# EMC FY15 Upgrade Review

N
C
E
P

# GEFS Upgrade

**Presented by:**

**Yuejian Zhu**

**Update: 07/10/2014**

# Next GEFS (V11.0.0) configuration

- Model
  - Current: GFS Euler model (V9.0.1)
  - Plan: GFS Semi-Lagrangian model (V10.0.0?)
- Horizontal resolution
  - Current:  T254 (55km for 0-192 hours), T190 (73km for 192-384 hours)
  - Plan: T574 (T382 physics - 34km for 0-192 hours), T382(T254 physics – 55km for 192-384 hours)
- Vertical resolution
  - Current: L42 hybrid levels
  - Plan: L64 hybrid levels to match with GFS and DA
- Computation cost:
  - Current: 84 nodes (+ post process) for 55 minutes
  - Plan: 300 nodes (first 35 minutes), 250 nodes (2$^{nd}$ 30 minutes)
- Output:
  - Current: every 6-hr for 1*1 degree pgrb files
  - Plan: every 3-hr for 0.5*0.5 degree pgrb files
- Challenges:
  - T574L64 configuration will cost 250-300 nodes for one hour (plus 5 minutes)
  - Option: T574L42 configuration will use less resources, but the forecast quality will be degraded.

# Evolution of NCEP GEFS configuration (versions)

| Revised Version | Implem entation | Initial uncertainty | TS relocation | Model uncertainty | Resolution | Forecast length | Ensemble members | Daily frequency |
|---|---|---|---|---|---|---|---|---|
| V1.0 | 1992.12 | BV | None | None | T62L18 | 12 | 2 | 00UTC |
| V2.0 | 1994.3 | | | | T62L18 | 16 | 10(00UTC)<br>4(12UTC) | 00,12UTC |
| V3.0 | 2000.6 | | | | T126L28(0-2.5)<br>T62L28(2.5-16) | | 10 | |
| V4.0 | 2001.1 | | | | T126(0-3.5)<br>T62L28(3.5-16) | | | |
| V5.0 | 2004.3 | | | | T126L28(0-7.5)<br>T62L28(7.5-16) | | | 00,06,12,<br>18UTC |
| V6.0 | 2005.8 | | TSR | | T126L28 | | | |
| V7.0 | 2006.5 | BV- ETR | | | | | 14 | |
| V8.0 | 2007.3 | | | | | | 20 | |
| V9.0 | 2010.2 | | | STTP | T190L28 | | | |
| V10.0 | 2012.2 | | | | T254L42 (0-8)<br>T190L42 (8-16) | | | |
| V11.0 | 2014.12 | EnKF (f06) | | | T574L64 (0-8)<br>T382L64 (8-16) | | | |

# Next GEFS Sciences

- Initial perturbations
  - Base: EnKF 6hr forecast
    - TS relocation
    - Centralization
    - Ensemble transform - un-necessary if there is no significant difference
    - Rescaling – un-necessary if we confirm EnKF parallels have the similar characteristics for different seasons
- Stochastic perturbations
  - Tune STTP for model change and initial perturbation changes
  - Turn off stochastic perturbations for surface pressure (lnPs) in STTP
- Expectations
  - Improve hurricane track forecast
  - Improve probabilistic forecast guidance
  - Improve predictability of HIW and extreme weather event

# GEFS Upgrade (Q4FY14/Q1FY15)

**Project Status as of 03/19/2014**

## G Project Information and Highlights

**Lead:** Yuejian Zhu, EMC, Chris Magee, NCO

**Scope**:

- Latest GFS model (SLG version with improved physics).
- Configurations: T574L64 and T382L64 out to 384 hours
  - 0-192hr - T574 (T382 for physics – 33-35km
  - 192-384hr – T382 (T254 for physics) – 51-54km
  - L64 – the same vertical resolution as EnKF, GFS
- Initial perturbations
  - EnkF 6h forecast with improved TS relocation and centralization
- Stochastic physics
  - Tuning parameters for STTP to upgrade GFS model
  - Turn off stochastic perturbation of log surface pressure
- Forecast data output
  - All GRIB II format
  - 0.5degree data for pgb files
  - 3 hourly output frequency

**Expected Benefits:**

- Improve TS trick forecast
- Increase probabilistic forecast skill
- Improve predictability of HIW and extreme weather event

## G Scheduling

| Milestone (NCEP) | Date | Status |
|---|---|---|
| EMC testing complete/ EMC CCB approval | 08/15/2014 | |
| Initial Code Delivery to NCO | 08/31/2014 | |
| Technical Information Notice Issued | 09/30/2014 | |
| Initial Test Complete | | |
| CCB approve parallel data feed | | |
| IT testing begins | | |
| IT testing ends | | |
| Parallel testing begun in NCO (Code Frozen) | 10/20/2014 | |
| Real-Time Evaluation Ends | 11/20/2014 | |
| Management Briefing | | |
| Implementation | | |

## G Issues/Risks

**Issues:** N/A

**Risks**:

**Mitigation:**

## G Finances

**Associated Costs:**

**Funding Sources**: EMC Base: NCO Base:

| | | | | | |
|---|---|---|---|---|---|
| R | Management Attention Required | Y | Potential Management Attention Needed | G | On Target |

# Preliminary results for period of May 22nd – October 31st 2013

## Extended Summer Season

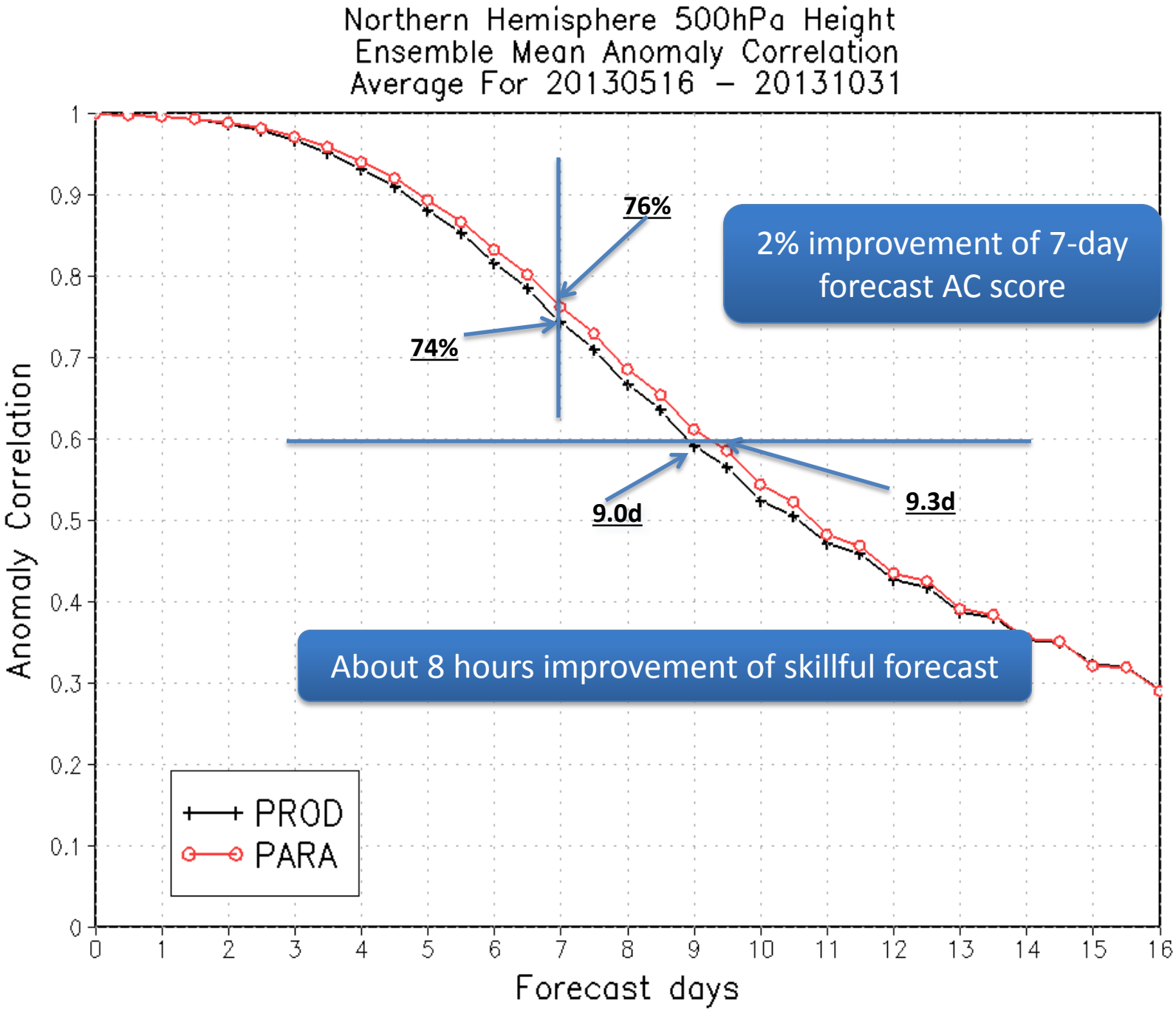
General stats:
http://www.emc.ncep.noaa.gov/gc_wmb/xzhou/EnKF_prhs13_10.HTML

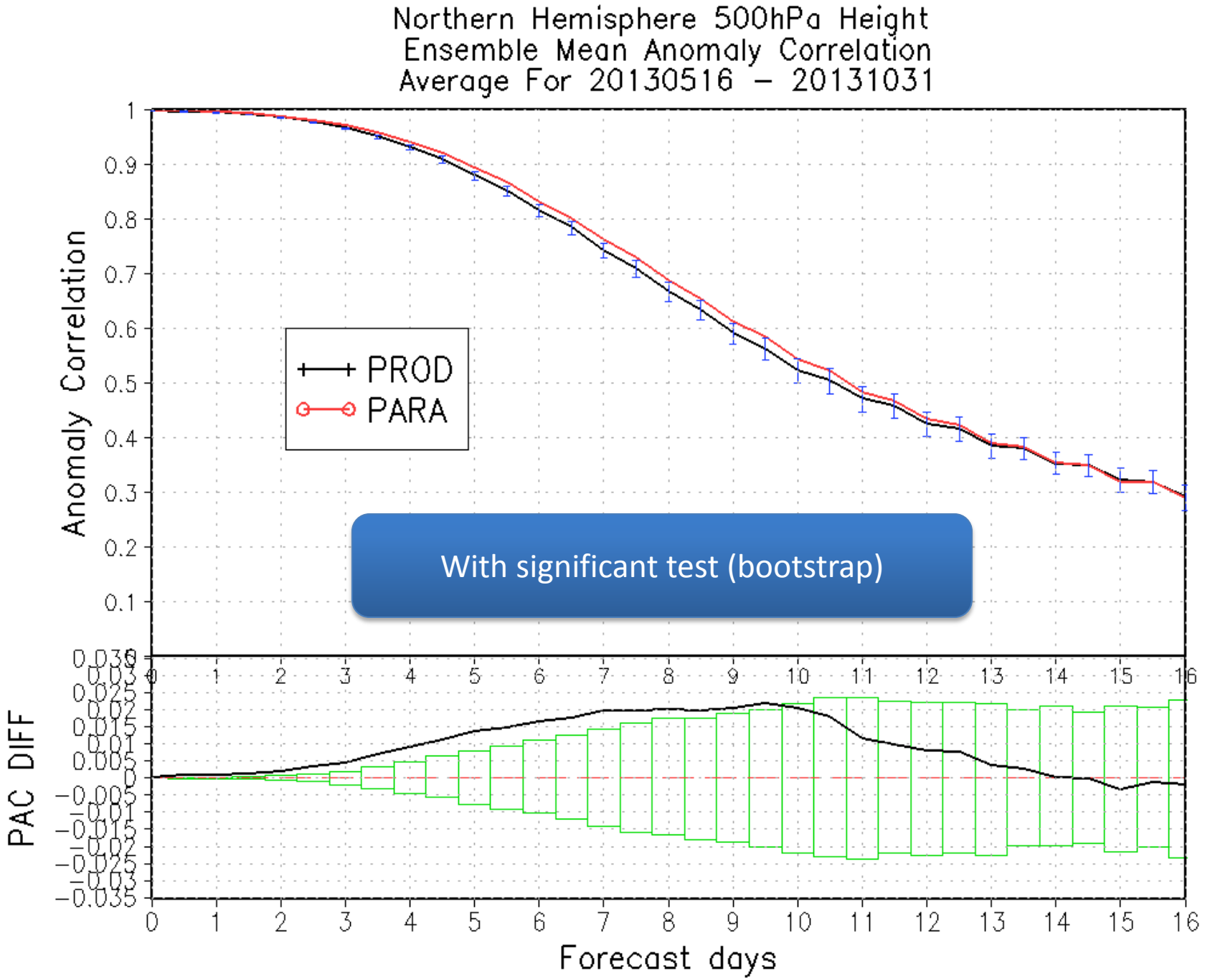
Surface against observations:
http://www.emc.ncep.noaa.gov/gmb/wx20cb/vsdb/geavg.20130601.20130831/g2o/

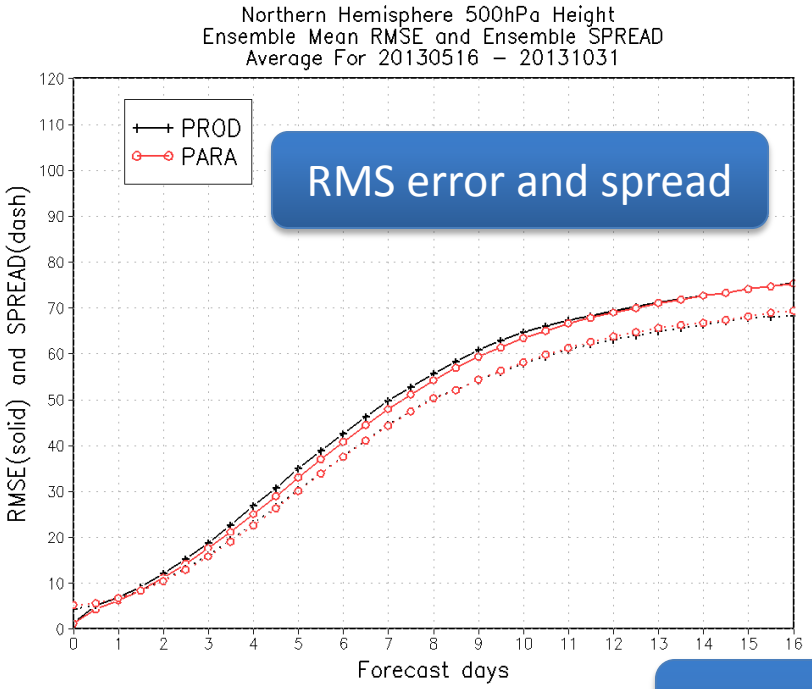
Precipitation:
http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/GEFS_PQPFvrfy_summer_test.html

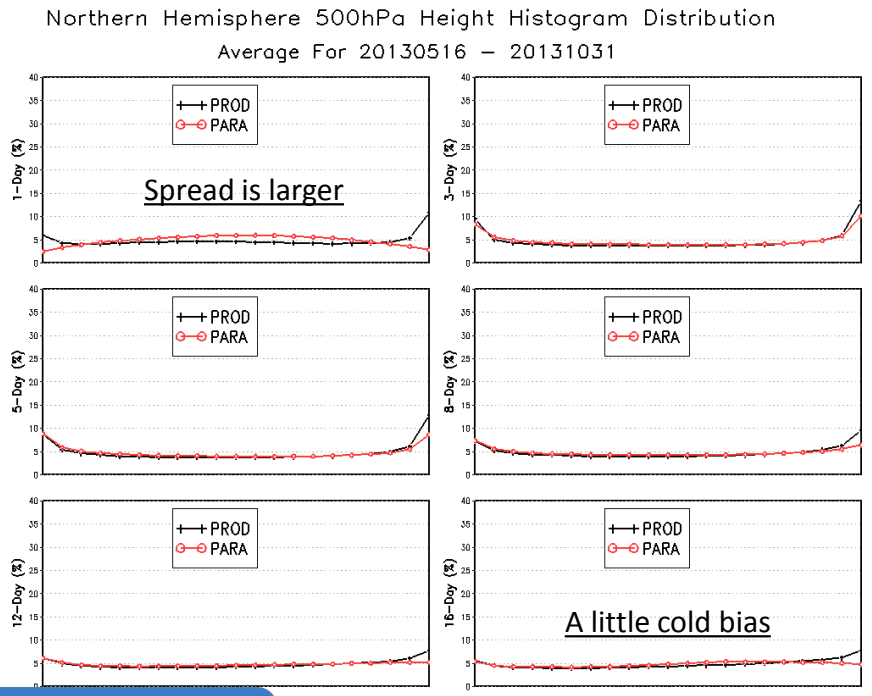
TC tracks (one slide)

**Note: model version may be slightly (minor) different during integration period.**

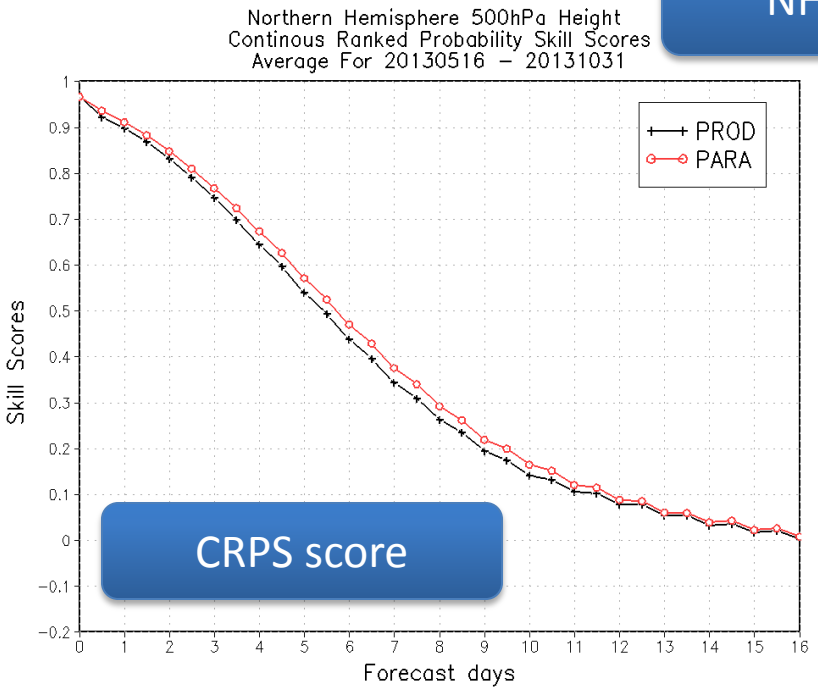

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20130516 – 20131031
Anomaly Correlation
Forecast days
76%
74%
9.0d
9.3d
2% improvement of 7-day forecast AC score
About 8 hours improvement of skillful forecast
PROD
PARA

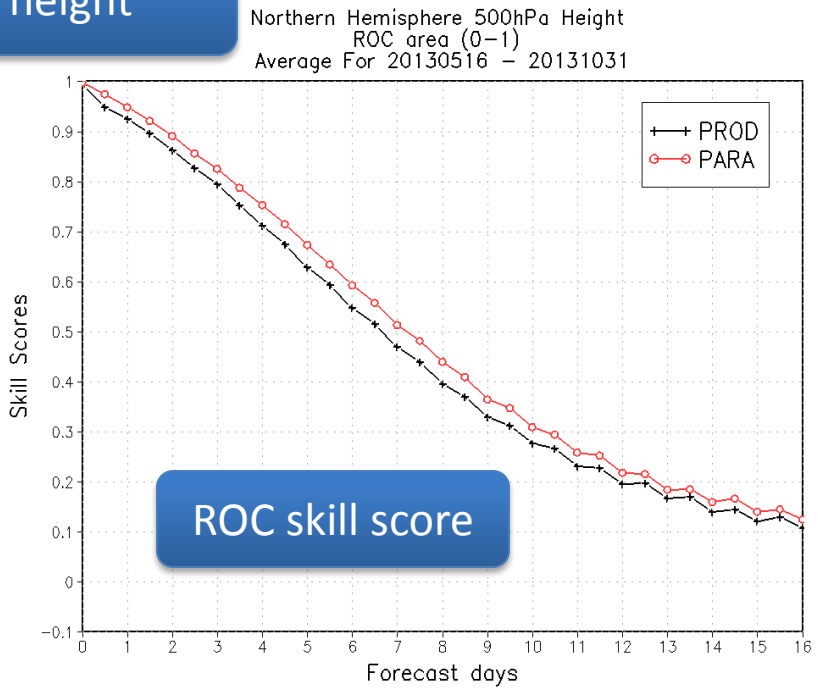

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20130516 – 20131031
Anomaly Correlation
PROD
PARA
With significant test (bootstrap)
PAC DIFF
Forecast days

