Coupling for Impacts, Adaptation and Vulnerability - Water

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This Talk: Water Balance Model Introduction

A. Unsustainable Ground Water
B. Coupling to Global Economy
C. Energy/Power Sector

Conclusion

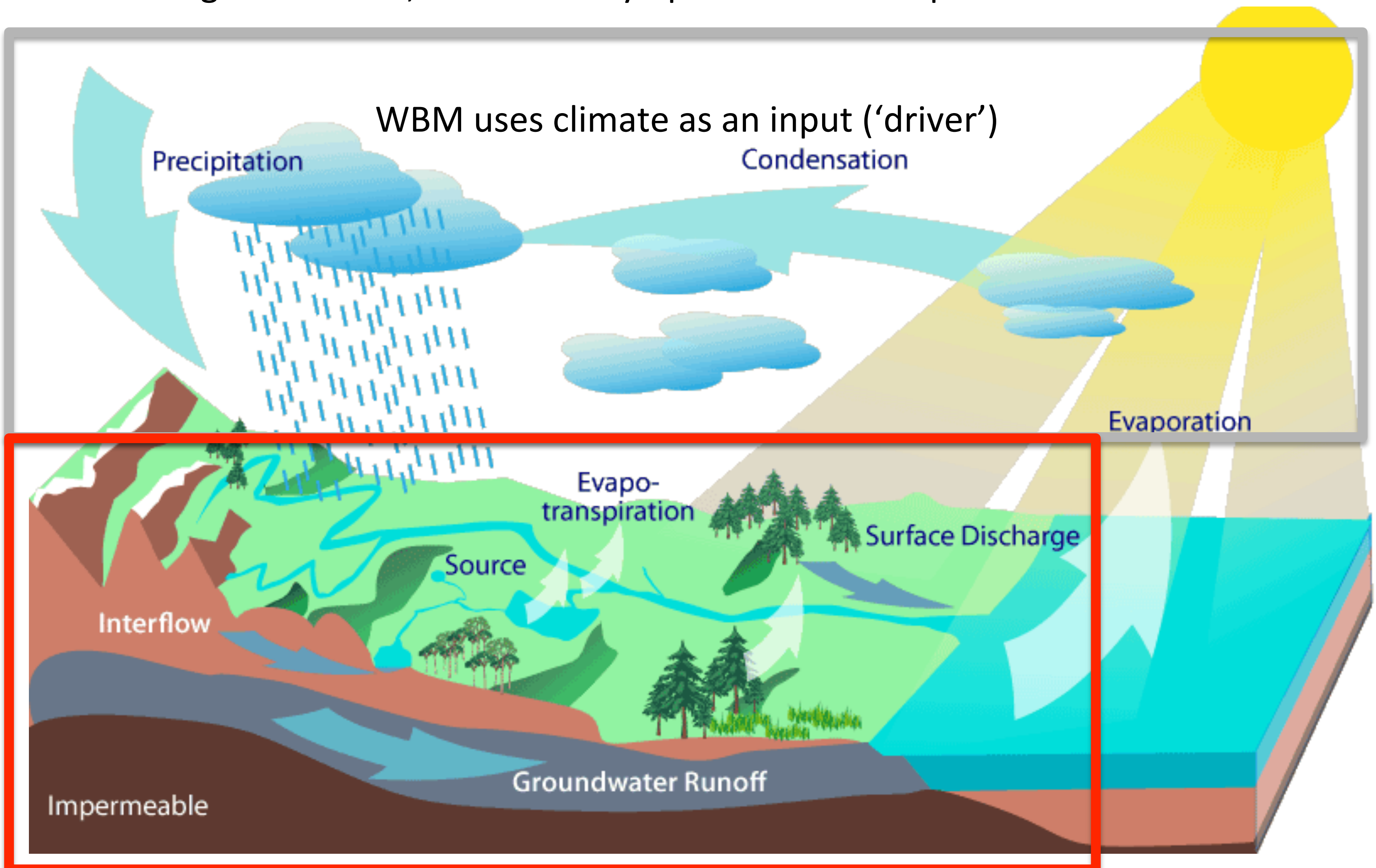
Snowmass, CO 25 July 2016

Water balance model

- Simulates the land surface component of the hydrologic cycle.
- Physics of water flow and mass balance (conservation of mass).
- WBM tracks water volumes as they move horizontally across the land surface, vertically down into soils and groundwater, and vertically up into the atmosphere.

