# Climate Change and Global Water Resources

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**Earth System Science and Climate Change Group, Wageningen UR and Watch Collaborators**

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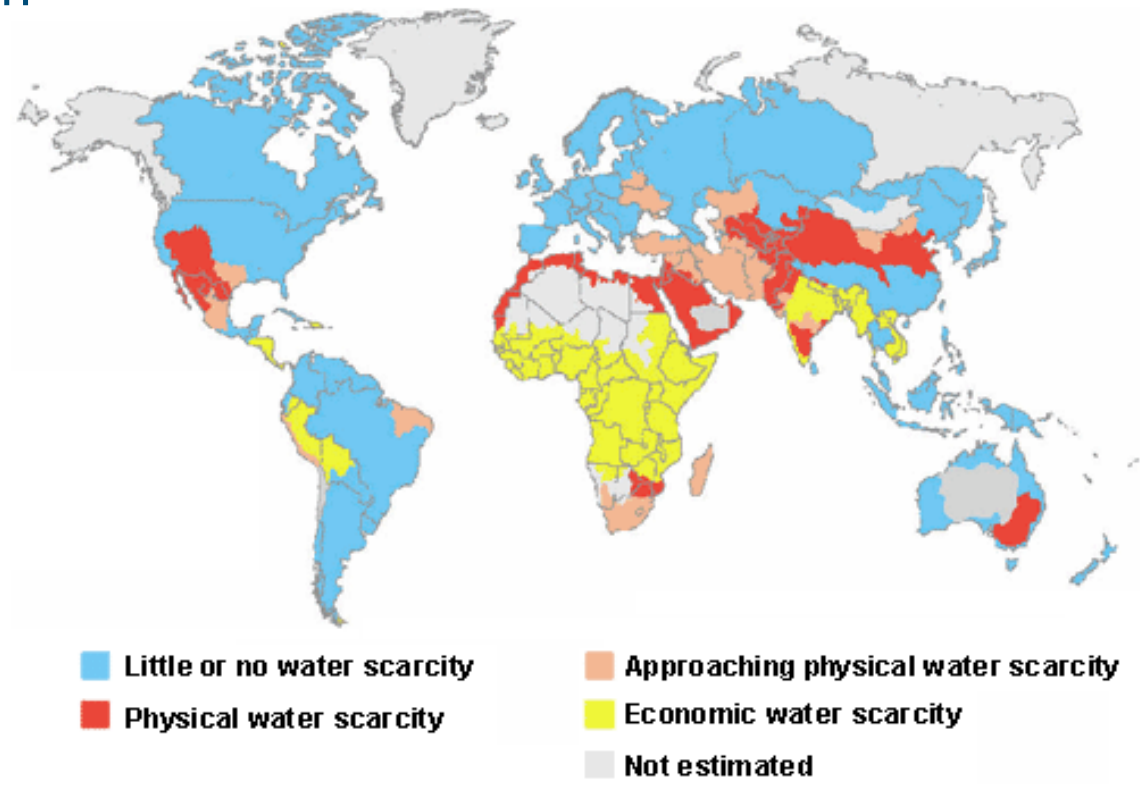
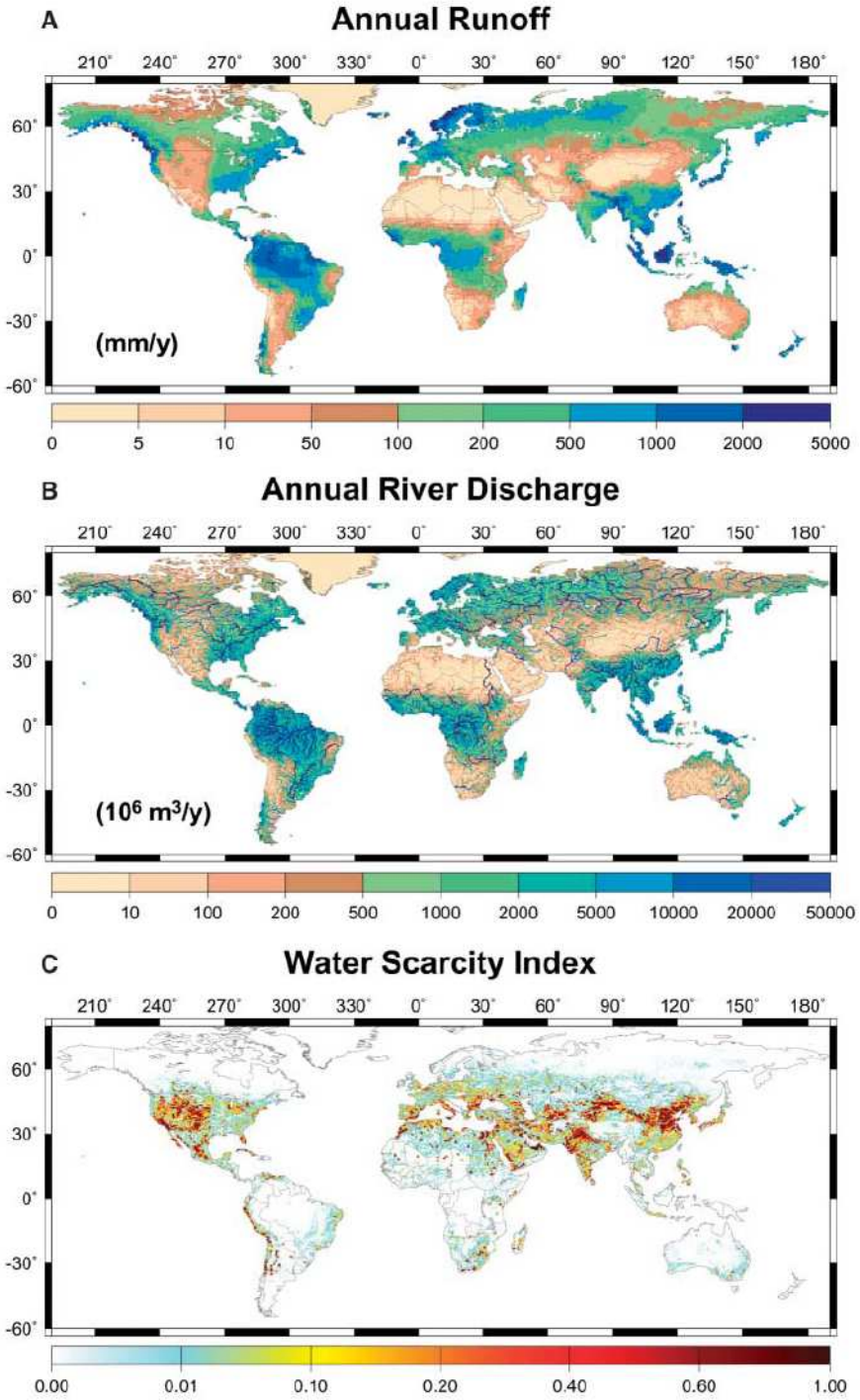
- Global Water Resources – the current situation
- Is the hydrological cycle speeding up?
- Climate change and global water resources
- Water and Global Change (Watch) Project and WaterMIP
  - Defining uncertainties in impact studies – towards a new approach for the IPCC working group two report

Global Water Resources:

- Increasing population
- Increasing water consumption
- Land cover/use change
- **Climate Change**

## Global Water scarcity according to IWMI






1.4 billion people in watersheds with < 1000m$^3$/capita/year

2.4 billion people with poor sanitation

1 billion people without access to safe drinking water

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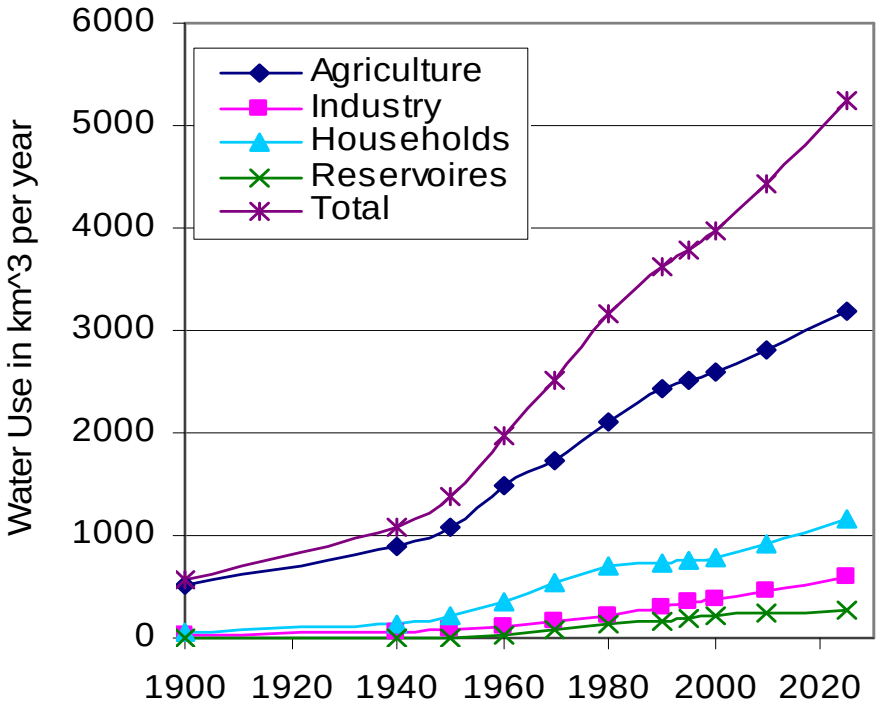
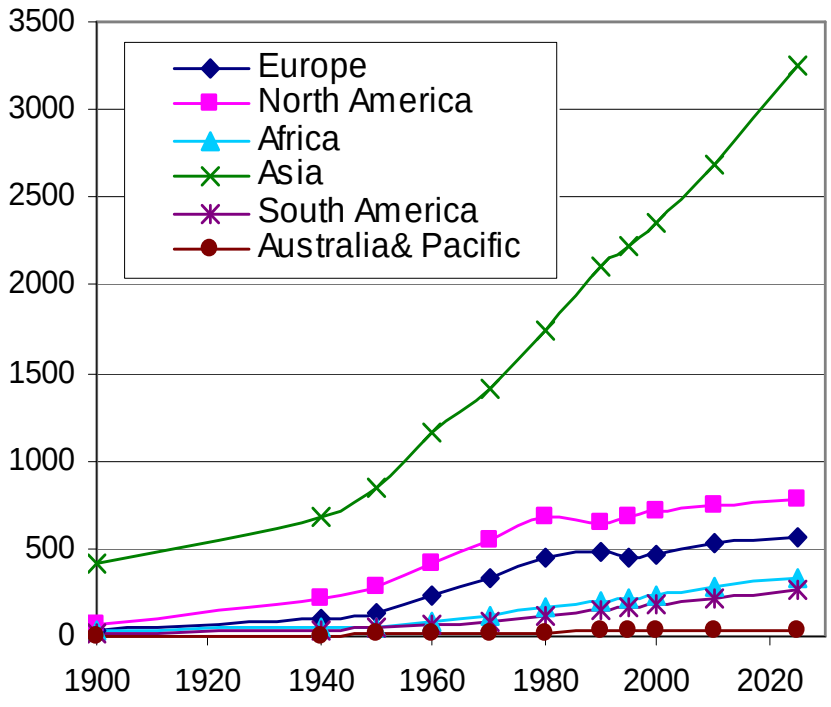
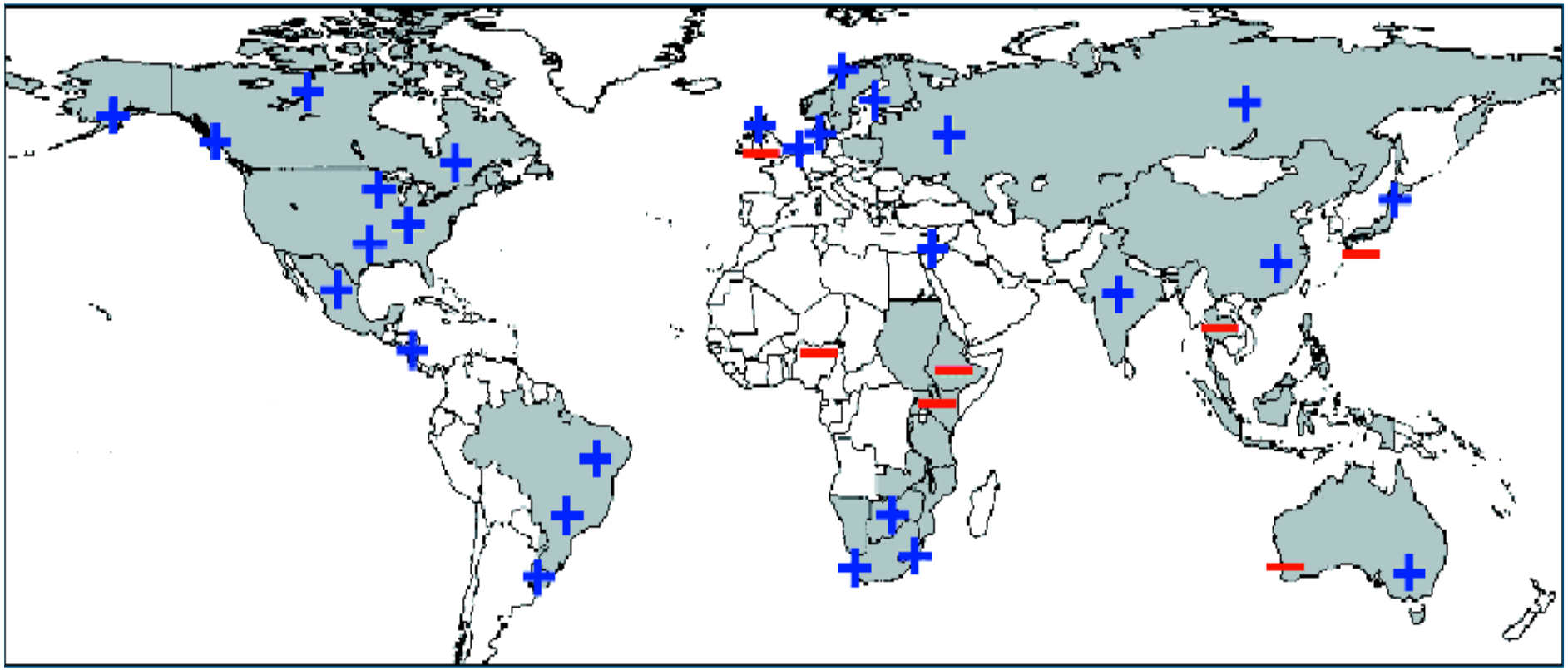
# Global water use by sector and continent



