Integrating Extreme Events into Scenarios for Climate Risk Management

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EMF Climate Change Impacts and Integrated Assessment (CCI/IA) Workshop

Snowmass, CO

July 2014

U.S. DEPARTMENT OF ENERGY

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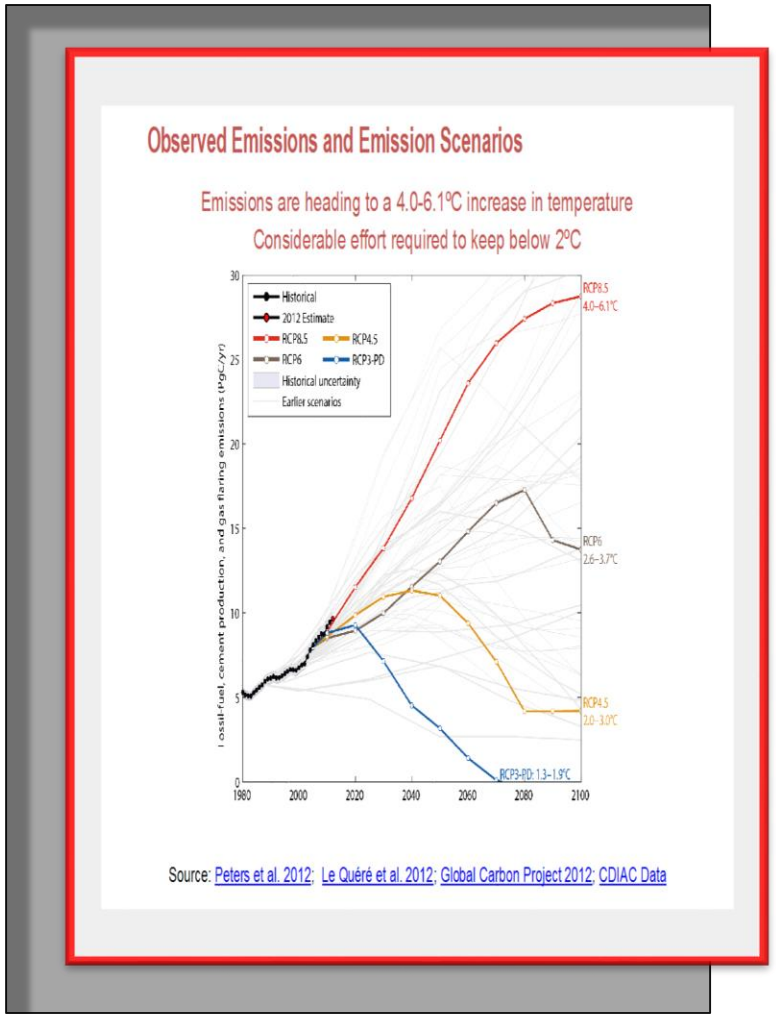
Concerns about climate change impacts, and especially extreme events, have changed in recent years:

- **Impacts of climate change are no longer hypothetical: they are being observed, and some of them are already becoming serious: IPCC AR5, NCA 2014**
- **Greenhouse gas emissions are continuing to rise, making severe climate change more likely than moderate climate change**
- **Meanwhile, in 2011, 2012, and 2013 the US experienced an unusual series of climate-related extreme events: severe storms (e.g. Sandy), droughts, floods, winter tornados, wildfires – some continuing in 2014**
- **The National Climate Assessment concludes that such extreme events are related to longer-term climate change**
- **Projecting extreme events over the next several decades, especially for critical infrastructures, has become a high national priority**



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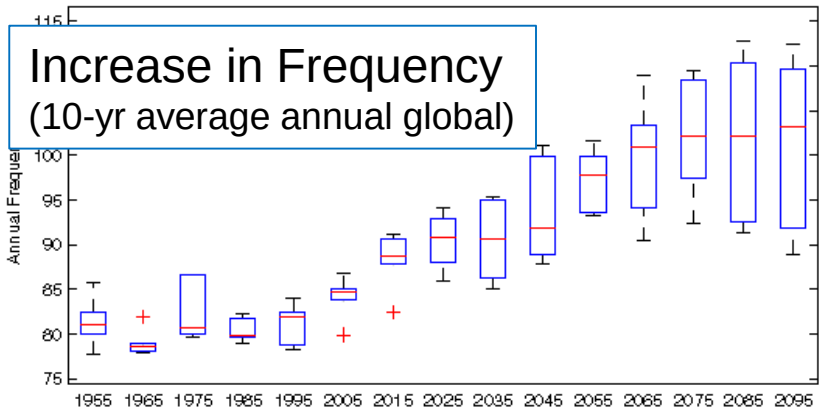
Projections of exposures to extreme weather events are based on:

