NCEP/EMC Contributions to the JCSDA

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1 May, 2007

Outline

I. **Overview: NCEP Gridpoint Statistical Interpolation (GSI) analysis**
II. **Data assimilation development strategy**
III. **GFS implementation - 1 May, 2007**
IV. **FY07-08 priorities**

GSI Overview

- Evolutionary combination of the global SSI analysis system and the regional ETA 3DVAR
  - Major code re-design
  - New features
- Uses a grid space definition of the background errors
  - Allows use of situation dependent background errors
- Operational for
  - North American Model (NAM)
  - Real-time Mesoscale Analysis (RTMA)
    - 2 dimensional surface analysis for NWS Offices
  - Global Forecast System (GFS) (today)
- Available for use in all WRF dynamical cores

GSI Overview (cont)

- Code re-designed for community use
  - Currently 38 registered groups/users
  - NCEP providing some support for external groups
- Major focus of NCEP and NASA/GSFC/GMAO atmospheric analysis development
  - Multi-organizational code management
- Re-structuring for ESMF compatibility (underway)

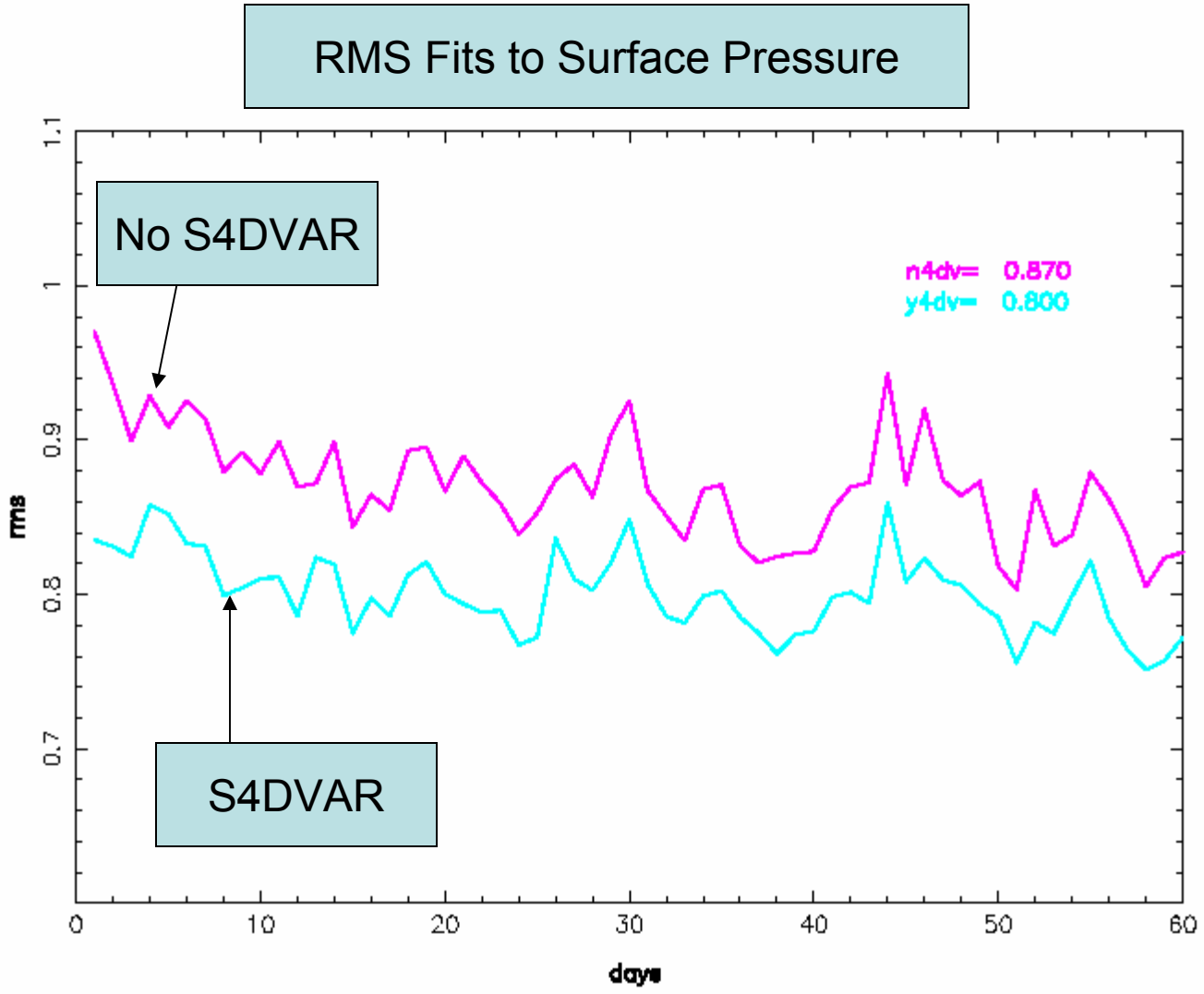
GSI Overview (cont)

- New features (implemented)
  - Spatial derivatives – allows:
    - non-local operators
    - improved definition of balance operators
    - dynamical balance constraints
  - Improved control over observational errors
  - Improved moisture analysis variable
  - Diagnostic files for background and each outer iteration
- New features (under testing)
  - Variational QC (global)
  - Variational bias correction for conventional data
  - SST analysis by direct use of radiances (global)
    - IR and MW data
  - Simplified 4DVAR (global)
  - Situation dependent background error (RTMA, regional)

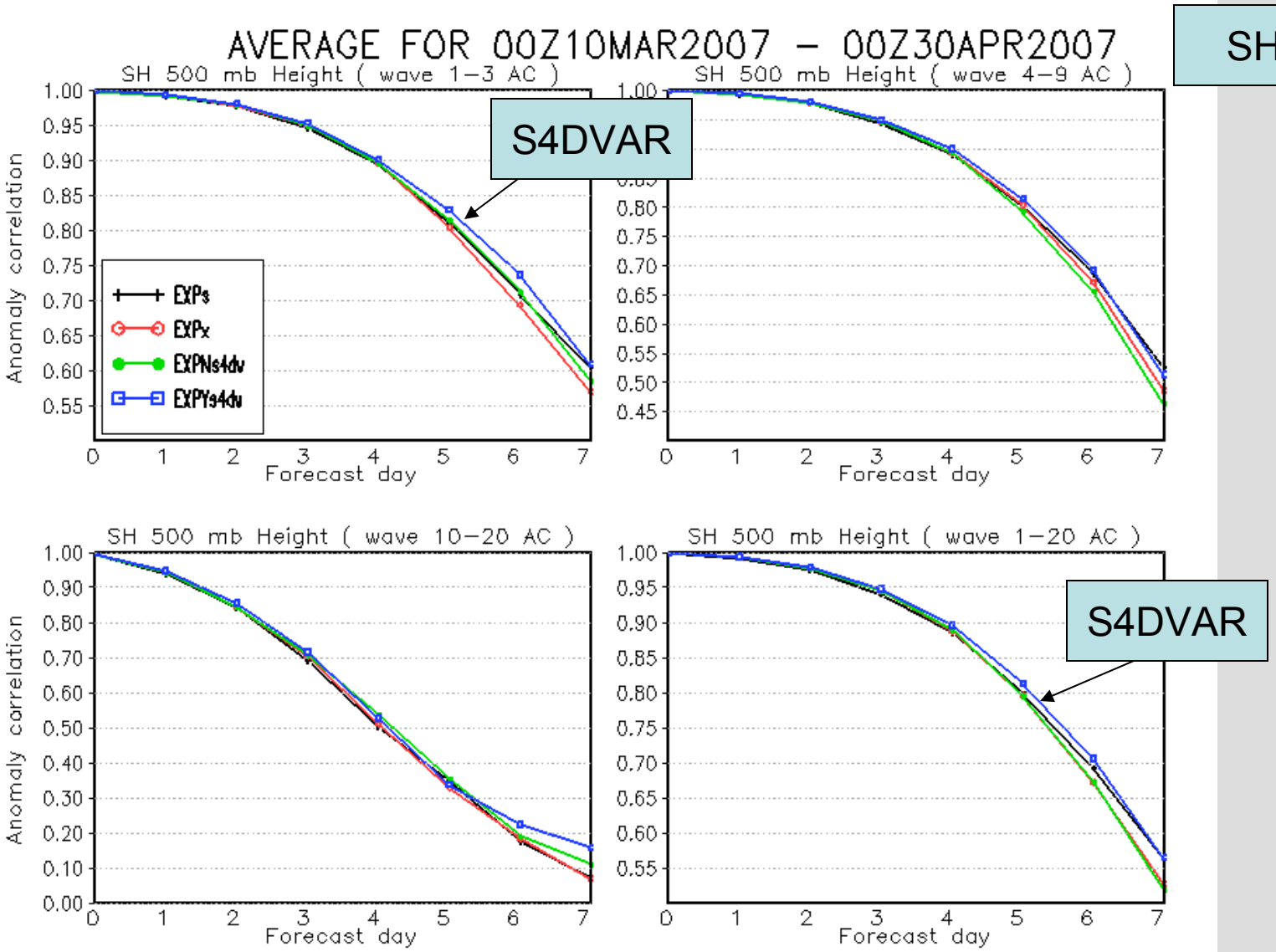
Ongoing work – Simplified 4DVAR

- Adiabatic time derivatives
  - Filtered to retain “slow” modes
  - Used to extrapolate state to obs times
  - Captures obs time changes due to slow modes
- No additional cost since calculations already included in constraint term

