GEOLOGICAL SURVEY OF CANADA
OPEN FILE 7404

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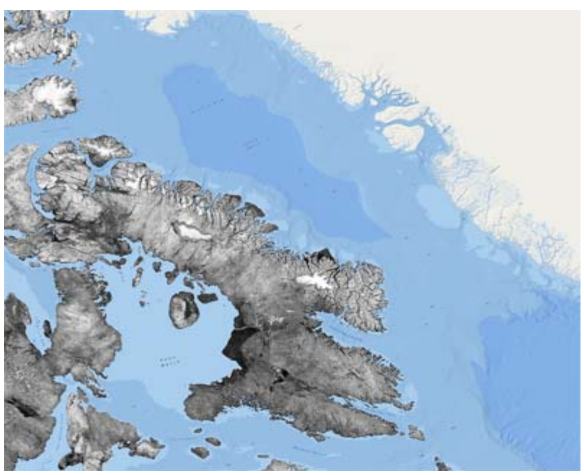

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Database of suspect oil seeps in the marine environment of Baffin Bay and Davis Strait, Nunavut, identified from a survey of RADARSAT-2 data

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Cover Image
Radarsat-1 mosaic created by CCRS in partnership with CSA with bathymetry from GEBCO, NOAA, National Geographic, DeLorme, and ESRI. Image spans across 2600 km.

Background

Satellite radar technology is employed for the detection of natural seeps in petroleum basins around the world because of the association of natural hydrocarbon seepage and subsurface accumulations of oil. Although the relationships are variable, natural seepage of hydrocarbons occurring from offshore petroleum fields has been recognized and proven significant for the exploration and discovery of active petroleum systems, particularly in the Gulf of Mexico (e.g. Sassen, 2000; Hood et al., 2002). 2D and 3D seismic, airborne geophysics, and marine-based exploration wells are costly exploration methods. Space-based imaging with synthetic aperture radar (SAR) on the other hand, enables wide areas of the offshore to be assessed for the presence of seeps as evidence of active hydrocarbon systems at relatively low cost (e.g., MacDonald et al., 1993; Williams and Lawrence, 2002; Miranda et al., 2004). The location of detected seeps and areas of suspected seeps enables these features to be placed within a regional interpretive framework.

Purpose

In Canada, very few seep investigations have been published in the open literature, particularly from the eastern Arctic where active petroleum exploration ceased about thirty years ago. The objective of this report is to present some results of dark features extracted from ocean SAR images collected during the years 2010-2012 with RADARSAT-2 in Baffin Bay and the Davis Strait (Figure 1). These features are of interest because they may be expressions of surfactants and one interpretation is that they originate from hydrocarbon seeps on the sea floor. The database presented can be used to guide follow up investigations in some areas of interest. Data from RADARSAT-2 with a Wide 2 beam mode were employed in this project (Two Standard Quad-pol image and an Ultra Fine beam were also used).

This work was carried out under the Geo-Mapping for Energy and Minerals (GEM) program, following promising results from an earlier project in the Davis Strait and vicinity of Scott Inlet using RADARSAT-1 data collected between 2002 and 2010 (Jauer and Budkewitsch, 2010; Jauer et al., 2011; Moir et al., 2012; Decker et al., 2013) and summarized in Open File 7068 (Budkewitsch et al., 2013). A complementary effort to this work (Decker et al., 2013) was carried out over Hudson Bay and Foxe Basin (Figure 1).

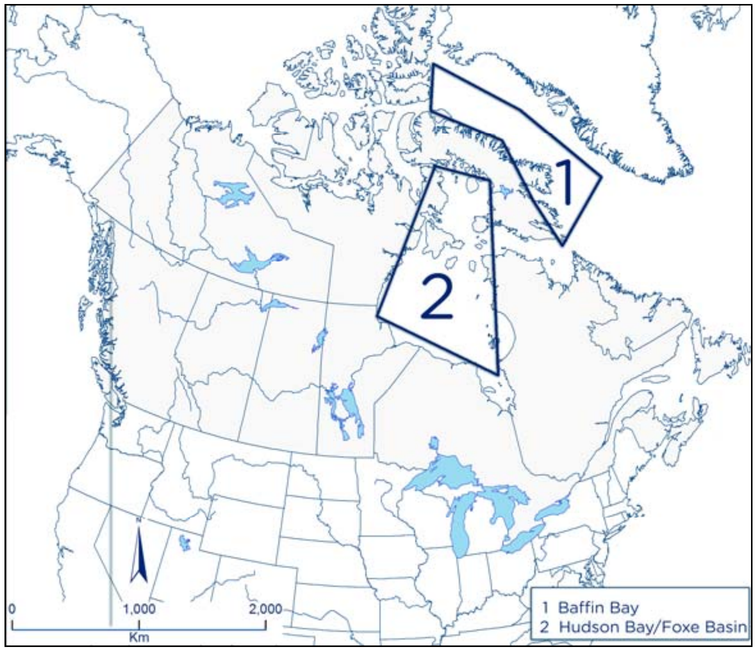


Figure 1 – Outline of (1) the Baffin Bay and Davis Strait region and (2) the Hudson Bay and Foxe Basin region that were examined with RADARSAT-2 data in 2010 to 2012 for the Geo-Mapping for Energy and Minerals (GEM) program.

RADARSAT survey of Baffin Bay – Davis Strait

One of the more promising areas for evaluating the potential of satellite SAR for the detection of hydrocarbon seeps in the eastern Arctic is near Scott Inlet, Nunavut (northwest of Clyde River), where a large natural hydrocarbon seep was directly recognized from ship observations, described by Levy (1978) and, Levy and MacLean (1981). Scott Inlet offers an ideal natural oil seep target to examine with SAR data and to monitor its activity over time. If one natural seep is known in this part of Baffin Bay, the possibility exists for other examples to be discovered. For these reasons, a multi-year pilot study was initiated to evaluate the potential of Canada's RADARSAT satellites for providing information about the offshore in these remote Arctic waters. Davis Strait and this part of Baffin Bay were first examined by Budkewitsch et al. (2013) to provide new observations in support of improving the very limited geoscience knowledge of the region. The northern part of Baffin Bay was not included in the earlier study, except for the area around Scott Inlet.

This report presents results from more recent RADARSAT-2 observations as a more comprehensive survey of the eastern Arctic offshore and builds upon the earlier database to support monitoring and detection of potential areas with seeps of this kind. The total area of the Davis Strait and Baffin Bay region imaged in this investigation exceeded 800,000 km^2 (Figure 2). The results presented in this report illustrate the conditions of the sea state when imaged and where natural seep occurrences may exist by identifying the locations of dark targets in SAR images. These features may or may not have a hydrocarbon origin; however these locations vastly reduce the area of interest for further examination.

Thus, a survey of this kind assists with targeting areas for offshore petroleum exploration and helps to establish an environmental baseline. This type of endeavor ideally requires long term data sets that have not been systematically collected in the area before.

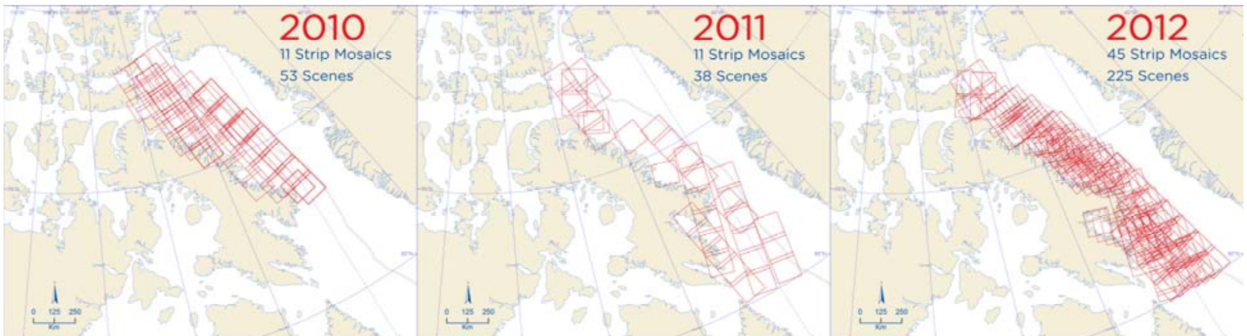


Figure 2 – Coverage of RADARSAT-2 data examined for the western part of Baffin Bay and Davis Strait over the three year period of this study. Each satellite pass produced a strip of images collected on a single date. In 2010 and 2011 there were 11 different data acquisition dates in both years, whereas 225 scenes were collected from 45 different dates in 2012.

It has been recognized that natural petroleum seeps annually release a significant volume of hydrocarbon into the marine environment. Few studies are available, however, that reliably document the flux of individual seeps, and the temporal variability of seep behavior is not well understood. Long-term observational data sets from spaceborne sensors may have a role to play in contributing to our understanding of seep behavior over time.

Oil slicks on water are often visible optically as colourful sheens, but they also modify the surface tension of water which has the effect of dampening capillary waves and small gravity waves on the ocean surface. In radar imaging systems, the reduction of overall surface roughness of ocean waves lowers the radar backscatter significantly and the area appears darker in images when compared with the surrounding sea state. The optimal wind speeds for contrast in roughening when surfactants are present lie within the range of about 3.5 to 7 m/s (Garcia-Pineda et al., 2009). The desired period of data acquisition was chosen from early September to early November. This time of year has the least amount of sea ice and maximum melt or passing of icebergs from the region. Sea-ice or icebergs otherwise clutter the ocean surface for most of the year and confound image interpretation. All scenes were visually examined from linearly scaled 8-bit images and relatively small or confined dark features with a clear brightness contrast from the surrounding sea state were selected and included in the database. A total of 316 RADARSAT-2 images and two RADARSAT-1 images were examined, providing a good representation of possible suspect seeps in the area.

Description and characteristics of dark targets

The authors were not concerned with trying to make determinations on the origin of dark targets that appear in the satellite SAR images. It is well known that dark features in SAR ocean images can be caused by a number of surface phenomena. Backscatter contrast and shape characteristics are the main parameters that govern the appearance of dark targets or suspect seeps. In our study, a dark target was included if (i) a backscatter contrast of about -10 dB between target and background exists, and (ii) sufficiently well-defined shape or boundary characteristics of the target area are present, isolating it from the surrounding sea state. An example is illustrated in Figure 3. For visual inspection, each dark target identified is illustrated as individual JPEGs, summarized as plates in the document of Annex 1. The geospatial data is also available as a zipped geospatial ESRI™ shape file and open keyhole markup language (kml) file in Annex 2.

