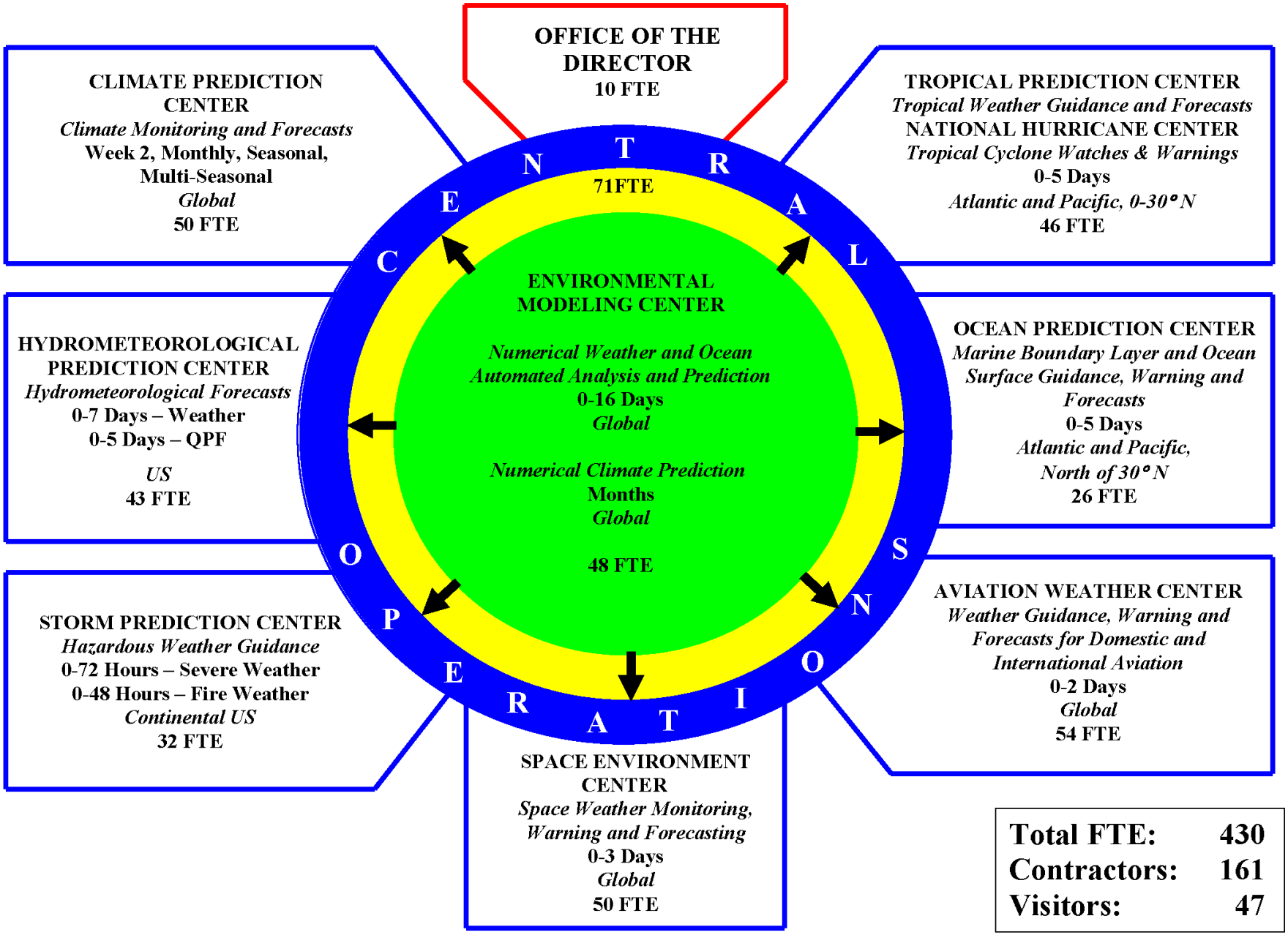
Overview of The Environmental Modeling Center

(with a focus on data assimilation)

Stephen J. Lord
Director
NCEP Environmental Modeling Center

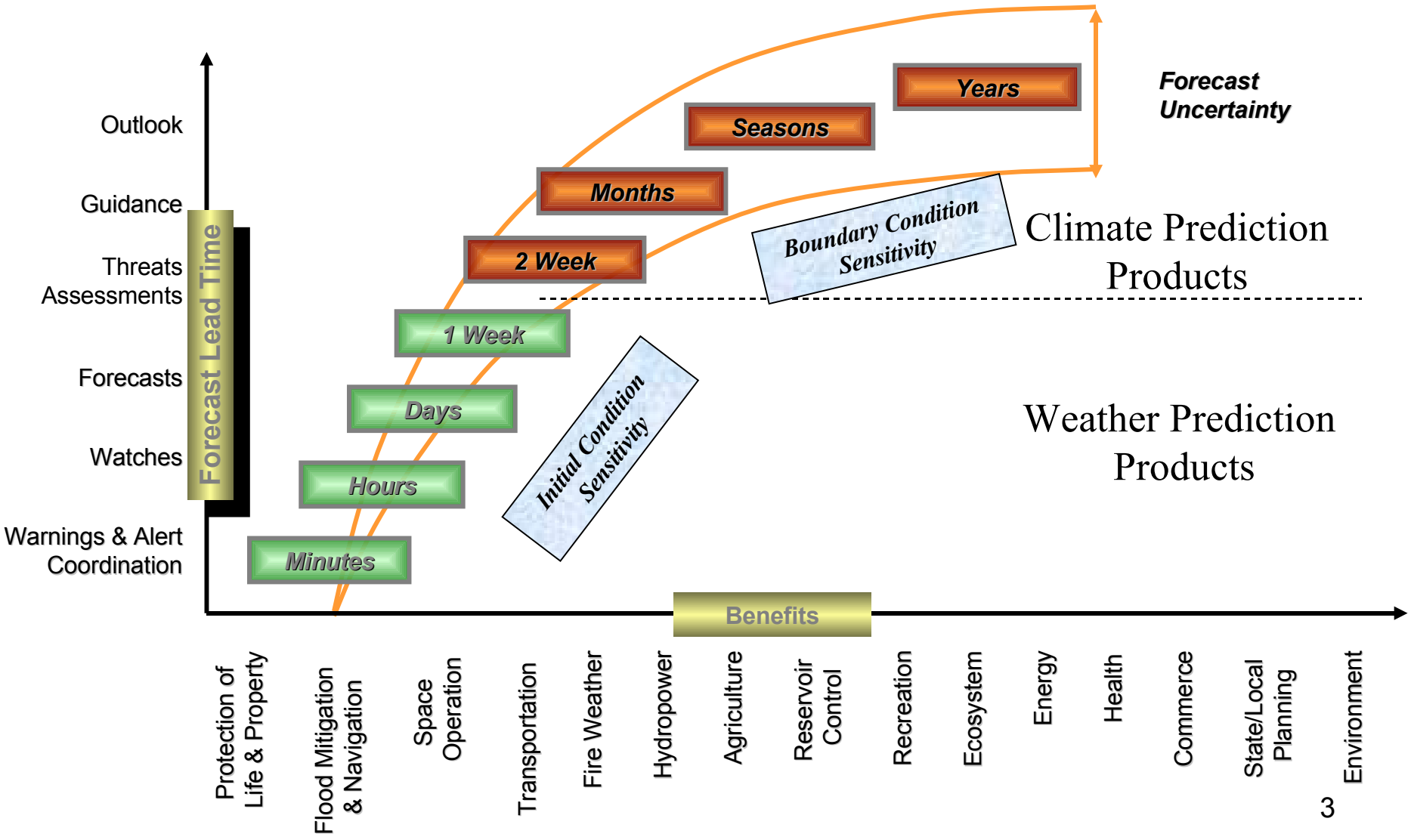
NCEP: "where America's climate, weather, and ocean services begin"

NATIONAL CENTERS for ENVIRONMENTAL PREDICTION

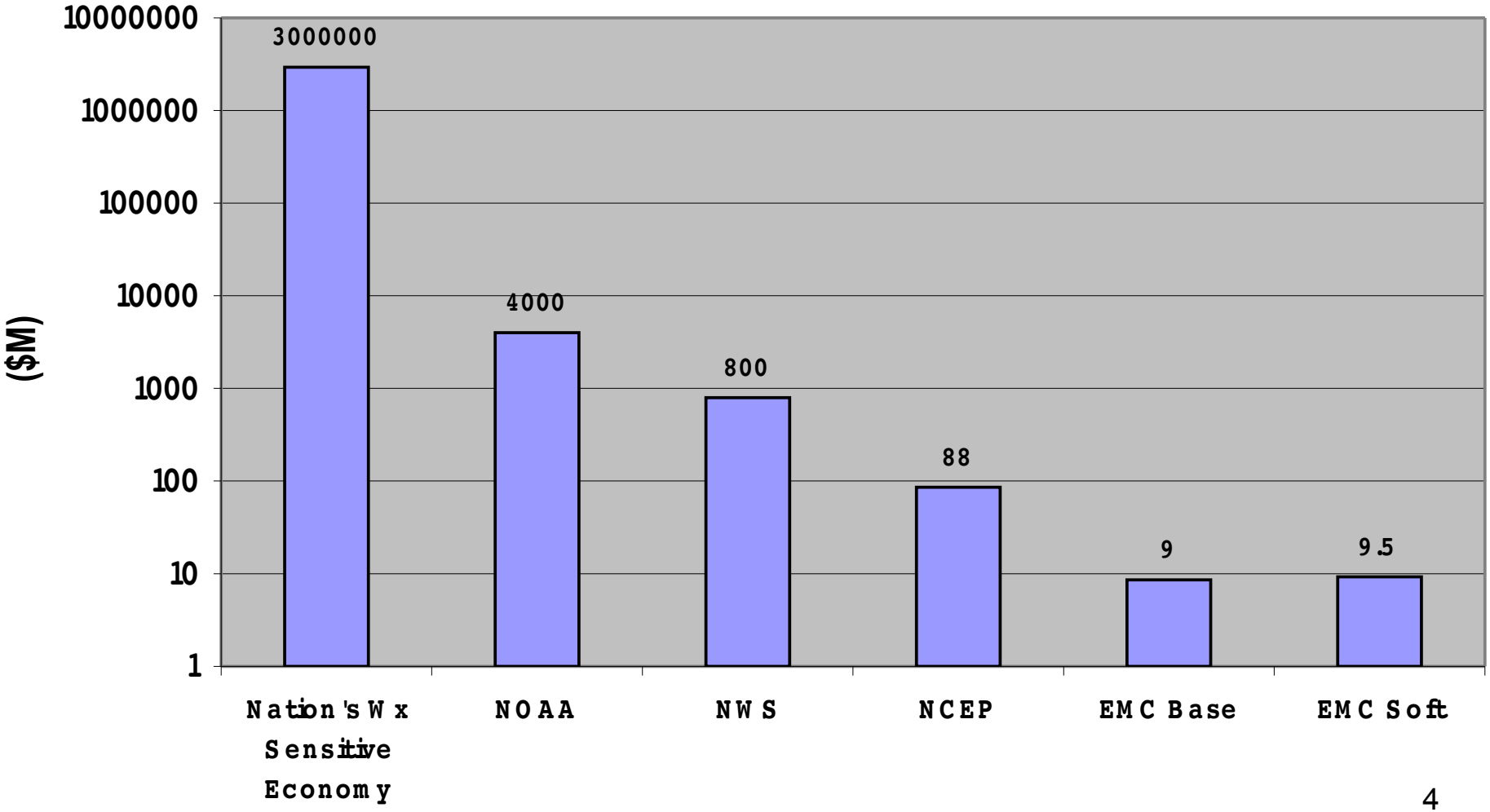


Total FTE:	**430**
Contractors:	**161**
Visitors:	**47**

NOAA Seamless Suite of Forecast Products Spanning Climate and Weather



EMC Support for the U. S. Economy



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

- Atmosphere

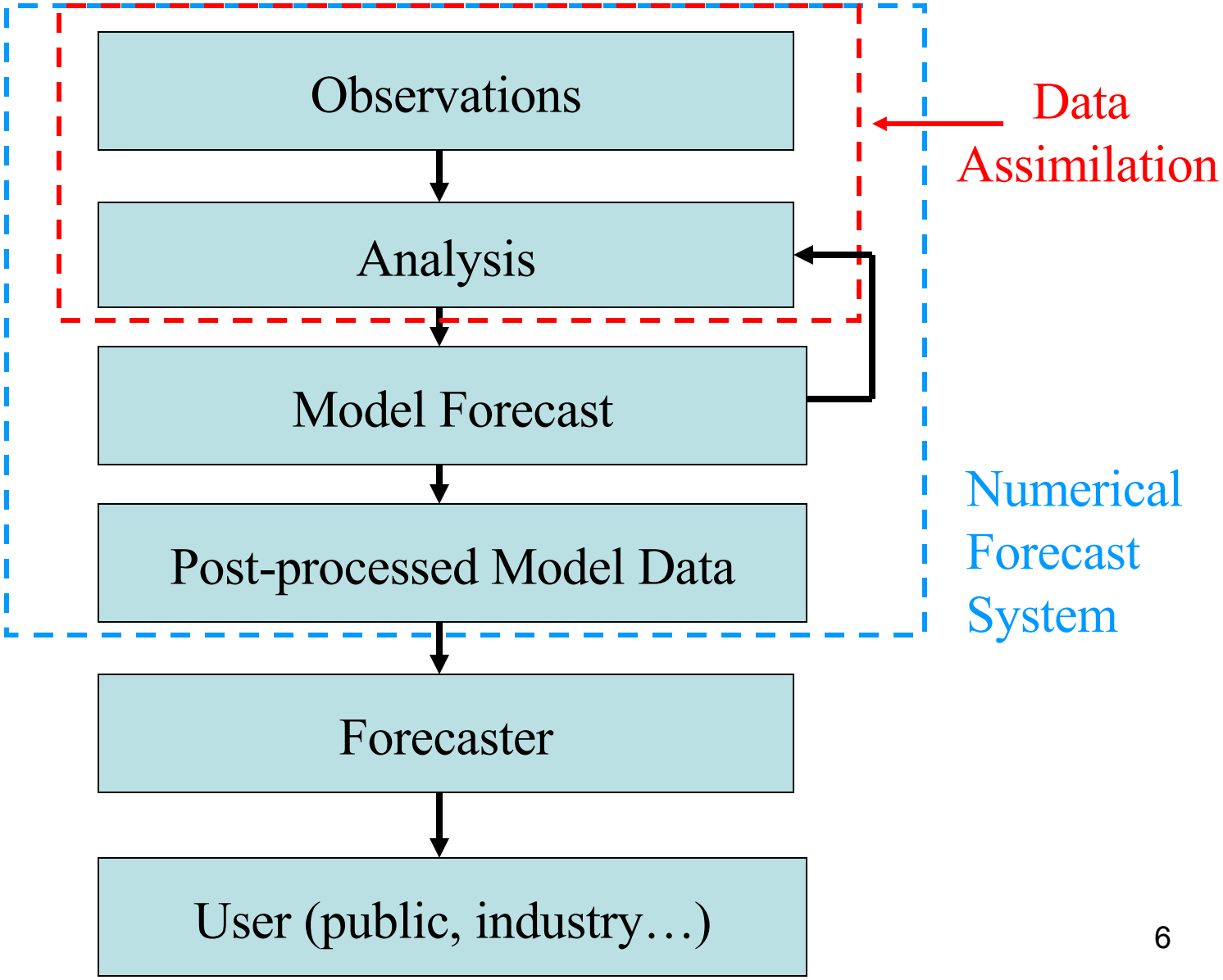
- Ocean

- Cryosphere

- Land

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

The Environmental Forecast Process

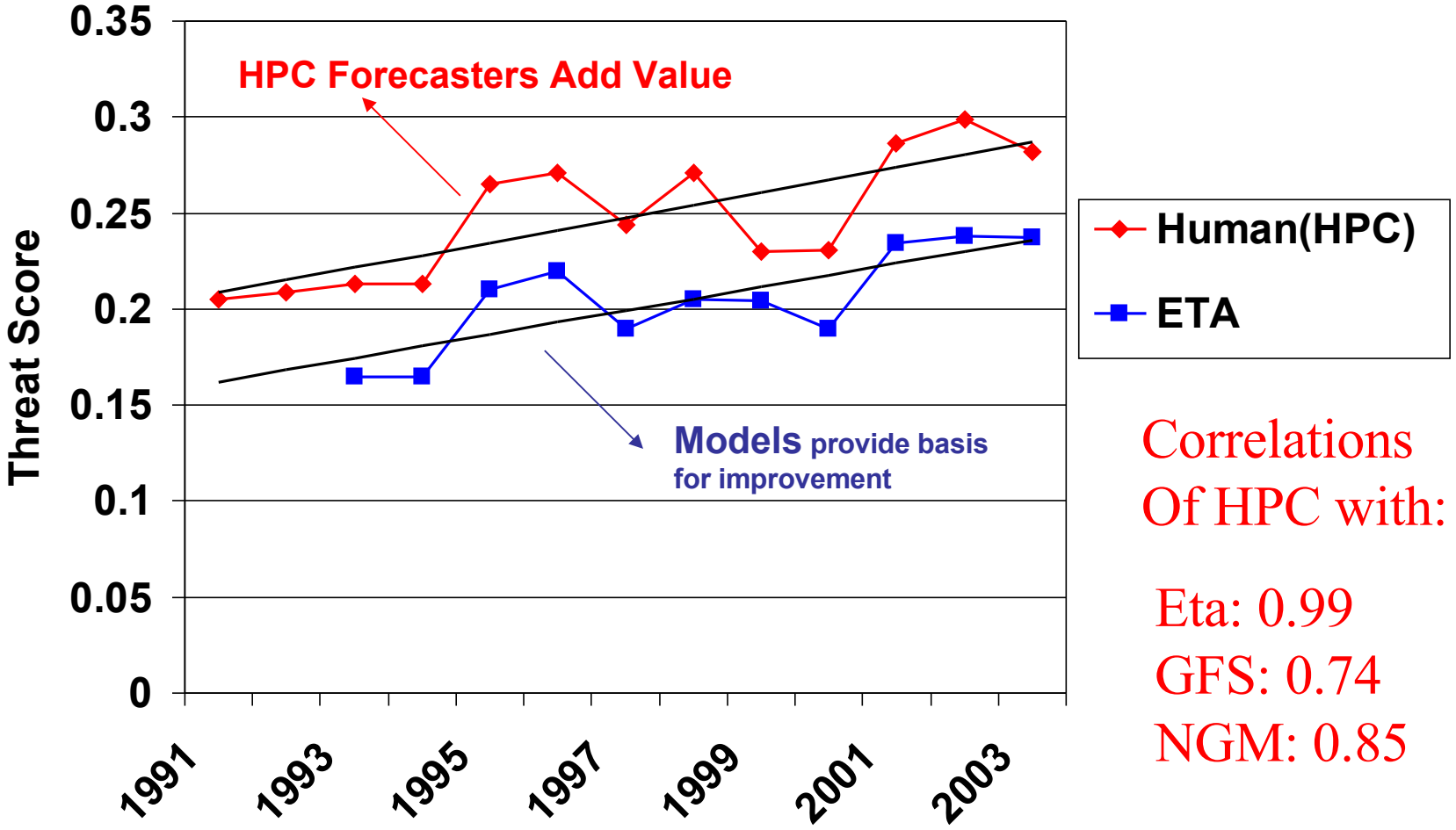


Why Models?

"As go the models, so go the forecasts"

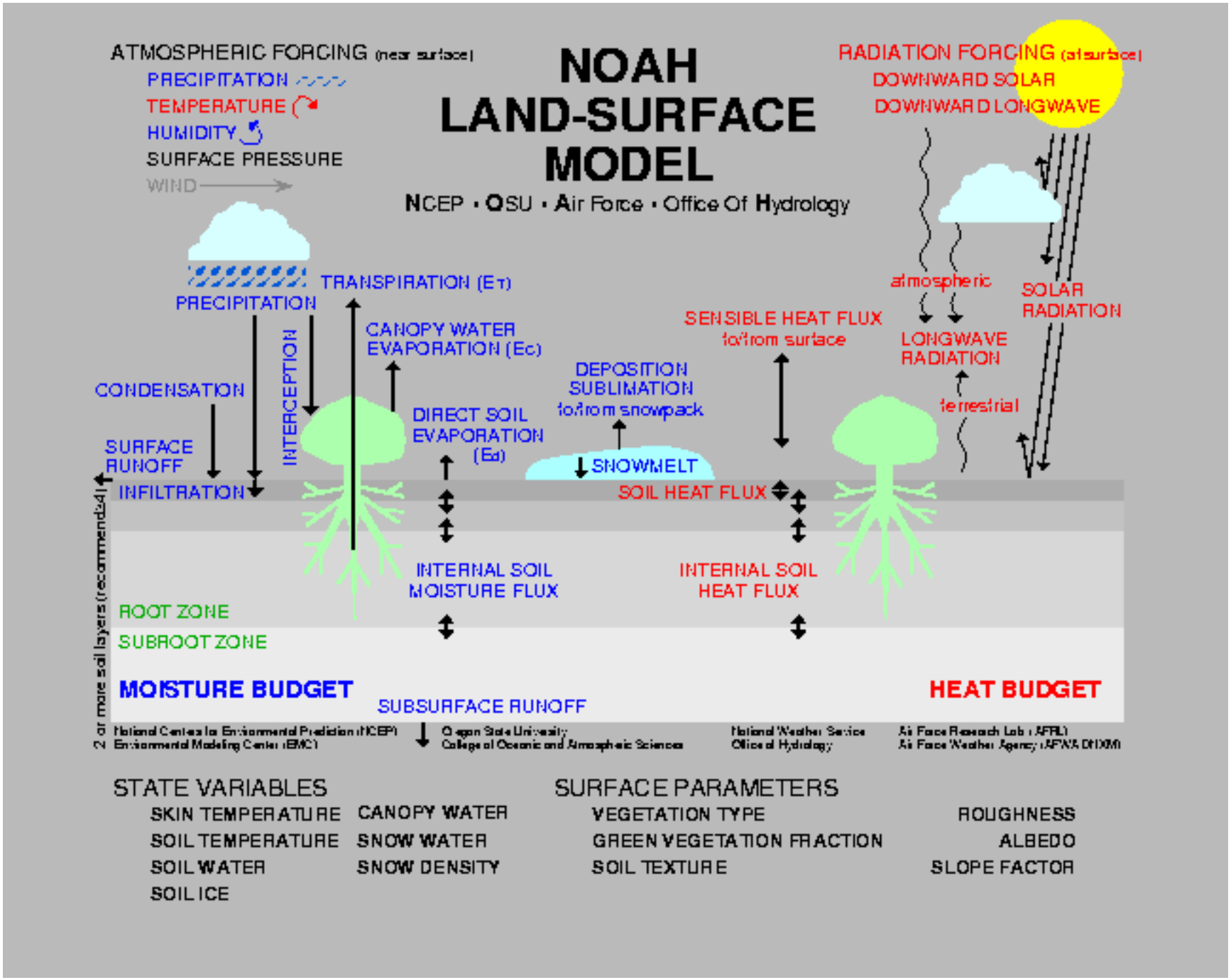
Impact of Models on Day 1 Precipitation Scores

(DOC GPRA goal)



Correlations Of HPC with:

Eta: 0.99
GFS: 0.74
NGM: 0.85



STATE VARIABLES

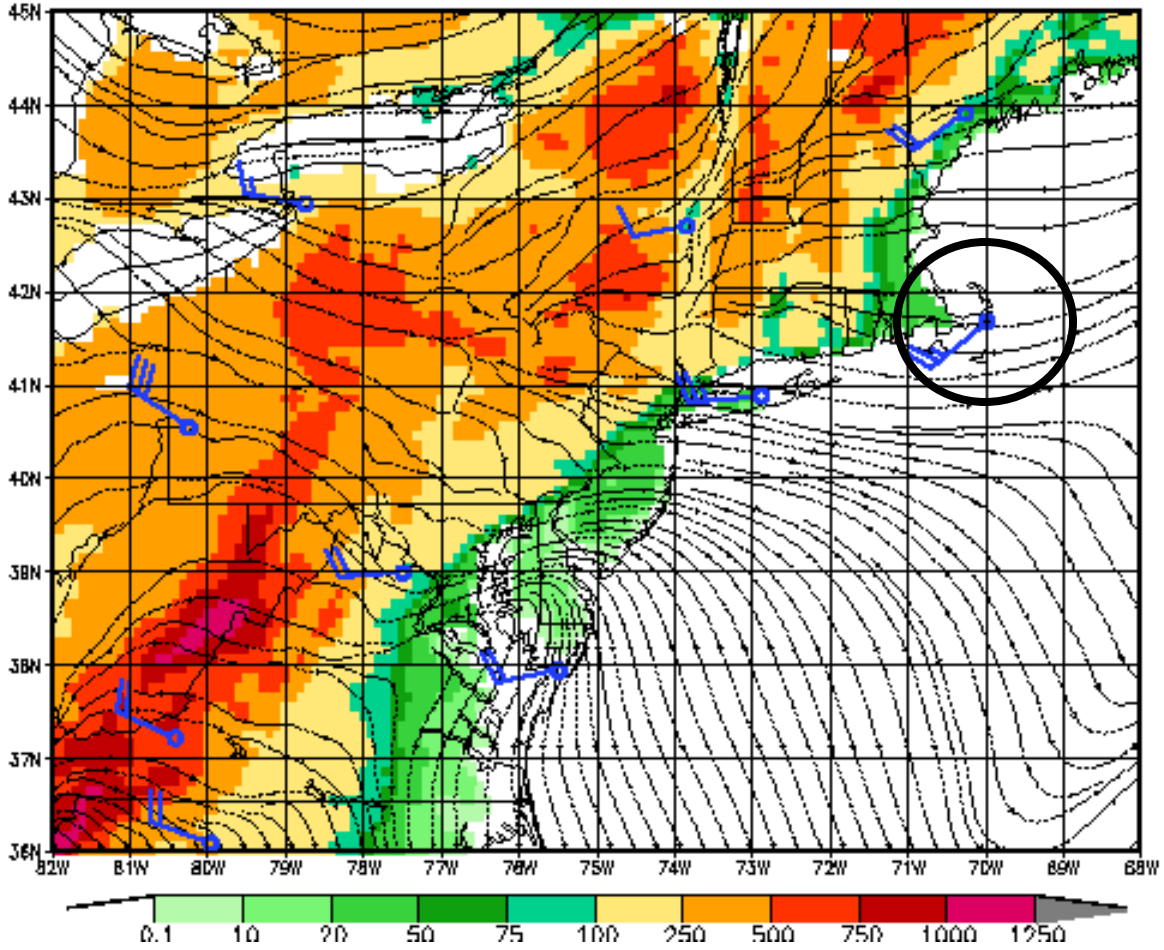
- SKIN TEMPERATURE
- SOIL TEMPERATURE
- SOIL WATER
- SOIL ICE
- CANOPY WATER
- SNOW WATER
- SNOW DENSITY

SURFACE PARAMETERS

- VEGETATION TYPE
- GREEN VEGETATION FRACTION
- SOIL TEXTURE
- ROUGHNESS
- ALBEDO
- SLOPE FACTOR

Why Data Assimilation?

