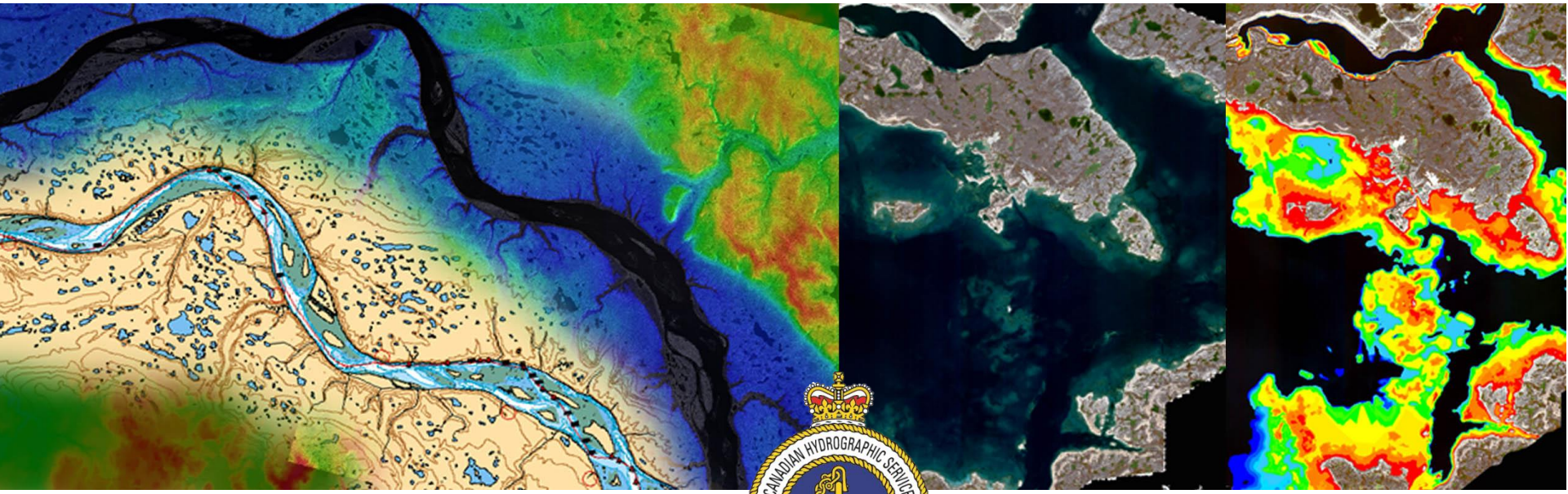
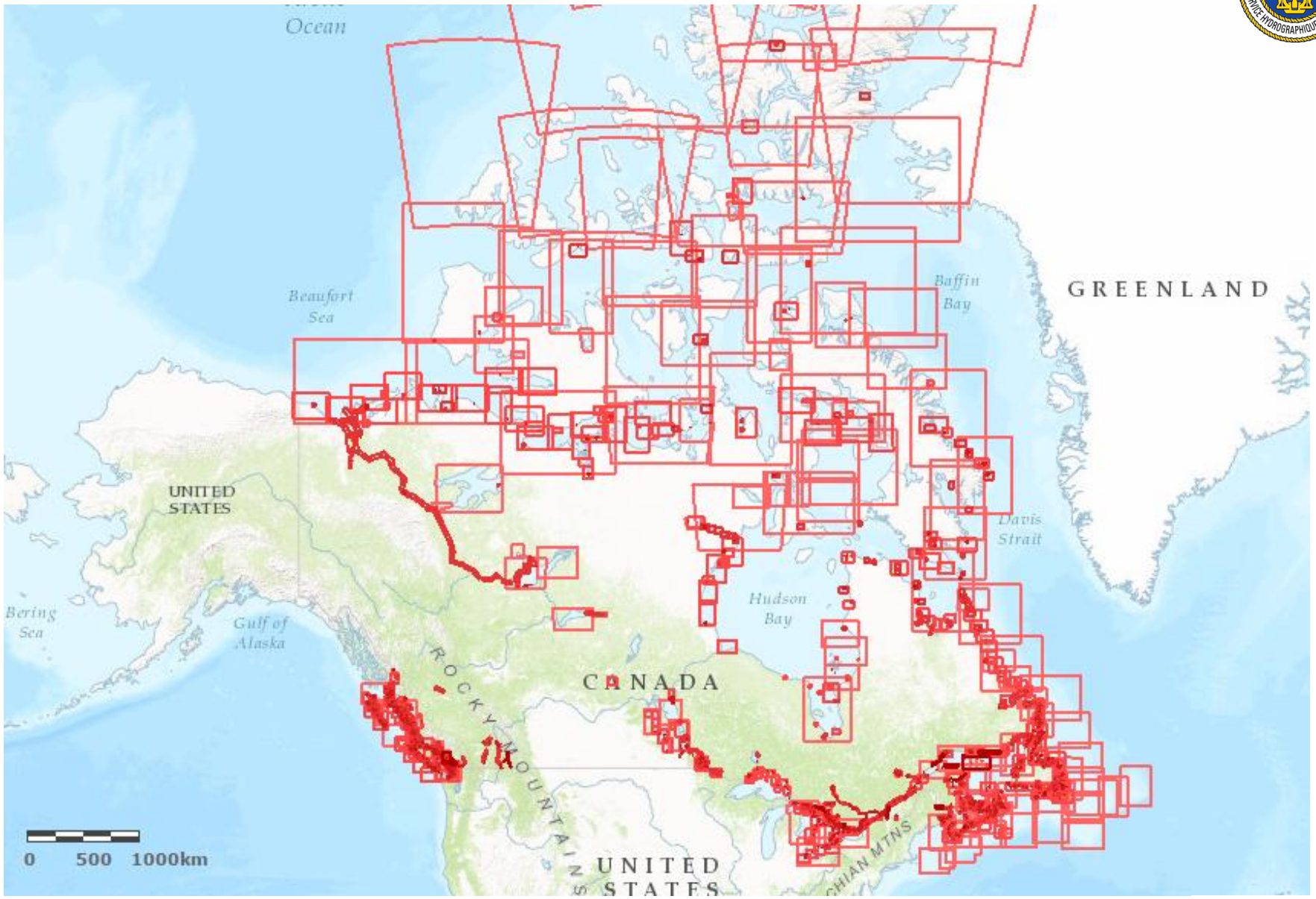
Improving Satellite Derived Bathymetry and Supporting Safety to Navigation in Canadian Waters through Remote Sensing

CHS Remote Sensing Group: René Chénier, Ryan Ahola, Marc-André Faucher, Khalid Omari, Yask Shelat, Mesha Sagram and Bradley Horner




Ocean
Beaufort Sea
Baffin Bay
GREENLAND
UNITED STATES
Davis Strait
Hudson Bay
Bering Sea
Gulf of Alaska
CANADA
ROCKY MOUNTAINS
UNITED STATES
0 500 1000km

Canada

Category Zone of Confidence (CATZOC) of Hydrographic Survey
Qualité générale des données bathymétriques (CATZOC)

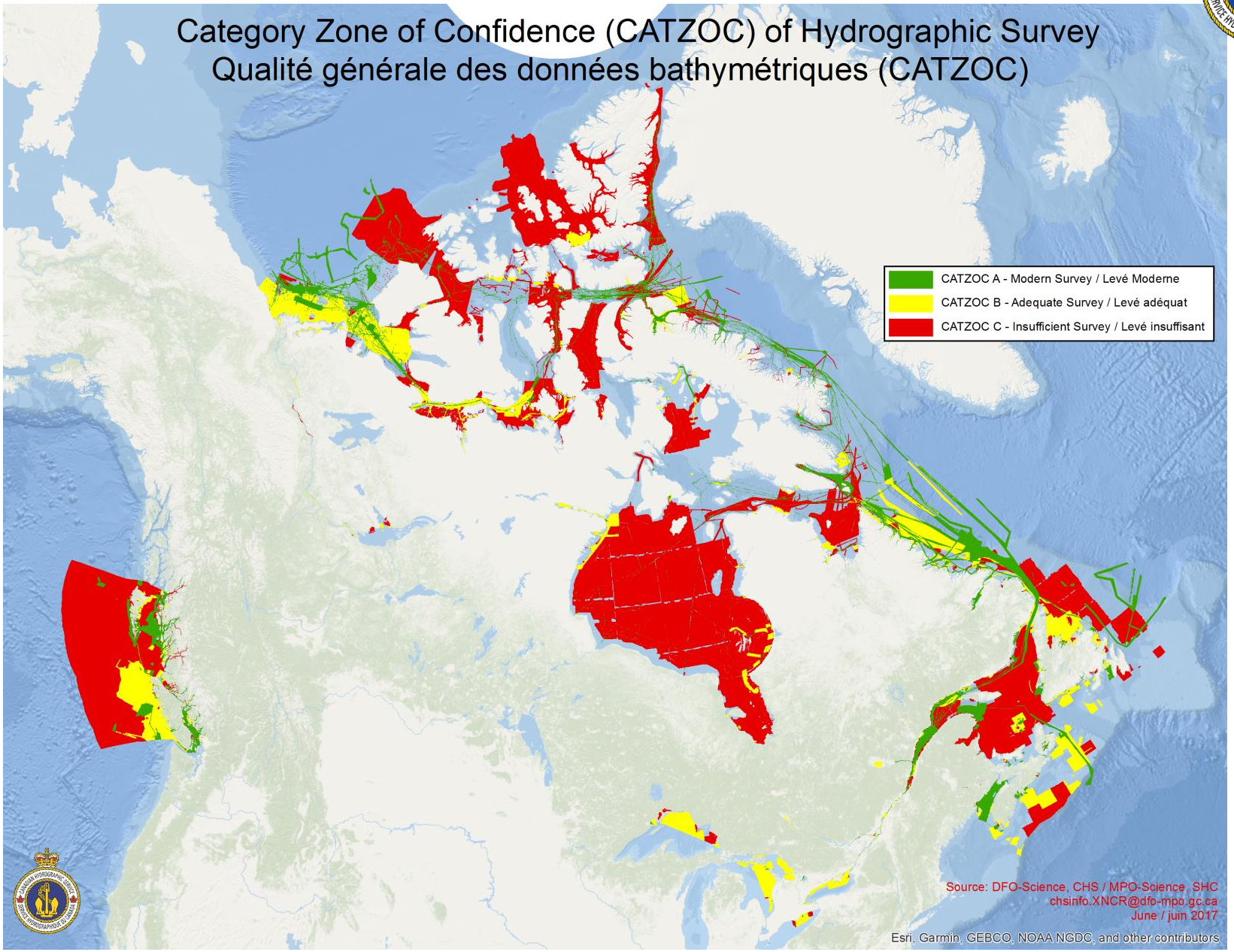


Chart White Space

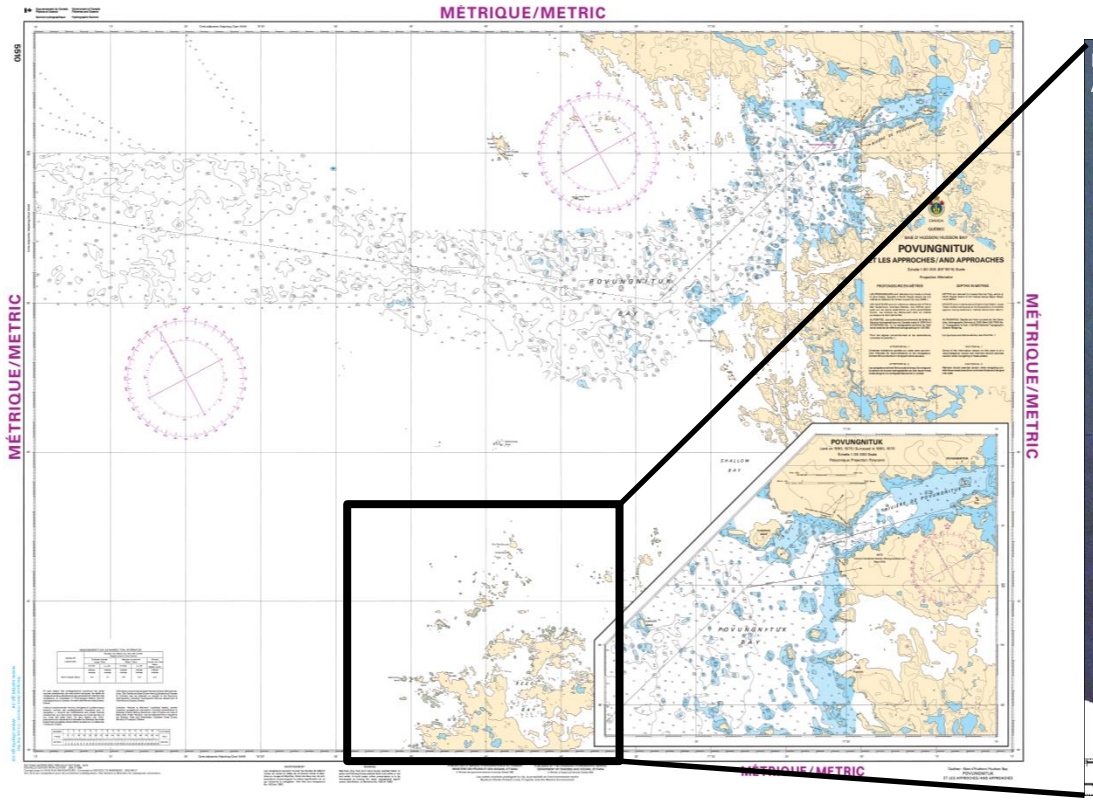


Chart 5510 (Povungnituk, QC). White areas are unsurveyed.

