



NCEP Satellite Data Assimilation Overview

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Outline

- I. Overview: NCEP Gridpoint Statistical Interpolation (GSI) analysis**
- II. Data assimilation development strategy**
- III. GFS implementation - 1 May (today)**
- 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
 - F90/95 structures and utilities
 - Improved efficiency
 - Re-designed data distribution
 - Some OpenMP
 - Better documentation
 - Improved portability
 - Less dependency on IBM
- Currently 38 registered groups/users
 - NCEP providing only minimal support for external groups due to lack of resources
- 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

GSI Overview (cont)

- New observations (implemented)
 - COSMIC
 - AIRS (all FOV)
- New observations (testing)
 - Summer 2007
 - METOP AMSU, HSB, HIRS
 - GOES 1x1 FOV sounder radiances
 - Fall/Winter 2007/08
 - AMSR-E
 - Windsat
 - SSM/IS
 - CHAMP
- Observations under development
 - IASI
 - OMI
 - ENVISAT altimeter
- New analysis variables
 - Constituent gas assimilation
 - Aerosols
- Improved radiative transfer
 - Surface emissivity models
 - Cloud absorption & reflection
- Data sets (albedo, vegetation, land type) from JCSDA
 - Unified land surface treatment (data assimilation, model)

Data Assimilation Development Strategy

- Three closely related efforts
 1. Develop Simplified 4D-Var (**S4DV**) and Situation-Dependent Background Errors (**SDBE**)
 2. “Classical” 4D-Var (**C4DV**)
 3. Ensemble Data Assimilation (**EnsDA**)
- Partners
 - NCEP/EMC
 - NASA/GSFC/GMAO
 - THORPEX consortium (**TC**)
 - NOAA/ESRL
 - CIRES
 - U. Maryland
 - U. Washington
 - NCAR

Data Assimilation Development Strategy (cont)

- Flexible schedule due to advanced nature of work
 - ~yearly upgrades of SDBE/S4DV from NCEP/EMC
- C4DV + EnsDA
 - 2007-2008
 - Prototype development
 - 2008
 - Full parallel testing
 - Transition decision (between 3 candidates)
 - 2009-2010 (if warranted)
 - Pre-implementation testing
 - Operational implementation

GFS implementation – 1 May 2007

- Unify the NCEP 3DVAR assimilation system under the GSI, improving some performance metrics without affecting others and preparing for future analysis improvements
- Change vertical coordinate to hybrid sigma-pressure, reducing some upper air model errors
- Add new observing systems
- Modernize the radiation package
- Increase output particularly for hydrology

GFS implementation – 1 May 2007

Upgrades

- Analysis
 - GSI (Gridpoint Statistical Interpolation)
- Observations
 - Full resolution AIRS
 - COSMIC GPSRO
- Model
 - Physics
 - Modularized radiation package
 - Dynamics
 - Hybrid sigma-pressure vertical coordinate
- Post processing and products
 - Output hourly GDAS files
 - Change to internal model history file
 - More fields output in model flux file

Physics changes

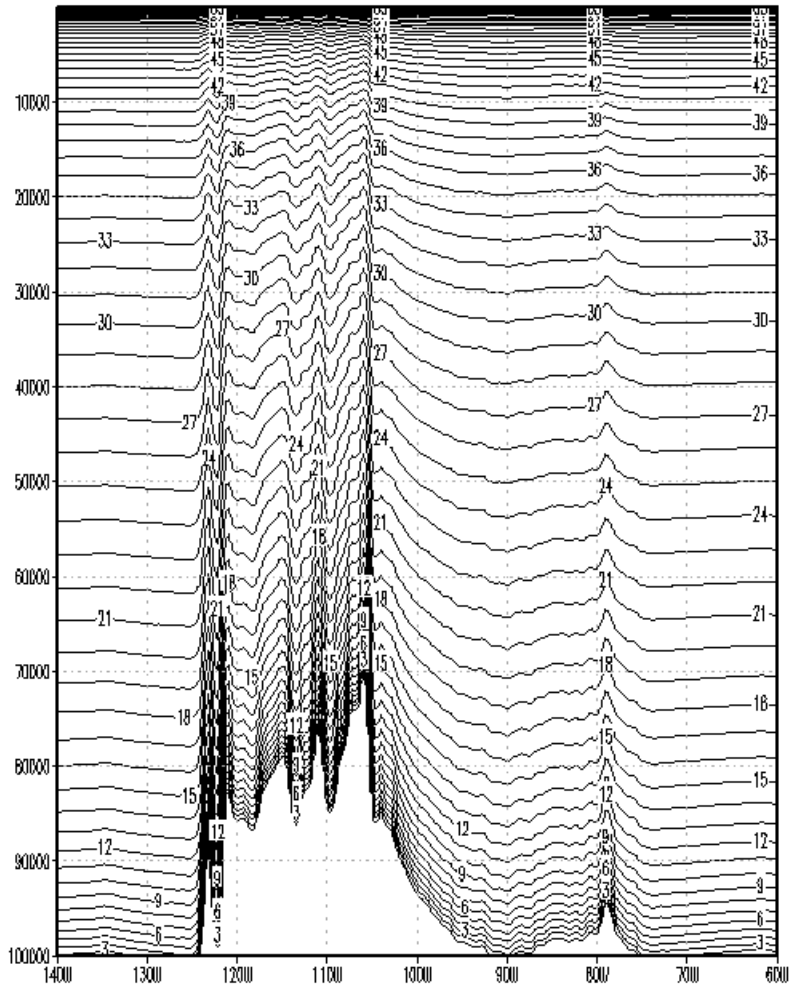
- Modularized radiation package
 - Overall restructuring of radiation related programs to help future development and upgrade.
 - In RRTM1-LW, minor upgrade of emissivity coefficient. Rare gas absorption effect turned on.
 - In aerosol calculation, vertical sigma based structure changed to pressure based structure
 - Minor bug correction in cloud related calculation
 - Performance of new radiation very close to operational model

