by Nikki Hembury & Ron Holle

FLASH OF INSPIRATION

Latest innovations in worldwide lightning detection

Recent advances provide a full range of lightning detection networks, from high-precision local systems to global coverage

Lightning is a fascinating phenomenon. For a small number of scientists around the world, it has been a prime focus of study for many years. As a result, the meteorological community is benefiting from a variety of innovations in lightning detection. All these technologies, which come from various sources, are helping to improve daily observations of lightning events and improve safety warnings for people and assets. An ideal situation would be when the world has no casualties due to lightning. But at present it is estimated that globally there are 24,000 fatalities and 240,000 injuries each year due to lightning, although these statistics are very difficult to verify (Holle, 2010). In addition, many billions of dollars in damages and avoidance costs are incurred internationally every year.

Detection technology

Each year new research further evolves detection technology, and new competition helps to push the members of the lightning detection community to keep challenging each other. Vaisala is no exception to this research initiative; it has been developing lightning detection equipment for more than 35 years, and has produced 15 generations of lightning detection equipment. The company's lightning detection sensors are currently operating in more than 45 countries; they have helped to save lives and also improve operational efficiency at weather-critical operationally based facilities such as airports, power utilities, mining operations, offshore platforms, and wind energy parks, as well as many other different applications.

Lightning detection technology started with various methodologies. It began by using the very low- and low-frequency power spectrum with only magnetic field-based detection (MDF). According to Cummins & Murphy (IEEE 2009), the earliest measurements directed at understanding the electromagnetic fields produced by distant lightning were carried out by the Russian physicist Popoff in 1895 (Norinder 1953), followed by quantitative analysis of atmospheric radio signals in the 1920s. This MDF methodology proved it is important to have a calibrated electric field measurement and to achieve a direction of detection. This was ultimately followed in the 1930s by time-of-arrival (TOA) only geolocation methodologies.

The TOA method uses the constant time difference in the arrival of the low-frequency signals to the ground-based sensors to calculate the locations of cloud-to-ground lightning events. This methodology is explained in detail in Cummins & Murphy (IEEE 2009). These early innovations have had challenges and limitations that have been identified over the years, such as terrain and conductivity effects to the propagation speed of lightning signals. This has resulted in new methodologies and refinements based on scientific discoveries, including new algorithms to improve the ability to accurately locate with higher detection efficiency of both cloud-to-ground (CG) and cloud lightning (IC) (Cummins, Murphy ILDC 2010).

The newly released 15th generation of detection equipment includes a combination of VLF/LF TOA and MDF with very high-frequency (VHF) digital interferometry. The best way to detect CG is in the VLF/LF frequency range (due to the radiation emissions signatures) and in the VHF range for IC. The digital VHF interferometry is now able to detect IC lightning twice as far and it has also improved the signal-to-noise ratio for better overall performance.

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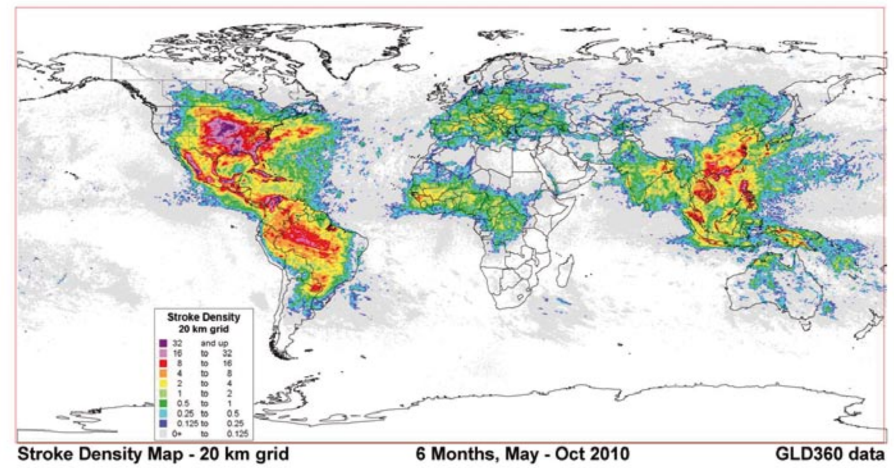


