LIGHTNING DETECTION AND AVIATION WEATHER FORECASTING

The MetraWeather TOA Systems Malaysian high-resolution lightning detection network
Weather, and particularly severe weather events, can significantly impact airlines and airport operations.

The frequency and severity of these extreme events, and the resulting losses have been increasing for the last few decades. Greater disruption to global aviation services may be anticipated. Lightning is one of the most dangerous and frequently encountered weather hazards. It can significantly disrupt airlines operations, airports and air traffic control. Leveraging meteorological science and technological advances promises fresh opportunities to mitigate these impacts and better manage disruptions.
AVIATION WEATHER FORECASTING IN NEW ZEALAND

MetService is New Zealand’s UN-sanctioned National Meteorological Service (NMS).

MetService is the Civil Aviation Authority of New Zealand (CAA) certified provider of aviation weather information for all six categories, in accordance with Civil Aviation Rule, Part 174. MetService is also certified to AS/NZ 9001:2015 standards.

MetService provides commercial airlines and recreational pilots with high-quality aviation weather forecasting to safely and efficiently conduct flight operations, and minimise weather-related risks and disruptions across New Zealand and the Pacific region.

MetService is a partner for New Southern Sky, the implementation phase of New Zealand’s National Airspace and Air Navigation Plan.

It provides a suite of MET-CDM products and services which are helping to shift the focus of aviation weather guidance from interpretation towards impacts and decision support for collaborative decision making by airlines, airport operations and air traffic management.

“Many Malaysians are not aware their country has the ‘third-highest lightning activity’ in the world.”

Professor Ir Dr Mohd Zainal Abidin Ab Kadir, a Director of the Centre for Electromagnetic and Lightning Protection Research at the Universiti Putra Malaysia

THUNDERSTORM FORECASTING AND LIGHTNING DETECTION IN NEW ZEALAND

Aviation services in New Zealand, both in the air and on the tarmac, are sometimes disrupted by severe weather events, thunderstorms and lightning strikes.

MetService integrates real-time lightning data to inform aviation forecasts and decision support services geared to improving safety, operations and customer experience both in the air, on the tarmac and in the terminal.

The areas within a storm cloud where lightning strikes can occur can produce damaging hail and strong winds that cause turbulence. Accurate meteorological forecasting can assist flight planners to optimise their flight paths and determine the severity and track of a storm.

MetService aviation forecasts and support services are aligned with the System Wide Information Management (SWIM) and Airport Collaborative Decision Making (A-CDM) programmes used by airlines, airports and air traffic controllers to improve operational decision-making both airside, landside and beyond the perimeter fence.

During severe weather events, this shared visibility of the forecast conditions, and specifically changes to user-defined thresholds, enables airport operations centres to proactively and collaboratively disseminate information to help to manage air traffic and reduce congestion in the air and on the apron and taxiways.

The adoption of these programmes is helping to bring improved efficiencies, better customer experiences and potential cost savings. MetService aviation forecasts include:

- Cloud cover
- Visibility
- Precipitation
- Wind speed
- Cross winds
- Lightning strikes
It is well documented that thunderstorms and cumulonimbus clouds are among the most hazardous weather affecting aviation.

The reason thunderstorms are avoided by aircraft in flight include the following dangers:

- The risk of lightning strike
- Severe turbulence associated with strong up and down drafts
- Severe icing
- Poor visibility in heavy rain and hail.

These dangers are even more concerning for aircraft on arrival and departure as during these phases of flight, a headwind is necessary to create the lift needed to maintain altitude. A sudden change in wind direction caused by the outflow from a thunderstorm can severely impact this required lift and cause an aircraft to suddenly sink.

When lightning is reported within a certain proximity of an airport (usually 5 nautical miles), all ground operations are suspended because airport managers do not want to put their personnel at risk of being struck by lightning and it is unsafe to refuel an aircraft when lightning is present.

When the lightning data available to us indicates thunderstorms approaching any of our TAF (Terminal Aerodrome Forecast) aerodromes, we often proactively amend the TAF for that aerodrome to include the expected arrival time of the thunderstorms and expected time they will cease to impact the aerodrome. We do this because of the known impacts of thunderstorms on arrival, departure and ground movements around the aerodrome. When a significant line of thunderstorms is expected to impact a major airport such as Wellington, Christchurch or Auckland; if time allows, we’ll also call the tower of the impacted aerodrome to give them a personal warning of the approaching storms and how long these are expected to affect the terminal. We’ll also call Christchurch radar control so they know to hold aircraft back from entering the airspace around that aerodrome.

The cirrus cloud associated with an area of thunderstorms can often spread far from the centre of the storms, thus we use lightning data within and outside the NZZC to better issue SIGMETs for a more targeted area of concern. Without lightning data we often find ourselves issuing these warnings for areas much larger than is likely necessary.

