NOAA's Observations, Modeling, and Research on Climate Variability and Change

Presenters:
Thomas R. Karl, *Director, National Climatic Data Center*
(Climate Services Lead)
V. Ramaswamy, *Director, Geophysical Fluid Dynamics Laboratory*
M. Hoerling, *Meteorologist, Earth System Research Laboratory*

February 23, 2009

The Climate Challenge

- **The Trends** (IPCC, 2007)
  - Climate is unequivocally warming and changing, projected to continue and increase
  - Humans are very likely responsible for the warming
  - Impacts already affecting many sectors and regions, some more than others

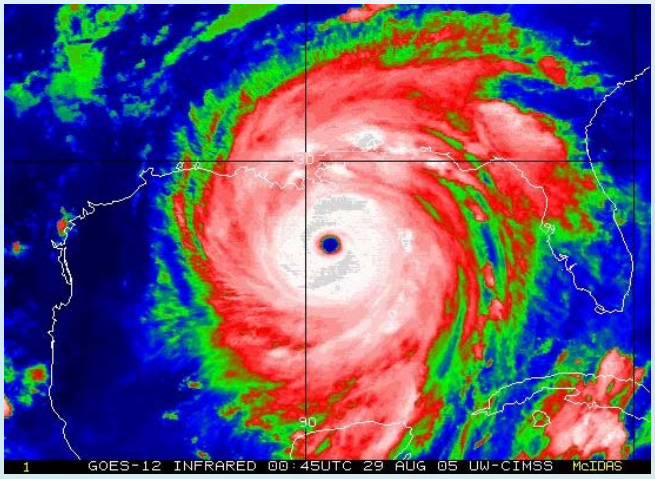
- **The Questions**
  - How can we distinguish between climate change and natural climate variability to guide and sustain climate policy?
  - How will climate evolve in the future?
  - What impacts will the future climate bring?
  - How will we adapt to an evolving climate?
  - How will we mitigate effects?

Climate information is needed now to inform decisions today and tomorrow

Briefing Outline

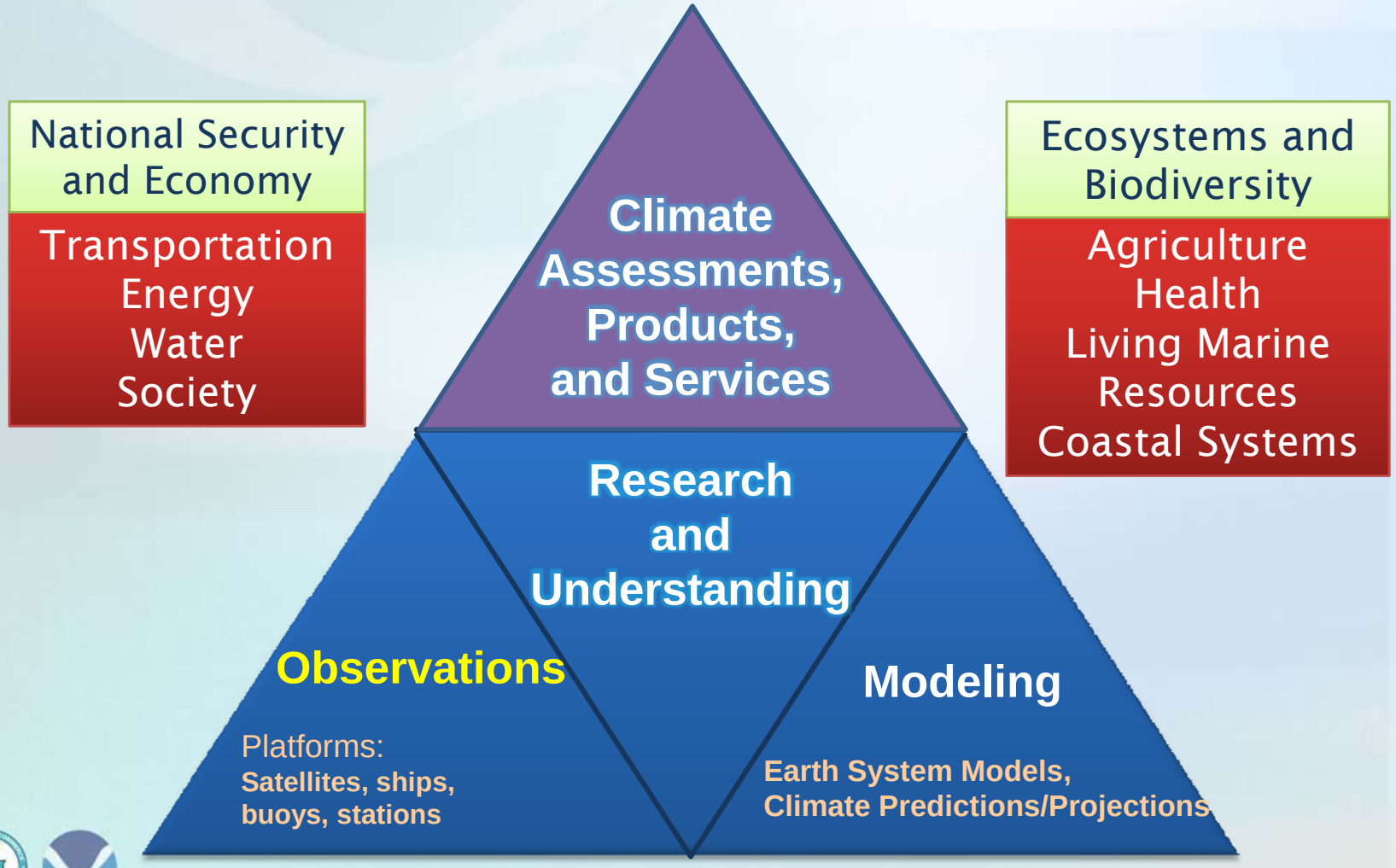
NOAA's climate science capabilities:

- Policy support
- Observations and monitoring
- Modeling, predictions and projections
- Understanding the causes and impacts of climate variability and change



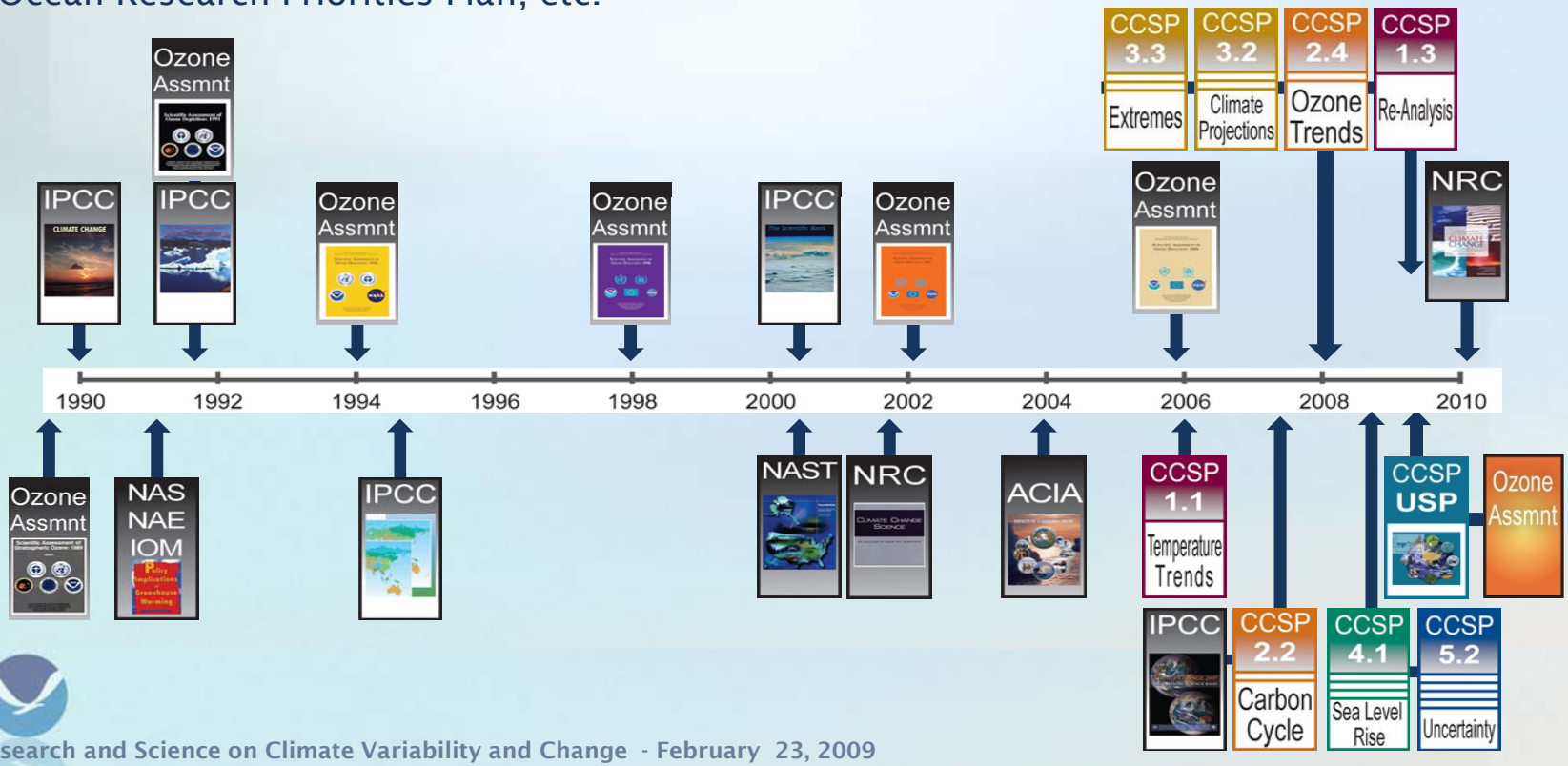
NOAA: Understanding Changing Climate For Climate Risk Management

NOAA's tool box



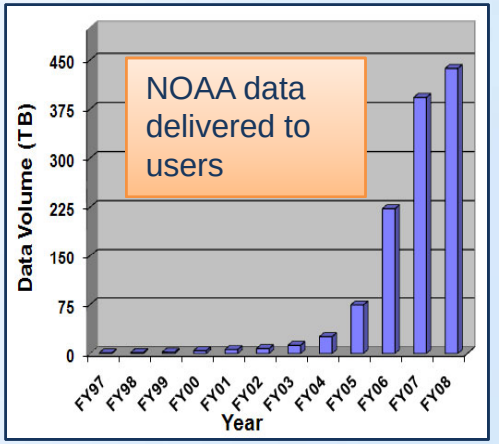
NOAA Responds to Policy Needs

- In the last 20 years, NOAA's climate assessment record includes:
  - 6 Ozone science assessments to support the Montreal Protocol
  - Lead roles in 5 Intergovernmental Panel on Climate Change (IPCC) assessments
  - 1st U.S. National Climate Assessment & ongoing Climate Change Impacts in the U.S. Assessment
  - 9 U.S. Climate Change Science Program (CCSP) assessments
- NOAA climate research priorities are also driven by strategic planning
  - 5-year NOAA Research Plan, 20-year NOAA Research Vision
  - Ocean Research Priorities Plan, etc.

