

Incorporating Hydrology into an Integrated Model of Human Earth Systems

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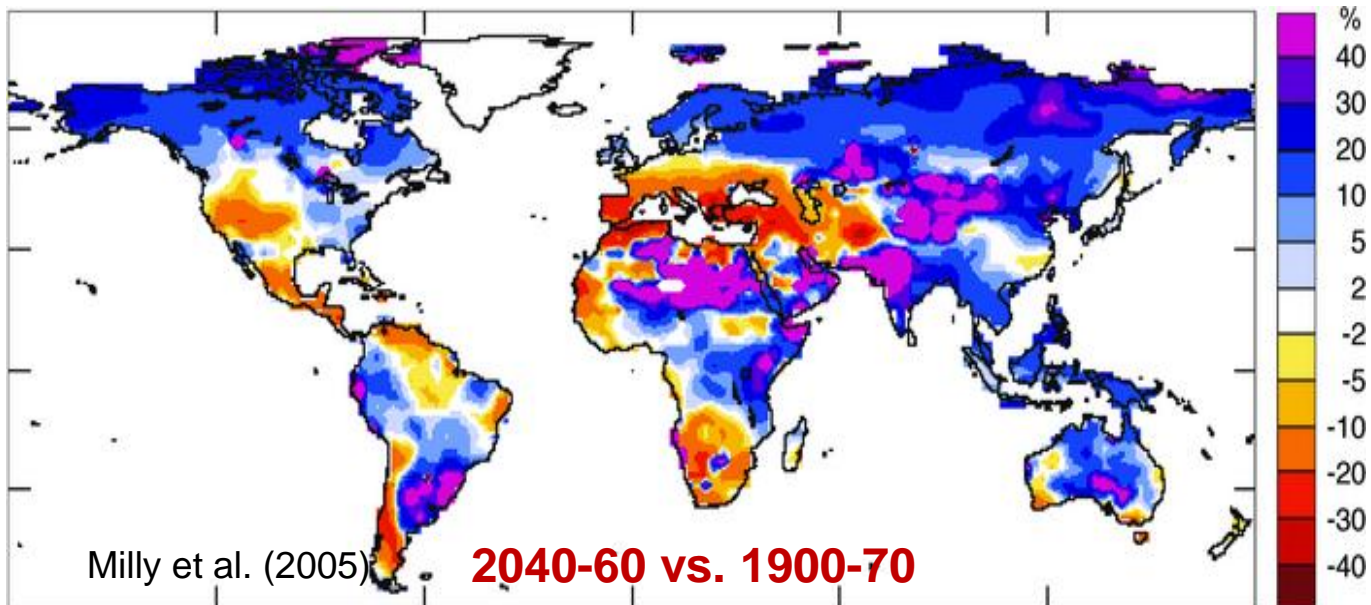
Joint Global Change Research Institute

September 21, 2011

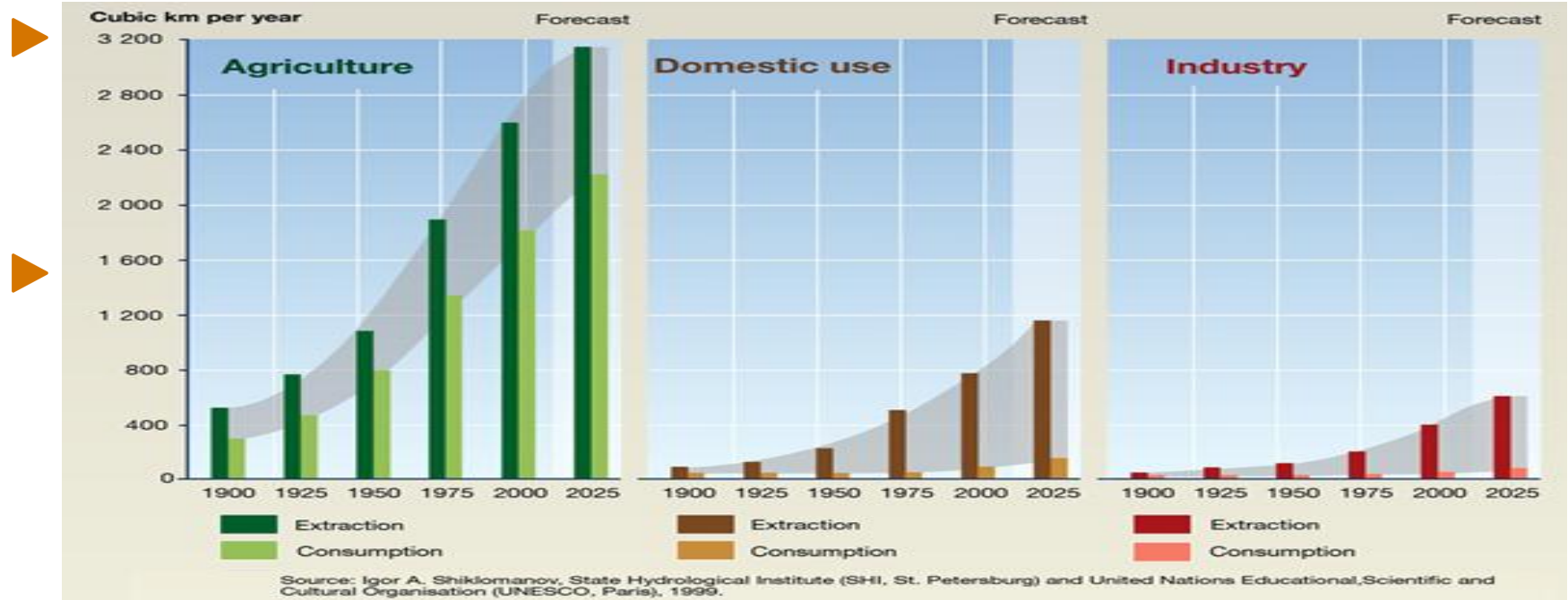
Washington, DC

Motivation

- ▶ Water is not fully integrated into any of the present generation of IAMs. Though all of the major IAM programs are working on the problem.
- ▶ Yet,
 - Climate change → hydrology (the amount, timing, and reliability of fresh water)
 - Changes in land use and land cover → hydrology

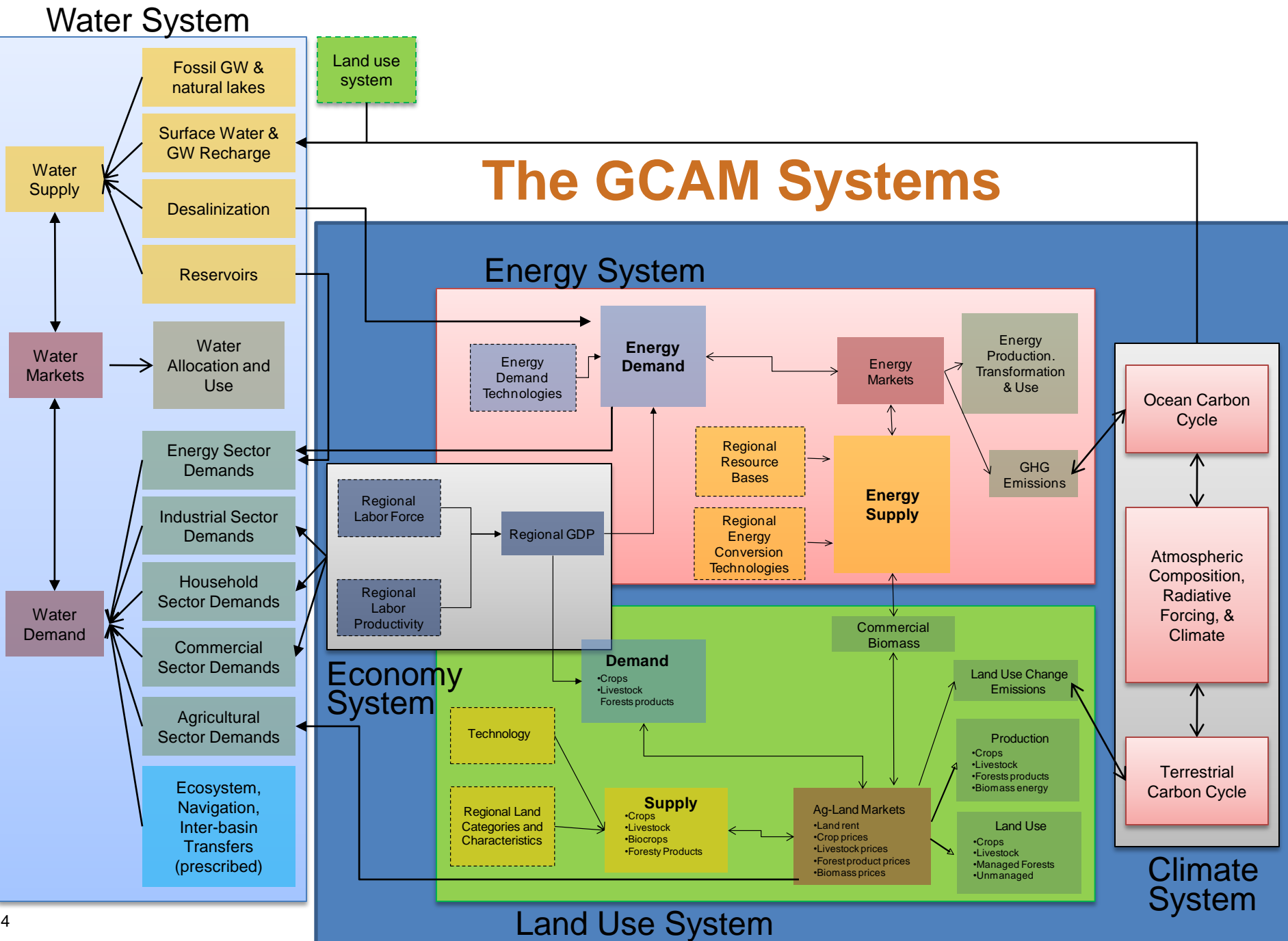


Motivation



- Changes in the number of humans, their income levels, and their energy and food demands → human water demands
- ▶ What are the implications of explicitly considering water in IAMs?
- ▶ Do we have sufficient water to realize a climate policy world?