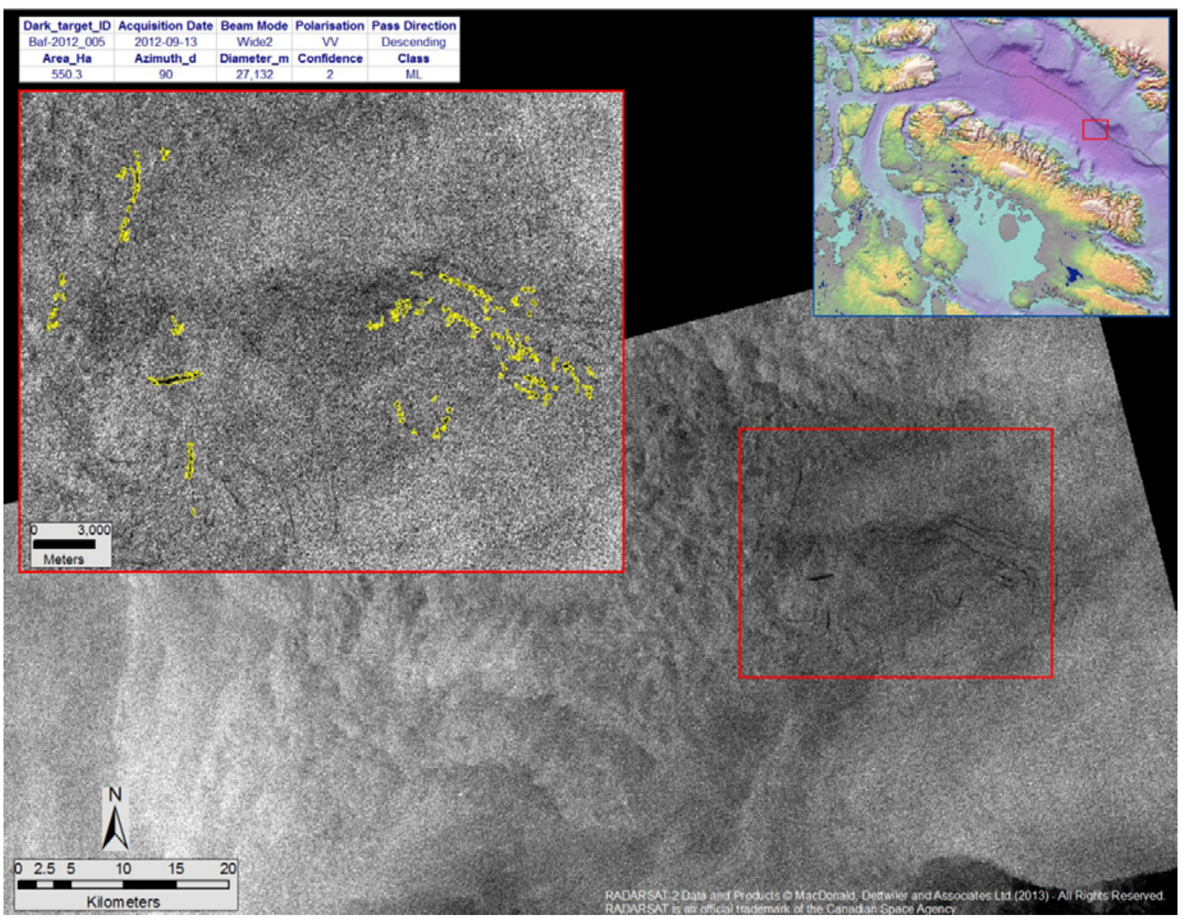


Figure 3 – Example (Id: Baf-2012_005) of the representation of each dark target. Maps at three scales with boxes in red to illustrate the successive RADARSAT scene and sub-scene pictured. Yellow polygons outline the dark target segmented from the image. In the upper left is a Table of 10 parameters associated with the identified target that is included in the database.

Very large dark areas (> 10,000 ha) were excluded as they often appeared to be related to zones where low wind speed characterized the background sea state at the particular time of acquisition. In some cases, smaller dark targets in areas adjacent to these larger zones were selected and included in the database. These suspect areas often appear as complex, multiple curvilinear dark features extending over many tens of kilometres. These features can be further examined by the user in the summary images provided in Annex 1 and JPEG browse images.

By excluding the very large areas in this study, 46 features were selected and segmented from the set of SAR images. Each are described and classified according to the criteria in Decker et al. (2013). Two of these dark targets are near Scott Inlet from older 2003 and 2008 RADARSAT-1 images (Budkewitsch et al., 2013) and the remaining 44 dark targets were observed in the RADARSAT-2 data, including 18 from 2010 images; 10 from 2011 images and 16 from 2012 images. Their distribution can be seen in Figure 4,

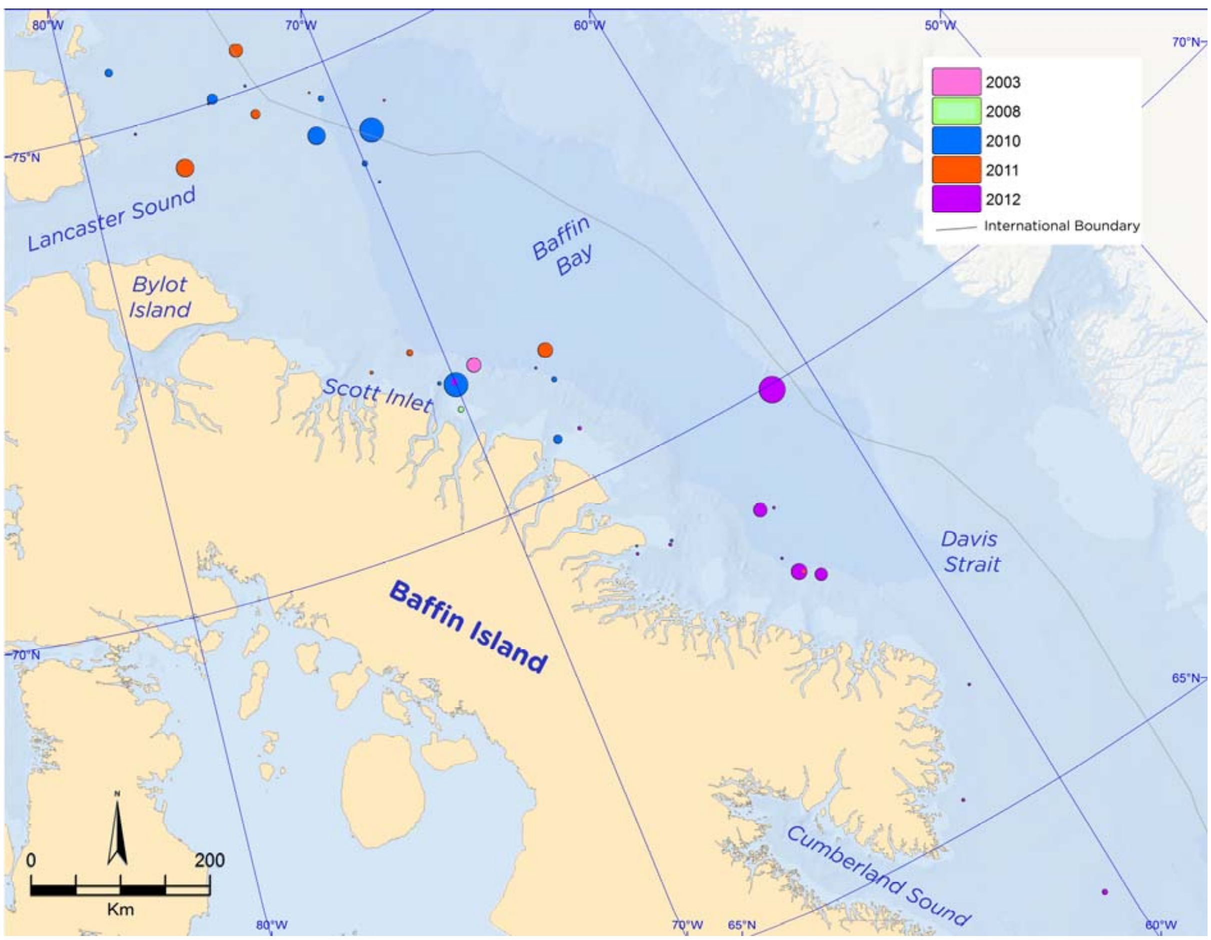


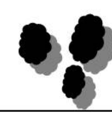
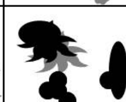
Figure 4 – A compilation of dark targets from SAR images collected from two scenes in 2003 and 2008 at Scott Inlet and over the entire survey area from 20010 to 2012. The diameter of the symbols plotted is not to scale of their total polygonal area but proportional to the length of the dark feature or extent of the cluster of features.

where three groupings are recognized. One grouping is located east of Lancaster Sound, in the northern part of the Baffin Basin. A second group falls around Scott Inlet and the third is at the south end of Baffin Bay towards Davis Strait. The size of 46 dark features extracted varied in area from 6.5 ha to 5,327 ha, with an average area of 746 ha.

The database consists of a geospatial polygon that defines the shape and outline of each dark target, or as several individual polygons when multiple, isolated patches in a group can be defined. Thus, the dark targets may be expressed as single or multiple features. Ancillary qualitative and quantitative characteristics, described below, are also part of the database. Details about the SAR image from which the target was extracted include the sensor (RADARSAT-1 or RADARSAT-2), time and date of data acquisition, the RADARSAT beam mode, ascending or descending pass, and polarization. RADARSAT-1 is a horizontal-transmit, horizontal-receive (HH) polarization sensor. Polarization mode can be selected for RADARSAT-2 and a vertical-transmit, vertical-receive (VV) polarization was employed.

The segmented dark target is stored as a vector and is described by: its total enclosing area in hectares; a long axis direction in azimuth; the diameter of the smallest circle which envelopes the vector outline(s); a qualitative rating on the potential of the dark target to represent an actual hydrocarbon slick, as a ranking scale from 1 to 3 representing low, medium and high; and lastly, a morphological classification scheme, divided into eight varieties, described in Table 1 below. Most of these parameters were adopted from the earlier study for consistency and are described in Budkewitsch et al. (2013) and Decker et al. (2013). An example of these descriptive parameters is in Figure 3.

Table 1 – Descriptive key for the morphological classification of dark targets extracted from the SAR images.

	Linear (string)		Areal (patch)	
Rectilinear / Regular				
Curvilinear / Irregular				
Database Code	SL	ML	SR	MR
	SC	MC	SI	MI
	single	multiple	single	multiple

RADARSAT monitoring of Scott Inlet

At Scott Inlet, oil slicks on the sea surface were observed repeatedly over several days at sea by Levy and MacLean (1981). Three decades later, observations of dark features appearing in SAR images have been detected in the same vicinity over five different years between 2003 and 2012. A summary representation of the dark targets seen in RADARSAT images near Scott Inlet is presented in Figure 5. In the central part of the figure, it can be seen from the 2010 and 2012 data that persistent dark targets were repeatedly observed on no less than six different occasions. Given the supporting observations by Levy (1978) and Levy and MacLean (1981), and confirmed geochemistry from slick samples (Moir et al., 2012), these dark targets are unlikely to be false positives. It is more plausible that they are caused by continuing oil seeps in the region and are promising evidence in support of an active petroleum system.

