



# Simulating Climate-Driven And Irrigation-Induced Future Water Resources Changes With A Global Climate Model

Jeanne Colin<sup>1</sup>, Bertrand Decharme<sup>1</sup> and Maya Costantini<sup>1</sup>

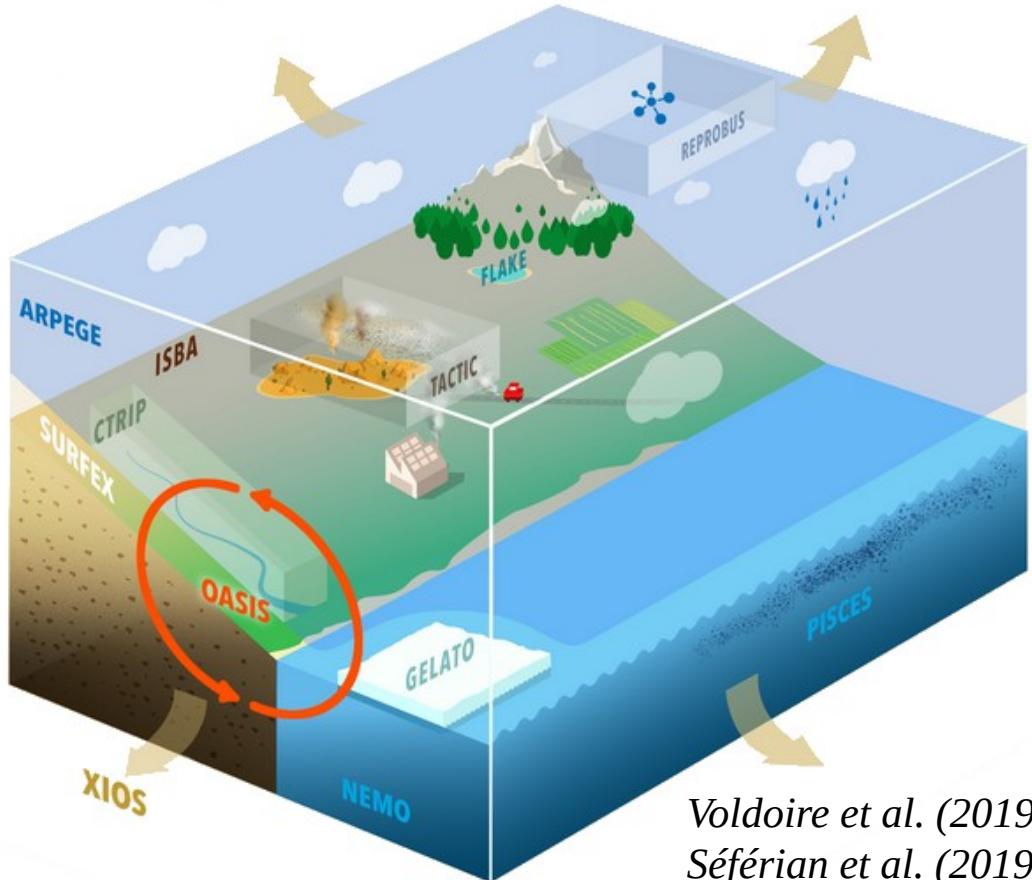
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**9th GEWEX meeting, Sapporo, July 9th**

# The global climate model (CNRM-CM6-1) and its land surface model (ISBA-CTRIP)

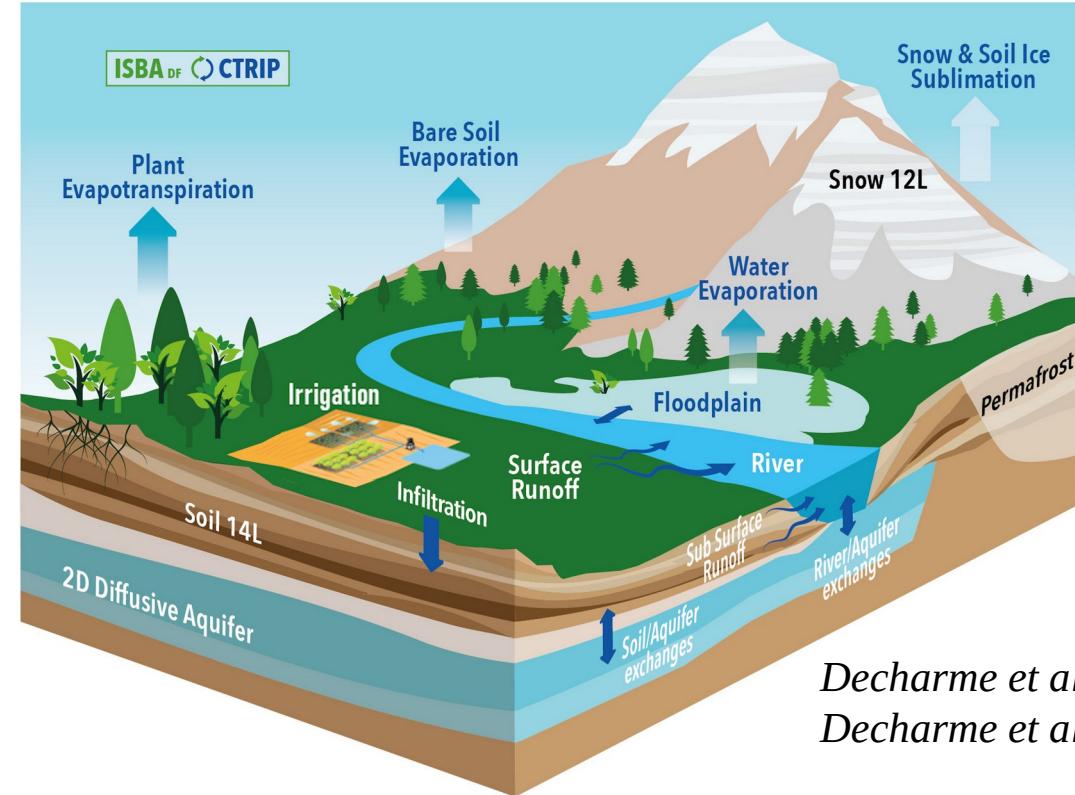
## CNRM-CM6-1/ESM2-1



Volodire et al. (2019)  
Séférian et al. (2019)

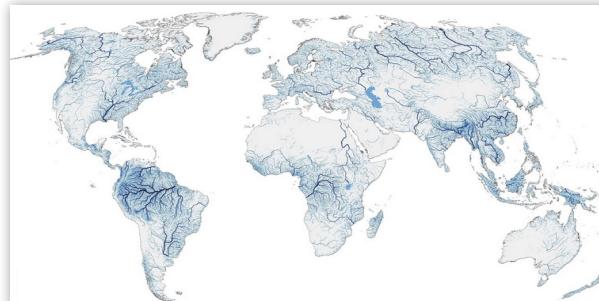
ARPEGE-ISBA (atmosphere-land) =  $1,4^\circ$  ( $\sim 150$  km)  
NEMO-GELATO (ocean-sea-ice) =  $1^\circ$  ( $\sim 100$  km)  
CTRIP (river routing) =  $0,5^\circ$  ( $\sim 50$  km)

## ISBA-CTRIP (within SURFEX)

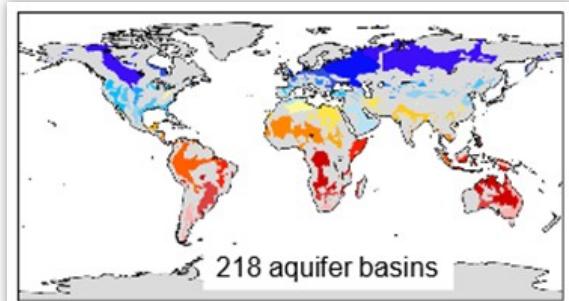


Decharme et al. (2019)  
Decharme et al. (sub.)

