Session 6. Sea Ice - Thickness & Dynamics

The Shift of Sea Ice Dynamics in the Ross Sea Caused by Atmospheric Forcings

Presenter: **Hongjie Xie[1)]**, co-authors: **Younghyun Koo[2)]**, **Stephen F. Ackley[1)]**

hongjie.xie@utsa.edu

1) University of Texas at San Antonio 2) University of Colorado Boulder

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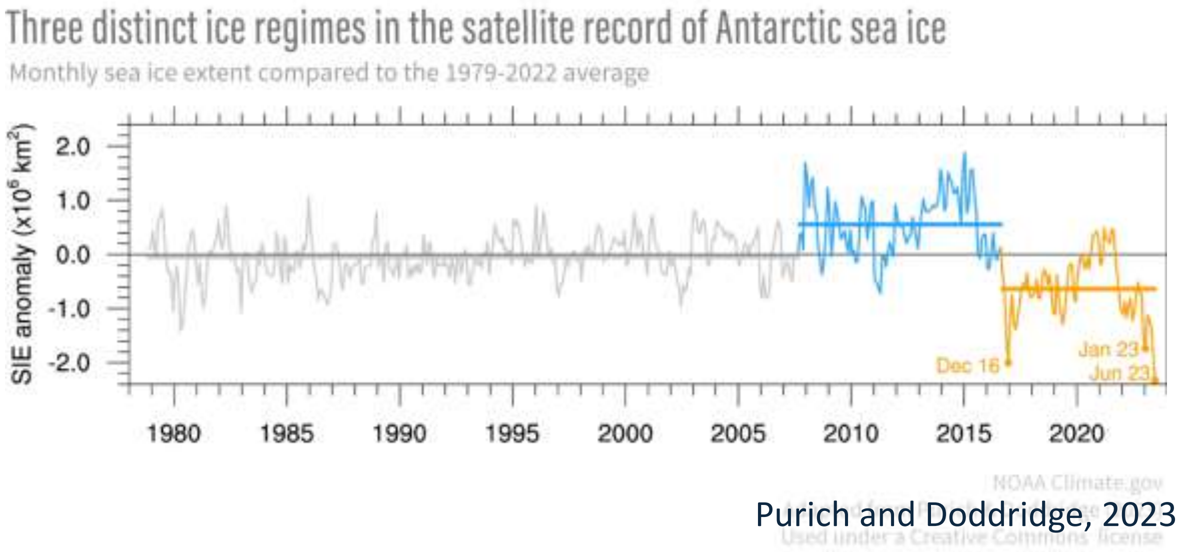
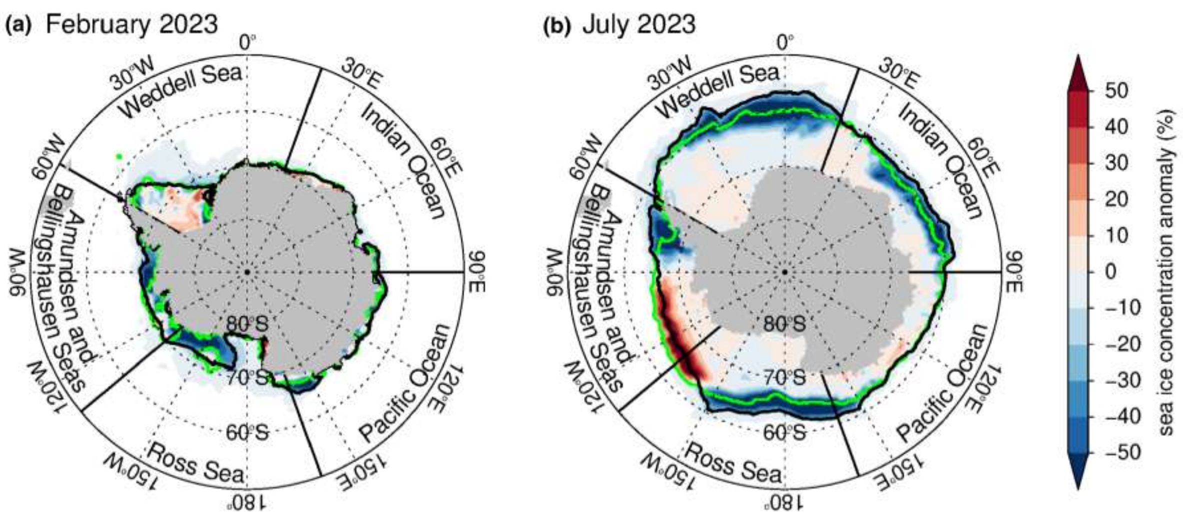
Koo et al., JGR Oceans, Accepted

Introduction

- **Record minimum of Antarctic sea ice extent (SIE) in 2023**
  - Significant ice loss in the Ross Sea
  - Driven by (i) atmospheric circulation and (ii) warming ocean temperature
- **Importance of understanding the interaction between sea ice, atmosphere, and ocean**