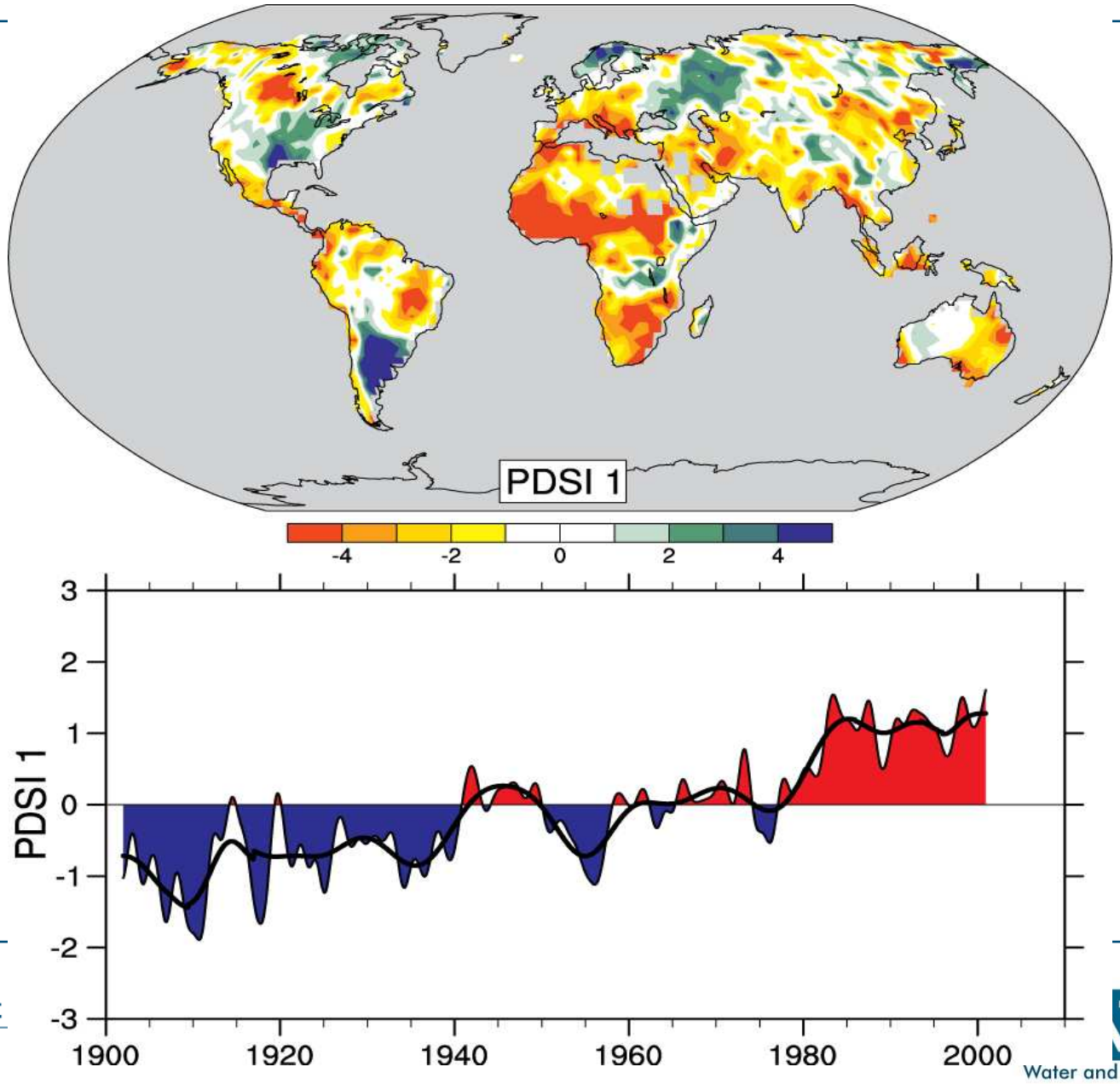



# Is the hydrological cycle speeding up

## Proportion of heavy rainfalls: increasing in most land areas



# Drought is increasing in most places

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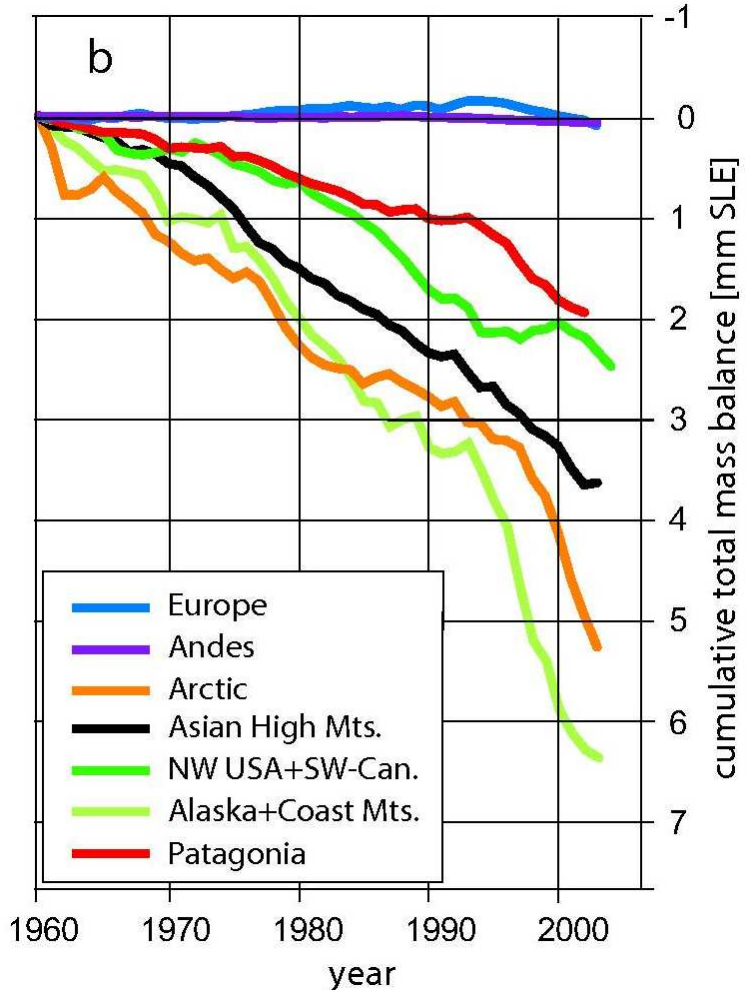
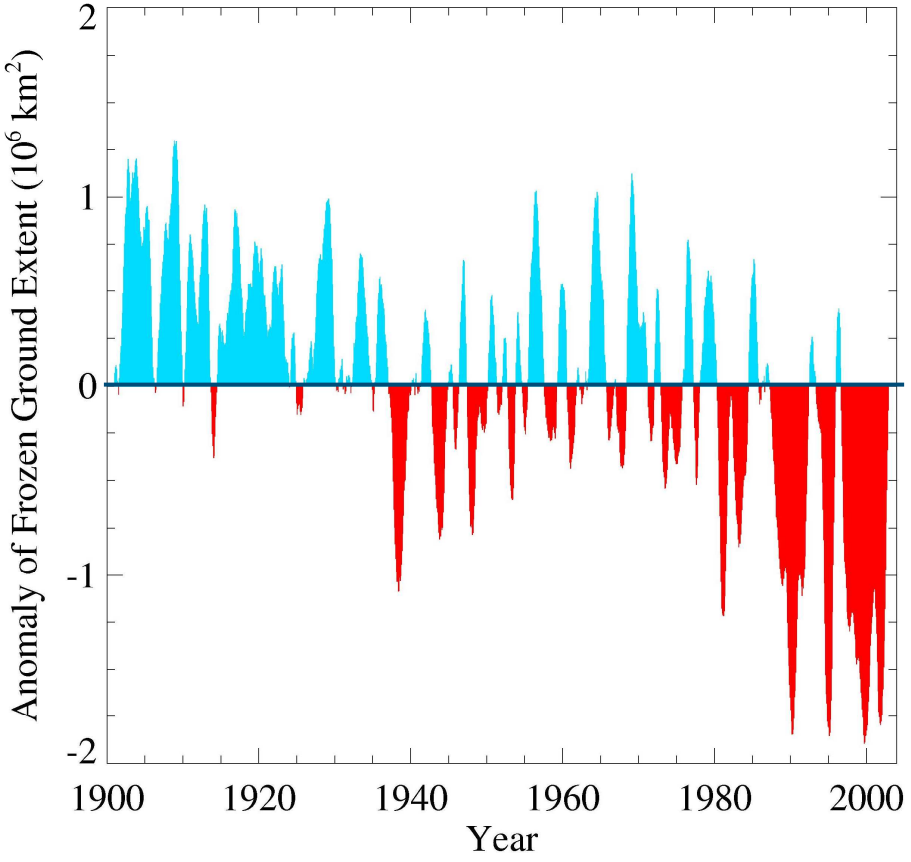
# Glaciers and frozen ground are receding



