Canada's New **Weather Radars**

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

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Abstract

The Canadian Weather Radar Replacement Project (CWRRP) has concluded after an extensive eight-year initiative aimed at replacing outdated weather radars across Canada. With 33 new state-of-the-art S-band dual-polarization radar systems now operational, this project marks a significant milestone in upgrading the country's weather forecasting capabilities. The new radars include replacements for 28 Environment and Climate Change Canada (ECCC) radars, three radars previously owned and operated by other organizations, one new radar in Northern Alberta, and one radar completely dedicated to testing and training.

These radars boast standardized features with variations in tower heights based on their geographical placement. The project also involved adapting radar software applications to ensure seamless data production from these new systems. With a conventional range of 330 km and a Doppler range of 240 km, the data generated by these radars are accessible for public use, contributing to enhanced weather monitoring and forecasting.

Assistant Deputy Minister message

The protection and safety of Canadians from the unpredictability of severe weather are foundational priorities for the government. That's why in 2016, the Government of Canada committed to and signed a $180.4 million contract to buy and install 33 new cutting-edge radars equipped with the latest technological advancements. This investment highlights the nation's dedication to safeguarding its citizens from potential hazardous weather occurrences.

We are pleased to announce that as of August 2023, all 33 new radars, including one training radar, are completed and transmitting data. This strategic placement of new weather radars across Canada significantly amplifies ECCC's capacity to forecast severe weather, empowering Canadians with increased lead-time to prepare for severe weather events, such as tornados, derechos, or hurricanes.

The Government of Canada remains focused on unlocking the full potential of weather technology. Recognizing social, economic, and environmental priorities, we remain committed to equipping Canadians with higher quality data and improved weather detection.

Introduction

In the expansive and varied landscapes of Canada, the importance of dependable weather and water services is paramount. Equally significant is the broader scientific community's capability to forecast unconventional weather patterns, underscoring the nation's resilience in the face of unpredictable conditions. This substantial investment in radar modernization signifies a pivotal stride toward enhancing Canada's resilience against severe weather events, epitomizing the government's dedication to providing state-of-the-art weather prediction technology.

This initiative to replace all existing weather radar infrastructure over an eight-year period was supported by provisions to add one additional operational radar in Northern Alberta and a radar dedicated to testing and training by March 31, 2024.

Beyond its primary role in weather prediction, data from these radars is used by various sectors of the Canadian economy, spanning health sciences, environmental management, agriculture, transportation, and more.

The initial radar network in Canada comprised a blend of aging systems. The ambitious endeavor to procure and install 33 new radars across the country aimed not only at replacing the outdated infrastructure but also expanding Canada's operational radar network.

A map shows location of weather radars across Canada as of 2024. There are 33 new radars across the country, providing coverage to more than 99% of Canadian population.

Importance of weather radars in Canada

The Canadian weather radar network consists of 33 weather radars covering Canada's most populated regions. Their primary purpose is the early detection of precipitation, its motion, and the threat it poses to life and property.

This radar modernization project has been an eight-year infrastructure program to replace aging radars with modern systems. Radars are a key element in forecasting short-term, severe weather such as thunderstorms, tornadoes, hail, extreme rain, and ice storms. Replacing the aging network with new modern weather radars helps ensure Canadians are better informed about changing weather. Due to aging technology, the previous radars (installed around the year 2000) were becoming less reliable. The new radars are more reliable and require less maintenance.

The new weather radars cover more of Canada and help ensure that we are better informed on changing weather. The Doppler coverage area/detection range of the new radars increased from just over 1 million square kilometers to over 4 million square kilometers, including almost all of Canada's most populated and thunderstorm-prone areas. The conventional range of the radars has increased from 240 km to 330 km surrounding each radar with more than 99 % of Canadians living within 330 km of a weather radar.

- Using modern technology, our new radars also have dual-polarization technology which helps meteorologists better detect and predict severe weather events such as tornadoes, at an extended range, and issue earlier severe weather warnings. This will give Canadians greater lead-time to take shelter.
- Economic sectors sensitive to weather events such as agriculture, natural resources, fisheries, construction, aviation, tourism, transportation, retail and investors will benefit from higher data quality and consistency for severe weather events, as weather information is an important part of their strategic planning.
- The improved weather data quality will contribute to more effective utilization of information in various domains, including water management. Radar images play a crucial role in understanding the effects of precipitation on drainage basins, particularly in support of flood forecasting by the provinces.

