Atmosphere-ice-ocean interactions: ICESat-2 Pan-Arctic Sea Ice Drag Coefficient Data

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Abstract

- **I**ce, **C**loud and land **E**levation **Sat**ellite-**2** (**ICESat-2**) **s**ea **i**ce **h**eight (**SIH**) data are used to calculate 10 m neutral drag coefficients using parameterizations by *Garbrecht et al. 2002.*
- **Motivation**: assessing the impact of sea ice topography on the air-ice energy/momentum exchange has thus far been limited to airborne measurements that are both temporally and spatially limited; here we try to extend these methods via remote sensing for large-scale analysis of the effect of sea ice roughness.

Hypothesis

ICESat-2 sea ice height data can be used to extrapolate drag coefficients derived from airborne topography data for an accurate pan-Arctic study of atmosphere-ice momentum transfer

1. Formulation

Adding together skin drag $\mathbf{C_{dn10,i}}$ (small-scale roughness) and form drag $\mathbf{C_{dn10,f}}$ (distinct obstacles e.g. ridges), the total 10 m neutral drag coefficient $\mathbf{C_{dn10}}$ may be calculated as

$$C_{dn10} = C_{dn10,i} + C_{d10,f},$$

- skin drag $\mathbf{C_{dn10,i}}$ is kept constant ($8.38 \cdot 10^{-4}$) and form drag is a function of obstacle height $\mathbf{H_e}$ and how far apart the obstacles are spaced $\mathbf{x_e}$.
- $\mathbf{c_w}$ is the the coefficient of resistance estimated as $0.185 + 0.147\mathbf{H_e}$.
- $\mathbf{z_0}$ is the surface roughness length over smooth ice given below.

$$C_{d10,f} = \frac{c_w}{\pi}\frac{H_e}{x_e}\frac{\left[\ln\left(\frac{H_e}{z_0}\right)-1\right]^2 + 1 - 2\frac{z_0}{H_e}}{\left[\ln\left(\frac{10}{z_0}\right)\right]^2}.$$

$$z_0 = 10\exp\left(-\frac{\kappa}{\sqrt{C_{dn10,i}}}\right).$$

κ = v. Karman constant (0.4)

Formulas retrieved from *Castellani et al. 2014*

2. ICESat-2 Data

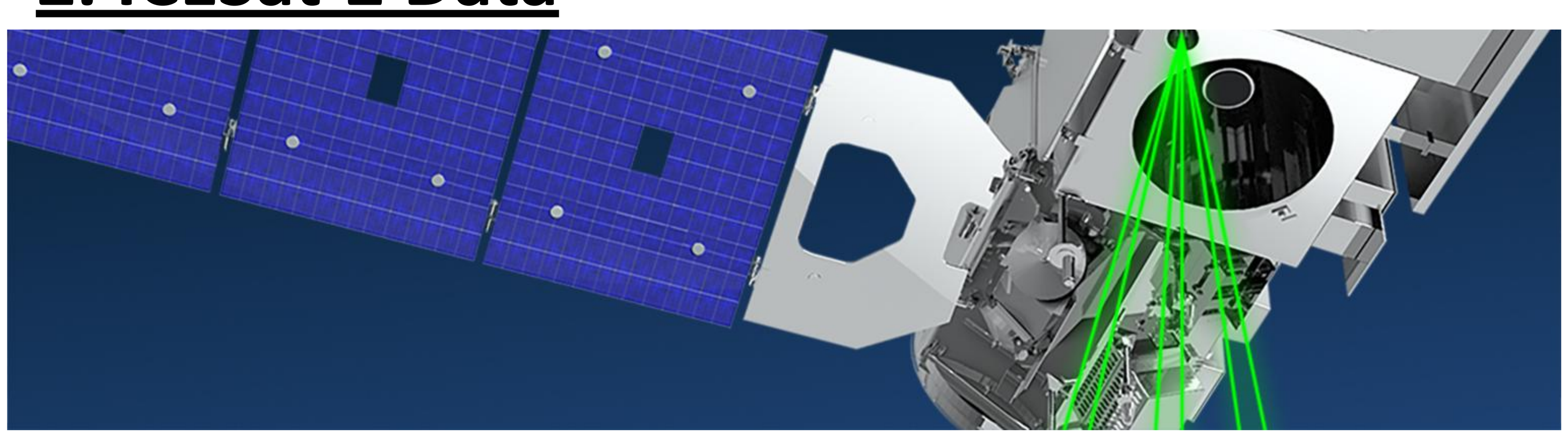

Fig. 1: Illustration of NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2), a mission to measure the changing height of Earth's ice. Credits: NASA

- The **A**dvanced **T**opographic **L**aser **A**ltimeter **S**ystem (**ATLAS**) onboard **ICESat-2** sends 10,000 laser light pulses every second: transmits laser pulses every 70 cm along the ground track.
- ATL07 (**ATLAS** data product no. 7) mean sea ice heights are calculated (via a double Guassian fit) for segments over which 150 signal photons are accumulated.
  - As a result, mean along-track resolution is lowered to 30 m and average point spacing becomes roughly 15 meters.

