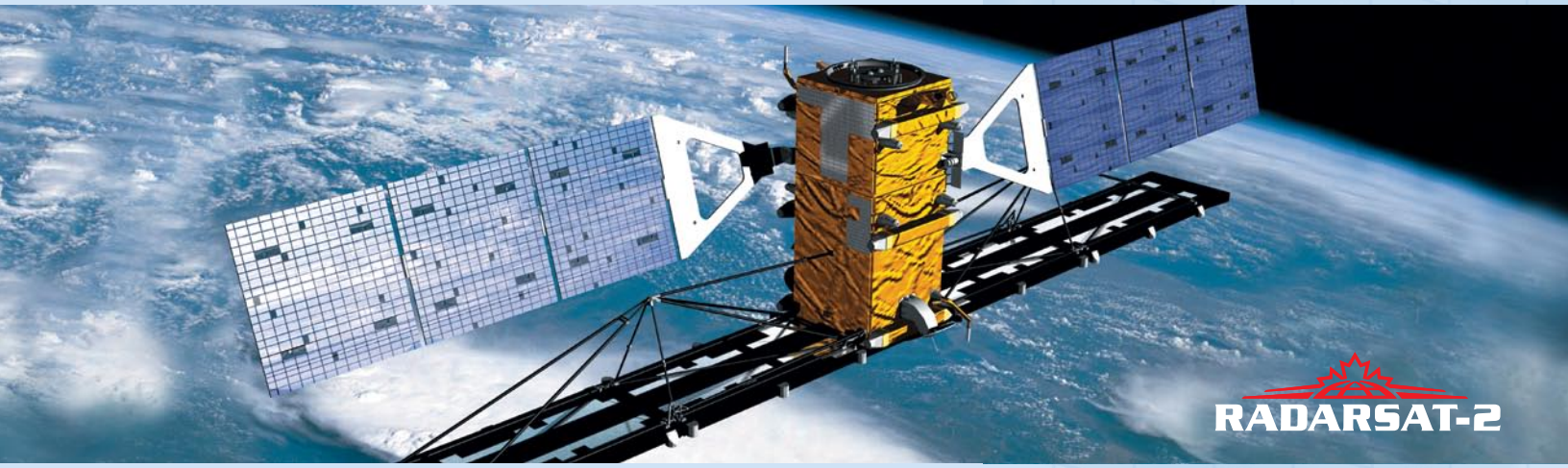
Canadian Space Agency | Agence spatiale canadienne

A New Satellite, a New Vision



RADARSAT-2

Canada

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THE CANADIAN SPACE AGENCY AND EARTH OBSERVATION

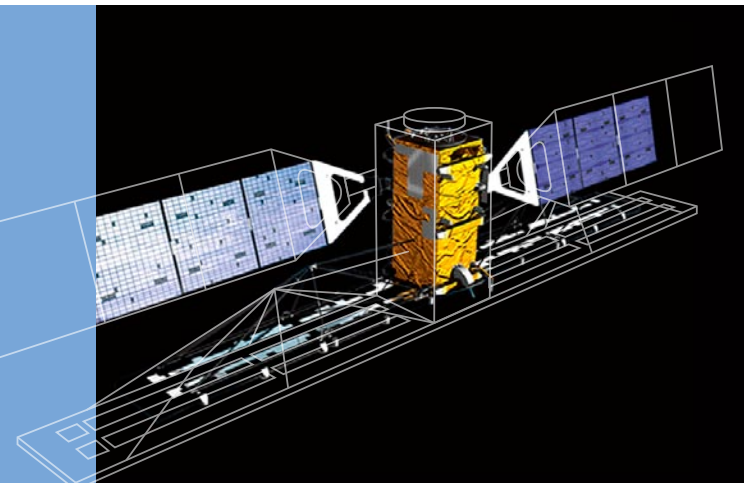
For a better understanding of our ocean, atmosphere, and land environments and how they interact, we need high-quality data provided by Earth observation satellites. RADARSAT-2 offers commercial and government users one of the world's most advanced sources of space-borne radar imagery. It is the first commercial radar satellite to offer polarimetry, a capability that aids in identifying a wide variety of surface features and targets.