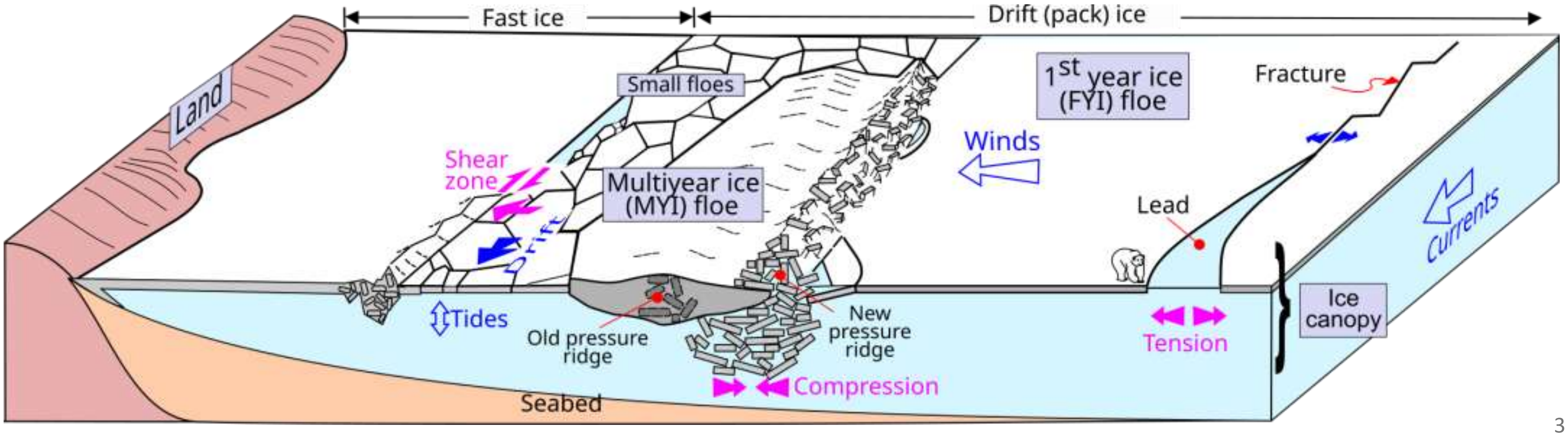
Purich and Doddridge, 2023



Gilbert and Holmes, 2024

Introduction

- **Sea ice processes** (formation, growth, deformation, and melt)
  - Thermodynamic contributions: freezing / melting
  - Dynamic contributions: sea ice deformation (e.g., formation of pressure ridges, leads)

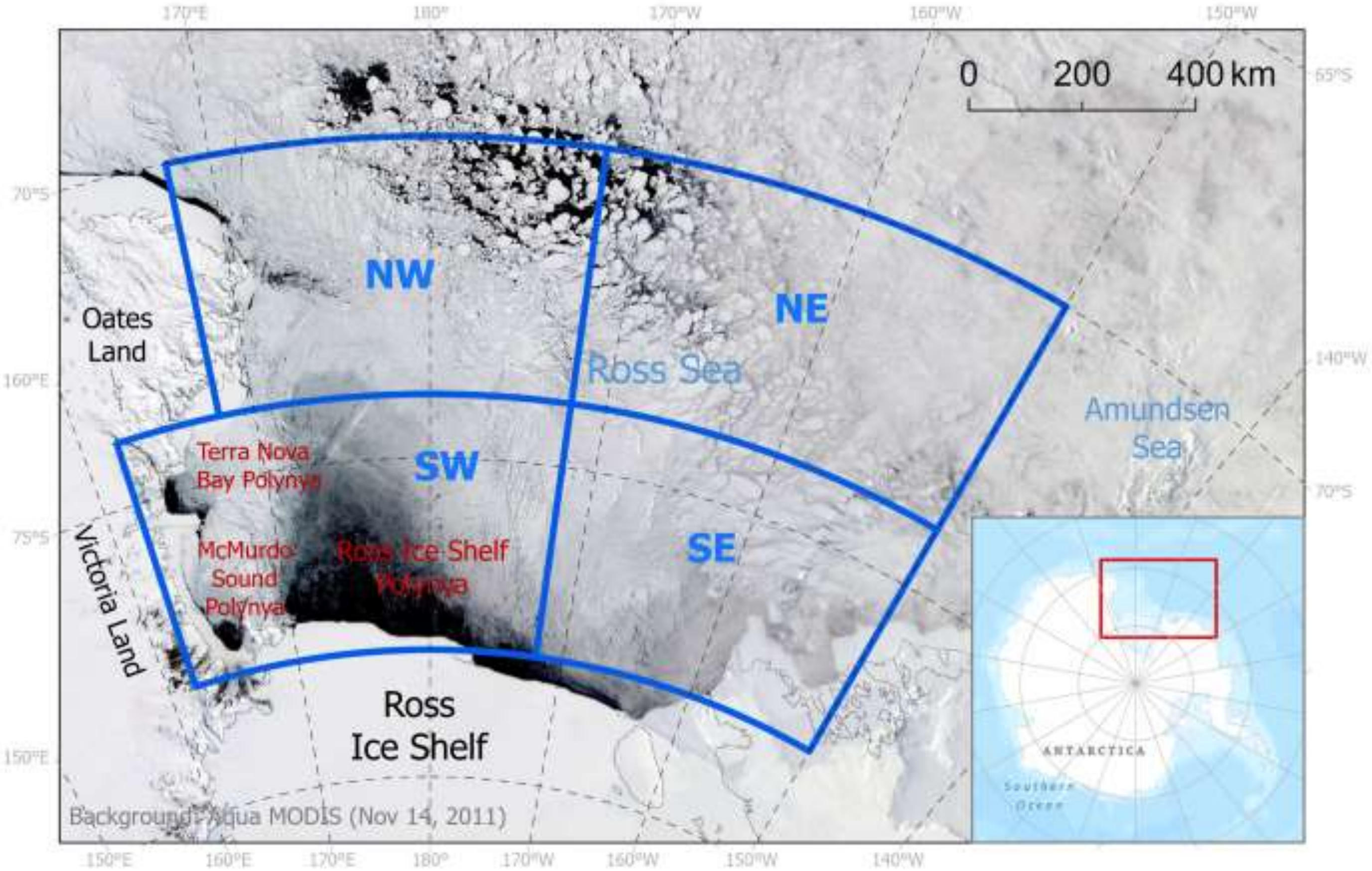


Objectives

- **Detect sea ice topographical features in the Ross Sea from 2019 to 2023 using ICESat-2 data**
- **Connect thermodynamic and dynamic characteristics of sea ice changes with the atmospheric conditions**

