Grand Challenge: Complex Systems

Climate, Energy, Environment and Risk Assessment

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My job ....

- summarize, synthesize, and provide focus to (at last count) 40 white papers presented by over 80 different scientists ....
- and do it in 15 minutes or less.
- Examples will be climate-related ideas, but other ideas will fit into the framework developed here.

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The scope is still broad, but it is not wide open ...

- Scientific depth and importance
- Long-term mission relevance
- Aligned with LANL capabilities and strengths

Let's start at the bottom and work our way up.

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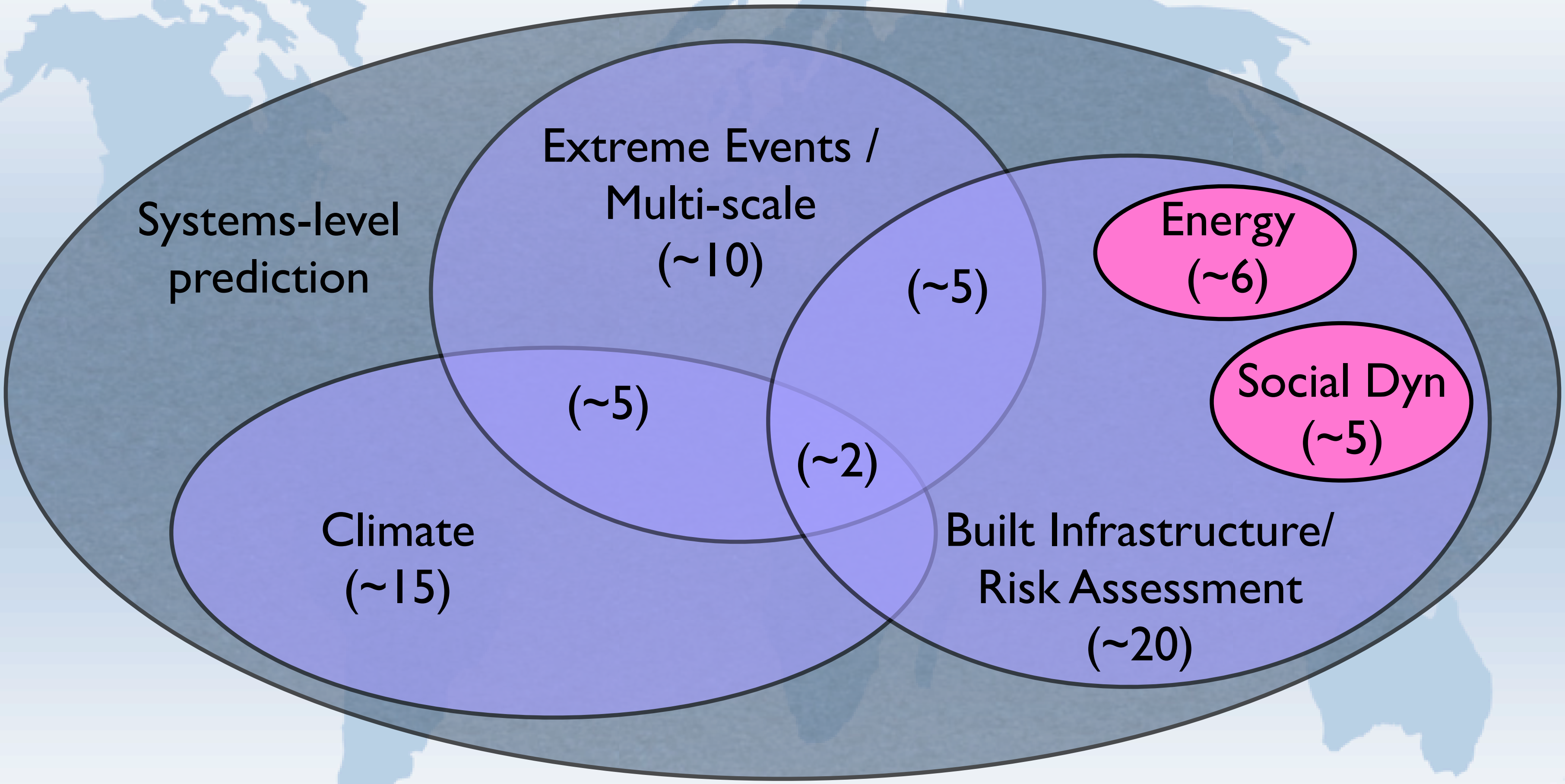
Capabilities and Strengths are closely aligned with interests, so what is in the white papers?



