Investigating Weather and Climate Drivers of Sea Ice Variability in the New Arctic

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ICESAT-2

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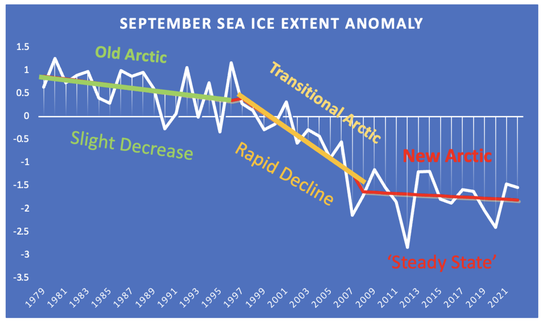
Objective

Investigate the influence of individual episodic weather events (i.e. cyclones) on local-scale Arctic sea ice thickness changes over the course of the event, and the cumulative effects of these events on monthly sea ice thickness and volume.

Introduction



Four-decade timeseries shows the transition from 'Old ' to 'New Arctic': characterized by high interannual variations in extent.

Sea ice in the New Arctic is more susceptible to atmospheric and oceanic forcings compared to the older, thicker ice cover in the 1980-1990s.

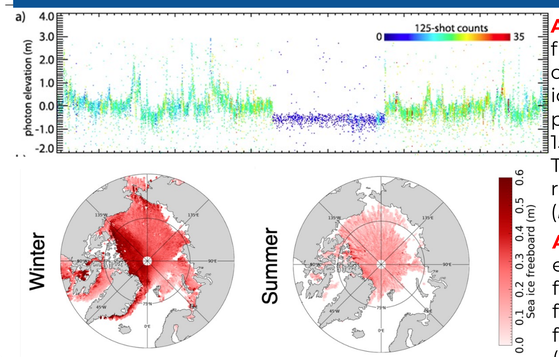
Episodic weather events like cyclones can immediately impact the sea ice state both dynamically & thermodynamically.

However, most studies exploring the response of sea ice to changes in weather & climate focus on SIE rather than the complete sea ice mass balance.

To accurately project trends in sea ice loss in the New Arctic, & how this will impact global weather & climate, it is crucial to pinpoint the key drivers of SIT & volume as well as SIE.

Data

ICESat-2



ATL10 along-track sea ice freeboards: segments derived from ATL07 sea ice & SSH segments, produced by aggregating 150 photons along-track. They have a variable resolution ~30-75 m. (*Kwok et al., 2023*)

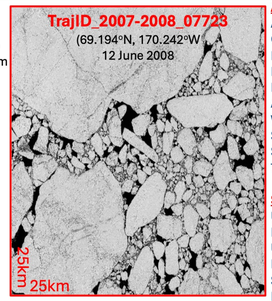
ATL20 monthly gridded estimates of sea ice freeboard is then derived from ATL10, by gridding freeboard at 25 km. (*Petty et al., 2023*)

Daily Lagrangian Arctic Sea Ice Parcel Database

Sea Ice Characteristics:
Ice Type (SSM/I): First Year
Concentration (NSIDC/CDR): 90%
Snow Depth (SnowModelLG): 0.06m
SIT (PIOMAS): 2.10m
Albedo (CERES): 0.50
Skin Temperature (AIRS): 269K

Life Cycle:
Formation: 22 Nov 2007
Duration: 211 days
End: 20 June 2008
Origin & End Region: Chukchi Sea
Survived: No

Flags:
Cyclone (Melborne U. Tracker): n/a
Cyclone Properties (ERA5): n/a/



Atmospheric State:
Air Press (ERA5/MERRA2): 1018 hPa
Cloud Cover (CERES): 15%
Precipitable Water (ERA/MERRA2): 19 kg m^{-2}
Liq. Water Path (CERES): 112 g m^{-2}
Ice Water Path (CERES): 96 g m^{-2}
Air Temp (AIRS): 274K
Wind Speed/Dir. (ERA5/MERRA2): 8.4 ms-1/39°
Specific Humidity (AIRS): 45%
Snowfall (ERA5/MERRA2): n/a
Total precipitation (ERA5/MERRA2): n/a

