



Canada's Ocean Color Activity Report

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Canadian Space Agency (CSA)



Canadian Space
Agency

Agence spatiale
canadienne

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Canada's Water Challenge

- With the longest coastline and close to 10% of the world's renewable freshwater supply, Canada is facing National and Global Water Challenges
- Canada invests in Oceans' Protection (1.5\$B) and Economy (2.3\$B)
 - Safer-Cleaner-Healthier -
- Canada is among the world leaders in Water sciences and a pioneer in Ocean Colour research initiatives
- Canadian Space Agency (CSA) supports Water Missions, most of Canadian Ocean Colour projects and continue supporting the IOCCG



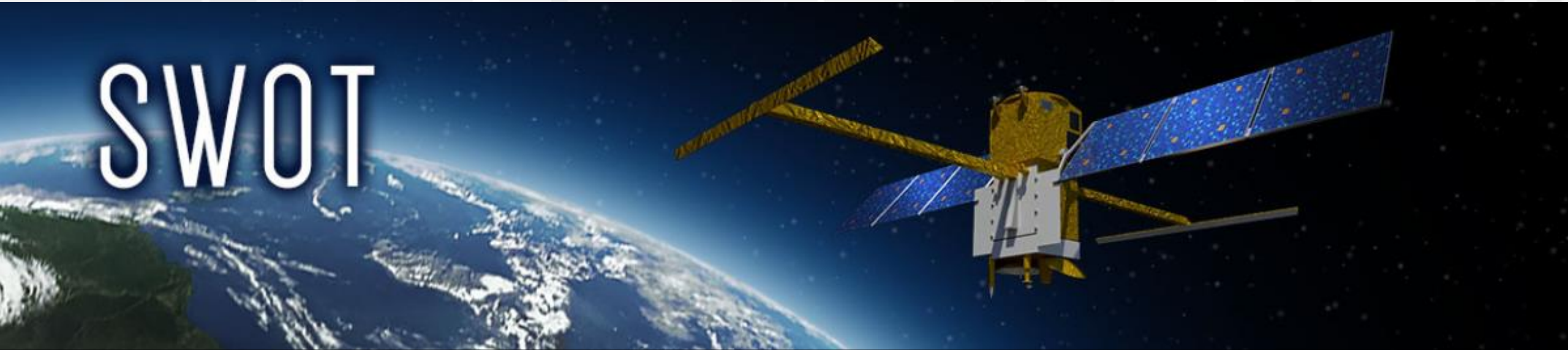
Canadian Space Agency (CSA) Water Initiatives

International
Satellites
With
Canadian
Participation

Canadian
Satellites



Surface Water and Ocean Topography (SWOT)



NASA-CNES led mission

SWOT will survey the ocean's surface topography, and measure how lakes, rivers, reservoirs and oceans are changing over time.

CSA is providing a key component of the radar instrument – a set of extended interaction klystrons (EIKs) will generate and amplify the microwave pulses needed by the main instrument

Launch scheduled in 2021





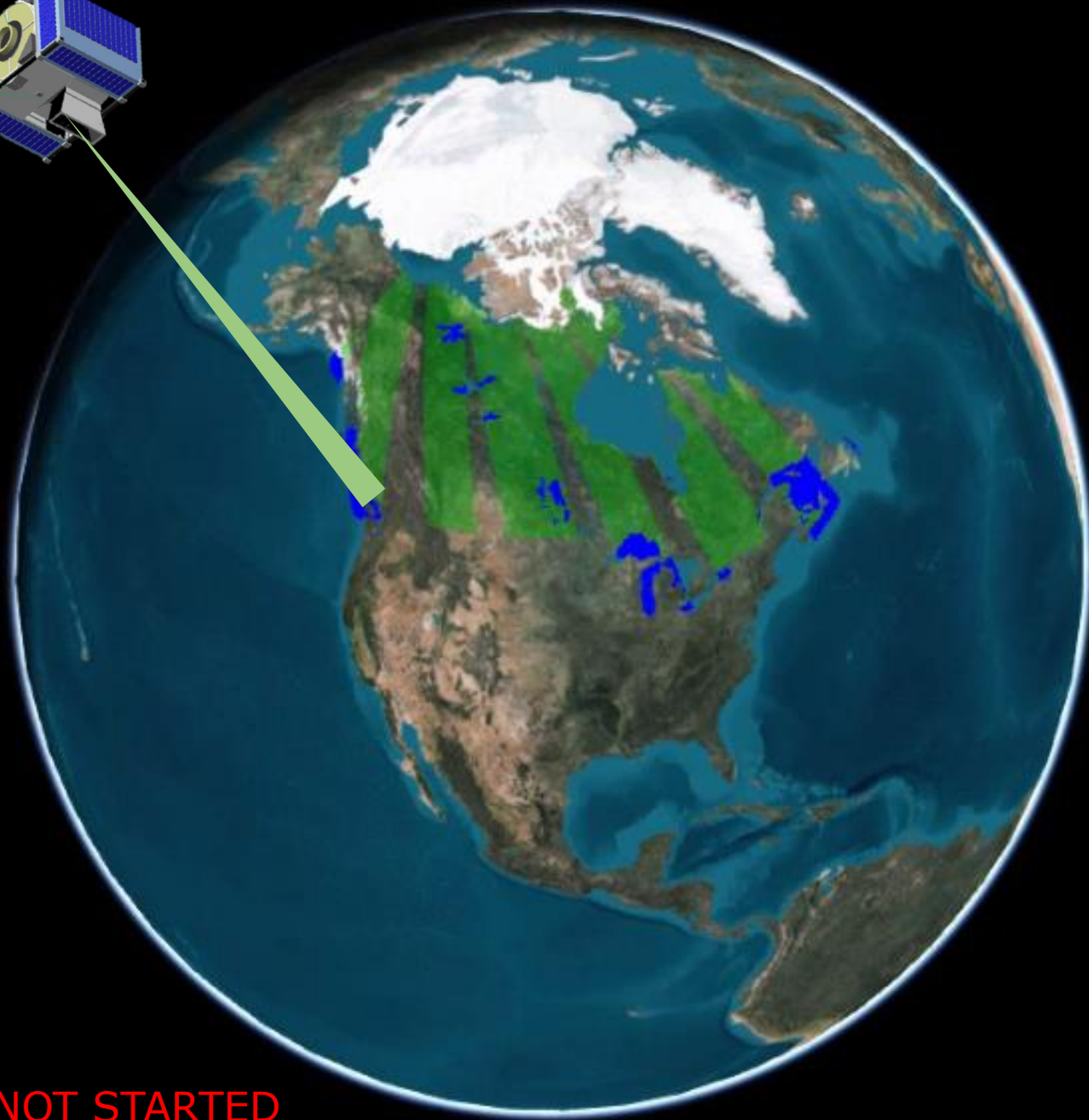
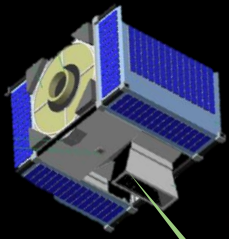
RADARSAT Constellation Mission (RCM)

- 3 identical satellites, evenly spaced on same orbital plane
- Altitude of 600 km
- Sun-synchronous orbit maintained within 100m orbital tube
- 12 days repeat cycle/satellite (4 days for constellation)
- 15 min. of imaging time (avg.) outside eclipse season
- Payloads:
 - ✓C-Band SAR – 5.405 GHz
 - ✓Automatic Identification System (AIS)
- 7 years design life

Single launch scheduled for May 2019

On Space-X Falcon 9 from Vandenberg





NOT STARTED

WaterSat



A satellite to monitor
the quality of Canada's
coastal and inland waters



CSA Hyperspectral Initiatives Update

2015 - WaterSat was one of the five microsats under CSA's Phase 0 studies. 5 departments & 3 universities defined the 1st version of the Canadian coastal & Inland waters mission.

