



Recent efforts to improve GFS physics

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EMC, NCEP

2010

Proposed Changes

■ Resolution and ESMF

- Eulerian T574L64 for fcst1 (0-192hr) and T190L64 for fcst2 (192-384 hr) .
- fcst2 step with digital filter turned on
- ESMF 3.1.0rp2

■ Radiation and cloud

- Changing SW routine from ncep0 to RRTM2
- Changing longwave computation frequency from three hours to one hour
- Adding stratospheric aerosol SW and LW and tropospheric aerosol LW
- Changing aerosol SW single scattering albedo from 0.90 in the operation to 0.99
- Changing SW aerosol asymmetry factor. Using new aerosol climatology.
- Changing SW cloud overlap from random to maximum-random overlap
- Using time varying global mean CO₂ instead of constant CO₂ in the operation
- Using the Yang et al. (2008) scheme to treat the dependence of direct-beam surface albedo on solar zenith angle over snow-free land surface

Proposed Changes

■ Gravity-Wave Drag Parameterization

- Using a modified GWD routine to automatically scale mountain block and GWD stress with resolution.
- Compared to the T382L64 GFS, the T574L64 GFS uses four times stronger mountain block and one half the strength of GWD.

■ Removal of negative water vapor

- Using a positive-definite tracer transport scheme in the vertical to replace the operational central-differencing scheme to eliminate computationally-induced negative tracers.
- Changing GSI factqmin and factqmax parameters to reduce negative water vapor and supersaturation points from analysis step.
- Modifying cloud physics to limit the borrowing of water vapor that is used to fill negative cloud water to the maximum amount of available water vapor so as to prevent the model from producing negative water vapor.
- Changing the minimum value of water vapor mass mixing ratio in radiation from $1.0e-5$ in the operation to $1.0e-20$. Otherwise, the model artificially injects water vapor in the upper atmosphere where water vapor mixing ratio is often below $1.0e-5$.

Proposed Changes

■ Upgraded Vertical Diffusion Scheme

- Include stratocumulus-top driven turbulence mixing.
- Enhance stratocumulus top driven diffusion when condition for cloud top entrainment instability is met.
- Use local diffusion for the nighttime stable PBL.
- Background diffusion in inversion layers below 2.5km over ocean is reduced by 70% to decrease the erosion of stratocumulus along the costal area.
- increased momentum background diffusivity for winds only

■ New mass flux shallow convection scheme

- Detrain cloud water from every updraft layer
- Convection starting level is defined as the level of maximum moist static energy within PBL
- Cloud top is limited to 700 hPa.
- Entrainment rate is given to be inversely proportional to height and detrainment rate is set to be a constant as entrainment rate at the cloud base.
- Mass flux at cloud base is given to be a function of convective boundary layer velocity scale.

Proposed Changes

■ Updated deep convection scheme

- Eliminate Random cloud top, and cloud water is detrained from every cloud layer of the single cloud.
- Finite entrainment and detrainment rates for heat, moisture, and momentum are specified.
- Similar to shallow convection scheme, entrainment rate is given to be inversely proportional to height in sub-cloud layers and detrainment rate is set to be a constant as entrainment rate at the cloud base.
- Above cloud base, an organized entrainment is added, which is a function of environmental relative humidity
- Reduce cumulus momentum mixing
- Relax upper bound for mass flux
- convective overshooting
- increased cloud water detrainment in upper cloud layers

Expected Benefits

■ Model Resolution Increase

- Small incremental improvement in overall model performance

■ Upgraded Physics Package

- Reduction in spurious excessive amounts of precip over small geographic areas (Grid-Point Storms)

Testing Methodology

■ Retrospectives

➤ 2008 Hurricane Season (June 15 – November 30)

❖ T574L64: 0 – 180, T382L64: 180 – 384

❖ T574L64: 0 – 180, T382L64: 180 – 384 with shallow convection package

➤ 2009 Hurricane Season (July 1 – November 30)

❖ T574L64: 0 – 180, T382L64: 180 - 384

➤ Winter 2009/2010 (November 1 – present)

❖ T574L64: 0 – 192, T382L64: 192 – 384

❖ T574L64: 0 – 192, T254L64: 192 – 384

❖ T574L64: 0 – 192, T190L64: 192 – 384

Testing Methodology

■ Special Cases

- 06Z 8 June 09 Precip Bomb in SD
- 00Z 16 June 09 Precip Bomb in IA (12h) & MI (36h)
- 18Z 15 July 09 Precip Bomb off AL Coast
- 12Z 21 July 09 Multiple Precip Bombs in Central US
- 00Z 13 Aug 09 Overprediction of low in Trop E Atl
- 00Z 15 Aug 09 Spurious low in 4-5 day fcst for Bill
- 18Z 13 Nov 09 Spurious cyclogenesis in post IDA
- 12Z 14 Nov 09 Spurious cyclogenesis in post IDA
- 06Z 12 Jan 10 Precip Bombs in Gulf

2008 Hurricane Season

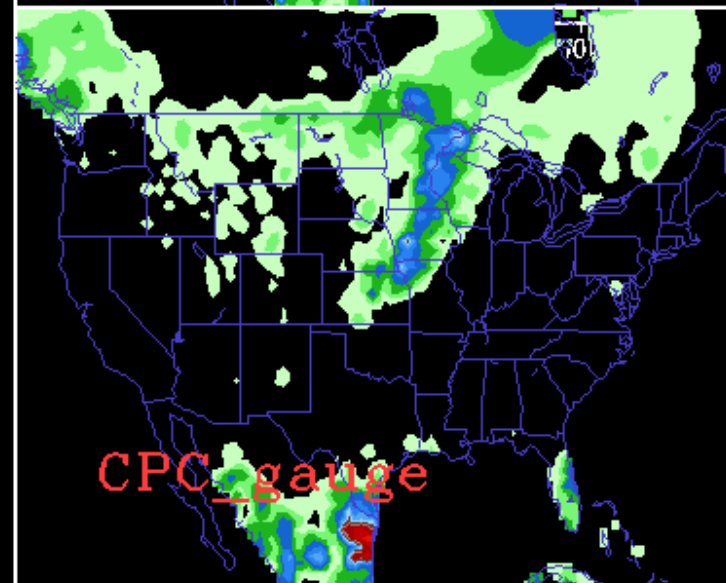
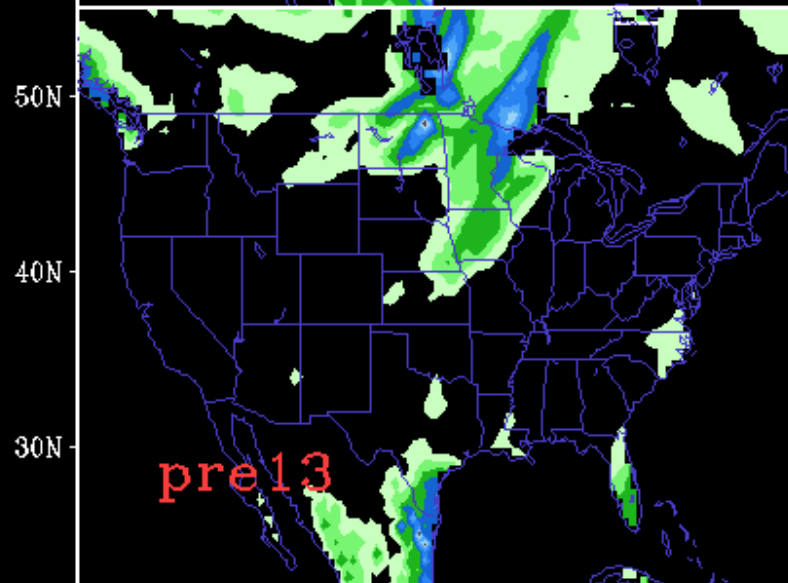
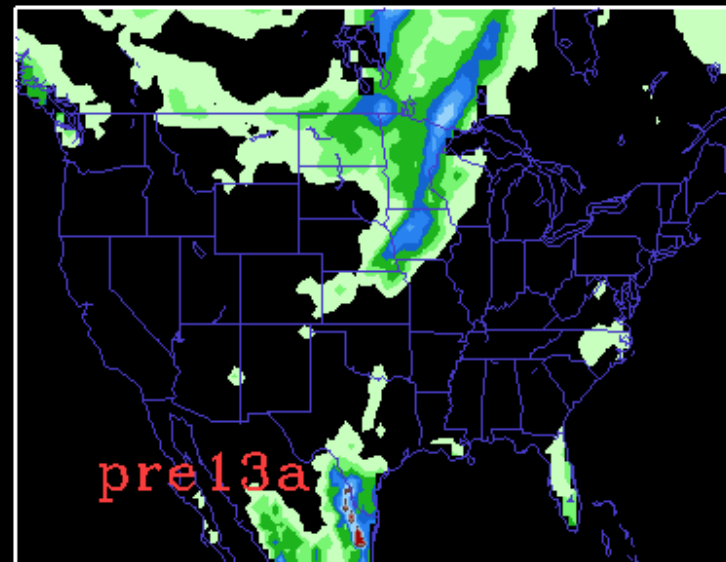
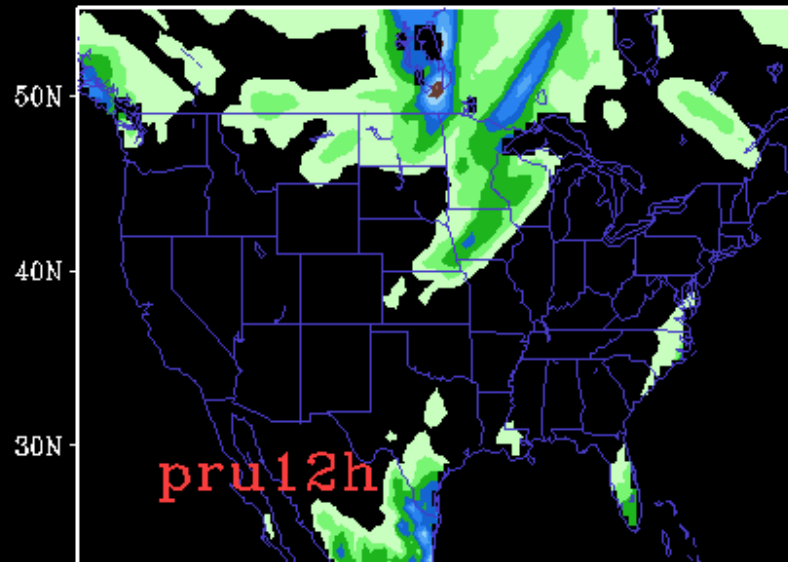
Legend:

PRU12 (U12H) – Baseline 1Q10 GFS

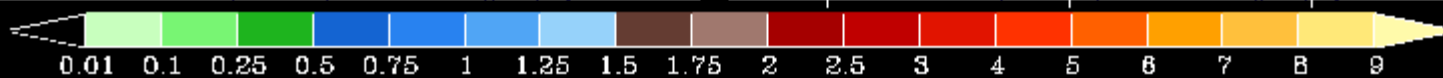
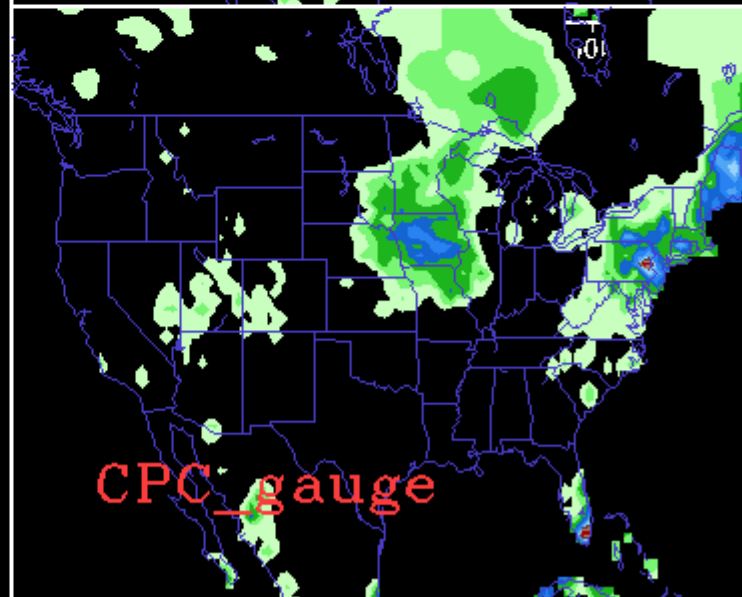
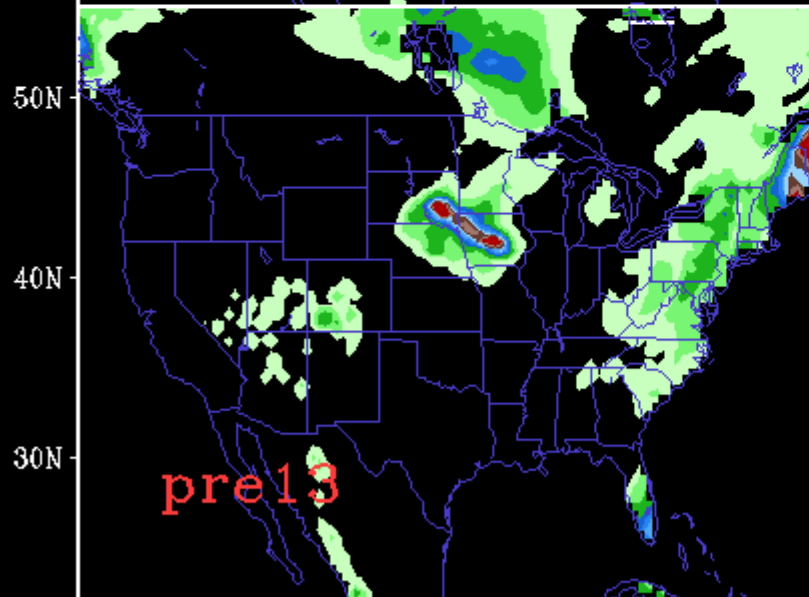
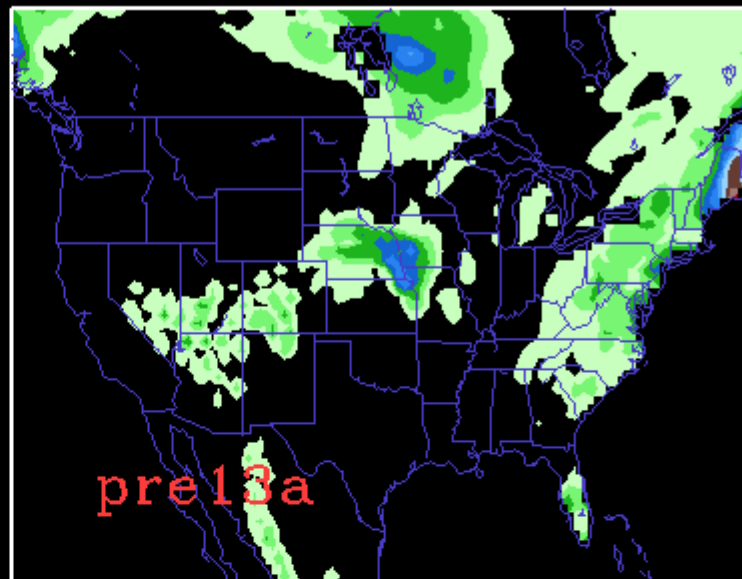
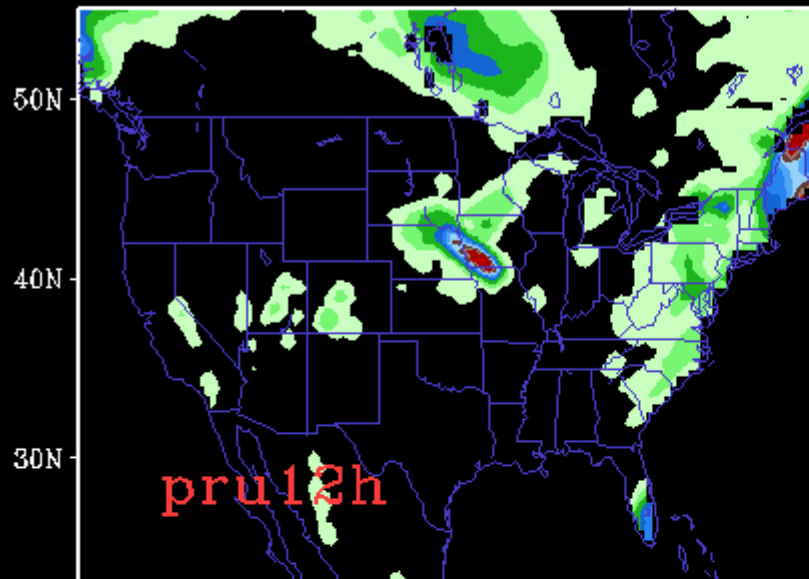
PRE13 – T574

PRU13a (574S) – T574 with Shallow Convection Package

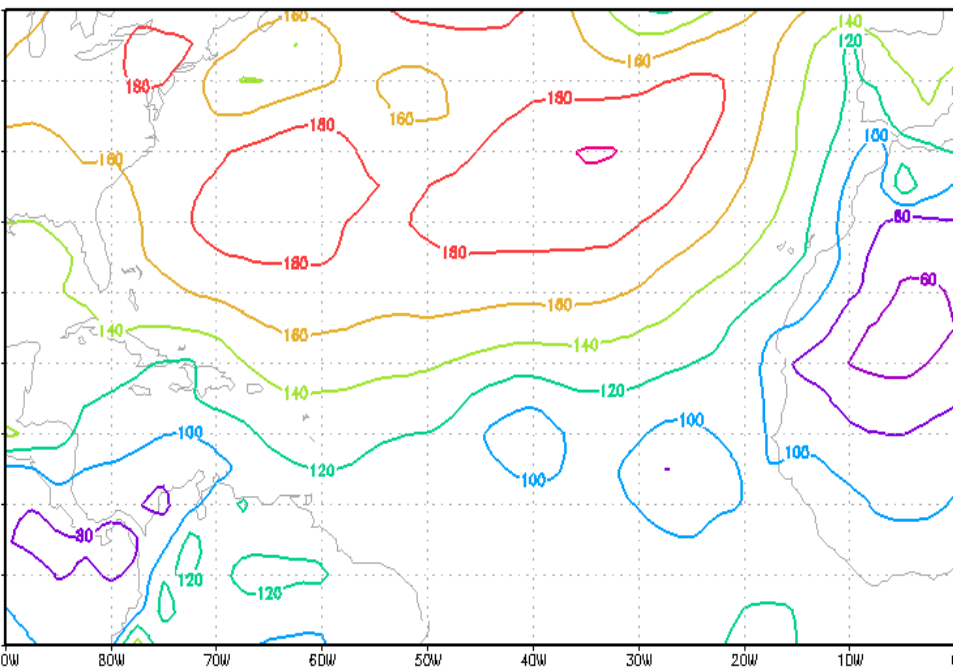
24-Hour Rainfall Ending at 2008092412 (0.5-deg, inch)
Forecast Cycle 2008092200, Fcst Hour: 36 from 60



