

On Suitability of ALOS-2/PALSAR-2 Dual-Polarized SAR Data for Arctic Sea Ice Classification and Parameter Estimation

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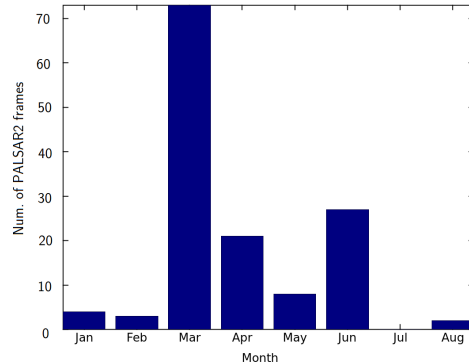
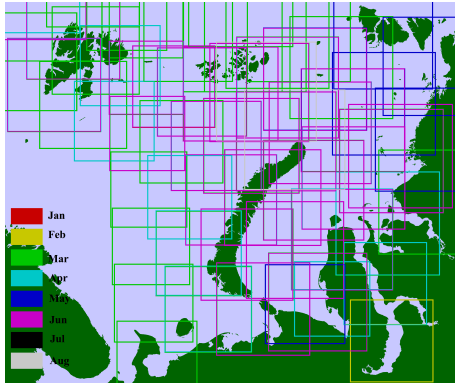


Introduction

- JAXA 6th Research Announcement for the Advanced Land Observing Satellite-2 (ALOS-2) project: Improved Sea Ice Parameter Estimation with L-Band SAR (ISIPELS), PI number 3029 (Juha Karvonen)
- Referred publications:
 - J. Karvonen, E. Rinne, H.Sallila, M. Makynen, On Suitability of ALOS-2/PALSAR-2 Dual-Polarized SAR Data for Arctic Sea Ice Parameter Estimation, IEEE Transactions on Geoscience and Remote Sensing, v. 58, n. 11, pp. 7969–7981, 2020.
 - J. Lehtiranta, S. Siiria, J. Karvonen, Comparing C- and L-band SAR images for sea ice motion estimation, The Cryosphere v. 9, n. 1, pp. 357–366, 2015.



Study Area and Data

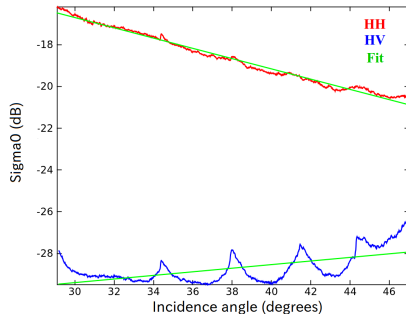


Locations of the test ALOS-2/PALSAR-2 imagery in the study area, indicated by the image bounding boxes, and Monthly distribution of the ALOS-2/PALSAR-2 imagery.



SAR Data Preprocessing

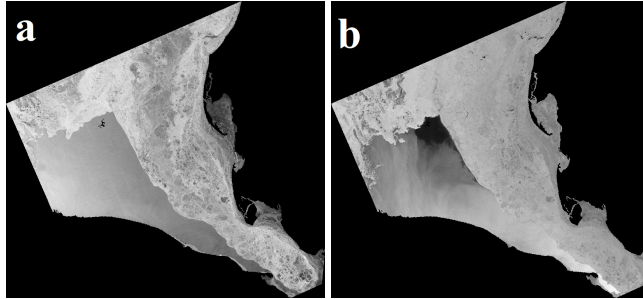
- Calibration and georectification to Polar Stereographic projection.
- The range dependence computed for a small set (20) images was used for incidence angle and range noise floor correction.



ALOS-2/PALSAR-2 statistical incidence angle dependence for HH (red curve) and HV (blue) channels and their linear least-squares fits (green).



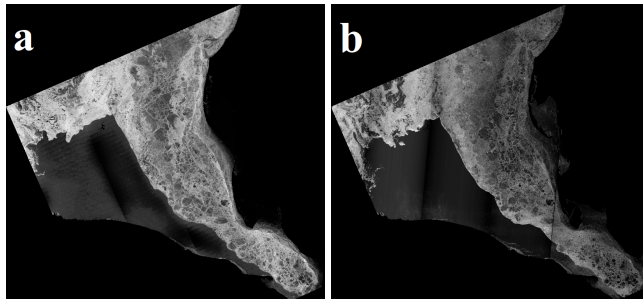
Comparison between C- and L-band SAR Data



A typical example of a HH channel of ALOS-2/PALSAR-2 (a) and a cropped Sentinel-1 image of the same day over the ALOS-2/PALSAR-2 image area (b), 26 March 2017.



