P3.8 A HYBRID APPROACH TO THE BIAS CORRECTION OF AMSU-A RADIANCE DATA

William F. Campbell and Nancy L. Baker
Naval Research Laboratory, Monterey, California

1. INTRODUCTION

Satellite radiances provide essential coverage of data-poor regions, especially over the oceans and in the Southern Hemisphere. Data assimilation schemes such as optimal interpolation (OI) must convert radiance data into vertical temperature and moisture profiles by solving the so-called inverse problem, which is mathematically ill-posed. The ability to assimilate data in observation space, and avoid the inverse problem, is the principal advantage of three-dimensional variational assimilation (3DVAR) over OI.

Like OI, 3DVAR blends forecasts, observations, and dynamical constraints to extend the spatial influence of incoming data. Many sources of error, both random and systematic, are present in the assimilation system. Random errors are handled within the framework of a 3DVAR system such as the NRL Atmospheric Variational Data Assimilation System (NAVDAS); systematic errors, or biases, are not. In order for 3DVAR to work well, biases must be minimized or eliminated. Variational assimilation of satellite radiance data has shown tremendous positive benefit at numerical weather forecast centers such as ECMWF, the Met Office, and BMRC.

Satellite radiance data is known to be biased. In particular, the brightness temperatures observed by the Advanced TIROS Operational Vertical Sounder (ATOVS) suite of instruments on NOAA 15-17 satellites show bias relative to Navy Operational Global Atmospheric Prediction System (NOGAPS), the global forecast model used at the Naval Research Laboratory (NRL). The two principal sources of bias are due to the instruments themselves as they scan the atmosphere at different zenith angles (scan bias), and to inaccuracies in the fast radiative transfer model, whose biases differ depending on the thermodynamic properties of the underlying atmosphere (air-mass bias).

2. BIAS CORRECTION SCHEMES

After the success of the simple regression scheme developed by Eyre (1992), almost all major weather centers adopted some form of linear regression to correct for radiance bias. The scheme previously used at NRL is taken directly from Eyre (1992). It employed a simple, global scan-bias correction, and a global linear regression against microwave brightness temperatures to correct air-mass bias in both the infrared and microwave channels of the TOVS instruments, which can easily be generalized for an all-microwave instrument such as AMSU. Another regression scheme, Harris and Kelly (1999), takes into account the latitudinal dependence of both scan and air-mass bias. More importantly, it corrects air-mass bias as a linear function of four model forecast fields (1000-300 and 200-50 hPa thickness, surface skin temperature, and total column precipitable water), rather than observed radiances. The change in philosophy is significant. Harris and Kelly (1999) state that their scheme shifts the focus away from correcting the observations, towards correcting the forward operator (fast radiative transfer model), which is the main source of air-mass bias. The background fields essentially retune the forward operator to better match observations.

One potential problem with the Harris and Kelly (HK) method is that it performs a separate air-mass bias correction in each of 18 ten-degree latitude bands. As a result, some linear artifacts in the innovations appear along the band boundaries. Recently John Derber from NCEP visited to advise NRL Monterey on radiance assimilation, with an emphasis on bias correction. He proposed going back to a global regression as in the Eyre scheme, but using a modified set of Harris and Kelly predictors, partitioning the thickness fields by multiplying them by the sine squared and cosine squared of latitude, and adding cloud liquid water as an additional predictor.

The Eyre scheme uses only observations as predictors; the HK and NRL test schemes use only model fields. A simple hybrid of the two methods should have superior performance, as it can predict the innovations by using information from both the observations and the model. An enhanced hybrid, using all available microwave channels as predictors, should perform even better.

