



## Impact of climate change on groundwater in aquifers: a global assessment with the CNRM climate models



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# What are aquifers ?



- Permeable geological structure
- Contain groundwater
- $\approx 30\%$  of the total fresh water available on Earth
- $\approx 1/3$  of the anthropological use of fresh water

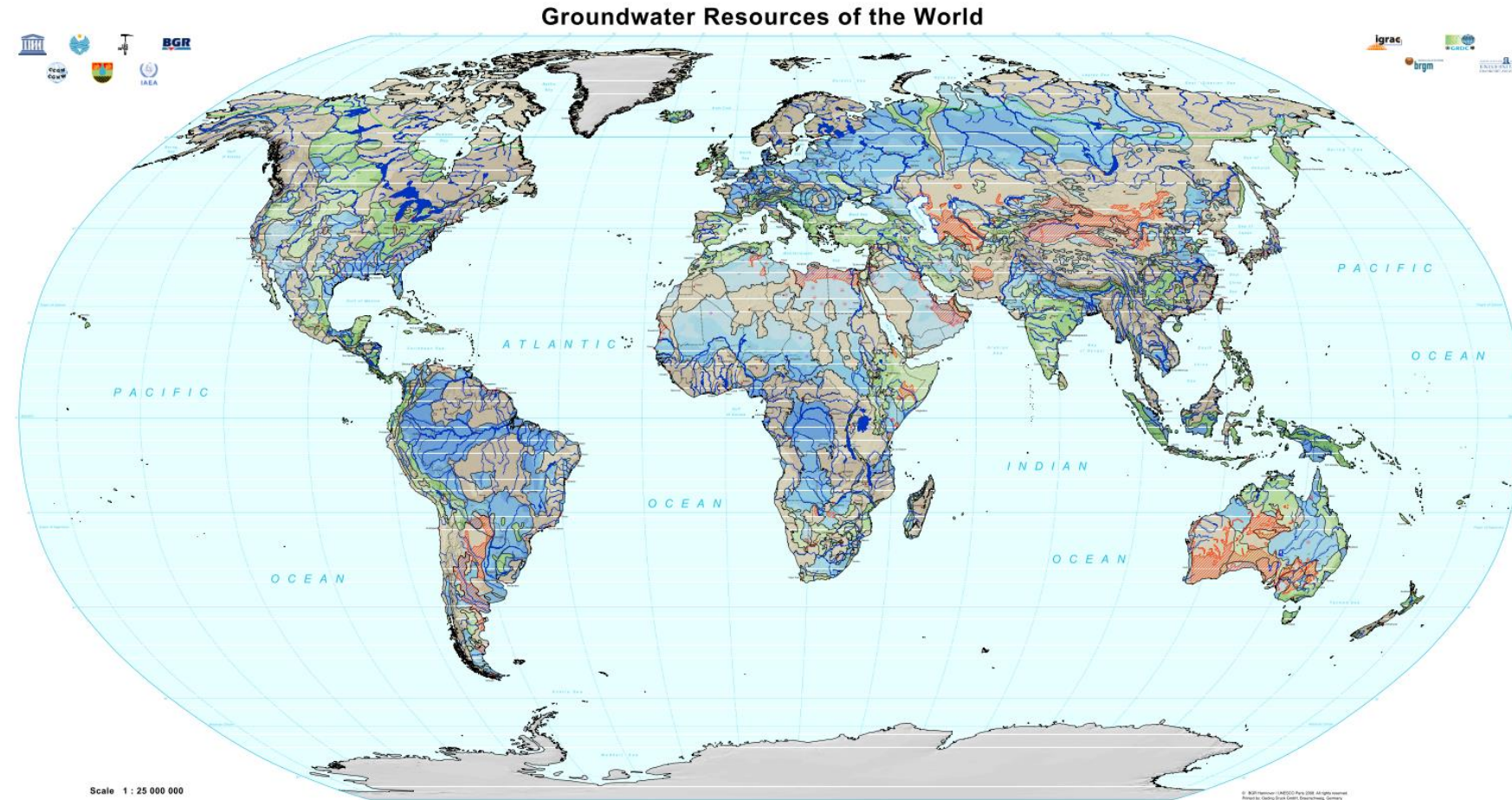
## Groundwater

 in major groundwater basin

 in complex hydrogeological structures



area of saline groundwater



extracted from:  
World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP)

# Aquifers in the CNRM climate models

## CNRM climate models:

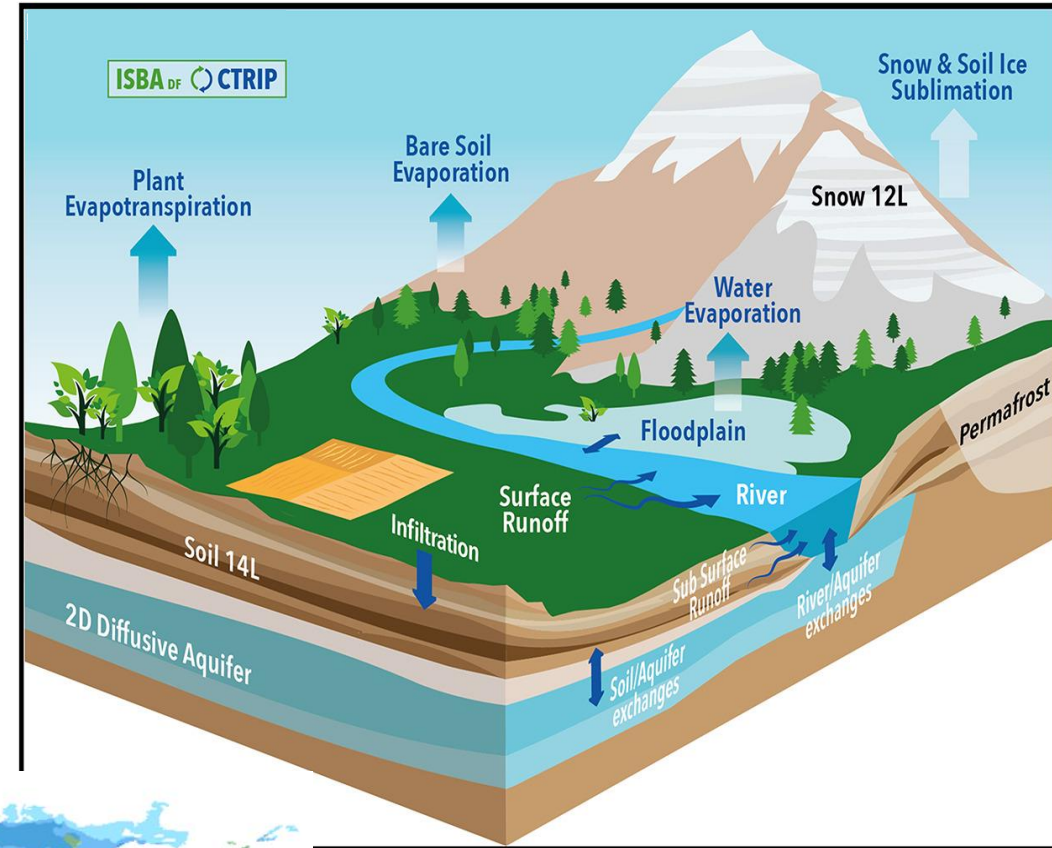
- CNRM-CM6<sup>1</sup>
- CNRM-ESM2<sup>2</sup>

