

# Our Changing Climate: Days of Future Passed (and Past)

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# DW: A Life Assessing the Environment

## From E.E. to Atmospheric Physics /Chemistry

- **Stratospheric Ozone**

- Aviation, CFCs, ODPs, policy studies, model developer
- Leader in most of the major assessments (WMO-UNEP)

- **Air Quality**

- Developed one of the first major air quality models
- Climate effects on air quality

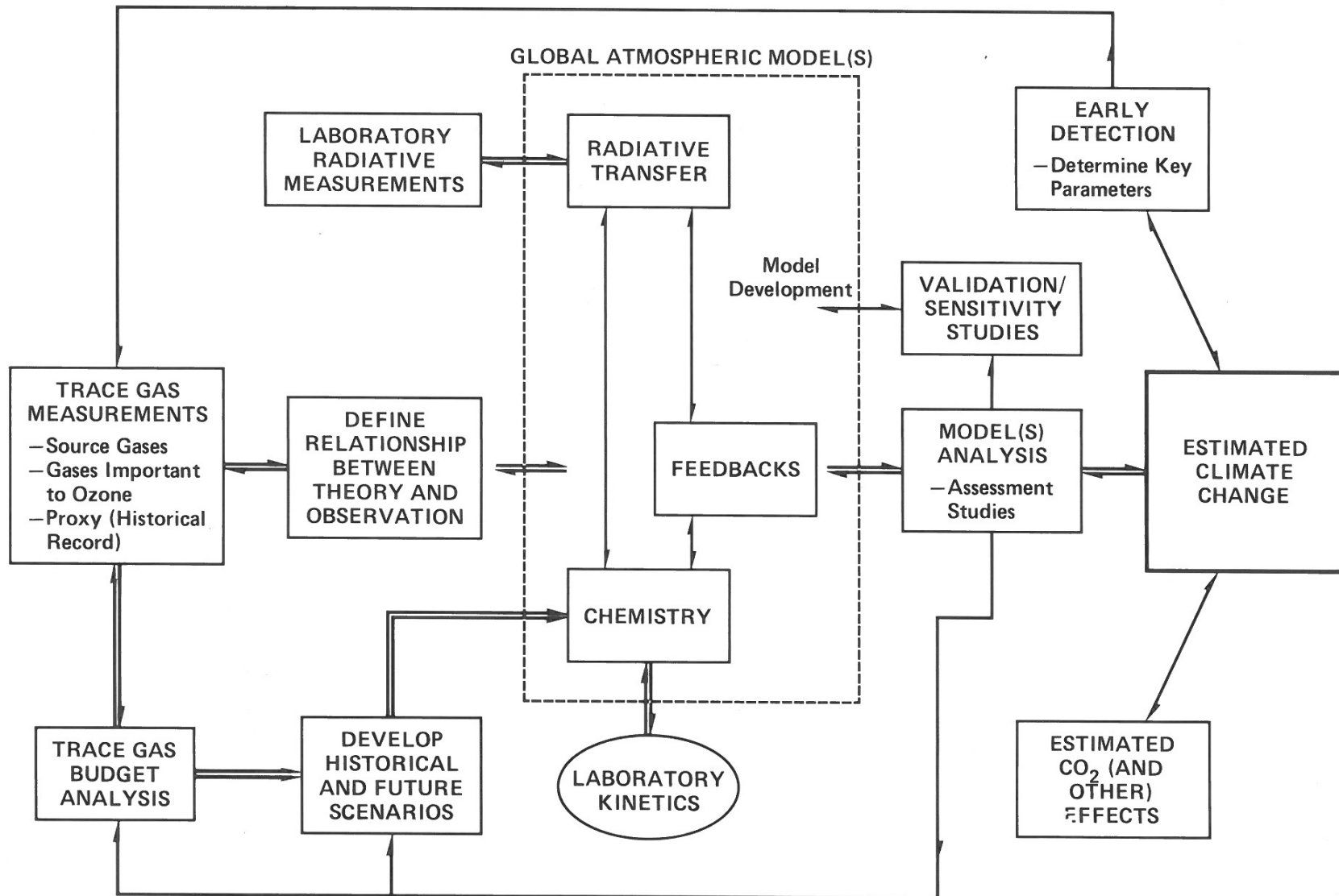
- **Climate**

- Radiative forcing, GWPs, Severe weather in a changing climate
- Leader in regional, national and IPCC assessments

- **AGCI**

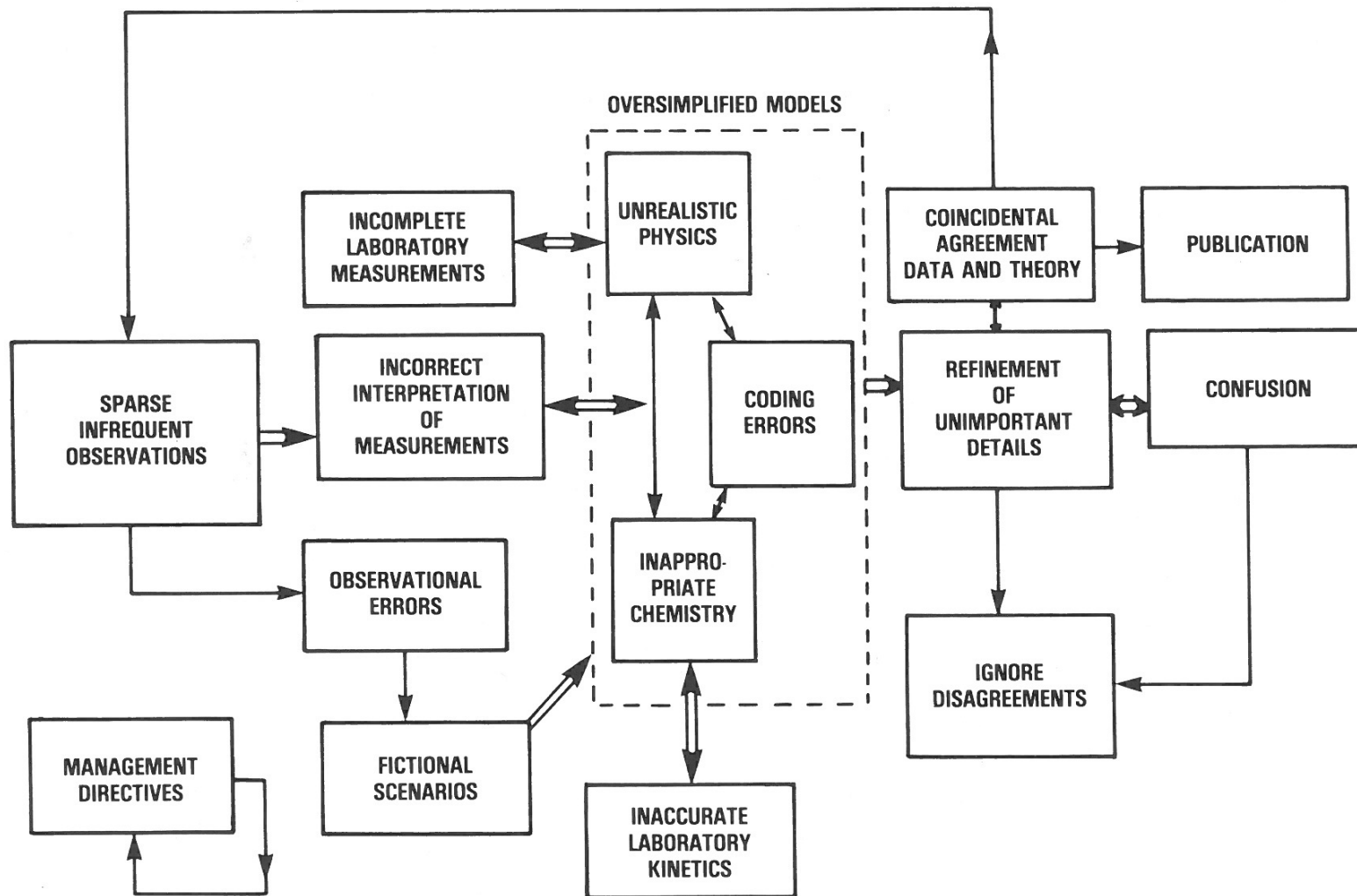
- Early participant; past co-chair; member of Advisory Board

