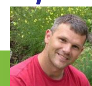
MIT Joint Program Sponsors Webinar Series

DECEMBER . 12 . 2012 10:30 am - 12:00 pm EST

Impacts of Human and Environmental Change on Regional and Global Water Resources

 **Dr. C. Adam Schlosser**  **Dr. Elodie Blanc**  **Dr. Ken Strzepek**

Webinar Format:

1. At the start of today's presentation, please self-monitor your background noise and mute your teleconference accordingly. You may be muted by the Moderator/Host in order to maintain sound quality during the presentation. If you are muted, a red line will appear across the telephone icon next to your name in the attendee list. You can manually un-mute your phone to ask a question.

2. During the presentation, the Moderator/Host and Presenter will be taking questions *for clarity only* (first 45-50 minutes of the webinar). All other questions will be addressed during the Q&A period (second 40-45 minutes of the webinar).

3. If you have a question, you may either use the *hand icon* to "raise your hand", type a message in the *chat section* to the Moderator/Host, or ask your question *via the teleconference* if you have joined by phone. You will be recognized by the Moderator so that you may ask your question.

4. When asking a question, *please first identify yourself and your organization*, for the benefit of all attendees.

5. This webinar series is a service provided to the Joint Program Sponsor members only. On occasion, we may have prospective companies representatives attending for purposes of exploring membership with the Joint Program.

6. At the conclusion of the Webinar, online attendees will be presented with a brief survey. We hope that you will take a few minutes to provide feedback on today's session and make suggestions for future webinar topics.

We welcome your comments at any time to Frances Goldstein (fkg@mit.edu).

Thank you for participating in the MIT Joint Program Sponsors Webinar series today.

The webinar will begin shortly.

Impacts of Human and Environmental Change on Regional and Global Water Resources

C. Adam Schlosser, Elodie Blanc, and Ken Strzepek

Joint Program Collaborating Researchers
Henry Jacoby, Xiang Gao, Chas Fant, Arthur Gueneau, Bilhuda Rasheed, Sebastian Rausch, Qudsia Ejaz, and John Reilly

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We gratefully acknowledge support from the Joint Program's industrial and federal sponsors

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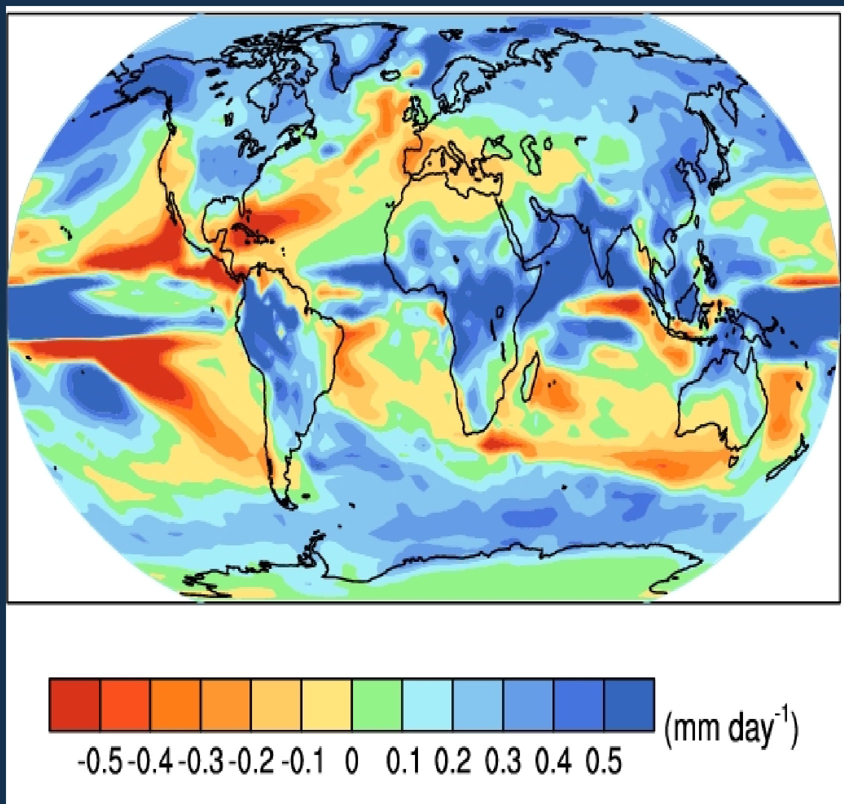
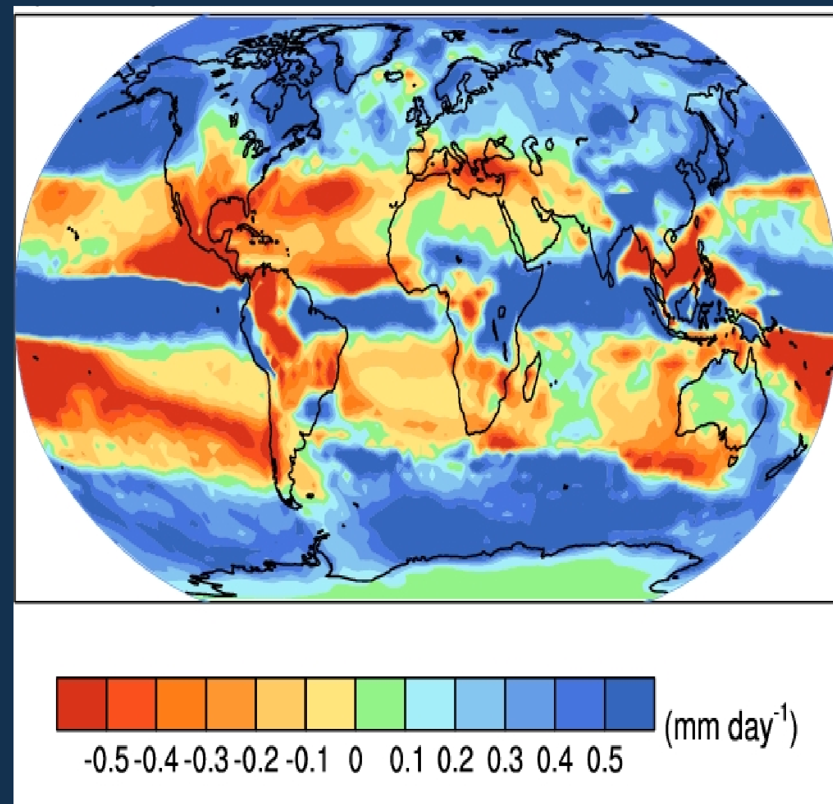
Uncertainty in Regional Change

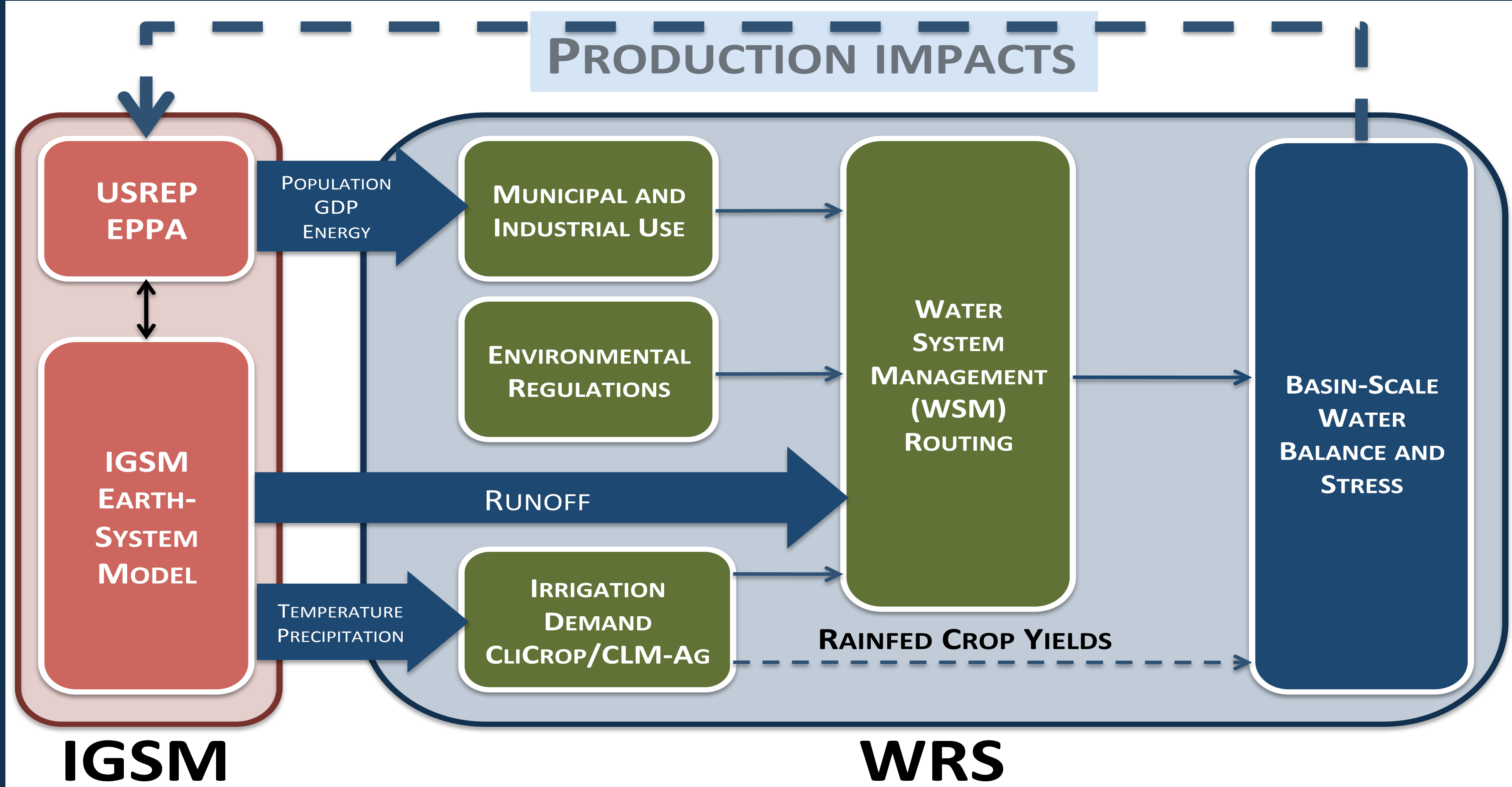
Simulated Precipitation Change in 21st Century: A1B Scenario
Opposing Climate Model Results at the Regional Scale





HOW CAN WE PREPARE WHEN REGIONAL CHANGES DIFFER IN SIGN?
WHAT ARE THE RISKS?

The Integrated Global System Model (IGSM) Water Resource System (WRS) Framework



$$\max \sum_{month} \sum_{sectors} \frac{\text{supply}_{month,sector}}{\text{requirements}_{month,sector}}$$

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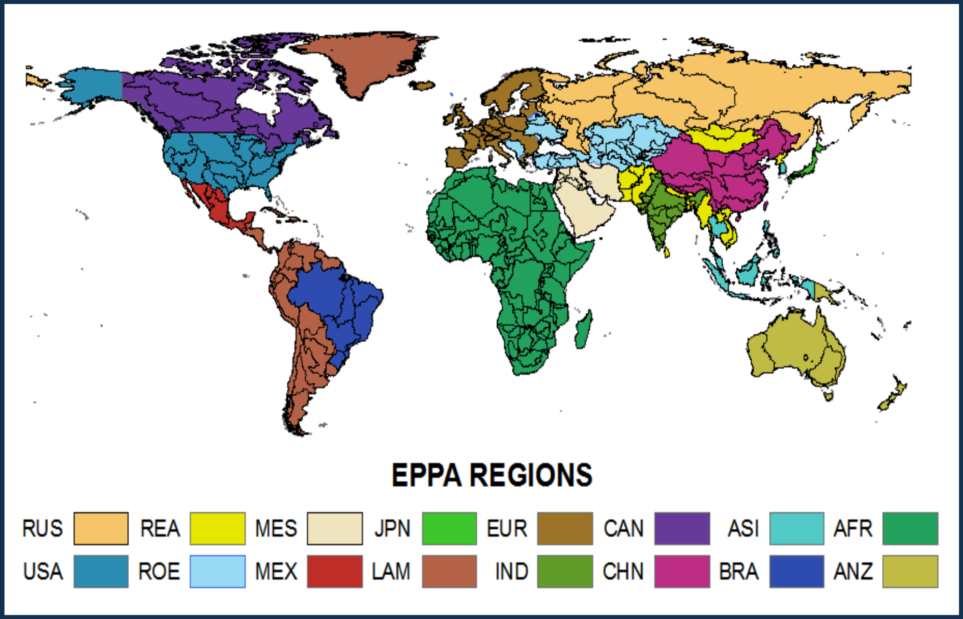
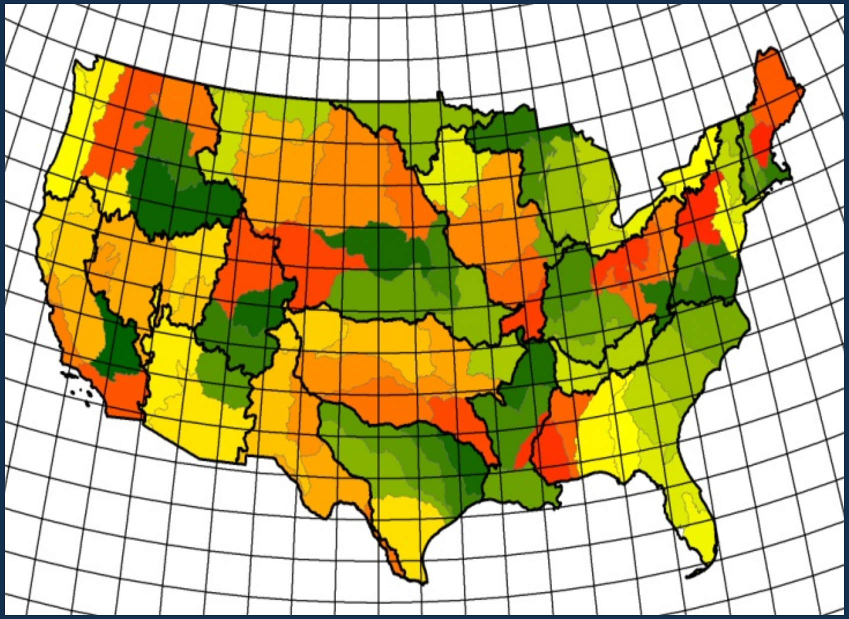
Modeling Water Resource Systems under Climate Change: IGSM-WRS, Strzepek, K., C. A. Schlosser, A. Gueneau, X. Gao, C. Fant, E. Blanc, and, B. Rasheed, and H. Jacoby (MIT Joint Program Report Series)

IGSM-WRS Basin Scales





- **<u>Global application: Modeling Impacts of Global Change on Water Resources</u>**, C. A. Schlosser, K. Strzepek, X. Gao, E. Blanc, A. Gueneau, C. Fant, B. Rasheed, T. Smith-Greico, H. Jacoby, and J. Reilly (MIT Joint Program Report, forthcoming)
- **<u>U.S. application: Water Resource System modeling for the U.S.</u>,** Blanc E., K. Strzepek, C. A. Schlosser, H. Jacoby, A. Gueneau, C. Fant, S. Rausch (MIT Joint Program Report, forthcoming)
- Zambezi River Basin Study: Special Issue of Climatic Change

IGSM Scenarios

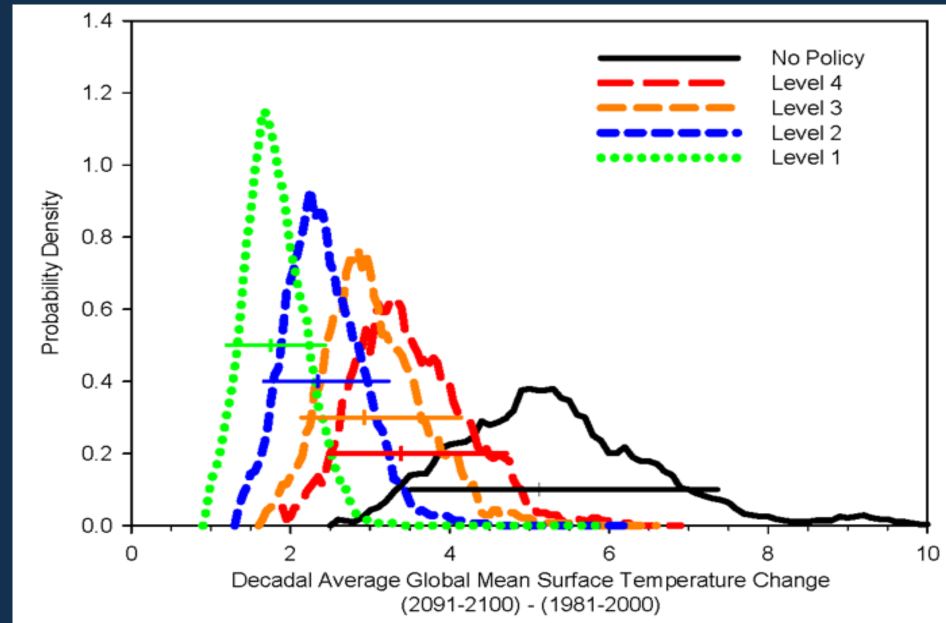
(Sokolov et al., 2009, and Webster et al., 2009)

No Policy (Reference):

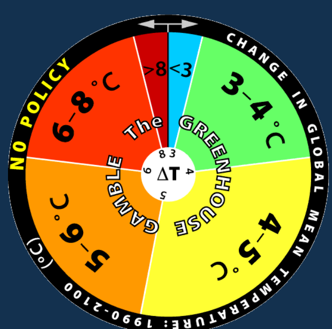
- "Unconstrained Emissions"