Dynamics changes

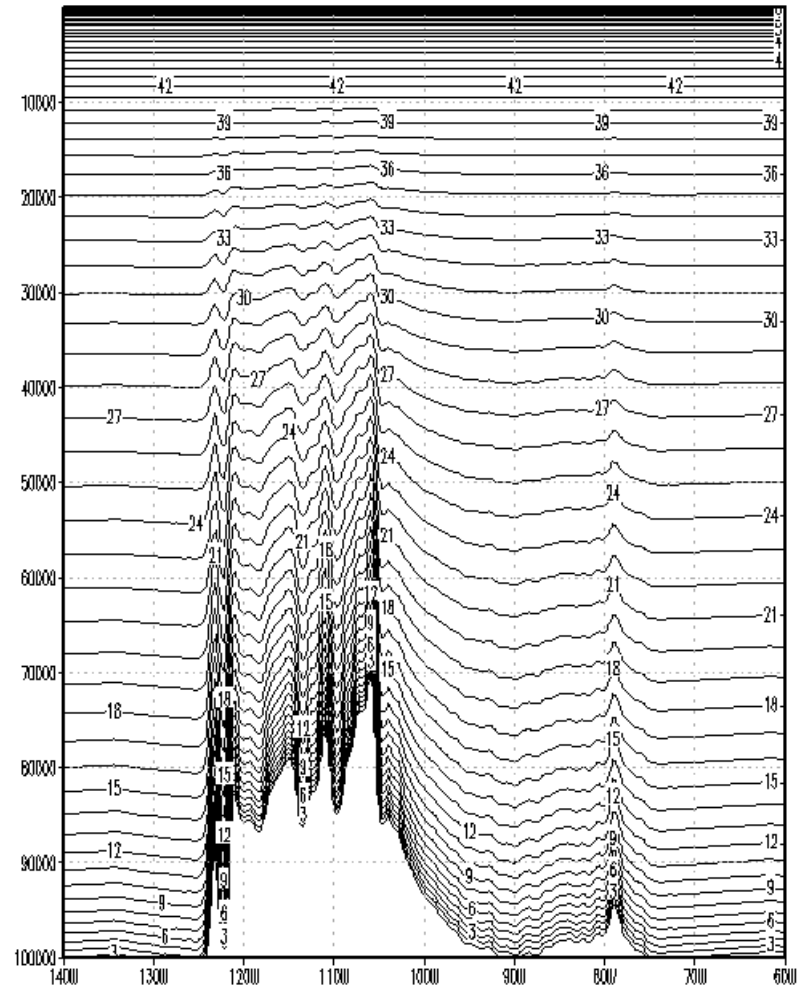
- Hybrid sigma-pressure vertical coordinate
 - Model surface remain terrain-following in the lower troposphere but become pure pressure surfaces in the stratosphere
 - Reduces vertical advection errors and pressure-gradient calculation errors in the upper part of the model
 - Data assimilation and physics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

Vertical coordinate comparison across North America

GFS Sigma Model Levels (lat=40N)



GFS Hybrid Model Levels (lat=40N)



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

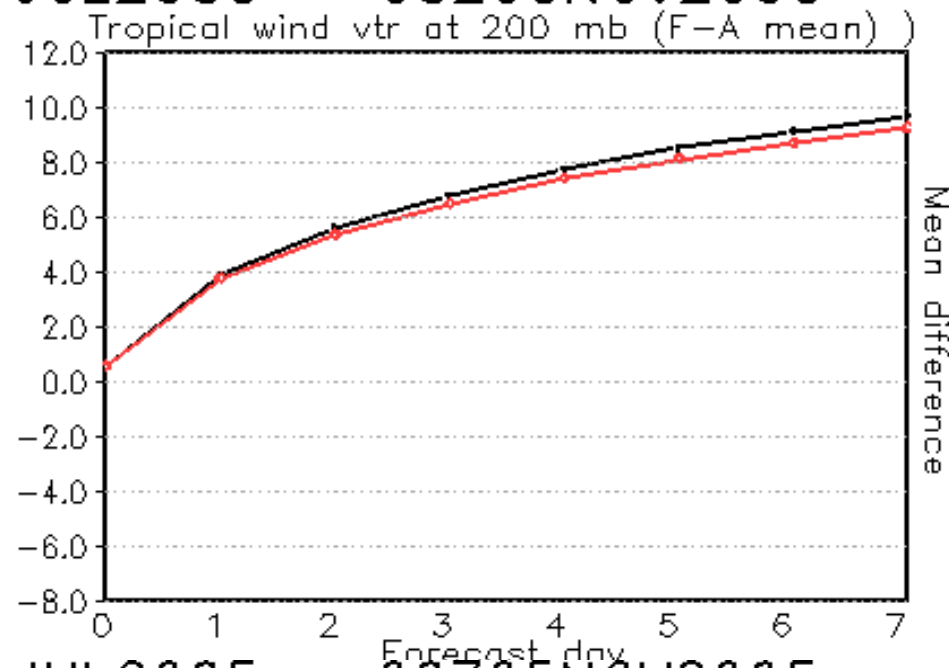
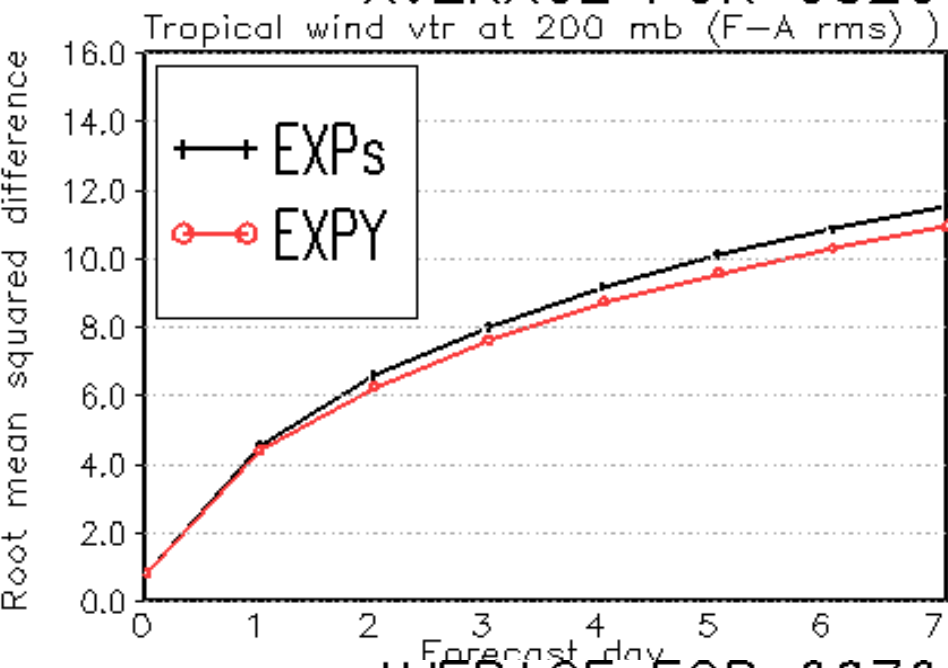
- http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.200607winter_retro_gsihybrid.html

