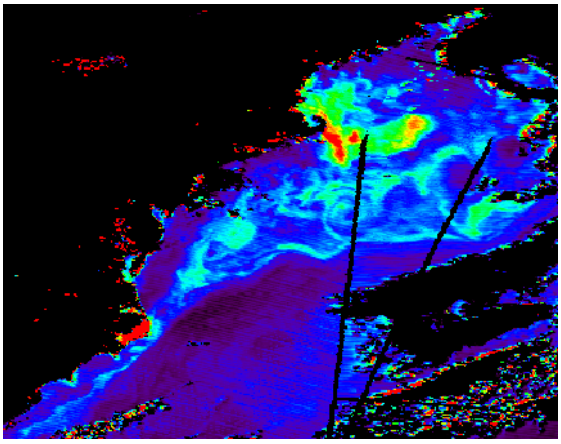
Summary Study of Canadian Marine, Freshwater and Land Requirements for Satellite Medium Resolution Imaging Spectrometer Sensor Data (MODIS-MERIS Study)



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Final Report December 2003

Cover: Fluorescence Line Height (M. Abbott), Northwest Atlantic, April 7, 2000, U.Miami/RSMAS This MODIS picture is showing FLI algorithm developed by Dr. Jim Gower at DFO/IOS, now used in processing both MODIS and MERIS data into ocean productivity maps.

Executive Summary

The Canadian Space Program through the Earth and Environment is working collaboratively with the federal departments and agencies to move from demonstration to operational use of EO satellite data sources. The new generation of medium resolution spectral imagers (MERIS and MODIS) are providing optical and IR data with increased sensitivity and spatial resolution. This has resulted in increased data volumes and higher data rate down link from satellite in X-band. This is necessitating a planned migration from the first generation sensors with lower data rates down linked on lower band width S-band. The main purpose of this report is to provide a summary of Canadian user requirements for data from this next generation medium resolution spectral sensors exemplified by MERIS and MODIS.

The study found that the main existing federal operational users acquire the first generation AVHRR and SeaWiFS sensor data on locally owned and operated reception and processing facilities. In the last decade, the reception of the S-band down link of these data has undergone dramatic changes with modern PC based digital processing. This has made regional reception and discipline specific processing a reality co-located with the disciplinary experts across Canada at 12 sites. These facilities and their users expect to have continuity in the cost effective access and product services based on PC technology systems.

Fortunately, this same system down sizing and cost reduction is also being realized for the higher data rate X-band reception and processing facilities. These PC based systems provide the opportunity for users to move to the use of medium resolution spectral sensors currently represented by MERIS and MODIS with their greater spectral selectivity, sensitivity and spectral coverage. The University of Wisconsin is demonstrating the RAPIDFIRE system for near real time forest fire information for North America. Canadian forest fire managers have been evaluating the RAPIDFIRE data products in addressing the containment of the 2003 forest fires in BC and Alberta.

Unfortunately although Canada is a cooperating partner on the ESA managed ENVISAT satellite program, the direct access to MERIS data over Canada remains to be arranged with ESA. Canadian users are finding the delayed mode MERIS Full resolution data services to be unacceptably slow and in order to achieve operational use of MERIS data Canadian users must have MERIS FR data as accessible as the data from MODIS. The other lesson learned from MODIS is that discipline specific operational products are best achieved by fostering regionally located direct reception and processing facilities with discipline specific scientific experts participate in the algorithm development, validation and on-going product assurance and upgrades. The direct reception and processing of MERIS data in Canada needs to be linked to having a follow-on MERIS satellite system to provide continuity of these data once commitments are made for operational usage.

On the basis of the replies from the return questionnaires and follow-up user detail gathering by email and telephone it is clear there is a growing federal end user group

relying on the discipline specific environmental information products and services provided by facilities operated by EC/MSC, DFO/Science, NRCan/CCRS and the Manitoba Remote Sensing Centre. These operator and end users are actively evaluating the data and products available from the currently operating MERIS and MODIS sensors and they will make a commitment to operationally use data from this new generation of medium resolution sensors once there is a n established plan by the sensor providers and operator to provide a continuity of data for a decade or more.

The WEB based data and information services offered my MODIS is setting a new standard in cost effective operational satellite based environmental information services world wide. The specific Canadian requirements for high latitude regional products is experiencing some difficulties using NOAA processed data due to the USA focus on global products; this can be best addressed at a Canadian reception and processing facility designed to meet Canadian user requirements. To meet user needs for timely data to monitor the ever changing coastal zone and freshwater lake environments, identified in the user survey, direct reception and processing facilities for MERIS full resolution data is required in Canada.

The lower cost PC technology is now available for both MERIS and MODIS and at least two Canadian suppliers have been identified who would respond to an RFP to establish Canadian direct reception facilities. CSA has the opportunity to negotiate access to these foreign data sources and coordinate an orderly implementation of the direct reception and processing facilities to meet the discipline specific products and services identified in the user survey.

1. Introduction

The Canadian Space Agency and other Federal Government Departments and Agencies involved in their mandated environmental services have common interest to make the optimum use of available satellite sensor data. The Canadian user interest in utilizing data from MERIS and MODIS medium resolution spectrometer sensors is built on a robust government user community and an internationally recognized Canadian products and services industry providing satellite-based Earth Observation (EO) information.

The objective of this report is to survey the government user requirements and identify the options for CSA to lead a coordinated federal government approach to meet the scientific and operational user requirements for medium resolution spectrometer sensor (MRSS) data. To this end, the report reviews the data requirements and issues identified by users in their questionnaire replies (Appendix B) completed by twenty-four respondents from Other Government Departments (OGDs) and Agencies and two from the EO information service industry. The replies are summarized in table 1 identifying the existing and potential operational users who are evaluating the MERIS and MODIS data in their application.

The MERIS and MODIS sensor systems represent the second generation satellite based medium resolution optical and infrared sensors providing daily revisit required for operational environmental monitoring. The MERIS sensor primary operations objective is to monitor marine phenomena and processes observable in the optical spectrum between 412 nanometres and 815 nanometres wavelengths (blue to red). The primary objective of the MODIS sensor is to demonstrate the next generation medium spatial resolution sensor providing high sensitivity data of narrow spectral bands in the ultra-violet, optical, near infrared and thermal infrared portions of the spectrum. The MODIS sensor whisk broom based scanning system is being evaluated for this scanning mechanism capability to meet the data quality and its ability to function reliably in the harsh space environment. The end to end MODIS systems includes the demonstration of near-real-time data and information services to end users, monitoring atmosphere, land, coastal zone and oceans environmental parameters of interest, to persons anywhere in the world using WEB based data services.

For the purposes of this report the medium resolution satellite sensor data includes sensors with spatial resolutions from 250 meters to 1100 meters per pixel. The Canadian users have developed many operational monitoring of the atmosphere, land and ocean environment of the earth with the 1100 meter spatial resolution data currently provided by the AVHRR and SeaWiFS sensor systems. These sensors applied previously available sensor technologies offering lower spectral resolution at a lower sensitivity that is now being offered in the MERIS and MODIS systems.

The specifications for the operational Visible Infrared Imaging Spectrometer Suite (VIIRS) is also included to provide an insight into the proposed operational medium resolution spectrometer sensor evolving, from the demonstration MODIS system, for operational implementation on the NPEOSS satellite system starting in 2006. The

Canadian meteorological users in particular will be organizing those applications specific development based on the reduced suite of spectral channels being proposed for VIIRS implementation. In general, to justify their investment of limited resources, the existing operation applications wish to develop their product specific processing using the data next generation MRSS system offering continuous data sets for decades.

2. Overview of MERIS and MODIS

2.1 Spectral Imaging

The MERIS and MODIS sensors are first generation medium resolution spectrometer sensor systems with ~10 nanometre (nm) band width in the visible and ultraviolet spectrum and MODIS also has ~20 nanometre Infrared spectral channels. The many spectral bands results in a high data rate which necessitates a 1 Megabyte/second X-band satellite data channel downlink from the satellite. These sensors provide narrow spectral bands and wide swaths supporting global monitoring. The MERIS 1150 kilometre swath width and MODIS 2340 kilometre swath width enables each to provide near daily coverage of the globe.

