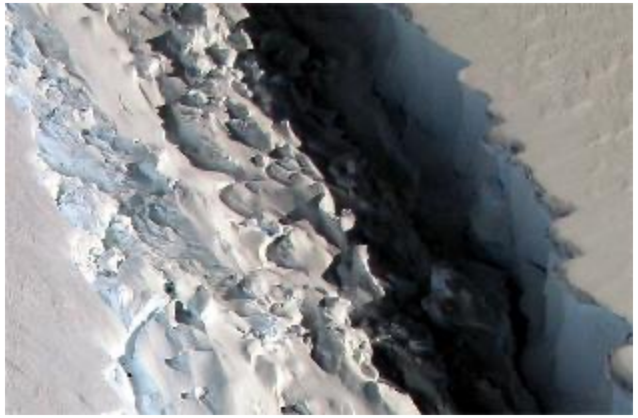
National Aeronautics and
Space Administration

SCIENCE



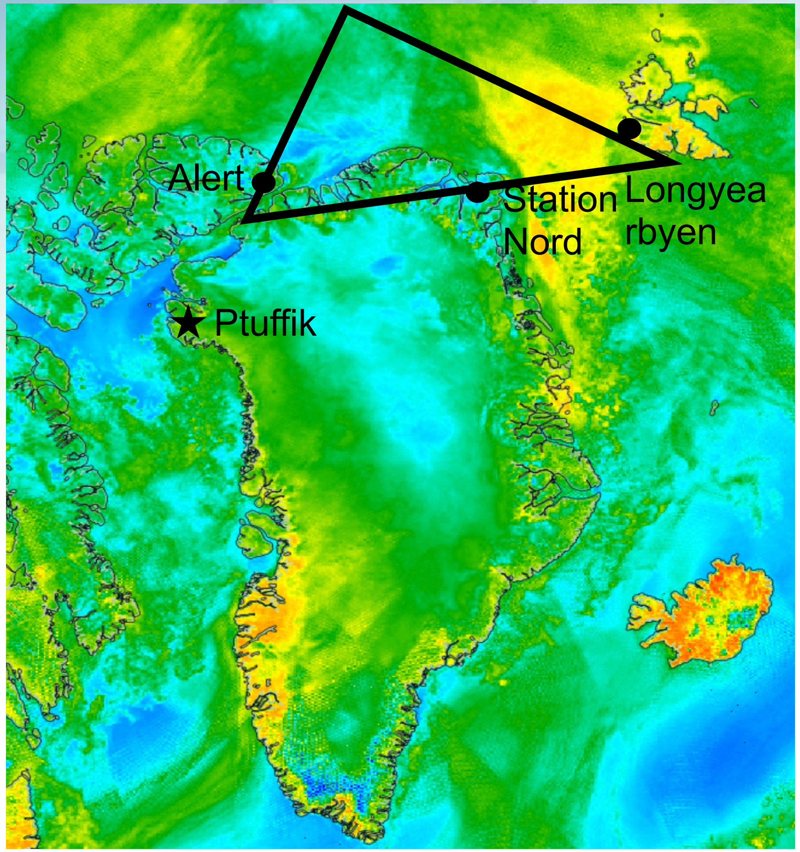



Patrick Taylor, Climate Research Scientist

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 (Univ. Colorado) and Patrick Taylor (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

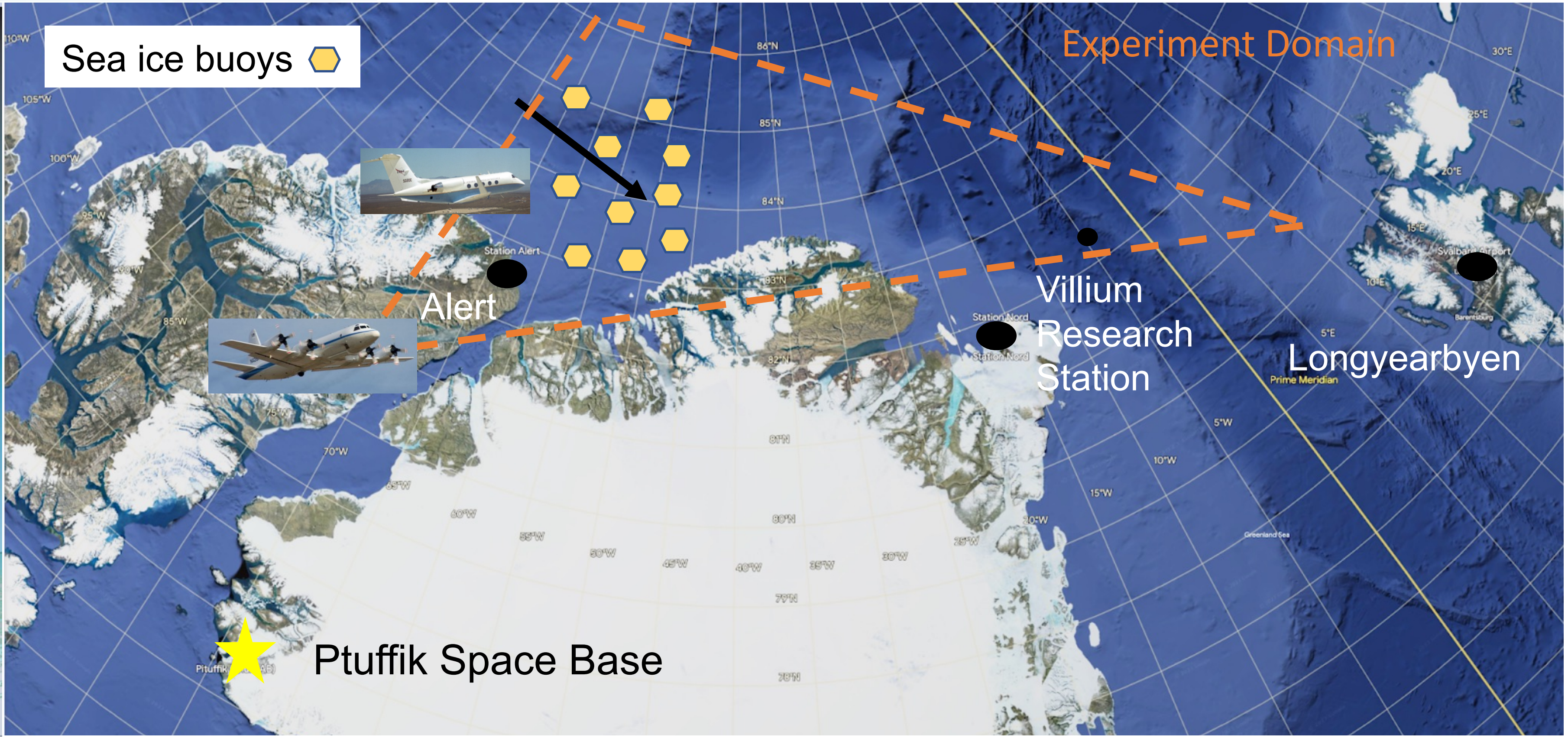
NASA ARCSIX 2024

What is ARCSIX: Deployment Concept

Airborne Assets:
- Low-flying, in situ platform (P-3), ~175 Flight hours
- High-flying, remote sensing platform (G-III), ~150 Flight hours

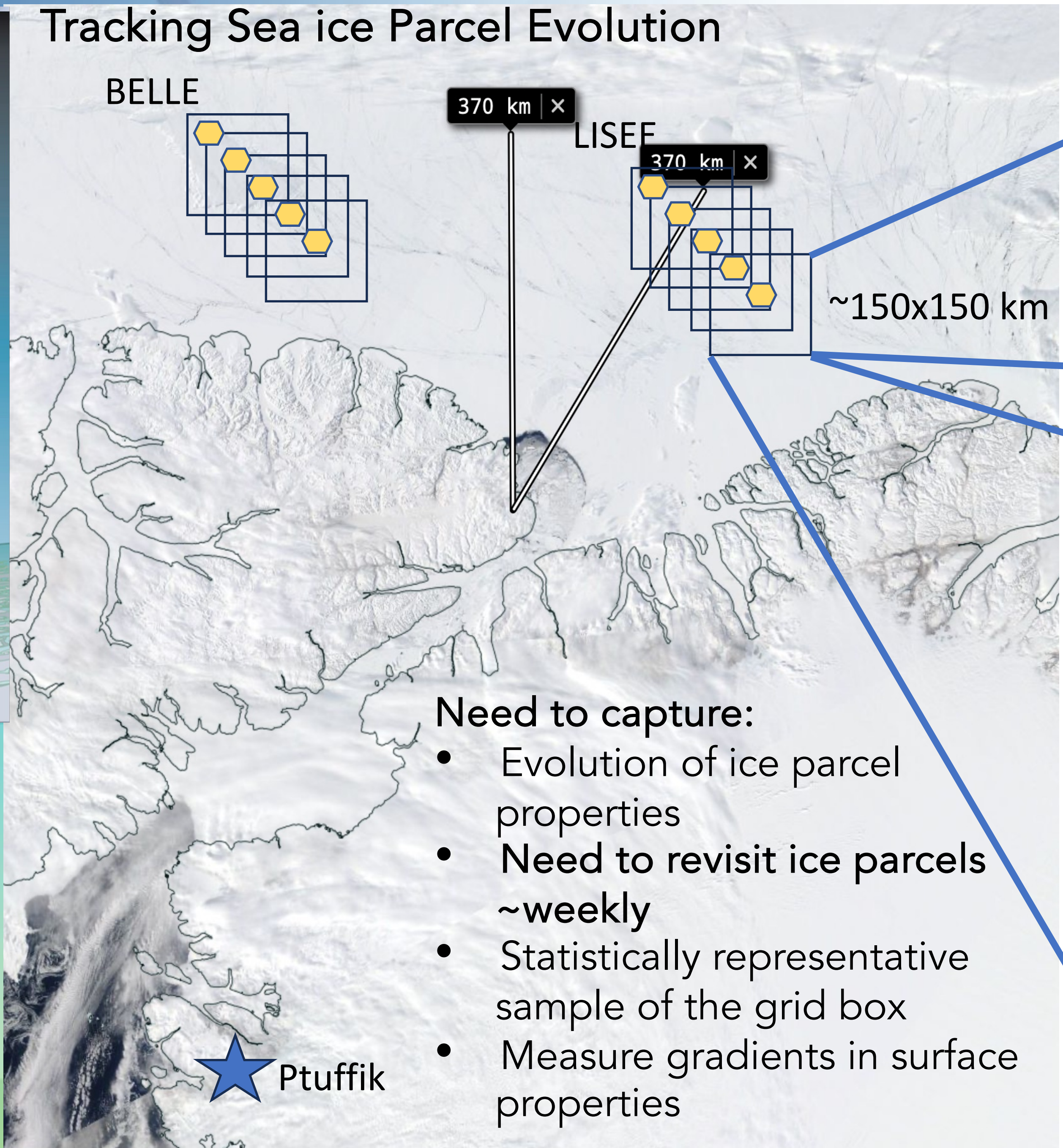
Satellite Assets:
- Available passive instruments (e.g., MODIS/VIIRS, CERES)
- Available active instruments (e.g., EarthCARE, ICESat-2)

