Optimum Usage of Prior Forecast Information for Bias Correction

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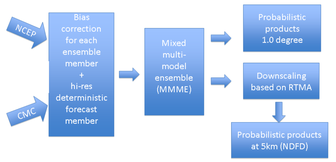
Review of NAEFS Statistical Post Process (SPP)

- Purpose
  - Improve reliability while maintaining resolution in NWP forecasts
    - Reduce systematic errors (improve reliability) while
    - Not increasing random errors (maintaining resolution)
      - Retain all useful information in NWP forecast
- Methodology
  - Use bias-free estimators of systematic error
  - Need methods with fast convergence using small sample
  - Easy implementation for frequency upgraded forecast system
- Approaches – Computational efficiency
  - Bias Correction : remove lead-time dependent bias on model grid
    - Working on coarser model grid allows use of more complex methods
    - Feedback on systematic errors to model development
  - Downscaling: downscale bias-corrected forecast to finer grid
    - Further refinement/complexity added
      - No dependence on lead time

Current NAEFS SPP System



- Bias corrected NCEP/CMC GEFS and NCEP/GFS forecast (up to 180 hrs), same bias correction algorithm
  - Combine bias corrected NCEP/GFS and NCEP/GEFS ensemble forecasts
  - Dual resolution ensemble approach for short lead time
  - NCEP/GFS has higher weights at short lead time
- NAEFS products
  - Combine NCEP/GEFS (20m) and CMC/GEFS (20m), FNMOC ens. will be in soon
  - 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/6km), CONUS and Alaska
  - Generate mean, mode, 10%, 50%(median) and 90% probability forecasts

NAEFS Bias Correction

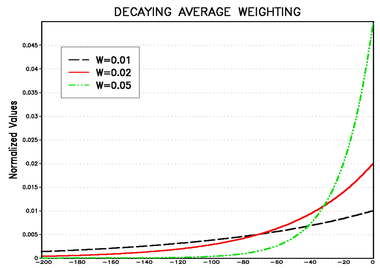
1). Bias Estimation: The bias (***b***) for each lead-time (***t***) (6-hour interval up to 384 hours), each grid point (***i, j***) is defined as the different of best analysis (***a***) and forecast (***f***) at the same valid time (***t₀***) which is up on latest available analysis.

$$b_{i,j}(t) = f_{i,j}(t) - a_{i,j}(t_0)$$

2). Decaying Average: Average bias will be updated by considering prior period bias and current bias by using decaying average (or *Kalman Filter method*) with weight coefficient (*w*).

$$B_{i,j}(t) = (1-w)\cdot B_{i,j}(t-1) + w\cdot b_{i,j}(t)$$

3). Decaying Weight: Through many experiments for different weights (***w*** = 0.01, 0.02, 0.05, 0.1 and etc…), and different parameters, and different lead times, overall, ***w*** equals to 0.02 has been used for GEFS bias correction which is mainly using past 50-60 days information (see figure).

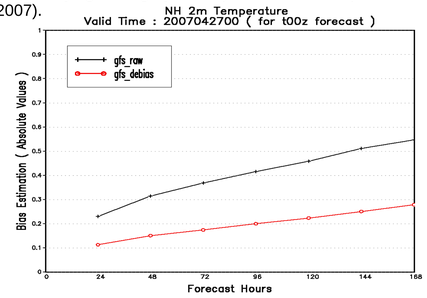


4). Bias corrected forecast: The new (or bias corrected) forecast (***F***) will be generated by applying decaying average bias (***B***) to current raw forecast (***f***) for each lead time, at each grid point, and each parameter.

$$F_{i,j}(t) = f_{i,j}(t) - B_{i,j}(t)$$

NAEFS Bias Correction (continue)

5). Performance: The performance is estimated by applying NAEFS bias correction method. The bias is calculated at each grid point for raw forecast (***f***) and bias corrected forecast (***F***), then using decaying average method (***w=0.02***) to get current average bias, taking absolute bias for each grid point, each lead time to generate domain average absolute error (bias) which smaller value is better (see figure: example for Northern Hemisphere 2 meter temperature, decaying average ***(w=0.02***) about 2 months period ended by April 27, 2007).



