Climate Science Now and in the Future

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Chair, Joint Scientific Committee,
World Climate Research Programme (WCRP)

Chair, NAS/NRC Board on Atmospheric Sciences and Climate (BASC)

Chair, NOAA Climate Working Group (CWG)

Mission & Objectives

- **World Climate Research Programme** supports **climate-related decision making** and planning **adaptation to climate change** by coordinating research required to improve

(1) climate predictions and

(2) our understanding of human influence on climate

"for use in an increasing range of practical applications of direct relevance, benefit and value to society"
(WCRP Strategic Framework 2005-2015).

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The Belmont Challenge

To deliver knowledge needed for action to mitigate and adapt to detrimental environmental change and extreme hazardous events.

This requires:

- Information on the state of the environment, through advanced observing systems;
- Assessments of risks, impacts and vulnerabilities, through regional and decadal analysis and prediction;
- Enhanced environmental information service providers to users;
- Inter-and transdisciplinary research which takes account of coupled natural, social and economic systems;
- Effective integration and coordination mechanisms, to address interdependencies and marshal the necessary resources.

BELMONT FORUM

ESSP DIVERSITAS IGBP IHDP WCRP

WCRP World Climate Research Programme

WMO IOC ICSU

WCRP OPEN SCIENCE CONFERENCE

CLIMATE RESEARCH IN SERVICE TO SOCIETY

Monday:	**The Climate System Components and their Interactions**
Tuesday:	**Observation and Analysis of the Climate System**
Wednesday:	**Assessing and Improving Model and Predictive Capabilities**
Thursday:	**Climate Synthesis and Assessments**
Friday:	**Translating Scientific Understanding into Climate Information for Decision Makers**

24–28 October 2011, Denver, Colorado, USA

conference2011.wcrp-climate.org

Future Directions: Actionable Science

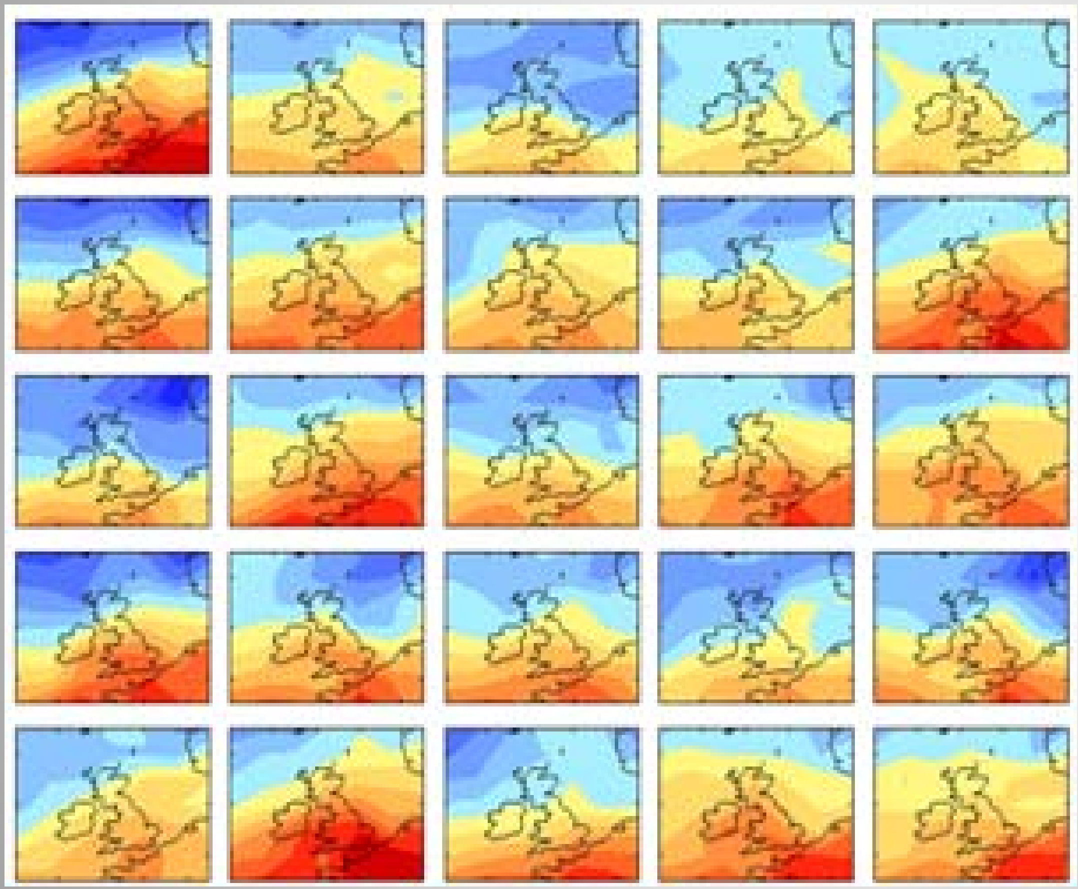
Defined as: data, analysis, and forecasts that are sufficiently predictive, accepted and understandable to support decision-making, including capital investment decision-making.

- World Climate Conference-3, OceanObs '09, ICSU Review and Visioning, acknowledge WCRP past contributions and identify future challenges and opportunities.

- Need for more flexibility/agility to respond to expanding users needs, that includes information:
  - At regional scale
  - For key sectors of global economy
  - For adaptation, mitigation and risk management

Grand Challenges

Seamless prediction from global to regional scales



Seamless Ensemble Prediction is about quantifying and understanding uncertainties in climate projections on a range of time scale (monthly to seasonal, decadal and long-term). Where it is feasible and justified, this involves making probabilistic projections from observations and ensembles of climate model simulations, so decision-makers can use them in risk-based approaches for planning their adaptation and mitigation strategies.

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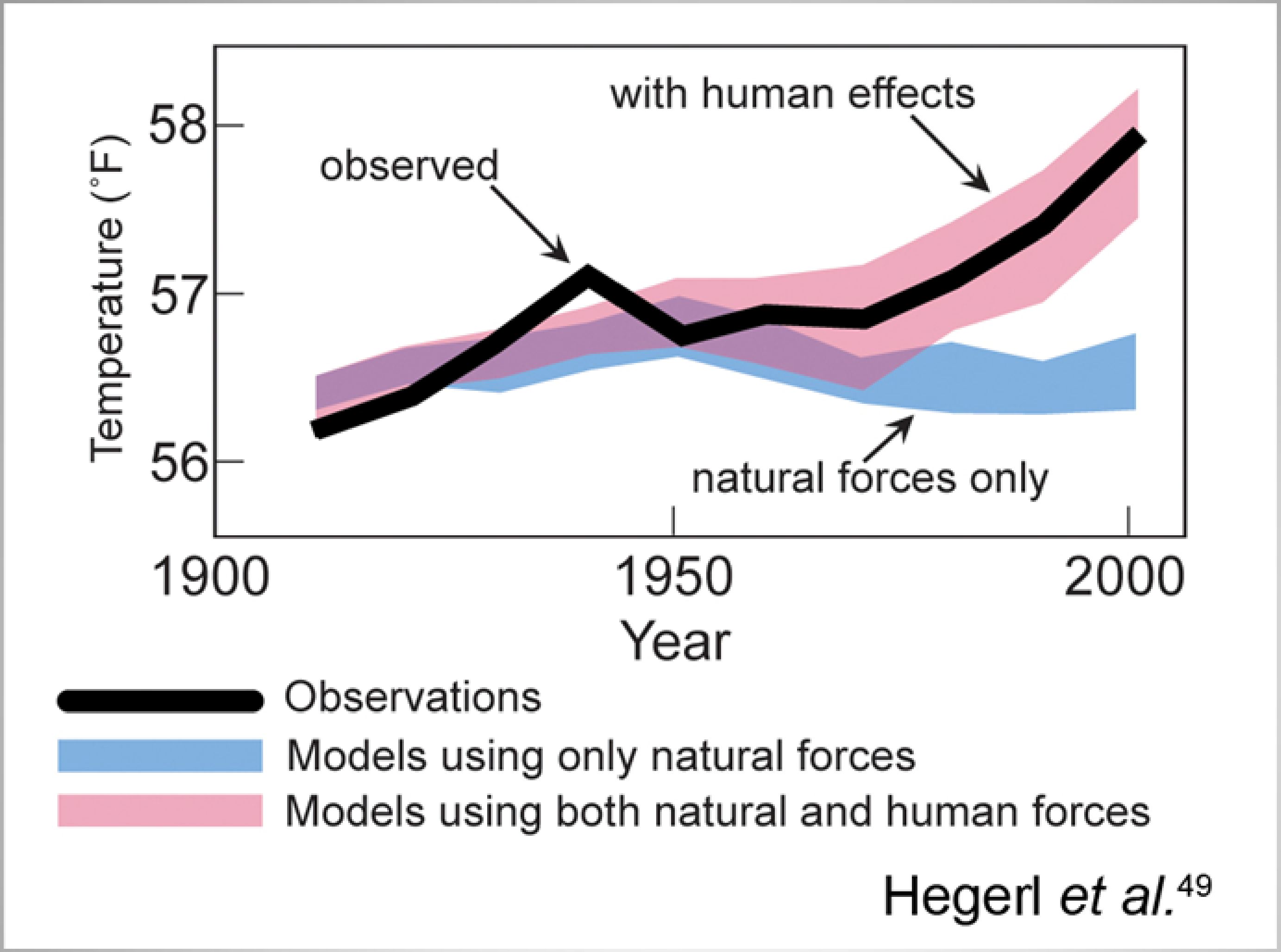

The blue band shows how global average temperatures would have changed due to natural forces, only as simulated by climate models. The red band shows model projections of the effects of human and natural forces combined. The black line shows actual observed global average temperatures. As the blue band indicates, without human influences, temperature over the past century would actually have first warmed and then cooled slightly over recent decades.

