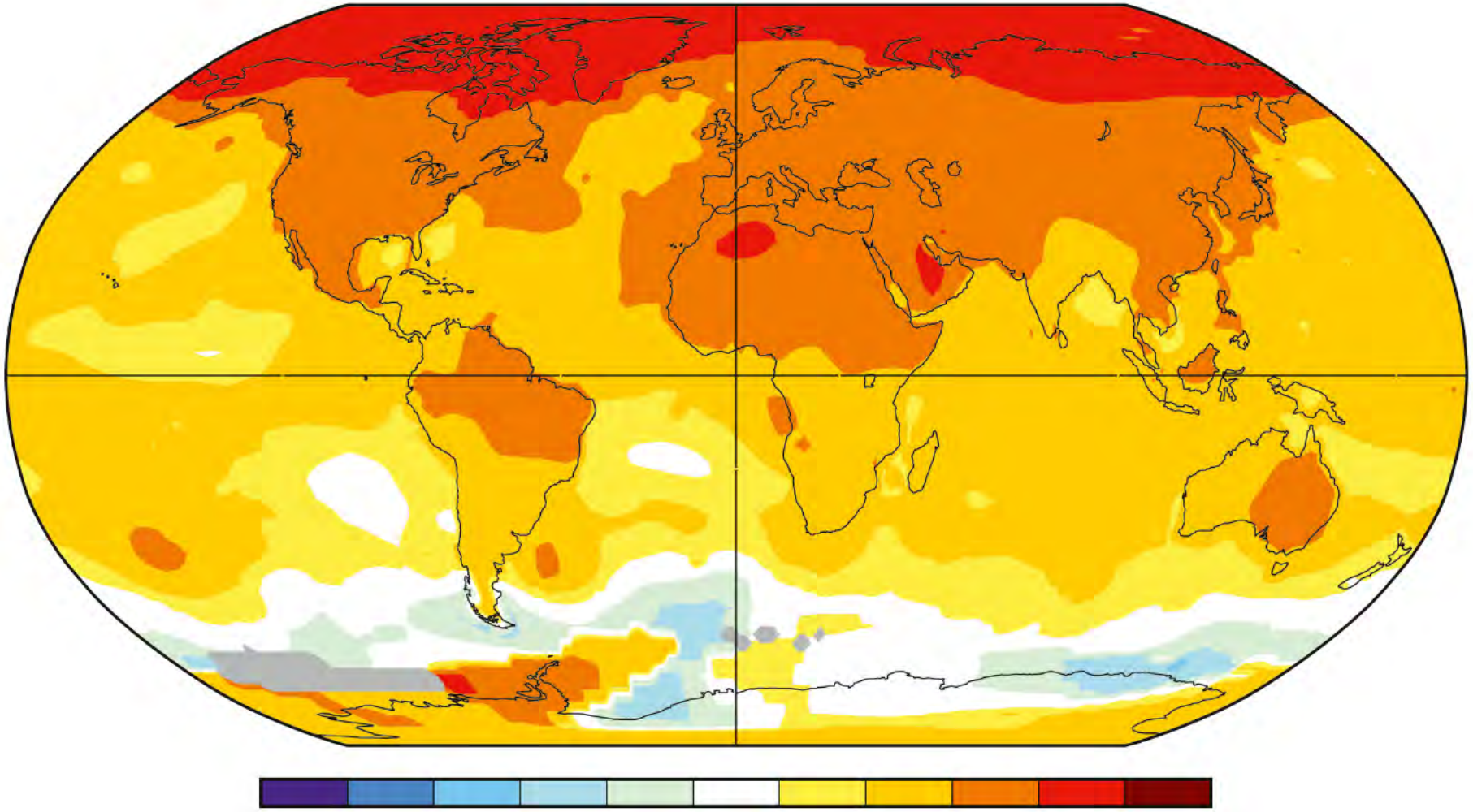
The MOSAiC Expedition for Understanding the Processes of Arctic Change

MOSAiC
Multidisciplinary drifting **O**bservatory
for the **S**tudy of **A**rcti**i**c **C**limate

Matthew Shupe
University of Colorado / NOAA-PSL
ARM-ASR, 25 October 2022

Photo: Markus Rex

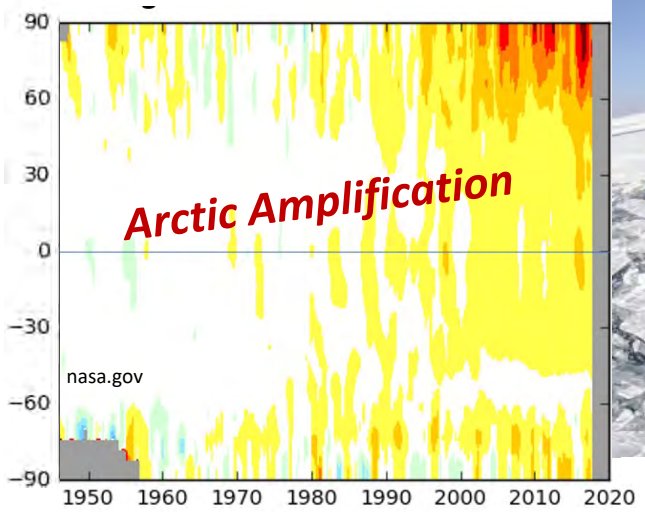
Arctic Leading Global Change

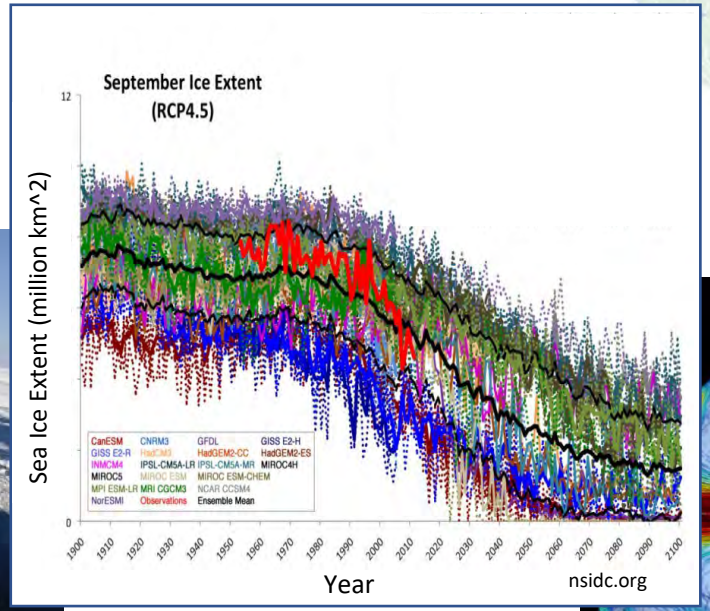


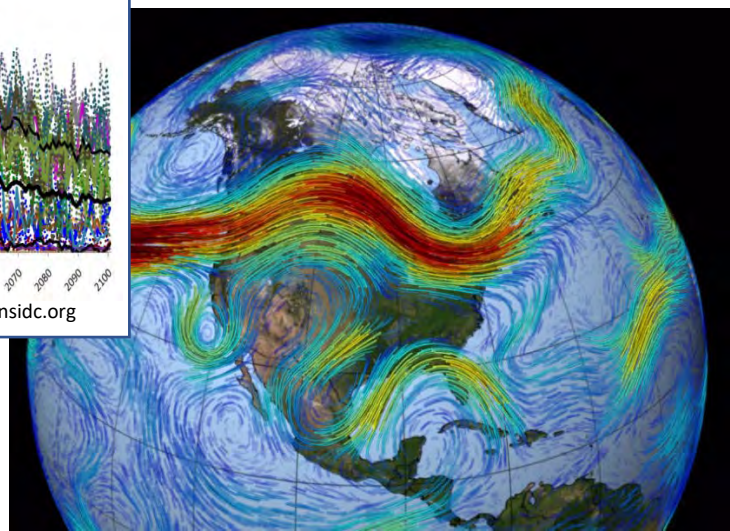
Temperature Change, 1970 to 2017, ˚C

Motivations

- Rapid change: sea-ice decline, amplification, ecosys.
- Poor model predictive capabilities
- Emerging operational/management needs
- Questions about global linkages
- Dearth of observations

