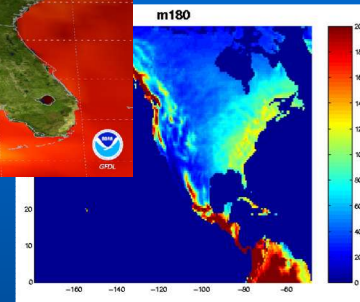
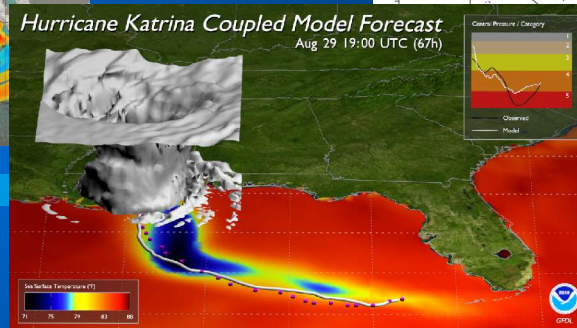
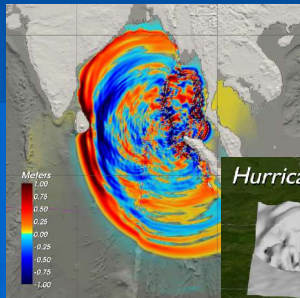


High Performance Computing and Research at GFDL



John Sheldon

*Geophysical Fluid Dynamics Laboratory / OAR
Princeton, NJ*

<http://www.gfdl.noaa.gov>

NOAA Tech 2006

November 1-3, 2005



GFDL Mission Statement

Department of Commerce Order 2-B
July 29, 1969

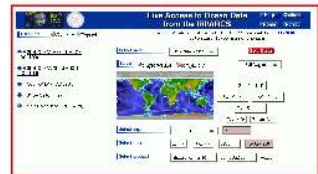
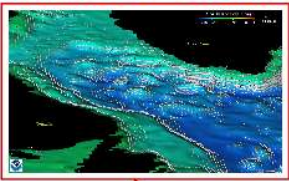
"... the Geophysical Fluid Dynamics Laboratory is to conduct investigations of the dynamics and physics of geophysical fluid systems to develop a theoretical basis, *by mathematical modeling and computer simulation*, for the behavior and properties of the *atmosphere and oceans.*"



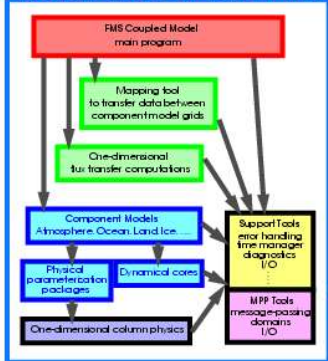
GFDL SCIENTIFIC COMPUTING ENVIRONMENT

The Computational Research Process

MODELING COLLABORATIONS



MODEL DEVELOPMENT



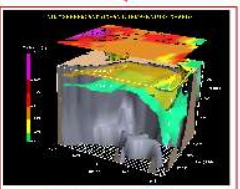
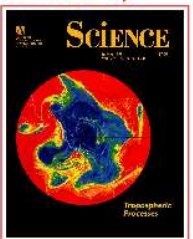
PRODUCTION COMPUTING