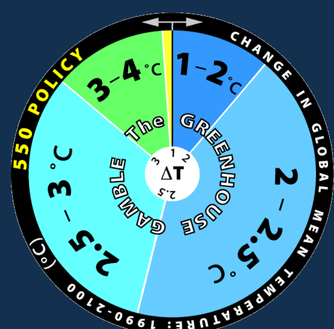
Stabilization Scenarios: U.S. CCSP

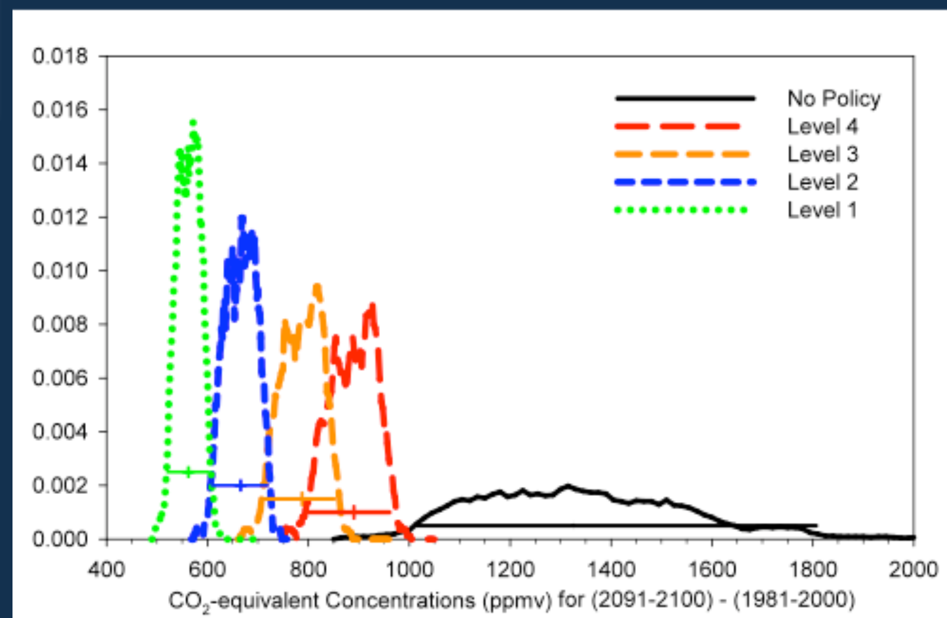
- Level 4 (750 CO_2, 890 CO_2-eq)
- Level 3 (650 CO_2, 780 CO_2-eq)
- Level 2 (550 CO_2, 660 CO_2-eq)
- Level 1 (450 CO_2, 560 CO_2-eq)



Temperature-change distributions conveyed as "The Greenhouse Gamble" wheels





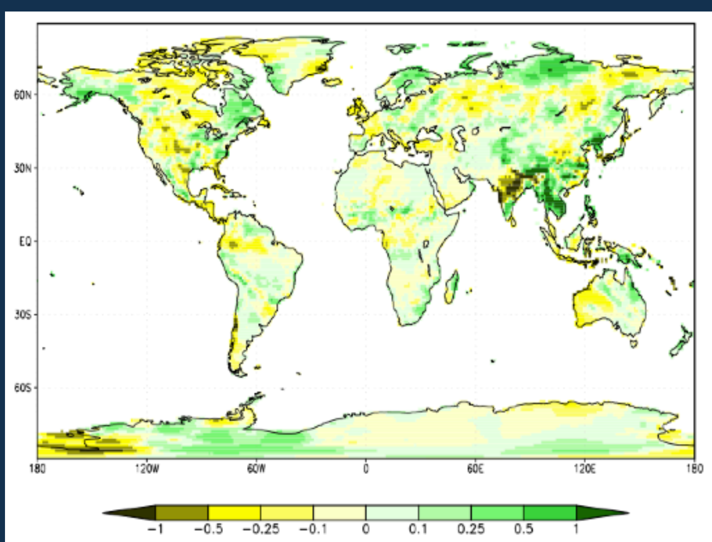


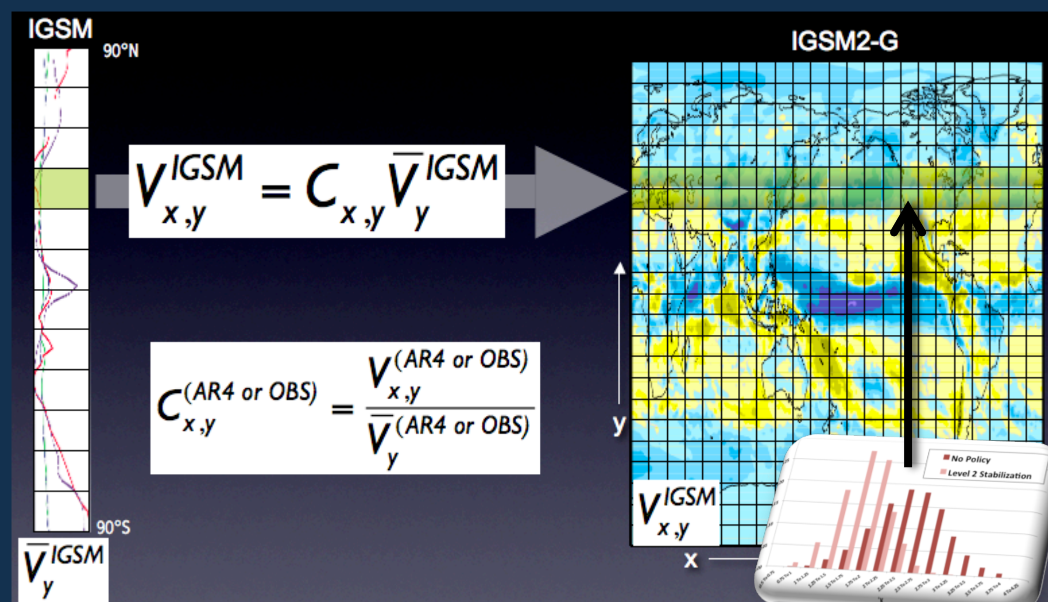
CHARACTERIZING REGIONAL CLIMATE-CHANGE UNCERTAINTY IN THE IGSM: A HYBRID APPROACH

Schlosser et al. (J. Climate, 2012)

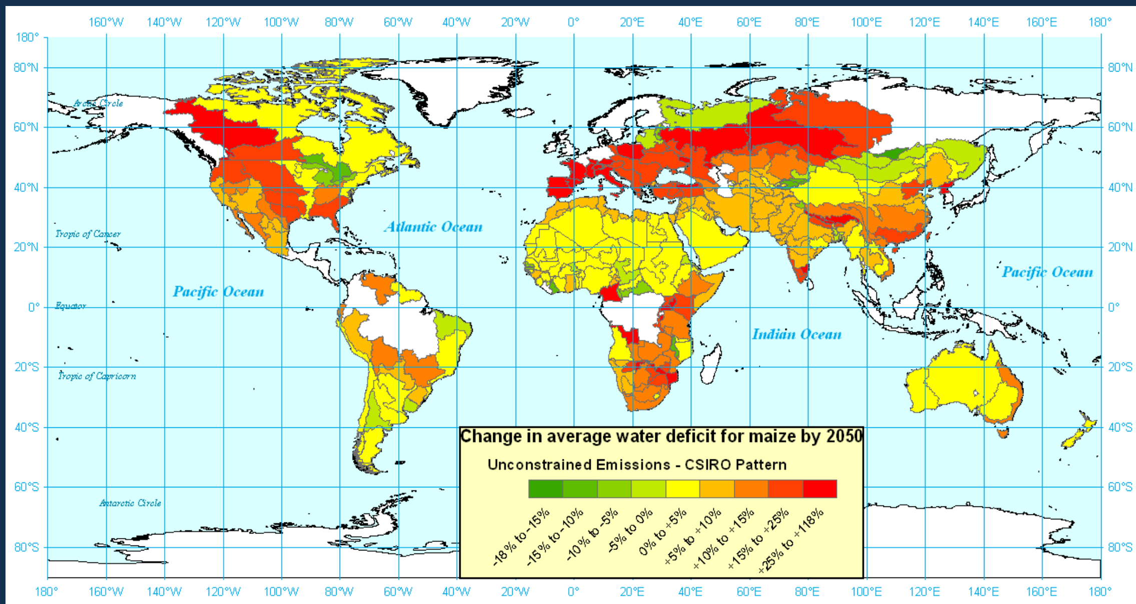
$$V_{x,y}^{IGSM} = \left(C_{x,y} + \frac{dC_{x,y}}{dT_{Global}} * \Delta T_{Global} + 0.5\frac{d^2C_{x,y}}{dT_{Global}^2}\Delta T_{Global}^2\right) * \overline{V}_y^{IGSM}$$

$\frac{dC_{x,y}}{dT_{Global}}$: Climate-change kernel describing the change of transformation coefficient, $C_{x,y}$ with global temperature , based on the CMIP3 climate models.





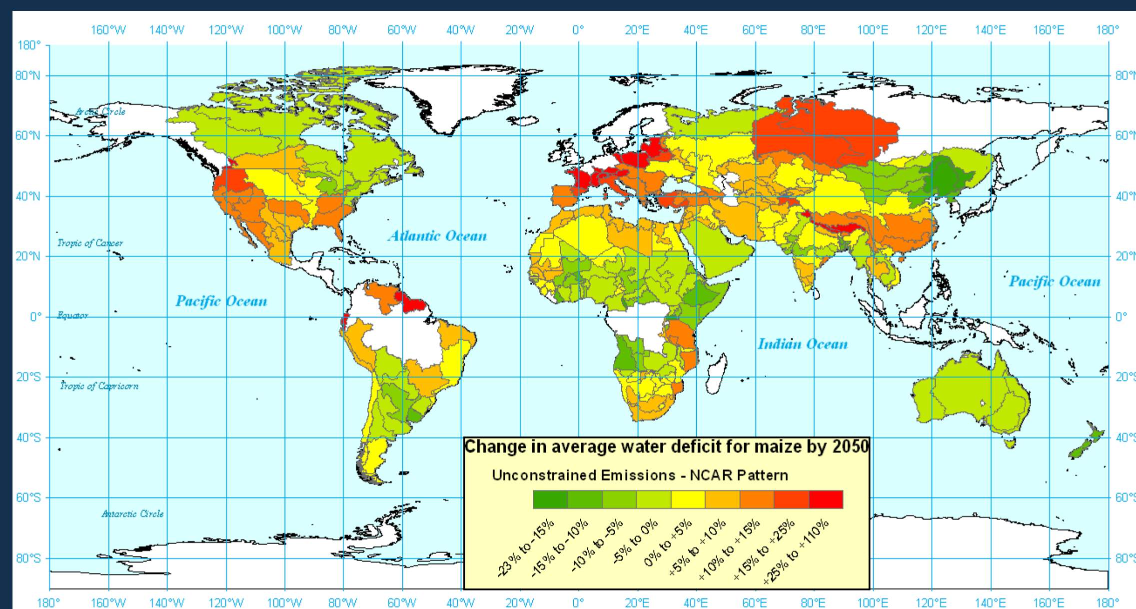
Changes in Irrigation Demand in 2050



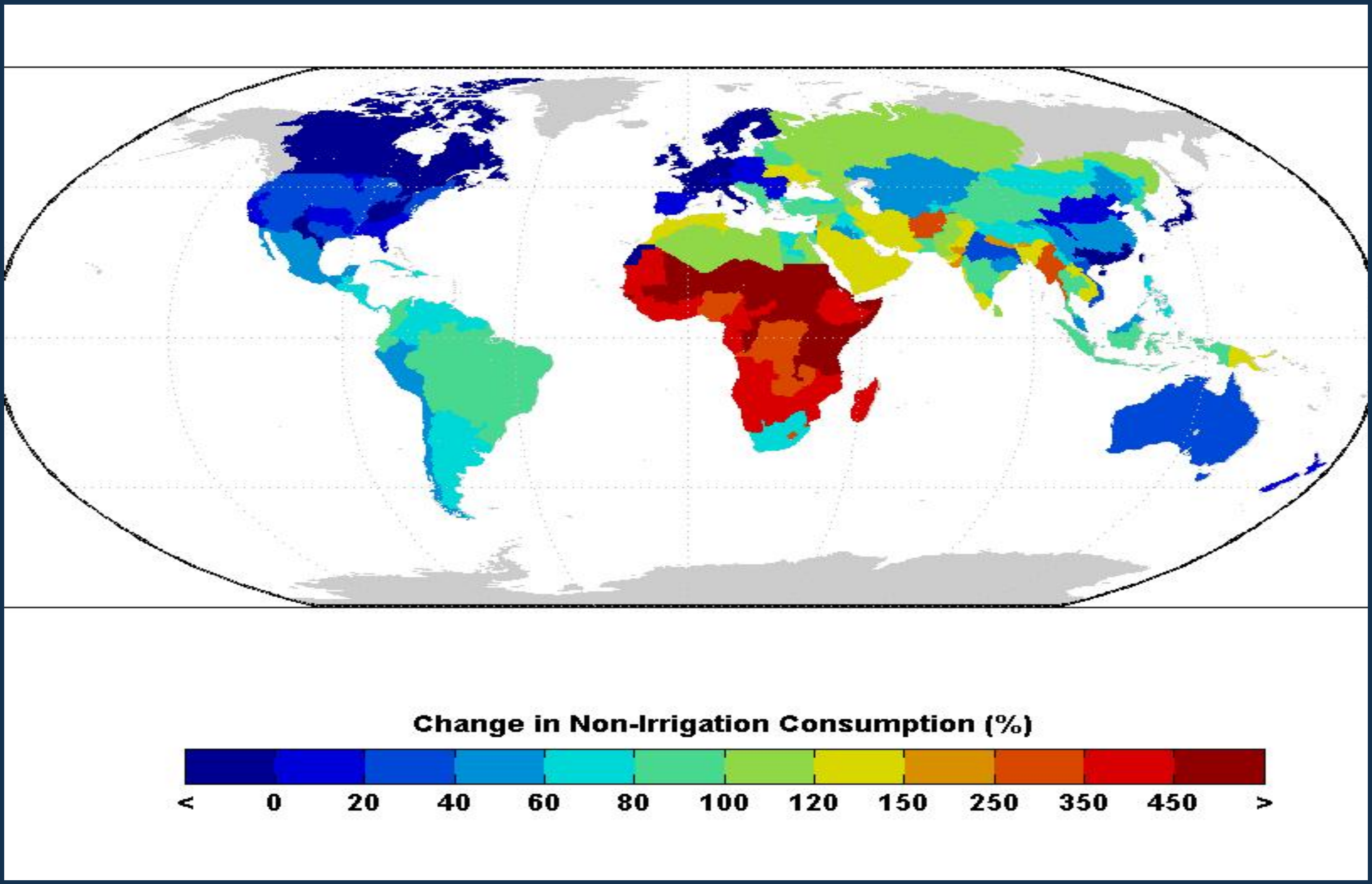
Unconstrained Emissions Scenario

Uncertainty in regional climate changes patterns lead to different consequences for agricultural water demand.

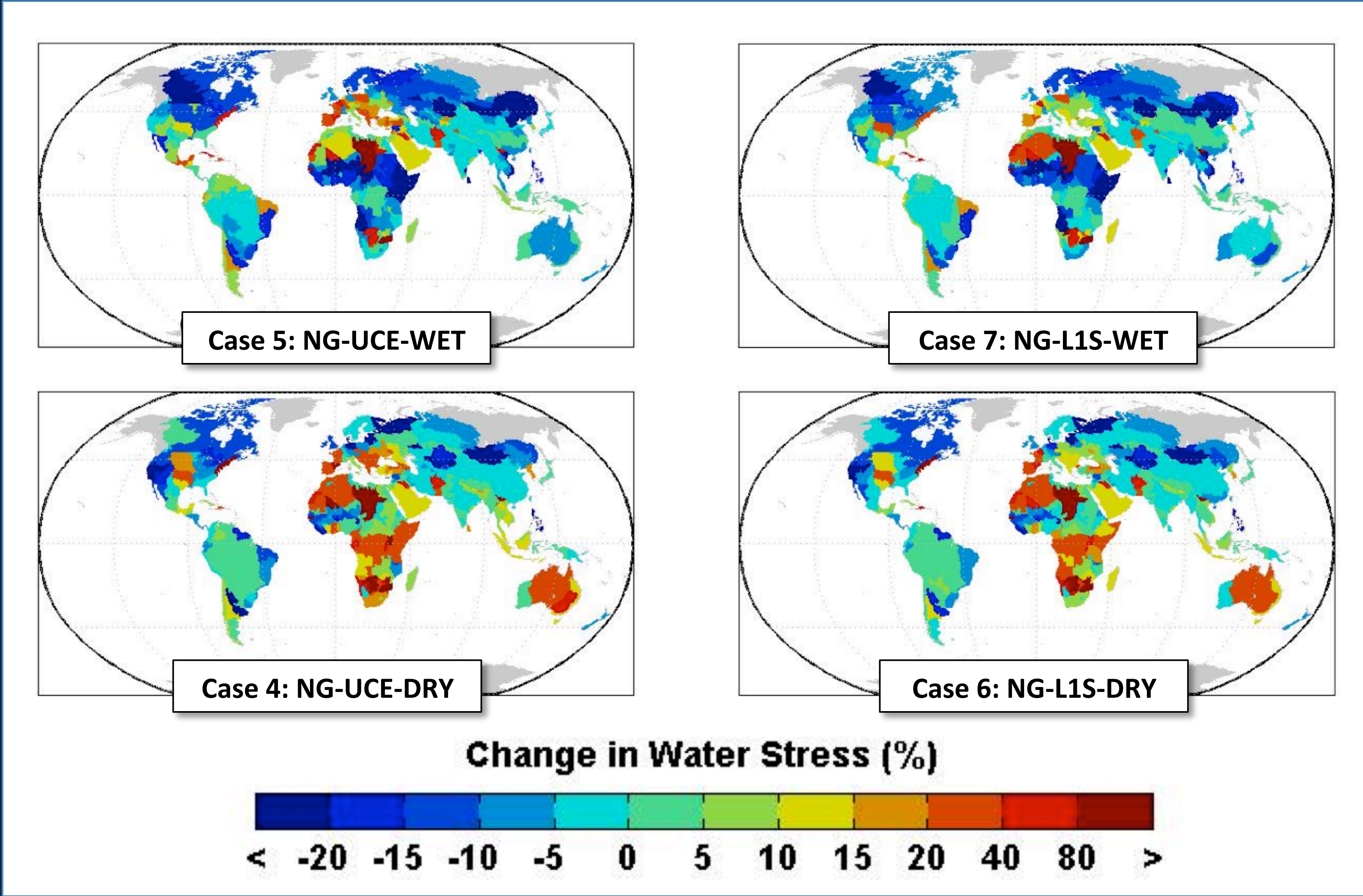
Simulations with CliCrop (Fant et al., 2012) the IGSM framework.



