

Global Weather & Climate Modeling

Mark Iredell and friends

NCEP Production Suite Review

December 12, 2007

GlobMoB review outline

- Recent Major Implementations
 - GFS (2007-05-01-12)
 - NCEP Post (2007-09-25-12)
 - NAEFS (2007-12-04-12)
 - CFS & GODAS (2008-01-??-??)
- Future Plans
 - GFS 2008
 - Collaboration Projects
 - **NEMS**

Recent Major Implementations

GFS Upgrade Implementation

May 1, 2007

Goals of this GFS implementation

- Unify the NCEP 3DVAR assimilation system under the GSI, improving some performance metrics without affecting others
- 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 changes

- Observation changes
 - Full resolution AIRS
 - COSMIC GPSRO
- Analysis changes
 - GSI (Gridpoint Statistical Interpolation)
- Forcing changes
 - None
- Physics changes
 - Modularized radiation package
- Dynamics changes
 - Hybrid sigma-pressure vertical coordinate
- Infrastructure changes
 - None
- Resolution changes
 - None
- Post processing and product changes
 - Output hourly GDAS files
 - Change to internal model history file
 - More fields output in model flux file

Observation changes

- Full resolution AIRS
 - Every field of view form of AIRS data now used to locate least cloudy profile rather than using just center spot AIRS data
 - Data available starting September 2006
- COSMIC GPSRO
 - First implementation of global positioning system radio occultation technology
 - Data available starting November 2006

Analysis changes

- GSI (Gridpoint Statistical Interpolation)
 - Unifies NCEP's 3DVAR with the operational mesoscale models, allowing more concentrated development
 - Enables future enhancements such as using non-isotropic background errors
 - Reduces analysis errors in the tropics where the global spectral background error assumptions were inappropriate

Physics changes

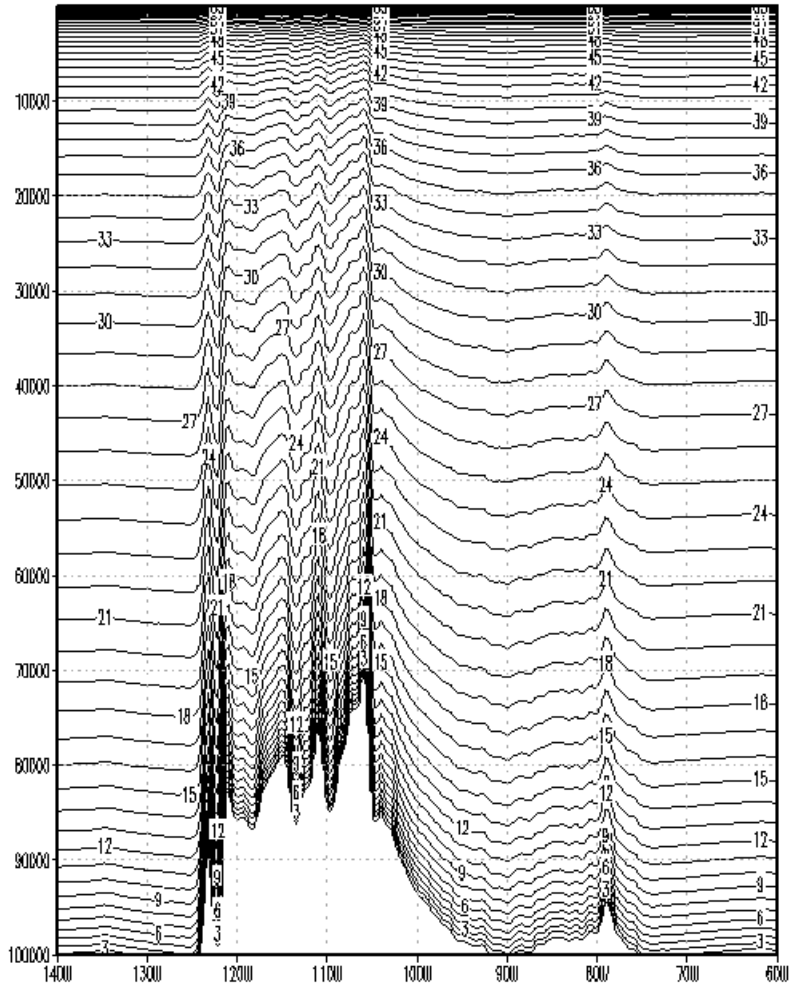
- Modularized radiation package
 - Overall restructuring of radiation related programs to help future development and upgrade.
 - In RRTM1-LW, minor upgrade of emissivity coefficient. Rare gas absorption effect turned on.
 - In aerosol calculation, vertical sigma based structure changed to pressure based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

Dynamics changes

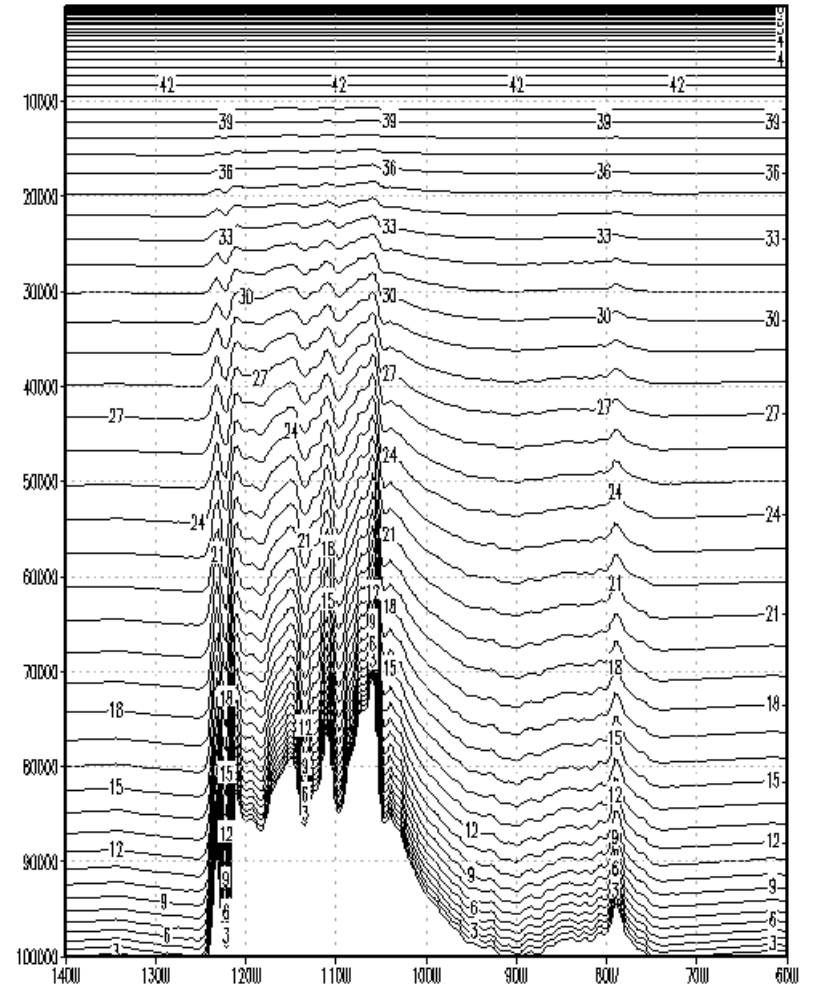
- Hybrid sigma-pressure vertical coordinate
 - Model surface remain terrain-following in the lower troposphere but become pure pressure surfaces in the stratosphere
 - Reduces vertical advection errors and pressure-gradient calculation errors in the upper part of the model
 - Data assimilation and physics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



Post processing and product changes

- Output hourly GDAS files
 - Supports hydrology and other needs
 - May be useful in data assimilation
- Change to internal model history file
 - Hybrid sigma-pressure vertical coordinate
 - Affects downstream codes
- More fields output in model flux file
 - Supports hydrology needs
 - No effect on downstream codes

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>

Overview of objective scores: Summer 2005 and 2006

500 hPa heights neutral in both Northern Hemisphere and Southern Hemisphere

rms vector wind error in pvy at 200 and 850 hPa in tropics reduced

GSI hybrid precipitation over continental US less positive bias, more skill

compared to radiosondes, GSI hybrid temperatures warmer, temperature forecasts improved in lower troposphere in Southern Hemisphere and tropics, improved in upper troposphere tropics

forecast heights fit radiosondes significantly better

bias of 200 hPa winds over East Asia substantially reduced in GSI hybrid

GSI hybrid analysed moisture closer to radiosondes

***500 hpa height anomaly correlations
July 1-Nov. 5, 2005***

	op	pry
NH day 5	.800	.811
SH day 5	.801	.794

Tropical rms vector wind error

	op	pry
200 day 1	4.56	4.40
Day 3	8.01	7.61
850 day 1	2.41	1.98
Day 3	3.77	3.37

500 hpa height anomaly correlations

Aug. 15-Nov. 6, 2006

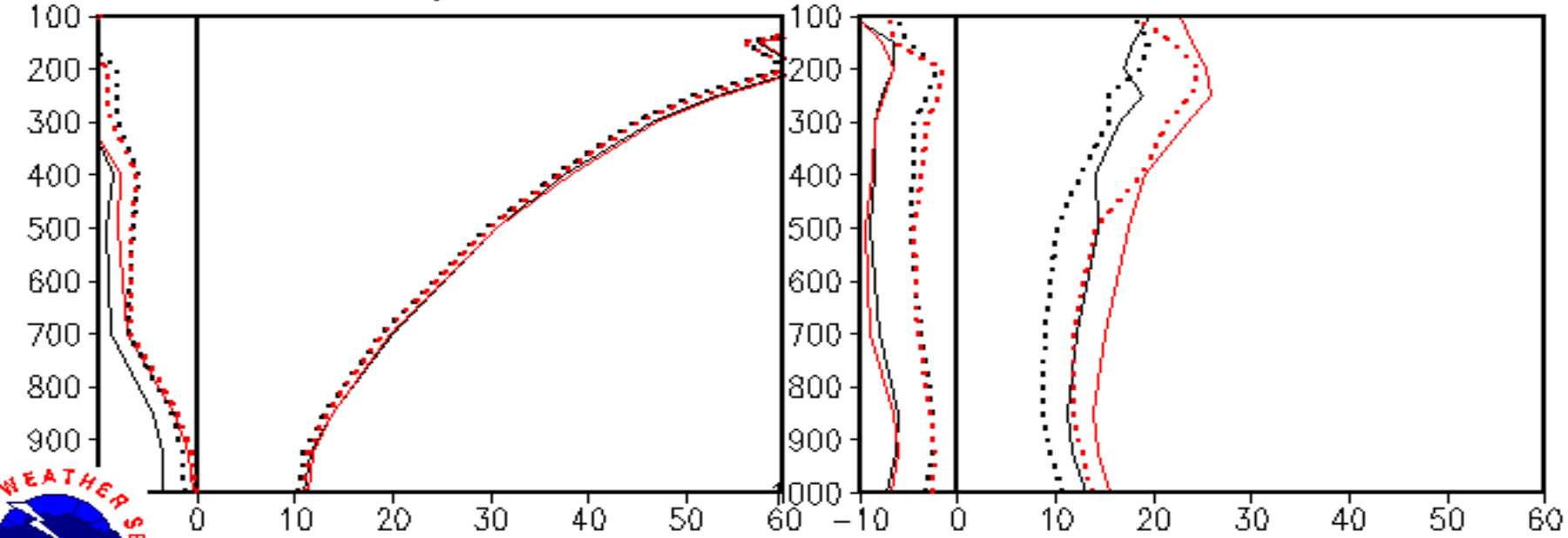
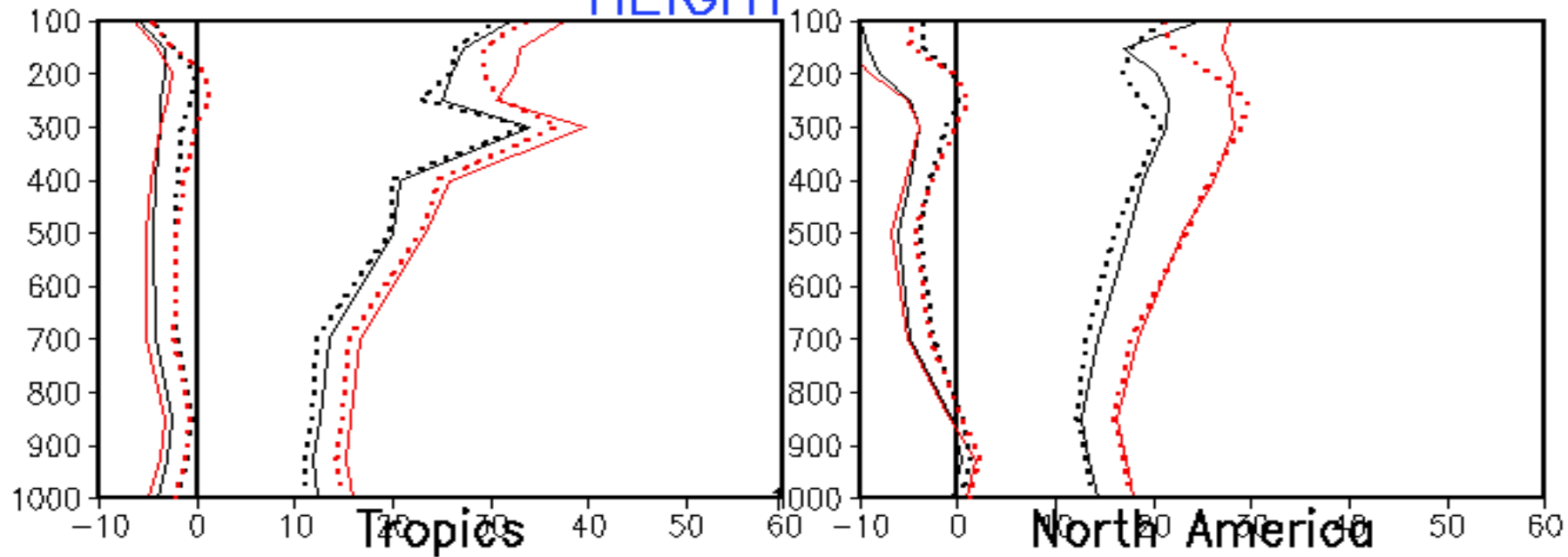
	op	pry
NH day 5	.818	.809
SH day 5	.761	.767

Tropical rms vector wind error

	op	pry
200 day 1	4.47	4.36
Day 3	7.74	7.48
850 day 1	2.38	1.91
Day 3	3.71	3.30

North HEIGHT

South



BIAS (F-O)

RMSE

BIAS (F-O)

