Antarctic sea ice extent from ISRO's SCATSAT-1 using PCA and an unsupervised classification

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SCATSAT-1

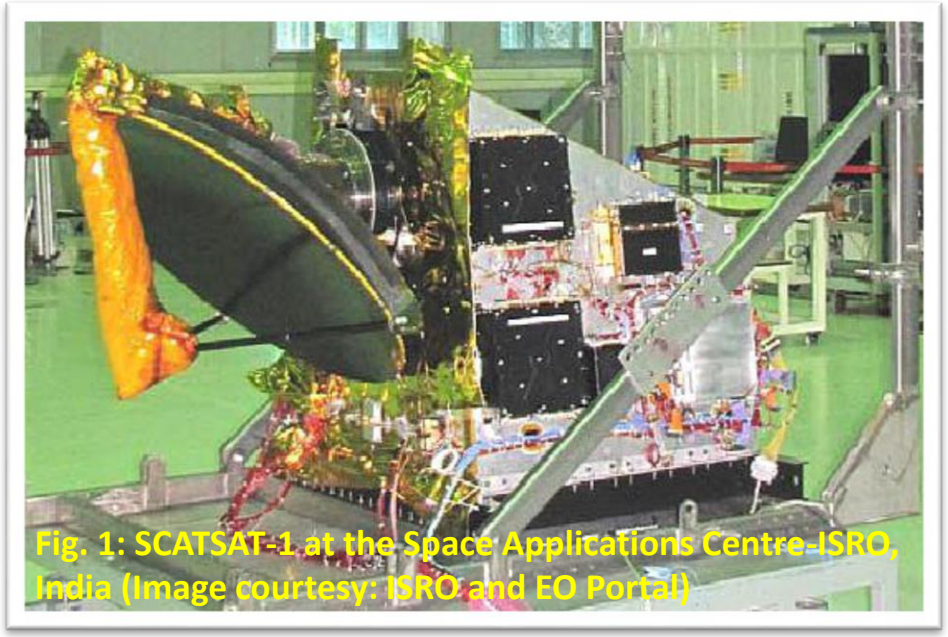

Fig. 1: SCATSAT-1 at the Space Applications Centre-ISRO, India (Image courtesy: ISRO and EO Portal)

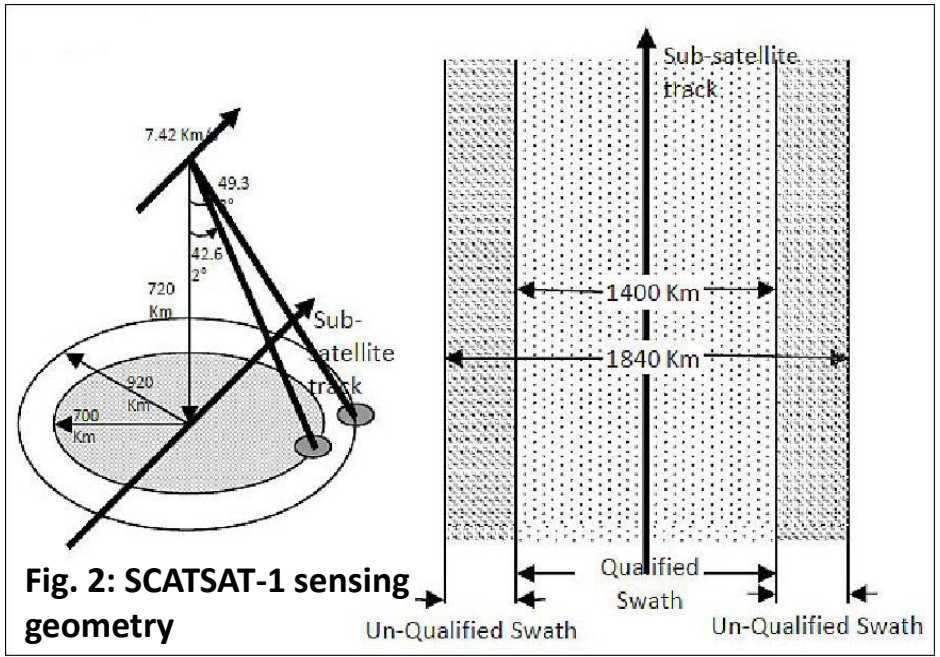

Fig. 2: SCATSAT-1 sensing geometry

1. Launched on 26 Sep 2016, SCATSat-1 (ISRO's first multi-orbit mission- 8 payloads), miniature satellite (371 kg) built from spares of previous missions (40%)
2. Continuity mission- acting as a successor to OceanSat-2 (OS2) and predecessor to OS-3
3. Main objectives- observing global ocean wind, a remote sensing capability with respect to global day and night weather forecasting
4. Orbit: Sun-synchronous, altitude = 720 km, inclination = 98.1º
5. Sensor specifications: Ku-band (13.515 GHz) dual-pencil beam conically scanning scatterometer.
6. Inner beam is HH polarized (incidence angle: 42°) and outer beam is VV polarized (incidence angle: 49°), leads to multiple azimuth angle measurement of the same scene. That means each point in the inner swath is viewed twice at different azimuth angles by both beams.