Changes in Non-agricultural Consumption at 2050: Unconstrained Emissions

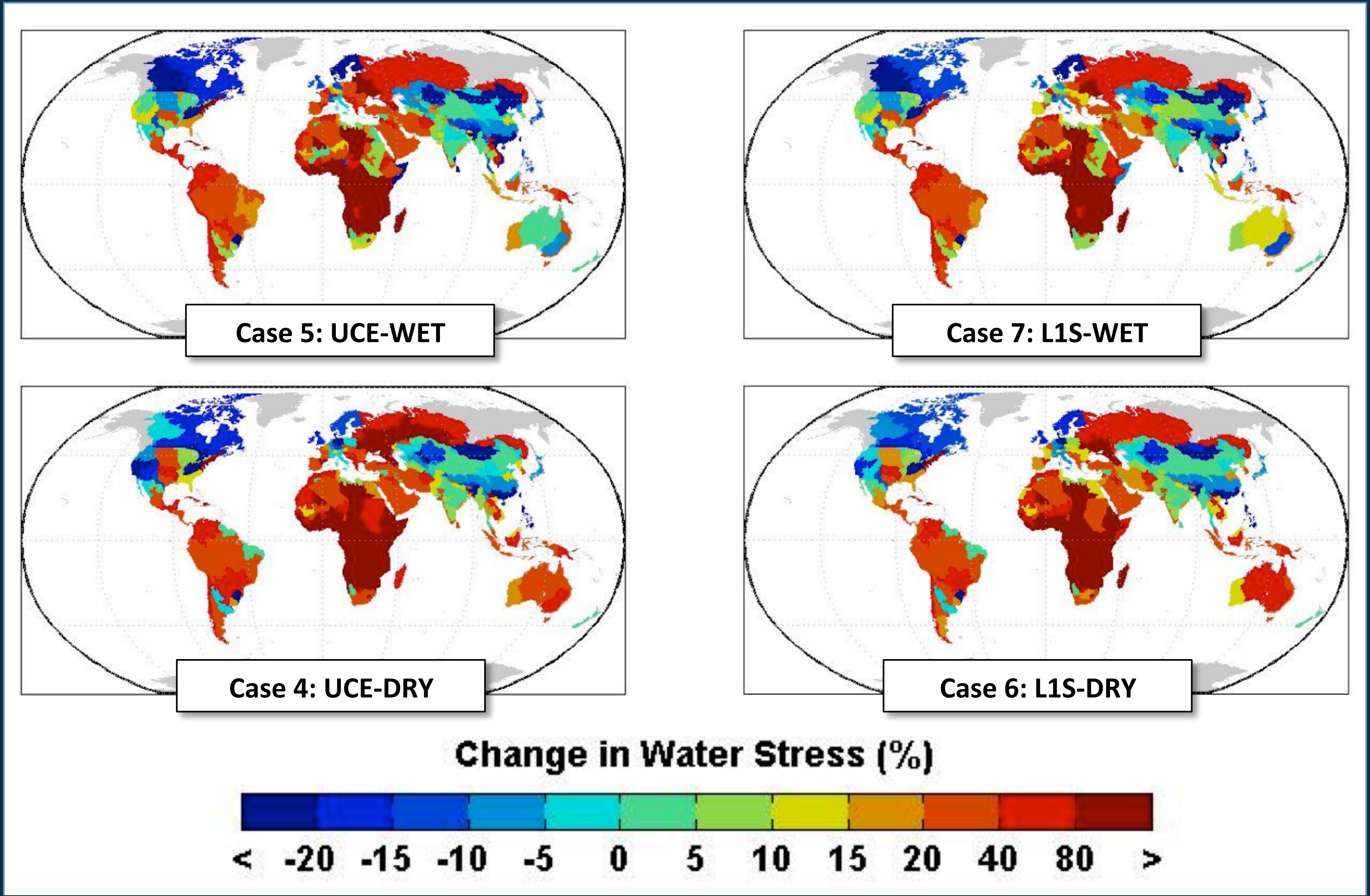


Changes to "Water Stress" at 2050
Unconstrained Emissions Scenario – No growth



Higher sensitivity to climate pattern than policy scenario.

Changes to "Water Stress" at 2050
Unconstrained Emissions Scenario with growth



Salient Effects of Growth in Non-Agriculture Demand

Water Resource System Modeling for the U.S.

Elodie Blanc, Kenneth Strzepek, Adam Schlosser, Henry Jacoby, Arthur Gueneau, Charles Fant, Sebastian Rausch, John Reilly

December 12, 2012

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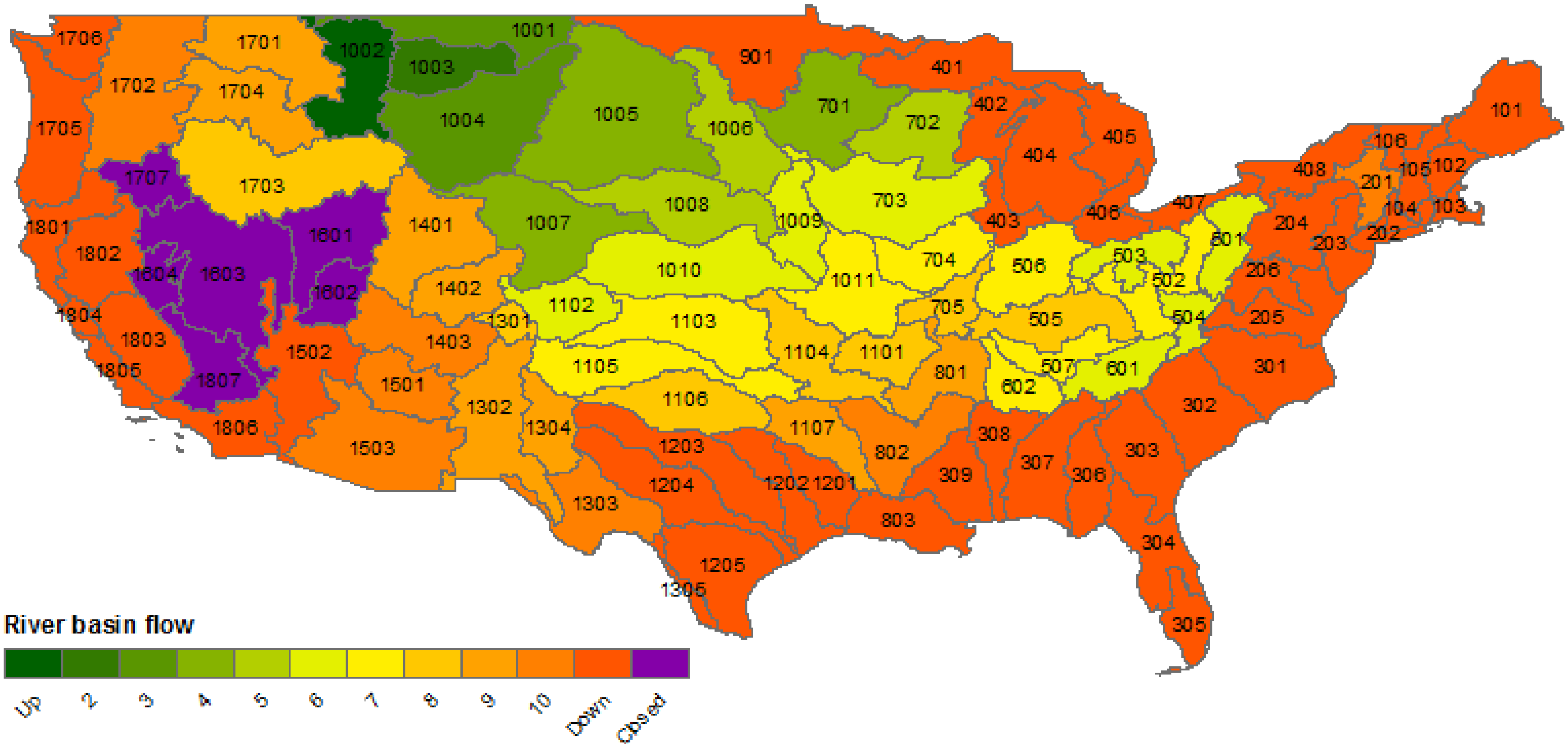
WRS-US

- WRS
  - Global model: 282 regions
  - 14 regions in the U.S.

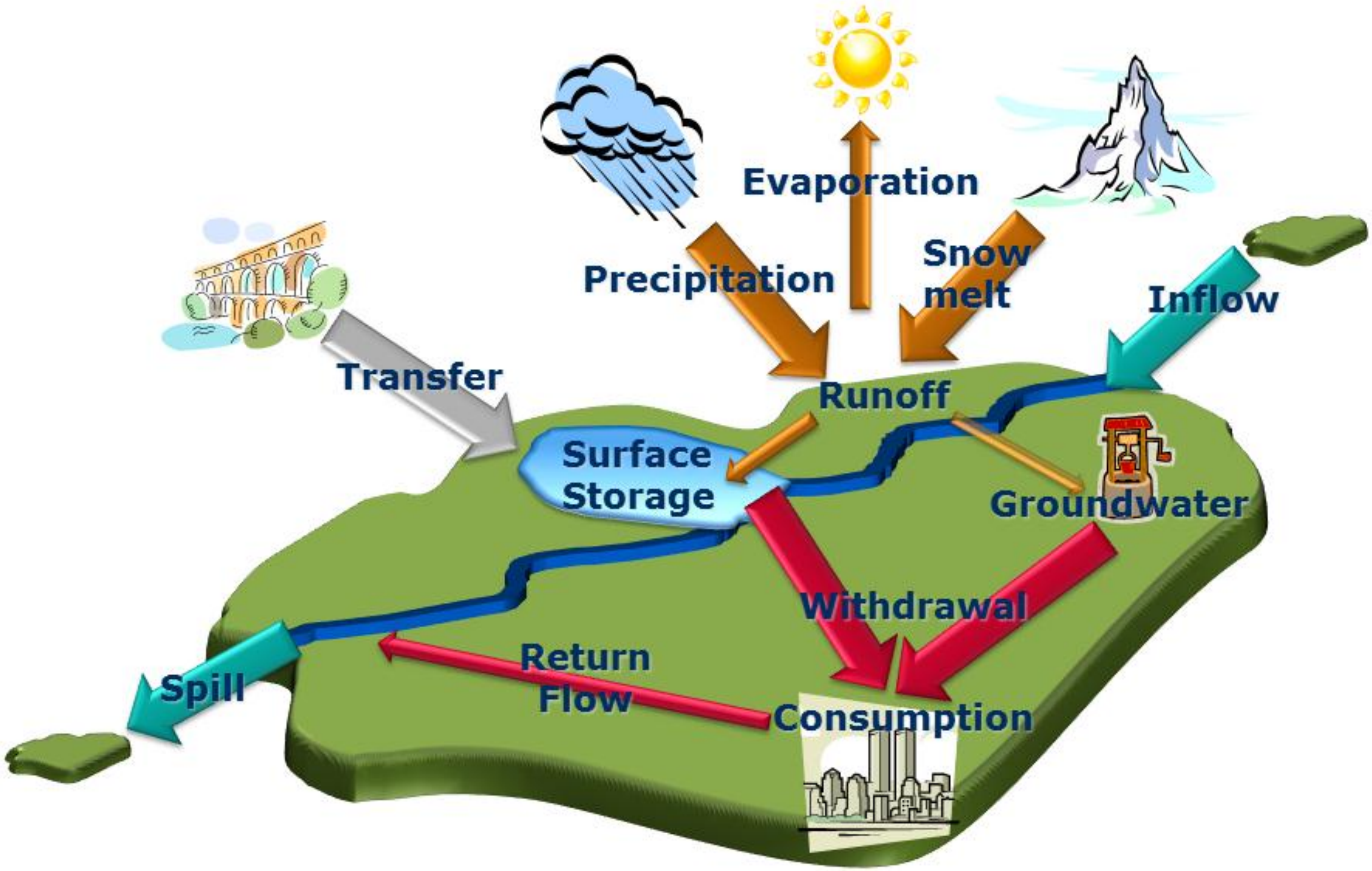
- WRS-US
  - WRS-US focuses solely on the continental US (excludes Hawaii and Alaska)
  - 99 river basins
  - Improved estimation methods for water requirements

River Basin Delineation

Upstream/downstream representation



Water System



Goal of the model

Allocate water to each sector (i.e. water depletion) across the year in order to minimize water shortages (i.e. unmet water requirements) at the river basin level. Subject to water resource and environmental constraints.

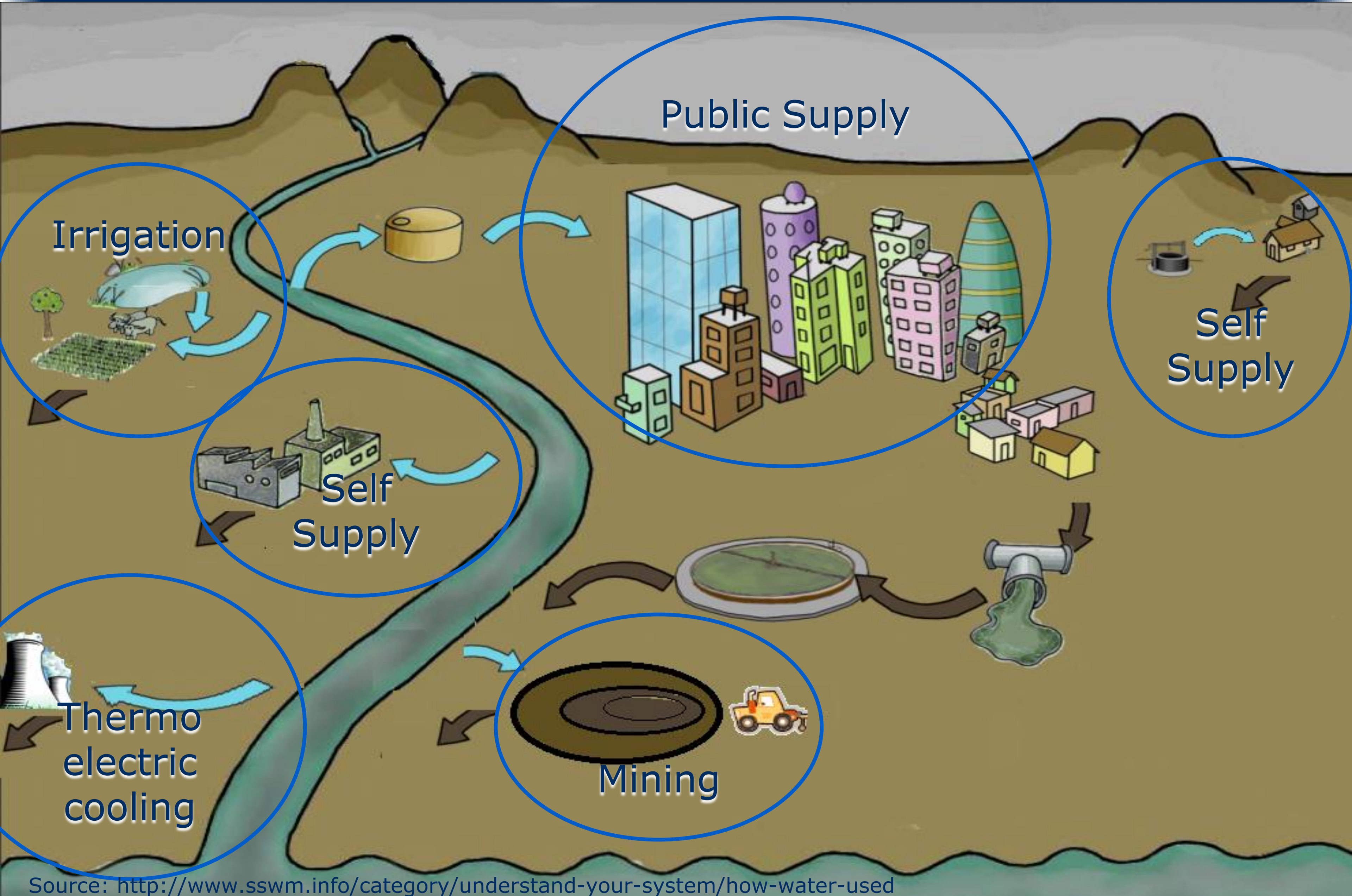
$$\max \sum_{month} \sum_{sectors} \frac{water\_supply_{month,sector}}{water\_requirements_{month,sector}}$$

$$s.t. \sum_{sector} water\_supply_{month,sector} \leq (water\_resources_{month} - environmental\_requirements_{month})$$

Water Resources

- Runoff/River flow
  - Estimated using the biophysical Community Land Model (CLM version 3.5; NCAR, 2012)
  - Accounts for precipitation, evaporation, water interception by plants, infiltration, snow melt and snow pack formation
  - Inflow from upstream basins calculated endogenously
- Inter-basin transfers
  - Large transfers via canals & aqueducts in the South West
  - Assumed to be constant at the 2005 level in each basin
- Ground water
  - No ground water recharge modeled (at this stage)
  - Assumed to be constant at the 2005 level in each basin

Water Requirements



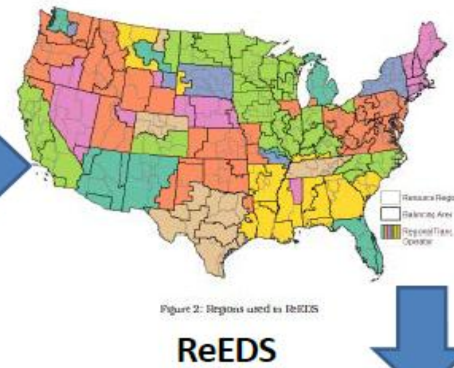
Source: http://www.sswm.info/category/understand-your-system/how-water-used

Water Requirements

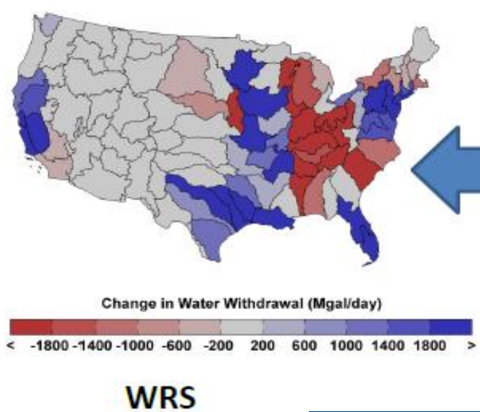
- Thermoelectric cooling

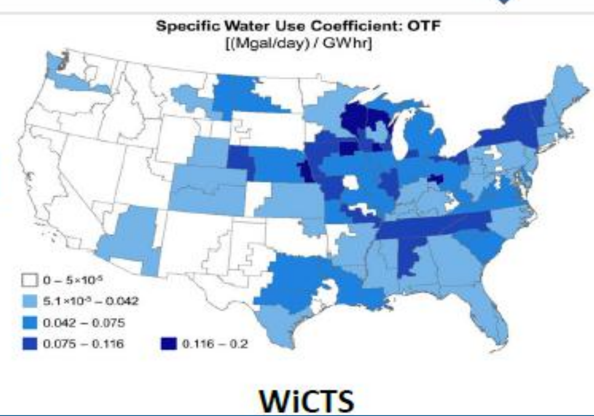
The US Regional Economic Policy (USREP) model estimates energy demand by fuel type