RMSE

48-hr fcst
24-hr fcst

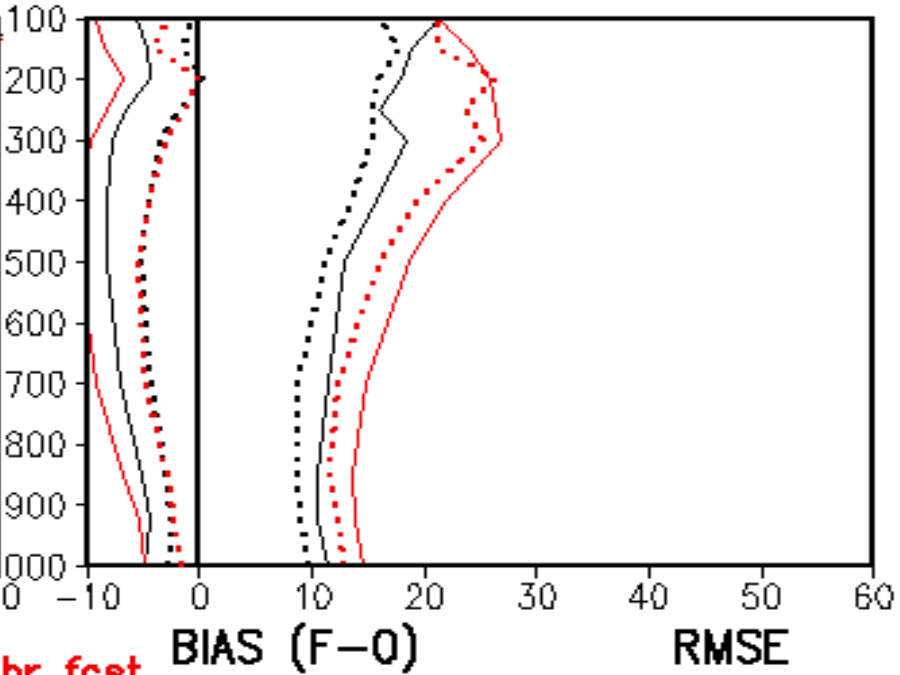
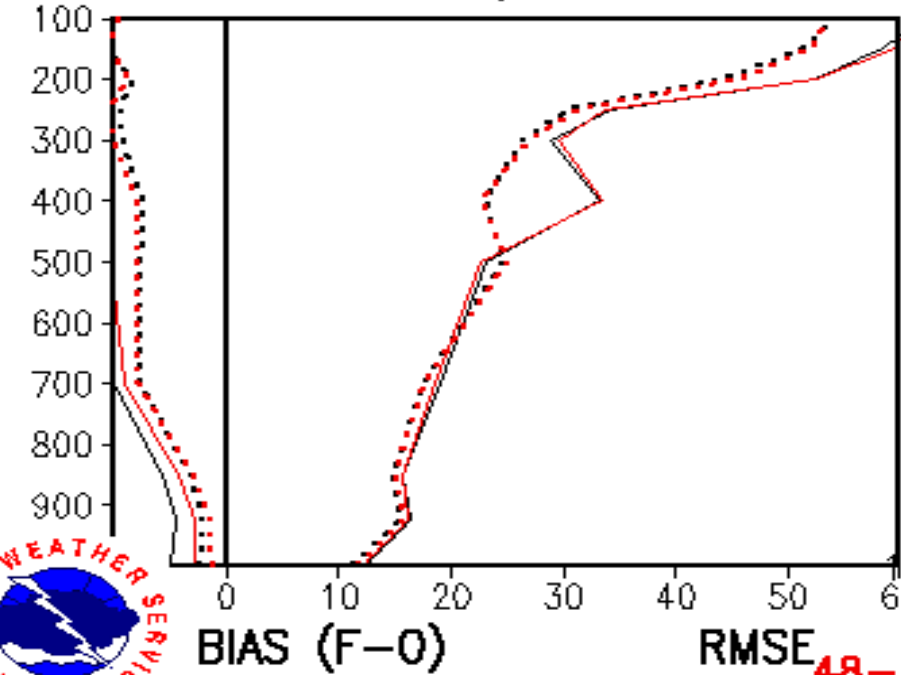
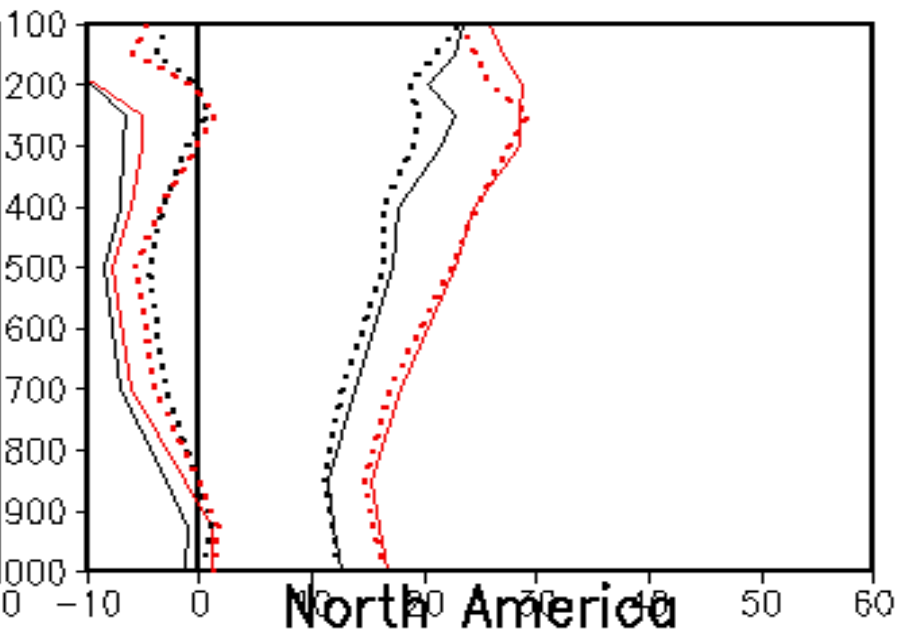
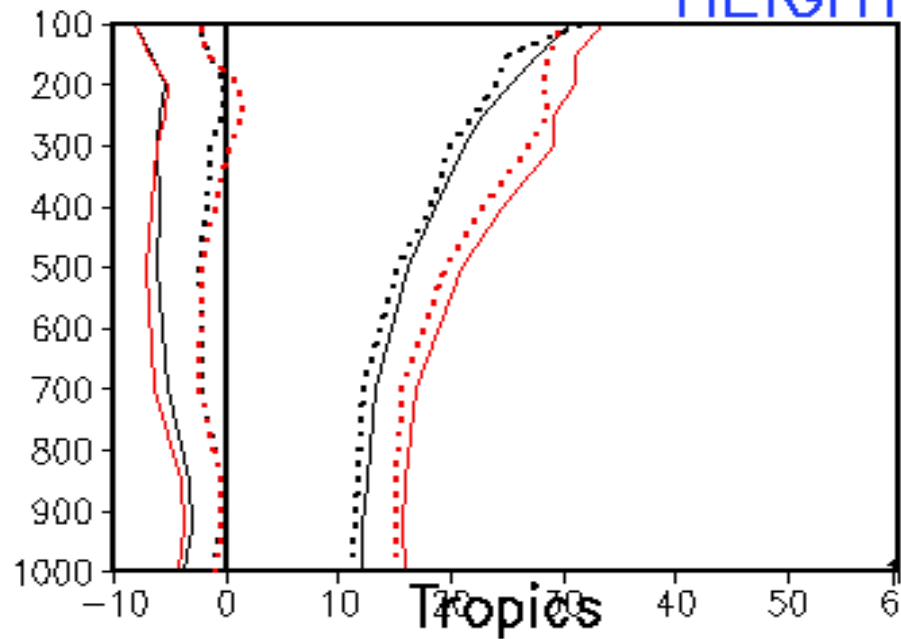
00z01jul2005 - 00z05nov2005



North

HEIGHT

South



BIAS (F-O)

RMSE

48-hr fcst
24-hr fcst

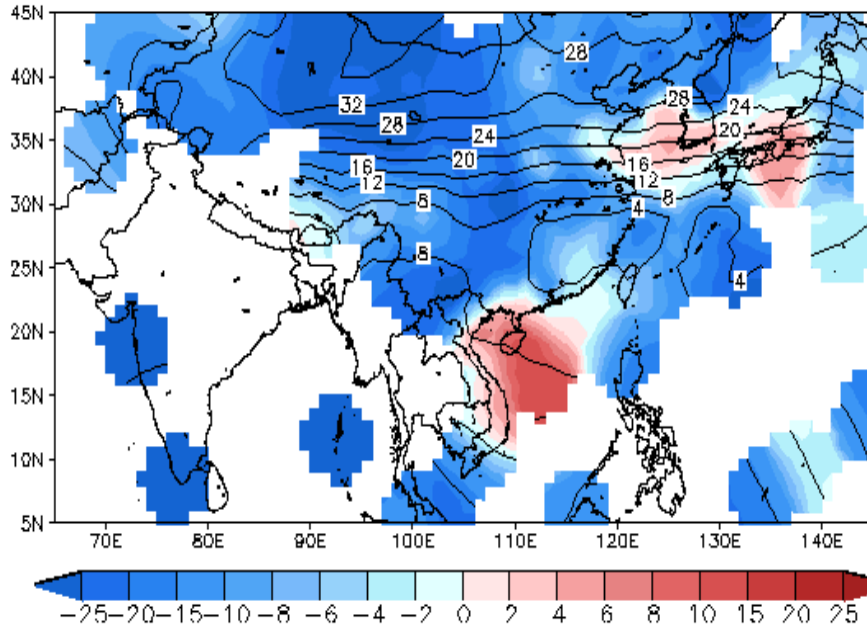
BIAS (F-O)

RMSE

00z15aug2006 - 00z06nov2006

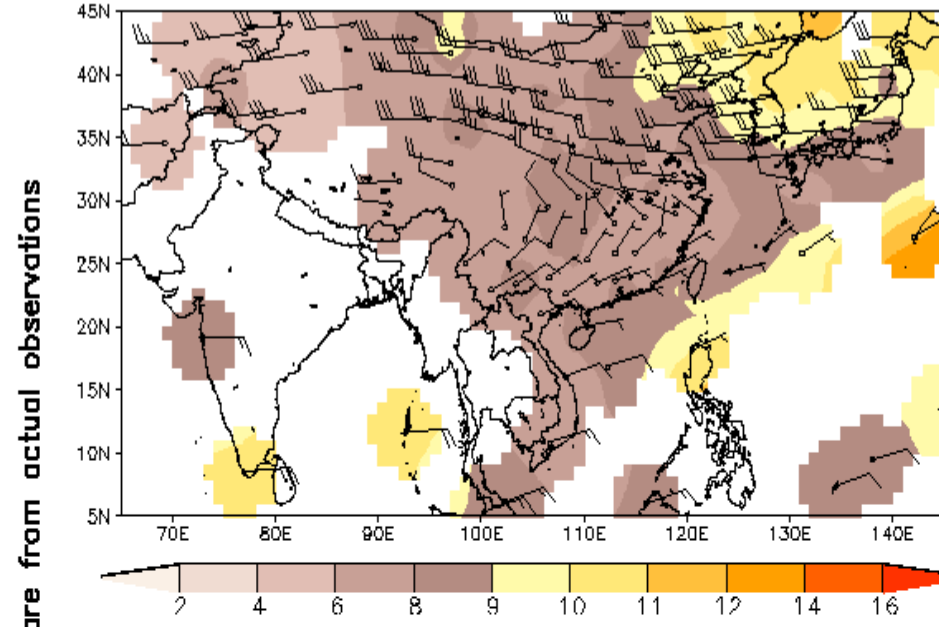
**Wind Speed 200 mb 48-HR BIAS in m/sec
from 00z01jul2005-00z15oct2005**

fnl-OBS : Station Count 123 RMSE of mean 16.29

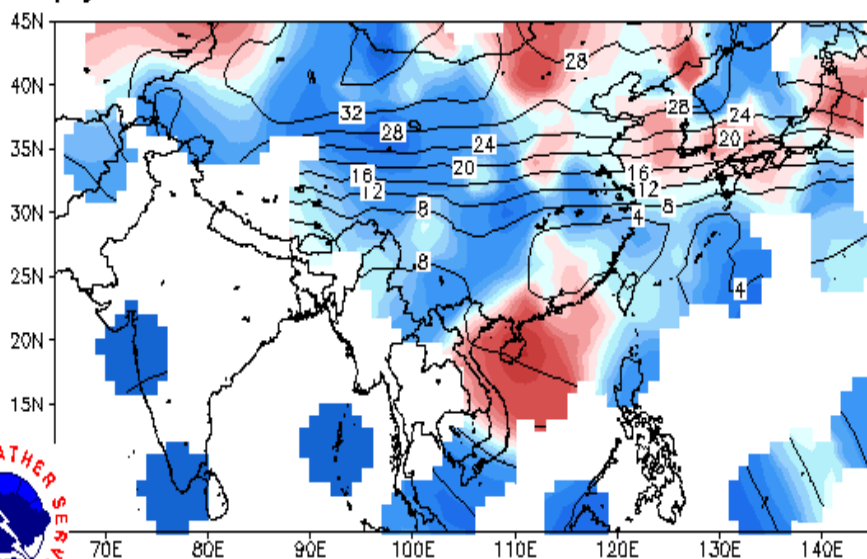


**Vector Wind 200 mb 48-HR RMS Error in m/sec
from 00z01jul2005-00z15oct2005**

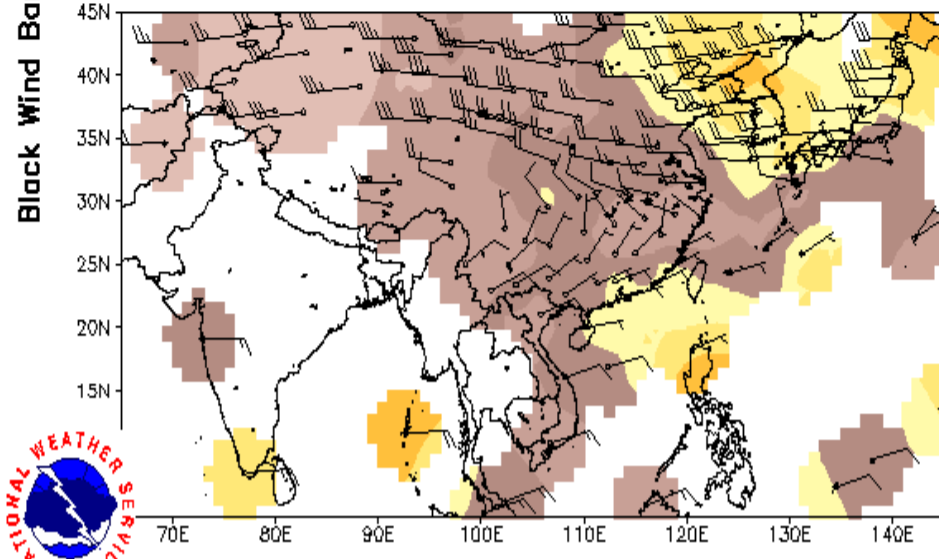
fnl-OBS : Station Count 123 RMS 8.31



pry05-OBS : Station Count 123 RMSE of mean 10.72



pry05-OBS : Station Count 123 RMS 8.50

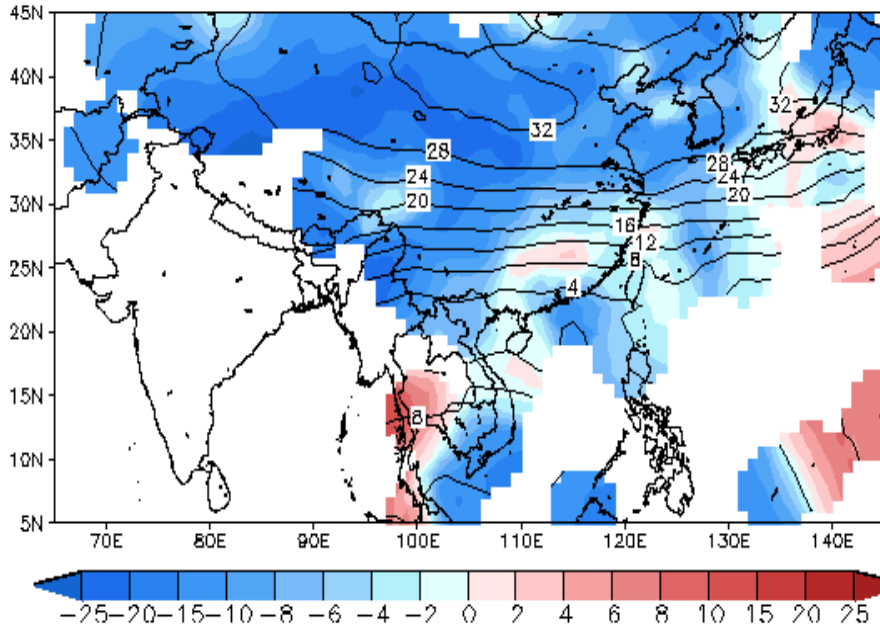


Black Isolines are from actual observations

Black Wind Barbs are from actual observations

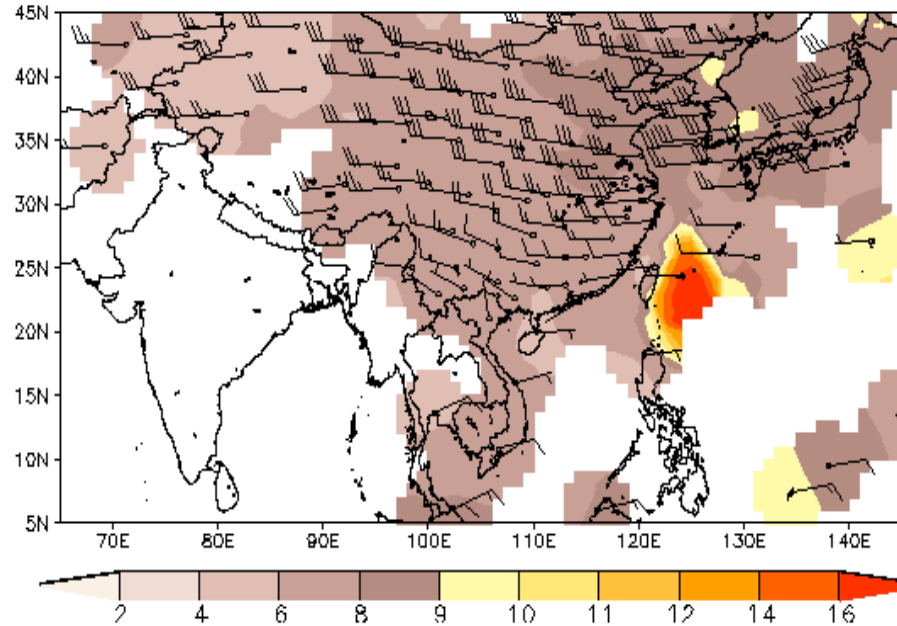
**Wind Speed 200 mb 48-HR BIAS in m/sec
from 00z15aug2006-00z06nov2006**

fnl-OBS : Station Count 124 RMSE of mean 11.34



**Vector Wind 200 mb 48-HR RMS Error in m/sec
from 00z15aug2006-00z06nov2006**

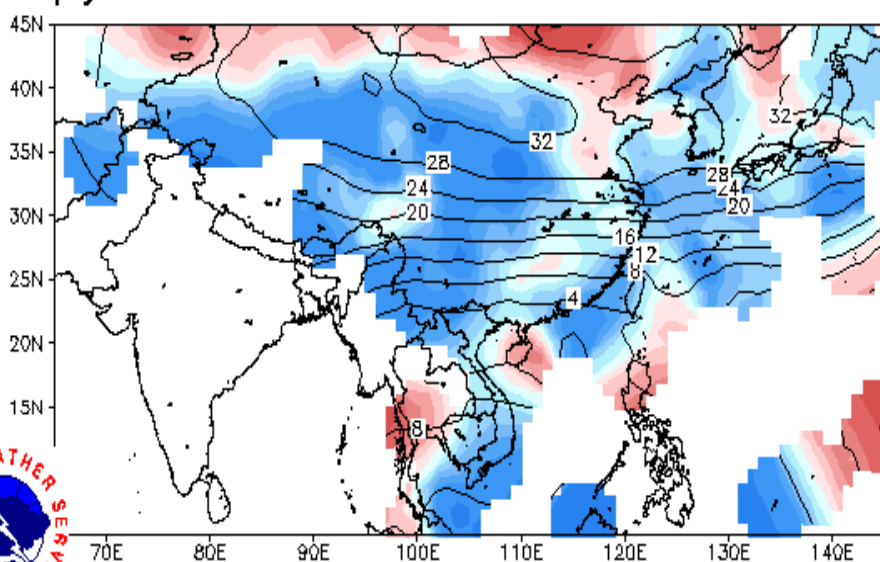
fnl-OBS : Station Count 124 RMS 7.68



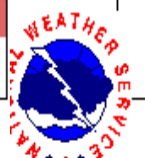
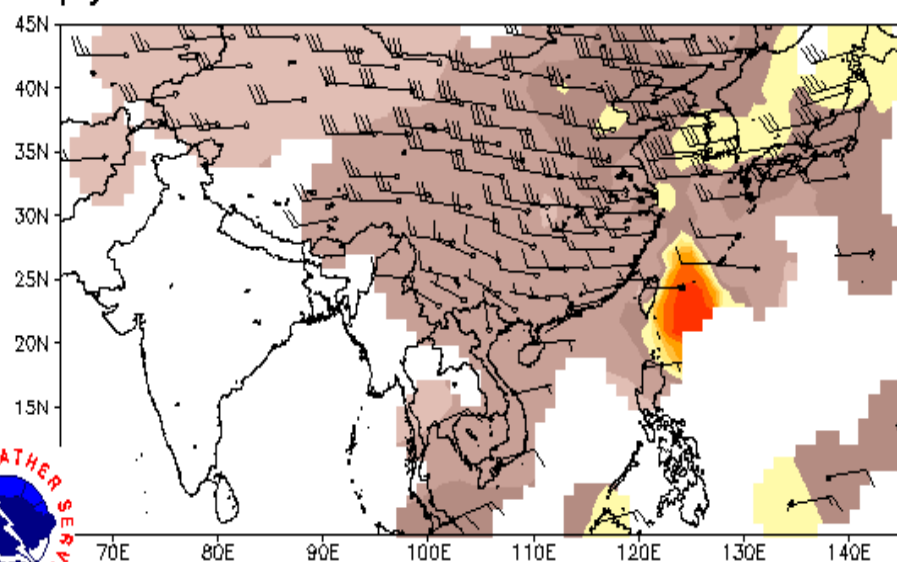
Black Isolines are from actual observations

