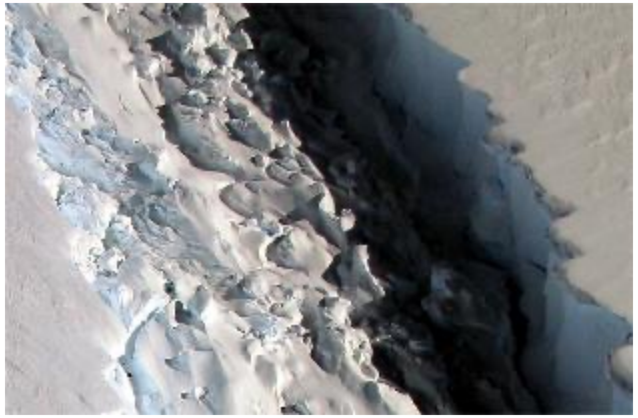
National Aeronautics and
Space Administration

SCIENCE



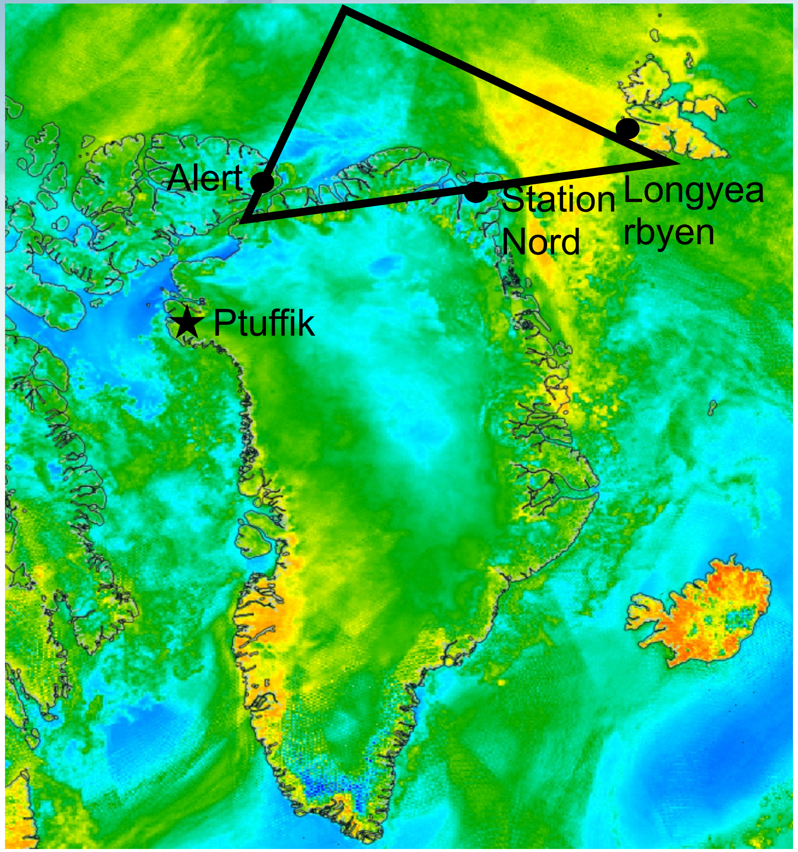



Patrick Taylor, Climate Research Scientist

Arctic Radiation-Cloud-aerosol-Surface Interaction eXperiment (ARCSIX)

May 16, 2024

What is ARCSIX: Project Overview



AMSR2 87 GHz Brightness temperature (June 11, 2023) showing the sea ice concentration contrast (from dark blue to green) in the primary sampling region.
Below are the primary platforms to be deployed.

- → Project: Arctic Radiation-Cloud-aerosol-Surface Interaction Experiment (ARCSIX)
- → Program Mgrs: Hal Maring, Radiation Sciences and Thorsten Markus, Cryospheric Sciences
- → Principal Investigators: Sebastian Schmidt (Mission Science Lead, Univ. Colorado) and Patrick Taylor (Deputy Mission Science Lead, Langley)
- → **Description:** The overarching goal is to **quantify the contributions of surface properties, clouds, aerosols, and precipitation to the Arctic summer surface radiation budget and sea ice melt** during the early melt season to advance understanding of rapid Arctic climate change and improve satellite retrievals.
- → Center Participants: LaRC, GSFC, JPL, AFRC
- → Partners: US academic researchers, NOAA, NCAR, NRL, NPS, SPEC
- → Deployment Dates: May 24-June 17 and July 22-August 16, 2024
- → Deployment Location: Pituffik Space Base, Greenland

Why ARCSIX: Science Goals

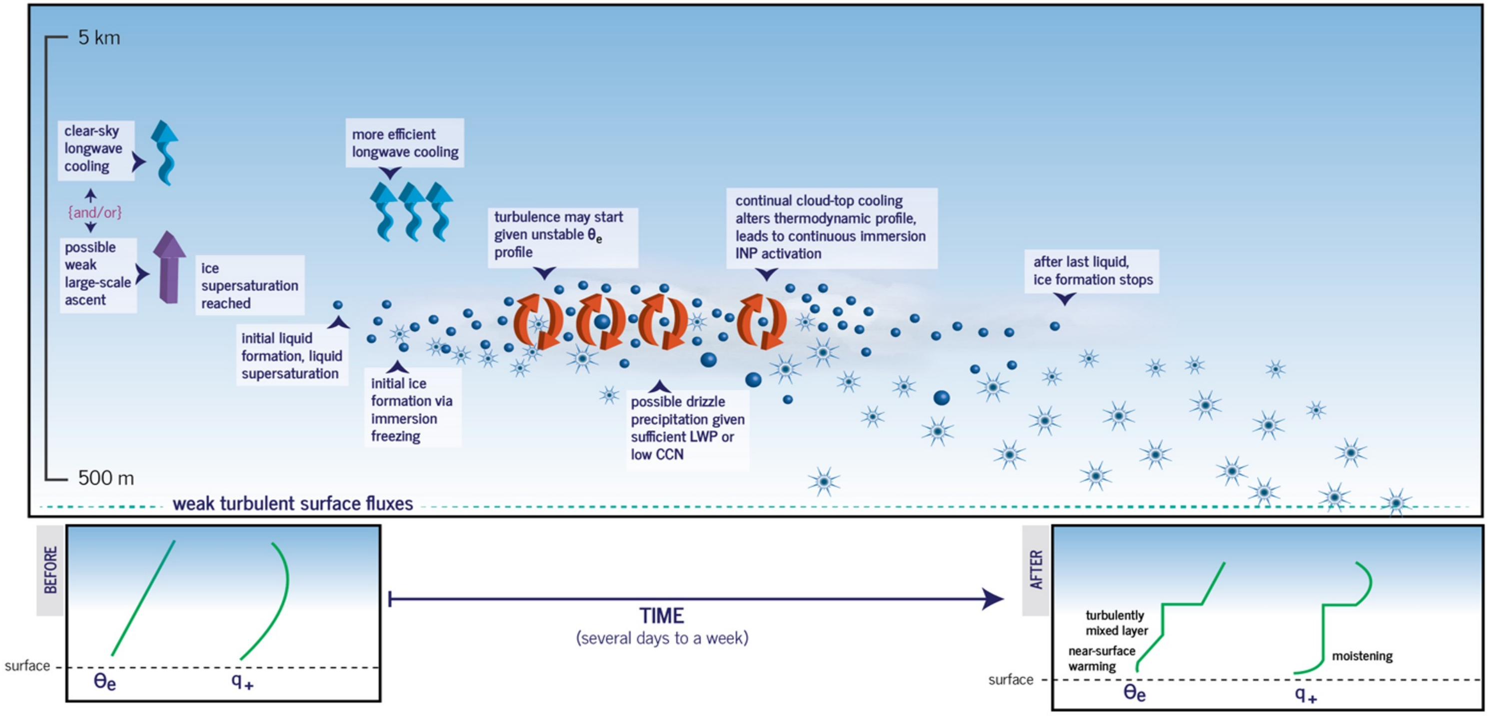
ARCSIX is a mission concept motivated by a science community white paper with over 30 contributors. The ARCSIX instrument teams were competed in NASA ROSES 2021.

ARCSIX is motivated by the need to:

1) Understand how coupling between radiative processes and sea ice surface properties influence summer sea ice melt;

2) Understand processes controlling the predominant Arctic cloud regimes and their properties; and

3) Improve our ability to monitor Arctic cloud, radiation, and sea ice processes from space.



ARCSIX Science Questions

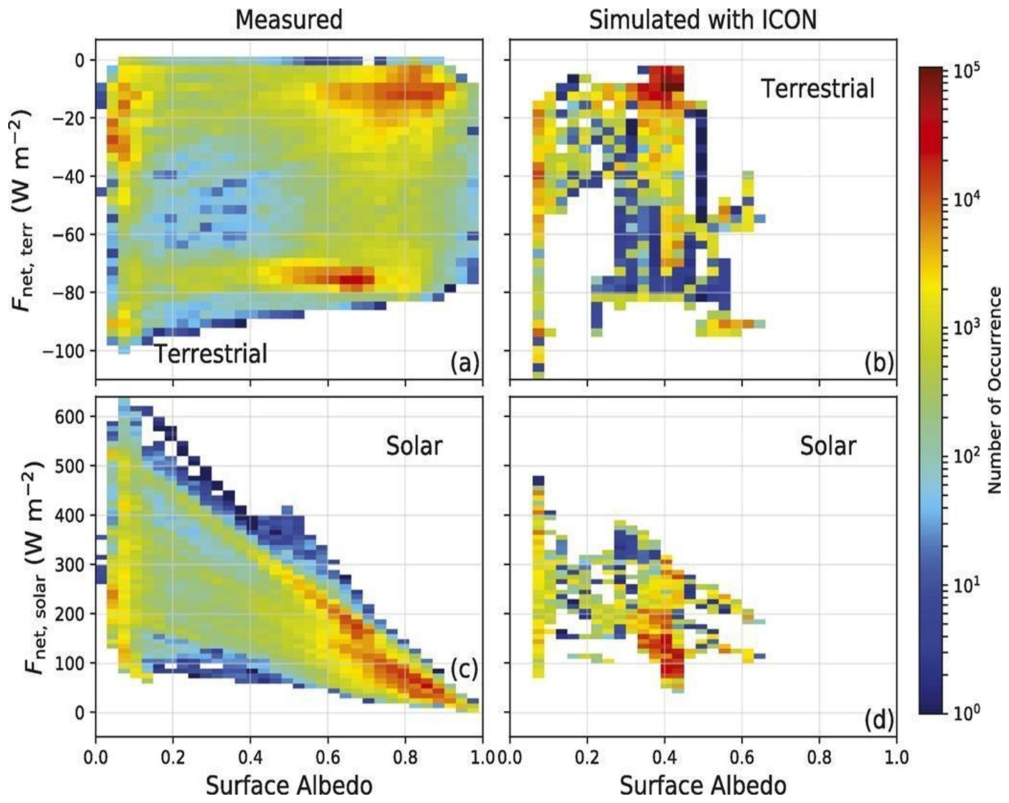
ARCSIX Science Questions:

● Science Question 1 (Radiation): What is the impact of the predominant summer Arctic cloud types on the radiative surface energy budget?

