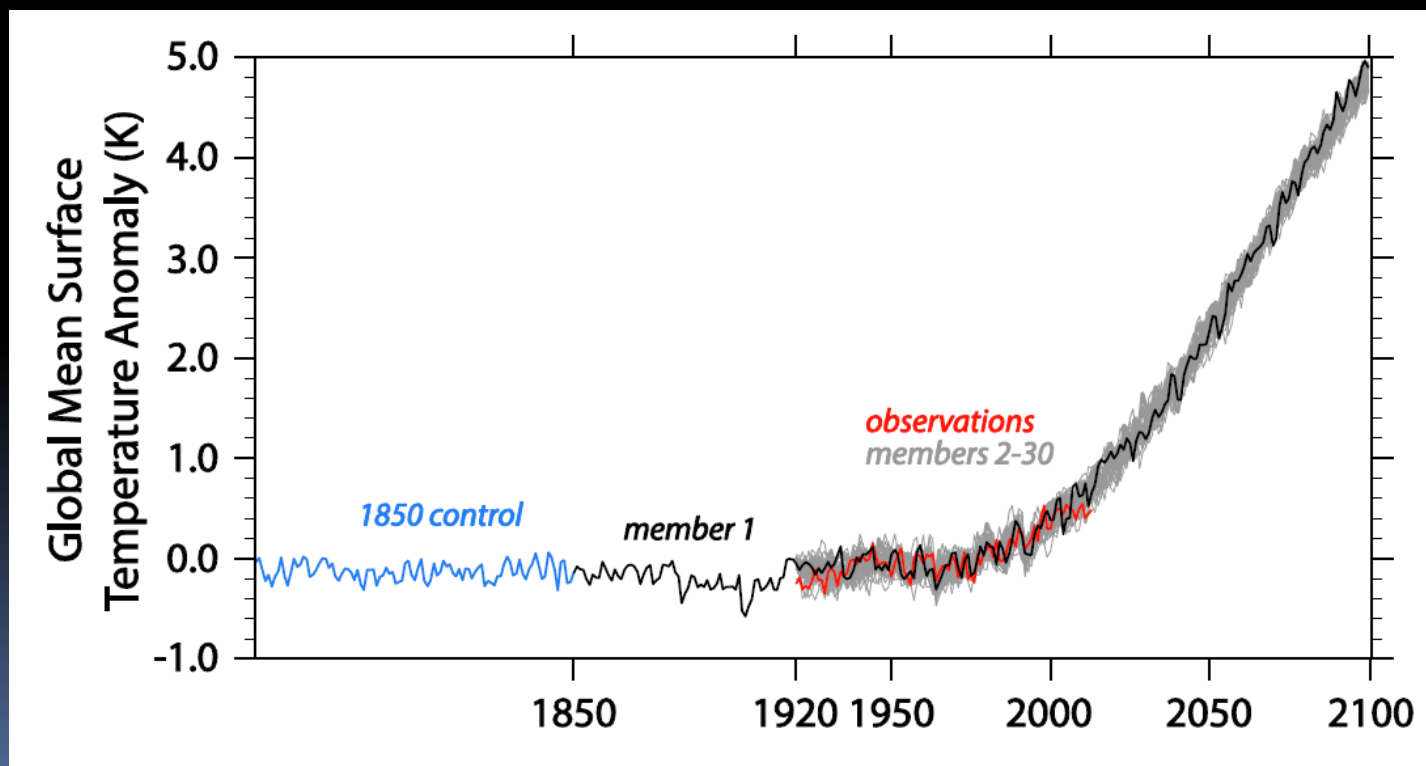
There are **feedbacks** of the groundwater hydrology to the atmosphere through land surface fluxes or even teleconnection of large-scale climate dynamics. (Maxwell et al., 2007; Anyah et al., 2008; Yuan et al., 2008; Jiang et al., 2009; ; Leung et al., 2011; Krakauer et al., 2013; Campoy et al., 2013...)

Spatial Variations of Precipitation

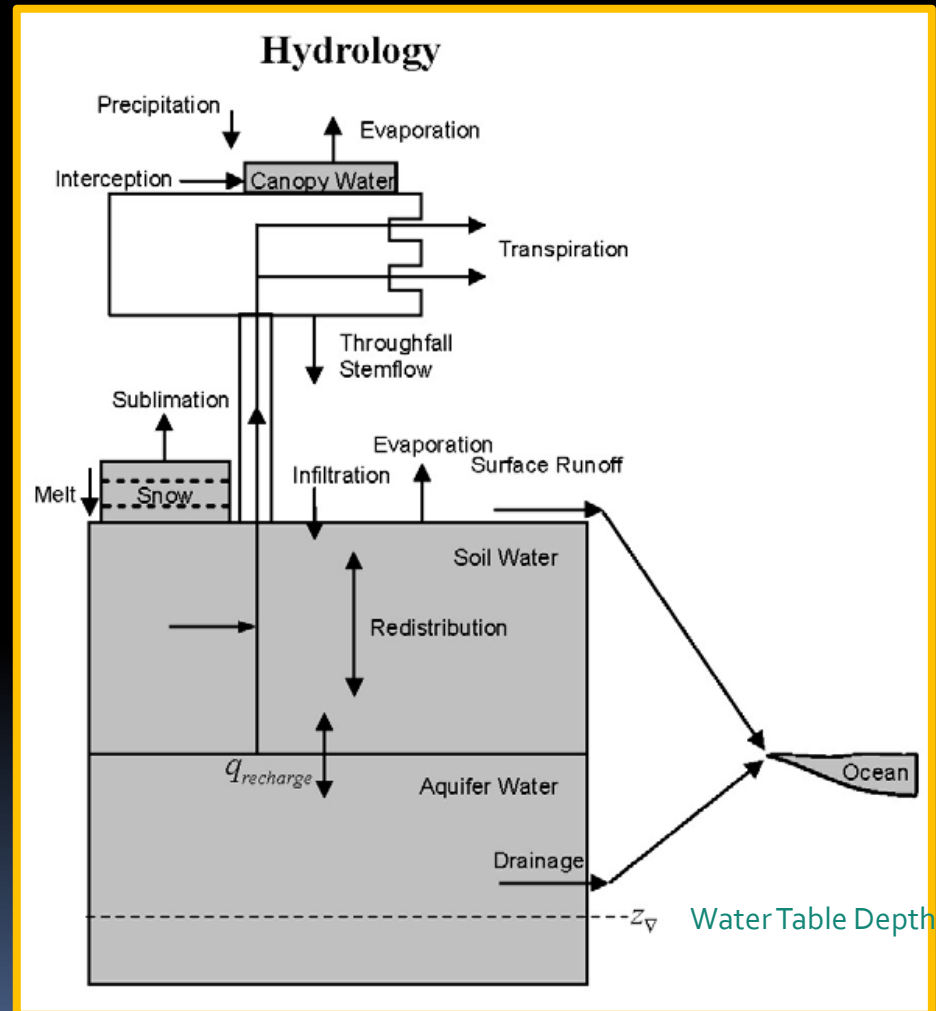


Community Earth System Model (CESM) Large Ensemble

- CESM: fully-coupled climate model; including land model: CLM4.0
- 1920~2005: historical + 2006~2100:RCP8.5
- includes 30-member initial-condition ensemble
- No human groundwater withdrawal activities