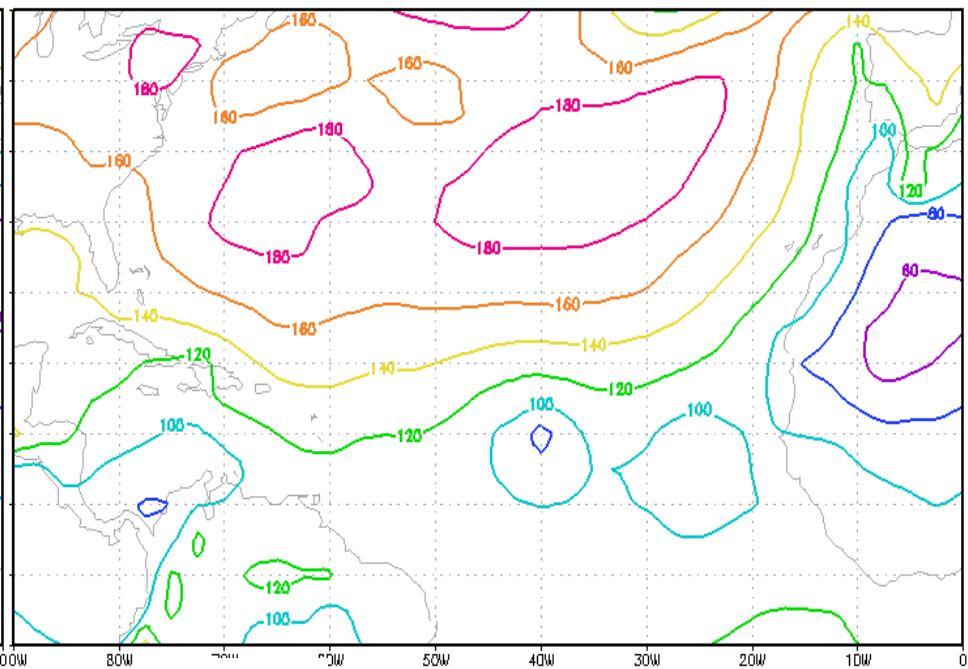
24-Hour Rainfall Ending at 2008092912 (0.5-deg, inch)
Forecast Cycle 2008092700, Fcst Hour: 36 from 60



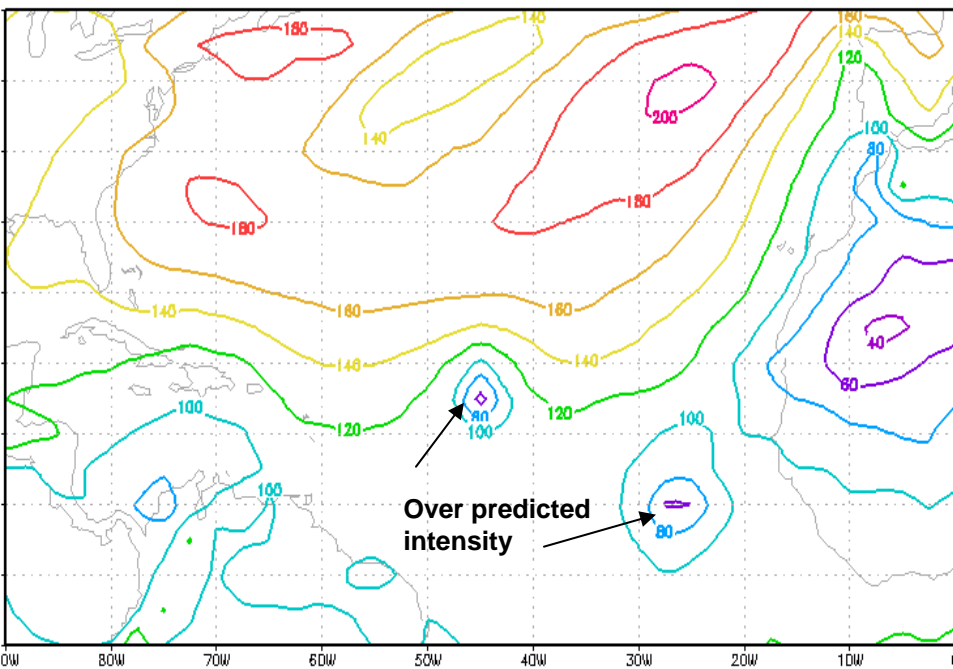
Z1000 opr anl 6Z Aug14 09



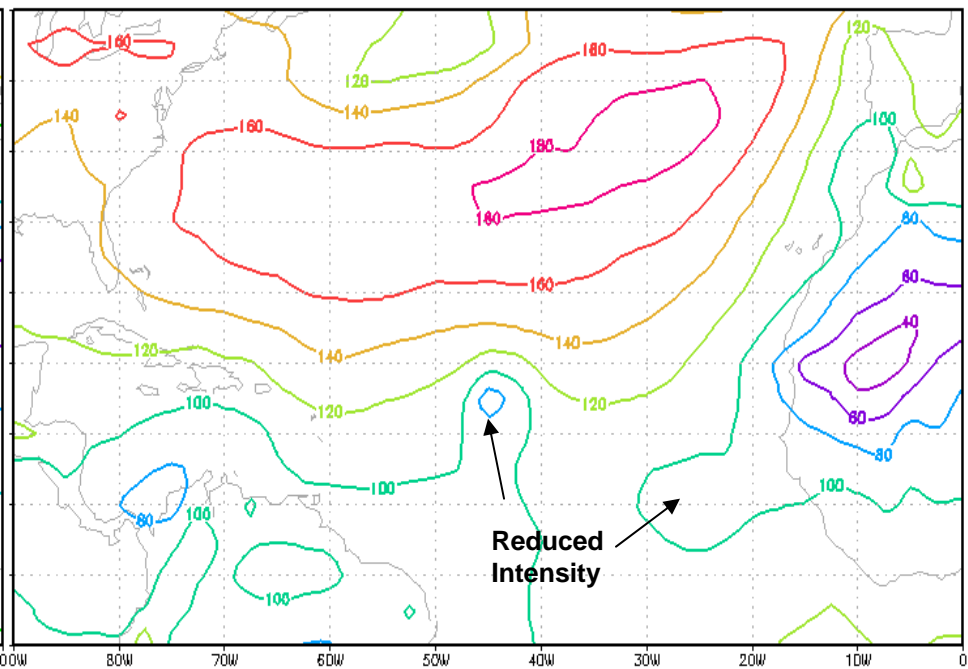
Z1000 T574 anl 6Z Aug14 09



PROD Z1000 op 126 hr fcst from 00z Aug 9 2009



Z1000 T574 126 hr fcst from 00z Aug 9 2009



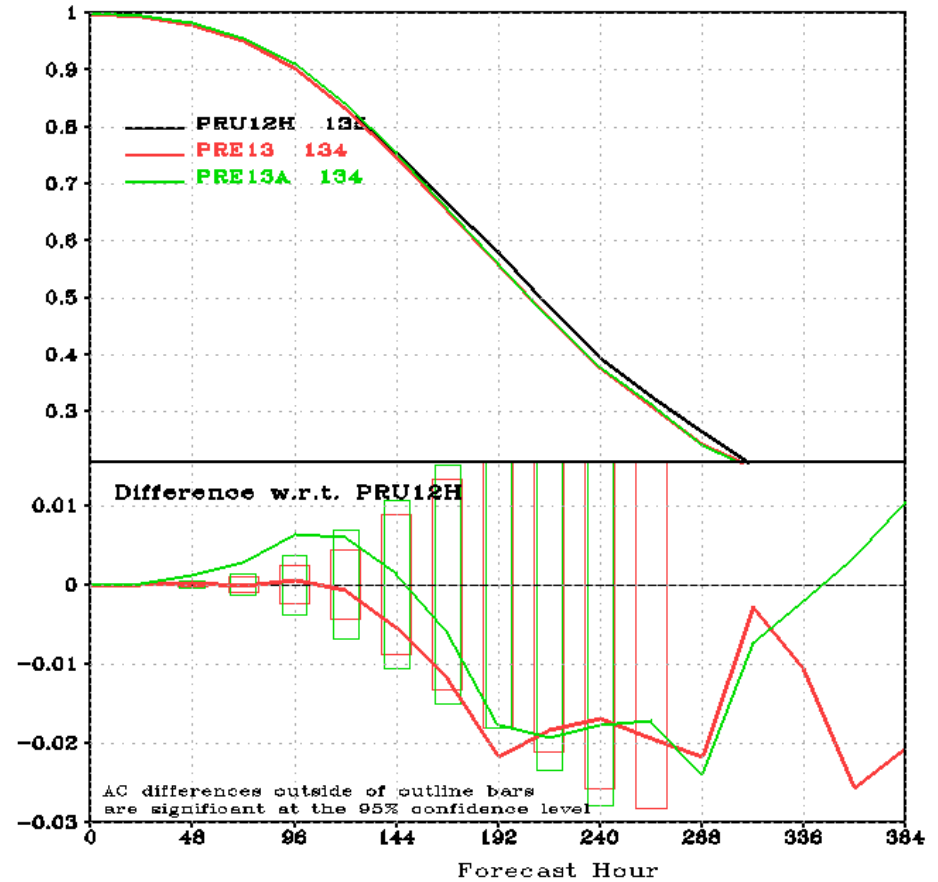
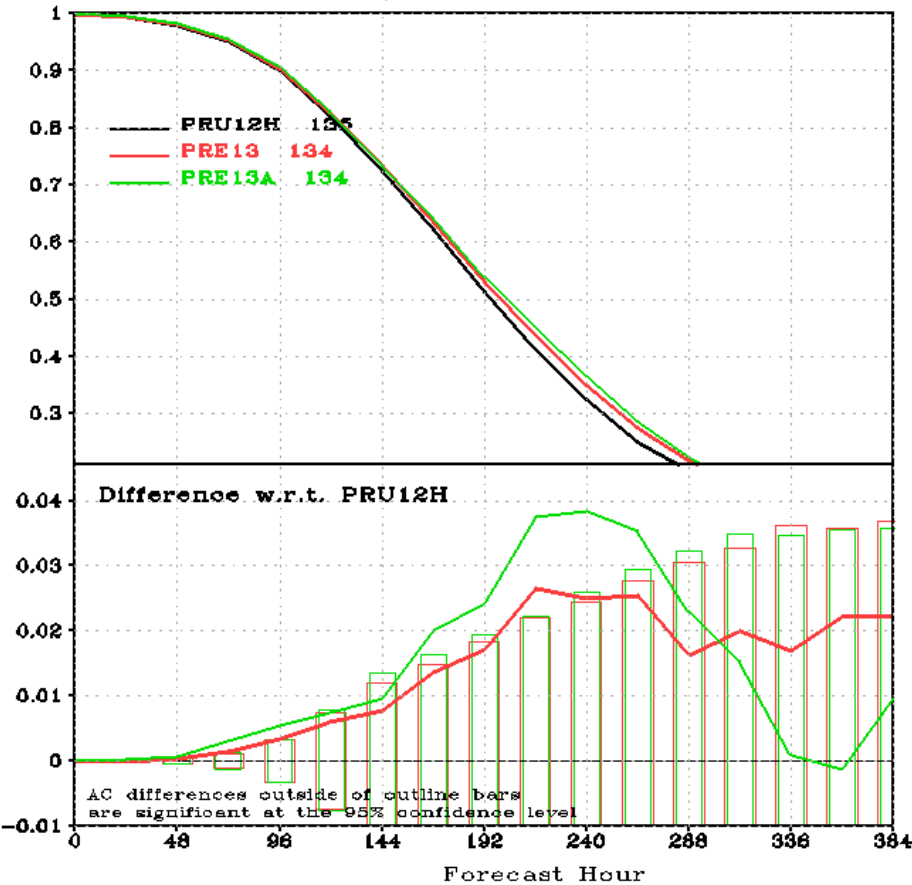
500 MB Anomaly Correlation

Northern Hemisphere

Southern Hemisphere

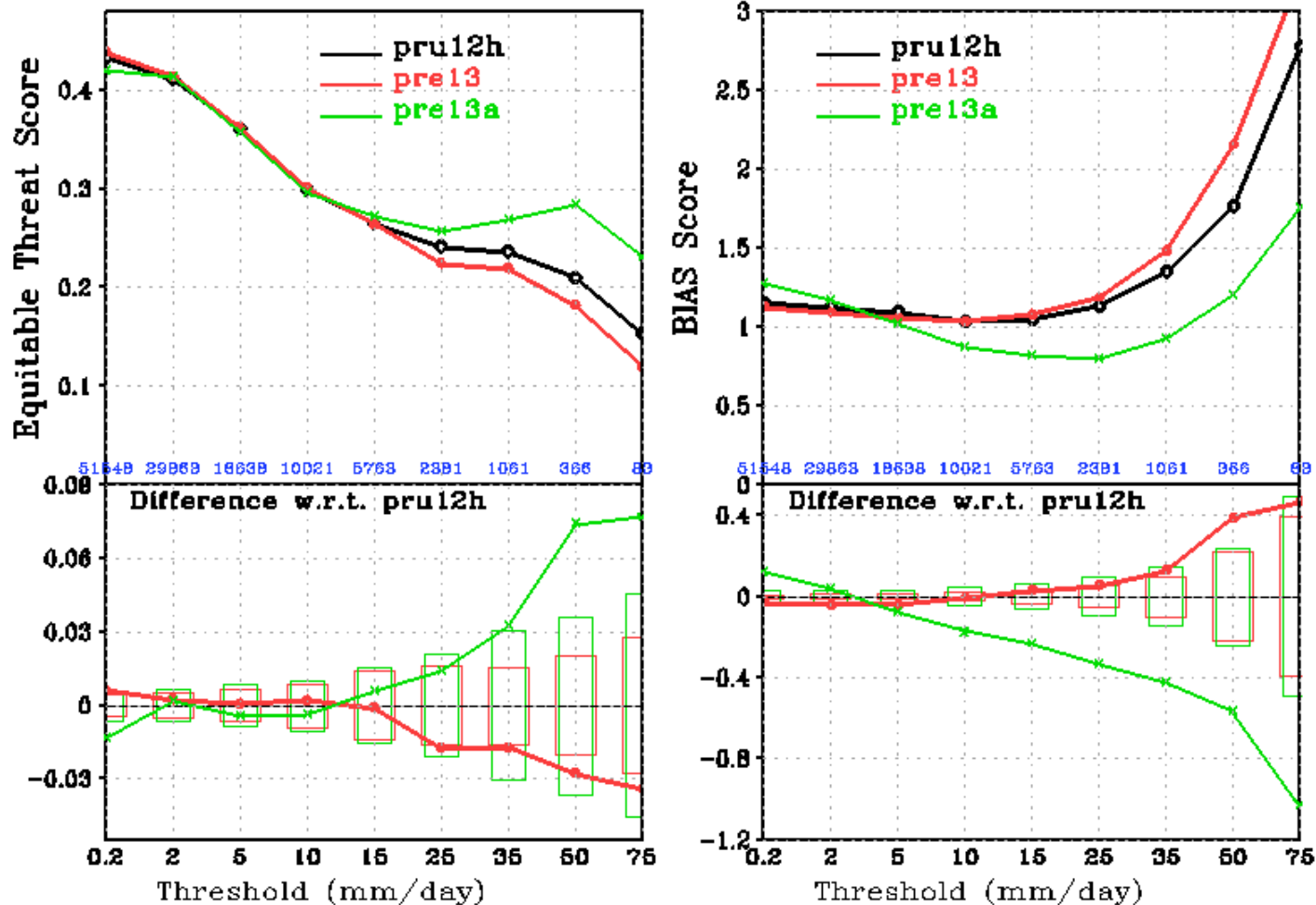
AC: HGT P500 Q2/NHX 00Z, 20080620-20081101

AC: HGT P500 Q2/SHX 00Z, 20080620-20081101



Precipitation Scores

CONUS Precip Skill Scores, f12-f36, 20jun2008-01nov2008



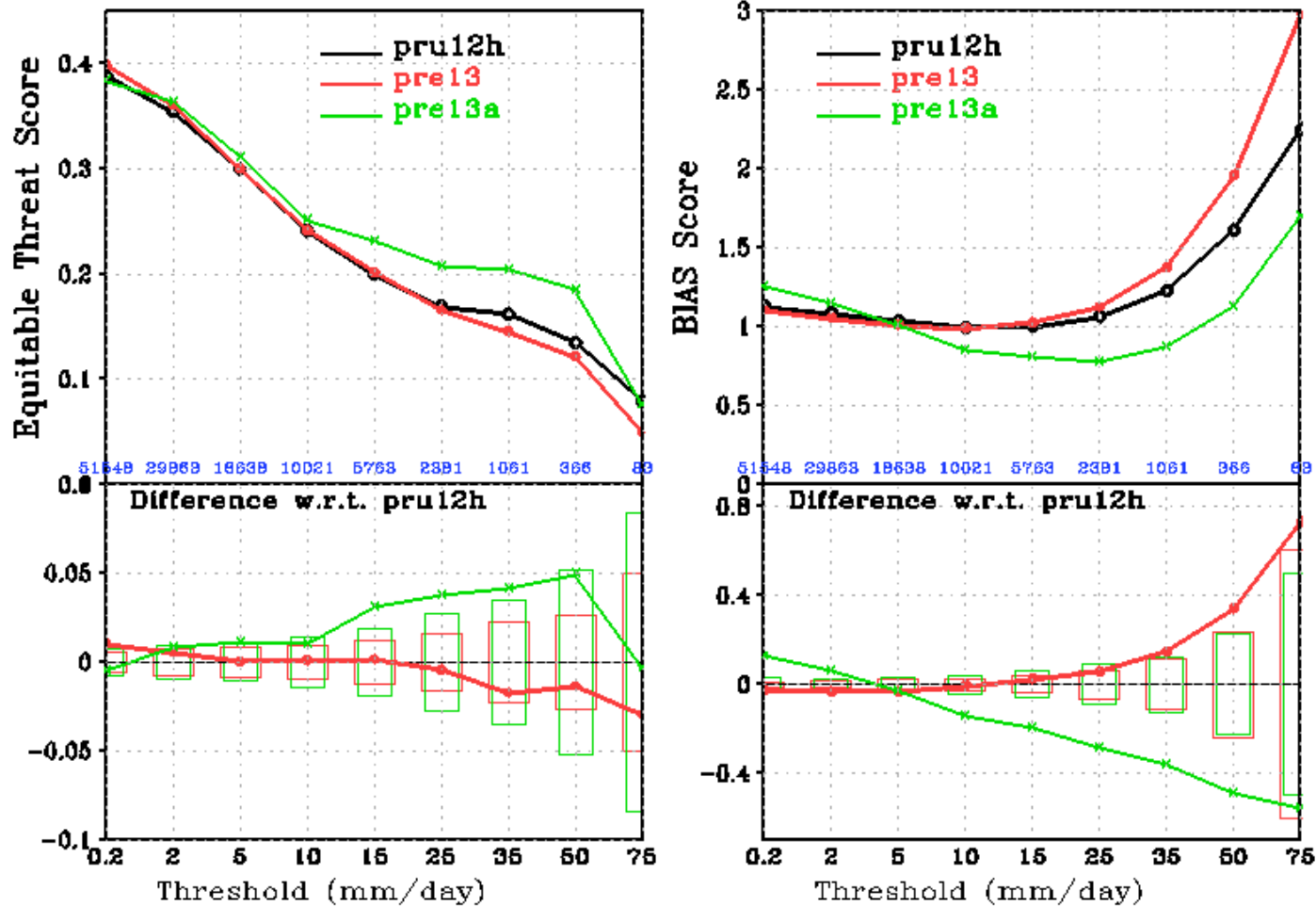
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Red – without Shallow Conv