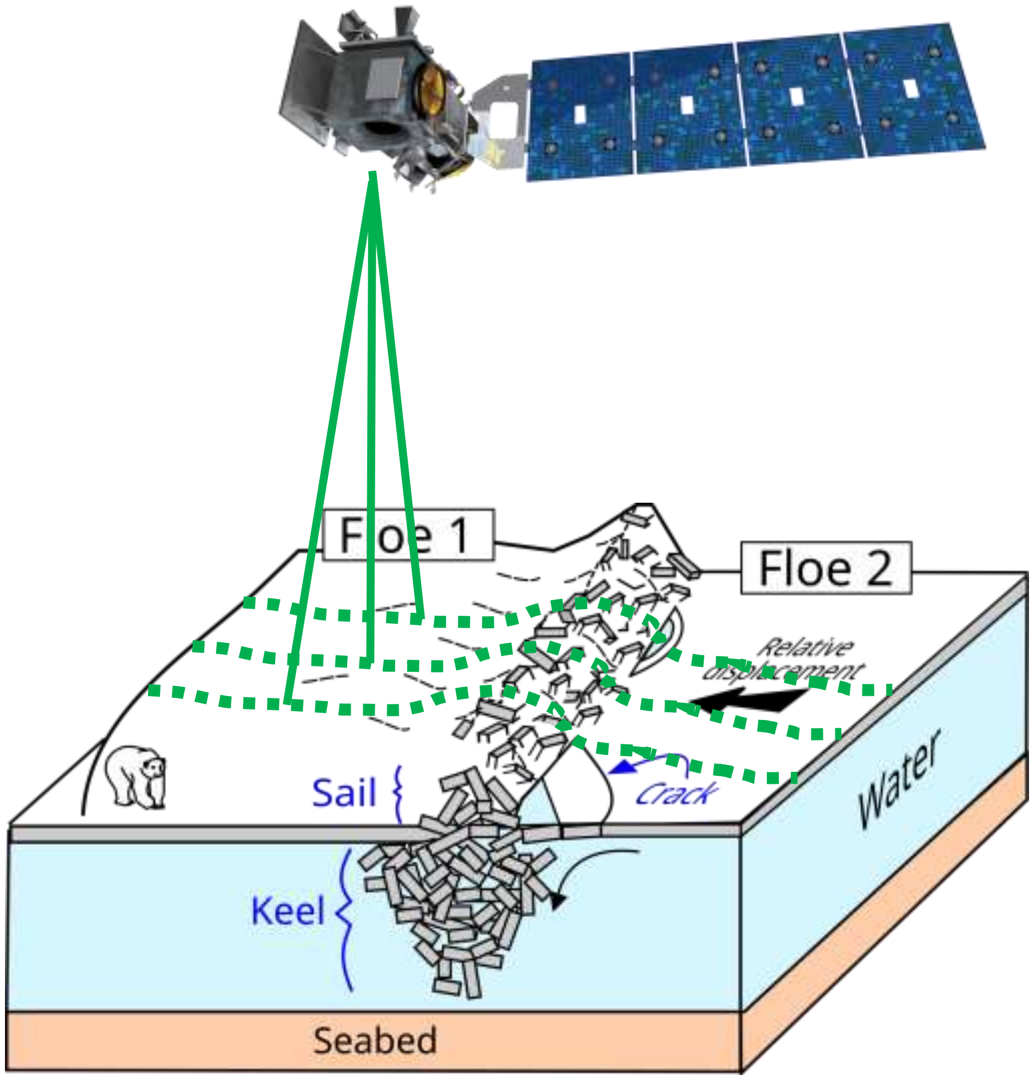
Study area

- **Ross Sea**
  - Strong katabatic wind → formation of large polynyas in the SW sector
  - Advection of thick sea ice from the Amundsen Sea
  - Sea ice drift and deformation have significant impacts on sea ice mass balance in the Ross Sea



Data

- **ICESat-2: laser altimeter**
  - Fine spatial resolution: 11 m footprint, 0.7 m spacing
  - Precision of vertical height measurement: ~2 cm
  - Good for detection of detailed **sea ice topography (pressure ridges, leads)** with tens of meters scale
- **ERA-5 reanalysis data**
  - Air temperature, wind velocity, surface pressure

