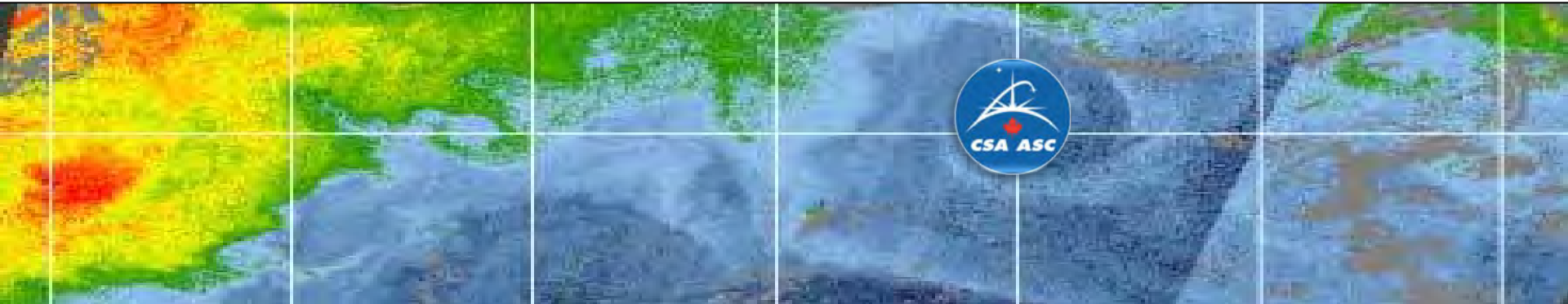


Canadian Space Agency

Report on Ocean Colour Activities



Martin Bergeron
Canadian Space Agency (CSA)

June 17th
2nd International Ocean Colour Symposium
San Fransisco, California, USA



Government
of Canada

Gouvernement
du Canada

Canada

Outline

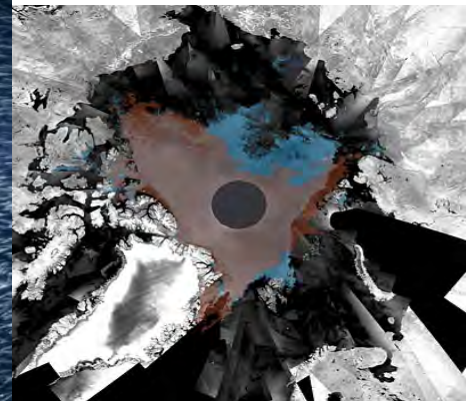
Introduction

Canadian Strategic Context
Canadian interest in Ocean Colour

Activities

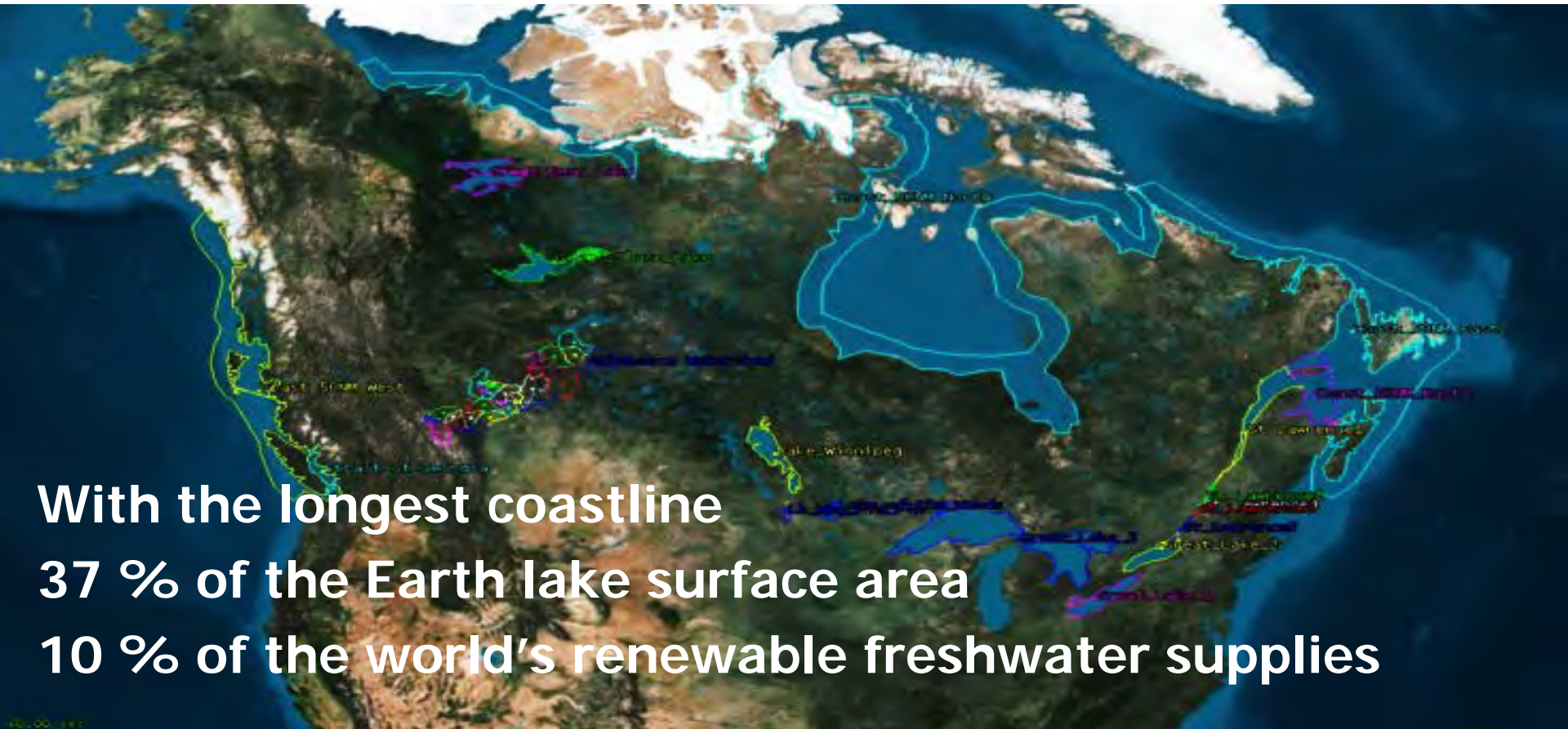
Canadian Ocean Colour Space Missions & Collaborations
Canadian Ocean Colour Initiatives supported by CSA