3. EXPERIMENTAL RESULTS

We have run a preliminary test comparing the standard Eyre and Harris and Kelly models with the NRL test model and a hybrid Eyre-NRL test-HK model (Campbell model) over oceans. Air-mass and scan bias coefficients were generated from NOAA-16 AMSU-A observations and a T159L24 NOGAPS model run from the first two weeks of April 2002, and applied to the second two weeks. Figure 1 shows the global root mean squared error in brightness temperature innovation for NOAA-16 AMSU-A channels 4 through 10. For the higher peaking channels (7-10), having 18 separate latitude band regressions (HK and Campbell, as opposed to Eyre and NRL test) has the greatest impact on rms error, but the use of model predictors, in particular the 200-50 hPa thickness field, is almost as important. For the lowest peaking channel considered (channel 4), cloud liquid water is an important predictor, and helps explain the superior performance of the NRL test and Campbell models (note that scenes with cloud liquid water content greater than .3mm are rejected by quality control). The Campbell hybrid has the best rms performance in all channels, including AMSU-A channels 1-3 and 11-15, which were passively monitored but not assimilated (or presented here). With the exception of channel 4, the Harris and Kelly scheme performed almost as well.

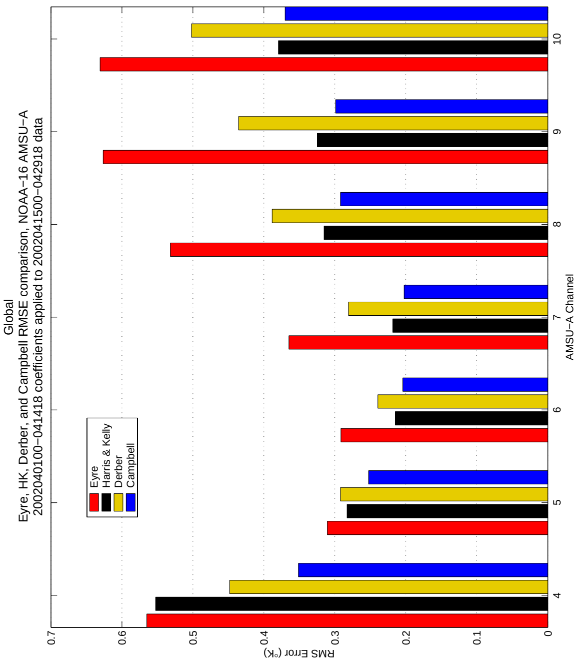

Figure 1. Global RMS error, NOAA-16 AMSU-A channels 4-10.

Minimizing the rms error is not the goal of bias correction, but neither is it simply the correction of the global mean to zero. If one can find a time scale over which there ought to be no large-scale spatial patterns in the time-averaged brightness temperature innovations, one can evaluate the bias correction by the presence or absence of those patterns. A two-week period approximately meets that criterion, and thus was chosen for our preliminary experiment. We can evaluate global maps of the time-averaged innovations, and judge them by their lack of spatial patterns; if spatial patterns exist, this indicates bias that can be removed, but was not.

Figures 2 through 5 show the bias-corrected brightness temperature innovations for weeks three and four of April 2002 for the Eyre, Harris and Kelly, NRL test, and Campbell bias correction models for NOAA-16 AMSU-A channel 4. The Eyre scheme (figure 2) shows broad areas of coherent bias, and the Harris and Kelly scheme (figure 3) shows similar patterns with somewhat reduced amplitude in the Eastern Tropical Pacific, North Atlantic, and Northeastern Pacific. The strongest bias is in the Western Pacific in both models. The NRL test and Campbell schemes (figures 4 and 5) show somewhat reduced amplitude, with the Campbell scheme doing markedly better except in the Southern Ocean.