Other Un-equal Weights (MDL tested)

Bias estimation: The accumulated bias (or average bias) could be generated from different methods. Decaying average (*Kalman filter*) method is one of them. MDL has tested un-equal weights (linear diagonal weights) which could be described as following for each lead time (t), at each grid point (i,j), and each parameter.

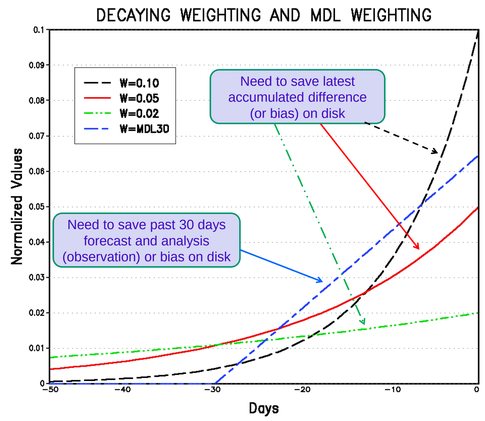
$$B_{i,j}(t) = A_n \cdot B_{i,j}(t-n) + A_{n-1} \cdot B_{i,j}(t-n-1) + \ldots + A_1 \cdot B_{i,j}(t-1)$$

where $A_k = \dfrac{n-k-1}{N}$ $N = \sum_{k=1}^{n} k$ $\sum_{k=1}^{n} A_k = 1$

n means past n days analyses and forecasts which should be available on line when calculating the accumulated bias

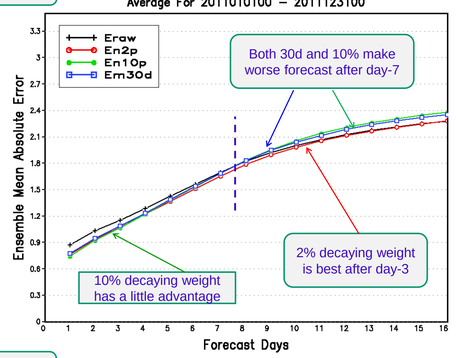
Comparison for Different Un-equal Weights

- Period: September 2010 – December 2011
- Variables: 2-m T, 10-m U and V, 850hPa T
- GEFS raw ensemble forecasts
- Globally at 2.5*2.5 degree resolution
- Proxy truth: GSI analysis at the same resolution
- Bias estimation: ensemble mean forecast – GSI analysis (every 24 hours, out to 16 days)
- Verification: against GSI analysis
- Weights:
  - NAEFS-decaying: w=0.02, w=0.05, w=0.10, w=0.20
  - MDL-un-equal: 30 days un-equal weighting average
- Result plots:
  - Only display raw, w=0.02, w=0.10 and 30d for 2-m T



The Results for Different Methods (and Weights)

Big domain



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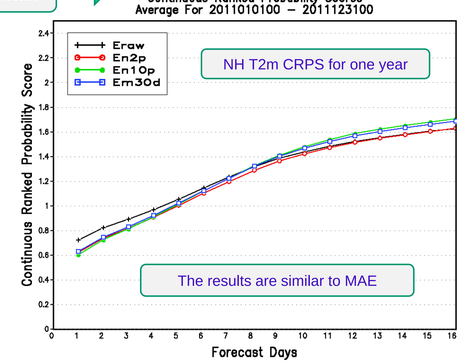
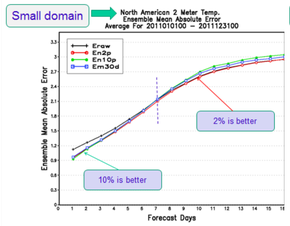


Small domain



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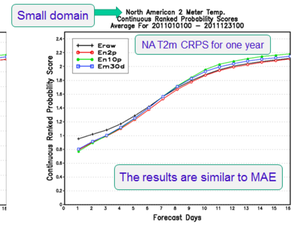

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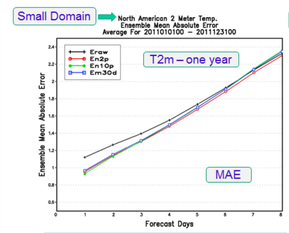

