# *SIDEx PROJECT*

Sea Ice Dynamic Experiment

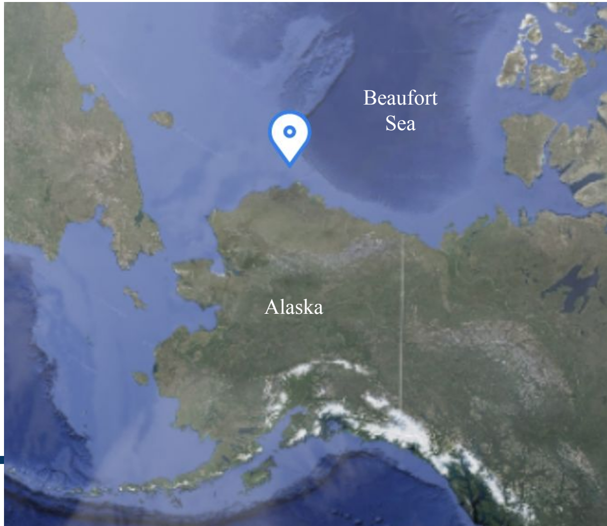
# *Background*

In March 2021 a distributed array of sensors and platforms will be deployed in 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**

1 image/2-3 days

5 m resolution

width 400 km

various products available

**TerraSAR-X**

4 images/day

(1/vehicle 2/day)

StripMap mode

3 m resolution

30 km x 50 km

**COSMO**

2 images/day

Spotlight mode

1 m resolution

10 km x 10 km

**MODIS**

~1 image/day

250 m+ resolution

width 2330 km

**Ice Tracking Buoys**

30 Buoys

10 km radius

fine-scale temporal resolution (tbc)

