“Spatio-temporal analysis of polar land ice dynamics”

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tent

roduction

oposed collaboration and responsibilities

erature Review

fferent Components of Study:

A. Development of Algorithm in order to derive velocity of

g objects/features.

B. Studying IceShelf advancement and Tracking Iceberg

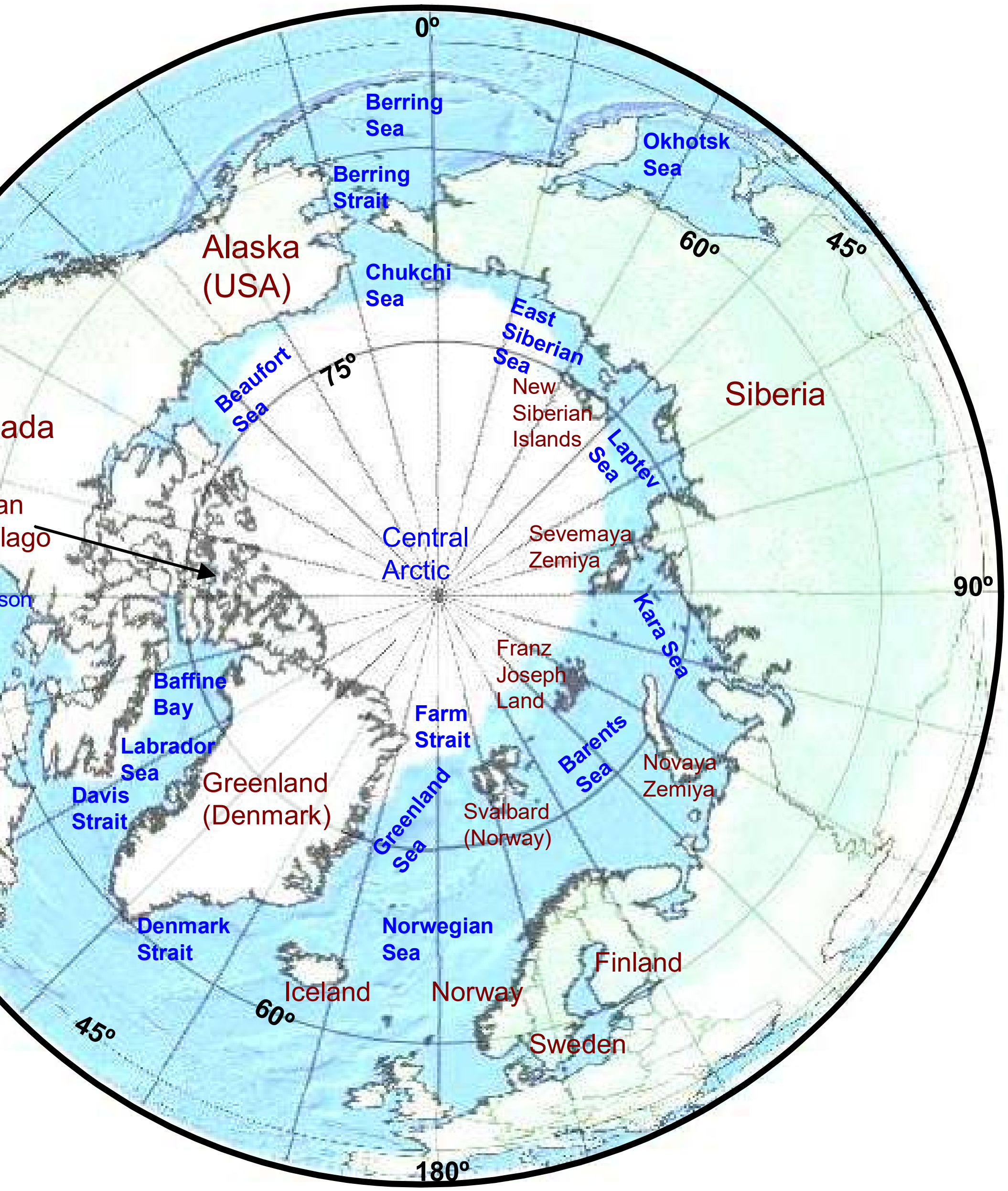
C. Mean IceSheet velocity near Maitri Research Station using

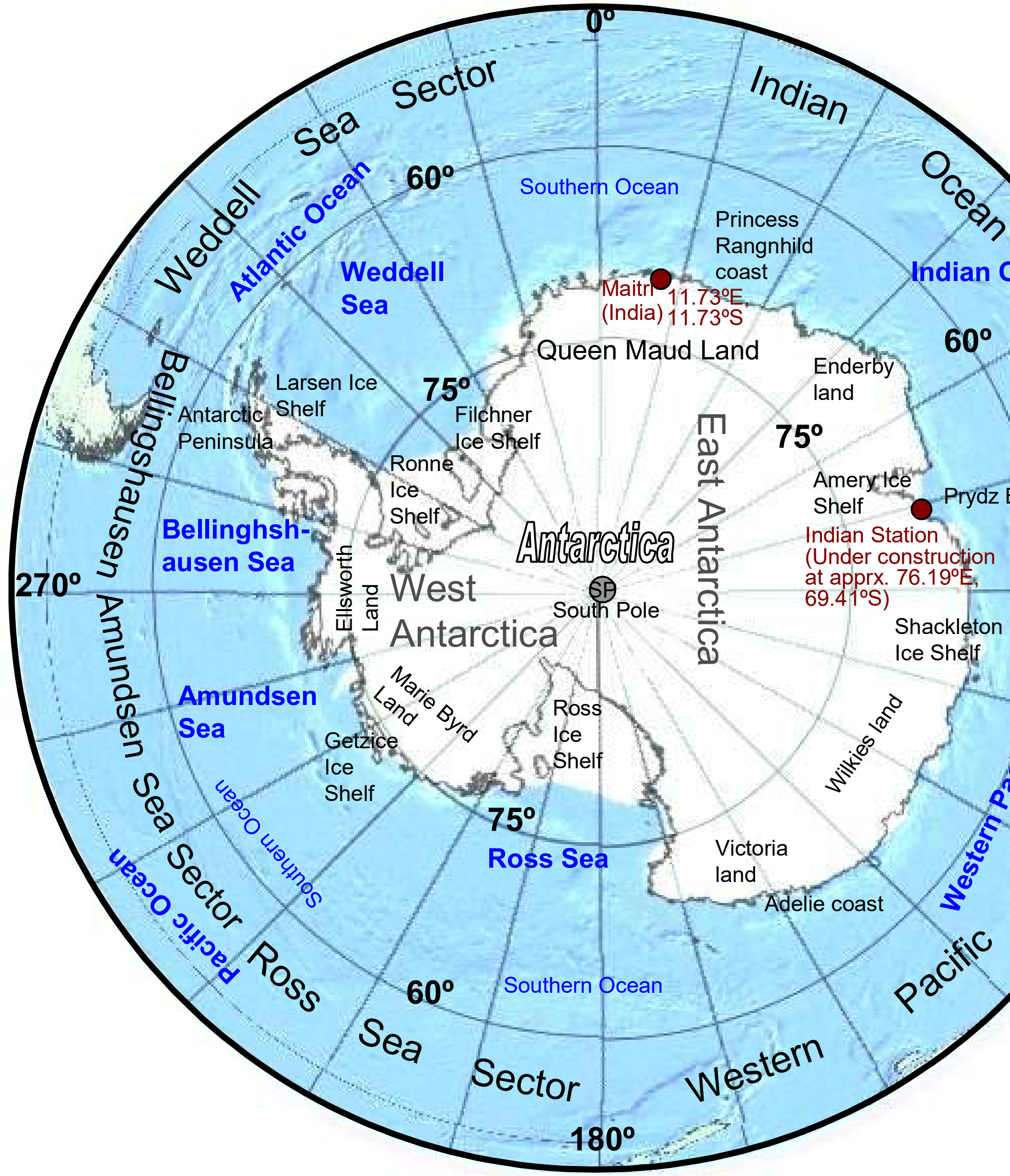
T Tracking in SNAP

D. DInSAR based velocity Estimation

troduction

- Out of all continents on the Earth, Polar regions are least explored and least understood owing t unique geographical location and associated climate, crustal and cryospheric process.
- Polar sea ice has an important climate, regulating impact by limitation exchanges of momentum, and moisture between the ocean and atmosphere.
- t modulates the normal exchange of heat and mass between the atmosphere and ocean by inso sea surface from atmosphere.
- Conventional methods of data collection over Polar Regions have certain limitations.
- But as increasing scope of Earth observation satellite there has been an increase in the availabilit remotely sensed data over Polar region related to ice sheets, ice shelves, polar glaciers, polar coa regions etc.
- Glacial ice is largest reservoir of fresh water on earth.


0º
Berring Sea
Okhotsk Sea
Berring Strait
Alaska (USA)
Chukchi Sea
60º
45º
East Siberian Sea
Beaufort Sea
75º
New Siberian Islands
Siberia
Laptev Sea
Central Arctic
Sevemaya Zemiya
90º
Kara Sea
Franz Joseph Land
Baffine Bay
Farm Strait
Labrador Sea
Barents Sea
Novaya Zemiya
Greenland (Denmark)
Davis Strait
Greenland Sea
Svalbard (Norway)
Denmark Strait
Norwegian Sea
Finland
Iceland
Norway
60º
45º
Sweden
180º


0º
Weddell Sea Sector
Indian Ocean
Atlantic Ocean
60º
Southern Ocean
Princess Rangnhild coast
Weddell Sea
Maitri (India) 11.73ºE, 11.73ºS
Queen Maud Land
60º
Bellingshausen Amundsen Sea
Larsen Ice Shelf
75º
Enderby land
Antarctic Peninsula
Filchner Ice Shelf
East Antarctica
75º
Ronne Ice Shelf
Amery Ice Shelf
Bellingshausen Sea
Antarctica
Indian Station (Under construction at apprx. 76.19ºE, 69.41ºS)
270º
Ellsworth Land
West Antarctica
SP
South Pole
Shackleton Ice Shelf
Amundsen Sea
Marie Byrd Land
Ross Ice Shelf
Getzice Ice Shelf
Wilkies land
Southern Ocean
75º
Ross Sea
Victoria land
Pacific Ocean
Adelie coast
Ross Sea Sector
60º
Southern Ocean
Western Pacific
180º

posed collaboration and responsibilities

proposed project aims at the following objectives:

study the seasonal and inter-annual variations observed in namics of polar glaciers, ice streams and ice sheet regions.

