Precipitation Calibration for the NCEP Global Ensemble Forecast System

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Objective

- Develop and enhance bias-correction and downscaling techniques that apply to the NCEP ensemble precipitation forecasts to gain more reliable and much finer resolution products.

NCEP GFS/GEFS precipitation forecast products

Level 1 products- model direct output

6h-QPF–
High Reso. GFS
Low Reso. GEFS/CTL
20 GEFS ensembles:
1 deg, globally

Level 2 products - 1st Post-processing

Bias corrected
6h-QPF/PQPF –
High Reso. GFS
Low Reso. GEFS/CTL
20 GEFS ensembles:
1 deg, globally

More reliable

Level 3 products – 2nd Post-processing

Downscaled
6h-QPF/PQPF –
High Reso. GFS
Low Reso. GEFS/CTL
20 GEFS ensembles:
5KM, NDGD, CONUS

Much finer

Green: operational, verified against 1deg CCPA
Blue: developed and tested, verified against 1 deg CCPA
Purple: developed and tested, verified against 5KM NDGD CCPA

Current capabilities in calibration of QPF/PQPF for NCEP GFS/GEFS ensembles

1. Bias correction for NCEP operational ensemble precipitation forecasts at higher temporal and spatial resolution

- An upgrade from May 2004 implementation (2.5*2.5 deg, daily)
- Frequency match algorithm
- Bias corrected at 1 degree model output grid, globally
- 4 cycles per day, 6-hr accumulation
- Every 6 hours, out to 384 hours
- GFS, GEFS 20+1 members
- Construct Cumulative Frequency Distribution for each River Forecast Center (RFC) instead of previously CONUS
- Select 9 thresholds: 0.2, 1, 2, 3.2, 5, 7, 10, 15, 25 mm/6hrs
- Use decaying weight = 0.02 (50 days decaying)
- CCPA used as best analysis (truth)

Current capabilities in calibration of QPF/PQPF for NCEP GFS/GEFS ensembles (cont'd)

2. Statistical downscaling bias corrected precipitation forecast to 5KM

- Use first 6 hours bias corrected forecast (at 1degree) as model analysis and interpolate to 5KM NDGD grid
- Use CCPA at 5KM NDGD grid as a proxy truth
- Generate downscaling vector by calculating two CDFs from the above for each RFC using high decaying weight = 0.1 (10 days decaying)
- Interpolate 1 degree bias corrected forecast to 5KM NDGD grid
- Apply downscaling vectors through frequency matching the forecast CDF to true CDF
- Produce downscaled GFS, GEFS 20+1 QPF/PQPF on 5km NDGD grid over CONUS
- 4 cycle per day
- Every 6 hours out to 384 hours

CCPA Dataset

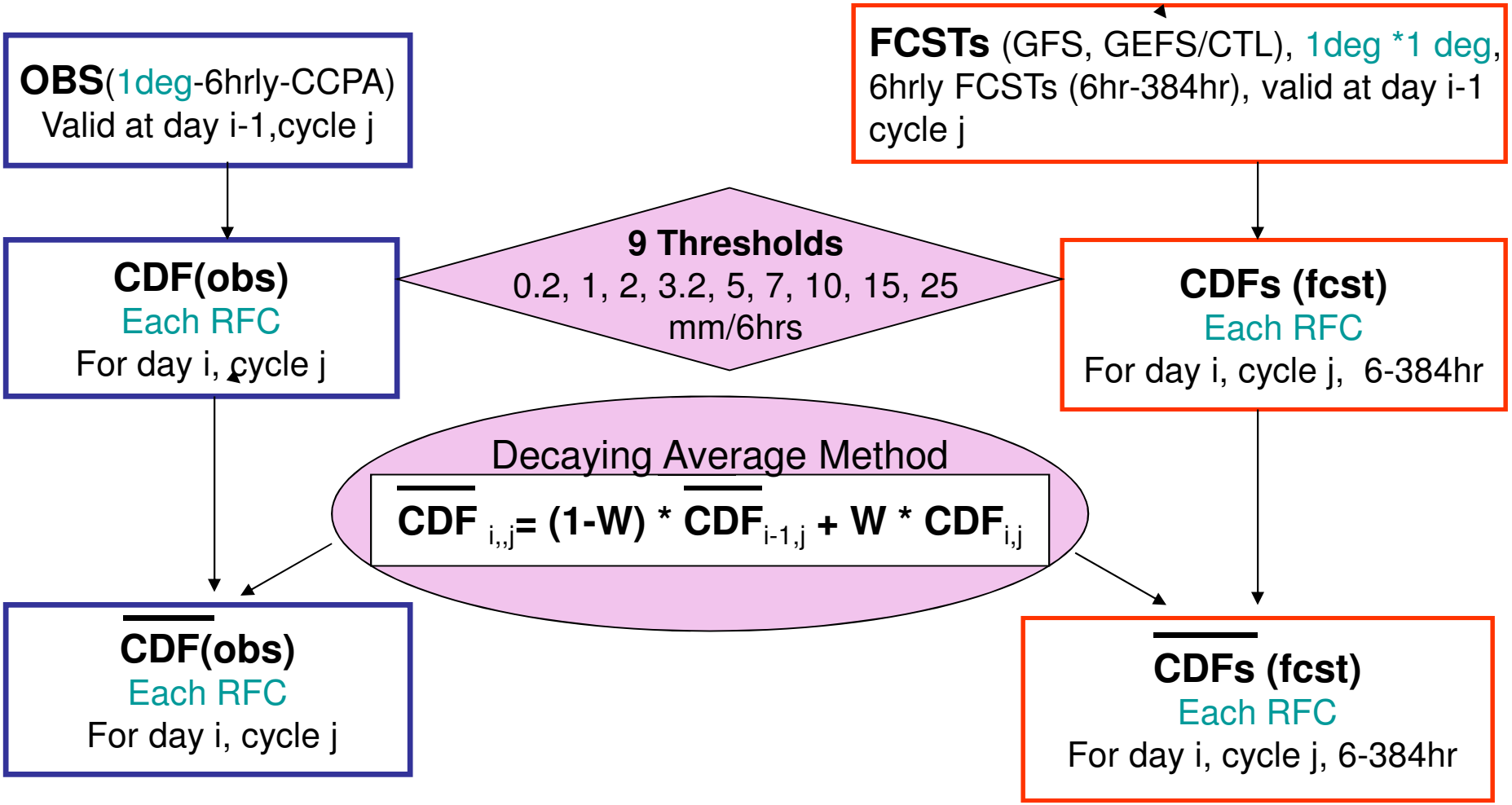
- Climatology-Calibrated Precipitation Analysis (CCPA)
  - A new dataset of precipitation analysis, over CONUS at 6h, ~4km resolution
  - Statistical adjustment of Stage IV data toward CPC analysis
  - Simple linear regression at 0.125 degree and 24h accumulation
  - Keep the fine scale structures of Stage IV
  - Closer to CPC Unified Precipitation Analysis, in the sense of climatology
- Application: Provide a proxy of truth for precipitation forecast calibration and downscaling
- Developed and distributed by NCEP/EMC for operation
- Operational implementation on July 13, 2010
- Product period: 2002 - present
- Product grids:
  - HRAP (primary)
  - NDGD, 0.125, 0.5 and 1.0 degree resolutions (byproducts)
- CCPA upgrade: Add 3-hourly precipitation analysis Q3 2011
- CCPA websites:

Introduction http://www.emc.ncep.noaa.gov/gmb/yzhu/html/imp/201007_imp.html

Image http://www.emc.ncep.noaa.gov/gmb/yluo/CCPA.html

How the Precipitation Calibration System Works

Part I: Bias Correction



$\overline{CDF}_0$: initialized from any a 365-day average of CDF

How the Precipitation Calibration System Works

Part I: Bias Correction (cont'd)

