The Next-Generation Wyoming King Air Aircraft: Research modifications and Capabilities

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Presented at the annual meeting of the Science Committee for Oceanographic Airborne Research, NCAR RAF, 4 Oct ‘22

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* LAPS, CU Boulder

History of Airborne Research at Wyoming and the current University of Wyoming King Air (UWKA)

1965
Twin-Beech (C-45)

→

1971
Beech Queen Air

→

1977
Beech King Air 200T

Focus: atmospheric science (cloud physics, dynamics, surface and boundary layer, turbulence, air quality, trace-gas chemistry, airborne remote sensing, education and training)

History of Airborne Research at Wyoming and the current University of Wyoming King Air (UWKA)

The UWKA …

- has been operating under Cooperative Agreements between UW-NSF since 1988
- is one of the three aircraft in NSF Lower Atmospheric Observing Facilities (LAOF) Fleet
- fills a 'niche' within LAOF as smaller, more agile, more accessible aircraft
- was retired in Sept 2022

The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)

- **Effort to replace UWKA began in 2015** with investigations *of potential platforms*, emerging *needs within the community*, and new instrument/measurement *capabilities*
  - exploring funding opportunities
  - meetings/discussions with UW administrators, possible donors, and NSF
  - development of technical plan

- **NSF 10 Big Ideas**

  #4 – Mid-Scale Research Infrastructure: RFP in 2019

  "aimed at transforming scientific and engineering research fields as well as STEM education … by making available new capabilities, …(and) training early-career researchers in the development, design, and construction of cutting-edge infrastructure."

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- **NSF 10 Big Ideas**

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NSF Mid-Scale Research Infrastructure (MSRI-1) Award

The Next Generation UWKA-2

Oct 2019 – Sept 2024

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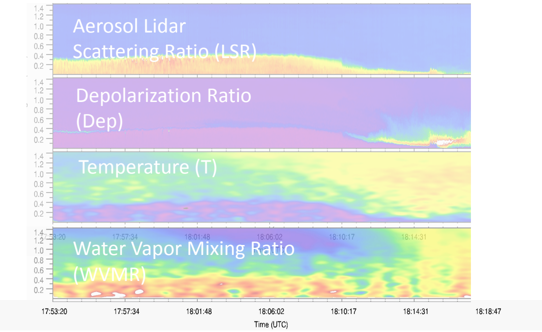
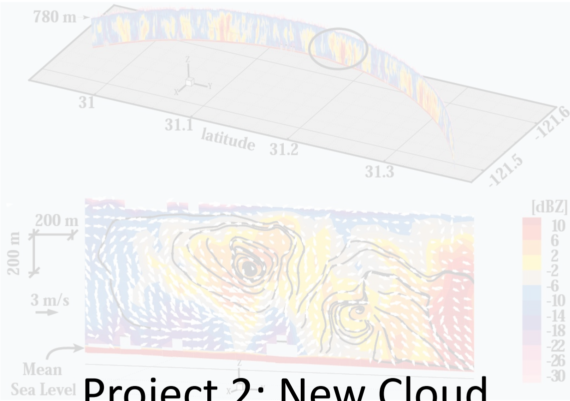
The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)



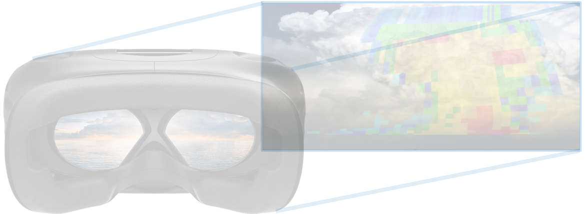
Project 3: New Airborne Lidars

Project 1: Acquisition, Modification, and Certification



Project 2: New Cloud Profiling Radars

Project 4: Trace Gas and Aerosol



Project 5: Immersive Environment for Science and Training

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Project 1: Acquisition, Modification, Certification of Aircraft
Five-Phase Implementation

Phase 1: Acquisition of Baseline Aircraft (*purchased by Univ. Wyoming)*

Phase 2: Special Mission Enhancements (Vendor Contract)

Phase 3: Research-Specific Modifications (Vendor Contract)

Phase 4: Final Certification (Vendor Contract)

Phase 5: Integration & Testing Instruments (Univ. Wyoming)

<u>Single STC for Certification in Restricted Category</u>

- ✔ Payload configuration certified for ‘flight envelopes’
- ✔ Removal of equipment returns aircraft to Normal Category

Project 1: Acquisition, Modification, Certification

Special Mission Enhancements

Upgrade to Blackhawk XP67A engines

- ✔ Increased rate of climb
- ✔ Improved single-engine & takeoff performance

Upgrade to 400 AMP Generators

- ✔ Increase from 600 to 800 Amp
- ✔ Mission specific Electrical Bus

Increased max takeoff weight landing gear

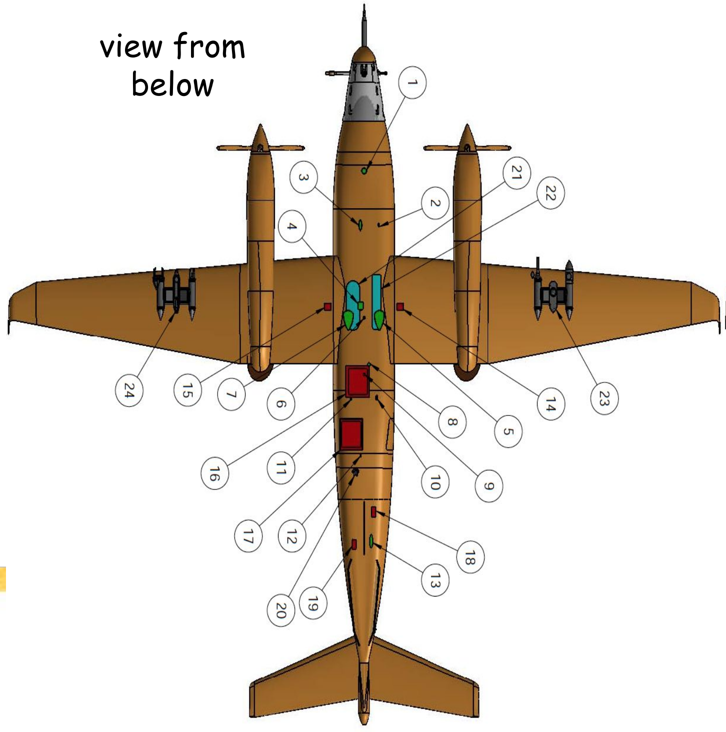
- ✔ Heavy-weight landing gear increases MTOW from 15,000 Lbs. to 16,500 Lbs,
- ✔ and ZFW from 12,500 Lbs. to 13,000 Lbs

