OVERVIEW

RESEARCH PROJECTS

Kelsey Kaplan

Hello, my name is Kelsey.

I am a first year PhD student in the Department of Computer and Information Sciences and Research Assistant in the Video/Image Modeling and Synthesis (VIMS) Lab, under the supervision of **Dr Kambhamettu**, at the University of Delaware.

This presentation gives an overview of the research I have been involved with since the Fall semester of 2020.

Research

My research interests include **Computer Vision**, **Deep Learning**, **remote sensing** and **sea ice**.

I am interested particularly in research that provides the opportunity for a collaborative and multidisciplinary approach, overlapping with fields that impact Climate and Polar Science.

I am currently focusing on the **development of algorithms that generate fine-scale motion analysis of sea ice from remote sensing data** using a traditional Computer Vision approach.

SIDEx PROJECT

Sea Ice Dynamic Experiment

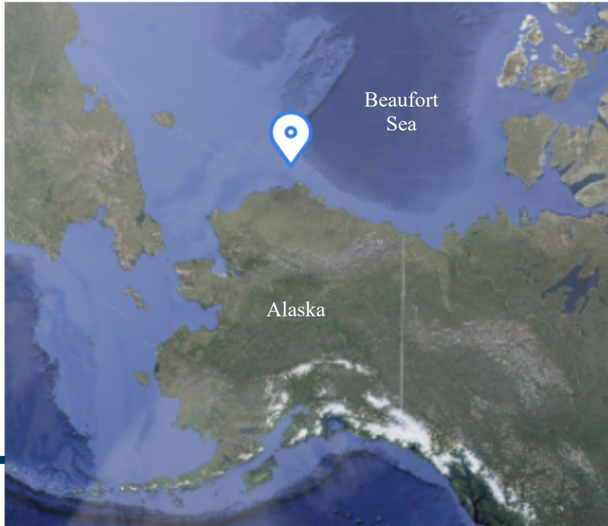
Background

In March 2021 a distributed array of sensors and platforms will be deployed on an ice floe in the Beaufort Sea off the Alaskan coast to monitor sea ice stress, strain and drift over several months.

Integrated with satellite imagery, this data will further our understanding of Arctic sea ice dynamics by improving models and predictions of sea ice formation, deformation and fracturing in response to atmospheric, wave and ocean forces at a fine-scale.

Knowledge of Arctic sea ice dynamics are important for navigation and climate change research and the recent decline in Arctic sea ice has significant implications for climate, marine life, and human activities [1].

This project involves collaborators from ONR, CRREL, Oregon State, Dartmouth University, MIT, UAF, WHOI and the University of Delaware



DATA

We will be working predominantly with satellite data and ice tracking GPS buoys

FIELD SUPPORT

We will be part of the ground team providing real-time monitoring of sea ice lead formation during the camp for safety purposes

MOTION ANALYSIS

Our primary objective in the project is to provide multi-scale drift and deformation products

Data Acquisition

Sentinel-1
TerraSAR-X
COSMO
RadarSAT

C-BAND SAR

MODIS
SkySAT
Worldview 1,2 and 3

OPTICAL

GPS Buoys
SATICE Buoys

GPS

C-BAND RADAR SATELLITES

	Beam mode	Number of images	Image resolution	Scene size	Available	Source
Sentinel-1	EW (Extra Wide Swath)	1 every 2-3 days	20 m x 40 m	> 250 km (swath width)	Within 3 days	ASF Portal
	IW (Interferometric Wide Swath)	1 every 2-3 days	5 m x 20 m	250 km (swath width)	Within 3 days	
TerraSAR-X	StripMap	4 per day (2 vehicles each providing 2 images per day)	3 m	30 km x 50 km	To be confirmed	Chris Polashenski
COSMO	Spotlight	2 per day	1 m	10 km x 10 km	To be confirmed	
RadarSAT	Fine quad-pol	1 every week	12 m	25 km (swath width)	Several months after field camp	Jenny Hutchings
	Medium resolution	1 every week	50 m	350 km (swath width)	Several months after field camp	

