Meeting objectives

Prepare ourselves for going out into the field, 22 Feb-7 April 2024

- remind each other of individual science objectives, hypotheses
- envision flight planning, flight strategy
- consider outreach, educational, collaborative activities

The history of CAESAR

2017 Bart leads CAESAR white paper, organizes NCAR workshop

2018 First EDO/SPO submission for field campaign in spring 2020. Declined.

2019
Second EDO/SPO submission for spring 2021 field campaign. Declined (too expensive) with encouragement to restructure & resubmit. Planning grant approved. NSF asks Bart to step down as PI (King Air MSRI), PZ continues.

2020 Third request for spring 2022 campaign. Pandemic requires a delay

2021
Clear desire by NSF to support CAESAR; successful COMBLE campaign more supportive federal administration. facility request resubmitted, individual proposals submitted. August 2021 planning meeting.
Dec 2021: CAESAR deployment deemed not feasible for FY23 (C-130 propeller installation), delayed to FY24

2022
NSF recommends 6 of 8 individual projects for funding, pending feasibility (Jan); positive NCAR site survey (October)
November 2022: the magic email from Nick Anderson telling us we can proceed

2023
Jim Doyle request to ONR for flight hour support successful, NSF supports an additional project

CAESAR funded Investigators

Paul DeMott/Russell Perkins — *Aerosol Influences on Ice Formation in Arctic Cold Air Outbreak Clouds During CAESAR*

Bart Geerts/Jeff French
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Jim Doyle (collaborator)

~~David Bromwich~~

International & national collaborations

3 recent but previous campaigns to draw from/complement
In Spring 2022, Kiruna

UK Arctic CAO campaign (Field/Abel)
German AC3 (Wendisch) HALO
ISLAS (Sodemann;   isotopes, SAFIRE)

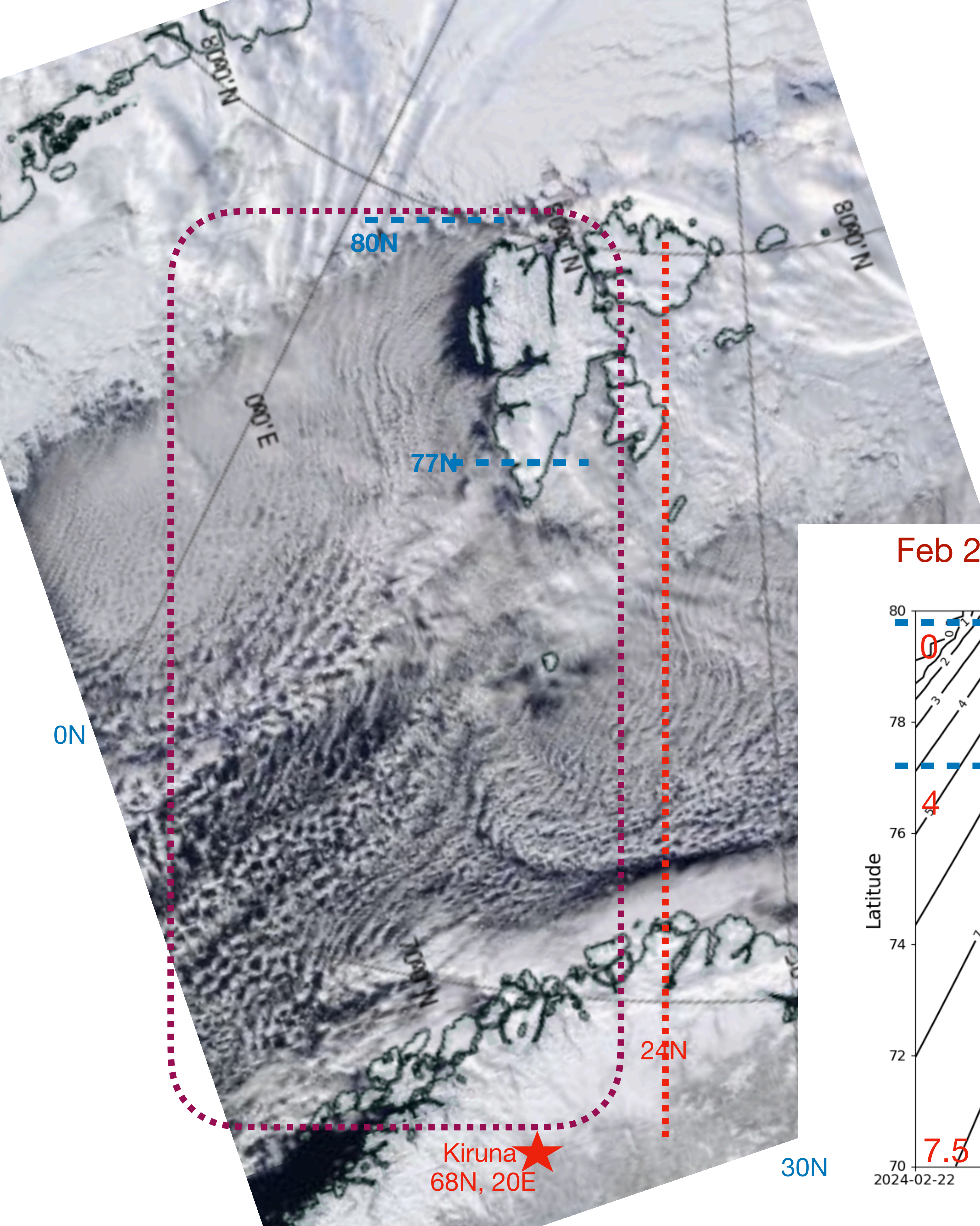
DOE COMBLE, winter/spring 2020

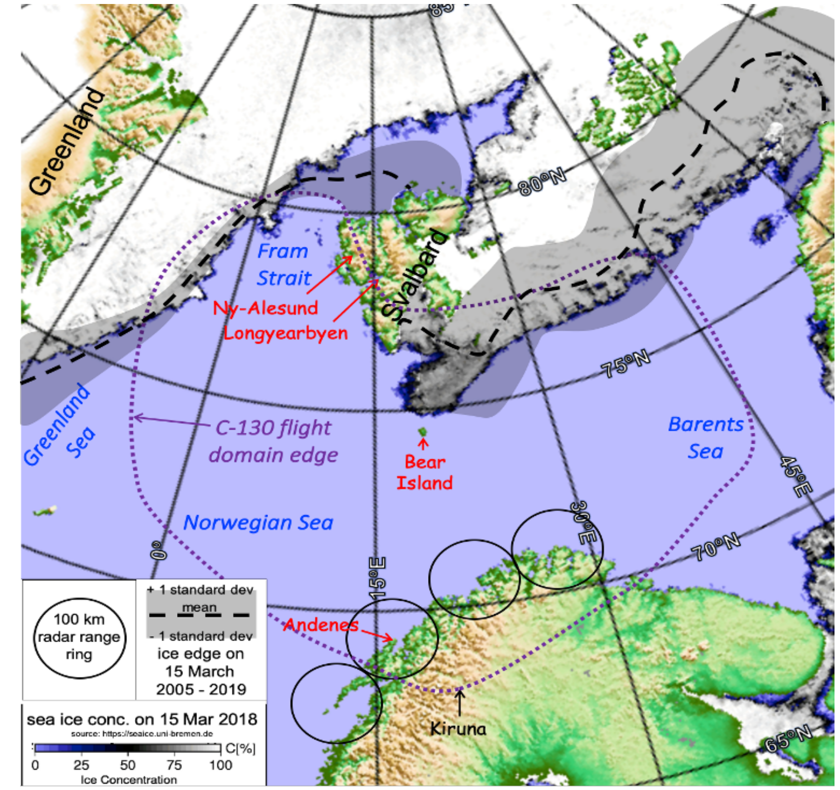
Good relationship w Met Norway (extra soundings, forecasts)