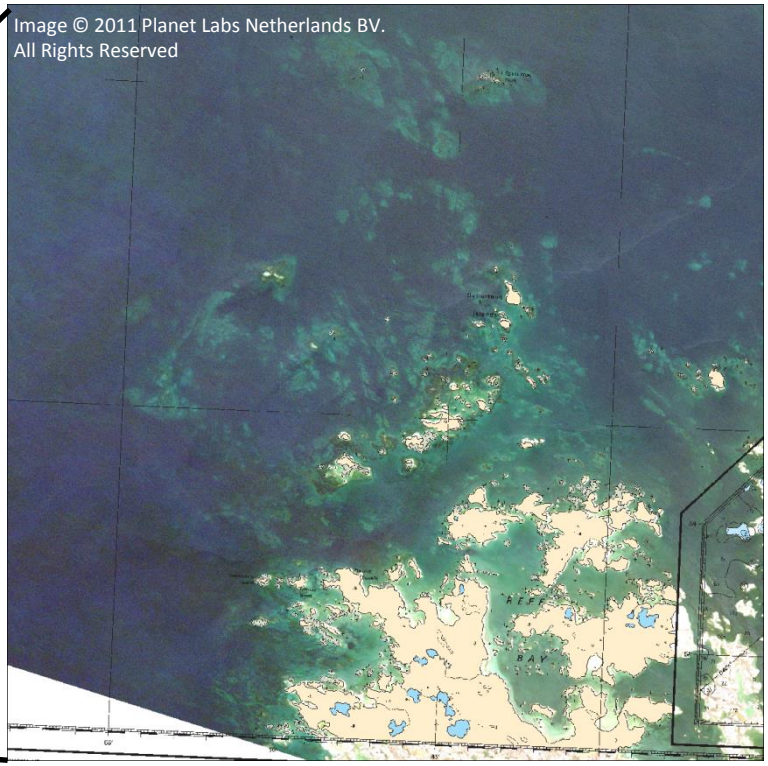


Chart 5510 overlaid on RapidEye image (July 12, 2011).

Canada

Government Related Initiatives Program

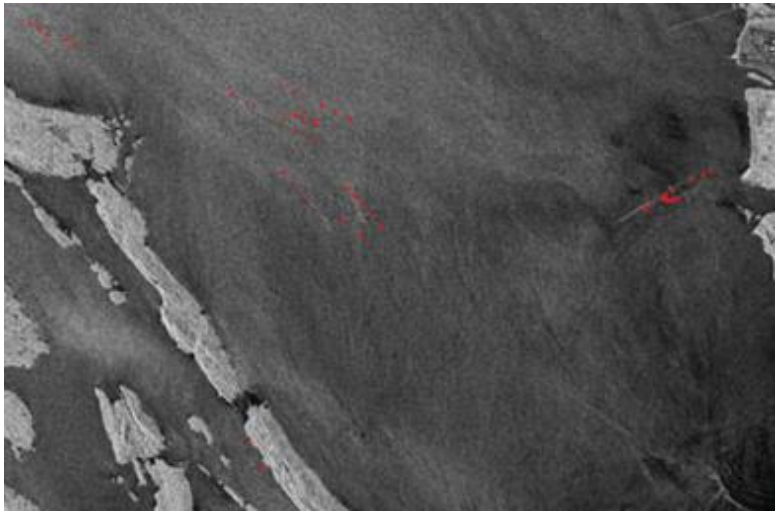
- **Funded through the Canadian Space Agency (CSA)**
- **Extraction of accurate Coastline and Intertidal Zones**
  - Radar and optical data
  - Improve accuracy of chart representation
- **Satellite Derived Bathymetry (SDB)**
  - Survey planning
  - Identification of new shoals
  - Extraction of bathymetry surface
- **Change Detection**
  - Determining areas and rates of change
- **Water Clarity Analysis**
  - Light Detection and Ranging (LiDAR) planning
- **Shipping Corridor Determination**
- **Data Integration in CHS Processes and Products**

Data Utilization and Application Plan

Additional funding through the CSA Data Utilization and Application Plan (**DUAP**) to further integrate GRIP objectives with the RADARSAT Constellation Mission (RCM).

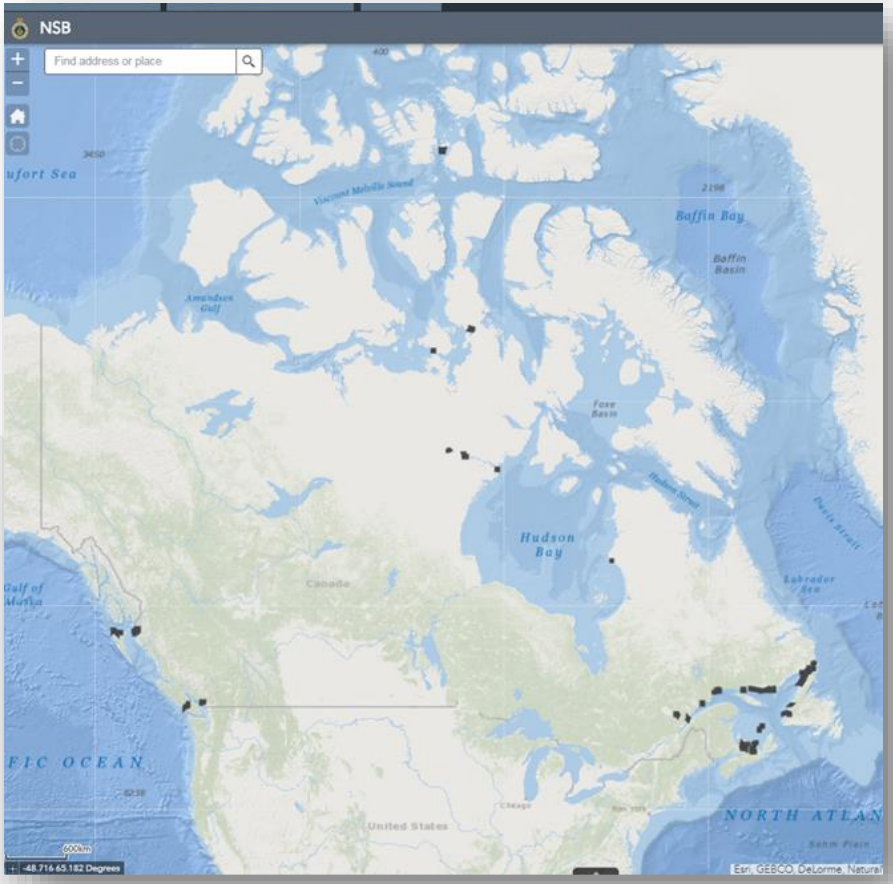
- **RCM Data Simulation**
  - Single and dual polarizations
  - Compact polarimetry parameters
- **Synthetic Aperture Radar (SAR) Bathymetry**
  - Wave and current simulation
  - Wave retrieval
- **Shorelines, Intertidal Zones and Tidal Height**
  - Interferometry
  - Polarimetric decomposition
- **Charting and Surveying Priorities**
  - Automated Identification System (AIS) detection

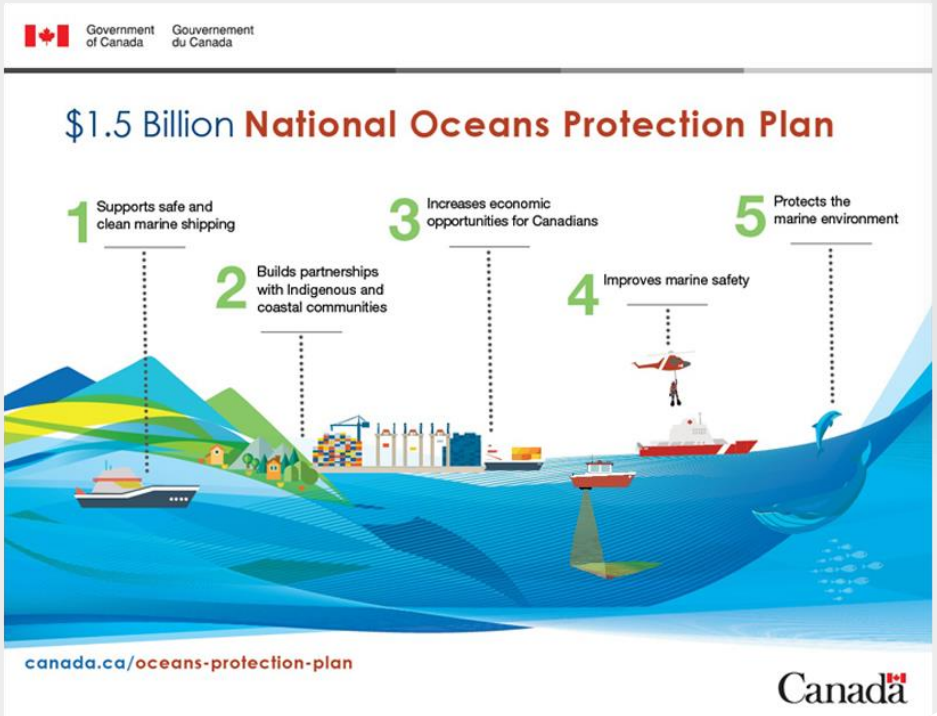
RS2 FQ9WS HH image and AIS ship locations



Oceans Protection Plan

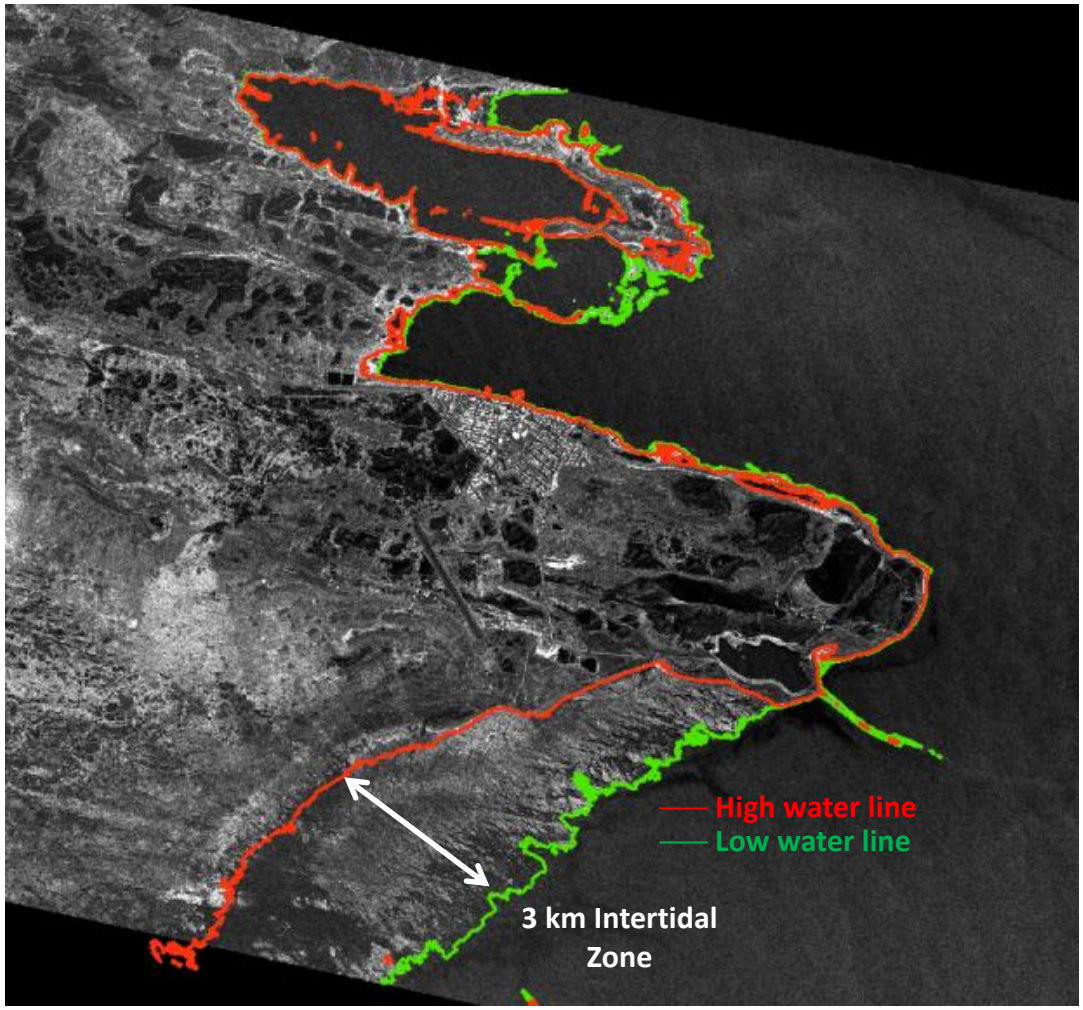
- Multibeam and LiDAR surveys for priority and high risk areas across Canada
- Support for remote sensing projects