Conclusion



Canadian Strategic Context

Canada has environmental, economic, safety and public health challenges to enhance water management practises and sustainability.



With the longest coastline
37 % of the Earth lake surface area
10 % of the world's renewable freshwater supplies



Canadian Space Agency Interest in Ocean Colour

- **To support our National OC community** (government, academic and private sectors);
- **To enable end-users to exploit Ocean Colour data** available in support of their programs for fisheries management, ecosystem protection, coastal zone management, safety and national security, environment and climate, etc.;
- **Focusing our investments;**
 - Investing in operationally focused sciences and ensuring transition towards operationalization;
 - Supporting and providing access to missions that meet user requirements;
 - Going beyond the science into Global Societal benefits.

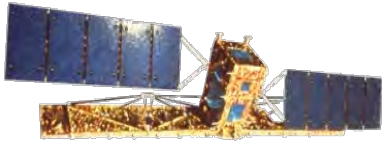
CSA has continued interest in supporting OC activities of national and international relevance and re-emphasize the importance of demonstrating societal benefits and outcomes that are expected from public sector investments in space



Canadian Water & Ocean Colour Space Missions & Collaborations

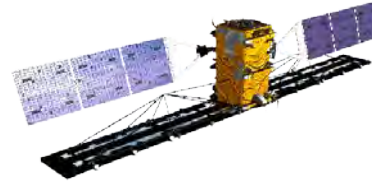


RADARSAT



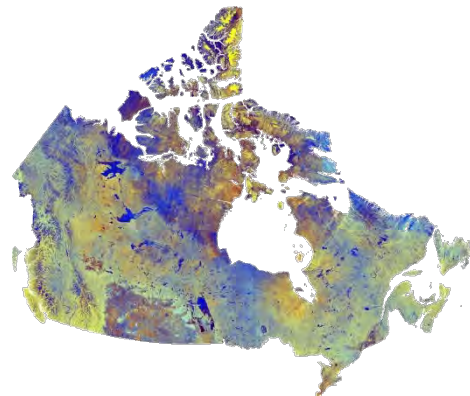
1995: RADARSAT-1

- First operational civilian SAR satellite
- Important R&D component
- GoC owned



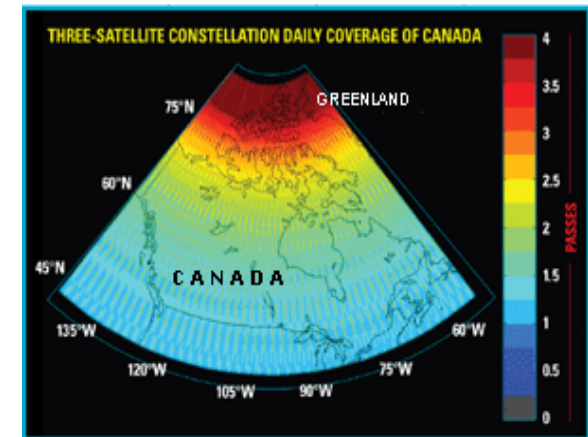
2007: RADARSAT-2

- Ops extended to DND, DFO, NRCan, and EC
- Numerous sci & ops modes
- MDA owned (PPP)



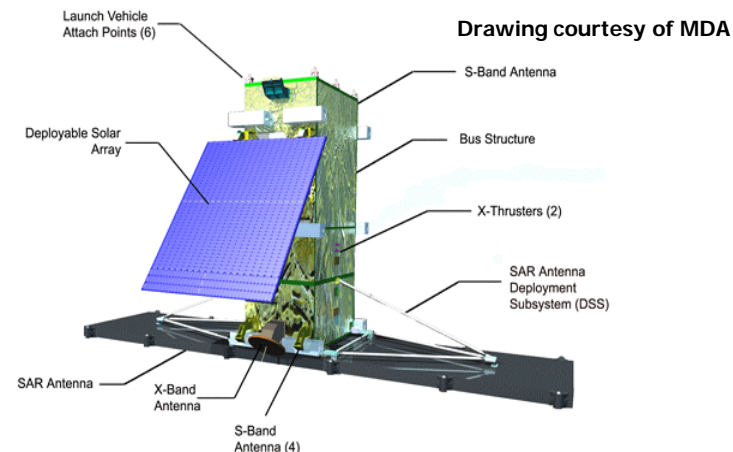
2018: RCM

- Fully operational
- Selected R2, Compact Pol. CCD
- Enhanced ship detection
- GoC owned
- Fast tasking, fast delivery
- *DUAP (Oper. Apps + products)