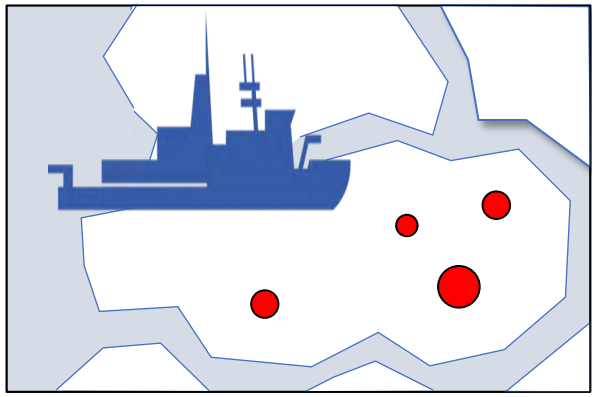


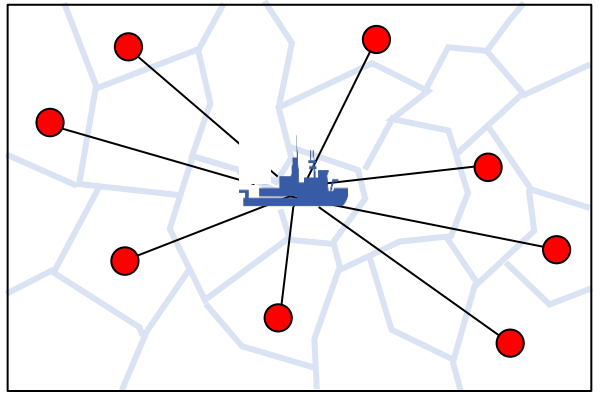


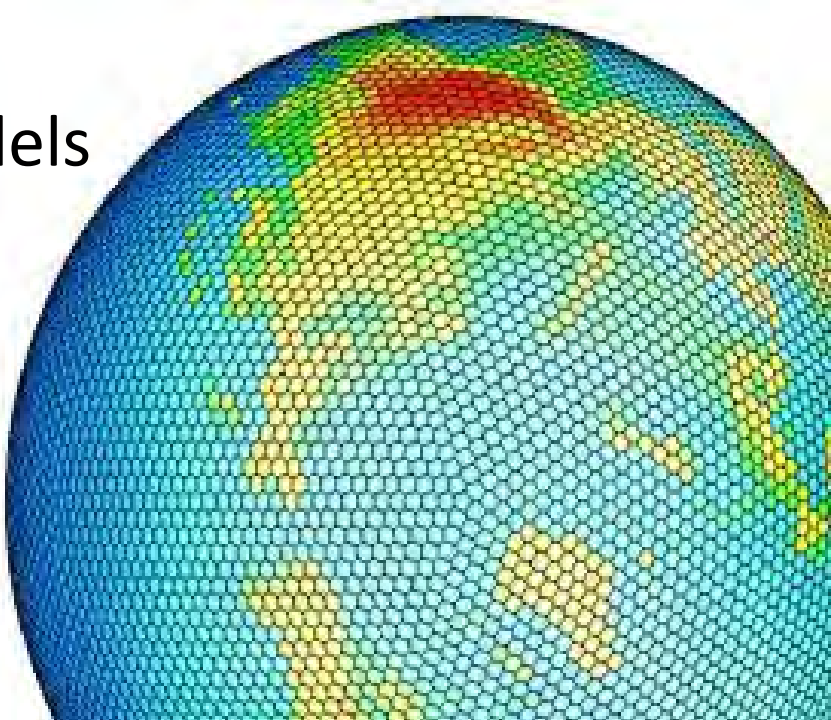


Plans for an Expedition

- International: 12 years of planning!
- Interdisciplinary: ATMOS-ICE-OCEAN, physical-chemical-biological
- Multiscale: Point, grid-cell, pan-Arctic
- Integration: Observations and Models
- Annual Cycle: Contiguous seasons in the ice
- Goal: Improve climate, weather, and process models







MOSAiC

Sept 2019 – Oct 2020

4 Oct 2019

21 Aug –
20 Sept 2020

15 Sept 2020
Ice edge

5 Mar 2020
Ice edge

31 July 2020

120°

90°

80°

-30°

30°

70°

What are the causes & consequences of an evolving & diminished Arctic sea ice cover?

20 Nations (funding)
37 Nations (participants)
7 Icebreakers/ships
>80 Institutions
>400 field participants
>$170M overall

Polarstern packed to capacity

Matthew Shupe

Scanning radar
Precipitation
Radiation
Aerosols
& Gases
Radar wind
profiler
Cloud
Radars
Doppler
lidar
Backscatter
lidars
ARM
Michael Gutsche

Entering the sea ice

Dave Stenssen

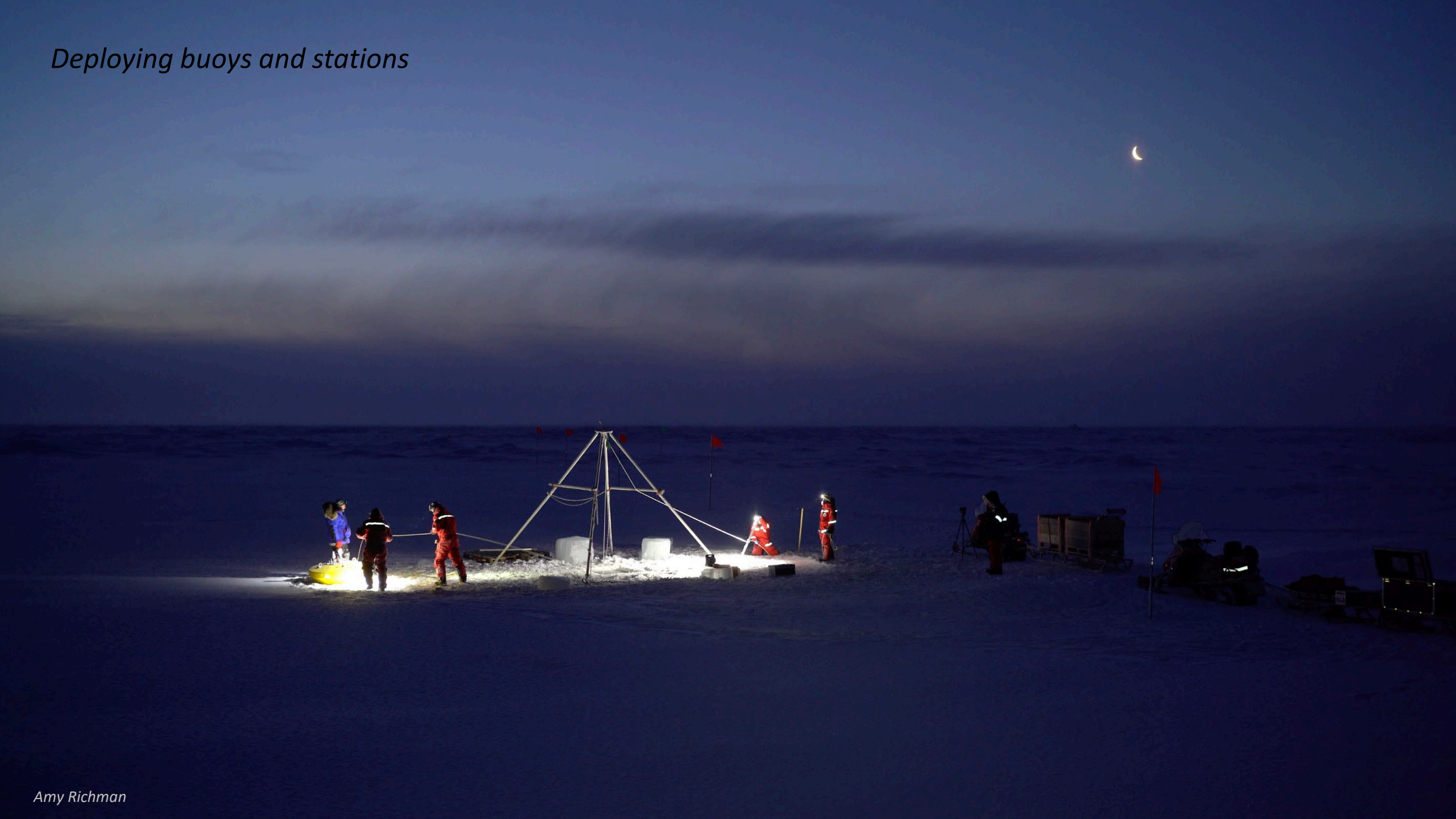
First exploration of MOSAiC floe

Sebastian Grote

Esther Horvath

Esther Horvath

Deploying buoys and stations



Amy Richman

“Cities” on the ice (picture taken mid-day!)

Matthew Shupe

ARM Team

Comprehensive physical measurement and sample programs

Marcel Nicolaus

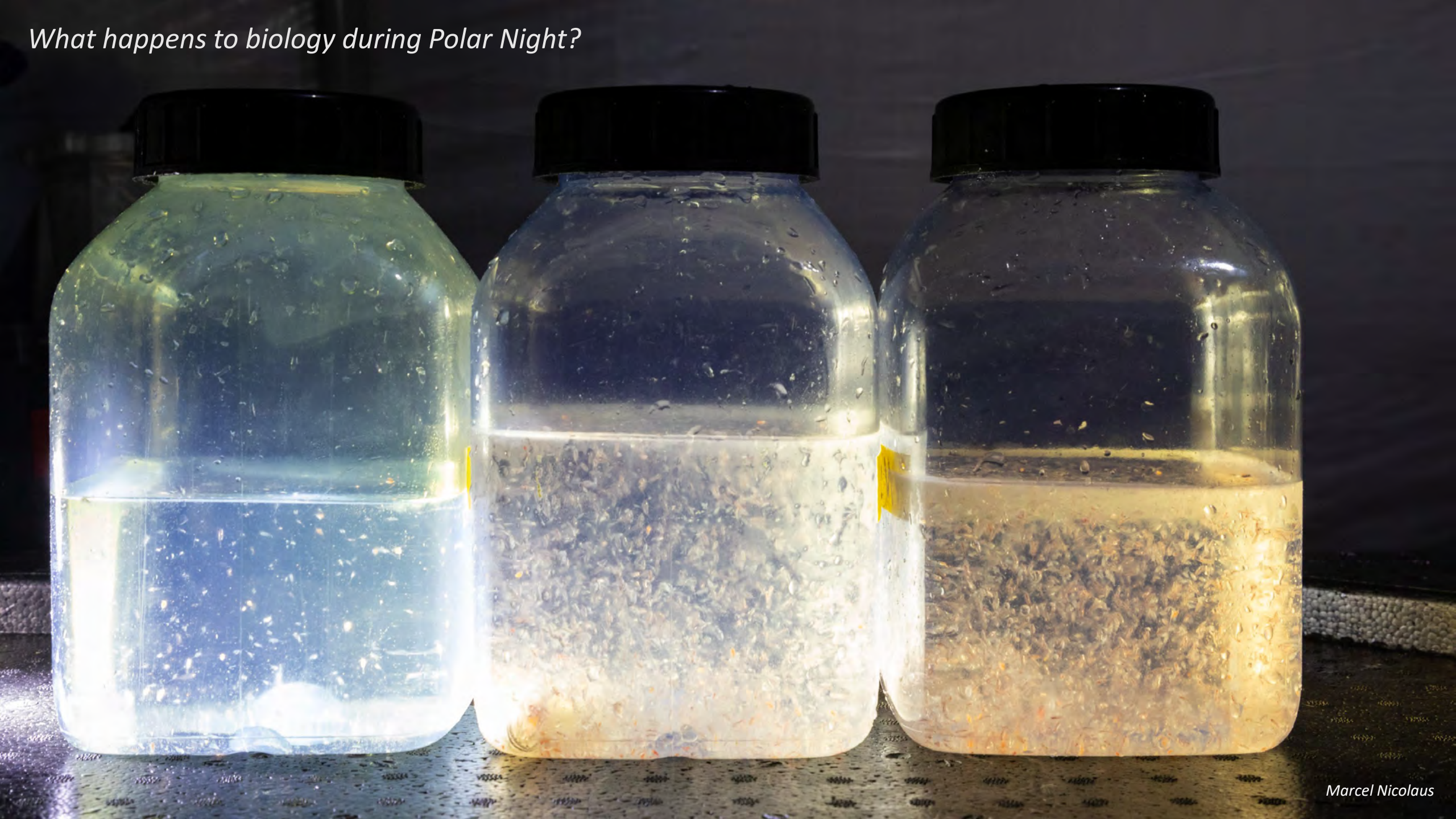
Ice dynamics…. early and often

Stephan Hendricks

Descent into in to Night

Michael Gallagher

What happens to biology during Polar Night?