First S4DVAR Results



First S4DVAR Results (cont)



GSI Overview (cont)

- New observations (implemented 1 May)
  - **COSMIC**
  - **AIRS (all FOV)**

- New observations (testing)
  - Implemented 29 May
    - **METOP AMSU, HSB, HIRS**
    - **GOES 1x1 FOV sounder radiances**
  - Fall/Winter 2007/08
    - **AMSR-E**
    - **Windsat**
    - **SSM/IS**
    - **CHAMP**
- Observations under development
  - **IASI**
  - **OMI**

- New analysis variables
  - Constituent gas assimilation
  - **Aerosols**

- Improved radiative transfer
  - **Surface emissivity models**
  - **Cloud absorption & reflection**
- **Data sets (albedo, vegetation, land type)**
  - **Unified land surface treatment (data assimilation, model)**

Data Assimilation Development Strategy (cont)

- Yearly upgrades of S4DVAR & SDBE from NCEP/EMC will
  - Result in improved analysis capability
  - Set the bar and provide risk reduction for other work
- C4DV + EnsDA
  - 2007-2008
    - Prototype development
  - 2008
    - Full parallel testing
    - Transition decision (between 3 candidates)
  - 2009-2010 (if warranted)
    - Pre-implementation testing
    - Operational implementation

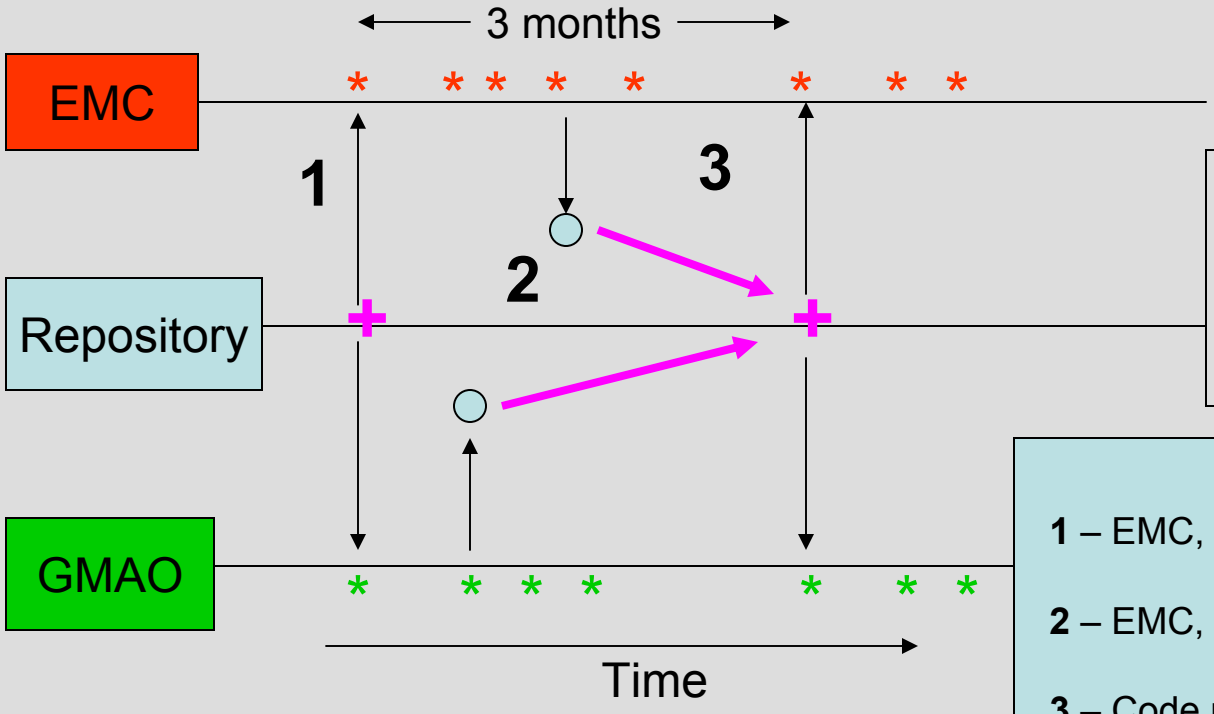
Data Assimilation Development Strategy

- Three closely related efforts
  1. Develop Simplified 4D-Var **(S4DVAR)** **and** Situation-Dependent Background Errors **(SDBE)**
  2. "Classical" 4D-Var **(C4DV)**
  3. Ensemble Data Assimilation **(EnsDA)**
- Partners
  - NCEP/EMC
  - NASA/GSFC/GMAO
  - THORPEX consortium
  - NOAA/ESRL
    - CIRES
    - U. Maryland
    - U. Washington
    - NCAR