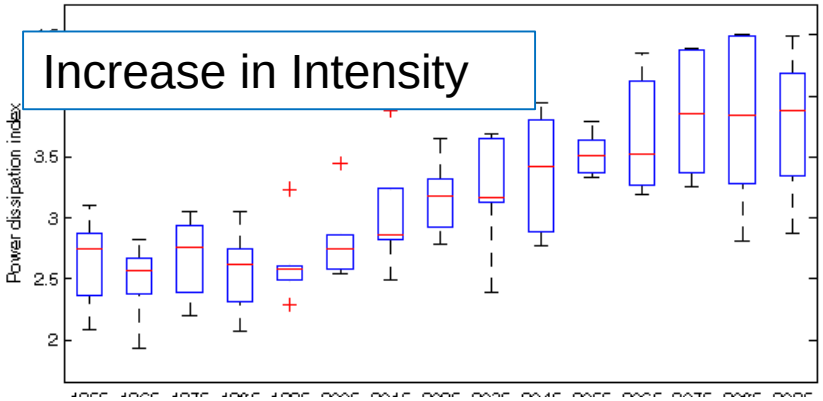
- **Climate change scenarios, which project some variables of interest: mainly temperature and precipitation changes over the long term -- e.g., SRES A2 and B1, the four RCPs**
- **Other sources of projections of extreme weather events not projected by climate models, at least for the next several decades, e.g.:**
  - **Events determined by climate variables not represented fully in climate models, e.g.: sea level rise, storms**
  - **Events determined in part by non-climate variables, e.g.: floods, droughts, heat waves, wildfires**

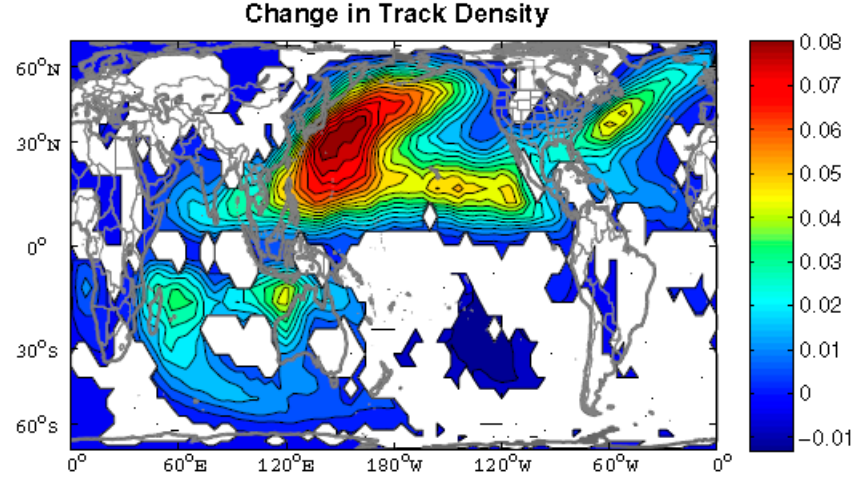
Most extreme weather events are projected over the next several decades in ways other than climate models:

- **Threat/event-specific emerging science by particular agencies and/or research communities, e.g. (from USGCRP Task Force on Catastrophic Risk Modeling):**
  - **Hurricanes: NOAA NCDC/GFDL/CSC/RISAs/National Hurricane Center-HURDAT; NCAR; MIT; LSU**
  - **Sea-level rise: PIK, NCAR, NOAA, Rutgers**
  - **Floods: NOAA, USGS, NCA regional chapters, FEMA/NFHL**
  - **Droughts: National Drought Mitigation Center, NIDIS – US Drought Monitor, US Drought Portal**
  - **Heat waves: NCAR and others (plus humidity/UHI: Rutgers and others)**
  - **Wildfires: NASA 2050, USDA 2050**
  - **General preparedness: FEMA ready.gov, EPA.Natural Disasters**
- **Often only indirectly connected with climate change scenarios, at best**

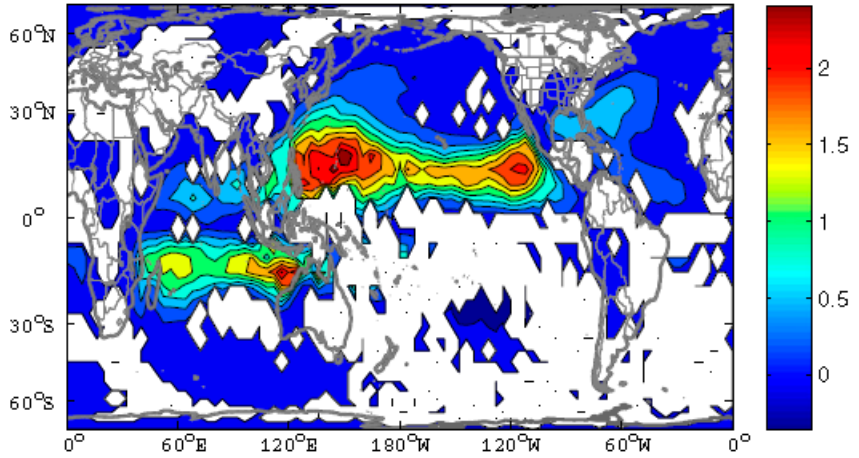
Tropical cyclone projections (CMIP5)







