P2.18

CORRELATING SATELLITE INFRARED TRENDS, TOTAL LIGHTNING FLASH RATES, AND RAINFALL TO CONVECTIVE INITIATION, DEVELOPMENT AND EVOLUTION

John R. Mecikalski[‡], Simon J. Paech[‡], and Kristopher M. Bedka[1]

[‡]Atmospheric Science Department
University of Alabama in Huntsville

[1]Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin–Madison (UW-CIMSS)

1 INTRODUCTION AND DATA

With the advent of the North Alabama Lightning Mapping Array (LMA) as operated by the NASA Marshall Space Flight Center (MSFC), *total* lightning (in-cloud, cloud-to-air, and cloud-to-ground) may be measured. The LMA, consisting of an array of 12 ground detectors, maps lightning at 1/80th second frequencies, and provides many unique pieces of information including source locations in 3-dimensional space, source numbers and rates, and cloud-to-ground flash information (location, polarity). The North Alabama LMA is outlined by Koshak et al. (2004).

To date, few studies address the prediction of lightning (e.g., Mazany et al. 2002). A number of studies, capitalizing on the Lightning Imaging Sensor (LIS) on the TRMM satellite, relate satellite-infrared (IR) and microphysical structures to lightning within convective clouds (Goodman et al. 1988; Rosenfeld and Woodley 2003). In contrast, several studies have been done toward correlating convective storm behavior and morphology to cloud-to-ground flashes (e.g., Livingston et al. 1996). With respect to total lightning however, few studies have yet been done to relate these data to radar data, much less to satellite information (D. Buechler, personal communications). This is the motivation for this research. [‡]

In 2002, work began toward identifying the main signals of convective initiation (*the first occurrence of a ≥25-30 dBZ radar echo*) in GOES 1 km resolution visible and 4-8 km resolution infrared data (see Poster 4.8 *Bedka and Mecikalski*). This research has culminated in 30-60 min nowcasts of convective initiation (CI) at the GOES visible resolution, 1 km, over this satellite's footprint (Mecikalski and Bedka 2004). For GOES-12, CI nowcasts covering the Eastern U. S. are planned by 2005. CI nowcasts are now available in realtime over the southeastern U. S. (see http://biscayne.nsstc.uah.edu/∼johnm/CI_home/).

For the Mecikalski and Bedka algorithm, several aspects of the GOES data stream are important when satellite IR–LMA lightning relationships are to be formed. Namely, GOES-12 provides three "interest field" of CI that are closely related to cloud growth, growth rates and characteristics (e.g., glaciation). They are the 10.7 μm IR cloud-top brightness temperature (T_{BB}), the local time-trend of 10.7 μm T_{BB} ($\partial(10.7\mu m)/\partial t$), and a glaciation indicator 13.3-10.7 μm (and its time rate of change). This satellite information, when tracked in time via the Bedka and Mecikalski (2004) wind methodology, can be used as surrogate indicators of updraft strength within developing cumulus. A breadth of research shows that charge separation is related to several aspects of convective clouds, those being the relationship between the freezing altitude and suspension of graupel and ice, the distance of the freezing level above ground, and updraft velocities (MacGorman and Rust 1998). Updraft strength is invariably related to lightning flash characteristics because it affects the suspension of hydrometeors and the depth of cloud above the freezing level. Therefore, relationships between satellite-derived cloud growth information and known lightning sources, in space and time, will be exploited using the LMA as a Testbed for this research.

[‡]*Corresponding author*: Prof. John Mecikalski, Atmospheric Science Department, National Space Science and Technology Center, University of Alabama in Huntsville, 320 Sparkman Drive, Huntsville, AL 35805. email: *john.mecikalski@nsstc.uah.edu*

2 METHODOLOGY

Ongoing, new research at the UAH and UW-CIMSS is toward relating satellite and radar signals of CI with total lightning. This will be done to *forecast first lightning* and *lightning intensity* in the 0-2 h timeframe. Research will be done to correlate IR signatures from the CI algorithm to radar reflectivity and co-located lighting information from the LMA (lightning source locations, source rates, polarity, lightning types), so that first lightning forecast may be made *based only on IR cloud information.*

For this work, issues of GOES parallax will be addressed prior to relating satellite infrared information from GOES to WSR-88D radar and to LMA lightning. In addition to lightning nowcasts, this will also facilitate use of multiple regression techniques as a means of determining the relative importance of each IR field for CI and lightning prediction from GOES (and MODIS), as well as to evaluate methodology skill. To begin, GOES-11 data from IHOP_2002 together with WSR-88D data over western Texas and Oklahoma are being processed so to isolate the magnitude of parallax errors. This will translate to North Alabama as other cases are assessed using the LMA.

