Detection and Classification of Ocean Features in SAR Imagery

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INTRODUCTION: The Spaceborne Ocean Intelligence Network (SOIN) is a six-year project initiated in June 2007 funded by the Canadian Space Agency (CSA) via its Government Related Initiatives Program (GRIP). The broad objective of the project is to develop and implement novel methods of maintaining an accurate representation of the current state of the ocean in a specified operational region (Figure 1). The key objective is to detect and track sea-surface temperature (SST) fronts associated with the Gulf Stream using RADARSAT-2 SAR imagery to supplement MODIS and AVHRR SST imagery. This work is complementary to DND's Polar Epsilon Project and is based out of MetOc Halifax.

Figure 1

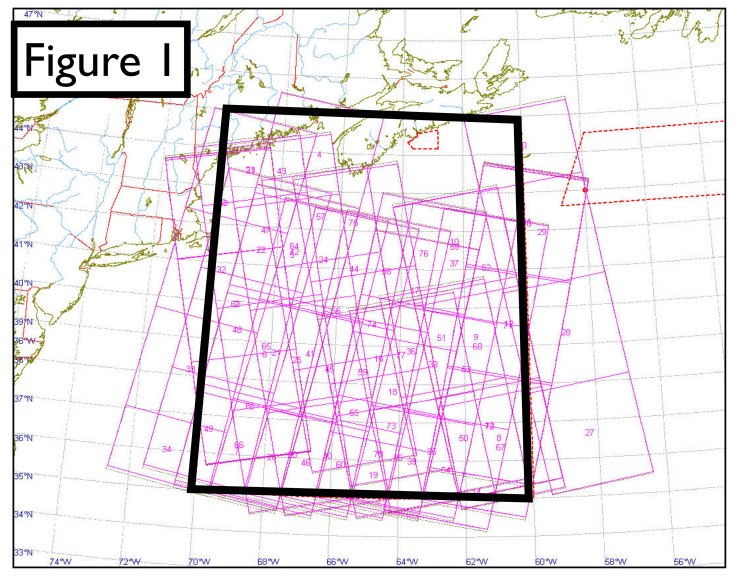
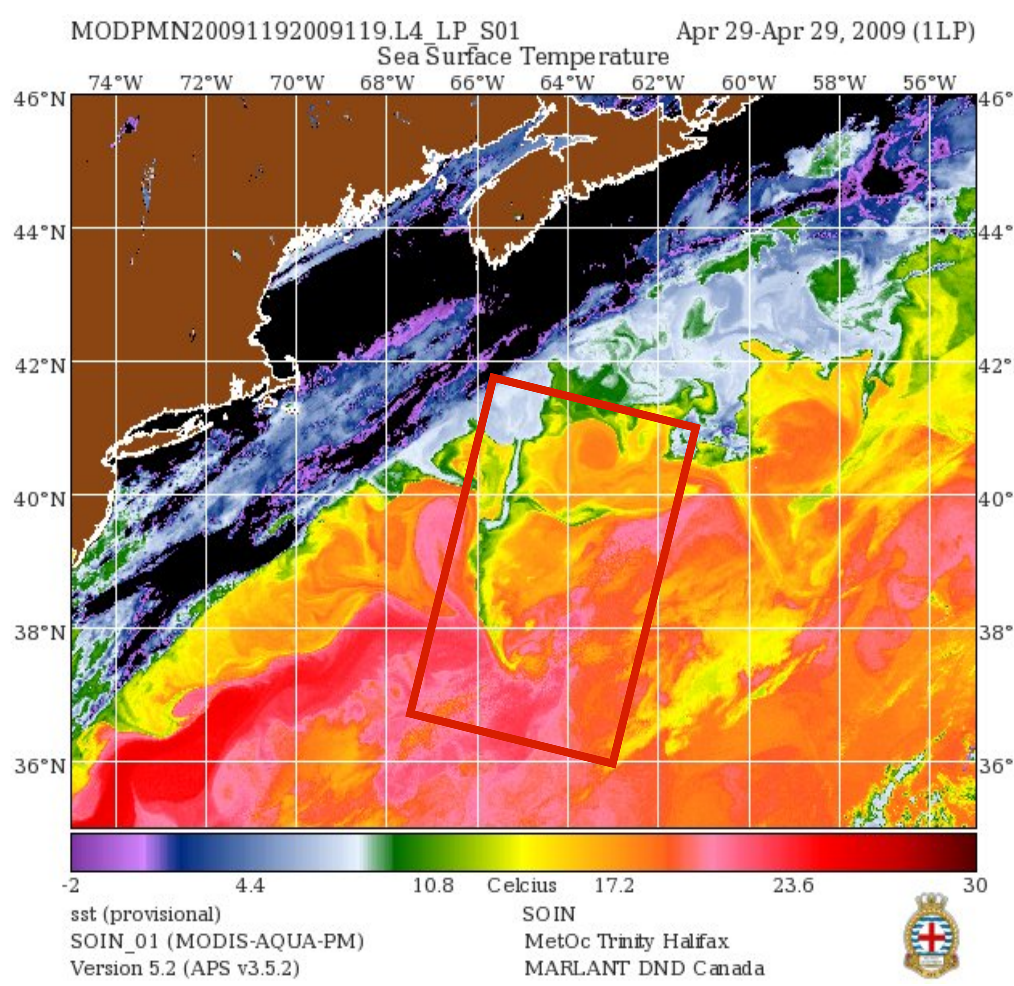
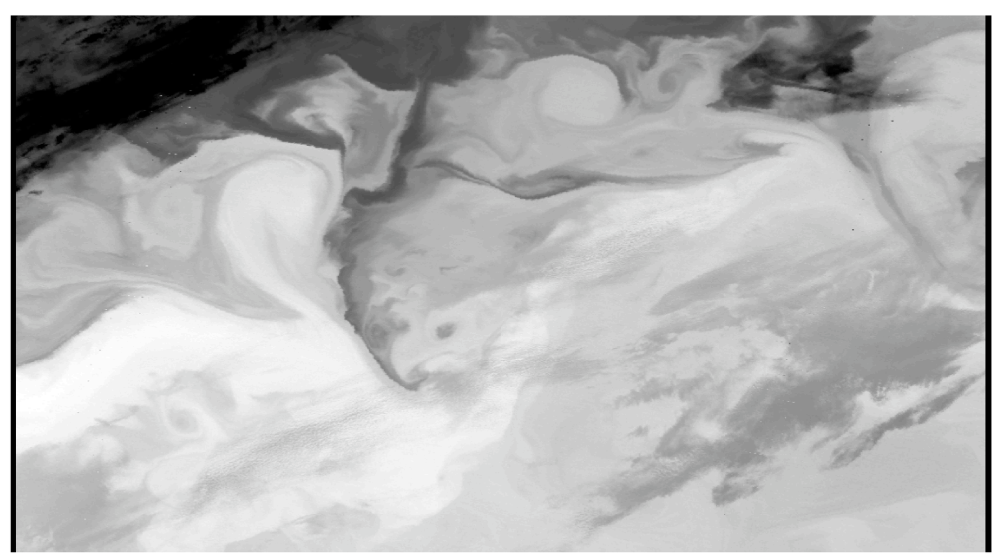