2016 - 17 WaterSat on PACE - US Naval Research Lab (NRL) and CSA teamed-up for a NASA's coastal ocean color imager (COCI) on PACE mission.

- **CSA stopped development of COCI on PACE** in March 2017. US administration questioned PACE and 5 other science missions.

2017-18 - CSA funded the Canadian Industry and Academia to build:

- **DICE** - **D**ual **I**maging spectrometer **C**OCI **E**xperiment - *ITRES and Honeywell*
- **WISE** - **W**aterSat **I**maging **S**pectrometer **E**xperiment an airborne water color instrument – *ITRES*
- **WISEMAN** - Fly the WISE instrument in field campaigns over coastal areas in Quebec for future water satellite. *UQAR, University de Sherbrooke, U. de Laval, UQAC, etc.*

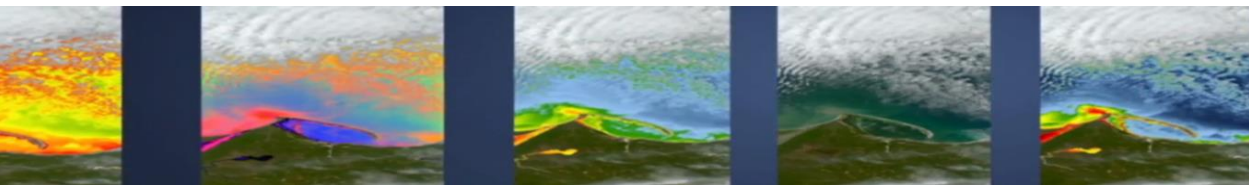
2019 – CSA is exploring national and international partnership opportunities to initiate Phase A of a 2nd version of the WaterSat mission.



WaterSat Mission Update

- **Canada has the world's longest coastline** and $\approx 10\%$ of the world's renewable freshwater supply
- **No existing satellite or in-situ methods can meet Canada's Coastal and Inland Waters Quality monitoring and management needs**
- **WaterSat** will assess and monitor:

- ☐ **Water Color of coastal and inland waters**
- ☐ **harmful algal blooms**
- ☐ **Nearshore bathymetry**
- ☐ **Oil spill characterization**



