Section 6: Bias correction and statistical down-scaling for 2-meter dew-point temperature and relative humidity

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2-meter dew point temperature (or 2-meter relative humidity) is a very important forecast field for users. In past years, NCEP service centers and NWS regions (WFOs) requested frequently to distribute bias corrected and down-scaled moisture variables, such as relative humidity, or specific humidity, or dew point temperature. However, there is well-know challenge for surface moisture field. It is mainly due to: 1). Less reliable (or lower quality) gridded analysis as proxy truth; 2). All moisture fields are non-continues variables, such as dew-point temperature that is bounded to end of temperature, relative humidity is bounded to 0% and 100%. In order to solve this problem correctly, we need to have further study, or introduce other process (or numerical model). In this implementation (Q2FY14), we decide to process 2-meter dew point temperature (bias correction) by applying simple treatment around the margin point first, then derive relative humidity from dew point and temperature to user community. The downscaled relative humidity will be generated by applying downscaling vector (DV).

1. Methodology: There is experimental formula to calculate vapor pressure, dew-point and relative humidity. An approximation from Bolton (1980) has been used in NCEP product post-process and this calculation (conversion). Following is the definitions and constants for this formula:

Saturation vapor pressure: $e_s = 6.112 * \exp\left(\frac{17.67*T}{T+243.5}\right))$

Vapor pressure: $e = e_s * \left(\frac{RH}{100}\right)$ or $e = 6.112 * \exp\left(\frac{17.67*T_d}{T_d+243.5}\right)$

Relative Humidity: $RH = \frac{e}{e_s} * 100\%$

Dew point temperature: $T_d = \frac{log\left(\frac{e}{6.112}\right)*243.5}{17.67-log\left(\frac{e}{6.112}\right)}$

Where: T is temperature in C°
e_s is saturation vapor pressure in hPa
e is vapor pressure in hPa
RH is relative humidity in percent
T_d is dew point in degree C°

2. Bias correction: In current NAEFS data exchange, 2-meter relative humidity and 2-meter temperature are directly exchanged between NCEP and CMC, therefore, we could use the experimental formula to calculate dew-point temperature at 1*1 degree resolution globally (ref. columns 2-4 of table 1). Decaying average (or Kalman filter) method will be applied to accumulate bias of dew-point for each grid point and each lead time (see Zhu and Cui, 2007a: Section 1: Summary of GFS bias correction). The decaying weight (w) will use 0.02 (or 2%) for this application. A bias corrected dew-point forecast will be generated from the formula (see Zhu and Cui, 2007a; Cui and et al, 2012) except for an additional step which will consider the case of dew-point temperature (*Td)* greater than temperature after adding extra positive value (assume) for bias. A dew-point temperature will be set to temperature if this is a case. After both 2-metre temperature and dew-point temperature are calibrated, the relative humidity is derived from the associated two variables (Bolton 1980). The derived relative humidity does not need the step for additional correction (self-adjustment). In order to confirm operational algorithm for this calculation, figure 1 is an instant example maps for the temperature, dew-point temperature, relative humidity and the difference of dew-point temperature and 2-meter temperature. A set of probabilistic products (10%, 50%, 90%, ensemble mean, mode and spread) at 1*1 degree globally will be generated by using the same method (Zhu and Cui, 2007b).

Schemes to develop T2m, Td2m, RH probabilistic products

Products	1x1 degree resolution			NDGD (5km) resolution		
	T2m	Td2m	RH	T2m	Td2m	RH
Raw ensemble members	Yes	Yes Derived from t2m and RH	Yes	N/A	N/A	N/A
Bias corrected ensemble members	Yes	Yes One end is bounded (T2m)	Yes Two ends are bounded (0,100)	N/A	N/A	N/A
Ensemble mean, mode, 10%, 50% and 90%	Yes	Yes One end is bounded (T2m)	Yes Two ends are bounded (0,100)	Yes Apply DV RTMA - Yes	Yes Apply DV RTMA - Yes	Yes Apply DV RTMA (T2m &Td2m)
					One end is bounded	Two ends are bounded
Ensemble spread	Yes	Yes	Yes	Yes Interpolated	Yes Interpolated	Yes Interpolated bounded
	Probabilistic products and spread of T2m and Td2m are not compatible to RH					10

