MIT Joint Program Sponsors Meeting

7 October 2015
Muldersdrift, South Africa

MIT JOINT PROGRAM
SCIENCE
POLICY
GLOBAL CHANGE

AGENDA

MIT Joint Program
on the Science and Policy of Global Change

Report to Program Sponsors

7 October 2015 • 14:00 – 17:00

The Springbok Room

The Misty Hills Country Hotel and Conference Center

Muldersdrift, South Africa

1. **Introductions**

2. **Program Overview and Future Forums**

3. **Program Highlights & Directions**

   (a) Update on the Hiatus/Non-Hiatus
   (b) Outlook for COP-21: an update
   (c) Expanded Research on Africa
   (d) Water Resource Risks

4. **Discussion of Emerging Issues & Assessment Needs**

Section 1

Introductions

New Sponsors and Projects

- New Program Sponsors
  - Nike
  - ClearPath Foundation
- New Funded Projects
  - U.S. Environmental Protection Agency (EPA)– *(N. Selin, J. Reilly, S. Solomon, S. Barrett)* "Projecting and Quantifying Future Changes in Socioeconomic Drivers of Air Pollution and its Health-related Impacts" (in collaboration with Harvard School of Public Health)
- Renewed Projects
  - Electric Power Research Institute (EPRI) – (*R. Prinn, J. Reilly*) "An Improved Framework for Analysis of Global Warming"

Collaborations

- Ongoing Research Collaborations (*selected examples*)
  - MIT Environmental Solutions Initiative, MIT Energy Initiative, MIT Climate Modeling Initiative, Darwin Project, Singapore-MIT Alliance
  - Ecosystems Center of the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts
  - Community Earth System Model (CESM) at the Nat'l Center for Atmospheric Research (NCAR)
  - Advanced Global Atmospheric Gases Experiment (AGAGE)
  - Global Trade Analysis Project (GTAP)
  - International Food Policy Research Institute (IFPRI)
  - Projects involving colleagues at NASA JPL, NASA GISS, NASA GSFC, NREL
  - Cooperative efforts with other Universities (*selected examples*)
    - Penn State University (Chris Forest)
    - Emory University (Eri Saikawa)
    - Tsinghua University (Zhang Xiliang)
    - Univ. Federal de Viçosa, Brazil (Angelo Gurgel)
    - Univ. of California, Davis (Kyaw Tha Paw U)
    - Lehigh University (Ben Felzer)
    - Univ. of Alaska, Fairbanks (K. Walter-Anthony)
    - Purdue University (Qianlai Zhuang)
    - Harvard School of Public Health (Petros Koutrakis, Elsie Sunderland)
    - Univ. of Rhode Island (Rainer Lohmann)
    - Michigan Tech (Judith Perlinger)

Personnel

- Internal Promotions
  - Jamie Bartholomay, promoted to communications coordinator
- New Appointments
  - Mark Dwortzan, appointed communications officer
  - Tochukwu "Tox" Akobi, BP Energy and Climate Fellow
- New Postdocs
  - Ben Brown-Steiner, Postdoctoral Associate
  - Sae Kwon, Postdoctoral Associate
  - Claudia Octaviano, Postdoctoral Associate
- New Visitors
  - Thomas Geissman, visiting student, ETH Zurich
  - Claire Nicolas, visiting student, University of Paris
- Departures
  - Audrey Resutek, resigned as communications coordinator
  - Robert Morris, resigned as administrative assistant
  - Rebecca Saari, graduated in June and accepted a faculty position at University of Waterloo
  - Justin Caron, accepted a faculty position at University of Montreal
  - Fernando Garcia Menendez, accepted a faculty position at North Carolina State University
  - Carey Friedman, accepted a faculty position at Maine Maritime Academy
  - Evan Couzo, accepted a faculty position at University of North Carolina
  - Rotem Bar-Or, returned to Israel
  - Giacomo Schwarz, returned to ETH Zurich

Section 2

Future Global Change Forums

- Discussion of future locations, topics and collaborators
  - *Cambridge, MA, USA* – 15-17 June 2016
    Theme: *Corporate Strategy and Climate Change*

Section 3

Program Highlights & Directions

a) Update on the Hiatus/non-Hiatus

b) Outlook for COP-21: an update

c) Expanded Research on Africa

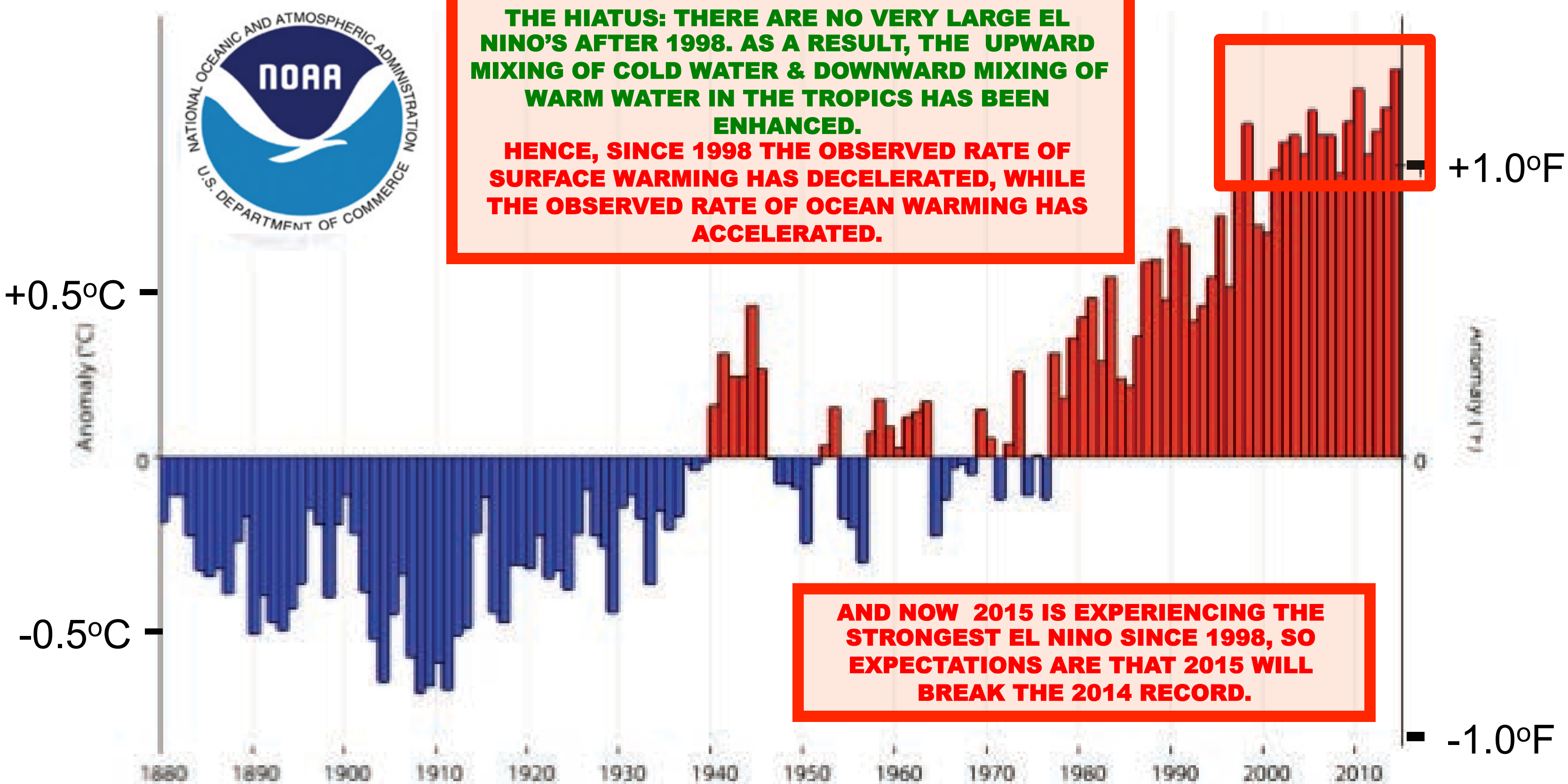
d) Water Resource Risks

HOW HAVE TEMPERATURES EVOLVED OVER 1880-2014: "NOISINESS" AND THE "HIATUS"?

Ron Prinn, Sponsors' Meeting

MIT Global Change Forum 38, 2015

Global annual surface air temperature anomaly (relative to 1901-2000 average) as estimated from observations by NOAA-NCDC (www.ncdc.noaa.gov)



THE HIATUS: THERE ARE NO VERY LARGE EL NINO'S AFTER 1998. AS A RESULT, THE UPWARD MIXING OF COLD WATER & DOWNWARD MIXING OF WARM WATER IN THE TROPICS HAS BEEN ENHANCED.

HENCE, SINCE 1998 THE OBSERVED RATE OF SURFACE WARMING HAS DECELERATED, WHILE THE OBSERVED RATE OF OCEAN WARMING HAS ACCELERATED.

AND NOW 2015 IS EXPERIENCING THE STRONGEST EL NINO SINCE 1998, SO EXPECTATIONS ARE THAT 2015 WILL BREAK THE 2014 RECORD.

THE TEN WARMEST YEARS RECORDED WITH THERMOMETERS SINCE RECORDS BEGAN IN 1880 WERE IN ORDER: 2014, 2010, 2005, 1998, 2013, 2003, 2002, 2006, 2009 & 2007 [but note accuracy of global averages is about +/- 0.1 °C (0.2°F)]

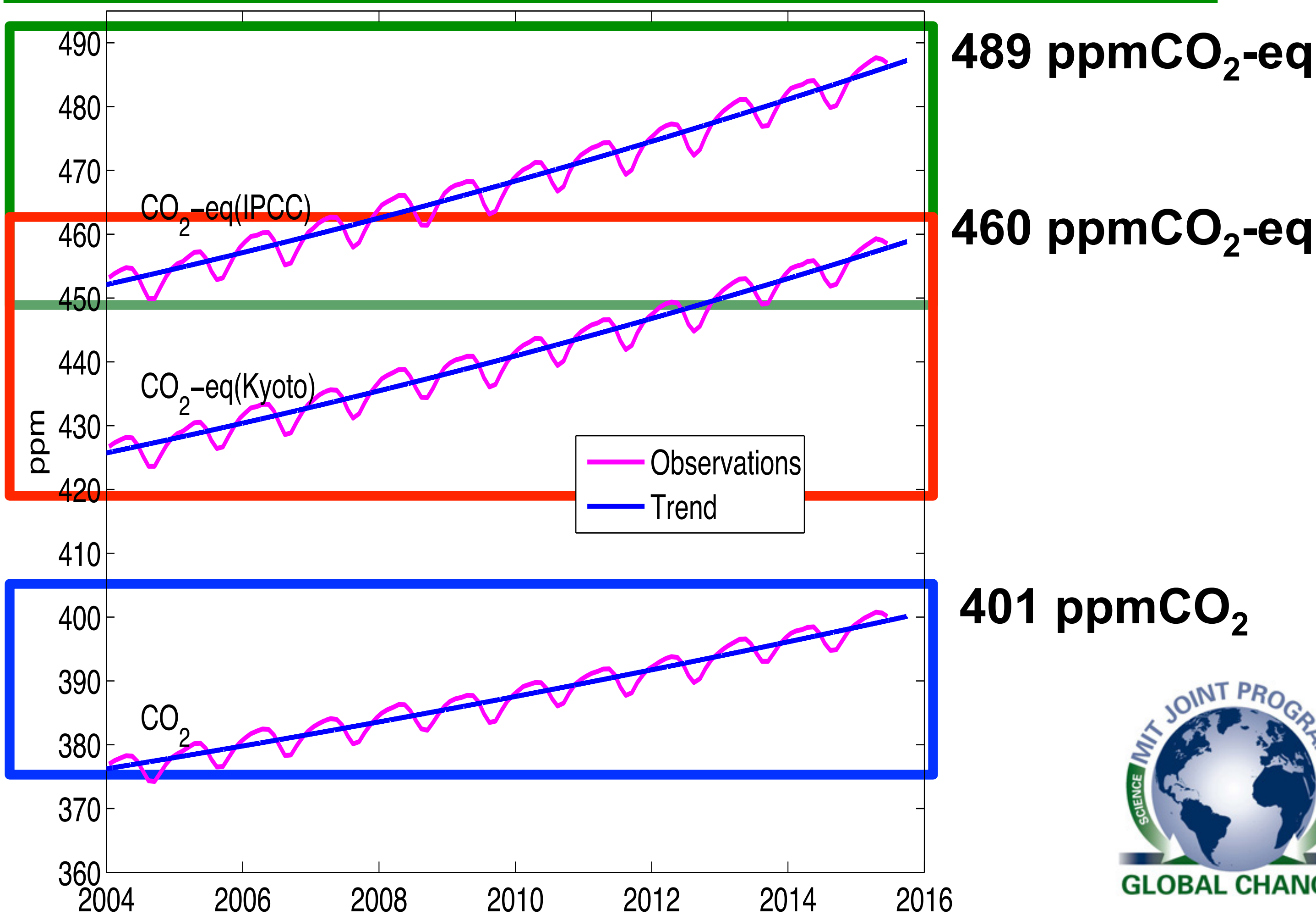
GLOBAL TRENDS IN MOLE FRACTIONS (ppm CO_2 equivalents) OF TOTAL LONG-LIVED GREENHOUSE GASES (GHGs).