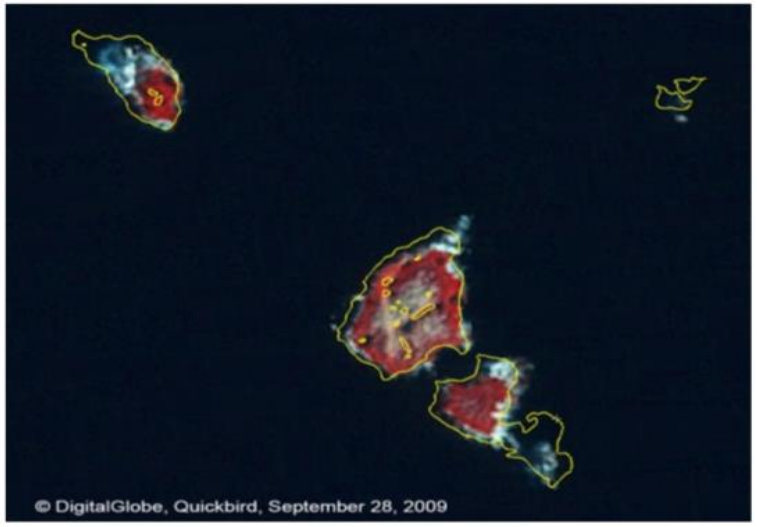




Canada

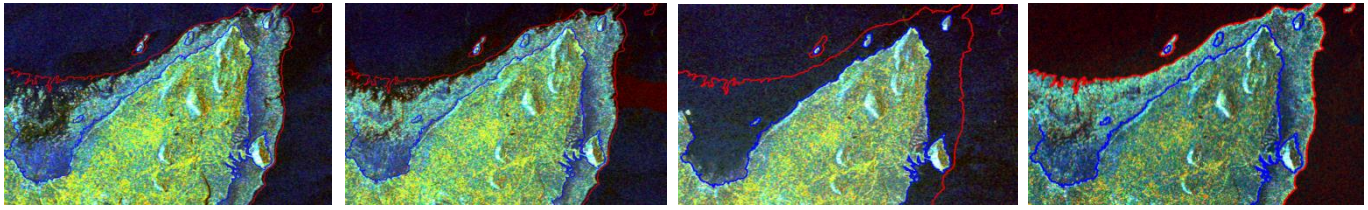
Shoreline and Intertidal Zone Extraction



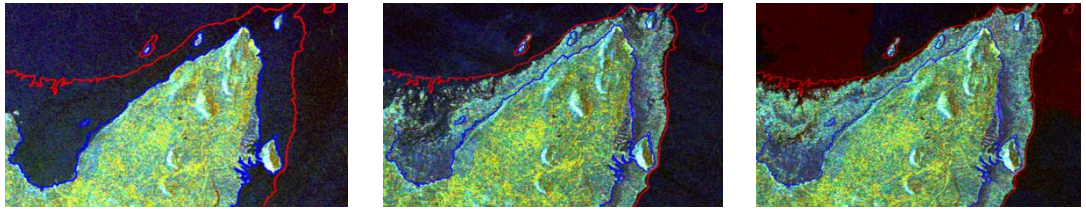


Shoreline and Intertidal Zone Extraction with RCM

- RCM compact polarimetry parameters may potentially be used to detect changes in rapidly changing costal areas such as intertidal zones due to the larger coverage and the high frequency revisit.



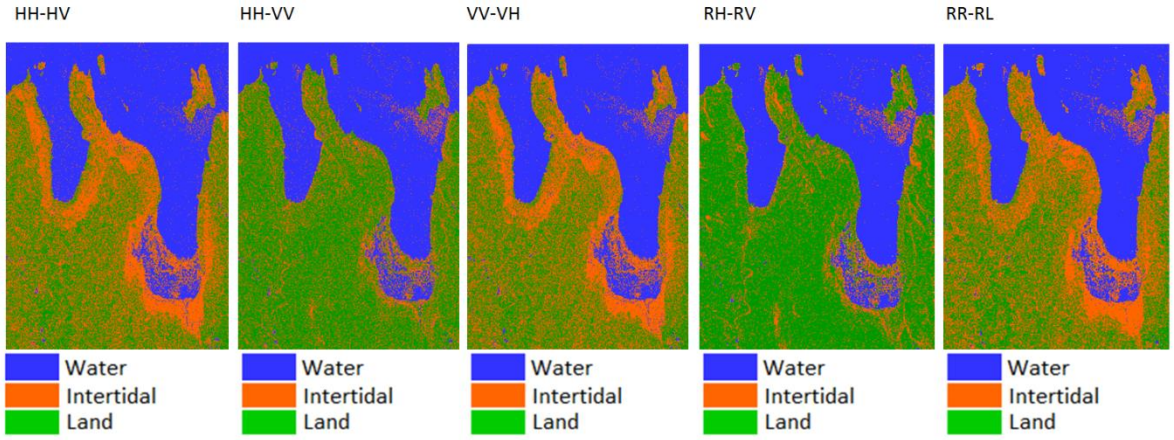
June 26, 2016 | July 20, 2016 | August 13, 2016 | September 6, 2016



June 21, 2017 | July 15, 2017 | August 8, 2017

m-delta parameters derived from RCM CP simulated product (5x5), NESZ: -25 dB

- RCM simulated products used for intertidal zone characterization: example of random forest classifier for different RCM dual polarization options.



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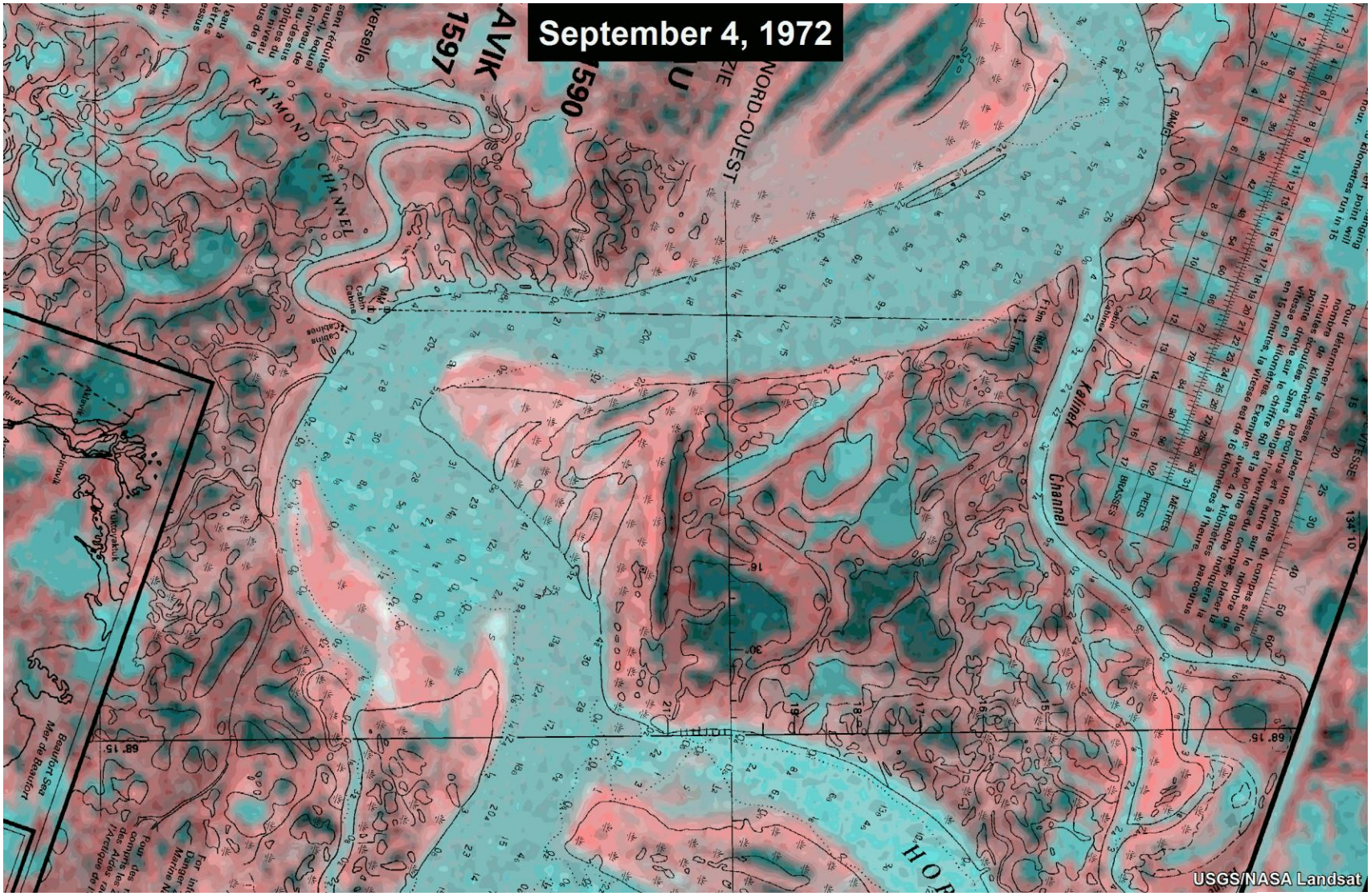
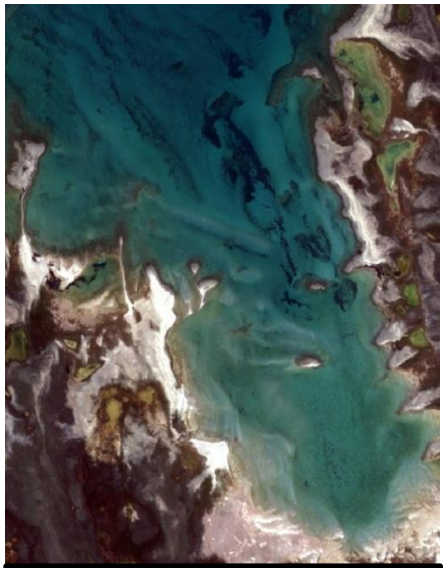
Change Detection



Satellite Derived Bathymetry: log-ratio



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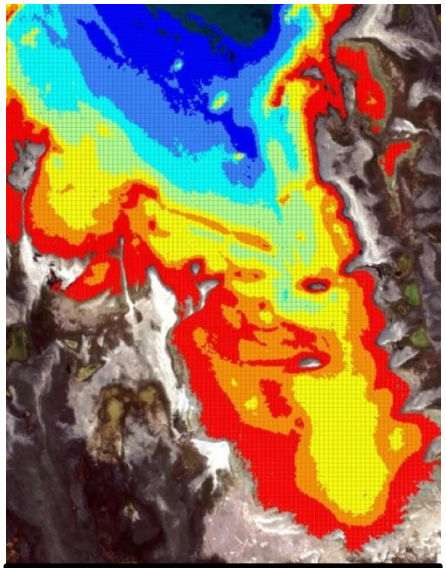


Image © 2012 DigitalGlobe, Inc.

