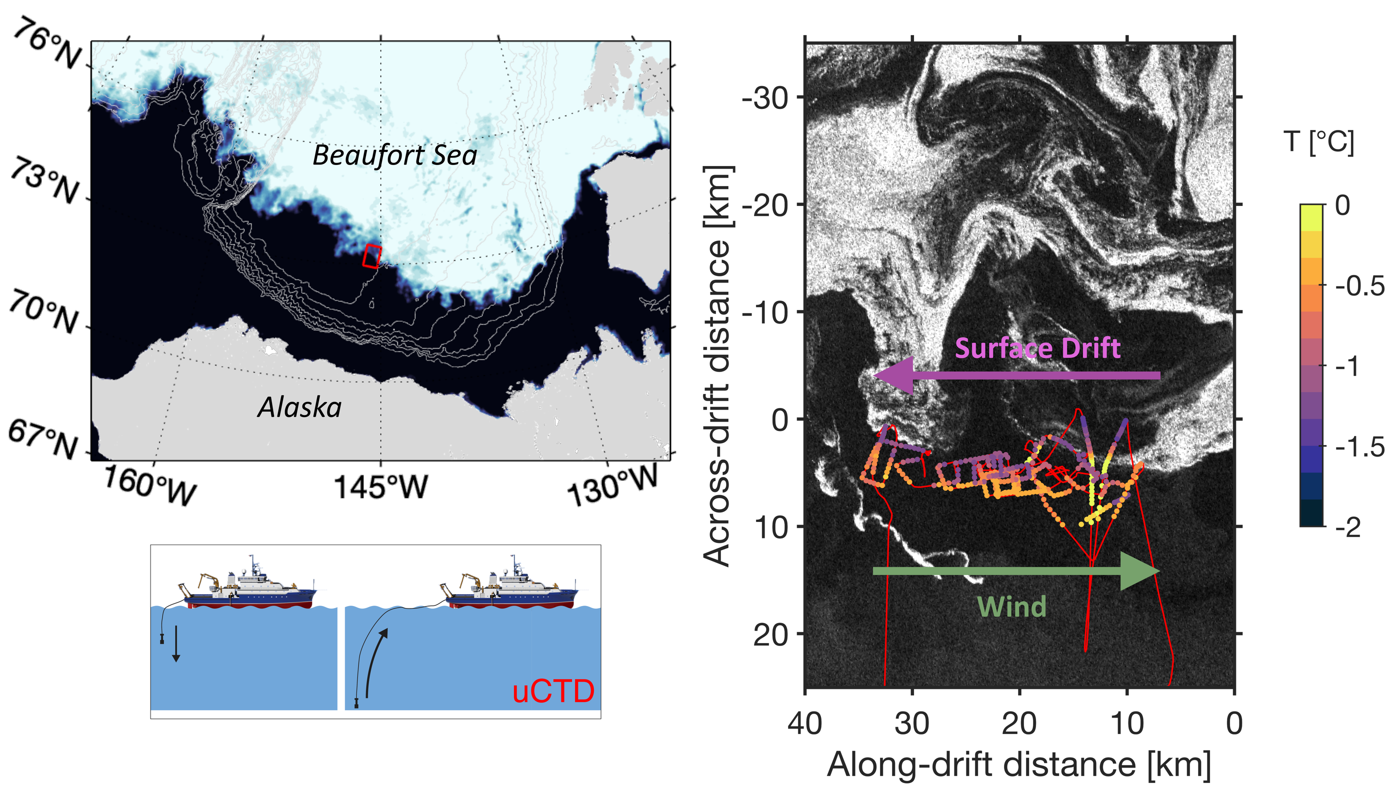
Evolution of an Arctic Meltwater Front

Samuel Brenner, Luc Rainville, Jim Thomson, Craig Lee

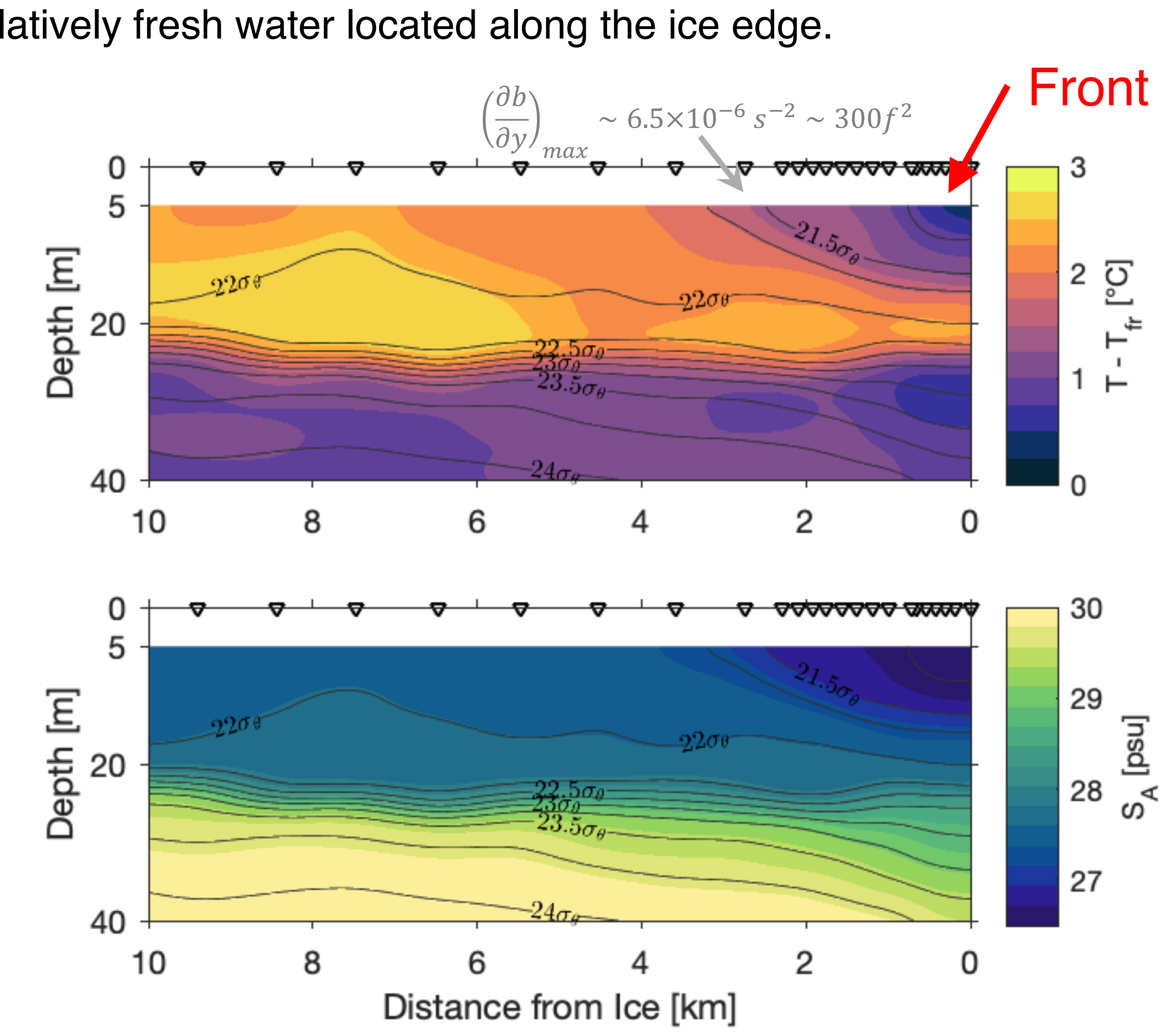
Applied Physics Laboratory, University of Washington, Seattle, WA, United States

Study location and observations

A ship-based survey took place in the along the edge of the marginal ice zone (MIZ) in the Beaufort Sea. The survey took place over 3 days in early October 2014, at the beginning of the fall freeze-up.



The ship performed short loops towards and away from the ice while following a coherent patch of drifting ice. This drift set a local coordinate system. High horizontal resolution casts from an underway profiling system (uCTD) casts show a strong, shallow front of near-freezing, relatively fresh water located along the ice edge.