The MERIS and MODIS sensors form part of the Integrated Global Observing System (IGOS) coordinated by the Committee on Earth Observations Systems (CEOS) comprised of representatives from countries operating an earth observation satellite system. CEOS provides a forum for participating nations to arrange complimentary orbits for national EO satellites and identifies opportunities for foreign sensor contributions to new systems. The objective is exchange complimentary EO data from an international series of satellite sensors to support long term observations to support global climate research. In the Global Climate Observing System, ESA and NASA coordinated the launch and orbits of the ENVISAT, TERRA and AQUA satellite platforms with MERIS and MODIS sensors on board.

Background on the Canadian Government Earth Observation Expertise

Natural Resources Canada (NRCan) through the Canada Centre for Remote Sensing (CCRS) managed optical and infra-red reception and applications development of the Landsat high spatial resolution MSS and TM sensors through agreements with NASA and NOAA since 1970. CCRS has concentrated primarily on land applications under the NRCan mandate. Since the 1980's CCRS has also acquired the medium resolution Advance Very High Resolution Radiometer (AVHRR) data. CCRS and the Manitoba Remote Sensing Center (MRSC) collaborated in developing the GEOCOMP system for deriving Normalized Difference Vegetation Index (NDVI) product used by an ever increasing number of end users. The NDVI product produced at MRSC is currently utilized by the Canadian Wheat Board, Stats Canada, Parks Canada and Environment Canada.

Under continental weather forecast agreements with The USA National Oceanographic and Atmospheric Administration (NOAA), Environment Canada (EC), Meteorological Services Canada (MSC) branch operationally acquire and utilize low resolution data from GOES satellite in geo-stationary orbit and the medium resolution NOAA polar orbiting satellite data. EC/MSC uses these data in operational production of daily weather and ice forecasts. EC/MSC acquires and process AVHRR data at their weather centres in Edmonton, AB, Downsview, ON and Bedford, NS. for use in weather prediction models.

Fisheries and Oceans Canada (DFO) acquire and process the medium resolution AVHRR sensor data from the NOAA/NESDIS under international oceans data exchange agreements, primarily for science purposes. DFO direct reception facilities located in Sidney, BC, Mont-Joli, QB, and Dartmouth, NS acquire and process AVHRR data into Sea Surface temperature products primarily for internal DFO use. These same DFO reception centres acquire and process the SEASTAR/SeaWiFS sensor data into primary productivity maps (phytoplankton) of the Pacific Ocean, Hudson's Bay, Arctic Ocean and Atlantic Ocean areas. Through a research application agreement with Orbital Sciences Corporation, the SEASTAR commercial satellite operator, and a science agreement with the National Aeronautic and Space Administration (NASA), DFO have direct reception and decryption to utilize SeaWiFS data for Canadian marine science applications. The one kilometre spatial resolution limits the use of these sensors to oceans and large freshwater lakes such as the Great Lakes.

Canadian federal government users are evaluating the MERIS and MODIS applications potential in their mandated areas of responsibility. DFO and EC users need spectral sensor data with an adequate spatial resolution available from MERIS and MODIS systems to monitor freshwater lakes and estuaries as well as to monitor near coast and bay areas from space in support of sustainable use of Canada's freshwater and coastal resources. NRCan and AAFC users need data for studying terrestrial climate trends and for disaster monitoring to support response planning.

2.2 MERIS

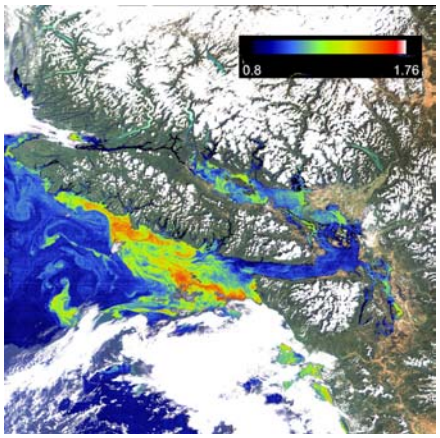

MERIS camera (ESA)

ESA launched the ENVISAT satellite with the MERIS sensor and provides ground processing through the European "Earthnet" ground station system. MERIS operates in the optical spectral range of 412nm to 825nm. The ENVISAT orbit has a 12:00 hrs and 24:00 hrs equator crossing times. The primary mission for MERIS is the measurement of sea colour in oceans and coastal zones providing global coverage in 3 days with the 68.5 deg FOV (1150 kilometre wide swath). ESA operates MERIS within its earth observation systems data policy whereby science users submit their project to ESA for approval and ESA supplies a limited amount of MERIS data at a nominal cost ($100 euro/scene). All other MERIS data users purchase their data from the designated commercial supplier at the commercial price pre scene ($1000 euro/scene).

This instrument has a wide range of applications. Main scientific objectives are

- Atmosphere: clouds (top height, optical thickness), water vapour content, aerosols (type, concentration, path radiance)
- Land: cover types (band characteristics)
- Ocean: upper ocean chlorophyll concentration, coastal erosion, transport and deposition

MERIS performs measurements of radiances in the wavelength band 0.4 - 1.05 µm with programmable spectral resolution between 2.5 and 20 nm. Up to 15 individual spectral bands can be selected via tele-command. An 1150 km wide swath (corresponding to MERIS's across track field of view of ±41°) will be observed thus giving global coverage within 2 - 3 days. Because of the dependence on the visible to near-IR spectral range, MERIS observations can only be performed with sufficient sun illumination. As in the case of AATSR, a sub-satellite sun elevation greater than 10° is required (obtained 43.5 min per orbit).



Ocean productivity map (DFO & Borstad)

MERIS offers two operation modes, the Full Resolution (FR) mode (300 meter resolution) and the Reduced Resolution (RR) mode (1000 meter resolution). In the former, the instrument generates Medium Rate data for which there is limited onboard recording capacity. Therefore, whenever MERIS is switched to FR mode, real time downlink to an approved ground station is preferred. MERIS is able to generate both the FR and the RR data stream simultaneously with the RR data nominally recorded for playback in Europe. The FR mode will be the primary MERIS mode over coastal zones and land where the direct reception capabilities exist. The RR mode is used to gather the global data set.

MERIS data Full Resolution (FR) mode provides 300 meter resolution across swath with only minor edge degradation. The FR mode swath width is 575km or one quarter size image of the Reduced Resolution RR mode. The RR mode provides 4x4 averaged pixels over the 1150km swath. The MERIS orbit and sensor RR swath provides global coverage every third day; Canada, being north of 45 deg latitude North, can be covered in less than two days. The MERIS is being operated in a nominal band configuration. Although it is technically possible, ESA are not offering applications specific user requested spectral band selection at this time.

MERIS Sensor Overview and Operations

MERIS, in its nominal spectral configuration, measures the solar radiation reflected by the Earth in following 15 spectral channels at 300 meter spatial resolution

No.	Band centre (nm)	Band width (nm)	Application
1	412.5	10	Yellow substance and detritus pigments
2	442.5	10	Chlorophyll absorption maximum

No.	Band centre (nm)	Band width (nm)	Application
3	490	10	Chlorophyll and other pigments
4	510	10	Suspended sediment, red tides
5	560	10	Chlorophyll absorption minimum
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption & fluorescence. reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	708.75	10	Fluorescence. reference, atmosphere corrections
10	753.75	7.5	Vegetation, cloud
11	760.625	3.75	O_2 R- branch absorption band
12	778.75	15	Atmosphere corrections
13	865	20	Vegetation, water vapour reference
14	885	10	Atmosphere corrections
15	900	10	Water vapour, land

Table 1: MERIS nominal spectral channels

This nominal set of spectral bands was recommended by the Science Advisory Group (SAG) and frozen before launch. The level 2 ESA products are being developed and will be validated for this set of bands.

