Evaluation of the Relative Contribution of Observing Systems in Reanalyses: Aircraft Temperature Bias and Analysis Innovations

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1. Motivation

Studies have shown that aircraft temperature measurements are biased warm (Cardinali et al (2002) and Ballish and Kumar et al. (2008). Using a new collection of data from the Modern-Era Retrospective-analysis for Research and Applications (MERRA) that includes the assimilated observations and forecast departure, we collocate 34 years of aircraft observations with radiosondes to evaluate the analysis (see Figure 1).

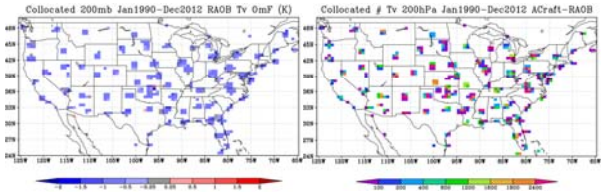

Figure 1 23-year average collocations forecast departure of the radiosonde 200mb temperature as collected in GIO bins. A negative forecast departure signifies RAOBs are colder than the forecast (and analysis). Some grid boxed with low data counts have been dropped for representativeness. The data counts are presented in the right figure.

2. Observations and Forecast Departure

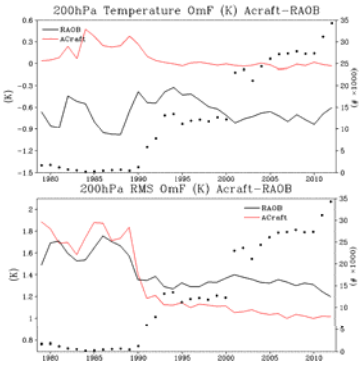

Figure 2 Mean temperature forecast departure (O-F) and RMS of the departure, monthly averages of collocated observations. The data count of the collocations is provided as dots for reference. (MDCRS starts in 1991, and MERRA begins using NCEP CDAS data for input in 2001)

The time series of forecast departure shows generally lower values for aircraft, even if data counts are low. The aircraft data are always warmer than radiosonde on averages (Figure 2).

3. Effective Gain and Contextual Bias

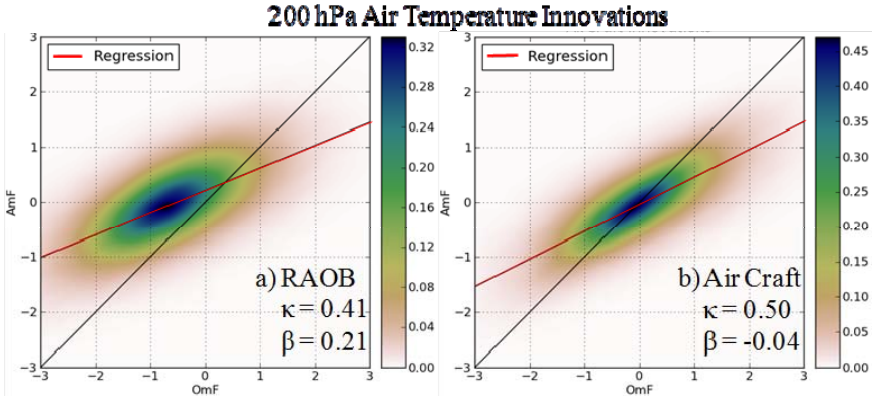

Figure 3 Six-hourly A-F and O-F from aircraft observations that are collocated with radiosonde measurements at 200mb over the United States for the period of 1991-2009 to solve the equation below for Gain and Bias.

Gridded Innovations and Observations (GIO)

The MERRA GIO collection of data includes the conventional and radiance observations that have been assimilated, and the forecast departure (O-F) and analysis departure (O-A). These provide useful statistics to evaluate the model and analysis (Rienecker et al. 2011). Here, we evaluate US radiosondes and aircraft.

$$A\text{-}F = \kappa(O\text{-}F) + \beta$$

where β represents the bias of each observing system against the full observational analysis, and κ which represents the gain, how much that observation contributes to the analysis. Solved through linear regression.

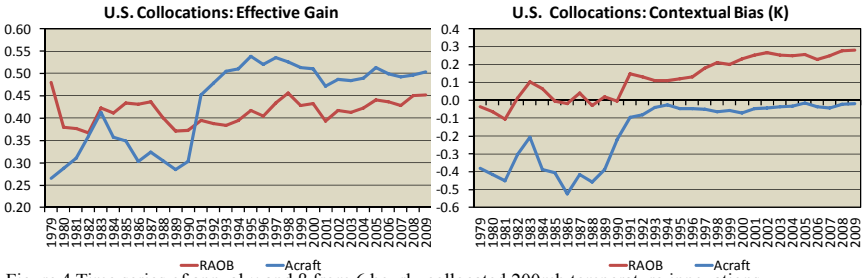

Figure 4 Time series of annual κ and β from 6 hourly collocated 200mb temperature innovations.

The κ and β show that before large volumes of aircraft observations, radiosondes influence the analysis (Figure 4). After aircraft volume increases RAOB bias increases and aircraft gain increases. It is also worth noting that despite the significant change in data volume, the RAOB effective gain maintains consistent values for the period. The ongoing effort aims at incorporating radiance data (Figure 6).

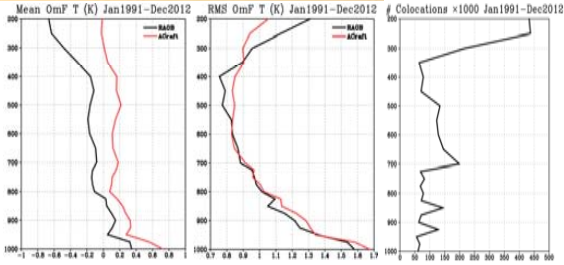

Figure 5 Mean vertical profiles of collocated temperature OmF, RMS OmF and data count. Low OmF and RMS OmF demonstrate the influence of Aircraft observations in the upper levels where they cruise. Lower levels have much fewer collocations and the statistics are more comparable.

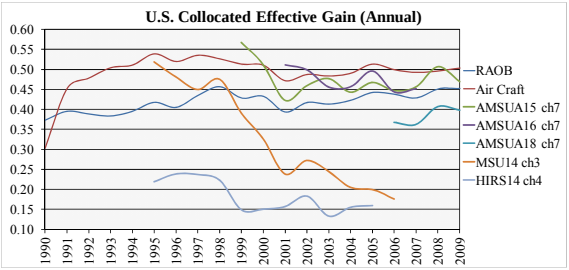

Figure 6 Effective Gain for several upper troposphere peaking channels assimilated along side of aircraft and RAOB observations.

4. Summary

Observations are the critical resource for reanalyses, yet many instruments can measure the same or similar quantities. The observations can be evaluated for the full reanalysis using GIO. More evaluation of the data is needed to better understand the interactions with radiance obs (Figure 6).

6. References

Ballish, B. A., and V. K. Kumar, 2008: Systematic Differences in Aircraft and Radiosonde Temperatures. Bulletin of the American Meteorological Society, 89, 1-20.

Cardinali, C., L. Isaksen, and E. Andersson, 2003: Use and Impact of Automated Aircraft Data in a Global 4DVAR Data Assimilation System. Monthly Weather Review, vol. 131, issue 8, p. 1865, 131.

Rienecker, M. R. and co-authors, 2011: MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. J. Climate, 24, Iss. 14, pp. 3624–3648.

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