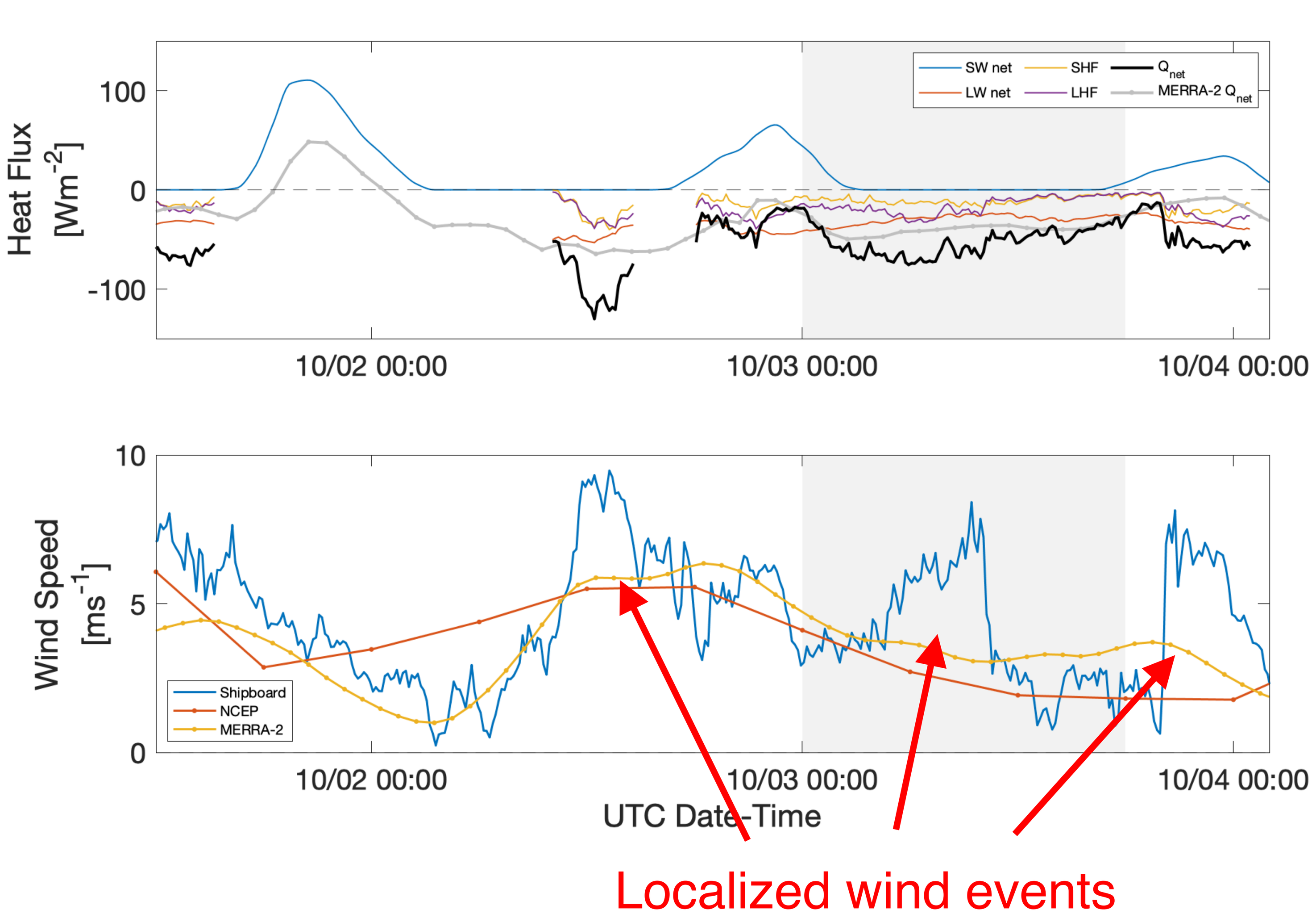


Atmospheric conditions

Surface heat fluxes during the survey shows consistent ocean cooling, consistent with fall ice-growth.

Wind was "up-front", which is aligned along the front going opposite the direction of a baroclinic jet. Observations show a number of distinct peaks in wind speed not captured by re-analysis products. We interpret these as local wind events.