# For DOE 25 Yrs ago: Climate-Chemistry Interactions





## ALL TOO TYPICAL LOGIC CHART

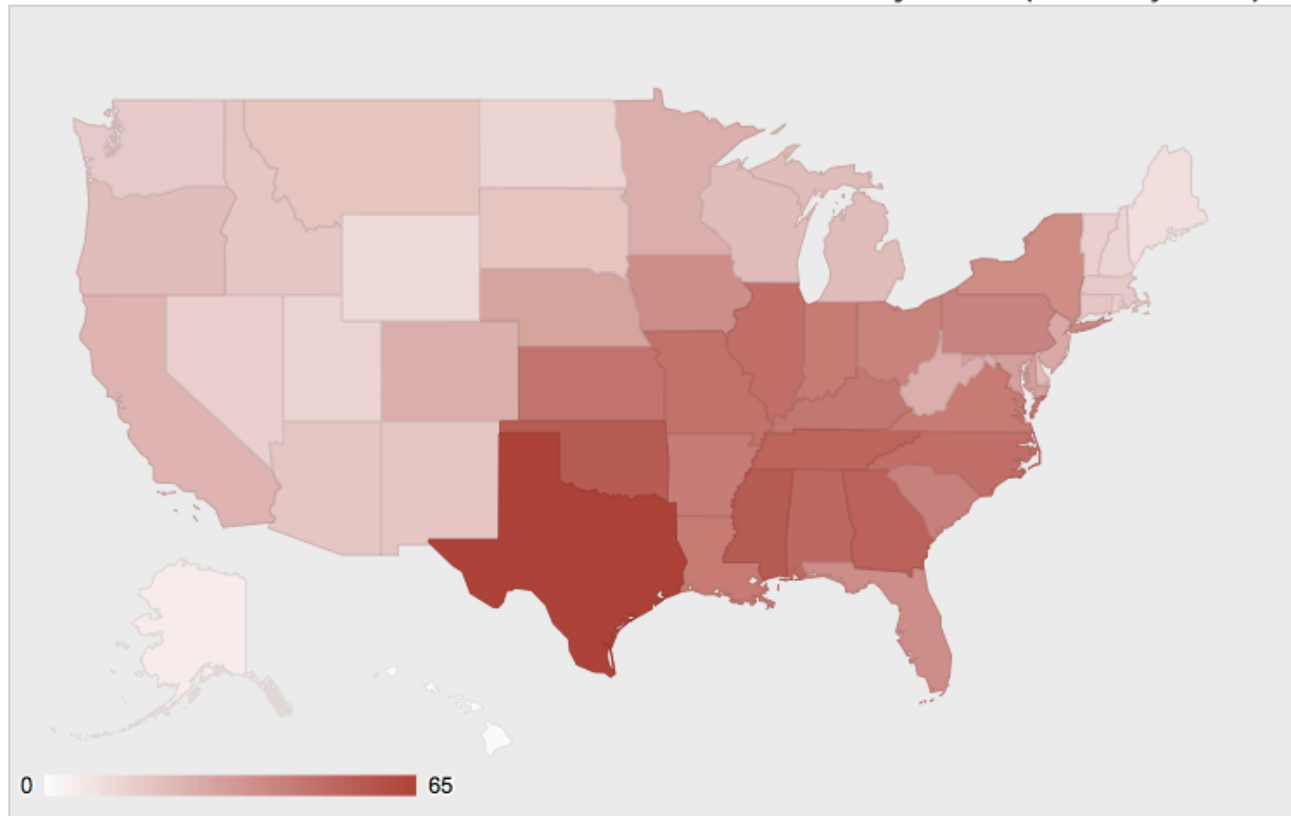




# The Challenge of Climate Science

- Measurable and costly climate change impacts are already occurring today

1980-2013 Billion-Dollar Weather/Climate Disasters By State (CPI-Adjusted)

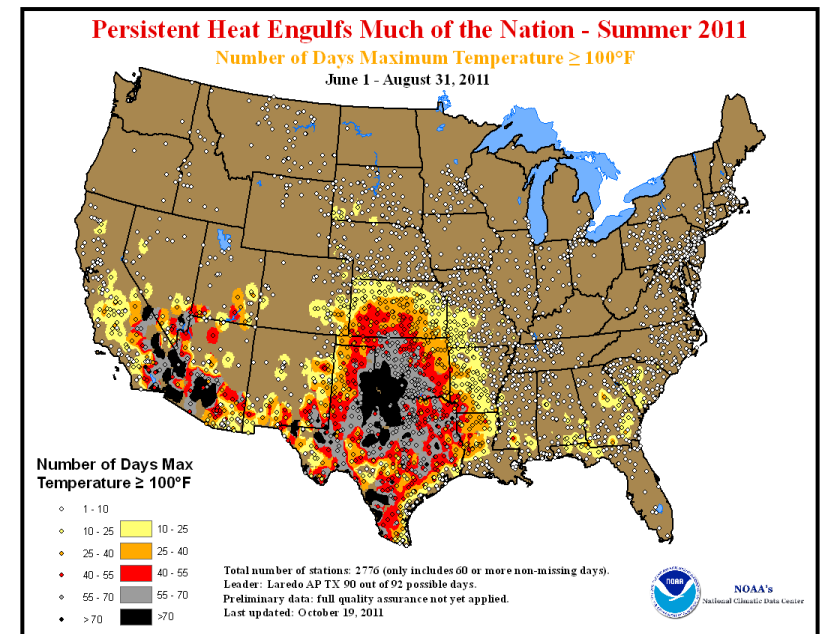


NOAA/  
NCDC

# There is a Detectable Human Influence on Recent Major Weather Events

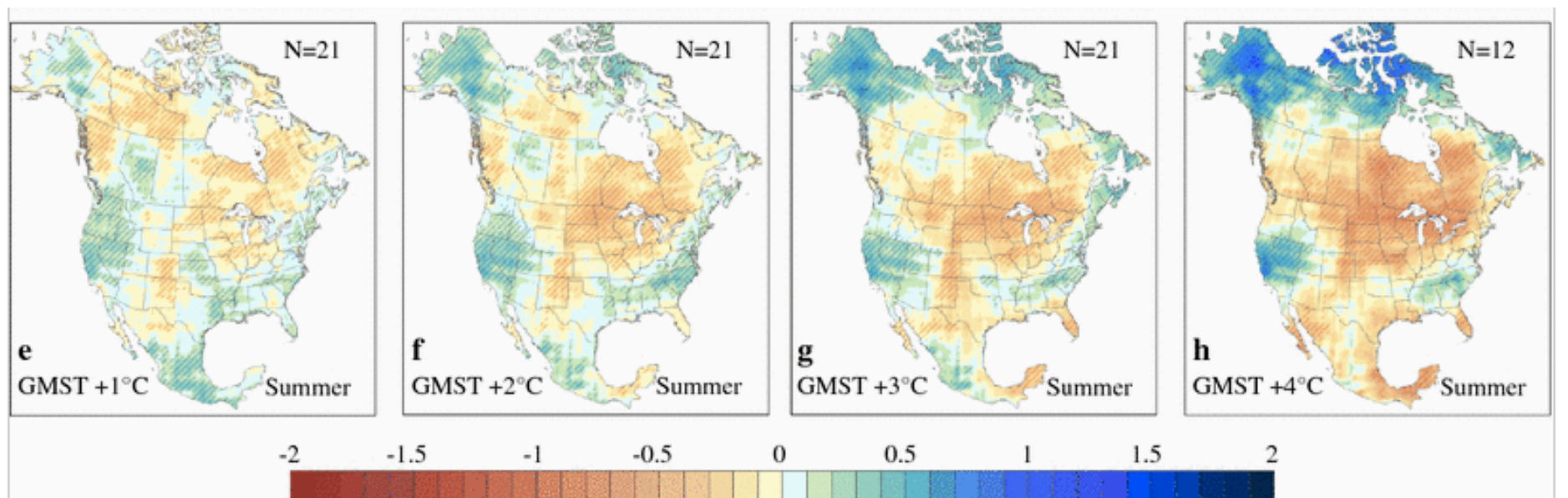
## Examples

- UK flooding in 2000
- European heat wave of 2000
- The cold U.S. of 2008
- Cold European winter 2009/2010
- Moscow heat wave of 2010
- The 2011 heat wave / drought in Texas and Okla.



