Published in the preprint volume of the SEVENTH CONFERENCE ON SATELLITE METEOROLOGY AND OCEANOGRAPHY, June 6-10, 1994, Monterey, CA, by the American Meteorological Society, Boston, MA.

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ANALYSIS OF MESOSCALE SATELLITE SOUNDINGS WITH AND WITHOUT CLUSTERING

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1. INTRODUCTION

Satellite sounding data collected during May of 1993 are being used to test clustering as a means of improving the analysis of mesoscale VAS satellite soundings. Clustering was developed to increase the signal-to-noise ratio of the satellite sounding radiance temperatures by grouping them optimally (Hillger and Purdom, 1990). Emphasis is upon detecting mesoscale temperature and water vapor features in the Colorado front range area (Hillger and Weaver, 1993). Analysis using clustering is compared with non-clustered, or blocked, retrievals for the same cases. Comparisons to surface observations and subsequent convective development are made, since no other mesoscale measurements are available.

Conclusions of this study are that satellite soundings have the ability to detect atmospheric characteristics significant for mesoscale analysis and forecasting and that clustering enhances the detection of mesoscale features above conventional analysis methods. Results for several case study days were analyzed, but due to space limitations only one case is shown.

2. DATA

During May of 1993 GOES VISSR Atmospheric Sounder (VAS) data were collected at short time intervals (1.5 h) during the morning hours. Several case study days were later analyzed to show how satellite soundings can be used to investigate the pre-convective environment for subsequent development of thunderstorms. Of the days analyzed, one case in particular proved to be very interesting. In this case the satellite soundings correctly identified areas of higher instability which turned into later convective development.

3. RESULTS FOR 13 MAY 1993

The one case presented is for 13 May 1993 (Julian day 133). As for all other days, VAS data were collected at about 1550 and 1720 UTC. Retrievals were performed at both times using clustering to optimize the signal-to-noise ratio of the data. Clustering, developed at CIRA, has also been used successfully by others to improve both research and operations (Rao, et al, 1993; Snook and Hillger, 1993).

Clustering is a method for grouping and averaging satellite data to increase the signal-to-noise ratio of the satellite measurements without destroying the mesoscale information in the measurements. Clustering also results in the need for fewer retrievals, but the outcome is to increase mesoscale detail over conventional blocking.

Figure 1a shows the clusters for 1720 UTC for the area being analyzed, which is the eastern portions of Colorado, Wyoming, and northern New Mexico, and the High Plains of South Dakota, Nebraska, and Kansas. Note that the clusters on this day are elongated north-south through central Colorado and New Mexico, showing that mesoscale features are aligned with the major mountain ranges in the area. Clouds in the mountains and to the west are not clustered.

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In contrast to the clusters, the blocks of 11x11 satellite measurements in Figure 1b are all the same size except for the blocks where cloudy Fields-of-View (FOVs) were eliminated.

The one parameter used to assess the potential for convective development is the equivalent potential temperature (commonly called theta-e) in the lowest 150 hPa of each sounding. This is the potential temperature an air parcel would have if all the latent heat was converted into sensible heat and the air parcel was taken to 1000 hPa.

Plots of the satellite-derived theta-e stability values at 1550 and 1720 UTC are shown in Figures 2a and b. Both figures show lower theta-e values on the high plains and the packing of more unstable (high theta-e) air up against the mountains. The air to the east is also unstable. From these two figures at separate times, it is hard to determine if there is a trend in the stability. A time-extrapolated field generated for 1900 UTC is shown in Figure 3. The extrapolated values are the highest in eastern Wyoming and extreme western South Dakota. Smaller areas of instability are just east of the southern Colorado front range, and an intense stability gradient exists in extreme eastern New Mexico. Users of this field, however, must realize that time-extrapolation alone does not take into account any advection of the mesoscale air masses being measured.

In contrast to the clustered retrieval method, satellite measurements have traditionally been averaged in 11x11 blocks to increase their signal-to-noise ratio. This blocking can smooth over gradients in the measurements. Figure 4 is the equivalent of Figure 3, a time-extrapolated field, but for blocked retrievals. The poorer resolution is apparent. Blocking results in a changed analysis of the region, with the most unstable air along the front range, but with less detail, and with the most unstable air in Colorado, not Wyoming or New Mexico.

4. SURFACE OBSERVATIONS AND VISIBLE SATELLITE IMAGE

For comparison to the satellite retrievals, surface observations were treated in a manner similar to the satellite measurements. Theta-e values were generated from the surface observations alone. The time-extrapolated field for 1900 UTC is shown in Figure 5. In contrast to the satellite analysis, the surface observations show the most unstable air along the front range only in extreme northern Colorado and on the Colorado/New Mexico border.

To show the outcome of a forecast on this day, the GOES visible image at 2000 UTC is given in Figure 6. As was most succinctly shown by the clustered retrievals, convective development forms close to the mountains along the front range of Wyoming and Colorado, with the most intense convection to the south in New Mexico.

