Improvements in the Lawrence Livermore National Laboratory Objective Analysis Scheme for Deriving Forcing Fields for Single-Column Models Using Atmospheric Radiation Measurement Data

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Introduction

The objective analysis method used for deriving Single-Column Model (SCM) forcing fields with Atmospheric Radiation Measurement (ARM) data (Leach et al. 1996) is undergoing continual improvement. Several improvements were identified at the SCM Workshop held at Lawrence Livermore National Laboratory (LLNL) in April 1996. These include incorporating large-scale analyses in the objective analysis, and time-filtering input data streams.

Methodology

The objective analysis uses temperature, moisture, and horizontal winds from readings taken every 3 hours from radiosondes launched from points indicated in Figure 1. Horizontal winds are incorporated from National Weather Service (NWS) profilers, also indicated in Figure 1. The domain of the objective analysis is outlined in the figure.

One of the improvements involves use of large-scale analyses, which we obtain from the NWS Rapid Update Cycle (RUC) numerical weather prediction model (Benjamin et al. 1991). This model has 60-km horizontal resolution and assimilates data every 3 hours. The grid points where we extracted numerical soundings for use in our objective analysis are indicated in Figure 1. The RUC analyses provide large-scale information that tempers the spatial gradients based on the local information alone.

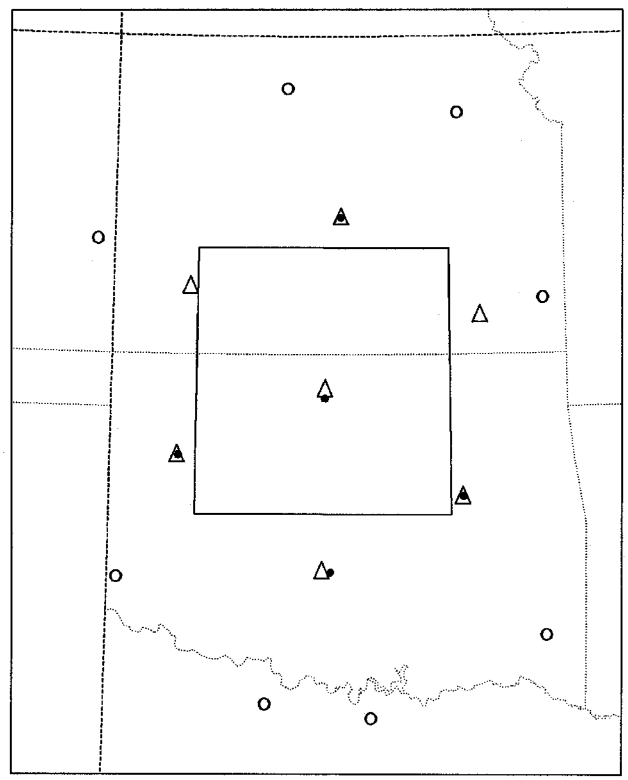

Figure 1. Location of ARM radiosonde launching points (dots), NWS profilers (triangles), and RUC grid points (circles) used in the objective analysis (domain outlined).

The temporal-filtering is accomplished by a Gaussian filter, with a standard deviation of 6 hours and a window of plus or minus 24 hours. The standard deviation and window width can be varied. We selected these values to filter the high-frequency temporal fluctuations in the gradient-based quantities, while still preserving diurnal effects in the SCM forcing.

Results

Objective analysis values with and without RUC boundary points were compared with objective analyses based only on RUC grid points beyond and within the SGP site domain. The RUC-only analysis provides a reference for comparison, but is not viewed as "truth." Mean quantities were highly correlated regardless of whether RUC boundary points were used. Quantities involving spatial gradients showed the effect of using the RUC boundary points. Scatter plots for the temperature advective tendency illustrate how the RUC large-scale analyses strongly influence the spatial gradients toward the RUC-only values (see Figures 2a and 2b).

Correlations were calculated for the above scenarios versus the RUC-only analyses for mean quantities (horizontal wind components, temperature, and specific humidity) and quantities involving gradients (horizontal wind divergence, vertical velocity omega, and advective tendencies of temperature and specific humidity), and are given in Table 1. The first column is without RUC boundary points, the second is with RUC boundary points, and the third is like the first, except a time filter is used. As mentioned previously, the mean quantities are highly correlated, regardless of the scenario. For the gradient quantities, it is not surprising that the correlation is best when the RUC boundary points are used. The time filter marginally improves the Cloud and Radiation Testbed (CART)-only analyses in relationship to the RUC-only reference.