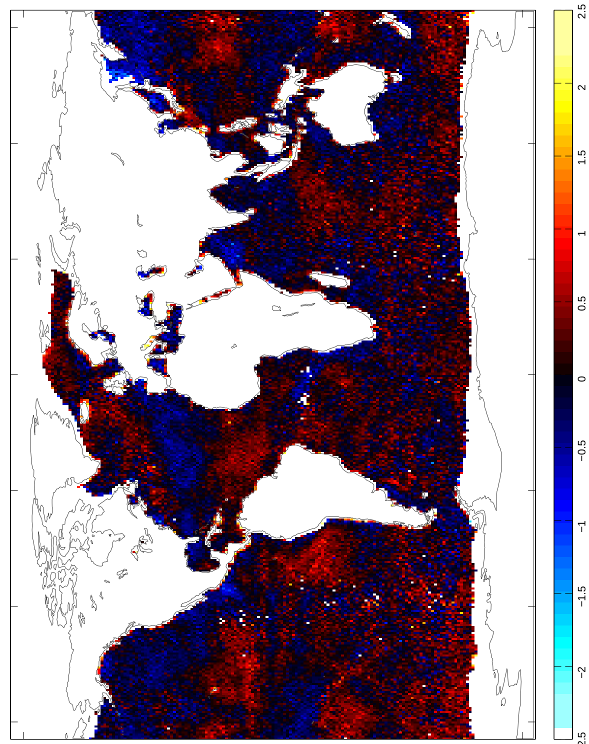

Figure 2. Eyre bias-corrected innovations, NOAA-16 AMSU-A Channel 4

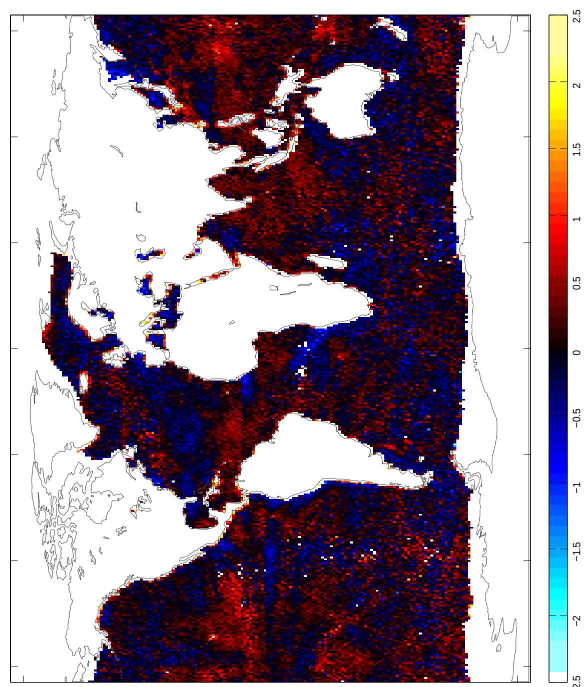

Figure 3. Harris and Kelly bias-corrected innovations, NOAA-16 AMSU-A Channel 4.

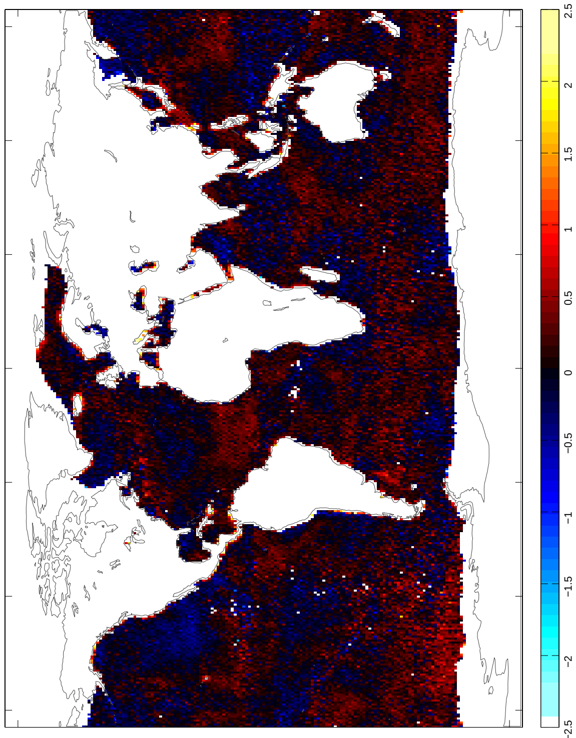

Figure 4. NRL test bias-corrected innovations, NOAA-16 AMSU-A Channel 4.