- Real-time parallel

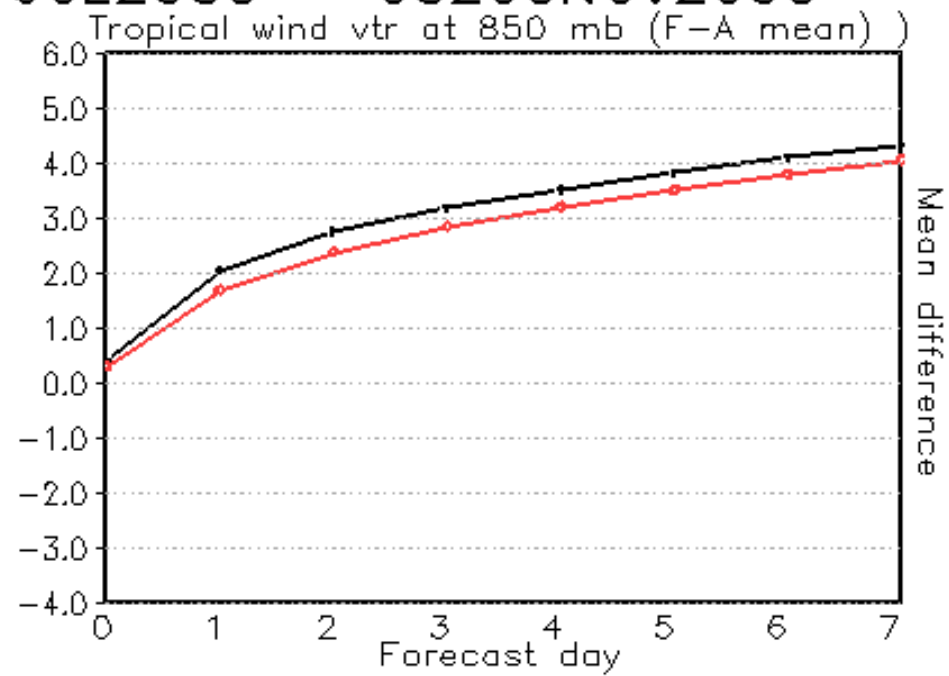
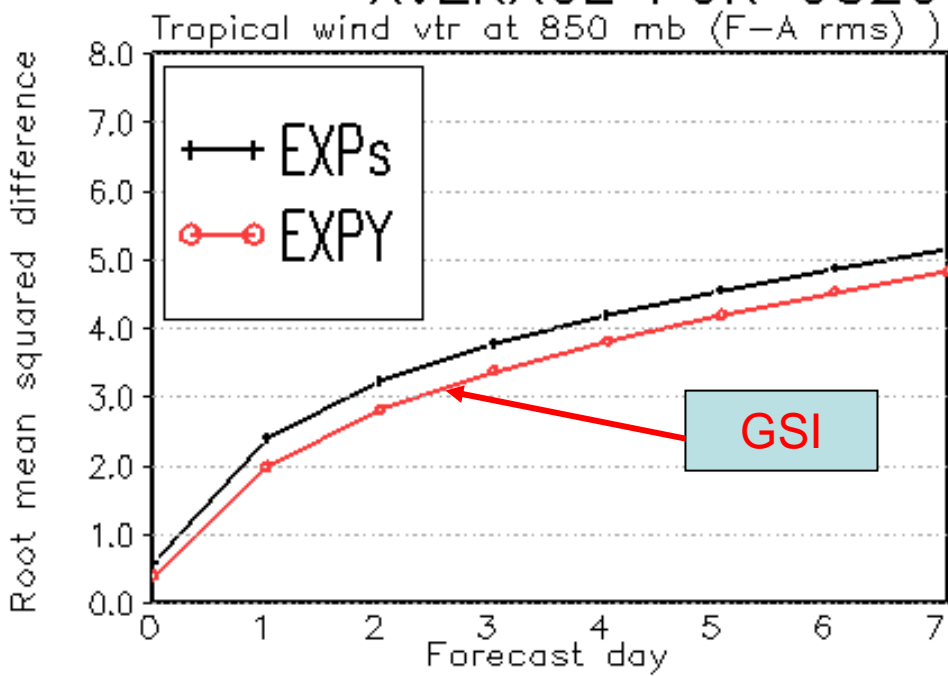
- NCO started January 2007; in fairly final form about March 1, 2007 to present

- <http://wwwt.emc.ncep.noaa.gov/gmb/para/paralog.gsihybrid.html>

AVERAGE FOR 00Z01JUL2005 – 00Z05NOV2005



AVERAGE FOR 00Z01JUL2005 – 00Z05NOV2005



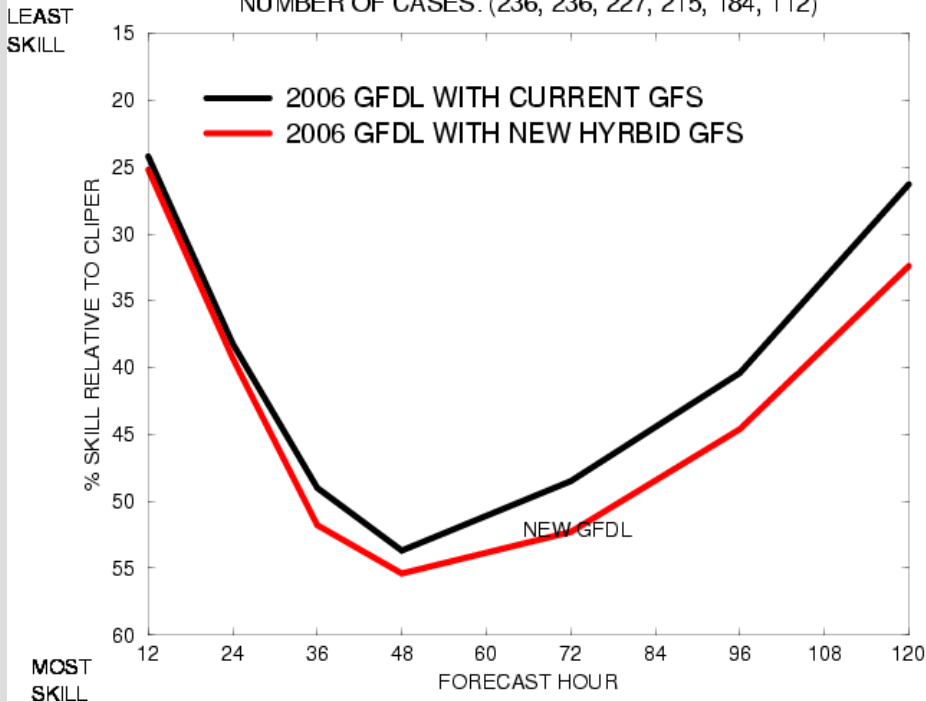
2005-2006 Atlantic Season Average Track Error Using The Current Operational and New GFS

