PICTURE OF THE QUARTER

An Interesting Mesoscale Storm–Environment Interaction Observed Just Prior to Changes in Severe Storm Behavior

JOHN F. WEAVER AND JAMES F. W. PURDOM

Regional and Mesoscale Meteorological Branch, NOAA/NESDIS, Fort Collins, Colorado

10 June 1994 and 11 January 1995

ABSTRACT

Satellite images are presented to illustrate an interesting interaction that occurred between a severe thunderstorm and a mesoscale feature that originated in its nearby environment. Immediately following that interaction, a series of tornadoes began, starting with a long-lived F5 tornado that produced major damage in Hesston, Kansas. Some speculation is presented regarding the physical processes that may have contributed to the observed changes in thunderstorm behavior.

1. Introduction

Violent tornadic outbreaks (those containing F4 or greater tornadoes) are often characterized by a large number of thunderstorms, among which only a small subset end up being tornadic. Frequently, violent tornadoes or tornado families seem to begin and end capriciously, and thunderstorms containing violent tornadoes can often be situated in close proximity to storms with nothing more severe than large hail, heavy rain, or strong winds. Nearby storms may not even be severe.

The following *GOES-7* satellite imagery shows an interaction that took place between a nontornadic thunderstorm southwest of Hesston, Kansas, and a small-scale, low-level stable region whose origin was a dissipating thunderstorm far to the south. The interaction occurred on 13 March 1990 just prior to the development of a family of strong tornadoes, one of which was a long-lived F5 tornado near Hesston. Some speculation is presented regarding the physical processes that may have contributed to the observed changes in the Hesston storm's behavior both during and after the observed interaction.

2. Data and analysis

Satellite data shown in this presentation are all 1-km resolution, visible imagery taken by the Geostationary Operational Environmental Satellite, *GOES-7*. Surface maps have been refined to account for mesoscale features, including features observed on satellite imagery.

To help isolate certain events that occurred in the rapidly changing environment in this case, the authors applied image manipulation software that was developed on our local version of the McIDAS interactive display system known as RAMSDIS (RAMM Advanced Meteorological Satellite Demonstration and Interpretation System—Molenar et al. 1995). One especially useful application allows the user to reload a sequence of satellite images *relative* to a specific moving feature. The result is a feature-relative "loop." Benefits of such a presentation include the ability to 1) focus attention on a feature of interest without being distracted by its movement across the screen, 2) study motions of nearby cloud elements relative to an individual storm, and 3) reload earlier images relative to some feature of interest in order to study its origin and evolution. In this case, storm-relative animated sequences were created to trace back the source of thunderstorm features that appeared around the time the Hesston storm underwent its transition from nontornadic to tornadic.

3. Case description

The Hesston, Kansas, F5 tornadic storm that occurred on 13 March 1990 formed within an environment described as "synoptically evident" by Doswell et al. (1993). Specific synoptic conditions for this case can be found in Davies et al. (1994). One of the noteworthy aspects of the Hesston storm was that it formed

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Corresponding author address: John F. Weaver, Regional and Mesoscale Meteorology Branch, NOAA/NESDIS, Fort Collins, CO 80523.

on, and propagated along, a mesoscale outflow boundary that had been created by an early morning, mesoscale convective system (Davies et al. 1994). Furthermore, the only other storm that produced a family of violent tornadoes on this day appeared to form on, and travel along, the northern edge of this same boundary. The evolution of the rain-stabilized region is shown in Fig. 1. Interestingly, the air mass modified quickly at the immediate surface and thus was difficult to find using conventional surface analysis after about 1800 UTC (Fig. 2). However, its effects throughout the depth of the boundary layer remained in place for many hours. The stable air mass could be identified on satellite imagery as a region of regularly spaced lines of stable wave (or billow) clouds across most of central and eastern Kansas. Its perimeter was marked by clusters of growing cumulus.