Black Wind Bars are from actual observations

pry06-OBS : Station Count 124 RMSE of mean 7.44



pry06-OBS : Station Count 124 RMS 7.80

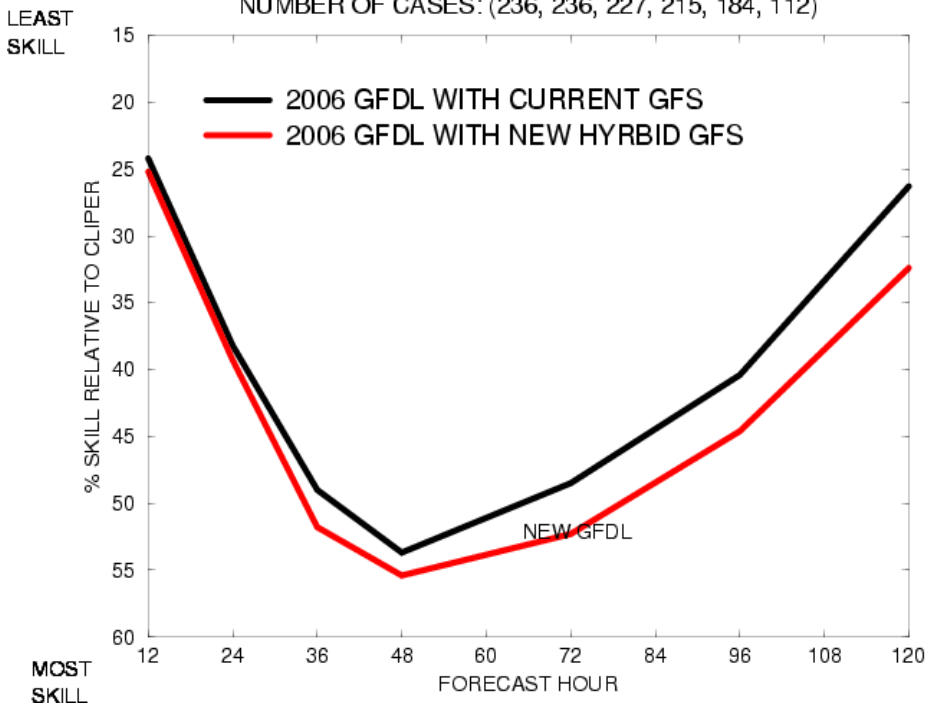


2005-2006 Atlantic Season Average Track Error Using The Current Operational and New GFS

GFDL

GFDL COMPARISON WITH CURRENT AND NEW HYBRID GFS

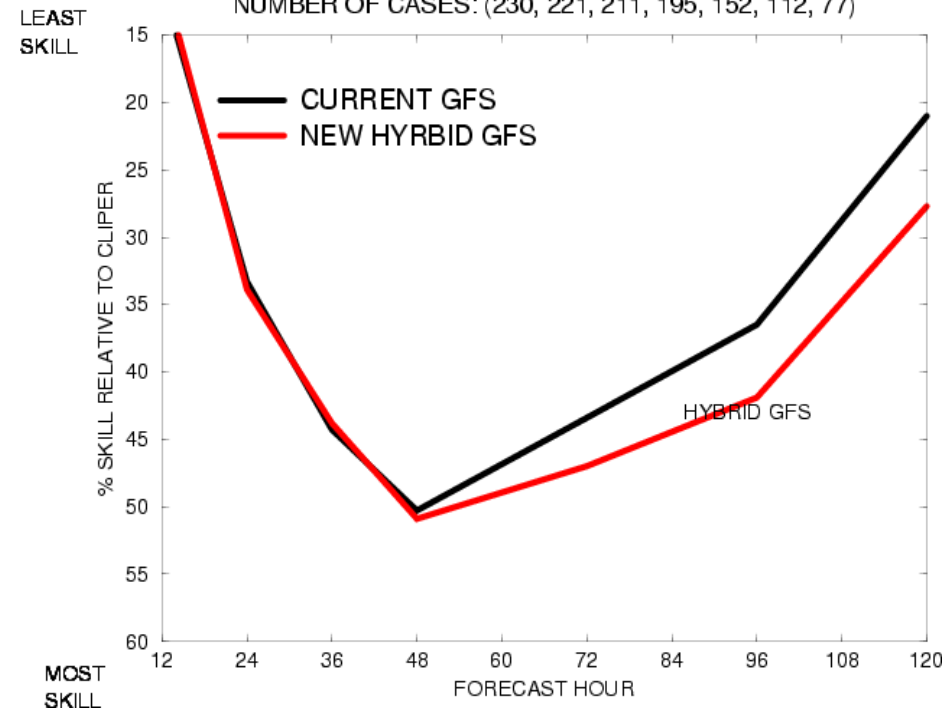
NUMBER OF CASES: (236, 236, 227, 215, 184, 112)



GFS

COMPARISON OF CURRENT AND NEW HYBRID GFS

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



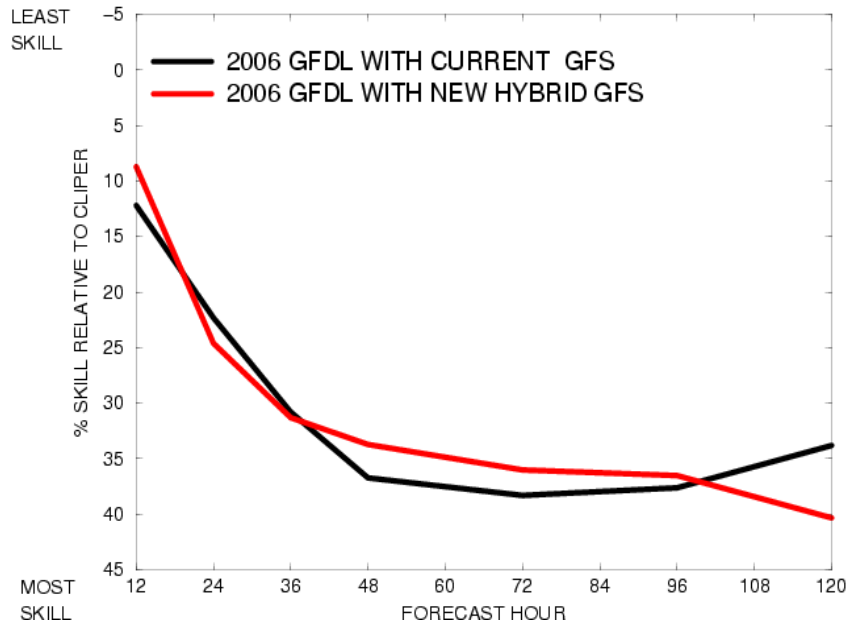
2005-2006 Eastern Pacific Average Track Error

GFDL

GFS

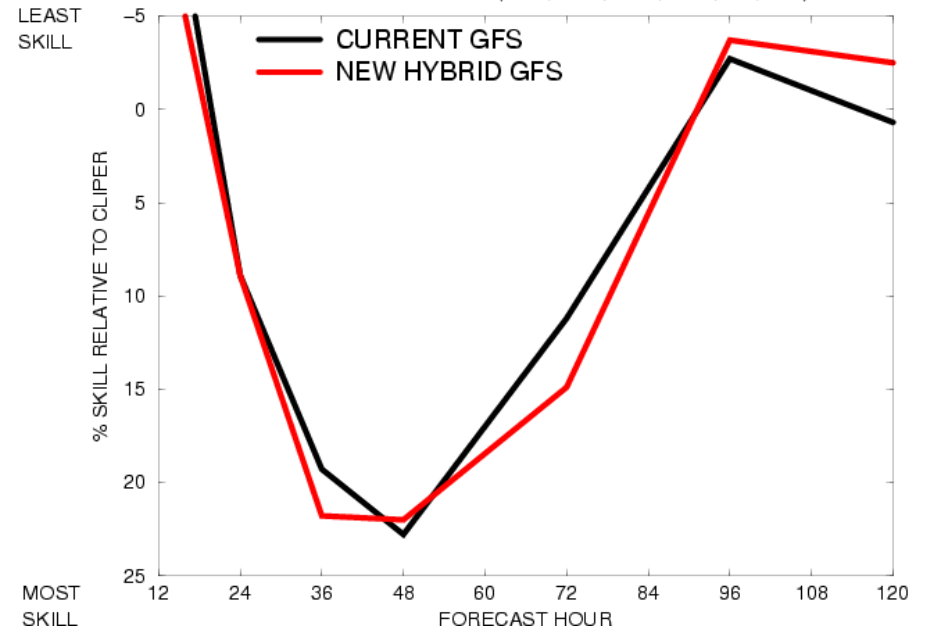
GFDL COMPARISON WITH CURRENT AND NEW HYBRID GFS

NUMBER OF CASES: (146, 144, 133, 120, 92, 70, 50)



COMPARISON OF CURRENT GFS AND NEW HYBRID GFS

NUMBER OF CASES: (161, 147, 127, 106, 70, 38)



Unified NCEP Post
Implementation
September 25, 2007

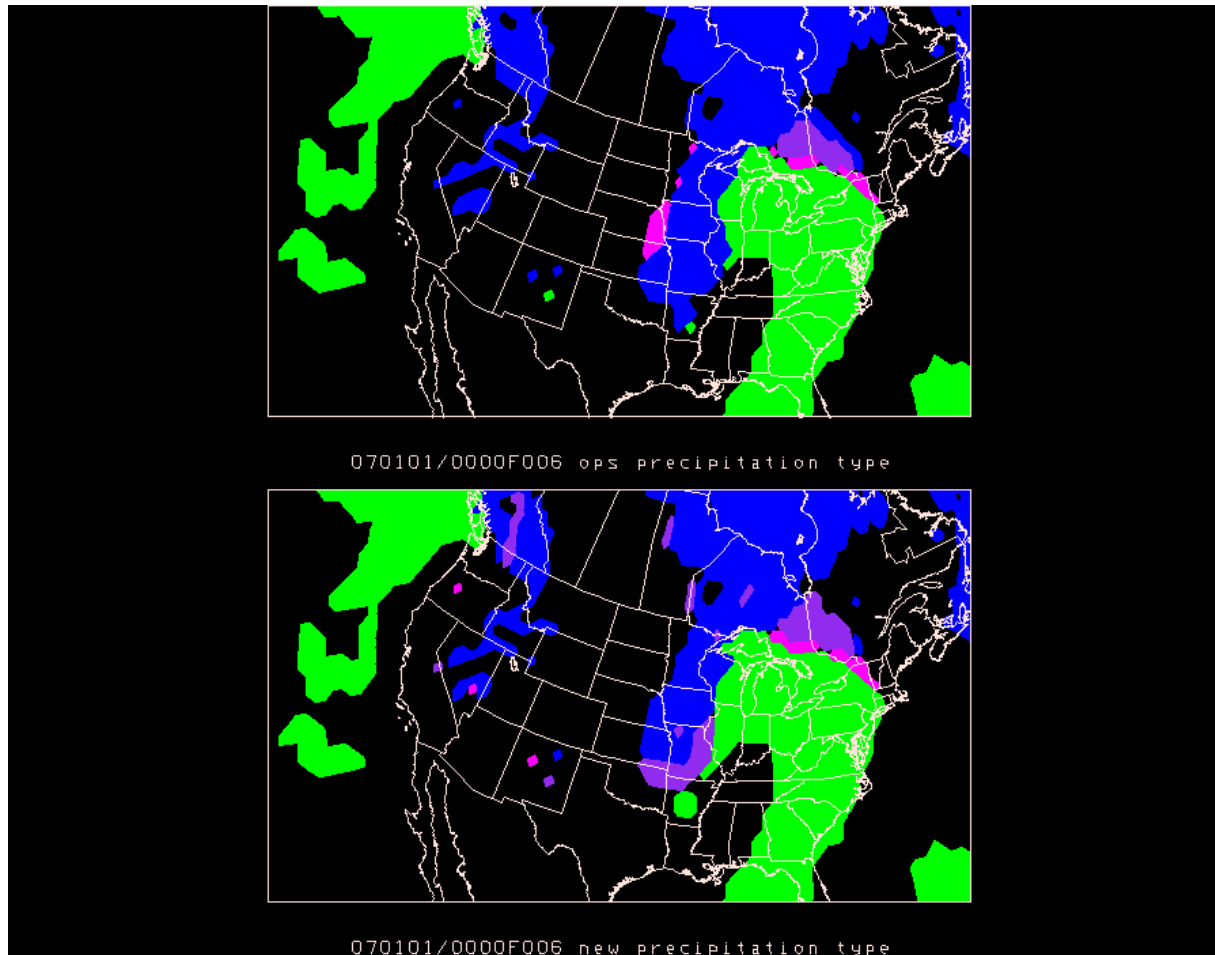
Purpose of change

- Unify NAM post procedures into GFS
 - Create new master native and master post files, both in GRIB1 and on the native model grid, in both GDAS and GFS
 - GFS post processing now run as a separate job for each forecast hour, as in current NAM post processing
- Unify algorithms
 - GFS will use NAM precipitation type algorithm
 - NAM will use GFS tropopause algorithm (future)
- Unify product identifications (future)
- Unify development of post processing across NCEP (future)
- Support TIGGE
- Add new GOES look-alike fields

GFS Post differences and new fields

- Differences between operational and NCEP posts:
 - Precipitation type: Baldwin in operational versus dominant in NCEP post
 - Vorticity fields: spectral computation in operational versus grid space computation in NCEP post
 - Master Grib grid types: half degree in operational versus finer Gaussian grid in NCEP post
 - Week 2: replace double interpolation (model grid to 1 degree to 2.5 degree) with direct interpolation to 2.5 degree grid
- New fields to be generated by NCEP post:
 - GOES look alike
 - Helicity

Precipitation type comparison

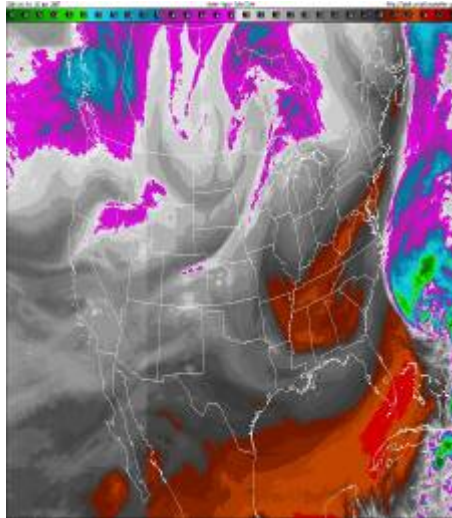


Snow: blue, Rain: green, Freezing rain: magenta, Ice pellets: purple

Tropical storm Noel. Verified at 12 UTC November 2 2007

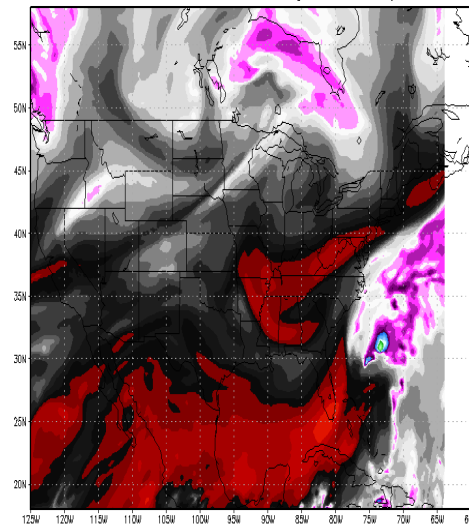
Water Vapor channel

GOES 12 Ch 3



NAM 12 h forecast

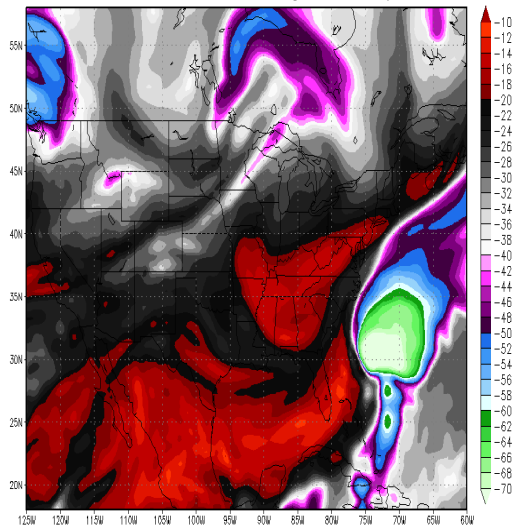
2007110200F12 GOES CH 3 Brightness Temperature



