ICESat-2 observations of melt ponds on Arctic sea ice

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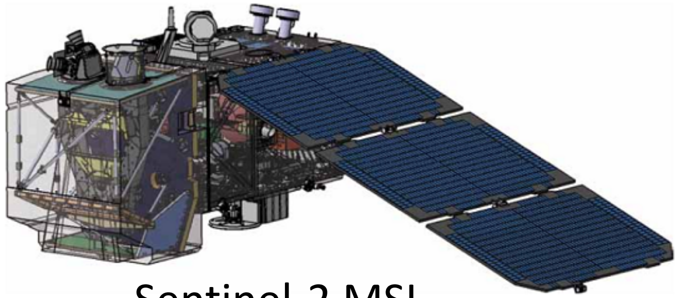
Abstract

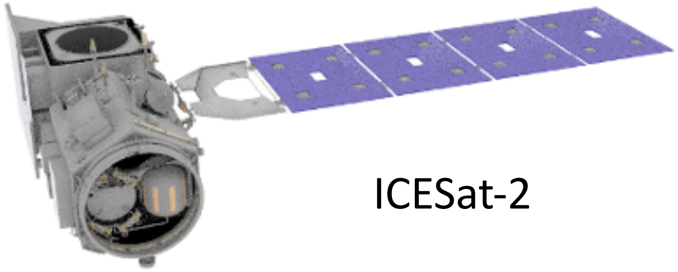
During the Arctic summer season, snow atop the sea ice melts and pools into low-lying areas on the surface. These melt ponds reduce surface albedo and increase solar absorption in the Arctic Ocean. Throughout the summer, melt ponds grow, drain, and connect, through a complex drainage system. Current melt pond schemes in sea ice models, such as the level-ice scheme in the Los Alamos Sea Ice Model (CICE), rely on a linear relationship between pond depth and fraction to predict the evolution of pond growth as the snow and sea ice melt. Although the inclusion of melt ponds in models has been shown to improve forecasts of end-of-summer sea ice extent, observations of melt pond depth and fraction guiding these models are from SHEBA, a spatially-limited field campaign which occurred over 20 years ago. Until recently, melt ponds characteristics have been difficult to resolve from spaceborne platforms due to their small size (10s - 100s m in diameter), and indistinguishable radiometric similarity to open water. Here we show that new, high-resolution laser altimetry measurements from ICESat-2 (IS2), combined with coincident high-resolution satellite imagery, provides a three-dimensional view of the melting sea ice cover. IS2, launched in September 2018, has now observed two summer melt seasons in the Arctic. IS2 operates at 532 nm, a wavelength that penetrates low turbidity water, and can therefore be used to capture the bathymetry of shallow water features. Building on previous work, we demonstrate IS2's ability to detect and measure melt ponds on multiyear sea ice. We validate the existence of melt ponds with high resolution (10 m) visible imagery from the Sentinel-2 (S2) MultiSpectral Instrument. We apply the "density dimension algorithm – bifurcate" (DDA-bifurcate), an auto-adaptive algorithm utilizing data aggregation with the ability to track two surfaces, as well as a second algorithm that tracks melt pond surface and bottom, to derive melt pond depth for dozens of melt ponds in 2019 and 2020. Applying a sea ice surface classification algorithm to S2 imagery, we are able to determine melt pond fraction. We compare our findings of coincident melt pond fraction and depth with the melt pond parameterization used in the level-ice scheme in CICE. We discuss our results in the context of the existing literature on pond depth and volume.

We extract melt pond parameters from high resolution satellite data to better understand melt pond characteristics.