5. CONCLUSIONS

From this case study and others tested, it is clear that clustering satellite measurements prior to producing retrievals, aids the analysis of low-level moisture on the mesoscale. Compared to blocked retrievals, the increase in detail is essential for the mesoscale forecaster, and compared to surface observations, the satellite adds useful information that is otherwise unavailable.

ACKNOWLEDGEMENTS: This research was sponsored by NOAA Grant NA85RAH05045.

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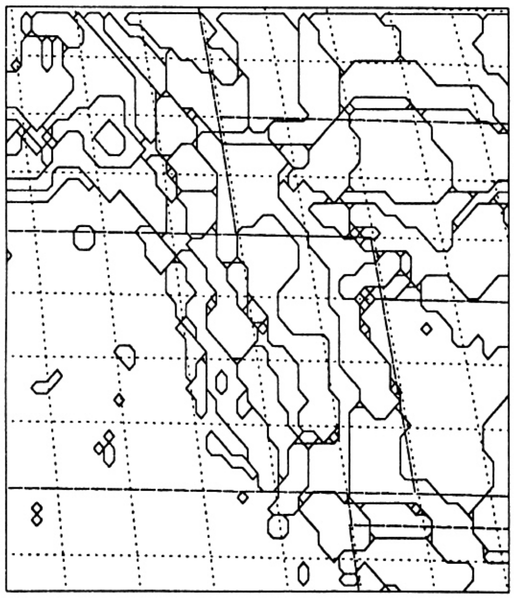

Figure 1a. Outlines of clusters of satellite measurements, groups of FOVs with similar measurements in all channels being analyzed. Some of the smaller clusters contain clouds, as does the blank area in western Colorado and New Mexico.

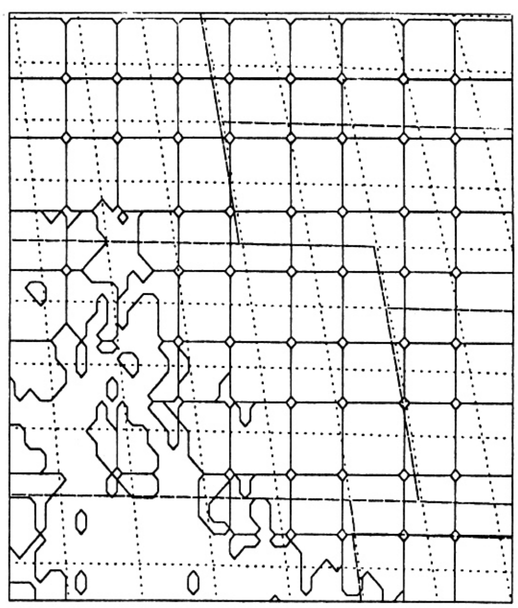

Figure 1b. Outlines of 11x11 blocks of satellite FOVs, except for FOVs which contain clouds. Such groups of FOVs are used to increase the signal-to-noise of single FOV satellite measurements.

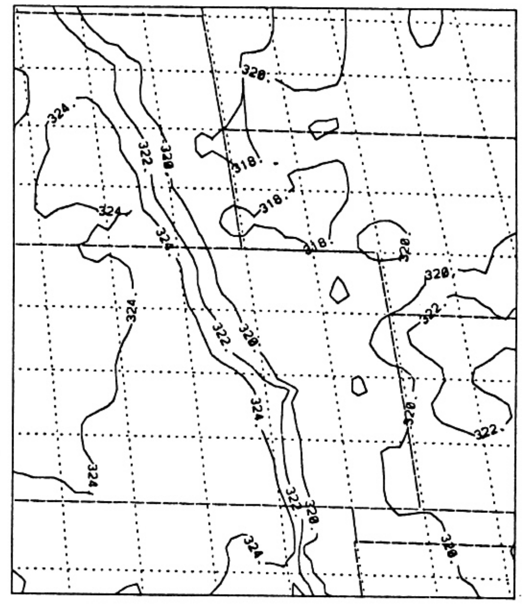

Figure 2a. Theta-e stability measurements from CLUSTERED satellite retrievals at 1550 UTC.

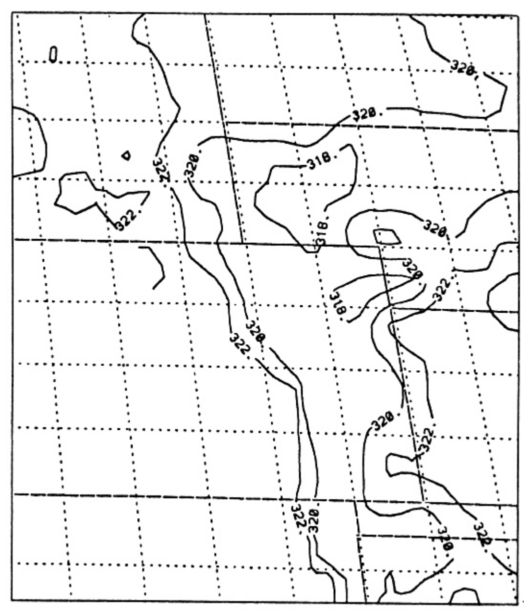

Figure 2b. Same as Figure 2a, except for 1720 UTC, about 1.5 h later.

