The Canadian Lightning Detection Network
Web Portal based Products, Services &
Indicators of Real Time Performance Measurement

Meteorological Service of Canada
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1.0 Introduction/Background

Canada is approximately 10,000,000 square kilometers in size, has a population of 32M (2004) and a comparative GDP of $959B (2003 - US Dollars). To put this in context, Germany is approximately 357,000 sq km in size, has a population of 82M (2004) and a comparative GDP of $2271B (2003).

The physical size of Canada coupled with the smaller population and tax base, poses unique challenges for the Meteorological Service of Canada (MSC) when designing, operating and managing monitoring networks. The Canadian Lightning Detection Network (CLDN) is one such MSC network. The CLDN Web Portal provides a suite of cost effective real time Performance Measurement indicators while simultaneously providing access to an archive of Flash Density summaries and geopolitical statistics.

1.1 Network Topology

The CLDN was designed in 1997 and deployed in 1998. The primary design objective was to have Detection Efficiency of 90%+ and Accuracy of 500m or better over those areas of Canada having 5 thunderstorm days or more.

In addition to the primary objective, MSC had to ensure that all major population centres, forested areas and electricity production and transmission facilities were adequately monitored as well as all major aviation corridors and areas.

The CLDN initially consisted of 81 Vaisala sensors. (30 Impact ES sensors + 51 LPATS IV sensors). Two additional IMPACT ES sensors were added in Yukon in 2003. A network recapitalization program commenced in 2005. Depending on budgets, from 3 to 6 LPATS IV sensors are being swapped out each year in favour of new Vaisala LS7000 sensors. As of Sept 2005, the CLDN consisted of a 6 LS7000's, 29 Impact ES and 48 LPATS IV sensors for a total complement of 83 sensors. See Fig. 1.

In order to avoid boundary conditions between Canada and the US, the CLDN operates in an integrated fashion with the National Lightning Detection Network (NLNDN) owned by Vaisala and covering the continental US. Data is shared with the Alaskan Fire Service during the summer months to add an additional 5 sensors in the northwest. This amalgam of approximately 200 integrated sensors is referred to as the North American Lightning Detection Network (NALDN).

Raw sensor Data flows from each CLDN sensor via VSAT transmission to the ANIK-2 geostationary satellite and then to a Telesat hub station near Toronto. A landline carries the data from the Telesat hub to Vaisala’s processing center in Tucson, AZ where the raw sensor data from all NALDN sensors is used to compute Flash and Stroke lightning solutions over Canada, the contiguous USA, Alaska and coastal waters. Flash solutions are then back hauled by landline to Toronto and broadcast via satellite to MSC and other clients. Typically clients have solution data on site within 60 seconds of the lightning event. A new dissemination topology is being developed in preparation for Telesat Canada’s plans to phase out ANIKOM service in the fall of 2006.

1.2 Lightning in Canada

The CLDN and associated communications infrastructure was designed to detect, resolve and communicate to users up to 45,000 flashes per hour.
We have not seen rates of this magnitude to date. A rate of 25,000 flashes per hour will occur 5-15 times a year, usually in the afternoon.

Typically since 1998 the CLDN detects 2-4 Million Flashes to Ground per year with an average of 1.7-2.3 Strokes per Flash depending on the year. Intra cloud and cloud to cloud lightning is also monitored on a low efficiency “survey” level but not used operationally at this time. The lightning season generally runs from April to October. Although winter lightning is detected it is infrequent & mainly confined to coastal areas.

Flash densities can be described as low to moderate with densities ranging from .25 to 4 flashes/sqkm/year. There are “hot” spots. Southern and in particular southwestern Ontario has Flash Densities that consistently range from 2 to 4 flashes/sqkm/year, large sections of central and southern Alberta consistently exceed 1 flash/sqkm/year. Spots in southeastern BC also exceed 1 flash/sqkm/year.

There is little in the way of reliable statistics on deaths caused by lightning in Canada. Anecdotal information suggests that 3-8 Canadians die from Lightning each year in Canada with approximately 80 additional injuries not causing death.

Environment Canada has undertaken a more scientific assessment that is incomplete at this time. As a component of this assessment, a preliminary review of newspaper reports studied between 2000 and 2005 found reports of 3-4 deaths per year with 4-5 times as many media reports of injuries.

Commercial losses are also difficult to measure. Estimates of insurance losses indicate that up to 40,000 claims are filed each year with the majority of them being in the $1000-2000 range mainly in homes. Industrial claims although fewer, are considerably more expensive with some each year in the $500,000 and up range.

Losses of timber and property resulting from lightning triggered forest fires run into the $100’s of Millions annually. In 2004, 6634 forest fires in Canada consumed 3.2M hectares of forest compared to ten year averages of 7631 fires and 2.8M hectares respectively. Nationally in 2002, 46% of forest fires in Canada were caused by lightning while across western and northern Canada, approximately 70% of forest fires are caused by Lightning.