To expand Canada's technology leadership in Earth observation, the Canadian Space Agency is working with national and international partners on shared objectives to enhance

- northern and remote-area surveillance
- marine operations and oil spill monitoring
- environmental monitoring and natural resource management
- security and the protection of sovereignty
- emergency and disaster management

RADARSAT-2 is the next Canadian Earth observation success story. It is the result of collaboration between the Canadian Space Agency and the company MDA. Together, they are poised to deliver to the international community a state-of-the-art remote sensing technology that improves applications in many fields.

PREPARING TO USE RADARSAT-2



The multiple mode capabilities of RADARSAT-2 respond to the evolving needs of clients and encourage the development of specialized applications. With three times the resolution of its predecessor, RADARSAT-2 offers more precision for identifying objects such as ships at sea. Its 512 separately controlled mini-antennas can be quickly reconfigured. With on-board digital recorders, data can be accessed more quickly, even while recording.

RADARSAT-2 can provide images of the Earth's surface with an advanced SAR system, all the imaging modes of RADARSAT-1 and many new features, some of which have never before been available on a commercial satellite.

Multiple opportunities

These new capabilities present many possibilities for the Earth observation community. Users welcome higher spatial resolution data, but to be able to take full advantage of multi-polarization and fully polarimetric data, awareness and guidance are needed.

Although many researchers have worked with polarimetric synthetic radar aperture (SAR) data, knowledge of polarimetric scattering behaviour for many types of surfaces is not well understood. And the development of commercial software tools for polarimetric data processing and analysis was limited to a small market, so that few have been trained to use polarimetric SAR data.

To address this need the Canadian Space Agency and the Canada Centre for Remote Sensing acquired polarimetric data to simulate RADARSAT-2 capabilities. Environment Canada's Convair-580 airborne C-band SAR facility and dual polarization data were used as well as the European Space Agency's ENVISAT satellite's ASAR (Advanced SAR). Some images are presented in these pages, and an image catalogue and other resources for users are available at www.radarsat2.info.

The Canadian Space Agency has facilitated applications development through collaboration with industry partners, such as MDA Geospatial Services, and government departments, including the Canada Centre for Remote Sensing of Natural Resources Canada. Technical and financial support is available for Government of Canada departments and agencies through the Government Related Initiative Program (GRIP) by contacting the Canadian Space Agency at radarsat-2info@space.gc.ca.

SOME RADARSAT-2 APPLICATIONS

AGRICULTURE

Conditions of soil and crops change each day and throughout the growing season. Observations of agricultural targets also vary spatially from field to field, and within individual fields.

Although agricultural mapping and monitoring present an enormous challenge, imagery acquired by orbiting satellites offers a tremendous opportunity to track temporal changes in soil and crop conditions and to map crop characteristics over large areas.

Satellites like RADARSAT-1 acquire radar imagery with a single transmit-receive polarization, providing a one-dimensional data set. Thus, more than one acquisition date is usually required to extract reliable crop information. However, crop information can be estimated from one image or acquisition date if the sensor uses multiple polarization capability, like that of RADARSAT-2. In fact, one of its most important new capabilities is the simultaneous acquisition of multiple polarizations on transmit and receive.

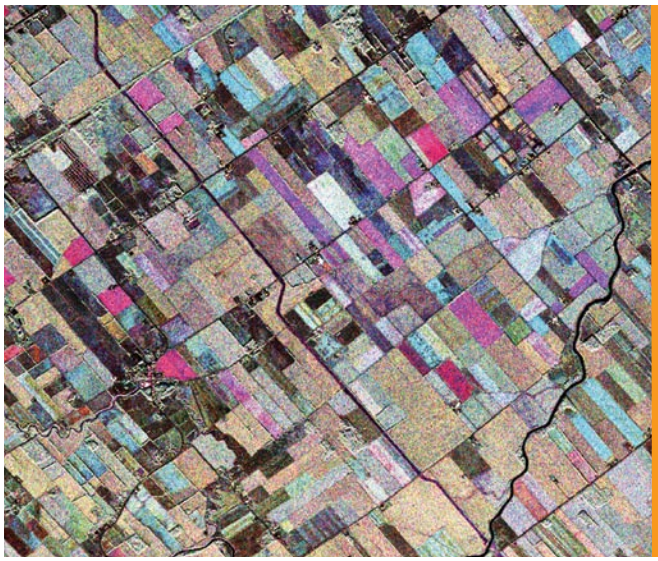
Vertically polarized microwaves are sensitive to vertical structures on the Earth's surface. Therefore, VV radar returns provide good contrast among vegetation types with various canopy structures. Horizontally polarized microwaves (HH) tend to penetrate the canopy more than vertically polarized microwaves. Thus, HH radar returns tend to provide more information about the soil conditions. Cross-polarized radar returns (HV or VH) result from multiple reflections from within the vegetation itself. HV and VH images are more sensitive to crop structure within the total canopy volume, thus providing information that is complementary to HH and VV images.

