

On Importance of Off-diagonal elements in Polarimetric Covariance Matrices: A Sea Ice Application Perspective

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Introduction:

The ESA Sentinel-1 Extra Wide mode GRDM products which is widely used for sea ice studies, provides only intensity information. In a quad polarimetric set up, the polarimetric channel *intensities* occur in the main *diagonal* of the PolSAR covariance matrix. Thus, this gives an impression that the diagonal elements alone suffice for segmenting sea ice scenes from PolSAR images.

Dierking (TGARS 2014) has shown that the co-polarization correlation coefficient ($CCorr$) carries substantial information of scattering from sea ice in C-band. And it is obtained using the (1,3) off-diagonal term in the covariance matrix.

Thus, it is worth investigating, if the availability of this additional feature (off-diagonal) can improve the sea ice segmentation over just intensity (diagonal) information.

Objective:

- Compare clustering results for sea ice, with and without the co-polarization correlation term.
- Verify whether the sea ice classes are meaningful or artifacts of the method in respective cases.

Methodology:

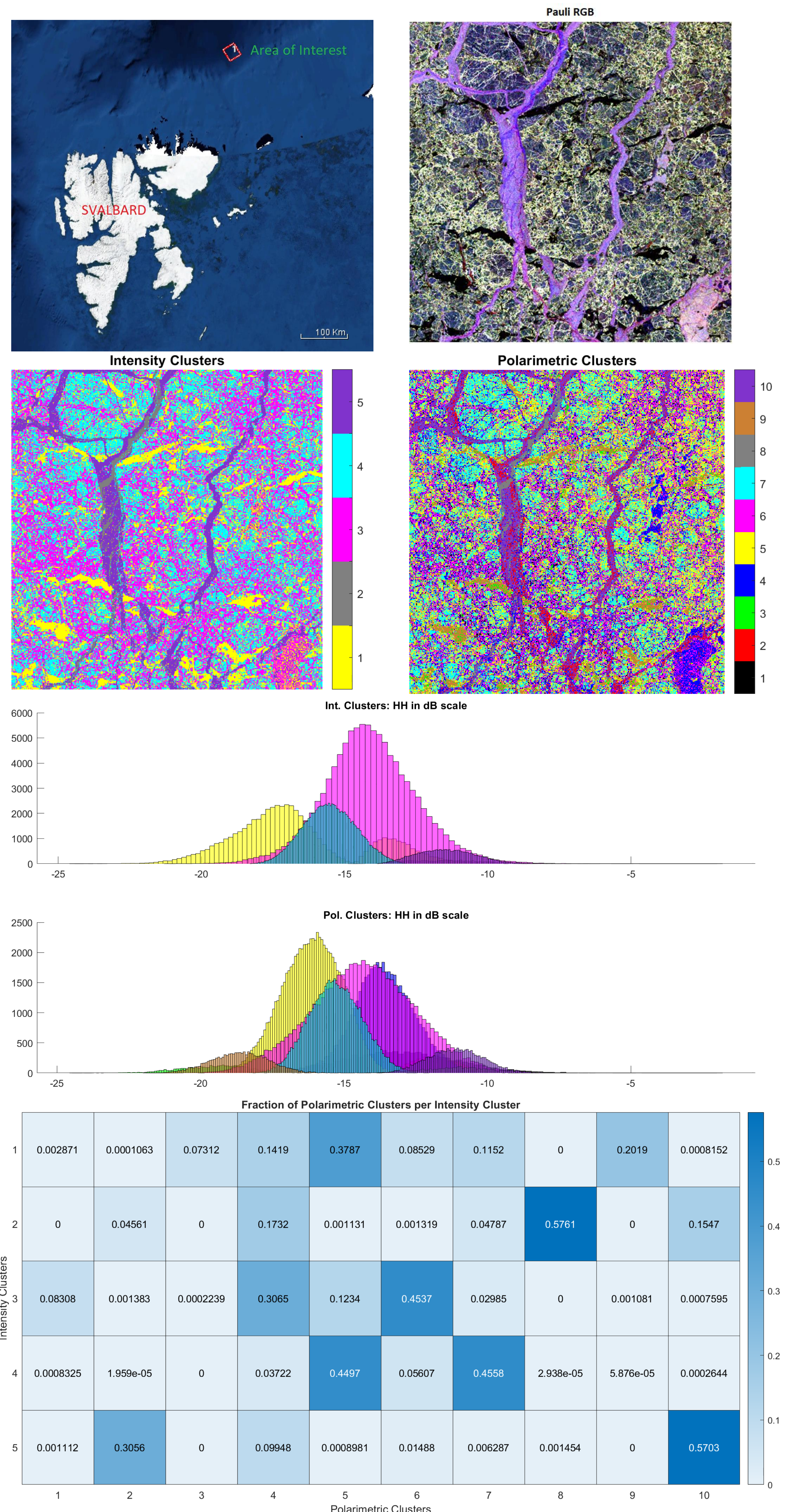
For our experiments, we choose a Mixture of Gaussians (AMoG)-based clustering, which also automatically determines the number of clusters in the PolSAR image (Doulgeris et al. JASP 2009). We consider **two different feature sets** and apply AMoG-clustering to it.

- **HH, HV, VV channel intensities** (log scale) [*Intensity*]
- **Geometric Brightness (GB)** (log scale; alternative to SPAN) **co- and cross polarization ratios (CR and XR)** (log scale) **Real and Imaginary parts of CCorr** (linear scale) [Extended *Polarimetric* Feature Space (EPFS)]

All the internal parameters of AMoG-clustering remain identical for the two separate runs.

Dataset:

A fully polarimetric C-band RADARSAT-2 image from December 2019, located north of Svalbard (Johansson et al. JSTARS 2020). The regional extent is 25 km x 25 km, and incidence angle $\sim 40^\circ$. The data is processed to Multi-look Complex form in PolSARpro to an effective mean ground range square pixel of 52.44 m.



Remarks and Conclusion:

- The number of clusters doubles from 5 to 10 implying that $CCorr$ carries significantly different information content.
- The polarimetric clusters belong to distinct visual segments in the Pauli RGB implying that the clusters can be attributed to sea ice types of different characteristics.
- The low backscatter regions in the Pauli RGB, show a mixture of polarimetric clusters (Row 1 of Table above) implying further in-situ data is needed to qualitatively analyze the sea ice types present.