Michael Tjenstrom, U of Stockholm - will come to the field

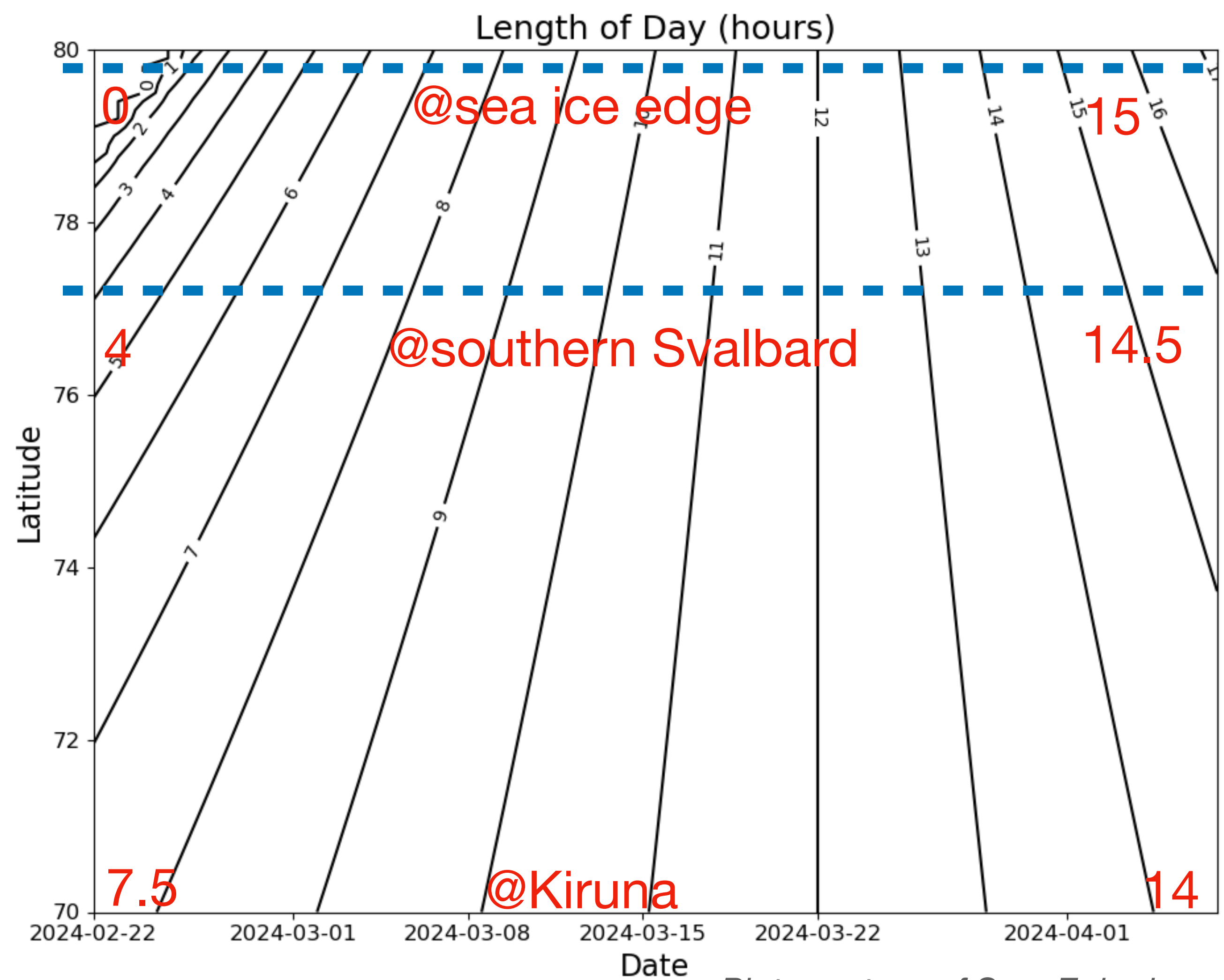
Trude Strovelmo, U of Oslo

=> potential common workshop ?
=> expand on a model-obs comparison at some time in future?