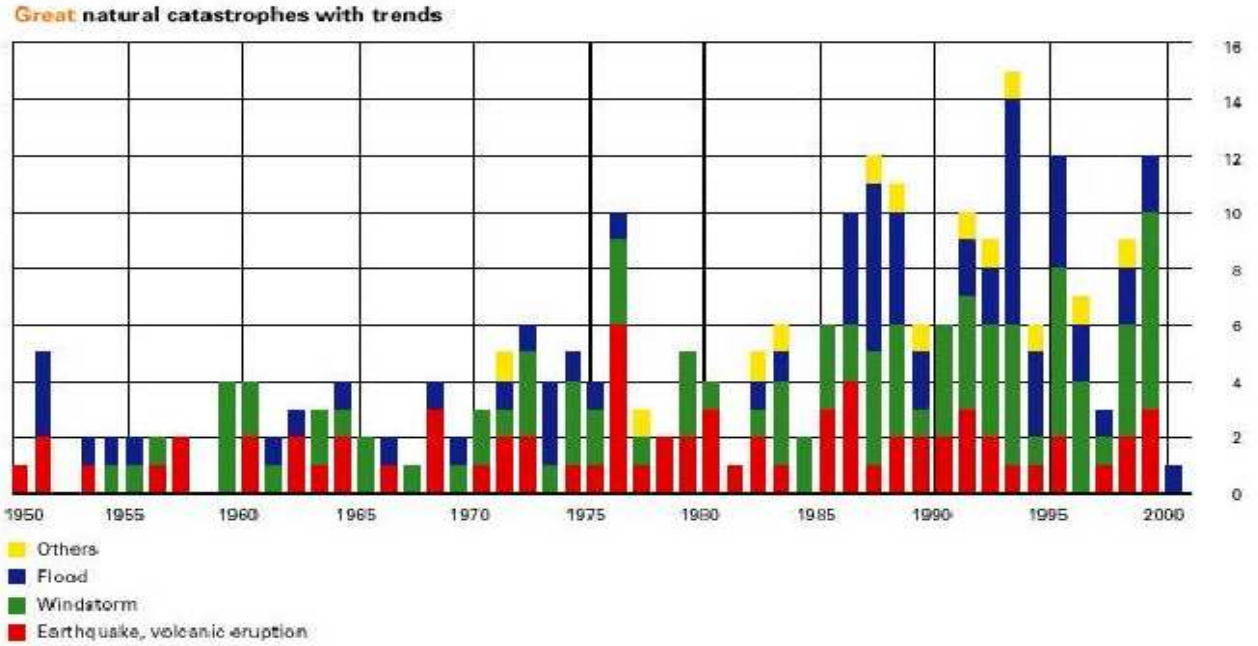



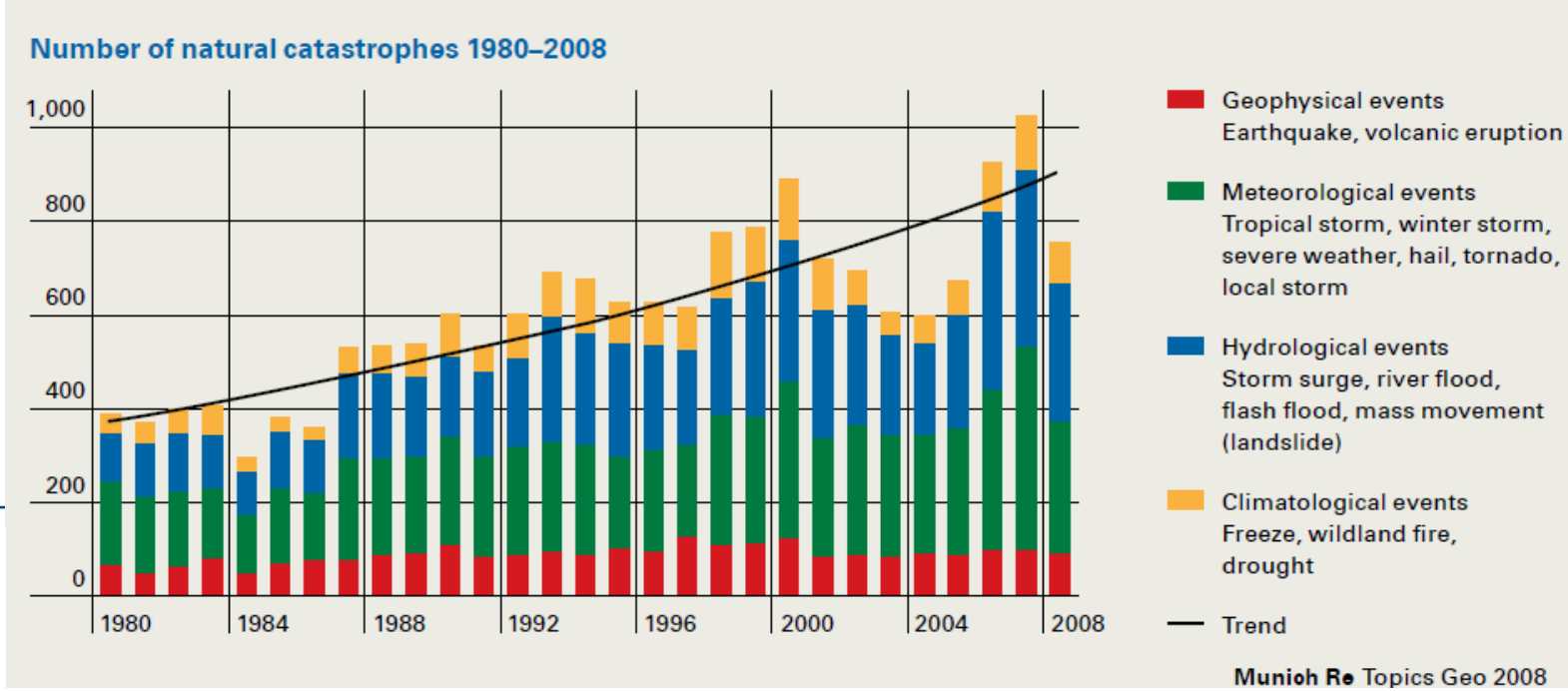

**Increased Glacier retreat since the early 1990s**

**Area of seasonally frozen ground in NH has decreased by 7% from 1901 to 2002**

Figure 3: Natural catastrophe trends in the 20th century

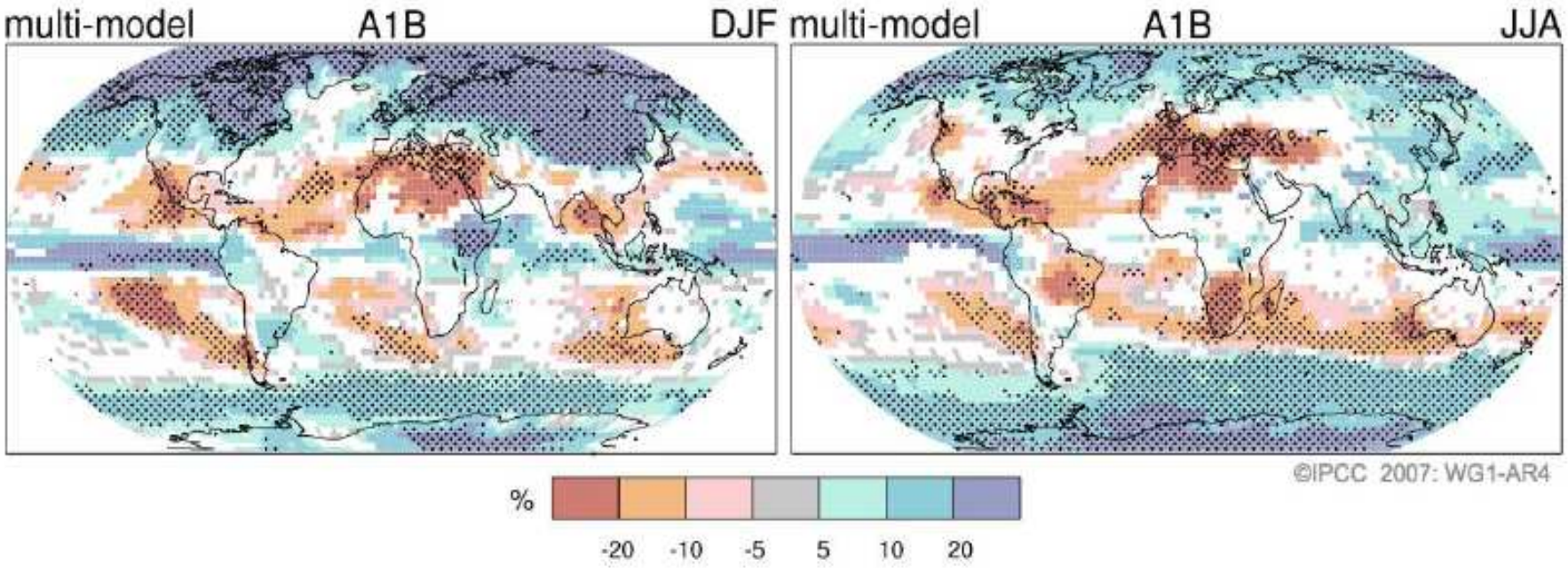
# Number of natural catastrophes is increasing



# How will climate change affect global water resources?

## Changes in Rainfall by the end of the 21st century

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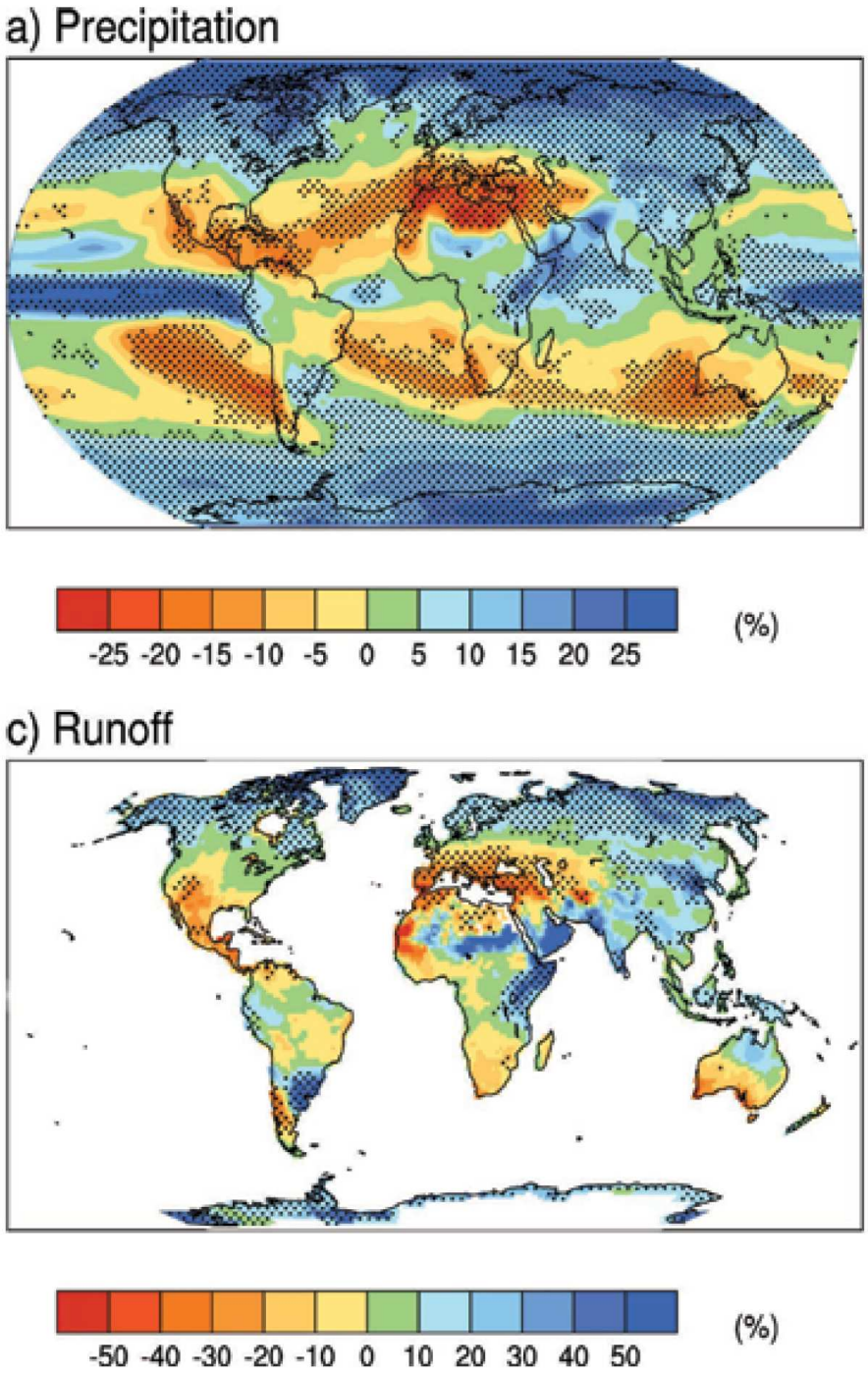
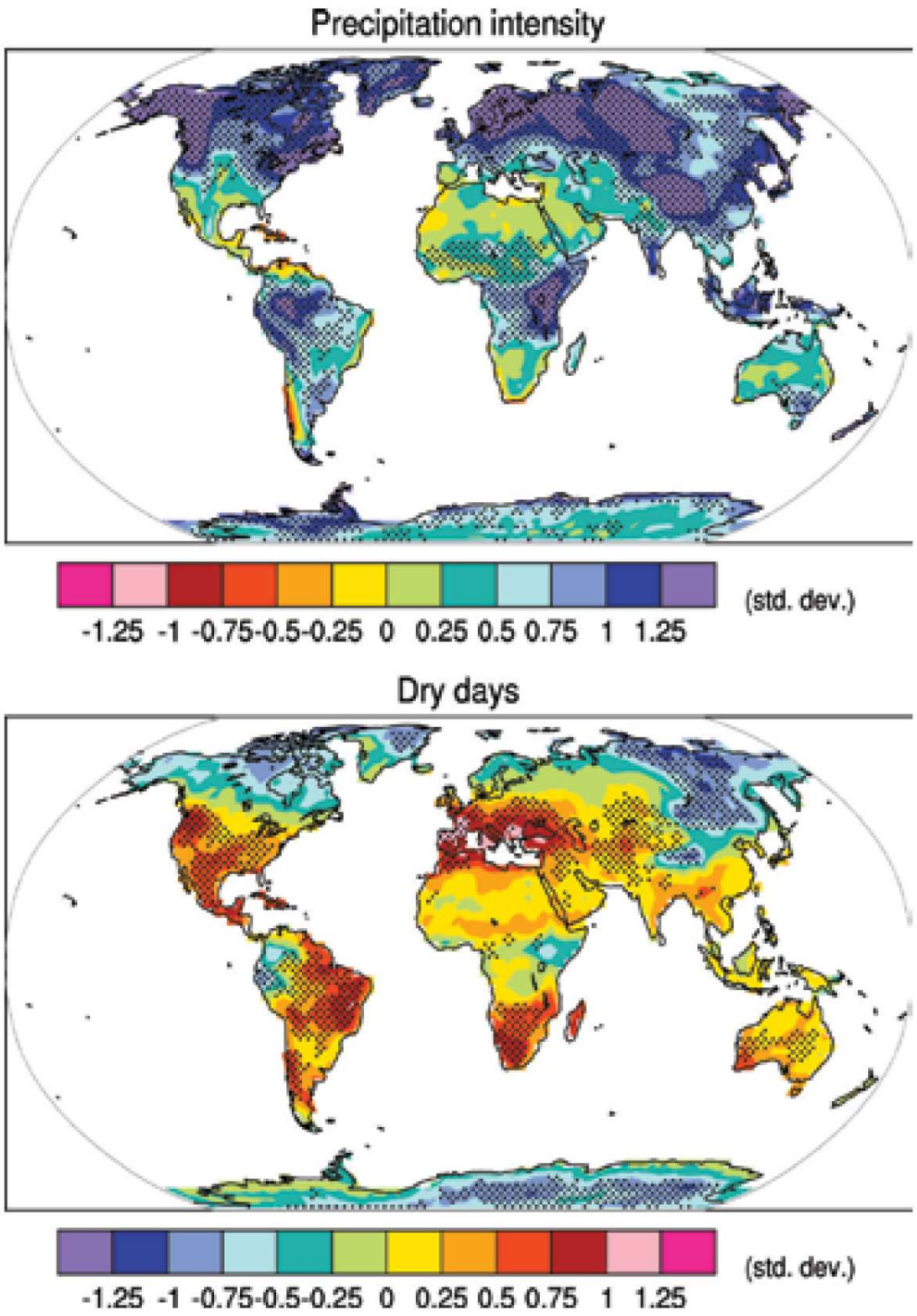
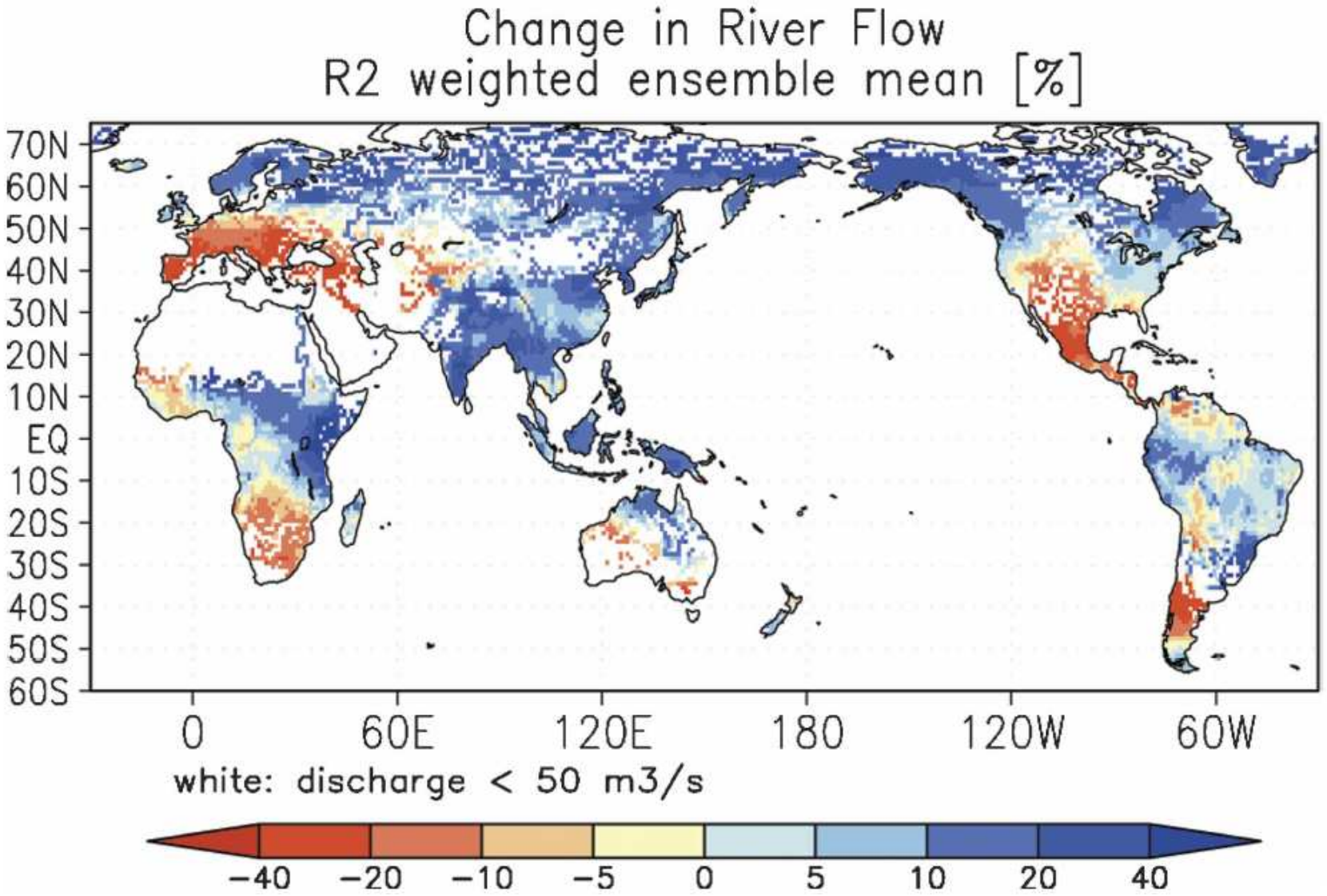
- Relative changes in run-off are larges than the changes in precipitation
- Uncertainty in runoff changes are also larger



- Both Wet and Dry extremes are predicted to increase in large areas around the globle