(CO_2 from NOAA and non-CO_2 from AGAGE; Ref-Huang et al, MIT Joint Program Report #174, 2009)

IPCC refers to Kyoto Protocol + Montreal Protocol greenhouse gases

GREENHOUSE GASES CONTINUE TO RISE STEADILY.

BUT WHY IS THE TEMPERATURE RESPONSE NOISY?



WHAT ARE THE RELATIVE CONTRIBUTIONS TO CLIMATE CHANGES OF VARIABILITY IN SPECIFIC NATURAL PROCESSES (El Nino, La Nina, Volcanoes, Solar Cycle) & ANTHROPOGENIC EFFECTS?

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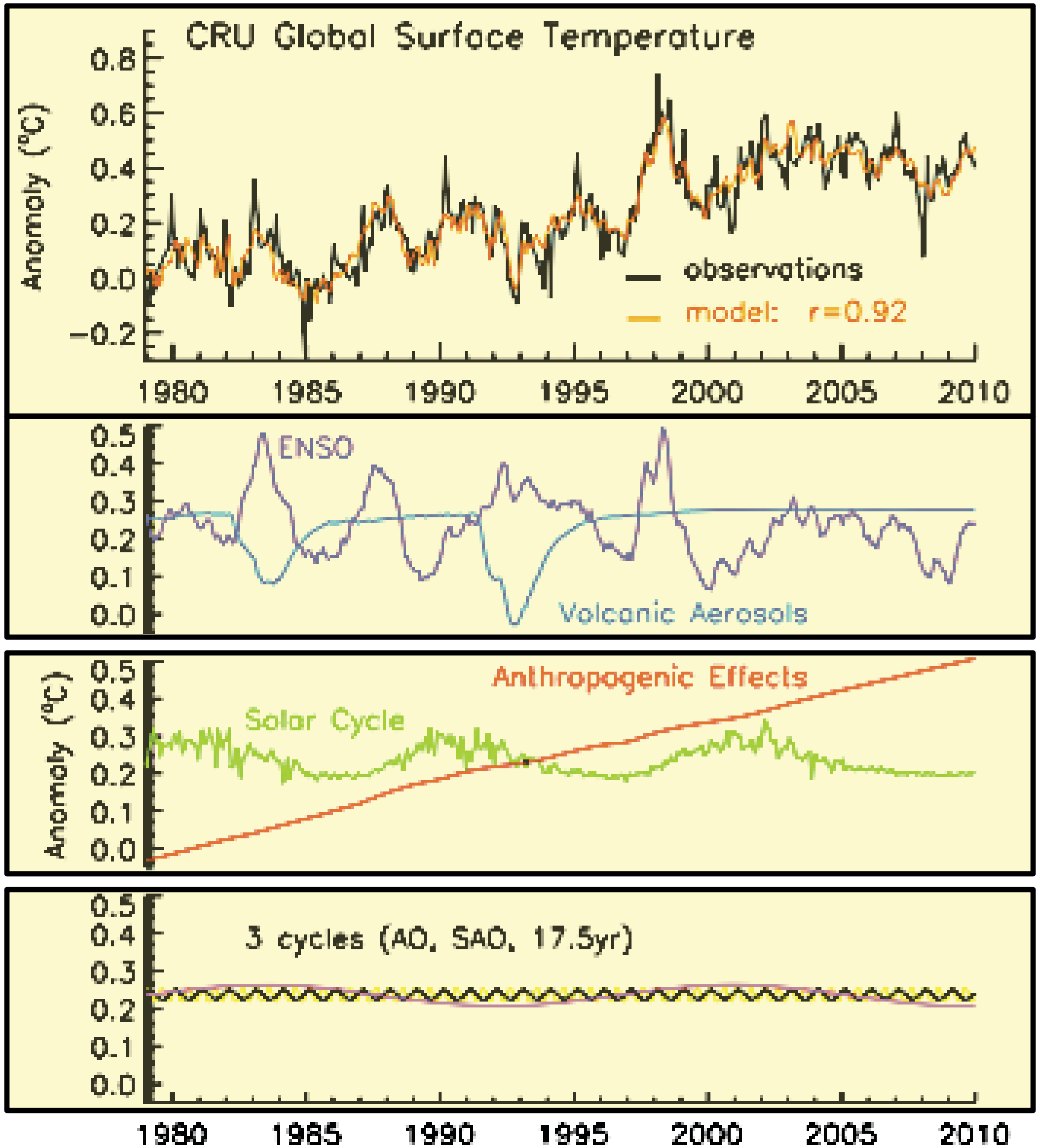
From theory, we expect warming during El Nino (suppressed tropical oceanic heat uptake), cooling during La Nina (enhanced tropical oceanic heat uptake), and cooling by sulfur-rich volcanic eruptions (reflecting aerosols)



Top panel shows monthly mean variations in the global temperature anomalies (relative to 1951-1980 avgs.) of the Earth's surface, from the Climatic Research Unit (CRU, black) and an empirical model (orange, following Lean and Rind [2009]) that combines four primary influences and three minor cycles shown in the 3 lower panels. After removing the four primary effects, namely ENSO (purple) at three different lags, volcanic aerosols (blue) at two different lags, solar irradiance (green), and anthropogenic effects (red), minor cycles identifiable as annual (AO, black), semi-annual (SAO, yellow), and 17.5 year oscillations (pink) are evident in the residuals

Ref: Kopp & Lean, GRL, 2011.

OBSERVATIONS CLEARLY SHOW THE PROBABILITY DISTRIBUTION FOR TEMPERATURE IS SHIFTING TO HIGHER VALUES

CHANGING AREAS OF HOT & COLD CLIMATE EXTREMES

(define cold/hot, very cold/hot, and extremely cold/hot areas that contain 50%, 5% and 1% of extremes. Ref: Hansen et al, Proc. National Academy of Science, 2012).

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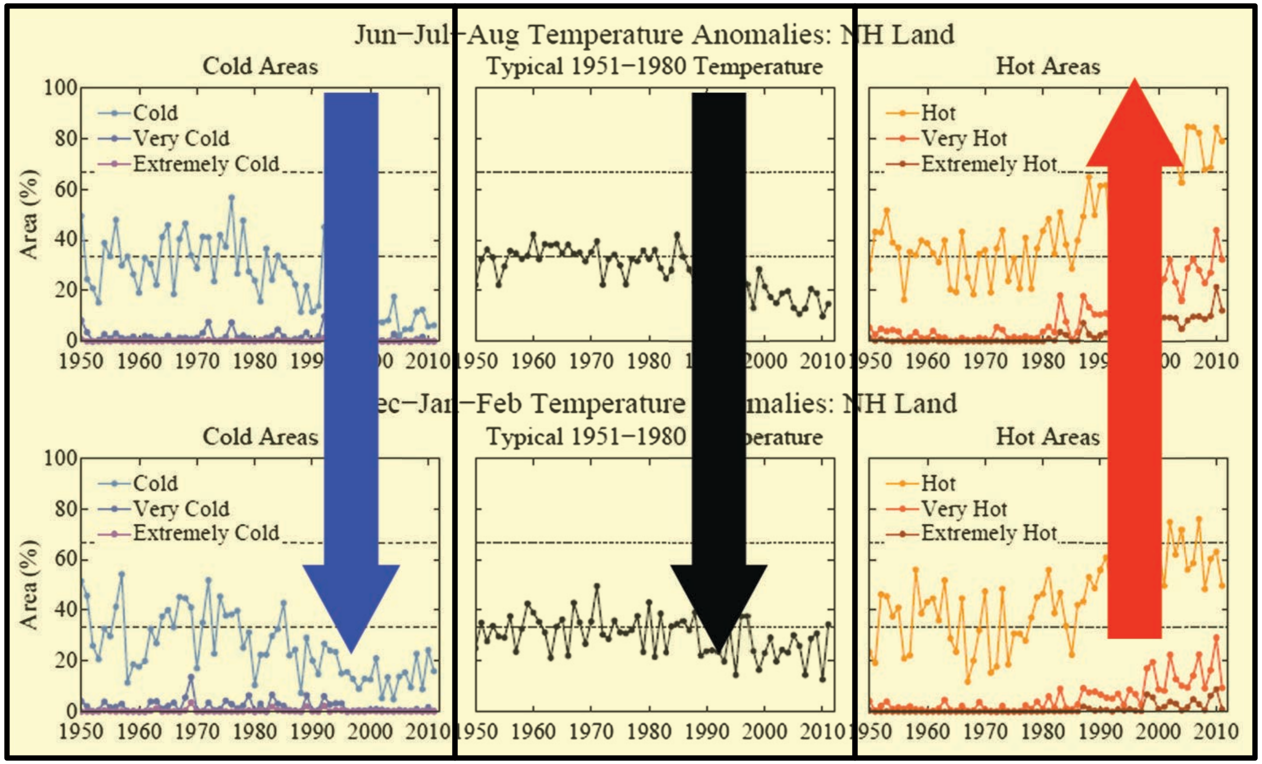
PERCENT OF LAND AREA COVERED BY TEMPERATURE EXTREMES (RELATIVE TO 1951-1980 PERIOD) FOR NORTHERN HEMISPHERE SUMMER AND WINTER.

THE AREA OF COLD EXTREMES IS SHRINKING

THE AREA OF TYPICAL 1951-1980 TEMPERATURES IS ALSO SHRINKING

THE AREA OF HOT & VERY HOT EXTREMES IS EXPANDING.