entification and monitoring of changes in sub-glacial lakes ected regions of Antarctica

onitoring of Changes Over Antarctic Land Ice Features in sele rts of Antarctica

y area includes the selected parts of Antarctica, Greenland oard regions.

sponsibilities

C	DES-GU	Joint responsibilities
to provide overall guidance satellite data (if required to be purchased from NDC, NRSC).	• development and validation of techniques; • analysis of data and • generation of maps/data and its investigation.	• Technique development, data analysis and cross-validation o the results.

nedule

ntification of study sites	T0+12 months
alysis of 25% of study area	T0+12 months
alysis of 25% of study area (Total 50%)	T0+24 months
alysis of 25% of study area (Total 75%)	T0+36 months
alysis of 25% of study area (Total 100%)	To+46 months
mpilation of results and report writing	To+48 Months

ature review

Paper	Author	Brief Description
eet Motion and raphy from Radar rometry	Ronald Kwok, Mark **A.** Fahnestock	Both topography and motion information are present in repeat ERS-1 interferograms over ice she demonstrate that the topography separable from the surface displacement field when a seque radar images are available. If the velocity field is constant over the span of observation, the topograp (can be derived from differential interferograms formed from sequ observations. With this measurem a pure displacement field can the obtained by removal of the topographic contribution to the interferometric phase at each pix

-source sea ice drift algorithm entinel-1 SAR imagery using a nation of feature tracking and pattern matching	Stefan Muckenhuber , Stein Sandven	Sentinel-1 data is used. In ord detect drift Feature tracking(OR detect distinct patterns in both in and tries to connect similar fea without accounting the loc information, for more acc detection of motion pattern mat is used which tries to find the co match in a given window prese the location information done by

heet Motion and Topography from Radar Interferometry by Ronald Kwok, Member, ZEEE, and Mark A. Fahnest

ier Surface Velocity Estimation & Facies Classification using InSAR and Multi-Temporal SAR Techniques in India va by ANIRUDHA VIJAY MAHAGAONKAR March, 2019

suring Seasonal Permafrost Deformation with Differential Interferometric Synthetic Aperture Radar by Carina vorth ,April 2008.

MUM CONDITIONS FOR DIFFERENTIAL SAR INTERFEROMETRY TECHNIQUE TO ESTIMATE HIMALAYAN GLACIER TY by Bala Raju Nela , Gulab Singh, Anil V. Kulkarni and Kapil Malik.

RIS, the "Open Source SAR Investigation System" for Automatized Parallel InSAR Processing of Sentinel-1 Time ith Special Emphasis on Cryosphere Applications by David Loibl, Bodo Bookhagen, Sébastien Valade and Chris ler.

rential InSAR for tide modelling in Antarctic ice-shelf grounding zones by Christian T. Wild, Oliver J. Marsh, and ng Rack

ating sub-pixel offset techniques as an alternative to D-InSAR for monitoring episodic landslide movements in
ed terrain by A. Singleton , Z. Li , T. Hoey , J.-P. Muller
LICATION OF D-INSAR TECHNIQUE ON GROUND MOVEMENT MONITORING by Guijie WANG, Mowen XIE, Jiehu
Weilun WU
ss D-InSAR for Estimation of Displacements Caused by October 2016 Central Italy Earthquake.
n, P.P. 1959. "A contribution to the geology of the western part of the Australian Antarctic Territory ." Bureau
Resources Geology and Geophysics Australia Bulletin 1-103.
i, S., S. Oza, R. Shah, B.P. Rathore, and I.M. Bahuguna. 2018. "Rift assessment and Potential calving zone of Ar
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uw, D. 1999. "DInSAR and Coherence tracking applied to glaciology: The example of the Shirase glacier." FRIN
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deswell, J.A., and T.J. Benhan. 2003. "A surge of Perseibreen, Svalbard, examined using aerial photography an
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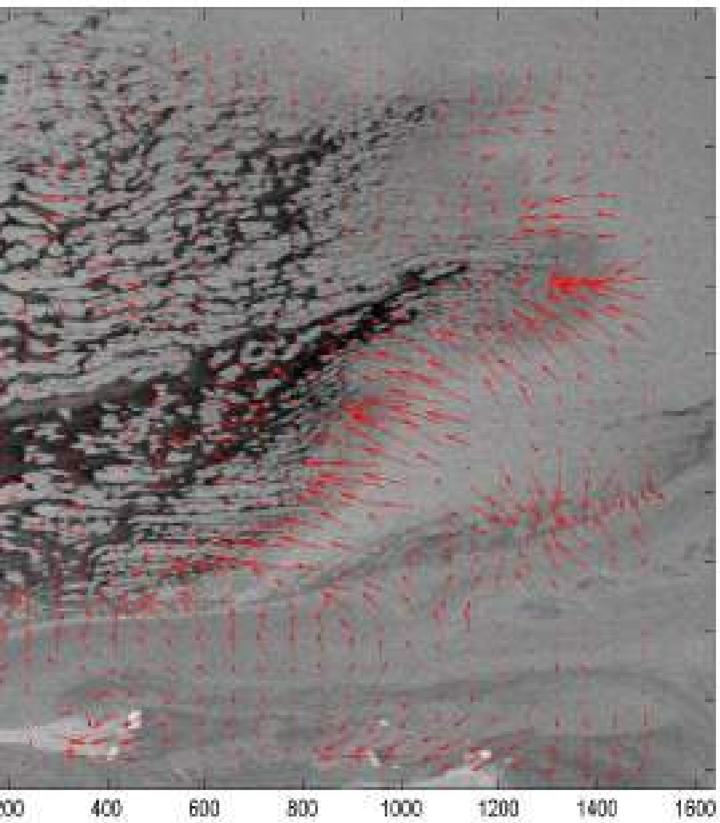
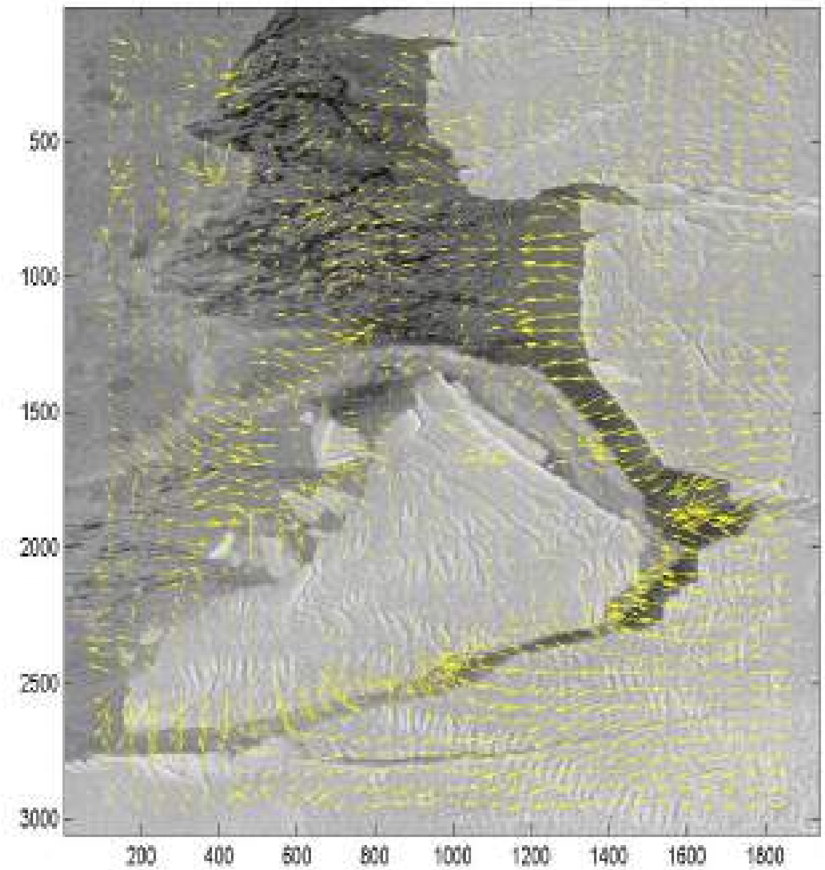
er, J. 1989. "Spectral signature of alpine snow cover from Landsat 5 TM." Remote Sensing of Environment .
nestocks, M.A., T.A. Scambos, C.A. Shuman, R.J. Arthern, D.P. Winebrenner, and R. Kwok. 2000. "Snow megadu
the East Antarctic Plateau: extreme atmosphere-ice interaction ." Geophysical Research Letters 3719-3722.
well, P., and H.D. al., et Pritchard. 2013. "Bedmap2: improved ice bed, surface thickness datasets for Antarctic
osphere 375-393.

elopment of Algorithm in order to derive velocity of moving objects/features.

- ally for velocity tracking Harris corner with Lucas Kanade optical flow was lemented.
- ad produced good results but it wasn't robust with respect to high degree of rotati
- nce we decided to go for a complex and robust algorithm SIFT (Scale Invariant Feat nsform)



cquired by Sentinel-1 (EW mode) on 5th March2021 & 6th March 2021

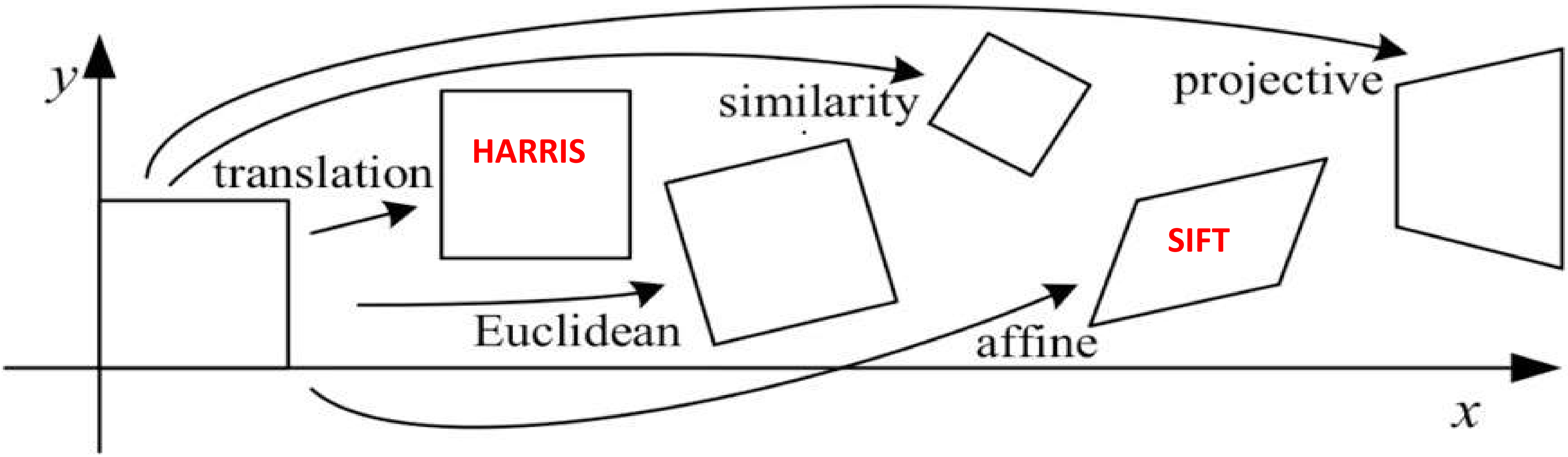


Vectors computed using LucasKanade with respect to two Sentinel-1 images acquired on 20210309 and 20210312 over BRUNT Ice Shelf Calving zone, search window size of 75 pixels.