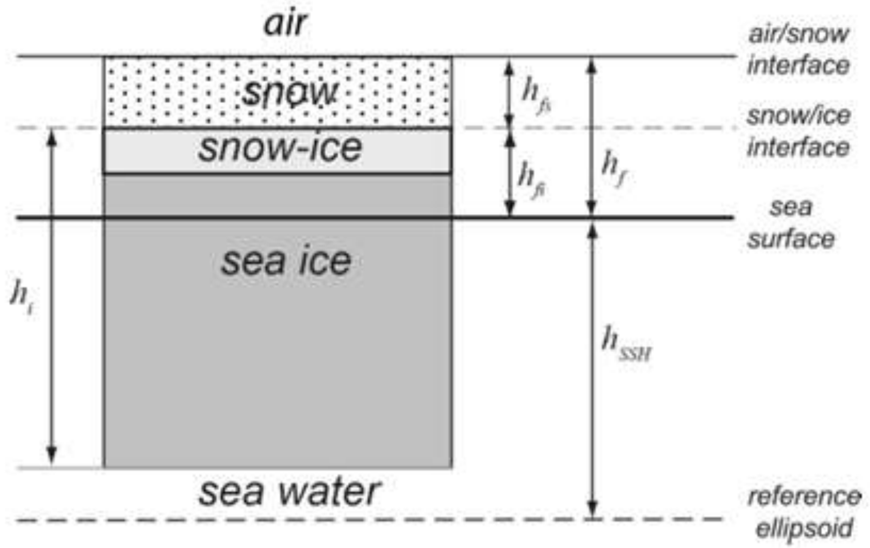


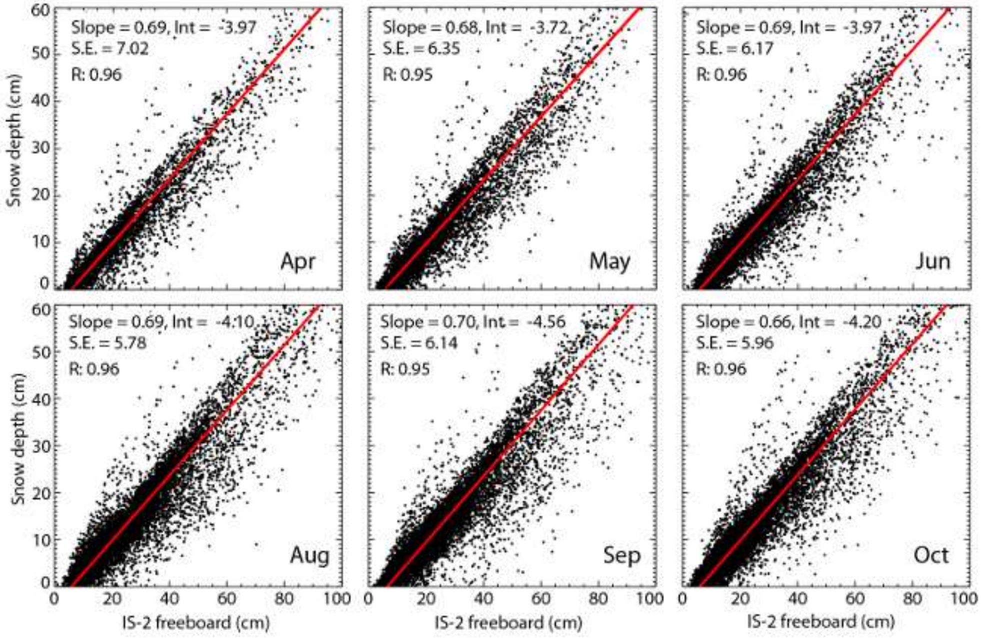
Data

- **ICESat-2 ATL10 sea ice freeboard product**
  - Freeboard: height of air/snow interface above sea level (total freeboard)
- **Convert freeboard to ice thickness**
  - Hydrostatic equilibrium between snow, sea ice, and sea water

$$h_i = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) h_f + \left(\frac{\rho_s - \rho_w}{\rho_w - \rho_i}\right) h_{fs}$$