Processes NOT modeled within WBM

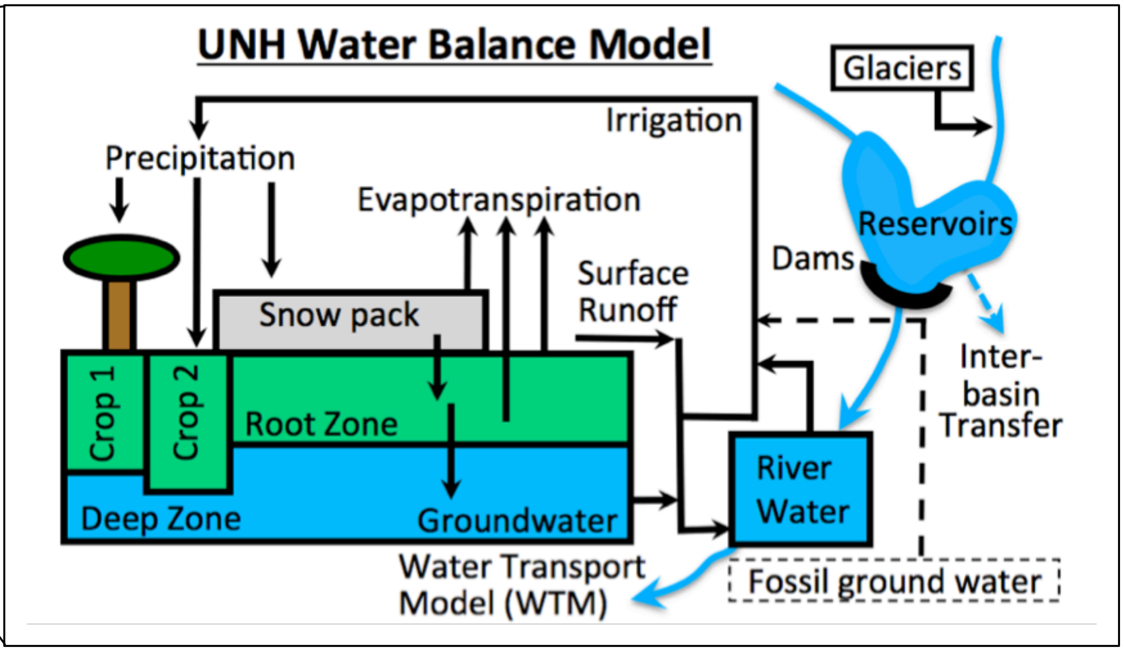
WBM processes

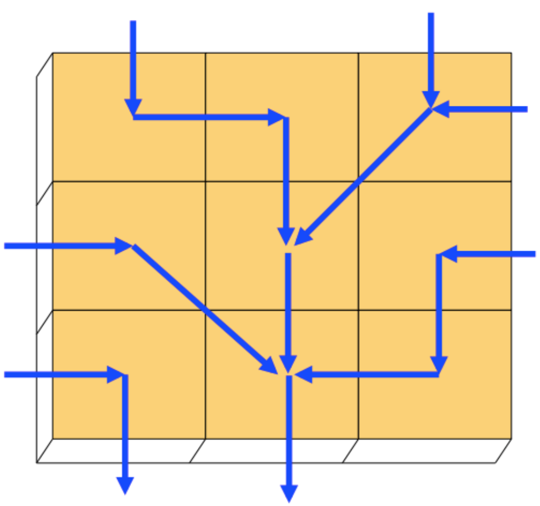


Water balance model

- WBM divides the study region into boxes (grid cells)
  - Study region can be any size – a single river basin, or the whole globe

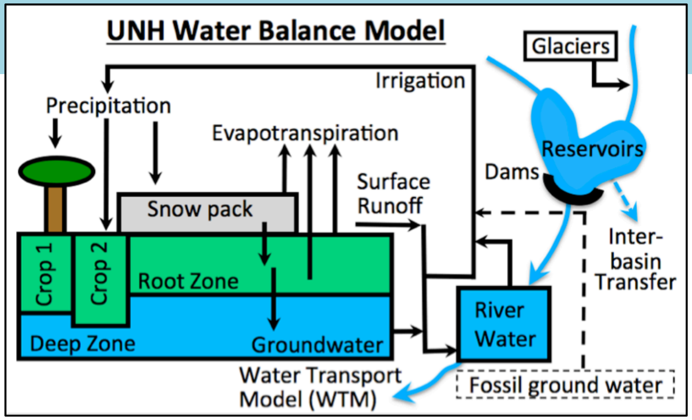
Every grid box has vertical movement of water: Evapotranspiration, infiltration, baseflow, irrigation, …





- Horizontal connectivity via the river network
- Grid cells can be any size (1/2 degree to 10^2 m)

Water balance model



- Model inputs (or 'drivers'):
  - Climate
    - Climate model projections to assess the hydrologic impact of climate change
  - Land use / land cover
    - Soil and vegetation types (includes agriculture, impervious surfaces, forests)
  - Infrastructure
    - Dams: location, capacity, primary purpose, date constructed
    - Large canals: location, capacity, date
    - Area equipped for irrigation, irrigation efficiency
  - Population (for domestic & industrial water demand)

- WBM human-based movement of water:
  - Irrigation water withdrawals (from surface water, renewable and fossil groundwater)
  - Domestic and industrial water withdrawals
  - Dam/reservoir water storage and release
  - Interbasin transfers of water
  - Rule-based systems dictate how and when to move water.

- Output: Water availability at all places and times.

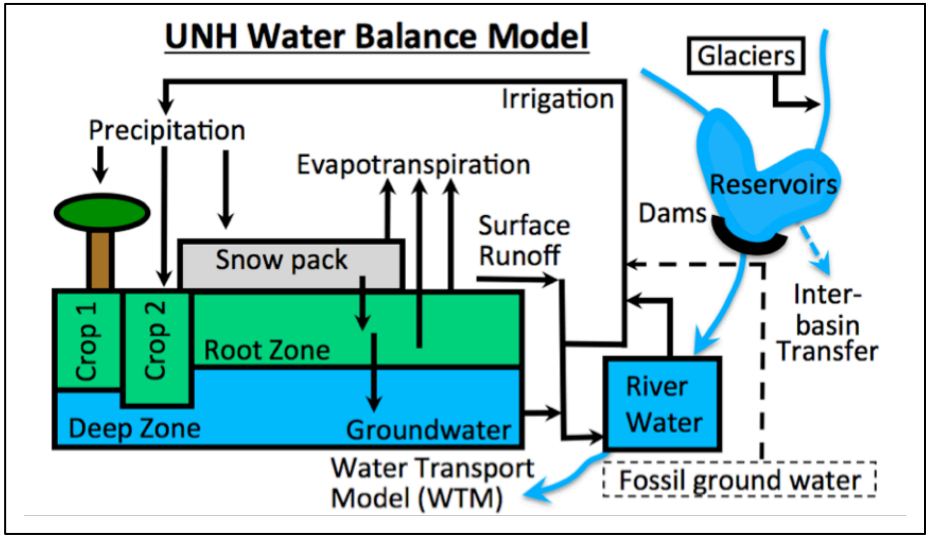
Water balance model

Tracking water components in runoff, river flow, and groundwater

Track Water By
Age
Runoff origin- • Glacial melt • Snow melt • Rain storm water • Baseflow water
Primary origin- • Glacial melt • Snow melt • Rain • Unsustainable water
Water use (irrigation)- • Pristine water • Irrigation return water

Why is this important?

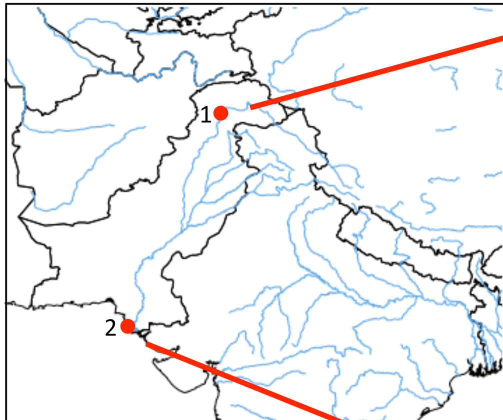
Allows for an understanding of the downstream impacts due to upstream changes (natural or human sources)