Basic set of 2-D Transformation

Richard Szeliski, "Computer Vision: Algorithms and Application"

- Need to register a patch of the current frame to another patch of the next frame
- Coordinate transformation can be done by different "motions"



APPROACH

ale Invariant Feature Transform (SIFT)

e **scale-invariant feature transform** (**SIFT**) is a computer vision algorithm to dete
scribe, and match local *features* in images, invented by David Lowe in 19
plications include object recognition, robotic mapping and navigation, ima
tching, 3D modelling, gesture recognition, video tracking, individual identification
ldlife and match moving.
s a technique for detecting salient, stable feature points in an image.
r every such point, it also provides a set of “features” that “characterize/describe
nall image region around the point. These features are invariant to rotation and sca
timation of affine transformation/homography between images
timation of fundamental matrix in stereo accuracy, stability, scale & rotational
variance
iciency / speed
tter error tolerance with fewer matches

y Area & Dataset used

- Polar regions both Arctic and Antarctica
- Specially near the Indian Maitri Research Station and Bharati Research Station in Antarctica

his trial run of SIFT algorithm: Sentinel-1 is main used as it works in rowave domain of EM spectrum, it has cloud penetration capabilities. nce it is used for our Study in order to get cloud free data on regular ba

ecifications	Sentinel - 1A (S1A)	Sentinel - 1B (S1B)
Launch	03 April, 2014	22 April, 2016
orbit	sun synchronous (693 km) with 12 days repeat cycle	
dar carrier frequency	C - Band (5.405 GHz)	
sation Options	Single (HH, VV) Dual (HH+HV, VV+VH)	

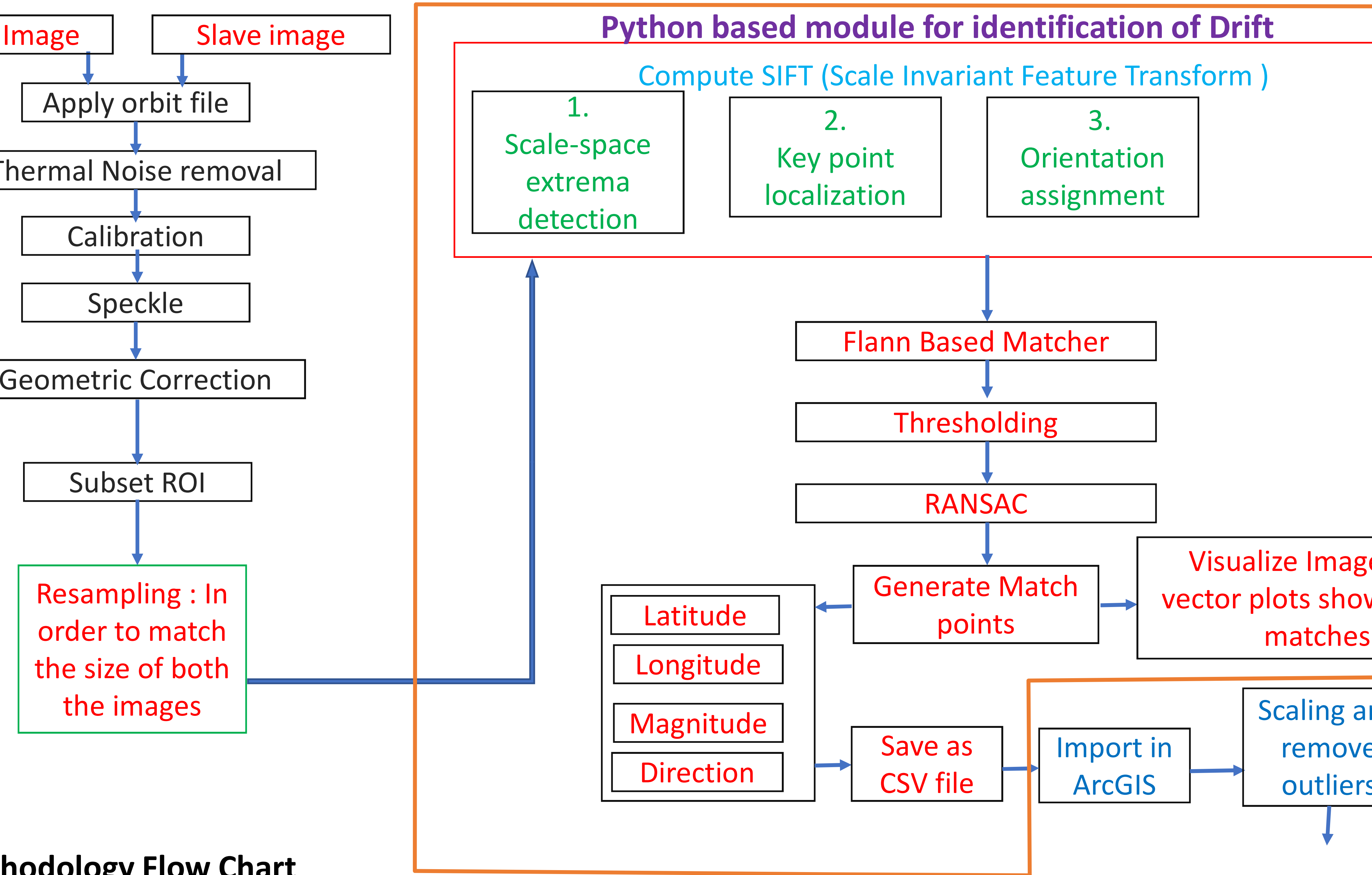
Note:

Sentinel-1 B has stop acquiring data from 2 Dec 2021

In Polar regions temp resolution varies from 5 days

dy Area & Dataset used

tellite	Acquisition mode	Product Type	Image 1 date	Image 2 date	Study Area	Polarizatio n
ntinel-	EW	GRD	23 Jan2020	25 Jan 2020	Arctic Ocean	HH
ntinel- /B	EW	GRD	22 Aug 2021	23 Aug 2021	Antarctica, Near Maitri Research Station	HH



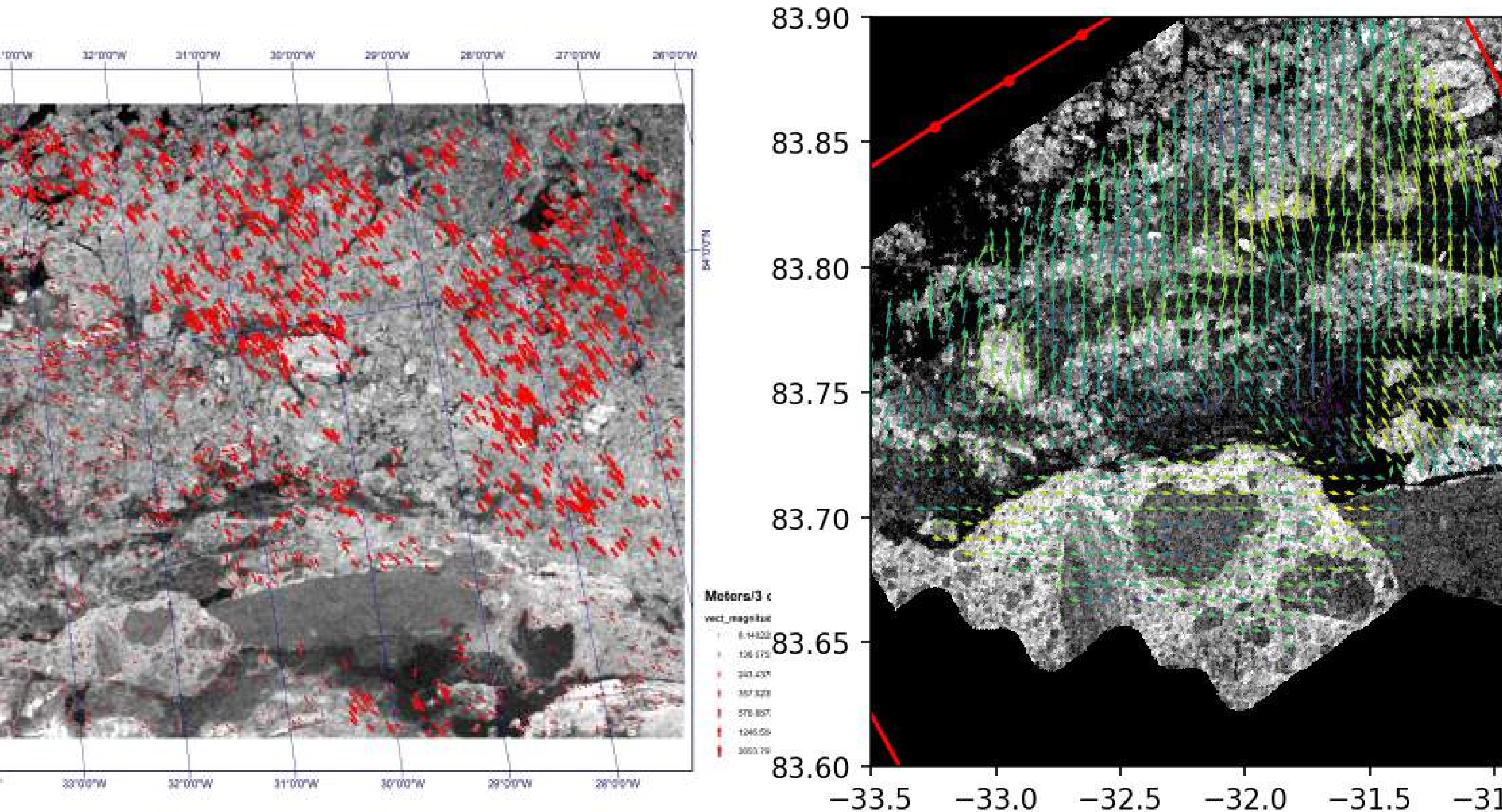
hodology Flow Chart

- **tep 1: Scale-space Extrema Detection** - Detect interesting points (invariant to
d orientation) using DOG.
- **tep 2: Keypoint Localization** - Determine location and scale at each candidate
cation, and select them based on stability.
- **tep 3: Orientation Estimation** - Use local image gradients to assign orientation
ch localized keypoint. Preserve orientation, scale and location for each feature.
- **tep 4: Keypoint Descriptor** - Extract local image gradients at selected scale aro
ypoint and form a representation invariant to local shape and illumination distort

