# Ice Floe Tracker: An Open-Source Tool Enabling Novel Observations of Sea Ice Motion from Visual Remote Sensing Imagery

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**IceFloeTracker.jl** is an open-source tool designed to retrieve floe-scale sea ice motion in the Arctic marginal ice zone during spring and summer. Sea ice is a key component of the polar climate. As seawater freezes, ice crystals aggregate and form into plates of ice (ice floes). Sea ice dynamics and thermodynamics show complex multi-scale behavior, as ice floes jostle, collide, break apart, and merge. Observing sea ice motion is important for Arctic marine traffic safety, for monitoring climate change, and for understanding the physics of sea ice so we can better represent sea ice in earth system models.

The summer marginal ice zone (MIZ) poses a particular challenge due to the highly dynamic, heterogeneous ice motion, including interaction of ice floes with ocean eddies. For passive microwave and SAR remote sensing, the mixture of various ice types and ocean water adds considerable uncertainty to estimates of ice motion, particularly in summer when meltwater appears on the ice and snow.

**The Ice Floe Tracker algorithm proposes a different mode of ice tracking.** By focusing on distinct ice floe shapes, we extract Lagrangian, floe-scale ice motion from optical images of the summer marginal ice zone. The algorithm enables observation of floe shapes, displacement, and rotation. From these observations, we can derive information about moderate-scale variability in the sea ice velocity field, characterize the sea ice floe size distribution, and infer properties of the near-surface ocean eddy field.

## PREPROCESSING

- Cloud masking
- Image sharpening
- Histogram equalization
- Morphological operations

## FEATURE EXTRACTION

- Segmentation via K-means
- Watershed function
- Ice/water discrimination
- Floe shape parameters
  - axes of best fit ellipse
  - area and perimeter
  - centroid

## FLOE TRACKING

- Rotation to minimize surface area difference
- Edge shape correlation via $\Psi$-s curve

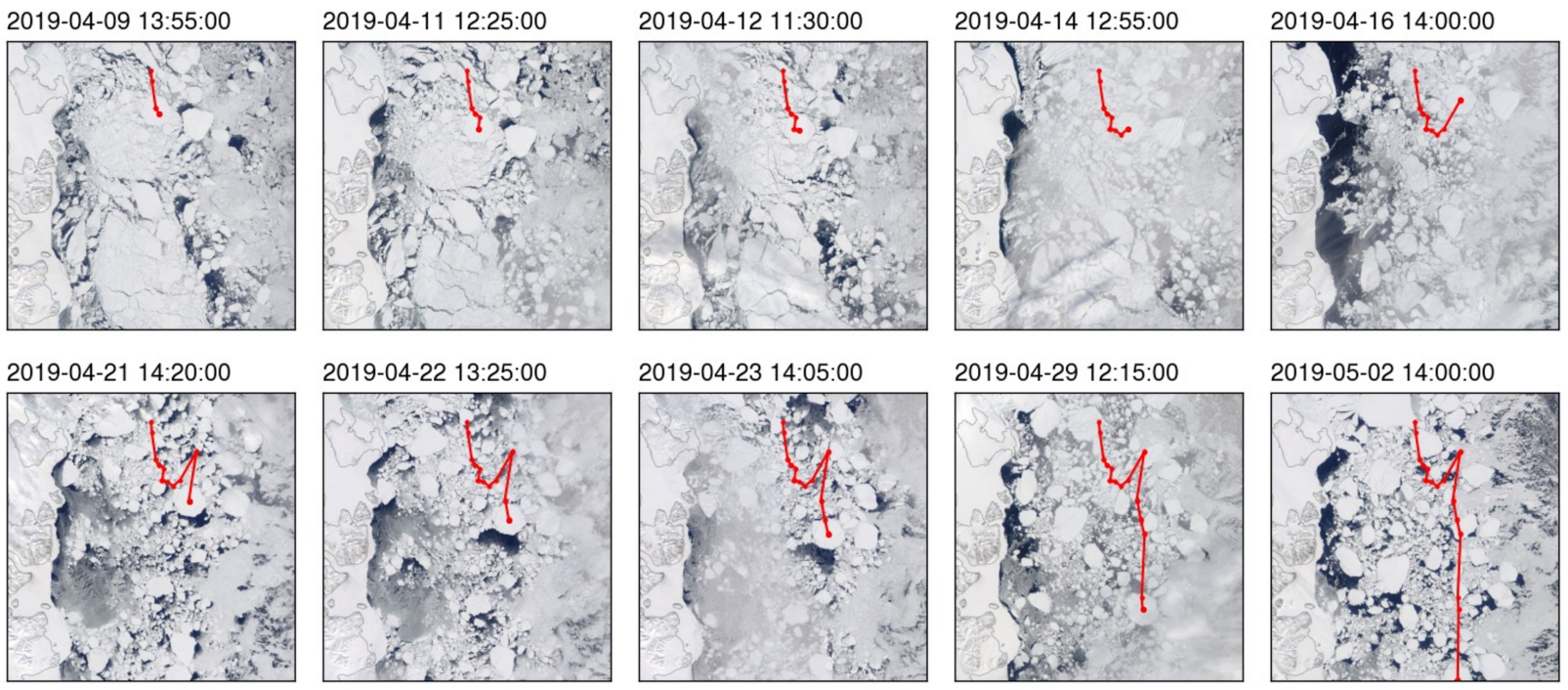
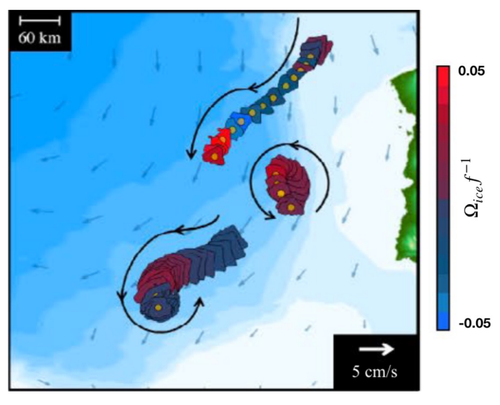