Delivering the vision: objectives and goals

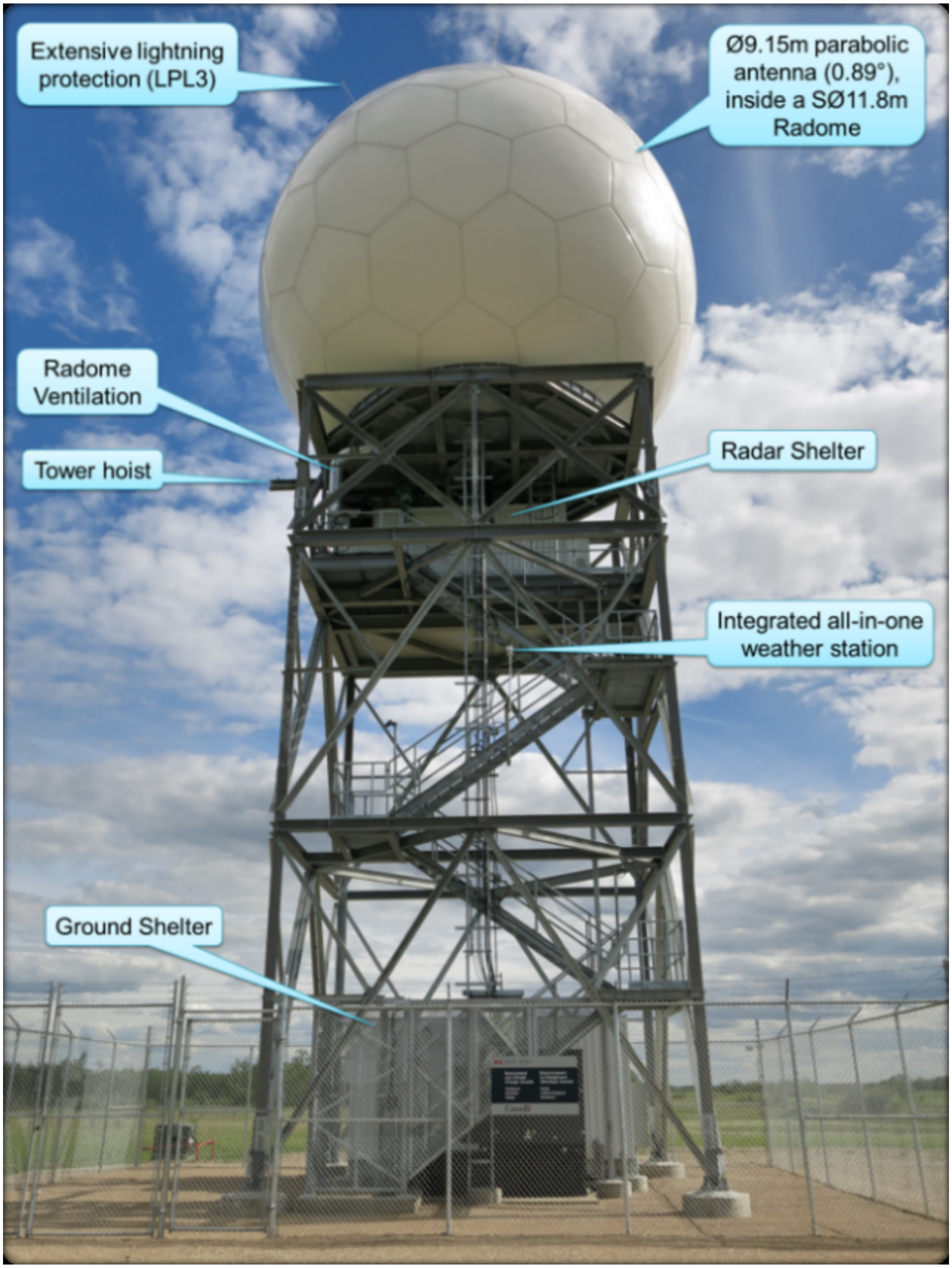


Photo of the new radar design. All ECCC radars are carbon-copies of each other – same technology, same design. The only difference between radars is the height of the tower and the specific frequency assigned to the radar.

A decade ago, the existing Doppler weather radars were beginning to exhibit signs of aging. Struggling to keep up with modern technology, they required frequent preventative maintenance and were increasingly interrupted by outages, with parts becoming more and more difficult to procure. The objective of the CWRRP was to replace Canada's obsolete and aging weather radars with new state-of-the-art systems.

Funded by the Government of Canada, the project aimed to replace 31 radars, including three operated by other agencies, one completely new site in Fort McMurray, Alberta and add a radar dedicated to the training of engineers and technologists for testing new hardware and software before deployment to the operational radars.

The project also included decommissioning 28 obsolete ECCC radars and adapting radar software applications to ensure the continued production of radar products from data provided by the new radars.

How radars work

The transition from C-band to S-band radars marks a substantial technological shift. S-band radars operate at a longer wavelength, enhancing their capabilities for long-range detection, particularly in severe weather. They offer improved surveillance by penetrating clutter, enabling the detection of distant storms even behind closer ones.

The change from magnetron to klystron transmitters is monumental. Klystron transmitters provide a more stable frequency output, increased efficiency, and higher average power compared to the older magnetron technology.

Moving from conventional Doppler to dual-polarization radar is another significant leap. While the older Doppler radar worked in one dimension, dual-polarized radars operate in two dimensions, allowing meteorologists to discern not only the location and intensity but also the type of precipitation, such as rain, snow, hail, or even other objects or material such as insects. This advancement grants a better understanding of particle shape and size within storms.

Shifting from in-house integrated systems to commercial off-the-shelf hardware solutions streamlines radar technology. The use of commercially available systems ensures easier procurement of modern repair parts, as opposed to the increasingly scarce components for the older radars.

Furthermore, the evolution in technology leads to a surge in data production, prompting the introduction of new file formats for data representation. These formats enable efficient sharing of data within the organization and globally.

Key features of Canada's new radar system

Dual Polarization: Fully integrated Dual Pol technology across the entire network allowing for more precise and timely weather alerts.

Extended Doppler Range: A 400 % increase in the Doppler coverage around each radar gives more Canadians greater lead-time when severe weather hits.

Reduced Attenuation: Storm penetration is improved to allow forecasters to see into and through dense weather systems.

Reduced Scan Time: A new scan strategy was developed by our science team to leverage the capabilities of the new radars.