Crop conditions

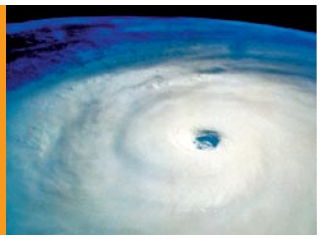
Unlike field-based crop type mapping, RADARSAT-2's Ultra-Fine mode is useful for in-field mapping of crop conditions. Research indicates that a single polarization image is limited in terms of its information content. Polarization diversity can also be very useful for deriving crop condition information.

Crop yield

For any crop type, it is difficult to estimate productivity or predict yield. Many variables influence productivity, including soil characteristics, meteorological conditions, and management practices. Even if these variables are known, models may not accurately predict crop yield. Nevertheless, predictions are usually more accurate if this information is gathered continuously throughout the growing season. The combination of SAR data with in-situ measurements of solar radiation, air temperature, and precipitation could lead to improved estimates of crop yield earlier in the growing season.



Agricultural fields south of Ottawa in a composite C/X-SAR multi-polarization image. Diversity of polarization, incidence angles, and spatial resolutions offered by RADARSAT-2 provide valuable information for agricultural management such as crop identification, soil conservation methods, and soil moisture. (Image: CCRS, 1998)



DISASTER MANAGEMENT

Disasters around the world cause tens of thousands of deaths each year. They adversely affect millions of people and cause hundreds of billions of dollars in damage annually. Spaceborne SAR sensors have proven their value in many disaster management operations. They offer reliable information, since they provide imagery regardless of light or atmospheric conditions.

The need to map damage in near real time is a prime concern for relief agencies that must locate victims and structures at risk and assess losses for future planning. RADARSAT-1 data have provided effective support of search and rescue teams and of disaster management efforts during floods, hurricanes, and oil spills. The technical enhancements offered by RADARSAT-2 provide additional operational information for disaster management, and less lead time is needed for operations planning.

Floods

RADARSAT-1 has proven to be an excellent source of data for flood extent mapping. Not only is the system configuration ideal for mapping flooded areas, but the steerable beam and choice of beam modes (resolution, swath width, and incidence angle) offer flexibility for emergency situations. RADARSAT-2 will increase the availability of optimal data for flood mapping with its right- and left-looking modes. Furthermore, the fully polarimetric data capabilities available on RADARSAT-2 enhance the flood information for land and forested regions.

Geological hazards

Landslide inventory maps are a primary planning tool for risk assessments. Multi-temporal images can be used to map changes in landslide distribution, vegetation, and land use, and to update existing landslide inventory maps. Images acquired in the Ultra-Fine mode (three-by-three-metre resolution) facilitate more accurate mapping of the geomorphology of landslides and related slope characteristics, including lithology and faults.

Effective volcanic hazard monitoring and mitigation requires access to high-quality geomorphic and topographic data to predict the direction of lava or pyroclastic flows and lahars. Mapping of young volcanic deposits is also essential for evaluating volcanic hazards. RADARSAT-2's Ultra-Fine mode and polarimetric capability should improve the potential for volcanic-area mapping.

Hurricanes

The marine atmospheric boundary layer processes that modulate the near-surface wind field often appear on SAR ocean images. Rougher areas, corresponding to higher wind speeds, appear bright on the image, while smoother areas, corresponding to lower wind speeds, appear relatively dark. RADARSAT-1's ScanSAR Wide mode, with a 500-kilometre swath width and 100-metre spatial resolution, has provided some striking images of mesoscale cyclones, including polar lows and hurricanes. SAR images of these important disturbances give a unique sea surface view that complements conventional remote sensing observations.