100+ spectral bands

100m spatial resolution 3x better than current satel

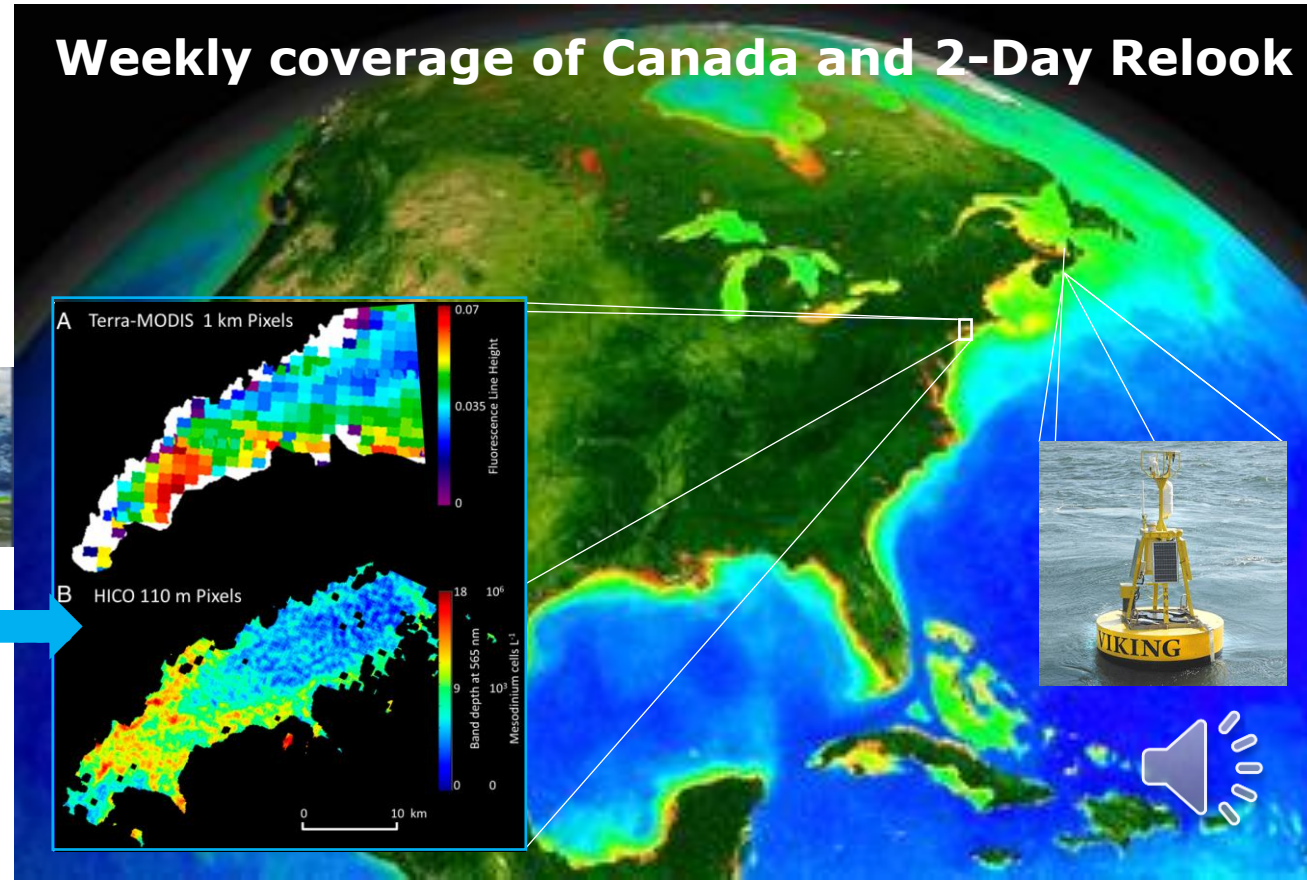
MAP LEGEND

Algae-free areas

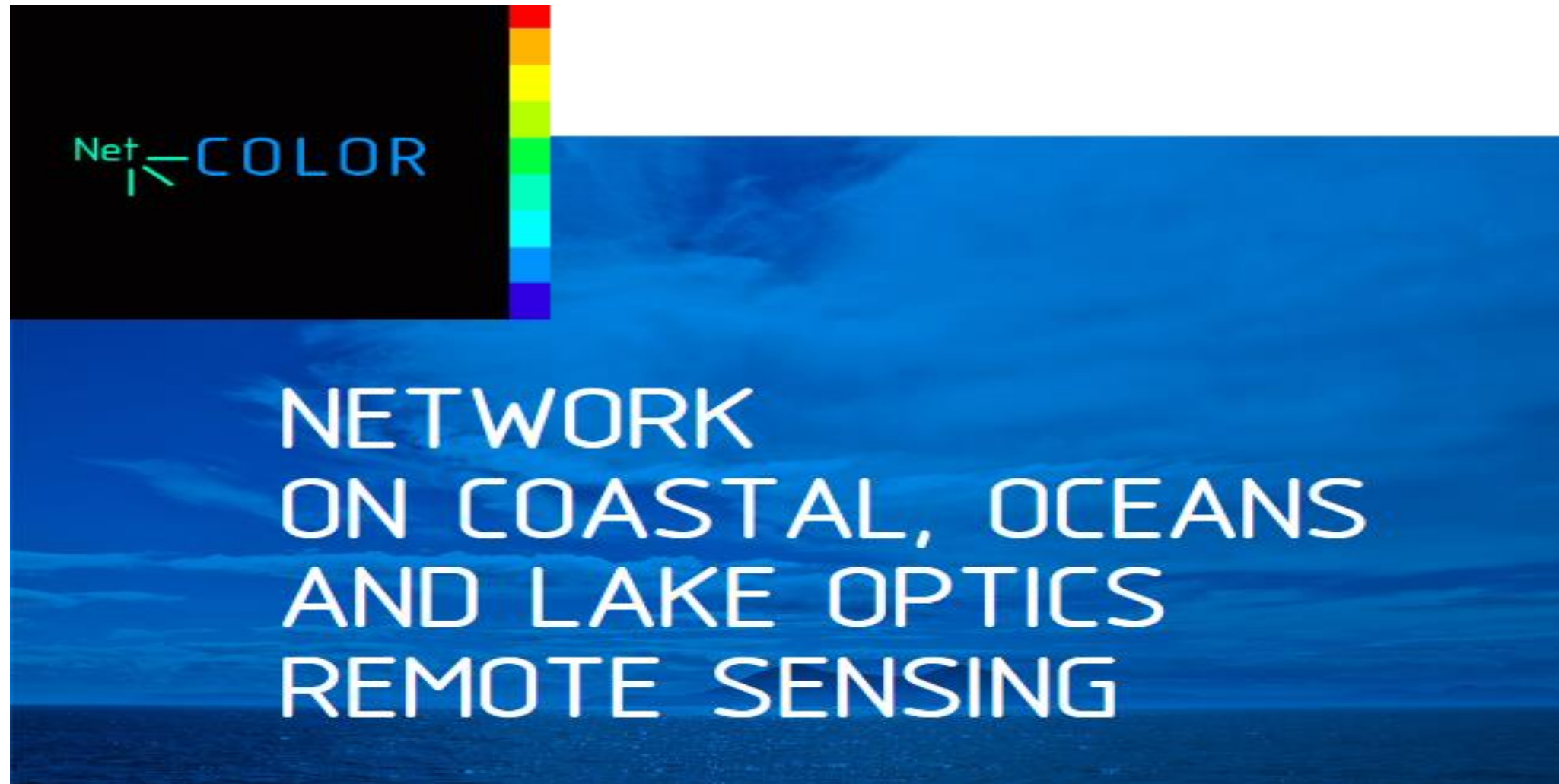
High algae productive areas

Phytoplankton and algae harmful blooms

Weekly coverage of Canada and 2-Day Relook



Canadian Ocean Colour Activities Report



Canadian Ocean Colour Activities – Arctic



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Research programs to improve our understanding of the northern environment and its impact on human beings and their health.



Canada Excellence Research Chair (CERC) in Remote Sensing of Canada's new Arctic Frontier

Marcel Babin



Studying how Arctic marine ecosystems will respond to climate change and new human-induced pressures.

CAD \$98M, 7 years started late 2016.

A joint UL/CNRS Laboratory designed to study both ocean and land ecosystems as well as the interaction between the two components.

The objective is to understand the dynamics of the phytoplankton spring bloom and determine its role in the Arctic Ocean of tomorrow, including for human populations.



Canadian Ocean Colour Activities - Ocean



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**Dalhousie University, Memorial
University and the Prince Edouard
Island University**

HYPERNAV float



- Established in September 2016
- A transnational hub for ocean research (North America and Europe)
- OFI's aim is to conduct research that advances policy decisions
- and advances the development of a blue — and sustainable — economy.
- OFI has launched its phase 2 and plans to invest \$16 million in projects
- Theme 1: The North Atlantic as a Climate Ocean
- Theme 2: Coastal Communities and the Ocean

Technological Innovation

- Co-Investigator: Design and fabrication of profiling hyperspectral radiometers for vicarious ocean colour calibration/validation.

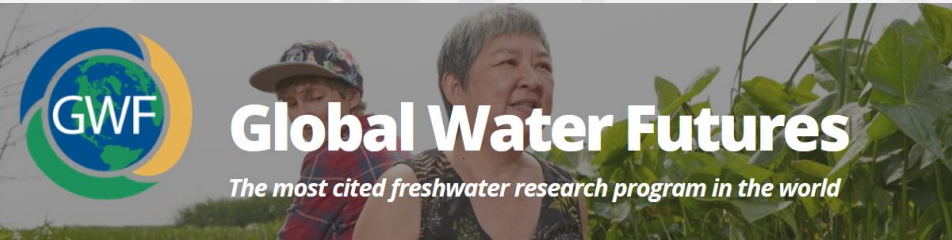


Canadian Ocean Colour Activities – Inland



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- 7 years and started in 2016
- Solutions to Water Threats in an Era of Global Change”.
- GWF has grown to a total funding package of \$143.67 million through linked contributions from the University of Saskatchewan (\$17.5 million), University of Waterloo (\$15 million), McMaster University (\$12.14 million), and Wilfrid Laurier University (\$10.58 million) and various industrial partners.



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Government
— of —
Saskatchewan



