Comments on "Nowcasts of Thunderstorm Initiation and Evolution"

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1. Introduction

In their article on experimental, space-specific 30-min nowcasts of thunderstorm initiation, evolution, and movement, Wilson and Mueller (1993, hereinafter WM93) present data that show that forecasters can often "anticipate thunderstorm initiation by monitoring radar-detected, boundary-layer convergence lines together with monitoring visual observations of cloud development in the vicinity of convergence lines." Wilson and Mueller effectively describe the difficulties inherent in the short-range forecast of thunderstorm development. Their proposed nowcasting guidelines shown in Fig. 5 of WM93 represent a logical approach to that very complex forecast problem.

The WM93 article correctly points out that the use of low-level convergence boundaries to forecast convective development is not new and that pioneering work in that area was done using high-resolution geostationary satellite imagery. In fact, Purdom (1982) not only demonstrated the utility of low-level convergence boundaries in the convective forecast process but also showed how differences in thunderstorm development along outflow boundaries can frequently be explained by variations in the cumulus field ahead of such boundaries.

Our major point of contention with WM93 is that, while most other studies urge forecasters to use the full complement of available observing tools, WM93 seems to suggest a reliance solely on Doppler radar and conventional observations. We feel WM93 is flawed by that particular inference, as well as by a few statements concerning the utility of high-resolution geostationary satellite imagery. For example, the paper states that "for monitoring [convective development], satellite cloud imagery was often of limited usefulness since, at best, it was available half hourly and there were frequent errors with earth registration of the data." This statement is not correct. There also seems to have been a difference of opinion concerning the usefulness of satellite data among the WM93 authors, since statements in different sections seem to contradict one another on satellite usefulness.

We believe that the erroneous statements presented in WM93 on the utility of satellite imagery were most likely the result of limitations in the display and analysis system used in their experimental program (which did not allow WM93 to use the full potential of satellite imagery), as well as through a lack of experience using and interpreting satellite imagery. For whatever reasons they occurred, our comments are directed toward correcting the misperceptions we feel exist.

2. WM93 satellite data display and analysis system

According to WM93, the satellite imagery available for their nowcasting experiment was restricted to 30-min interval imagery displayed on an experimental forecast workstation (known as DARRRE) developed at the National Oceanic and Atmospheric Administration's Forecast Systems Laboratory. However, during the period discussed in WM93, the National Severe Storms Forecast Center in Kansas City, Missouri, routinely placed the *GOES-7* geostationary satellite into rapid scan surveillance mode in order to monitor severe storm development both in Colorado and other regions of the United States. Rapid scan data provided 11 images per hour over the entire lower 48 states for each of the designated days. Rapid scan imagery was available for the 16 July 1988, 14 August 1989, 20 August 1989, and 5 September 1990 cases presented in WM93. Thus, finer time resolution satellite imagery was available for selected cases to those able to display it. Such imagery would have certainly been useful within the