Figure 1: The operational region for SOIN is indicated by the black box. A typical set of monthly RADARSAT-2 VV SCN A acquisitions consists of 80 frames, each approximately 300 km by 300 km.

Figure 2



MODIS AQUA SST 29 Apr 0622 UTC



R2 VV SCNA 29 Apr 1024 UTC

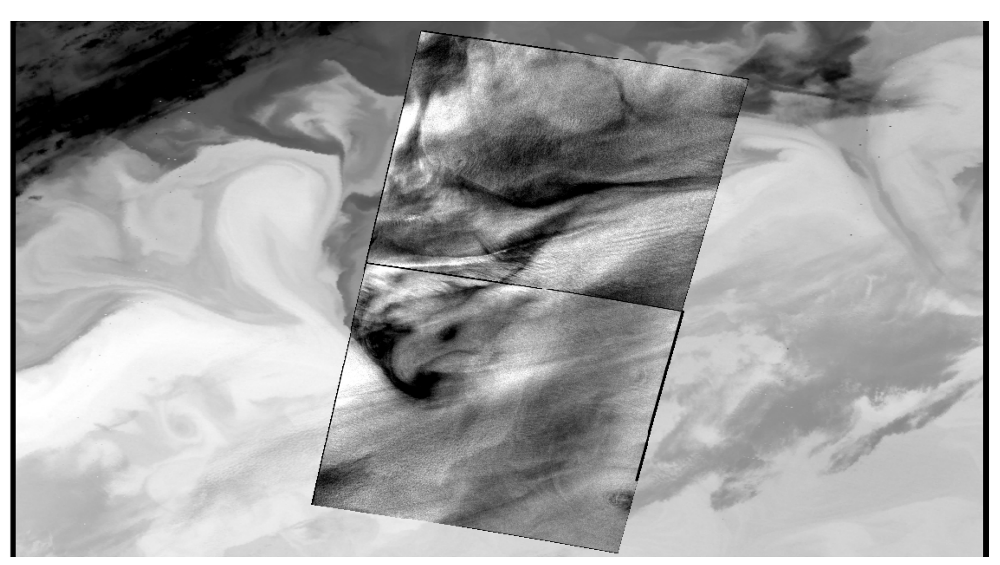


Figure 2: Synthetic Aperture Radar (SAR) is an active sensor whose signal and return penetrates cloud cover. The backscatter in SAR imagery is a measure of surface roughness, caused by capillary waves and small-scale gravity waves. Patterns in SAR correlate strongly with SST because warm water bodies are often rougher than cold water bodies due to air-sea interactions. This correlation between backscatter and SST is demonstrated by the two grayscale images. Our research intends to exploit this correlation to track the Gulf Stream using SAR imagery when cloud cover precludes the use of traditional remote sensors.