OPTICAL SATELLITES

	Number of images	Image resolution	Scene size	Available	Source
MODIS	1 per day	250 m and 500 m	2330 km x 10 km	Immediately	Jenny Hutchings
SkySAT	~1 per week	0.8 m	2 km (swath width)	Several months after field camp	
Worldview 1,2 and 3	~1 per week	1 m	13.1 - 17.6 km (swath width)	Several months after field camp	

BUOYS

	Number of buoys	Transmit resolution	Spatial resolution	Layout	Available	Source
GPS	30	Every 10 min	2 m (relative), 20 m (absolute)	12 at 5 km radius from camp, 12 at 10 km radius from camp, 4 at corners of camp, 1 each at emergency tent and main tent	Immediately	Jenny Hutchings
SATICE	12	Every 1 second	To be confirmed	Configurations of 2 and 3 at 2 to 5 km from camp, across multi- and first-year ice	To be confirmed	Pedro Elosegui

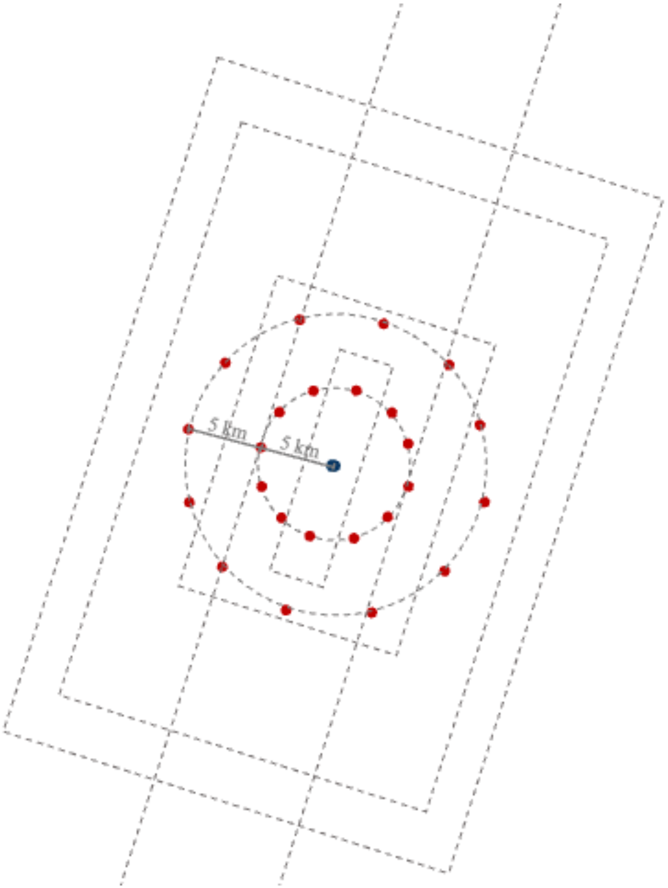
Camp Layout

- Camp
- GPS Buoys
- SAR images
- Optical images

As camp is situated on a drifting ice floe its exact position will change throughout the duration of the campaign.

The GPS buoys will provide up-to-date coordinates for the satellite acquisition.

Diagrammatic plan of camp showing the approximate spatial and temporal resolutions for satellite data (right).



