ATMOSPHERE
Observing System

National Aeronautics and Space Administration

EARTH SYSTEM OBSERVATORY

Update on the ALICAT lidar and recent NASA sponsored airborne field campaigns

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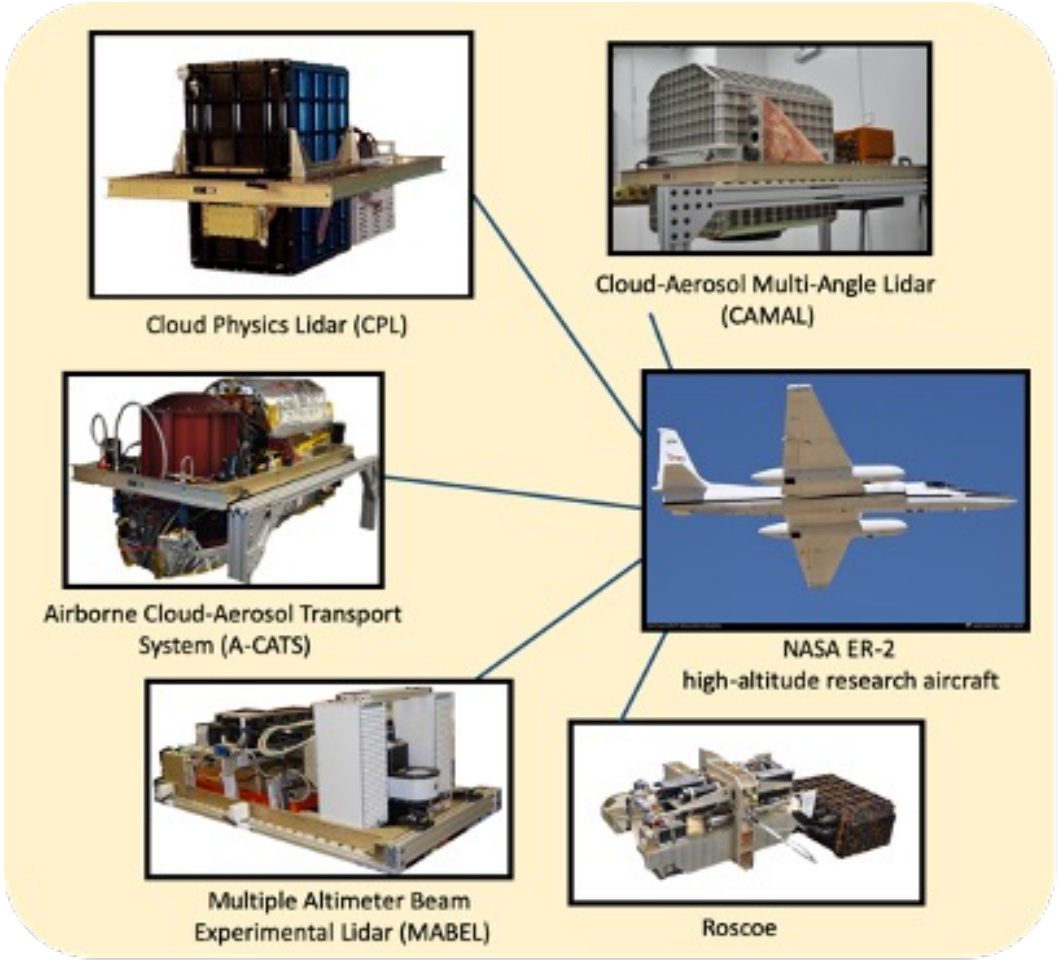
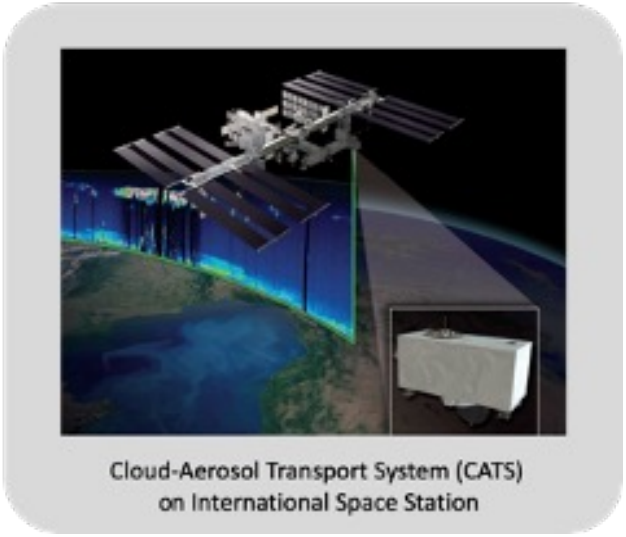
GODDARD EARTH SCIENCES

