**JP1.6** LIGHTNING NOWCASTS USING WSR-88D DERIVED PRODUCTS AND AWIPS

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## 1. Introduction

The NWS Spaceflight Meteorology Group (SMG) issues forecasts in support of Space Shuttle and International Space Station (ISS) operations. Lightning is a critical forecast element for both the Space Shuttle and resource protection at the Johnson Space Center (JSC). The Space Shuttle flight rules protect the vehicle from exposure to either natural or triggered lightning. Space Shuttle flight rules require that no lightning be forecast to occur within specified distances from the orbiter's flight path during landing. In addition, advisories for lightning occurrence within 5 nm of JSC are issued to protect important communication and computer equipment used for Space Shuttle and ISS operations in their respective mission control centers. JSC flight controllers take precautions based in part upon SMG lightning advisories to isolate communications system hardware from nearby lightning strikes. Power for mission critical computer systems may be transferred from commercial power sources to JSC generators upon notification of a lightning advisory.

The Virtual Institute for Satellite Integration Training (VISIT) (Zajac and Weaver, 2002), the National Weather Service Training Center (http://www.nwstc.noaa.gov/METEOR/Lightning/Ltng_home.htm), and a NWS Southern Region Operational Applications of Lightning Data Workshop in 1998 are all examples of recent education and training efforts concerning lightning. All three of these training programs used the Advanced Weather Interactive Processing System (AWIPS) to illustrate lightning concepts and short-range forecasting techniques. Forecaster training with lightning more frequently addresses integration of lightning data for nowcasts and short-range forecasts of convection, rather than the initiation or cessation of cloud-to-ground lightning itself. In addition, training materials covering the detection and forecasting of conditions favorable for "triggered" lightning are very rare.

Various studies have provided radar-based guidelines for short-term forecasts of lightning occurrence. The likelihood of lightning occurrence and mean time to first flash have been correlated with reflectivity values at specified temperatures in the atmosphere. Derived products from the WSR-88D provide the data needed for using these guidelines. The AWIPS display system provides an easy-to-use capability to build user-customized displays of derived WSR-88D and other products. In particular, AWIPS has the capability to mosaic multiple radar site imagery into a single display. This has proven quite useful in SMG operations. This paper will review lightning forecast techniques used at SMG. Some examples using AWIPS imagery will be presented. Some suggestions for additional data types that AWIPS has the capability to ingest now or in the near future will be discussed.

## 2. Existing Lightning Information at SMG

Lightning and electric field tools and detection systems used at SMG include the National Lightning Detection Network (NLDN), the UK Meteorological Office spherics network (Lee, 1986), the Cape Canaveral Air Station (CCAS) cloud-to-ground lightning sensor system, the CCAS network of ground-based electric field mills, the Kennedy Space Center (KSC) Lightning Detection and Ranging (LDAR) system, and the Spanish National Institute of Meteorology's (INM) cloud-to-ground lightning detection network. These systems are complemented by satellite imagery, radar imagery, and conventional meteorological data via the NOAAPORT data stream and other sources available to SMG. Not all of the data is available for display in AWIPS and must be viewed using other computer systems.

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## 3. Potential Lightning Forecast Parameters

Observations of radar reflectivity at various temperature levels have been related to the onset of lightning in numerous studies. A review of the literature revealed some useful parameters and issues for detecting and forecasting natural and triggered lightning that are candidates for AWIPS displays.