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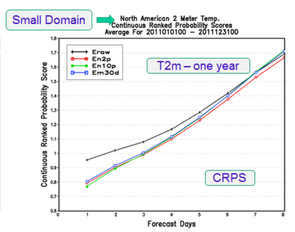
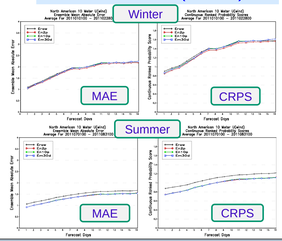
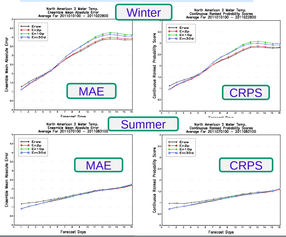


Surface wind (10m U)



Surface temperature (2m T)



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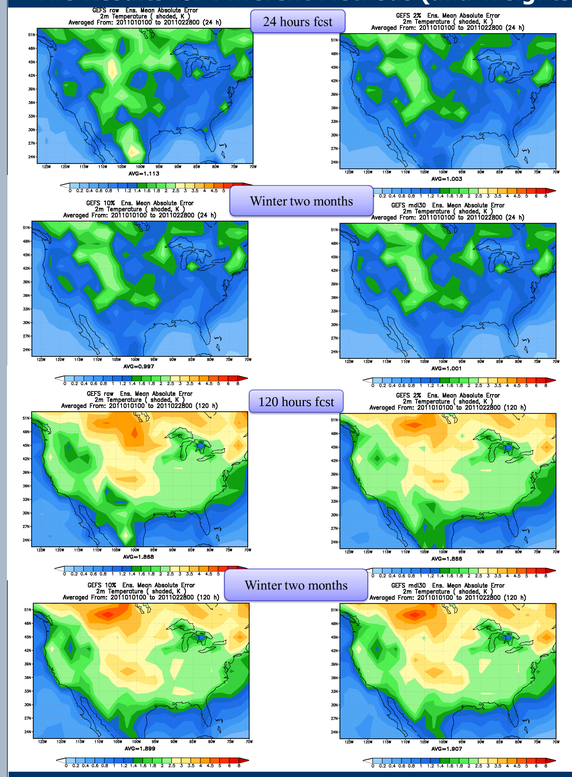

Summary for this Study

- There are the differences for decaying weights and other un-equal weighted for bias accumulation
- This investigation does not show an advantage of 30-day non-equal weight (MDL's method)
- The improvement of forecast depends on weighted bias accumulation. Apparently, higher weight is good for short lead time, lower weight is good for longer lead time.
- The weight is function of forecast lead time, variables, seasonal and geographic location.
- Surface wind is not sensitive to weight changing.
- For overall consideration, w=0.02 is still optimum option.
- There are only limited variables we investigate in this study.

Acknowledgements

- EMC: Ensemble team members
- MDL: Drs. Yun Fan and Kathryn Gilbert

Background Information

Implementations

First NAEFS implementation – bias correction - May 30 2006
NAEFS follow up implementation – CONUS downscaling - December 4 2007
Alaska implementation – Alaska downscaling - December 7 2010
Implementation for CONUS expansion – Q42012

Applications:

NCEP/GEFS and NAEFS – at NWS
CMC/GEFS and NAEFS – at MSC
FNMOC/GEFS – at NAVY
NCEP/SREF – at NWS

Publications:

Cui, B., Z. Toth, Y. Zhu, and D. Hou, D. Unger, and S. Beauregard, 2004: *"The Trade-off in Bias Correction between Using the Latest Analysis/Modeling System with a Short, versus an Older System with a Long Archive"* The First THORPEX International Science Symposium. December 6-10, 2004, Montréal, Canada, World Meteorological Organization, P281-284.

Zhu, Y., and B. Cui, 2006: *"GFS bias correction"* [Document is available online]

Zhu, Y., B. Cui, and Z. Toth, 2007: *"December 2007 upgrade of the NCEP Global Ensemble Forecast System (NAEFS)"* [Document is available online]

Cui, B., Z. Toth, Y. Zhu and D. Hou, 2012: *"Bias Correction For Global Ensemble Forecast"* Weather and Forecasting, Vol. 27 396-410

Cui, B., Y. Zhu , Z. Toth and D. Hou, 2012: *"Development of Statistical Post-processor for NAEFS"* Submitted to Weather and Forecasting (In process)

Zhu, Y., and B. Cui, 2007: *"December 2007 upgrade of the NCEP Global Ensemble Forecast System (NAEFS)"* [Document is available online]