Datasets

Enhanced resolution SCATSAT-1 Data

- Microwave Data Processing Division/Signal and Image Processing Group at the Space Applications Centre-ISRO, Ahmedabad produces enhanced resolution Level 4 products at various temporal and spatial resolutions
- Generated from Level 1B products using Scatterometer Image Reconstruction (SIR) algorithm
- The datasets used in this study is the SouthPolar24 (VV and HH). This dataset is generated from Level-1B data using both ascending and descending passes of the backscattering coefficient (sigma-0) and other radiometric parameters for the past 24-hr
- Parameters used are σ_0, Υ_0 and T_b. The dataset is archived at the ISRO's data archival centre, Meteorological & Oceanographic Satellite Data Archival Centre, MOSDAC (https://mosdac.gov.in/)

AMSR2 sea ice concentration

- Institute of Environment Physics (IUP), University of Bremen generates sea ice conc. using ASI and Bootstrap algorithm @ 3.125 km and 6.25 km resp.
- At 15% SIC threshold, SIE are calculated for comparison with SC1-derived SIE

Other datasets

- Sentinel-1A/1B SAR Level-1 Extra Wide (EW) Ground Range Detected (GRD) swath imageries at medium resolution from Alaska Satellite Facility, Univ. of Alaska, Fairbanks
- ice chart shapefiles from the U.S. National Ice Center/Naval Ice Center
- MOSDAC/ISRO Sea ice occurrence probability for creating probable max ice boundary