- Lightning is imminent when the 40 dBZ echo reaches –10C and the echo top is > 9km (29,500 ft) with lead times ranging from 4 to 33 minutes (Buechler and Goodman, 1990).
- Lightning occurs within 5 minutes after the 30 dBZ echo reaches the –20C isotherm (Michimoto, 1991).
- 10 dBZ echoes reaching 0C isotherm have a median lead time of 15 minutes, but the False Alarm Rate is fairly high (Hondl and Eilts, 1994)
- Garner et al (1997) described the problems with detecting and forecasting the location, transparency, and lightning potential of detached thunderstorm anvil clouds in relation to space launch and landing operations.
- Lightning occurs within 5 minutes when the 30 dBZ echo reaches –15C to –20C and if storm top divergence indicated a vigorous updraft (Forbes and Hoffert, 1999).
- Oram (1999) describes a technique using the WSR-88D Layer Reflectivity Mid-Level (LRM) product. A 30 dBZ threshold in the 24,000 – 33,000 ft (7.3 – 10 km) layer was related to lightning occurrence with a very low False Alarm Rate.
- Minimum thresholds for cloud-to-ground lightning of 35 to 45 dBZ reflectivity at –10C and a minimum cloud top temperature of –25 to –30C (Zajac and Weaver, 2002).
- Gremillion and Orville (1999) tested various combinations of temperature levels and reflectivity thresholds and found the best predictor for lightning to be 40 dBZ and –10C in east central Florida. This combination yielded a median lead-time of 7.5 minutes to the first cloud-to-ground lightning strike.

## 4. AWIPS Displays

The simplest AWIPS display, of course, is to plot the locations of NLDN cloud-to-ground lightning data on an individual map, radar image, or satellite image. One may also build animated loops. These simple techniques are not sufficient to predict the initial occurrence of lightning. Satellite imagery and animated loops are particularly useful in conjunction with radar imagery to determine the cloud top temperatures, cloud top heights, and age of clouds with lightning potential. The AWIPS 5.1.2.1 software loaded on the SMG AWIPS (as of May 2002) also contains a mouse-driven tool that displays IR cloud top temperatures and an estimate of the cloud top height using the nearest rawinsonde station or model forecast soundings. WSR-88D reflectivity cross-sections are a valuable tool available in AWIPS to determine many of the lightning onset parameters described above. The disadvantage of reflectivity cross-sections is that they are manually intensive for the forecaster, take a few minutes to retrieve from the radar product generator, and the forecaster must select the proper location for a cross-section. SMG forecasters have found the technique described by Oram (1999) using the mid-level Layer Reflectivity Maximum product (LRM-Mid) to be particularly easy to implement using AWIPS and avoids the problem of selecting the proper area to build the cross-section. Conveniently, the bottom of the LRM-Mid layer (24,000 ft) corresponds well to the –15C to –20C isotherm most of the year. The forecaster needs to be aware of any departure of the –20C isotherm from this height and adjust accordingly. In addition, the forecaster may mosaic surrounding areas onto a single display, mitigating the problems of radar's "cone of silence." The disadvantage of the technique is that the LRM 2 product is only created following the entire WSR-88D volume scan, so it is one of the last products distributed. This delay is on the order of the lead-time estimated for the initial lightning. Monitoring individual elevation scans that are near critical isotherm heights can resolve this timing problem somewhat, but is labor intensive during high workload periods.

## 5. Future Considerations and Conclusions

AWIPS has the capability to ingest many different types of data sets that are available to local offices using the Local Data Acquisition and Dissemination (LDAD) hardware and software. Already local mesonet data from around the Kennedy Space Center, Florida; White Sands Missile Range, New Mexico; Galveston Bay, Texas; and Edwards AFB, California are ingested and displayed in the SMG AWIPS. Total area divergence over the Kennedy Space Center has been documented as a precursor to lightning by Watson et al (1991). The total area divergence could be calculated using the KSC mesonet data in AWIPS and displayed using various scripting and graphical user interface (GUI) tools. Data from the CCAS surface-based electric field mill network should be easily ingested into AWIPS via LDAD and displayable in the AWIPS D2D display software given proper configuration. Three-dimensional display of lightning data from the LDAR system should also be displayable using the D3D display software soon to be implemented in AWIPS if the data can be properly transmitted to LDAD and AWIPS. Simple configuration changes to display the normalized strength of the NLDN data is anticipated at SMG. Data from the Spanish cloud-to-ground detection network (using similar NetCDF structures and D2D displays as the NLDN) and the UK Meteorological Office spherics network could be ingested and displayed in AWIPS. SMG AWIPS programmers and managers have already created a Spanish localization to display routine data over Spain and Morocco in support of Space Shuttle Transoceanic Abort Landing weather operations (Keehn, 2002). Forecasting the location of attached and detached non-transparent thunderstorm anvils is difficult. The NASA Applied Meteorology Unit in has developed a tool to display threat sectors based upon local sounding or model forecast soundings that overlays upon maps, satellite, or radar imagery in a McIDAS environment (AMU, 2002). This tool needs to be converted into an AWIPS application. One possible method is to use the temporary user defined maps available in the D2D display. These maps are already used to display Space Shuttle entry trajectories and could be modified to display the anvil threat sectors. AWIPS has the capability to display cloud-to-ground lightning data, satellite imagery, radar imagery, and other complementary data for forecasting the onset of lighting. The image combination feature and the newly added cloud top height tool are particularly useful tools for lightning forecasting used at SMG. AWIPS also has the potential for displaying and computing other data and parameters useful for lighting forecasting not already present in the current software builds. Some suggestions for future data sources include other lightning detection networks and 3D displays. AWIPS offers NWS forecasters a unique opportunity to view lightning information in a multitude of current and future displays.

