Interactions between atmosphere and sea ice-ocean in the Arctic

D03

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1. Summary

Research questions

We evaluate the contribution of cyclones, sea-ice dynamics and thickness changes to Arctic amplification using models and satellite data.

Q1 How are sea-ice dynamics affected by changing lead fraction and thinner sea ice?

Q2 How do cyclones impact the sea ice in present and future climate?

Q3 Does a clustering of cyclones amplify these sea-ice impacts?

Contribution to CCA2 & SQs 1 and 3

Hypothesis

Intensified cyclone impacts, enhanced sea-ice dynamics, and thinner ice thickness contribute significantly to Arctic amplification.

2. Achievements phase II

ICESat-2 pan-Arctic monthly average drag coefficient estimates

- Spatial distribution of sea ice–atmosphere (and total) form drag from ridges
- Annual variation and temporal variability of total drag
- Ready to implement form drag from ridges into coupled model HIRHAM-NAOSIM

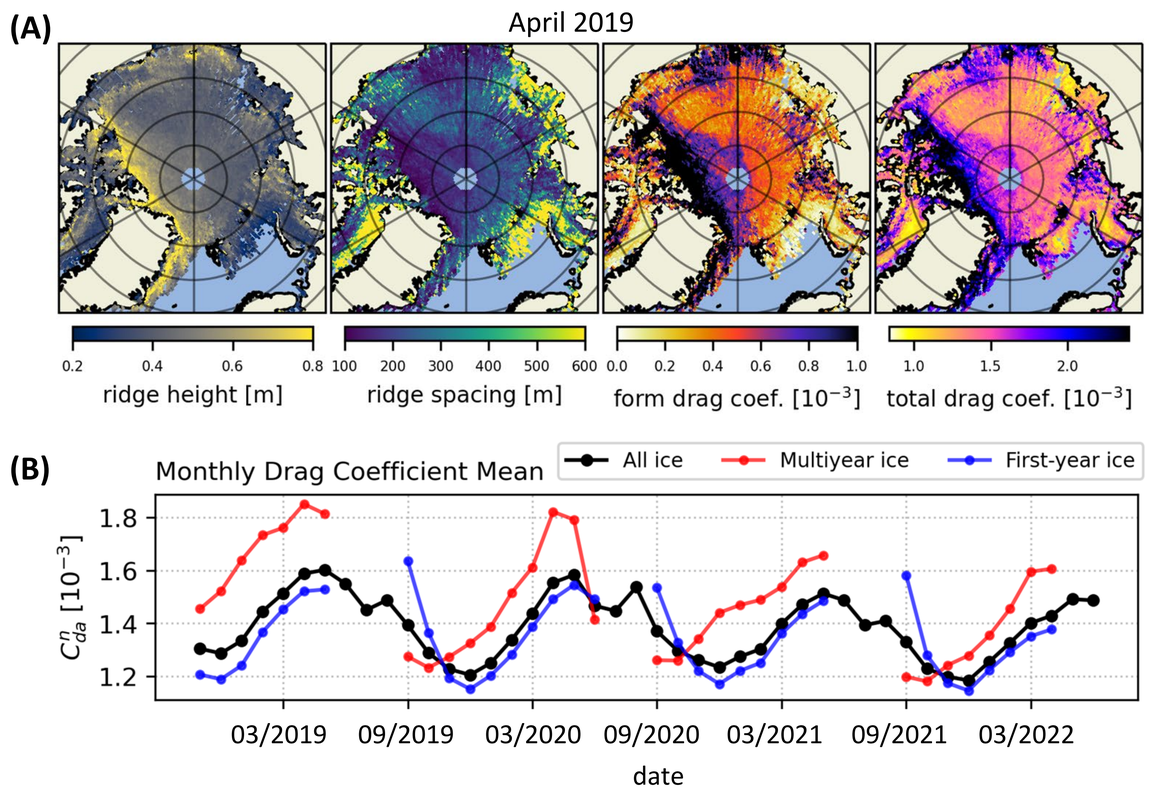


*Fig. 1: **(A)** ICESat-2 ridges and drag maps **(B)** Total drag time series Nov. 2018 to June 2022; pan-Arctic **in black**; multiyear ice **in red;** first-year ice **in blue** (no summer multiyear ice data).*