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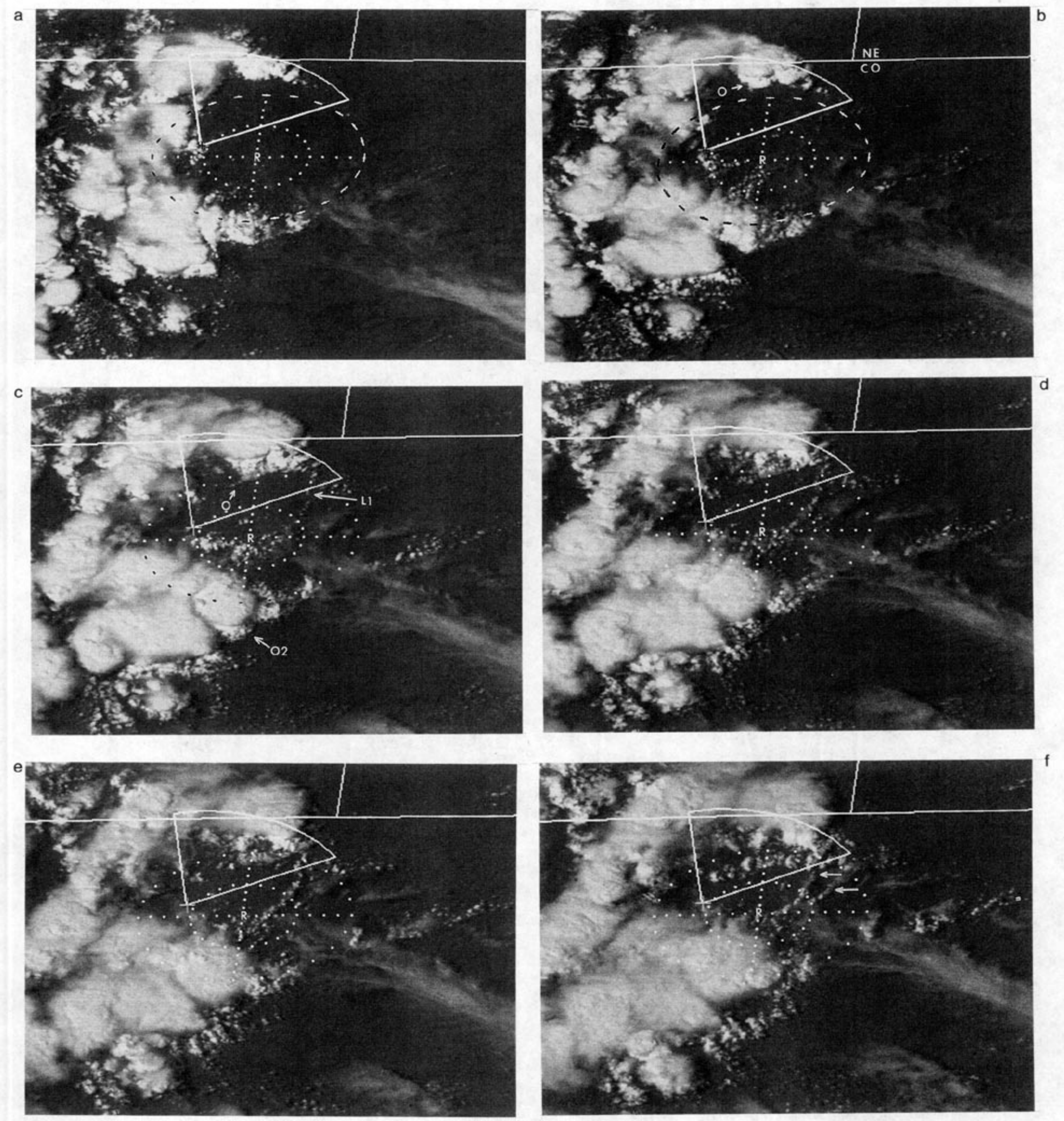

FIG. 1. Series of visible satellite images from the *GOES-7* satellite taken on 5 September 1990 for (a) 2000 UTC, (b) 2030 UTC, (c) 2100 UTC, (d) 2120 UTC, (e) 2130 UTC, (f) 2150 UTC, and (g) 2200 UTC. The dotted circle represents the 40-km, and dashed the 80-km, range rings centered on the Mile High Doppler radar, and the sector outlined by the solid line is the assumed 120-km viewing range of the video camera located at Boulder. The O's are outflows referred to in text, and L1 points out one of the convective lines.

short-range forecast time constraints of their experiment.

Also, we agree that earth registration can be a problem with Geostationary Operational Environmental Satellite (GOES) imagery. However, while earth registration errors do occur, images can be displayed correctly by using "landmark navigation" information to update appropriate navigation parameters. That tech-

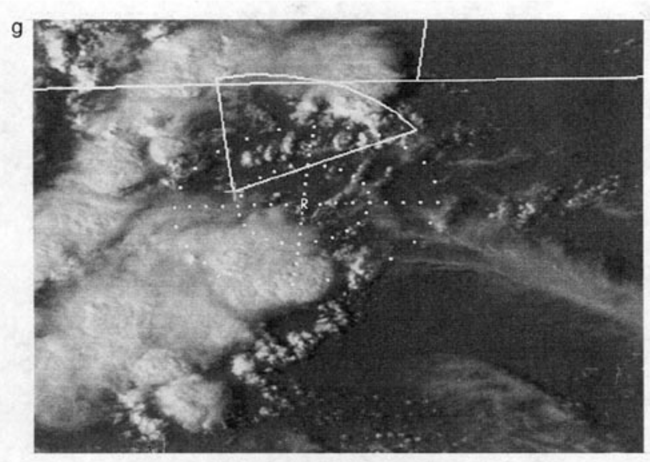

FIG. 1. (*Continued*)