Key point matching

- Match the key points against a database of
  that obtained from training images.
- Find the nearest neighbor i.e. a key point w
  minimum Euclidean distance.
  - Efficient Nearest Neighbor matching
    - Looks at ratio of distance between best and 2nd best match (.8)

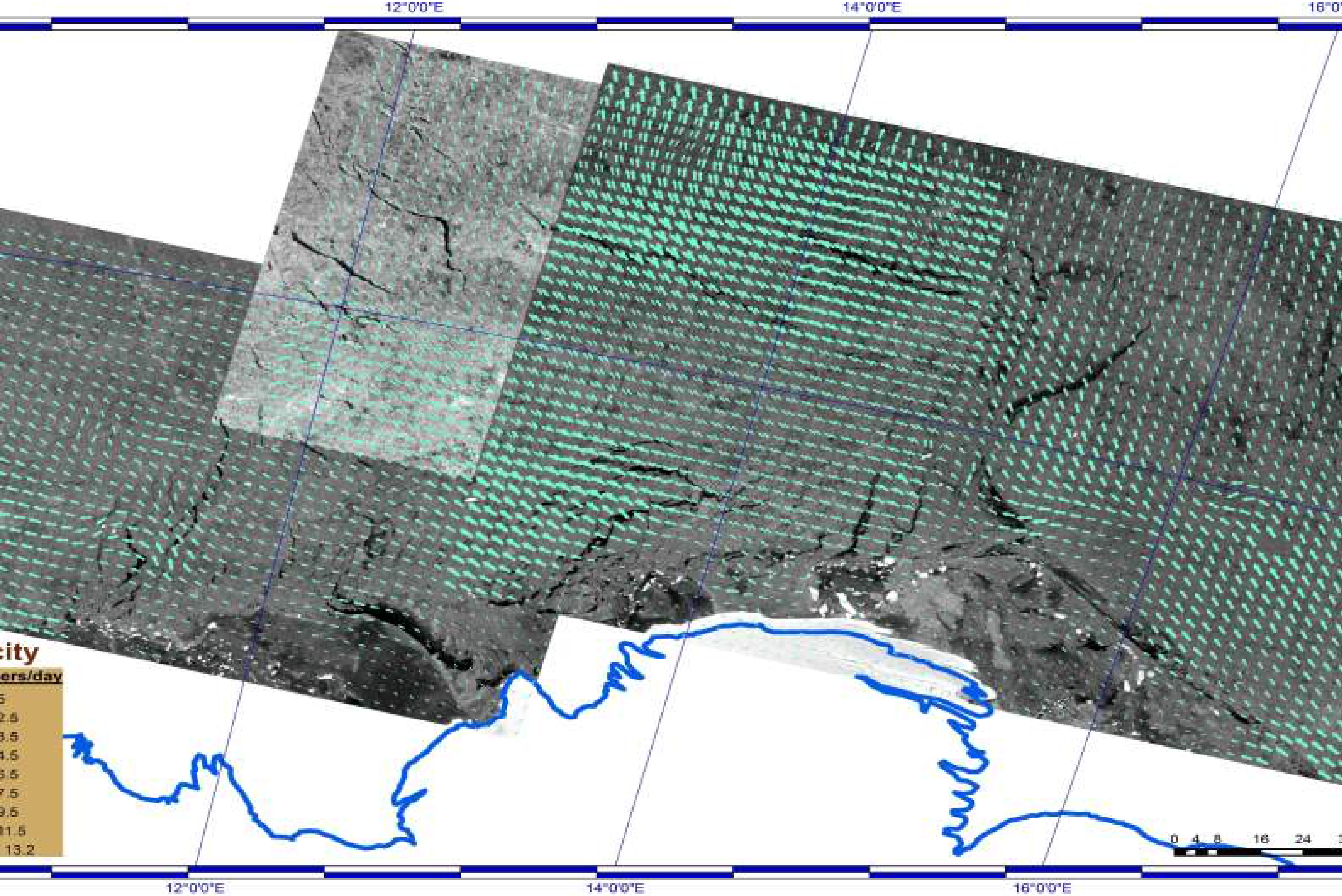
ugh Lowe's Ratio gives a acceptable number of matches but still there will be a large number of outliers d ilarity between false descriptors & true descriptor in that case we implement RANSAC which uses Affine mo er to minimize outliers.



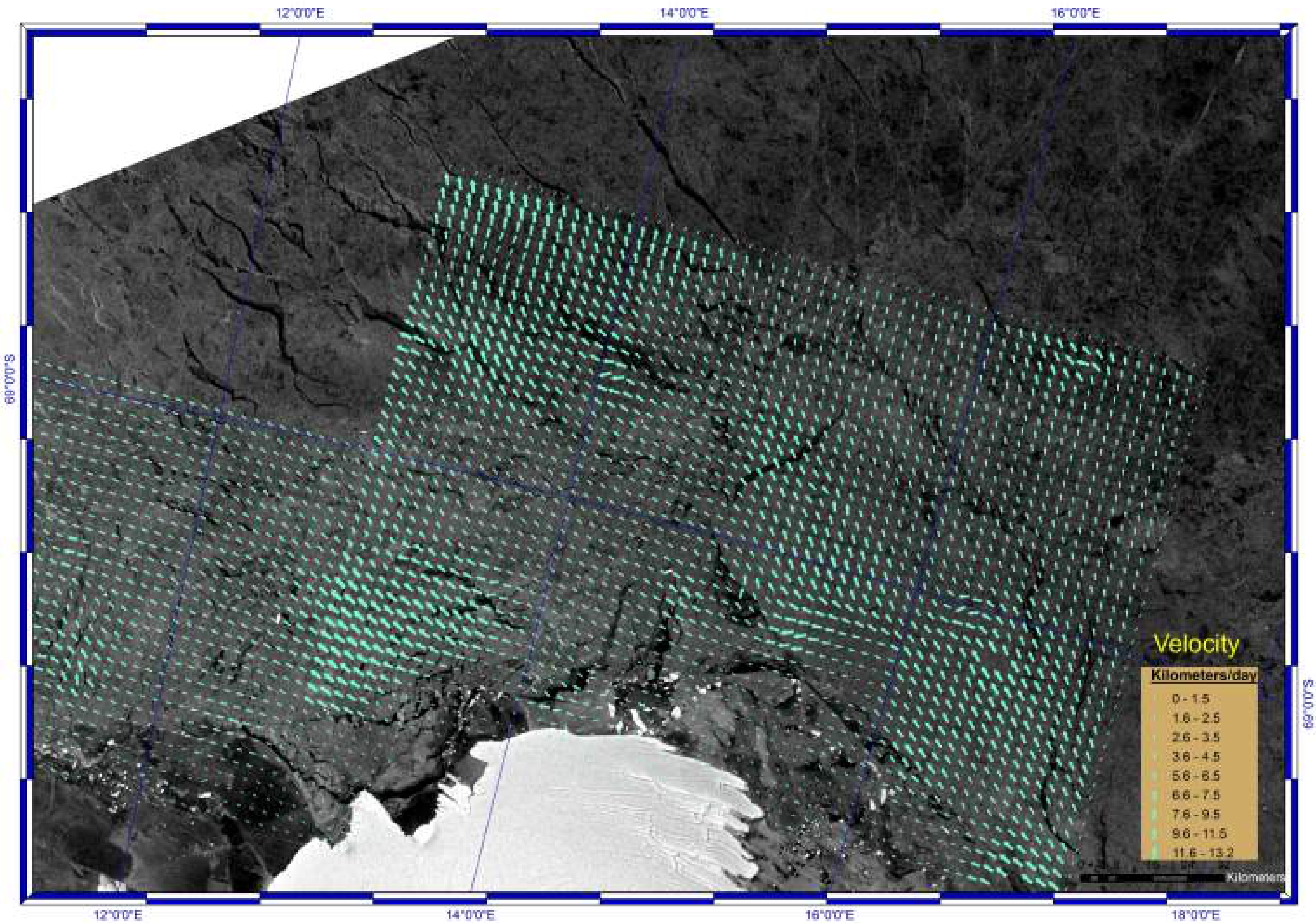
(a)

(b)

ison of Sea Ice Drift over Arctic Ocean selected region obtained using SIFT Algorithm (a) with NANSEN genera
using ORB (b). It can be observed how robust our algorithm is, if we look at the bottom portion of the image
see fast ice which didn't have any motion during acquisition of both images, which is also clearly reflected by
m but not in case of ORB