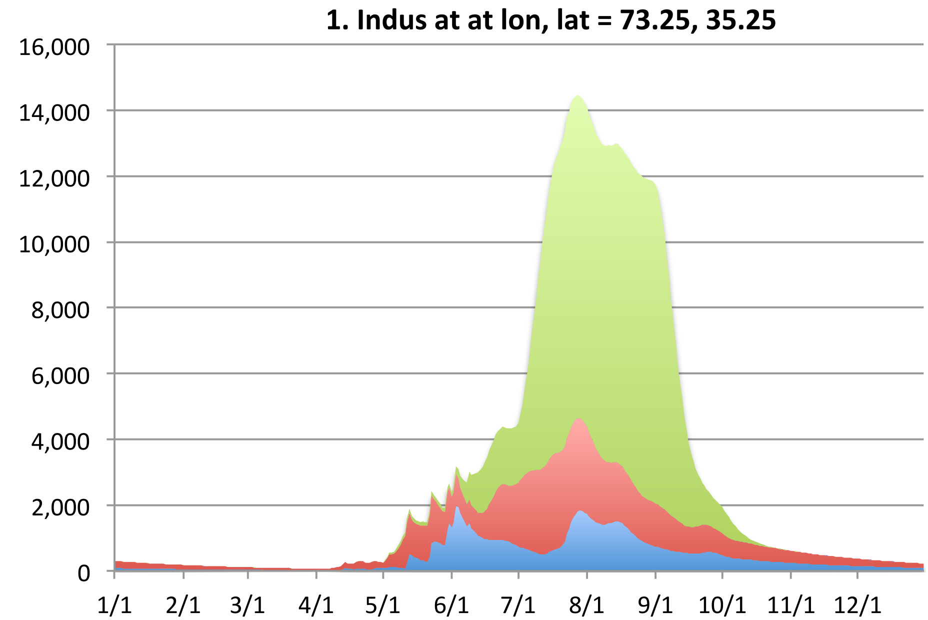


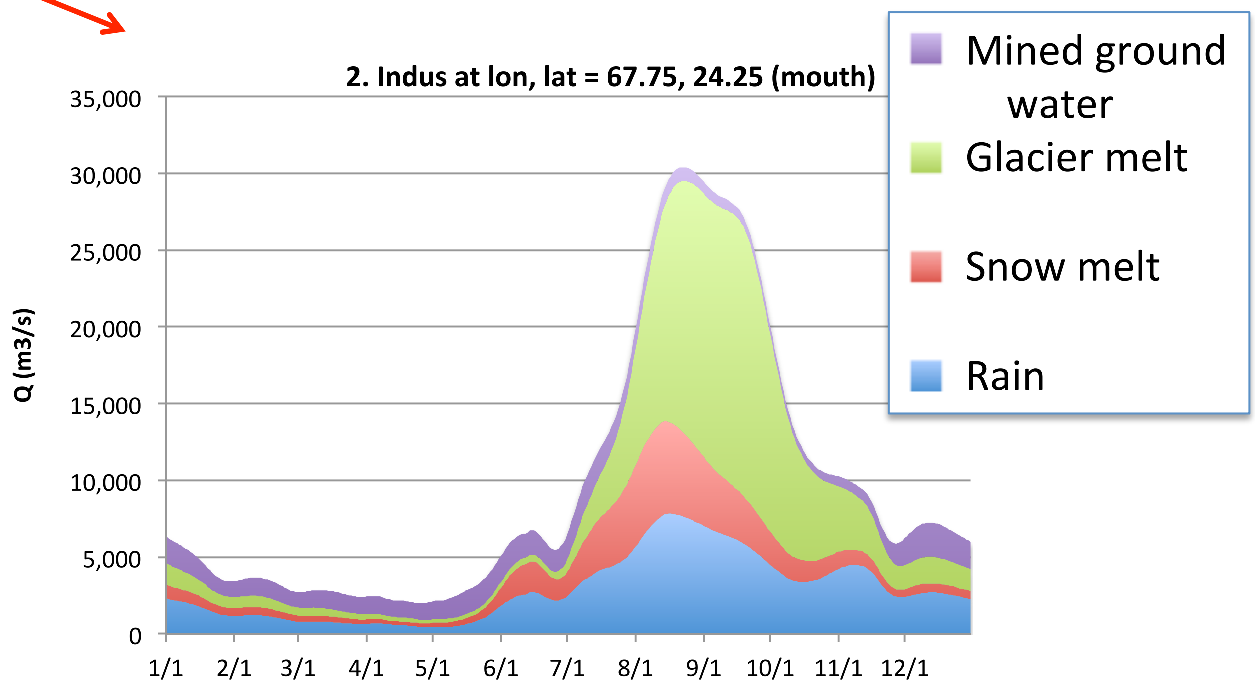
Component concentrations change as water is routed downstream due to local runoff tributary inflow and additional water use.

Stacked components

Hydrograph locations







WBM daily river discharge for the year 2000.
Resolution: 0.5°
climate: MERRA
Glaciers: from Regine Hock

Grogan et al, in prep.

A. Unsustainable Ground Water (UGW)

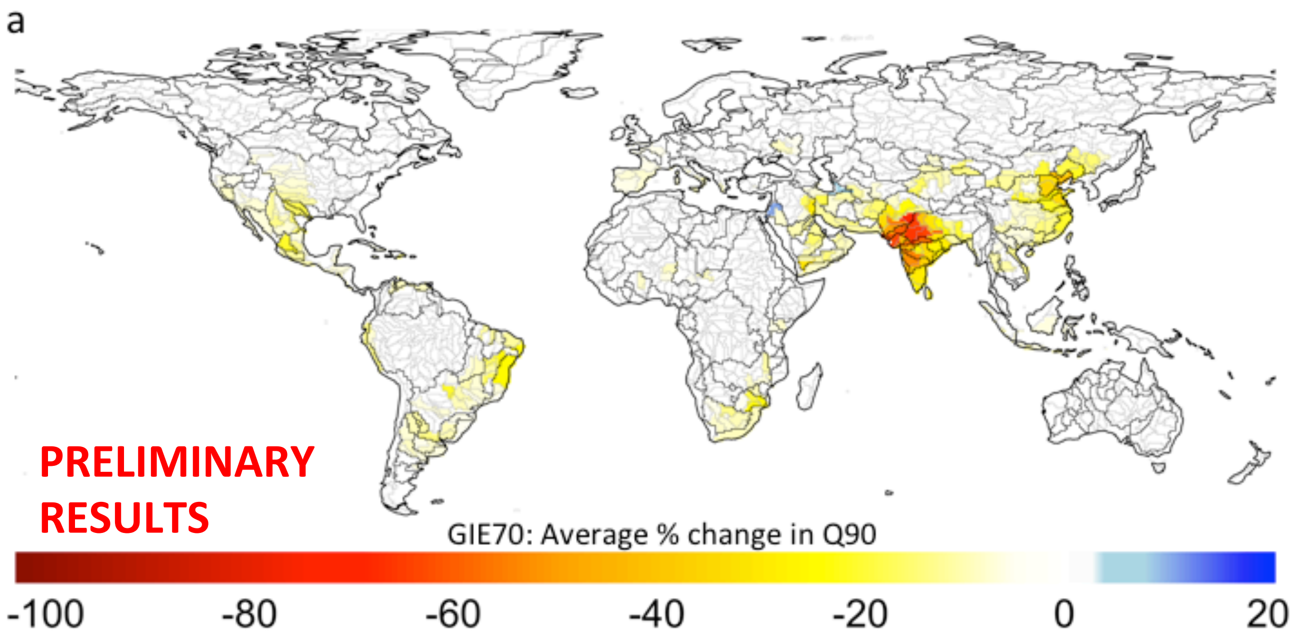
From the physical model only or
Coupled to economics model.