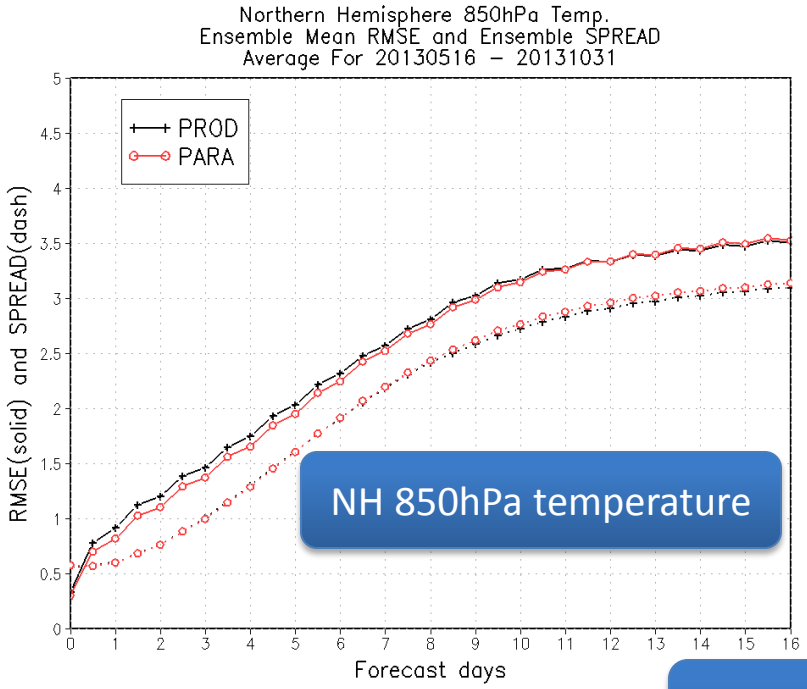


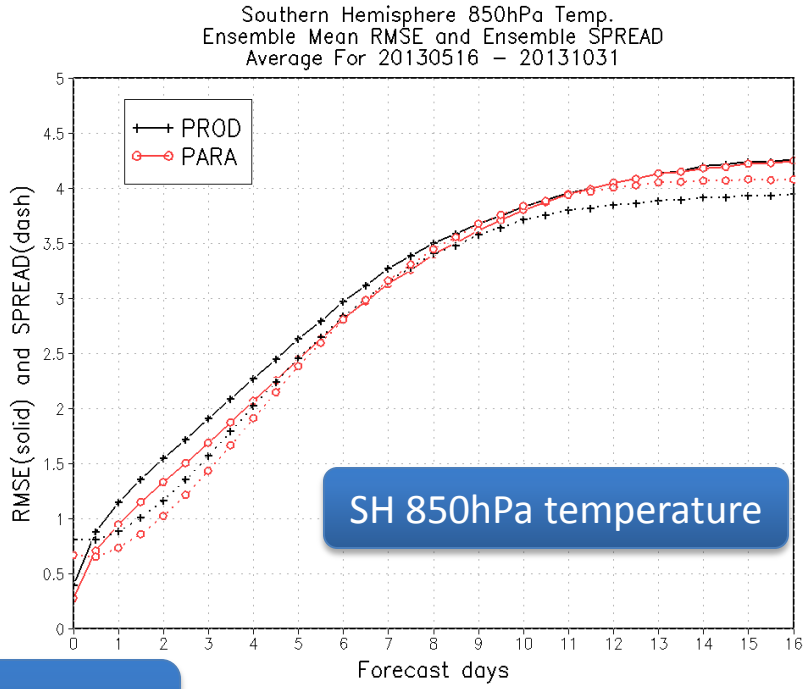




NH 500hPa height

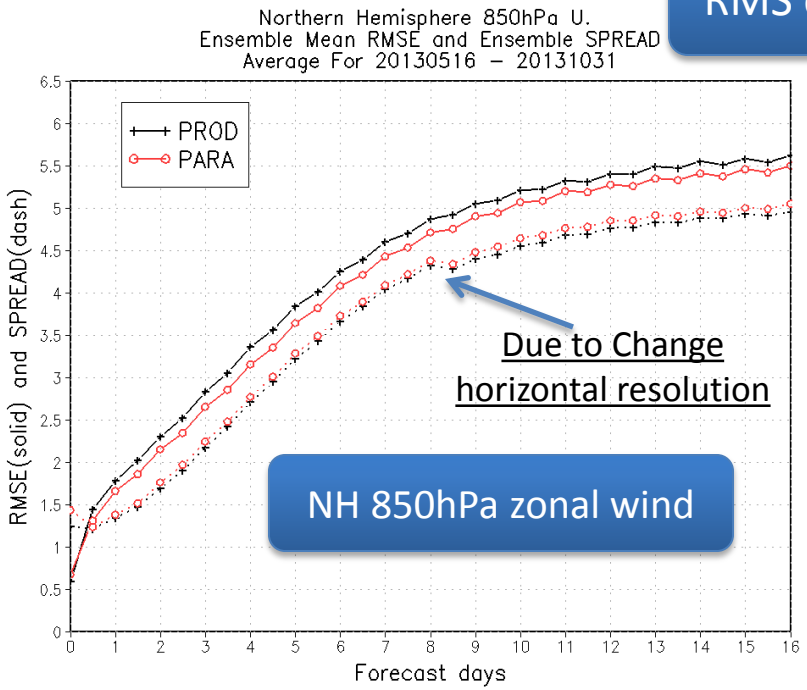


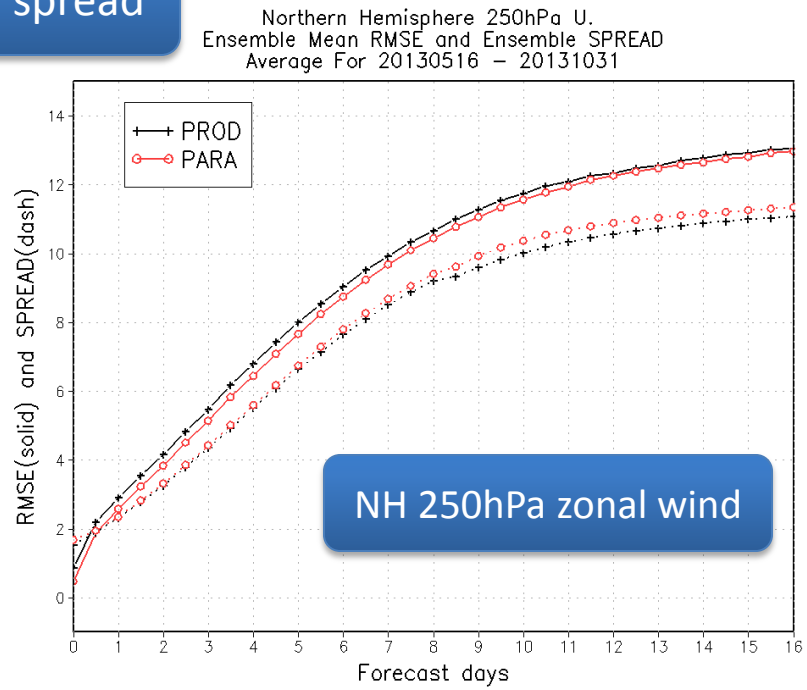



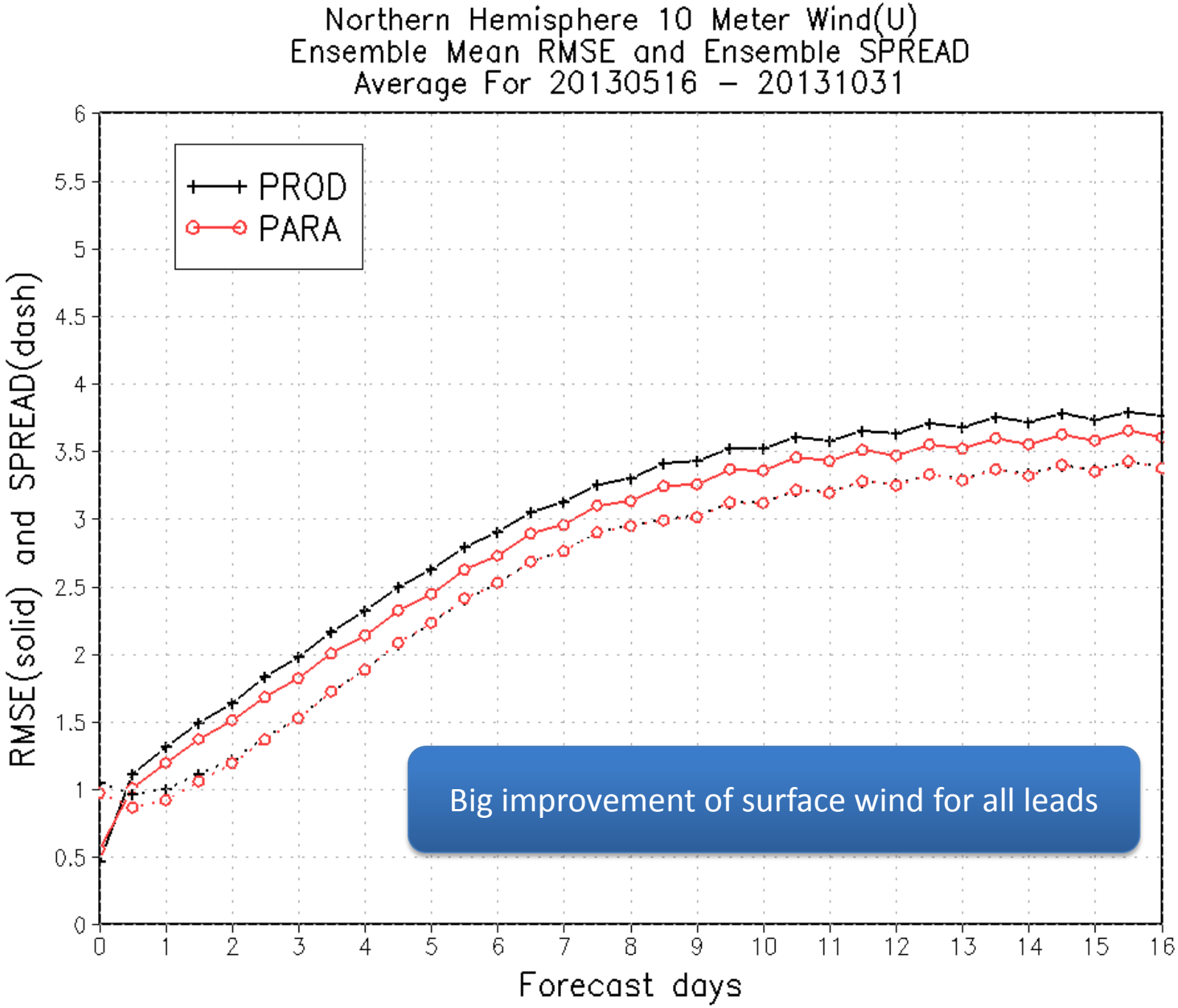


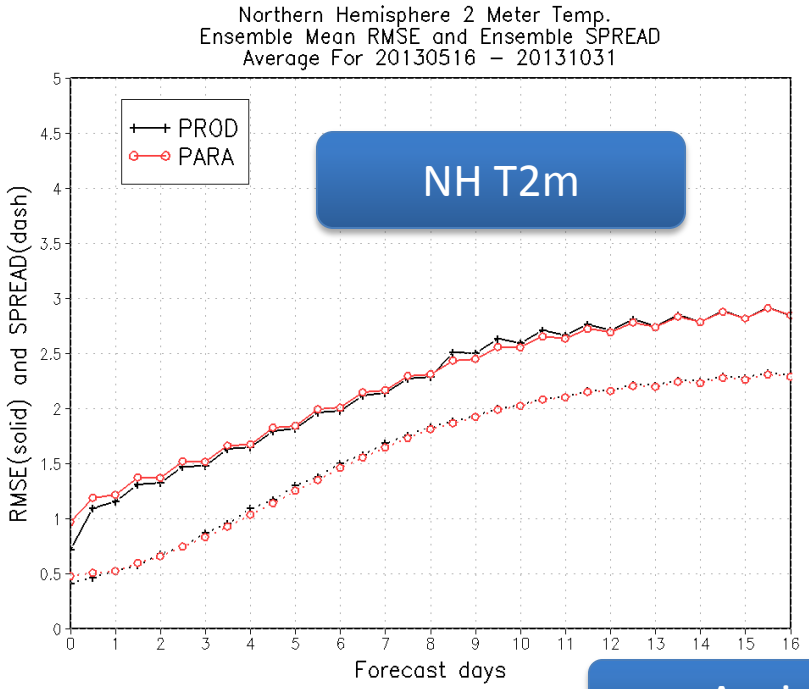




RMS error and spread




Northern Hemisphere 10 Meter Wind(U)
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20130516 – 20131031
PROD
PARA
RMSE(solid) and SPREAD(dash)
Forecast days
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Big improvement of surface wind for all leads



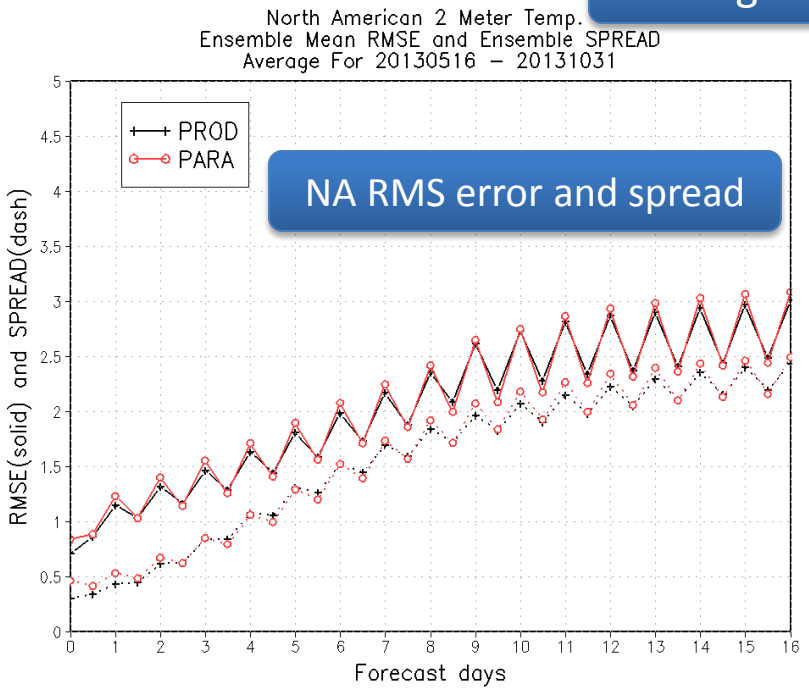

NH T2m

# Interesting to review surface temperature

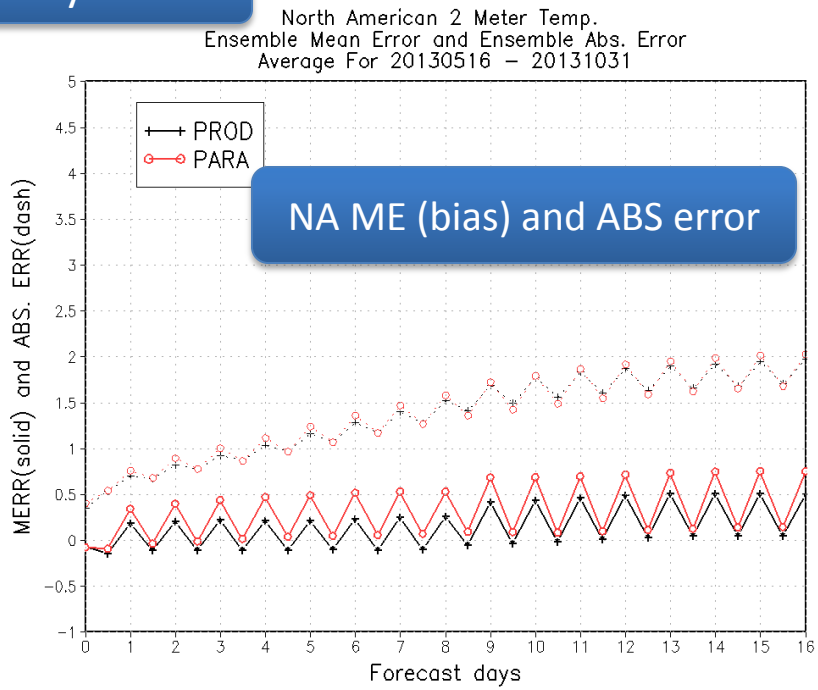
Analysis differences of surface temperature (T2m)
Period: 05/01/2013 – 8/15/13
RMS errors for 107 days (against obs)

| Regions | PROD | PARA |
|---|---|---|
| West | 3.227 | 3.383 |
| East | 2.637 | 2.465 |

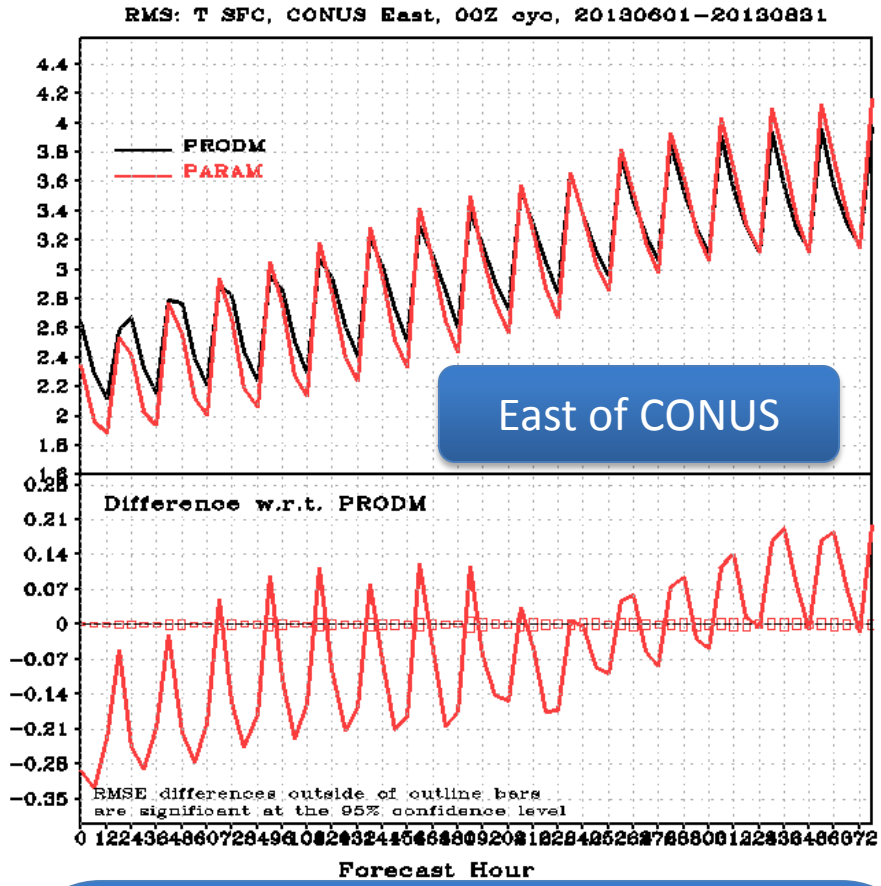
Against own analysis



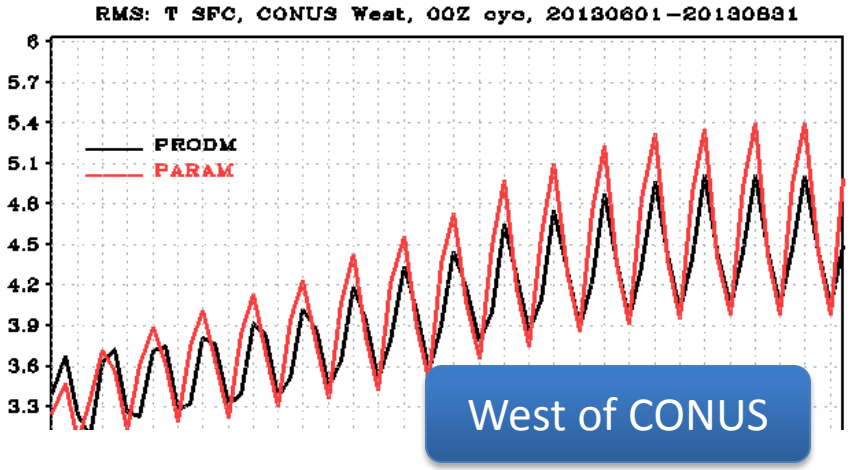

NA RMS error and spread



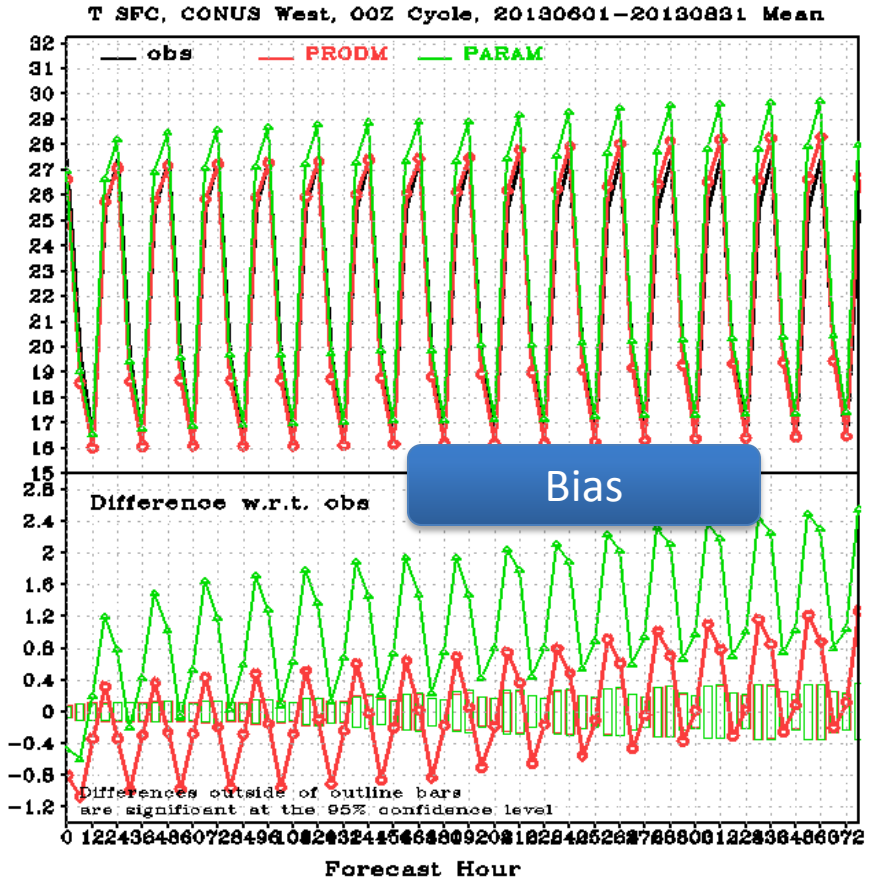

NA ME (bias) and ABS error




East of CONUS




West of CONUS



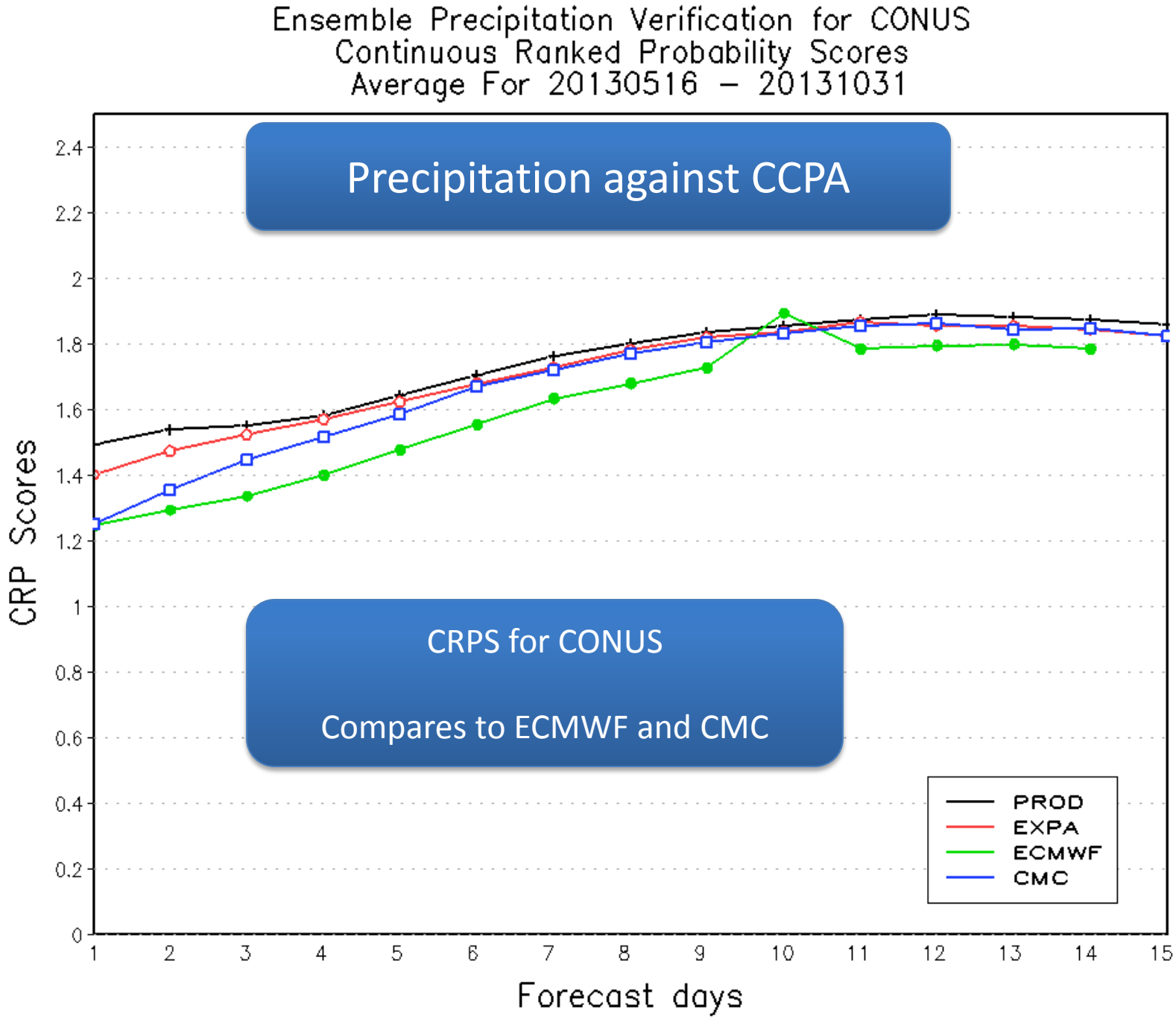

Bias

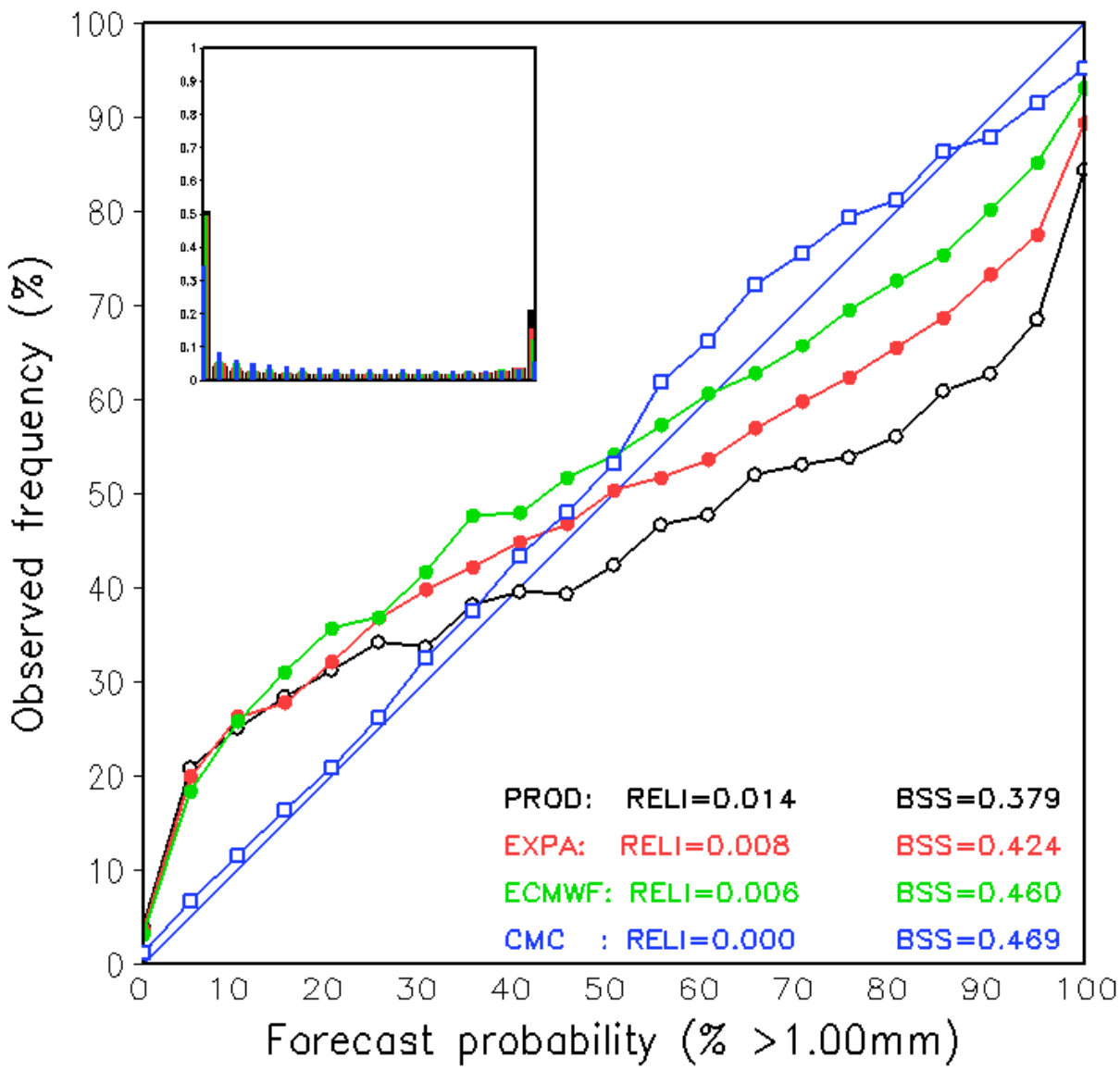
## 3-month (summer) average (against obs)