One fascinating aspect of the Hesston storm was that the storm did not become tornadic until just after 2230 UTC, even though it was first detected on radar at 2046 UTC. This is a relatively long delay for an active thunderstorm to become tornadic in an environment favorable for strong tornadic activity. Figure 3 shows the Hesston storm at the time of its transition to the tornadic phase. Arrow A indicates a large region of enhanced congestus that appeared on the southern flank of the storm about 15 minutes earlier, and arrow B points out lines of regularly spaced cumulus that first appeared at the time of this image. By focusing on the enhanced congestus region (feature A) at 2216 and 2231 UTC, then reloading earlier images relative to that feature, we were able to trace the origin of the enhancement back to a small ring of outflow that came from a short-lived storm in northern Oklahoma (refer to the series of images shown in Fig. 4).

Several short lines of cumulus may be seen on the 2231 UTC image along the western edge of the storm (feature B, Fig. 3). These cumulus lines were not present prior to this time and first made their appearance within about 10 minutes of the time that

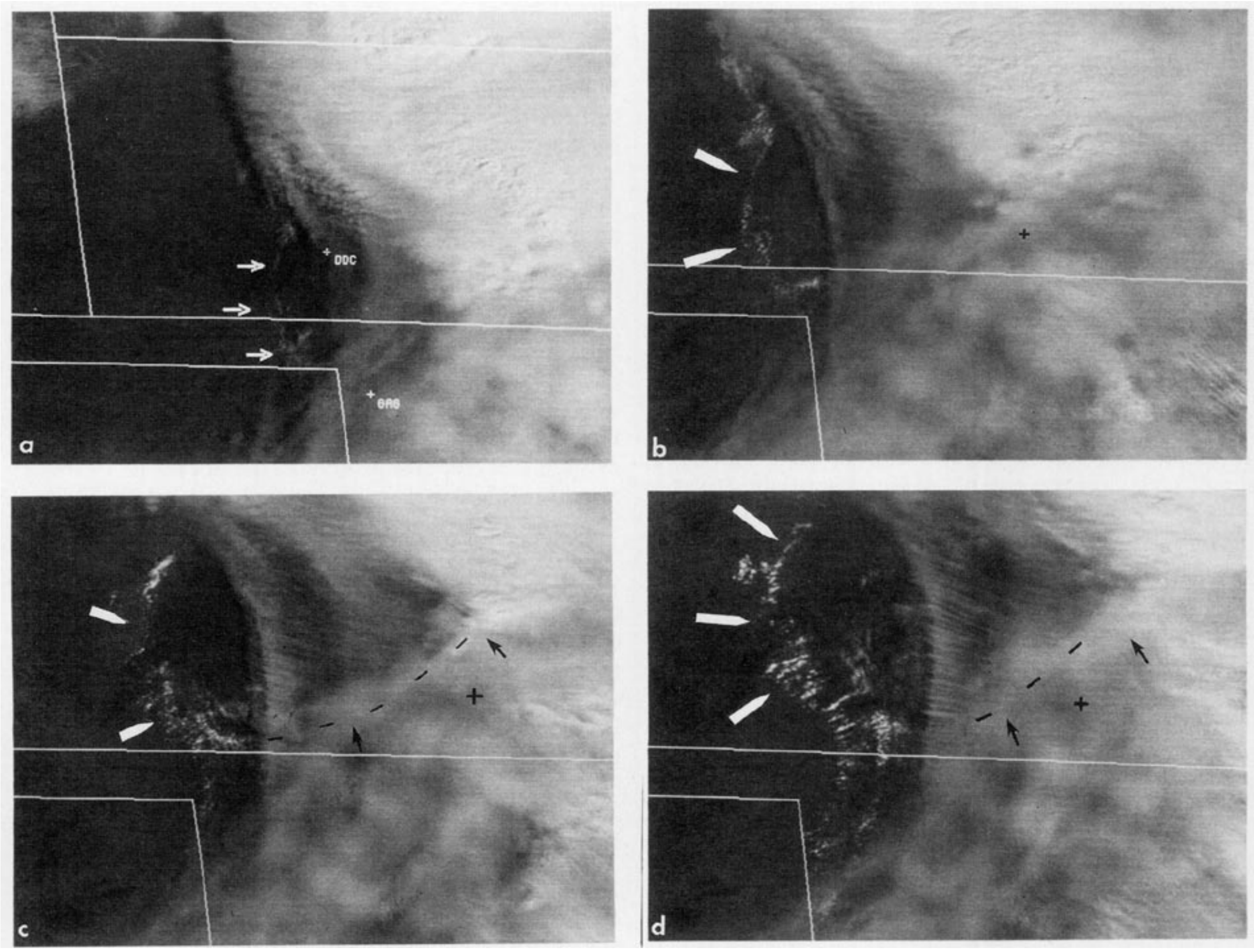

FIG. 1. *GOES-7* visible satellite images taken on 13 March 1990. Times are at (a)–(d), respectively, 1631, 1716, 1801, and 1846 UTC. Arrows indicate location of mesoscale outflow boundary discussed in text. Dark colored "+" is at Wichita, Kansas.