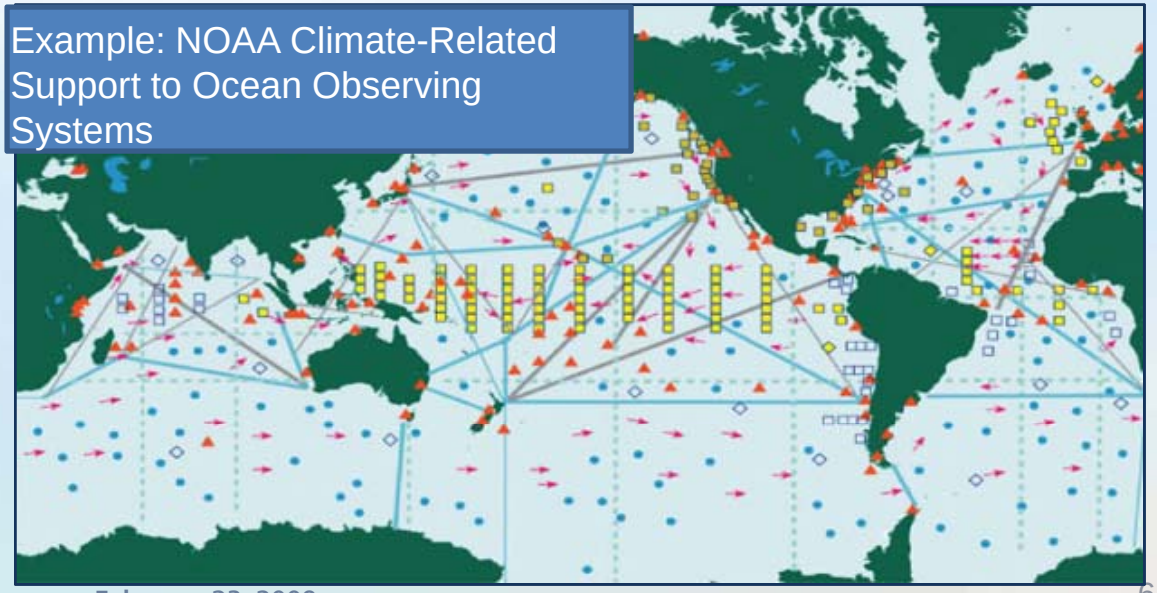


NOAA Operates 109 Observing Systems

- 50+ years of CO_2 Observations
- Ocean and Coastal Observation Systems
- Atmospheric Observations
- Remote sensing/satellite observations
- Land-based Observations
- Many observation systems built with extensive international partnerships
- Plans to complete, enhance, and deliver more climate information to users
- NOAA maintains large databases of both historical and current climate data

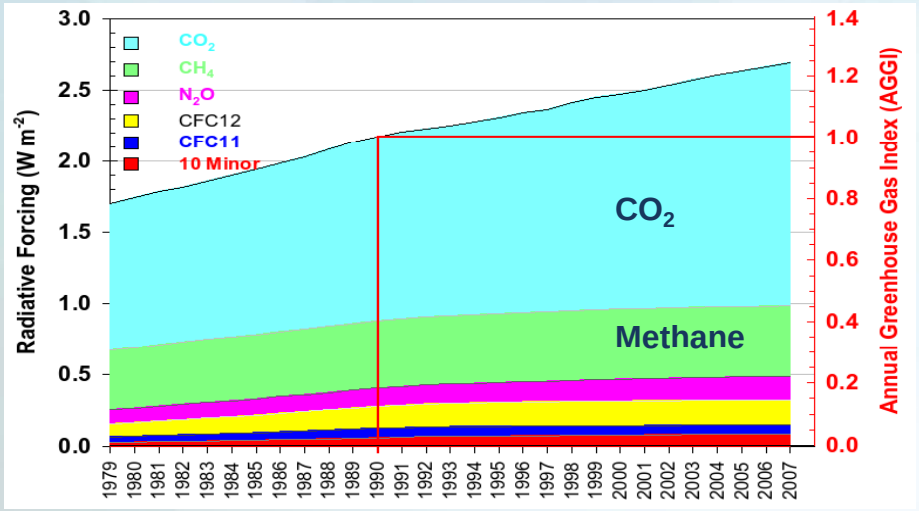


Example: NOAA Climate-Related Support to Ocean Observing Systems

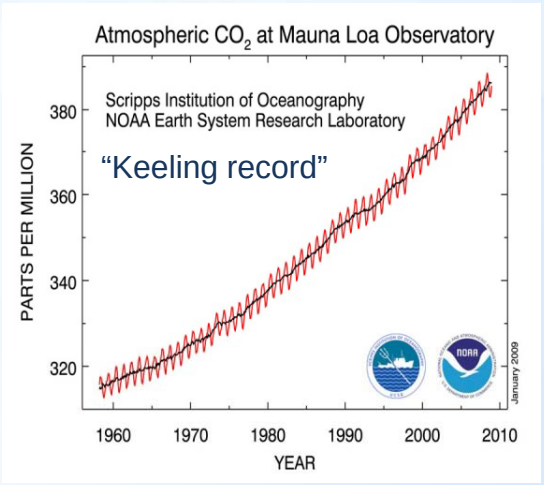


NOAA Monitors Atmospheric Carbon Dioxide and other Greenhouse Gases

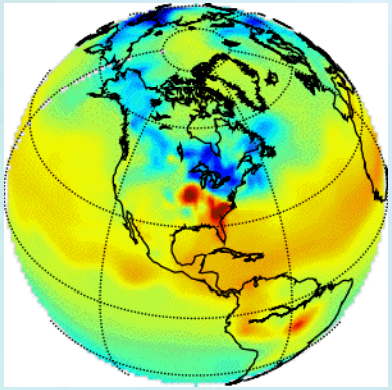
NOAA Annual Greenhouse Gas Index



CO_2 Trends



Carbon Tracker: Atmospheric CO_2



carbontracker.noaa.gov

CO_2 Accounting

Atmospheric CO_2 Account		10^{15} grams of carbon per year*
Date	**Origin**	**Balance**
annual	Biosphere	− 3
annual	Ocean	− 2
annual	Fossil Fuel Burning	+ 7
annual	Deforestation	+ 2
Annually Reported Atmospheric Balance		**+ 4**

* These numbers are approximate and are for the whole globe

NOAA Also Monitors Ocean Carbon

- The ocean absorbs 1/3 of the CO_2 released in the atmosphere. CO_2 is converted in ocean water to carbonic acid.

- As carbon dioxide levels increase in the atmosphere, the ocean increases in acidity which impacts marine life including coral reefs and shellfish.

Current and Future Activities:

- Deployment of buoys to measure the exchange of CO_2 between the atmosphere and ocean

- Analysis of satellite data to better understand the exchange of CO_2 between the atmosphere and sea

- Improve our understanding and modeling capability for ocean carbon chemistry to predict future acidification

World's first ocean acidification buoy (NOAA, 2007)

Double Whammy: Coral growth is threatened by both the warming and acidification of the ocean

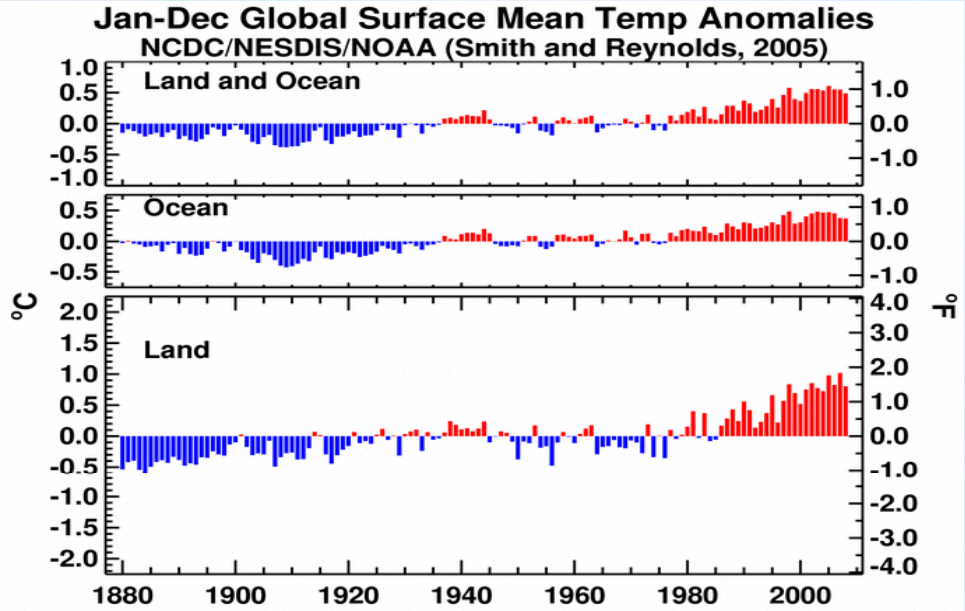
NOAA: Continuous Climate Monitoring & Reporting