Marcel Nicolaus

MOSAiC Floe 2.0

Markus Rex

Adventures in field operations

Lianna Nixon

TROPOS
POLARSTERN
Scintec
Scintec
Scintec

Lianna Nixon

Lianna Nixon

Lianna Nixon

Matthew Shupe

Lianna Nixon

Getting ready to freeze in….

Michael Gallagher

Information to improve satellite techniques

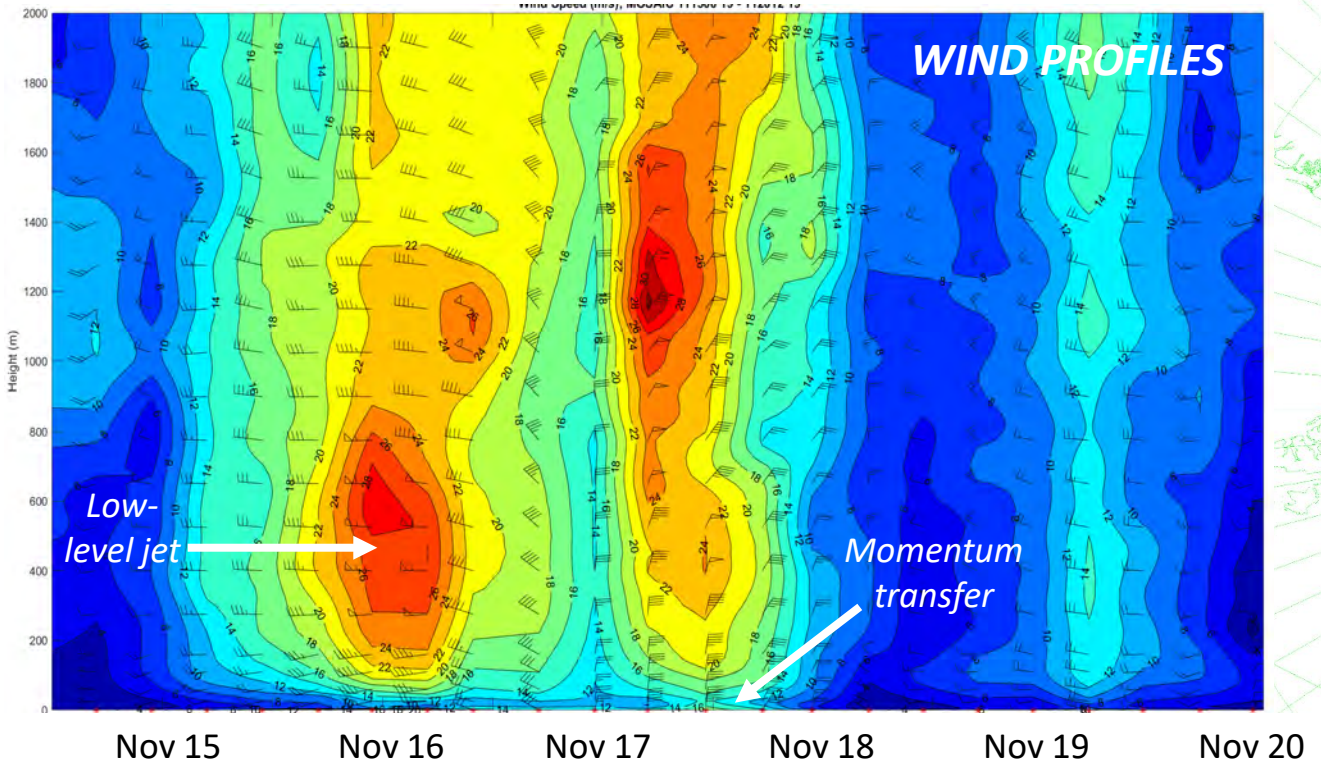
Lianna Nixon

AMF in action!

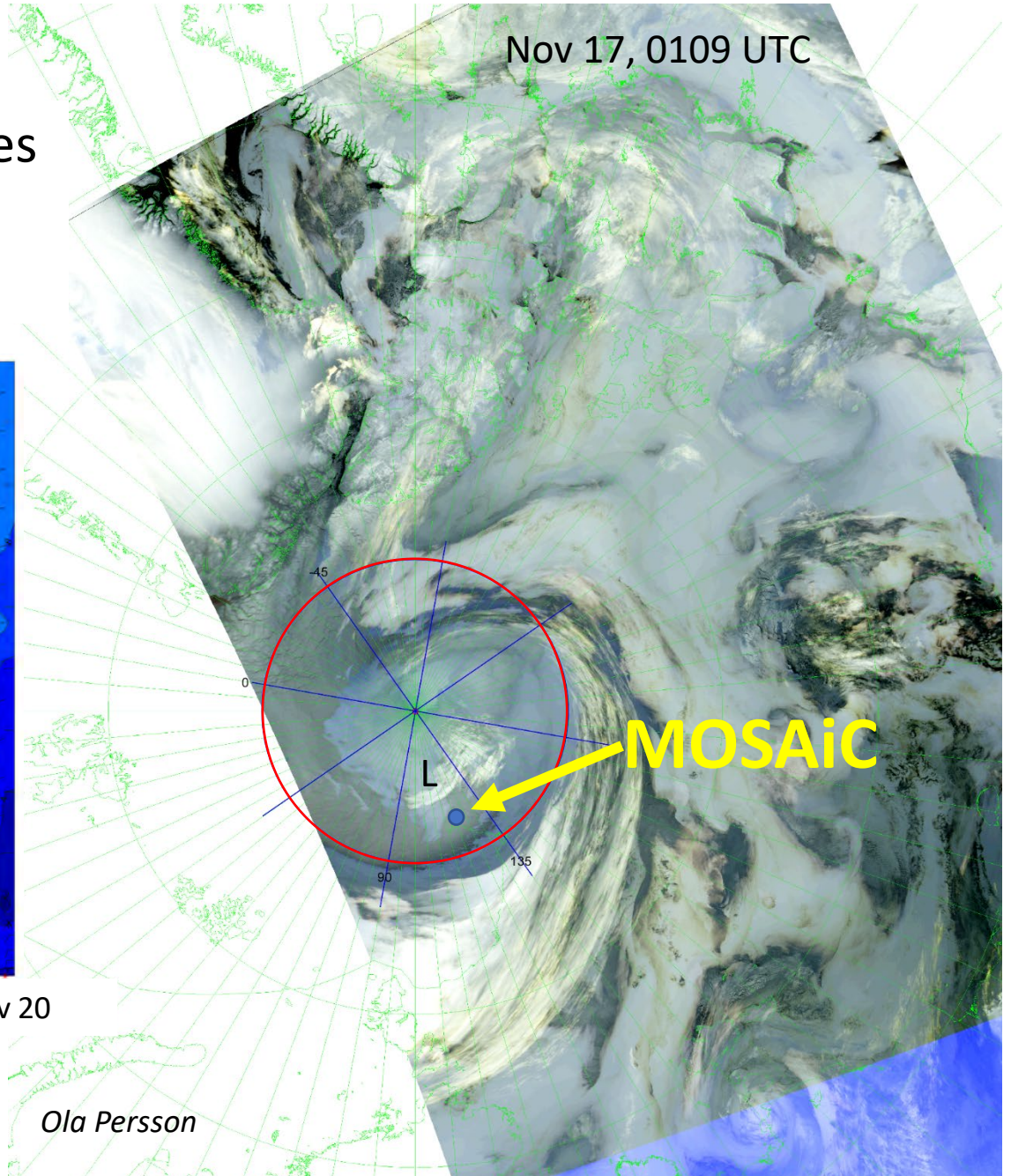
Lianna Nixon

Arctic Cyclones

- different structure/evolution than at mid-latitudes
- important impacts on the sea ice & upper ocean
- ~20 cyclones impacted MOSAiC

