RIVER ICE MONITORING USING GNSS-IR AND SAR DURING CAL/VAL

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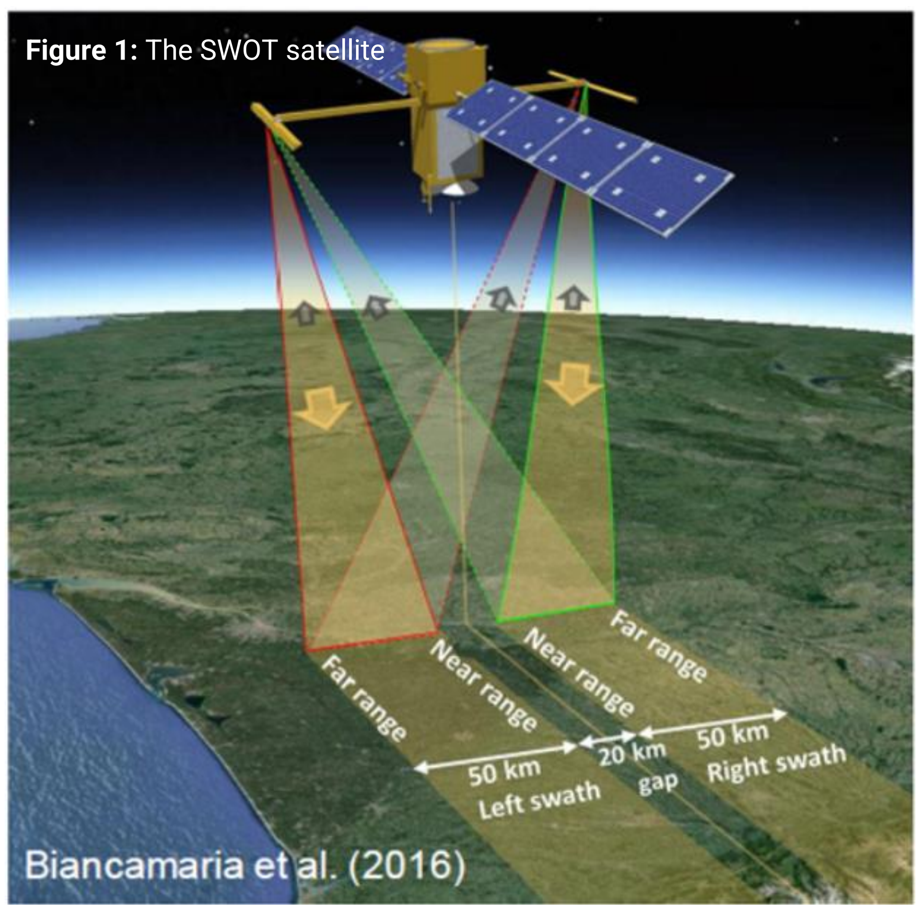
Figure 1: The SWOT satellite