Modeling Assets:
- Real-time atmosphere and sea ice forecasts and trajectories
- Multi-scale modeling for post-campaign analysis



ARCSIX: Sea ice parcel sampling strategy

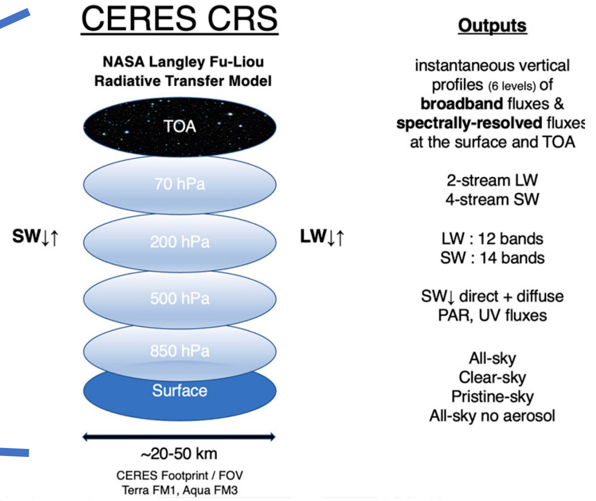
Tracking Sea ice Parcel Evolution

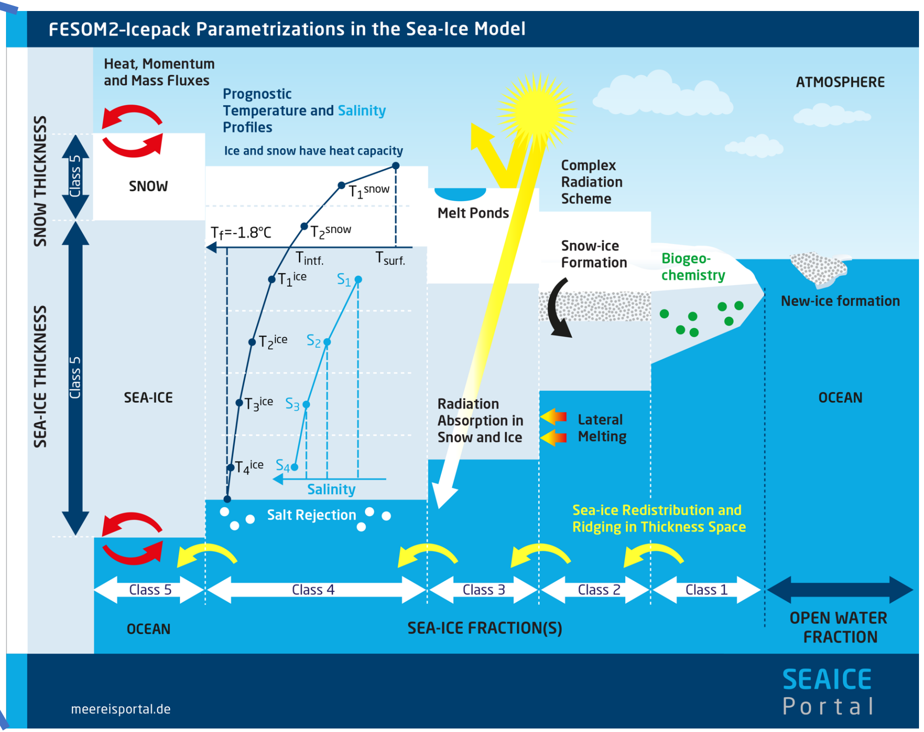


Need to capture:

- 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

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

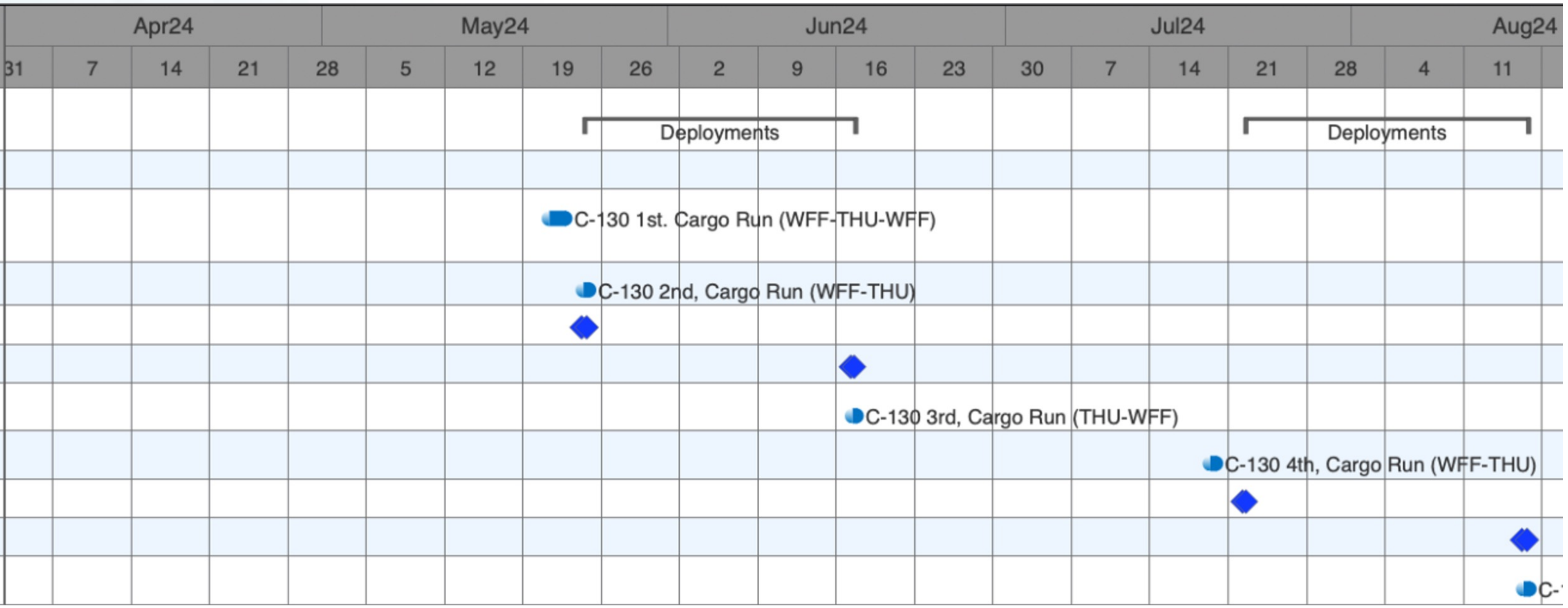
Univ. Dartmouth:
- Chris Polashenski

International Arctic Buoy Programme:
- Ignatius Igor

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

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:

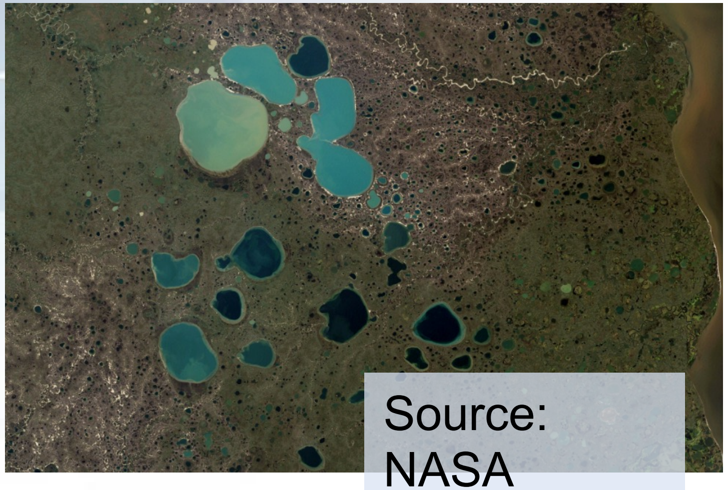
- ARCSIX will use the WFF C-130 for airlift, cargo and personnel.
- May 21 - 22, Max Cargo run, WFF - THU - WFF assume no pax
- May 24 - Cargo run WFF -THU w/ 50 pax

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?

Source: CNN


Source: NASA


Source: BBC

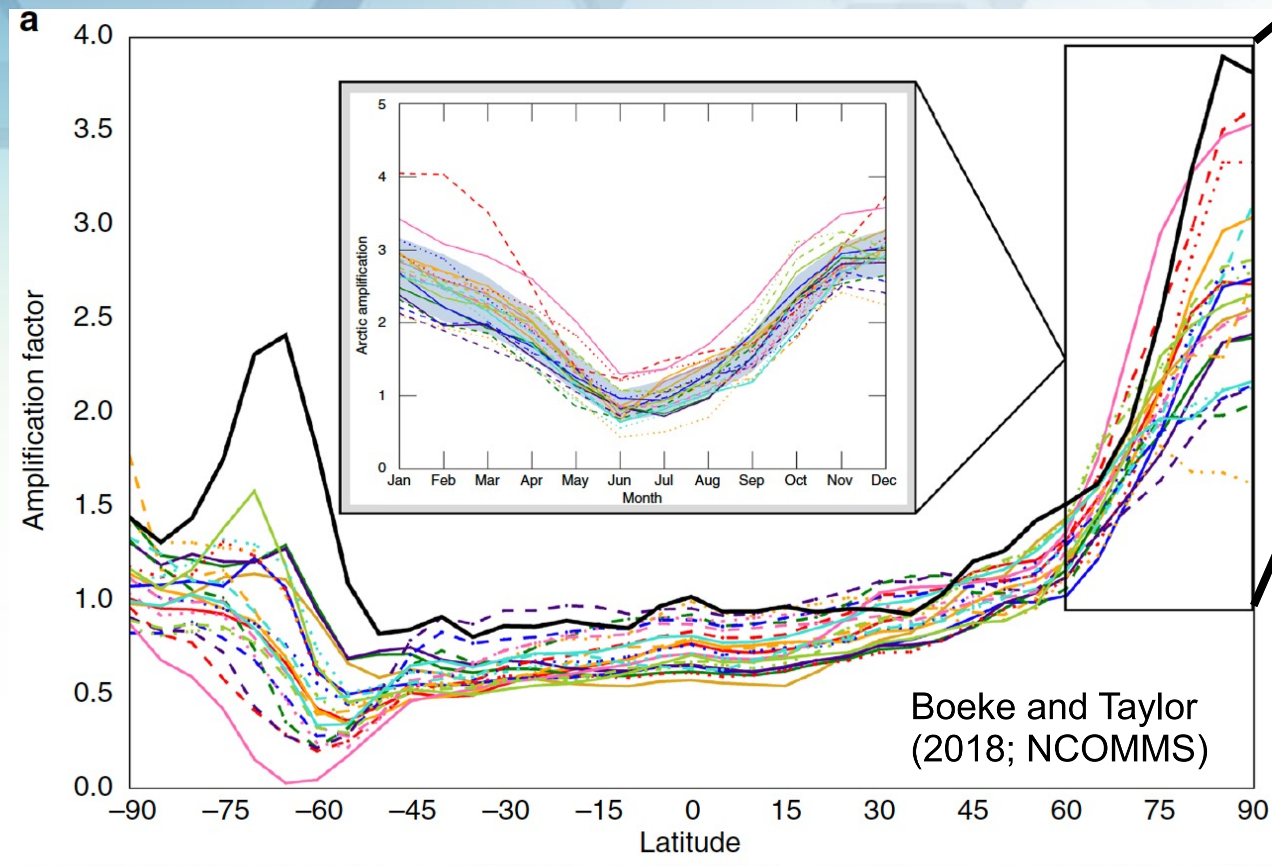
These rapid changes have consequences for human and natural systems.