Green – With SC

Precipitation Scores

CONUS Precip Skill Scores, f36-160, 20jun2008-01nov2008

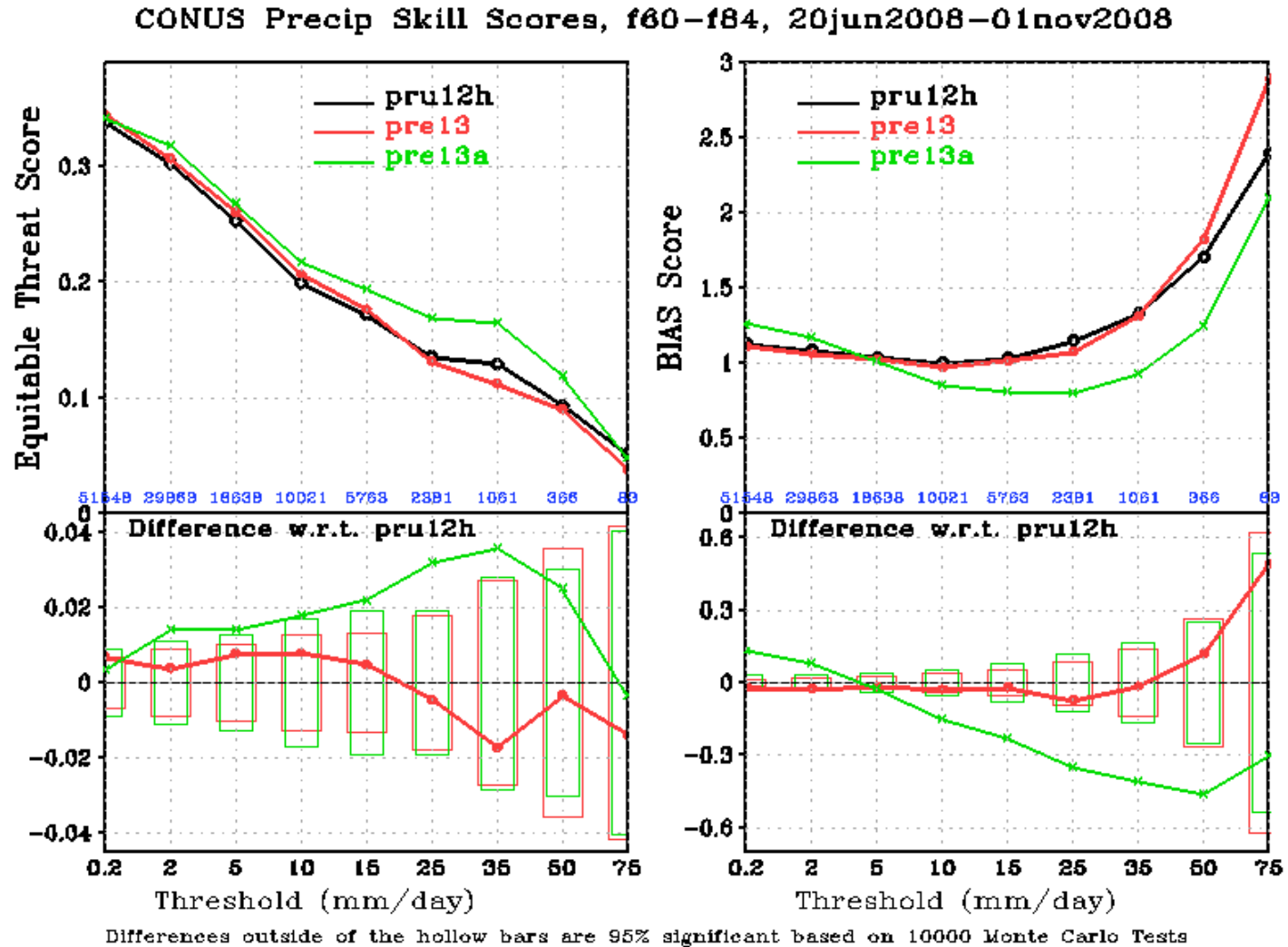


Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Red – without Shallow Conv

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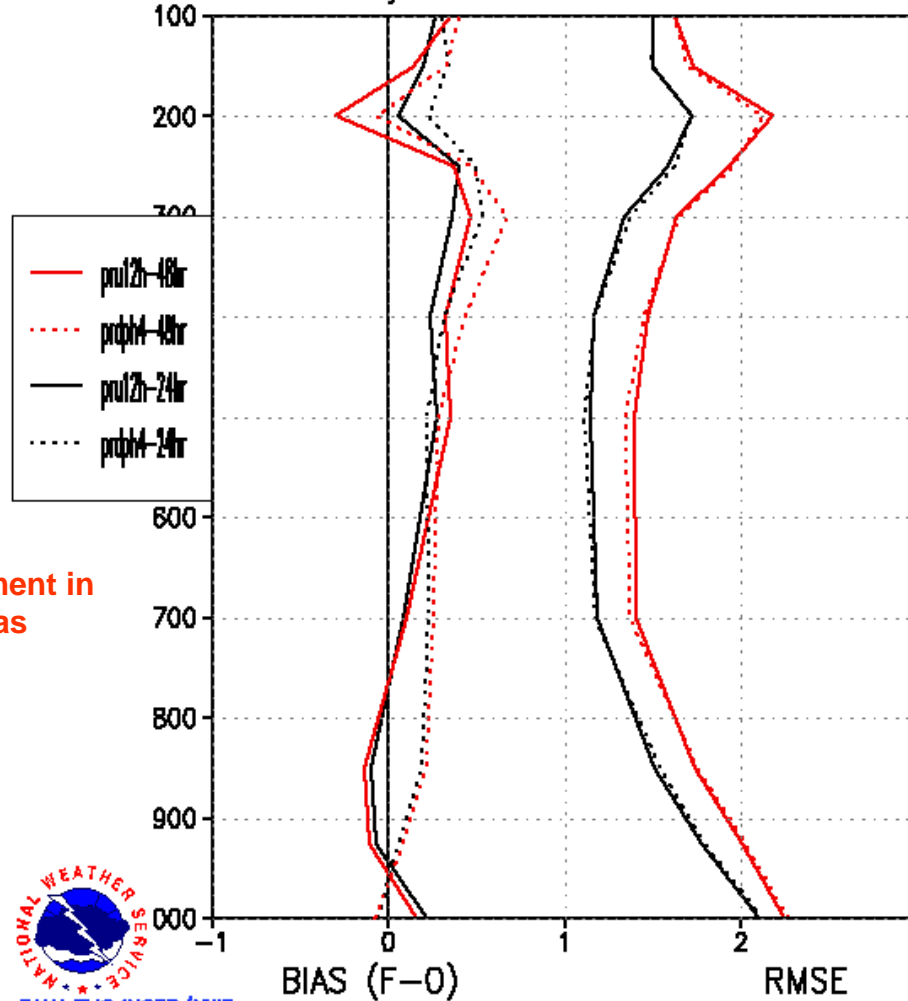
Precipitation Scores



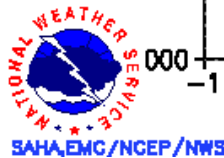
Red – without Shallow Conv
Green – With SC

Fit-To-Obs

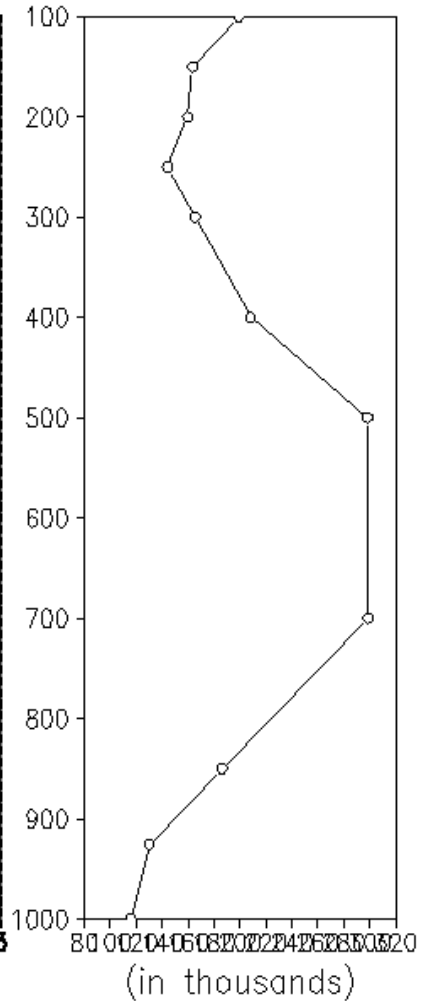
NH Temp Fits to RAOBS
00z20jun2008 - 00z09nov2008