Table 1: The flow chart of bias correction and downscaling of *Td* and *RH*

3. Downscaling: A downscaling vector (Zhu and Cui, 2007c) for temperature (already in the exist process), and dew-point temperature could be calculated from interpolated dew-point temperature and dew-point temperature from RTMA (De Pondeca and et al, 2011). For downscaled dew-point temperature (by applying *DV*), we need to use downscaled temperature as a mask to reduce exceeded dew-point temperature value if there is. Since the probabilistic products and spread of T2m and Td are not compatible to RH, the downscaled relative humidity could not be generated from *T* and *Td* but also gotten by applying DV. The downscaled relative humidity must need the step for additional correction (self adjustment). The final (downscaled) probabilistic products (10%, 50%, 90%, ensemble mean, mode and spread) will be generated as previous method.

4. Statistics and performance: The performance of final products (after bias correction and downscaling) has been verified against RTMA for a period of Feb. 20 – Mar. 30 2012. Many probabilistic verification tools have been used for this validation. Root mean square error (RMSE) of ensemble mean (solid) with ensemble spread (dash) has been selected here for the performance of dew-point temperature and relative humidity (top two map of figure 2). Continuous ranked probability score (CRPS) has been used to measure overall performance of probabilistic forecast (include reliability and resolution). For dew-point temperature, final product (NAEFS) improves the RMSE (and increases the spread) and CRPS for first week (out to 10 days). The similar improvements will be fund for relative humidity. Meanwhile, improvement of dew-point temperature for COUNS of the same period has been displayed from mean absolute error (MAE) (figure 3). There is about 15.4% (2.485/2.154 *100%) MAE overall reduction for 24-hour forecast.

