Lightning Research Through the Years

Tohoku Electric Power Company and Vaisala partnered to advance lightning detection.

Research projects that span several years or even decades are common for scientists, and many times these projects have resulted in some amazing discoveries. At Vaisala, a team of scientists, engineers, meteorologists and researchers are working on research projects about a variety of weather phenomena, one of which is lightning.

Vaisala scientists have been working for nearly 20 years on a Winter Lightning Research Project in Japan. While this is a long time, the outcome has been worth the wait, especially for Tohoku Electric Power Company in Japan and now other electricity companies in the region as well.

In the Beginning

The history of the Winter Lightning Research Project dates back to the 1995/1996 timeframe, although researchers were studying the phenomena as early as in the 1970s. Tohoku Electric Power Company...
serves a region of Japan that is plagued by winter lightning. The interesting part is that winter lightning characteristics are significantly different from “traditional” summer lightning.

The technology that Tohoku was using at the time, the IMPACT sensor from Global Atmospherics Inc. (purchased by Vaisala in 2002) did not do a good job of detecting winter lightning. In fact, many papers had been written detailing the poor lightning detection efficiency of networks employed in Japan during winter, so it was a well-documented problem.

Tohoku Electric Power was already involved in a project in cooperation with a local university, observing current waveforms and the discharge waveform features of lightning strikes to an isolated tower on the coast of the Sea of Japan in winter. Some important findings from that study were included in the “Winter Lightning in Japan” section of the book “Lightning Physics and Effects”, written by Dr. Vladimir A. Rakov and Dr. Martin A. Uman from University of Florida.

When the system for tower observations was decommissioned, Tohoku started making observations at other locations to identify the characteristic field waveforms associated with lightning that struck transmission lines in winter. The company succeeded in this effort by using network of fast antennas with no dead time. This put Tohoku in a good position to provide data for the Winter Lightning Research Project; and thus, the venture was initiated.

A proposal was created in 1996, and Global Atmospherics Inc. (now Vaisala) and Tohoku agreed to work jointly on a solution to improve winter lightning detection efficiency and location accuracy.

Developing and Executing the Plan

Many researchers in Japan were anxious to see Lightning Location System (LLS) performance improved, but Tohoku Electric Power was the only company to step forward with funding under the Winter Lightning Research Project. The proposed solution was the development of a Remote Programmable Sensor (RPS) whose firmware could be upgraded in the field, and whose waveform detection parameters might be adjusted in accordance with the season in an effort to improve winter lightning detection efficiency.

Mr. Noriyasu Honma at Tohoku Electric Power had also been very interested in the effect of propagation time differences on LLS location accuracies in the mountainous terrain of Japan. His research indicated that the timing errors resulting from a system based on a flat earth model caused reduced location accuracy. Thus, it was important to also study making propagation corrections to the collected data.

The original planned features for the RPS were:

- Field upgraded from IMPACT to RPS
- Detect and report both cloud-to-ground and cloud discharges
- Remote configuration, programming and download
- 32 Bit CPU, support multiple GPS subsystems
- Automatic calibration and Selftest
- Zero dead time (continuous sampling)
- DSP based signal processing
- Flexible waveform feature extraction and selection

“Global lightning research is happening all the time at universities, private companies and government agencies. This research has produced great insight to lightning’s effects on our lives.”

1,675 strokes (green) and 594 cloud pulses (black) located by a six sensor LS network in Tohoku region during an evaluation period.
Tohoku Electric Power Company provided an initial investment to fund the engineering expense associated with the RPS development, along with an order for nine upgrades to the RPS in November 1996.

The original timeline planned for completion of the RPS in late 1999 or early 2000. However, the first generation RPS sensors were not produced until 2003. They were the Vaisala Thunderstorm CG Enhanced Lightning Sensor LS7000. The LS7000 employed low frequency, combined magnetic direction finding and time-of-arrival technology to provide the highest level of detection efficiency and most accurate location for cloud-to-ground strokes.

On the Tohoku side, an existing lightning central processor (APA283T) and nine IMPACT sensors were used initially for field research. During the project the lightning sensors were continually evolving, and the IMPACT sensors turned into the IMPACT-ES and then the IMPACT-ESP sensors, all due to enhancements made along the way.

In 2002, a waveform recording device was added to the IMPACT-ESP sensors in the field, giving scientists more substantial data to review. Then in 2003, four Vaisala LS7000s were purchased along with a new central processor (the LP2000). Two more LS7001s (the next generation of LS sensors) were added in 2008.

While the enhancements made to the lightning sensors were good, there was still more to be done. Tohoku had its own waveform (Lightning Electromagnetic Pulse, or LEMP) recording equipment, which was invaluable in the development and verification of the current lightning sensor’s waveform processing capability. Transmission line fault locators were also used to provide insight about the timing and location of faults, which could then be linked to a possible lightning event.