on-site observers (Davies et al. 1994) reported development of a strong rear flank downdraft (RFD). It is possible that these lines of cumulus are a reflection of that event, but the relationship would be difficult to define and is well beyond the scope of this note. We also mention that the development of the RFD and sudden appearance of cumulus lines occurred about 15 minutes after the interaction of feature A with the Hesston supercell. Thus, a connection between these events seems, at the very least, possible. The authors have observed similar flanking cumulus lines in satellite imagery on several occasions near the time of RFD development and storm transition.

4. Discussion

The fact that thunderstorms can alter their behavior upon interaction with mesoscale features in the nearby environment is not a new idea. For example, Purdom (1976) discussed the transition of a large thunderstorm from severe to tornadic as it intersected a mesoscale outflow boundary, and Weaver and Nelson (1982) found outflow interaction to be the primary cause for tornadic activity in an Oklahoma case. More recently, Przybylinski et al. (1993) presented radar evidence of important interactions between updrafts of one storm and outflows from another, and Weaver et al. (1994) found a series of such interactions to be important in the tornadic storms that occurred on the eastern Plains of Colorado in June of 1990. Purdom (1993) presented a conceptual model of these occurrences based on satellite observations.

For the case presented in this paper, and several others not discussed, we have observed lower-end mesoscale (i.e., mesobeta scale) features interacting with thunderstorm updraft regions just prior to significant changes in the parent storm's behavior. In this case, it