  - Snow depth: linear relationship with total freeboard



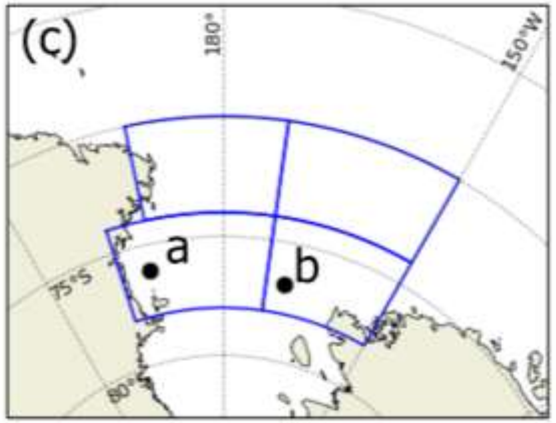


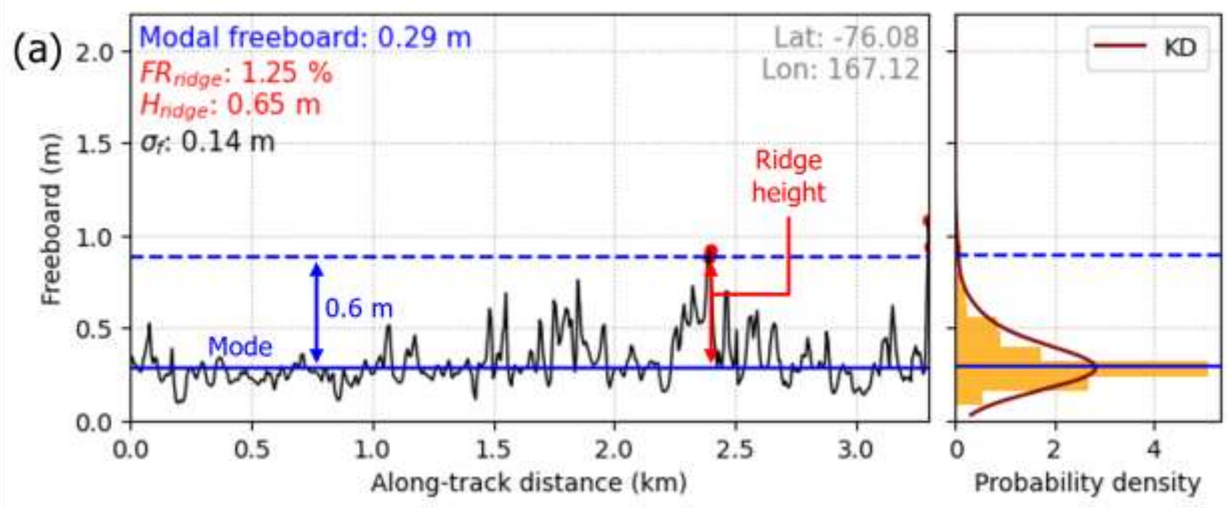
Kacimi and Kwok, TC, 2020

Methods

- **Quantification of sea ice topographical features**

Modal sea ice thickness (SIT)	Thermodynamic
Areal fraction of pressure ridges (FR_{ridge})	Dynamic (deformation)
Ridge height (H_{ridge})	
Surface roughness (σ_f)	



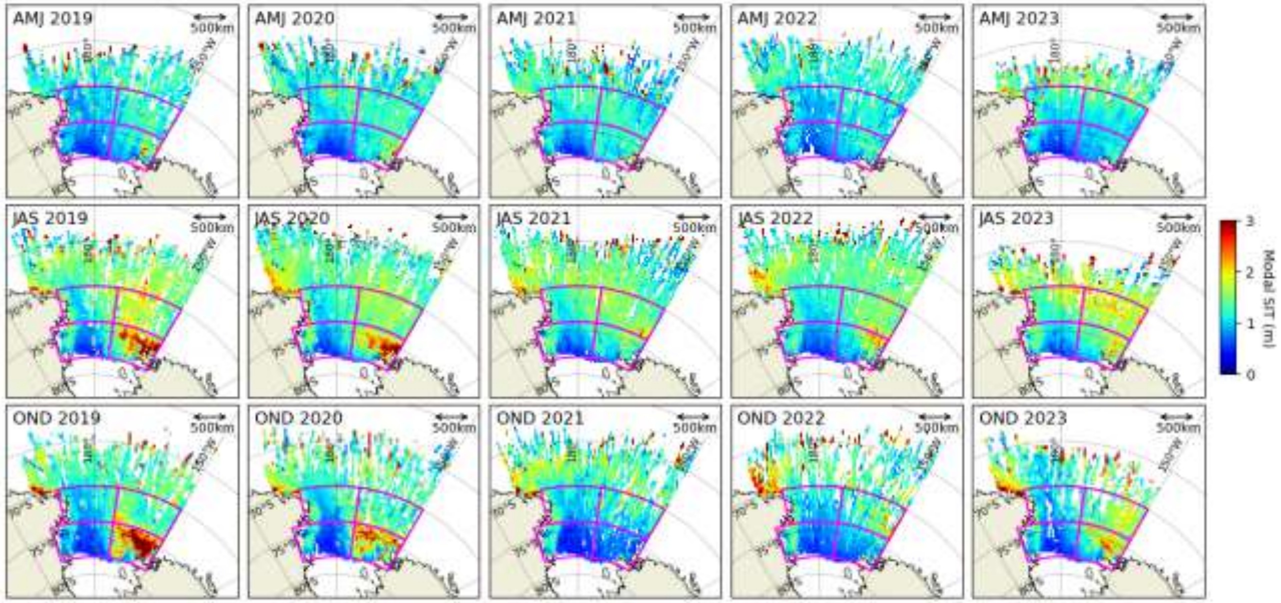


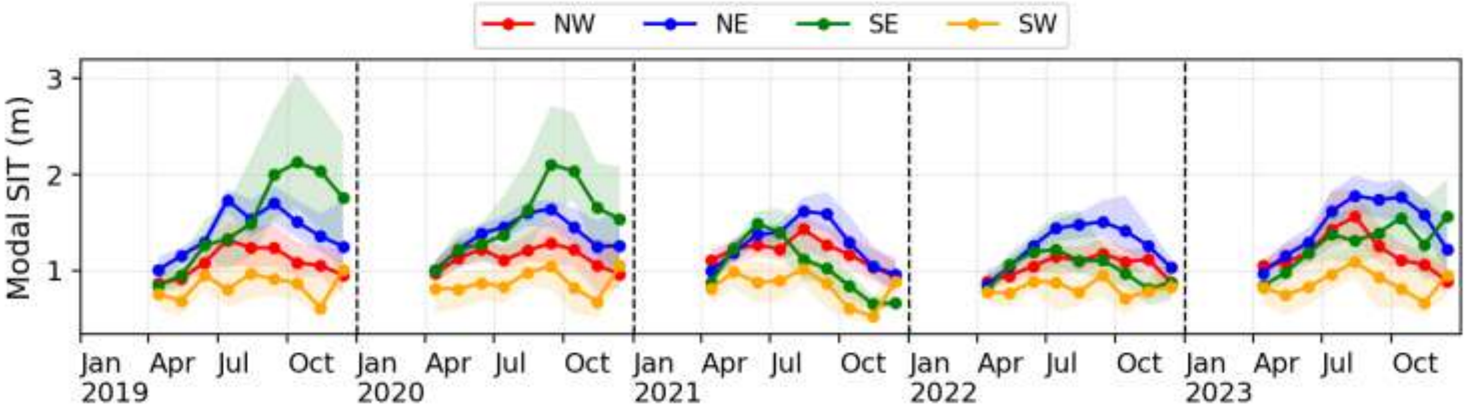
Duncan and Farrell, 2022, Koo et al., 2023

