RADARSAT-2; Are its Technical Capabilities Expected to Provide Potential for Remote Sensing Applications ?

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Abstract – In this paper, we preview and demonstrate how the technical improvements included in RADARSAT-2 will impact the system's potential utility for 32 applications in the fields of agriculture, cartography, disaster management, forestry, geology, hydrology, oceans, and sea and land ice.

I. Introduction

To date, Synthetic Aperture Radar (SAR) data have been widely available from single channel, (single frequency and polarization) spaceborne radars including ERS-1 and 2 (C-VV), JERS-1 (L-HH), and RADARSAT-1 (C-HH). In the near future, satellites carrying SARs with enhanced imaging capabilities in terms of polarization and spatial and temporal resolution are expected to be operational. The planned Canadian RADARSAT-2, which is scheduled for launch in 2003, is an example of such a system. In this paper, we preview and demonstrate how the technical improvements included in RADARSAT-2 will impact the system's potential utility in applications in the fields of agriculture, cartography, disaster management, forestry, geology, hydrology, oceans, and sea and land ice. Evidently, the applicability of the RADARSAT-2 data will govern the satellite's economic viability and as such its part in the operationalisation of space-borne radar remote sensing. Our evaluation relies on bibliographic sources and, in particular, case studies drawn from ongoing applications development work at the Canada Centre for Remote Sensing [1].

II. New Capabilities of RADARSAT-2

RADARSAT-2 will provide all imaging modes of the current RADARSAT-1 satellite, as well as some new modes that incorporate significant innovations and improvements. Hence, the satellite will offer data continuity to RADARSAT-1 users and new data that will support development of new applications and refinement of existing ones. Table I lists selected specifications of RADARSAT-2. From an applications perspective, the most prominent technical enhancements embodied by RADARSAT-2 are those relating to look direction, spatial resolution, polarization, and orbit control. These enhancements will be discussed in some detail below.

RADARSAT-2 will be outfitted with an electronically steerable antenna. This will allow for imaging to either the right or the left of the sub-satellite track. Thanks to a new Ultra-Fine beam mode, RADARSAT-2 will be able to offer the highest spatial resolution commercially available in spaceborne SAR data (3 m by 3 m, 1 look). Depending on the beam, RADARSAT-2 will have the capability to operate in the Selective Single Polarization (SSP), the Selective Dual Polarization (SDP) or the Quad Polarization (QP) mode. The SSP mode will provide images that comprise a single channel the polarization of which is HH or HV or VV or VH. In the SDP mode the satellite will acquire images that comprise both a like- and cross-polarized radar channel, i.e. either an HH and HV channel or a VV and VH channel. Finally, in the QP (fully polarimetric) mode, the RADARSAT-2 SAR will measure the amplitude and phase of the backscattered wave for the four available transmit and receive linear antenna polarization combinations (HH, HV, VV, VH). Improved control over the satellite's orbit and attitude will be achieved through onboard GPS receivers and star-trackers.

III. Anticipated Resulting Applications Potential

Table II summarises our assessment of the effect of the most important technical enhancements of RADARSAT-2 on the information content and hence the application potential of its data. The table shows that the SSP mode of operation will moderately advance the potential of RADARSAT-2 for

TABLE I
Selected Specifications of RADARSAT-2

General specifications	
Expected launch date	2003
Mission life	7 years after commissioning
SAR characteristics	
Centre frequency	5.405 GHz (C-band)
Bandwidth	100 MHz
Polarization	HH, HV, VH, VV
Nominal spatial resolution	3 – 100 m
Nominal swath width	20 – 500 km
Nominal incidence angle	10° - 60°
Look direction	Right or left
Imaging modes	11
Orbit characteristics	
Altitude (average)	798 km
Inclination	98.6º
Sun-synchronous	14 orbits per day
Repeat cycle	24 days

applications the information needs of which can generally be met by single channel C-band data but for which the HH-polarization as offered by RADARSAT-1 is not the most favourable. As a rule, the information needs associated with hurricanes, oil spills and winds are better met through application of VV-polarized images. Similarly, the requirements pertaining to clearcuts, fire-scars, ships, and selected sea and land ice applications are more easily satisfied when HV or VH images can be applied.