Source: WWF


Source: shifting-ice.blogspot

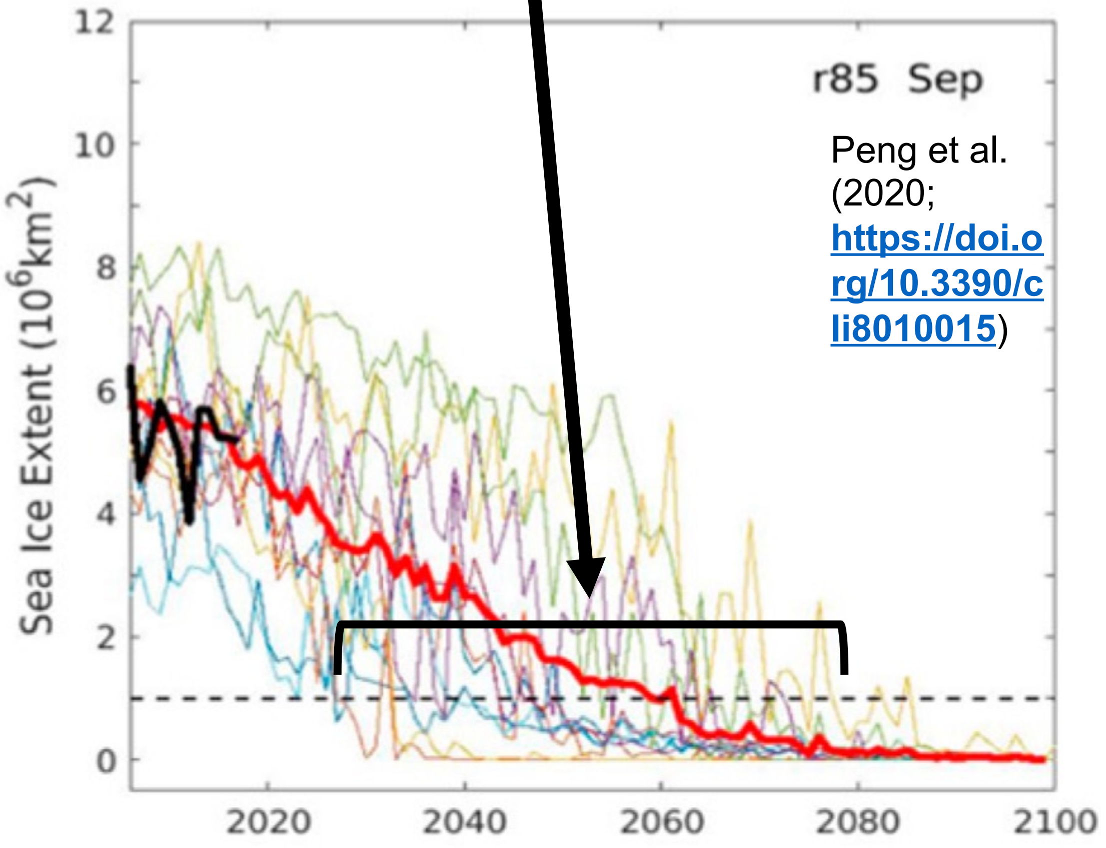

Source: Climate Central

Why ARCSIX?



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

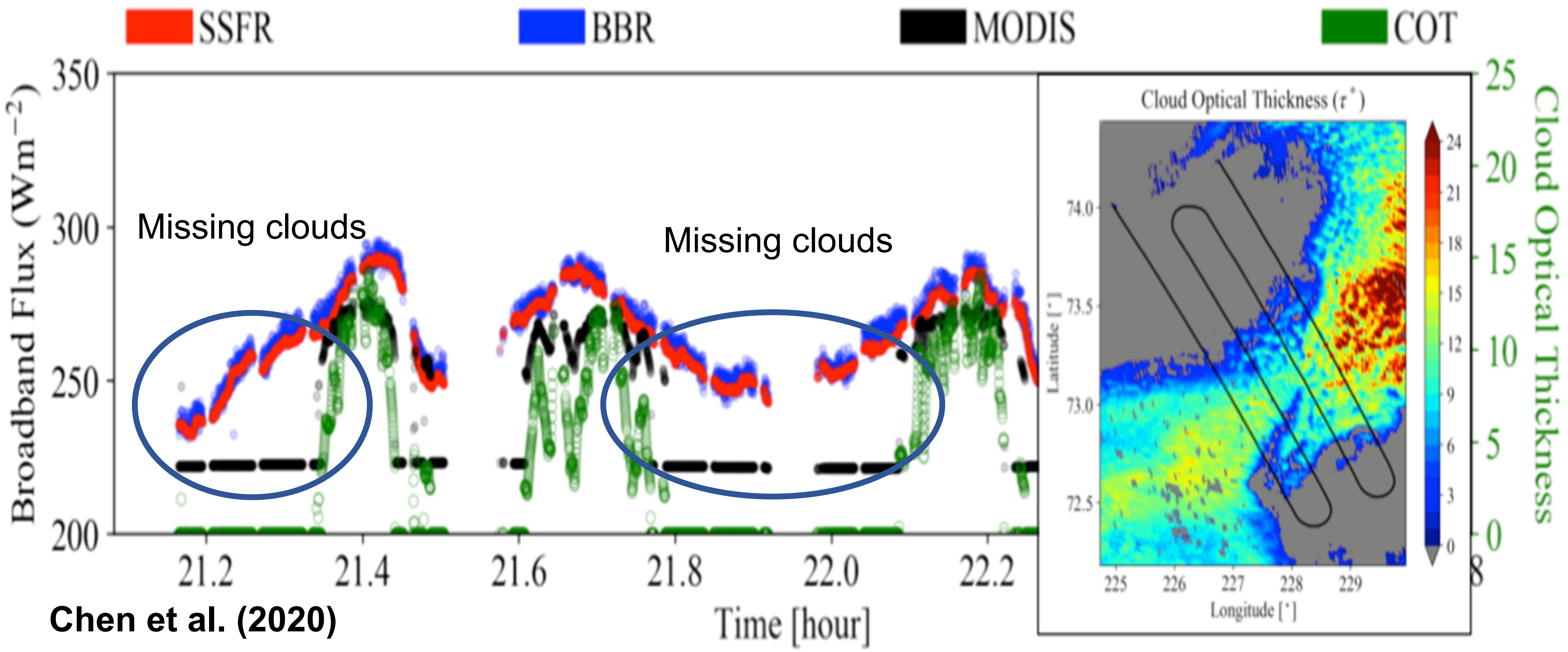
~50 year spread in the timing of the first ice free Arctic summer



…our models are inadequate to inform society.

Why ARCSIX?

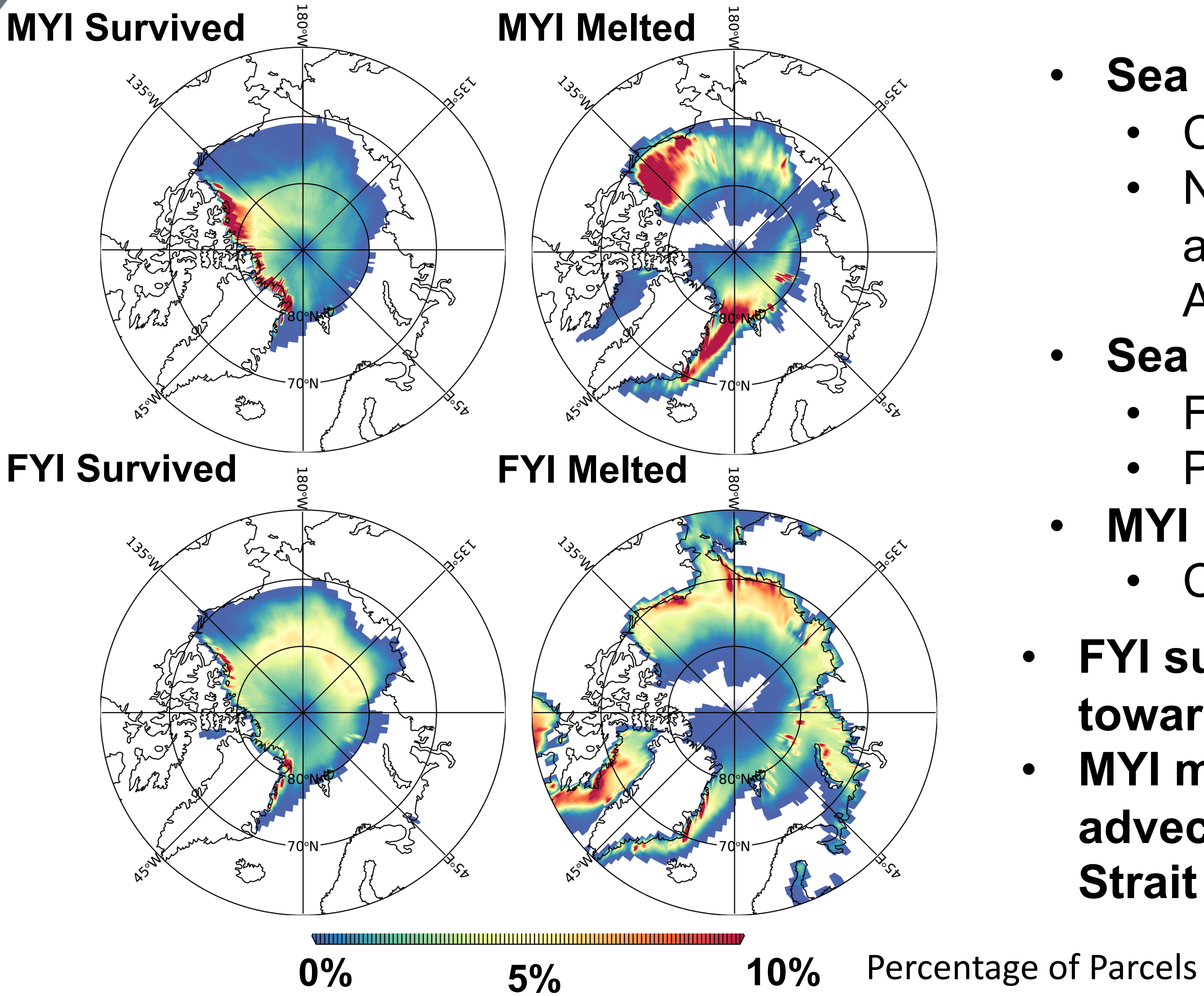
…model uncertainty stems challenges in observing Arctic clouds and other properties from space.