UNIVERSITY OF
SASKATCHEWAN



UNIVERSITY OF
WATERLOO



McMaster
University



LAURIER
Inspiring Lives

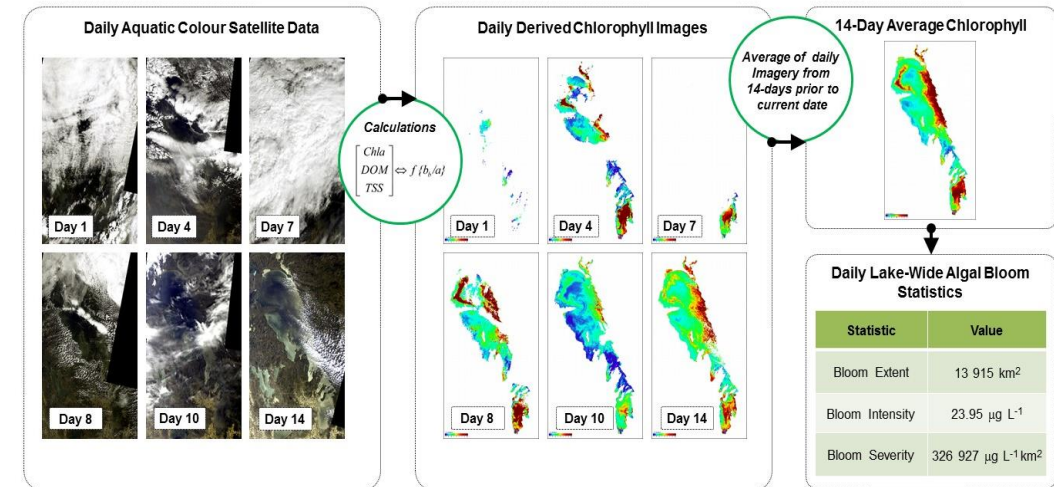


Canadian Ocean Colour Activities – Lakes & Nearshore

Environment & Climate Change Canada (ECCC)
Caren Binding, Yi Lou

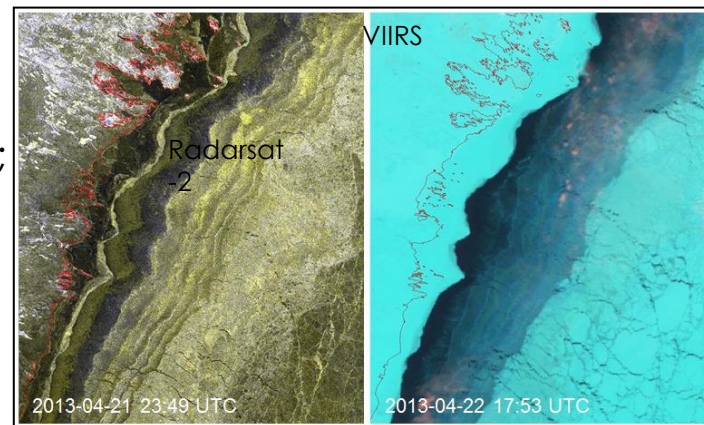
Water Quality

- Semi-operational detection & monitoring of inland water algal blooms using satellite derived bloom indices;
- Understanding biogeochemical processes in inland waters (DOM, whiting events, suspended sediments, water clarity);

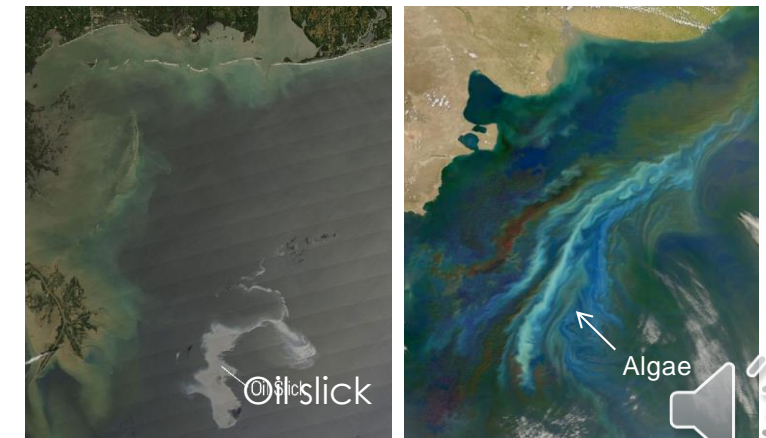


Marine & Ice Services

- Integrated Satellite Tracking of Pollution (ISTOP);
- Differentiating oil from algae, oil slick thickness;
- Coastal & inland lake ice detection.



VIIRS shows solid fast ice & gradient in thickness & concentration



Oil slick and algae in MODIS imagery

Canadian Ocean Colour Activities – Coastal



First International IHO Hydrographic Remote Sensing Workshop

- Co-sponsored by CHS, NOAA and SHOM with the support of the IHO
- Three-day workshop in Ottawa, Ontario, Canada: September 18-20, 2018
- Attended by Private Sector, Academia and Government
- Goal: Accelerate the implementation of remote sensing and Satellite Derived Bathymetry (SDB) in Hydrography.

Contact: Rene.Chenier@dfo-mpo.gc.ca



Canadian Ocean Colour Activities – Coastal

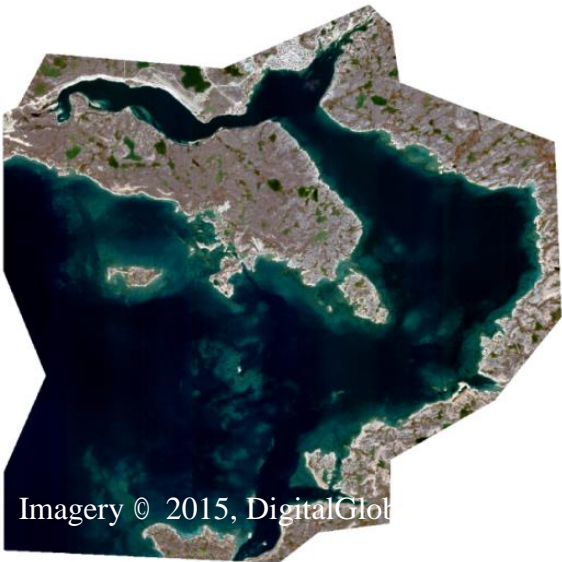
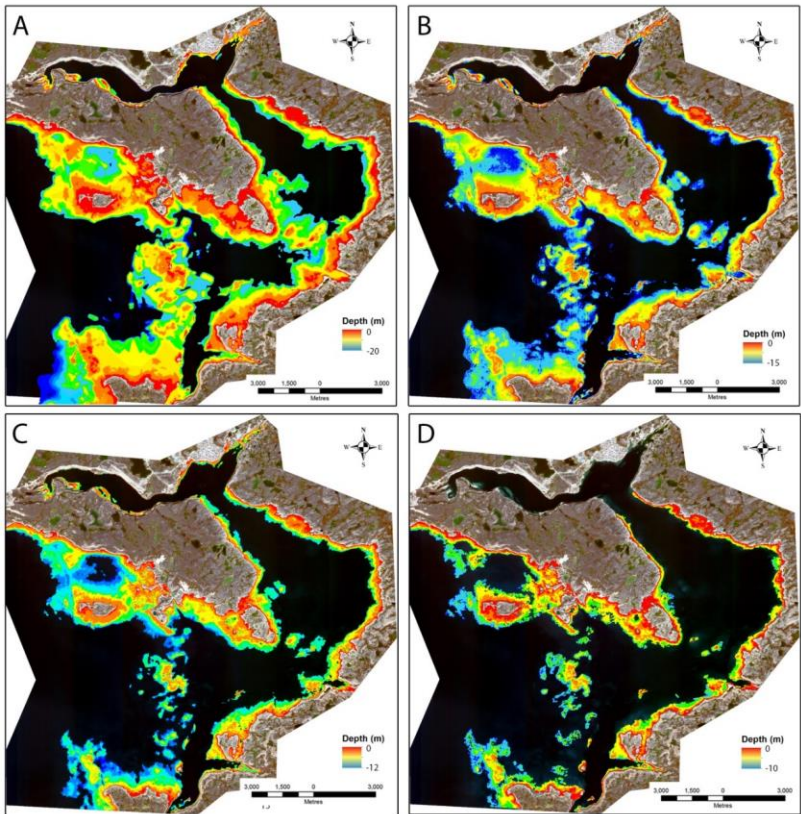
Rene.Chenier@dfo-mpo.gc.ca