The GCAM Systems



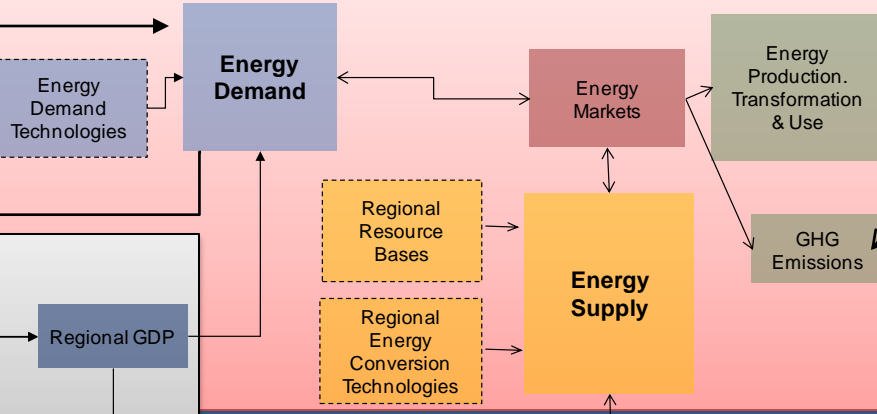
Water System

WATER SUPPLY

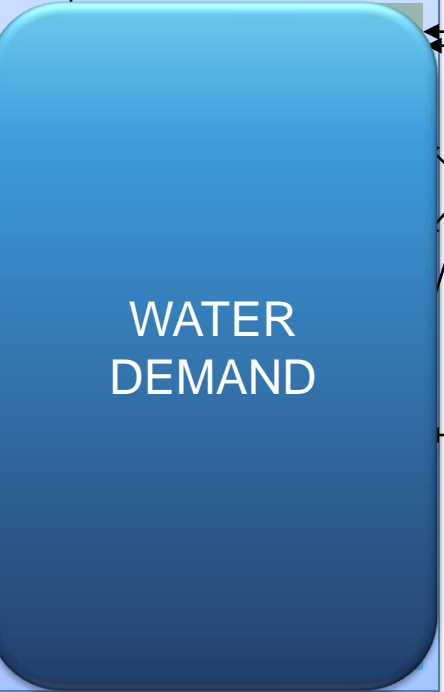
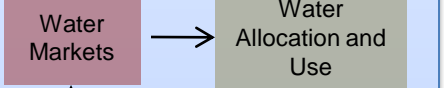
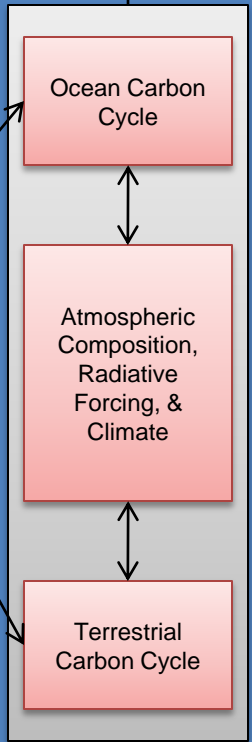
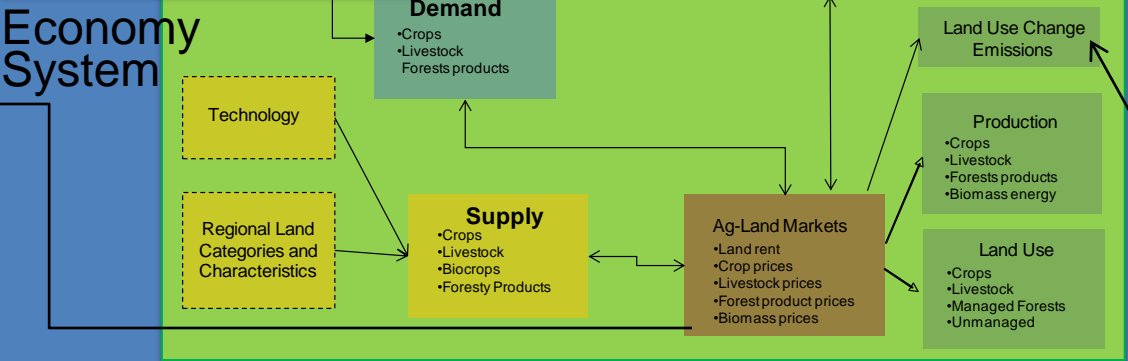
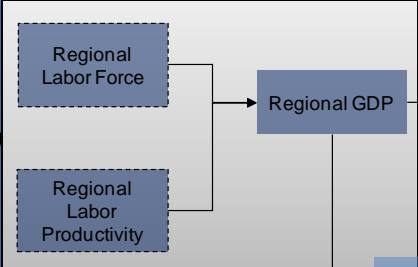
Land use system

The GCAM Systems

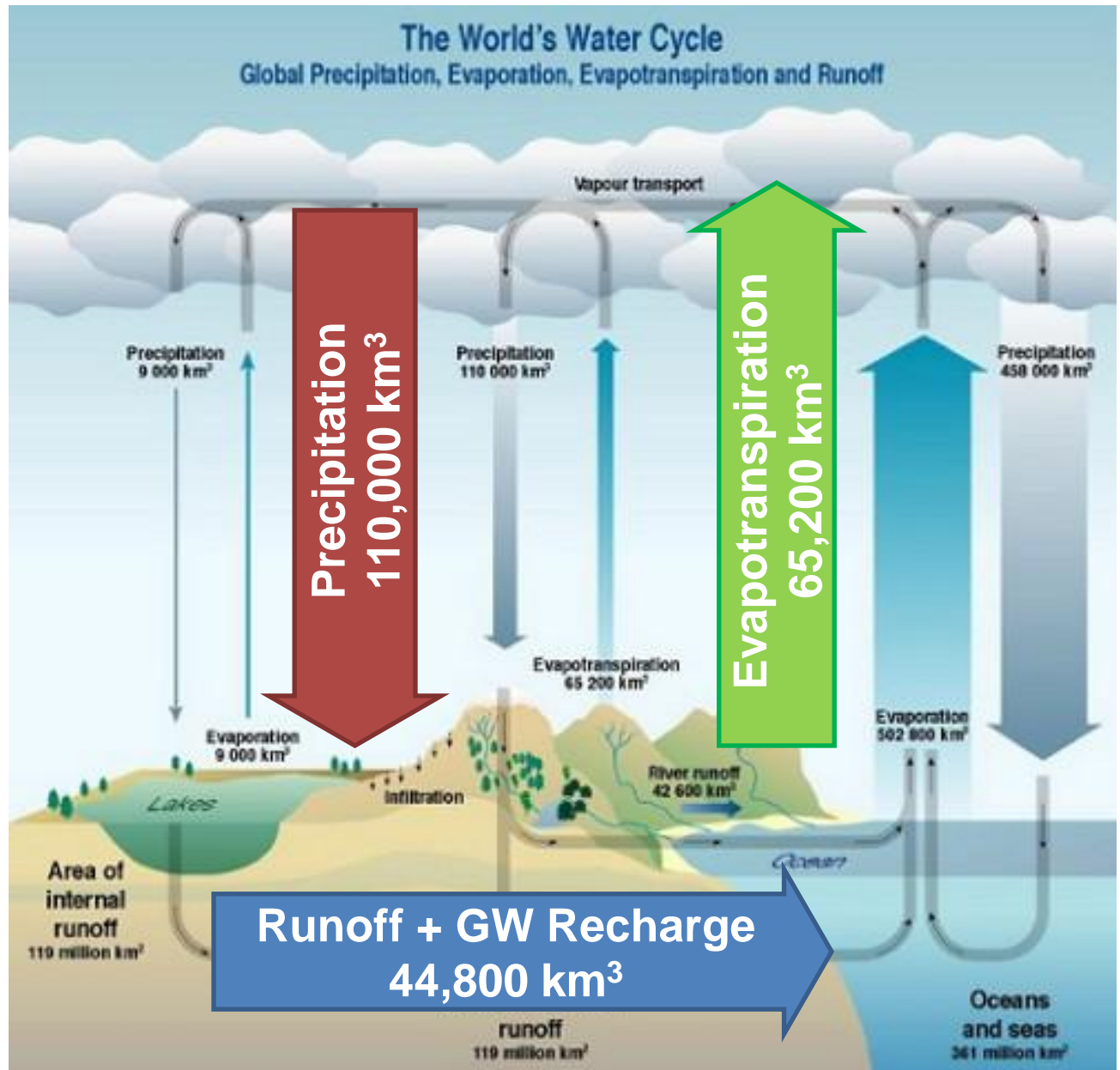
Energy System



Economy System



Model & Results
**WATER
 SUPPLY**



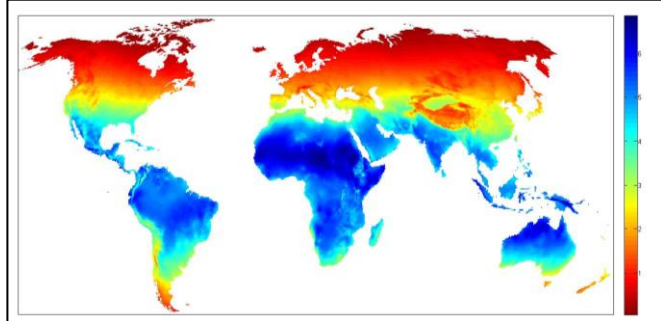
Source: <http://www.wildfire-burning-thirsts.com/water-cycle.html>

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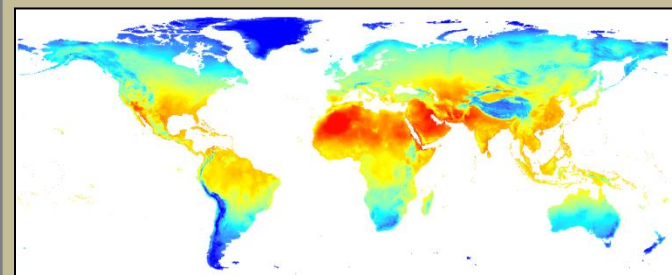
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Water Supply Model

