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Collaborations enhance advanced lightning applications

Vaisala lightning partners committed to expansion of coverage

Vaisala and its research partners have expanded their study of long-range lightning tracking data techniques, performance, and applications. Long-range lightning data over ocean areas shows promise for improved thunderstorm nowcasts for densely populated coastal areas and improved rainfall estimation that should lead to better forecasts by numerical weather prediction models. It also improves hazardous weather observations that greatly impact aviation and shipping transportation routes and safety.

Extensive research and development

Vaisala has been working for many years to expand the North American Lightning Detection Network (NALDN) cloud-to-

ground (CG) lightning detection capability to encompass long-range Very Low Frequency (VLF) detection. This long-range lightning product is the result of experimental research and development since 1997.

Vaisala first explored the concept using east and west coast sensors to detect lightning 1200-1600 km away in the interior of the United States. Most recently, Demetriades and Holle (2006) analyzed Vaisala Long-range Lightning Detection Network (LLDN)-detected lightning associated with tropical cyclones over the Atlantic basin to assess the value of this data in tropical cyclone nowcasting.

Early in 2007, Vaisala will migrate the LLDN from experimental status to a full, production-quality dataset avail-

able in real-time. The geographic scope and performance of the LLDN network will continue to evolve as Vaisala expands its global footprint of sensors and establishes relationships with other networks.

Partnerships vital for success

Significant contributors to the LLDN include Meteorological Services of Canada (MSC), the National Weather Service's usage and applications development department, particularly the Aviation Weather Center, as well as Vaisala's new partnership with the Bahamian Met in the critical Caribbean region. The MSC's joint data processing partnership of the Canadian Lightning Detection Network (CLDN) and Vaisala's National Lightning Detection Network (NLDN) has created

a seamless process of lightning detection spanning the two borders.

Multiple applications for lightning data

Identification of convection over oceanic areas is a challenge due to a lack of ground-based radar coverage. Geostationary satellite data is the tool most often used for identifying convection over ocean areas, but it has limitations due to convection often being obscured by benign cold top cirrus clouds. Long-range lightning complements geostationary satellite imagery by helping to identify and track convection over ocean areas. Advantages of long-range lightning detection include, but are not limited to, (1) true identification of convective areas associated with thunderstorms, (2) a continuous data stream that allows for more rapid updates on rapidly evolving weather situations than the typical satellite update intervals and (3) a valuable dataset to improve numerical weather prediction over data sparse ocean areas.

Current LLDN research efforts are focused upon lightning structure in tropical cyclones and lightning/convective rainfall relationships. Molinari et al. (1999) have shown that lightning exhibits preferential spatial patterns in hurricanes. The eyewall (or inner core) usually contains a weak maximum in lightning flash density. There is a well-defined minimum in flash density extending 80 to 100 km outside the eyewall maximum. This is due to the stratiform rain processes that generally dominate most of the region of the central dense overcast. The outer bands typically contain a strong maximum in flash density. These features have been observed using LLDN data in numerous recent hurricanes in the Atlantic and Eastern Pacific tropical cyclone basins, most notably in Hurricanes Katrina and Rita in 2005 and Charley and Ivan in 2004.

Demetriades and Holle (2006) have shown that the LLDN has detected eyewall lightning outbreaks in many hurricanes from both the Atlantic and Eastern Pacific tropical cyclone basins. The larger eyewall lightning outbreaks tend to occur over relatively small time and space scales. Lightning bursts in the eyewalls of hurricanes sometimes rotate counterclockwise around the center of circulation for some distance before they dissipate. However, Vaisala eyewall lightning outbreak studies since 2002 show that these outbreaks often preferentially occur on one side of the hurricane track. An example of this

phenomenon from Hurricane Lili in 2002 is shown in Figure 1.

Pessi et al. (2004) have started to quantify lightning/convective rainfall relationships over the north-central Pacific Ocean. Low orbiting satellites that carry microwave radiometers, such as NASA's Tropical Rainfall Measuring Mission (TRMM) Microwave Imager, only provide information on convective precipitation twice a day over any given area on earth. Unfortunately, they do not allow continuous monitoring of the evolution of convective weather systems from space. Pessi et al. (2004) have found that lightning frequency and convective rainfall rates are relatively well correlated over the north-central Pacific Ocean, suggesting that lightning data over the Pacific can be assimilated into numerical weather prediction models as a proxy for latent heat release in deep convective clouds. Using Vaisala LLDN data as a proxy for latent heat release has the advantage of providing numerical weather prediction modelers with a continuous dataset for monitoring the evolution of convective weather systems over the oceans.

Identification of convection over oceanic areas is a challenge.

The technology behind it all

The U.S. and Canadian sensors that constitute the NALDN are wideband sensors capable of detecting lightning in the frequency range between 0.5 and 400 kHz. Return strokes in CG flashes radiate most strongly in this frequency range, with their peak radiation coming near 10 kHz, in the middle of the VLF (3-30 kHz). Signals in the VLF band are trapped in the earth-ionosphere waveguide and suffer relatively less severe attenuation than higher frequency signals. Whereas Low Frequency (LF; 30-400 kHz) and VLF ground wave signals are attenuated strongly and are almost imperceptible after a propagation distance of about 500-1000 km. VLF signals may be detected at distances of several thousand kilometers after multiple reflections off the ground and ionosphere.

Detection is best when both the lightning source and sensor are on the night side of the earth because of the improved ionospheric propagation conditions at night. Because the standard NALDN

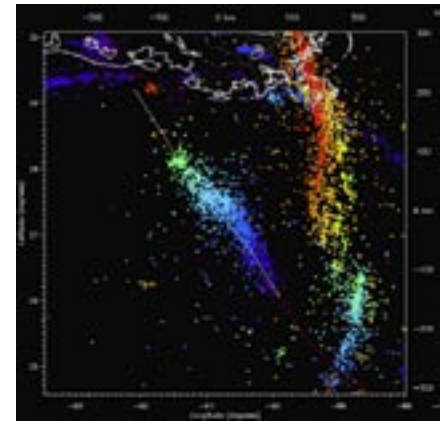


Figure 1. CG lightning detected by the LLDN in Hurricane Lili between 2100 UTC October 2 and 1200 UTC October 3, 2002. The track of the center of Lili during this 15-hour period is shown by the white line. Nearly continuous bursts of eyewall lightning are located along the right side of the track of Lili for several hours (shades of purple and blue) before switching to a pattern that is more centered on the track (shades of light blue and green) as the storm moved toward the northwest (upper left).

sensors detect across a broad band that includes all of the VLF, the NALDN can easily detect and process signals from lightning up to 3000 km in range. Only minor modifications to the location algorithm configuration are needed in order to handle long-distance VLF lightning signals.

State-of-the-art sensors

Currently, many of the standard NALDN sensors contribute to the LLDN consisting of the combination of the U.S. and Canadian networks and the Pacific Lightning Detection Network (PacNet). PacNet currently consists of several sensors located in and around the North Pacific Ocean that are specifically designed to detect lightning over long ranges (several thousand km).

It is important to note that the same broadband (VLF and LF) sensors that provide the high-quality NALDN CG data are also capable of detecting signals propagated over long distances. Information from these NALDN sensors, plus the PacNet sensors, is employed in a separate location processor that is specifically configured to accept and process ionospherically-propagated signals. This combination of networks has been shown to detect CG strokes in sufficient numbers and with sufficient accuracy to identify even small thunderstorm areas. The network detects lightning to varying degrees over the northern Atlantic and Pacific oceans and Caribbean Sea. ■