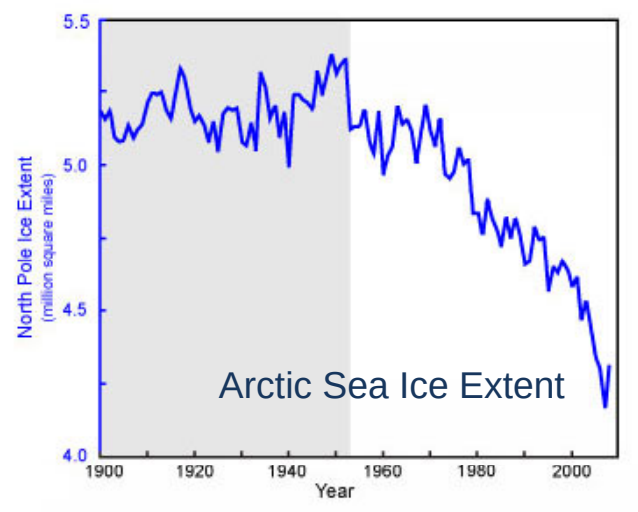
2008 Global Temperatures

Global land + ocean – 8th **warmest**
- Above average by **+0.49 ºC**

Land Only– 6th **warmest**
- Above average by **+0.81 ºC**

Ocean Only– 10th **warmest**
- Above average by **+0.37 ºC**

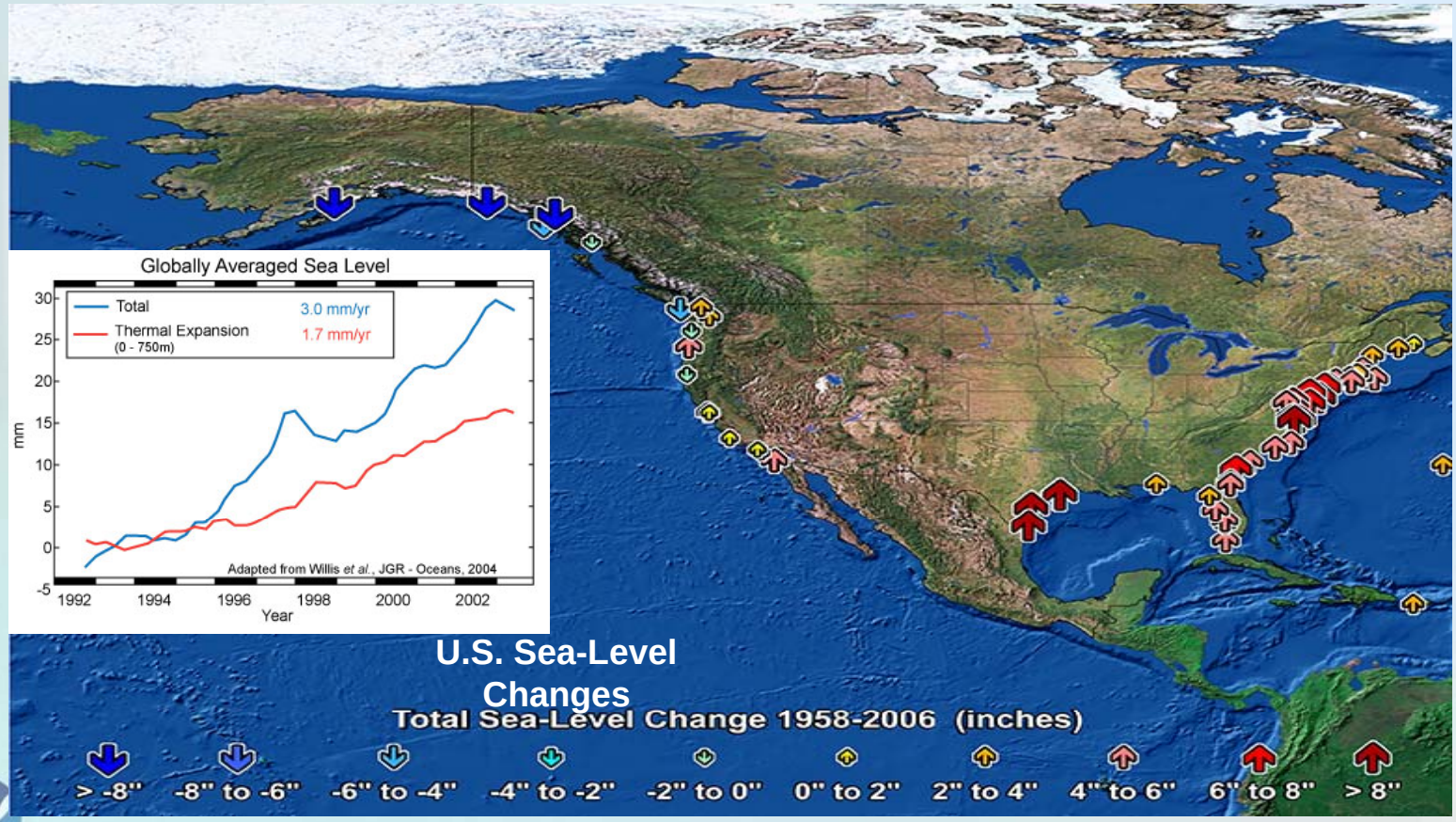




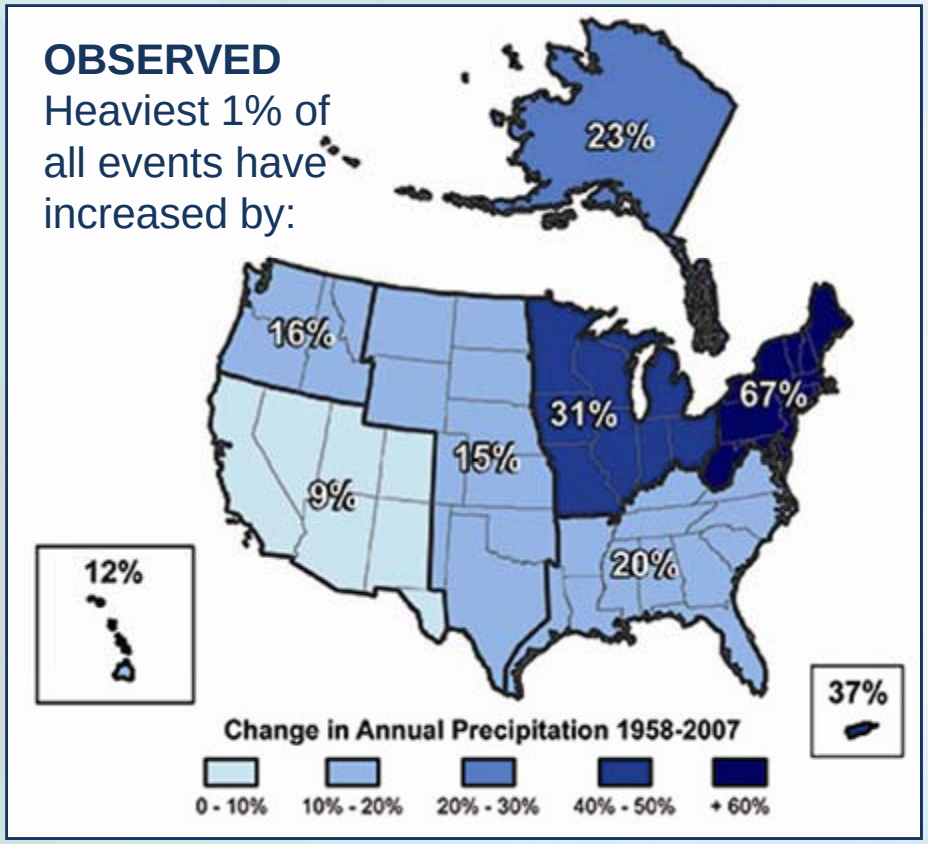
The 2008 sea ice extent was the lowest, second only to the 2007 record.

NOAA Measures Change in Sea Level

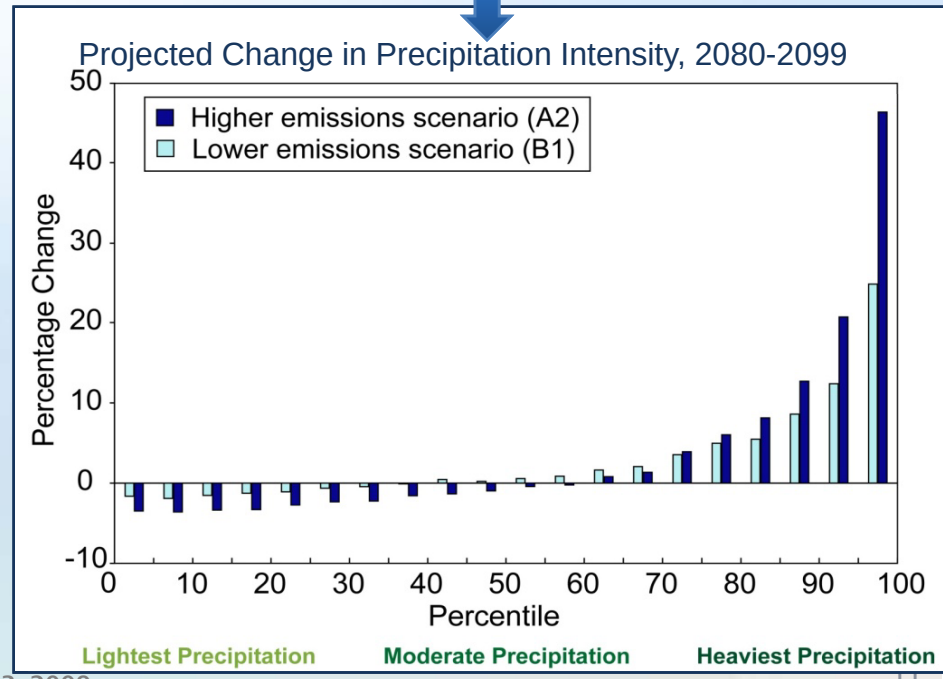
- NOAA integrates measurements of water level, land elevation, ocean temperature, sea ice extent and thickness
- Need to address both global drivers and local differences in sea level rise
- Combining physical impacts of sea level change with improved understanding of coastal vulnerability and resilience
- Over the past 50 years, the world's oceans have absorbed 84% of the heat from global temperature increases, causing the oceans to warm and to expand.



NOAA Monitors Heavy and Extreme Precipitation



- Urgent need to provide climate information about changing extremes for:
  - public safety purposes
  - engineering design for infrastructure projects.
- Observed increase in heavy precipitation is not expected to abate



Updated from Groisman *et al.*

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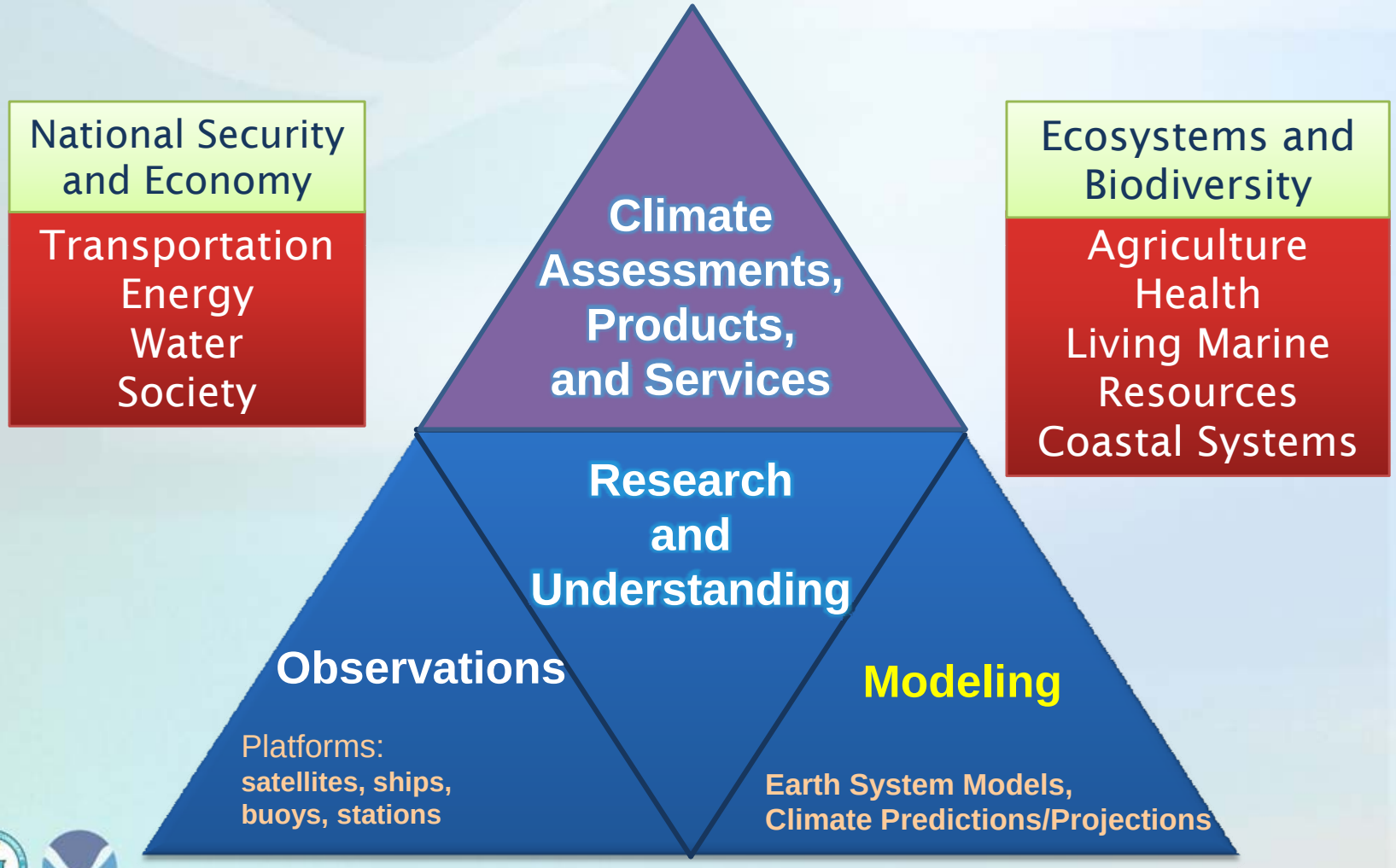
NOAA's tool box