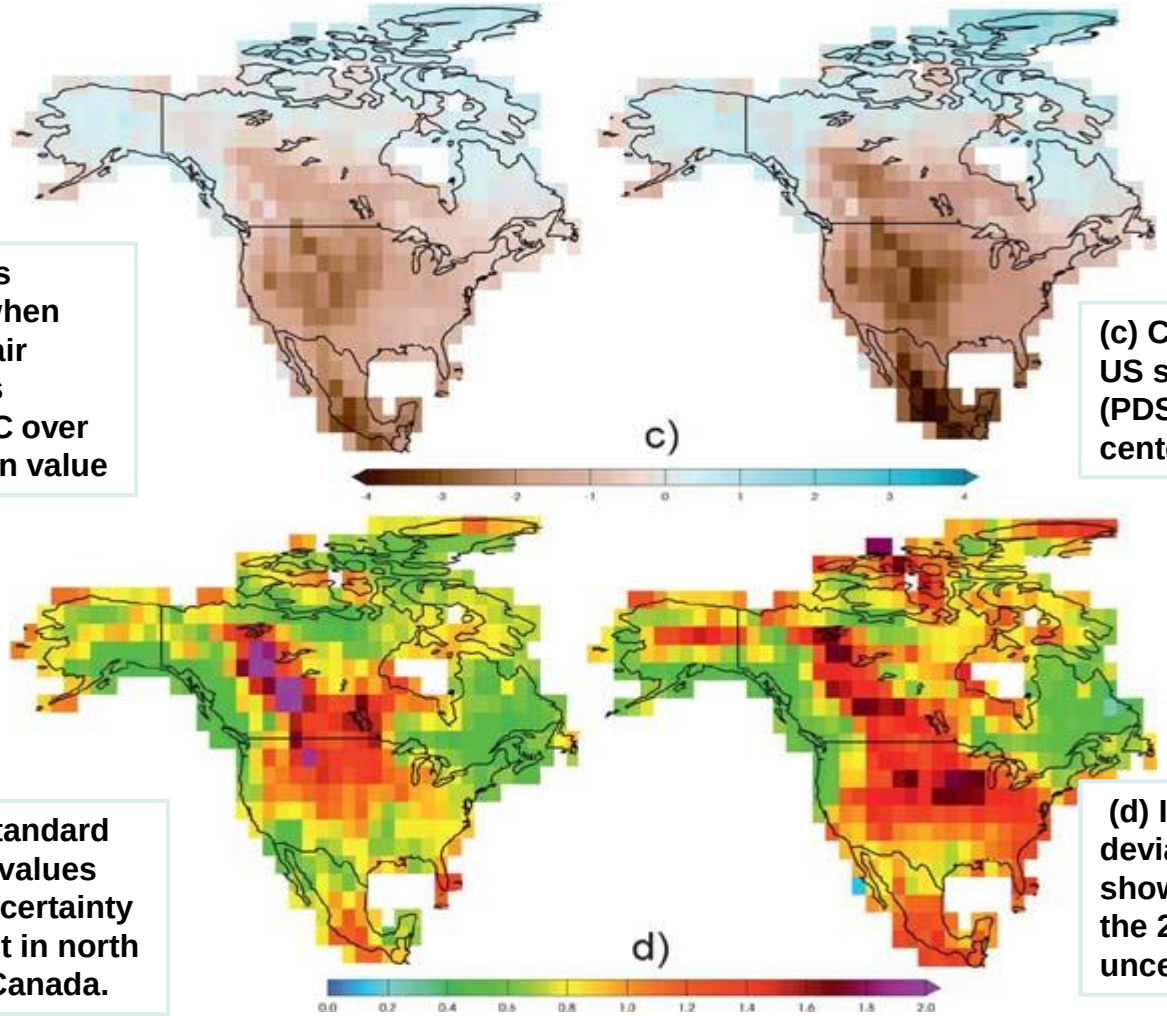
Highest increase in intensity in North Pacific, North Atlantic and South Indian Ocean



Highest increase in power dissipation in North Pacific and South Indian Ocean

Emanuel, K.A., 2013. Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century. *Proc. Nat. Acad. Sci.*, **110**, doi/10.1073/pnas.1301293110.

Projected drought conditions for the Continental United States and Mexico



(a) Entire US has negative PDSI when global average air temperature has increased 2.5˚ C over its 1900–09 mean value

(c) Central and Southwestern US significantly drier (PDSI < -2) for the decade centered at 2070

(b) Intermodel standard deviation of the values shown in (a). Uncertainty for (a) is greatest in north central US and Canada.

(d) Intermodel standard deviation of the values shown in (c). Projections for the 2070s are far more uncertain in most locations.

Source: Wehner, Michael, David R. Easterling, Jay H. Lawrimore, Richard R. Heim, Russell S. Vose, Benjamin D. Santer, 2011: Projections of Future Drought in the Continental United States and Mexico, J. Hydrometeorology, 12, 1359-1377.