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

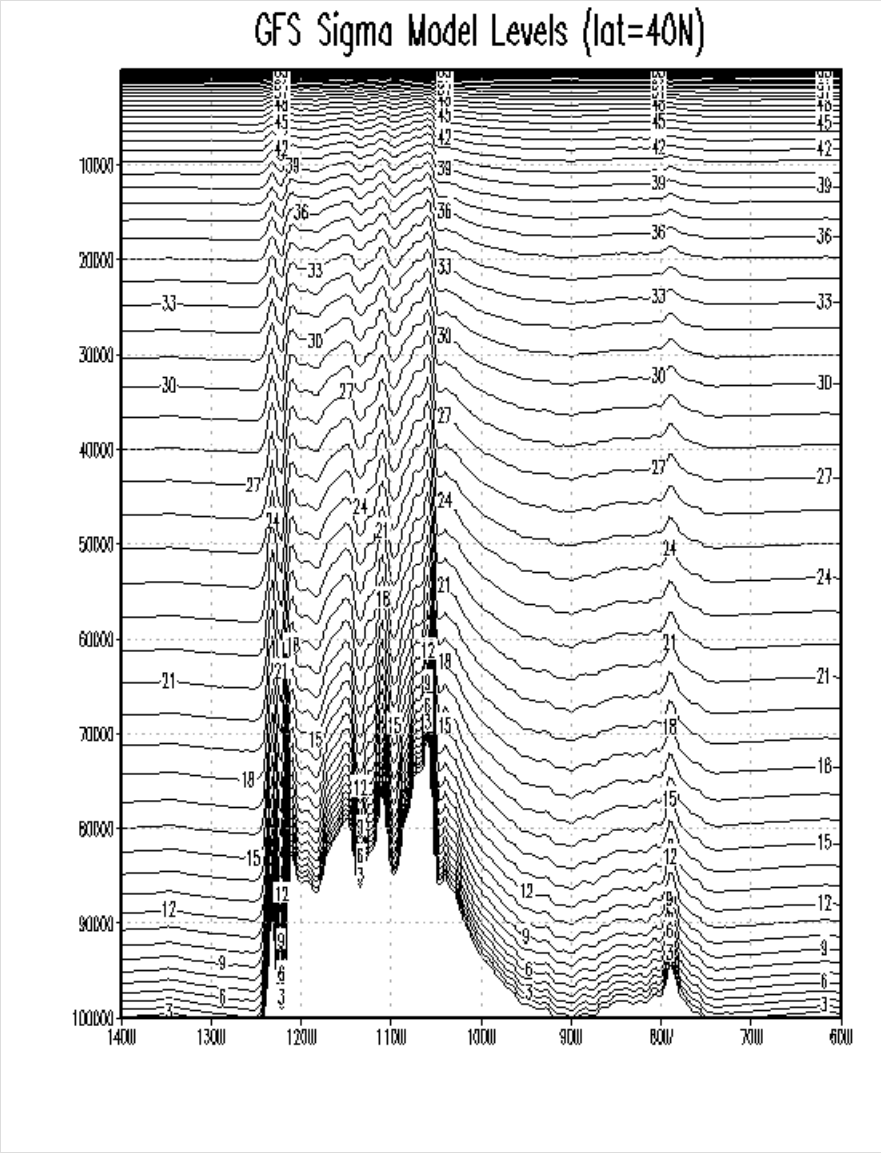
GFS implementation – 1 May 2007

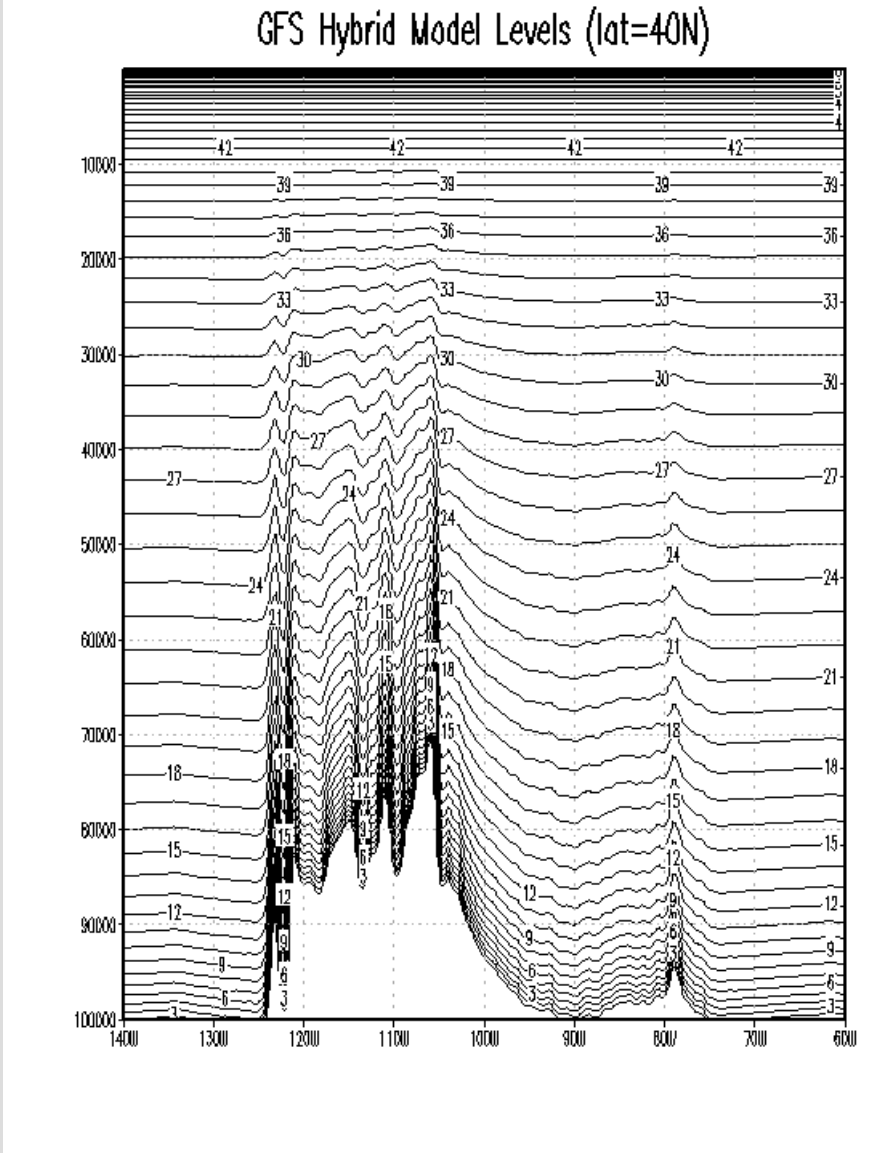
- GSI
  - Unify the NCEP 3DVAR assimilation system
  - Some performance metrics improved (but most neutral)
  - Prepare for future analysis improvements (e.g. S4DVAR)
- Add new observing systems
- Change vertical coordinate to hybrid sigma-pressure, reducing some upper air model errors
- Modernize the radiation package
- Increase output particularly for hydrology

Dynamics changes

- Hybrid sigma-pressure vertical coordinate
  - Model surface remain terrain-following in the lower troposphere but become pure pressure surfaces in the stratosphere
  - Reduces vertical advection errors and pressure-gradient calculation errors in the upper part of the model
  - Data assimilation and physics done on hybrid sigma-pressure coordinate as well

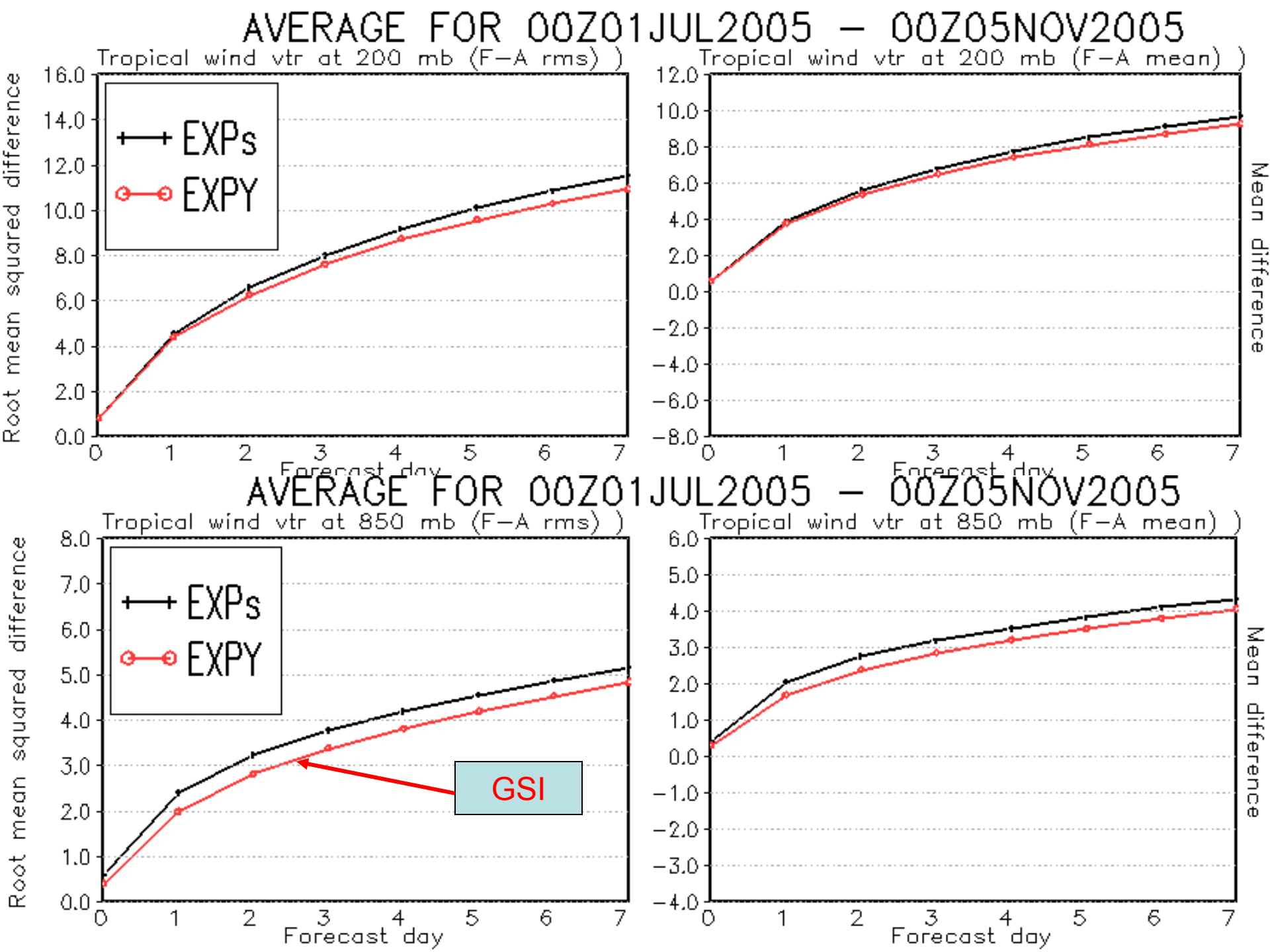
Vertical coordinate comparison across North America