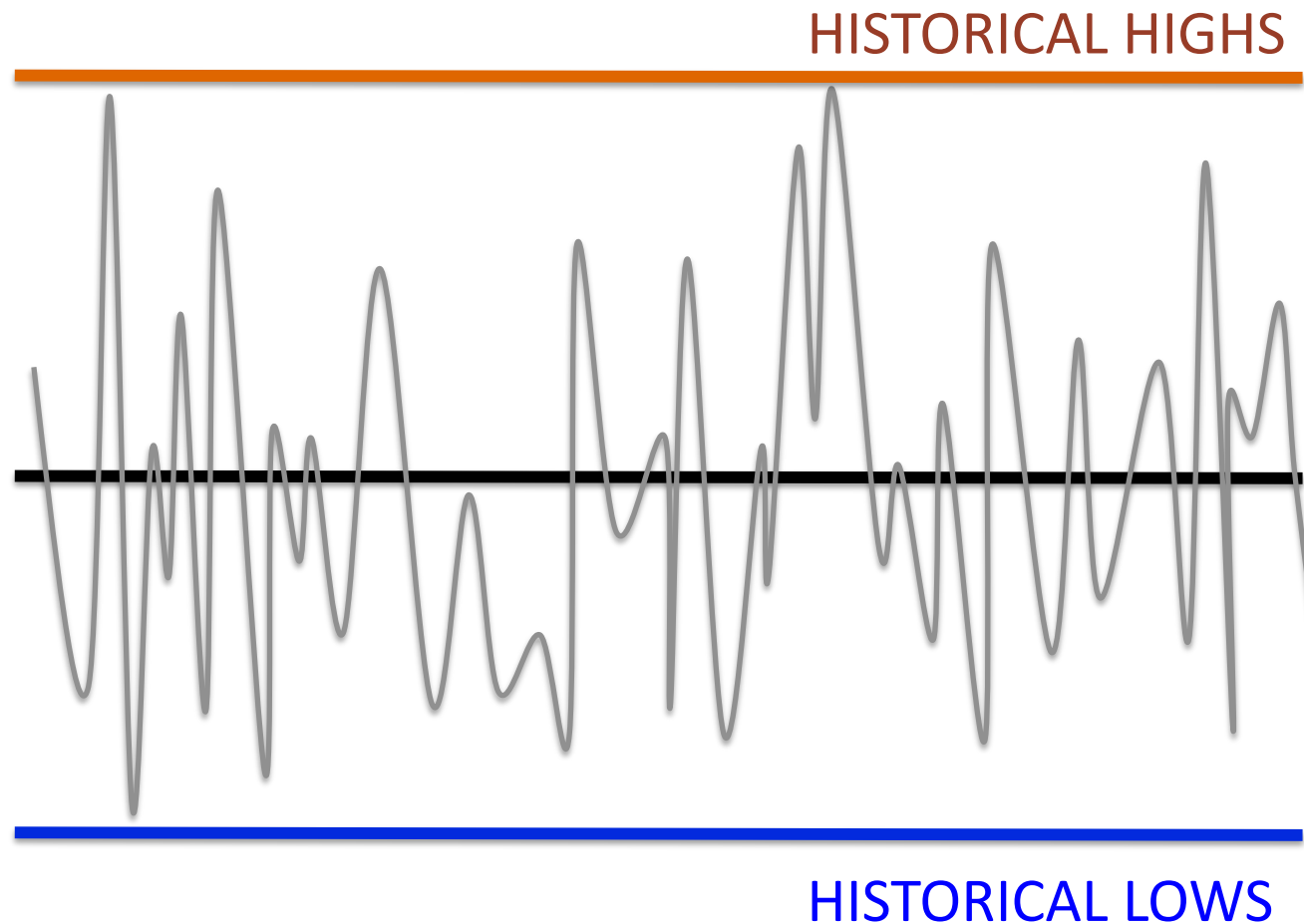
# The Challenge of Climate Science

- Measurable and costly climate change impacts are already occurring today
- For many such impacts, the magnitude and/or rate of change increases with human emissions

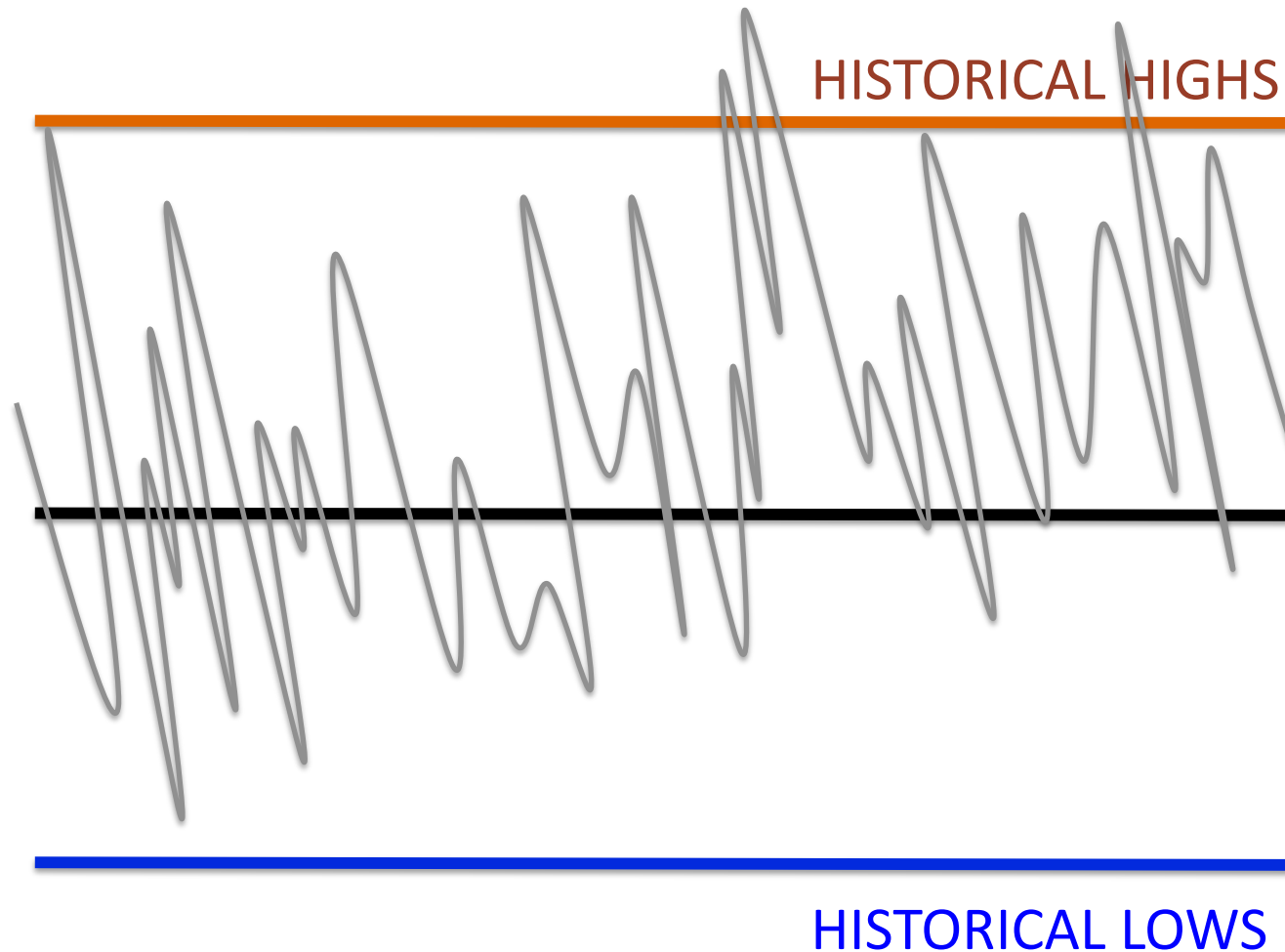




# Our civilization is built on the assumption of a stable climate



# What happens if that climate isn't stable any more?



# The Challenge of Climate Science

**FOR MANY SECTORS AND REGIONS,  
FAILING TO ACCOUNT FOR CLIMATE  
CHANGE IN FUTURE PLANNING WILL GIVE  
THE WRONG ANSWER.**