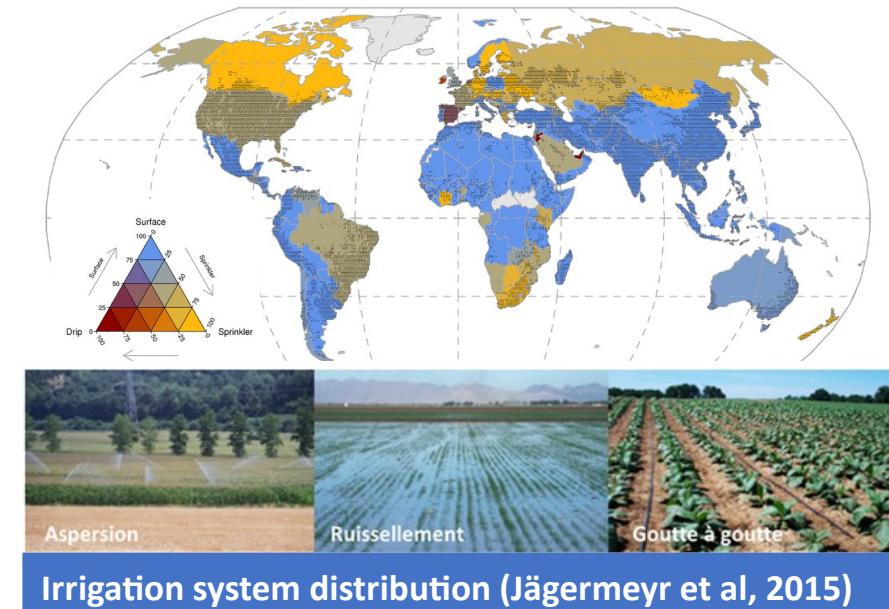
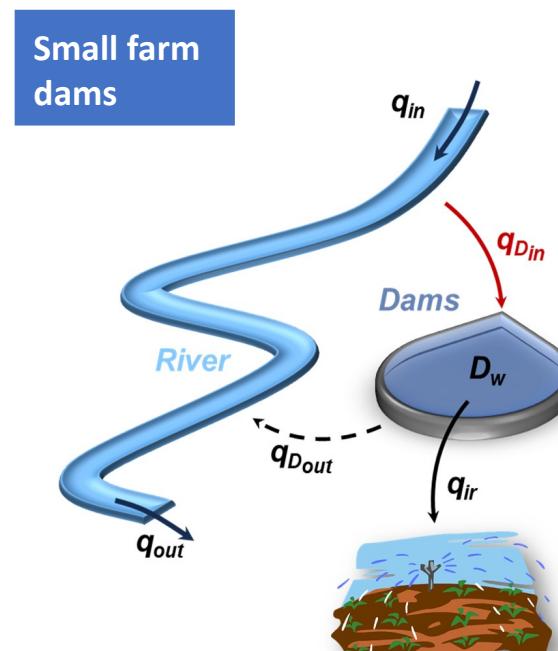
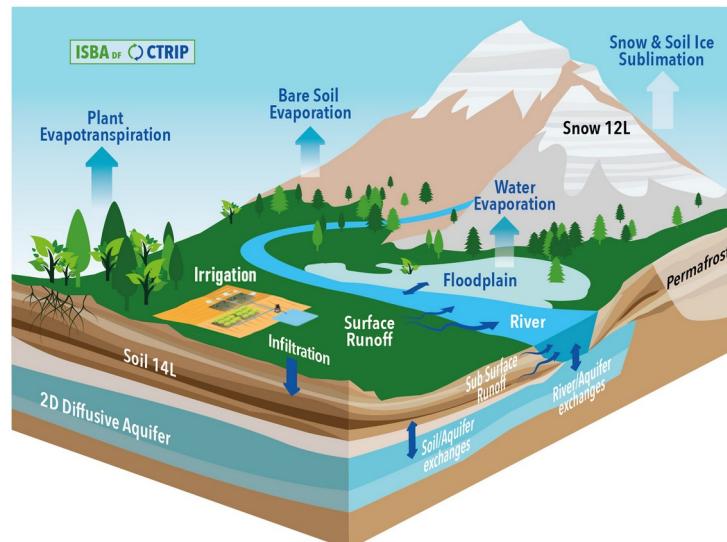
Rivers (50 km)



Unconfined aquifers (50 km)



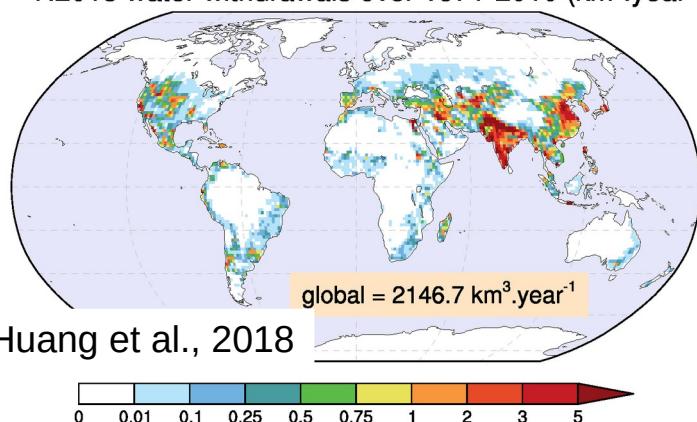
# Irrigation in ISBA-CTrip : scheme



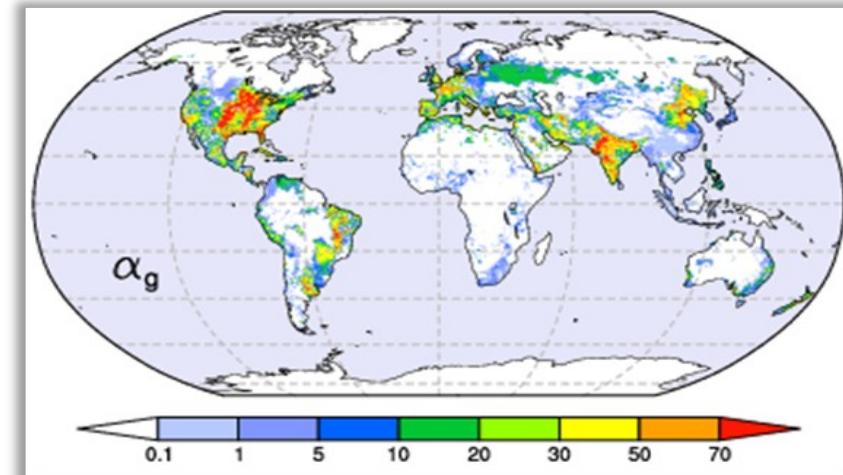
Irrigation system distribution (Jägermeyr et al, 2015)

## Prescribed water withdrawals

H2018 water withdrawals over 1971-2010 ( $\text{km}^3 \cdot \text{year}^{-1}$ )