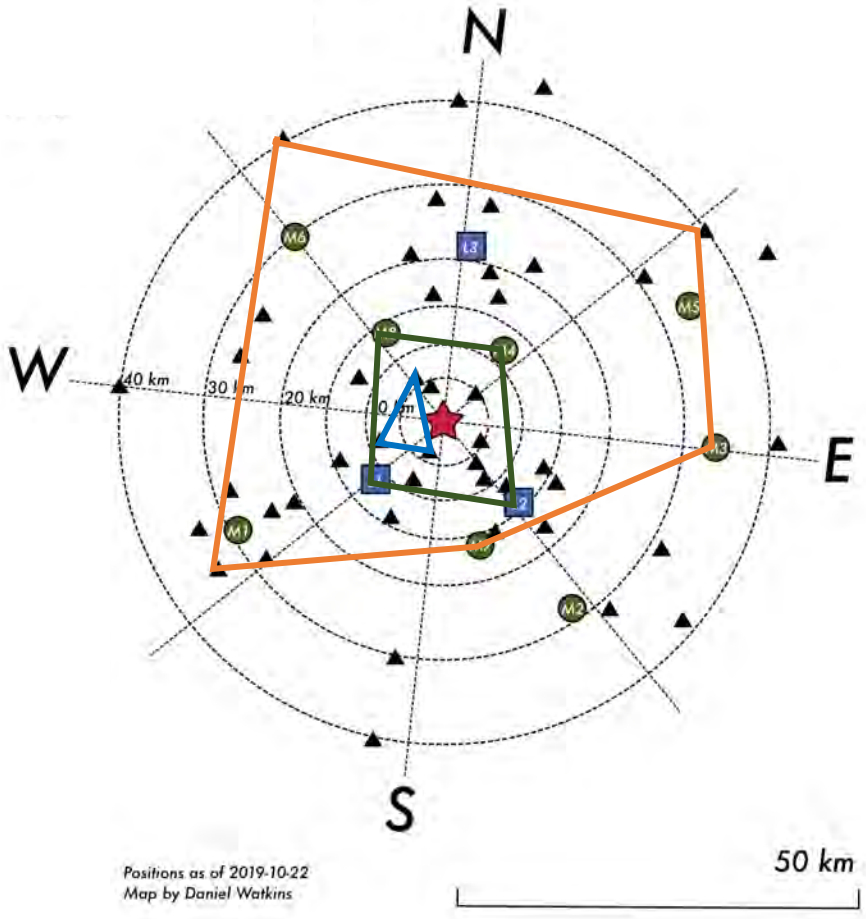


Detailed wind, divergence, and momentum analysis

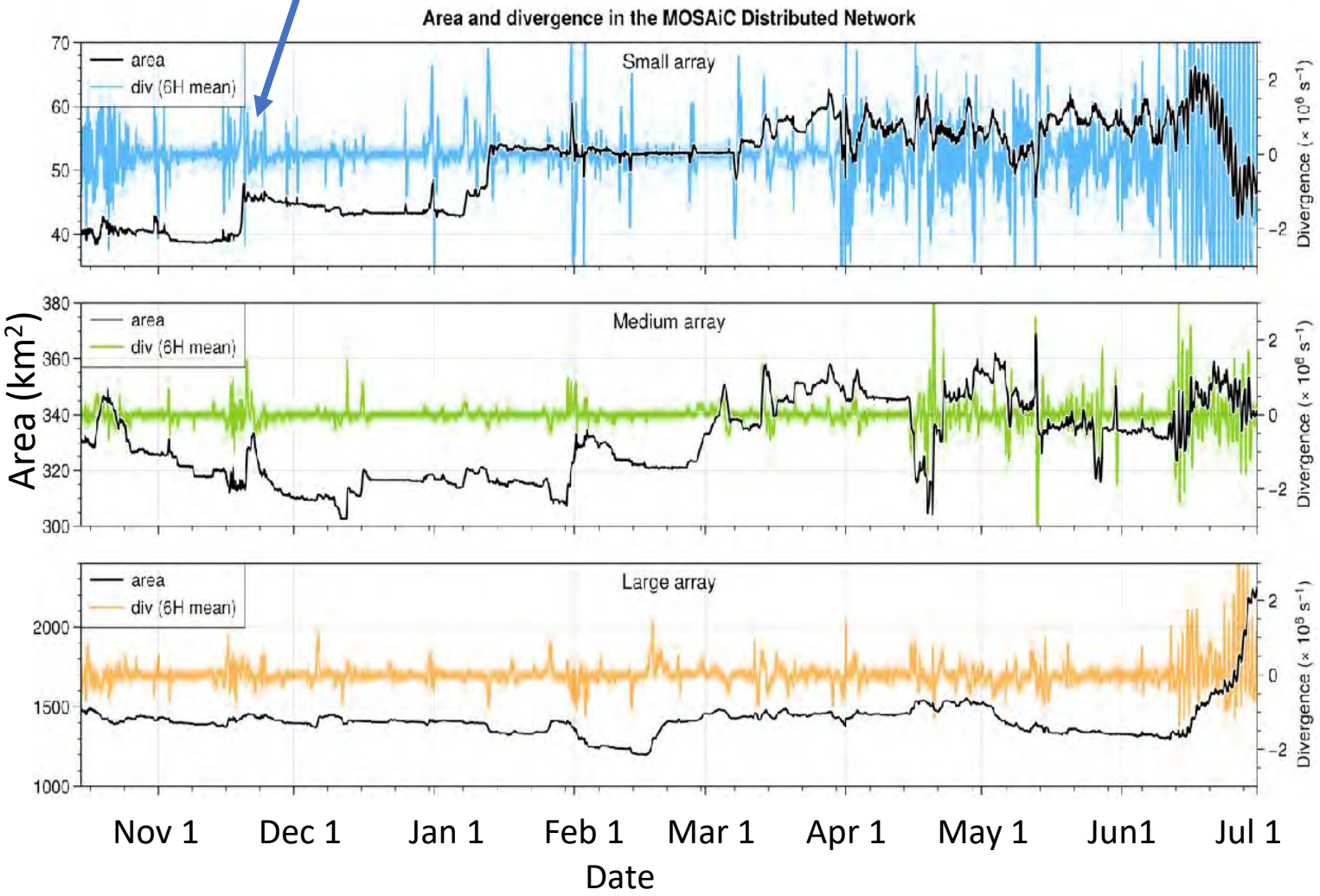


Sea Ice Dynamics

MOSAiC Distributed Network



Strong deformation



Daniel Watkins & Jenny Hutchings

Multi-scale ice dynamics essential for improved model representation.

Cloud Impact on Ice Thermodynamics

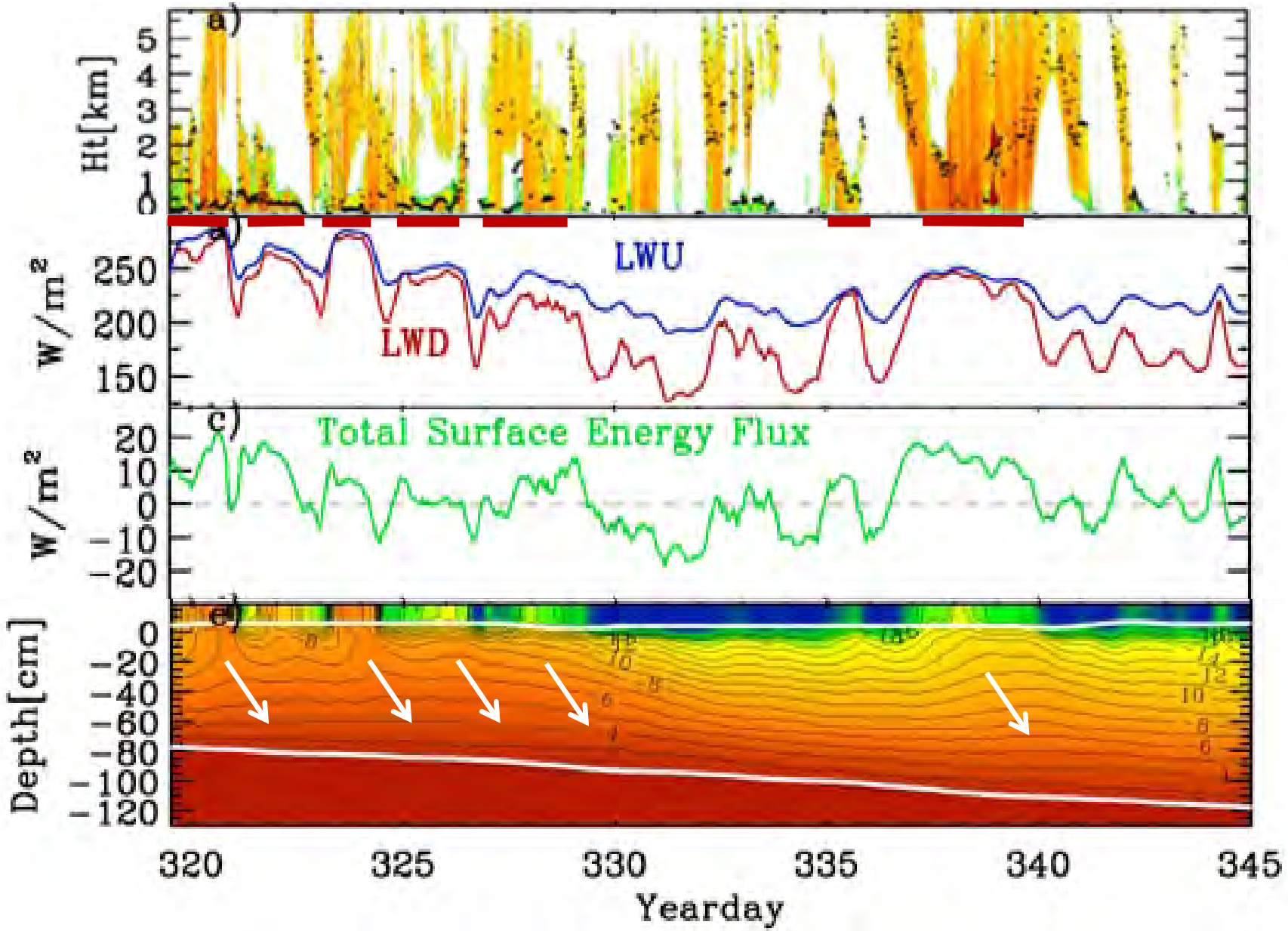
25-day Nov-Dec case study

Radar shows clouds with height
Microwave shows liquid water
(Cloud product available in Archive)

Strong increase in atmospheric emitted longwave radiation when liquid clouds are present