NOAA's Research and Science on Climate Variability and Change

Modeling of the Earth System

Presenter:
V. Ramaswamy, Director, Geophysical Fluid Dynamics Laboratory

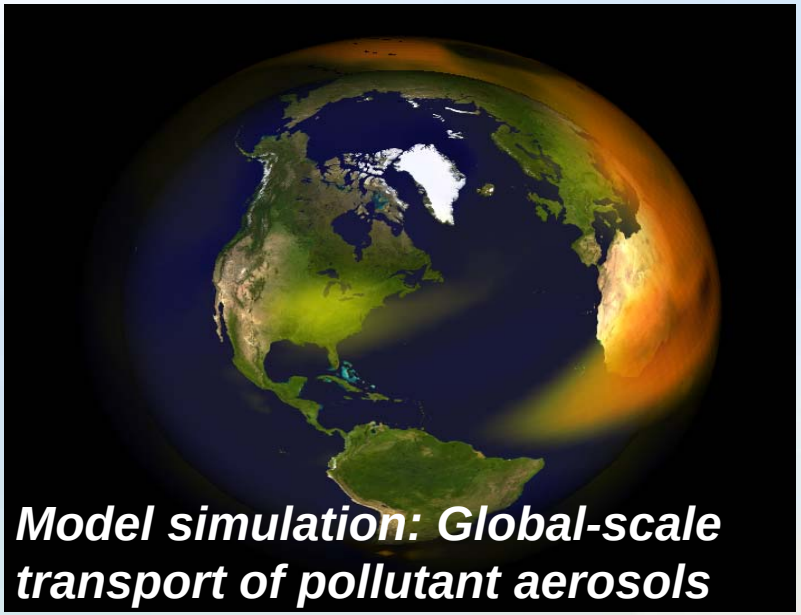
February 23, 2009

NOAA Modeling Addresses Emerging Issues in Climate

- NOAA models future climate variations and change on a spectrum of timescales

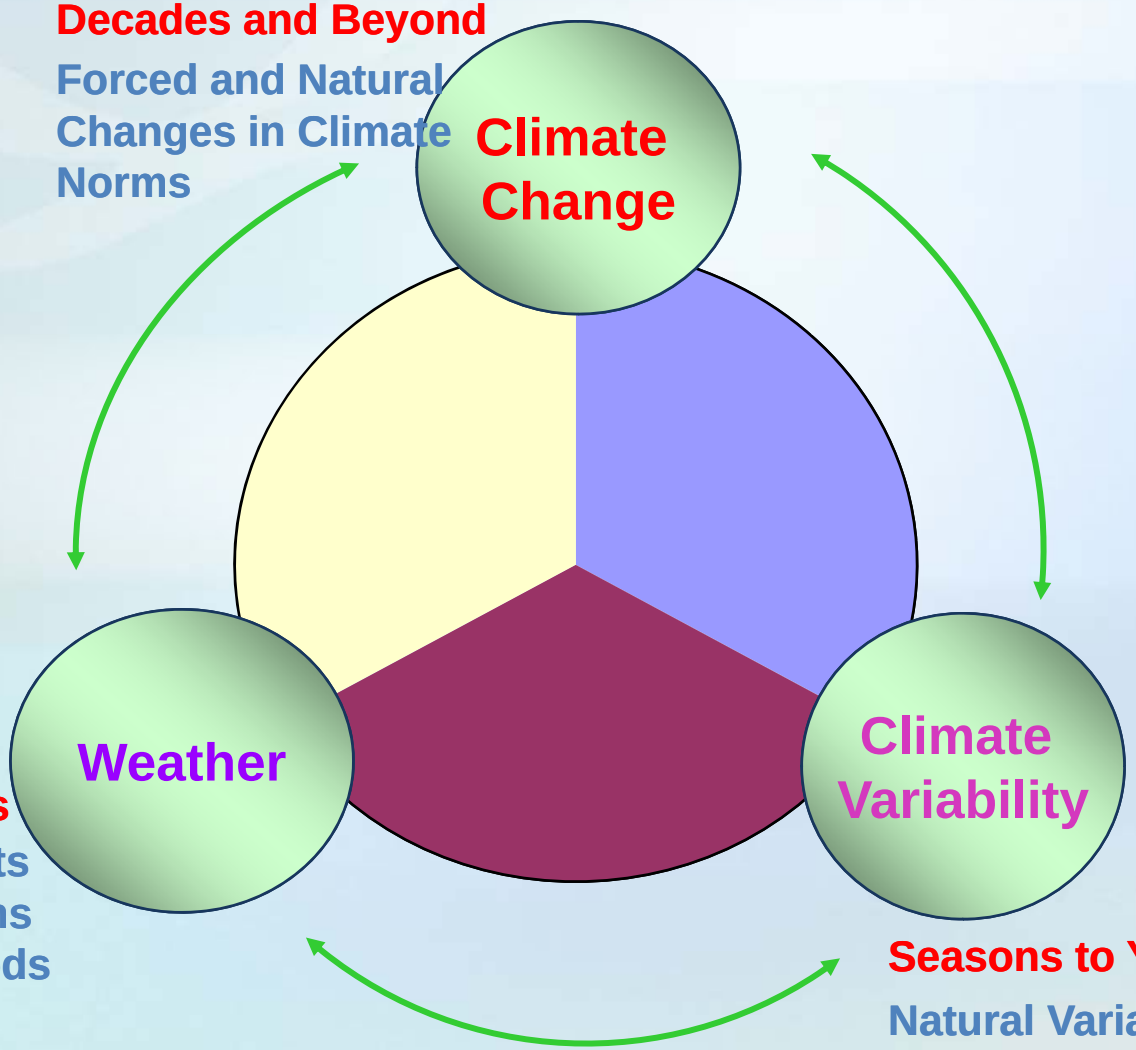
  Seasonal ⟷ annual ⟷ decadal ⟷ centennial

- Emission scenarios are used as inputs into earth system models, which inform decision-making
  - NOAA operates two global climate models used for IPCC assessments
- Identification of causes of observed climate change
- Regional climate change and related local impacts
- Climate and air pollution
- Abrupt change and climate extremes
- Complex climate system feedbacks (e.g., carbon cycle, clouds, etc.)



Model simulation: Global-scale transport of pollutant aerosols

NOAA Models Across the Weather – Climate Spectrum



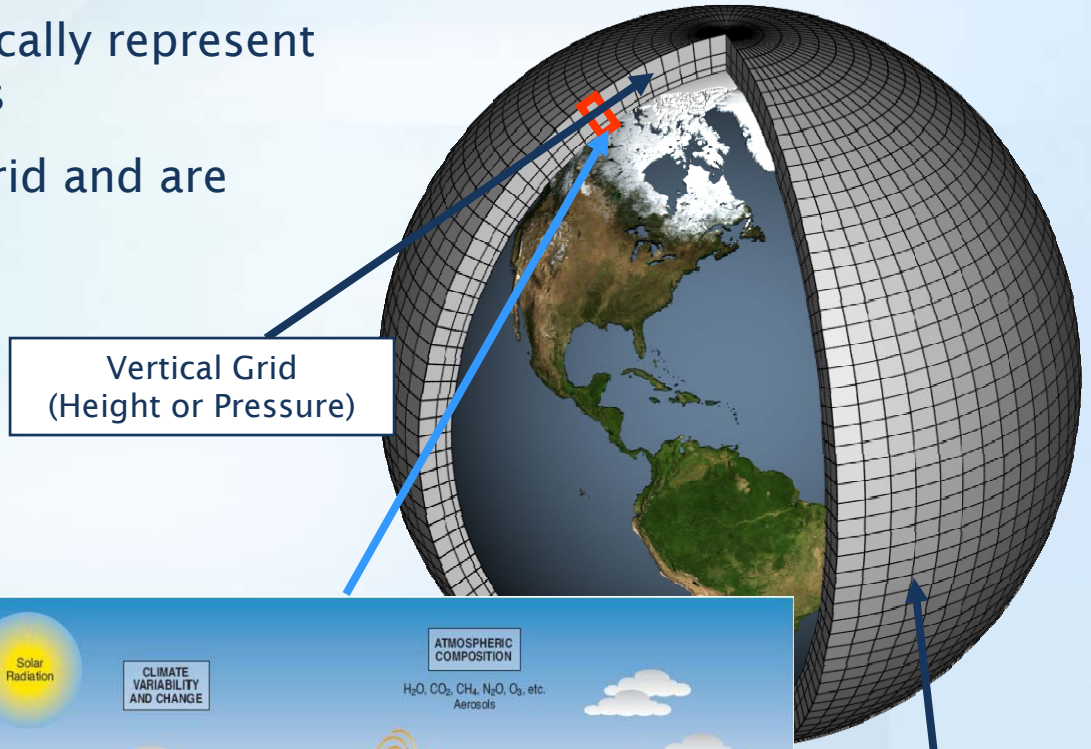
NOAA Develops Earth System Models for Climate Prediction and Projection

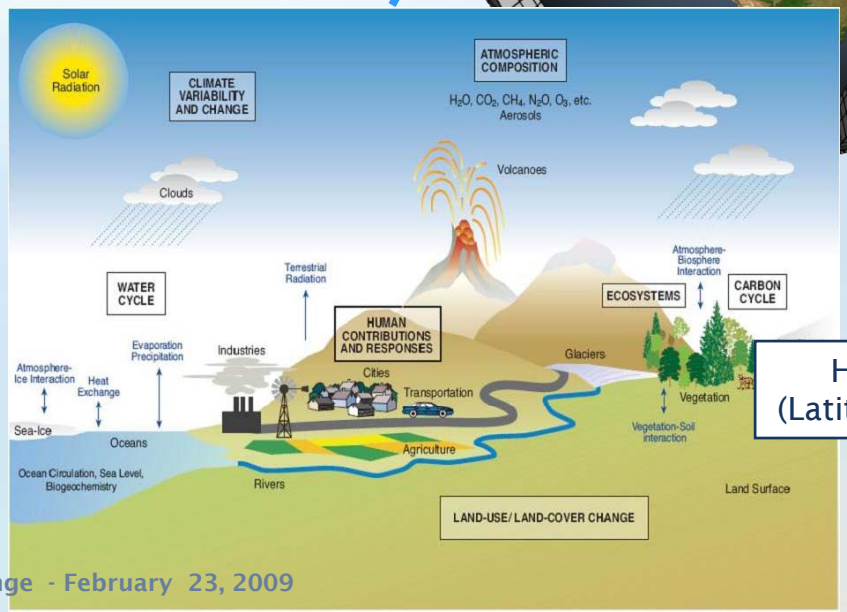
- Earth System Models mathematically represent Earth's major physical processes
- Model equations operate on a grid and are solved on a supercomputer.