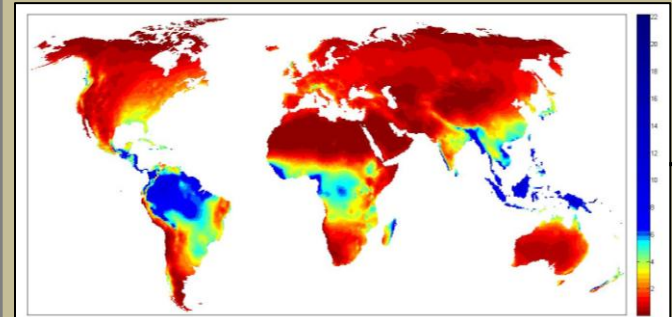
Potential Evapotranspiration (PET)



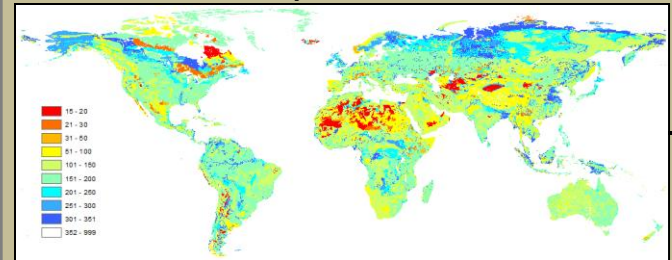
MODEL INPUTS



Temperature



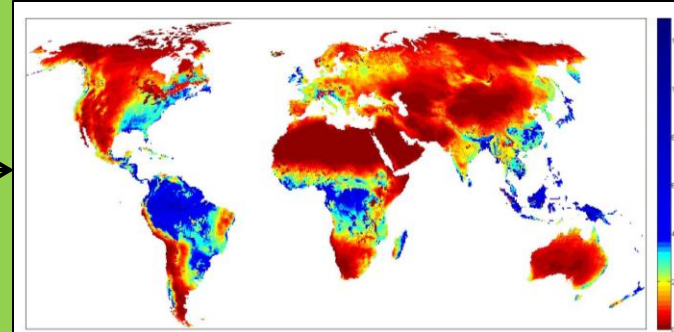
Precipitation



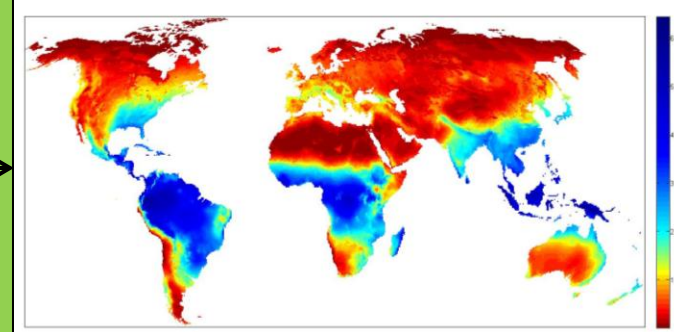
Maximum Soil Moisture Capacity

Monthly Water Balance Model

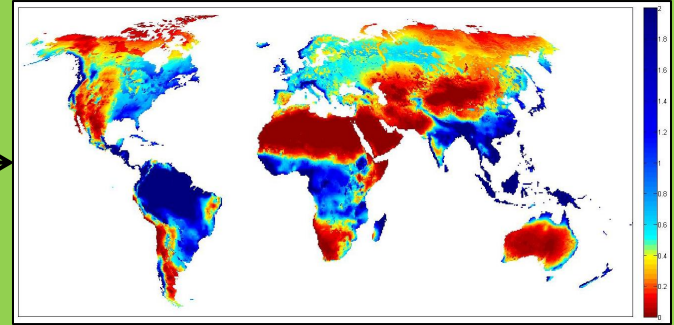
MODEL OUTPUTS



Storage



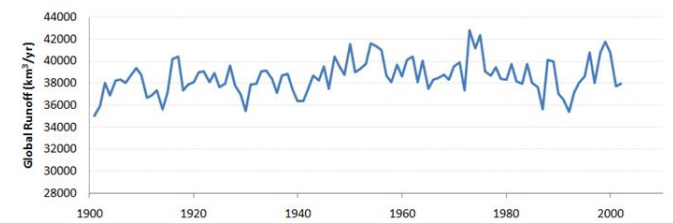
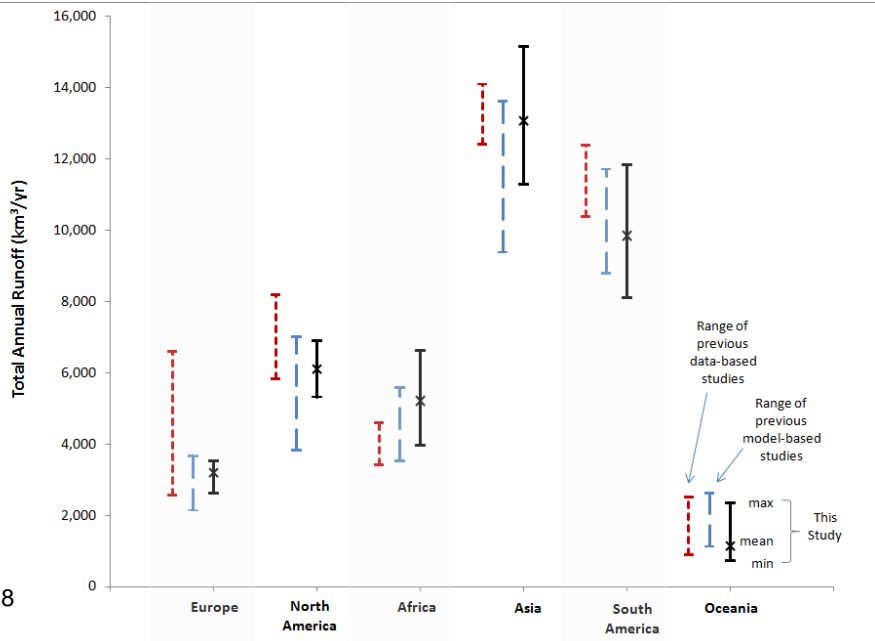
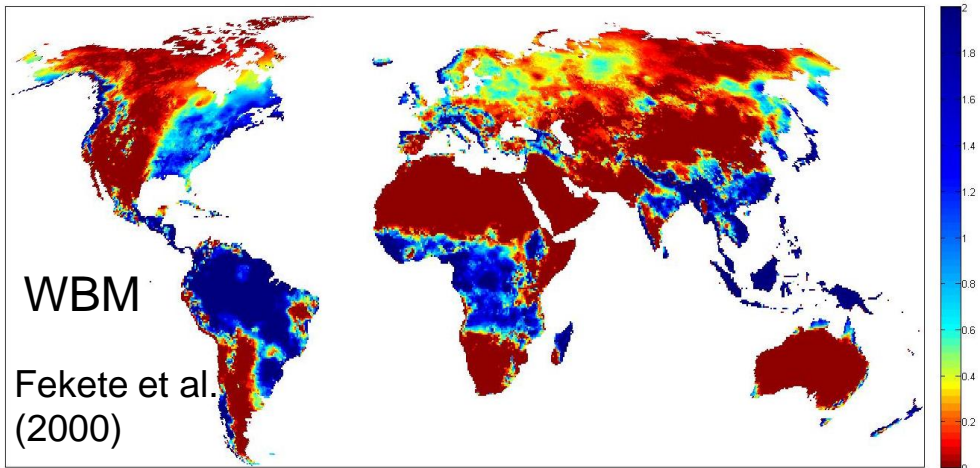
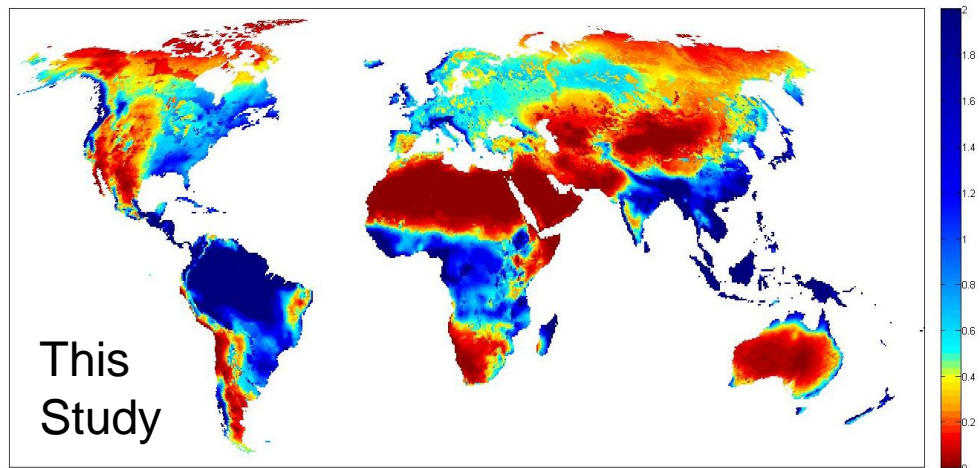
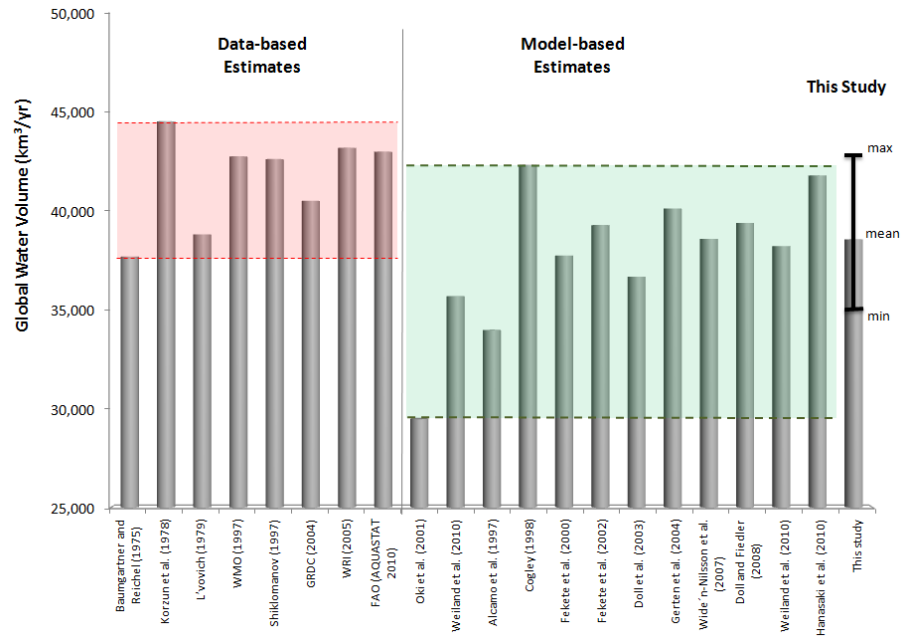
Actual Evapotranspiration (AET)



