

## **PB2NC Virtual Temperature Problem**

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This whitepaper discusses the details and impact of a problem involving virtual versus sensible temperature in the PB2NC (PREPBUFR to NetCDF) tool within the Model Evaluation Tools (MET) package. This bug is the result of incomplete logic when extracting temperature observation values from PREPBUFR files.

PREPBUFR files contain multiple versions of each observation. As the observation goes through processing and quality control steps, each version of it is stored in an event stack. The various processing steps are indicated in the event stack by a program code and reason code. Generally, the bottom of the event stack contains the most raw, least quality-controlled observations while the top of the event stack contains the opposite. The default in the configuration file for PB2NC is to select observations from the top of the event stack.

However, using the top of the event stack is problematic for temperature observations. One of the data assimilation processing steps converts sensible temperature values to virtual temperature. The temperature observations at the top of the event stack contain a mixture of virtual and sensible temperature. Only sensible temperature observations should be used for verification.

A bugfix was created and distributed for METv4.0 and METv4.1 on July 16<sup>th</sup>, 2013. Prior versions of MET still contain this bug. The fix implements the following logic:

- For temperature observations, search the entire event stack looking for the virtual temperature (VIRTMP) program code.
- If found with a reason code of 3, skip the observation entirely since all entries in the event stack contain virtual temperature.
- Otherwise, step down to the next event in the stack and use its observation value.
- If the VIRTMP program code is not found, use the location in the event stack specified in the configuration file.

This bugfix results in only sensible temperature observations being included in the output of PB2NC.

Virtual temperature is the temperature that dry air must have in order to have the same density as the moist air at the same pressure. Moist air is less dense than dry air, thus, virtual temperature is always greater than the sensible temperature. The more moisture present in the atmosphere, the larger that difference will be, up to a few degrees. Therefore the difference is more pronounced during the summer months and at the surface than it is during the winter months and at higher pressure levels.

Observations of temperature which are up to several degrees higher than they should be can lead to a perceived cold-bias in the model being evaluated. The Developmental Testbed Center (DTC) performed a sensitivity test to see how this bug impacts their model evaluations. The results of these tests were aggregated over 3 geographic areas (Continental United States (CONUS), Eastern US, and Western US), 2 seasons (summer and winter), and multiple vertical levels (surface and upper-air pressure levels). The remainder of this whitepaper illustrates the differences in the verification output before/after the virtual temperature bugfix. In these plots, the purple line shows the model's temperature bias before the bugfix, the red line shows the model's temperature bias after the bugfix,

and the green line shows their pairwise difference. The vertical bars through each point show the 99% confidence interval. Confidence intervals on the green difference lines that do not encompass zero are considered statistically significant.

Figures 1 and 2 below show surface temperature bias aggregated over the continental United States (CONUS) for the summer months (Figure 1) and winter months (Figure 2). Notice that the differences are much more pronounced during the summer (around 2 degrees C); however, the differences still approach 1 degree C during the winter. All of these differences are statistically significant.

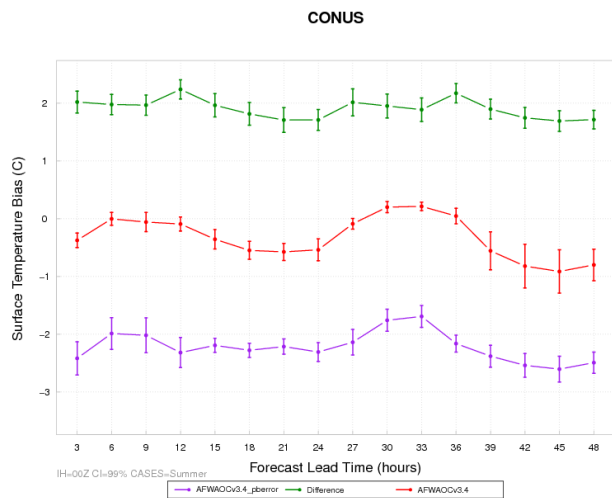


Figure 1: Summer Season

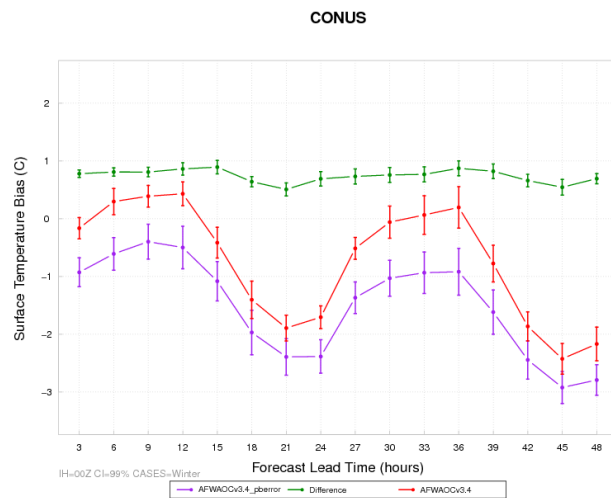


Figure 2: Winter Season

Figures 3 and 4 below show a vertical profile of upper-air temperature bias for the summer months aggregated over the Western (Figure 3) and Eastern (Figure 4) United States. Notice that the differences are larger in the Eastern US and are statistically significant from 850 hPa all the way up to 400 hPa.

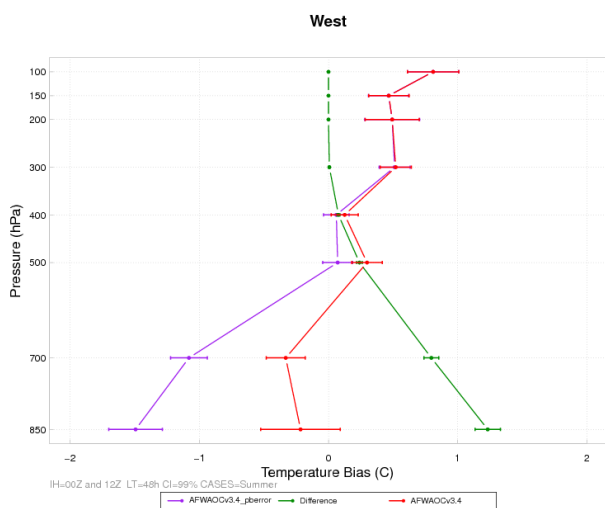


Figure 3: Western United States

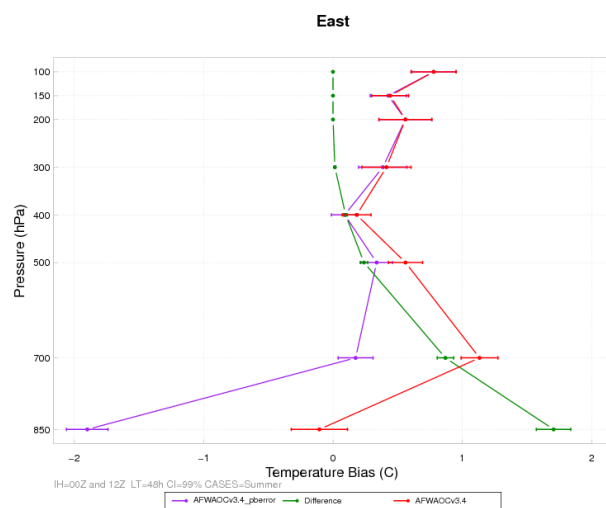


Figure 4: Eastern United States