These models are used to produce:

Climate Predictions: an estimate of future climate in the ***short-term***, based on climate conditions now.

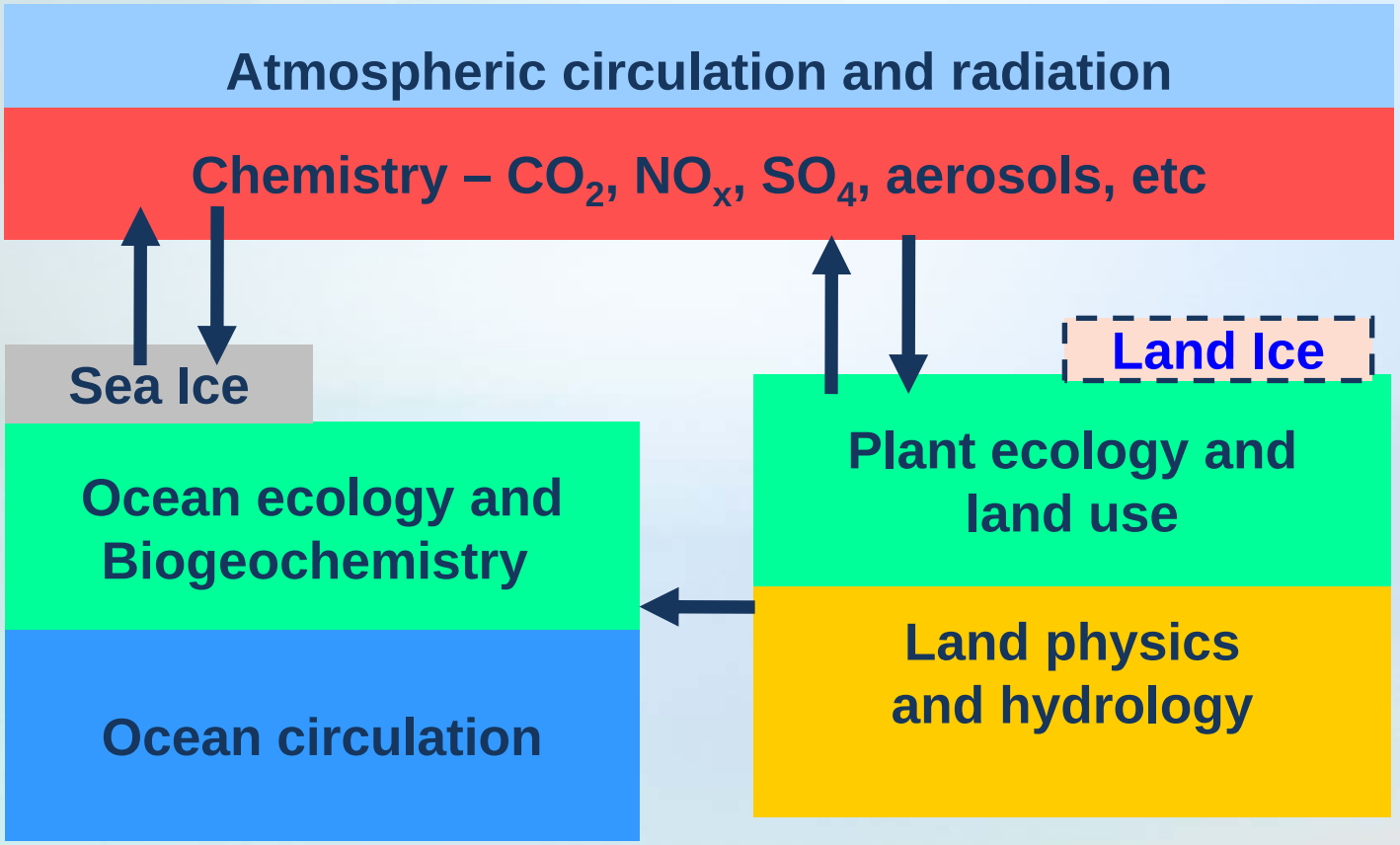
Climate Projections: an estimate of future climate on ***longer timescales***, based on expected changes like increased carbon dioxide.





NOAA Continues to Improve Earth System Models

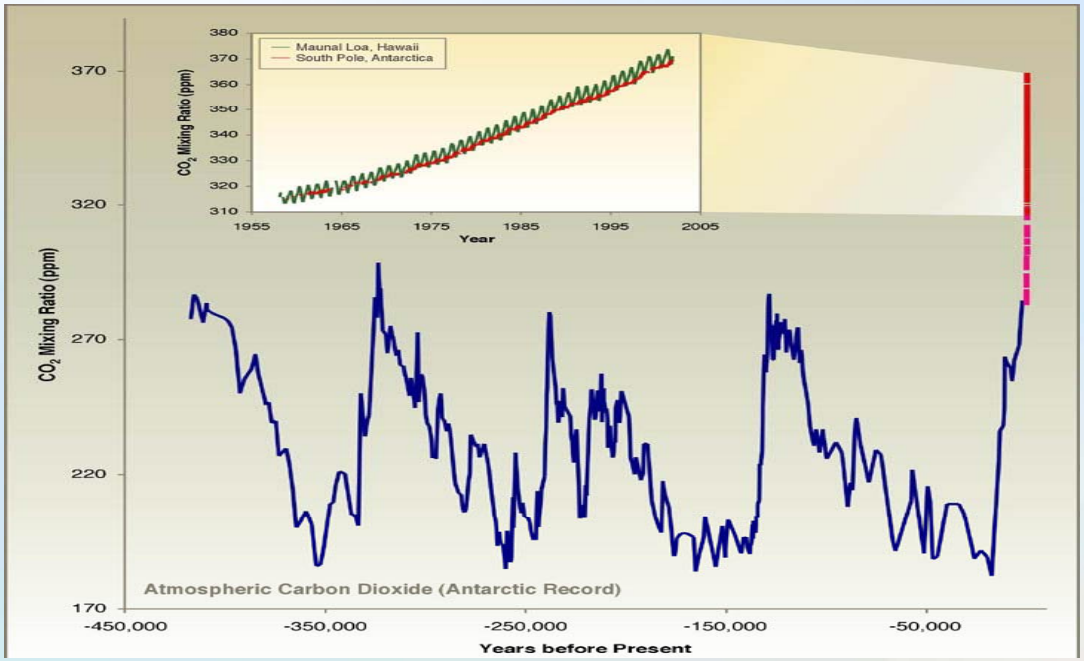
Models provide a better understanding of the climate system, and climate simulations provide inputs for decision-making (e.g., IPCC)



NOAA Models: Used to Understand the Role of Carbon in the Climate System

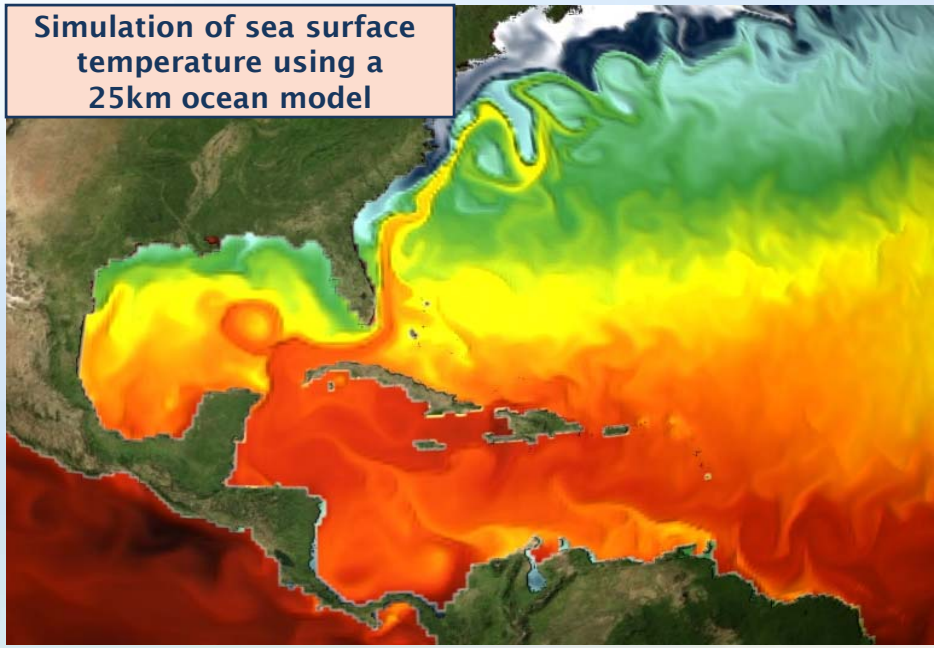
- What happens to the carbon we burn from fossil fuels?
  - The ocean and land currently have been absorbing about 1/2 of the additional carbon we emit into the atmosphere.
    - Will this continue as the climate system evolves?
- There are large uncertainties in our carbon cycle knowledge:
  - How much extra CO_2 will be absorbed by land plants?
  - Will barren ocean areas begin to absorb CO_2 and initiate ocean plant growth?