C-BAND SAR

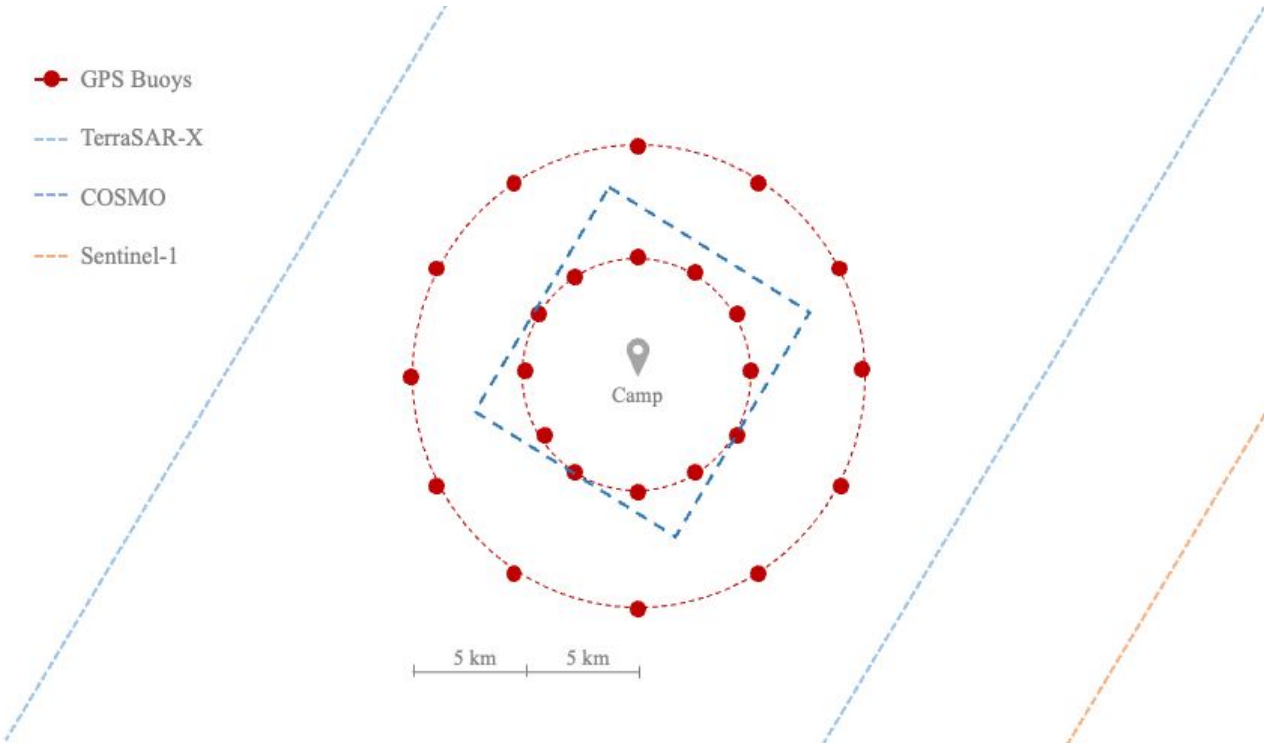
OPTICAL

GPS

# Camp Layout

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.