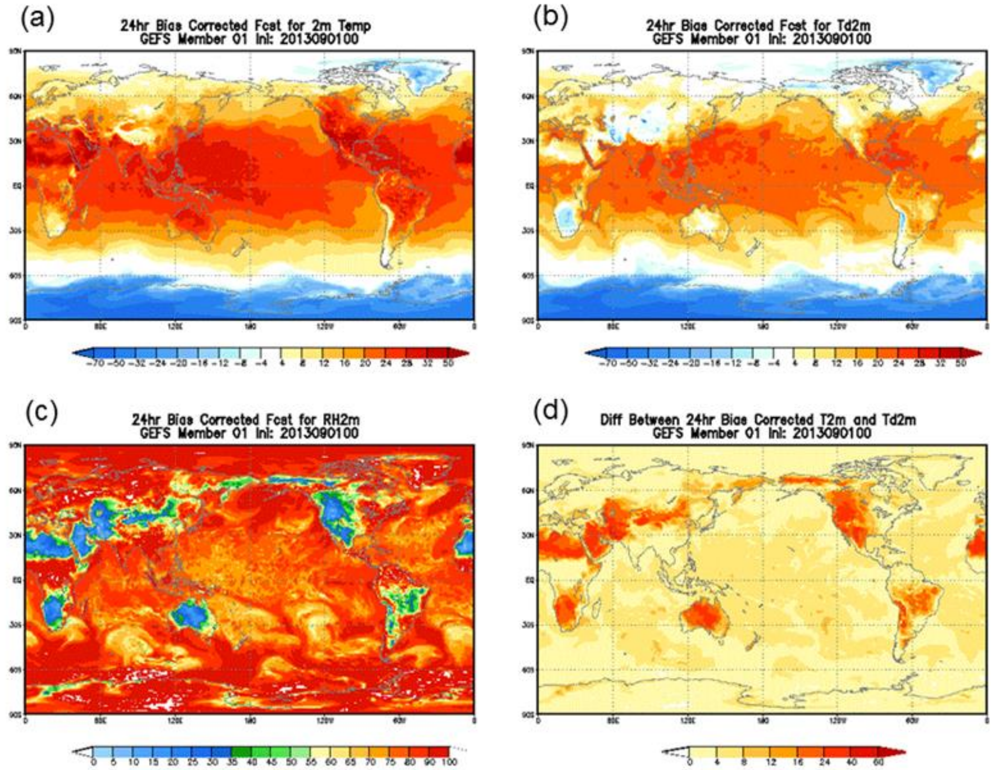

Figure 1: Example maps of 24-hr bias corrected forecasts for (a) 2-meter temperature (T2m), (b) dew-point temperature (Td), (c) relative humidity and (d) difference between T2m and Td. Initial time is September 1, 2013.

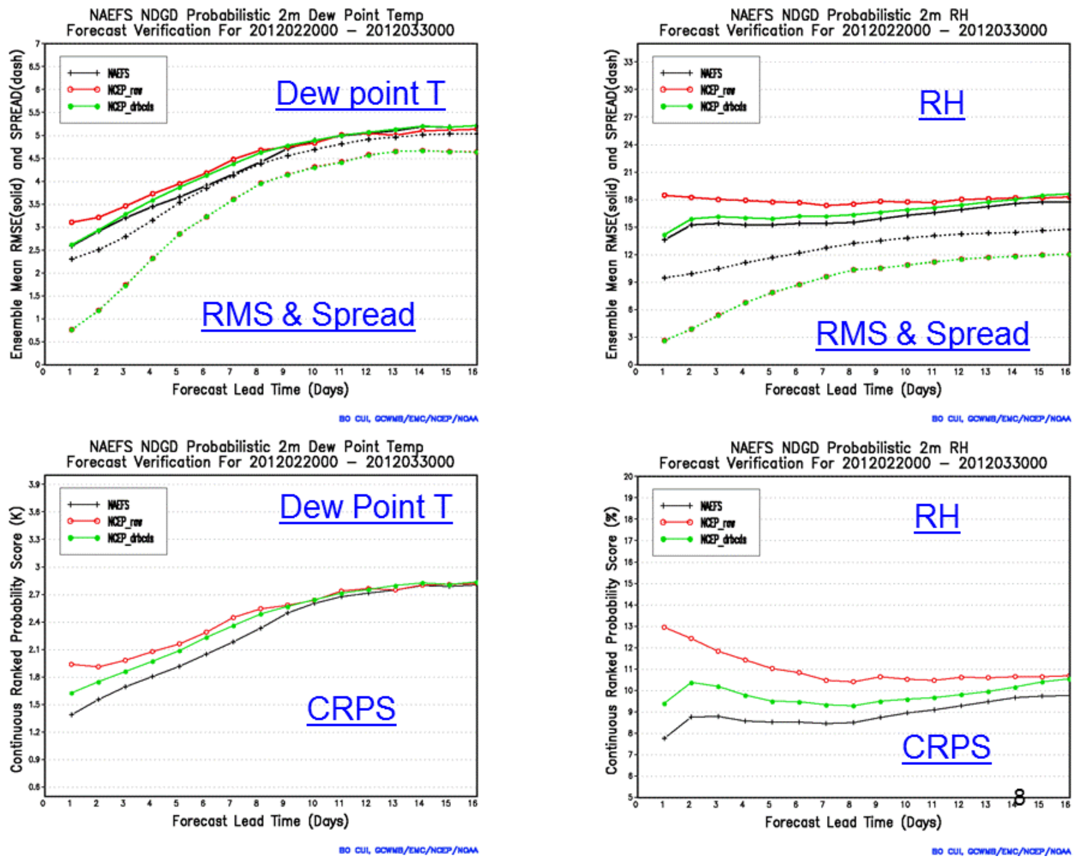

Figure 2: A verification scores of CONUS dew-point temperature and relative humidity for the period of February 20 – March 30 2012. There are six lines on the top two plots, the solid lines are the RMSE of ensemble mean, while dash lines are for ensemble spread. The bottom two plots are for CRPS that measure the probabilistic performance.

