J8.6 SATELLITE, LIGHTNING, AND MODEL DATA FOR NOWCASTING HEAVY RAINFALL FROM MESOSCALE CONVECTIVE SYSTEMS (MCS'S)

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1. INTRODUCTION

Researchers and operational forecasters now have access to meteorological information from a wider range of sources than ever before, and have clearly shown that the use of these complementary sources of information provides a far superior picture of the state of the atmosphere than any individual source. In the particular case of mesoscale convective systems (MCS's), data from radar, satellites, lightning detection networks, and numerical weather models all can be exploited to improve skill at predicting the behavior of these systems and of the heavy rainfall that they can produce. Since radar data have already been extensively covered by other authors, the contributions of each of these other data sources for nowcasting MCS's are described separately in this paper, followed by a case study in which the combination of these data is illustrated.

2. DATA SETS AND THEIR APPLICATIONS

2.1 Satellite Data

Long-wave infrared (IR) window data from geostationary platforms such as the Geostationary Operational Environmental (GOES) Imager provide longitudinal information on the life cycle of MCS's. These data can also be used as the basis for rainfall estimates from these systems to complement information from radar and rain gauges.

On a larger scale, water vapor (WV) absorption band data from instruments such as the GOES imager provide information on the large-scale circulation and on smaller-scale features (Thiaw et al. 1993) that are too small to be depicted by the radiosonde network and may not be accurately located in a numerical weather model analysis. Furthermore, high-level plumes of moisture (which can overlay deep-layer moisture conveyors) also are easily detected using water vapor imagery.

Visible (VIS) band data from geostationary imagers provide a higher-resolution view of MCS's (1-km vs. 4-km for the IR) and also detect the cumulus cloud growth that can indicate synoptic scale and mesoscale boundaries (Purdom and Sinclar 1988). These features can also be detected via convergence-induced "fine lines" in radar imagery, but only within a relatively short range of a radar unit.

GOES Sounder data are the basis for hourly soundings of the atmosphere in clear areas (Hayden et al. 1996), which include not only broad moisture and stability information (Scofield et al. 2000) but also retrievals of atmospheric soundings. The requirement of clear air is a limitation; however, these data are excellent for diagnosing the pre-convective environment or the environment into which an MCS is propagating. Furthermore, the advent of single field-of-view sounder products (now available via the Web in near-real time; Daniels et al. 2006) has resulted in better coverage in partially cloud-covered regions than was possible with previous versions of these products.

Finally, microwave data also provide information that are useful for this purpose, most notably estimates of rainfall rate from instruments such as the Advanced Microwave Sounding Unit-B (AMSU-B) aboard the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellite (POES) platform (Ferraro et al. 2005). These estimates are generally more accurate than their IR-based counterparts, though the coarser spatial resolution (16 km vs. 4 km), less frequent looks (twice per day per satellite), and data latency of up to 3 h are significant drawbacks for operational application. The proposed future implementation of a microwave

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imager on GOES (e.g., Lambrigtsen 2005) would significantly improve upon present capabilities, however.

2.2. Cloud-to-Ground Lightning Data

The National Lightning Detection Network (NLDN; Cummins et al. 1996) provides data on cloud-to-ground lightning strikes, including lightning polarity. These data are highly important for properly locating the heavy convection from the satellite data (which must be adjusted for parallax effects, and which may be affected by the shearing of the cold cloud tops), as well as providing information about the intensity of convection and time trends in its strength to complement the GOES data. It has been demonstrated that using both data sources together for nowcasting MCS propagation and mergers is more effective than using GOES data alone (Goodman et al. 1998; Mecikalski et al. 2005). It should also be noted that a Geostationary Lightning Mapper is planned as a baseline instrument on GOES-R (Goodman et al. 2006) and will provide information on total lightning (in-cloud as well as CG) for diagnosis of heavy convective rainfall.