Forecasters are however far from the only user of real time lightning data. Air Traffic Control will use radar and lightning data to route aircraft around areas of thunderstorms in real time and to determine when to delay aircraft on arrival or departure to avoid these crucial phases of flight being performed in a thunderstorm.

Airlines will use this data to plan routes around areas of thunderstorms. Airport managers will use lightning data to determine when to halt ground operations when lightning comes within a certain threshold distance to maintain the safety of their ground crew.
MetraWeather Asia and TOA Systems, Inc, with the support of Malaysian partner Riajati Sdn Bhd, are deploying a new high-resolution lightning detection network.

TOA Systems is a pre-eminent vendor of lightning sensors, detection networks and associated data. It has installed more than 600 sensors in over 50 countries.

The network will integrate more than 19 state-of-the-art TOA lighting detection sensors to provide extensive coverage across both East and West Malaysia.

Cloud-to-ground (CG) lightning strikes are extremely dangerous to the safety of collocated teams working outdoors, workers on airport aprons and people congregating for events in places such as public parks and university campuses.

Detection of the more common but much lower energy intra-cloud (IC) or cloud-to-cloud (CC) lightning is also crucial in providing advanced forecasting about potential risks.

Real-time detection of IC/CC lightning, when combined with other sources of meteorological data such as satellite imagery, rain radar and numerical modelling, can help forecasters to better understand and accurately categorize events.

“Malaysia experiences an average of 180 to 260 thunderstorm days each year.”

The US National Lightning Safety Institute
TOA SYSTEMS SENSOR TECHNOLOGY

The LPS-200 Advanced Lightning Sensor with digital signal processing is designed to bring the latest technology and precision to the market today. Offering LF/VHF dual-band operation, the LPS-200 processes lightning strokes from both cloud-to-ground (CG) and cloud lightning (CL) simultaneously.

Utilizing a high sensitivity, low noise wide-band receiver, state-of-the-art digital filters and equalizers, along with precision GPS time reference, the sensor can characterize and categorize the lightning stroke. Once identified, the LPS-200 initiates a TCP/IP message to the Central Analyser Processor (CAPTM) where the precise lightning location is calculated.

The LPS has enormous advantages over other lightning sensor designs, in particular those based on magnetic direction finding (MDF) which suffers from significant site introduced errors and consequent high siting costs. Precision lightning sensors used by GPATS do not monitor magnetic field signals as do Direction Finding (MDF) based sensors, therefore sensors have liberal siting criteria.

The LPS can be installed on existing structures, towers, and buildings where access to electric power and communications is readily at hand. TOA also offers remote site installation utilizing solar power. The LPS is also extremely adaptable in terms of communications; its design allows it to transmit data by telephone, network, internet, or radio as is deemed best suited to the requirement.

LIGHTNING DETECTOR

The detector part of the sensor is a broadband receiver. This picks up a substantial amount of the lightning energy that allows the system to distinguish between ground lightning and cloud lightning. With a broadband detector, the different characteristics of ground strokes and cloud strokes can be identified. This allows classification of the detected strokes by the LPS sensors.

In a time-of-arrival based system, timing is an important part of the receiver. The LPS receiver uses commercial GPS timing as a reference. The sensor uses a high frequency timing source that makes the timing more stable, accurate and increases the resolution. The timing is constantly monitored and corrected. This results in more accurate lightning locations.

An on-board processor handles communications and monitors the over-all operation of the sensor. It keeps track of the timing system. The sensor is designed for remote configuration of the hardware. This is accomplished using Field Programmable Gate Array (FPGA) technology. This allows remote configuration of the hardware using bit patterns. Upgrades can be performed without visiting the site.

The sensor is also designed for remote configuration of the software. Software is downloadable over the communications link. The programs are stored in non-volatile memory on the board. It is not affected by power glitches, losses, or outages.

CLOUD LIGHTNING DETECTOR

Cloud lightning generates much higher short-term energy at higher frequencies than cloud-ground strokes, which the sensor identifies. The precise timing of a cloud
RUGGED AND RELIABLE ANTENNA SYSTEM

The LPS has two antennas; the first is an active GPS antenna used for the timing reference. The second is used for stroke detection and is typically ~1 meter in length, with the precise length determined by network performance requirements. Both antennas are small and lightweight, have a small wind resistance, and are easily mounted on existing structures without requirements of extensive civil works. They are designed for easy maintenance; and since there are no sensitive electronics mounted outdoors, site selection is simplified and reliability enhanced.

FLEXIBLE COMMUNICATIONS

The sensor supports various communications methods. It has an on-board 10-Base-T network controller that allows TCP/IP communications over a network. There is also a standard serial communication circuit for modem or satellite communications.

Data from the TOA Systems’ network includes precise date and time (to millisecond) resolution, latitude and longitude coordinates for each detected event, calculated peak current/amplitude and confidence error estimates.