GFDL

GFS

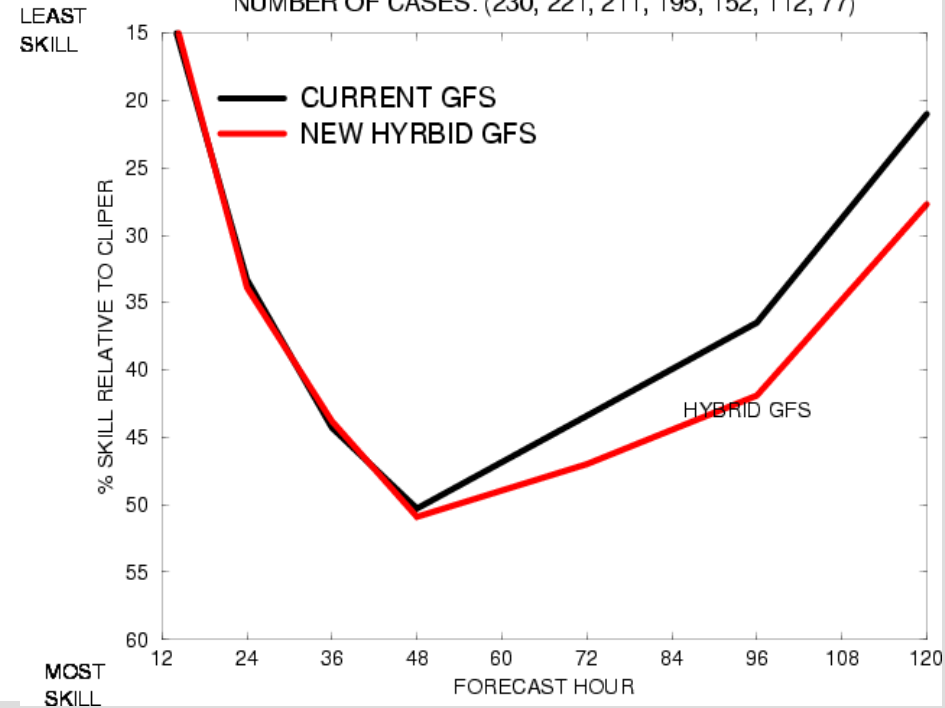
GFDL COMPARISON WITH CURRENT AND NEW HYBRID GFS

NUMBER OF CASES: (236, 236, 227, 215, 184, 112)



COMPARISON OF CURRENT AND NEW HYBRID GFS

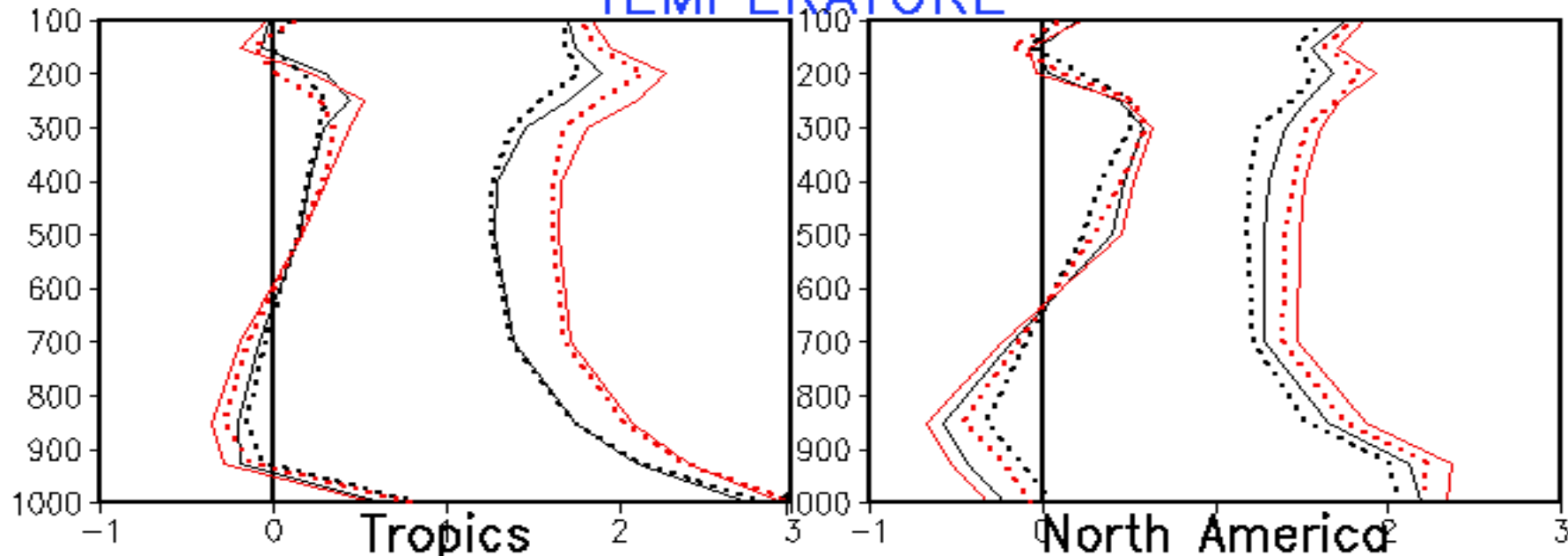
NUMBER OF CASES: (230, 221, 211, 195, 152, 112, 77)