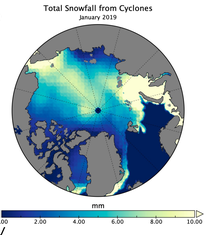
Surface Energy Budget:
Upwelling SW (CERES): 134 W m^{-2}
Downwelling SW (CERES): 267 W m^{-2}
Upwelling LW (CERES): 312 W m^{-2}
Downwelling LW (CERES): 284 W m^{-2}
Sensible Heat (AIRS): -30 W m^{-2}
Latent Heat (AIRS): -1 W m^{-2}

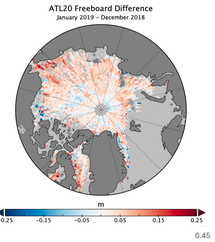
>1,000,000 Arctic sea ice parcel drift tracks with coincident ice & atm. conditions from 2002-2020 (*Horvath et al., 2022*)

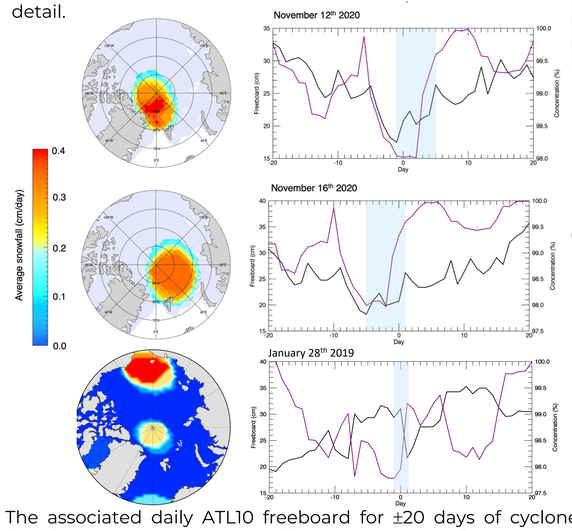
Results

Cumulative Effects: Eulerian Framework

Monthly cyclone snowfall (*Webster et al., 2019*) show reasonable agreement with monthly ATL20 freeboard changes, but many more processes at play which need to be studied in more detail.



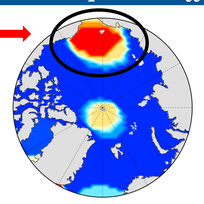




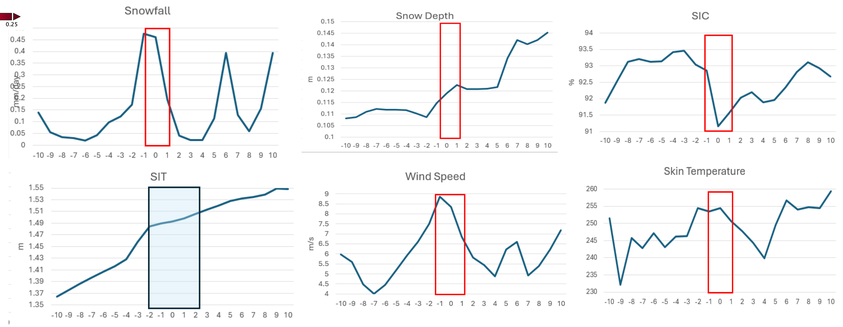
The associated daily ATL10 freeboard for ±20 days of cyclone Day 0 is calculated for each IS2 granule within ±5 days of the day of interest (black line). SIC NOAA/NSIDC CDR (purple line). **For all cyclones analysed, freeboard decreased significantly over the course of each event.**

Episodic Effects: Lagrangian Framework

All sea ice parcels affected by the cyclone on 01/28/2019

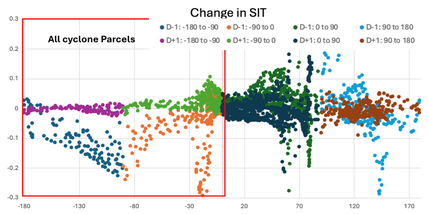


Using the Lagrangian parcel database we can look at how a single cyclone (on January 28, 2019) affects the sea ice +/- 10 days (x-axis, on plots below) surrounding the event (day 0).