MERIS provides noticeably sharper FR images at 300m for all spectral bands but the FR image has reduced signal to noise in dark ocean targets. The FR image resolution enables one to look for red tides in narrow inlets around fish farms. The FR mode MERIS data could be used for land applications requiring medium resolution with adequate signal to noise over terrestrial targets. The sensitivity and dynamic range of the MERIS system provides continuous imagery in both the land and oceans/fresh water portions for coastal applications and lake monitoring. This contiguous land to water imaging helps monitor the interactions between land and water processes.

In the ENVISAT background mission, ESA collects limited FR MERIS data over most land and coastal areas but does not process all scenes limiting FR data for Science Team and paying customers. Currently the FR MERIS data can be collected and recorded onboard for 20 minutes of each orbit. Canadian science and operational users are interested in acquiring increased amounts of the FR MERIS data of Canada but the

delayed mode ESA data processing and distribution system because Canadian data is acquired by on-board recording with playback in Europe. The FR data is put on a CDROM and mailed resulting in significant time delay to the Canadian user. The RR MERIS data is created on-board by applying a 4X4 aggregation of pixels over the full swath which is used to collect a global ocean data set at 1200 meter resolution.

ESA recently tested the real time relay of FR mode data through the European "Artemis" data relay satellite system for near-real-time disaster information capture and processing for European and African Continents. The ARTEMIS near-real-time relay of the FR data from MERIS is being evaluated for disaster management such as flooding and forest fire mapping. Over oceans areas only, the RR data are routinely acquired and relayed in near-real-time via the ARTEMIS system. Reduced resolution MERIS data is made available on an ESA ftp site for electronic network download within a day.

2.3 MODIS

NASA has launched two satellites under their Earth Observation System (EOS) series; TERRA began operation in 1999 and AQUA began operation in 2002. Each of the AQUA and TERRA platforms operate a MODIS sensor under NASA management. The TERRA platform orbit has a 10:30 hrs and 22:30 hrs equator crossing optimized for land observations while the AQUA platform has a 13:30 hrs and 01:30 hrs equator crossing which is optimized for oceans observations. The optimization is determined by the best clear sky period of the day for each respective platform to monitor its respective land and oceans target. NASA provides free near-real-time access to all levels of MODIS data on its Earth Observation Distribution System (EOSDIS) sensor web site. This is facilitating easy evaluation and utilization of the data by a broad spectrum of users. A dedicated reception and processing of MODIS data into a forest fire product is also distributed via the WEB by USA Forest Service.

The MODIS sensor provides data in 36 spectral bands in both the visible (20 bands) and IR (16 Bands) parts of the spectrum making it useful for many Earth Observation applications. The green and red visible bands provide 250m data and there are 5 visible and short wave IR channels at 500m resolution while another 13 VIS and IR bands provide 1000m resolution data. The MODIS operates continuously and NASA processes and makes the level 1 and higher level products available on the WEB after a short delay. The MODIS dual platform system provides daily global coverage.

2.4 Options for Direct Reception

A Canadian ground station reception and PC based processing facility for MODIS data could be purchased at an estimated cost of $250,000.00 US. The operations support cost need to be confirmed with a service provider (estimated to cost $50,000 per year). In order to embark on the implementation of a Canadian reception and processing facility CSA need to negotiate a MODIS data reception agreement with NOAA. Further discussion of cost is included in section 5.

3. Canadian spectrometer data interests

3.1 Study results

This study looks at the user requirements and issues relating to the spectrometer class of satellite based earth observations sensor represented by the recently launched medium resolution spectrometer sensor (MRSS) systems MERIS and MODIS. The study is focusing on the Canadian federal government user's current level of knowledge and experience with these two sensor systems. Canadian users are currently using data from the first generation AVHRR and SeaWiFS medium resolution sensor systems and need to plan the transition to using MERIS and MODIS and follow-on missions. The users were asked to identify issues that were limiting their ability to move from scientific evaluation and algorithm development to operational use of MERIS and MODIS in meeting their CSA supported GRIP project objectives over the next 5 years.

The approach taken was to:

1. Undertake a WEB search gathering MERIS and MODIS sensor system details for distribution to potential users.

2. Identify individuals in federal departments and agencies currently using first generation medium resolution satellite earth observation sensor data in the delivery of their respective mandates in environmental management. Also identify those already using MERIS and MODIS data sources.

3. Arrange a project kick-off teleconference of representatives from federal departments, university and value added industry with presentations by a person most knowledgeable in the characteristics and use of MERIS and MODIS systems.

4. Prepare and distribute a questionnaire to survey users via the email system

5. Tabulate the results from the returned questionnaires

6. Gather additional information through telephone contact with selected users.

7. Based on survey results, prepare opportunities for CSA to consider in promoting the operational use of data from the MERIS and MODIS class of medium resolution sensors.

A teleconference, with twenty-seven participants from various departments and agencies including university and EO industry leaders, was held on 16 July, 2003 to update current and potential users on the status of MERIS and MODIS operations and user experience in Canada. Appendix A contains the minutes of the teleconference.

The teleconference participants agreed to provide a contact list and complete a questionnaire to determine user requirements and issues related to MERIS and MODIS data. The Questionnaire provided in Appendix B was circulated by email to thirty-five government, university and industry contacts. The twenty-seven completed questionnaires are included in Appendix C.

The applications interests are divided into the present and future planned use of medium resolution spectrometer sensor (MRSS) data sources. MODIS data are used operationally by the Alberta Minister of Agriculture, Forest Fire Centre and by both consulting companies AERDE Environmental and Borstad and Associates. The largest operational user group utilizes the medium resolution sensor (MRS) data from AVHRRR and SeaWiFS sensor systems. Operational users include seven federal organizations utilizing data and products from the AVHRR sensor (EC/MSC, EC/CIS, Parks Canada, Stats Can, the Canadian Wheat Board, DFO/CCG, and DFO/Science). The Manitoba Remote Sensing Centre (MRSC) in Winnipeg, Manitoba produces Normalized Difference Vegetation Index (NDVI) maps of Canada from weekly composite image mosaic from AVHRR on the GEOCOMP processing system. MRSC electronically distribute the NDVI products end users across Canada. Environment Canada process and integrate the relevant AVHRR information into their weather and ice information products utilized by a wide variety of internal and external end users. DFO/Science process the AVHRR data into Sea Surface temperature (SST) and the SeaWiFS data into Marine Primary Productivity map products of Canadian marine areas of interest distributing these products on the WEB.

Recent developments in computer and communications technologies are revolutionizing the way reception, processing and end users of EO data and information services interact. The advent of the, commercially available, PC-based reception and processing system in 1985 ushered in the era of end user direct reception and processing to support regional operational applications. On the communications side the WEB based FTP image distribution is having an additional impact on the ability to share all levels of data and products from the MRS and MRSS systems. The MRSC acquires level 0 AVHRR data from CCRS covering the western Canada region and from DFO/IML covering the remaining eastern Canada region. This enables the MRSC to provide a node with disciplinary expertise to process and distribute the NDVI products of all of Canada through a subscription service. Similarly EC/CIS operates a disciplinary node dedicated to production of ice information integrating data from several EO sensors from a variety of platforms. Users electronically access ice information from CIS through their ice subscription service. DFO/IML, DFO/BIO and DFO/IOS reception and processing facilities provide marine scientists access to AVHRR and SeaWiFS data and information products of the Atlantic, Arctic and Pacific Ocean and large river estuary areas for their disciplinary applications.