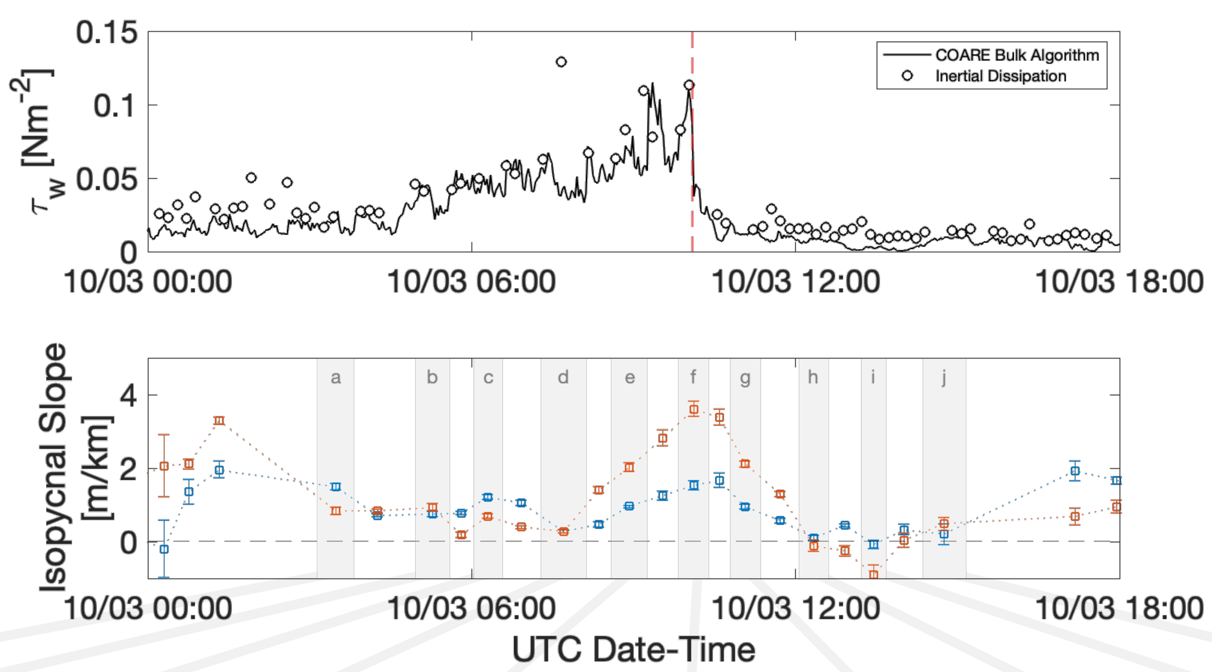
One of these events coincided measurements of frontal evolution.



Frontal evolution

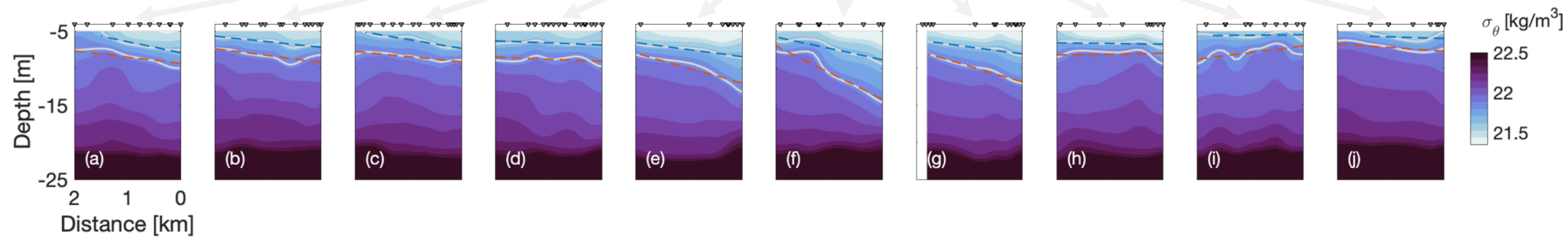
Two methods were used to estimate wind stress during one of localized wind events.

Linear fits of characteristic isopycnal slopes are used to track frontal evolution. We show the $21.65\sigma_\theta$ and $21.85\sigma_\theta$ isopycnals.



The front shows a reaction in response to the wind. As the wind stress increases, the front steepens. After wind stress stops, the front slumps.

This steepening behavior is **opposite** from what would be expected for open-ocean fronts with up-front winds.