SCATSAT-1 L4

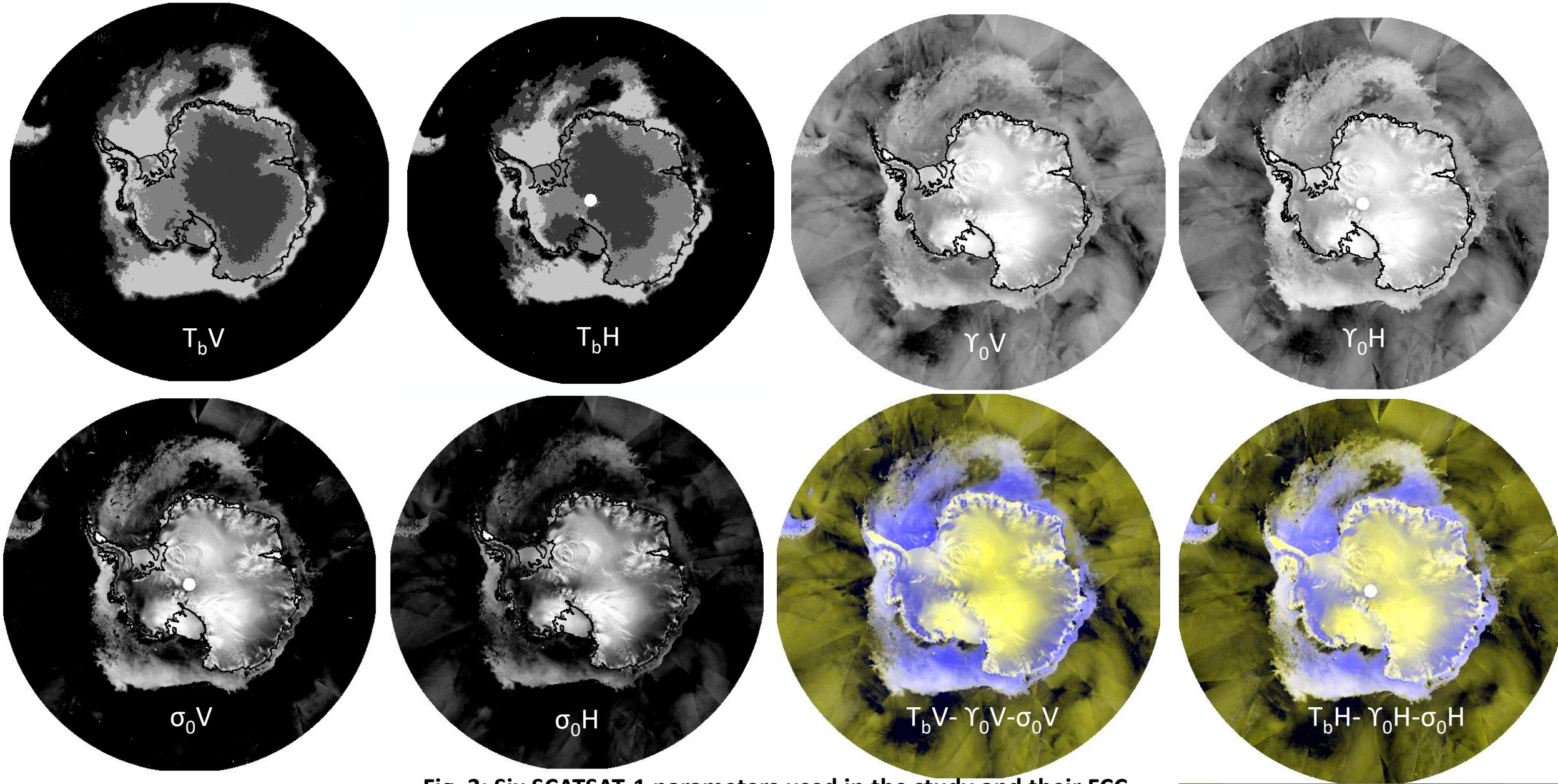

Fig. 3: Six SCATSAT-1 parameters used in the study and their FCC

Principal Component Analysis

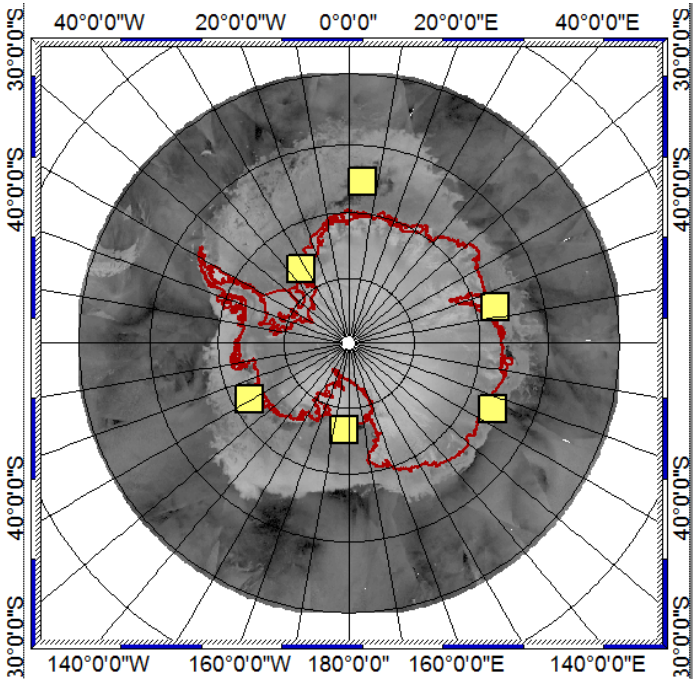

Fig. 4: Location map of sites selected for PCA

- Ten dates chosen for PCA: 1/12/2016, 14/12/2016, 30/12/2016, 1/2/2017, 15/2/2017, 28/2/2017, 2/5/2017, 16/5/2017, 30/5/2017 & 7/10/2017; **240000** usable data points
- Using Minitab, PC coefficients are generated from six SC1 parameters
- Principal Components generated using these coefficients
- Proportion of variation explained by the i^{th} principal component = eigenvalue for that component divided by the sum of the eigenvalues

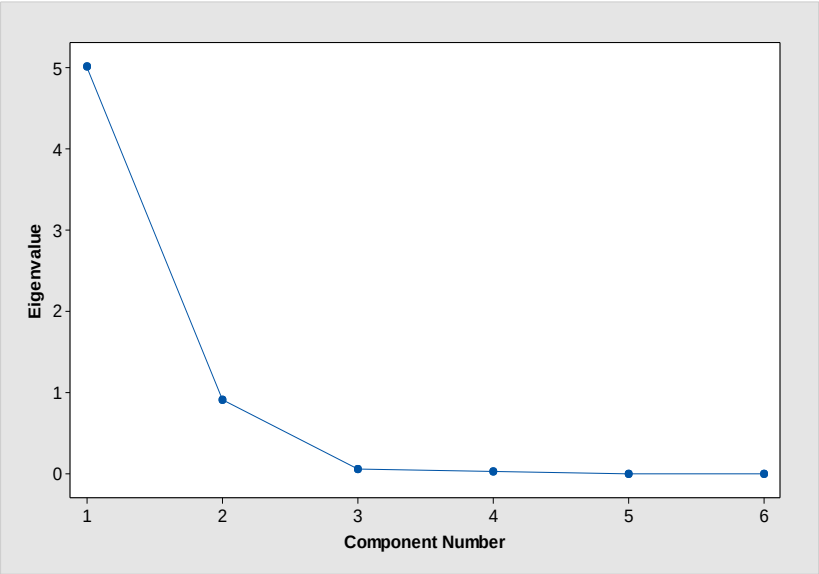

Fig. 6: PCA Scree plot

Coeff ▶ Parameters ▼	Coeff 1	Coeff 2	Coeff 3
Tb_H	0.3623	-0.6015	-0.08589
Tb_V	0.3668	-0.5857	-0.1571
Gam_H	0.4379	0.1604	0.5315
Gam_V	0.4185	0.3493	-0.4514
Sig_H	0.4380	0.1602	0.5303
Sig_V	0.4186	0.3490	-0.4476