● Science Question 2 (Cloud Life Cycle): What processes control the evolution and maintenance of the predominant cloud regimes in the summertime Arctic?

● Science Question 3 (Sea Ice): How do the two-way interactions between surface properties and atmospheric forcings affect the sea ice evolution?

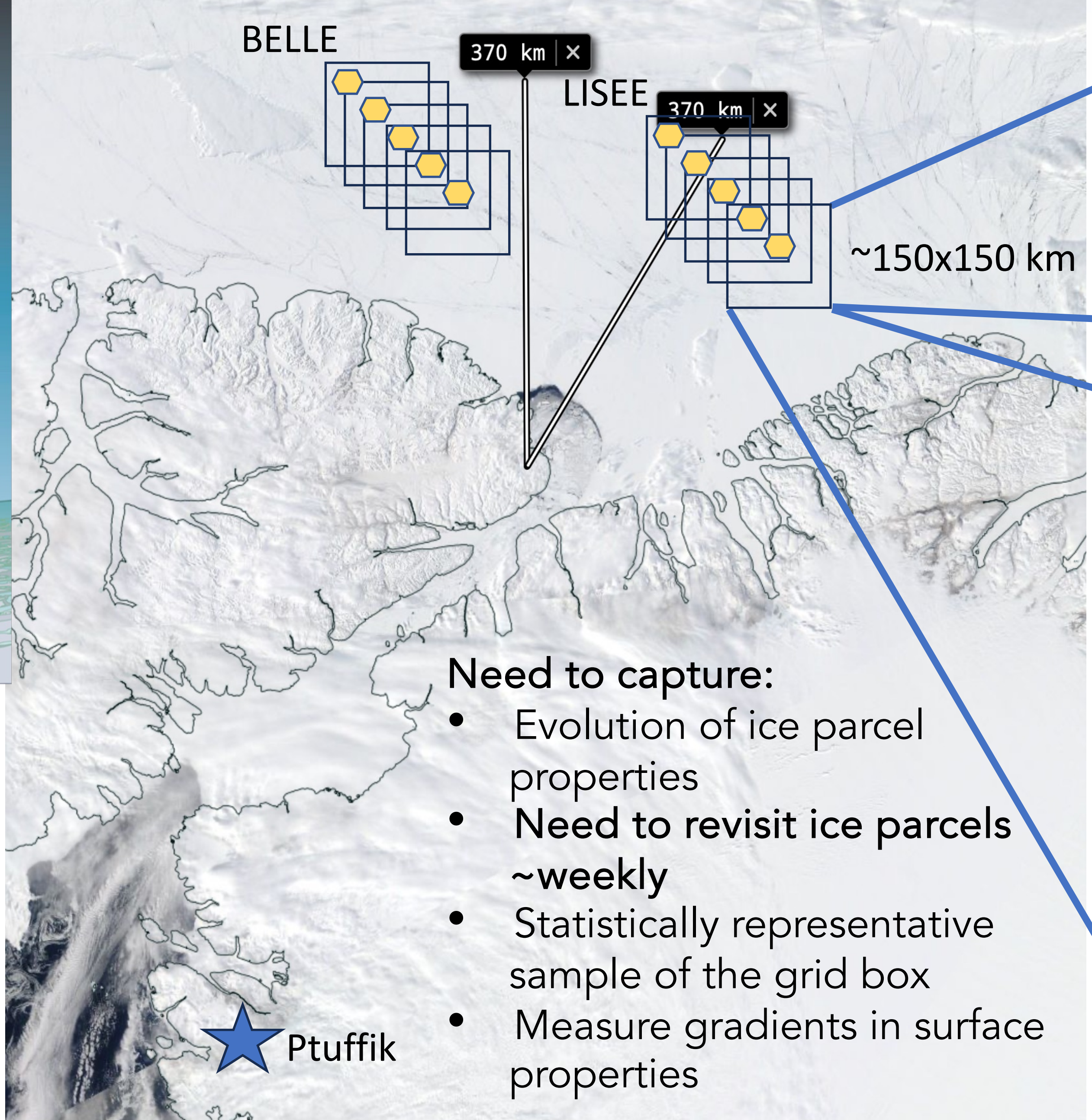
● Remote Sensing and Modeling Objective: Enhance our long-term space-based monitoring and predictive capabilities of Arctic sea ice, cloud and aerosols by validating and improving remote sensing algorithms and model parameterizations in the Arctic.



Wendisch et al. (2019)

ARCSIX: Sampling concept

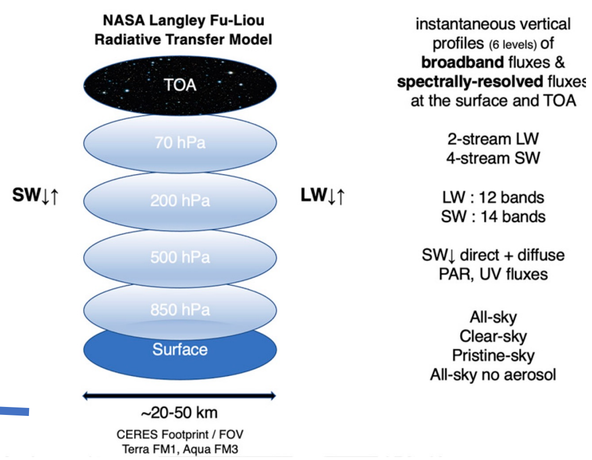
Tracking Sea ice Parcel Evolution

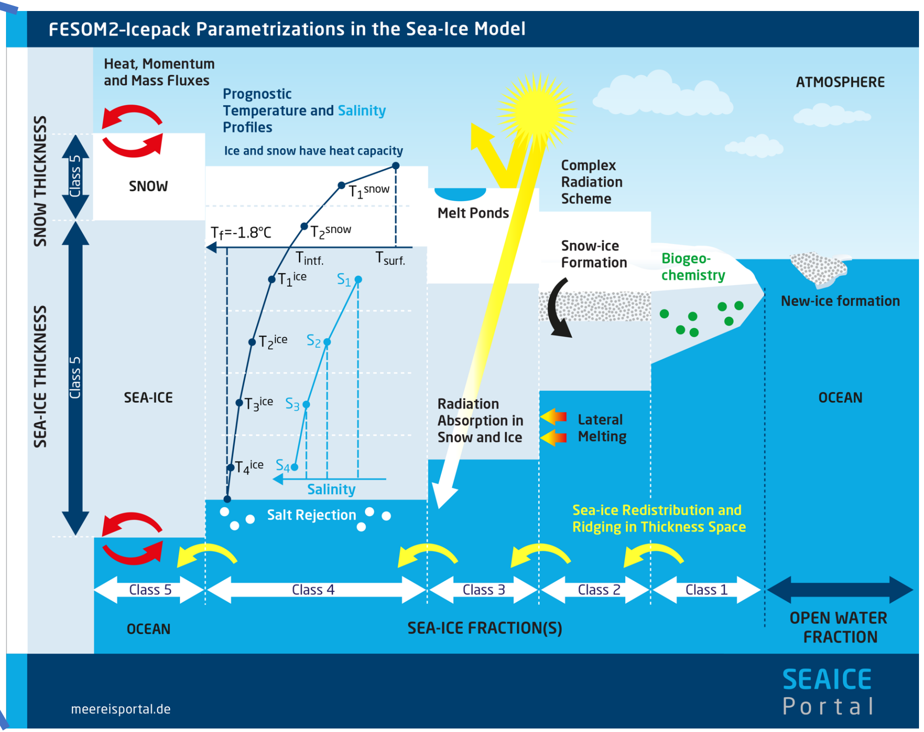


Need to capture:

- Evolution of ice parcel properties
- **Need to revisit ice parcels ~weekly**
- Statistically representative sample of the grid box
- Measure gradients in surface properties

