ATLANTIC COASTAL ZONE INFORMATION STEERING COMMITTEE

Inventory of Remote Sensing Technologies for Coastal and Ocean Management

Final Report (abridged)

ACZISC Secretariat

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Introduction

This report is the final deliverable in Environment Canada contract K4B20-14-0348-1 with the Atlantic Coastal Zone Information Steering Committee Secretariat to provide an inventory of potential remote sensing technologies that could support coastal and ocean management. The report describes how the inventory was developed, and discusses its implications**.**

Remote Sensing Technologies Inventory

The ACZISC Secretariat has prepared an inventory of over 53 different remote sensing technologies. The inventory provides basic information on the technology and in most cases a bibliography and links to useful websites. The technologies are divided into three classes: airborne, vessel borne or satellite based. Some technologies are mature (e.g. terrestrial LiDAR), and some are in development (e.g. Synthetic Aperture Sidescan). Some satellite based technologies are yet to be launched. Of particular interest in this last category is the development of "small satellites". An example of this is the Italian satellite PRISMA, scheduled to be launched in 2017, which combines a hyperspectral scanner with a panchromatic camera. PRISMA data could be very useful for a number of coastal applications.

Process for developing the inventory

The inventory was developed by soliciting expert advice to complete a template for each technology. An expert or experts were subcontracted for satellite based technologies, airborne technologies, and LiDAR. The ACZISC Secretariat Director developed the vessel based templates exploiting his experience with these technologies while employed by the Geological Survey of Canada. The various experts employed are detailed in the acknowledgements.

Implications of the inventory

At first inspection the inventory is overwhelming. No single technology is likely to be entirely adequate in providing all of the required data for each individual coastal application of interest. This means that multiple technologies may be required for one application in the coastal zone, i.e. flood mapping. Technologies can be combined either directly during data acquisition (e.g. mounting other sensors on an aircraft collecting LiDAR data) or post mission (e.g. merging contemporaneous satellite data with LiDAR data).

Automated classification of habitats, vegetation, land use is a complicated process best supported by multi-band sensors, either airborne for high resolution applications or satellite based for more regional applications.

Accurate storm surge and coastal flooding forecasting requires detailed bathymetry out to 20-30 m water depth to calculate the wave run-up contribution to the extreme water level. In most locations in Maritime Canada, this is unachievable using airborne bathymetric LiDAR. Multibeam and / or interferometric sidescan surveys either vessel mounted or AUV mounted are required to reach 20-30 m water depth.

Aerial photography and oblique photography have been included in the inventory because several applications have been already based on these technologies (e.g. historical coastline delineation and coastal change rates in PEI) and because the provincial governments have already made a significant investment in this technology. In addition, the Geological Survey of Canada (GSC) has acquired a complete oblique video survey of the coastlines of the Maritime Provinces which is in the public domain although now quite old (GSC Open Files 4428 (2002), 4020 (2001), 3656 (1998), 3301(1996), 2580(1992)). Some of this video has been manually interpreted and stored in a GIS. The GSC has used older navigation technology. Newer technologies can provide accurately georeferenced oblique images.

Future possibilities

Several future satellite sensors show promise for coastal applications. The airborne sensor PAL being tested by NASA for future satellite missions may be of particular interest for coastal applications. The “small satellite” developments like the Italian PRISMA may also have significant benefits for coastal applications especially if researchers and satellite developers can be encouraged to develop mission-specific for coastal applications.

The RadarSat Constellation Mission will provide new opportunities to exploit high resolution radar data with an increased revisit frequency.

The data from the European Sentinel series of satellites that includes a SAR sensor will be “free” to users under the European open data policy.

The analysis of sonar backscatter and sidescan information for habitat mapping is reasonably well developed discipline although still requiring expert interpretation of the image data and the collection of ground truth information through video, photography and sample collection.

The analysis of intensity and waveforms from LiDAR is not as mature but shows promise in a number of areas (e.g. eel grass mapping). This is still a research field that could be encouraged with pilot projects.

Coastal water levels from satellite altimetry is starting to be used for research in storm surge modelling and prediction and may soon become part of operational forecasts for extreme water levels.