Fig. 5: PCA Coefficients

PCA

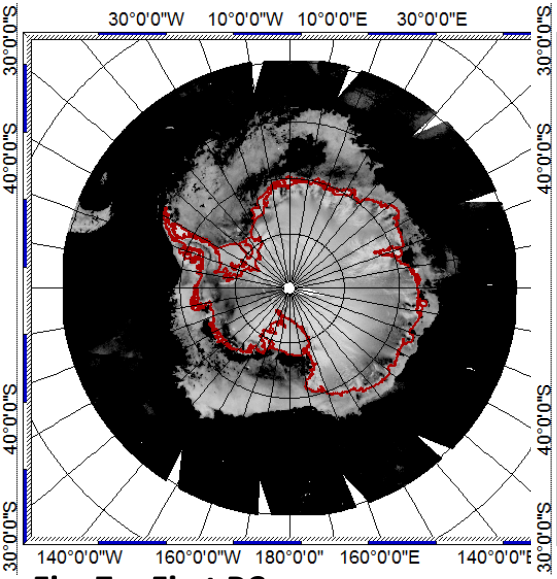

Fig. 7a: First PC
Proportion of Variance Explained: 83.4%

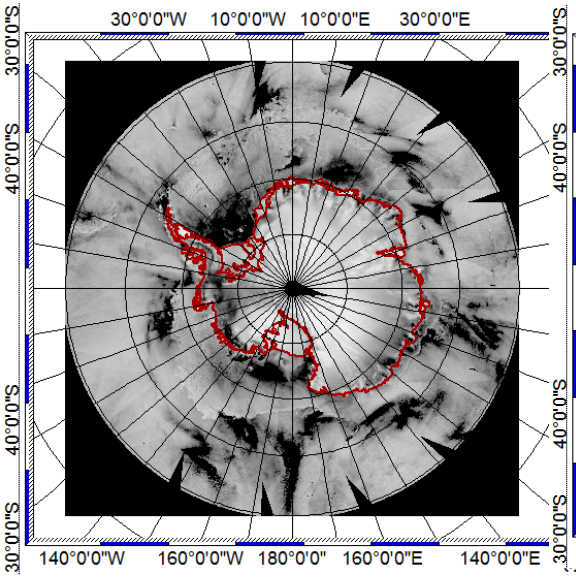

Fig. 7b: Second PC
PVE: 15.2%

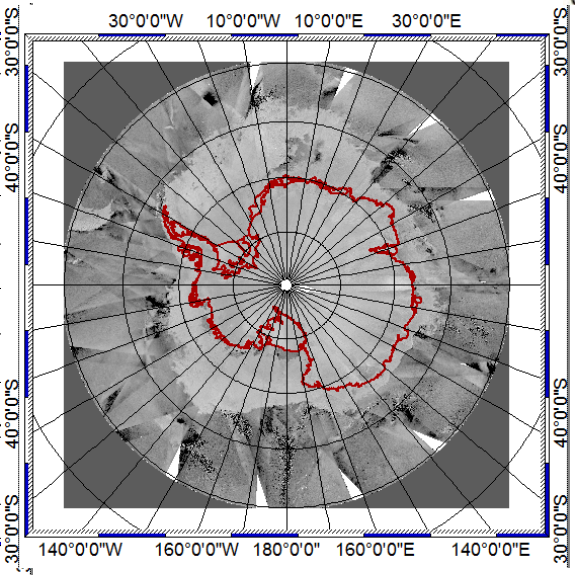

Fig. 7c: Third PC
PVE: 0.9%

Total Variance explained by First three PCs: 99.5%

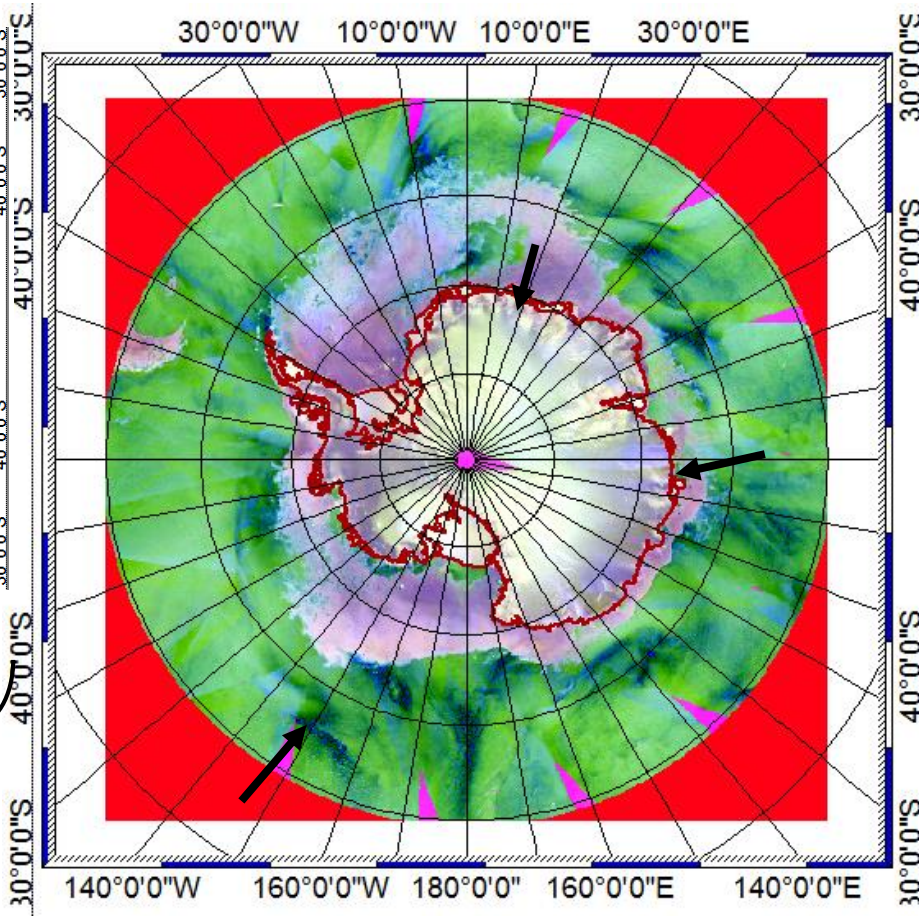

Fig. 8: FCC of first three PCs

Sea ice map and extent

- HSV transformation to sharpen the FCC
- ISODATA/k-mean clustering in ArcMAP/ArcGIS to get Antarctic sea ice map and SIE calculated
- Post classification technique: Majority filter and masking using SIOP probable max sea ice boundary