DATA STORAGE

ANALYSIS COMPUTING

COLLABORATIVE DATA-SHARING

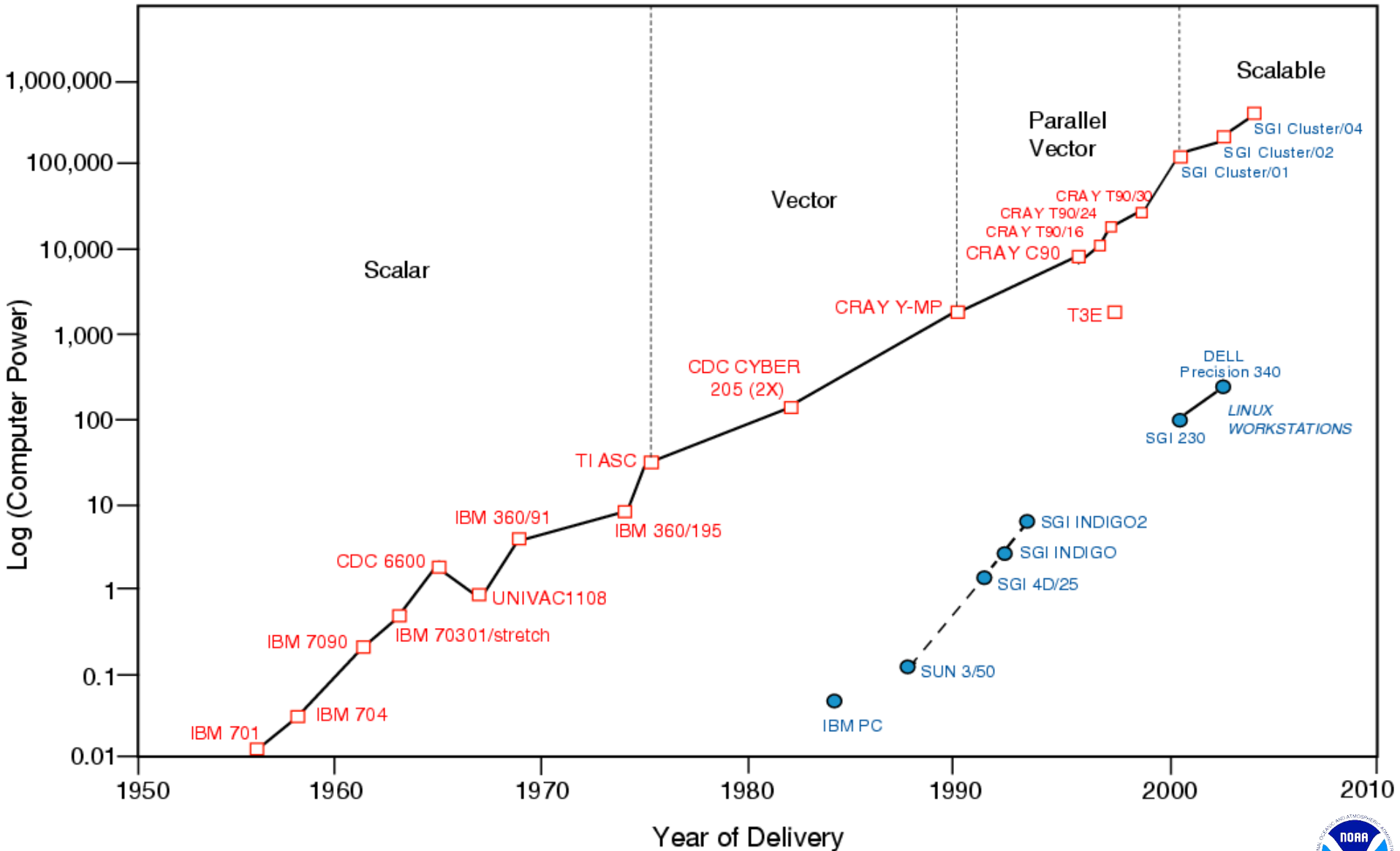
SCIENTIFIC KNOWLEDGE and OUTREACH



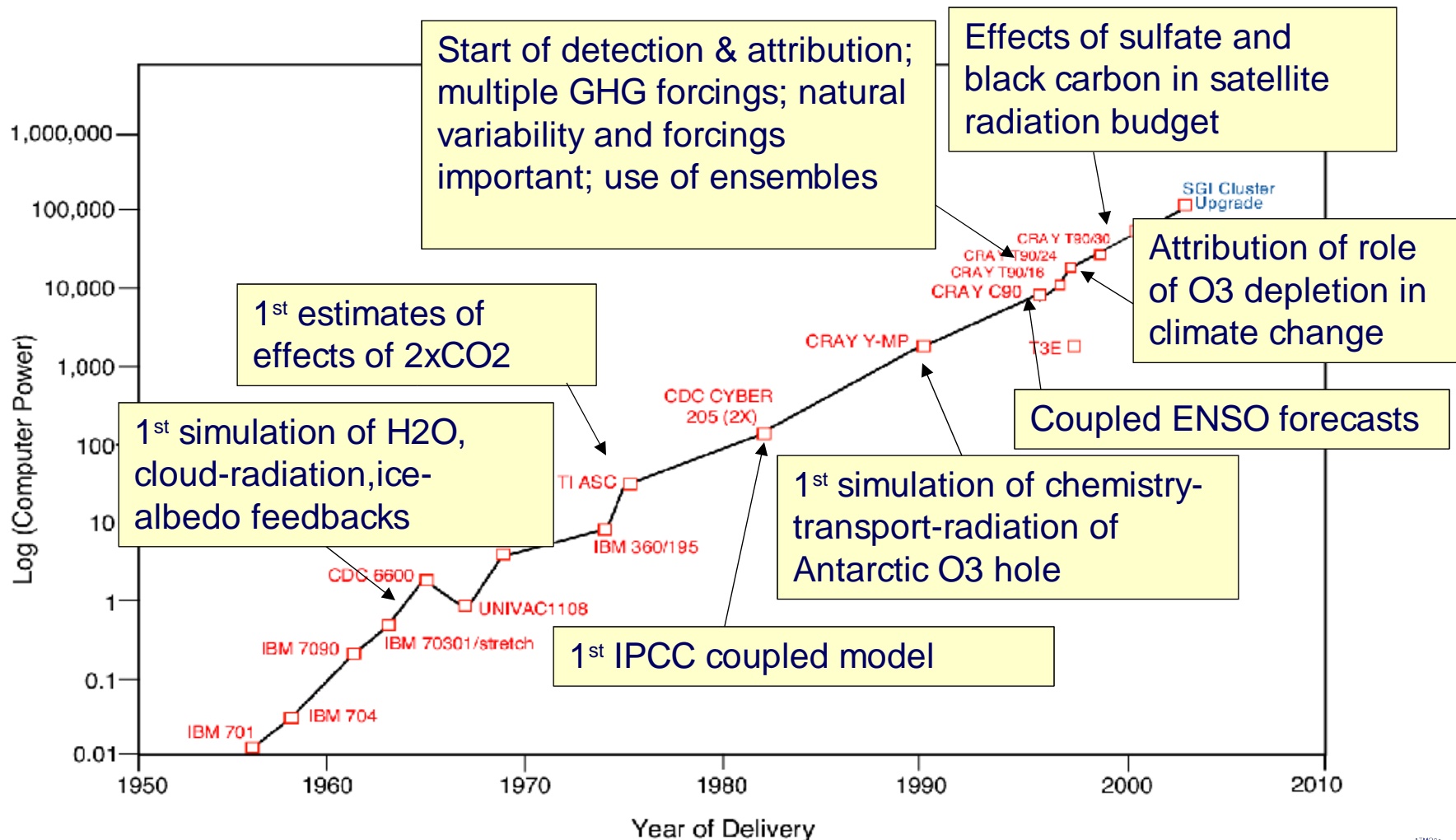
DIAGNOSTIC COLLABORATIONS

HISTORY OF GFDL COMPUTING

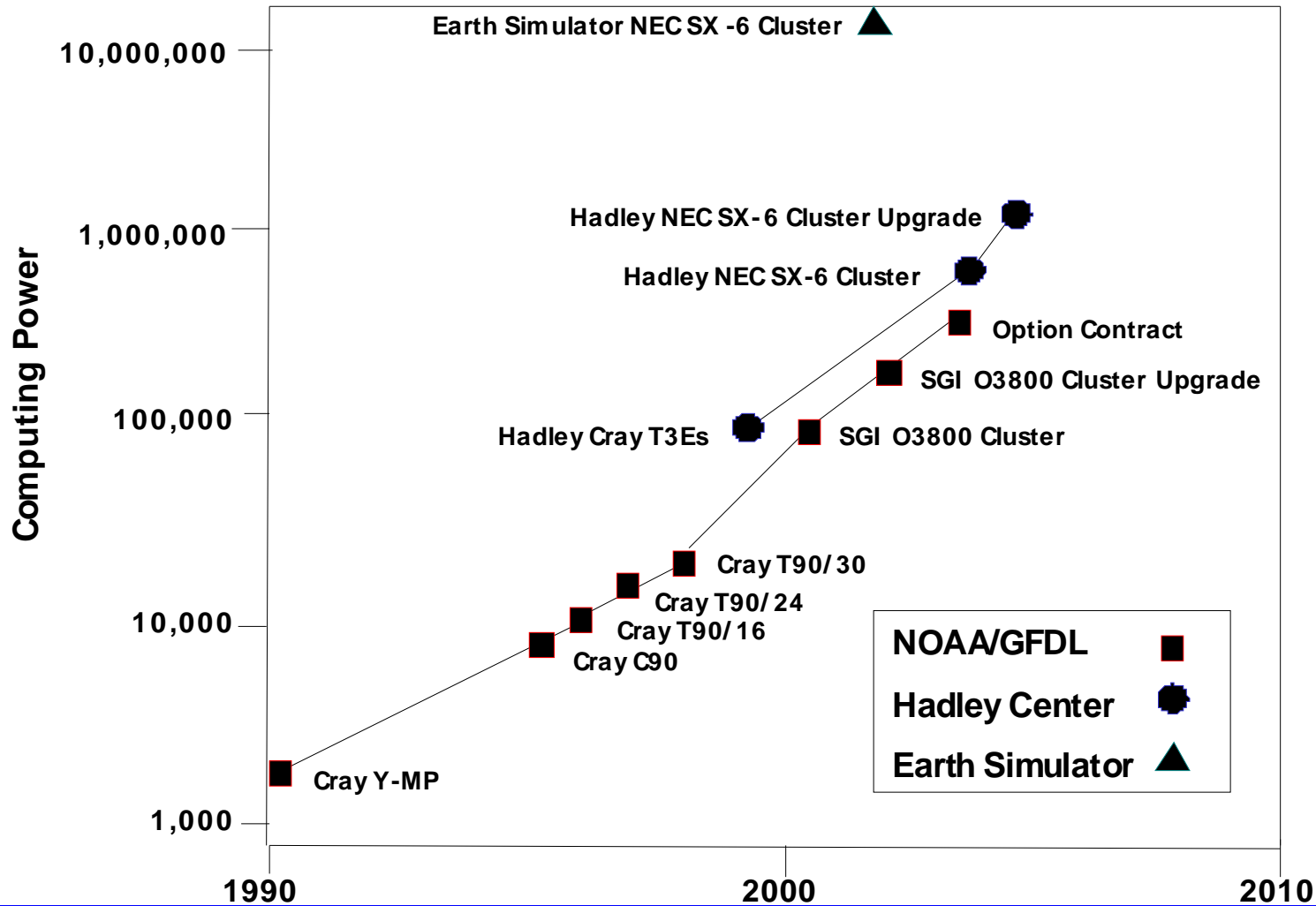
Growth of Computational Power with Time



GFDL Scientific Advances in Climate Dynamics and Prediction are Linked to Computer Power



Comparison of Computing Power by Climate Center



NOAA's HPCS at GFDL

July 2005

Computational Capability & Capacity

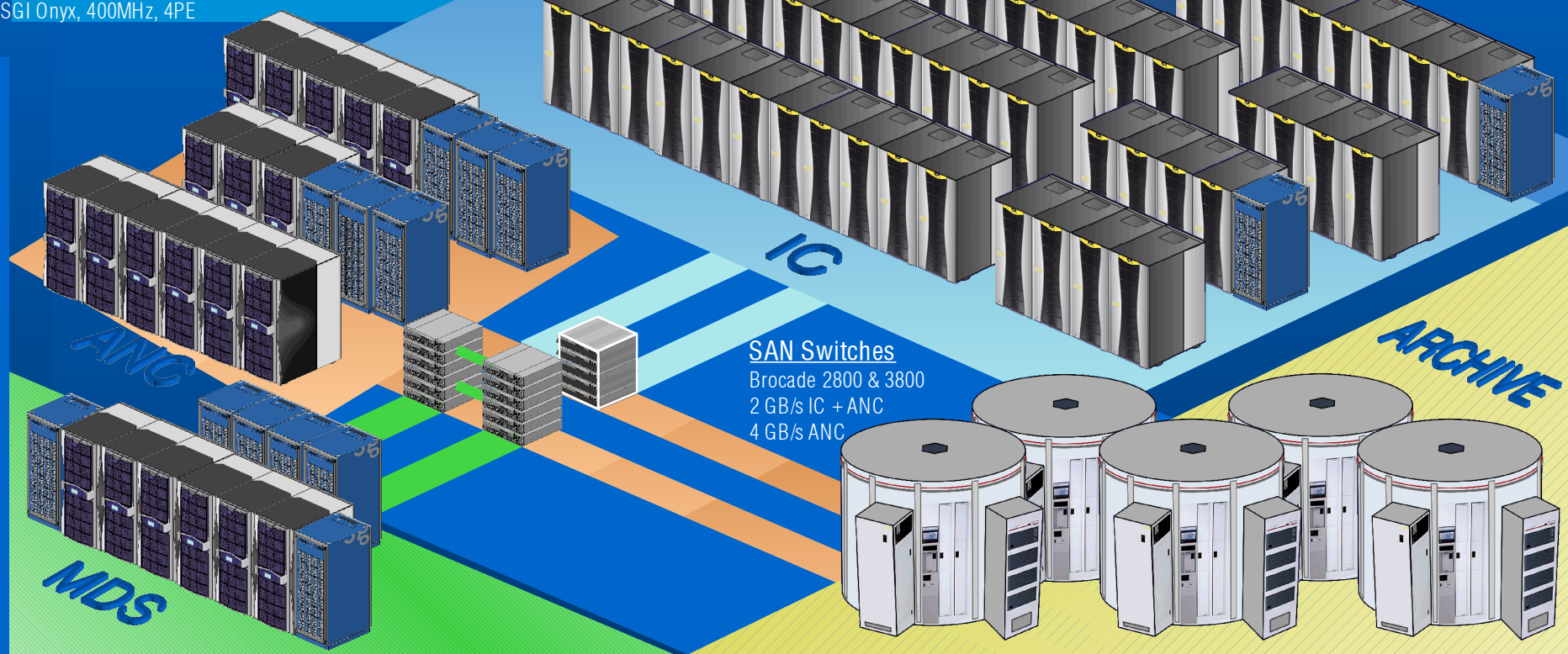
171 Coupled Climate Model Years
Per Computational Day
1 deg. Ocean Model
2 deg. Atmosphere

Computational Batch Cluster (IC)

SGI Altix 3700, 1.5GHz
(128, 4 x 256, 3 x 512) PE
2 GB memory/core

Analysis Cluster (ANC)

SGI Origin 3800, 600 MHz, (128, 256) PE,
(6.5, 5.6) TB disk, 1 GB memory/core
SGI Onyx, 400MHz, 4PE



SAN Switches

Brocade 2800 & 3800
2 GB/s IC + ANC
4 GB/s ANC

MetaData Server (MDS)

HFS & HSMS Server
SGI Origin 3800, 600 MHz,
2 Nodes x (64 PE + 64 GB)
Disk SAN: 4 GB/s per MDS Node
Tape SAN: 1 GB/s per MDS Node
Failsafe, DMF, CXFS

Disk SAN

23.6 TB SAN Disk
TP9100B
5+P+HS RAID5
w/Dual Controllers
2 Gb/s Fibre

LAN

Cisco Catalyst 6509
4 x 16 Gb/s
2 x 48 Fast Ethernet

Tape SAN (Archive)

5 x STK 9310 Tape Libraries
36 x 9940B Drives (200 GB, 30 MB/s)
22 x 9840A Drives (20 GB, 10 MB/s)
3.8 PB Tape Storage On-Line
5 PB Off-Line



Consolidating NOAA R&D HPC

Past State:

Stove-piped HPC



Emerging:

Integrated management, functional alignment



Features of HPCS Procurement

Balanced Requirements

Analysis and storage requirements to match computing

Comprehensive Benchmarking Strategy

Emphasize production throughput + analysis workload

Staged Delivery and Base/Option Contract Structure

Tracks growth in user demand & promotes competition

Performance-Based

Shortfall in cycles deliver more equipment



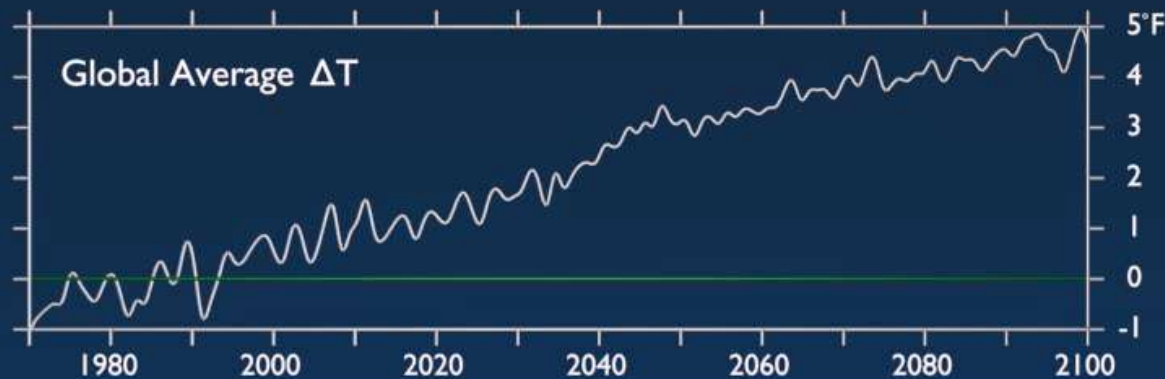
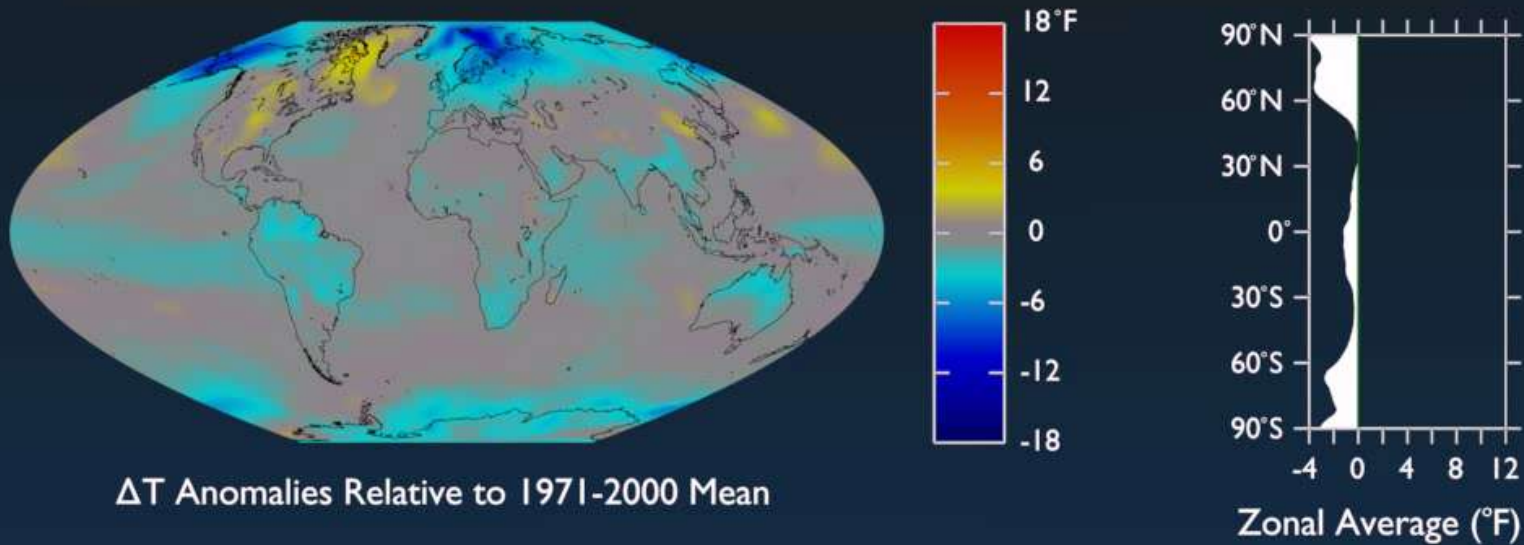
Selected Research Results