The intersection of interests corresponds to the intersection of capabilities.

Long-term mission relevance: providing focus to our ideas.

- The lab of choice for national security.
  - Energy security is a key component of national security.
  - Energy security is a key part of non-NNSA DOE programs.
- Fundamental science important for DOE/Others
  - Office of Science
  - Fossil Energy
  - Others
- Foster certain capabilities
  - High performance computing and simulation
  - Remote and in-situ sensing

The intersection of mission relevance and complex systems is both broad and compelling.

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Systems-level prediction of environmental change and its impacts

- **Energy Systems Modeling**
  - Cross-cutting with the Carbon-Neutral Grand Challenge
  - Secure energy solutions require knowing how those solutions interact
- **Environmental Systems Modeling**
  - Joins both climate modeling and extreme events modeling
  - Understand the unwelcome consequences of each energy solution
  - Environmental risks are less understood than the energy solutions
- **Infrastructure Systems Modeling**
  - Understanding the risk to energy/water/transport/social systems
  - Risks are both internally generated and externally forced

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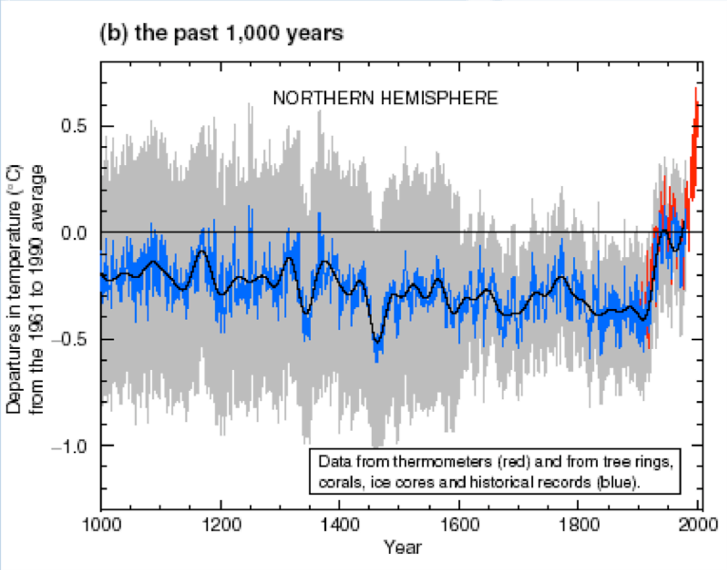
Environmental Systems Modeling in the context of climate change

- The primary risk of the current world-wide energy portfolio is CO_2-forced global climate change.