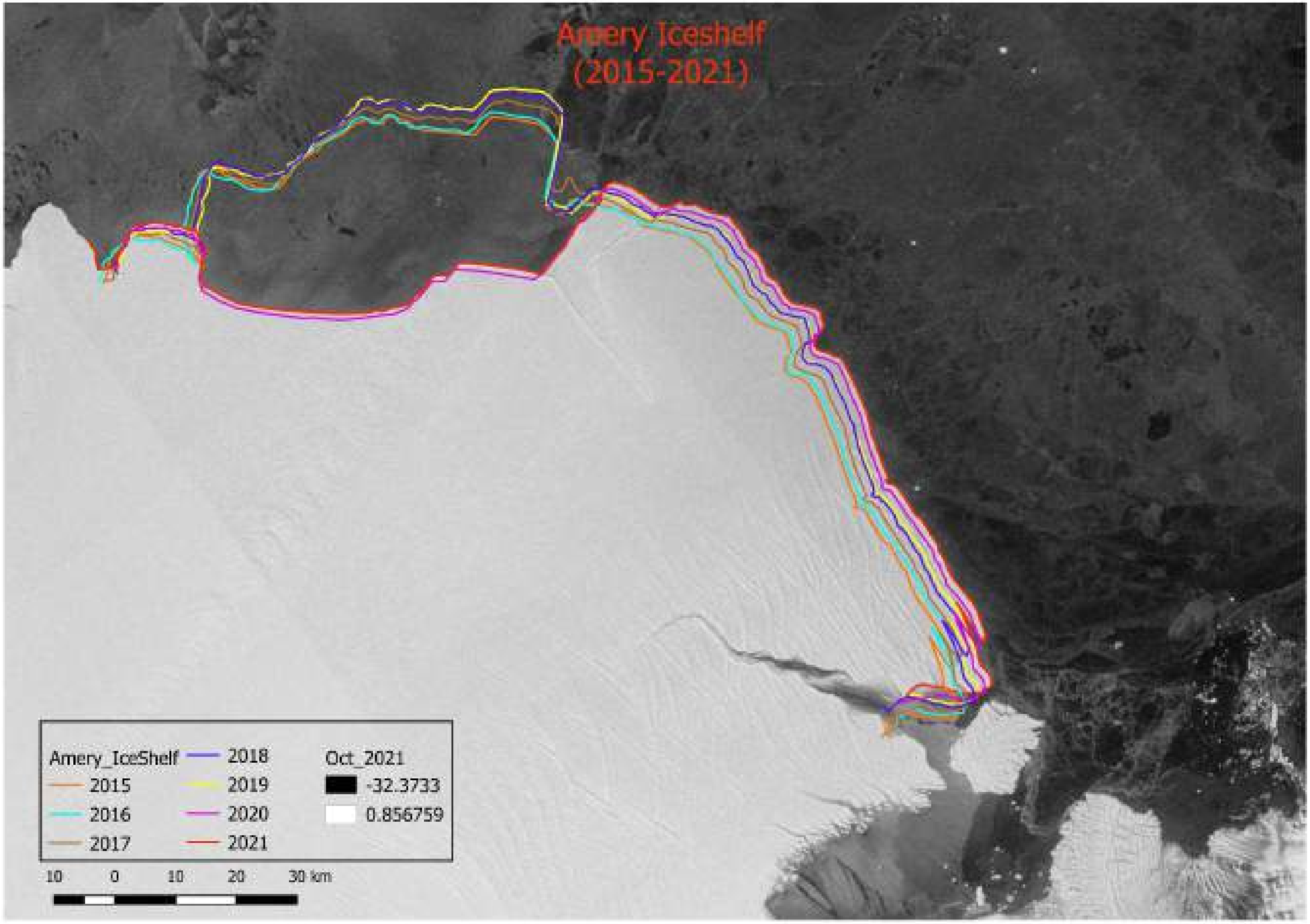
12°0'0"E
14°0'0"E
city
ers/day
13.2
0 4 8 16 24
12°0'0"E
14°0'0"E
16°0'0"E

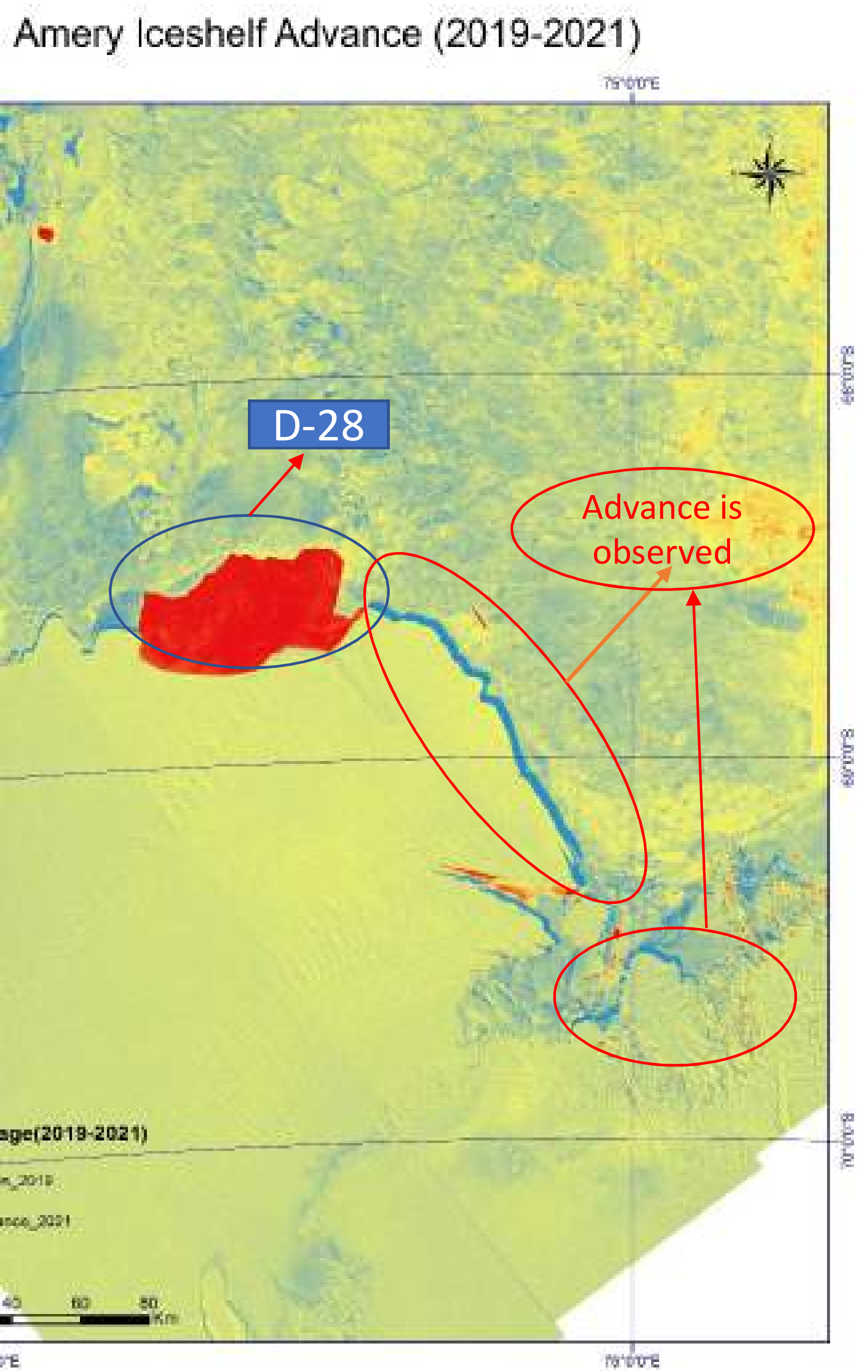

12°0'0"E
14°0'0"E
16°0'0"E
69°0'0"S
Velocity
Kilometers/day
0 - 1.5
1.6 - 2.5
2.6 - 3.5
3.6 - 4.5
5.6 - 6.5
6.6 - 7.5
7.6 - 9.5
9.6 - 11.5
11.6 - 13.2
Kilometers
69°0'0"S
12°0'0"E
14°0'0"E
16°0'0"E
18°0'0"E

ture Scope

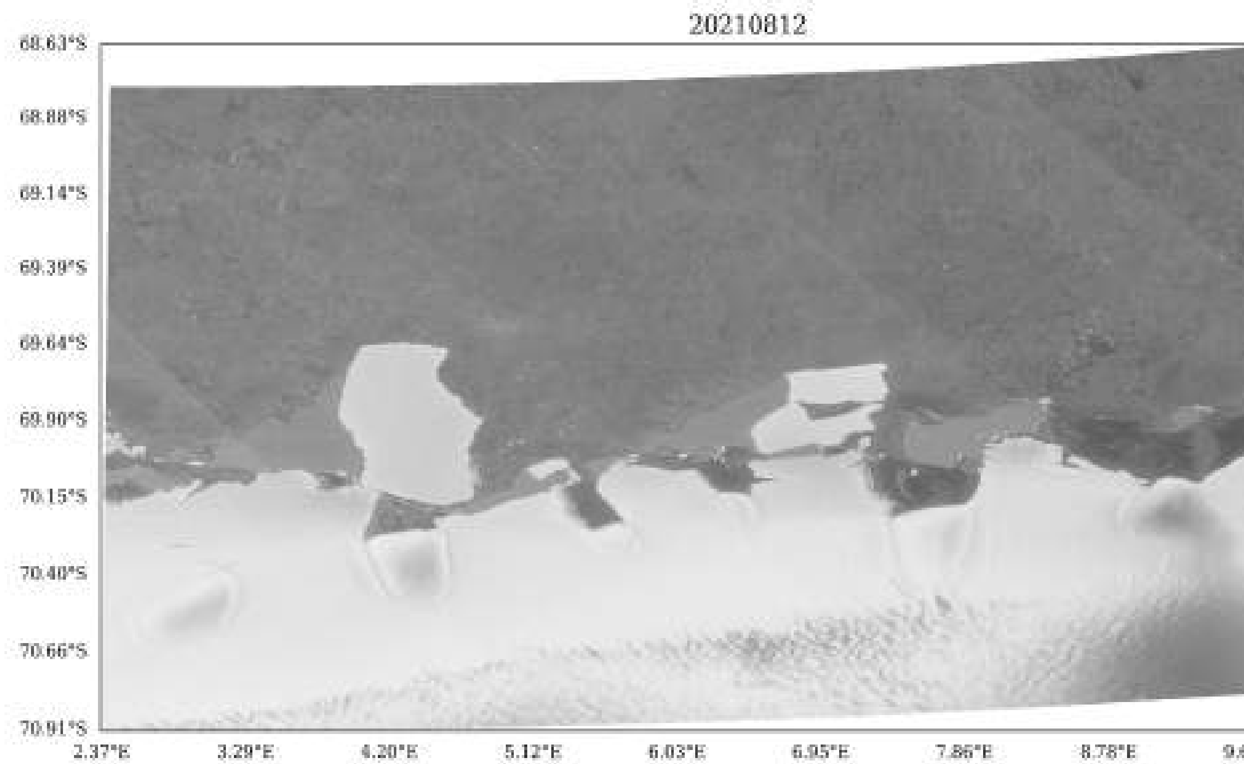
- A key input in-order to estimate the Ice Flux.
- Estimating Ocean Eddies
- Measuring Drift would provide a better navigation of ships in the Polar region.
- Measuring the Motion of Sea ice also helps in understanding different phenomer which combinedly acts on the Sea Ice motion.
- t can play important role in studying the albedo difference with difference in mot of sea ice.
- Also how polynya and leads are formed can be better estimated or studied.
- This algorithm can be further modified in order to derive the velocity vectors o Glaciers.
- Tracking Ice Bergs.
- Also to validate our output with wind data and SCATsat datasets

udying IceShelf advancement and Tracking Iceberg





D-28 Iceberg calved from Amery in end of Sept 2019, a
1614 sq. km is found drifting near Maitri Research Stat
12 Aug 2021. It has traveled more than 3000km in 2 y