## Simulations run under the CMIP6 experiments :

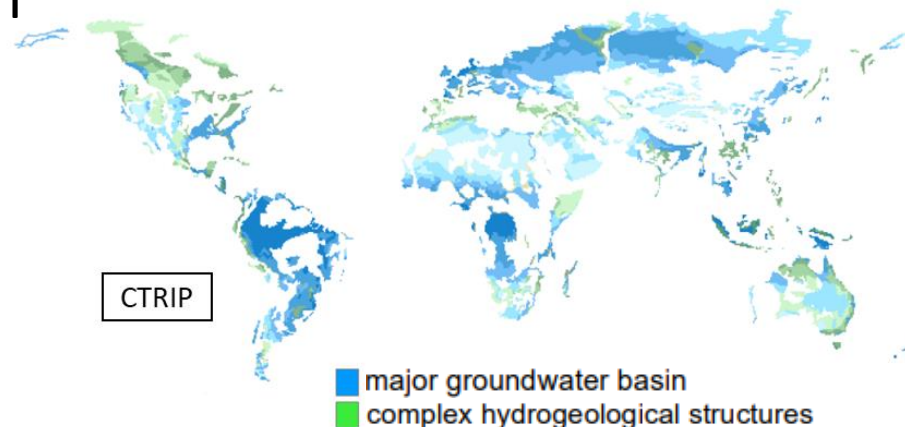
- Historical
- SSP126, 245, 370 and 585

## ISBA-CTRIP<sup>3</sup> :

- Land surface system model
- Physical and realistic simulation of the continental hydrology
- Contains the parametrization of aquifers processes



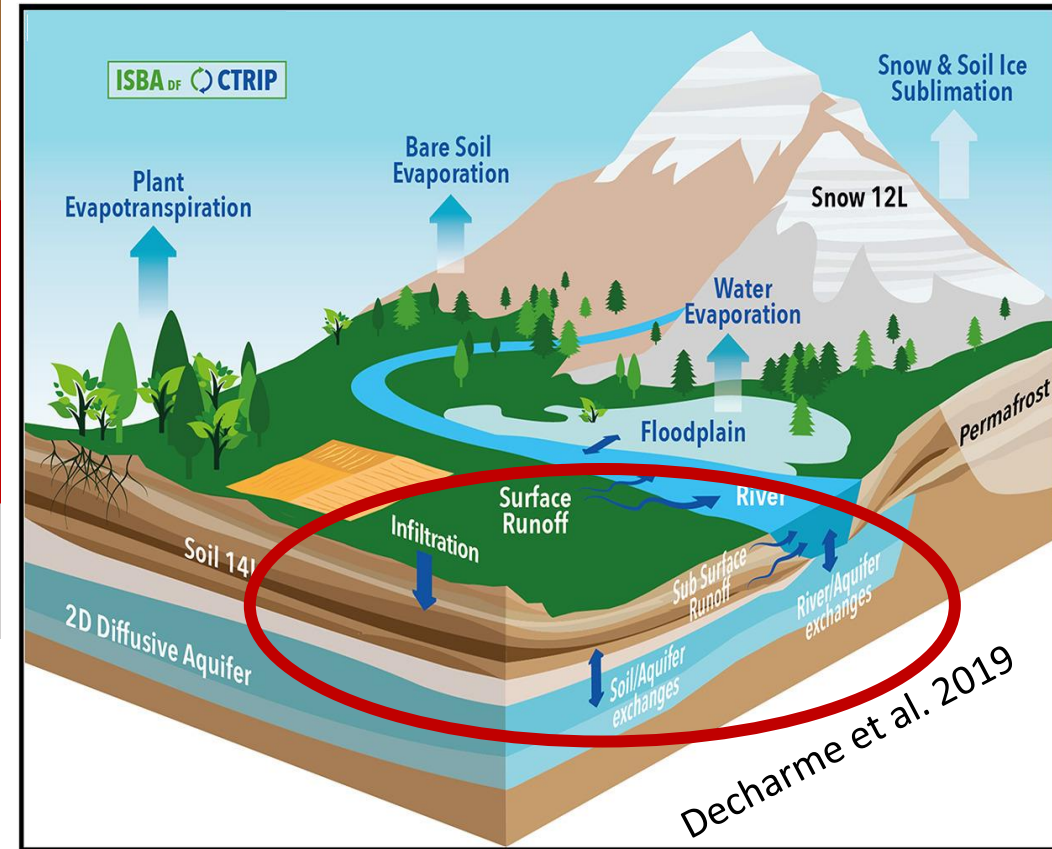
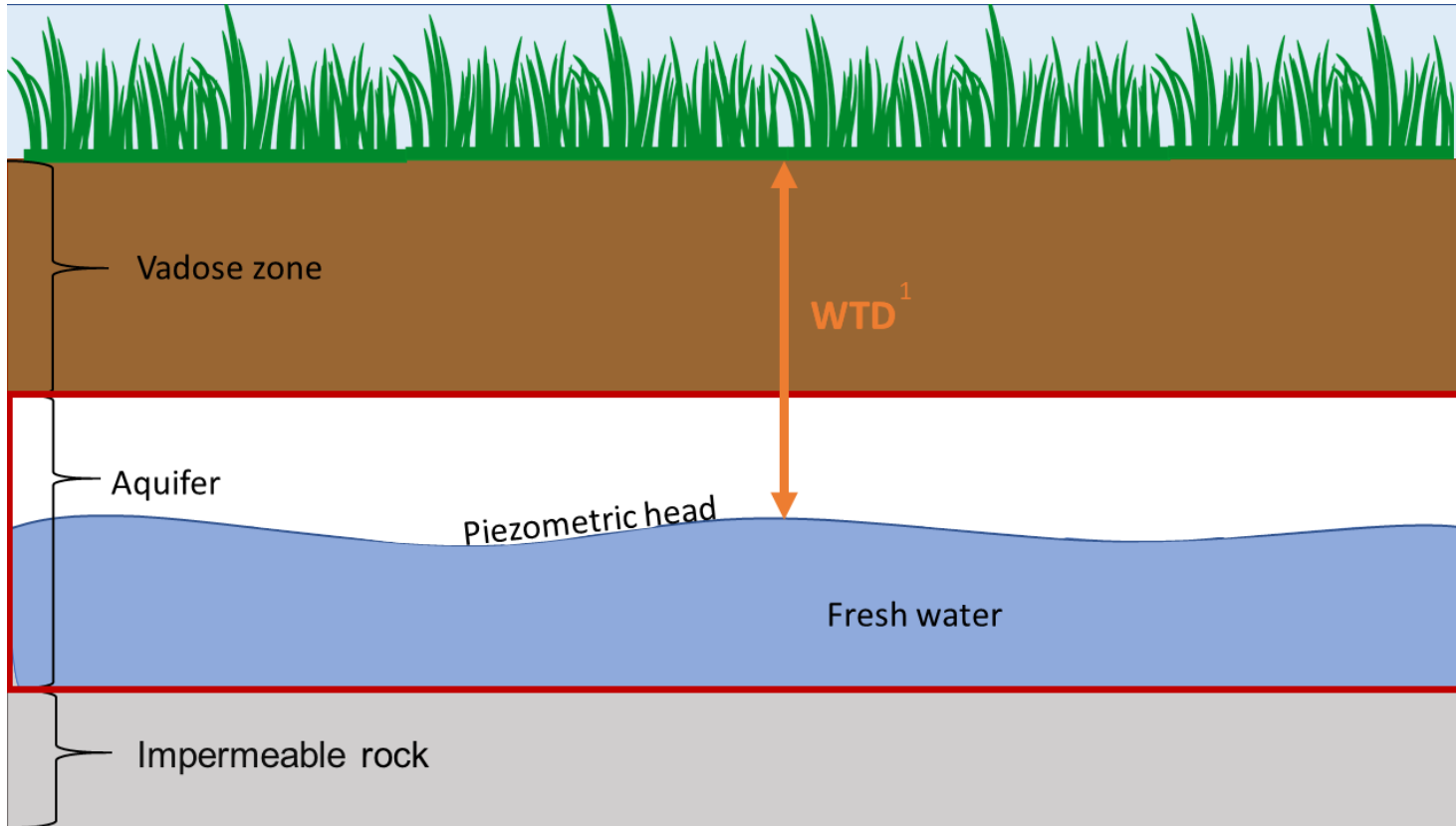
Decharme et al. 2019