Tohoku is one of those rare places in the world where there are multiple observation systems detecting the same events. Mr. Honma was the main researcher at Tohoku, but he was supported by assistants throughout the project to collect and study data. In addition, four or five Sankosha engineers participated at various times during the life of the project.

Sankosha is a local engineering company in Japan and their role was to support both Tohoku and Vaisala with installations and maintenance of all of the sensors and central processors. Sankosha engineers helped Mr. Honma collect, analyze and reprocess data, while also functioning as a liaison between Vaisala and Tohoku, sometimes providing support for writing portions of project-related papers.

Tohoku, Sankosha and Vaisala all knew the Winter Lightning Research Project would take years of research and development, and as the project progressed each year, all parties maintained their commitment to the project. Although progress in the research was minimal for quite a few years, the project agreement continued to be renewed throughout the early 2000s.

“Have you ever thought about lightning’s effect on the electricity grid? Electric companies do, and their help has supported the further development of lightning detection technologies.”

One concrete example of the project’s results: The Vaisala Thunderstorm CG Enhanced Lightning Sensor LS7001. It detects low frequency signals using magnetic direction finding combined with time-of-arrival technology to deliver double the detection accuracy of high peak current winter lightning discharges compared to earlier sensors.
In January 2009, Mr. Honma wrote a letter to Vaisala emphasizing that Tohoku’s commitment to the project remained strong, accepting revised conditions of the project agreement, ordering two more lightning sensors, and pledging to submit additional LEMP waveforms correlated with lightning events detected by the LLS.

Progress increased dramatically after Mr. Honma’s letter. His commitment and vision for better lightning detection inspired everyone involved in the project. The past few years have seen the development of waveform processing capability in the sensor, improved onset correction techniques and the application of propagation corrections in the processor.

The final item in the project is the design and testing of effective classification parameters for “Ground to Cloud” (GC or Upward) lightning. Tohoku Electric Power is anxious to see the waveform classification parameters completed, and they have the waveform recording equipment required for verification. Thus, research and enhancements to lightning detection capabilities continue.

Results

The main objective of the Winter Lightning Research Project was to improve winter lightning detection efficiency and location accuracy. Was it achieved? The short answer is “Yes,” but many other positive outcomes were achieved during the research period as well.

First, the elimination of dead time leading to continuous sampling may have been the most significant result of the project as it caused a dramatic improvement in detection efficiency. Earlier, a lightning sensor might be busy processing small-signal, minor lightning events and miss damaging, large-amplitude strikes because some amount of time was required for the sensor to return to the state where it could process signals again. This is no longer true.

Second, the ability to detect events with more complicated lightning waveforms has resulted in a dramatic increase in winter lightning detection efficiency. Third, the implementation of improved onset corrections enabled better timing, hence improving location accuracy. And fourth, propagation corrections now instituted in the Vaisala Total Lightning Processor TLP have also improved location accuracy. Today, when propagation corrections are applied to data in the processor, location accuracy can be improved to the 150-300 meter range.

In addition, other significant advancements were realized. The sensor can now “replay” waveforms in order to evaluate performance, and sensor improvements can be made remotely by uploading software over a network, for example.

The Winter Lightning Research Project has had a dramatic effect on the lightning detection market in Japan, and the improvements in detection efficiency and the expected improvements in location accuracy (once propagation corrections have been implemented) are viewed as very important by local electric power companies. Of the nine electric power companies in Japan, all but two now have upgraded lightning sensors that include the improvements that came from this project, and the remaining two are working toward it. Franklin Japan Corporation, owner and operator of the Japan Lightning Detection Network (JLDN) has also started to upgrade its network of 30 sensors.

Further information: www.vaisala.com/lightning

Credits and Papers

As with any research, papers were written and presented throughout the project. Specifically, papers on the Winter Lightning Research Project were presented at the International Lightning Detection Conference (ILDC) in 2010, and at the International Symposium on Winter Lightning in Sapporo, Japan in 2011. In addition, a paper on “Improved Detection of Winter Lightning in the Tohoku Region of Japan using Vaisala’s LS700x Technology” was subsequently published in the IEEJ Journal.

Along with Mr. Honma and Vaisala, Dr. Kenneth L. Cummins, Professor at the University of Arizona, and Dr. Alburt E. Pifer, Consultant for Vaisala Inc., have been key players throughout their involvement in the Winter Lightning Research Project. Both Dr. Cummins and Dr. Pifer worked for Vaisala during the early research period, providing their expertise on lightning science and creative solutions to enhance lightning detection capabilities. Critical product development work was carried out by Dr. Martin Murphy and Tim Rogers of Vaisala Inc., and Michael Pezze, formerly of Vaisala Inc.