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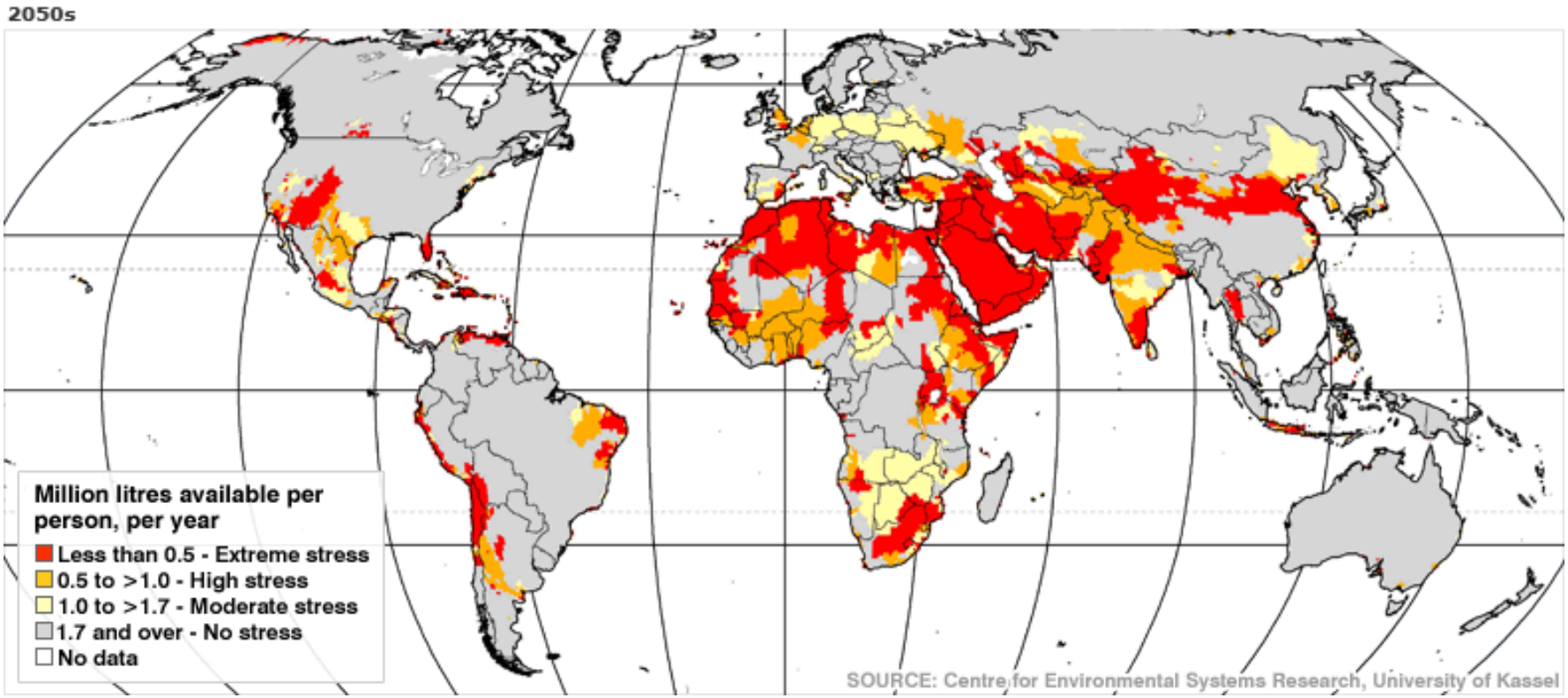
# Water stress by 2050

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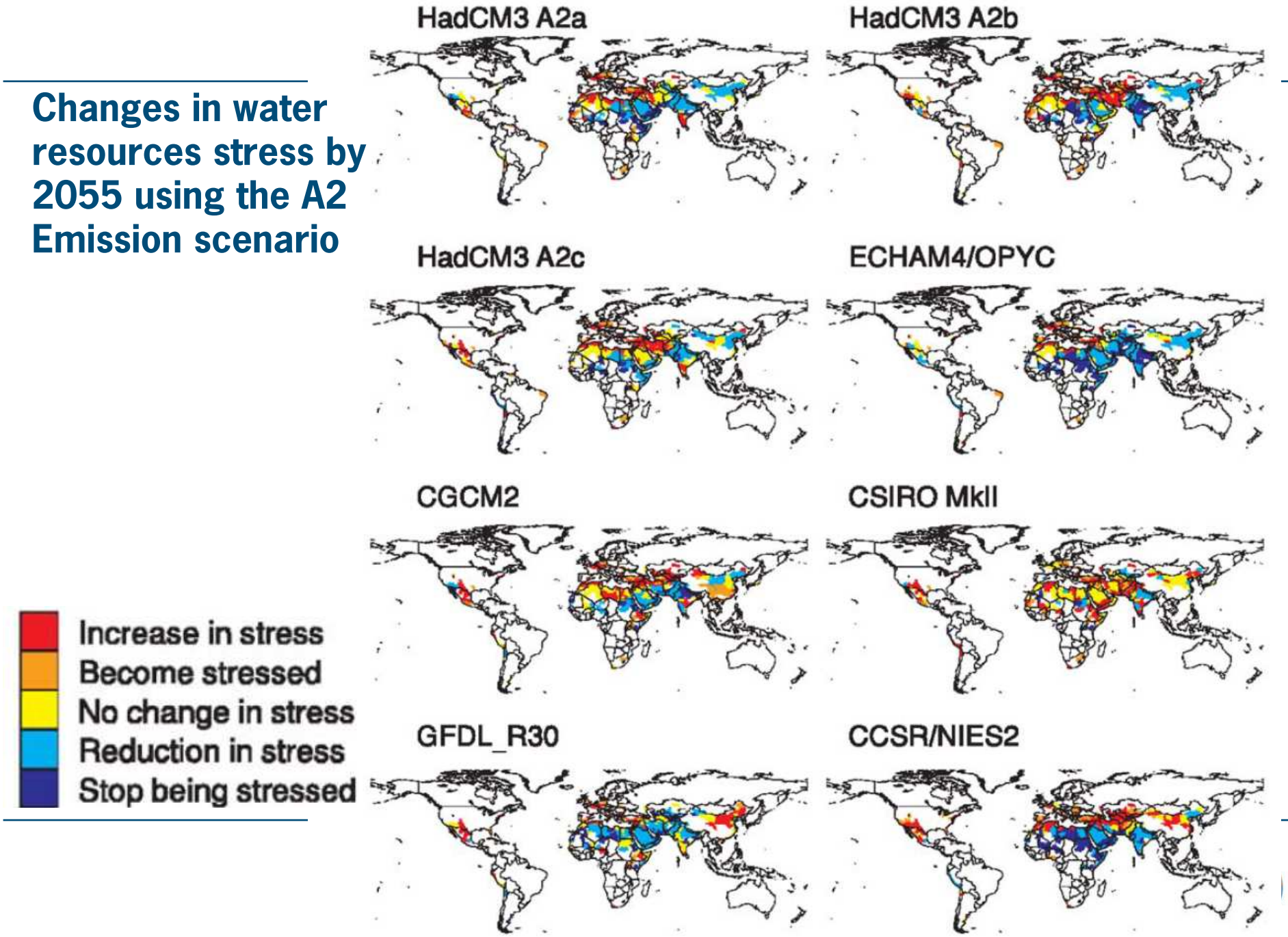
## Changes in water resources stress by 2055 using the A2 Emission scenario

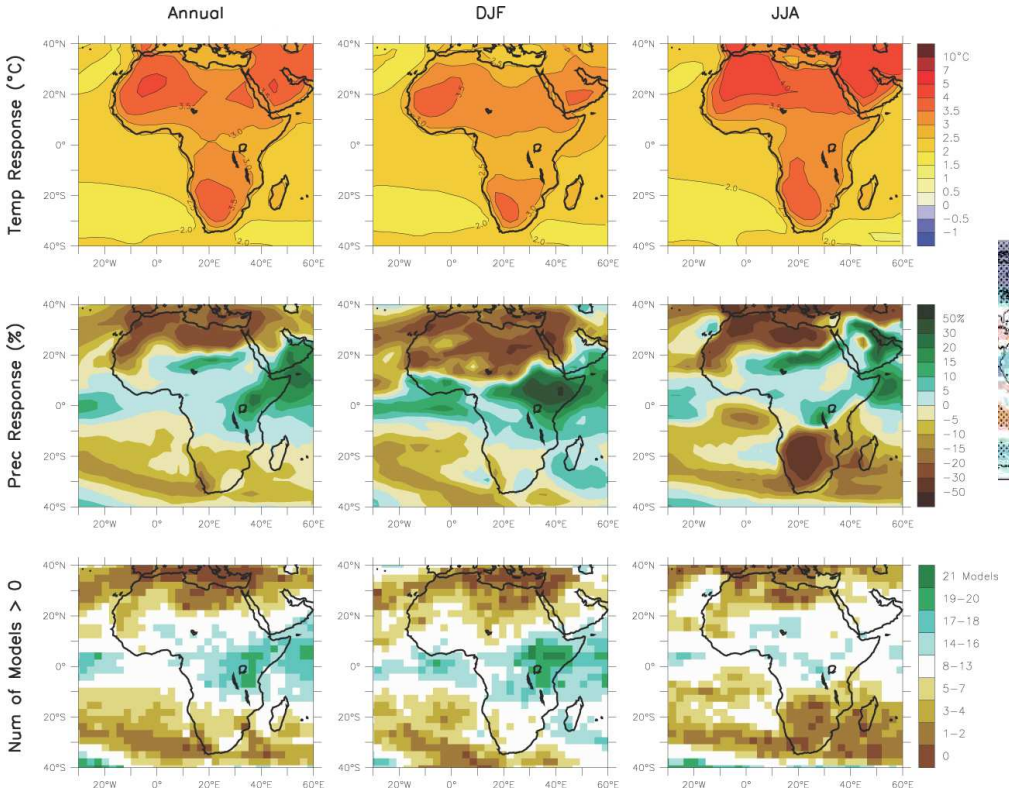


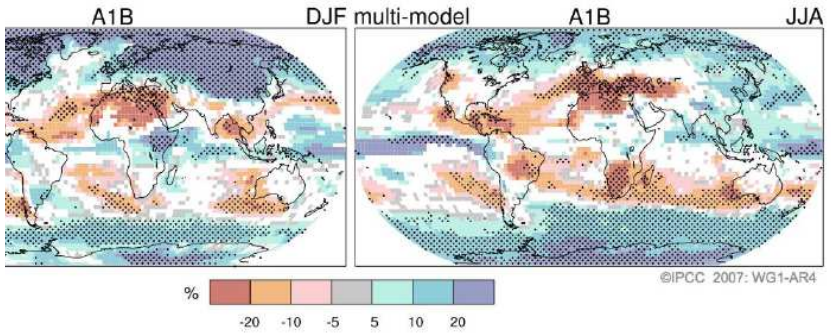
# Watch Project - Water and Global Change

- Developing a new modeling framework for the assessment of global change impacts on water resources
  - Linking climate and hydrological models
  - Reducing uncertainties – feedbacks, improved bias corrections
  - Improved quantification of the uncertainties – multi model approaches
  - Improved representation of human impacts – dams, extractions, irrigation

# The last IPCC reports Working Group 1 (the physical science basis vs. Working Group 2 (Impacts, adaptation and vulnerability.

## Working Group 1: A well coordinated Model Intercomparison of 21 Global Climate Models – running a range of scenarios

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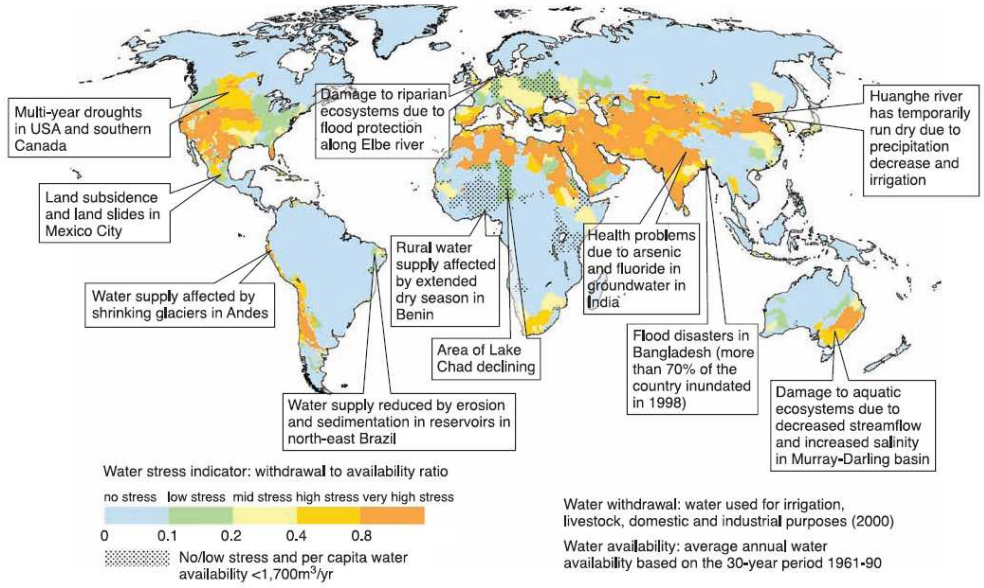
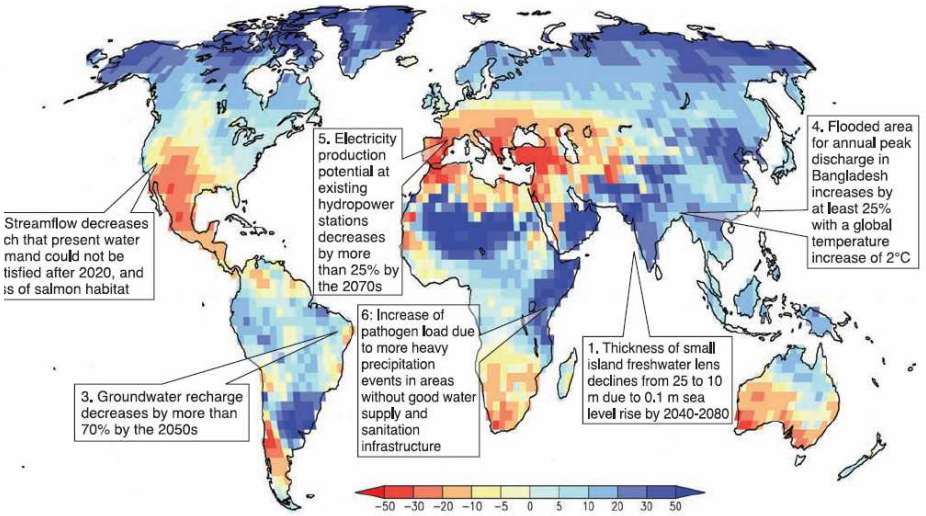
# The last IPCC reports Working Group 1 (the physical science basis vs. Working Group 2 (Impacts, adaptation and vulnerability.