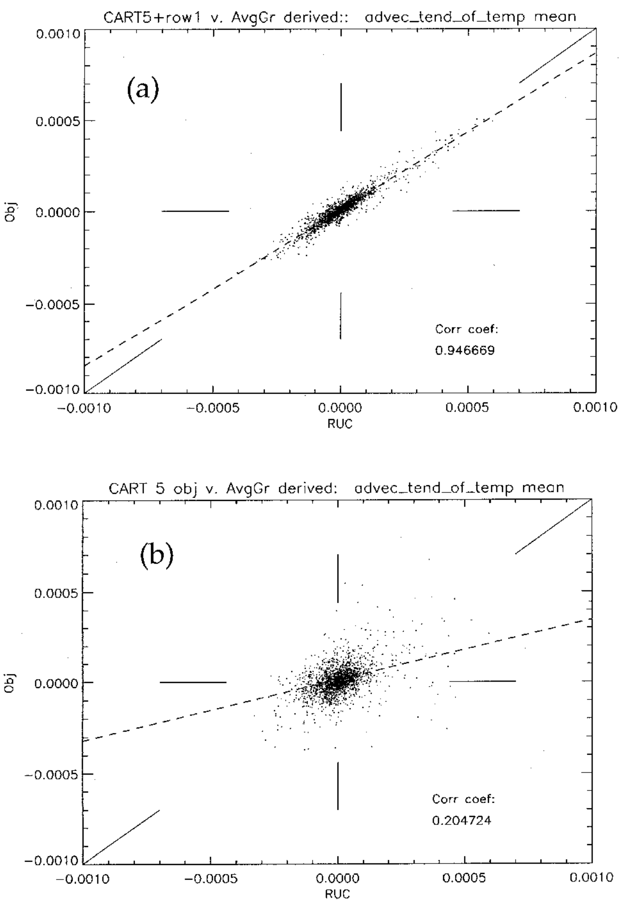

Figure 2. Scatter plots of temperature advective tendency for RUC-only objective analyses versus objective analyses (a) with and (b) without RUC boundary points.

Table 1. Correlation Coefficients Between LLNL Objective Analysis Versions and RUC-only SCM Derived Fields.

Derived Field	CART only	CART plus RUC	CART with time filter
u wind component	0.96	0.98	0.96
v wind component	0.92	0.98	0.93
temperature	1.00	1.00	1.00
specific humidity	0.98	0.99	0.99
wind divergence	0.32	0.85	0.38
vert. vel. (omega)	0.30	0.72	0.43
temp. advect. tend.	0.20	0.95	0.61
humid. advect. tend	0.43	0.92	0.35

The Gaussian time filtering is a low pass filter, retaining features with longer time scales, while eliminating shorter time scale information. The effects of the time filtering are shown in Figures 3 and 4. Time-height sections of the mean specific humidity, unfiltered and filtered, are presented in Figure 3a and 3b, respectively. The unfiltered field contains significant features which appear as small-scale variability. It is not clear whether these small-scale features are truly physical phenomena or are noise due to errors either in the observations or the analysis technique. Because of this, it is assumed that they are noise. Among the features that are on a larger scale, a diurnal cycle is obvious. The purpose of the time filtering is to preserve information that is large scale, including the diurnal cycle, while eliminating the small-scale features. The effect of the Gaussian time filter is obvious (Figure 3b). Much of the small-scale variability has been eliminated, but the large-scale features, including the diurnal cycle, are retained.

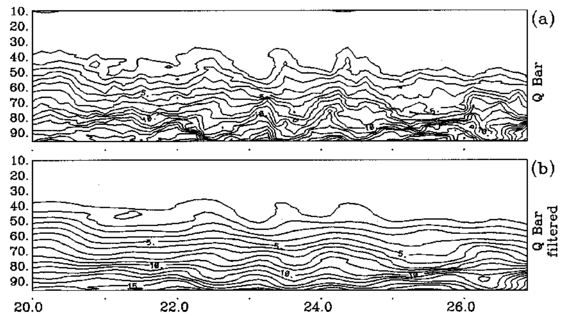

Figure 3. Time-height sections of (a) unfiltered and (b) time-filtered mean specific humidity for 7/20 - 7/26/95; pressure (vertical coordinate) is in kPa, and specific humidity is contoured in increments of 1 g/kg.