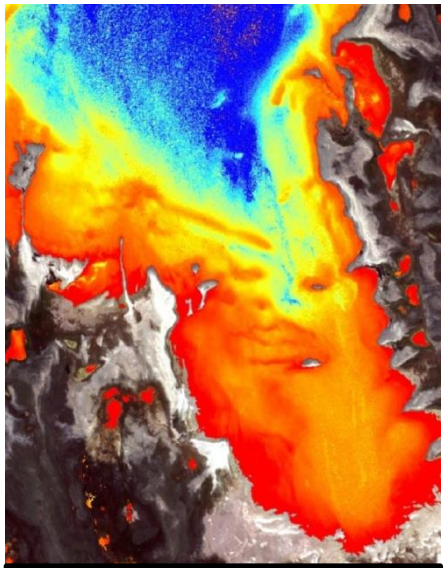
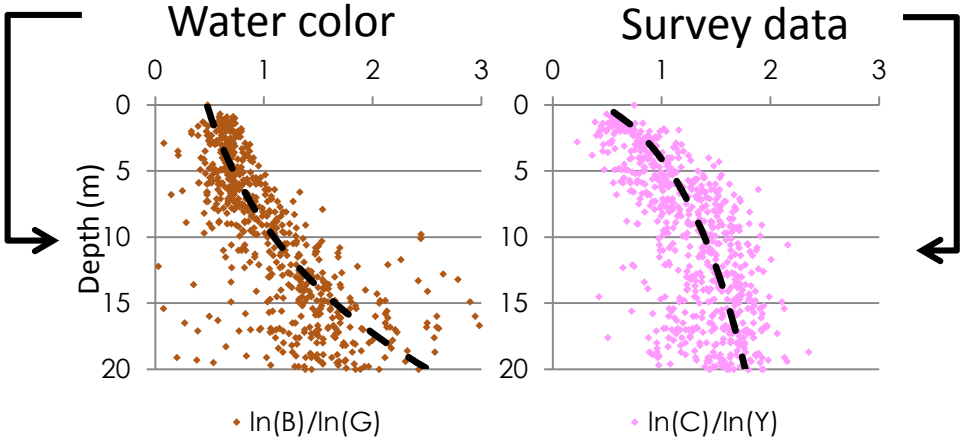


Image © 2012 DigitalGlobe, Inc.

SDB



Using pixel values, depth can be calculated in shallow waters following empirical models.

SDB offers a quick and cost efficient way for CHS to assess depth in coastal environments.

Canada

Satellite Derived Bathymetry: LookUp Table

The training data is used to generate a LookUp Table (LUT) to link the pixels band values to a characteristic depth for each specific set of values.

Yellow (Rrs) = 0.15

Green (Rrs) \ Blue (Rrs)	0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
0.05	25	18	17	12	13	NULL	15	NULL	NULL	NULL	NULL
0.10	22	22	16	14	12	14	NULL	NULL	NULL	NULL	NULL
0.15	19	21	15	12	13	12	13	12	NULL	NULL	NULL
0.20	NULL	19	17	13	11	11	12	11	NULL	NULL	NULL
0.25	NULL	NULL	15	11	10	11	10	10	11	NULL	NULL
0.30	NULL	18	12	9	11	10	9	8	9	NULL	NULL
0.35	NULL	NULL	13	10	9	9	8	7	7	6	NULL
0.40	NULL	NULL	NULL	NULL	10	8	7	4	3	3	NULL
0.45	NULL	NULL	NULL	NULL	9	5	5	2	1	1	-2
0.50	NULL	NULL	NULL	NULL	NULL	6	4	0	0	-1	-3
0.55	NULL	NULL	NULL	NULL	NULL	4	2	-1	-1	-2	-3

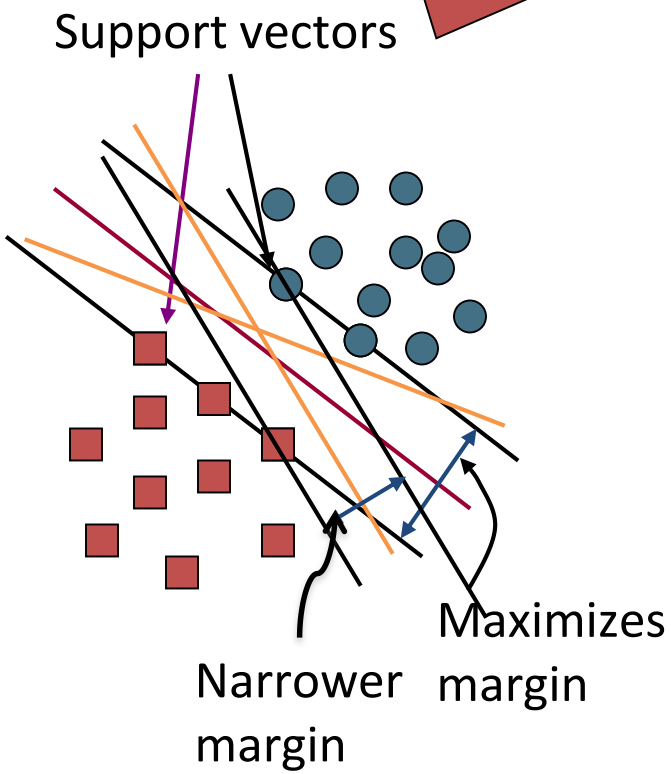
Support Vector Machine

- Supervised Machine learning algorithm
- Robust model for large number of variables and small samples
- Most cases **avoids "overfitting"**
- Finds an optimal solution for separating **"hyperplane"** (Linear decision surface)

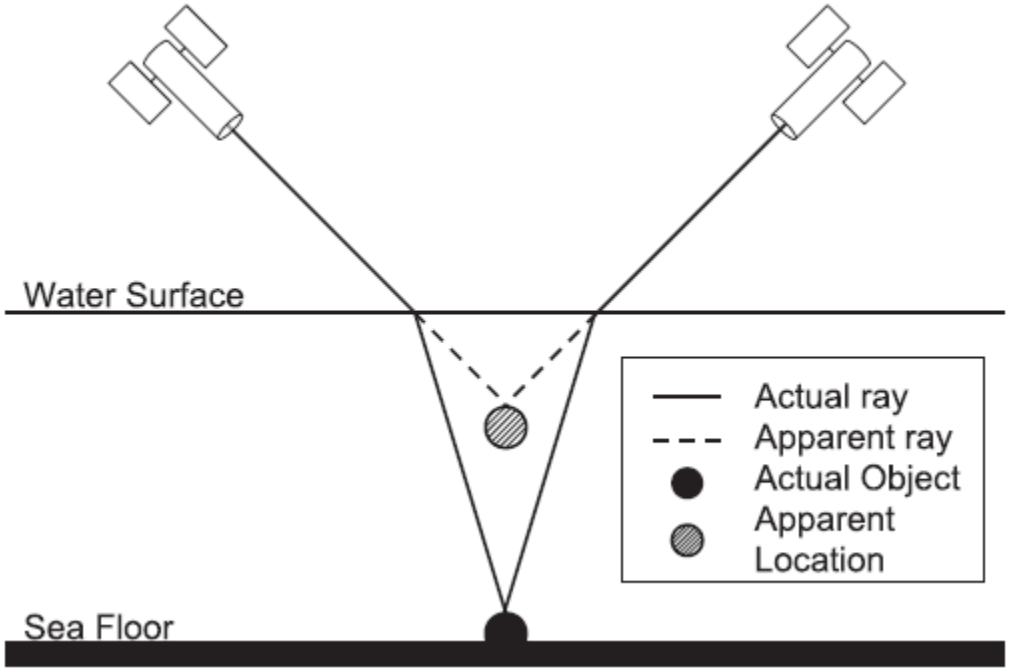
Lots of possible solutions for a, b and c

decision boundary:
$ax + by - c = 0$

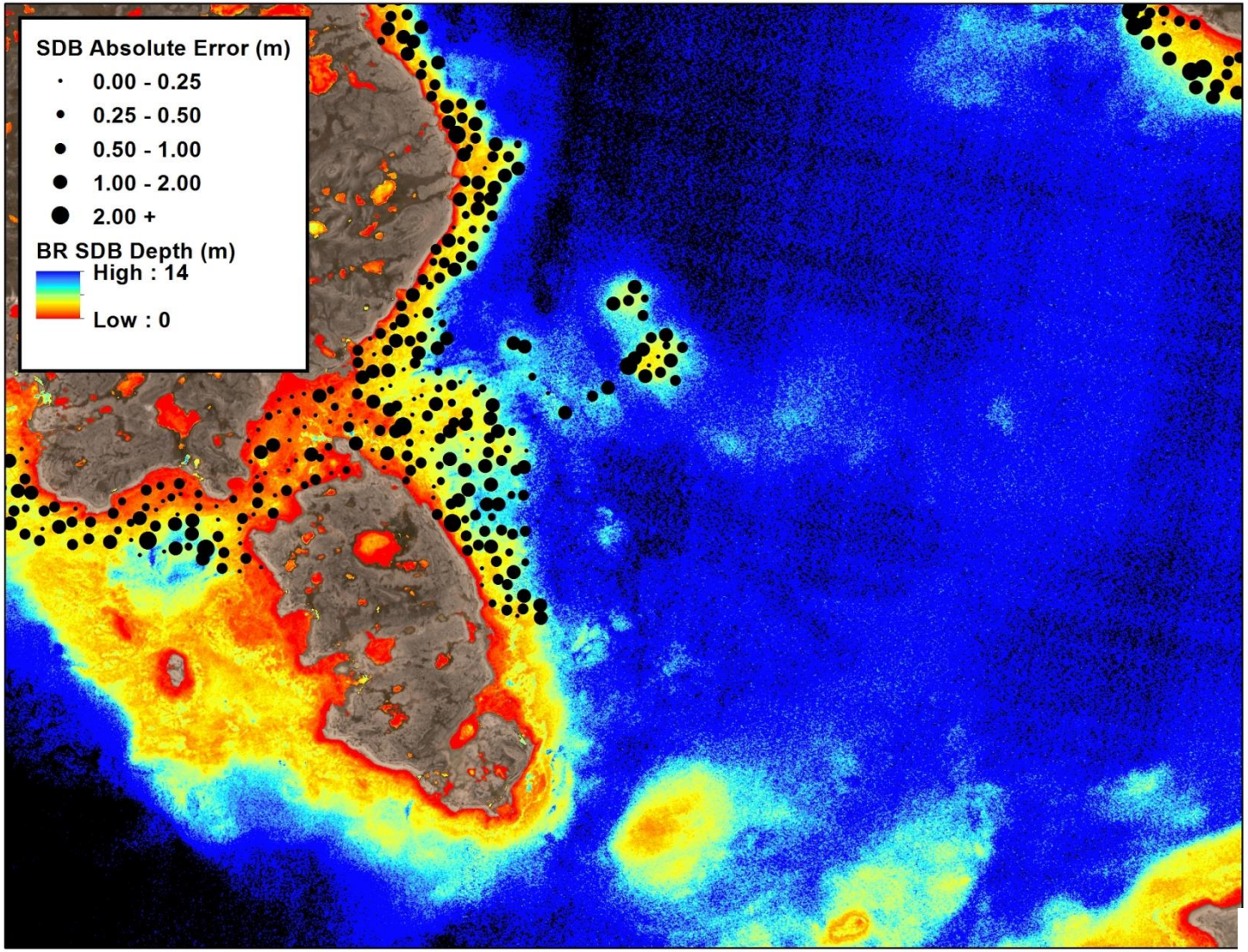
- SVM finds hyperplane that can separate two different classes and maximizes the margin between two border class objects (called "support vectors")
- Very effective for high dimensional spaces