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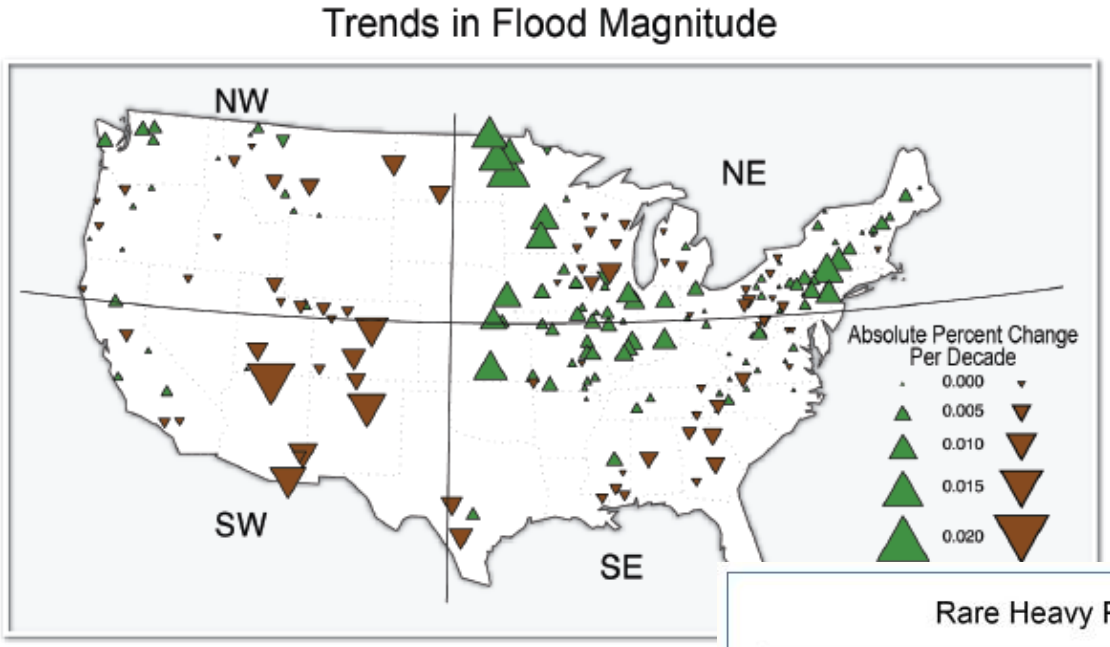
Flooding—US historical and projected



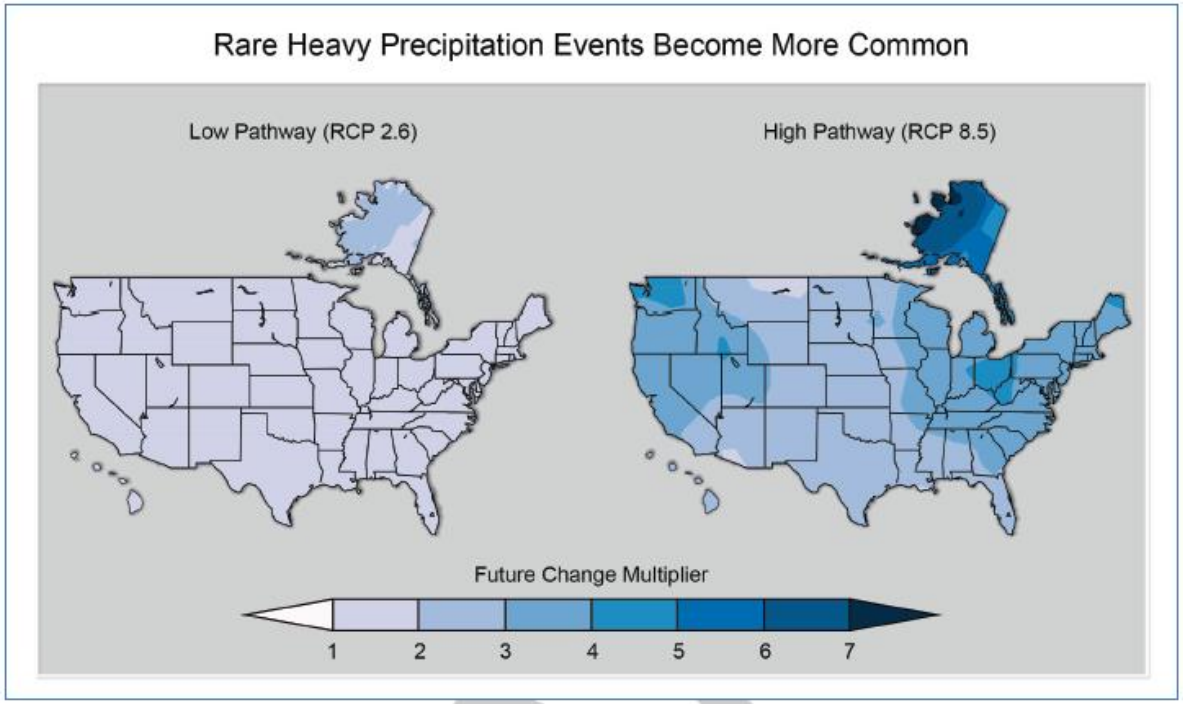
Historical

Trend magnitude (triangle size) and direction (green = increasing trend, brown = decreasing trend) of annual flood magnitude from the 1920s through 2008

Source: http://ncadac.globalchange.gov

Projected

Increase in frequency of extreme daily precipitation events by the later part of this century (2081-2100) compared to later part of last century (1981-2000). Under RCP 2.6, these events would occur up to about twice as often. For RCP 8.5, these events would occur up to five times as often.