Chen et al. (2020)

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

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.**

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 ROSES 2021 (NNH21ZDA001N-ARCSIX)

<u>Project Goals</u>

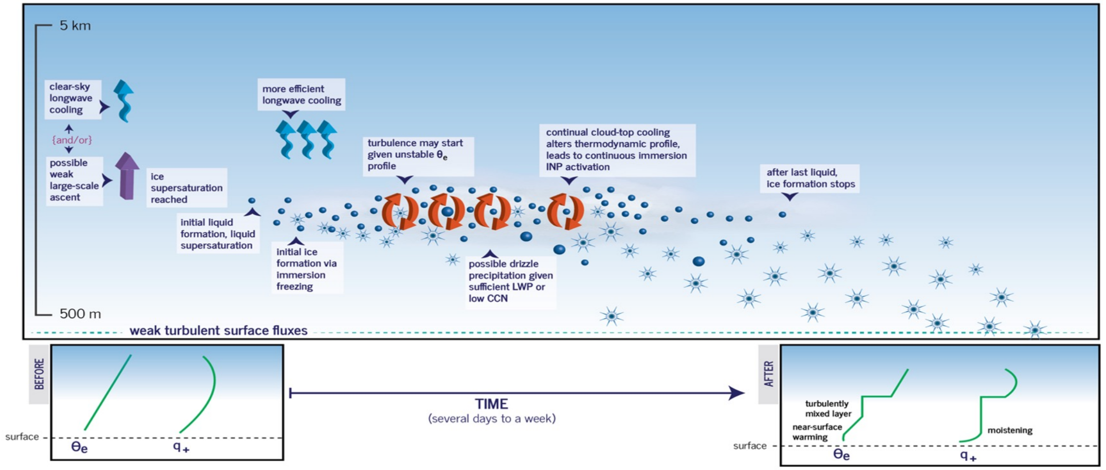
Provide an unprecedented data set of the clouds, aerosol, and surface properties in the region of multi-year sea ice North of Greenland to quantify the contributions to summer sea ice melt:

ARCSIX is driven 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

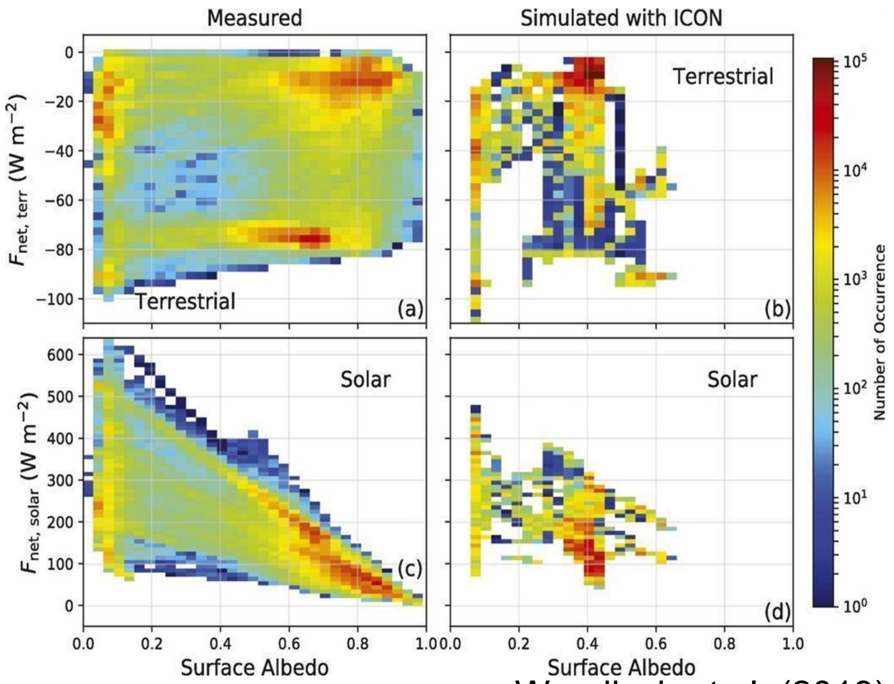
ARCSIX Science Questions:

● 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)

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

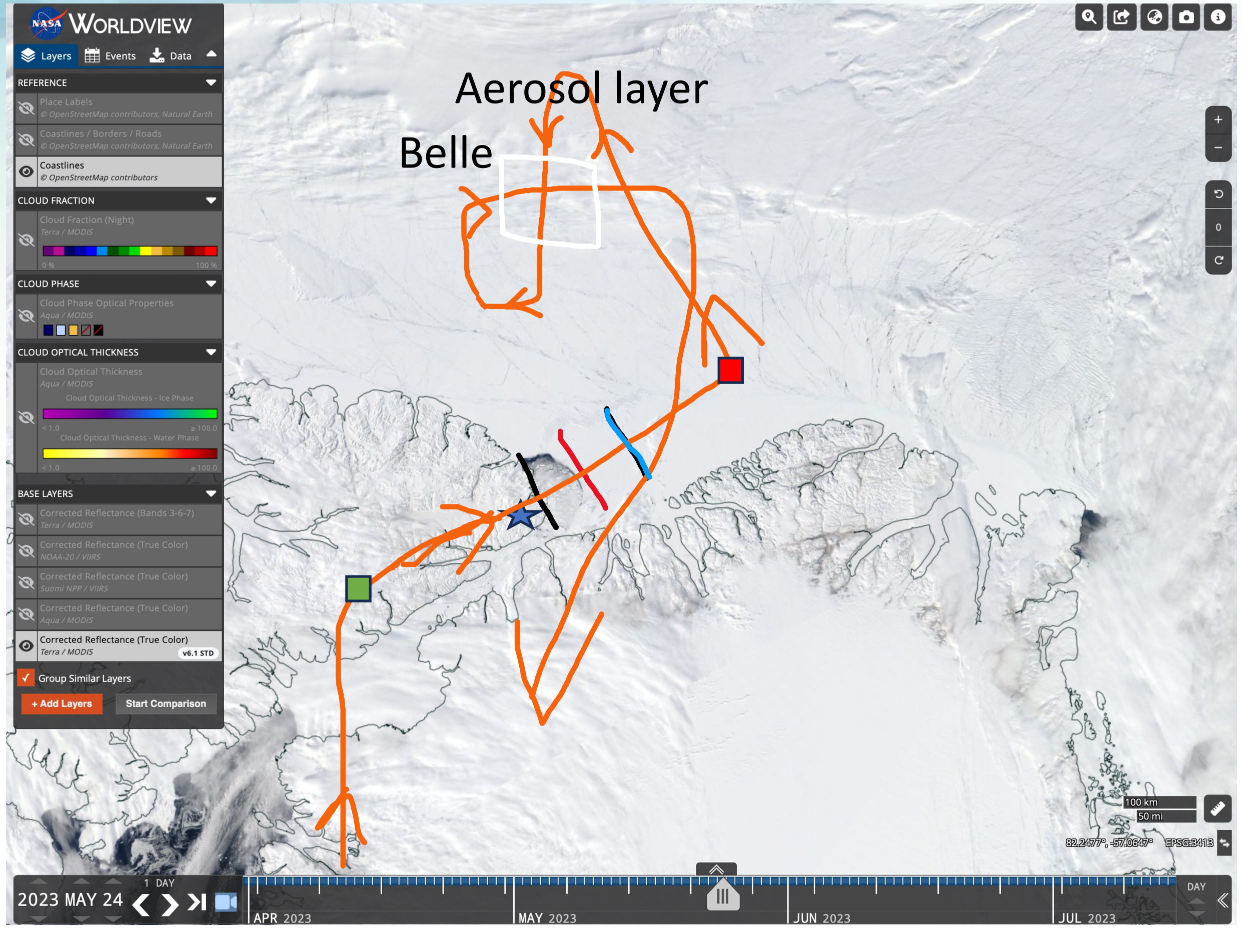
Clouds:

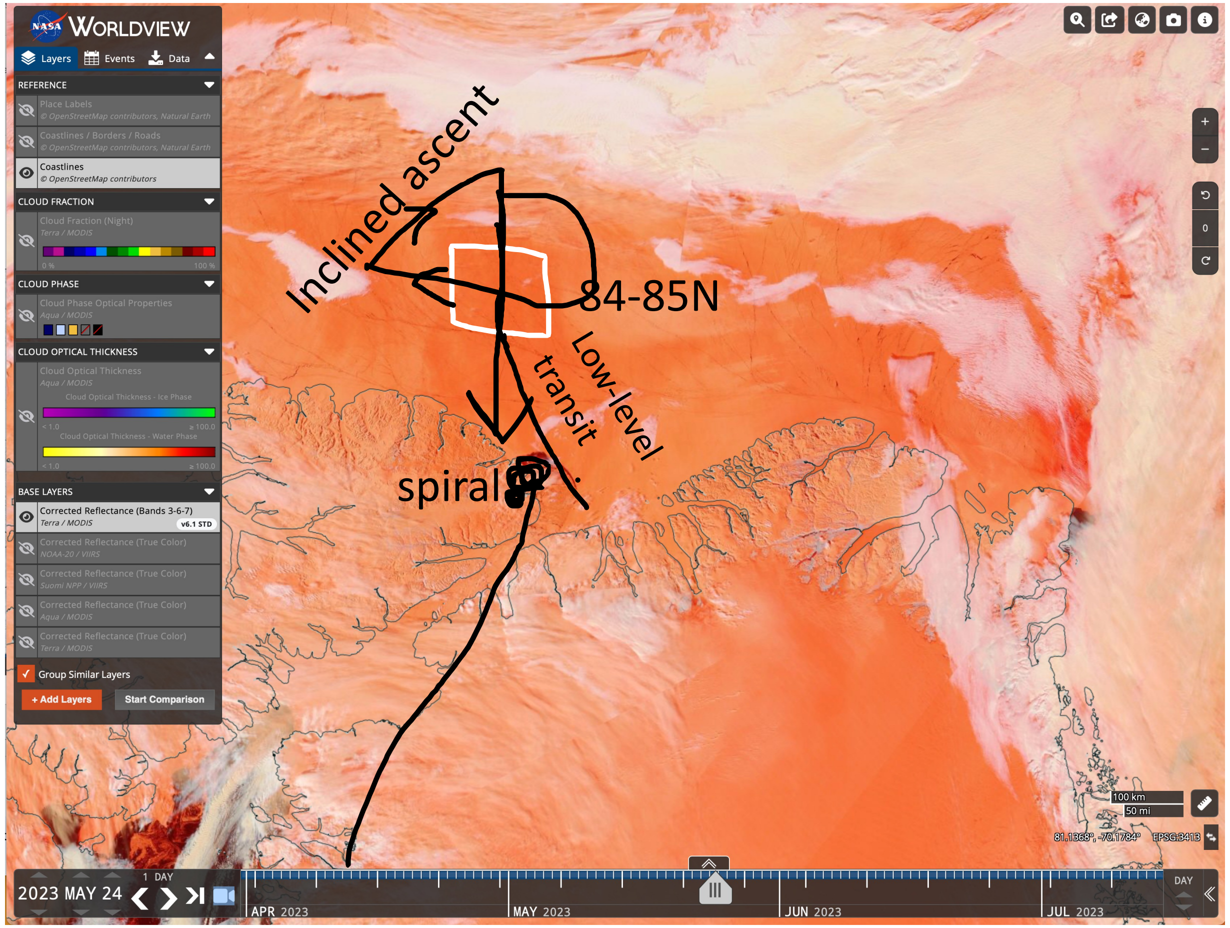
- Ice phase production in single-layer clouds
- Lagrangian cloud sampling/water vapor transport

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)

Clear sky radiation and surface characterization flight plan





What We Are "Doing" Now

- Weekly Leadership tag-ups
- Bi-weekly Aircraft operations meetings
- Bi-weekly All-hands meetings
- Bi-weekly Flight planning sessions
- In-person Science Team Meeting (HQ, April 16-18)
- Finalized Field Code of Conduct Document
- Finalizing Comms strategy and travel arrangements

ONGOING and UPCOMING

- Distribution of Anti-harassment Training slides
- P-3 and G-III Integration and test flights
- Sea Ice Mass Balance Buoys deployment (now)
- Deployment 1 May 24-June 17, 2024
- Deployment 2 July 19-August 17, 2024

Arctic Radiation · Cloud · Aerosol · Surface Interaction Experiment

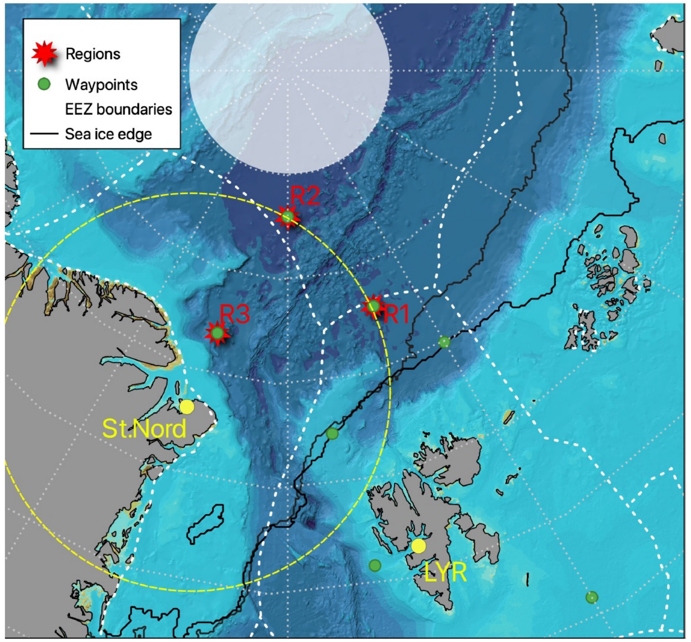
NASA ARCSIX 2024

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



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

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.

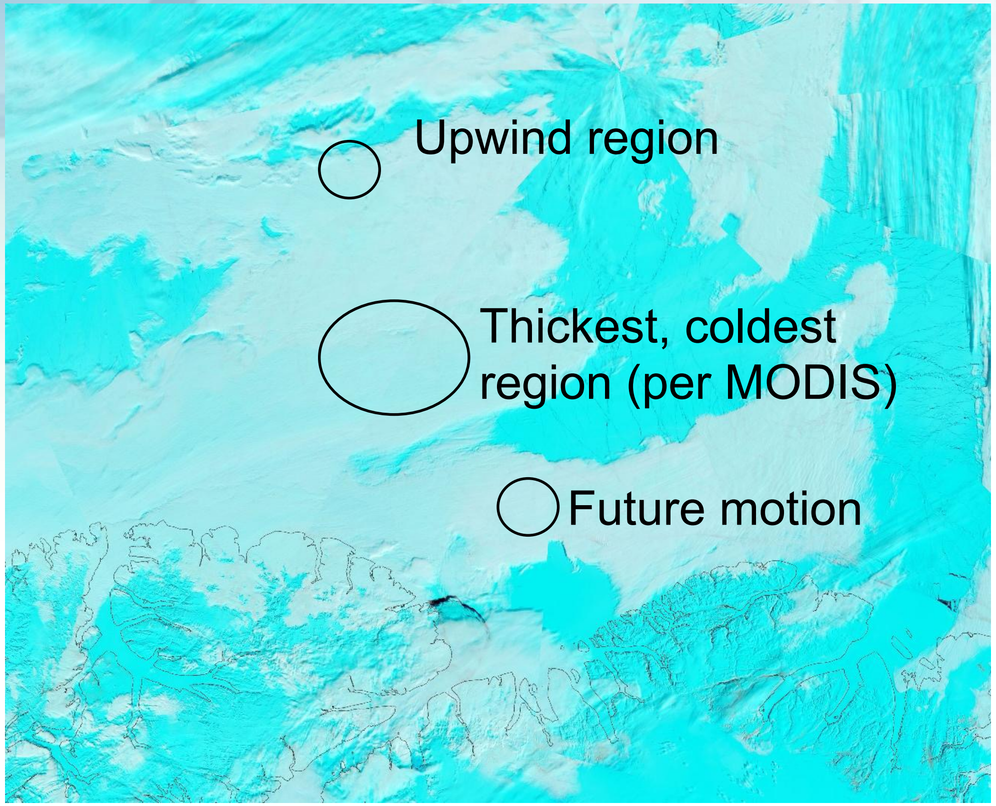
Questions?

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

Back Up Slides

LaGrangian cloud evolution flight plan

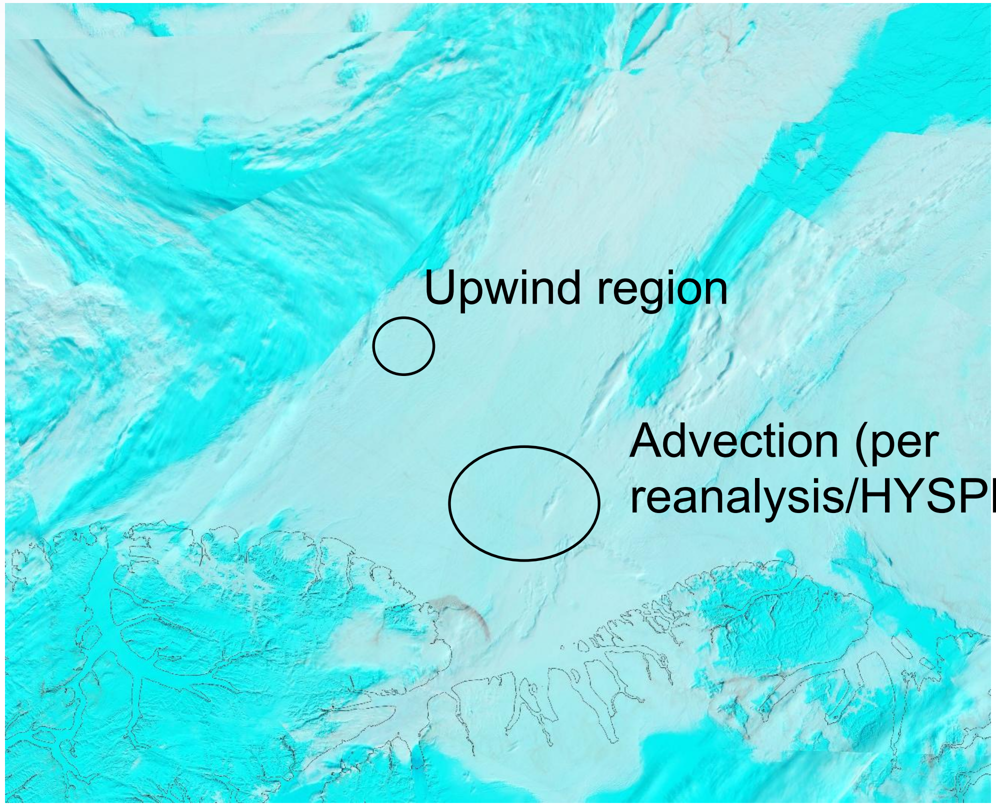
2023-05-19



Conceptual plan:

- Survey along the transport axis linking these 3 regions
- Dropsondes spaced along this axis
- Background aerosol characterization (no indication of significant intrusion)
- 2 wall patterns oriented across the wind (upwind and main)
- Main wall: more time, more G3 coordination, Lear limited

2023-05-20



Conceptual plan:

Revisit locations of previous wall patterns to evaluate changes to aerosol and cloud properties