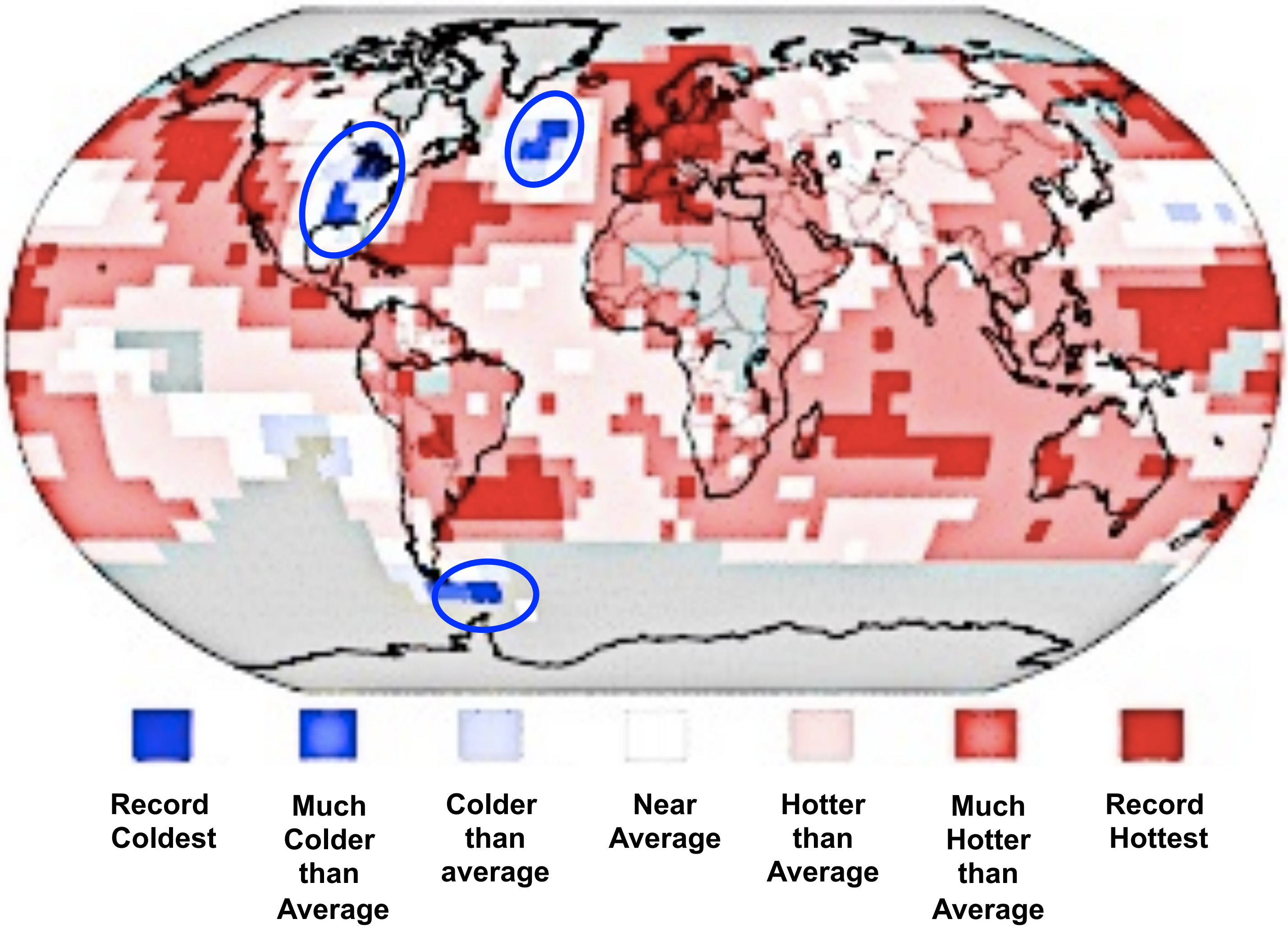


IN THE NEW RECORD WARM YEAR OF 2014, THERE WERE VASTLY MORE NEW HOT TEMPERATURE RECORDS BROKEN THAN NEW COLD TEMPERATURE RECORDS.

Ref: NOAA-NCDC, LAND & OCEAN TEMPERATURE PERCENTILES FOR JAN-DEC 2014 (www.ncdc.noaa.gov)

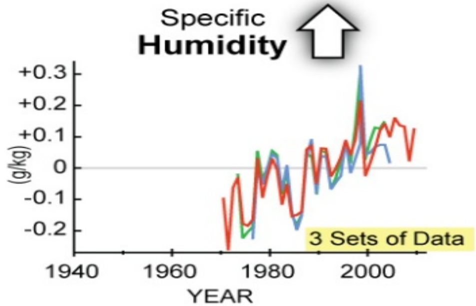
AGAIN, OBSERVATIONS CLEARLY SHOW THE PROBABILITY DISTRIBUTION FOR TEMPERATURE IS SHIFTING TO HIGHER VALUES

BUT, GLOBAL AVERAGE HIGHS DO NOT IMPLY HIGHS EVERYWHERE



BEYOND RISING TEMPERATURES, THERE ARE NOW MULTIPLE INDICATORS OF GLOBAL CLIMATE CHANGE

Refs: Arndt, D. S., M. O. Baringer, and M. R. Johnson, Eds., 2010: State of the Climate in 2009. Bull. Amer. Meteor. Soc., 91 (7), S1-S224; **Rodell et al, Bulletin AMS, 92, S50-S51, 2011; IPCC, 2013; NOAA, 2015.**



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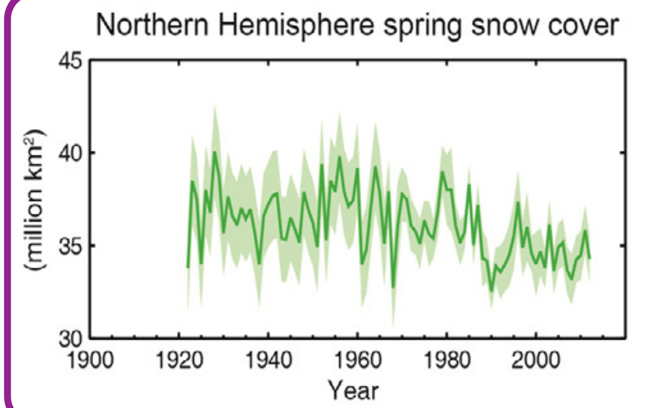
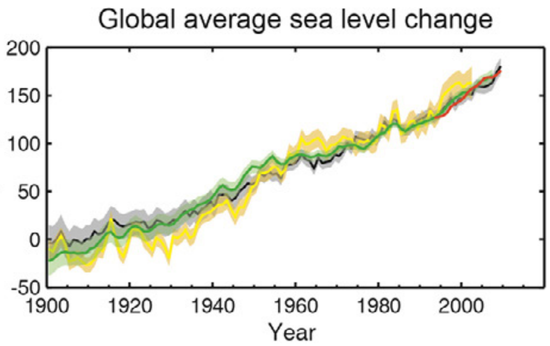
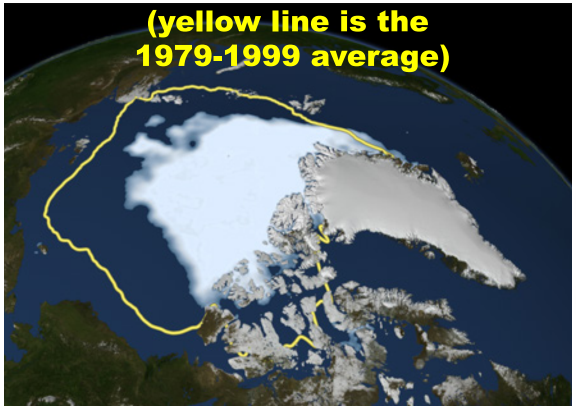
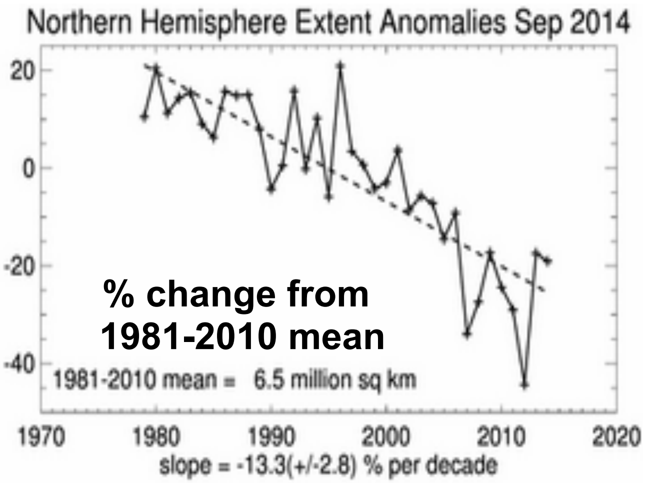
Shown are changes from the time averages except for Arctic sea ice extant

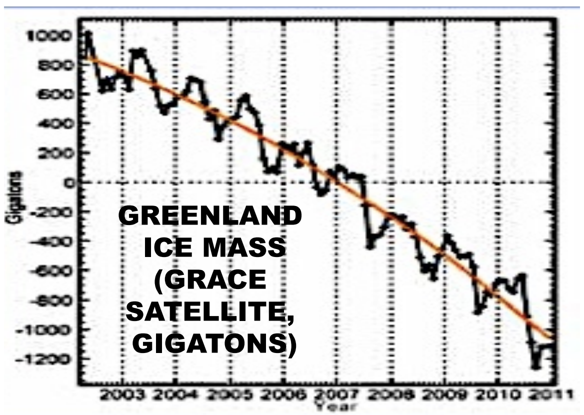




2012 RECORD LOW ARCTIC SUMMER SEA ICE







RISING HUMIDITY & DECREASING SEA ICE, LAND ICE, & SNOW COVER, ARE ALL "POSITIVE FEEDBACKS" THAT ACCELERATE THE WARMING.

COP-21 Update

- Revisit: Jacoby & Chen, 2014. JP Report No. 264, Expectations for a New Climate Agreement
- Include targets from Indicated Nationally Determined Contributions (INDCs) for those countries submitting them to the UN Framework Convention on Climate Change (UNFCC)

