Presented at the 11th Conf. on Satellite Meteor. and Oceanography, 15-18 October 2001, Madison, WI, Amer. Meteor. Soc., 397-401.

P3.53

Observations of a Severe Supercell Thunderstorm on 24 July 2000 using GOES-11 Sounder and Imagery

by

John F. Weaver (NOAA/NESDIS/RAMMt)[1]
John A. Knaff, Dan Bikos (CIRA/CSU)
Jaime M. Daniels (NOAA/NESDIS/ORA)
Gary S. Wade (NOAA/NESDIS/CIMSS)

1. Introduction.

On 27 April 1994, the fourth in a series of new NOAA geostationary satellites, GOES-11, was launched. As with the other satellites in this series, it is fitted with instruments that provide frequent scans of the western hemisphere in 5 imaging channels, and 19 sounder channels.

Following the launch and orbit stabilization, a six week science test was conducted (from 30 June - 13 August 2000). The first half of the test was devoted to instrument optimization, the latter half focused on capturing real-time weather events. During the second half of the experiment, the default programming called for the imager to routinely collect 5-minute interval imagery over the continental United States. The sounder was set to collect routine 30-min interval data. Science-test coordinators also had the option of increasing the scan frequency of the imager to a one-minute interval (a scheduling strategy commonly referred to as super-rapid scan operations, or SRSO), over a limited area to capture significant mesoscale weather events.

On 24 July 2000, NOAA's Storm Prediction Center issued a moderate risk for severe thunderstorms over the central Plains of the United States, and GOES-11 project forecasters requested that the satellite be placed into its SRSO scan mode. At approximately 21:00 UTC a storm formed in south-central South Dakota. Shortly thereafter, the storm appeared to split. The left–moving component propagated to the east, while the right-mover traveled due south across central Nebraska. During a 10-hour period, the right-moving storm produced hail exceeding 2 inches in diameter, and 3 confirmed tornado sightings – all of which were in rural areas.

This paper presents an overview of the pre-storm environment, a general synopsis of the evolution of the sub-synoptic environment throughout the day, and a brief overview of the thunderstorm's formation and unique behavior. GOES-11 sounder products are presented that illustrate the added value of having frequent interval sounder data available to forecasters.

[1] NOAA – National Oceanic & Atmospheric Administration, NESDIS – National Environ-mental Satellite Data & Information Service, RAMMt – Regional & Mesoscale Meteorological team, CIRA – Cooperative Institute for Research in the Atmosphere, CSU – Colorado State University, ORA – Office of Research and Applications, CIMSS – Cooperative Institute for Mesoscale Meteorology Studies.

2. Data Sets.

a. Satellite data. The standard five imaging channels on the current GOES instruments include a visible channel (responding from 0.52 – 0.72 μm), as well as four infrared channels with central wavelengths at 3.9 μm, 6.7 μm, 10.7 μm and 12.0 μm.

The GOES sounder has instrumentation to measure emitted radiation in 1 visible wavelength band as well as in 18 thermal infrared bands sensitive to temperature, moisture, or ozone. The "footprint" or spatial sampling resolution at satellite sub-point is 8 km, with 13-bit data transmitted to the GOES receiving facilities.

In this study, plotted horizontal fields of lifted index (representing air mass instability) and precipitable water are utilized. For more information on the characteristics and capabilities of both the imager and sounder channels refer to Menzel and Purdom (1994).

b. Other data. Radar data used in this study are from the National Weather Service (NWS) Weather Surveillance Radar – 1988 Doppler (WSR-88D) located at North Platte, Nebraska. Conventional data include standard NWS surface and upper air observations, along with model output from the National Center for Environmental Prediction (NCEP).

3. 24 July 2000 case study.

