The Canadian Lightning Detection Network
Novel Approaches for Performance Measurement and Network Management

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ABSTRACT

The Canadian Lightning Detection Network (CLDN) was established in 1998 and now provides lightning detection coverage for over 95% of Canadians. This paper will provide some background on the CLDN, describe how the network is managed and discuss some operational issues. Some novel approaches to using the internet for real-time performance monitoring network management and data display will also be presented.

1.0 Introduction/Background

Canada is approx 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 approx 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. This paper will provide an overview of the CLDN, explain how it is managed and describe some novel approaches that have been undertaken to measure and display the performance of the CLDN in real-time.

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.

Initial capital requirements (approx $7M) were met via an internal loan to MSC. Loan repayment and operating costs are covered by a blend of MSC operational budgets and revenues from CLDN clients including Provincial Forest agencies, Public Utilities and NAV CANADA (Air Transport).

The CLDN is largely unchanged from when it was first installed in 1998. Two additional sensors were added in the Yukon in 2003 . The network consists of 51Vaisala (ex GAI) LPATS IV sensors and 32 Vaisala IMPACT ES 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 (NLDN) 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 199 integrated sensors is called 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 backhauled 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.

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 5-10 Million Flashes to Ground per year with an average of 1.7-2.3 Strokes per Flash depending on the year. Intracloud 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 and 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 consistenly range from 2 to 4 flashes/sqkm/year, large sections of central and southern Alberta consistetly exceed 1 flash/sqkm/year. Spots in southeastern BC also exceed 1 flash/sqkm/year.

We do not have accurate statistics on death and injury rates due to Lightning in Canada. However anecdotal information suggests that 3-8 Canadians die from Lightning each year in Canada with approx 80 additional injuries not causing death..

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 trigged 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, 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.

To enable rapid response to numerous post event lightning inquiries from police, fire officials, insurance companies, coroners and infrastructure managers, MSC has implemented a data archive and retrieval system that serves as a backend data repository and interfaces with Microsoft Mappoint. Microsoft Mappoint is a low cost (approx $400) low-mid capability shrink wrap GIS tool that can easily display lightning data plotted on maps of terrain, roads, locations and geo-political areas and includes postal code boundaries for Canada and the USA.

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 adminstrators.

Communications, Sensor Status Monitoring and Solutions Processing is contracted out to Vaisala on a fixed cost multiyear 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 non-contributing 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.

In 2005 we will be continuing with an upgrade plan developed with input from Vaisala that will swap out older LPATS IV sensors in favour of IMPACT LS7000 sensors in order to further improve network performance in 10 priorized areas.

As noted earlier, the CLDN is funded with a blend of MSC resources and revenues from third parties. Since 2003, the CLDN has been operationally self sufficent. Small operational surpluses are being used to fund the development of new products and services, to improve network performance through the upgrading of sensors, and most importantly to extend the life cycle of the network itself.

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. 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 occured and where it actually occured. 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 occured. 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 offline 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. Improvements are under development for deployment in 2005.

An archive of Accuracy and Efficiency Maps is also being implemented to provide the ability to determine CLDN past performance on an hour by hour basis.

4 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.