As populations continue to grow, forest fires are becoming a more serious threat to lives and properties in settled areas adjacent to forested areas. During the summer of 2003, fires caused by lightning partially enveloped numerous communities in British Columbia. Hundreds of homes were destroyed or damaged BC causing insured property damage that exceeded $150M.

In addition to direct support for Forest Fire Suppression and infrastructure managers, MSC makes use of CLDN information to support its public and aviation forecast programs. Lightning serves well as an integrated indicator of hazardous high impact weather, particularly when used in real time in conjunction with Satellite Imagery and Radar. See Fig. 2.

2.0 Network Management.

In addition to MSC using the CLDN for meteorological and high impact public safety purposes, a number of important clients use CLDN data to support their operational mandates. Keeping the CLDN healthy and producing high quality lightning solutions is important to us.

Given that the CLDN utilizes a network of sensors dispersed widely across most of Canada, management and maintenance of the network poses some unique challenges, particularly in the face of limited resources.

To assist with providing MSC personnel with access to information, most resource materials related to the CLDN are stored on line in two internal MSC web sites, one for staff to support operational use of the CLDN and a second password protected web site for managers and financial administrators.

Communications, Sensor Status Monitoring and Solutions Processing is contracted out to Vaisala on a fixed cost multi year basis.

Sensor and communications (VSAT) management and maintenance is undertaken primarily by MSC personnel while Vaisala is available to MSC for service
depot and specialized on site work when required. Under contract to MSC and utilizing the VSAT communications capacity, the “health” of each sensor is continuously monitored by Vaisala as data is gathered. Sensor problems that cannot be resolved remotely are reported to MSC’s National Monitoring Desk and then actioned as a “Trouble Ticket” to regional service personnel for resolution.

A “tiered” approach to sensor and communications maintenance is used. Site hosts serve to fulfill tier one tasks such as processor resets, power cycling and site physical examinations. MSC technicians provide on-site tier two sensor maintenance and repair. Vaisala specialists provide tier three support for those situations that are not resolvable by tier one or tier two personnel. Tier three may entail a sensor site visit by Viasala staff but to date most tier three work has been done in house at Vaisala’s location in Tucson.

As a network of sensors, the CLDN can continue to generate quality lightning solutions with a considerable number of noncontributing sensors. Although this network approach is inherently fault tolerant, beginning in 2004 with the life of the network at 5+ years, a higher emphasis was placed on ensuring that sensor outages are resolved as quickly as possible.

During 2005 we embarked upon an upgrade plan developed with input from Vaisala that replaces older LPATS IV sensors in favour of IMPACT LS7000 sensors to further improve network performance in prioritized areas and extend the life cycle of the CLDN.

In addition to reinvesting in the sensor network the CLDN is periodically able, depending on budgetary resources, to fund the development and operational implementation of new products and services.

3.0 Performance Measurement.

To assist with efficient Network Management and as an aid to improving the performance of the CLDN, a suite of CLDN Performance Measurement (PM) tools were designed and deployed in 2004 and 2005. The design premise for the PM tools was as follows:

- That whatever indicators were chosen the measurement of those indicators should be available “On Line” by staff using a simple web browser such as Microsoft Internet Explorer (IE).

- Metadata about the sensors themselves is important and although not subject to frequent change the information needs to be accurate and available immediately upon demand.

- For all but static data, the frequency of reporting should be at least daily and where possible as frequently as hourly or half-hourly.

- The presentation of the Performance Indicators should be suitable for managers, technical staff and in some case clients. As such the presentation should be simple to comprehend while offering links to more technical detail that can be mined quickly from a database when required.

- Snapshots of the state of the CLDN should be archived with a view towards satisfying possible due-diligence considerations and better understanding any recurring problems and what sensor outages mean to the network as a whole.

- That in the balance, it is the quality of CLDN solutions as measured by the Accuracy and Efficiency values that “grade” the performance of the CLDN from a users perspective. Users are more concerned about the Accuracy and Efficiency of the lightning solutions than they are about the state of any particular sensor. Hence a dynamic indicator of the Accuracy and Efficiency of the CLDN as a whole is required in addition to indicators related to sensors themselves.

The CLDN Performance Measurement tools that resulted from the design premise are as follows:

- Sensor Status and Performance Data
- Network Performance
- Dynamic Accuracy and Efficiency Maps

A secure web portal was developed to host these tools and to offer password protected access to MSC managers, maintenance personnel from MSC and Vaisala and selected clients.

3.1 Sensor Status and Performance Data.

Three indicators are used to track sensor information:

- A map of North America with color coded sensor status updated and archived every 1/2 hour. See Fig. 3. & Fig. 4.
- Diagnostic information obtained by clicking on any sensor. See Fig 5.
- Sensor metadata updated daily. See Fig. 6.
3.2 Network Performance.