Table summary of user completed questionnaires:

General	**Sectors consulted**	Agriculture	4
		Climate	6
		Environment/Weather	3
		Forests	4
		Ice	1
		Freshwater	3

		Land	4
		Oceans	6
		TOTAL	**31**
Present Use	MODIS users	19	
	MERIS users	5	
	Respondents using neither	12	
	Users of other sensors	At least 6 AVHRR, 2 SeaWiFS, 2 SPOT-VGT, 2 EO-1 and 2 Landsat. These are all potential users of MERIS and MODIS.	
	Main products of interest:		
	Marine and water application requiring medium resolution data and products	Ice products (ice edge, ice extend, ice movement)	10
		Map algal blooms in Coastal Bay and beach areas	7
		Monitor algal concentrations in large fresh water lakes	7
		Map sea surface temperature on shelf and ocean basin scale	7
		Map Coastal zone productivity on shelf scale or regional scale	6
		Map lake surface temperature on large lake scale	2
		Map ocean productivity on ocean basin scale	2
		Monitor suspended sediments and dissolved organic matter in freshwater lakes	2
		Lake/River/Ice and temperature monitoring	1
		Study properties of fluorescence and red tide signatures	1
		Snow monitoring	1
		Map Biomass field on ocean basin and regional scale	1
	Land application requiring medium resolution data or products	Land cover mapping (N classes)	17
		Land cover change detection product / habitat preservation	13
		Crop monitoring (NDVI, crop type, area, crop vigour, seasonal progress)	11
		Biophysical properties (leaf area index, biomass)	10
		Forest monitoring (deciduous forest area, forest stress, fires, re-growth, clear cut)	7
		Phenology, snow cover	4
		Land surface temperature	3
		Hydrology (flood, snow cover)	2
		Chemical properties of forests	2
		Rangeland biomass production and rate of production for grazing recommendations	2

		Canada-wide coverage		1
		Continuous vegetation cover		1
		Soil moisture		1
		Seasonal progress of vegetarian state (phenology) as input to land surface-atmosphere interaction models.		1
	Atmospheric application requiring medium resolution data or products	Cloud map		11
		Aerosol concentration map		2
		Atmospheric correction of optical sensors		2
		Real-time operational marine, aviation and public weather forecasting for the Arctic		2
		Radiation budget		1
		Dust storms		1
		Cloud/ice/snow separation, particularly in high latitudes		1
		Smoke		1
		Motion of cloud features between successive passes to estimate winds at various altitudes		1
Future use	Expressed interest in direct reception in Canada	14		
	Do not feel/unsure Canadian reception is useful/a priority	16		
	Ongoing need for data	21		
	Prepared to invest resources in future direct reception	4 (2 of them in kind: staff, resources)		
	Main barriers to	MERIS use	1. Need to get familiar with MERIS data and information services 2. Cost of data 3. Need to submit a science project to ESA and wait for approval 4. Waiting for ESA to deliver MERIS science data ordered from Canadian area	
		MODIS use	1. Need to access MODIS swath data with radiometric and geometric corrections 2 Need algorithm to operationally change projection of MODIS products. 3. Need to get familiar with MODIS data and various information services 4. Developing algorithms for product continuity from AVHRR to MODIS then to VIIRS	

Table 2: summary of user completed questionnaires

3.2 Agriculture

The agriculture community is represented by a full spectrum of users from fully operational to scientific applications development. Several users acquired the derived NDVI product prepared at the MRSC in Winnipeg, MB from AVHRR data while the Alberta Ministry of Agriculture is evaluating the NDVI products available from MODIS. At the scientific end of the spectrum AAFC scientists are evaluating satellite sensor data for a variety of new applications in the departmental initiative to measure the impact of agricultural practices on the environment.

AAFC is now embarking on a study of the agricultural impacts on the environment which will require frequent synoptic imaging spectrometer data to analyze seasonal agriculture practices and track ecosystem changes in a timely manner to effect in-situ data gathering and more detailed analysis of ecological conditions of areas with MRSS sensor observed changes.

3.3 Climate

The Land Cover Map of Canada under the Canadian Climate Program is currently heavily dependent on using data from the AVHRR and the SPOT/VGT sensors which are well defined and providing consistent data over several decades. CCRS is leading the acquisition, processing and mosaic land cover map production.

Glaciers on Ellesmere Island (MODIS/NASA)

The scientists at NRCan/CCRS have attempted to integrate data from the MODIS sensor available from EOSDIS but find the ISIN map projection used in the NOAA global product processing used has distortions at high latitudes, which need to be better understood before they can integrate MODIS into the CCRS land cover product. Before CCRS process their land cover products from level 1 MODIS data, considerable effort is required to understand the whisk broom scan and other MODIS characteristics to achieve a compatible Canadian national and North American continent product.

CCRS has evaluated MODIS derived snow cover products have found them to be sufficiently accurate for most applications. However, the relatively conservative cloud screening algorithm for MODIS products results in less than 50% of the observations labelled as cloud free. An integrated 500m resolution MODIS snow cover maps with 4km resolution GOES based maps is under production. A feasibility study for using these maps within operational fire-danger index systems is being conducted in collaboration with the Canadian Forest Service.

3.4 Weather Prediction

Environment Canada is the Canadian government user with the most years of experience in using medium resolution sensor data from the VHRR and AVHRR for integration into the weather forecasts that they prepare and provide to a wide spectrum of government and commercial end users. These end users, down to the individual farmer and ship captain, use these EC products for their operational decisions on a daily basis.

EC is very interested in the additional information contained in data from MODIS and its operational follow-on (VIIRS on NPP and NPOESS beginning in 2006) for use in its forecast operations. However until the present EC/MSC has been unable to identify resources for systematic evaluation of the value of MODIS-type images or products in Canadian forecast operations. EC are establishing a new national laboratory on nowcasting (very short range forecasting severe weather) in Toronto, and a new laboratory focussing on the Arctic in Edmonton, EC/MSC expect their non-real time use of MODIS data for weather forecasting R&D will increase, developing operational applications in a few years. Potential applications of MODIS data for numerical weather prediction have also been identified especially for verifying cloud properties. MODIS data will be used in conjunction with AIRS data for improved cloud information. MODIS data will also be used in the Cloudsat program to improve the interpretation of the Cloudsat radar data.

Additionally EC/MSC is planning to use land surface information derived from MODIS images to provide improved surface field information on vegetation, snow cover, albeto and sea surface temperature to improve the short range forecasts. The regional and mesoscale weather prediction models require timely access to medium resolution data from MODIS possibly necessitating regional direct reception. MSC require daily MODIS/VIIRS type spectral data extending out 2500 km from the Atlantic, Arctic, Pacific oceans and south from the Canada/USA border to cover an area equal to the are weather systems move in one day. This coverage range necessitates a data reception facility at each boundary to provide the full direct reception coverage.

3.5 Forests

Fires in Montana and Alberta (MODIS/NASA)

The operational component of forest harvest and management falls under Provincial Government jurisdiction as a natural resources in their territory. The Federal Government forest activities are primarily focused on forest ecosystem research and trans-provincial disease management. All operational users are provincial or regional forest harvest focused industry.

The Alberta and British Columbia provincial governments began testing the Forest Fire products derived from MODIS for the 2003 forest fire season. They report reasonable success but need the data closer to real time. They are interested in using snow cover, precipitation NDVI and other EO derived products in modeling the potential forest fire hazard months before the forest fire

season in the summer so resources are available to control fires quickly. Forest managers would benefit from a derived from combined SAR/Optical/IR sensors in a surveillance mode to support early detection of changes in forest vigour and forest ecosystem health.

3.6 Ice

The Canadian Ice Service (CIS) of EC utilizes the thermal IR channels of the AVHRR to seasonally map the sea surface temperature of the North Western Atlantic, Labrador Sea, Hudson's Bay, the Northwest Passage, Great Lakes and St Lawrence Seaway and prepares ice information products of these areas. These ice products are distributed electronically to paying subscribers. The AVHRR data are integrated with data from other satellite sensors such as RADARSAT-1, ERS and ASAR into the final ice product for operational use.

Melting Ice across Hudson Bay (MODIS/NASA)

EC/CIS plan to evaluate the medium resolution MERIS and MODIS optical and IR data for integration into the ice products. CIS is particularly interested in evaluating the 250 meter and 300 meter optical data for near shore details at a scale closer to the 100 meter RADARSAT-1 ScanSAR data.