# Water Table Depth

## Aquifer recharge:

- Water exchanges between soil and aquifer: mainly precipitation infiltrations through soils
- Water exchanges between river and aquifer



<sup>1</sup> Water Table Depth

Test of False Discovery Rate :  
Wilks 2016  
Wilks 2006

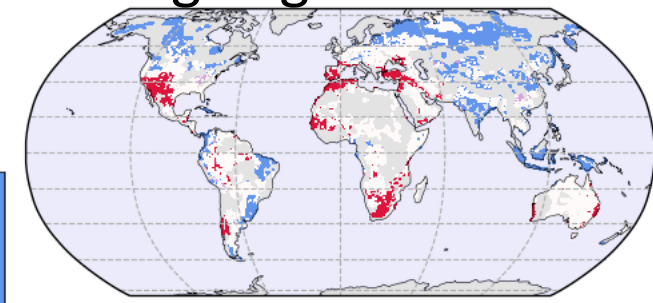
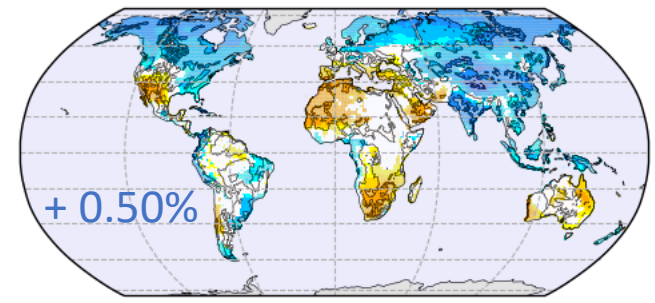
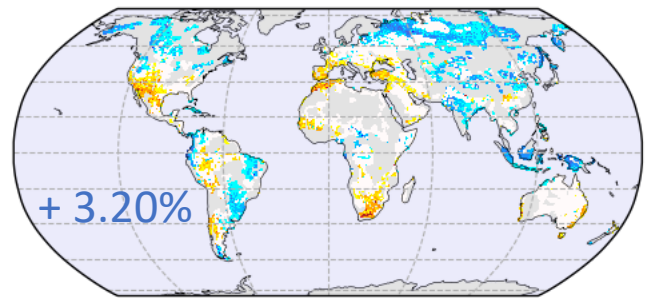
### WTD

Historical (1985-2014)  
vs SSP (2071-2100)

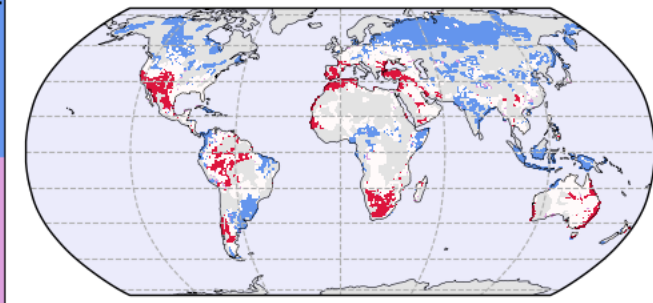
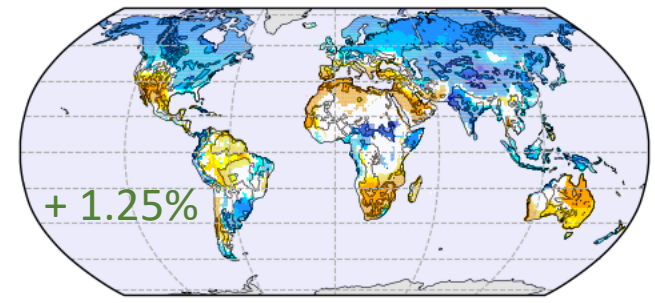
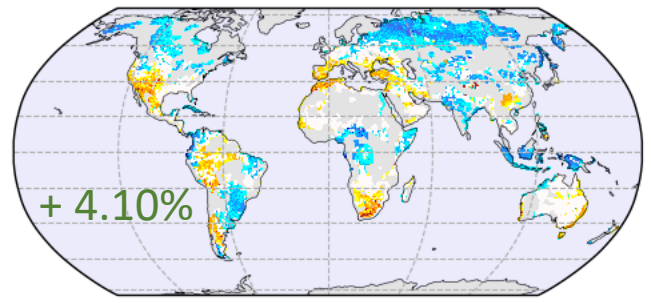
### Precipitation