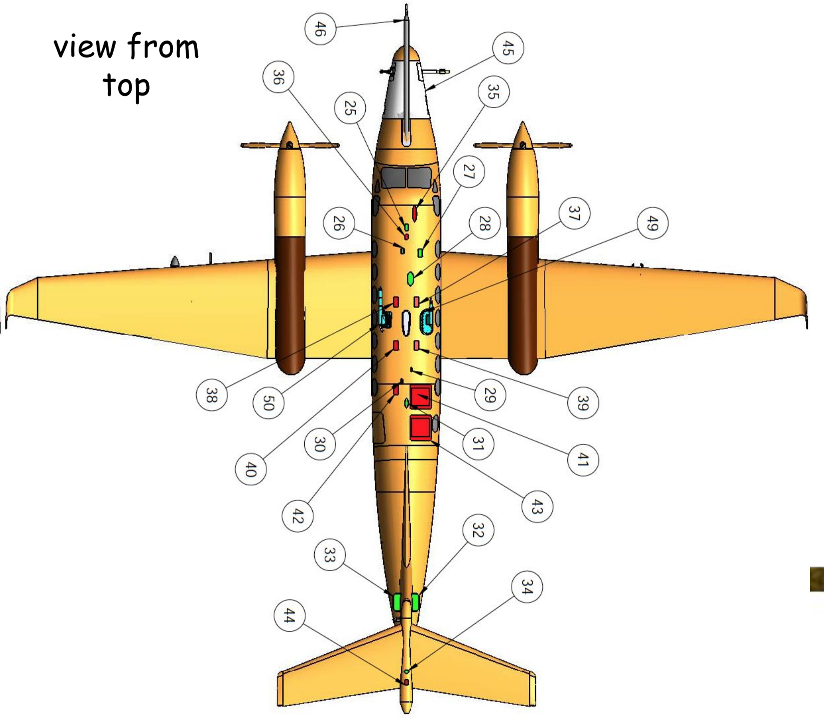
190 G Centex fuel tanks

- ✔ Increase flight endurance to at least 4 hrs

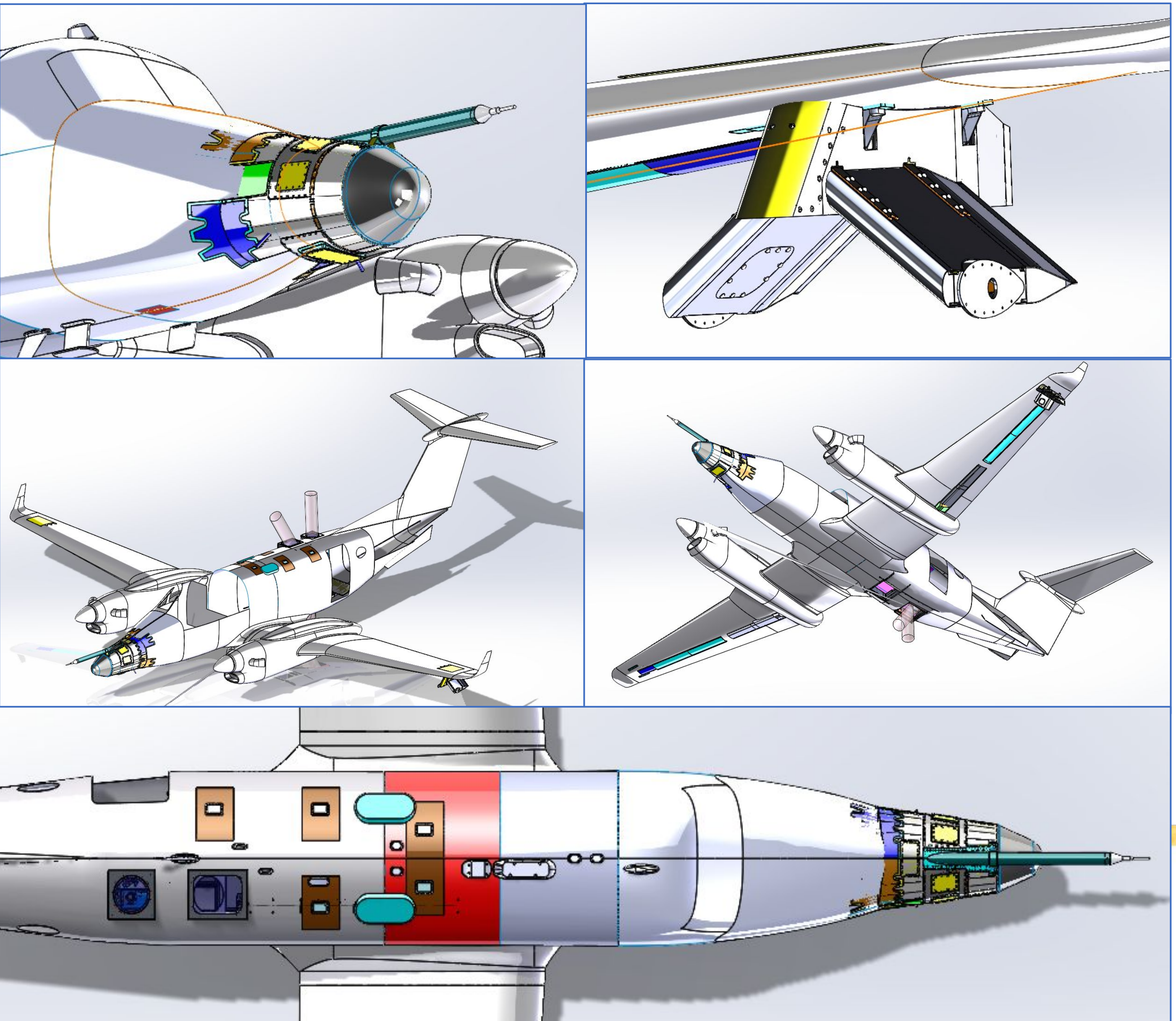
Research-specific Modifications

- *Design and complete 53 research-specific modifications to special-mission aircraft*
- *Development includes 3 new STCs*





Project 1: Acquisition, Modification, Certification
Research modifications



- nose extension, and boom with gust probe
- hardpoints near wingtip for PMS cans (4)
- two large nadir ports
- two large zenith ports, in blue
- dropsonde chute
- inlets
- several smaller ports
- satcom antennas


Nose extension and gust probe boom


Nose extension and gust probe boom


dual Zenith port


Aft Nadir port
Fore Nadir port

The Next-Generation Wyoming Research Aircraft
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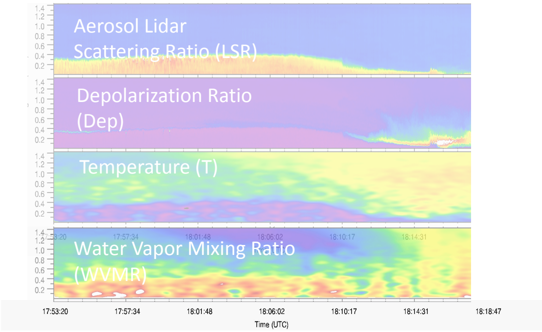
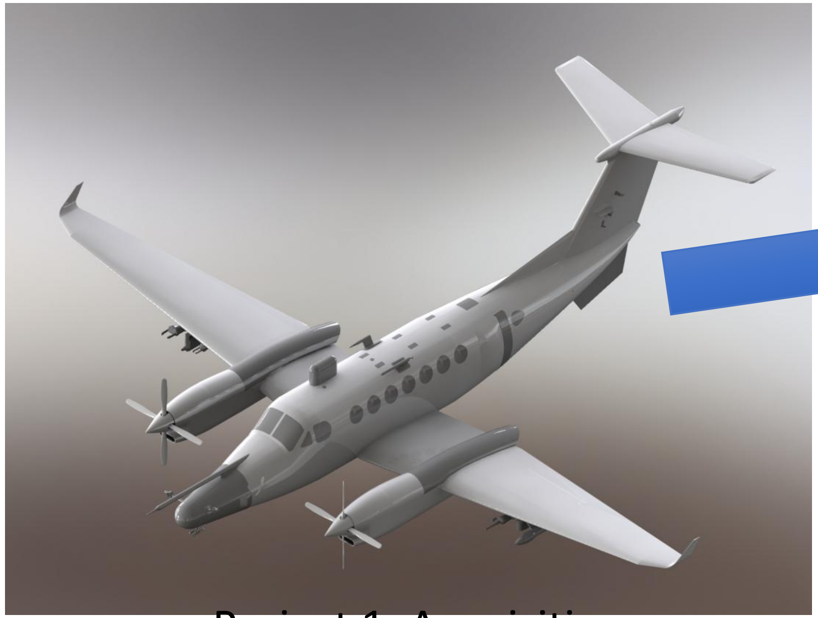
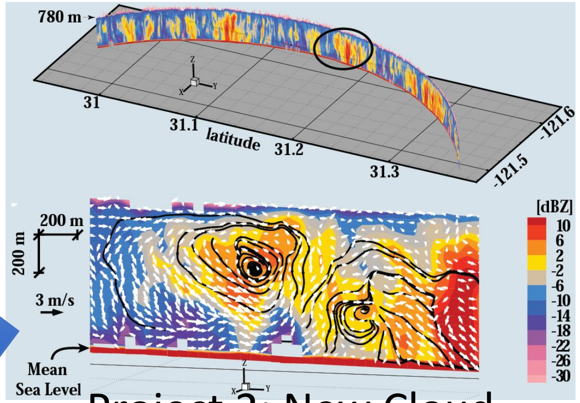