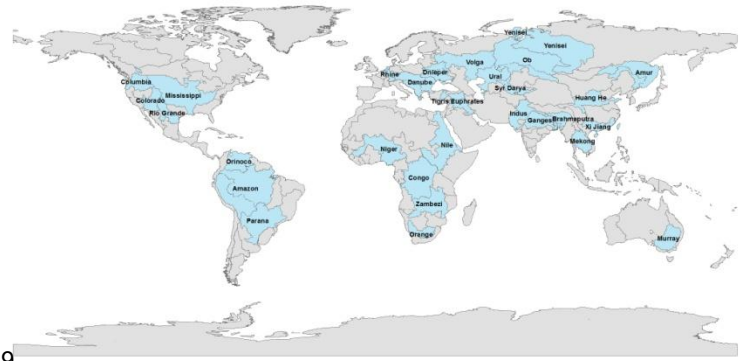
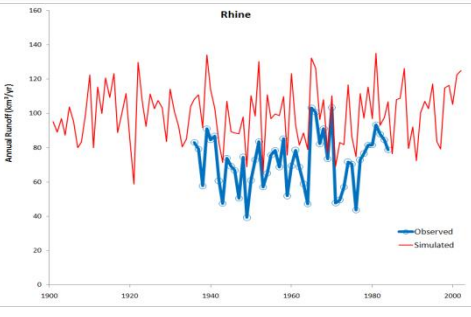
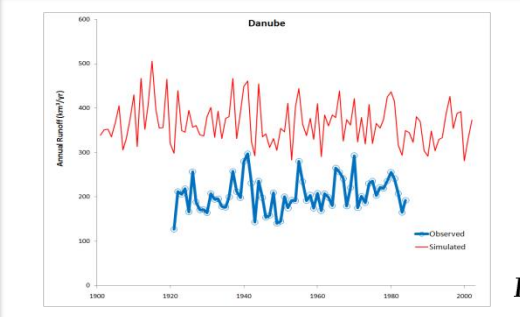
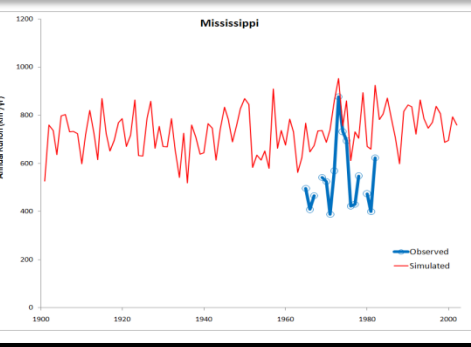
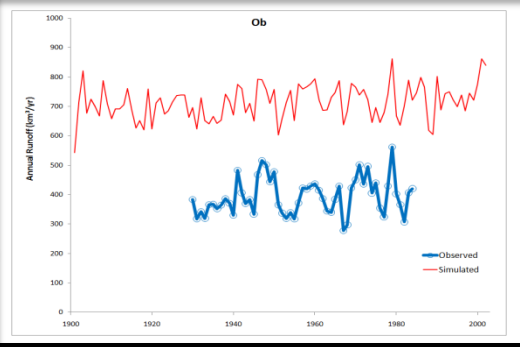
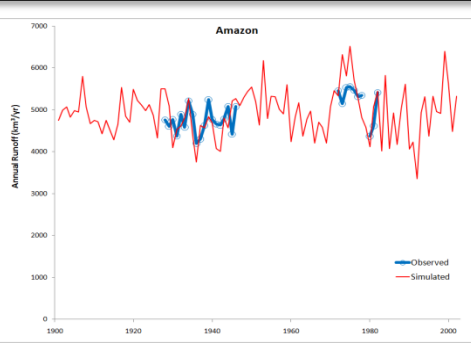
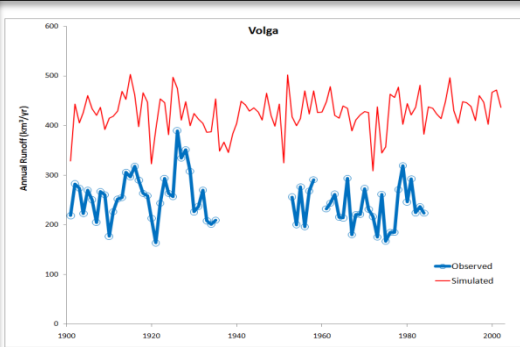
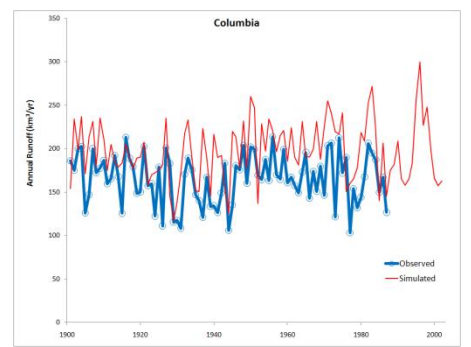
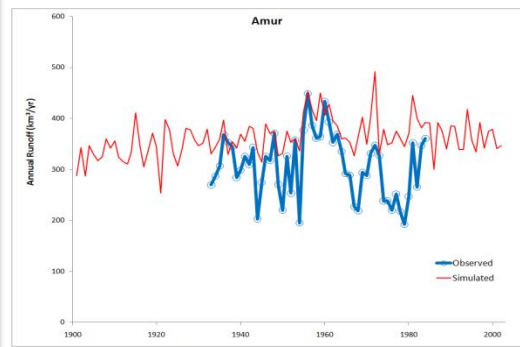
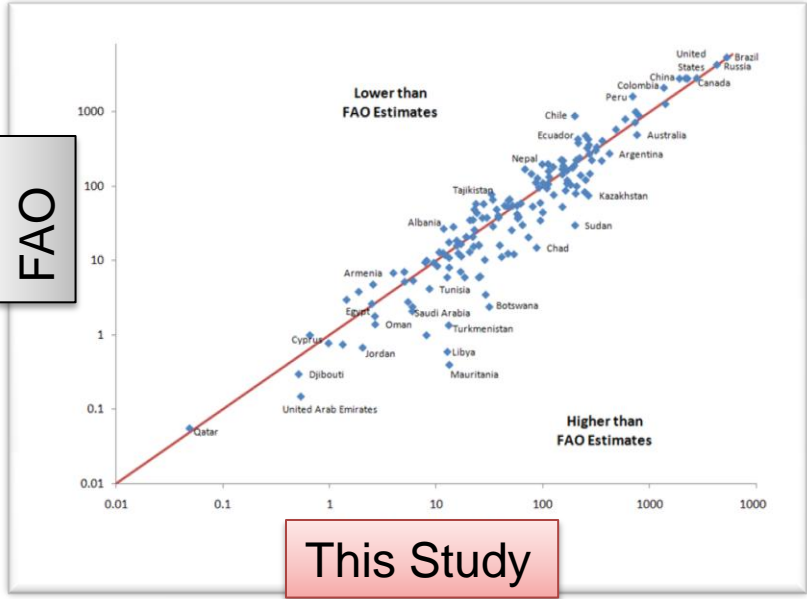
Runoff

7

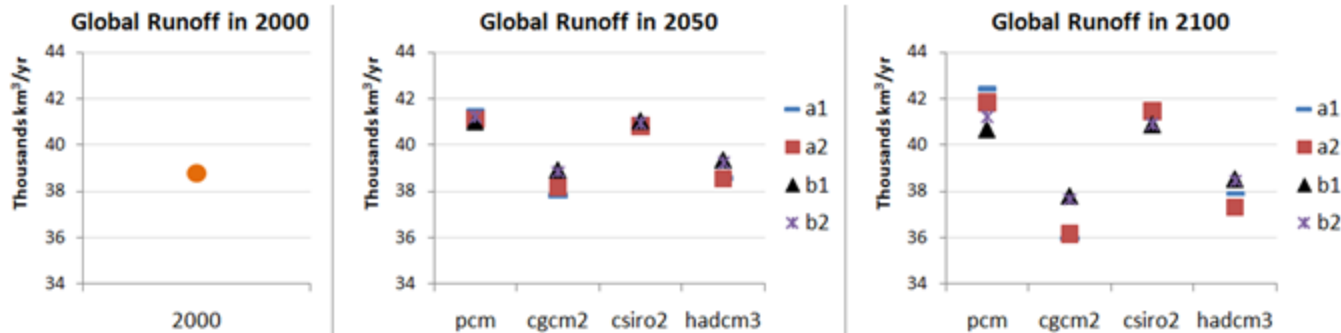
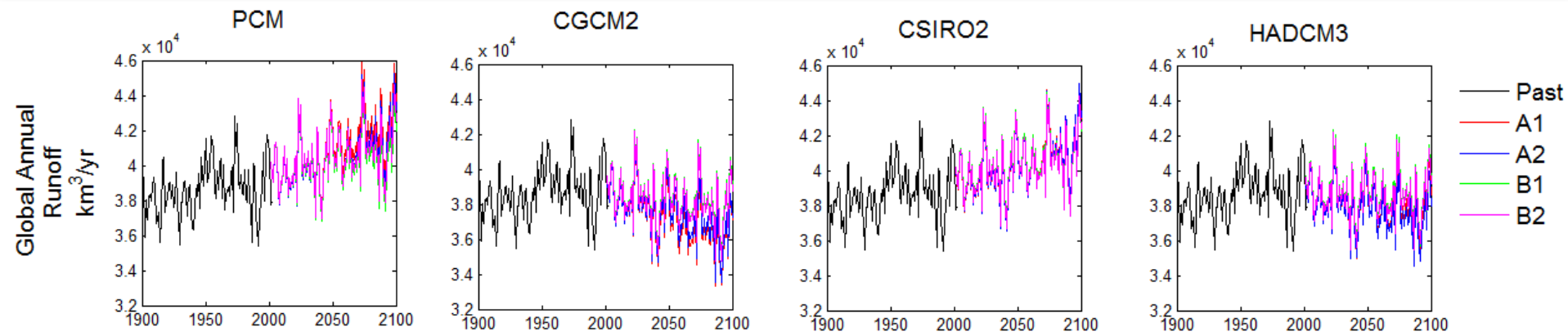
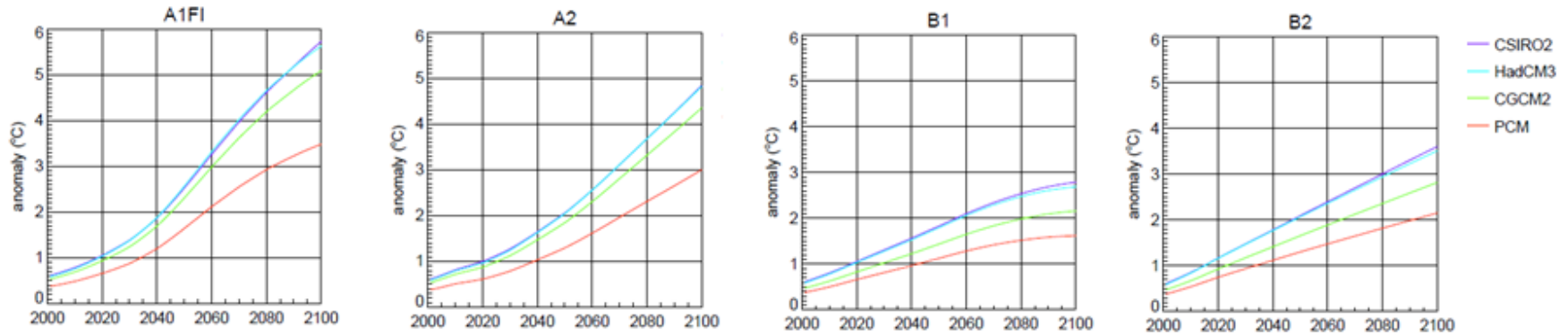
Model Validation