Questions:

a) How will future UGW withdrawals change?
b) Are there adaptations to offset these changes?
c) Are they sufficient?

Unsustainable groundwater:
    groundwater extracted in excess of recharge

Change in low flows for a) irrigation efficiency increased and b) UGW removed

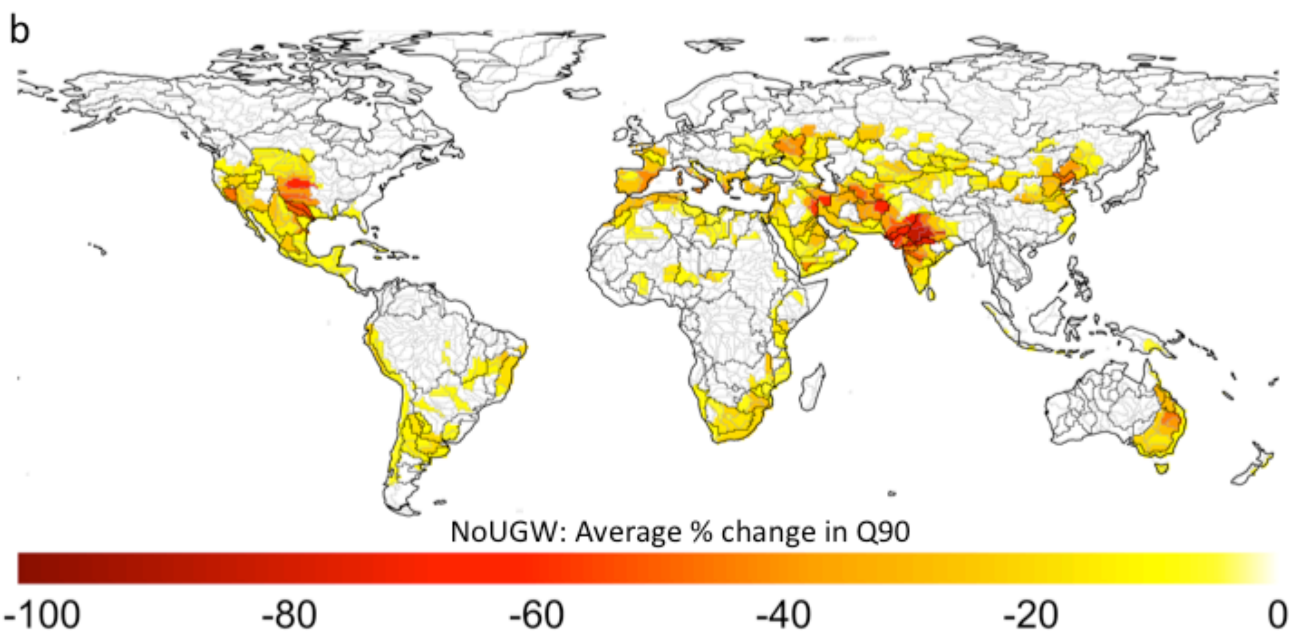


Change in low flows when irrigation efficiency is 70% in all countries (current FAO maximum)

Scenarios:

Technology transfer

Investment increased



Change in low flows by removing unsustainable ground water (UGW).

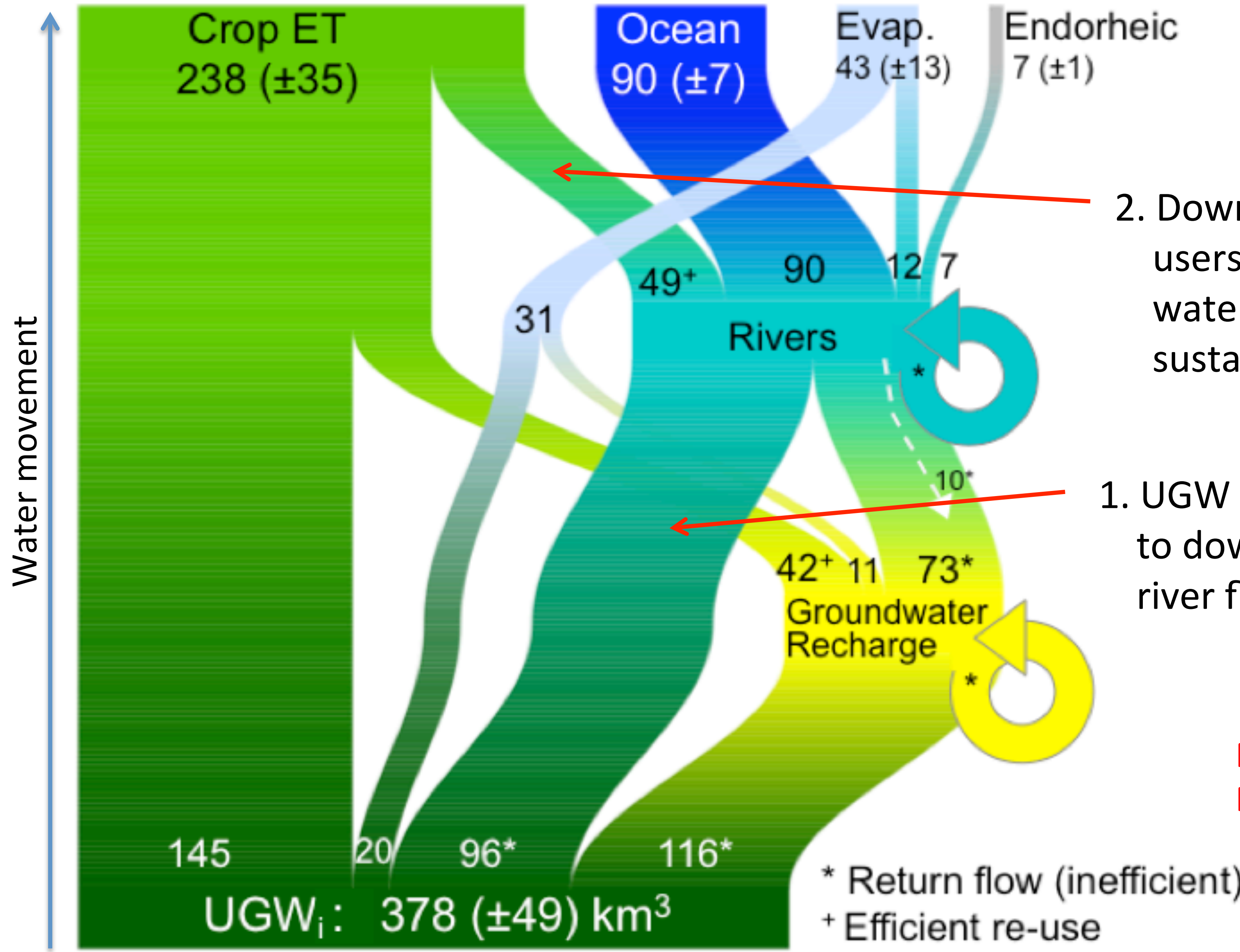
Scenarios:

UGW runs out (physical)

Pumping stopped (policy)

-5% and 5% are masked

Where does unsustainable groundwater used for irrigation go?