Extra scheduling opportunities are possible with RADARSAT-2's left- or right-looking geometry. Furthermore, reductions in ordering lead-time improve scheduling accuracy, so that RADARSAT-2 data could be useful for storm tracking and better predictions of hurricane landfall.

Oil spills

The capability of radar remote sensing systems to locate and map the extent of oil spills has been well known for several decades. Combined airborne and satellite radar systems are used routinely to target oil pollution in the world's oceans.

RADARSAT-2 offers more detailed images with its Ultra-Fine Mode. And the left- or right-look imaging capability reduces the time between the occurrence of an oil spill and the first image acquisition opportunity for areas at risk.

Search and rescue

Man-made objects such as aircraft and vessels are targets that are easily recognizable with polarimetry. RADARSAT-2 is the first commercial system capable of acquiring full polarimetric radar image data from space. Although detection methods require further development, research indicates that polarimetry advances the use of SAR in support of search and rescue activities.

FORESTRY

There are two categories of forestry applications:

- Forest resource-assessment applications, including the inversion of dendrometric or structural parameters at the stand level, such as biomass, forest species, and stand structural organization
- Forest resource-monitoring applications, including the routine mapping of deforestation, clear cuts, fire (scars) and flooding.

Forest type

We know that C-band frequency is sensitive to the structure of the scattering elements used in measuring the upper part of most tree canopies and the polarization of the radar backscatter. With its multiple polarization and polarimetric capabilities, RADARSAT-2 is useful for forest mapping and the detection of structural differences between forests. The Ultra-Fine and Multi-Look Fine modes of RADARSAT-2 offer the potential to improve forest-type mapping using textural analysis.

Resource monitoring

Forest resource monitoring applications are promising and have potential as economically sustainable applications. RADARSAT-1 has been used successfully to map clear cuts in a boreal environment. Studies have shown that, with cross-polarization images from RADARSAT-2, land managers can monitor forest change more accurately and in a timelier manner.

Moreover, cross-polarization images offer the greatest potential for burn mapping, with more sensitivity for capturing structural damage to the forest canopy.

GEOLOGY

From detecting petroleum and mineral resources to identifying geological hazards, geology exploration and mapping applications contribute to protective measures, economic growth, and an enhanced quality of life.

SAR data provides a synoptic perspective and great spatial detail in a consistent manner of almost any part of the Earth's surface. With an increase in development of SAR applications comes a growing appreciation of the information content of the data.

It is now recognized that radar can provide geophysical terrain information such as surface roughness, which is useful for understanding processes such as bedrock weathering and the sorting of surface materials.

Terrain mapping

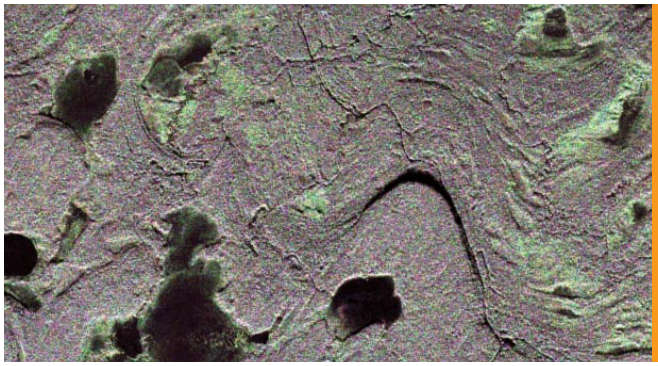
The most significant improvements of RADARSAT-2 over other radar and optical space systems for terrain mapping are the Ultra-Fine mode and fully polarimetric capabilities. Detailed mapping of glacial terrain features, outcrops, and fine geological structures becomes possible.

Structure identification

The identification of structural features with subtle expression in topographic relief is enhanced by the sensitivity of radar backscatter to the local incidence angle. The resolution of the SAR system is another important factor in the identification of these structural features, perfectly suited to the Ultra-Fine mode. For land targets, like-polarized data (HH or VV) have similar content, while cross-polarized data (HV or VH) are more sensitive to the larger scale (larger than the radar wavelength) geometry of the surface or volume scatterers. In cross-polarized data, bedrock fracture zones and fault scarps are typically highlighted in backscatter returns by a much stronger contrast to the surroundings than like-polarized.