Project 3: New Airborne Lidars

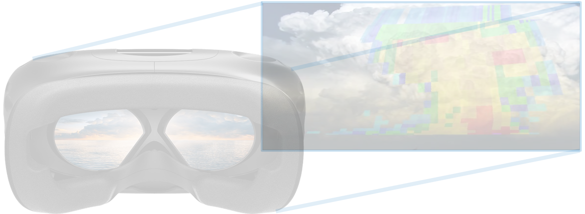


Project 1: Acquisition, Modification, and Certification



Project 2: New Cloud Profiling Radars

Project 4: Trace Gas and Aerosol

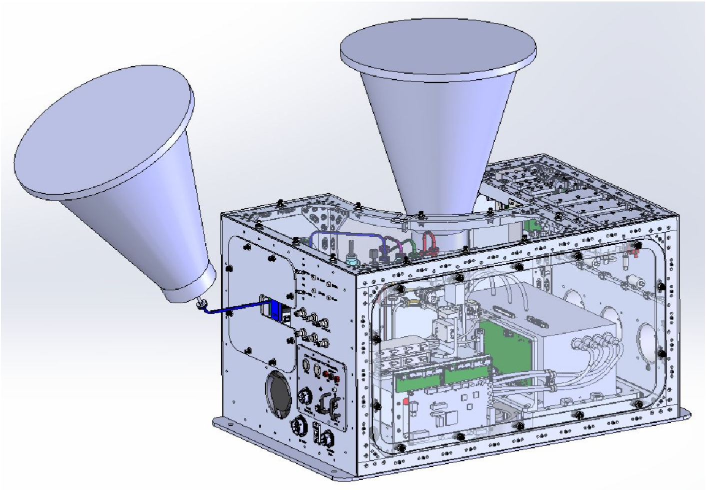


Project 5: Immersive Environment for Science and Training

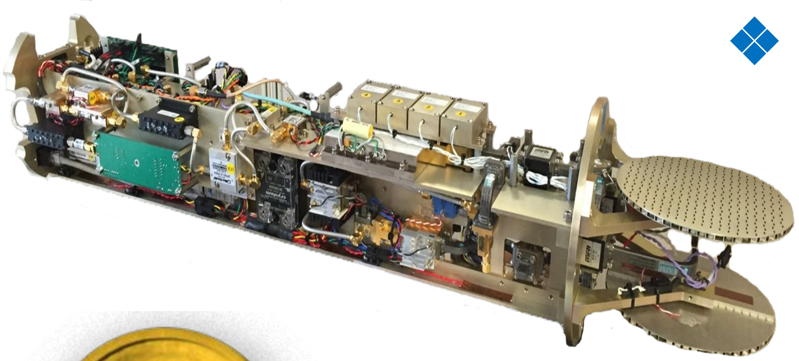
Project 2: improved cloud profiling radars

❖**WCR-4** ***W****-band cloud radar*:

- Utilize 4 antennas: near Nadir, Down-fore, near Zenith, Up-fore
- Enables Vertical-Plane Dual-Doppler above and below aircraft
- New and upgraded RF hardware, including new W-band modulator
- Improved internal calibration sub-system
- RF unit repackaging for optimal antennas connection
- Upgraded Data Acquisition System and Display Software



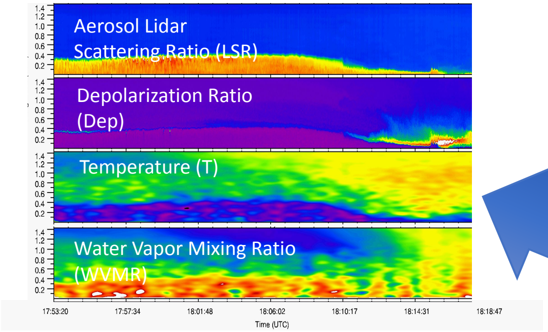
Both radars can be deployed on the NSF/NCAR C-130



❖ **KPR-2** ***K_a****-band precipitation radar:*

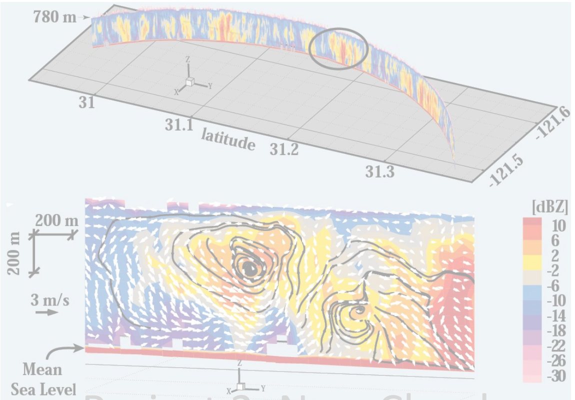
- Larger passive array antennas (2.2° HPBW)
- Upgrade RF for higher duty cycle of the solid state transmitter (up to %50)
- New Quadratic Phase Code Mode for higher sensitivity and weak side lobes
- New hybrid acquisition mode combining short pulse, compression chirp, and QPC

The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)



Project 3: New Airborne Lidars

Project 1: Acquisition, Modification, and Certification



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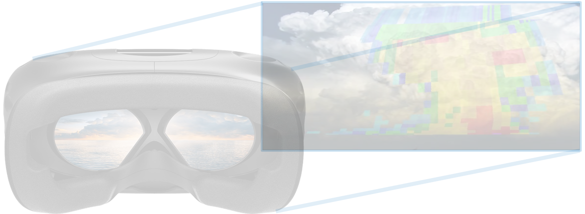


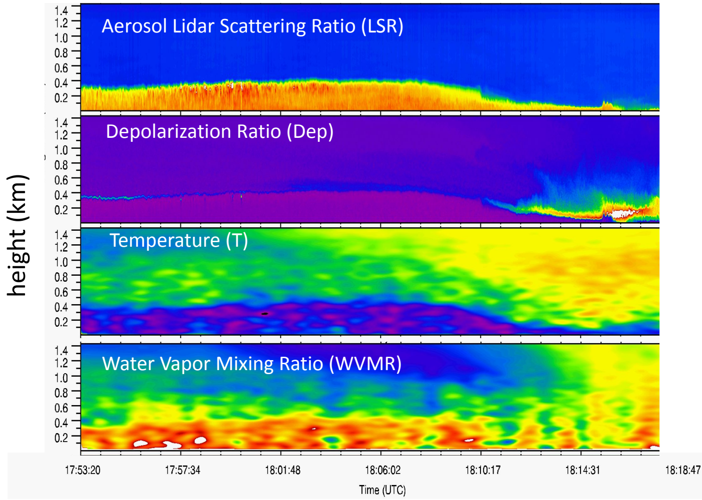
Project 5: Immersive Environment for Science and Training

