Modeling and Simulation for Weather and Climate

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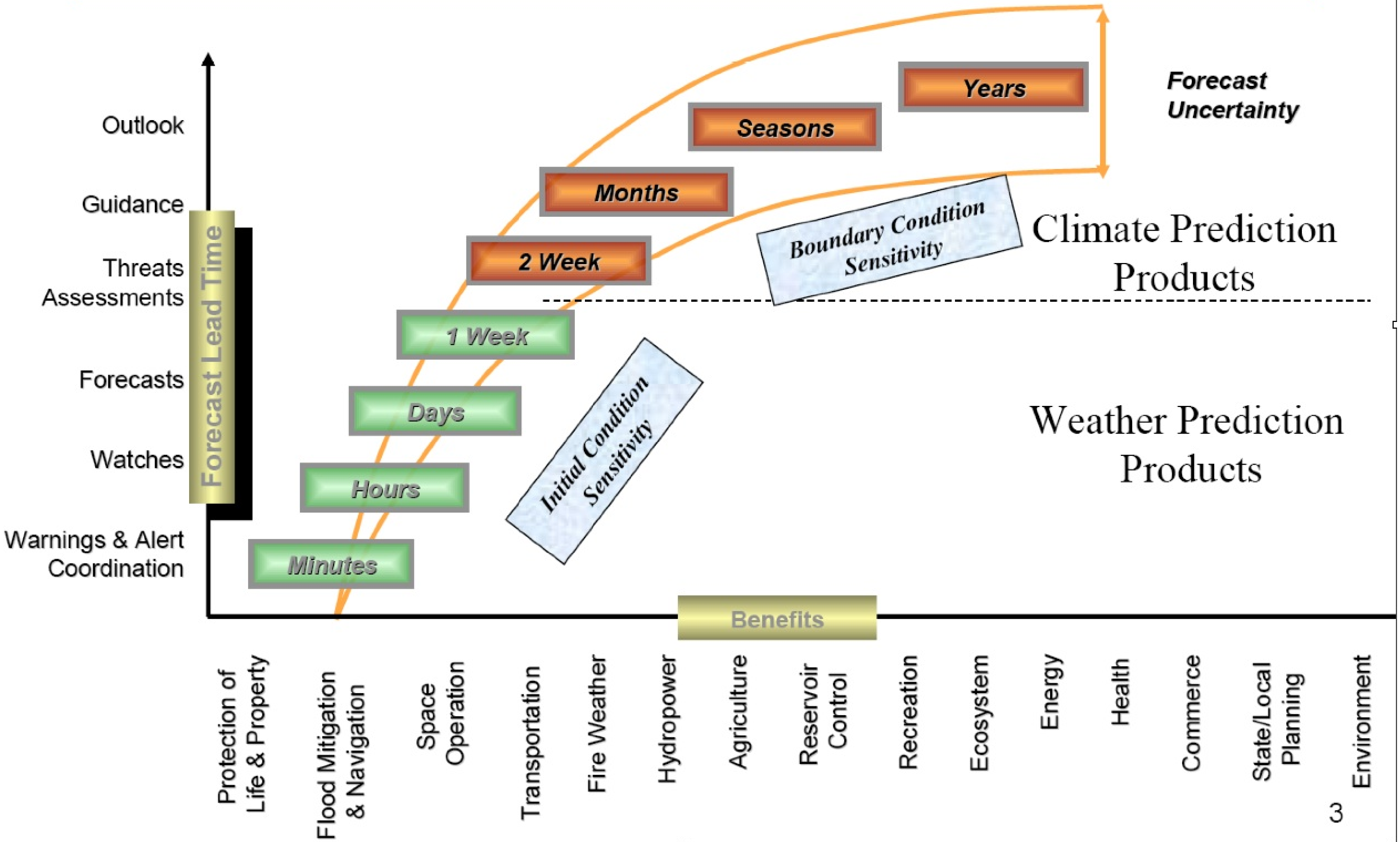
NOAA Mission

NOAA's mission: To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs.

Provides the requirement for accurate weather and climate modeling

NOAA Seamless Suite of Forecast Products Spanning Climate and Weather



Prediction Requires "Coupling" of Basic Earth "Systems" within Global Numerical Forecast Models