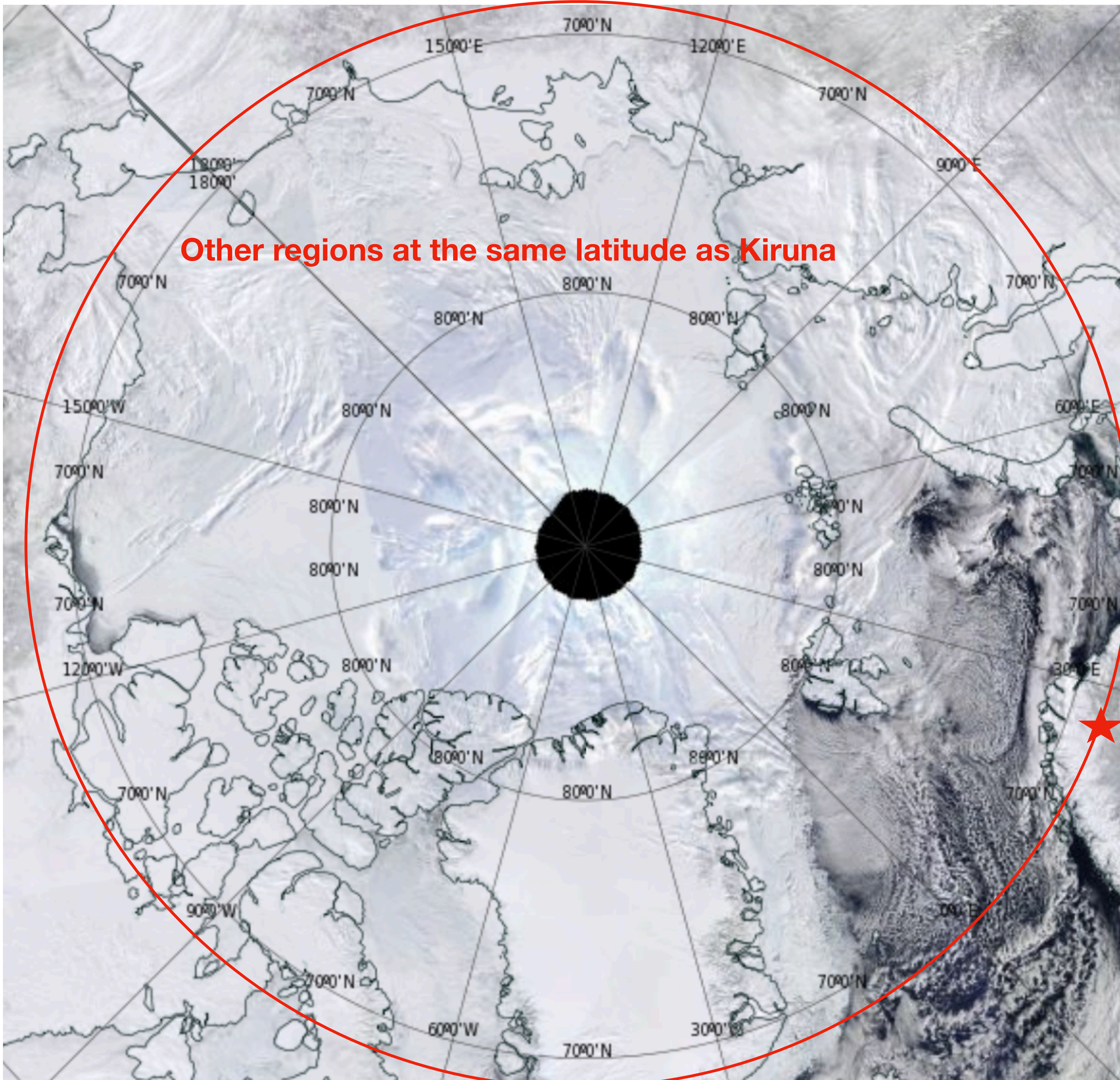




Feb 22-April 7: how much daylight?



Plot courtesy of Sam Ephraim


Other regions at the same latitude as Kiruna
Kiruna

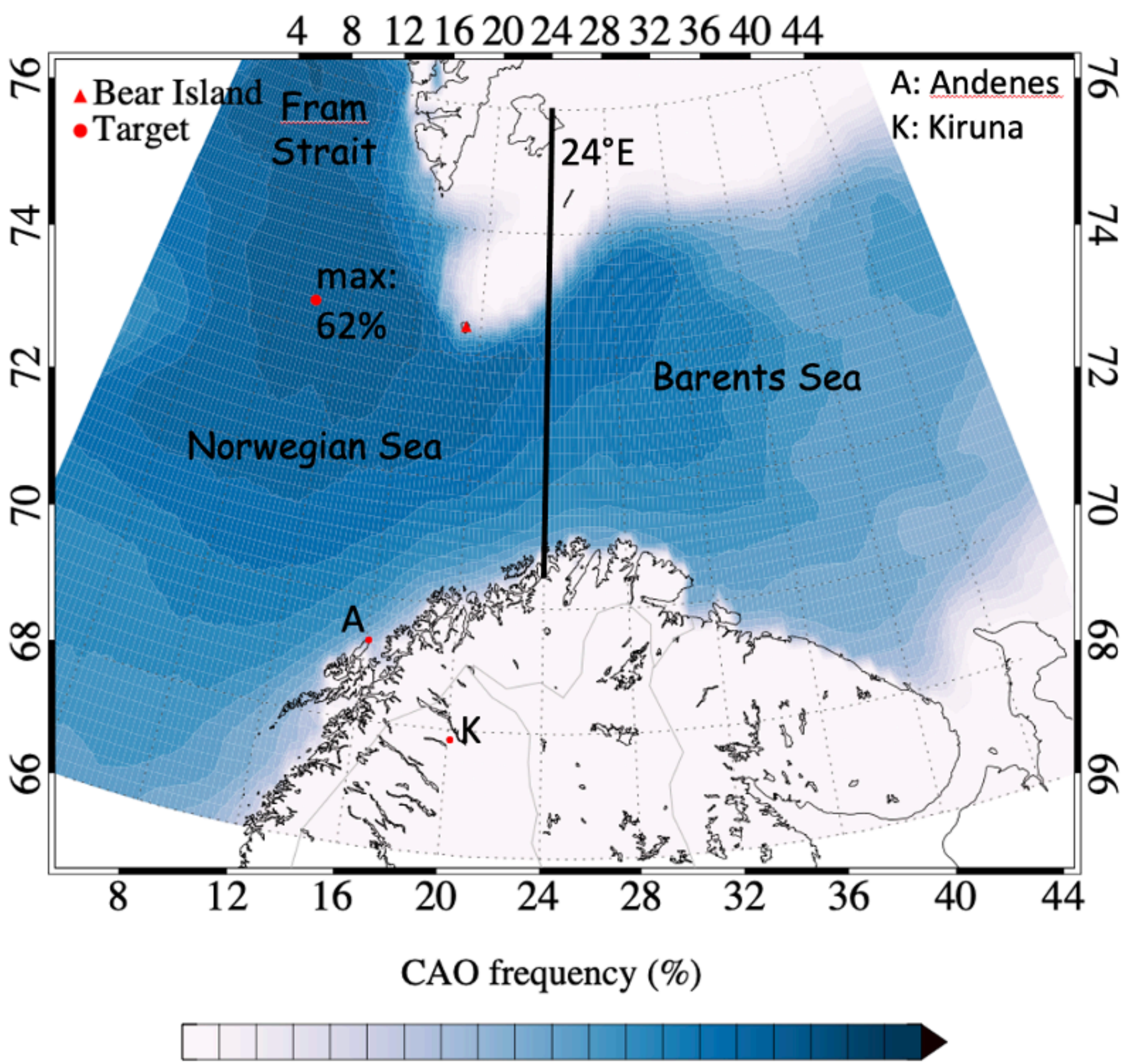


Fig. 1: CAO frequency during the proposed CAESAR period (between 22 Feb and 7 Apr) for 2017-2022 (ERA5 data). CAO conditions are defined based on environmental conditions that are conducive to the CAO cloud regime: $M > 0$ ($M = \theta_{skin} - \theta_{850\ mb}$ (K)), $v < 0$ (v is meridional wind), and SIC < 10% (SIC is sea ice concentration).