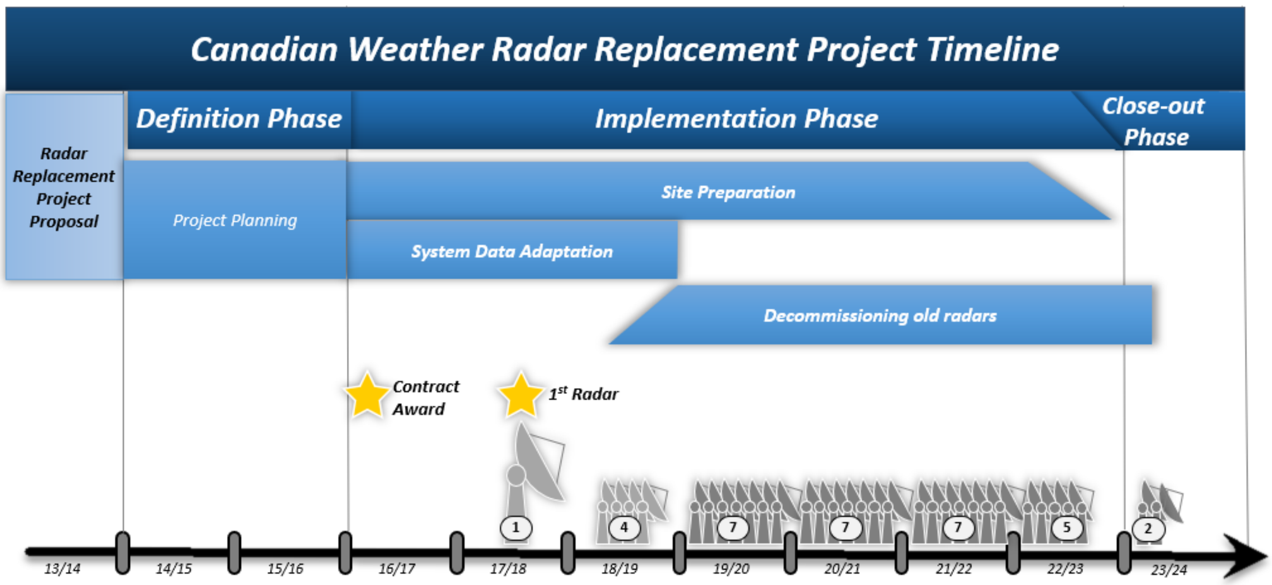
Reduced Maintenance Visits: A major driver of operational costs is travel to unmanned radar sites due to Canada’s geographic size.

Project Timeline

The extensive project to replace all the weather radars across Canada was a meticulously planned endeavor that commenced in 2013. The initial stages involved the definition phase, outlining user requirements for the new radars while engaging in consultations with the industry to explore available options. This phase culminated in a meticulous evaluation of proposals, paving the way for the commencement of the project planning phase.

The project was strategically structured into phases. Year one marked the installation of a single radar, serving as a crucial learning experience for subsequent phases. Building upon this knowledge, the following years 32 radars were installed with up to seven radars completed in some years. Concurrently, the decommissioning of old radars was an ongoing process, meticulously coordinated to ensure the continuity of radar data, minimizing any potential gaps.

The project's design reflected a calculated and systematic approach, utilizing phased implementation, gradual scaling, and the strategic retirement of old infrastructure to seamlessly integrate state-of-the-art radar technology across Canada's weather monitoring network.



A schematic chart of the project timeline. Initiated in fiscal year 2013/14 with a treasury board submission, the project involved strategic phases, with the first year serving as a learning experience for subsequent installations. Throughout the project, the outdated radars were successfully replaced, ensuring a seamless transition and continuity of radar data.

Public engagement

The planning and execution of each new radar installation were significantly influenced by public engagement. The consultation phase, initiated well before any installation, served as a foundational step, involving diverse stakeholders and perspectives to ensure comprehensive decision-making.

Whether relocating or replacing radars, adherence to strict guidelines, including compliance with Health Canada and Innovation, Science, and Economic Development Canada's Safety Code 6, mandated thorough public consultations. Beyond regulatory obligations, comprehensive community outreach efforts involved newspaper announcements, coordination with First Nations for Land Use Authority approvals, and direct engagement with radar neighbours through information packages and public meetings.

Addressing queries and concerns via various channels, the project's commitment to extensive public engagement fostered community involvement, transparency, and a positive sentiment among affected groups, ensuring that the installation process was not only efficient but also respectful of the concerns and needs of the communities.

Decommissioning

Decommissioning and removing old weather radars involved a careful process considering safety, environmental impact, and resource management, particularly with the 28 old ECCC radars. Each replacement required strategic decommissioning to restore the land to its original state, posing challenges due to limited space at many radar sites. This process spanned eight years, systematically replacing up to seven radars annually while ensuring continuous operation during construction. Temporary measures, such as blanked data sectors and the use of smaller radars, facilitated the transition, allowing old radars to operate until construction reached a safe height for the new towers.

Efforts to maximize the utility of old radar components were crucial, salvaging functional parts as spares for remaining radars. Recycling metal, selling assets, and donating equipment showcased commitment to resource management and community support. Sustainability efforts extended beyond decommissioning, with donations to the University of Western Ontario fostering research initiatives. This reflects a commendable commitment to the ethos of "reduce, reuse, recycle" and a conscientious approach to technological transitions, contributing to both community and research endeavors.

Importance of radar in meteorology

The weather radar network in Canada plays a crucial role in the early detection and forecasting of precipitation-related threats, like thunderstorms, tornadoes, and extreme rain. The replacement of aging radars was necessary due to their declining reliability, ensuring better coverage, increased detection range, and the implementation of dual-polarization technology. These upgrades not only enable meteorologists to provide earlier severe weather warnings for Canadians but also benefit various weather-sensitive industries and aid in areas like water management and flood forecasting. The new radars offer improved data quality and consistency, which is pivotal for strategic planning in multiple economic sectors sensitive to weather events.

In addition, the weather radar network plays a pivotal role in modern meteorology, providing invaluable insight into atmospheric conditions. These systems utilize radio waves to detect precipitation, its intensity, and movement within a specific region. They offer meteorologists a real-time view of ongoing weather patterns, enabling accurate forecasts and timely warnings. In parts of Canada, where weather can be notoriously unpredictable and severe, radar technology serves as a crucial tool for monitoring storms, identifying potential hazards, and issuing alerts to safeguard the public.

Meteorologists rely on radar data to track storm systems, predict their paths, and anticipate severe weather events. By analyzing radar imagery, they can identify developing patterns, assess the severity of precipitation, and pinpoint areas at risk of flooding, blizzards, high winds, or other hazardous conditions. This information is instrumental in issuing early warnings, allowing emergency services and the public to prepare and take necessary precautions, ultimately saving lives and minimizing property damage.