North

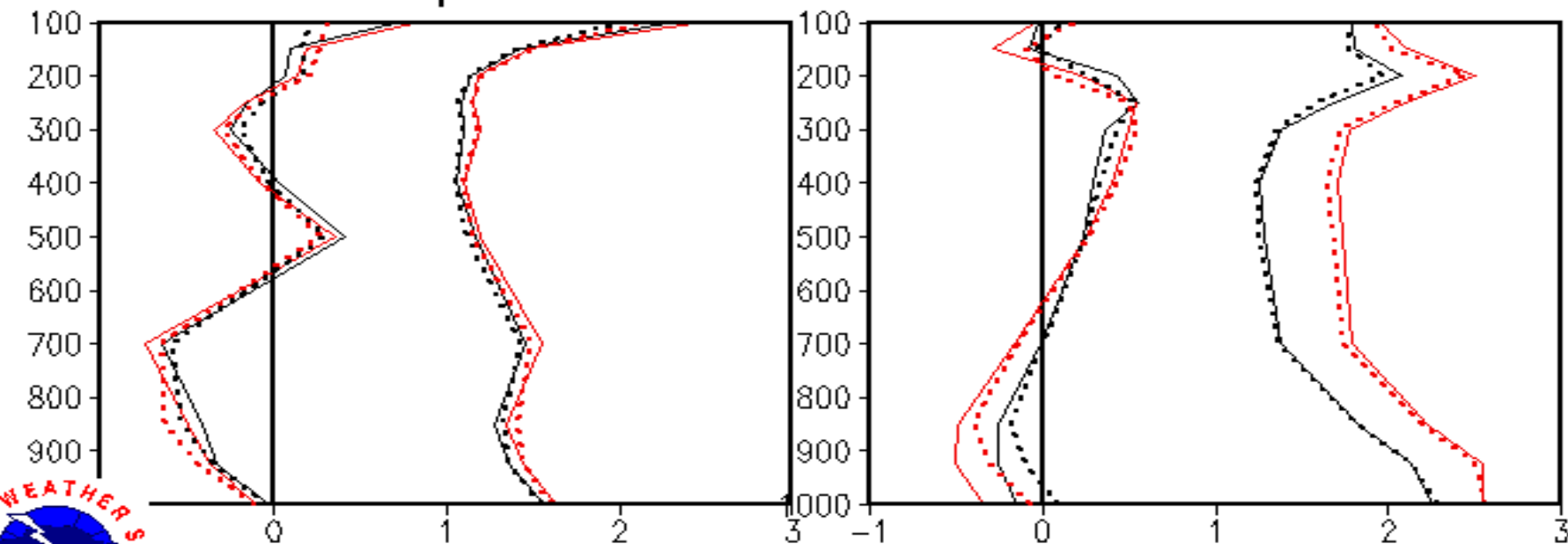
TEMPERATURE

South



Tropics

North America



BIAS (F-0)

RMSE

BIAS (F-0)

RMSE

48-hr fcst
24-hr fcst

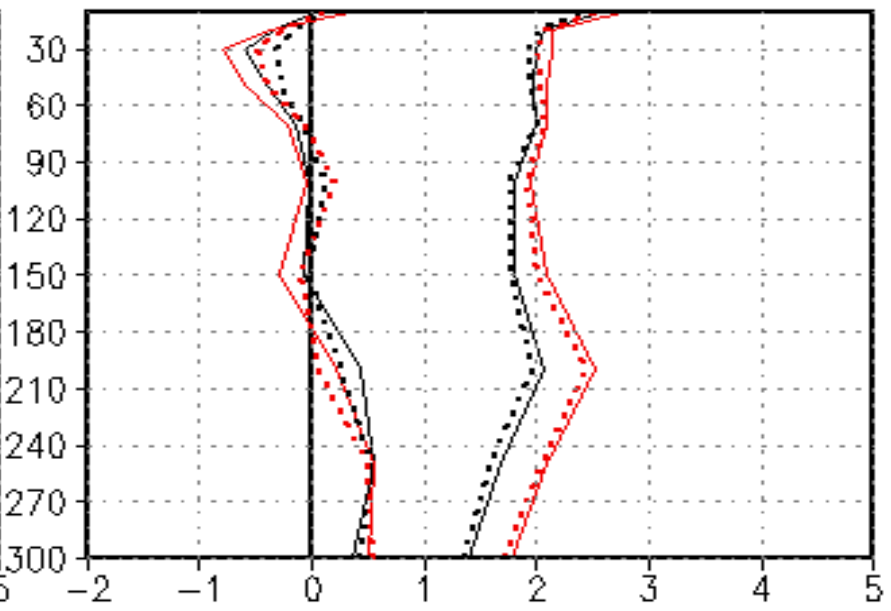
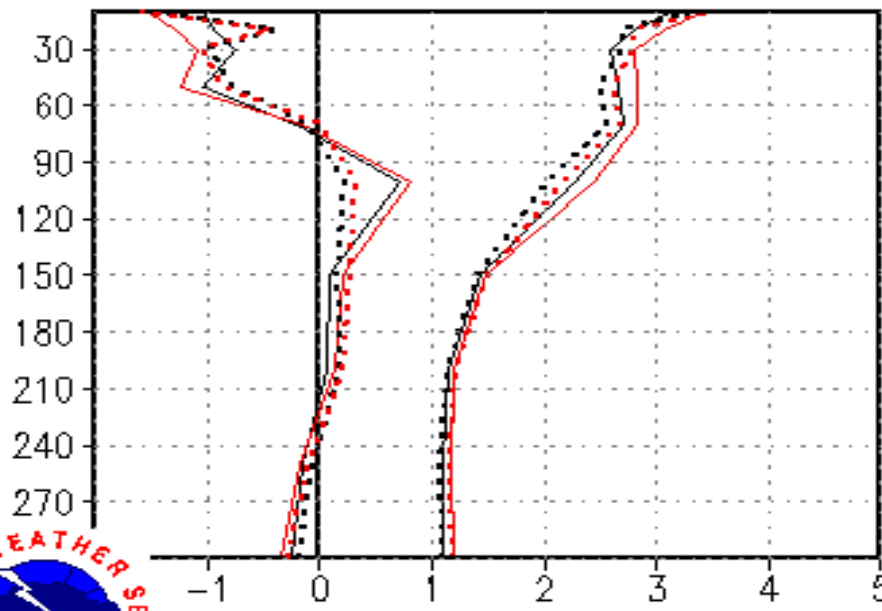
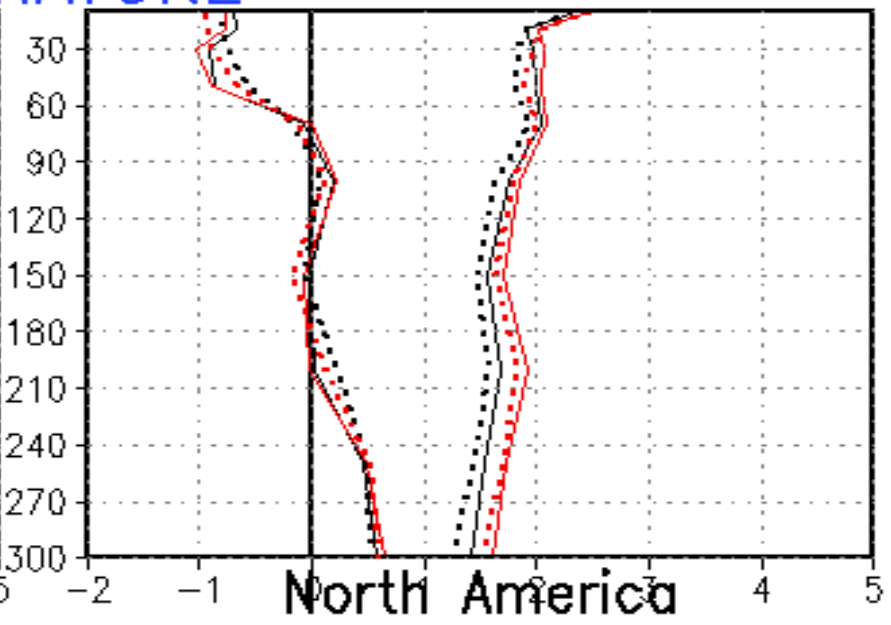
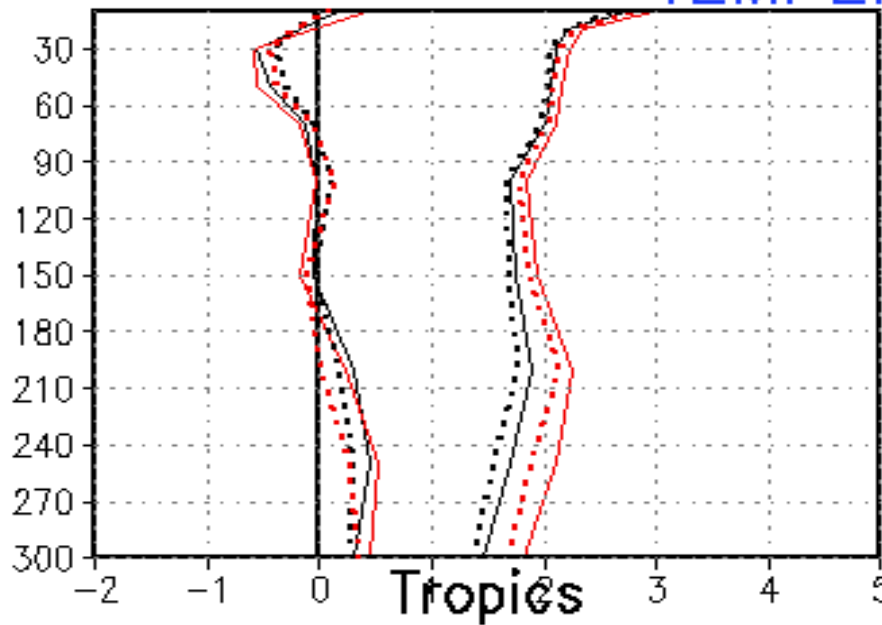
00z01nov2006 - 00z05feb2007