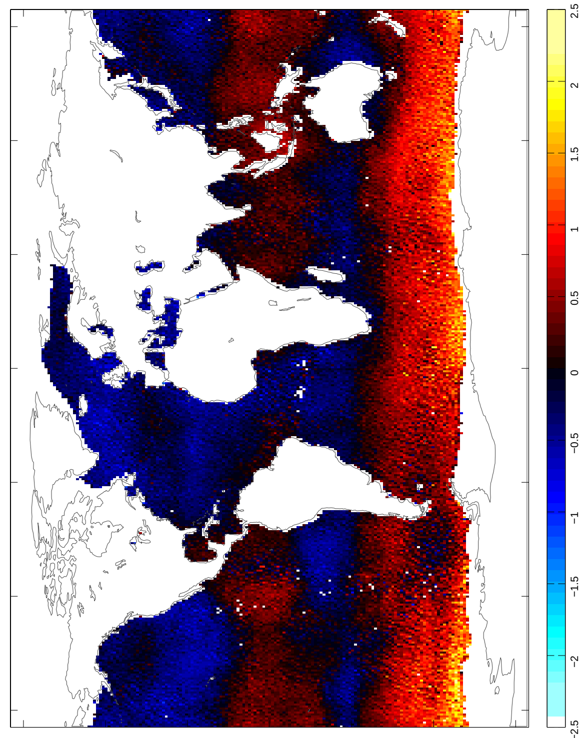

Figure 6. Eyre bias-corrected innovations, NOAA-16 AMSU-A Channel 10.

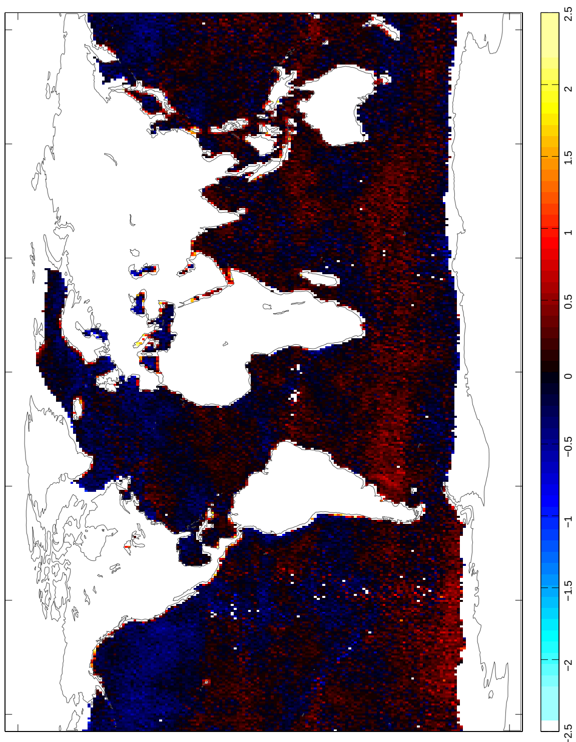

Figure 5. Campbell bias-corrected innovations, NOAA-16 AMSU-A Channel 4.