Lithology

The wide range in surface roughness of volcanic lava flows often illustrates the best examples for discrimination of different flow units. However, lithological discrimination among other rock types, such as sedimentary or metamorphic rock types, is considerably more challenging with a single polarization state and radar frequency. The advantages of multi-polarized SAR, particularly the dual combination of a like-polarized and cross-polarized data pair for discriminating different geologic units, are the subject of ongoing research.



This CV-580 C/X-SAR image was acquired for geologic mapping over Anticosti Island. Multipolarized data provides information on the distribution and orientation of lineaments and increases the potential of SAR systems for geological and structural mapping. (Image: CCRS, 2002)

HYDROLOGY

Water is a precious resource. In the coming years, the global community will continue to stress its water resources. The need to understand the hydrological processes that distribute water around the globe is more important than ever.

Radar imagery is well suited for hydrological applications, as the scattering properties for water and land result in distinct radar returns. Water areas are usually associated with low returns, while land and vegetated areas are associated with higher returns. Radar scattering is extremely sensitive to changes in the dielectric constant, which makes it a suitable choice for remote sensing of hydrological parameters such as mapping

soil moisture, snow pack, and wetlands. And cloud cover, which often occurs in coastal regions or during hydrologically significant events, does not affect SAR imagery.

Soil moisture

Soil moisture is an important parameter for natural resource applications such as hydrological modelling, stream-flow forecasting, and agricultural practices or flood forecasting.

The extraction of soil-moisture measurements from single-polarization radar images requires a substantial amount of supporting information. The problem has been that many of these parameters affect radar signals independently of the moisture content and must be taken into account. RADARSAT-2, with its polarimetric capabilities, provides increased data availability as well as enhanced information content for soil-moisture measurement.

Snow

Snow pack and distribution are very important inputs to hydrological models for management activities, such as flood forecasting, agriculture, hydroelectric power and storm-water control, as well as for understanding changes in climate.

Common snow parameters estimated by SAR techniques include snow-water equivalent, snow extent and snow wetness. Snow depth, grain size and snow pack structure are topics of ongoing research. The relationships between snow pack characteristics and radar backscatter are quite complex. SAR backscatter is influenced by a number of parameters including surface roughness, topography, land cover, incidence angle, and moisture content. The use of polarimetric SAR imagery provides more accurate information on snow packs.

As seen in this image of wetland mapping over the Mer Bleue Bog using a CV-580 C/X-SAR multi-polarization composite image, multiple polarization provides accurate land mass discrimination and identification of cartographic features. Information on the spatial distribution and temporal evolution of land use and land cover can be extracted. (Image: CCRS, 1995)

Wetlands

Wetlands are an important component in the hydrological cycle and are involved in patterns of evaporation, transpiration, water distribution, and flow. Wetland classification and monitoring are the first steps toward the protection of these valuable resources.

Research along the shores of the St. Lawrence River has suggested that a combination of radar parameters is needed to be able to discriminate classes of wetlands. RADARSAT-2's polarimetric capabilities are instrumental for wetland mapping.

Hydrogeology

Synthetic aperture radar imagery can been used to map soil conditions and land surfaces. Research has proven the utility of multi-polarization and high-resolution radar sensors for mapping surface parameters that support water management and ground-water exploration. One goal is to improve recharge modelling and mapping for the key aquifers of Canada.

OCEANS

Increased consumption, diminishing resources, and advances in technology have intensified offshore resource-based operations such as fishing, and oil exploration and production. Government and industry have looked towards satellite remote sensing as a monitoring tool.

Satellite SAR images have advanced the global ocean surveillance capacity for operational applications such as ship detection, oil spill monitoring, sea-bottom topography measurement, and wind field estimation. SAR is also of great use in ocean wave surveillance.

Government of Canada marine services have already incorporated oil spill, ship, and wind information from RADARSAT-1 into their operations. RADARSAT-2 offers new forecasting capabilities.