1. Projections from Latest Coupled Climate Model (CM 2.x)
2. High-Resolution Global Atmospheric Model
3. GFDL Hurricane Model



CM 2.1 Climate Model Projection

SURFACE AIR TEMPERATURE ANOMALIES



1971
(Model Year)

GFDL CM 2.1
Climate Model

High Resolution Climate Modeling

Regional climate assessment requires higher resolution models

High-resolution models are too expensive for long-range climate experiments

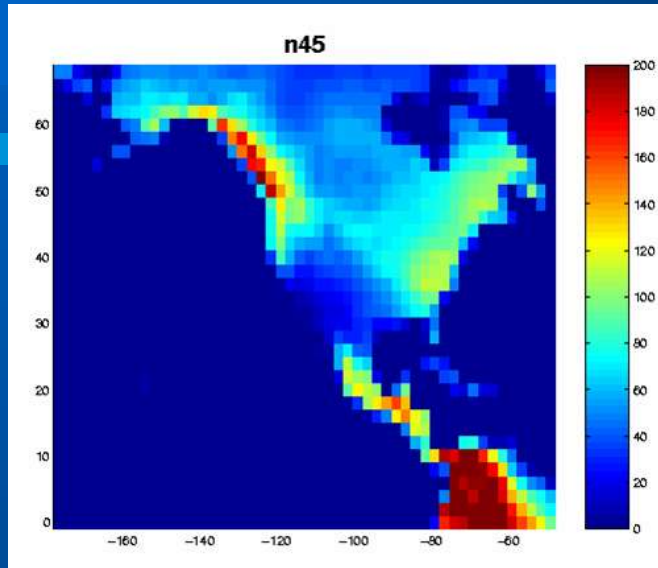
Solution:

- Run low-res models out to longer time scale
- Use low-res result as starting point for hi-res integrations