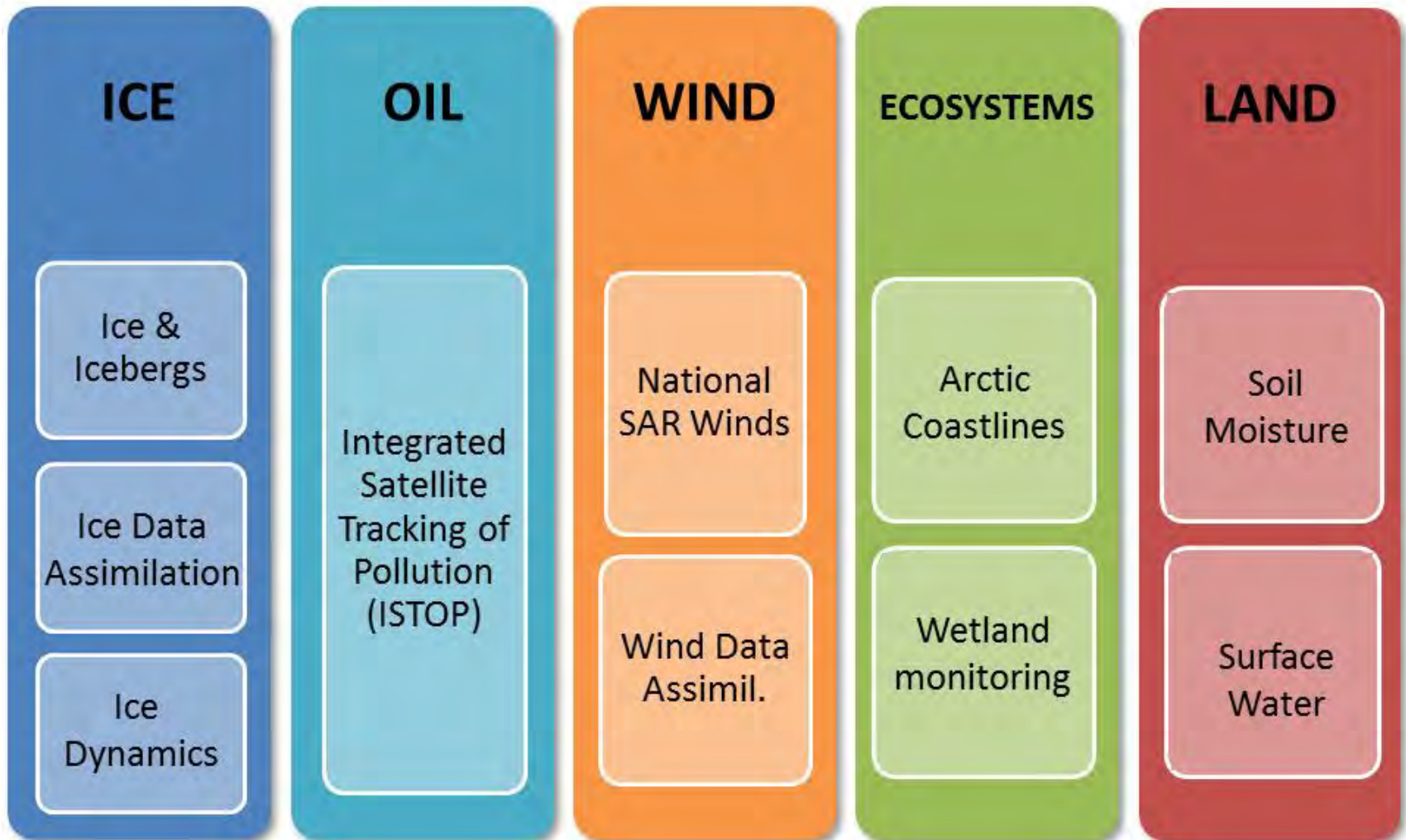
RCM

Specifications	
Nominal Altitude	592.7 km circular (12 days repeat)
Ascending Node Crossing Time	18:00 LTAN (Dusk-Dawn, Sun Synchronous, Frozen)
SAR Frequency	C band – 5.405 GHz
Power	<1600 W peak; <220 W average
Polarisation	Single Pol / Dual cross selectable pol & Compact polarimetry available on all modes; One fully polarimetric mode
Imaging Time	15 min/orbit average (peak 25 min every 3 orbits) 10 minutes continuous imaging
On-board data storage	500 Gbit (EOL)
Coherent Change Detection Period	4 days
Fast Tasking	Imaging requirement can be uploaded in less than 4 hours for emergency situation
Lifetime	7 years (each satellite)

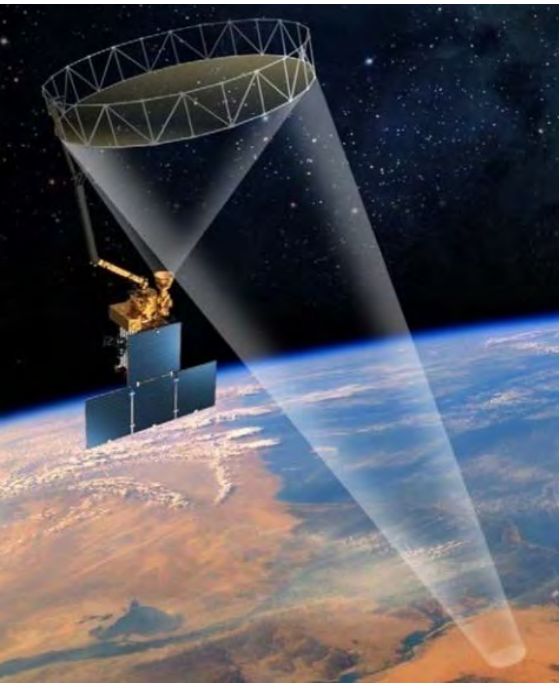


Mode	Res. m	Swath Width (accessible) km
Low Resolution	100	500 (500)
Medium Resolution	50	350 (500)
Medium Resolution	16	30 (350)
Medium Resolution	30	125 (350)
High Resolution	5	30 (500)
Very High Resolution	3	20 (500)
Low Noise	100	350 (500)
Ship Detection	var.	350 (600)
Spotlight	1 x 3	20 (350)
Quad-Polarization	9	> 20 (>250)