Evaluating IR trends of convective clouds to predict first lightning has high potential to yield 60-75 min lightning nowcasts. Extending this research to lightning flash rates and type, and lightning source numbers, will provide insights on how satellite information (in addition to NWP fields) can be used to infer *lightning intensity*. There is the strong promise that cloud-top cooling rates [$\partial(10\mu$m $T_B)/\partial t$] and glaciation information (e.g., using the 8.5 μm MODIS channel) are well-enough correlated to make regional 2-6 h forecasts of lightning intensities possible. This assumes that inferred satellite-cloud growth rates can be related to parameters like updraft strength (in light of freezing level height), important for dictating lightning flash frequencies (Stolzenburg 1996).

Once tested over the continental U.S., over a variety of atmospheric conditions, we will extend the lightning predictions to other regions that the CI algorithm is operated. These include areas covered by GOES (GOES-9–GOES-12; 100° E eastward to 30° W) and the MeteoSat Next Generation (MSG) satellite over Europe. A partial-global (∼45° N–45° S) 0-2 h CI and 0-6 h lightning forecast procedure is the vision, especially as computational capabilities improve. Each step of this development will involve UAH Graduate students connecting to various end users who will benefit from this new research (e.g., the NWS).

The main goals as part of this research over the coming 2-3 years are:

1. Develop software infrastructure to begin correlation analysis of CI (i.e. the first occurrence of a 25-30 dBZ radar echo) with respect to satellite infrared and total lightning information;

2. Develop relationships between growing cumulus and eventual lightning from cumulus in a variety of atmospheric environments (Midlatitudes and Tropics);

3. Develop these relationships for lightning of different types (in-cloud and cloud-to-ground), and lightning flash rates.

As a means of validating these lightning–satellite IR relationships, collaboration with NASA Marshall Space Flight Center scientists will occur toward using a lightning parameterization within a cloud-resolving model. We expect to report on some of this research via peer-reviewed publication shortly.

3 ACKNOWLEDGEMENTS

Much of this research through 2005 will be supported by NASA through the New Investigator Program Grant NAG5-12536.

4 BIBLIOGRAPHY

Goodman, S. J, D. E. Buechler, and P. J. Meyer, 1988: Convective tendency images derived from a combination of lightning and satellite data. *Wea. Forecasting*, **3**, 173–188.

Koshak, W. J., R. J. Solakiewicz, R. J. Blakeslee, S. J. Goodman, H. J. Christian, J. M. Hall, J. C. Bailey, E. P. Krider, M. G. Bateman, D. J. Boccippio, D. M. Mach, E. W. McCaul, M. F. Stewart, D. E. Buechler, W. A. Petersen, and D. J. Cecil, 2004: North Alabama Lightning Mapping Array (LMA): VHF source retrieval algorithm and error analyses. *J. Atmos. Ocean. Tech.*, **21**, 543–558.

Livingston, E. S., J. W. Nielsen-Gammon, and R. E. Orville, 1996: A climatology, synoptic assessment, and thermodynamic evaluation for cloud-to-ground lightning in Georgia: A study for the 1996 summer olympics. *Bull. Amer. Meteorol. Soc.*, **77**, 1483–1496.

MacGorman, D. R., and W. D. Rust, 1998: *The Electrical Nature of Storms*, Oxford Univ. Press, 422 pp.

Mazany, R. A., S. Businger, S. I. Gutman, and W. Roeder, 2002: A Lightning prediction index that utilizes GPS integrated precipitable water vapor. *Wea. Forecasting*, **17**, 1034–1047.

Rosenfeld, D., and W. L. Woodley, 2003: Spaceborne inferences of cloud microstructure and precipitation processes: Synthesis, insights, and implications. In *Meteorological Monographs*. Vol. 29(51), 59–59.

Stolzenburg, M., 1996: An observational study of electrical structure in convective regions of mesoscale convective systems. Ph. D. dissertation, Univ. of Oklahoma, Norman, 137 pp.