Atmospheric radiative closure





Sea ice modeling of evolution

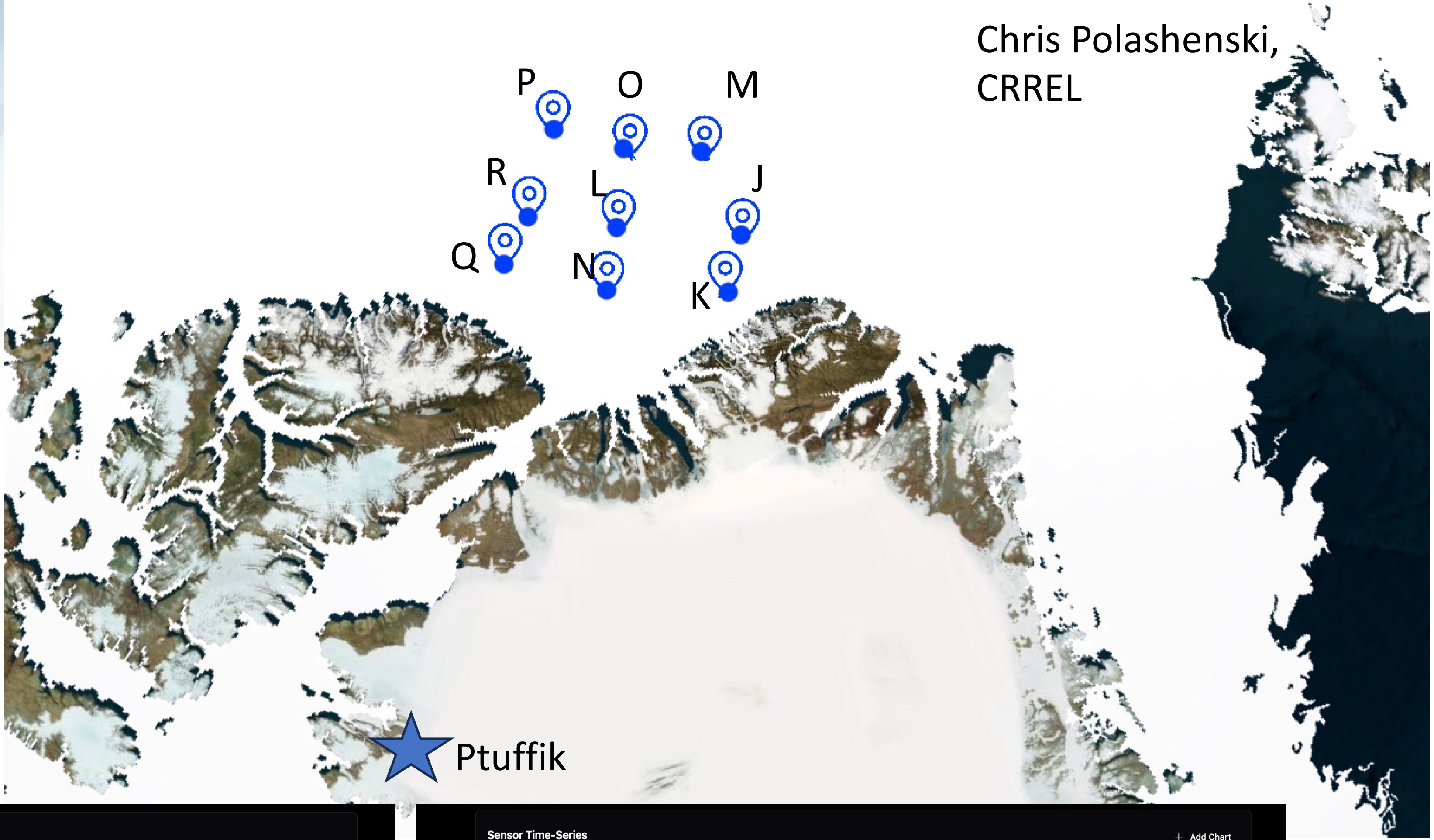
Belle Buoy Array

https://www.cryosphereinnovation.com/data

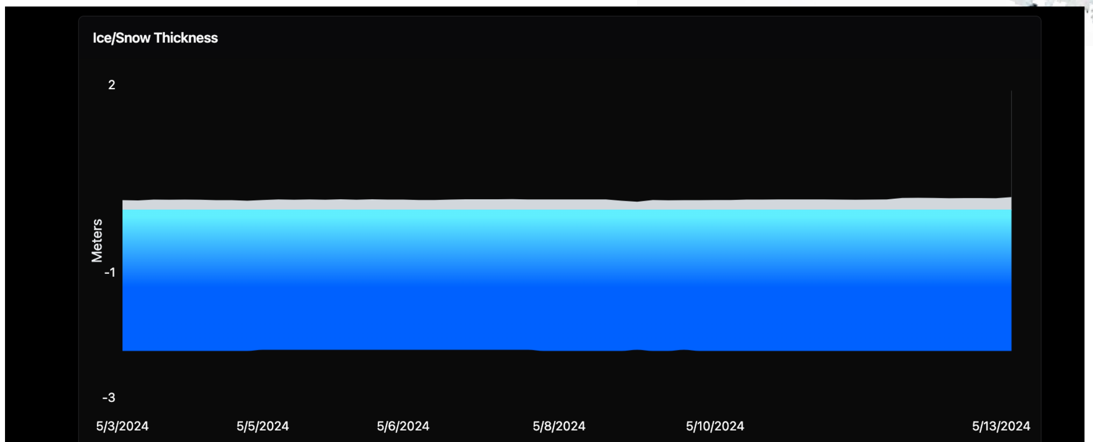
Chris Polashenski, CRREL

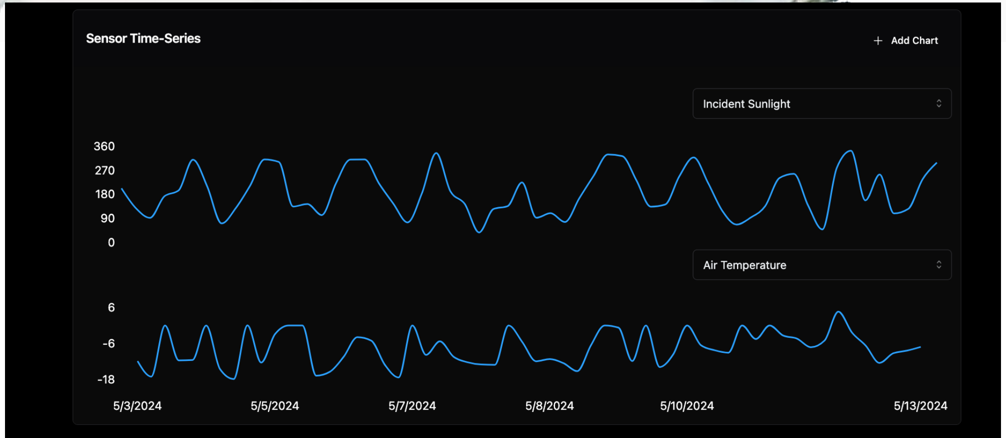
Measurements:

- Ocean-ice-atmosphere thermistor string (1.6 m depth)
- Air temperature
- Barometric pressure
- Snow depth (4 buoys)
- Upward and downward solar radiation (wavelengths < 1100 nm)

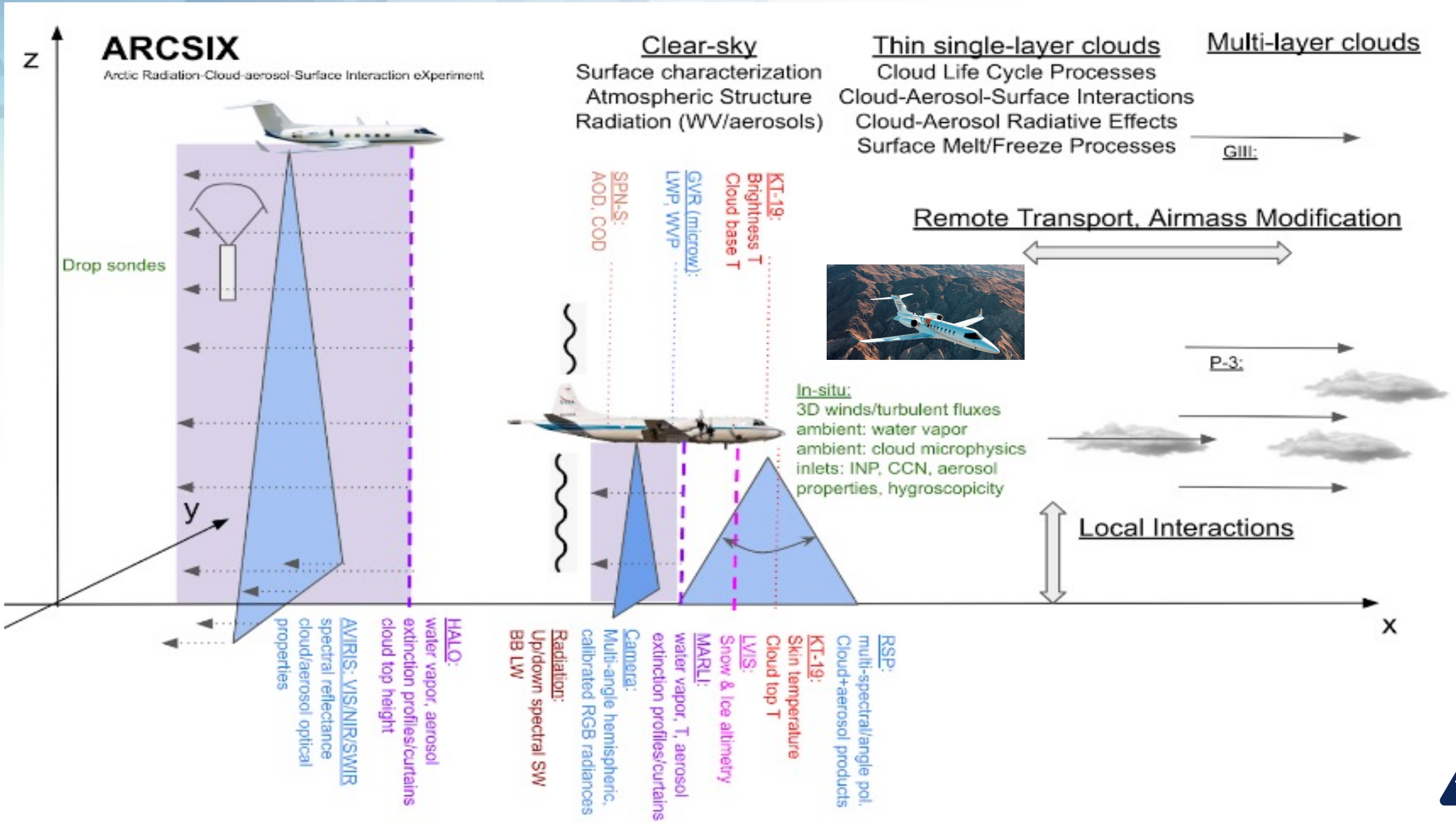


Data Dashboard excerpts:



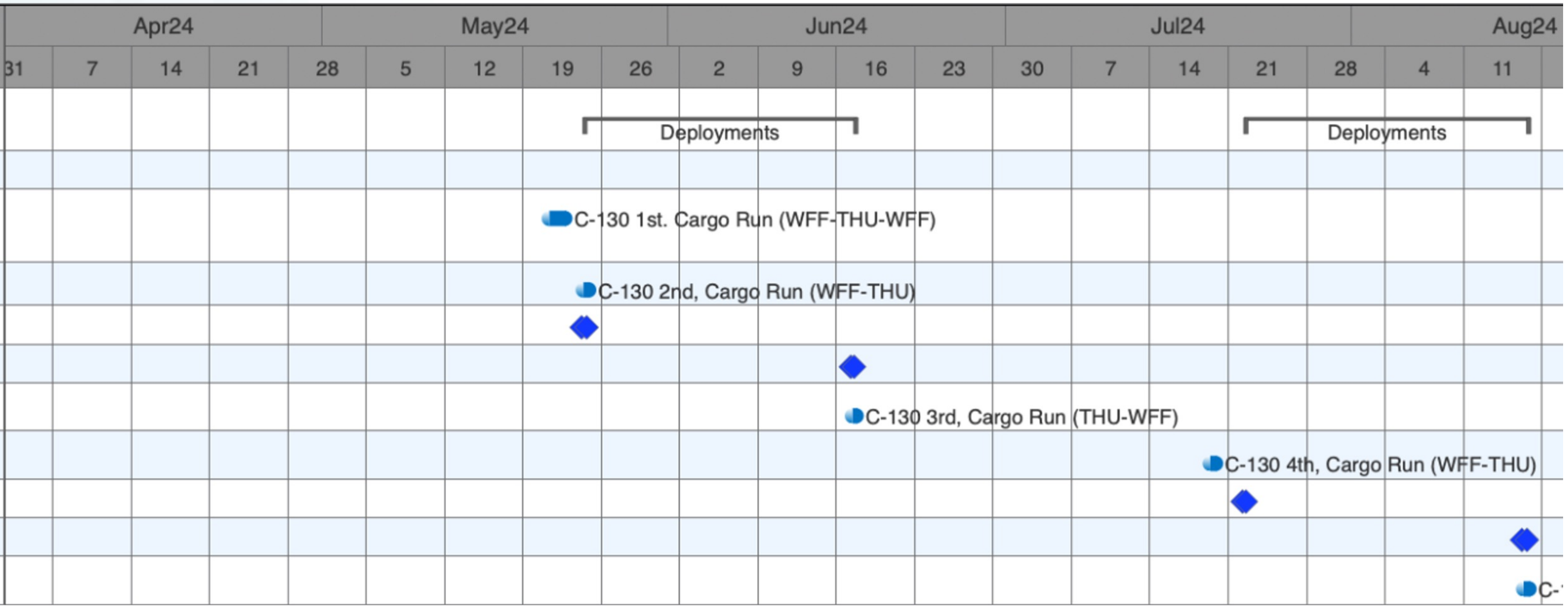


Instrument Configuration Plan



ARCSIX Schedule

Activity Name	Duration (Days)	Start Date	Finish Date	Location
Deployments	25.00 26.00	5/24/24 7/22/24	6/17/24 8/16/24	THU
C-130 1st. Cargo Run (WFF-THU-WFF)	2.00	5/21/24	5/22/24	
C-130 2nd, Cargo Run (WFF-THU)	1.00	5/24/24	5/24/24	
G-3 & P-3 Transit -> THU	1.00	5/24/24	5/24/24	
G-3 & P-3 Transit -> USA	1.00	6/17/24	6/17/24	
C-130 3rd, Cargo Run (THU-WFF)	1.00	6/17/24	6/17/24	
C-130 4th, Cargo Run (WFF-THU)	1.00	7/19/24	7/19/24	
G-3 & P-3 Transit -> THU	1.00	7/22/24	7/22/24	
G-3 & P-3 Transit -> USA	1.00	8/16/24	8/16/24	
C-130 5th, Cargo Run (THU-WFF)	1.00	8/16/24	8/16/24	