2.3 Sounding Data

Although the rawinsonde network is sparse relative to the spatial scales of MCS's, these data, complemented by the aforementioned GOES Sounder products, provide information on moisture availability, stability, and shear. In addition, vertical sounding profiles can be used to detect the presence of a stability reversal—a change in the thermal lapse rate from potentially unstable in the lower portion of the airmass to potentially stable in the region of the profile between the 0ºC and -20ºC isotherms. In this temperature range, dendritic ice growth evolves into graupel, which in turn impinges on supercooled water droplets and produces lightning discharges (Scofield et al. 2005).

2.4 Numerical Weather Model Data

Additional information relevant to MCS initiation and propagation can be obtained using fields from NWP models such as the National Centers for Environmental Prediction Global Forecast Model (GFS) or North American Model (NAM). A detailed description of how to apply NWP models to quantitative precipitation forecasting (QPF) is given in Junker (2001), and

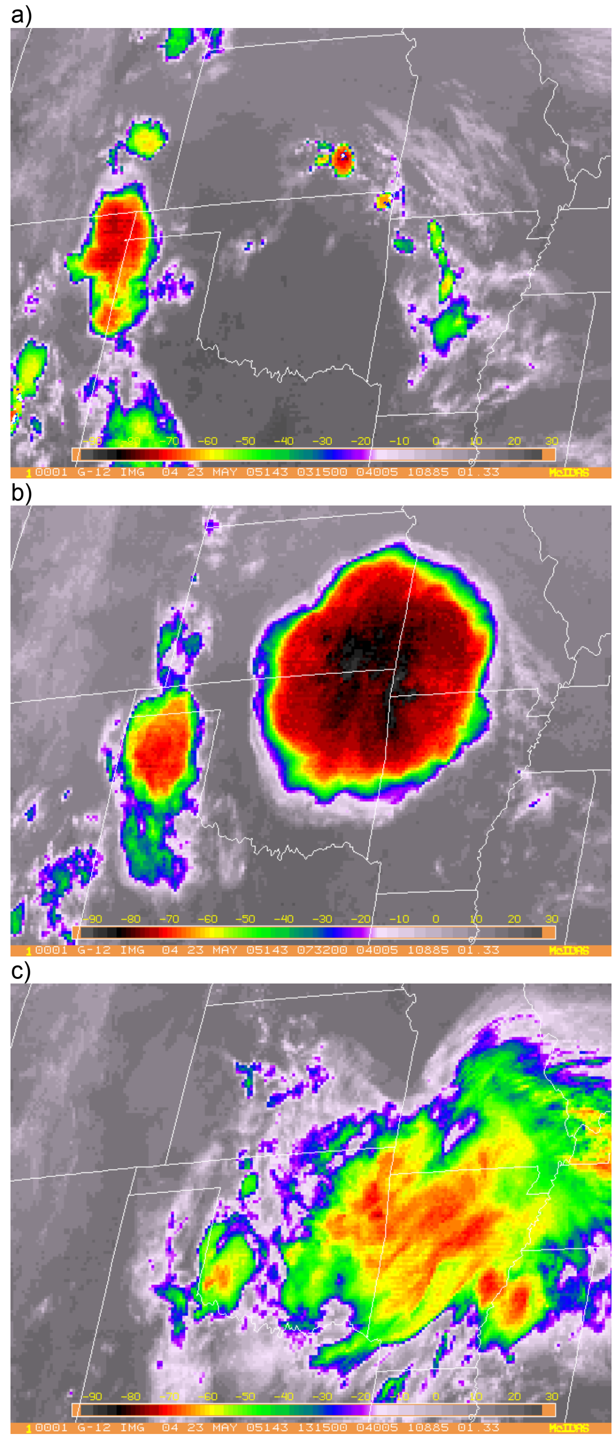

Figure 1. GOES-12 10.7-μm imagery depicting the life cycle of a MCS over northeastern Kansas on 20 May 2005. Image times are (a) 0315 UTC; (b) 0732 UTC; and (c) 01315 UTC.

emphasizes using model mass and thermodynamic fields as the basis of QPF rather than relying on the model QPF fields themselves. Gradients and ridge axes in the low-level equivalent potential temperature (θ_e) are often regions where MCS's are triggered or toward which they propagate (Shi and Scofield 1987). Jet streaks, regions of positive vorticity advection, wind shifts, and areas of horizontal temperature advection all indicate regions of upward vertical motion that can favor MCS development and/or propagation.