Mean IceSheet velocity near Maitri Research Station using OFFSET Tracking in

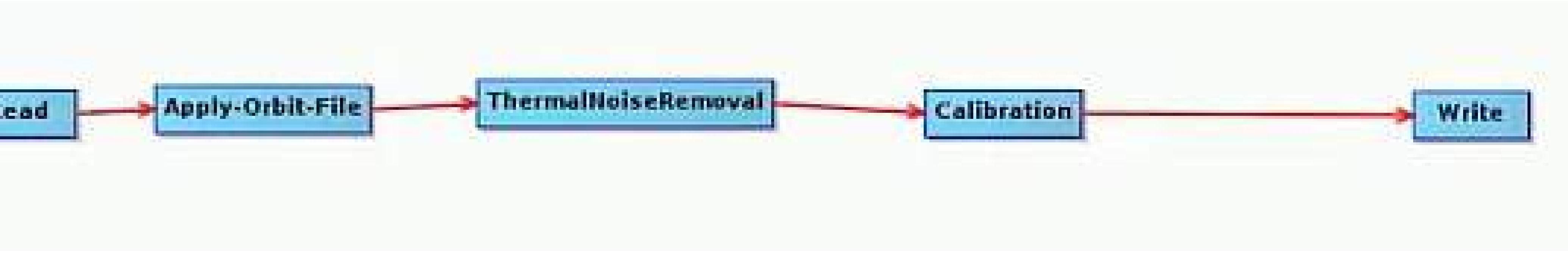
y Area and Datasets

Location of Corner Reflectors installed at near Maitri Research Station Antarctica

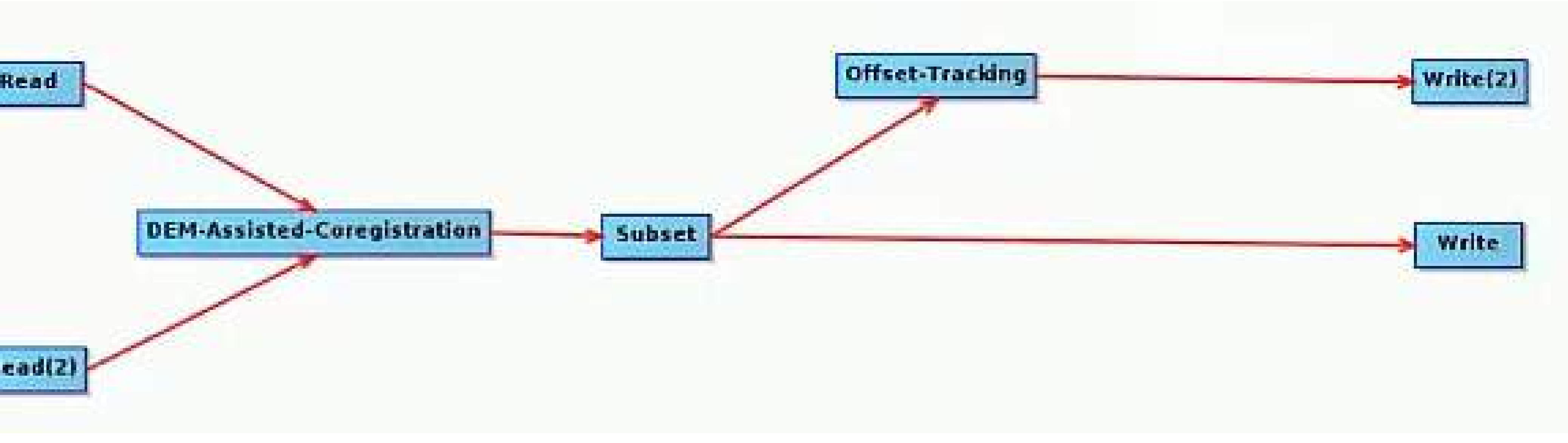
2m	Ice sheet (Maitri)	70 48' 39.8" S, 11 40' 22.8 E	Ascending
3m	Ice sheet (Maitri)	70 49' 36.48" S, 11 32' 19.32" E	Descending

In order to derive velocity of CR3m location using Offset tracking**, Sentinel-1 images** was used in
pan of 1 year corresponding dates are 21 Nov 2020 and 22 Nov 2021. Displacement of 21 to 22
meters/year is observed.
In order to derive velocity of CR2m location using Offset tracking, **Sentinel-1 images** was used in
pan of 1 year corresponding dates are 4 Dec 2020 and 5 Dec 2021. Displacement of 4 to 5
meters/year is observed.