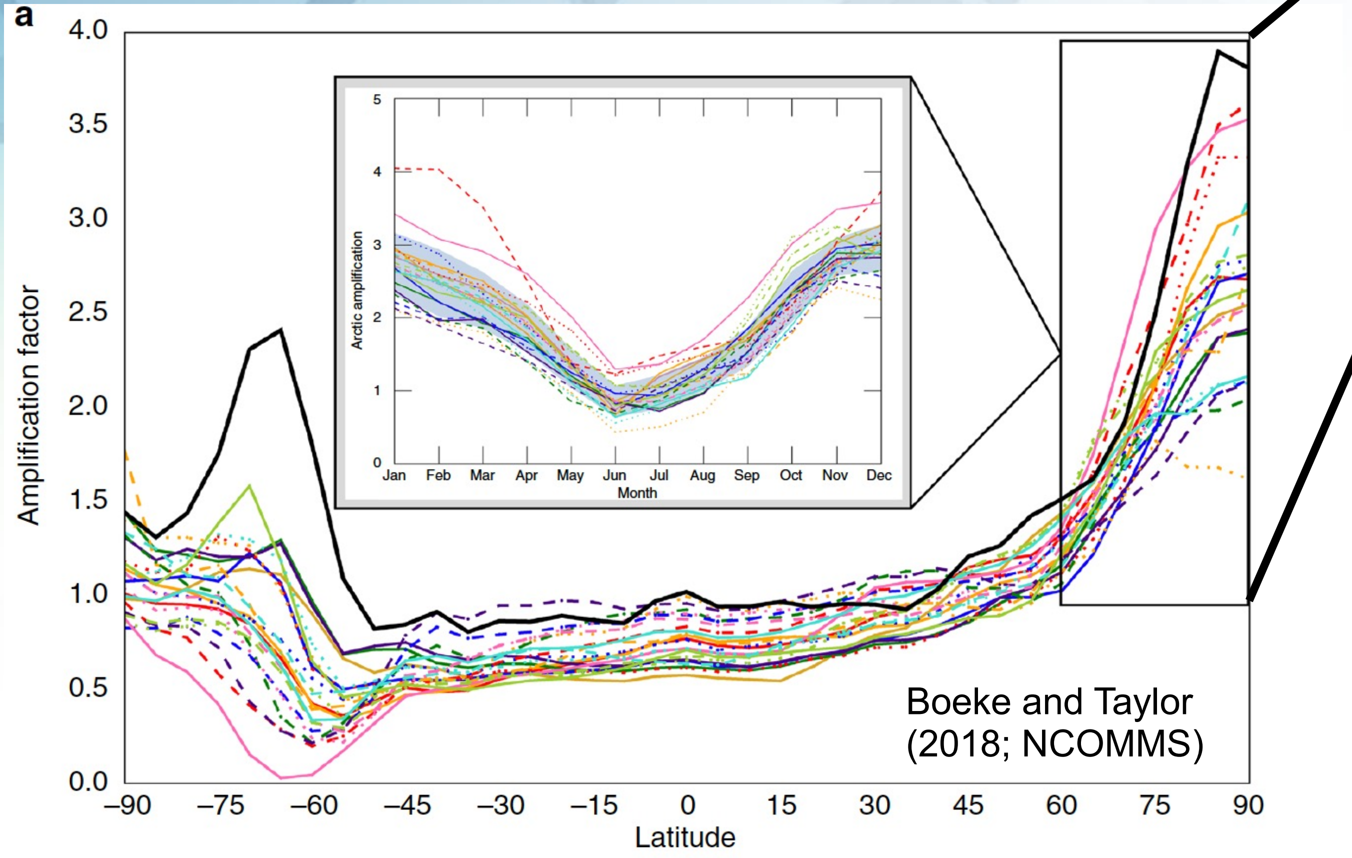
Transit to Pituffik:

- ARCSIX will use the WFF C-130 for airlift, cargo and personnel.
- May 21 - 22, Max Cargo run, WFF - THU - WFF assume no pax
- May 24 - Cargo run WFF -THU w/ 50 pax

Key dates:

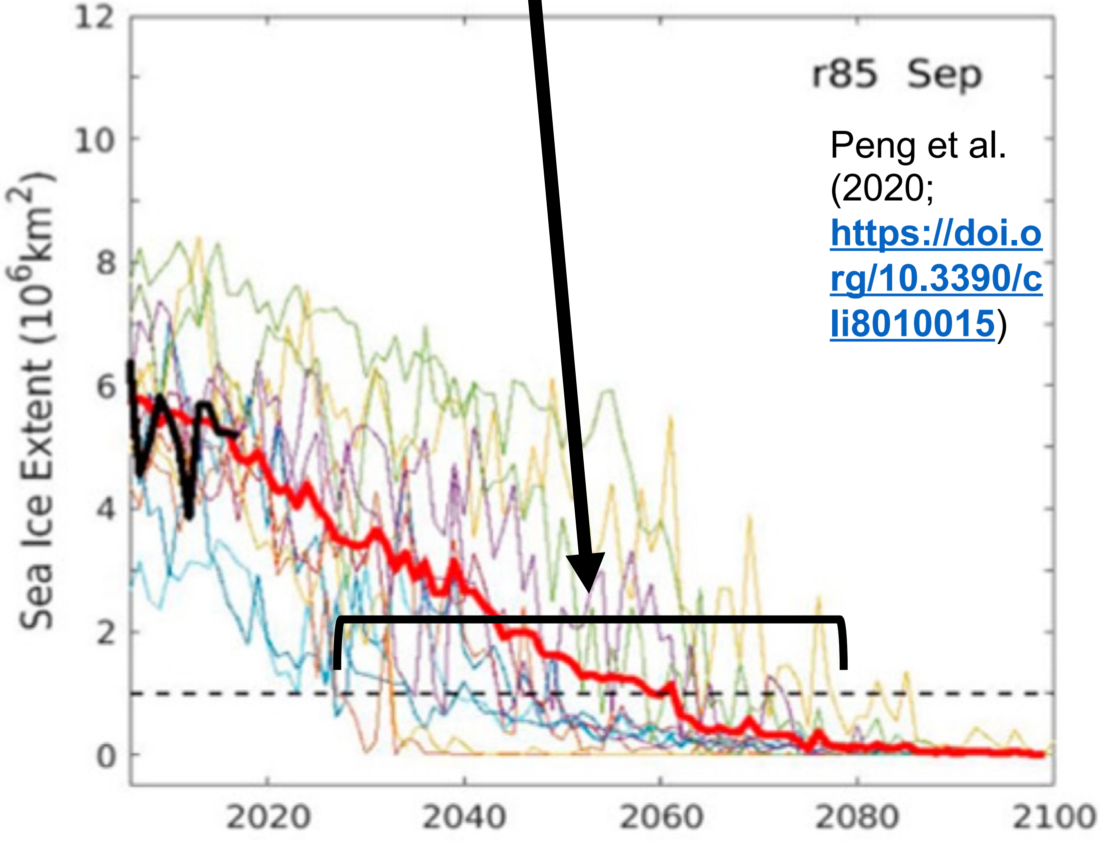
May 17: P-3 Instrument Check Flight
May 24: P-3 Transit to Pituffik
May 20: G-II Instrument Check Flight
May 28: G-III Transit to Pituffik

Why ARCSIX?



Considering a +3 K global temperature increase the range of Arctic warming is from 4.5 to 12K

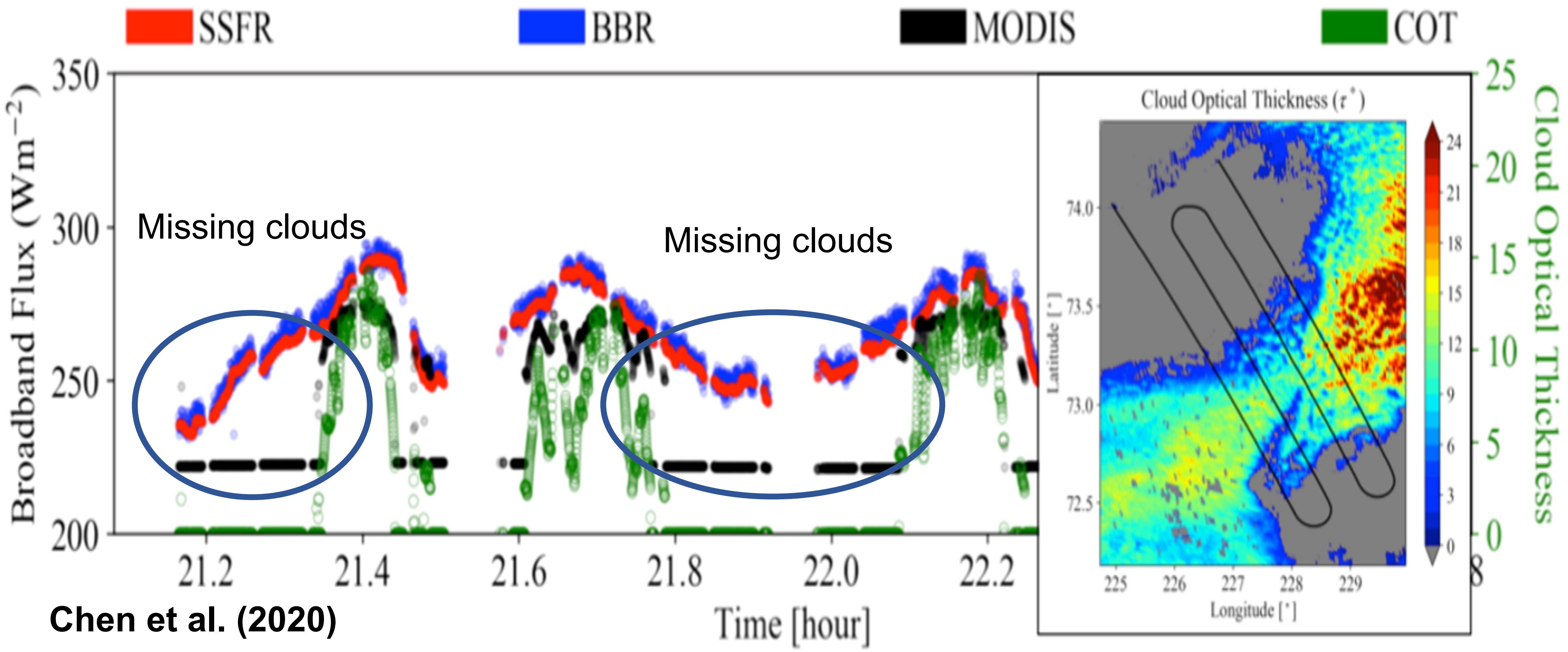
~50 year spread in the timing of the first ice free Arctic summer



…our models are inadequate to inform society.