Instructions to Paris Negotiators

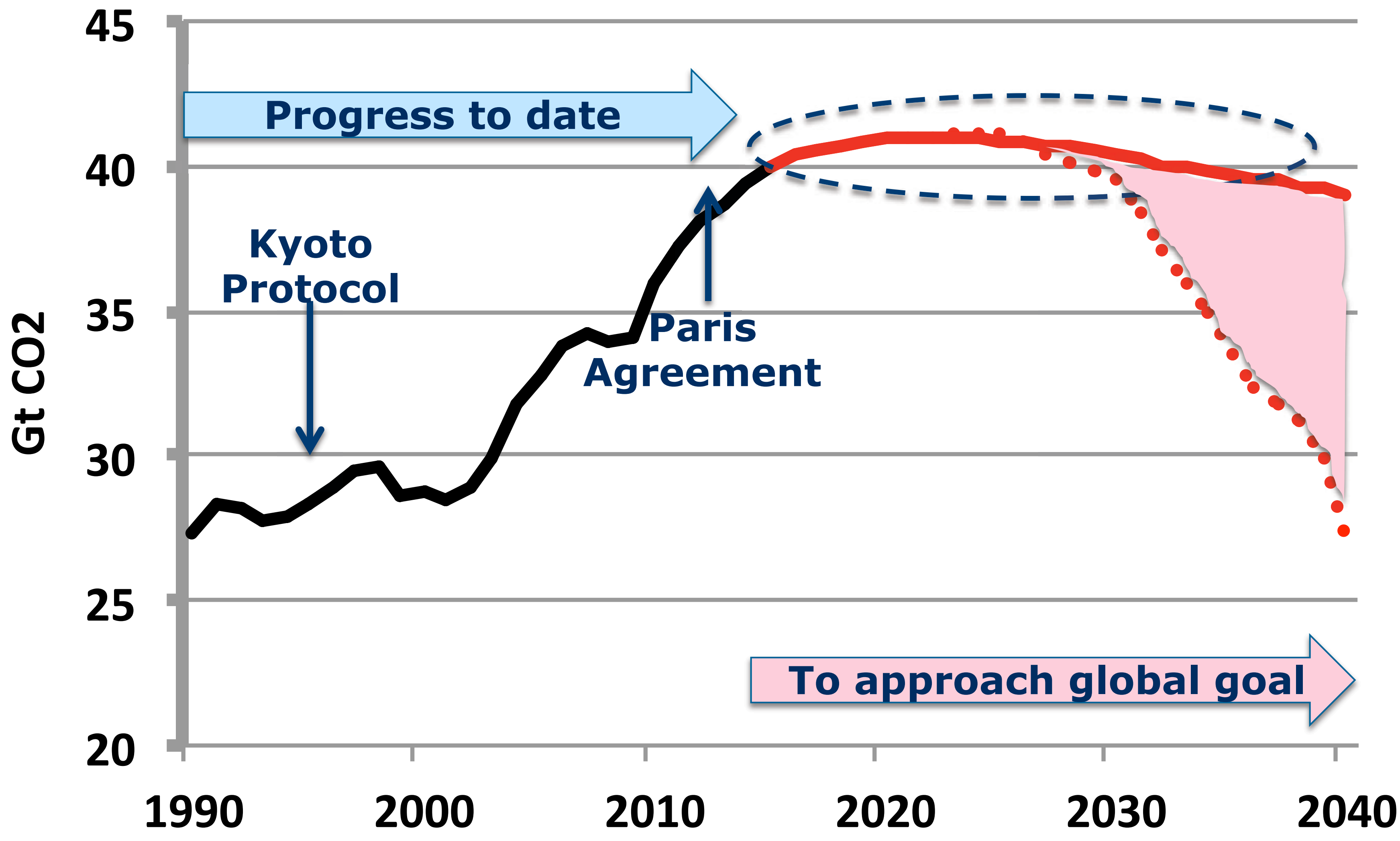
- "Note with grave concern" . . . a 2°C goal
- Nationally Determined Contributions (NDCs)
  - ✓ Pledge (voluntary) targets and/or actions
  - ✓ To take effect from 2020
  - ✓ With a review process
- Indicated Contributions (INDCs) by mid-2015
- Common but differentiated responsibilities
- Other themes
  - ✓ Adaptation
  - ✓ Finance
  - ✓ Technology transfer
  - ✓ Capacity building

<u>From Copenhagen:</u>
By 2020, mobilize $100 billion per year to aid mitigation and adaptation

Not Yet Agreed, on Mitigation

- First target date (5 or 10 years?)
- Review of performance
  - ✓ Monitoring, reporting and verification (MRV)
  - ✓ Procedure: who does what?
  - ✓ Ex ante *and* ex post?
  - ✓ Timing
- Future cycles of pledges
- Scope of mitigation "contributions"
  - ✓ Role of markets and trading
  - ✓ Offsets or joint crediting
- Legal form

The First Step: Peak Emissions



Expected Measures (differ by group)

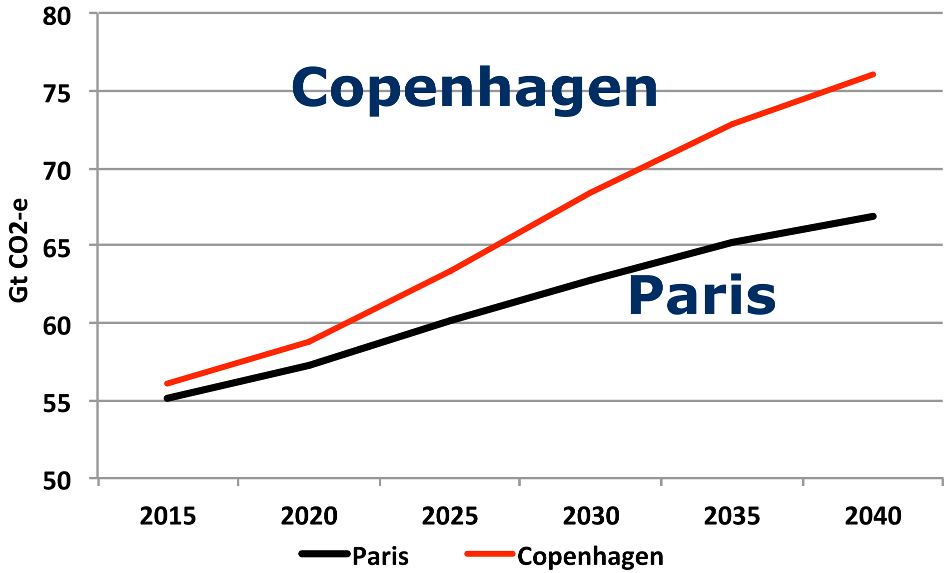
- Electric Sector
  - ✓ Coal
  - ✓ Renewables
- Transport
  - ✓ Auto mileage standards
  - ✓ Efficiency standards for trucks
- Household: subsidies, regulations
- Land Use: reduced tropical deforestation
- Methane
  - ✓ Reduced leakage in natural gas systems
  - ✓ Improved agricultural practices

EPPA Model: Nations & Regions

Developed	Other G20	Rest of World
*ANZ Australia-NZ	BRA Brazil	AFR Africa
*CAN Canada	*CHN China	MES Middle East
*EUR E.U.+	ASI Dynamic Asia	LAM Latin America
*JPN Japan	*IND India	REA Rest of E. Asia
*USA United States	*MEX Mexico	ROE Rest of Eurasia
	*RUS Russia	

* = INDC submitted to the FCCC

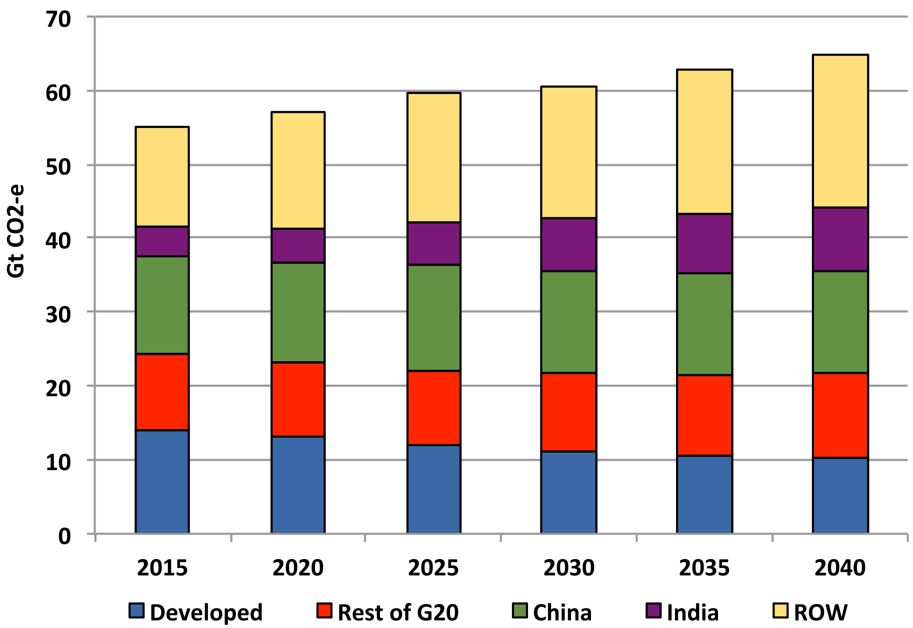
Expected Global Emissions (CO_2-e)



- about 3-4 Gt less in 2025 than JP Report No. 264
- about 2 Gt less in 2040

Regional Emissions

- With Developed G20 bring emissions under control future attention must shift to ROW
- of course if a Joint Crediting Mechanism as used to get them in it won't change global emissions unless those using credits tighten further.



Needed for Ultimate Success

- Credible, timely review process
- Durable cycles of increased effort
- Finance to support conditional pledges

Climate, Land, Energy, Water, and Development in Africa

- A new effort responding to interests of sponsors
- Similar in some ways to the China Energy and Climate Project
- However, broader focus on impacts of climate and environmental change, water-energy-land interactions, and sustainable development

Current Sponsors

- UNU-WIDER
  - Interests in the hydroelectric development across the continent, climate effects on water resources, and implications for economic growth and development
  - Focused on modeling electrical power grid and potential to link power pools—can excess hydro capacity be used to firm up intermittent renewables
- AFD
  - Interests in water-energy investment decision-making under the uncertainty of climate and economics
  - Stochastic dynamic model development with a focus on developing methods for practical decisions making
- ENI
  - Business models for renewables in the African context
  - Broader interests in renewable resource potential on the continent

Economic Projection and Policy Analysis (EPPA) Model Development

Currently, Africa is a single EPPA region

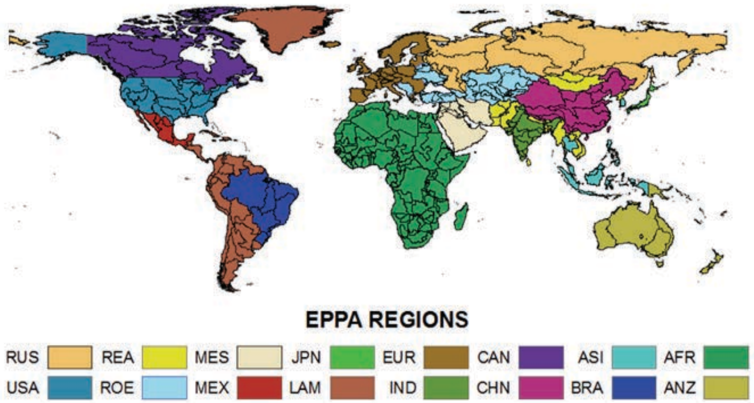
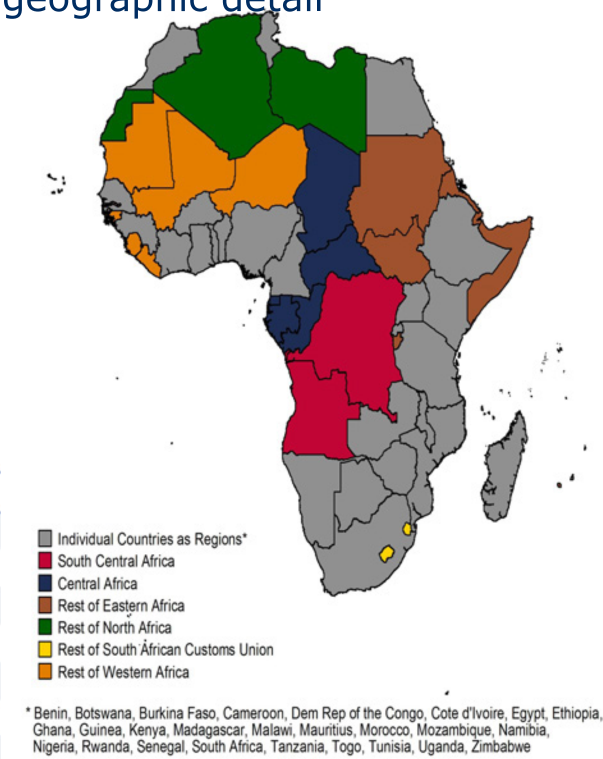