$\overline{\text{CDF}}$(obs)
Each RFC
For day i, cycle j

IN

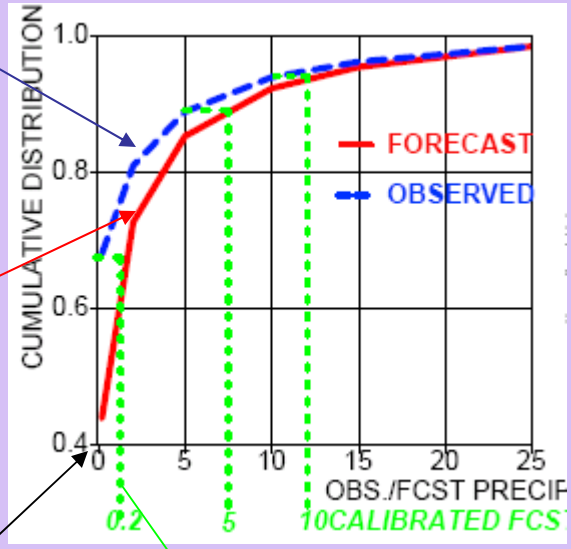
$\overline{\text{CDF}}$s (fcst)
Each RFC
For day i, cycle j, 6-384hr

IN

RAW FCSTs
(GFS, GEFS/CTL,GEFS/20m)
INI at day i, cycle j, for 6-384hr
At each model output grid

IN

Frequency match algorithm



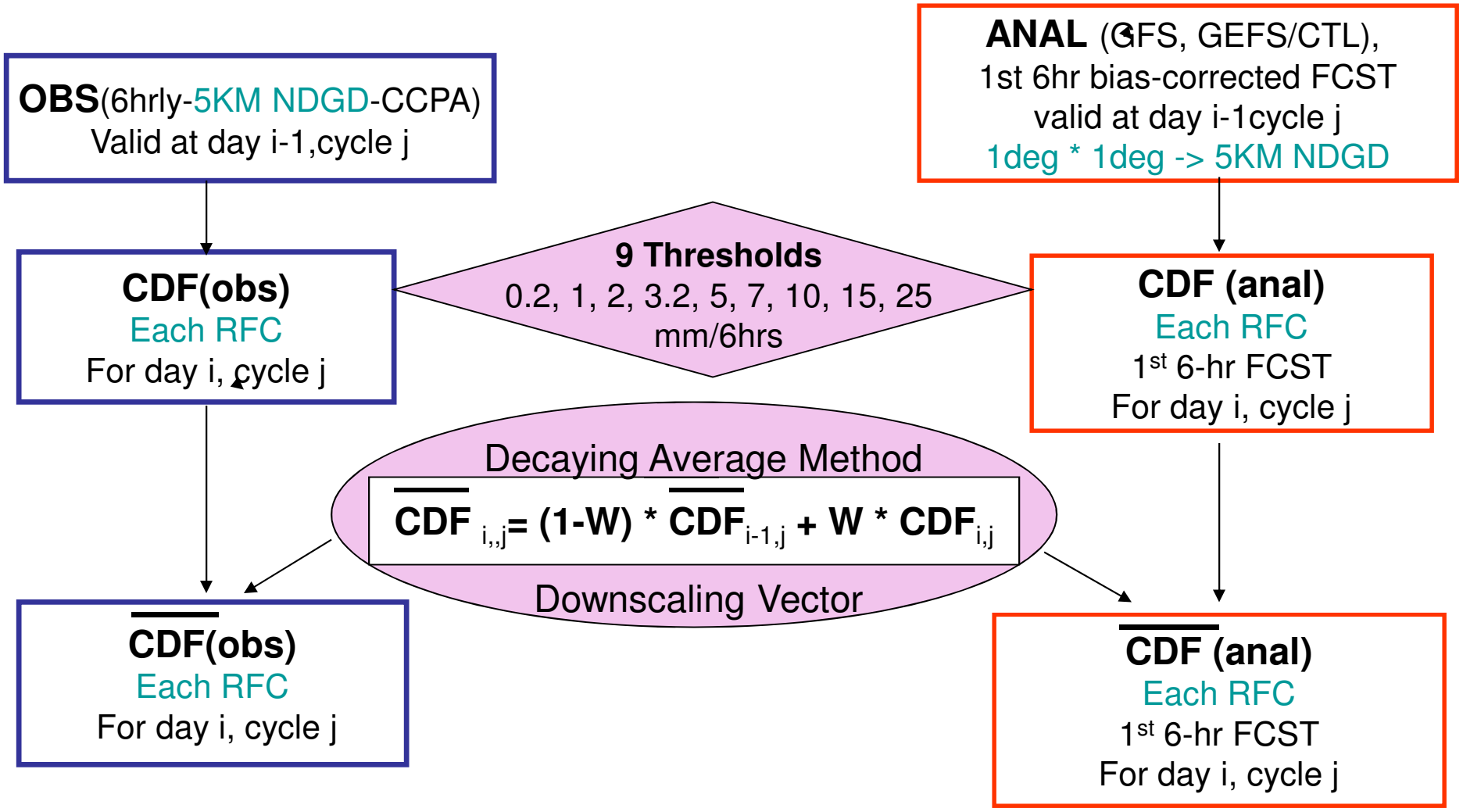
Local Polynomial inter/extrapolation
No bias correction on zero forecast value

OUT

Bias Corrected FCSTs
(GFS, GEFS/CTL,GEFS/20m)
INI at day i, cycle j, for 6-384hr
At 1*1 deg grid

How the Precipitation Calibration System Works

Part II: Statistical Downscaling



$\overline{CDF}_0$: initialized from any a 365-day average of CDF

How the Precipitation Calibration System Works

Part II: Statistical Downscaling (cont'd)

$\overline{\text{CDF(obs)}}$
Each RFC
For day i, cycle j

IN

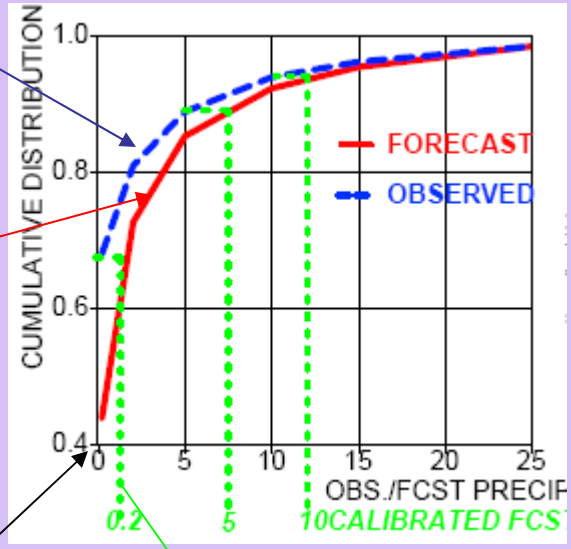
$\overline{\text{CDFs (anal)}}$
Each RFC
1st 6-hr FCST
For day i, cycle j

IN

Bias Corrected FCSTs
(GFS, GEFS/CTL,GEFS/20m)
INI at day i, cycle j, for 6-384hr
1deg * 1deg -> 5KM NDGD