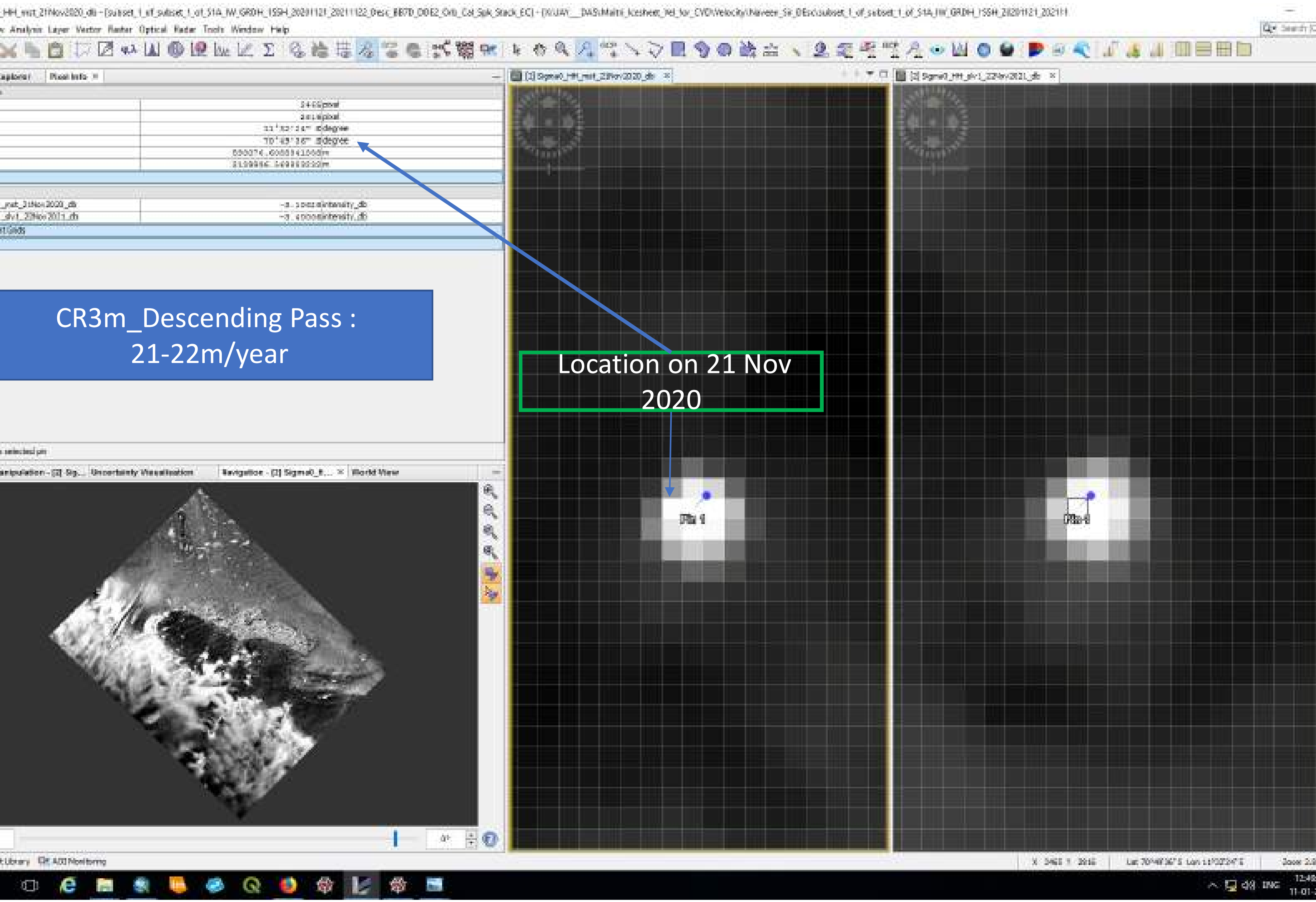
odology

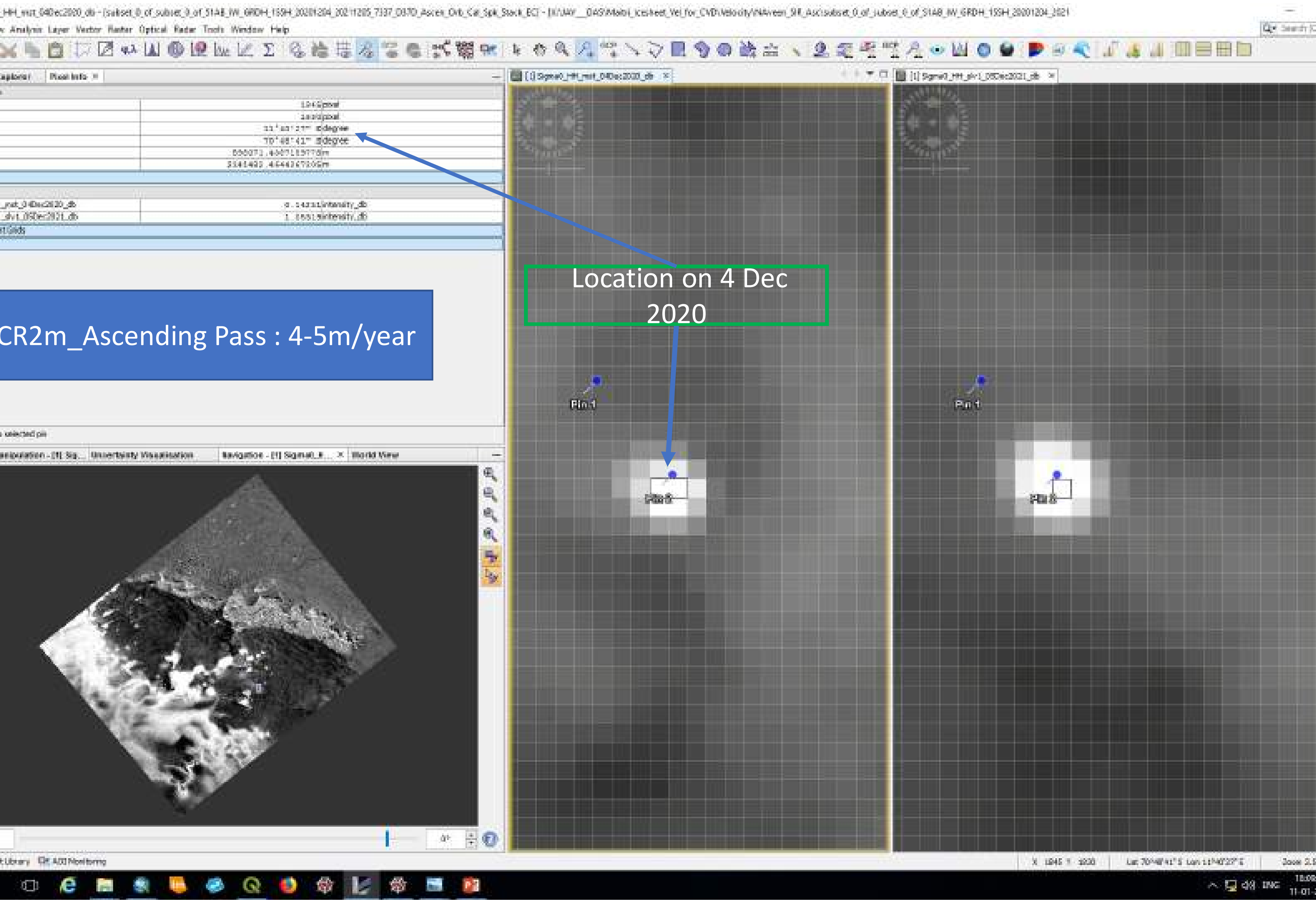


ead
Apply-Orbit-File
ThermalNoiseRemoval
Calibration
Write

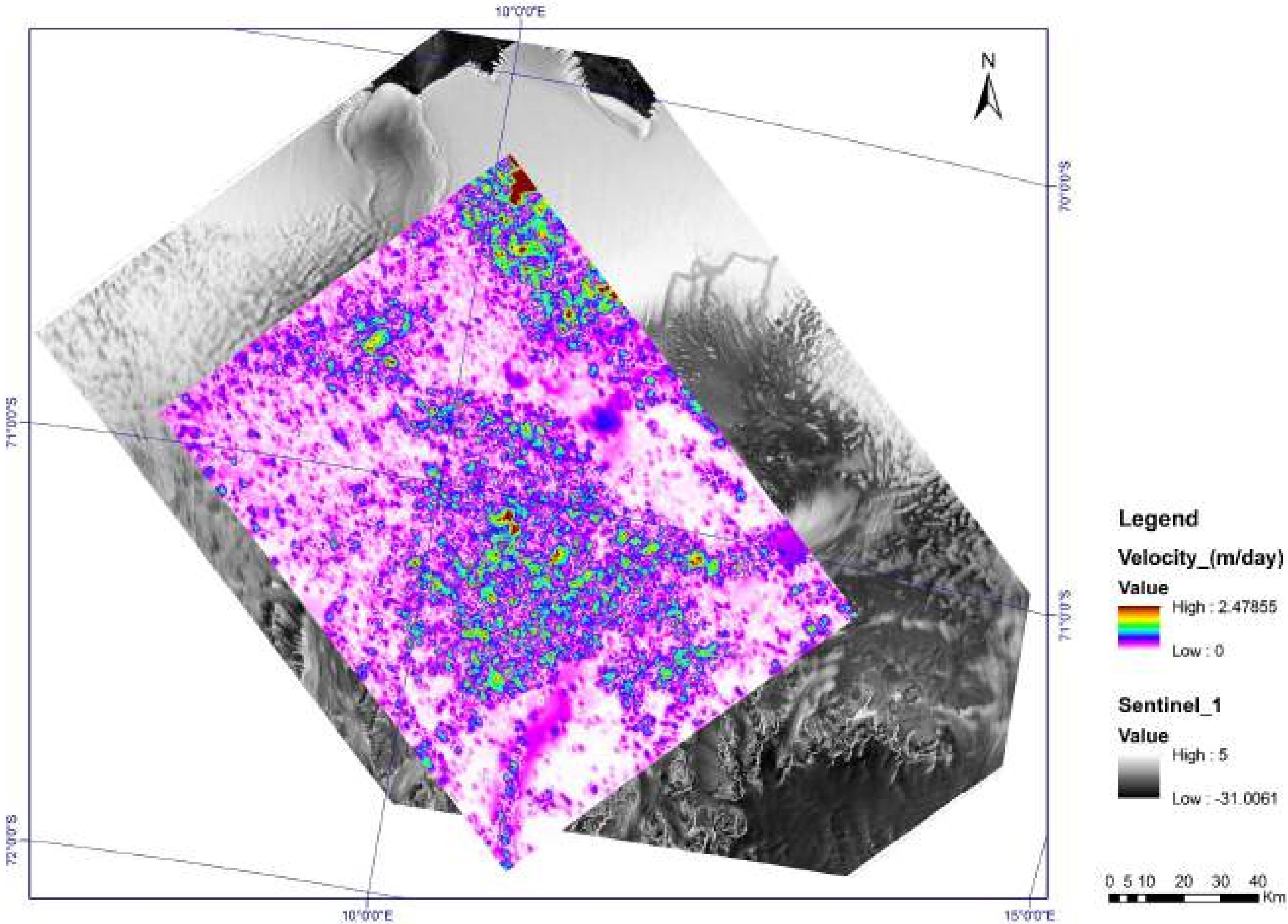


Read
ead(2)
DEM-Assisted-Coregistration
Subset
Offset-Tracking
Write(2)
Write


CR3m_Descending Pass : 21-22m/year
Location on 21 Nov 2020

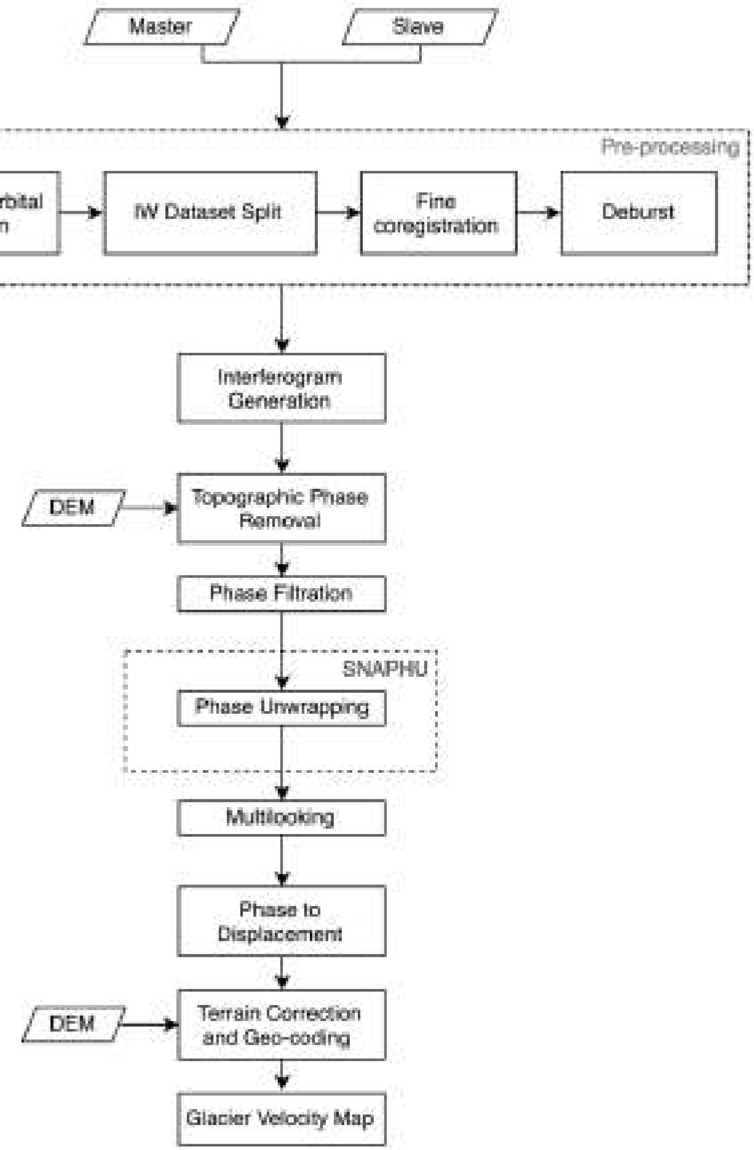


Location on 4 Dec 2020
CR2m_Ascending Pass : 4-5m/year
Pin 1



Offset obta
using
Sentinel-1
IW_11Nov
and 22Nov
dataset

R based velocity Estimation

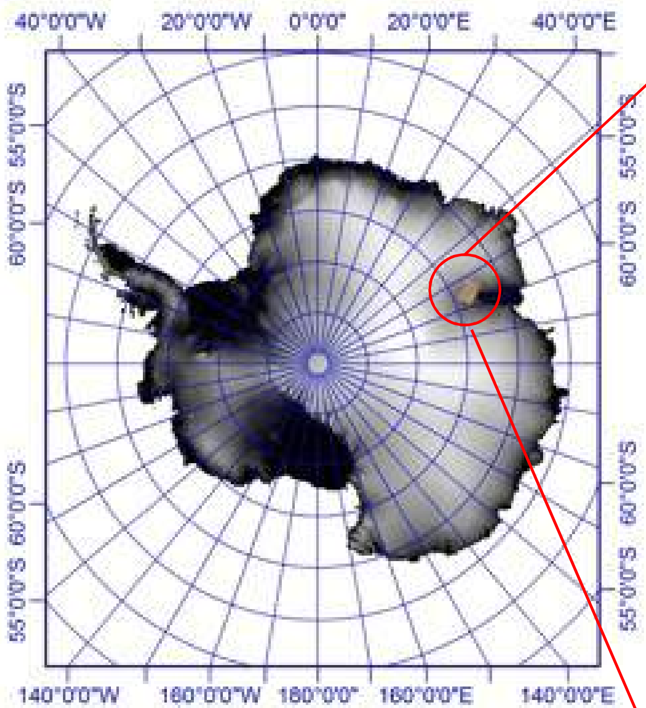


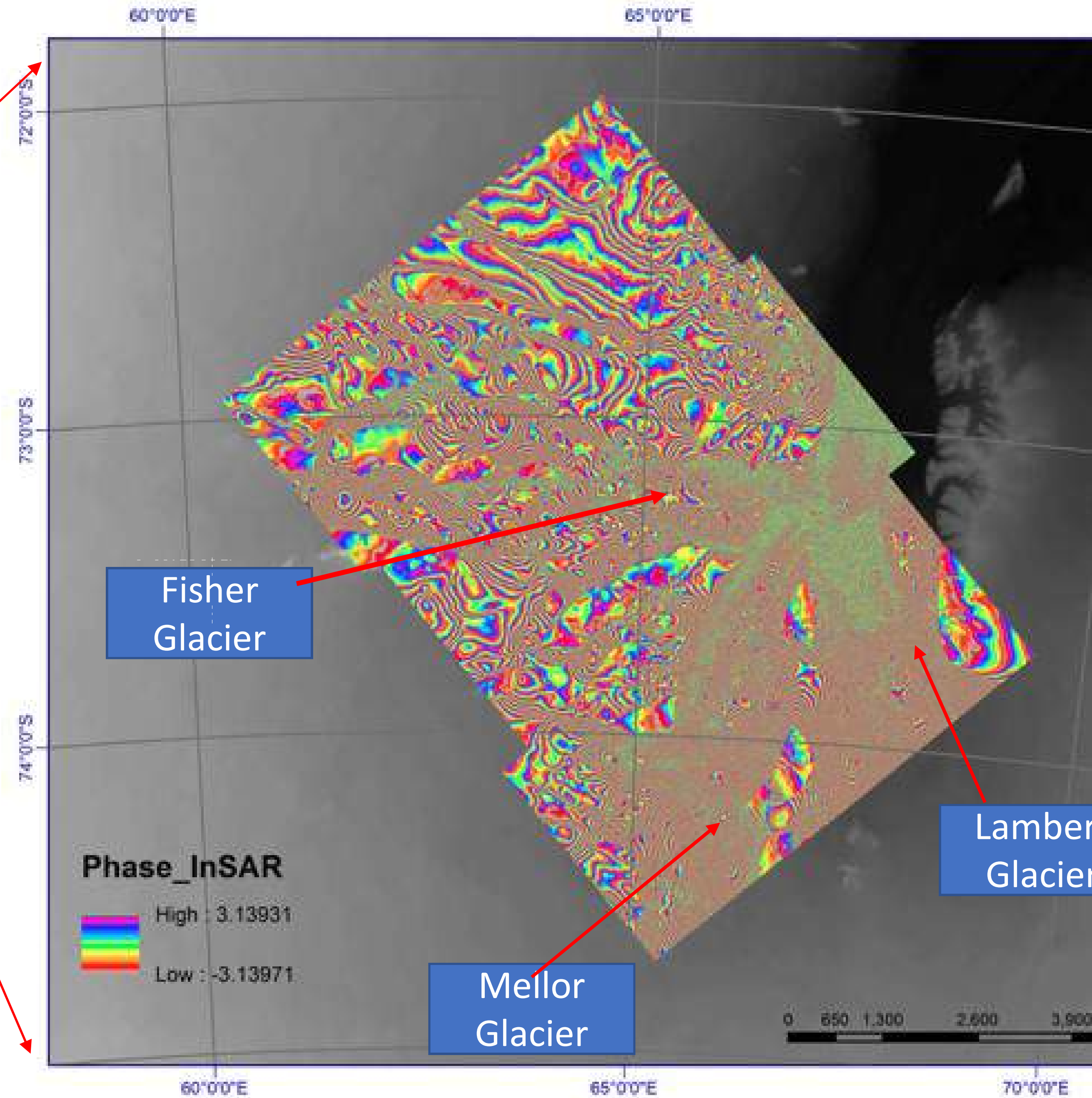
gical flowchart for surface velocity estimation using DInSAR

Key characteristics of ESA's Sentinel-1a and -1b Satellites from S1 Missio

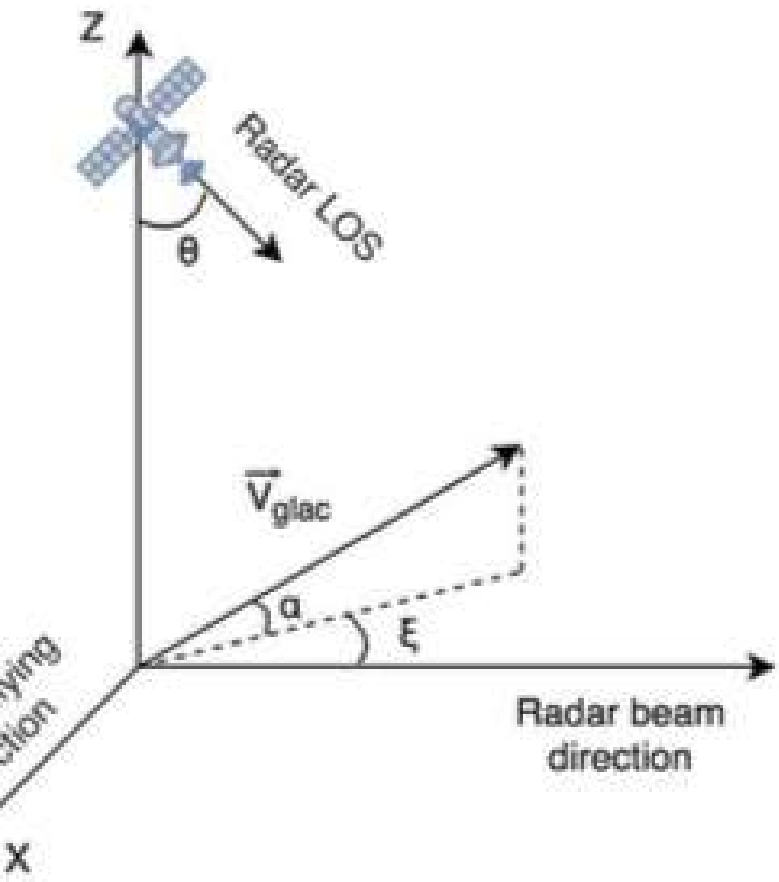
Specifications	Sentinel-1a (S1a)	Sentinel-1b (S1b
Launch	03-Apr-14	22-Apr-16
Orbit	Sun Synchronous Orbit (693km)	
Sensor	C Band (5.6cms) – SAR Sensor	
Temporal Repeat Cycle	12 Days individually, 3-6 days (varies with region consideration) when S1a and S1b are used in combination	
Acquisition modes	Strip-map (SM), Interferometric Wide Swath (IW Extra Wide Swath (EW) and Wave mode (WV).	
Polarization	Single (HH or VV) or Dual Polarization (HH + I VV + VH).	
Data Format(s)	Level - 0 RAW	
	Level – 1 Single Look Complex (SLC)	
	Level – 1 Ground Range Detected (GRD)	
	Level – 2 Ocean (OCN) Product	

Glacier DInSAR Map





s acquired: Sentinel(1B-1A) IW, SLC,
ending path, 20210706-20210712,
Baseline:26m



tion of Surface velocity from InSAR geometry where α is
is angle between glacier movement direction and radar
irection and θ look angle. V_{glac} vector represents the
n of glacier movement