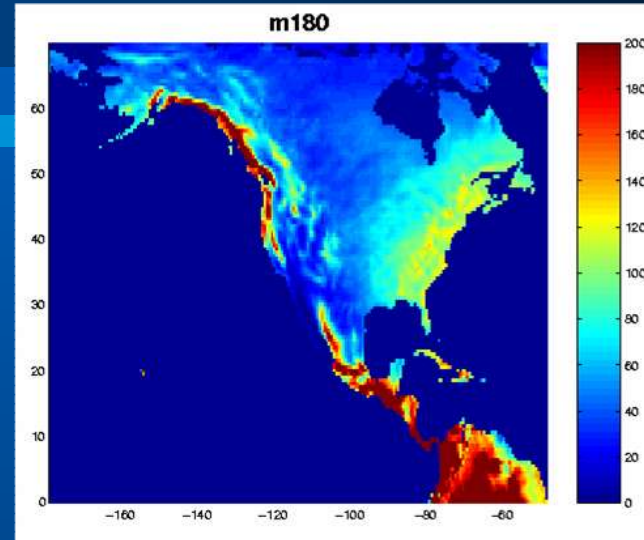


Effect of Resolution on Annual Mean Precipitation

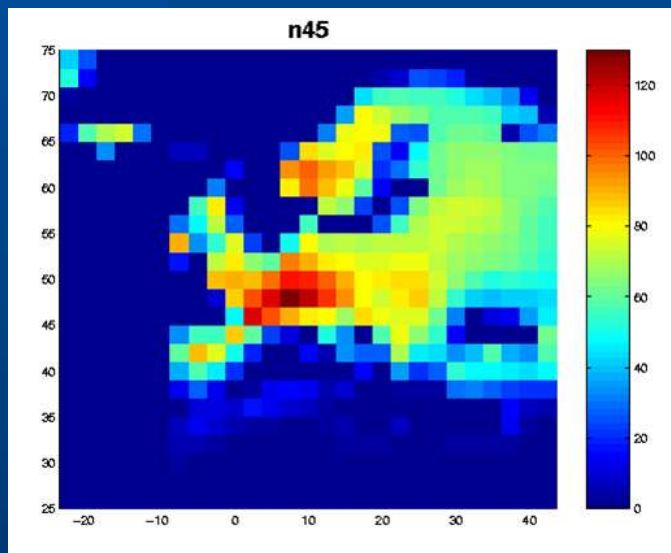
200 km



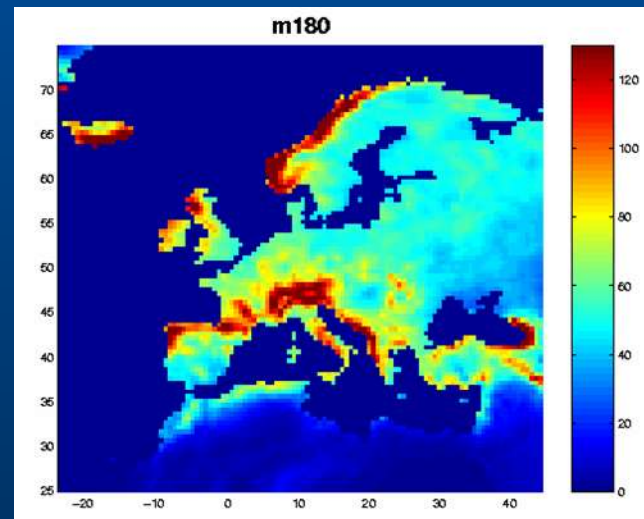
50 km



n45

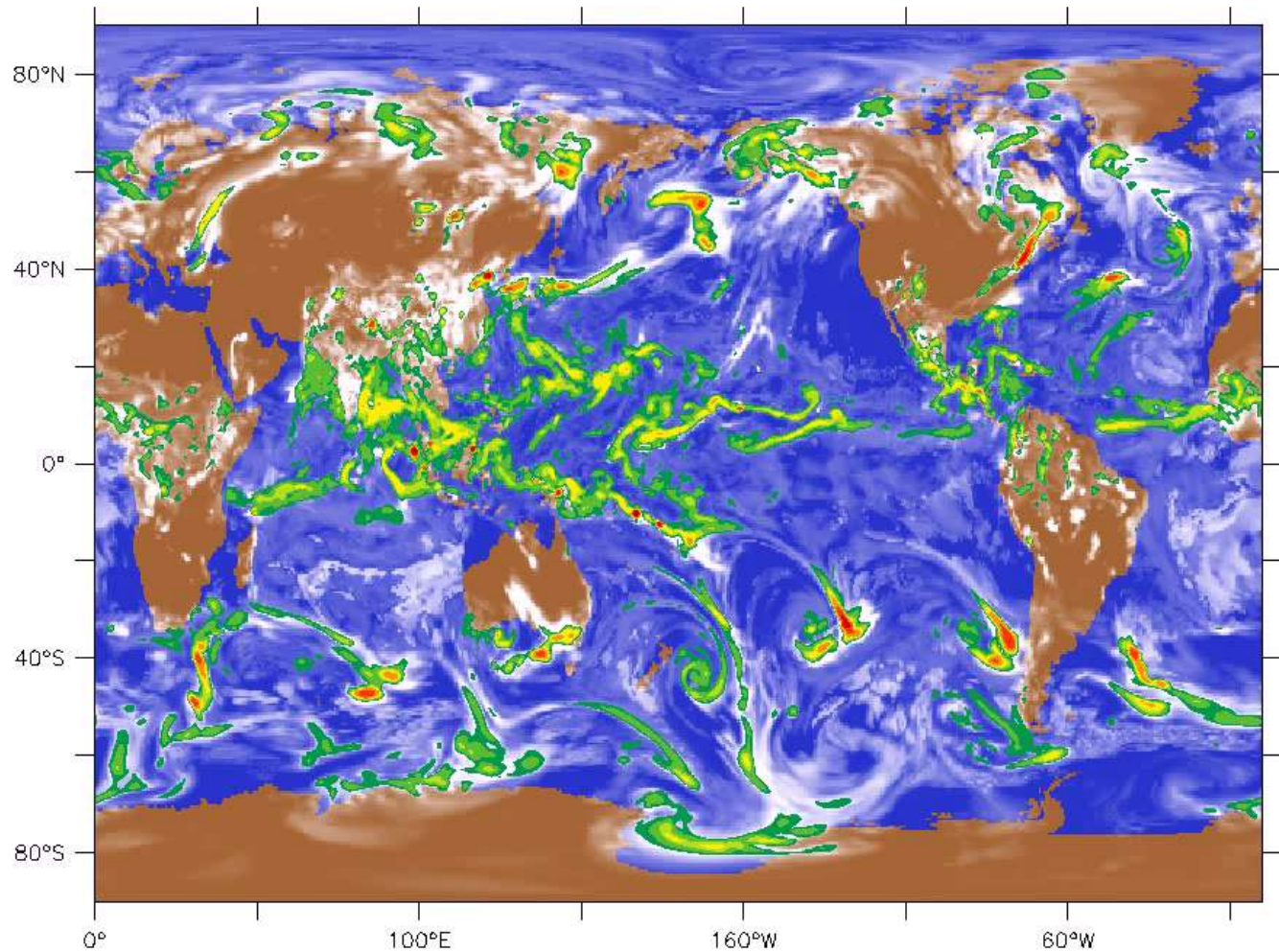


m180

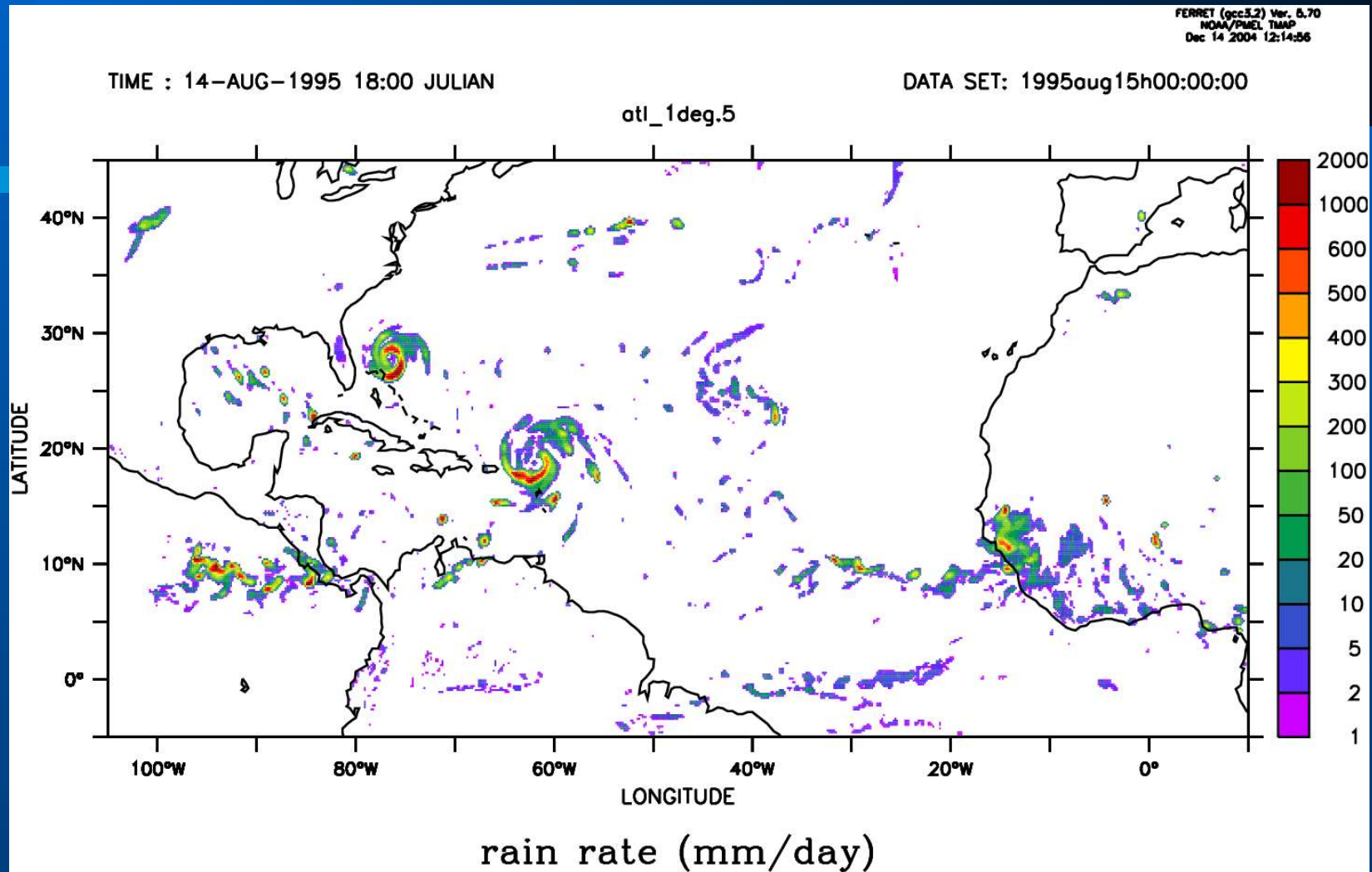


Sample 0.5 deg Global Model 60-day Simulation

01-SEP



Interannual Hurricane Variability



Experiments are underway to understand the year to year fluctuations in the numbers and spatial distributions of hurricanes in the Atlantic basin. Because of the high resolution required these experiments run only a little faster than “ real time ” , i.e. progress will be slow.

Hurricane Research and Prediction

GFDL Hurricane Model Development:

Result of 25-year GFDL research program

First became operational in 1995

The leading operational prediction tool

GFDL researchers investigating climate effects on future hurricanes



The GFDL Hurricane Forecast System

Triple-nested, with very high resolution (5 miles) near the storm center, decreasing (to 60 miles) well away from the storm

Only hurricane model that can correctly resolve the hurricane' s detailed structure

Only hurricane model with skill at track, and intensity, and precipitation

Coupled to the Princeton Ocean Model to represent the mixing/cooling of the ocean surface due to the hurricane' s strong winds



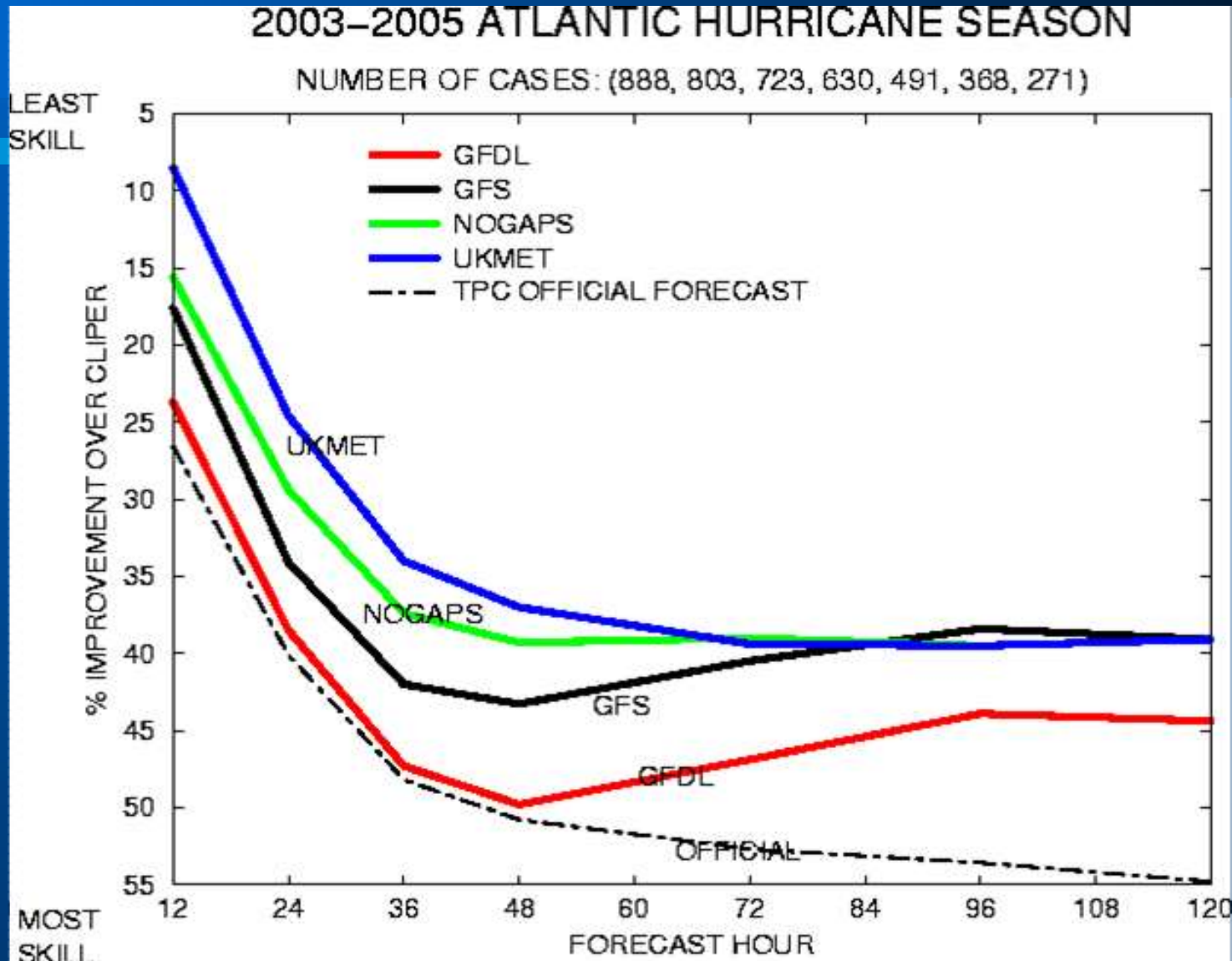
2004 Hurricane Season Forecasts



GFDL



Track Forecast Performance, 2003-2005



GFDL Hurricane Development

GFDL Model Upgrades

- Addition of third nest, doubling of highest resolution to $1/_{12}$ degree
- New vortex initialization
- Coupled ocean

Improved Forecasts of Landfall (Using T254 GFS)