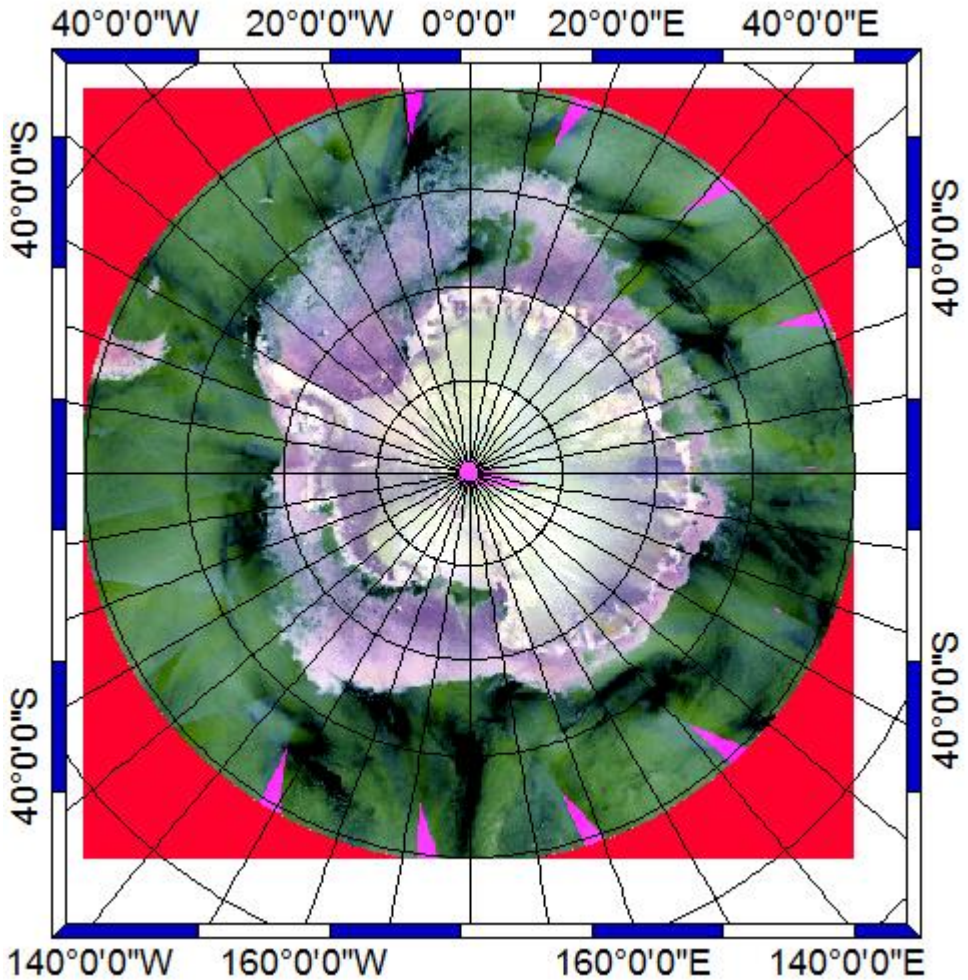

Fig. 9: HSV Sharpened FCC

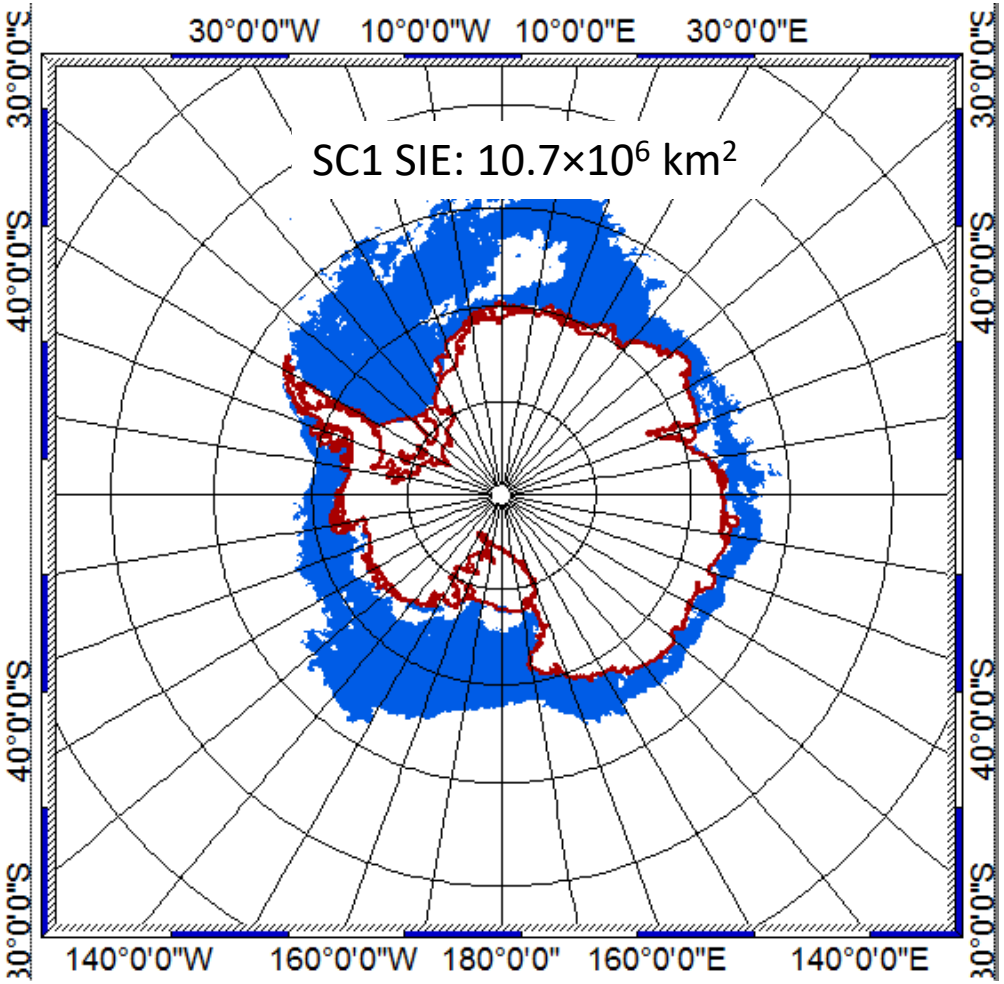

Fig. 10: Austral sea ice map

Comparison with well known datasets

i. SC1 Versus ASI & Bootstrap (AMSR2)