Comparison between C- and L-band SAR Data



HV channel of ALOS-2/PALSAR-2 (a) and the cropped Sentinel-1 HV channel image of the same day (b), 26 March 2017, corresponding to the HH channel images. in the previous figure.



Comparison between C- and L-band SAR Data

- We compared ALOS-2/PALSAR-2 L-band and C-band (Sentinel-1 EW GRDM HH/HV) SAR imagery over the same area acquired during the same day both visually and numerically.
- Both visual and numerical (e.g. histogram width, average local gradient) comparisons indicate that L-band data have better local contrast and can better distinguish sea ice details than C-band.
- Obvious explanation is the deeper penetration at L-band and increased amount of information of the ice below the ice surface.



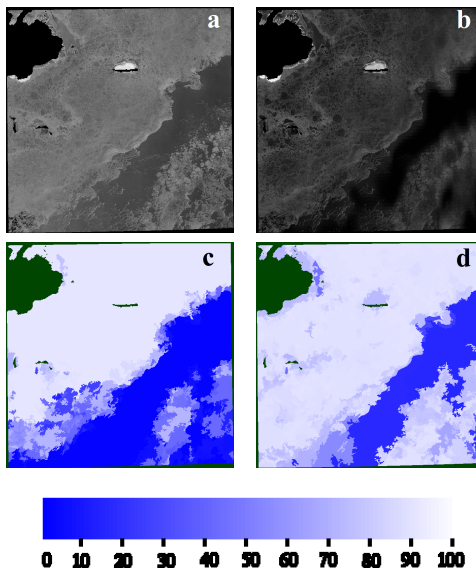
SI/OW Discrimination and SIC Estimation

Table: OW/SI discrimination power of selected texture features using a Bayesian thresholding.

Method	OW	SI	total
σ_{HH}^0 (L-band)	0.22	0.86	0.60
σ_{HV}^0 (L-band)	0.17	0.99	0.66
σ_{HH}^0 (C-band)	0.55	0.70	0.62
σ_{HV}^0 (C-band)	0.82	0.70	0.76
E_{HH}	0.70	0.94	0.84
E_{HV}	0.69	0.85	0.79
C_A^{HH}	0.79	0.94	0.88
C_A^{HV}	0.77	0.87	0.83
C_C	0.62	0.80	0.72
V_1^{HH}	0.78	0.89	0.84
V_1^{HV}	0.74	0.70	0.72
SNR_{HH}	0.11	0.99	0.59
SNR_{HV}	0.17	0.98	0.65



SI/OW Discrimination and SIC Estimation



SI/OW Discrimination and SIC Estimation

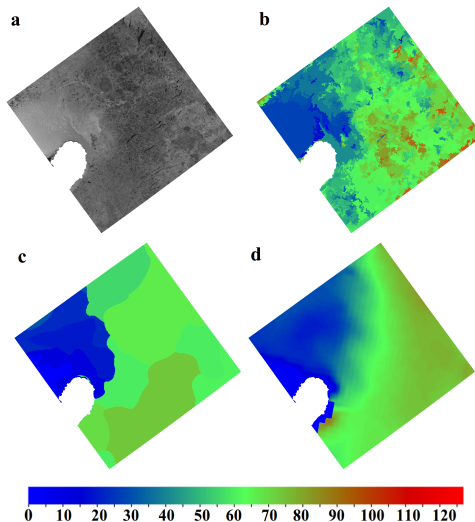
Table: Error measures for the MLP SIC estimation, in percentage points.

Data set	Bias (D_{sgn})	L1 difference (D_{L1})	RMSE
Train	1.7 (5.6)	7.9 (5.8)	13.1 (7.9)
Test	3.2 (9.9)	10.8 (8.6)	17.1 (10.8)

- The SIC estimation results are slightly better than for C-band (L1D about 13 ppt).



SIT Estimation



ALOS-2/PALSAR-2 HH channel (a), 14 March 2017 (©JAXA) and SIT estimate (b), SIT derived from AARI ice chart (c), SIT from TOPAZ4 ice model (d). Ice thickness unit is cm.



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Sea Ice Volume

- Sea ice volume over an area W can be computed from SIC (C) and SIT (H) over the area:

$$V_{ice} = A_p \sum_{(r,c) \in W} C(r,c)H(r,c), \quad (1)$$

where A_p is one product grid cell (pixel) area (0.25km^2 in our 500 m grid).