University of Wyoming

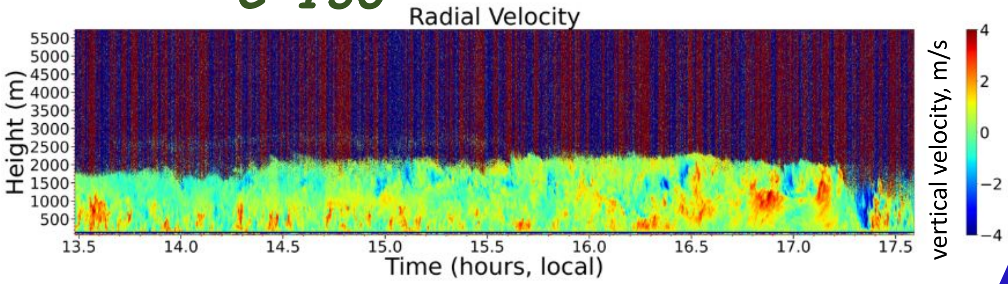
Project 3: airborne atmospheric profiling lidars

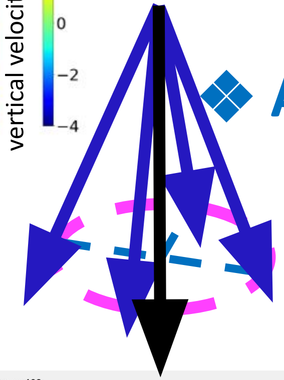
MARLi-2 Multi-function Airborne Raman Lidar:

- **Temperature and water vapor profiling below aircraft**
- A new diode-pumped laser: reduces power consumption and weight
- Uses a novel 355nm Raman/fluorescence module
- A new set of filters for warm boundary layer measurements



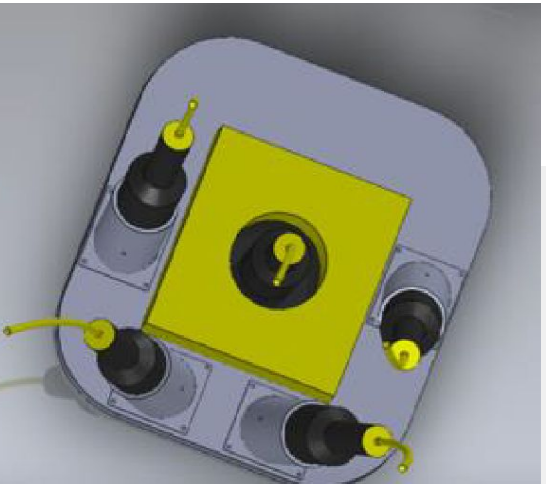
Both lidars can be deployed on the NSF/NCAR C-130

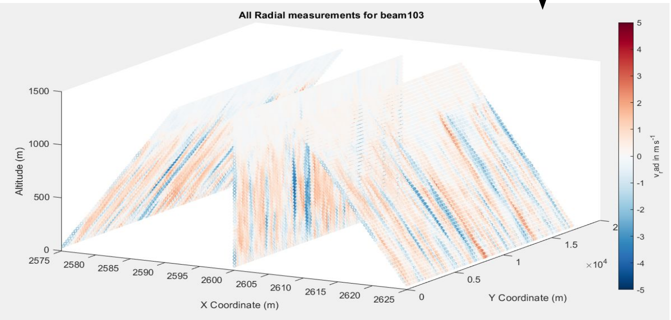




ADL Airborne Doppler Lidar (new):

- **Fine-scale (sub-km) three-dimensional wind profiles in clear air**
- Prototype design and test key technology completed
- Single beam on stabilized platform completed, tested aboard van
- Five-beam system in development, testing on ground in early 2023
- Airborne testing and validation in 2023 (probably on C-130)
- STC development and certification for UWKA-2 in 2024





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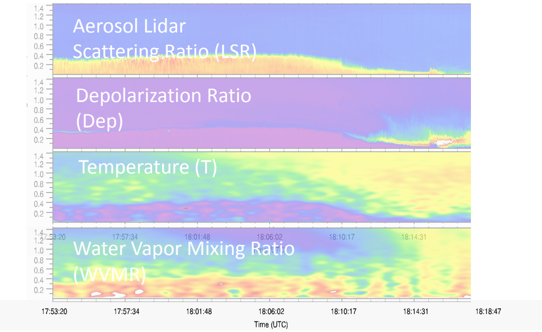
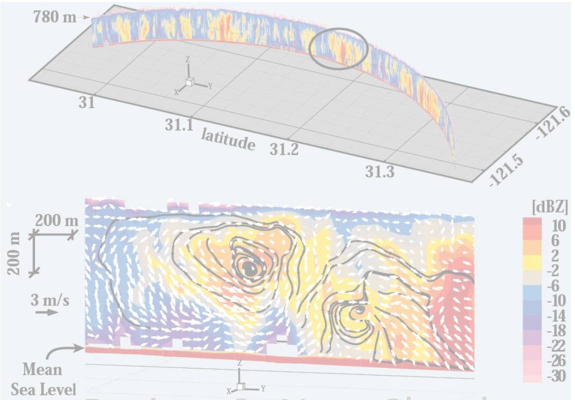


Project 3: New Airborne Lidars



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Project 1: Acquisition, Modification, and Certification

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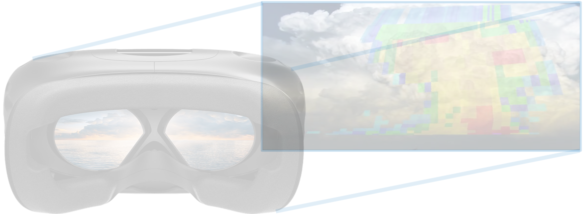

Project 5: Immersive Environment for Science and Training

Project 4: New trace gas capabilities

- NO_x analyzer: Laser-Induced Fluorescence (LIF – NCAR) or Cavity Attenuated Phase Shift (CAPS - Aerodyne) (2023)
- Picarro G2401-m in-flight analyzer
  - CO, CO_2, CH_4, and H_2O @ 0.3 Hz
- Two Aeris MIRA Ultra sensors
  - CH_4, C_2H_6, and H_2O
  - CO, N_2O, and H_2O
- O_3 detector, O_3 calibration unit and recommended flight upgrades
- Brechtel Model 1204 CVI inlet

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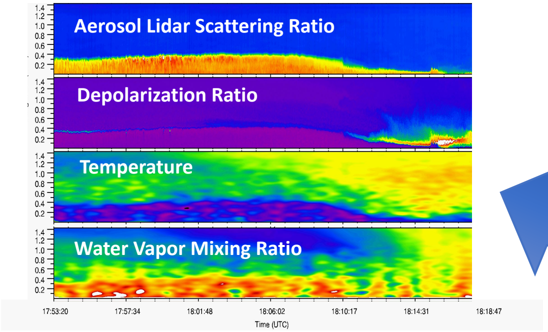