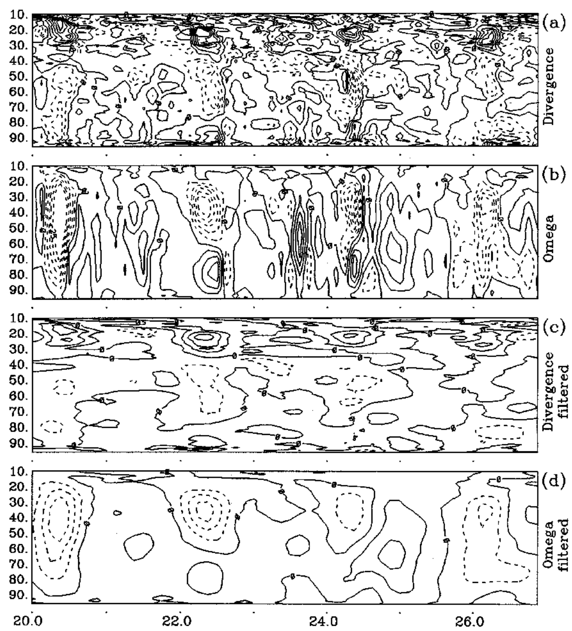

Figure 4. Time-height sections of *unfiltered* (a) divergence and (b) vertical velocity, and *time-filtered* (c) divergence and (d) vertical velocity for 7/20 - 7/26/95; pressure (vertical coordinate) is in kPa; divergence is contoured in increments of 0.05 hr^{-1}, and vertical velocity in increments of 5 hPa/hr.

To further illustrate the effect of the time filtering, divergence, and vertical velocity, omega time-height sections are presented in Figure 4. These variables are derived quantities, rather than directly observed. As derived quantities, they are subject to greater error (Mace and Ackerman 1996) due to the small-scale, unresolved features and errors which appear as noise. In Figures 4a and 4b, we show the unfiltered divergence and vertical velocity, while in Figures 4c and 4d, we show the filtered fields. The effect of the filtering is again obvious. The filtering eliminates the small- scale features while preserving the large-scale phenomena. However, the amplitude of the large-scale features is reduced.

Summary

Improvements have been made in the LLNL objective analysis scheme that address issues of spatial and temporal representativeness. The incorporation of large-scale analyses via the RUC model output reduces extreme values of the spatial gradients. Similarly, time-filtering the input data streams results in more well-behaved SCM forcing fields.

Work is continuing on evaluating the impact of these improvements in the objective analysis on simulations with SCMs. An SCM Intercomparison is planned that will provide additional information on the sensitivity of various SCM formulations to the objectively-analyzed forcing fields. We plan to implement the variational analysis method of Zhang and Lin (1997); results of their analysis will be used in the SCM Intercomparison.

Acknowledgments

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References

Benjamin, S. G., K. A. Brewster, R. L. Brummer, B. F. Jewett, T. W. Schlatter, T. L. Smith, and P. A. Stamus, 1991: An isentropic three-hourly data assimilation system using ACARS aircraft observations. *Mon. Wea. Rev*., **119**, 888-906.

Leach, M. J., J. J. Yio, and R. T. Cederwall, 1996: Estimation of errors in objectively analyzed fields and sensitivity to number and spacing of stations. *Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, pp. 149-151. CONF-9603149, U.S. Department of Energy, Washington, D.C.

Mace, G. G., and T. P. Ackerman, 1996: Assessment of error in synoptic-scale diagnostics derived from wind profiler and radiosonde network data. *Mon. Wea. Rev*., **124**, 1521-1534.

Zhang, M. H., and J. L. Lin 1997: Constrained variational analysis of sounding data based on column-integrated budgets of mass, heat, moisture, and momentum: Approach and application to ARM measurements. *J. Atmos. Sci*., **54**, 1503-1524.