IN

Frequency match algorithm



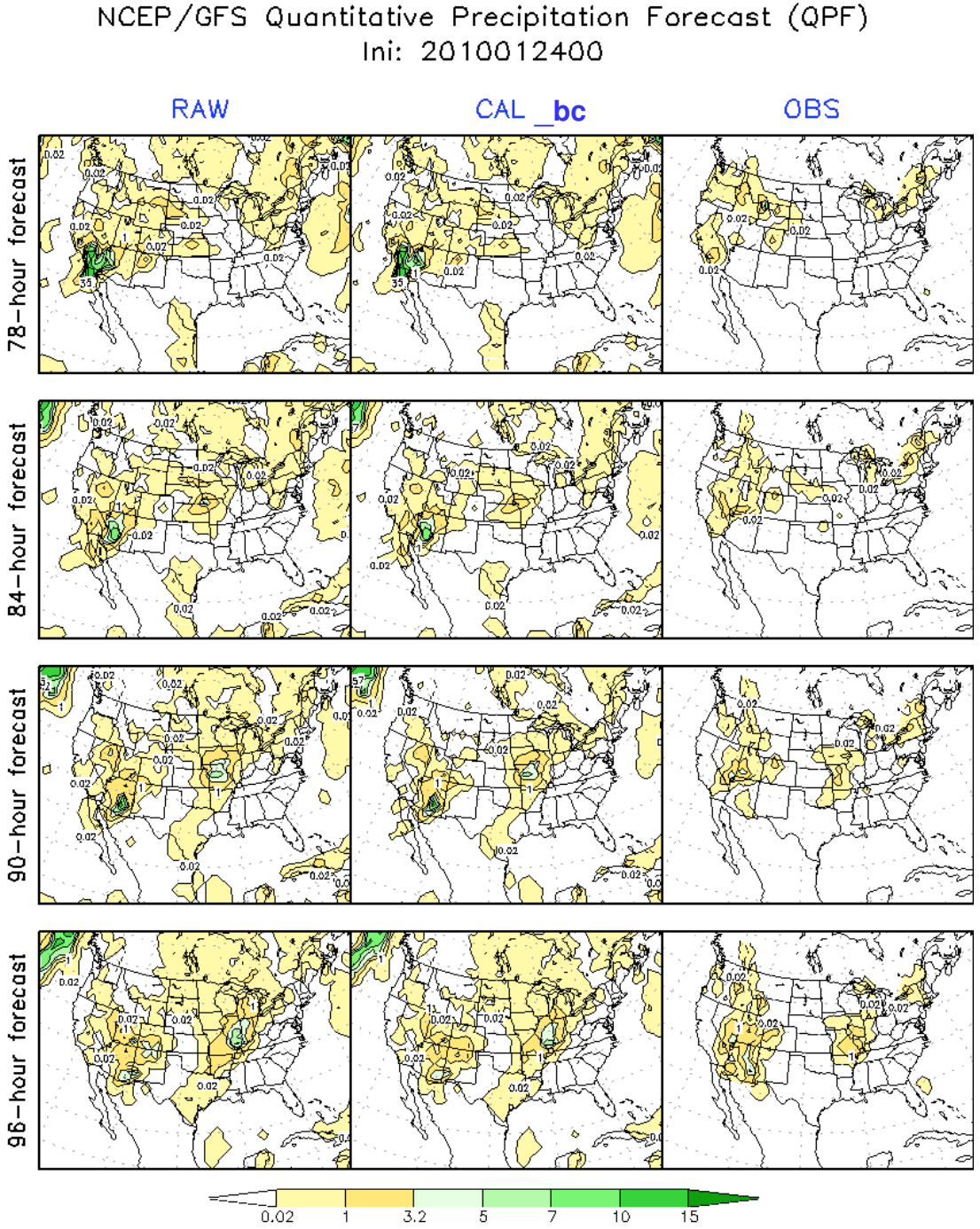
Local Polynomial inter/extrapolation
No downscaling on zero forecast value

OUT

Downscaled FCSTs
(GFS, GEFS/CTL,GEFS/20m)
INI at day i, cycle j, for 6-384hr
At 5KM NDGD grid

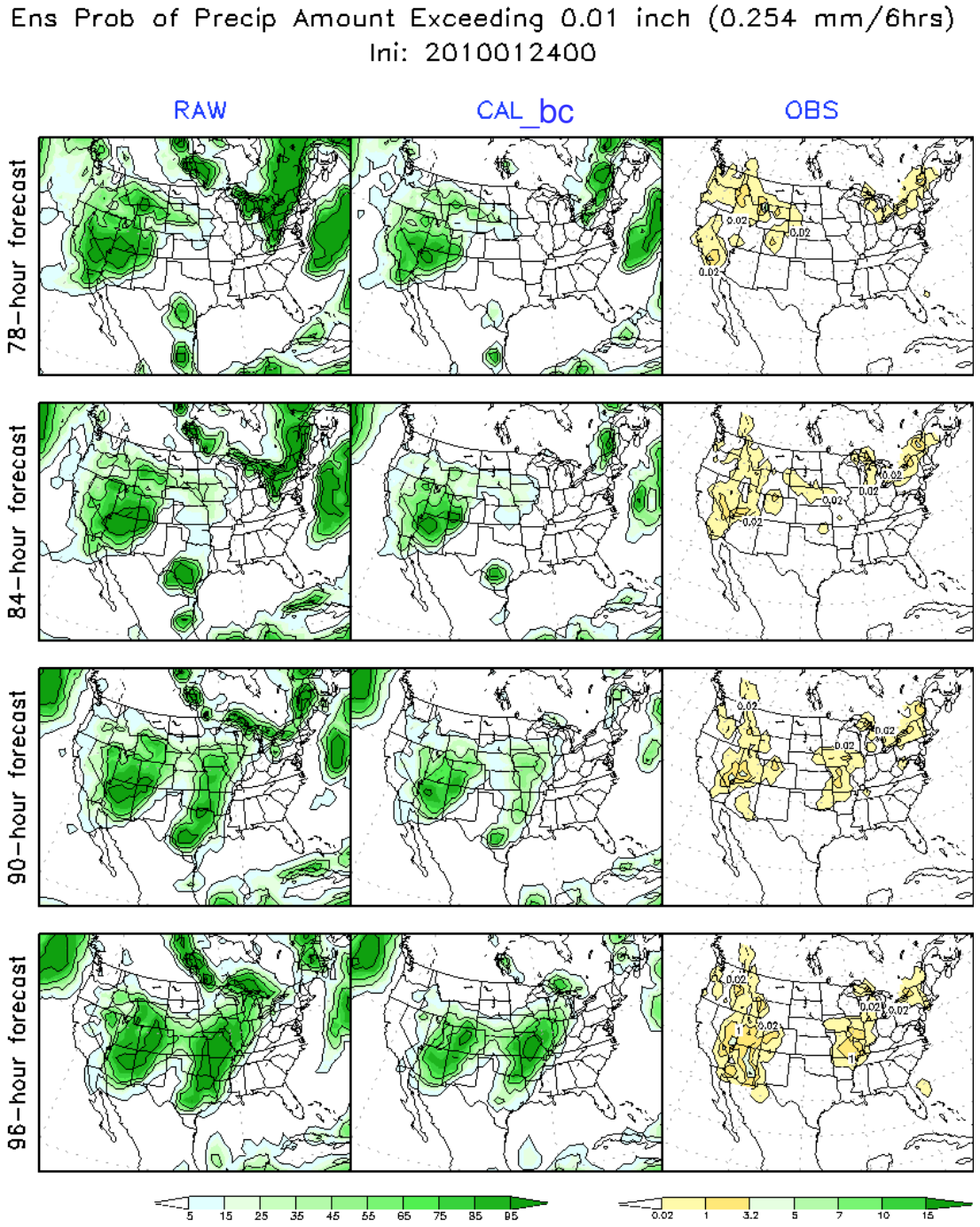
QPF EXAMPLE (1*1 deg)

- Larger reduction in precipitation extent
- Slight reduction in QPF amounts
- Much closer to OBS(CCPA)