3.7 Inland waters

EC, DFO and Provincial Ministries of Environment have increased emphasis on assuring the fresh water quality in Canada. Monitoring the primary productivity in the freshwater lakes of Canada has been an ongoing requirement to map the distribution and seasonally changing productivity conditions. The recognition that acid rain can destroy the wildlife in freshwater lakes has added pressure to map the health of the lakes on a periodic basis to assure sustainable fish and wildlife conditions of the lake ecosystem. The increased threat, to drinking water sources, posed by human, animal, and industrial wastes getting into lakes, streams and ground water reservoirs is resulting in the need for periodic monitoring and change detection on a national wide scale.

Lake Winnipeg, Manitoba (MODIS/NASA)

A University of Manitoba graduate student is leading a multiyear study of Lake Winnipeg to determine the human induced and natural influences of the primary productivity in the lake. This is of interest to hydro-electric dam management, agriculture runoff and human waste management in the lakes watershed areas. The spatial resolution, radiometric sensitivity, dynamic range and repeat coverage available from MERIS and MODIS are important to gathering an ecosystem relevant data set of the watershed (lake, streams and surrounding land). This Lake Winnipeg study is using MODIS data and is awaiting access to MERIS data. The objective is to produce an operational system

to monitor algal concentrations and model lake production using the available medium resolution spectral sensor data.

3.8 Land

The land applications of the medium resolution sensor data is the second most developed operational user group. Several Canadian users utilize the weekly NDVI product derived from AVHRR data by MRSC using GEOCOMP system developed and to-date maintained by CCRS.

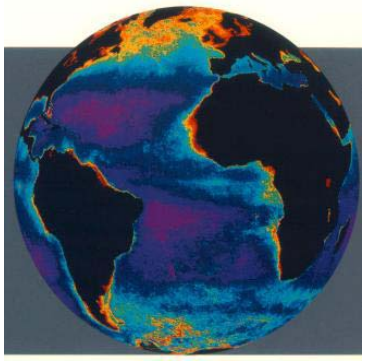
The NOAA planned end to AVHRR operations now scheduled for phase-out starting in 2006 and complete replacement with the VIIRS sensor by 2009 will require a major change in NDVI processing. The director of MRSC has also expressed the Centre's concern as to who is going to maintain GEOCOMP if NRCan/CCRS withdraws (after 2005) as an option within their refocused mandate to primarily serve the Earth Sciences Sector.

3.9 Oceans

Phytoplankton bloom off Newfoundland (MODIS/NASA)

The Canadian ocean scientists at DFO, universities and end users have been utilizing the medium resolution spectrometer imagery since the 1970s beginning with AVHRR for Sea Surface temperature mapping which provided the first map of the Gulf Stream and its associated warm and cold core eddies. The Coastal Zone Colour Scanner (CZCS) provided the first synoptic view of the variation in productivity at ocean basin scale and established the synoptic analysis of the carbon sink of the oceans and their contribution to removal of atmospheric green house gases.

The SeaWiFS sensor system is the operational ocean colour sensor available since 1997 from a commercial supplier Orbital Sciences and has enabled DFO to produce monthly productivity maps of the ocean areas surrounding Canada. DFO have four reception and processing facilities acquiring AVHRR and SeaWiFS data in direct down link from satellite passes of interest. DFO produce and make available electronically the SST and Productivity maps for Canadian scientific applications. DFO operate 4 ground stations acquiring and processing AVHRR and SeaWiFS data at its regional facilities where scientists with disciplinary expertise maintain algorithms and assure product quality.



Global distribution of pigments (MERIS/ESA)

Starting in 1982, DFO led the development of the Fluorescence Line Imager (FLI) with funding from the Canadian Space Program (CSP). The FLI deployed on a CCRS remote sensing aircraft in 1984 proved the concept of

imaging spectrometer sensor system with a high sensitivity and programmable narrow bands in the optical spectrum for mapping the primary productivity in the ocean, coastal zone and fresh water lakes. The Canadian collaboration in ESA on marine primary productivity monitoring resulted in the MERIS sensor design based on the FLI design. DFO scientists are developing the Fluorescence Line Height (FLH) algorithm for mapping ocean productivity in near shore areas with dissolved sediments and organics.

Canadian industry has developed a low cost Compact Airborne Spectral Imager (CASI) which has been sold around the world and applications information services are being provided by companies deploying a CASI system to gather target specific spectral information. These CASI systems are deployed on under flights to validate the MERIS and MODIS satellite data.

DFO and industry scientists are invited members of both the MERIS and MODIS Science teams recommending sensor spectral configurations and developing applications algorithms for coastal zone and oceans applications. DFO scientists on MERIS and sensor team have acquired a number of full resolution MERIS images and have begun the application for coastal bay productivity analysis and are responsible for the development of FLH algorithm for MERIS level 2 processing to a primary productivity product. Canadian VARS are pursuing contracts for the FLH product demonstration with foreign coastal zone managers.

3.10 Canadian government data needs summary

The Canadian government requires a range of medium resolution spectrometer sensor data and information products to meet the information needs of both operational and scientific users. The scientists and algorithm developers generally require the signal level data or at least the data with systematic errors removed. Generally scientists with discipline specific expertise form the foundation for applications development and information products and quality assurance through the life cycle of the sensor. Science applications are primarily using delayed mode data services but more often benefit from NRT Information to help direct field programs to monitor environmental hot spots.

The operational end user groups in Canada rely on a discipline specific processing center or a commercial information service provider with discipline specific expertise for the provision of operational MRSS products and services. Canada has several examples of federal government, provincial government and commercial service providers processing the first generation AVHRR and SeaWiFS data into end user specified information products used by and increasing number of federal departments and agencies. The operational end users all require near-real-time (NRT) delivery of data and information products to support their decision time table. The main opportunity is to prepare the equivalent operational products and services from the MERIS and MODIS sensor data since they are the demonstration sensor systems upon which future operational MRSS sensor systems will be based

The federal government departments and agencies have come to rely on their own direct reception and processing of AVHRR and SeaWiFS data sources which have been available based on the low cost/low data rate S-band systems. The higher data rates and data volumes of future MRSS systems exemplified by MERIS and MODIS has spurred the development of lower cost PC based high bandwidth X-band reception and processing facilities. Atlantis Inc. in Ottawa has developed a PC-based X-band reception and processing system

4. Conclusions

Based on the user responses, operational near real time MODIS data and selected information products are available from NOAA on the WEB for operational evaluation. A case can be made for direct reception of MODIS data to satisfy needs for a Canadian regional specific product for monitoring environmental change, snow cover and surface bio-physical parameters under the Land Cover Map initiative of the Canadian Climate Change Programme. The Canadian region specific products can only be achieved through local processing the level 1 data since USA is concentrating on global monitoring and disaster information services and use an incompatible image projection (ISIN). The article in Remote Sensing of Environment[1] John Townshend states "it was still found necessary to transfer responsibility for production of terrestrial MODIS data to a PI-led facility to ensure generation of products" and that "one of the lessons learned from MODIS is that development of science data systems benefit greatly from close interaction with scientists who are responsible for the data products and will use resultant data."

Using existing Canadian image analysis expertise to analyze these foreign operated sensors would enable Canada to offer a specific set of environmental information products in return for continued direct access to these sensor data. It may also be prudent to have at least one MODIS direct reception system to establish the access to the signal level data for the future operational VIIRS sensor system currently being discussed. There is a real possibility that USA will only provide processed level products from their routine production for global scale analysis which could severely limit high latitude applications due to the distortions inherent in the ISIN projection.

The study concludes that current Canadian users of medium resolution data lack experience in the analysis and application of MERIS data due to the very limited access to FR data of North America. For Canadian users to gain better access also in near real time for operational demonstrations, then a direct reception facility for MERIS is required in Canada. The user community is further deterred by the relative high cost of MERIS FR data being charged by ESA and the lack of a European plan to implement a future operational MERIS sensor. USA on the other hand makes MODIS data freely available and has a clear path to implement the operational VIIRS sensor following the MODIS proof of concept demonstration.