## Working Group 2: A range of different studies using different climate models and different impact models

### Current/historic vulnerabilities




### Future vulnerabilities/ impacts

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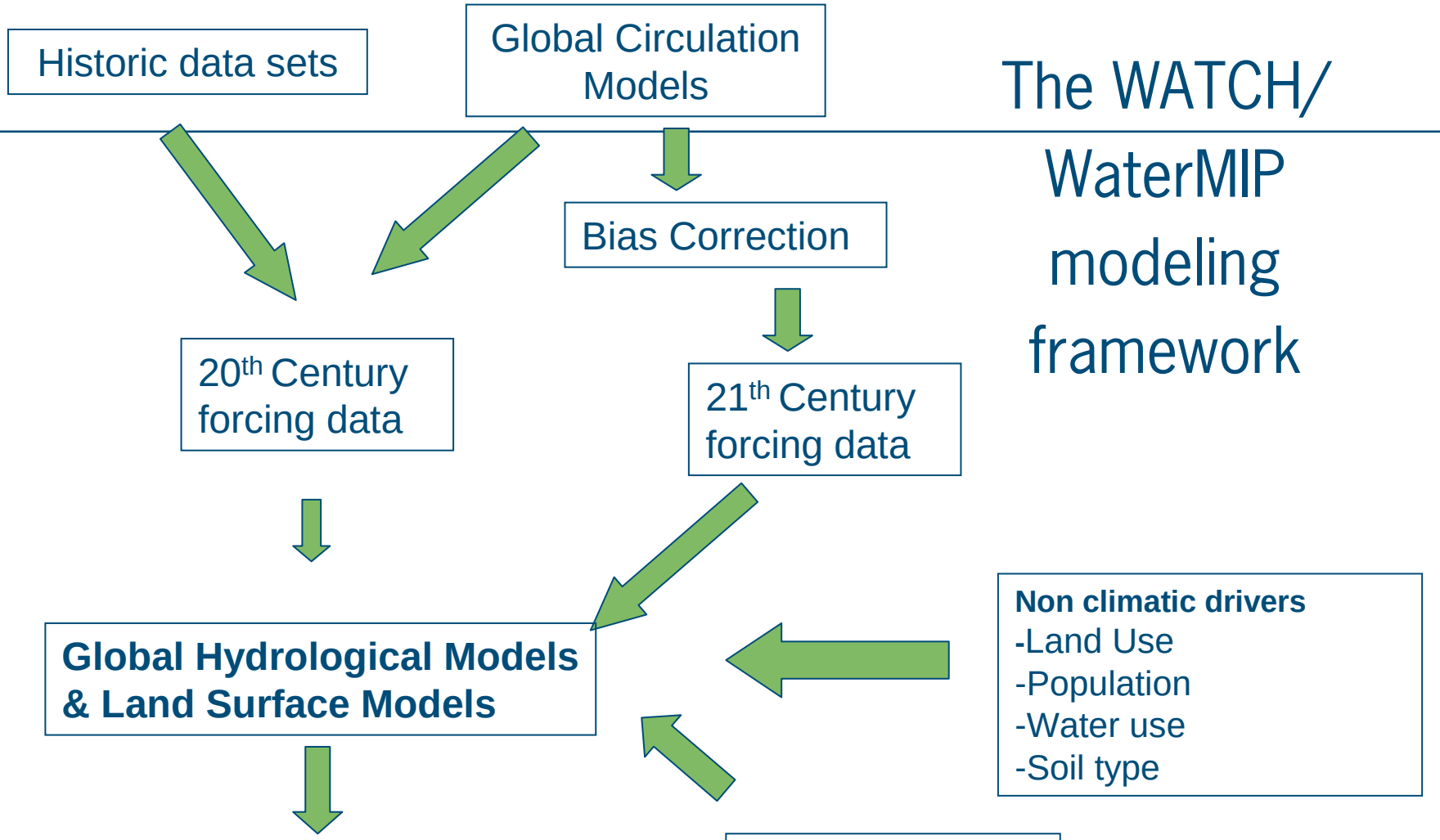
# The WATCH/ WaterMIP modeling framework

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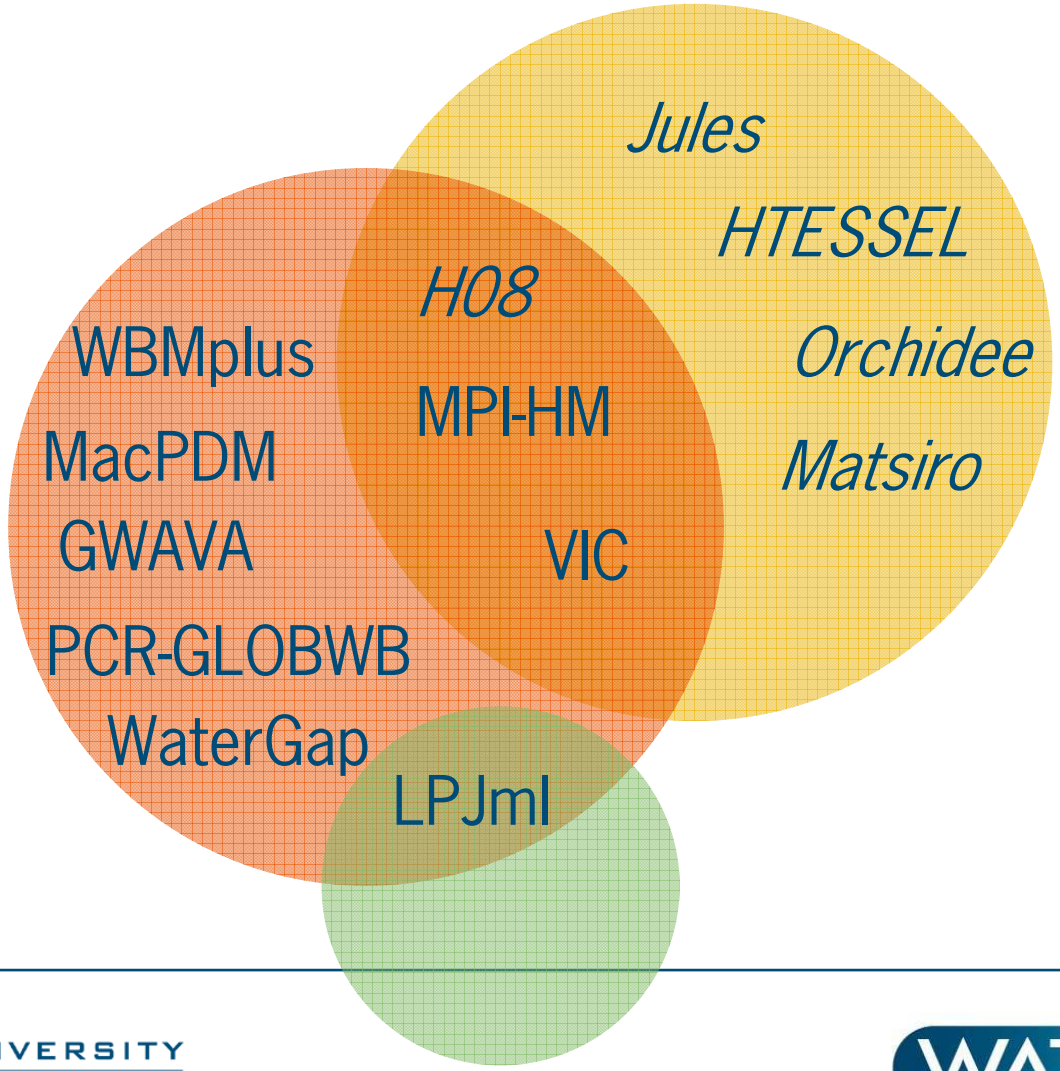
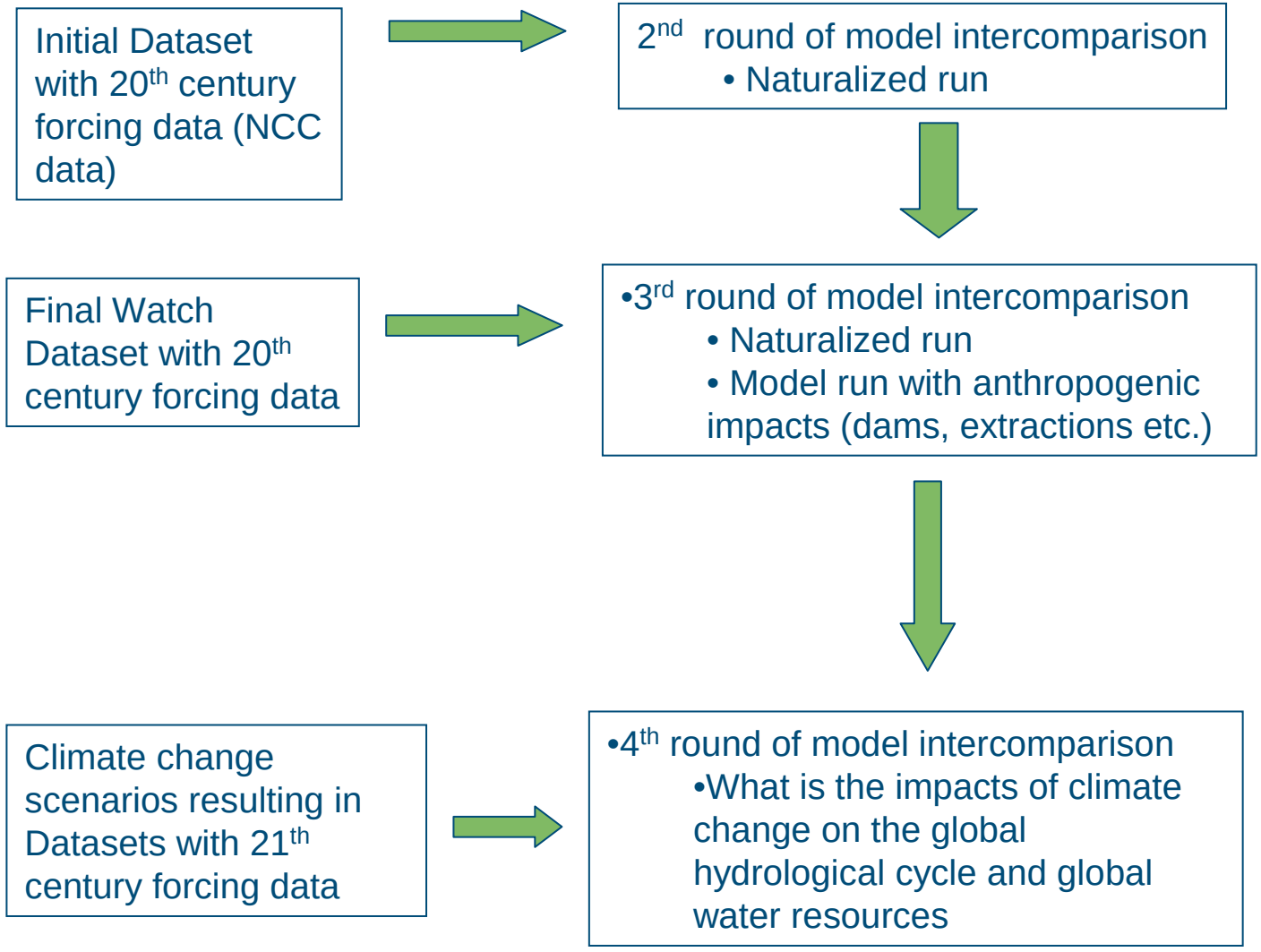
# Core of the modelling framework is 13 global hydrological models and Land Surface Hydrological models



# Sets of model intercomparisons



# Protocol of the intercomparison

**Forcing data**

- Watch Forcing Data
  - Some model used subdaily and other used daily data

**Time period**

- 1980-1999
  - First five years used as spin-up – data analysed 1985-1999

**Standardization issues**

- Land Mask (CRU)
- Routing Network
- Alma convention
- NET CDF

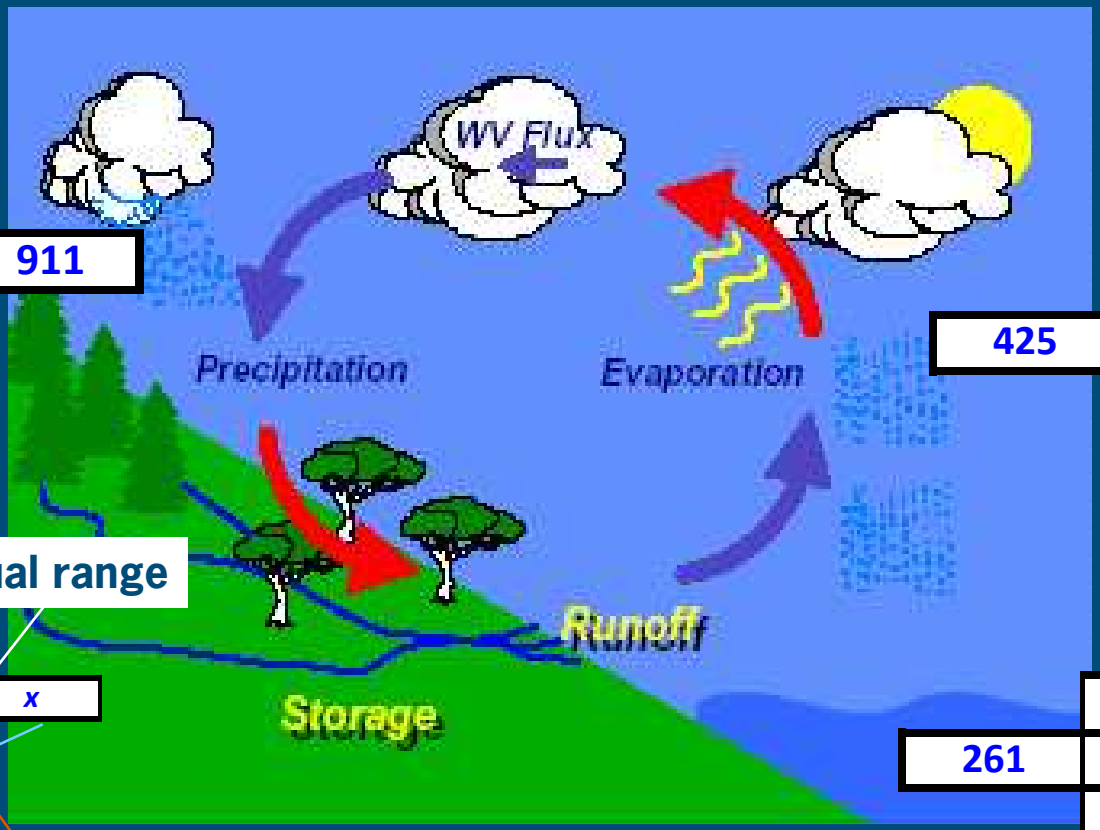
**Date reported**

- Gridded fields, land points, 0.5 dd
  - Monthly for 15 years – 1985-1999
  - Daily for 1987-88
  - State (water) at beginning and end of simulations