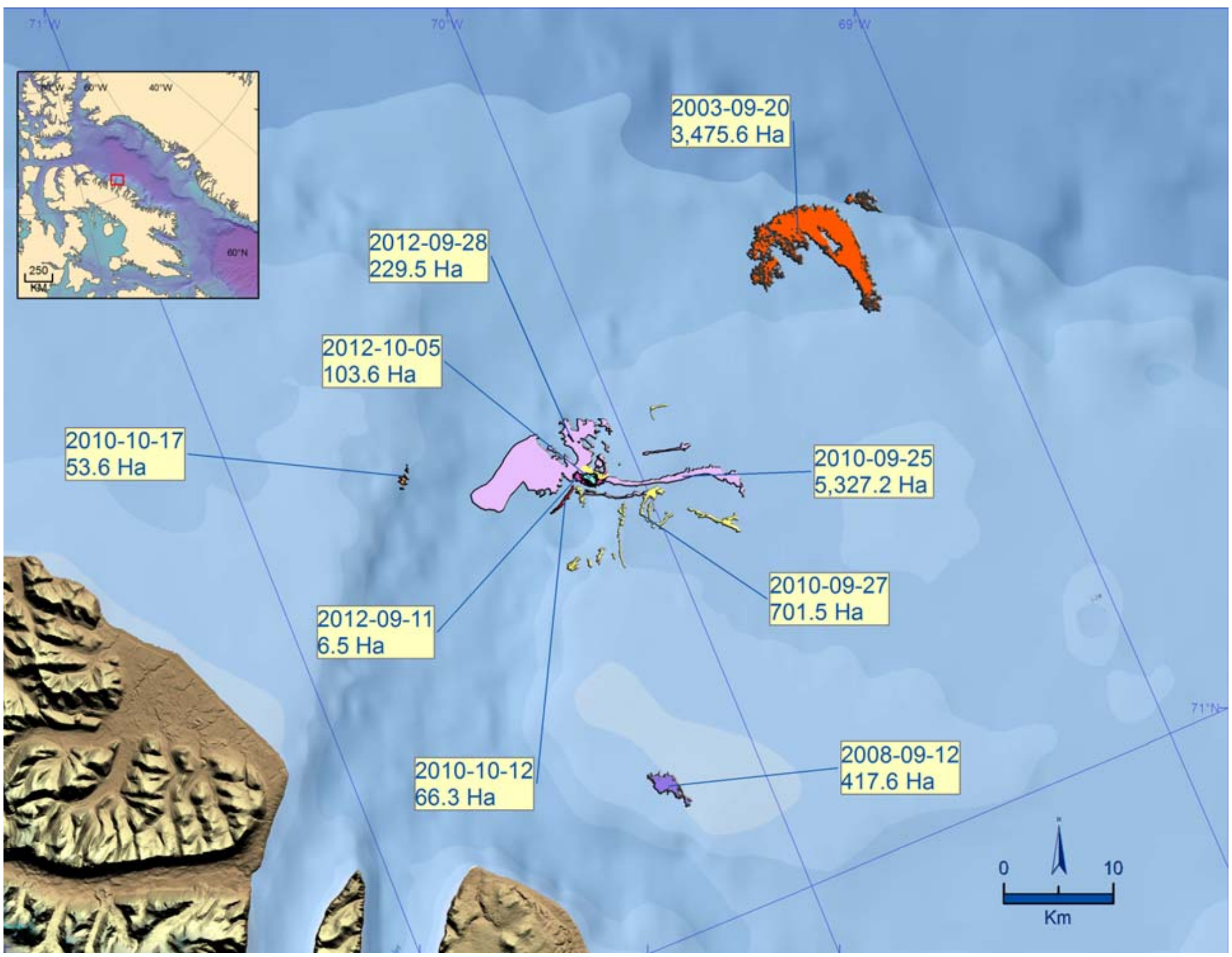


Figure 5 – A compilation of dark targets near Scott Inlet (lower left) identified from SAR images collected from 2003 to 2012. Date of image acquisition and area in hectares are labeled for each observation. Numerous independent dark targets from 2010 and 2012 appear to cluster as repeat occurrences near the centre of the map, about 35 km NE of Scott Inlet (71°23'30"N / 70°07'00"W).

Other locations where repeat dark targets are recognized in spatial proximity have been revealed from this survey. One pair (see Id:Baf-2010_005 and Baf-2011_001) exists in the northern part of Baffin Bay near 75°19'N / 73°12'W. In the southern part of Baffin Bay (Id:Baf-2010_016 and Baf-2012_013), an example of a rather small pair of dark targets (< 50 ha) four to five kilometers apart are near 68°59'N / 66°07'W. Another superimposed pair occurs nearby at 68°06'N / 63°10'W (Id:Baf-2011_006 and Baf-2012_002). Repeat observations of dark targets on the ocean surface over different years provide some of the best evidence of a natural hydrocarbon seep particularly if the seep is a persistent phenomenon. Co-occurrence of dark target observations raises the potential that the feature has a sea floor hydrocarbon source; however, additional observations or other independent data are needed to confirm this interpretation of their origin.

Summary

Forty-six dark targets were identified and described from 316 RADARSAT-2 and two RADARSAT-1 images collected from the upper part of Davis Strait and the eastern side of Baffin Bay. A digital database of the extracted features is made available in GIS compatible formats and as individually viewable browse images for context. This data set provides a valuable baseline for supporting further targeted investigations and serves to aid in understanding the subsurface geology and hydrocarbon potential of the eastern Arctic basins.

The spatial and temporal persistence of the Scott Inlet seep is demonstrated from a sequence of SAR images and provides further supporting evidence of an actively discharging petroleum system. Recognition of seep activity in the region and the potential discovery of new occurrences, expressed by other dark targets (suspect seeps), provide valuable, unconventional geoscience information about hydrocarbon resources in the offshore of the eastern Arctic.

It is understood that many of the 46 features may have origins other than from oil slicks; however the identification of these features, false positives included, greatly reduces the areas meriting further investigation from the entire 800,000 km^2 area surveyed. Examples of repeat observations from spatially coincident dark features raises the probability that other natural seep occurrences exist in the eastern Arctic and helps to identify new regions of interest where further investigation is required.

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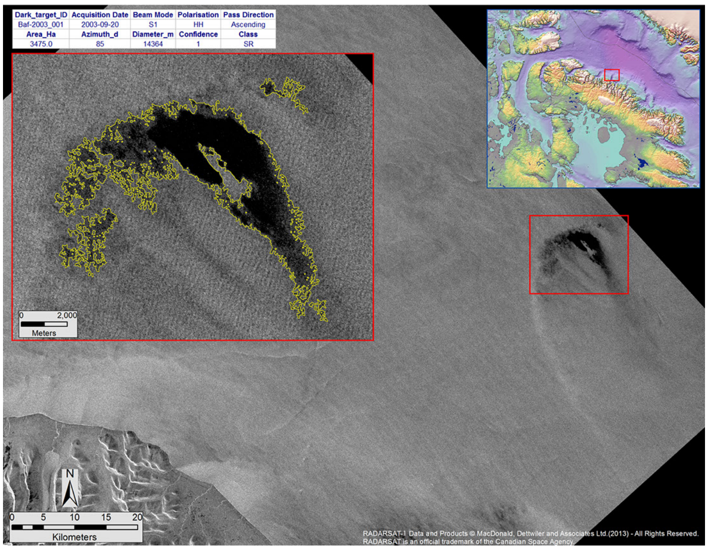

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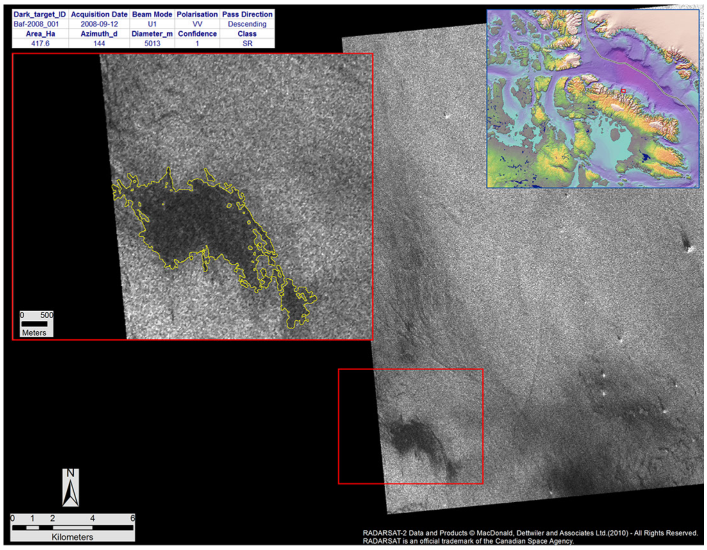

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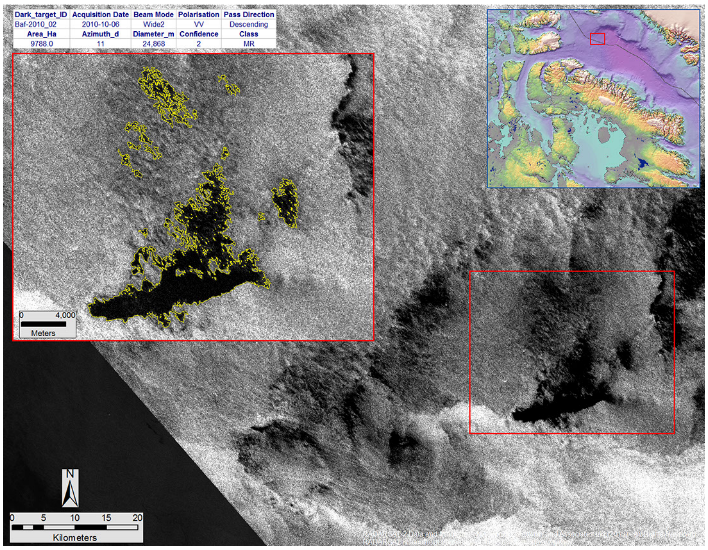

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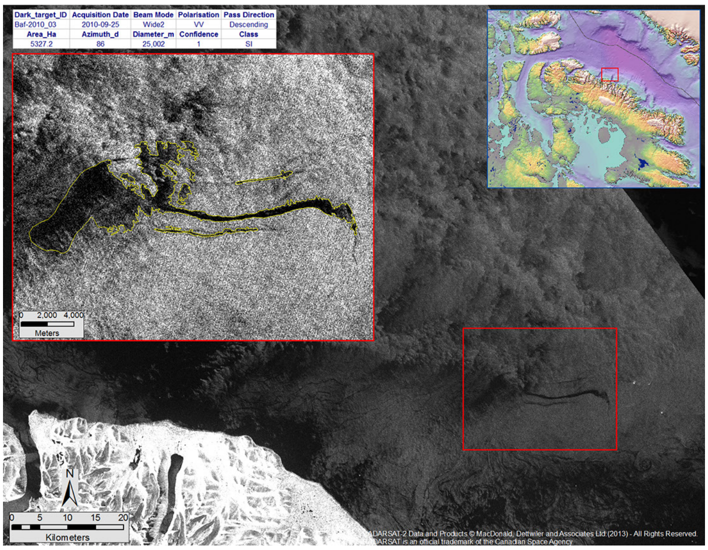