The data formats and delivery channels are highly flexible. Commercially available software includes the Google Earth Lightning Service, which directly ingests real-time lightning data into the Google Earth software. Features include:

- detailed lightning event information (location, time, and amplitude)
- storm cell representation at higher altitudes to expedite display
- advanced features such as error ellipse analysis and circular alerting regions
- user authentication and individual profiles.

COMPREHENSIVE DIAGNOSTIC CAPABILITIES

Built-in diagnostics monitor the system and allow remote diagnostics if the communications software is running. Sensitivity and other system settings are user adjustable depending upon the needs of system.

PERFORMANCE VERIFICATION

The characteristics of ground lightning are well known and the LPS sensors are programmed to look for these characteristics. The sensors discriminate ground strokes by monitoring the characteristics of the radiated energy at the lower frequencies.

The engineers of TOA as well as many other scientists, engineers and operators around the world have measured the detection efficiency and location accuracy of time-of-arrival lightning location systems. To achieve this understanding, one can monitor high towers which receive many lightning strikes. Investigations using three 1000-foot and larger towers located in Florida were performed, allowing for accuracy and consistency to be validated.

A pulse of a certain magnitude will allow the accurate location of that pulse using time-of-arrival mathematics. Due to their very high sensitivity, LPS sensors have no problem detecting cloud stroke signatures; because of the comparatively weaker peak voltages received at the antenna and the effects of propagation delays over longer distances, signal strength thresholds will also be lower than for ground strokes.
Campbell Scientific is an international group of companies with offices in Australia, Brazil, Canada, China, Costa Rica, France, Germany, South Africa, Spain, Thailand and the UK as well as the original American parent company formed in 1974.

The company manufactures dataloggers, data acquisition systems, and measurement and control products used worldwide in research and industry. Their instrumentation is known for its flexibility, precision measurements, and dependability—even in harsh, remote environments.

Safely and effectively alerting workers on airport tarmacs to the proximity of lightning strikes can be difficult.

Ambient noise, hearing protection, ignition risks and alerting workers across a diversity of roles and workplaces poses specific communication issues. The Campbell Scientific RA110 device enables an alerting alarm system to be located several miles from the lightning detection sensor network. It uses telemetry to receive field information from the field. When the electric fields indicate that there is a potential for lightning, the RA110 triggers visual and audible alarms that warn of the threat. Multiple RA110s can receive information from one lightning detection network.

The RA110 consists of an RA100 Remote Strobe and Siren Alarm, a CR800 datalogger, a power supply, communications device, and an ENC14/16 enclosure. Communication options include fibre, spread-spectrum radio, and Internet. There are also several options for mounting the enclosure and the RA100 alarm system.
BENEFITS AND FEATURES

- SAE Class II LED beacons with 100,000 hour rated lifetime
- 120 dB siren
- “All clear” notification when lightning threat has passed
- rugged construction
- stainless-steel brackets for mounting to a flat surface
- optional pole mount kit allows mounting to a pole with a 1.5- to 4-in. outside diameter

CASE FILE

On the evening of 11 April 2018, a lightning strike at Wellington Airport knocked out some of its runway lights shortly after 7 pm, grounding flights and stopping landings. About 8.15 pm, Airways New Zealand reported that the lights were restored and operations had resumed.

MetService aviation meteorologists had forecast showers, hail and thunderstorms for the evening.

The weather event at Wellington Airport was the latest in a string of weather-related travel disruptions. Flights were grounded at Auckland International Airport the day before, when winds of 90 km/h were recorded and gusts reached up to 120 km/h.
PARTNERS

**MetraWeather Asia**
www.metraweather.com

MetraWeather is a specialist commercial weather company that provides customers in Europe, South East Asia, Australasia and the Pacific with weather guidance, decision-support and actionable weather insights. It is a wholly-owned subsidiary of the Meteorological Service of New Zealand Limited (MetService), New Zealand’s WMO accredited National Meteorological Service (NMS).

**TOA Systems, Inc.**
www.toasystems.com

TOA Systems is a pre-eminent vendor of lightning sensors, detection networks and associated data. It has installed more than 600 sensors in over 50 countries. TOA owns and operates, for example, the 250-sensor North American Precision Lightning Network (NAPLN) and the Australian lightning network incorporating over 100 sensors. It also supports networks in a diverse range of environments in Canada, Central America, South America, Africa, Asia, the South Pacific and New Zealand. TOA Systems is headquartered in Florida, USA.

**Riajati Sdn Bhd**
www.rj.my

Riajati is a wholly-owned Bumiputera company with 22 years of experience based in Kuala Lumpur. Riajati has grown over the years diversifying its interests into specialised fields including Information Communication Technologies (ICT), meteorological solutions, and engineering and system integration.

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