3. EXAMPLE: MCS OVER SOUTHEASTERN KANSAS

As an overview of this event, Figs. 1a-c show the GOES-12 10.7-µm imagery of a MCS over Kansas on 23 May 2005 during its initiation, mature, and dissipation stages, respectively. The GOES-12 6.7-µm water vapor imagery a few hours prior to the MCS initiation (Fig. 2a) shows a plume of water vapor over this same region, and this corresponds well with the corresponding NAM 850-hPa θ_e pattern, which is superimposed along with the NAM 850-hPa wind field over the GOES-12 image at 0015 UTC (Fig. 2b). The area of MCS development in southeastern KS is in the θ_e gradient just to the north of the maximum in a region of positive θ_e advection. The corresponding GOES Sounder TPW image (Fig. 2c) indicates the availability of significant amounts of moisture to feed MCS initiation. It should also be noted that the forcing for this event came primarily from the low levels, since no nearby jet streaks can be identified in either the WV imagery or in the overlaid isotachs (Fig. 2a).

The initiation stage of MCS development is depicted in Figs. 3a-c, which show negative CG lightning strikes overlaid on the corresponding GOES-12 10.7-µm imagery and indicate a rapid increase in their intensity, particularly between 0315 and 0332 UTC. The positive CG strokes (not shown) exhibited a similar pattern but were fewer in number than the negative strokes.

Since lightning indicates the presence of significant quantities of ice, microwave-based estimates of rainfall rate (which are based on scattering from cloud ice over land) should correspond to some extent with the extent of lightning activity. Indeed, Fig. 4 shows an AMSU-B overpass at approximately 0400 UTC 23 May 2005 that corresponds quite well with the regions of heaviest lightning activity.

Finally, a sounding from nearby Springfield, MO at 1200 UTC 22 May 2005 (Fig. 5) indicates a stability reversal between the 0ºC and -20ºC isotherms, suggesting an environment favorable