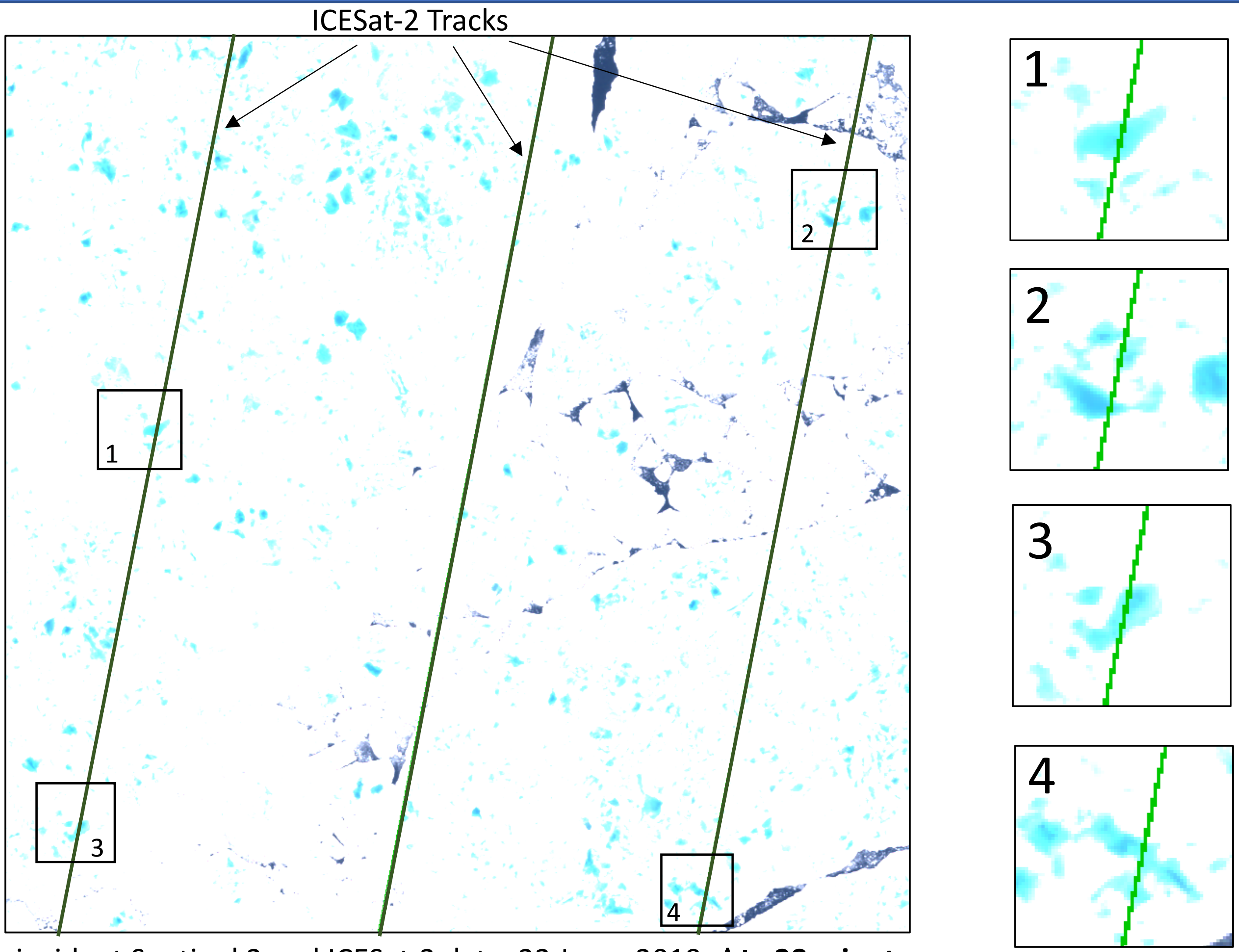
Sentinel-2 MSI

- Melt pond fraction



ICESat-2

- Melt pond width
- Melt pond depth



Coincident Sentinel 2 and ICESat-2 data. 22 June, 2019. Δt= **38 minutes**