Energy Supply/ Demand



The Regional Energy Deployment System (ReEDS) model produces electricity production outputs by fuel type and cooling type (once through and recycle)





The WIthdrawal and Consumption for Thermoelectric Systems (WICTS) model estimates water withdrawal and consumption

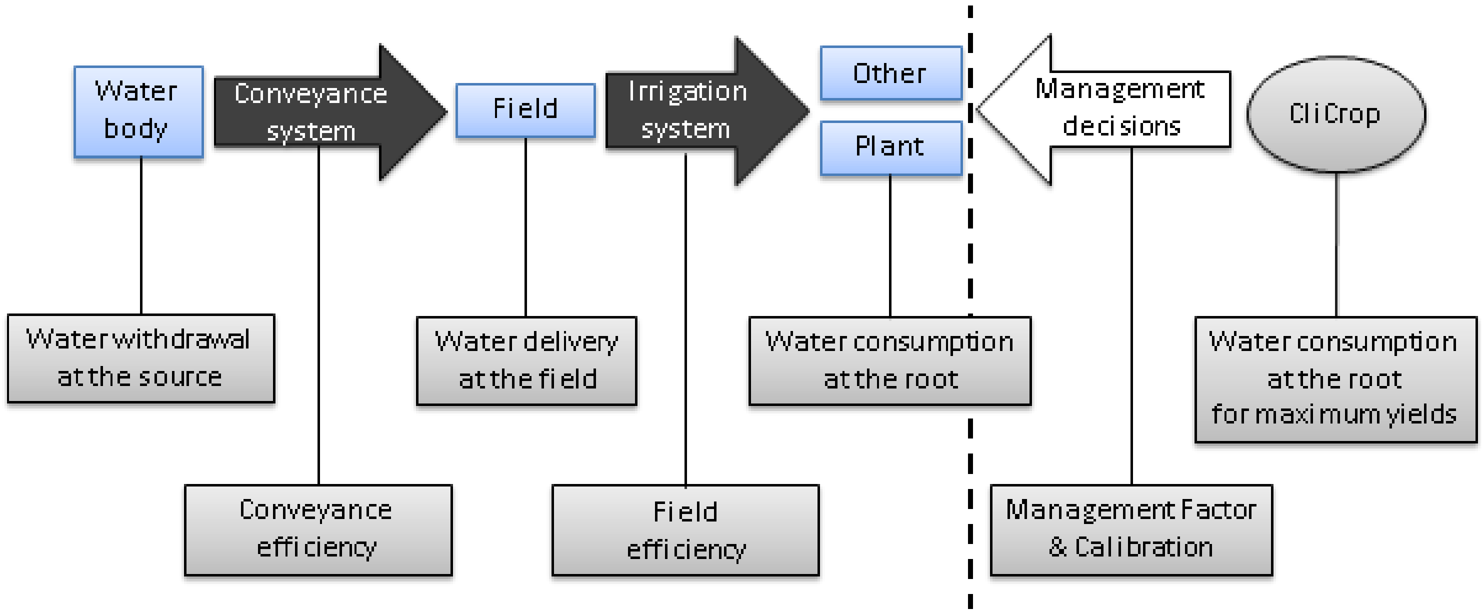
Strzepek, K, Baker, J., Farmer, W., Schlosser, C. A., 2012. Modeling Water Withdrawal and Consumption for Electricity Generation in the United States, MIT Joint Program Report No 222
Rausch, S., and Mowers, M., 2012. Distributional and Efficiency Impacts of Clean and Renewable Energy Standards for Electricity, MIT Joint Program Report No 225

Water Requirements

- Public Supply (PS): Residential, some industrial and commercial
- Self Supply (SS): industrial, commercial, agriculture (except irrigation)
- Mining (MI): all types of mining
  - Calculated using econometric estimates of water withdrawals
  - Sector withdrawals are a function of population and GDP
  - Water withdrawal & Population data from USGS (2011) at the county level data, every 5 years from 1985 to 2005
  - State-level GDP data from the Bureau of Economic Affairs (BEA, 2011)
  - Annual withdrawal estimates are assumed to be spread evenly across the year
  - Future water requirements estimated using GDP and population growth estimated using USREP (Rausch et al., 2009)

Water Requirements

- Irrigation
  - Irrigation system schema



- CliCrop (Fant et al., 2011) estimates crop water consumption at the root of plants (in mm/crop/year) for maximum yields
- Calculate a management factor (M factor) varying by crop to obtain water consumption for actual yields
- Apply conveyance and system efficiencies to determine how much of the water withdrawn is actually consumed

Water Requirements

- Environmental requirements
  - Spills to downstream basins are constrained by minimum environmental flows
  - Releases from surface storage are limited to a proportion of the storage capacity in order to respect an environmental minimum storage threshold.

Predictions

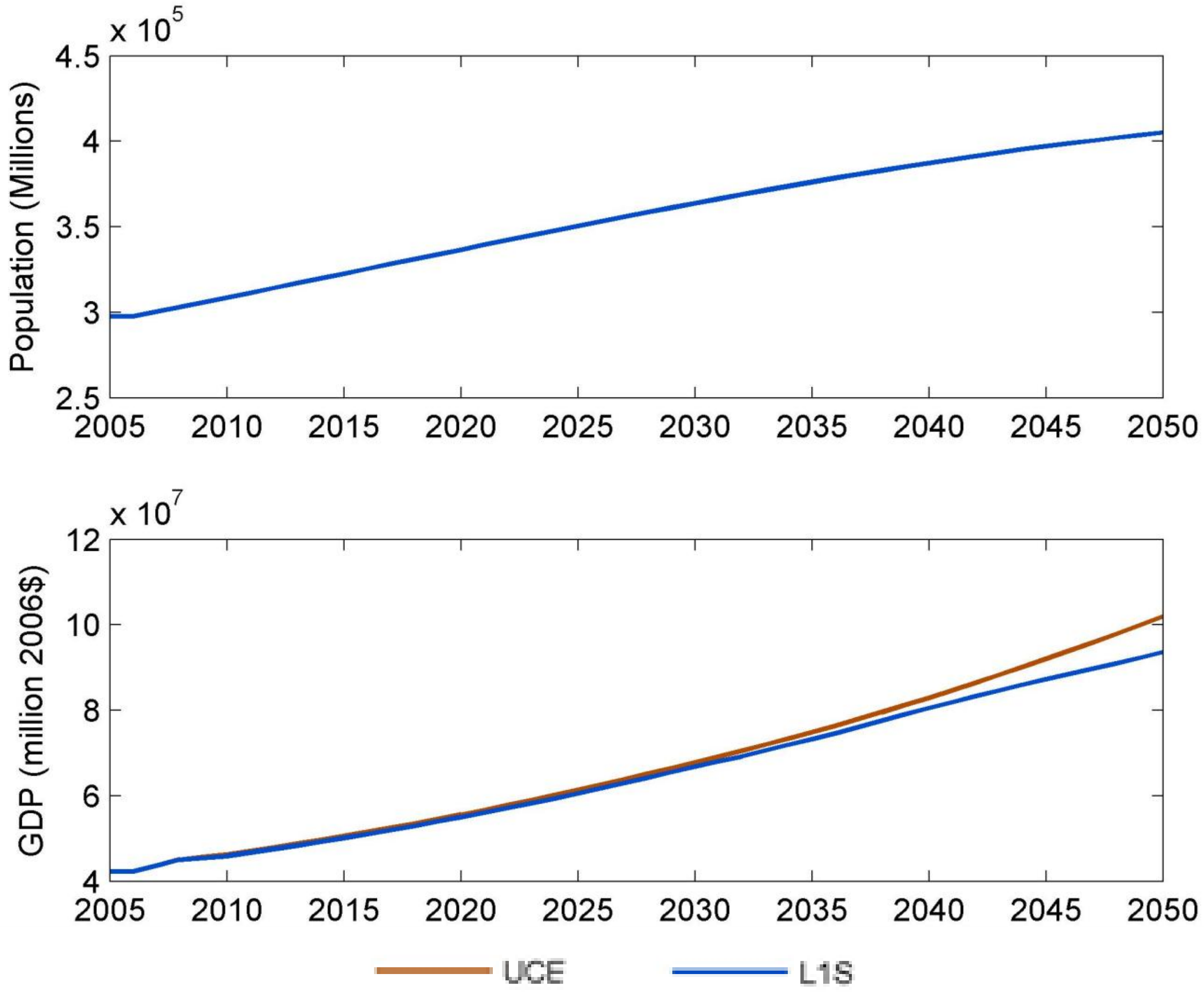
- Water resources and requirements are modeled from 2005 to 2050

- 2 GHG emissions scenarios:
  - **UCE**: Unconstrained emissions scenario
  - **L1S**: Level 1 stabilization

- Two climate patterns:
  - GLOBAL WET
  - GLOBAL DRY

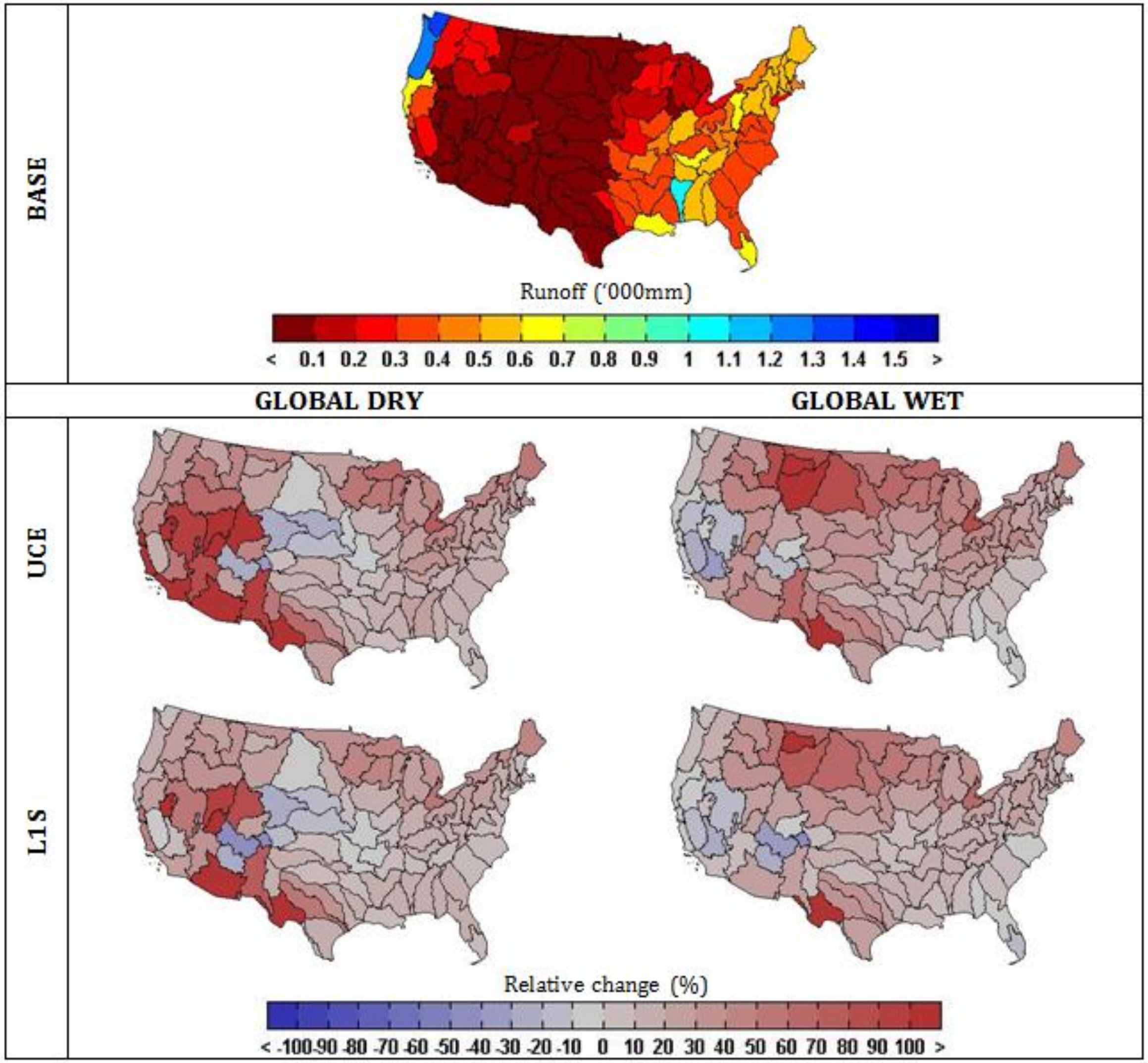
Predictions Inputs

Total population and total GDP in the US



Prediction Inputs

Average annual runoff (in '000mm) for the base period (2005-2009) and relative change (in %) for the prediction period (2041-2050)



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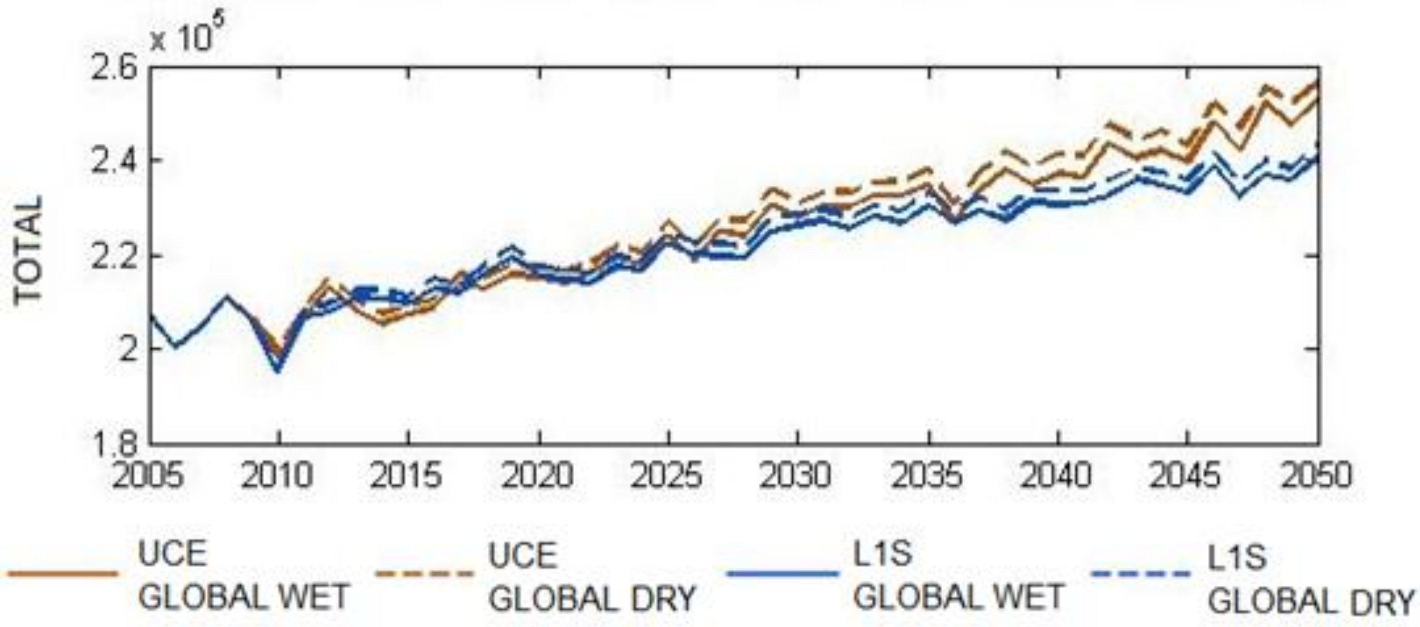
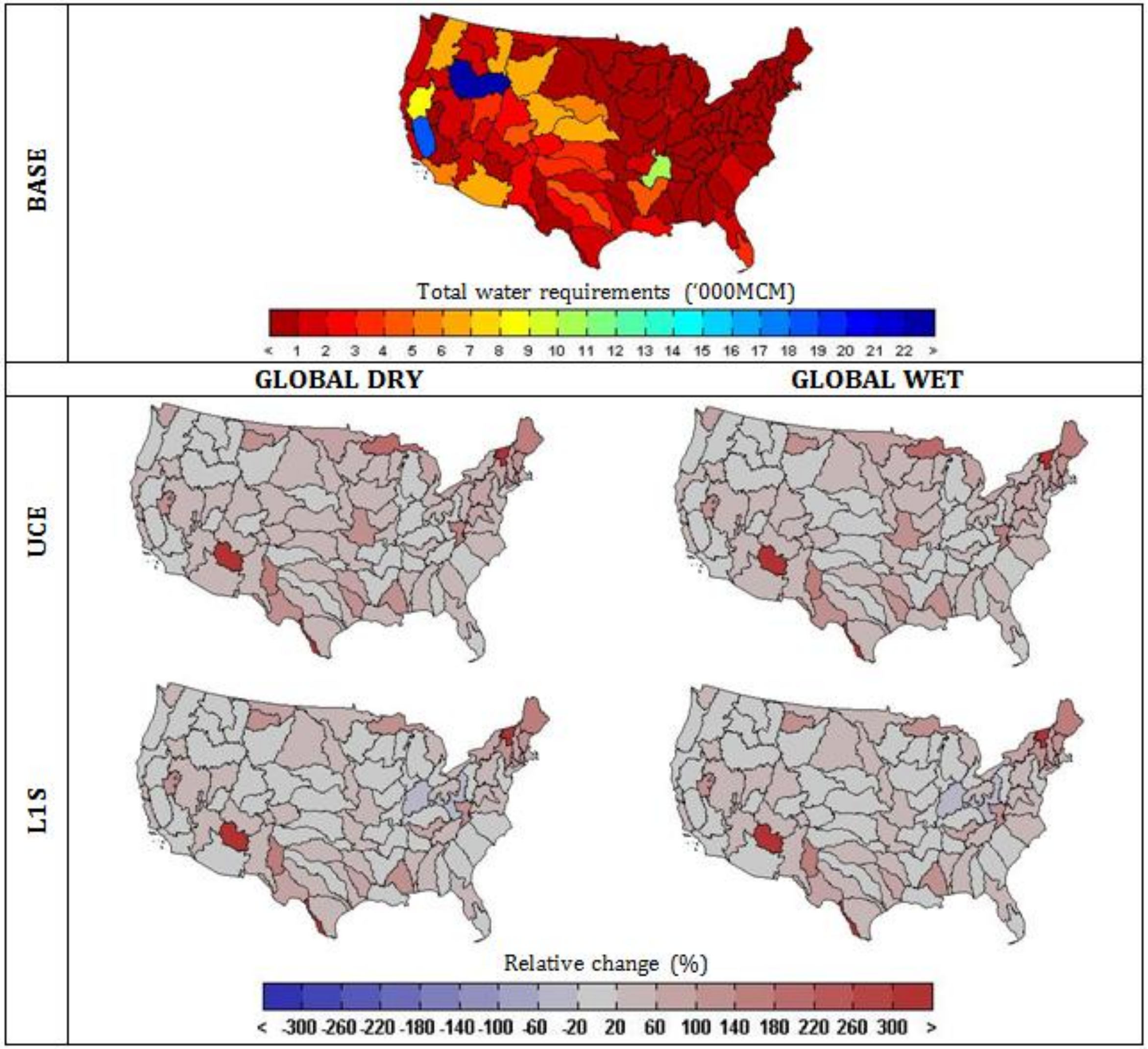
Predictions: Total Water Requirements