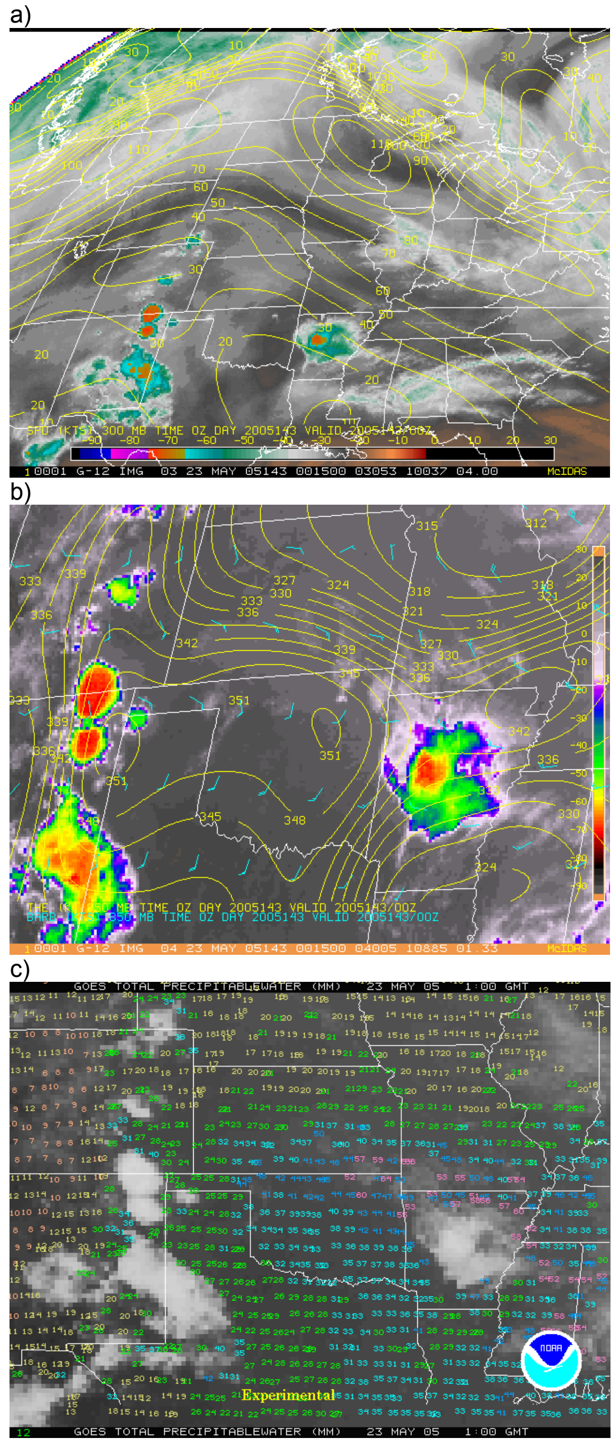

Figure 2. Depiction of the pre-MCS environment using (a) GOES-12 6.9-µm imagery with overlaid NAM 300-hPa isotachs; (b) GOES-12 10.7µm imagery with overlaid NAM 850-hPa θe (K) contours and winds (kts); and (c) GOES-12 Sounder derived precipitable water (mm).

for dendritic ice growth and evolution into graupel that can in turn impinge on supercooled water