04DS: COLA/YES

GFS 12 h forecast

2007110200F12 GOES CH 3 Brightness Temperature



2007-12-07-13:39

04DS: COLA/YES

2007-11-02-08:03

NAEFS Implementation

December 4, 2007

Planned Changes - Summary

- ❑ Bias corrected GFS forecast
 - Use the same algorithm as ensemble bias correction
 - Up to 180 hours
- ❑ Combine bias corrected GFS and ensemble forecast
 - Dual resolution ensemble approach for short lead time
 - GFS has higher weights at short lead time
- ❑ NAEFS new products
 - Combine NCEP/GEFS (20m) and CMC/GEFS (20m)
 - Produce Ensemble mean, spread, mode, 10% 50%(median) and 90% probability forecast at 1*1 degree resolution
 - Climate anomaly (percentile) forecasts also generated for ens. mean
- ❑ Statistical downscaling
 - Use RTMA as reference - NDGD resolution (5km), CONUS only
 - Generate mean, mode, 10%, 50%(median) and 90% probability forecasts

NAEFS current configuration

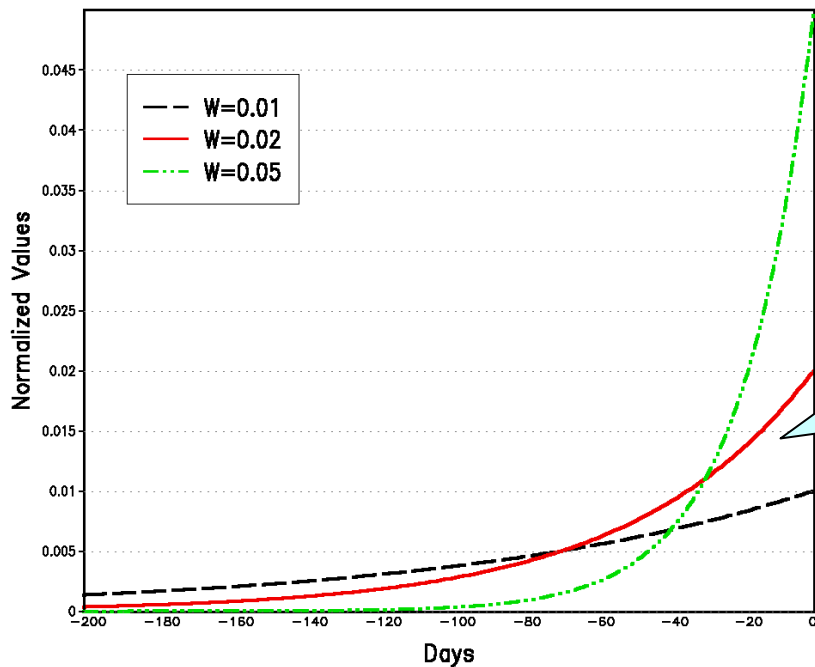
Updated: July 2007

	NCEP	CMC
Model	GFS	GEM
Initial uncertainty	ETR	EnKF
Model uncertainty	None	Yes
Stochastic physics	None	Yes
Tropical storm	Relocation	None
Daily frequency	00,06,12 and 18UTC	00 and 12UTC
Resolution	T126L28 (d0-d16) ~90km	(d0-d16) ~1.0degree
Control	Yes	Yes
Ensemble members	20 for each cycle	20 for each cycle
Forecast length	16 days (384 hours)	16 days (384 hours)
Post-process	Bias correction for ensemble mean	Bias correction for each member
Last implementation	March 27 th 2007	July 10 th 2007

New Products in CCS - Summary

- ❑ Bias corrected GFS forecast
 - Directory: /com/gens/para/gefs.yyyymmdd/cyc/pgrba_bc
 - Files: gegfs* (up to 180 hours)
- ❑ NAEFS new products: (early run: NCEP/GEFS only)
 - Probabilistic forecasts at 1*1 degree resolution (global)
 - Directory: /com/gens/para/gefs.yyyymmdd/cyc/pgrba_bc
 - Files: geavg*, gespr*, gemode*, ge10p*, ge50p*, ge90p* represent ensemble mean, spread, mode, 10%, 50% (median) and 90% probability forecast
 - Anomaly forecast for ensemble mean at 1*1 degree resolution (global)
 - Directory: /com/gens/para/gefs.yyyymmdd/cyc/pgrba_an
 - Files: geavg*
 - At 5km resolution (down-scaling for CONUS only)
 - Directory: /com/gens/para/gefs.yyyymmdd/cyc/ndgd
 - Files: geavg*, gemode*, ge10p*, ge50p* and ge90p*
- ❑ NAEFS new products: (later run: combine NCEP and CMC's ensemble)
 - Probabilistic forecast at 1*1 degree resolution (global)
 - Directory: /com/gens/para/naefs.yyyymmdd/cyc/pgrba_bc
 - Files: geavg*, gespr*, gemode*, ge10p*, ge50p* and ge90p*
 - Anomaly forecast for ensemble mean at 1*1 degree resolution (global)
 - Directory: /com/gens/para/naefs.yyyymmdd/cyc/pgrba_an
 - Files: geavg*
 - At 5km resolution (down-scaling for CONUS only)
 - Directory: /com/gens/para/naefs.yyyymmdd/cyc/ndgd
 - Files: geavg*, gemode*, ge10p*, ge50p* and ge90p*
 - File: dvtma.t00z.ndgd_conus (down-scaling vector)

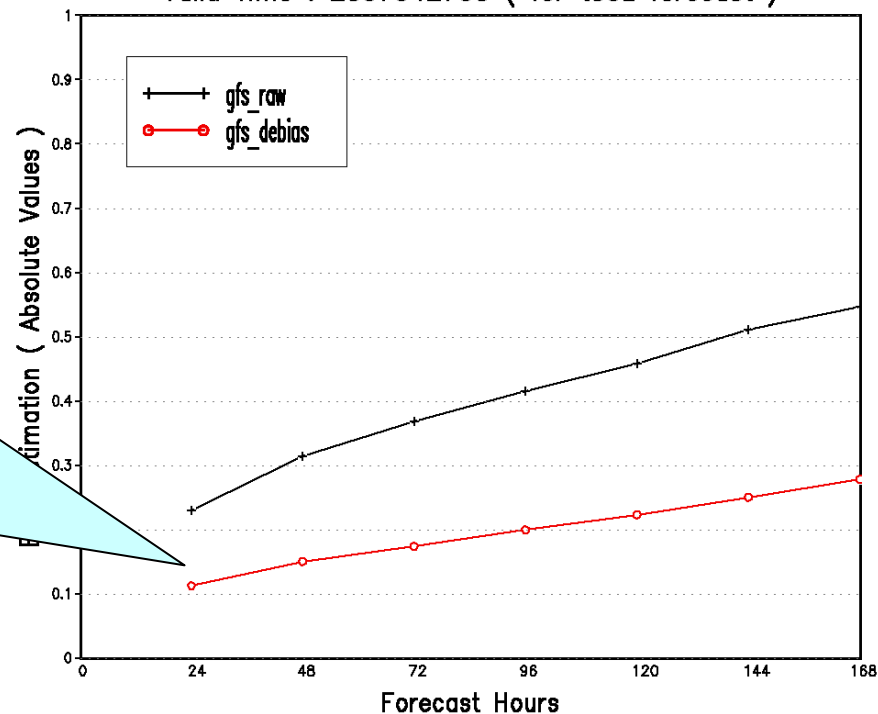
DECAYING AVERAGE WEIGHTING



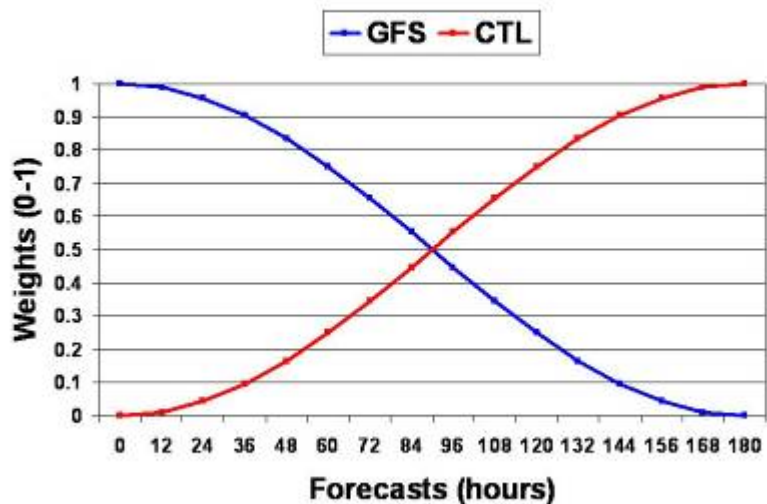
GFS bias correction based on an accumulated bias by using decaying average weight (0.02) which is the same as GEFS used

The absolute errors are reduced after bias correction for 2-meter temperature (The stats are accumulated from 0.02 decaying average)

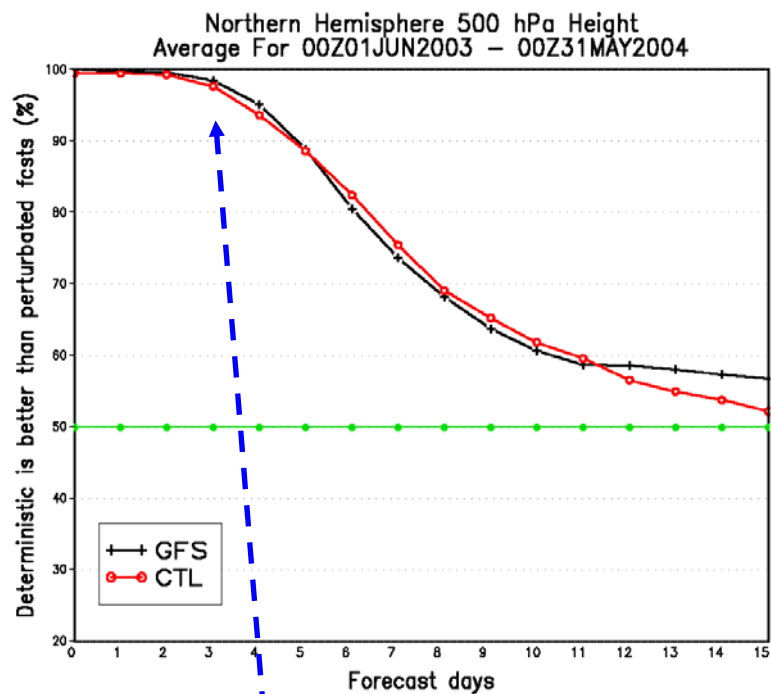
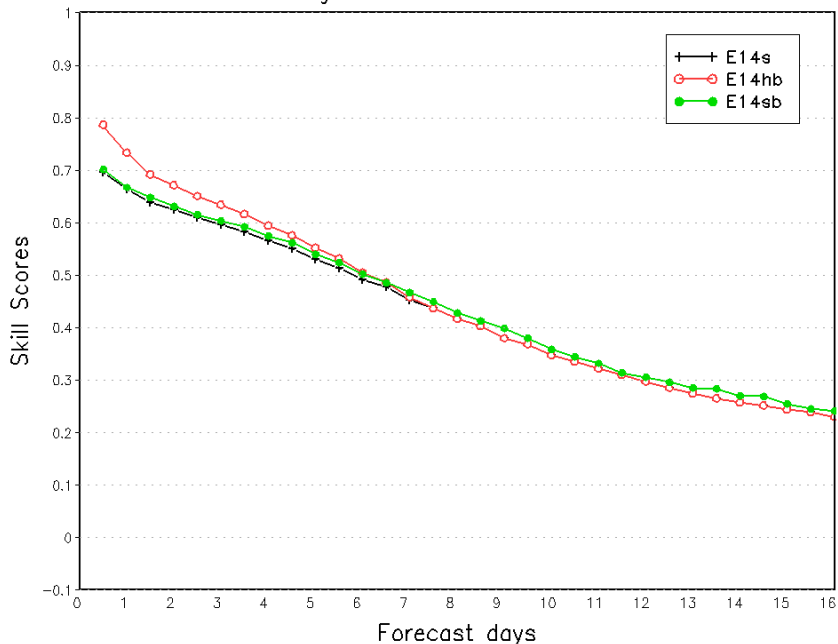
NH 2m Temperature
Valid Time : 2007042700 (for t00z forecast)



Combined GFS and GEFS forecasts at first 180hr



Northern Hemisphere 2 Meter Temp.
ROC area (0-1)
Average For 20070301 - 20070510



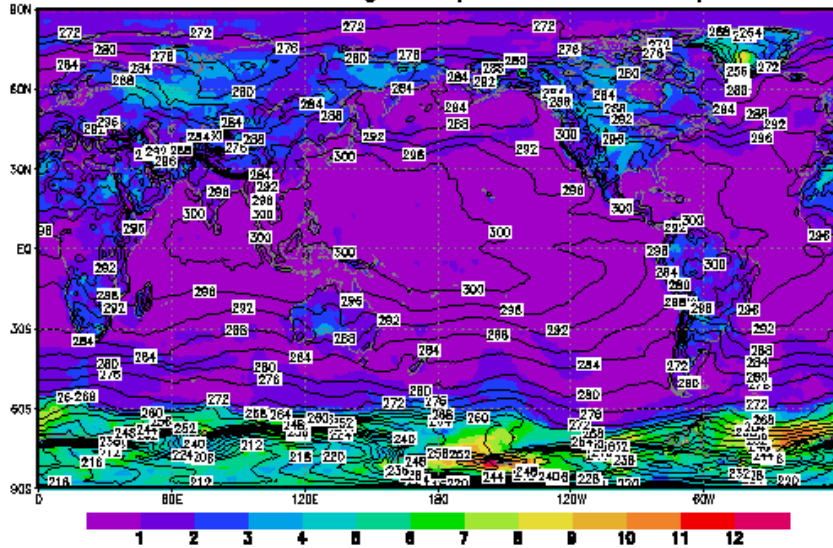
GFS has more skill than ensemble control for short lead time

Combined GFS and GEFS Forecast has more skill (red) than GFS only (black)

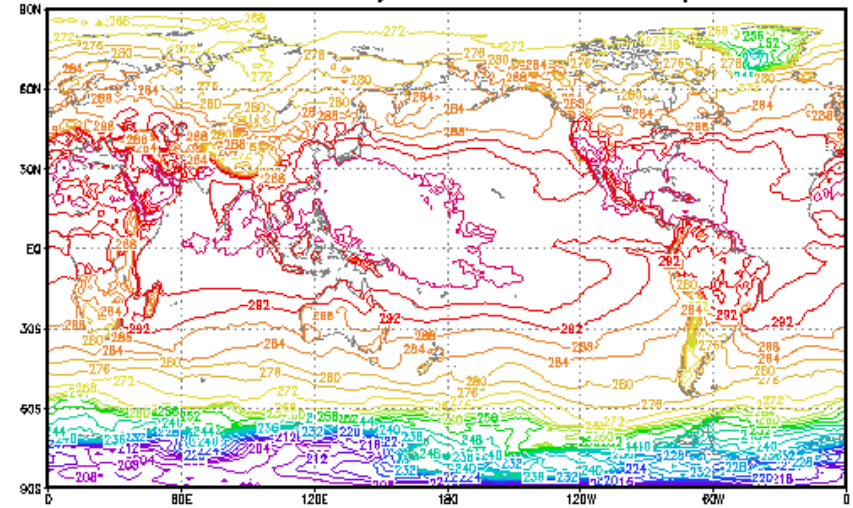
Jun Du first introduced dual-resolution to SREF, by using constant weight