- Atmosphere

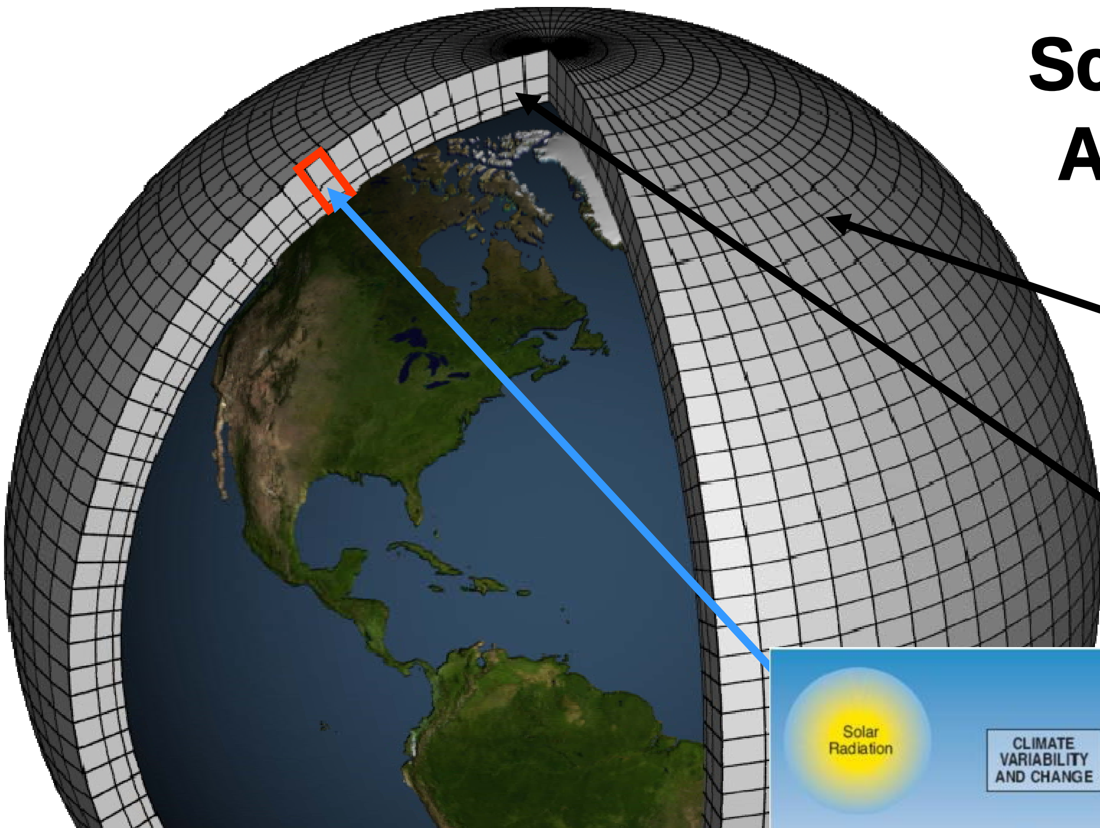
- Ocean

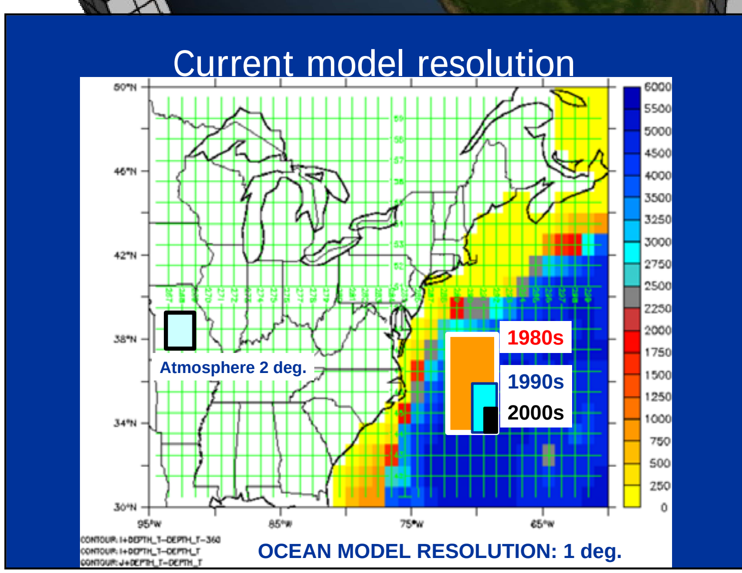
- Cryosphere

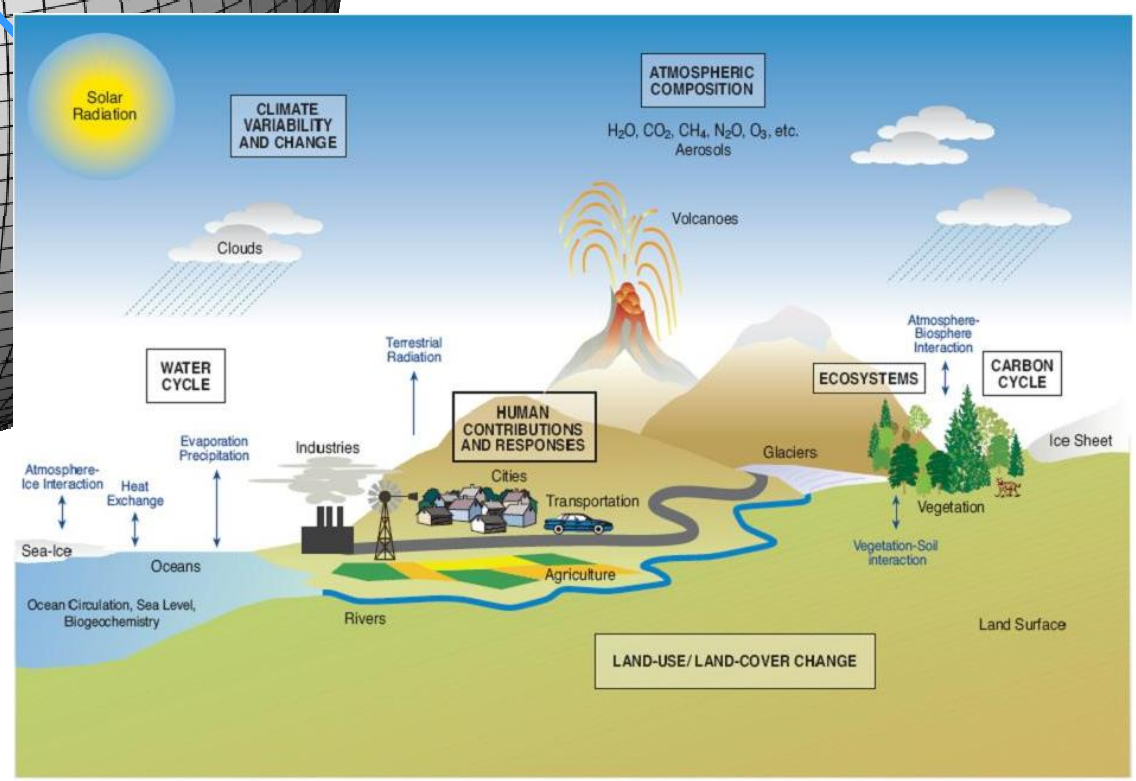
- Land

- Predictions Driven by Global Observing Systems
- Real-time operations require world's largest computers

Schematic for Global Atmospheric Model







Climate Models for the IPCC & CCSP

(http://www.ipcc.ch)

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Every 5 or 6 years, an international group of scientists assemble a report documenting the state of scientific knowledge related to climate change. IPCC reports are ratified by ~180 member nations.