Community Earth System Model (CESM) Large Ensemble

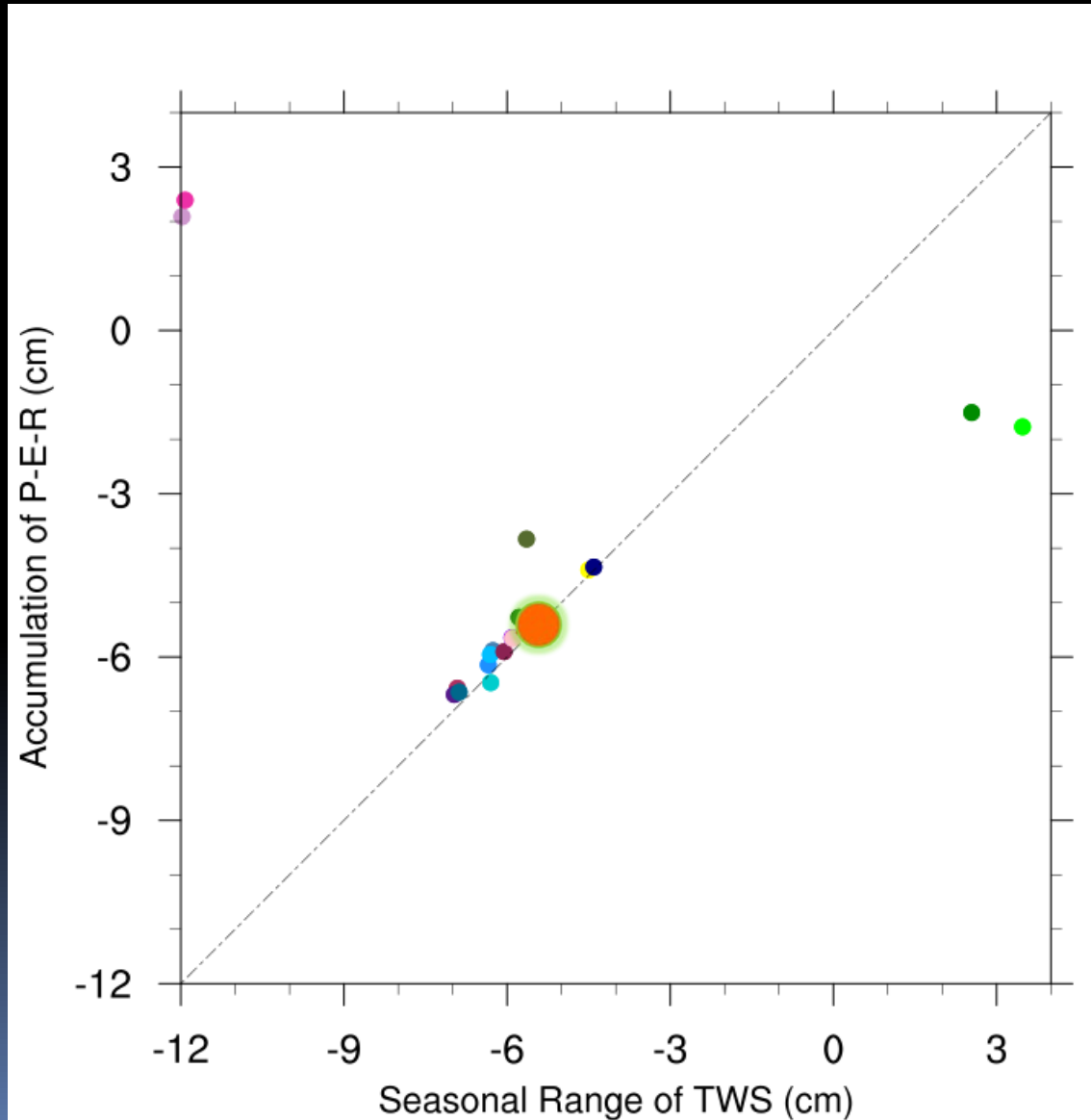
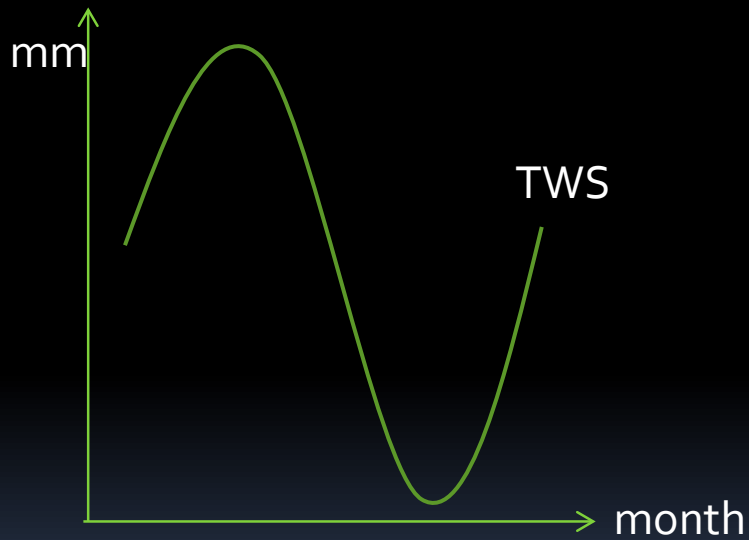