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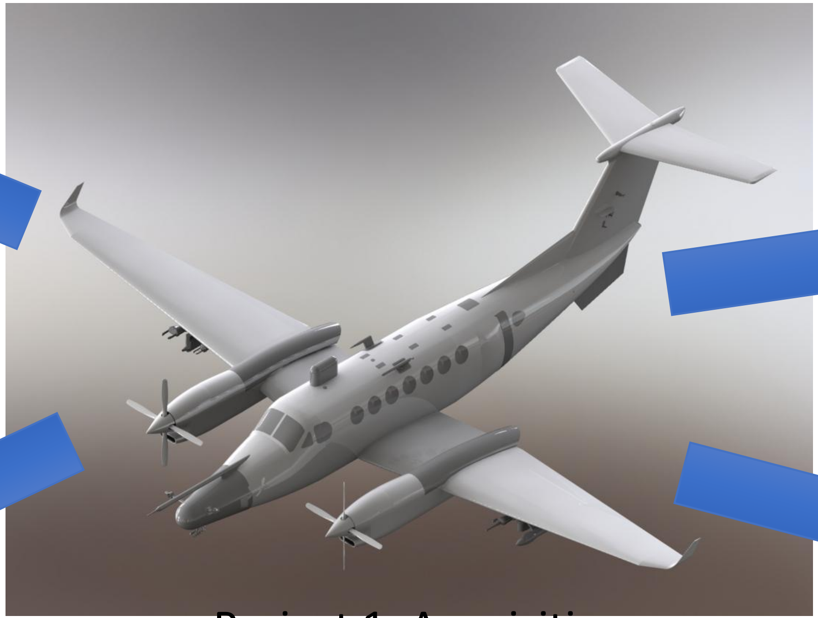

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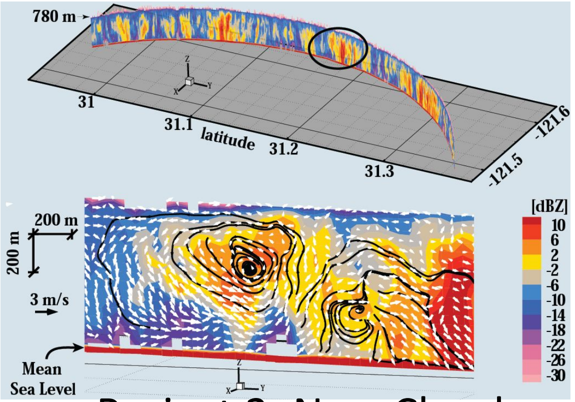

Project 2: New Cloud Profiling Radars

Project 4: Trace Gas and Aerosol

Project 5: Immersive Environment for Science and Training

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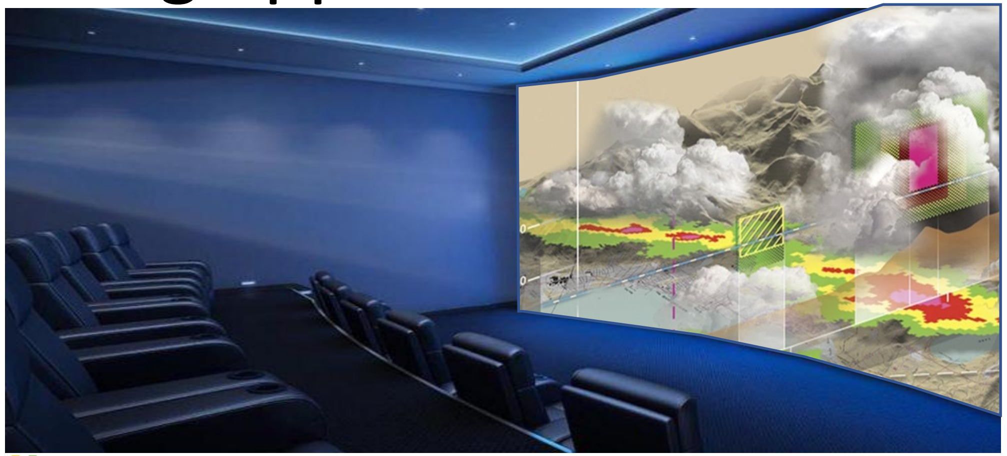
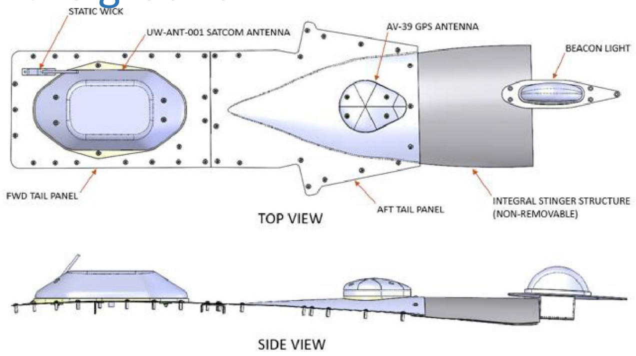
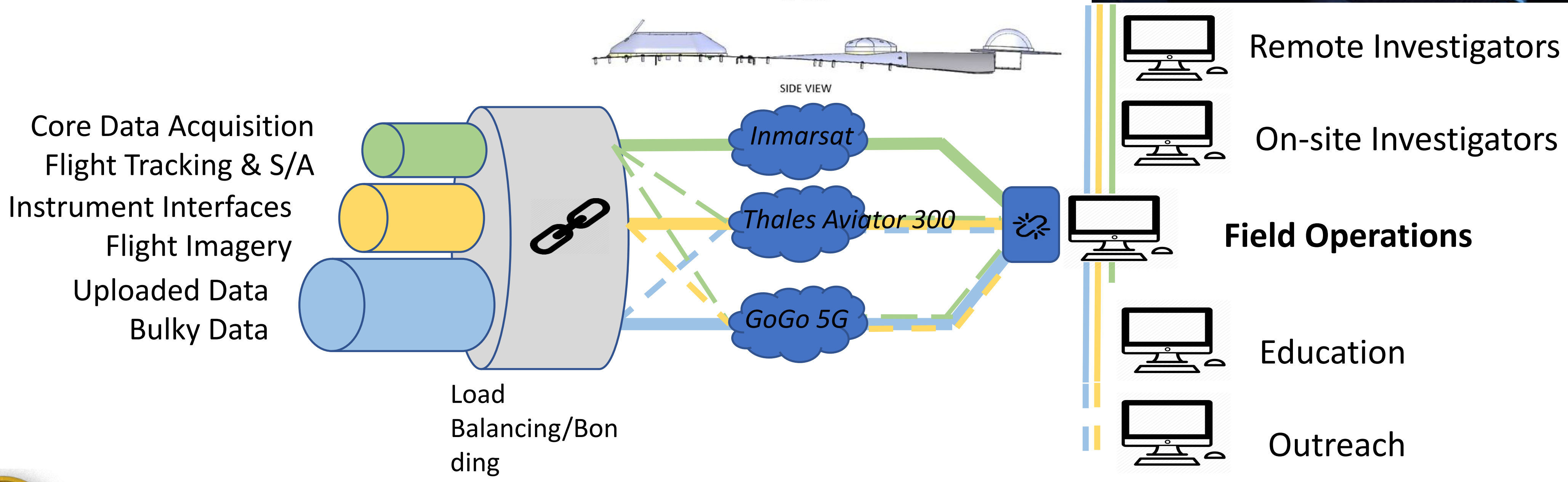
Project 5: Immersive environment to enhance science, flight decisions, and student training opportunities

