AN EXAMINATION OF A DATA-CONSTRAINED ASSIMILATION

Wesley Ebisuzaki [(1)(2)], Robert Kistler [(3)]

(1) Climate Prediction Center, NCEP, Washington, DC, 20233, USA
(2) Research and Data Systems, Greenbelt, MD, 20770, USA
(2) Environmental Modeling Center, NCEP, Washington, DC, 20233, USA
E-mail: ebis@wesley.wwb.noaa.gov

A goal of the various reanalysis efforts is to produce consistent analyses by using a consistent assimilation system. That has helped tremendously in reducing the spurious "climate" shifts that were seen in earlier analyses. However, smaller but still spurious "climate" shifts were found in reanalysis data sets. These shifts were traced back to changes in the observational network such as the introduction of satellites, the widespread availability of aircraft data and even changes with the surface stations. One suggestion to reduce these spurious climate shifts is reanalyze the data with a "fixed" observing network. Of course, it is not practical to use a truly fixed observing network as, for example, a large fraction of the observing stations have changed locations and others have changed radiosonde types. Either factor could introduce a bias into the analyses. Nevertheless, one can wonder whether analyzing using an approximately fixed observing network would be a worthwhile. In our study, we have compared an assimilation for 1998 made without which aircraft and satellite data (the circa 1958 network had no satellite and essentially no aircraft data) with similar assimilations that use all the available data. We will show the impacts as a function of the time scale.

The three assimilations used are (1) the NCEP/NCAR Reanalysis (R1, only data from 1979-1998 used), (2) NCEP/DOE AMIP-II Reanalysis (R2, only data from 1979-1992 were used) and (3) X58, an assimilation for 1998 which is identical to R1 except that aircraft, PAOBS and satellite data were not used. R1 serves as the control, R2 shows the effect of modest improvements in the data assimilation system and X58 shows the basic impact of the modern observing systems. (It is realized that there has been a tremendous increase in surface observations, for example, and that a more accurate assessment would require keeping the regional observation densities constant with time.)

The impacts of the improved model (R2) and satellite and aircraft data (X58) depend on the time scale. For example, Figs. 1a, 2a and 3a show the RMS difference between R2 and R1 (500 hP temperature) scaled by the climatological standard deviation of the instantaneous (1a), monthly means (2a) and annual means (3a). Figs. 1b, 2b and 3b are similar to 1a, 2a and 3a, respectively, except that they show the difference between X58 and R1. In Figs. 1a and 1b, the Northern hemisphere land areas have small unexplained variances. This corresponds to condition "A" in the following table. In these figures, the equatorial region has large unexplained variances. This suggests that either the current observational network is insufficient to resolve the temperatures or that current assimilation system is unable to use the current observed data to determine the temperatures accurately (condition "D" in the table). In the Southern mid-latitudes, it appears that the current observational network is able to resolve daily to annual variability whereas the X58 is deficient especially in the annual means (condition "B" in the table).

The analyzed precipitation from these assimilations is model derived so it is not surprising that unexplained variance (Fig. 4) is much higher than for the 500 kP temperatures (Fig. 1). (Note that regions without rain in the respective December are shaded white.) What is surprising is that X58 had better results than R2 for the monthly and annual means in the Northern hemisphere continents (Figs. 5 and 6, respectively). This corresponds to condition "C" in the table which states that there is enough data in the circa 1958 network but the results are sensitive to the data assimilation system. In the case of the precipitation, knowing the annual-mean atmospheric water flux gives you a good estimate of the precipitation. The models will give different results because of different amounts of evaporation and moisture increments (an artificial source term needed for assimilation system budgets).

In conclusion, we have looked at three assimilations in order to estimate errors in a circa 1958 analysis and the current analysis. The differences between the analyses depend strongly on the time scale. For the annual means, the circa 1958 analysis is expected to have large errors over much of the globe (Fig. 3b). This suggests that trend studies using NCEP/NCAR Reanalysis should be restricted to Australia, New Zealand, North America, Asia and Europe. Encouraging is that the current observational network is able to resolve both mid-latitudes on all examined time scales. Also encouraging is that we found some derived variables (ex. precipitation) are resolved by the circa 1958 network so that with further improvements in the data assimilation systems, one could hope very reasonable analyses.