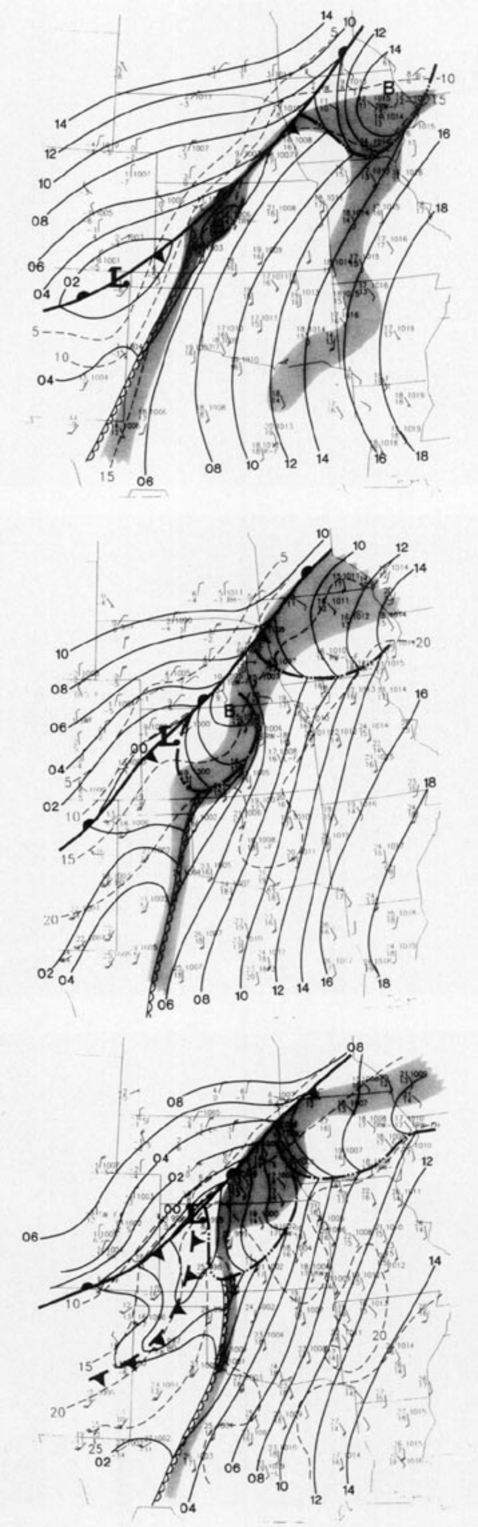

FIG. 2. Surface analyses from 13 March 1990 from data taken at (a) 1500, (b) 1800, and (c) 2100 UTC. Standard analyses have been refined to account for mesoscale features, including features observed on satellite imagery. Scalloped line is the dryline, solid lines are isobars, and dashed lines denote isotherms. (Analysis courtesy NSSL, see acknowledgments.)

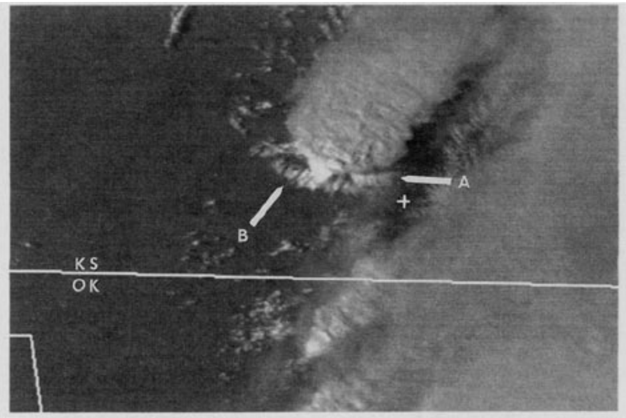

FIG. 3. *GOES-7* visible satellite image taken at 2231 UTC 13 March 1990. Storm-scale features A and B as discussed in text. Here "+" is at Wichita, Kansas.