Examples of NAEFS product

Ensemble Average & Spread for 2m Temp

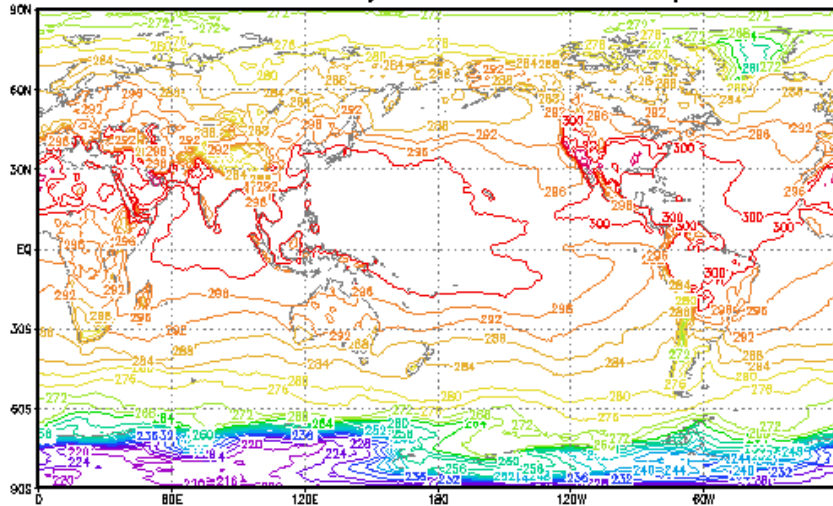


10% Probability Forecast for 2m Temp



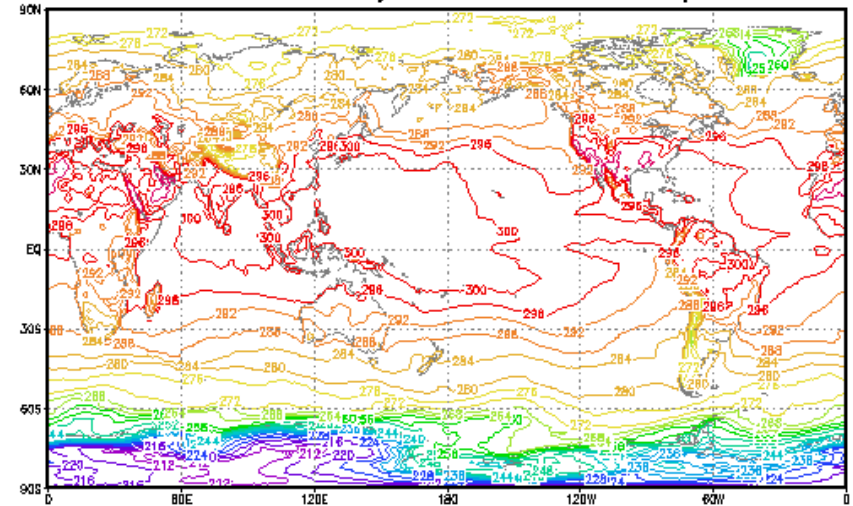
BNDS: DOLA/10ES

90% Probability Forecast for 2m Temp



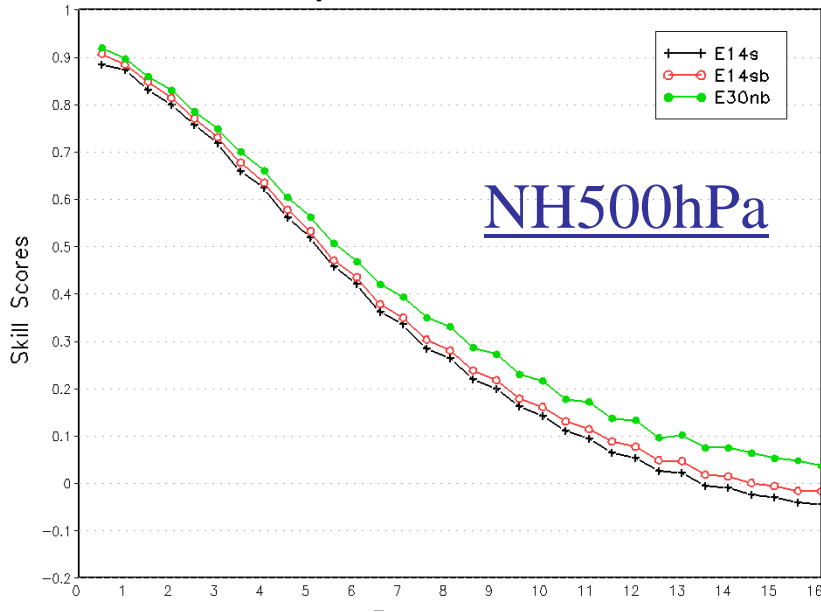
BNDS: DOLA/10ES

50% Probability Forecast for 2m Temp

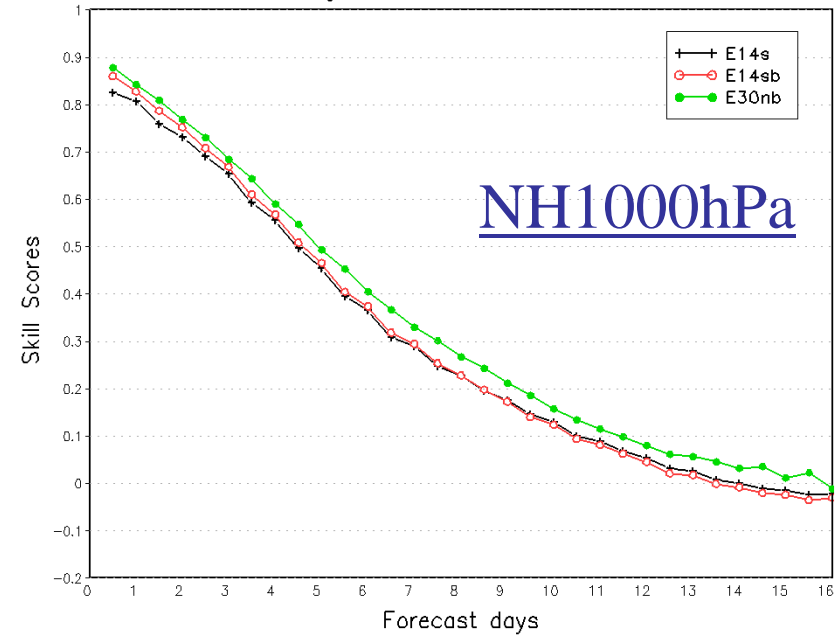


BNDS: DOLA/10ES

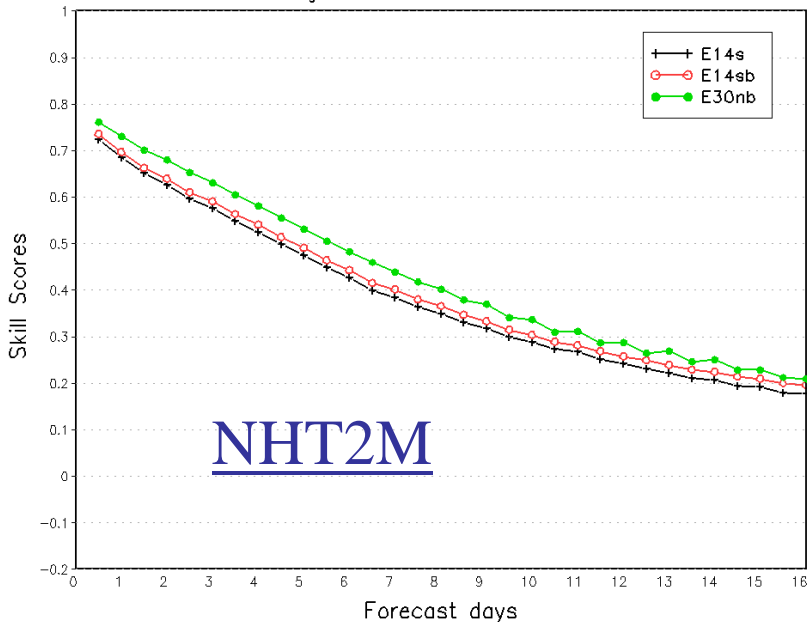
Northern Hemisphere 500hPa Height
Continuous Ranked Probability Skill Scores
Average For 20061201 - 20070228



Northern Hemisphere 1000hPa Height
Continuous Ranked Probability Skill Scores
Average For 20061201 - 20070228



Northern Hemisphere 2 Meter Temp.
Continuous Ranked Probability Skill Scores
Average For 20061201 - 20070228



All these stats show the best values from probabilistic distribution of joined ensemble (NAEFS) for upper atmosphere and near surface. Green line is from NAEFS.

Statistical downscaling for NAEFS forecast

- Proxy for truth
 - RTMA at 5km resolution
 - Variables (surface pressure, 2-m temperature, and 10-meter wind)
- Downscaling vector
 - Interpolate GDAS analysis to 5km resolution
 - Compare difference between interpolated GDAS and RTMA
 - Apply decaying weight to accumulate this difference – **downscaling vector**
- Downscaled forecast
 - Interpolate bias corrected 1*1 degree NAEFS to 5km resolution
 - Add the downscaling vector to interpolated NAEFS forecast
- Application
 - Ensemble mean, mode, 10%, 50%(median) and 90% forecasts

Statistical Downscaling Verification

-Contributed by MDL

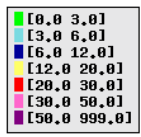
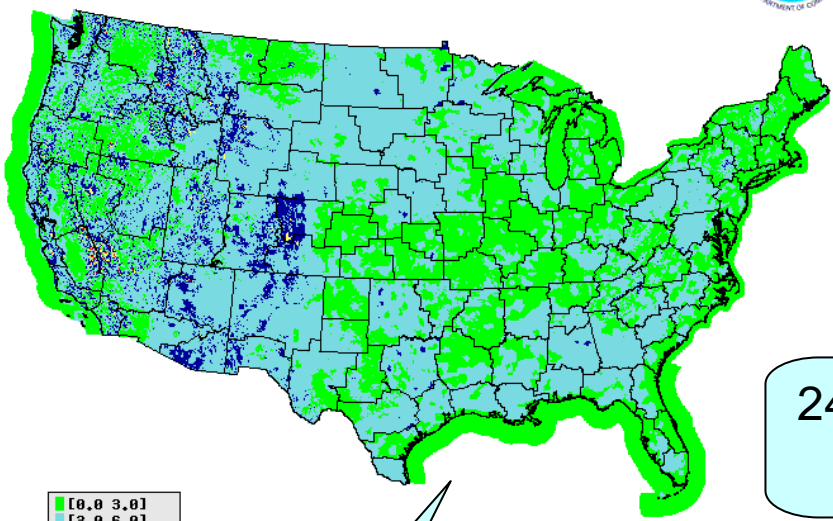
- 2-meter temperature only
- Period: July 20 – August 28 2007 (40 days)
- All verifications against **RTMA**
- NDFD: forecasts from 12UTC
- GMOS: forecasts from 00UTC
- GEFS: forecasts from 00UTC
 - Bias corrected NCEP GEFS ensemble mean only
 - Expect more improvement from:
 - Downscaling weight changes from 0.1(current) to 0.3(optimal)
 - Bias corrected GFS hybrid/multi-resolution (not applied in this verification)
 - Bias corrected CMC GEFS (NAEFS-joint ensemble)



NDFD vs RTMA Surface Temp. MAE (deg F)
012-h NDFD Proj. from 12Z Ref. Time
July 20-August 28, 2007



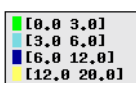
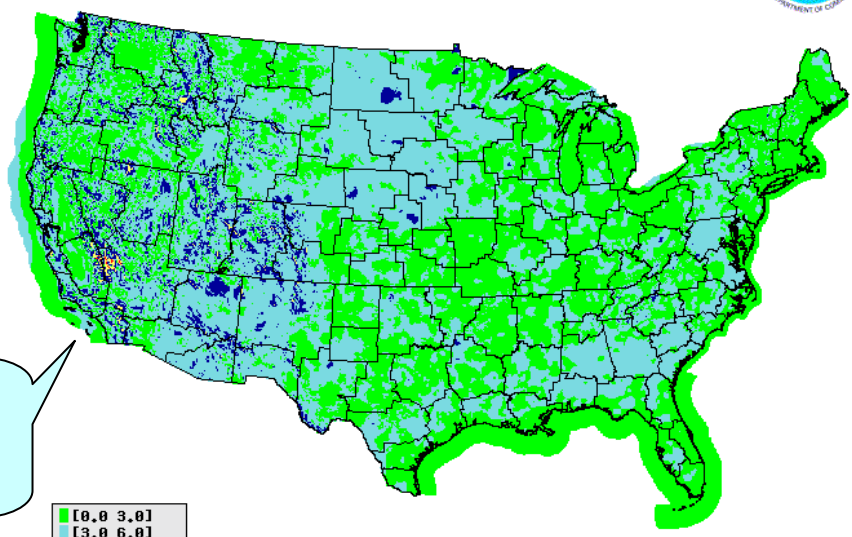
GMOS vs RTMA Surface Temp. MAE (deg F)
Matches 012-h NDFD Proj. from 12Z Ref. Time
(024-h GMOS fcst available ~5:30Z)
July 20-August 28, 2007



CONUS	3.60
EASTERN	2.92
CENTRAL	3.55
WESTERN	4.26
SOUTHERN	3.27



24-h GMOS
Forecast



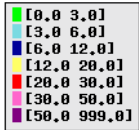
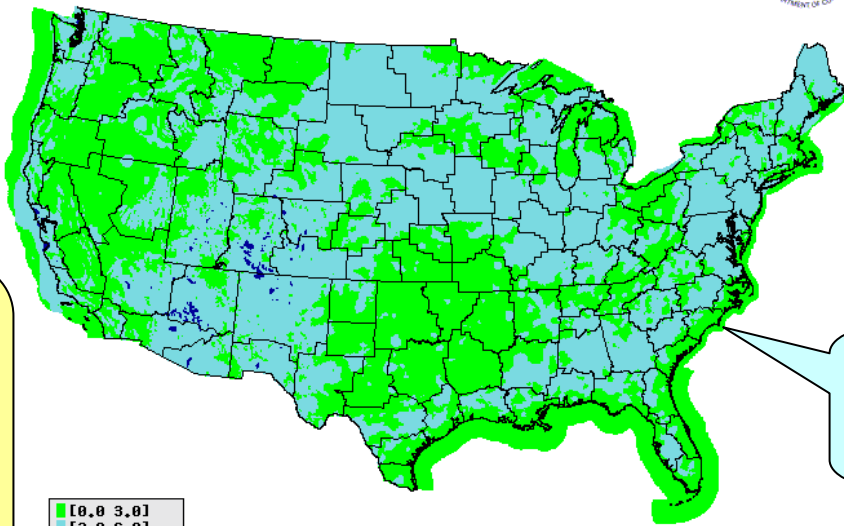
CONUS	3.37
EASTERN	2.80
CENTRAL	3.43
WESTERN	3.98
SOUTHERN	2.92



ENS vs RTMA Surface Temp. MAE (deg F)
Matches 012-h NDFD Proj. from 12Z Ref. Time
(024-h ENS fcst available ~??:??)
July 20-August 28, 2007

12-h NDFD
Forecast

For CONUS:
GEFS(3.07) : NDFD(3.60)
GEFS (+17%)
GEFS(3.07) : GMOS(3.37)
GEFS (+10%)

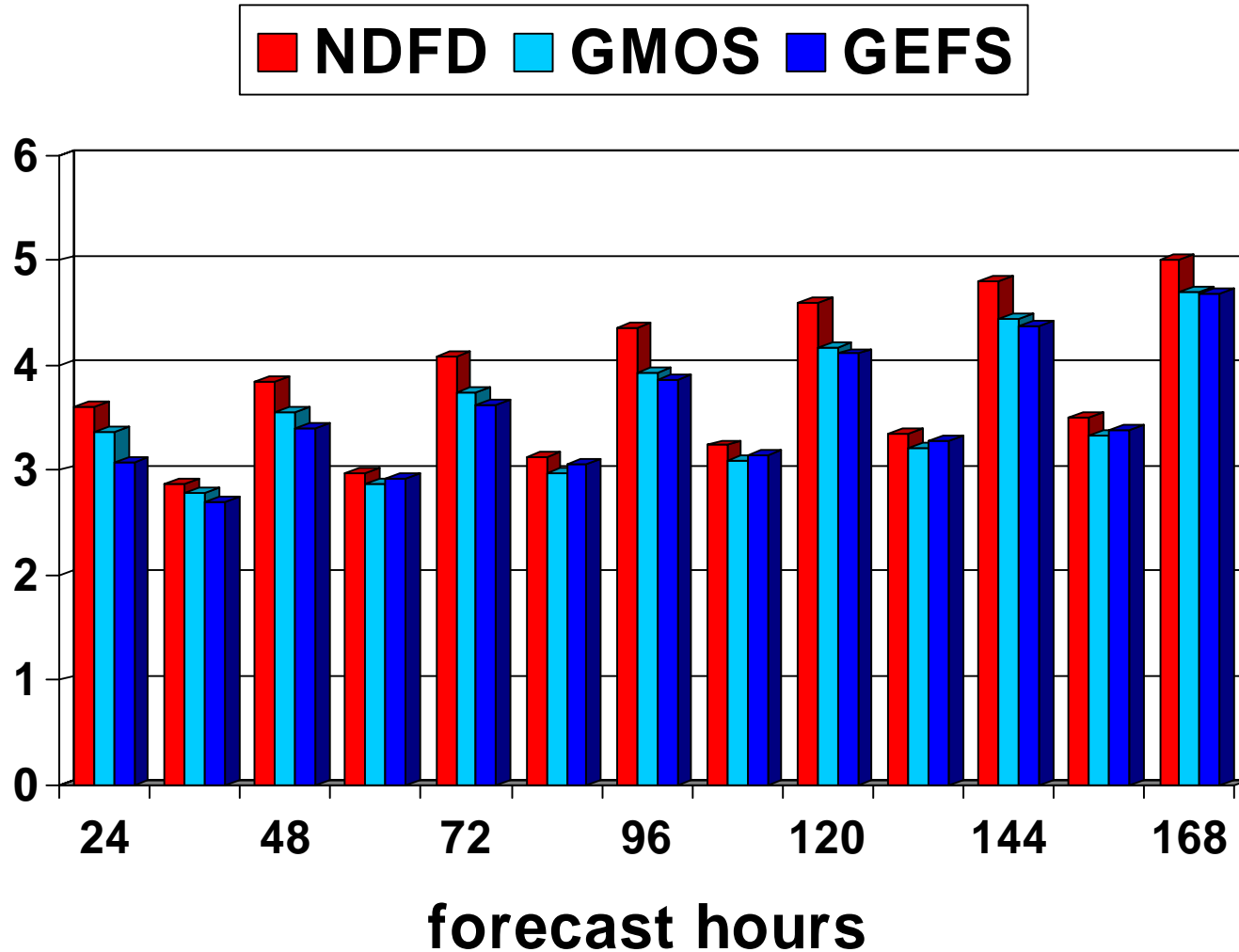


CONUS	3.07
EASTERN	3.12
CENTRAL	3.41
WESTERN	3.01
SOUTHERN	2.72

24-h GEFS
Forecast

CONUS only – verified against RTMA

2-m temp. forecast errors



Summary

- This is a major implementation
- System delivery: September 11
- NCO Initial testing: September 17-October 12
- Parallel testing: October 16 – present
- Final version of system delivered: October 16
- NCO parallel evaluation period:
 - Request for participation - 10/16/07
 - Evaluation period is 10/24/07 through 11/23/07
 - Evaluations are due 11/26/07
- Implementation date: December 4th
- Full summary of this implementation:
http://wwwt.emc.ncep.noaa.gov/gmb/yzhu/html/imp/200711_imp.html
- This package will be suitable for SREF, too.