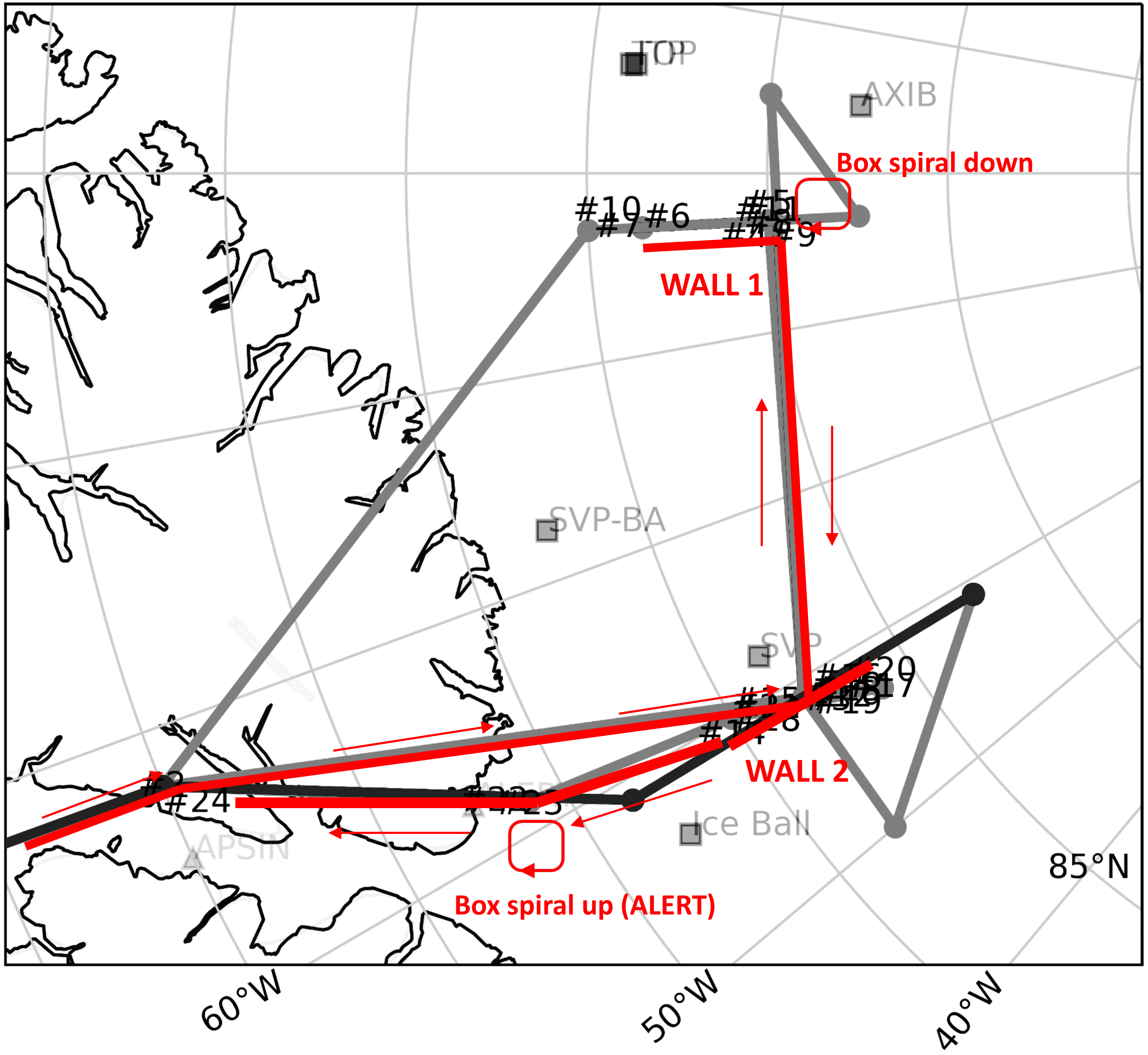
Dropsondes spaced along the advected axis

2 wall patterns oriented across the wind (upwind and main)

Main wall: more time, more G3, more Lear.

P3

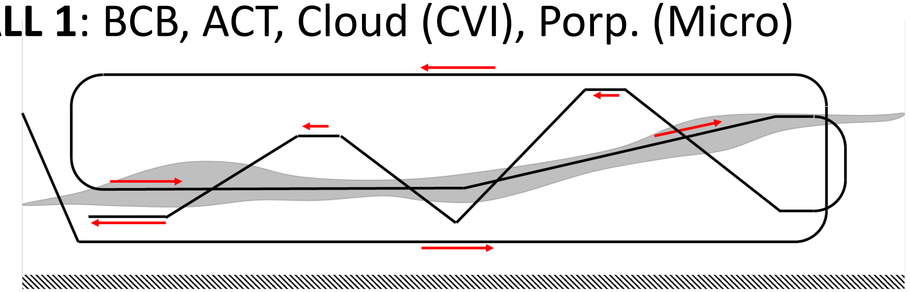
2023-05-20



Survey: RS and trop. bkg. aerosol/gas (5-6 km)

- Long duration at constant alt for INP & MS
- Near Principal Plane

WALL 1: BCB, ACT, Cloud (CVI), Porp. (Micro)



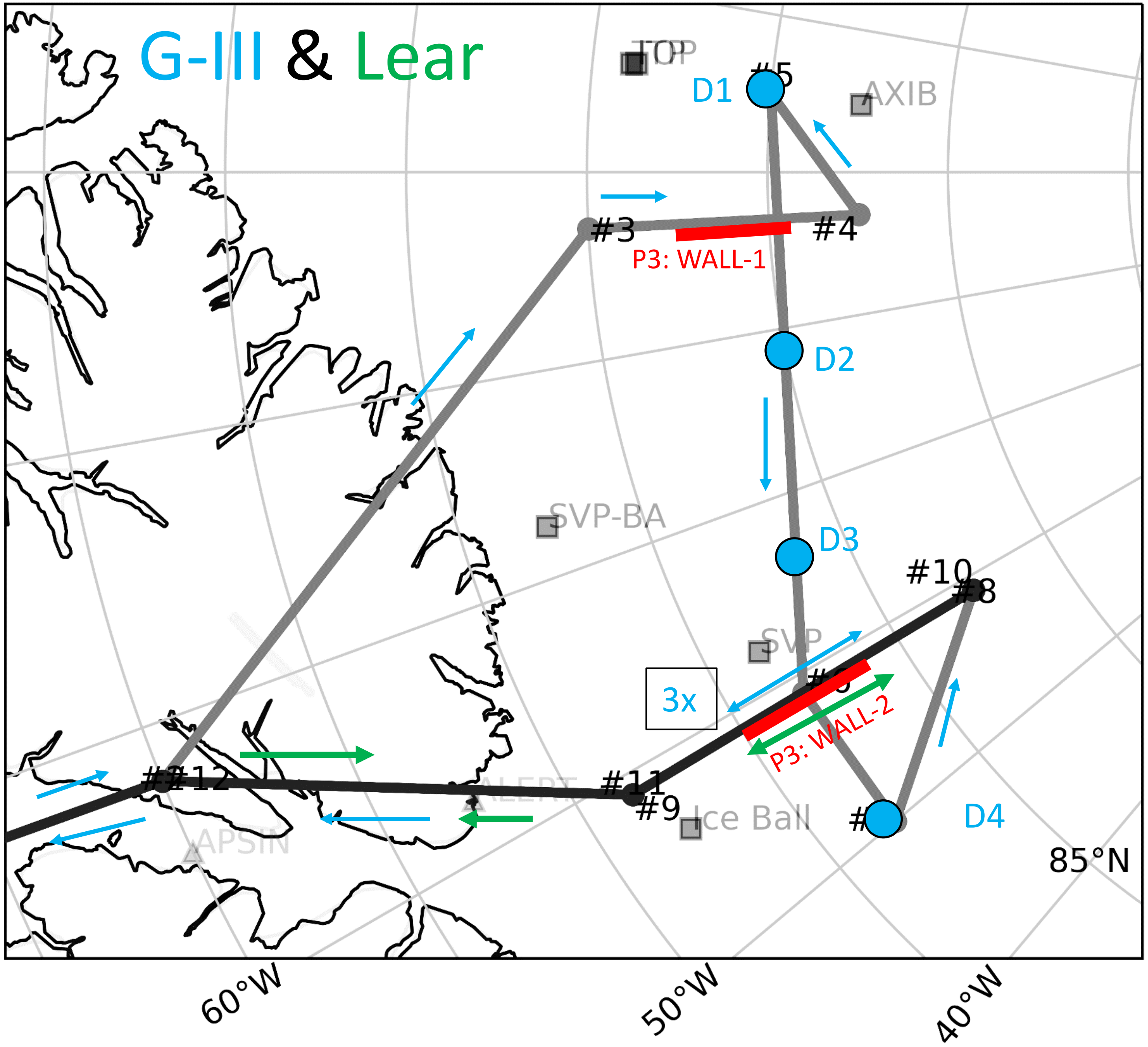
WALL 1 to WALL 2: Porpoise with pauses (flight scientist call)

WALL 2: As Wall 1 but adding RS (2.5 km) at end

- For 2.5 km leg, Lear and P3 switch (timing critical)
- Near Principal Plane

Low Level + ALERT spiral: Move to ALERT spiral location at low altitude

2023-05-20



G-III notes:

- 4 dropsondes on leg between upwind of WALL-1 and downwind of WALL-2
- FL250 for science legs (pt #3-11)

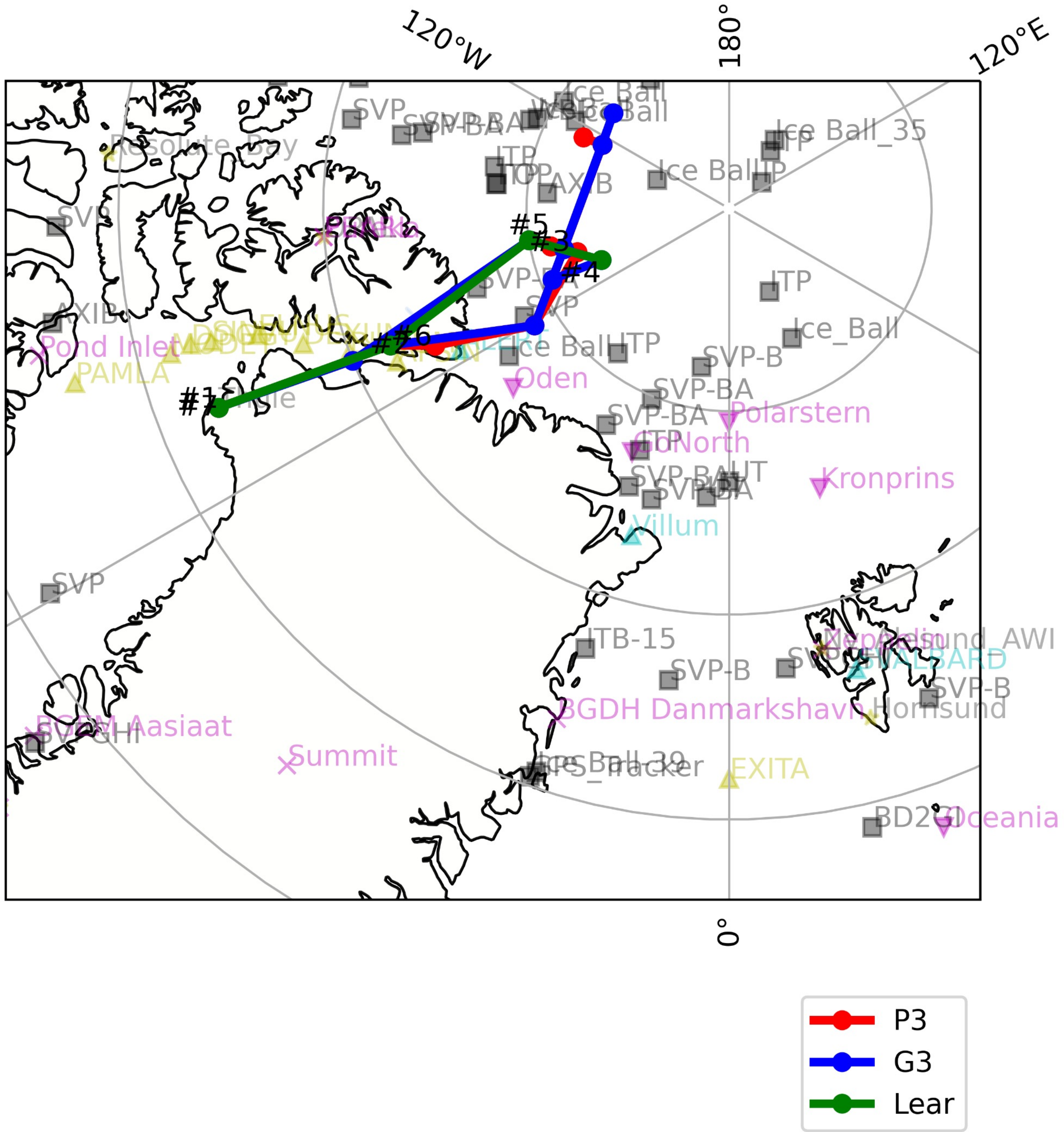
Lear notes:

- Radar overpass (~4 km) at WALL-2 followed by P3-Lear switch for cloud in situ along same line

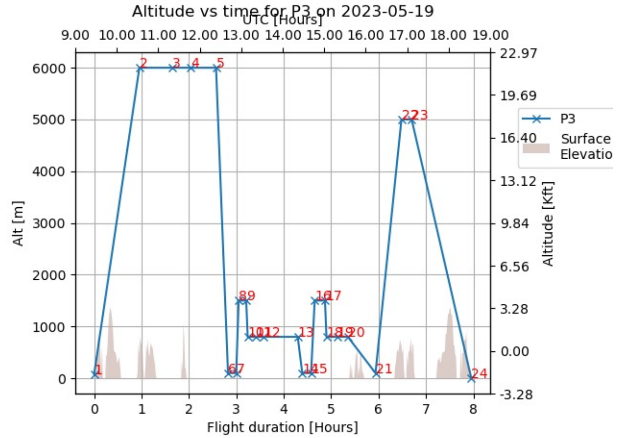
Coincidence points:

UTC	Loc	P3	G-III	Lear
1315	W1	N. porp	#3-#4	-
1410	1→2	~60W	~60W	-
1440	W2	ACT, N	S	(~Alert)
1500	W2	S. End CVI	N	N, Rad.
1525	W2	RS, S	S	S, insitu

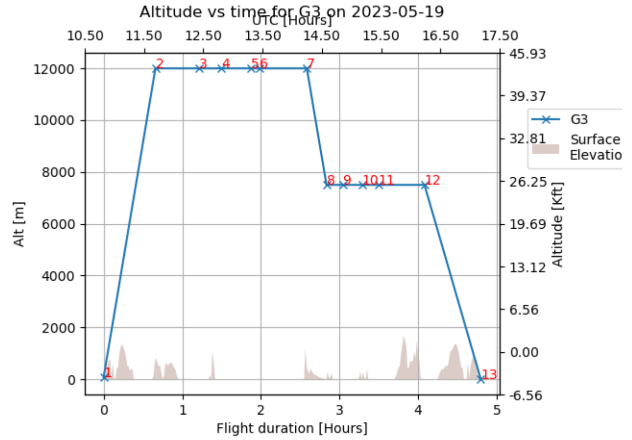
2023-05-19



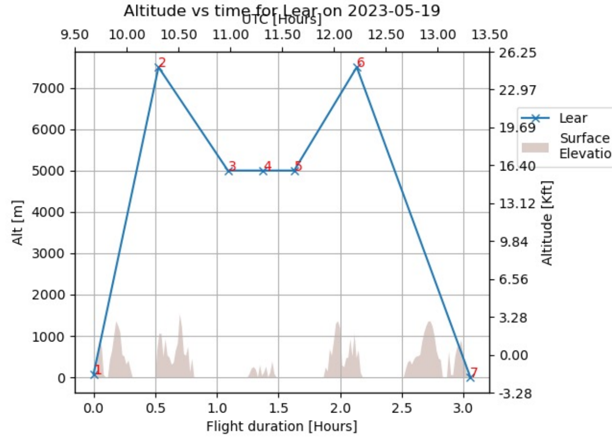
P3: 7h 57m
T/O 0800 local



G3: 5h 4m
T/O 0930 local



Lear: 3h 4m
T/O 1130 local



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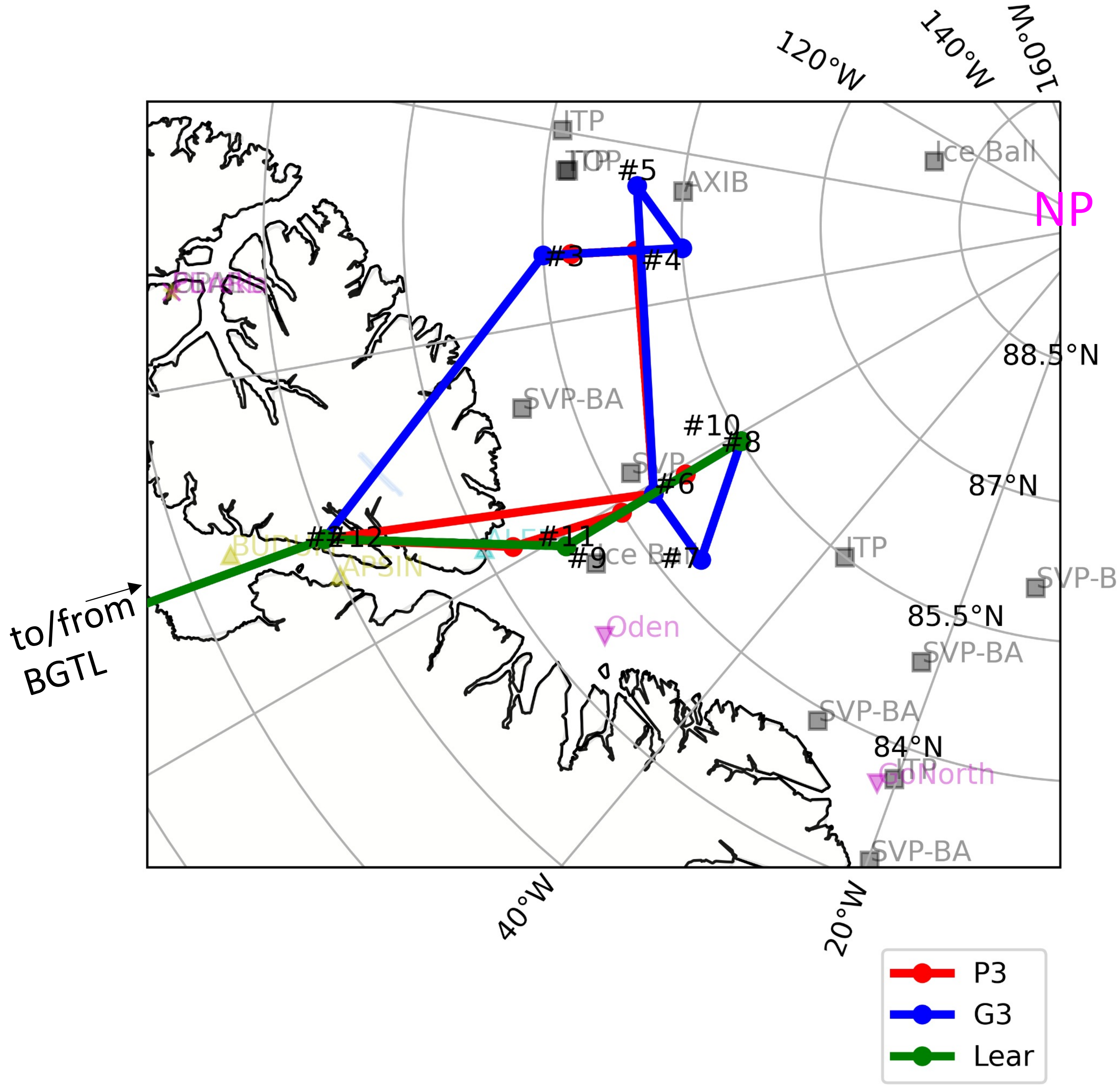
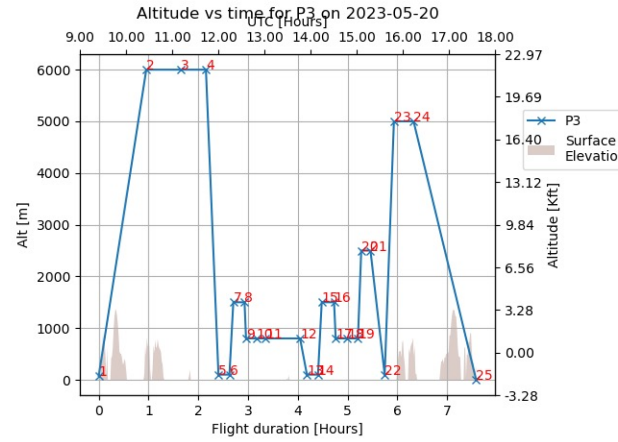
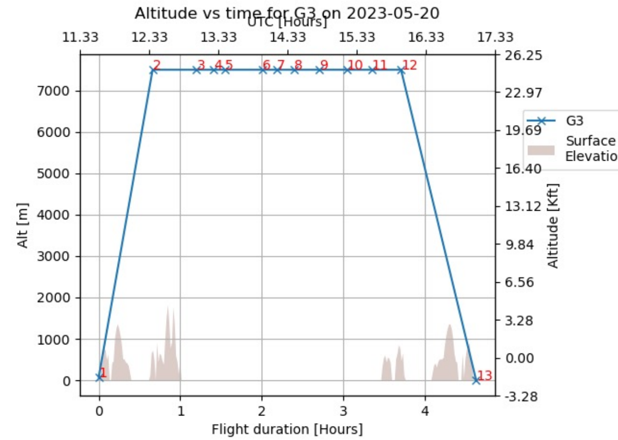