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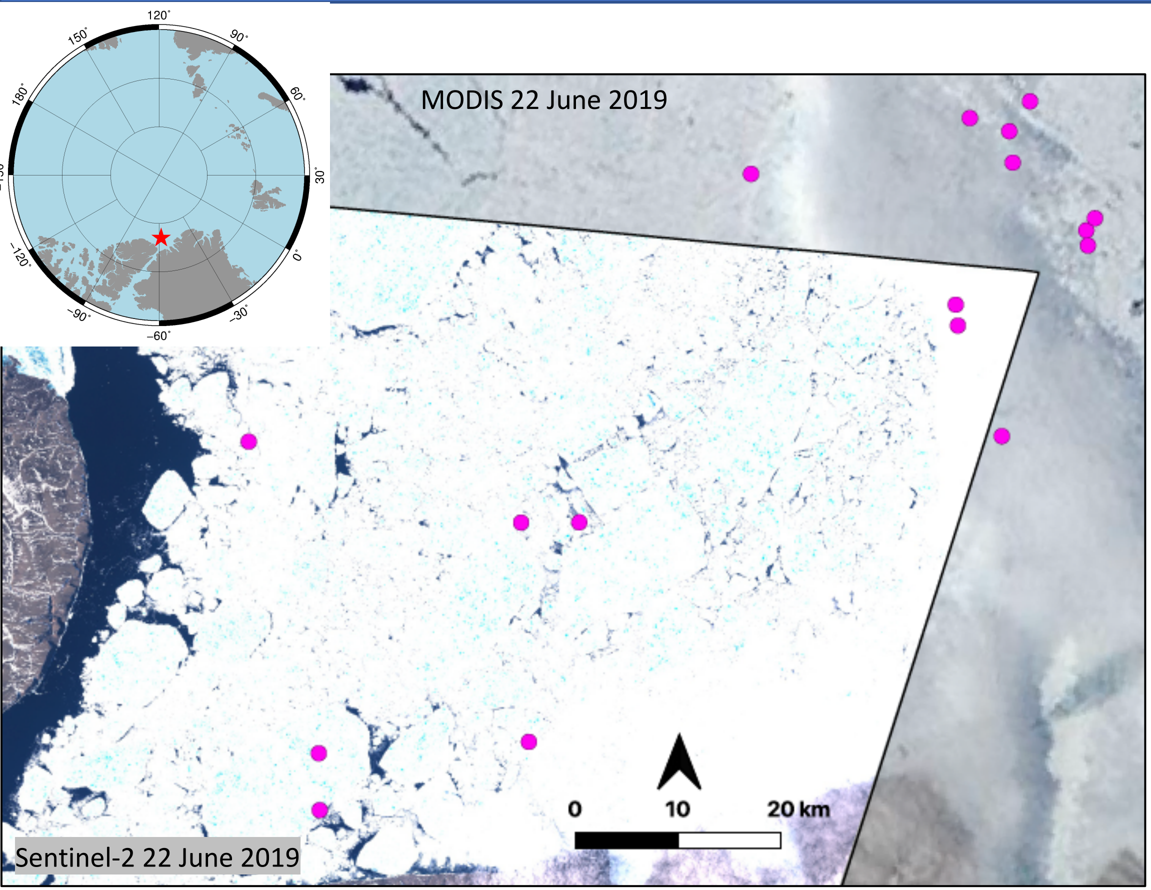
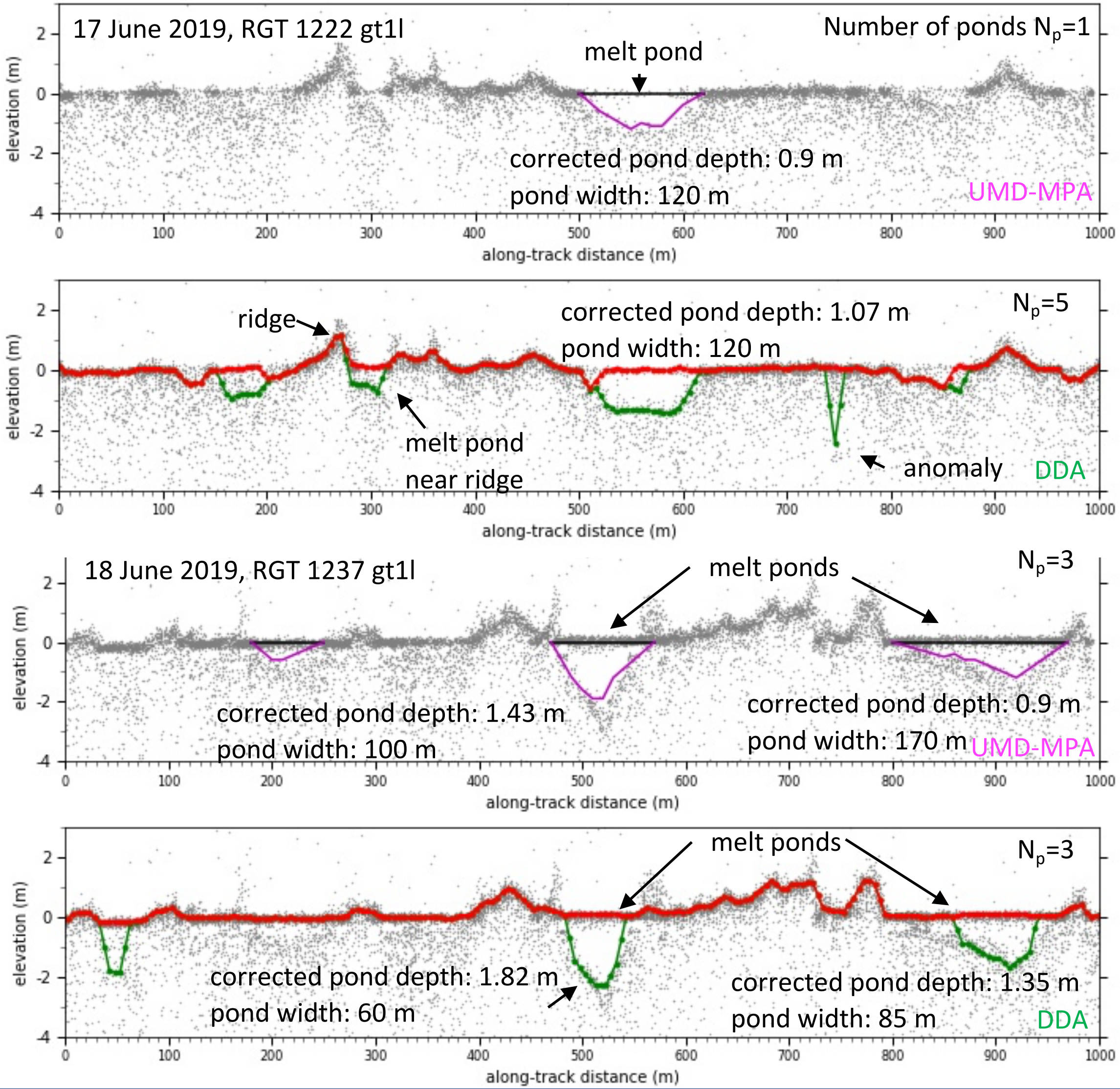
We use two surface tracking algorithms: the density dimension algorithm – bifurcate (DDA) and the UMD melt pond algorithm (UMD-MPA)