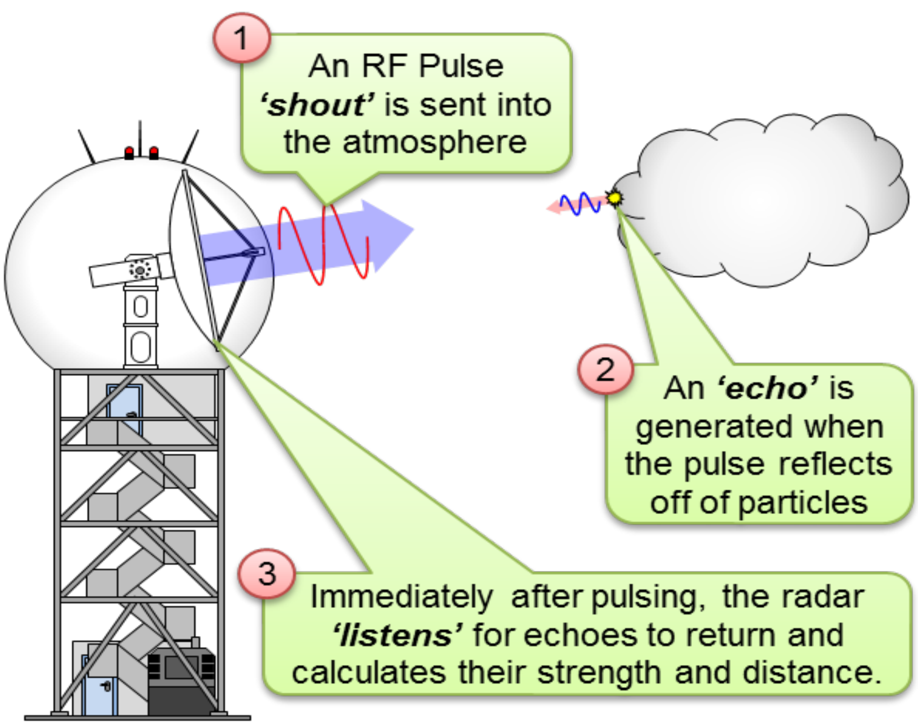
Canadians benefit significantly from the use of weather radar as it enables timely and accurate forecasts, critical in a country known for its diverse and often extreme weather conditions. From farmers planning harvests to aviation authorities ensuring safe travel routes, various sectors rely on meteorologists' radar-derived insights to make informed decisions and mitigate weather-related risks. Ultimately, the utilization of weather radar empowers both professionals and the public by enhancing preparedness and safety in the face of ever-changing atmospheric conditions.

Safety of the new radars

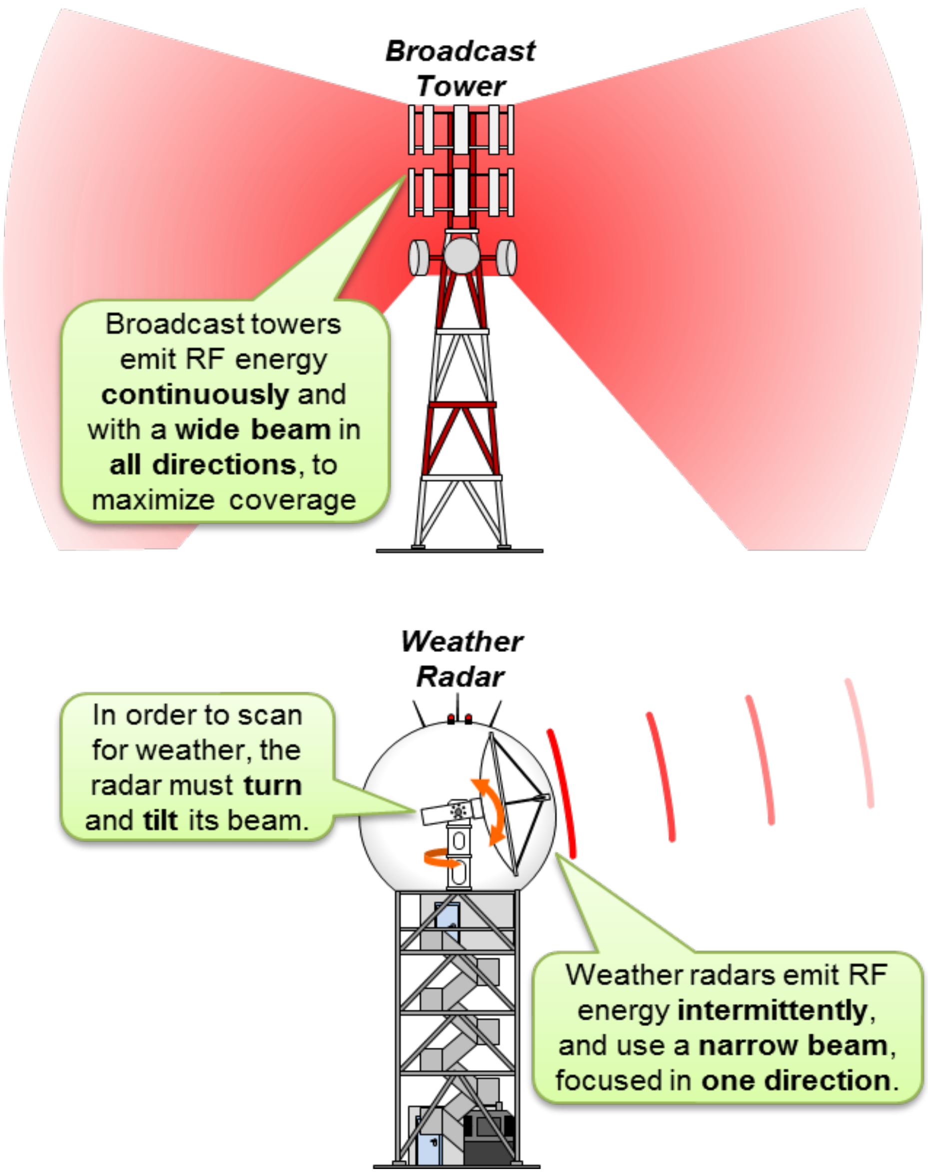
The implementation of new radars in our project ensures full compliance with Health Canada's radio frequency exposure limits across all operational modes. These limits, aimed at establishing safe distances for radio frequency exposure to the public, are rigorously verified by a third party before Industry Canada grants an operating license. These radars operate with a focus on listening rather than emitting, sending brief pulses and recording echoes during the listening phase.

