Momentum fluxes across the air-ice-ocean interface in the Beaufort Sea

How does ice cover mediate momentum transfer into the Arctic Ocean?

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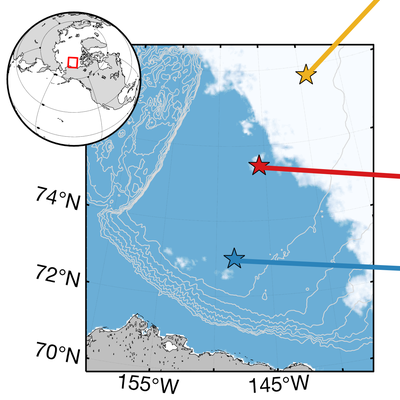
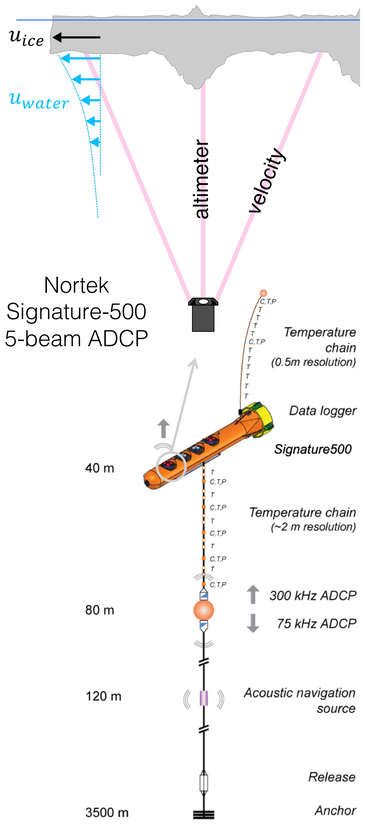
Key ideas

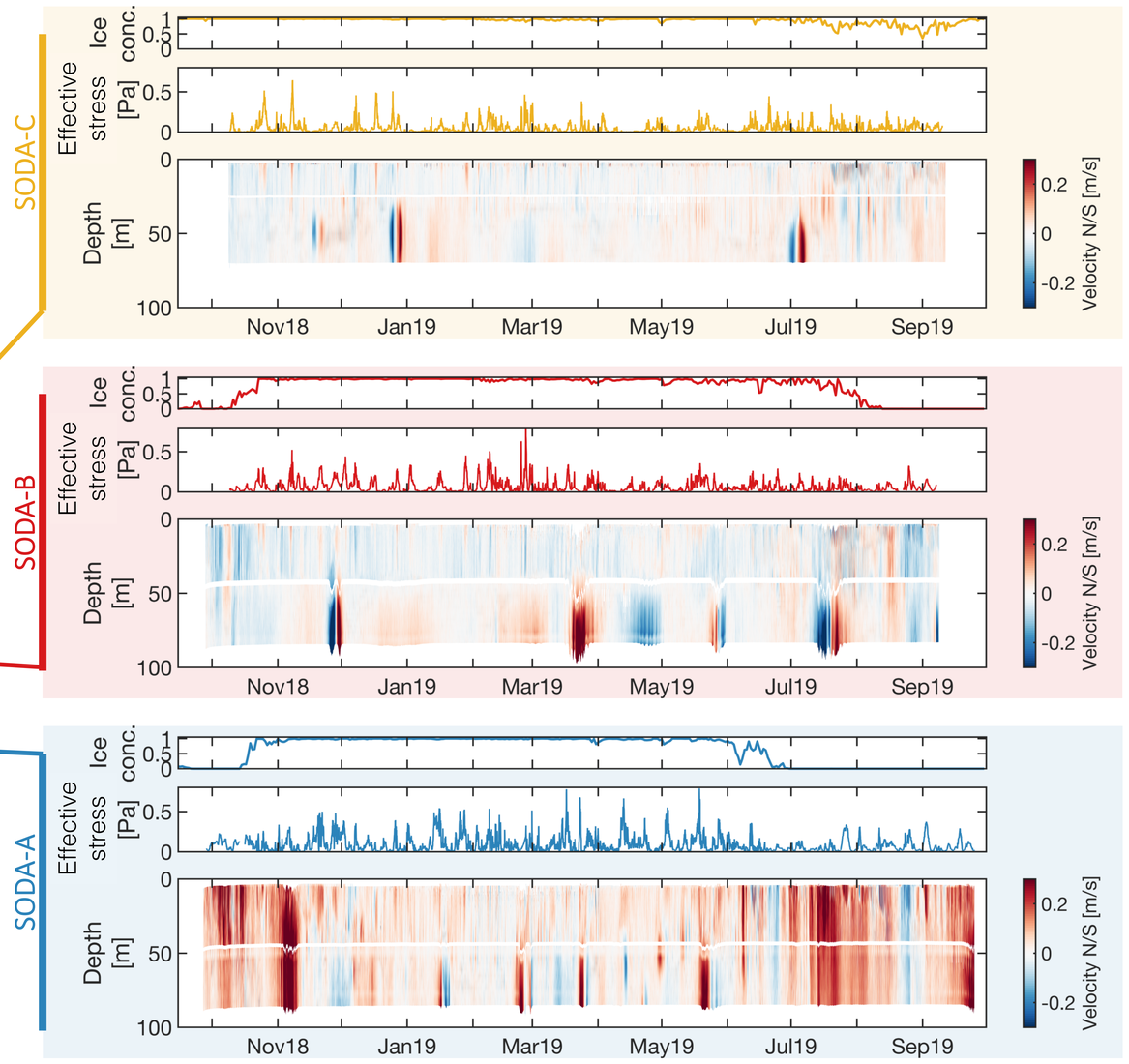
1. We can recover estimates of ice-ocean drag from moorings
2. Ice draft bursts allow ice geometry characterization for use in parameterizations
3. Differences in the upper-ocean momentum match differences in surface stress