Top: T2m RMS error of East region
Top right: T2m RMS error of West region
Bottom right: T2m bias of West region

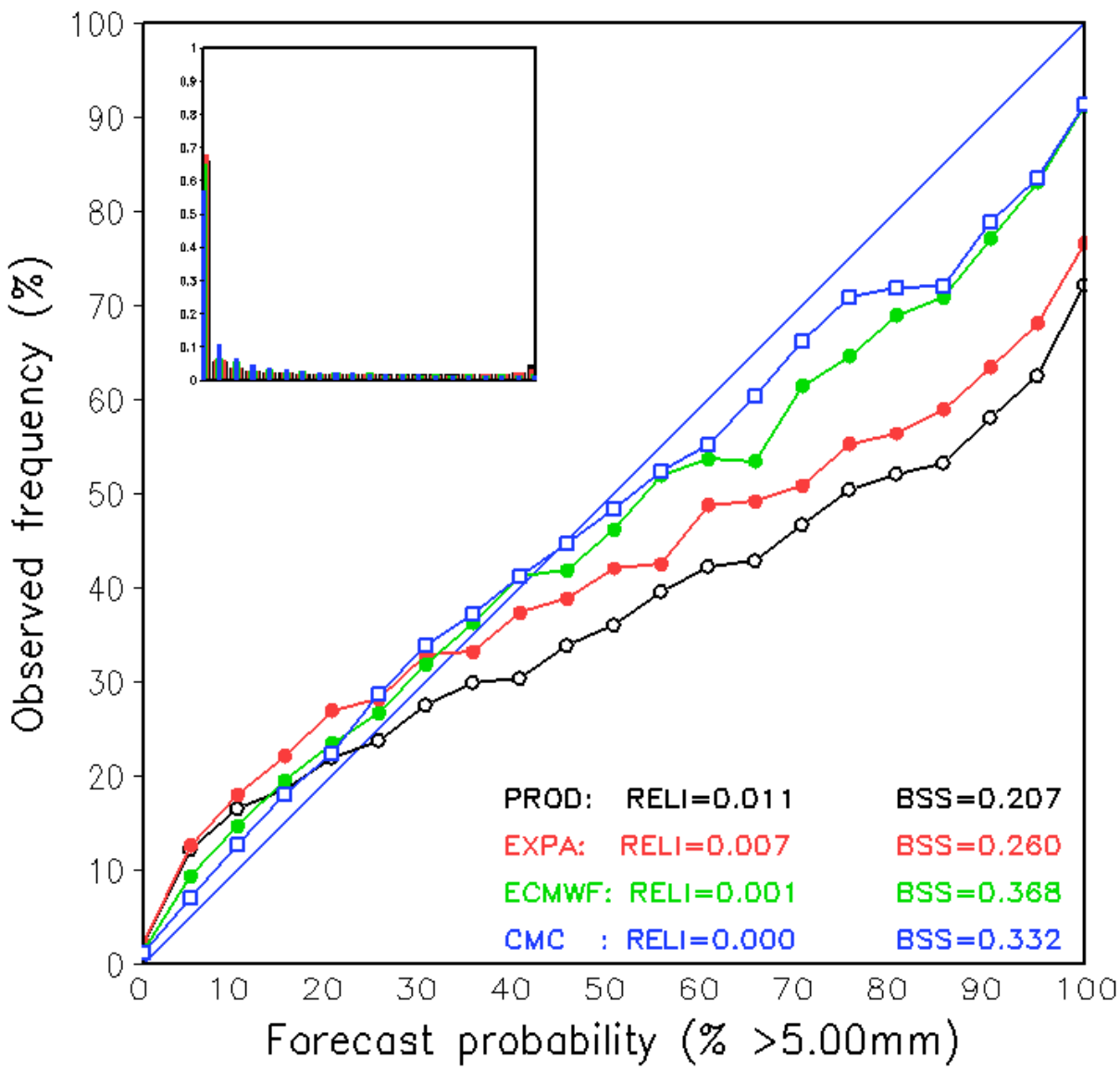
## Conclusion for summer:

New model has large warm bias (reduce cold bias for night – good; increase warm bias for day – bad) in summer for west region, therefore, RMS error is increased


Ensemble Precipitation Verification for CONUS
Continuous Ranked Probability Scores
Average For 20130516 – 20131031
Precipitation against CCPA
CRPS for CONUS
Compares to ECMWF and CMC
CRP Scores
Forecast days
PROD
EXPA
ECMWF
CMC
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15



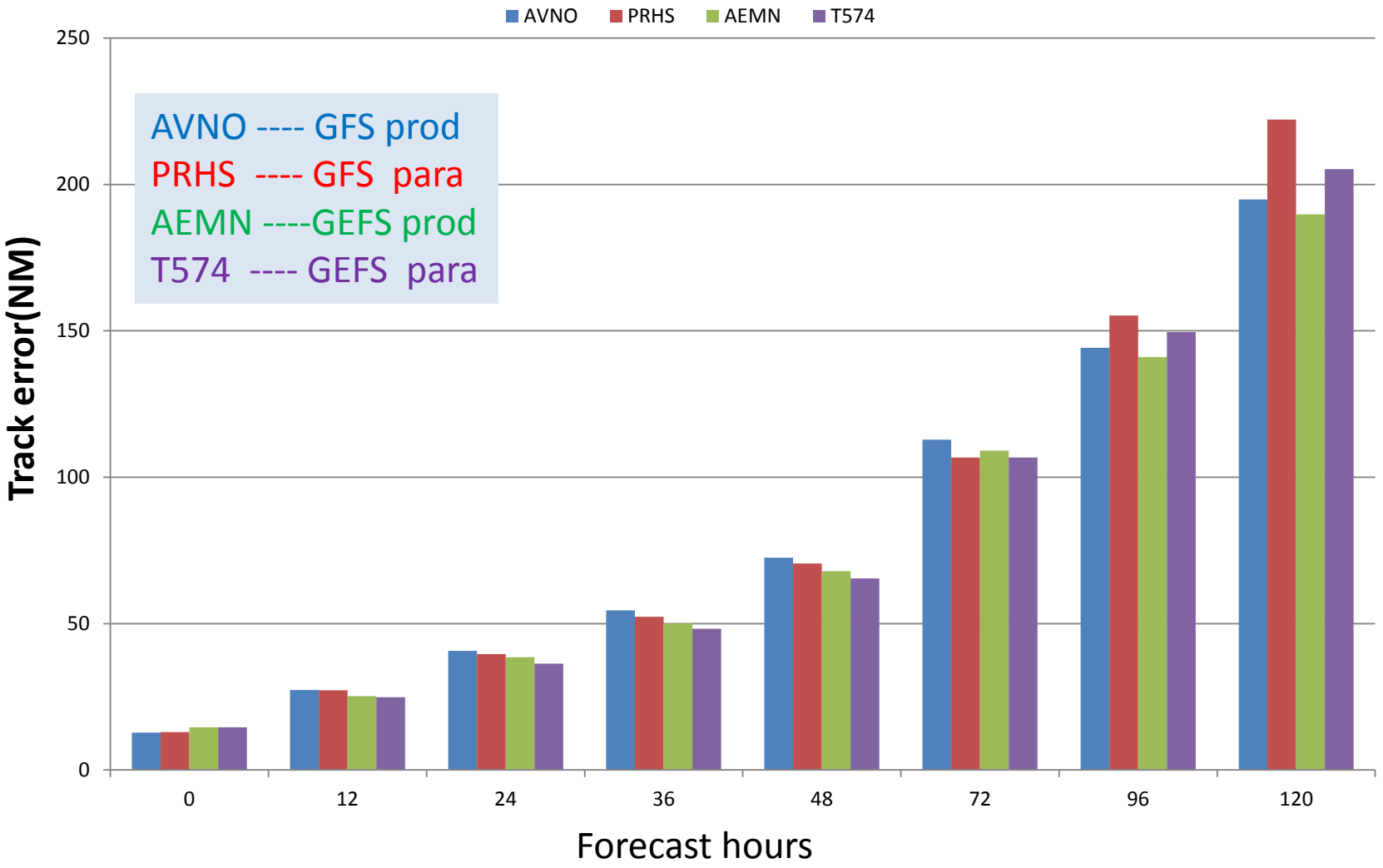

Precipitation reliability for 12-36hr and greater than 1mm/day




Precipitation reliability for 36-60hr and greater than 5mm/day

# May 15 – Oct. 31 2013 AL/EP/WP TC Track Verifications

Retrospective runs – once per day at 00UTC




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CASEs | 236 | 207 | 185 | 158 | 133 | 93 | 61 | 39 |

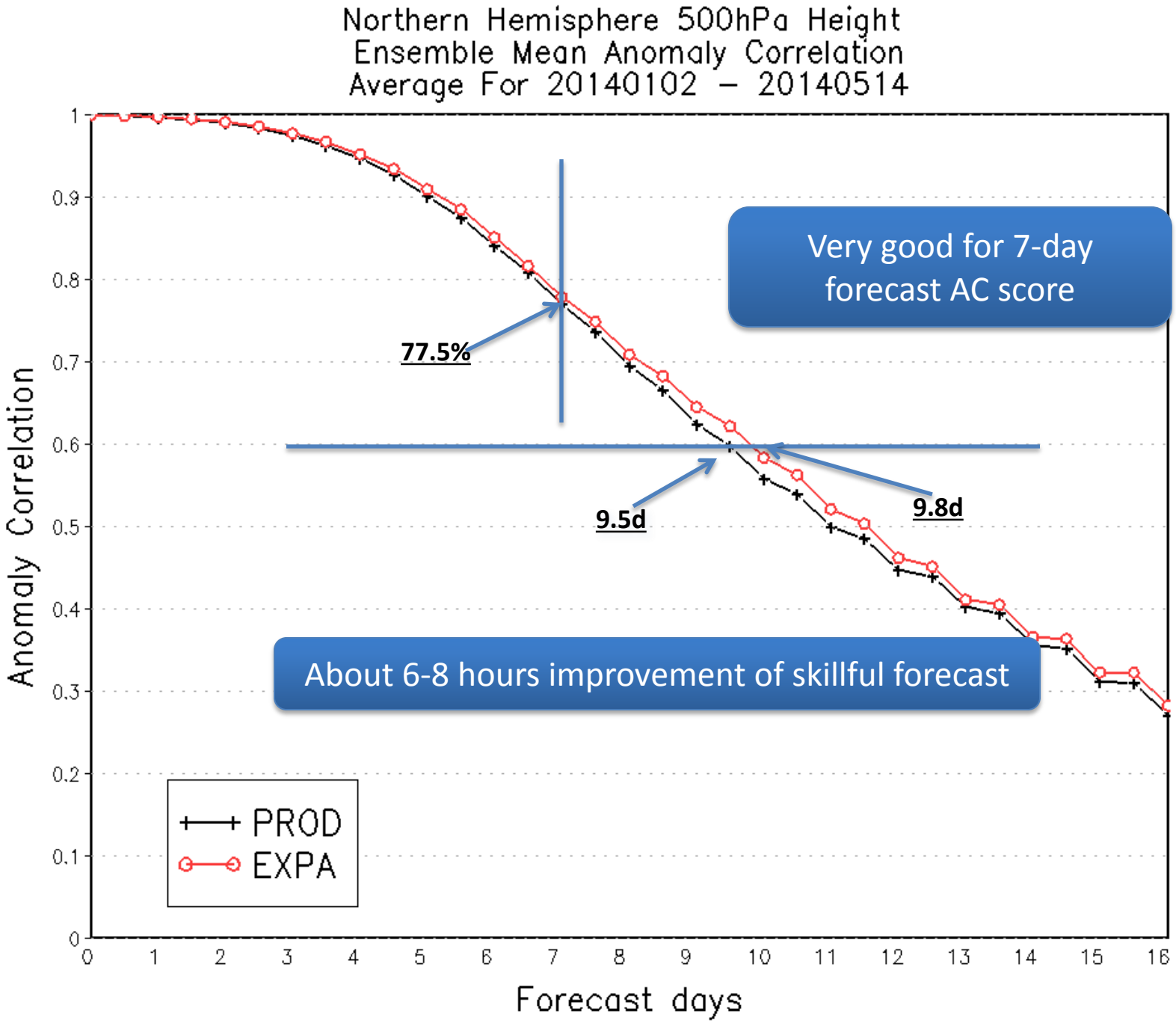
**Preliminary results for period of January 2nd – May 14 2014**

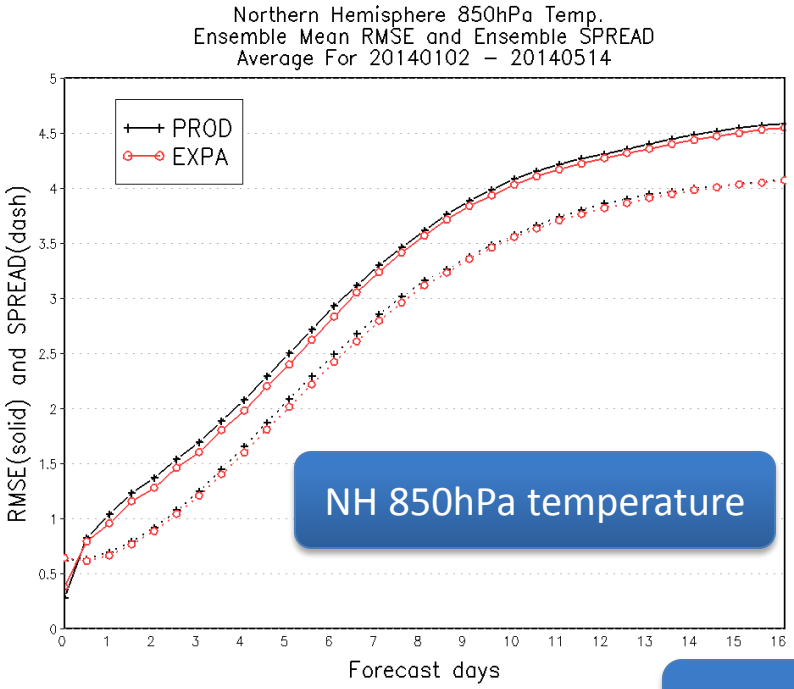
**Extended Winter Season**

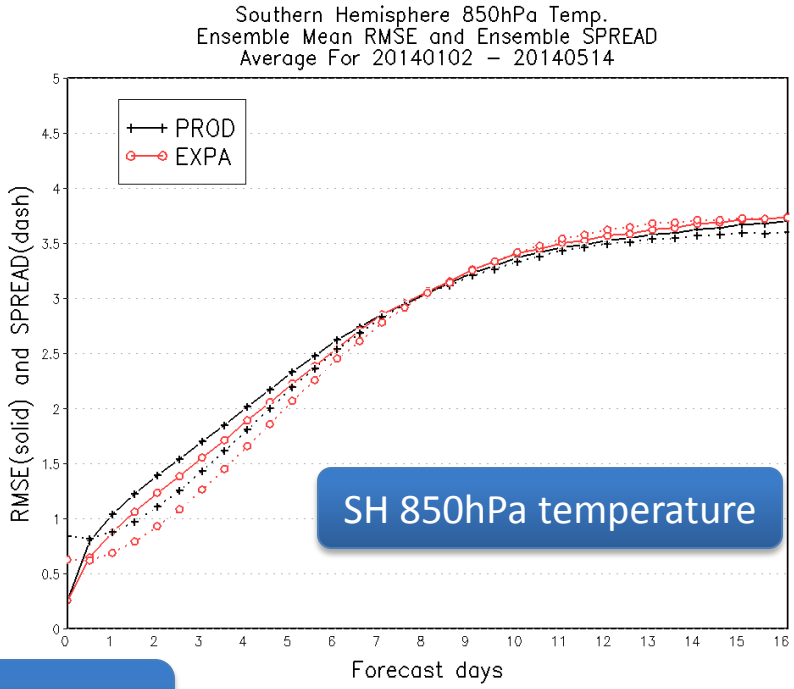
General stats:
http://www.emc.ncep.noaa.gov/gmb/wd20dh/STTP2014/PROB_OoFa.HTML

Precipitation:
http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/GEFS_PQPFvrfy_spring_test.html

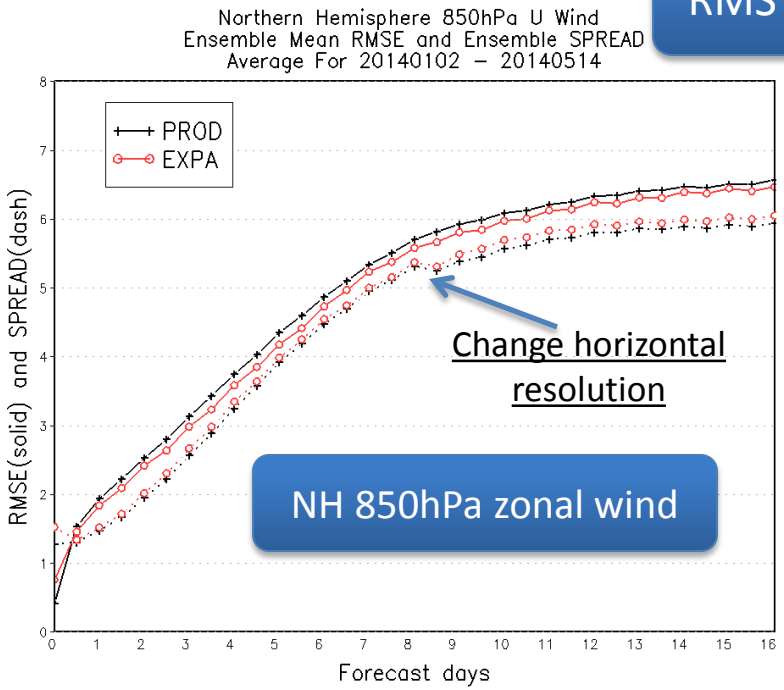
**Note: model version may be slightly (minor) different during integration period.**

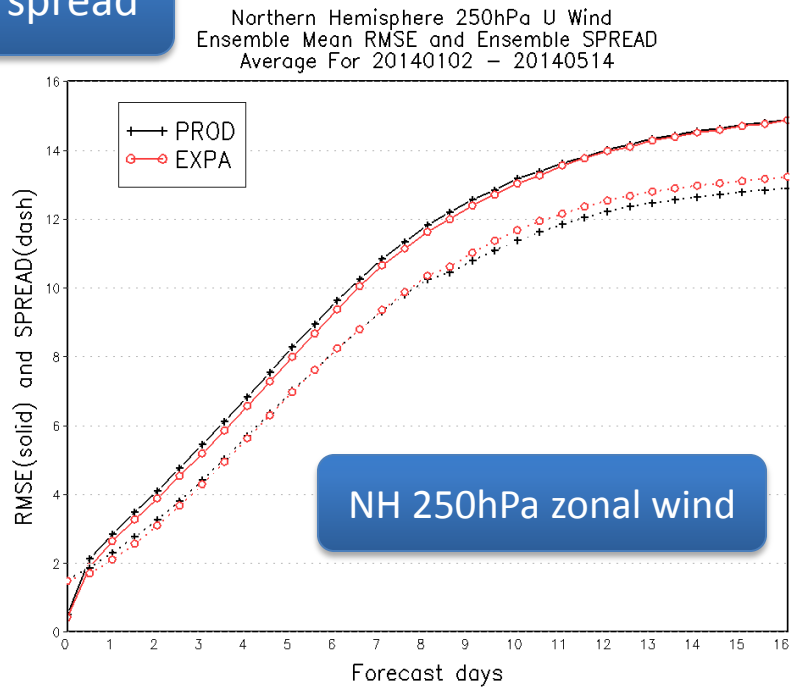

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20140102 – 20140514
Anomaly Correlation
Forecast days
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
PROD
EXPA
77.5%
9.5d
9.8d
Very good for 7-day forecast AC score
About 6-8 hours improvement of skillful forecast