Some improvement in
RMSE & Bias

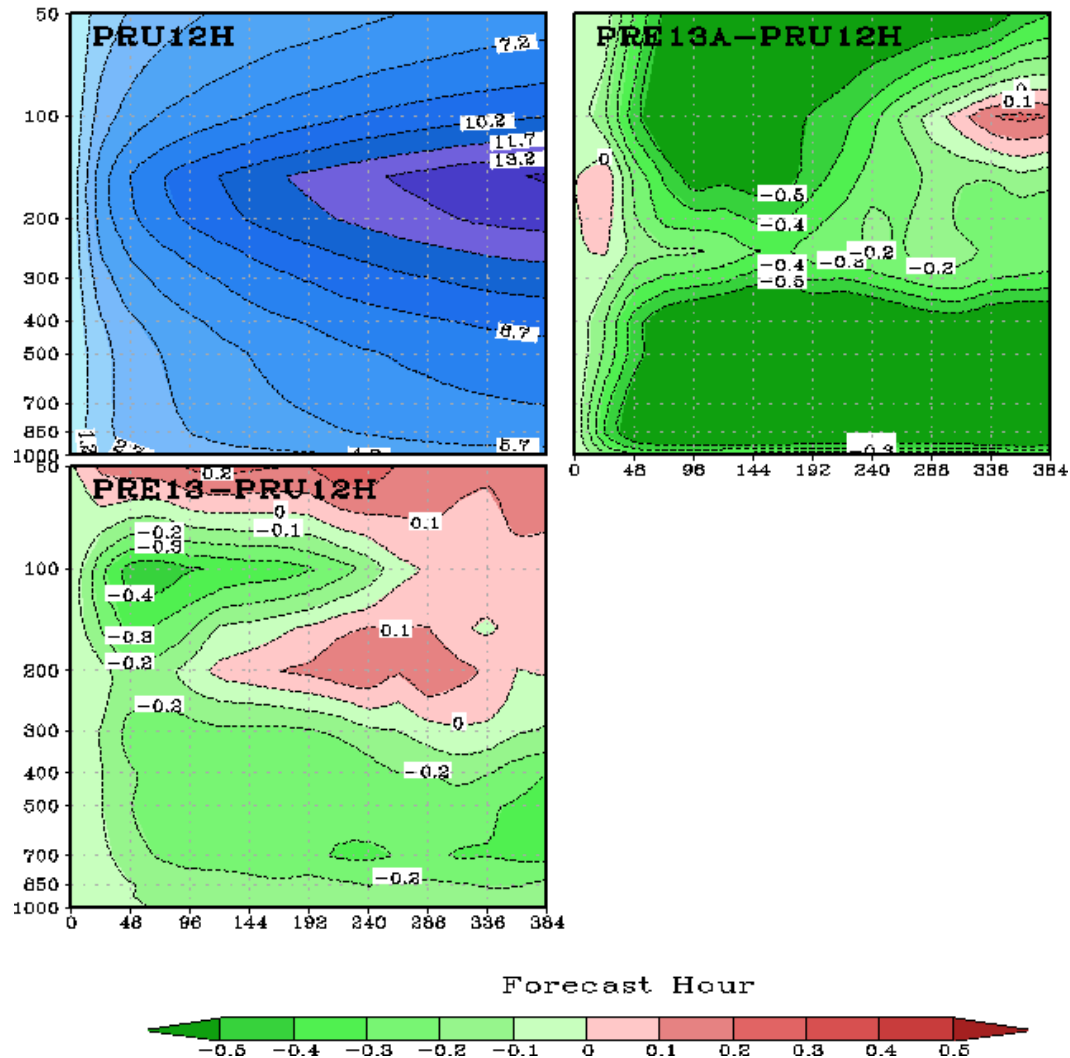


NH
Data Counts



Tropical Vector Wind RSME

RMS: 20080620-20081101 Mean for WIND G2/TRO 00Z

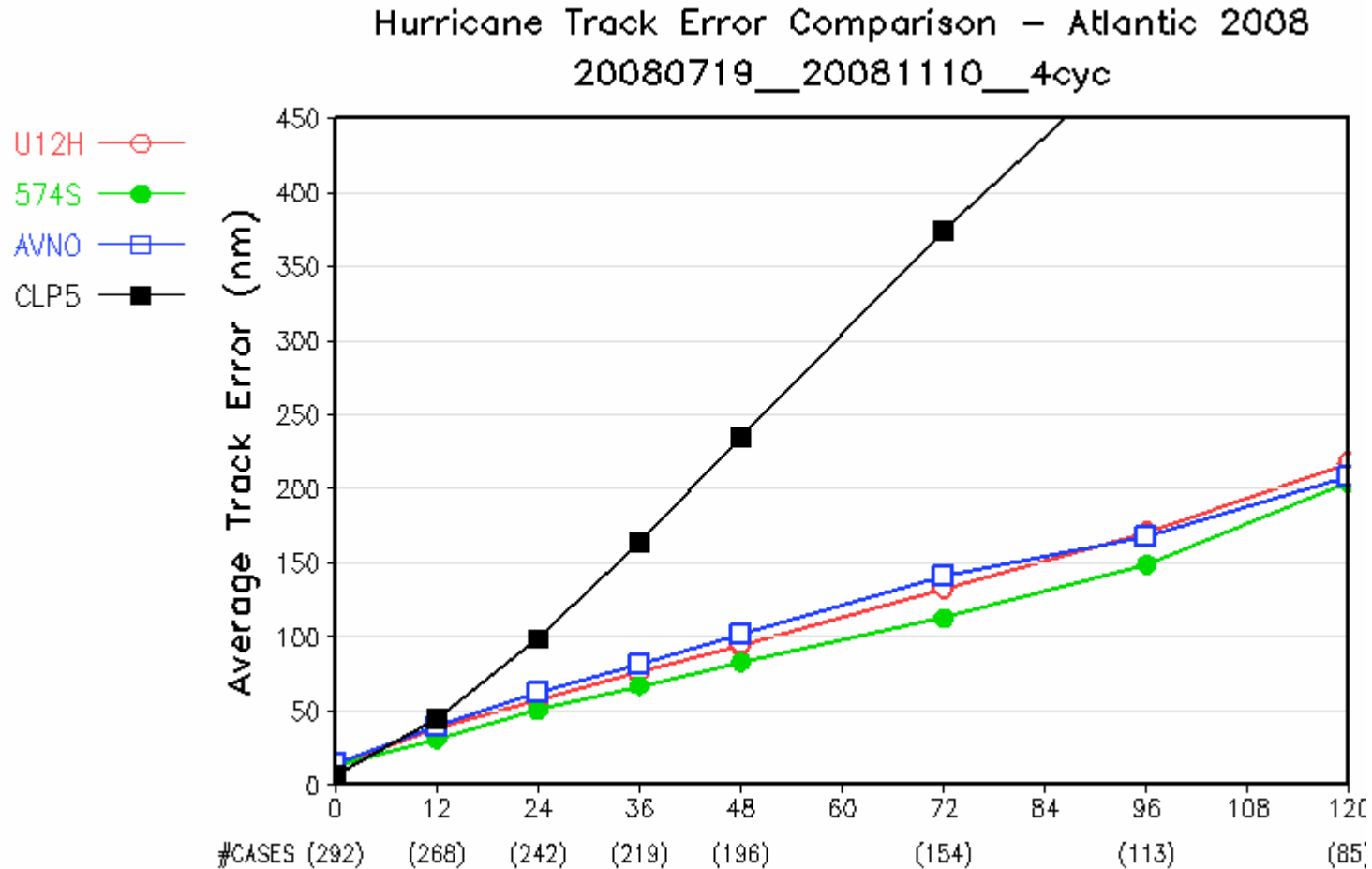


With
Shallow Conv

Without
Shallow Conv

GFS Atlantic Hurricane Track Error

2008 Hurricane Season – Without Bertha



2008 Operational – Blue

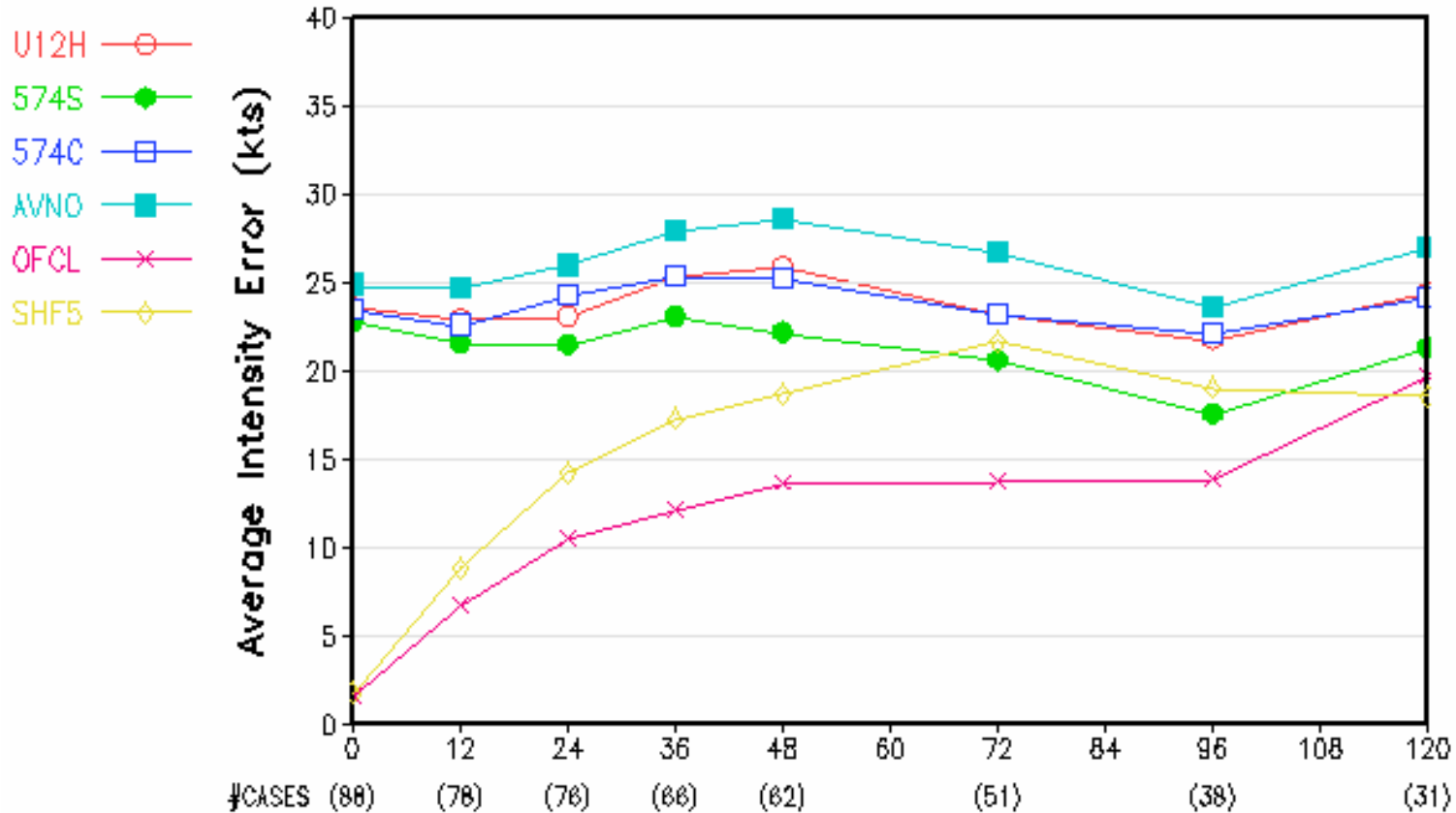
December GFS Package – Red

T574 with upgraded Physics - Green

GFS Atlantic Hurricane Intensity Error

2008 Hurricane Season

Hurricane Intensity Error Comparison – Atlantic 2008
20080602_20081110_4cyc

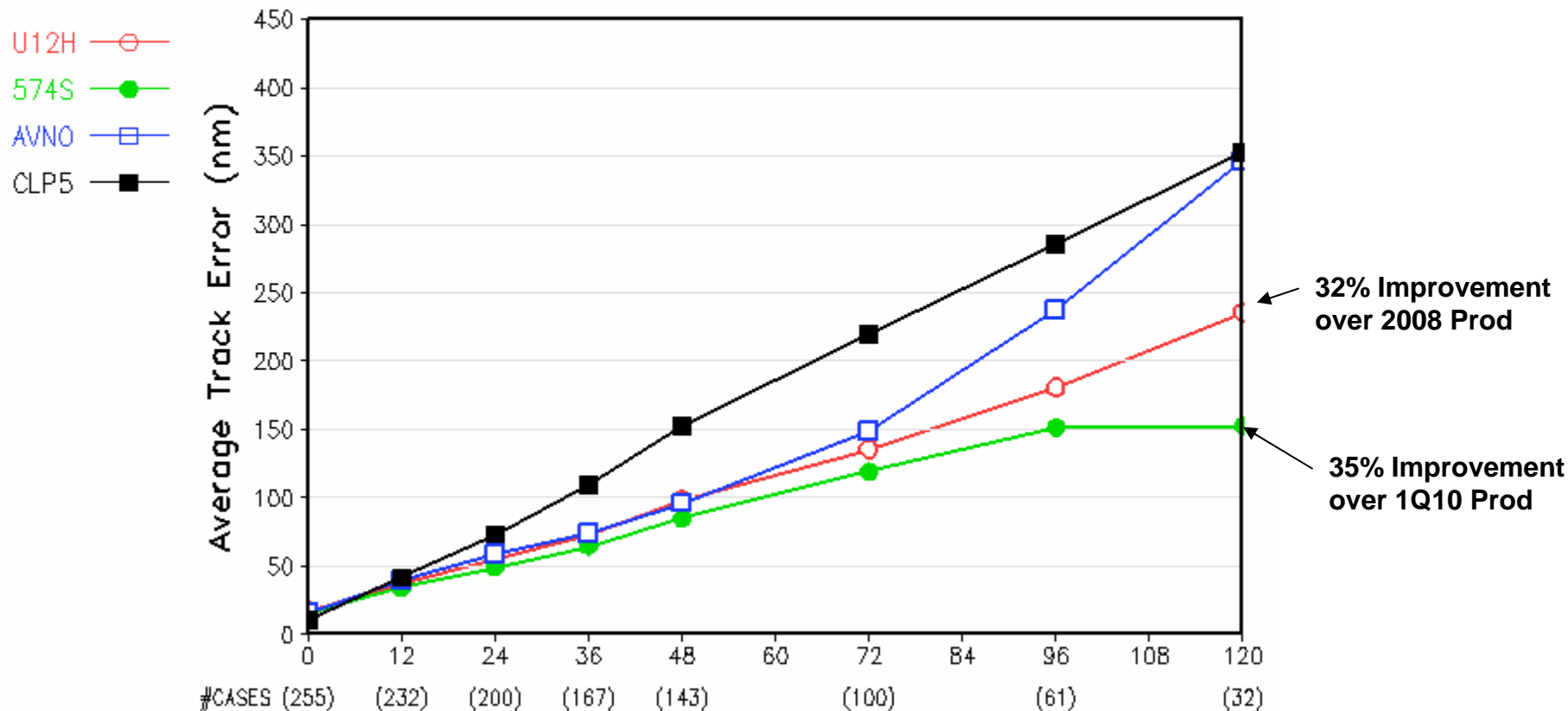


2008 Operational
December GFS Package
T574 with December Package
T574 with upgraded Physics

GFS EPAC Hurricane Track Error

2008 Hurricane Season

Hurricane Track Error Comparison – East-Pacific 2008
20080602__20081110__4cyc



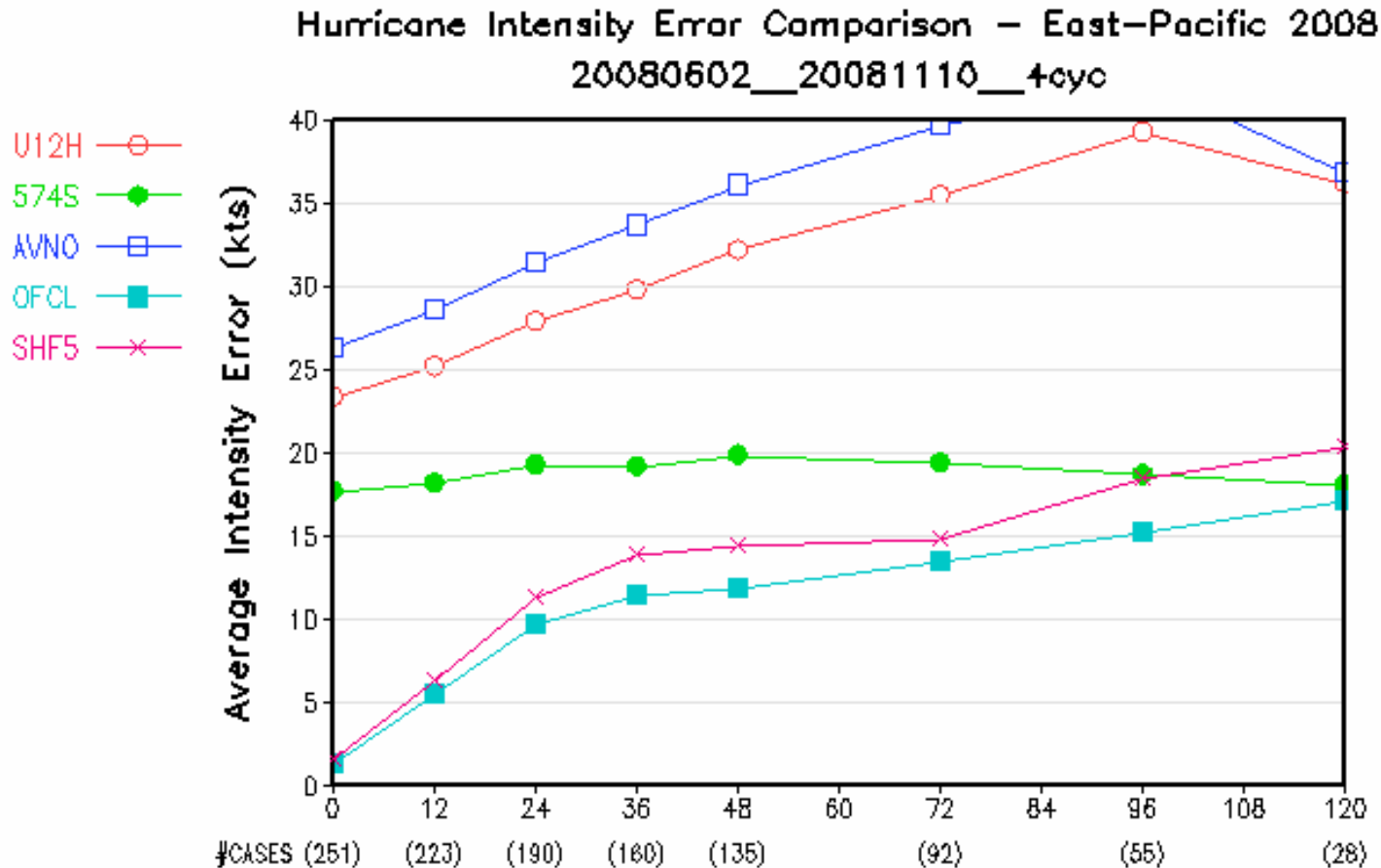
2008 Operational – Blue

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GFS EPAC Hurricane Intensity Error

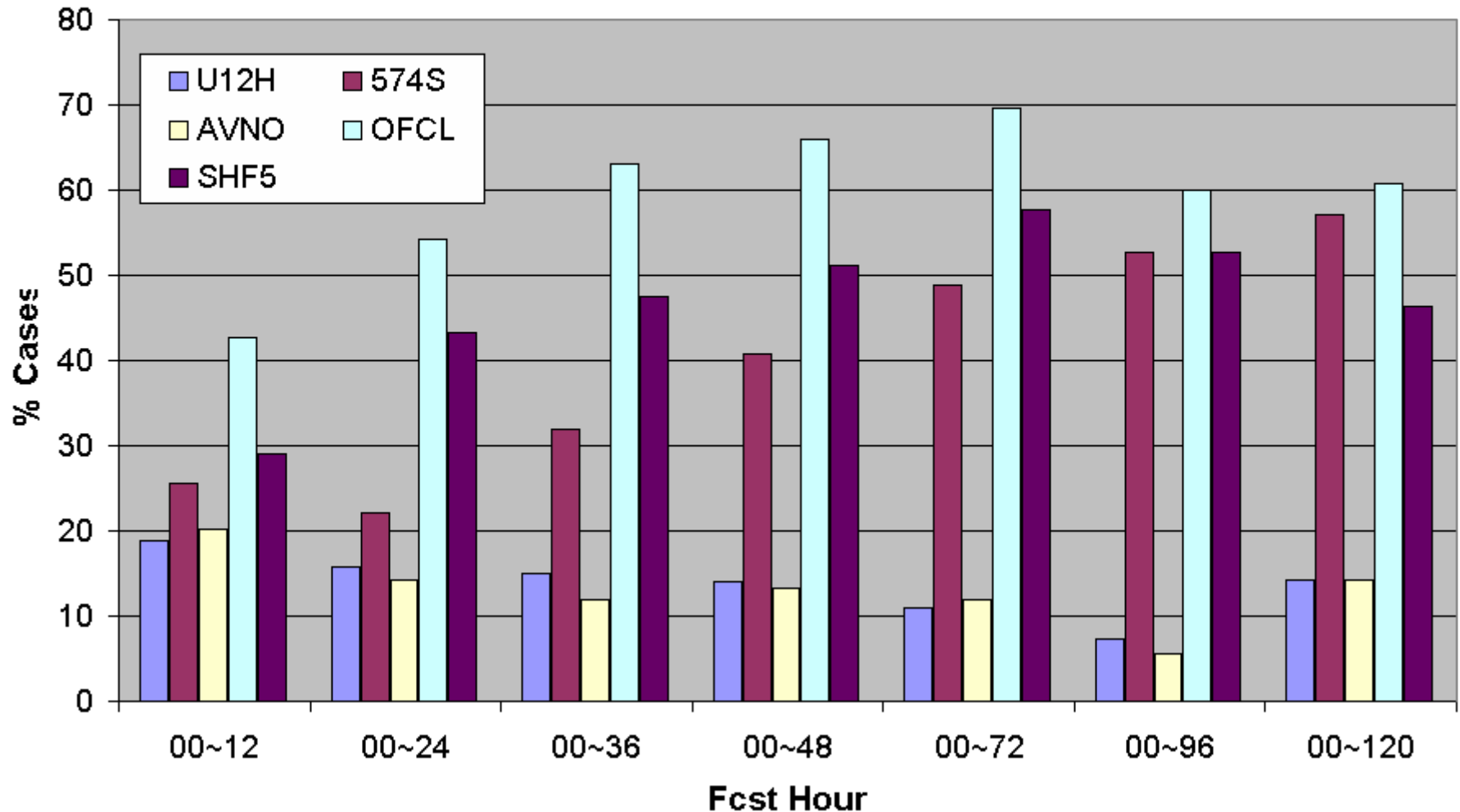
2008 Hurricane Season



December GFS Package – Red
Without Shallow Convection - Green
With Shallow Convection - Blue

Intensity Change Verification 2008 East Pacific

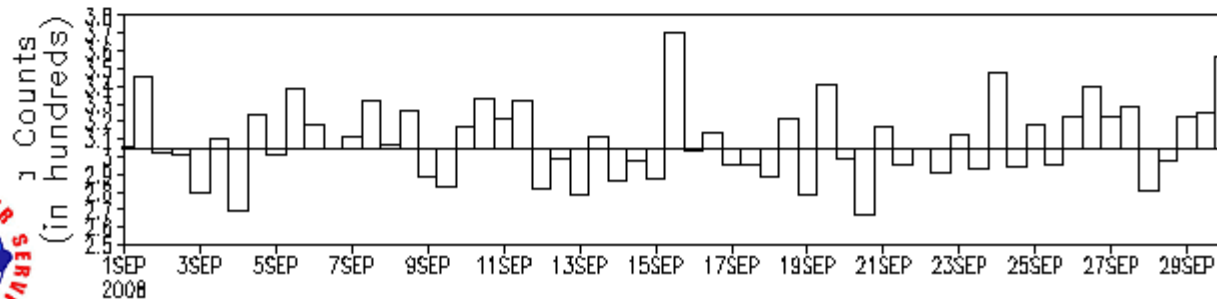
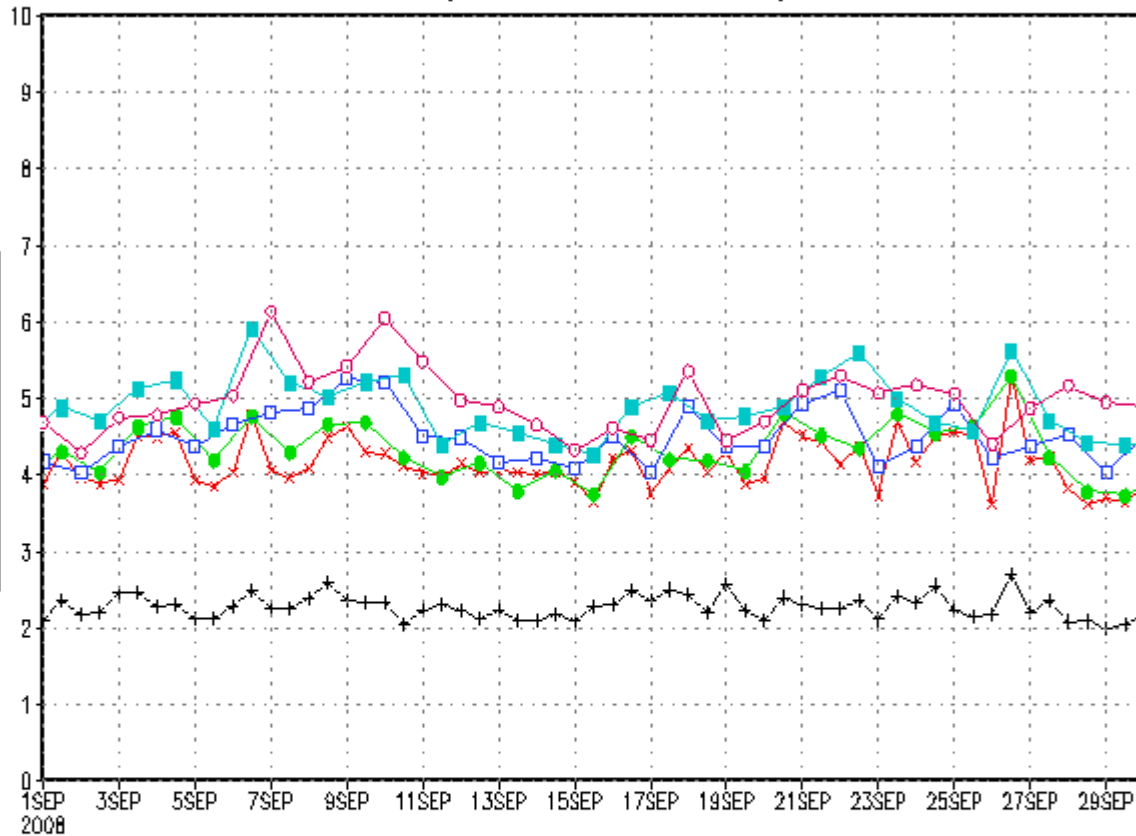
Values listed are percentages of cases that the models correctly predicted the intensity tendency (i.e., fcst_intens->obs_intens, fcst_weak->obs_weak or fcst_nochge->obs_nochge) for the indicated forecast interval.