Science Traceability Matrix

CAESAR instrument / data traceability table	Instruments → PI initials	AB	DB	PD	BG	GM	MP/JS	YW	ZW	PZ
2D along-track winds (u,y)	WCR, ADL	3	1	2	LEAD	2	1	2	1	2
2D cloud & precipitation structure	WCR, KPR, WCL	2	1	2	LEAD	2	2	1	1	1
retrieved 2D aerosol structure and properties	WCL, MARLi	2	3	2	2	2	2	2	LEAD	3
2D humidity, temperature, & vertical velocity in clear air	MARLi, ADL	2	1	2	1	2	2	1	LEAD	1
retrieved 2D precip. properties (IWC, IWP, particle size)	WCR, KPR, WCL, MARLi GVR	2	1	2	1		2	1	LEAD	1
LWP	GVR	2	1	3	1	2	2	1	2	LEAD
flux profiles, entrainment rate	VCSEL, RFT, gust probe, MARLi	LEAD (VCSEL)	1	2	2	3	2	3	LEAD	3
soundings (LEAD: NCAR)	AVAPS	2	1	3	1	2	2	1	1	2
sea state, SST	MARLi, nadir camera, Heimann IR	1	1	2	2	3		2	1	3
surface fluxes	VCSEL, RFT, gust probe	LEAD	1	2	1	3	2	1	2	2
state variables, pressure perturbations, wind, TKE (LEAD: NCAR)	VCSEL, RFT, radiometric T, gust probe, HADS	1	1	2	1	2	2	2	1	3
broadband hemispheric radiation (LEAD: NCAR)	SW & LW radiometers	3	2	3	3	3		3	2	1
in situ bulk condensed water content (LWC, IWC)	Nevzorov, King, Rosemount	2	1	3	1	LEAD w/ NCAR	2	1		1
in situ bulk condensed water content (LWC, IWC)	CVI	LEAD	1	3	1	1	2	1	2	2
droplet size distribution	CDP	2	1	3	1	LEAD w/ NCAR	1	1	2	3
precip size distribution	2D-S, 2D-C, HVPS-3	2	1	3	1	LEAD w/ NCAR	2	1	2	2
in-situ hydrometeor spatial structure (LEAD: NCAR)	HOLODEC-II	2	2	3	1	1	3	2	3	3
hydrometeor imaging, habit fraction	PHIPS-HALO HOLODEC-II	2	2	3	1	LEAD (PHIPS)		2	3	2
hydrometeor imaging, habit fraction	2D-S, 2D-C, HVPS3	2	2	3	1	LEAD w/ NCAR		2		2
$\delta^{18}O$ isotope ratios of qv and bulk condensed water	CVI/SDI, cavity laser absorption, cold trap	LEAD	3	1	3	2		3	2	3
aerosol size distribution	PCASP, UHSAS, SMPS	1	3	1	2	2	LEAD	3	3	3
black carbon concentration	SP-2	2	3	1	3	2	LEAD	3	3	3
INP concentration & chemical make-up	CFDC with aerosol IS filters	2	1	LEAD	2	2	2	1	2	2
CN and CCN concentration	UWyo CCN, DMT CCN	1	1	1	2	2	LEAD	1	3	2
carbon monoxide conc. (LEAD: NCAR)	cavity enhanced laser absorption	2	3	2	3	2	2	3	3	3
mapped cloud/precip structure (LEAD: NCAR EOL)	met.no radars, satellite imagery	2	1	3	1	2	3	1	3	2
Visible/IR satellite imagery+products (LEAD: NASA LARC, PI: W. Smith, contact PZ)	experimental satellite imagery	3	1	3	2	2	3	2	3	1

Table 1: Left column: Physical measurements; Middle column: Relevant NCAR (black) and user-supplied (blue) instruments, followed by the 9 proposing Investigators and their relationship to the measurements. LEAD PIs are indicated for each observational category, and includes responsibility for its value-added products. Other designations are for core (1), important (2) and useful (3) datasets for the individual proposers. CAESAR PIs most familiar with relevant NCAR base-funded observations will lead development of value added products. DB represents David Bromwich, PD Paul DeMott, BG Bart Geerts, GM Greg McFarquhar, MP Markus Petters, JS Jeff Snider, YW Yonggang Wang, ZW Zhien Wang, and PZ Paquita Zuidema. Rows color-coded by topic: vertical profile data (yellow), sea surface data (blue), flight level data (orange), external data (purple).

1. air-sea exchange and BL development	examine fetch-dependent surface fluxes, the MBL top entrainment rate, and the vertical profiles of temperature, humidity, wind, and turbulence in the CAO MBL and their dependence on upstream conditions

D.8.1 Air-sea exchange and MBL development: *Key hypotheses*

H1a. The low-level stratification of the airmass over the Arctic ice (related to the presence / absence of low Arctic clouds), wind direction and boundary-layer structure critically impact the downstream growth rate of the convective MBL and the formation of a low-level jet (LLJ).

H1b. Helical convective roll (HCR) circulations and convectively-induced motions enhance surface heat fluxes and lead to mesoscale variability in boundary layer depth, temperature, and moisture.

H1c. The rate of entrainment of free-tropospheric air into the MBL has a measurable influence on not only the profiles of wind, temperature, humidity, aerosol, heat fluxes, and TKE within the MBL, but also on cloud microphysical and macrophysical properties.

H1d. The primary buoyancy source for MBL TKE results from surface heat fluxes at close fetch, and from cloud top cooling in generating cells at far fetch, where cloud coupling to the surface diminishes.

2. mesoscale organization	examine the mesoscale organization of the boundary-layer circulation, the impact of this on surface fluxes and entrainment, and the resulting organization of clouds and precipitation

D.8.2 Mesoscale organization of clouds and precipitation: *Key hypotheses*

H2a. Measurable helical convective roll (HCR) circulations with up/down-drafts approaching O(1 m/s) exist in the sheared convective BL, but convective updraft strength typically exceeds that of the HCRs.

H2b. Convective cells are organized into cloud streets by the boundary layer winds whose spacing is controlled by BL winds and cloud processes, not by convectively-induced gravity waves above the MBL.

H2c. Transitions in mesoscale organization (linear to cellular convection, and open to closed cells), is more correlated with precipitation-induced stratification within the cloud-topped MBL, than with wind shear.

3. cloud and precipitation	describe the cloud microphysical properties in all types of CAO MBL clouds, in relation to observed profiles of static (in)stability and vertical velocity, in order to understand fundamental mixed-phase processes (ice initiation, ice multiplication, riming) and precipitation development

D.8.3 Clouds and precipitation: *Key hypotheses*

H3a. Ice crystals are re-circulated in vigorous convection just off the ice edge, where ice particles may be introduced in young clouds through seeding from the ice surface below or possibly from clouds aloft.

H3b. Primary nucleation becomes increasingly important with fetch. Ice-nucleating particles (INPs) are present in insufficient numbers to fully consume liquid mass. When present, cloud-top generating cells are the primary loci for increased primary nucleation and result in local regions of increased ice mass and depleted super-cooled liquid water (SLW).

H3c. Glaciation is principally driven by secondary ice production. Where this occurs along the fetch is strongly correlated with the thermodynamic and microphysical structure of the clouds. Secondary production of ice requires clouds of sufficient depth to support growth of cloud droplets of at least 20 μm in diameter, varying with the specific secondary process.

H3d. Turbulence in MBL convection modulates the precipitation-LWP relationship, through riming.