Vaisala GLD360 global lightning detection network, stroke density map at 20km grid from May-October 2010

Cloud lightning

The improved ability to detect cloud lightning over wide areas has a number of applications for lightning safety. Vaisala research during the last decade in the Dallas-Fort Worth area showed that some cloud flashes were over 50 miles long. The longest single flash detected was actually 120 miles long, produced two cloud-to-ground flashes along its path, and lasted nearly two seconds. In a similar case, a very long cloud flash produced a cloud-to-ground flash that injured an airport worker at DFW airport. A large amount of research has occurred in recent years to identify the structure of how such long cloud flashes are produced. These cloud flashes are always inside a cloudy area such as a squall line or mesoscale convective system. Cloud flashes tend to precede cloud-to-ground lightning by several minutes in most storms; these variations vary with location and season.

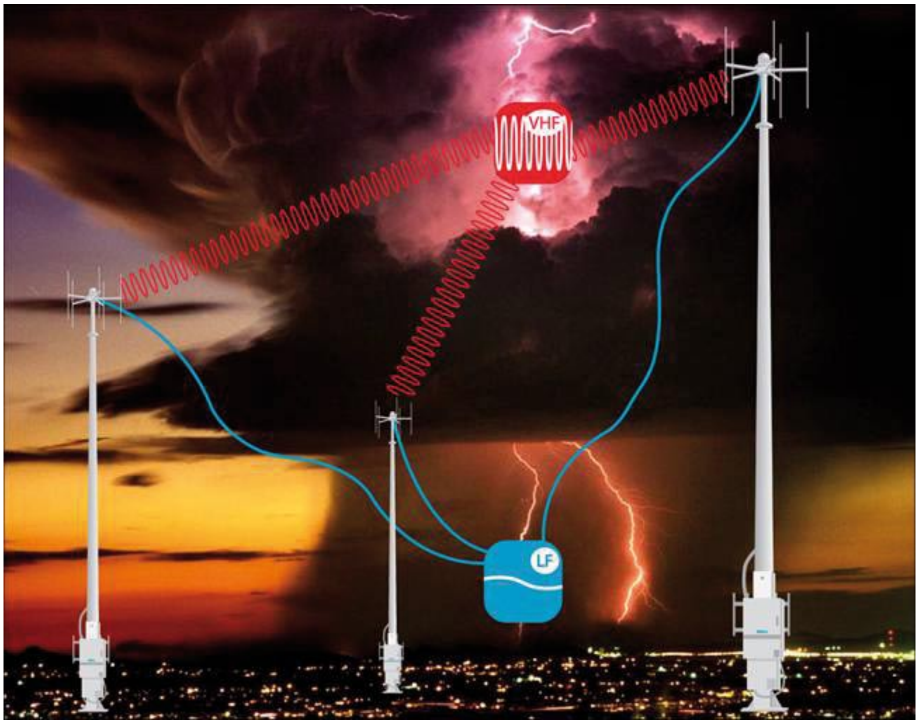
Knowing that cloud flashes can also have a cloud-to-ground component indicates that cloud lightning detection gives a more complete view of the cloud-to-ground lightning threat in space and time. This improved characterization of the threat is important not only for airports, but also other workplace and recreational applications. The improvement comes from using cloud lightning to detect more of the real lightning threats that are very near an asset, rather than using more distant cloud-to-ground lightning as a sometimes overly cautious indicator of the local lightning threat. In such cases, the high accuracy of the cloud and cloud-to-ground lightning network allows the user to be more efficient in working around the lightning threat.

Global lightning

At the other end of the spatial scale, there are long-range worldwide lightning detection networks emerging, such as Vaisala Global Lightning Dataset GLD360. This network allows for continuous and seamless monitoring around the world.