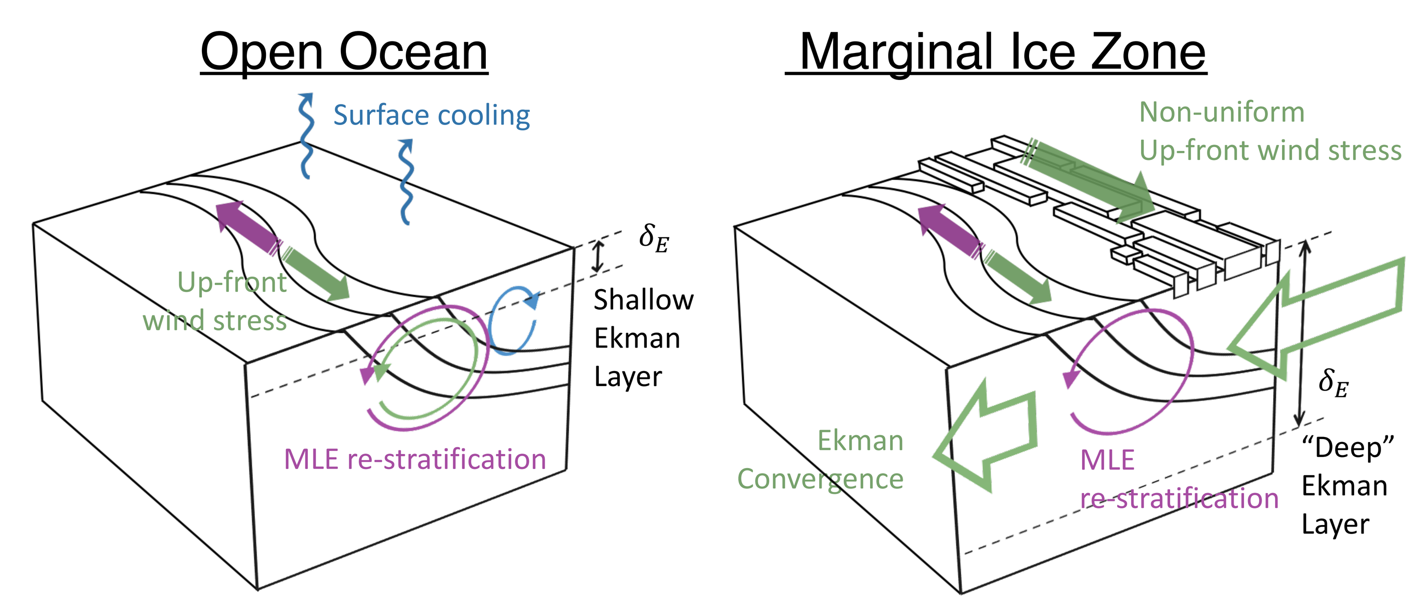


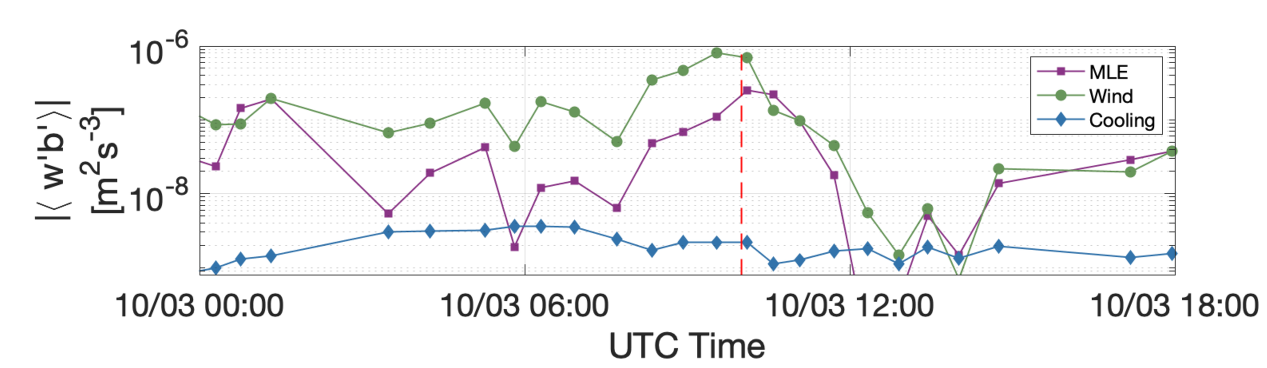
In the open ocean, frontal slope is driven by mixed-layer eddies (MLE), cross-front Ekman transport, and surface cooling. A balance can be evaluated by comparing their vertical buoyancy fluxes:

$$\langle w'b'\rangle_{MLE} = \frac{C_e H_{ml}^2 M^4}{f}$$

$$\langle w'b'\rangle_{wind} = \frac{(\tau_w \times \hat{k})}{\rho_0 f} \cdot \nabla b_s$$