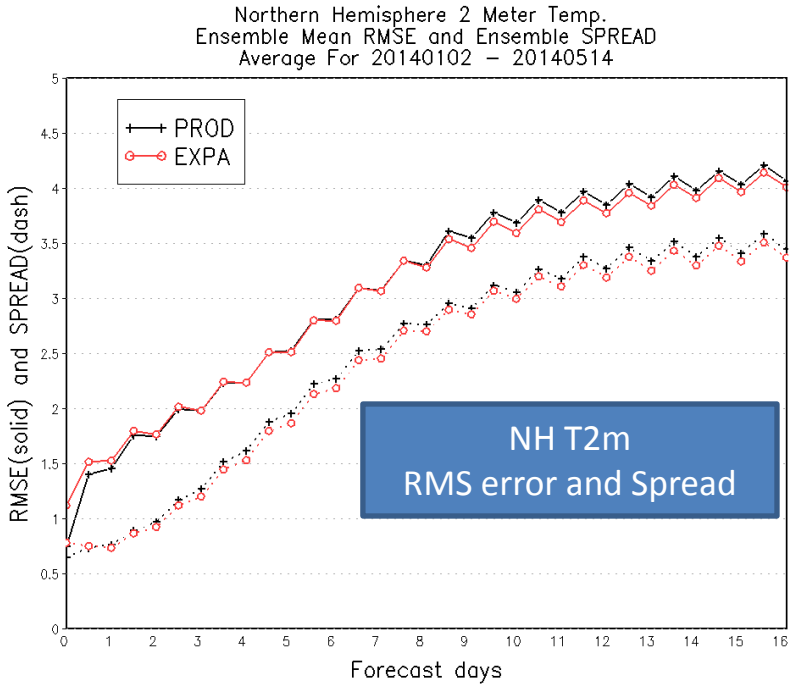


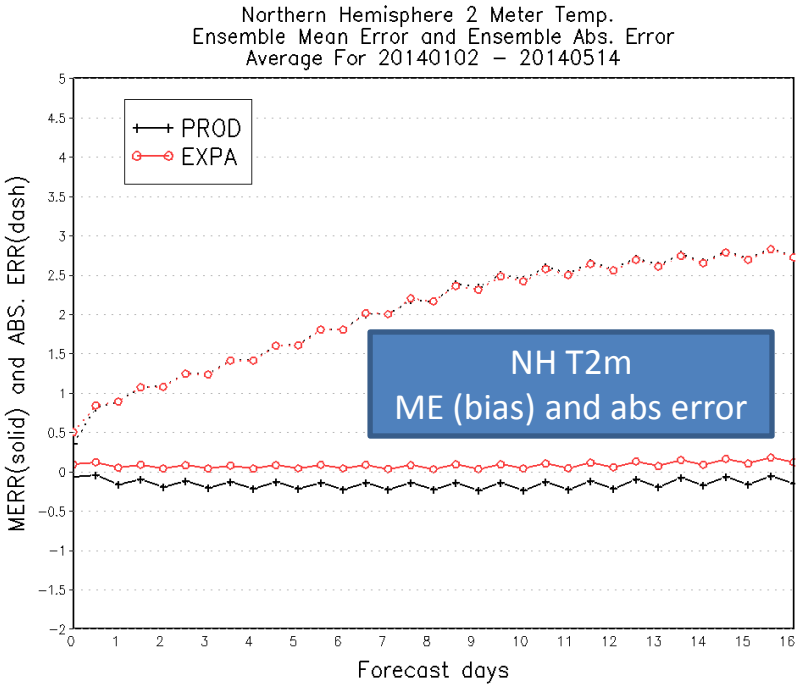



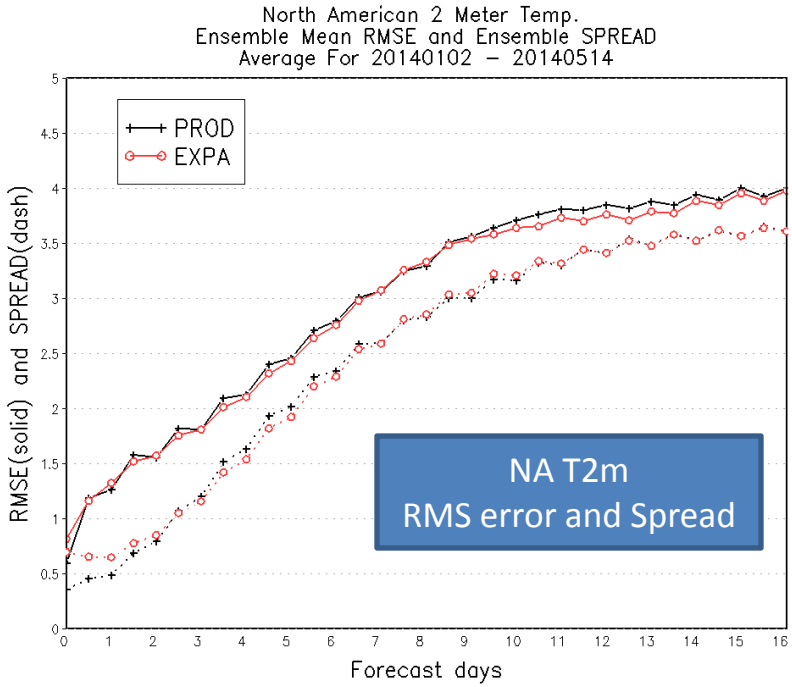

RMS error and spread

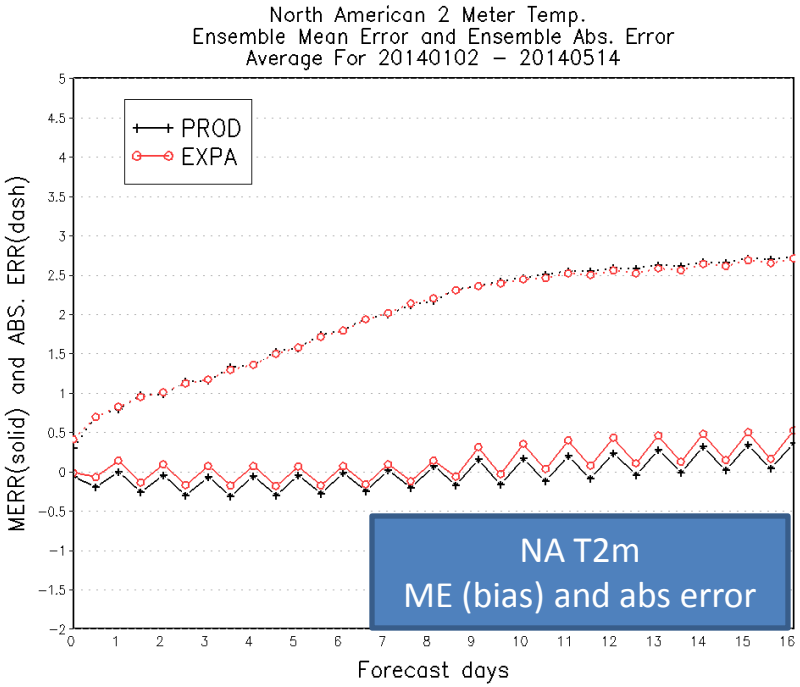



Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20140102 – 20140514
PROD
EXPA
RMSE(solid) and SPREAD(dash)
Forecast days
NH T2m
RMS error and Spread

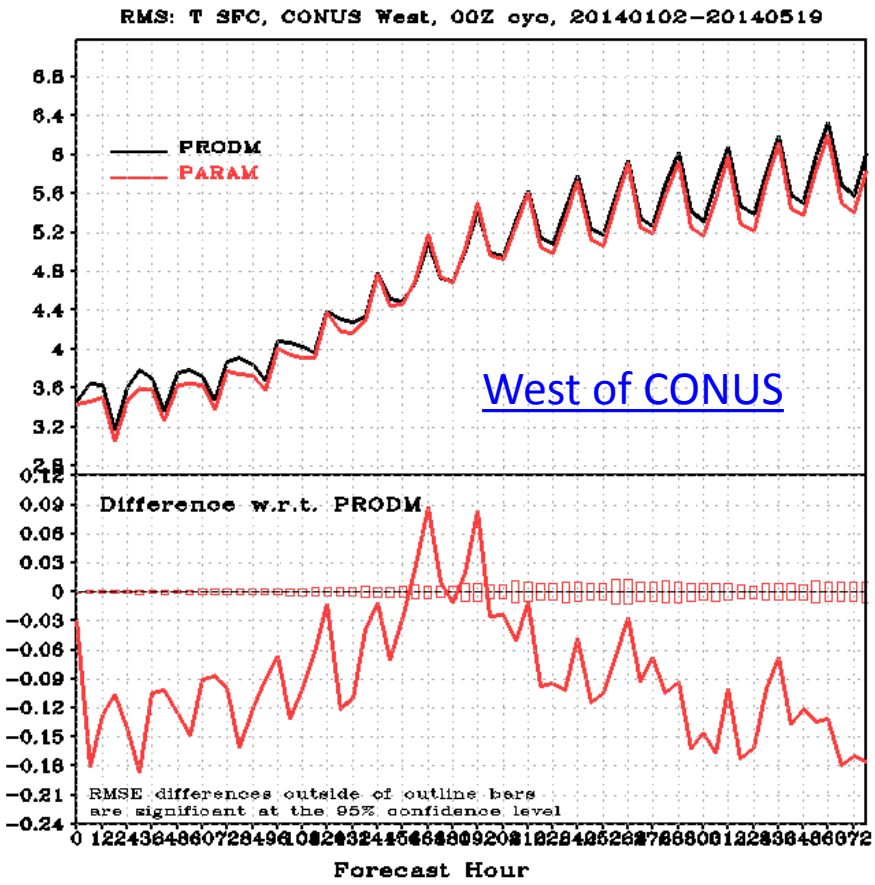

Northern Hemisphere 2 Meter Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 20140102 – 20140514
PROD
EXPA
MERR(solid) and ABS. ERR(dash)
Forecast days
NH T2m
ME (bias) and abs error


North American 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20140102 – 20140514
PROD
EXPA
RMSE(solid) and SPREAD(dash)
Forecast days
NA T2m
RMS error and Spread

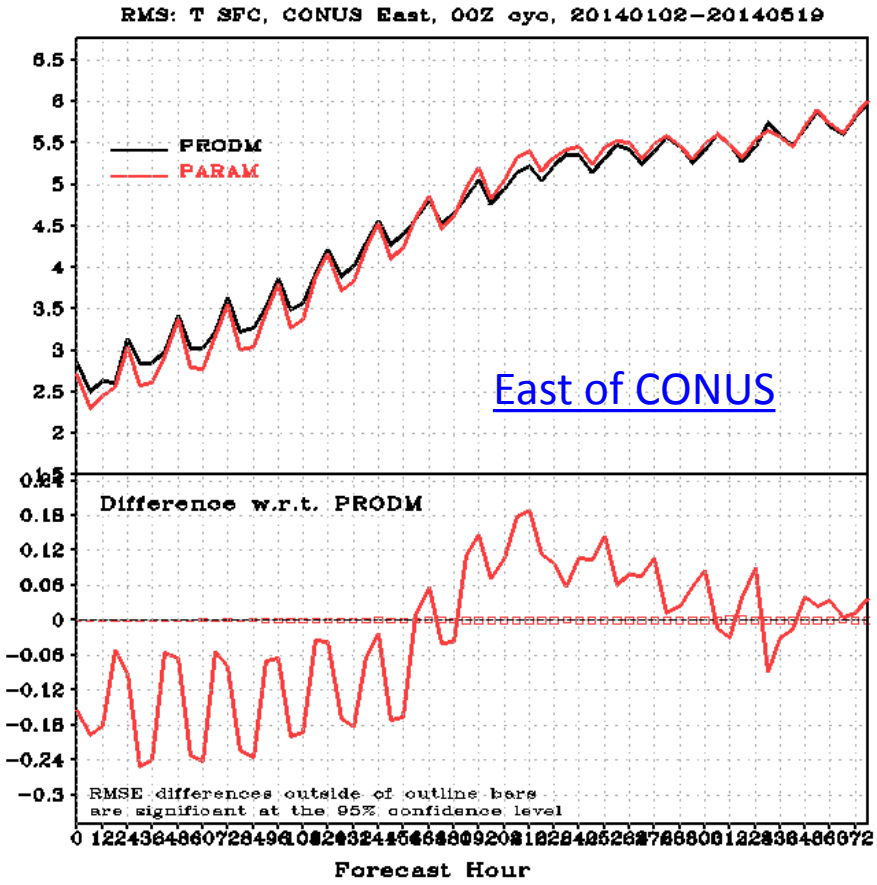

North American 2 Meter Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 20140102 – 20140514
PROD
EXPA
MERR(solid) and ABS. ERR(dash)
Forecast days
NA T2m
ME (bias) and abs error

# T2m verification statistics

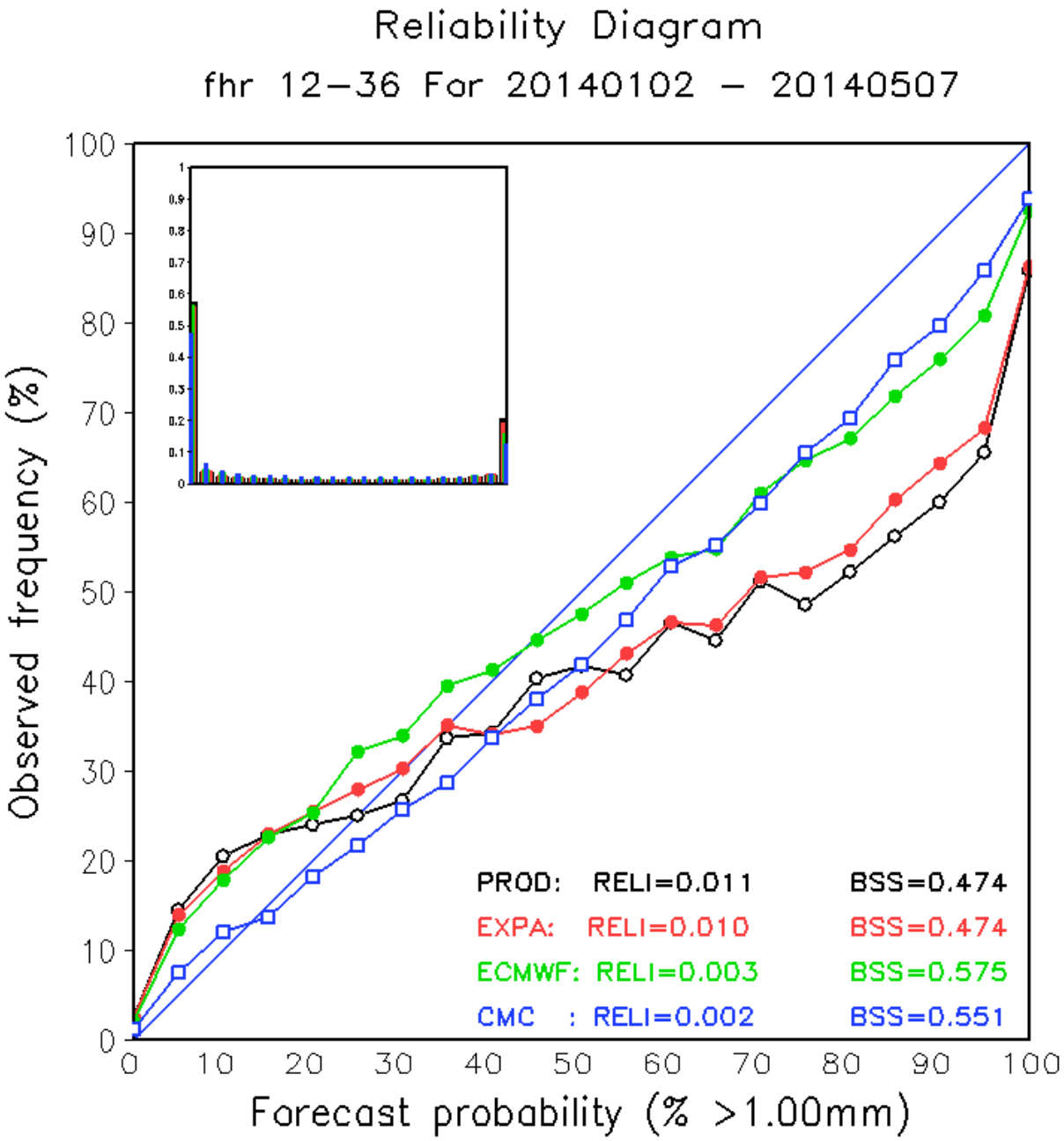
(against observation: 01/01 – 05/19/2014)



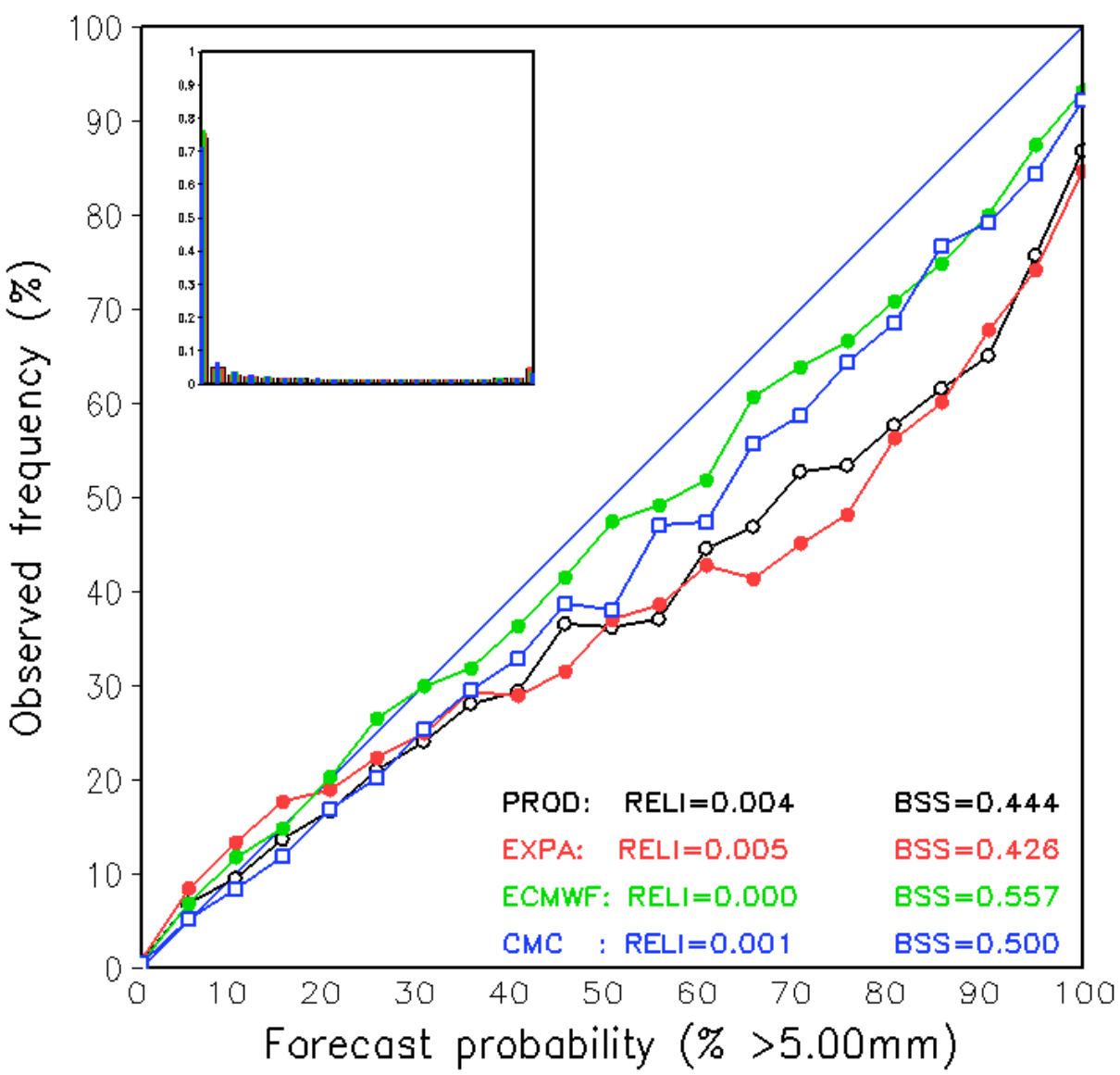

West of CONUS




East of CONUS




Precipitation reliability for 12-36hr and greater than 1mm/day




Precipitation reliability for 36-60hr and greater than 5mm/day

# Summary

- Extended summer (05/15 – 10/31/2013)
  - Improvement:
    - Over-all large scale circulation in terms of AC, RMS error, CRPS and other measures
    - Hurricane tracks out to 3 days (less sample beyond 3 days, especially for Atlantic basin)
    - Precipitation – improved reliability and skill
    - Surface temperature – improved for east of CONUS
    - Surface wind
  - Neutral:
  - Degrade:
    - Surface temperature – degraded for west of CONUS (large warm bias)
- Extended winter (01/1 – 05/14/2014)
  - Improvement:
    - Over-all for many atmospheric variables
    - Surface wind
    - Surface temperature - improved error and bias for short lead-time
  - Neutral:
    - Surface temperature errors for west of CONUS
    - Precipitation
  - Degrade:

# Test Plan for Next GEFS

- Keep monitoring the performance of STTP's parameter setting and EnKF f06 initial perturbations.
  - It is still possible to have an minor modification for STTP parameters and initial perturbations.
- At least to run retrospective experiments for three full seasons
  - Hurricane seasons (2012, 2013)
  - Winter (2013-2014)
  - Twice per day (00UTC and 12UTC)
- Have full probabilistic evaluations (or performances) of
  - Upper atmospheric fields (against own analysis)
  - Surface elements which include precipitation for CONUS
    - Will against observations for T2m and precipitation for CONUS
  - Hurricane tracks (also intensity, even there is less skill comparing to others)

# GEFS Reforecast (hindcast)

Yuejian Zhu
Contributions from ensemble team

EMC/NCEP/NWS
June 2014

# Global Ensemble Forecast System (GEFS)

| System | Current | End of Phase 1 | End of Phase 2 (FY18) |
|---|---|---|---|
| **GEFS** | **T254 (55 km) 0 to 8-d** | **T574 SL (35 km) 0 to 8-d** | **T1148 SL (17 km) 0 to 10-d** |
| | **T190 (70 km) 8 to 16-d** | **T382 SL (55km) 8 to 16-d** | **T574 SL (35km) 10 to16-d** |
| | | | **T574 SL (35km) 16 to 32-d (new request)** |
| | **20 Members @ 42 Vertical Levels** | **20 Members @ 64 Vertical Levels** | **20 Members @ 64 Vertical Levels** |
| | | **Semi-Lagrangian<br>EnKF integrated with others for initial perturbations<br>Full stochastic physics** | **NEMS, coupled ocean<br>MME (multi-model ensemble)<br>Extended to week 3 & 4** |
| **GEFS reforecast** | **None** | **None** | **Same GEFS (and GFS) model<br>Same resolution<br>Less membership and runs<br>Past 20 Years** |

GEFS reforecast is in WCOSS phase II plan

# Real-Time Reforecast

- Advantage:
  - Users will receive upgraded numerical guidance more frequently along with associated hindcasts
- Issues:
  - Frequent upgrades implies constant adaptation efforts for downstream prediction systems (CPC, waves, hydro)
  - Hindcasts length and membership will be limited by computer resources

# GEFS Reforecast Configuration (WCOSS Phase-2)

- GEFS configuration for WCOSS phase-2
  - T1148L64 SL (17km) for 0-10 days
  - T574L64 SL (34km) for 10-35 days
  - 21 members, 4 cycles per day
  - Coupling with ocean model from day-0 or day-10 (debate?)
- Reforecast configuration (white paper recommended)
  - For past 20 years
  - 5 members for each initial run, twice per day for every other 5 days
- If we run in real time reforecast (WCOSS)
  - 5 members (two cycles per day) to contrast of 21 members (four cycles per day) in operation
  - Run 5(m)*2(c)*20(y)=200 members during 5 days to contrast of 21(m)*4(c)*5(d)=420 members (less 50%)
  - Start to accumulate the reforecast from NCO real time parallel
- If we run it on R&D computer (offline)
  - We could run 20 years at once
  - Depends on resource availability, it could be finished in 3 months for whole 20-year reforecast, which based on above configuration, if we could run 162 members in one day (in the contrast of 84 members per day in operation)
- Issues or challenges:
  - Freeze model?
    - It needs at least 3 months ahead to freeze the model
    - How to deal last minute changes (minor) or bug fix ?
  - Preparing downstream applications:
    - CPC's week-2 and sub-seasonal bias (systematic error) calculation
    - WPC's daily probabilistic forecast calibration
    - OHD's application
    - MDL's statistic post process

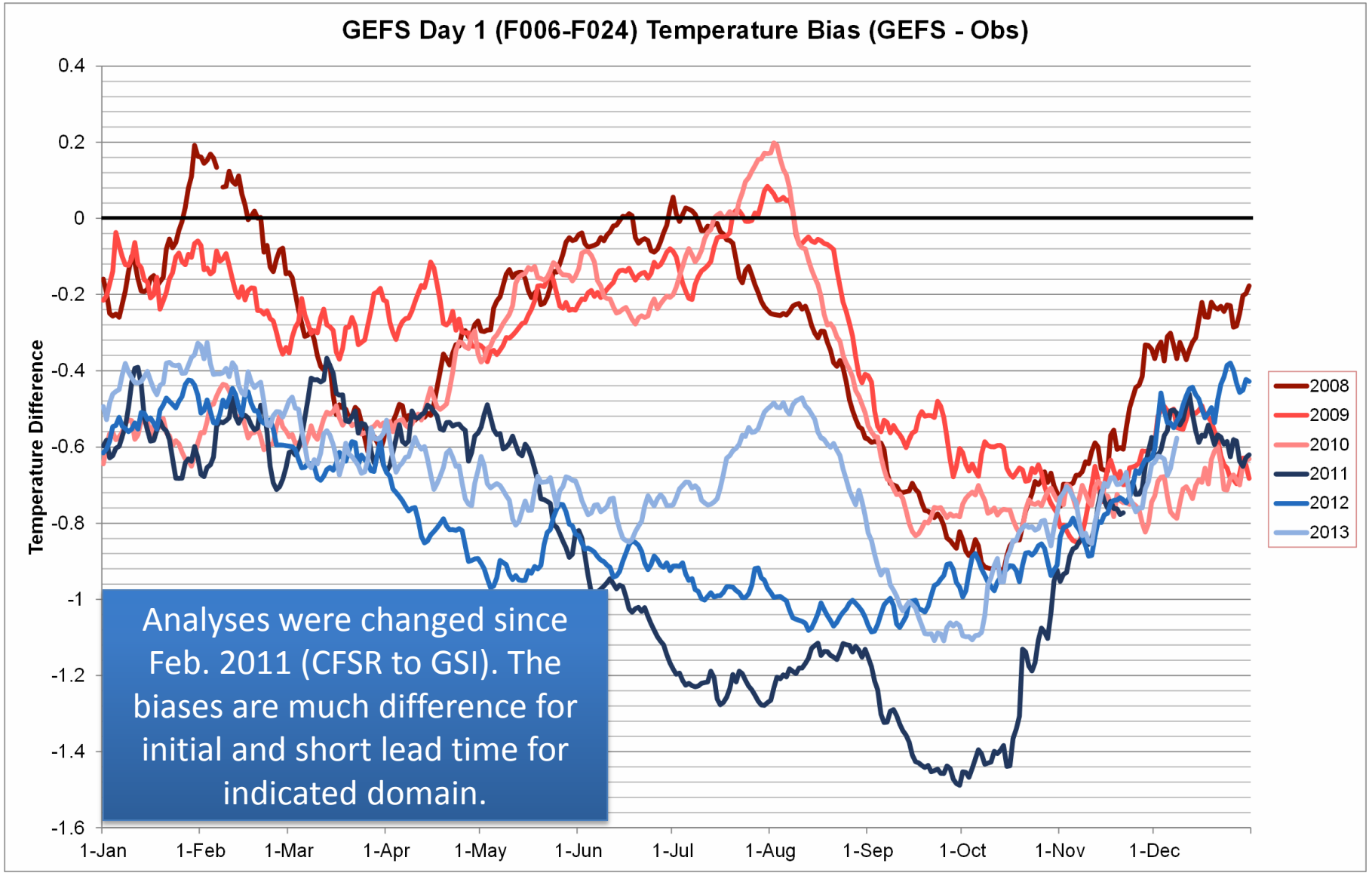
# Real time GEFS reforecast cost

- White paper recommended:
  - Configuration: 20 years, every 5 days, twice per day (00 and 12UTC), 5 members (1 control, 4 perturbed forecast) only.
  - Reforecast: 20(y)*2(cycles)*5(members) = 200 members in 5 days
  - GEFS: 21(members)*4(cycles)*5days) = 420 members in 5 days
  - Cost: 48% resource of operational GEFS
- Option one: to reduce the cost:
  - Every 7 days, 5 members only.
  - Reforecast: 20(y)*2(c)*5(m) = 200 members per 7-day
  - GEFS: 21(m)*4(c)*7(d) = 588 members per 7-day
  - Cost: 34% resource of GEFS
- Option two: to reduce the cost:
  - Every 7 days, 3 members only.
  - Reforecast: 20(y)*2(c)*3(m) = 120 members per 7-day
  - GEFS: 21(m)*4(c)*7(d) = 588 members per 7-day
  - Cost: 20% resource of GEFS