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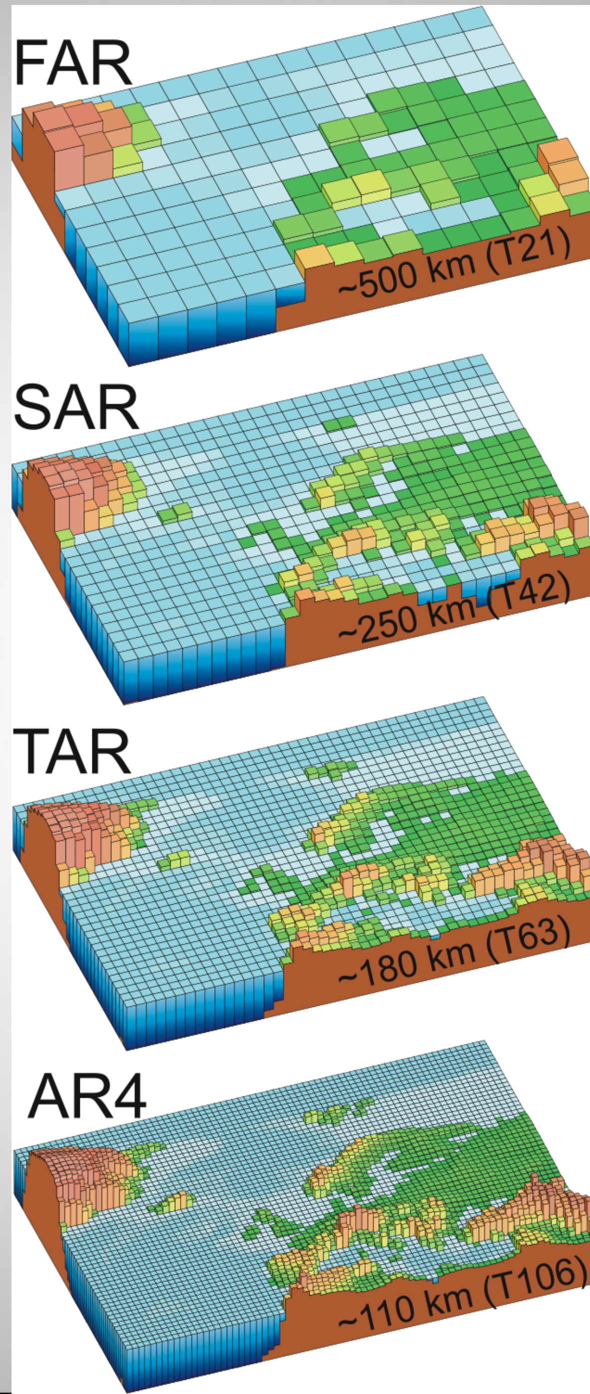


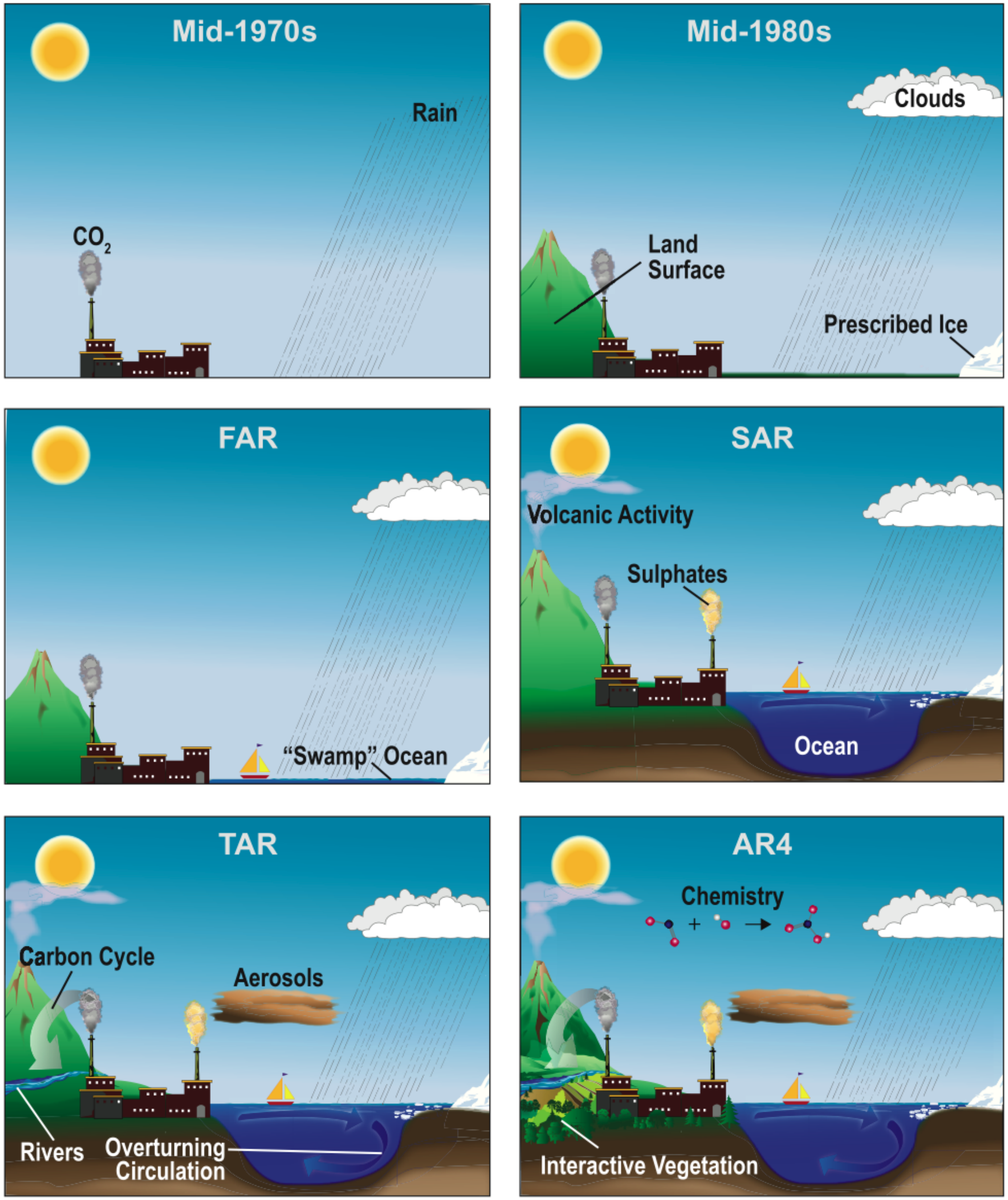
1990

1996

2001

2007

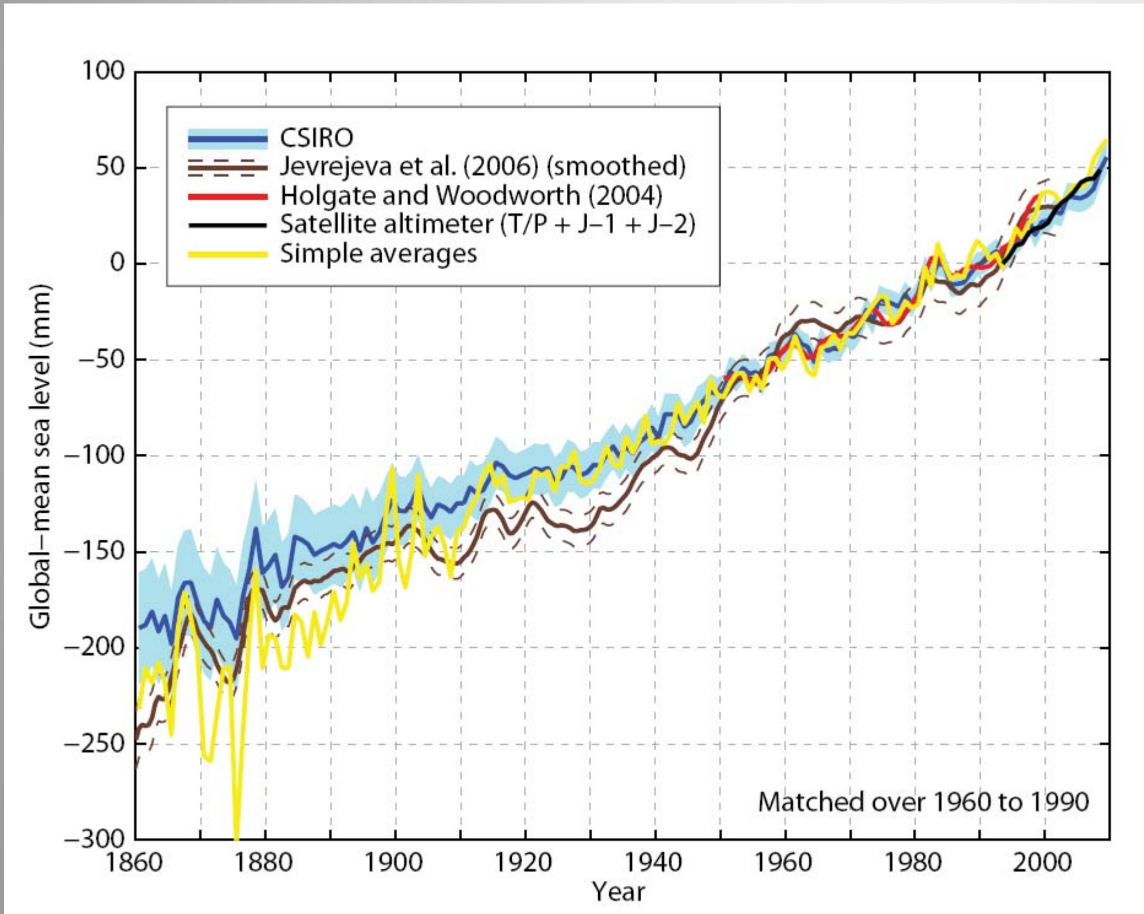
The World in Global Climate Models



Grand Challenges

Regional sea level rise

Yearly sea level anomalies (mm)



Multi-decadal (>10 yrs), decadal (~10 yrs) and interannual variability (<10 yrs) superimposed on a **multi-century rising trend** (**1880-2009**) of about **2.1 mm/yr (Church and White, 2011)**. Larger uncertainties (less observations) in the earlier part of the record.