# Global terrestrial water budget using Watch Forcing Data – the range of outcome from WaterMIP models

## Precipitation

| | | |
|---|---|---|
| | 870 | |
| 835 | 872 | 911 |
| | 873 | |




## Evaporation

| | | |
|---|---|---|
| | 452 | |
| 425 | 512 | 595 |
| | 582 | |

## Run-off

| | | |
|---|---|---|
| | 255 | |
| 261 | 354 | 453 |
| | 415 | |

**Interannual range**

| | | |
|---|---|---|
| | x | |
| x | x | x |
| | x | |

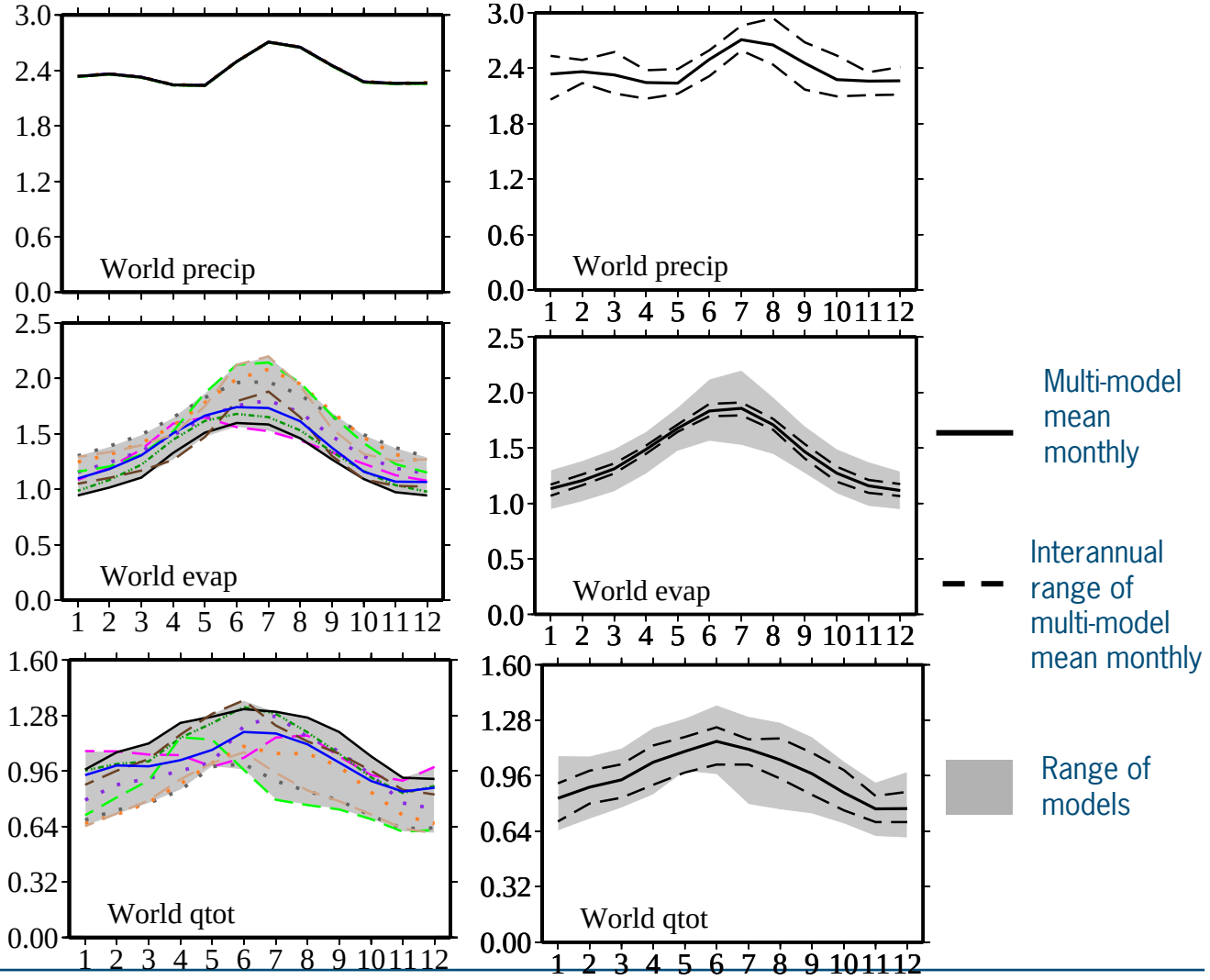
**Annual cycle range**

**Annual mean**

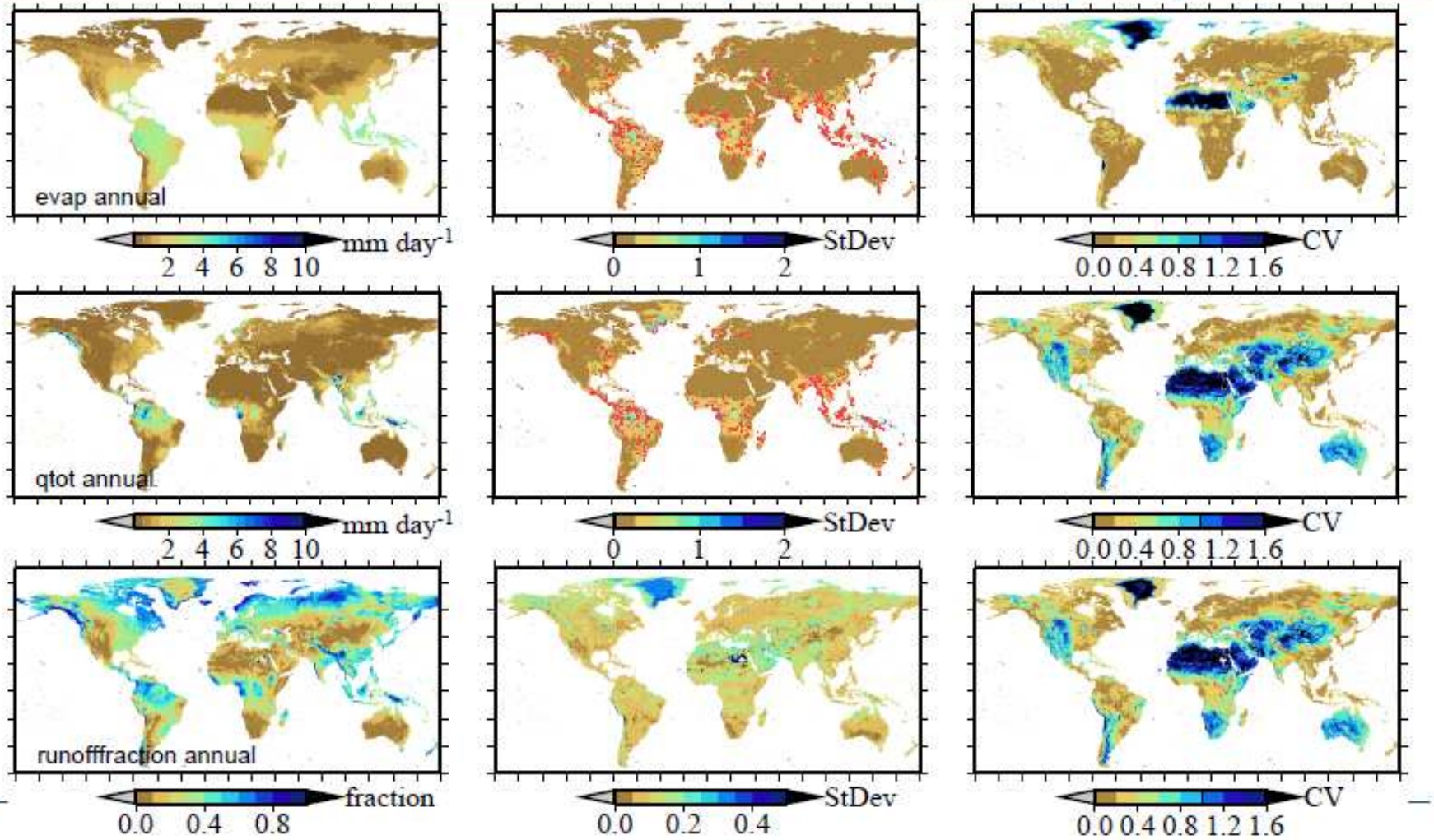
Numbers in mm year-1

# Mean monthly (mm day$^{-1}$)

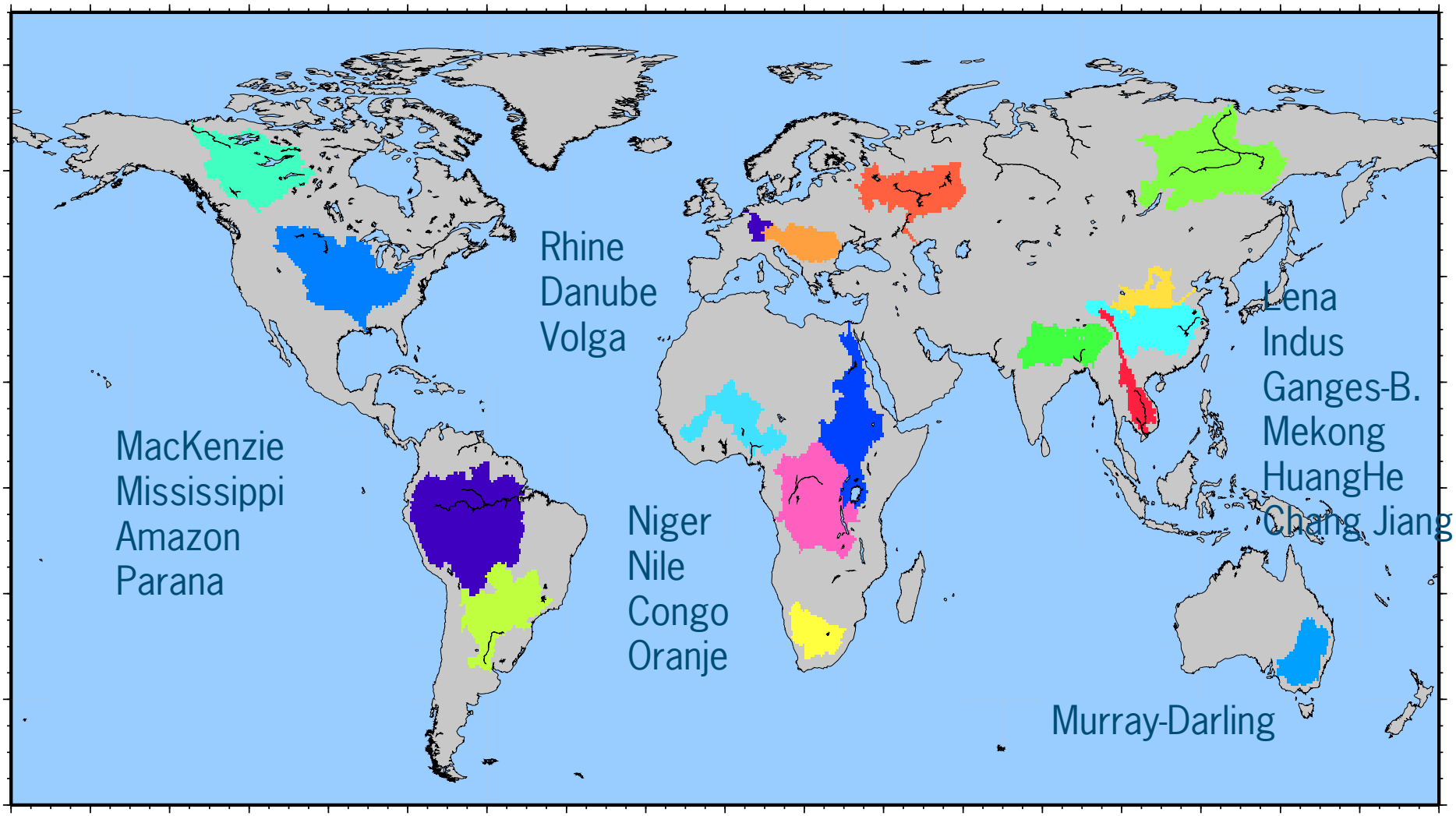
- 15-year mean monthly values, all models
- Multi-model mean monthly, and interannual range of multi-model mean monthly values