- Model initial condition known everywhere
- Insufficient observations
- Observations and model both have errors



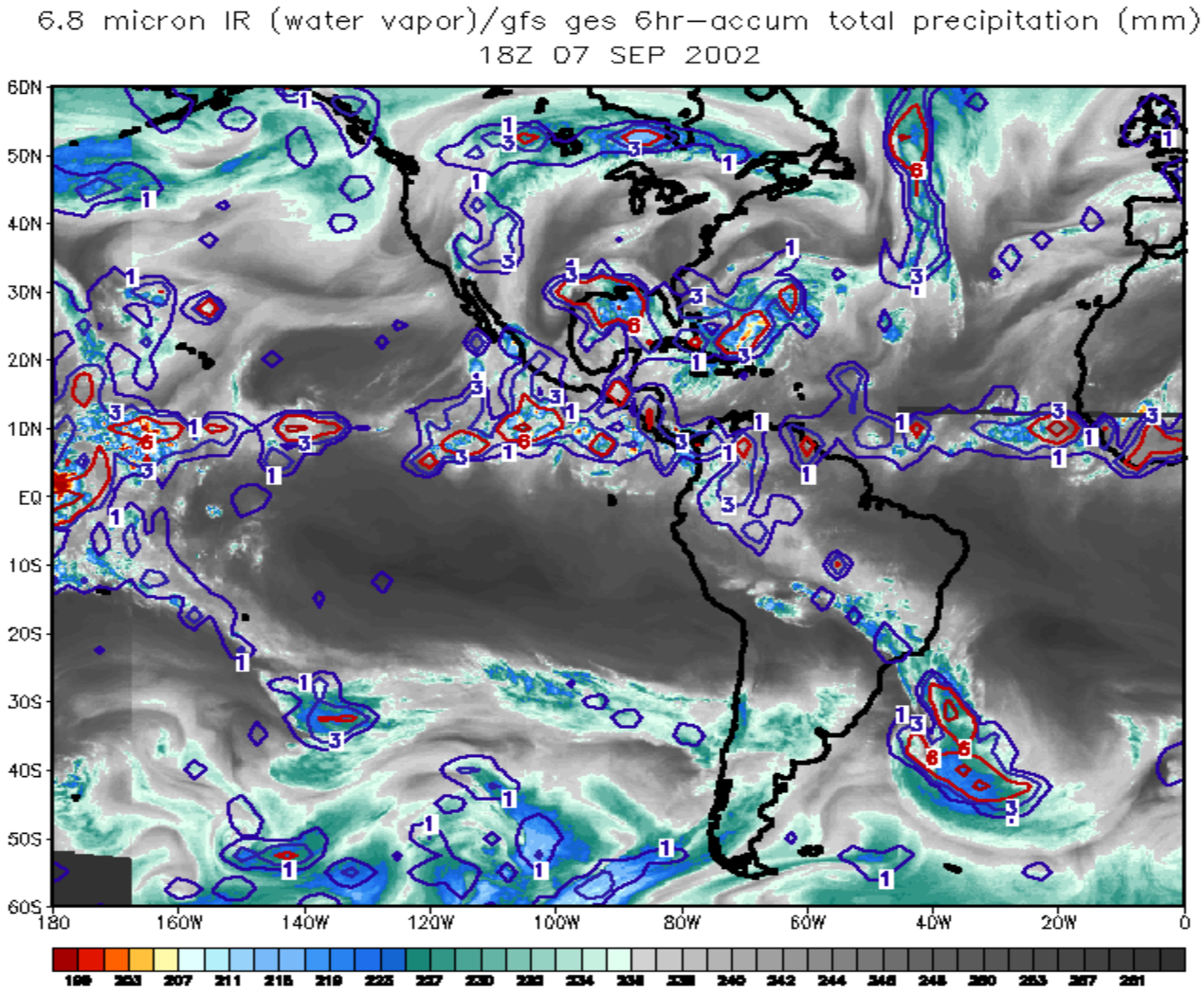
Must Initialize at:
4536 grid points at
64 levels (sfc to 50 km)

Number of Upper Air Observations:
10

Typical Number of Satellite Obs (over Water only):
600

700 mb Wind, Wx Balloon Obs Topography

NCEP Global Forecast System
6 hr Forecast and WV Imagery



EMC Mission

In response to operational requirements:

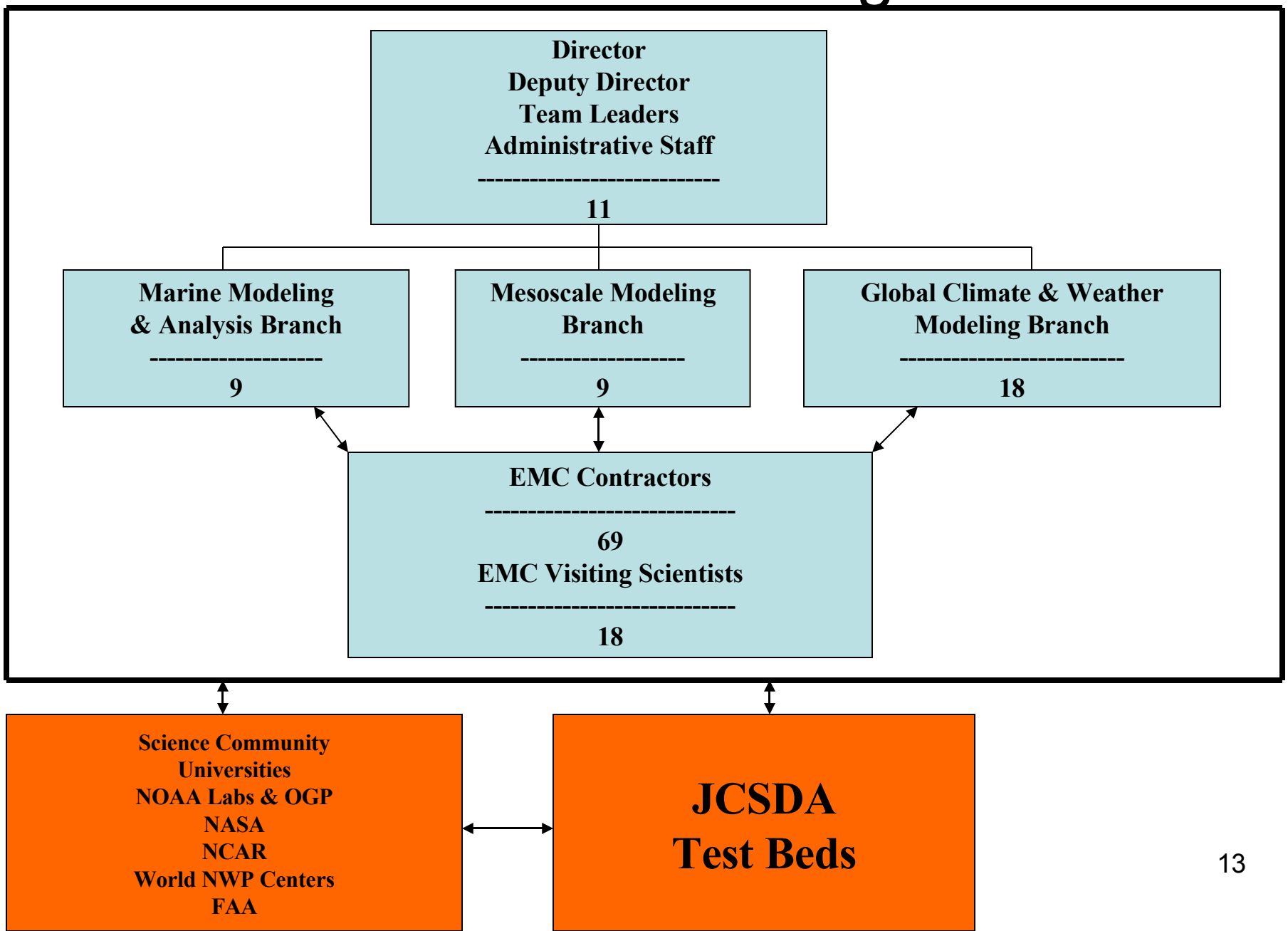
- Maintain the scientific correctness and integrity of operational forecast systems
  - Adapt to format changes and other changing operational requirements
  - Adapt to new computing hardware
  - Monitor and ensure the integrity of operational observing systems
- Enhance (Test & Improve) Numerical Forecasts Through Advanced
  - Data assimilation techniques
  - Model physics (parameterizations)
  - Numerical methods
  - Computational efficiency
- Transition and Develop Operational Numerical Forecast Systems for:
  - Weather prediction (domestic, global, 1-15 days)
  - Ocean prediction (daily to annual, coastal to global)
  - Climate prediction (seasonal to inter-annual)

Maintain: Modify current operational system to adapt to ever-present external changes	**Enhance**: Test and improve NCEP's numerical forecast systems via scientific upgrades, tuning, additional observations, in response to user requirements	**Transition and Develop**: transform & integrate code, algorithms, techniques from research status to operational status on NCEP computers

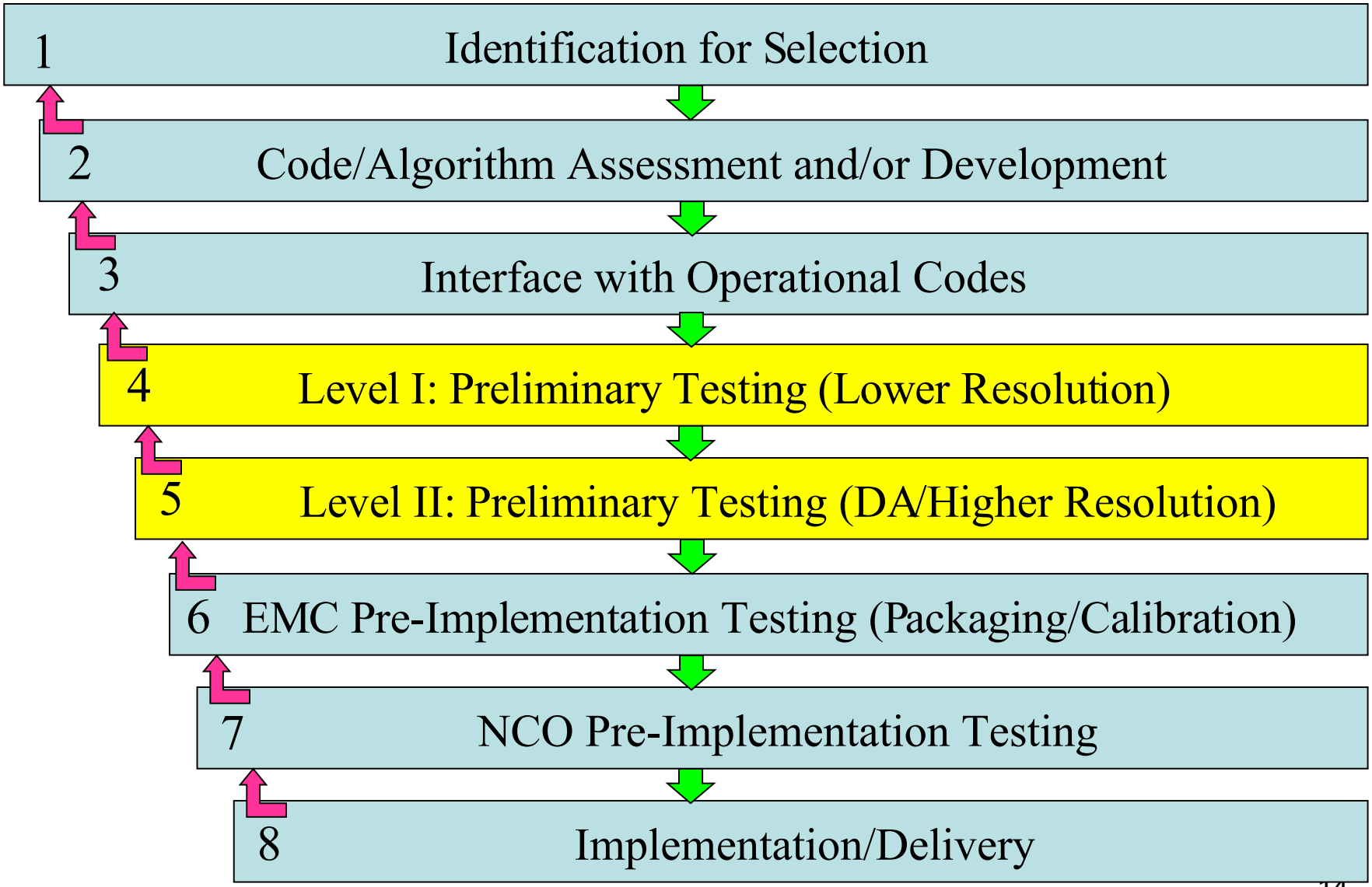
Mission Requirements & Forecast Suite Elements

Suite Elements	Global NWP	Reg. NWP	Fire Wx Rapid Update Reg. Hurricane	Air Quality	Global Ensembles	Regional Ensembles	Real Time Ocean	S/I Climate
NCEP	X	X	X	X	X	X	X	X
UKMO	X	X		X		X	X	
ECMWF	X				X			X

Environmental Modeling Center

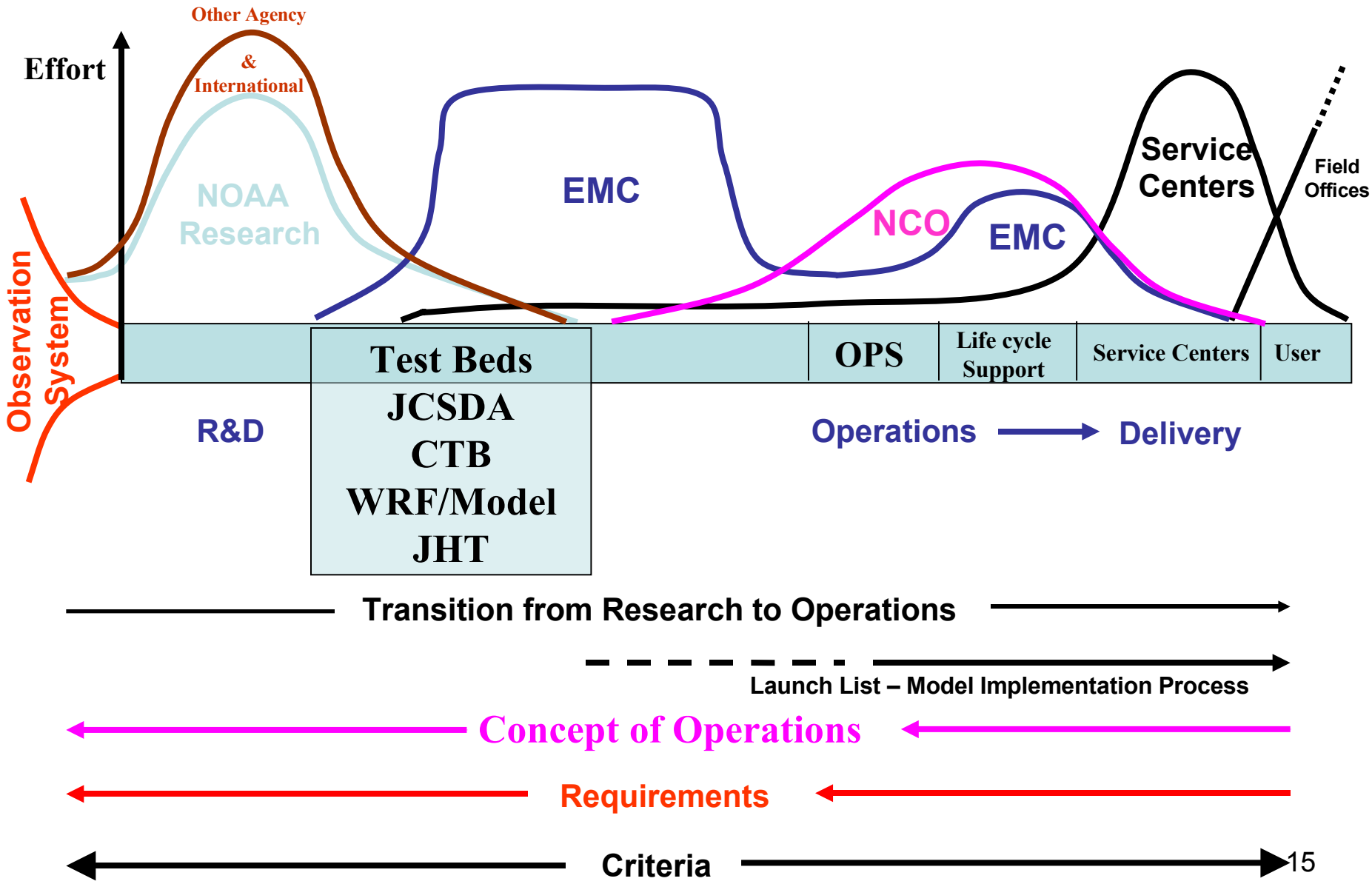


Transition Steps (Modeling)



NCEP's Role in the Model Transition Process

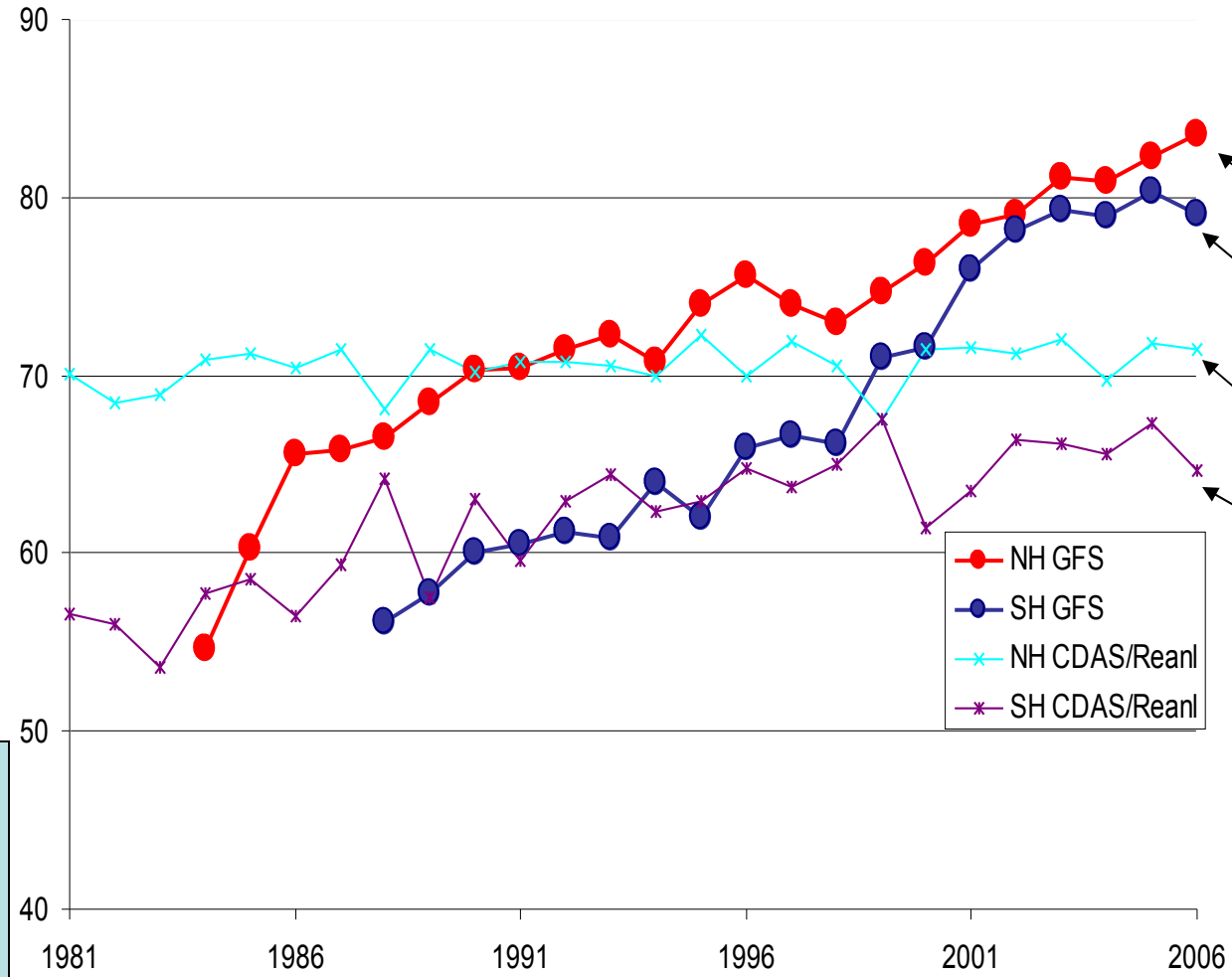
EMC and NCO have critical roles in the transition from NOAA R&D to operations



Ingredients for Improved Numerical Forecast Systems

- **Primary ingredients**
  - **Observations**
  - **Data Assimilation & Model technology**
  - **Computing resources**
- **Secondary ingredients**
  - **Post-processing and dissemination**
  - **Research to Operations (R2O) process**

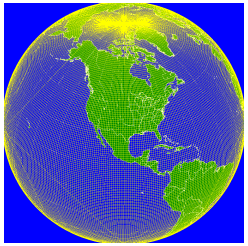
Impact of Observations and Numerical Forecast System Technology Growth on Global Forecasts

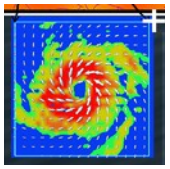


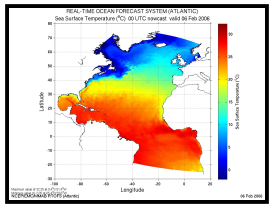
NFS Tech Growth:
Computing
Data Assim.
Models
Ensembles

Contribution:
Tech growth: 70%
Improved Obs: 30%

NOAA's NWS Model Production Suite



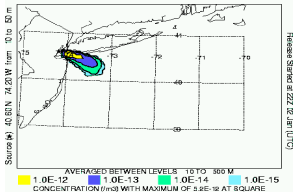




Global Ensemble Forecast System (w/ Canada)