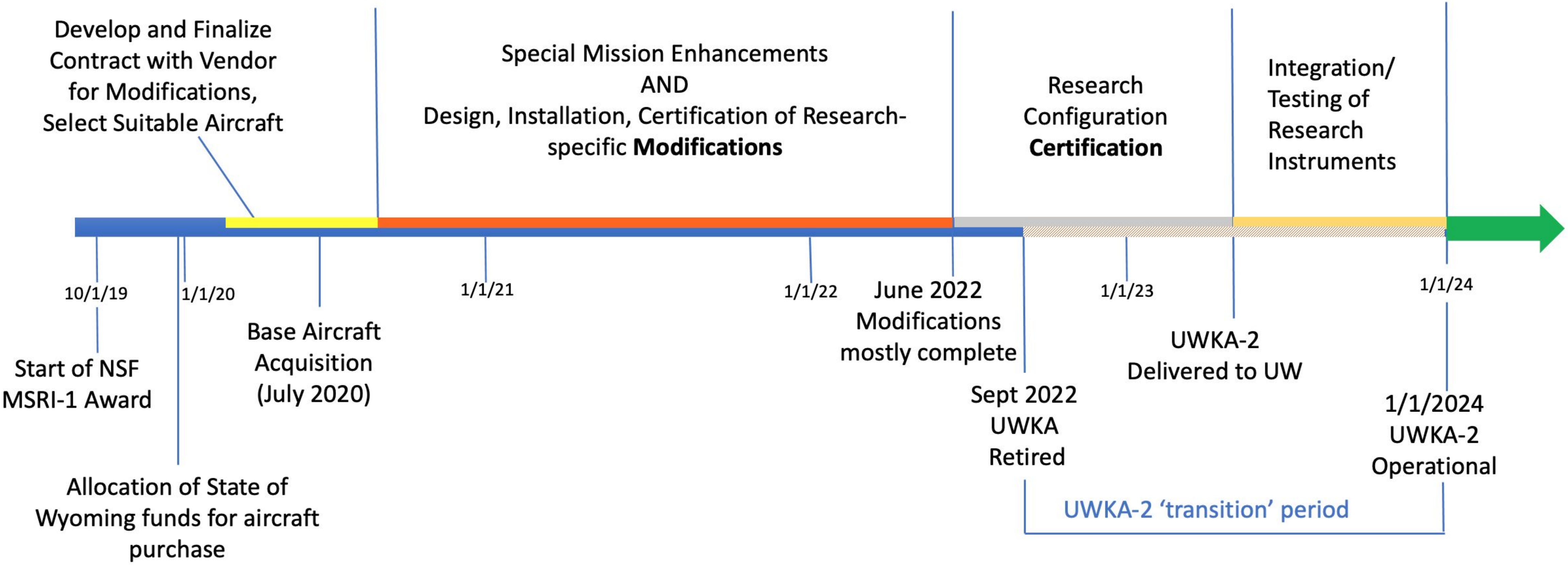
- ❖ Engaging more investigators given limited space
- ❖ Training and captivating students (virtual immersion)
- ❖ Complimentary situational awareness on the ground
- ❖ Maintaining an interactive platform







UWKA – 2 Timeline

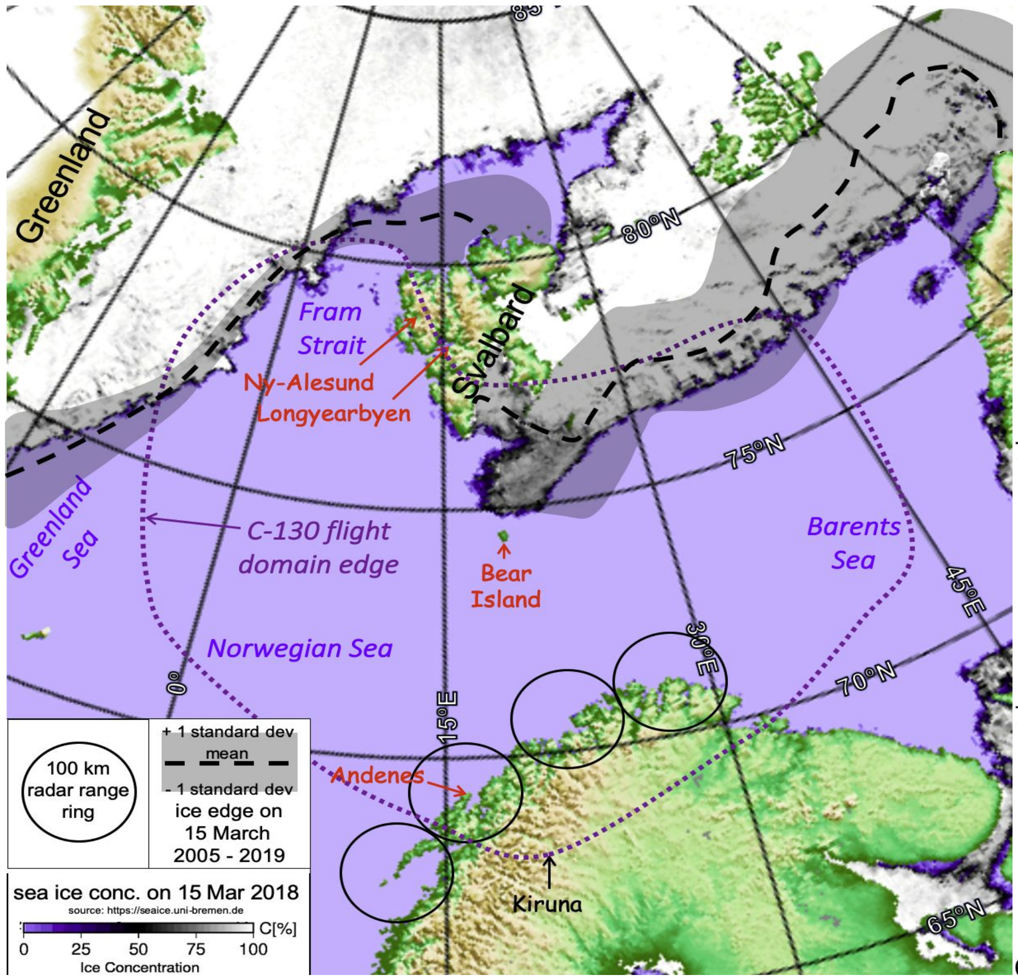


CAESAR: C-130 over the Norwegian Sea

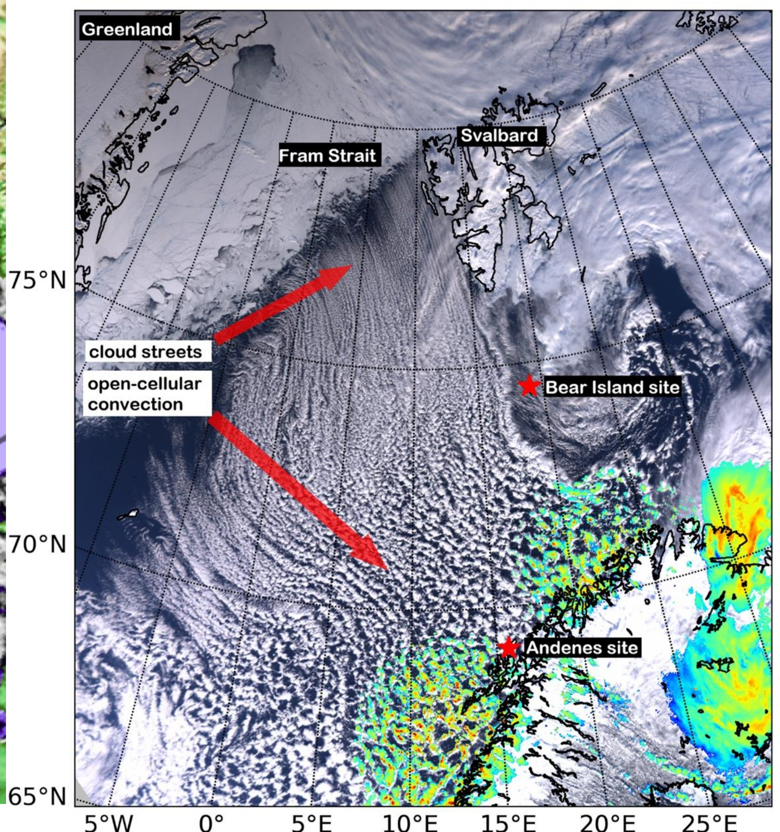
P/Is: Zuidema, Geerts, McFarquhar, Bailey, Cassano, DeMott, French, Wang