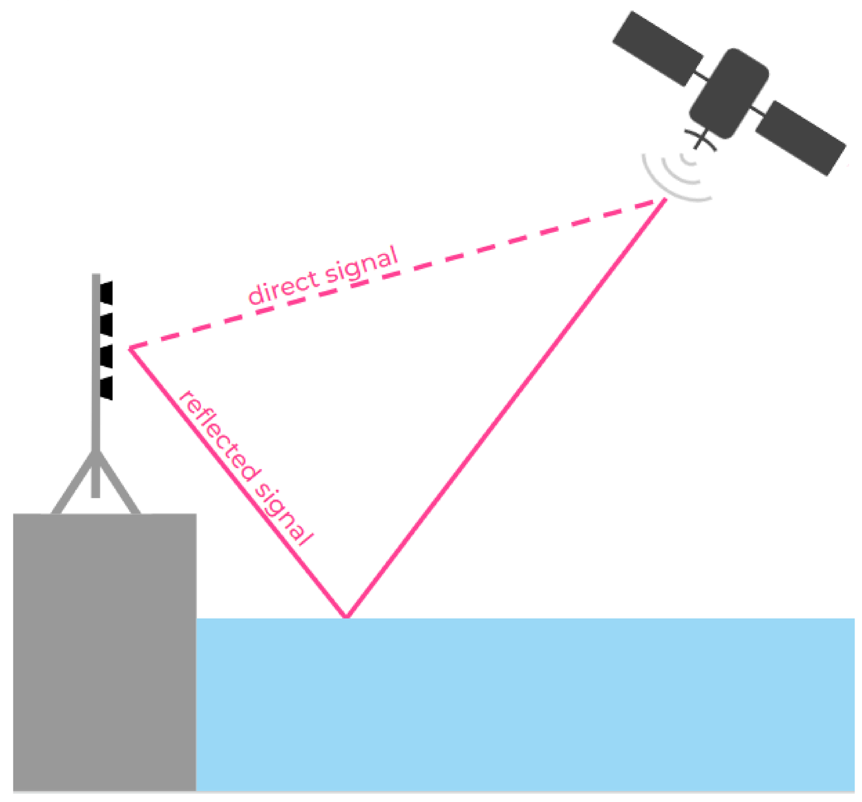
RELEVANCE TO SWOT

- Select areas in Canada that were frozen in March when SWOT began collecting data
- Opportunity to assess performance of SWOT products during ice cover
- GNSS-IR, SAR and camera data can provide useful information about ice
- The RADARSAT Constellation Mission (CSA) provided high resolution C-band SAR data during SWOT Cal/Val phase
- Ongoing field projects across Canada using GNSS-IR:
  - 13 Instruments currently installed on Saint Lawrence Estuary (Québec, Canada)
  - 4 instruments currently installed in Peace-Athabasca Delta region (Alberta, Canada)
  - See example GNSS-IR sensors in Figures 2-3

Figure 2: GNSS-IR sensor on the Île d'Orléans bridge in Québec, Canada.

Figure 3: GNSS-IR sensor at Saint-Laurent-de-l'Île-d'Orléans.

Figure 4: GNSS-IR schematic



GNSS INTERFEROMETRIC REFLECTOMETRY (GNSS-IR)

- Coastal GNSS antennas can be used to monitor water levels and provide other environmental information [2]
- Key advantages for water level monitoring:
  - antennas can be installed up to 10s of meters away from shoreline
  - Instruments can be installed during winter (e.g., during SWOT Cal/Val)
  - Precise water level monitoring can be achieved using co-located low-cost antenna arrays [3]

Theory:

- Changing path length difference between direct and reflected signals causes interference
- Interference causes oscillation in Signal to Noise Ratio (SNR) data
- Frequency of oscillations approximately linearly related to the reflector height (see h in Fig. 5) or water level

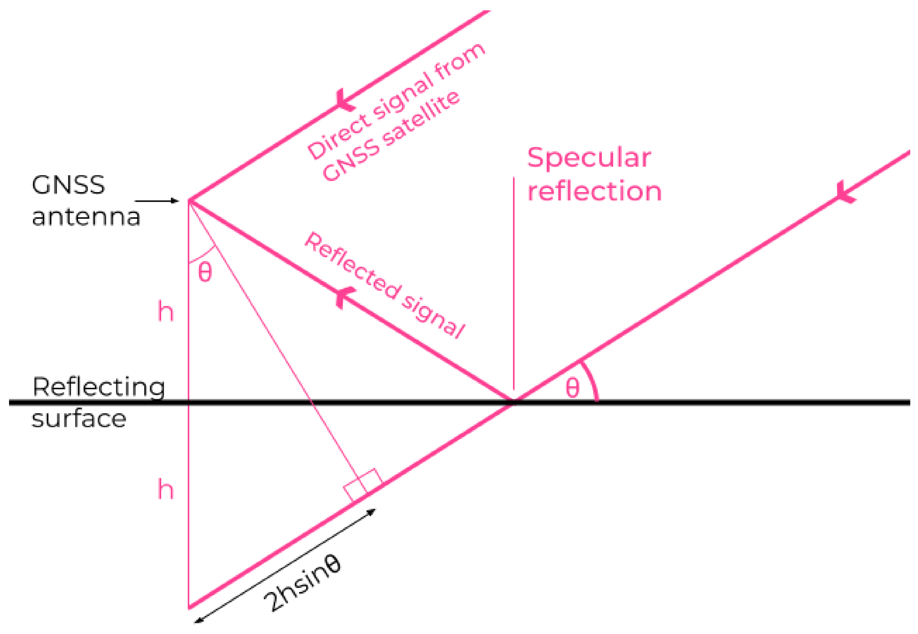


Figure 5: GNSS-IR geometry, where h refers to the reflector height (which increases as water level decreases) and 2hsinθ is the difference in path length between the direct and reflected signals.