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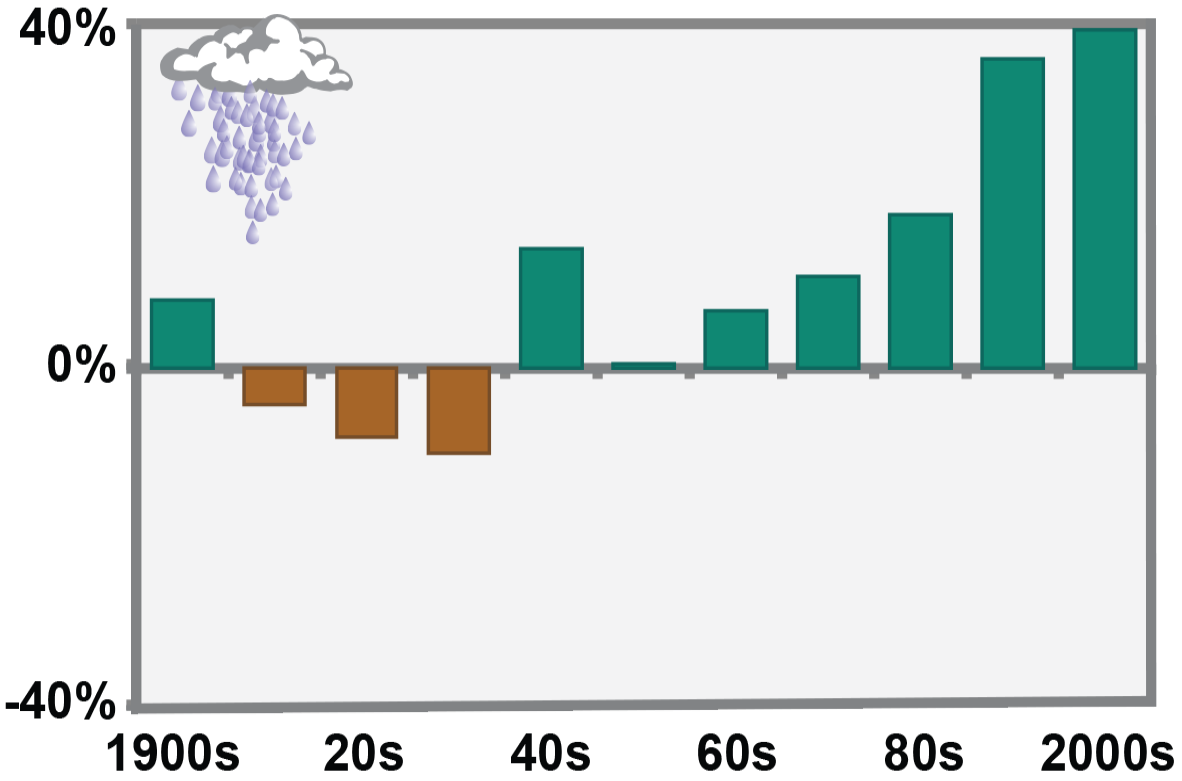
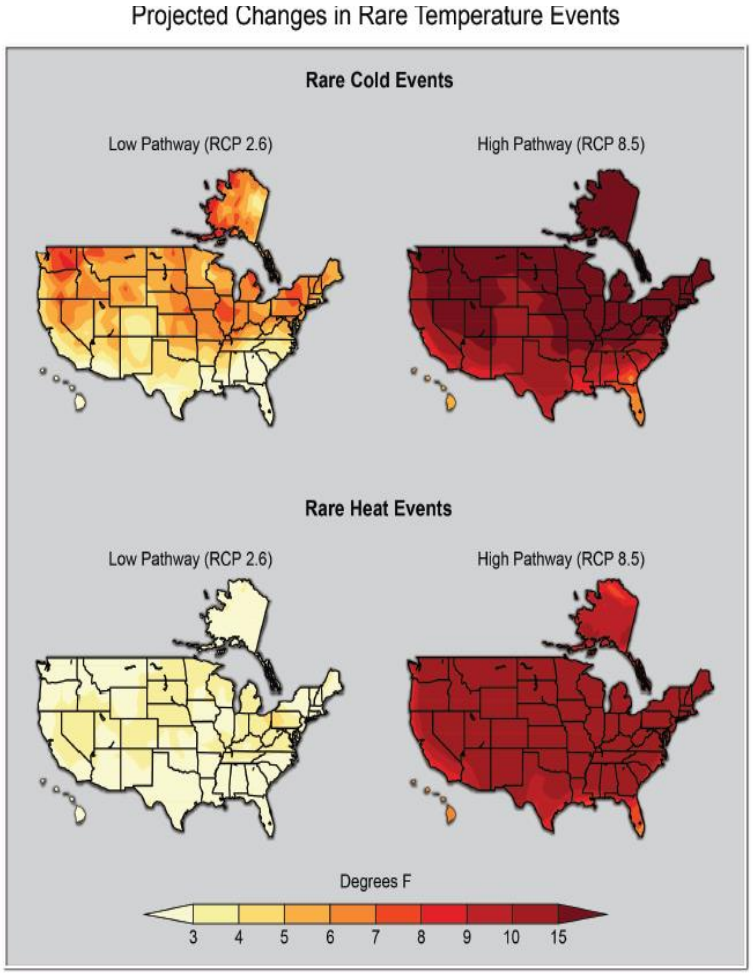
Trends in Heavy Precipitation