Figure 3

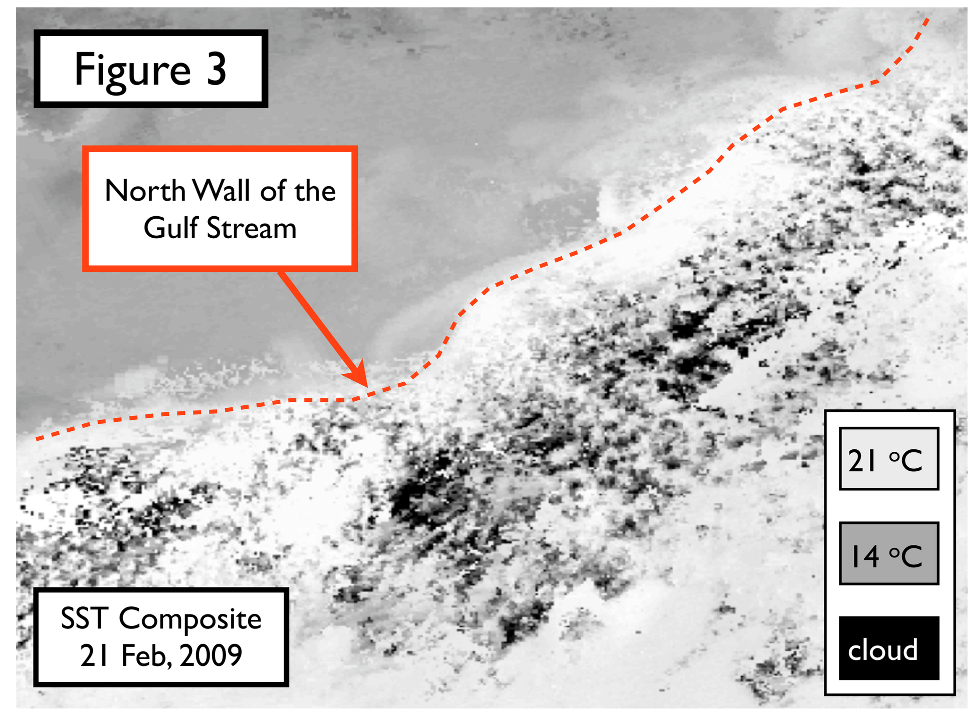


Figure 4

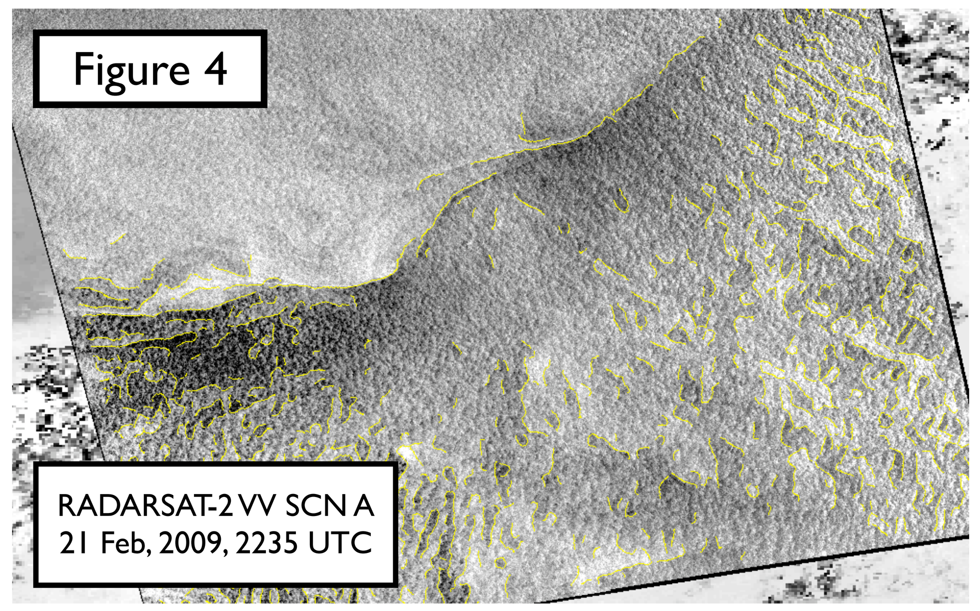


Figure 5

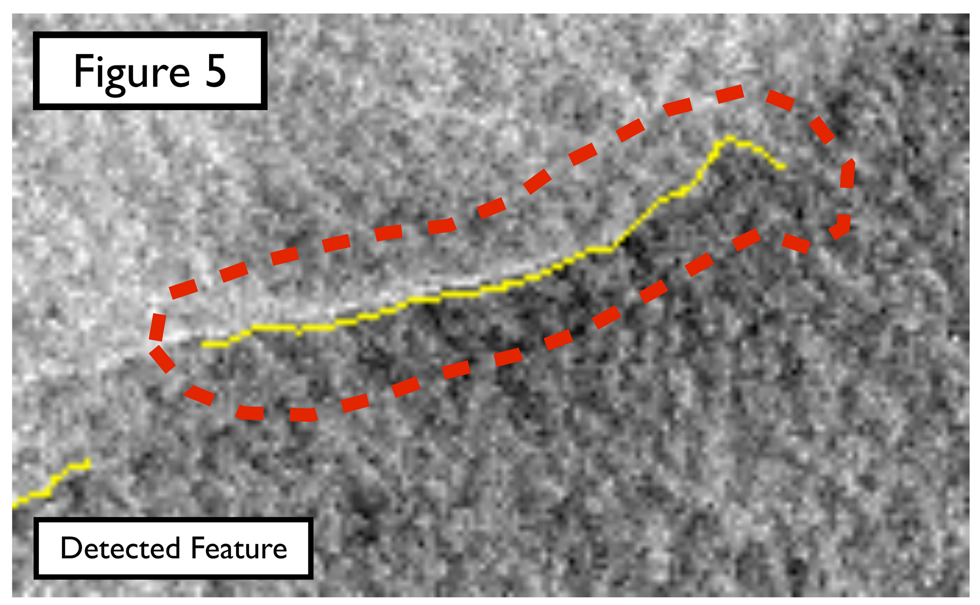
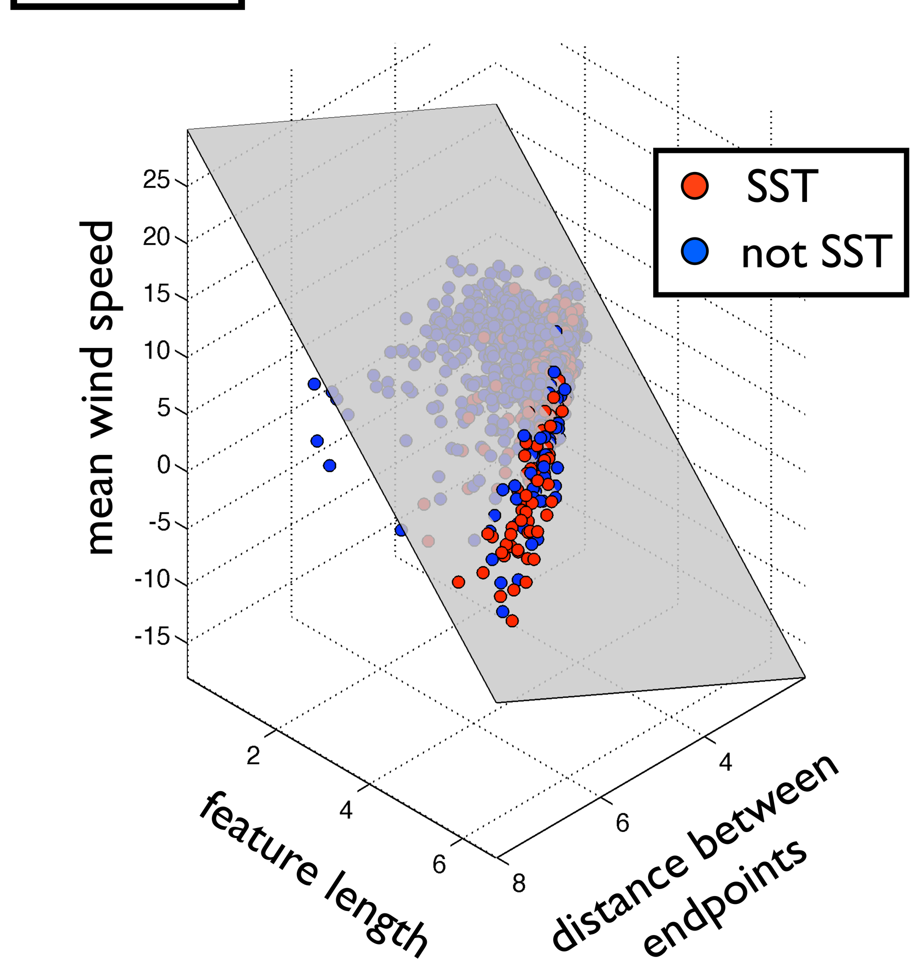
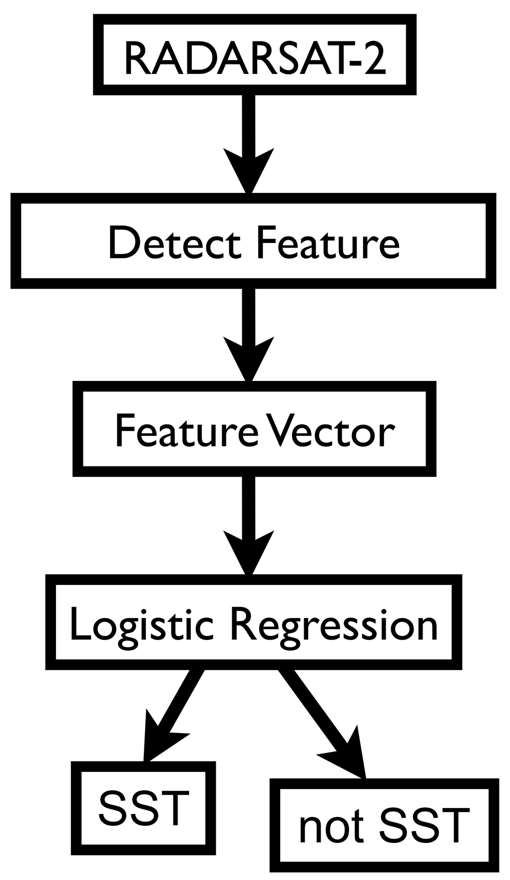


Figure 6



METHODS: A total of 58 SAR/SST image pairs were analyzed in Image Analyst Pro (IAPro), a software package developed by DRDC Ottawa. SST fronts, such as the North Wall of the Gulf Stream, were identified using composite SST images (Figure 3). Features in RADARSAT-2 images were detected using a Canny edge detector (yellow lines in Figure 4). Each detected feature was assigned a feature vector, consisting of 37 contextual and textural measures derived from surrounding pixels (red dashed line in Figure 5). Each feature vector was labeled as being either the signature of an SST front, or not, by manual comparison of the feature with the corresponding SST image. A total of 1441 labeled feature vectors were used to train and evaluate a classification model, consisting of logistic regression with a decision bound. A forward selection procedure was used to find a subset of the 37 components of the feature vectors that gives the best classification model. With the addition of each component, the model was evaluated using cross-validation based on a random 70% training data 30% test data split. The methodology is summarized in the flow chart below.