The capability to operate in SDP mode is projected to moderately improve the potential of RADARSAT-2 to provide information in support of applications dealing with targets that include transparent vegetation / ice volumes with varying structural properties or land / ice surfaces with varying degrees of roughness. Applications that are expected to gain little information from having access to two image channels instead of one image channel (in SSP mode) have been given the 'minor' rating.

Data acquired in the QP mode will facilitate the computation of a wide variety of variables that relate to the strengths, polarizations or phases of the radar return signals as received from the observed objects. The introduction of this imaging mode is expected to moderately advance the potential of RADARSAT-2 for most applications. Applications for which the QP data are anticipated to be particularly valuable or essential ('major' rating) are concerned with crop type, crop condition, DEM polarimetry, and search & rescue. Once again, 'minor' ratings have been given whenever the increase in terms of radar data is not expected to result in a significant increase in applicable information. Due to technical limitations the swath width of the images acquired in the QP mode is restricted to 25 km. This will pose a definite problem for the operational use of QP data in applications that require information on extended areas, e.g. forestry, oceans and sea ice applications.

RADARSAT-2's capacity to acquire images with Ultra-Fine spatial resolutions is restricted to the SSP imaging mode. It is our expectation that this capability will enhance the potential of RADARSAT-2 for cartographic applications and applications concerned with point targets, that is, ships and icebergs, in particular. In addition there is a considerable number of applications that are foreseen to moderately benefit from the upcoming availability of these very high resolution space-borne SAR data. Like the QP data products, the Ultra-Fine data products have a limited swath width (20 km). Again, this will obstruct the operational use of this data type in certain applications.

The selective look direction feature of RADARSAT-2 is expected to have a 'major' effect on its potential for applications in the fields of disaster management and polar glaciology. Disaster management applications will benefit form the reduced average response time and the generally increased revisit frequency. On the other hand, the polar glaciology application will gain from the fact that the left-looking configuration will enable routine imaging of the most southerly regions on Earth including Antarctica. Applications expected to benefit from the increase in the number of imaging opportunities but dealing with circumstances that are not usually life-threatening have been given the 'moderate' rating.

The improved knowledge about and control over the RADARSAT-2 orbit will enhance the potential of the image data products for applications that make use of interferometric processing techniques in particular. Table II therefore shows the 'major' rating in connection with the following applications: DEM interferometry, geological hazards, search and rescue, terrain mapping and polar glaciology. The cartographic mapping applications and other applications will benefit considerably from the improved accuracy with which scenes will be georeferenced have been given the 'moderate' rating. For the remaining applications the enhancements in terms of orbit knowledge and control are projected to be useful but not essential ('minor' rating).

IV. Applications Potential of RADARSAT-1 and RADARSAT-2

Table III shows our assessments of the overall application potential of RADARSAT-1 and the anticipated overall application potential of RADARSAT-2. The difference in the ratings for the two satellites illustrates the degree to which we expect the technical innovations contained in RADARSAT-2 to enhance the information content of the data products and hence to expand the applications potential of these products.

Comparison of the ratings for RADARSAT-1 and –2 shows that the biggest improvement in application potential is projected to be associated with the crop type, crop condition, and sea ice topography / structure fields (change in ratings from 'limited' to 'strong'). This is primarily the result of the enhancement of RADARSAT-2 in terms of polarization. Of the 29 remaining applications fields, the DEM polarimetry field is one that cannot currently be attended to with data from RADARSAT-1. The potential of RADARSAT-2 for this particular application is rated as 'limited' because of the minimal flexibility in terms of viewing geometry and the fact that the elevation information is limited to the azimuth direction. For 18 out of the 32 fields considered we predict that the introduction of RADARSAT-2 will result in a modest increase in application potential. Going from RADARSAT-1 to RADARSAT-2 the potentials associated with these applications are ranked one category higher. The RADARSAT-2 features that instigate these changes in application potential may differ from one application to another. For 10 fields we foresee no increase in application potential. Among these are the applications concerned with DEM stereoscopy and floods, that is, applications for which the potential of RADARSAT-1 data products is already ranked as 'strong'. For the DEM interferometry and hurricanes fields the application potential stalls at the 'moderate' rating because of restraints imposed by atmospheric conditions and swath width, respectively. The orbital characteristics of RADARSAT-1 and RADARSAT-2 make that the application potential for the waves field halts at

the ‘limited’ rating. Generally speaking, the information requirements of the five remaining applications can only be better satisfied by low- or multi-frequency SAR systems (e.g. forest type, forest biomass, sea ice type) or by optical remote sensing systems (e.g. oil spills, lithology).