North

TEMPERATURE

South



BIAS (F-0)

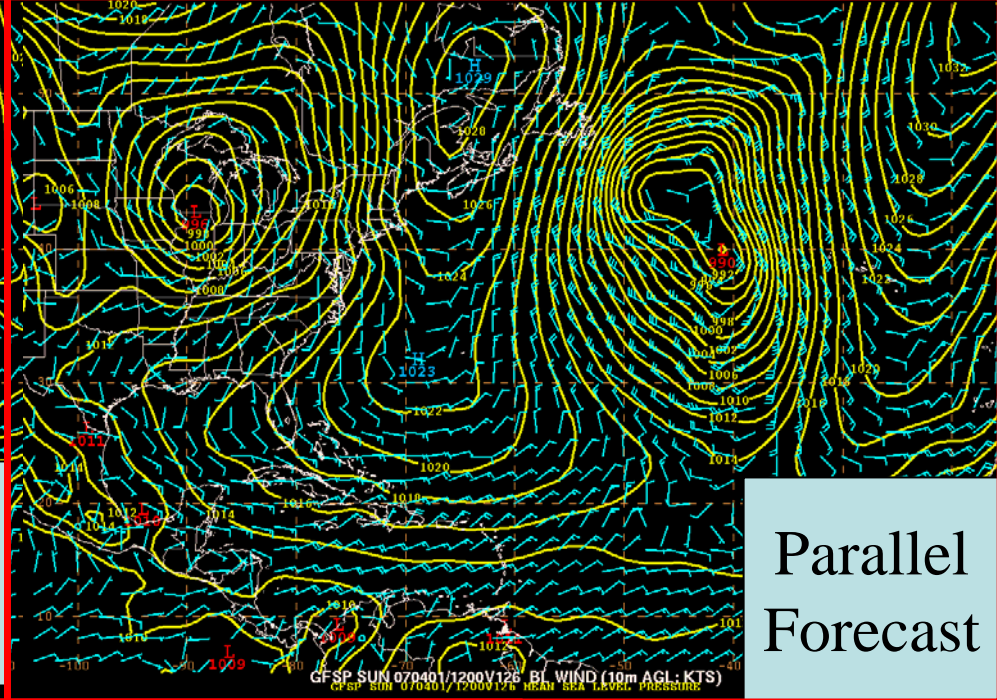
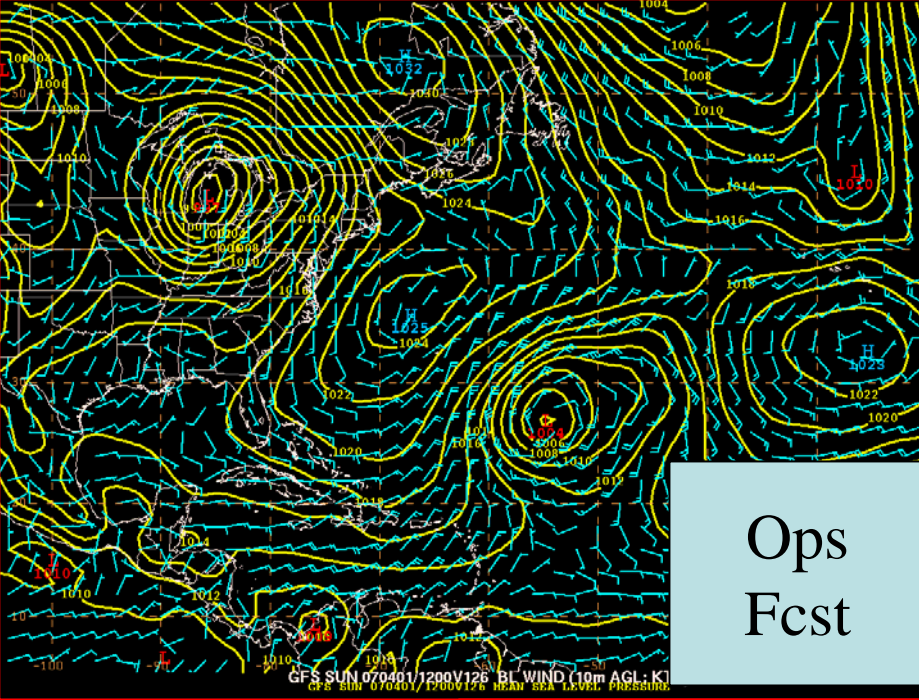
RMSE
48-hr fcst
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BIAS (F-0)