Unsustainable groundwater (UGW) used for irrigation

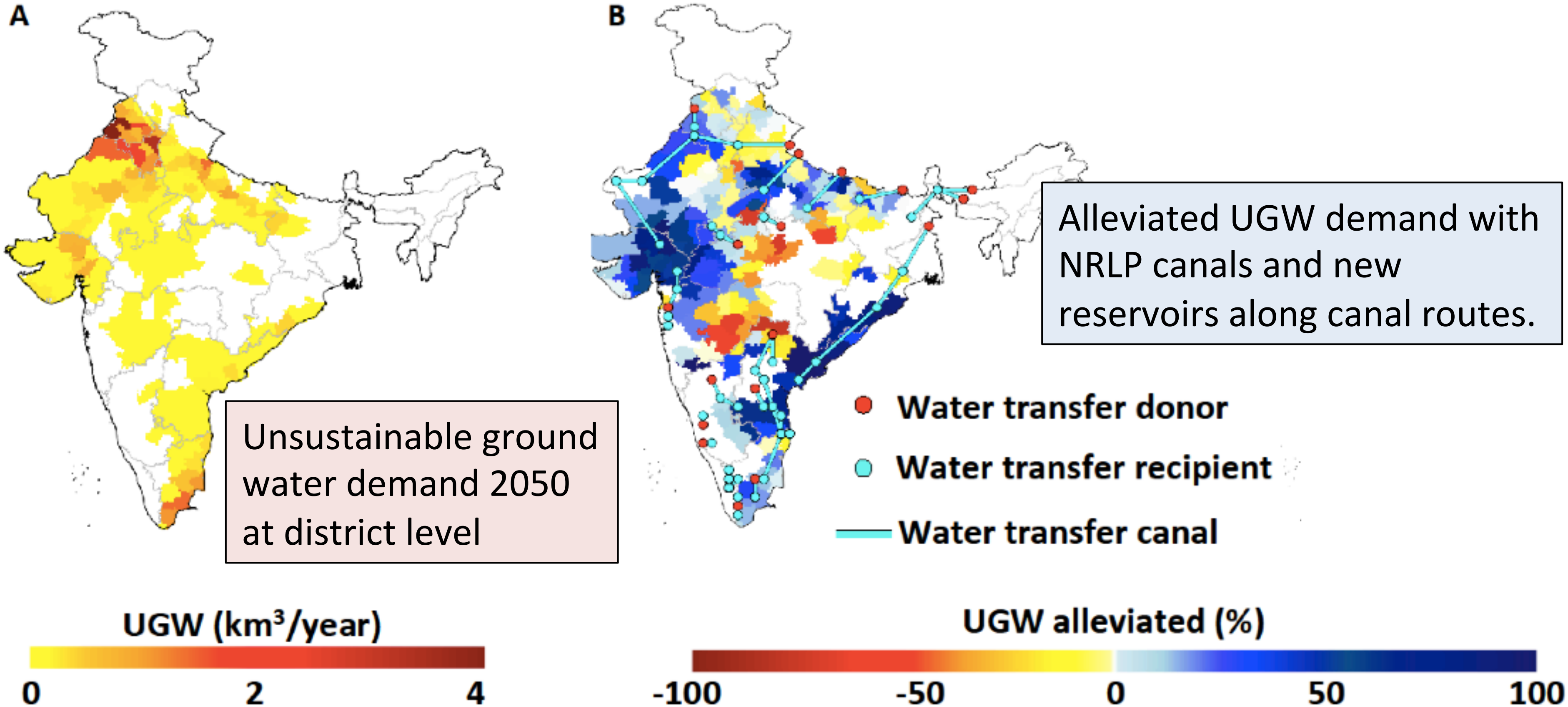
2. Downstream users view this water as sustainable

1. UGW contributes to downstream river flow

PRELIMINARY RESULTS

Grogan et al, in prep.

National River Linking Project (NRLP) – India
Coupled econometric and hydrology models to understand impacts



Unsustainable ground water demand 2050 at district level

Alleviated UGW demand with NRLP canals and new reservoirs along canal routes.

A) The NRLP is a proposed solution for alleviating UGW demand.

B) Blue: UGW demand is alleviated
Yellow/Red: UGW demand is worsened.

National total UGW alleviation is 16%.

Zaveri, Grogan, et al (in press) ERL

B. Economy – Global scales

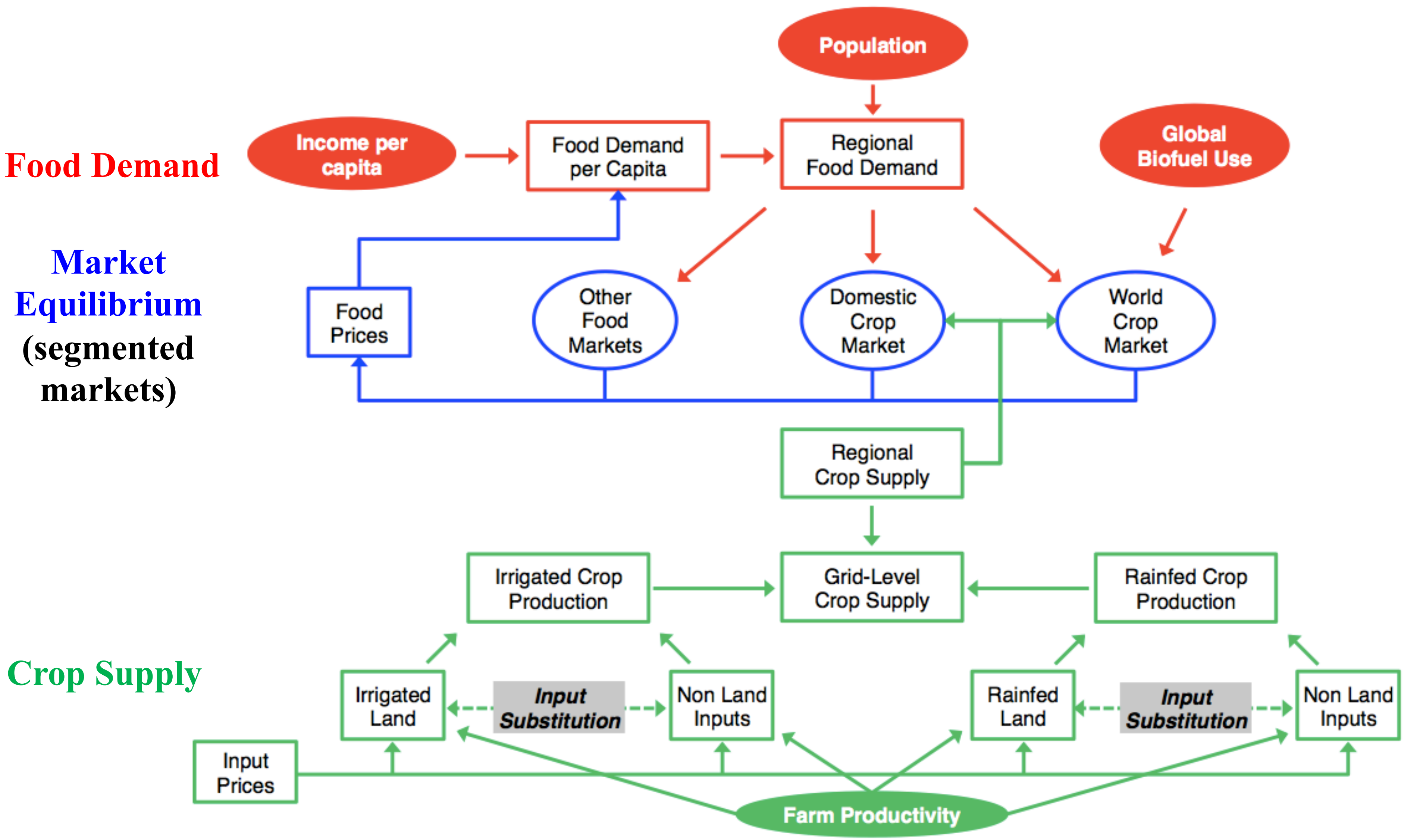
Coupling to SIMPLE-on-a-Grid
(Purdue economics model with Tom Hertel, Jing Liu, and Uris Baldos)