Hurricane Forecasts

Real-Time Ocean Forecast System



Dispersion

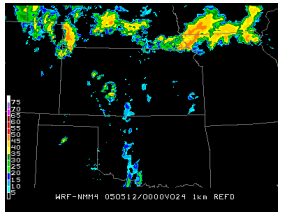
Global Observations

Global Analysis

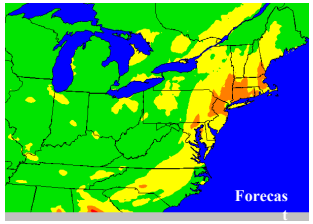
Global Forecasts

Regional Analysis

Regional Forecasts



Severe Weather

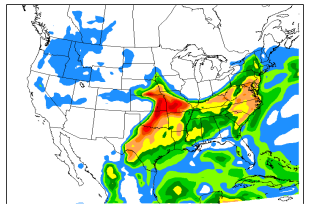


Air Quality With EPA

Short-Range Ensemble Forecast

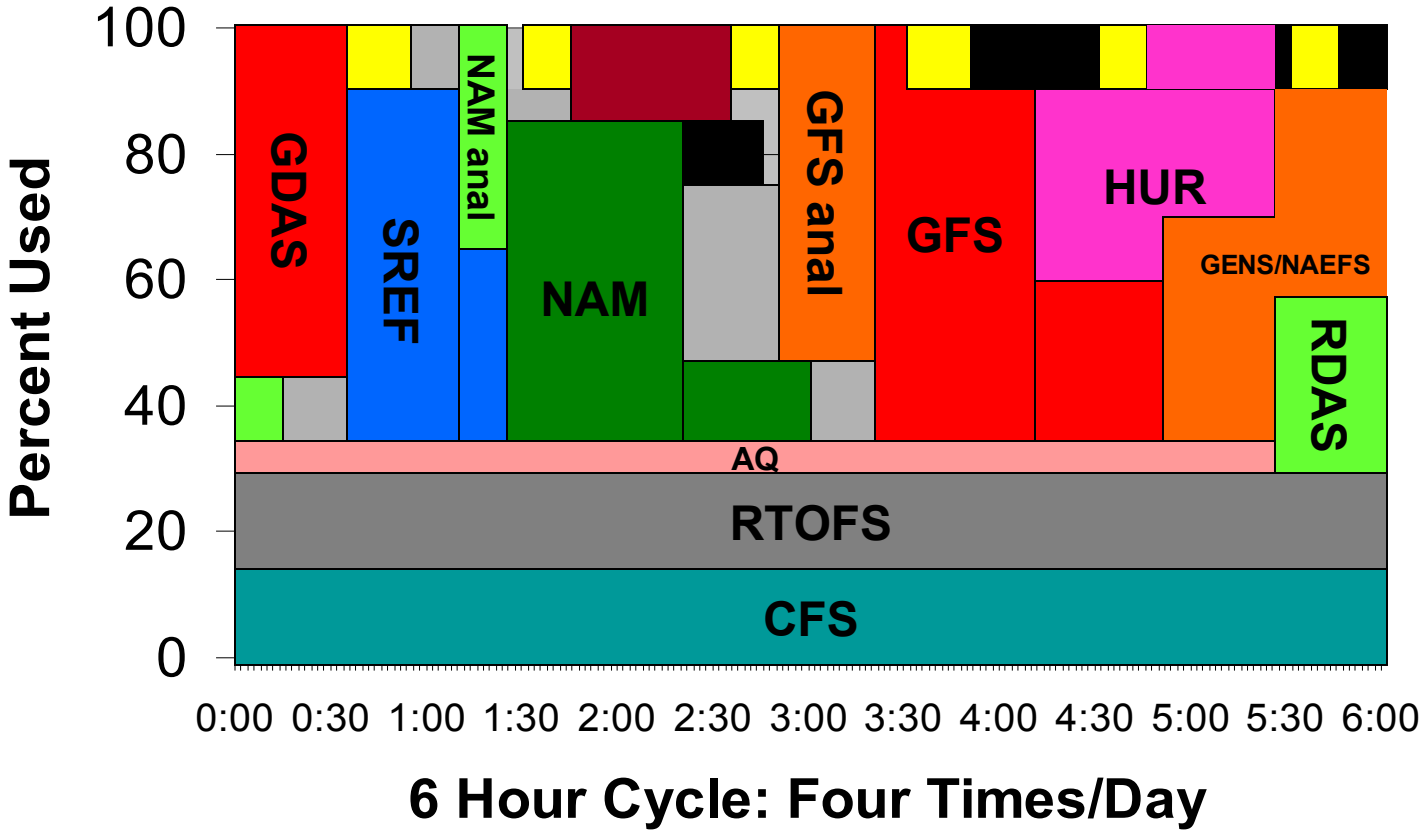
Climate Forecast System

Rapid Update for Aviation

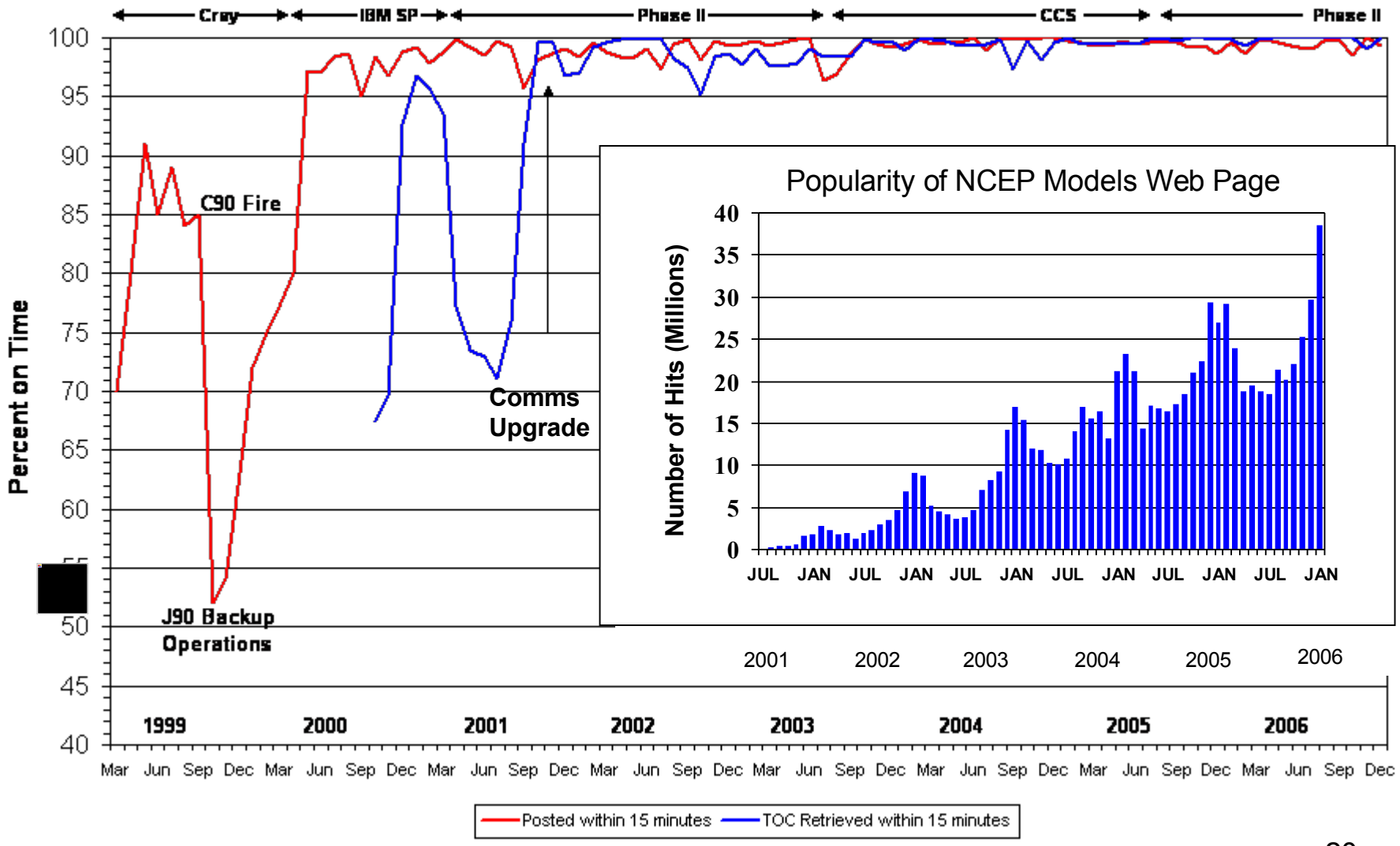


NCEP Production Suite
Weather, Ocean, Land & Climate Forecast Systems

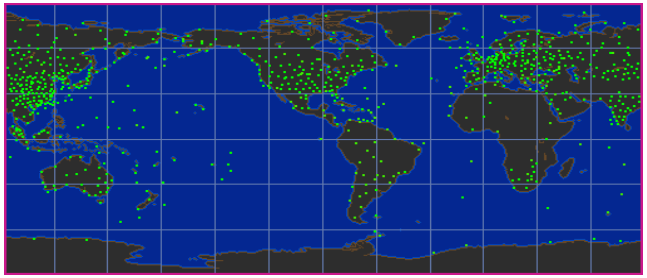
Current - 2007



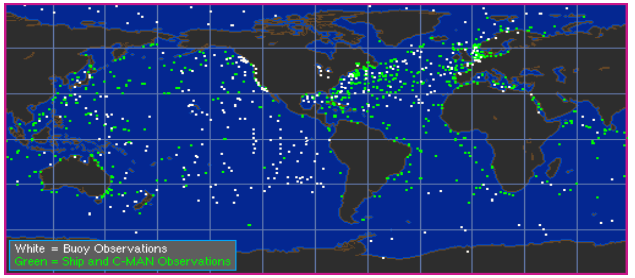
Product Generation Summary



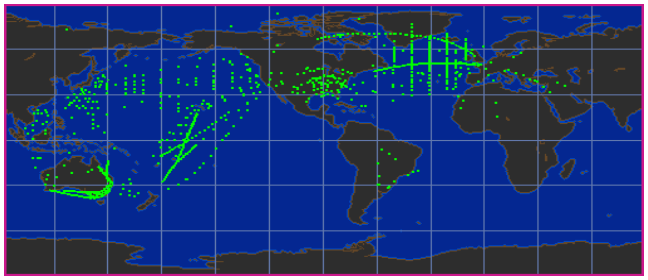
Global Observations 12 UTC
6 hour window



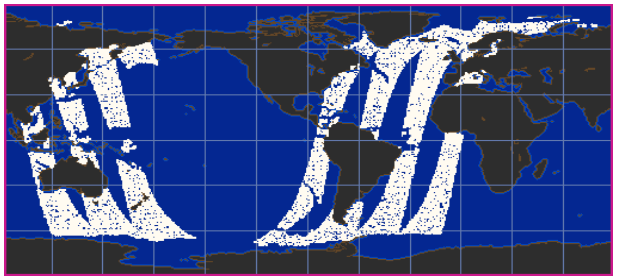
Global Rawinsondes



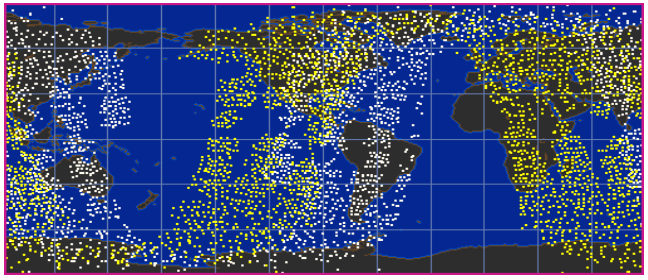
Marine Obs -- 12 Hour Total



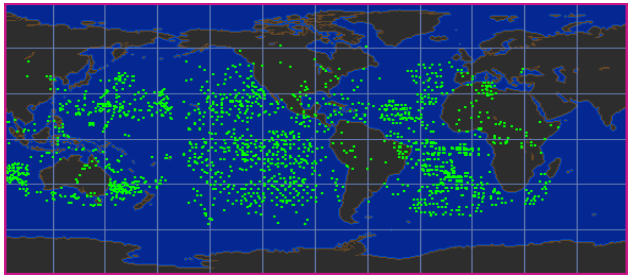
Aircraft Wind/Temp Reports



DMSP Imager – Sfc winds/PW



Polar Satellite Radiances (2 sat)



Satellite Winds

SATELLITE DATA STATUS – May 2007

Jason Altimeter	Implemented into NCEP GODAS
AIRS with All Fields of View	Implemented – 1 May
MODIS Winds	Implemented– 1 May
NOAA-18 AMSU-A	Implemented– 1 May
NOAA-18 MHS	Implemented– 1 May
NOAA-17 SBUV Total Ozone	Implemented– ???
NOAA-17 SBUV Ozone Profile	Implemented– ???
SSMI/S Radiances	Preliminary forecast assessment completed
GOES 1xa imagery	Forecast Assessment in progress
METOP AMSU-A, MHS, HIRS	Forecast Assessment in progress
COSMIC/CHAMP	Implemented (COSMIC – 1 May) CHAMP Data in prep.
MODIS Winds v2.	Test and Development
WINDSAT	Preliminary forecast assessment completed
AMSR/E Radiances	Preliminary forecast assessment completed
AIRS/MODIS Sounding Channels Assim.	Data in Preparation
GOES – SW Winds	To be Tested
GOES Hourly Winds	To be Tested
GOES 11 and 12 Clear Sky Rad. Assim(6.7μm)	To be Tested
MTSAT 1R Wind Assim.	Data in Preparation
AURA OMI	Test and Development
TOPEX,ERS-2 ENVISAT ALTIMETER	Test and Development (Envisat) ERS-2 (dead) TOPEX implemented in NCEP GODAS
FY – 2C	Data in Preparation

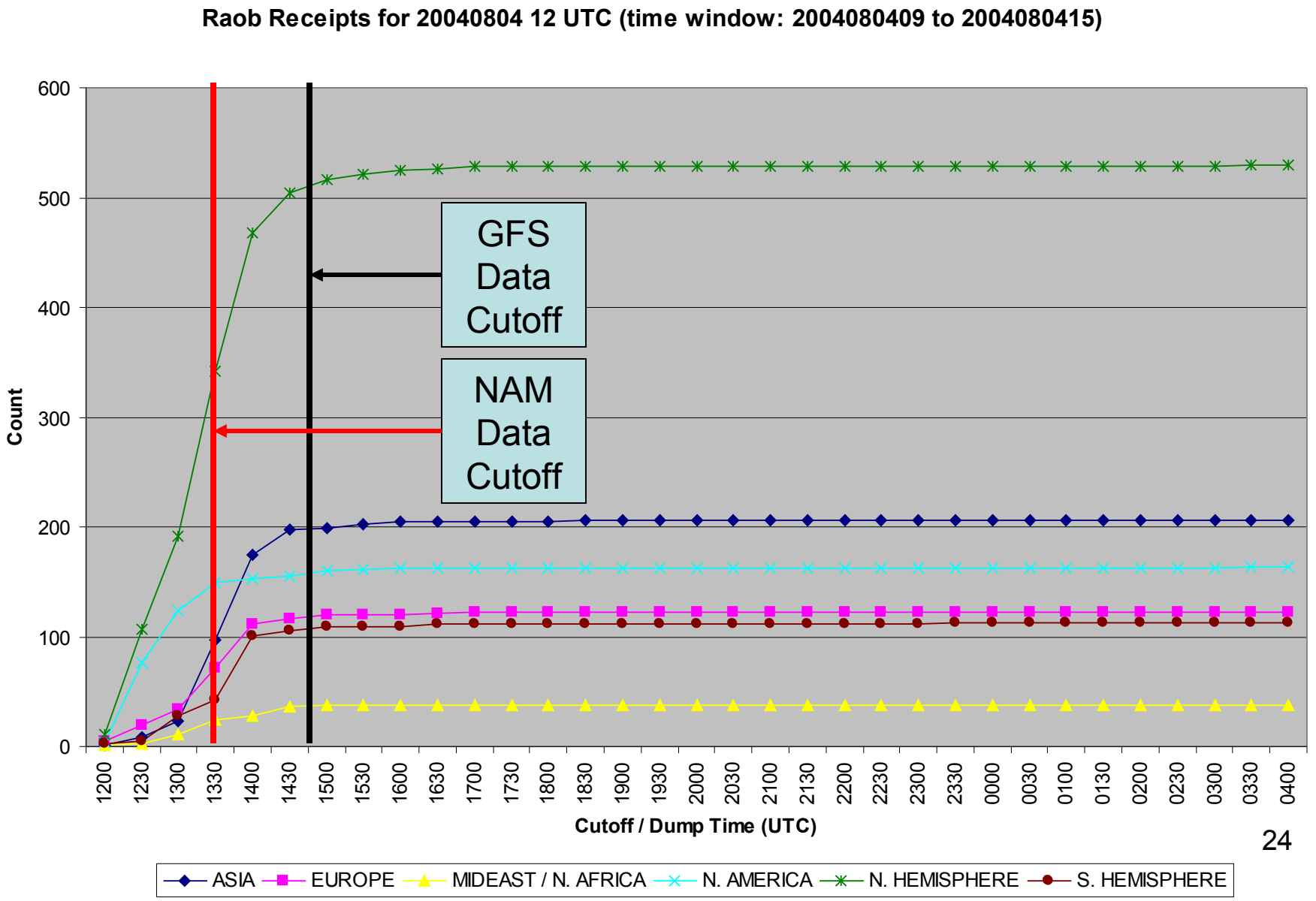
Integration and Testing of New Observations

- Data Access (routine, real time) 3 months
- Formatting and establishing operational data base 1 month
- Extraction from data base 1 month
- Analysis development (I) 6-18 months
- Preliminary evaluation 2 months
- Quality control 3 months
- Analysis development (II) 6-18 months
- Assimilation testing and forecast evaluation 1 month
- Operational implementation 6 months
- Maintain system* 1 person “till death do us part”

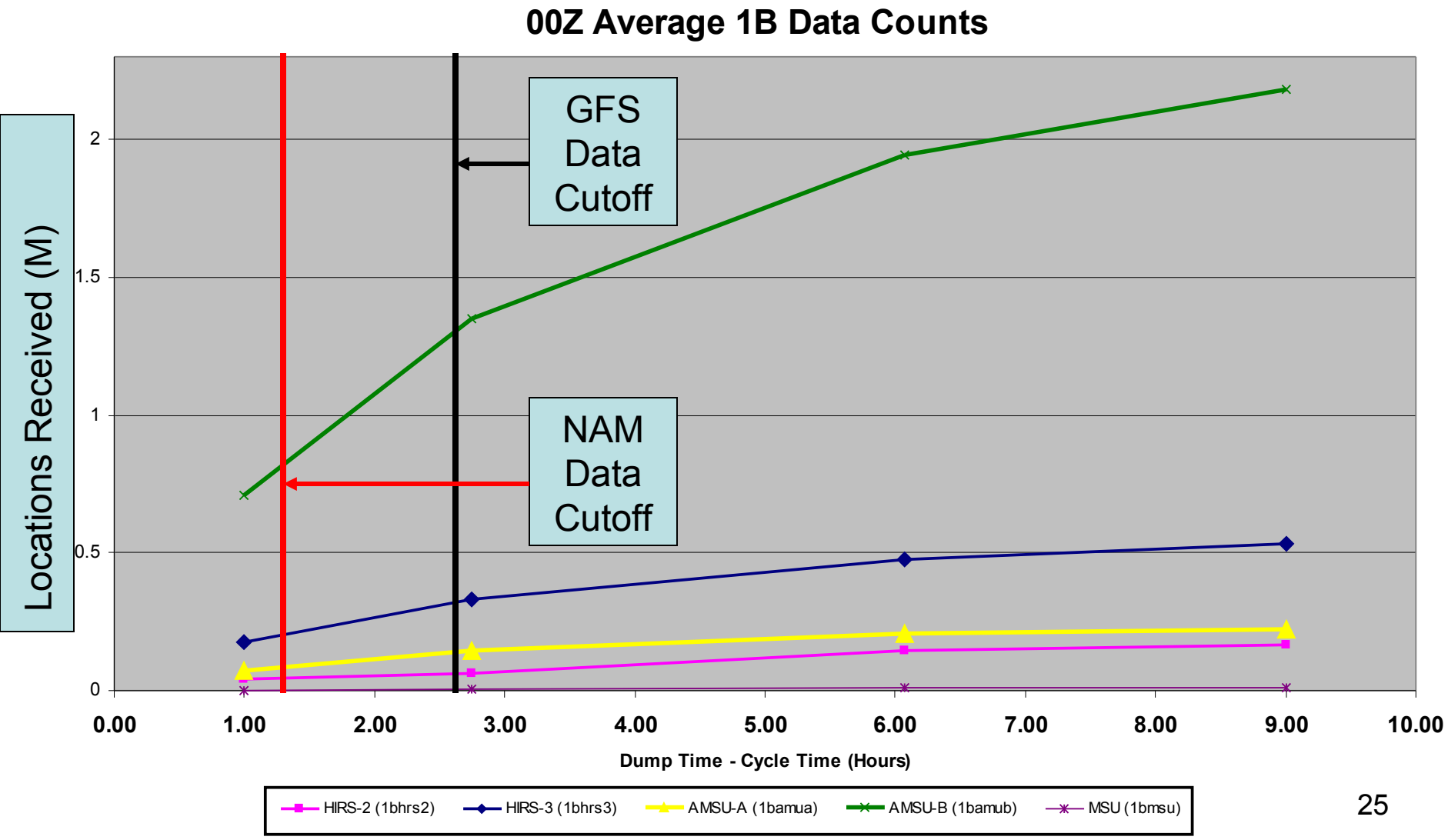
Total Effort: 29-53 person months per instrument