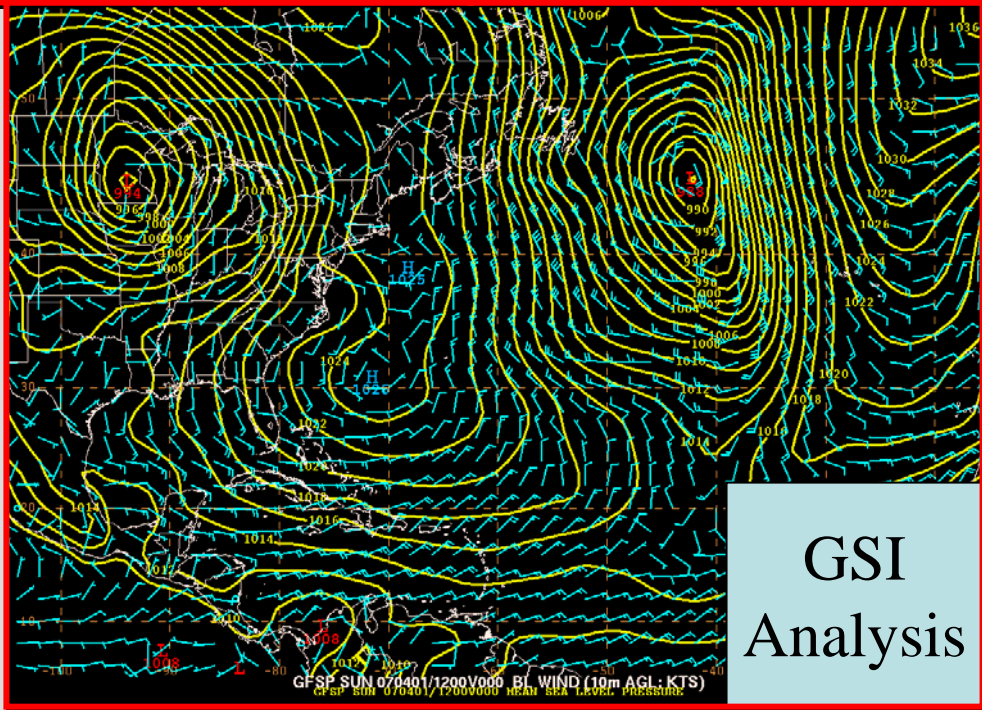
RMSE

00z01nov2006 - 00z05feb2007





~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

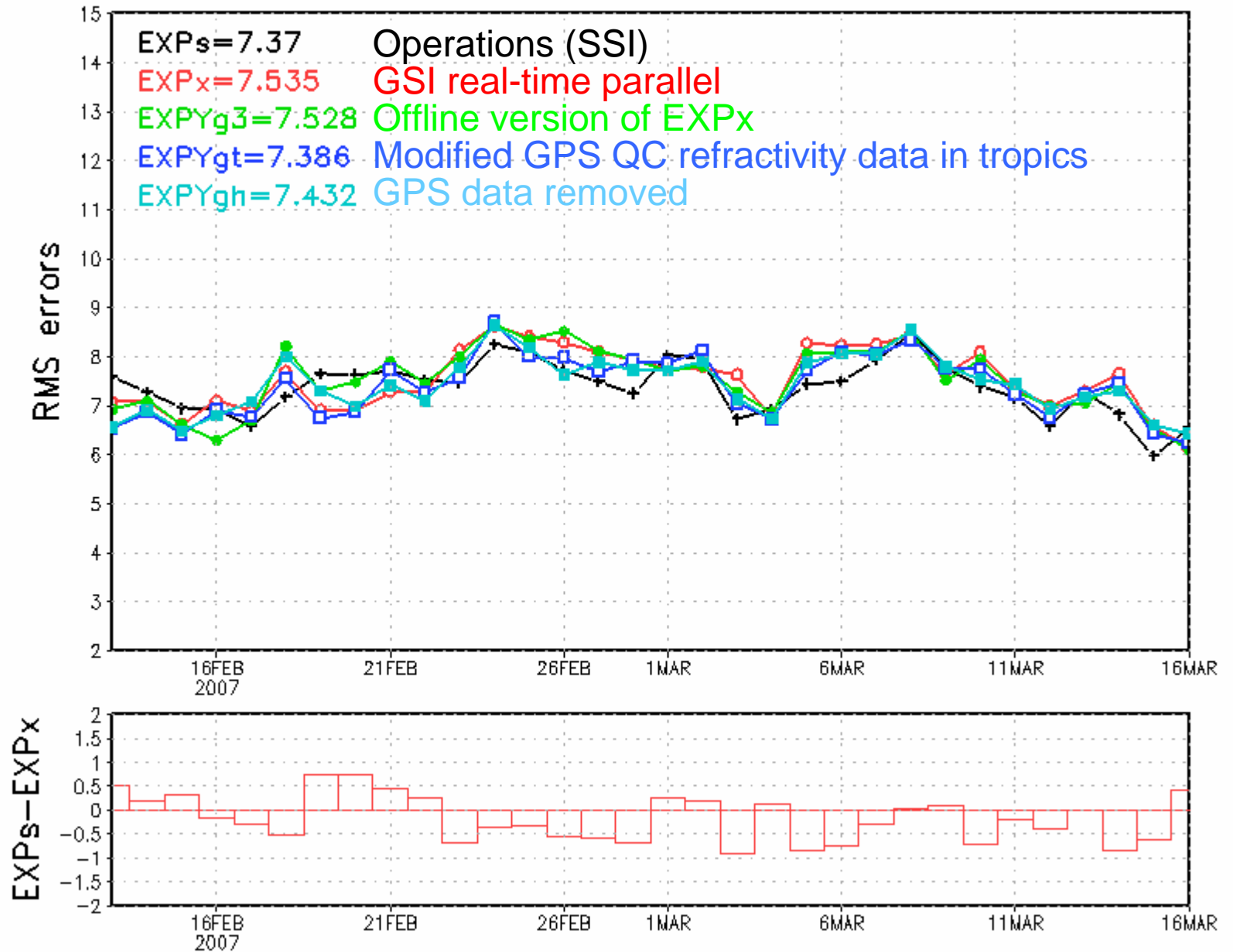


**Example
Of 5 day
Forecast
10 m wind
Valid
1 April 2007
NCEP
Parallel
System**

Tightening COSMIC QC in the tropics

- COSMIC experiments in fall 2006 and early winter 2007 showed positive impact
- In February 2007, several changes related to satellite winds went operational, and at the same time new observations including COSMIC were included real-time parallel data assimilation.
- *The tropical upper troposphere scores degraded*
- Several experiments were run to determine why.
- It was determined that tightening COSMIC QC in the tropics had the best effect at improving the performance.
- Further work is ongoing

TROPICAL 200 mb Vector at day 3 for 00Z13FEB2007 - 00Z16MAR2007



Summary

- **Outlined a comprehensive Data Assimilation (DA) development strategy**
 - 2007-2010
- **Phased evolution of the NCEP Production Suite**
 - 2009-2015
 - **Results in**
 - Improved services for high impact weather
 - Application of advanced data assimilation techniques for improved model initial conditions
 - More efficient
 - Use of computing
 - Incorporation of new product lines for improved services