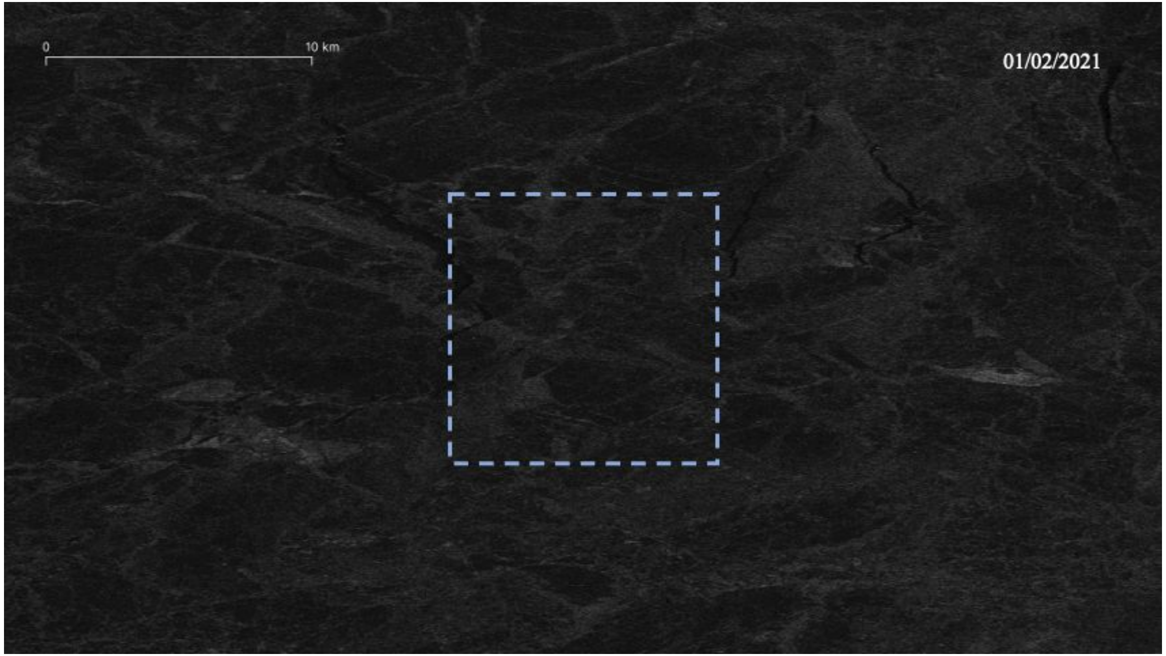

**Diagrammatic plan of camp showing the approximate spatial and temporal resolutions for satellite data.**

# *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.

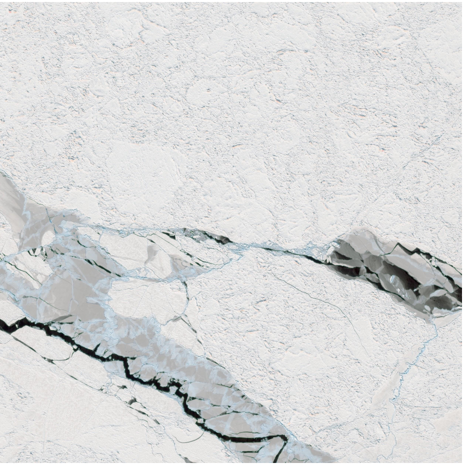



**Sentinel-1 imagery from the month of January 2021 showing an example of a 10 x 10 km camp area. The exact area of camp is still TBC but will be within this general vicinity.**

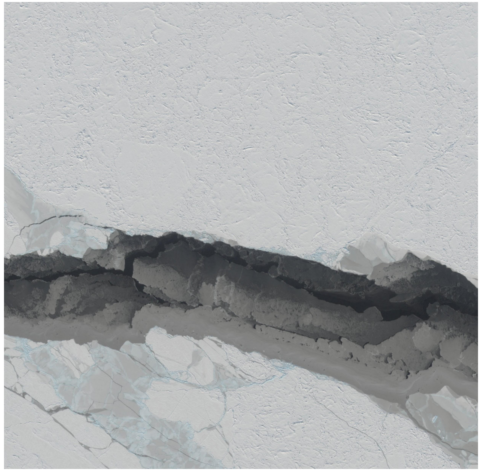
# *Motion Analysis*

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.

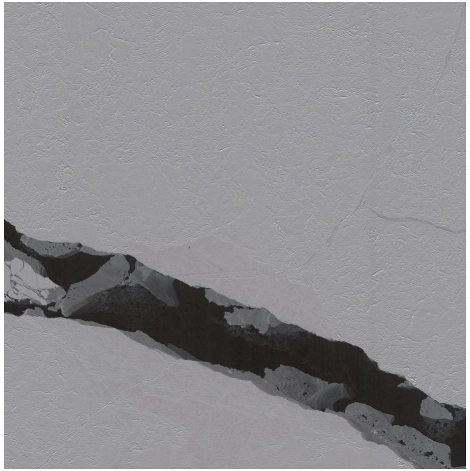
Optical satellite data from ICEx in 2019 was provided to begin development of our motion analysis algorithm.



