Sensitivity of the Vertical Velocity and Advective Tendencies Analyzed Over the ARM SGP Site to Input Data and Analysis Methods

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Introduction

The main problem in deriving accurate objective analysis from a field experiment is the insufficient sampling of measurements, attributed not only to invalid or missing measurements, but also to scale aliasings. The actual measurements contain information of all scales including those that the observational network cannot resolve. Thus, it is not always appropriate to directly use point measurements to extract area-mean quantities. Limitation in the accuracy of instruments and measurements is another source of concern. When a field experiment is conducted in a small region, instrument and measurement errors can have a large impact on the derivative fields.

After the completion of GATE (Global Atmospheric Research Program [GARP] Atlantic Tropical Experiment) in 1969, Ooyama made a five-year concentrated effort to analyze the GATE data (Ooyama 1987). For the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE), Lin and Johnson (1996) used several methods to analyze sounding measurements. They used the Barnes interpolation scheme in the final analysis (Barnes 1964). Frank et al. (1997) also analyzed the TOGA-COARE data but used the line-integral method. Moisture budget from their analysis is very different from that in Lin and Johnson. For example, the intensive observation period (IOP) mean of diagnosed precipitation is 10.5 mm to 11.8 mm day-1 in Frank et al. (1997) versus 5.7 mm to 6.1 mm day-1 in Lin and Johnson (1996). This magnitude of uncertainty is likely to be typical of most existing objective analyses. Uncertainties in the transient data are even larger. Continued efforts are therefore needed to improve these analyses. This study reports sensitivities of the Atmospheric Radiation Measurement (ARM) Program objective analyses to the use of different input data and different analysis schemes. To highlight the impact of the ARM variational constraining procedure (Zhang and Lin 1997) on the sensitivities, we present results for analyses with the Obrien type of mass conservation constraint only, and with the full conservation constraints of mass, moisture, energy, and momentum.

Sensitivity Results

Four sets of experiments are carried out. The first set of experiments is designed to test the impact of the free parameters in the Barnes and Cressman schemes on the analysis, namely the length scale and the number of iterations. The second set of experiments is designed to examine the sensitivity of the analysis to the use of the Barnes scheme, the Cressman scheme, and the statistical interpolation scheme. The third set is to test the sensitivity of the analysis on the availability of input data, including profiler data, sounding data, and rapid update cycle (RUC) output. The fourth set tests the sensitivity of the data on the constraint variables from surface measurements and on the weighting coefficients in the variational cost function.

For brevity, we only present results by using the analyses from the Barnes scheme, and from using different data sources. The reader is referred to Zhang et al. (1999) for more results. The vertical velocities for the July 1995 ARM IOP from the Barnes scheme, analyzed with mass constraint only, are shown in Figure 1. In Figure 1a, only one iteration is performed in the Barnes scheme with a four-dimensional length scale of (Lx = 50 km, Ly = 50 km, Lp = 50 mb, Lt = 3 hr). Figure 1b is the same except that a larger length scale of (Lx = 100 km, Ly = 100 km, Lp = 50 mb, Lt = 6 hr) is used. Figure 1c is the same as Figure 1b except with three iterations. It is seen that much smoother and weaker vertical velocity is produced with a larger length scale, and with less iteration. It is noted that the difference in the vertical velocity is significant between the analyses (e.g., the intensity of the continuous upward motion after day 212).

Figures 1d-f show analyses of vertical velocity corresponding to the same three experiments except with all constraints imposed. It is seen that most events in these three figures are also qualitatively present in Figures 1a-c. Quantitatively, however, they are very different from those in Figures 1a-c. The analyses of vertical velocity in Figures 1d-f are intrinsically consistent with the surface and top of atmosphere (TOA) measurements of precipitation and energy fluxes. It is also seen that use of the surface and TOA measurements significantly reduces the sensitivity of the analyses. We note also that differences still exist between the analyses, which could be large for some applications. For example, the upward motion in day 203 in Figure 1e is much weaker than that in Figure 1d.

We now show results with using only sounding data, only profiler data, and the RUC model output as our upper air data sources. Figures 2a-c show the analysis with mass constraint only from using (a) sounding data only, (b) profiler data only, and (c) RUC model output. Since the profiler data are only available for winds, analyses of temperature and water vapor in Figure 2b are taken from RUC. It is seen that the analysis from using the profiler data alone is very different from that by using all data, especially in the last period. The vertical velocity from the profiler data alone is too weak. It even missed the major event in the last period.