* Scientific improvements, monitoring and quality assurance

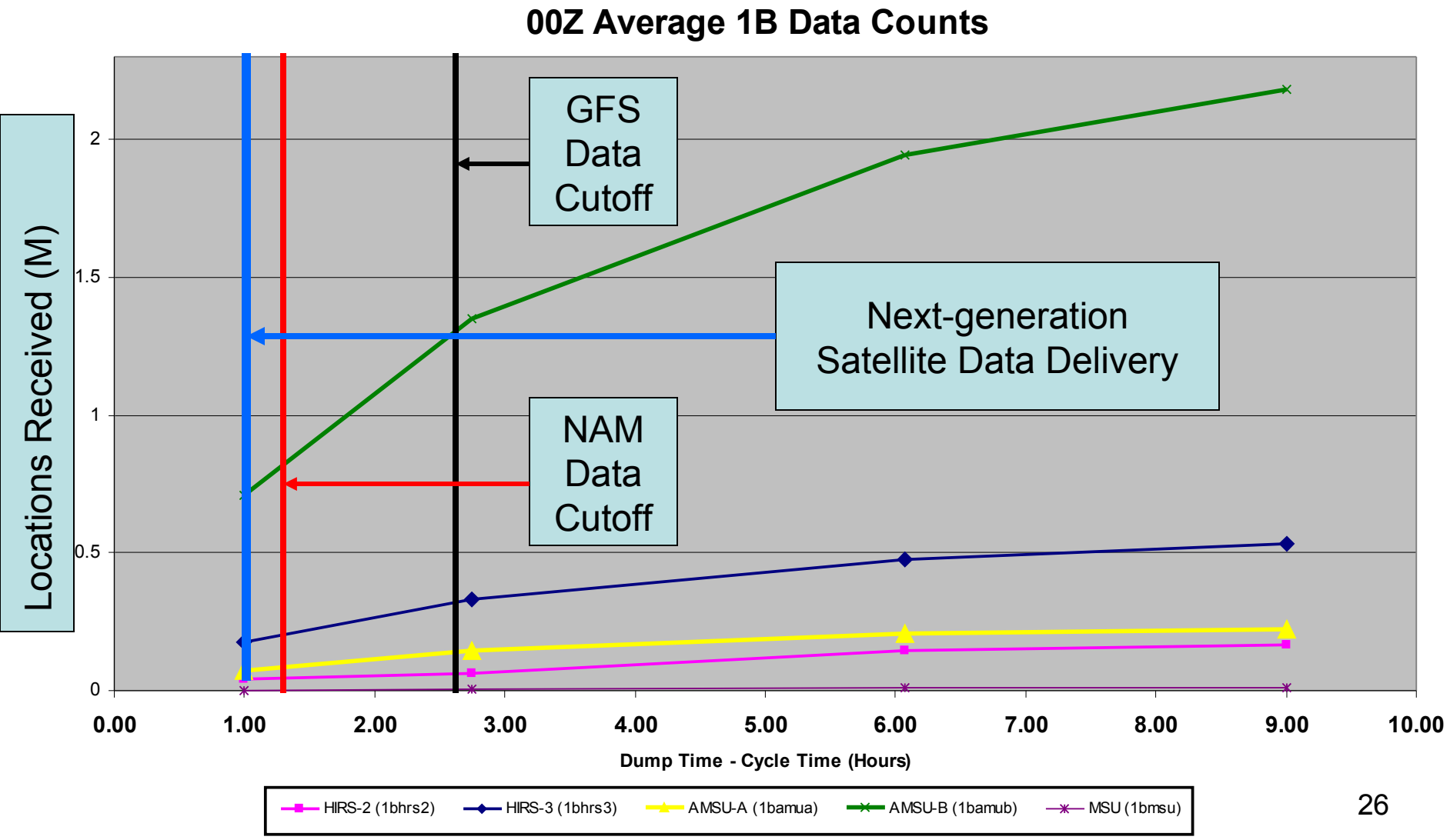
Rawinsonde Delivery



POES Data Delivery

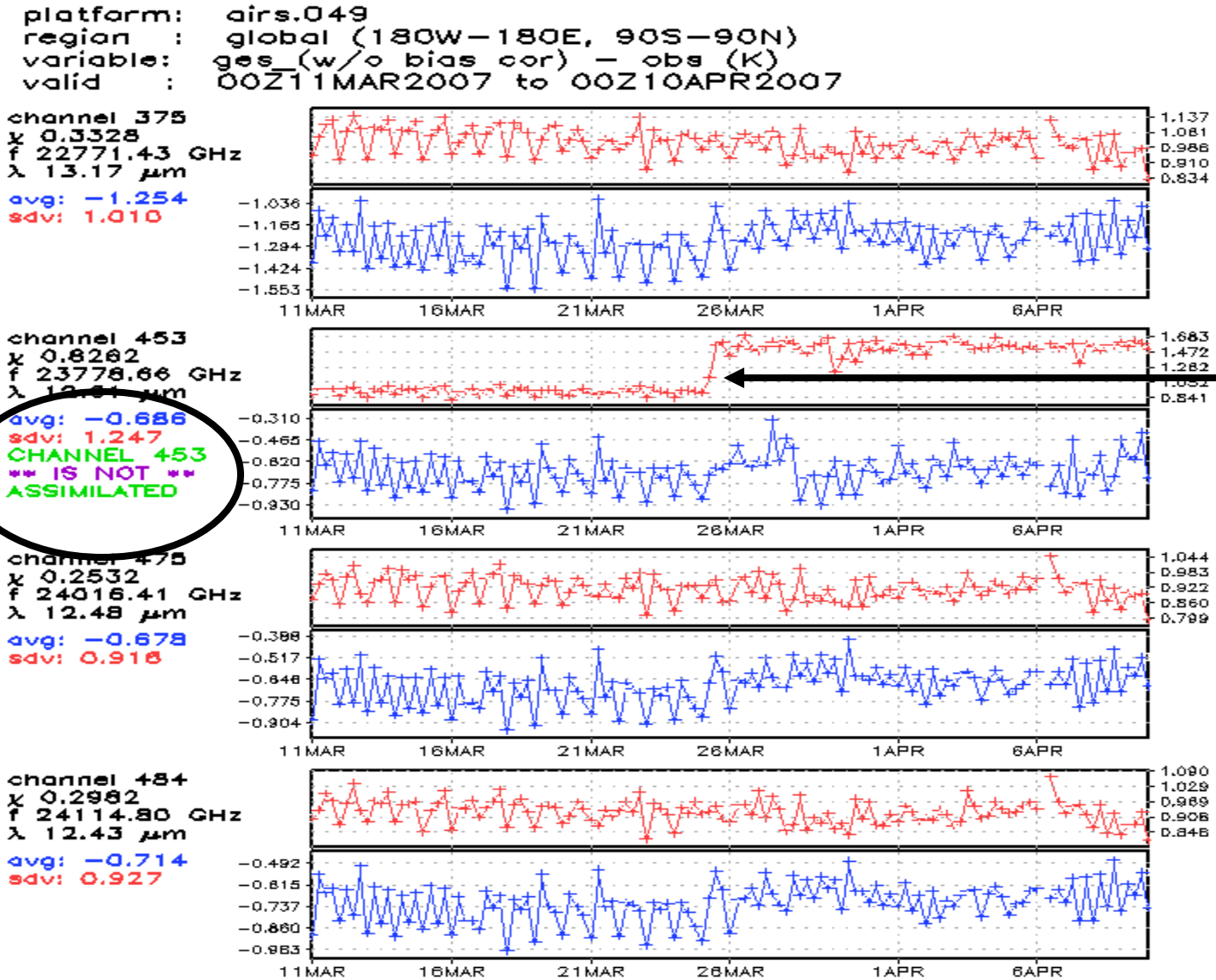


POES Data Delivery



Quality Monitoring of Satellite Data

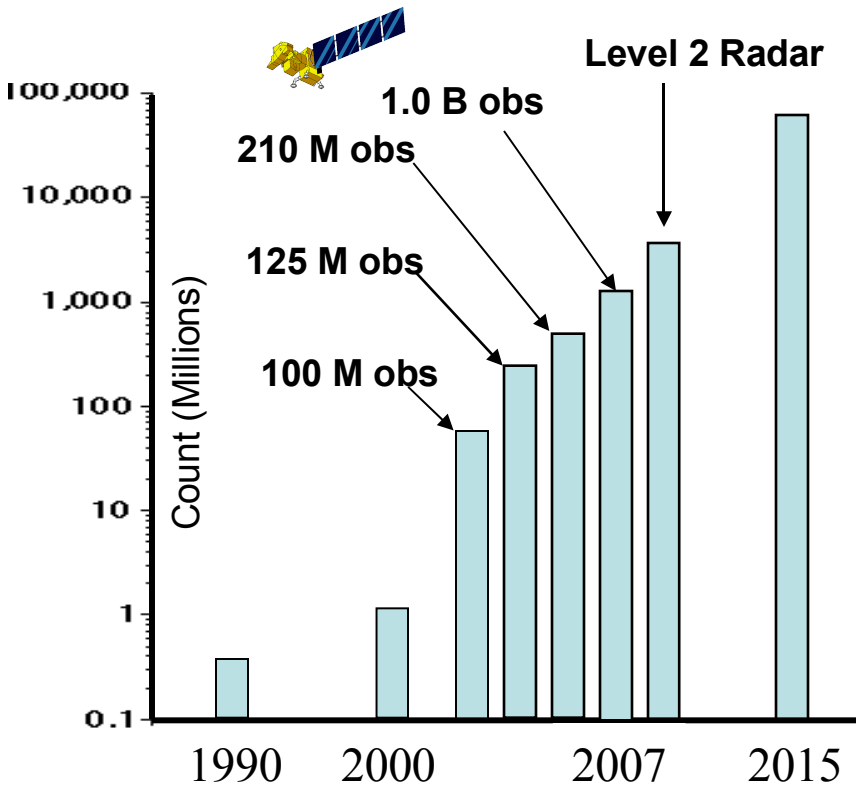
AIRS Channel 453 26 March 2007



Increase in SD Fits to Guess

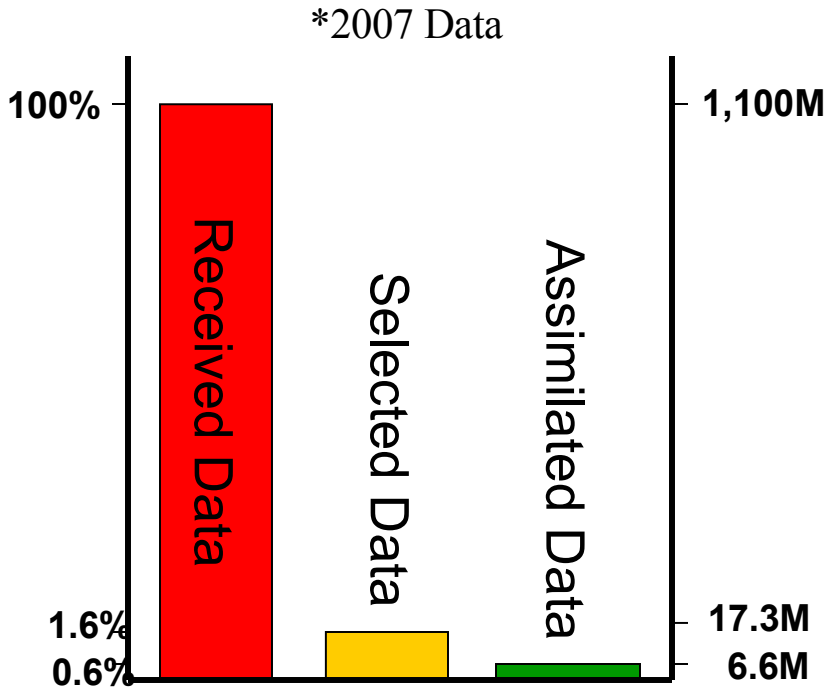
Satellite Data Ingest

Daily Satellite & Radar Observation Count



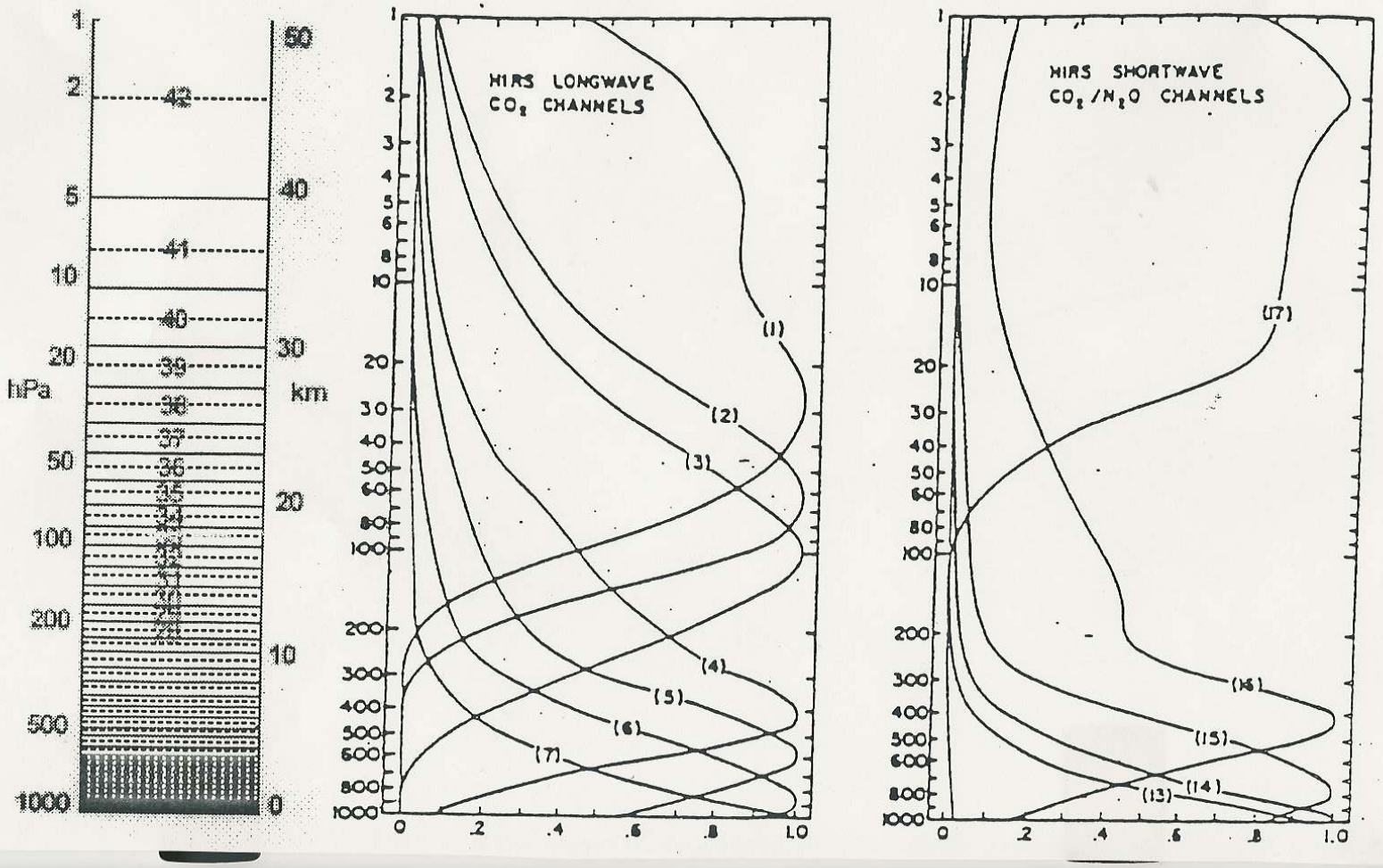
Five Order of Magnitude Increases in Satellite Data Over Fifteen Years (2000-2015)

Daily Percentage of Data Ingested into Models



Received = All observations received operationally from providers
Selected = Observations selected as suitable for use
Assimilated = Observations actually used by models

NCEP 42 Level Model and HIRS Radiance Response Functions



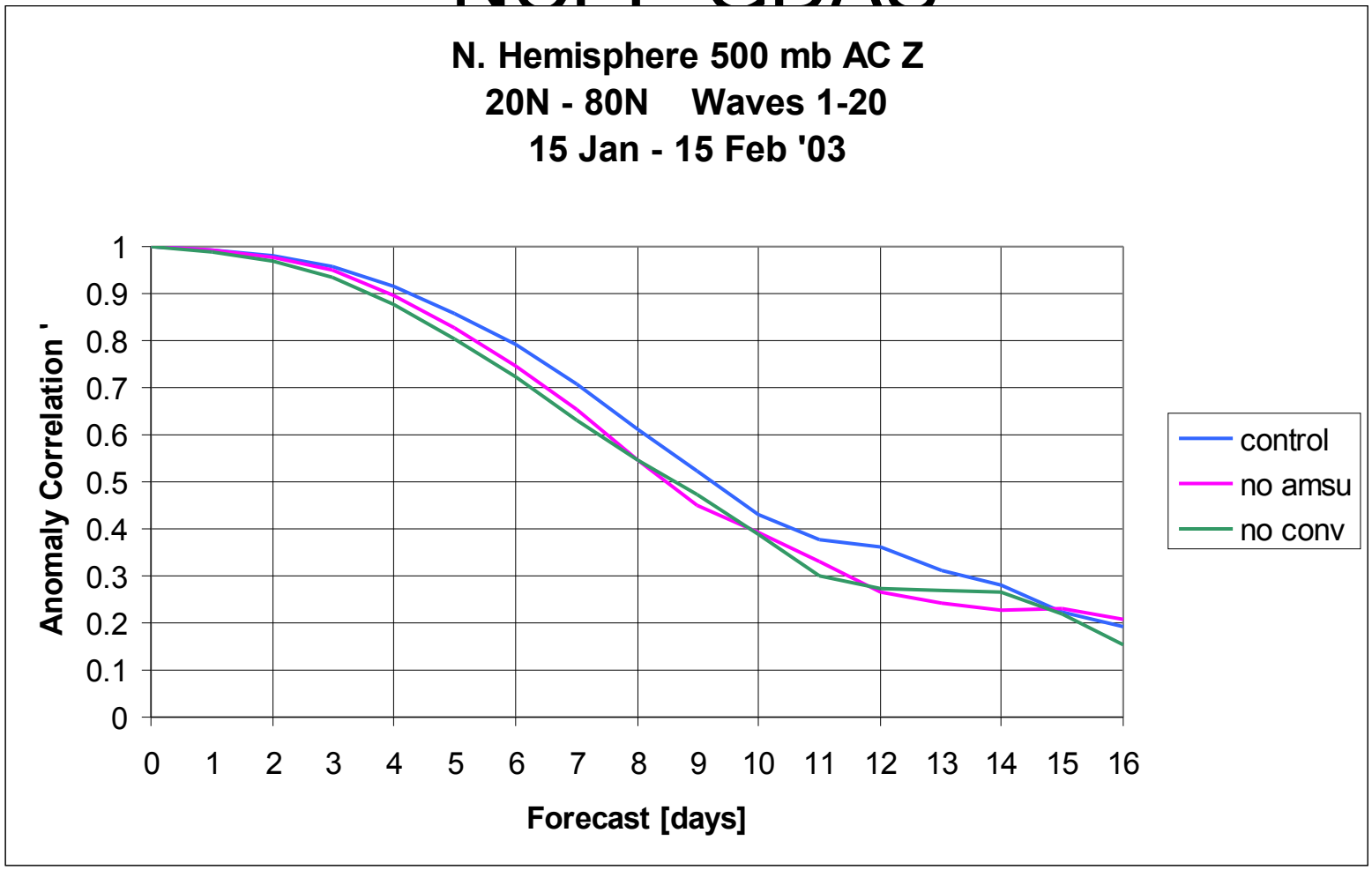
NASA-NOAA-DOD Joint Center for Satellite Data Assimilation (JCSDA)

- **NOAA, NASA, DOD partnership**
- **Mission**
  - **Accelerate and improve the quantitative use of research and operational satellite data in weather and climate prediction models**
    - **Current generation data**
    - **Prepare for next-generation (NPOESS, METOP, research) instruments**
- **Supports applied research**
  - **Partners**
  - **University, Government and Commercial Labs**

JCSDA Scientific Priorities 2006-2009

1. Improve radiative transfer model
2. Prepare for advanced instruments
3. Advance techniques for assimilating cloud and precipitation information
4. Improve land and sea ice surface emissivity models and land surface and sea ice products
5. Improve use of satellite data in ocean and land data assimilation
6. Air quality (aerosols, ozone and trace gases)

Data Assimilation Impacts in the NCEP GDAS



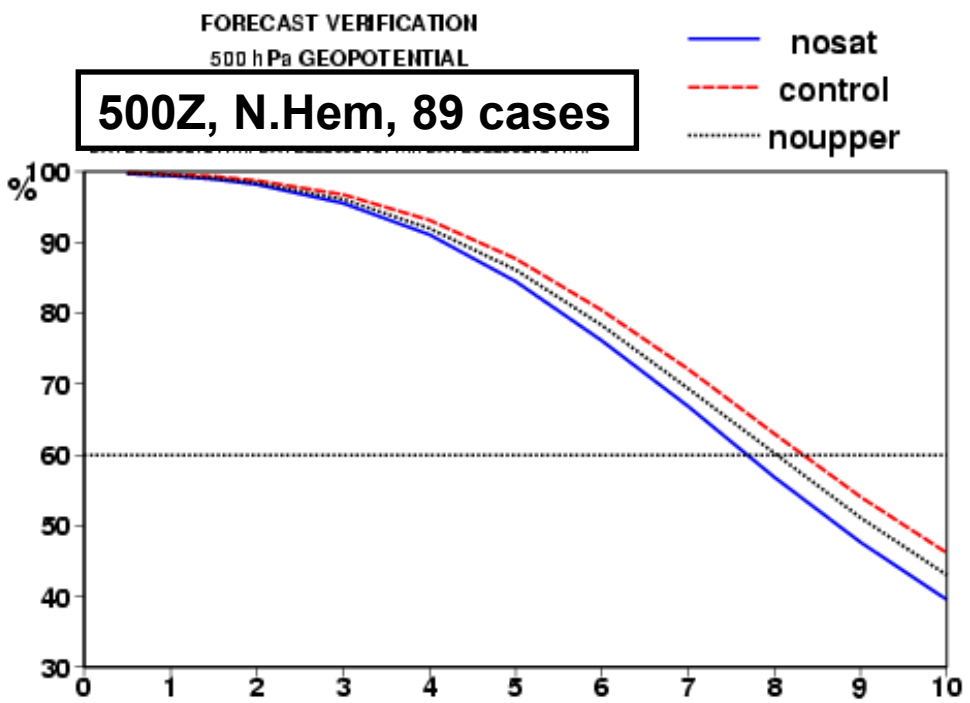
AMSU and "All Conventional" data provide nearly the same amount of improvement to the Northern Hemisphere.

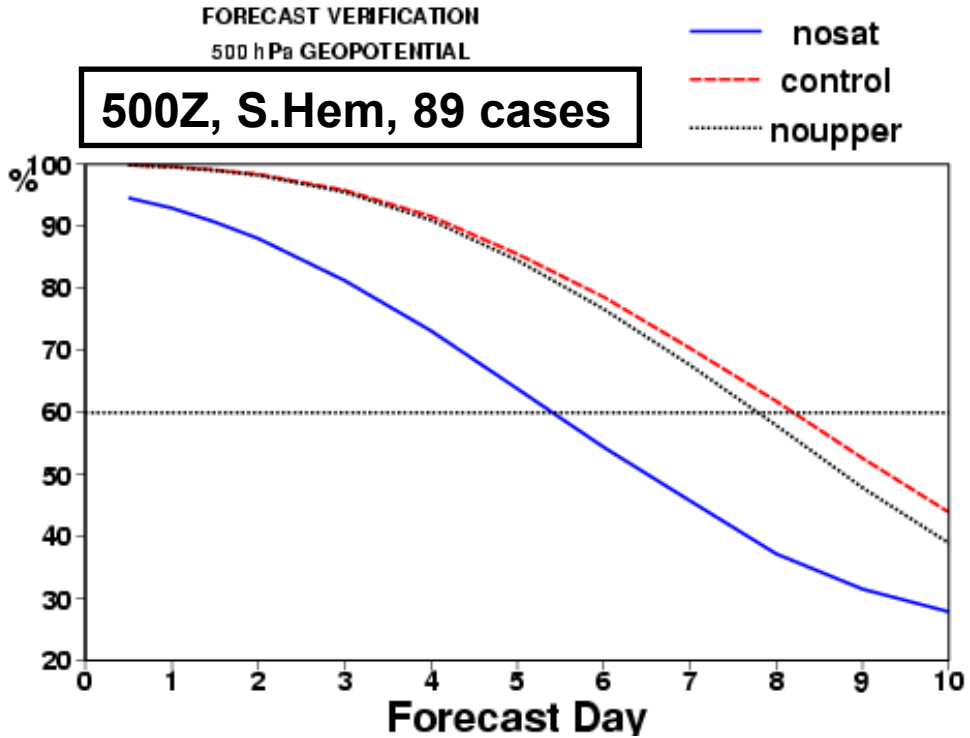
Observing System Experiments (ECMWF - G. Kelly et al.)