Although from a maintenance perspective, sensor status and performance is extremely important, from a user perspective, the ability of the CLDN to detect lightning and correctly locate lightning is a more relevant indicator of overall performance.

A “performance measurement grid” has been developed (see Fig. 7.) that assesses one sensor and four network performance parameters for each of 112 regions in North America. Each region is then color coded and the resultant network performance map is generated and archived every 30 minutes.

Current network performance can now be examined at any time, and from anywhere via a standard web browser having access to the CLDN portal. The archive feature provides users with the ability to go back to any critical time and examine the performance of the CLDN.

3.3 Dynamic Accuracy and Efficiency Maps.

Two of the most important performance indicators for a lightning detection network are Location Accuracy and Detection Efficiency.

Location Accuracy is defined as the distance between where the network says a lightning stroke occurred and where it actually occurred. Accuracy is generally measured in kilometers.

Detection Efficiency is defined as the ratio of the number of lightning strokes detected by the network divided by the number of lightning strokes that actually occurred. Efficiency is generally stated as a percentage %.

Vaisala has a modelling algorithm that can predict Accuracy and Efficiency of a network based on the location, density and type of lightning sensors. This algorithm has historically been used to plan and adjust networks and is run off-line as a design and assessment tool on a demand basis with typical run times in the order of hours.

It is not the purpose of this paper to review the algorithm and how it works per se, but to show instead how we are using this tool in a real time mode to better monitor the performance of the CLDN.

Given that Accuracy and Efficiency are the most relevant indicators of network performance, MSC contracted Vaisala to implement a similar algorithm that could be run automatically in near real time at least once per hour. This would provide users of the CLDN with an immediate indication of Accuracy and Efficiency using the actual operational sensor suite.

Some compromises have been made to facilitate timely generation of the Location Accuracy (Fig. 8.) and Detection Efficiency (Fig. 9.) maps. The contouring is somewhat coarse and in the case of Efficiency there is an observed trend to report lower values than seen from the original algorithm run off line. While improvements are under consideration MSC is using the Dynamic Accuracy and Efficiency plots internally to compare performance of the CLDN in a relative sense. Although the values of Efficiency over Canada are depressed from that found using the “full blown” model running off-line, the dynamic near real time output is useful to MSC when making relative comparisons from hour to hour, day to day and with varying sensor topologies.

An archive of Accuracy and Efficiency Maps was implemented in 2005 to provide the ability to review & compare CLDN past performance snapshots every 30 minutes.

4. Areal Statistics

When Lightning has an impact in Canada, the Meteorological Service of Canada is often called upon for information related to the incident. These requests can be well after the fact but also come in even as the lightning storm is still underway.

MSC and Vaisala both have tools that enable detailed flash by flash, stroke by stroke analysis of lightning overlaid upon GIS maps and integrated with other data sets. However, until recently MSC was somewhat lacking in real time constantly updated survey type tools that were able to support our staff in responding to queries from the public, media, managers and elected officials, particularly regarding frequency, statistics and areal distribution to support comparisons between different years, months and jurisdictions.
Acting on concepts developed in 2004, MSC contracted Vaisala to develop and deploy several new services to help fill this gap between the highly detailed well after the fact type of analysis and the need for more general near real time oversight and survey level tools needed to meet the broader requirements of our mandate.

Two new tools emerged from this work and are operational at this time. The first is a real time calculation of flash density over North America that serves as an indicator of lightning risk. For further information see Broad Scale Real Time Flash Density Maps - Lightning Risk Indicators for the General Public - International Lightning Meteorology Conference (ILMC) - Tucson, AZ, 2006.

The second tool is near real time areal statistics which are updated every 15 minutes for all major geopolitical areas in Canada (10 provinces + 3 Territories). Statistics are also being derived within a growing number of 50 km circles around key points such as airports, large cities and other spots of particular interest.


These statistics are available via the CLDN Web Portal to MSC personnel and authorized clients. Users first select their area of interest (See Fig 10.) to which the system responds with a yearly summary distributed by month for both flash and stroke. See Fig 11.

Clicking on a month of interest produces a detailed day by day data presentation for the month. Statistics are presented for each day with lightning including totals, averages, maximums and minimums related to polarity, current, and multiplicity. See Fig 12.

5. Future Developments.

Plans for further enhancements to the Areal Statistics system in the future include enabling the system as a front end search and query GUI to assist researchers and users with on demand, near real time, web based data retrieval.

6 Summary:

The Canadian Lightning Detection Network provides lightning detection coverage for over 95% of Canadians. New internet accessible Performance Measurement tools enable the Meteorological Service of Canada (MSC) to efficiently monitor and effectively display the status of the lightning detection sensors and the accuracy and efficiency of the CLDN in real time. Through use of the Performance Measurement tools, MSC managers and staff are able to see the effects of sensor outages and act quickly to minimize sensor down times.