- **NOAA's Earth System Models answer these questions by:**
  - **Including complex physical and chemical processes**
  - **Representing all facets of the carbon cycle**



NOAA Models: Used to Understand and Predict Decadal Climate

- Understanding how climate changes over the course of decades is a pressing societal need, and is a current **modeling challenge**
- NOAA's decadal climate model predictions include:
  - Natural climate variability
  - Effects of increasing greenhouse gases and aerosols
- Decadal climate simulations inform important policy decisions
- NOAA will continue to improve its modeling at decadal time scales as:
  - Climate observation networks continue to grow
  - Computing capabilities advance
  - Climate scientists achieve a greater understanding of the climate system

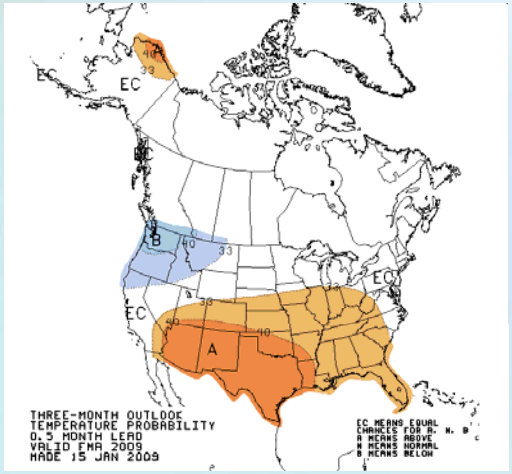


NOAA Models: Used For Operational Climate Outlooks and Prediction Products

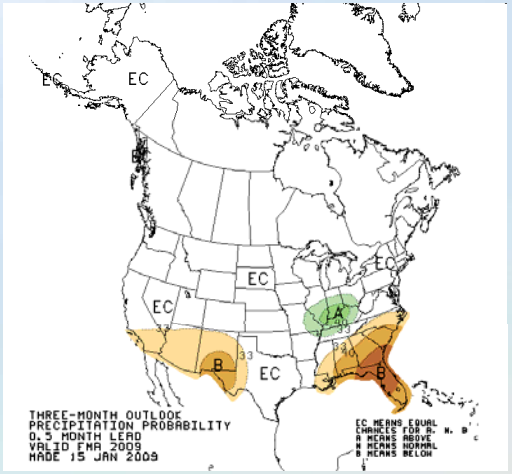
Focus on months, seasons, and year-to-year

- Regular Hazards Risks Assessments (US, Global Tropics)
- Monthly & Seasonal Precipitation & Temperature
- Seasonal Drought Outlooks
- Seasonal Hurricane Outlooks (Atlantic and Eastern Pacific)
- El Nino/La Nina Outlooks

Feb-Apr 2009
Temperature Outlook



Feb-Apr 2009
Precipitation Outlook



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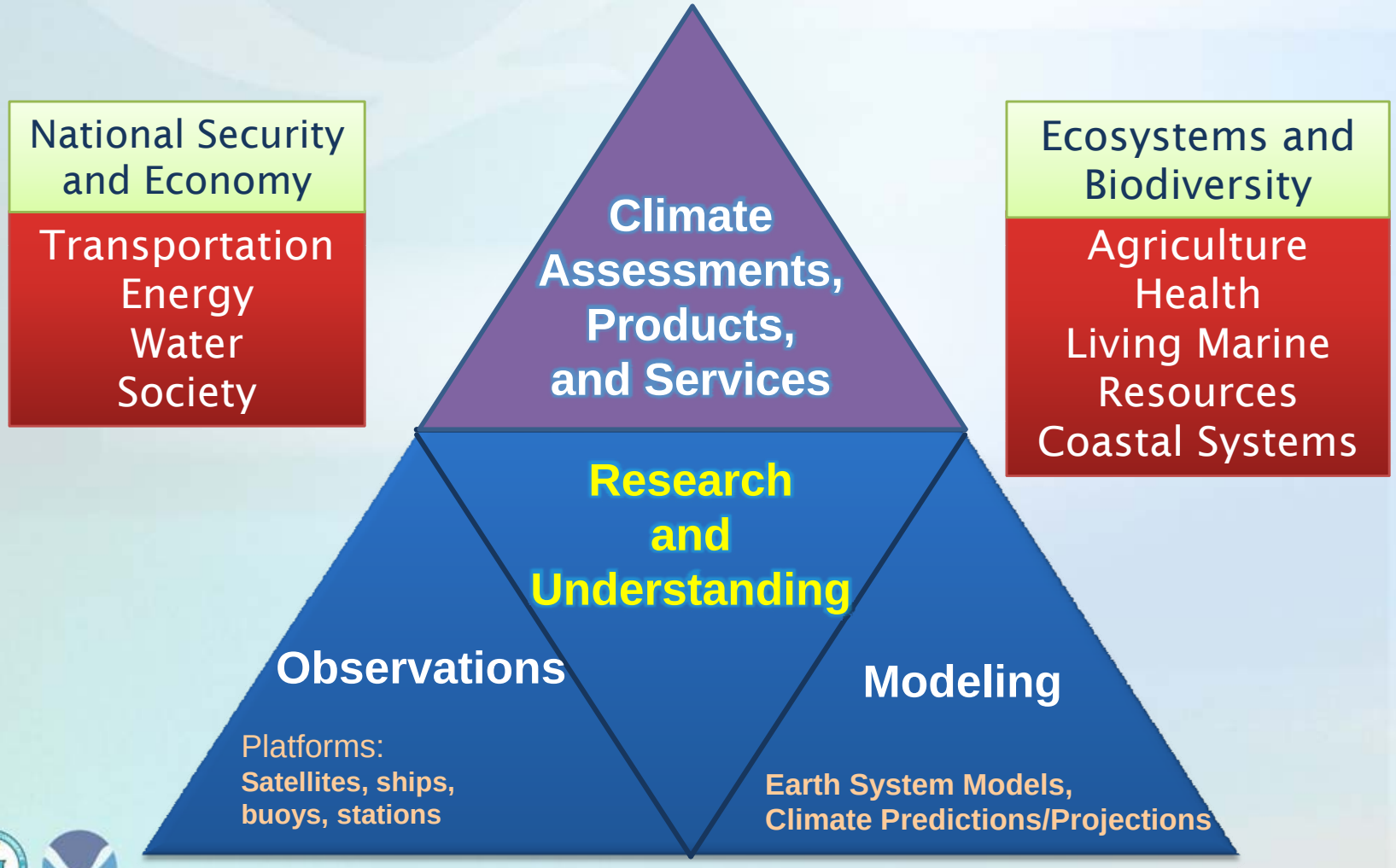
NOAA's tool box



NOAA's Research and Science on Climate Variability and Change

Understanding the Causes and Impacts of Climate Extremes

Presenter:
M. Hoerling, Meteorologist, Earth System Research Laboratory

February 23, 2009

NOAA's Tools for Understanding the Causes of Climate Extremes

Observations : What is Happening?

- Observed climate state
- Historical context (variations vs trend)

Diagnosis & Modeling : Why is it Happening?

- Consistent Earth System analysis through time
- Model experimentation (cause-effect linkages)
- High resolution & multiple simulations (robustness)

NOAA Researches High-Impact Climate Conditions:

- Extreme hurricane seasons
- Extreme drought and flooding events
- Unexplained warm or cool trends, etc.

The 2005 Extreme Atlantic Hurricane Season: >$100B Losses

What NOAA Currently Knows

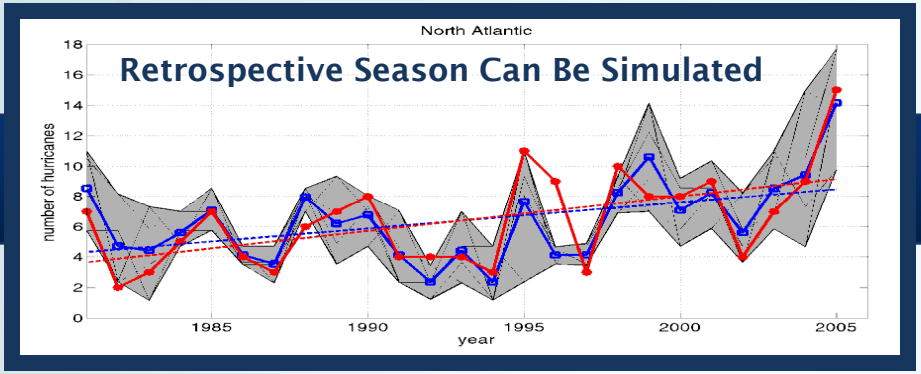
- Atlantic hurricane intensity is related to warmer North Atlantic sea surface temperatures.
- Additional greenhouse gases have contributed to a warming of ocean temperatures where hurricanes begin forming.

Opportunity for Improving Hurricane Predictions

- Improvements in understanding and predicting hurricane behavior will require new modeling capabilities: better equations, better models, more computing capacity, and more observations

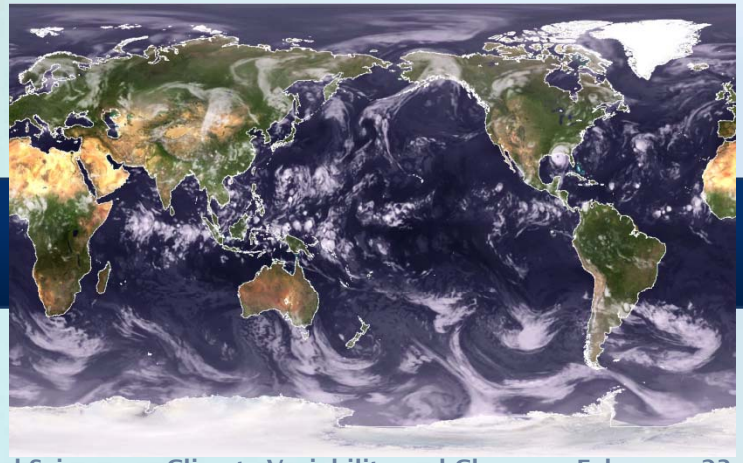
NOAA's Strategy for Improved Understanding Hurricane-Climate Linkages

Current Capabilities: NOAA can simulate past hurricane seasons on a **regional** scale



Atlantic Hurricane Count: 1981-2005
Observed vs NOAA regional model simulation

Future Capabilities: NOAA is developing prototype atmospheric models on a **local** scale



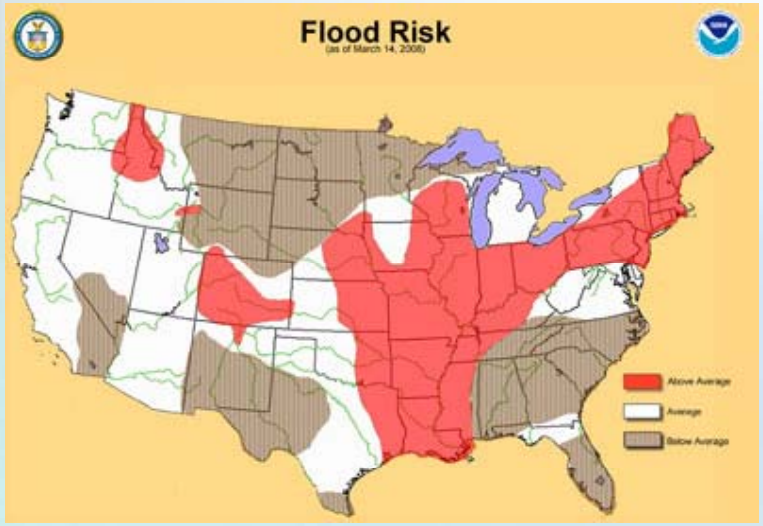
Prototype 25km global simulation of clouds and storms