Total water requirements (in MCM) from 2005 to 2050



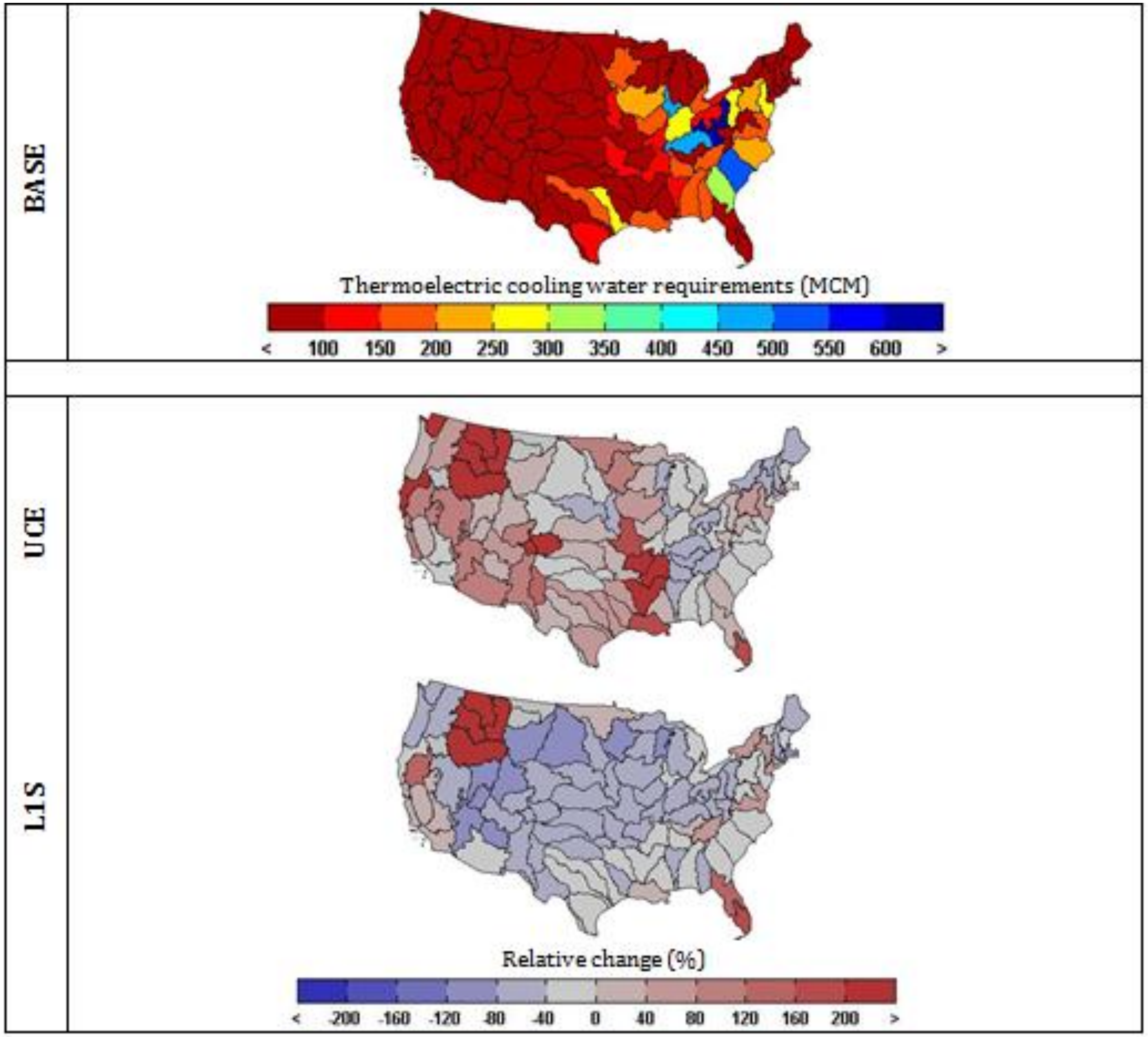
Predictions: Total Water Requirements

Total water requirement (in '000MCM) for the base period (2005-2009) and relative change (in %) for the prediction period (2041-2050)



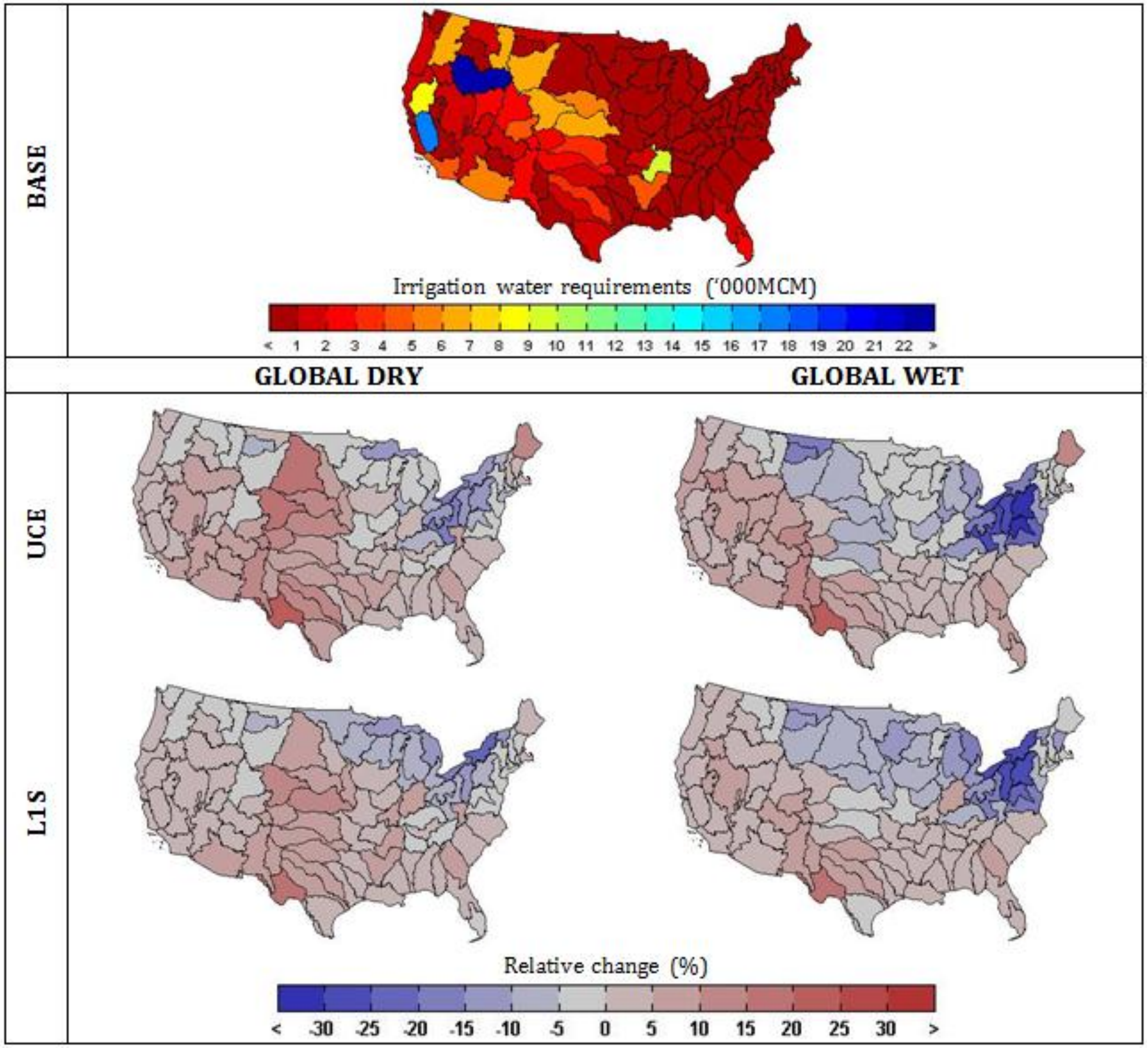
Predictions: Thermoelectric Cooling Water Requirements

Thermoelectric cooling water requirement (in '000MCM) for the base period (2005-2009) and relative change (in %) for the prediction period (2041-2050)



Predictions: Irrigation Water Requirements

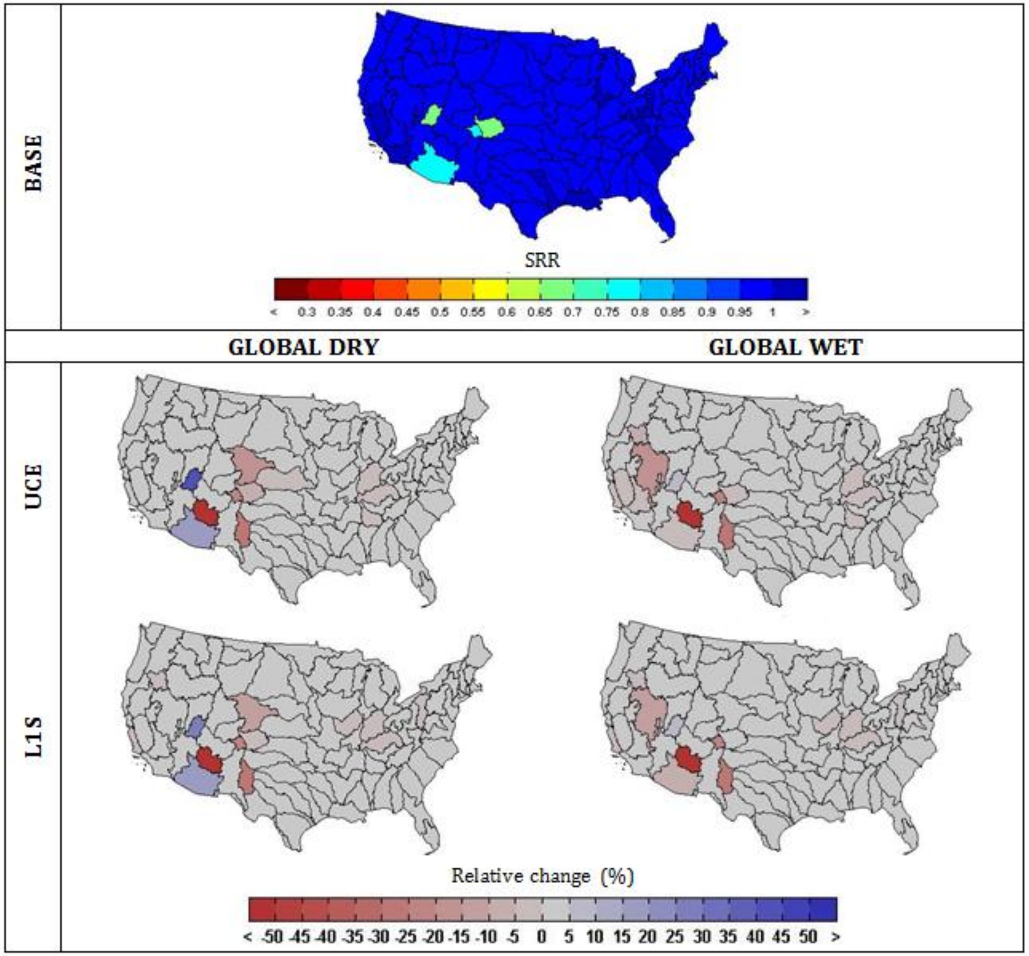
Irrigation water requirement (in ‘000MCM) for the base period (2005-2009) and relative change (in %) for the prediction period (2041-2050)



Predictions: Water Stress

Supply Requirement Ratio = supply/requirement

Annual average SRR for the base period (2005-2009) and relative change (in %) for the prediction period (2041-2050)



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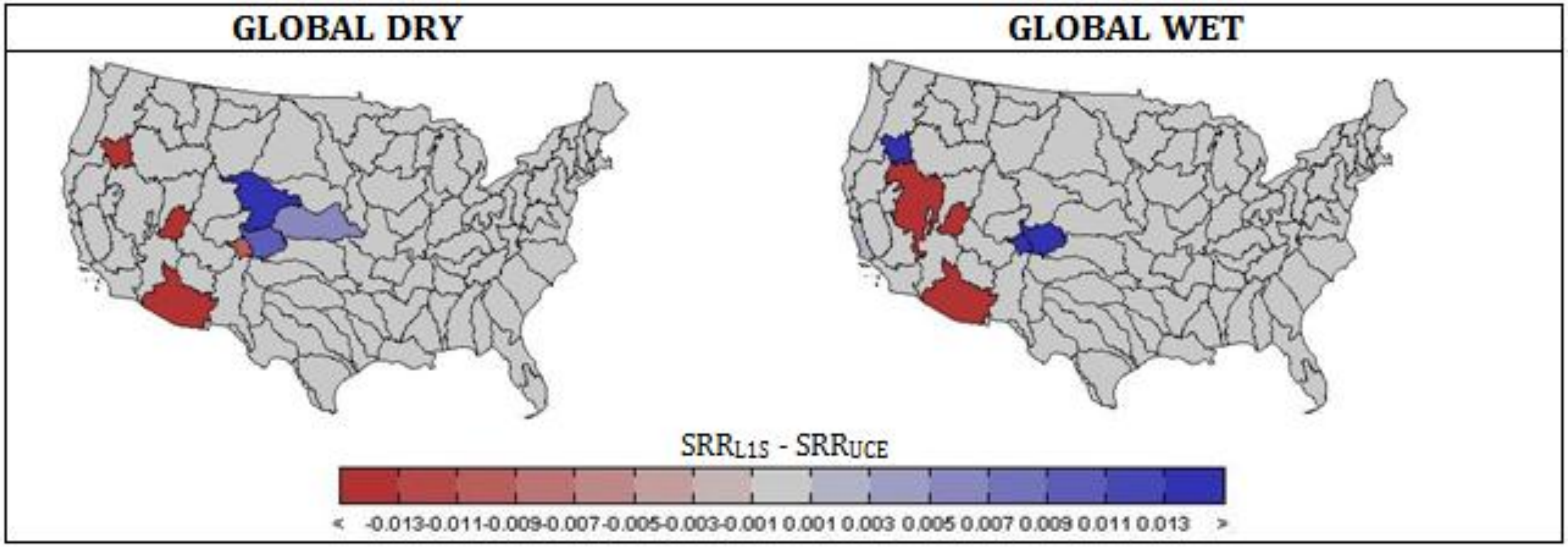
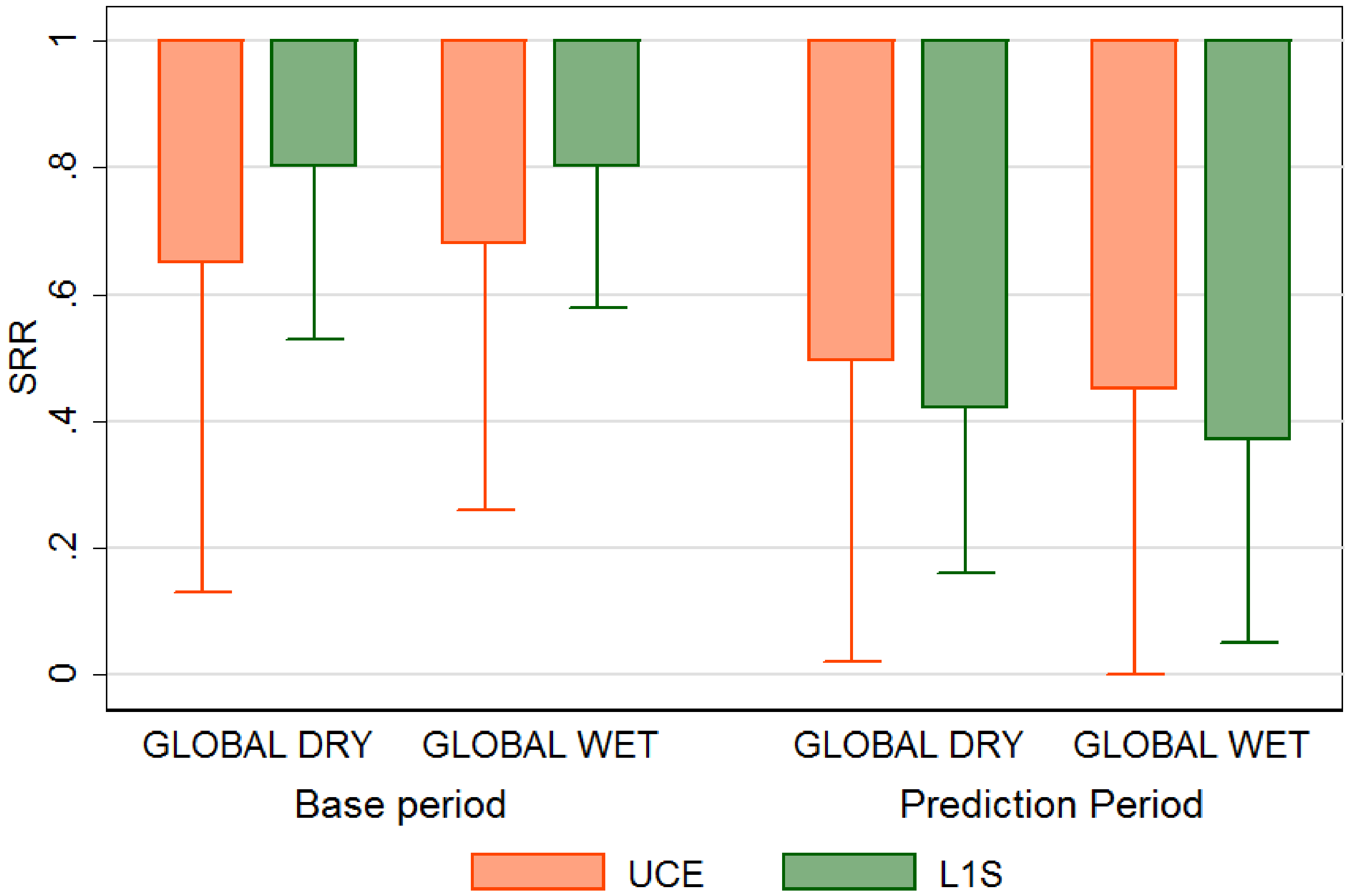
Predictions: Water Stress

Difference between the average SRR under the L1S and UCE scenarios in the prediction period (2041-2050)



Predictions: Water Stress

Box plot of monthly SRRs over stressed ASRs for the base period (2005-2009) and the prediction period (2041-2050)



Notes: the boxes represent, for each climate pattern, scenario and projection period, the range of SRRs over selected ASRs (1603, 1602, 1501, 1503, 1301, 1102, 1007) between the 25th and 75th percentile. The whiskers represent adjacent values.