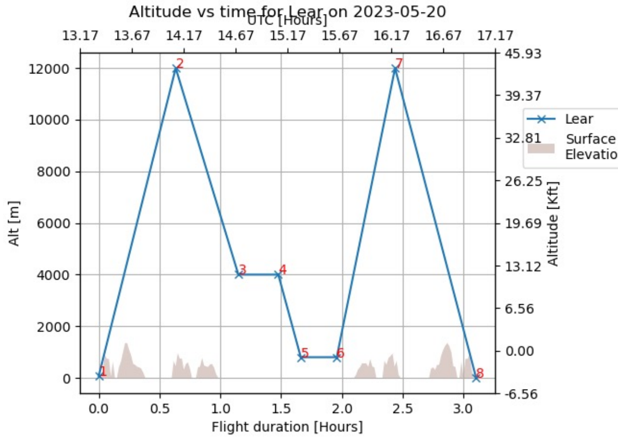
P3: 7h 39m
T/O 0800 local

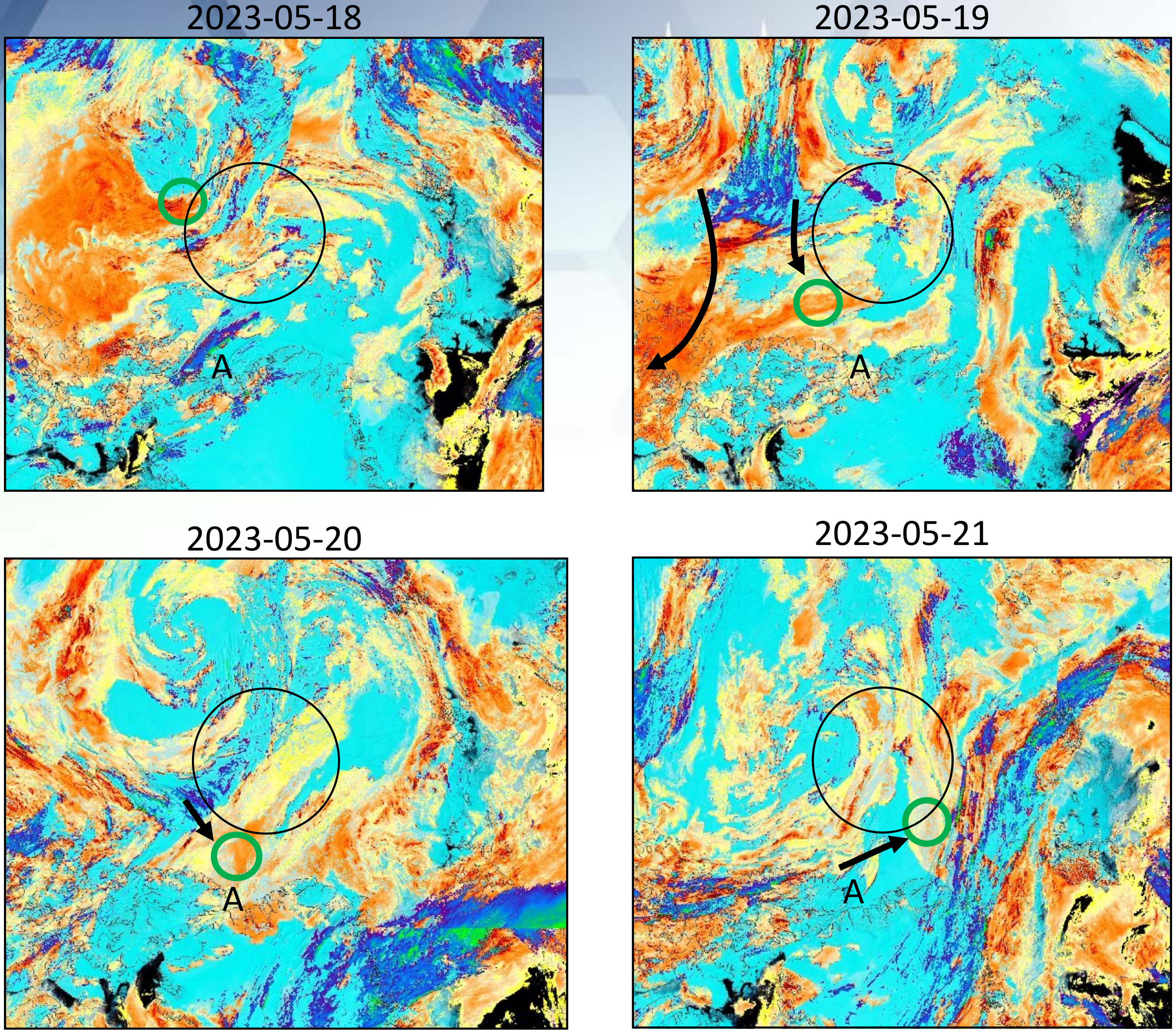


G3: 4h 35m
T/O 1000 local



Lear: 3h 1m
T/O 1140 local

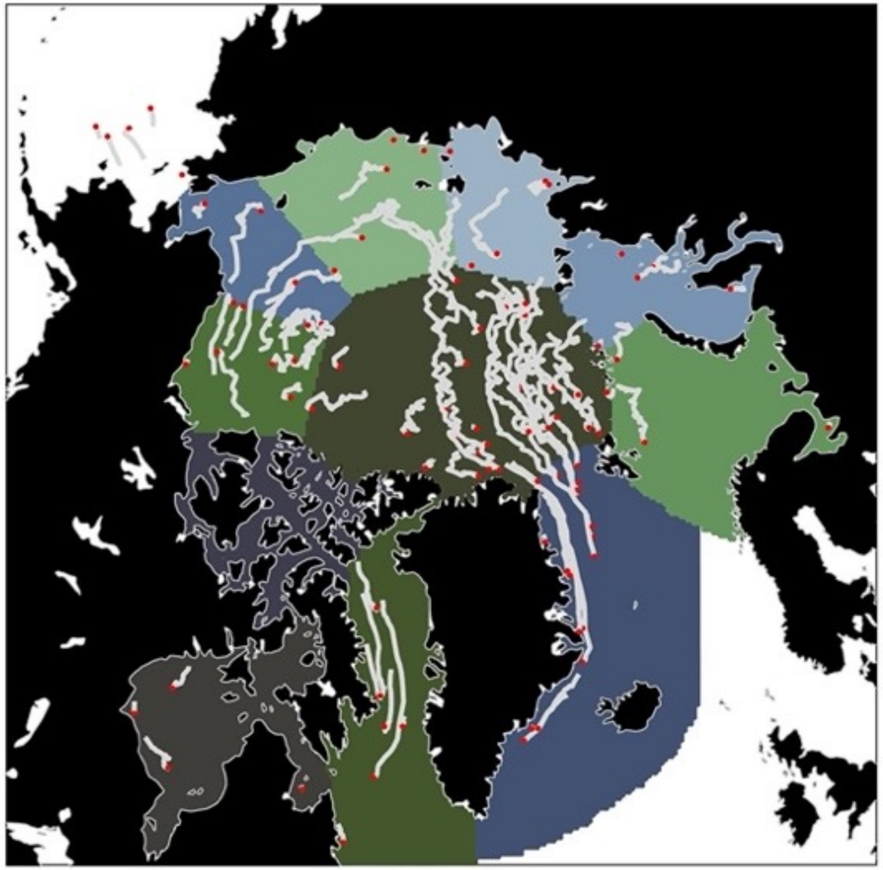




Aqua MODIS Band 7-2-1 with cloud water path overlay:
LWP (red/yellow), IWP (green/blue)
Cyan = sea ice

Orange/Red: >150 g/m2

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

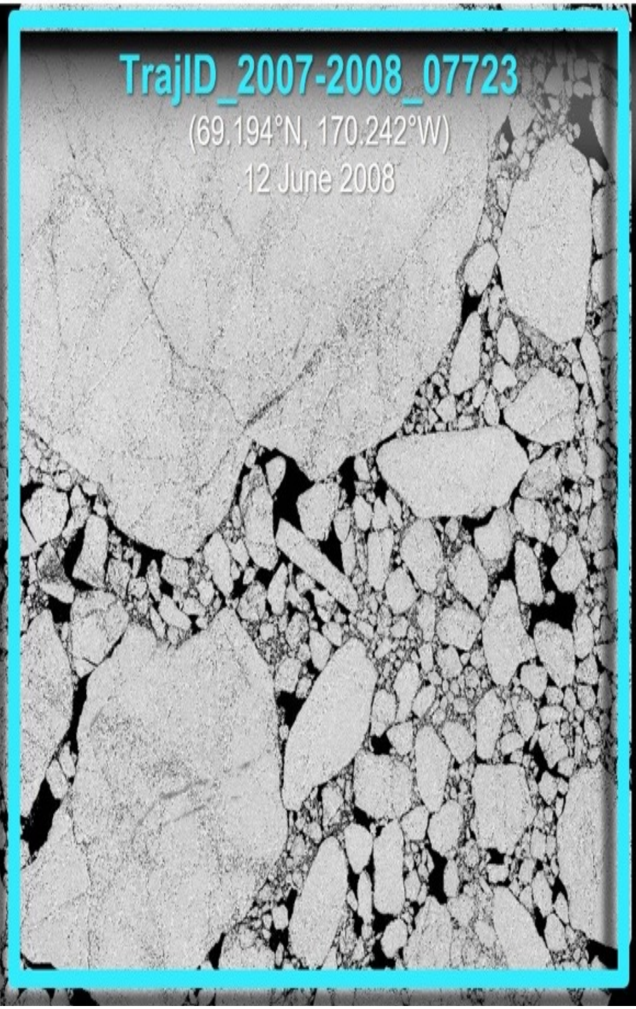


Sea Ice Characteristics:
Ice Type (Buoys/SSM/I): First Year
Concentration (NSIDC/CDR): 90%
Snow Depth (SnowModelLG): 0.06 m
Sea Ice Thickness (PIOMAS): 2.10 m
Surface Albedo (CERES): 0.50
Ice Surface Temperature:

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

Flags:
Cyclone (Melbourne U. Tracker): n/a
Cyclone properties (ERA5): n/a

(Horvath et al. 2023)



Atmospheric State:
Air Press. (ERA5/MERRA2): 1018 hPa
Cloud Cover (CERES): 15%
Precipitable Water (ERA5/MERRA2): 19 kg m^{-2}
Liq. Water Path (CERES): 112 g m^{-2}
Ice Water Path (CERES): 96 g m^{-2}
Air T.(ERA5/MERRA2): 0.95°C
Wind Speed & Direction (ERA5/MERRA2): 8.4 m-s^{-1} & 39°
Spec. Humidity (ERA5/MERRA2): ~0%
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): ~0 W m^{-2}

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