Under a GRIP project with the CSA, CHS has been testing different SDB approaches like:

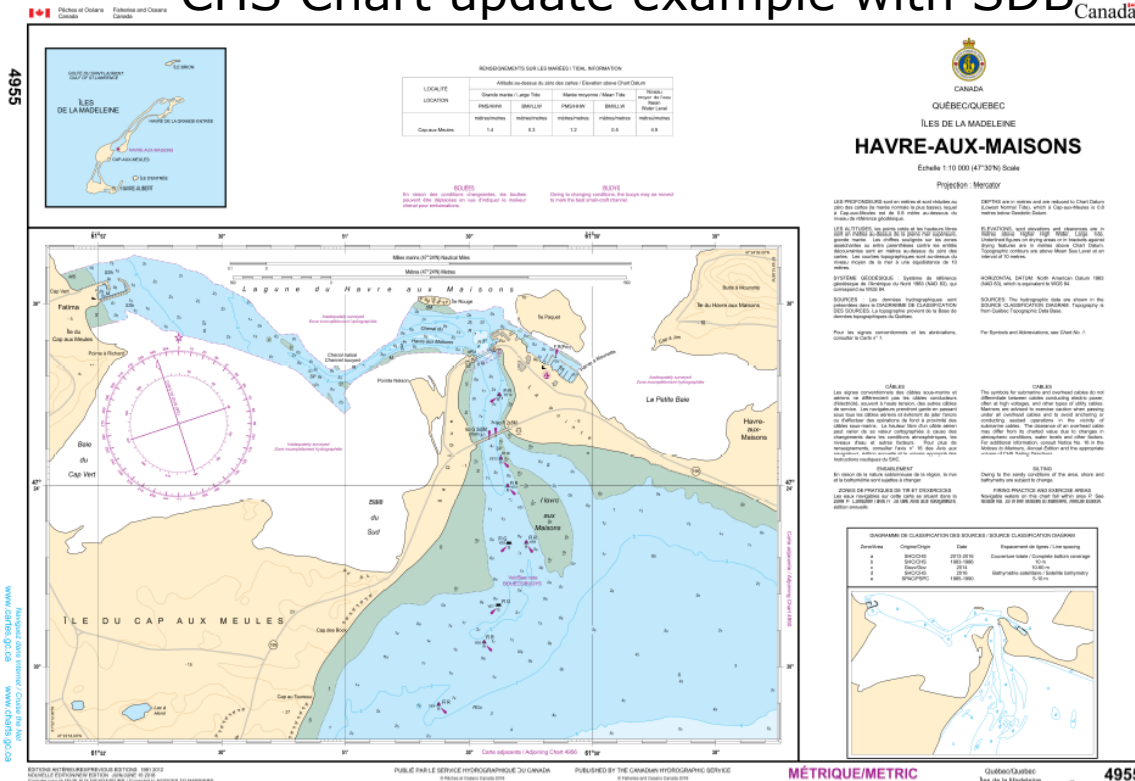
- Photogrammetry
- Classification
- Empirical

Approach	Coverage 0-20 m
A- 3D Manual Photogrammetry	100 %
B- Classification Random Forest	81 %
C- Empirical Multiband	59 %
D- Automatic Photogrammetry	39 %



Imagery © 2015, DigitalGlobe

CHS Chart update example with SDB



2019-René Chénier *, Ryan Ahola , Mesha Sagram , Marc-André Faucher , Yask Snelat , Consideration of Level of Confidence within Multi-Approach Satellite Derived Bathymetry, ISPRS Int. J. Geo-Inf. 2019, Geo-Information <https://www.mdpi.com/2220-9964/8/1/48>

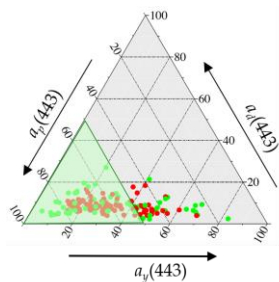
Canadian Ocean Colour Activities – Marine

Fisheries & Oceans Canada, Bedford Institute of Oceanography (BIO)
Emmanuel Devred

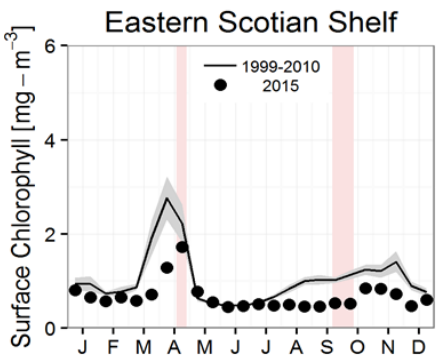
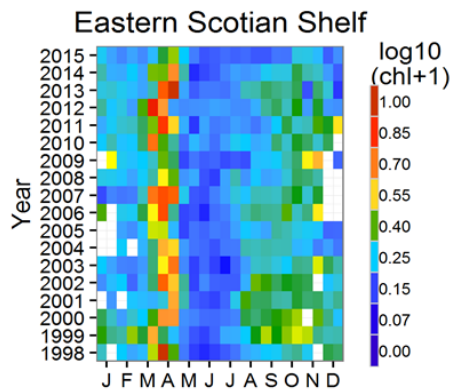
OC for Monitoring and Operational Science

- Bio-optical documentation of coastal and pelagic environment;
- Archive and distribution of OC and SST products;
- Phytoplankton ecology in support of ecosystem-based approach to fisheries management;
- Coastal water transparency, harmful algal blooms.