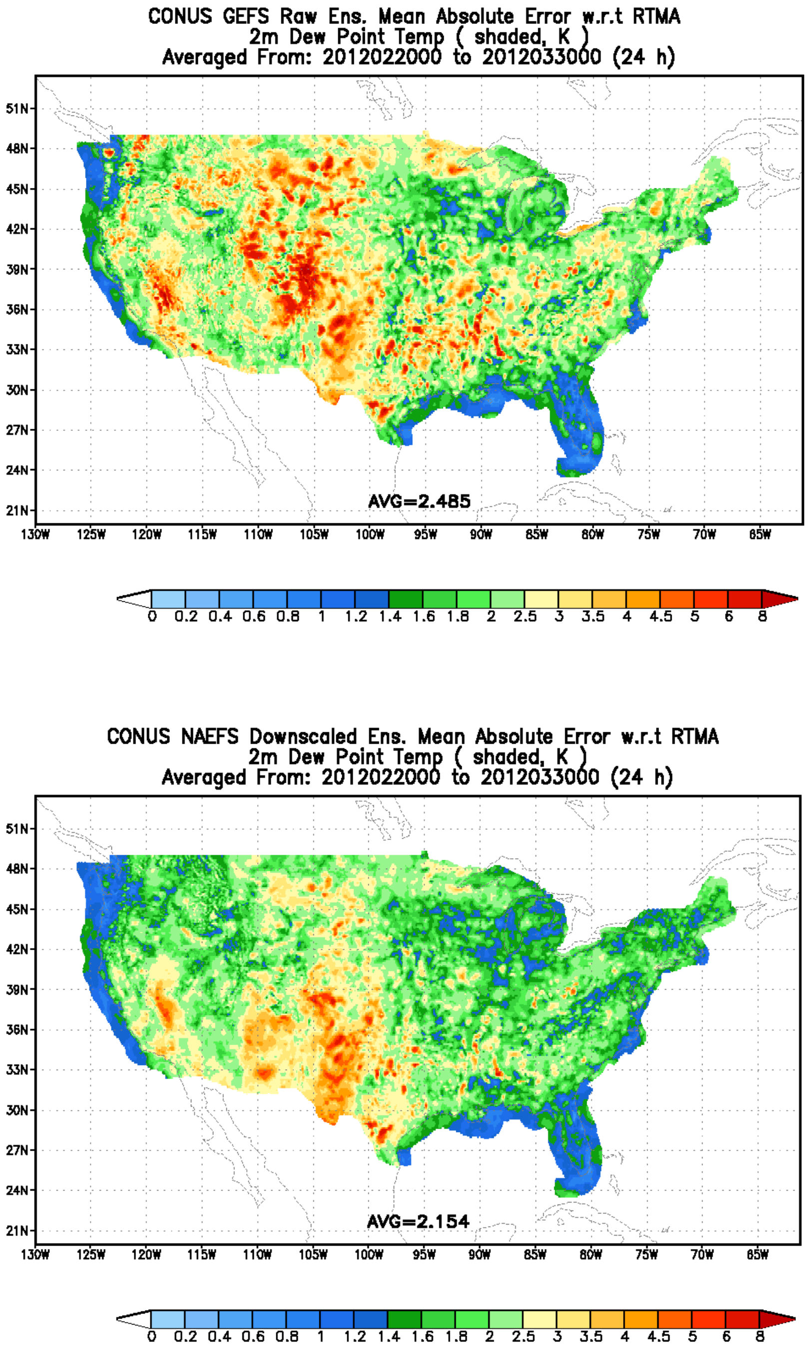

Figure 3: The same as figure 2, but for dew-point temperature only, and measure mean absolute error of each grid point of CONUS.

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