Health Canada's Safety Code 6 limits are adhered to, incorporating large safety margins to protect the public and personnel near radiofrequency sources. The radars utilize a parabolic antenna atop a tower, emitting a narrow pencil beam directed away from the ground. Safety compliance is further demonstrated through voluntary radiofrequency level measurements, showcasing values well below Health Canada limits.

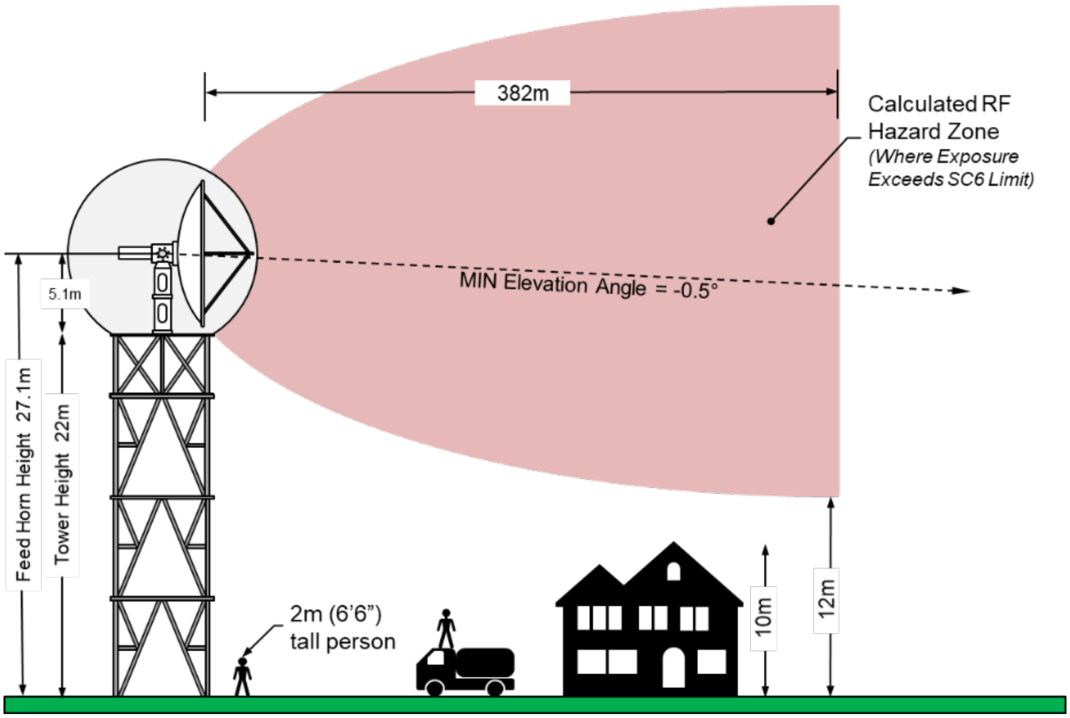
Unlike continuous radiofrequency sources, weather radars intermittently emit radiofrequency energy, spending the majority of their time listening. The operational principles and safety measures, including secured areas and monitoring, prioritize the well-being of Canadians, addressing concerns related to radiofrequency radiation exposure.



A schematic diagram of the transmitting of radio frequency pulse. An RF Pulse is sent into the atmosphere then returns echo when the pulse reflects off particles. Immediately after pulsing, the radar "listens" for echoes to return and calculates their strength and distance.



A schematic diagram of transmitting difference between a broadcast tower and a weather radar. Broadcast tower emits RF energy continuously and with a wide beam in all directions to maximize coverage; whereas weather radar emits RF energy intermittently, and use a narrow beam focused in one direction.



A schematic diagram of how RF hazard zone is calculated, where exposure exceeds SC6 limit. Considerations include tower height, feedhorn height, and distance. Large safety margins are applied to protect the public and personnel near radiofrequency sources.

Significance of the radar replacement project

How the team dealt with building radars during a pandemic

The CWRRP faced significant challenges due to the pandemic, impacting various facets of the radar replacement initiative. Initially, warnings arose in February 2020 when the contractor highlighted potential delays. As March unfolded, further complications emerged, straining international and domestic travel, hampering not just the movement of goods but also personnel.

Despite the geographically dispersed ECCC team already being adept at remote work, the pandemic necessitated enhanced communication and technological adaptations. Increasing online meeting frequencies and swiftly evolving online meeting tools became pivotal to maintaining progress amidst the uncertainties. Embracing a flexible approach, the team crafted multiple scenarios contingent on the evolving situation, preparing for various potential outcomes.

The pandemic-induced travel bans hindered the arrival of crucial staff from the main radar contractor until the late spring of 2020, resulting in a brief pause in the CWRRP construction projects. Mitigation strategies were devised to ensure uninterrupted radar data flow at the sites. Delays in the construction season led to the reactivation of old radars at certain sites where work had already commenced, albeit with modifications to accommodate the new tower direction.

Adapting to the constraints imposed by the pandemic, the project adjusted construction schedules, incorporated quarantine periods, minimized travel, and implemented stringent on-site safety measures. Despite these challenges, the CWRRP team and the contractor persevered, achieving their target of delivering seven new radars in 2020. This accomplishment included the installation of six replacement S-band radars and one training and test radar located at ECCC's Centre for Atmospheric Research Experiments property near Egbert, Ontario. Moreover, the removal and decommissioning of old radar equipment at each site was also successfully completed on time, reflecting the team's resilience and adaptability.

Interference bands

The radar displays occasionally showcase peculiar anomalies termed "interference radials," caused by the overlap of radiofrequency signals from external sources like cell towers. Particularly prevalent in densely populated regions like Southern Ontario, these spikes occur when the signals from other radiofrequency emitters intersect with those from our or neighboring emitters. To address this issue, collaborative efforts with Innovation, Science and Economic Development Canada were undertaken.