### WTD & Precipitation: Sign agreement

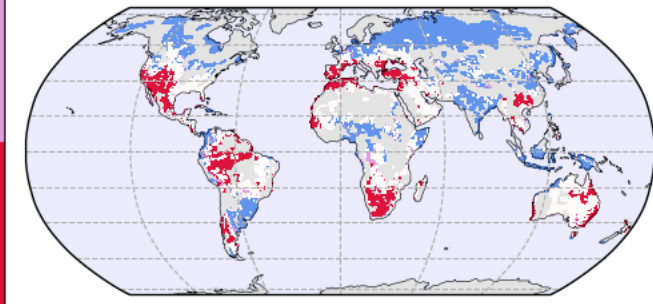
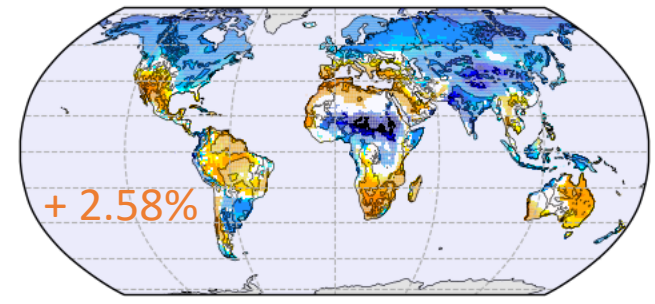
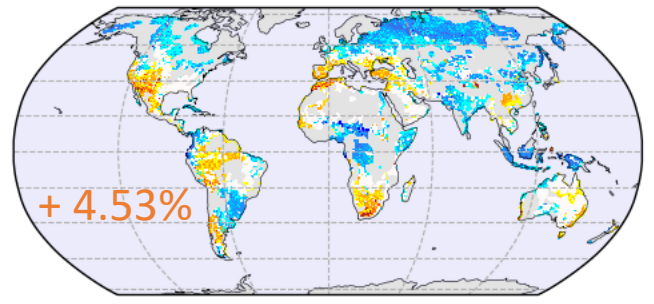
SSP126



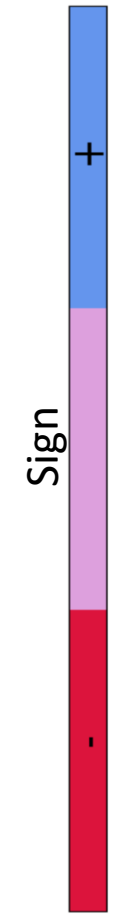
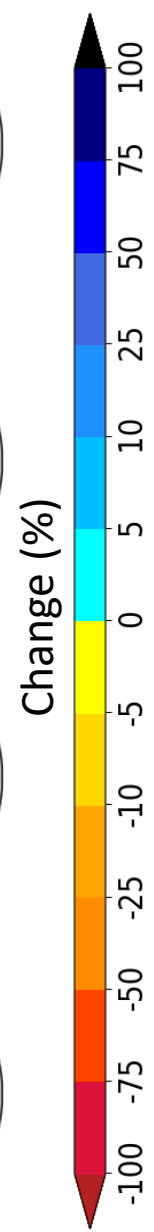
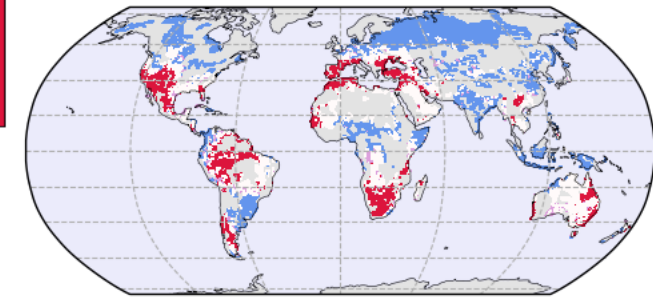
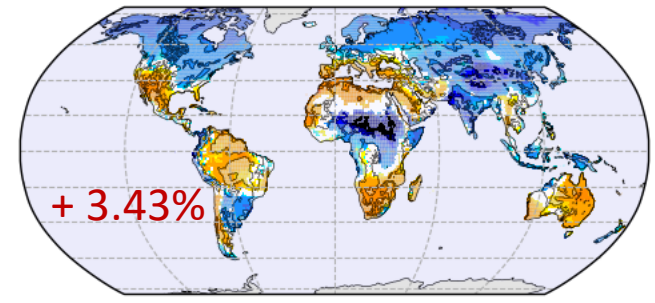
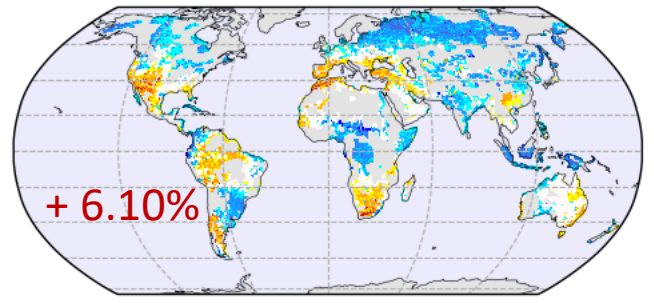
SSP245