**Figure 1** An example of a tracked floe in the East Greenland marginal ice zone using imagery from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS).

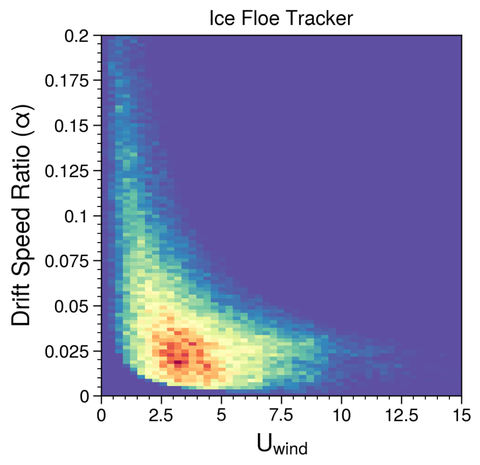
## Results

Case studies using the Ice Floe Tracker protype were run using MODIS imagery from 2003-2020 during the spring/summer period (April-September). These studies provide examples of how this novel form of sea ice observation can be used for Arctic science.



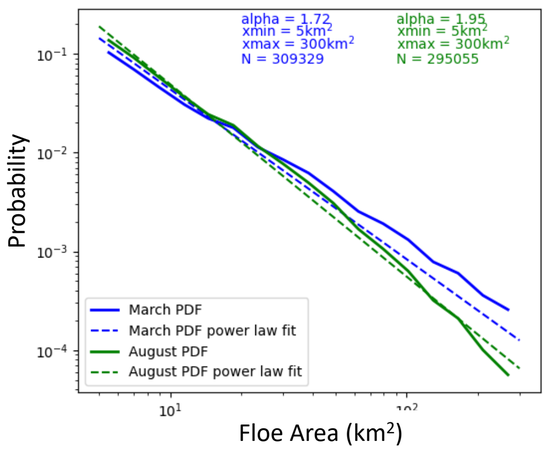

### Sea ice floe rotation rates show intensification of mesoscale eddies

- Manucharyan et al. 2020, *Scientific Reports*
- Scaled rotation rates correlate with EKE observations from moorings




### Spatial gradients in ocean forcing on sea ice in the Fram Strait region

- Watkins et al., 2023, *GRL*
- Enhanced drift speed ratios (wind speed / drift speed) for moderate wind speeds




### Seasonal evolution of the Floe Size Distribution in the Beaufort Sea

- Buckley et al., in prep
- Floe size distribution (FSD) steepens throughout the season
- Evolving floe orientation

## IceFloeTracker.jl

The IFT Julia package includes the core functions for the three main steps of the algorithm. These functions can be used independently and can be customized for specific use cases.

## Ice Floe Tracker Pipeline

The IFT Pipeline implements the functions in the Julia package for use analyzing MODIS imagery. It uses the Cylc python library to automate multi-step analysis.

## Summary

- Case studies with the Ice Floe Tracker algorithm demonstrate acquisition of novel Lagrangian observations of small-scale ice motions during the spring-to-summer transition period
- Open-source Julia implementation available now
- Early results demonstrate range of use cases
  - Ice motion in the presence of strong gradients
  - Seasonal floe size evolution
  - Inferring eddy properties

## Next steps

- Extending to other sensors (VIIRS, Sentinel-2, SAR)
- Arctic-wide MIZ dataset for MODIS period (2003-present)
- Implementation of improved segmentation method for FSD

## References

Buckley et al. (in prep) "Seasonal Evolution of the Sea Ice Floe Size Distribution from Two Decades of MODIS Data"
Lopez-Acosta et al. (2019) "Ice Floe Tracker: An algorithm to automatically retrieve Lagrangian trajectories via feature matching from moderate-resolution visual imagery," *Remote Sensing of Environment*
Manucharyan et al. (2022) "Spinning ice floes reveal intensification of mesoscale eddies in the western Arctic Ocean", *Scientific Reports*
Watkins, Bliss, Hutchings, and Wilhelmus (2023) "Evidence of abrupt transitions between sea ice dynamical regimes in the East Greenland marginal ice zone," *Geophysical Research Letters*

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