RCM – Enabling Water Related Applications



CSA Participation to NASA SMAP Mission



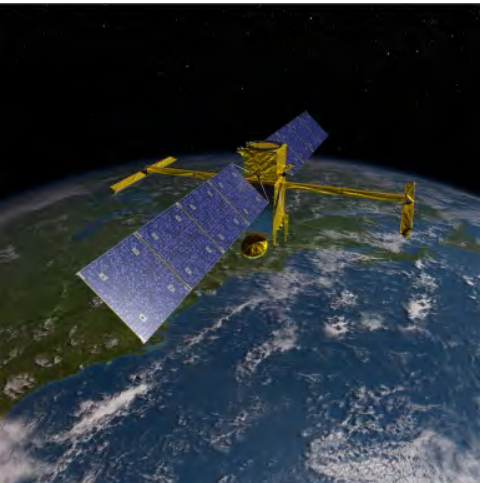
Soil Moisture Active and Passive (launched Jan 15)

Provide global measurements of soil moisture present at the Earth's land surface and distinguish frozen from thawed land surfaces.

- Canada contributes to the Calibration Validation of the instruments;
- CSA is supporting Environment Canada and Agriculture and Agri-Food Canada through its GRIP program (\pm \$1M over 3 years);
- CSA is providing more than \$1.4M in Grant funding over 3 years to support Canadian academic research using SMAP data;
- Builds on previous work done on **ESA-SMOS**.



CSA Contribution to SWOT Mission (NASA-CNES-CSA-UKSA)



Surface Water Ocean Topography (launch 2020)

Characterize the ocean mesoscale and sub-mesoscale circulation at spatial resolutions of 10 km and larger;

Provide a global inventory of all terrestrial surface water bodies >250 m² (lakes, reservoirs, wetlands) and rivers width >100 m (50 m goal).

- Canada is providing a set of Extended Interaction Klystrons (EIKs) to the mission, a \pm \$11M investment;
- Through IMOU, CSA is providing \$155K/y to both Environment Canada and Fisheries and Oceans Canada to support their research on SWOT;
- Through its Grants and contribution program, CSA is transferring \$300K over 3 years to Canadian universities to support their research;
- CSA's total investment will be close to \$17M.

OC Data Access for Canada

In 2008, Canadian ground infrastructure was up-dated for the reception and processing of ENVISAT MERIS Data (Full Resolution /Near Real Time);

Systematic acquisition of 16000 images yearly under mask reception areas of North America;

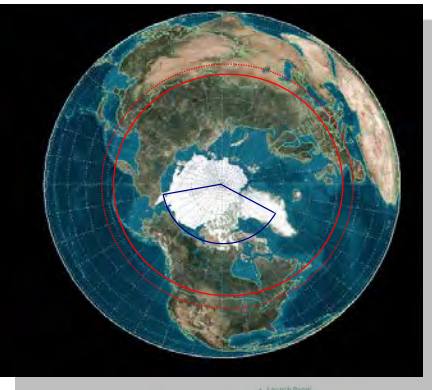
CSA and NRCan are supporting MERIS archived data availability since the end of the Envisat mission;

CSA investment led to improved management of Canadian marine resources and prepared Canadian users to take advantage of the upcoming Sentinel-3 Mission.

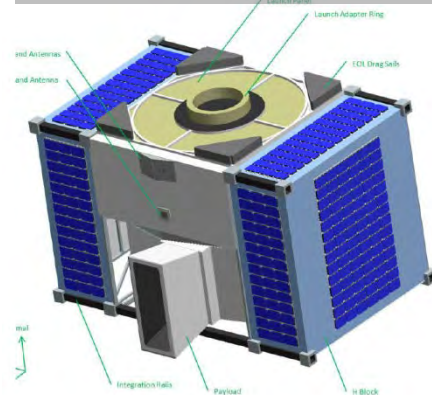
CSA is discussing with Europe about a Sentinel-3 fluid data Access (*Mirror* site through NRCan EODMS). Support the Canadian teams involved in S3VT.



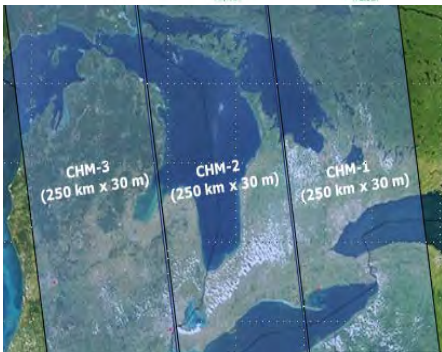
Canadian Prospective Missions Relevant to Water



PCW (Polar Communication Weather) proposes a Constellation of 2+ satellites in HEO providing 24/7 communications and high temporal/spatial resolution meteorological data above 50°N in support of numerical weather prediction, environmental monitoring, emergency response and climate monitoring. *Phase 0+A Completed.*



WaterSat investigated a medium resolution (100m) Visible and Near-Infrared (VNIR) hyperspectral microsatellite dedicated to Canadian coastal and inland waters monitoring and management. *Phase 0 completed.*



CHM (Canadian Hyperspectral Mission) proposes a Constellation of 3 high resolution (30m, 10m goal) satellites orbiting in LEO providing more than 60 bands in the Visible and Near-Infrared (VNIR) spectrum each with a 250km swath-width. *Phase 0 to start Autumn 2015.*