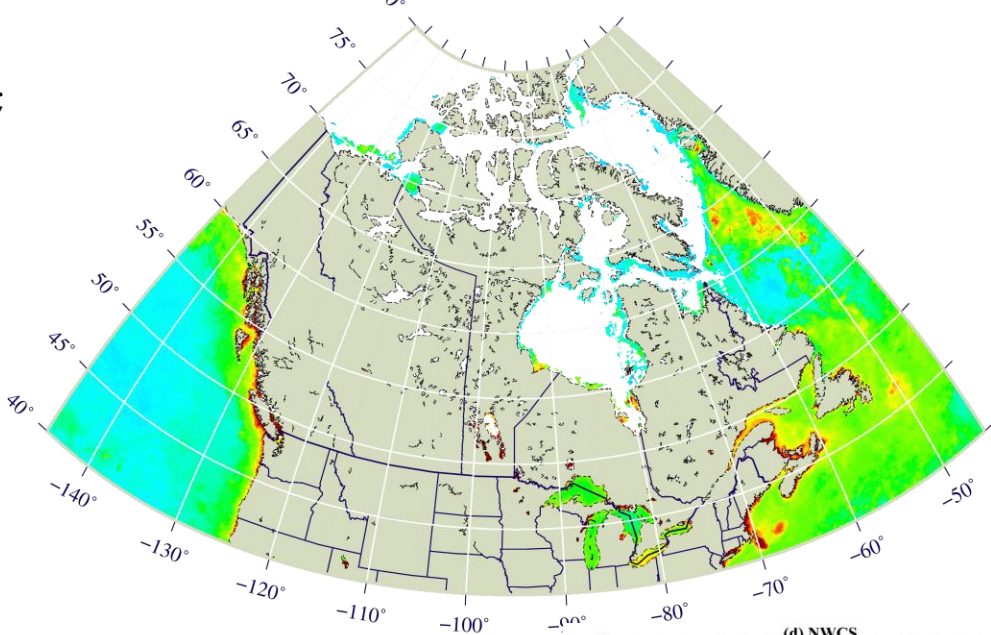
Absorption budget for NW Atlantic



Phytoplankton phenology

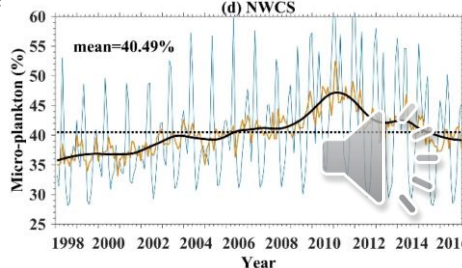


Processing of OC data products for all Canadian waters



Source MODIS OBP-NASA

Microphytoplankton time series (CCI-OC)



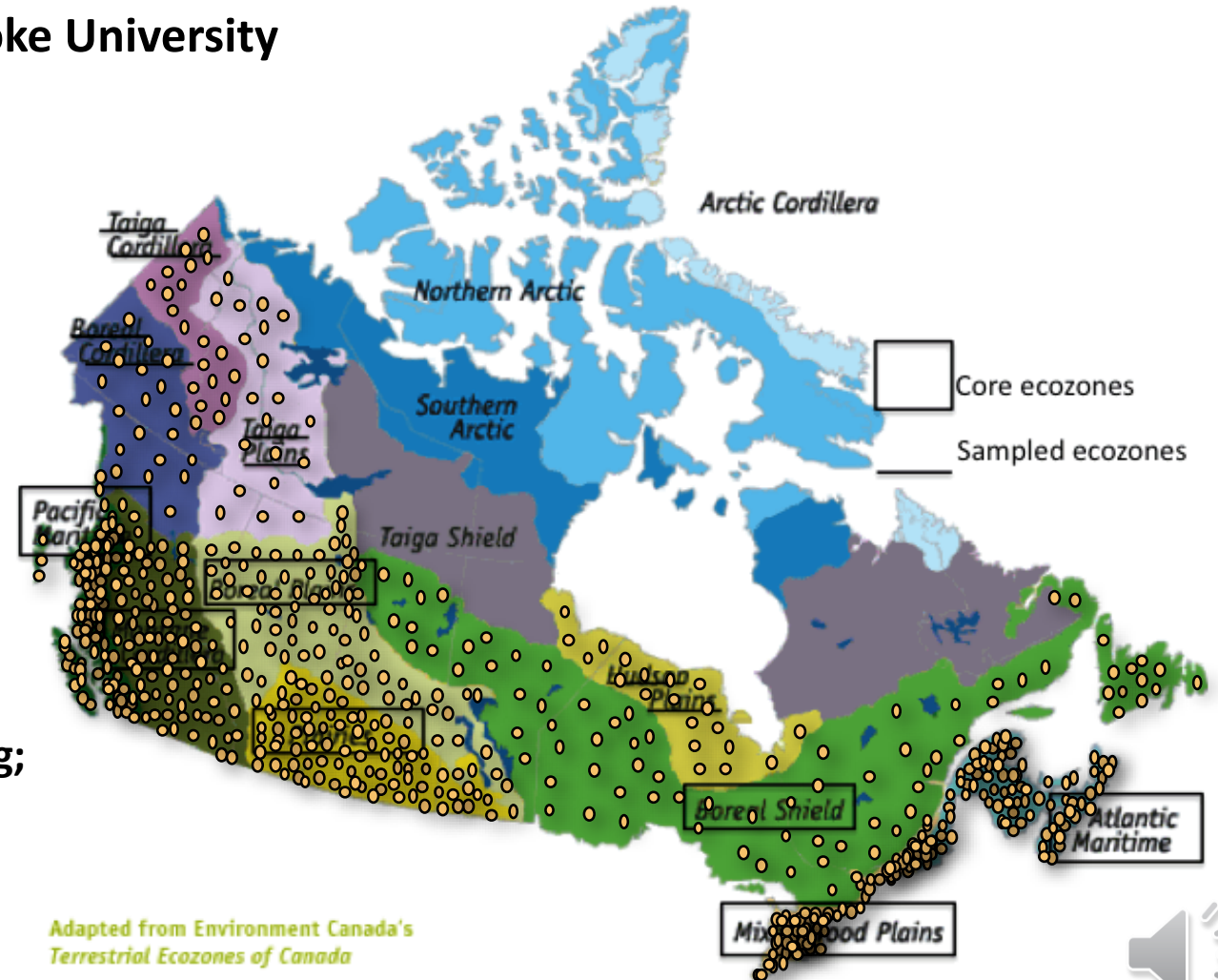
Canadian Ocean Colour Activities – Lakes & Nearshore

Canadian Lake Pulse Network
Yannick Huot, Sherbrooke University

Distribution of lakes in the study

Funded by Natural Sciences and Engineering Research Council of Canada (NSERC) 2016-21

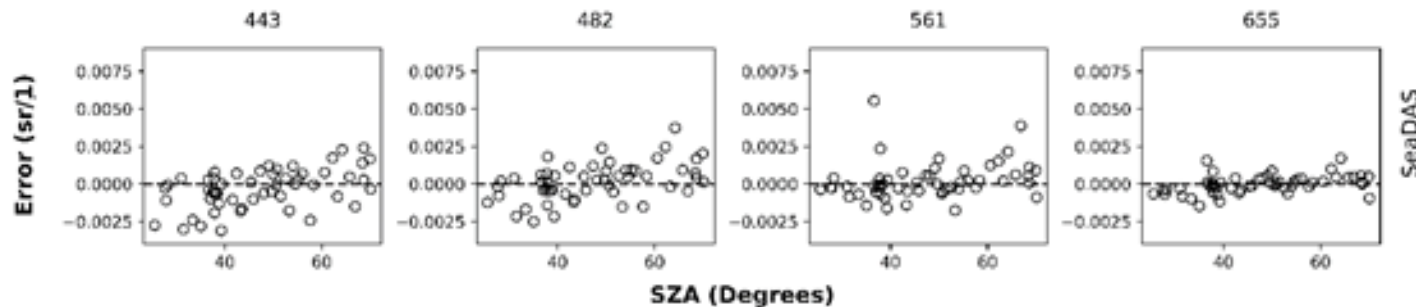
- Study of 680 lakes in 11 ecozones;
- Assess health of Canadian lakes (stressors & biogeochemical functioning;
- Forecast future changes;
- Develop new observational approaches – **remote sensing**;
- Looking for financial partnership to purchase 3 buoys.