Future Plan

- Correct NAEFS downscaling algorithm
 - Error in software implementation found on Nov. 15
 - Downscaling of Canadian ensemble data affected
 - Negatively affects primarily forecasts from 06, 12, 18Z cycles
 - Must implement correction operationally as soon as practical
- Apply statistical down-scaling method to other regions, Alaska, Hawaii, Puerto Rico and Guam, when RTMA is available
 - Streamline implementation process?
- Add new variables to NDFD grids, such as wind speed/direction, maximum/minimum temperature, 2-meter dew point temperature etc...
- Enhance products by
 - Improvements to RTMA
 - Bias correction of forecast first guess using recursive algorithm

CFS & GODAS upgrade January, 2008

Purpose of change

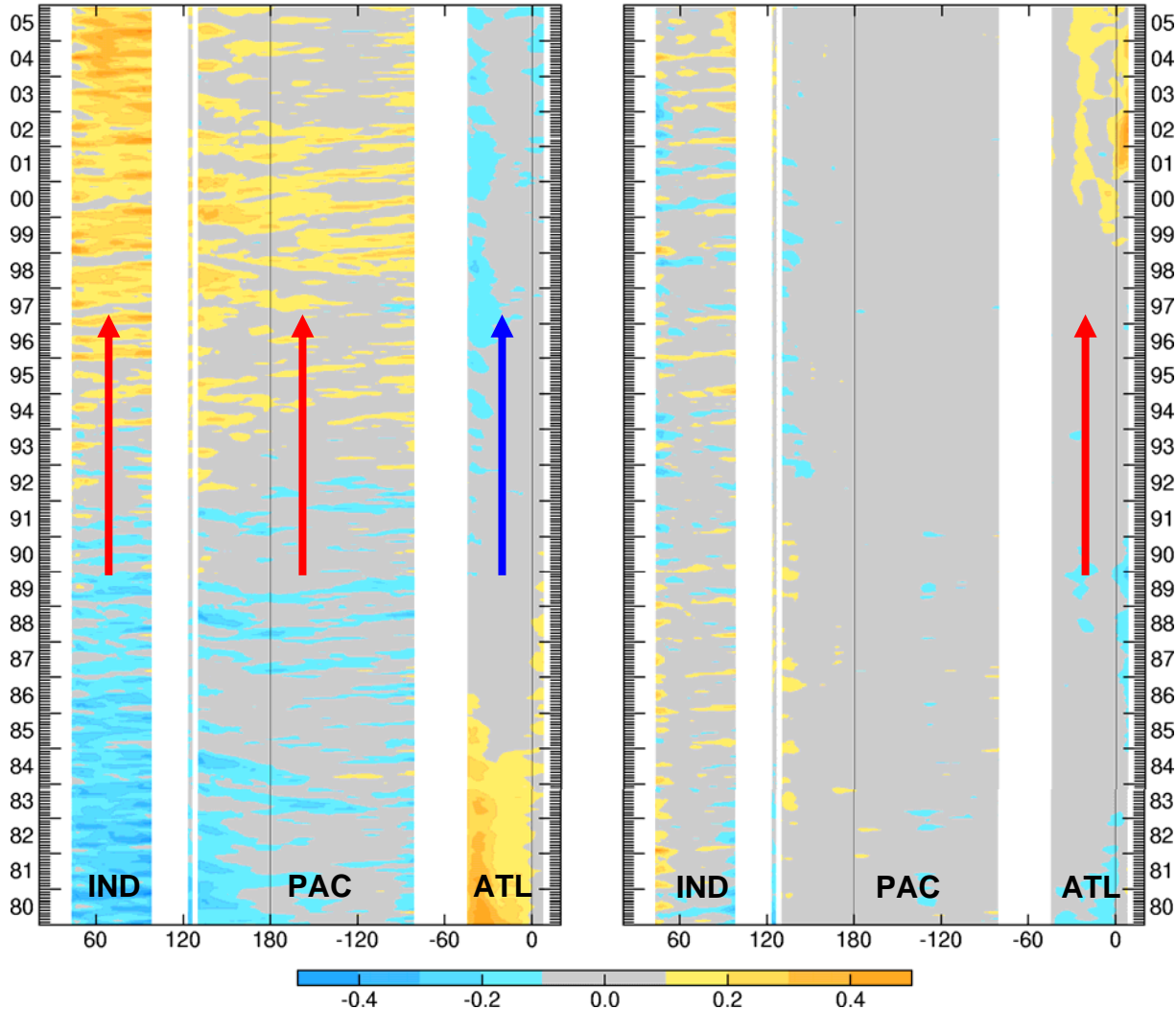
- Deep water GODAS
 - Extend the GODAS assimilation to 2175 meters
 - Correct a temperature bias in the global intermediate waters
- CFS upgrade
 - Reduce the 8-day lag in the initial conditions to a 1-day lag for both ocean and atmosphere.
 - Introduce 2 new members (T62L64) out to 9 months. These 2 new members would initiate from perturbed initial conditions similar to the current 2 members.
 - Both these upgrades aim to improve upon the week 3-6 / monthly forecast leads

Standard vs. Deep assimilation

Equatorial Temperature 1200m (Mean Removed)

GODAS

GODAS-X



The standard assimilation extends down to **750 m.**

Shallow assimilation can't control temperature drift at 1200 m.

The deep assimilation extends down to **2200 m.**

Deep assimilation eliminates drift in the Indian and Pacific Oceans and allows true positive trend in the Atlantic

Future Plans

GFS 2008 Implementation

Proposed data assimilation changes

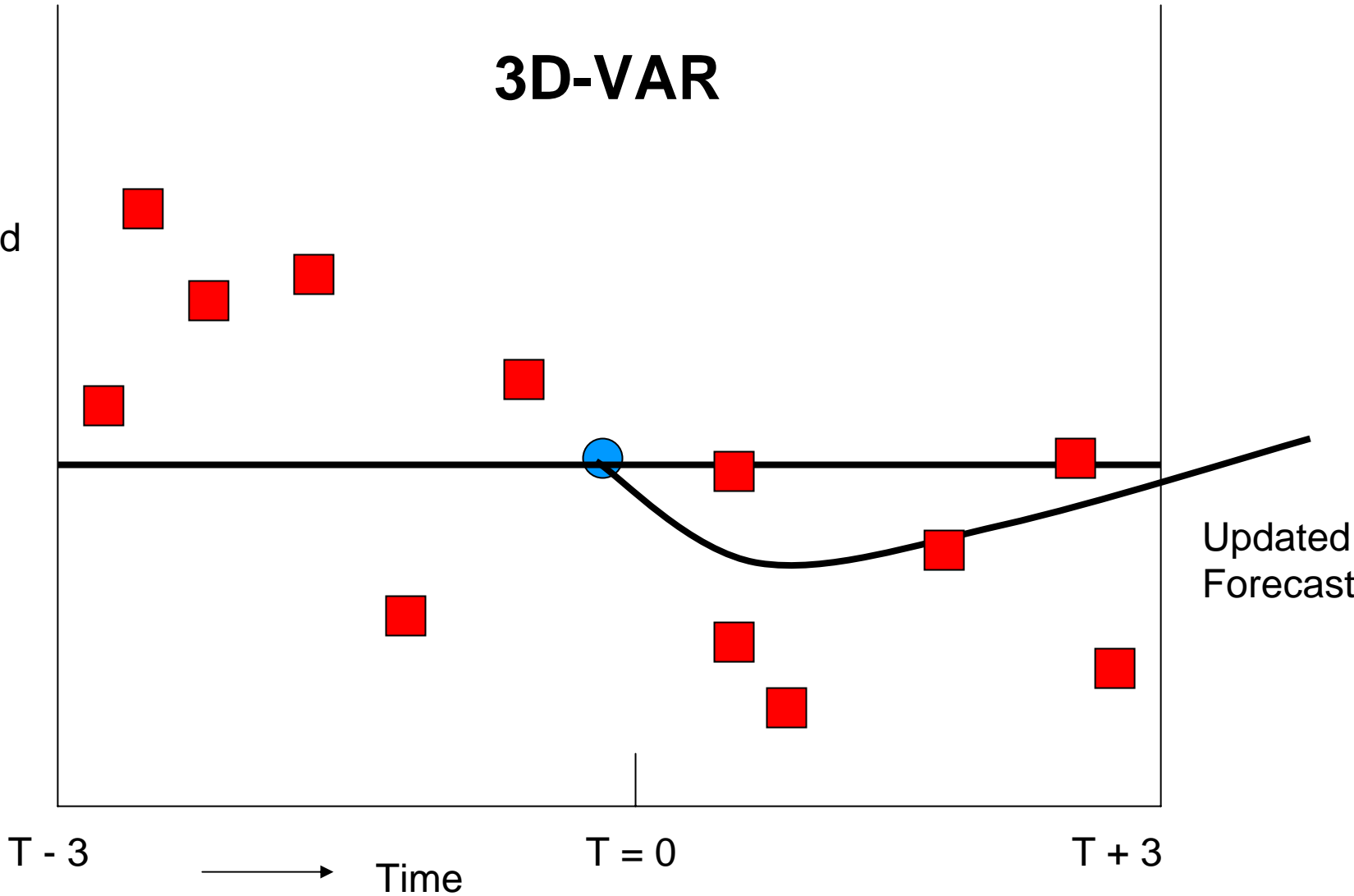
- FOTO (First-Order Time-extrapolation to Observations)
- Variational QC – tighter Gross checks
- Change in land/snow/ice skin temperature variance
- Situation dependent variances
- Changes to COSMIC QC
- Use of WINDSAT and ASCAT

FOTO

- (formerly called Simplified 4d-Var)
- At no additional cost includes:
 - Includes time extrapolation to observation using slow modes
 - Improves fit to obs
 - Some slowing of convergence

3D-VAR

Difference
from
Background
Forecast

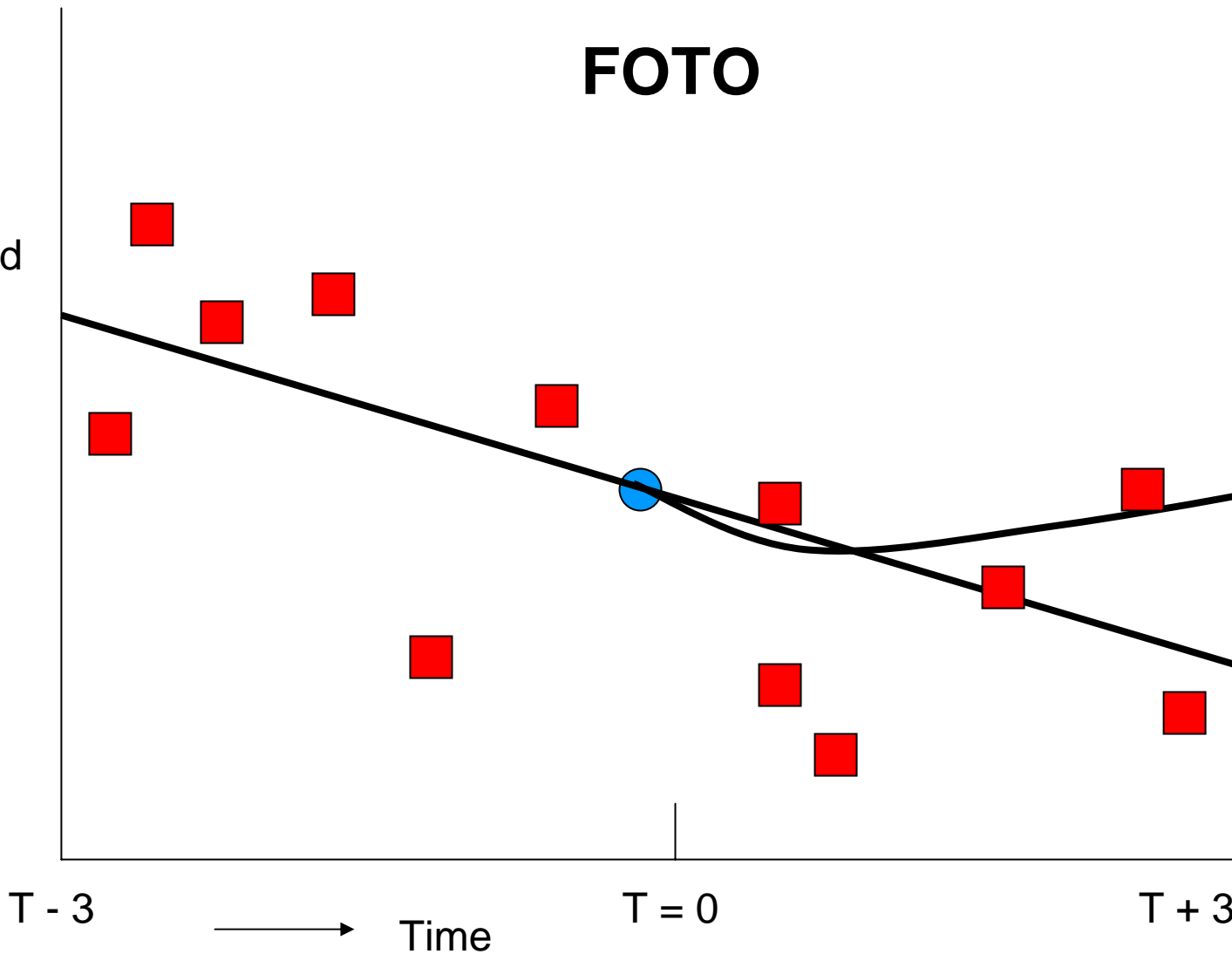


■ Obs - Background

● Analysis

FOTO

Difference
from
Background
Forecast

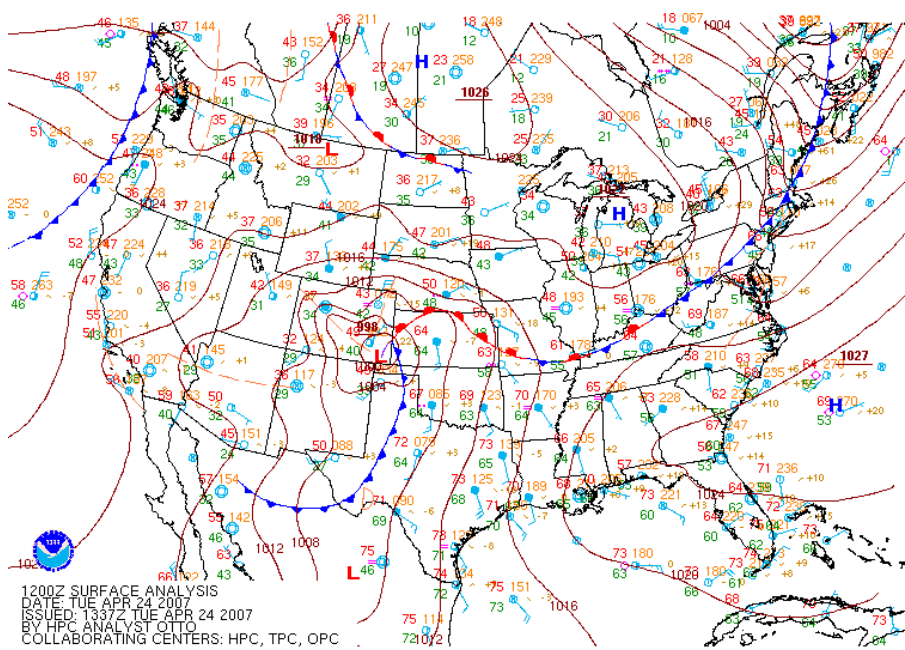


■ Obs - Background

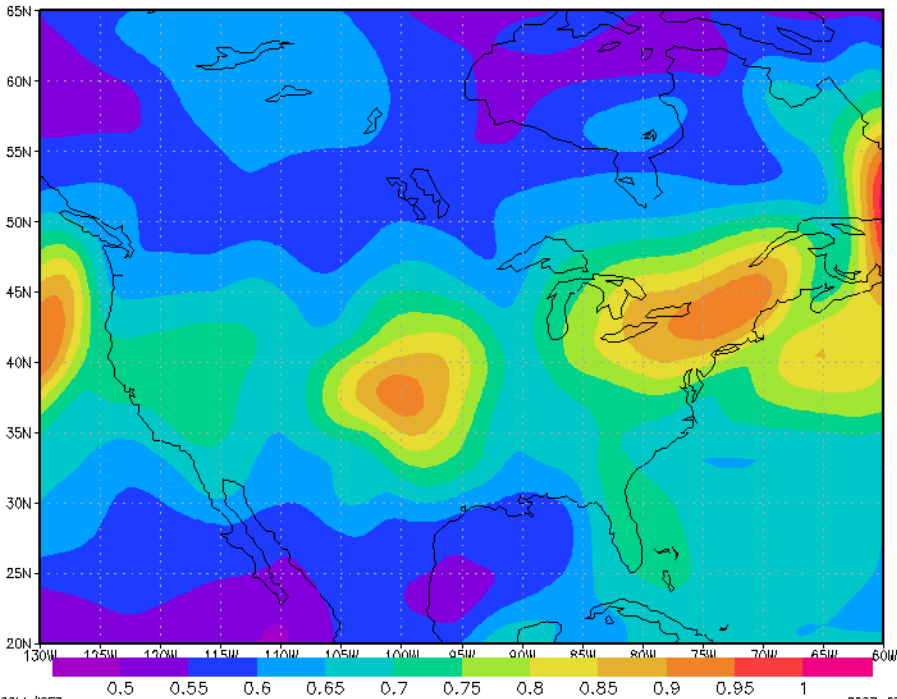
● Analysis

Situation dependent background variances

- Variances modified based on 9hr-3hr differences
 - Increased in rapidly changing locations
 - Decreased in others (global mean preserved)
- No additional cost



z=1 StFctn Rescaled StDev 2007042412



HPC Surface analysis (top) and
 z=1 Streamfunction (1e6)
 Background Error Standard
 Deviation for new flow-
 dependence algorithm (bottom)
 valid at 2007042412

