Advancing Climate Modeling through NOAA/DoE Collaboration

NOAA/OAR/GFDL

October 12, 2007

Three Projects for CY07-08

- Decadal Variability
- Trends in Tropical Cyclones
- The Next Frontier in Earth System Modeling

Decadal Variability

Science Goal:

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

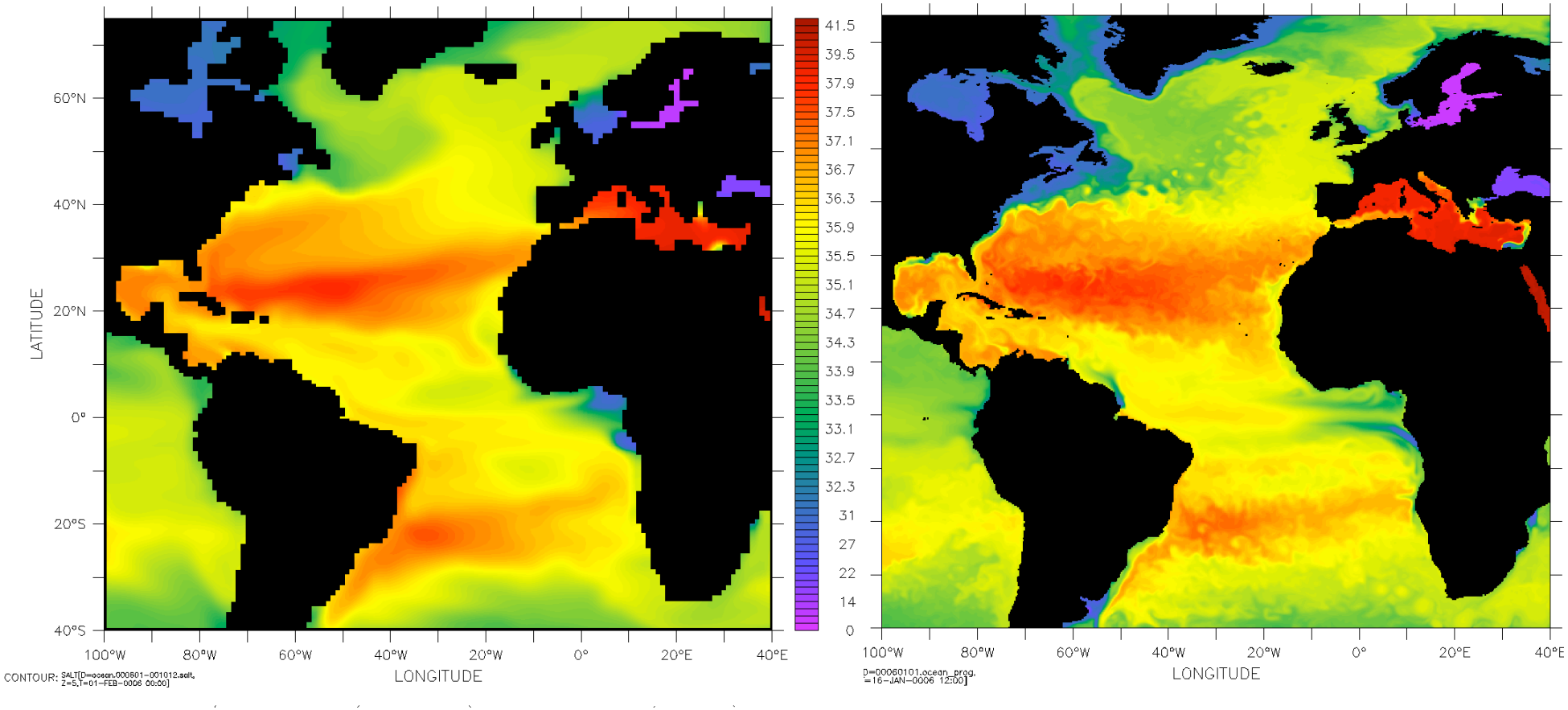
Background:

- NOAA/GFDL has developed a high resolution global coupled climate model: CM2.4, a follow-on to the IPCC AR4 models CM2.0 and CM2.1. 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.