nique uses such features as lakes, rivers, coastlines, etc., as a guide for registration corrections. The National Environmental Satellite Data and Information Service routinely corrects geographical gridding parameters through daily landmark navigation adjustment. Such corrections provide the user with extremely well-registered data. The McIDAS (man–computer interactive data access system) (Soumi et al. 1983) system, for example, uses these updated navigation parameters. A set of randomly sampled McIDAS images were recently tested by the first author for navigation accuracy. It was found that landmarks on those images matched to within two visible pixels (roughly 2.6 km at mid-U.S. latitudes) in 47 of the 49 cases tested. Software to carry out this sort of correction may not have been in use on the prototype workstation during the 1989–90 nowcasting exercises described in WM93. Incidently, the reader will be interested to know that with the next generation of geostationary satellite (the first to be in operation by October of 1994), registration is routinely expected to be within 2 km, without further reregistration. Also, the new collection schedule calls for routinely available imagery at 15-min intervals.

We believe that the ability of researchers in the nowcasting experiment described by WM93 to effectively use satellite imagery was hindered by the ingest scheduling on the DARRRE workstation and by the lack of reregistration software. We want to be sure that the WM93 authors, as well as the *Weather and Forecasting* readership, do not perceive the limitations of their workstation as a limitation in satellite imagery. In the discussion in section 6, WM93 reinforce their assessment by stating that "satellite imagery provides only limited utility [in part because] images are typically only every 30 min, cloud–earth registration is often in error and cirrus clouds often obscure the lower cumulus clouds."

The cases described herein use satellite imagery that was available in real time, along with contradictory statements in the body of WM93 itself, to refute the WM93 assertions concerning the utility of satellite imagery.

3. 5 September 1990

Figure 1 presents a series of 1-km visible images for the 5 September 1990 case described in WM93. The images are at 2000, 2030, 2100, 2120, 2130, 2150, and 2200 UTC, thus providing a blend of 30-, 20-, and 10-min interval satellite data. The 40- and 80-km range rings of the Mile High Doppler radar (MHR) are superimposed along with a slice of the 120-km viewing range of the video camera located in Boulder, Colorado, during the 1988–90 nowcasting experiment.

During the first hour (2000–2100 UTC) one can clearly see the development of two thunderstorms north and south of the radar outside of the 80-km radar range. Earlier satellite imagery tracked this development effectively. A gust front is visible by 2101 UTC as it emerges from the northern storm. This gust front is easily followed as it heads southward toward MHR. The two horizontal roll clouds (shown in Fig. 11a of WM93) can be seen on satellite imagery as early as 2031 UTC. In fact, WM93 notes that "satellite imagery in this case showed north–south lines of cumulus clouds in advance of the moving boundary." However, that is the extent of their observation. Actually, these cloud lines intensified with time, indicating that the low-level stability was eroding. Enhanced cumulus growth occurred where the southward-moving gust front intersected the westernmost roll.

The main point of Fig. 1 is to show that real-time satellite data were available in this case to effectively monitor storm evolution in the region covered by MHR. Additionally, this seven-part figure illustrates the more general utility of satellite imagery as compared with visual observations from a roof-mounted video camera. As with any form of visual observation, the roof-mounted camera is often not practical due to line-of-sight and range restrictions. Furthermore, without multiple camera photogrammetry, accurate cloud location is not possible. Finally, the obscuration problem mentioned by the WM93 authors regarding satellite imagery is much more severe with a ground-based camera system. Intervening cloudiness of any sort—from a field of small cumulus, to cumulus towers, to cumulonimbus—would prevent camera observations of convective boundaries. For this case, we note that the roof-top video camera would have been unable to detect the easternmost convective roll cloud in the 5 September 1990 case. Also, poor contrast due to the backdrop of the northern storm is likely to have made recognition of the gust front extremely difficult as it moved southward toward MHR.