# How can Climate Science inform Impacts and Policy?

We need to improve **the two-way flow of information between science and policy** on:

1. Projected climate changes at the **spatial scale** of impacts and decision-making “spatial units” (e.g. cities, counties, states)
2. **Interactions between sectors** (e.g., water and energy) and/or **between decisions and impacts** on human society and ecosystems.
3. **Interactions** between climate change, other stresses, local changes, and natural variability

# How can Climate Science better inform Societal Needs?

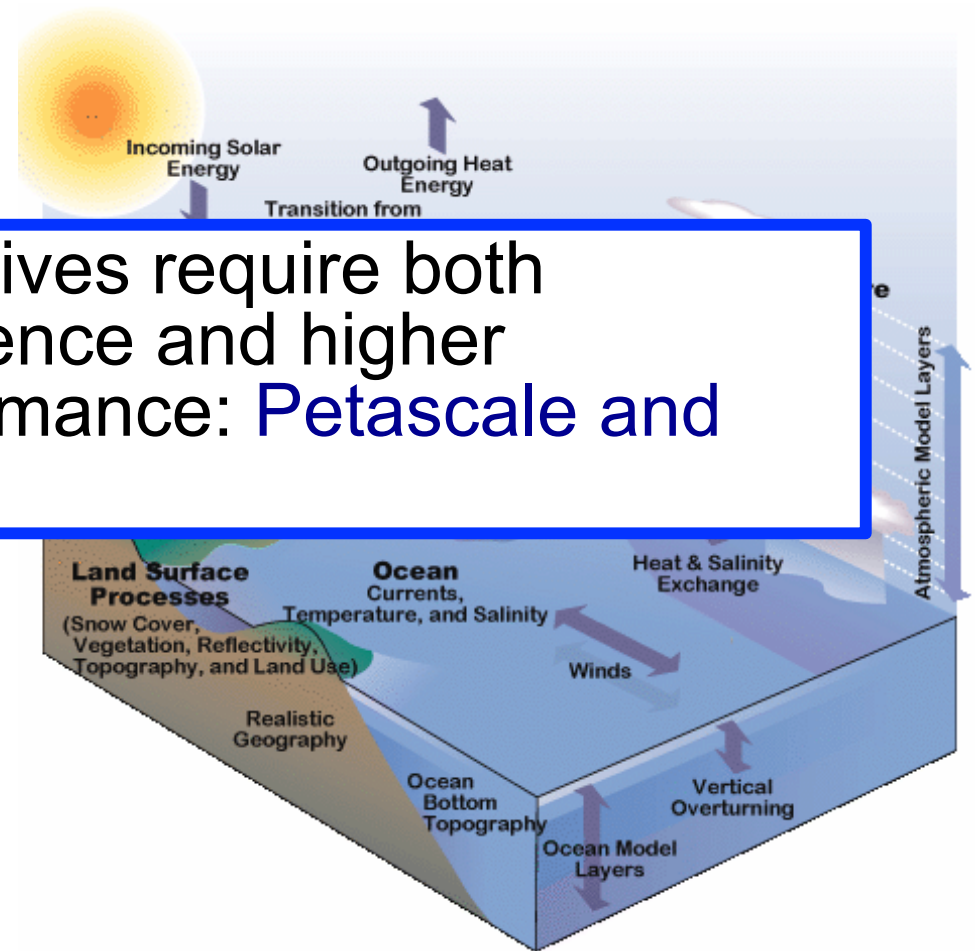
We need to improve **scientific understanding** of:

1. Regional change and resulting impacts
  - High-resolution earth system modeling
  - Enhanced dynamical and statistical downscaling
2. Severe weather events
  - Extreme temperature events (heat and cold)
  - Extreme precipitation (flood, drought)
  - Severe storms, hurricanes, tornadoes, wind
3. Sea level rise (global and regional)

# 1. Regional Change

- Enhancements to climate modeling needed to understand potential impacts on society and ecosystems.
- Our changing climate is responsible for an increased likelihood for severe, dramatic impacts.
- We need help understanding the evolution of the Earth's climate and to project future changes in our climate.
- To be more accurate and reduce uncertainties, climate models need higher resolution and more/better components that influence climate.

## Earth System Models



Meeting these objectives require both enhanced model science and higher computational performance: **Petascale and Beyond**



# Enhanced Treatment of All Climate Processes is a High Priority



## Community Earth System Model



# Likely Resolution of Climate Projections in Next Climate Assessments

	Now	Next Assess.
<b>Global Climate Models</b>	1-2° horiz (100-200 km)	0.25-0.50 (25-50 km)
<b>Regional Climate Models</b>	50 km (limited cases)	~10 km (many cases)
<b>Statistical Downscaling</b> (also at obs. Stations)	10 km (global models only)	~6 km (global and regional models)

# Going to the Next Level: Global Cloud System Resolving Climate Modeling

Direct simulation of cloud systems replacing statistical parameterization.



**Individual cloud physics fairly well understood**



**Parameterization of mesoscale cloud statistics performs poorly.**

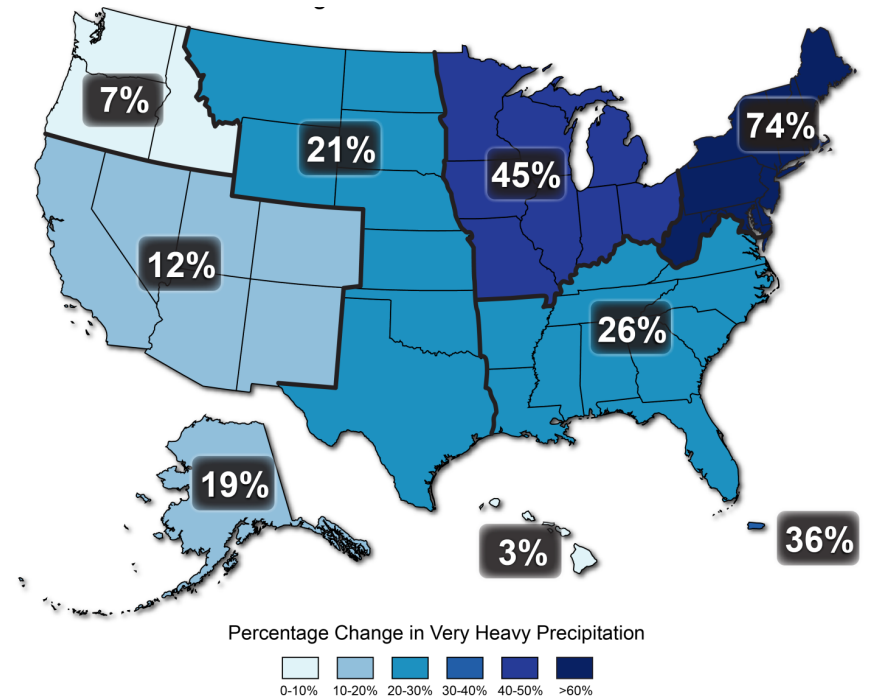


**Direct simulation of cloud systems in global models require advanced computational abilities**



## 2. Climate Extremes

- Heat waves are generally increasing; will likely become longer and more severe.
- Cold waves are decreasing.
- **More precipitation coming as larger events.**
- Increasing risk of floods in some regions (NE, MW).
- Droughts increasing in some regions (SW, SE).
- Increasing intensity of Atlantic hurricanes is likely.