Synoptic data from 12:00 UTC on the morning of 24 July, found the north-central Plains under northwesterly flow aloft (Figure 1). A shortwave trough over South Dakota (SD) and Nebraska (NE) was exiting the region, a second was expected to arrive in the area by mid-afternoon (Figures 1, 2a, and 2b). This second disturbance would trigger deep convection – lapse rates in the area were nearly dry adiabatic in a very unstable air mass (Figure 3).

The Convective Available Potential Energy (CAPE), using an assumed mixed dewpoint of 63°F with the morning sounding at North Platte, NE was estimated at over 4,000 J/Kg. This estimate was realistic, given that low-level moisture advection into central NE and south-central SD was anticipated (Figure 2c, 2d). Synoptic analysis also revealed a surface low in western NE at 12:00 UTC (not shown). This low was forecast to move into central

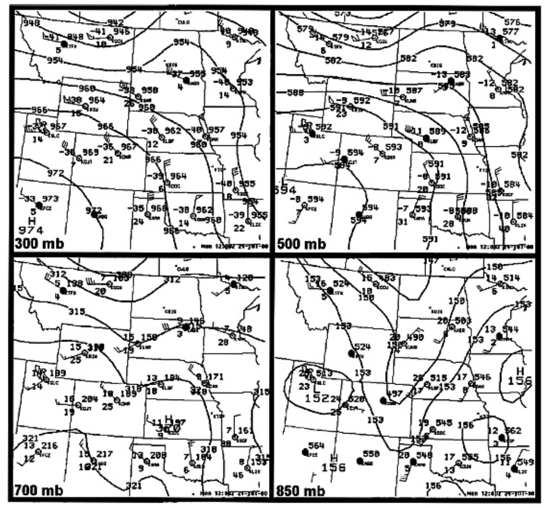

Figure 1. Synoptic analyses from 12:00 UTC on 24 July 2000. Station plots are standard U.S. Heights in dm. The four panel includes analyses at 300 mb, 500 mb 700 mb and 850 mb.

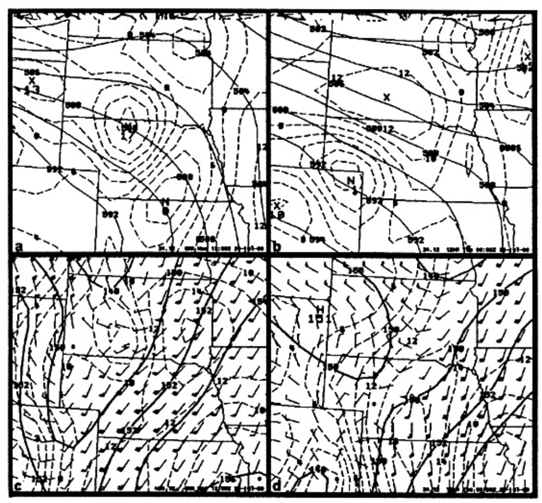

Figure 2. Top: ETA model 500 mb heights and vorticity valid at a) 12:00 UTC on 24 July 2000 (initial analysis), and b) 00:00 UTC on 25 July 2000 (12-hr forecast). Bottom: ETA model 850 mb heights and dewpoints with standard wind barbs valid at a) 12:00 UTC on 24 July 2000, and d) 00:00 UTC on 25 July 2000.

NE by late afternoon, bringing with it a dryline/trough to its south.

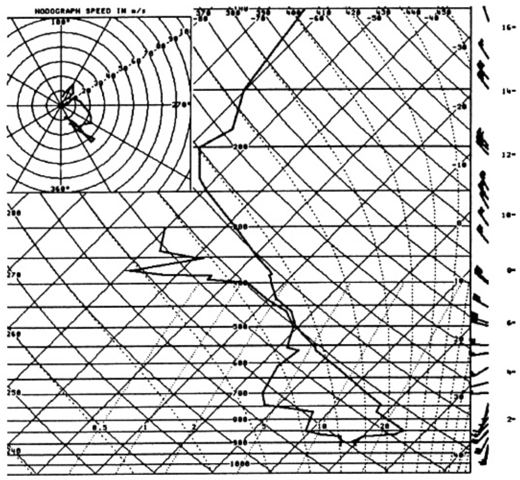

Figure 3. Radiosonde data from North Platte, NE at 12:00 UTC on 24 July 2000 plotted on a Skew-T/Log-P diagram. Winds are in knots.