Matching Coastal and Ocean Information and Data Interests with Remote Sensing Technologies from the Inventory

Table 1 shows an aggregated list of coastal and ocean information and data interests defined by a survey of the RCCOMcc conducted in early 2015 and the potential remote sensing technologies that could be applied to those applications. It should be noted remote sensing data alone is not sufficient to meet the needs of the applications of interest. In all cases the collection of ground truth or calibration information is also required.

Table 1: Potential remote sensing technologies related to coastal and ocean information and data interests (coastal applications).

Coastal Application	Potential Remote Sensing Technologies
Elevation / Bathymetry / SAR DEMs / Satellite derived bathymetry	Hyperspectral / Thermal (airborne several sensors) / Bathymetric / Bathy-Terrestrial / Terrestrial LiDAR / High Resolution Optical Satellites (WorldView-3) / SAR satellites
Water levels (incl. tides, sea-level, storm surge) / Sea surface height and currents	Terrestrial LiDAR / Satellite altimeters (Jason-3)
Local historic and forecasted high tide events	See water levels above
Erosion / Accretion / Map and track temporal impacts / Satellite derived vector shoreline	Aerial / Oblique Photography (Airborne) / High resolution panchromatic satellite / Terrestrial LiDAR / SAR satellite
Habitat classification (wetland)	Hyperspectral / Thermal (airborne or satellite several sensors) / SAR satellite
High resolution habitat mapping (location, classification and extent) / Habitat change detection / Habitat inventory / Distinguishing vegetation states	Hyperspectral / Thermal (airborne several sensors) / High Resolution multi-spectral satellites / SAR satellite
Lake algal monitoring	Hyperspectral / Thermal (airborne several sensors) / High Resolution multi-spectral satellites
Flood extent mapping / Hydraulic model	Terrestrial LiDAR (elevation and river water level) / Coastal altimetry (Jason 3) coastal water levels / Bathymetric LiDAR / Multibeam bathymetry (wave run up modelling, bottom type for bottom friction)
Impervious surface	Terrestrial LiDAR / High resolution multi-spectral satellites / SAR Satellite
Sources/location of fill	High Resolution multi-spectral satellites
Feature mapping / Coastal delineation/classification Coastal infrastructure	Aerial / Oblique Photography (Airborne) / High resolution optical satellites
Bottom classification	Bathymetric LiDAR (intensity,waveform analysis) / Multibeam Bathymetry (back scatter) / Sidescan and interferometric and synthetic aperture sidescan
Water quality monitoring (impact of run-off) / Penetration of water and below subtidal	Hyperspectral / Thermal (airborne and satellite several sensors)
Land-use	High Resolution multi-spectral satellites / Terrestrial LiDAR (3D buildings)
Higher resolution ocean colour (to assess coastal productivity, spill and aquaculture effects)	Hyperspectral / Thermal (airborne several sensors) / EU Sentinel satellites (2015-)
Snow depth / Ice in rivers	SAR satellite
Sea ice	SAR satellite

Airborne and satellite based technologies and their applicability to coastal applications are summarized in Tables 2, in Appendix 1 and Tables 3, and 4 in Appendix 2.

Considerations Arising From the Inventory

The scope of this contract is limited: a detailed needs assessment is still required. The needs assessments could be done individually by the various federal and provincial departments or through RCCOMcc members and then compared for overlap and possible collaboration on product development and data acquisition or it could be completed together. If done individually, results should be compared at each step so that overlaps and collaborative opportunities could be realized at an early stage. Suggested components of the needs assessment are outlined below:

1. **Policy / Regulatory drivers:**

   The needs assessment should first identify the policy / regulatory / and / or departmental mandate needs for information. (e.g. Aquaculture Strategy)

2. **Products needed to meet policy / regulation:**

   To meet the information needs described above, what specific information products are required? A product could be a single entity like a map or series of maps (e.g. map of aquaculture leases), a data base of products derived from processed data (e.g. primary productivity maps / images for coastal inlets) or an interactive computer application that uses a data base for forecasting or sensitivity analysis (e.g. risk assessment tool for aquaculture siting).

3. **Processes to develop products**:
   What are the evidence-based process choices for developing products? Should they always be processes that are already operationalized or are research choices acceptable? Do the research choices require pilot projects?

   The processes for developing the required products may not be obvious. Examining practises of other jurisdictions may be useful but would have to be evaluated for the appropriateness of application in Maritime Canada's coastal zones. Deciding on an approach will require some literature searching and consultation with local and international experts. If upon conducting the research no obvious process is already in use, establishment of pilot projects to examine approaches would be required, possibly through partnerships with local university and college researchers.