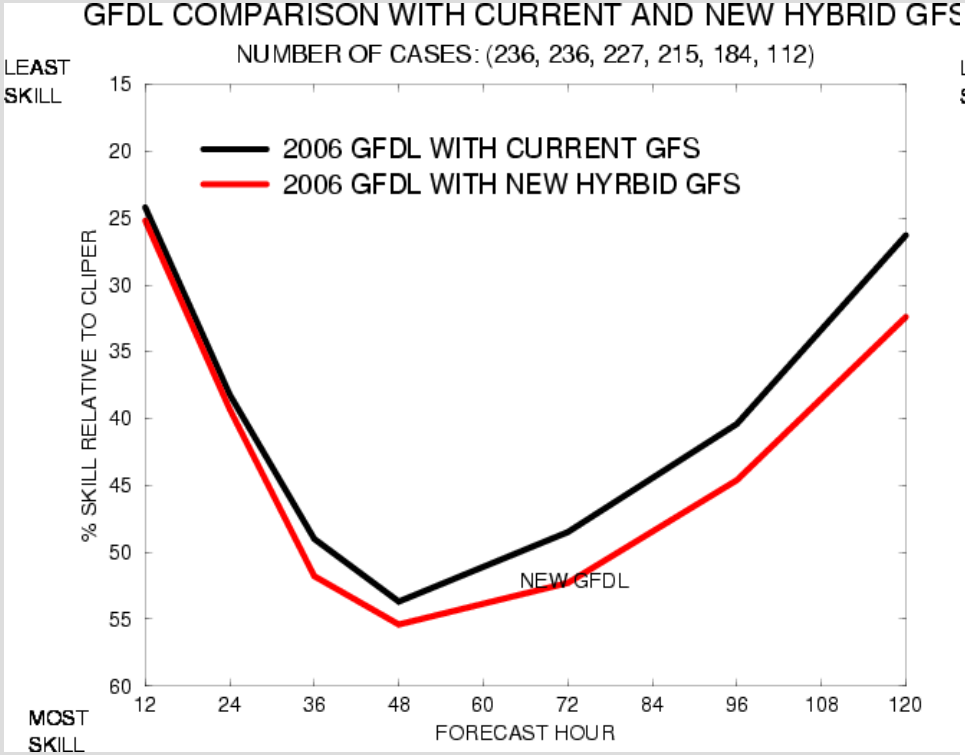
Final testing set

- Retrospective testing
  - 15 June 2005 to 5 November 2005
    http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.2005tropics_retro_gsihybrid.html
  - 31 July 2006 to 5 November 2006
    http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.2006tropics_retro_gsihybrid.html
  - 24 October 2006 to 5 February 2007
    http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.200607winter_retro_gsihybrid.html
- Real-time parallel
  - NCO started January 2007; in fairly final form about March 1, 2007 to present
    http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.gsihybrid.html

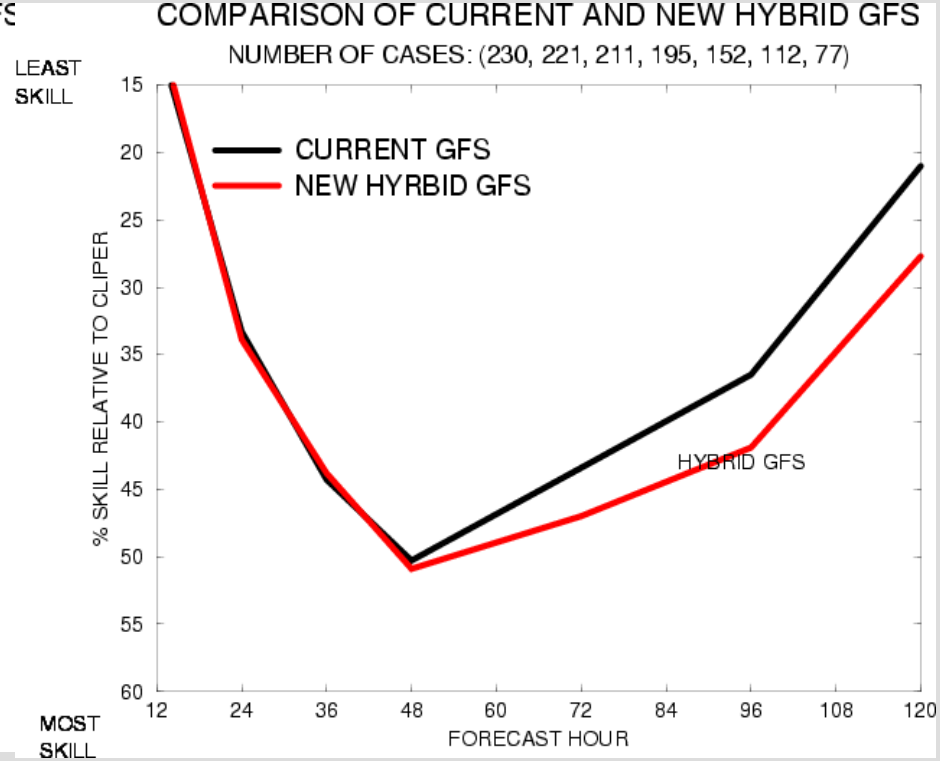

AVERAGE FOR 00Z01JUL2005 – 00Z05NOV2005
Tropical wind vtr at 200 mb (F–A rms)
Root mean squared difference
EXPs
EXPY
Forecast day
Tropical wind vtr at 200 mb (F–A mean)
Mean difference
AVERAGE FOR 00Z01JUL2005 – 00Z05NOV2005
Tropical wind vtr at 850 mb (F–A rms)
Root mean squared difference
EXPs
EXPY
GSI
Forecast day
Tropical wind vtr at 850 mb (F–A mean)
Mean difference

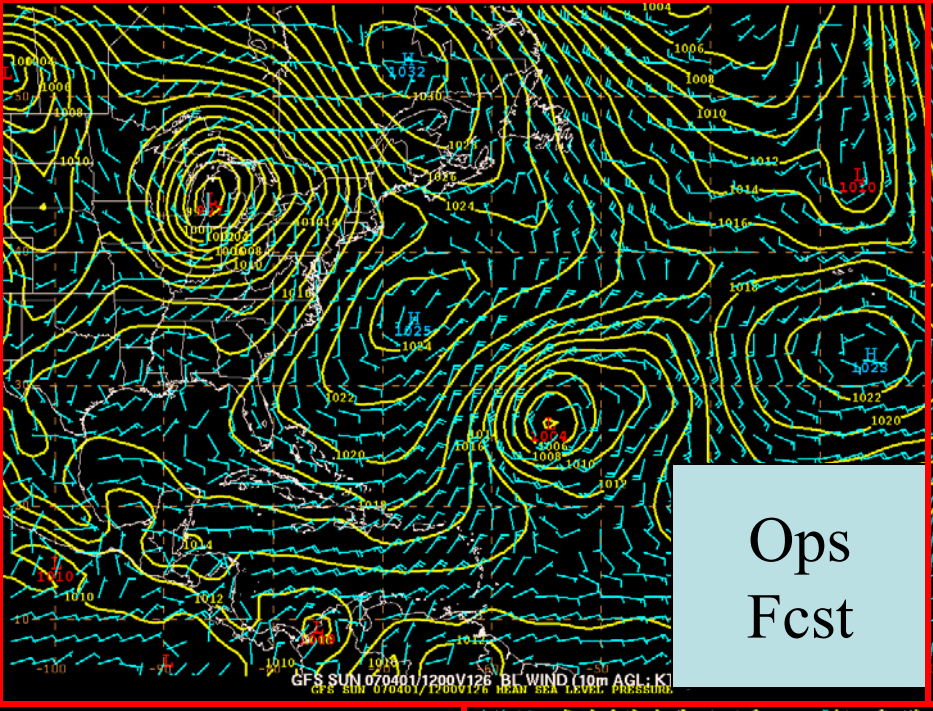
2005-2006 Atlantic Season Average Track Error Using The Current Operational and New GFS