SSP370



SSP585



# Multi-model analysis

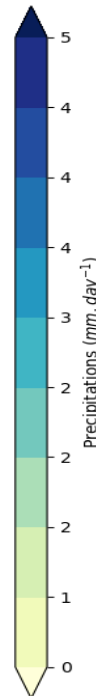
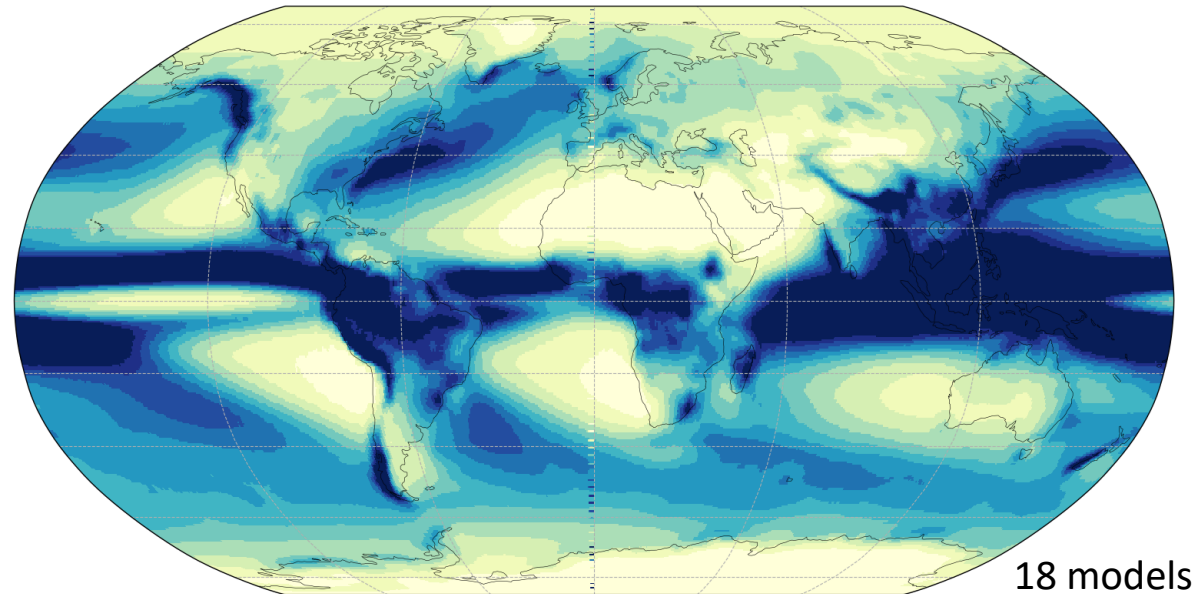
**Question:** Are the CNRM results consistent with those of the CMIP6 models ?

**Issue:** CNRM models are the only global climate models simulating the physical processes involving aquifers

└───▶ Multi-model study for WTD: impossible

**Solution:** Using the link between the trend in precipitation and WTD and studying the multi-model precipitation

CMIP6 historical: 1985-2014

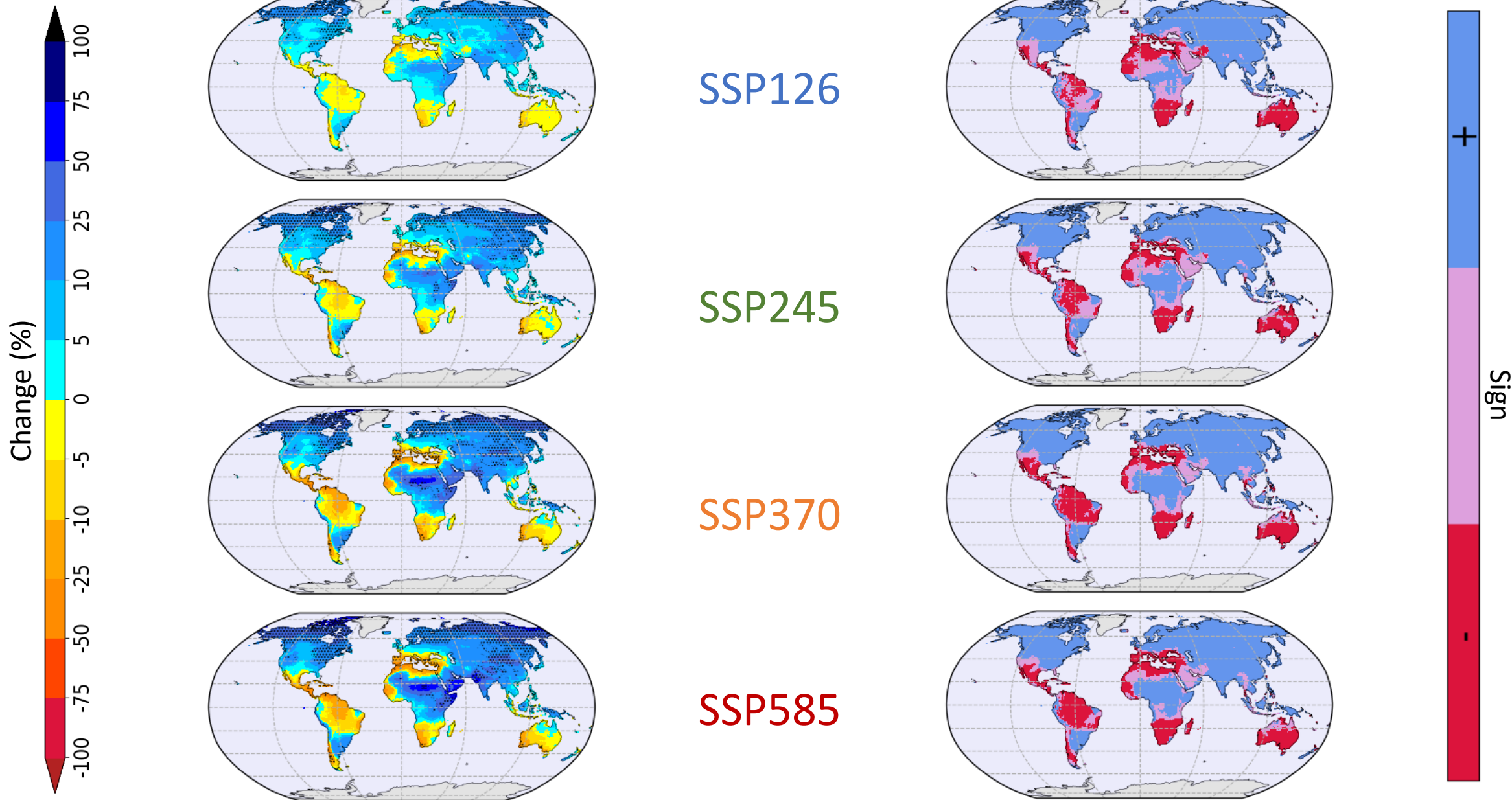


## Models used (18):

- |                     |                       |
|---------------------|-----------------------|
| BCC_BCC-CSM2-MR     | MIROC_MIROC6          |
| CAS_FGOALS-f3-L     | MIROC_MIROC-ES2L      |
| CAS_FGOALS-g3       | MOHC_UKESM1-0-LL      |
| CCCma_CanESM5-CanOE | NASA-GISS_GISS-E2-1-G |
| CCCma_CanESM5       | NCAR_CESM2            |
| CSIRO_ACCESS-ESM1-5 | NCAR_CESM2-WACCM      |
| INM_INM-CM4-8       | NIMS-KMA_KACE-1-0-G   |
| INM_INM-CM5-0       | NOAA-GFDL_GFDL-ESM4   |
| IPSL_IPSL-CM6A-LR   | UA_MCM-UA-1-0         |

Dots: Agreement on the evolution trend  
of at least 90% of the CMIP6 models (17/18)