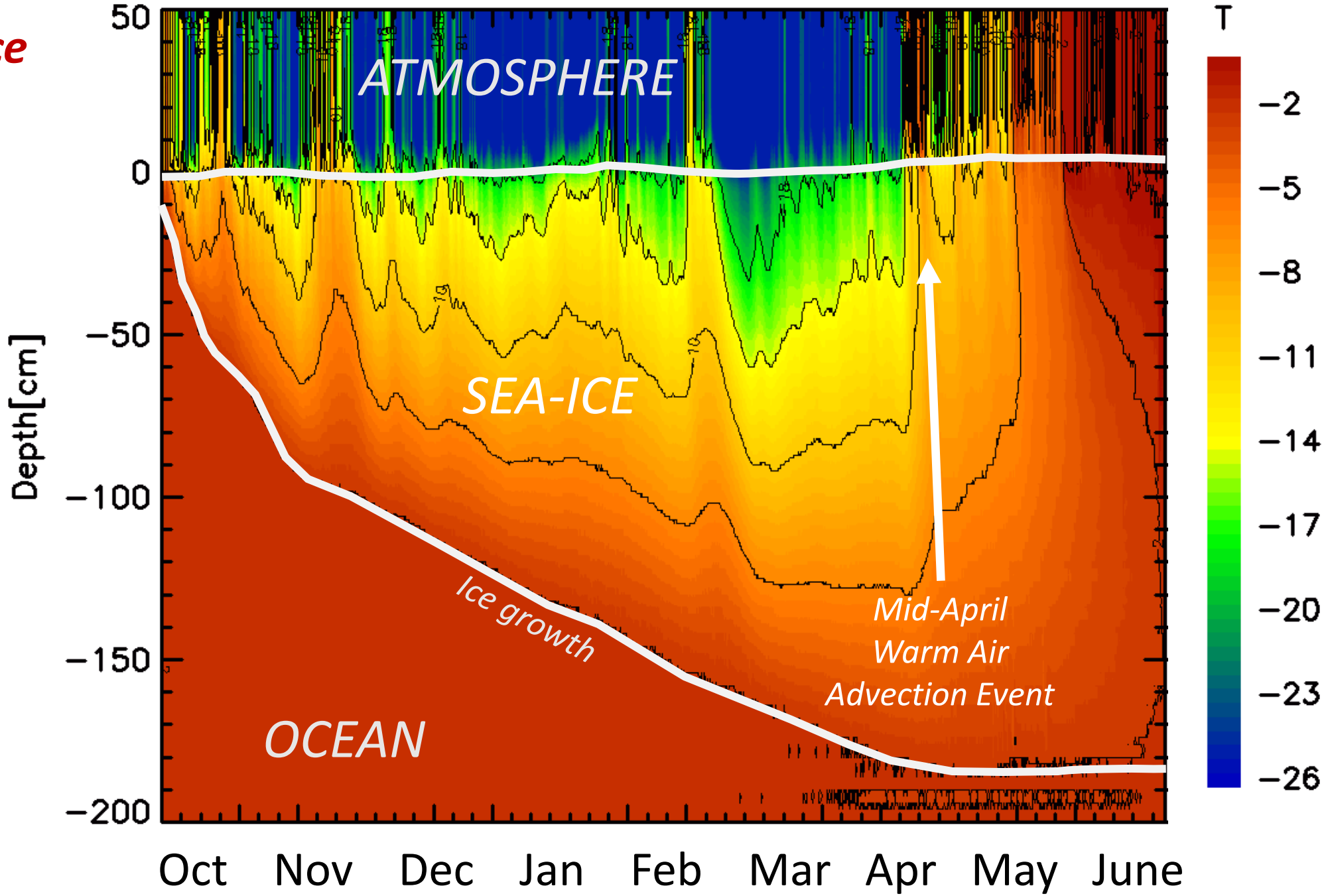
Total atmospheric surface flux strongly driven by LW radiation from liquid clouds

Cloud-driven variability impacts sea-ice temperature, conductive heat flux, and growth



Shupe et al.

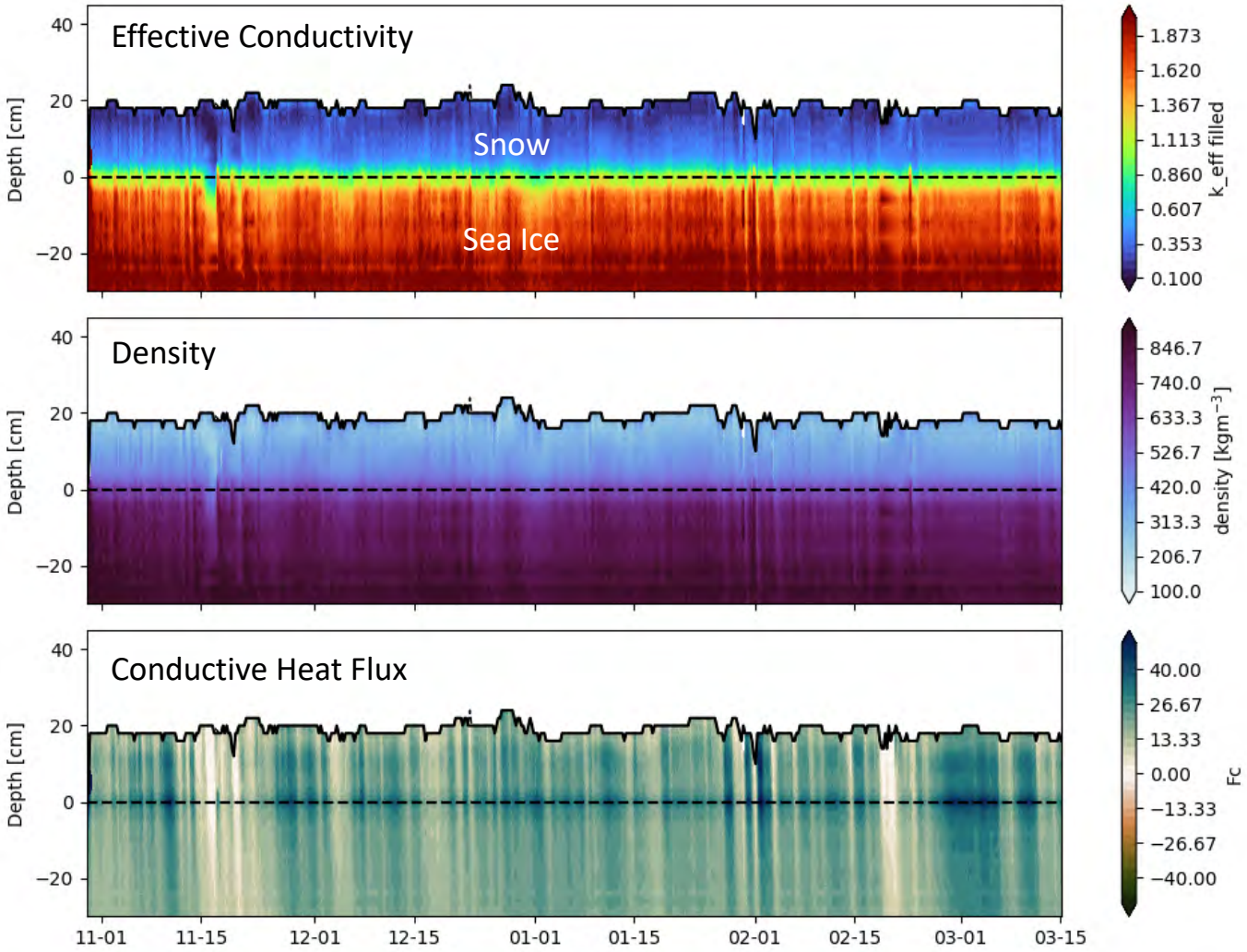
Towards Ice Melt

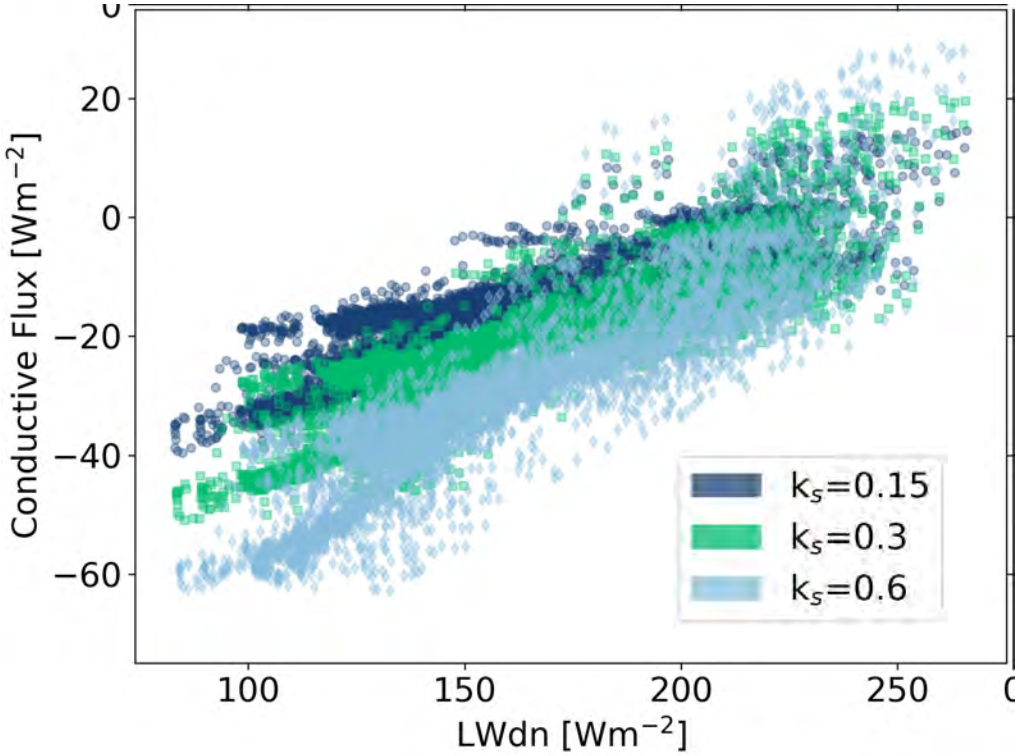


data: Don Perovich

Thermal Conductivity

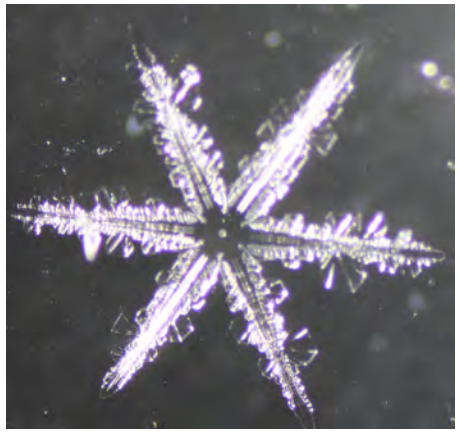
Deriving thermal properties from temperature profiles





- Can derive time-depth profiles of ice & snow thermal properties
- Balance of SEB terms is sensitive to model-assumed snow conductivity
- MOSAiC info suggests ks is larger than most models assume