TerraSAR-X
3 m resolution
4 images/day

COSMO
1 m resolution
2 images/day

Sentinel-1
~5 m resolution
1 image/3 days

RadarSAT
12 m resolution
1 image/week

MODIS
12 m resolution
1 image/week

SkySAT
12 m resolution
1 image/week

Worldview 1,2 and 3
12 m resolution
1 image/week

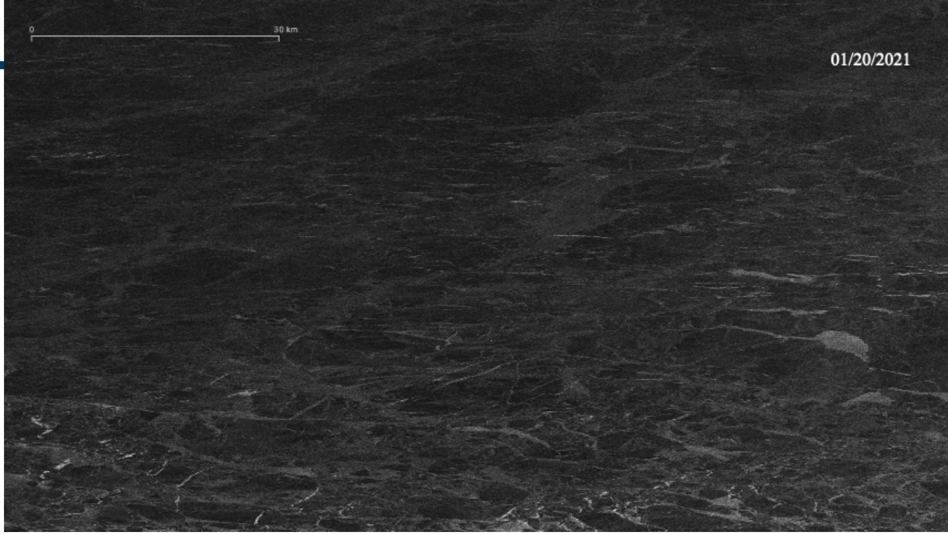
Field Support

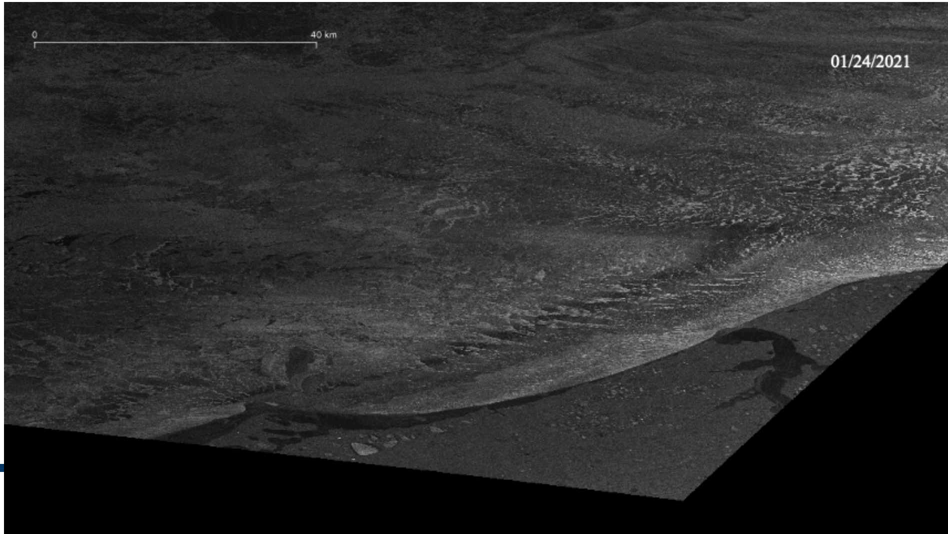
A combination of **Sentinel-1** and **MODIS** satellite imagery will be used to track lead and crack formation around the camp.

The ground support team will provide the field team with daily reports of the sea ice drift and fracture based on manual analysis.

In addition, sea ice imagery dating back to September 2020 will be obtained to track large-scale motion of the ice floe selected for camp.

Sentinel-1 imagery from January 2021 showing the changing sea ice over two different two day periods. The exact location of the camp is to be confirmed but will be within this general vicinity (right) .