Is what is happening to PIOMAS SIT during the cyclone happening in reality? Previous results from ATL10 freeboards (left) with other cyclones show differing results.

Future Work

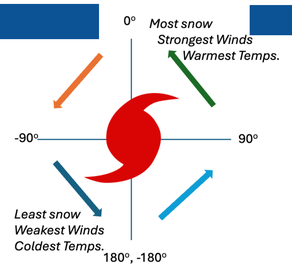


Orange & blue dots: SIT decreased from Day-1 to day
Purple & green dots: SIT increased/stayed the same

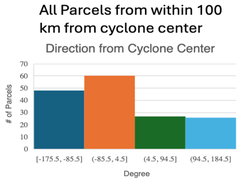
<u>Location and timing matter:</u>

Investigate freeboard changes in different cyclone sectors in all seasons.
Determine cumulative effects of these events on overall SIT seasonally.

Direction from Cyclone Center Matters

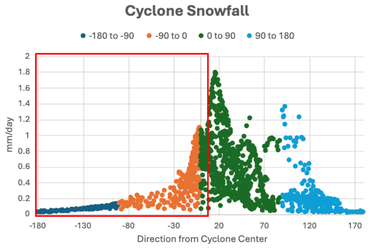


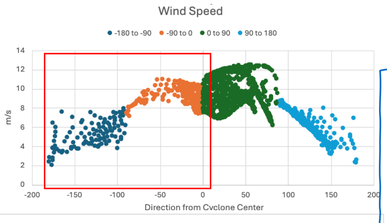
ATL10 freeboards calculated from all parcels within 100km from cyclone center where:
1. Data exists for +/-2 days for each parcel
2. Datapoints are within 50 km of each parcel

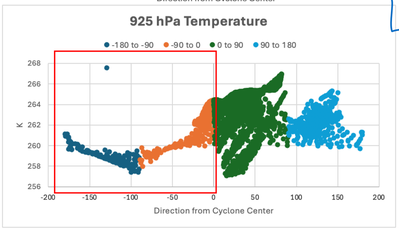


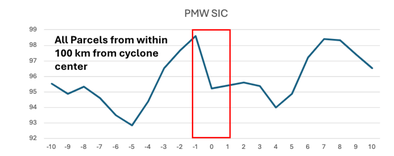
Majority of these parcels exist in areas of the cyclone (-180° to 0°) with weaker winds, less snowfall & cooler temps.

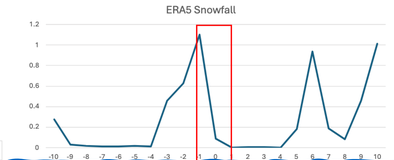
Parcels experience a decrease in all variables between Day -1 and Day 0 (below).

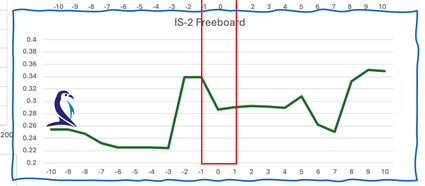


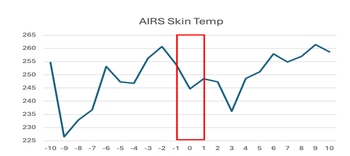


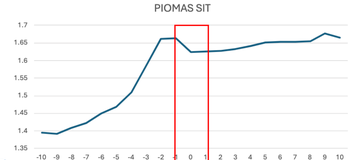


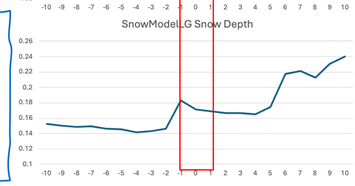












Promising Results: ATL10 freeboards show clear signal of an increase as cyclone approaches (Day-3) & decrease at Day 0 due to converge/divergence of ice floes & snowfall, although freeboards remain higher than prior to the cyclone (Day-10).

First time that we use IS-2 freeboards to look at the effects of an episodic weather event & see a clear signal!