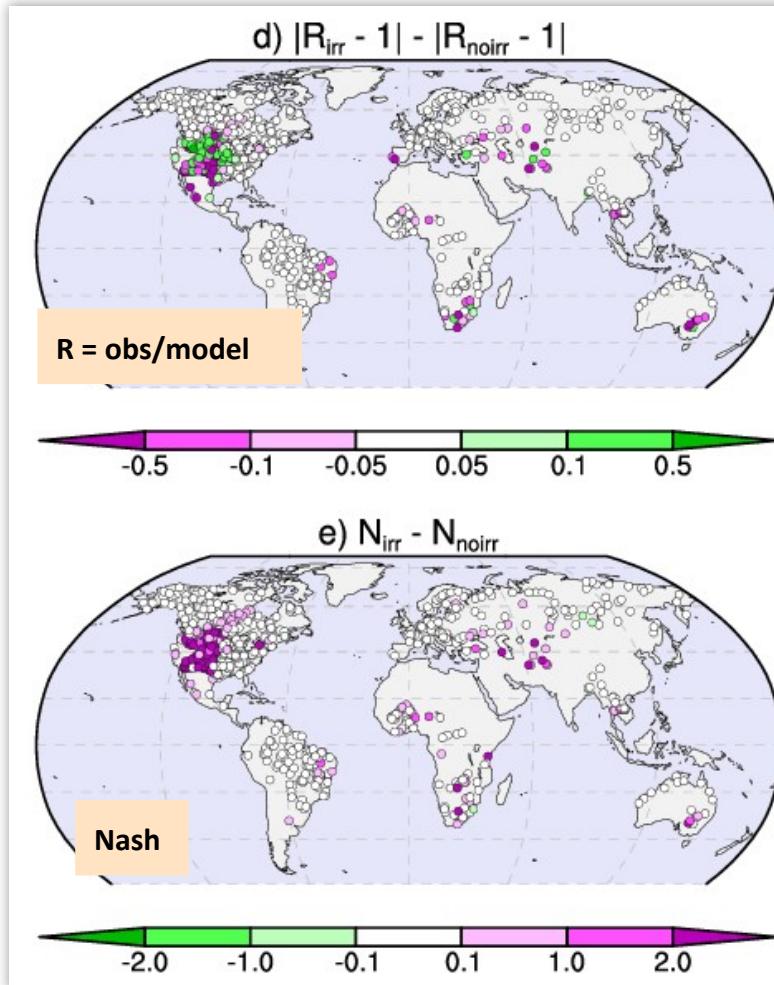
## Aquifers + subsurface reservoirs



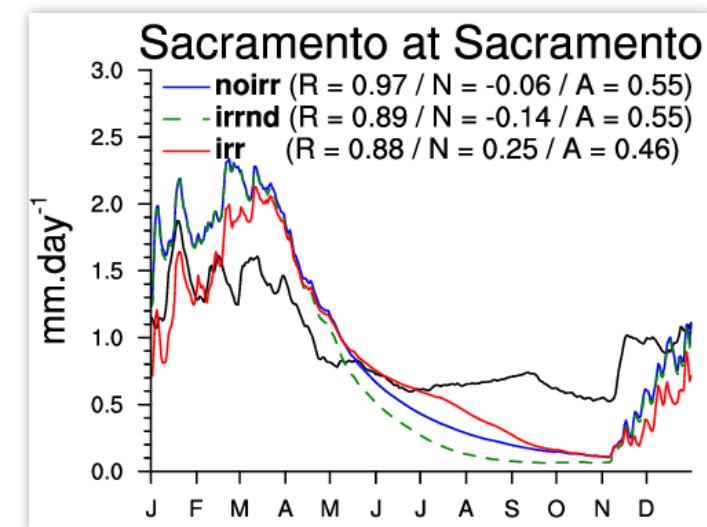
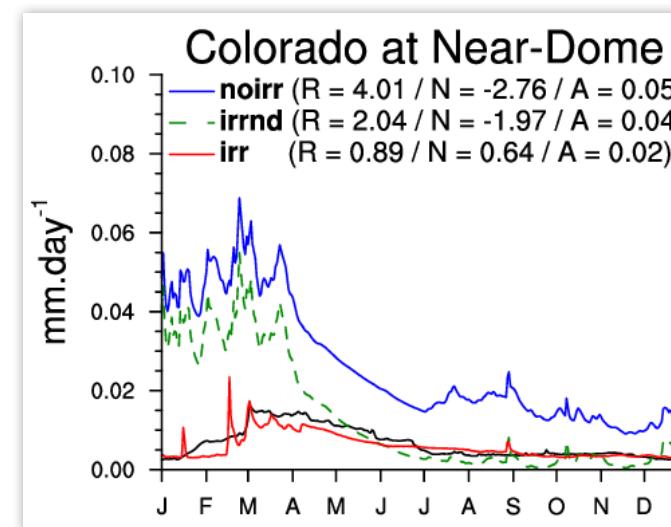
Share of groundwater withdrawals