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## 7. References

Applied Meteorology Unit, 2002: Improved Anvil Forecasting: Phase II Final Report, NASA Contractor Report NASA/CR-2002-211170.

Buechler, D. E. and S. J. Goodman, 1990: Echo Size and Asymmetry: Impact on NEXRAD Storm Identification, *J. Appl. Meteor*, 29, 962-969.

Forbes, G. S., and S. G. Hoffert, 1999: Studies of Florida Thunderstorms Using LDAR, LLP, and Single Doppler Radar Data, *11th International Conference on Atmospheric Electricity*, Guntersville, AL, 496-499.

Garner, T., R. Lafosse, D. G. Bellue, and E. Priselac, 1997: Problems Associated with Identifying, Observing, and Forecasting Detached Thunderstorm Anvils for Space Shuttle Operations, Preprints, *7th Conference on Aviation, Range, and Aerospace Meteorology*, Long Beach, CA, Amer. Met. Soc.

Gremillion, M. and R. E. Orville, 1999: Thunderstorm Characteristics of Cloud-to-Ground Lightning at the Kennedy Space Center, Florida: A Study of Lightning Initiation Signatures as Indicated by the WSR-88D Radar, *Wea. Forecasting*, 14, 640-649.

Hondl, K. D. and M. D. Eilts, 1994: Doppler Radar Signatures of Developing

Thunderstorms and Their Potential to Indicate the Onset of Cloud-to-Ground Lightning, *Mon. Wea. Rev*., 122, 1818-1836.
Keehn, M. J., 2002: AWIPS as a Global Meteorological Analysis and Display System, Preprints: *Symposium on the Advanced Weather Interactive Processing System (AWIPS),* Orlando, FL, Amer. Met. Soc.
Lee, A. C. L., 1986: An Operational System for the Remote Location of Lightning Flashes Using a VLF Time Difference of Arrival Technique, *J. Atmos. Ocean Tech*., 3, 630-642.
Michimoto, K., 1991: A Study of Radar Echoes and Their Relation to Lightning Discharge of Thunderclouds in the Hokuriku District, Part I: Observation and Analysis of Thunderclouds in Summer and Winter, *J. Meteor. Soc. Japan*, 69, 327-335.
Oram, T. D., 1999: Forecasting Lightning for Space Shuttle Landings Using the WSR-88D Layer Reflectivity Maximum Mid-Level Product, *National Weather Association Annual Meeting*, Biloxi, MS, Nat. Wea. Assoc.
Watson, A. I., R. L. Holle, R. E.
LÌ ez, R. Ortiz, and J. R. Nicholson, 1991: Surface Wind Convergence as a Short-Term Predictor of Cloud-to-Ground Lightning at Kennedy Space Center, *Wea. Forecasting*, 6, 49-64.
Zajac, B. A. and J. F. Weaver, 2002: Lightning Meteorology I: An Introducto
ory Course on Forecasting with Lightning Data, Preprints, *Symposium on the Advanced Weather Interactive Processing System (AWIPS)*, Orlando, FL, Amer. Met. Soc.