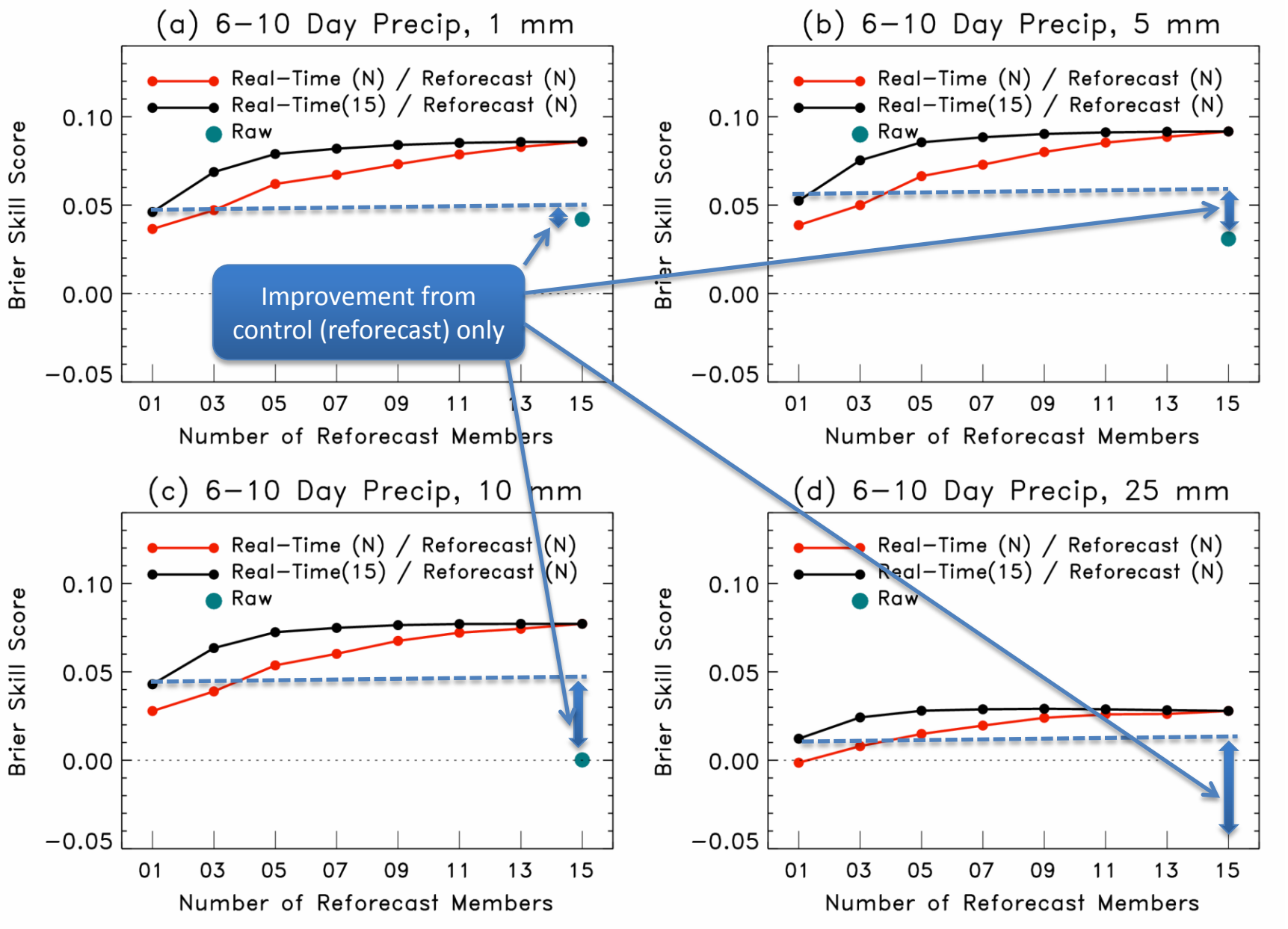
# What we could do for next GEFS upgrade?

- There are no additional resource from WCOSS phase I for real time GEFS reforecast
- Who will be affected immediately when GEFS upgrade
  - CPC, OHD and others
- Alternately option - off-line runs
  - Seeking for R&D resources, or development of WCOSS
  - Limited samples (ensemble control only) – this configuration is much cheaper than ensemble runs (we don't need to run cycling for initial perturbation of past 20 years).
  - Limited benefits (yes!!!)
  - Option 1: 20 years * 73 runs/per year (every 5 days) * 2 (00&12UTC) = 2920 (approximated to 140 full ensemble runs)
  - Option 2: 20 years * 52 runs (every week) * 4 (00,06,12,18UTC) = 4160 (approximated to 200 full ensemble runs)
- Pre-evaluations (using exist retrospective runs)
  - Characteristics of bias – deterministic and ensembles (STTP impact)
  - Uncertainties – there is no model uncertainties from control only runs
  - Lag ensembles – possible to make up the uncertainties/diversities
  - Others

# Reference from current GEFS reforecast (white paper)




Temporally smoothed (45---day centered average) plots of day +1 temperature forecast Bias For The Geographic Region 103°W To 90°W, 30°N To 37°N.



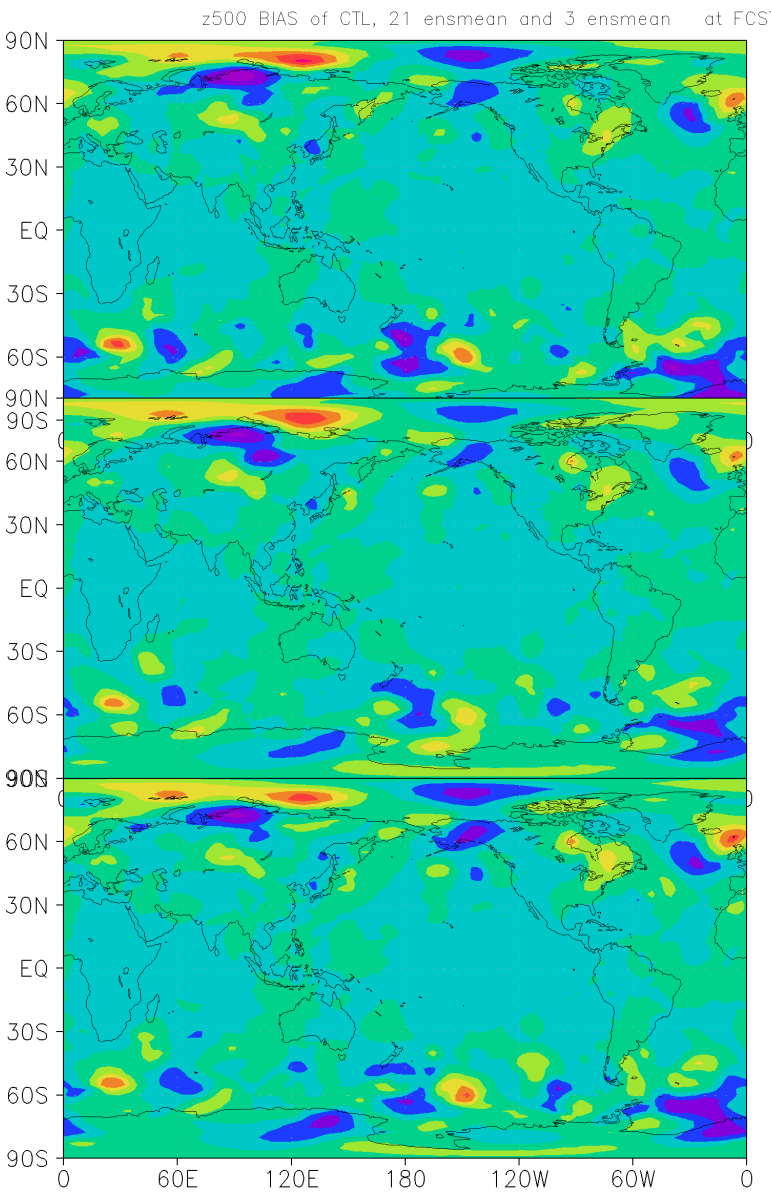

6-10 day precipitation forecast Brier Skill Score (larger is better) as a function of the number of reforecast members and the number of real-time members (from white paper)

# Pre-evaluation (control .vs ensembles)

- Use current retrospective runs
  - New GEFS version 11.0.0 (GFS v12.0.0)
  - T574L64 (0-8 days), T382L64(8-16 days)
- Period: 02/20 – 05/14/2014
  - Once per day at 00UTC only
- Three variables
  - 500hPa height
  - 850hPa temperature
  - 2m temperature
- Diagnostic analysis
  - Spatial bias distribution for selected lead-time (4-, 8-, 12-, 16-d)
  - Absolute errors of selected ensemble for different domains
  - Absolute errors departure from full ensemble (21 member)
  - Fraction area exceeding particular threshold
- Summary
  - Spatial distributions of bias are very similar
  - There is no much difference of absolute error for first week
  - It is very difficulty to convert this number to a benefit directly
  - One possible estimation (slide #20 – CONUS) – about 15% degradation?