The 2008 Midwest Floods:
$15B in Damages/Costs, 24 deaths

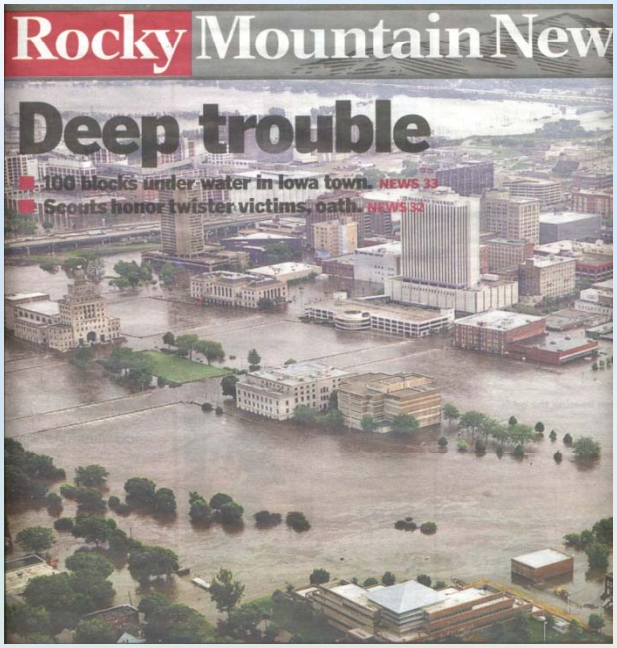
What NOAA Currently Knows

- Late winter: saturated soils primed the region for flooding even if normal spring rains had fallen.

- Subsequent April-June Spring Rains were Extreme:
  - >1000 daily rainfall records set in the U.S., the heaviest 1% of daily precipitation events increased by 20% over the past century
  - Increases in greenhouse gases increase air temperatures and evaporation, allowing the atmosphere to hold more moisture.



NOAA Flood Risk Outlook: March 2008

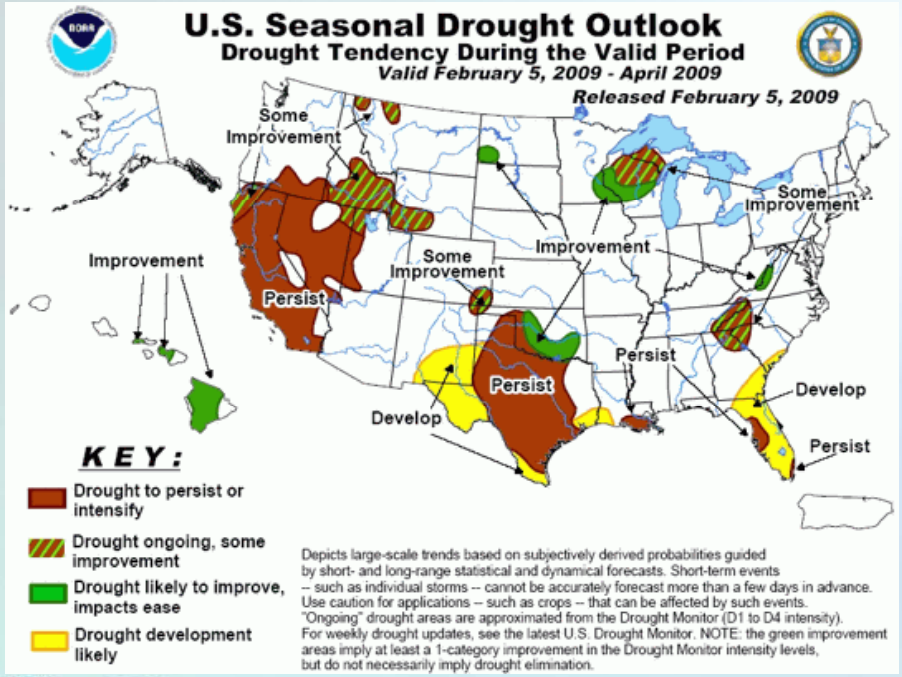


NOAA's Strategy for Improved Understanding of Water-Climate Linkages

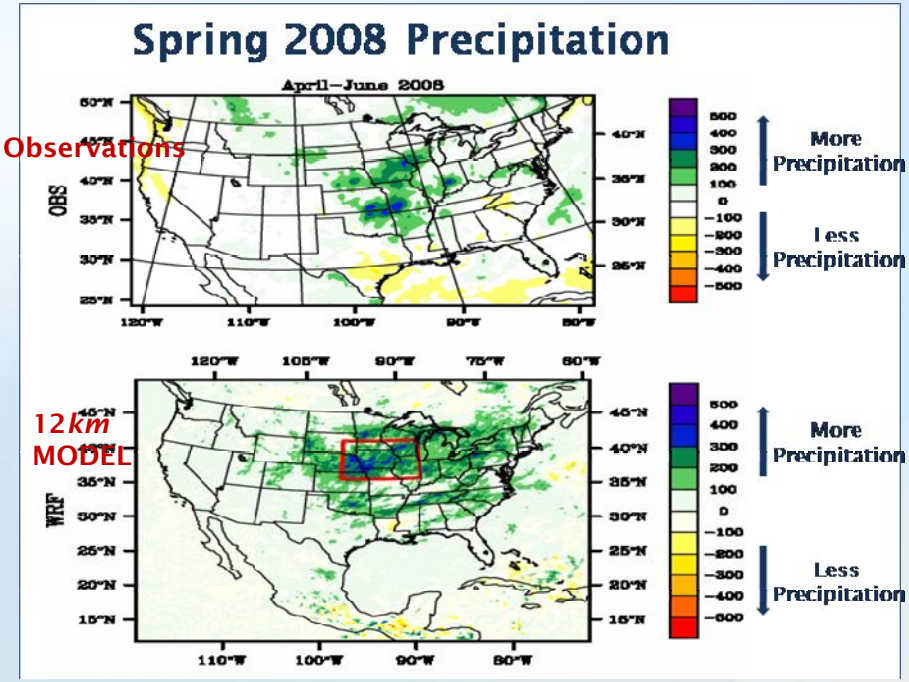
Current Capabilities: NOAA currently issues **regional scale** seasonal drought outlooks

Future Capabilities: NOAA is researching prototype high resolution climate models that incorporate soil moisture and land observations on the **local scale** to deliver earlier flood and drought warnings

Current Drought Outlook



Prototype High-Res Climate Model

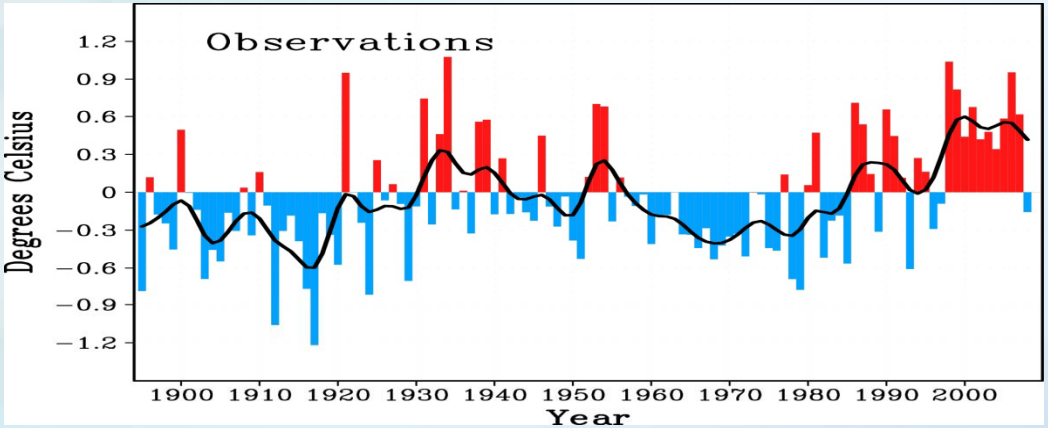


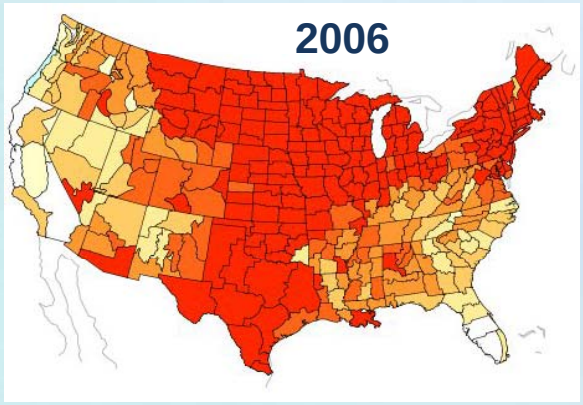
2008 U.S. Annual Temperatures:

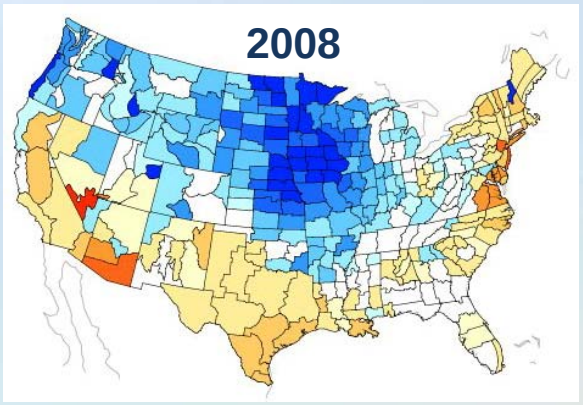
Is the Warming Trend Reversed?

What NOAA Currently Knows

- 2008 was the coolest year for the U.S. since 1996, coming just 2 years after a near-record hot year.
- 2008 coolness is well within the range of natural historical climate variations, based on model experiments and analysis.