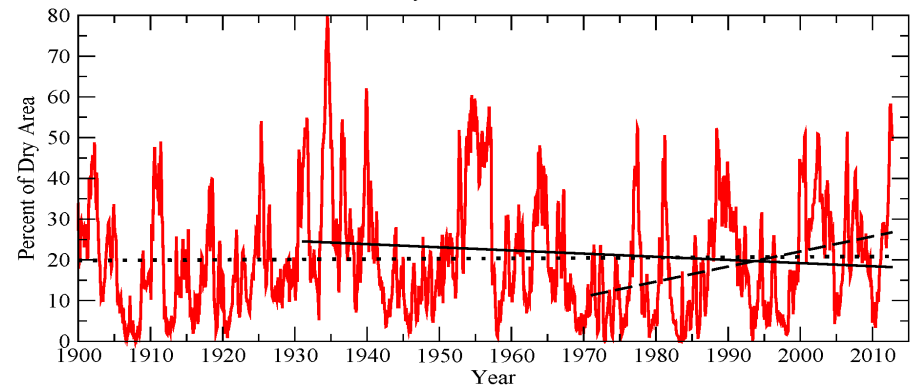
Observations show major increase in very heavy precipitation events over last 50 years

# Floods and Droughts: Clear Trends in Certain U.S. Regions

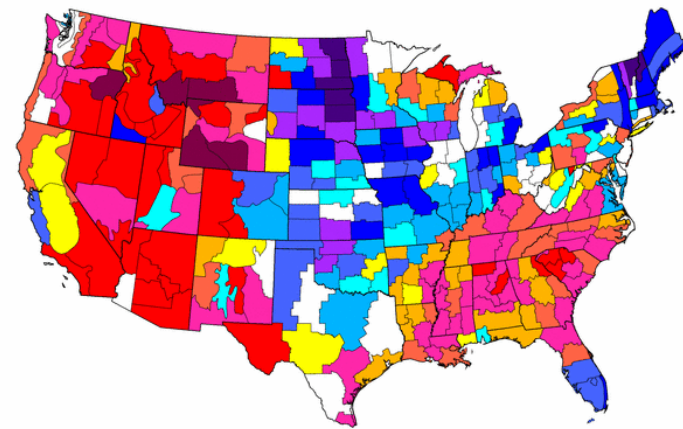
**Droughts: No strong national trend, but increasing trends in the Western states and the Southeast**