Why ARCSIX?

…model uncertainty stems challenges in observing Arctic clouds and other properties from space.

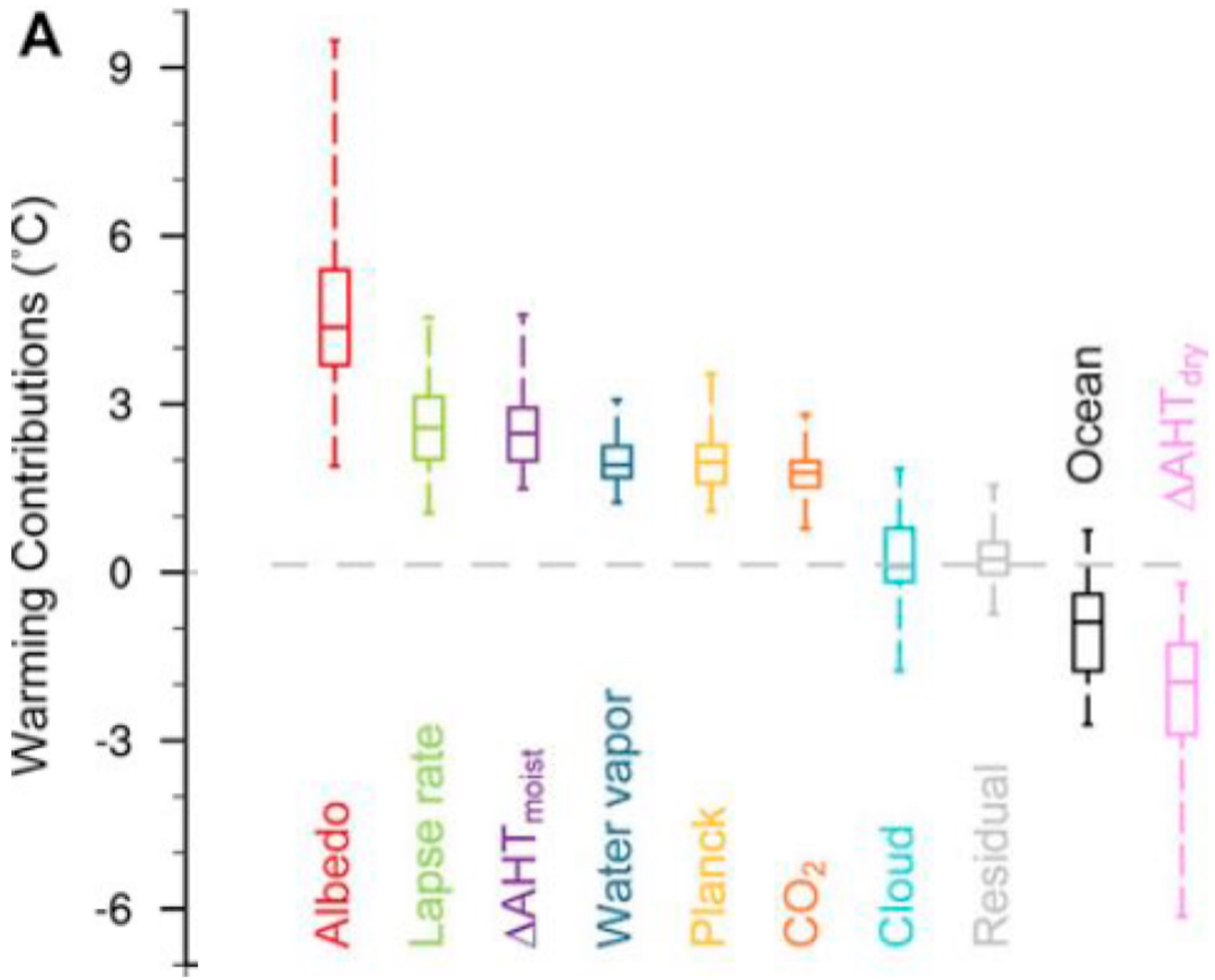


Chen et al. (2020)

Thin, radiatively important clouds are challenging to observed from space.

Number one uncertainty in projected Arctic warming: Surface albedo feedback

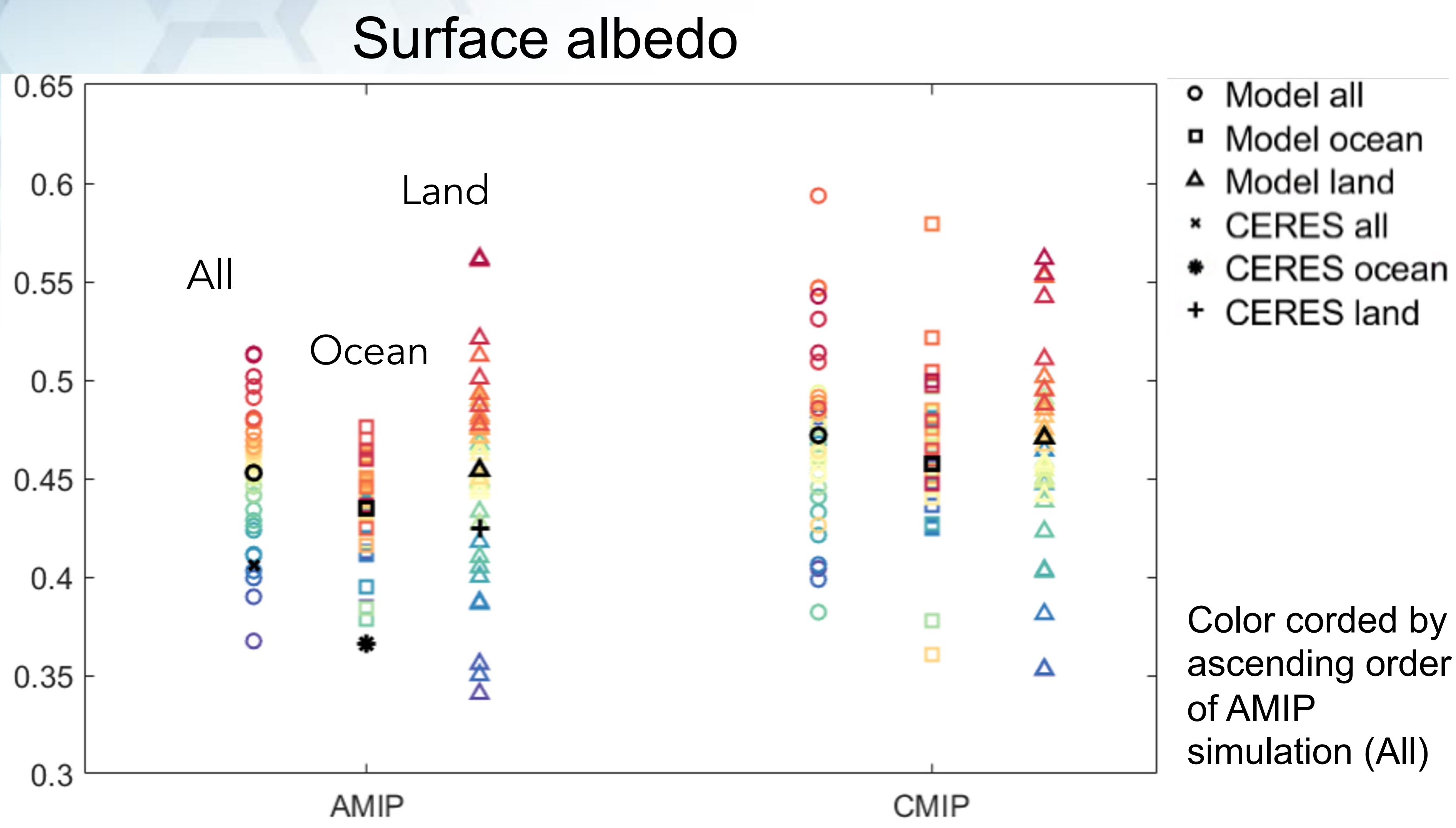
Surface albedo feedback is still the largest factor contributing to the inter-model differences in Arctic warming.



Hahn et al. (2021)

The wide spread in surface albedo across climate models

Substantial inter-model spreads remains in present-day Arctic surface albedo.