3. Pan-Arctic Drag Coefficient Map

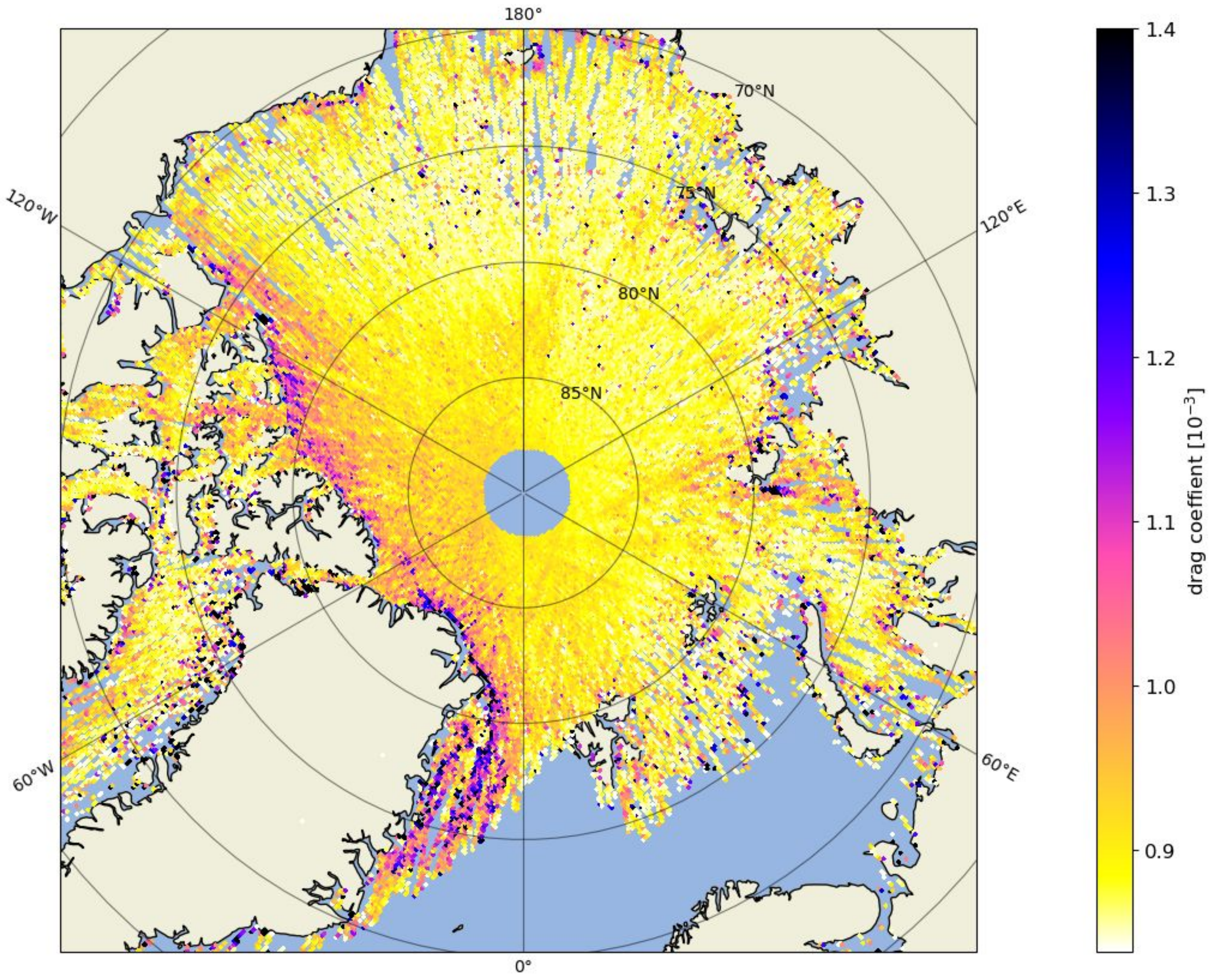

Fig. 2: Pan-Arctic drag coefficients calculated from all ATL07 SIH tracks from March 2020.