Figure 4. WRS Geographic Resolution

Table 3. EPPA-Africa regions

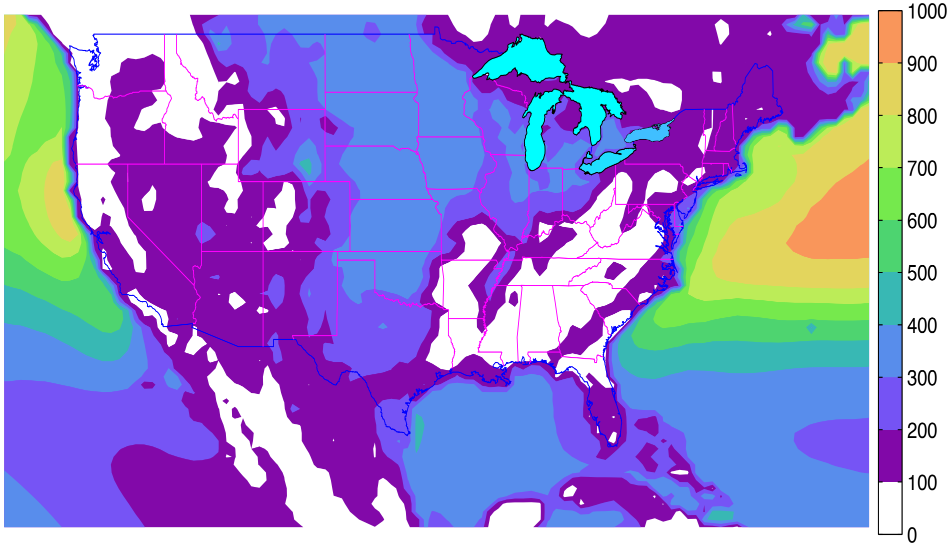
EPPA-AFRICA REGIONS IDENTIFIED BY GTAP COUNTRIES/REGIONS	
EASTERN AFRICA	**WESTERN AFRICA**
Ethiopia	Ghana
Kenya	Ivory Coast
Madagascar	Nigeria
Malawi	Senegal
Mozambique	Rest of Western Africa
Tanzania	
Uganda	**NORTHERN AFRICA**
Zambia	Egypt
Zimbabwe	Morocco
Rest of Eastern Africa	Tunisia
	Rest of North Africa
SOUTHERN AFRICA	
Botswana	**MIDDLE AFRICA**
Namibia	Cameroon
South Africa	South Central Africa
Rest of South African Customs Union	Central Africa

GTAP Data set allows for considerably more geographic detail



The initial 5-region Africa model would allow further breakout of individual countries.

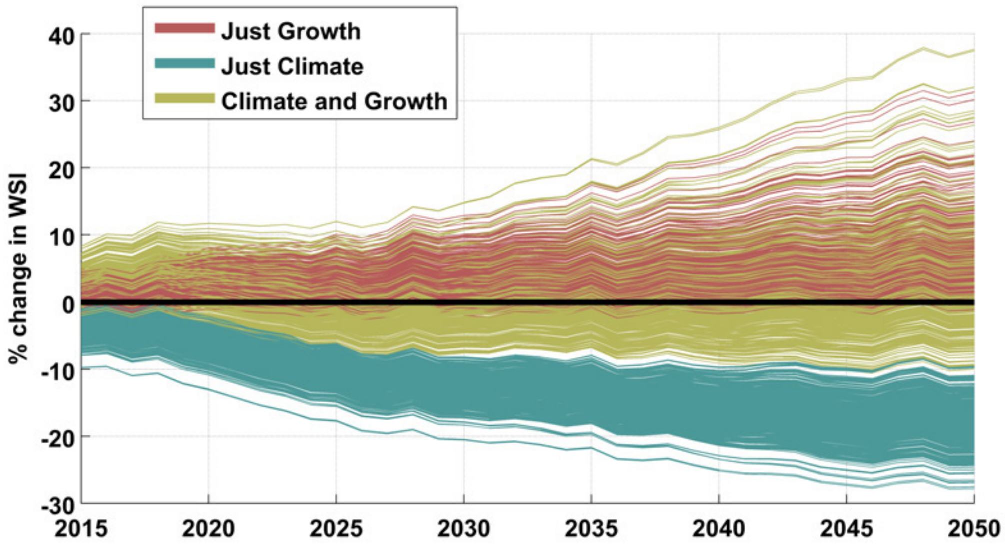
As Funding allows…



Geographical variations in mean wind-power density (WPD) at 80 meter hub height (from Gunturu and Schlosser, 2012). Units are in W/m^2

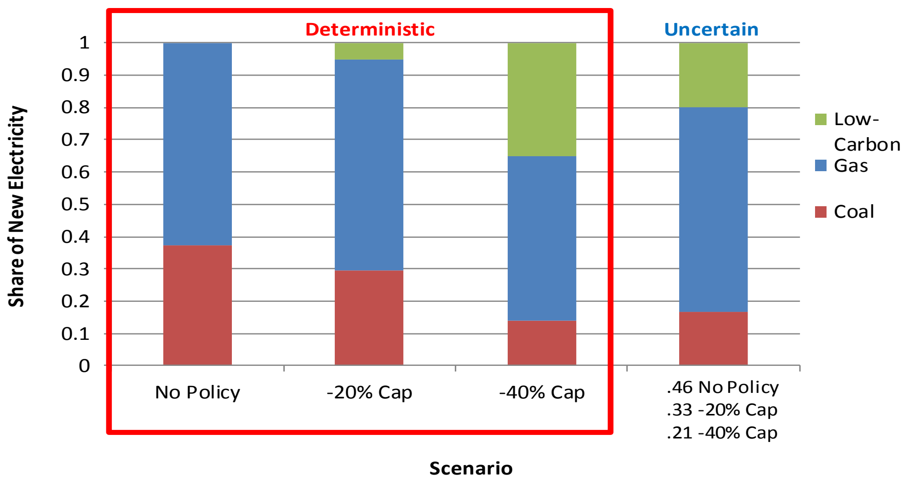
Investigation of wind and solar resource potential and its intermittency, reliability for Africa as we have done in other regions

As Funding allows…



Investigation of uncertainty in future water resources by river basin and implications for hydropower, with a focus on new investments

Use of the HFD approach with the IGSM and WRS to examine the implications of growth in population and economy and changes in climate on water stress. Example here is for India



Explicit stochastic decisions, when future uncertain gives different optimal investment strategy then a deterministic solution

Optimal Near -Term Investment in Generation Capacity Recognizing Policy Uncertainty: Example New US Electricity Investment

As Funding allows…

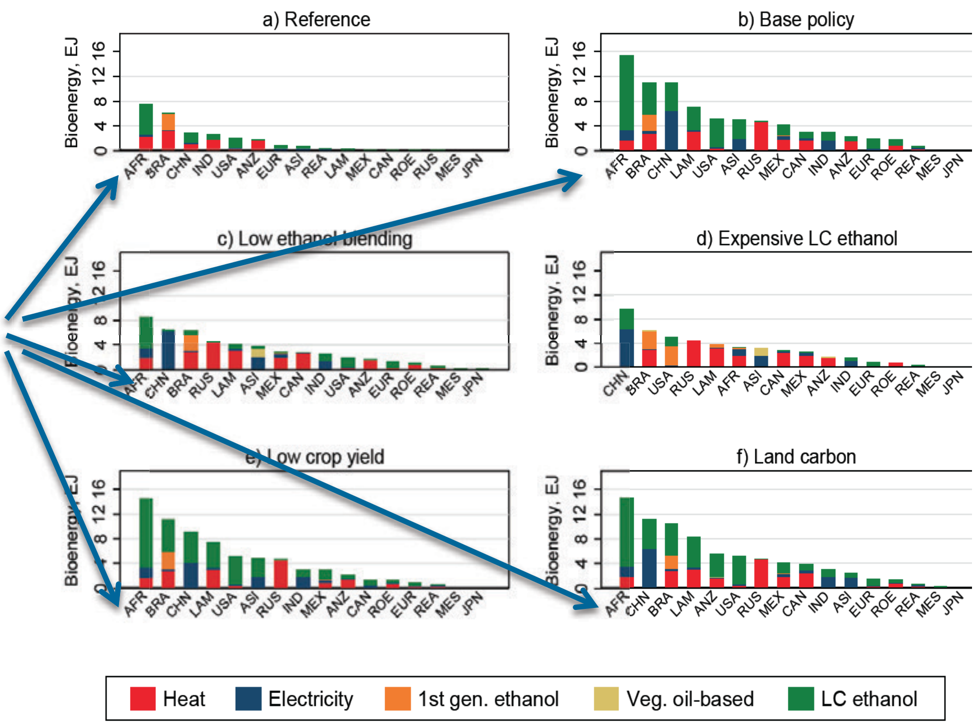
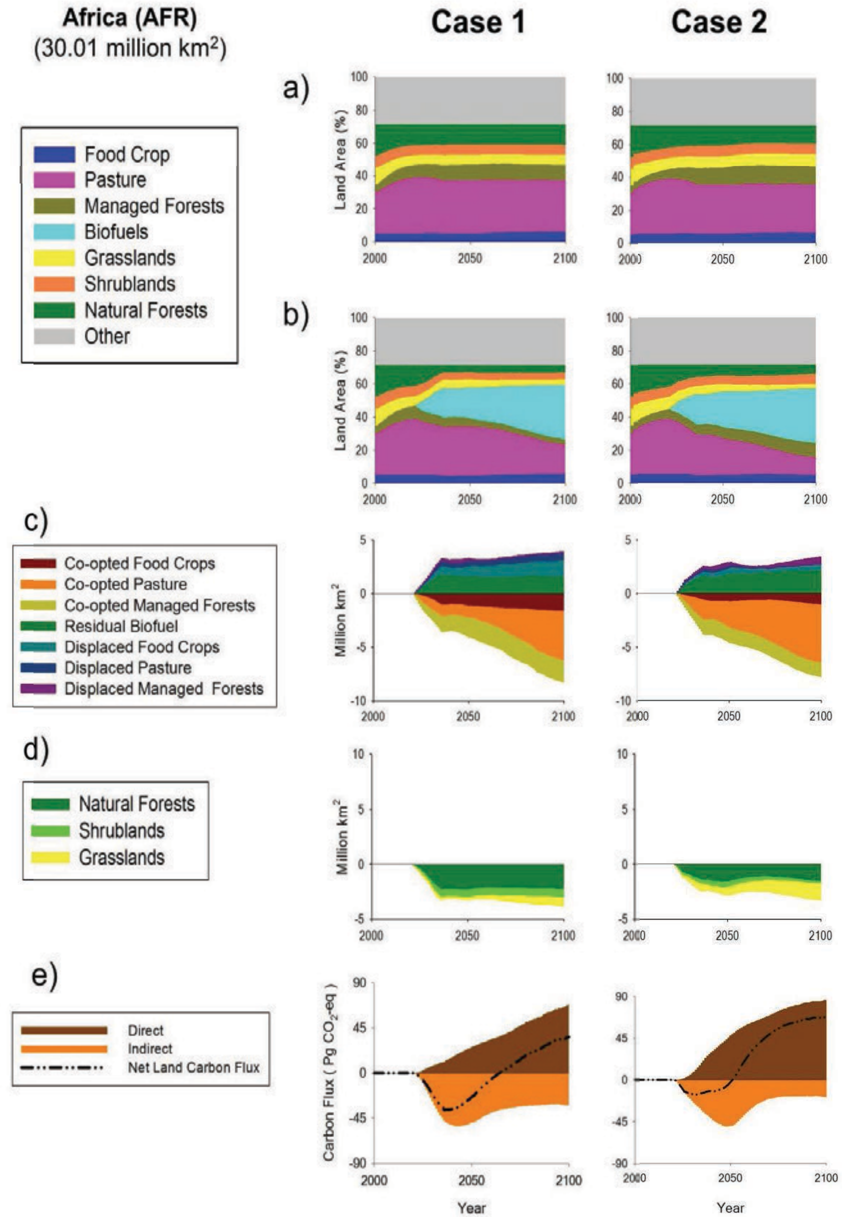


Figure 14. Regional final bioenergy by scenario in 2050.