Percent of U.S. Area in Moderate to Extreme Drought

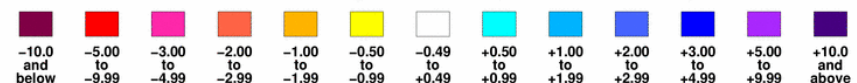
January 1900 to October 2012



Palmer Hydrological Drought Index  
1971–2010 linear regression trend, Annual



1971–2010 linear regression trend, PHDI units/century

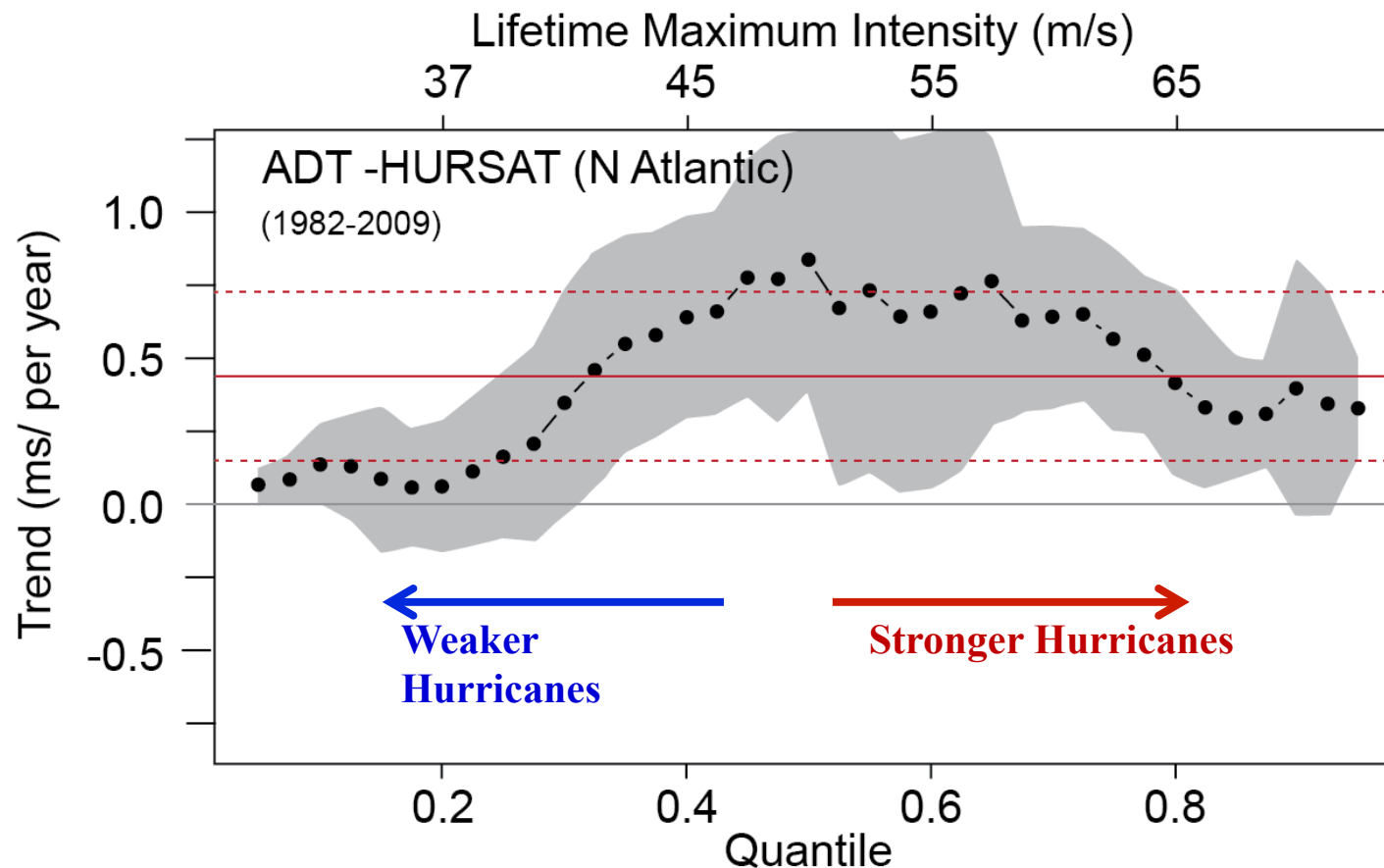


Based on Peterson et al., 2013

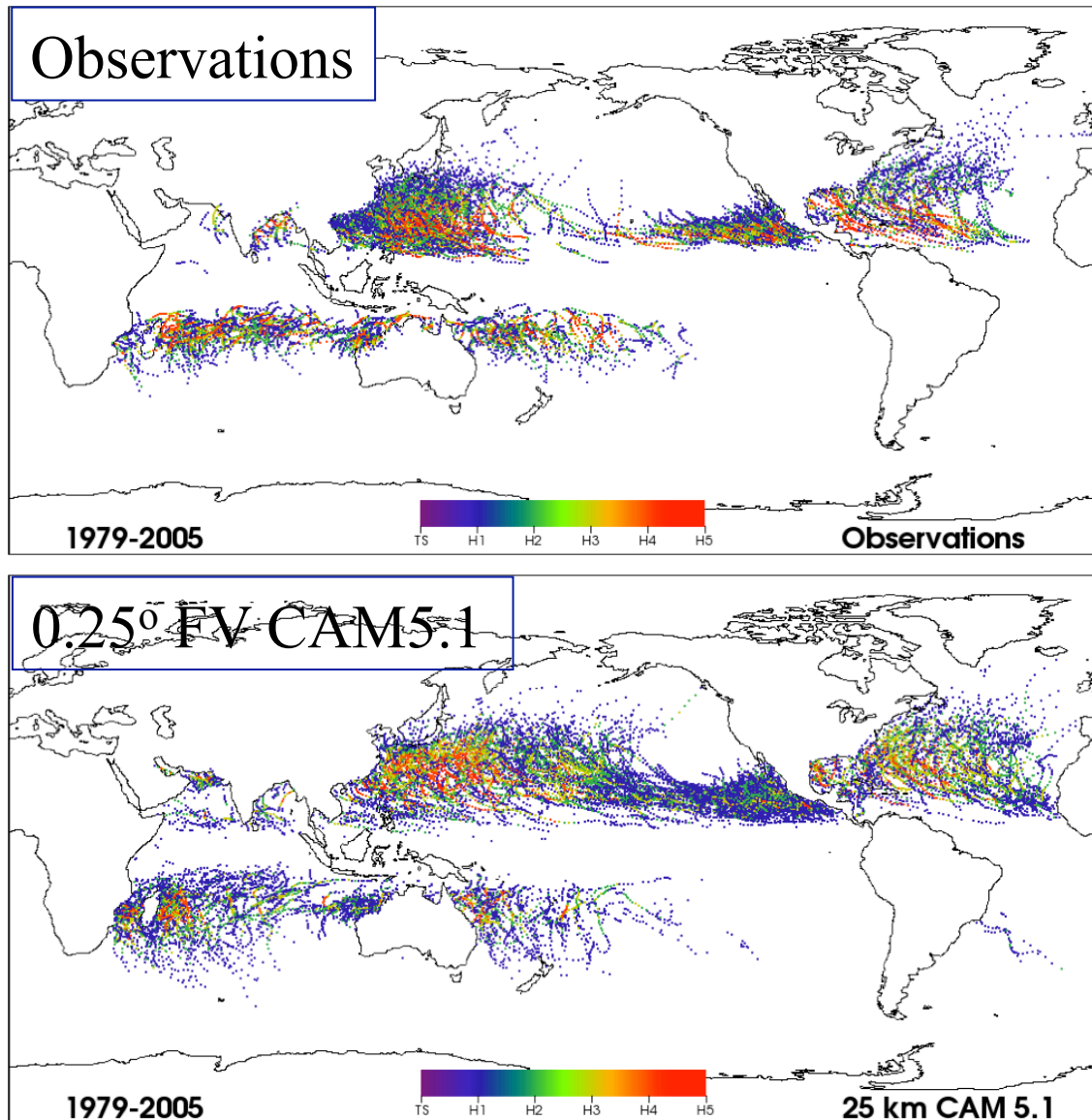
**Floods: Similarly, no strong national trend, but increasing trends in Midwest and Northeast, and decreasing trends in Southwest**

# North Atlantic Hurricanes have Become More Intense since 1980

## Storm Surge Relevant

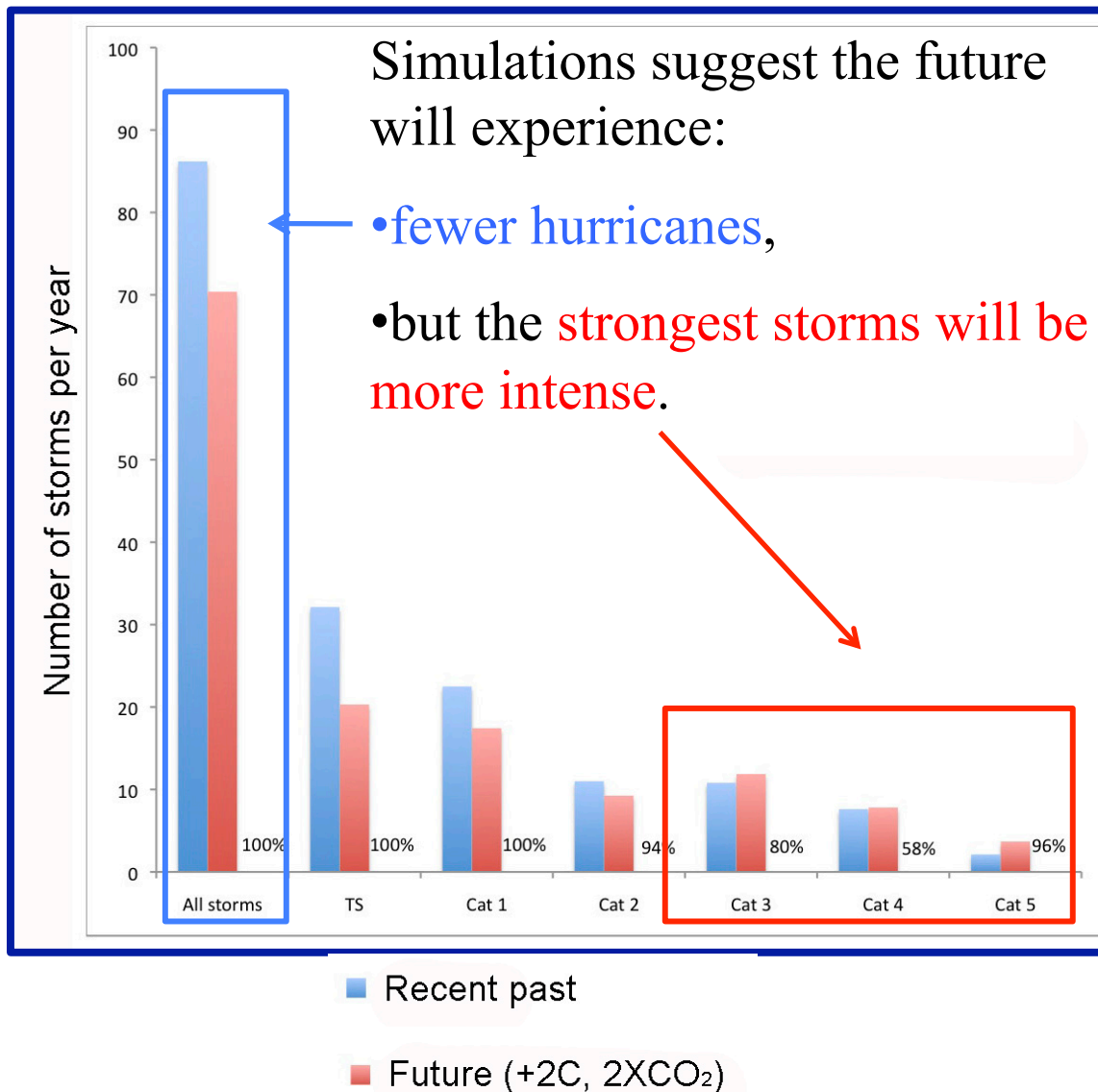


# Projected Changes in Tropical Cyclones



High resolution (0.25°) atmosphere CAM simulations produce an excellent global hurricane climatology