# Irrigation in ISBA-CTRIP : evaluation river discharge

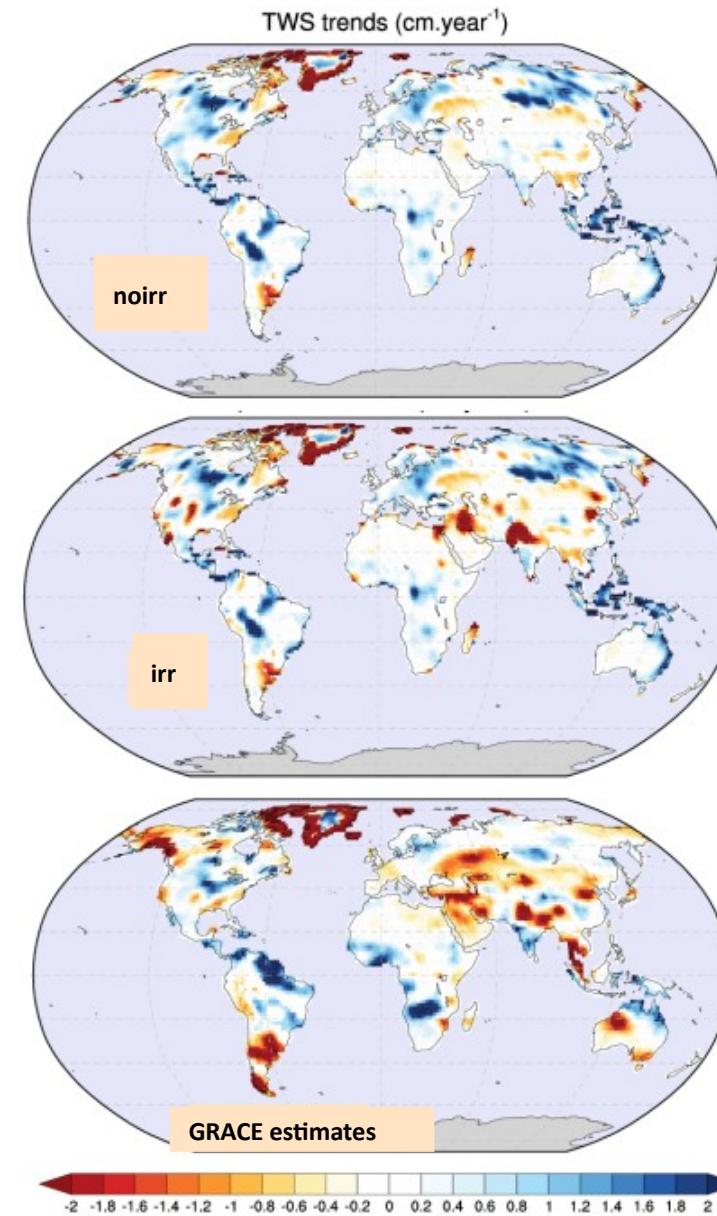
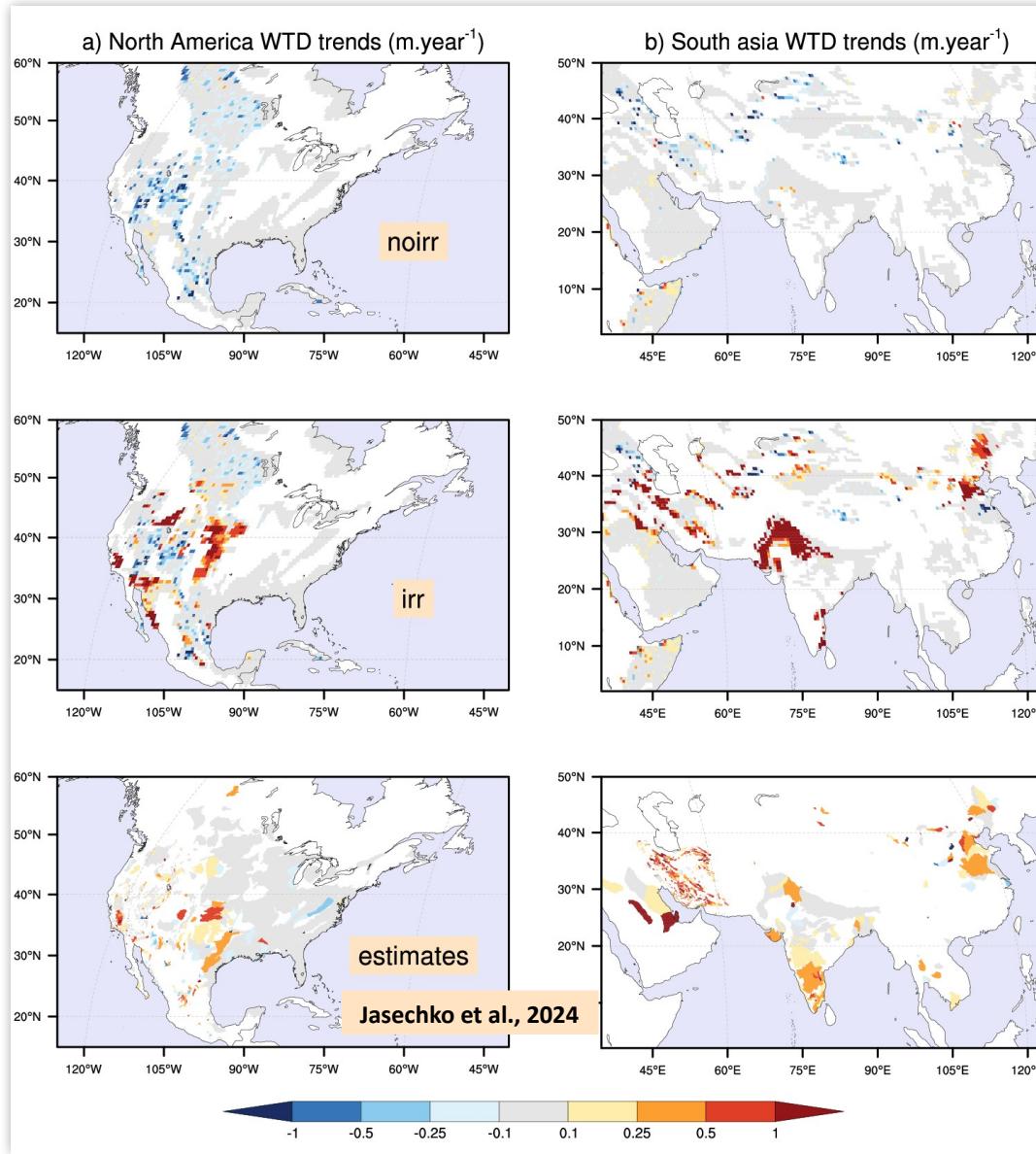
ISBA-CTRIP offline simulations, with irrigation (irr) and without (noirr)  
Atmospheric forcing 1971-2010 : Princeton (PGF) + GPCC precipitation



750 observation points  
Improvement (worsening) of R for 18 % (13%)  
Improvement (worsening) of N for 29 % (1%)  
**=> Better annual cycle**



# Irrigation in ISBA-CTrip : evaluation Water Table Depth (WTD) and Terrestrial Water Storage (TWS) Trends



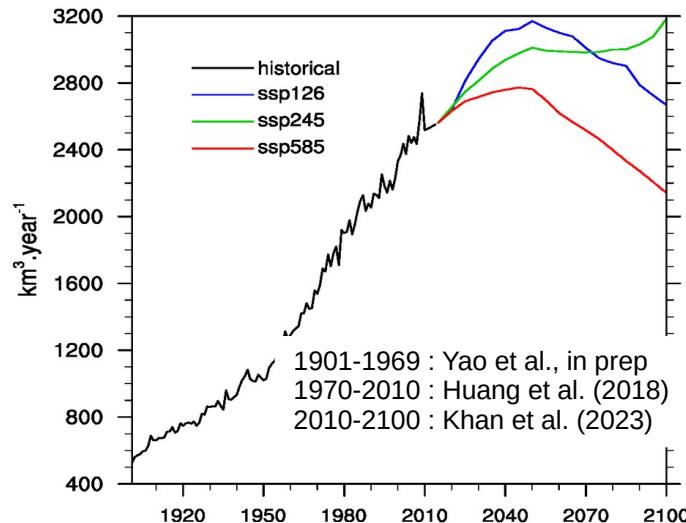
=> Trend sign  
corrected in heavily  
irrigated regions

# Simulating future water resources changes

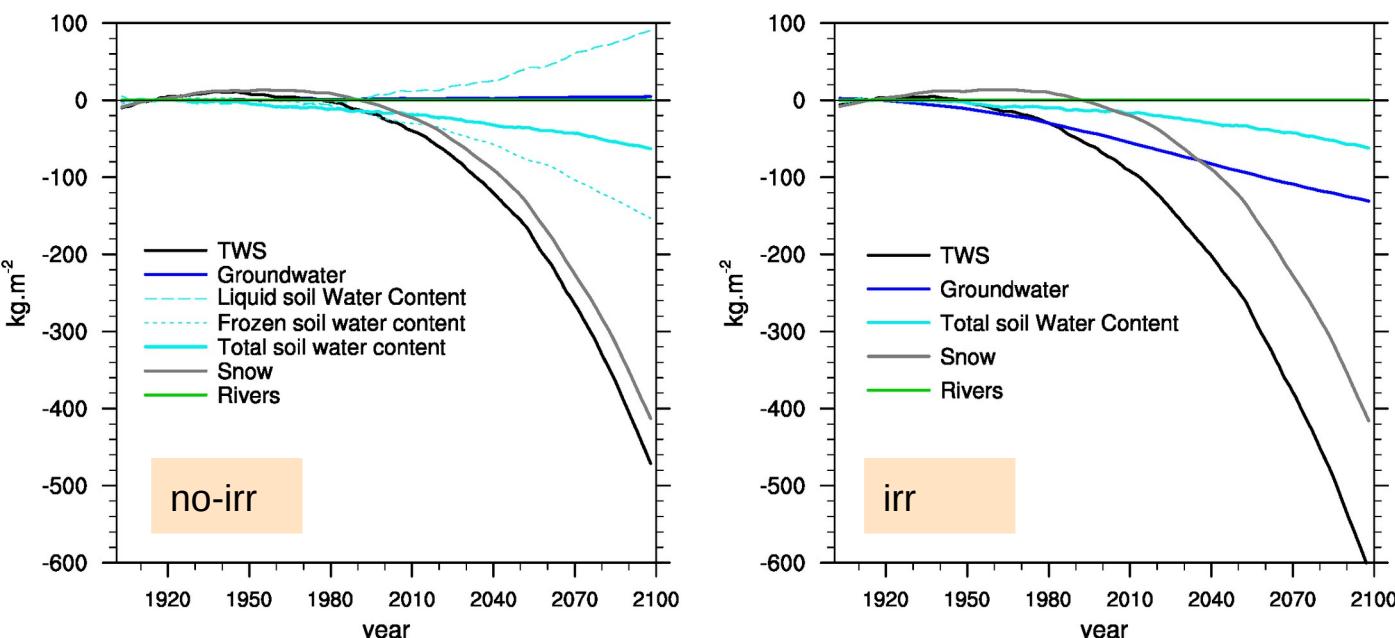
## Simulations

Land-atmosphere (prescribed SST/SIC)  
10-member ensembles :  
- hist (1901-2014), ssp126, ssp245, ssp585  
(2015-2100)  
- irr/no-irr