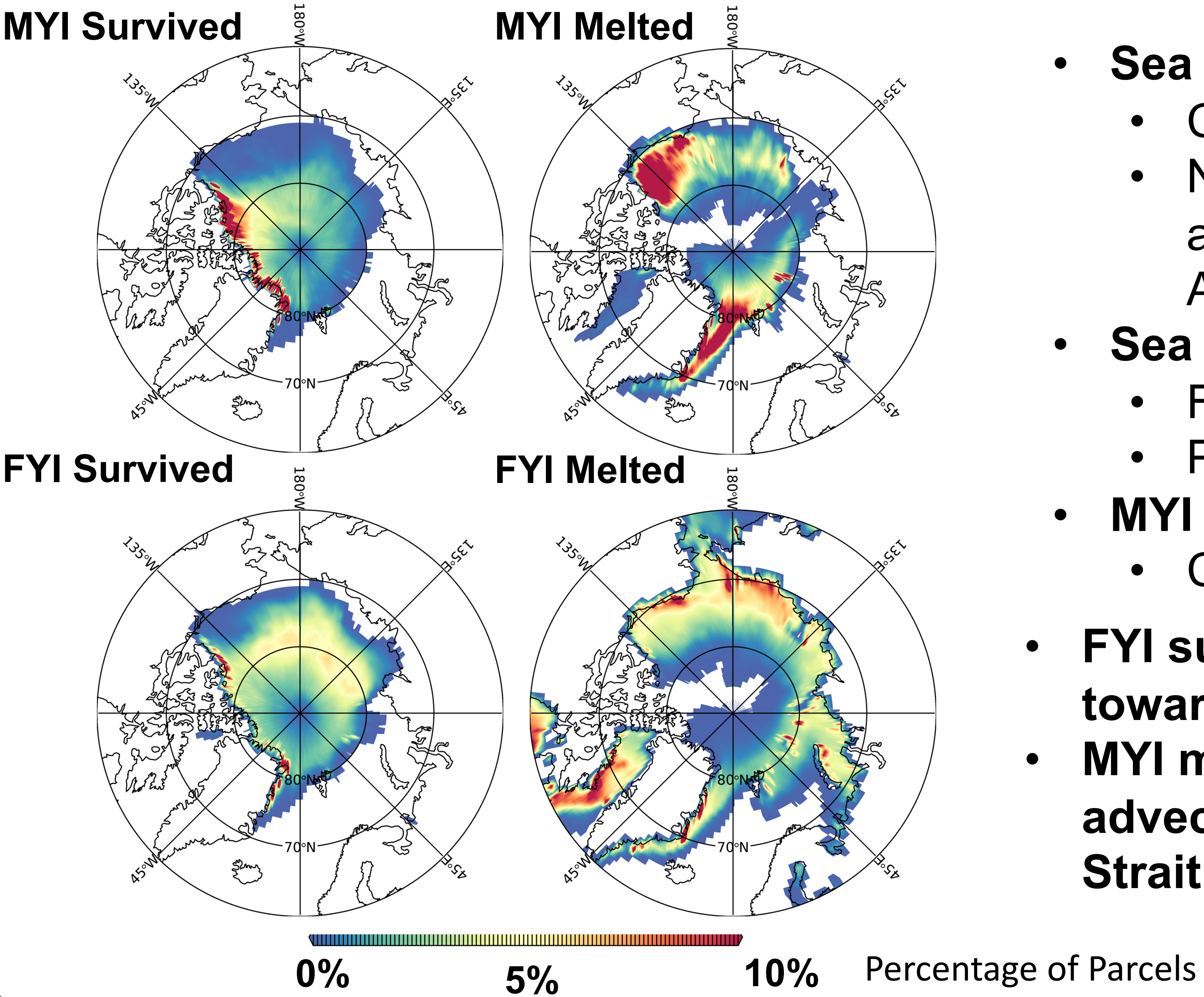


Color corded by ascending order of AMIP simulation (All)

- 39 models
- Sunlight season average (Mar – Sep)

Courtesy of Doyeon Kim (NPP)
Kim and Taylor (in prep)

Why ARCSIX: Sea ice havens, graveyards, and nurseries



- **Sea ice Havens:**
  - Central Arctic
  - North of Greenland and the Canadian Archipelago
- **Sea ice Graveyards:**
  - Fram Strait
  - Peripheral Seas
- **MYI Nursery**
  - Central Arctic.

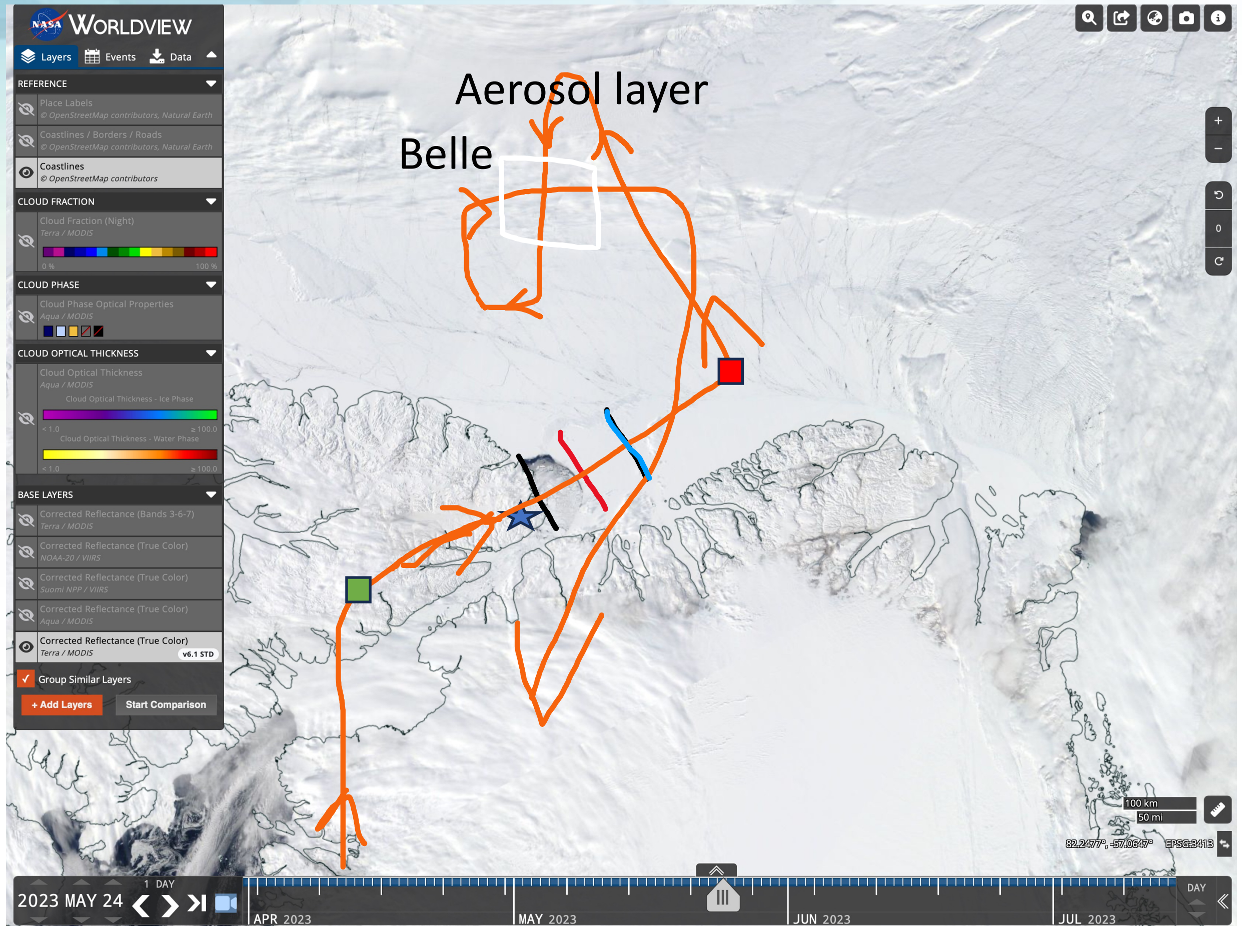
- **FYI survives when it moves towards the central Arctic.**
- **MYI melts out when it is advected into the Fram Strait and Beaufort Sea.**

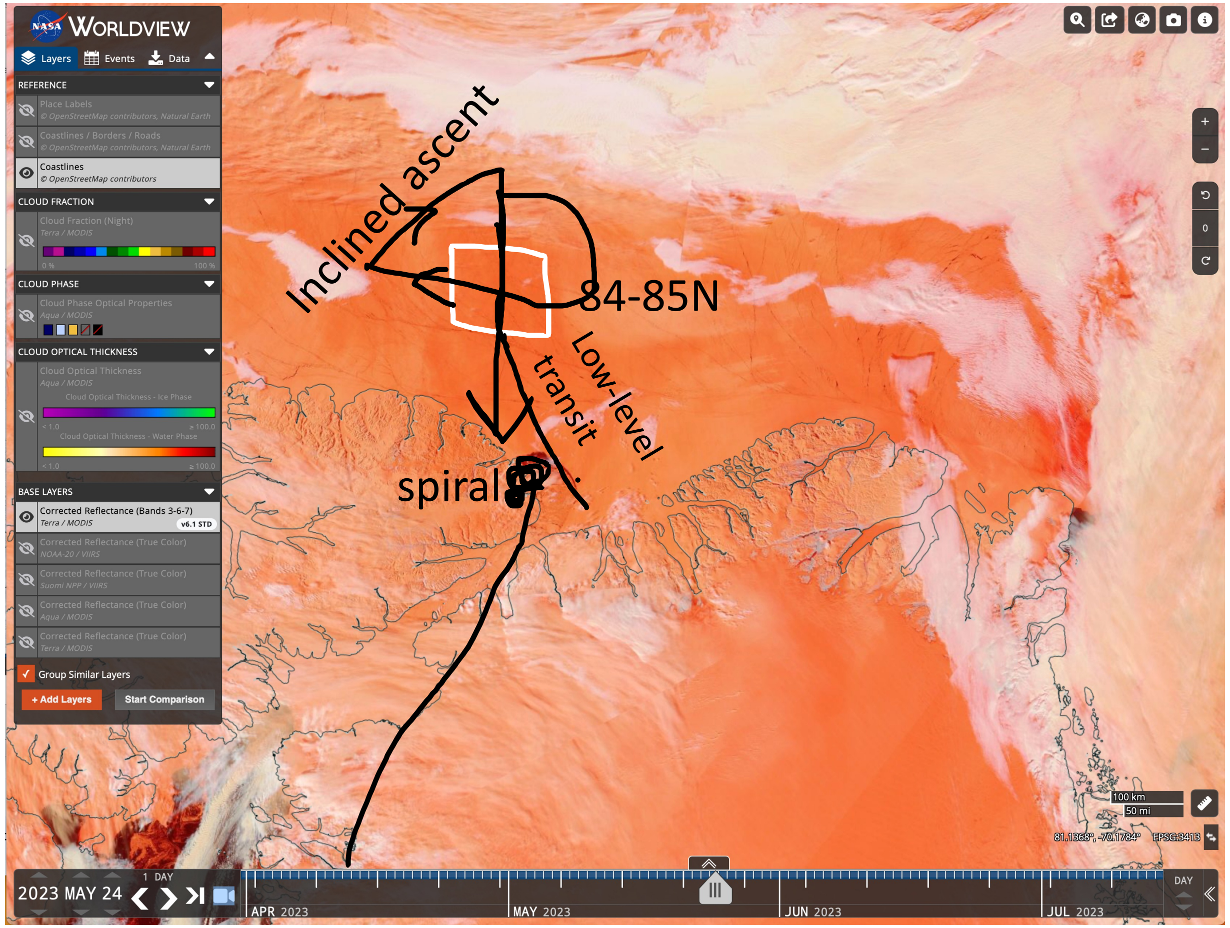
The Arctic surface rapidly evolves and is complex…