# Projected Increasing Hurricane Intensity

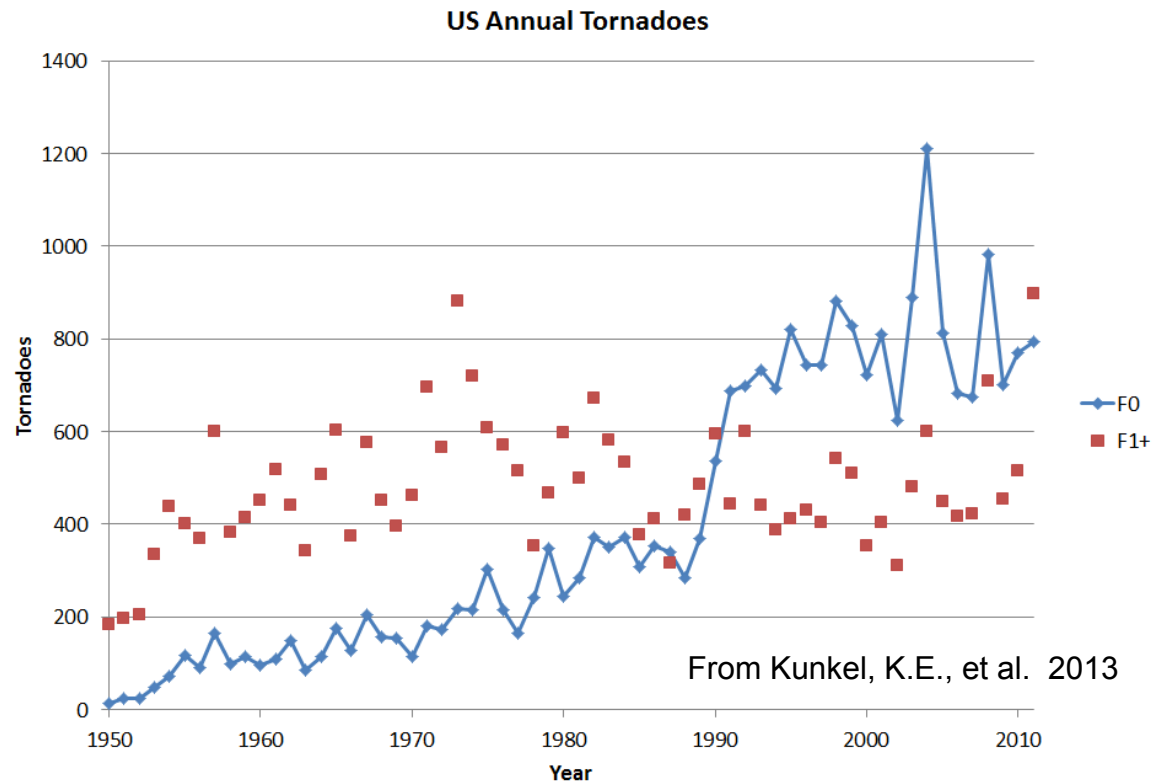


High resolution (0.25°) atmosphere simulations produce an excellent global hurricane climatology



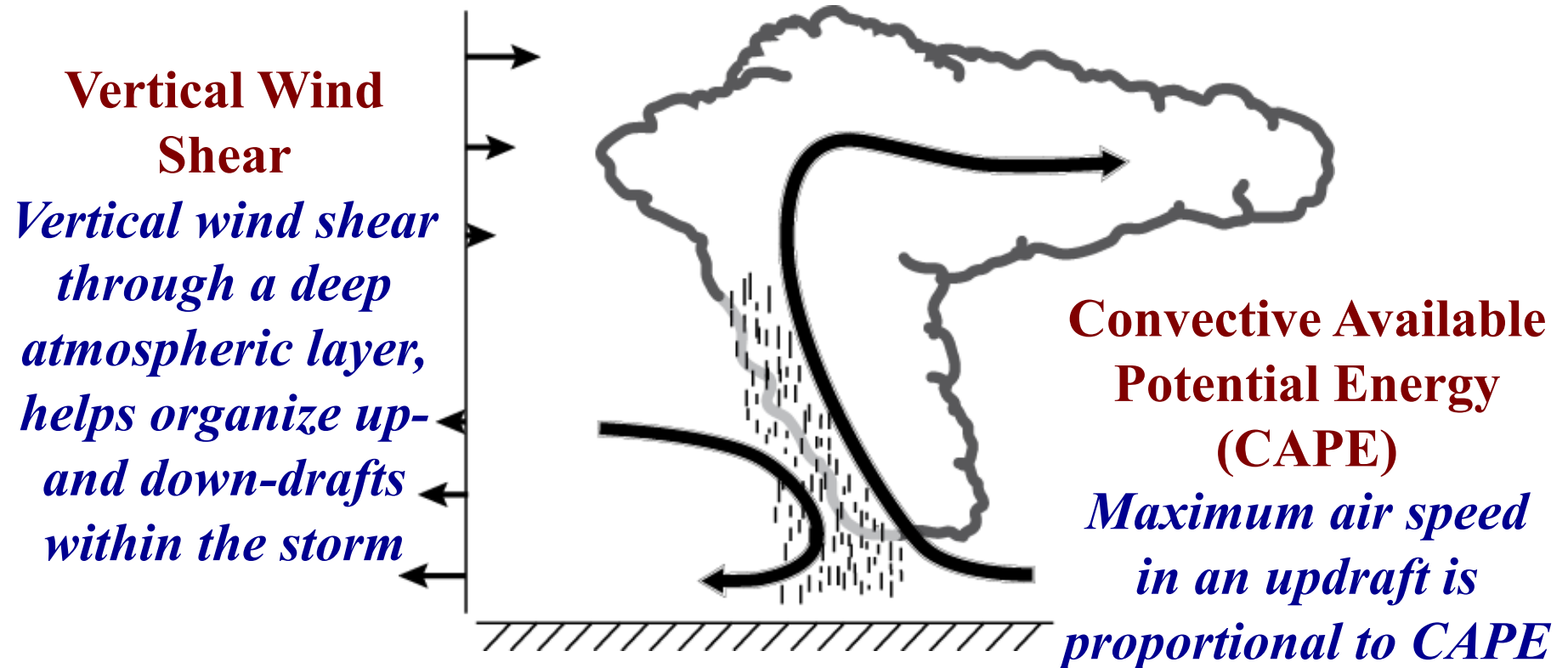
# Severe Thunderstorms: Lack of Quality Data

Large increase in small (F0) tornadoes is almost certainly due to better detection because there is no increase in stronger tornadoes. Probably no overall trend.



**Current Confidence in Projected Severe Thunderstorms: LOW**

# Two Key Processes Affecting Formation of Tornadoes



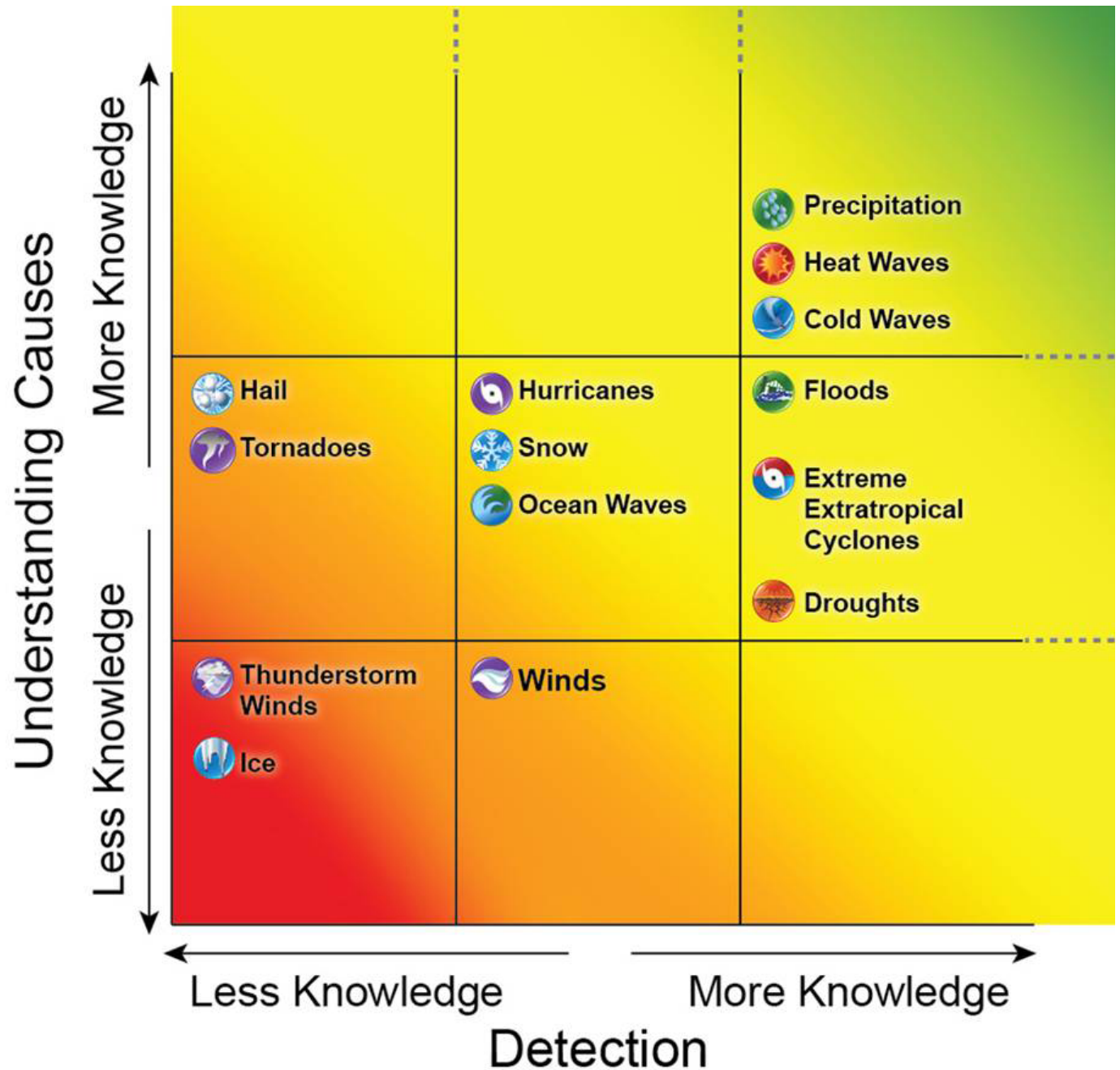
# **CMIP5 projections suggest an increase in the number of days supportive of severe thunderstorms in the U.S.**