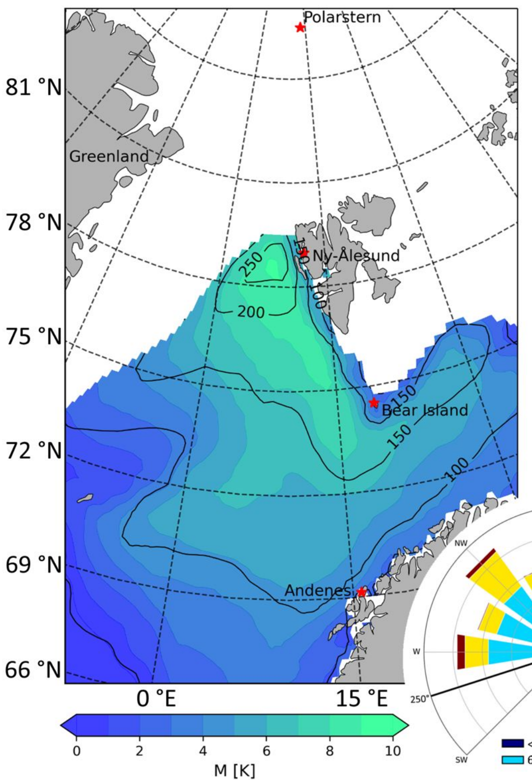
CAESAR aims to study how heat and momentum fluxes from the sea surface, boundary layer circulations, and cloud processes interact over the far northern Atlantic to produce the iconic cloud structure during cold-air outbreaks over open water.

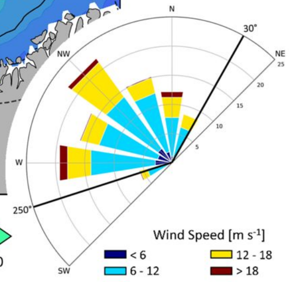
Cold-Air outbreak Experiment in the Sub-Arctic Region
NCAR C-130
Norwegian Sea
CAESAR 2024



The heat loss during CAOs in the near-surface ocean layers may be sufficiently strong in some areas for the surface waters to become negatively buoyant, sink to depth and form deep ocean water. Therefore, changes in frequency and intensity of CAOs in a changing climate and changing Arctic sea ice extent may have profound feedbacks on the climate system.







thermal instability (color) and SHF (contour) during CAOs in 2019-’20

CAESAR science traceability matrix

measurement requirements

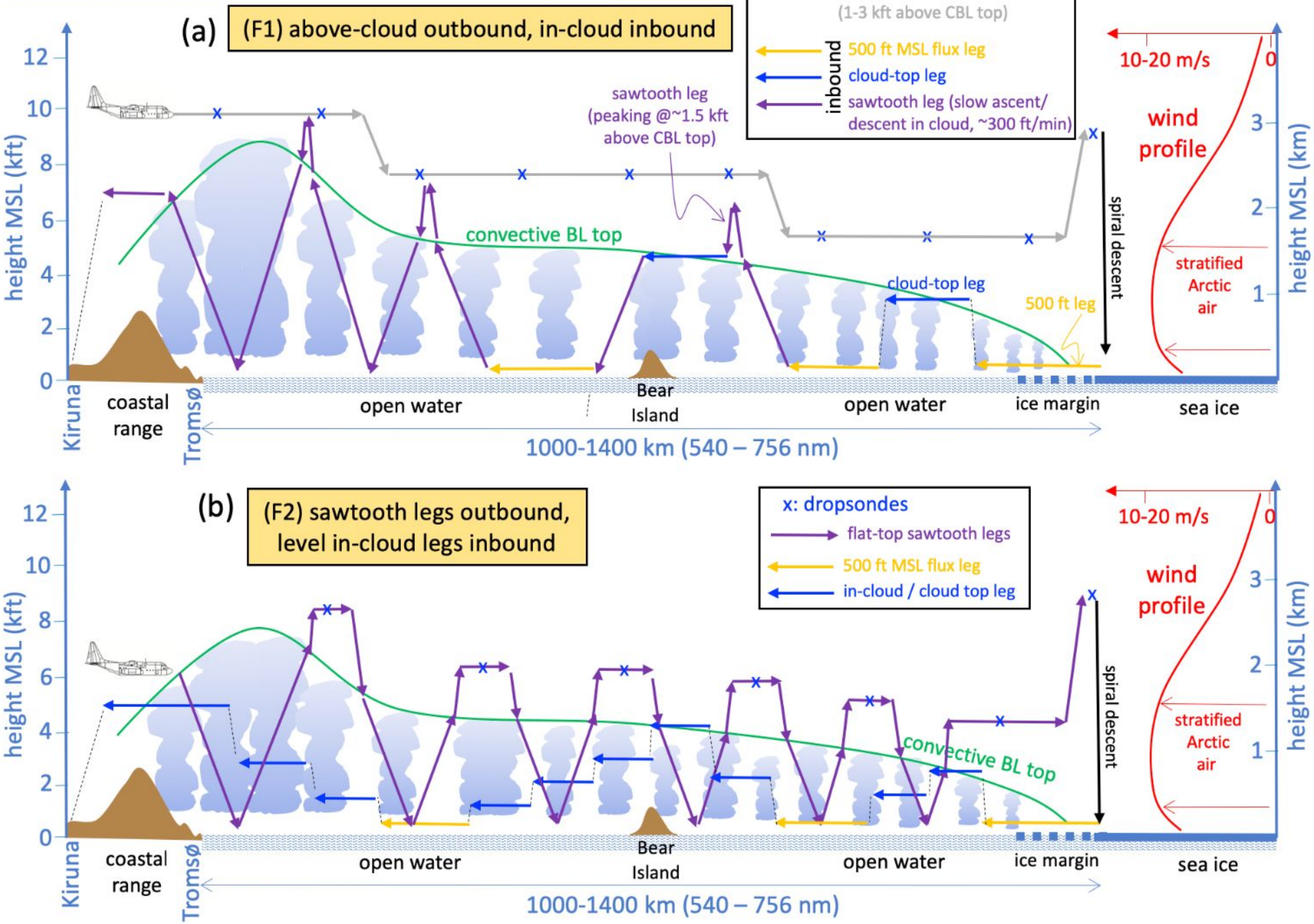
instruments (base, user-supplied)