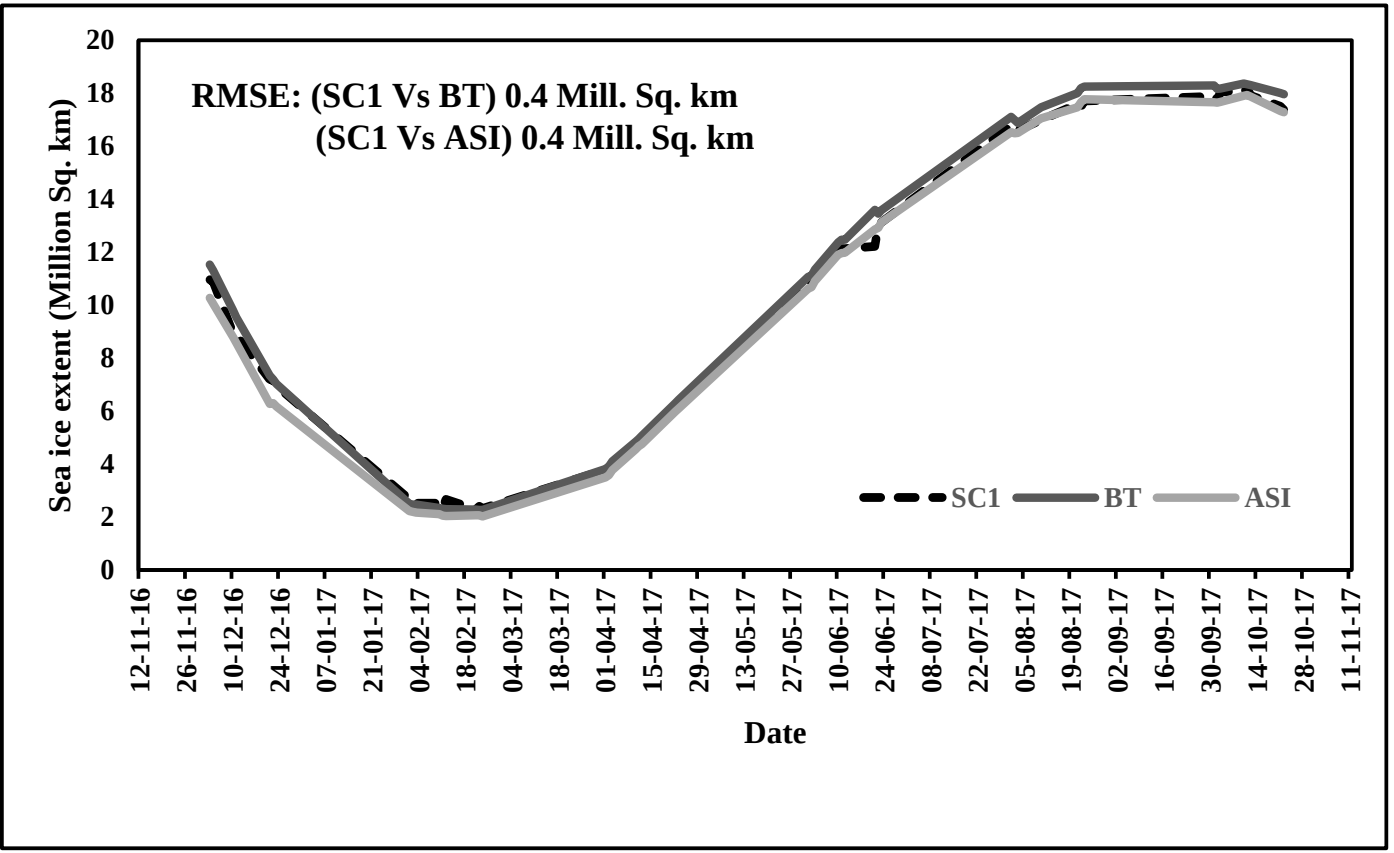

Fig. 11: SC1 Vs ASI & BT SIE

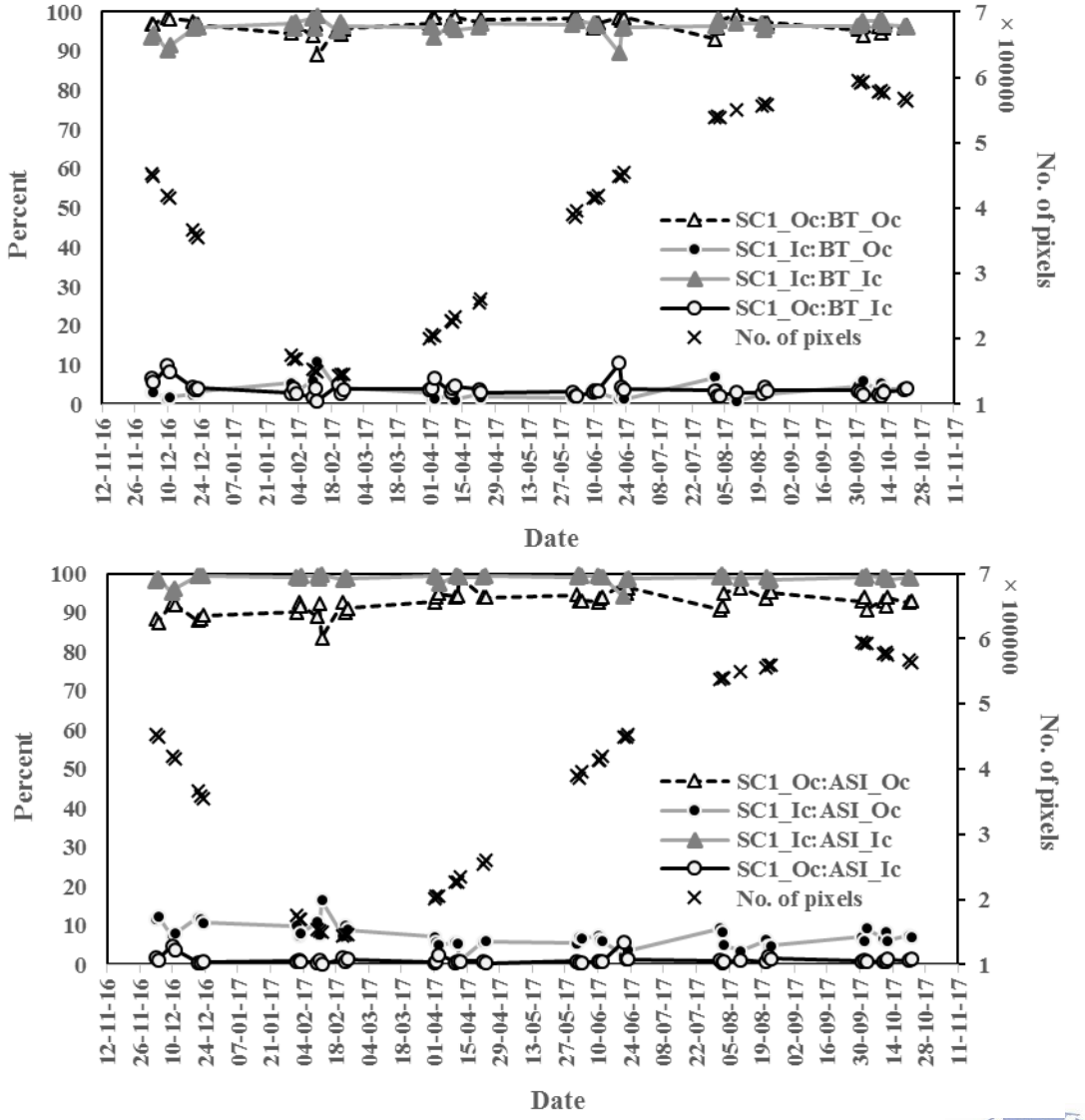

Fig. 12: Pixel-wise mapping accuracy for SC1 Vs BT and SC1 Vs ASI