Results

Modal SIT

- **SW sector**
  - Continuously thin ice because of large polynyas
- **SE sector**
  - Advection of thick ice from the Amundsen Sea → thickest ice
  - Decrease in modal SIT of the SE sector in **2021-2022**

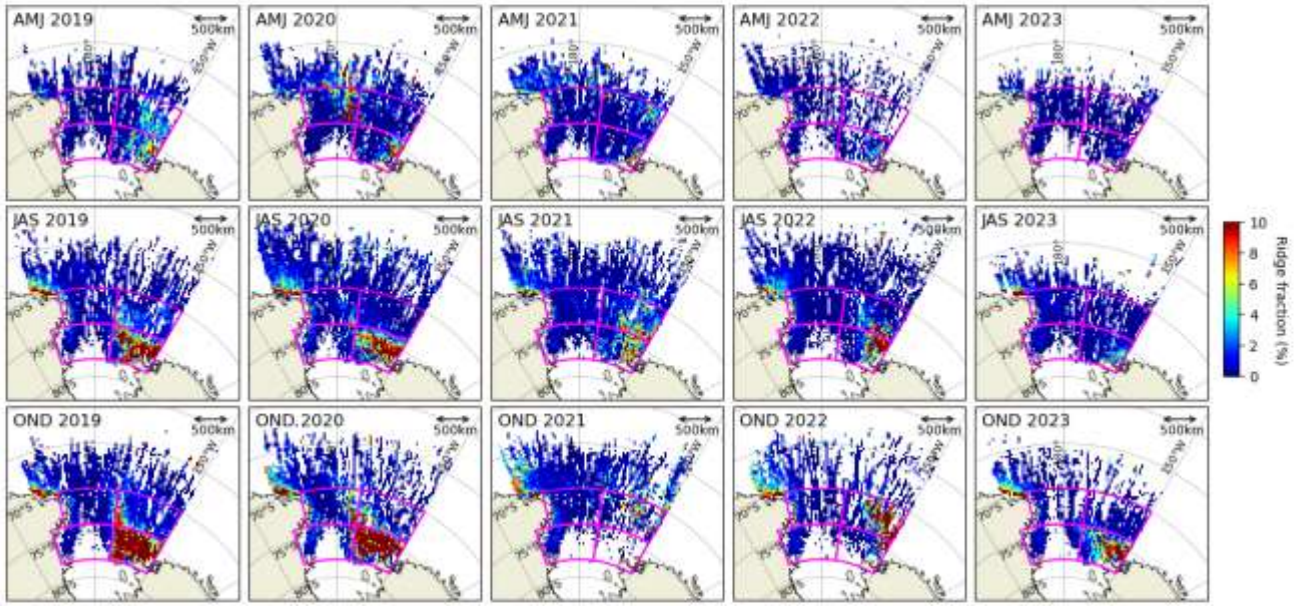


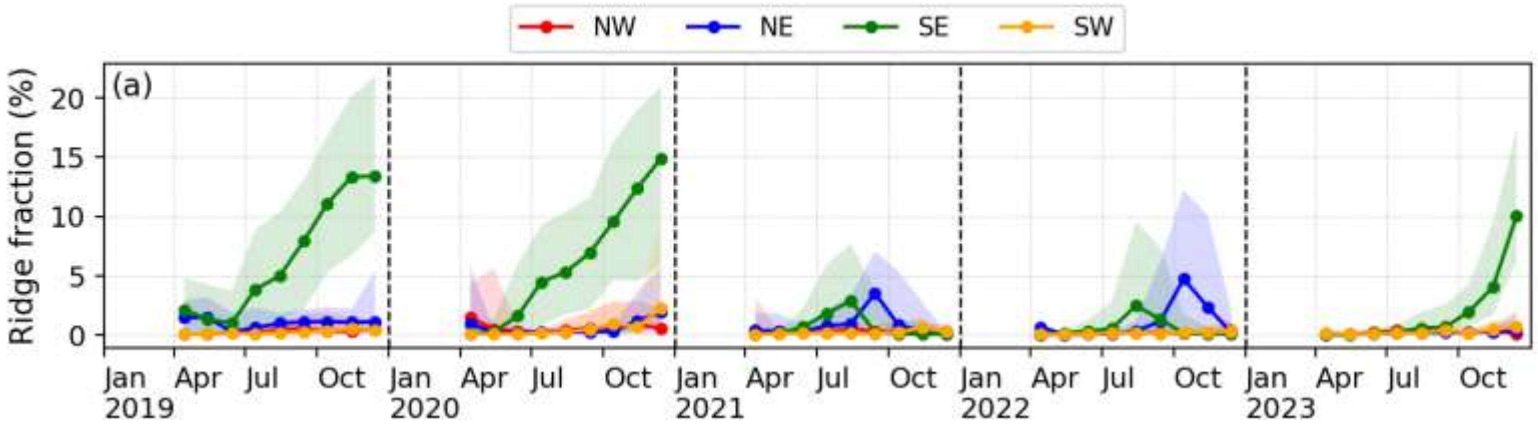


Results

Ridge fraction

- **SE sector**
  - Much decreased in FR_{ridge} in 2021-2022
  - Increased a little in 2023