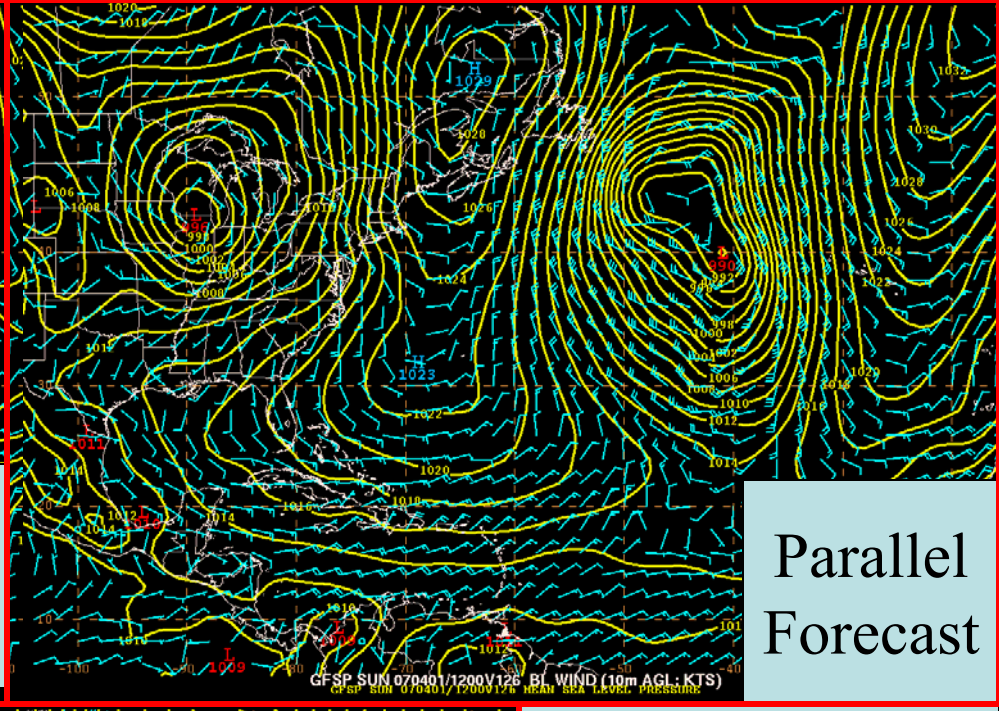
GFDL

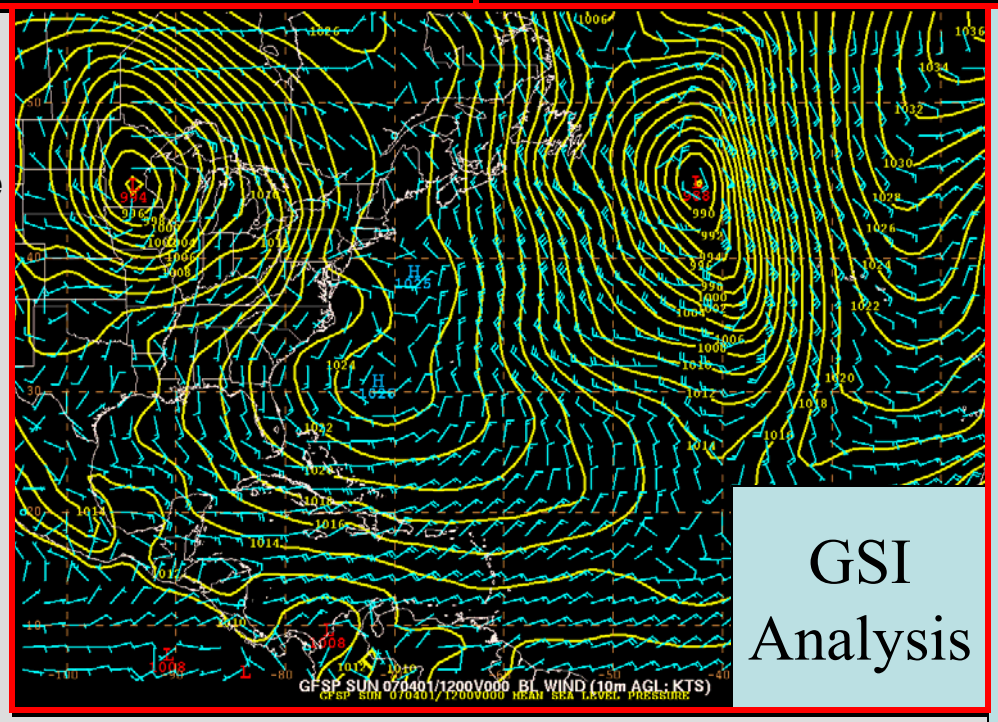


GFS









~5 day forecasts from the operational GFS (top left) and the hybrid/GSI GFS (top right) and verifying analysis (bottom) on 1 April 1200 UTC