The morning run of the ETA model suggested that Lifted Indices (LIs) less than (–7) would develop by noon in the area of interest. The output also predicted that a narrow axis of maximum instability would stretch from north-eastern SD into southwest NE. This is approximately what occurred. However, a mesoscale convective system (MCS) – one that did not appear in the model run – crossed SD during the morning hours. This morning system altered the picture somewhat.

Figure 4 presents a direct comparison between the model forecast LIs and those computed from the satellite sounder data. The background image is an LI product from GOES-11. It is overlaid with the ETA-model, 6-h forecast fields. As noted, the model forecast finds a tongue of maximum instability (LI = -7) stretching southwest, from northeastern SD into southwest NE. However, note some important differences. The remnants of the MCS can be seen in eastern SD/NE. Southwest of there, a cloud line along a low-level thunderstorm outflow (LTO) boundary is seen in central NE. The tongue of maximum instability is actually oriented more north-south, and is located in western portions of both states. It intersects the LTO boundary in south-central SD. However, notice that sounder-based values are roughly the same magnitude (-8, -9) as those forecast by the ETA.

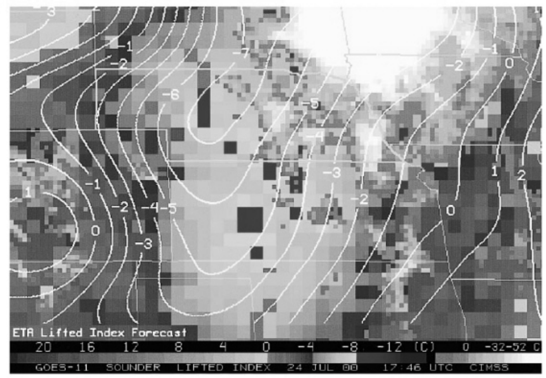

Figure 4. Surface-based lifted index image computed from GOES-11 sounder data overlaid with the ETA-model, 6-h forecast LI fields. Beginning scan time is 17:46 UTC. Model forecast valid at 18:00 UTC. Central column of states (from top to bottom) are South Dakota Nebraska, Kansas, and Oklahoma.

SRSO began on schedule at 19:15 UTC, and at approximately 21:00 UTC a thunderstorm formed near the intersection of the LTO boundary with the ridge of maximum, low-level instability. The genesis region was just northeast of the surface low noted above, and the timing also coincided with the arrival of the shortwave trough from the west. It is not known whether any one of these factors played a dominant role in storm formation.

Within an hour of formation, the storm appeared to develop a right- and left-moving component. However, satellite imagery reveals that the process was not a "classical" storm split, i.e. one in which shear-induced pressure gradients on the flanks of the original updraft enhance lift, and produce two new updrafts (e.g., Rotunno and Klemp 1982, 1985). Figure 5, along with sequential imagery, shows that the left-moving storm in this case formed along an LTO boundary on the north side of the storm. Furthermore, the hodograph was curved cyclonically in this case. Were this a classical split, one might expect a region of high pressure to develop above the low pressure area on the left flank, and the left-moving updraft to quickly dissipate (Wilhelmson and Klemp 1981). This storm did not dissipate, but continued east for nearly three hours and produced severe weather all along its path.