# 500hPa height bias distribution for the period of 02/20 – 05/14/2014

Forecast lead: 96 hours

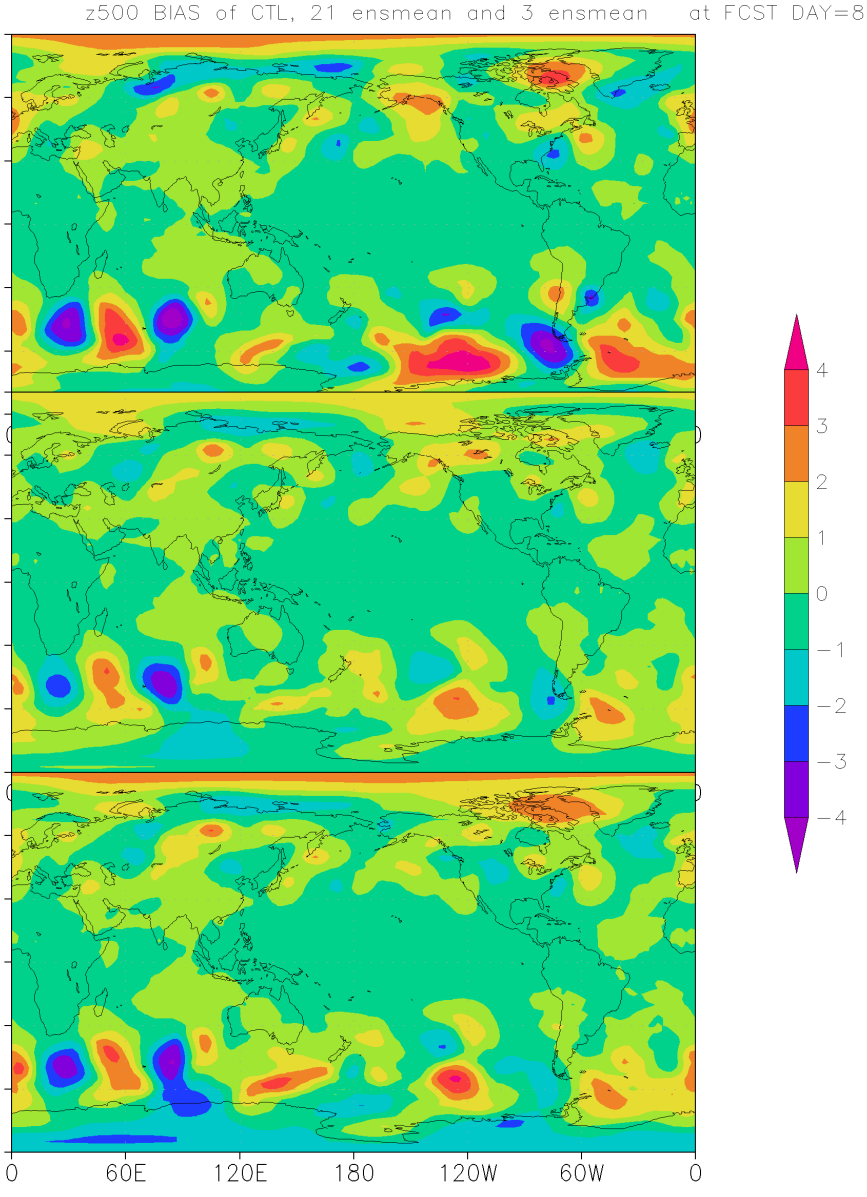



Control

21-mem

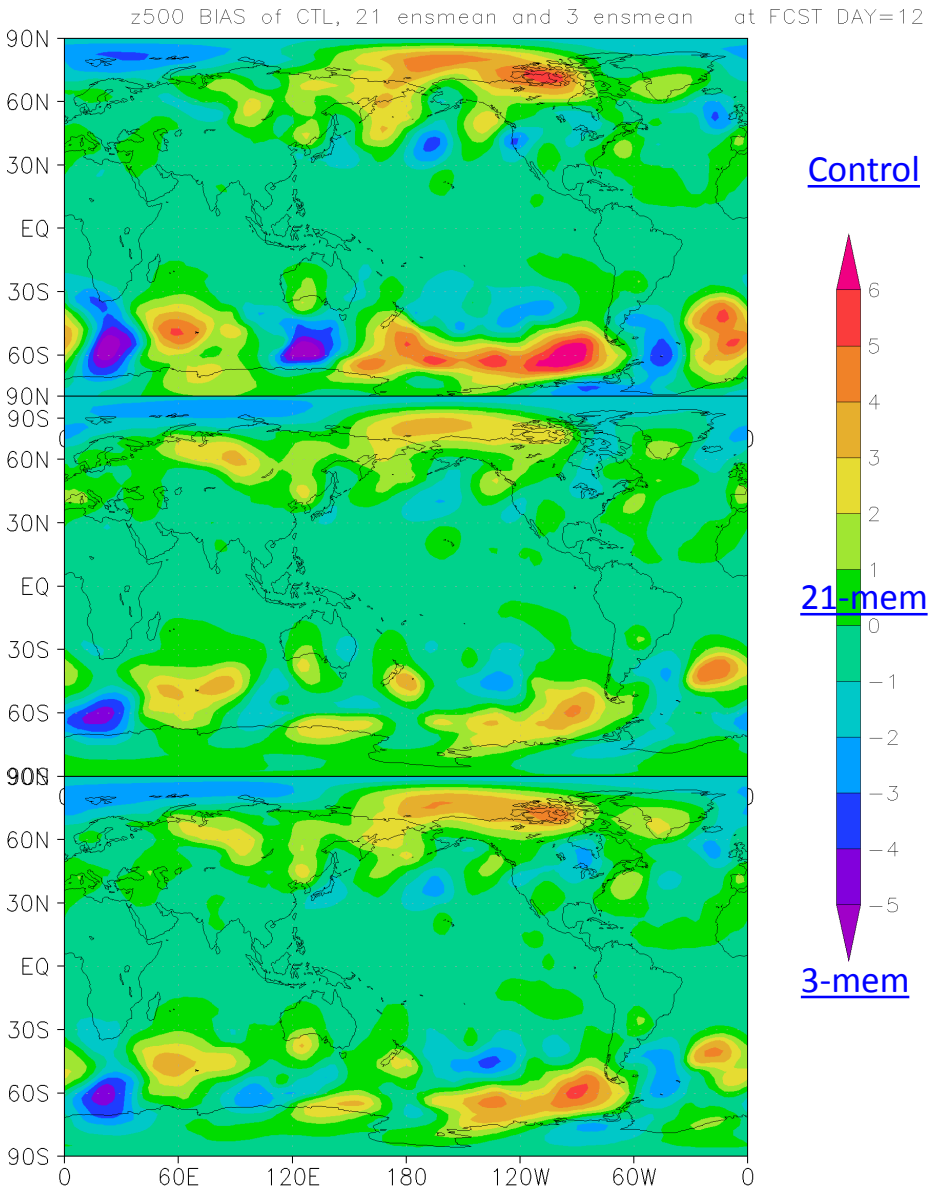
3-mem

Forecast lead: 192 hours

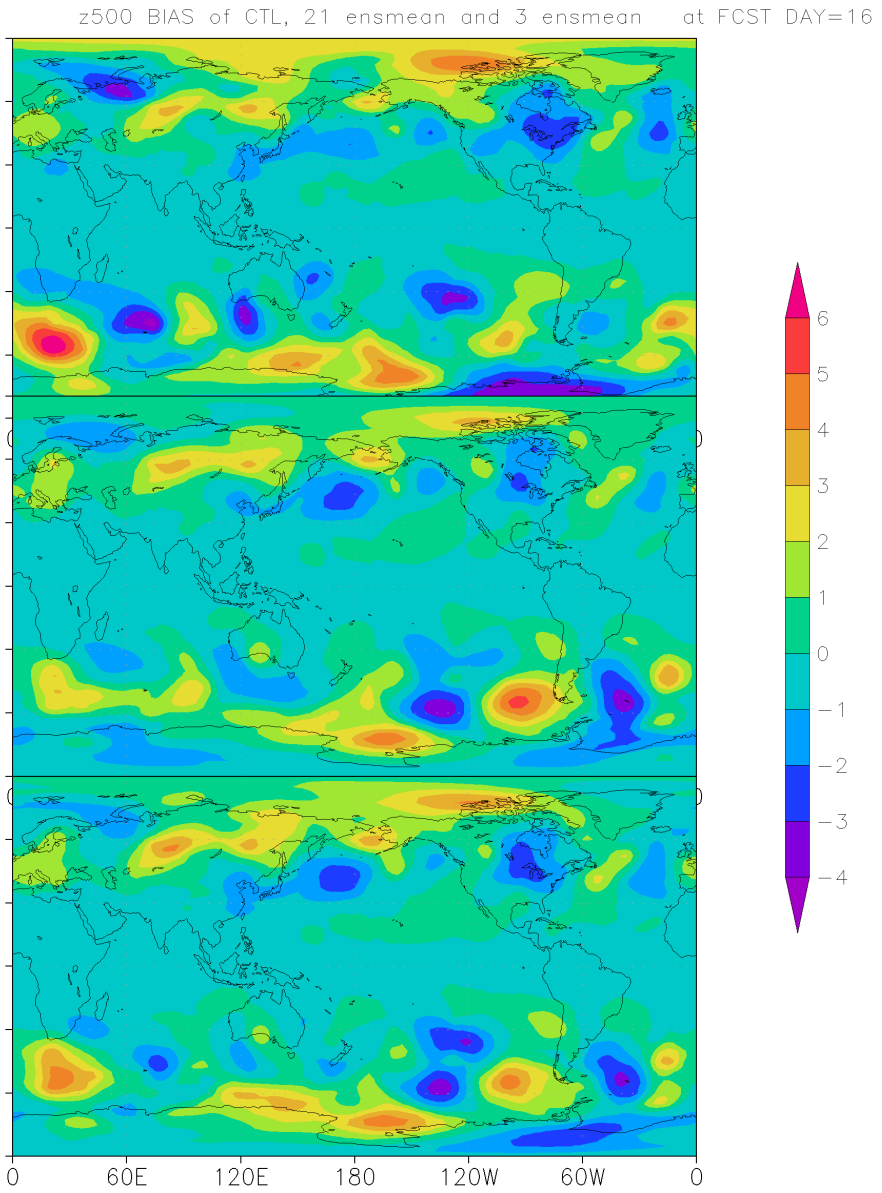


# 500hPa height bias distribution for the period of 03/01 – 05/14/2014

Forecast lead: 288 hours

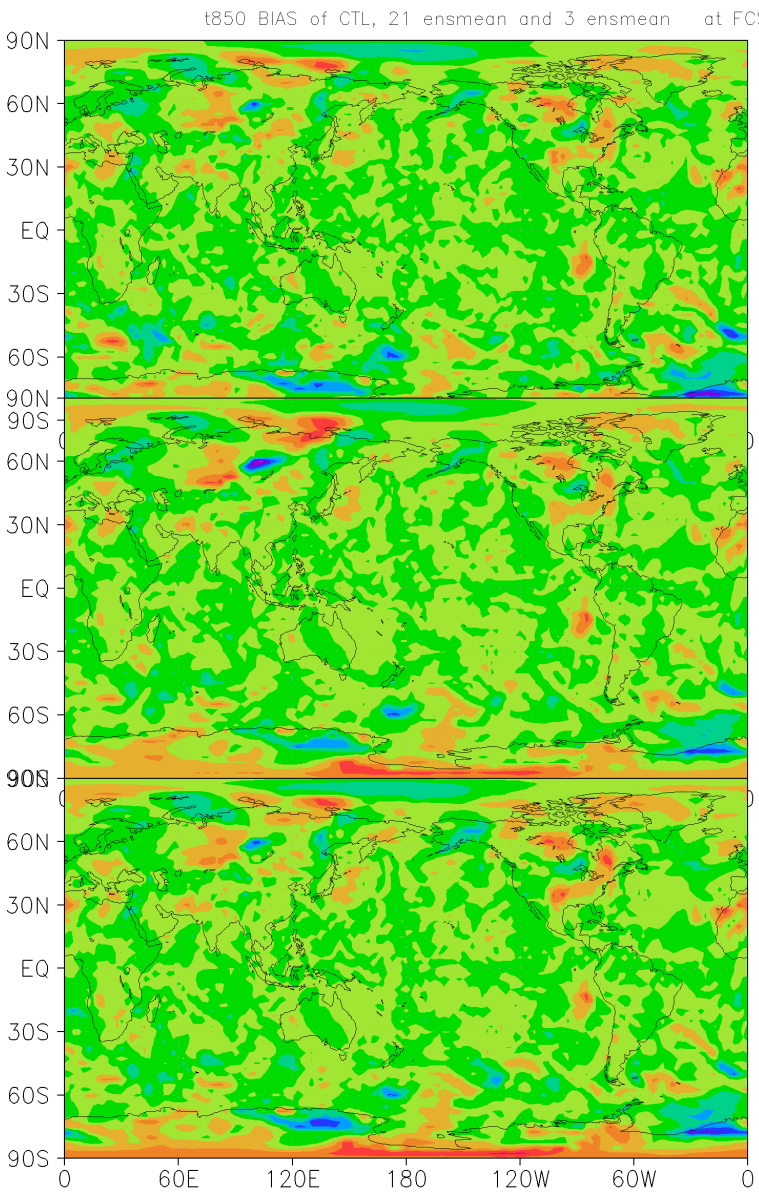



Forecast lead: 384 hours



# 850hPa temp bias distribution for the period of 02/20 – 05/14/2014

Forecast lead: 96 hours

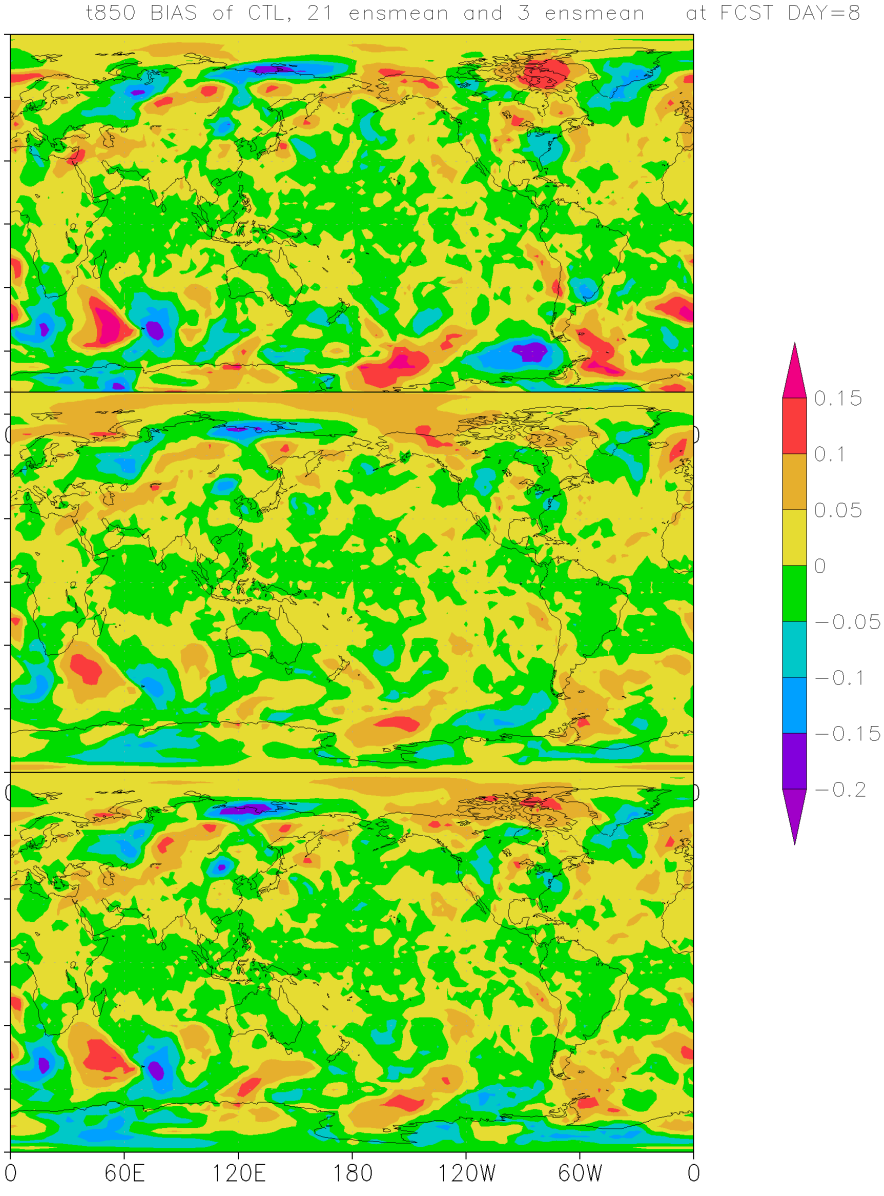



Control

21-mem

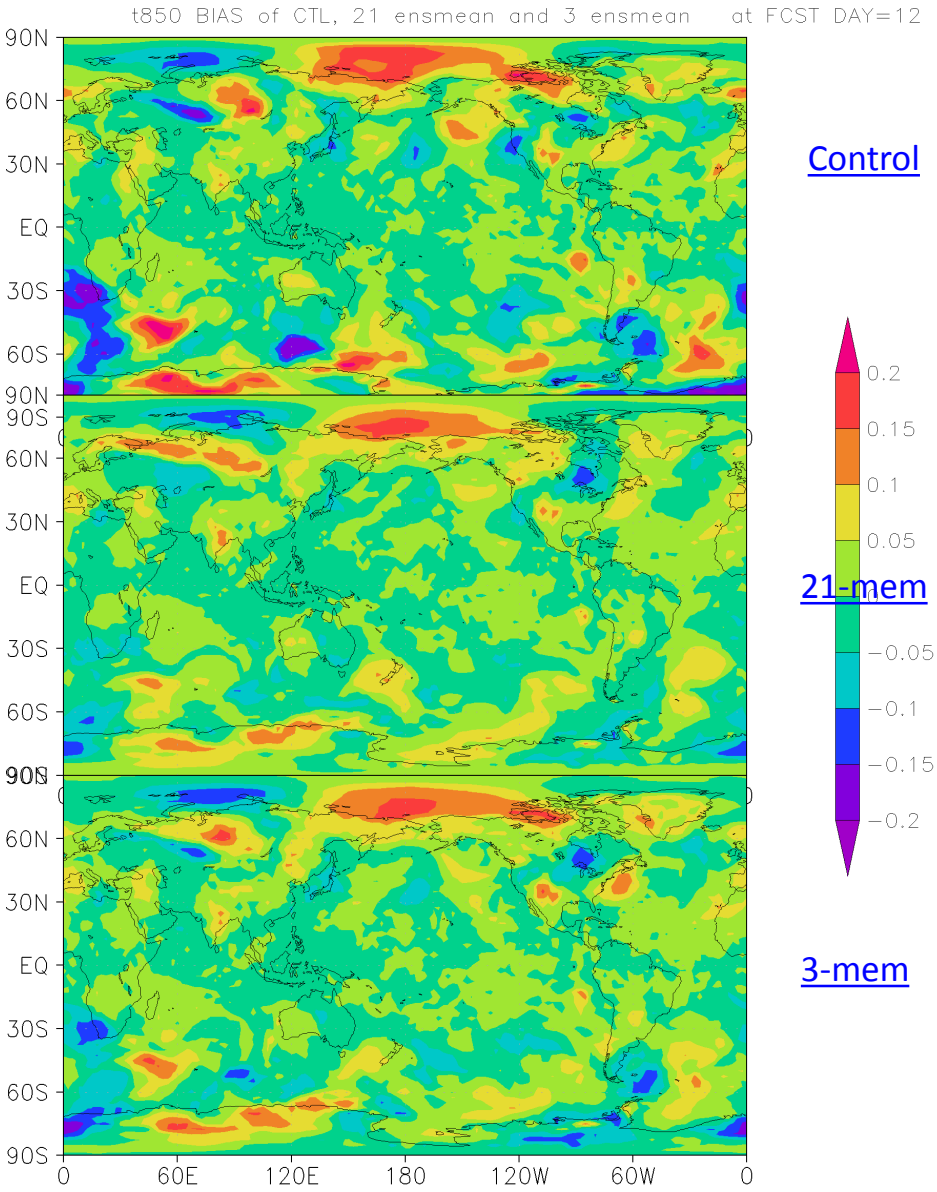
3-mem

Forecast lead: 192 hours



# 850hPa temp bias distribution for the period of 02/20 – 05/14/2014

Forecast lead: 288 hours

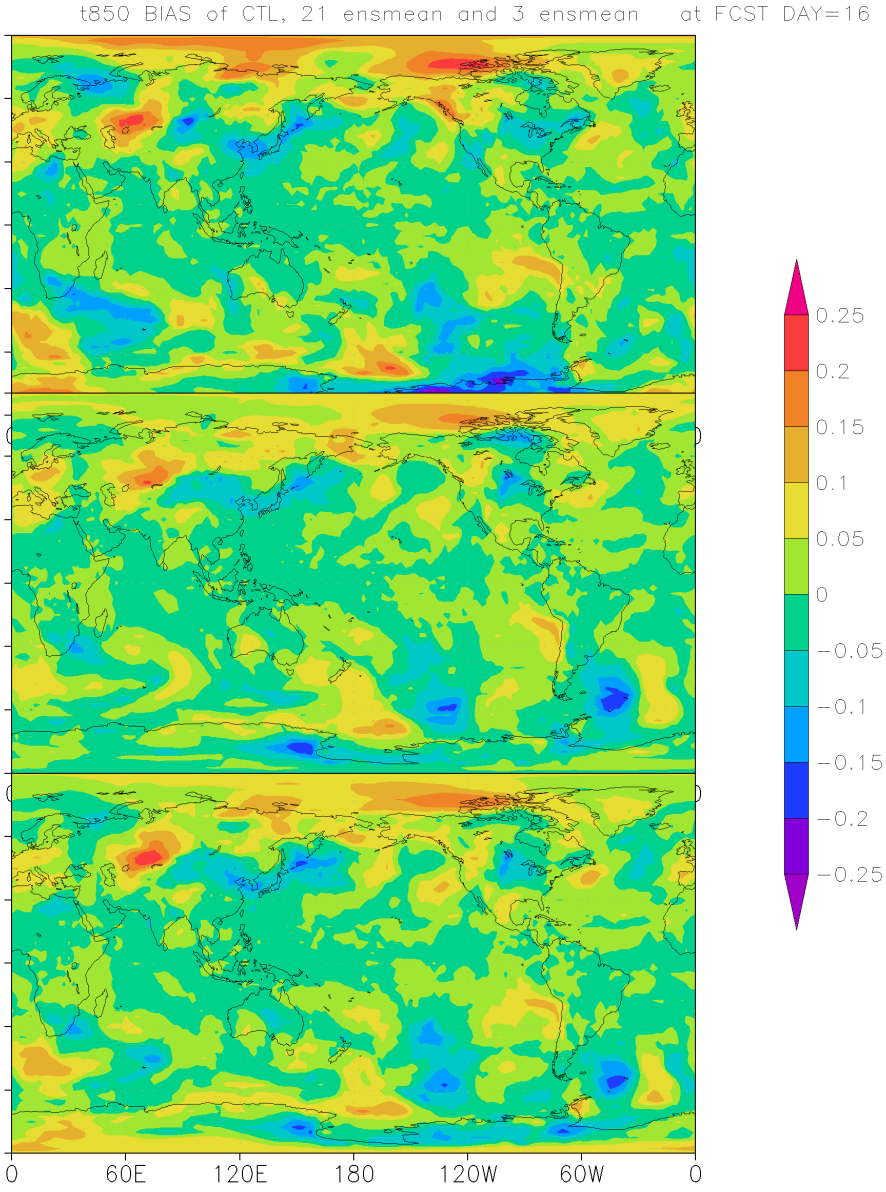



Control

21-mem

3-mem

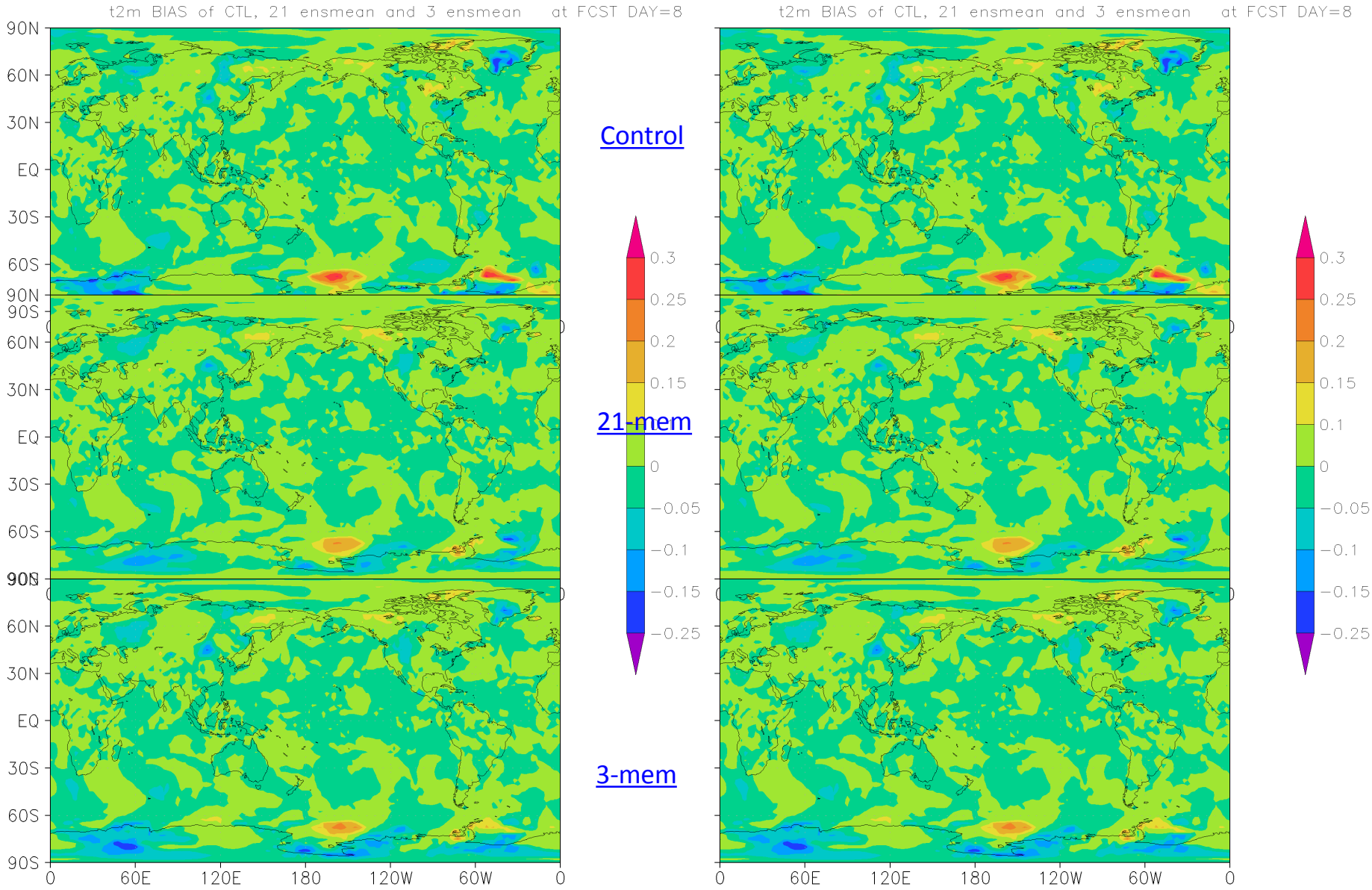
Forecast lead: 384 hours



# 2m temperature bias distribution for the period of 02/20 – 05/14/2014

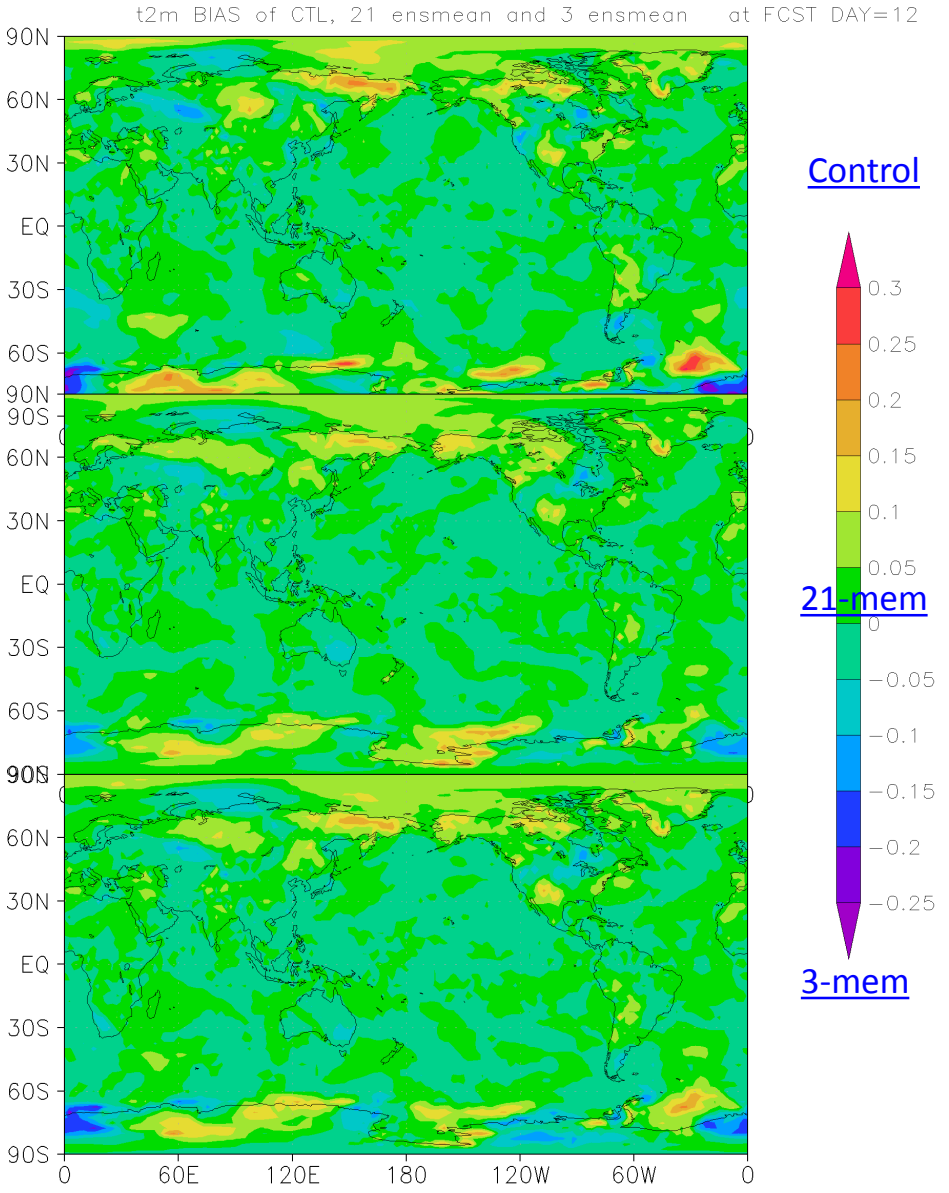
Forecast lead: 96 hours

Forecast lead: 192 hours



# 2m temperature bias distribution for the period of 02/20 – 05/14/2014

Forecast lead: 288 hours

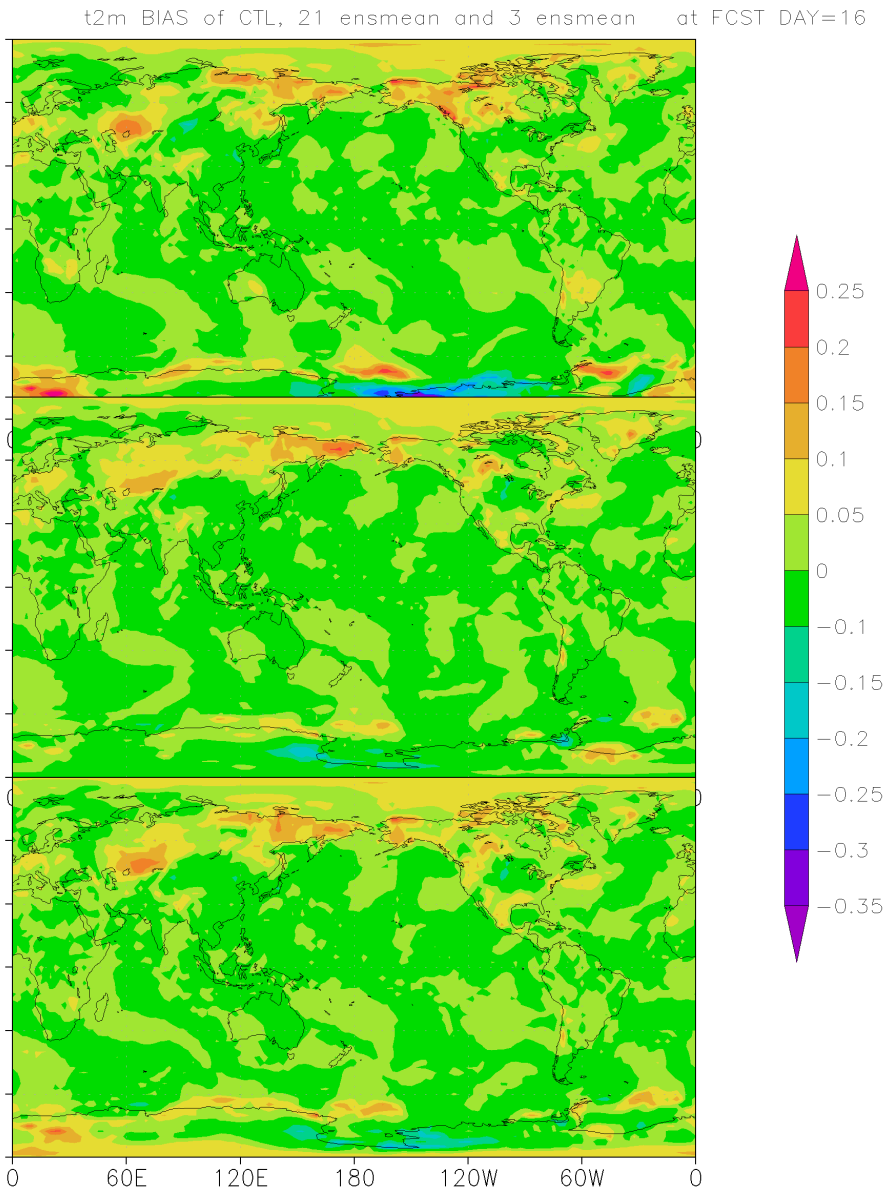


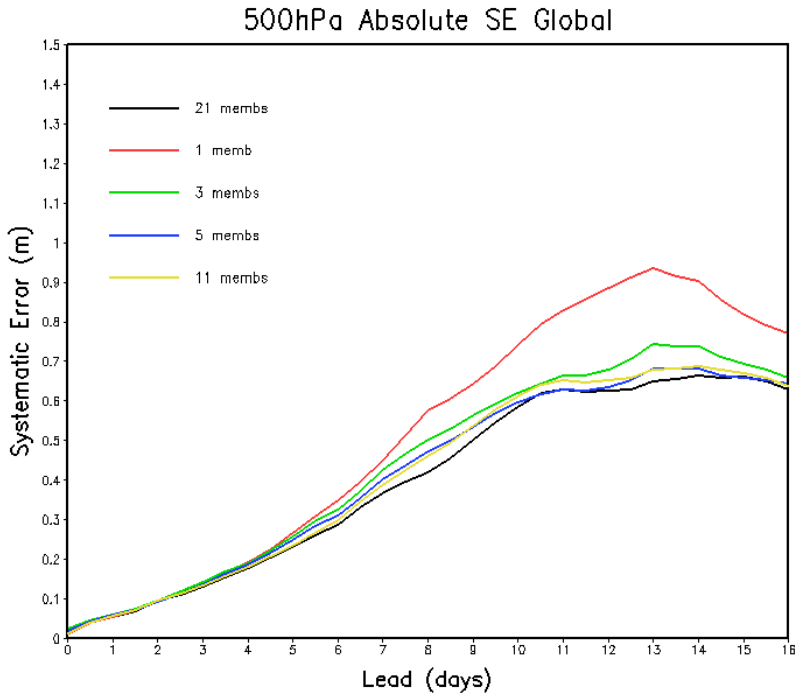

Control

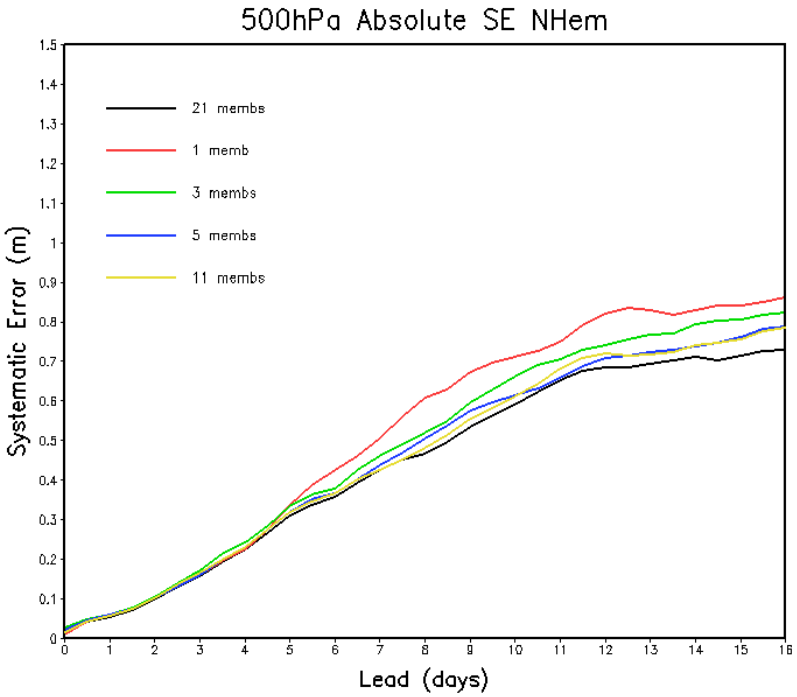
21-mem

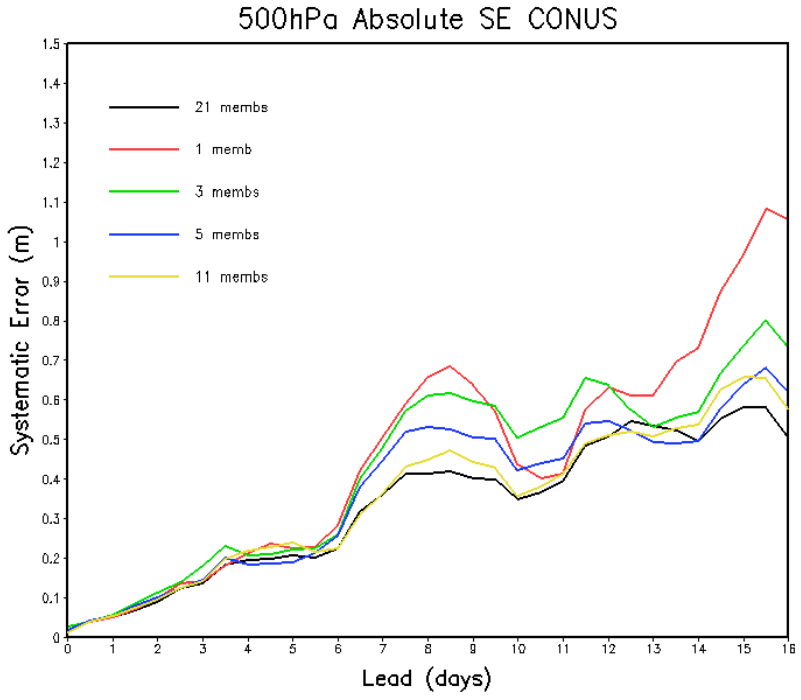
3-mem

Forecast lead: 384 hours





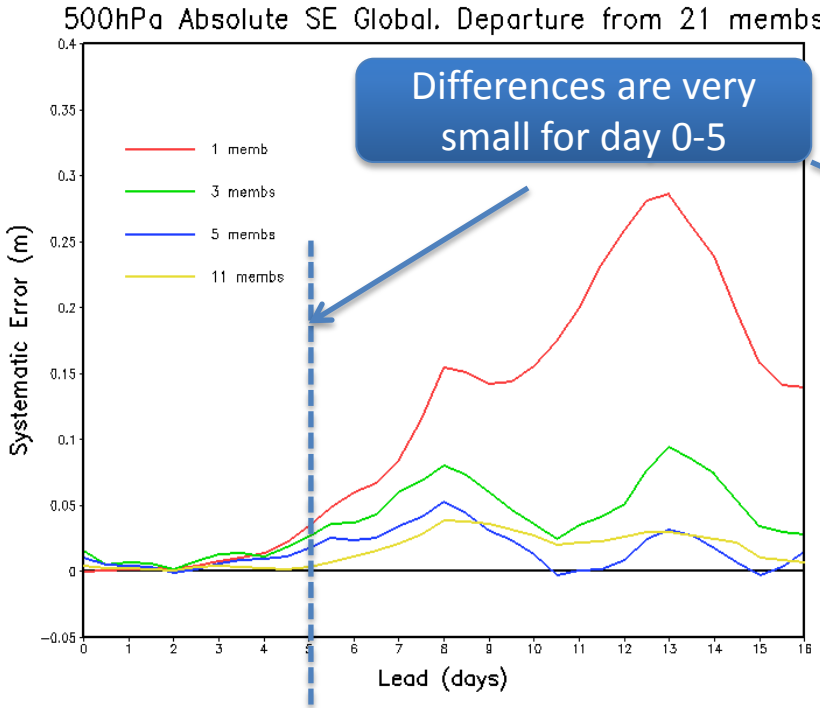



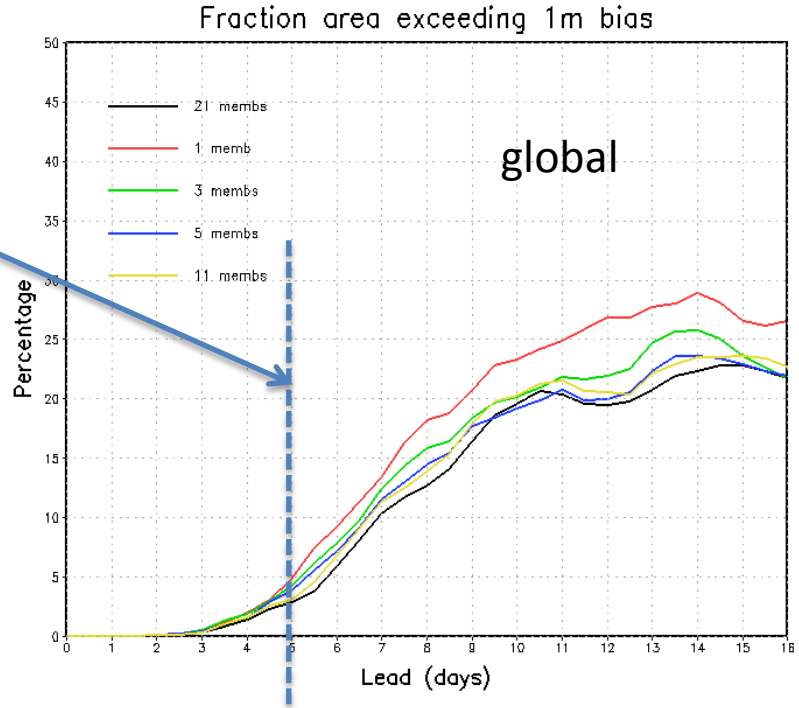

# 500hPa geopotential height

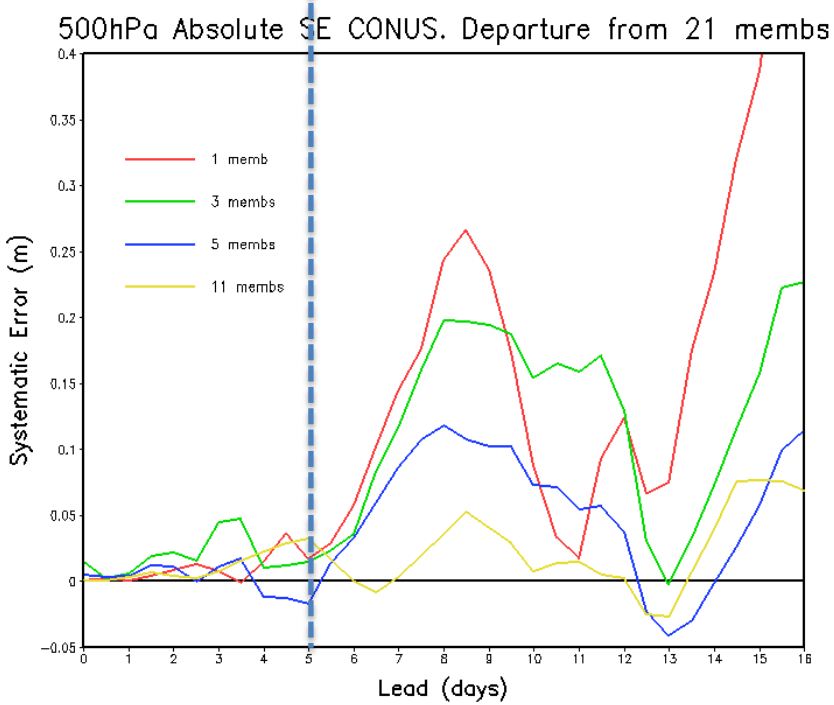
Mean absolute error for difference domains, and selected members

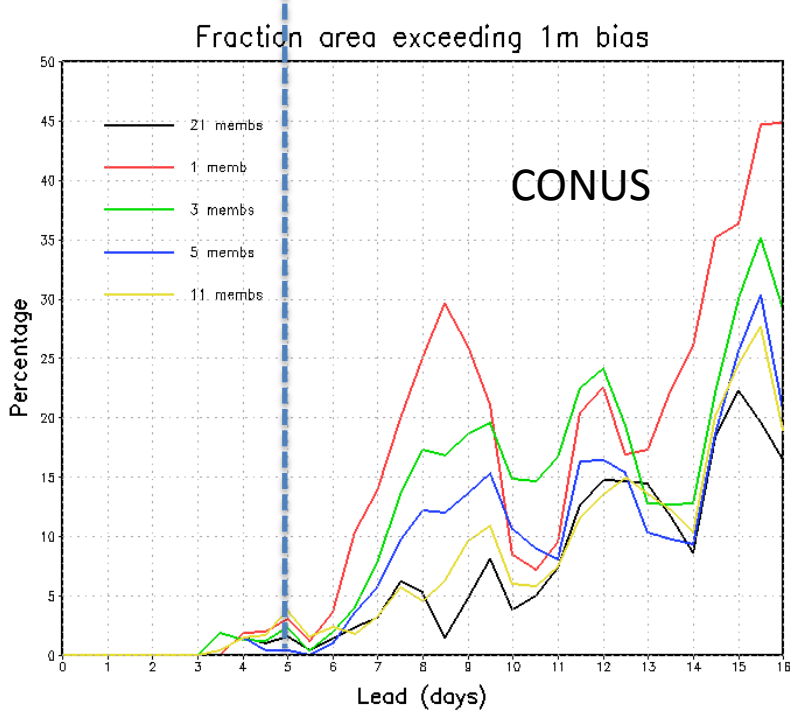
1 member → control only
3 members → control + 2 perts
5 members → control + 4 perts
11 members → control + 10 perts