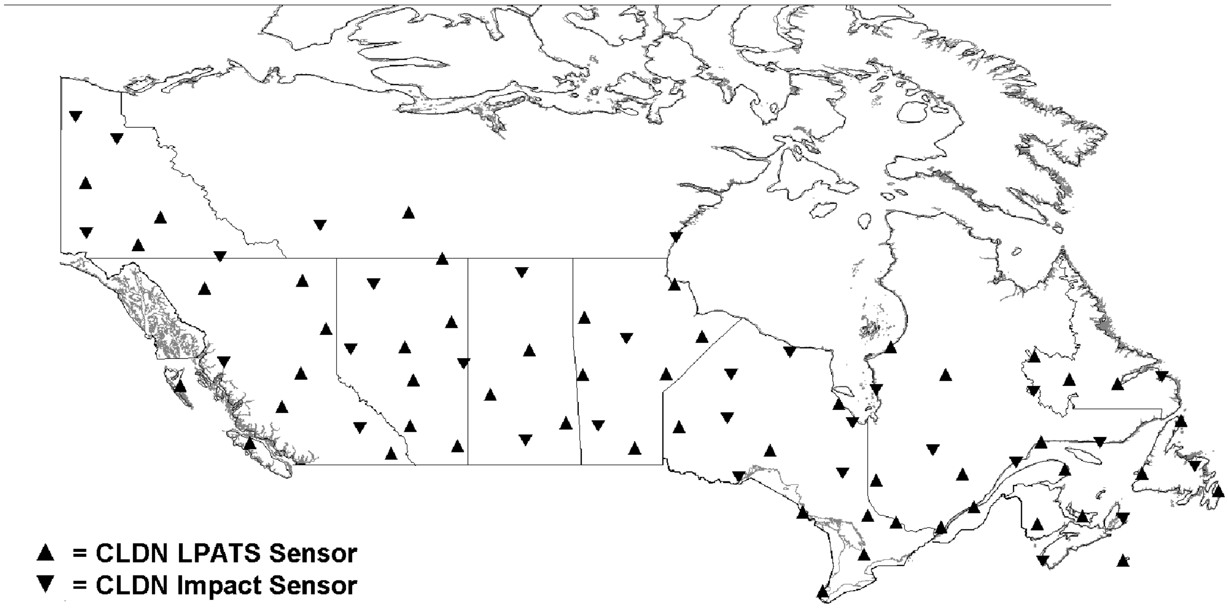


Fig. 1. CLDN Sensor Locations (Feb 2005)

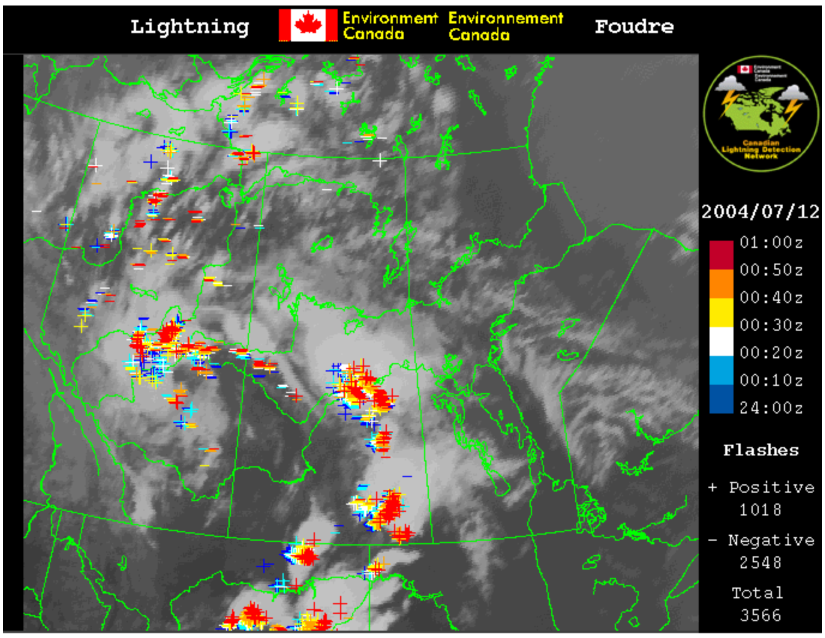


Fig. 2. Integrated CLDN and IR Satellite Image over Edmonton, Alberta (20040712 01:00 UTC)

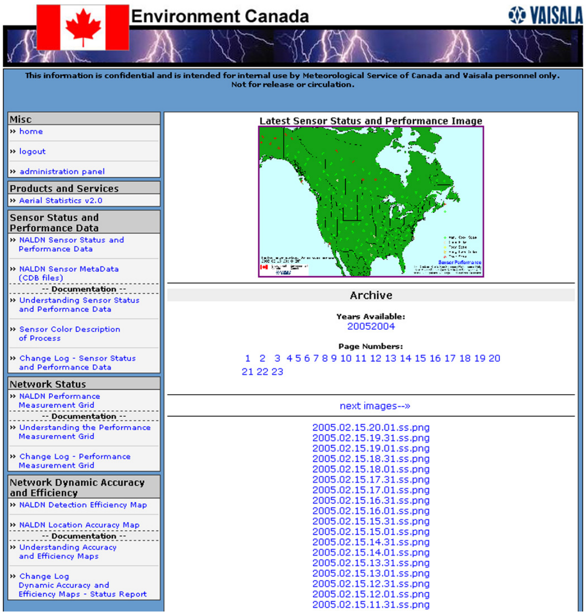


Fig. 3. Current Sensor Status & access to archive

CDB Information:

Name: "Sydney_NS"	**Type:** "IMPACT ES"	**Lim:** "TO-1"
Latitude: 46.162796020507812	**Longitude:** -60.042083740234375	**Altitude:** 61
Random Error: 10 1.5	**Threshold:** 100	

Sensor Availability:
Transitions (last 24 hours): 0
Total Time Down (last 24 hours): 24:00:03

Fig. 5. Diagnostic information

[sensor:62] Name "Fort_St._John_BC" "SJ" "" "CLDN" "SeriesIV" "TO-1" Type "SeriesIV" Transport 62 Network 0 0 Participation "yes" Location 56.248073577880859 -120.73606109619141 705 RandomError 10 1.5 AngleRandomError 0.75 0.28867501020431519 7 UsableMeasurements ".st" Cloud 10 0x0 Threshold 100 Rotation 0 SiteCorrection 0 0 0 0 0 0 0 0 SignalAttenuation 100 1 1 1000 Gain "EField6_Lpats" GainCorrection 1.3400000333786011

Fig. 6. Sensor metadata

Fig. 4. Sensor Status with roll over and click-on information.

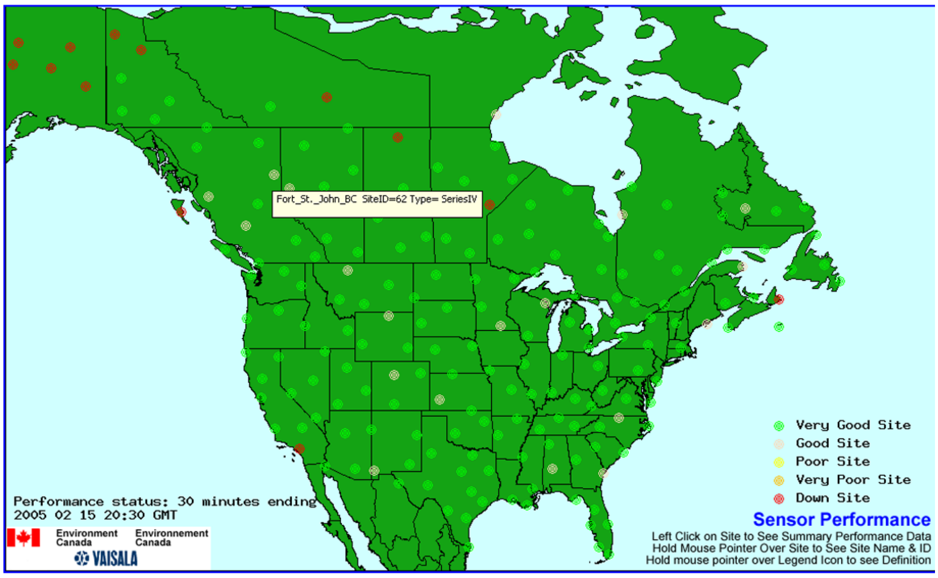
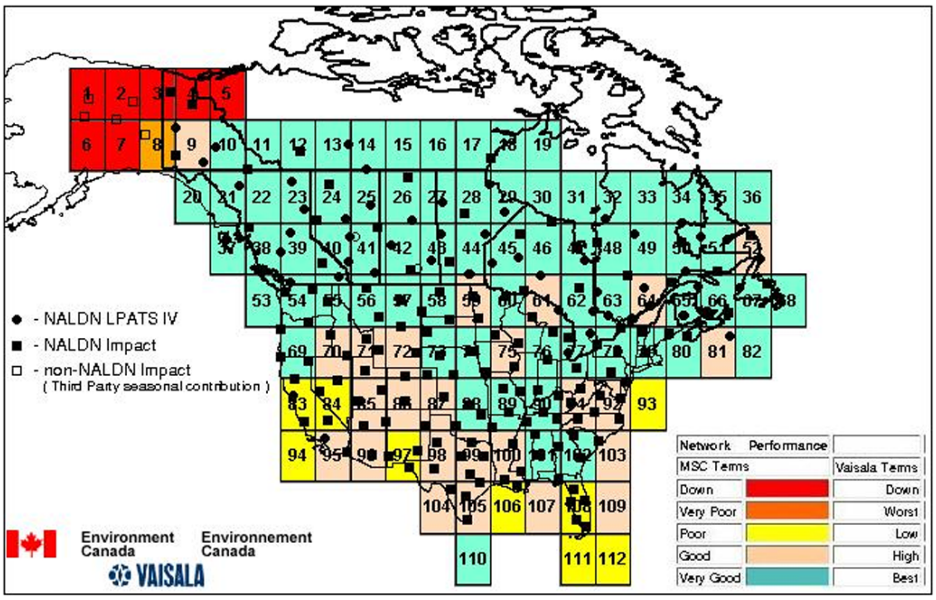