fnl TROPICS Vector Wind 850 mb RMS Fit to RAOBS 00z01sep2008 – 00z30sep2008

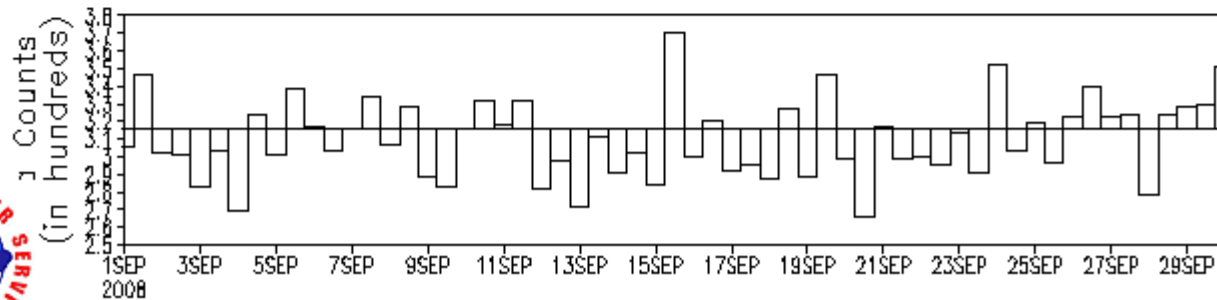
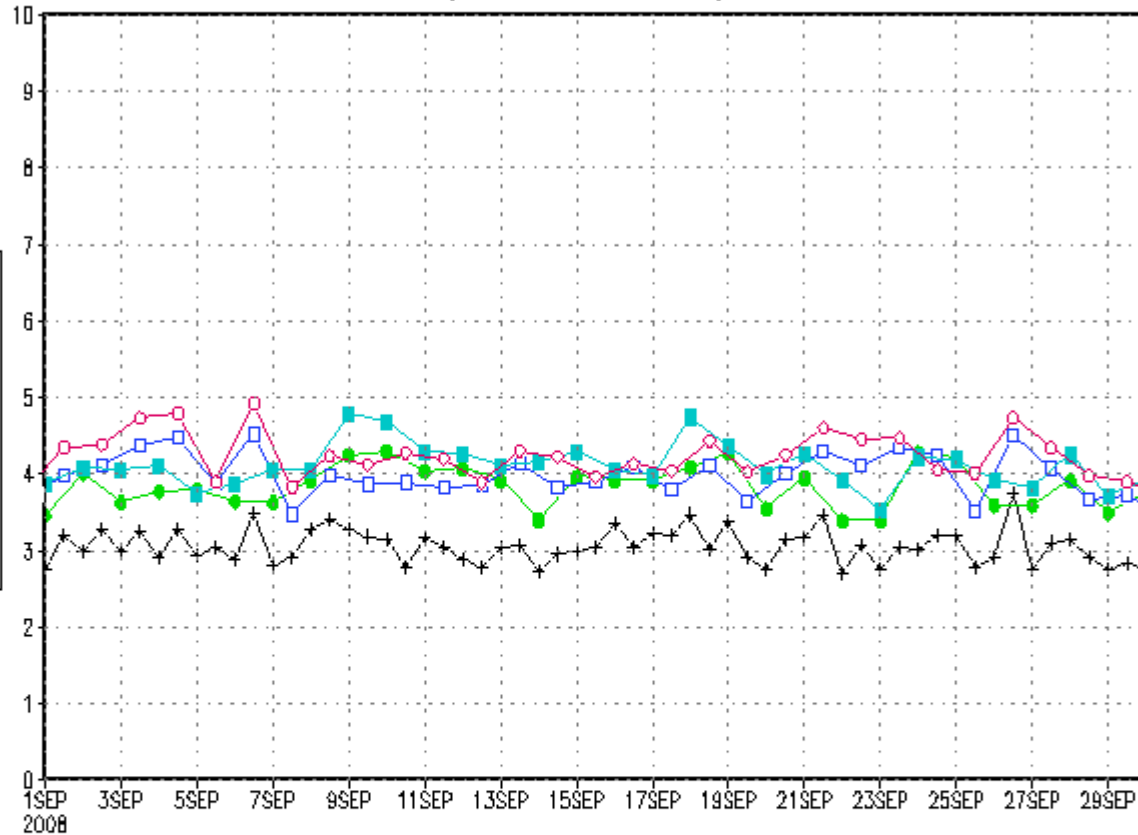
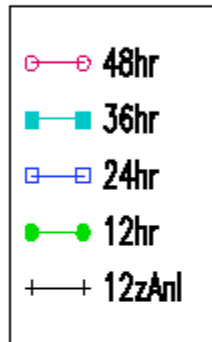
fnl
4.99
4.90
4.51
4.34
4.16
2.28

- GFS-48hr
- GFS-36hr
- GFS-24hr
- GFS-12hr
- × GFS-Ges
- + GFS-Anl



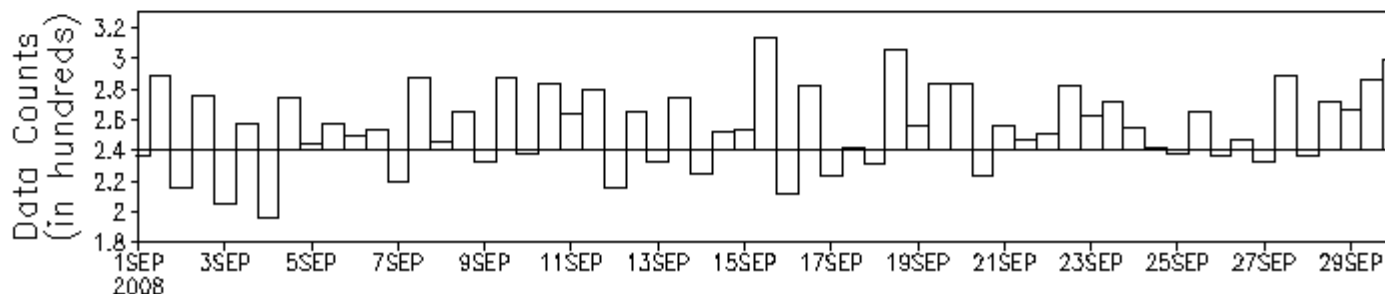
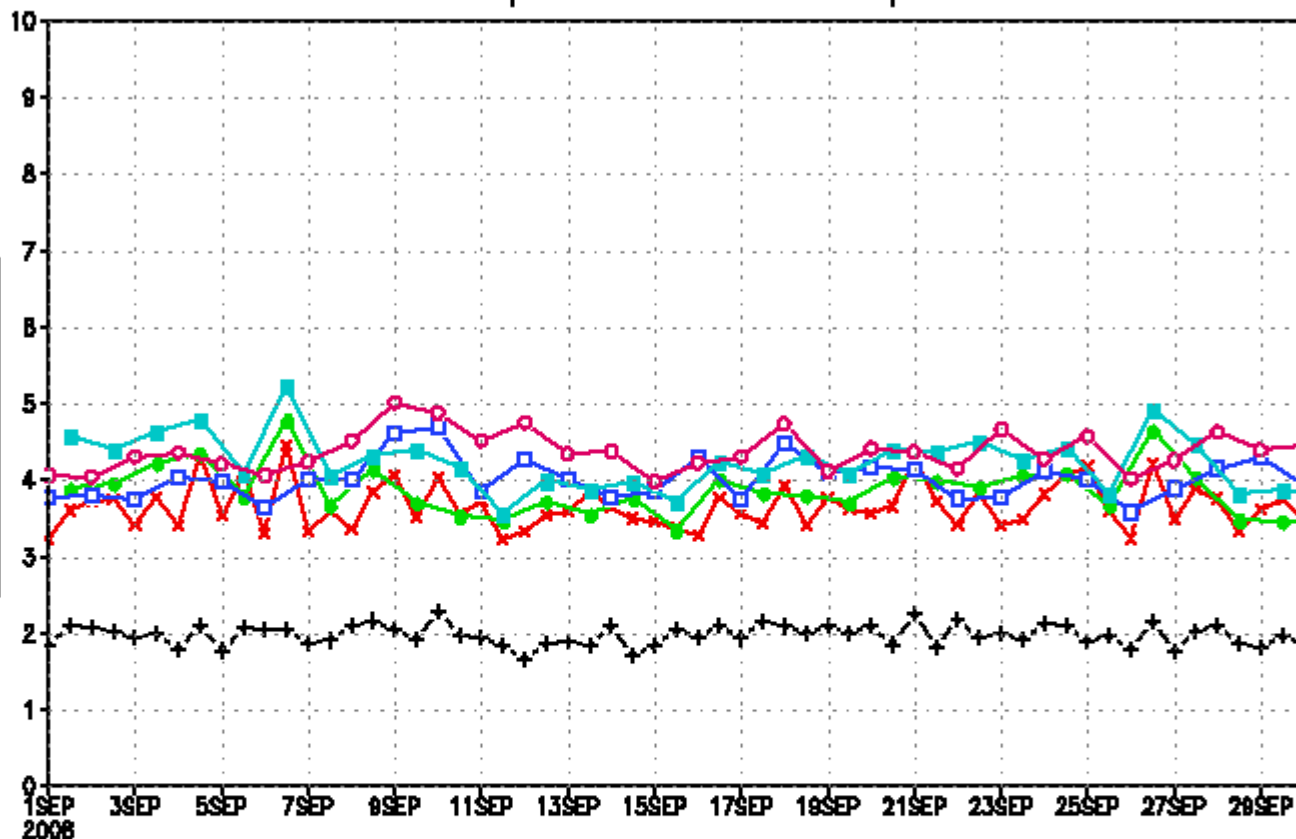
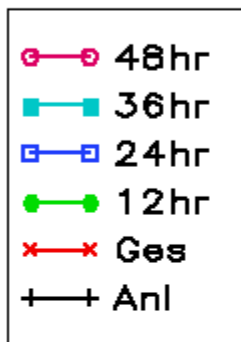
ecm TROPICS Vector Wind 850 mb RMS Fit to RAOBS 01sep2008 – 30sep2008

ecm
4.26
4.11
4.01
3.85
3.06



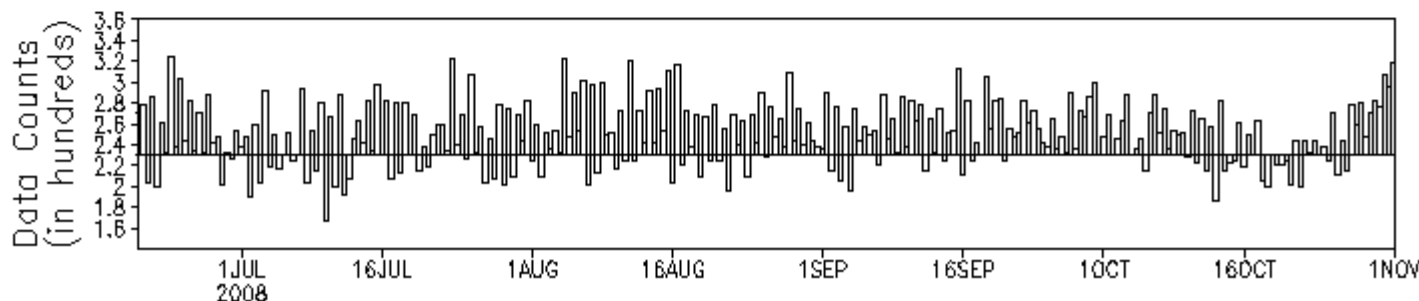
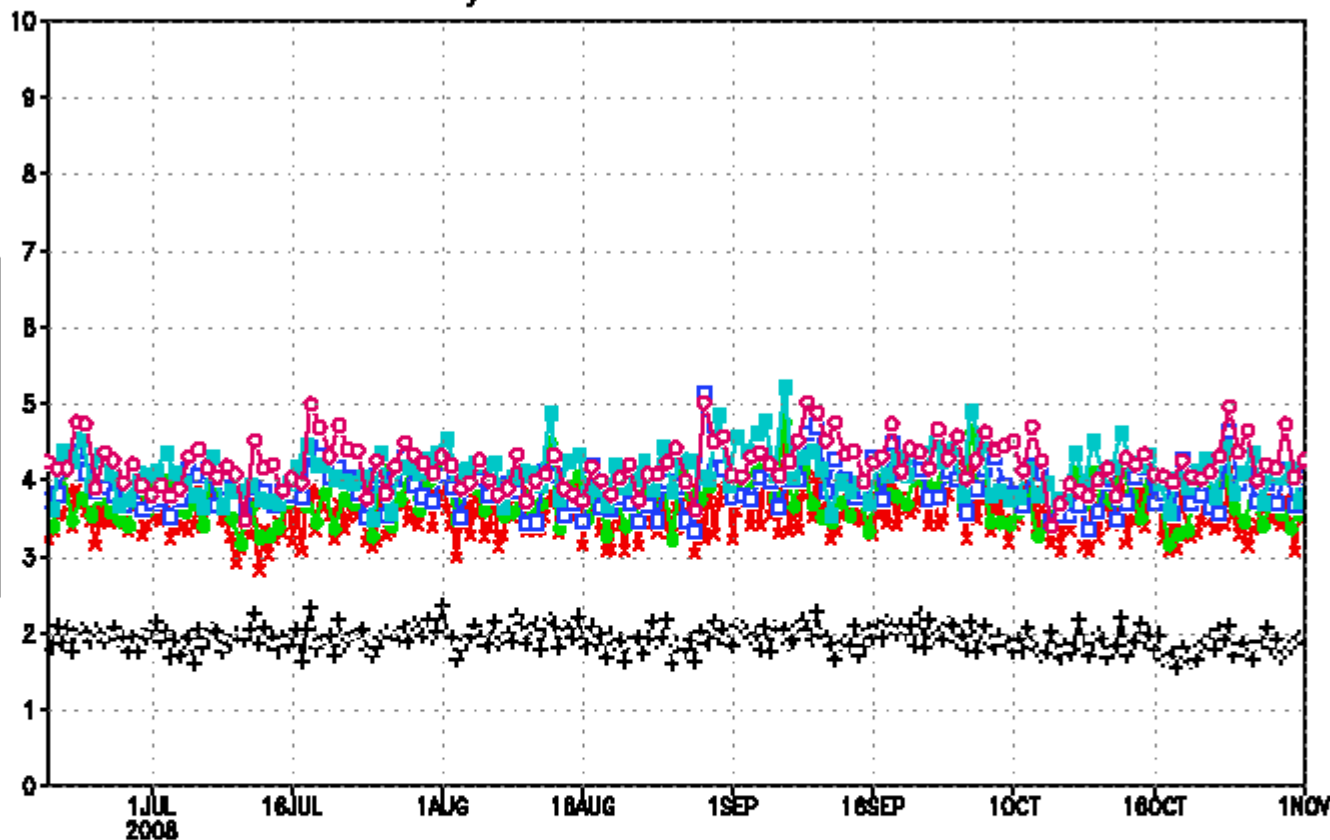
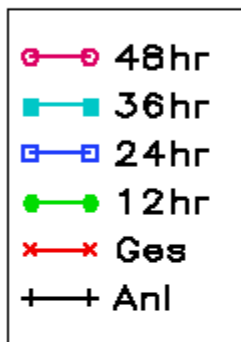
pre13a TROPICS Vector Wind 850 mb RMS Fit to RAOBS 00z01sep2008 – 00z30sep2008

pre13a
 4.37
 4.25
 4.02
 3.88
 3.66
 1.97



pre13a TROPICS Vector Wind 850 mb RMS Fit to RAOBS 00z20jun2008 – 00z01nov2008

pre13a
4.21
4.12
3.89
3.76
3.55
1.92



2009 Hurricane Season

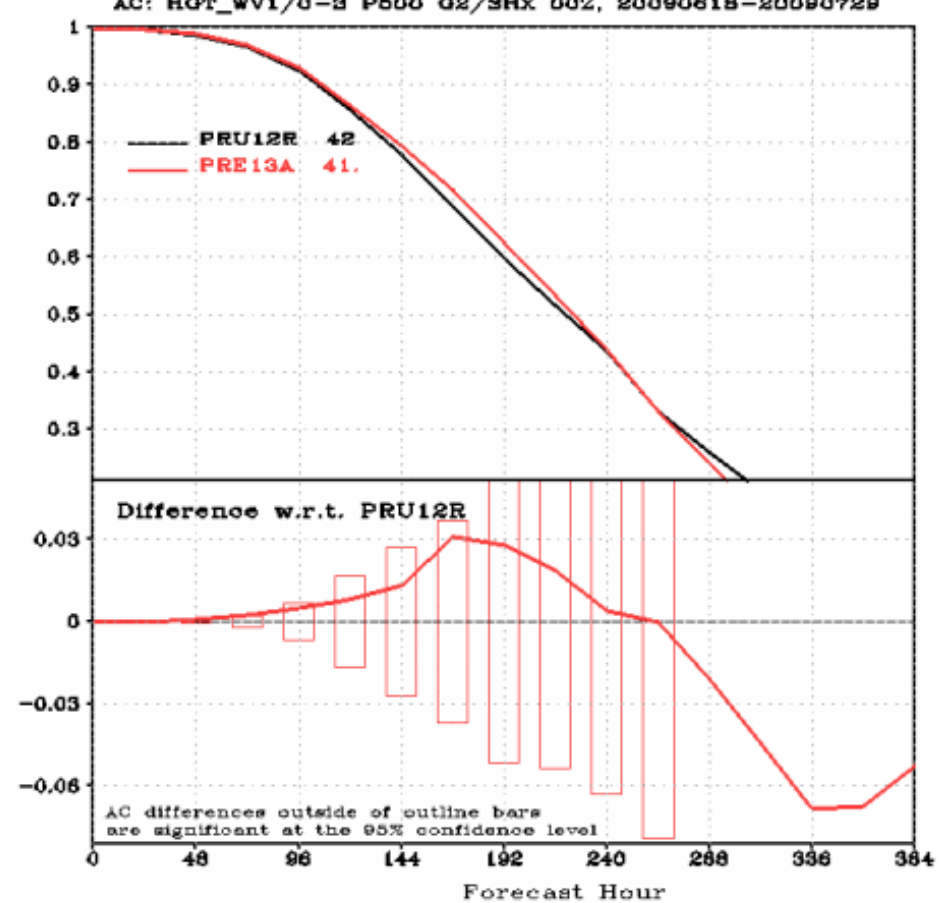
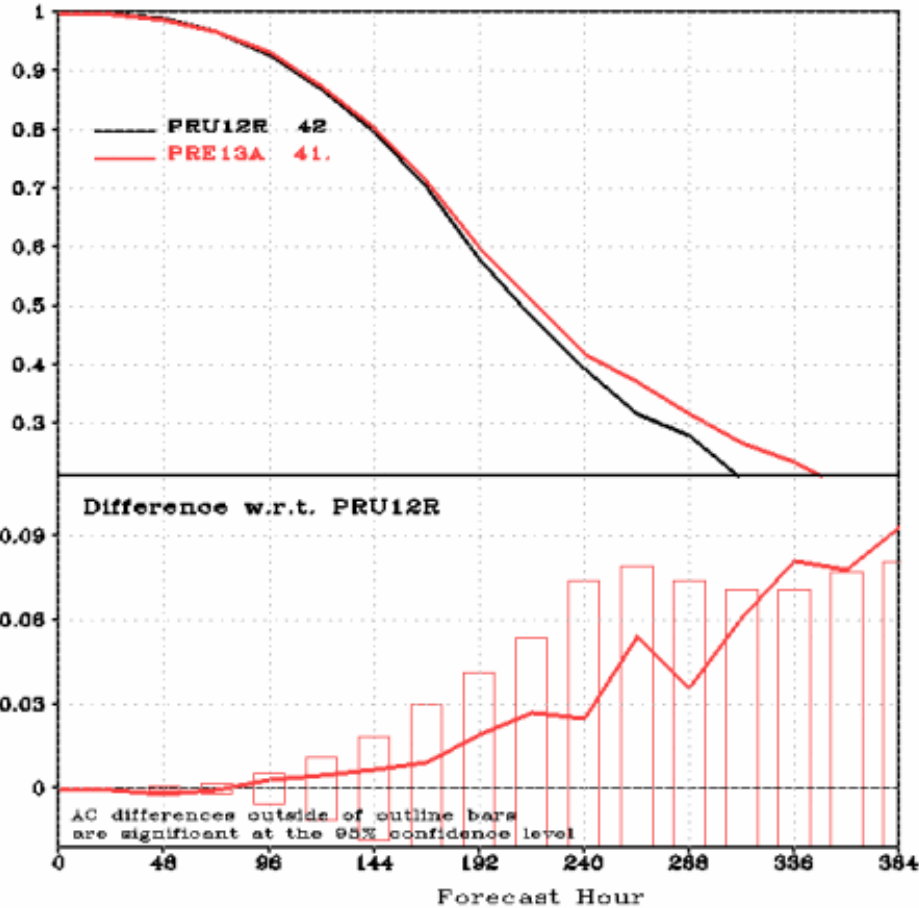
500 MB Anomaly Correlation