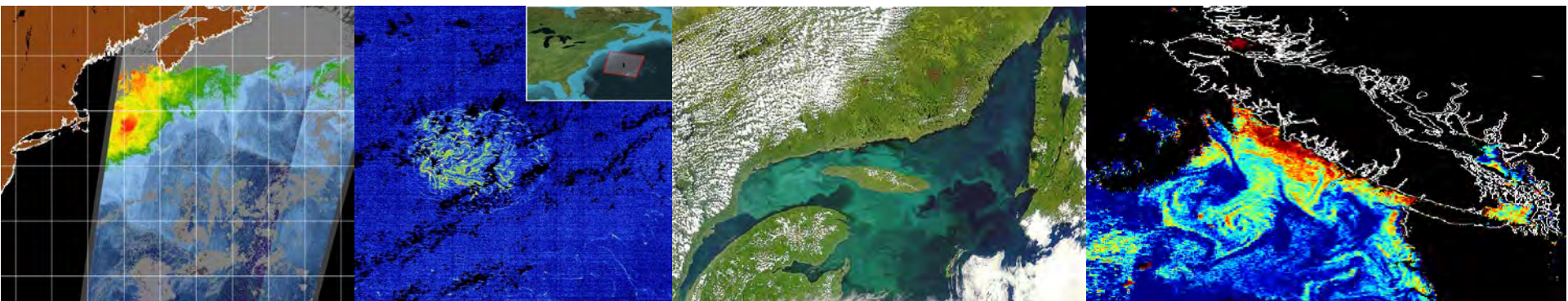
Canadian Ocean Colour Initiatives Supported by CSA



Investing in Operationally Focused Science

Near \$10M over the last 6 years

- Building satellite data into operational oceanography (DFO);
- Building ocean color into DFO operations (DFO);
- Estimating primary production in the Canadian Arctic (DFO);
- Monitoring of Harmful algae in the Lower Great Lakes (EC-NWRI);
- Spaceborn Ocean Intelligence Network (SOIN) (DND–METOC);
- Fresh Surface Water Mapping and Monitoring (NRCAN-CCRS);
- Water Quality Products for inland and coastal waters (Borstad, DFO);
- Water Quality of Great Lake (EC).

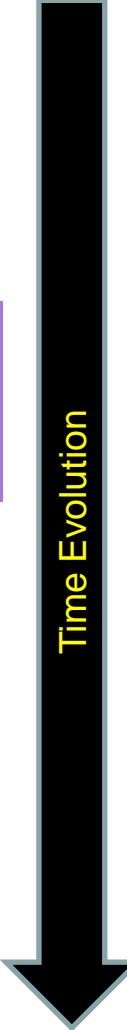
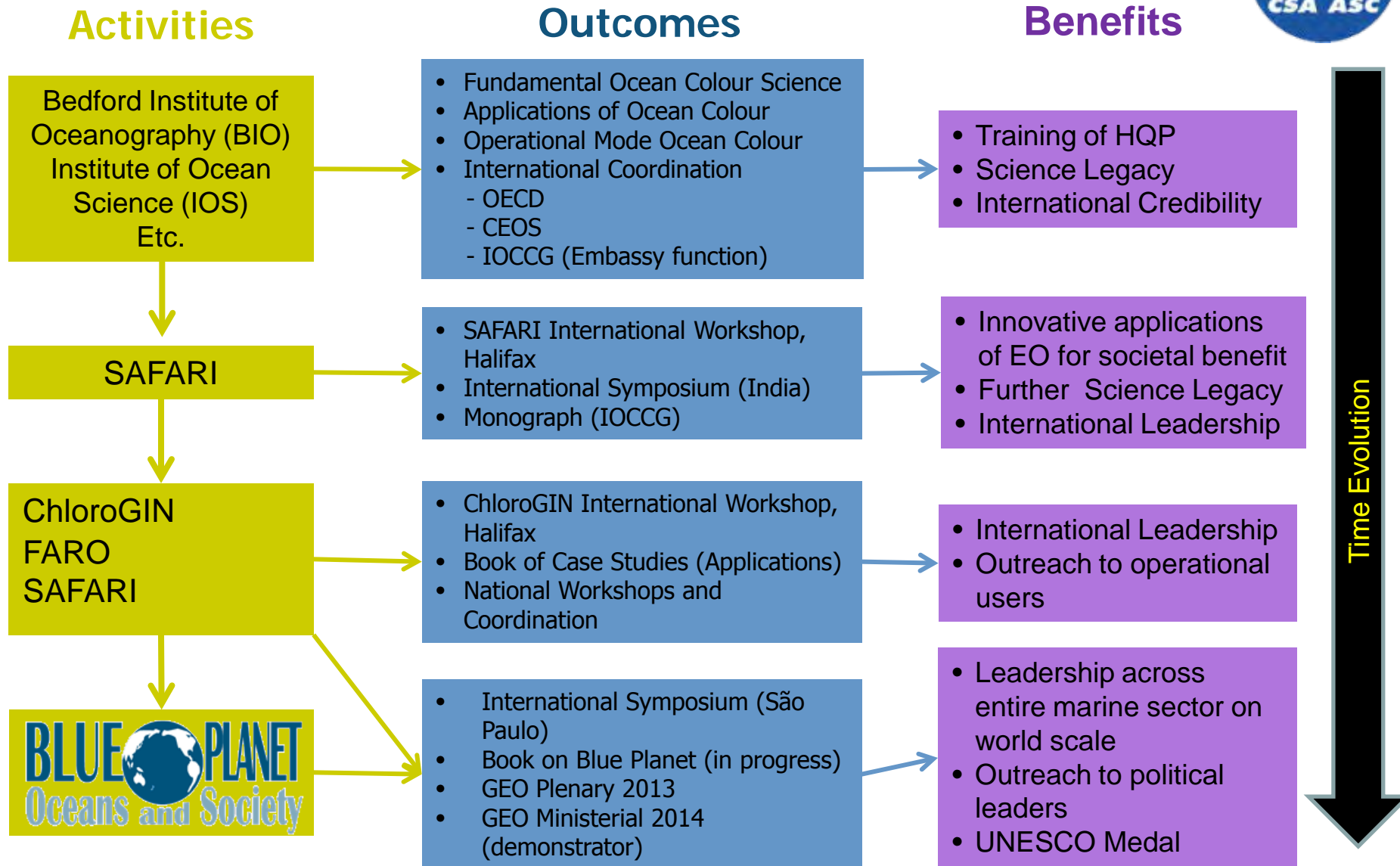