Proposed forecast model changes

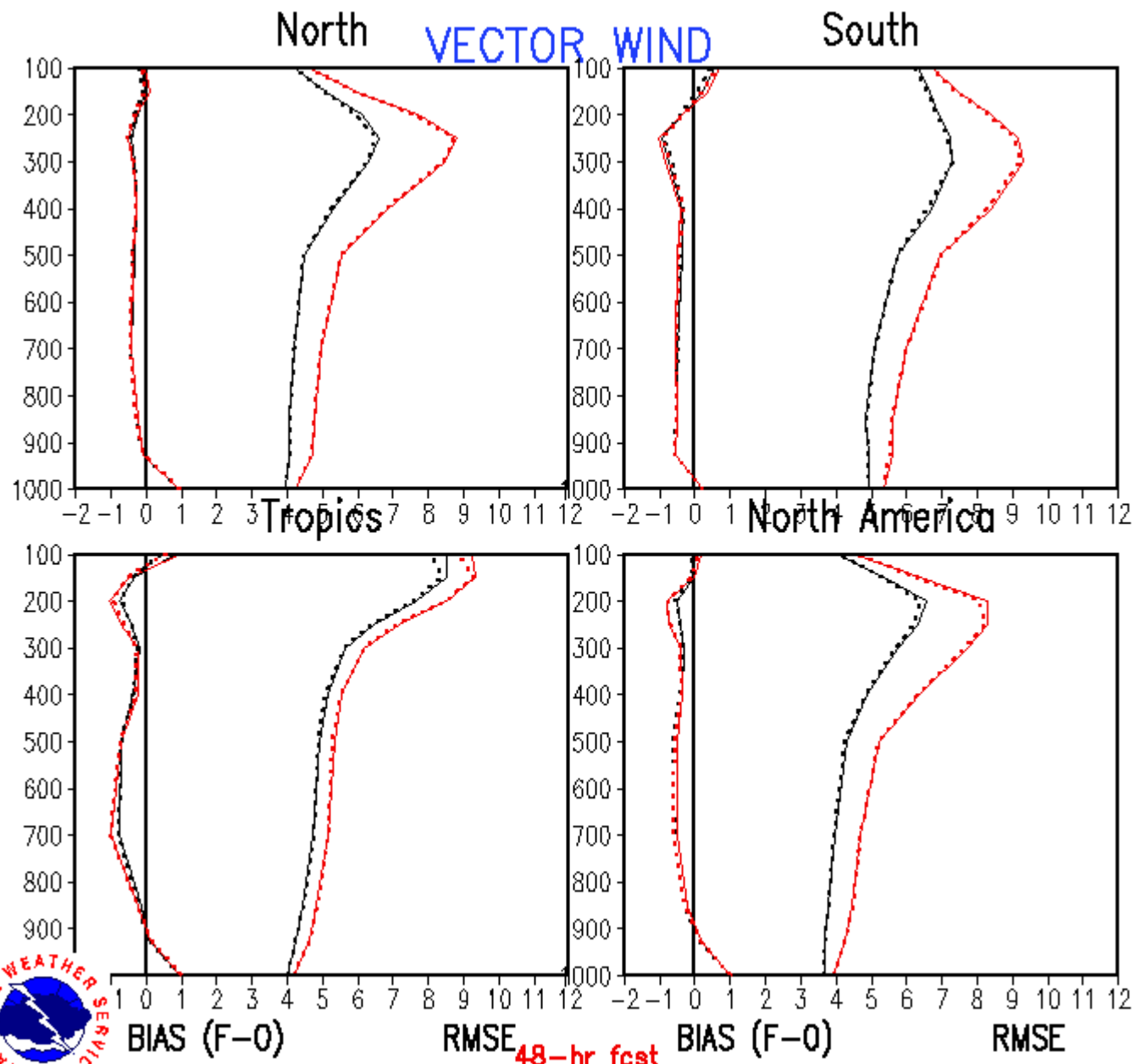
- Radiation parameterizations
 - RRTM1 longwave radiation
 - RRTM shortwave radiation
 - Maximum-random cloud overlap for shortwave
 - Hourly longwave radiation
 - Generalized aerosol treatment
 - Realistic CO₂
- Other physical parameterizations
 - Retuned mountain blocking
 - Orographic gravity wave variance range limits
 - Shallow convection up to sigma 0.7
- Dynamical core
 - Enthalpy thermodynamic prognostic variable

Deferred forecast model changes

- Physical parameterizations
 - Microphysics from the NAM
 - Planetary Boundary Layer and Convection
- Dynamical core
 - Hybrid isentropic vertical coordinate
 - Semi-Lagrangian

VECTOR WIND

Effect of new model (dotted line) on fits to sondes



SURANJANA SAHA, GMB/EMC/NCEP/NWS

BIAS (F-0)

RMSE

48-hr fcst
24-hr fcst

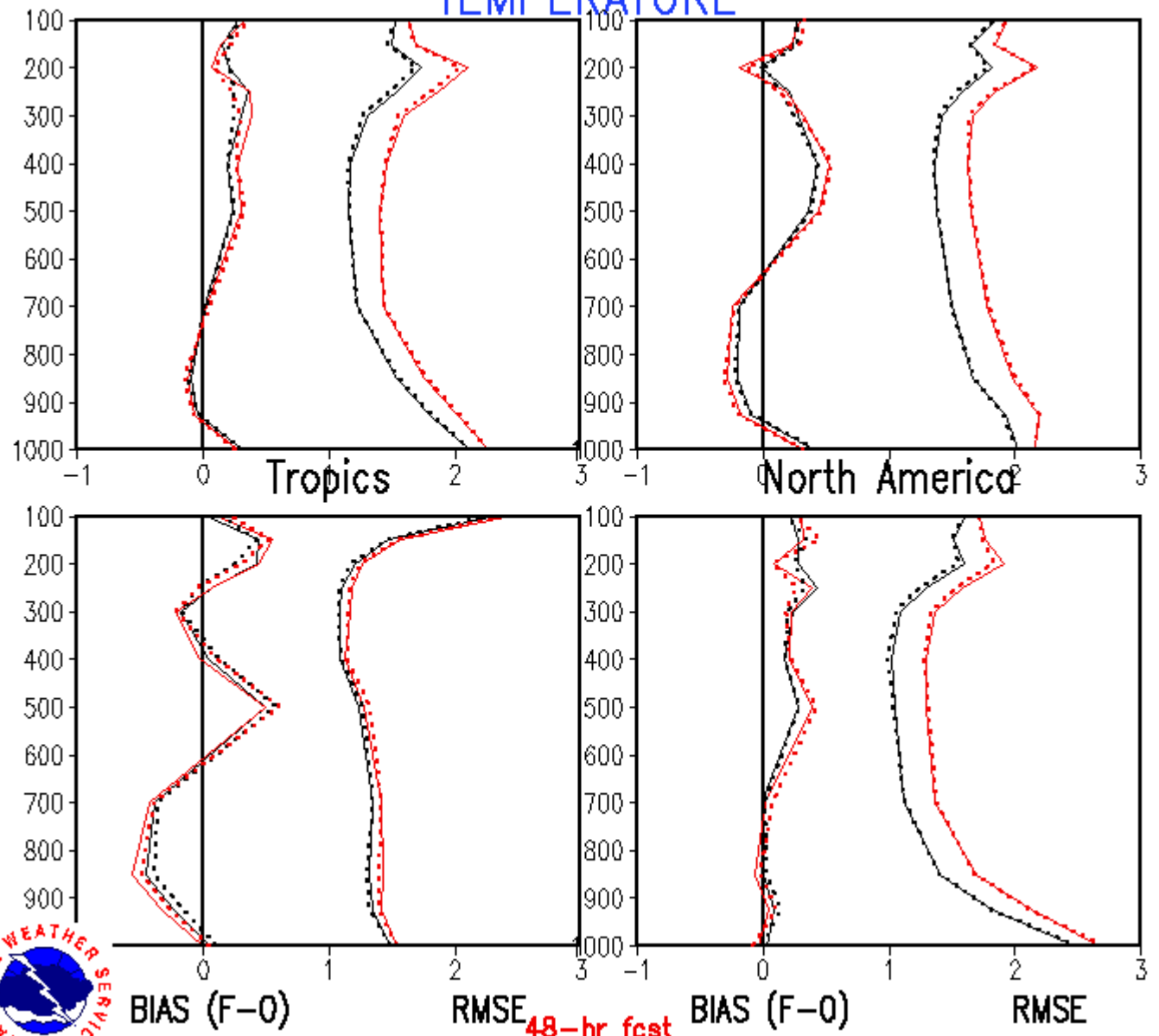
BIAS (F-0)