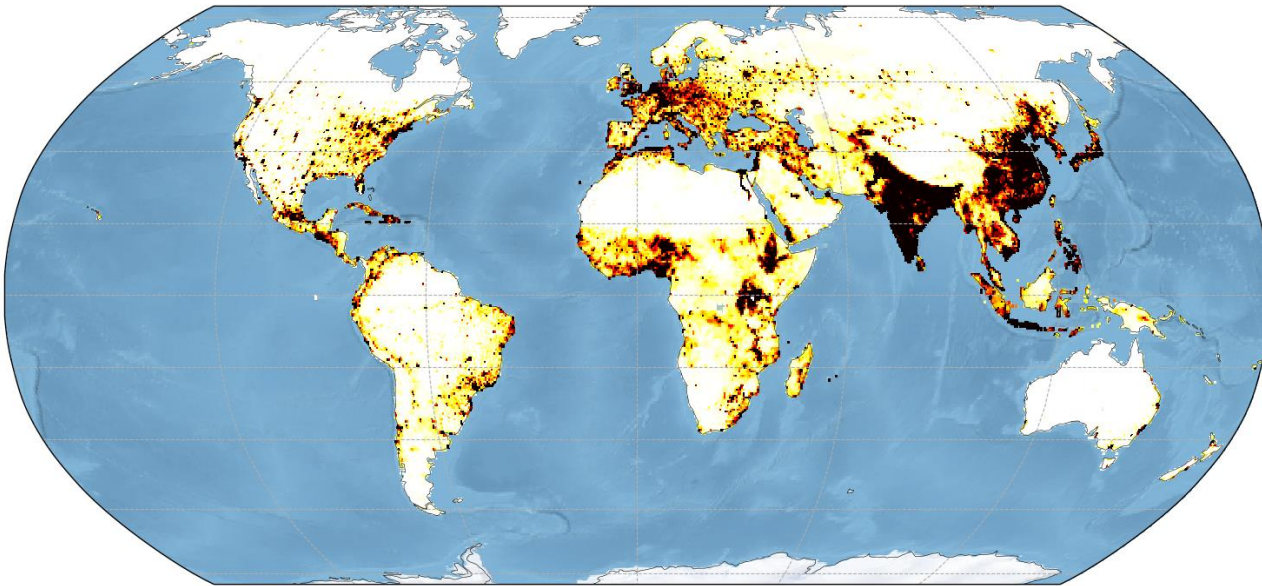
Agreement on the evolution trend between  
the CMIP6 and CNRM models



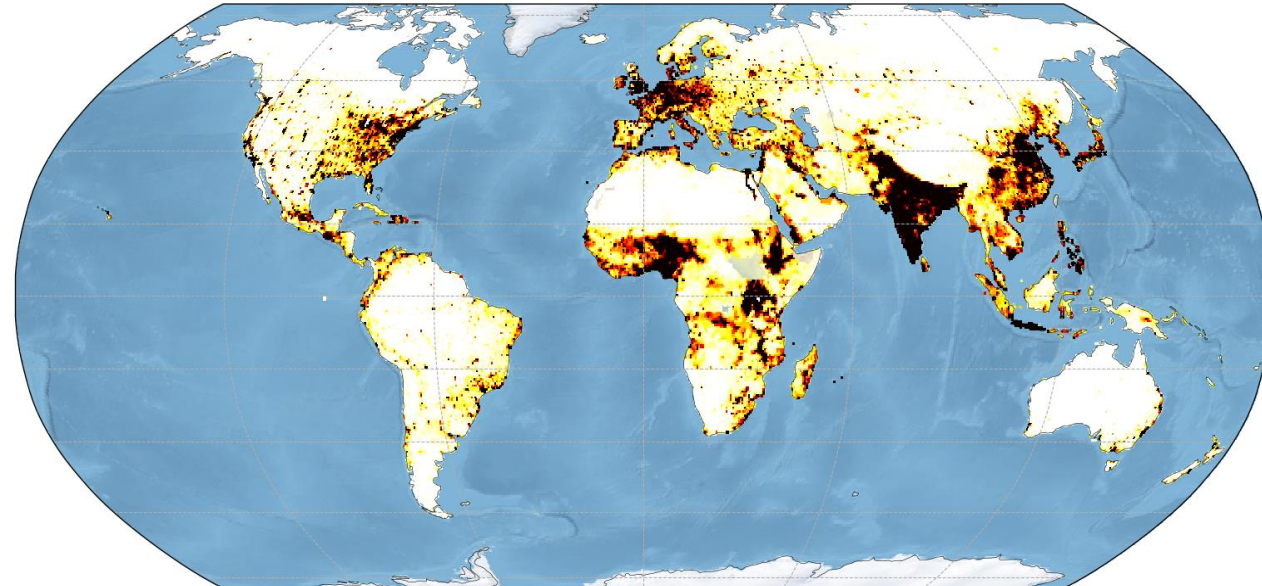
# Consequences for the water resources

**Question:** What will be the possible evolution of the population's water requirement ?

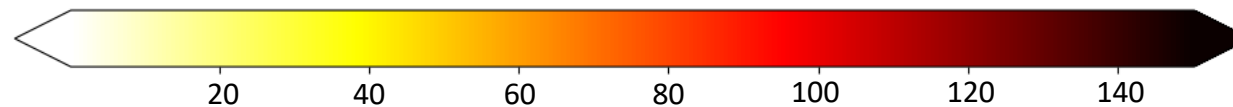
Population density: 2015



Population density: 2100 (SSP585)