Study description

The Stratified Ocean Dynamics of the Arctic (SODA) program took place in the Beaufort Sea, including 3 moorings deployed for a year from Sept. 2018 to Sept. 2019.

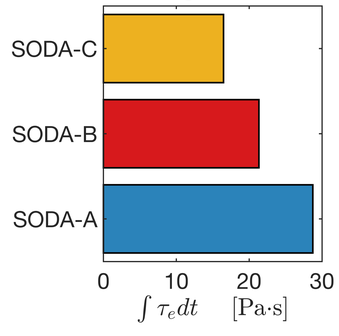






Effective surface stress input

Time-integrated stress



Changes in effective stress are driven by both the individual atmosphere and ice stresses and sea ice concentration (A):

$$\boldsymbol{\tau_e} = (1-A)\boldsymbol{\tau_{ao}} + A\boldsymbol{\tau_{io}}$$

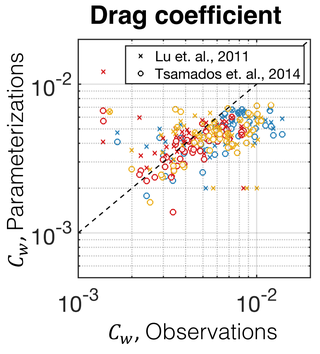
Differences in upper-ocean momentum across moorings matches with differences in effective surface stress input

Ice-ocean stress: $\boldsymbol{\tau_{io}} = \rho_w C_w(\boldsymbol{u_i} - \boldsymbol{u_w})|\boldsymbol{u_i} - \boldsymbol{u_w}|$

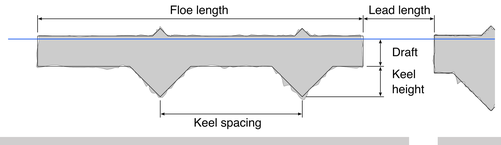
Atmosphere-ocean stress: $\boldsymbol{\tau_{ao}} = \rho_a C_{ao} \boldsymbol{U_{10}}|\boldsymbol{U_{10}}|$

Ice-ocean drag parameterization

Drag coefficient



Tsamados et. al. (2014), and Lu et. al. (2011) parameterize the ice-ocean drag coefficient, C_w, in terms of idealized geometric features. We test the parameterizations against estimates from our observations with known ice geometry.