Question:

What are the effects of including physical constraints (water supply for irrigation) on agricultural production?

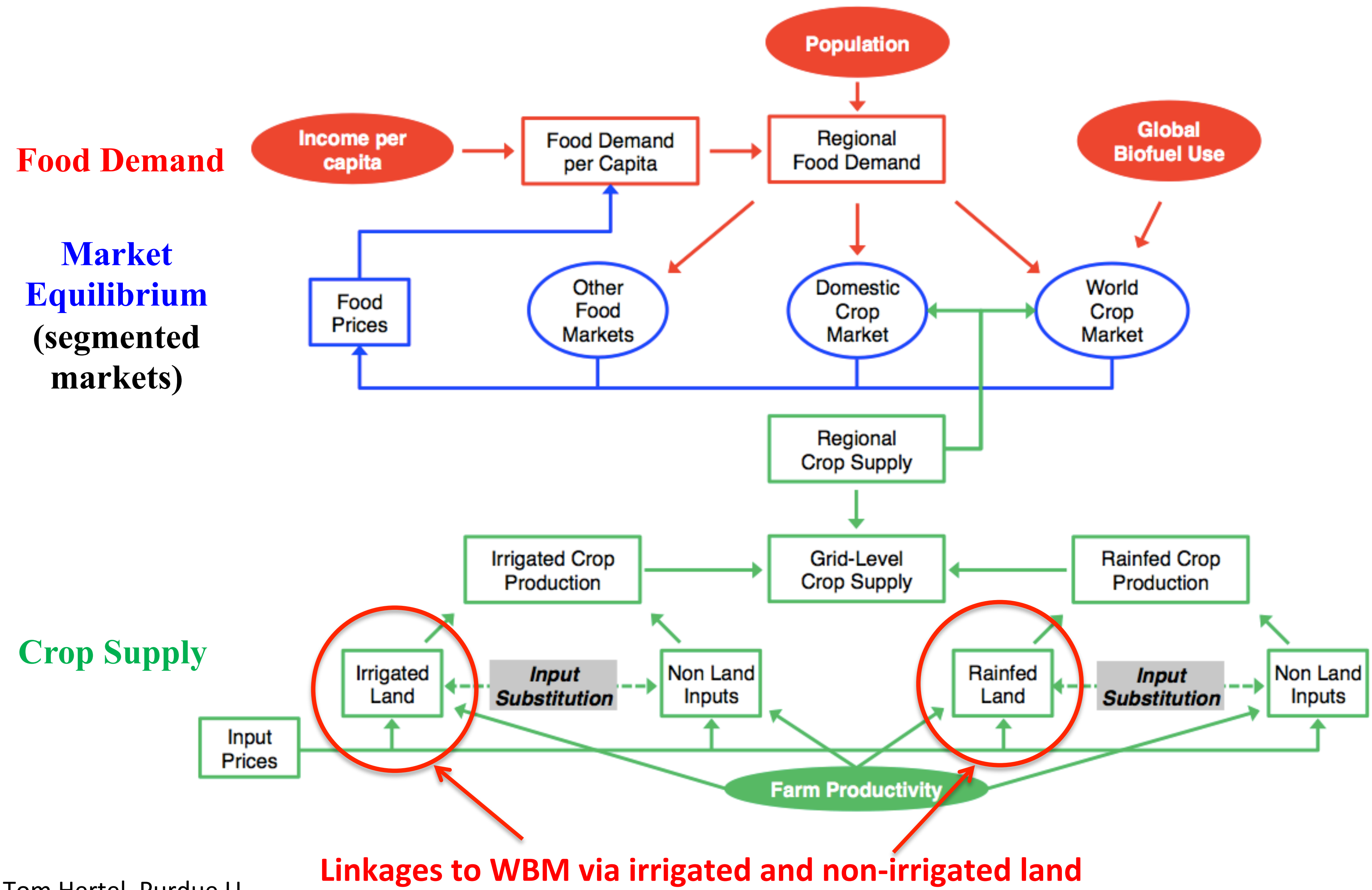
(This effort resulted directly from discussions at Snowmass 2015)