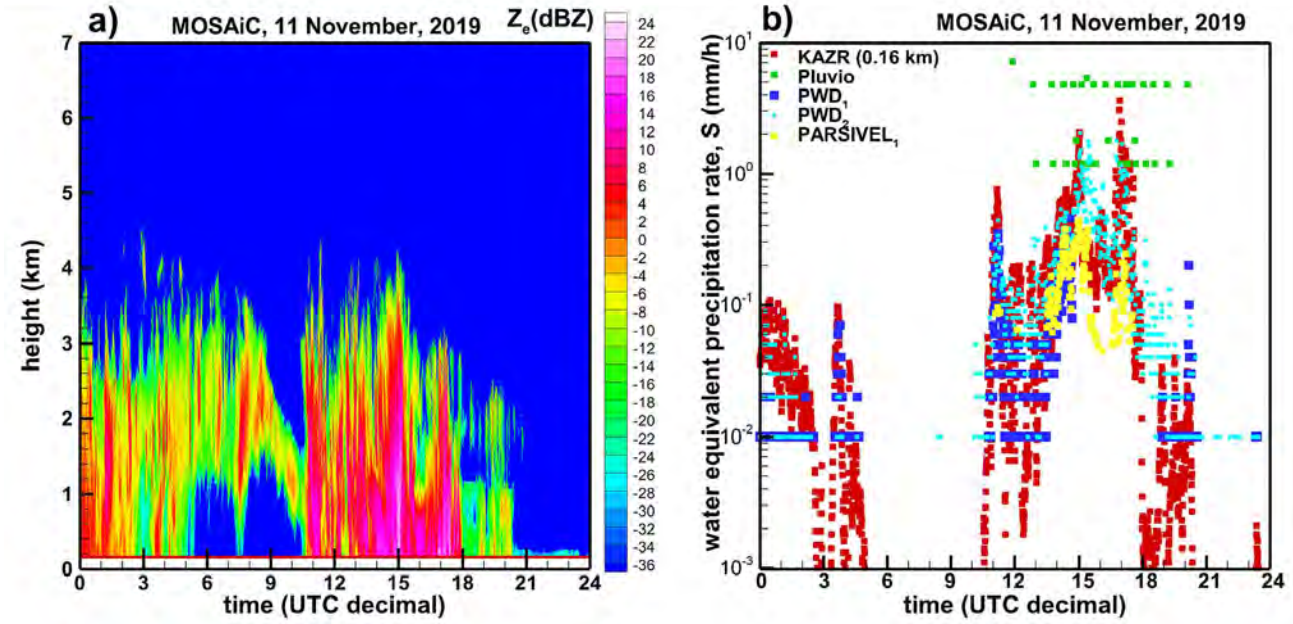
Anne Sledd



Snowfall and Snow on Ice

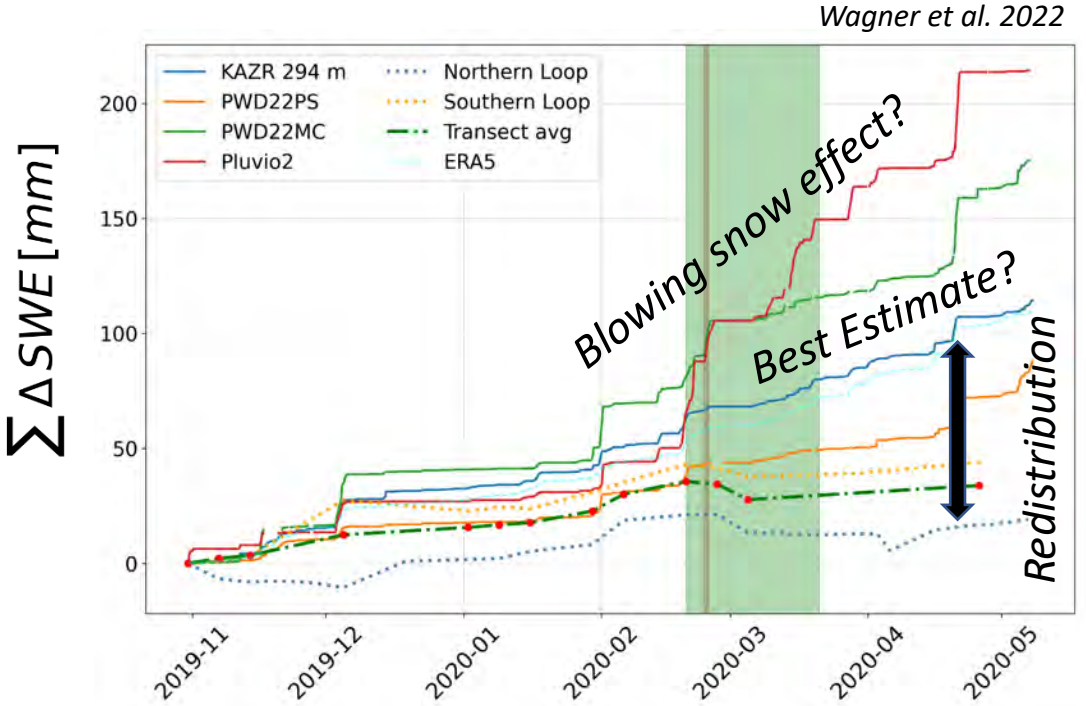
An insulator and reflector……

Matrosov et al. 2022



- Comprehensive intercomparisons
- Continuous radar-based estimates of snowfall
- PI Product available in the ARM Archive

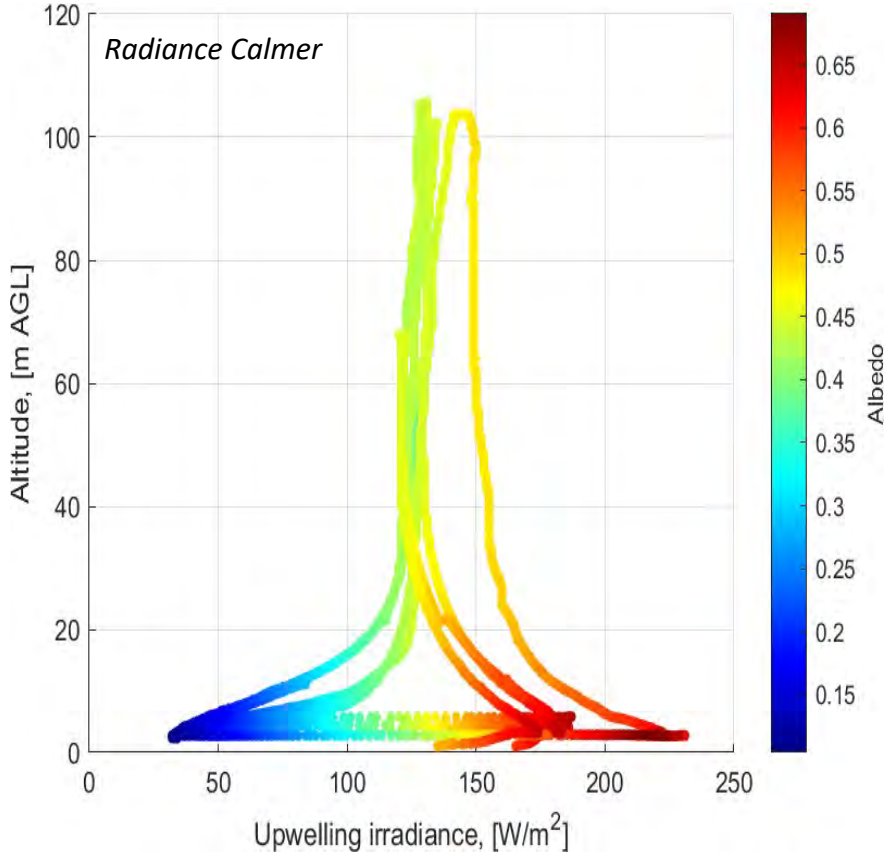
Wagner et al. 2022



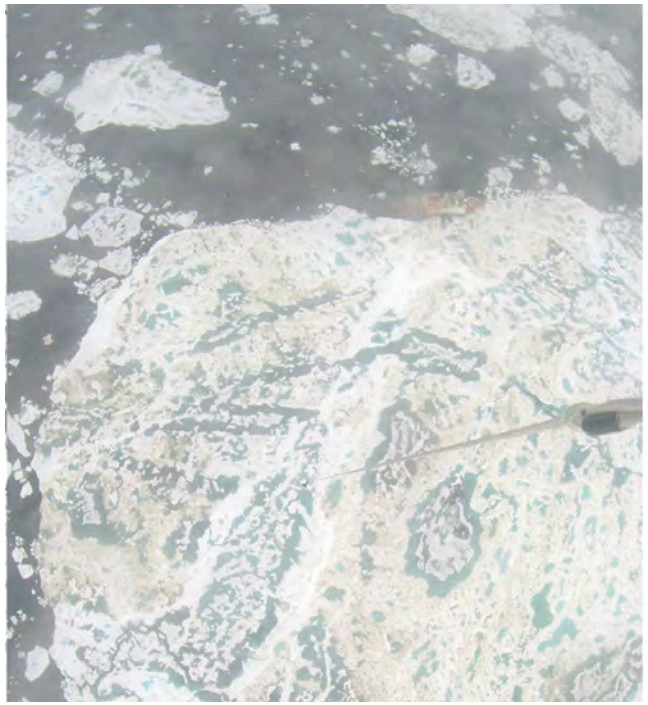
- Comparisons with manual measurements
- Differences offer insight into snow redistribution / erosion