20 Years of Lidar Instrument Heritage

Since 1999 multiple high-altitude autonomous instruments have been built by our lidar group at GSFC. All are photon-counting/high rep-rate designs.

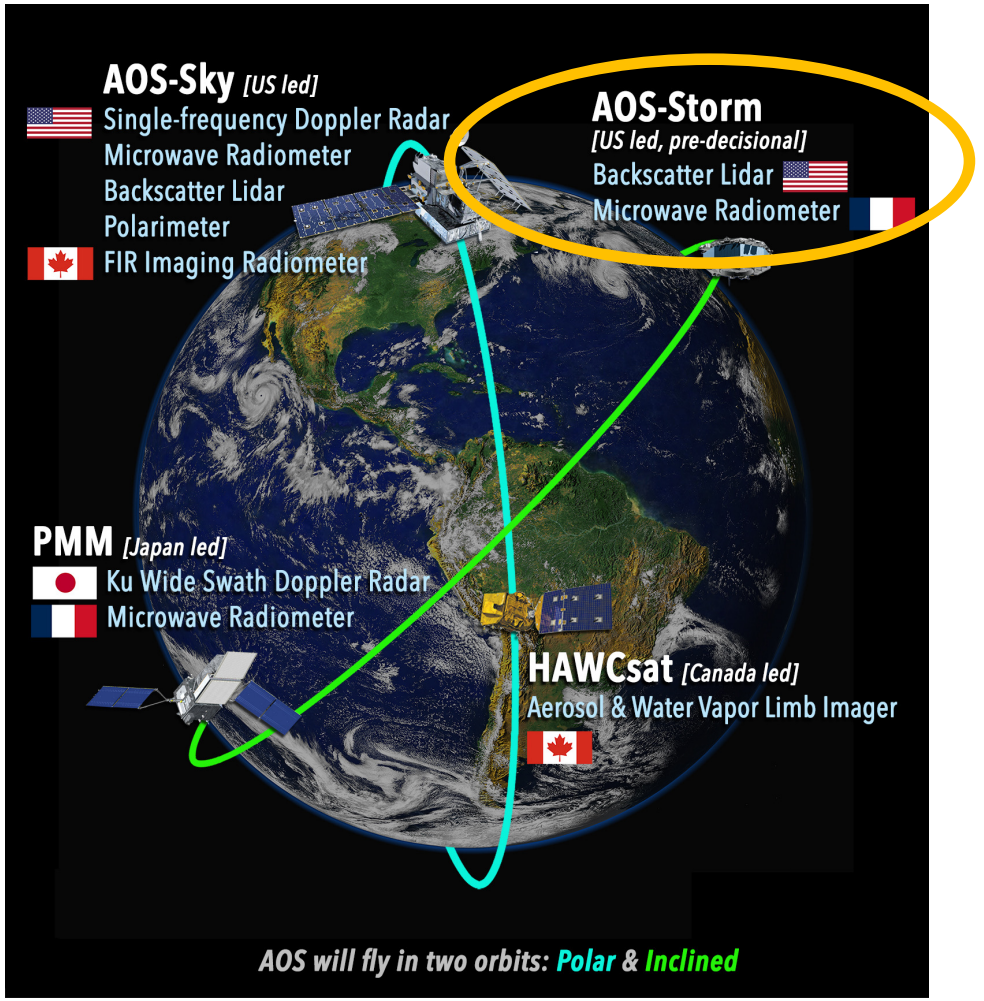




ALICAT for AOS-Inclined Science

- Elastic backscatter lidar that provides measurements of attenuated backscatter and linear depolarization at 532 and 1064 nm for detection of clouds and aerosols
- Will deliver near-real time (<6 hours) data products to the applications community
- Provides a new exciting opportunity for synergistic products in an inclined orbit (e.g. Ku radar+radiometer+lidar products) not possible with CALIPSO or CATS
- Offers early science delivery for AOS by launching this decade – there is a NASA spaceborne atmospheric lidar gap as CALIPSO stopped data collection in 2023