If sea level were to rise as much as 1-meter (3.3 foot), the areas in pink would be susceptible to coastal flooding. With a 6-meter (19.8 foot) rise in sea level, areas shown in red would also be susceptilbe. The pie charts show the percentage area of some cities that are potentially susceptible at 1-meter and 6-meter sea level rise. Source: National Research Council, 2010a.

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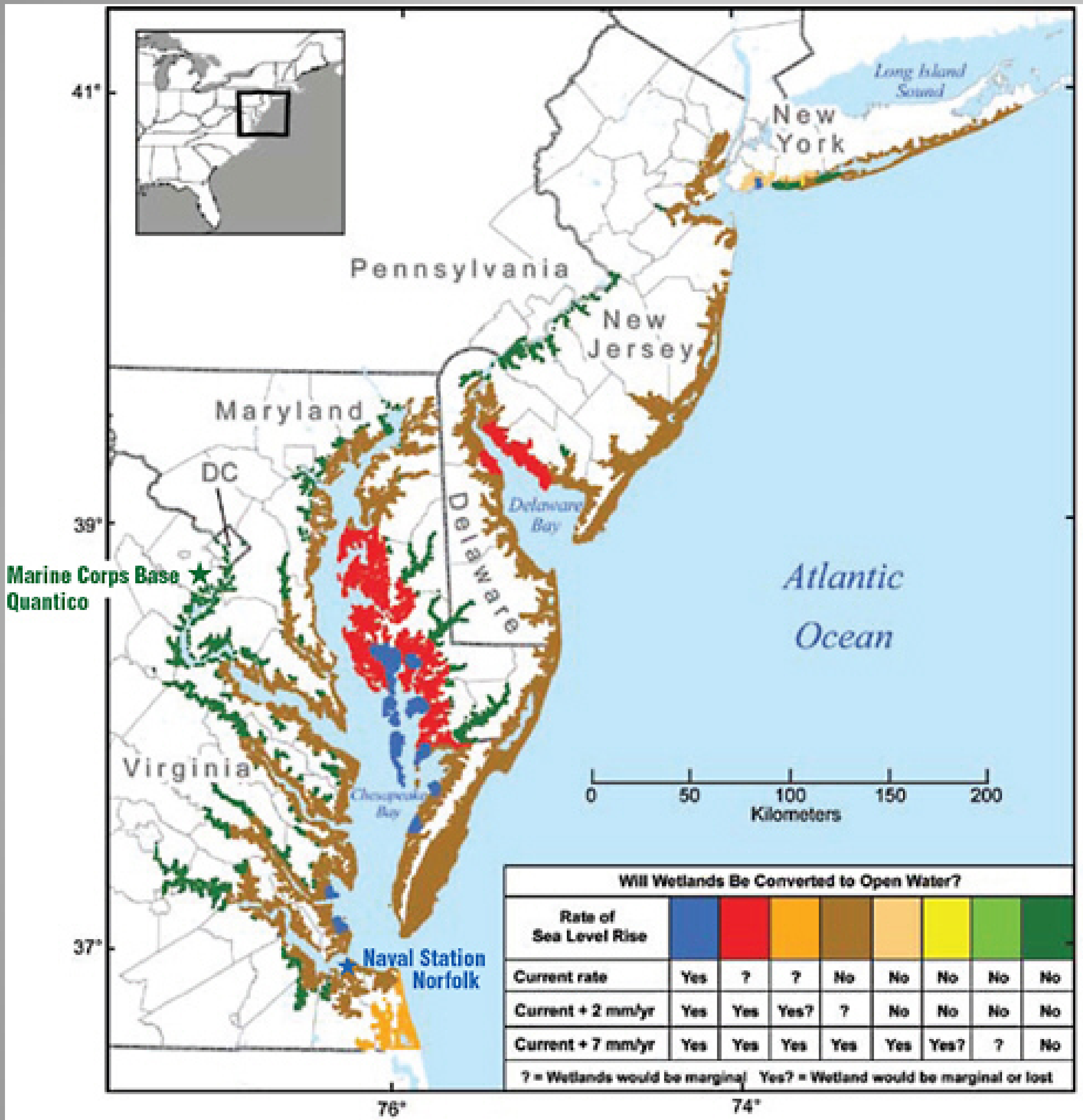

Potential regional impact of future sea-level rise. Several static and dynamic models are being developed for projecting the regional impact of sea-level rise. This figure shows potential impact to wetlands in the U.S. mid-Atlantic region under various sea-level rise scenarios (areas where wetlands would be marginal or lost [i.e., converted to open water] under three sea-level rise scenarios, in millimeters [mm] per year [yr]). Such scenarios may be applicable on a gross scale for judging first-order impact on naval installations. SOURCE: Reprinted from Figure ES.2, *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region*.

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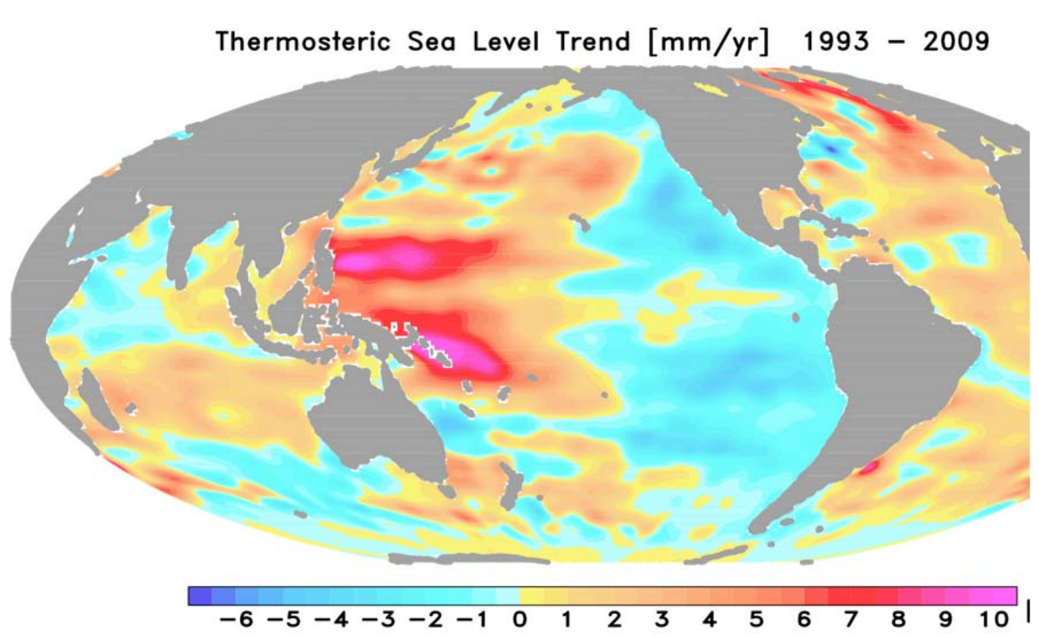
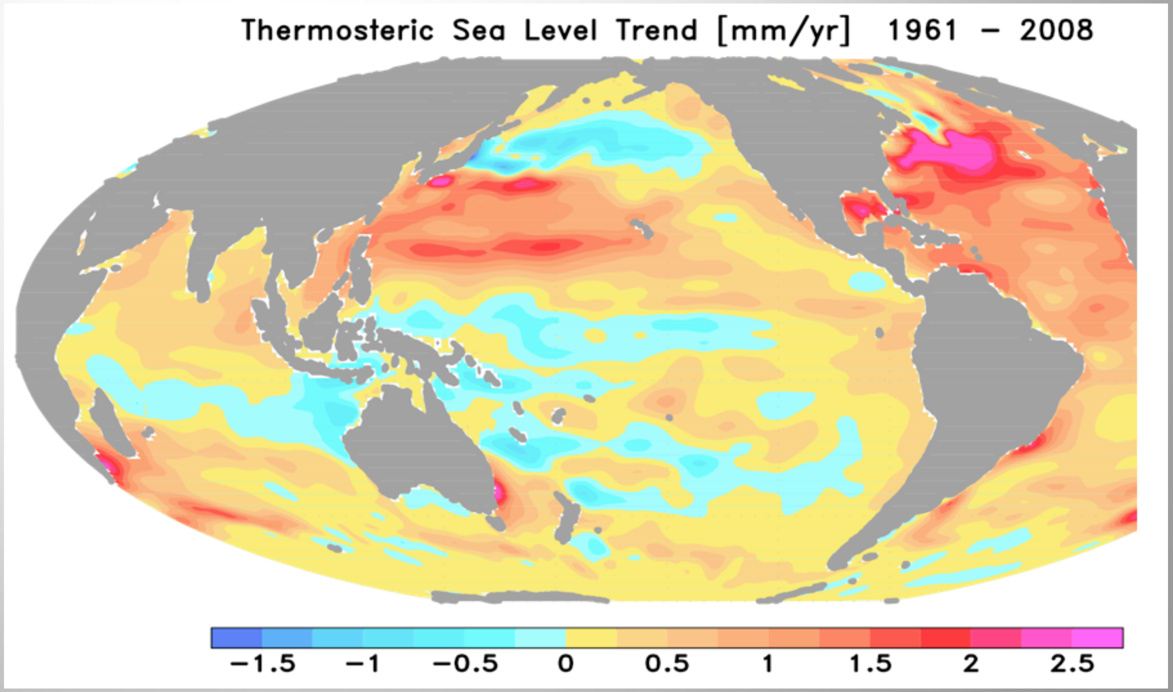