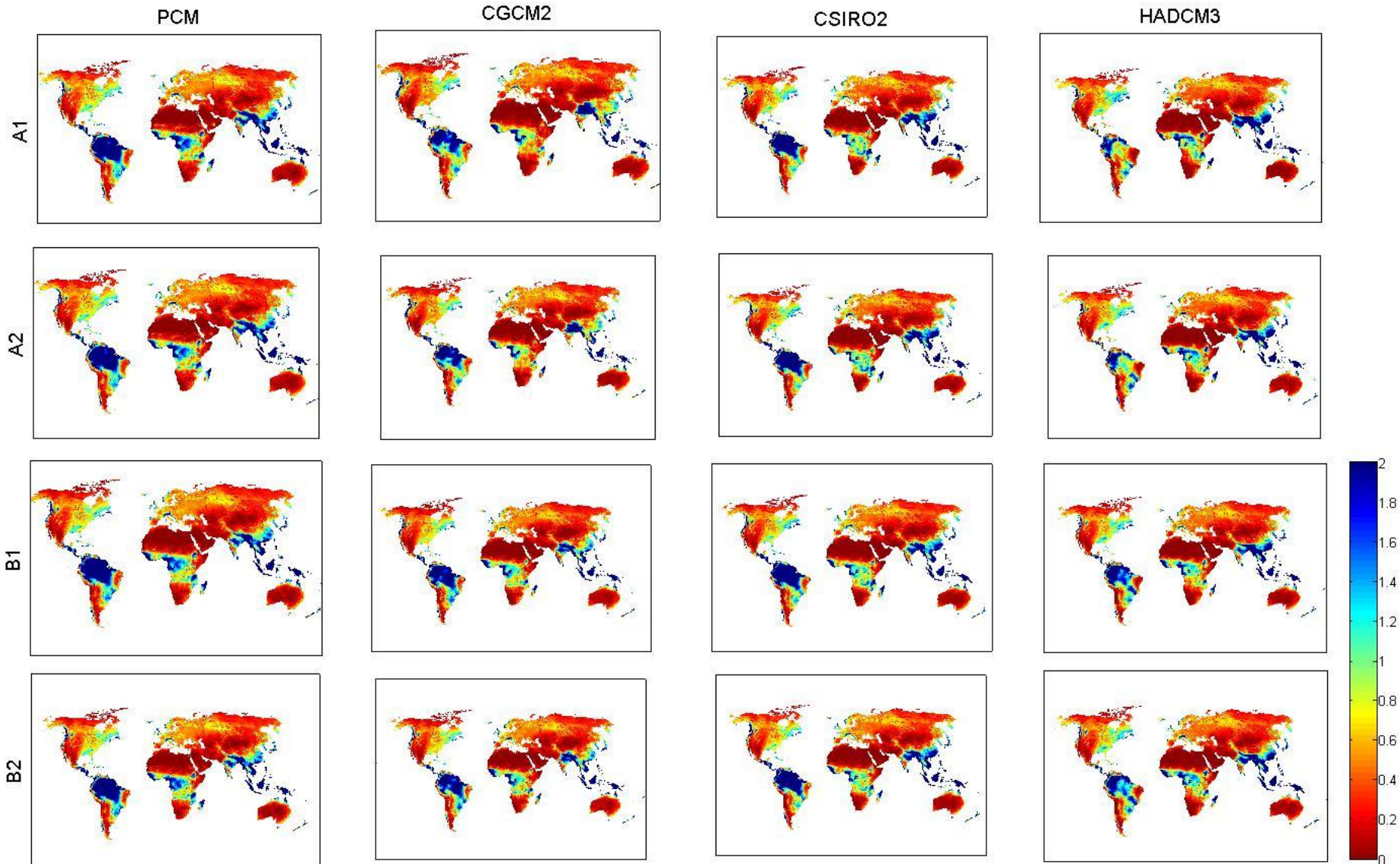
Continue... Model Validation



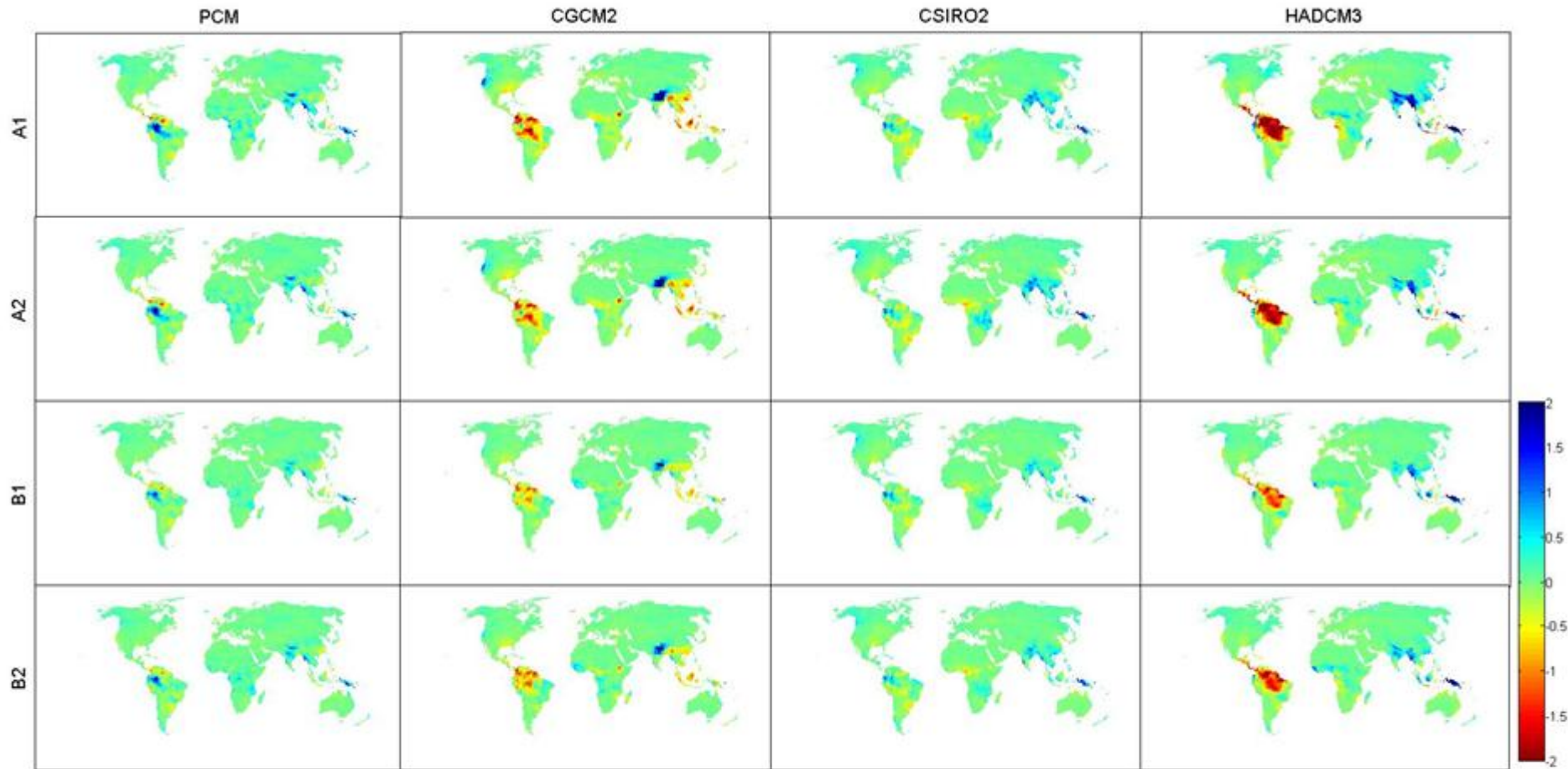
Climatic Future Projections (2100 vs 2000)



Climatic Future Projections (2100 vs 2000)



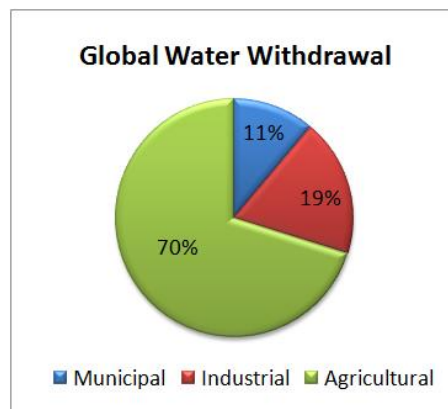
Climatic Future Projections (2100 vs 2000)