Fig. 7. Network Performance.



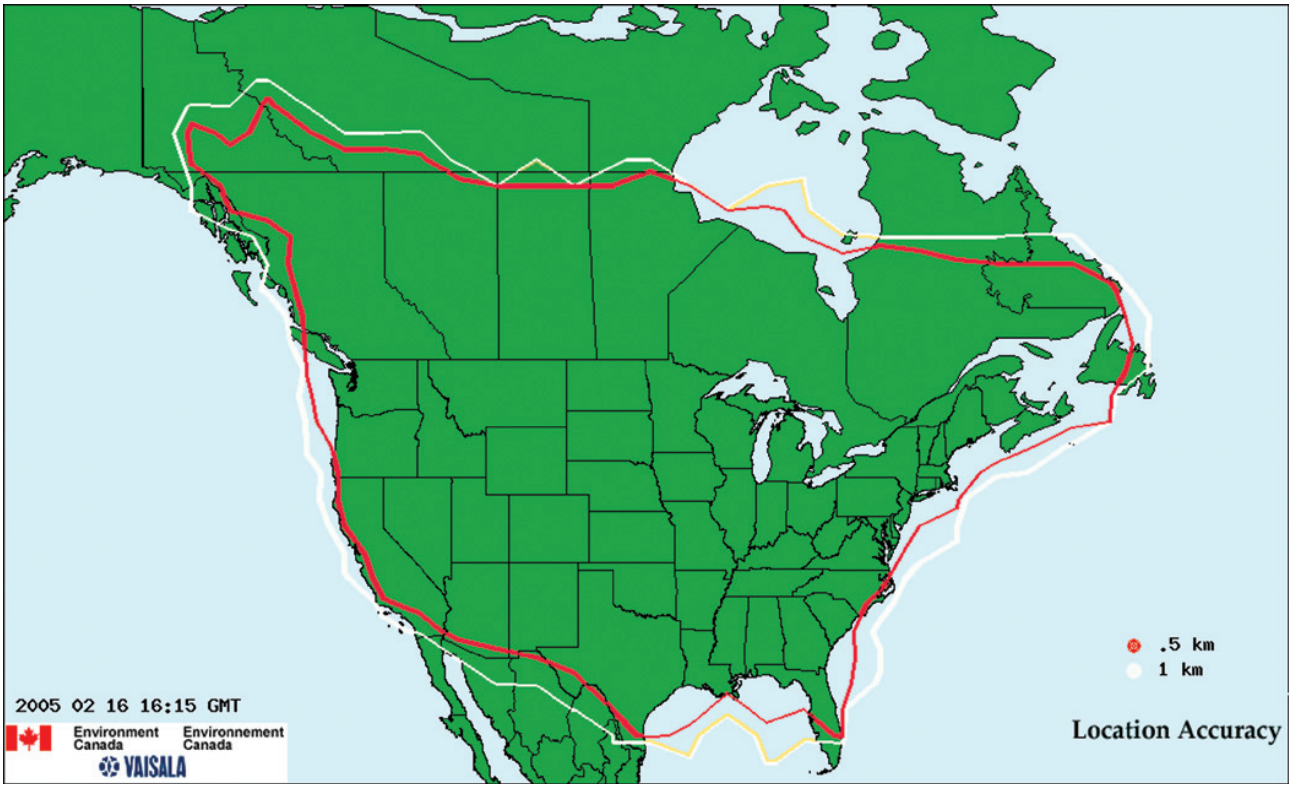


Fig. 8. Dynamic Location Accuracy Map (contours at .5 & 1 km)