GREEN EDGE

- The GreenEdge is a remote sensing consortium of marine and arctic marine environment specialists;
- A \$7M and 5 years initiative funded by France/Canada organizations such as
 - ArcticNET, CNRS, Canadian Excellence Research Chair, TOTAL Foundation, CNES, LEFE, CSA (\$375k), NSERC and Pau-Emile Victor Institute.
- More than 80 Contributors from several laboratories from France, Canada and Greenland.
- The main research focuses are to:
 - **Study Phytoplankton Spring Blooms (PSB) in the Arctic ocean;**
 - Understand PSB species and growth model, key physical, chemical and biological process;
 - Predict the fate of the PSB related carbon transfer through the food chain and toward the bottom sediments over few decades;
 - Determine how the PSB responded to past climate variations.



CSA Supporting OC Activities for Societal Benefits



NetCOLOR Network on Coastal, Oceans and Lakes Optical Remote sensing

Network of Canadian experts and end-users in water colour remote sensing funded by CSA in 2014 (3 years) to develop and coordinate a Canadian strategy for research, training and dissemination of water colour products.

- 3 key science sectors;
 - ① Monitor water quality in lakes, rivers and coastal environments;
 - ② Monitoring bio-optical properties in the Arctic Ocean;
 - ③ Study biogeochemical cycles on various scales (local to global).

NetColor is committed to:

- Organize a national annual science meeting (Fall 2015 at CSA, St-Hubert);
- Develop a strategy to ensure that *in situ* water colour data are archived and readily available to the research community;
- Develop its website and publish a report proposing a national strategy for research, training and dissemination of water colour products in Canada.



Conclusions

- EOAU programs are available to support Canadian OC activities;
- Support access to foreign missions OC data to Canadian Co-PI;
- International collaboration on water related missions (SWOT and SMAP);
- On-going investigation of prospective missions (PCW, WaterSat, CHM);
- CSA is supporting International coordination through IOCCG & Blue Planet;
- Through NetColor, propose a national strategy for research, training and dissemination of water colour products in Canada.



10th Atelier ASAR Workshop

October 20 to 22, 2015

- The Workshop will review the advancement in the field of SAR technology.
- Over 100 Abstracts received as of June 1st (closing date for submission)
- 200 participants are expected

- The topics to be presented at the workshop include:
 - SAR Missions
 - Calibration/Validation
 - **Maritime Applications**
 - Disaster Management
 - Ecosystem Monitoring
 - System Technologies (Antennas, T/R modules, etc.)
 - Polarimetry
 - Compact Polarimetry
 - SAR techniques: Interferometry / CCD / GMTI
 - Emerging Applications
 - Any others SAR-related topics



<http://www.asc-csa.gc.ca/eng/events/2015/asar.asp>



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Backup Material



CSA – IOCCG Mutual Agreement

IOCCG

- Value in science and advocacy roles;
- Outcomes need to be translated into societal benefits;
- Importance of IOCCG in front of the Space agencies;
 - Definition of new missions;
 - Link the science with the end-users needs within the context of new system development and definition;
 - Provide a common global perspective.

CSA

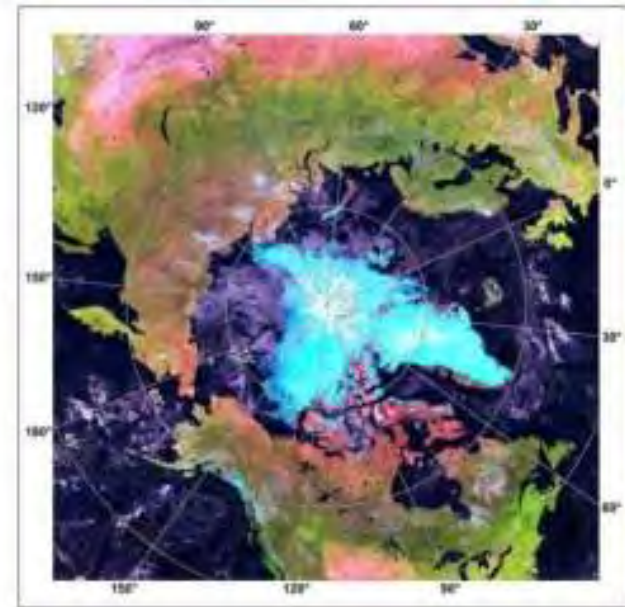
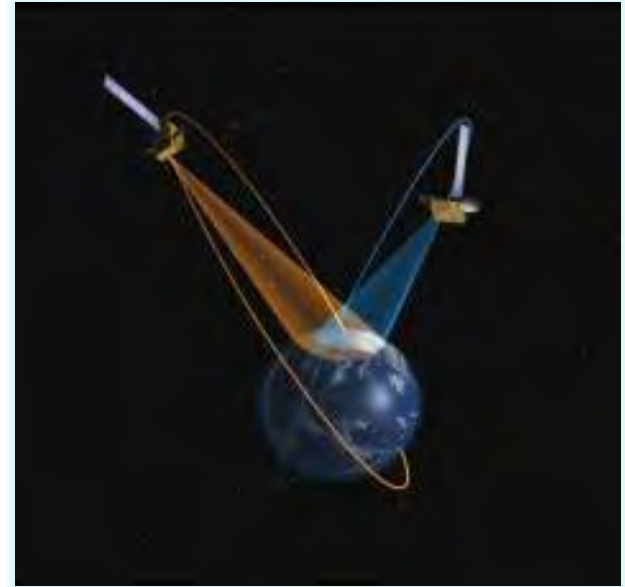
Expressing continued interest in the National and International Ocean Colour activities:

- Support and contribute to IOCCG through Blue Planet;
- Accessibility to Meris data archives and discuss with Europe a Sentinel-3 fluid data access model;
- Support OC future Canadian missions feasibility studies and Phase 0 (WaterSat & CHM);
- Ensure Canadian presence on International Ocean Colour panels.



What is PCW

- A unique Canadian satellite program to significantly enhance communications, weather and space weather services in the Arctic;
- Communications
 - Military and civilian wideband;
 - Military narrowband (tactical).
- Weather Monitoring
 - Continuous imaging of Arctic circumpolar region for weather forecasting and emergency response, environmental and climate monitoring.
- Space Weather Monitoring
 - Monitoring of solar magnetic and particle storms.



PCW Imager Specifications

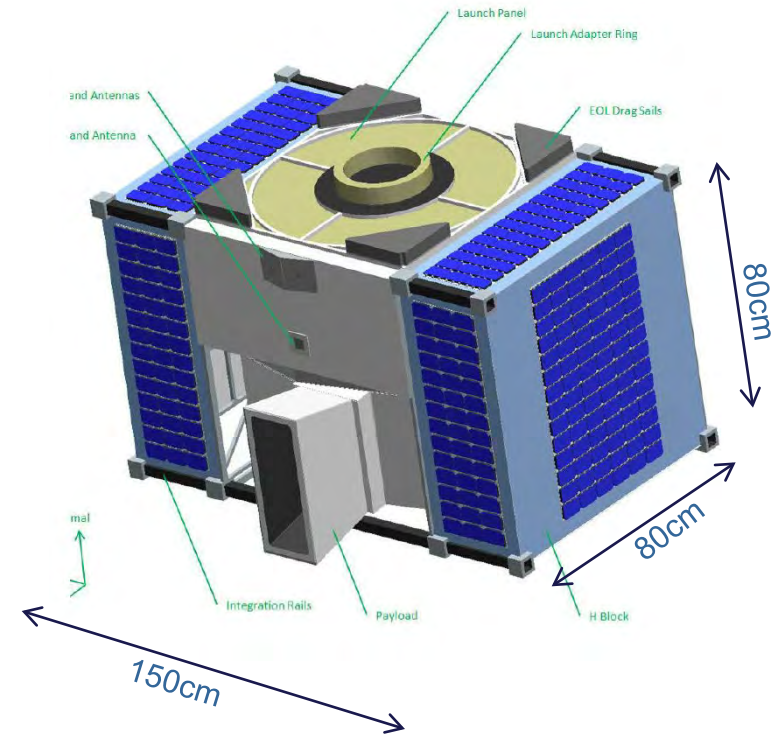
Band No.	subgroup	Wavelength (microns)	Heritage	Priority	GSD (km) Goal Max	Main applications
1	VNIR	0.45-0.49	ABI, FDHSI	1	0.5 1.5	Surface, clouds, aerosols
2		0.59-0.69	ABI, FDHSI	1	0.5 1.5	Wind, clouds, ice mapping
3		0.704-0.714	MERIS-09	2	0.5 1.5	Water quality, chlorophyll
4		0.85-0.89	ABI, FDHSI	1	0.5 1.5	Wind, aerosols, vegetation
5	SWIR	1.04 – 1.06	SGLI SW1	2	1.0 3.0	Snow grain and clouds
6		1.37-1.39	ABI, FDHSI	2	1.0 3.0	Cirrus detection
7		1.58-1.64	ABI, FDHSI	1	0.5 1.5	Snow-cloud distinction, ice cover
8		2.22-2.28	ABI, FDHSI	1	1.0 3.0	Aerosol, smoke, cloud phase
9	MWIR	3.80-4.00	ABI, FDHSI	1	2.0 3.0	Fog, fires, ice/cloud separation, wind, cld.phase
10		5.77-6.60	ABI, FDHSI	1	2.0 3.0	Wind, high level humidity
11		6.75-7.15	ABI, MTSAT	1	2.0 3.0	Wind, mid level humidity
12		7.24-7.44	ABI, FDHSI	1	2.0 3.0	Wind, low level humidity
13	LWIR	8.30-8.70	ABI, FDHSI	1	2.0 3.0	Total water, cloud phase
14		9.42-9.80	ABI, FDHSI	2	2.0 3.0	Total ozone
15		10.1-10.6	ABI, FDHSI	2	2.0 3.0	Cloud, surface, cirrus
16		10.8-11.6	ABI, HIRS	1	2.0 3.0	Cloud, SST, ash
17		11.8-12.8	ABI, FDHSI	1	2.0 3.0	Ash, SST
18	LIRCO2	13.0-13.6	ABI, FDHSI	1	2.0 3.0	Cloud height
19		13.5-13.8	MODIS,HIRS	2	2.0 6.0	Cloud height, low level temperature
20		13.8-14.1	MODIS,HIRS	2	2.0 6.0	Cloud height, mid level temperature
21		14.1-14.4	MODIS,HIRS	2	2.0 6.0	Cloud height, high level temperature



WaterSat Mission Overview

WaterSat is intended to be a medium resolution (100m GSD), proto-operational, Visible and Near-Infrared (VNIR) hyperspectral microsatellite dedicated to Canadian coastal and inland waters monitoring and management.