Table

	X58 small unexplained variance	X58 large unexplained variance
R2 small unexplained variance	A: resolved by 1958 data, analysis system improvements yield small improvements	B: resolved by 1998 data but not by 1958 data
R2 large unexplained variance	C: resolved by 1958 data, analysis system improvements can yield large improvements	D: (a) not resolved by 1998 data or (b) analysis system does not use existing data well

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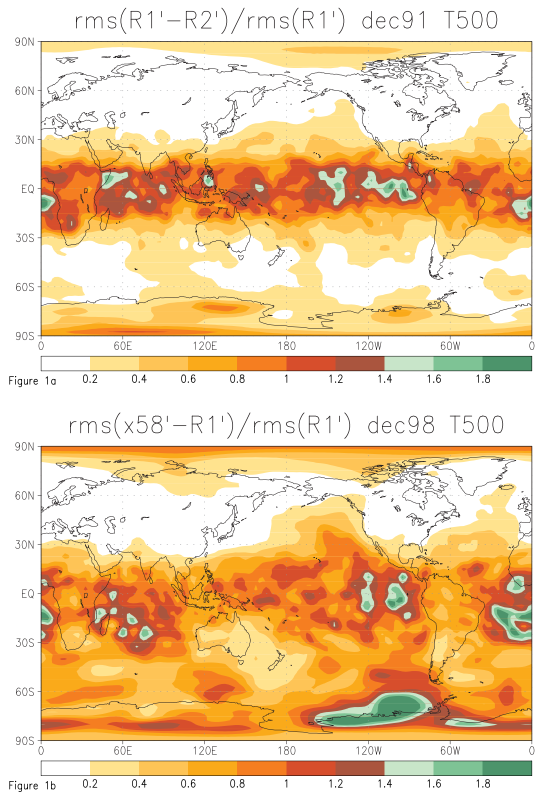

Figure 1 (a) RMS(T_{R1}' - T_{R1}') / RMS(T_{R1}') for December 1991 where T_Y' is the anomaly of the 500 hPa temperature from the December 1991 mean for assimilation Y and RMS(x) is the value of "x" averaged over the month. Smaller values correspond to areas where the R2 assimilation has little unexplained variance. (b) RMS(T_{X58}' - T_{R1}') / RMS(T_{R1}') for December 1998 where T_Y' is the anomaly of the 500 hPa temperature from the December 1998 mean for assimilation Y and RMS(x) is the value of "x" averaged over the month.

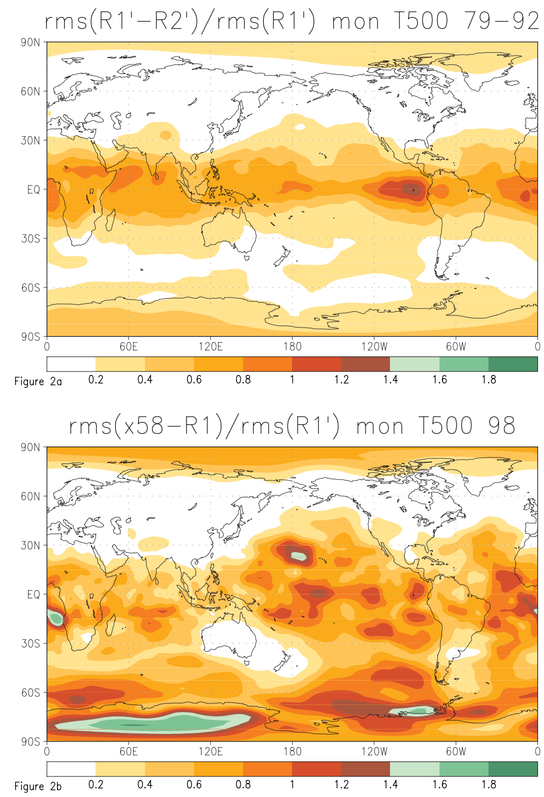

Figure 2 (a) RMS(T_{R2}' - T_{R1}') / RMS(T_{R1}') for 1979-1992 where T_Y' is the anomaly of the 500 hPa monthly mean temperature from the 1979-1992 climatology for assimilation Y and RMS(x) is the value of "x" averaged from 1979-1992. (b) RMS(T_{X58} - T_{R1}) / RMS(T_{R1}') for 1998 where T_Y is the 500 hPa monthly mean temperature from assimilation Y, T_Y' is the anomaly of T_Y from the 1979-1998 R1 climatology and RMS(x) is the value of "x" averaged from 1979-1998.