Northern Hemisphere

Southern Hemisphere

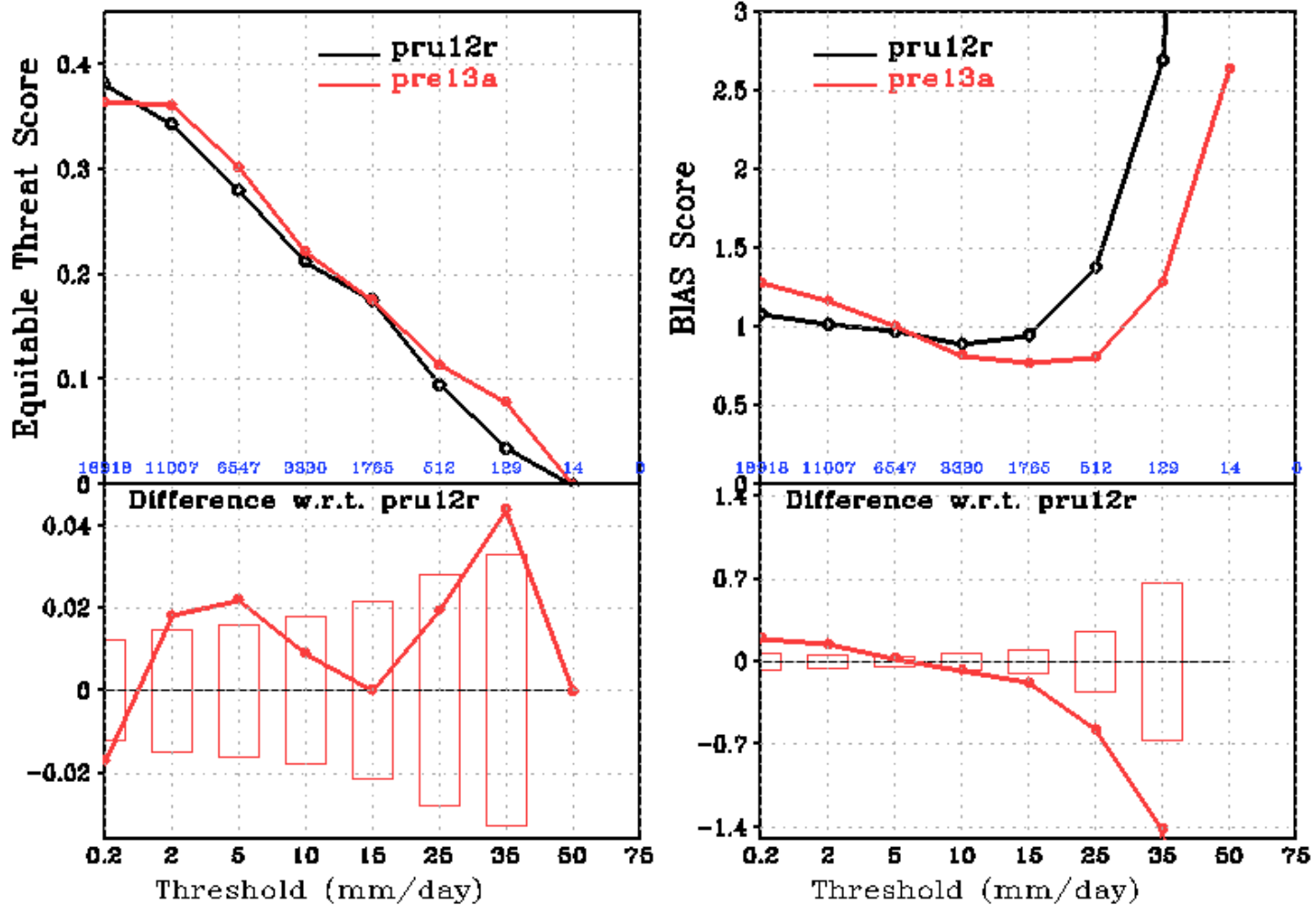
AC: HGT_WV1/0-3 P500 G2/NHX 00Z, 20090618-20090729

AC: HGT_WV1/0-3 P500 G2/SHX 00Z, 20090618-20090729



Precipitation Scores

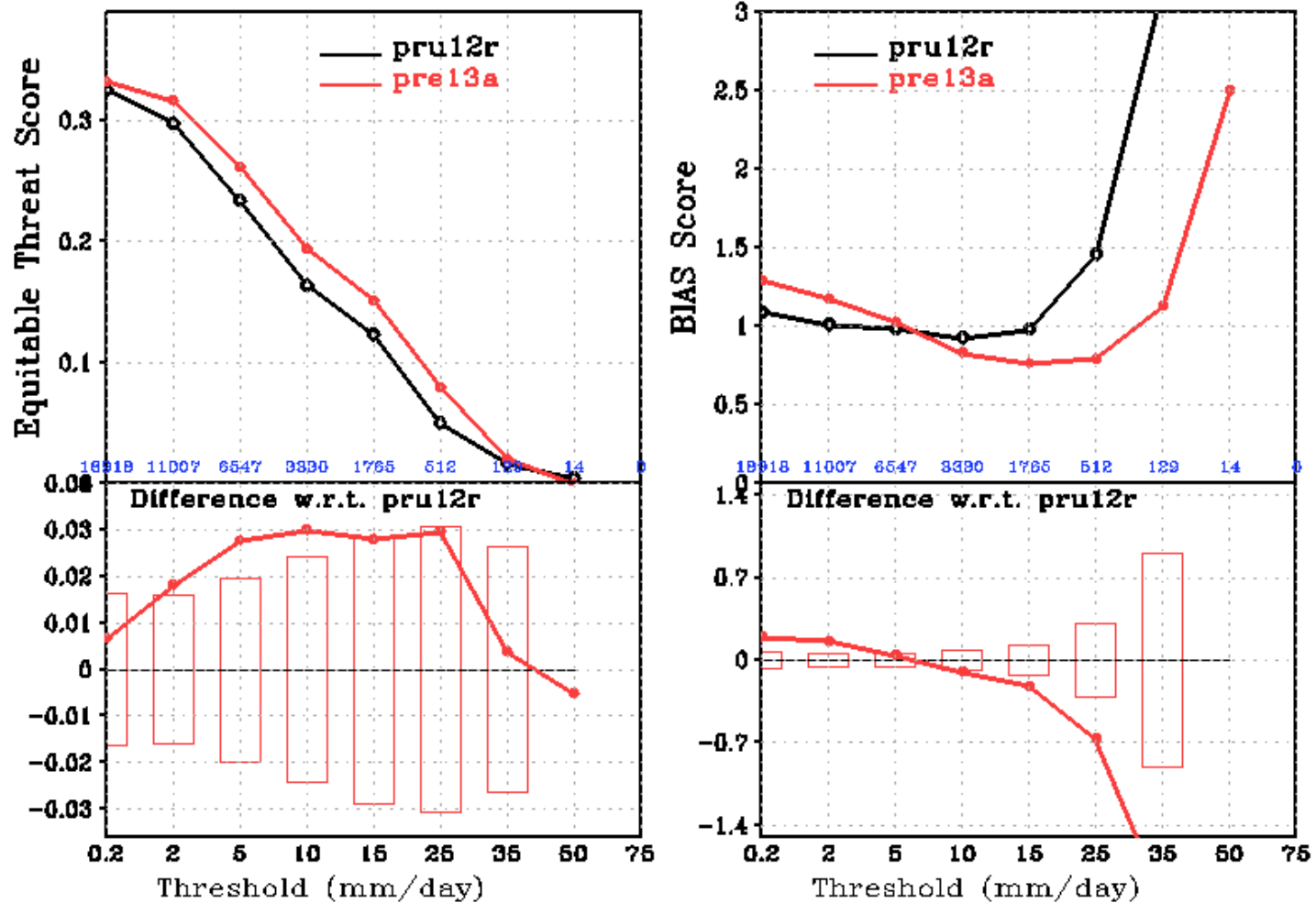
CONUS Precip Skill Scores, f12-f36, 18jun2009-29jul2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Precipitation Scores

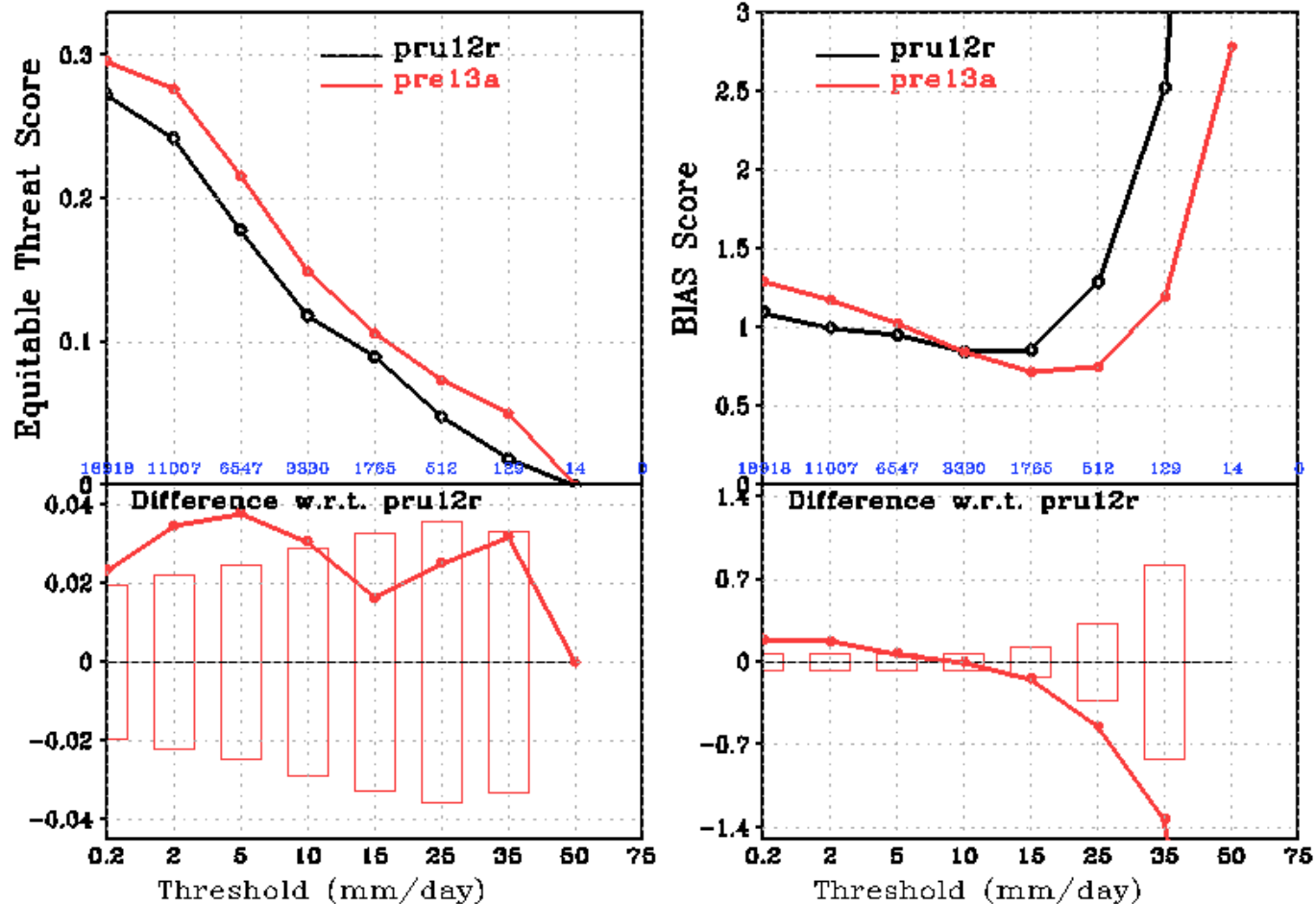
CONUS Precip Skill Scores, f36-f60, 18jun2009-29jul2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

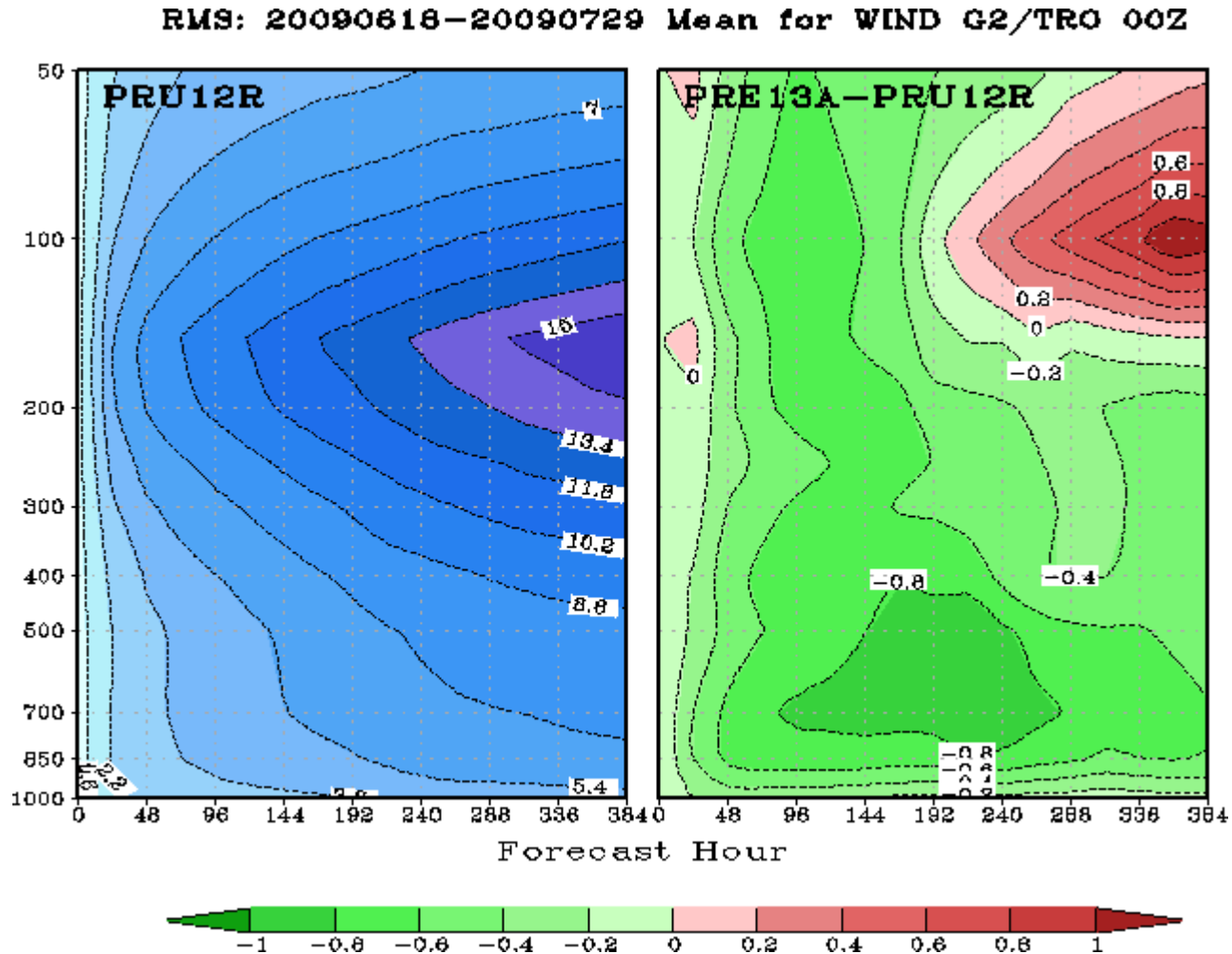
Precipitation Scores

CONUS Precip Skill Scores, f80-f84, 18jun2009-29jul2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