$$\langle w'b'\rangle_{cooling} = \frac{\alpha Q g}{\rho c_p}$$

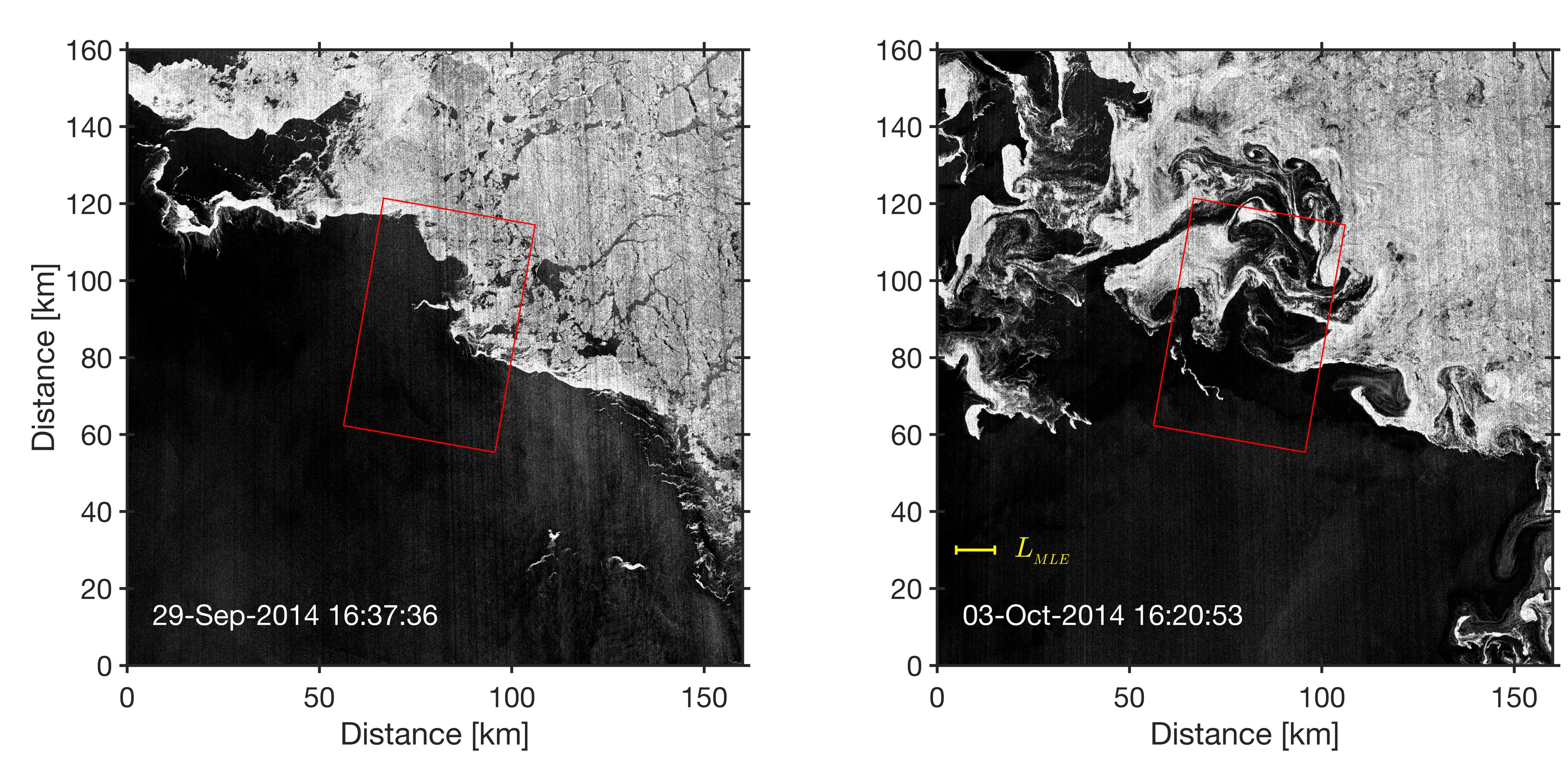




Sea ice modifies wind stress by changing the drag coefficient. There is a local maximum of stress in the MIZ. The Non-uniform wind stress causes convergence of the Ekman transport across the full depth of the front.

Relaxation of the wind forcing leads to MLE re-stratification.

Ice edge evolution



Synthetic aperture radar (SAR) images show the development of an eddy field within the MIZ over a period of only a few days. The eddies have a scale comparable to the expected MLE diameter (10 km).

Key Points

- In-situ measurements of frontal evolution in response to localized wind conditions
- Frontal dynamics are modified compared to the open ocean by the shallowness of the front and presence of ice
- Concurrent evolution of MIZ eddy field

Acknowledgements:

We would like to thank the Office of Naval Research (ONR) for funding support, the National Ice Centre (NIC) for providing satellite imagery, and the captain and crew of the Norseman II for operational support.

For more information about the MIZ program, visit: http://www.apl.uw.edu/miz

Corresponding author:
Samuel Brenner
Applied Physics Lab
University of Washington
sdbren@uw.edu