RMSE

00z11jul2005 - 00z25oct2005

North TEMPERATURE South

Effect of new model (dotted line) on fits to sondes

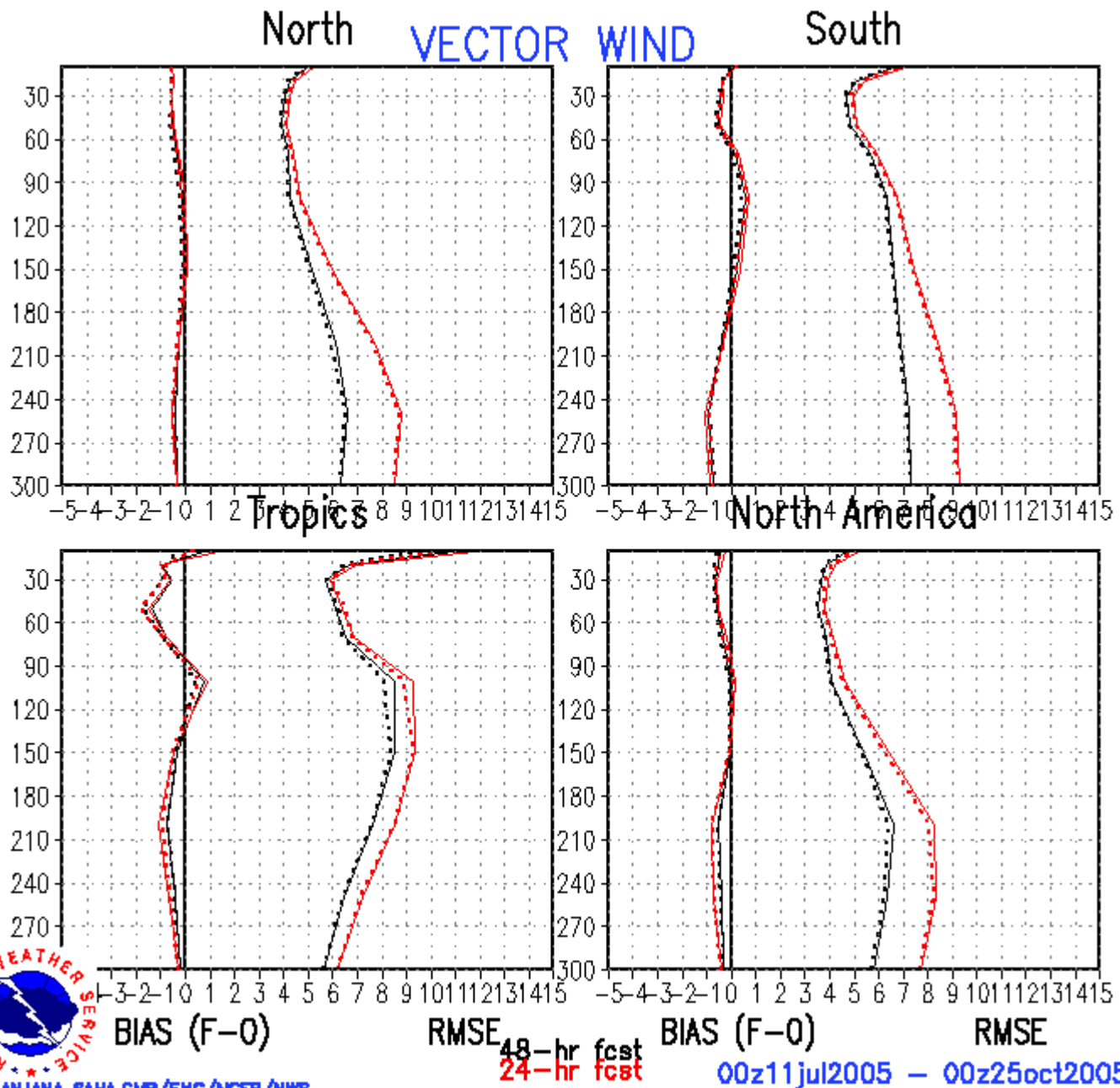


SURANJANA SAHA,GMB/EMC/NCEP/NWS

48-hr fcst
24-hr fcst

00z11jul2005 - 00z25oct2005

Effect of new model (dotted line) on fits to sondes

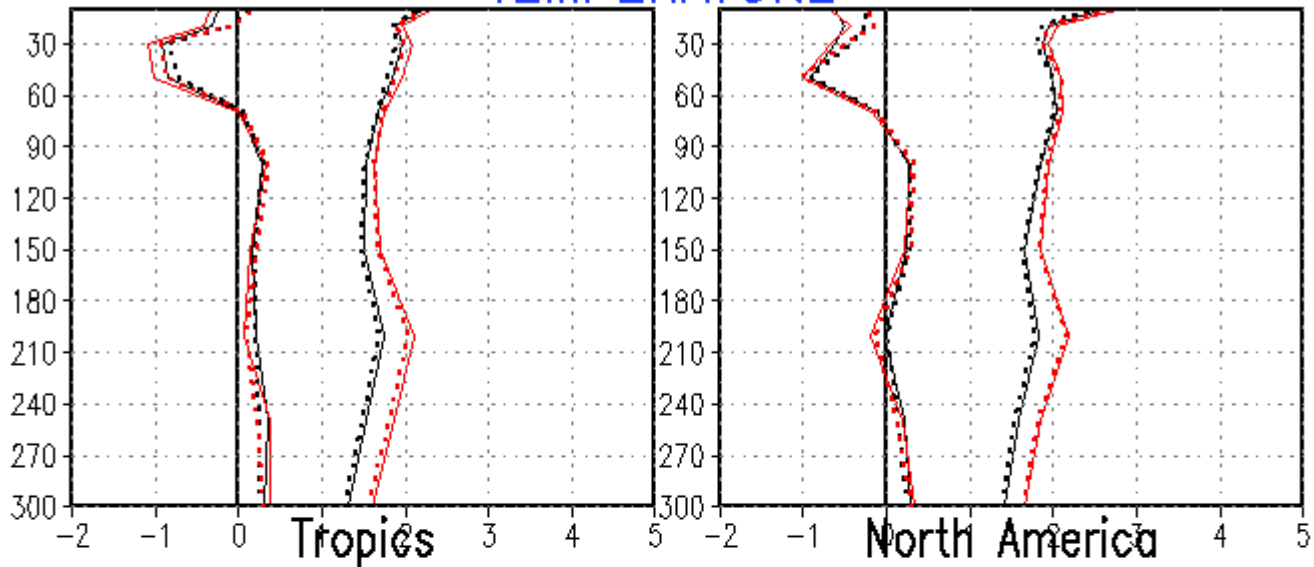


SURANJANA SAHA,GMB/EMC/NCEP/NWS

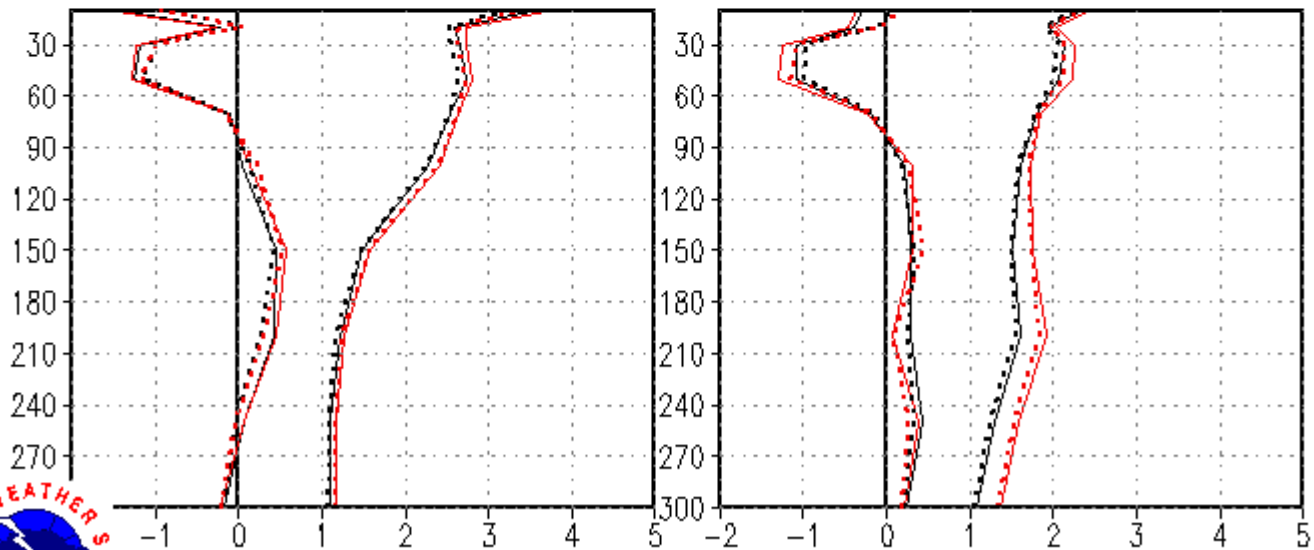
RMSE
48-hr fcst
24-hr fcst

00z11jul2005 - 00z25oct2005

North TEMPERATURE South



Effect of
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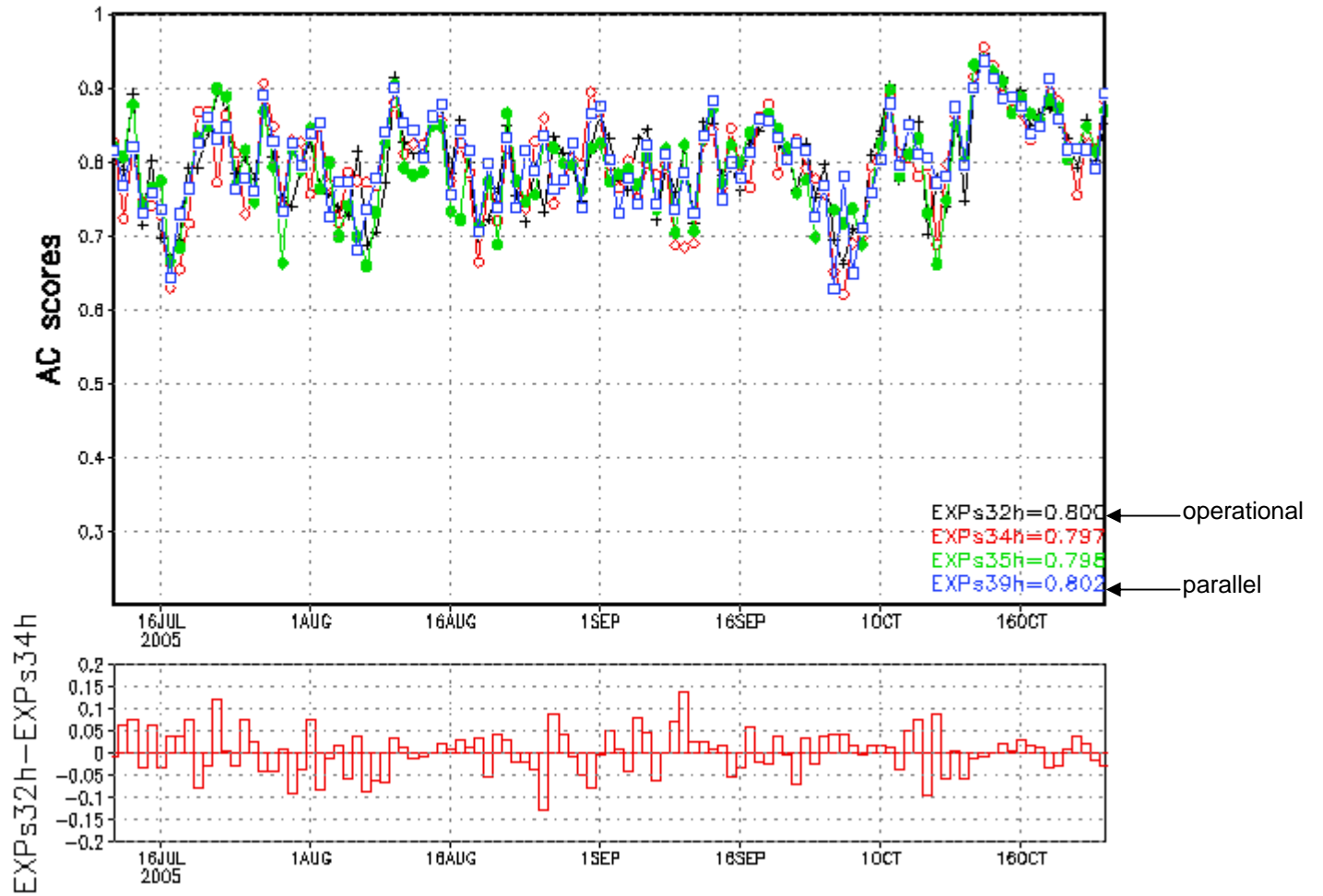


SURANJANA SAHA,GMB/EMC/NCEP/NWS

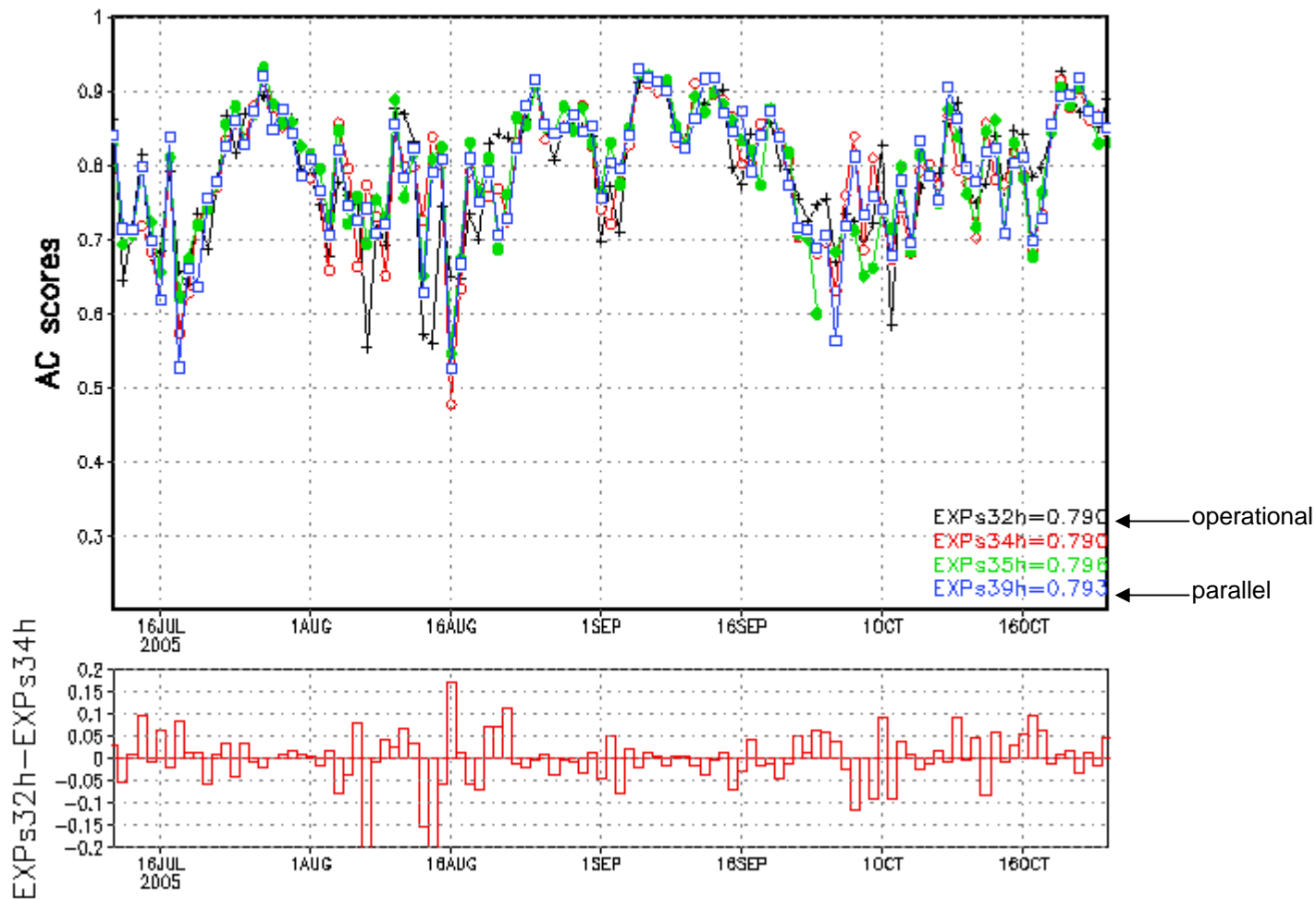
RMSE
48-hr fcst
24-hr fcst

BIAS (F-0)
RMSE
00z11jul2005 - 00z25oct2005

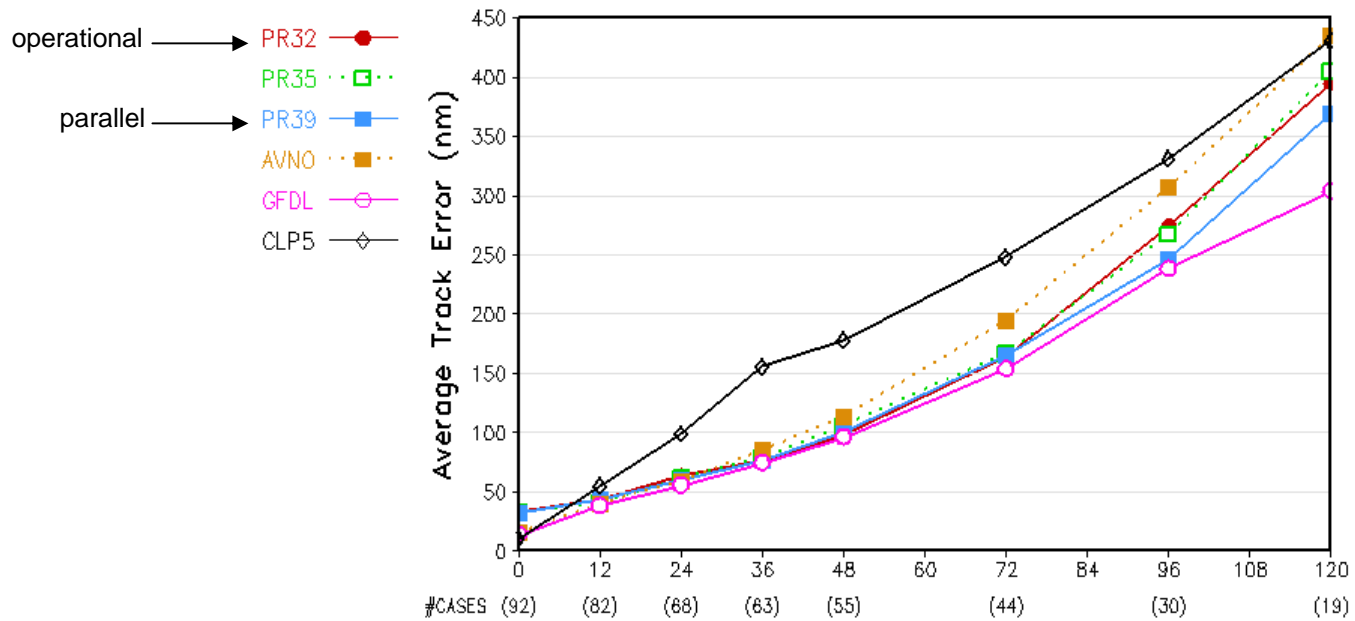
NH 500 mb Geopotential Height at day 5 for 00Z11JUL2005 – 00Z25OCT2005



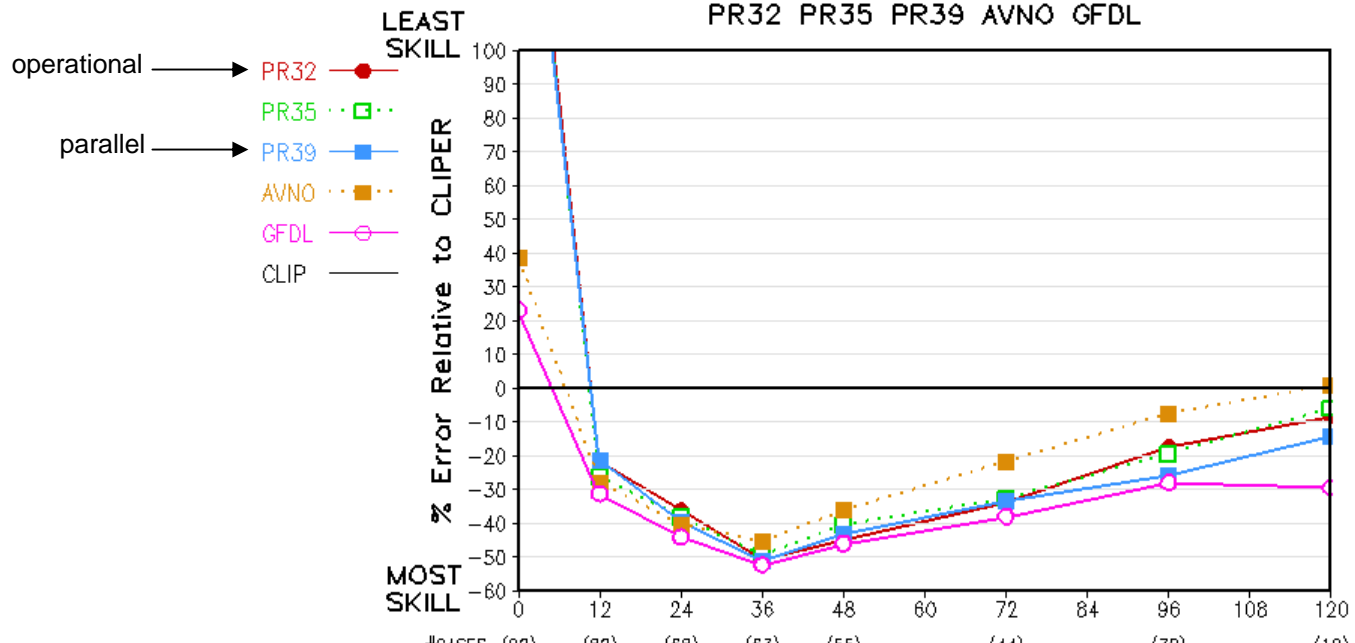
SH 500 mb Geopotential Height at day 5 for 00Z11JUL2005 – 00Z25OCT2005



Track Error Comparison, Atlantic Hurricanes (2005)
PR32 PR35 PR39 AVNO GFDL



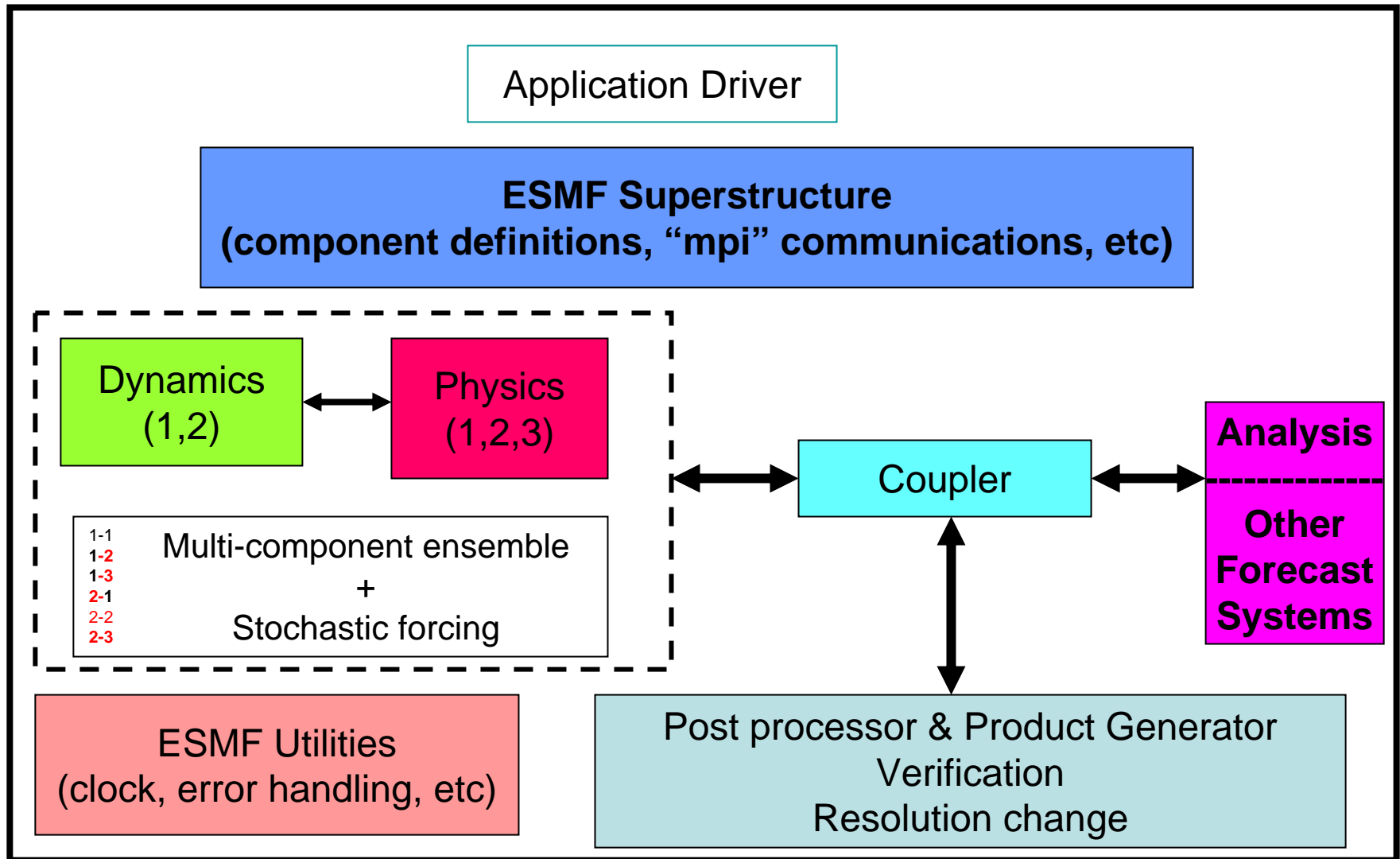
Track Error Comparison, Atlantic Hurricanes (2005)
PR32 PR35 PR39 AVNO GFDL



a partial list of Collaboration Projects

Advanced Data Assimilation	NASA
Atmospheric Dynamics	ESRL, NASA, MesoMoB
Physical Parameterizations	MesoMoB
Aerosols and Chemistry	NASA, EPA
Land Interaction	NASA
Ocean Interaction	GFDL, Navy
Thermosphere and Ionosphere Interaction	SWPC
NEMS	*

NEMS – you *will* be assimilated



* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC) 63

2, 3 etc: institutionally (non-NCEP) supported thru NUOPC or NOAA commitment

What is **NEMS**?

- **N**ational **E**nvironmental **M**odeling **S**ystem
- A Tinkertoy™ model of NCEP systems.
- Uses ESMF to isolate model system into well-defined “components” and “couplers”.
- Each component can be developed by a different group and have multiple uses.
- As modeling systems gets more complex, component robustness gets more critical.

NEMS requirements

- Clear and complete interfaces
- Coding standards adherence
- Documentation and support
- Stand-alone driver
- Regression test set
- ESMF

NEMS prototype

- Components
 - NAM NMM-B dynamics *working*
 - NAM WRF physics *working*
 - GFS spectral dynamics *working*
 - GFS digital filter initialization *working*
 - Basic I/O component *working*
 - GFS physics *under development*
 - Flexible I/O component *under development*
 - ESMF 3.1 conversion *under development*
 - NCEP Post *under development*
- Schedule
 - Initial prototype with NAM and GFS working in 2008
 - Possible initial operational implementation in 2009

Questions