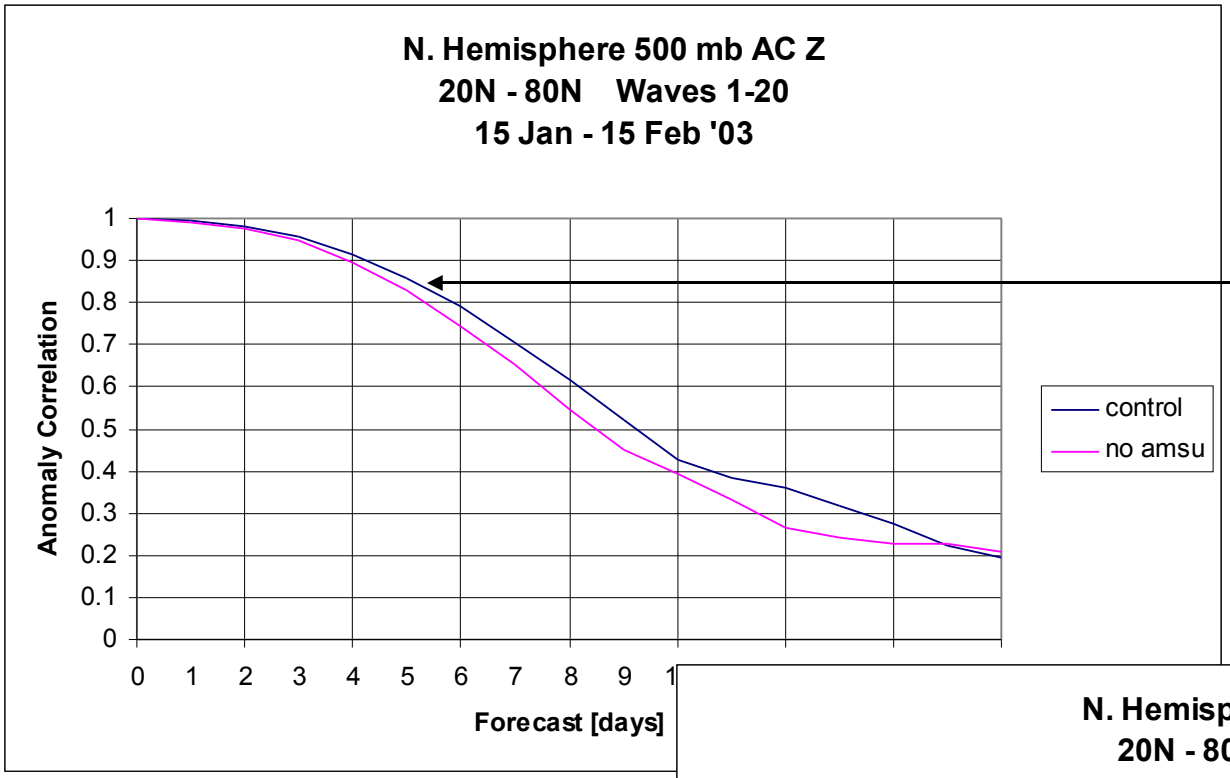
NoSAT= no satellite radiances or winds

Control= like operations

NoUpper=no radiosondes, no pilot winds, no wind profilers





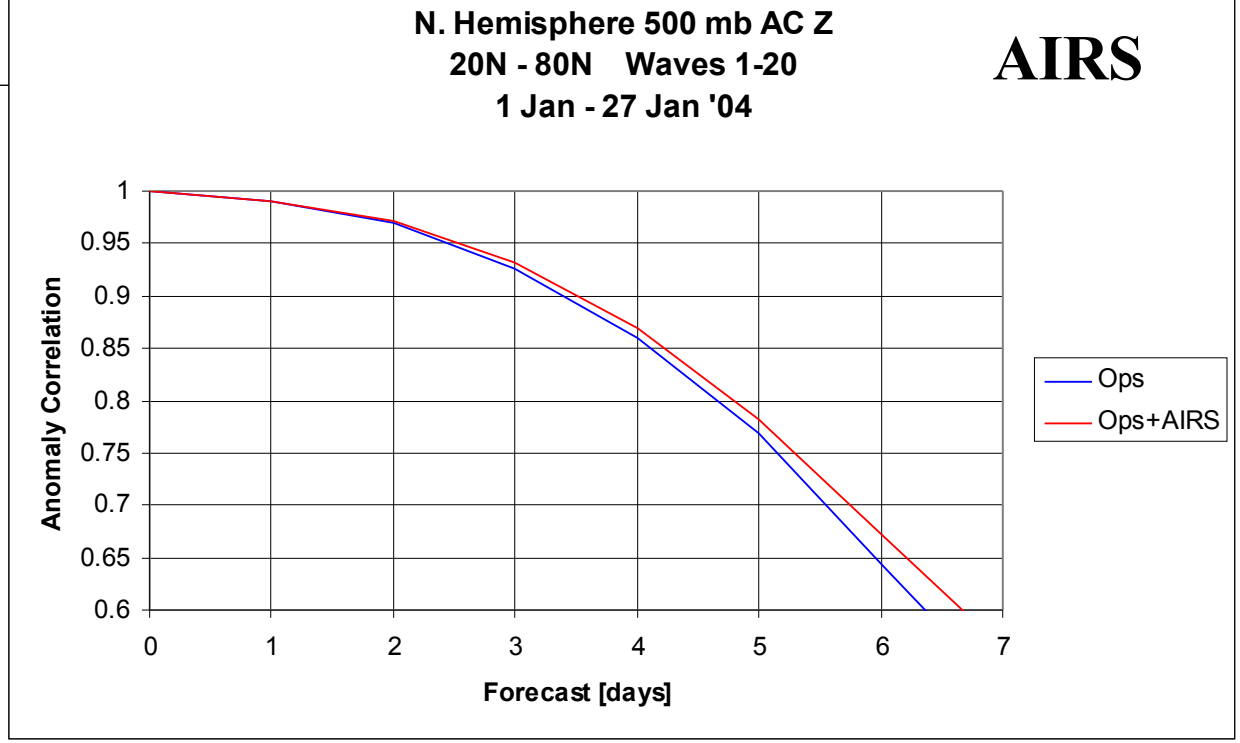


AMSU: 0.5 day improvement at 5 days

N. Hemisphere 500 mb ht anomaly correlation

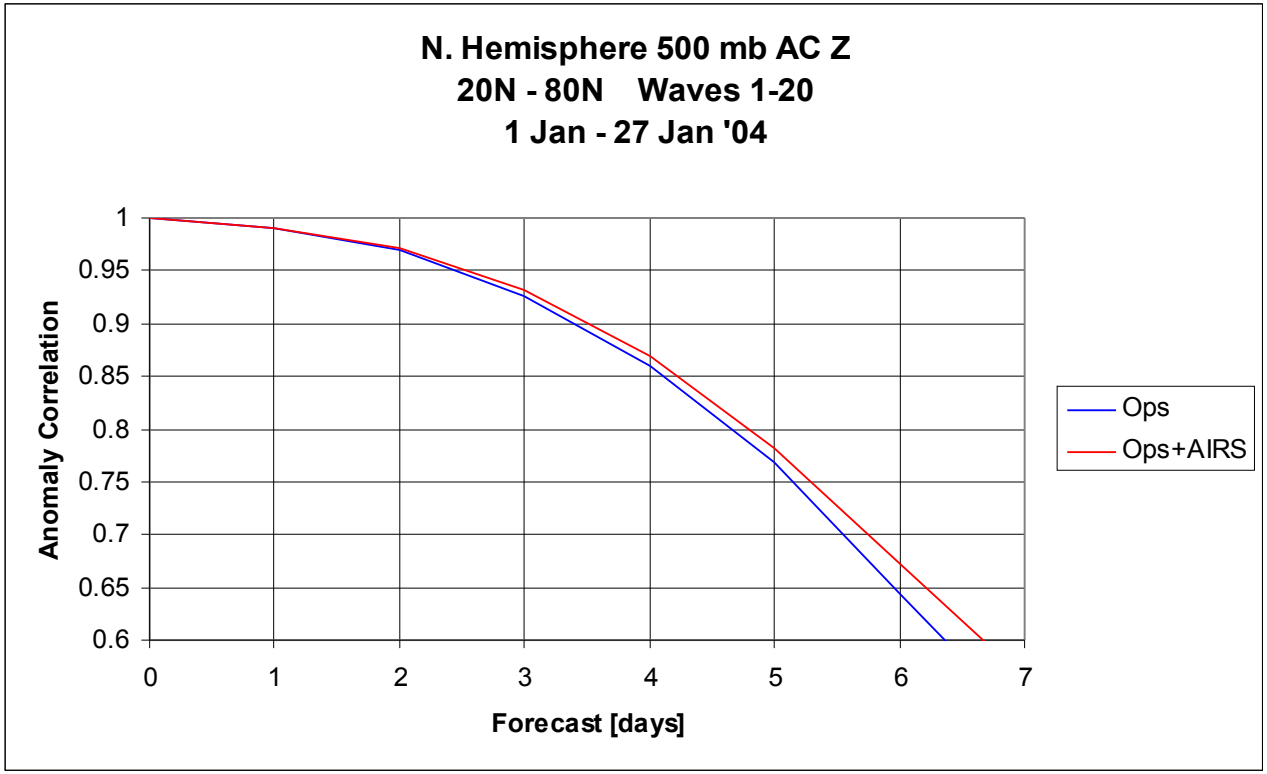
Inhomogeneous data set

AIRS



JCSDA AIRS Testing

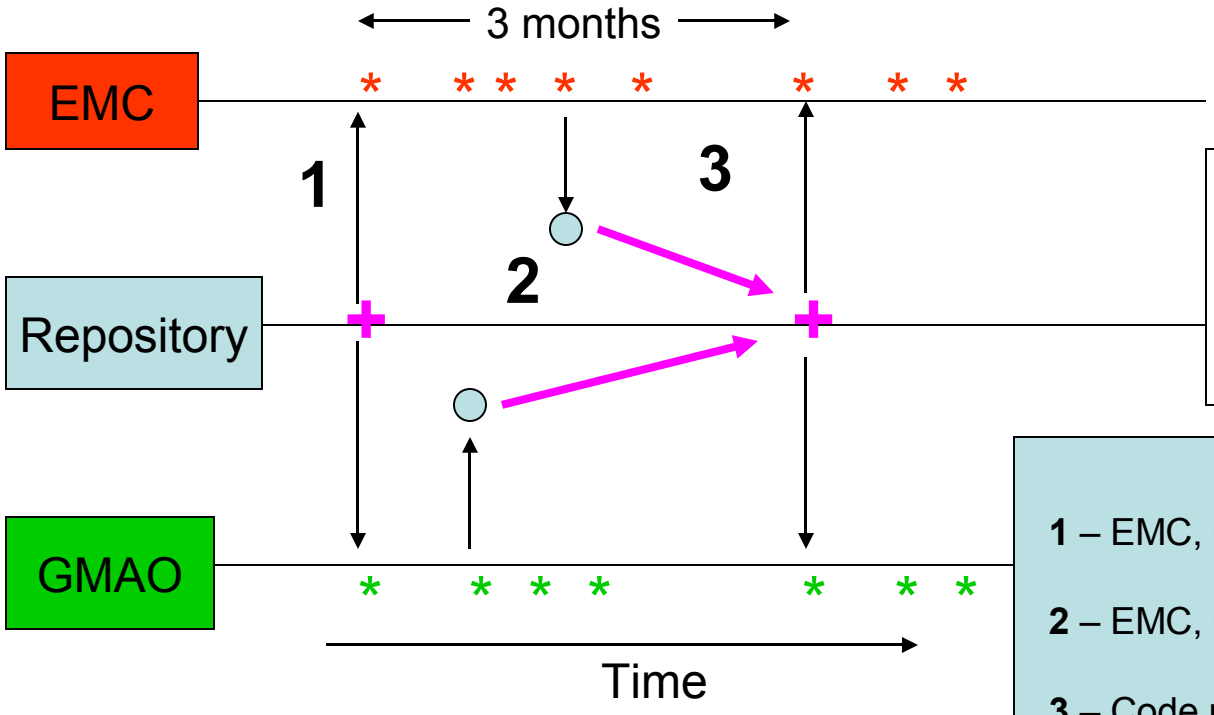
- NCEP operational system
  - Includes first AIRS data use
- Enhanced AIRS data use
  - Data ingest includes all AIRS footprints
  - 1 month at 55 km resolution
  - Standard data selection procedure



EMC-GMAO-STAR Code Management for Atmospheric Data Assimilation

Process: similar to ECMWF & Météo-France who have annual code mergers
But, to promote collaboration, EMC and GMAO **use same repository** and mergers are more frequent (**3 months**)

GSI & CRTM supported



Accepted changes
EMC, GMAO System change
Repository change
Repository Merger (new tag)

Protocols
1 – EMC, GMAO take (agreed-upon) merged code from repository to begin work
2 – EMC, GMAO incorporate developments into repository
3 – Code mergers, repository changes and timing are NCEP's decision

NASA-NOAA-DOD JCSDA

AMSR, GOES, AIRS, JASON, WindSat, MODIS

Advanced ODA Techniques

$1451 K (total)

$341 K (direct)

Observations

Satellite (AVHRR, JASON, QuikSCAT)

In situ (ARGO, Buoys, Ships)

Data Cutoff

CFS: 2 week data cutoff

RTOFS: 24 hour data cutoff

OCEAN DATA ASSIMILATION

CFS-GODAS

NCO/ODA -$446 K

EMC- $170 K

NOPP-JPL (ECCO)- $34 K

Shared history, coding and data processing

RT-OFS-GODAE

NOPP- $285 K

EMC- $350 K

CLIMATE FORECAST

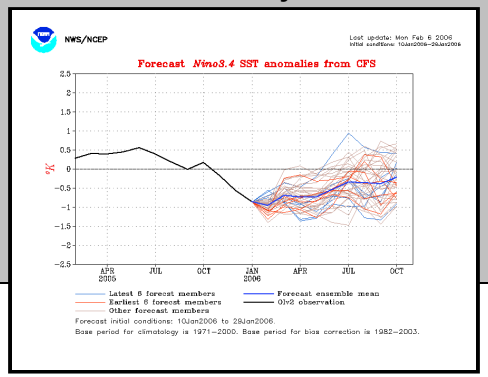
OCEAN FORECAST

MOM-3 → MOM-4 → HOME

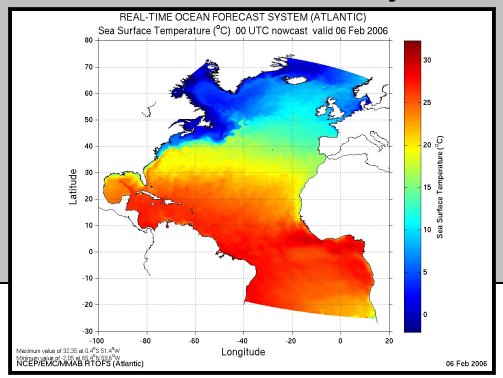
OPNL OCEAN FORECASTS

HYCOM → HOME

Climate Forecast System



Real-Time Ocean Forecast System

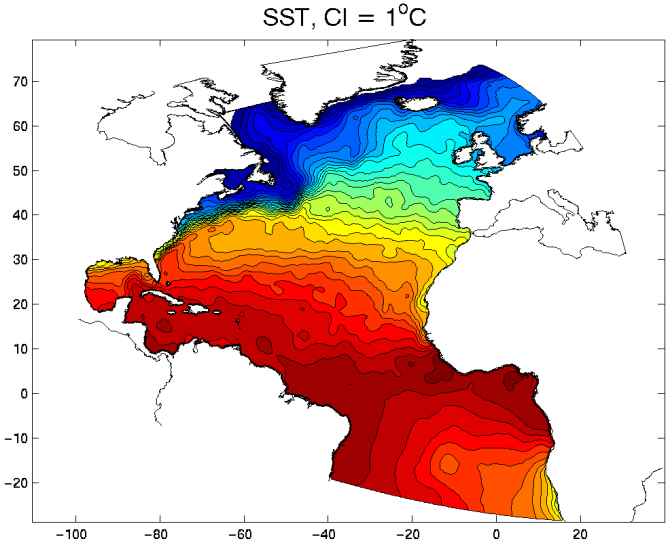


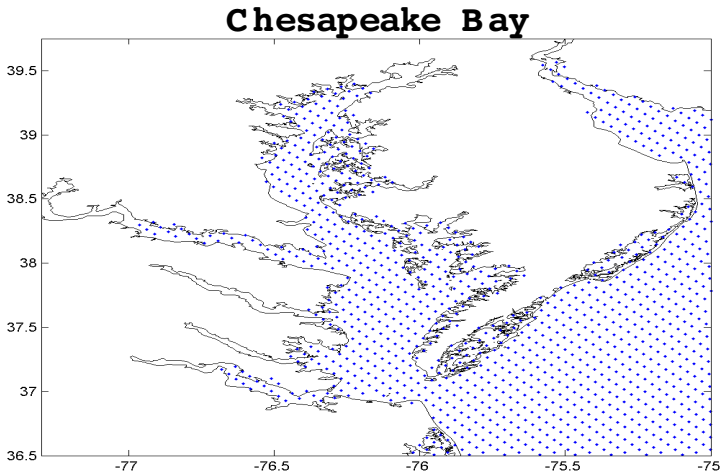
http://cfs.ncep.noaa.gov/

http://polar.ncep.noaa.gov/ofs/

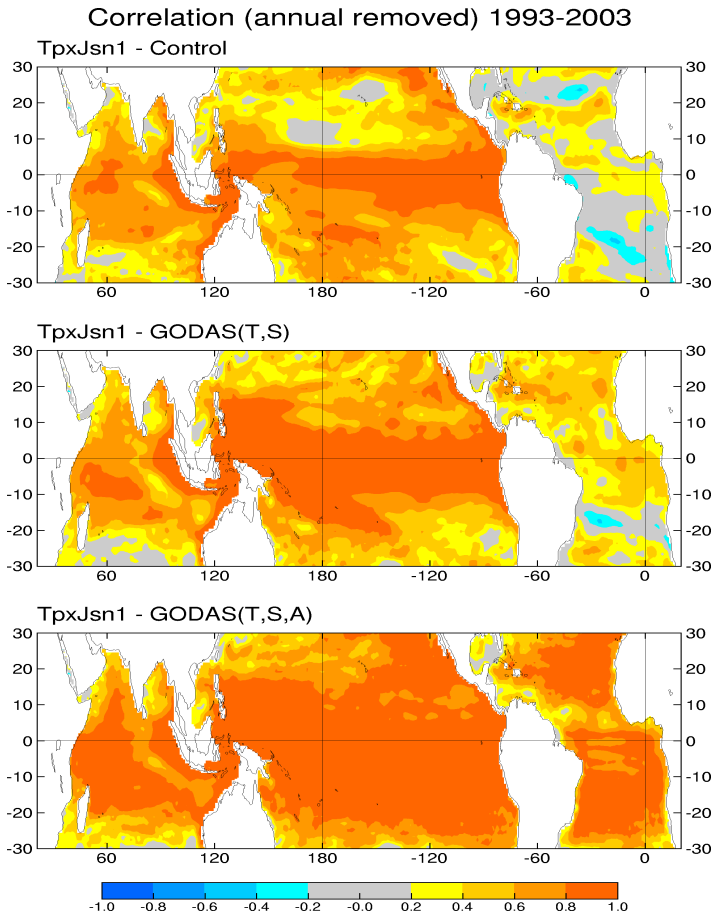
NCEP Real-Time Ocean Forecast System (RTOFS) Operational December 2005, upgraded June 2007

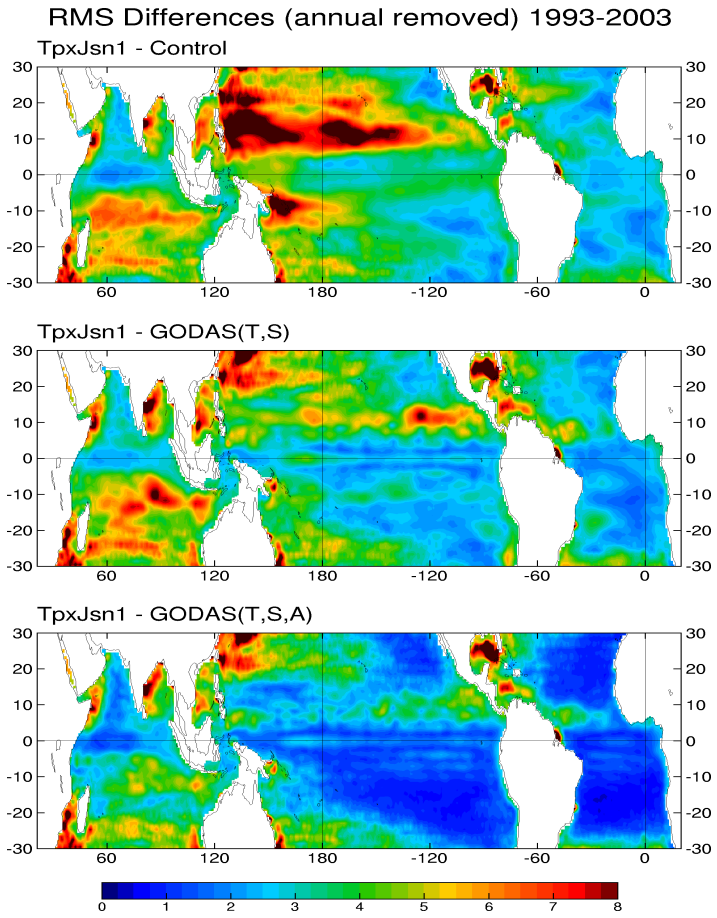
- RTOFS provides
  - Routine estimation of the ocean state [T, S, U, V, W, SSH]
    - Daily 1 week forecast
  - 5 km coastal resolution
  - Initial and boundary conditions for local model applications
- Applications
  - Downscaling support for water levels (with NOS) for shipping
  - Water quality
  - Ecosystem and biogeochemical prediction
  - Improved hurricane forecasts
  - Improved estimation of the atmosphere state for global and regional forecasts





Adding TOPEX/Jason-1 satellite altimetry to NCEP GODAS





No assimilated data

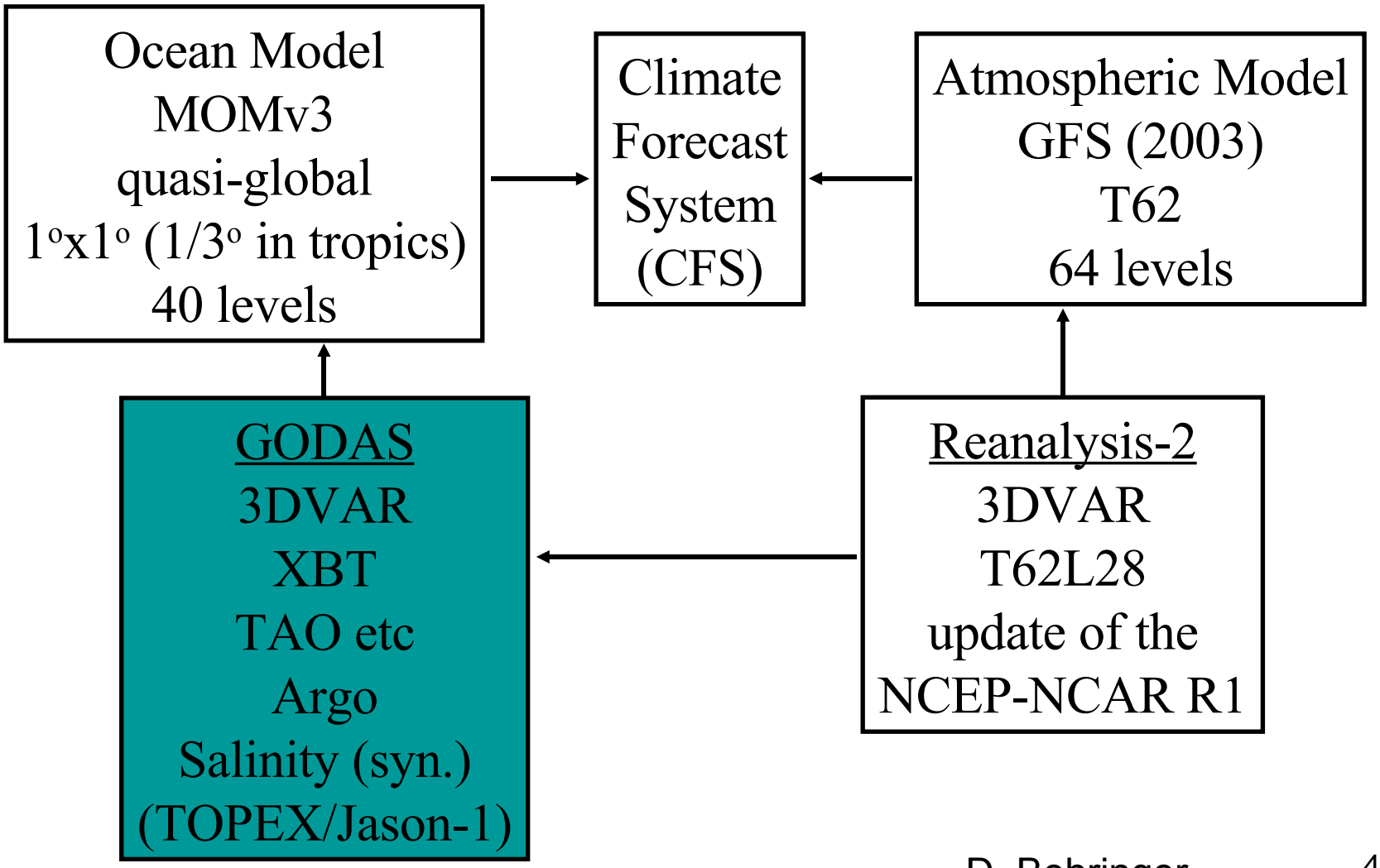
In situ data Assimilated (operational)

Operational Plus altimeter

Larger correlations between GODAS and Altimeter data in Indian and Atlantic Oceans

Smaller RMS errors

Seasonal to Interannual Prediction at NCEP



Standard vs. Deep assimilation

Two long (1980-2005) experiments

Standard or operational GODAS

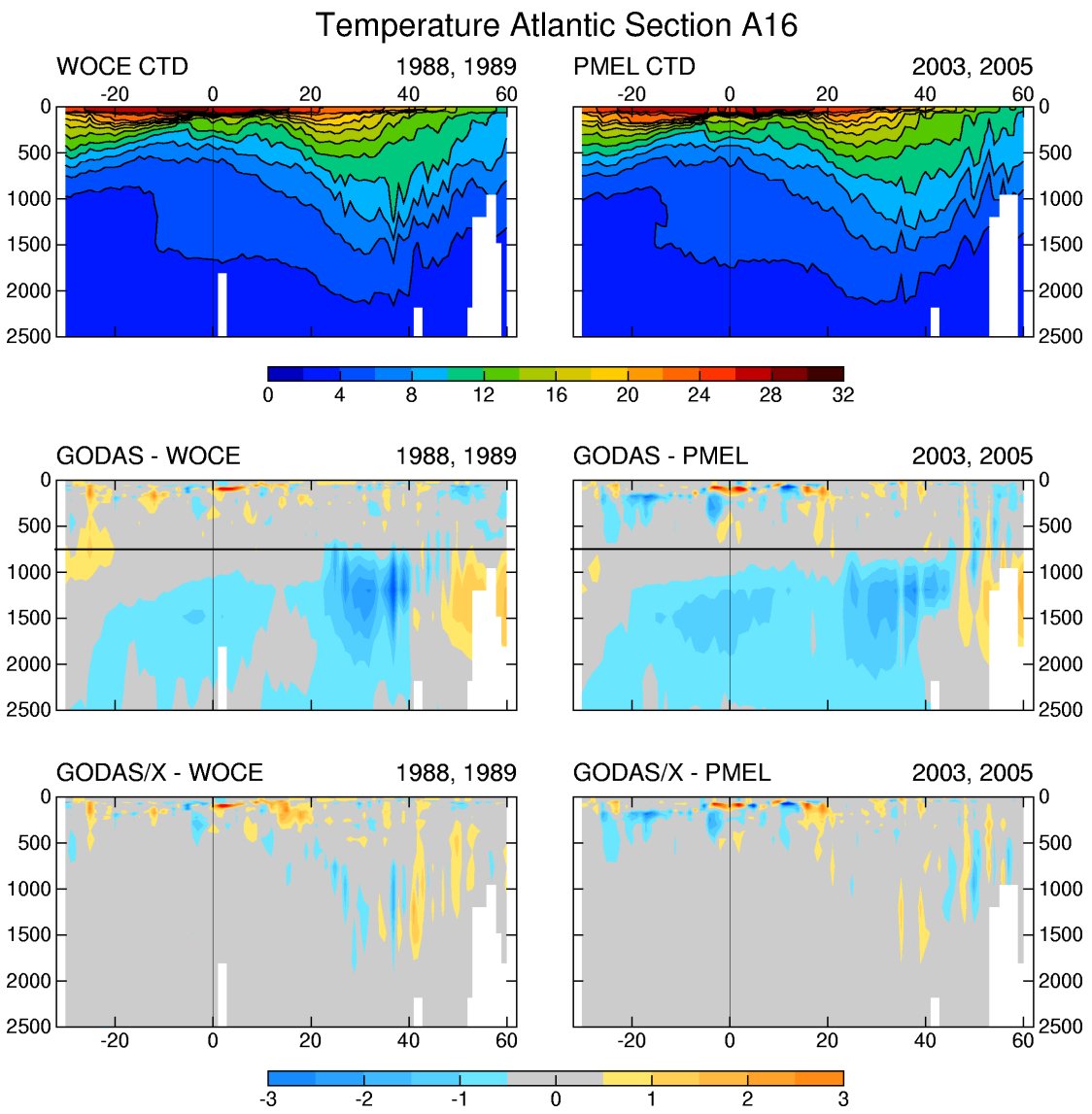
- Temperature profiles from Argo, XBTs, TAO moorings
- Depth of assimilation is **750 m**.

Deep GODAS-X

- Temperature profiles from Argo (2200), XBTs (750), TAO (500) moorings
- Depth of assimilation is **2200 m**. Shallow profiles (XBT, TAO) are augmented with climatology.

Standard vs. Deep assimilation

Independent WOCE CTD section completed in 1988 & 1989 …



…and repeated in 2003 & 2005 by PMEL. Shallow assimilation has a strong cold bias of 1-3°C below 750 m.

Deep assimilation eliminates the cold bias.