Reduced track and intensity errors

- Reduced northward bias

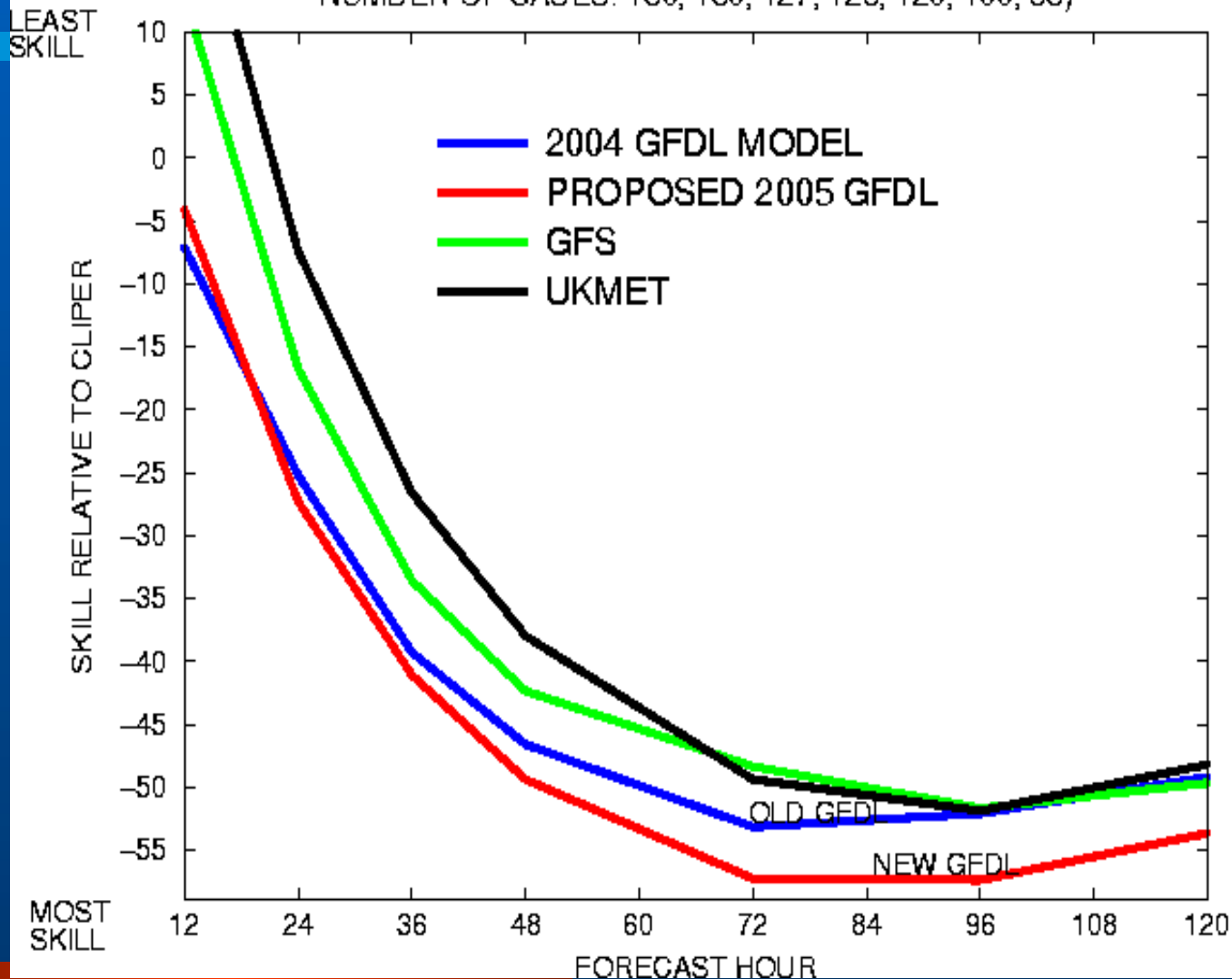


Expected Track Forecast Skill Improvement

OVERALL REDUCTION IN TRACK ERROR ~10% AT 3-5 DAYS

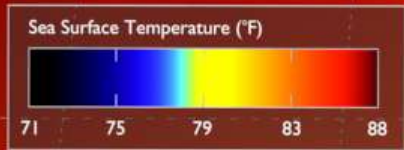
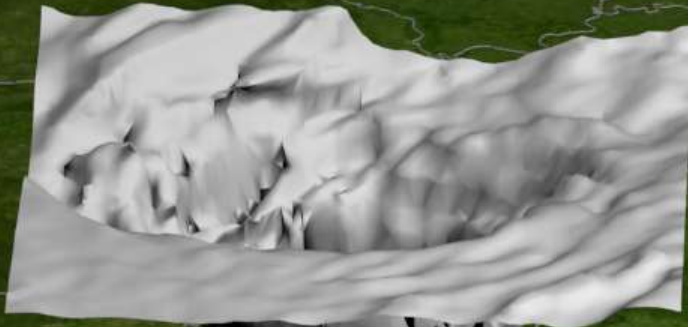
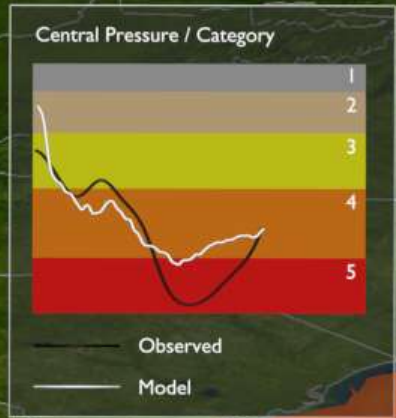
ISABEL, DANIELLE, CHARLIE, FRANCES, IVAN, JEANNE, KARL, LISA

NUMBER OF CASES: 130, 130, 127, 126, 120, 100, 83)



Hurricane Katrina Coupled Model Forecast

Aug 29 19:00 UTC (67h)



Cold wake

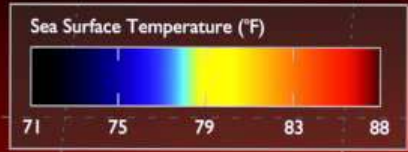
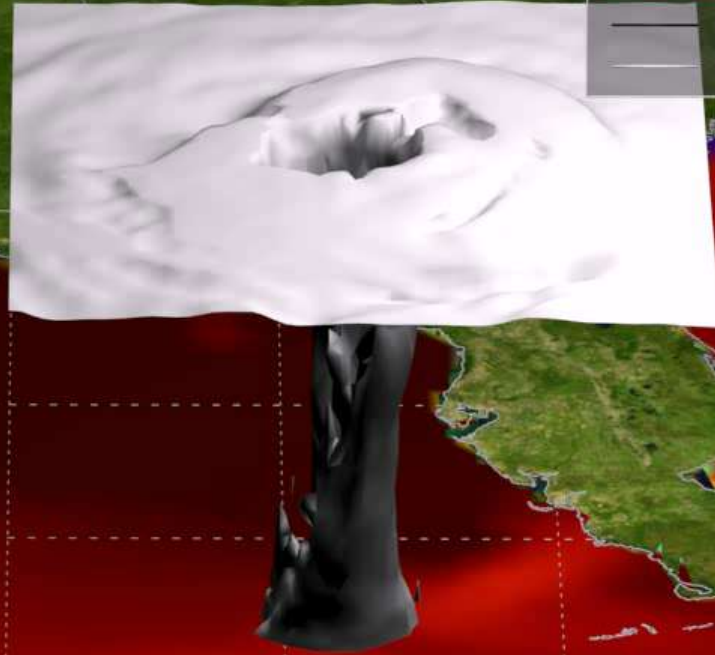
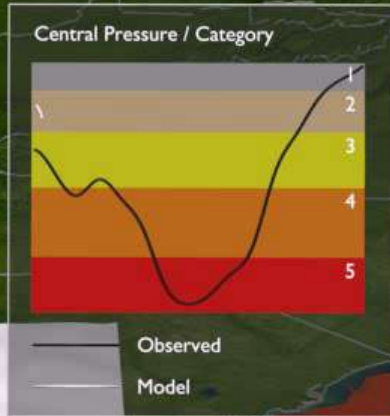
Forecast track