Ships

By building on RADARSAT-1 successes, RADARSAT-2 provides improved target detection with multiple and fully polarimetric data, higher resolution imagery, and an increased revisit schedule. These improvements show potential for ship classification and better relating ship detection information to commercial needs, such as the monitoring of offshore fishing activities. Improvements by RADARSAT 2 to ship-sea contrast come through its polarimetric data, to ship and wake detection through its dual polarization channels (VH with VV), and to better ship analysis and classification through Ultra-Fine mode imagery.

Winds

SAR images of the ocean surface often show the imprint of atmospheric phenomena caused by the near-surface wind field. The faster the near-surface winds, the rougher the ocean's surface and the larger the radar backscatter. Research suggests that RADARSAT-2's VV polarization is a good choice for wind-field retrieval.

In this CV-580 C/X-SAR multi-polarization composite image of the Minas Basin, Nova Scotia, acquired during low tide conditions, the colourful patterns indicate differences in the information content of the three images. The yellow line marks the boundary between dry land and tidal plane. Oceans and coastal applications benefit from the versatility of RADARSAT-2. (Image CCRS, 1999)

Currents

To obtain quantitative ocean current information, you can carry out a detailed Doppler analysis and ascribe any systematic Doppler components to ocean current effects. With its VV polarization and larger incidence angles RADARSAT-2 can make this type of measurement. Its high quality satellite position information also makes RADARSAT-2 a good choice for this type of analysis.

Coastal zones

A large part of the world's population lives in coastal areas and the pressure from urban growth, commerce, industry, and tourism is intense. Coastline mapping, mapping of tidal and near-shore terrestrial areas, and mapping of near-shore bathymetry are a few of the applications that could benefit from radar data.

RADARSAT-2's HV-polarized images enhance shoreline mapping and show greater contrast of water and land backscatter regardless of the incidence angle. Coastal applications could also benefit from the Ultra-Fine mode that shows more spatial detail. This resolves what has been a major drawback in the application of satellite data to coastal zone management.

SEA AND LAND ICE

One of the primary drivers behind the development of the RADARSAT-1 program was the capability of a SAR satellite to monitor Canada's icy waters effectively in support of shipping operations. RADARSAT-1 has proven highly successful in providing operational information for this application. Canada has become as a world leader in the operational use of radar information for sea ice monitoring.

RADARSAT-2 offers many improvements for these applications. For operational sea ice monitoring the beam mode of choice is ScanSAR because of its wide swath coverage. The left- or right-looking capacities enhance the revisit capability of imaging activities. This benefits sea ice monitoring, particularly at mid-latitudes where the current revisit time with RADARSAT-1 is every two to three days.

Sea ice edge and ice concentration

Identifying the boundary between ice and open water, that is, the ice edge, is the primary task for sea ice mapping. The backscatter contrast between ice and water determines ice edge definition. RADARSAT-2's cross-polarization capability reduces ocean backscatter and improves ice edge definition significantly.

Sea ice topography and structure

Ice topography and structure, and ice deformation features, such as ridging, are important parameters, as these features pose an impediment and hazard to navigation. Cross-polarization ScanSAR data from RADARSAT-2 is more sensitive to structural information and enhances discrimination between smooth and deformed ice, improving detection of ice topography and structure.