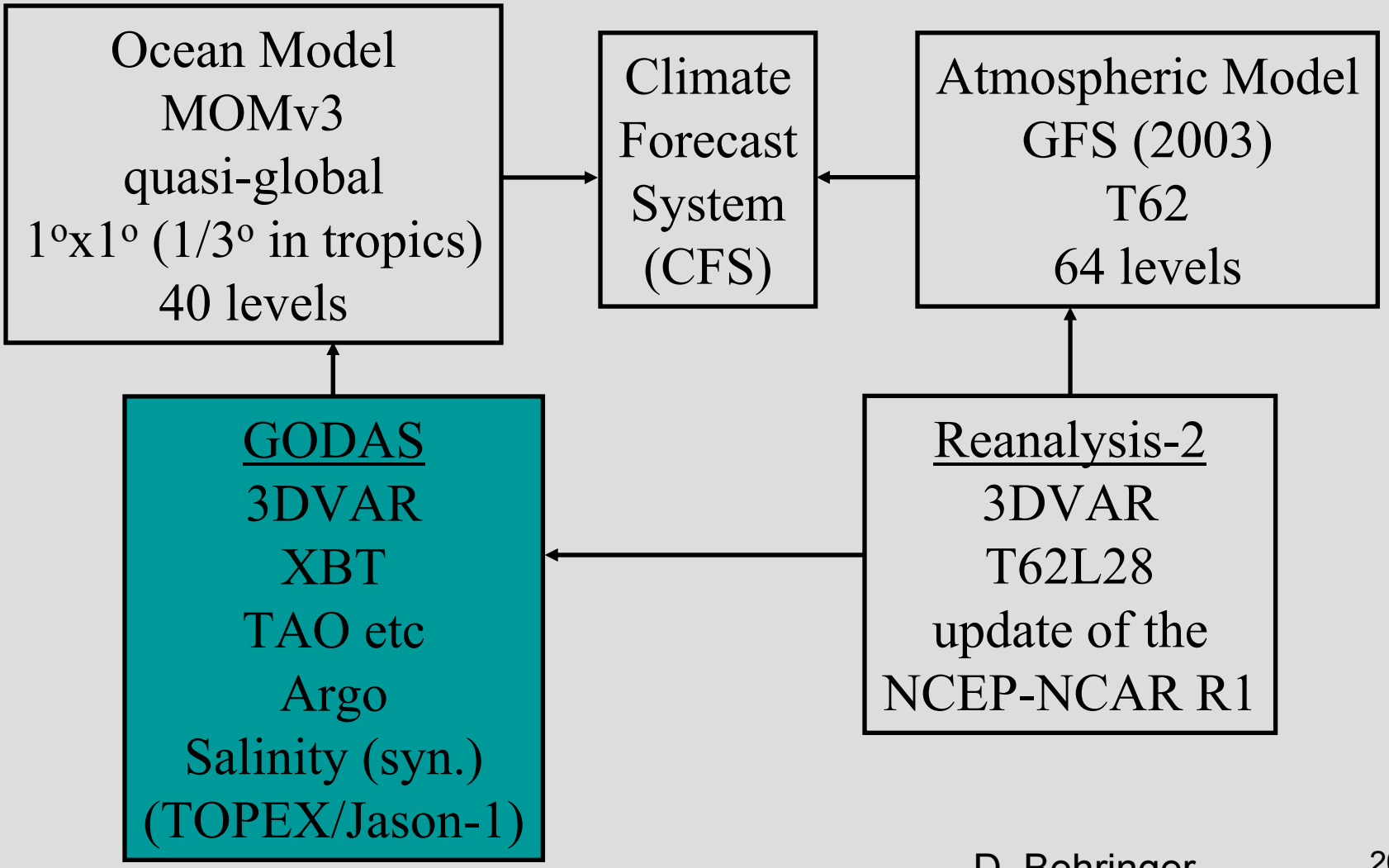
Example Of 5 day Forecast

10 m wind

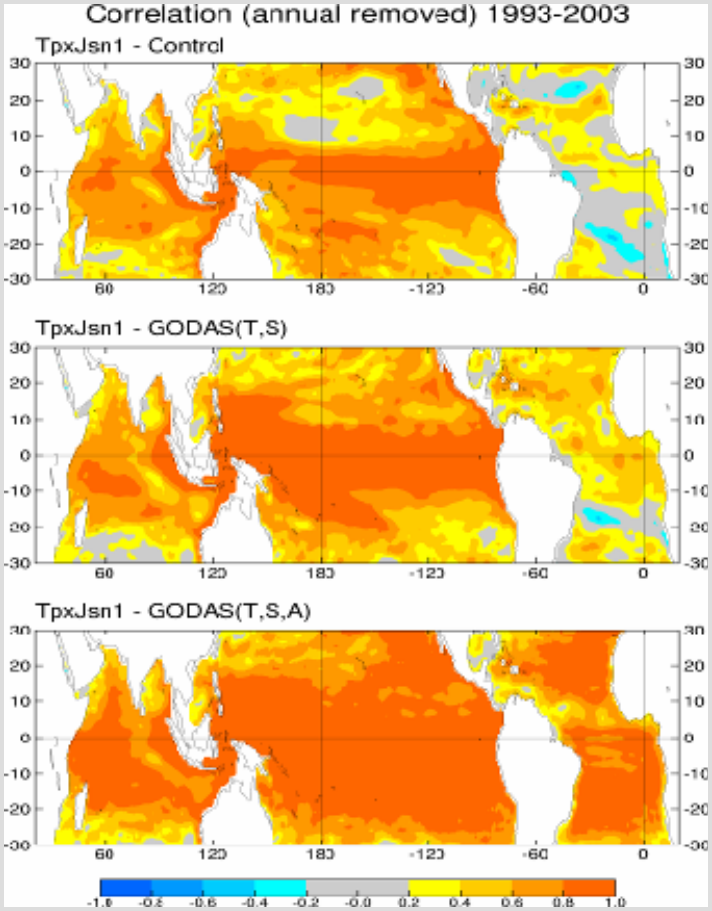
Valid 1 April 2007

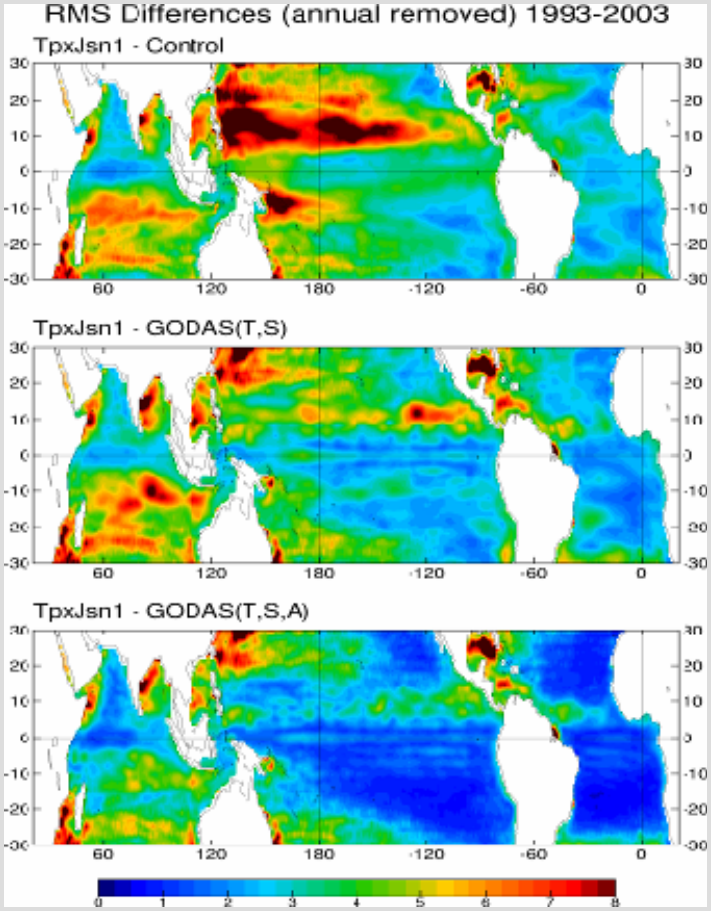
NCEP Parallel System

Seasonal to Interannual Prediction at NCEP



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

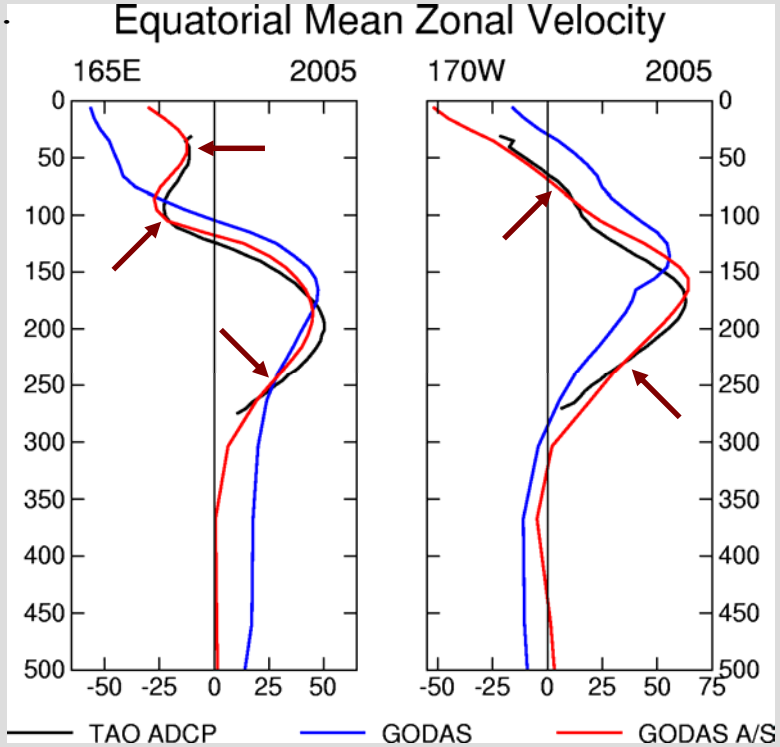
Smaller RMS errors

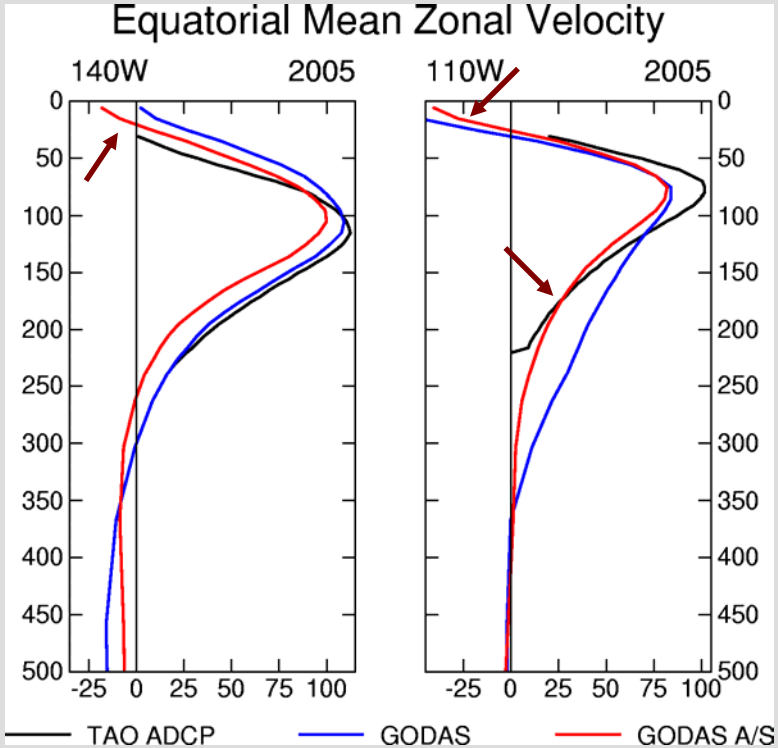
Assimilating Argo Salinity

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.