A Canadian ground station capability for FR MERIS data reception and processing is required to facilitate NRT coastal zone monitoring, ice mapping and disaster information, etc. A Canadian station would enable Canadian industry to showcase their PC based X-band reception and processing of medium resolution spectrometer sensor data and demonstrate information services to growing user community. According to the Borstad report, there is an opportunity for Canadian industry to provide information services to a growing international coastal zone and fresh water user community[2]. In a more general

[1] John R.G. Townshend, Christopher P. Justice, "Toward operational monitoring of terrestrial systems by moderate-resolution remote sensing, Remote Sensing of the Environment 83 (2002) 351 -359

[2] Borstad Report, "Trends and Opportunities in Marine and Freshwater Remote Sensing Technology" May 2002.

sense, there is a growing concern amongst Canadian government users that ground infrastructure be maintained and that data from these and other sensors are readily available across government at reasonable cost. The CSA could play a leading role in ensuring all government departments are able to access these sensors in an efficient manner.

5. Options for Meeting Canadian needs

5.1 Direct Reception Description

Both MERIS and MODIS satellites transmit their data to ground stations over an X-band data channel to match the sensor data rate. The recent introduction of PC based ground stations for X-band reception and processing has resulted in an order of magnitude price reduction for the system and its ongoing maintenance. The lower cost X-band ground station system makes it more attractive for Canada to have regionally located facilities to maximize coverage over ocean areas and serve the growing market for coastal zone data.

Feature	MERIS	MODIS
Satellite Data Down Link	X-band	X-band
Sensor Configuration	15 channels Optical Only Push Broom imaging	20 channels Optical and 16 channels IR Whisk Broom Scanning
Data Rate & Data configuration Operational Data Source	.5 megabits per second Push Broom Multiplexed with LBR sensor data ESA commercial supplier	1 megabit per second Whisk Broom Scanning EOS-HDF format archive WEB access from EOSDIS
Follow-on Sensor System for operational use	NONE planned at this date Possible collaboration under the GMES operational sensors (TBC)	VIIRS on NPP 2005 VIIRS on NPOESS 2007
Future operational sensor	None Planned by ESA EU planning for GMES a Canadian opportunity	VIIRS Preparatory 2006 VIRRS Operational 2009
Commercial Suppliers for current sensors	ACRI France (development software) MDA Canada (complete system TBC) Atlantis Canada (complete PC based system available OTS)	EOSDIS on WEB Atlantis Canada (complete PC based system available OTS)

Table 3: Comparison of MERIS and MODIS systems

5.2 Direct reception of MERIS

ESA encourages Canada to acquire the standard MERIS processing software, developed under ESA contract, including algorithm development support. Canada already has an agreement with ESA for direct reception of ASAR data from ENVISAT for Canadian government use; this agreement could be extended to include MERIS data.

For this study MDA was asked to quote a price for MERIS reception and processing at the Gatineau Satellite Station (GSS). In addition, a quotation for software was received ACRI in France the European company contracted by ESA for MERIS standard product processing on a PC base system. ACRI also provided a quotation for ongoing maintenance and upgrades to the software algorithms. Atlantis Scientific Systems has also recently announced an off-the-shelf PC based reception and processing system for both MERIS and MODIS. This provides an opportunity for CSA to have a request for proposal for a quotation from Canadian suppliers for a direct reception facility in Canada.

The MODIS data are available on the WEB in near-real-time for both level one and higher products at no cost. A justification for implementing a MODIS direct receive capability would be justified on strategic positioning of Canada in negotiations for access to the follow-on VIIRS sensor data. EC is already anticipating the need for direct reception of all NPOESS meteorological sensor data including VIIRS. A centralized Canadian node for MODIS data reception and processing would be especially useful to produce selected projections of MODIS products (without losses due to reprojection from ISIN) for the Canadian Climate Program. Canadians could be involved in retuning global MODIS algorithms and the addition of special quality flags when applied over Canada.

5.2.1 Cost

The MDA quoted price for installation of a MERIS reception capability at Gatineau Satellite Station is $C 95,000.00; MDA is currently pricing the processing system but have not produced an estimate. Canada could purchase the MERIS processing software (developmental software package) from ACRI in France at a price of 300,000 Euros (~$C500,000) with an annual software maintenance cost of $C 45,000. The modifications for MERIS at Gatineau could be handled by CCRS at an estimated cost of $C 100,000 (TBC). The operations support cost need to be confirmed with a service provider (estimated to cost $C 50,000 per year). In order to embark on the implementation of a Canadian reception and processing facility CSA and CCRS need to negotiate amendments to the existing Envisat/ASAR reception agreement. ESA currently charges 10,000 Euro per station and 10,000 Euro per year access fees. Atlantis has not had the opportunity to provide a quotation on the cost of their off the shelf PC based system.

5.2.2 Impact

Having direct MERIS reception would provide near-real-time data over the full optical range for the development and implementation of coastal zone, freshwater lakes and fluvial areas supporting ecological studies of these environmentally sensitive areas. MERIS has the necessary broad dynamic range in sensitivity to simultaneously monitor both the water and land targets in the scene. The combined sensitivity, dynamic range and increased spatial resolution are making ecosystem monitoring and surveillance from space a reality.

Having a direct reception and processing of MODIS data would add to the Canadian scientific expertise in processing whisk broom type data sets and add to the suit of MRSS ground station services provided by Canadian industry. It would enable Canada to provide a discipline specific product serving the Land Cover Map project (the project involves more than land cover and is within the Climate Change Program) on a continental basis as a Canadian contribution to the Global Terrestrial Observing System (GTOS) system and services.

5.3 Direct Reception of MODIS

The direct reception and processing system for MODIS data is being operated at two university sites (Wisconsin and Miami) to demonstrate specialized discipline specific near real time products and WEB based information services. The article in Remote Sensing of Environment[3] John Townshend states "one of the lessons learned from MODIS is that development of science data systems benefit greatly from close interaction with scientists who are responsible for the data products and will use resultant data."

5.3.1 Cost

A PC based MODIS direct reception and processing system can also be purchased from Canadian and USA suppliers; the second generation system is estimated to be $250,000 US, based on e-mail correspondence with Gary Borstad and Jim Gower and their recent discussions at the MODIS science team meeting. The operations costs are also likely to be in the range of $C 50,000 per year. Atlantis needs to be given the opportunity to provide a quotation of the cost of their off the shelf PC based system for MODIS.

5.3.2 Impact

A Canadian direct reception facility would enable Canada to develop regional and continental information products from MODIS that are compatible with existing products without the reprojection from ISIN and possible introduced distortions due to reprojection. This facility would also enable Canadian scientists to demonstrate disciplinary specific products and services as a contribution to the Global Climate Program. This would also continue the development of the regional nodes for discipline specific products based on the next generation medium resolution spectral sensor systems being demonstrated for future operational services.

5.3.3 Case study: Fire service

The US Forest Service and the University of Wisconsin co-manage the development operation of a special purpose rapid response system "RapidFire" by-passing most of EOSDIS system to process the optical and thermal IR channels into standard forest fire information products in near-real-time. This dedicated fire information system provides the operation fire information in a more timely fashion and is able to provide operational fire monitoring with MODIS data (ref. Townshend).

The Canadian Forest Service is evaluating these data in the 2003 forest fires in Alberta and British Columbia reported from a telephone conversation with an Alberta Government employee.

[3] John R.G. Townshend, Christopher P. Justice, "Toward operational monitoring of terrestrial systems by moderate-resolution remote sensing, Remote Sensing of the Environment 83 (2002) 351 -359

5.4 Indirect reception

It is possible to continue to develop the Canadian user community based on indirect reception of MODIS and MERIS data and products. The essential difference between direct and indirect reception lies in the real time signal data access and Canadian specific product development as well as the ability to establish a Canadian product processing node which would integrate MODIS and MERIS data into one product. The indirect option for MERIS data acquisition is the least expensive option for CSA but the most expensive for the end user. Indirect mode provides very limited FR data from MERIS and then only in delayed mode so no operational tests of Canadian and North American sites can be undertaken with indirect/delayed mode MERIS data in FR mode.