4. aerosol	examine the impact of varying aerosol conditions [INP, CCN] originating from within both the boundary layer and free troposphere on supercooled cloud liquid water properties, ice initiation, and snow growth mechanisms in a range of wind and temperature regimes

D.8.4 Aerosol: *Key hypotheses*

H4a. Oceanic emissions are the primary CCN source.

H4b. The springtime Arctic free troposphere is often polluted as a consequence of long-range transport.

H4c. The major source of INPs for CAO MBL clouds is from the stratified free troposphere, dominating the sea surface source, except perhaps under strong winds (> 10 m/s).

H4d. Immersion freezing is the dominant ice nucleation process across the full range of SLW temperatures (-5 to -25°C) typically encountered in the CAO cloud regime.

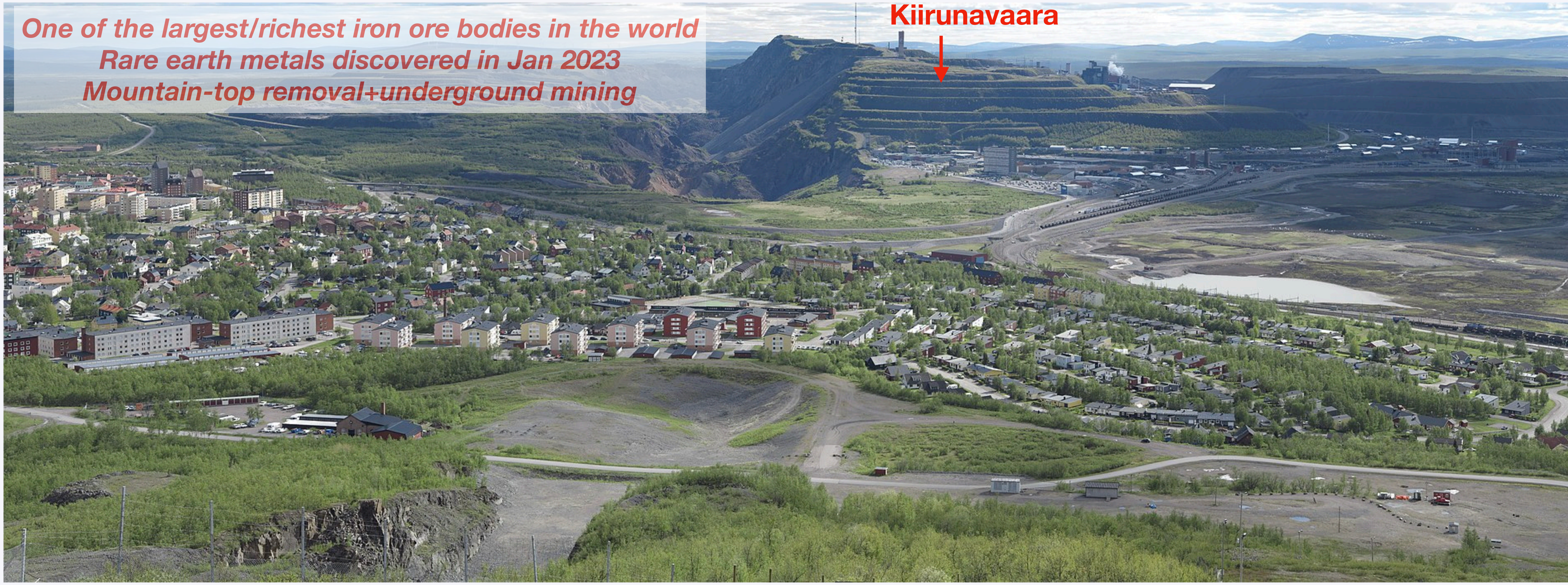
5. polar lows	Within regions of opportunity, examine the relationship between the BL, cloud, and surface flux characteristics of CAOs to the formation and evolution of *polar lows* and their structure

D.8.5 Polar Lows: *Key hypotheses*

H5a. Polar low clouds are mostly convective and result from rapid local ascent (potential instability release) rather than slow, broad ascent (symmetric instability, frontogenetic ascent, QG ascent).

H5b. Polar cyclogenesis requires low-level potential vorticity (PV) generation driven by liquid phase latent heating, driven by the clustering and deepening of convective cells in a convergent frontogenetic shear zone. In the region of interest, the formation of such zone is aided by shallow baroclinicity resulting from differential surface heating of air parcels advected southbound along Svalbard. Further intensification of polar lows requires baroclinic interaction with an upper level PV anomaly.

H5c. Polar lows enhance the dissipation of CAOs.



Kiruna city panorama, taken from Luossavaara, 2014

Older mined iron ore body, now a ski hill

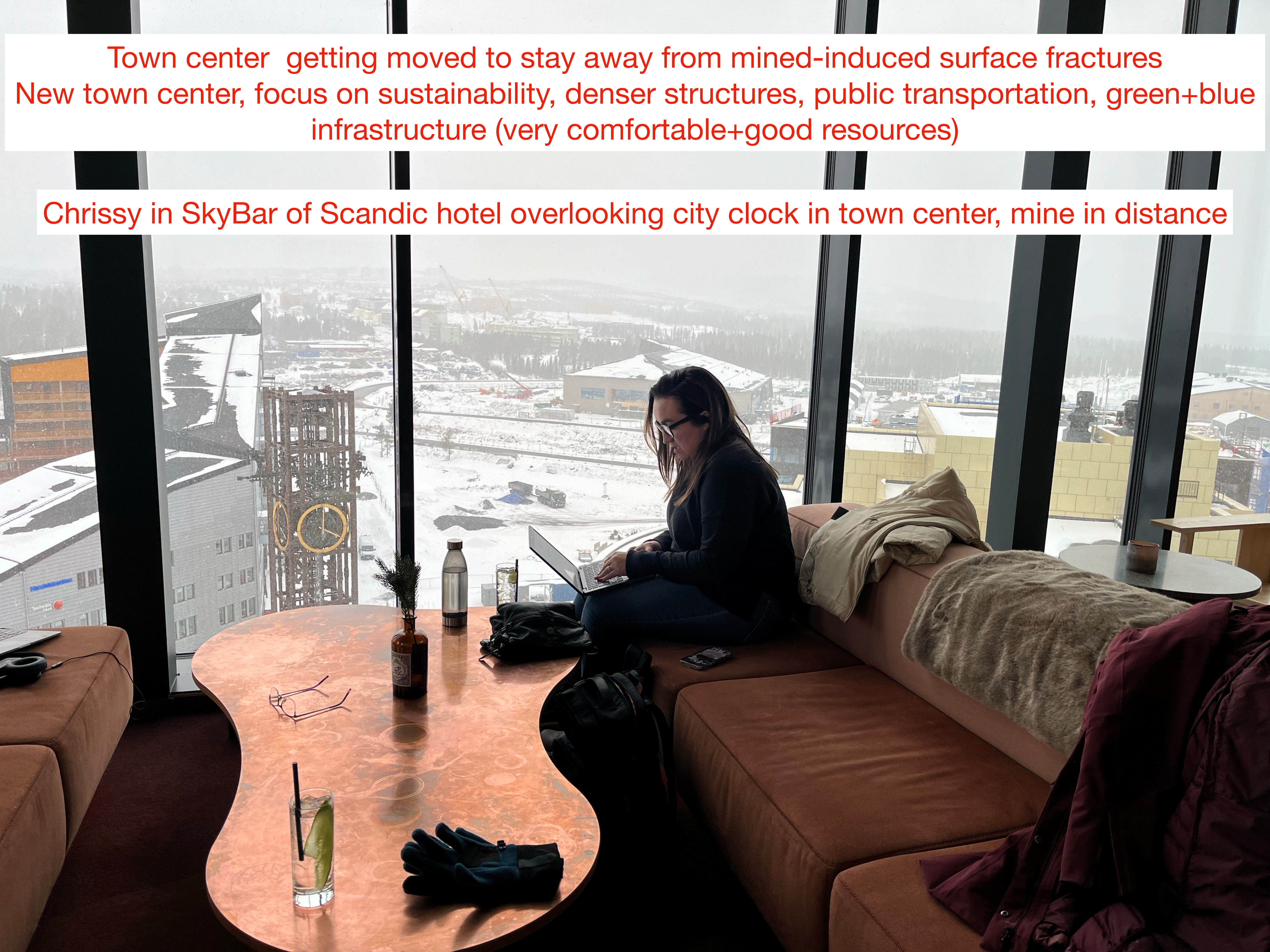
Kiruna: 68N, 20E, in between the two iron ore deposits, 150 km north of Arctic circle
Population of ~25,000 people