Scaling Surface Albedo

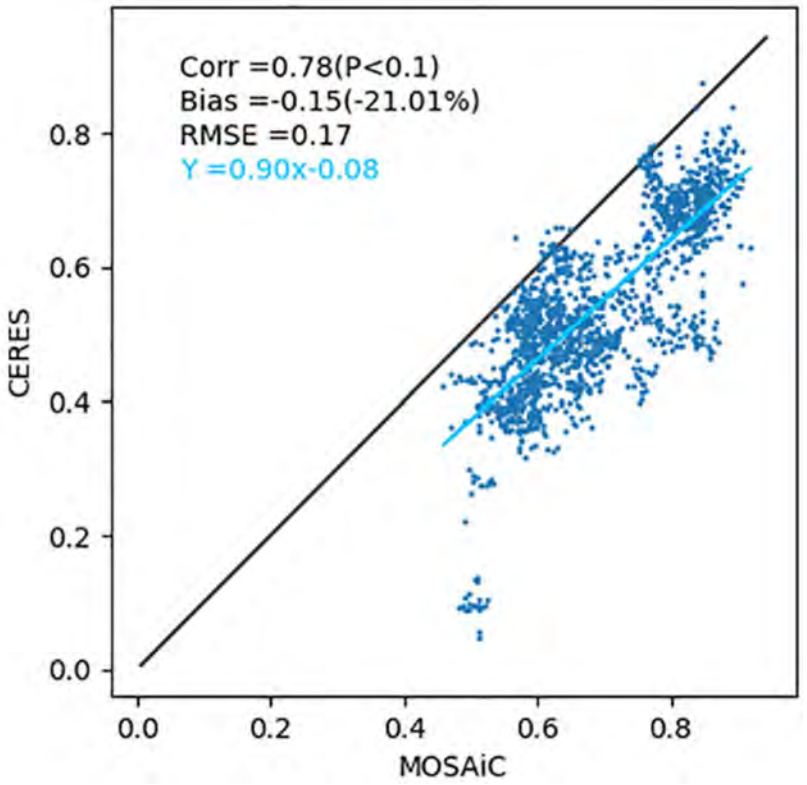
Multi-rotor drone measurements



Lonardi et al. 2022



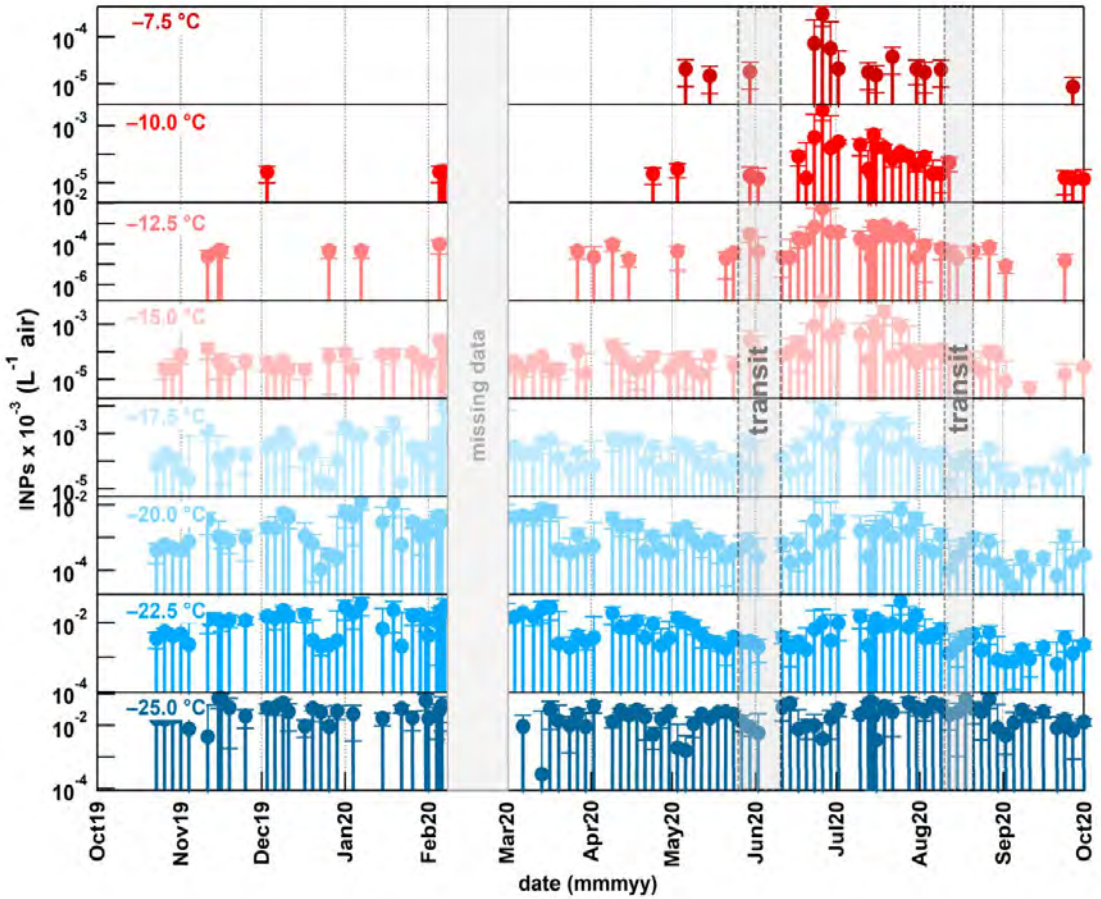
Huang et al. 2022



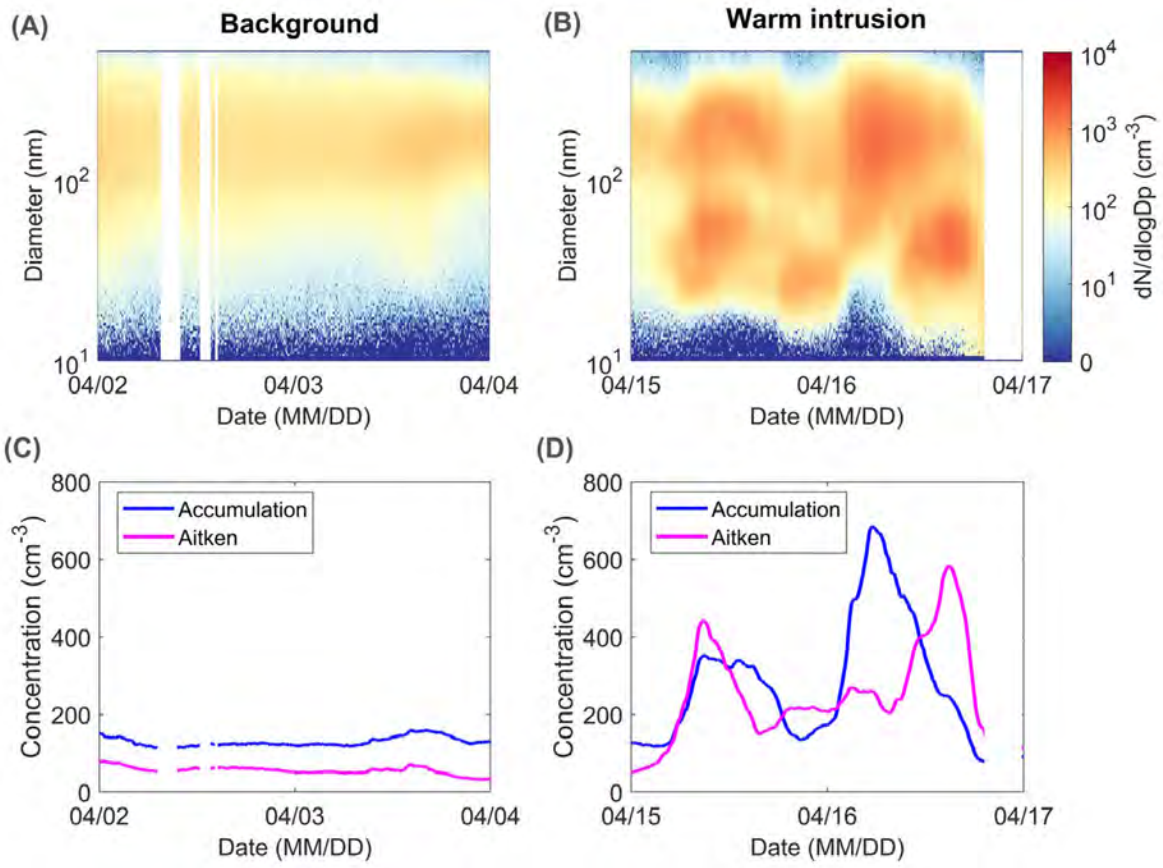
- *Point vs floe vs regional*
- *GNDRAD –> Drone –> Tethered Balloon –> Satellite*
- *Albedo convergence for radiometer view above 40 m altitude*
- *Satellite – ground "bias" related to sea ice concentration*
- *Other papers looking at albedo annual cycle (Light et al. 2022) and surface scattering properties (Smith et al. 2022)*

Aerosols and their variability

- *Annual cycle of INPs, including bio sourced*
- *CCN from blowing snow*
- *Ultra clean episodes*
- *Event with city-like pollution*
- *New particle formation events*