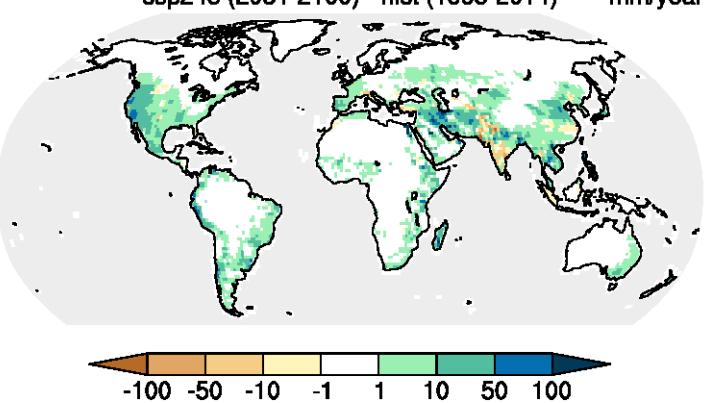
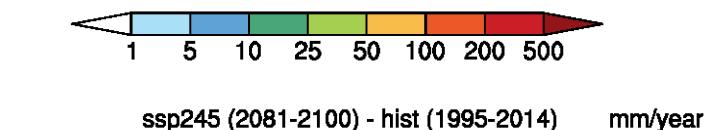
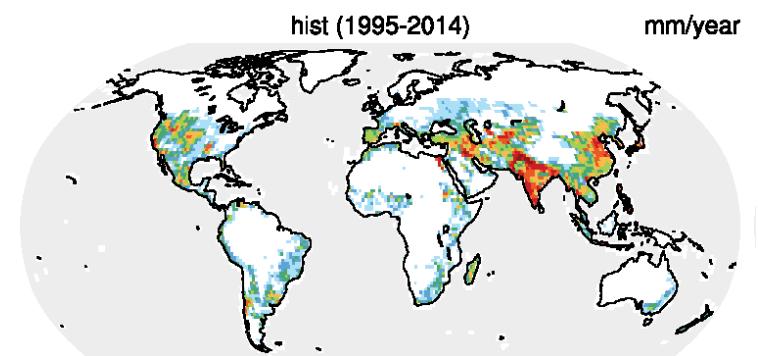
## Irrigation withdrawals forcing



## Anomalies of TWS and its components 1901-2100 hist+ssp245 (reference : 1901-1930)



=> Slight increase of groundwater storage with climate change, but large irrigation-induced depletion. affecting TWS decrease

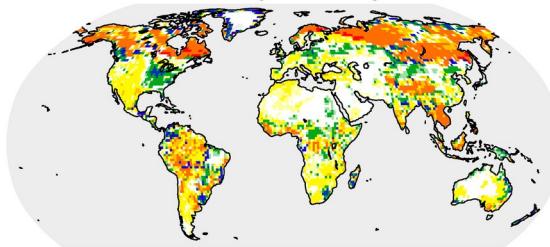


# Simulating future water resources changes

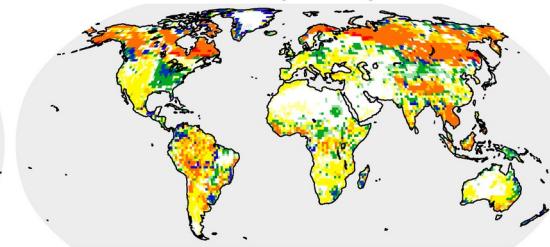
ssp245 (2081-2100) - hist (1995-2014)

Mean total soil water content ( $\text{kg/m}^3$ )

Climate change without irrigation

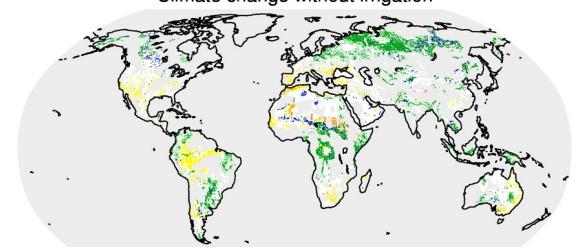


Climate change with irrigation

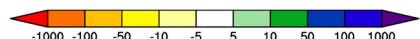
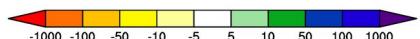
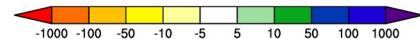
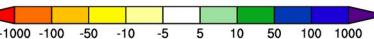
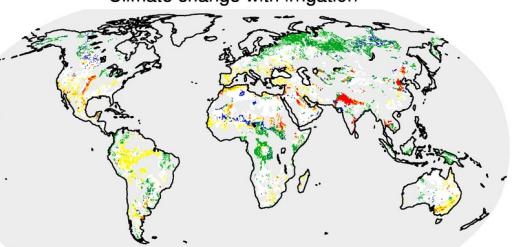


Groundwater storage ( $\text{kg/m}^3$ )

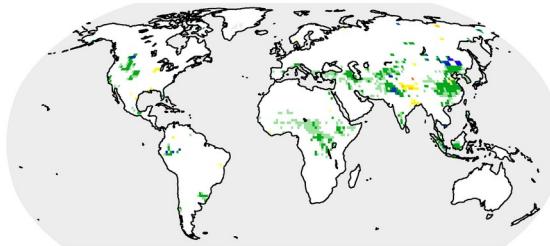
Climate change without irrigation



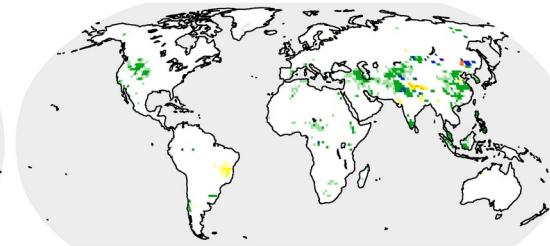
Climate change with irrigation



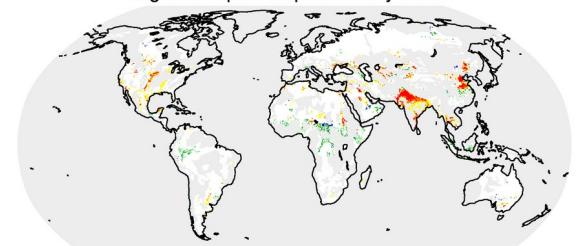
Irrigation impact on present-day climate