Higher frequency of days with high CAPE, but also:

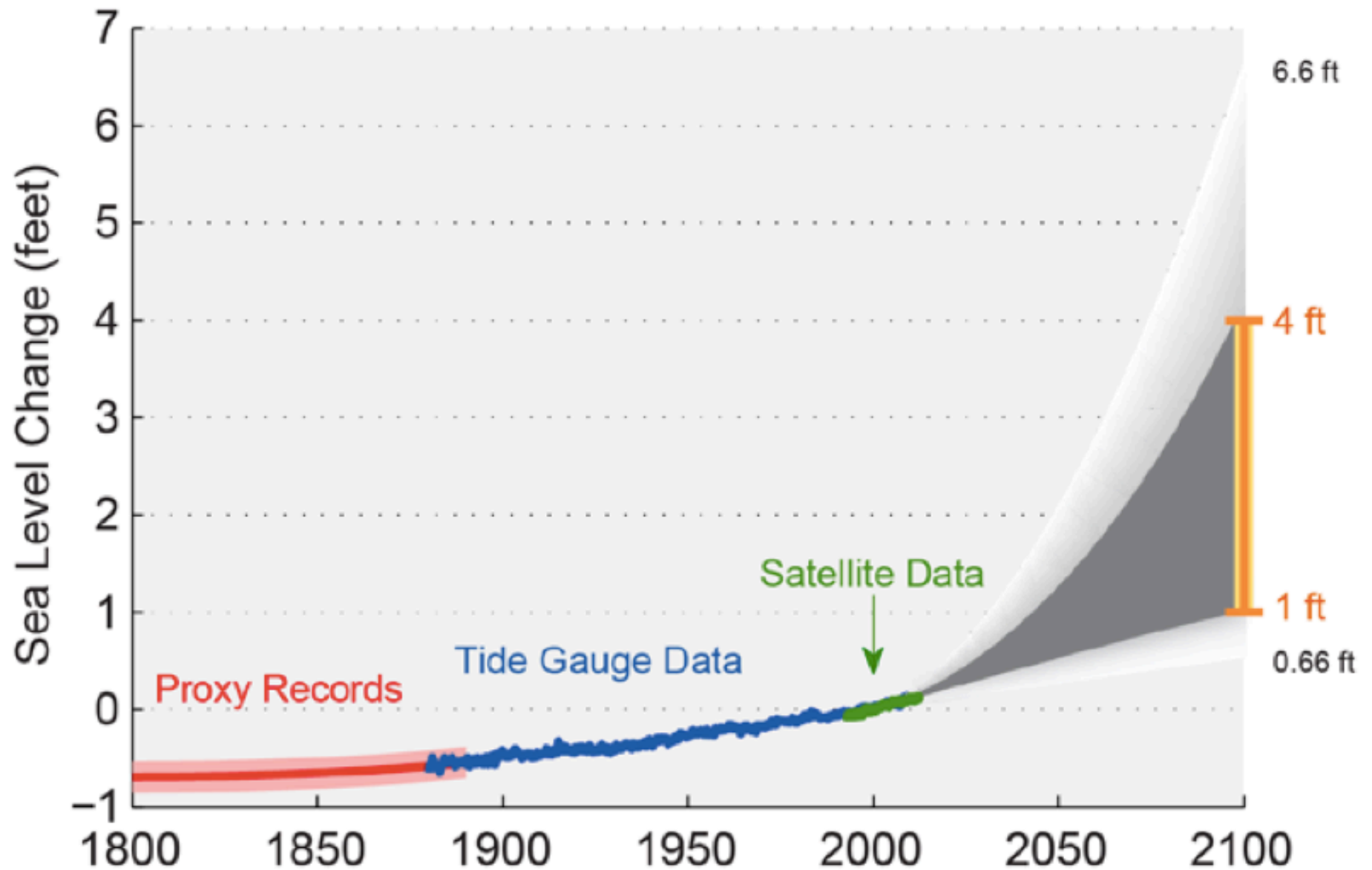
- moderate-to-high deep-layer vertical wind shear → more intense, organized thunderstorms
- moderate-to-high low-level vertical wind shear → more thunderstorms with tornadic potential
- relatively low convective inhibition (CIN) → less atmospheric resistance to the initiation of convection

**There could be an increased understanding of tornadoes and severe storms by the next assessment**

**Evaluating  
Extremes:  
The results  
from four  
special  
Workshops  
– papers  
published in  
BAMS**



### 3. Sea Level Rise





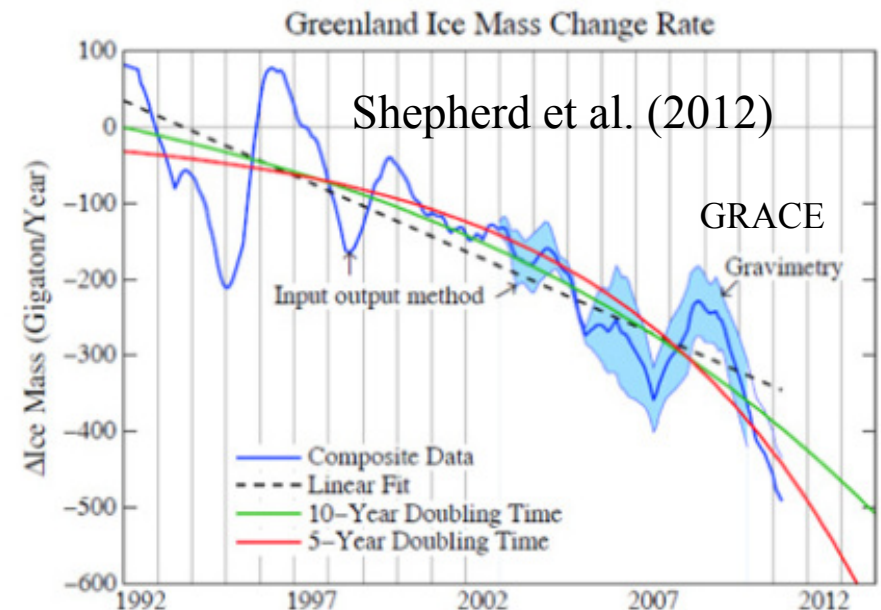
# Projecting Changes in the Greenland and Antarctica Ice Sheets

## ➤ Greenland

- Mass is being lost, but questionable as to how much can be lost during the 21<sup>st</sup> century
- “Bumpiness” of terrain is an issue

## ➤ Antarctica

- Major questions about potential large losses this century in West Antarctica
- Depends on melting of the “flying buttresses”



# Looking at the Next U.S. National Climate Assessment

- **The U.S. climate is changing: temperature is increasing and growing season is getting longer**
  - The next generation of models and analysis tools likely to be further advanced through the enhancement of model processes while going to higher resolution.
  - The net result is better analyses at the local and regional scales needed for impacts and policy analyses.
- **Some types of extreme weather events are becoming more common. Trends are likely to continue.**
  - Enhanced understanding of these events to be expected.
  - We may see much better understanding of some events that we currently cannot adequately address (e.g., tornadoes, hail).



*Thank You*