SIMPLE Model



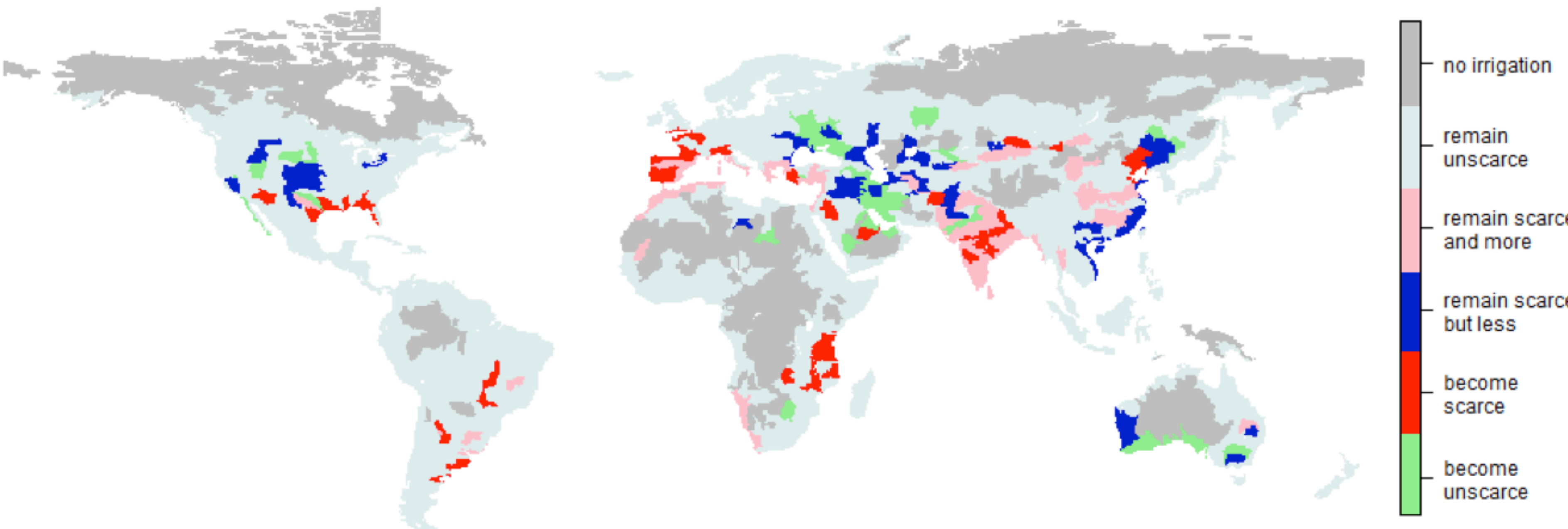
Tom Hertel, Purdue U.

SIMPLE Model



Tom Hertel, Purdue U.

The changing extent of irrigation scarcity at the sub-basin level 2050 relative to 2006



(Red and pink are bad)

'Business-as-usual' future in 2050 is assumed, which means no sustainability requirement and adaptation policy interventions, high emissions scenario RCP8.5, and a stagnant Total Factor Productivity (TFP) growth.

Based on irrigation demand and supply simulated by WBM and *SIMPLE-on-a-grid*.

PRELIMINARY RESULTS

Jing Liu, Tom Hertel, Purdue U. (Liu et al., in prep.)

C. Energy/Power Sector

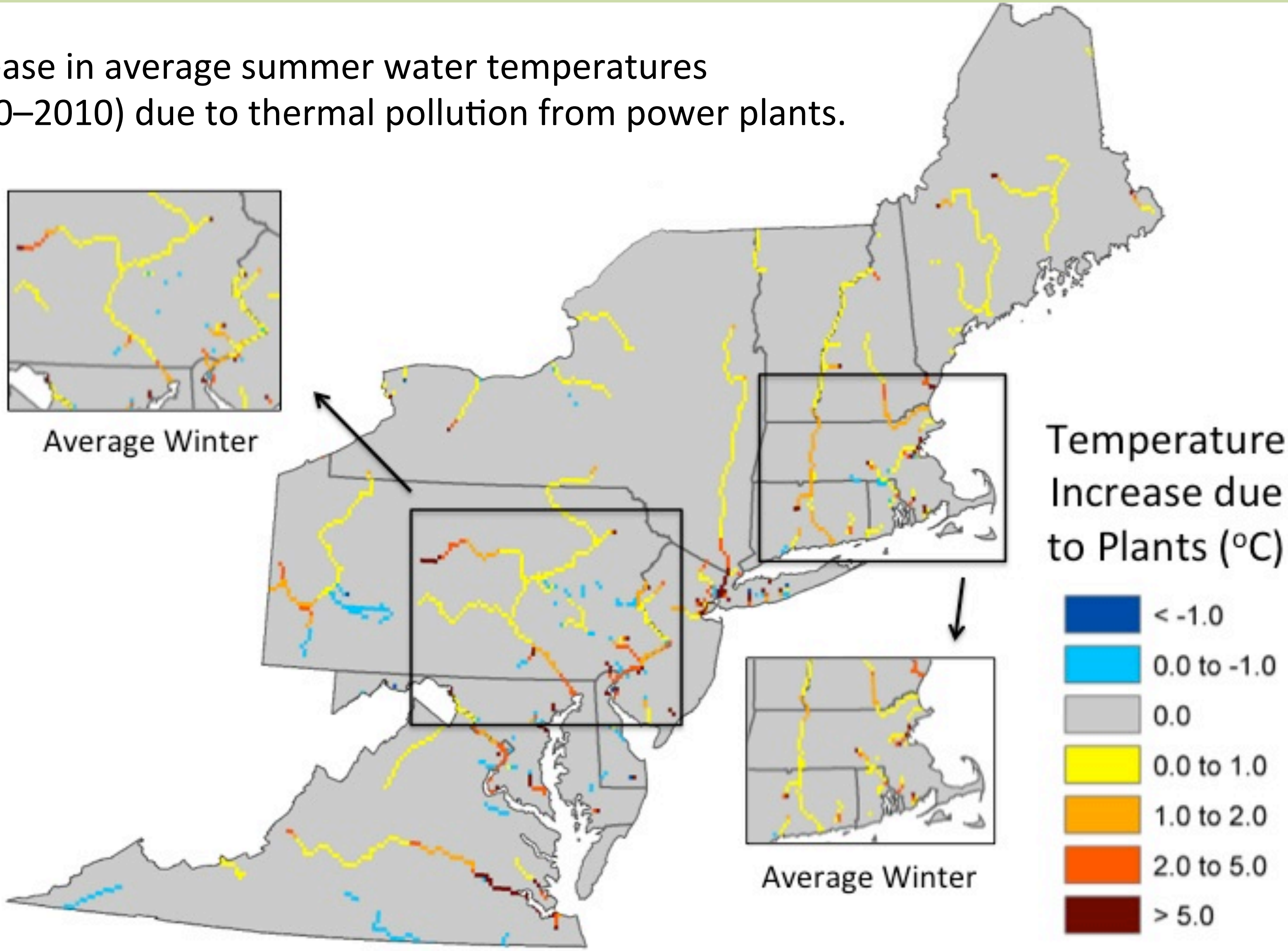
With Mort Webster (PSU)

Questions:

a) Where is the energy-water system most vulnerable?
b) How can we make the energy-water system more resilient to change?
c) What kind of adaptations should we consider?

Previous Research: WBM and power plants

Increase in average summer water temperatures (2000–2010) due to thermal pollution from power plants.