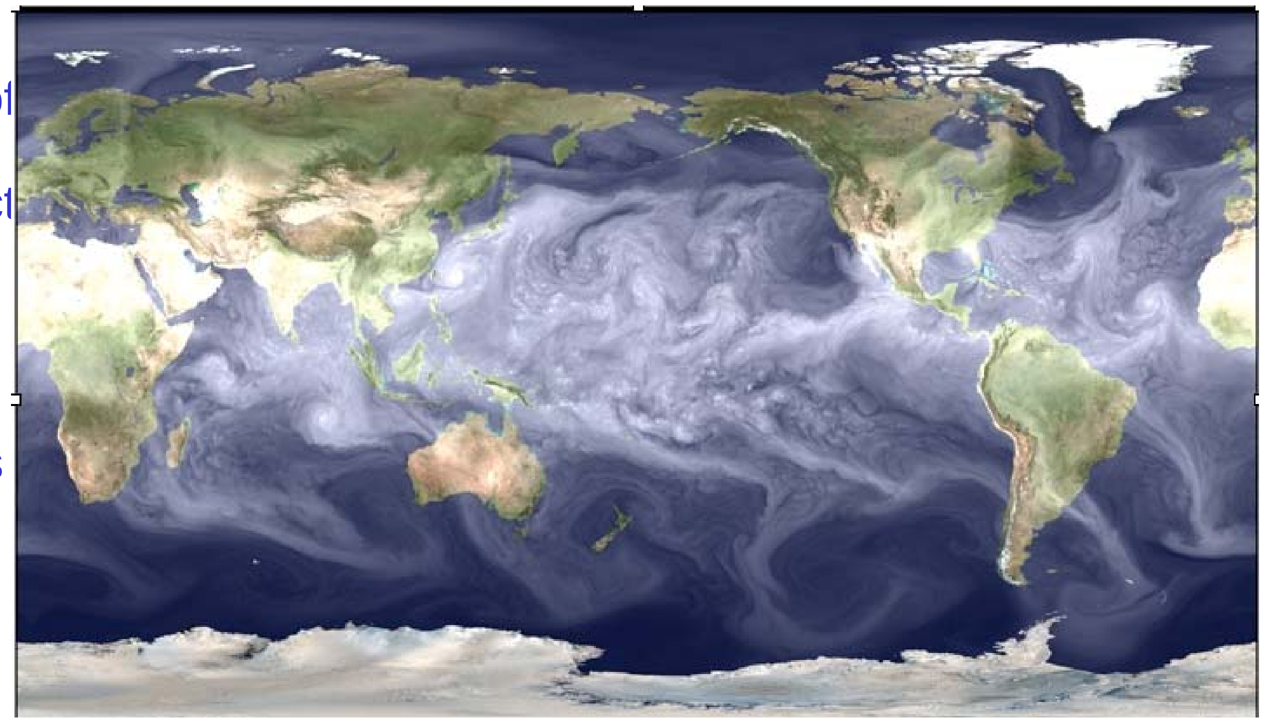
NOAA has been a prime player in all the Working Group I IPCC assessment reports, including the IPCC 4th Assessment Report (AR4) published in Feb. 2007. Two new global climate models developed by NOAA Research for AR4 are two of the best out of ~24 models and will be used in the US CCSP.

US Climate Change Science Program
www.climatescience.gov

“best available science”

The US CCSP is a presidential initiative that seeks to integrate federal research on climate change. More than 20 synthesis & assessment reports on key topics relevant to decision makers are planned.