Work on biomass energy shows Africa a potentially large resource



But with potentially significant implications for land use, deforestation, and farming

With Mitigation and Climate Impacts

- Challenges in poorer countries
  - Meeting energy needs
  - Populations still growing
  - Hope for rapid (and sustainable) economic growth

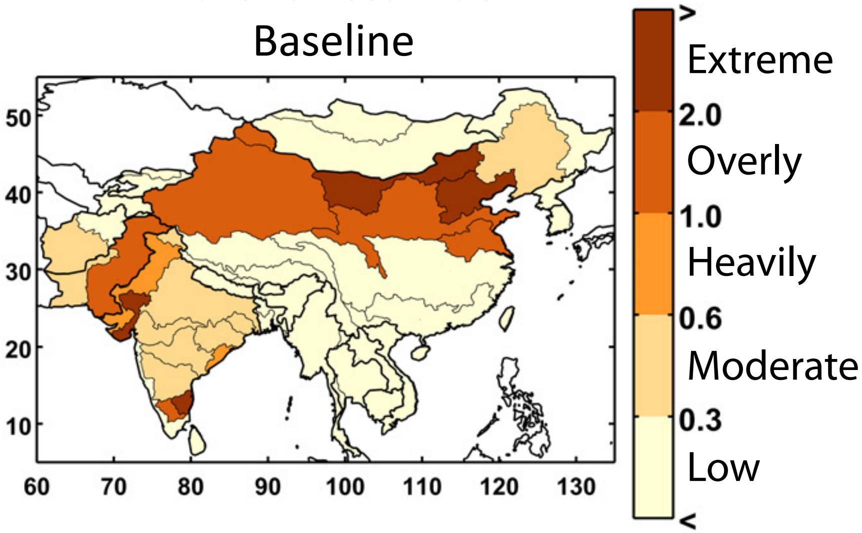
- These issues make Africa an interesting and important research focus.

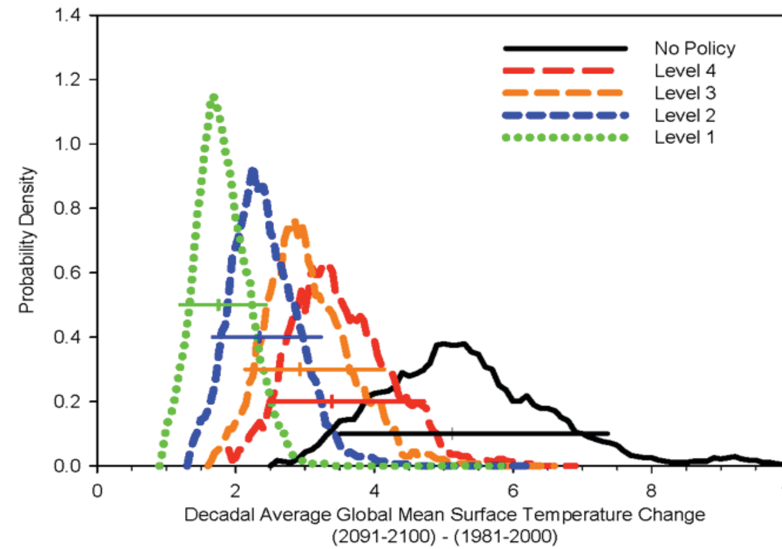
Future Risks to Water Systems: Attribution and Options Studies over Asia and the United States

C. Fant, C. A. Schlosser, X. Gao, K. Strzepek and J. Reilly, 2015: Projections of Water Stress Based on an Ensemble of Uncertain Socioeconomic Growth and Climate Change: A Case Study in Asia, PLOSone (in review), JP Report #269

Forthcoming papers: Xiang et al. (2015) and Schlosser et al. (2015) to focus on mitigation and adaptation effects.

Water Stress Index
Baseline





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UNU-WIDER
World Institute for Development Economic Research

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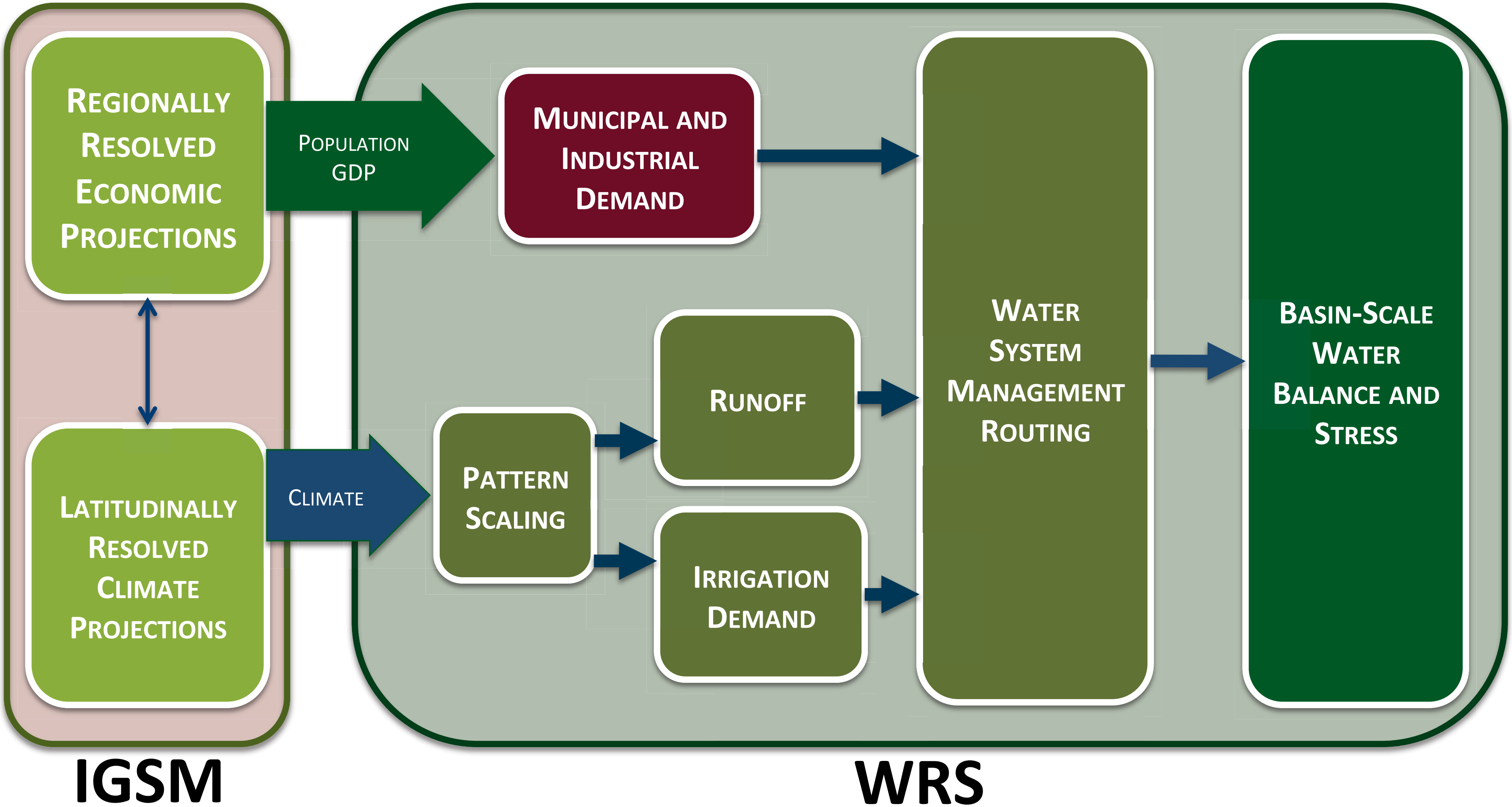
The Integrated Global System Model (IGSM) Water Resource System (WRS) Framework



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 (JAMES, 2013).

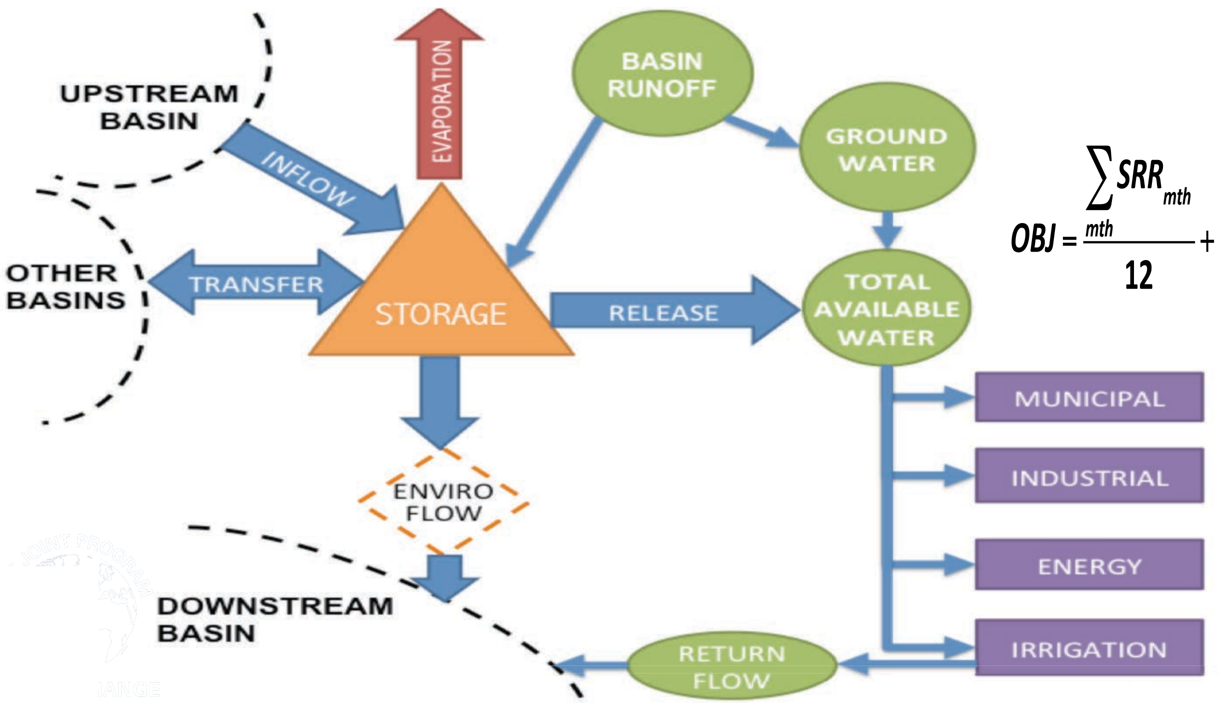
WATER STRESS SCHEME AND INDICATORS

1. WATER STRESS INDEX (WSI) [UNITLESS]
   - MEASUREMENT OF SYSTEM/ENVIRONMENT STRESS
   - BASED ON SMAKHTIN ET AL. (2005)

$$WSI = \frac{\text{Withdrawal (Dom, Ind, Irr)}}{\text{Supply (Runoff, Inflow)}}$$