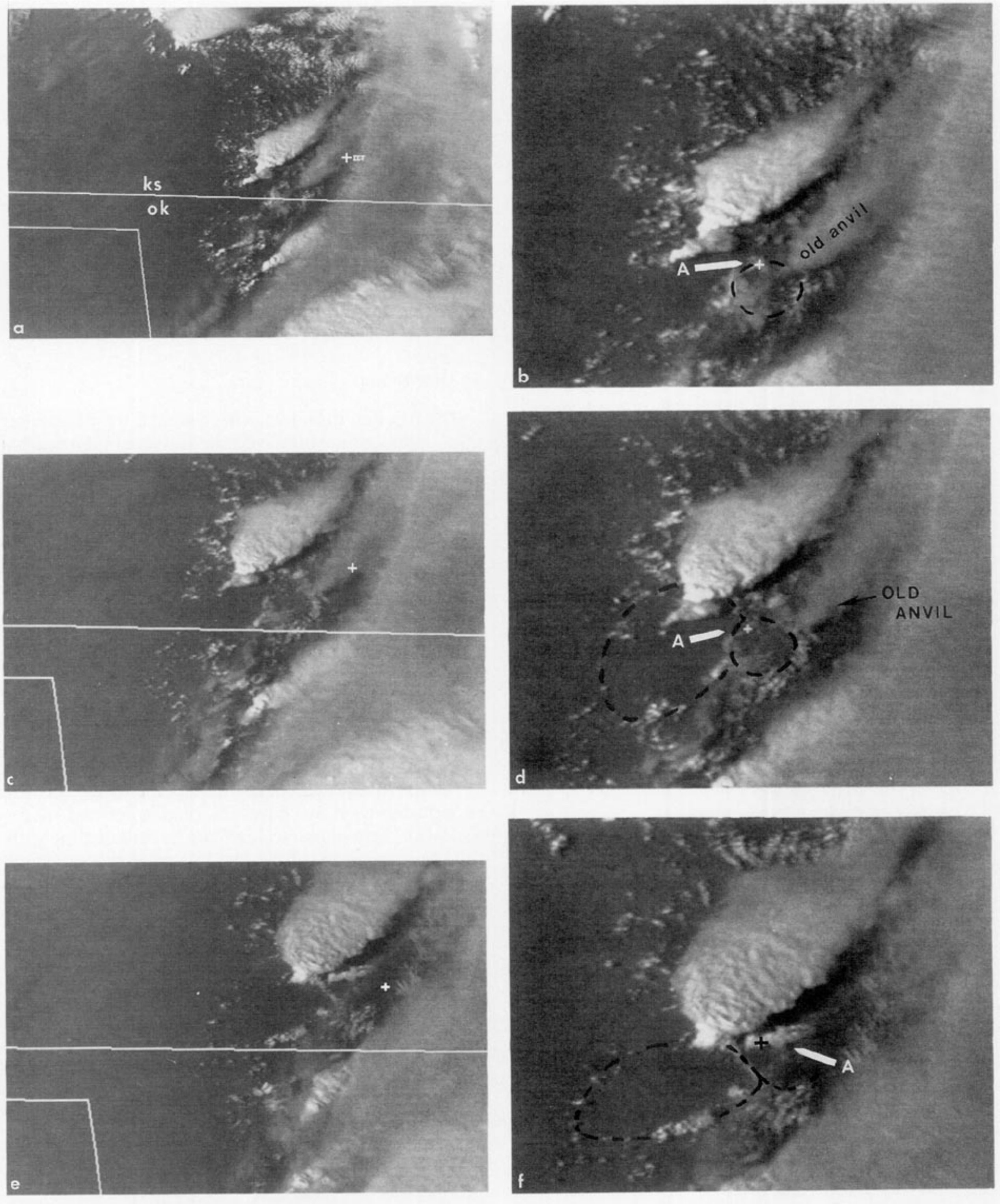

FIG. 4. *GOES-7* visible satellite images taken on 13 March 1990. (a) The 2131 UTC image showing an overview of the pretornadic Hesston supercell and a dissipating storm to its south. The "+" is at Wichita, Kansas. (b) Blowup of 2131 UTC centered on the Hesston storm. The "A" indicates computer-positioned spot where the rearward extrapolation software positioned feature A (from Fig. 3) at this time. The dashed line outlines a small outflow region associated with the dissipating storm. (c) Same as (a) but for 2146 UTC. (d) Same as (b) but for 2146 UTC. Outline of the larger outflow from the Hesston storm has been added. (e) Same as (c) except at 2216 UTC. (f) Same as (d) except at 2216 UTC.

was immediately following such an interaction that the nontornadic Hesston storm seemed to change its structure into one that could tap the potential of its environment to produce a family of violent tornadoes. One might reasonably suspect the existence of very small-scale features relating to such transitions, given the singular nature of the most severe activity. It would seem that both the scale of interaction as well as the mechanisms involved are equally the issue.

Unfortunately, sufficient data do not exist in the present case to specify the relationship leading to the observed transition in storm character. Thus, the interactions described herein are not presented as a finished product or a new nowcasting tool, but rather as a potential research topic for those interested in the very short-range forecast problem. Most of the events described in previously published studies of such interactions (e.g., Rotunno and Klemp 1985; Wilson et al. 1992) are on a somewhat larger scale than what we have discussed. Thus, the governing physical principles may, or may not, be the same. Perhaps the storm-scale interaction described herein is simply happenstance. But with more and more thunderstorm modelers recognizing the importance of the nonhomogeneous atmosphere, numerical methods should soon be available to investigate such events in detail. And, because violent storms are normally a small subset of the total on a severe weather day, such localized events cannot be dismissed out of hand.

Acknowledgments. The observations discussed in this paper were noted while carrying out ongoing mesoscale research under NOAA Grant NA37RJ0202. The authors would like to express their appreciation to Dr. Charles Doswell of the National Severe Storms Laboratory for his helpful comments concerning this case, as well as for the copies of the surface analyses shown in Fig. 2.

APPENDIX

Electronic Correspondence

Those readers having access to a 486 PC (works best at 33 mHz or greater), a good graphics card, and Windows software can obtain an electronic version of this paper that contains animated loops to illustrate key points. Readers on the InterNet can use IP address ORBIT1S.NESDIS.NOAA.GOV and log into account name "anonymous," password "w." All the files in the subdirectory \pub\wp should be copied, including the README file that describes a share statement that may need to be added to your AUTOEXEC.BAT file. Run "setup.exe" to create the application. For readers not having access to the InterNet, instructions on receiving a copy may be obtained by contacting the corresponding author at the address given or by phoning him at 970-491-8342.

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