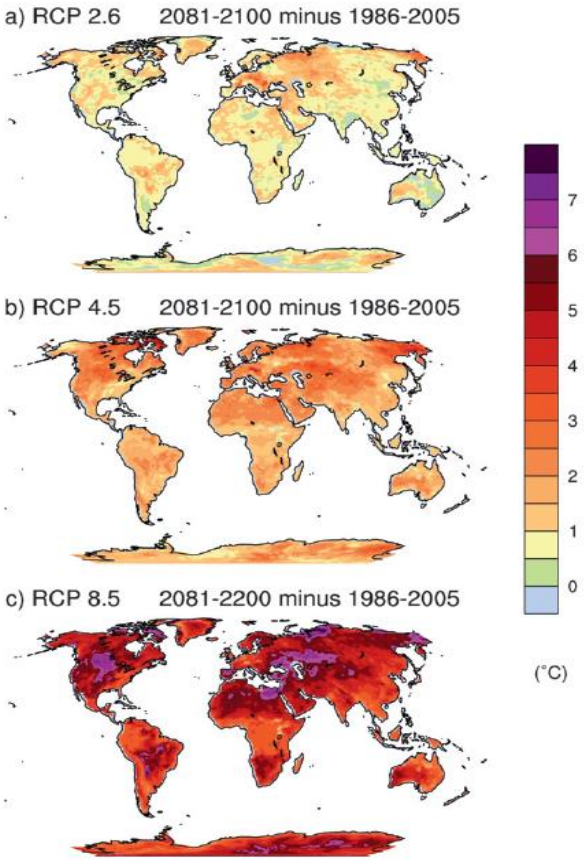
Heat wave projections

Projected Changes in Rare Temperature Events, RCP 2.6 left, RCP 8.5, right.



Source: http://ncadac.globalchange.gov

Changes in average heat wave intensity between 2081–2100 and 1986–2005. Heat wave intensity is defined as the average minimum temperature during the warmest three consecutive nights of the year.



Source: Meehl, G. A., and Coauthors, 2012: Climate system response to external forcings and climate change projections in CCSM4. *J.Climate*, **25**, 3661–3683

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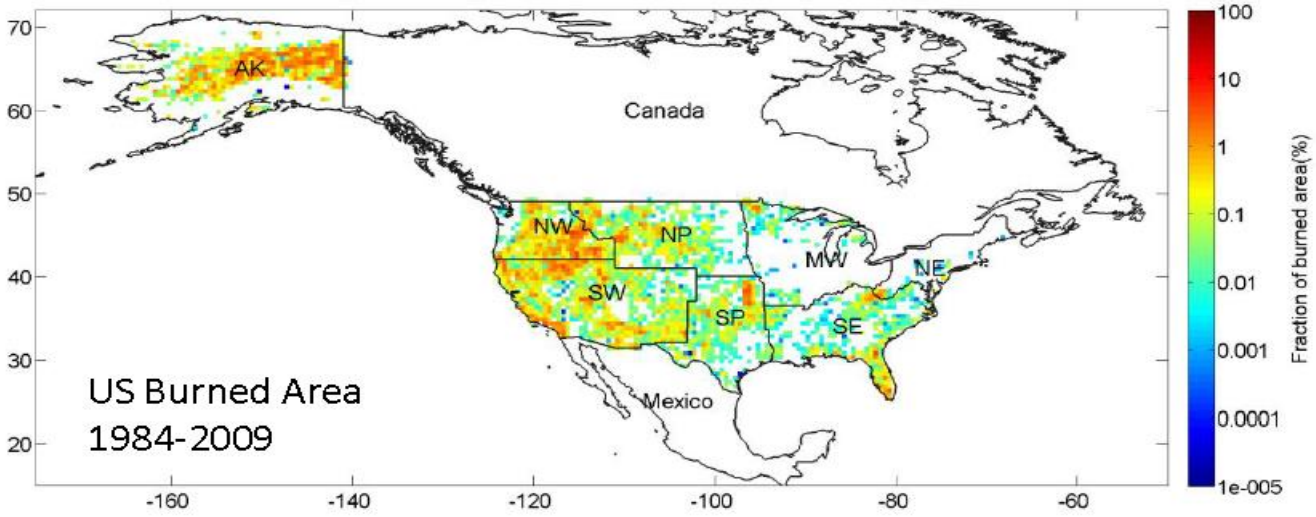
US wildfires projected (NASA)

Drier conditions by mid-century increase projected burned area under middle and high emissions scenarios.