21 members → control + 20 perts

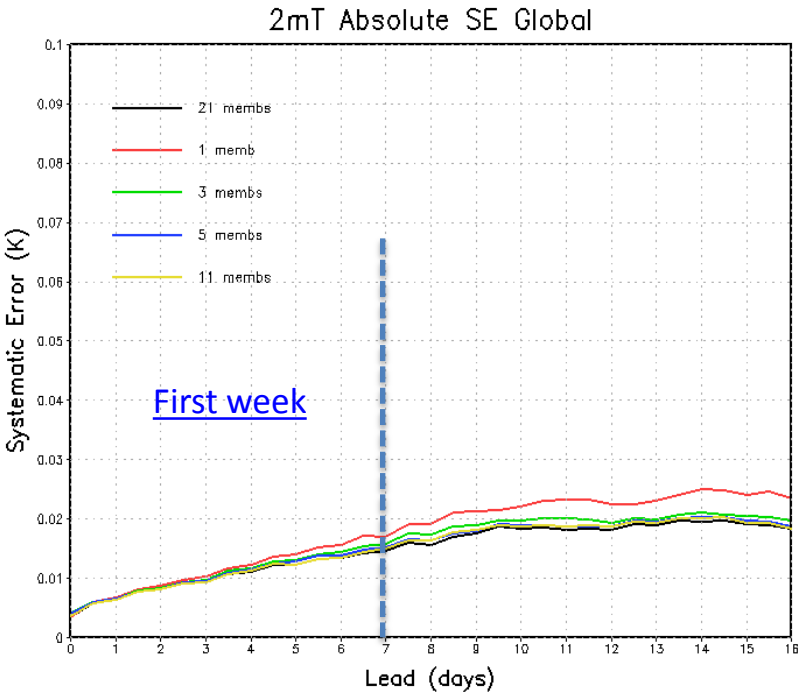


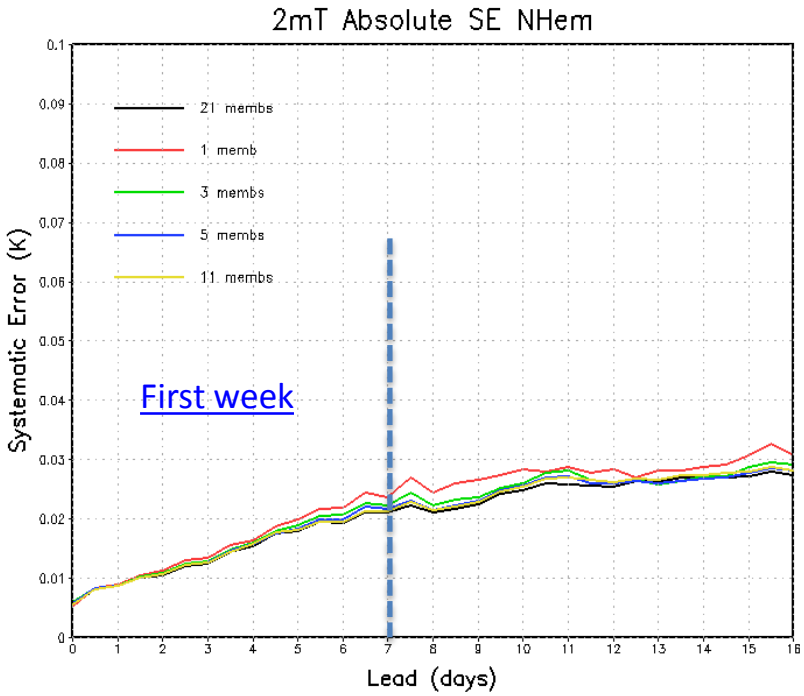

Differences are very small for day 0-5

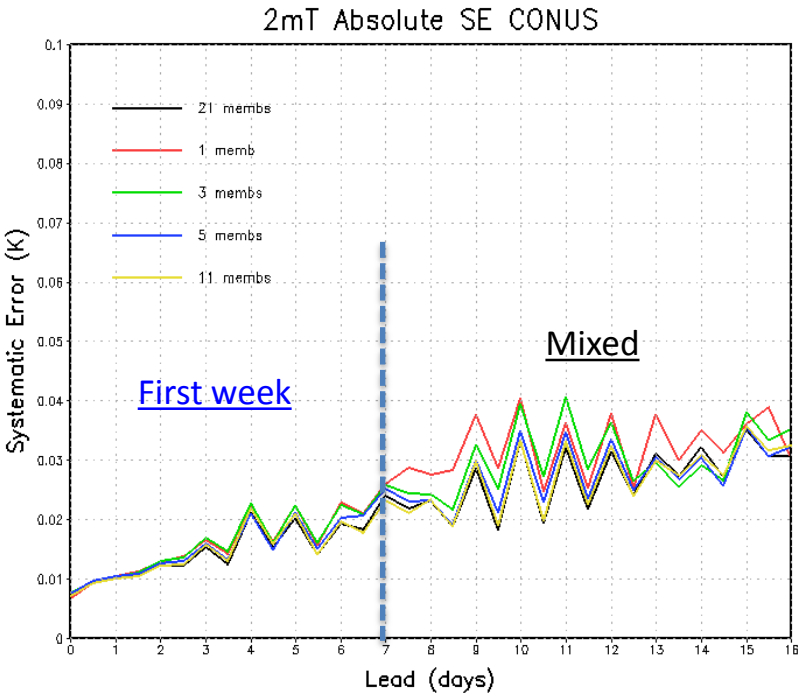




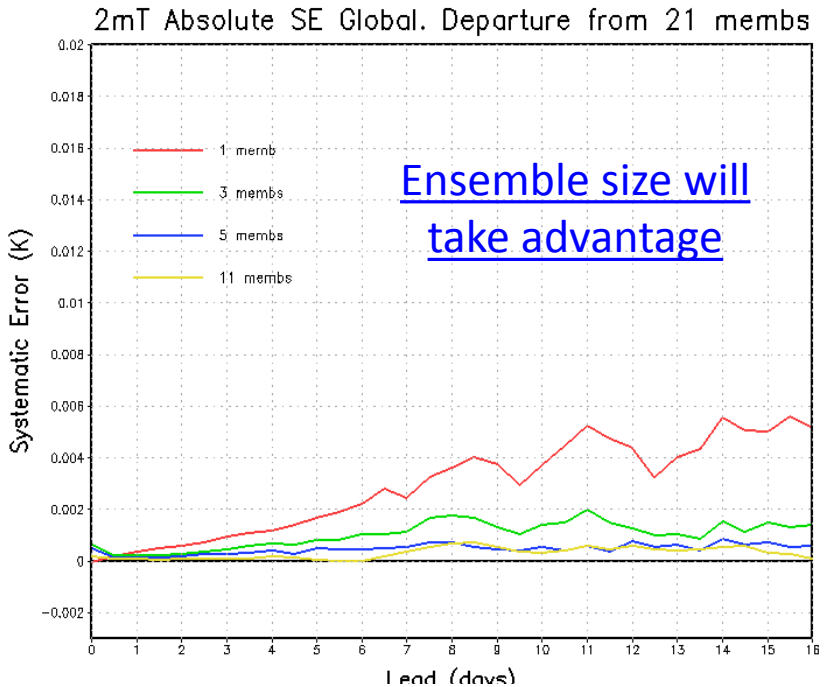



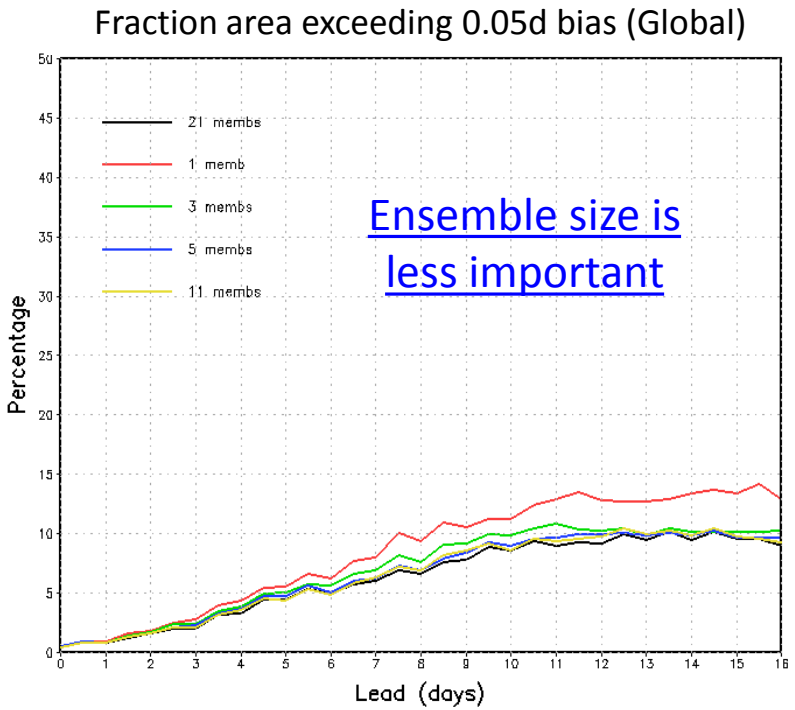



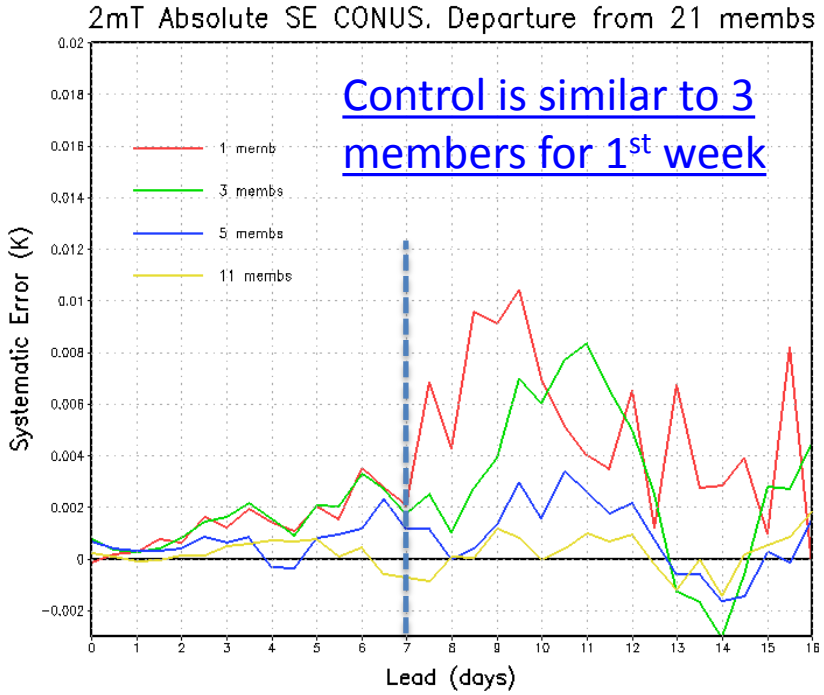

## 2m temperature

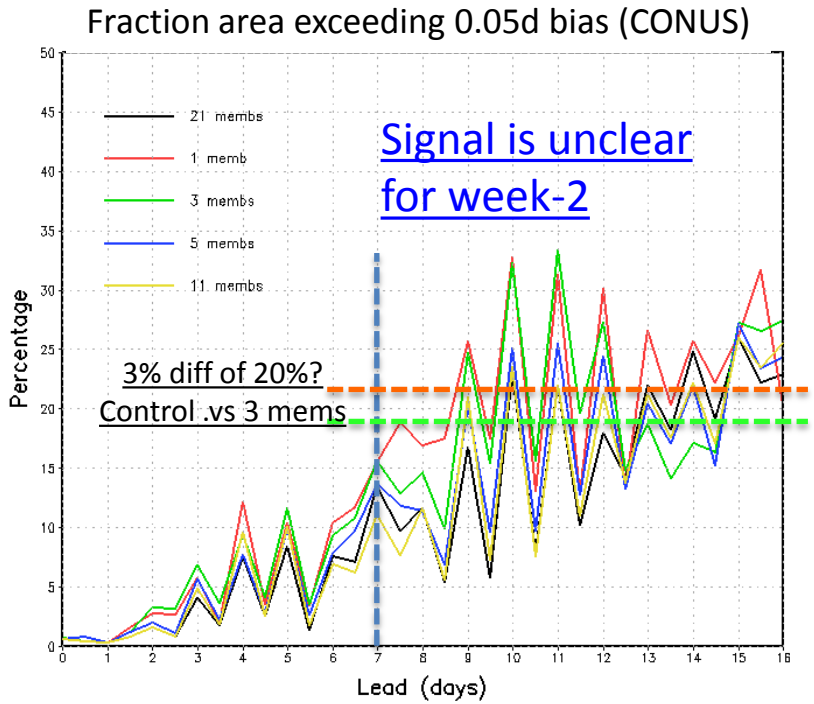
Mean absolute error for difference domains, and selected members

1 member → control only
3 members → control + 2 perts
5 members → control + 4 perts
11 members → control + 10 perts
21 members → control + 20 perts


2mT Absolute SE Global. Departure from 21 membs
Systematic Error (K)
Lead (days)
1 memb
3 membs
5 membs
11 membs
Ensemble size will take advantage


Fraction area exceeding 0.05d bias (Global)
Percentage
Lead (days)
21 membs
1 memb
3 membs
5 membs
11 membs
Ensemble size is less important


2mT Absolute SE CONUS. Departure from 21 membs
Systematic Error (K)
Lead (days)
1 memb
3 membs
5 membs
11 membs
Control is similar to 3 members for 1st week

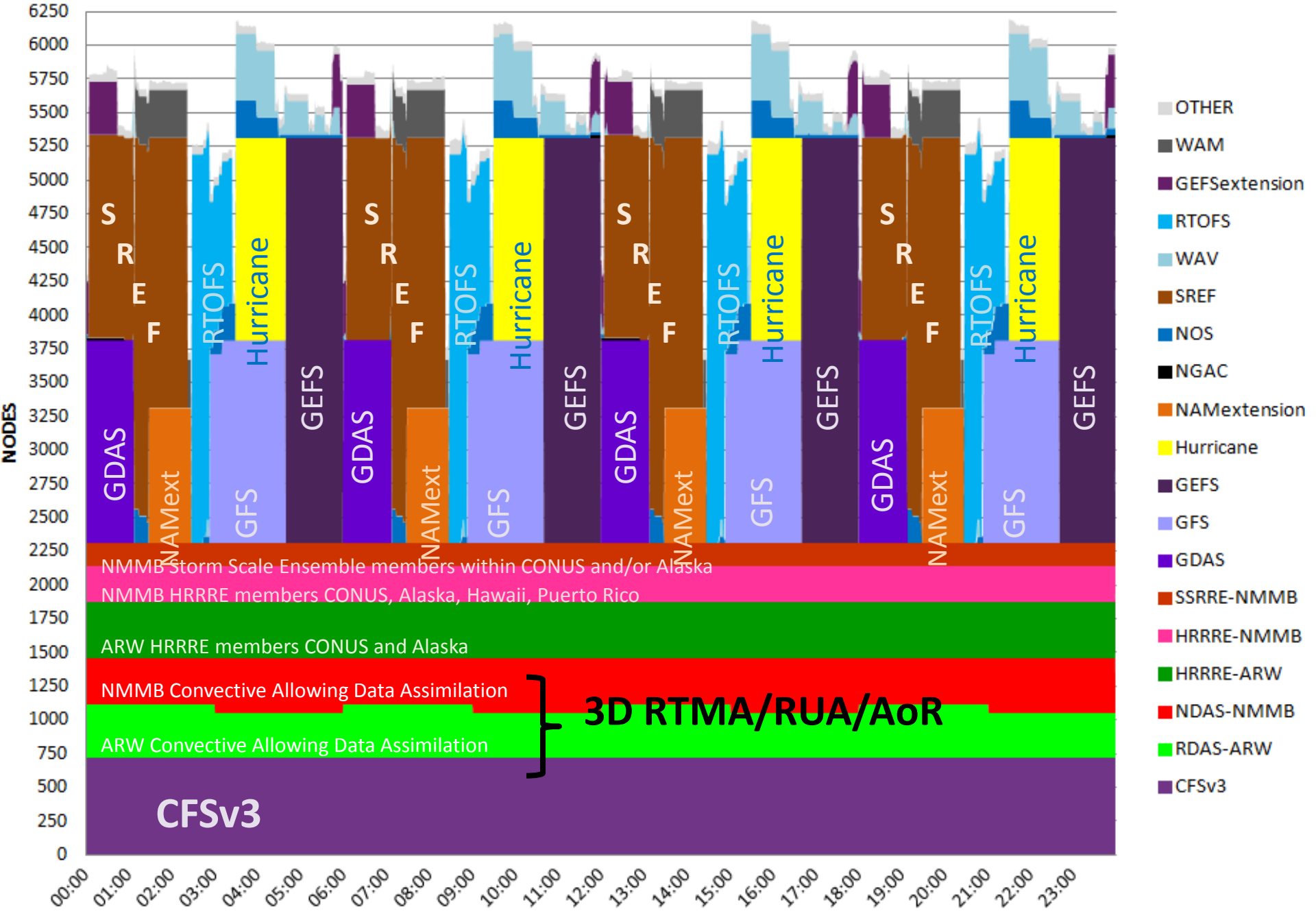

Fraction area exceeding 0.05d bias (CONUS)
Percentage
Lead (days)
21 membs
1 memb
3 membs
5 membs
11 membs
Signal is unclear for week-2
3% diff of 20%?
Control .vs 3 mems

# Continue this study

- Separated phase and amplitude of errors?
- How to convert the numbers to benefit?
- Possible lagged ensemble to recover part of forecast uncertainties
- To understand two model systems (opr .vs new)
  - Difference of bias – systematic errors
  - Difference of uncertainty – forecast uncertainty and climatological uncertainty - distribution of model climatology to generate EFI or anomaly forecast
  - Help to answer question – how much value left over for exist reforecast (or hindcast) when model upgrade?