$$V_{glac} = \frac{V_{los}}{(cos\alpha\ cos\xi\ sin\theta + \ cos\theta\ si$$

V_{glac} is the actual surface velocity in flow direction, V_{los} is velocity in LOS direction and α, ξ, θ are the slope, aspec with respect to radar beam direction and look angle res

- Downloaded SLC datasets (sept-oct 2021) over Iceshelf in Antarctica for DInSAR. 6 pairs of datasets a done with processing, 8 pairs of datasets are und processing.

Future Scope:

1) Exploring the capabilities of InSAR a DInSAR deriving surface velocity, Gla velocity.
2) Deriving the surface velocity from D over major Glacier in Antarctica.

pected Deliverables

major deliverables expected from the project are the set of images for glacier velocity fi pectively (i) velocity magnitude and (ii) horizontal velocity component and (ii) vertical velo nponent. Horizontal and vertical components indicate the resultant direction of the ice movement. a set will be generated for all the selected fast moving glaciers of the Antarctica and Greenland.

ferences:

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Heid, Torborg. 2011. "Deriving glacier surface velocities from repeat optical images." PhD Thesis, Department Geoscience, Faculty of Mathematics and Natural Sciences.

oughin, I.R., R. Kwok, and M.A. Fahnestock. 1998. "Interferometric estimation of three dimensional ice flow u scending and descending passes." *IEEE Transactions on Geoscience and Remote Sensing* 25-37.

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Nakamura, K., K. Doi, and K. Shibuya. 2007. "Estimation for seasonal changes of Shirase Glacier flow by using ERS-1/SAR image correlation." *Polar Science* 1: 73-83.

THANK YOU