REFERENCES

[1] CCRS, RADARSAT-2 Demonstration Website, http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/radarsat/r2demo/r2demoe.html, 2000.

TABLE II
ANTICIPATED EFFECT OF NEW RADARSAT-2 FEATURES ON APPLICATIONS POTENTIAL IN TERMS OF DATA INFORMATION CONTENT.
KEY: ‘-‘ MINOR, ‘-/+‘ MODERATE, ‘+’ MAJOR.

	RADARSAT-2 Feature					
Application	**Selective Single Polarization**	**Selective Dual Polarization**	**Quad Polarization**	**Ultra-Fine Spatial Resolution**	**Selective Look Direction**	**Improved Orbit Control**
Agriculture						
Crop type	-	-/+	+	-	-	-
Crop condition	-	-/+	+	-/+	-/+	-
Crop yield	-	-	-/+	-/+	-	-
Cartography						
DEM interferometry	-	-	-	+	-	+
DEM stereoscopy	-	-	-	+	-	-/+
DEM polarimetry	N.A.	N.A.	+	N.A.	-	-/+
Cartographic feature extraction	-	-	-/+	+	-	-/+
Disaster Management						
Floods	-	-	-	-	+	-
Geological hazards	-	-/+	-/+	-/+	+	- (+) [1]
Hurricanes	-/+	-	-/+	-	+	-
Oil spills	-/+	-	-	-/+	+	-
Search and rescue	-	-	+	-/+	+	-/+ (+) [1]
Forestry						
Forest type	-	-	-/+	-/+	-	-
Clearcuts	-/+	-	-	-/+	-	-
Fire-scars	-/+	-	-	-/+	-	-
Biomass	-	-	-	-	-	-
Geology						
Terrain mapping	-	-/+	-/+	-/+	-	- (+) [1]
Structure	-	-/+	-/+	-/+	-	-
Lithology	-	-	-	-	-	-
Hydrology						
Soil moisture	-	-	-/+	-	-/+	-
Snow	-	-	-/+	-	-/+	-
Wetlands	-	-/+	-/+	-/+	-	-
Oceans						
Winds	-/+	-	-	-	-	-
Ships	-/+	-	-/+	+	-/+	-/+
Waves	-	-	-/+	-	-	-
Currents	-	-	-	-	-	-
Coastal zones	-	-/+	-/+	-/+	-	-
Sea and Land Ice						
Sea ice edge and ice concentration	-/+	-	-/+	-	-/+	-
Sea ice type	-	-	-/+	-	-	-
Sea ice topography and structure	-/+	-/+	-/+	-	-	-
Icebergs	-/+	-	-/+	+	-/+	-/+
Polar glaciology	-/+	-/+	-/+	-	+	- (+) [1]

1) Using InSAR techniques.

TABLE III
APPLICATION POTENTIAL[1] OF RADARSAT-1 AND RADARSAT-2. KEY:
‘-‘ MINIMAL, ‘-/+‘ LIMITED, ‘+’ MODERATE, ‘++’ STRONG

	Satellite	
Application	**RADARSAT-1**	**RADARSAT-2**
Agriculture		
Crop type	-	-/+
Crop condition	-	-/+
Crop yield	-	-
Cartography		
DEM interferometry	-	-
DEM stereoscopy	-	-
DEM polarimetry	N.A.	N.A.
Cartographic feature extraction	-	-
Disaster Management		
Floods	-	-
Geological hazards	-	-/+
Hurricanes	-/+	-
Oil spills	-/+	-
Search and rescue	-	-
Forestry		
Forest type	-	-
Clearcuts	-/+	-
Fire-scars	-/+	-
Biomass	-	-
Geology		
Terrain mapping	-	-/+
Structure	-	-/+
Lithology	-	-
Hydrology		
Soil moisture	-	-
Snow	-	-
Wetlands	-	-/+
Oceans		
Winds	-/+	-
Ships	-/+	-
Waves	-	-
Currents	-	-
Coastal zones	-	-/+
Sea and Land Ice		
Sea ice edge and ice concentration	-/+	-
Sea ice type	-	-
Sea ice topography and structure	-/+	-/+
Icebergs	-/+	-
Polar glaciology	-/+	-/+

1) Use of single date images assumed.