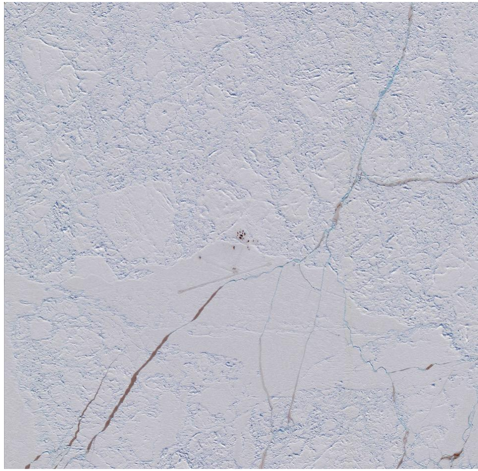
**Camp_03_21**



**Camp_03_28**



**Camp_04_11**



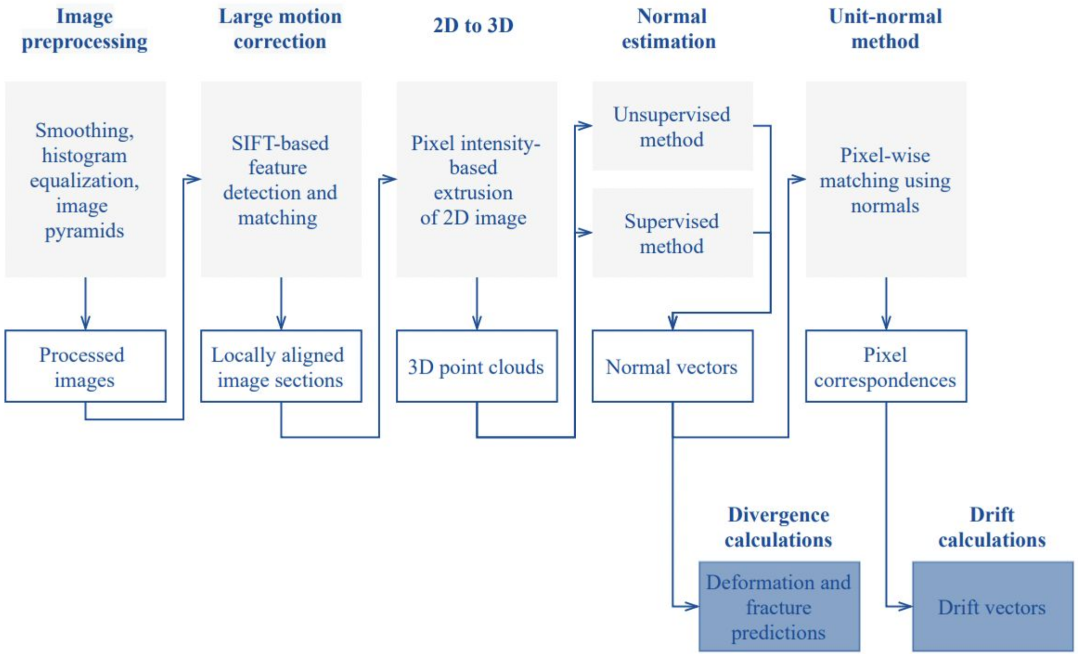
**Camp_04_14**

# *Processing Pipeline*

INPUTS
Satellite images

OUTPUTS
Drift and deformation products, 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

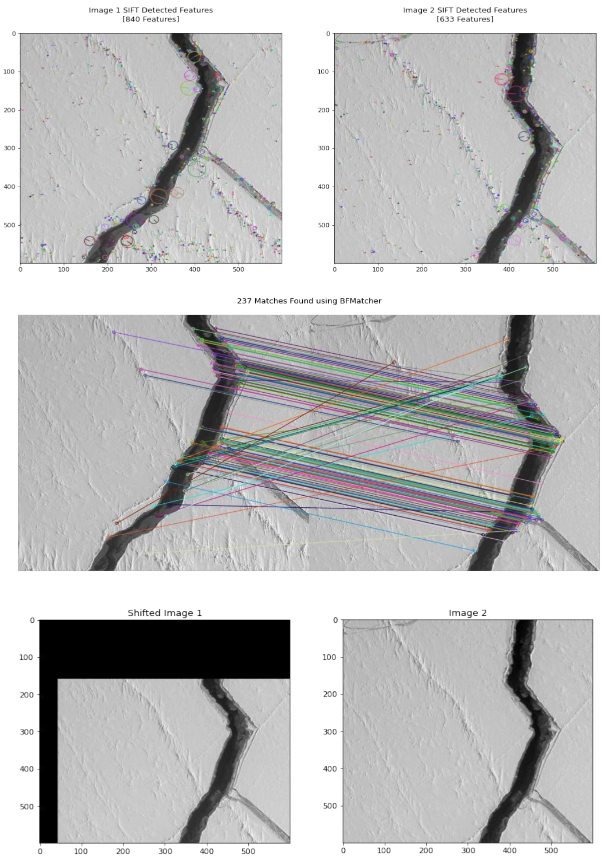
(3) Corrected left image

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

(1)

(2)

(3)