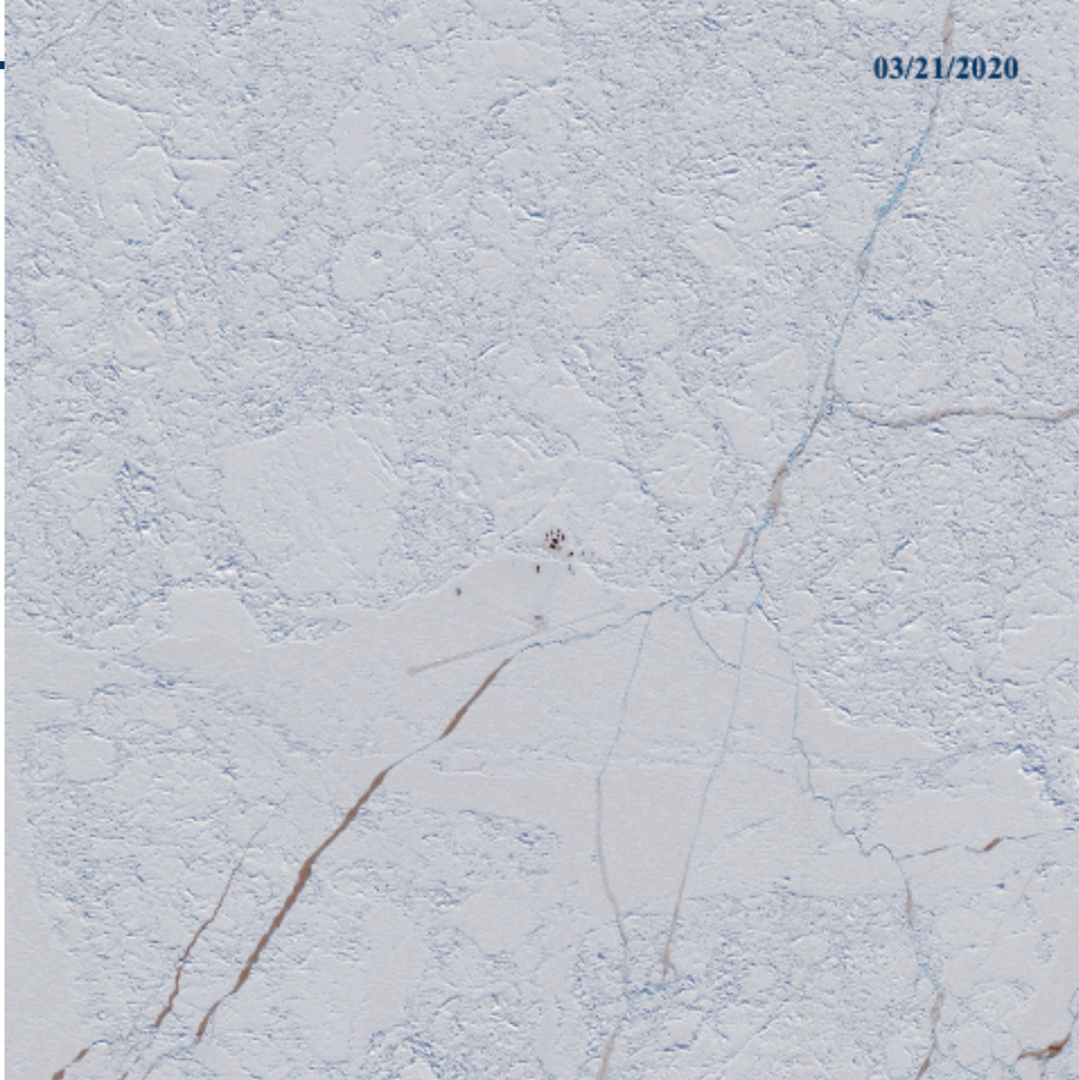




Motion Analysis

A motion analysis pipeline using the Unit-Normal method [2] is under development and aims to generate fine-scale drift and deformation products. Additionally, we will look at divergence of normals as a potential tool for lead and fracture prediction.