Sea level fall along the U.S. west coast and rise in the western tropical Pacific Ocean since early 1990s appears to result from the phase change of the Inter-basin Pacific Decadal & multi-decadal Variability

(Weiqing Han et al., University Colorado, 2011)



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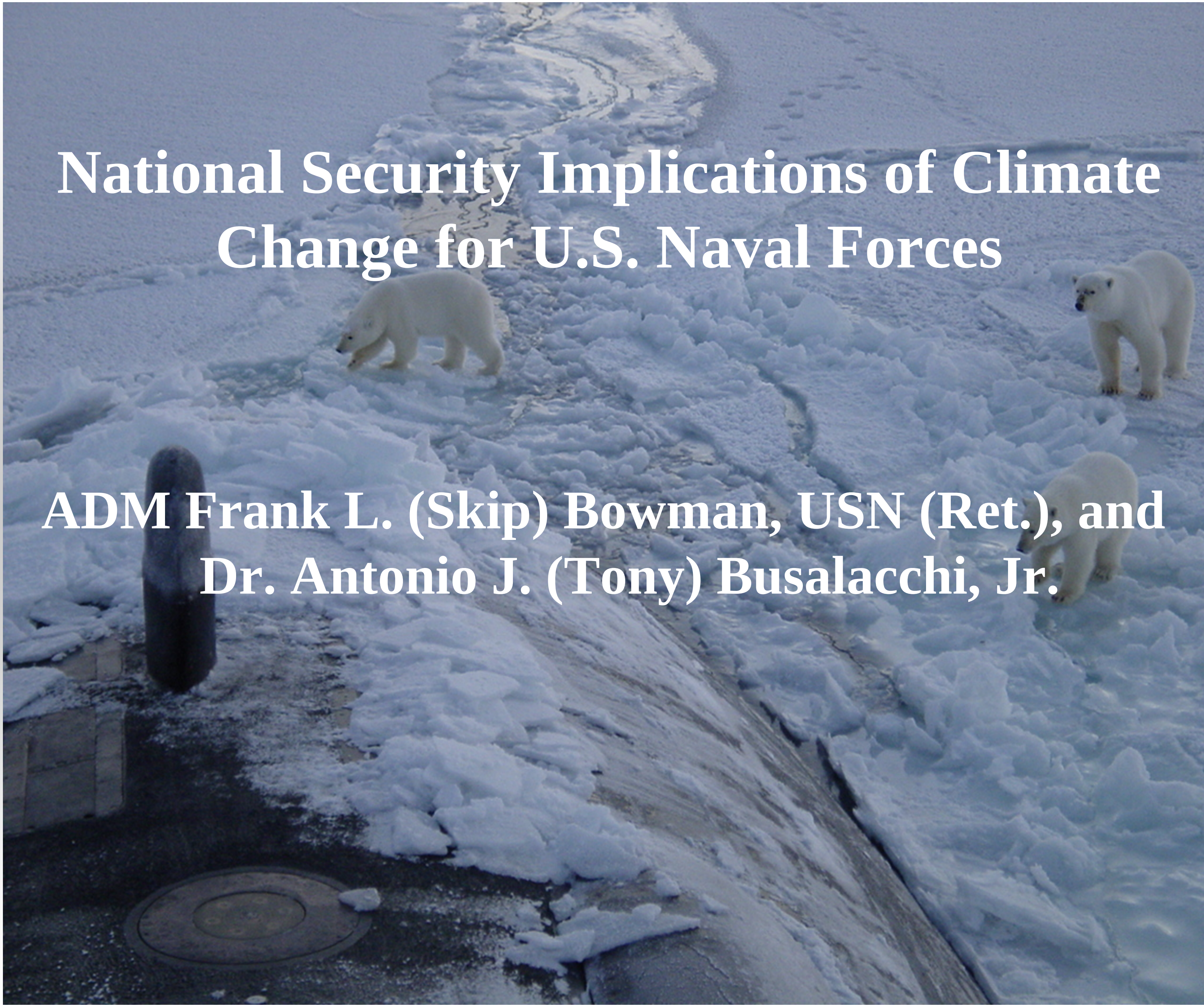
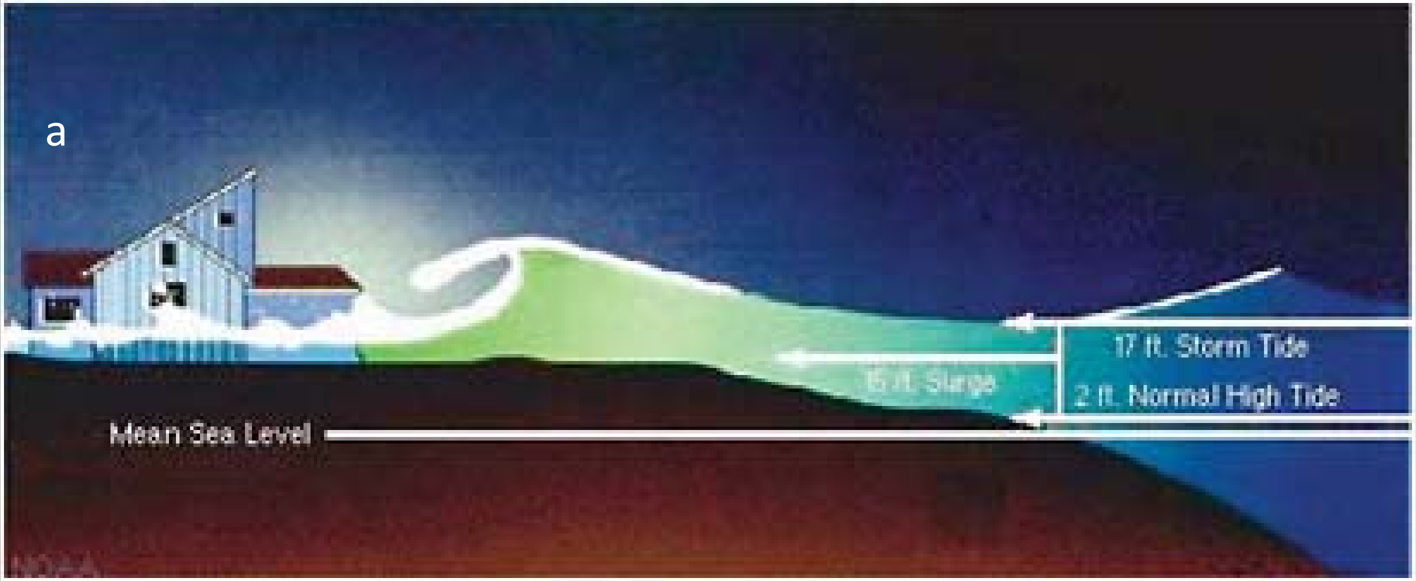


National Security Implications of Climate Change for U.S. Naval Forces

ADM Frank L. (Skip) Bowman, USN (Ret.), and
Dr. Antonio J. (Tony) Busalacchi, Jr.

NAVAL STUDIES BOARD



Courtesy of NOAA

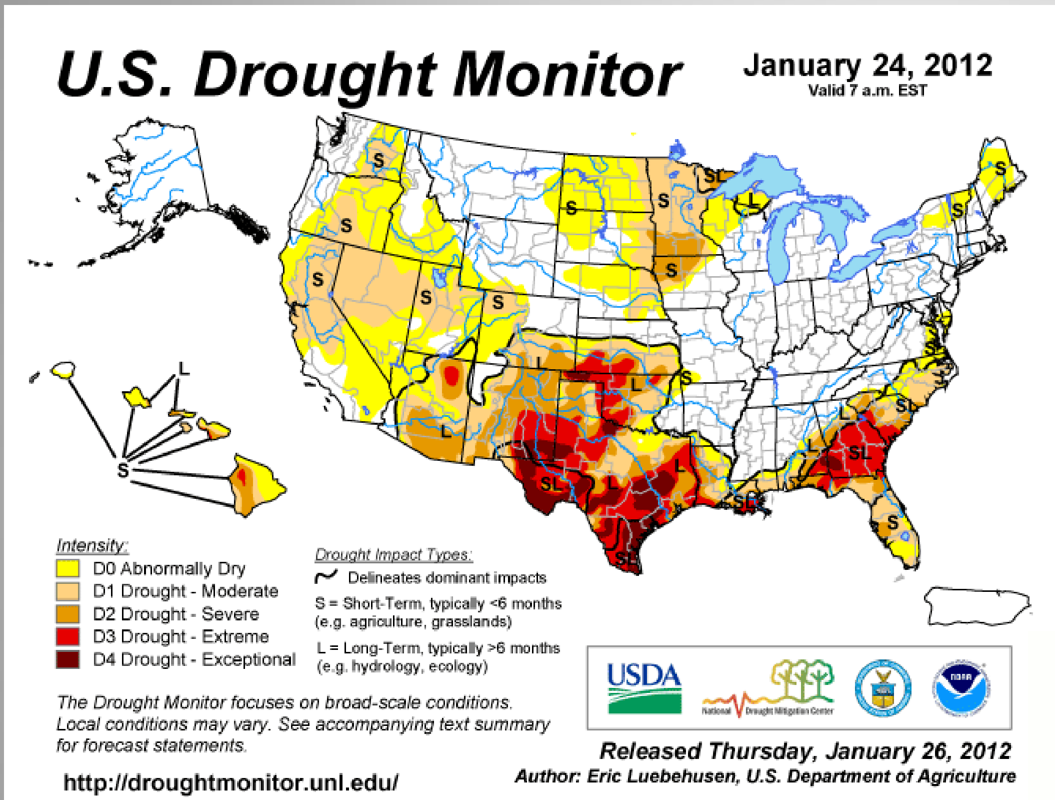
- **Much like global mean temperature, global mean sea level is a convenient metric but tells us little about future sea level rise on regional scales**