Observed positions

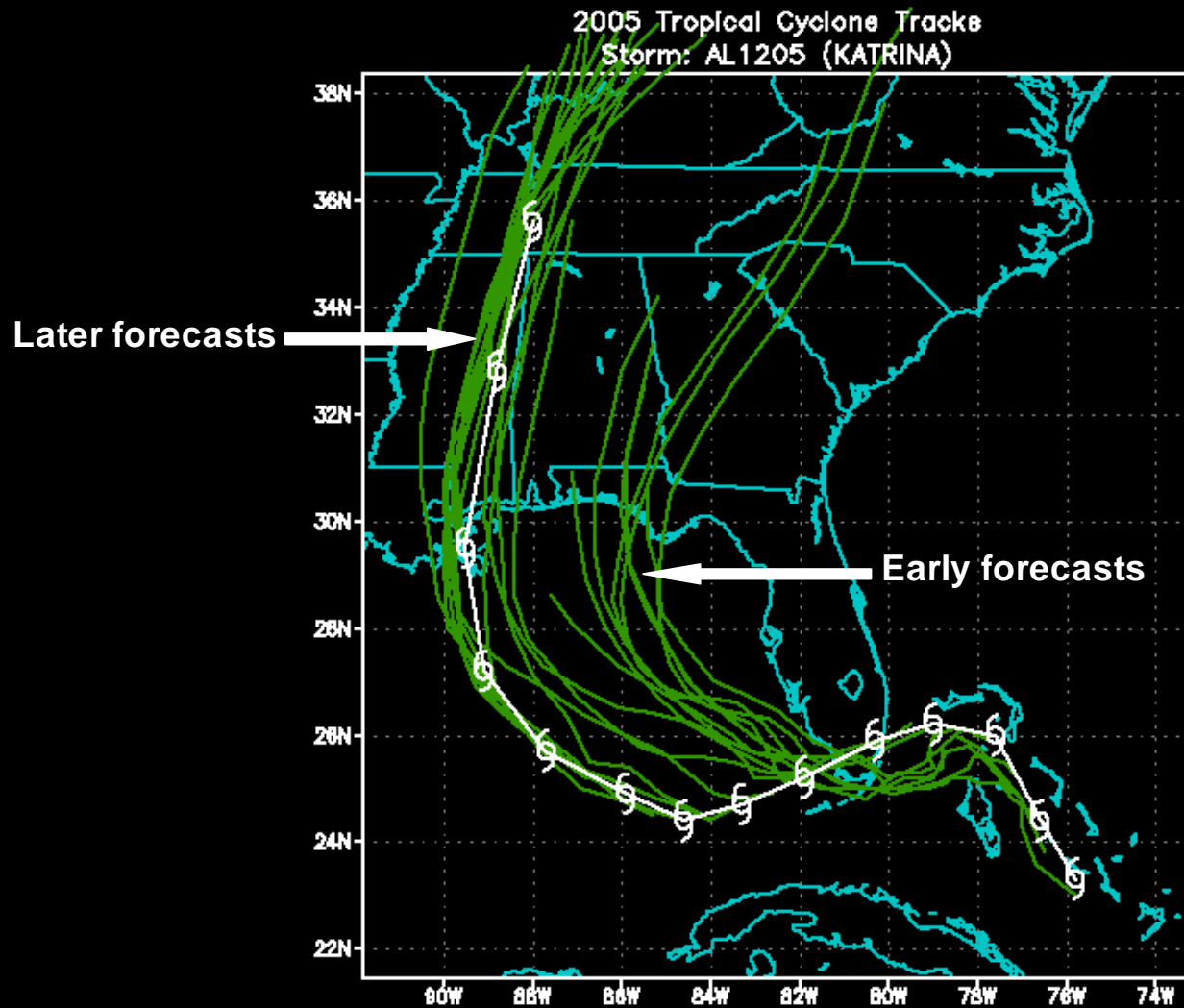


Hurricane Katrina Coupled Model Forecast

Aug 27 02:30 UTC



GFDL Katrina 5-Day Track Forecasts

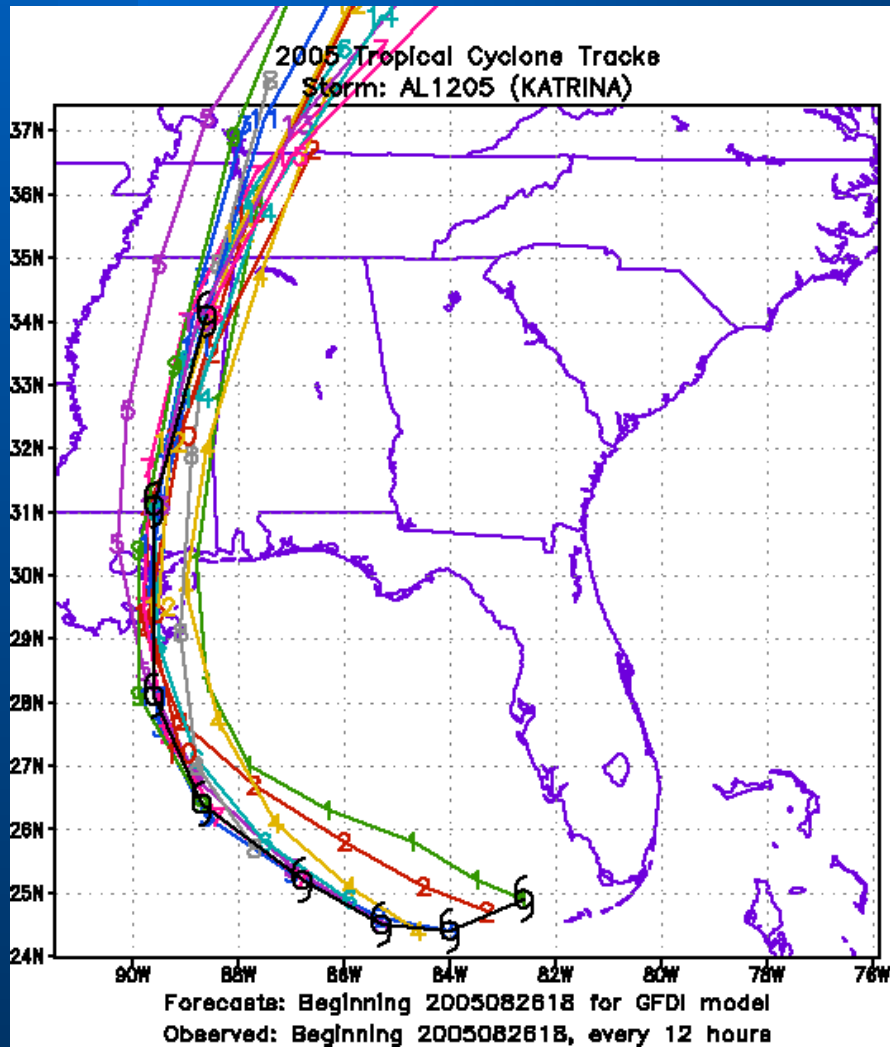


GFDL Hurricane Dynamics Group