Besides the mine, also space work (rocket launches into auroral zone)+tourism

Seemed well-off

Town center getting moved to stay away from mined-induced surface fractures
New town center, focus on sustainability, denser structures, public transportation, green+blue infrastructure (very comfortable+good resources)

Chrissy in SkyBar of Scandic hotel overlooking city clock in town center, mine in distance



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Jim Doyle (collaborator)

~~David Bromwich~~

Zuidema: Arctic cold-air outbreak mixed-phase cloud characteristics, processes and impacts in observations and models

Over-riding objective is to understand the liquid-ice partitioning as the cold-air outbreaks evolve

Hypothesizing that LWP and CCN modulate liquid-phase precip (similar to warm clouds) and that INP are a 2nd-order control on LWP

2nd hypothesis is that ice multiplication is only observed after LWP-modulated liquid phase precipitation has started

3rd hypothesis is that glaciation hastens the CAO transition (as in Tornow et al., 2021); counter-hypothesis is that a microphysical impact on the transition cannot be detected in observations

Relying on a combined observational - modeling approach

Observational:

- Deploy a 4-channel 183-Ghz (G-band) microwave radiometer (GVR) to the field,

Retrieves column above-plane liquid water and water vapor paths;
Distinguishes super-cooled water component of mixed-phase clouds

- Originally developed for the cold, dry Arctic environment
- Plan to use same RT model as the Germans
- Zhien's lidar moisture vertical structure expands science objectives
- Will want to construct a meta-dataset of physical variables based on remote measurements, combined w CCN/INP

Small, upward-looking only, deployed during VOCALS (C-130), never used since, gifted to U of Miami, was evaluated by ProSensing this past year, still looks good

Now back at ProSensing to get new data acquisition software

Will bring to DOE SGP site to calibrate against DOE radiometers

Once dataset determined, collaborate w Florian/Ann on the analysis of a set of quasi-Lagrangian CAESAR-motivated simulations

Example from the prior SPO

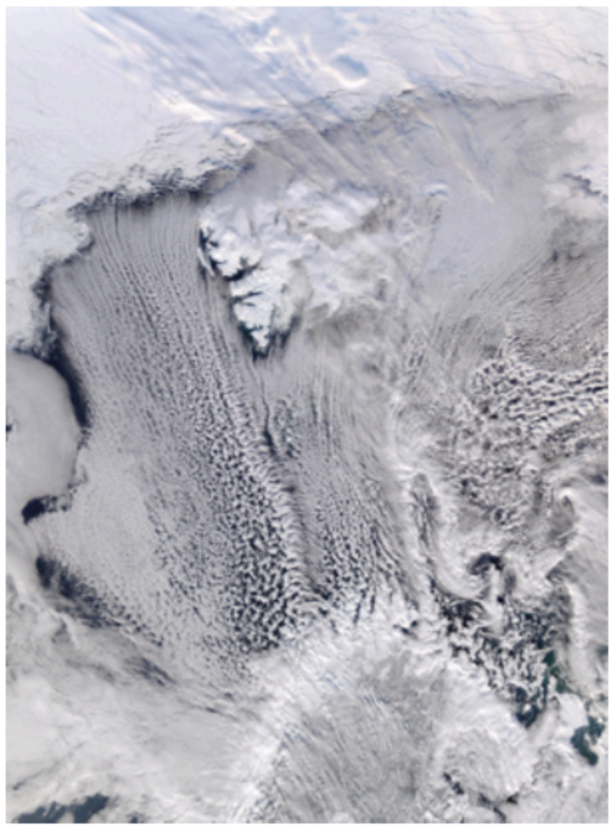
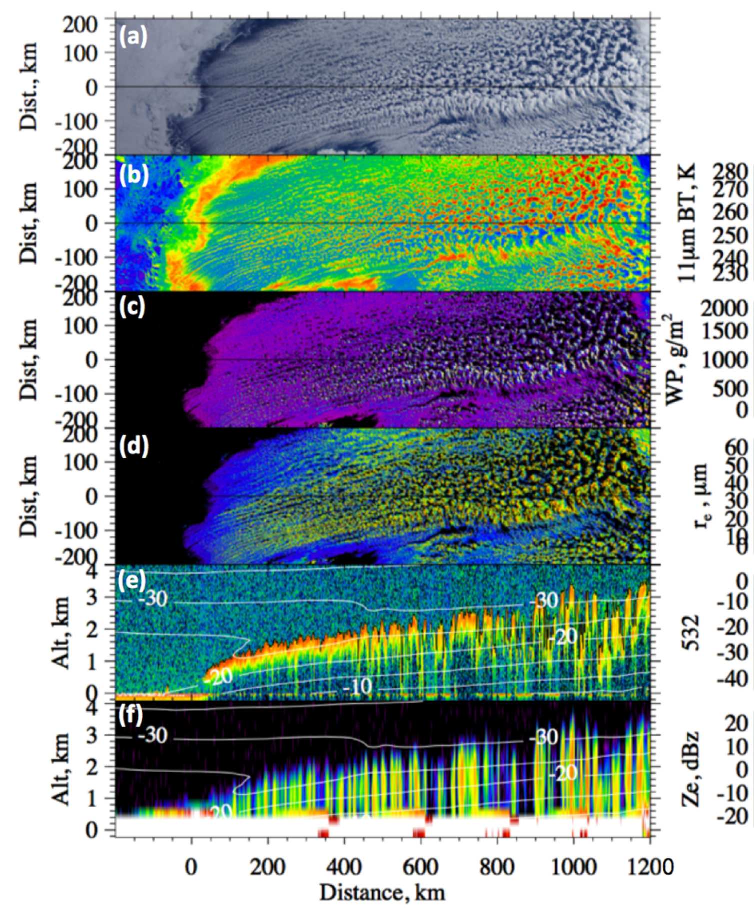
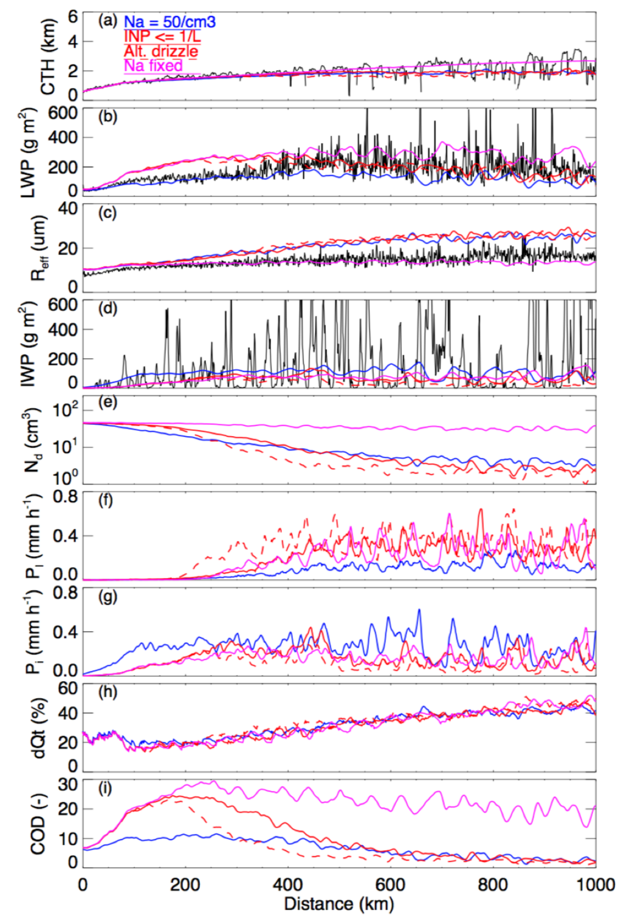