Lidar Instrument	ALICAT	CALIPSO	CATS
Operational Period	2028 – 2030+	2006 - 2023	2015-2017
532 nm Total Backscatter	•	•	
1064 nm Total Backscatter	•	•	•
532 nm Depolarization	•	•	
1064 nm Depolarization	•		•
Inclined Orbit	•		•
< 6 Hr Data Latency	•		•



Central AOS Science Addressed by ALICAT

EARTH SYSTEM OBSERVATORY

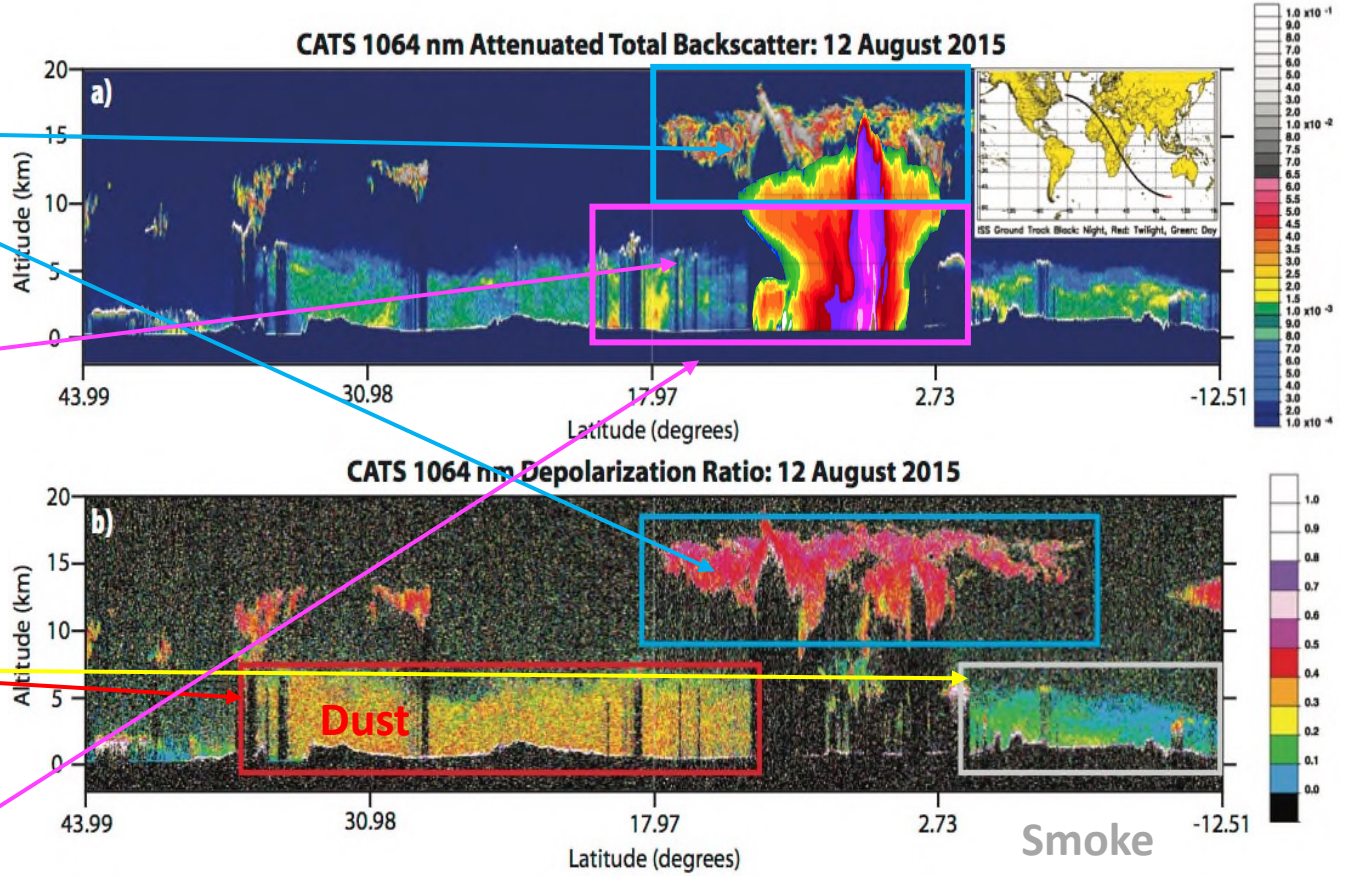
AOS is a process-focused mission with lidars and radars as centerpieces to provide critical vertical measurements of aerosols, clouds, and precipitation – ***and their diurnal variability***