Figures 2d-f show the same analysis of vertical velocity when all constraints are used. The differences from using the different data sources are reduced. Substantial difference, however, still exists. For example, the upward motion from using the profiler data alone appears to be at a lower altitude than that in the sounding data. These differences are more clearly seen in the wind divergence field (not shown). The variational procedure has adjusted the profiler winds to force an upward motion. Yet, the largest

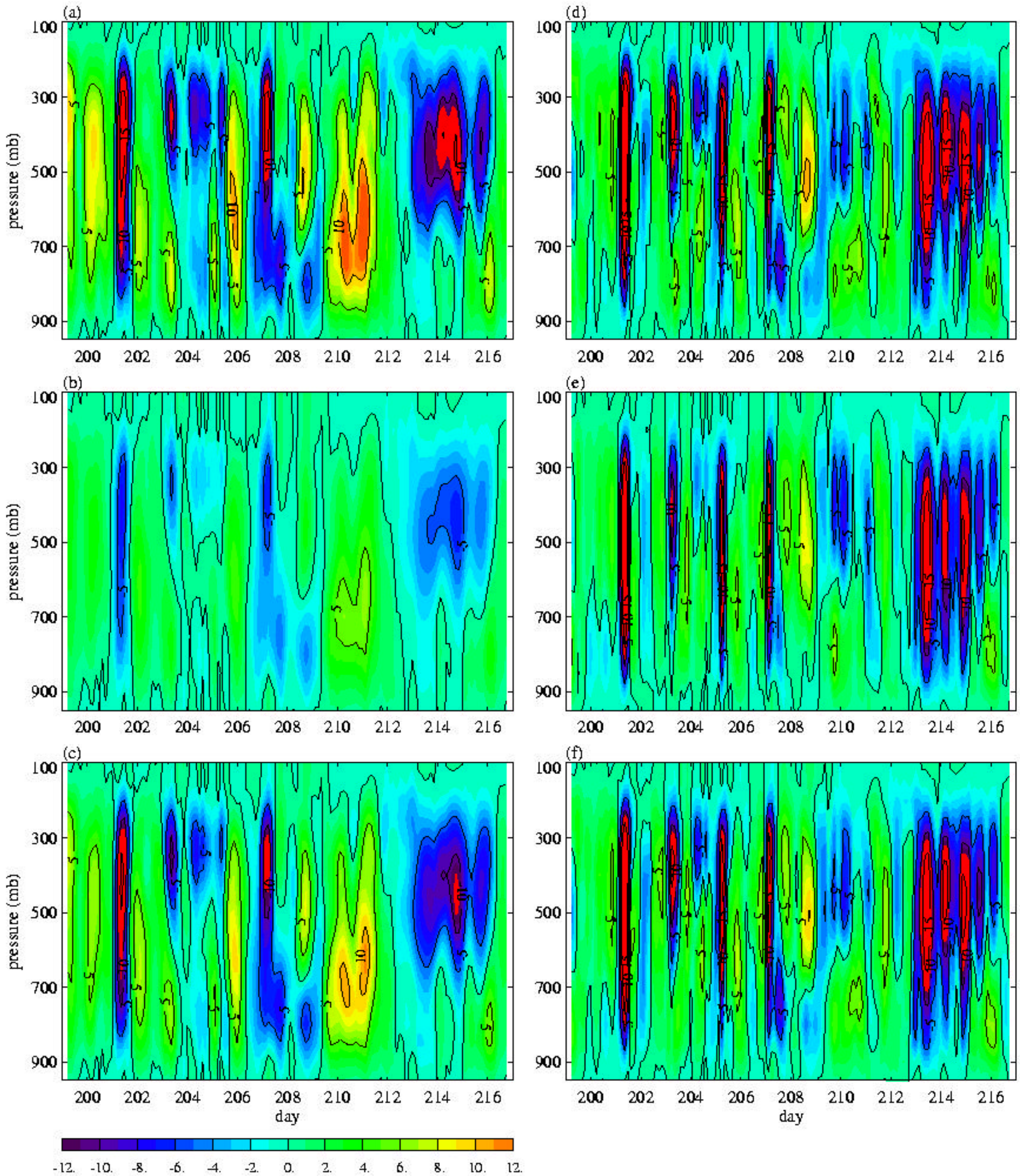

Figure 1. Sensitivity of the analysis of vertical velocity (mb hour-1) to the implementation of the Barnes scheme. (a)-(c): with mass balance constraint only. (a) (Lx, Ly, Lp, Lt) = (50 km, 50 km, 50 mb, 3 hr), first iteration. (b) (Lx, Ly, Lp, Lt) = (100 km, 100 km, 50 mb, 6 hr), first iteration. (c) (Lx, Ly, Lp, Lt) = (100 km, 100 km, 50 mb, 6 hr), three iterations. (d)-(f): same as (a)-(c) except with all constraints imposed.