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

Comparison with independent ADCP currents.





ADCP GODAS GODAS-A/S

Real-Time Ocean Forecast System Mission

- Now
  - Routine estimation of the ocean state [T, S, U, V, W, SSH].
    - Daily 1 week forecast
    - Every 5 years
      - Evaluation
      - Re-initialization

- Future
  - Downscaling support for water levels (with NOS)
  - Improve ocean interaction in (nested) sub-domains for hurricane forecasts
  - Support estimates of chemical components (water quality) and organisms distributions in the water (ecosystems)
  - Improved estimation of the atmosphere state
    - In short term global forecast
    - In short term regional forecast

CURRENT RT-OFS Atlantic Description (S1)

Dynamical Model (HYCOM)

- State variables: Temperature, Salinity, Velocity, Sea surface elevation.
- Primitive equation with free surface.
- Horizontal grid: orthogonal, dx/dy~1
- Open boundaries (climatology and tidal model)
- Sub-grid scale parameterizations. Vertical and horizontal eddy viscosity and mixing.
- Tides, river outflow (USGS, climatology)
- Atmospheric fluxes (GDAS, GFS)

CURRENT RT-OFS Atlantic Description (S1)

Data Assimilation

- Data:
  - SST: AVHRR, GOES, In-situ
- 2DVAR with vertical projection.
  - SST: Time interpolated analysis values are nudged during nowcast in the mixed layer.

CURRENT RT-OFS Atlantic Description (S1)

Daily Operations and Product Distribution

- Once daily (4Z)
  - Nowcast 1 day
  - Forecast 5 days
- Grib files for nowcast and forecast
  - Hourly surface T,S,U,V, SSH, barotropic velocity, mixed layer depth
  - Daily T,S,U,V,W, SSH for 40 depths
- Product distribution
  - NCO servers (ftpprd)
  - NOMADS [sub-setting] (full data server functions)
  - MMAB Web server (ftp, graphics)

Updates (S2)

- MODEL ALGORITHMS
  - Surface initialized Montgomery Potential
  - Modify boundary condition, giving two invariant external modes
  - Stabilization of density function (T, p)
  - Enforced salinity minimum by refreshing the water column
- DATA ASSIMILATION ALGORITHM
  - SST: spatially varying bias removal algorithm
  - SSH
    - Assimilation of absolute sea surface height
    - 2D variational sea surface height, with 1D vertical covariance of sea surface height and layer thicknesses
    - Reset layer transports preserving momentum
  - Temperature & Salinity
    - Assimilation of vertical profiles of temperature and salinity (ARGO & CTD)
    - 2D variational of density, temperature and layer thickness anomalies
    - Re-layering preserves volume, momentum; and updated mass and heat

Updates (S2)

DATA INPUTS:

- Revised vertical grid parameters:
  - 26 layers, with
    - higher resolution in the shallow waters
    - better resolution on the shelf break
    - better representation of Denmark & Iceland overflows
    - resolving 4 vertical dynamical modes in major sub-basins
- Improved barotropic / baroclinic inputs at open boundaries
  - Updated Climatology (NCEP – version 6)
  - Mean dynamic topography (Rio 5)
  - Historical transports
- Revised river inflow data (location and strength) from USGS
- Remove noise in net heat flux

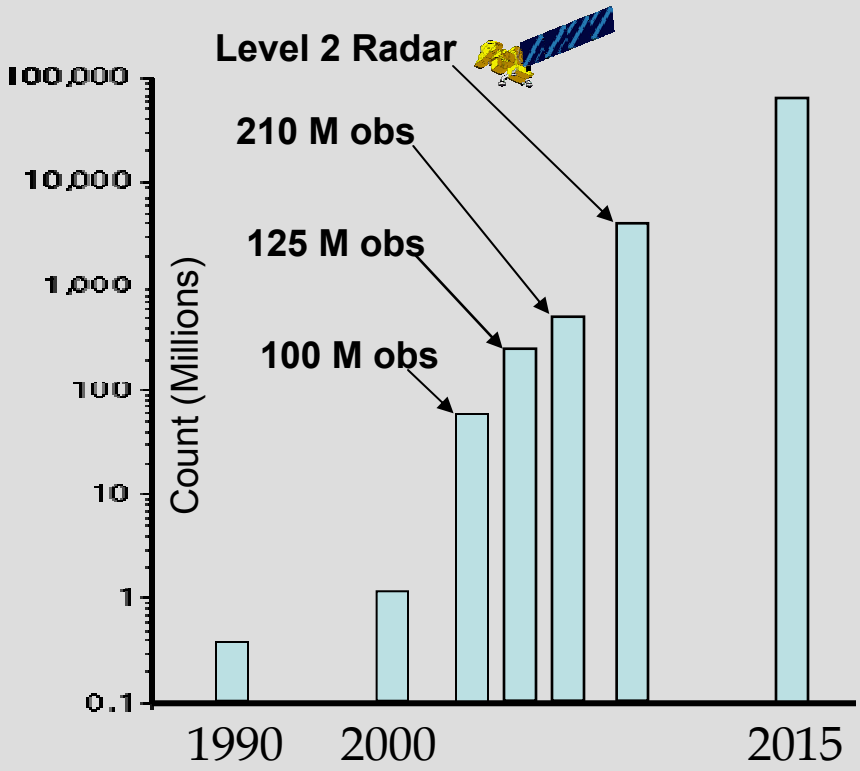
GFS+GOCART Offline System

- GFS
  - NCEP/EMC Global Forecast System
- GOCART
  - NASA Goddard Global Ozone Chemistry Aerosol Radiation and Transport Model
- Steps
  - (1) dust modeling
  - (2) aerosol modeling
- Work with NRL (NAAPS)