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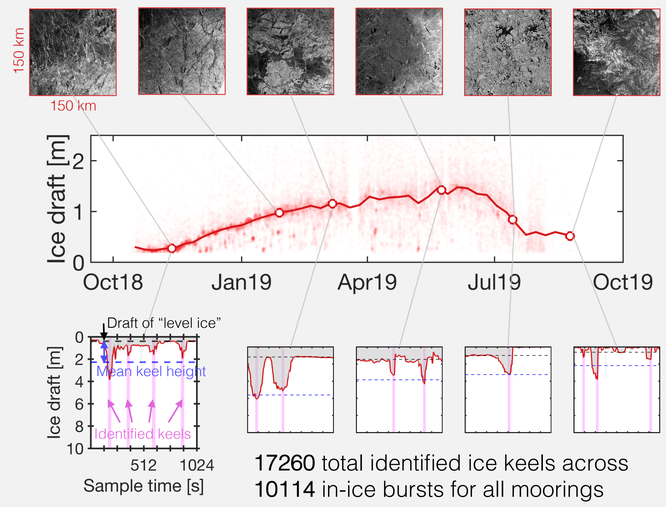
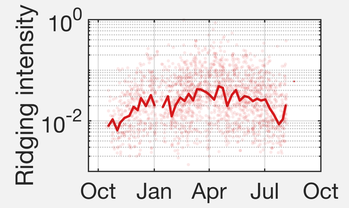
Methods

Ice Geometry

- Burst altimetry data from Signature-500 ADCPs (1024 s @ 2Hz collected every 2 hours) allows for identification and assessment of ice keels and leads
- SAR imagery provides additional context



- Bursts give temporal variation in keel height & spacing, and can be used to derive additional geometric properties



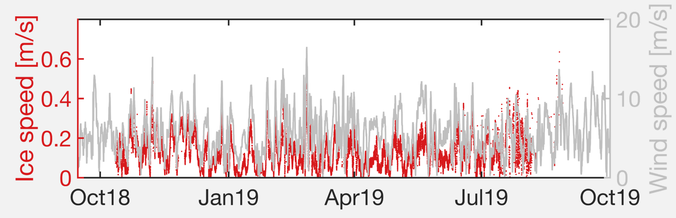
Ice-ocean momentum transfer

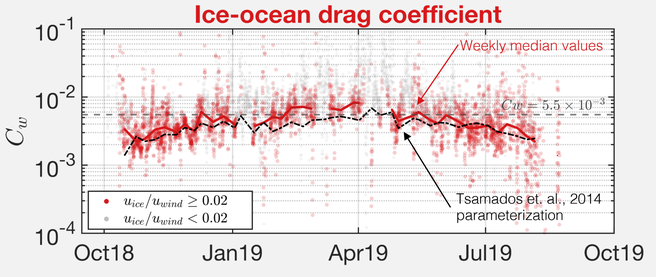
Ice momentum equation: $\rho_i h_i \left[\frac{d\boldsymbol{u_i}}{dt} + \boldsymbol{f}\times\boldsymbol{u_i}\right] = \boldsymbol{\tau_{ai}} + \boldsymbol{\tau_{oi}} + \nabla\cdot\boldsymbol{\sigma}$ if $u_{ice}/u_{wind} \geq 0.02$

Ocean-ice stress: $\boldsymbol{\tau_{oi}} = \rho_w C_w e^{i\beta}(\boldsymbol{u_w} - \boldsymbol{u_i})|\boldsymbol{u_w} - \boldsymbol{u_i}|$

- We estimate the ice-ocean drag coefficient by inverting ice momentum in terms of the ocean-ice stress
- This is only valid if internal ice stresses are negligible, which we assume occurs for a high enough ice/wind speed ratio
- Results are sensitive to the inclusion of water velocity $\boldsymbol{u_w}$

Ice-ocean drag coefficient: $C_w = \left|\frac{\boldsymbol{\tau_{ai}} - \rho_i h_i(\boldsymbol{f}\times\boldsymbol{u_i})}{\rho_w(\boldsymbol{u_w} - \boldsymbol{u_i})^2}\right|$





References

Lu, P, Li, Z, Cheng, B and Leppäranta, M 2011 A parameterization of the ice–ocean drag coefficient. *J Geophys Res*, 116(C07): 019. DOI: https://doi.org/10.1029/2010JC006878

Tsamados, M, Feltham, D, Schroeder, D, Flocco, D, Farrell, SL, et al. 2014 Impact of variable atmospheric and oceanic form drag on simulations of Arctic sea ice. *J Phys Oceanogr*, 44: 1329–1353. DOI: https://doi.org/10.1175/JPO-D-13-0215.1

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