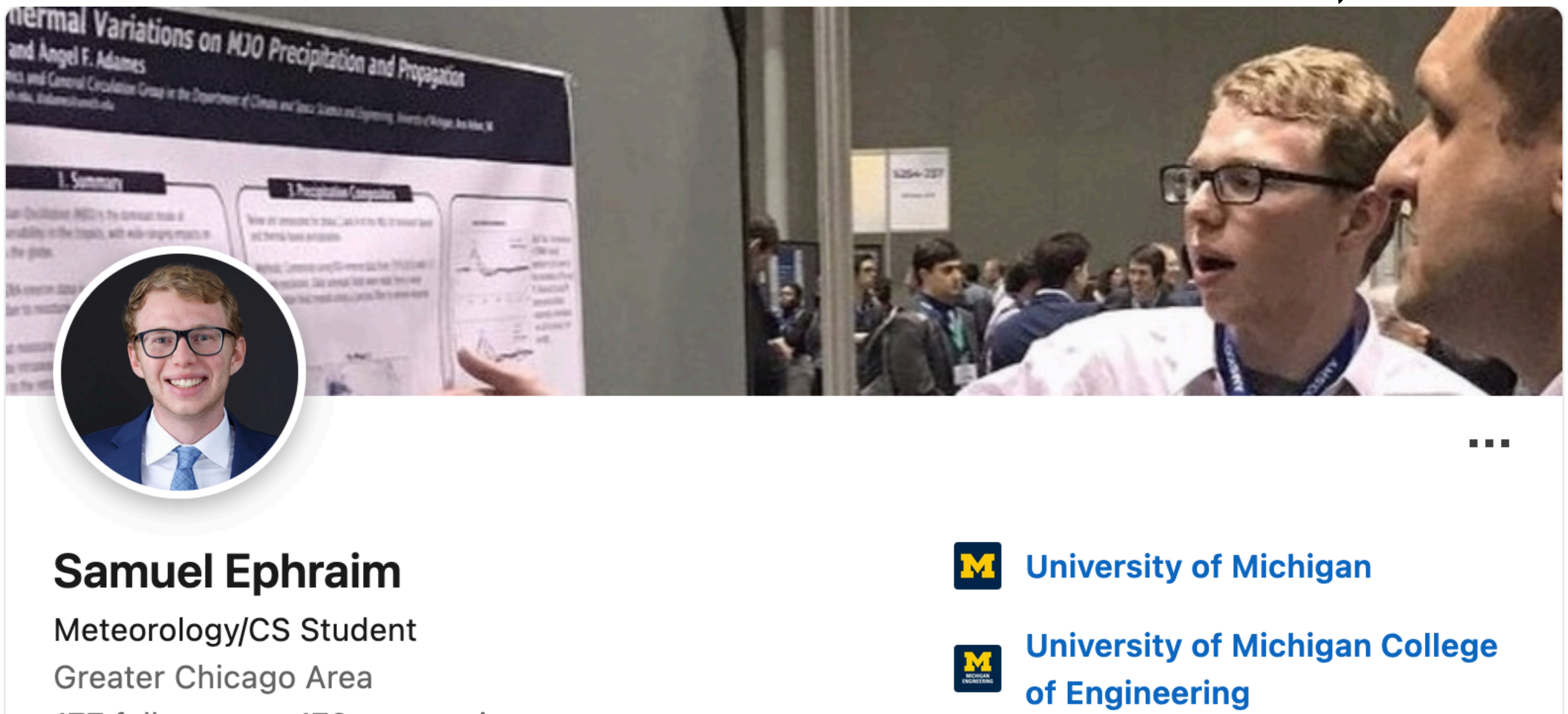
Fig. 1: MODIS visible image of an intense cold-air outbreak over the Norwegian Sea on 17 March 2016.





- Investigate factors affecting LWP by idealizing each observed case study & varying conditions over the range of moisture, stability, subsidence, SST, CCN and INP
- Revisit subset with varying CCN & INP to look for changes in the LWP mesoscale structure

Introducing the UM students: Sam Ephraim, Tyler Tatro



Tyler has integrated ERA5 reanalysis with HYSPLIT, suggest to do the same with EC forecasts in the field & integrate that into the forecasting discussions

Outreach ideas/efforts for CAESAR

- Virtual regularly-scheduled presentations aimed at graduate students, could be for class credit. Keep presentations/recording on EOL CAESAR website

- SOARS student (Geerts/French)
- Involvement of undergraduate (Yonggang Wang's proposal), graduate students
- Public outreach materials (handouts, professional video)

Dan Zietlow, Evy McUmber from NCAR Education, Engagement & Early-Career Development (EdEC)

SUPPORTING BROADER IMPACTS IN FIELD CAMPAIGNS

NCAR EDUCATION, ENGAGEMENT & EARLY-CAREER DEVELOPMENT (EdEC)

DANIEL W. ZIETLOW & EVY McUMBER

NCAR EdEC

9 MAY 2023

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

NCAR Education, Engagement & Early-Career Development (EdEC)…

…supports, enhances, and extends the capabilities of the university community and the broader Earth system science community.