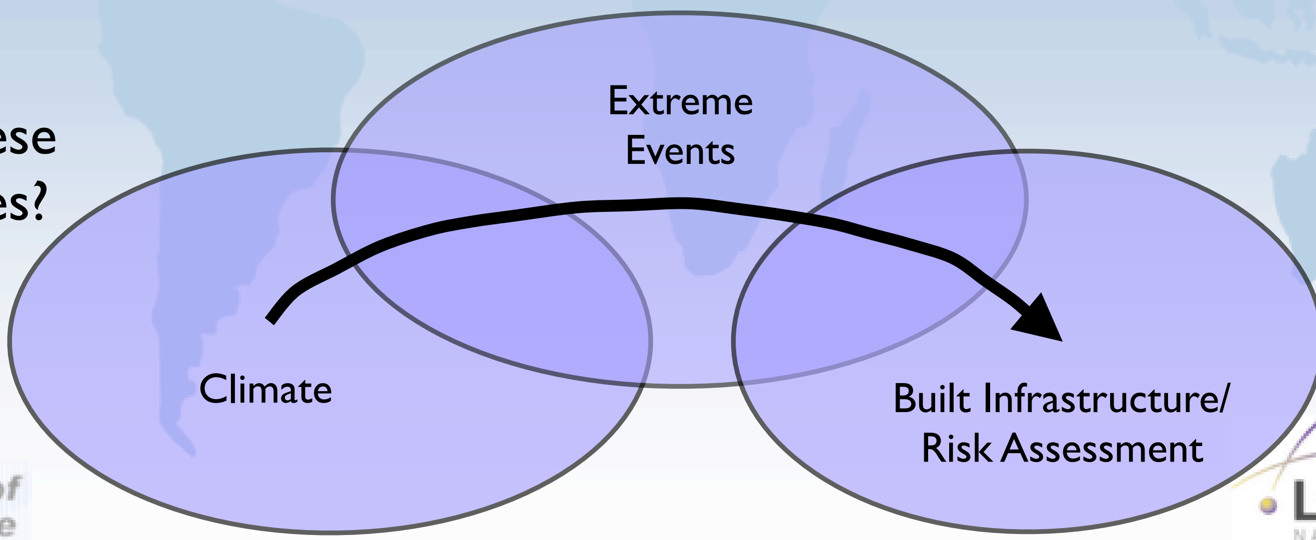


- These risks are manifested primarily at the regional level.
- The climate-change driven events that are most troublesome are those events that exceed the resilience of society.

Abrupt Climate Change: climate-change driven events that exceed our resilience.

- change in hurricane numbers and intensity -- O(years)
- change in the ocean thermohaline circulation -- O(decades)
- change in ecological function -- O(decades to century)
- change in the Greenland Ice Sheet -- O(century)

Why these examples?



Hurricanes

The Issue:

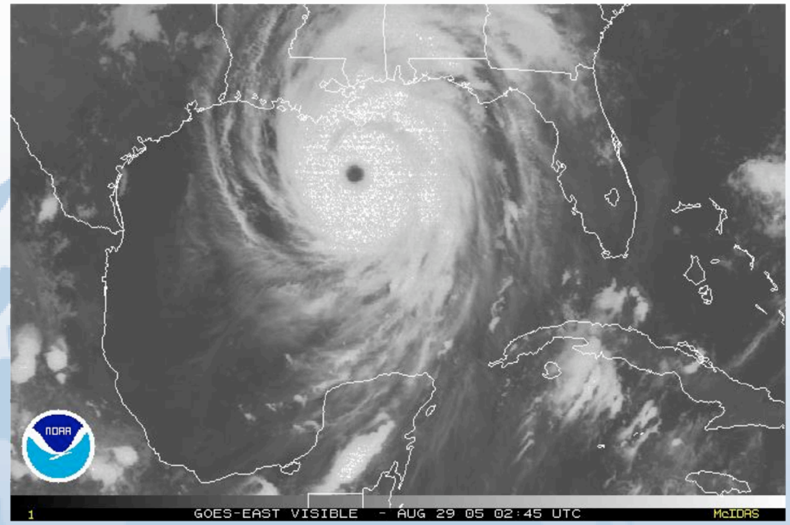
- maximum wind speed increases with increasing SST.
- power dissipation increases
  - -cube of peak speed
  - -increased duration

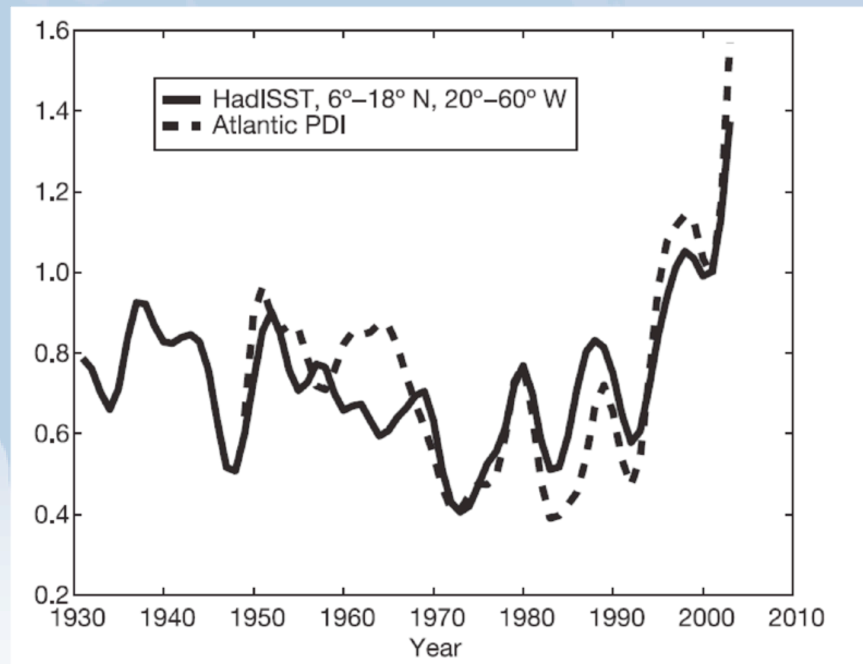
The Core Question:

How will hurricane numbers and intensity change with warming SST?