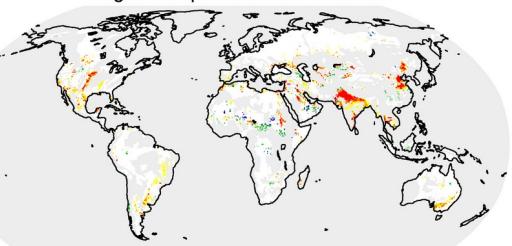
Irrigation impact on future climate



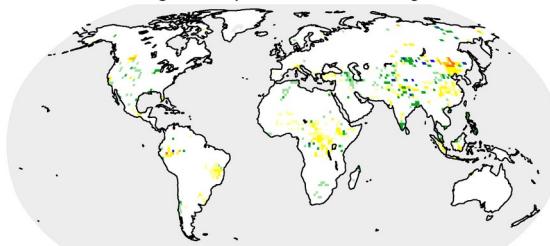
Irrigation impact on present-day climate



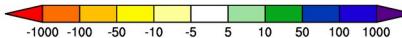
Irrigation impact on future climate



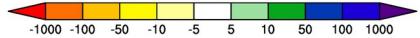
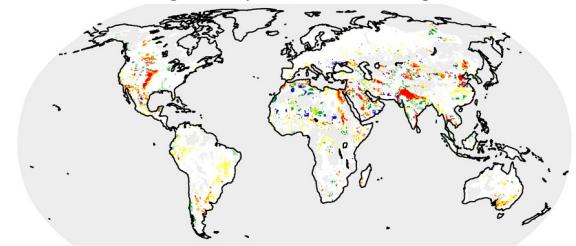
Irrigation impact on climate change



=> Soil moisture increase  
with irrigation.  
Does not affect much the  
climate-induced changes  
of soil moisture.



Irrigation impact on climate change



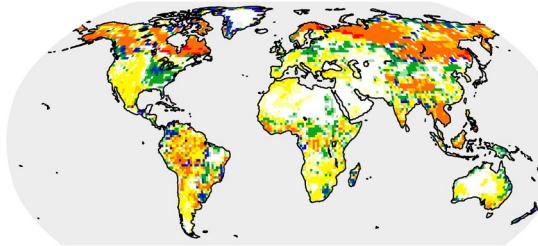
=> Groundwater depletion  
localized in heavily irrigated  
regions.  
Affects the climate induced  
changes of groundwater  
storage

# Simulating future water resources changes

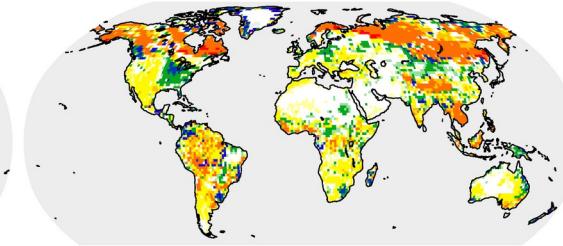
ssp245 (2081-2100) - hist (1995-2014)

Mean total soil water content ( $\text{kg/m}^3$ )

Climate change without irrigation

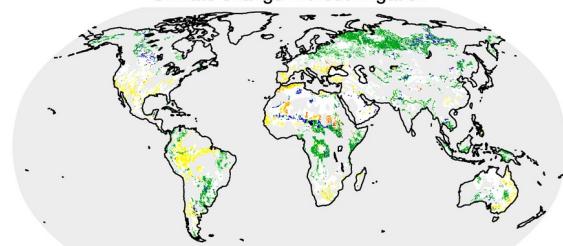


Climate change with irrigation

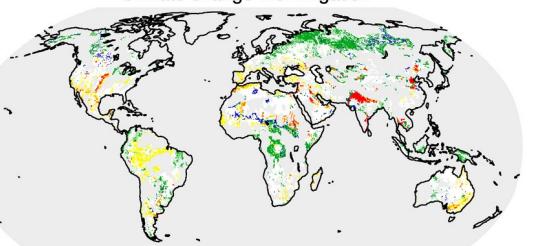


Groundwater storage ( $\text{kg/m}^3$ )

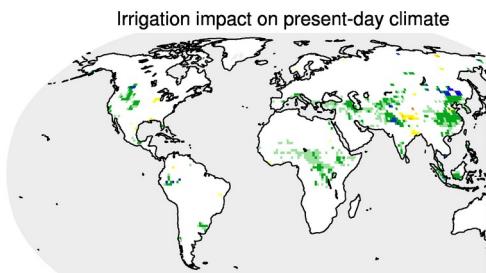
Climate change without irrigation



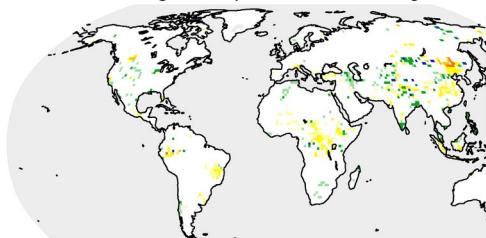
Climate change with irrigation



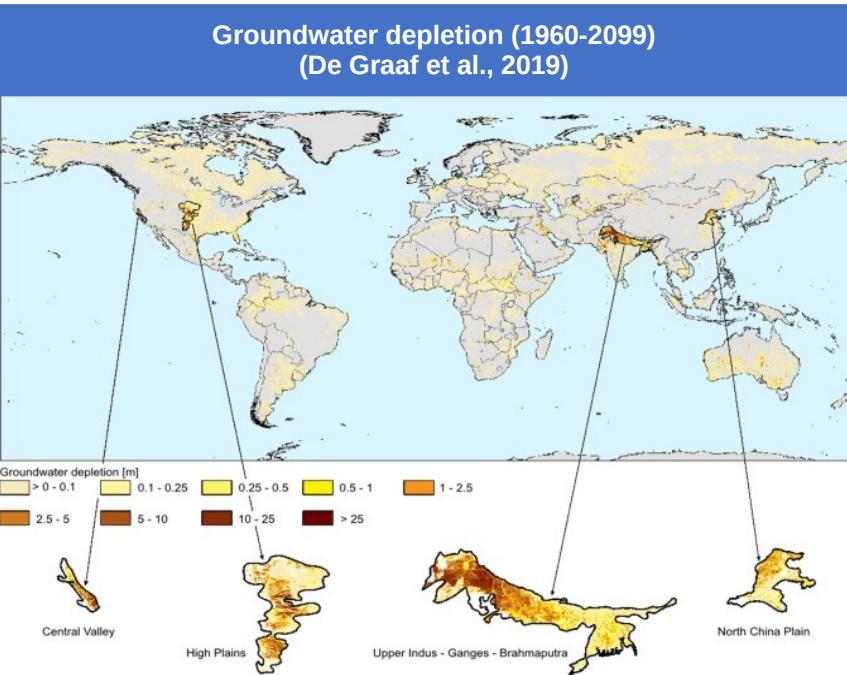
Irrigation impact on present-day climate



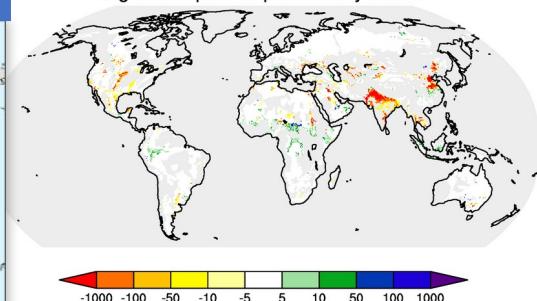
Irrigation impact on climate change



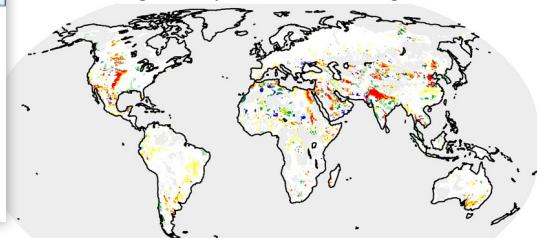
Groundwater depletion (1960-2099)  
(De Graaf et al., 2019)