Conclusions

- Western part of the US is the most concerned by water issues
- Average water stress is not expected to be generally alleviated by a constrained GHG emission policy (L1S mitigation) by 2050
- However, monthly water stress variability is projected to be slightly smaller under the L1S scenario

Evaluating Climate Change Impacts and Adaptation for Investments in Southern African Water Resources Infrastructure: *An Uncertainty Approach*

Kenneth Strzepek, Chas Fant,
Yohannes Gebretsadik, Adam Schlosser

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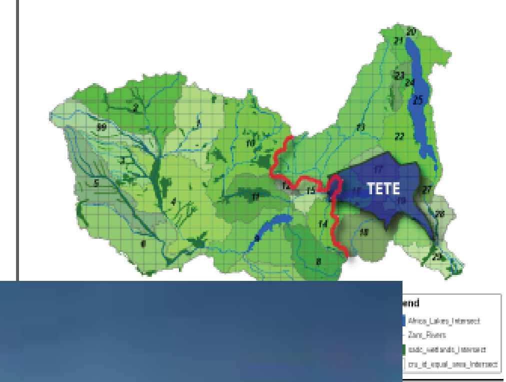
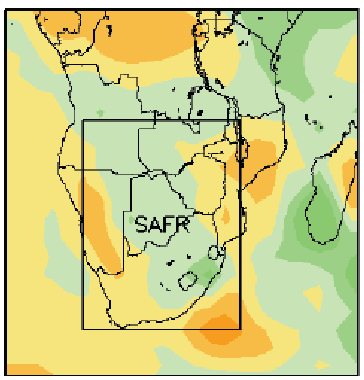
Difficulty with Anticipating Climate Change

There is uncertainty about some aspects of regional climate change

- Direction
- Magnitude
- Timing
- Path



AR4 Model Mean



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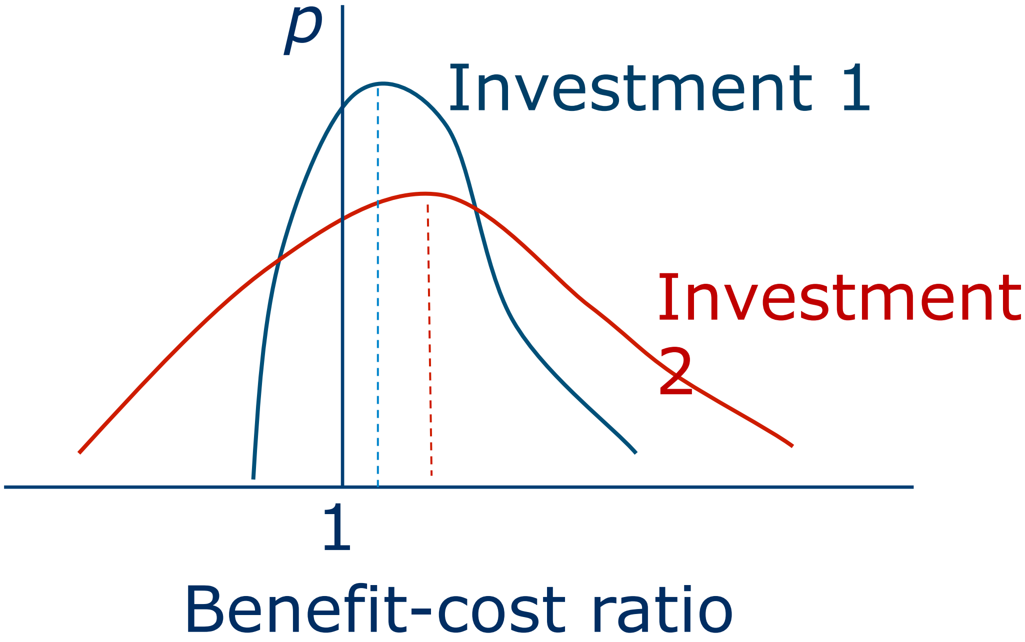
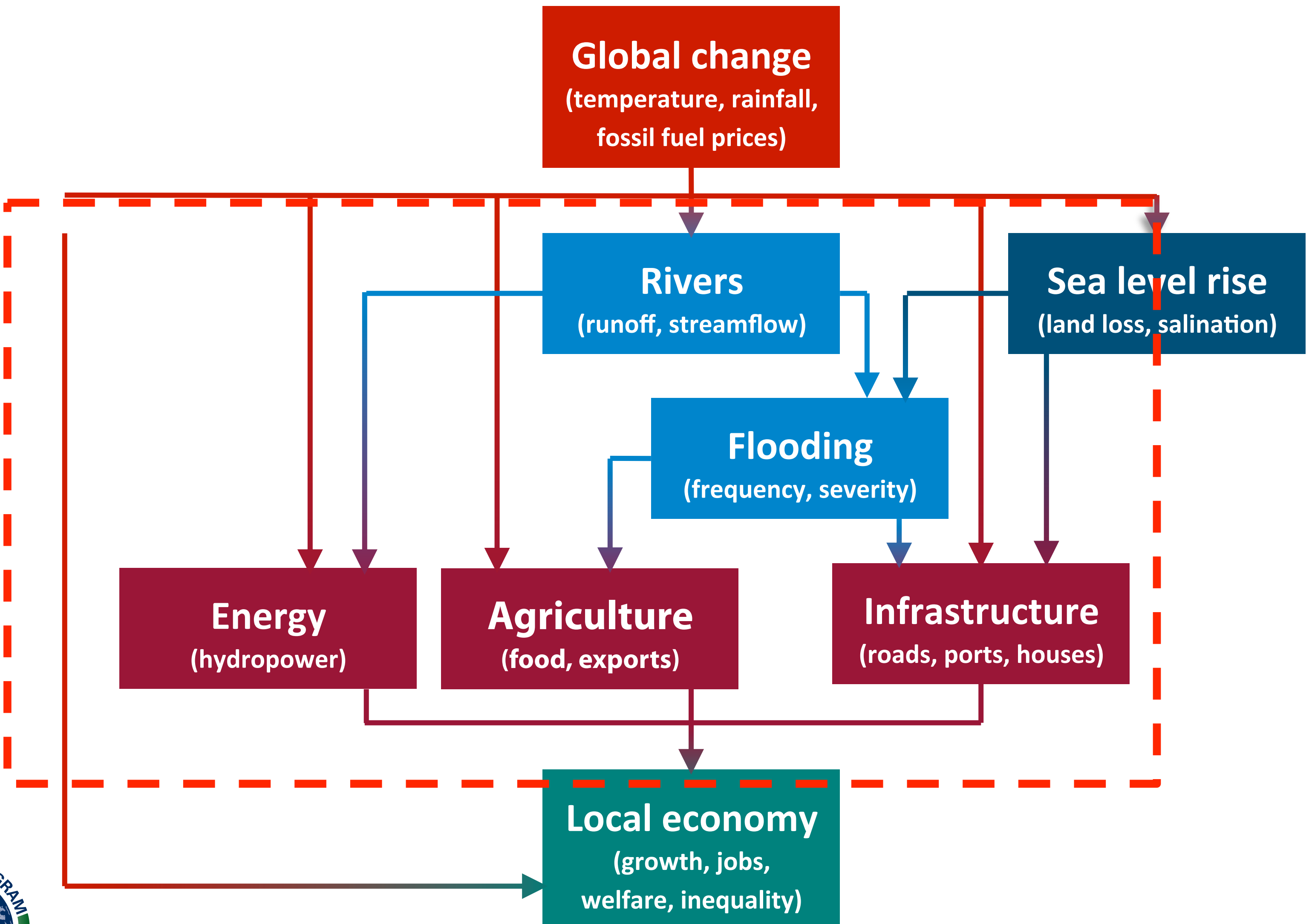
Infrastructure Investment under RISK

- Probabilistic approach means that we can compare investments based on both expected net benefits and risks



Integrated Analytical Framework



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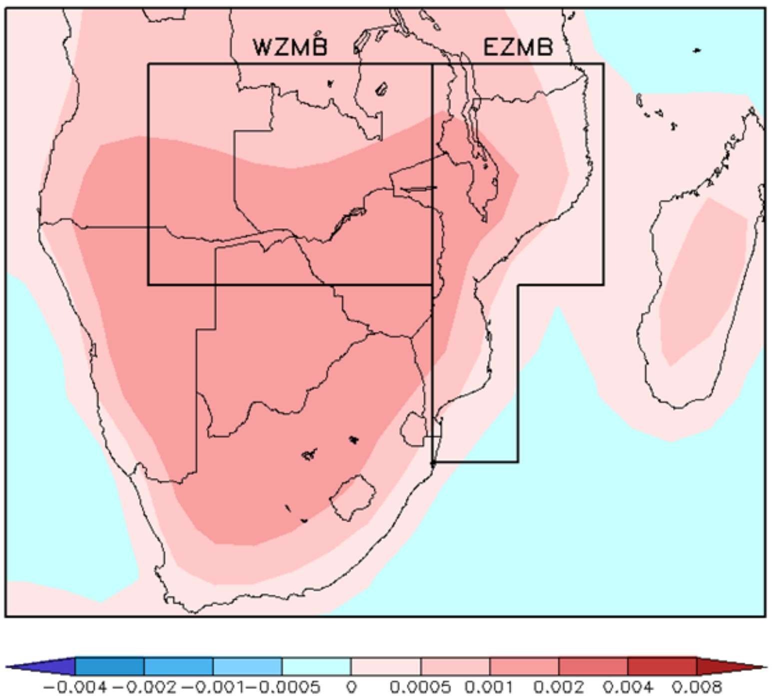
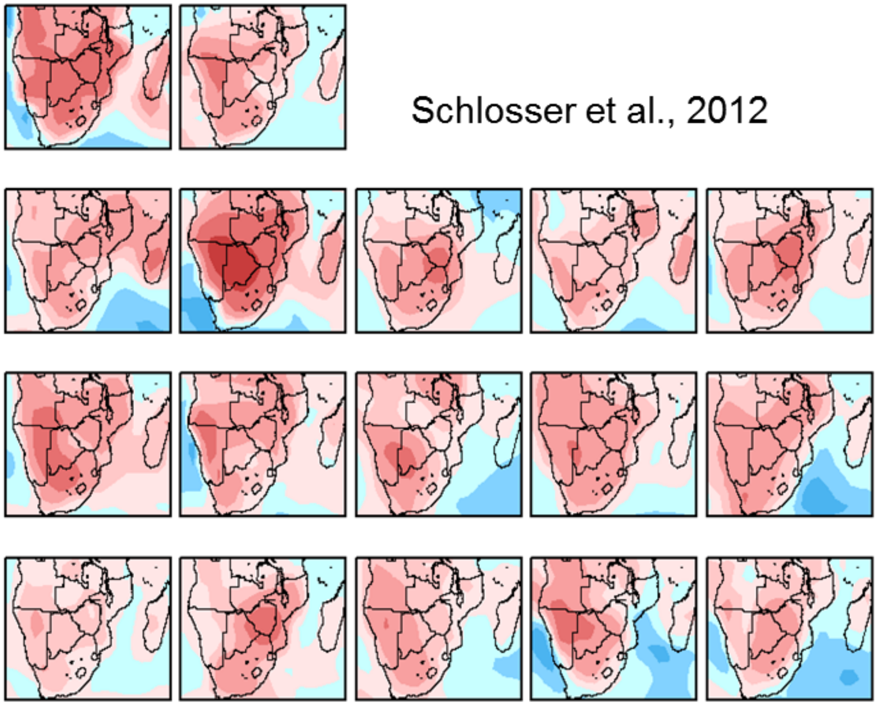
DJF Southern Africa Temperature

CMIP3/IPCC Model Mean



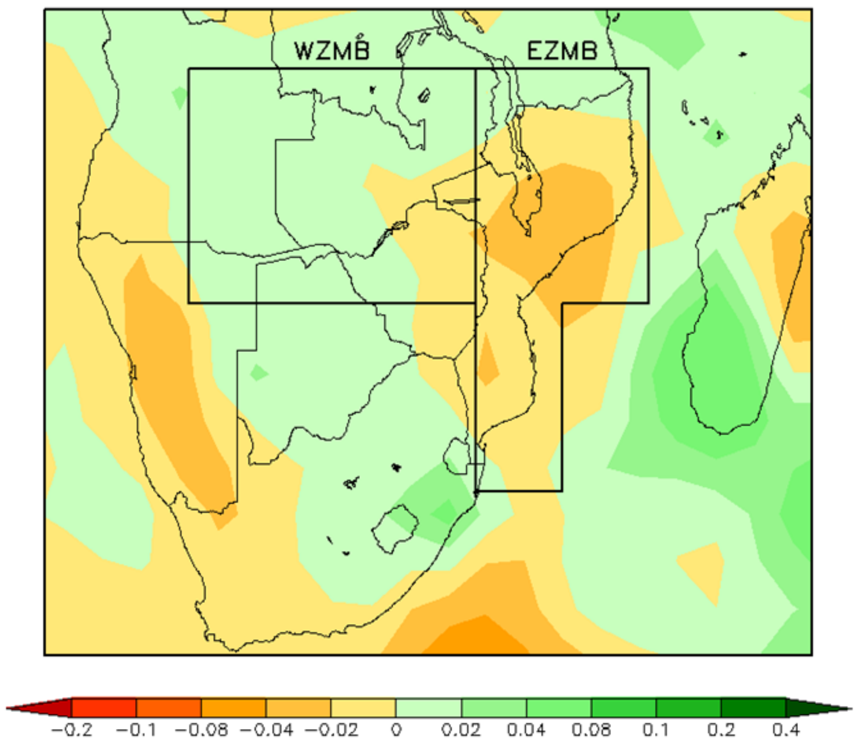
CMIP3/IPCC Models



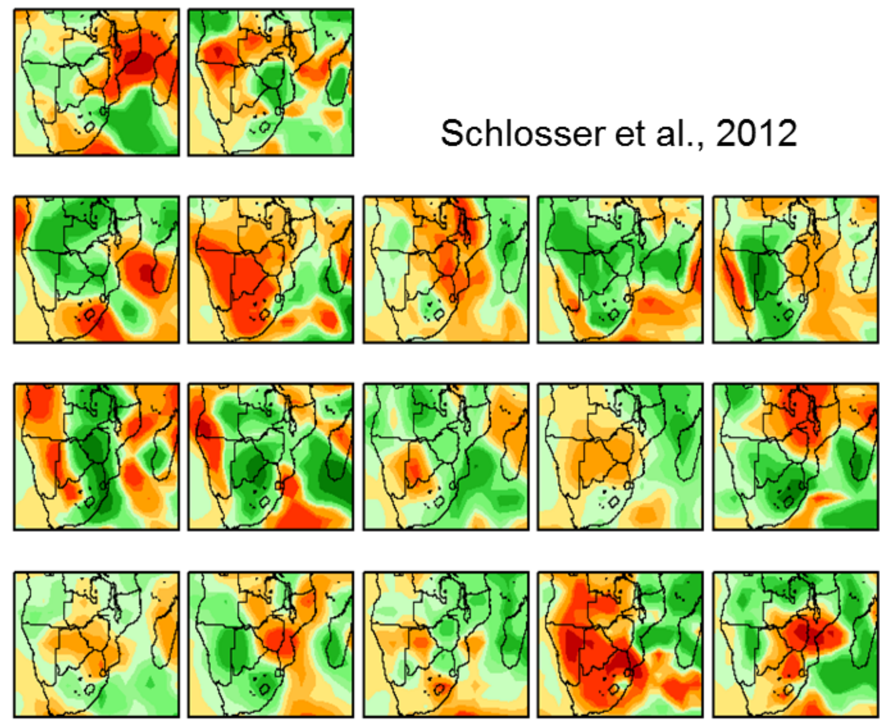
Schlosser et al., 2012

DJF Southern Africa Precipitation

CMIP3/IPCC Model Mean



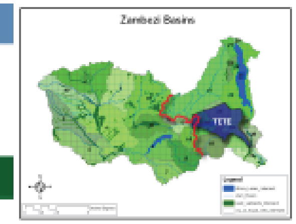
CMIP3/IPCC Models

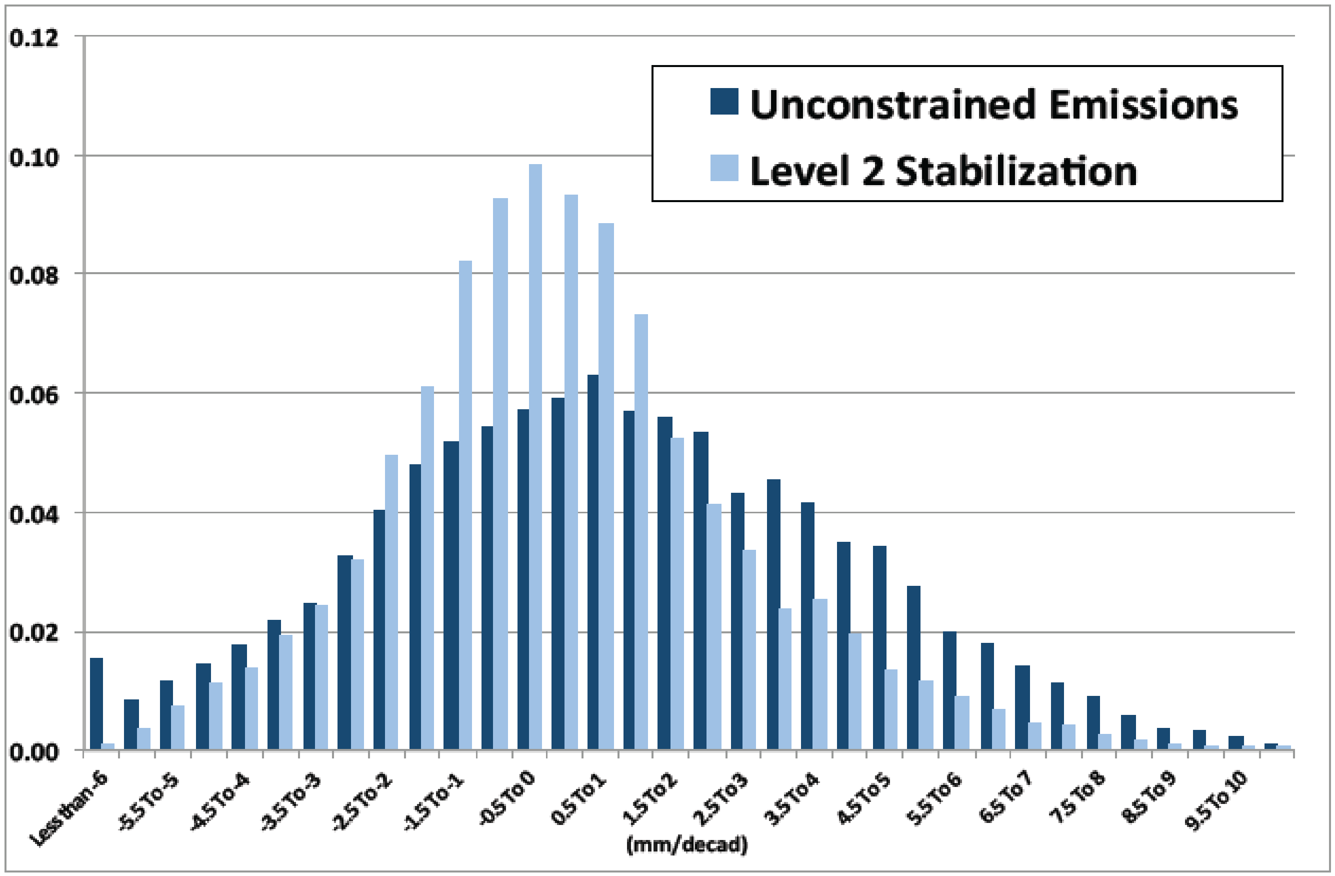


Schlosser et al., 2012

DJF Eastern Zambezi Precipitation

Eastern Zambezi Frequency Distributions
2050 Decadal Average Precipitation Change: DJF