New insights into cyclones impact on sea-ice cover in Atlantic Arctic

- Dynamic and thermodynamic mechanisms, with overall dominance of the former
- Strong spatio-temporal variation ← cyclone intensity & traversed ice conditions
- Recent intensification: Strongest in Barents & Kara seas in fall → reduced sea ice

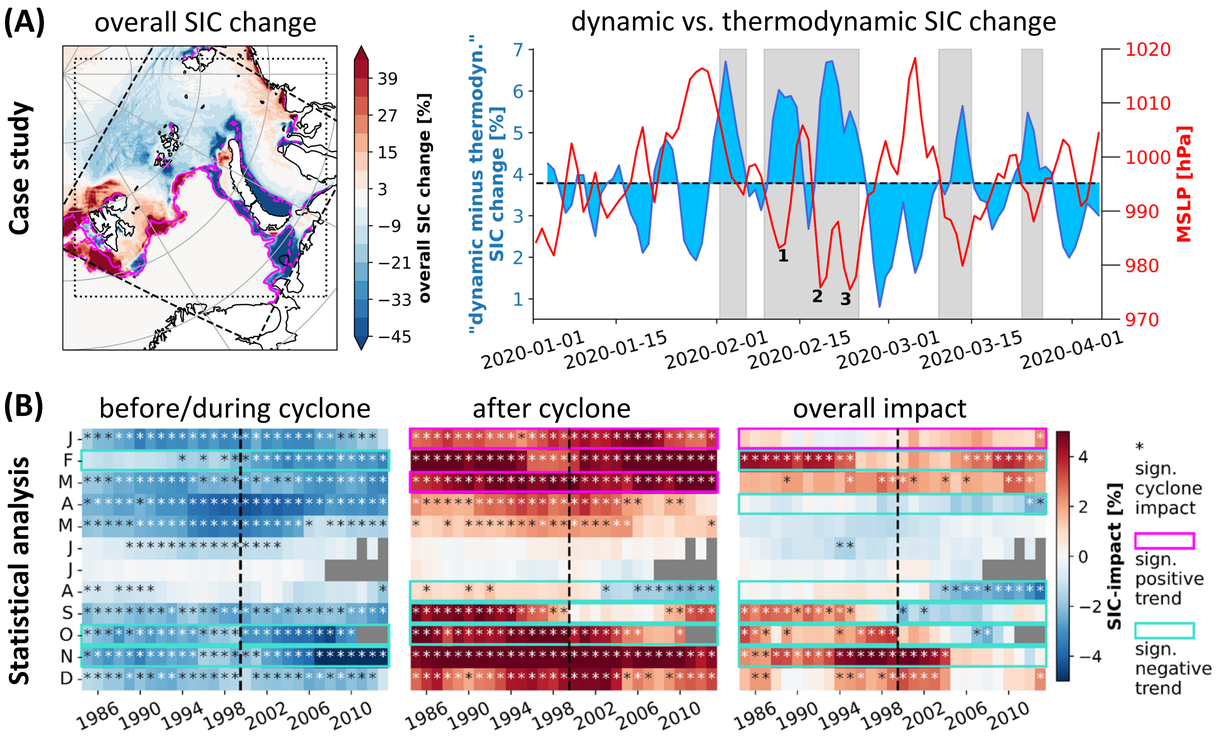


*Fig. 2: **(A)** Case study of sea-ice changes during 3 cyclones (9–25 Feb., 2020) based on HIRHAM-NAOSIM and **(B)** statistical analysis of cyclone-related sea-ice changes (11-year running means for each month) in the Barents Sea based on ERA5.*

3. Research plan phase III

WP1 Leads and ice dynamics

Impact of changing sea-ice characteristics, namely thinner sea ice, roughness, and more leads / open water on ice dynamics (faster drift, increased deformation):