Satellite Derived Bathymetry: Photogrammetry

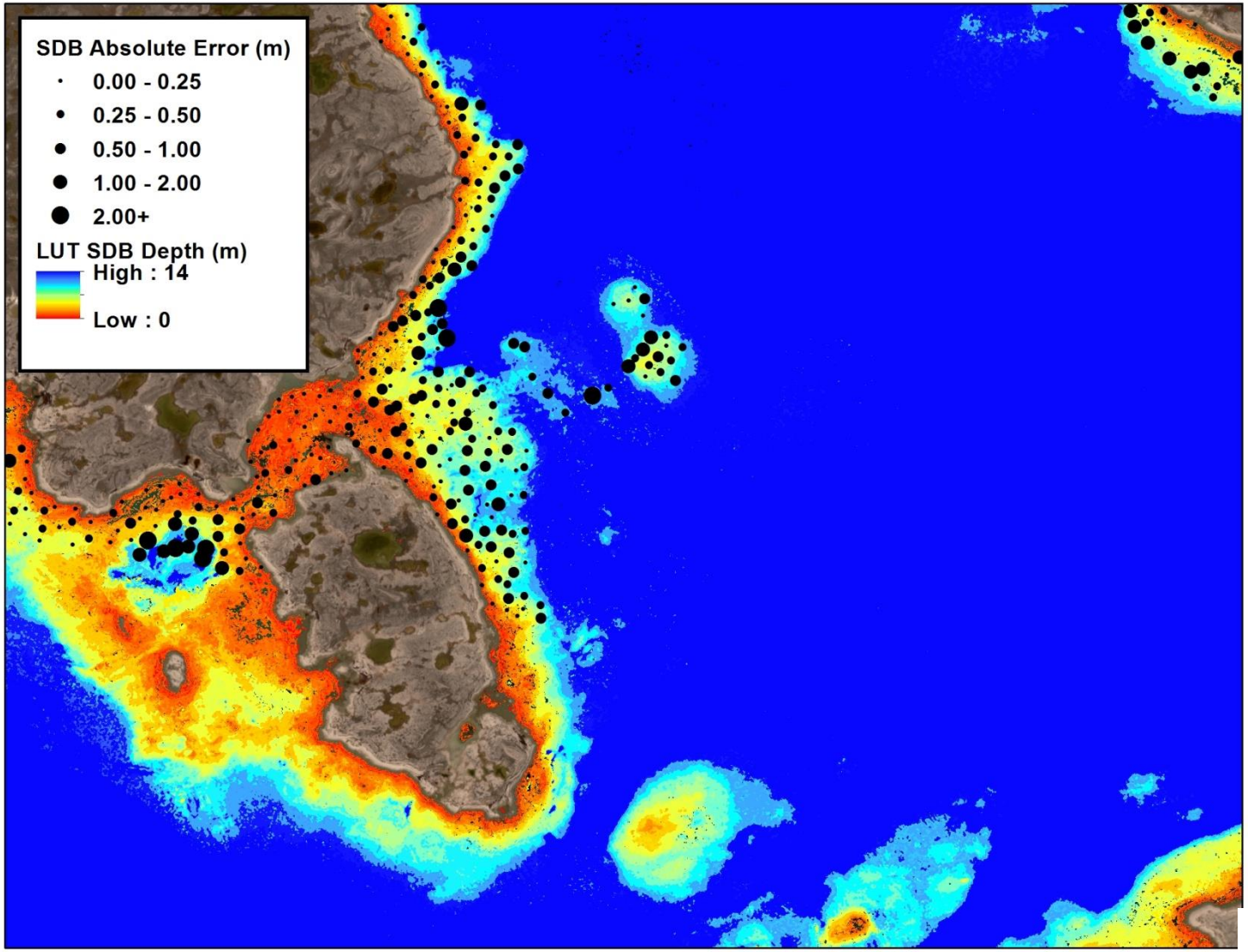


Band Ratio Model: Cambridge Bay

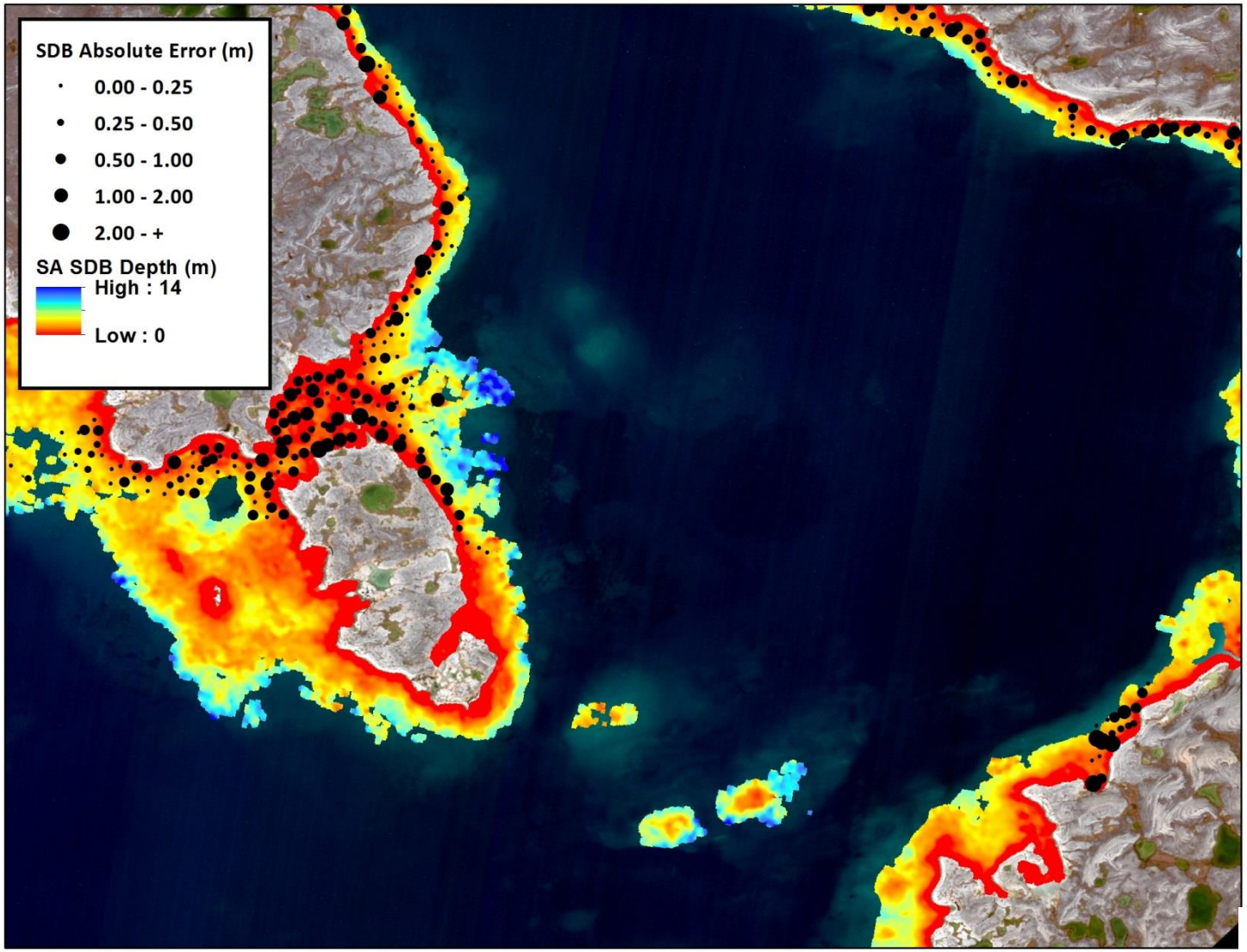


Canada

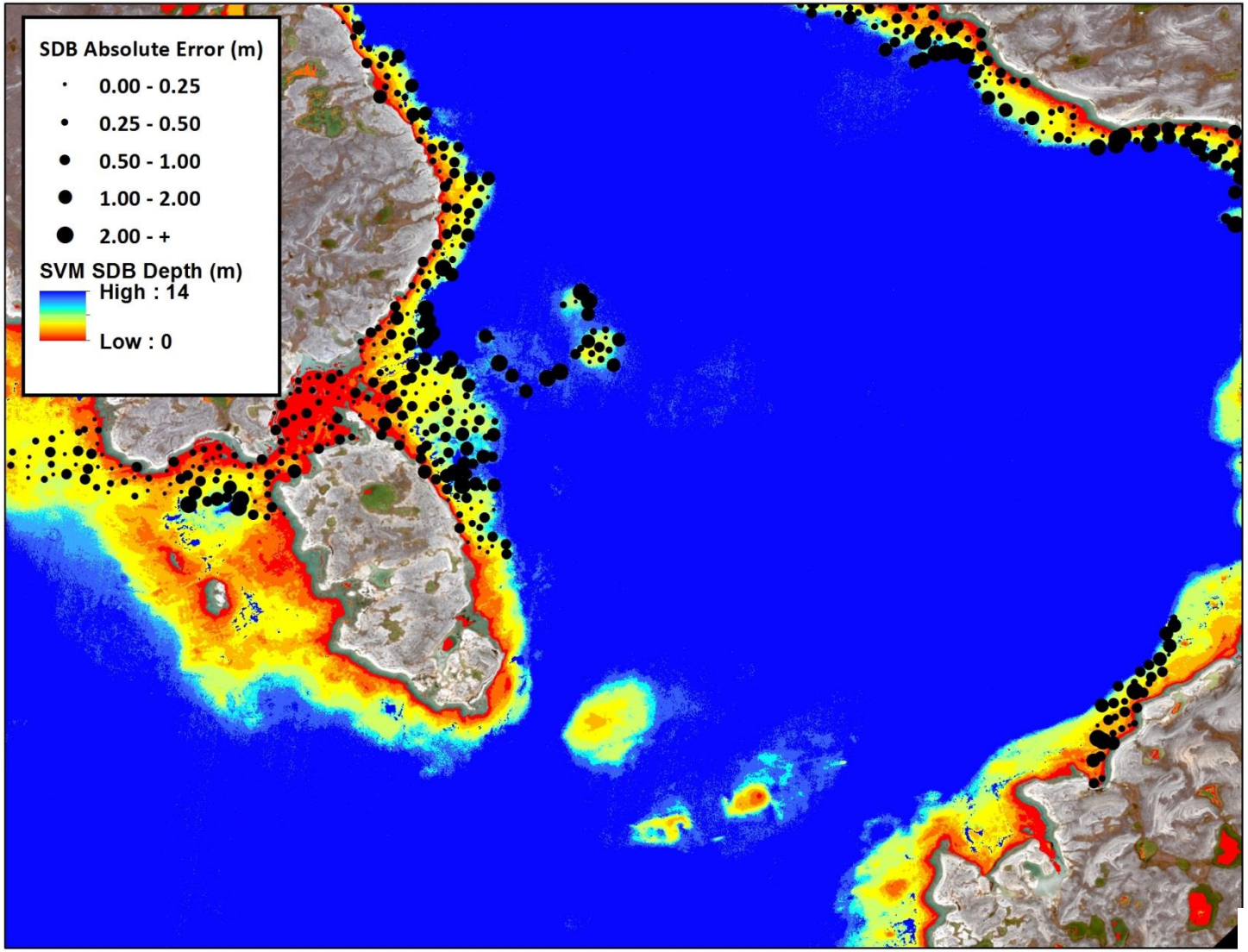
LookUp Table Model: Cambridge Bay



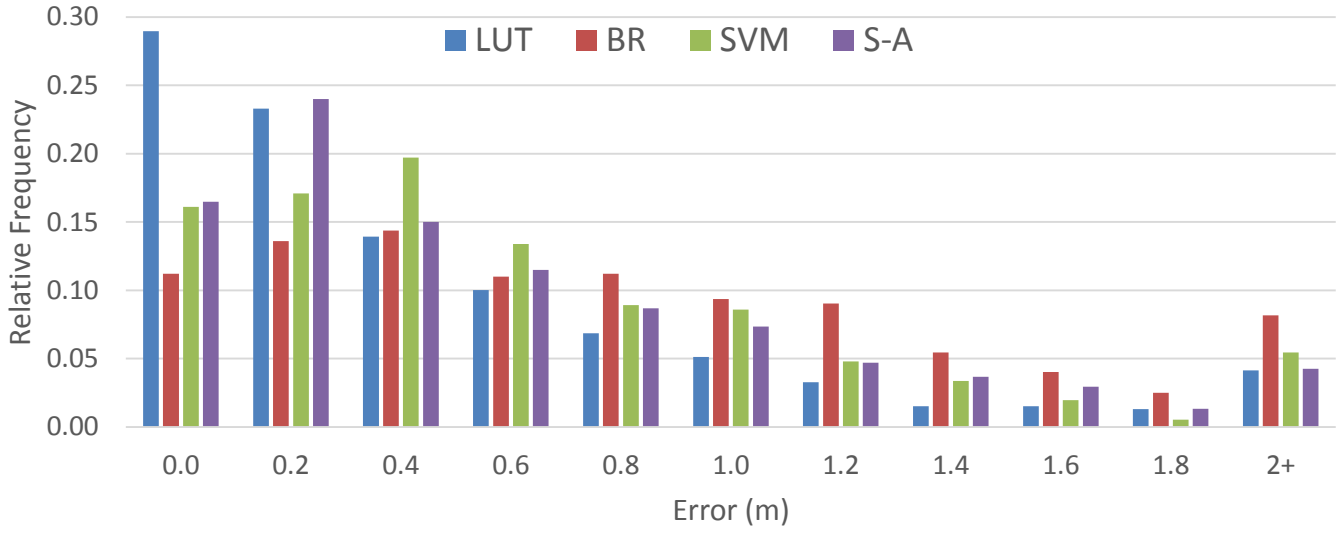