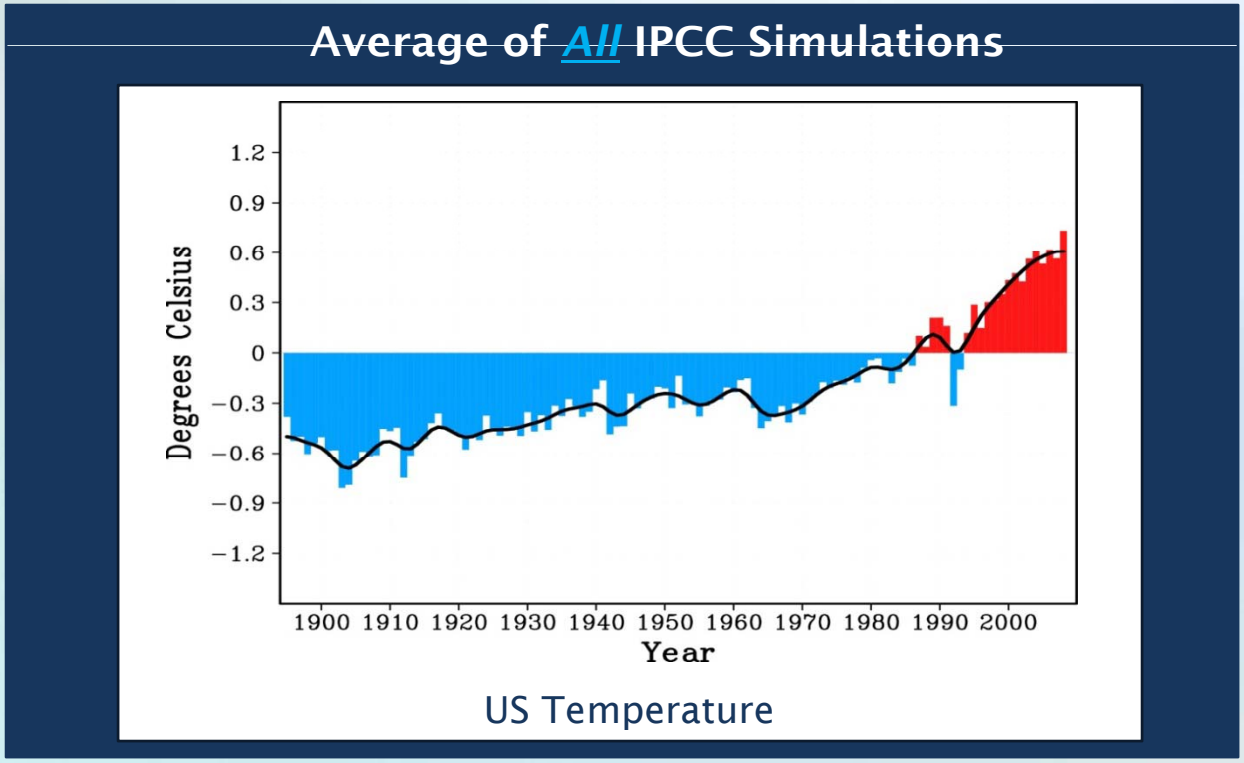




NOAA's Strategy for Improved Understanding of U.S. Annual-Decadal Temperature Extremes

Future Capabilities:

- NOAA will better monitor and understand factors that determine persistent climate states (oceans, sea ice, land surface)
- Updates in Earth System analysis will help improve NOAA's methods of annual-decadal climate predictions.



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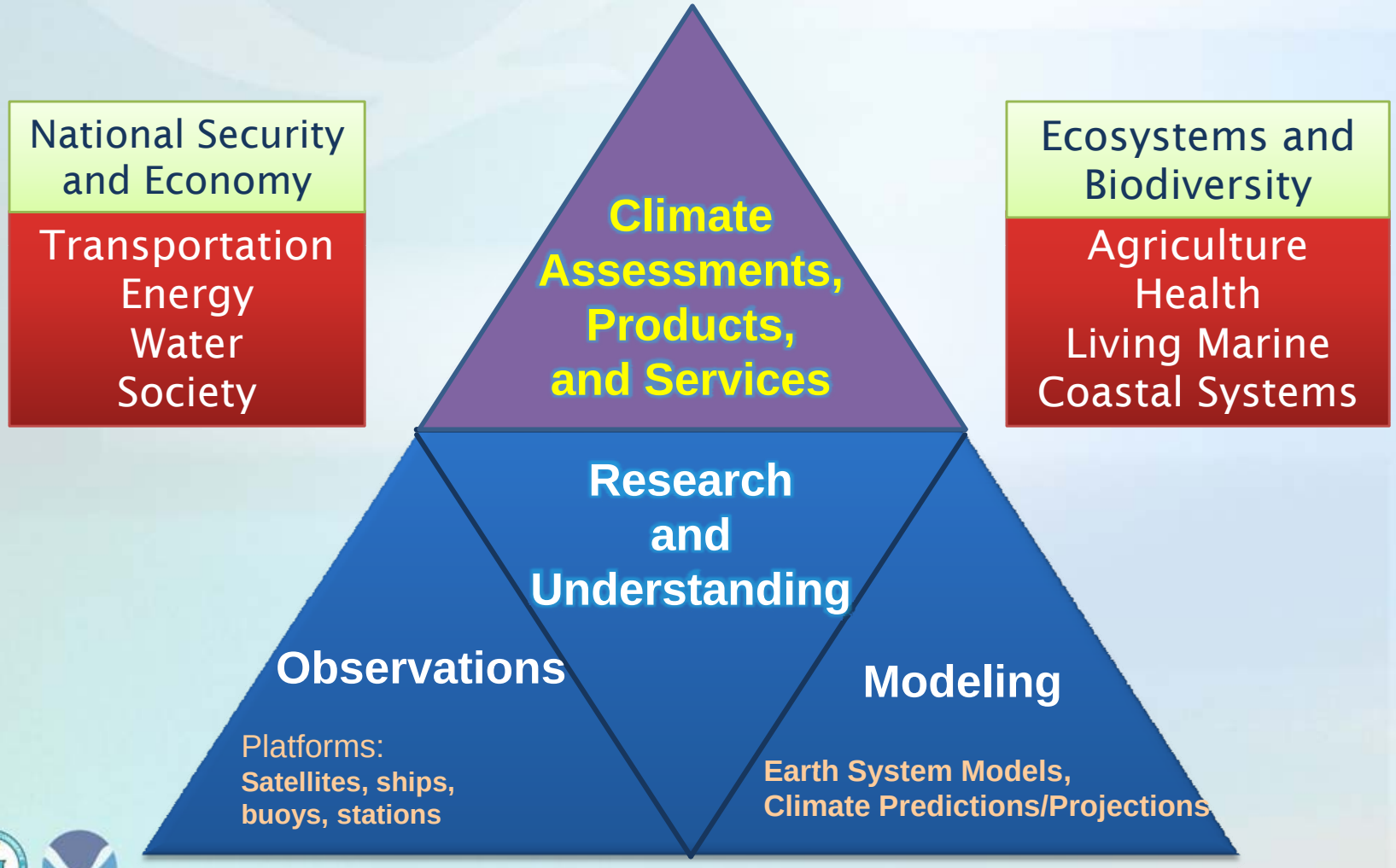

FOR MORE INFORMATION

Please Contact:

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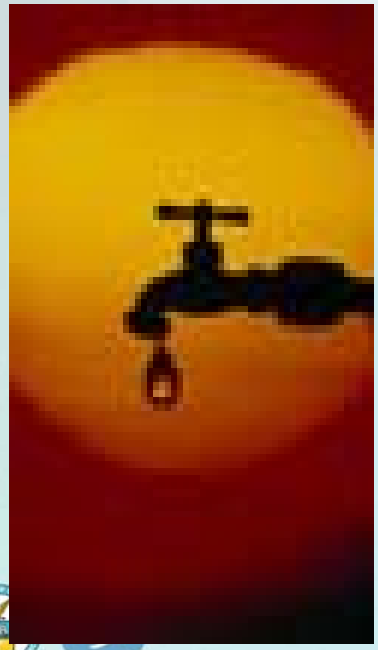
Jonathan.Kelsey@noaa.gov

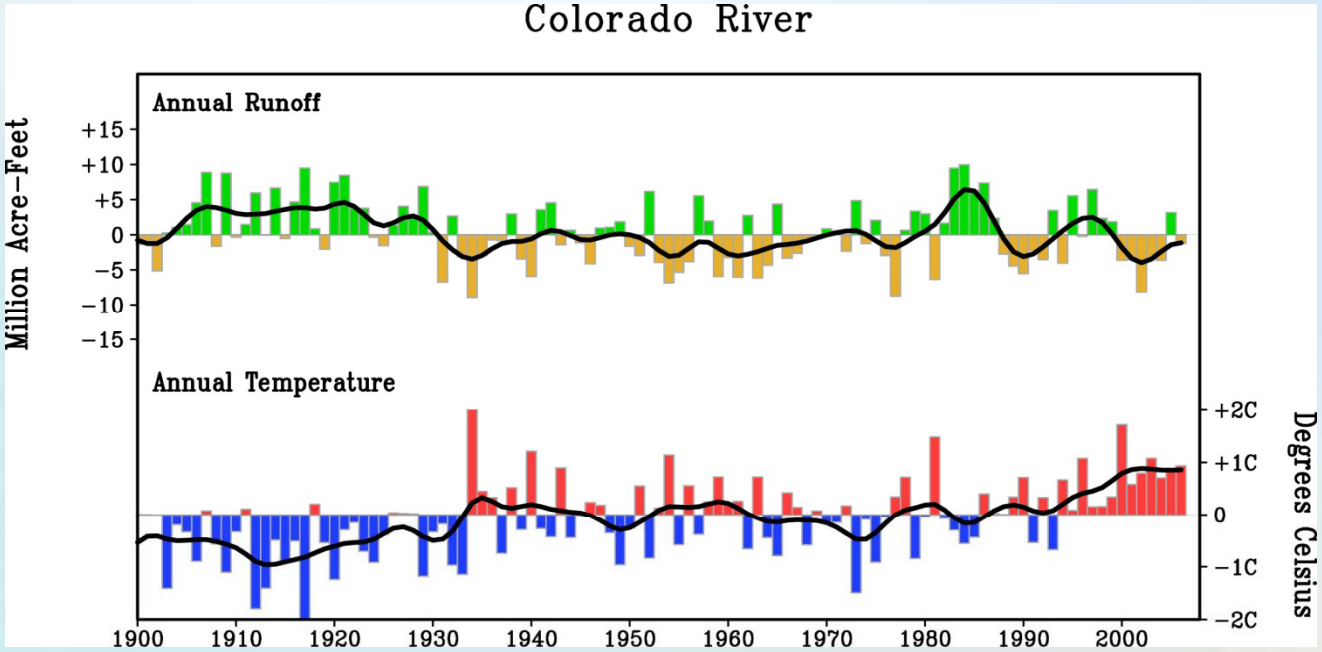
Backup Slides

Ongoing Western US Drought
>$8B in Fire-Related Losses Alone

What NOAA Currently Knows

- Lakes Mead/Powell…the primary water storage on the Colorado River, have declined 50% in the last decade.
- Annual Colorado River flow has been below normal virtually every year in the last decade.
- Annual temperatures have shown the greatest increase over the Western U.S.: +2°F over Colorado in the last 30 years.





NOAA's Strategy for Improved Understanding of Drought, Its Predictability, and Impacts

Current Capabilities: NOAA is Leading the Development of a National Drought Information System (**NIDIS**)

NIDIS research priorities are to understand regional differences in drought impacts, assess and develop capabilities for region-specific drought monitoring and prediction.

Lake Mead

Lake Lanier

Grainbelt

NOAA Empowering Decision Makers