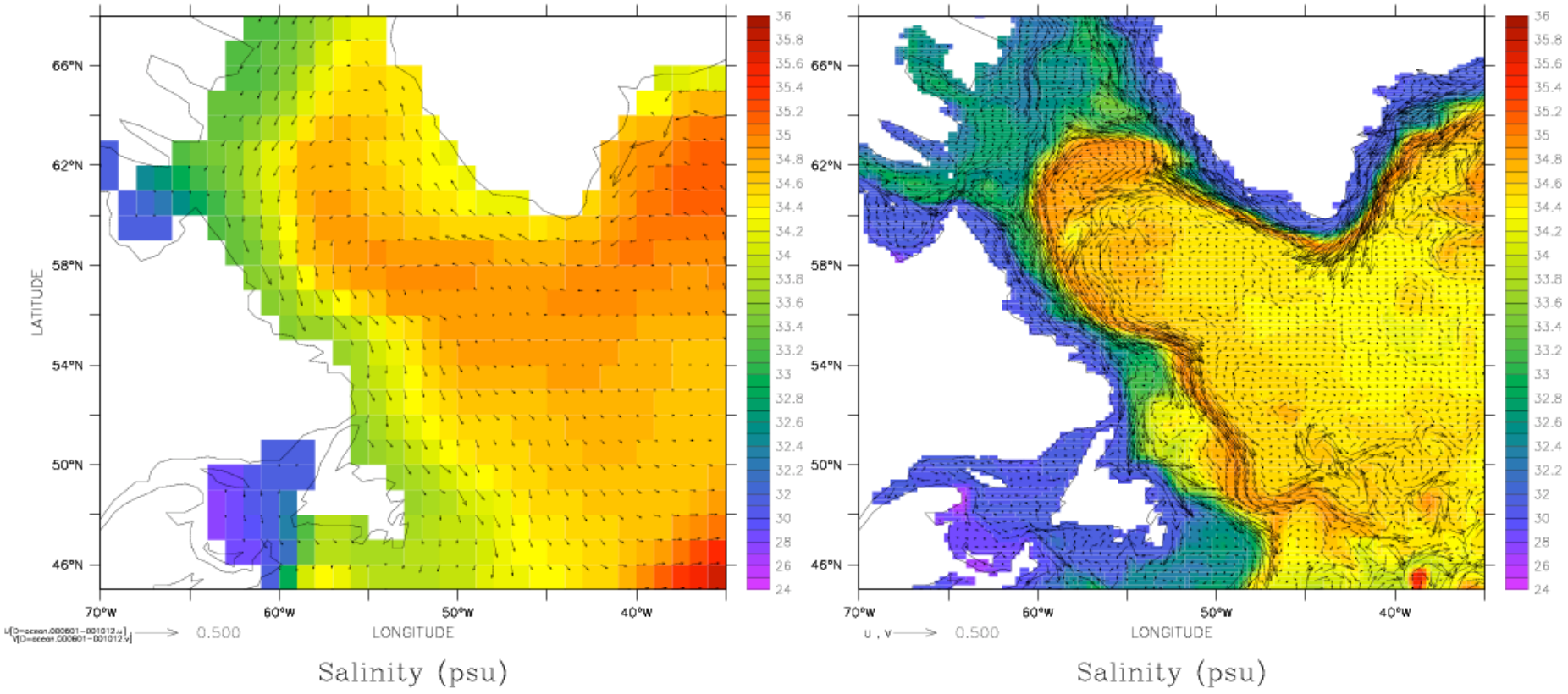
CM2.4: Progress in ocean circulation

CM2.1

CM2.4



CM2.4: Progress in ocean circulation



Decadal Variability (cont'd)

Status and Plans for CY07 (~400K CPU-hours):

- Code port to the Cray XT3 at NERSC. [complete]
  - Currently achieving 1 model year per day on 660 cores
- Conduct multi-decadal control simulation to evaluate natural variability of the climate system. [In progress]

Plans for CY08:

- Conduct multi-century control simulation to evaluate natural variability of the climate system. Assess implications for decadal modulation of hurricane activity and droughts.
- Conduct multi-century climate change simulations. These will evaluate the impact of ocean eddies and other small-scale processes on the climate system response to increasing greenhouse gas forcing.
- Conduct ensembles of predictability experiments to assess potential for decadal-scale predictions of the climate system.

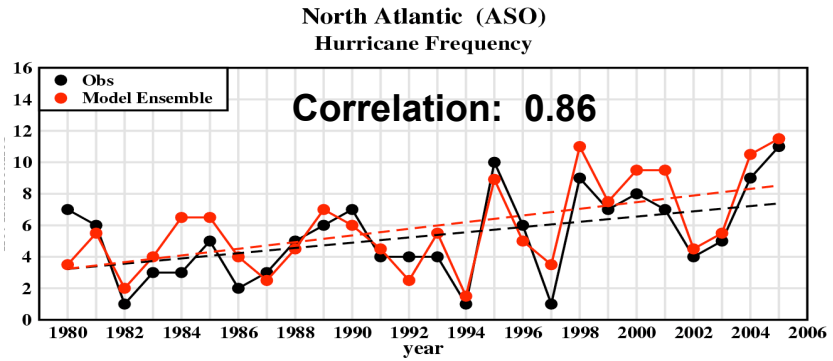
Trends in tropical cyclones

Science Goal:

- Understand the impact of climate change on tropical cyclone activity by integrating our tropical cyclone research into NOAA's global climate modeling efforts.