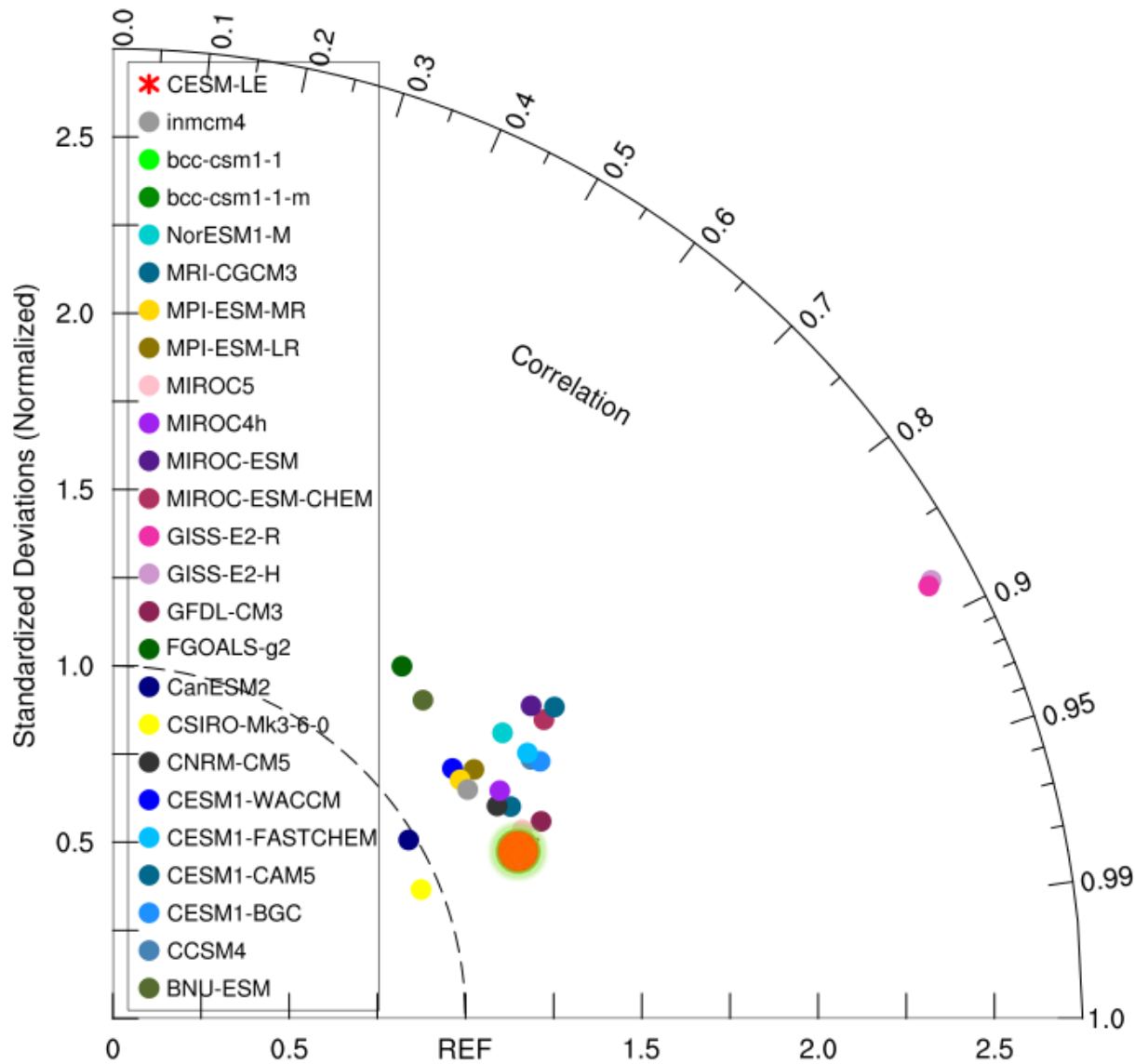


Performance of CESM-LE

- water budget
- seasonal cycle of total water storage changes

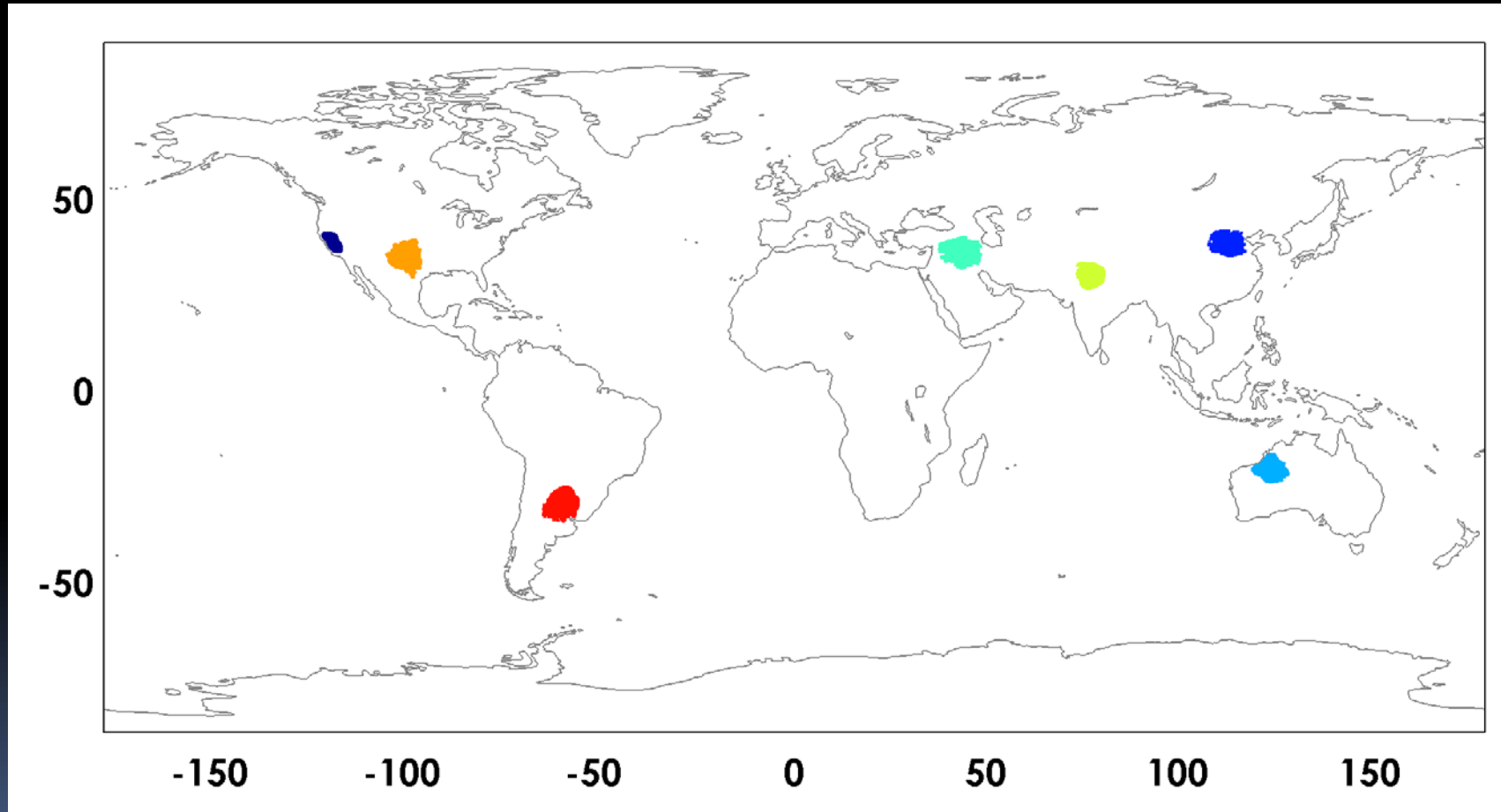
Relationship between seasonal range of water storage and corresponding P-E-R simulated by CMIP5 climate models and ensemble mean of CESM-LE.