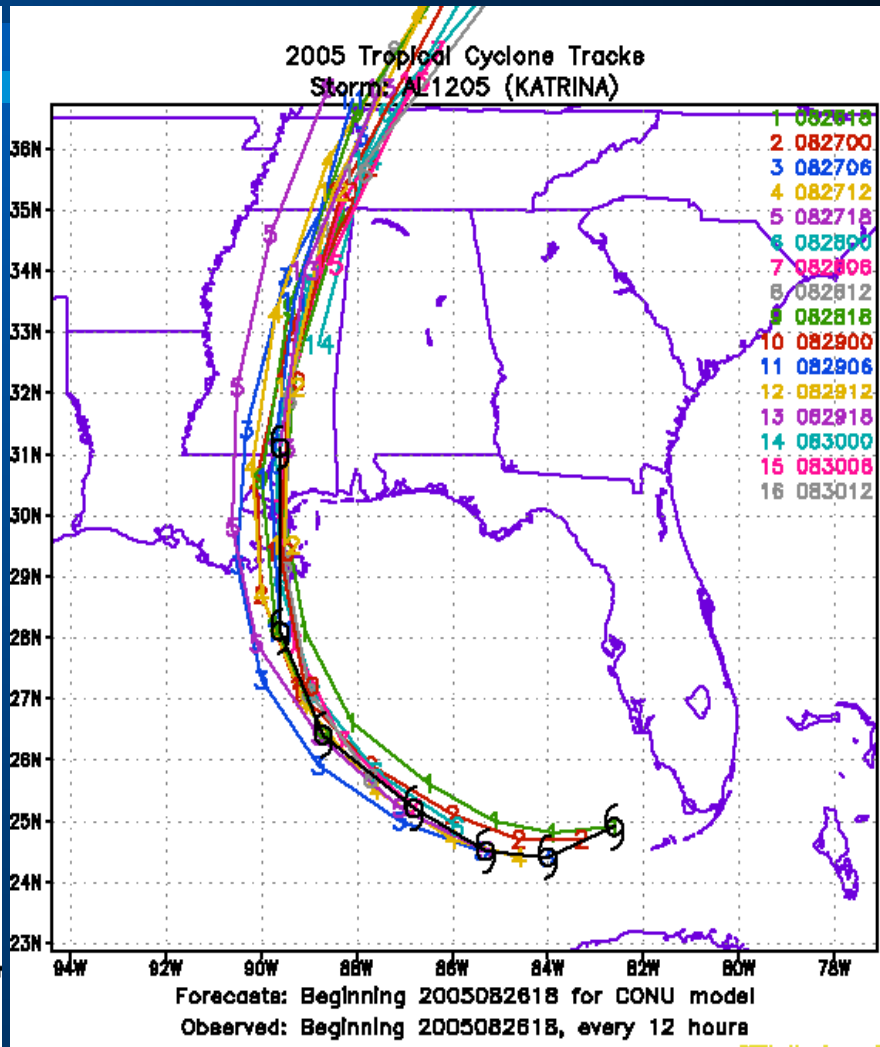


Hurricane Katrina Forecasts

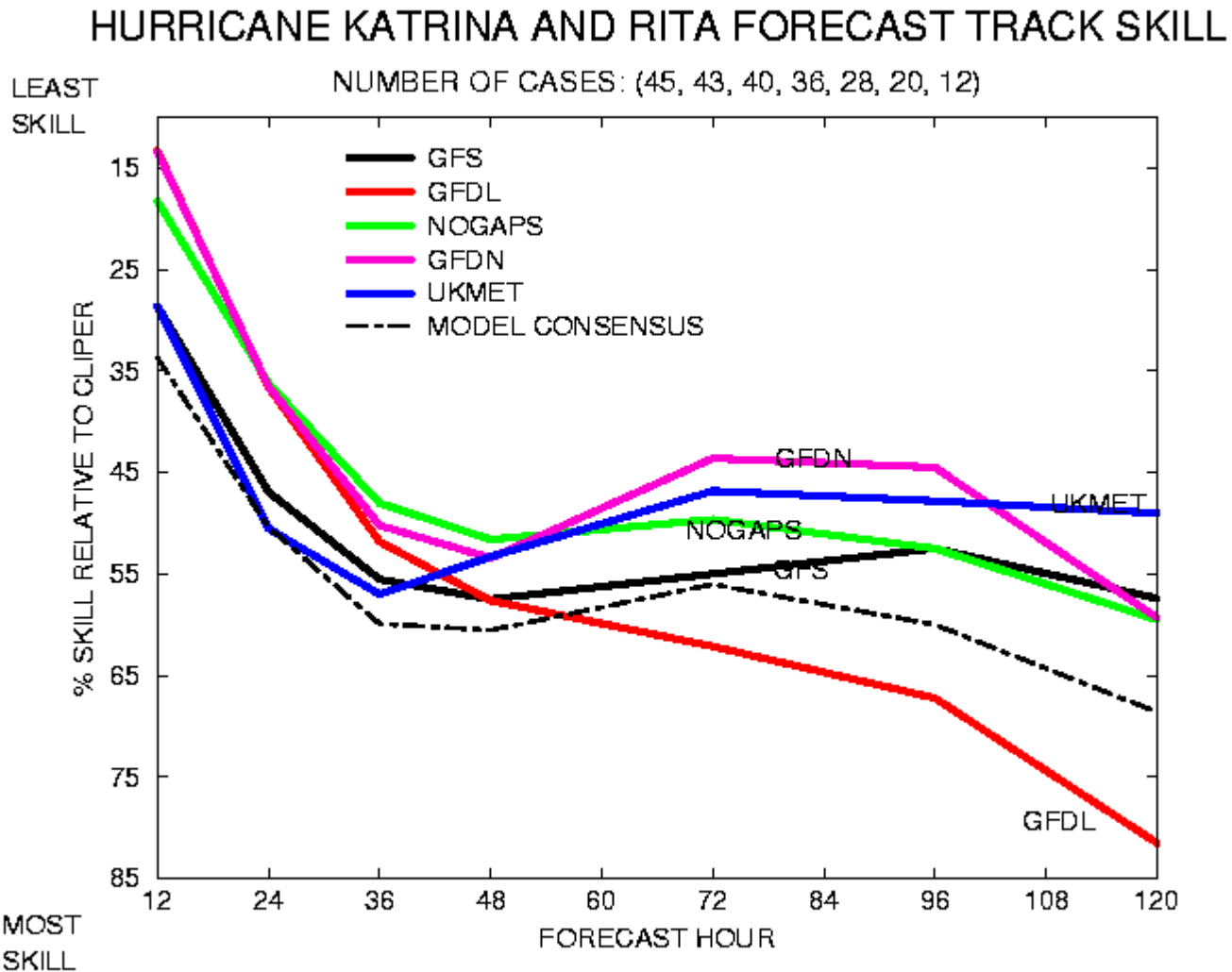
GFDL



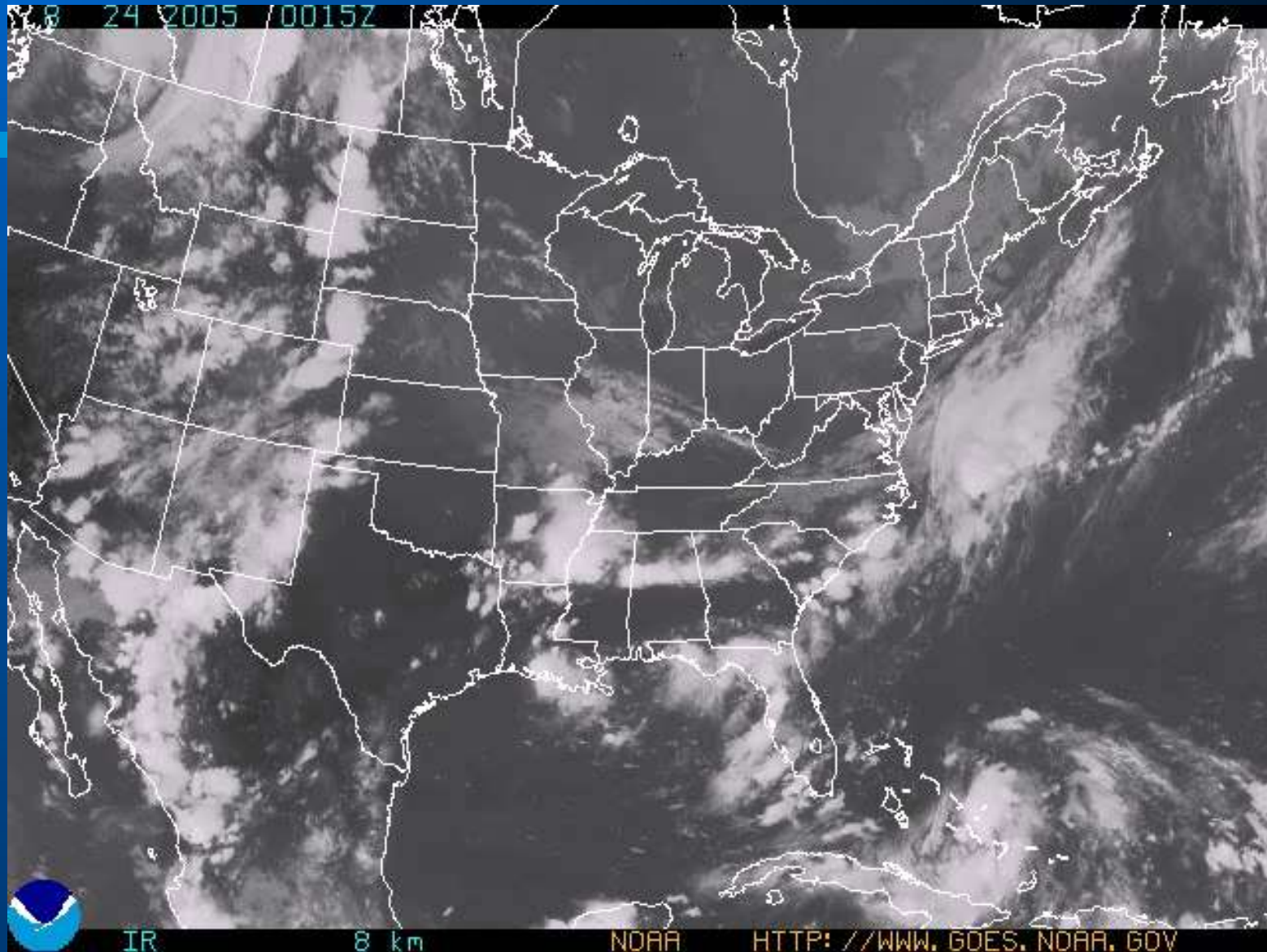
Model Consensus



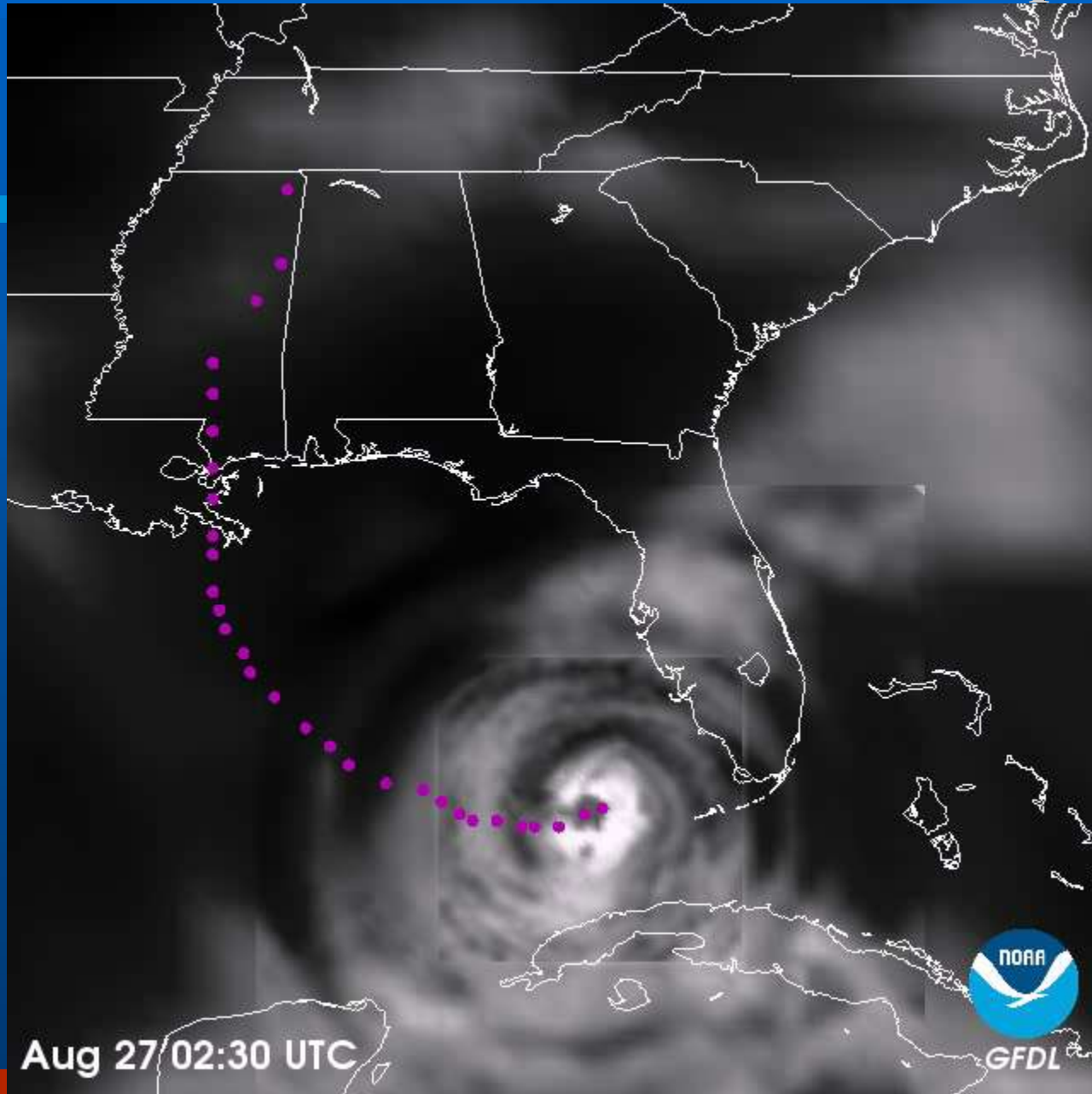
Model Track Performance for Katrina and Rita