4. Remarks on specific WM93 nowcast situations

WM93 discusses nowcast guidelines for several types of convective initiation situations. We would like to comment on each one of these topics separately.

a. Extrapolation

As Wilson and Mueller intimate, extrapolation is not a very reliable forecast method, particularly in regions where complex geography can help "lock" different air masses to terrain features. For example, Weaver and Toth (1990) describe a case in which topographic features to the east of the Colorado Rockies played the key role in the severe storm outbreak of 2 August 1986. However, in situations where extrapolation is a viable option, satellite imagery can provide just as accurate an estimate of storm motion as radar within optimal radar range, and a *better* estimate outside of that range.

1) STATIONARY BOUNDARIES

As quoted directly from the discussion of stationary boundaries in WM93, "the best way to anticipate storm development was [in their nowcast situations] to monitor cloud development visually or with satellite imagery." Indeed, the literature is replete with examples that confirm this impression. In Purdom (1982), case studies are presented that use satellite imagery to show how stationary boundaries contribute to thunderstorm development. More recently, Davies et al. (1994) found that a stationary boundary left behind by an early morning mesoscale convective system in eastern Kansas was associated with both the formation and propagation of an F5 tornado-producing thunderstorm on 13 March 1990. When marked by cumulus development, such boundaries are easily monitored using both visible and infrared satellite imagery. Cumulus development did occur in most of the cases presented in WM93.

2) MOVING BOUNDARIES

The case described in WM93 (5 September 1990) to illustrate the effects of moving boundaries was discussed in detail in the previous section. As shown in that presentation, satellite data identified all aspects of the developing interactive situation well in advance of new storm formation.

3) COLLIDING BOUNDARIES

A study using satellite imagery to diagnose the mechanisms responsible for triggering convection over the southeastern United States during the summer of 1979 (presented in Purdom 1982) show that, by late afternoon, about half of the new convection occurred due to colliding boundaries. As WM93 points out, evolutions that include colliding boundaries represent "one of the easier forecast situations." It is a situation that can be monitored quite effectively from GOES.

b. Cell intensification by boundaries

Nearly two decades ago, Purdom (1976) used GOES imagery to document a severe thunderstorm event in which convection intensified significantly as it intersected a preexisting airmass boundary. In that case, a severe thunderstorm that intersected an outflow boundary left behind by an earlier mesoscale convective system turned sharply right. Then, traveling along the old boundary, that cell produced four tornadoes near Abilene, Texas, while nearby storms resulted only in large hail.

5. Concluding remarks

While the study presented in WM93 apparently finds the monitoring of cumulus clouds to be useful for assessing changing stability conditions, those authors mistakenly assert that satellite cloud imagery was of limited usefulness in their experiment, because it was available half hourly, at best, and there were frequent errors with earth registration of the data. We would like to qualify WM93's statement by specifying that the described limitations were due to restricted display capabilities and were not inherent to the dataset.

The example of 5 September 1990 demonstrates that, even at time intervals as long as 30 min, high-resolution geostationary satellite imagery can detect mesoscale convergence zones, monitor boundary-layer stability changes, and reveal convective-scale interactions both within and outside of optimal radar ranges. One need only glance at Fig. 1 to observe low-level boundaries and boundary interactions occurring well beyond the optimal 80-km Doppler range ring.

We also feel it is important to emphasize that, while highly sensitive Doppler systems are able to do an excellent job of identifying boundary-layer features in their local area, those observations are most useful when combined with satellite imagery because satellite can provide a context to the mesoscale setting within which the Doppler view is confined. Often the organization and extent of convective systems cannot be seen in the limited range of the Doppler radar. It is clear that the more frequent the interval between satellite images the better for nowcasting, but an experienced satellite meteorologist can obtain a plethora of useful information from 30-min satellite imagery.

It should go without saying that when one accents the strengths of atmospheric observing systems, rather than their weaknesses, systems such as the U.S. geostationary satellite series and the WSR-88D (Weather Surveillance Radar–Doppler 1988) Doppler radars can serve as superlative adjoints. This complementary relationship will surely be extremely important in future severe weather forecast situations. The message is that the greatest advances in developing short-range forecasts of thunderstorm initiation and evolution will be achieved by integrating data from a wide variety of observing systems.

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