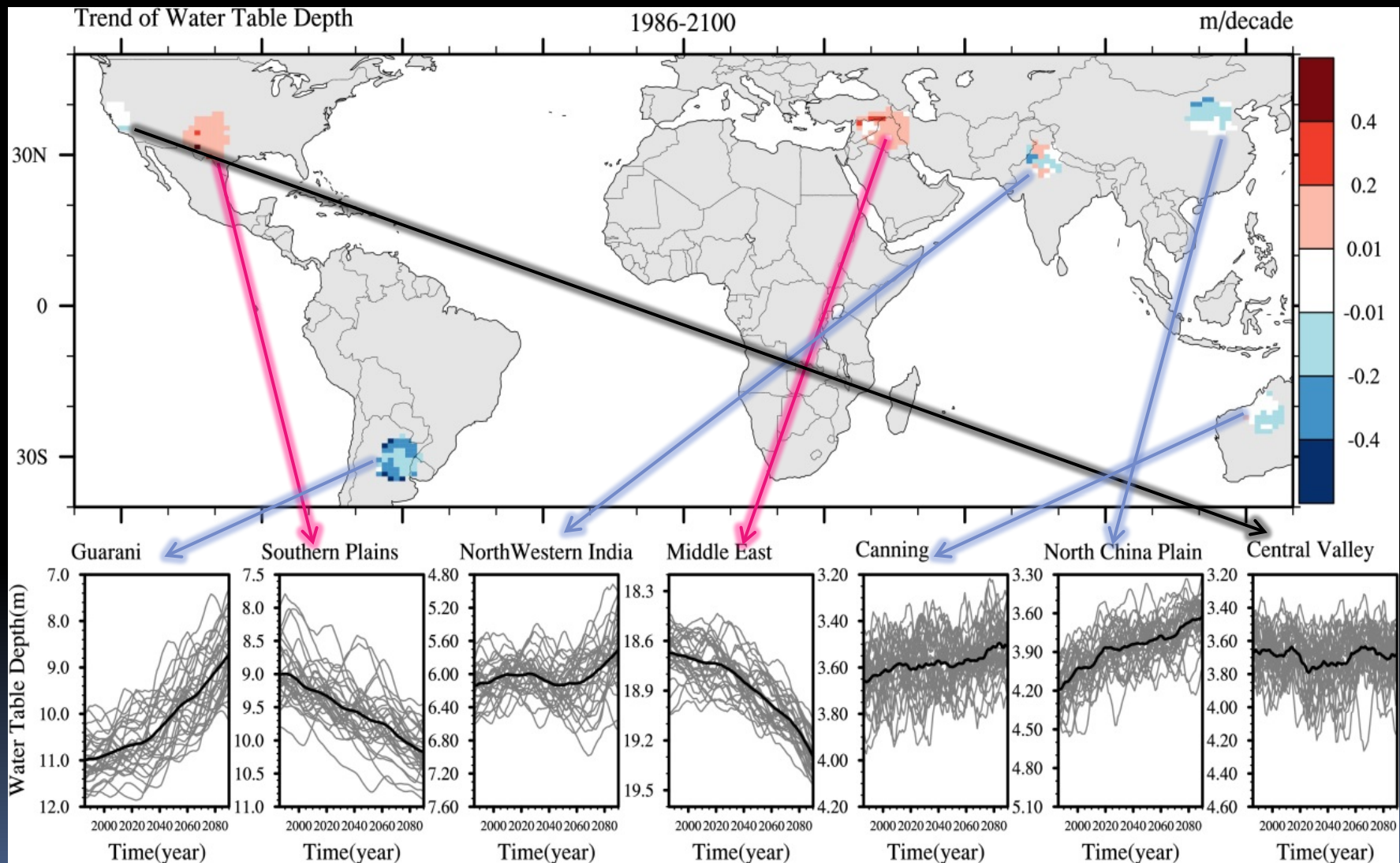


- CESM-LE has better agreements with GRACE total water storage changes

Groundwater changes in the future



Trend of Water Table Depth



Trend of Variables in the aquifers 1986~2100

Variable	Unit	Guarani	Southern Plains	Northwest India	Middle East	Canning	North China Plain	Central Valley
Total Precipitation	mm/yr/ dec	9.38	1.70	5.97	1.02	8.31	20.62	9.10