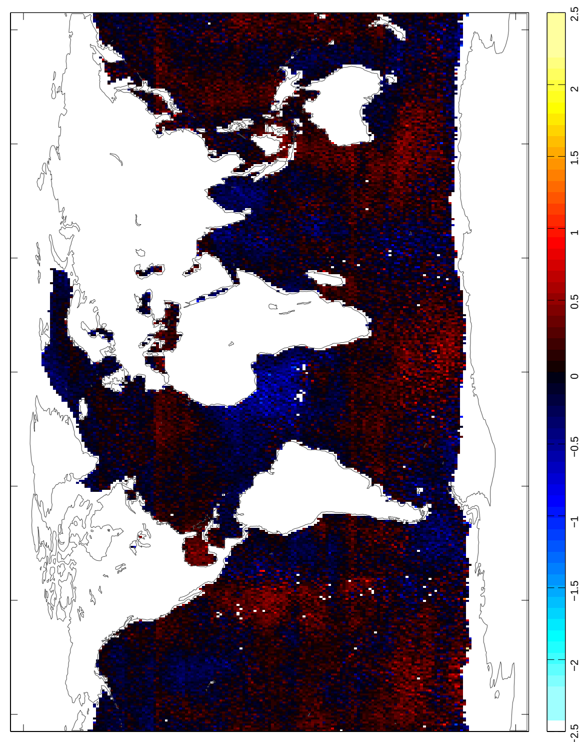

Figure 7. Harris and Kelly bias-corrected innovations, NOAA-16 AMSU-A Channel 10

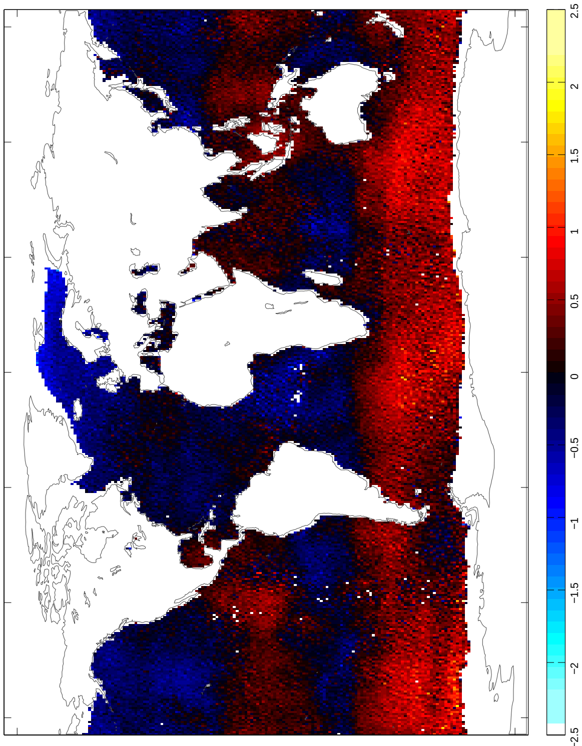

Figure 8. NRL test bias-corrected innovations, NOAA-16 AMSU-A Channel 10

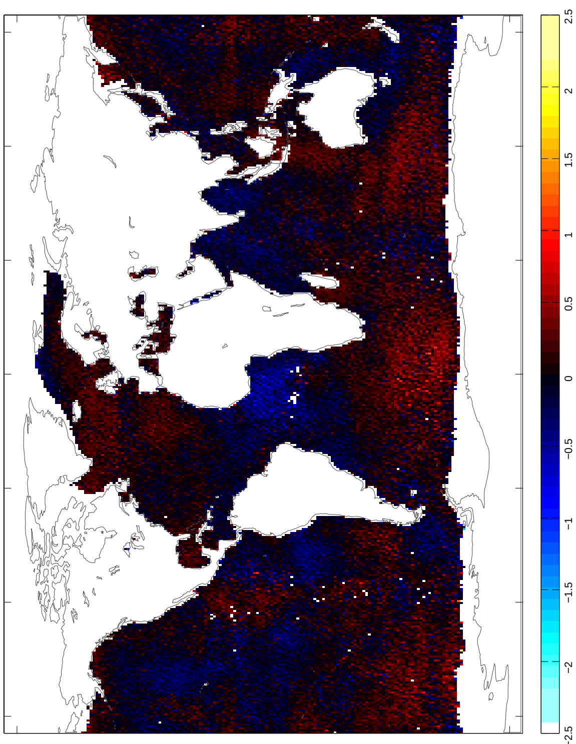

Figure 9. Campbell bias-corrected innovations, NOAA-16 AMSU-A Channel 10.

Figures 6 through 9 show the same maps for AMSU-A channel 10, whose weighting function peaks at approximately 50 hPa. Both of the global schemes, Eyre (figure 6) and NRL test (figure 8), have a great deal of trouble in the Southern Ocean, and broad patterns of bias near the ITCZ. The banded regression models perform much better, although the presence of linear artifacts is clear in the Harris and Kelly model (figure 7).

4. SUMMARY

In order to comprehensively evaluate how well a bias correction scheme performs, it is necessary to run the full prediction/assimilation system in which it is embedded. For many channels, a scheme that uses multiple regressions seems to be better than a single global regression, although it remains to be seen how much impact linear artifacts along the band boundaries have on subsequent bias correction and variational assimilation. Judicious choice of predictors can have a positive impact on rms error in some channels, as seen in the NRL test case for cloud liquid water; however, the use of moisture variables for bias correction is controversial, and may adversely affect performance. Hybrid methods appear quite promising, and we will soon be able to evaluate a variety of different models for the NOGAPS/NAVDAS prediction/assimilation system here at NRL. We hope to generalize such methods to better address future bias correction problems that will arrive with the next generation of satellite sensors.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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