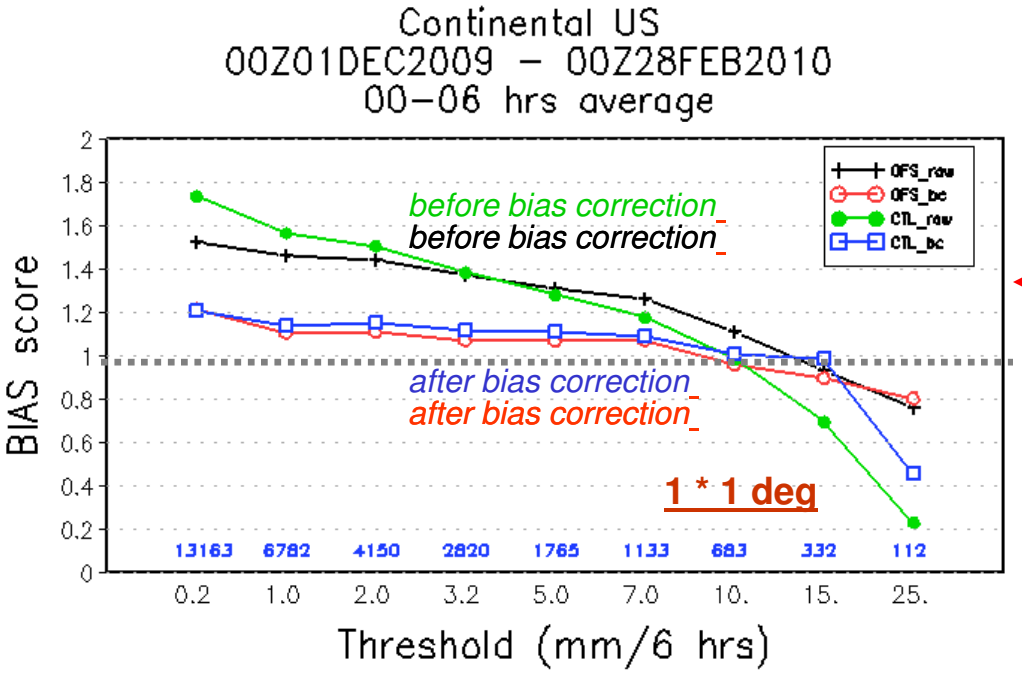


PQPF EXAMPLE (1*1 deg)

- Larger reduction in precipitation extent
- Slight reduction in QPF amounts
- Agree much with OBS(CCPA)

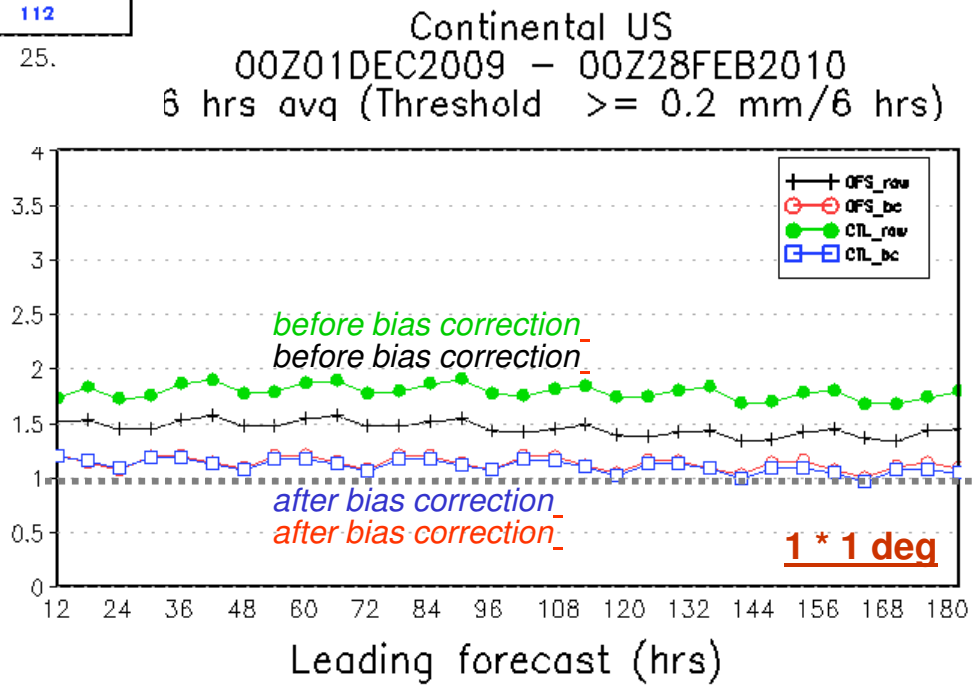


Significantly reduced bias

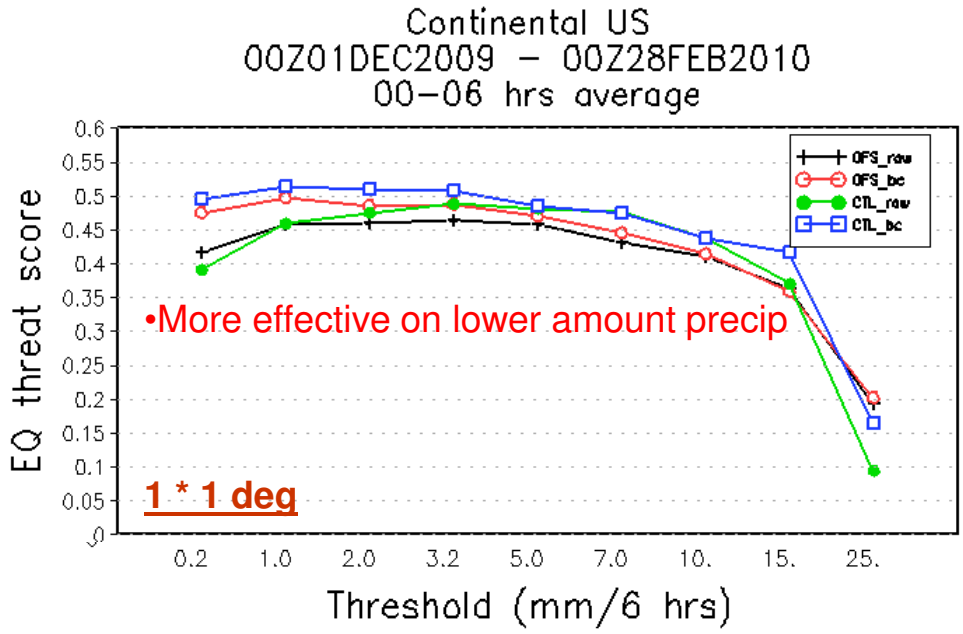


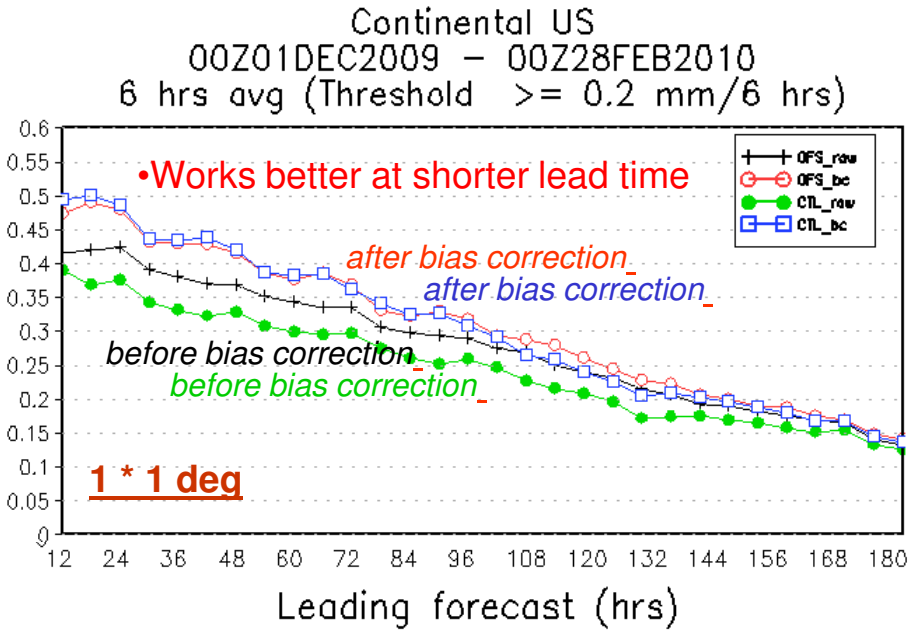
More effective on
low and mid amount precip