- **In addition to thermosteric changes, regional sea level rise will be influenced by changes to:**
  - **Storm surge**
  - **Ocean circulation**
  - **Atmospheric circulation and storm tracks**
  - **Tidal amplitudes**
  - **Subsidence**

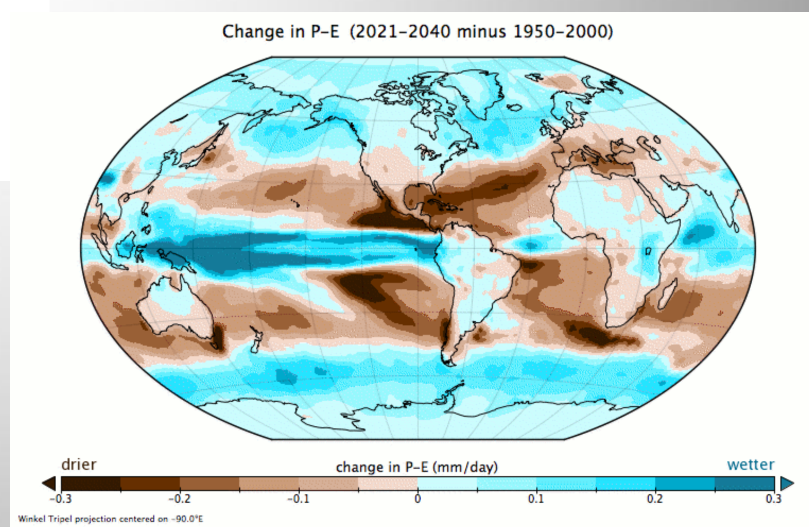
- **Taken together, regional sea level rise can be 10X the global mean**

Grand Challenges

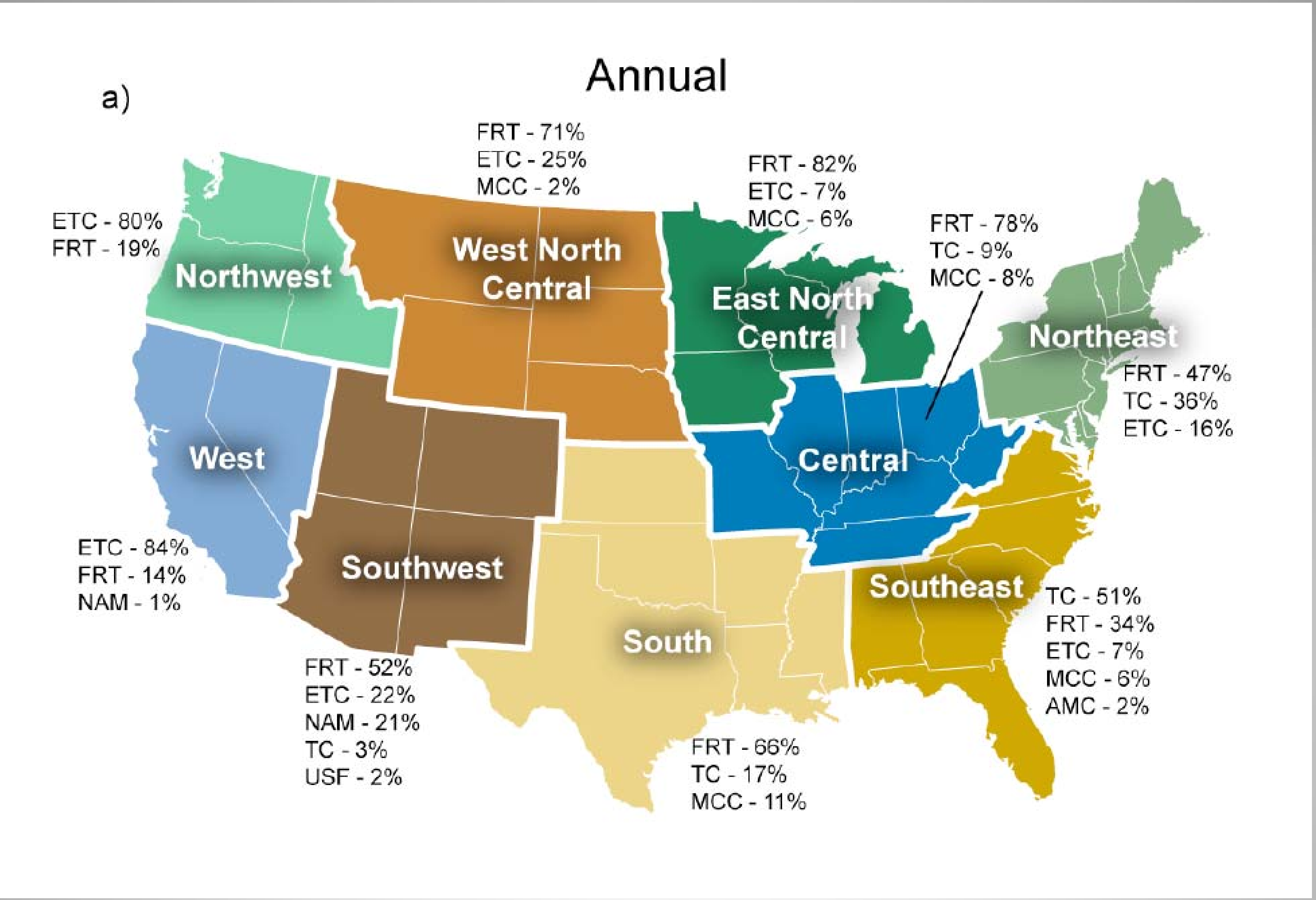
Extreme Events



National Integrated Drought Information System (NIDIS)



Change in precipitation (P) minus surface evaporation (E) for the 2021-2040 period minus the average over 1950-2000. Results are averaged over simulations with 19 different climate models. P-E is the net flux of water at the surface that, over land, sustains soil moisture, groundwater and river runoff. Figure by N. Naik.



TC – Tropical Cyclones
FRT – Fronts
ETC – non frontal Extratropical cyclones
MCC – mesoscale convection
AMC – air mass convection
NAM – north american monsoon
USF – upslope flow

Cause (%) of US Extreme Events from 1908-2009
(K. Kunkel 2011 WCRP Open Science Conference)

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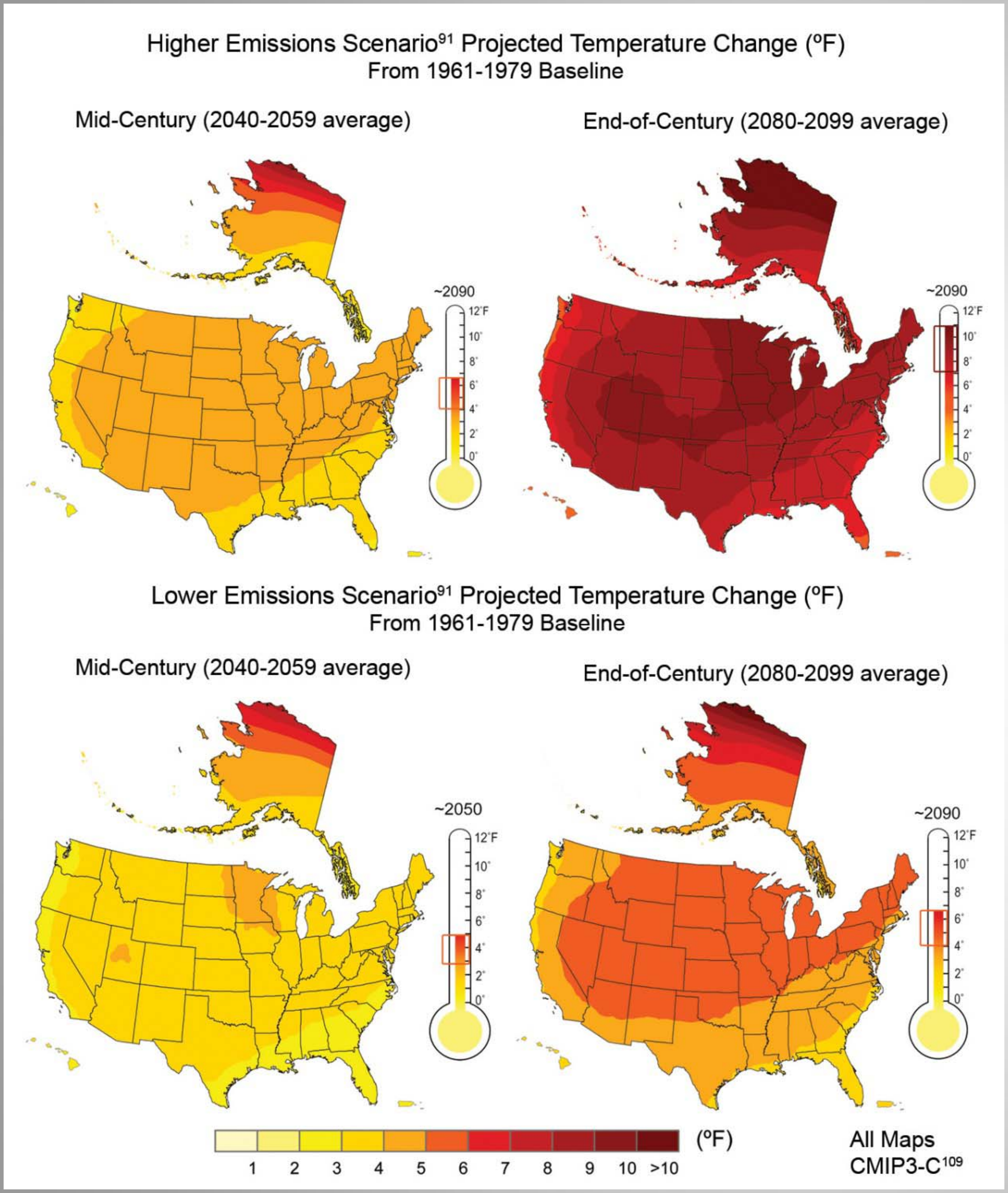

The maps are based on projections of future temperature by 16 of the Coupled Model Intercomparison Project Three (CMIP3) climate models using two emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC) *Special Report on Emission Scenarios* (SRES). The “lower scenario here is B1, while the “higher” is A2. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible.