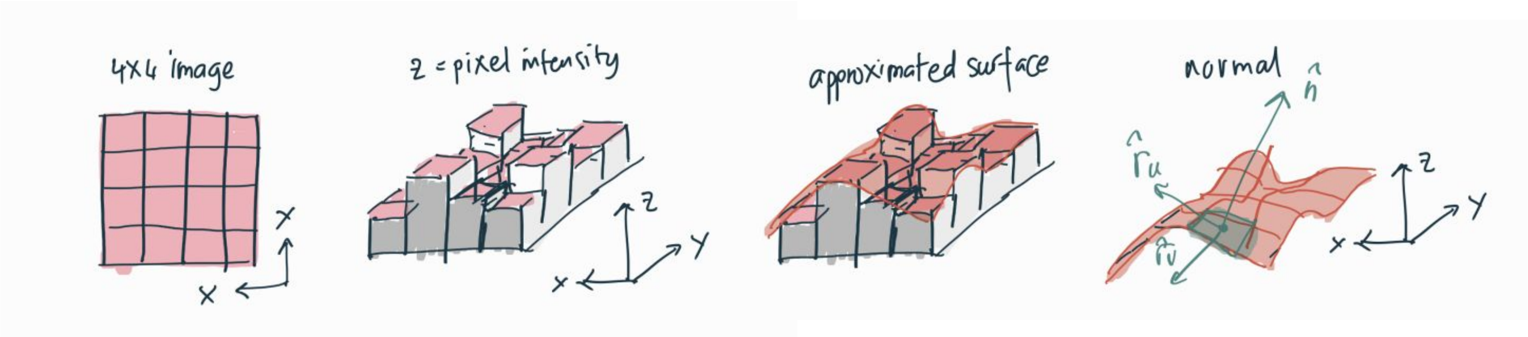

**Large motion correction stage of the pipeline results**

# *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 based on two adjacent pixels
(2) Applying trained DeepFit [3] model to point cloud (supervised approach)
(3) Surface fitting using interpolation (unsupervised approach)




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

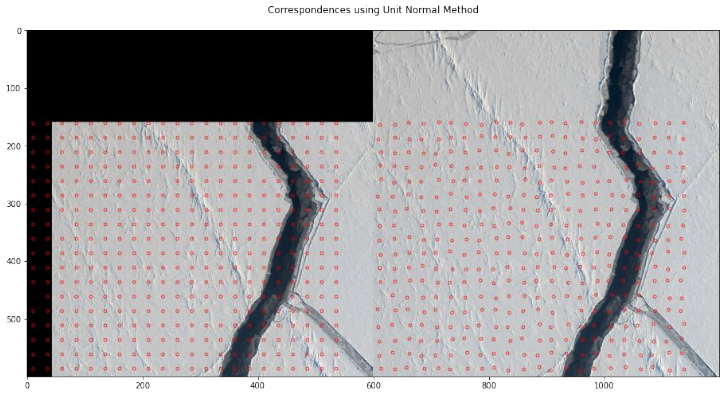
# *Unit-Normal Method*

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

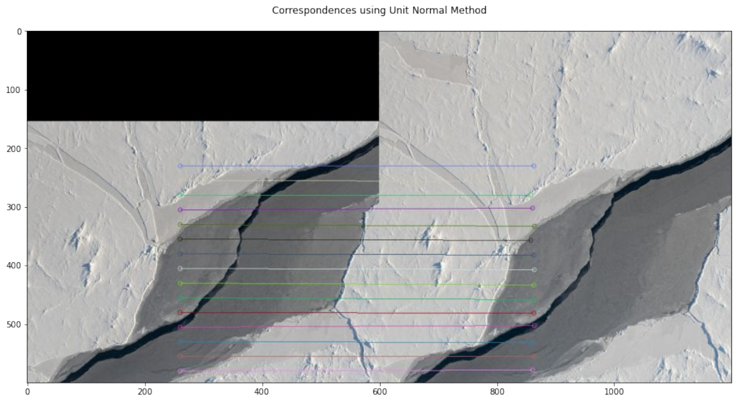
Preliminary results from unit-normal applied to large motion corrected image pairs using method (1) normal estimates:

(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 first year-round expedition into the Arctic Ocean.

Spearheaded by the Alfred Wegener Institute, the project involved hundreds of researchers with the primary objective of better understanding global climate change through observations of changes in the Arctic [4].

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

Images from [4]

## 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].