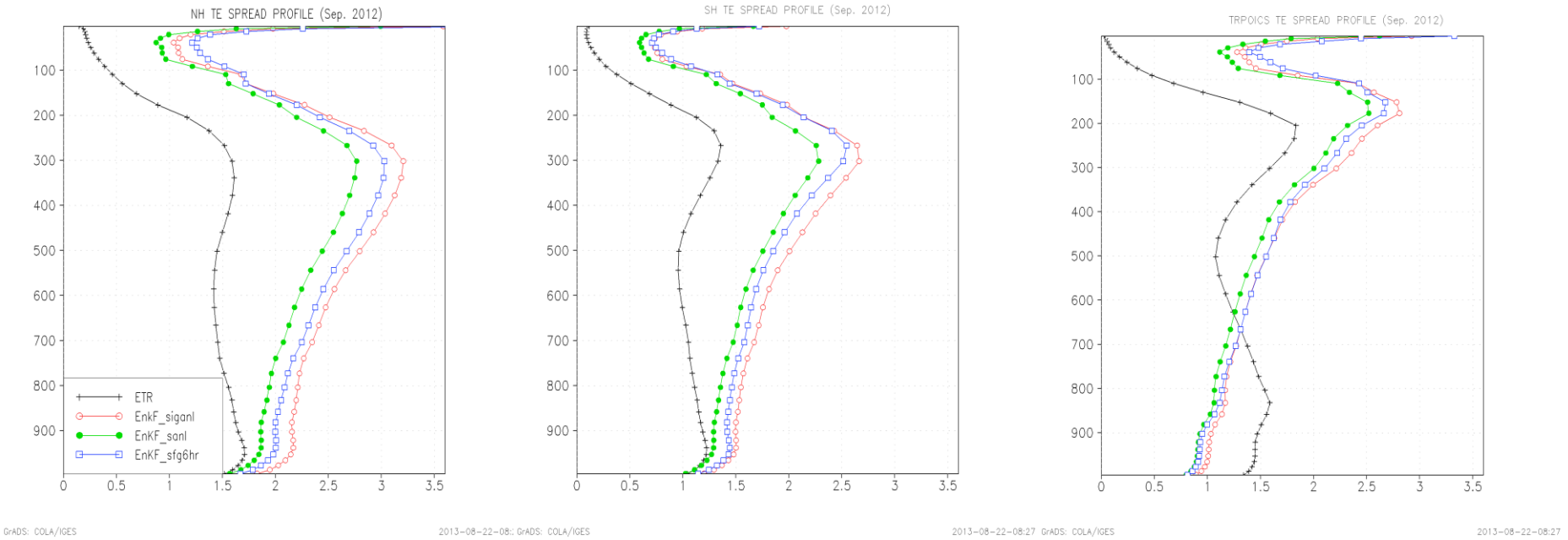
Background!!!

# Projected WCOSS Phase 2 (2 Petaflop) End State 2018



# Vertical distribution of perturbation amplitude

Early study (2011-2012)

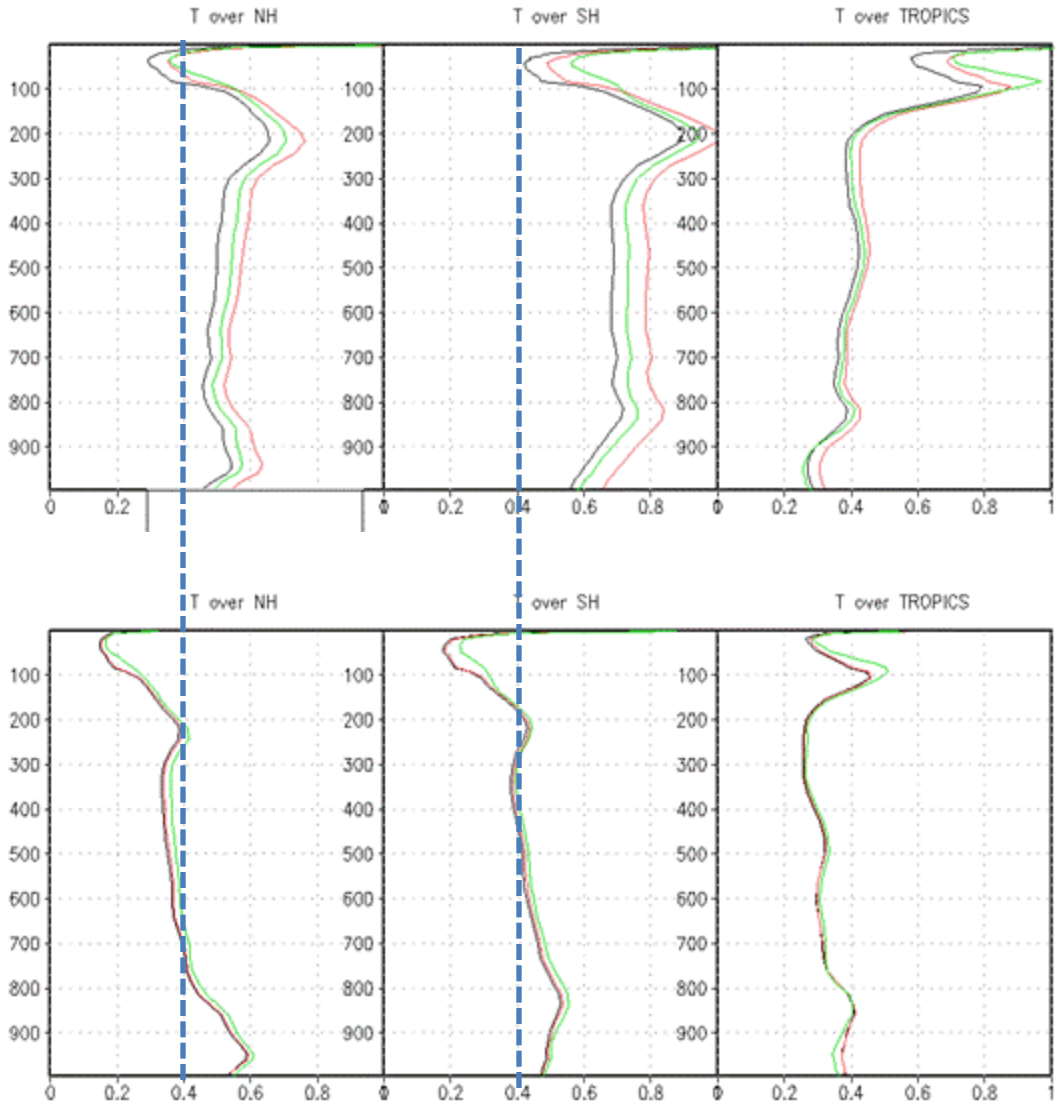



Black-BV-ETR; Green-EnKF analysis without additive inflation; Red-EnKF analysis; Blue-EnKF f06

Vertical profiles of initial perturbation spread in terms of total dry energy in the ETR and EnKF experiments over a) NH, b) SH and c) Tropics. Three EnKF profiles represent the spread of EnKF perturbations after multiple inflations (green curves), additive inflation (red) and 6-hr forecast (blue). The profiles are averaged from 1 July – 17 Oct. 2011.

# Vertical distribution of perturbation amplitude

One case for 2013070318




Current operation

Black – EnKF first analysis

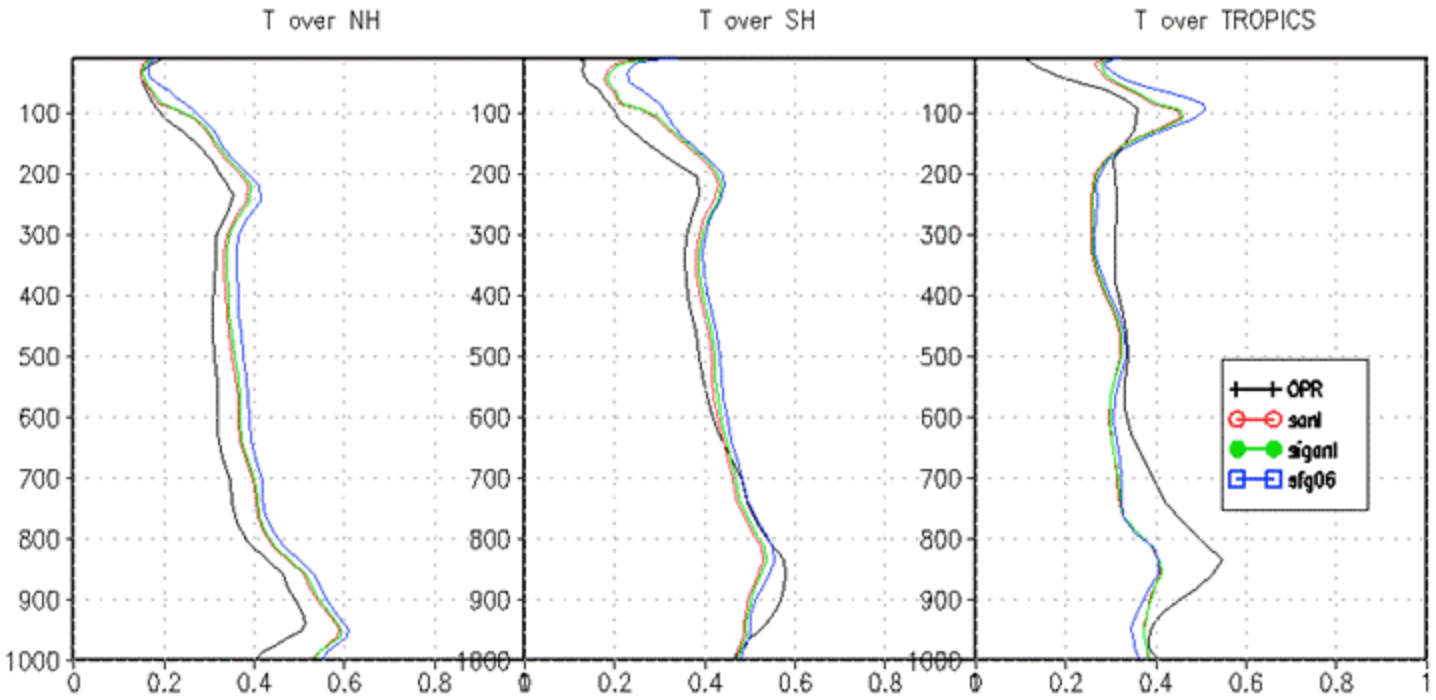
Red – EnKF final analysis

Green – EnKF 6-hr forecast

Parallel

# Vertical distribution of perturbation amplitude

One case for 2013070318



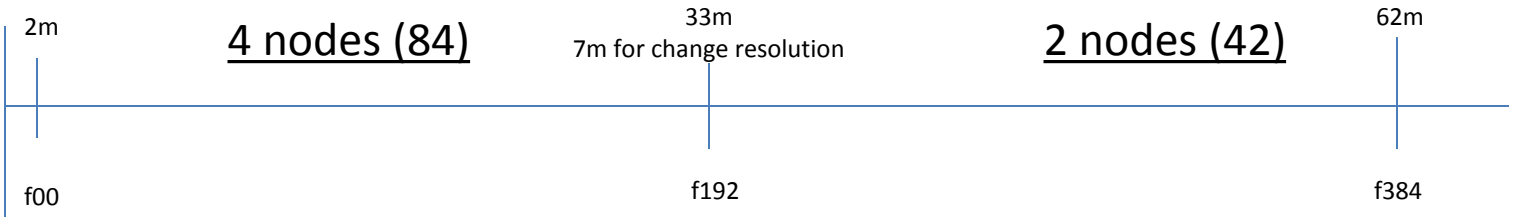

Black – current operational BV-ETR perturbations

Red – parallel EnKF first analysis

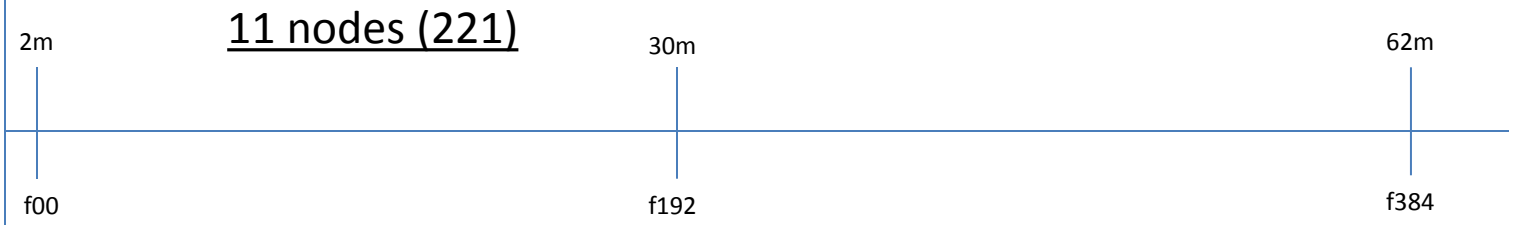
Green – parallel EnKF final analysis

Blue – parallel EnKF 6-hr forecast

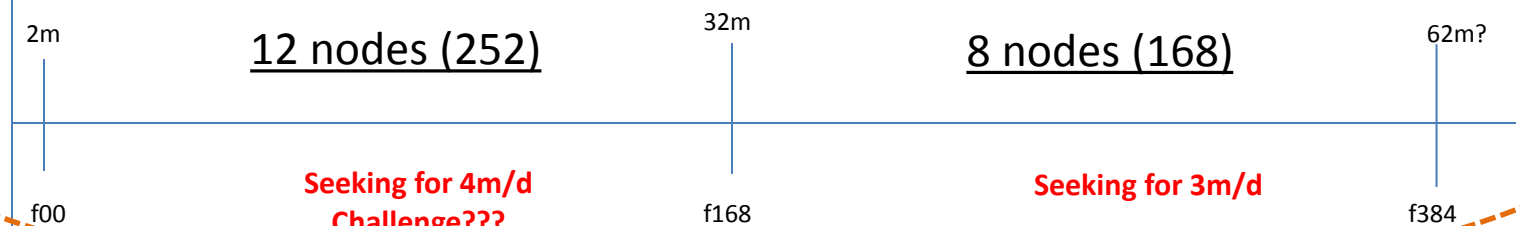
Current WCOSS operation (T254L42 0-192hr, T190-L42 180-384hr)




Option one: T574L42 SL (T382 physics) 0-384hrs for 210 nodes (with minimum phys.)

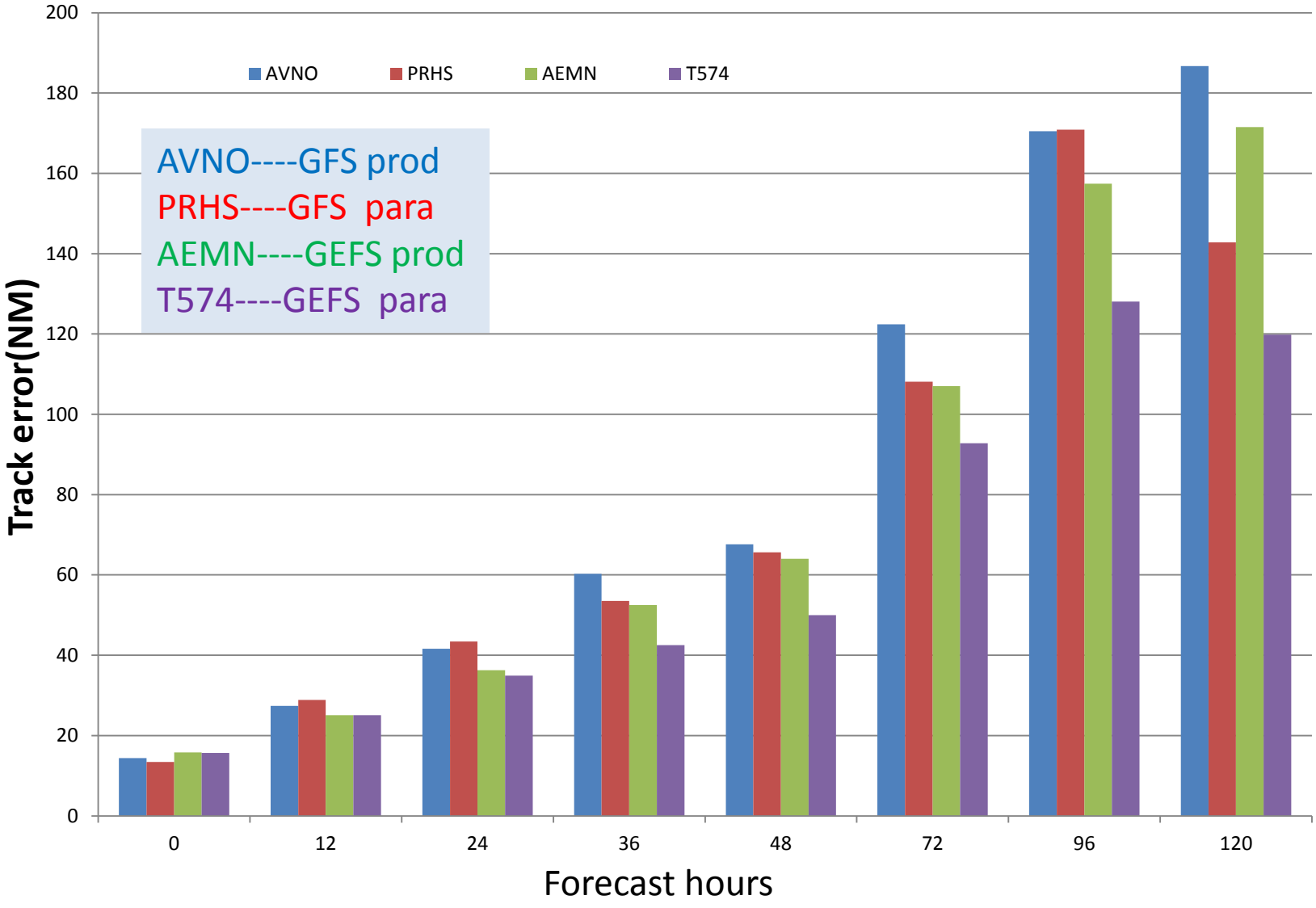



Option two: T574L64 SL (T382 physics) 0-168hrs, T382L64 SL (T254 physics) 156-384hrs



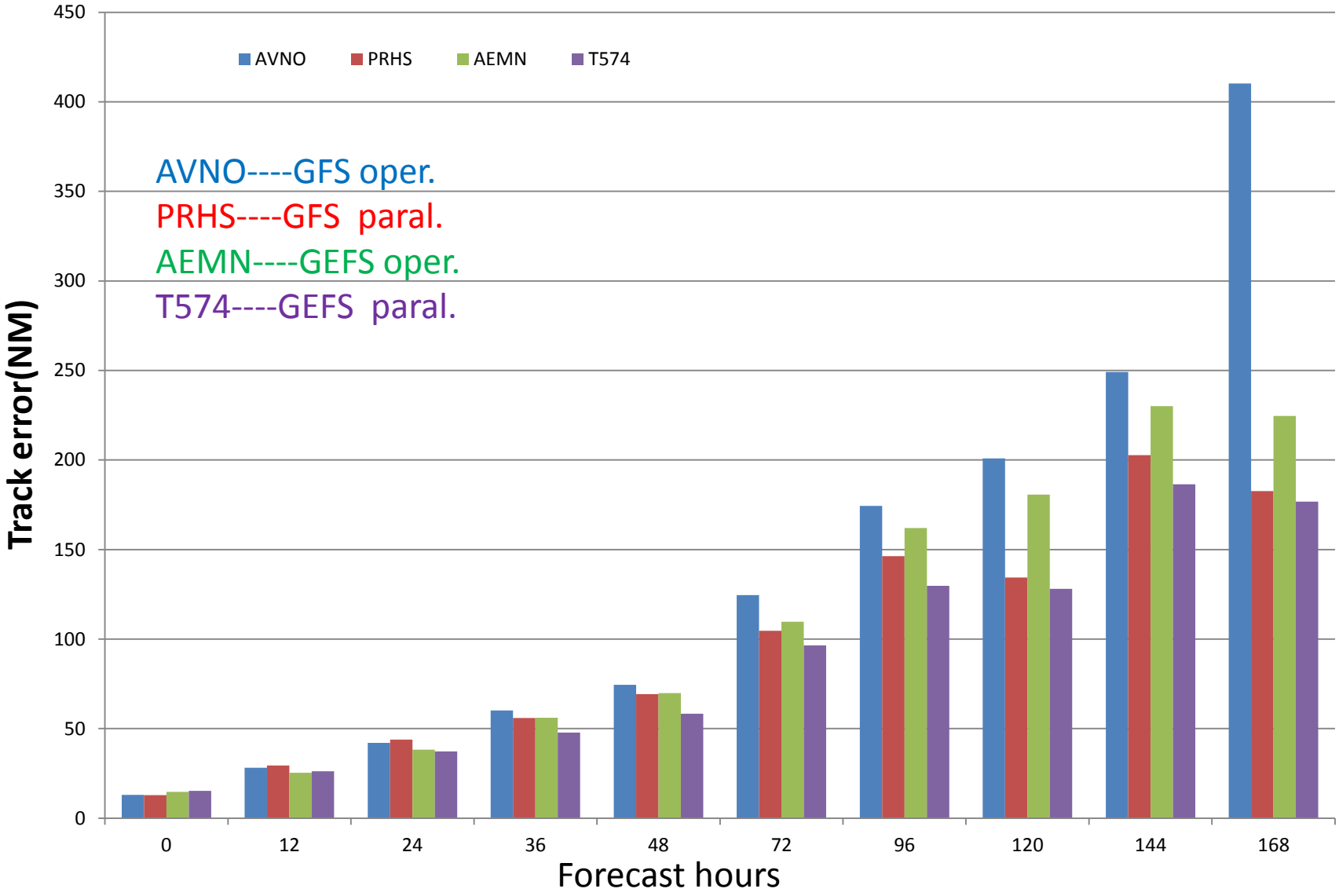

Please consider the timing of first 96 hours output for SREF boundary condition

# May 21—August 2, 2013 TC Track verifications




| CASEs | 69 | 66 | 56 | 54 | 39 | 27 | 17 | 9 |
|---|---|---|---|---|---|---|---|---|

# May 16—August 20, 2013 TC Track verifications (7-days)




| CASEs | 103 | 99 | 85 | 79 | 61 | 44 | 29 | 17 | 9 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|