Consistently effective
along with leading time

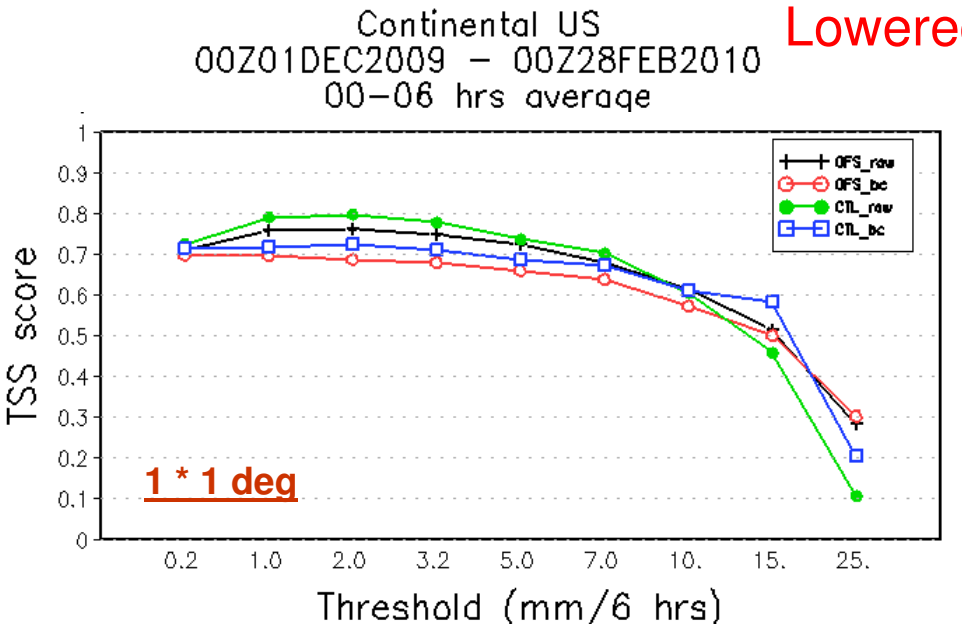


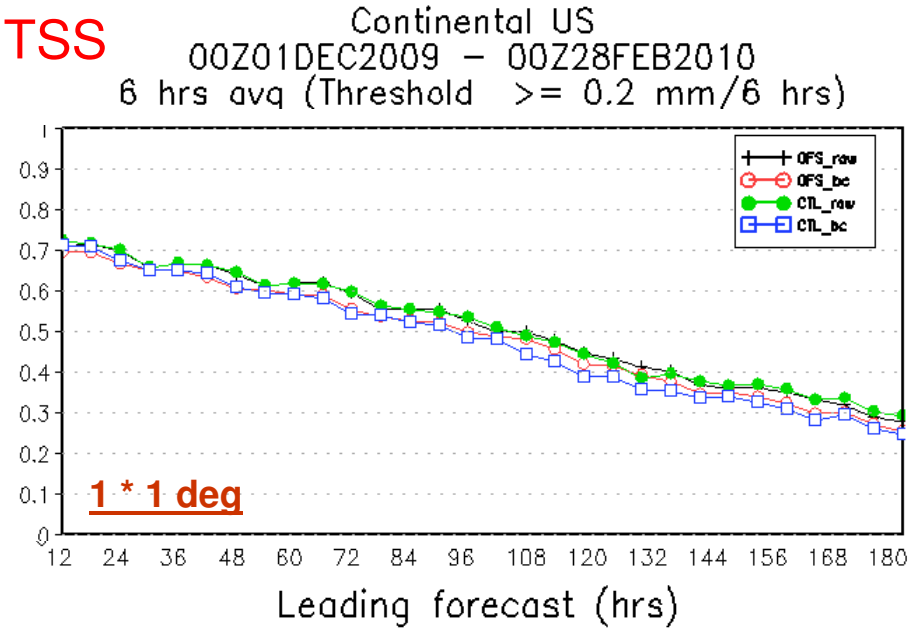
Mostly improved ETS





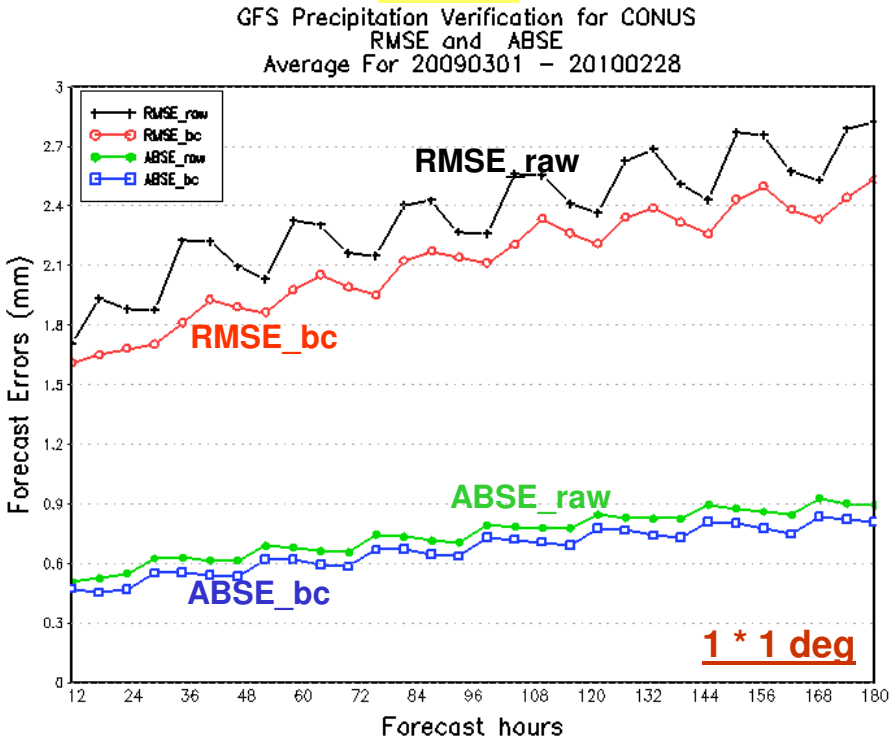
Lowered TSS



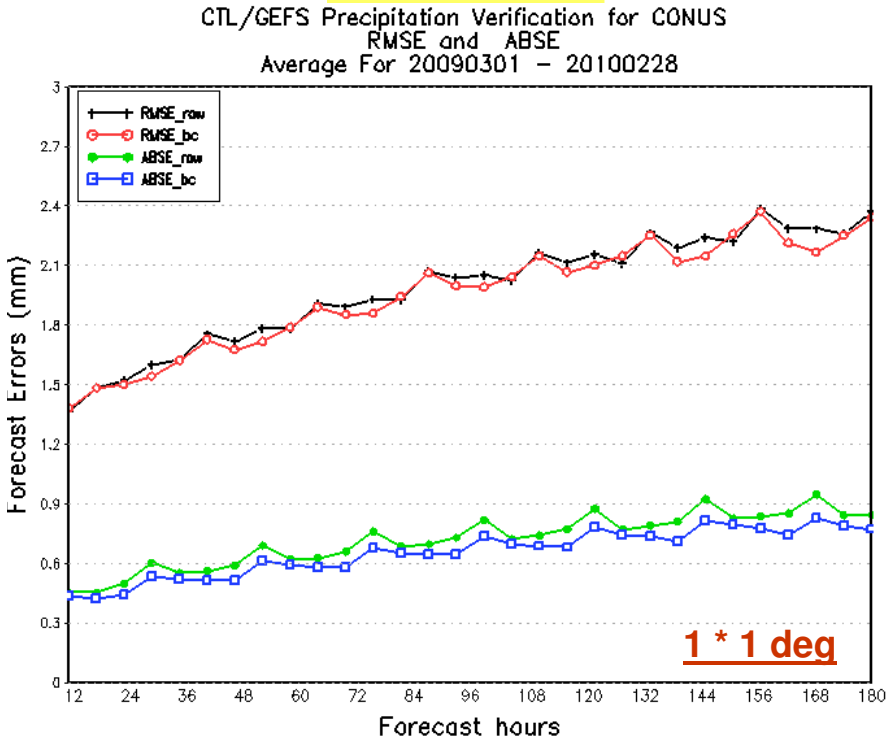