CASE STUDY: ICE BREAKUP AT PEACE RIVER IN 2022

- Location in Northern Alberta, near Lake Athabasca, prone to ice jams
- GNSS-IR sensor installed with hunting camera from March 13 to September 8
- Preprocessed Sentinel-1 GRD images retrieved from Google Earth Engine and then cropped to GNSS-IR reflection area (Fig. 6)
- Sentinel-1 is dual polarized C-band whereas GNSS-IR is circularly polarized L-band
- Comparison between GNSS-IR mean spectral power and Sentinel-1 VV backscatter (Fig. 7) shows strong negative correlation of -0.76

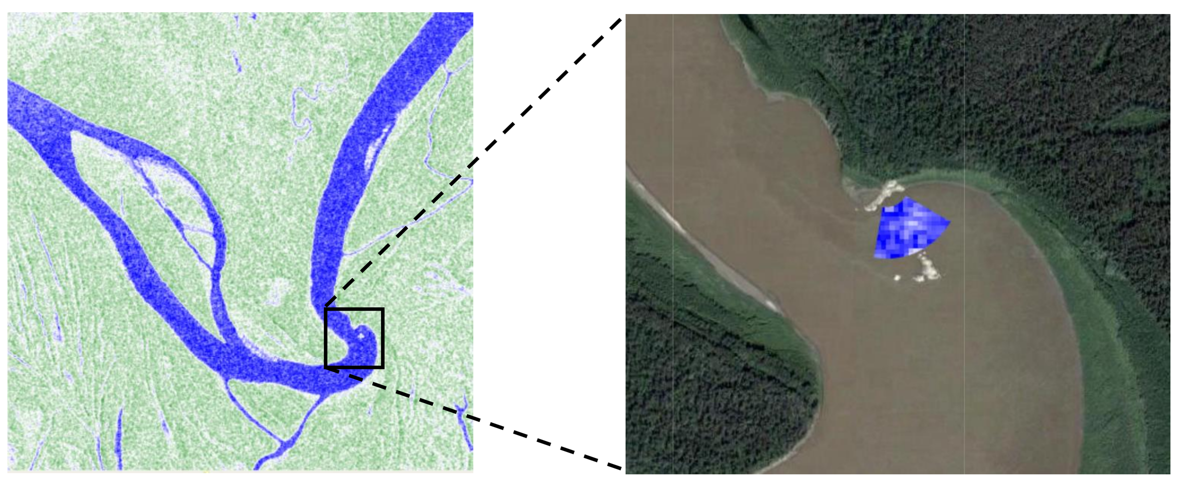


Figure 6: (left) An example image showing VV backscatter from Sentinel-1 over the Peace River. (right) the same image cropped to show the pixels (in blue) being used for comparison with GNSS-IR