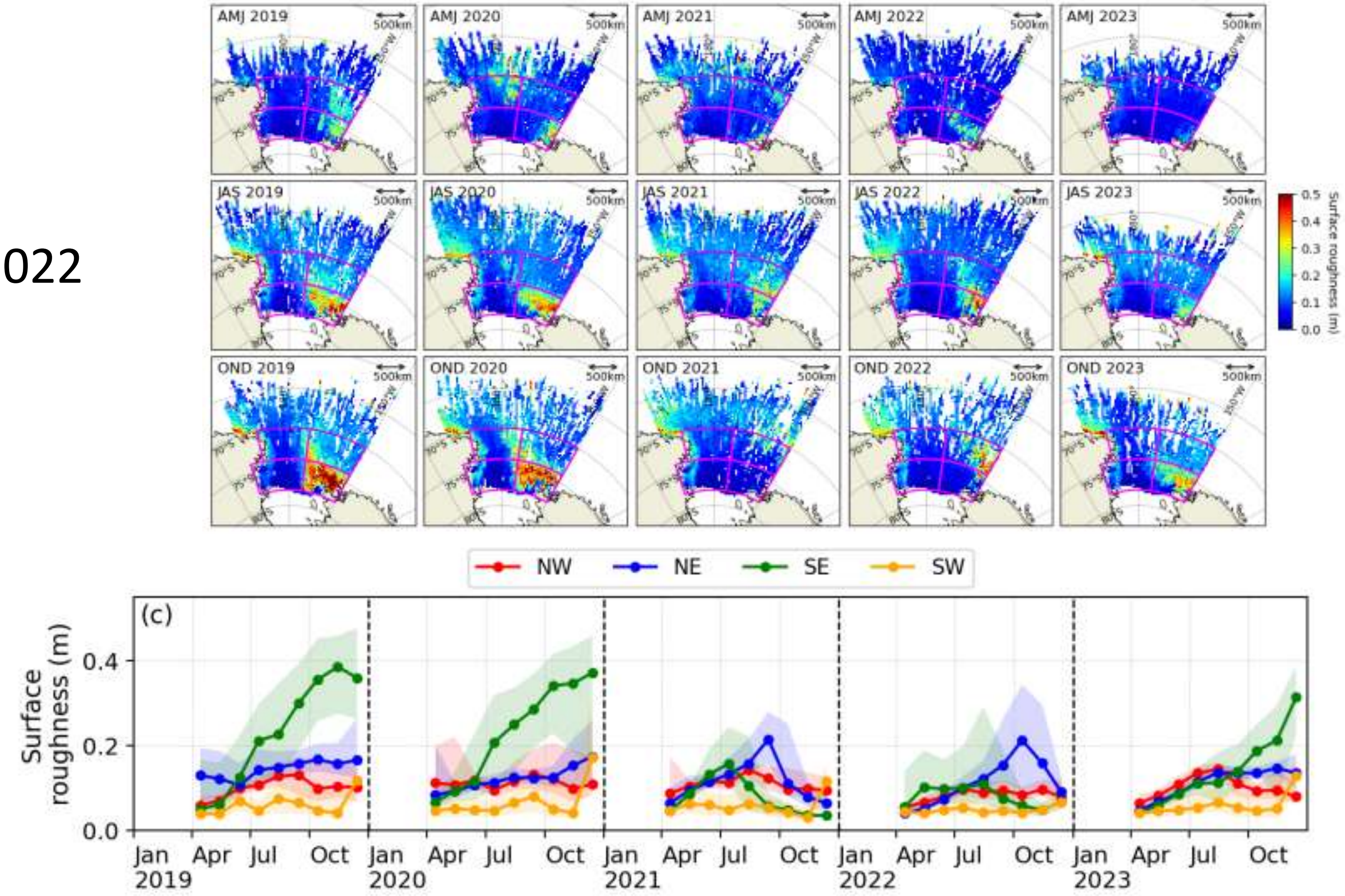




Results

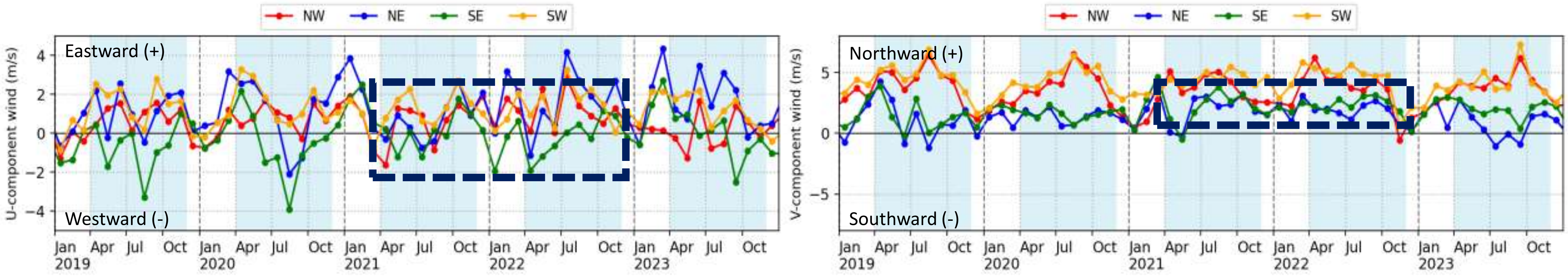
Surface Roughness

- **SE sector**
  - Decreased in σ_f in 2021-2022
  - Increased a little in 2023



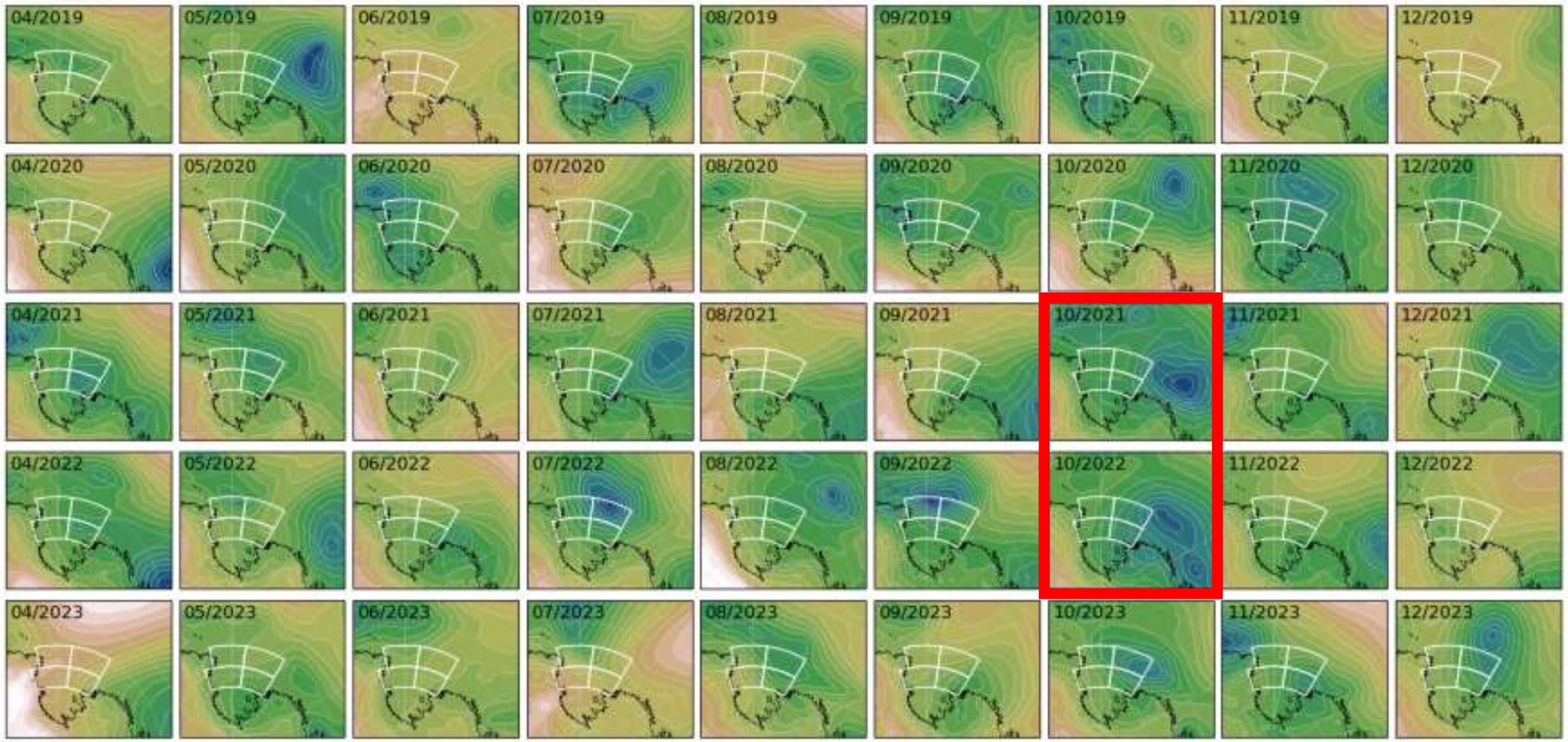
Discussion

- **The reason for the dramatic transition in 2021-2022**
  - Changes in atmospheric circulation in the Ross Sea in 2021-2022
  - Weak westward wind & strong northward wind in the east sectors (SE & NE) in 2021-2022
  - Reduction of thick ice inflow from the Amundsen Sea due to the Amundsen Sea Low (ASL)



Discussion

- **Amundsen Sea Low (ASL) in 2021-2022**
  - ASL in winter-spring changes the atmospheric circulation and sea ice drift



Summary & Conclusion

- **ICESat-2 for monitoring of sea ice topography**
  - Fine resolution & high precision
  - Detect sea ice topographical features: modal SIT, areal fraction of pressure ridges, ridgh height, surface roughness
- **Sea ice dynamics in the Ross Sea from 2019 to 2023**
  - SW sector was generally thin ice
  - SE sector was generally the thickest & most deformed ice
  - In 2021-2022, SIT and ridge fraction decreased dramatically in SE sector
  - The sea ice changes in SE sector are mainly caused by changes in the atmospheric circulation (i.e., Weak westward wind & strong northward wind and **Amundsen Sea Low**)

Thank you!

Hongjie Xie, hongjie.xie@utsa.edu

Younghyun Koo, younghyun.koo@colorado.edu

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Koo et al., JGR Oceans, to appear soon