 - Earlier product delivery
 - More uniform and informative product stream
 - Advanced ensemble suite including components supported outside NCEP
 - Improved statistical post-processing
 - Reforecast and Reanalysis become operationally supported
 - **Consistent with**
 - **ESMF**
 - **DA development strategy and interagency collaborations (current and anticipated)**

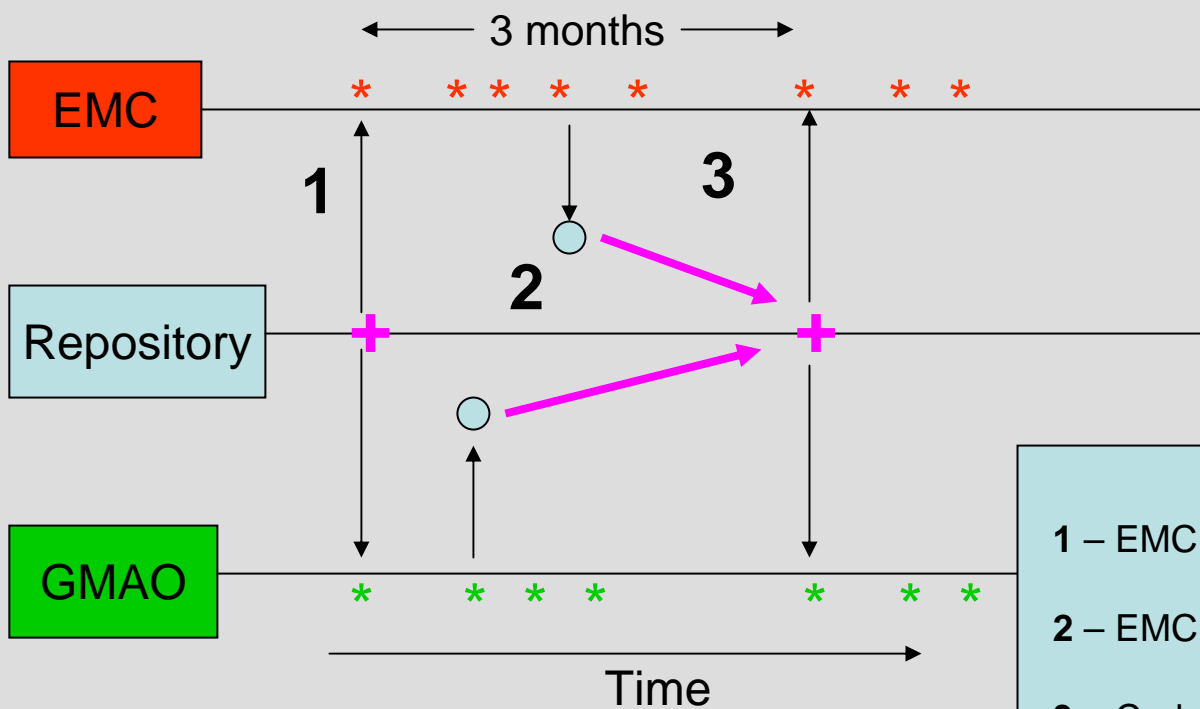
Data Assimilation Development Strategy (2)

	Description	Lead Org.	Encouraging	Risk Factors All: cost (computer+human) increase ~3-10x
SDBE +S4DV	Extension of GSI	NCEP/ EMC	Evolutionary development path Experience through RTMA GSI operational 2007:Q3	Definition of appropriate covariance uncertain Multiple approaches (incl. ensembles)
C4DV	Strong constraint Model Adjoint + Tangent Linear (ATL)	NASA/ GMAO	Positive impact at other WX centers (ECMWF, UKMO, CMC, JMA) Various approximations	Cost + (3x code) Which forecast model will be used?
EnsDA	Several algorithms proposed Supported by THORPEX	TC	Good results at low res & low data volumes No ATL Relatively simple algorithms	Ens. DOF may not be sufficient (esp. hires) Data handling for large data volumes challenging Obs & model bias correction Covariance inflation req.

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