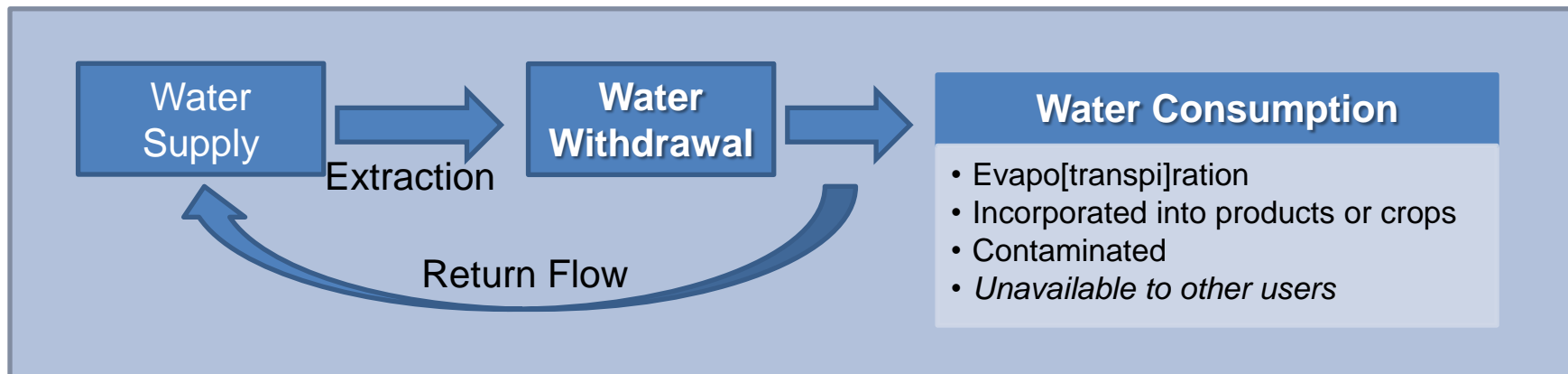
Model	Long name	IPCC number
CGCM2	Canadian Centre for Climate (Modelling and Analysis) (Canada)	7
CSIRO mk 2	Commonwealth Scientific and Industrial Research Organisation (Australia)	10
DOE PCM	Parallel Climate Model (NCAR - USA)	30
HadCM3	Hadley Centre Coupled Model	23

Water use in three parts:

1. Domestic
2. Industrial
3. Agricultural



Differentiate between withdrawal and consumption



Model & Results

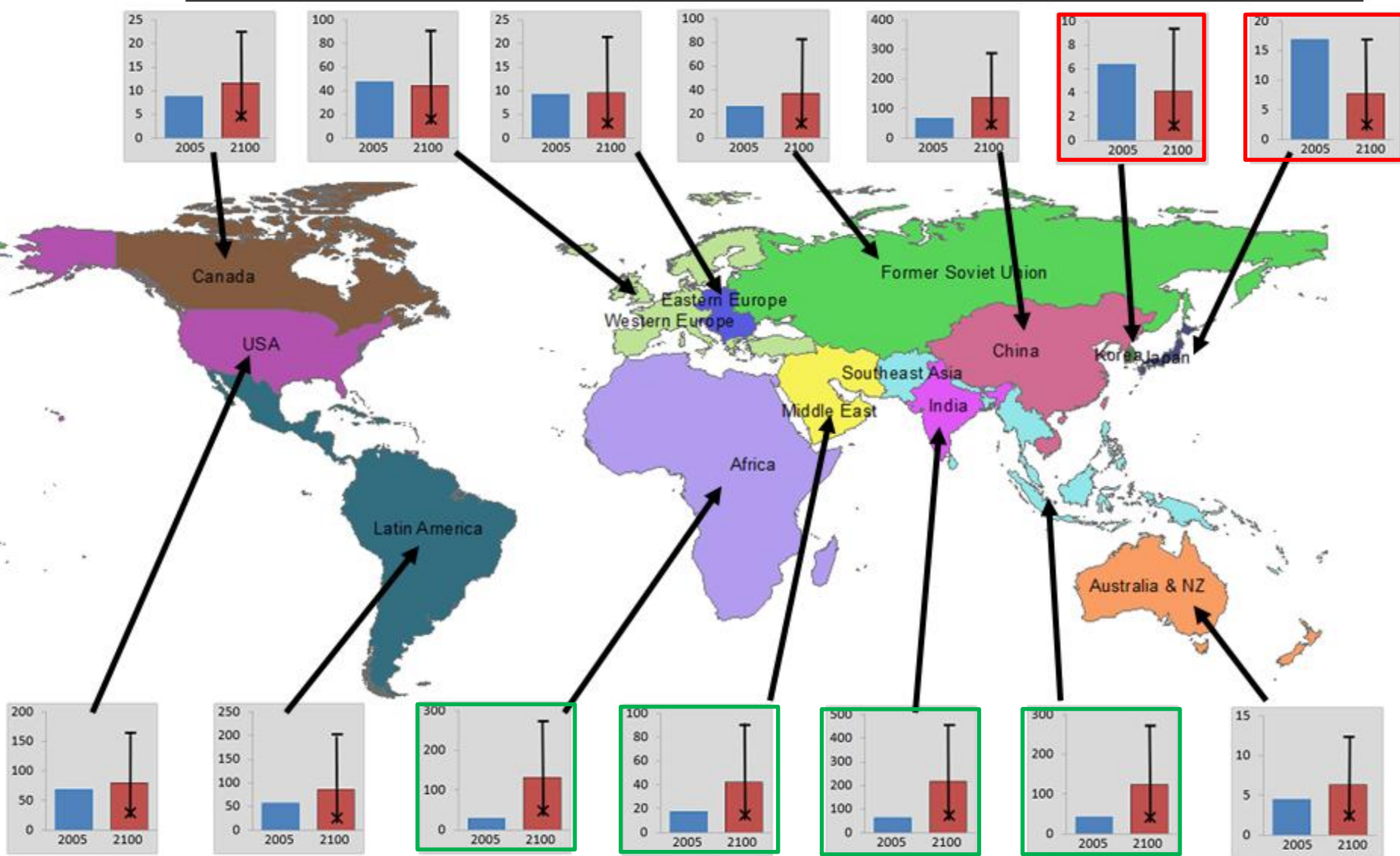
WATER DEMAND



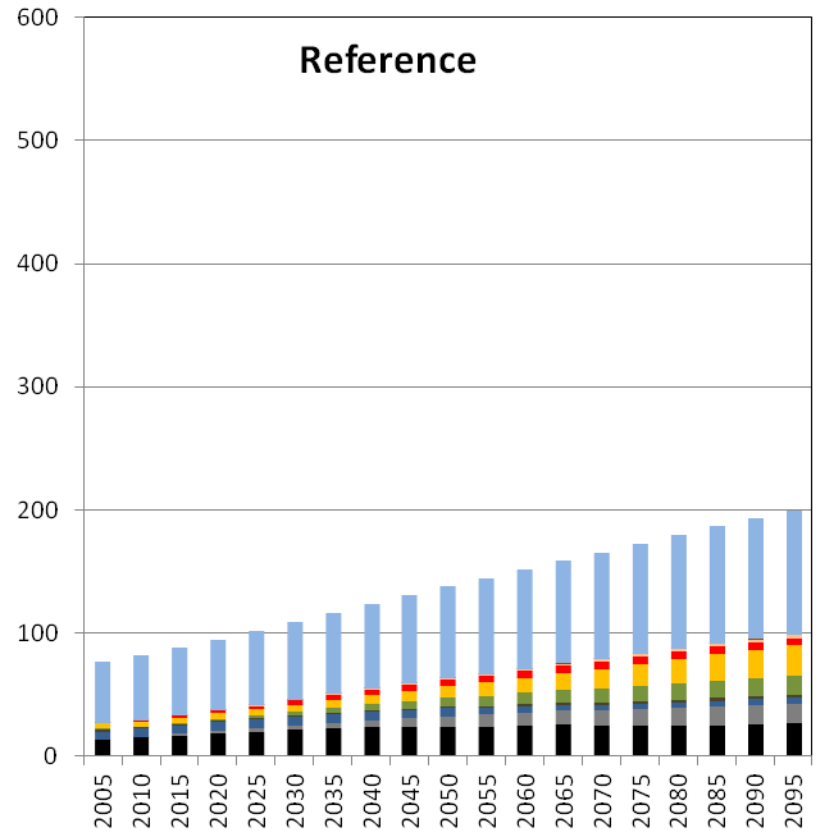
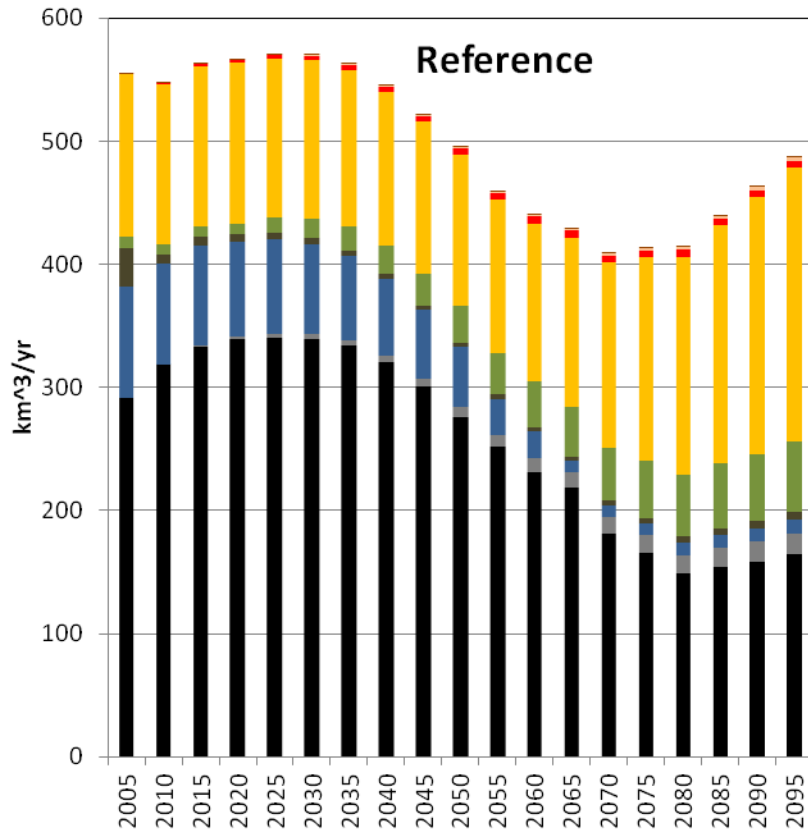
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Domestic Water Withdrawals (2100 vs. 2005)