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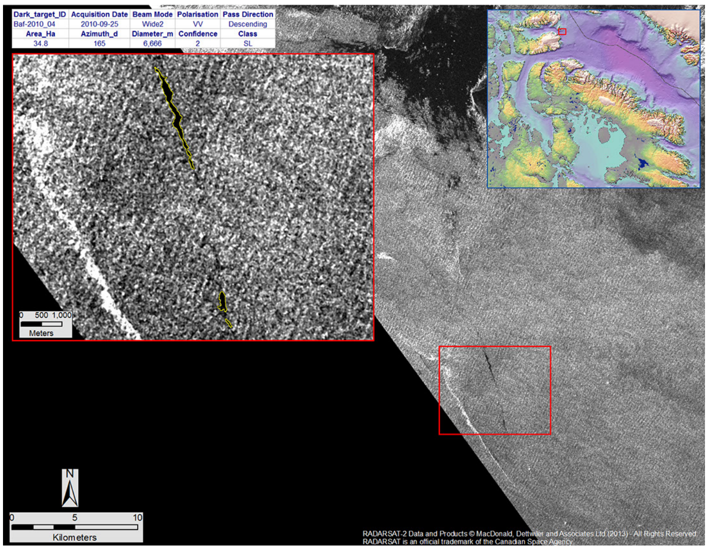

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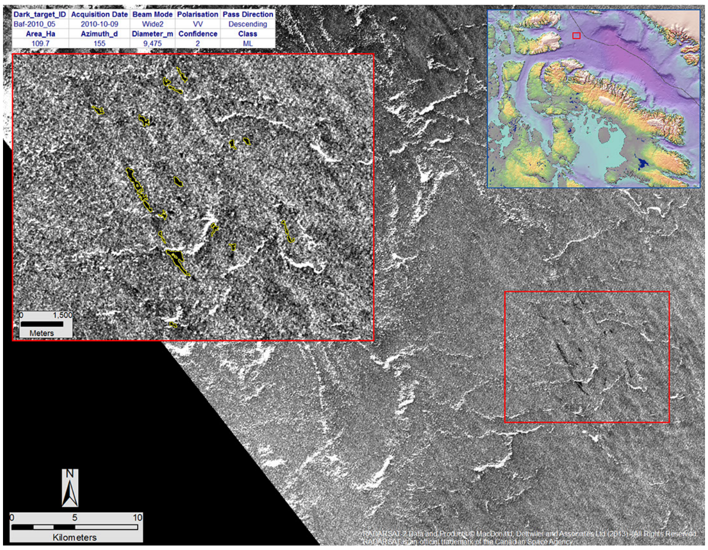

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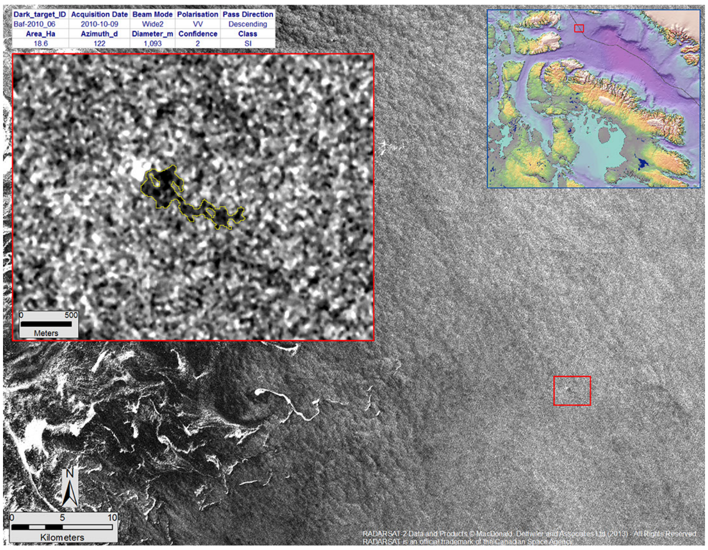

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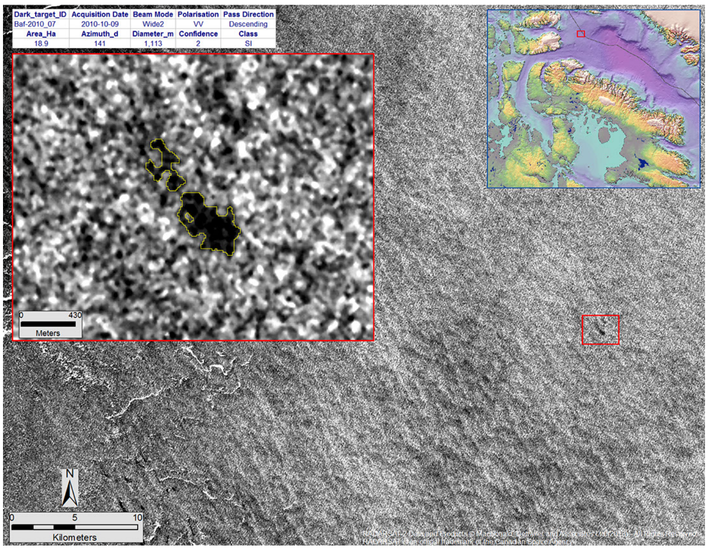

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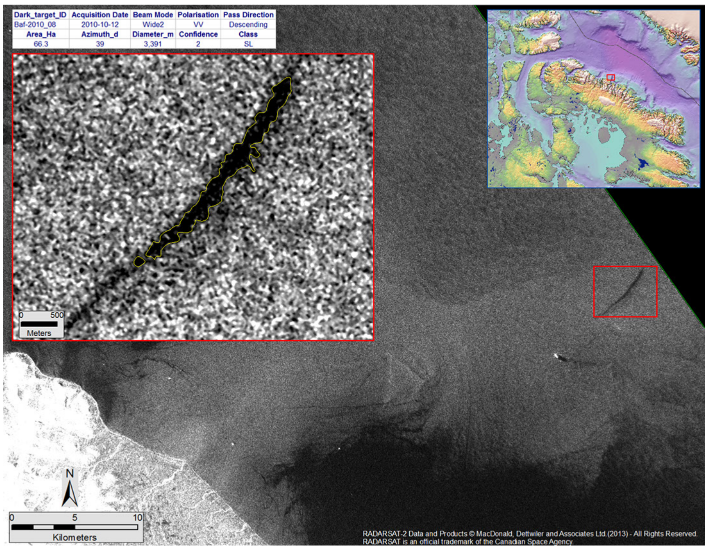

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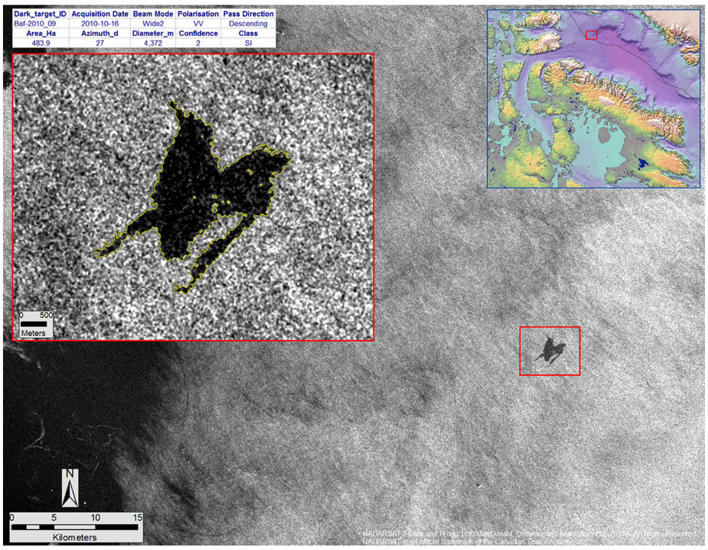

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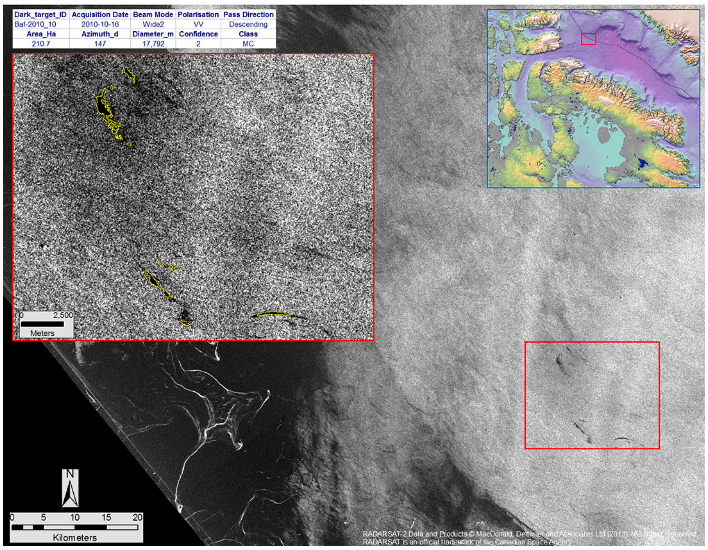

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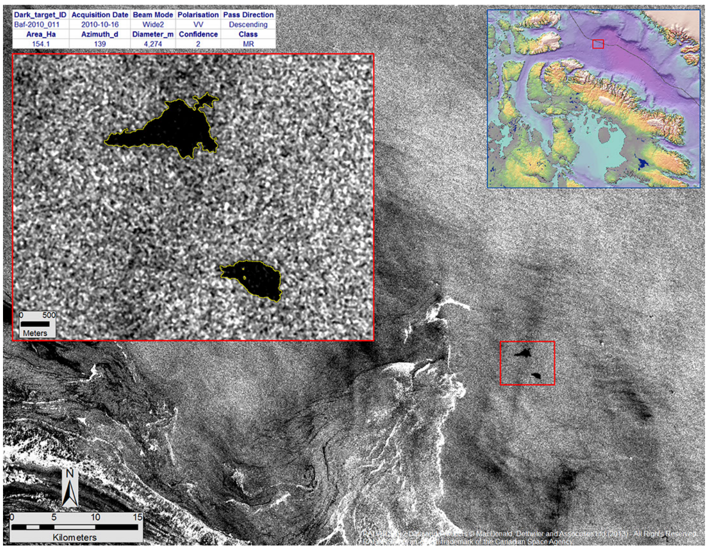