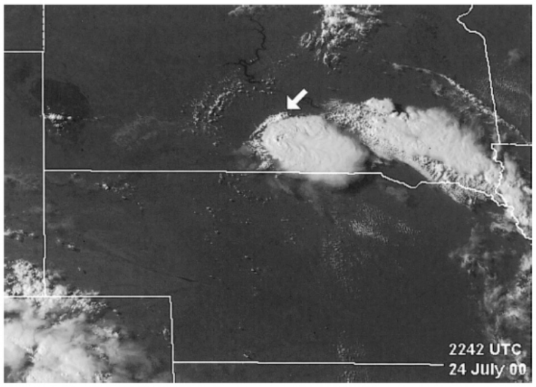

Figure 5. GOES-11 visible image from 22:42 UTC on 24 July 2000. Arrow points to an LTO boundary formed by the large storm in south-central South Dakota. There is a new storm forming on the boundary that will move left of the mean flow and produce severe weather.

Animated sounder imagery reveals that the right-moving component traveled along the western side of the tongue of high values of surface-based CAPE. Figure 6 shows an example of the surface-based CAPE derived from GOES-11 sounder data. The arrow points along the path that the storm will take over the next 8-hr. This path also coincides with the eroding edge of the Convective Inhibition (CIN) as computed from half-hourly sounder data (not shown). Thus, the right-mover's motion can readily be explained by factors other than shear-induced pressures.

4. Concluding Remarks.

Before successfully creating an accurate meteorological prediction, it is necessary to understand the current state of the atmosphere, and to identify those conditions that are present which might alter the current state. In this sense, more data is better than less. Without sufficient information, one might assume that one process is occurring (in this case, a classical storm-split), when something else entirely is actually taking place (in this case a new storm formed and propagated along an LTO boundary, while the original cell traveled along a pre-existing tongue of extreme instability).

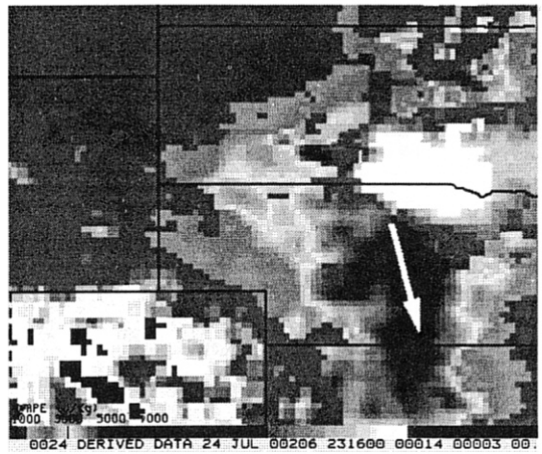

Figure 6. Surface-based CAPE derived from GOES-11 sounder data valid at 23:16 UTC on 24 July 2000. Arrow portrays path of the storm from about 00:00 - 08:00 UTC on 25 July 2000. CAPE values along the dark ridge-line are in the range of 5,000 - 6,000 J/Kg.

The example presented in this paper illustrates how frequent interval satellite data can supply information to 'fill the gap' between other data sources. The LTO boundary was seen only on satellite imagery – the tongue of instability, only on sounder imagery. Without this information, the forecaster might have expected the northern component to dissipate quickly. Instead it intensified and produced severe weather for more than two hours. The right-mover produced severe weather for more than ten hours as it traveled the length of the instability tongue – from South Dakota, all the way into central Kansas.

5. Acknowledgements.

A portion of the research presented in this study was performed under NOAA Grant #NA67RJ0152.

6. References

Menzel, W.P., and J.F.W. Purdom, 1994: Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites. *Bull. Amer. Meteor. Soc.*, 75(5), 757-781.

Rotunno, R., and J.B. Klemp, 1982: The influence of the shear-induced pressure gradient on thunderstorm motion. *Mon. Wea. Rev.*, **110**, 136-151.

Rotunno, R., and J.B. Klemp, 1985: On the rotation and propagation of simulated supercell thunderstorms. *J. Atmos. Sci.*, **42**, 271-292.

Wilhelmson, R.B., and J.B. Klemp, 1981: A three dimensional numerical simulation of splitting severe storms on 3 April 1964. *J. Atmos. Sci.*, **38**, 1581-1600.