SA Model: Cambridge Bay

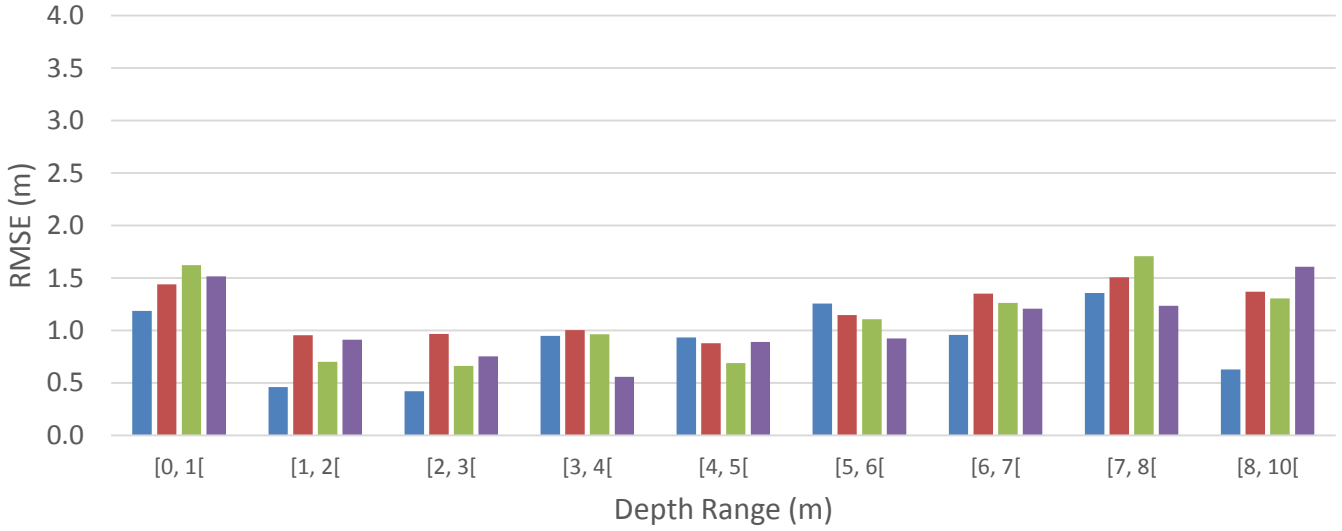


SVM Model: Cambridge Bay

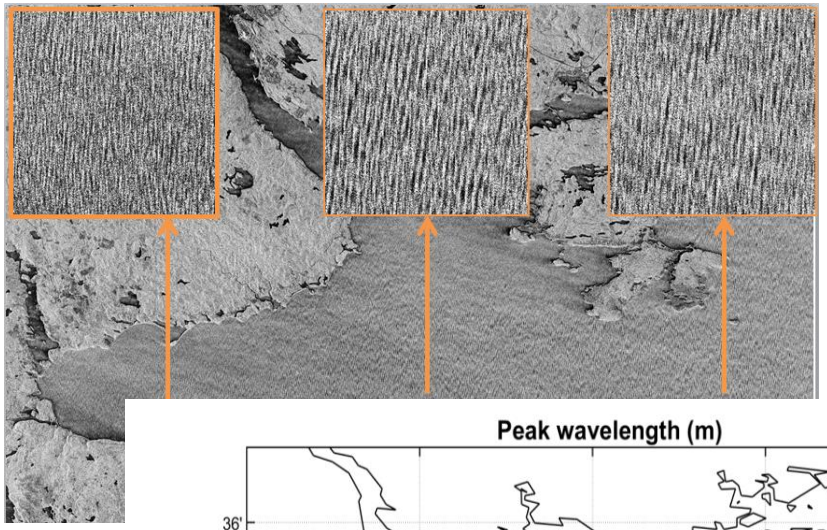


Satellite Derived Bathymetry: Photogrammetry

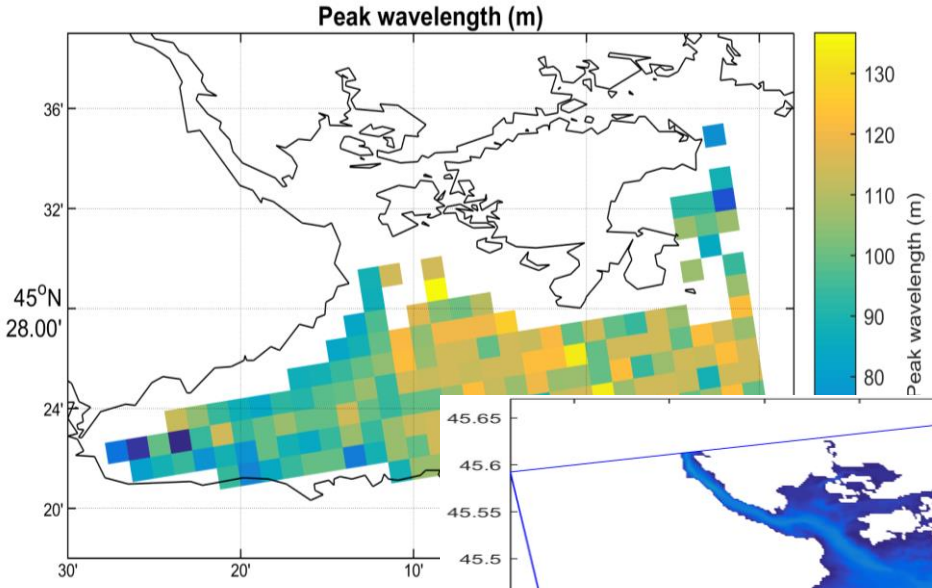




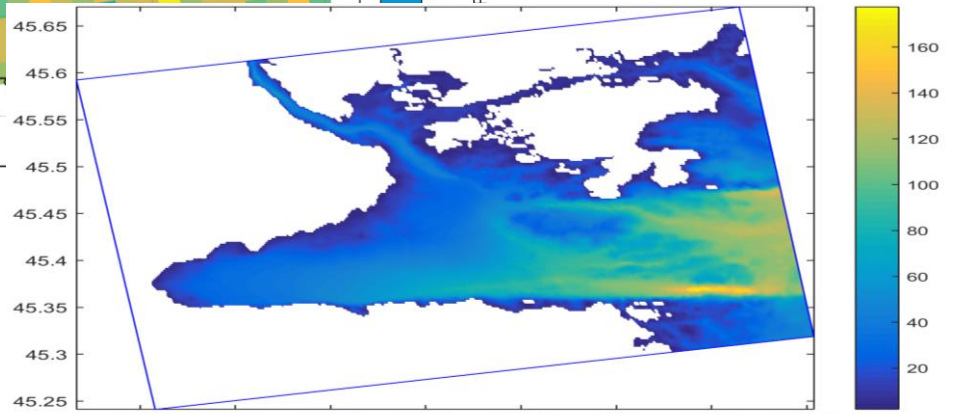
Wave Kinematics Bathymetry (WKB) from SAR