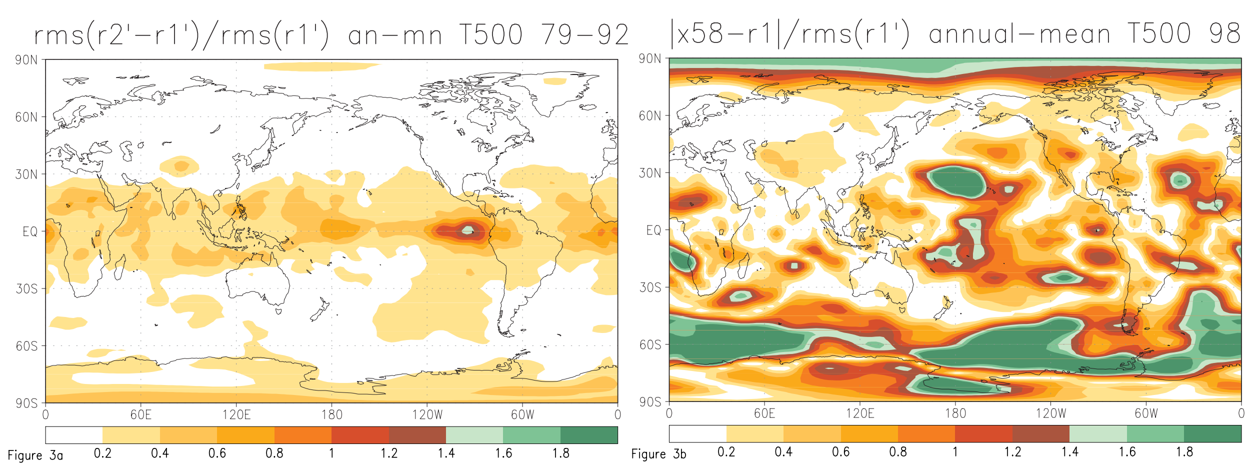

Figure 3(a) RMS(T_{R2}' - T_{R1}') / RMS(T_{R1}') for 1979-1992 where T_Y' is the anomaly of the 500 hP annual mean temperature from the 1979-1992 climatology for assimilation Y and RMS(x) is the value of "x" averaged from 1979-1992.(b) abs(T_{X58} - T_{R1}) / RMS(T_{R1}') for 1998 where T_Y is the 500 hP annual mean temperature from assimilation Y, T_Y' is the anomaly of T_Y from the 1979-1998 R1 climatology and RMS(x) is the value of "x" averaged from 1979-1998.

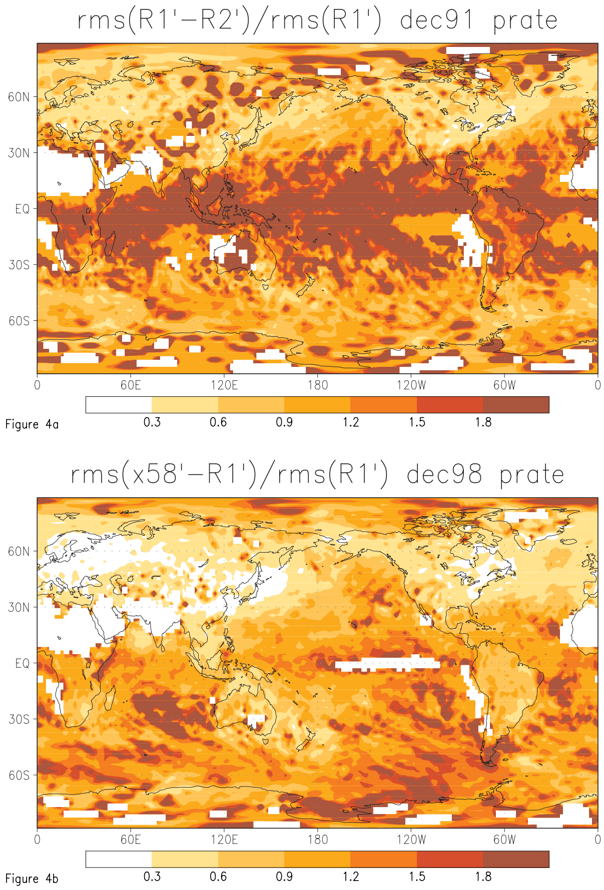

Figure 4: Like figure 1 except precipitation is shown.