The Science Required:

- better hurricane intensity prediction
- better SST prediction





power dissipation index
Emanuel 2005

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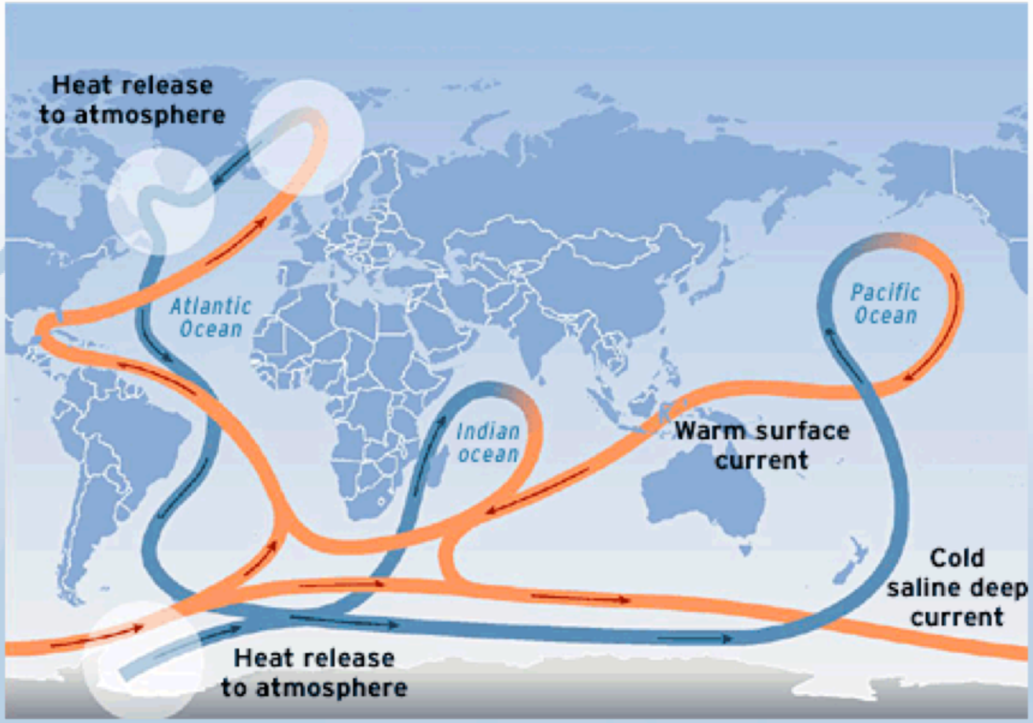
Thermohaline Circulation



The Issue:

- largely responsible for relatively mild climate in Europe.
- paleo-data and theory suggest bimodal character.

The Core Question:

How likely is a shutdown of the thermohaline circulation?

The Science Required:

- bringing multi-scale numerical algorithms, including physics, into Environmental Systems Modeling.

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Ecosystem Collapse

The Issue:

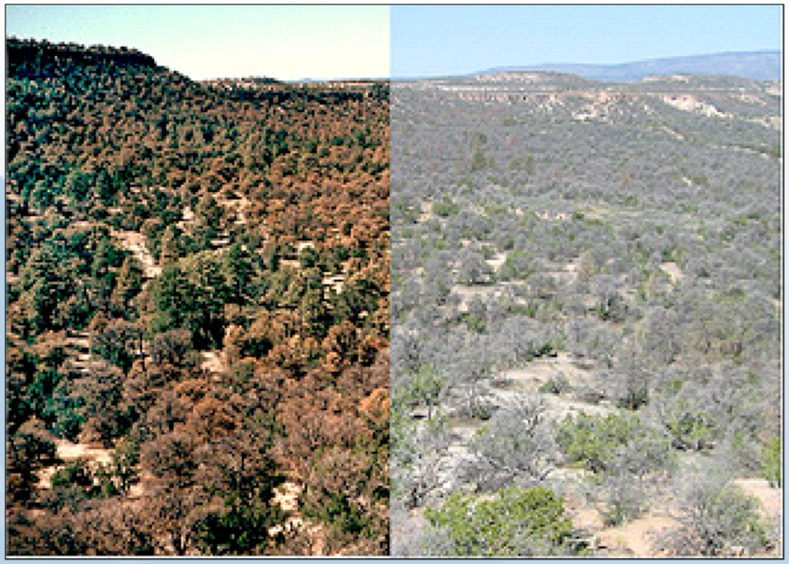
- ecosystems respond rapidly to environmental forcing.
- impacts are profound
  - changes in vegetation
  - changes in sfc/ground water
  - changes in precipitation
  - changes in carbon storage
  - viability of local agriculture