RESULT: The Model

$$P\{SST \mid (x_1, x_2, x_3)\} = \frac{1}{1+e^{-Z}}$$

$$Z = -3.5 - 0.66x_1 + 1.5x_2 + 0.29x_3$$

x_1 = distance between endpoints

x_2 = feature length

x_3 = mean wind speed

RESULT: Model Evaluation

bound	0.40 (aggressive)	0.50 (balanced)	0.60 (conservative)
capture	0.26	0.16	0.11
efficacy	0.52	0.57	0.70

DISCUSSION: Classifications are determined by comparing the modelled probability that a feature is the signature of an SST front with a decision bound probability. For example, if the bound is 0.50, then features are classified SST if the modelled probability is greater than 0.50, and not SST otherwise. The model is evaluated by determining the **capture probability** = the probability that a feature labeled SST is classified SST, and the **efficacy** = the probability that a feature classified SST is correctly classified, both of which are determined using test data. A good model will have high values for both of these probabilities. The performance of our model is poor, indicating that the labeled feature vectors are not well separated. This is shown in Figure 6, where it can be seen that red (SST) and blue (not SST) points intermingle heavily. The grey plane in Figure 6 corresponds to a decision bound of 0.50. All points above the plane are classified as SST, and those below as not SST. We are currently investigating ways of improving the separation, such as dividing the region of surrounding pixels into two regions and extracting measures from each portion (illustrated in Figure 7 below), and aggressively filtering out noise.

Figure 7

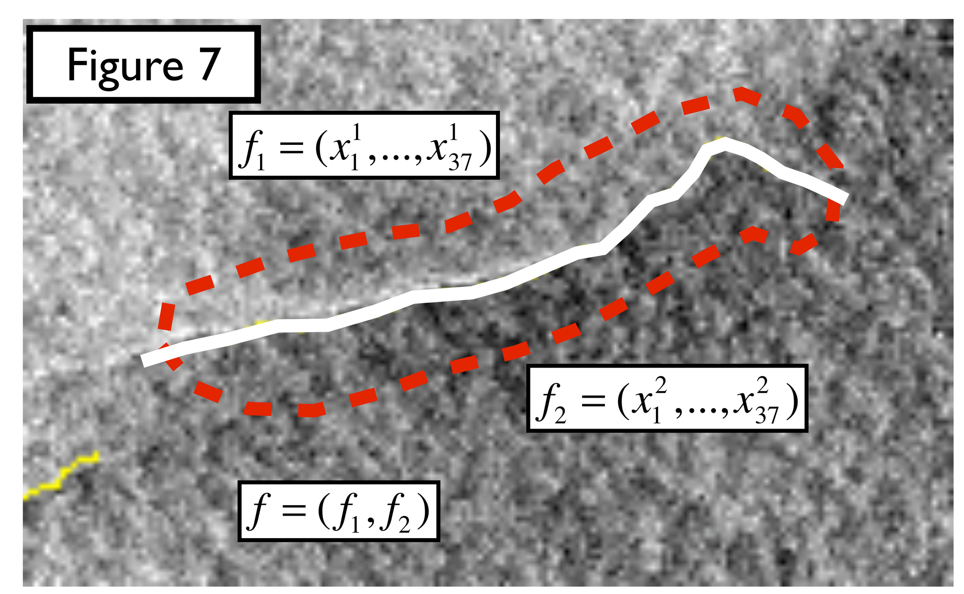


Figure 7: The SAR images used in this study have been median filtered to remove noise. The figure shows that significant speckle remains after this process. As we want to identify features that are spatially large, more aggressive filtering may be used without loss of information. By filtering more aggressively, feature vectors extracted from either side of a Canny edge will contain contrast information that should result in better separation of the labelled feature vectors.

PARTNERS: MetOc Halifax, DRDC Ottawa, DRDC Atlantic, DFO (Bedford Oceanographic Institute, Institute Maurice Lamontagne, Institute of Ocean Sciences), Royal Military College, Dalhousie University, NRL Stennis, CSA

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