Bathymetry modulated surface wave features

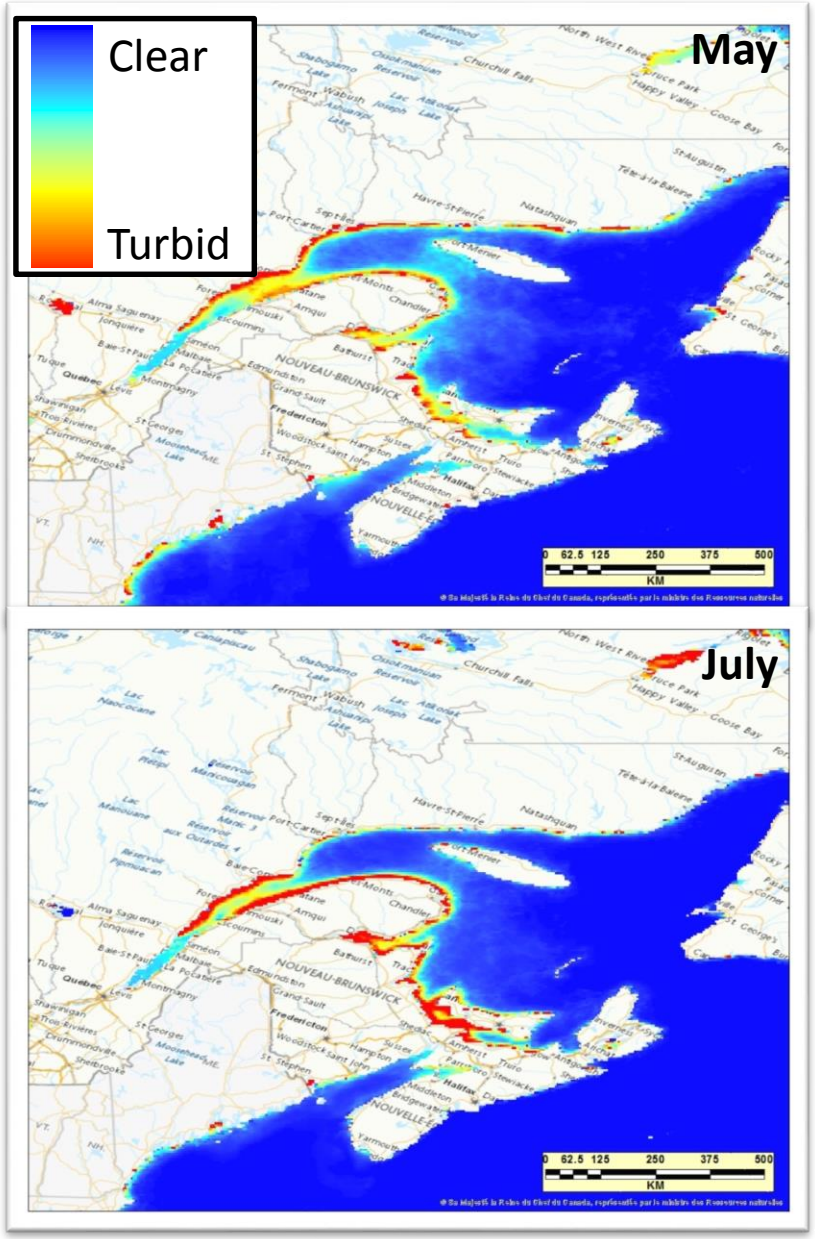


Retrieved wavelength from SAR image



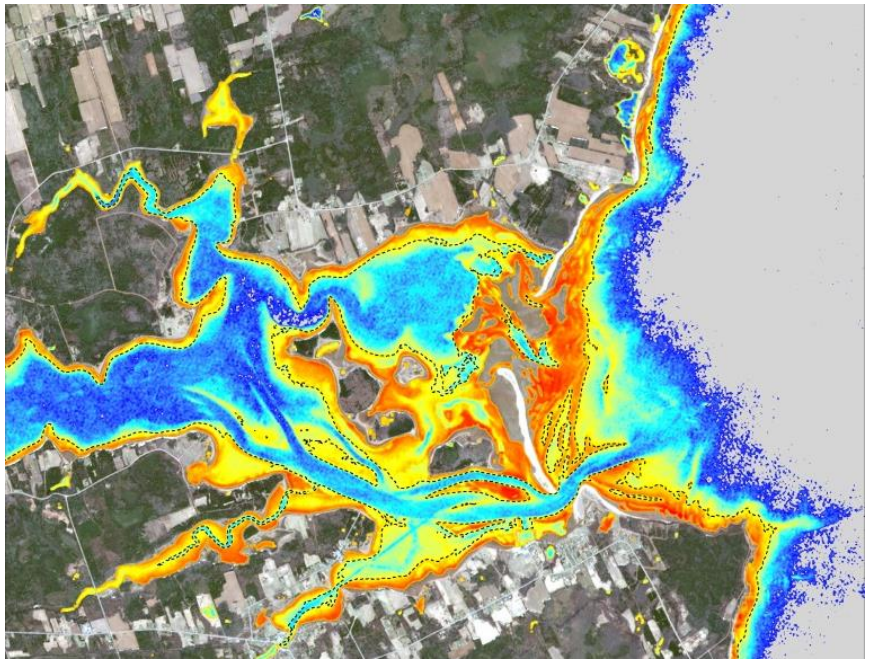
Retrieved bathymetry

Water Clarity: In support of LiDAR survey planning



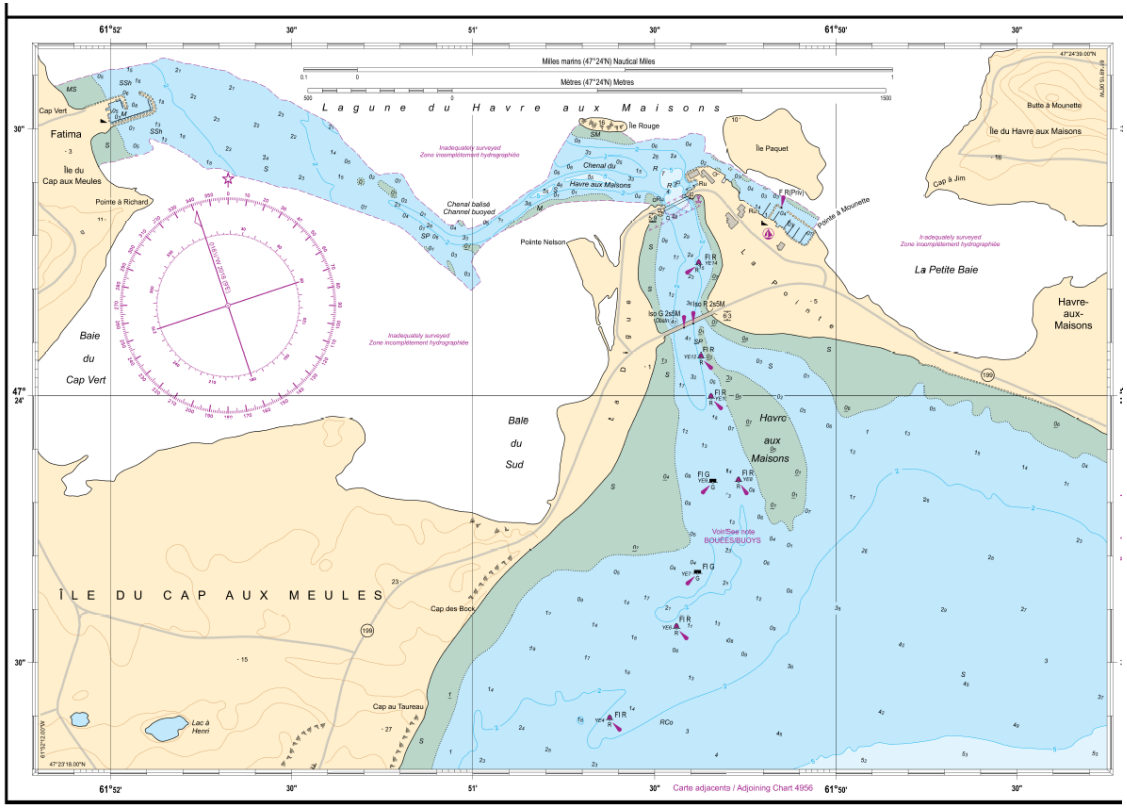
Concluding Remarks

- CHS is actively exploring multiple remote sensing approaches to support its chart production activities.
- Using optical and radar information.
- Aiming to assist with increasing use of remote sensing within international hydrographic offices.
- Hosting International Hydrographic Remote Sensing workshop – September 18-20, 2018 in Ottawa, Ontario, Canada.



Additional Slides

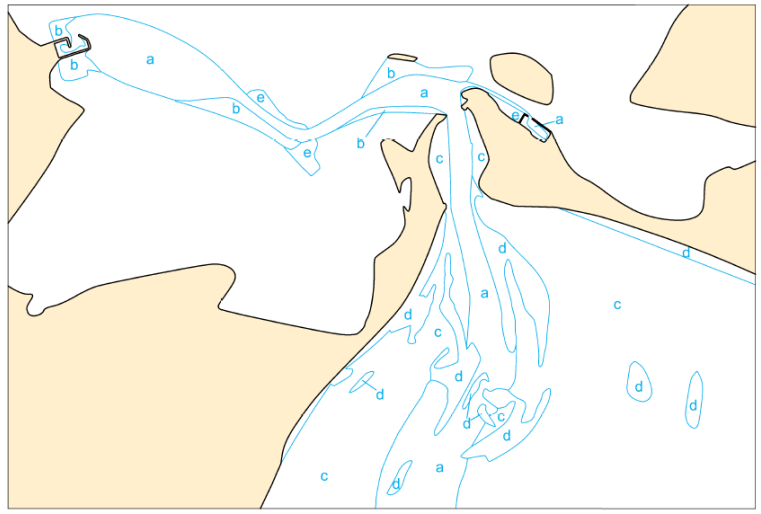
Chart 4955



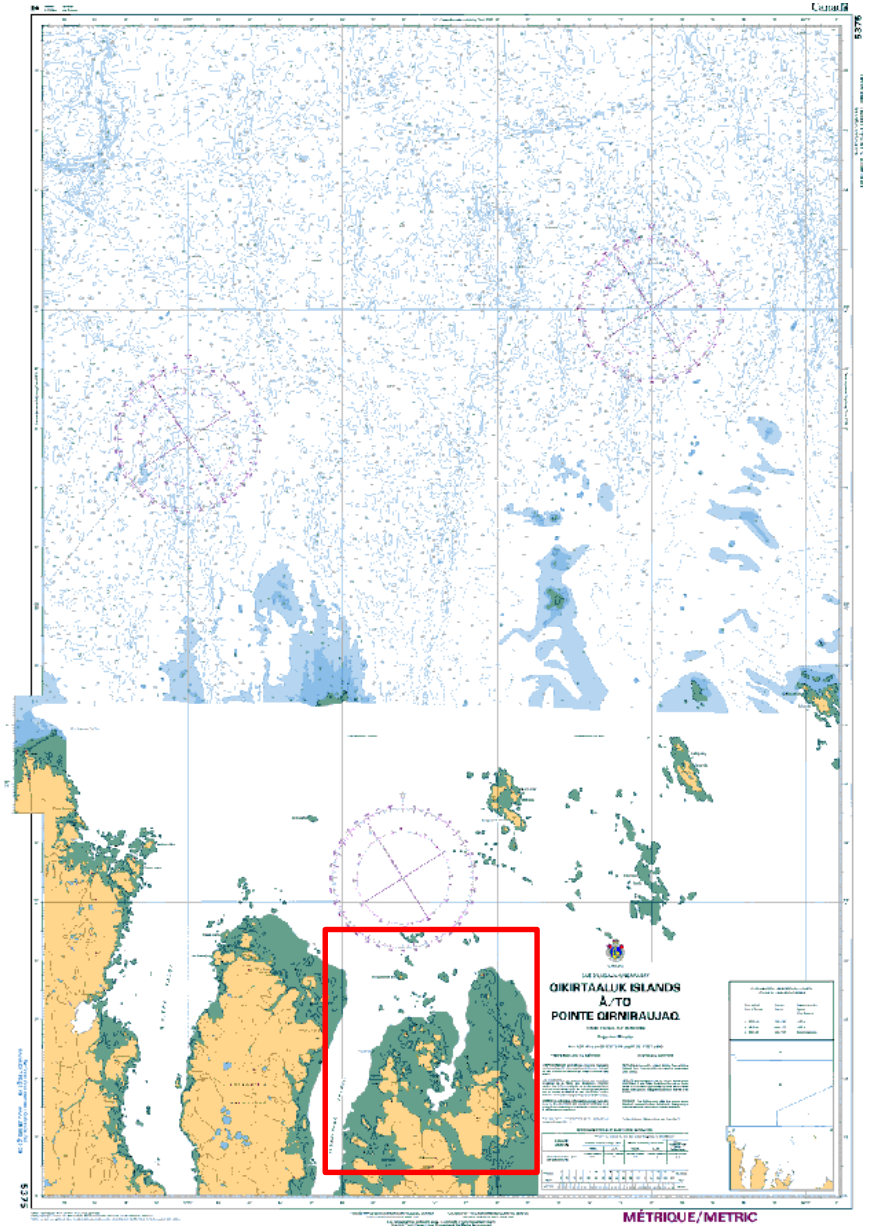
- First inclusion of SDB within a CHS source classification diagram.

DIAGRAMME DE CLASSIFICATION DES SOURCES / SOURCE CLASSIFICATION DIAGRAM

Zone/Area	Origine/Origin	Date	Espacement de lignes / Line spacing
a	SHC/CHS	2013-2016	Couverture totale / Complete bottom coverage
b	SHC/CHS	1983-1986	10 m
c	Gouv/Gov	2014	10-60 m
d	SHC/CHS	2016	Bathymétrie satellitaire / Satellite bathymetry
e	SPAC/PSPC	1985-1990	5-10 m



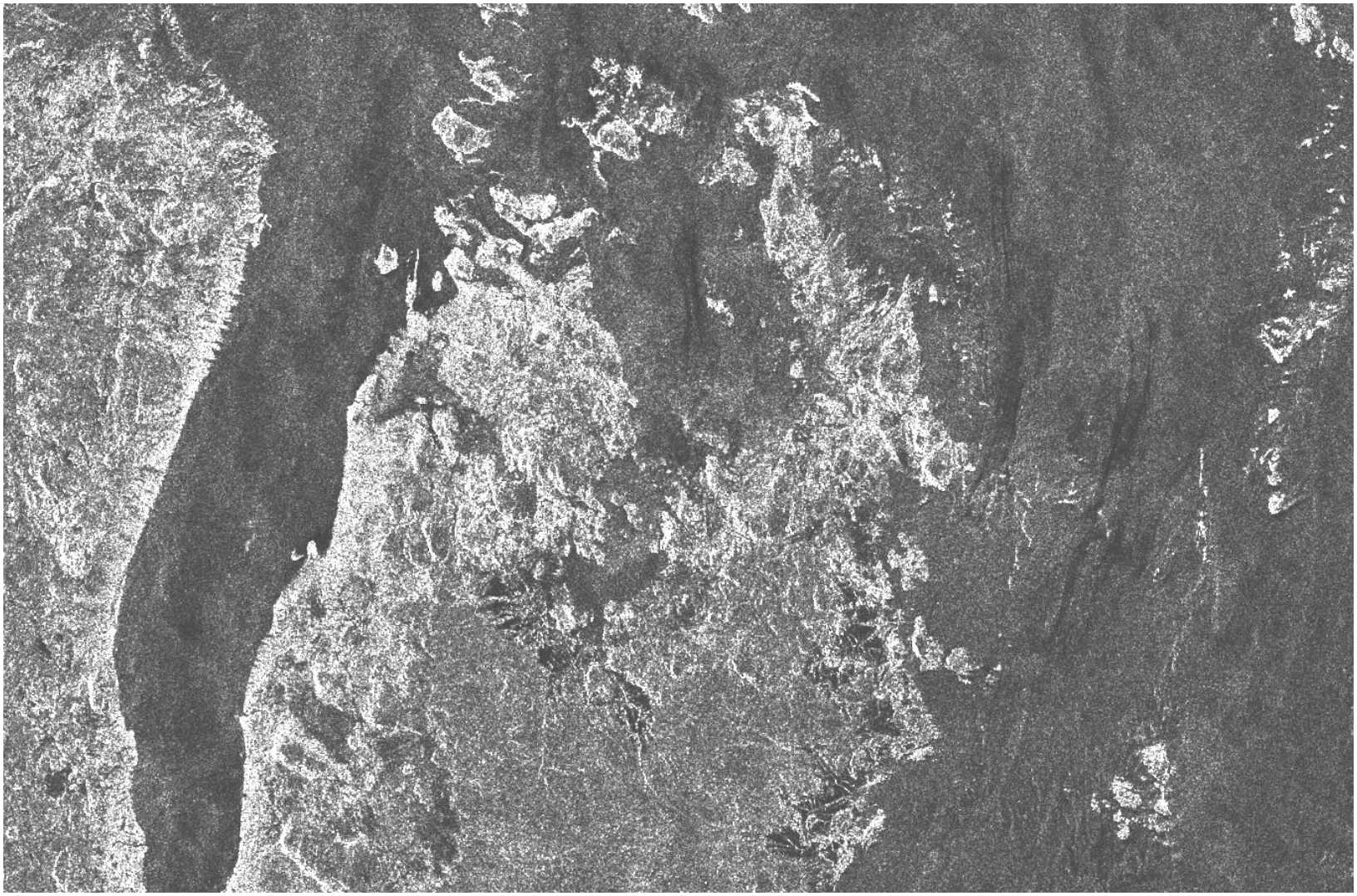
Example of Shoreline Extraction for Chart 5375 – Ungava Bay