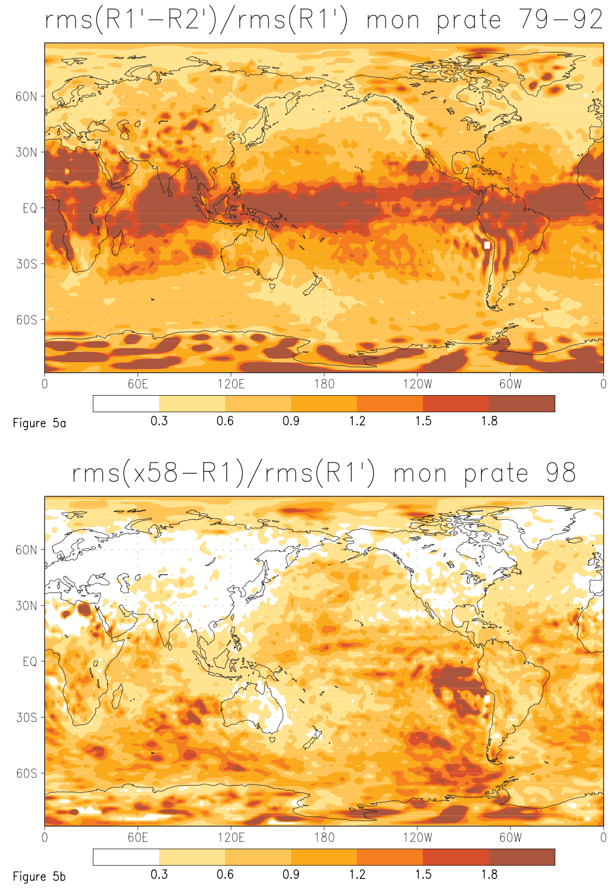

Figure 5: Like figure 2 except precipitation is shown.

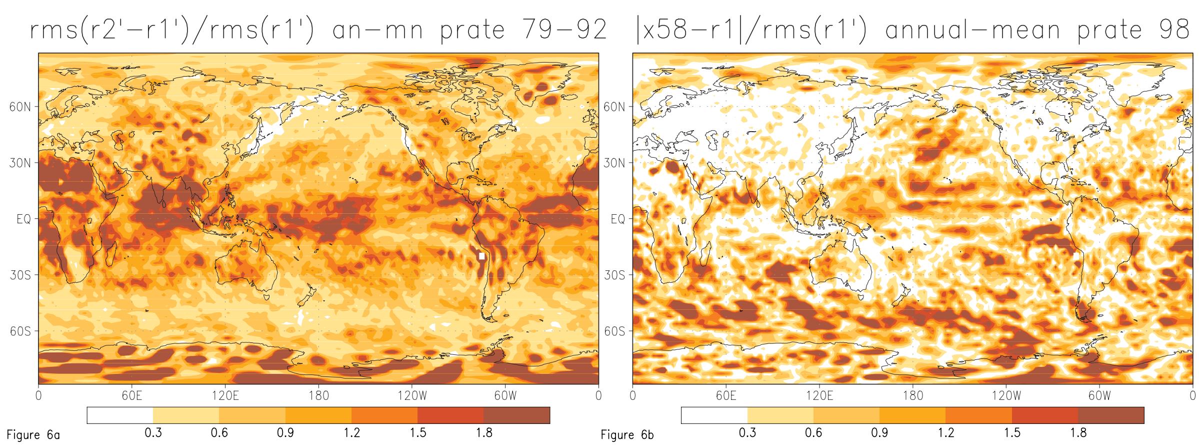

Figure 6: Like figure 3 except precipitation is shown.