Energy Water Demand in the future (No Policy vs. Climate Policy)



Withdrawal

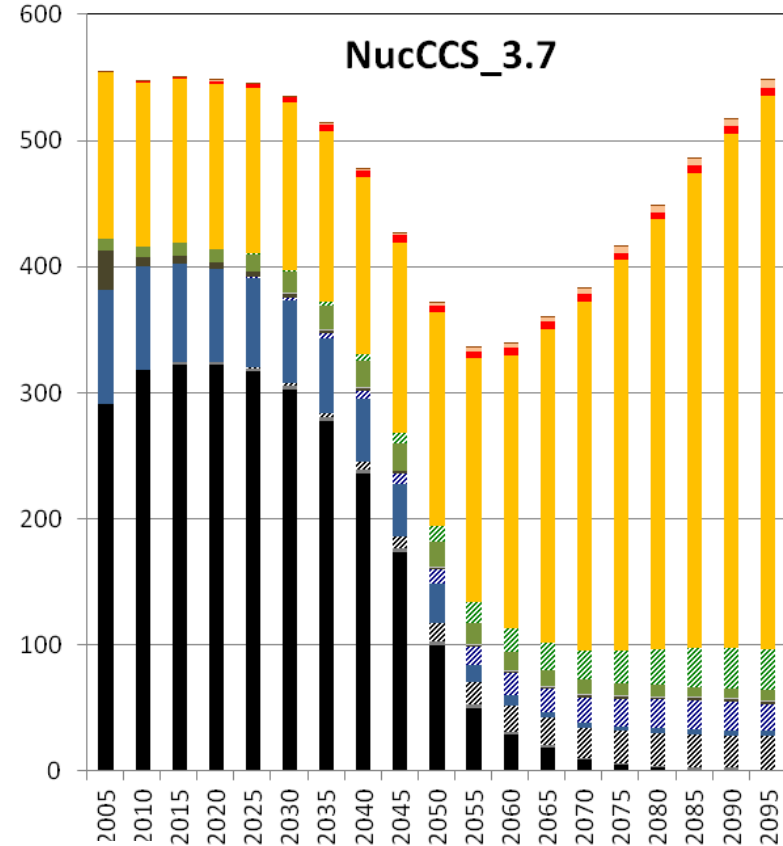
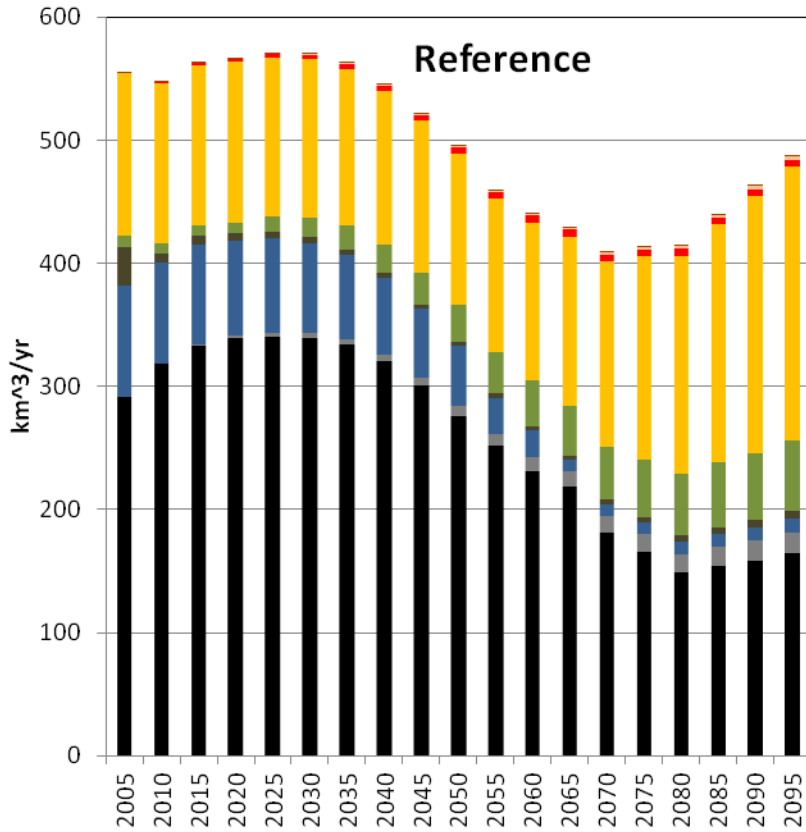
Consumption

- Hydro
- Wind
- PV
- CSP
- Geothermal
- Nuclear
- Biomass CCS
- Biomass
- Oil CCS
- Oil
- Gas CCS
- Gas
- Coal IGCC CCS
- Coal IGCC
- Coal



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Energy Water Demand in the future (No Policy vs. Climate Policy)



Withdrawal

- Hydro
- Wind
- PV
- CSP
- Geothermal
- Nuclear
- Biomass CCS
- Biomass
- Oil CCS
- Oil
- Gas CCS
- Gas
- Coal IGCC CCS
- Coal IGCC
- Coal

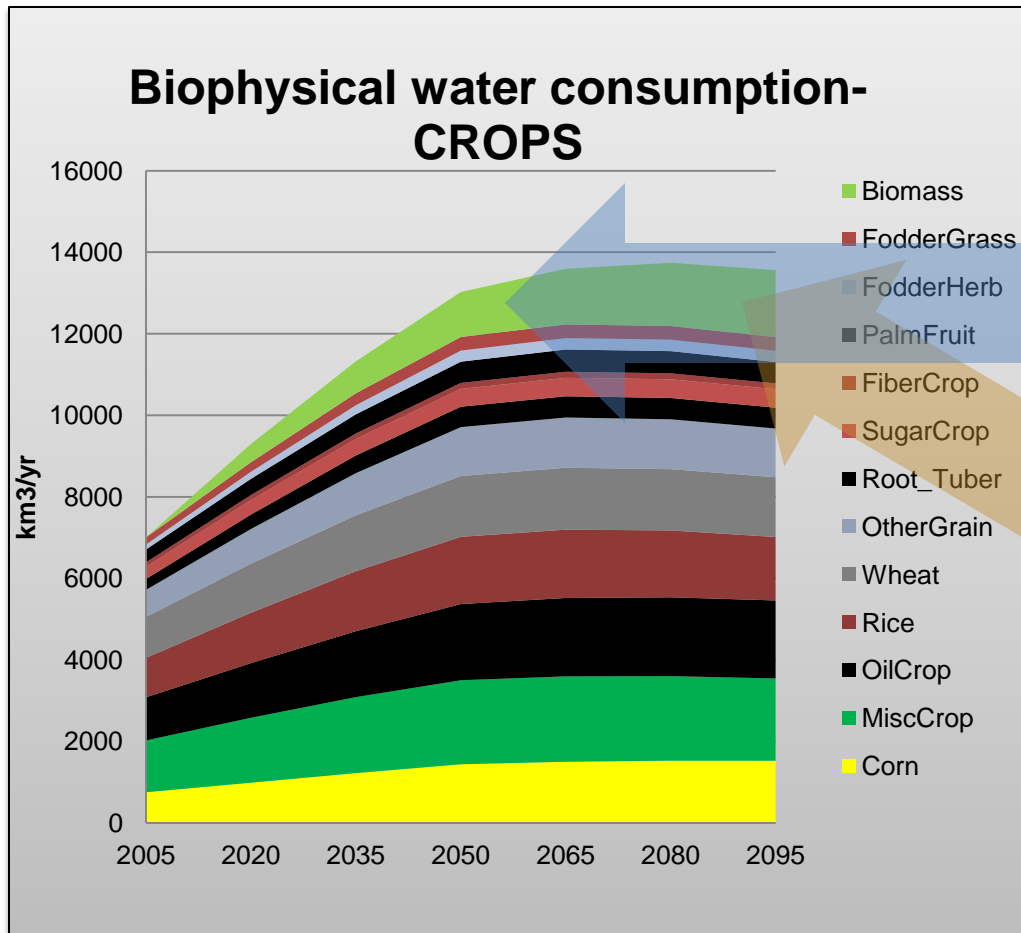
Withdrawal



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Biophysical Water Consumption



Total biophysical water consumption to almost double by 2050, after which the increase will be marginal