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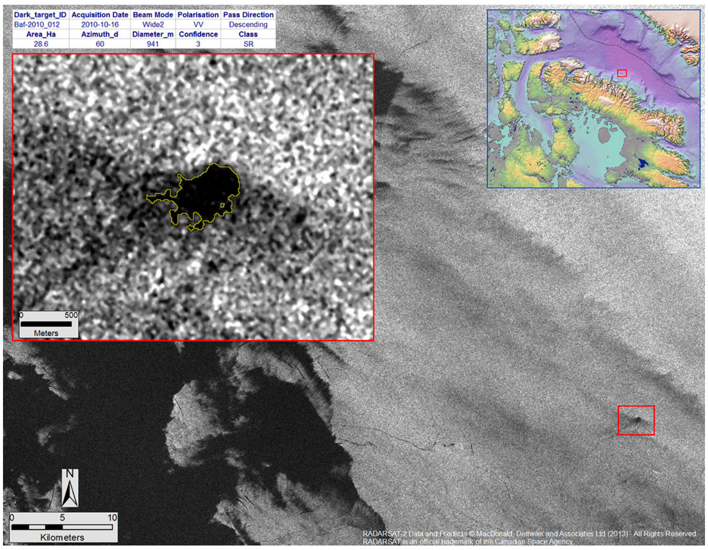

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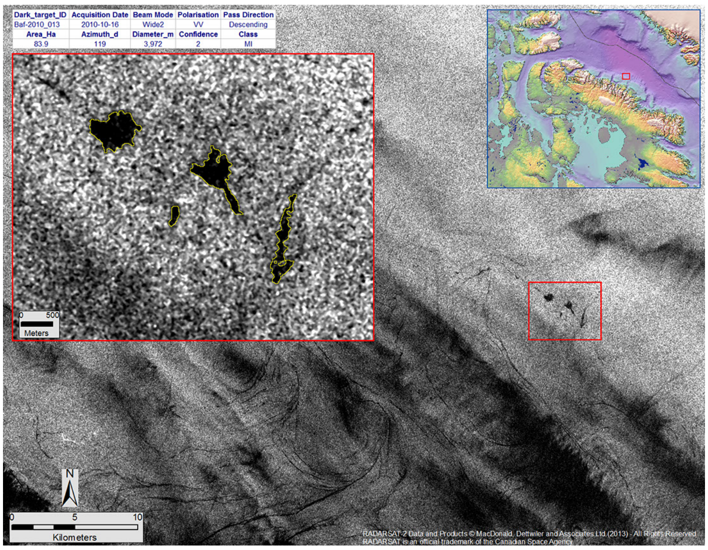

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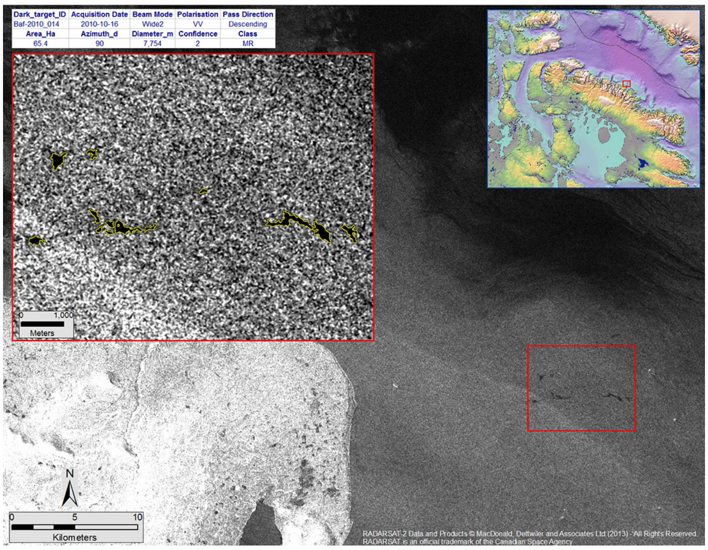

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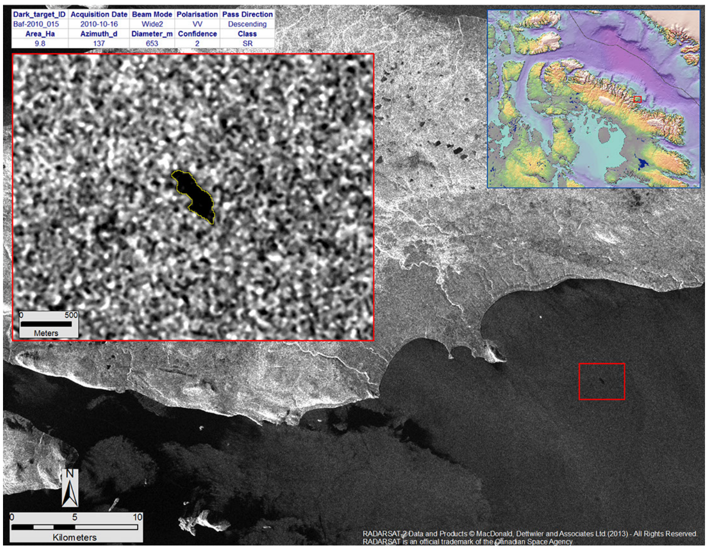

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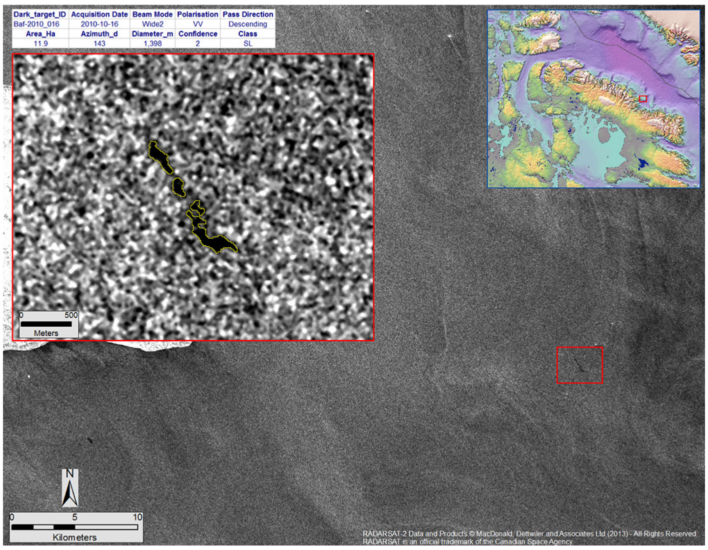

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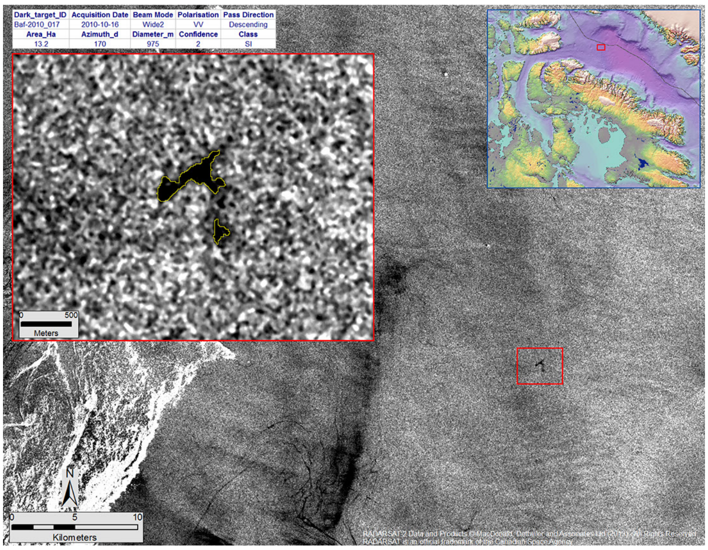

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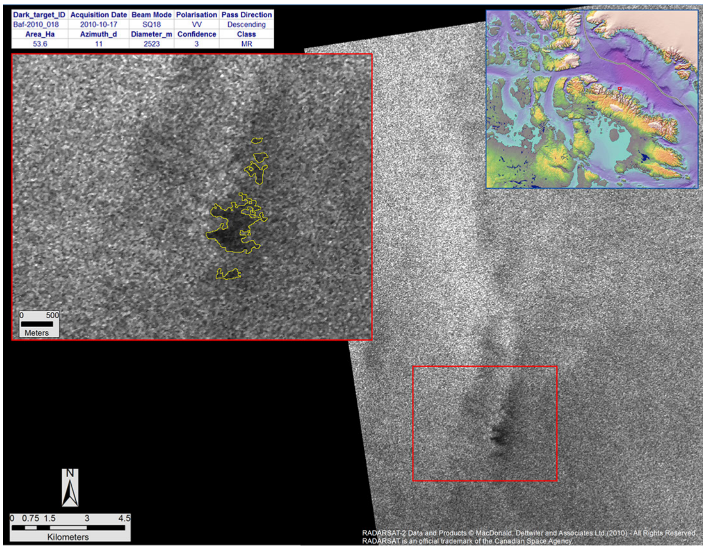

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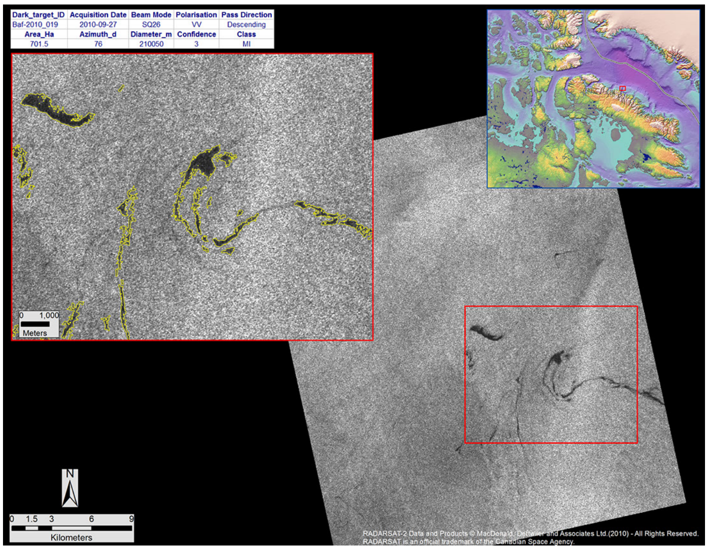

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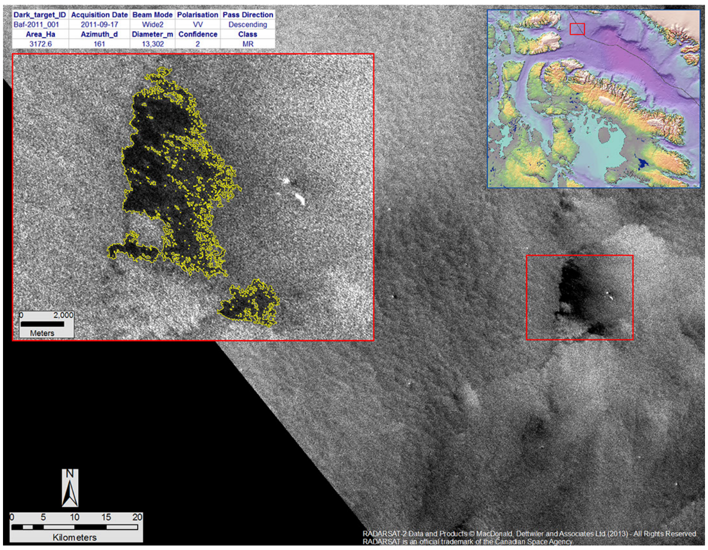