	Alaska	No. Plains	So. Plains	Midwest	Northwest	Southeast	Southwest	US
RCP 4.5	13%	73%	264%	125%	19%	135%	34%	78%
RCP 8.5	101%	117%	407%	164%	44%	202%	61%	125%



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Regarding sea-level rise:

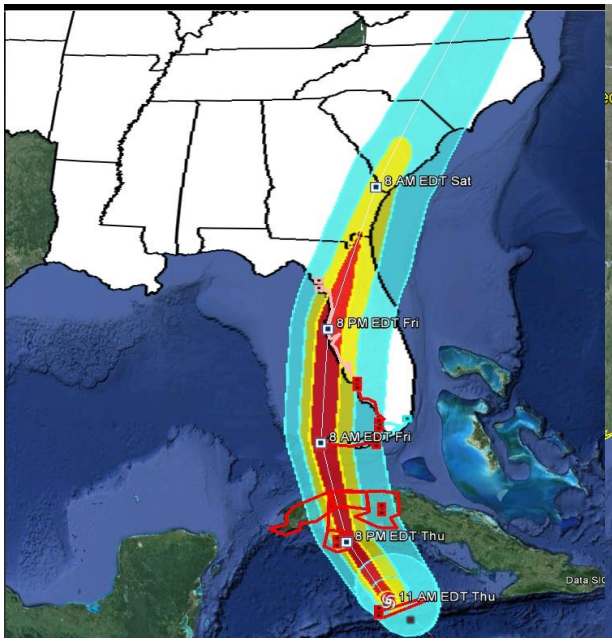
- **At a conference in College Park, MD, in December 2013, Margaret Davidson – NOAA's highest ranking coastal expert – said: "Sea-level rise will be 3 to 5 feet in 30 years, and the Gulf Coast is toast." One meter is now the general expectation, with 2.5 meters considered possible by the end of the century.**
- **Combined with land subsidence in this region, plus continued coastal demographic and economic growth, the Gulf Coast is likely to become the first climate-related regional catastrophe in this country.**
- **Some assessments of this risk under way: e.g., a few years ago, a major regional utility, Entergy, commissioned an assessment of the vulnerability of its customer base to this combination of threats and adaptations to keep vulnerabilities from rising.**

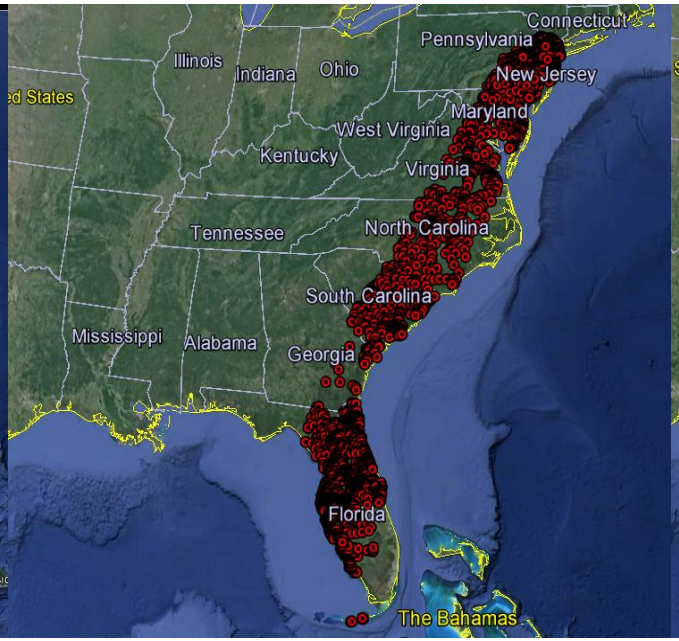
In general, the science of projecting extreme weather events is not as mature or accessible as the science of projecting longer-term climate change:

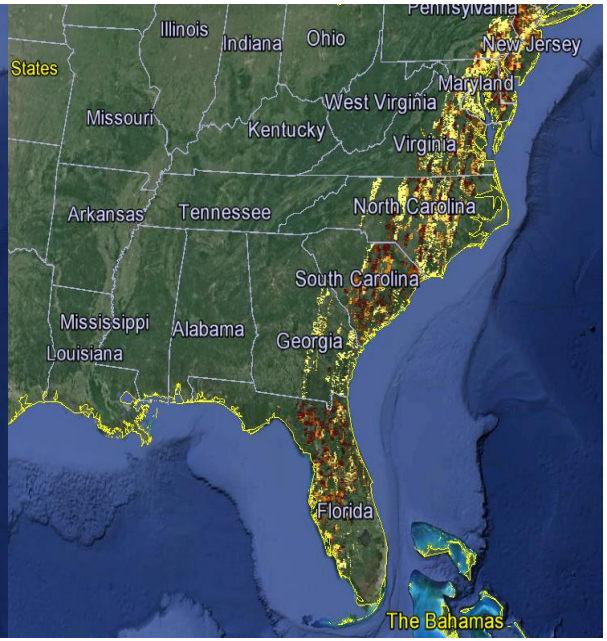
- **Emerging in a variety of research fields and agencies to meet different needs**
- **Focused on particular threats and concerns of separate categories of extreme events**
- **Highly uneven in its treatment of estimates of probabilities of exposure**
- **Not being brought together to provide a capacity to support coherent multi-threat risk management/resilience enhancement strategies**
- **But if projections of threats can be provided, even as hypothetical "shock scenarios," impacts can be simulated**

Energy infrastructure impact simulation capacities are impressive, if threats can be projected (or postulated), e.g.:

Hypothetical Hurricane Charley impacts on the electric grid







Charley-Category 4 Advisory 13

Sub Stations Affected

Service Areas Recovery Estimates

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This growing risk of exposure to climate-related extreme weather events is a national need for data and analysis that is starting to get considerable attention:

- **A focus of "climate preparedness" in the President's Climate Change Action Plan, which calls for:**
  - **Boosting the resilience of buildings and infrastructures**
  - **Identifying key vulnerabilities and reducing risks**
  - **Assessing impacts based on actionable science**
  - **Launching a data initiative**
  - **Providing a toolkit for climate resilience**
- **Being followed up by a number of activities, including a White House Council on Resilience and Preparedness, its Working Group on Infrastructure Resilience, a White House Local, State, and Tribal Leaders Task Force, the interagency task force on catastrophic risk modeling and analysis through public-private sector partnerships, and an NAS/NRC Roundtable on Risk, Resilience, and Extreme Events**

Toward incorporating climate-related extreme events in scenarios to support risk management – the interest:

- **Concerned parties are becoming aware that research is under way for nearly all of the extreme events of particular concern, even if it is too scattered and idiosyncratic to support much multi-event integrated analysis**
- **Growing interest in projecting threats of exposure using whatever science is aveailable, especially in the next 2-3 decades, at national, state, and local scales of climate risk management and emergency preparedness, e.g.:**
  - **National: NOAA: Sustainable Coastal Cities; DHS: Regional Resiliency Assessment Program**
  - **Regional: Gulf Coast: severe storms and sea-level rise; south-central US: droughts and flooding; urban NE: another Sandy or Irene**
  - **State: California: droughts, wildfires; Florida: severe storms and sea-level rise**
  - **Local: Portland, ME**
  - **Plus private sector: insurance, finance, tourism, infrastructures in vulnerable areas**

Toward incorporating climate-related extreme events in scenarios to support risk management – the challenge:

- **Using our currently available tools for scenario development and use will be challenging, e.g.:**
  - **The focus on the relatively near term: limits uses of climate models and integrated assessment modeling structures intended for longer-term perspectives**
  - **The focus on events that are episodic, usually relatively short-term, and usually regional or local in geographic scope: very different in time frame and spatial scale from most of the components of most of our scenarios**
  - **A focus on events whose impacts reflect factors other than climate and weather variables alone, including interdependencies among systems and infrastructures, human choices regarding uses of vulnerable areas, and adaptive risk management and resilience enhancement**
  - **The fact that infrastructures and other systems are changing over time, due both to normal cycles of revitalization and to changes in driving forces**

Toward incorporating climate-related extreme events in scenarios to support risk management – some possible starting points:

- **With internal funding, encouraged by OSTP, USGCRP, and interests from a number of agencies, ORNL is developing an extreme events data center to facilitate access to extreme events science and data, past and projected, and to encourage collaboration among the community in moving toward common practices to facilitate integrated analysis of multiple threats**
- **Possible approaches for experimenting with extreme event scenarios as a national need for integrated assessment and scenario research include:**
  - **Extrapolating exposures from the early extreme event research – possibly several scenarios, most likely working at a regional scale**
  - **Using the early research to frame hypothetical disruptive exposures (DHS: "shock scenarios") to assess implications and risk management strategies related to possible major threats**
  - **Defining several different end states at a future time, e.g., framed by several different RCPs (and/or SSPs), working back from those end states to explore different trajectories of extreme event exposure as the different climate change trajectories unfold**
  - **Considering scenarios that include a convergence of multiple event exposures and multiple other forces affecting vulnerabilities (e.g., connections with SSPs, connections with emerging NCA scenarios of land use, etc.) – a true challenge to integrated scenario development!**

THANK YOU !

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