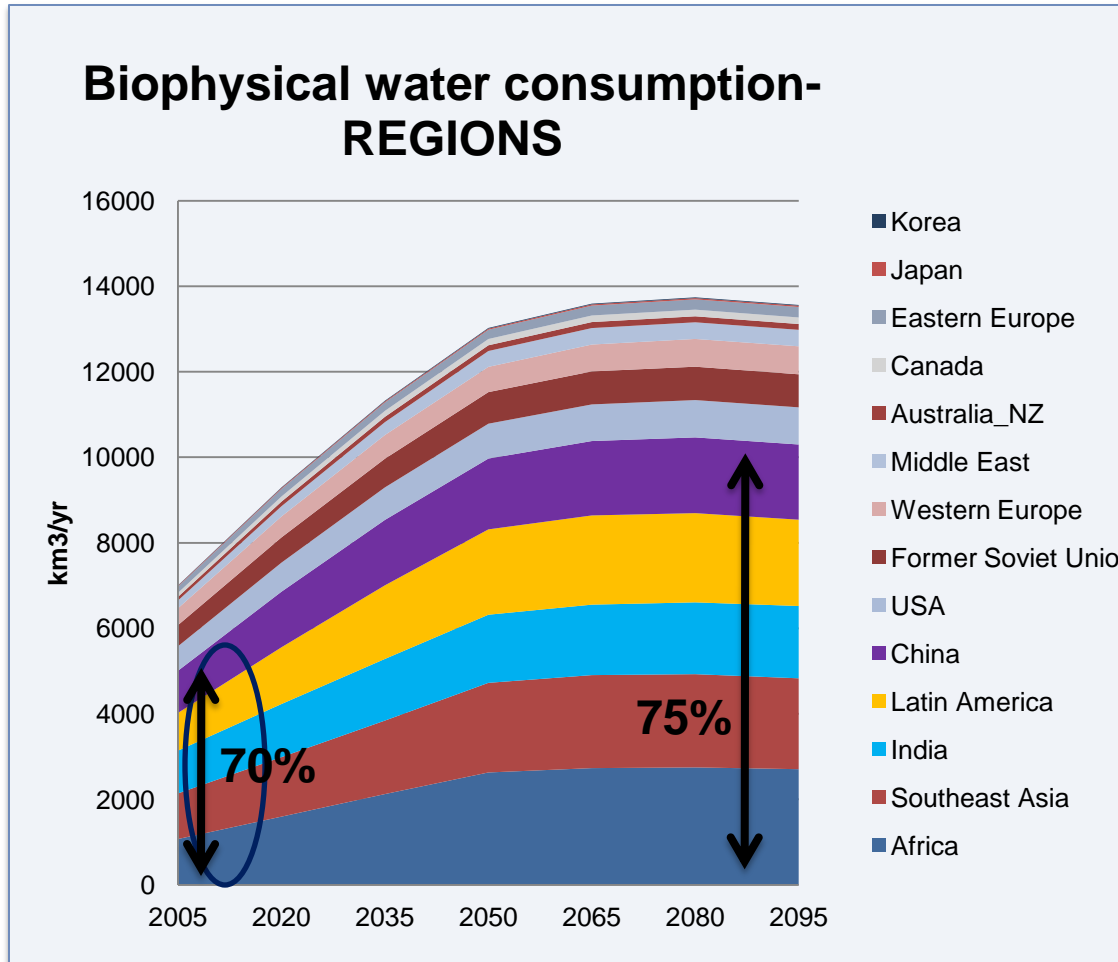
Energy crops' water consumption also increases, especially in the later half of the century



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Biophysical Water Consumption



Most of the water demand is in the developing nations of the world

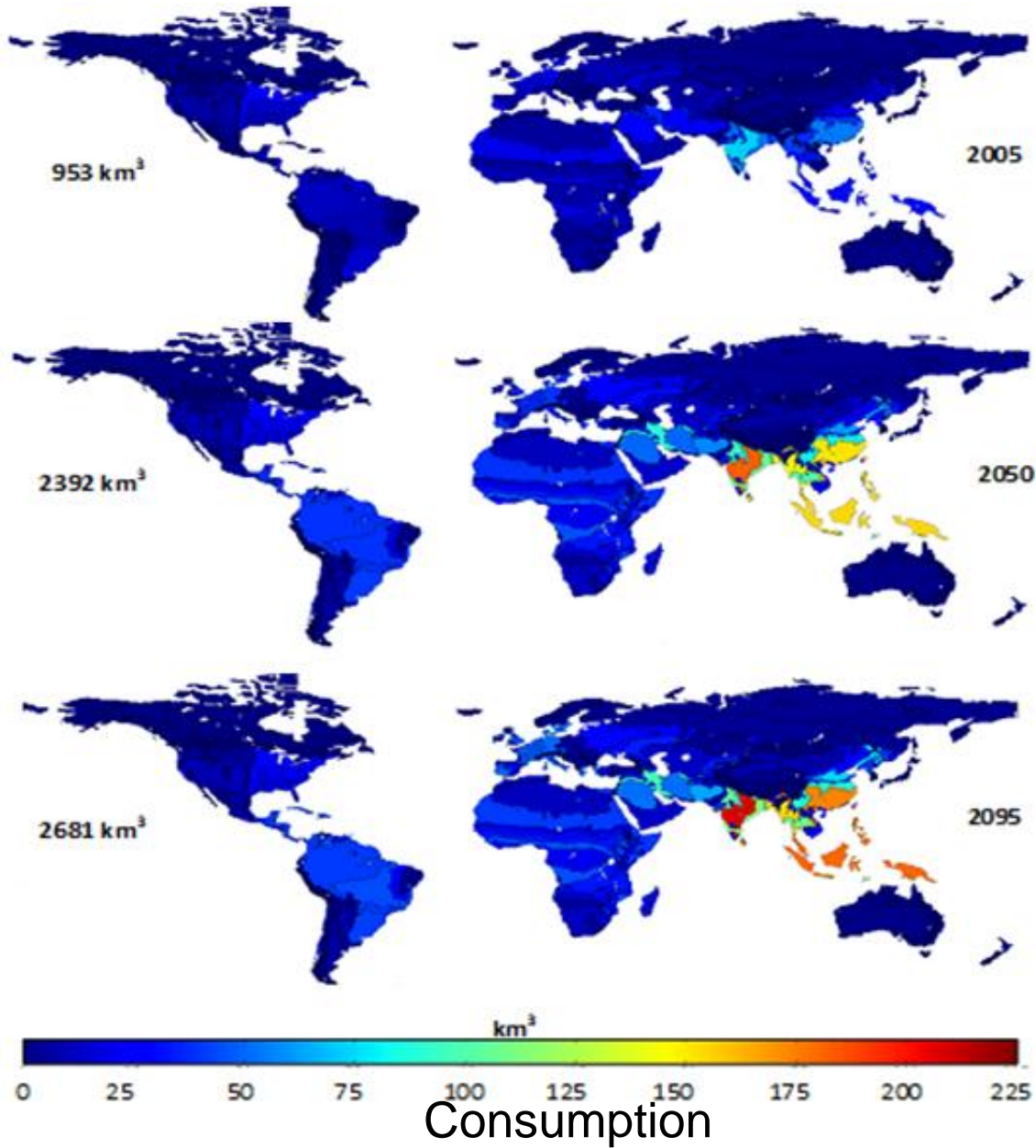
More than 70% of water for agriculture is consumed by developing regions, which increases to above 75% in 2095



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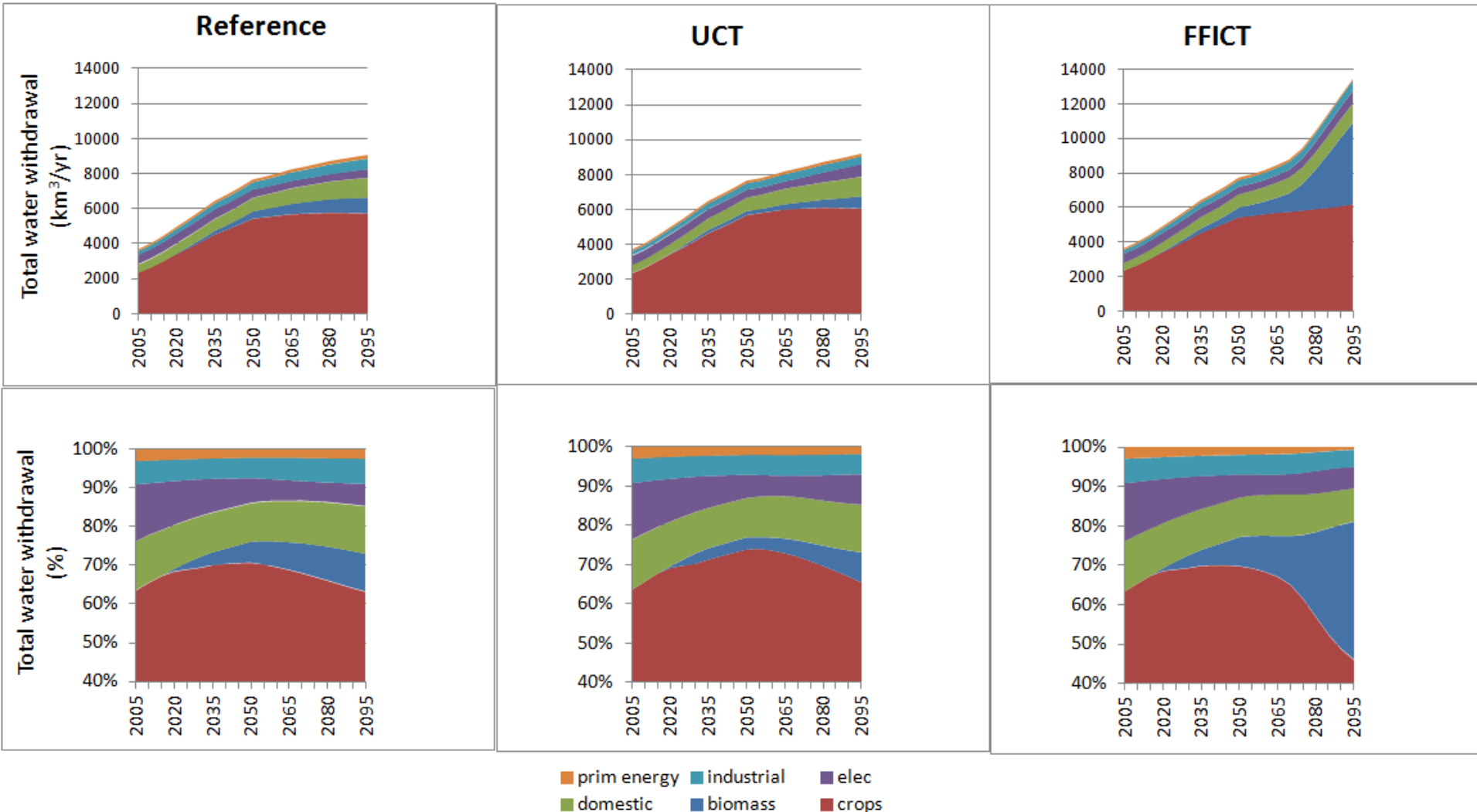
Agricultural Water Demand



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Effect of Climate Policy: Total Water Demands



Some Preliminary Observations from GCAM Water Systems Research

- ▶ Agriculture is the largest user of water (70% withdrawals; 85% consumption) - Bio-energy crops can potentially become important source of water demand in the future
- ▶ Developing countries demands for water can be expected to grow over time, particularly in the first half of the century.
- ▶ Energy systems need water—large source of withdrawals, much smaller consumer.
- ▶ Cooling water demands for power generation (the largest energy user of water) can be expected to grow in the future, particularly in the developing world.
- ▶ New cooling technologies could dramatically reduce fresh water withdrawals, but increase fresh water consumption.
- ▶ NEXT: Allocate water among the competing water users