Photo: Marco Bagnardi

ARCSIX will observe the full sea ice albedo evolution

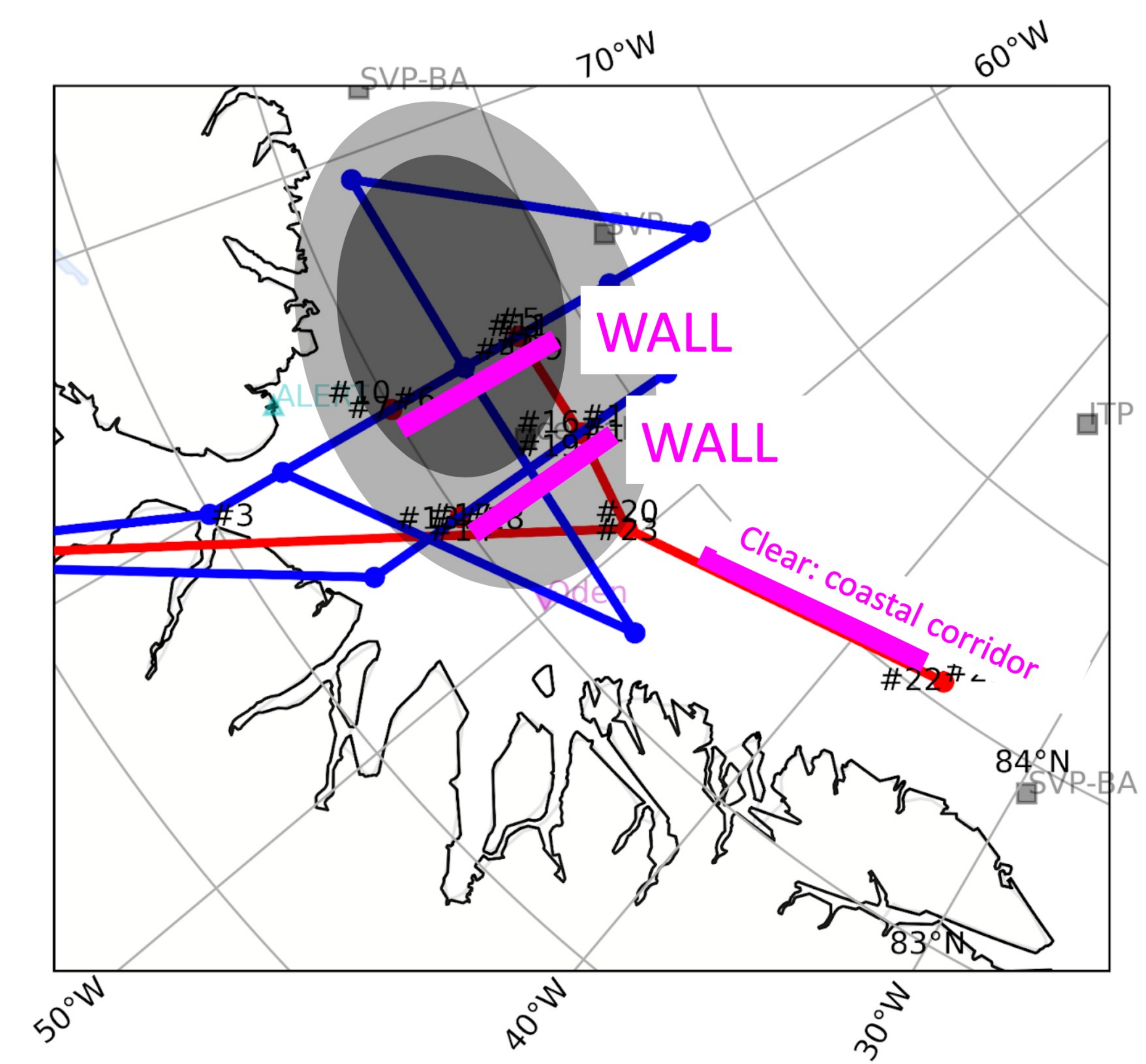
Clear sky radiation and surface characterization flight plan





Cloud lifecycle flight plan

Goal: Sample gradients in cloud properties and covariance with cloud microphysical properties and radiation. (SQ 1 and 2)



Takeaways

https://espo.nasa.gov/ARCSIX_White_Paper

What is ARCSIX? A NASA airborne investigation planned for late spring/early summer 2024 based in Pituffik, Greenland driven by the need to understand how the coupling between the atmosphere and the surface influence energy flows and ultimately sea ice melt.

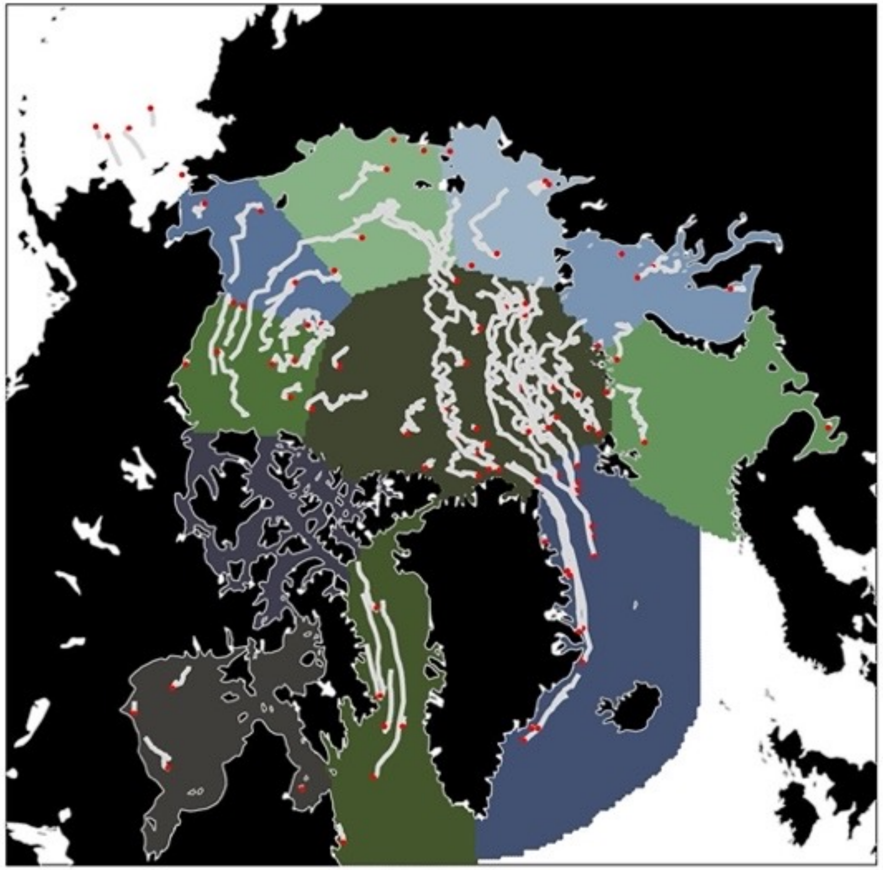
Why ARCSIX? The Arctic is a region that is changing fast with implications for natural and human systems within and outside of the Arctic. Collecting and analyzing data that advances our understanding of the factors that influence sea ice loss will enable better projections and decisions, helping humans thrive on a changing planet.

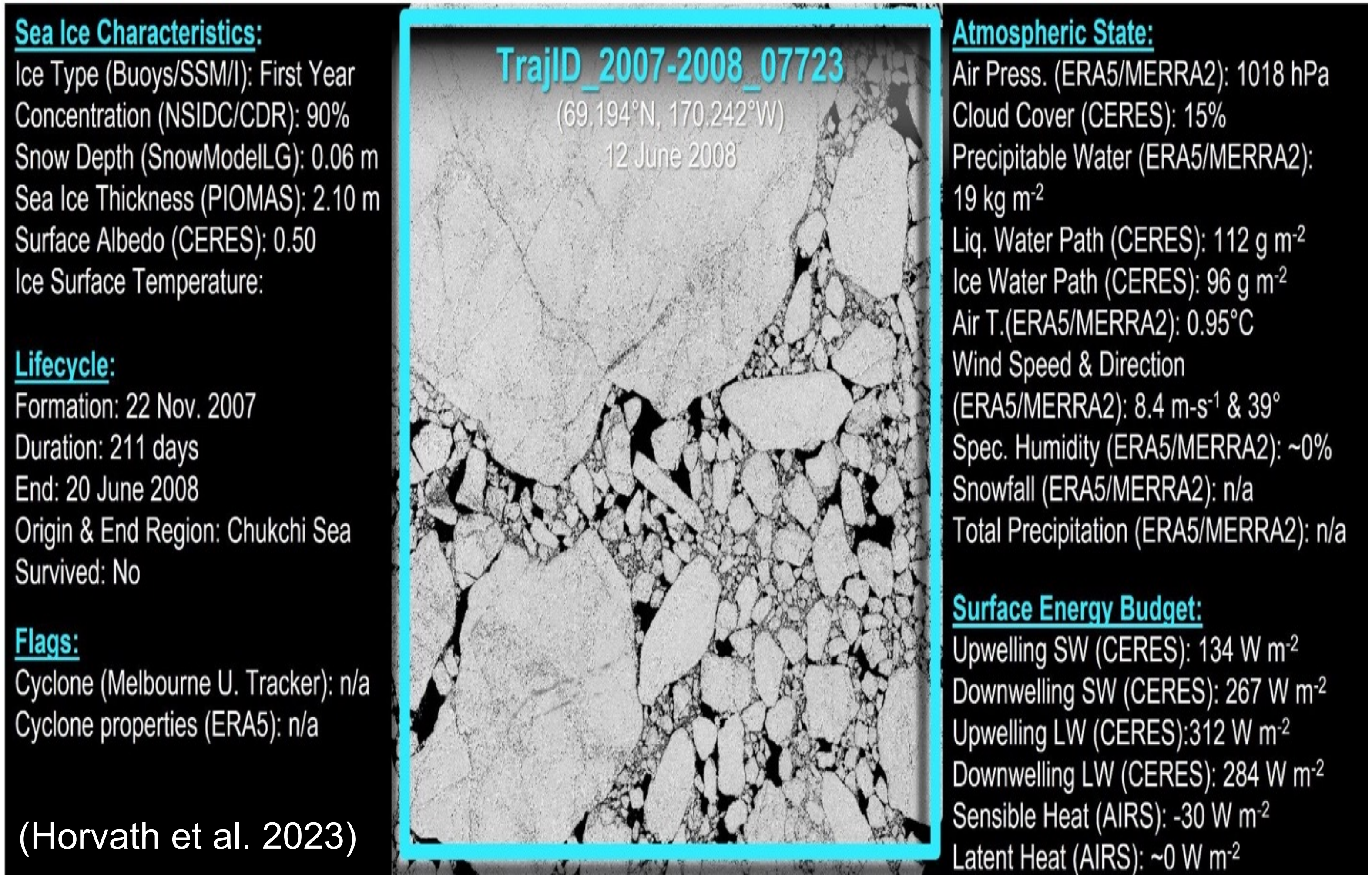
Questions?