Assimilating Argo Salinity

Two 2005 experiments

Standard or operational GODAS

- Temperature profiles from Argo, XBTs, TAO moorings
- Salinity profiles are 100% synthetic (via TS-relationship)

Argo salinity in GODAS-A/S

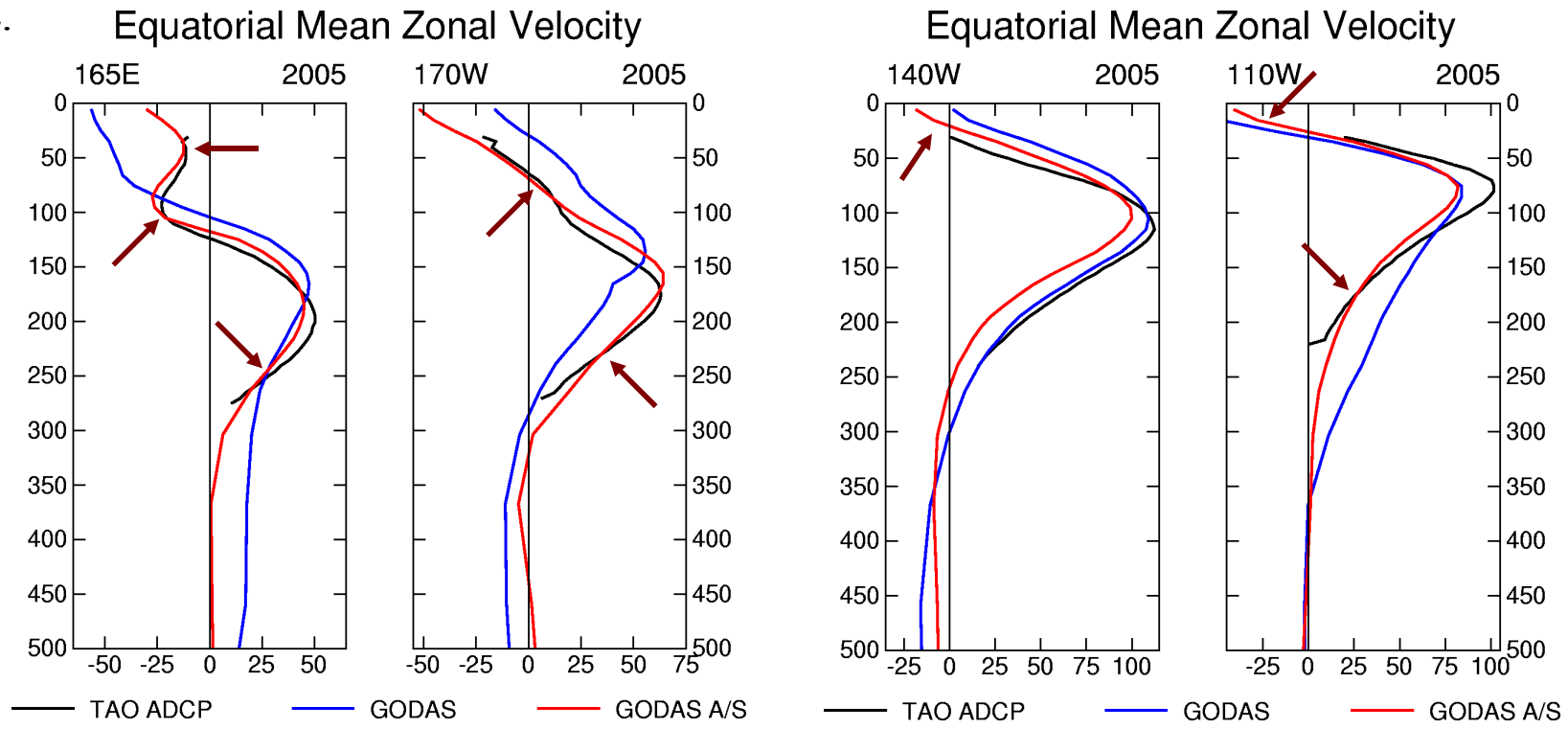
- Temperature profiles from Argo and XBTs only
- Salinity profiles are 75% observed (Argo) and 25% synthetic (XBTs)

Assimilating Argo Salinity

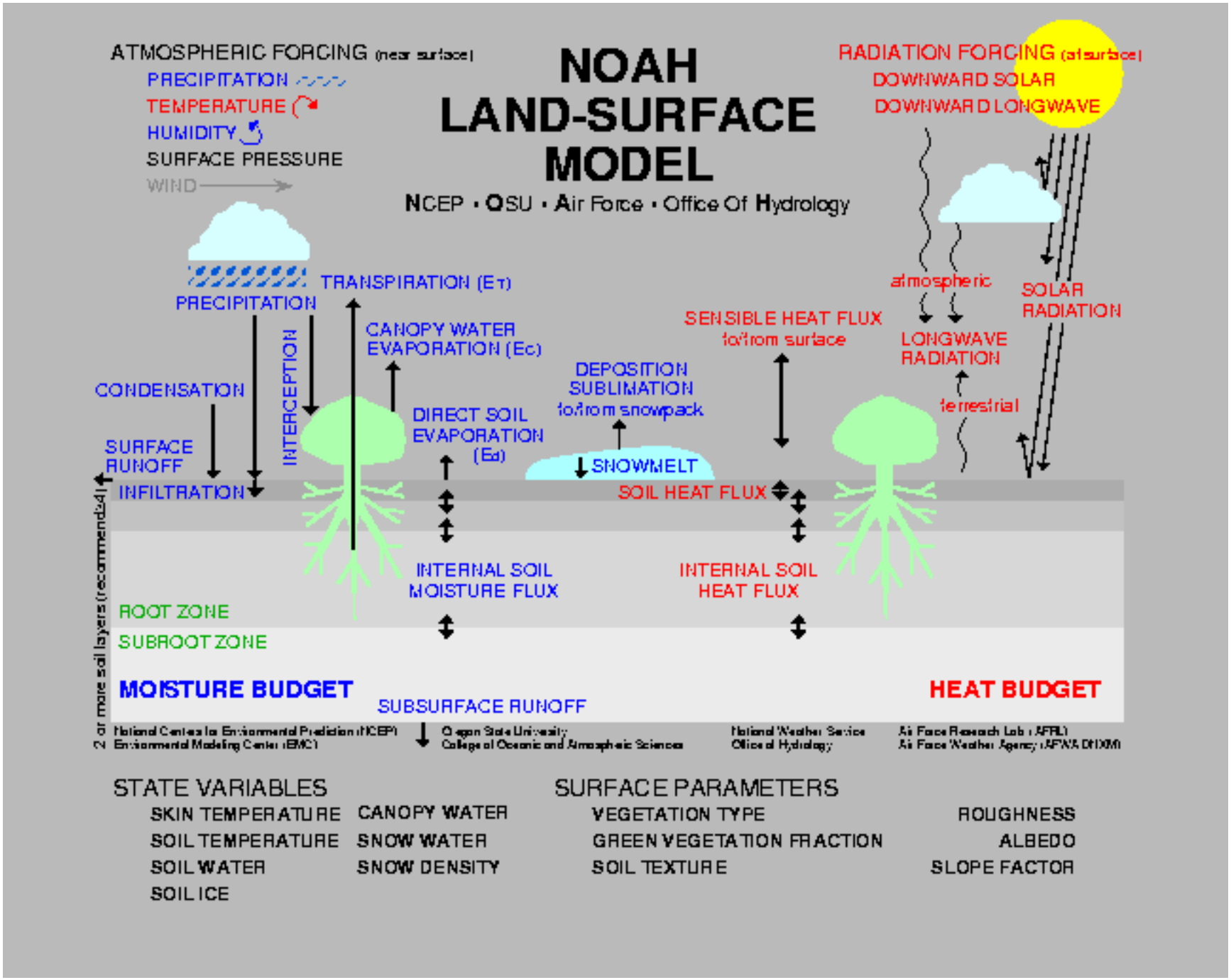
In the west, assimilating Argo salinity corrects the bias at the surface and the depth of the undercurrent core and captures the complex structure at 165°E.

Comparison with independent ADCP currents.

In the east, assimilating Argo salinity reduces the bias at the surface and sharpens the profile below the thermocline at 110°W.



ADCP GODAS GODAS-A/S



STATE VARIABLES

- SKIN TEMPERATURE
- SOIL TEMPERATURE
- SOIL WATER
- SOIL ICE
- CANOPY WATER
- SNOW WATER
- SNOW DENSITY

SURFACE PARAMETERS

- VEGETATION TYPE
- GREEN VEGETATION FRACTION
- SOIL TEXTURE
- ROUGHNESS
- ALBEDO
- SLOPE FACTOR

Improving coupled NCEP NWP Forecasts via Land-Surface Influences

- NWP prediction improvement goals
  - air temperature and humidity
    - -- especially near-surface
  - wind vector
    - -- especially near-surface via improved surface drag
  - PBL T and Td vertical profiles
  - convective stability indices (CAPE)
  - integrated moisture flux convergence
  - precipitation and cloud cover

LAND-SURFACE IMPROVEMENTS FOR CFS

- NCEP LSM models
  - OSU model (1990's)
    - Current LSM in CFS
  - Noah (supported by NOAA Climate Office CPPA)
    - Tested in operational regional model (North American Model)
    - Applied to Global Forecast System (2005)
      - Improved global precipitation and surface fluxes
    - Tested for seasonal prediction (2006)
- Future
  - NASA Land Information System
    - Includes 4 LSMs
      - Noah
      - VIC (Princeton, U. Washington)
      - MOSAIC (NASA)
      - Sacramento (NWS/OHD)
    - ESMF compliant component
  - Run offline with observed forcing to determine land surface states
  - Noah run as forecast module

K. Mitchell

LAND DATA ASSIMILATION SYSTEMS:

- **Three Broad Approaches**
  - **1)** Coupled Land/Atmosphere 4DDA
    - precipitation forcing at land surface is from parent atmospheric model
    - **Precipitation may have large bias: >large soil moisture bias**
    - **Soil moisture may be nudged to reduce impact of precipitation bias**
  - **2)** Uncoupled Land 4DDA (land model only)
    - **observed precipitation used directly in land surface forcing**
    - should execute same LSM on same grid & terrain as coupled model
      - **Exp: EMC uncoupled GLDAS**
        - » **GLDAS provides initial land states for CTB tests of CFS/Noah**

→

  - **3)** Hybrid Land 4DDA e.g.Regional Reanalysis
    - Coupled land/atmosphere, but:
      - **observed precipitation is assimilated for driving the land surface**

N-LDAS Design
(The Uncoupled Approach)

1. Force models with 4DDA surface meteorology (Eta/EDAS), except use actual observed precipitation (gage-only daily precip analysis disaggregated to hourly by radar product) and hourly downward solar insolation (derived from GOES satellites).

2. Use 4 different land surface models:

- NOAH (NOAA/NWS/NCEP)
- MOSAIC (NASA/GSFC)
- VIC (Princeton U./ U. Washington)
- Sacramento (NOAA/OHD)

3. Evaluate results with all available observations, including soil moisture, soil temperature, surface fluxes, satellite skin temperature, snow cover and runoff.

LDAS Run Modes:
1) Realtime, 2) Retrospective

- **REALTIME: 15 Apr 1999 to 15 Dec 2001**

  -- NCEP realtime forcing

- **RETROSPECTIVE: 01 Oct 1996 to 30 Sep 99**

  -- Mandated largely by spin-up issues

  -- NASA-assembled retrospective forcing

  --- Higgins NCEP/CPC reprocessed precipitation forcing:

  ---- more gages obs, more QC

  --- Pinker U.Md reprocessed solar insolation forcing

  ---- better cloud screening, more QC

Rutgers University compared the soil moisture, soil temperature, surface flux results from the retrospective LDAS runs to observations over Oklahoma/Kansas for last retro year.

LDAS Model Mean Annual Evaporation (mm) over Oct 97 – Sep 99

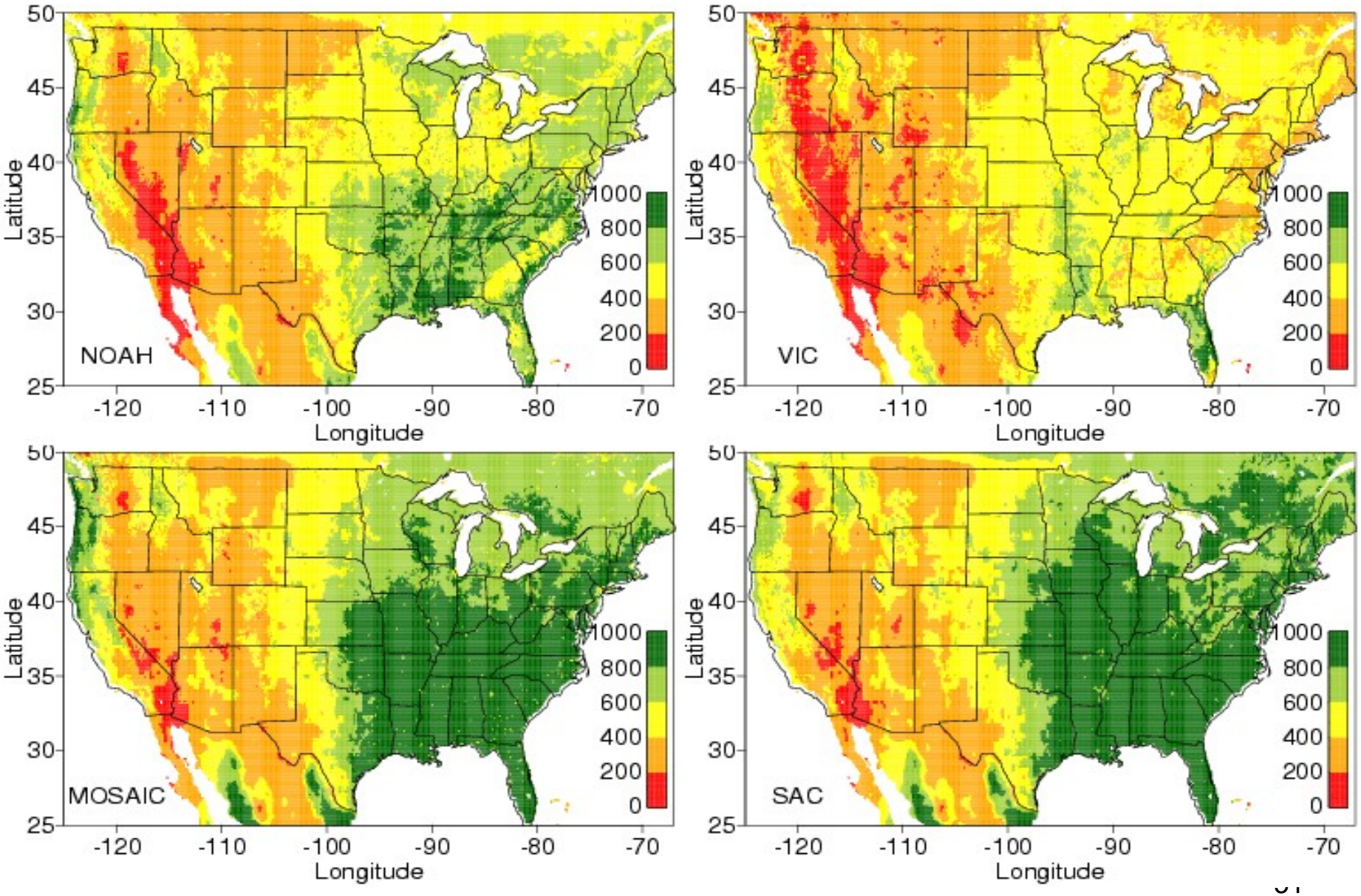
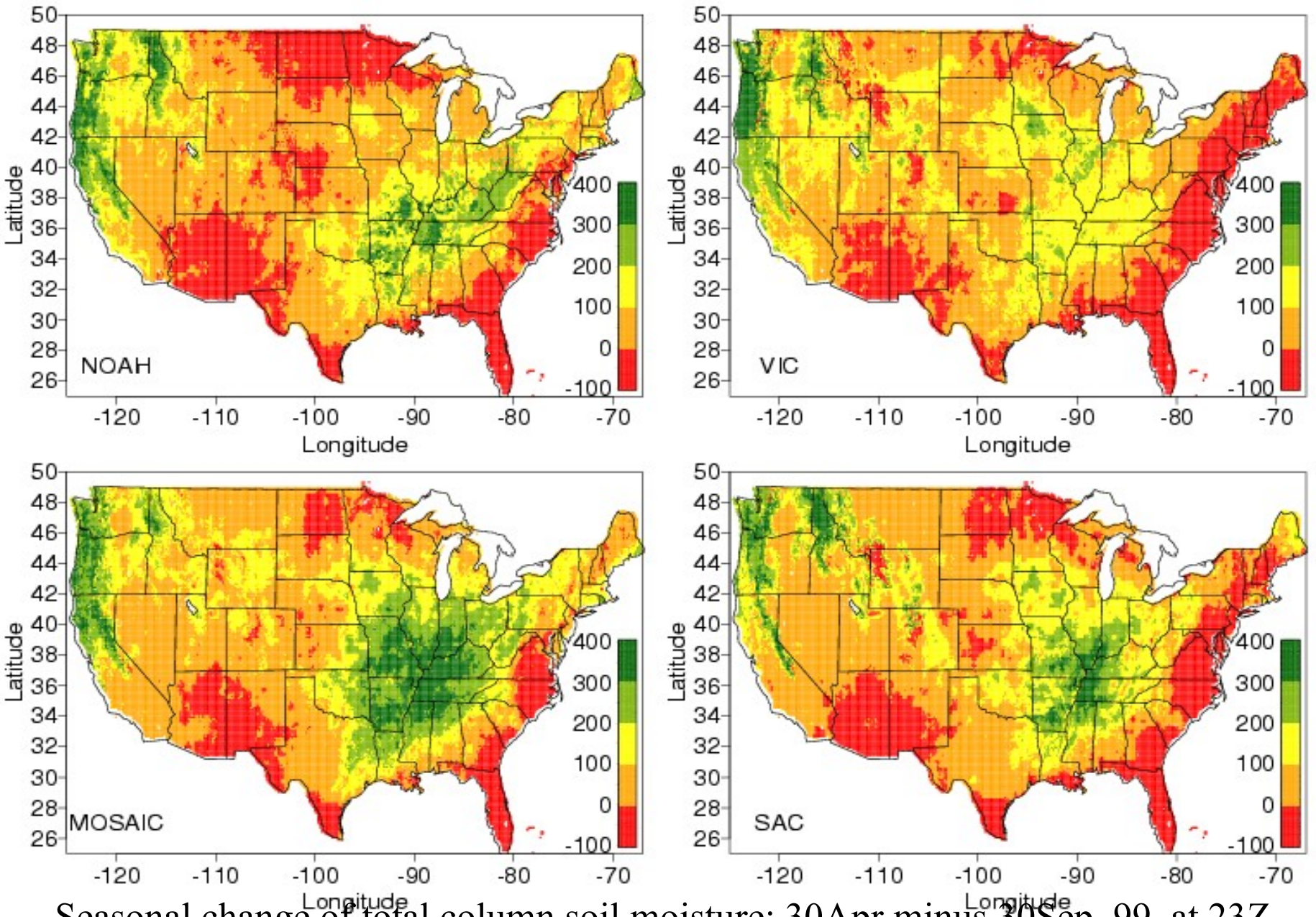


Fig. 5



Seasonal change of total column soil moisture: 30Apr minus 30Sep, 99, at 23Z

Large intermodel differences in transpiration through the vegetation cover (canopy conductance, root density/depth/seasonality).

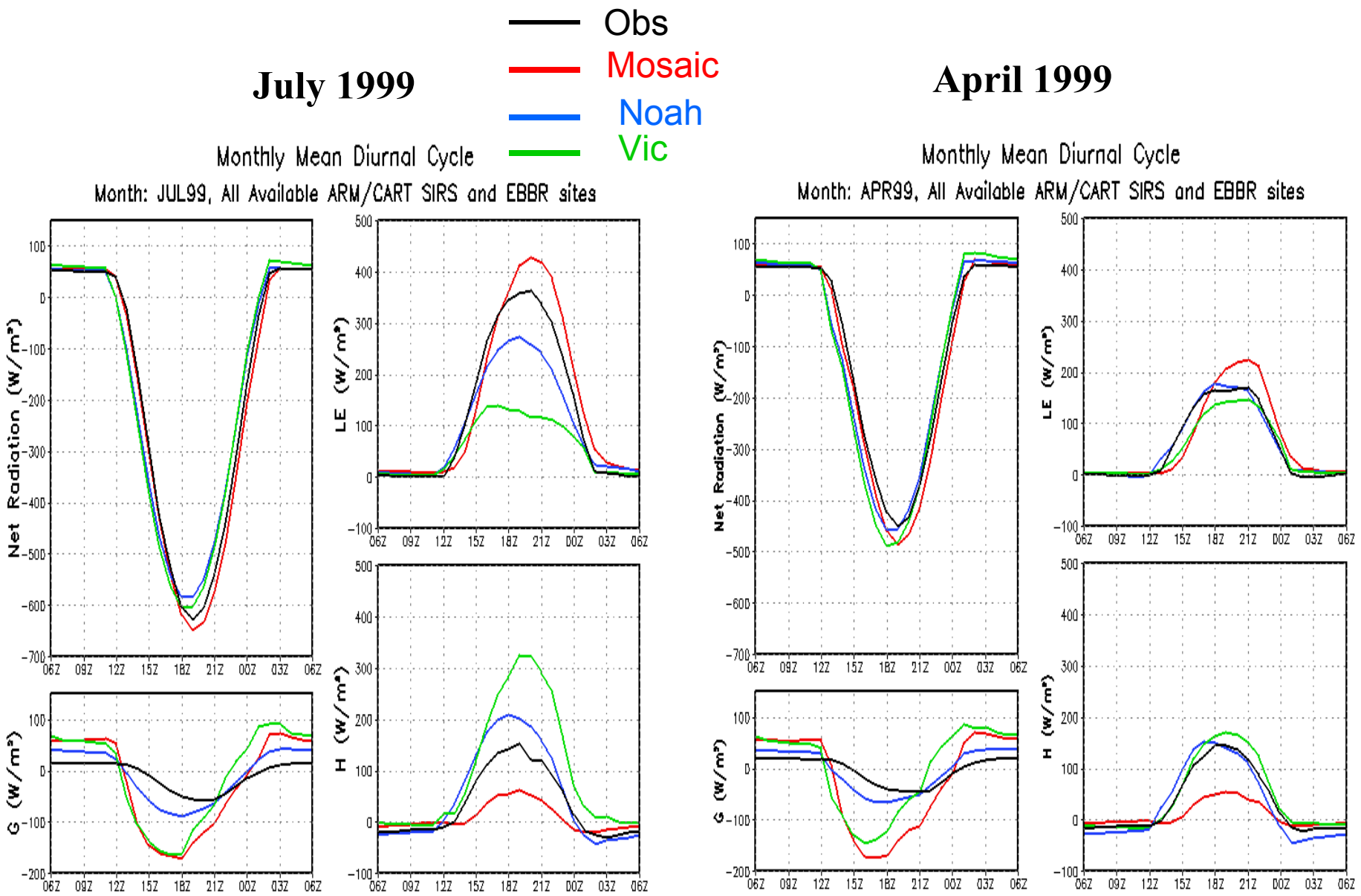
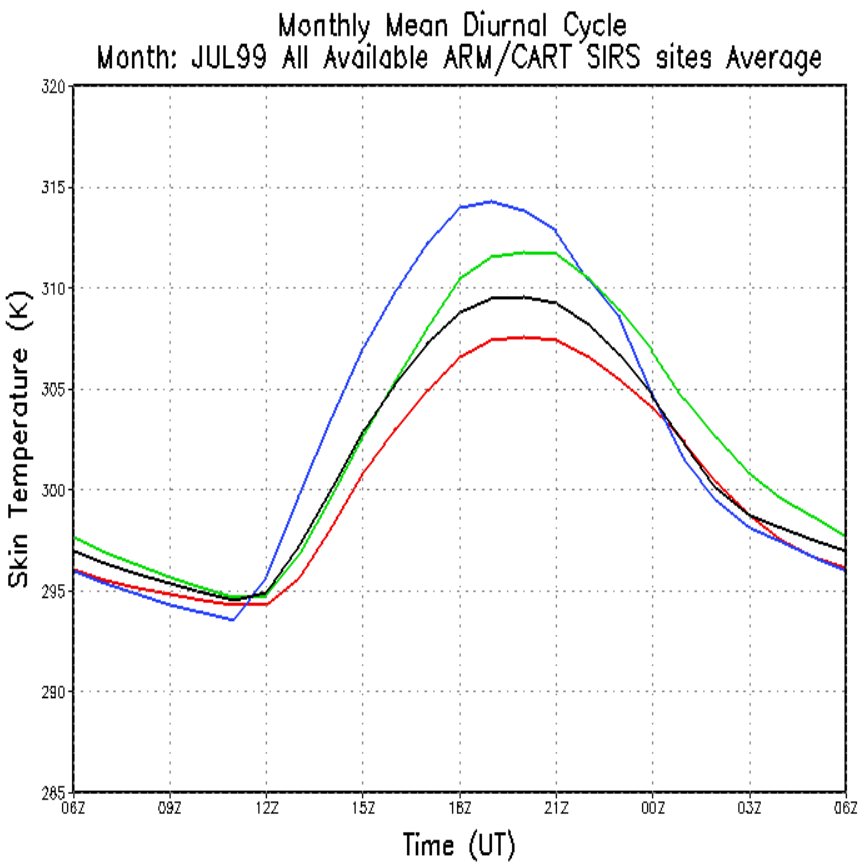


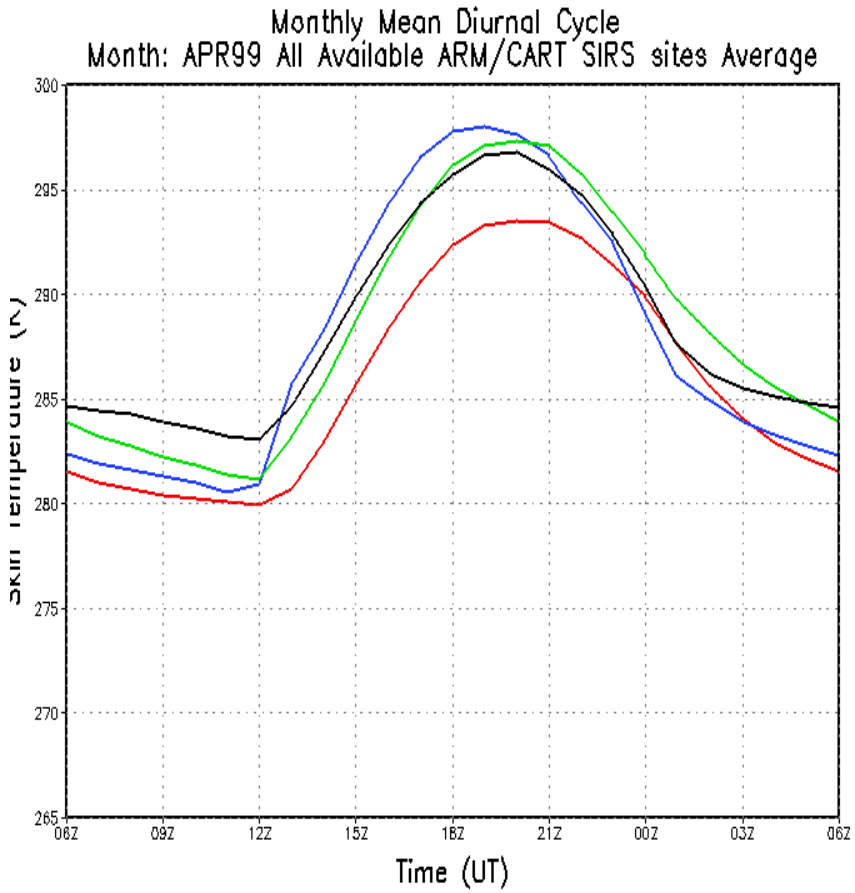
Fig. 22 SGP ARM/CART Monthly Mean Diurnal Cycle of Surface Energy Fluxes

Obs
Mosaic
Noah
VIC

July 1999

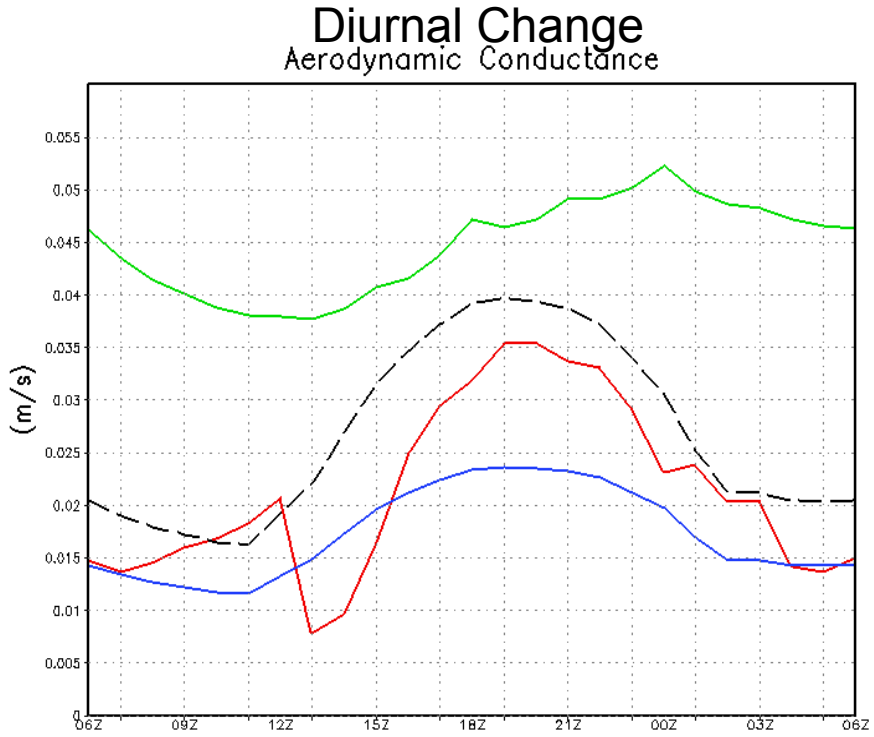


April 1999



Monthly Mean Diurnal Cycle of Surface Skin Temperature of the four NLDAS Land Models.