Optical satellite data from ICEx in 2019, provided to begin development of our motion analysis algorithm (right).

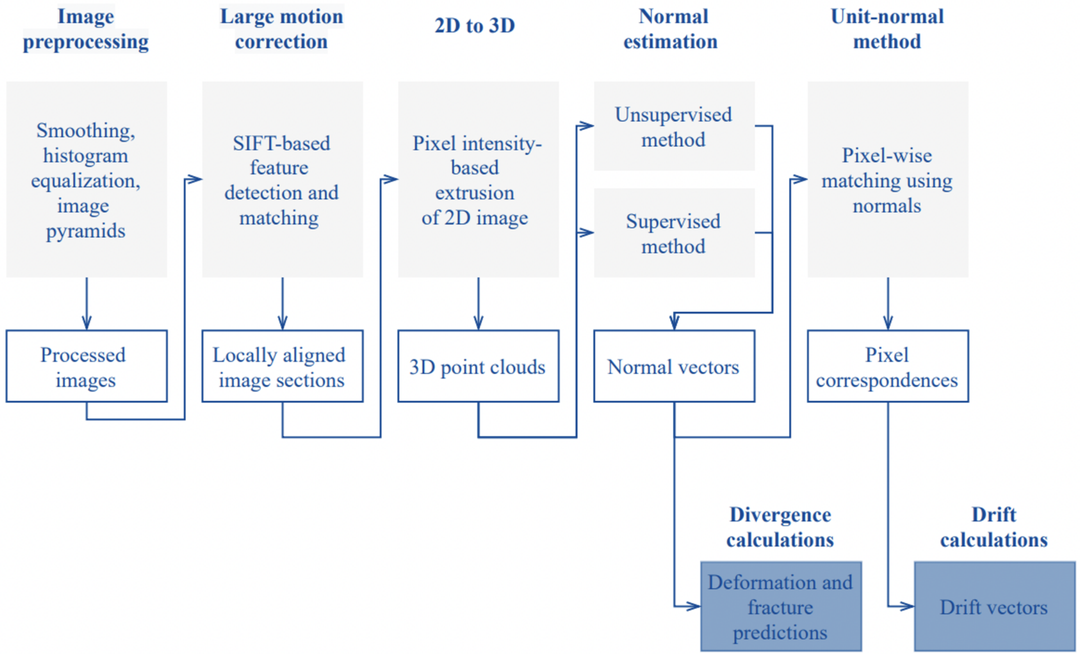


Processing Pipeline

INPUT
Satellite images

OUTPUT
Drift and deformation products (such as divergence and curl), fracture predictions

VALIDATION
Manual motion analysis, existing motion products, GPS buoy data



Processing pipeline being developed for motion analysis algorithm.

Large Motion Correction

(1) SIFT detected features

Parameters were experimentally tuned to successfully detect features for this dataset

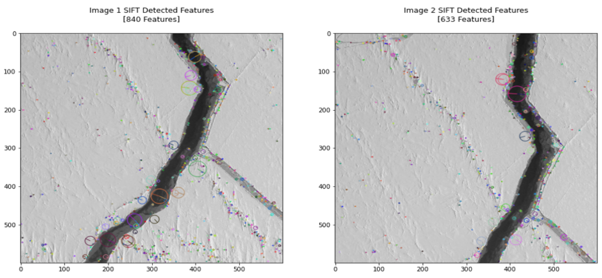
(2) Feature correspondences

The 20 matches with the best matching score, determined using the ratio of first to second best candidate match per feature, are selected