2. UNMET DEMAND (UD) [FRACTION OR %]
   - INDICATOR OF THE DIRECT HUMAN IMPACT

$$UD = 1 - \frac{\text{Total Consumption}}{\text{Total Demand}}$$



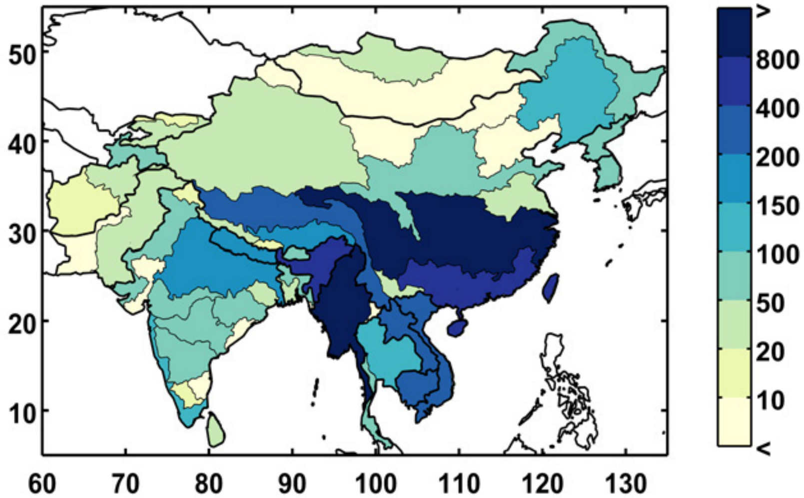
$$OBJ = \frac{\sum_{mth} SRR_{mth}}{12} + \min(SRR) - \frac{\sum_{mth} SPILL_{mth}}{STC} + \frac{ST_{end\_yr}}{STC} - 100(\min(ST - EVAP, 0))$$

DESCRIPTION OF ENSEMBLE SIMULATION GROUPS

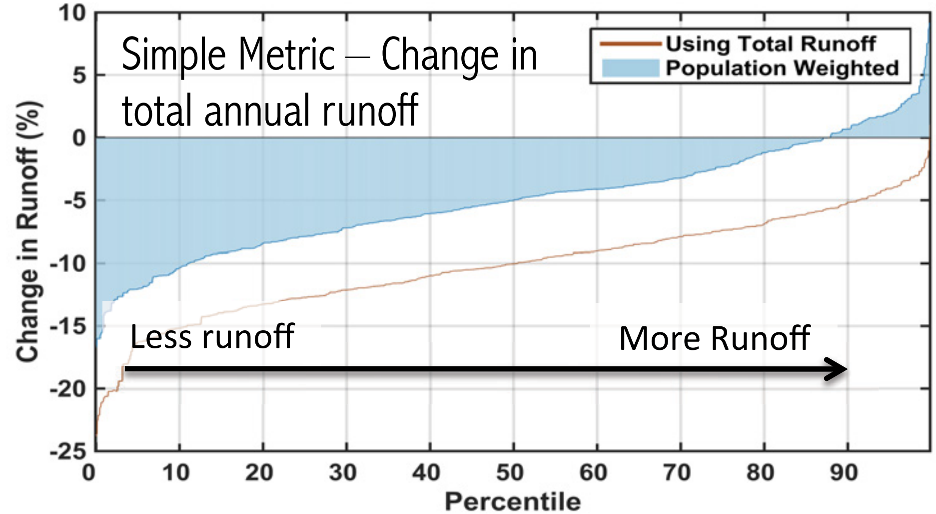
- **BASELINE:**
  - PRINCETON DATA (1951-2000)
  - DETRENDED
  - DETRENDED TIMESERIES IS ALIGNED TO 2000 MEAN.
- **JUST GROWTH:**
  - BASELINE CLIMATE
  - GDP AND POPULATION FROM THE EPPA UNCERTAINTY WORK (400 SCENARIOS)
- **JUST CLIMATE:**
  - SUBSET OF CLIMATES (551) SELECTED FROM THE 6,800 PAIRED CLIMATE/SOCIO-ECONOMIC PROJECTIONS USING GAUSSIAN THINNING PROCEDURE
  - GDP AND POPULATION ARE SET TO YEAR 2000 VALUE
- **CLIMATE AND GROWTH:**
  - SUBSET OF PAIRED CLIMATE AND SOCIO-ECONOMIC PROJECTIONS (551)
  - GDP AND POPULATION FROM EPPA UNCERTAINTY
- **BOOTSTRAP:**
  - K-NN BOOTSTRAP FOR HISTORICAL VARIABILITY (500)

CHANGES IN CLIMATE – RUNOFF (%)

Baseline (BCM)



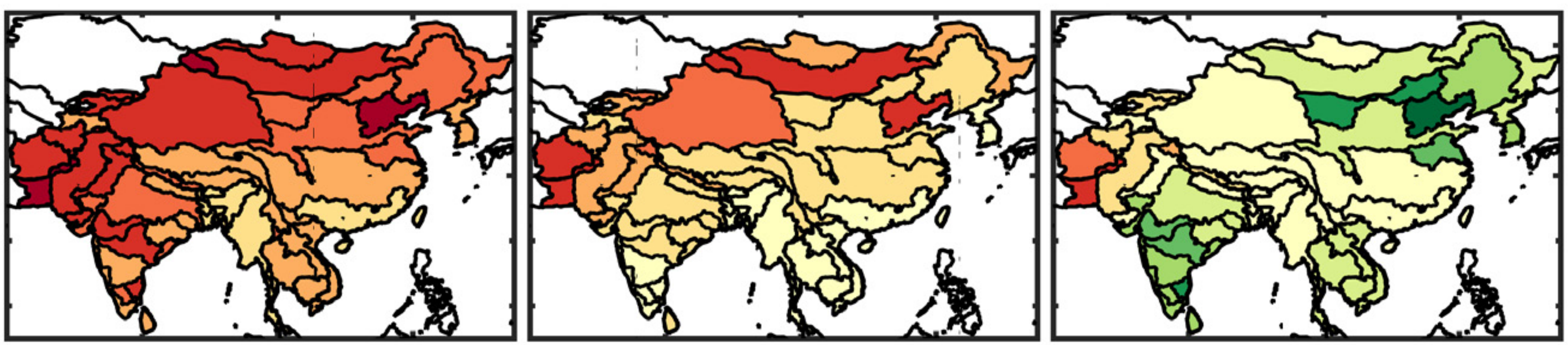
Scenarios Sorted from Driest to Wettest

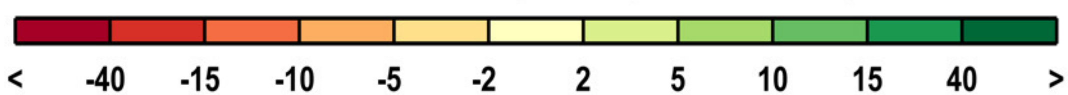


10th Percentile

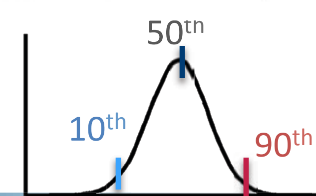
Median

90th Percentile





Runoff (%) – Change from Baseline



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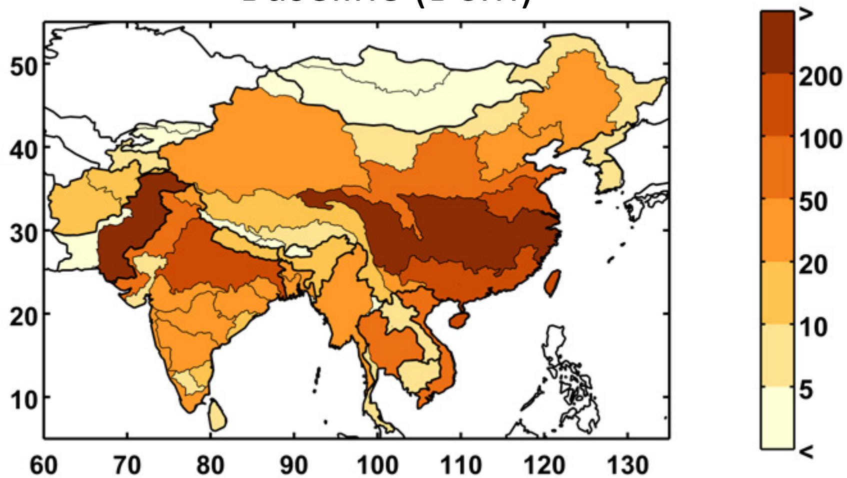
Changes in Climate - Irrigation Requirement

Fant et al., 2015

Baseline (BCM)



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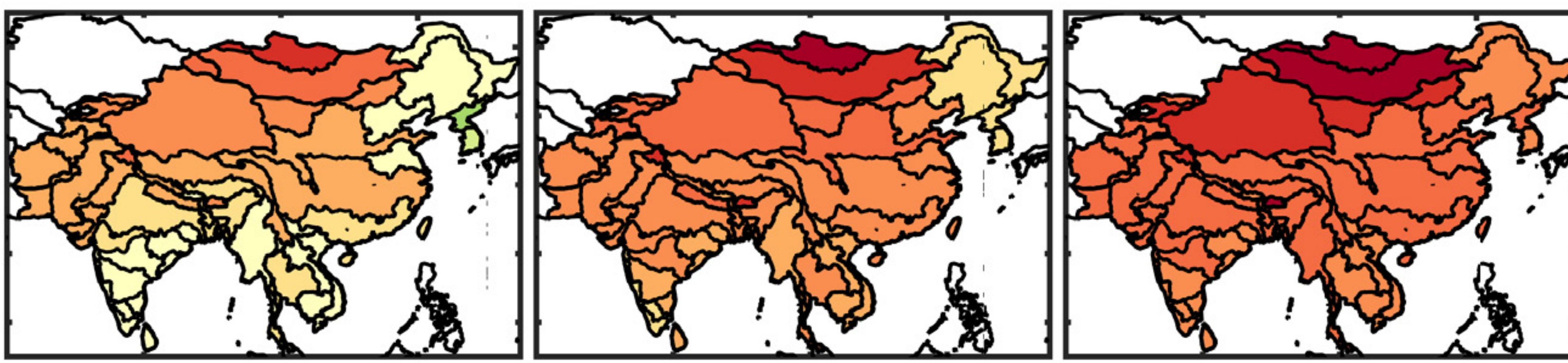
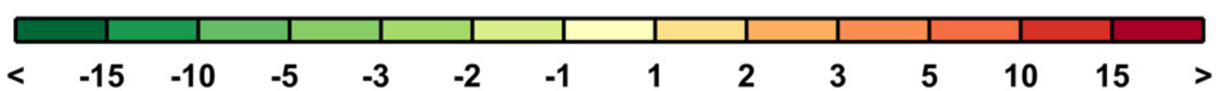
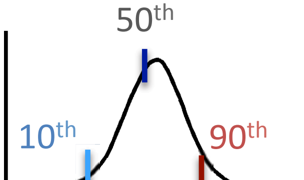
90th Percentile







Irrigation Demand (%) – Change from Baseline

http://globalchange.mit.edu/

MIT Joint Program on the Science and Policy of Global Change

Change in decadal averaged water stress (2041-2050) Effect of Mitigation Policy (L2E)