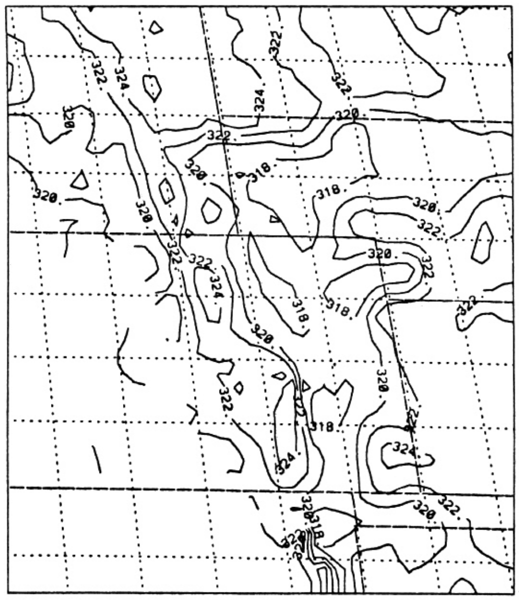

Figure 3. Theta-e stability from CLUSTERED satellite retrievals extrapolated to 1900 UTC (1.5 h after the last retrieval time).

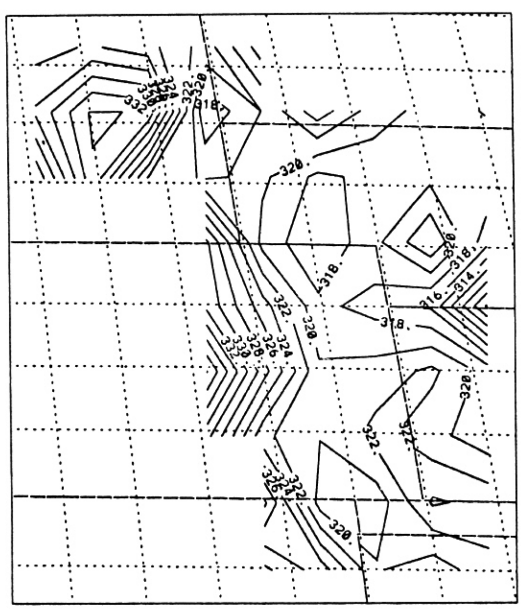

Figure 4. Theta-e stability from BLOCKED satellite retrievals extrapolated to 1900 UTC (1.5 h after the last retrieval time).

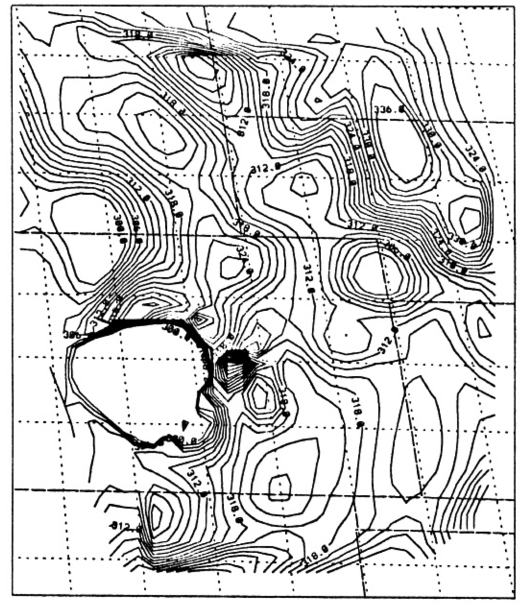

Figure 5. Theta-e stability extrapolated to 1900 UTC from surface observations at 1600 and 1700 UTC.

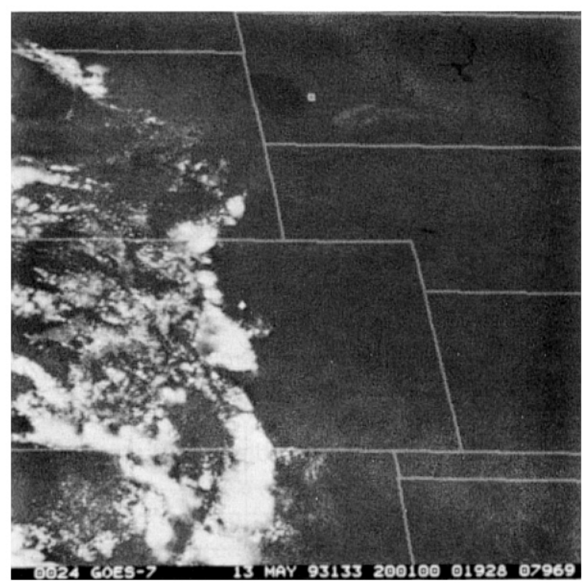

Figure 6. Visible satellite image at 2000 UTC, showing convection forming in the area of maximum increase in instability as best determined by the clustered and extrapolated satellite retrievals.