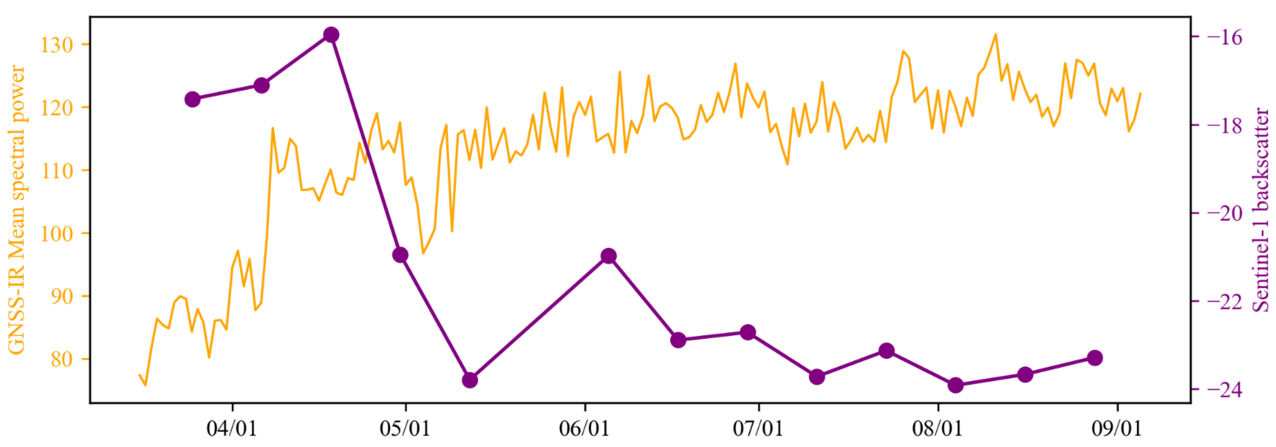


Figure 7: A comparison between GNSS-IR and Sentinel-1 backscatter during the ice breakup period. The GNSS-IR mean spectral power can be interpreted as the strength of the interference between the direct and reflected signals.

Figure 8: Pictures of the GNSS-IR sensor during ice breakup at Peace River, taken on April 22, May 5, 6 and 7 (top to bottom).

ICE CLASSIFICATION USING GNSS-IR AND K-MEANS CLUSTERING

- GNSS-IR data has previously been used in literature for detecting sea ice and monitoring ice thickness [4-5]
- We have examined the use of several GNSS-IR parameters for classifying river ice and found promising results
- Fig. 9 shows the results from using a 'k-means' clustering algorithm to separate GNSS-IR data into two clusters based on two parameters (the peak value from spectral analysis and the ratio of the peak to background noise)
- Using camera data for validation (Fig. 8), we found that the two clusters corresponded to times with ice and ice-free data, with an accuracy of 91%

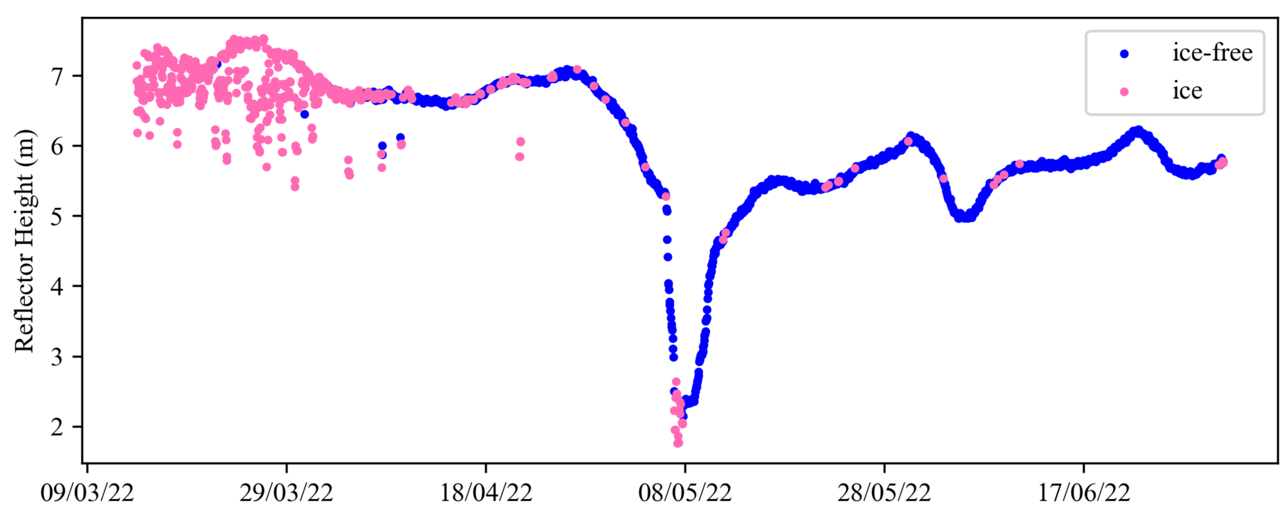


Figure 9: A time series of GNSS-IR reflector height (see h in Fig. 5) at Peace River during the ice breakup period. The data is labelled according to the output from the k-means clustering algorithm.

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