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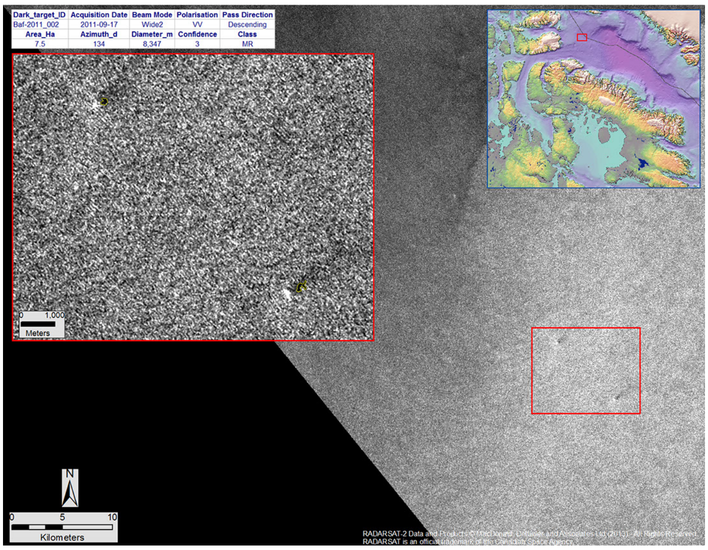

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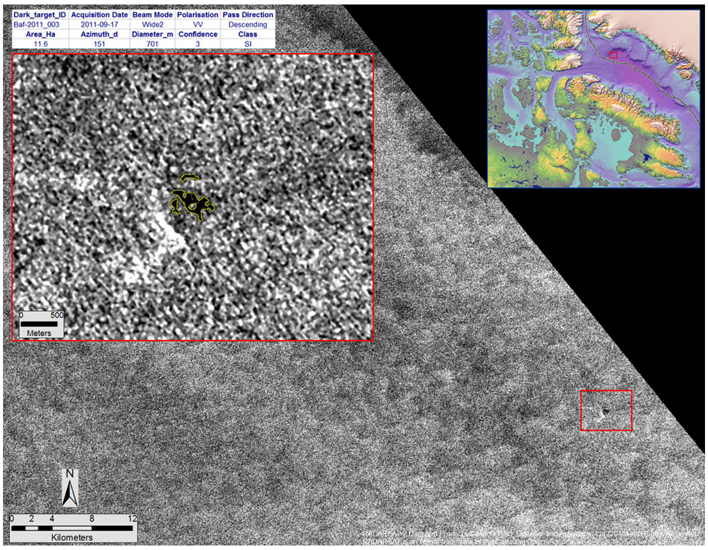

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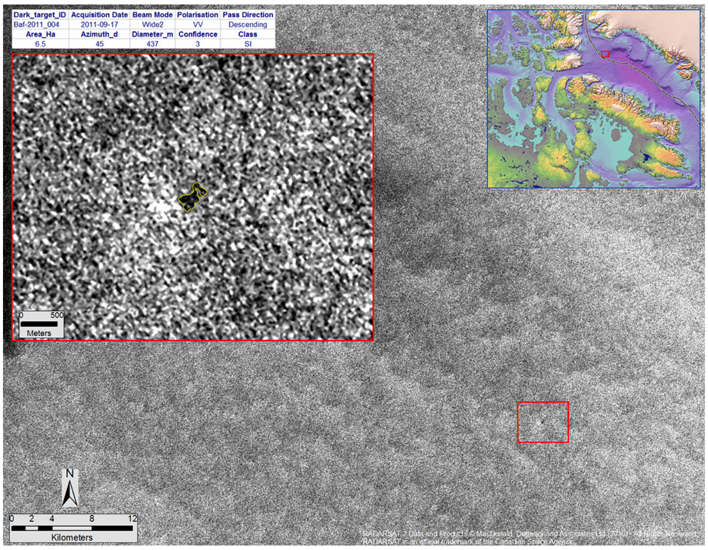

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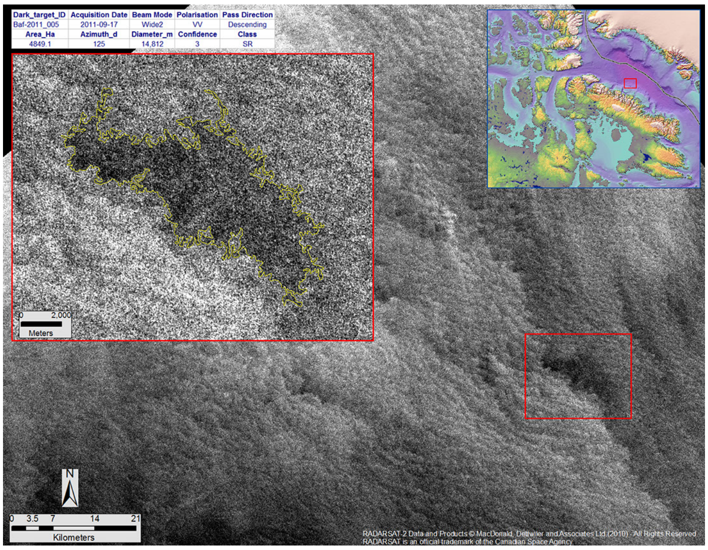

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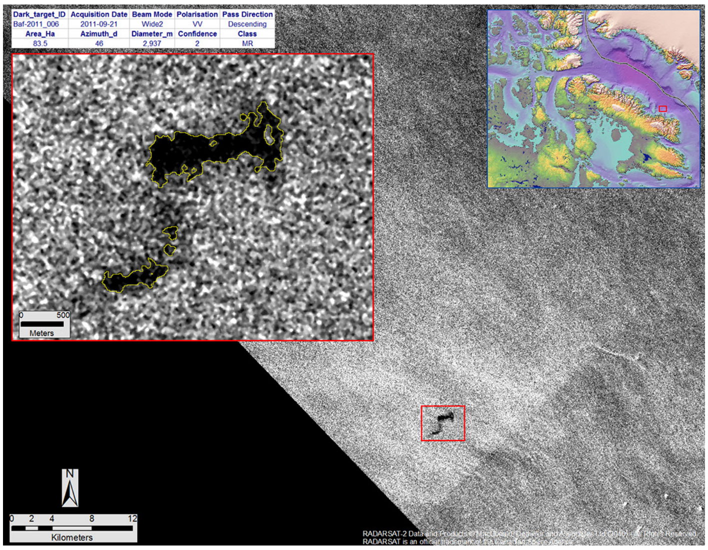

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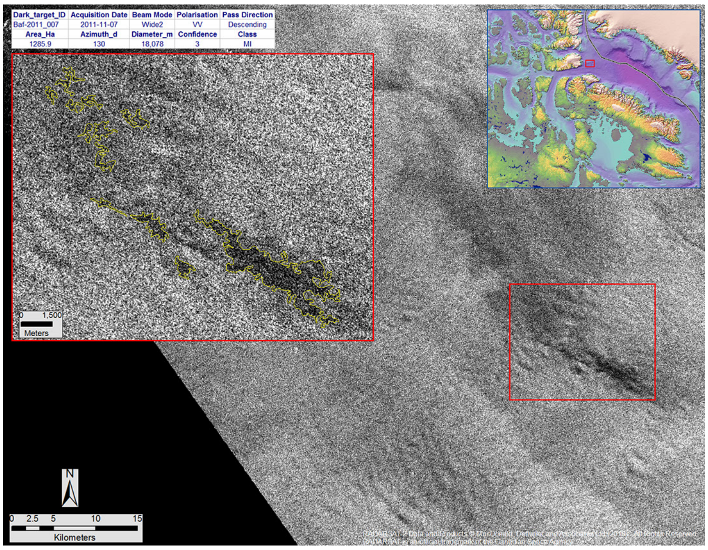

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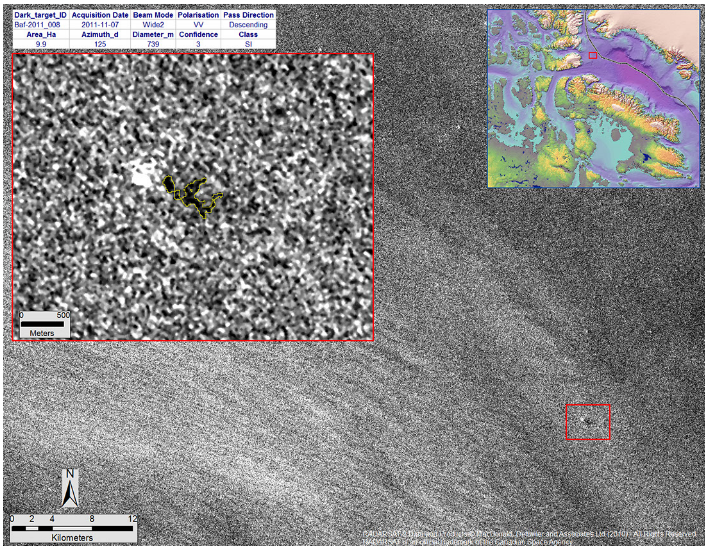

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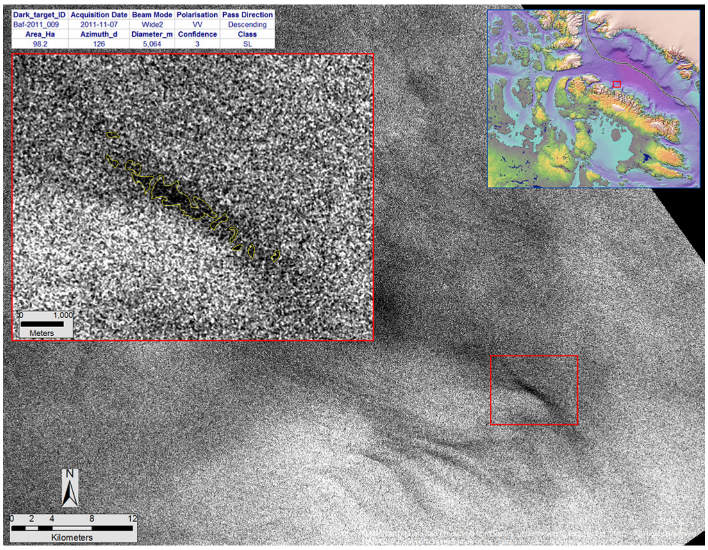