hab/km<sup>2</sup>

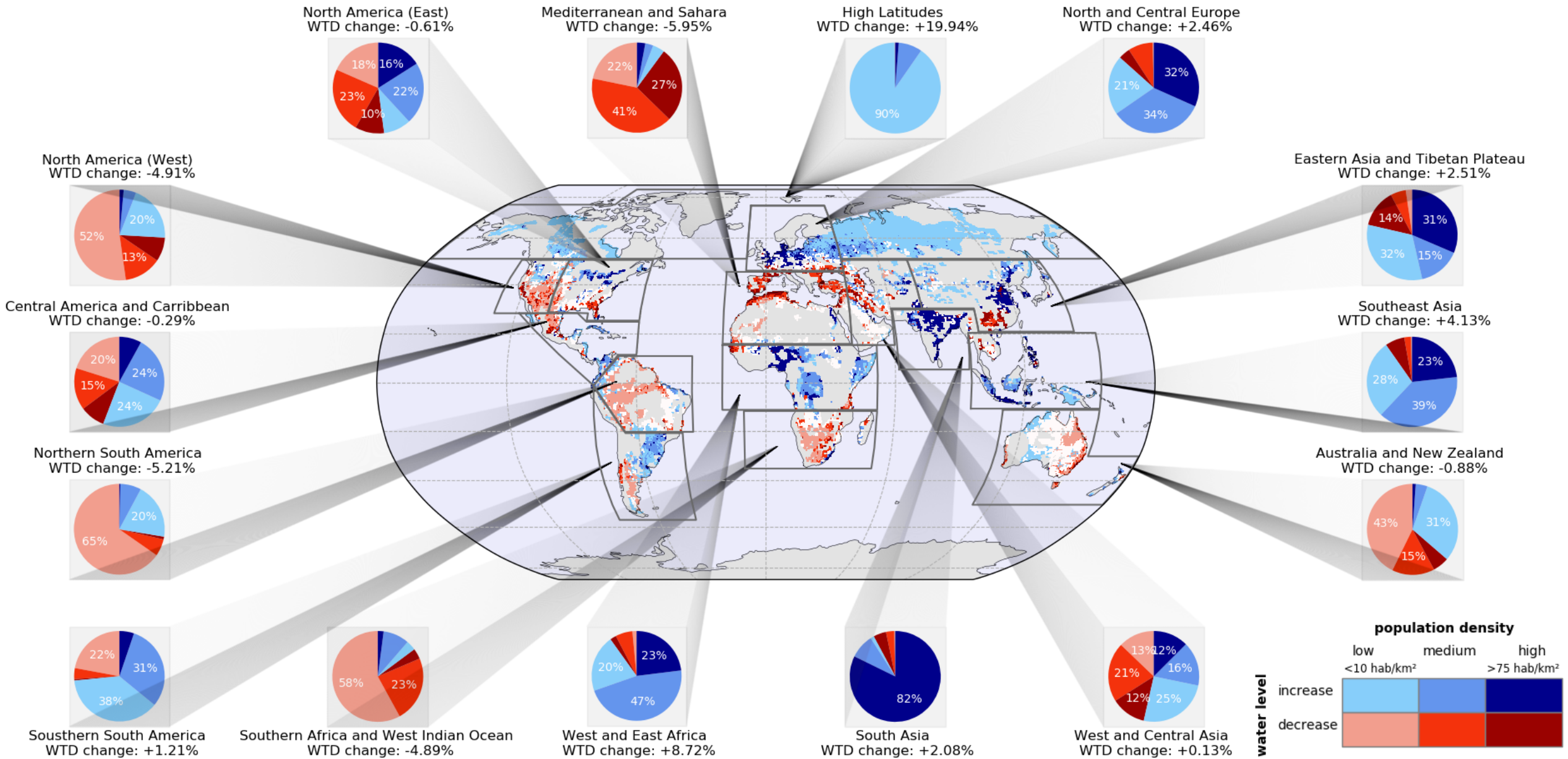


Data extracted from :  
Center for International Earth Science Information aNetwork - CIESIN -  
Columbia University. 2016. Gridded Population of the World, Version 4  
(GPWv4): Population Count. Palisades, NY: NASA Socioeconomic Data  
and Applications Center (SEDAC).

Data extracted from SSP Database : Development  
of population by country scenarios  
Riahi, K. *et al. Glob. Environ. Chang* (2017)