The MODIS indirect access of data on the WEB is cheapest data acquisition option for both CSA and the end users. The drawback is mainly the designated data formatting into ISN projection for all level 1 and higher MODIS products that seem to introduce undesirable distortions in Canadian regional data sets of interest for land cover analysis.

5.4.1 Description

The terrestrial high bandwidth electronic communications and data exchange possible on the World Wide Web is revolutionizing the way the sensor level data and derived products are shared among many widely dispersed users.

The complete global data set acquired by MODIS is relayed via the TDRSS data relay satellite to White Sands New Mexico from where it is integrated into the EOSDIS system. The EOSDIS system then processes MODIS data into level 1 and higher products which are placed into a WEB accessible archive making it freely available electronically to all users world wide. Canadian users in both the scientific and commercial communities have been evaluating the MODIS data and information services in their respective applications (see questionnaire reply from Dirk Werle).

The MERIS system relays the MERIS RR global data to Europe in near-real-time which is then distributed via the WEB; access must be approved by ESA. The Canadian users with ESA approved projects have been accessing the MERIS data unacceptably limited accessibility through the MERIS indirect mode offered by ESA. . Limited FR MERIS data of Canada are recorded for ENVISAT Announcement of Opportunity projects and ESA approved projects then down loaded to a European reception facility and in delayed mode copied to CDROM for slow mail delivery to Canada. Because Canadian users are mainly interested in evaluating the MERIS capability to monitor lakes and coastal zone areas, the FR data are necessary but Canadian users are experiencing

5.4.2 Cost

The biggest advantage of the MODIS data service on the WEB is that it is available at no cost to the user, whereas ESA distributors charge a subscription fee for MERIS RR data and cost recovery charge for FR data on CDROM. Since both sensor systems are experimental, many more users are utilizing MODIS data and higher level products. The

Canadian users are exercising their need to integrate satellite data in the most cost effective manner. Greg McCullough summarized the user perspective well in an email; "MODIS has given us the frequency and affordability and the series promises some longevity. If we are to use MERIS operationally, it has to compete with the MODIS example."

5.4.3 Impact

The rapid and easy access to electronic data made available on the WEB is making it possible for many widely dispersed users to share the same data in near-real-time. One of the biggest Canadian opportunities is to have regionally located discipline specific product processing nodes providing dedicated processing of local, national, continental up to global products. These nodes can be located in close proximity with the discipline specific scientific expertise to assure a high quality product is available as sensor configurations change. This builds on the existing model working in Canada providing AVHRR and SeaWiFS products and information from discipline specific facilities providing meteorological, ice, oceans and NDVI products.

6. Case study: MRSC, EC/CIS and DFO product nodes

The MRSC, located in Winnipeg, Manitoba, receives western Canada AVHRR data from the CCRS AVHRR reception facility at Prince Albert Saskatchewan and eastern Canada data from the DFO AVHRR reception facility in Mont-Joli, Quebec. They acquire AVHRR data over Europe from a reception center in Norway. MRSC are able to process these data into NDVI products for the users at the Canadian Wheat Board and Stats Can.

Similarly the CIS facility, located in Ottawa, Ontario, receives its AVHRR of the whole Arctic Ocean and North eastern Atlantic as well as the Great Lakes areas from EC operated AVHRR reception facilities in Edmonton, Alberta, Downsview, Ontario and Bedford, Nova Scotia. The CIS integrate the AVHRR data into its ice information products distributed electronically to regional users after a short processing delay.

The DFO reception facility at Mont-Joli, Quebec operationally processes the AVHRR data into the Sea Surface temperature products of Hudson's Bay, the Labrador Sea and the North West Atlantic placing the sensor signal level data and the derived SST on a FTP site accessible to regional users at DFO and other departments.

The DFO reception facility at Dartmouth, Nova Scotia operationally processes AVHRR and SeaWiFS data into weekly Primary Productivity products covering the North Atlantic Ocean area and offers these derived products via FTP.

In all cases the processing nodes utilize the scientific disciplinary expertise located at the processing center to maintain the accuracy and viability of the product services. These dedicated processing nodes are all evaluating the MODIS data and await the approval and access to MERIS data for evaluation.

7. The Visible Infrared Imaging Spectro-radiometer Suite (VIIRS) Specifications

VIIRS was designed as the operational follow-on to the AVHRR and DMSP instruments for NOAA and DOD, and provides significant improvements to these two sensors; more spectral bands, higher sensitivity and higher spatial resolution. In absence of a follow-on to the two NASA MODIS instruments, it must now be considered their successor also. VIIRS however provides fewer spectral bands (omitting the 520 nm water colour band, and combining the 660 and 670 bands into one, for example) and lower maximum spatial resolution. It will not provide the chlorophyll fluorescence imaging capability. However, it will provide improved spatial resolution at the swath edges, a low light day/night band (DNB) and a number of technical design improvements.

VIIRS will be initially flown on the NPOESS Preparatory Program satellite (NPP) in about 2006. When it is flown on all 3 (National Polar-Orbiting Operational Environmental Satellite System) NPOESS satellites (about 2009), it will provide imaging at three times during the day, instead of two for MODIS.

VIIRS will have 22 spectral bands, chosen as a subset of the MODIS bands, but including also a day/night high sensitivity visible/NIR panchromatic band (DNB), see table. Bands M1 to M5 and M7 and M13 have dual gain (as for SeaWiFS). Digitization is 12 bit. The DNB will use a CCD detector to give about a factor 10^6 improvement in sensitivity over "ocean bands," but with a signal to noise ratio of only about 6.

Moderate resolution bands (M) will have a resolution of 740 m at nadir. Imagery bands (I), 370 m. The instrument will use whisk-broom mechanical scanning (as for MODIS) with 8 (M) or 16 (I) detectors per scan. Swath width will be 3000 km, with the instrument scanning out to +/- 56 degrees at a satellite altitude of 824 km for NPP, 833 km for NPOESS. The VIIRS orbit will be 16-day repeat, mimicking MODIS.

Pixel growth with scan angle is constrained along the scan direction (cross-track), by degrading nadir resolution to better match that at the edge of the scan. At nadir, 3 rectangular pixels are summed to make a square pixel. Further from nadir, two pixels are summed. Near the edge of scan there is no summing. The summing will improve sensitivity near nadir. This summing applies to both M and I bands in the visible and near infrared (VISNIR). DNB spatial resolution is also 740 m at nadir. It is not clear how this will grow towards swath edges. Two references refer to no, or very slight growth, suggesting that the DNB may rely on push-broom imaging with a multi-element CCD detector.

Band Name	c(nm)	(nm)	Spatial resolution	Focal Plane Assembly
M1	412	20	740 m	VISNIR
M2	445	18	740 m	VISNIR

M3	488	20	740 m	VISNIR
M4	555	20	740 m	VISNIR
M5	672	20	740 m	VISNIR
M6	746	15	740 m	VISNIR
M7	865	39	740 m	VISNIR
M8	1240	20	740 m	SMWIR
M9	1378	15	740 m	SMWIR
M10	1610	60	740 m	SMWIR
M11	2250	50	740 m	SMWIR
M12	3700	180	740 m	SMWIR
M13	4050	155	740 m	SMWIR
M14	8550	300	740 m	LWIR
M15	10763	1000	740 m	LWIR
M16	12013	950	740 m	LWIR
DNB	700	400	740 m	DNB
I1	640	80	370 m	VISNIR
I2	865	39	370 m	VISNIR
I3	1610	60	370 m	SMWIR
I4	3740	380	370 m	SMWIR
9I5	11450	1900	370 m	LWIR

8. Reception Options Summary

The table below summarizes the pros and cons of direct and indirect reception for MODIS and MERIS data.