July 1998



Rev. Noah
Mosaic
Noah
VIC

Large inter-model differences in land surface temperature (LST) shown in previous slide turned out to emerge more from inter-model differences in aerodynamic conductance than from inter-model differences in surface sensible and latent heat fluxes (Bowen ratio).

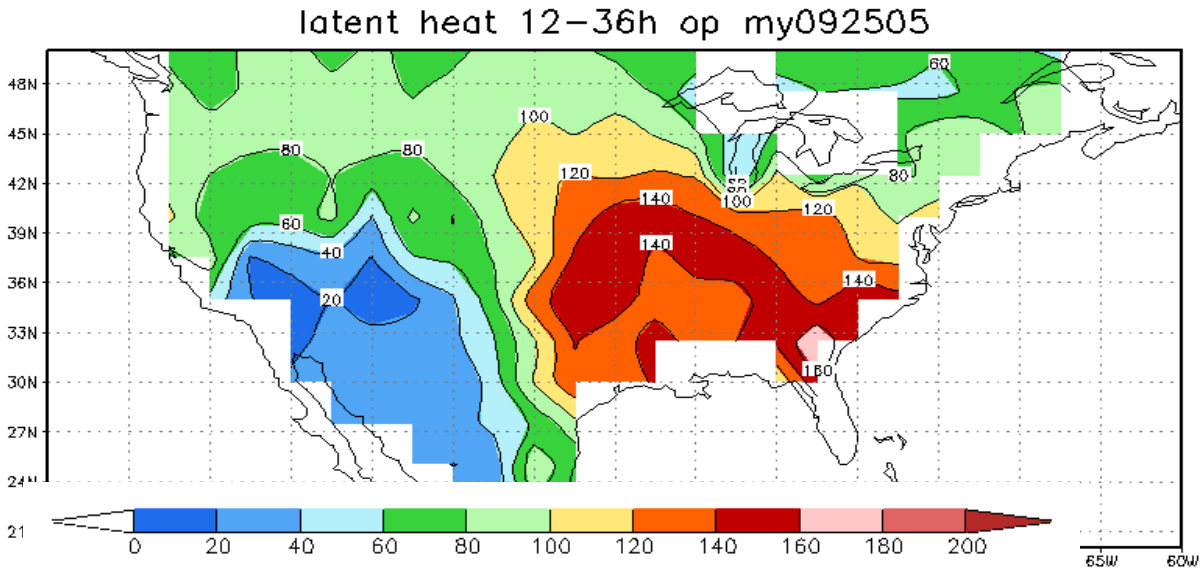
This cast doubt into the expectation of using validations of land model LST with satellite-retrieved LST as a measure of goodness of model Bowen ratio over large scales.

Testing Impact of Replacing OSU LSM with Noah LSM in the NCEP Medium-range Global Forecast System (GFS)

Impact of Noah LSM implementation in GFS: example of warm season forecasts

Noah LSM changes reduce longstanding high bias in GFS surface evaporation over east half of CONUS

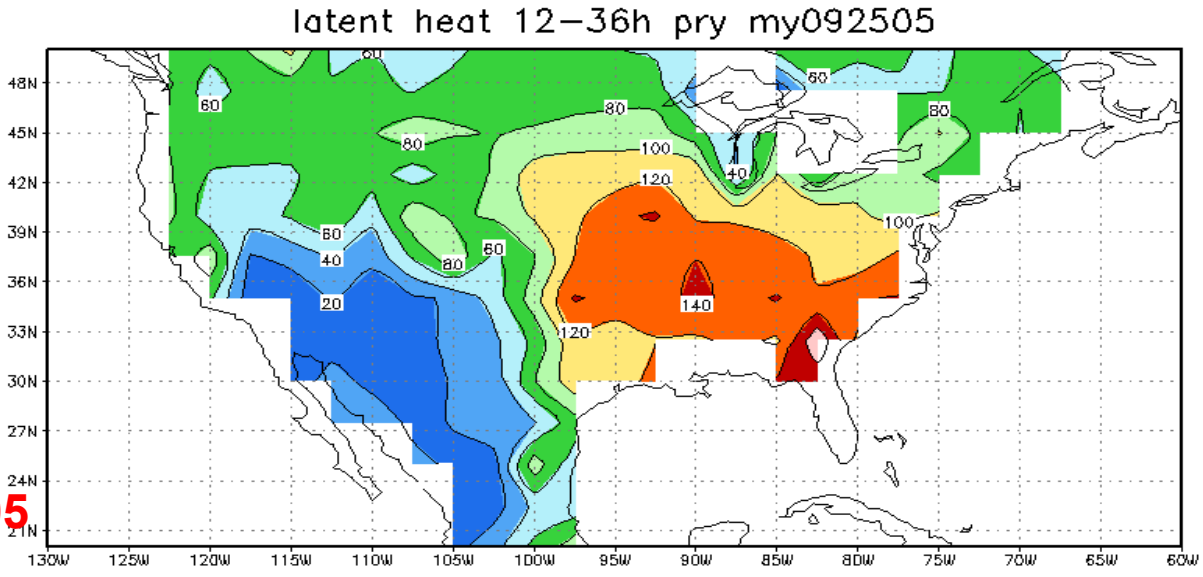
Operational GFS



09-25 May 2005

17-day mean surface Latent heat flux

Parallel GFS test using improved Noah LSM



Noah LSM implemented in NCEP GFS in late May 05

Impact of Noah LSM improvements in GFS warm season forecasts:

Noah LSM changes reduce longstanding high bias in GFS precipitation over east half of CONUS

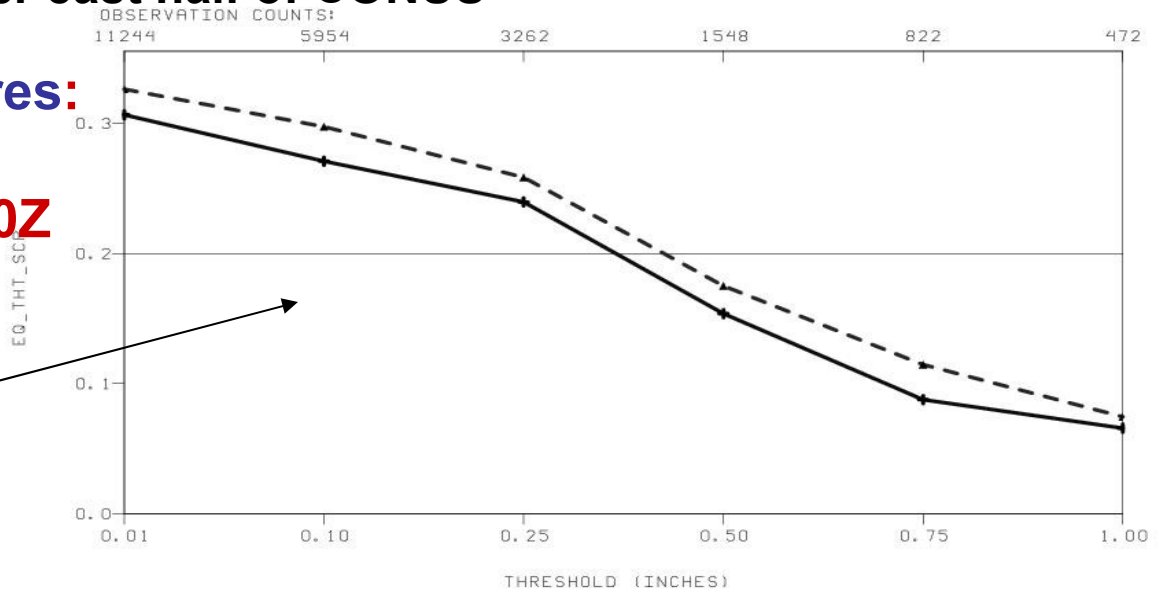
Precipitation Validation Scores:

East half of CONUS

60-84 hour GFS fcst from 00Z

12-31 May 2005

Equitable Threat Score

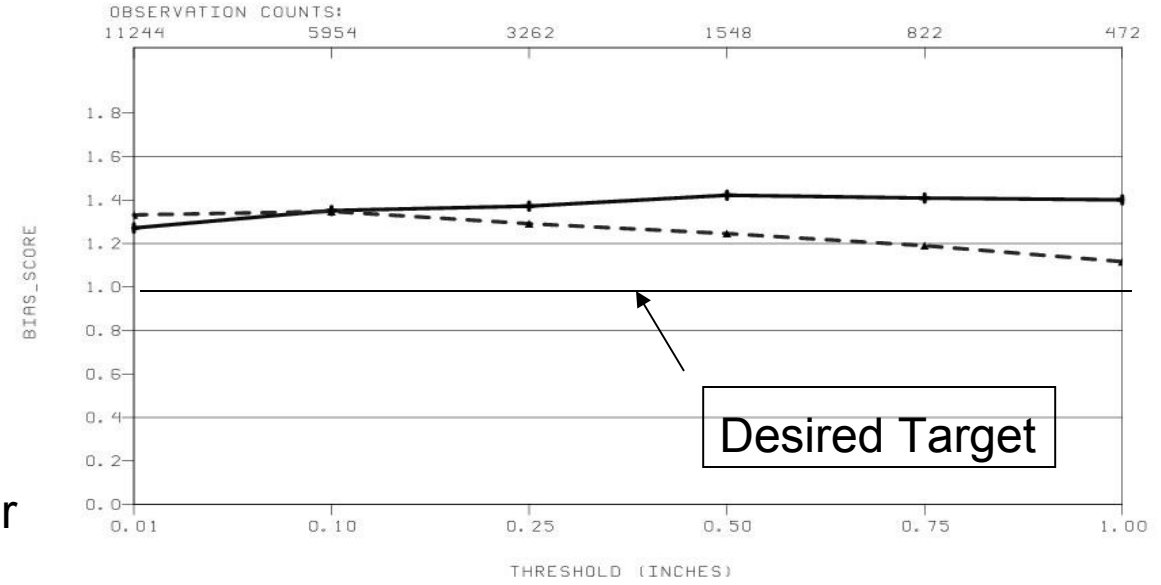


Ops GFS: solid line
(uses old OSU LSM)

Test GFS: dashed line
(uses new Noah LSM)

Bias

Ratio of forecast amount to Observed amount (Y-axis) as Function of amount of 24-hour Precipitation (X-axis)

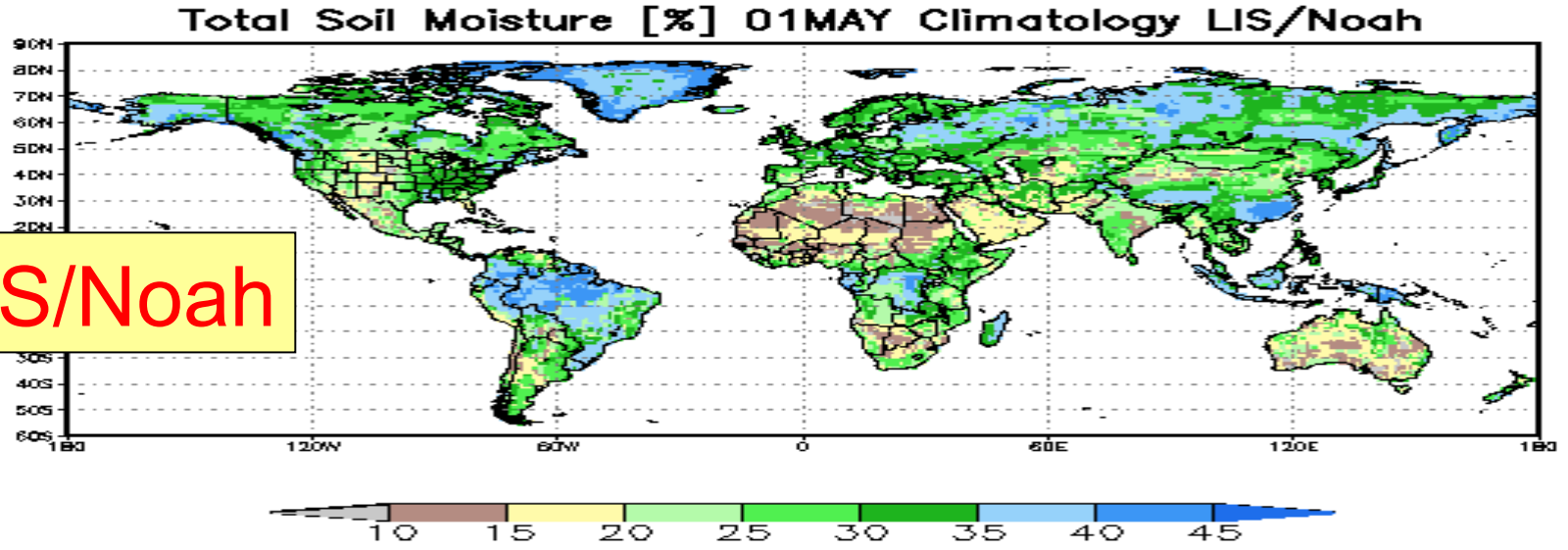


Improving CFS Land Physics

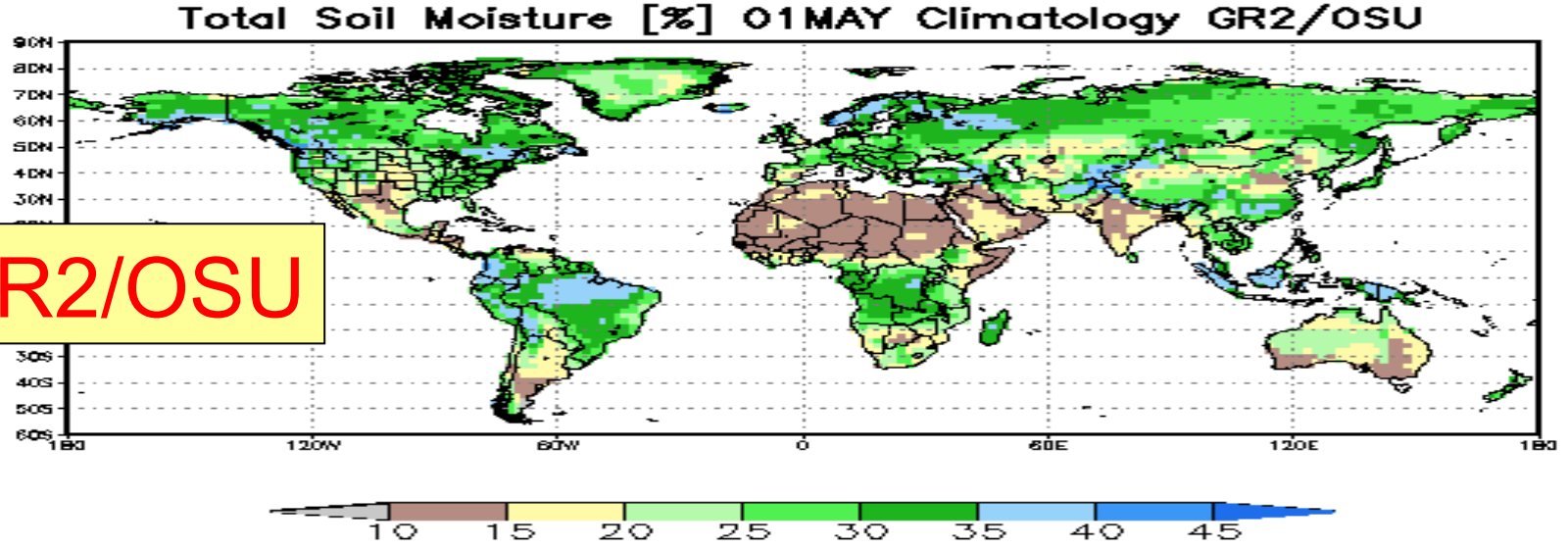
- **Current Ops CFS applies OSU LSM**
  - OSU LSM
- **Next-Generation CFS in NCEP-CPO Climate Test Bed**
  - Applies Noah LSM
  - Applies GLDAS-Noah initial conditions

2-m total soil moisture [%]: 01 May Climatology

(climo in each frame based on 27-years of its given system)

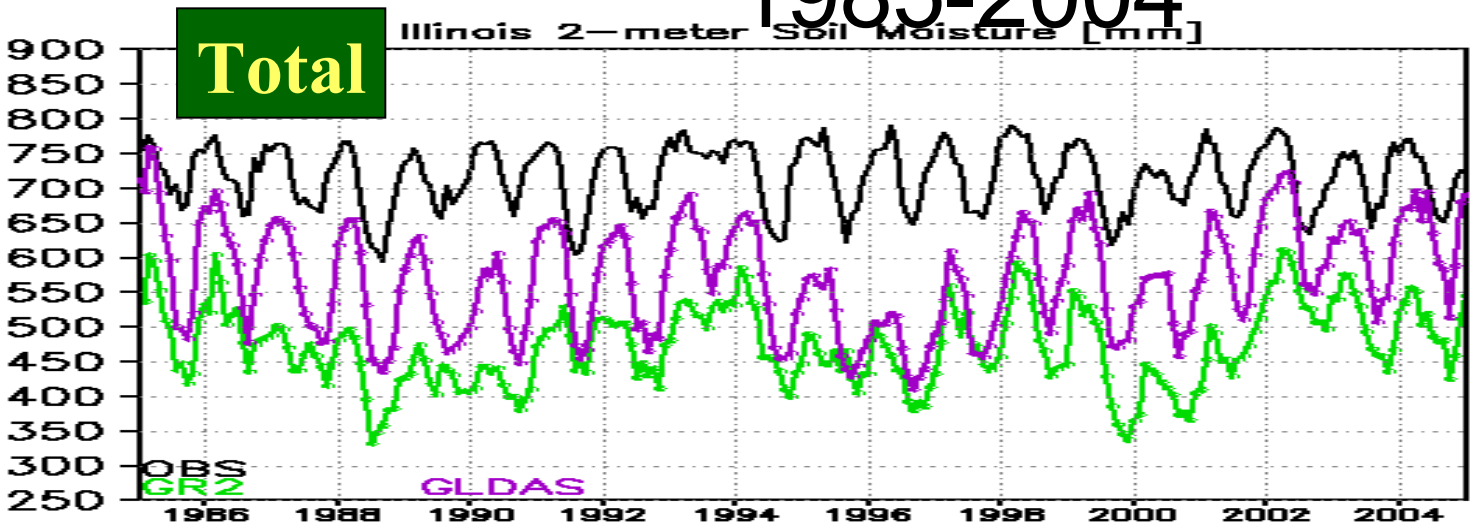


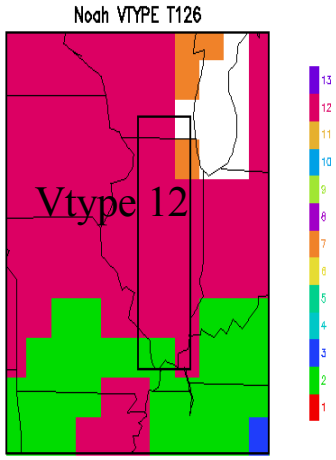
LIS/Noah

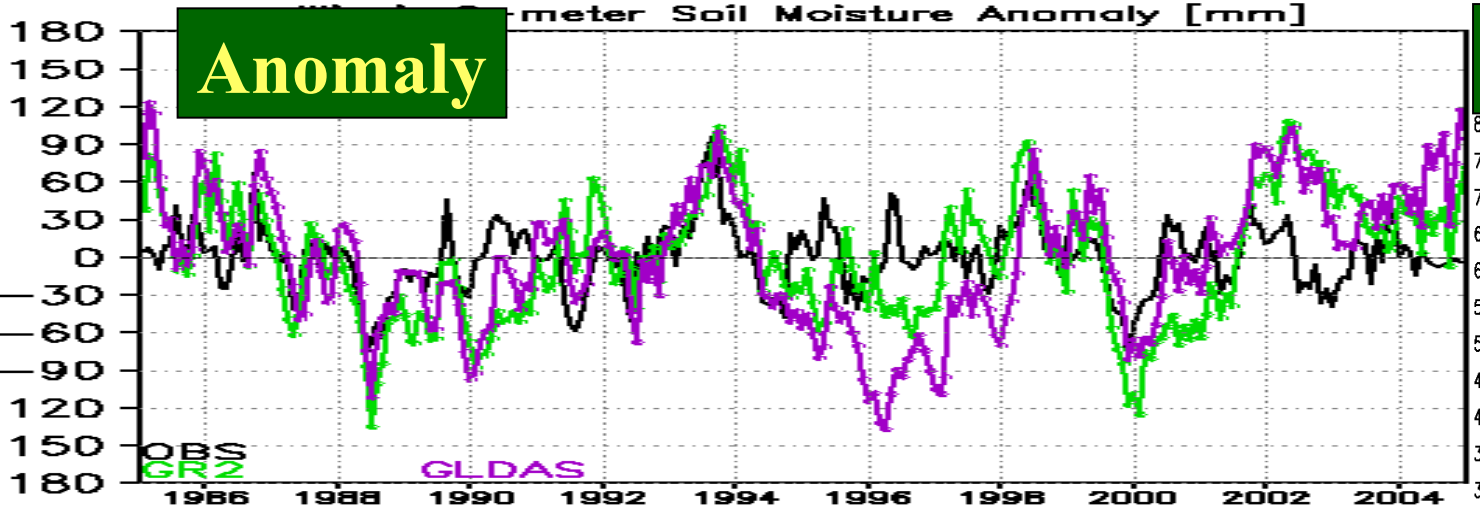


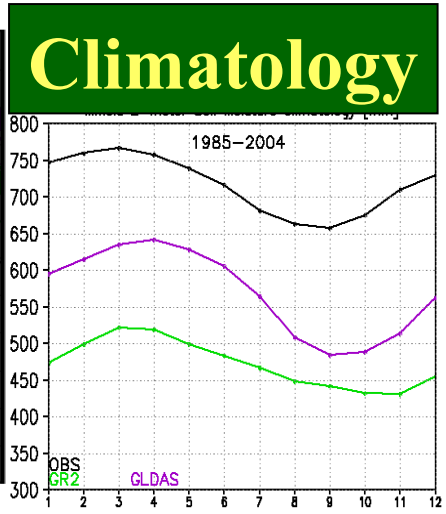
GR2/OSU

Illinois 2-meter Soil Moisture [mm] 1985-2004









Progress of CTB Transition Project Team for Land Data Assimilation:

Impact on CFS of: A) new land model (Noah LSM)

B) new land initial conditions (from 27-year T126 GLDAS/Noah)

- **10-year 10-member 6-month T126 CFS runs (GFS-OP3T3,MOM-3)**
  - Four configurations of T126 CFS:
    - A) CFS/OSU/GR2: - OSU LSM, initial land states from GR2 (CONTROL)
    - B) CFS/Noah/GR2: - Noah LSM, initial land states from GR2
    - C) CFS/Noah/GLDAS: - Noah LSM, initial land states from T126 GLDAS/Noah
    - D) CFS/Noah/GLDAS-Climo: - Noah LSM, initial land states from GLDAS/Noah climo
  - 10 summers: (88, 90, 91, 93, 99, 00, 01, 02, 03, 04)
    - Initial conditions: 00Z daily from Apr 19-23, Apr 29-30, May 1-3
  - 10 winters: (83, 88, 89, 90, 98, 00, 01, 02, 03, 04)
    - Initial conditions: 00Z daily from Nov 29-30, Dec 1-3, Dec 19-23
- **For summers 1999 & 2000 only**
  - Ensemble size test (Case B only, 5 added members from April 9-13 I.C.s for total of 15)
  - Lead time test (Cases B & C, 10 added members run from May 30-31, Jun1-3, Jun 19-23 I.C.s)
    - Also for test of CFS version (in FY06 CTB, we tested current ops CFS with Noah at T126)
- **For summer 2003 only** (to compare with Augustin's CTB CFS tests)
  - 7 members, 2-month fcsts (same July initial dates as Augustin, for Aug fcst)

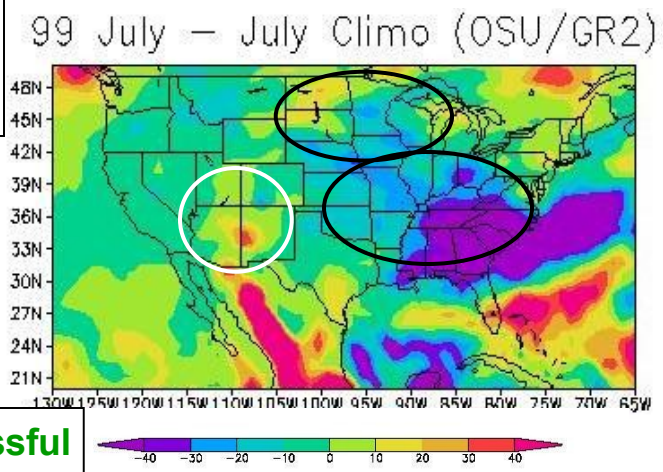
- 10-year 10-member runs just finished on CTB/HAZE on April 8
  - Only time thus far for evaluation of 1999 summer ensemble over U.S. for precip
  - Results of above pilot evaluation of CFS experiments shown in next frame
  - Plus 3 additional frames comparing GLDAS/Noah and GR2/OSU soil moisture

Impact of Upgrading Land Surface Model and Land Surface Initial Conditions in Seasonal 3-Month Forecasts of the Experimental NCEP Climate Forecast System