Surface Evaporation

Snowmelt

Surface Runoff

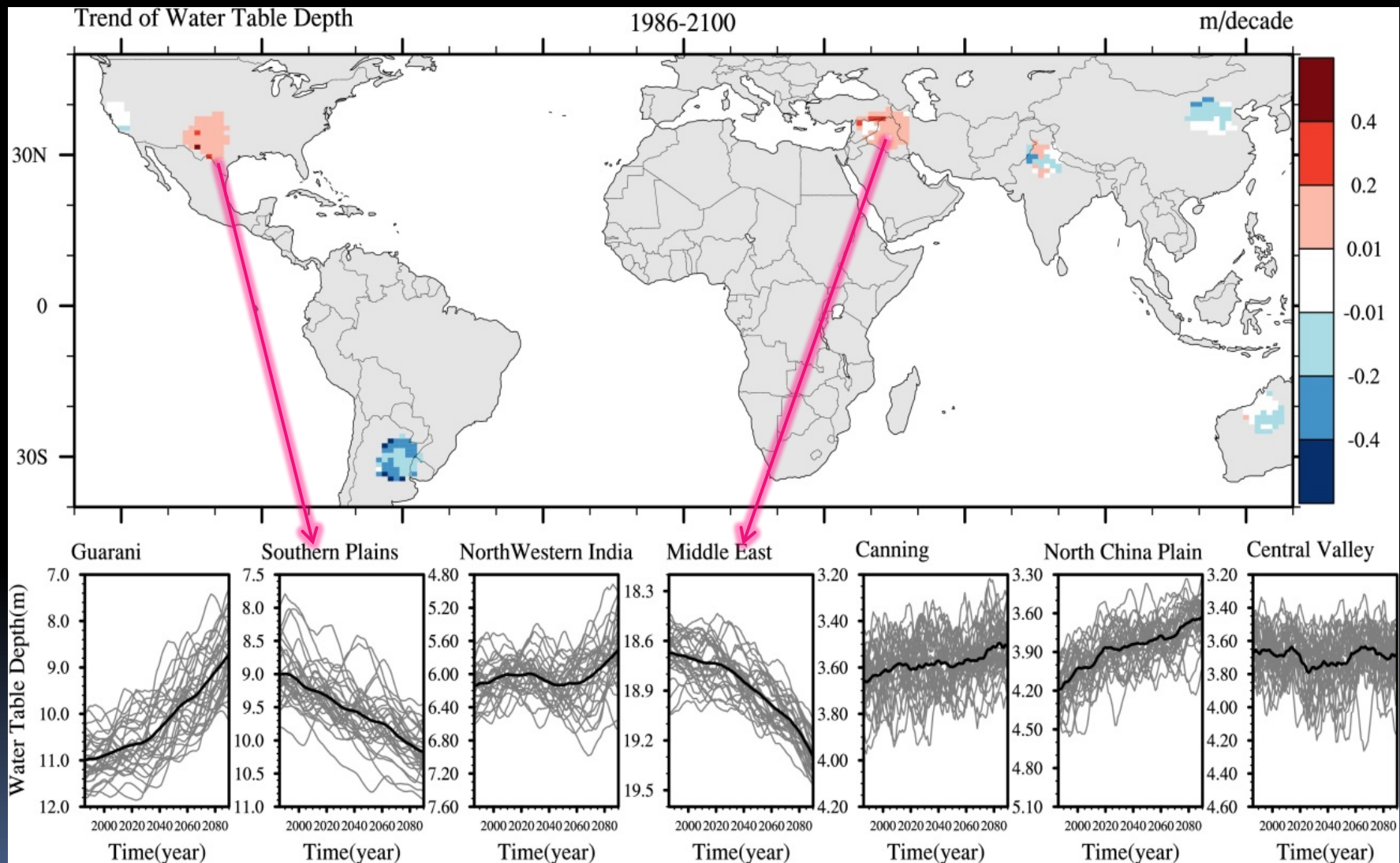
Infiltration

Transpiration

GW Recharge

Leaf Area Index

Trend of Water Table Depth



Southern Plains in US