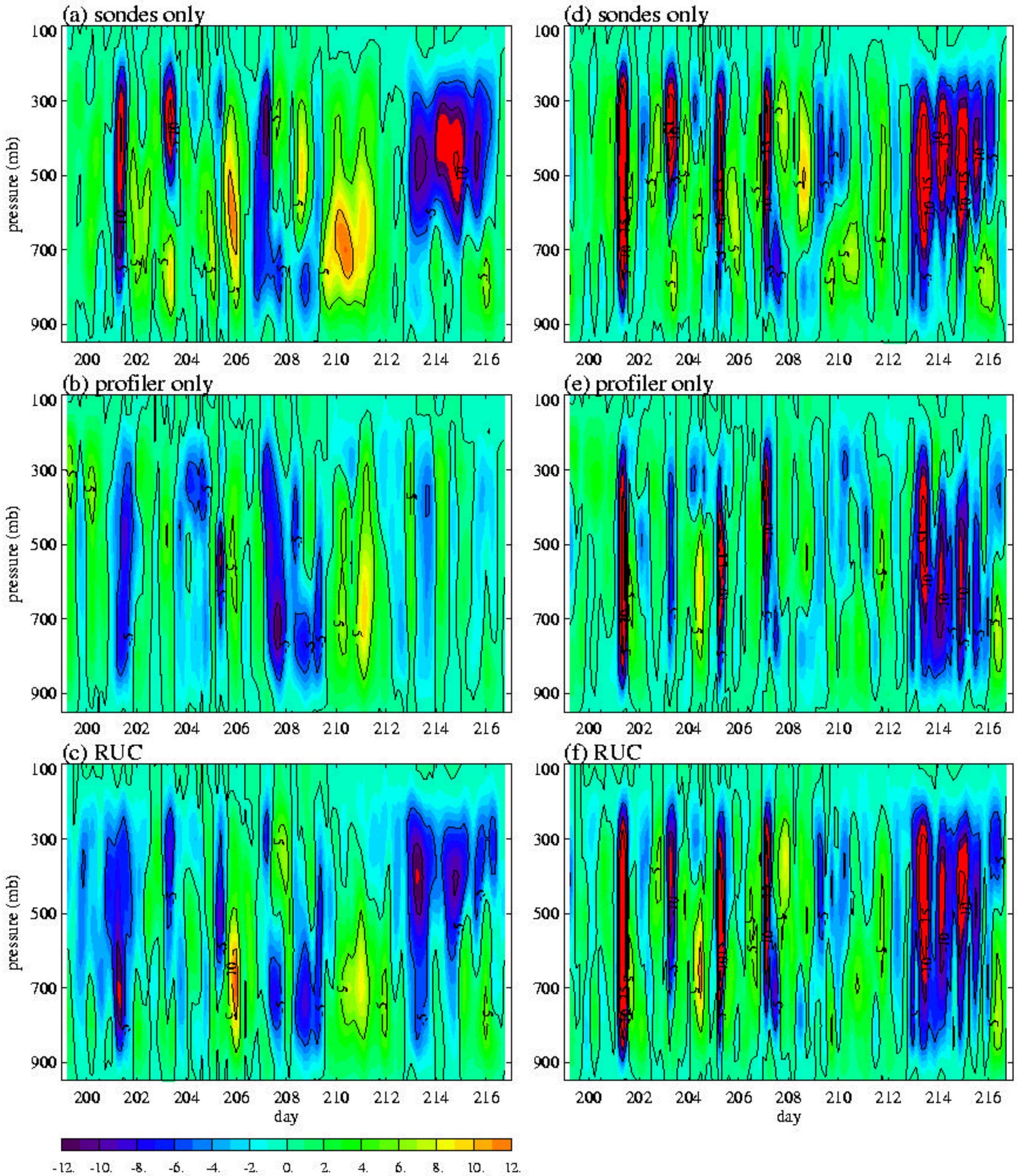

Figure 2. Sensitivity of the analysis of vertical velocity (mb hour-1) to upper air data sources. (a)-(c): with mass balance constraint only. (a) sounding data alone, (b) profiler data alone, and (c) RUC analysis. (d)-(f): same as (a)-(c) except with all constraints imposed.

adjustments are made near the surface where adjustment to the water vapor balance is most efficient. Thus, the variational constraints can reduce the sensitivity of the data product, but it can not substitute for the quality of the original upper air data.

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