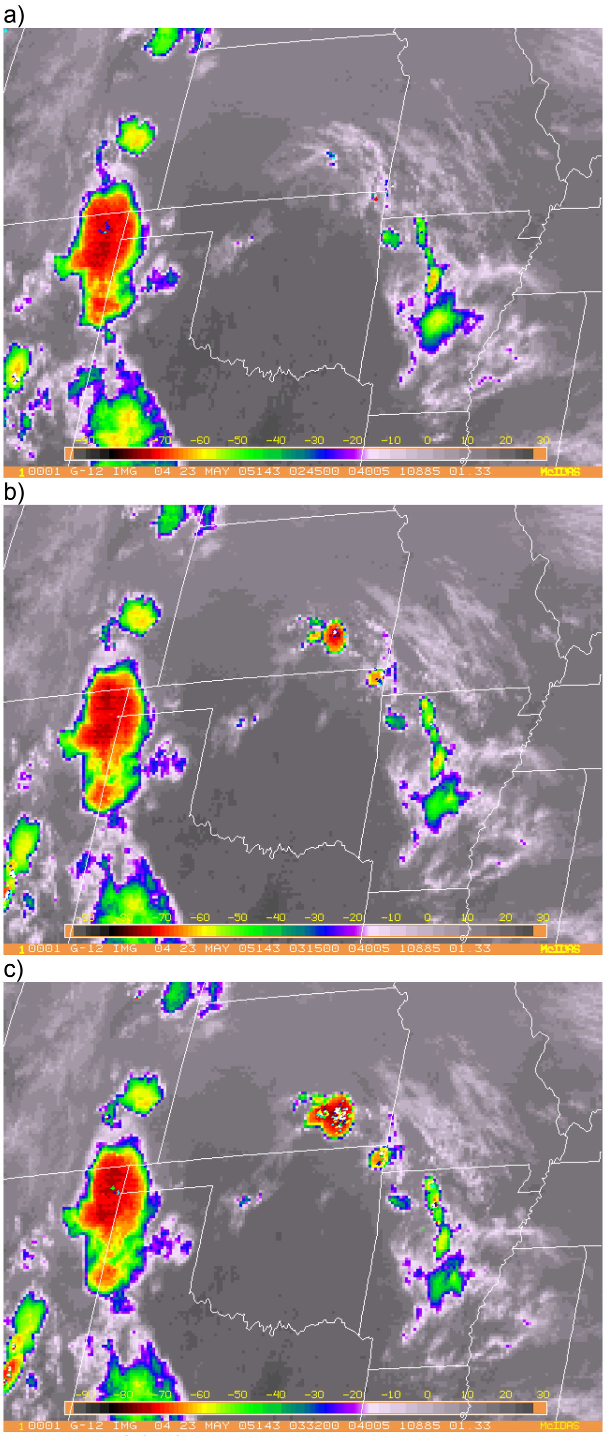

Figure 3. GOES-12 10.7-μm imagery with overlaid negative lightning strokes from the NLDN for (a) 0245 UTC; (b) 0315 UTC; and (c) 0332 UTC 23 May 2005.

droplets and produce intense CG lightning discharges.

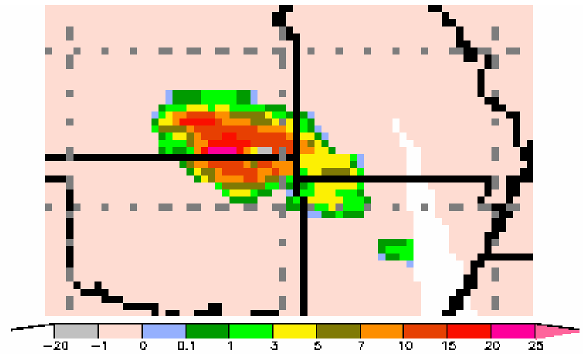

Figure 4. Rainfall rates (mm/h) for approximately 0400 UTC derived from the AMSU-B instrument onboard NOAA-17.

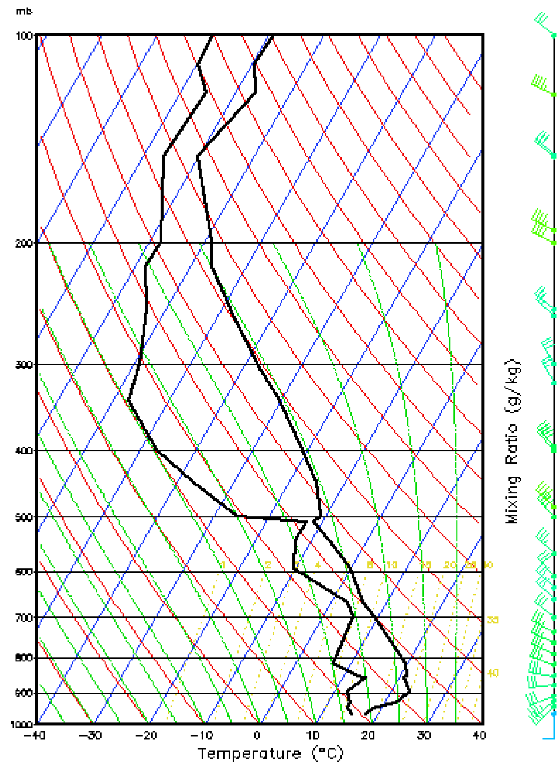

Figure 5. Radiosonde profile from Springfield, MO at 1200 UTC 22 May 2005.

4. SUMMARY

In addition to commonly used radar data, data from geostationary and polar weather satellites, lightning detection networks, soundings, and numerical weather prediction models can be used to provide complementary information on MCS's and their environment, and consequently on their development and propagation. This paper has outlined the individual data sources and illustrated their combined use for a MCS over southeastern Kansas.

5. ACKNOWLEDGMENTS

This work was partially supported by the GOES I-M Product Assurance Plan (GIMPAP) of the NOAA/NESDIS Office of Systems Development.

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