7. References:


8. Acknowledgements:

The author wishes to acknowledge the contribution of information and support from the following:


Morris, A. Data Services Manager, Vaisala, Inc. Tucson AZ.
Fig. 1. CLDN Sensor Locations (Sept 2005)

Fig. 2. Integrated CLDN and IR Satellite Image over Edmonton, Alberta (20040712 01:00 UTC)
Fig. 3. Current Sensor Status & access to archive

Fig. 4. Sensor Status with roll over and click-on information. (not shown)
Fig. 5. Diagnostic information

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<th>CDB Information:</th>
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<tr>
<td>Name: Sydney_NS</td>
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<tr>
<td>Type: IMpACT ES</td>
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<tr>
<td>Latitude: 46.162796020507812</td>
</tr>
<tr>
<td>Longitude: -60.042083740234375</td>
</tr>
<tr>
<td>Random Error: 10.15</td>
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<td>Threshold: 100</td>
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Sensor Availability:
Transitions (last 24 hours): 0
Total Time Down (last 24 hours): 24:00:03

Fig. 6. Sensor metadata

[sensor:62] Name “Fort St. John BC” “SJ” “CLDN” “SeriesIV” “TO-1” Type “SeriesIV” Transport 6 2 Network 0 0 Participation “yes” Location 56.248073577880859 -120.73606109619141705 RandomError 10.15 AngleRandomError 0.75 0.288675010204315197 UsableMeasurements “.st” Cloud 10 0x0 Threshold 100 Rotation 0 SiteCorrection 0 0 0 0 0 0 SignalAttenuation 100 1 1 1000 Gain “EField6_Lpats” GainCorrection 1.3400000333786011

Fig. 7. Network Performance.
Fig. 8. Dynamic Location Accuracy Map (contours at .5 & 1 km)

Fig. 9. Dynamic Detection Efficiency Map (contours at 70% & 90%)
Fig. 10. Areal Statistics - Selection of Area of Interest.

Fig. 11. Areal Statistics - By year and month for area selected.

Environment Canada

The information is confidential and is intended for internal use by Meteorological Service of Canada and Vaisala personnel only; not for release or circulation.

Alberta
The breathtaking views, abundant natural resources, and skilled workforce make Alberta an excellent place to work, live and do business.

2005 Lightning Flash/Stroke Detail

<table>
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<tr>
<th>Month</th>
<th>Total Flashes</th>
<th>Total Strokes</th>
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<tr>
<td>Jan</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
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<tr>
<td>Mar</td>
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<td>May</td>
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<td>Jun</td>
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<tr>
<td>Jul</td>
<td>129,757</td>
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<tr>
<td>Aug</td>
<td>37,792</td>
<td>79,992</td>
</tr>
<tr>
<td>Sep</td>
<td>10,972</td>
<td>23,493</td>
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<tr>
<td>Oct</td>
<td>74,471</td>
<td>156,106</td>
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<tr>
<td>Nov</td>
<td>34,766</td>
<td>72,404</td>
</tr>
<tr>
<td>Dec</td>
<td>67,458</td>
<td>138,757</td>
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Flash: a Stroke:  
Fig 12. Areal Statistics - Daily totals, averages, maximums and minimums related to polarity, current, & multiplicity.

<table>
<thead>
<tr>
<th>Day</th>
<th>Month</th>
<th>Day #</th>
<th>Year</th>
<th>Time Period</th>
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</thead>
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<tr>
<td>Fri</td>
<td>Jul</td>
<td>01</td>
<td>2005</td>
<td>00:00-23:59:59 GMT/UTC</td>
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</table>

**Flashes**
- Negative: 4043
- Positive: 400
- Total: 5246
  - Max Mult: 14
  - Avg Mult: 2.31
  - MinkA: -4.00
  - MaxkA: 133.50
  - AvgkA: -16.40
  - +MinkA: 3.90
  - +MaxkA: 102.70
  - +AvgkA: 13.50

**Strokes**
- Negative: 11676
- Positive: 454
- Total: 12130

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<tr>
<th>Sat</th>
<th>Jul</th>
<th>02</th>
<th>2005</th>
<th>00:00-23:59:59 GMT/UTC</th>
</tr>
</thead>
</table>

**Flashes**
- Negative: 2238
- Positive: 283
- Total: 2521
  - Max Mult: 11
  - Avg Mult: 1.64
  - MinkA: -4.60
  - MaxkA: -161.50
  - AvgkA: -22.90
  - +MinkA: 3.50
  - +MaxkA: 173.30
  - +AvgkA: 26.30

**Strokes**
- Negative: 3818
- Positive: 314
- Total: 4132