# Mean annual results: Evap and Qtot (qs+qsb)



# River basins

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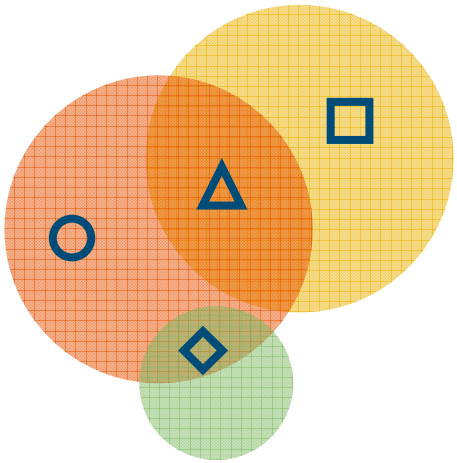
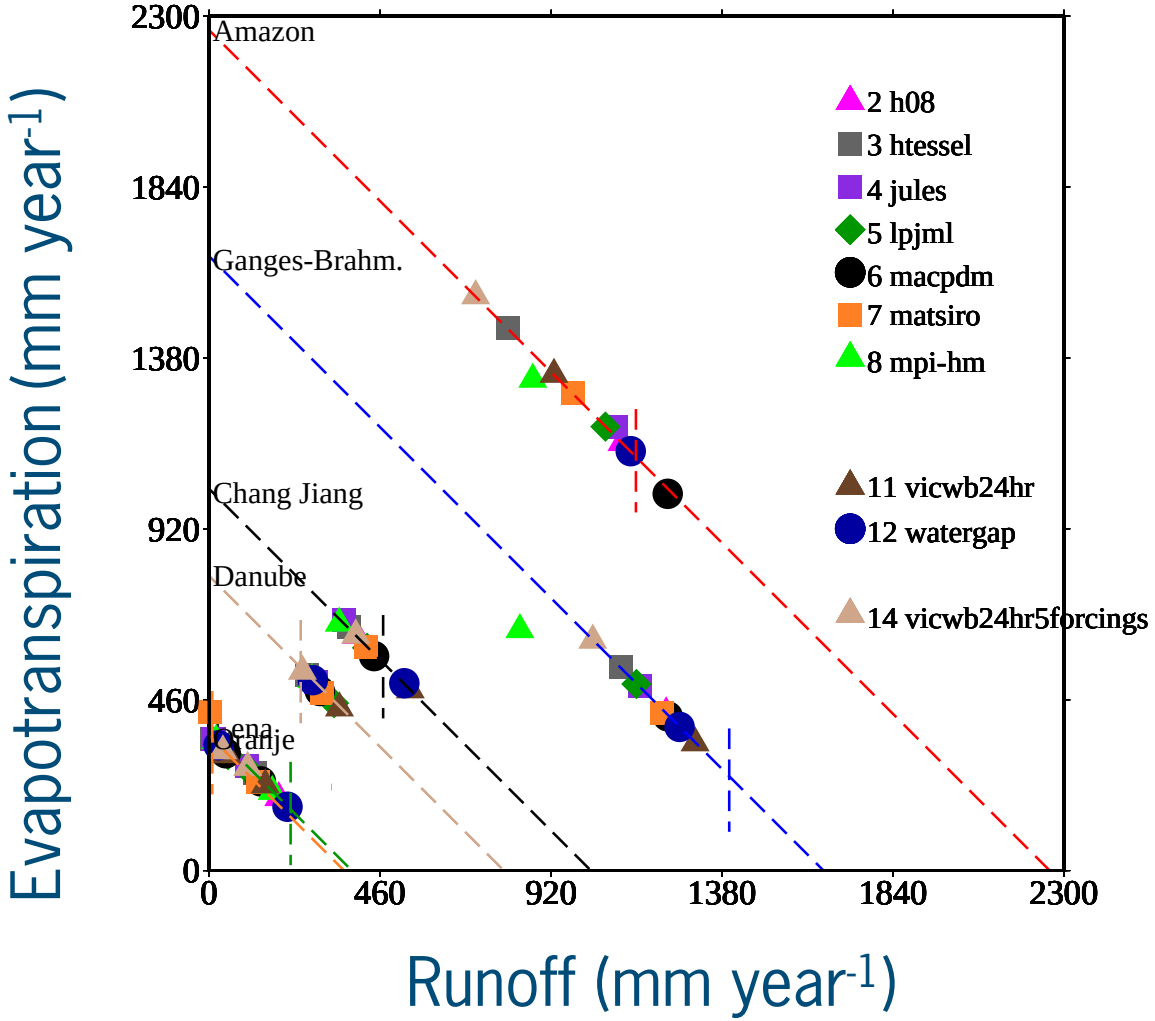
# Mean annual water fluxes (mm year$^{-1}$)



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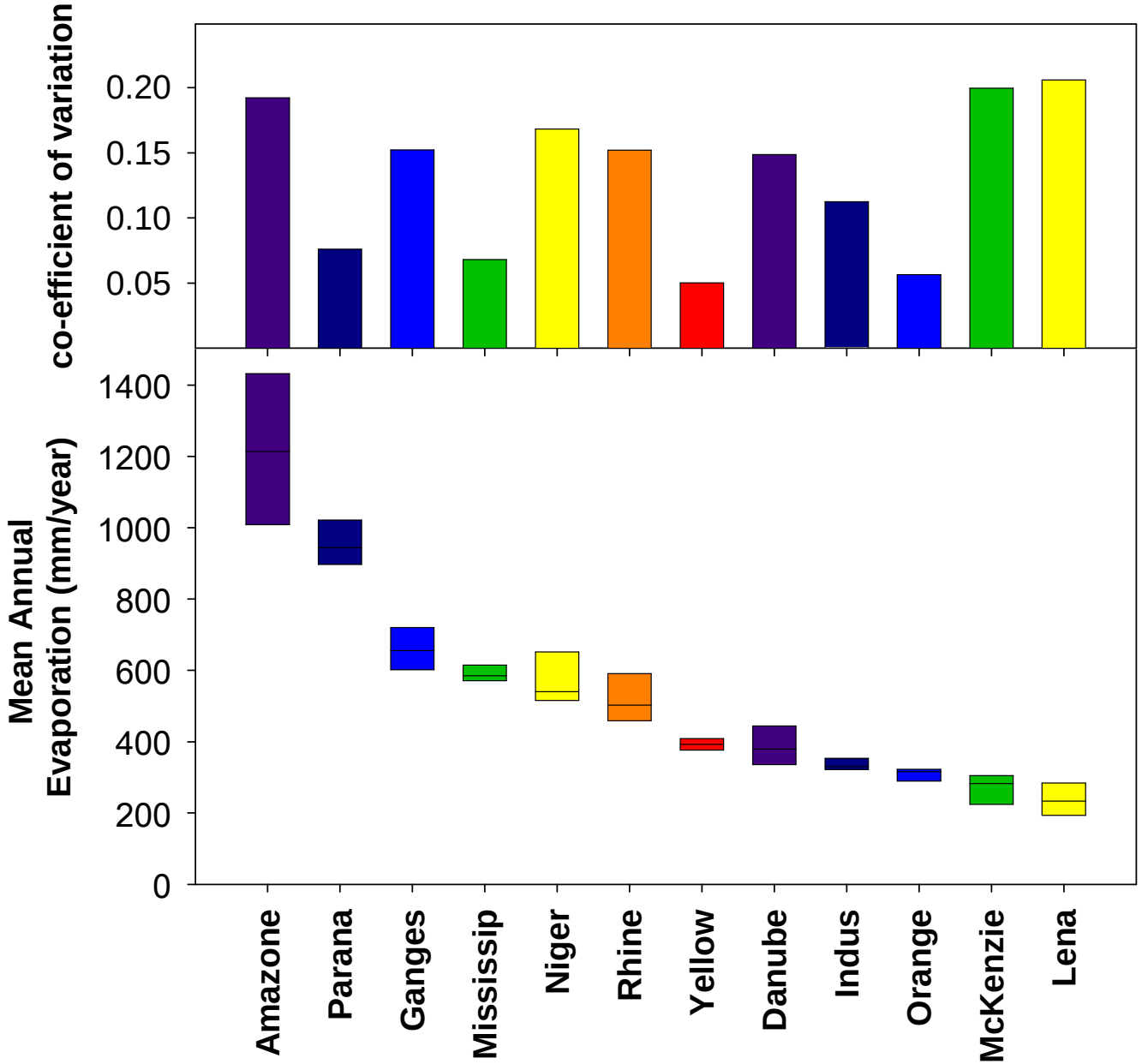
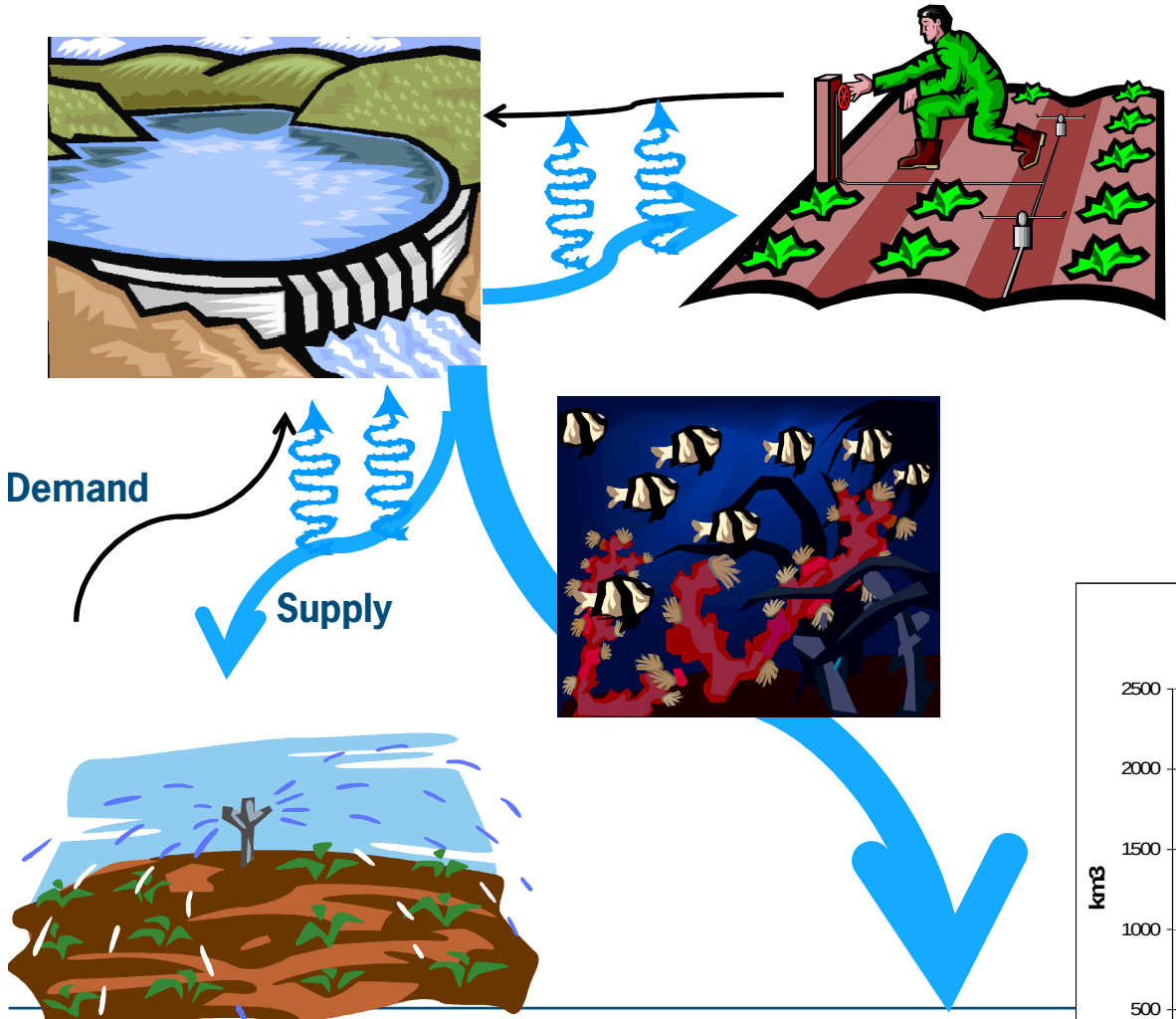
# Model variation in average evaporation in large basins

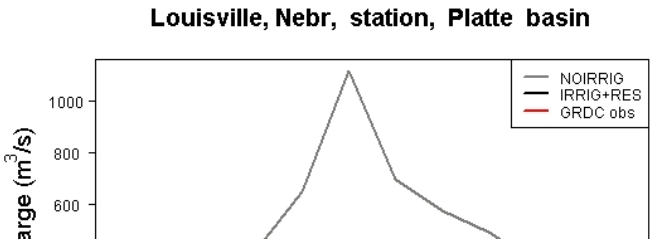


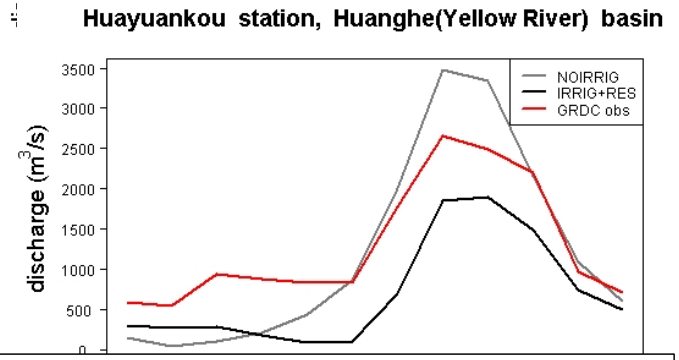
# Human impacts on the global water cycle

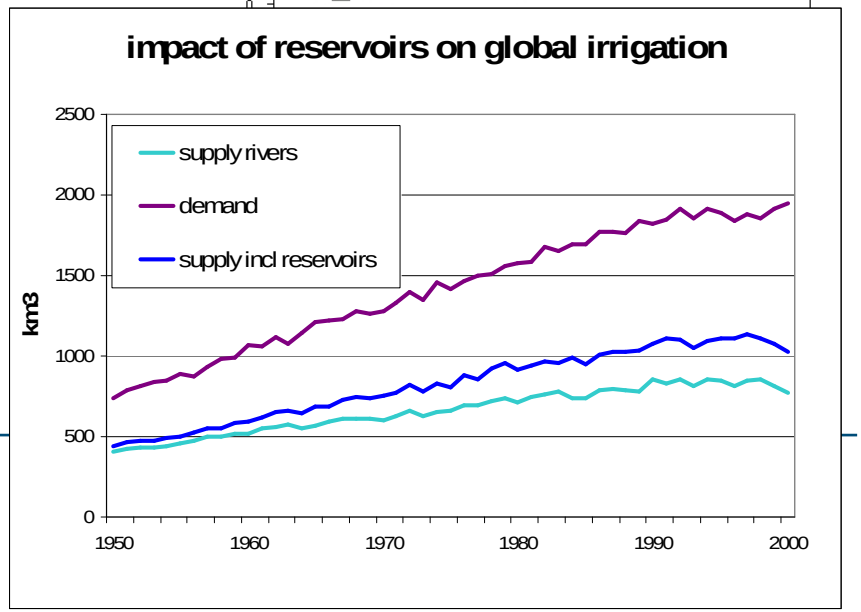
- Storage / Dams
- Irrigation
- Water extraction for industry and domestic use
- Land use change
- Water Quality

# New module: Reservoir operations
## Impact of human built reservoirs on water availability

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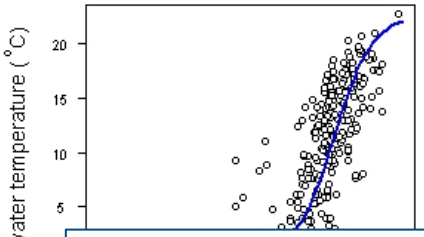


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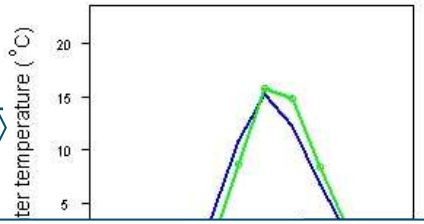
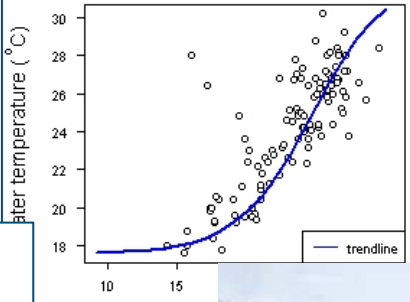



MEKONG ( LUANG PRABANG (VIENGKHAM)