High-resolution modeling of hurricane activity

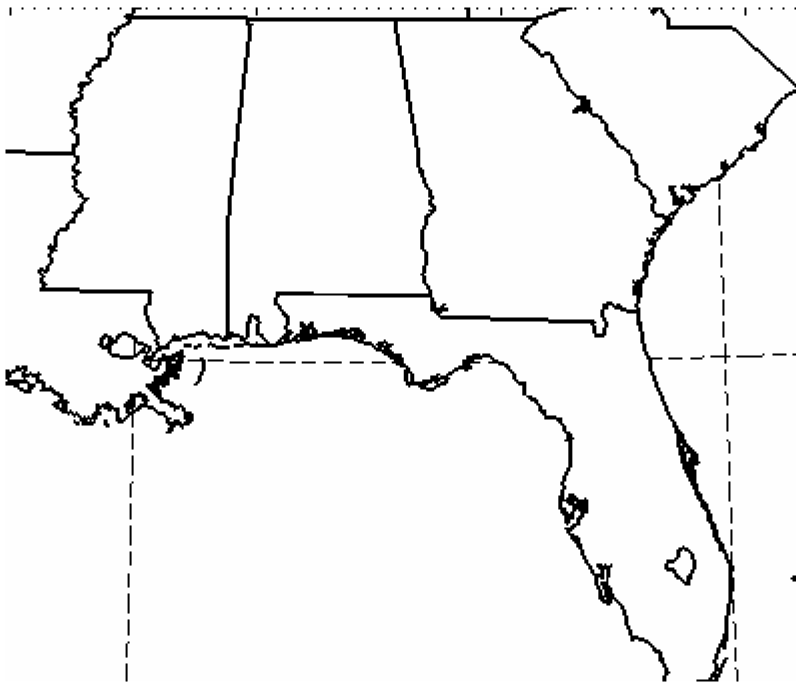
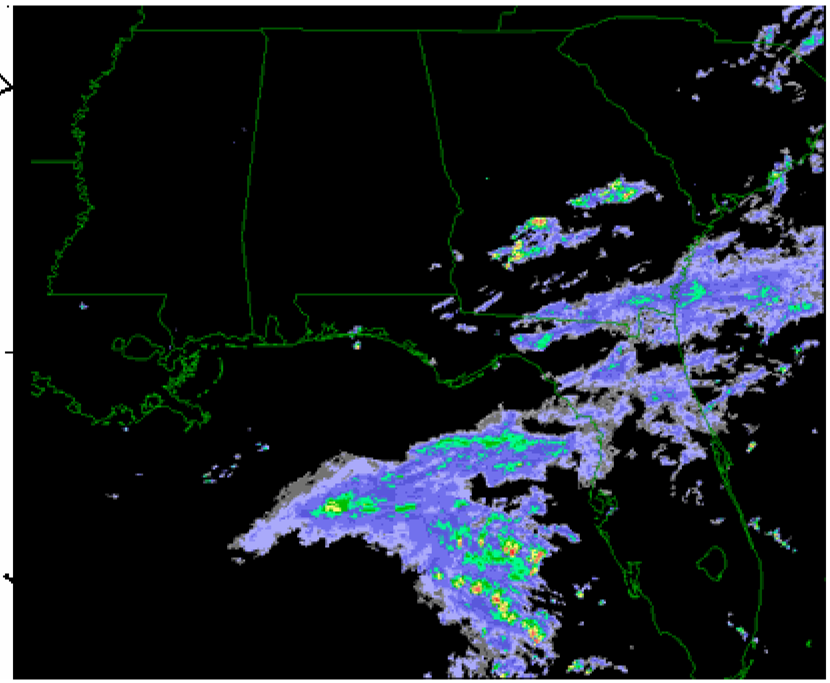


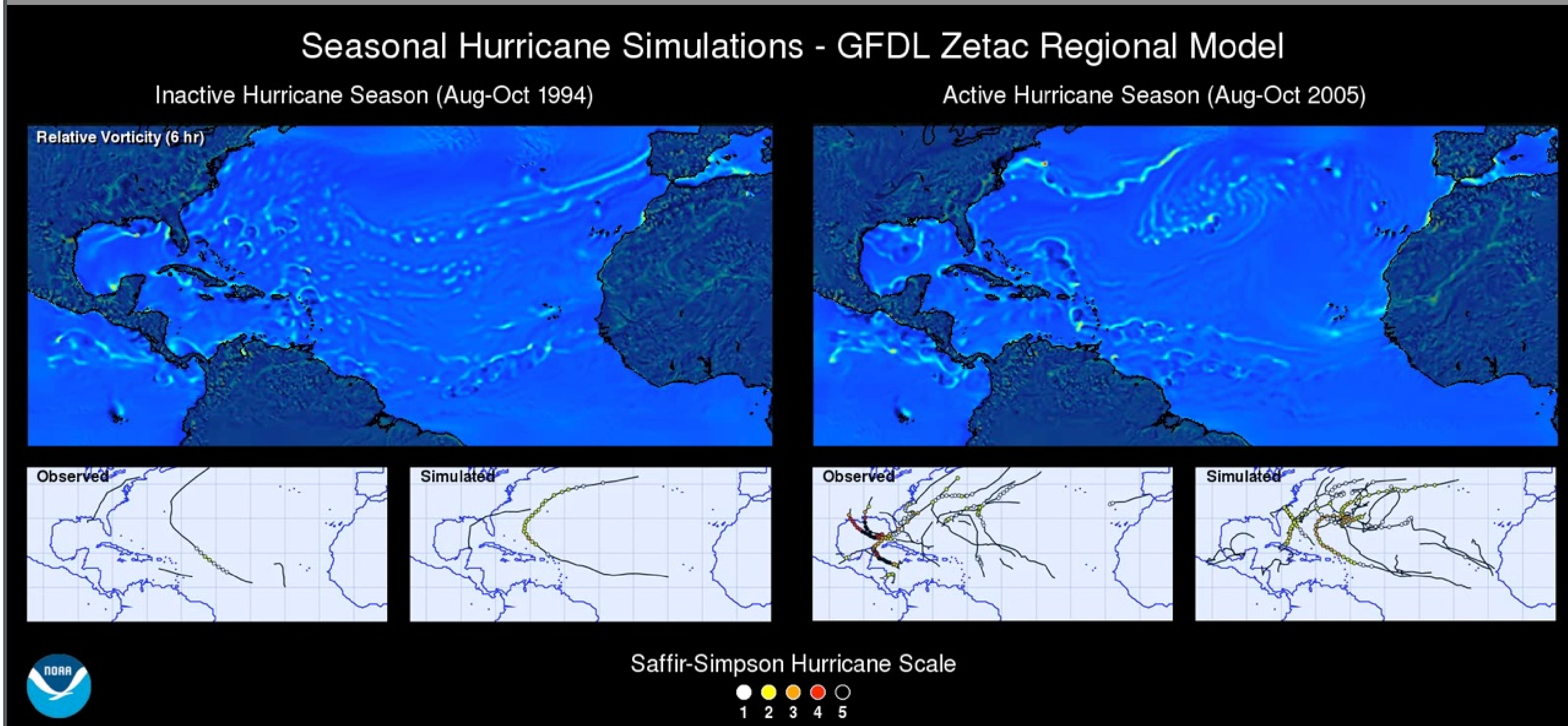
Science Goal:

- Improve forecasting of hurricanes and understand the impact of climate change on tropical cyclone activity by integrating our tropical cyclone research into NOAA's modeling efforts.

Background:

- NOAA has experience and success in developing models for operational hurricane forecasting and, more recently, with regional simulations of the Atlantic hurricane season.
- Results from regional modeling suggest that a 25 km global model has the potential to be a powerful tool for studies of predictability and of the processes by which SSTs and wind shear control cyclone activity.

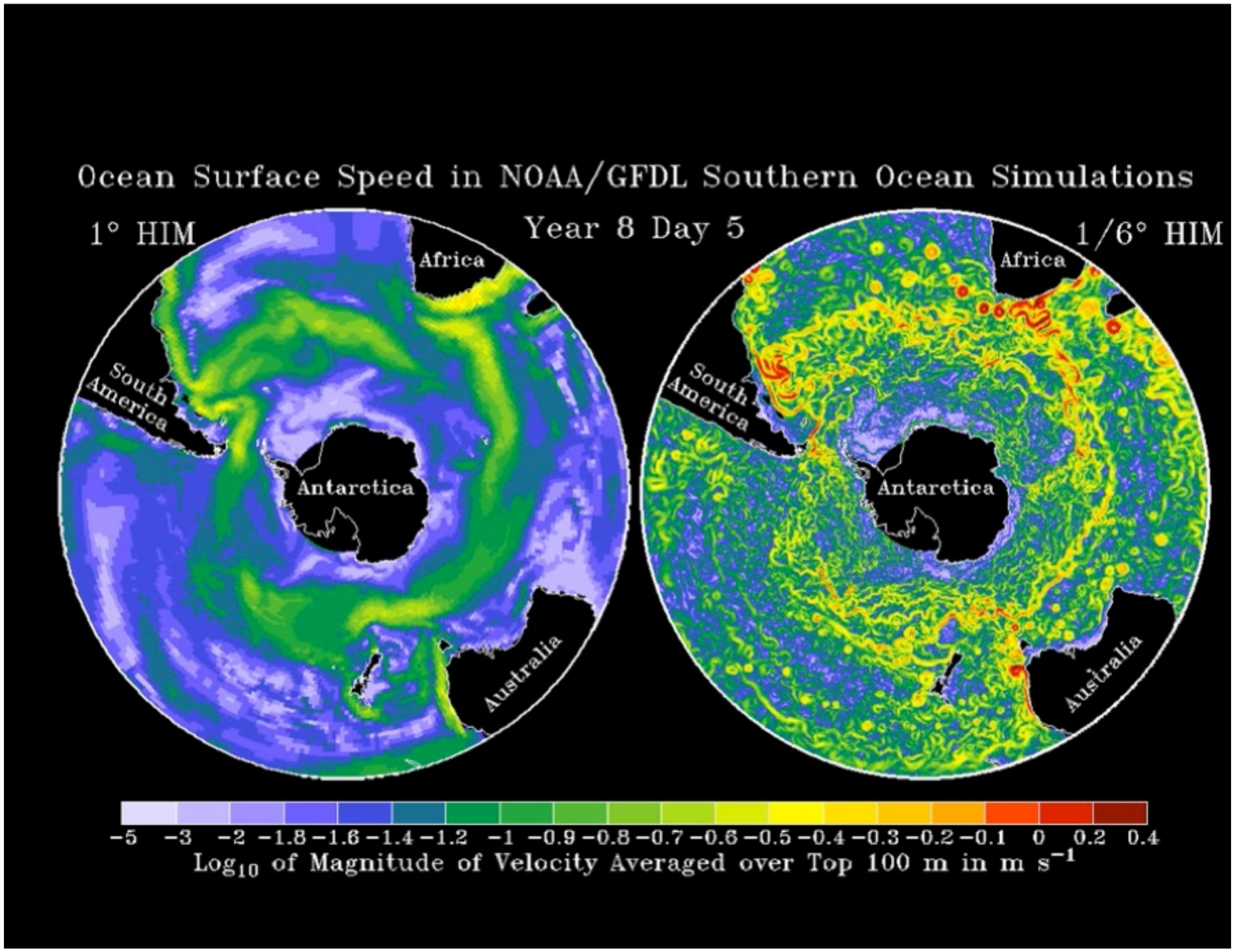


Prototype model for future global hurricane forecasting system…

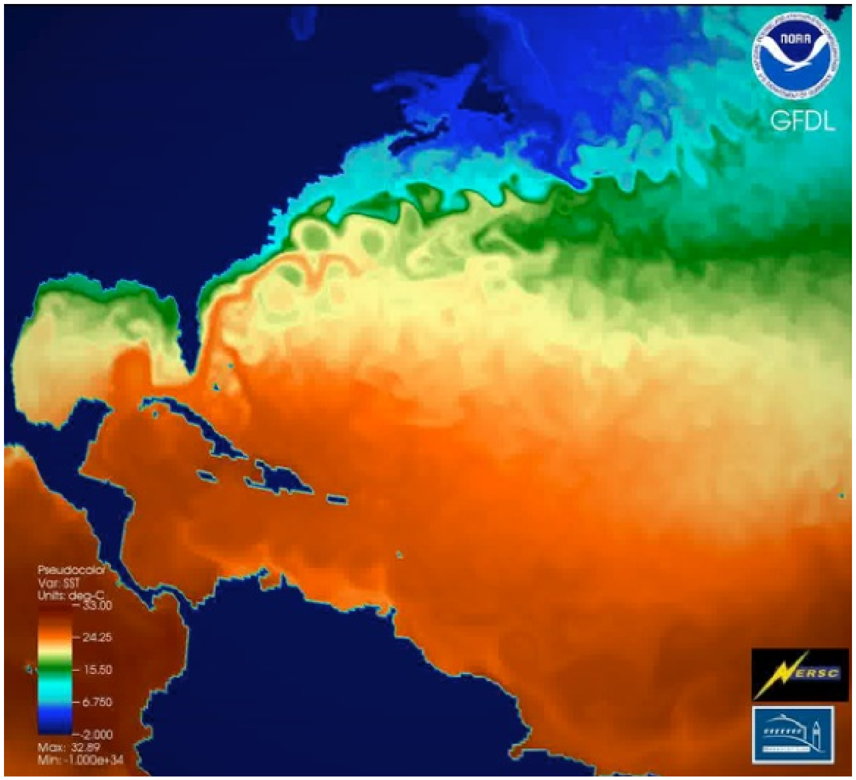
A fundamental breakthrough in ocean models at scales of 10 km

High resolution simulation of Southern Ocean (GFDL's MESO project).

Small vortices affect oceanic carbon uptake heat, transport of heat towards Antarctic continent, marine ecology of Southern Ocean



Decadal prediction using high-resolution coupled climate models



Science Goal:

- Use high resolution coupled models to study decadal variability and predictability of the climate system

Background:

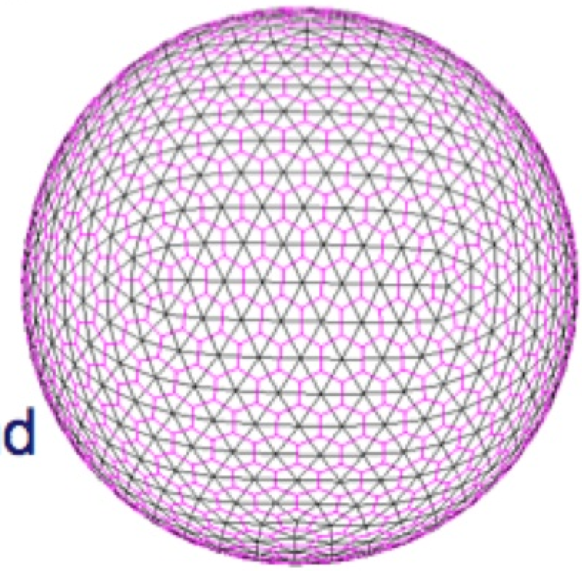
- NOAA has developed a high resolution global coupled climate model, a follow-on to its successful contributions to the IPCC AR4. Ocean resolution is variable, from 25 Km in Tropics to 10 Km in polar regions. Atmospheric resolution is about 100 Km.
- Preliminary work with this model has shown outstanding simulation of ocean circulation, including regional circulation, eddies and small-scale structures that may be important for processes such as the Atlantic Meridional Overturning Circulation (AMOC) and ENSO.

Extremely accurate advection scheme, low viscosity, and fine resolution have contributed to a model with very energetic, realistic ocean circulation. This model resolves ocean processes not previously resolved in IPCC AR4 class models, and will offer pioneering insights on decadal variability.

Road Map of the high-end Earth System Modeling

A plan by NOAA researchers to develop the worlds best model for weather and climate prediction.