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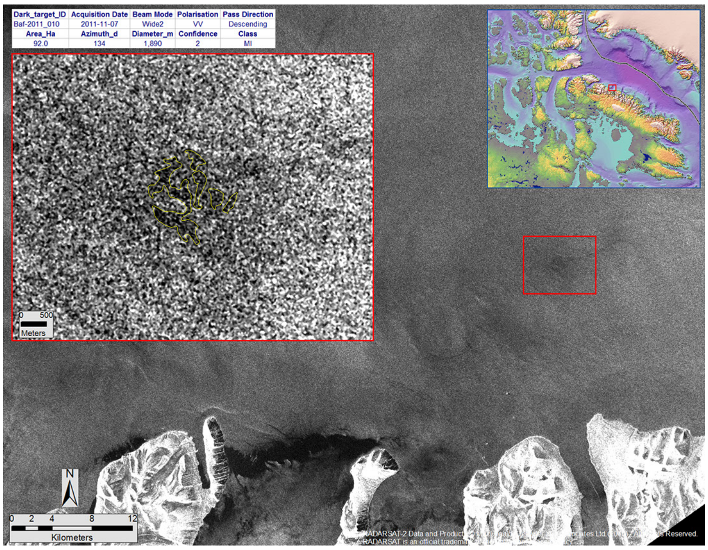

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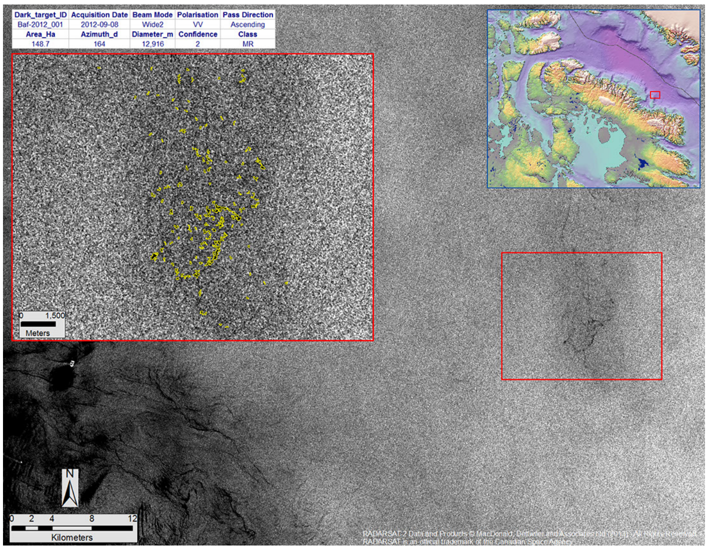

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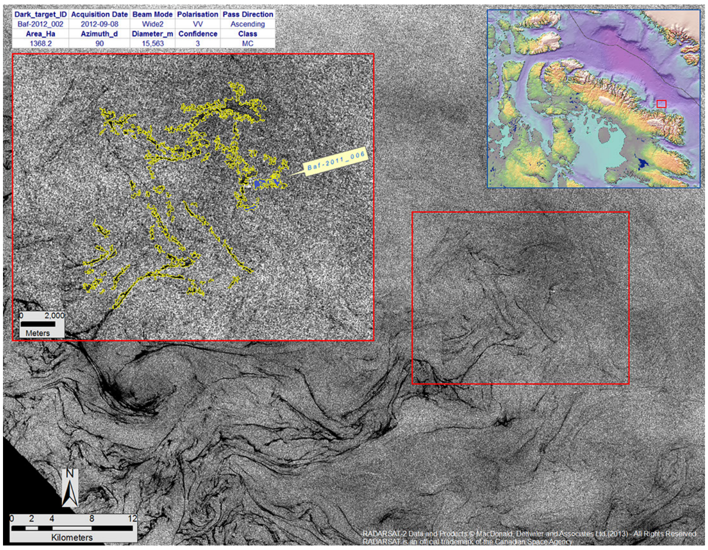

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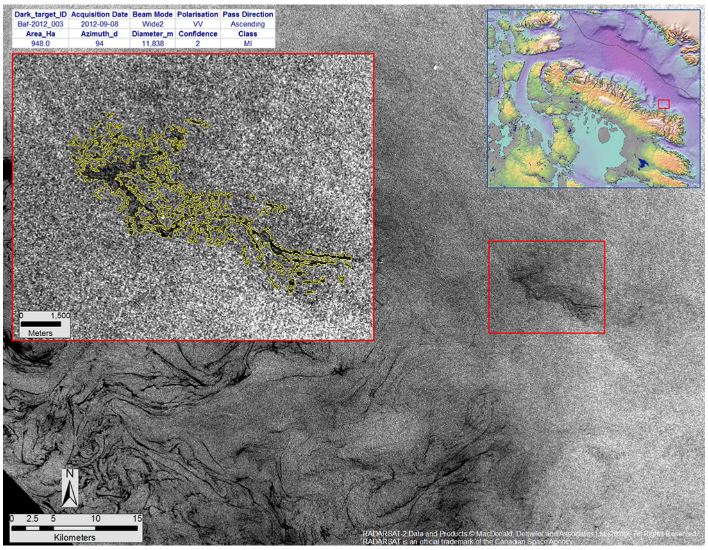

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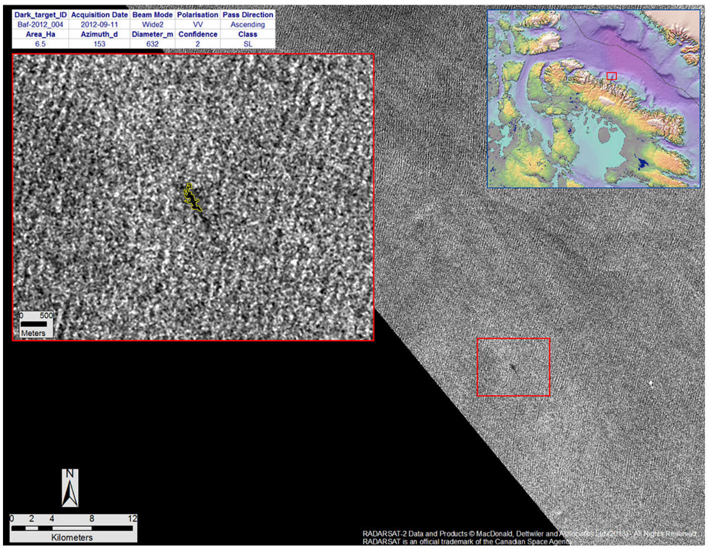

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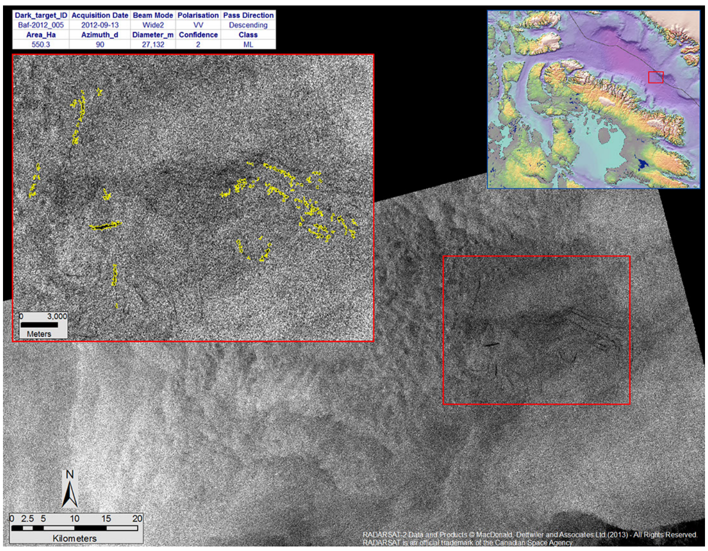

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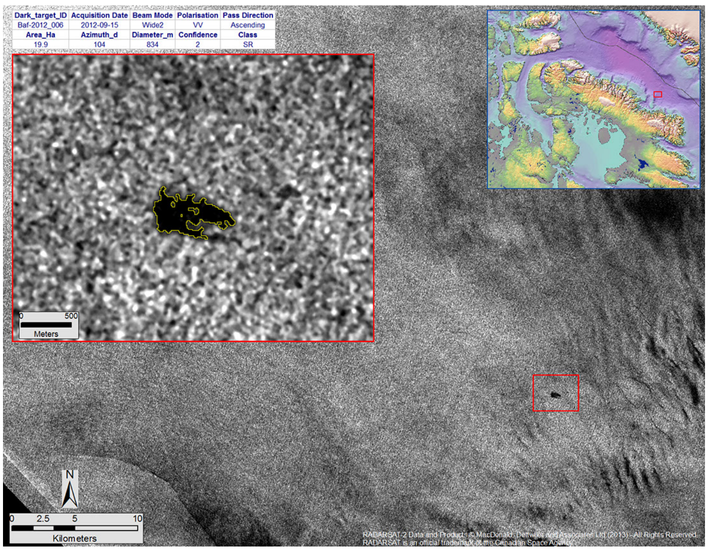

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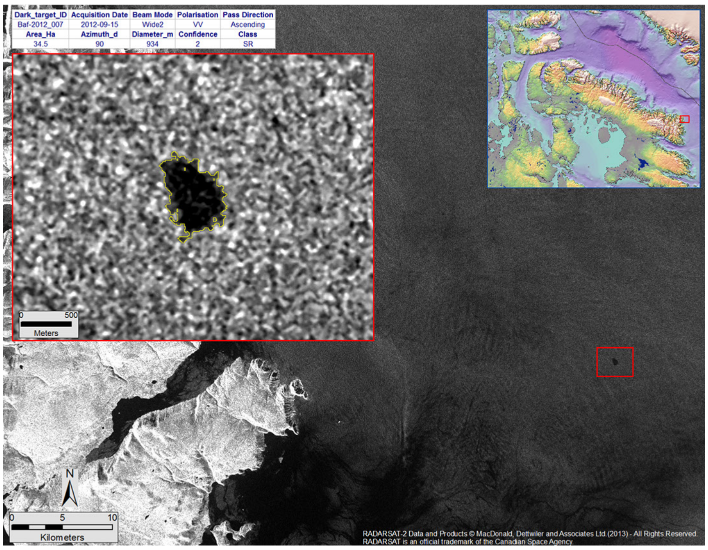

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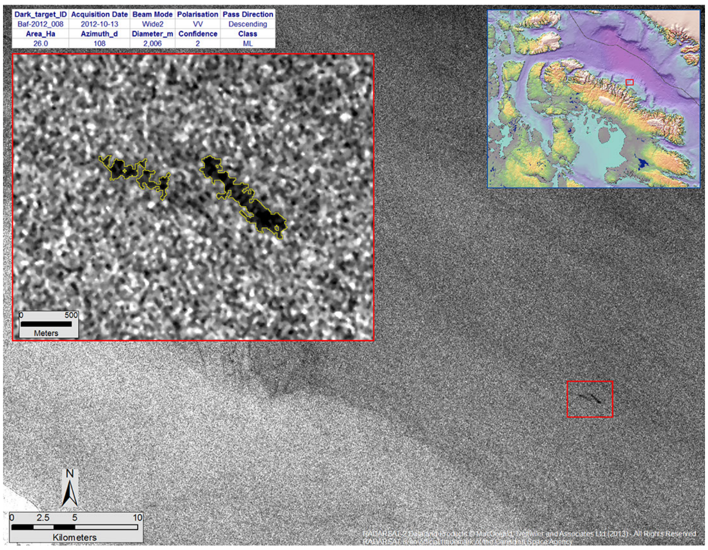