Irrigation impact on present-day climate



Irrigation impact on climate change

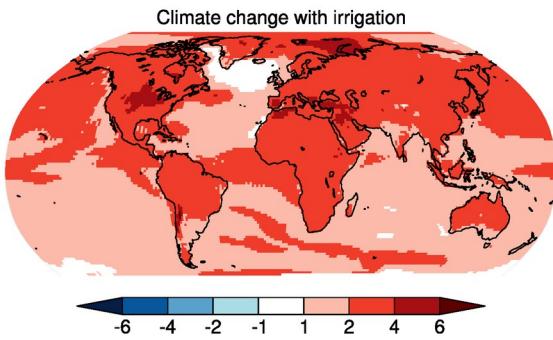
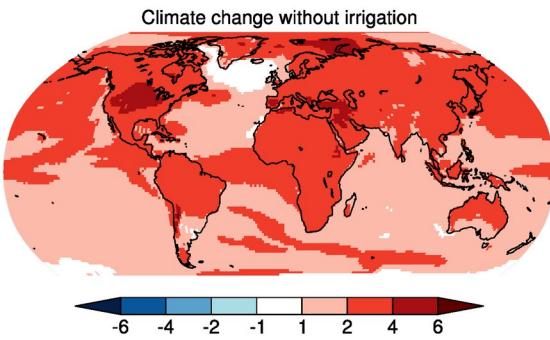


=> Groundwater depletion  
localized in heavily irrigated  
regions.  
Affects the climate induced  
changes

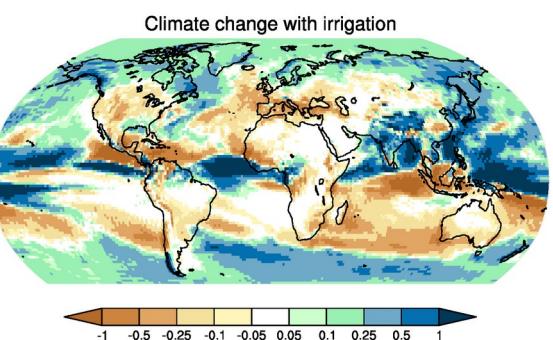
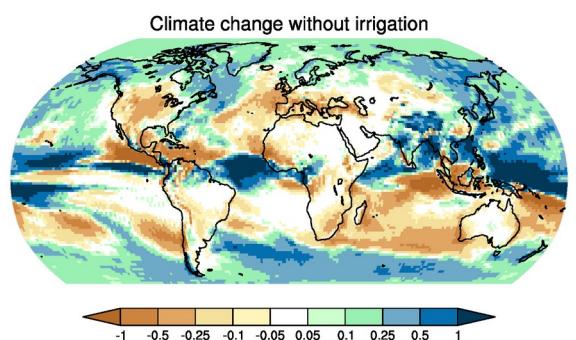
# Effect of irrigation on climate change

ssp245 (2081-2100) - hist (1995-2014)

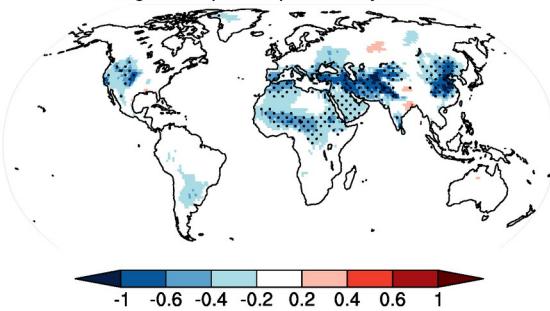
Summer (JJAS) mean daily Tmax (K)



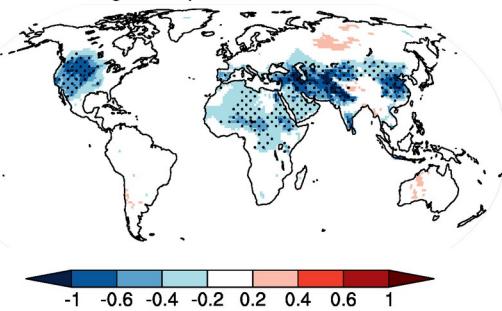
Summer (JJAS) daily precipitation (mm/day)



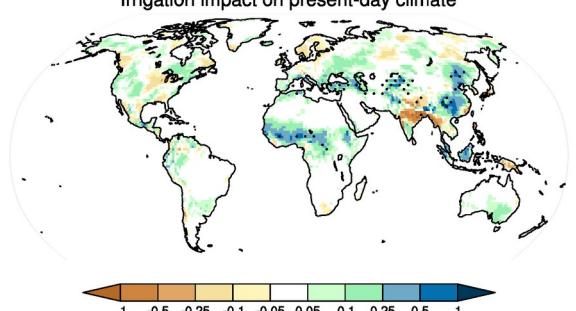
Irrigation impact on present-day climate



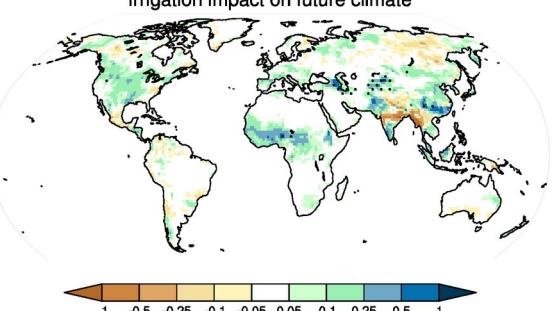
Irrigation impact on future climate



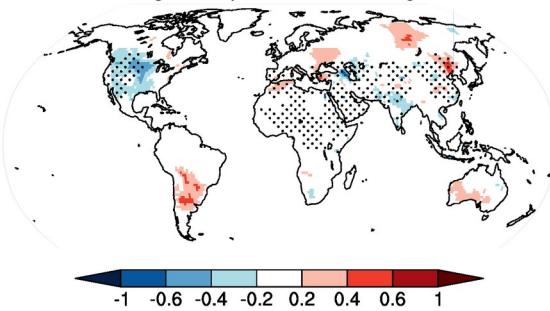
Irrigation impact on present-day climate



