Arctic Sea Ice Classification Using ALOS-2 Palsar-2 L-Band SAR Images

Singha S [1] , Johansson M [2] , Doulgeris A [2]
[1] German Aerospace Center (DLR), Bremen, Germany
[2] UiT The Arctic University of Norway, Tromsø, Norway

Safe passage in ice infested areas is important for the maritime industry. L-band synthetic aperture radar (SAR) images are not regularly used operationally though multiple studies have shown that L-band SAR can detect and separate deformed sea ice from the surrounding sea ice and provide easier separation between first year ice (FYI) and multi-year ice (MYI) in the early and advanced melt season than C-band SAR. Here we want to evaluate the suitability of L-band sensors with regard to Near Real Time (NRT) operational services in ice infested water and quantify the two major challenges, effects of incidence angle and seasonal variation.

We use 108 fully polarimetric ALOS-2 Palsar-2 images acquired during freezing and early melt conditions during the Norwegian Young Sea Ice Cruise 2015 (N-ICE2015) drift study and the Polarstern's (PS92) transitions in the Arctic Seasonal Sea Ice Zone. We use a supervised sea ice classification (neural network) to classify open water (OW), newly formed sea ice (NI), smooth FYI and deformed FYI and MYI within these scenes.

For training and validation of the neural network we use overlapping in-situ data from N-ICE2015 and PS92 to identify different sea ice areas and from this generate a training and validation dataset. The in-situ data consists of airborne electromagnetic (AEM) sea ice thickness measurements combined with photographs. The AEM has an accuracy of ±0.10m (Haas et. al., (2009), enabling easy separation of NI from surrounding thicker sea ice, though there are limitations in separating NI from OW. The photographs taken during the flights are therefore an essential part of the training area identification. The study area used here is located in the Arctic Ocean north of Svalbard, between 80°N to 84°N and 8°W to 25°E. The sea ice within the study areas was primarily a mixture of FYI and second year ice (SYI) though areas of thinner sea ice types such as nilas, young grey ice and young white ice were observed. Overlapping optical images from Landsat-8 show stages of new ice formation, grey ice and grey-white ice.

The SAR scenes were acquired with 5 different incidence angles from late March until early June where approximately 20 scenes acquired for each incidence angle. Each different incidence angle was used for a fixed number of days and are season specific. One training and validation dataset was therefore extracted for each incidence angles. Out of the 5 different incidence angles 3, where acquired during the freezing season and 2 of them during early melt season. The freezing season was defined as when the air temperatures are below -5°C and the snow cover is dry. Temperature records from N-ICE2015 show a range from -25°C to +2°C at the time of satellite image acquisitions. Until mid-May the temperatures were below -5°C, thereby ensuring that approximately half of our satellite images were acquired during the freezing season and half during the early melt season. This enables us to study not only incidence angle dependency but also seasonal changes for sea ice classifications using L-band SAR data.

The L-band SAR images used here are fully polarimetric and polarimetry has been shown to improve sea ice classification in C-band SAR (Dabboor and Geldsetzer (2014) and Geldsetzer et. al. (2015)). In addition, has studies by e.g. Wakabayashi et. al. (2004), Dabboor et. al. (2017) and Singha et. al. (2018) shown that for L-band SAR polarimetric parameters, such as entropy and anisotropy, are useful for separation of open water, thin sea ice and thicker sea ice. We extract 18 polarimetric features for each pixel and investigate the importance of different polarimetric parameters for sea ice classification and how the incidence angle affects those parameters. Earlier work by Mahmud et. al. (2018) and Wakabayashi et. al. (2004) among others have investigated the incidence angle dependency for different polarimetric parameters for different sea ice types for L-band SAR though not simultaneously with the seasonal changes. Here we classify the sea ice in two different ways, firstly with an incidence angle dependent training and validation dataset (self-training) and secondly, we train the algorithm with one incidence angle dataset and validate it using another incidence angle dataset (cross-training). This enables us to quantify the effects of incidence angle and seasonal variation.

For the self-training we found an accuracy of 92% or higher. In the cross-training results we observed seasonal variations, where cross-seasonal cross-training data achieves 51% to 82% accuracy. The highest values are observed when freezing season data is used to classify early melt season images (70% to 82%). When cross-training is used within season the accuracy is between 60% to 90%, where the early melt season cross-training has the smallest range of between 69% to 80% accuracy. From this we observe that for an automatic sea ice classification we need to address both the seasonality and the incidence angle.

Earlier studies have shown that L-band SAR has an advantage over C-band SAR for detection of deformed sea ice areas as well as is less sensitive to the onset of the melt season. L-band SAR can therefore be considered a useful complement to the ongoing C-band SAR missions and with the ongoing mission of ALOS-2 Palsar-2 and planned new missions such as SAOCOM (2018), ALOS-4 PALSAR-3 (2020) and NASA-ISRP's NISAR (2021) a continued availability of L-band SAR is foreseen.

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