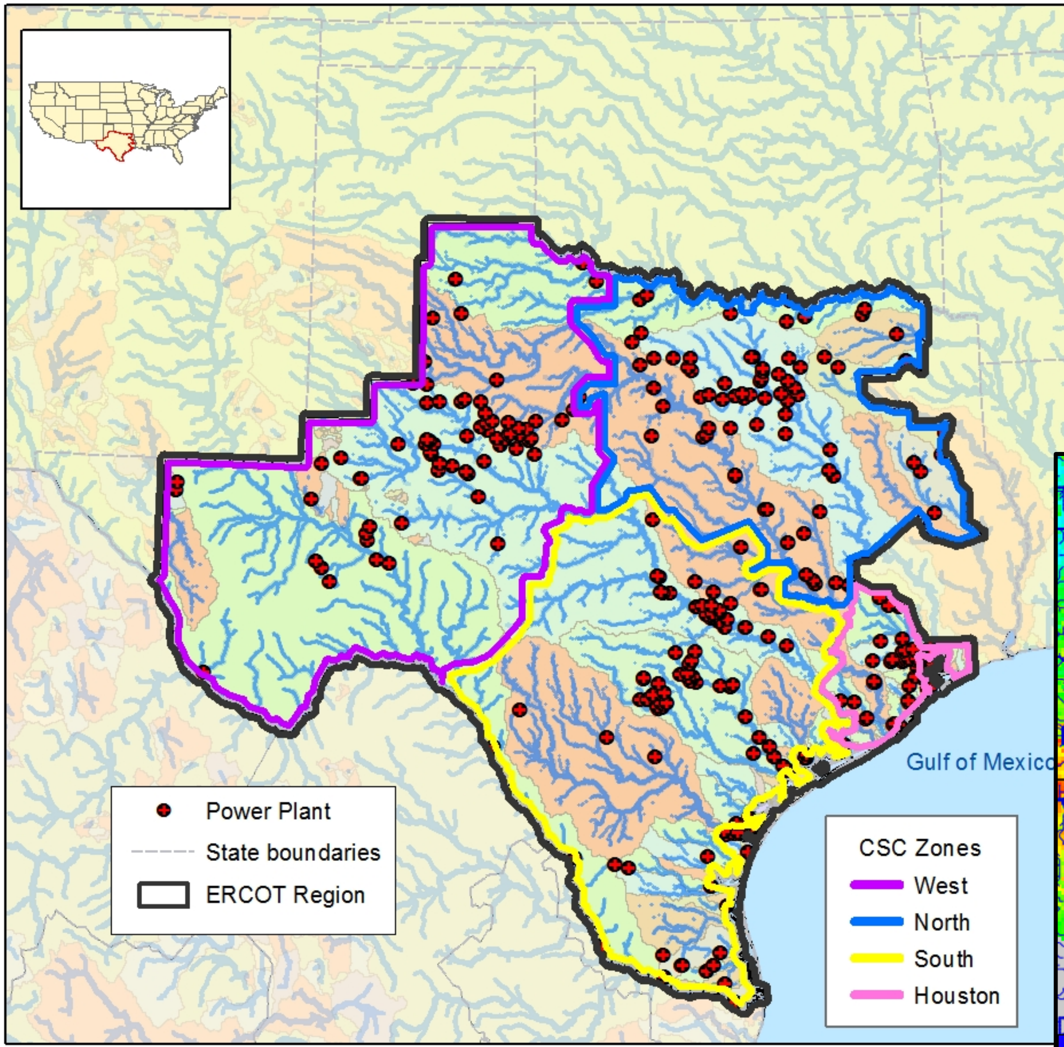


Callout boxes show results for average winter conditions. Power plants which use recirculating cooling tower technology often reduce downstream water temperatures while "once-through" cooling technologies return water to the river at much higher temperatures.

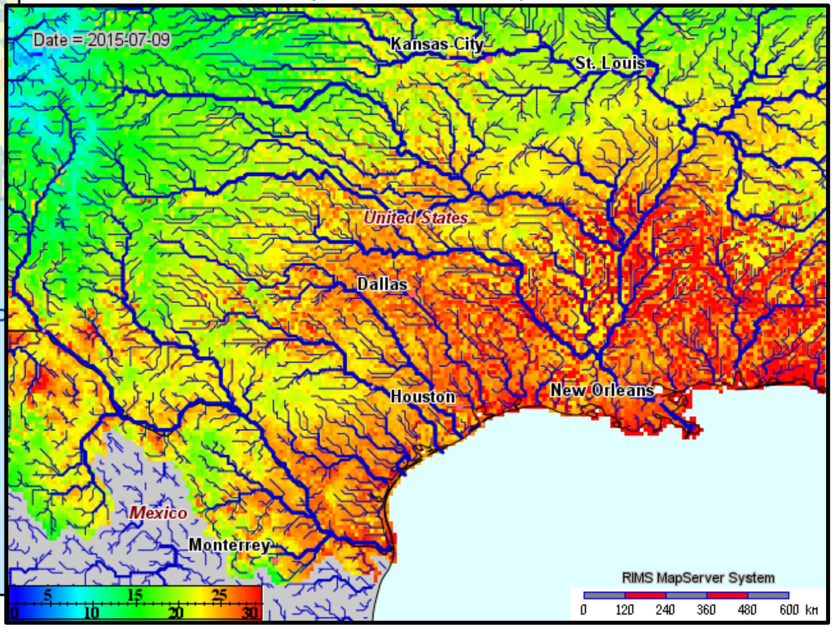
Stewart et al. (2013) Env. Res. Lett.

River network and power networks

ERCOT Zones with Power Plants and Rivers



WBM Simulated River Temperature (2015-07-09)



What does hydrological modeling need?

Better representation of decision making by humans.

We can use simple rules approximate some of the ways humans move water but this is not sufficient

Process	Short time frame (this is about water volume)	Long time frame (this is about infrastructure)
Dams and Interbasin Transfers	How much water to release/ move and when	When to build or decommission dam/canal/pipeline
Irrigation	How much to irrigate, which crops to plant	When to add additional fields to be irrigated; improvements in agricultural technology (giving improved water use efficiency)
Livestock	Size and type of herd	Conversion to/from crops
Domestic Use	Household water demand, climate response	Changing attitudes, laws, planning codes and messaging
Industrial Use	Limitations due to regulation, supply/demand of industry	Structural shifts in economy

WBM can do some of this *WBM does not do this*

In return hydrological modeling offers:

- **How much water is available for use**
- **Where and when is it available.**

More Coupling → More information → More Constraints

Coupling also gives all of us:

- **Improved representation of the larger system**
- **Identification of the impacts**
- **Recognition of the trade-offs that need to be made**
- **Better understanding of the vulnerabilities in different sectors and regions**
- **Ability to test a variety of adaptations**