2006-2013: The "Geodesic Grid" Planet Simulator, 3rd generation *non-hydrostatic* finite-volume model with ***1-4 km*** or finer resolution.



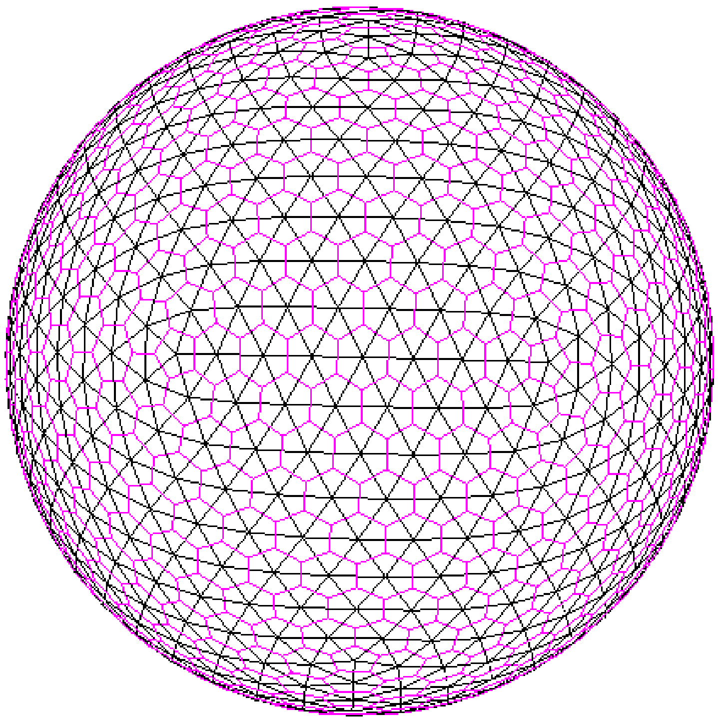
Primary model for:

- Medium Range Weather Prediction 0 to 2 weeks, including improve hurricane track and intensity.
- Seasonal to Inter-annual Prediction 2 weeks to 2 years
- Decadal to Centennial projection

Components of the next-generation model

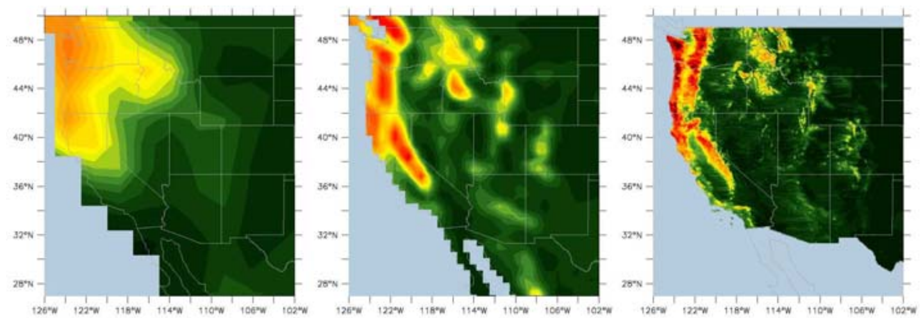
- Cumulus parameterization-free "cloud microphysics"
- High-order finite-volume (fv) non-hydrostatic dynamics
  - Gravity-wave & cloud resolving resolution (1-4 km or finer)
  - Model top at or above the mesopause (80 km)
  - Scalable to over 10,000 CPUs
  - Coupled to an eddy resolving ocean model
  - Coupled to a dynamic sea ice model
  - Coupled to a ultra-high-resolution land model
  - Coupled to a full chemistry with 50 plus species

Virtual Planet on fv-Geodesic Grid



Computing power is limiting our progress

- Increase model resolution
  - Doubling a model's resolution makes it ***16 times*** more expensive to run
  - Assessing regional impacts requires a horizontal resolution of 50km, making the model ***64 times*** more expensive to run
  - Hurricane response to climate requires a horizontal resolution of 10 km, making the model ***4000 times*** more expensive to run



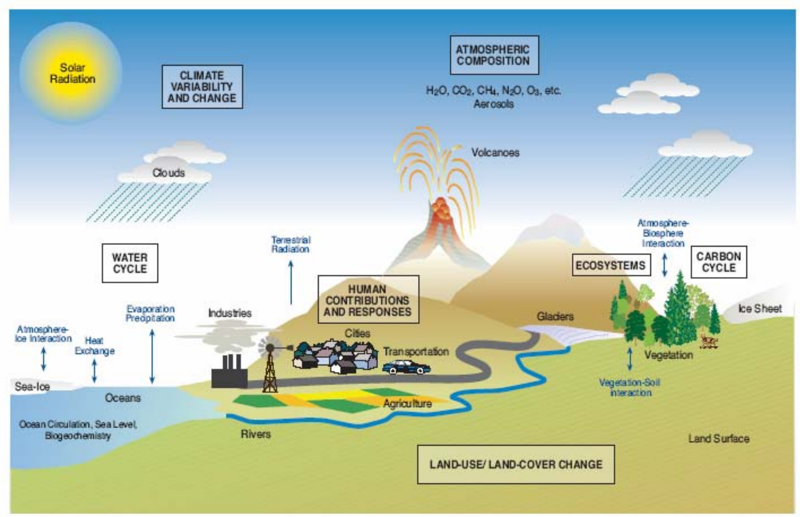


Figure 2-5: Major components needed to understand the climate system and climate change. Source: Adapted from IPCC (2001a).