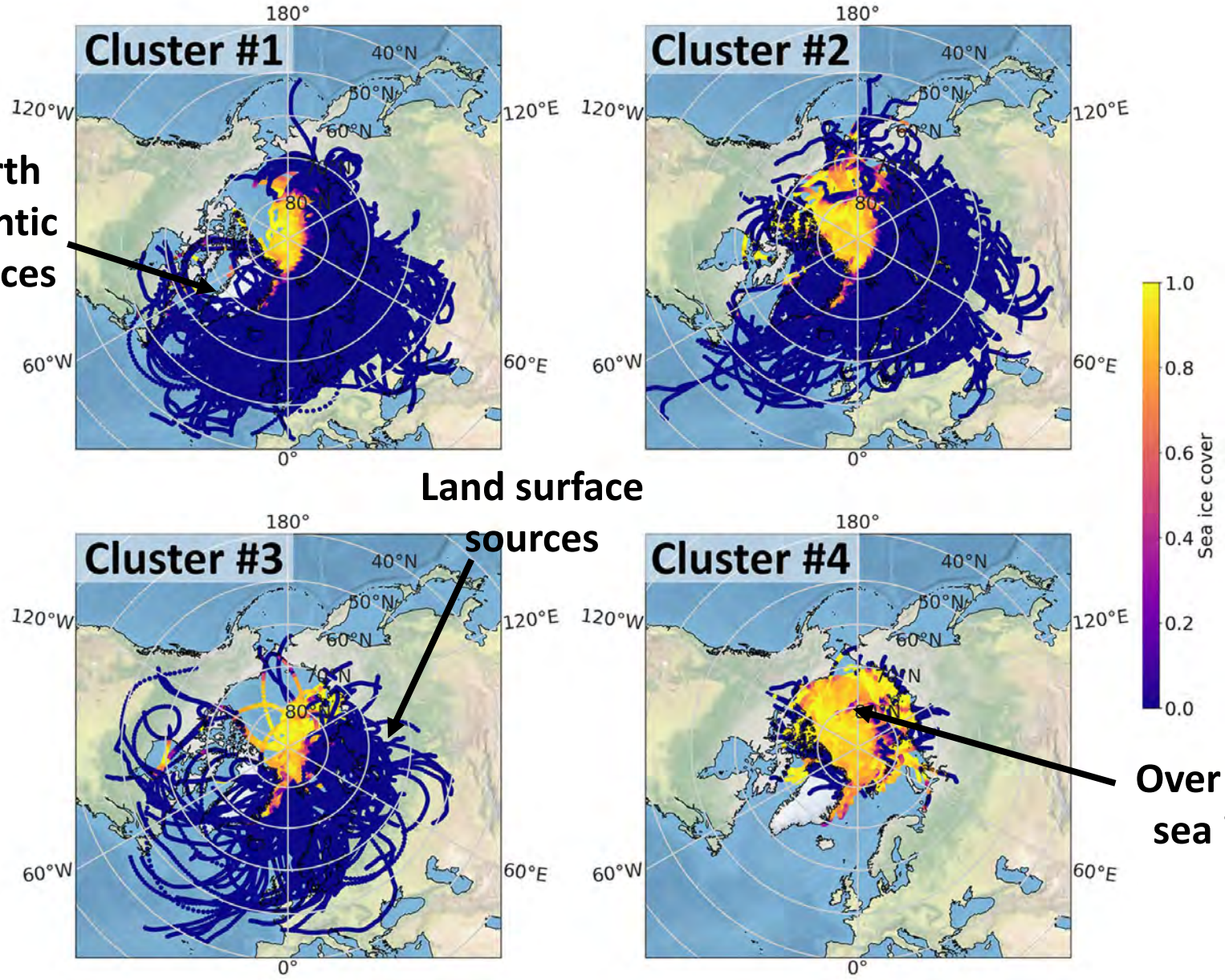


Creamean et al. 2022, Nature Comms.



Dada et al. 2022, Nature Comms.

Liquid Water Cloud Trajectories



North Atlantic sources

Land surface sources

Over the sea ice

Analysis

- *5-day back trajectories for liquid clouds*
- *Cluster based on time since open water, ice concentration, change in moisture, etc. along trajectory*
- *Provides insight into cloud formations mechanisms and pathways*

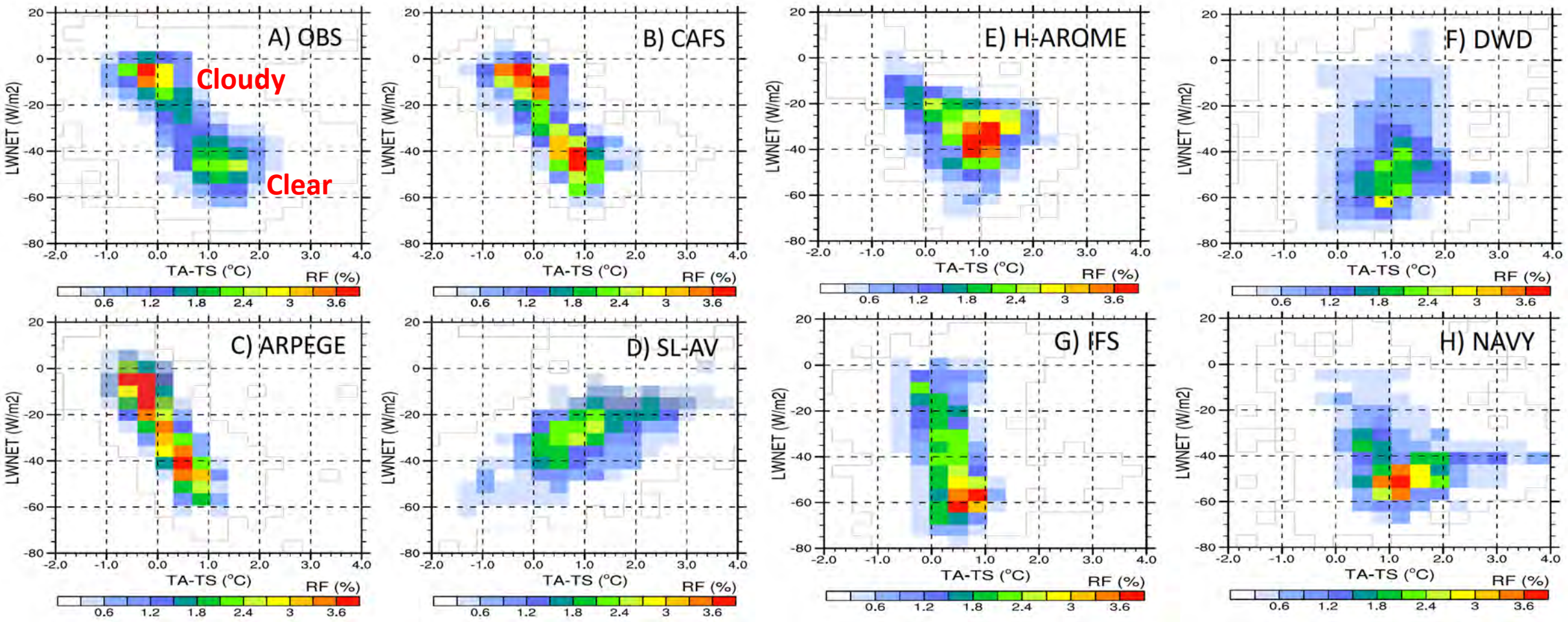
Silber and Shupe 2021

Process-based Model Evaluation

Net LW vs T2m-Tsfc

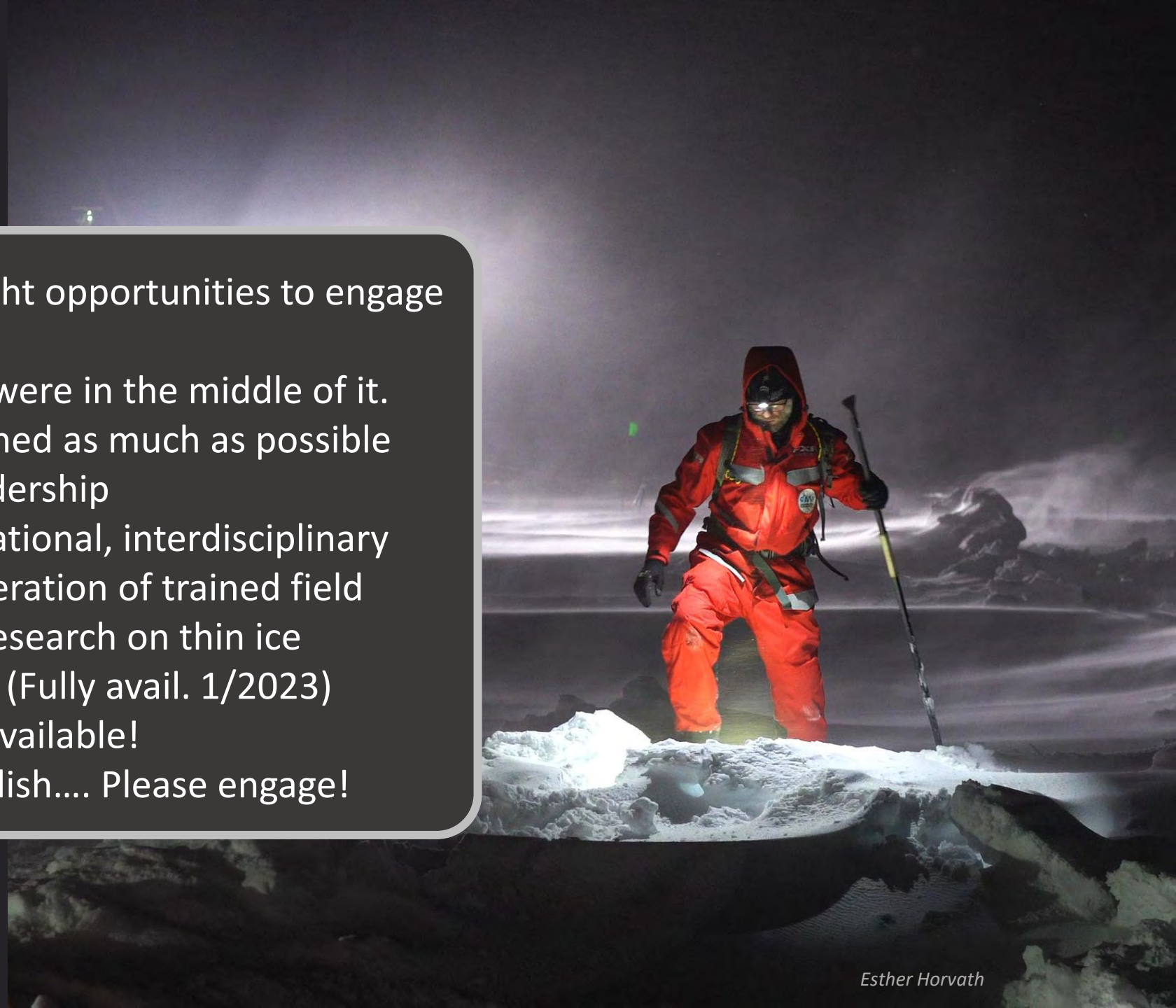
Amy Solomon

- Cloudy sky mode often missing or poorly represented
- Near surface stratification often too weak
- Can examine many other “process relationships”



Summary

- Many challenges that brought opportunities to engage the emerging Arctic
- Thin, dynamic sea ice! We were in the middle of it.
- Tons of science! Accomplished as much as possible
- DOE showed important leadership
- Broad participation: International, interdisciplinary
- Capacity building: New generation of trained field scientists; new concepts for research on thin ice
- Legacy of Data for all to use (Fully avail. 1/2023)
- ARM data and PI Products available!
- So much science to accomplish…. Please engage!



Esther Horvath

Lianna Nixon

2nd International MOSAiC Science Conference

13-17 February 2023 Boulder, CO

https://mosaic.colorado.edu/second-science-conference

You are invited!

www.mosaic-expedition.org mosaic.colorado.edu

Search: MOSAiC Planetarium on YouTube

"Arctic Drift" documentary streaming on NOVA-PBS

Lianna Nixon