Such uniform observations are useful over the large ocean areas of the world for aviation, shipping, and monitoring of meteorological systems as they form, grow, and dissipate. Most storms over the ocean, for example, last six to 12 hours. During that stretch of time, lightning data shows the shape, size, orientation, and time changes of lightning over remote areas, which helps identify the type of thunderstorm complex that is occurring, in a more precise way than satellite data alone. One example is shown in the image of Tropical Storm Agatha 24 hour rainfall estimation and GLD360 lightning density.

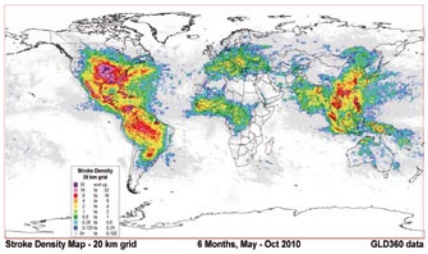
Over the many land areas of the world where there are no meteorological radar networks, GLD360 lightning data provides a means to monitor the most active storms over a country or region. At nearly any time of the year in almost any area of the world, meteorological processes can be intense enough to provide the necessary upward motion and mixture of supercooled water and ice particles to produce lightning. In areas of the world where radar coverage exists, lightning data continues to provide added information that specifies not only the lightning threat to people and assets on the ground, but where the most intense storms are located for such interests as aviation and defense. GLD360 is also the only global network that provides polarity and signal strength information. With the availability of such a globally consistent and high-quality data set, lightning-vulnerable interests can obtain data from a single source.



VHF signals are best for detecting IC lightning and VLF/LF signals are best for detecting CG lightning. Combinations of these two technologies have proved to yield greater than 90% detection of total lightning with channel mapping

Quality lightning

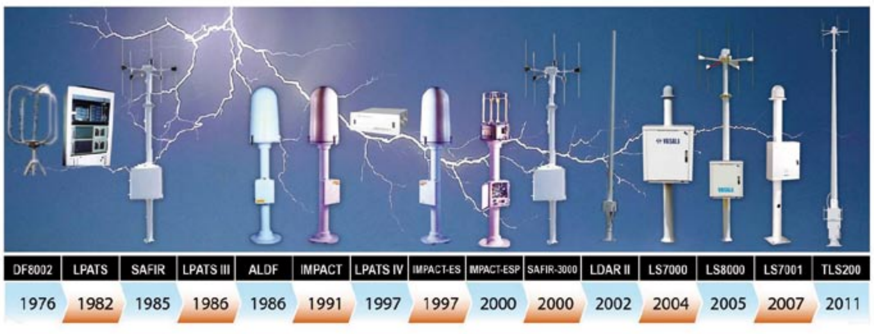
In recent years, in light of new competition, there have been many upgrades to existing lightning networks to greatly improve existing regional and national networks of cloud-to-ground sensors. For example, location accuracy in the US National Lightning Detection Network (NLDN) has been halved to 250m or better with the addition of patented terrain modeling; results have been verified by independent third-party ground truth studies using rocket-triggered lightning. Latency in delivering the data has been halved to 15 seconds from the time the lightning event occurred until arrival at the customer.



Vaisala Global Lightning Detection Network GLD360, stroke density map at 20km grid from May - October 2010

Cloud lightning detection is being enhanced to the NLDN with the new TLS200 sensor, which will provide much higher detection efficiency of cloud lightning than existing sensors. All of these updates are available for customers in the 45 other countries with Vaisala-provided networks as well.

In summary, the field of lightning detection has moved forward at both extremes of the time and space scales over the most recent years. These additions provide high-accuracy data for local applications, and also range up to quality lightning detection on a global scale. All these improvements are the result of continued collaboration and awareness of the relatively small scientific community that is dedicated to furthering the understanding and impacts of lightning worldwide to improve public safety and operational efficiency at weather-critical operations. ∎



Vaisala sensor technology evolution. 35 years of sensor improvements

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