4. **Data required for product development:**

   Upon deciding upon product development approaches or pilot projects, the data required to support the product development or pilot project will need to be determined. There may be more than one approach for a product that may require different types of remote sensed or other data.

Example Needs Analysis Work Flow:

*1. **Regulation:** coastal development set-back*

*2. **Products:** 1. Spatial data base and publicly available maps of historical shoreline change and rates of erosion or accretion on a scale suitable to support the regulation. This product would need to be updated on a regular basis to monitor for changes in rates. 2. Erosion sensitivity map (needed because the historic record may not be adequate to define erosion risk in a changing climate)*

*3. **Processes:***

1. PEI shoreline change mapping after (Webster and Brydon, 2012) – important to be consistent in shoreline delineation and use tide corrected images.

2. After Shaw 1998 (J. Shaw, R.B. Taylor, D.L. Forbes, M.-H. Ruz, and S. Solomon. 1998. Sensitivity of the Coasts of Canada to Sea-level Rise. Geological Survey of Canada Bulletin 505. Ottawa.) and Catto 2012 Coastal Erosion in Newfoundland.

*4. **Data:***

1. Series of High resolution colour aerial photos accurately georeferenced, could be high resolution satellite imagery for more recent time periods

2. Data for all the sensitivity index parameters

There may be cost and resolution trade-offs that would influence the final decisions on data acquisition.

5. Existing data in the hands of government partners in the Maritimes and elsewhere:

Some of the data required to develop products or a pilot project may already be in the possession of RCCOM agencies or other organizations in the Maritime Provinces. A search for this existing information would be significantly facilitated by collaboration between agencies to develop and maintain a shared catalog of existing data sets. The federal government is developing the National Earth Observation Data Framework & Catalogue which may be very helpful in discovering satellite sensor data that has already been acquired by the Government of Canada.

Campaign planning

If a coordinated approach is the objective of discussions on remote sensing, data acquisition, campaign planning is required. Priorities need to be set on which products over which geography. The partners in each product or geographic location would be determined by alignment with RCCOM member mandates. A risk based approach might be a useful method to assist in the determination of the priorities. Dr. Ron Pelot at Dalhousie University Faculty of Engineering is an expert in risk assessment in the coastal and marine environments and could be approached to assist in a risk based approach.

Project Planning – for each data acquisition

For each type of remote sensing technology in the inventory a section on considerations is included. For those technologies that require a platform (aircraft or vessel), planning should begin with a comprehensive desk top exercise to ensure data acquisition will meet the standards needed for the application (i.e. density of survey lines, amount of overlap, etc.). Since weather can play an important role on the success of an expedition, alternative survey locations should be planned so mobilizations costs are not wasted.

For some satellite based technologies (i.e. Radarsat), the satellite may have to be tasked to acquire the data needed (i.e. specific Location, time of year, low tide etc.).

Acquiring satellite data that has already been acquired may be facilitated through the National Earth Observation Data Framework & Catalogue.

Resources Needed

1. Data management requirements

   The requirement for creating a sufficient level of metadata on the data acquired will be important for understanding the processes used to develop products. It is also necessary for future discovery of the data's existence and to prevent duplicate data collection and costs. The appropriate data management infrastructure needs to be in place, with the data stored, archived and accessed in standardized formats and data bases.

Data processing / analysis requirements

   Many of the products will require sophisticated data processing systems and expertise in data processing techniques. This is particularly true for the automated classification of satellite and airborne imagery and point cloud processing for multibeam and LiDAR data. Once established through literature search or pilot project, the data processing techniques for each product should be established and used consistently over time to allow for effective inter-comparison over time. If changes in the established data processing regimes are required due to changes in technology or improvements in algorithm, comparison between old and new processes should be conducted and documented. Forward and backward interoperability of data formats should be maintained wherever possible.

2. Product development and dissemination

   The products developed (not necessarily the data) should be widely available for external users in widely accepted formats and internet services.

3. Evaluation

   A formal program of evaluation of the products and their impact on the regulatory, policy or mandate objectives should be established.

Acknowledgements

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Terrestrial LiDAR – Taylor Davis, Terra Remote Sensing Inc.

Aerial Photography - Emma Mathieson, Leading Edge Geomatics