Supporting Field Campaigns Through Public Engagement

We can support the engagement component of your field campaign:

- Instrumentation Open Houses
- K12 & University Classroom Visits
- Students in the Field
- Teacher Curriculum
- Video Production
- Educational Handouts

The PI of the OTREC field campaign is interviewed for a video series about the field campaign.

Kiruna=UTC+2

A day-in-the-field straw man

Considerations: airport wants a daily schedule for when they need to be there (takeoff/landing
Met Norway changes its shifts at 14 UTC (4pm) => plan on a 15 UTC forecast time (5pm)

=> need a regular schedule

Day prior to a flight

5 pm LT forecast discussion +flight planning

Day of flight

6am update?

7 am takeoff (takeoffs without sun okay)

8am arrive at Norwegian Sea, work for 4-6 hours

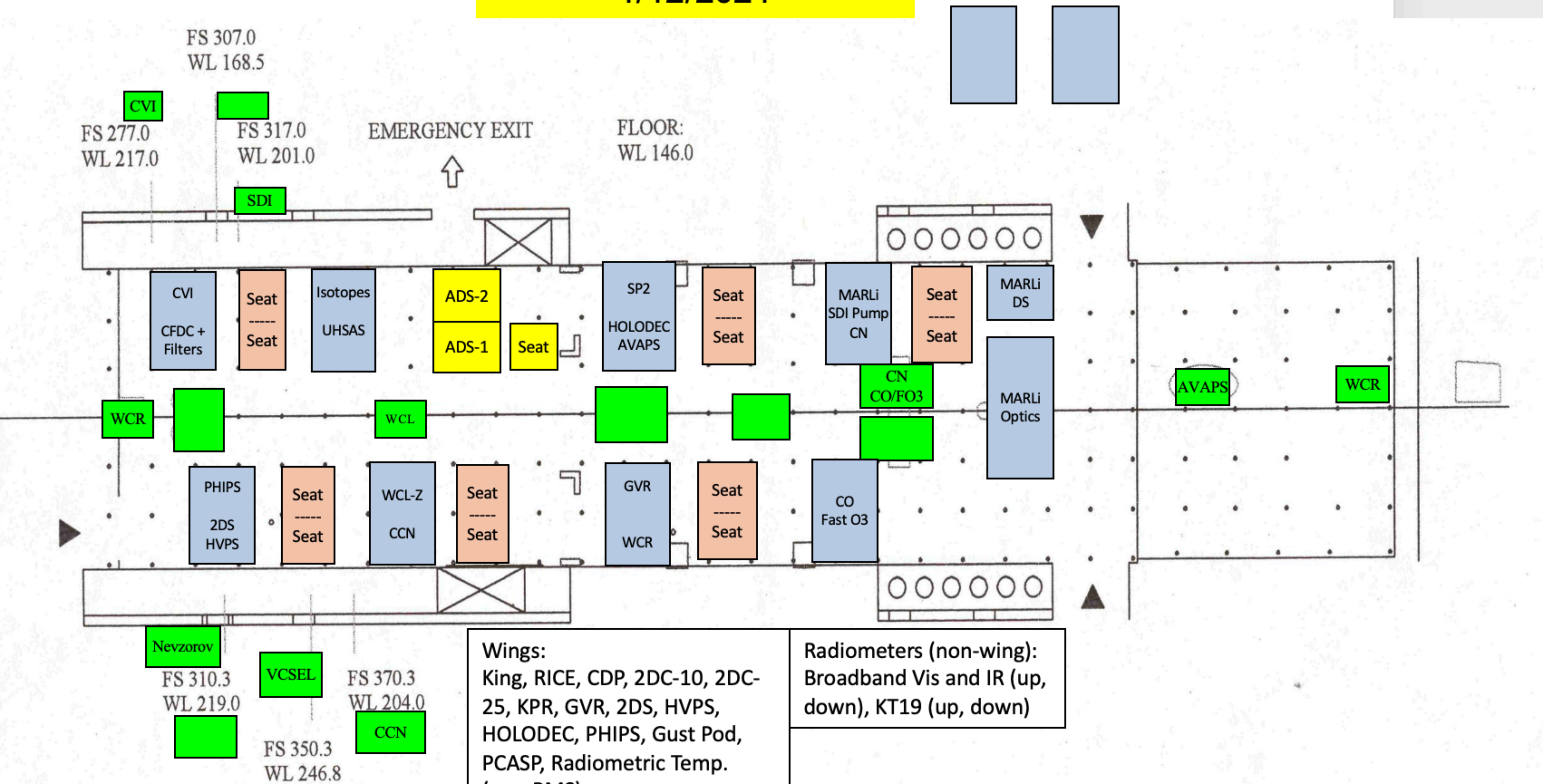
4pm return at Kiruna, debrief

5pm forecast discussion+potential next flight

(Rotate mission scientist, scientist liaison on ground)

Extra

Draft Payload - C130
CAESAR
1/12/2021



Wings:
King, RICE, CDP, 2DC-10, 2DC-25, KPR, GVR, 2DS, HVPS, HOLODEC, PHIPS, Gust Pod, PCASP, Radiometric Temp. (non-PMS)

Radiometers (non-wing):
Broadband Vis and IR (up, down), KT19 (up, down)

CAESAR_2023: CAESAR Dry Run

Summary

One of the most intense air mass transformations on Earth happens when cold Arctic air flows out over the much warmer open oceans in so-called Cold-Air Outbreaks (CAOs). The surface heat fluxes are amongst the highest observed on Earth, supporting highly convective clouds capable of producing heavy snowfal and occasionally spawning intense “polar lows”. Surprisingly little is known about their Lagrangian evolution, relationship between up- and downstream condition and between the surface fluxes, boundary-layer structure, cloud and precipitation properties, and mesoscale circulations. These clouds provide a powerful model test bed for improving the representation of mixed-phase cloud processes in large-eddy simulations, numerical weather prediction and global climate models. Thu we propose a dedicated field campaign, CAESAR, to examine the structure of marine boundary layer clouds during CAOs. CAESAR will deploy the NSF/NCAR C 130 aircraft, with in situ and remote sensors sampling Arctic airmasses from the CAO origin at the ice edge throughout their transformation downstream. A rich ar of airborne radars and lidars, aerosol, cloud, precipitation and trace gas probes, deployed during CAO events over the open waters between northern Norway an the Arctic ice edge.

Data access

Datasets from this project

Additional information

Field catalog	CAESAR_2023 field catalog

Temporal coverage

Begin Date	2023-02-13 00:00:00
End Date	2023-03-31 23:59:59

CAESAR Data Policy