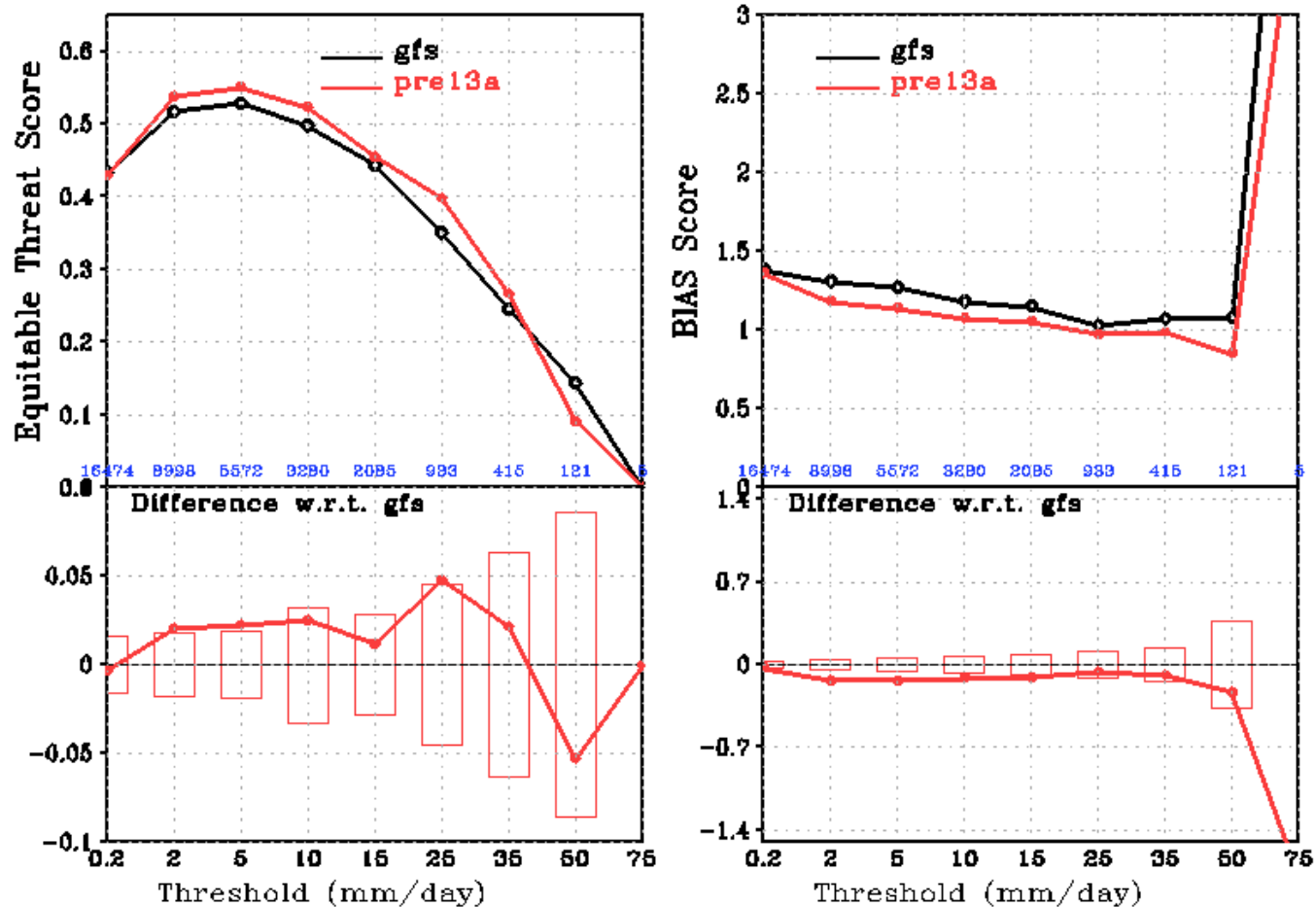
Tropical Vector Wind RSME



Winter 2009/10

Precipitation Scores

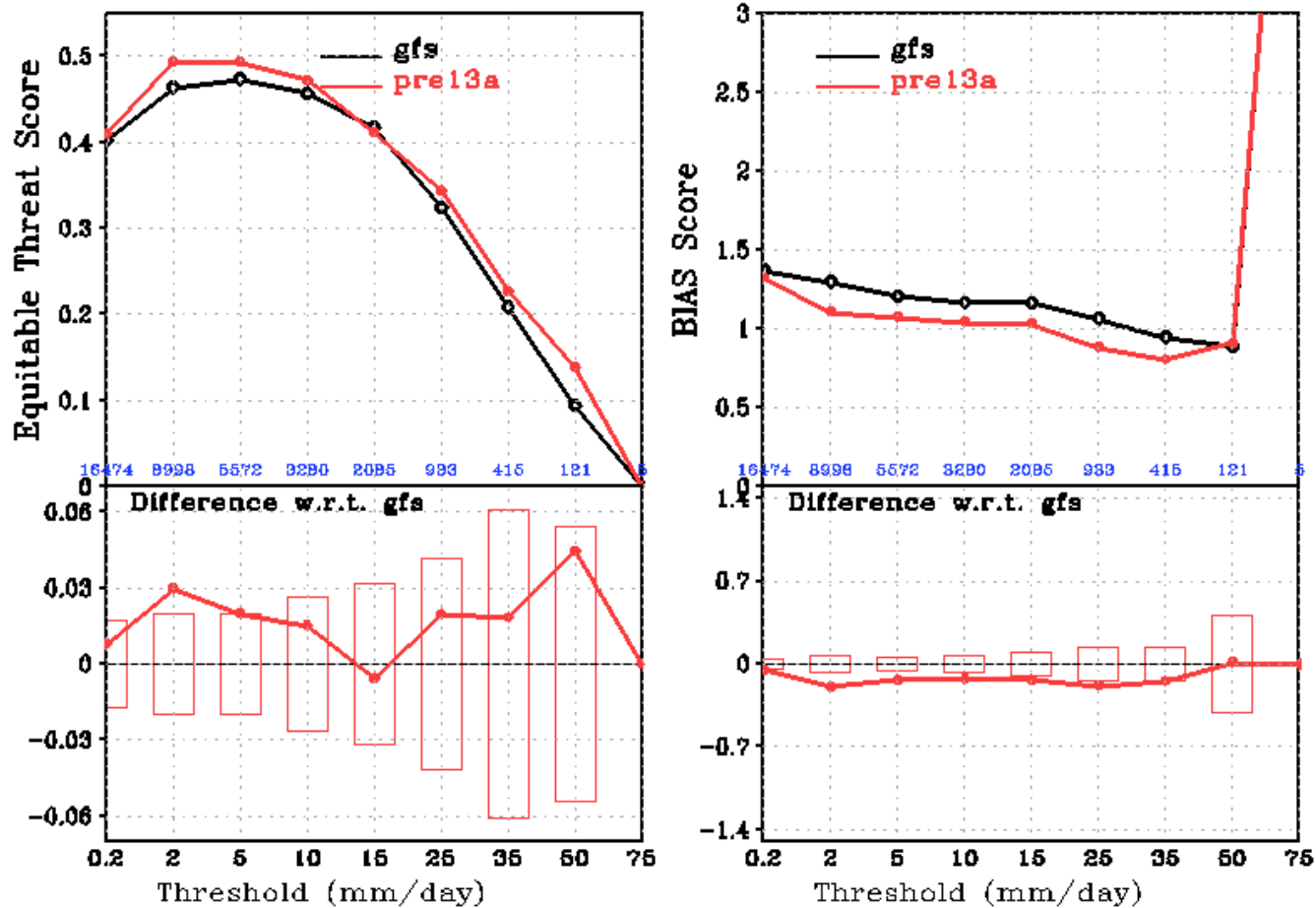
CONUS Precip Skill Scores, f12-f36, 17nov2009-29dec2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Precipitation Scores

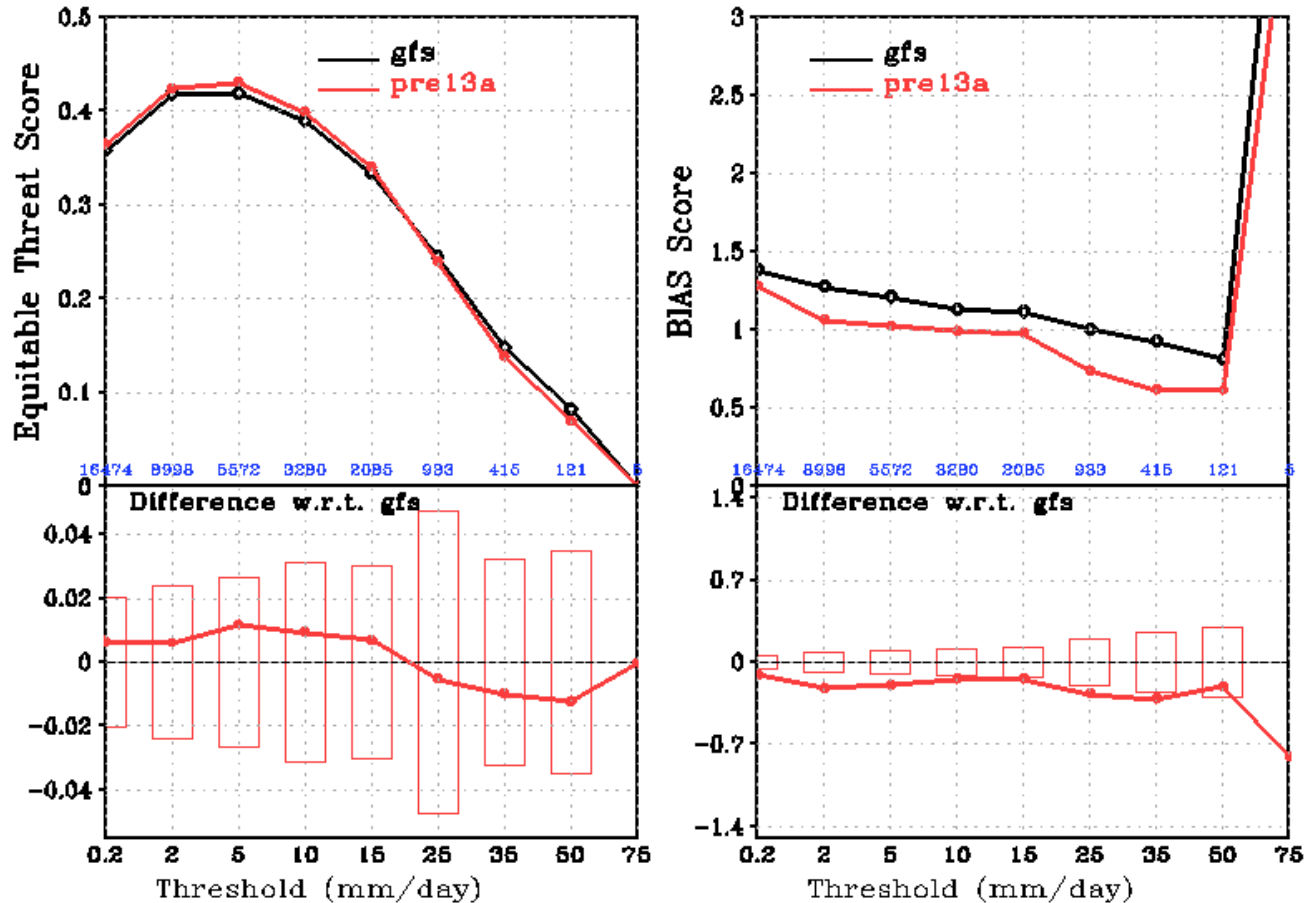
CONUS Precip Skill Scores, f36-f60, 17nov2009-29dec2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Precipitation Scores

CONUS Precip Skill Scores, f60-f84, 17nov2009-29dec2009



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

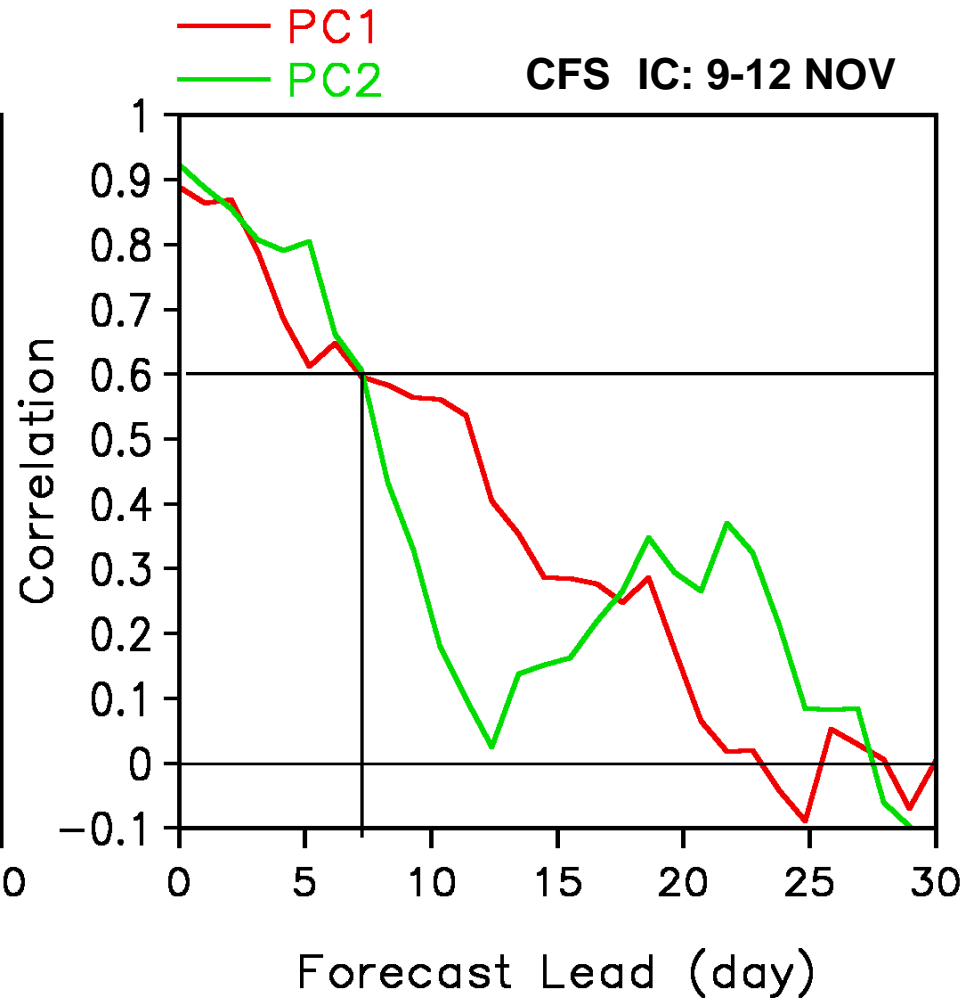
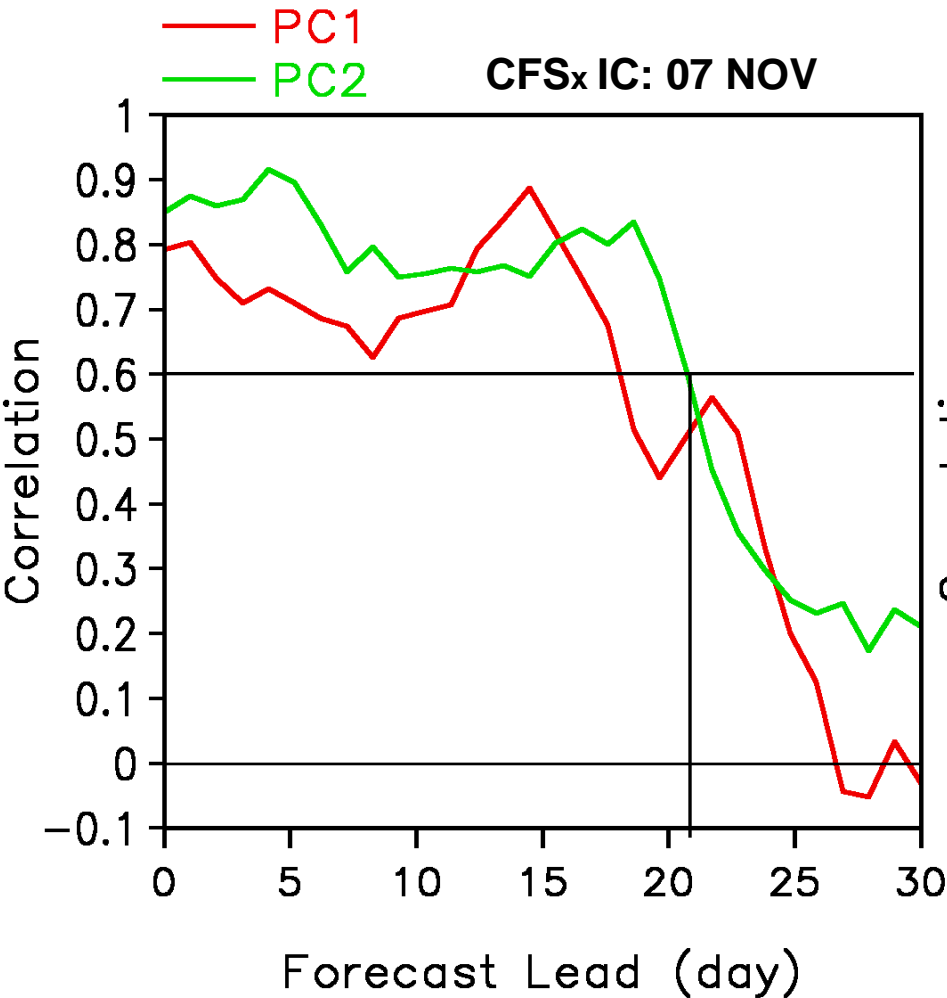
Summary

- Significant improvement in Precipitation Threat Scores
 - Summer Precip Bias now less than observed
 - Winter Precip Bias closer to observed
 - Significant Improvement in Grid-Point Storms
- Significant Improvement in GFS Hurricane Track & Intensity Error
- Improved GFDL Track error & intensity out to day 3
- Improvement in NH 500 MB Anomaly Correlation
 - Some degradation in week-2 SH 500 AC
- Significant Improvement in Tropical RMS Vector Wind Score

Current efforts

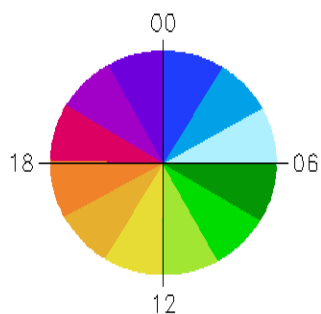
- Moist conserving turbulent mixing
- Advanced microphysics : predicting total condensate but distinguishing cloud water, rain water, large ice and small ice
- Cloud-radiation calibrations using observed cloud fraction and total condensates

PC1 & PC2 forecast correlation skill CFSx & CFS

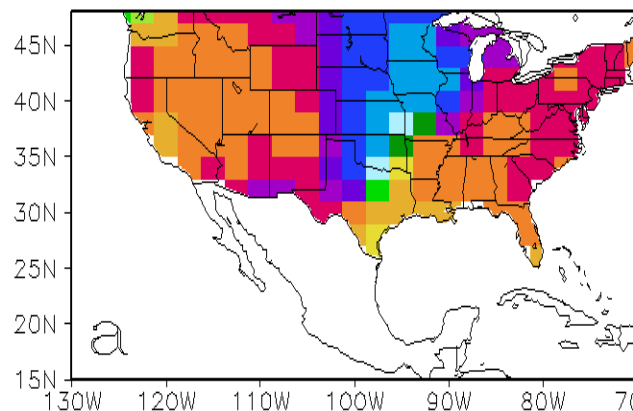


Phase (local time) of Maximum Precipitation (24-hour cycle)

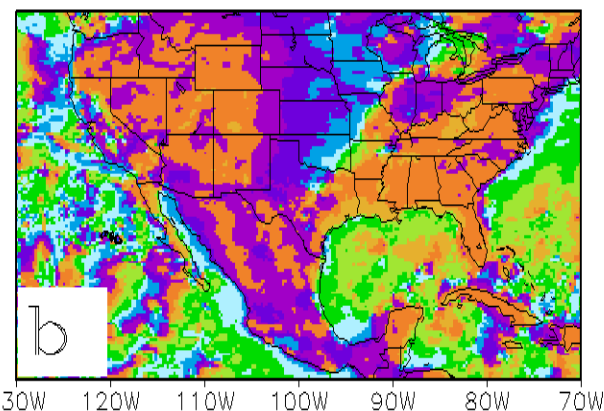
Diurnal Phase
(LST)