Strategically integrating technology from our latest radar systems into the ECCC WeatherCAN app and radar displays such as, the WeatherOffice website and the GeoMet layers, proved pivotal in minimizing or entirely eradicating these interference spikes. The innovation behind this enhancement lies in the incorporation of Dual Polarization Qualitative Precipitation Estimates technology from our new radars. This technology adeptly separates authentic precipitation imagery from the disruptive interference imagery, ensuring a clearer and more accurate representation for users.

Working alongside Innovation, Science and Economic Development Canada, the regulatory body for microwave bands in Canada, a solution was devised to combat interference at its source rather than merely cleaning up raw data post-transmission. This inventive approach involves the installation of two bandpass filters targeting the specific radiofrequency bands responsible for the spikes. This proactive solution effectively bypasses the problematic radiofrequency bands, significantly reducing or eliminating interference. An illustrative example from the Franktown radar near Ottawa vividly demonstrates the radar's appearance without filtering and the subsequent display of actual precipitation after filtering is implemented. The deployment of such filtering measures has been underway or planned for numerous radars, especially in densely populated areas across the country where interference spikes pose greater challenges.

Figure 1:

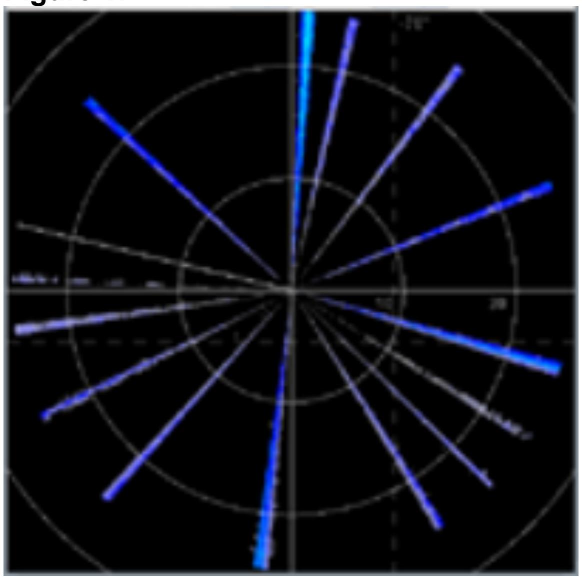


Figure 2:

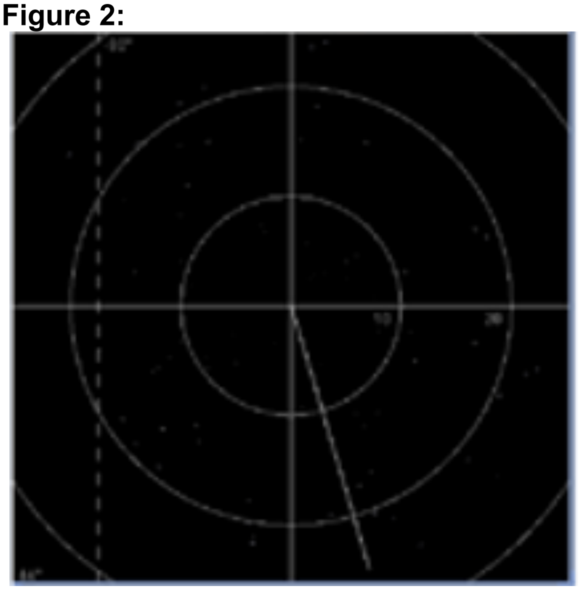
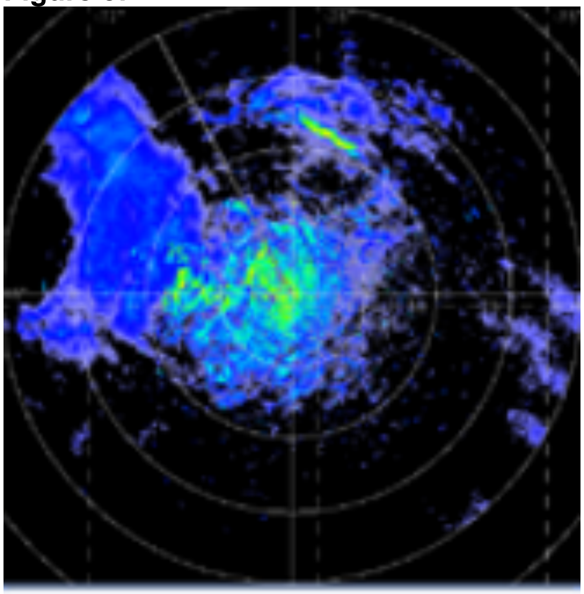


Figure 3:



Images of Radio-Frequency Interference (RFI) Filter testing conducted at the Franktown radar. Figure 1 shows what the interference looked like even when the radar was not transmitting. Figure 2 in the centre shows the impact of the new band pass filters even when the radar was not transmitting with no contaminated RFI radials visible. Figure 3 shows a clean product with weather when transmitter was turned back on with filters in place.

Radar data

Accessing radar data and images from the new radars has become conveniently widespread for weather enthusiasts and professionals alike. Canadians passionate about radar data can now easily view the outcomes of these new radars across various platforms.

For a comprehensive view of the new radar results, ECCC offers access to data and images on multiple fronts. Firstly, the ECCC weather webpages serve as an accessible hub showcasing these radar outcomes. Additionally, the ECCC WeatherCAN application provides a user-friendly interface for accessing radar data conveniently on mobile devices. The ECCC online datamart and historical radar data sites, further offer detailed insights and access points for radar information.

Moreover, Geographic Information Systems users can leverage the open data made available via GeoMet, allowing them to incorporate radar imagery into their geographic information systems seamlessly.

For those preferring third-party applications, there are providers who receive raw data feeds, enabling them to cater to their clients effectively. Some of these third-party apps even exhibit the full 330 km range, providing a comprehensive radar experience for their users.

This widespread availability of radar data and images across ECCC platforms and through third-party providers ensures that Canadians can readily access and analyze weather-related information, fostering a more informed and engaged community.

For more information, visit: [About Canadian historical weather radar - Canada.ca]().