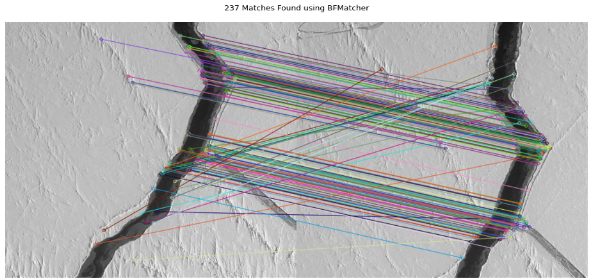
(3) Corrected left image

Left image is shifted according to the average offset calculated using the 20 best matches

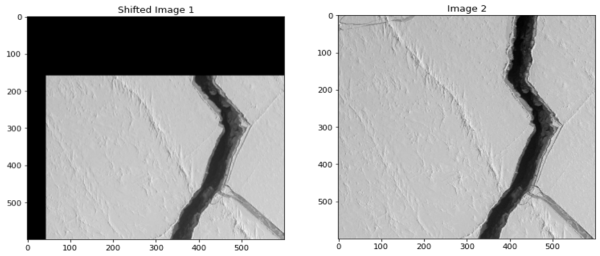
(1)



(2)



(3)



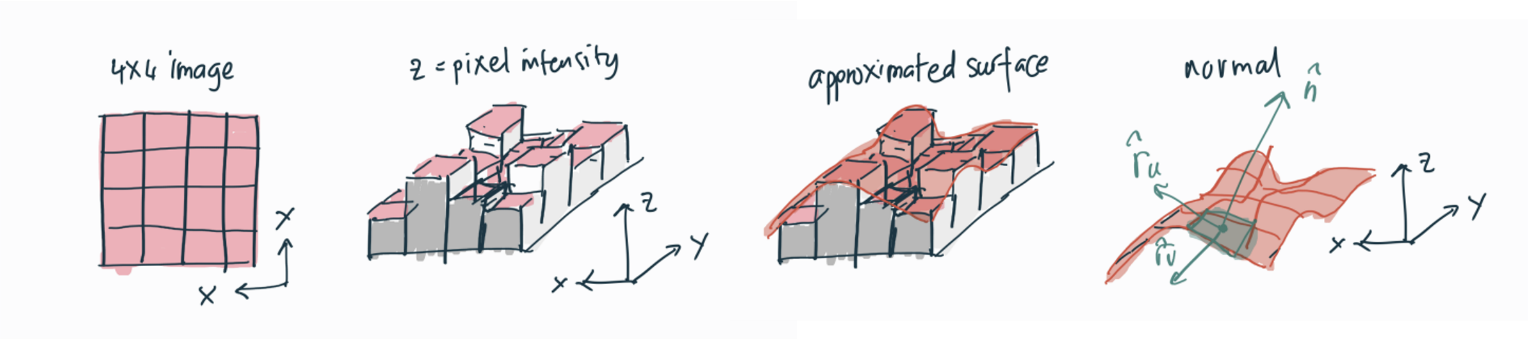
Large motion correction stage of the pipeline results

Normal Estimation

2D image data is transformed into 3D data using pixel intensity as a z-coordinate.

Three methods of normal estimation have been explored:

(1) Pixel-wise gradients using multiple adjacent pixels
(2) Applying trained DeepFit [3] model to point cloud (supervised approach, a pre-trained model)
(3) Surface fitting (unsupervised approach)



Diagrammatic explanation of transforming 2D image data to 3D for normal estimates

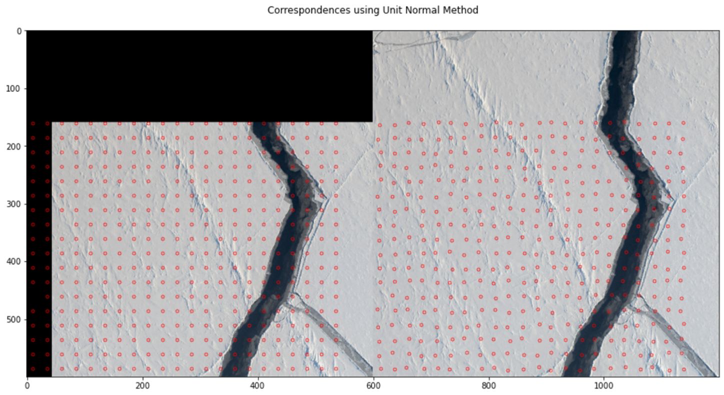
Unit-Normal Method

A novel method, using differential-geometric constraints, for finding point correspondences between 3D surfaces under small nonrigid motion [2].