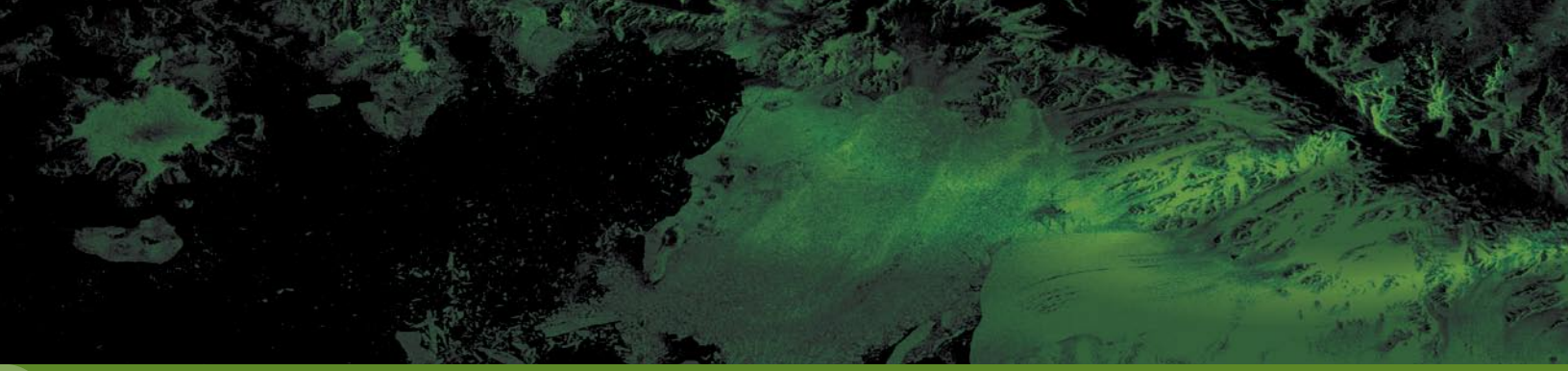
Icebergs

Icebergs, like ships, show up in C-band radar images as bright point targets. As with ship detection, cross-polarization data helps in detecting icebergs, especially at steeper incidence angles. The availability of cross-polarization from RADARSAT-2's various beam modes is particularly useful, depending on the coverage area and the resolution required. Fully polarimetric radar systems could facilitate the discrimination of icebergs from ships.

Polar glaciology

Continuing the study and monitoring of the Arctic and Antarctic is important because of changes in climate. RADARSAT-2 facilitates the study and monitoring of change in various polar sea ice and glaciological sites and conditions. Because it can readily change from right- to left-looking modes, it is key to Antarctic glacial ice monitoring, and can image parts of Antarctica not accessible by other high-resolution remote sensing satellites. The pioneering 1997 and 2000 Antarctic mapping missions with RADARSAT-1 could be repeated.

In the Arctic, RADARSAT-2 data continues the temporal record of SAR coverage, which becomes increasingly important for the study of the impact of climate change in the North.



KEY FEATURES

Selective single polarization mode

In addition to the HH polarization offered by RADARSAT-1, RADARSAT-2 can image using HV, VH, or VV polarization. Depending on which single polarization mode is selected, specific targets can be highlighted or more easily discriminated. For example, the information needs associated with hurricanes, oil spills, and winds are better met with VV polarized images. Likewise, the requirements of clear-cut and fire-scar mapping, ship detection, and select sea and land ice applications, are more easily satisfied with HV or VH images.

Selective dual polarization mode

RADARSAT-2 can acquire two coincident images using either HH with HV, or VV with VH polarizations. These modes support applications for targets that include radar-transparent vegetation and ice volumes with varying structural properties or land and ice surfaces with varying degrees of roughness.

Quad polarization or fully polarimetric mode

The RADARSAT-2 synthetic aperture radar can measure the amplitude and phase of the backscattered wave for the four available transmit and receive linear antenna polarization combinations (HH, HV, VV and VH). These measurements enable the computation of a wide variety of variables that relate to the strengths, polarizations and phases of the radar signals returned by the objects.

The introduction of quad polarization enhances most applications, including those concerned with crop type, crop conditions, and search and rescue. However, the swath width of images acquired in the quad-polarization mode is 25 kilometres, which limits, for example, forestry, oceans, and sea-ice operational applications where coverage of extended geographical areas is needed.

Ultra-Fine spatial resolutions

Nominally, three-by-three metres and single-look, these are available in the single polarization imaging mode of operation. This capability enhances applications in cartography—those concerned with point targets such as the classification of ships and icebergs. As with quad polarization, Ultra-Fine data products have a limited swath width (20 kilometres), which reduces the operational use of this data type for applications such as clear-cut and fire-scar mapping.

Selective look direction

While the satellite images about 75 per cent of the time to the right by default, left looking is available on demand. This feature should have a significant effect on applications in disaster management. Average response times are reduced and revisit frequency is generally increased. Polar glaciology applications can benefit from the satellite's left-looking configuration, ensuring that all of Antarctica can be imaged.

Orbit control

Enhanced control over the satellite's orbit improves imaging for data products in applications that make use of interferometric processing techniques. This has a major impact on applications such as geological hazards, search and rescue, terrain mapping, and polar glaciology. Cartographic mapping applications and others benefit from improvements to scene georeferencing accuracy.