- Increase model complexity
  - Adding the global carbon cycle makes the model ***2 times*** as expensive to run
  - Adding chemistry to address global air quality and climate change makes the model ***3 times*** as expensive to run

- These factors multiply!
  - A global model for regional impacts, including carbon and air quality, is ***384 times*** (64 x 2 x 3) more expensive to run than the current model

Continued progress toward addressing the climate problem requires …

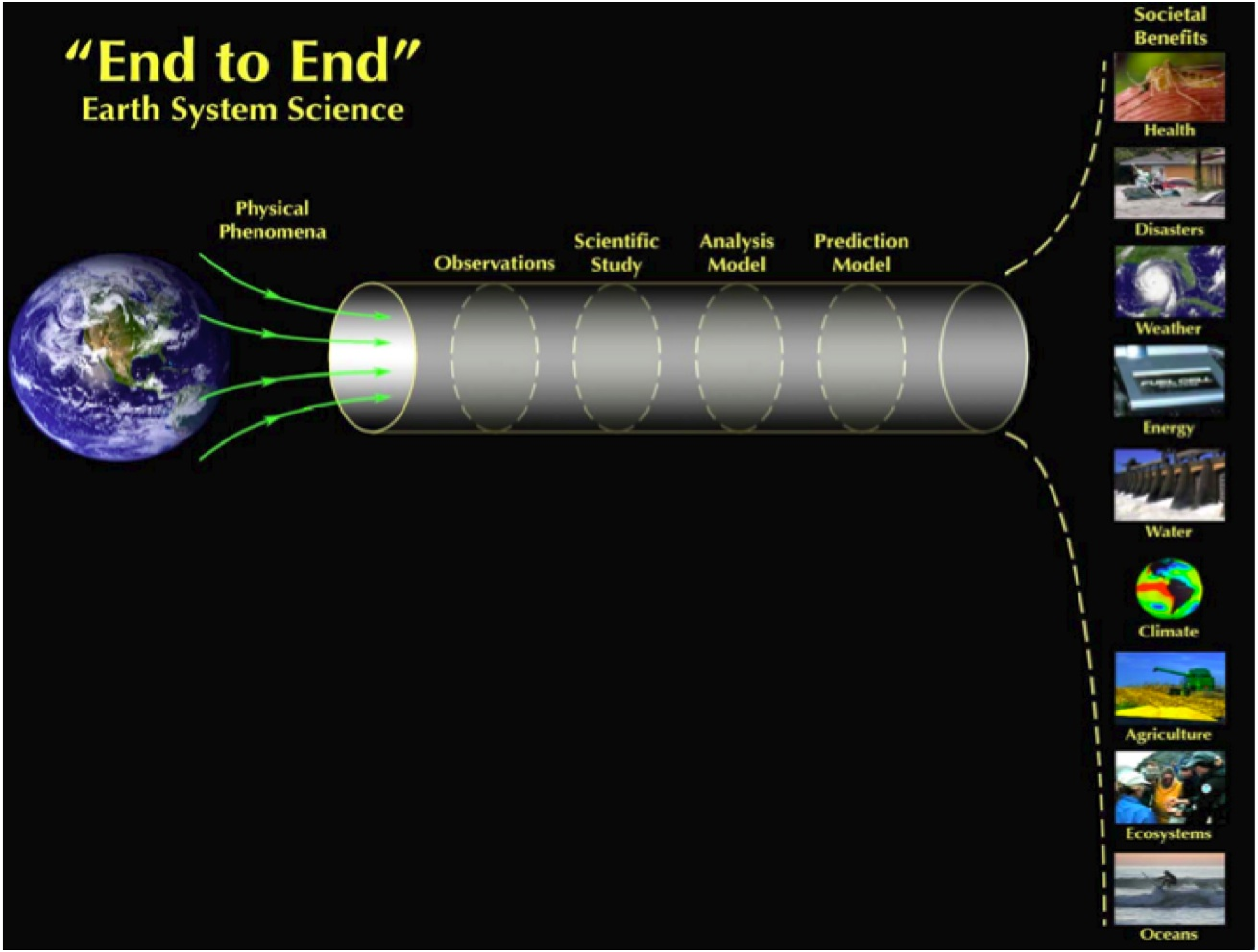
- Fresh approaches to computational techniques
- Cross-disciplinary capability in the atmospheric, oceanic, and biogeochemical sciences
- Integration of technological solutions into projections of climate change
- Application of scientific outcomes to assess societal and economic impacts

Education Issues

– Undergraduate programs often do not contain sufficient scientific programming.

– Agencies typically do not fund sufficiently or work closely enough with universities in numerical model and data assimilation development.

– Big gap between scientific education and software engineering skills. With models becoming highly complex, M.S. and Ph.D. Graduates often need both to excel in the field.


"End to End"
Earth System Science
Physical
Phenomena
Observations
Scientific
Study
Analysis
Model
Prediction
Model
Societal
Benefits
Health
Disasters
Weather
Energy
Water
Climate
Agriculture
Ecosystems
Oceans