Comparison with well known datasets- contd.

ii. SC1 Versus Sentinel-1A/B EW GRD

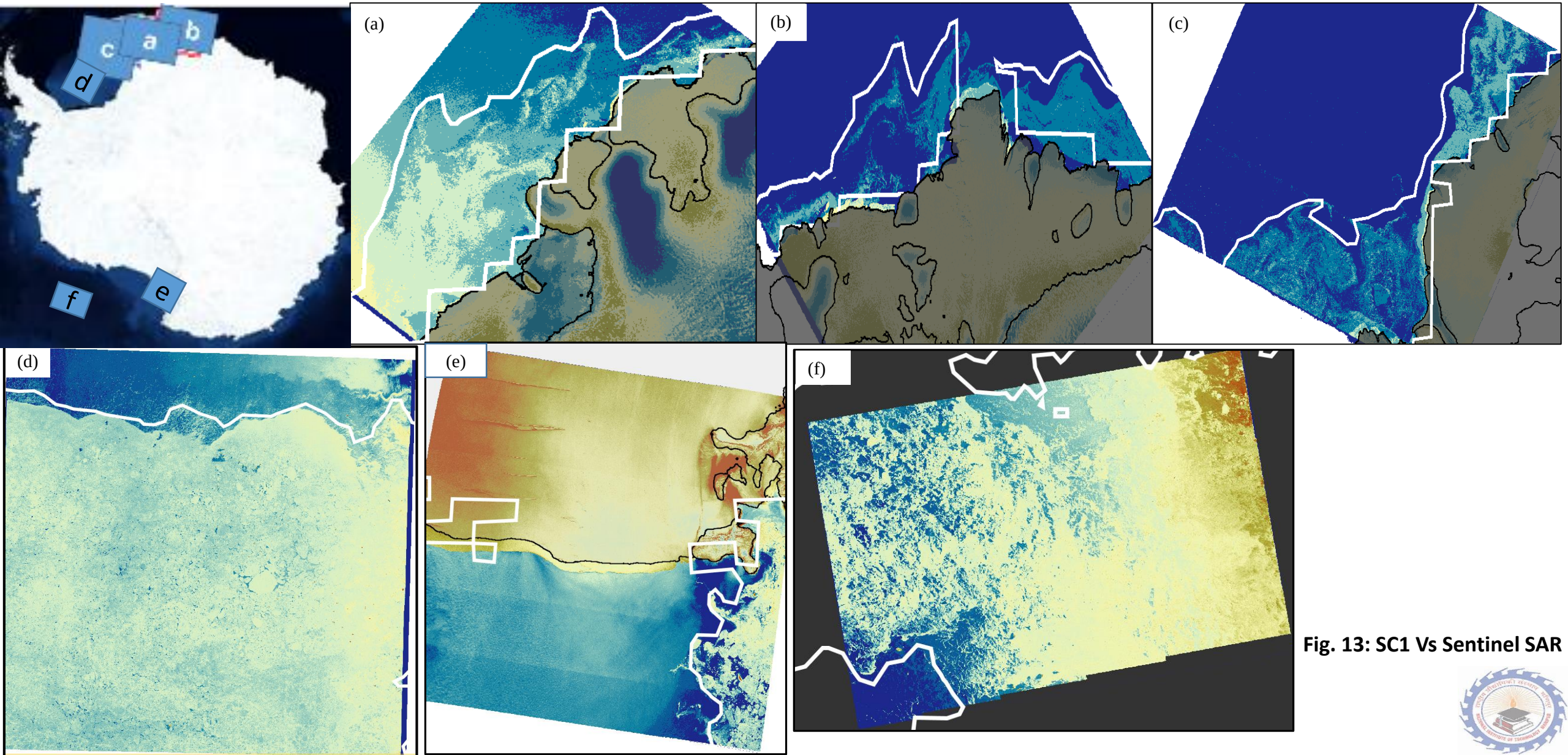

Fig. 13: SC1 Vs Sentinel SAR

Comparison with well known datasets- contd.