The Core Question:

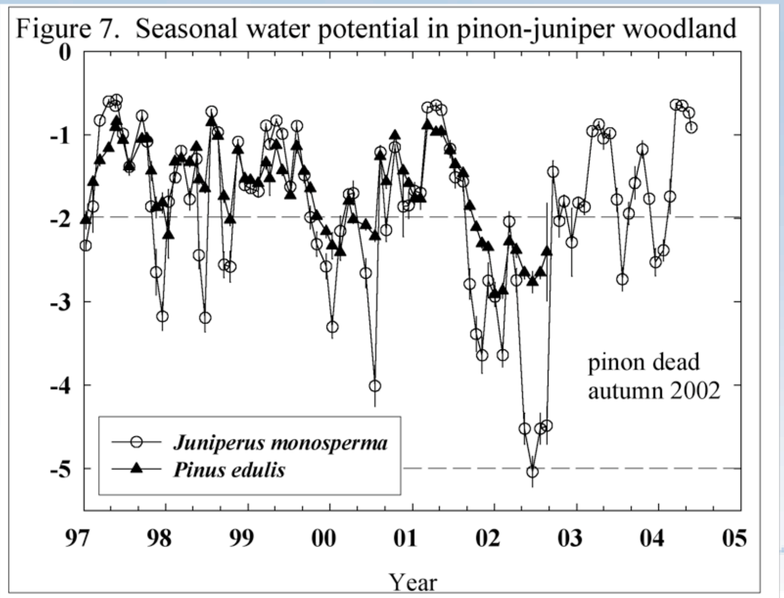
Can we predict climate-change driven changes in ecosystem function?

The Science Required:

- fundamental science in ecology, hydrology, geology, and climate modeling.

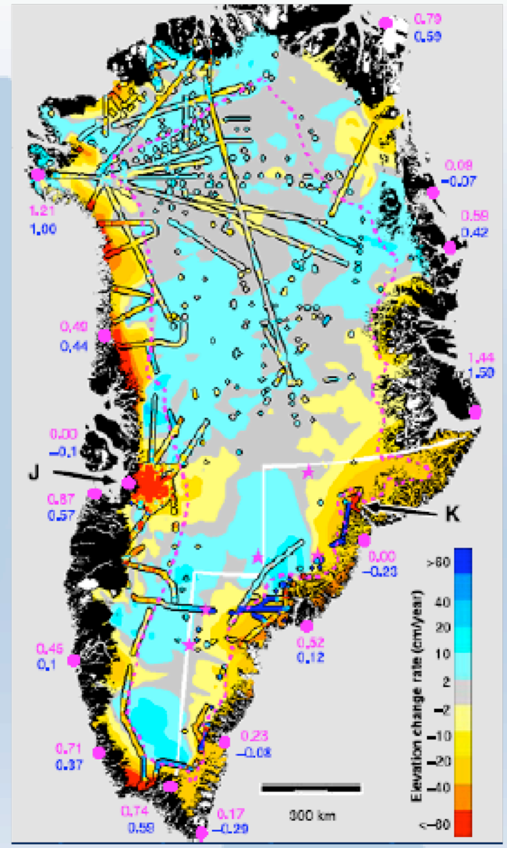


from Allen



from McDowell

Ice Sheet Collapse



The Issue:

- melting ice sheets lead to increase in sea level
- bimodal, i.e. point-of-no-return
- Greenland holds the equivalent of 7m of sea level.
- migration and adaptation

The Core Question:

How fast will ice sheets melt under various climate-warming scenarios?

The Science Required:

- closing the mass budget for Greenland
- increased remote sensing to aid in our understanding
- improved predictive models of ice-sheet dynamics

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So in summary ...

- Where can complex systems plug into the lab mission?
  - Energy Systems Modeling
  - Environmental Systems Modeling
  - Infrastructure Systems Modeling

- Energy security as a possible unifying theme
  - relevant to long-term mission of the Lab and DOE
  - fundamental science issues are pervasive
  - sufficiently broad to accommodate a wide-range of science

- The grandest of the Grand Challenges are going to sit at the intersection of energy, environment, and infrastructure modeling.