Background:

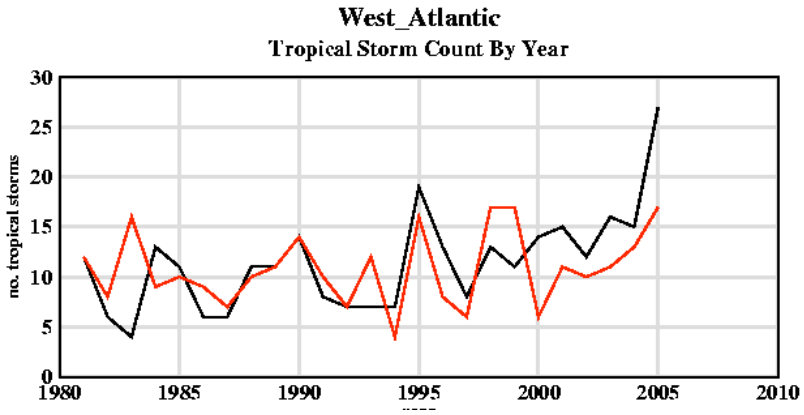
- NOAA/GFDL has experience and success in developing models for operational hurricane forecasting and, more recently, with regional simulations of the Atlantic hurricane season.
- Results from regional modeling suggest that a 25 km global model has the potential to be a powerful tool for studies of predictability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



Trends in tropical cyclones (cont'd)

Status and Plans for CY07 (~700K CPU-hours)

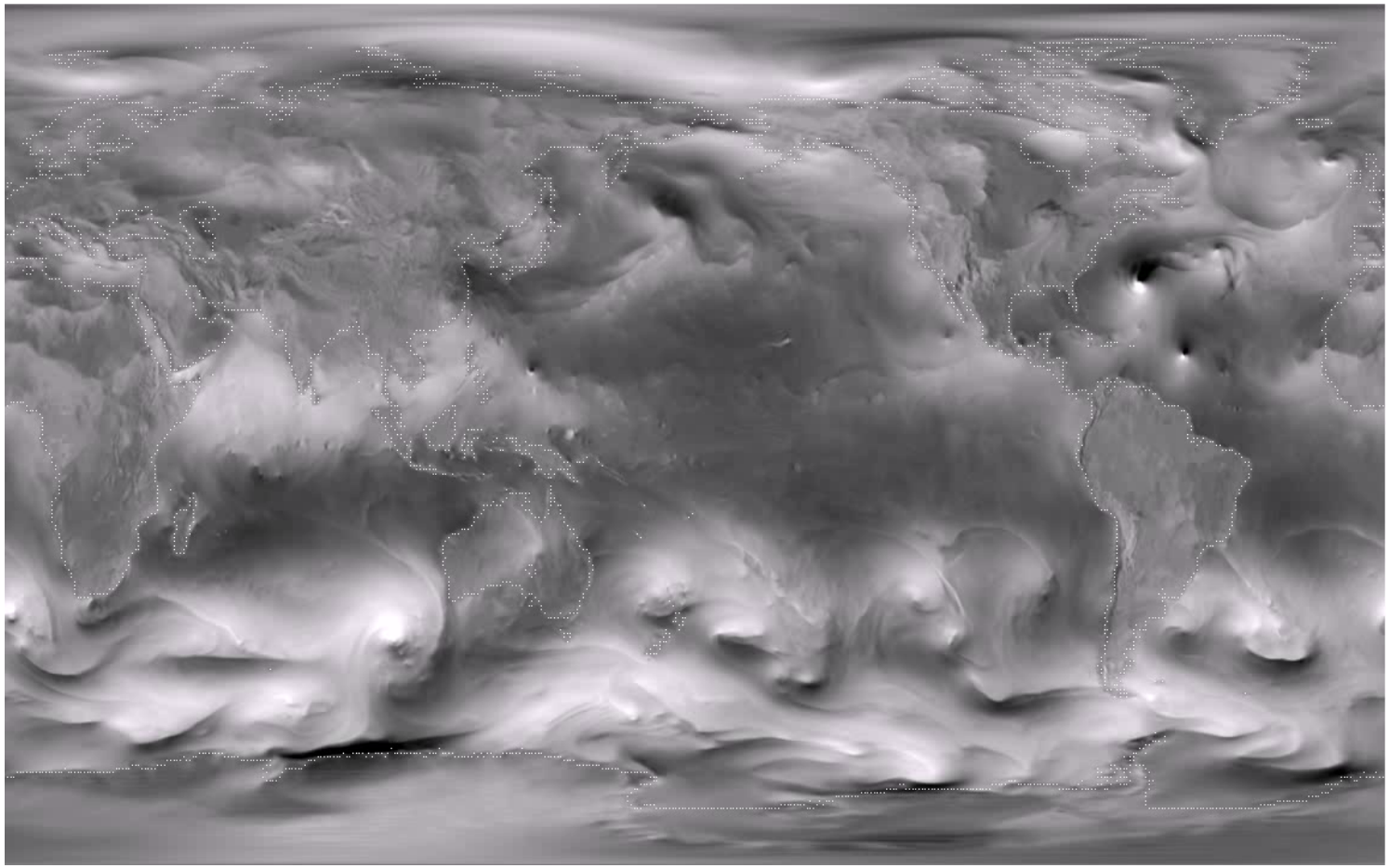
- Port an existing 25 km model with AM2 physics (CS360) to DoE machines. [complete]
  - Currently achieving 1.6 model years per day on 1526 cores at ORNL
- Run several years to examine quality of tropical storm climatology forced with observed SSTs. [In progress]
- Evaluate new physics package with refined deep convection that we believe will significantly improve this application, currently being tested at 100km and 50 km resolutions at GFDL. [Not yet begun at DoE]