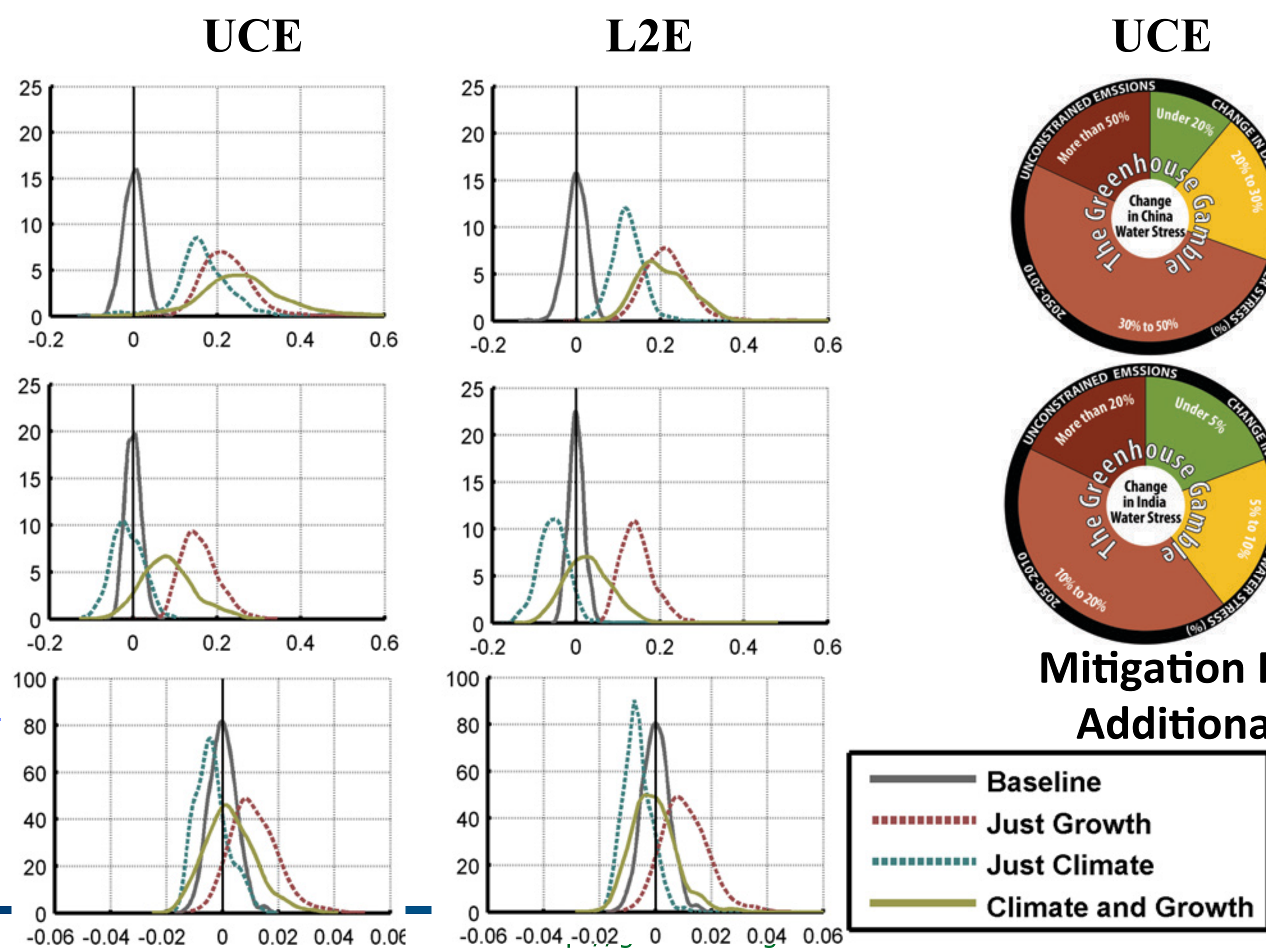
Change in Water Stress Index (WSI)

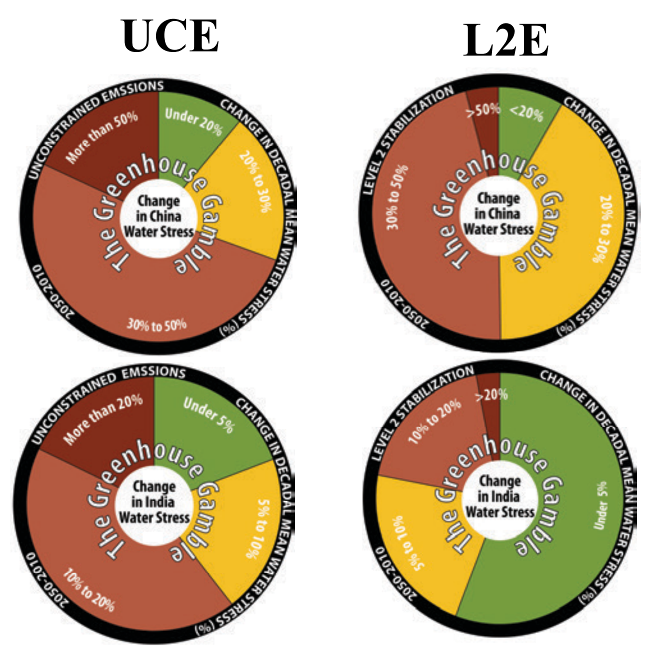
“Gamble” of WSI Change

China
Baseline
WSI : 0.87

India
Baseline
WSI: 0.70

Mainland SEA



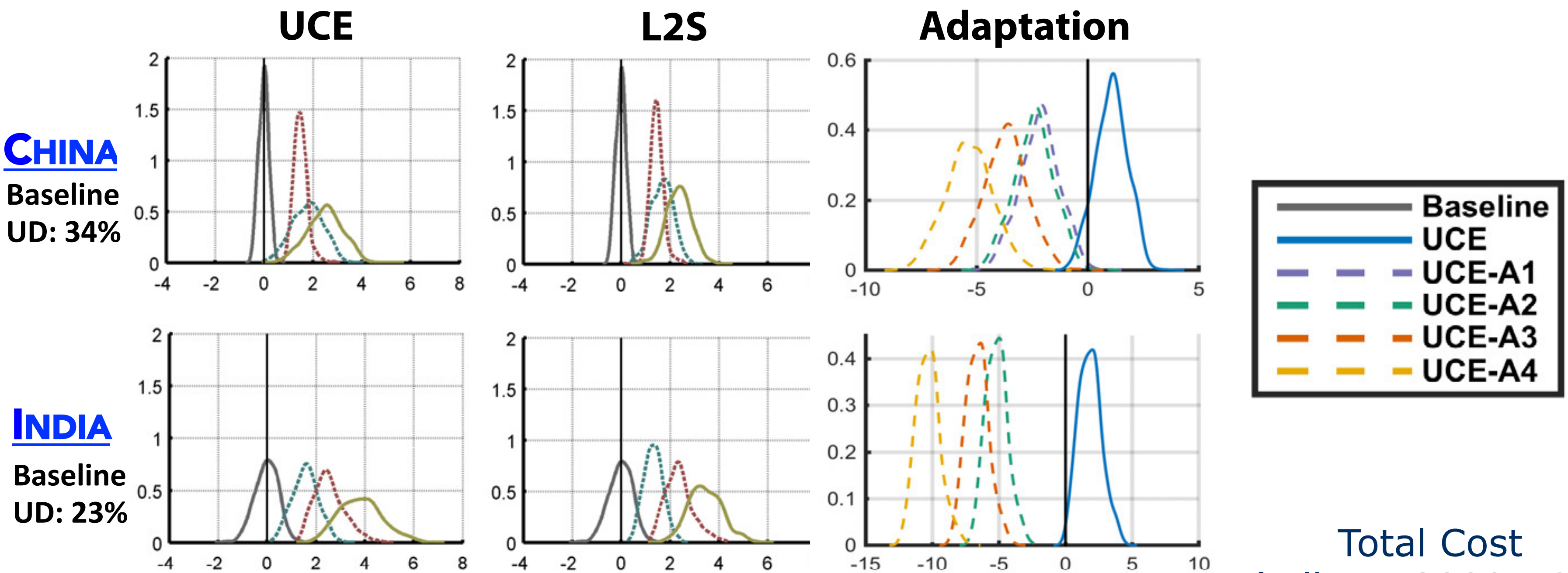


Mitigation Reduces Risks to Additional Water Stress

Gao et al., 2015 (forthcoming)

GLOBAL CHANGE

Change in decadal averaged Unmet Demand in 2040s
Mitigation Vs. Adaptation



Adaptation Scenarios

A1: UCE with lined canals
A2: A1 with all irrigated lands at least furrow
A3: A1 with all irrigated lands at least low efficiency sprinklers
A4: A1 with all irrigated lands high efficiency sprinklers

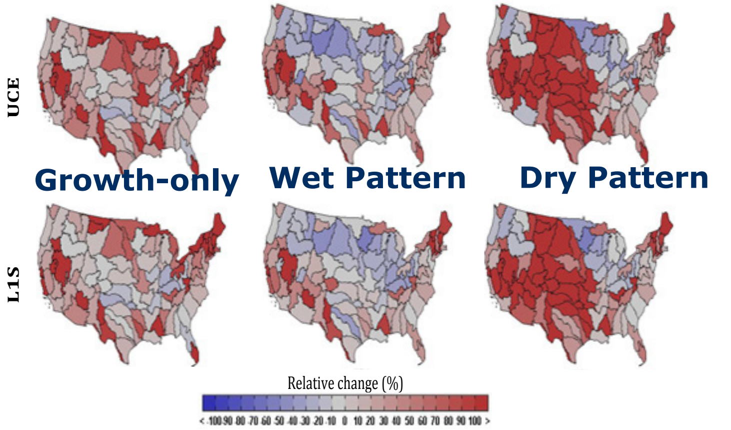
Total Cost
(Billions 2000 US$)

	China	India
L2S	400	40
A1	35	23
A2	6	2
A3	81	73
A4	142	114

China 2050 population: 1.4 billion people
India 2050 population: 1.7 billion people

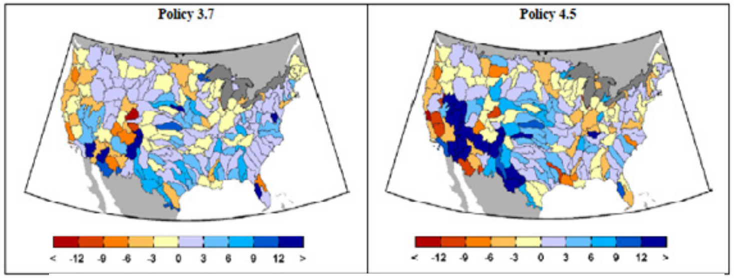
Upcoming Studies For the United States

- **Impacts and Risks to Water and Crops**
  - Repeat Asia and CIRA ensemble-scenario framework with WRS-US model.
  - Assess impacts of mitigation policies and adaptation strategies on water-stress changes.

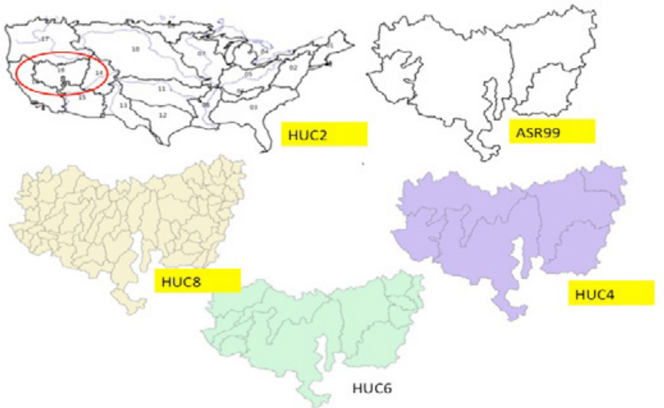


- **Water Quality and Temperature**
  - Implement QUALIDAD model into IGSM framework.
  - Augment the existing WRS-US model configuration.
  - Apply subset of IGSM scenarios and evaluate.
  - Consider a number of water quality aspects.
    - DO, nitrogen, phosphorus, (generic) metal, and salinity

Percentage Change: Dissolved Oxygen (DO)



- **Appropriateness and Efficacy of Resolution**
  - Exercise WRS-US and QUALIDAD in IGSM framework.
  - Consider range of Hydrologic Unit Code (HUC) scales.
  - What is minimal scale to provide reliable response?
  - Consider a variety of US-WRS outputs.



THANK YOU

- Growth impact on water requirement
- Granularity of regional climate change
- Land-use, irrigation change, and other uncertainties
- Population, urbanization, resource interplay
- Mitigation modal & marginal distributional effects
- Nature vs. Nourishment: Why should we adapt and the social cost(s) of water

Section 4

Discussion of Emerging Issues and Assessment Needs