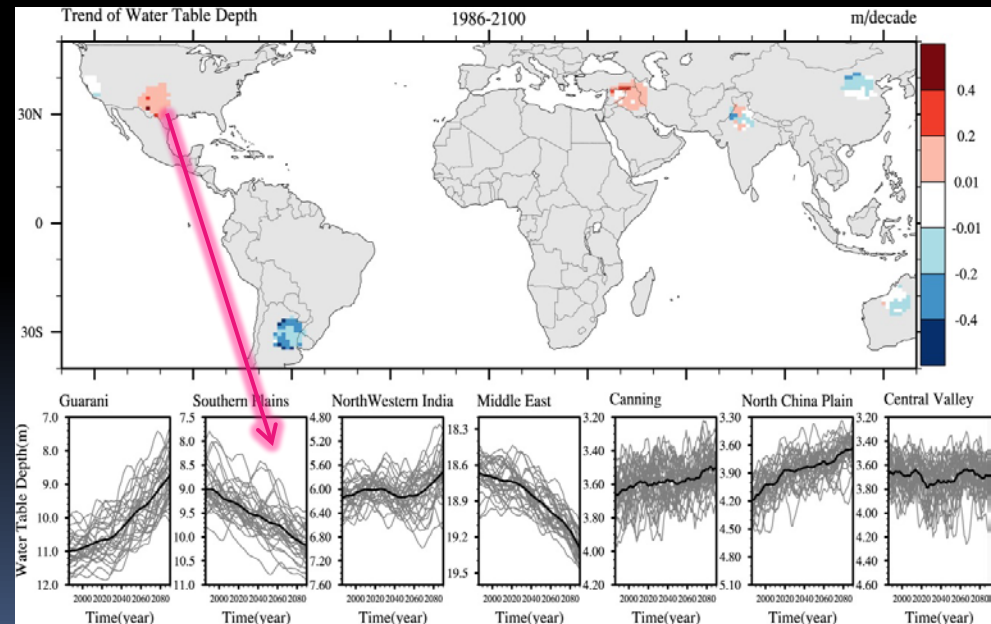
- less groundwater recharge

Snowmelt ↓

Surface
Evaporation ↑

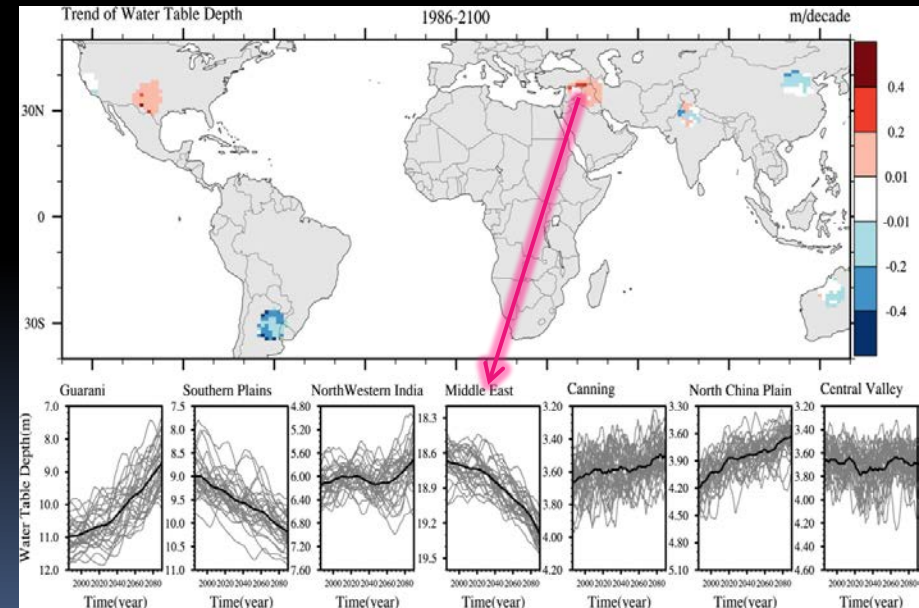
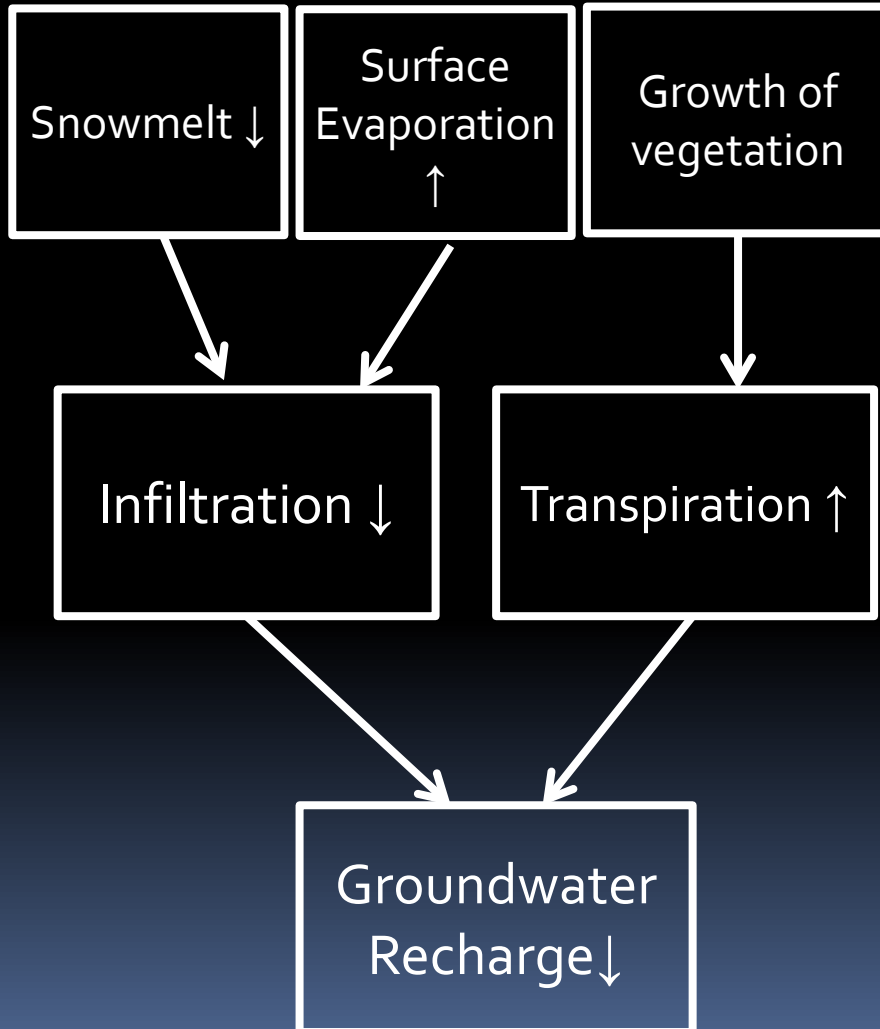
Infiltration ↓