Plans for CY08 :

- Conduct multiple decadal model integrations to assess potential for decadal-scale predictions of hurricane activity in a changing world.

AM2-C360 surface zonal wind



The Next Frontier in Earth System Modeling

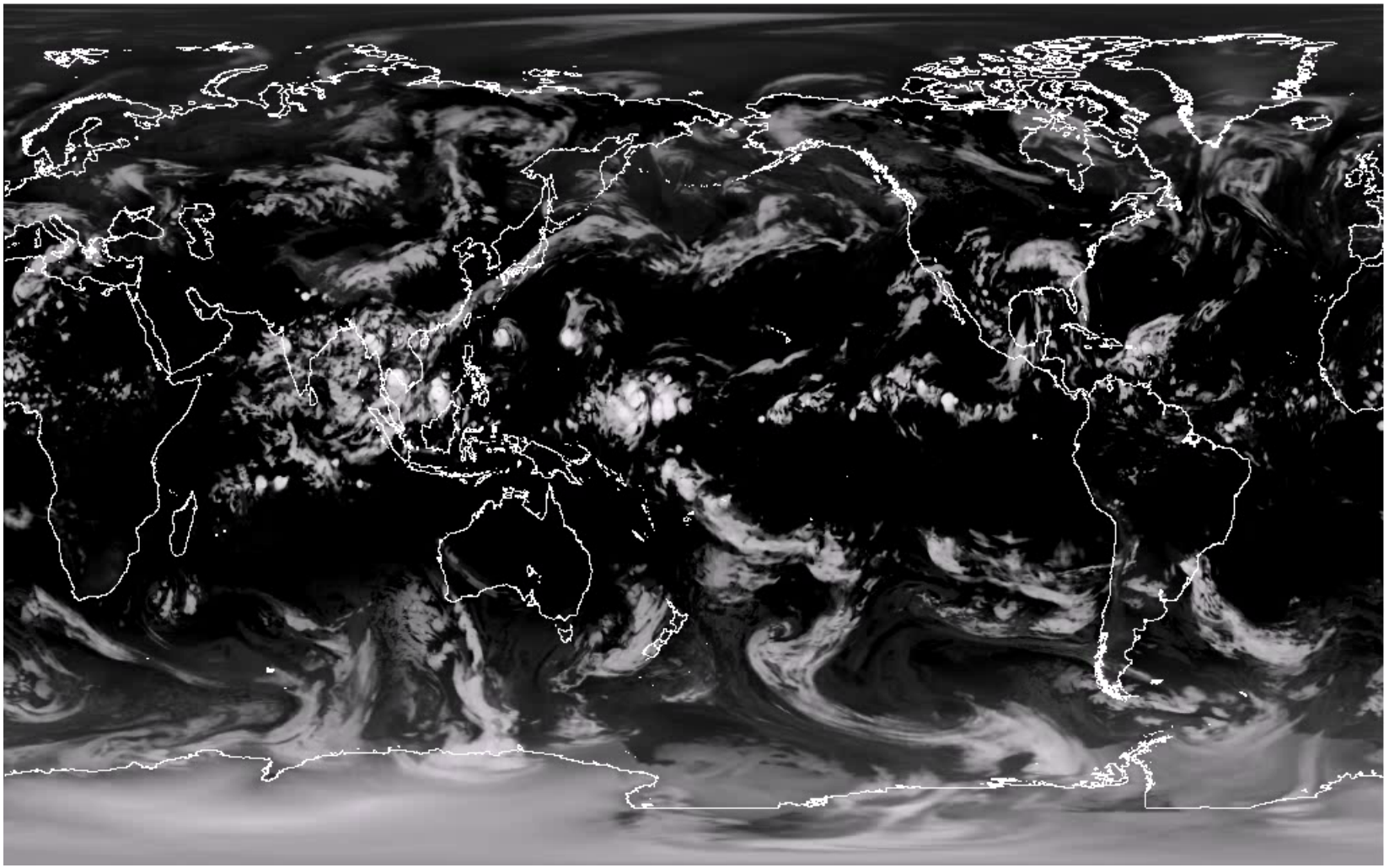
Science Goal:

- Reduce uncertainty in climate predictions and offer unprecedented regional fidelity beyond today's highly parameterized climate simulations by explicitly resolving deep convective clouds, tropical cyclones, and extreme weather events.
- Explore seamless weather-climate prediction within a unified modeling framework.

Background:

- An extension of the GFDL AM2 climate model at ~5 km global resolution (C2000) has been developed, with a new cubed-sphere non-hydrostatic dynamical core and sophisticated cloud micro-physics.
- There are no identified barriers to scalability; it is expected that this model is capable of efficiently utilizing more than 100,000 processing cores.
- As experience with this class of models develops, we expect to be able to address issues of cloud feedback and climate sensitivity that remain problematic in lower resolution models.
- This model is fast enough to be used for real-time 10-day hurricane predictions on a petascale system, yet it has a finer spatial resolution than the operational regional hurricane models. It therefore can potentially offer significant improvements in hurricane track and intensity predictions.

One step forward ….



The Next Frontier in Earth System Modeling (cont'd)

Status and Plans for CY07 (~300K CPU-hours) :

- Port existing 5 km model to DOE machines [complete]
  - Estimating 0.04 model years per day (12 model days per day) on 8214 cores at ORNL
- Run initialized experiments for 2-3 weeks to examine quality of simulation [in progress]

Plans for CY08

- Evaluate the quality of cloud simulations as first step in addressing fundamental cloud feedback issues
- If feasible, conduct integrations of multiple hurricane seasons to assess potential for seasonal predictions of hurricane activity.

Immediate Risks for CY07

- Turnaround on DoE machines
  - Models like CM2.4 that are run at the limits of scalability must remain in the system 24x7 in order to use the CY07 allocation.
    - A high-level discussion with DoE may be required to implement this request.
- Remote computing
  - The use of remote computing increases the risk of data unavailability.
    - This risk is mitigated by moving data back to GFDL for storage and analysis, which experience indicates is best done locally. High bandwidth national networks with established service level agreements are required.
- State of parallel I/O
  - True parallel I/O constrains model performance, particularly at the scale of thousands of processors.
    - Work is underway to immediately explore more efficient paths to parallel I/O.

Issues

- Although projects in decadal variability, seasonal hurricane activity, and seamless weather-climate prediction are moving forward using DoE computing, these projects could efficiently utilize many times more computing than is currently being offered in CY07 and CY08.
  - The INCITE proposal submitted by NOAA for climate research adds 30% to NOAA's computing capability, but NOAA has defined requirements for at least 600% its current climate computing capability.
- Progress in climate science requires a combination of "large" jobs that can run intermittently and "smaller" jobs that must run 24x7. The computing resources provided to this collaborative NOAA/DoE activity must meet this need.

Issues (cont'd)

- Numerical integration is only one aspect of the balanced HPC enterprise required to advance climate science:
  - Integrations typically span months of the calendar and so require sustained access to a dedicated set of resources.
  - Models with higher resolution and additional complexity generate vastly increased quantities of data that must be efficiently stored, accessed, and analyzed. Experience to date implies that this is best done locally.
    - NOAA/GFDL and DoE/PCMDI have an active collaboration in designing and implementing data archives for climate science and analysis methods for large quantities of data.
  - Remote computing requires additional technical local expertise in NOAA and from NOAA's DoE partners.