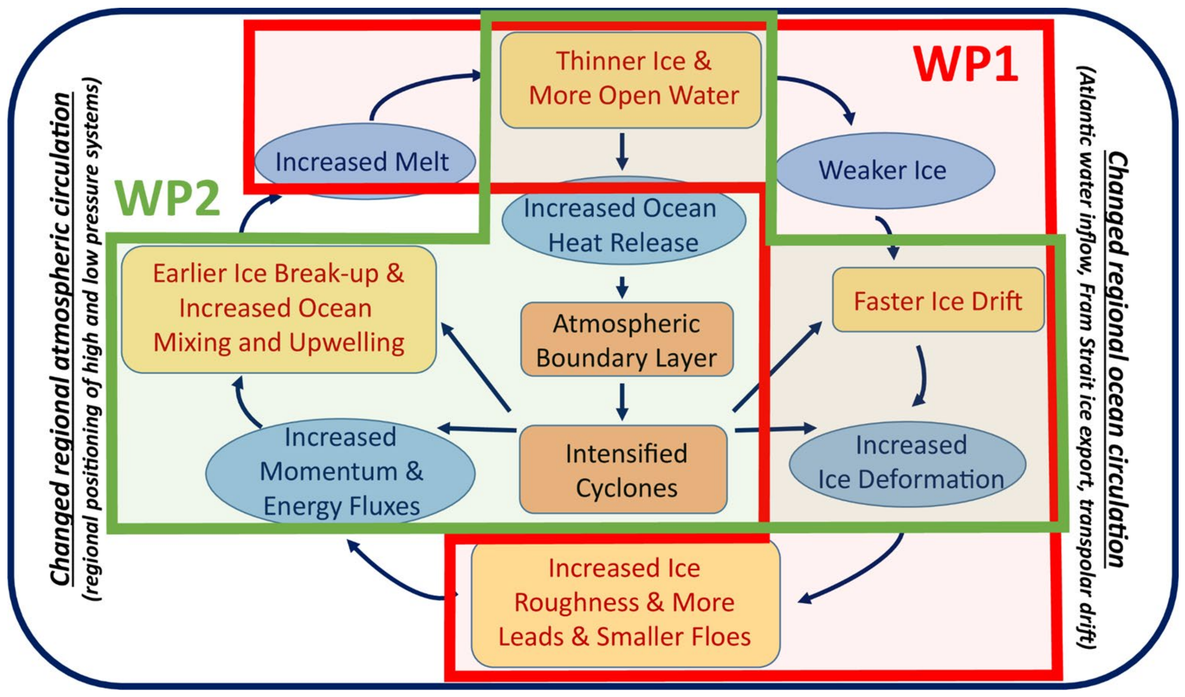
- Spatio-temporal Arctic-wide lead distribution changes from radar (since 2015) and optical (since 2003) satellite data
- Connection between enhanced sea-ice dynamics and sea-ice thinning → positive feedback; analysis using both satellite observations and HIRHAM-NAOSIM model
- Causes for enhanced ice dynamics and ice thinning and connection to Arctic amplification (satellite observations, ERA5, and HIRHAM-NAOSIM 1990–2022)

WP2 Cyclones and sea ice

Impacts of cyclones on sea ice and related dynamic and thermodynamic mechanisms:

- Effect of changing cyclone occurrence and intensity on the sea ice and its drift
- Preconditioning of this effect by the actual ice conditions (thinner vs. thicker ice, lower vs. higher ice concentration)
- Extreme cyclone events (cyclone clusters): cluster-sensitive regions → circulation patterns, cumulative vs. individual cyclones impact on sea ice
- Recent changes (ERA5) and projections of future changes (CMIP6, AWI-CM: Role of upper-ocean mesoscale processes)

Positive feedback loops considered, involving sea ice and atmosphere



4. Legacy & major expected results

Project Legacy

- Satellite remote sensing methods for next-generation satellite missions
- New and advanced sea-ice climate data observations
- Improved representation of cyclone - sea-ice interactions in models

Major expected results within phase III

- Process understanding of the ice thickness & leads to sea-ice dynamic feedback loop, associated with Arctic amplification
- Projections of future cyclone impacts on sea ice and related mechanisms

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