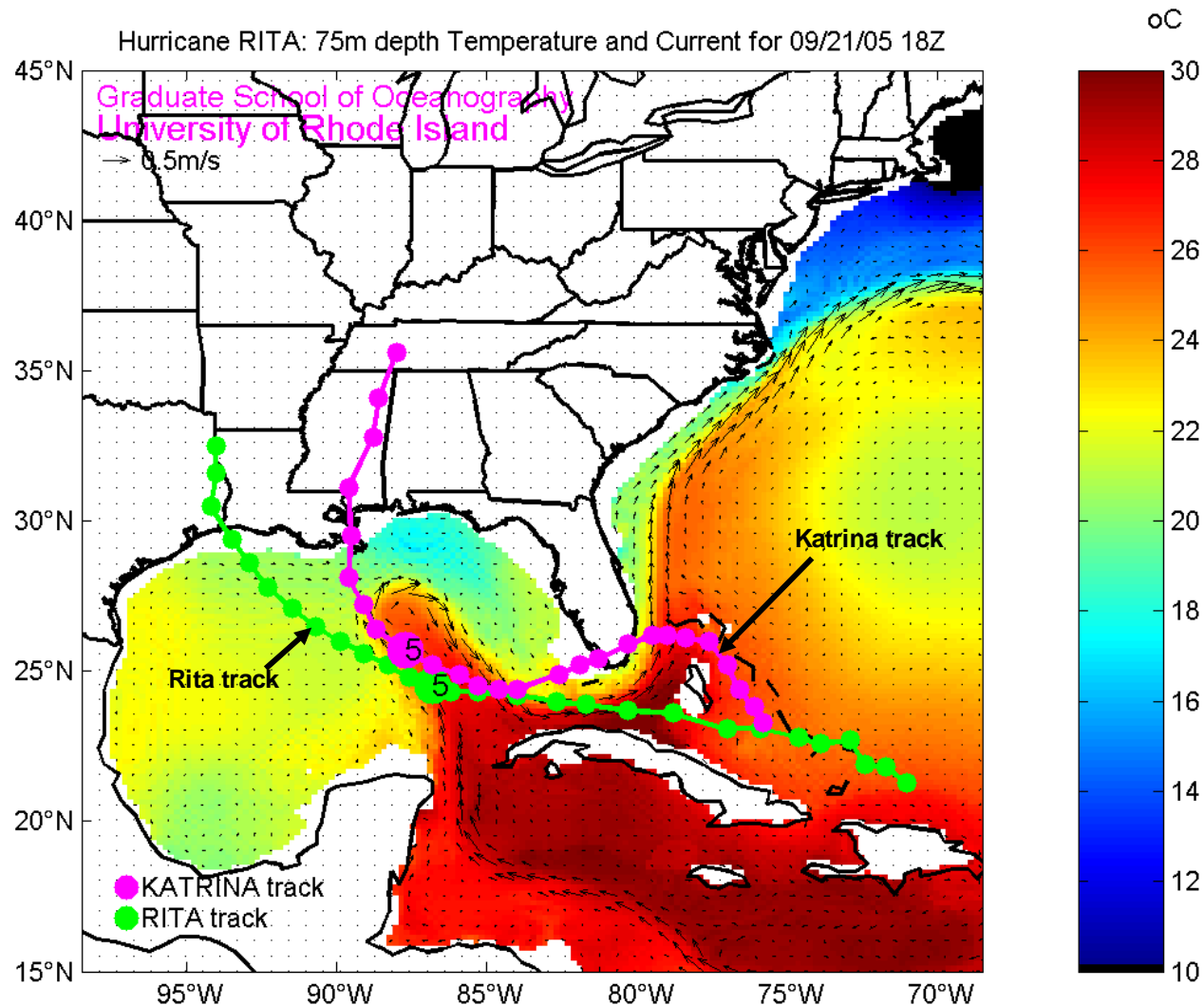
Hurricane Katrina Satellite Loop



Hurricane Katrina Model Loop

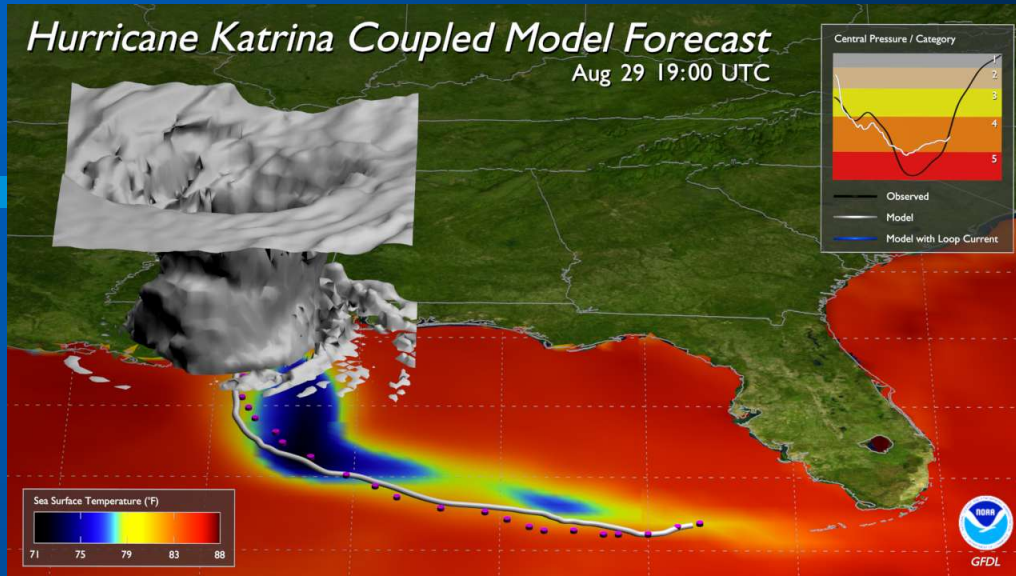


Strong Gulf Loop Current in 2005

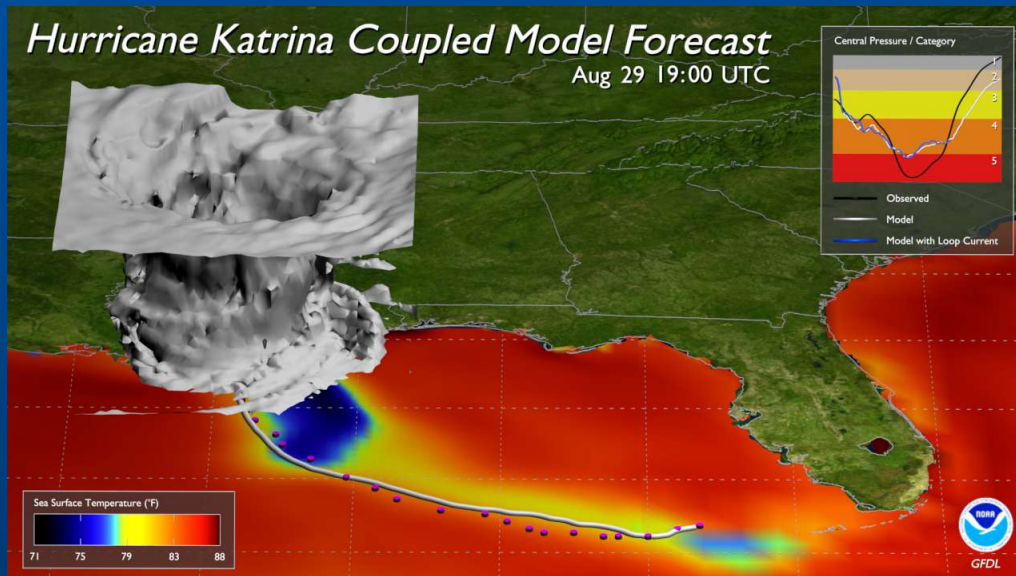


Thick Mixed Layer and Large Oceanic Heat Content of the Loop Current Limited the Ocean Cooling from Rita and Katrina. This Contributed to the Explosive Deepening in the Gulf

Effect of Strong Gulf Loop Current

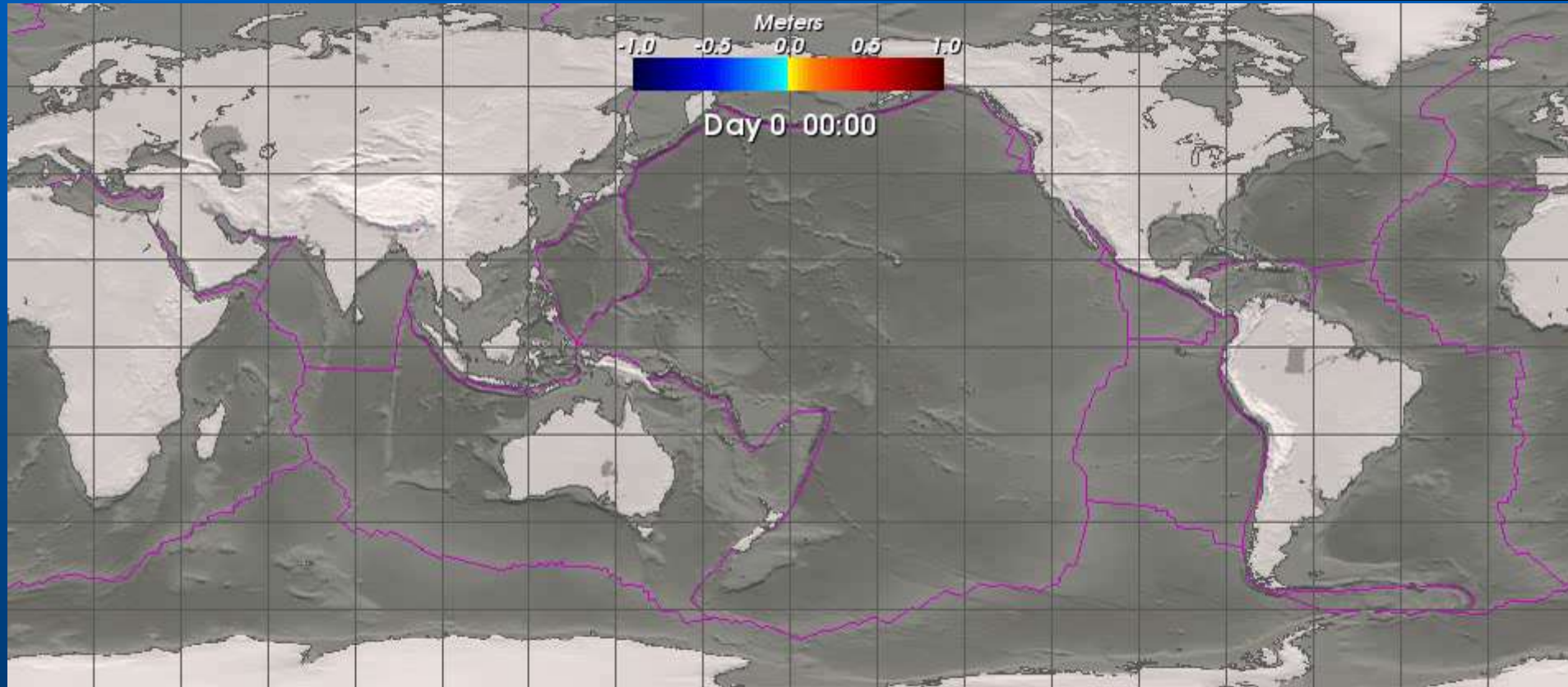


Climatology Gulf
Conditions



Observed Gulf
Conditions

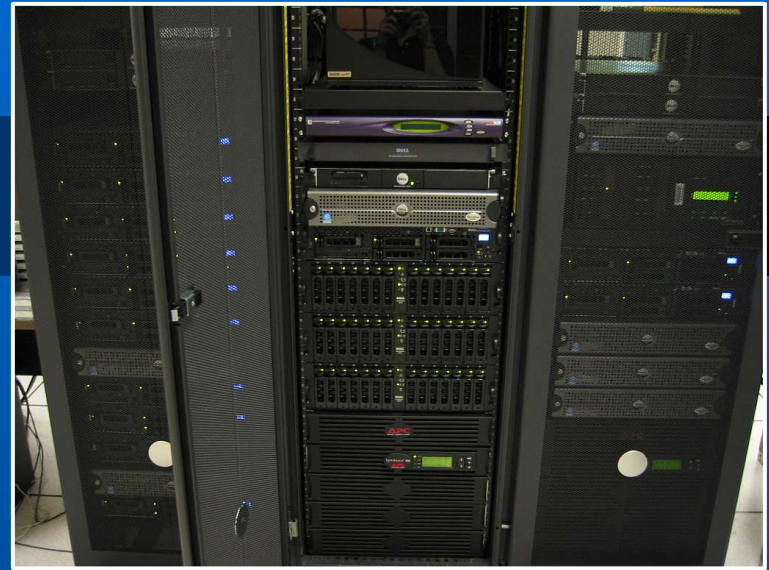
HIM Tsunami Simulation



GFDL Data Portal

nomads.gfdl.noaa.gov

- Registered users: **582**
- Data delivered to date: **19.1 TB**
- Average data transferred per day: **42 GB**
- Distinct hosts served to date: **850**
- Data added since Nov 2004: **8 TB**
- Data currently available: **10.8 TB**
- Capacity: **12.2 TB**
- Papers submitted using GFDL data: **>100**



NOMADS

The NOAA Operational Model
Archive and Distribution System



GFDL Data Portal History

Data Portal launched in 1995 as simple FTP server

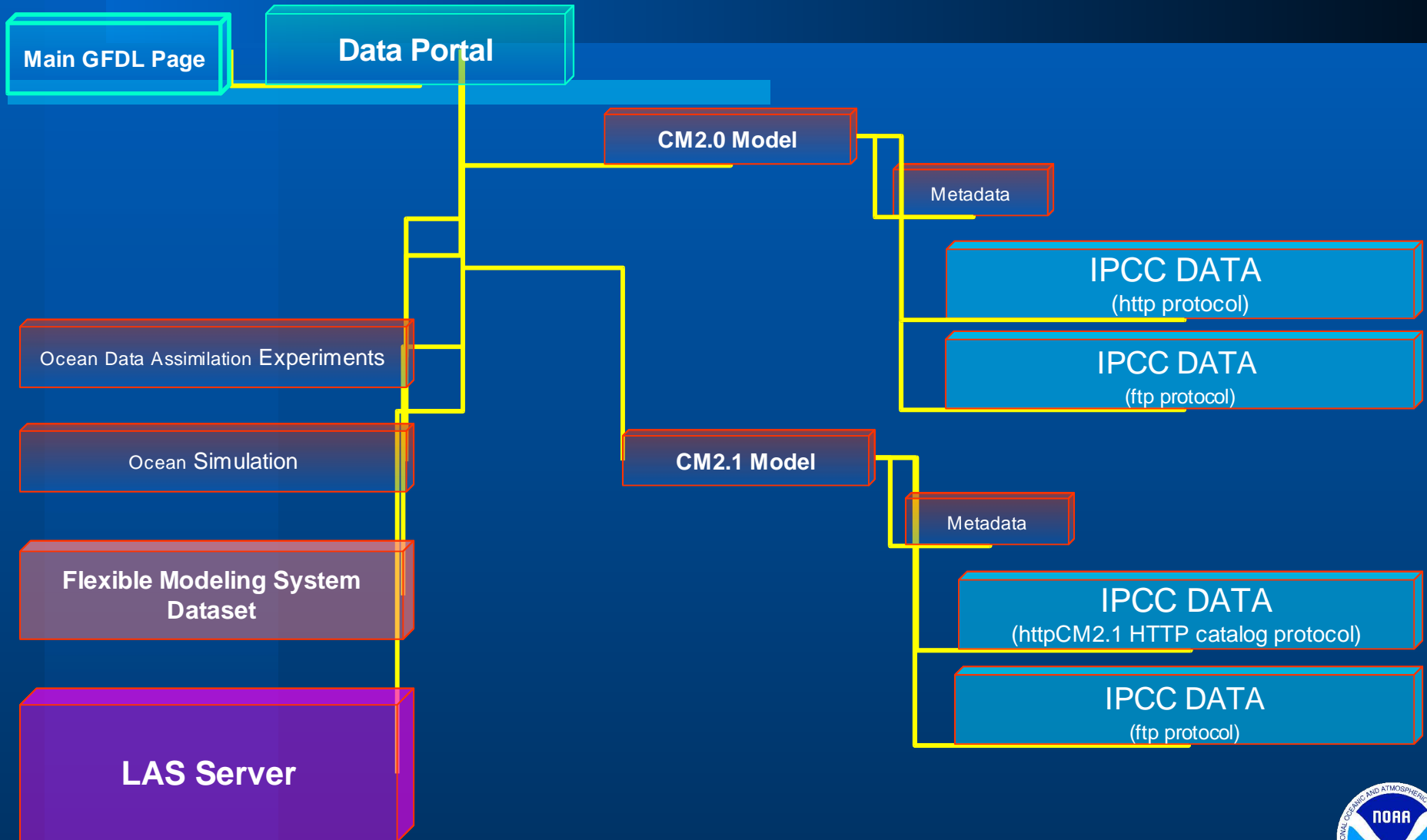
The idea, and term “ Data Portal” , arose in 2002

Originally, data was served on request

Current primary data assets are IPCC data



Data Portal Web Site Structure



Current Data Portal Work/Data flow