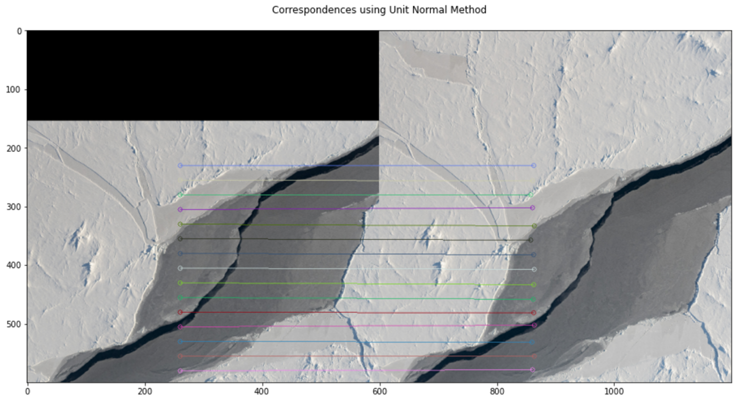
Preliminary results from unit-normal applied to large motion corrected image pairs using method (1) normal estimates:

(a) Dense correspondences can be computed using this method
(b) Fewer correspondences calculated for the purposes of performing manual validation

(a)



(b)



Unit-Normal method correspondence results

MOSAiC PROJECT

Multidisciplinary Drifting Observatory
for the Study of Arctic Climate

Background

The MOSAiC expedition is the largest polar expedition ever to have taken place and is the first year-round expedition into the central Arctic Ocean [4].

Spearheaded by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, the project involved hundreds of researchers from 20 countries with the primary objective of better understanding global climate change through observations of changes in the Arctic [4].

MOSAiC in-situ observations centered around climate processes that couple atmosphere, sea ice, biogeochemistry, ocean and ecosystem [4].

With the expedition coming to a close in October 2020 and the return of the icebreaker, the RV Polarstern, to Bremerhaven, Germany, the extensive data collected will now be made use of in numerous research projects and papers.

(Right) Images from [4] showing the RV Polarstern during the MOSAiC Expedition in various sea ice environments.

RESEARCH

We are collaborating with the MOSAiC Sea Ice Dynamics and SAR Drift and Deformation Teams.

DATA

We will be working mainly with Sentinel-1 satellite data for drift and deformation analysis.

PLANNED PAPERS

“Fine-Scale Characterization of Surfaces/Images Under Deformation using Sentinel-1 Data”

References

[1] Dyre Oliver Dammann, Mark A. Johnson, Emily R. Fedders, Andrew R. Mahoney, Charles L. Werner, Christopher M. Polashenski, Franz J. Meyer, and Jennifer K. Hutchings. Ground-based radar interferometry of sea ice. *Remote Sensing*, 13(1), 2021.

[2] Chandra Kambhamettu, Dmitry Goldgof, Matthew He, and Pavel Laskov. 3d nonrigid motion analysis under small deformations. *Image and Vision Computing*, 21(3):229 – 245, 2003.

[3] Yizhak Ben-Shabat and Stephen Gould. Deepfit: 3d surface fitting via neural network weighted least squares. arXivpreprint arXiv:2003.10826, 2020.

[4] "Sea ice," *MOSAiC Expedition*, 15-Dec-2020. [Online]. Available: https://mosaic-expedition.org/science/sea-ice/. [Accessed: 28-Jan-2021].