4. Comparison with Operation IceBridge

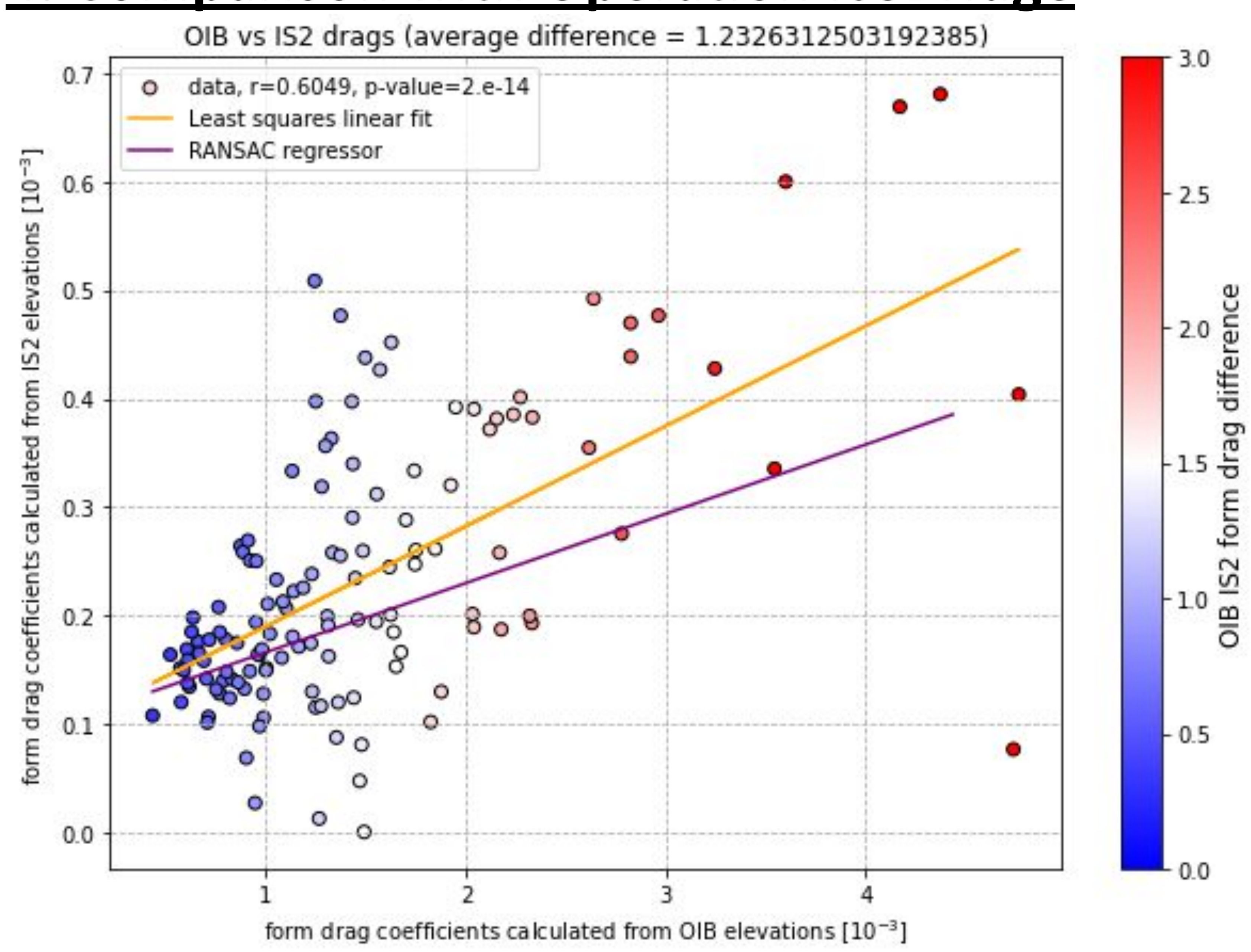

Fig. 3: OIB data-derived and ICESat-2 ATL07-derived form drag coefficients plotted against each other for the time period of April 2019; the colorbar shows the average difference between the two.

5. Conclusion & Outlook

- Using high-precision satellite altimetry, it is possible to retrieve monthly pan-arctic drag coefficients.
  - The retrieved drag coefficients heavily underestimate actual drag due to length of **ICESat-2** segments.
- Using additional airborne topography data it should be possible to remedy this underestimation and fine-tune existing parametrization to retrieve more accurate drag coefficients with **ICESat-2 SIH** data.
- Post-refinement the dataset is meant to be implemented in the coupled Arctic atmosphere-ocean-sea ice model HIRHAM-NAOSIM; where it is expected to improve model simulations.

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printed at Universitätsrechenzentrum Leipzig