specific objectives

observational category	instruments	1. surface fluxes & BL growth	2. mesoscale structure	3. clouds & precipi-tati on	4. aerosol	5. polar lows
2D along-track wind (u,w)	WCR					
2D cloud & precipitation structure and properties	WCR, KPR, WCL, MARLi					
2D aerosol structure and properties	WCL, MARLi					
2D along-track q_v, T in clear air	MARLi					
LWP, WVP	GVR					
soundings	AVAPS, plus Met Norway (hourly, Bear island)					
state variables, pressure perturbations, wind, TKE	VCSEL, RFT, radiometric T, gust probe, HADS					
broadband hemispheric radiation	SW & LW radiometers					
surface fluxes	VCSEL, RFT, gust probe					
sea state, SST	MARLi, nadir camera, Heimann IR sensor					
bulk condensed water (LWC, IWC)	Nevzorov, CVI, King, Rosemount					
droplet size distribution	CDP					
precip size distribution	2D-S, 2D-C, PIP					
hydrometeor spatial structure	HOLODEC-II					
hydrometeor imaging	PHIPS-HALO, 2D-S, 2D-C, PIP, HOLODEC-II					
$\delta^{18}O$ isotope ratios of q_v and bulk condensed water	CVI/SDI, cavity enhanced laser absorption					
aerosol size distribution	PCASP, UHSAS					
black carbon concentration	SP-2					
INP concentration & chemical make-up	CFDC, IS filters					
CCN concentration	CCN counter					
carbon monoxide conc.	cavity enhanced laser absorption					
mapped cloud/precip structure	met.no radar network, satellite imagery					

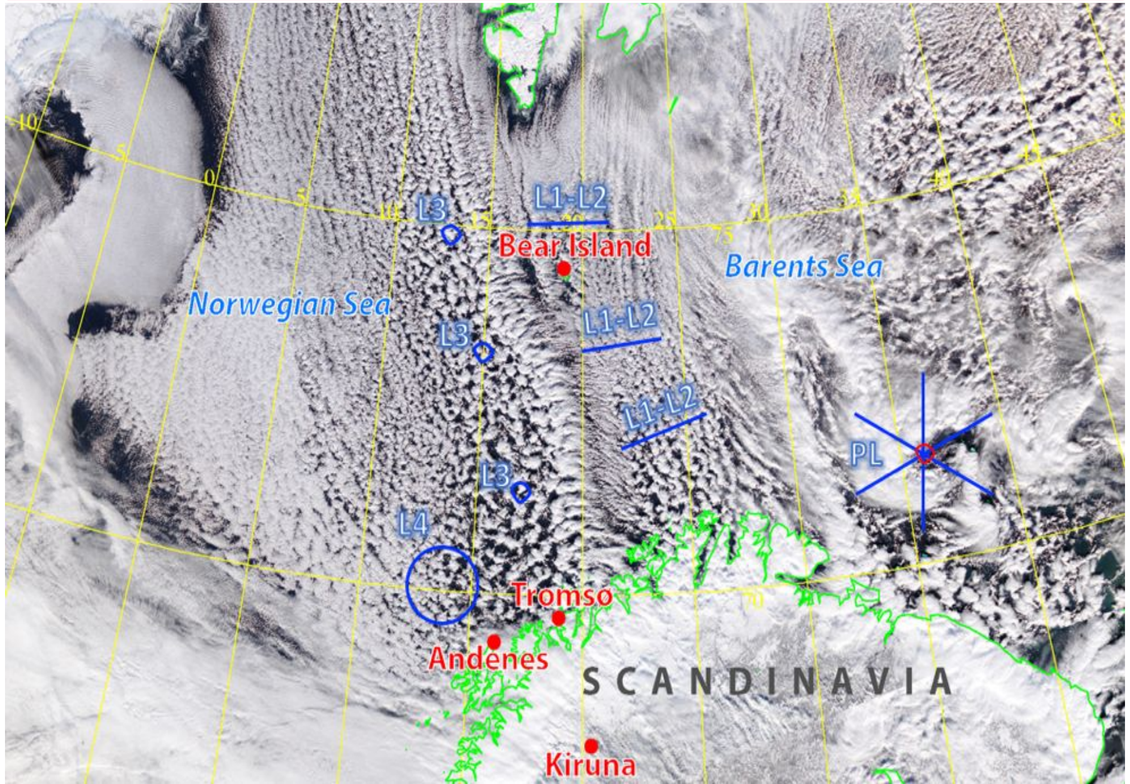
priority greyscale: **not needed** — **useful** — **essential**

CAESAR to-the-ice-and-back flight patterns



Local CAO cloud and polar low sampling

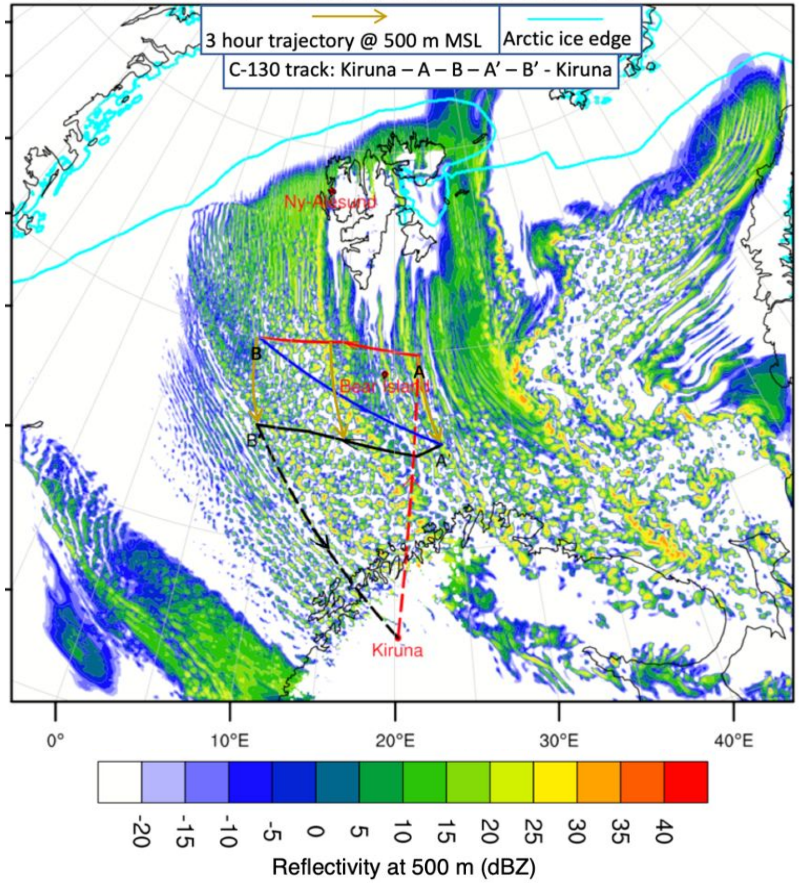
ref	flight patterns
L1	Level legs <u>across</u> the prevailing wind and cloud streets, @ multiple levels, ~150 km
L2	Porpoising legs <u>across</u> the prevailing wind, long enough to transects several cloud bands (two rises above BL and two dives to SL, ~150 km)
L3	Spirals from ~500 m above cloud top to near-surface, slow ascent/descent rate
L4	Large circles, drifting with the wind, two levels (just above cloud top & in-cloud)
PL	A rosette pattern of 200-300 km long traverses across a polar low, at multiple levels



Quasi-Lagrangian sampling

CAO type	flight patterns
Weak winds	Resampling the BL air on next-day flight
Strong winds	Resampling on the same flight (illustrated below)

background: WRF at 03/17/2016 10:50 UTC
C-130 take-off at ~8 am LT, return 8.1 hours later



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Questions?