Groundwater
Recharge ↓

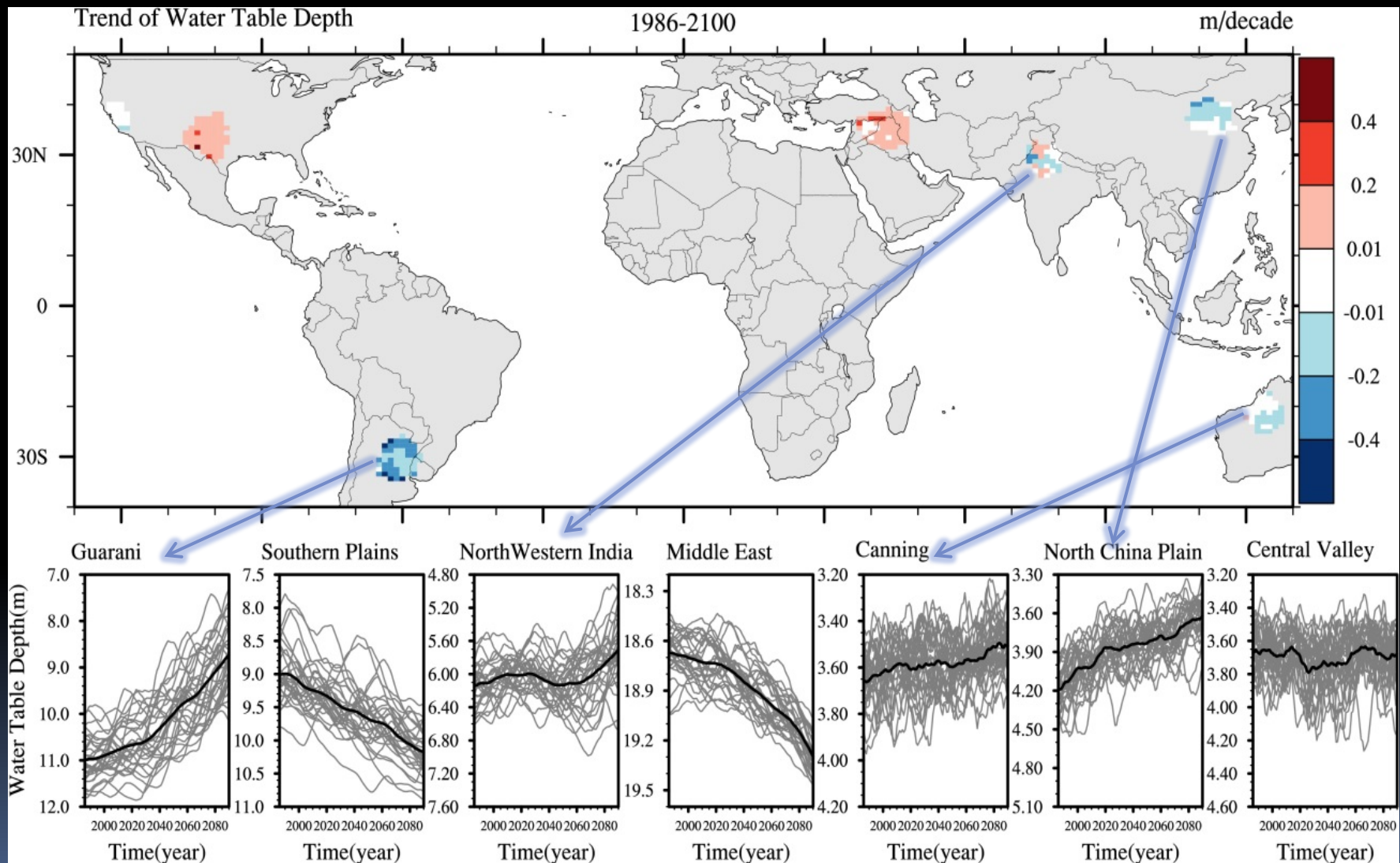


Middle East

- less groundwater recharge



Trend of Water Table Depth






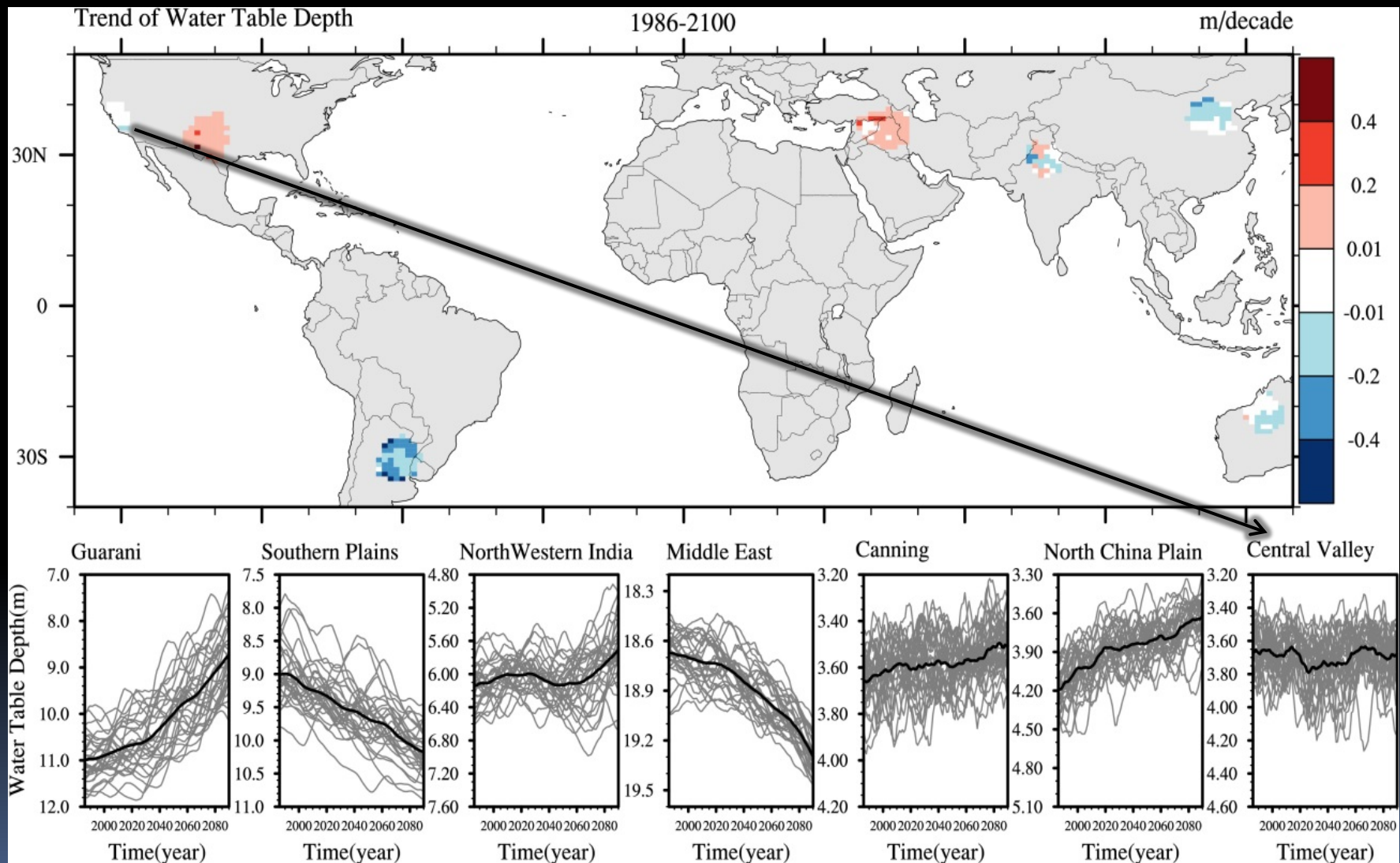
Northwest India, North China Plain, Guarani, Canning
-more groundwater recharge

Precipitation increases far exceeding the increase in evapotranspiration.

The large increases in precipitation overwhelm other negative feedbacks and result in an increase in groundwater recharge.