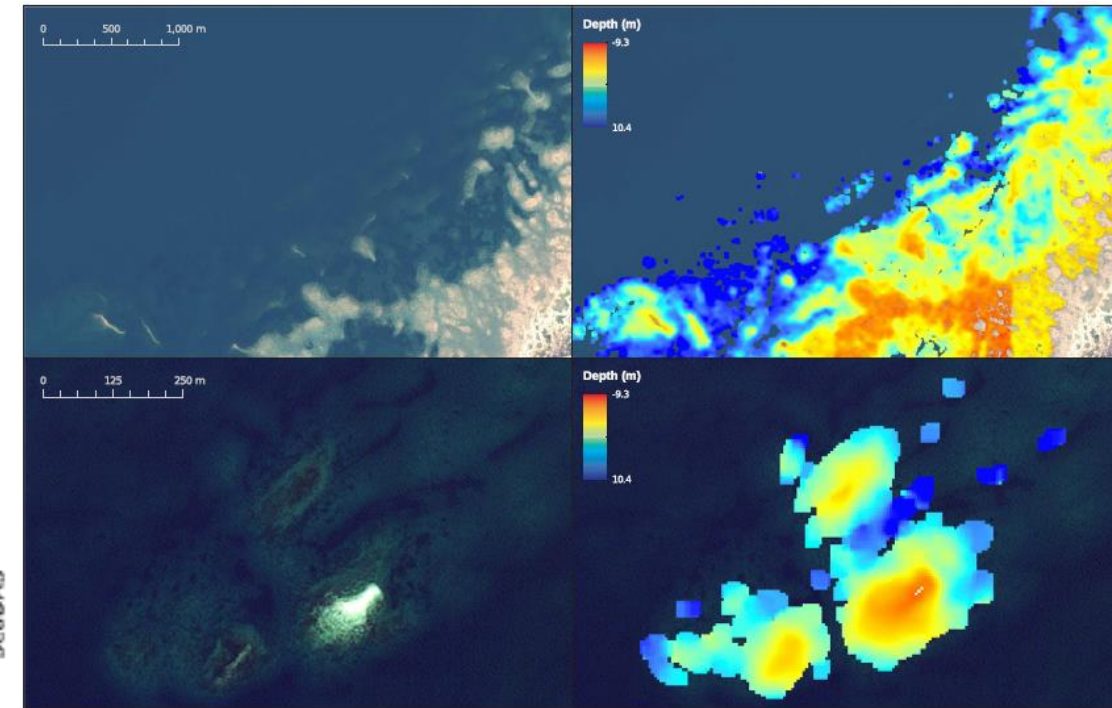
Canadian Ocean Colour Activities – Coastal

University of Ottawa, Shallow-Water Earth Observation Lab
Anders Knudby

- Validation of Atmospheric Correction methods (NASA I2gen, ACOLITE, 6S, LaSRC) for coastal R_{rs} retrieval (*University of Ottawa*)
- In-situ R_{rs} data collection in Resolute Bay to improve Atmospheric Correction in the Arctic (*Canadian Space Agency*)
- Satellite-Derived Bathymetry (*Nunavut General Monitoring Plan*)



Solar Zenith Angle currently influences R_{rs} retrieval from Landsat 8 OLI, with NASA's standard algorithm (data from Ilori et al. 2019, *Remote Sensing*)



WorldView-2 imagery (left) and corresponding Satellite-Derived Bathymetry (right) for a section of Cambridge Bay, Nunavut (Hodul et al. 2018, *ISPRS Journal of Photogrammetry and Remote Sensing*)

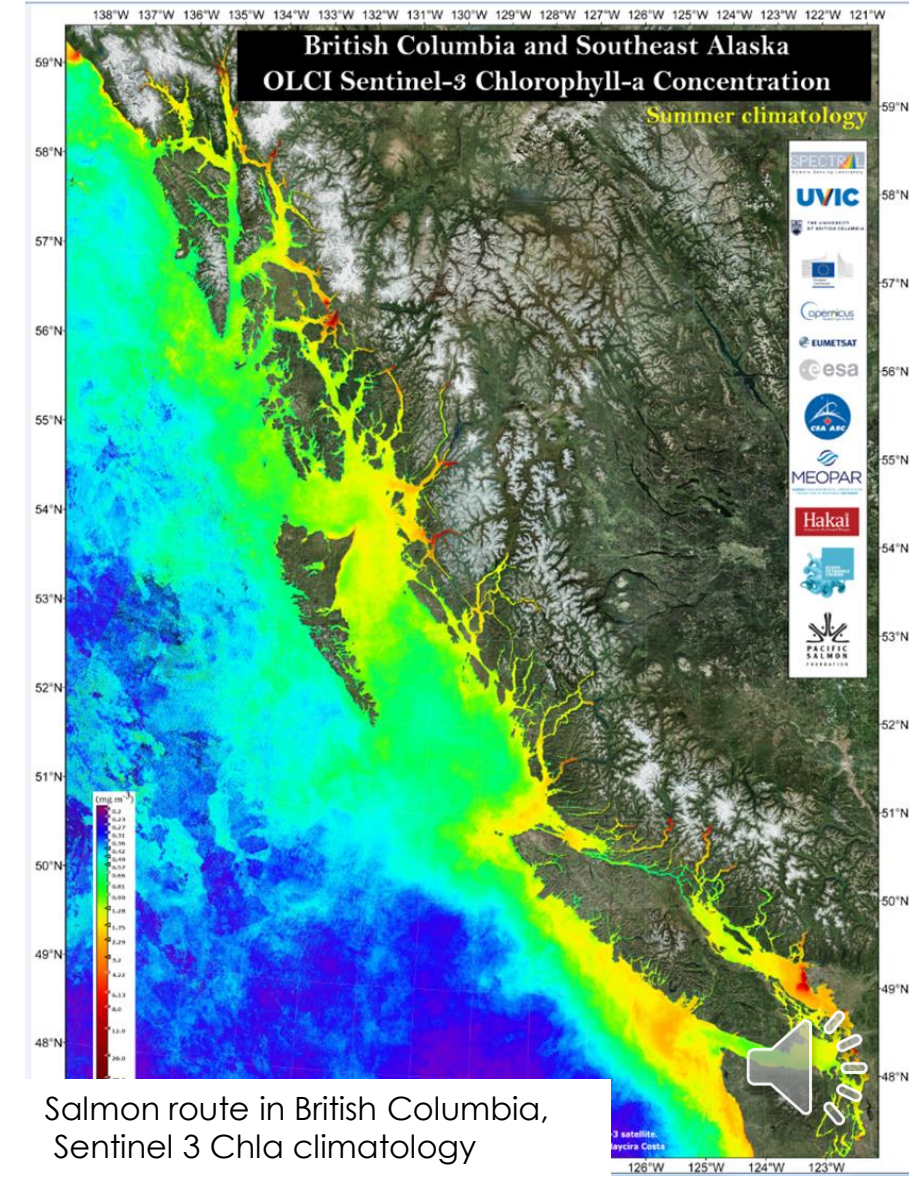
Canadian Ocean Colour Activities – Coastal

University of Victoria, SPECTRAL Remote Sensing Laboratory
Maycira Costa

- Autonomous data acquisition from ferries – Ferry Ocean Colour Observation Systems (FOCOS); and cruise ships
- In situ above-water R_{rs} for satellite validation & model development: Sentinel-3, MODIS & VIIRS;
- Chl phenology & salmon health;
- Bloom initiation; phytoplankton groups, harmful algal blooms