iii. SC1 Versus US NIC ice chart

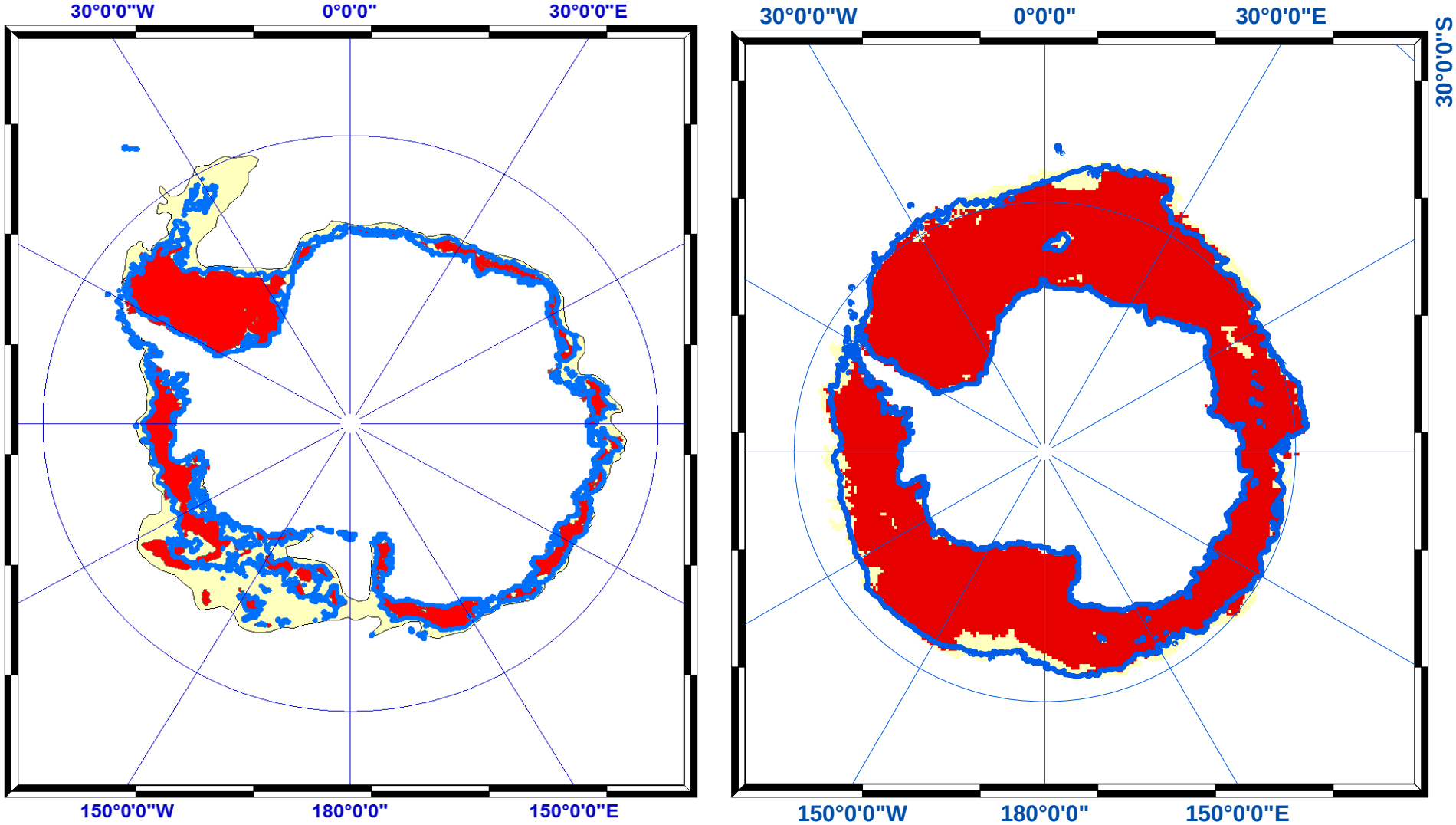

Fig. 14: SC1 Vs NIC Ice chart. Sea ice pack in red = 8/10th or greater of sea ice

Conclusions

- An algorithm for the detection of sea ice in the Southern Oceans and to estimate the austral sea ice extent using SCATSAT-1 enhanced resolution data (@2.225 km)
- Combination of Principal Component Analysis and ISODATA k-means image classification
- Sea ice estimates from this method are found to have a high degree of correlation with other available high quality sea ice products. Pixel-wise accuracy mapping reveals there is an overall ice-to-ice mapping accuracy of about 99% when compared with ARTIST Sea Ice (ASI)-derived sea ice extent and 96% when compared with Bootstrap. Ocean-to-ocean mapping accuracy is also high (in excess of 90%).
- Moreover, in comparison with high resolution SAR and ice chart data, the algorithm tends to perform satisfactorily.
- In future, the algorithm will be applied for the detection of important Antarctic polynyas such as those occurring in Weddell Sea and Ross Sea, to study their dynamics.

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THANK YOU