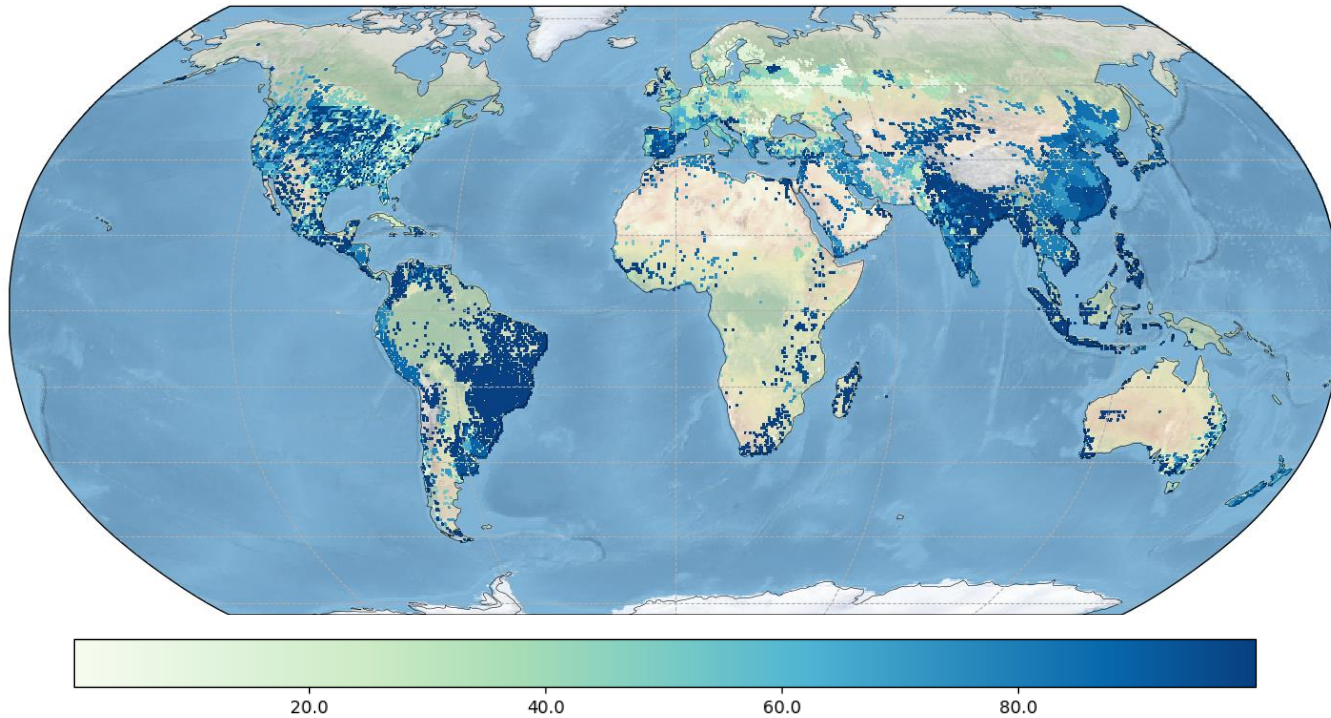


# Future population density and WTD evolution (SSP585)



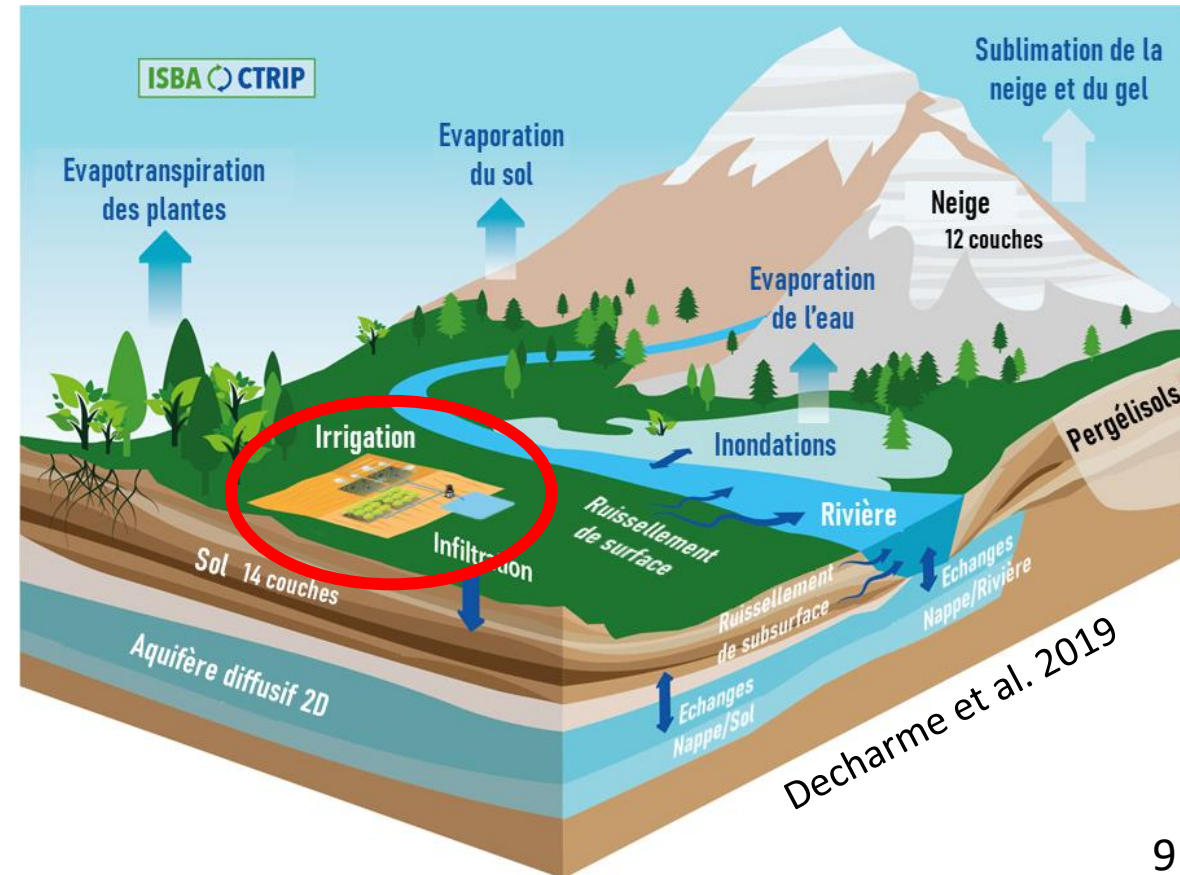
# Future work

Irrigated areas (%)



Data extracted from :  
FAO: AQUASTAT – FAO’s global information system on water and agriculture,  
FAO, <https://data.apps.fao.org/aquamaps/>

- Main limitation of the study: Non-inclusion of the anthropogenic effects, mainly **irrigation**
- Future objectives: implementation of a parametrization of **irrigation** inside the CNRM climate models

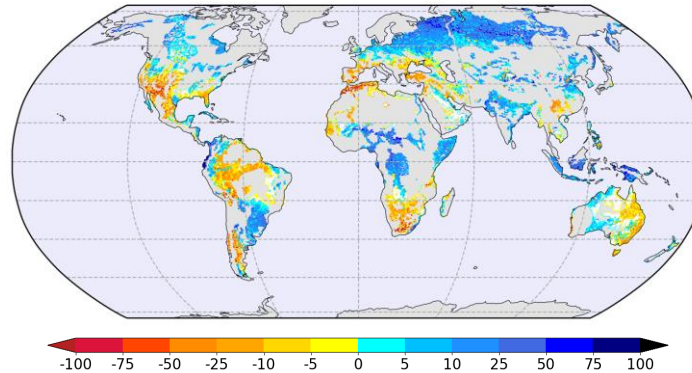


# Thank you for your attention !

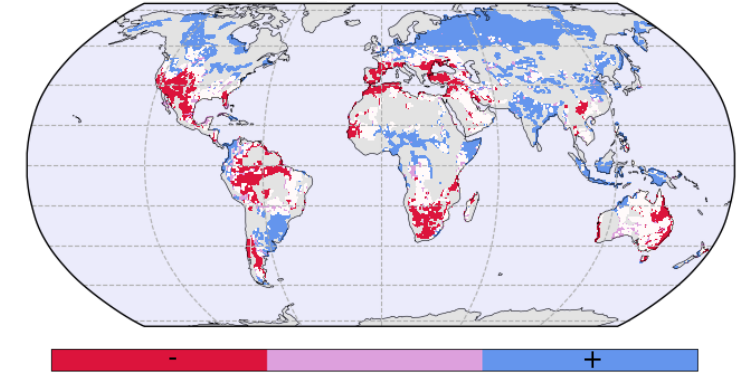
1) Future global water level in aquifers: increase

SSP126: +3.20%  
SSP245: +4.10%  
SSP370: +4.53%  
SSP585: +6.10%

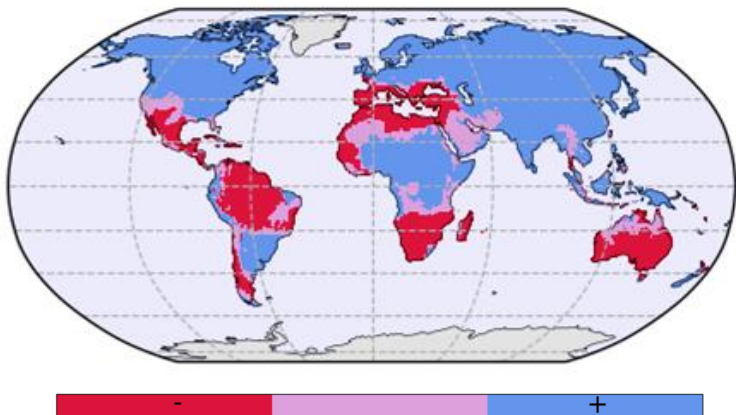
2) WTD change: large regional disparities



3) Link between the precipitation and WTD evolution trend



4) Agreement between the precipitation trend of the CMIP6 and the CNRM models



5) The decrease of WTD associated with high population density widens the risk of water stress in some already groundwater-dependant regions

Necessity to represent irrigation processes in global climate models