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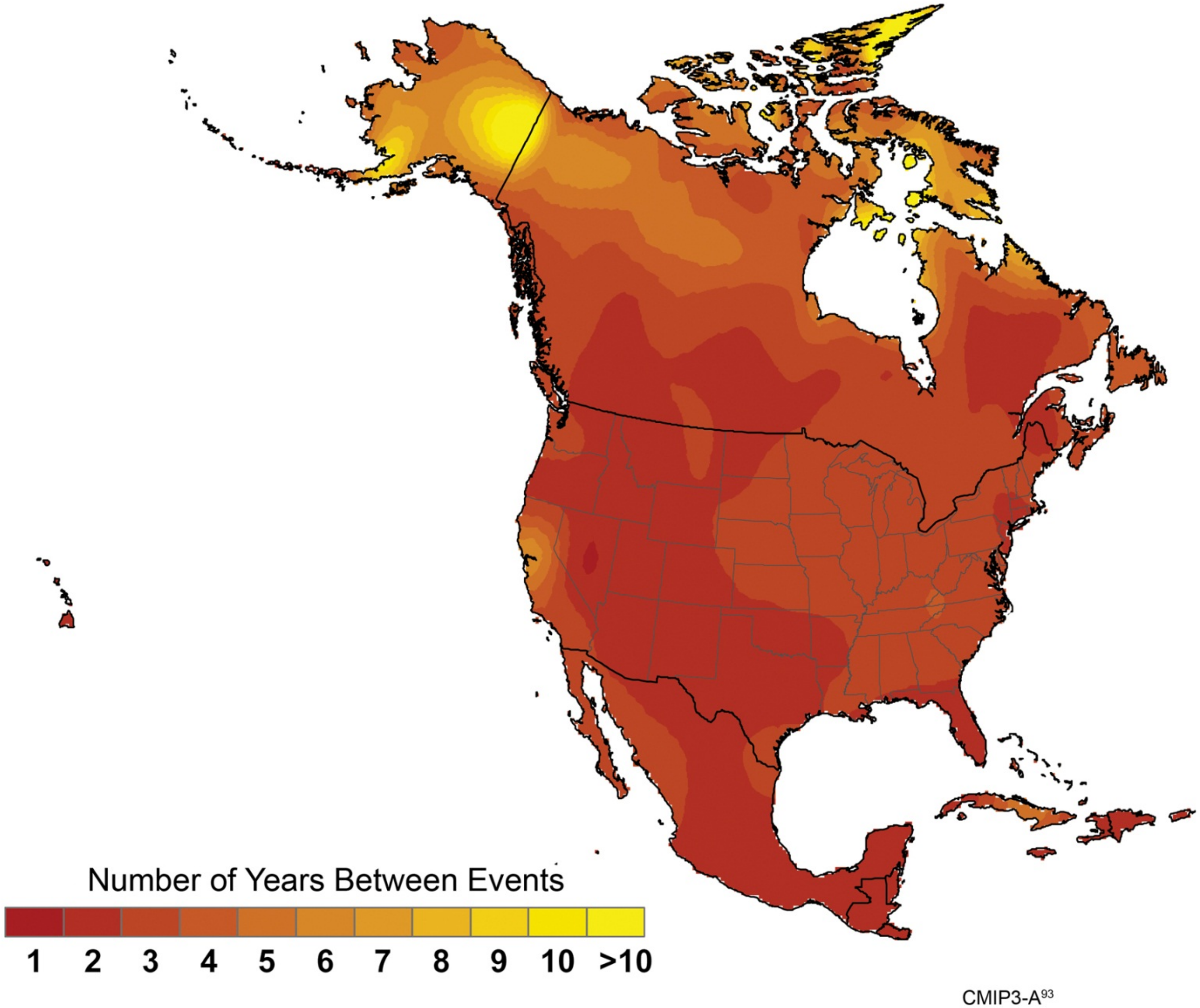

Simulations for 2080-2099 indicate how currently rare extremes (a 1-in-20-year event) are projected to become more commonplace. A day so hot that it is currently experienced once every 20 years would occur every other year or more frequently by the end of the century under the higher emissions scenario.[91]

"A day so hot that is currently experienced once every 20 years would occur every other year or more frequently by the end of the century"

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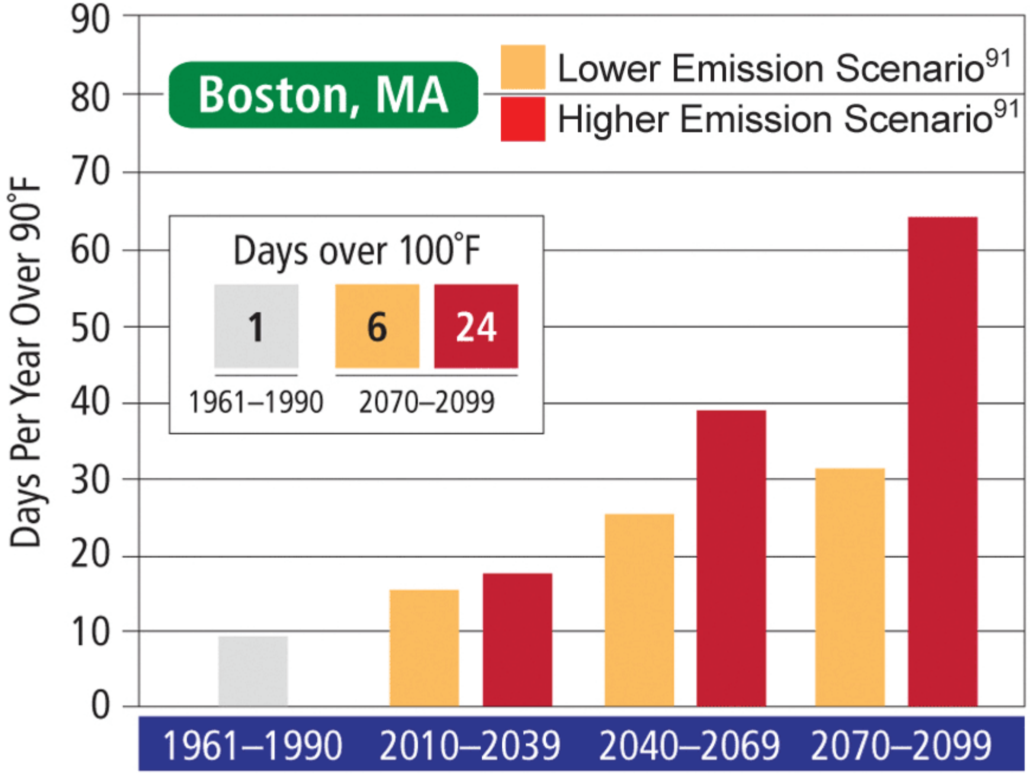
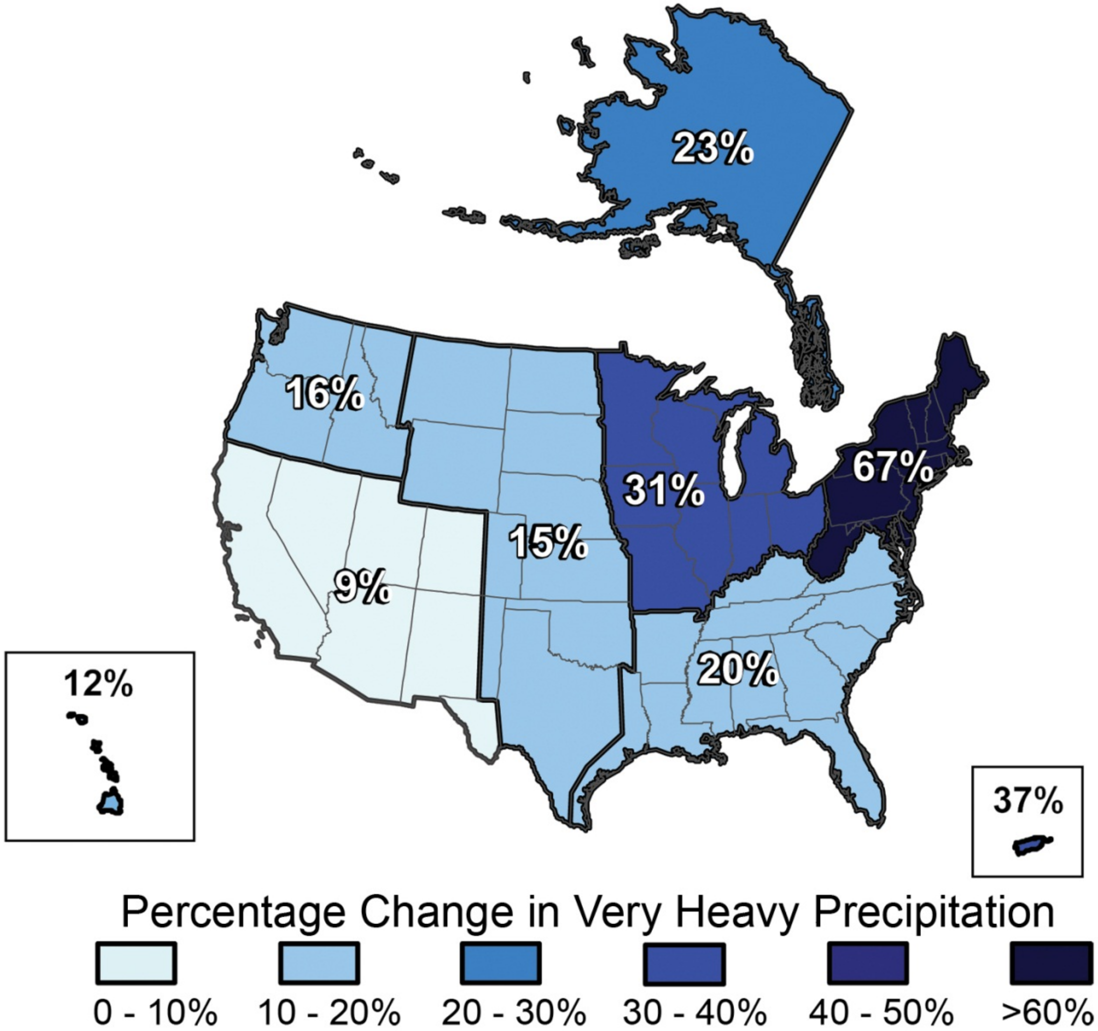