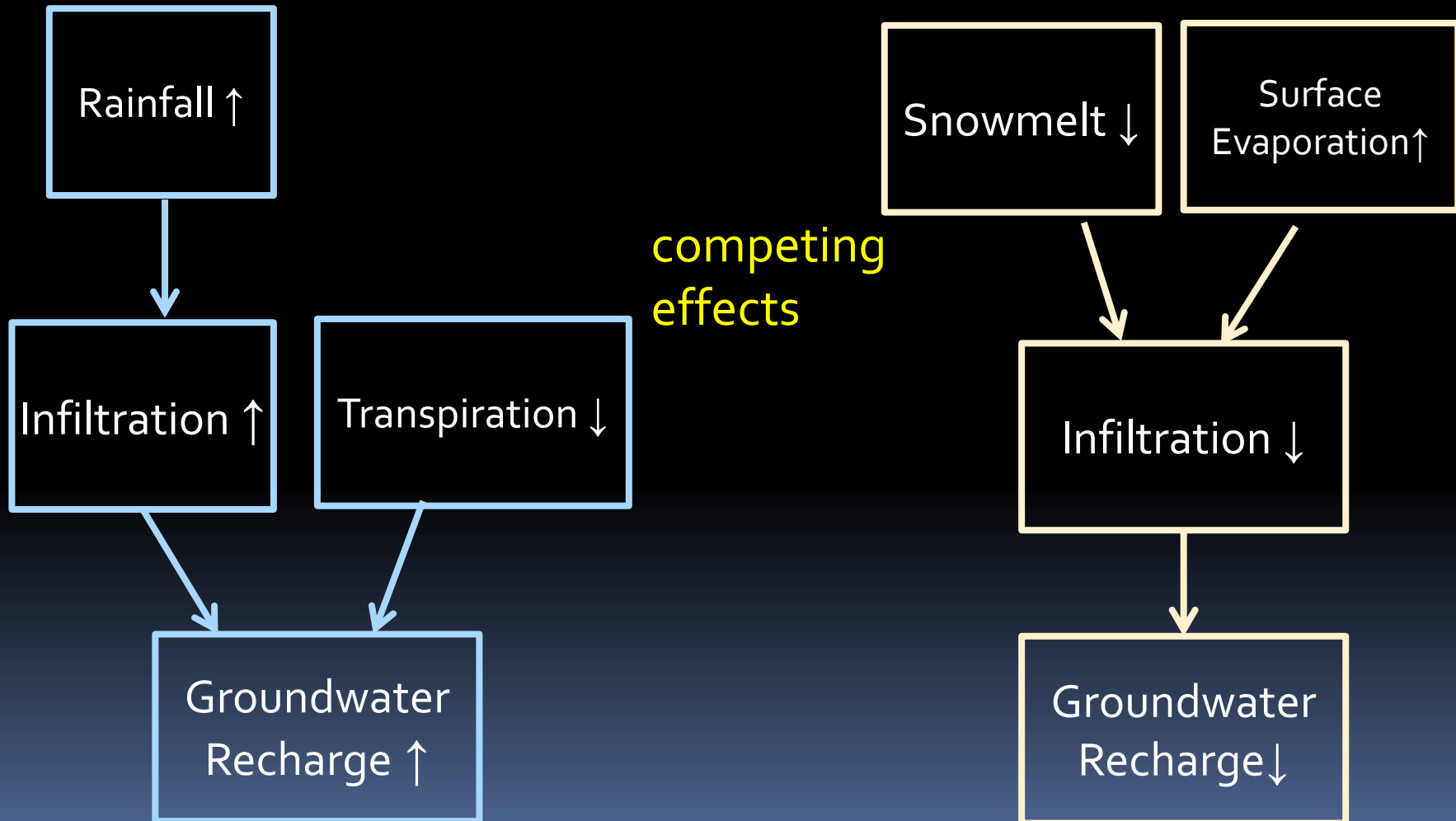


Trend of Water Table Depth



Central Valley in California

-no significant trend (less groundwater recharge)



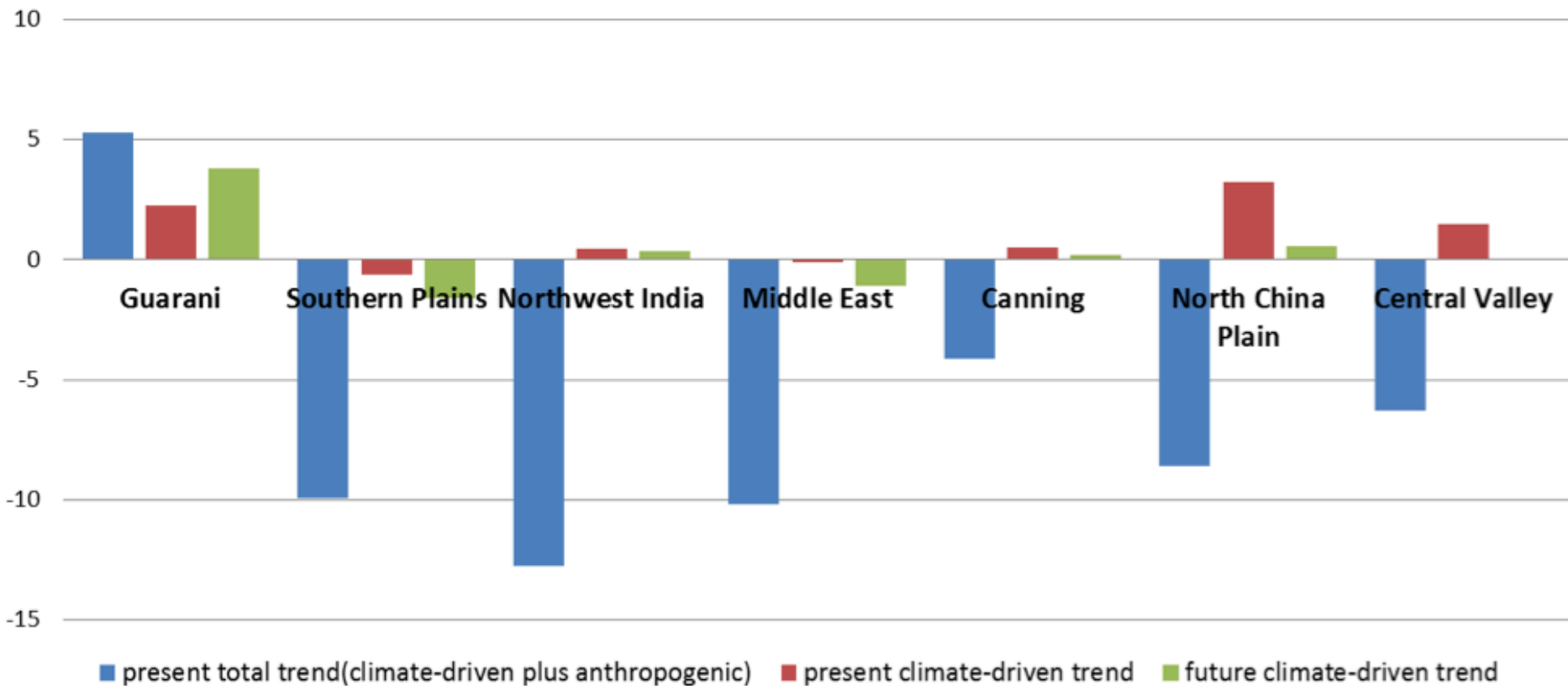


Summary

- The projections show that climate change contributes to changes in groundwater recharge not only via changes in precipitation, but also through changes in plant transpiration, reductions in snowmelt, and enhancement of surface evaporation.
- Thus, changes in groundwater recharge do not necessarily intuitively mirror the long-term trends in precipitation; other factors also need to be considered.
- Combined with human groundwater withdrawal?

Climate-driven vs Anthropogenic

Trend of Groundwater Storage(km³/yr)





Any Questions?