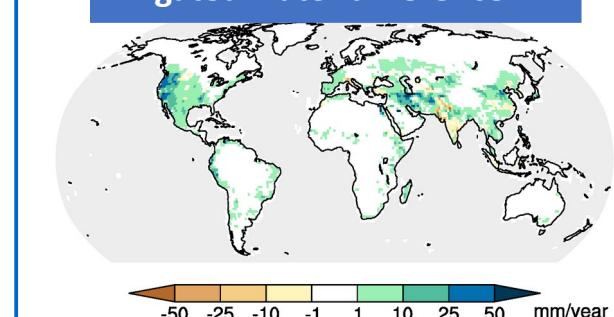
Irrigation impact on future climate



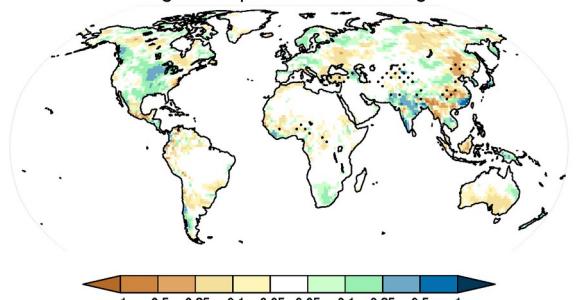
Irrigation impact on climate change



Irrigated water difference



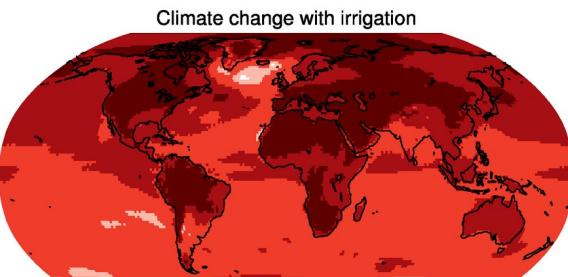
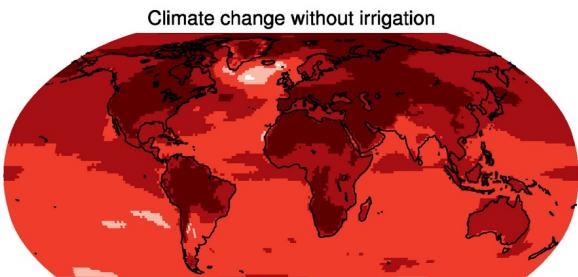
Irrigation impact on climate change



# Effect of irrigation on climate change

ssp585 (2081-2100) - hist (1995-2014)

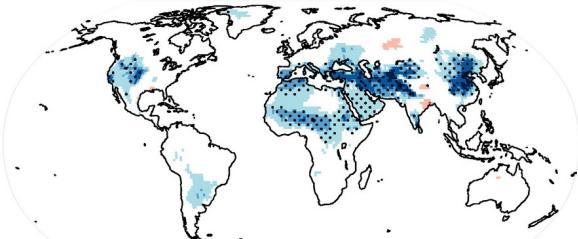
Summer (JJAS) mean daily Tmax (K)



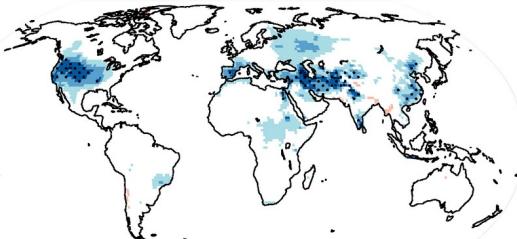
-6 -4 -2 1 2 4 6

-6 -4 -2 1 2 4 6

Irrigation impact on present-day climate



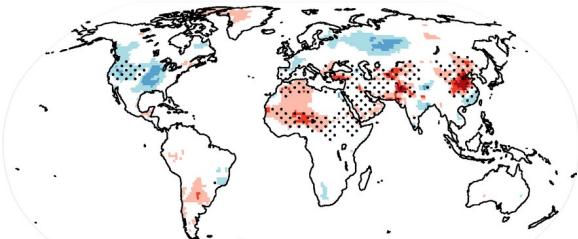
Irrigation impact on future climate



-1 -0.6 -0.2 0.2 0.6 1

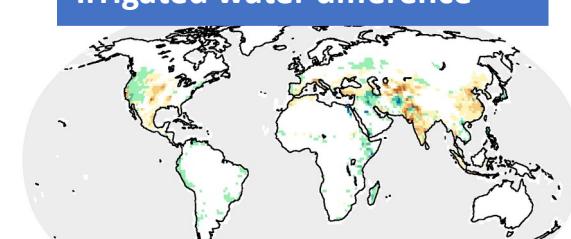
-1 -0.6 -0.2 0.2 0.6 1

Irrigation impact on climate change



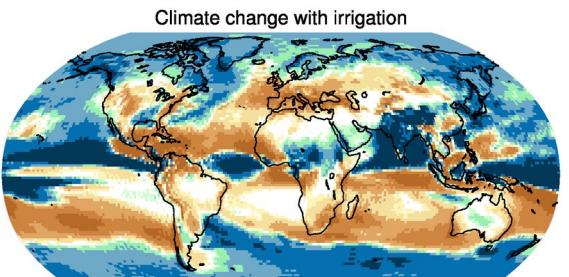
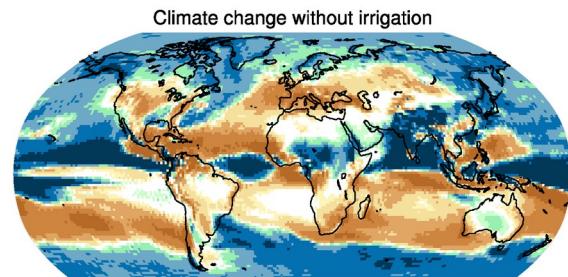
-1 -0.6 -0.4 -0.2 0.2 0.4 0.6 1

Irrigated water difference



-50 -25 -10 -1 1 10 25 50 mm/year

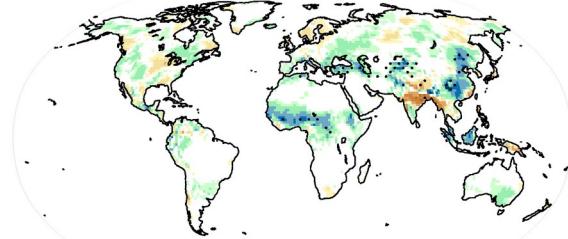
Summer (JJAS) daily precipitation (mm/day)



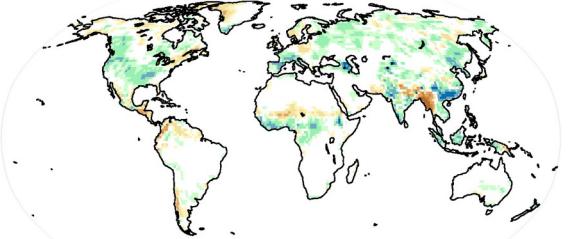
-1 -0.5 -0.25 -0.1 -0.05 0.05 0.1 0.25 0.5 1

-1 -0.5 -0.25 -0.1 -0.05 0.05 0.1 0.25 0.5 1

Irrigation impact on present-day climate



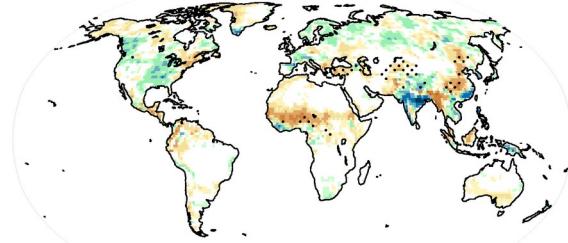
Irrigation impact on future climate



-1 -0.5 -0.25 -0.1 -0.05 0.05 0.1 0.25 0.5 1

-1 -0.5 -0.25 -0.1 -0.05 0.05 0.1 0.25 0.5 1

Irrigation impact on climate change



-1 -0.6 -0.4 -0.2 0.2 0.4 0.6 1

=> Decrease (increase) of warming where irrigation increases (decreases). Increase of PR with irrigation, possibly affecting the climate change signal.

## To conclude

**It is possible to represent irrigation in GCM/ESM ?** Yes. And more and more models do so (IRRMIP).

**It is worth it ?** Yes. It can affect the simulated climate and climate change.

**What about (ground)water resources ?** Their variations can also affect climate and climate change (Colin et al., 2023).

## Moving forward...

**Large uncertainties on withdrawals forcings =>** compute the water demand inline (also uncertain)  
**Uncertainties on the effects of irrigation on climate=>** Inter-comparison project IRRMIP

**Could GCM/ESMs be used as tools to inform Land Use Change Scenarios on irrigation-induced future water scarcity ?**

Ensures simpler and shorter workflow with IAMs, than through the use of impact models.