Schlosser et al., 2011

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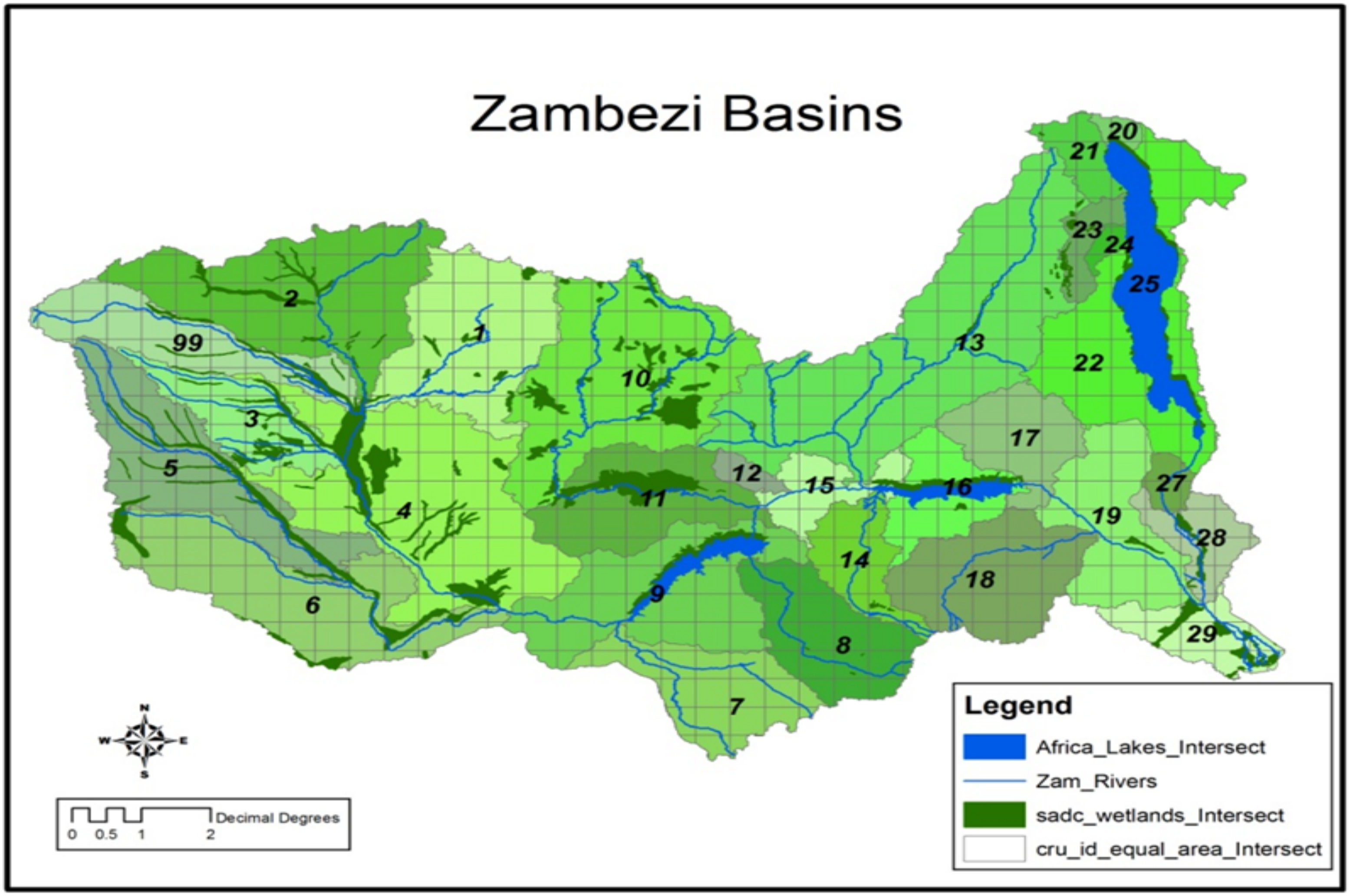
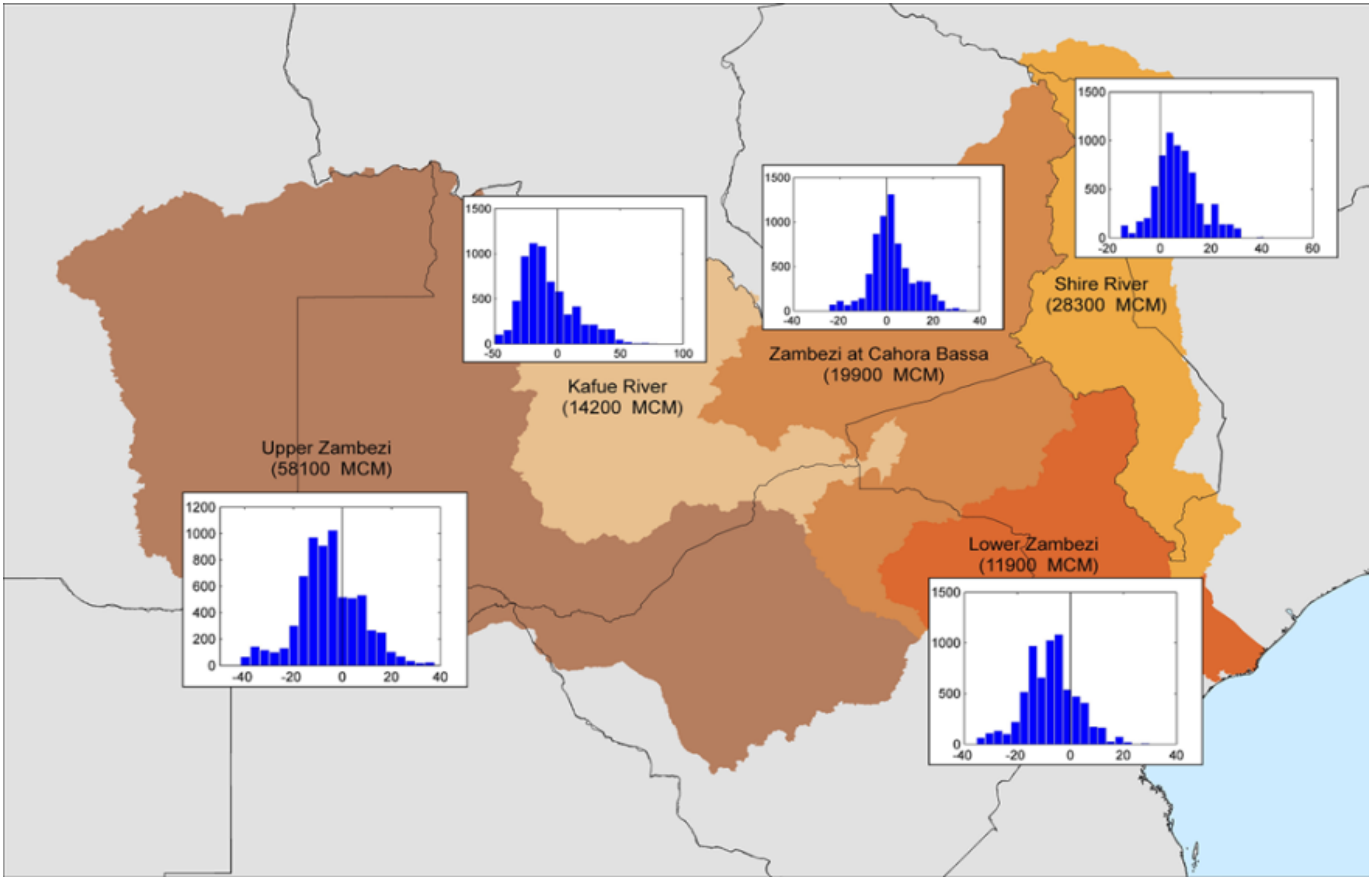
Zambezi River Sub Catchments



Runoff Under Unconstrained Emissions



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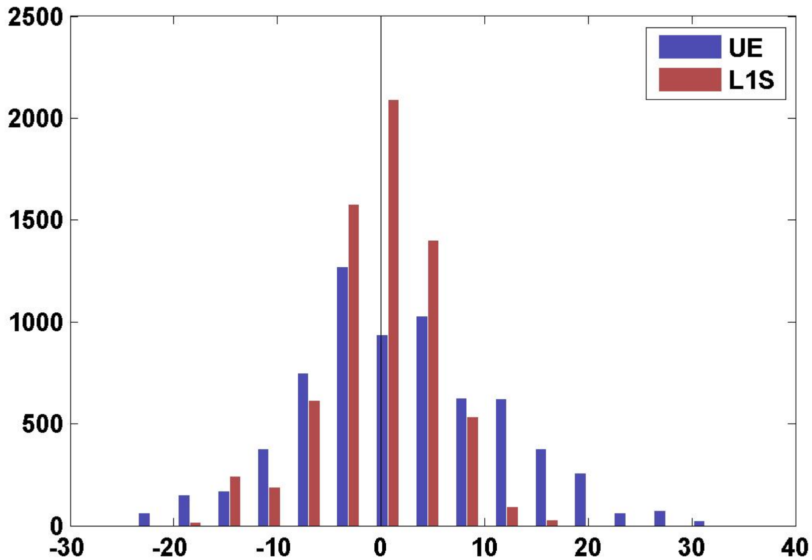
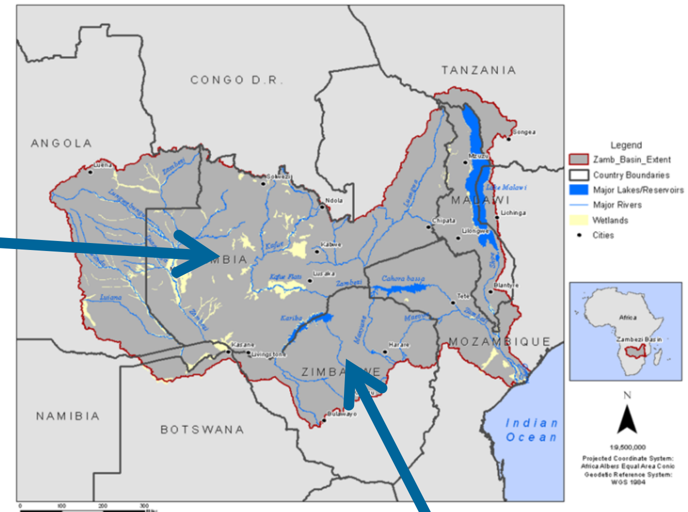
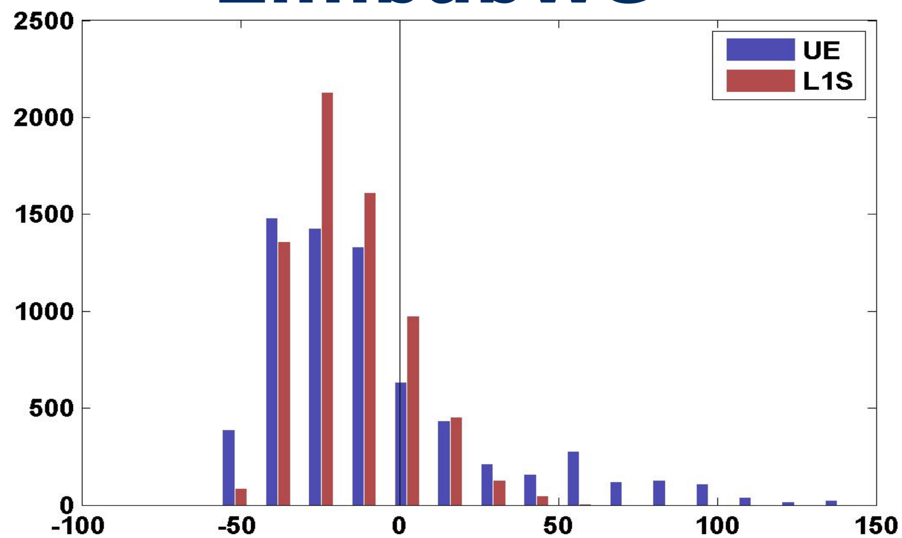
The Uncertain Future of Runoff in Zambezi River

Zambia





Zimbabwe



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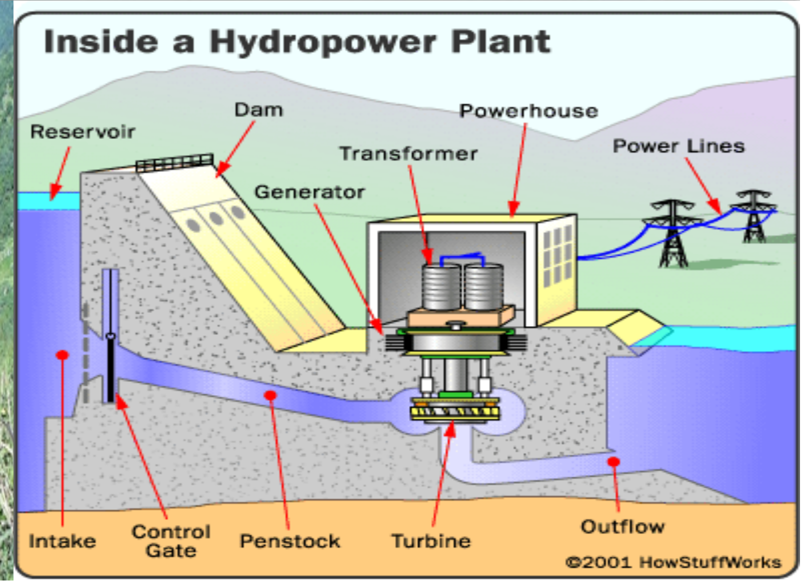
What Does It Mean For Hydropower Development?