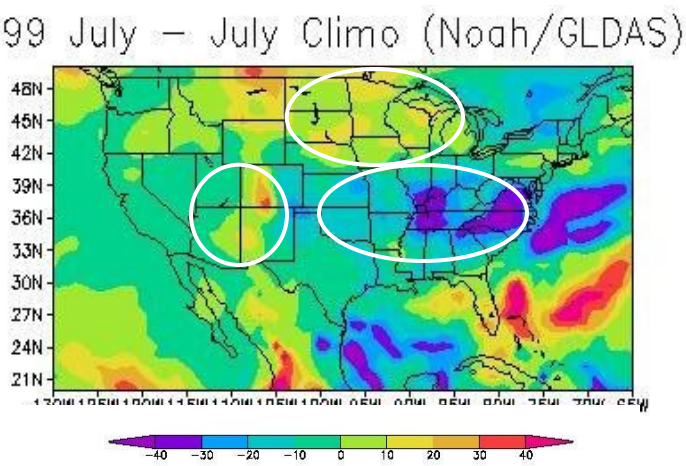
With respect to 10-year climate of given CFS model from 10-member ensemble of CFS forecasts from April initial conditions

CFS Predicted July 1999 Precipitation Anomaly (mm)

CFS Test A: Control
T126 CFS / OSU / GR2



CFS Test C:
T126 CFS / Noah / GLDAS



CFS Test A: Control
- old OSU LSM
- GR2 initial land states

CFS Test B:
- new Noah LSM
- GR2 initial land states

CFS Test C:
- new Noah LSM
GLDAS initial land states

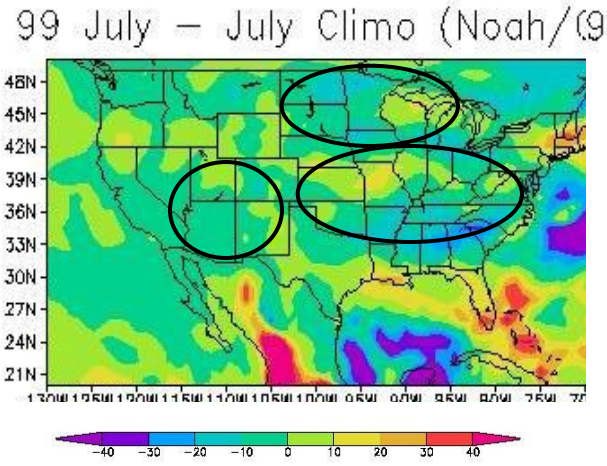
CFS Test D:
New Noah LSM
GLDAS climo initial land states

Most successful configuration

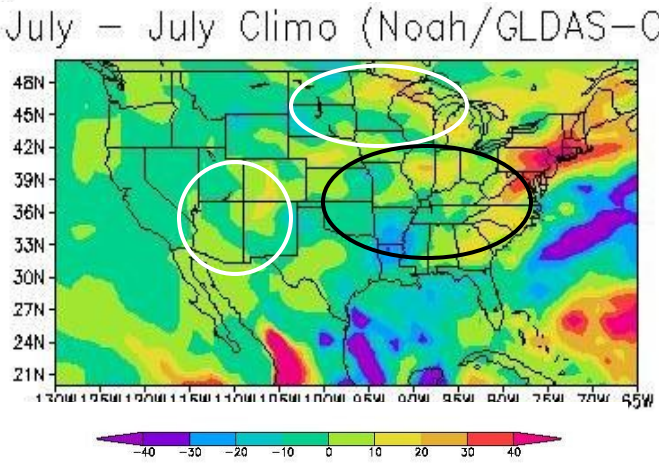
Black Circles: Worse than Case C

White Circles: Best or decent

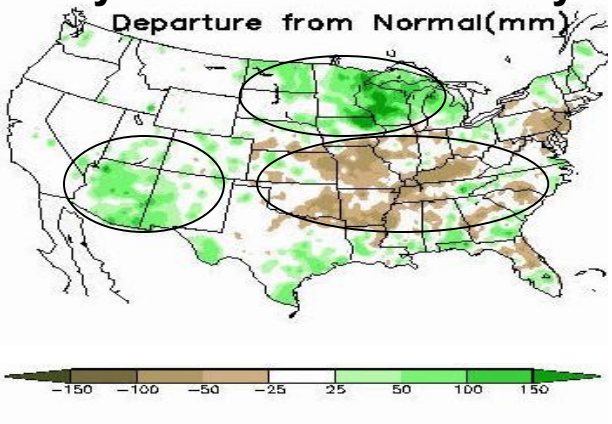
CFS Test B:
T126 CFS / Noah / GR2



CFS Test D:
T126 CFS / Noah /GLDAS-climo



July 99 Observed Anomaly



Appendix
Anatomy of an Implementation

Global Forecast System
May 2005

Focus of the implementation

- Inferior GFS winter scores
- Set the stage for improved AIRS assimilation with a conservative implementation
- Transition JCSDA work to operations
- Include technology upgrades for
  - Land surface
    - Another step in unifying LSM in NCEP's models
  - Sea ice model
    - First in a series of upgrades
    - Replaces ultra-crude 1980's code
- Improved resolution affordable due to computer upgrade (T254 implemented 2 ½ years ago)
- Major changes in model structure and efficiency (+ 15%), allowing work on hybrid vertical coordinate and prototype ESMF compatibility

List of Upgrades

- Model
  - Increase resolution from T254 (55 km) to T382 (35 km)
    - Old: T254/L64 (0-84 h) T170/L42 (84-180h, T126/L28 to 384h
    - New: T382/L64 (0-180 h) T190/L64 (180-364 h)
  - Modified vertical diffusion
  - Enhanced mountain blocking
  - New sea ice model
    - Fractional sea ice & leads
    - Impacts surface fluxes
  - New code structure
    - Increased computational efficiency
    - ESMF compatible superstructure
    - “Hybrid (sigma-pressure) ready”

List of Upgrades (cont)

- Model (cont)
  - Upgrade to Noah Land Surface Model
    - 2-4 soil layers
    - Reduction of early bias in snow pack depletion
    - Improved treatment of
      - Frozen soil
      - Ground heat flux
      - Energy and water balance at surface
    - Reformulated infiltration and runoff functions
    - Upgraded vegetation fraction (NESDIS)
    - Improved, plug-compatible, code structure

List of Upgrades (cont)

- Analysis
  - Increase resolution to T382
  - Surface emissivity model for snow and ice (JCSDA)
    - 3 X data used in NH polar latitudes
    - 1.3 X in SH polar latitudes
  - AQUA AIRS and AMSU-A (new data)
  - Upgraded thinning algorithm for radiances
  - QC algorithm for clouds

List of Upgrades (cont)

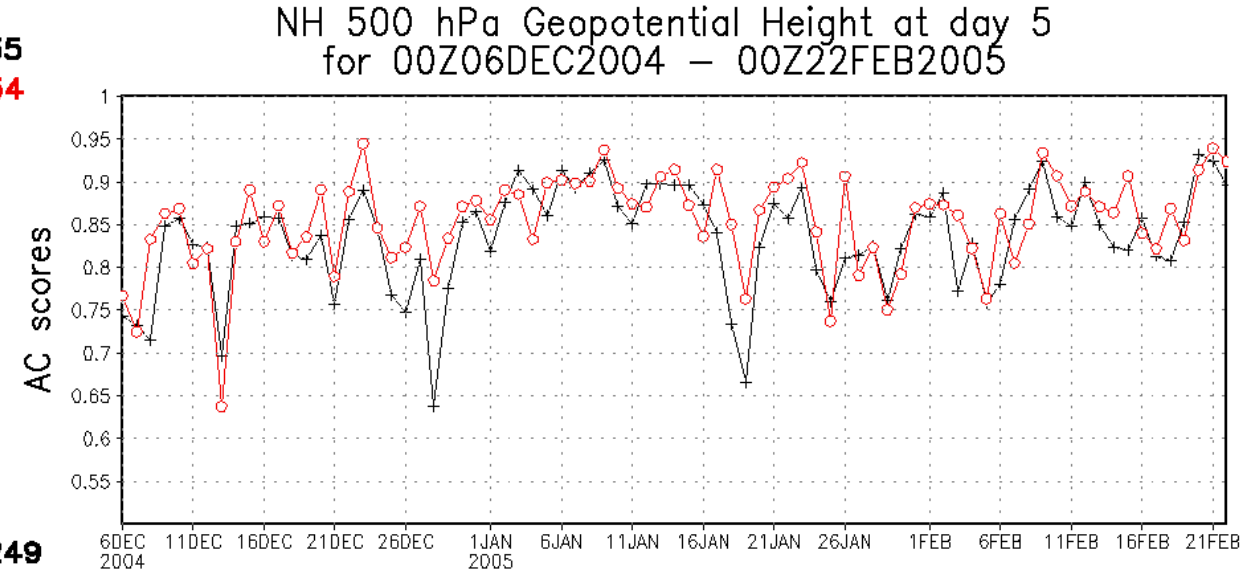
- **NCEP Service Center Product changes to Master File**
  - Increased stratospheric products at 7, 5, 3, 2, and 1 mb
  - New format (added records) to accommodate the NOAH land surface model ADDED 15 records: Clear & All-sky UV-B downward SW flux, Soil moisture/Temperature for deep soil layers (10-40cm, 40-100cm, 100-200cm), Liquid soil moisture for all 4 soil layers, Plant canopy surface water, Snow depth (frozen not water equiv), Sea Ice thickness.
  - . DROPPED 12 records and ADDED 24 records: Potential Vorticity in corrected units (500, 1000, 1500, 2000 PV units), each contains 6 records: geopotential height, temperature, pressure, vertical wind shear, u, v wind.
  - . DROPPED 2 records: Soil moisture/Temperature for the single 10-200cm layer.
  - . CHANGED 5 records: Maximum wind level 500-100mb (not 500-70mb): pressure, temperature, geopotential height, u, v wind
- **For external users**
  - Minor change to units
  - Additional soil moisture levels corresponding to levels in new Noal LSM

Testing

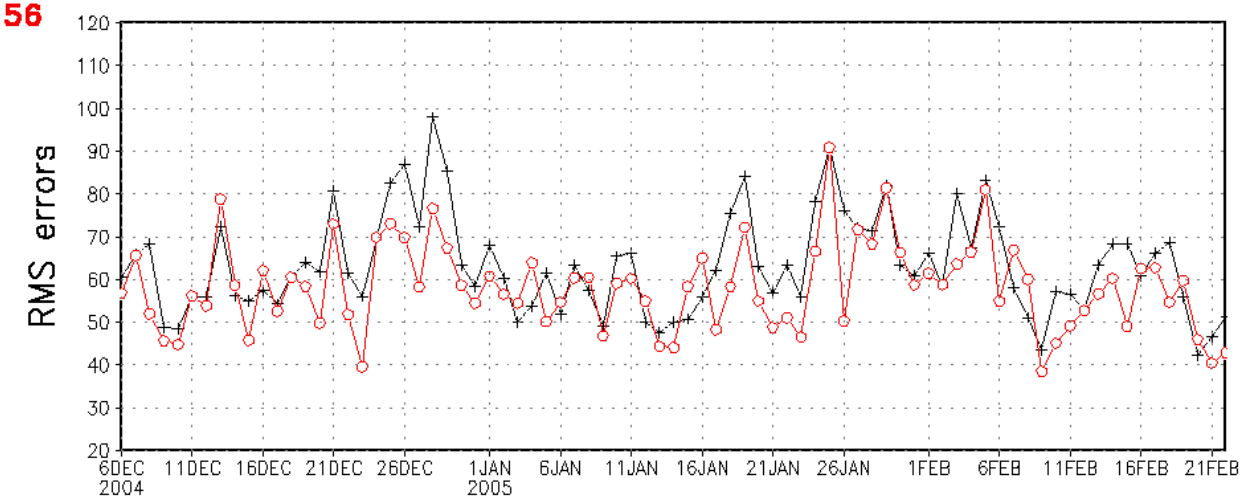
- Winter
  - 1 December – 28 February
  - Statistics and case study requests from field (HPC, NWS Regions)
- Summer
  - 20 August – 30 September
  - GFS Hurricane tracks
  - GFDL runs (2005 system)
- Real time
  - 1 April – present
  - N-AWIPS Products to Service Centers

Performance Results - Winter

GFS=0.835
PRY=0.854



GFS=63.249
PRY=58.156

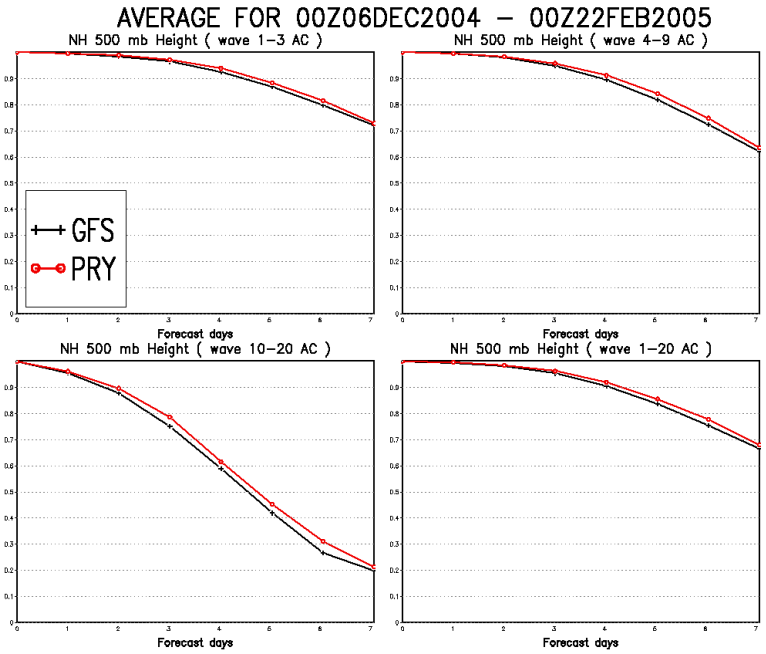


AC +2%
RMS - 8%

Consistent day-to-day performance

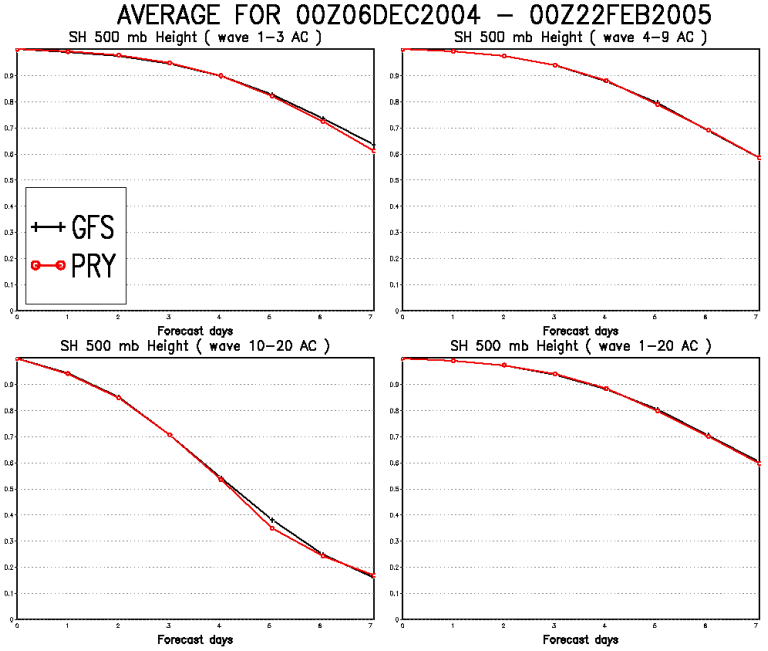
Performance Results – Winter (cont)

NH Z500 AC



Clear positive impact in for all wave categories

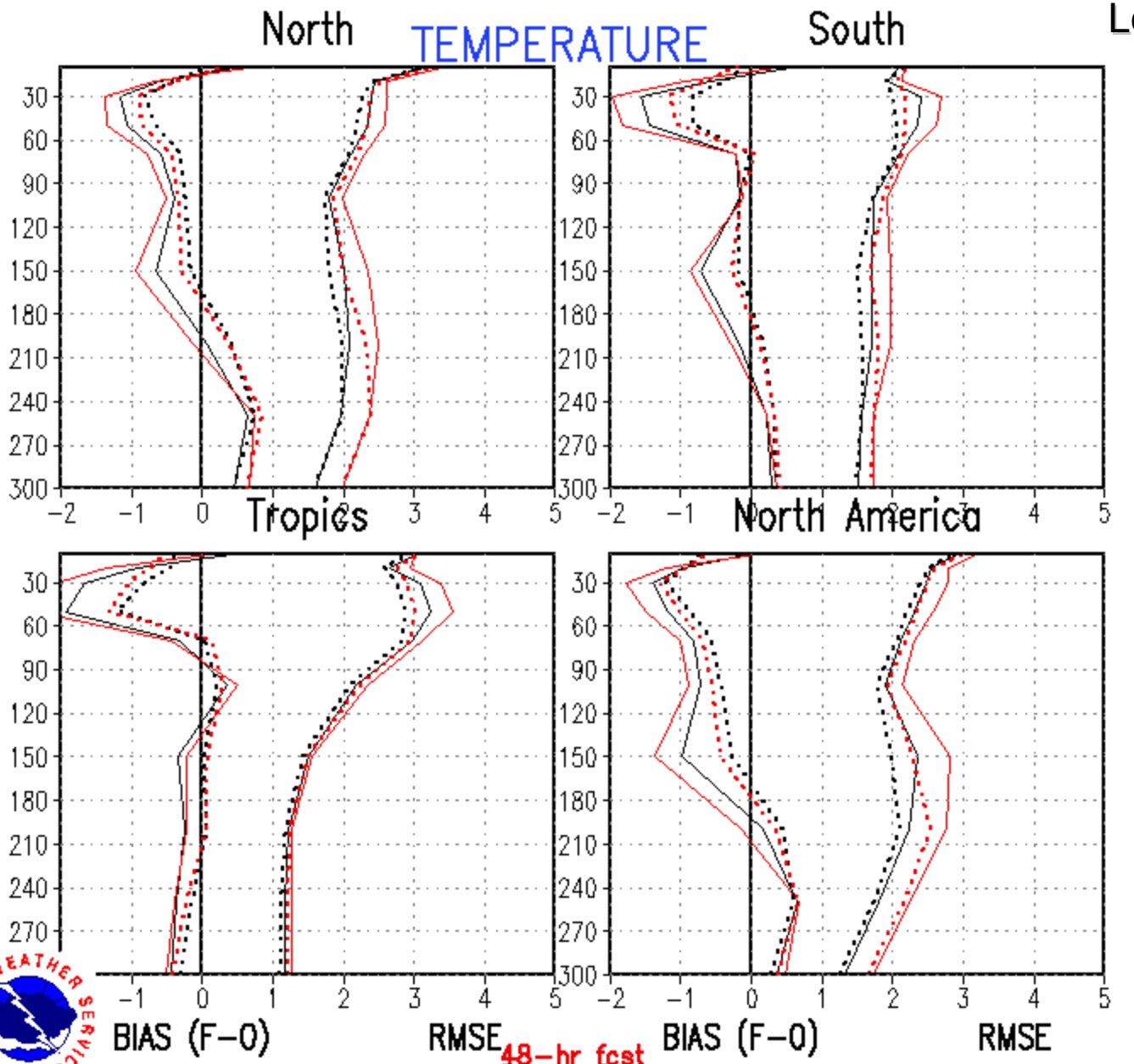
SH Z500 AC



Neutral impact

Fits to Rawinsondes

Upper Trop & Lower Strat.



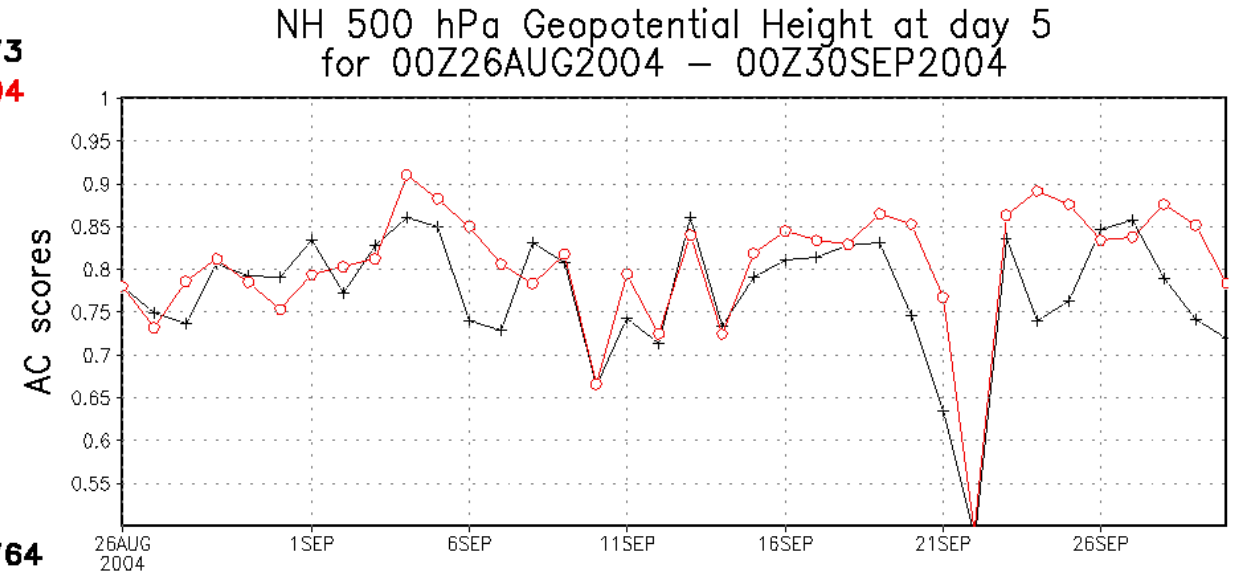
Ops – solid
Par. - dashed

24 h
48 h

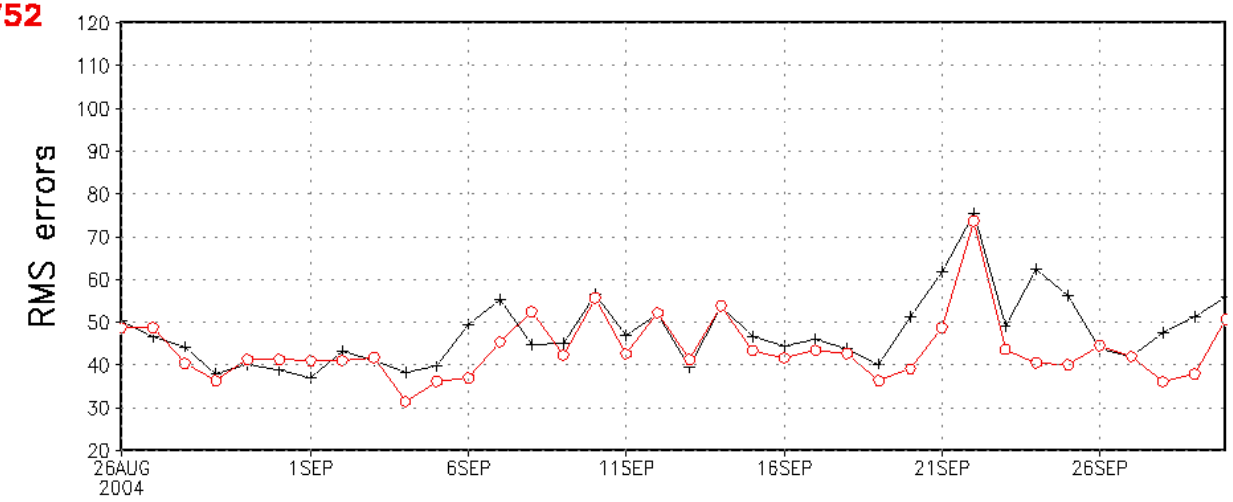
Major Improvement

Performance Results – Summer & Hurricanes (cont)

GFS=0.773
PRY=0.804



GFS=47.764
PRY=43.752

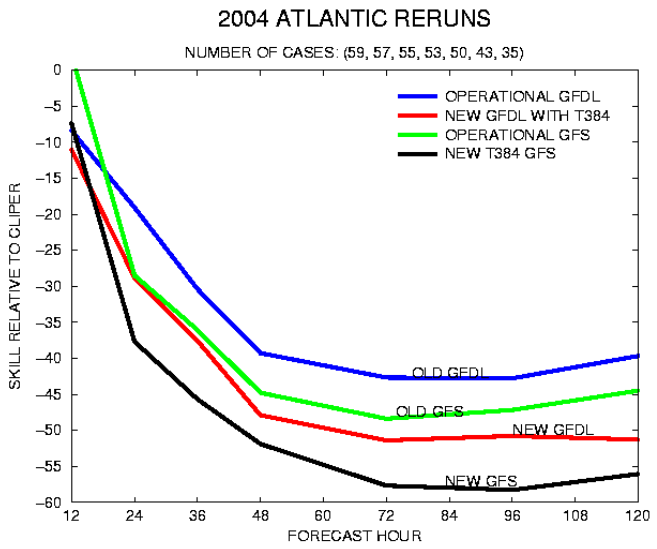


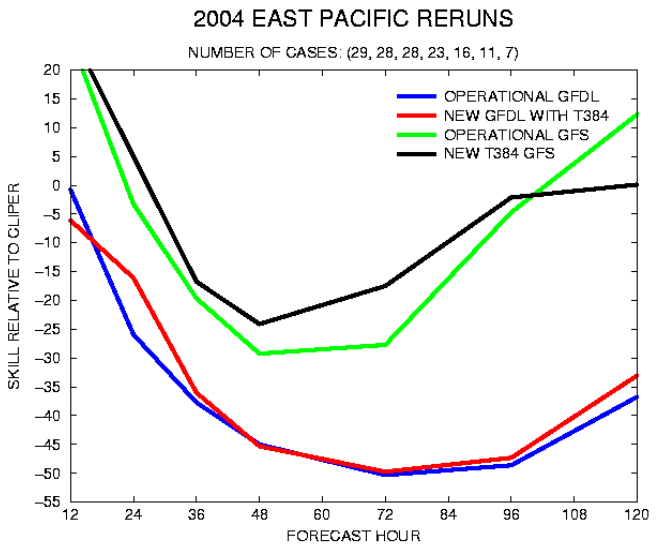
AC +3%
RMS - 8%

Consistent day-to-day performance

Performance Results – Summer & Hurricanes (cont)

Hurricane Track





Improved Skill for both GFS and GFDL in Atlantic
Neutral in EPAC (focus of current work)