Supplementaries

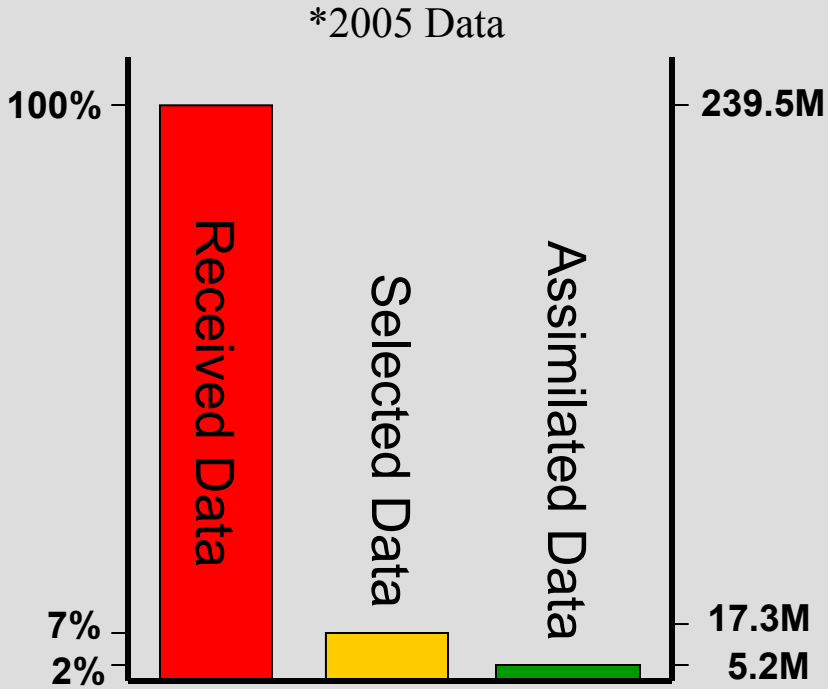
Satellite Data Ingest

Daily Satellite & Radar Observation Count

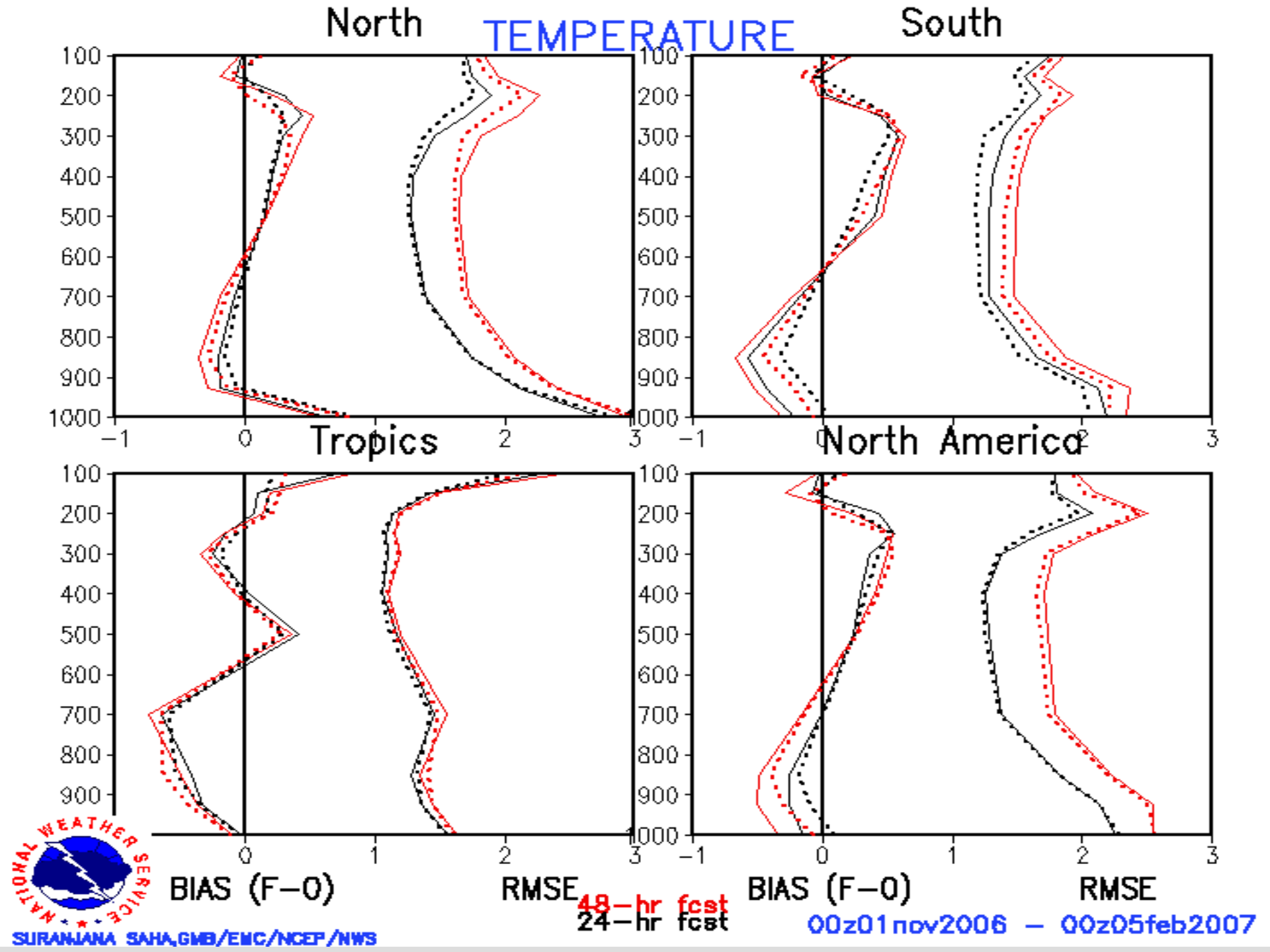


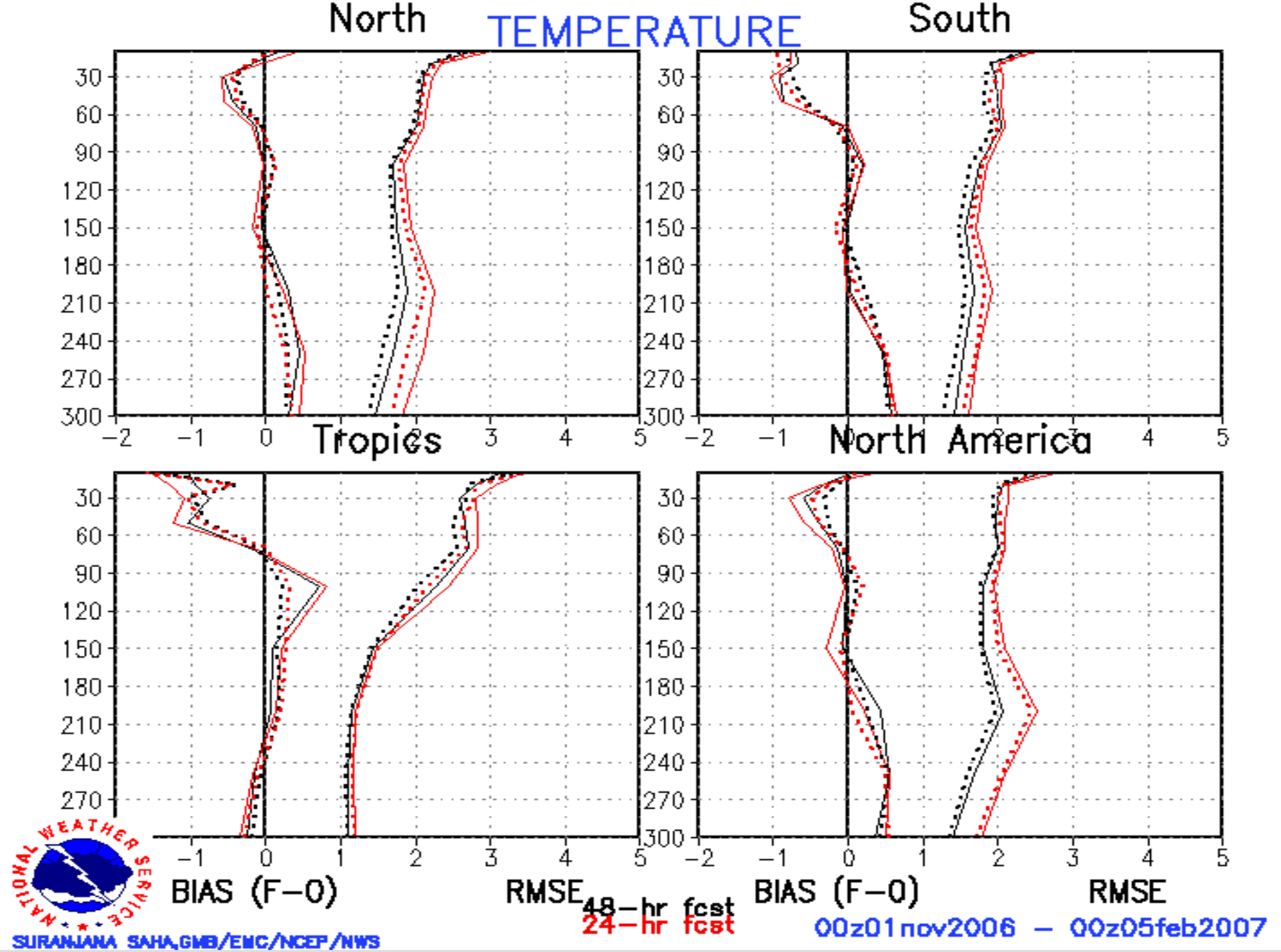
Five Order of Magnitude Increases in Satellite Data Over Fifteen Years (2000-2015)

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


North
TEMPERATURE
South
Tropics
North America
BIAS (F−O)
RMSE
BIAS (F−O)
RMSE
48−hr fcst
24−hr fcst
00z01nov2006 − 00z05feb2007
NATIONAL WEATHER SERVICE
SURANJANA SAHA,GMB/EMC/NCEP/NWS


North
TEMPERATURE
South
Tropics
North America
30
60
90
120
150
180
210
240
270
300
−2
−1
0
1
2
3
4
5
BIAS (F−O)
RMSE
48−hr fcst
24−hr fcst
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NATIONAL WEATHER SERVICE
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