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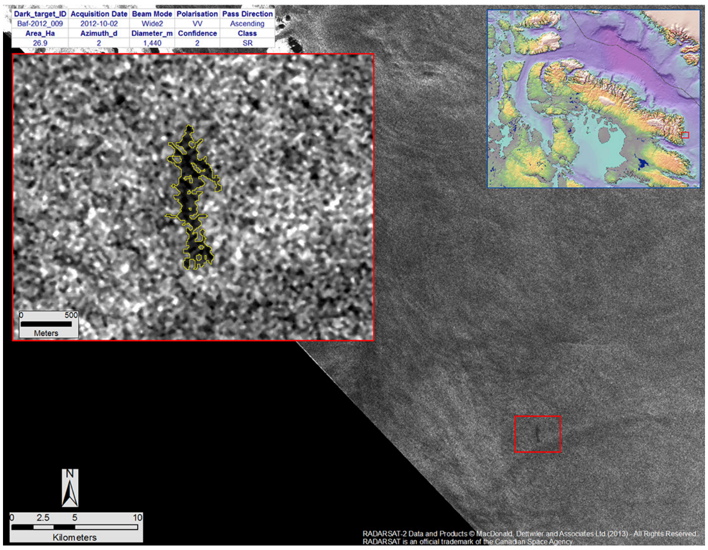

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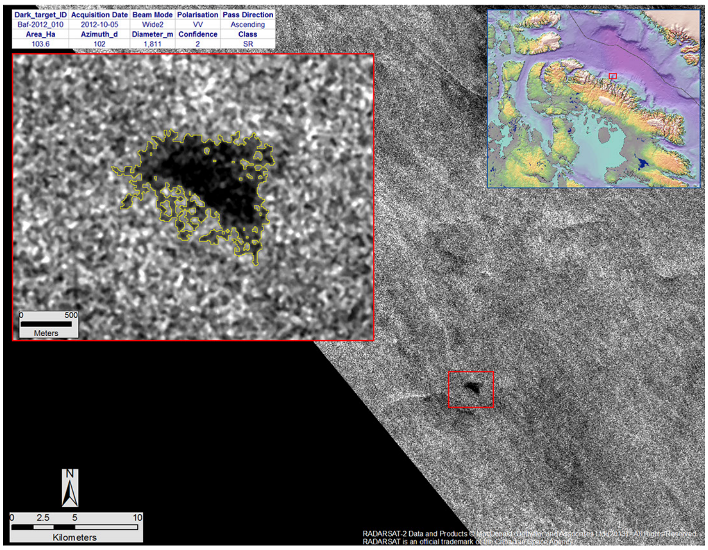

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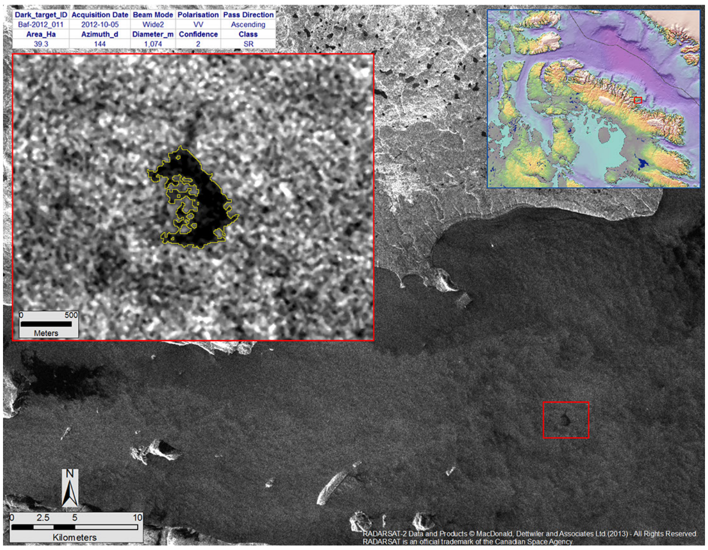

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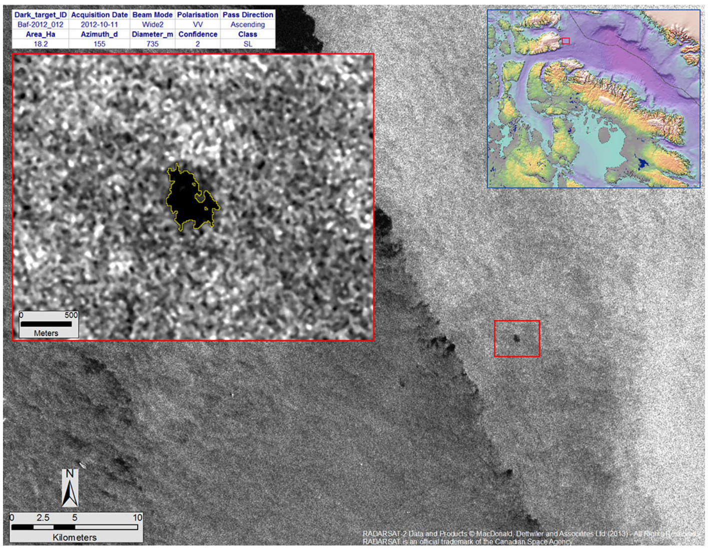

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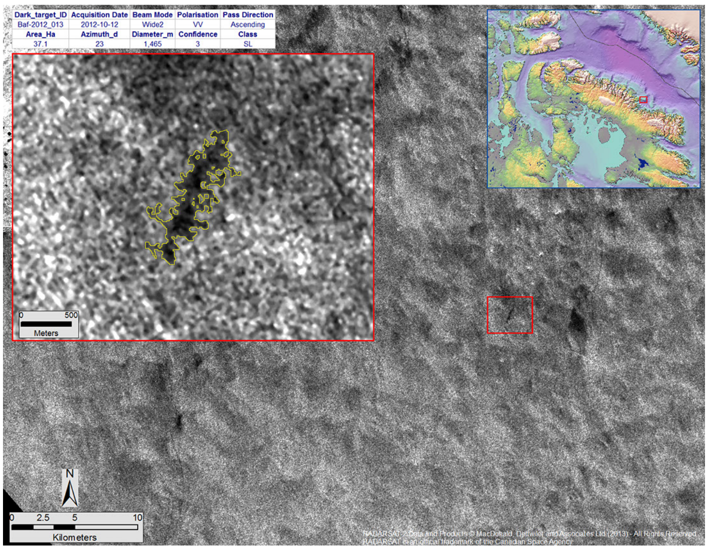

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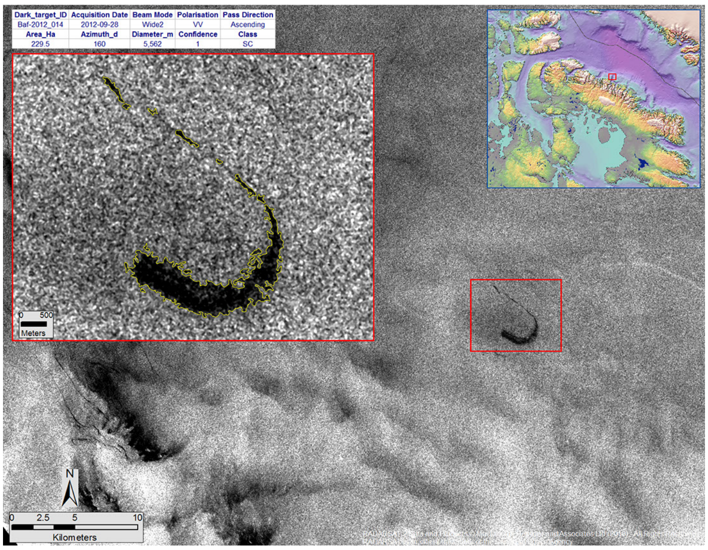

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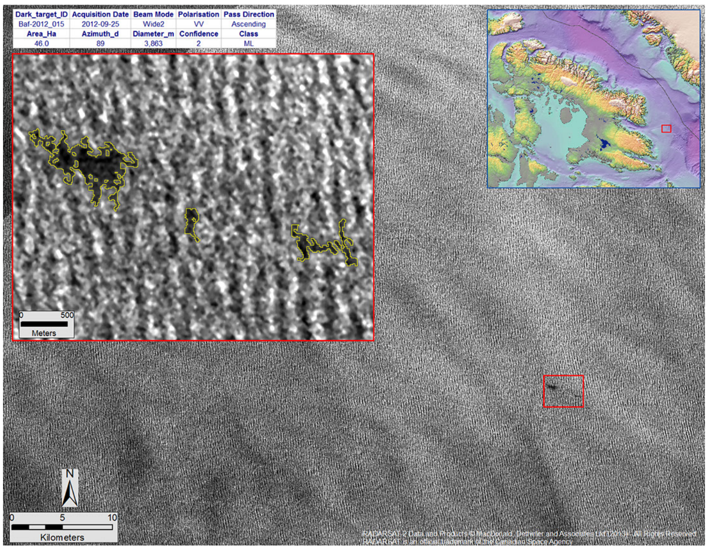

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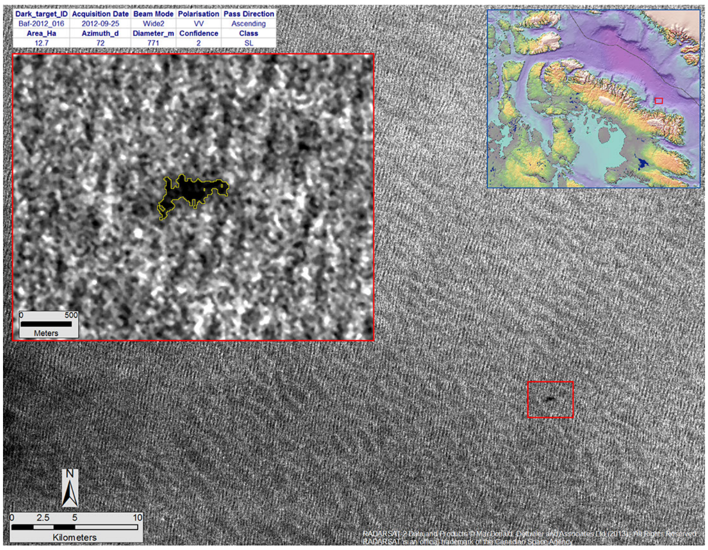

Baf-2012_016