	MERIS	MODIS
User focus	Science & OPS Demo	Operations (and Science)
Indirect Reception	**Operational users** can access MERIS global coverage of RR data via Ftp in NRT via subscription at ESA commercial price. Purchase FR data from ESA commercial supplier **User Cost:** 1K euro (~$1.6K) (expensive) **Science users** receive limited data and products of project areas of ESA approved projects in delayed mode **User Cost:** 100 euro/image + 60 euro /tasking (~$500/swath =3 images) (slow delivery of CD by mail	**Operational Users** can access derived products of global MODIS coverage on the WEB in NRT from USA sources (EOSDIS & Other product nodes). **User cost: $0** **Science users** and access MODIS data level 0 & 1 and higher on the WEB from EOS-DIS in NRT **User Cost $0**
Direct Reception	**Cost:** MDA DAF upgraded at both GSS & PASS ~ $500K est.[1 is less] ACRI single license full product processor $100K euro (~$160K/5yr) ACRI software warranty & support $30K euro (~$46K) for 5 years CSA supplied processor ~$50K Tasking 60K euro (~$100K/5yr) [total coverage of Canada] {Coastal only less} **Total Cost est. ~ $850K for 5 years** **Plus yearly operations support** **Pros:** Acquire FR mode data and deliver products in NRT of all Canadian coastal zone and terrestrial areas to facilitate operational demonstrations Prepare Canadian Ground Systems services industry for future operational MRSS systems e.g. SmallSat MERIS Covers all 3 oceans and coastal areas **Cons:** $850K +OPS Cost (5 years) MERIS focus marine applications dev. and sensor proof of concept Require CSA & ESA negotiate MERIS operational data direct downlink for Canada Users await CSA/ESA/EU collaboration for future MERIS systems within GMES to assure continuity of MERIS data.	**Cost:** PC based reception system and PC based processor with many automated functions ~$300K $US (~$400K $C) **Total Cost est. ~ $400K $C (5 years)** **Plus yearly operations support** **Pros:** Develop Canadian MODIS Node to produce specialized operational information products to meet specific identified Canadian environmental information needs in near-real-time. Continue the Canadian direct receive node facilities and contribute environmental products to International Climate Program **Cons:** $400K +OPS Cost for a 5 year MODIS ground station program New system required for VIIRS operational sensor system in 2007 -2009 One system required to provide coverage of the Arctic and one each on the East and West coast areas of Canada
Issues	Timely access, data cost, data continuity, suitability for operational users	Resolution, Level-1 data access (ISIN projection correction to NTS)

Annexes

Organizations consulted

Organization	Contact person	Telephone No.	Sector
Aerde Environmental Research International EO service provider	Dirk Werle	(902) 423 2211	Oceans/Land
Agriculture and Agri-Food Canada	Heather McNairn	(613) 759 1815	Agriculture
Agriculture and Agri-Food Canada, Research Centre	Anne Smith	(403) 317 2285	Agriculture
Alberta Agriculture, Food and Rural Development / Conservation and Development Branch	David V. Hildebrand	(780) 427 3558	Agriculture
Borstad Associates Ltd. International EO service provider	Gary Borstad	(250) 656 5633	Oceans/Coastal Zone
DFO / Ocean Science Division / Biological Oceanography	Trevor Platt	(902) 426 3793	Oceans
DFO / Science/IOS	Jim Gower	(250) 363 6558	Oceans
DFO /IML/Ocean Science Div.	Pierre Larouche	(418) 775 0569	Oceans
DFO/ Science/HQ	Jim Helbig	(613) 990 0314	Oceans
EC / Atlantic Region	Joe Pomeroy	(902) 426 6131	Land
EC/ Meteorological Service Canada / Meteorological Research Branch	Dave Steenbergen	(416) 739 4257	Environment /ops weather & science
EC/ Meteorological Service of Canada / Climate Research Branch	Anne Walker Tom Agnew Normand Bussieres	(414) 739 4357	Climate
EC/Meteorological Service Canada	Ron Goodson Ed Hudson	(780) 951 8791 (780) 951 8878	Environment / terrestrial and marine weather
EC/MSC/Canadian Ice Service	Roger De Abreu	(613) 995 5125	Ice
Government of Alberta / Sustainable Resource Development Department / Forest Protection Division	Bob Sleep	(780) 422 0218	Forest

Manitoba Conservation / Remote Sensing / Geomatics	Roy Dixon	(204) 945 6597	Land
National Water Research Institute / AEMRB	Robert P. Bukata John H. Jerome	(905) 336 4670 (905) 336 4922	Freshwater
NRCan/ Canadian Forest Service / Fire Management Systems	Peter Englefield	(780) 435-7254	Forest/ Fires
NRCan/ Canadian Forest Service/ Pacific Forestry Centre	David G. Goodenough	(250) 363 0776	Forest
NRCan/ Canadian Forest Service/ Pacific Forestry Centre	Jim Wood David Goodenough	(250) 363 6008 (250) 363 0776	Forest
NRCan/ CCRS, Environmental Monitoring Section	Alexander P. Trishchenko	(613) 995 5787	Climate
NRCan/CCRS, Applications Div.	Richard Fernandes	(613) 947 1292	Groundwater
NRCan/CCRS, Applications Div.	Paul Budkewitsch	(613) 947 1331	Climate
Parks Canada Agency	Thomas M. Naughten	(204) 984 6227	Land cover/ changes
Parks Canada/National Parks Directorate	Jean Poitevin	(819) 953 9376	Land cover/ changes
Statistics Canada / Agriculture Division / SAGA	Frédéric Bédard	(613) 951 3861	Agriculture/ Crop vigour
University of Manitoba / Centre for EO Science / Dept. of Geography	Greg McCullough	(204) 783 9456	Freshwater

How to Get the MODIS Ocean Data[4]

Important: The current collection is **"4"** for **Terra** and **"3"** for **Aqua**. Do not use data from older collections. Please see the Product Version in the filename, as in these examples:
Terra Level 2: MODOCL2.A2003111.2255.004.2003119152946.hdf
Terra Level 3: MO04MD01.nLw_412.ADD2003108.004.2003114081523.hdf
Aqua Level 2: MYDOCL2.A2003116.1330.003.2003118233243.hdf
Aqua Level 3: MY04MD27.chlor_a_3.ADD2003080.003.2003089040048.hdf

Search and Order Interface:

Steps to order data:

1. Go to the **Goddard DAAC** **MODIS Data Support** website
2. Click on **Data Ordering**
3. Click on **GES DAAC Search and Order**
    - Become a registered user by clicking **New User Registration**
4. Click on **Data Sets**
5. Click on **MODIS-Terra** or **MODIS-Aqua**
6. Click on **Ocean**
7. Click on Processing Level of interest:
    - Level 2
    - Level 3 Binned
    - Level 3 Mapped
    - Level 3 QC
8. Click on **Data Type**
9. Click on time increments (each click increases temporal detail)
10. Use temporal or geographic query to narrow files of interest
11. Add selected files to order
12. Follow ordering steps; files will be staged for FTP pull.

Or link directly to the Search and Order interfaces:

GDAAC Search and Order - Terra hierarchical web interface

- Multiple Data Ordering - Terra

GDAAC Search and Order - Aqua hierarchical web interface

- Multiple Data Ordering - Aqua

EOS Data Gateway:

EOS Data Gateway Operational site
EOS Data Gateway Hidden site for Science Team access to initial products (password needed)

Data Pool:

FTP download of recently processed data:

Data Pool Search & Order Interface
FTP Interface

Sample data files or images:

FTP download:

MODIS samples

Browse Tool:

MODIS Ocean QA Browse Imagery (MQABI)

[4] Page author: Ron Vogel, SAIC GSO (ron.vogel@gsfc.nasa.gov)
Authorized by: Wayne E. Esaias, Code 971, NASA Goddard Space Flight Center

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