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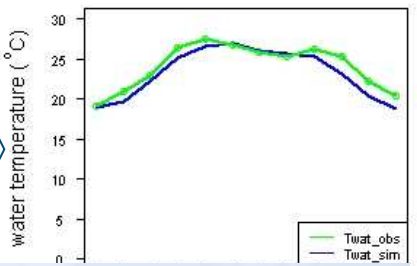
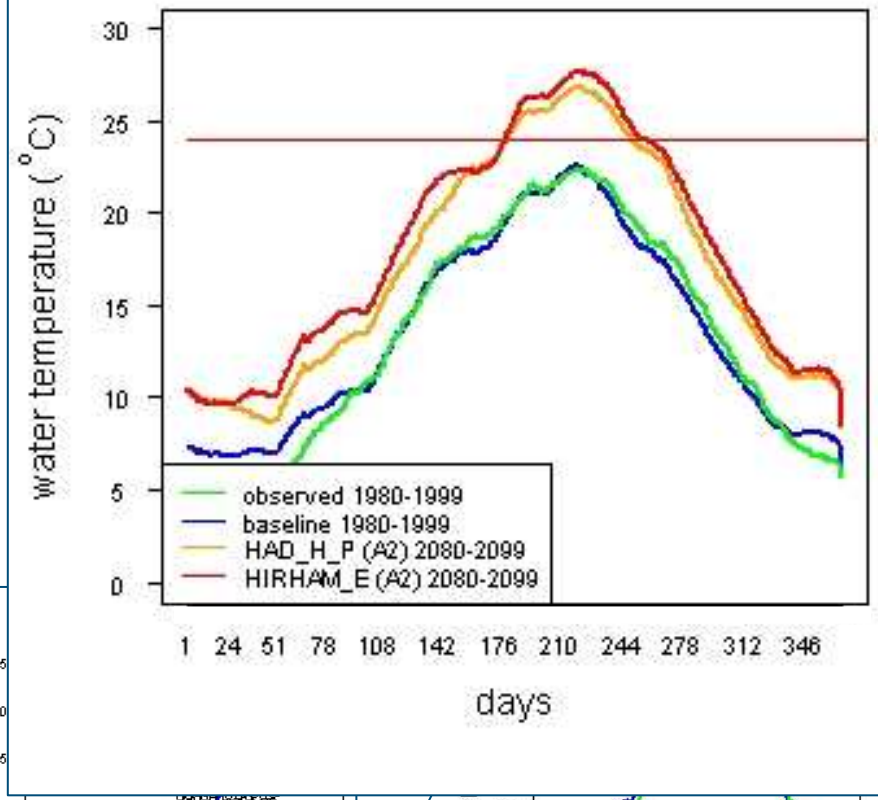
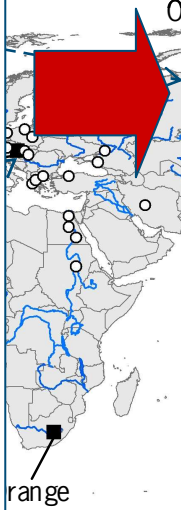
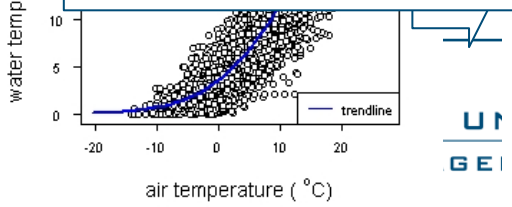
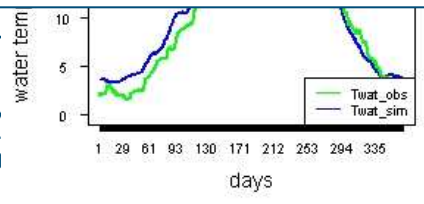



RHINE RIVER ( LOBITH )

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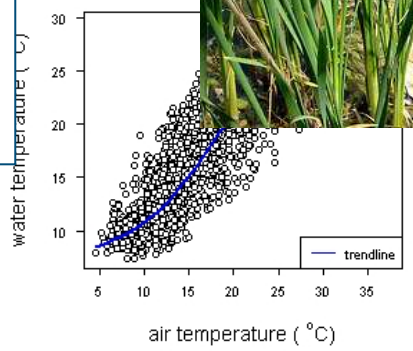
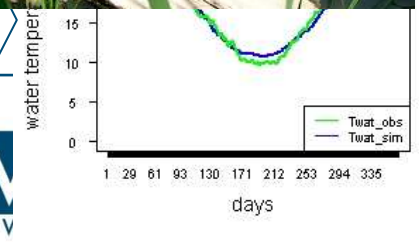
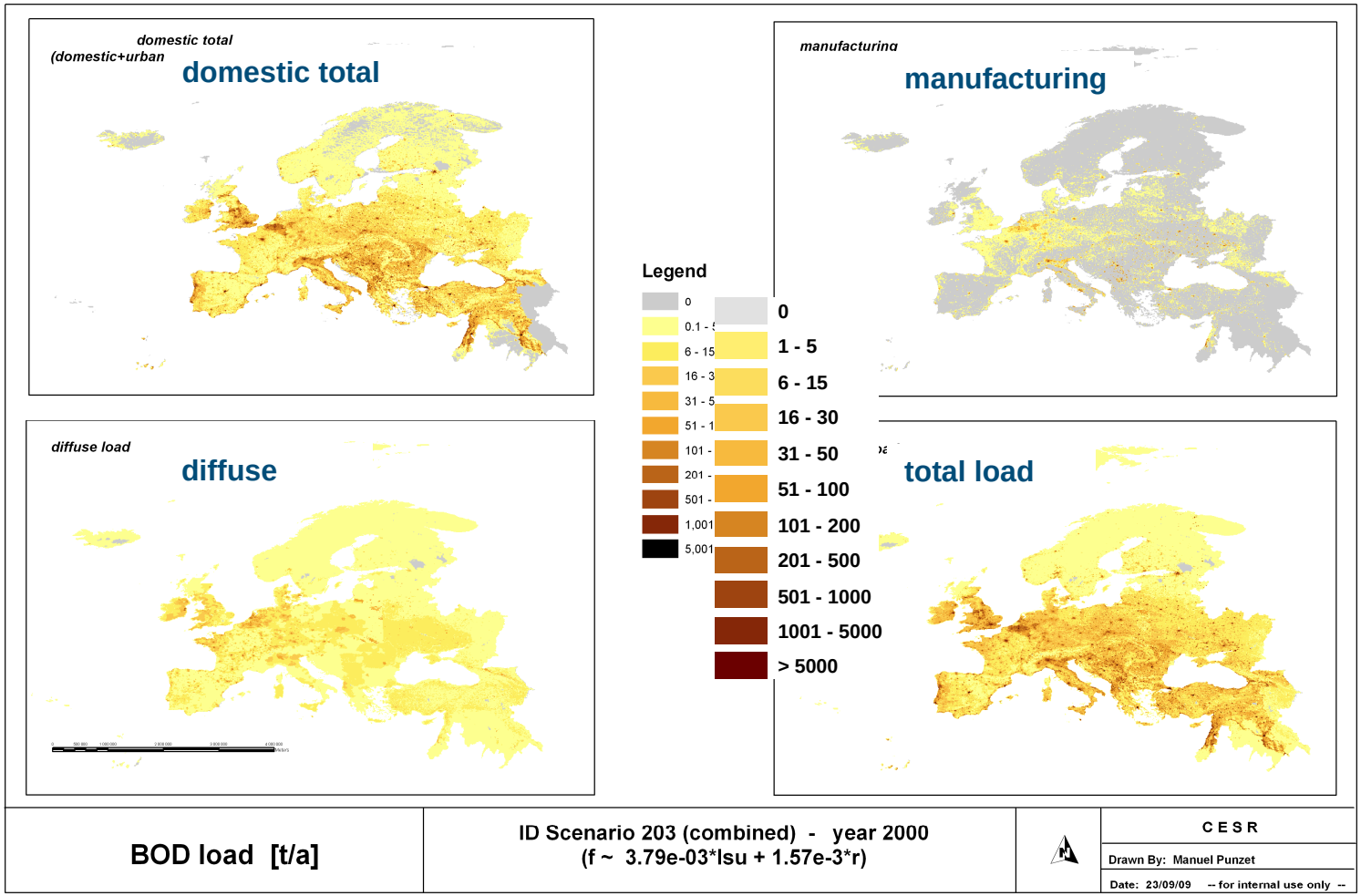


# Calculation of pollution loadings

## Grid cell loadings – BOD [t/a]

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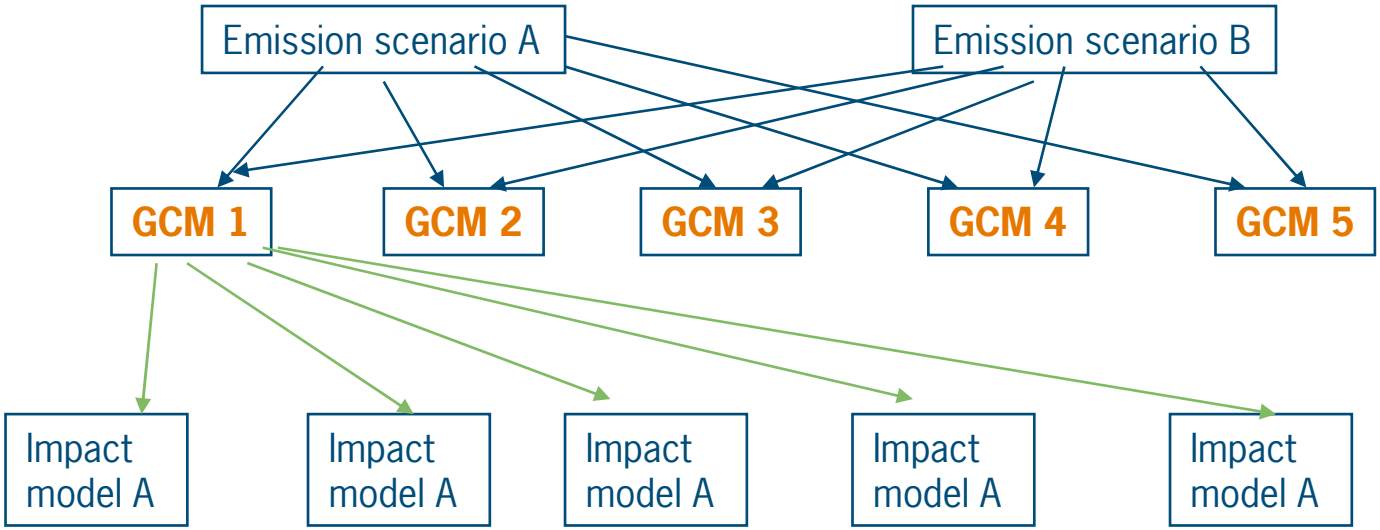
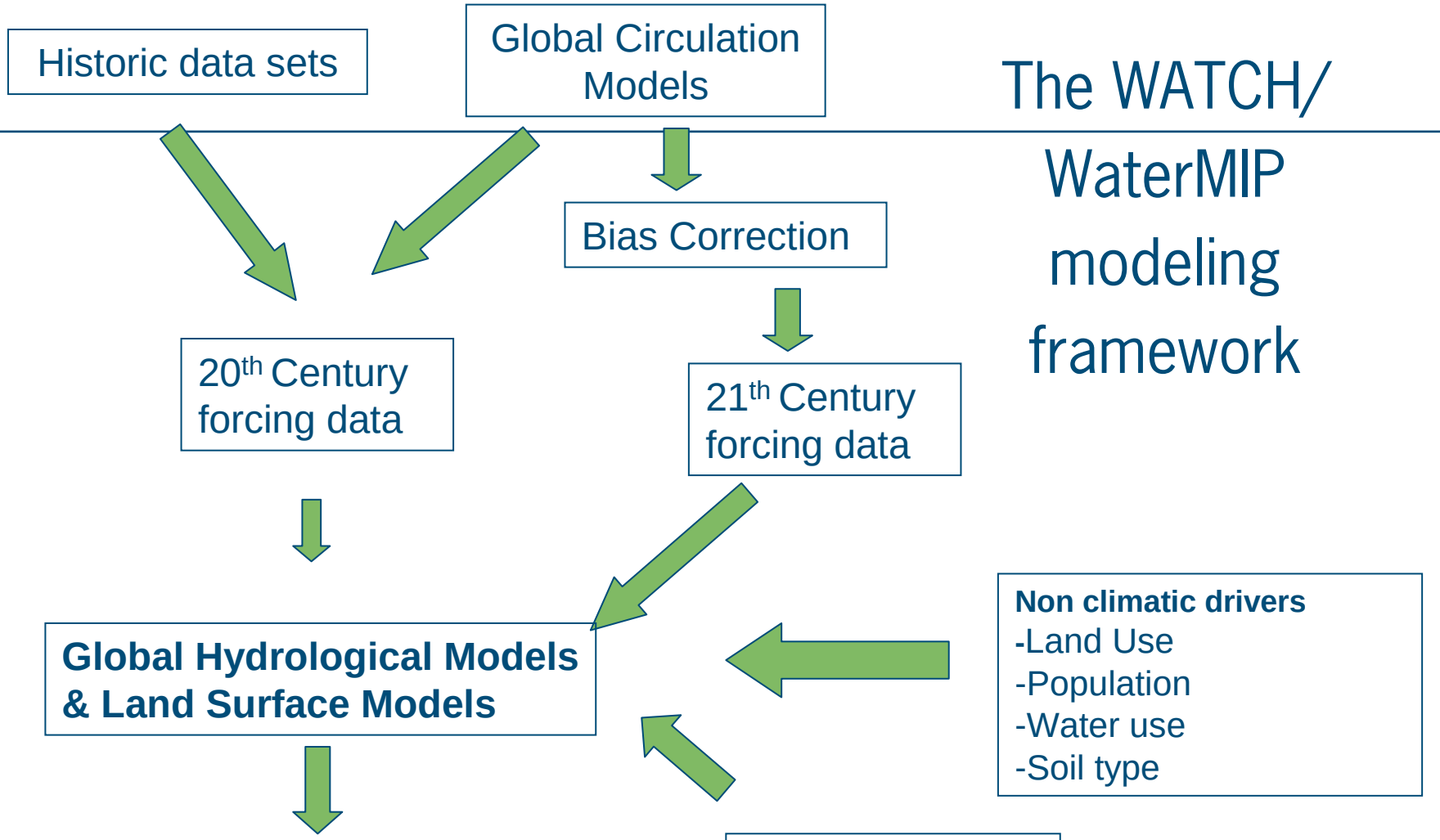
# The Way Forward – an ensemble of projections of global water resources – a better estimate of the impacts and the related range/uncertainty



# The WATCH/ WaterMIP modeling framework

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# Conclusions

- The global cycle is speeding up causing changes in rainfall amounts and variability
- Global water resources will affected by climate change and other anthropogenic impacts
- An improved modeling framework is needed to better quantify climate change impacts – this is necessary to improve decision making on adaptation
- The IPCC AR5 represents a unique opportunity to improve climate change impact research