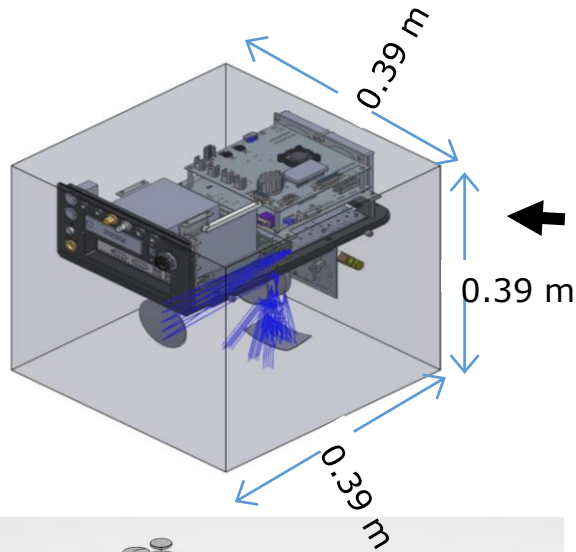
Ship of opportunity-based
autonomous water reflectance



Canadian Ocean Colour Activities – Coastal

WaterSat Imaging Spectrometer Experiment (WISE) for optically shallow coastal waters assessment
– The WISE-Man project –

Simon Bélanger et al. Université du Québec à Rimouski **UQAR**

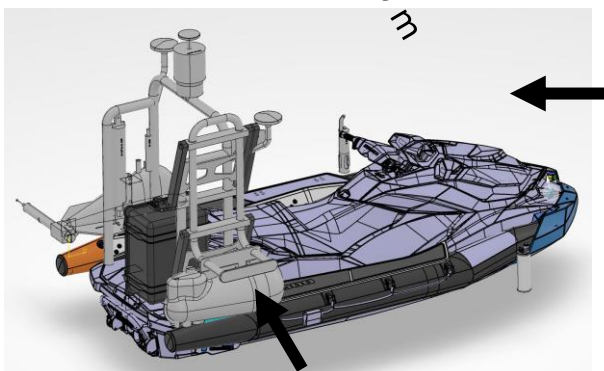


WISE data acquisition,
calibration and corrections

Hyperspectral inversion for
bathymetry, water
constituents and bottom type
mapping

Development and exploitation
of novel in situ platforms for
EO validation

EO applications to coastal
ecosystems discrimination and
assessment (NPP, benthic
mapping)



Hyperspectral + active optical sensors

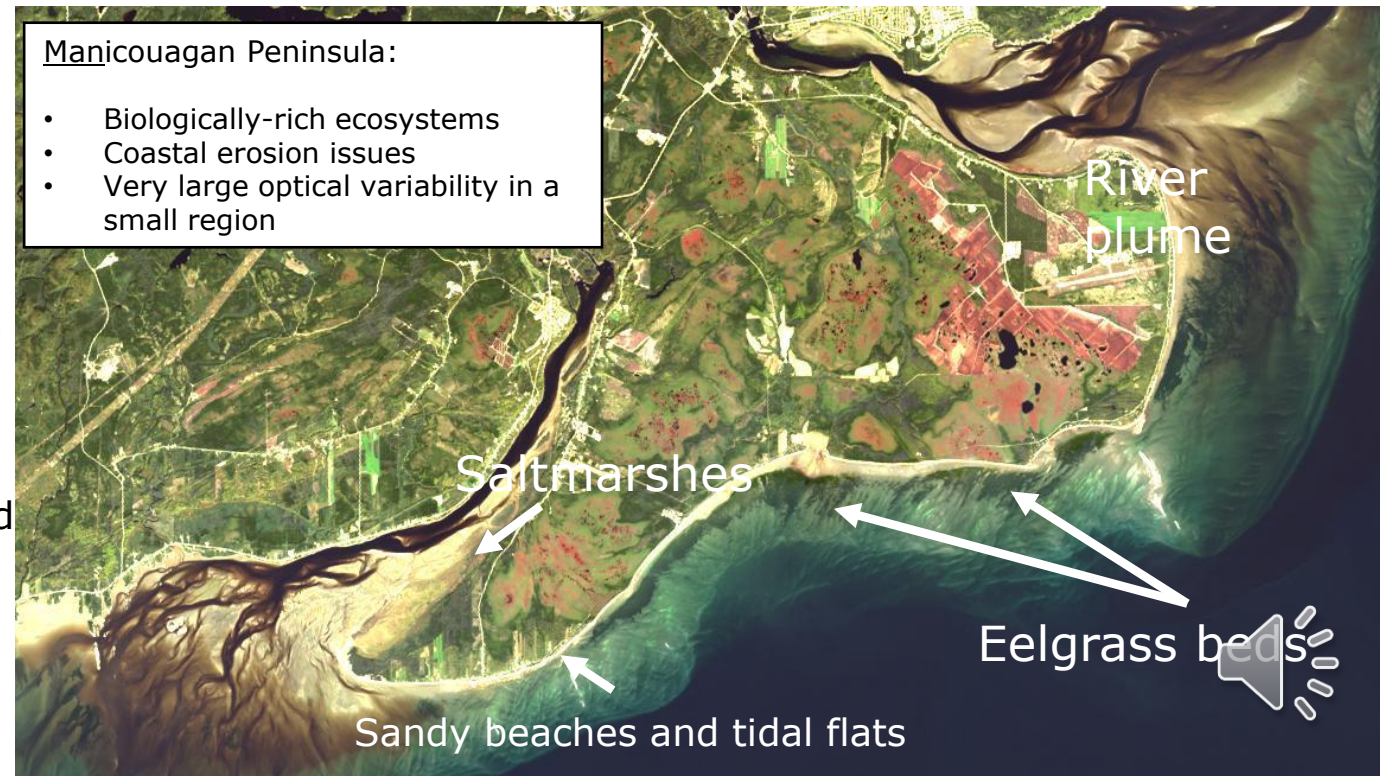


Fisheries and oceans Canada
Department Research & Development Canada
National Research Council - Flight Research Lab



Manicouagan Peninsula:

- Biologically-rich ecosystems
- Coastal erosion issues
- Very large optical variability in a small region



Conclusions

- **Canada is taking steps to ensure we have safer, cleaner and healthier oceans**
- **CSA supports Canadian Ocean Sciences and Ocean Colour projects**
- **CSA will continue to explore potential avenues for the WaterSat mission and see the IOCCG as a great forum to foster common efforts**



Thank you

laurent.giugni@canada.ca



WaterSat Mission Concept

A proto-operational, Visible and Near-Infrared (VNIR) hyperspectral microsatellite dedicated to Canadian coastal and inland waters monitoring and management.

WaterSat Parameter

Altitude	702km
Orbit	Sun-synchronous
Revisit at Nadir	102 Orbits
Relook Rate/Repeat coverage	1-3 days/7 days
Swath/width	240km
Max. viewing angle	45°
Spatial Resolution	< 150 m (goal < 90 m)
Spectral sampling interval range	350–1000nm (goal)
Spectral sampling interval	5-7.5nm
Weight	150kg (payload 20kg)
Peak SNR	400:1 to 950:1 at 5% albedo