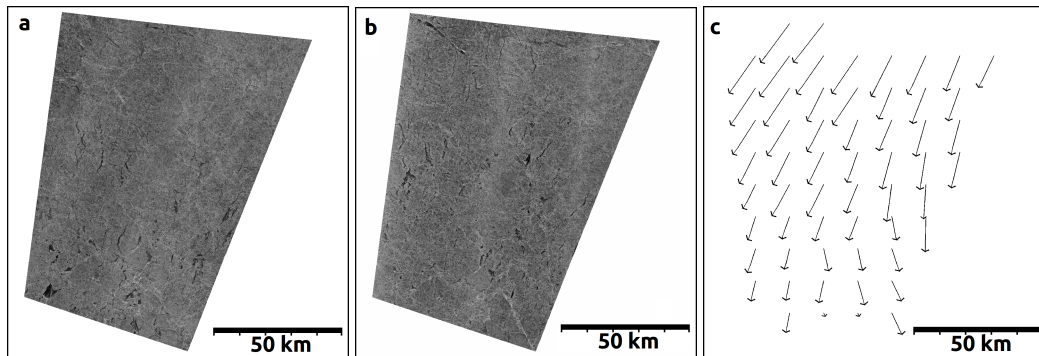
- First-order estimation error or accuracy ΔV_{ice} can thus be estimated as

$$\Delta V_{ice} \approx A_p(C\Delta H + H\Delta C). \quad (2)$$

- Assuming 2 m thick ice and 100% ice concentration and using L_1 differences of C and H w.r.t. reference data $\Delta H=0.2$ m and $\Delta C=0.11$, we get a relative accuracy of about 20% for the ice volume estimates.
- For thinner ice the relative uncertainty would then be some larger, e.g. for 1 m sea ice around 30%, assuming a high SIC.



SID Estimation



Overlapping areas of the PALSAR-2 images of 20 March 2017 20:05:19 UTC (a) and 23 March 2017 14:28:57 UTC (b) and the corresponding ice drift vector field between the acquisitions (c). The SAR images gray scales have been normalized for better visual quality. The vector field is presented in sparse resolution and the vectors have been scaled longer for better visual quality. The dominant ice drift direction is to south/southwest.

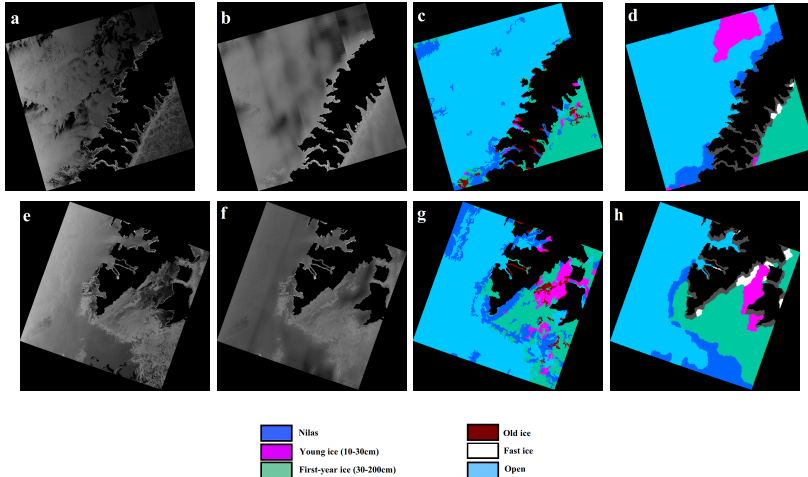


SID Estimation

- Only a few overlapping image pairs with a reasonable time difference (≤ 3 days).
- Tests were made using our operational (C-band Sentinel-1/RADARSAT-2) algorithm, based on ORB feature matching and optical flow → The results well correspond to the visual interpretation of motion of details in the imagery.
- It was shown already in Lehtiranta et al. (2015) that L-band SAR is well suitable for SID estimation using MCC approach. Also mixed detection is possible with C-band imagery.



Sea Ice Classification



The HH (a,e) and HV (b,f) SAR images of two SAR images FMI classification (c and g), and AARI ice types (d and h) corresponding to two SAR images. Both SAR images shown were acquired on 18 April 2017.



Conclusion

- ALOS-2/PALSAR-2 ScanSAR HV-channel processing parametrization was changed on April 11 2018: the onboard ATT (attenuator) setting was changed from 25 dB to 20 dB. Before changing (and this study) this setting ScanSAR HV-polarization images sometimes became dark and blurred over ocean and coastal regions → reduced performance for HV band features.
- L-band data are good for estimating the studied sea ice parameters, in general some better than C-band SAR data.
- L-band sea ice (type) classification works better than C-band classification. L-band texture features have better discrimination power.
- Does L-band continue all the information at C-band or will C-band be needed to complement L-band (or how is C-band needed)? To be able to answer to this will still require additional research.
- Only FYI included in this study.



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