Summary

Project success
Despite supply chain issues and other challenges, this project was delivered on schedule and budget even throughout the height of the COVID-19 pandemic. The outcome of this project has been a modern, affordable, and sustainable network of reliable weather radars. More specifically, the new radars provide:

- Higher data quality, better ability to detect through storms, and better overall severe summer and winter weather detection, which will improve the overall performance of weather warnings;
- An extended range covering more of Canada, increasing the geographic area that forecasters can monitor for severe weather;
- Increased frequency of data, as the data will be available every six minutes, rather than the old ten-minute data cycle;
- Better business continuity because the extended coverage allows for an overlap with neighbouring radars; and
- A network based on a commercially available system, making it more efficient and less costly to operate and support.

Change in radar locations
When preparing this radar replacement project, some radars were relocated to better locations to address gaps in radar coverage, and to provide better access to the radar sites for our technologists. The radars that were relocated include Blainville, Quebec, replacing McGill University's radar, Cold Lake, Alberta, replacing Department of National Defence's Jimmy Lake radar, Mont Apica, Quebec, replacing the Department of National Defence's Lac Castor radar, Shuniah, Ontario replacing Lasseter Lake radar, and Halfmoon Peak, British Columbia replacing Mount Sicker radar.

In addition to replacing all existing weather radars in Canada's radar network, two additional radars were installed. This includes the addition of one new radar in the lower Athabasca region of Fort McMurray, Alberta and a non-operational testing and training radar in Egbert, Ontario.

Lessons learned

The lessons learned process conducted for the CWRRP project involved a comprehensive survey in April 2023, engaging stakeholders from both within and outside the ECCC department. The objective was to gather diverse perspectives and experiences to assess the project's performance, primarily focusing on the implementation phase and project management. This exercise aimed to identify strengths, challenges, and improvement areas by assimilating insights and feedback from stakeholders. The findings were instrumental in shaping the project's trajectory by trialing and integrating suggested improvements throughout its course. The ultimate goal of the lessons learned exercise was to build a repository of knowledge for future projects, enhancing implementation strategies and refining project management practices.

Ten specific areas of exceptional performance have been highlighted:

Team Dedication and Expertise: The success of the project was attributed to the exceptional dedication and expertise of the team members, fostering easier project management.

Robust Project Governance: Strong governance structures ensured effective oversight and communication, allowing streamlined processes and focused deliverables.

Successful Collaboration: Effective coordination among stakeholders, contractors, and various committees ensured engagement and alignment throughout the project.

Resilience in Challenges: Despite hurdles like the global pandemic and technical limitations, the team showcased adaptability and mitigated disruptions effectively.

Stakeholder Engagement: Active engagement with stakeholders facilitated feedback incorporation and a collaborative approach to project enhancements.

Leadership and Continuous Improvement: Strong leadership, coupled with a commitment to continuous improvement, fostered an environment conducive to success.

Mitigation Strategies: Implementing strategies to minimize downtime and adjusting construction schedules effectively ensured uninterrupted radar coverage during critical weather seasons.

Financial Prudence: Sound financial management allowed for effective resource allocation, enabling successful project completion within budgetary constraints.

Efficient Construction and Decommissioning: Efficient construction, acceptance procedures, and environmentally responsible asset disposal highlighted project execution excellence.

Acknowledgment and Celebration: Acknowledging and celebrating project successes contributed significantly to team motivation and cohesive functioning.

The synthesis of these exceptional performances and areas for improvement will serve as a valuable resource for future projects, contributing to refined practices and optimized outcomes.

Figure 1:

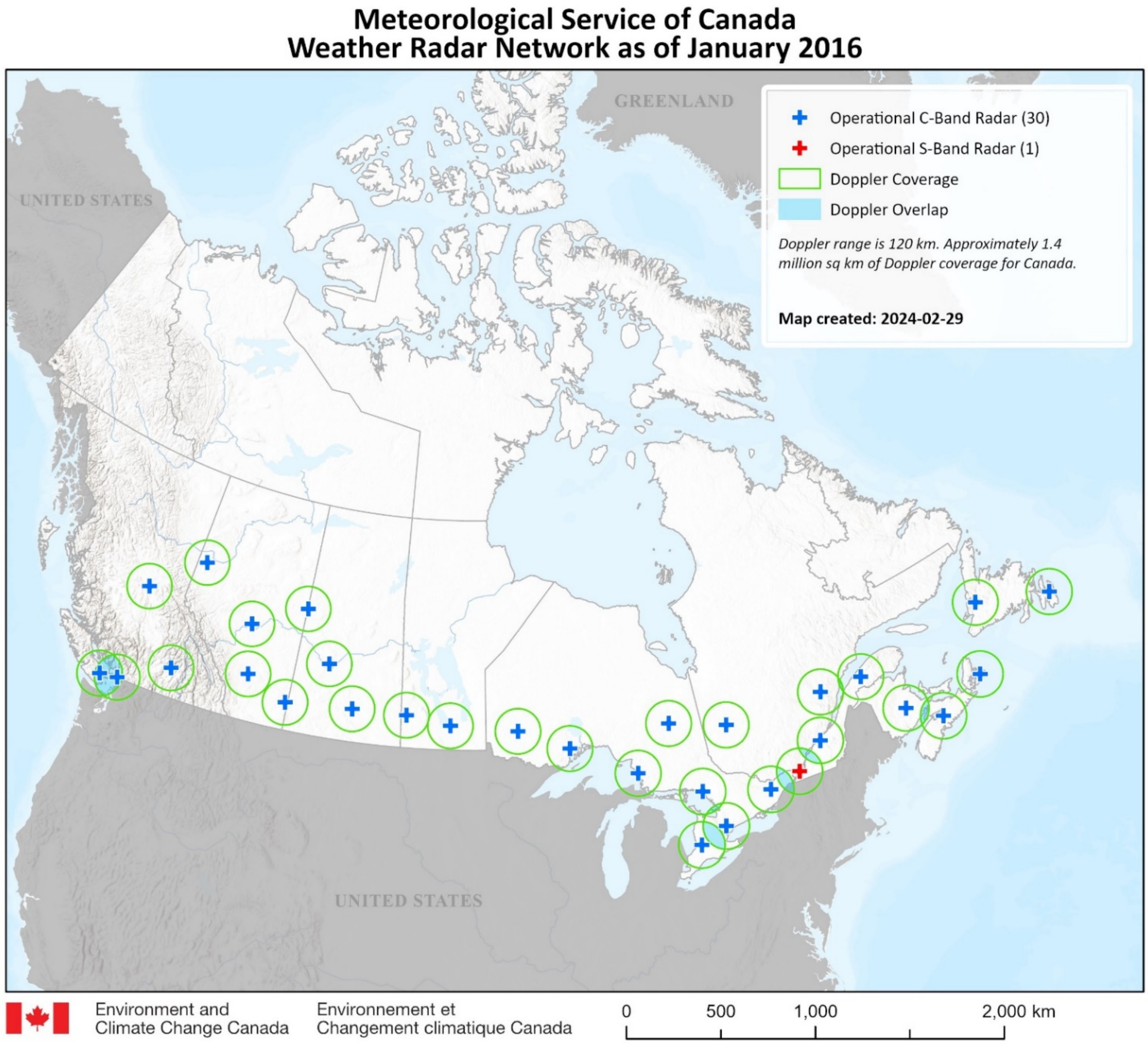


Figure 1 is the first of two maps of the radar coverage. This map of Canada illustrates the Doppler coverage of the old radar network (circa 2016) prior to the new radars being installed. With each radar having a Doppler range of 120 km, there were significant gaps in coverage between the radars across the country.

Figure 2:

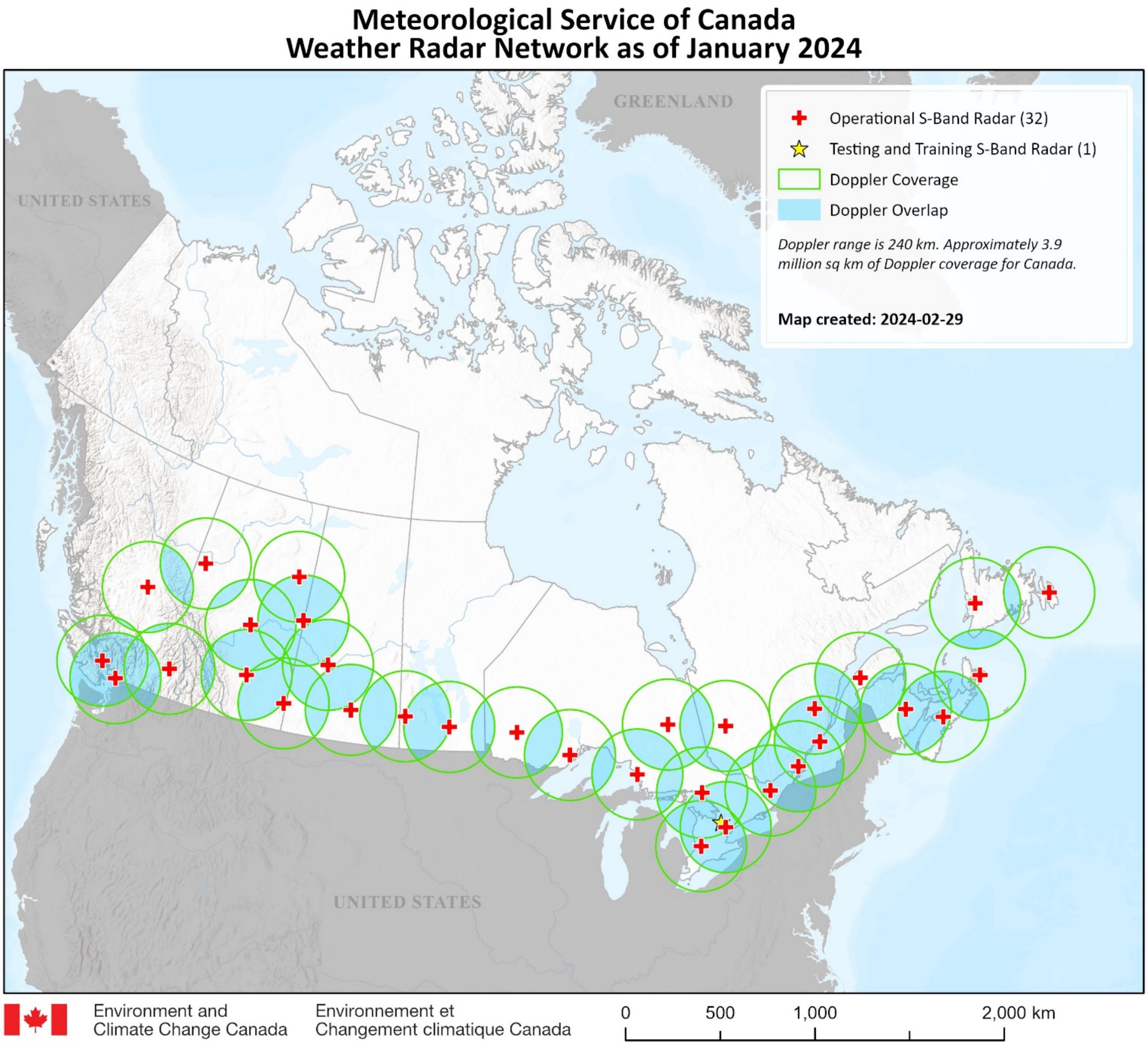


Figure 2 shows a map of Canada with the Doppler coverage of the new radars. The new radar network has an extended Doppler range of 240km. Blue shading shows where the range of neighbouring radars overlaps, providing additional data in some areas. In addition, two new radars were installed in Alberta and Ontario (non-operational training radar). The conventional range of the new radars is 330 km providing coverage to an even larger area.

Additional Resources

[Weather radar and satellites - Canada.ca](),
[Radar overview - Canada.ca](),
[About Canadian historical weather radar - Canada.ca](),