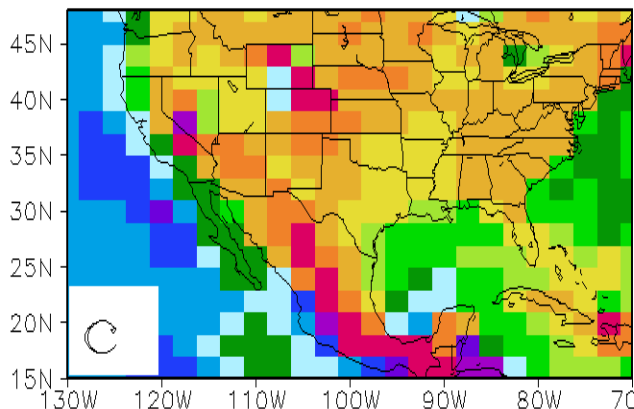
HPD



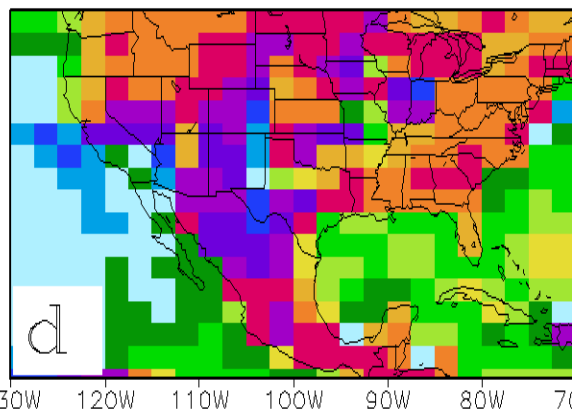
CMORPH



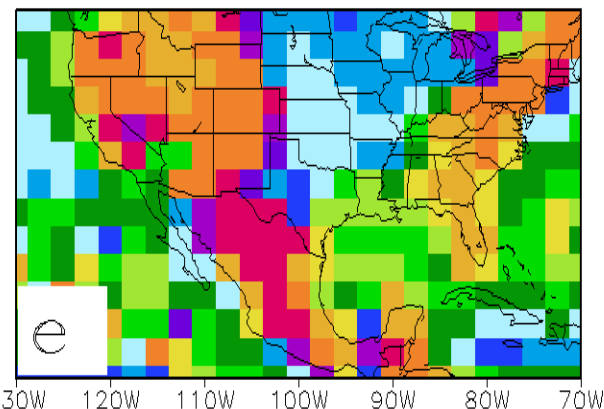
NASA 2 DEG



GFDL 2 DEG



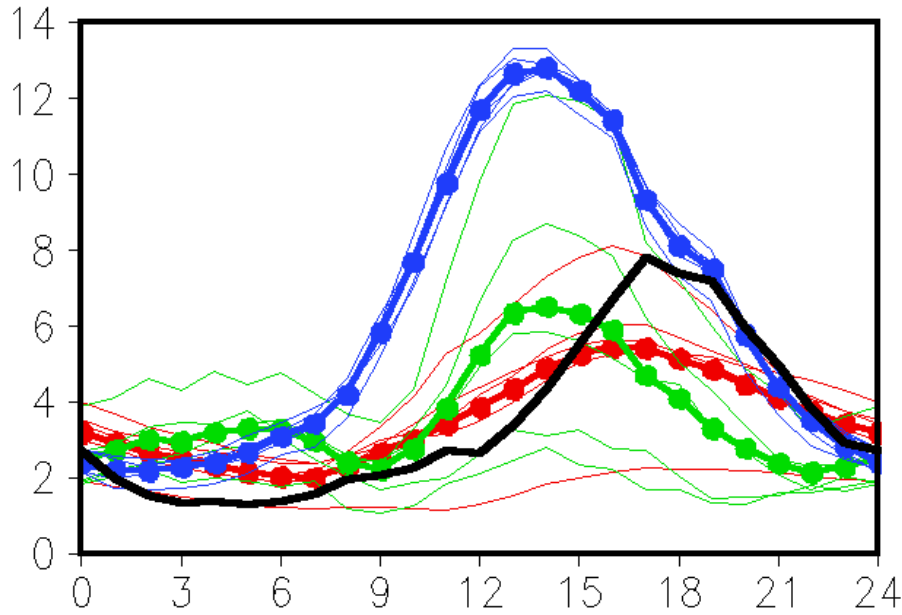
NCEP T62



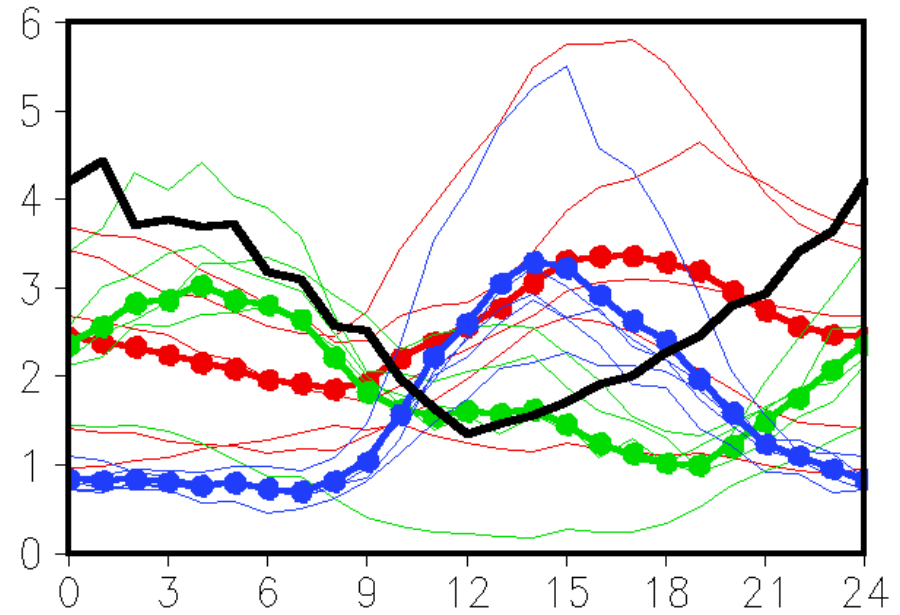
Five-member ensembles driven by Climatological SST forcing (1983-2002 avg)

Diurnal Cycle of Rainfall – Ensemble Mean and Spread

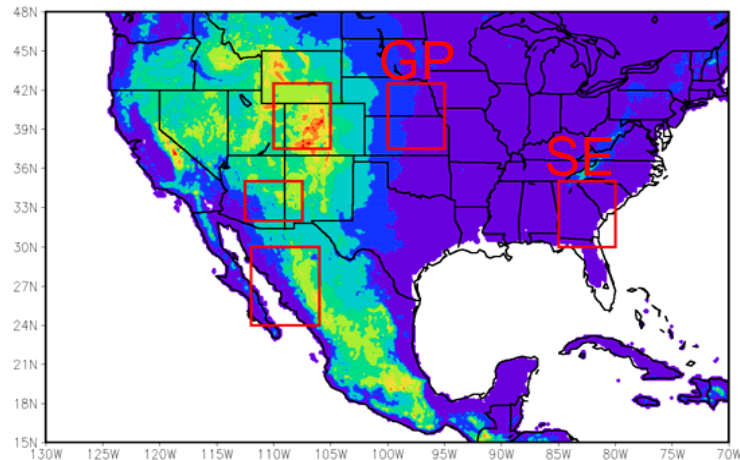
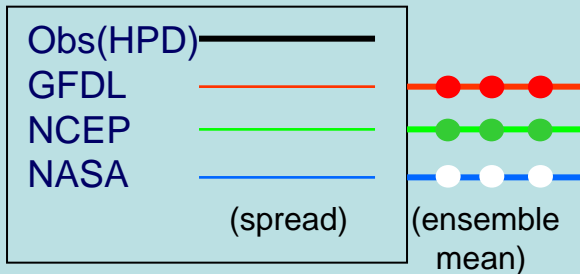
SE (85–80W,30–35N)



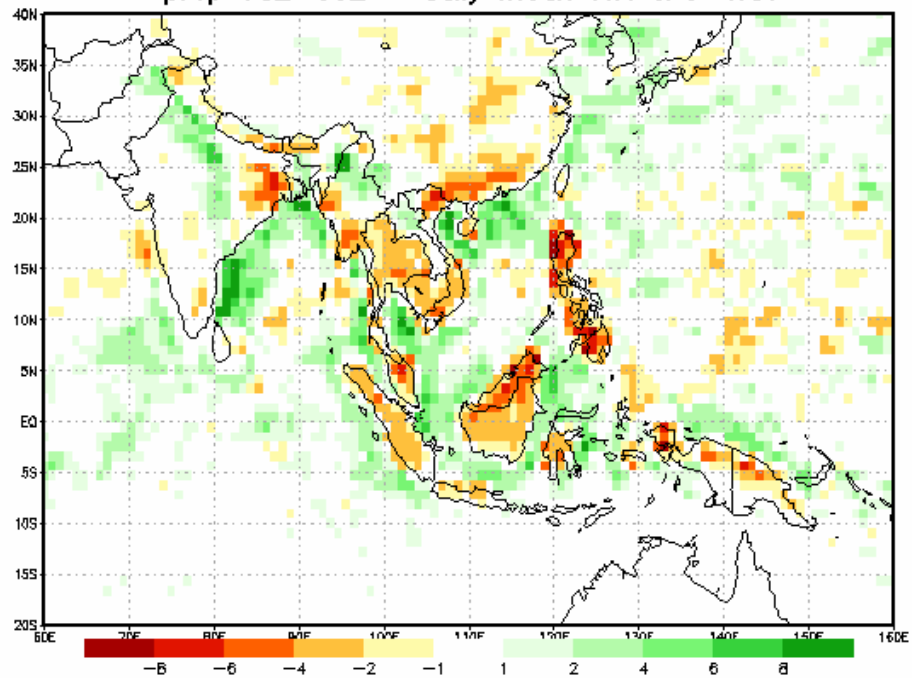
GP (100–95W,37.5–42.5N)



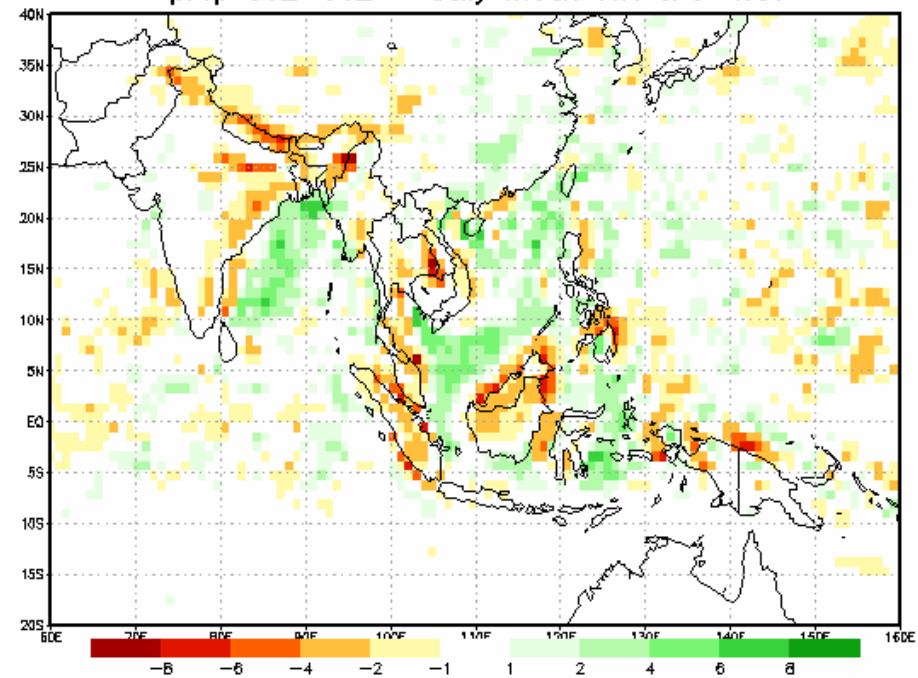
LST



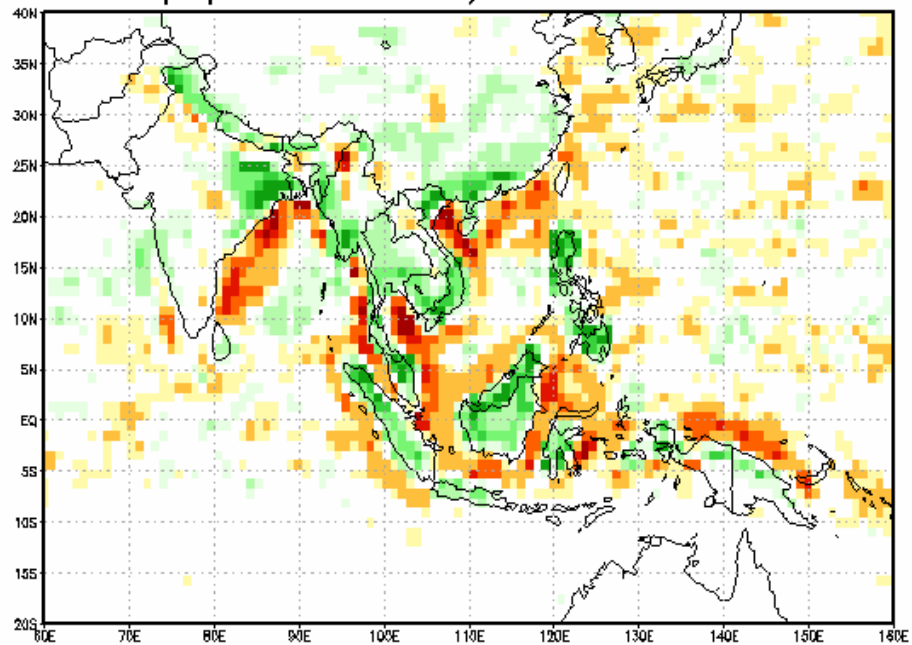
prcp 18Z-00Z - daily mean JJA CFS-test



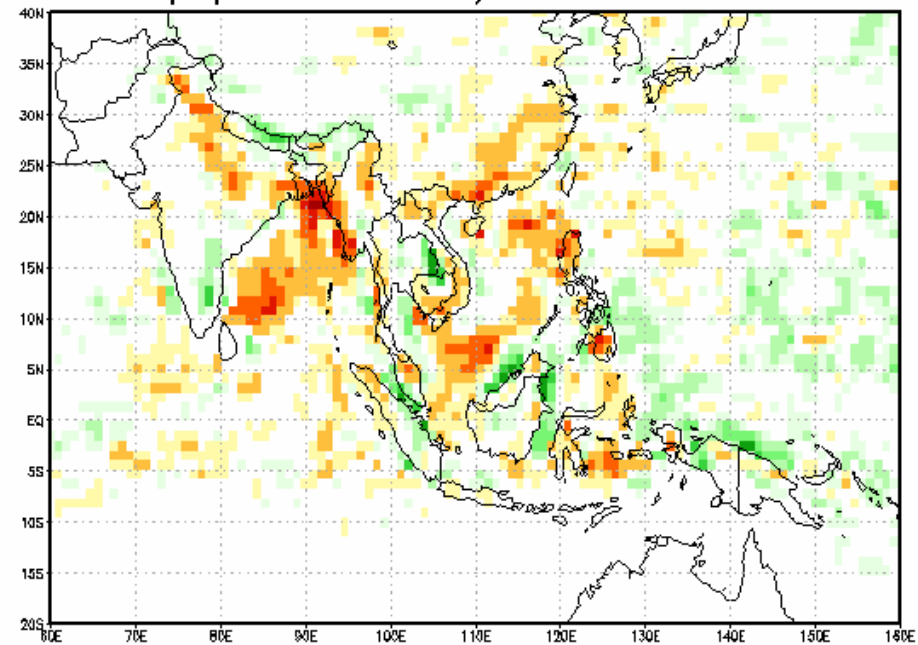
prcp 00Z-06Z - daily mean JJA CFS-test



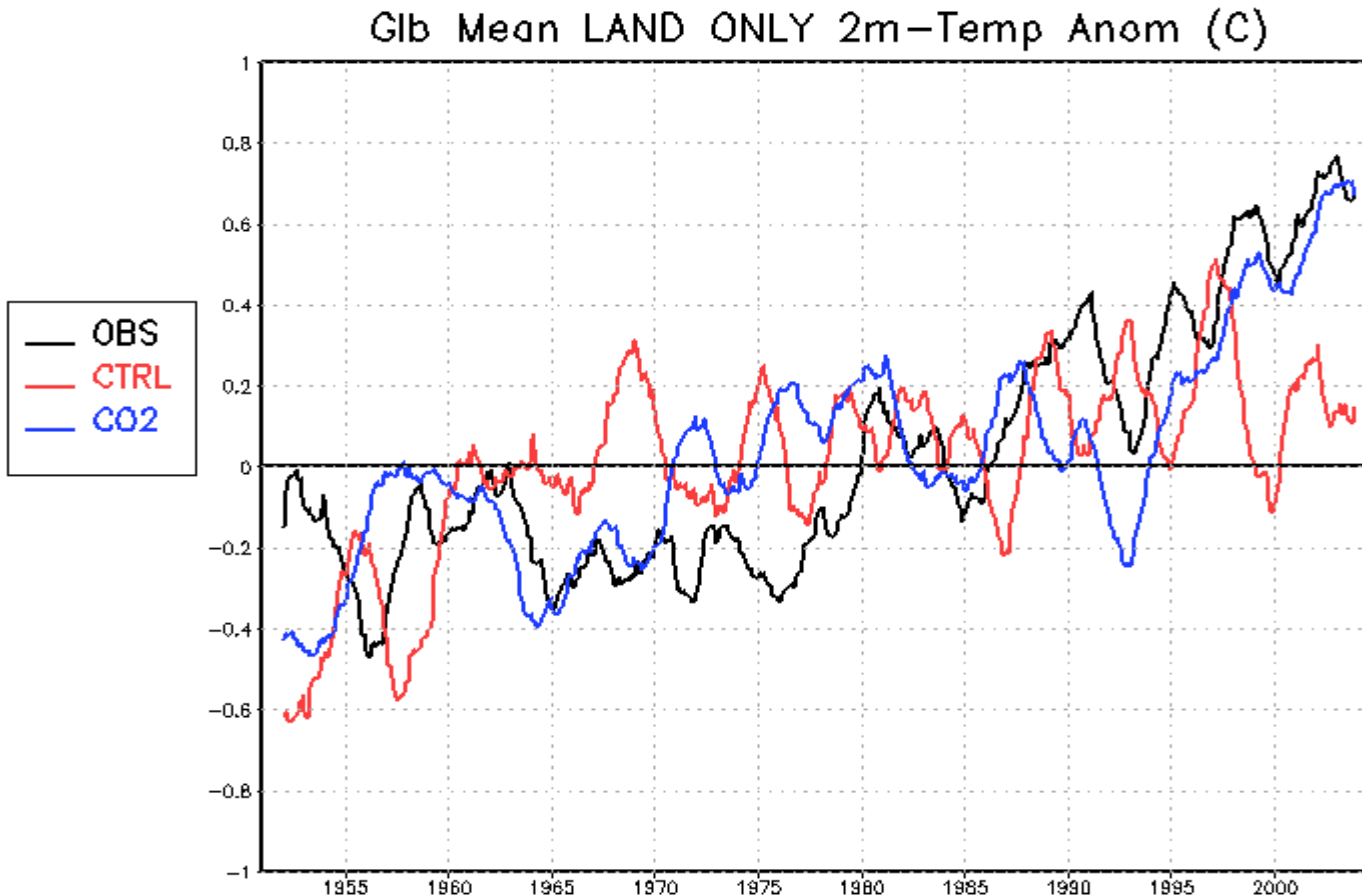
prcp 06Z-12Z - daily mean JJA CFS-test



prcp 12Z-18Z - daily mean JJA CFS-test



Testing with CMIP Runs (variable CO2)



OBS is CPC Analysis (Fan and van den Dool, 2008)

CTRL is CMIP run with 1988 CO₂ settings (no variations in CO₂, current operations)

CO2 run is the ensemble mean of 3 NCEP CFS runs in CMIP mode

- realistic CO₂ and aerosols in both troposphere and stratosphere

Processing: 25-month running mean applied to the time series of anomalies (deviations from their own climatologies)