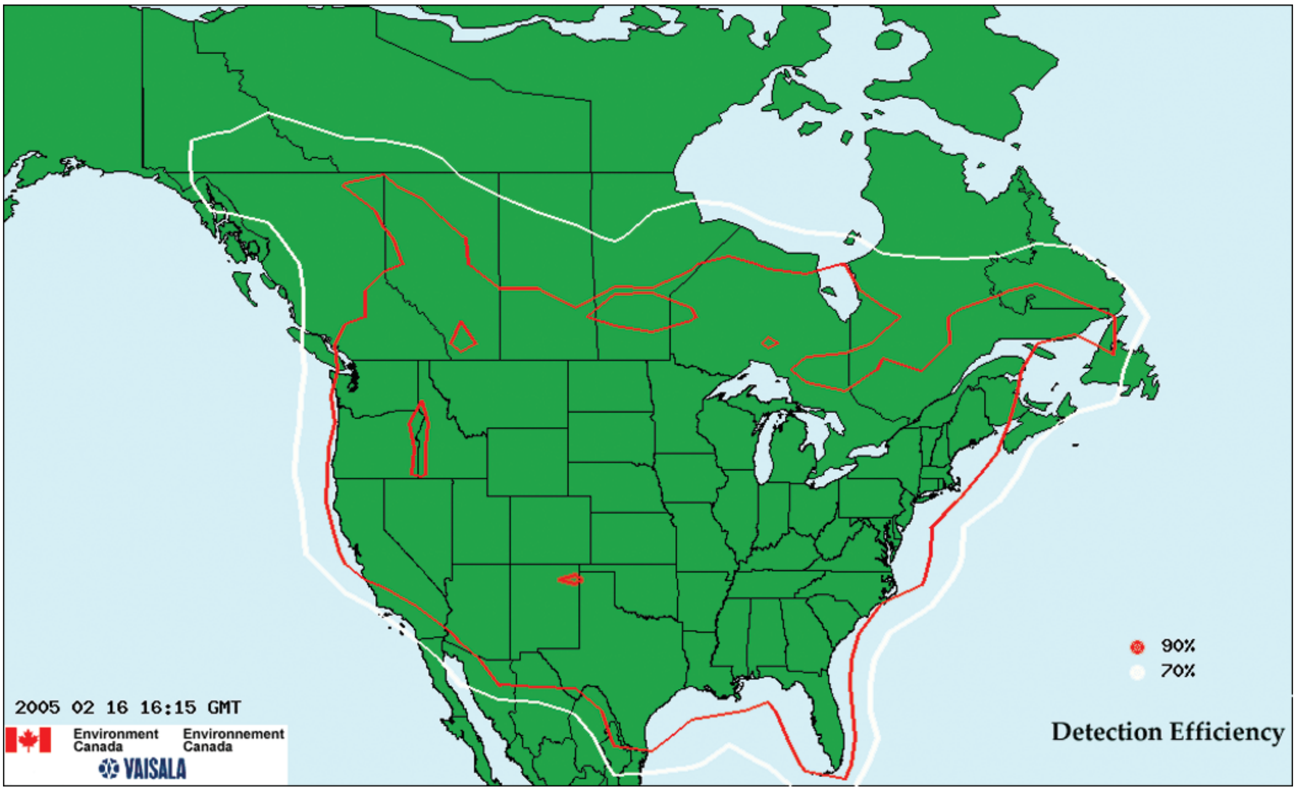


Fig. 9. Dynamic Detection Efficiency Map (contours at 70% & 90%)