Email: Patrick.c.taylor@nasa.gov
Website: https://espo.nasa.gov/arcsix

Back Up Slides

Arctic sea ice parcel database: >1,000,000 parcels from 2002-2020

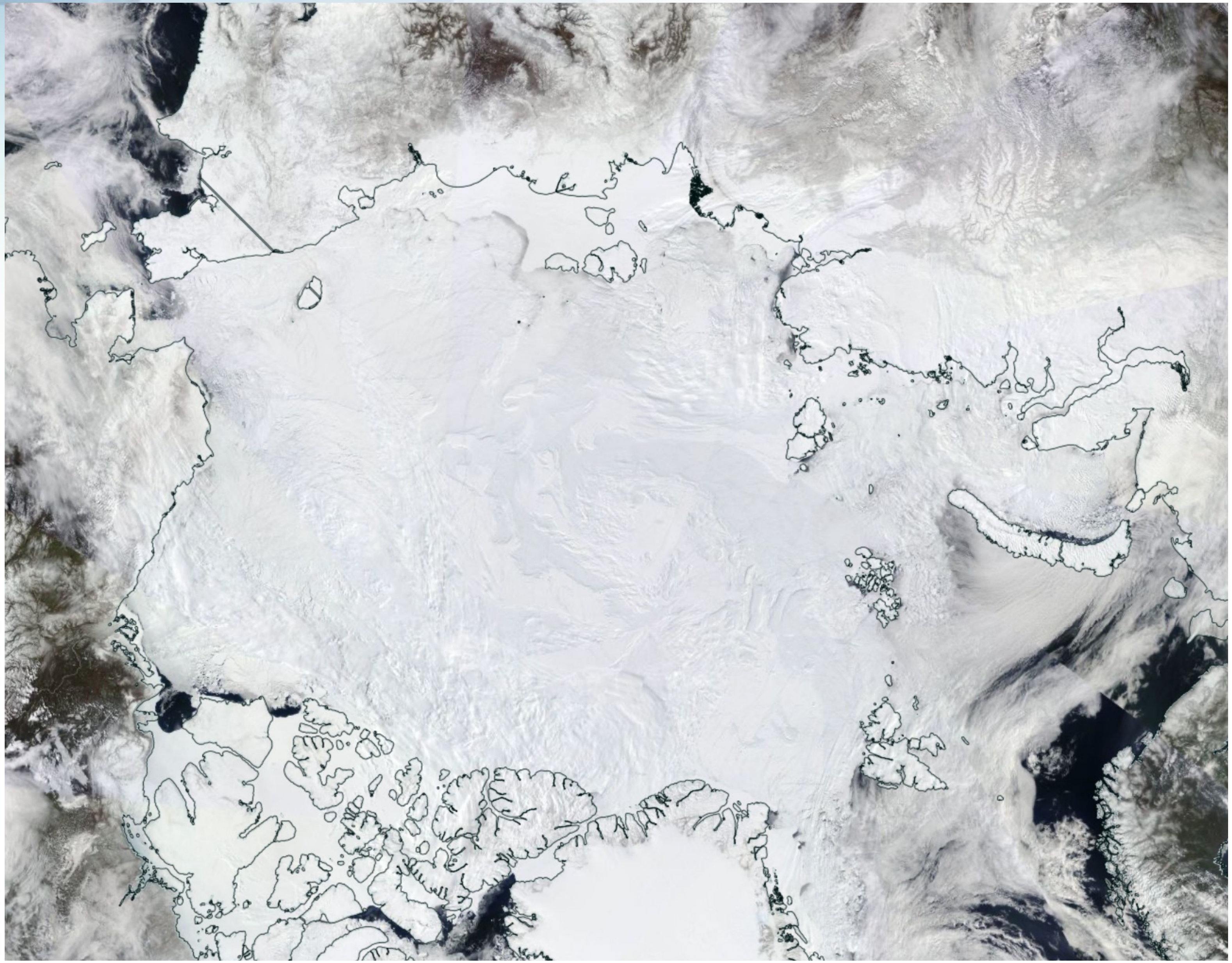




(Horvath et al. 2023)

- New database enables novel studies on the factors influencing on sea ice parcel survival.

The Arctic is a cloudy place



Terra-MODIS May 15, 2023: Worldview

Who is ARCSIX: Project Team

HQ: Hal Maring and Thorsten Markus
Co-PIs: Sebastian Schmidt (radiation) and Patrick Taylor (clouds and surface interactions)
Project Management: Dan Chirica (ESPO)
Flight Planning: Samual LeBlanc (AFRC/BAERI)
Weather Forecasting: Amy Solomon (NOAA), Rei Ueyama (AFRC)

- **G-III:** Brian Baxley (RSD/LaRC)
  - **HALO:** Amin Nehrir (PI:LaRC), Ewan Crosbie (AMA/LaRC)
  - **AVIRIS-NG:** David Thompson (JPL), Steven Platnick (GSFC)
  - **Winds and Dropsondes:** Lee Thornhill (PI: LaRC)
- **P-3:** Brian Bernth (WFF)
  - **SSFR:** Sebastian Schmidt (PI: CU)
  - **BBR:** Anthony Bucholtz (PI: NPS)
  - **LARGE:** Luke Ziemba (PI: LaRC)
  - **DASH-SP:** Armin Sorooshian (PI: U. Arizona)
  - **ATOFMS:** Kerri Pratt (PI: U Mich)
  - **LVIS:** Bryan Blair (PI: GSFC)
  - **MARLI/GVR:** Z. Wang (PI: CU, Boulder) P. Zuidema (U. Miami)
  - **CFDC:** Paul DeMott (PI: CSU)
  - **RSP:** Brian Cairns (PI: GISS)
  - **FIMS:** Jian Wang (PI: WUSTL)
  - **DLH:** Glenn Diskin and Josh DiGangi (co-PI: LaRC)
  - **Aerosol and Cloud optical probes:** Paul Lawson (PI: SPEC)
- **AERONET:** A. Smirnov (GSFC/SSAI)
- **Data management:** Gao Chen and Michael Shook (LaRC)

External Partners/Collaborators:

Villium Research Station
- Henrik Skov

Alfred Wegener Institute (Ice Bird):
- T. Krumpen

Oden, Swedish Ice Breaker
- Åsa Lindgren, Martin Jakobsson,Michael Tjernström

GoNorth, Norwegian Ice Breaker
- Jan Inge Faleide

Univ. Dartmouth:
- Chris Polashenski

International Arctic Buoy Programme:
- Ignatius Igor

University of Leipzig, (AC)^3:
- Manfred Wendisch

How ARCSIX: 12 Scorecard elements

Cryosphere:

- Influence of precipitation on surface properties
- Surface melt evolution tracking (influence of initial surface conditions on melt)
- Surface influence on Atmosphere (gradient module)

Radiation/Remote Sensing:

- Surface BRDF and albedo
- Evaluating and improving passive remote sensing retrievals of cloud presence, phase classification, cloud optical/microphysical properties (including mixed phase clouds)
- Thin cloud surface radiative effects

Clouds:

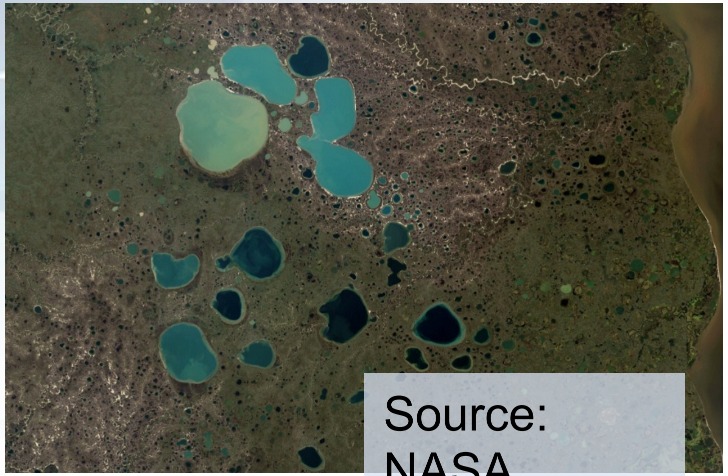
- Ice phase production in single-layer clouds
- Lagrangian cloud sampling/water vapor transport

Aerosol:

- Aerosol types contributing to CCN/IN budgets and INP Characterization
- Aerosol-driven freezing effects on clouds/radiation/precip
- Evolution of aerosol and BL structure during transport events
- Improve satellite remote sensing of aerosol and aerosol transport modeling (amount and type)

Why ARCSIX?

Source: CNN


Source: NASA


Source: BBC

These rapid changes have consequences for human and natural systems.


Source: WWF


Source: shifting-ice.blogspot


Source: Climate Central

ARCSIX Legacy and Future

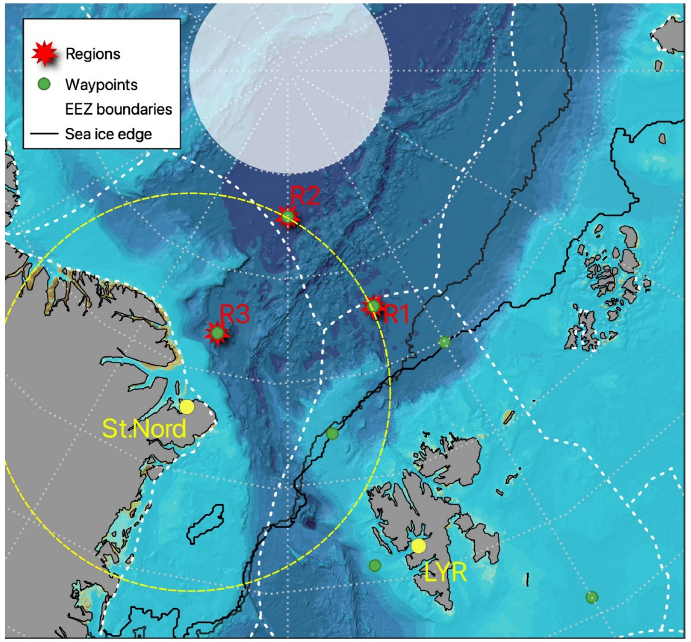
- Sea ice mass balance buoy array, contribution to the Arctic Observing System contribution
- One-of-a-kind data set to advance Arctic System understanding.
- Unexpected/new samples of Arctic Atmospheric Composition.
- Improvements in polar satellite retrievals.
- New case studies of Arctic cloud systems to improve understanding and climate modeling.

Future:

Lead, support, and enhance international Arctic science community activities.

CONTRASTS – Objectives

AWI



Characterize the key processes that determine the observed sea ice, ocean, atmosphere, and ecosystem changes in the Arctic Ocean

- Contrasting ice regimes (3 regions)
  - R1) seasonally ice covered MIZ
  - R2) year-round mixture of FYI and MYI in the central basin / Transpolar drift
  - R3) year-round MYI north of Greenland
- Improved understanding of causes and future impacts
  - Process understanding
  - Model parameterizations
- First study of this kind