17 melt ponds in the Lincoln Sea tracked by both MPA and DDA algorithms from 17-22 June 2019



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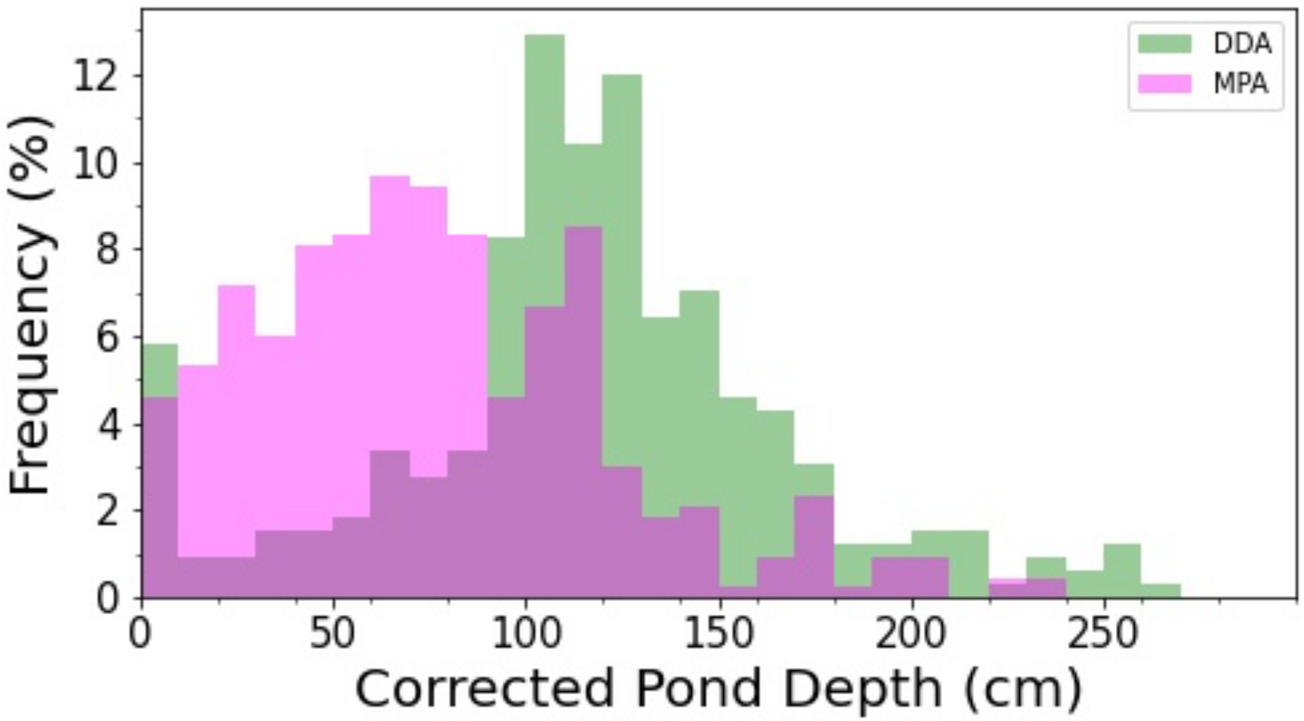
We find good agreement between the two algorithms, and we plan to expand the melt pond tracking across the Arctic



	MPA	DDA
Ponds tracked (#)	17	17
Depth measurements (#)	434	326
Corrected depth mean (m)	0.77	1.16
Corrected depth mode (m)	0.65 +/- 0.05	1.05 +/- 0.05
Corrected depth std (m)	0.47	0.52
Corrected depth max (m)	2.40	2.64
Percent of measurements less than 1 m (%)	71 %	30 %
Range of pond widths (m)	70 - 280	35 - 230
Integrated approximate pond volume (m^3)	~ 170,000	~ 130,000
Average approximate pond volume (m^3)	~ 10,000	~ 7,800

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