Hayhoe *et al.*[359]

The graph shows model projections of the number of summer days with temperatures over 90°F in Boston, Massachusetts, under lower and higher (referred to as "even higher" on page 23) emissions scenarios.91 The inset shows projected days over 100°F.[359]



Updated from Groisman *et al.*[113]

The map shows the percentage increases in very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

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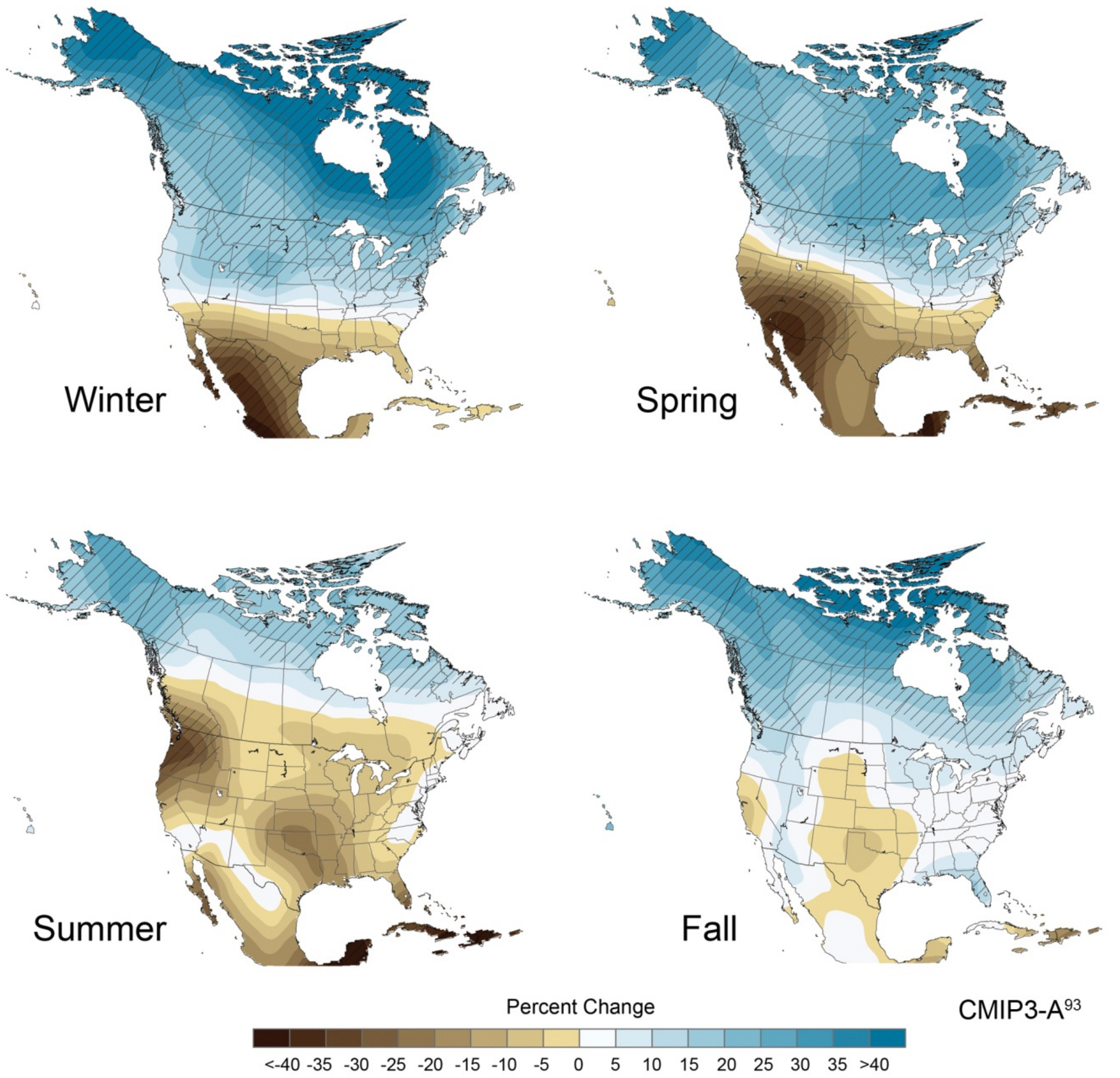

The maps show projected future changes in precipitation relative to the recent past as simulated by 15 climate models. The simulations are for late this century, under a higher emissions scenario.[91] For example, in the spring, climate models agree that northern areas are likely to get wetter, and southern areas drier. There is less confidence in exactly where the transition between wetter and drier areas will occur. Confidence in the projected changes is highest in the hatched areas.

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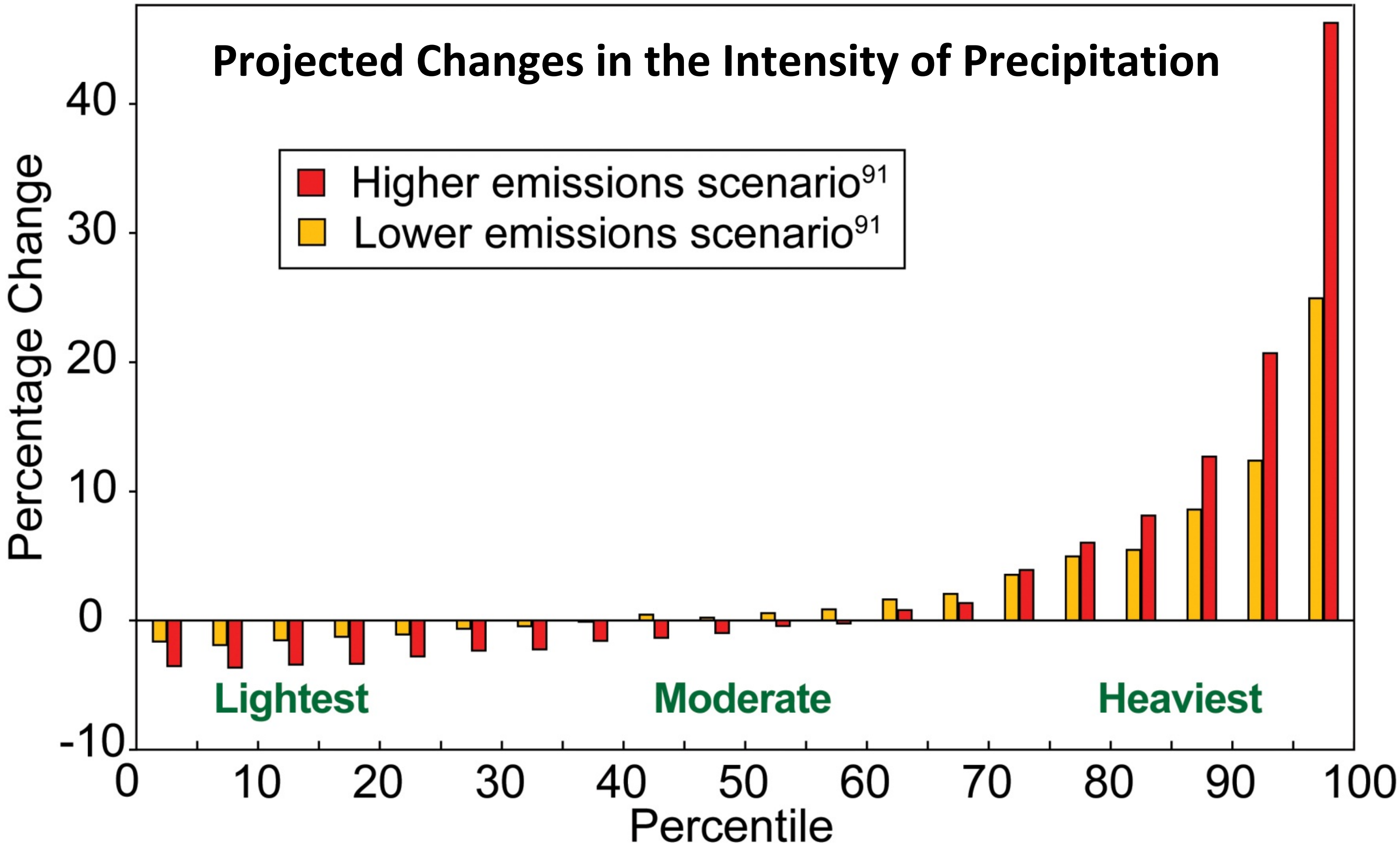

CCSP SAP 3.3[68]

The figure shows projected changes from the 1990s average to the 2090s average in the intensity of precipitation in North America displayed in 5 percent increments from the lightest drizzles to the heaviest downpours. As shown here, the lightest precipitation is projected to decrease, while the heaviest will increase, continuing the observed trend. The higher emission scenario[91] yields larger changes. Projections are based on the models used in the IPCC 2007 Fourth Assessment Report.