WaterSat Parameter	
Altitude	702km (sun-synchronous)
Relook Rate/Repeat coverage	1-3 days/7 days
Swath/width	300km
Max. viewing angle (tilting)	45°
Ground Sampling Distance (GSD)	100m (goal 60m)
Spatial Resolution	<150 m (goal < 90 m)
Spectral range	350–1000nm (goal)
Spectral sampling interval	7.5nm (goal 5nm)
Weight	150kg (payload <50kg)
Peak SNR @ 5% albedo	400:1 to 600:1



CHM Mission Concept Summary

Notional Imaging Requirements for a 3-satellite constellation:

Spectral Band →	Pan	VNIR	SWIR	MWIR/LWIR
Coverage	<ul style="list-style-type: none"> Canada + Coastal areas (minimum) North America, Europe, other (goal) 			<ul style="list-style-type: none"> Canadian Fires (min) Fires over any global point (goal)
Repeat Rate		3-7 day repeat coverage		Daily Revisit of selected targets
Spectral Bands	<ul style="list-style-type: none"> ~490-690 nm (TBC) 	<ul style="list-style-type: none"> 50+ bands 400-900 nm (min) 400-1050 nm (goal) ~10 nm FWHM 	<ul style="list-style-type: none"> 3 bands (min) 1360-1390 nm 1560-1660 nm 2100-2360 nm 75+ bands (goal) 1000-2500 nm ~10-20 nm FWHM 	<ul style="list-style-type: none"> 3 bands (min) (NIRST) 3.8 μm 10.85 μm 11.85 μm 4 + bands (goal) add 8.8 μm
GSD	15 m 10 m (goal)	30 m (max) 20 m (goal)	50 m (max) 30 m (goal)	~350 m (based on NIRST)
Swath		~246 km x 3 satellites		~185 km (based on NIRST)
SNR / NEΔT	TBD	>200:1 @ 650 nm, 30% albedo (min) >500:1 (goal)	TBD	<ul style="list-style-type: none"> <0.5K @ 3.8 μm, 600 K <0.3K @ 10.85 μm, 300 K <0.4K @ 11.85 μm, 300K

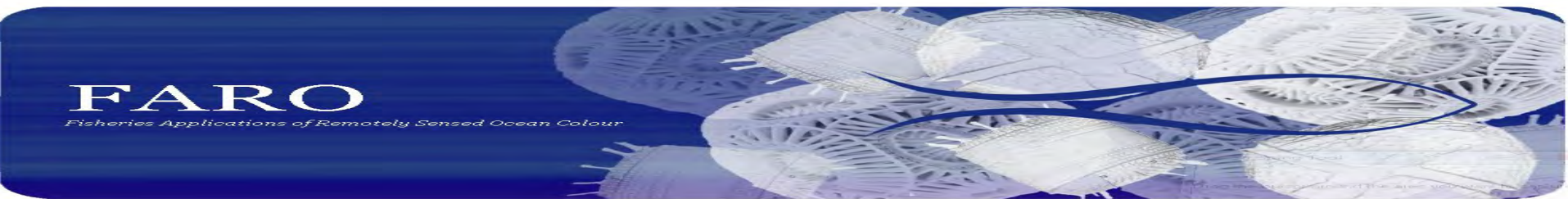
Key Drivers



From SAFARI & FARO to Blue Planet



SAFARI aimed to accelerate the assimilation of Earth Observation (EO) into fisheries research and ecosystem-based fisheries management on a global scale (2007).



The FARO Project was a two pronged program funded by CSA to showcase Canada's leadership in the application of remotely sensed ocean colour data for societal benefit (2012).

BLUE PLANET
Oceans and Society

Blue Planet is the over-arching Marine Task within the Group on Earth Observations (GEO). The creation of the Blue Planet Task was an initiative of the Partnership for Observation of the Global Oceans (POGO) (2012).



NetCOLOR

- Opportunity:
 - To federate and coordinate ocean colour activities within Canada at various levels (academia, private sector, and government, coast to coast). To develop a critical mass of scientists to influence and advise the Canadian Space Agency on specific thematic needs and requirements. Define a set of priorities and related implementation strategy at National Level and contribute to international activities.
- Objectives:
 - Review of the status of various current and future international ocean colour missions with a view to assessing the availability of data relevant for the requirements of Canadian scientists;
 - Identify the opportunities for Canadian contribution to space missions and to the development of ocean colour data utilization technologies;
 - Establish a national strategy to update Canadian user needs;
 - Identify Canadian technological capacity;
 - Identify national priorities for research in the field of remote sensing – water optics;
 - Improve the synergy within the academic, private and government sectors by creating an active network of Canadian ocean colour experts to engage in multi-institutional research projects.



Why monitor water quality from space?

- Detecting, monitoring, and forecasting of water quality from EO satellites provides valuable augmentation of EC's extensive water quality monitoring network by offering prompt, frequent, low-cost, synoptic observations over large expanses of Canada's natural waters;
- Water impairments due to eutrophication and resulting algal blooms are an ongoing concern due to potential taste and odour problems, algal toxins, and unsightly surface scums;
- Preventing the use of water bodies for drinking water and recreation → \$ losses to recreational boating/angling, lake property values, drinking water treatment costs, biodiversity & ecological costs.

From Environment Canada



Chlorophyll-a (ug l-1)