Canada

RapidEye	July 17, 2014	16:52 UTC	5375	Riviere Koksoak	11.385 m

Sentinel-1	October 20, 2016	22:05 UTC	5375	Riviere Koksoak	0.483 m



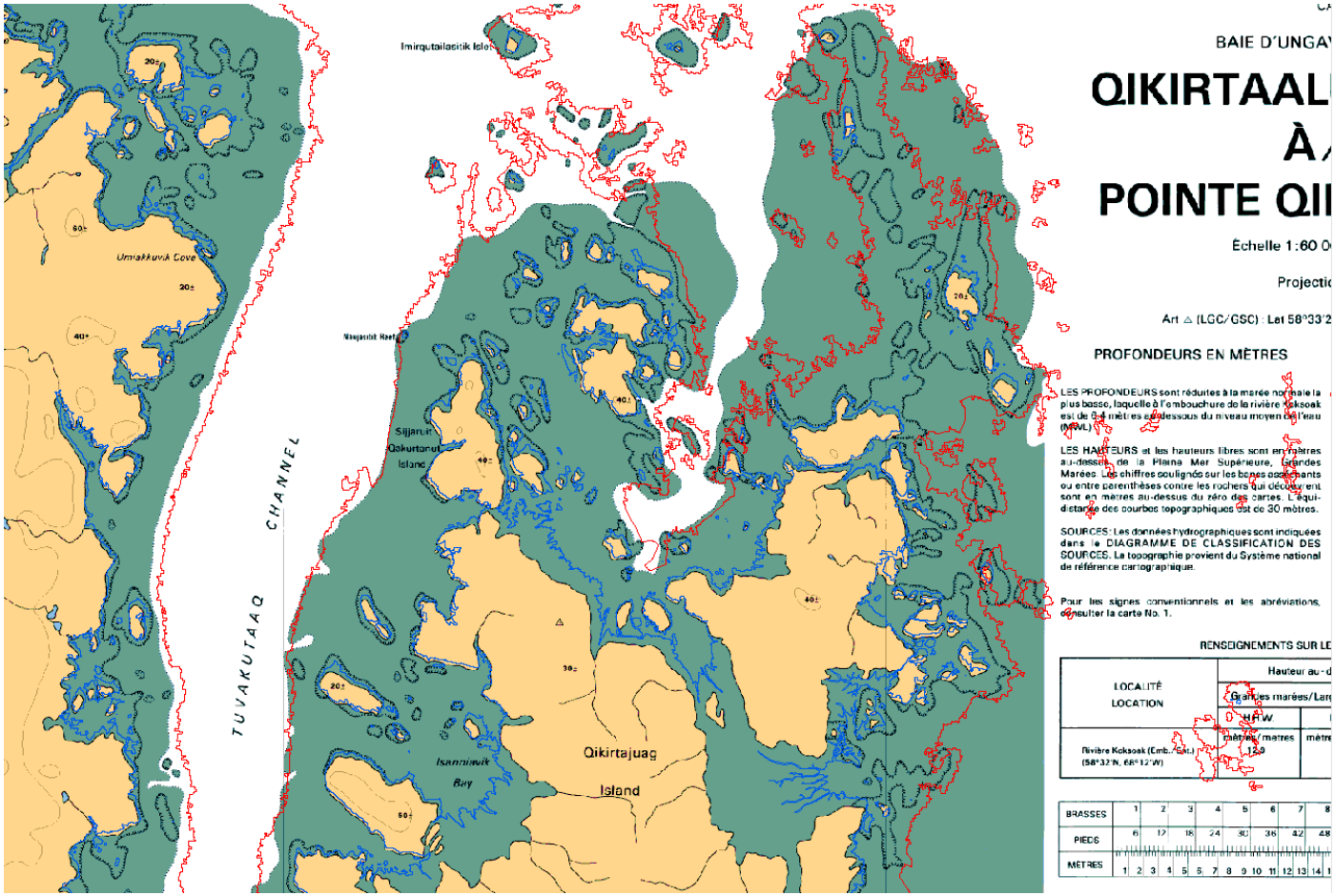
European Space Agency - ESA

Red line = Low tide

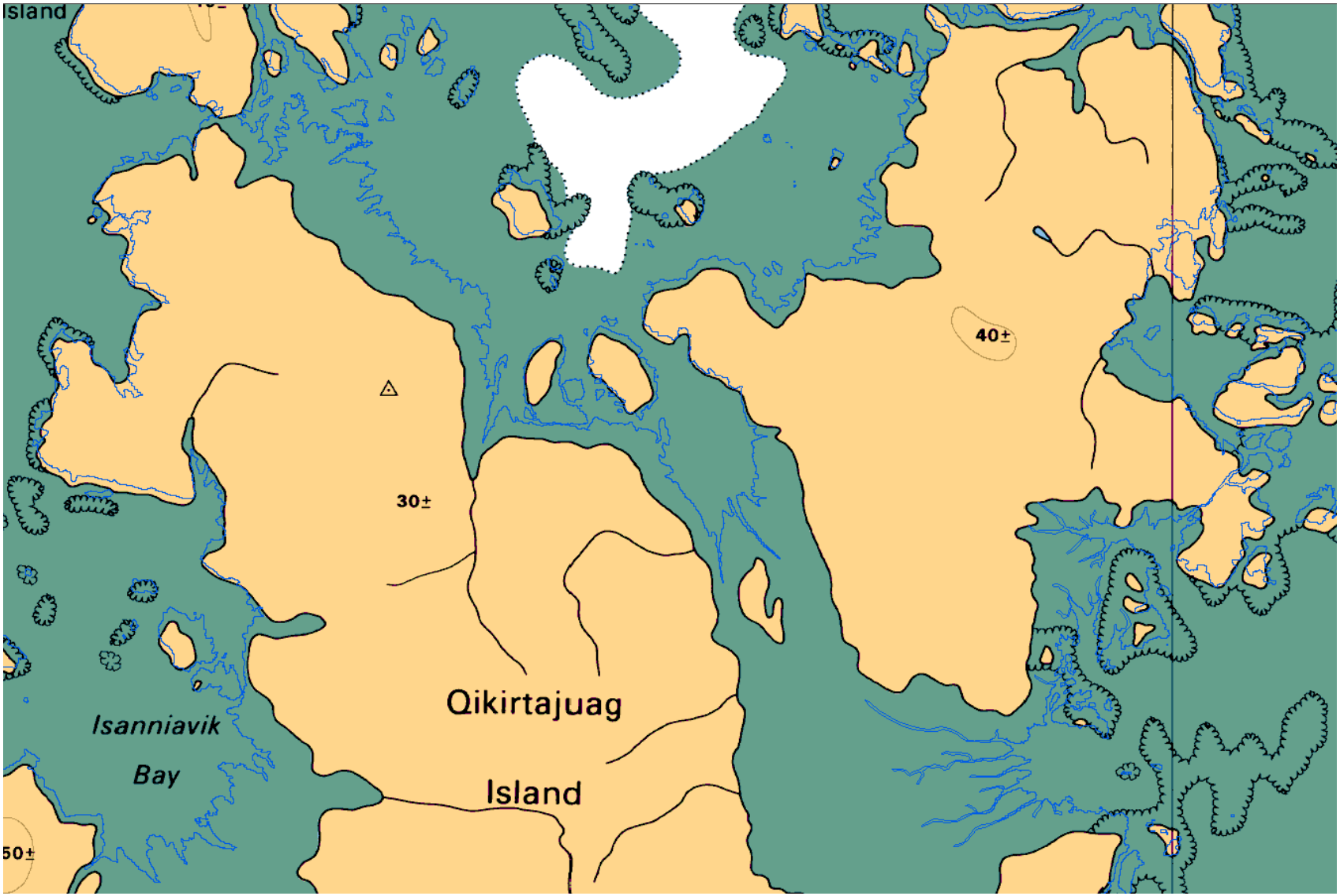
Blue line = High tide

Total Ungava Bay high tide length of ~11,276 km

Final Extraction



Final Extraction - High Tide Shoreline Change



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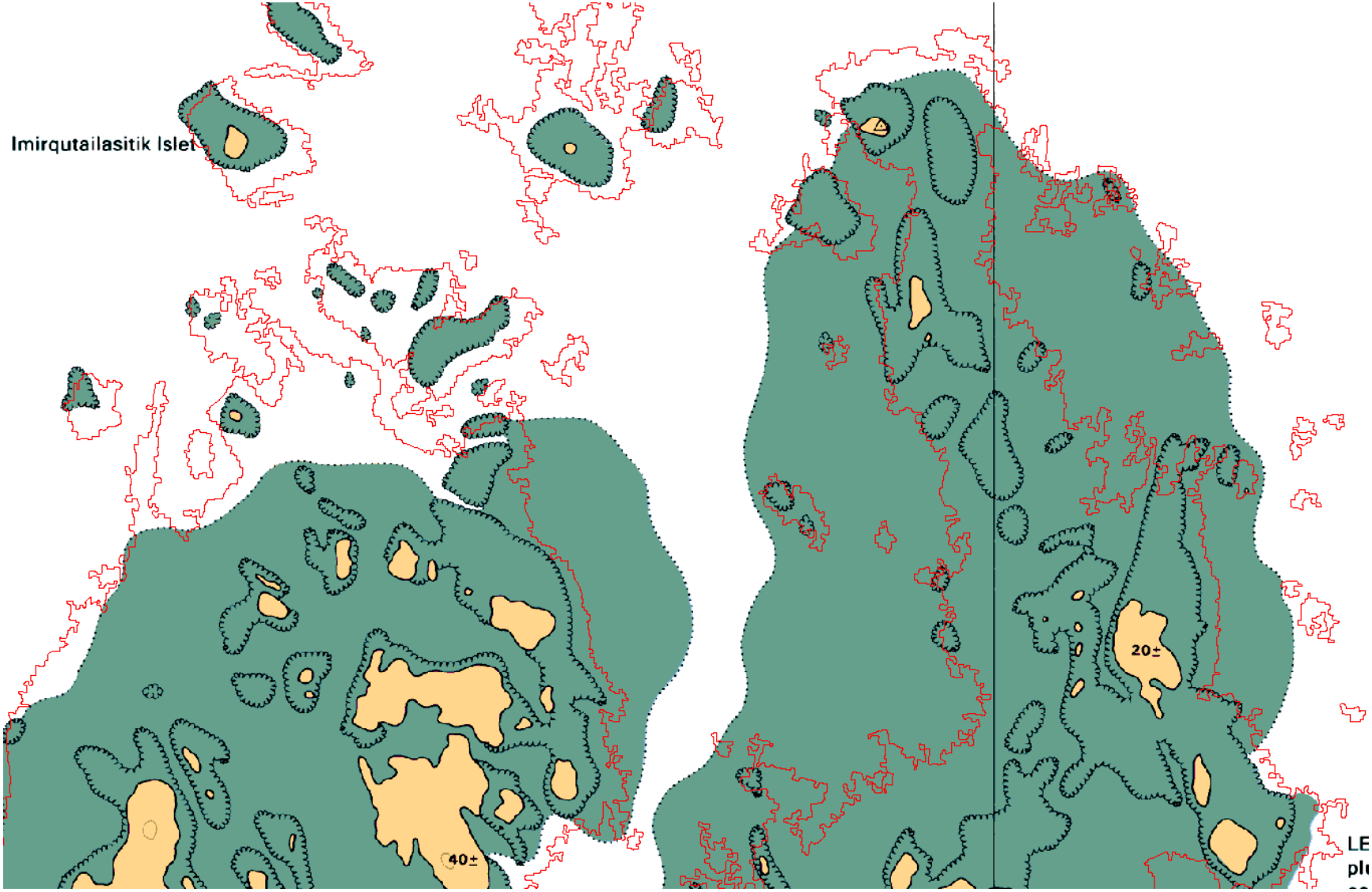
Final Extraction – Low Tide Shoreline Change



Canada