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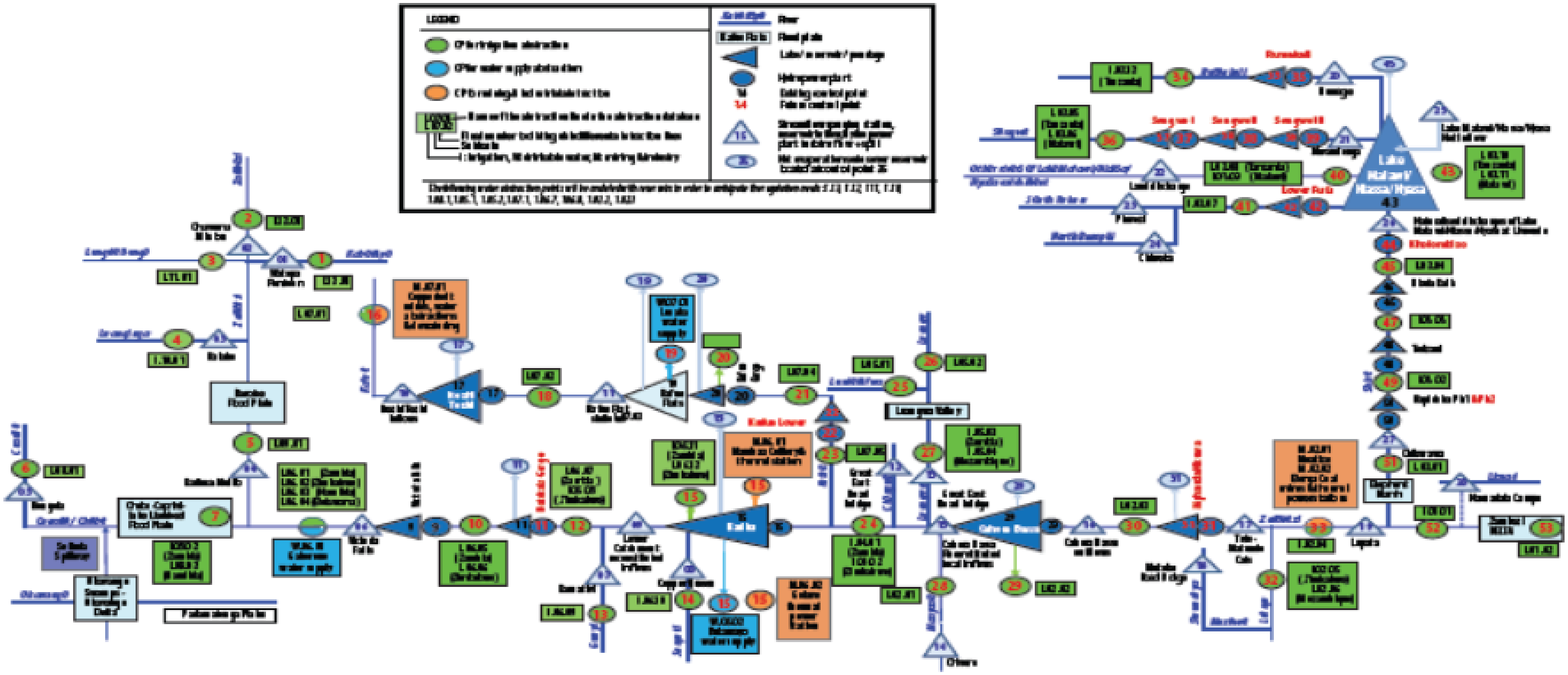
Zambezi River Development Plan



The World Bank

River Basin Simulation Model – WEAP

Assessment of the Impacts of Climate Change on *Multi-Sector Investment Opportunities* in the Zambezi River Basin

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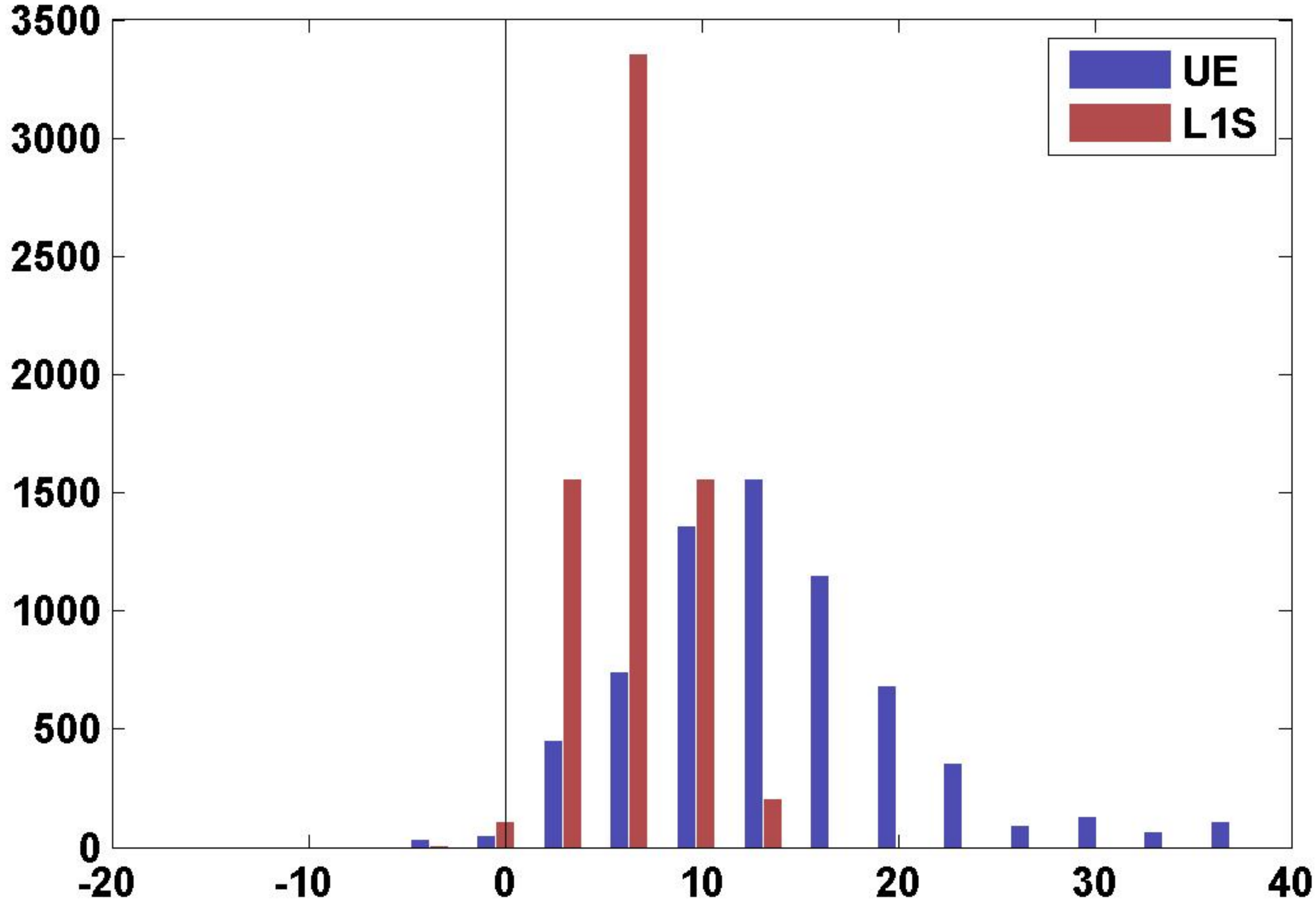
Impacts on Irrigation Demand in Mozambique



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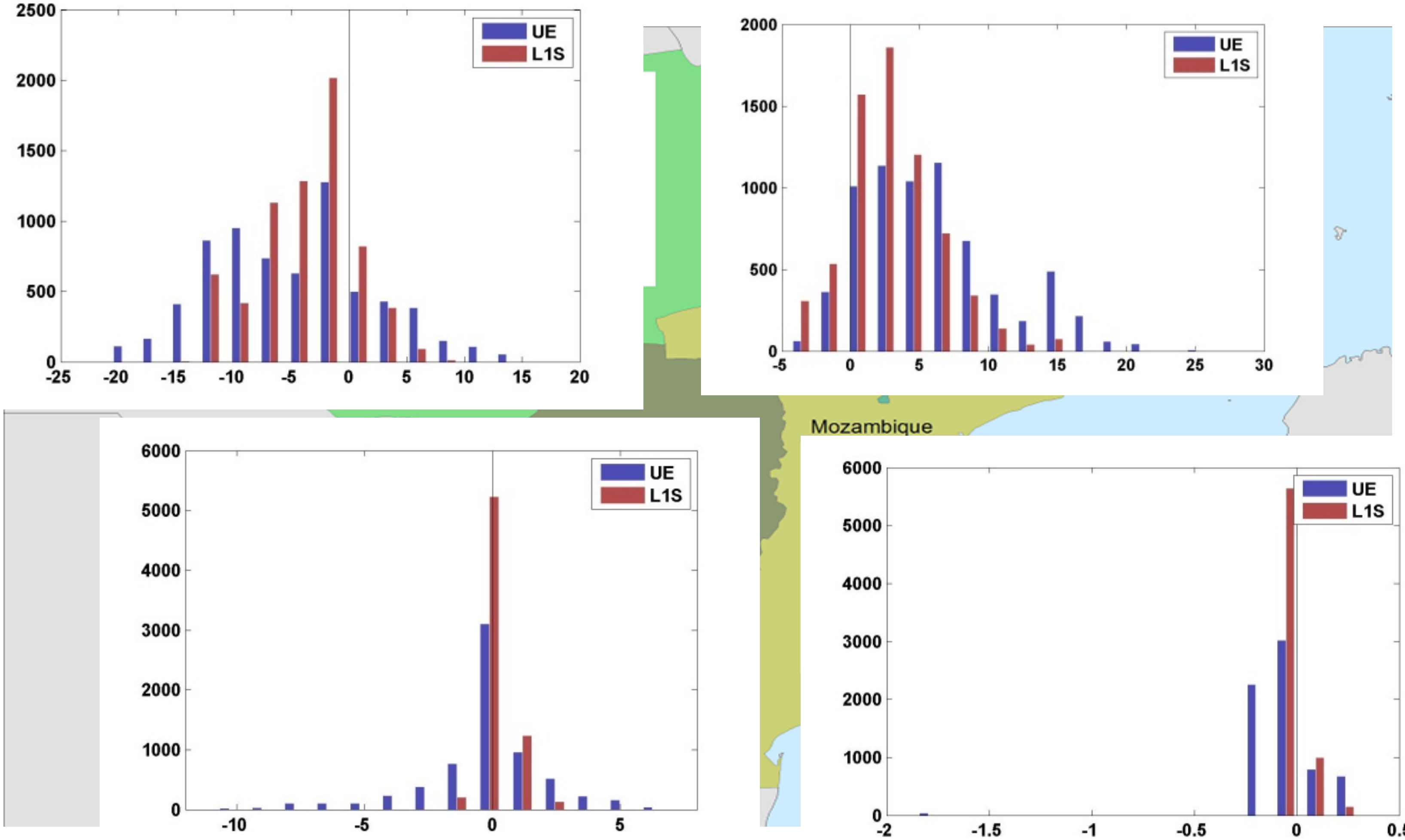
Impacts on Hydropower in 2050



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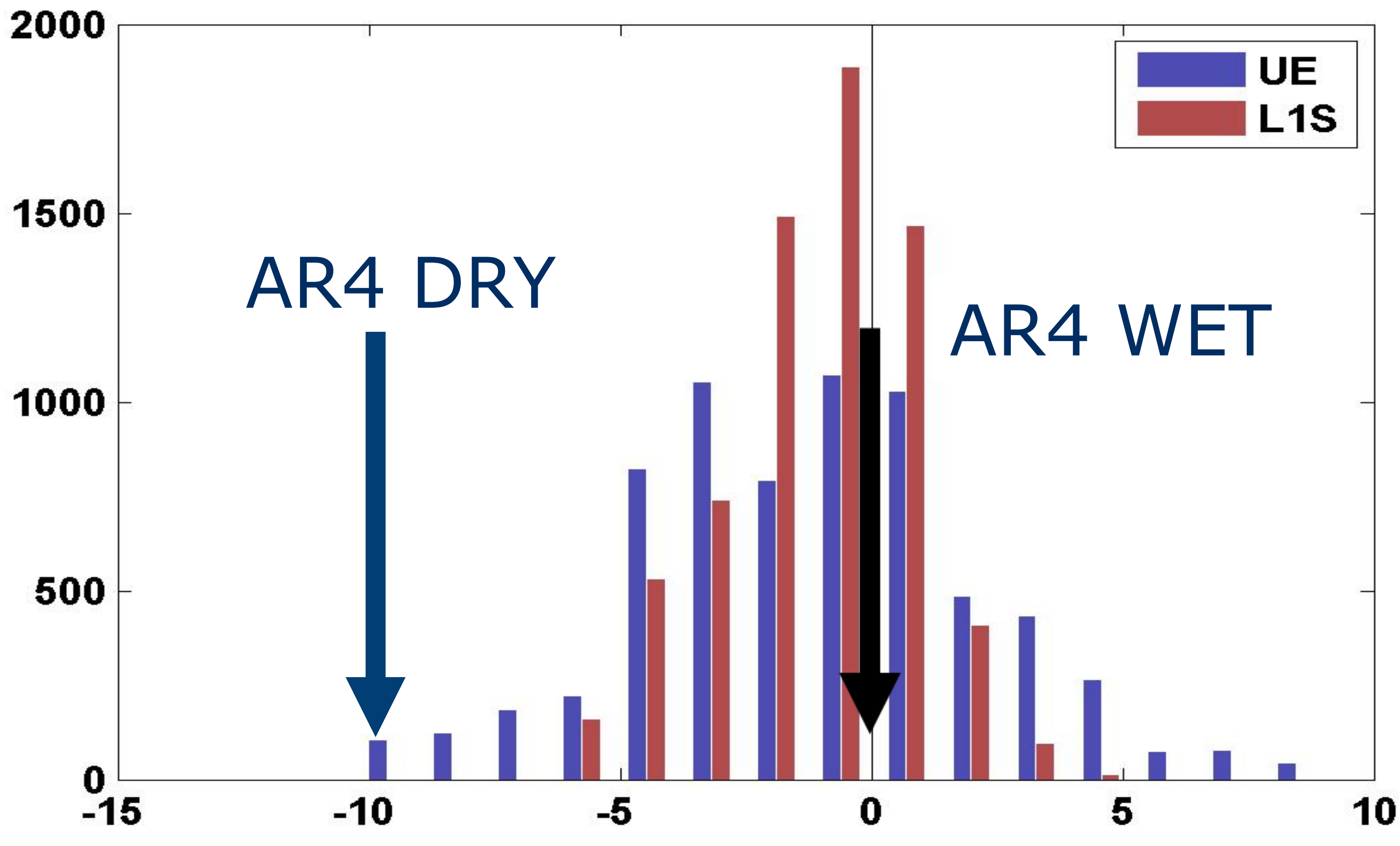
Basin-wide Impacts on Hydropower in 2050



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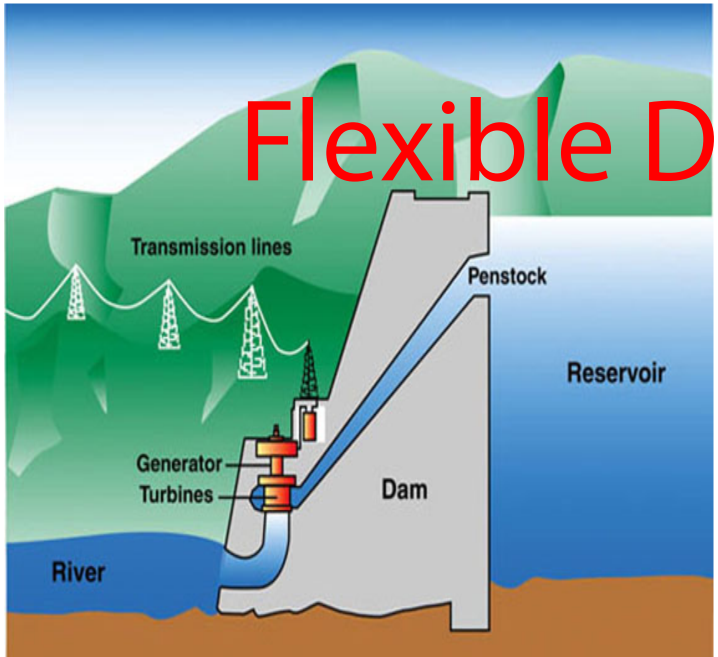
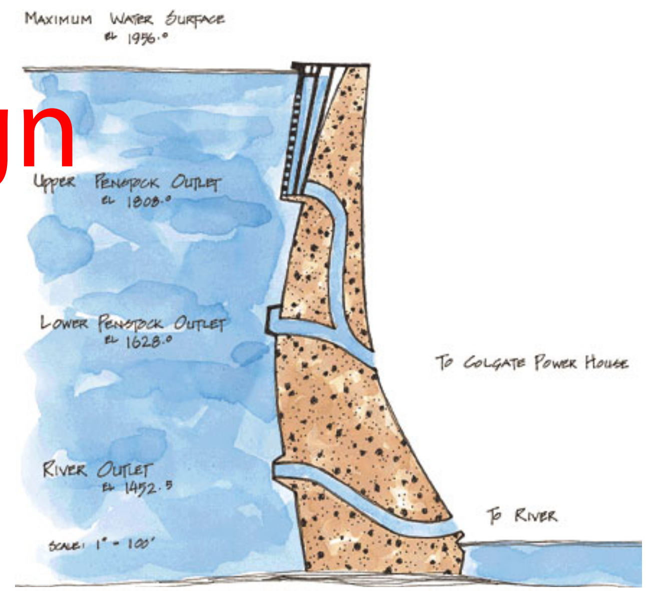
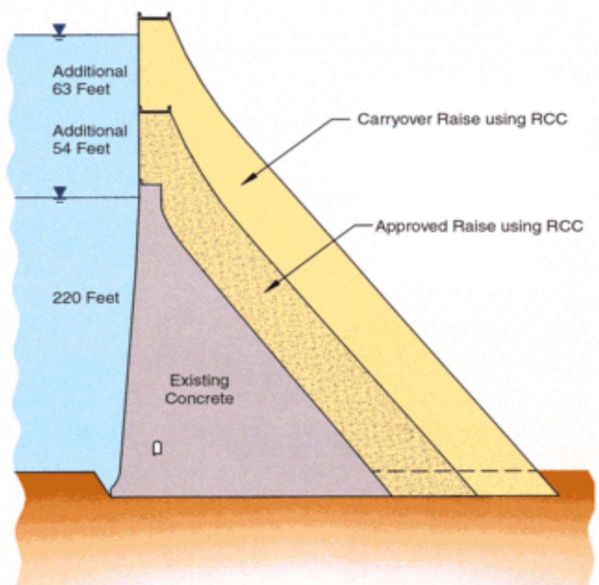
What Do These Results Imply for Investments in the Zambezi ?

Flexible Design







Alternative Designs

Florida circa 1900

Myrtle Beach, South Carolina 1999

MIT-OXFAM LOUISIANA HOUSE DESIGN -2006

Housing in the Coastal Zone in Light of Potential Inland flooding, Storm Surge and Sea Level Rise

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Adaptation for Flood Plain Management

Public Works Building, City of Boulder, CO USA

CONCLUSIONS

Anticipatory Adaptations Should Meet Two Criteria:

- Flexibility
  - Performs well under a variety of climates
    - Current climate
    - Hotter and drier
    - Hotter and wetter
- Efficiency
  - Benefits exceed costs
  - Consider
    - Timing of climate change benefits
    - Benefits under current climate

MIT Joint Program Sponsors Webinar Series

DECEMBER . 12 . 2012   10:30 am - 12:00 pm EST

Impacts of Human and Environmental Change on Regional and Global Water Resources

Dr. C. Adam Schlosser   Dr. Elodie Blanc   Dr. Ken Strzepek

1. Thank you for joining us today at the MIT Joint Program Sponsors Webinar series.

2. At the conclusion of today's Webinar, online attendees will be presented with a brief survey. We do hope that you will take a few minutes to provide feedback on today's session and make suggestions for future webinar topics. For those participating by telephone only, we welcome your comments at any time to Frances Goldstein by phone (**+1.617.253.2682**) or email (fkg@mit.edu).

3. Today's webinar has been recorded, and will be available in our webinar archive in the 'Sponsors Only" section of the Joint Program website, at:

   http://globalchange.mit.edu/sponsors/sponsorsonly/webinars.html

   (Click on the "Archived webinars" tab)

4. The next webinar in the series will be:

   Date: **February/March 2012**
   Time: **10:30 a.m. - 12:00 p.m. EST**
   Title: **TBD**
   Presenter: **TBD**

We do hope you hold this date on your calendar and plan to attend.
Details will be sent as we move closer to the event.

Thank you for participating in the MIT Joint Program Sponsors Webinar series today.