Reduced RMSE and ABSE for GFS and GEFS/CTL

GFS



GEFS/CTL



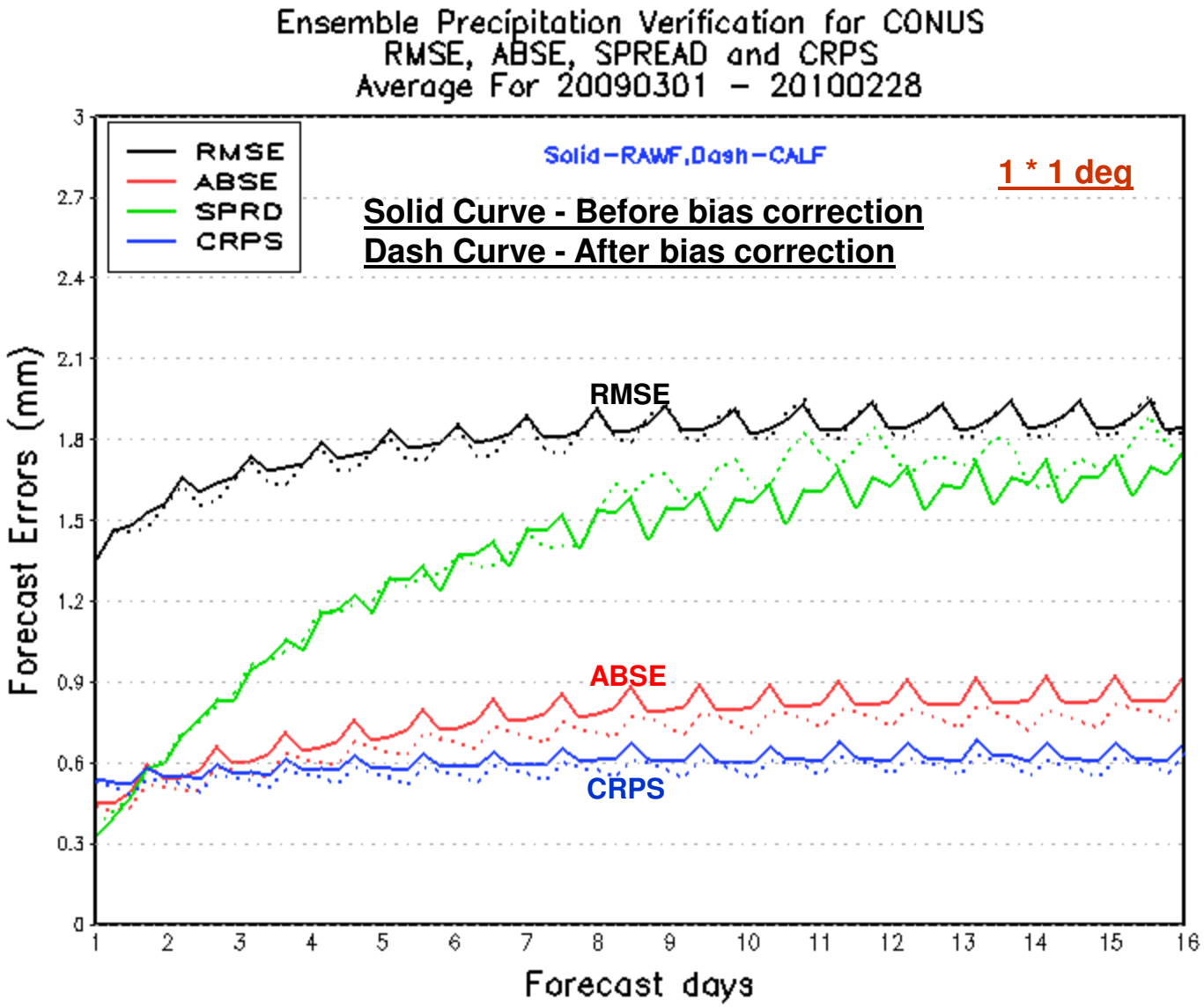
RMSE:

- Significantly smaller RMSE in GFS
- Marginally smaller RMSE in GEFS/CTL

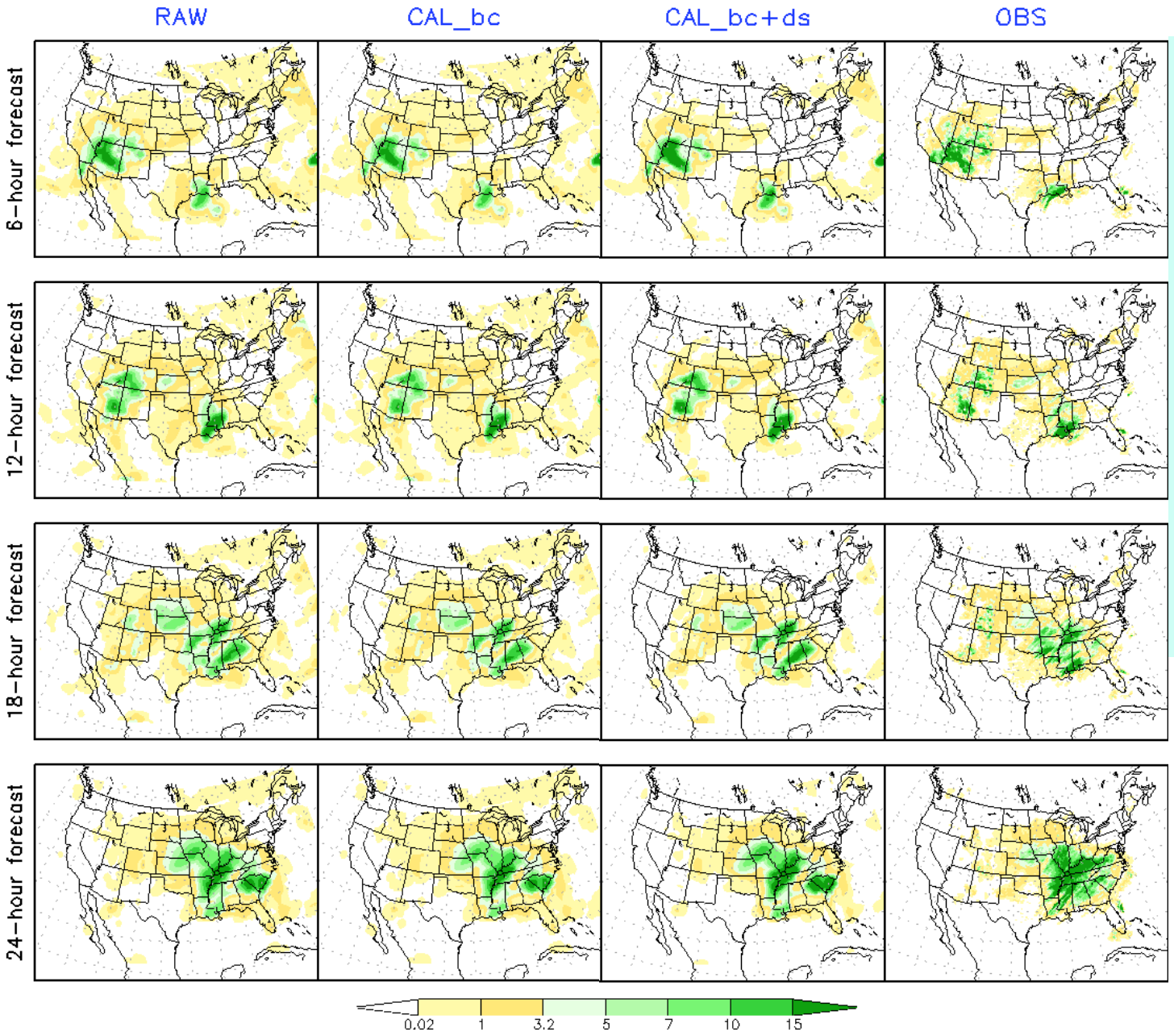
ABSE:

- Both smaller than raw FCSTs.