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Grand Challenges: Prediction of the Earth System

GOALS:

- Deliver knowledge to respond to global change
- Engage a new generation of researchers
- Transition to the full range of sciences and humanities

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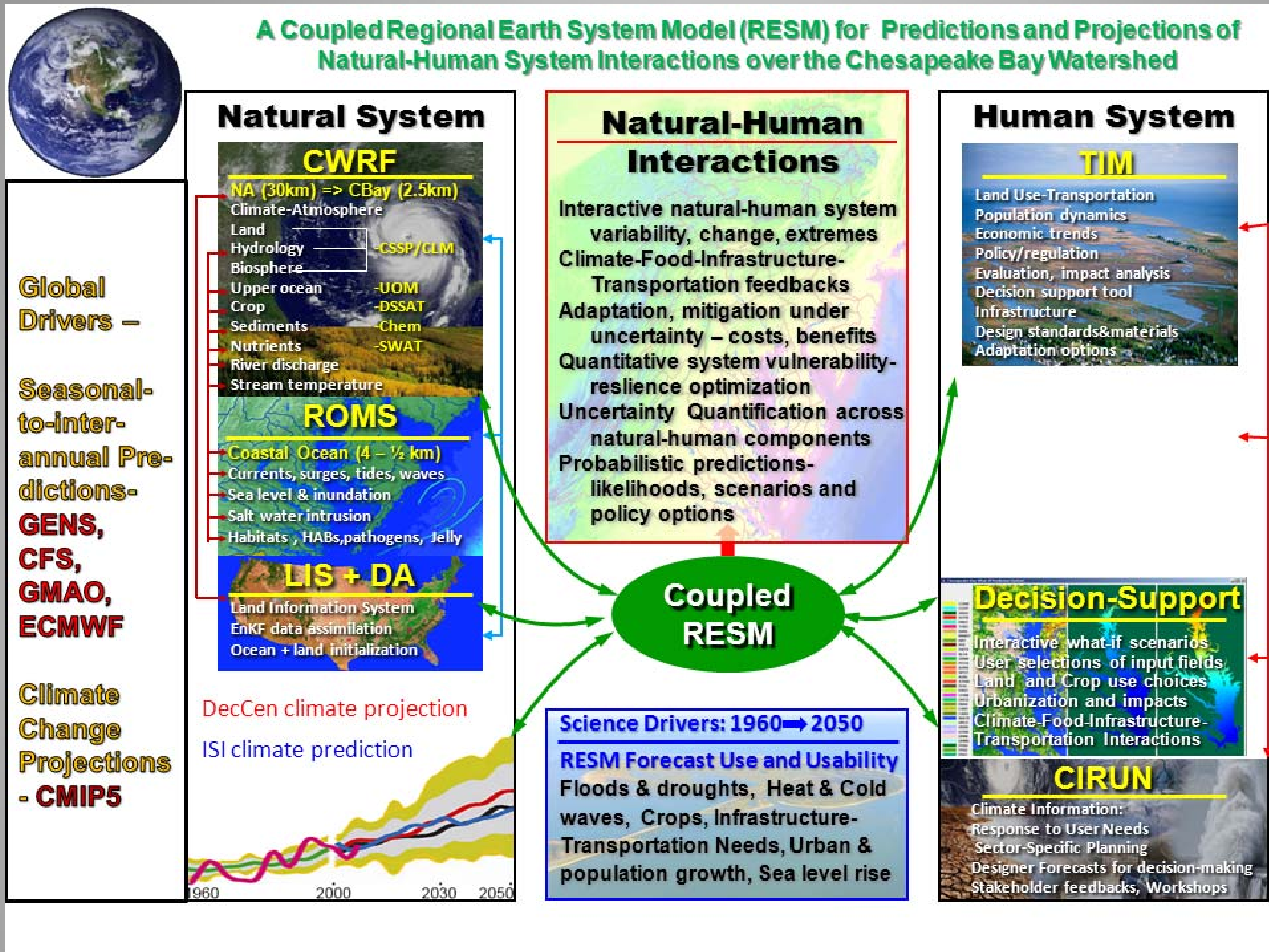

Regional Earth System Model (RESM) framework for predictions and projections of natural-human system interactions over the Chesapeake Bay watershed. The Natural System is represented by CWRF and is fully coupled with transportation-infrastructure and vulnerability-resilience models. Predictions and projections from days to decades will be delivered to users from various sectors.

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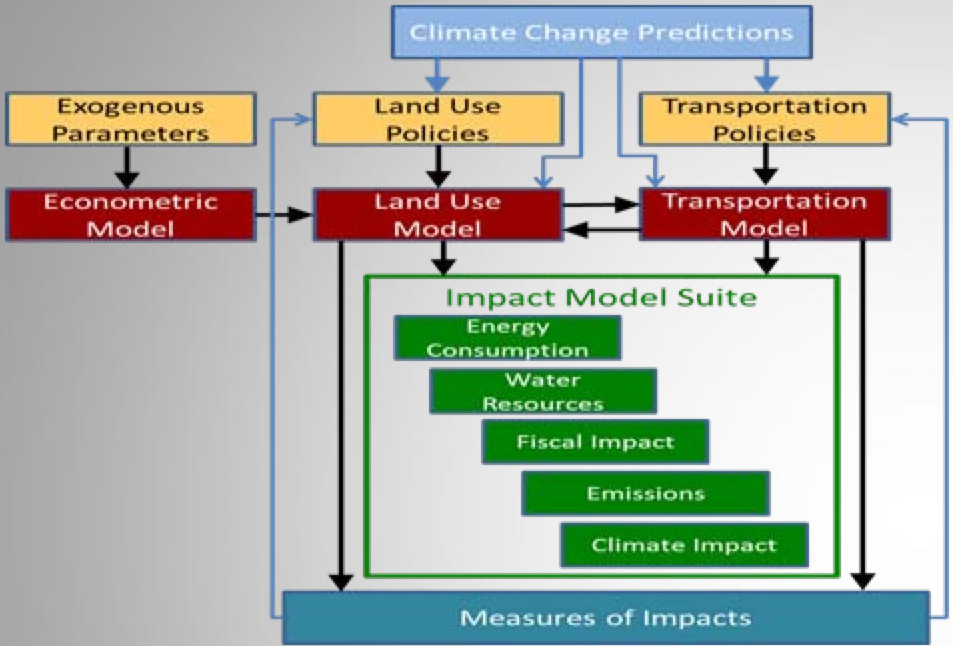

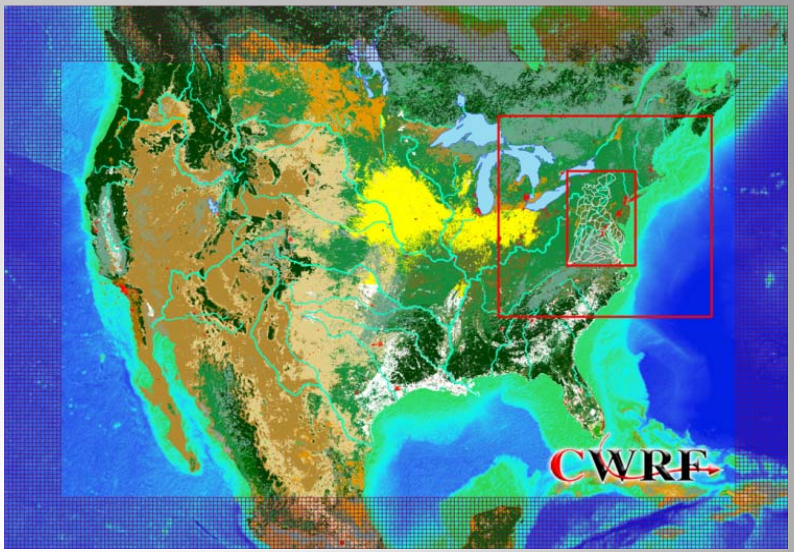

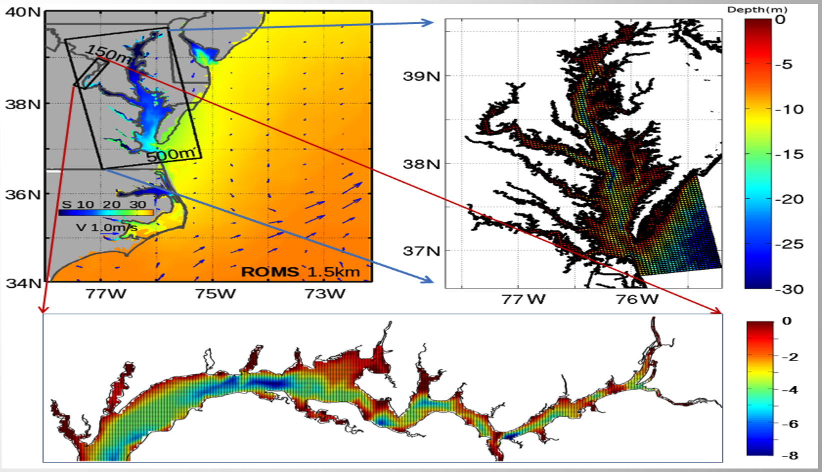

A state-of-the-art model to represent the human system components of land use, transportation, and infrastructure that are being coupled to the natural system model CWRF. Together with the Vulnerability-Resilience Indicator Model, the RESM is a comprehensive prediction-projection model with natural-human system interactions.

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Summary

- Climate science in the future will transcend the physical, natural, and social sciences
- The concept of Climate Services has influenced the need for Actionable Climate Information in response to the needs of end users, with an emphasis on the time scales from years to decades
- Greater emphasis on the regional scales
- Greater emphasis on the attribution and prediction of extreme events