Improved RMSE, ABSE and CRPS for GEFS ensembles



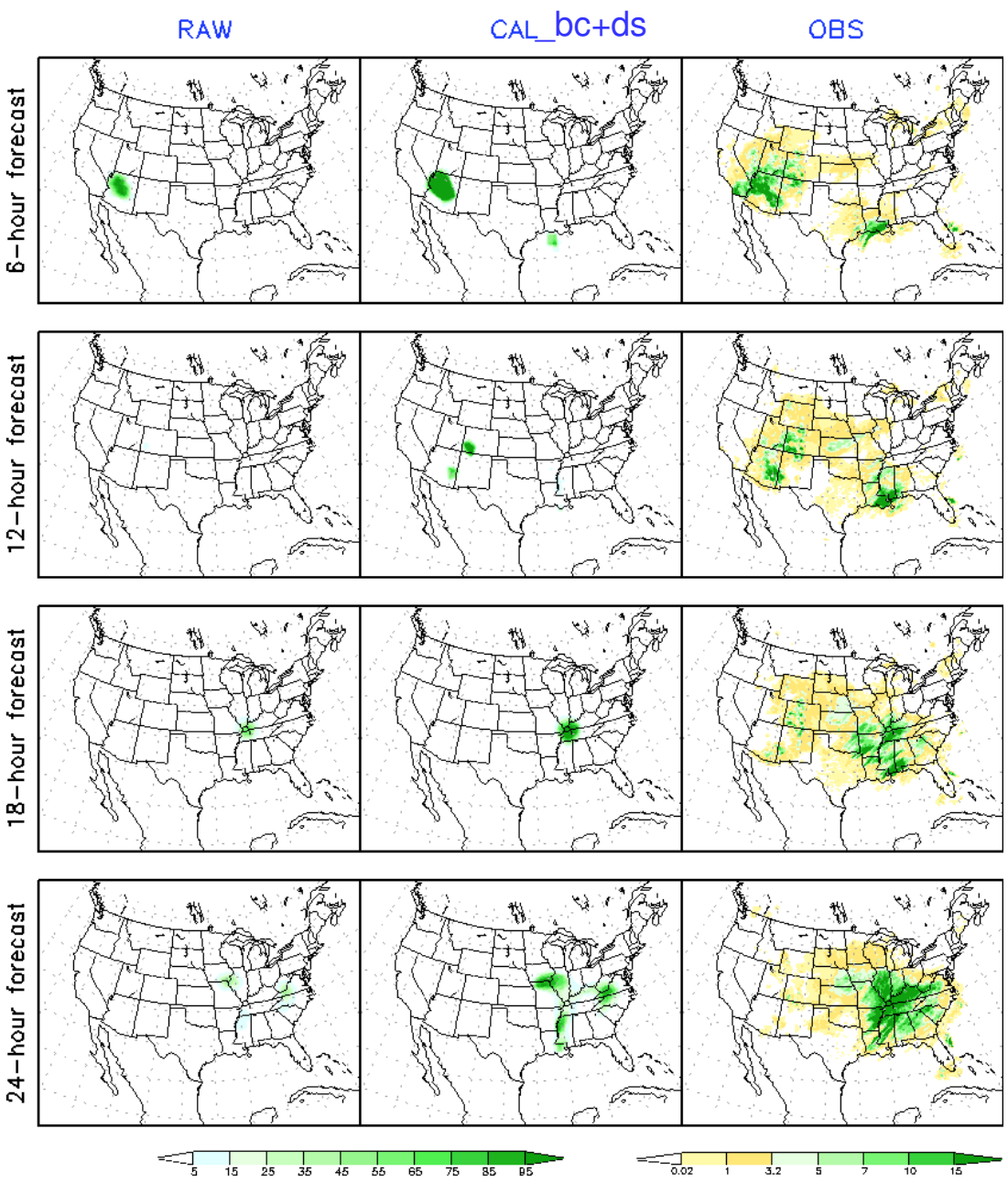
QPF EXAMPLE (5KM NDGD)



Downscaling to 5Km NDGD:

- Further reduction in precipitation extent
- Slight increased in high QPF amounts
- Much closer to OBS(CCPA)
- Still less detail than OBS

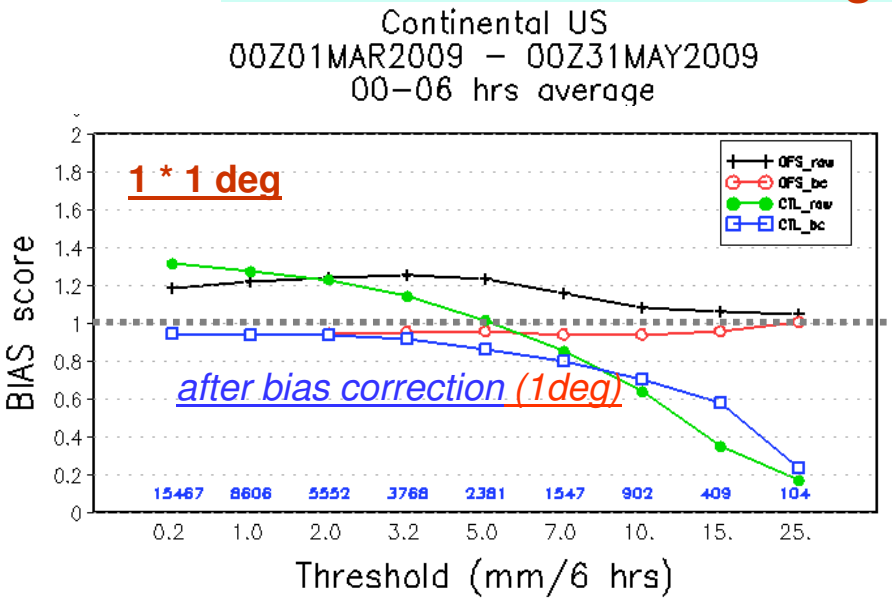
PQPF EXAMPLE (5KM NDGD)

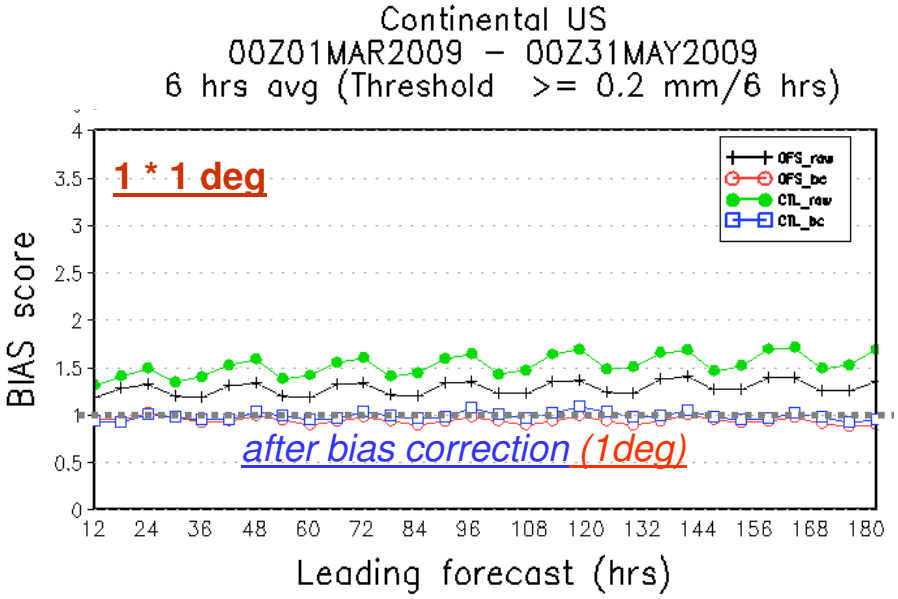


Downscaling to 5Km NDGD:

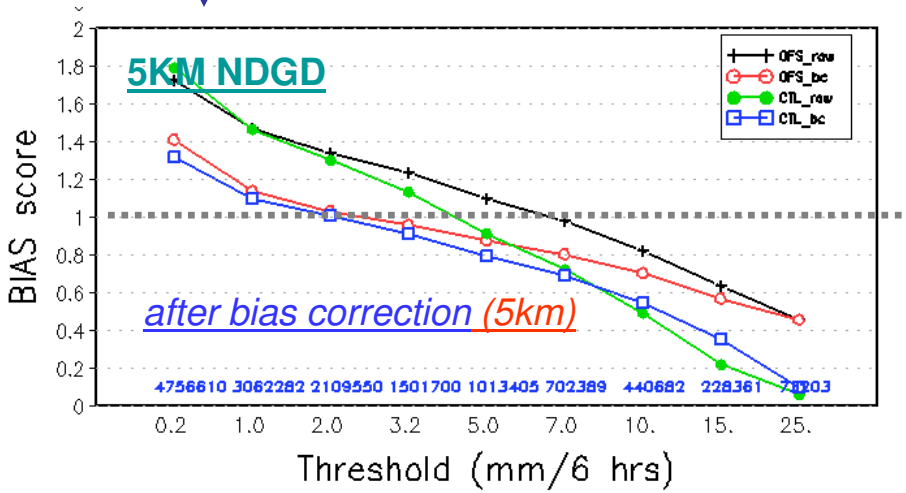
- Better capture high amount QPF in area and amount
- Much closer to OBS(CCPA)
- Still less detail than OBS

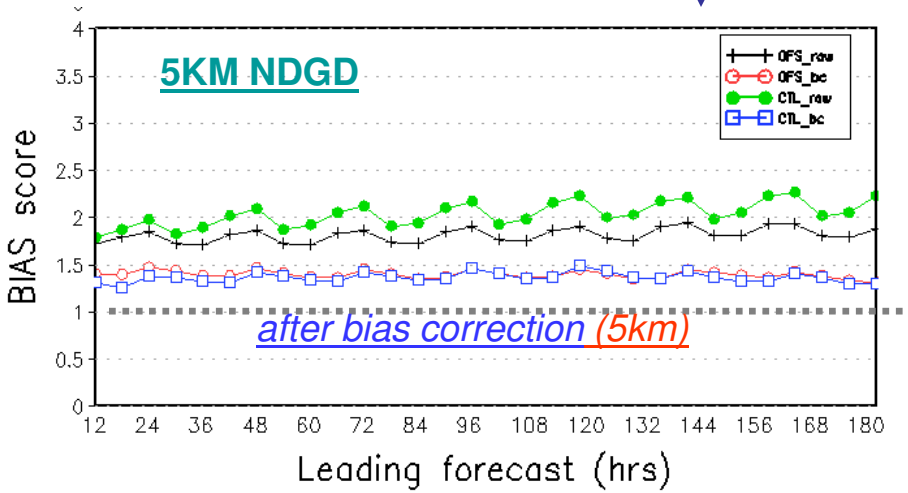
Comparison of bias score after bias correction @ 1*1 deg V.S. 5KM NDGD



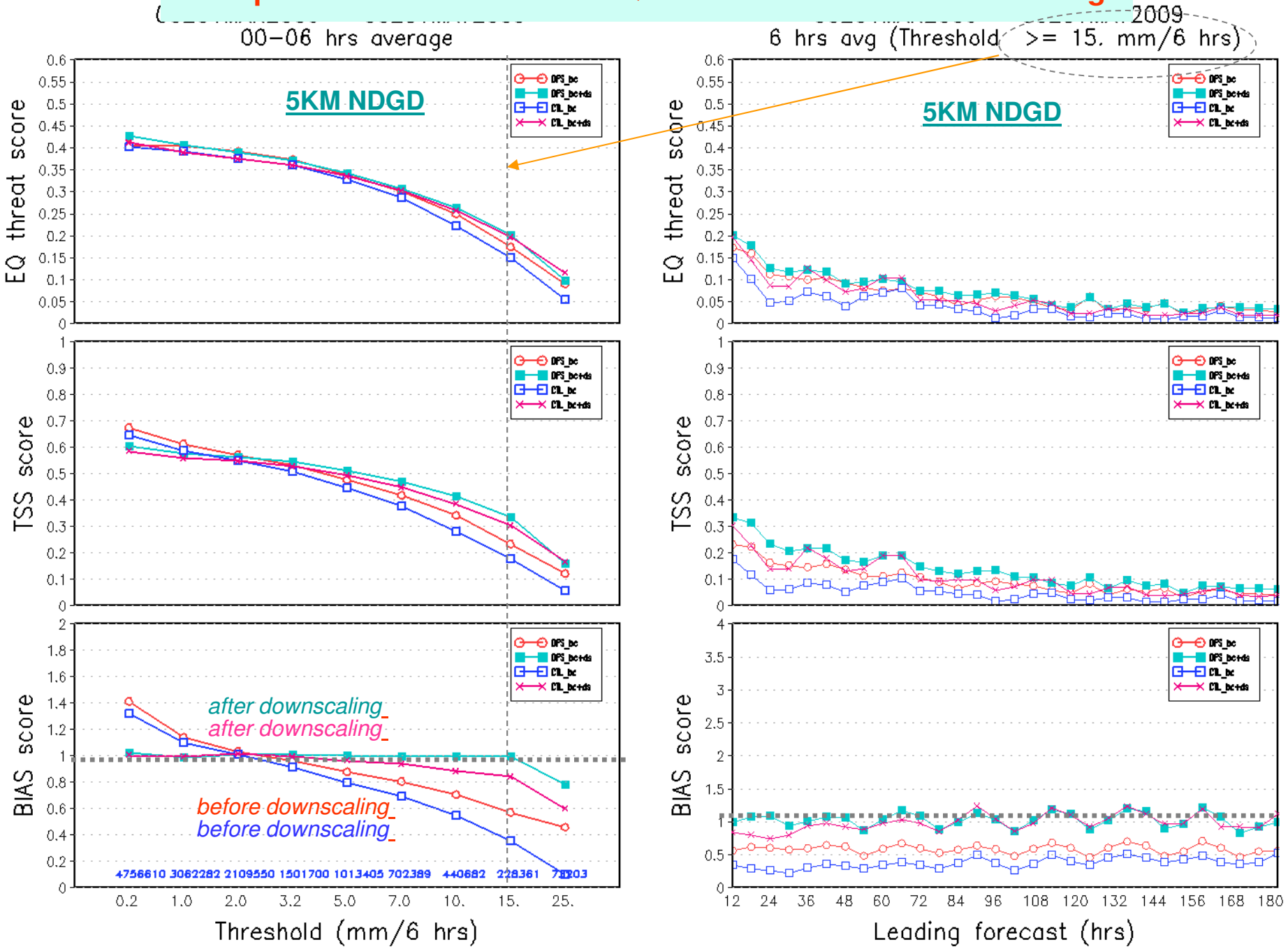


Directly interpolate QPF from 1 * 1 deg to 5KM NDGD





Comparison of bias corrected QPF before and after Downscaling



Summary

- Frequency match algorithm is an effective way to remove model bias
- 1-deg bias-corrected forecasts
  - Much reduced bias.
  - Improved skill scores for ETS, reduced RMSE, ABSE and CRPS
  - Work well for low amount precipitation
- 5km NDGD downscaled forecasts
  - Much reduced bias.
  - Improved skill scores for ETS and TSS for high amount precipitation

Future Work

- Transition the precipitation bias correction component within NAEFS to NCEP operations Q4 2011
- Evaluate calibrated products
- Explore Pseudo Precipitation approach by collaborating with GSD/ESRL (Testing Bayesian Process of Ensemble).
- Explore Analog method by introducing 30yr ensemble reforecast (Tom Hamill)