High Clouds
Measurements of thin high clouds, especially in the presence of convection

Convective Storms
Detection of environmental aerosols in the presence of convection

Aerosol Attribution/Air-Quality
Measurements of optically thick dust, smoke, and anthropogenic aerosols in source regions above and within the PBL

Aerosol Removal & Redistribution
Synergistic observations of aerosols and convective precipitation/vertical motions



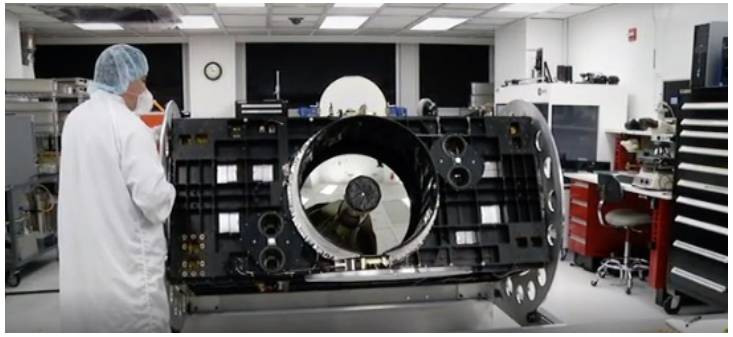
ALICAT's strengths are detection and quantification of optically thin high clouds and dust/smoke aerosols, all features with diurnal variability

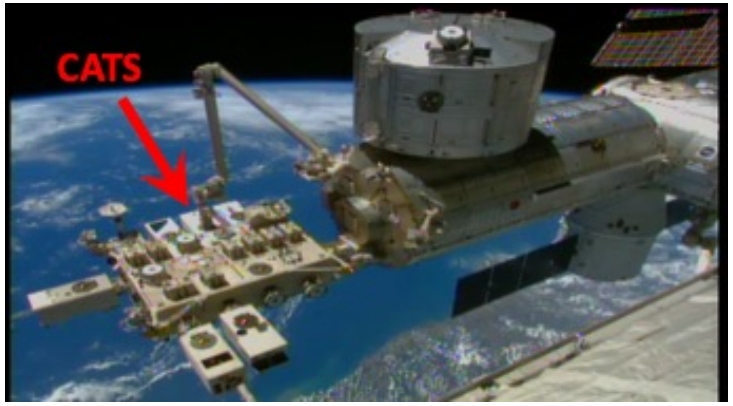
ALICAT Heritage from CATS

The Cloud-Aerosol Transport System (CATS) was a cloud-aerosol lidar utilizing ISS as an affordable Earth Science observing platform.

- CATS was not a flight mission, was not driven by science requirements
- CATS provided in-space demonstration of measurement capability and technologies
- Designed to operate on-orbit for at least 6 months, CATS operated for 33 months
- Very low cost ($15 million), CATS was not limited by mass and power so functionality was the focus, not overly refined design for optimal mass/power/etc.
- Much of the design and many of the CATS components are re-used for ALICAT, just repackaged to fit the SmallSat form factor
- Algorithms – will leverage proven algorithms from both CATS and CALIOP with additional optimization for AOS

ALICAT offers ***improved SNR*** compared to CATS and an opportunity to provide CALIPSO quality measurements with an added ***time dimension*** in an affordable package





TIMELINE:

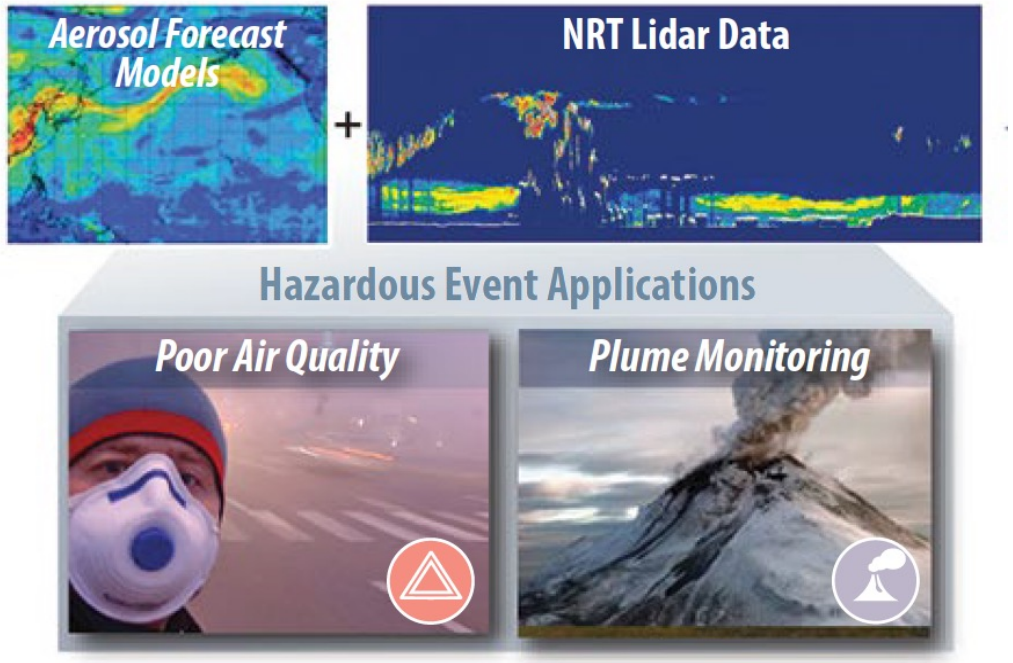
Jan 10, 2015: CATS launched on SpaceX-5
Jan 22, 2015: installed to JEM-EF
Feb 5, 2015: "first light" with laser
Feb 10, 2015: first "science quality" data
Oct 30, 2017: end of science operations

>200 billion laser pulses on-orbit
14,000+ hours data collected

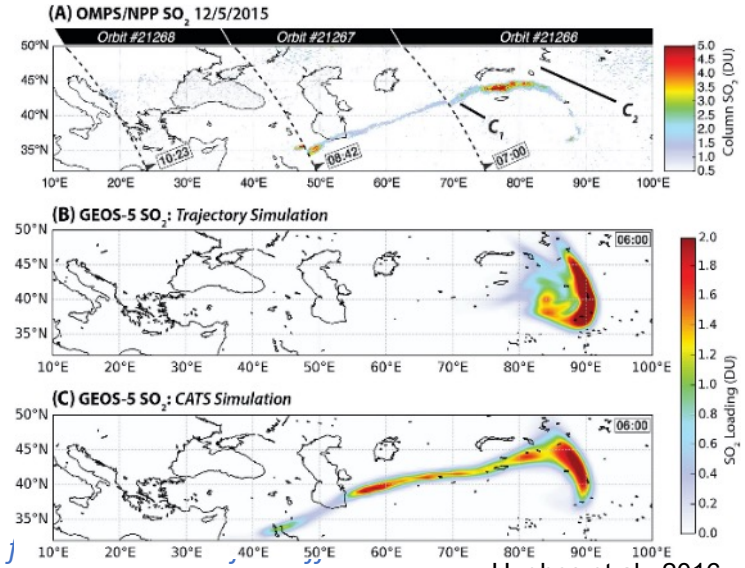
Applications: A Progression from CATS

ISS provided real-time data downlink, allowing CATS to pioneer near-real time (<6 hours) data processing for the application community

Our algorithms and infrastructure are already in place to handle the more stringent latency requirements of AOS



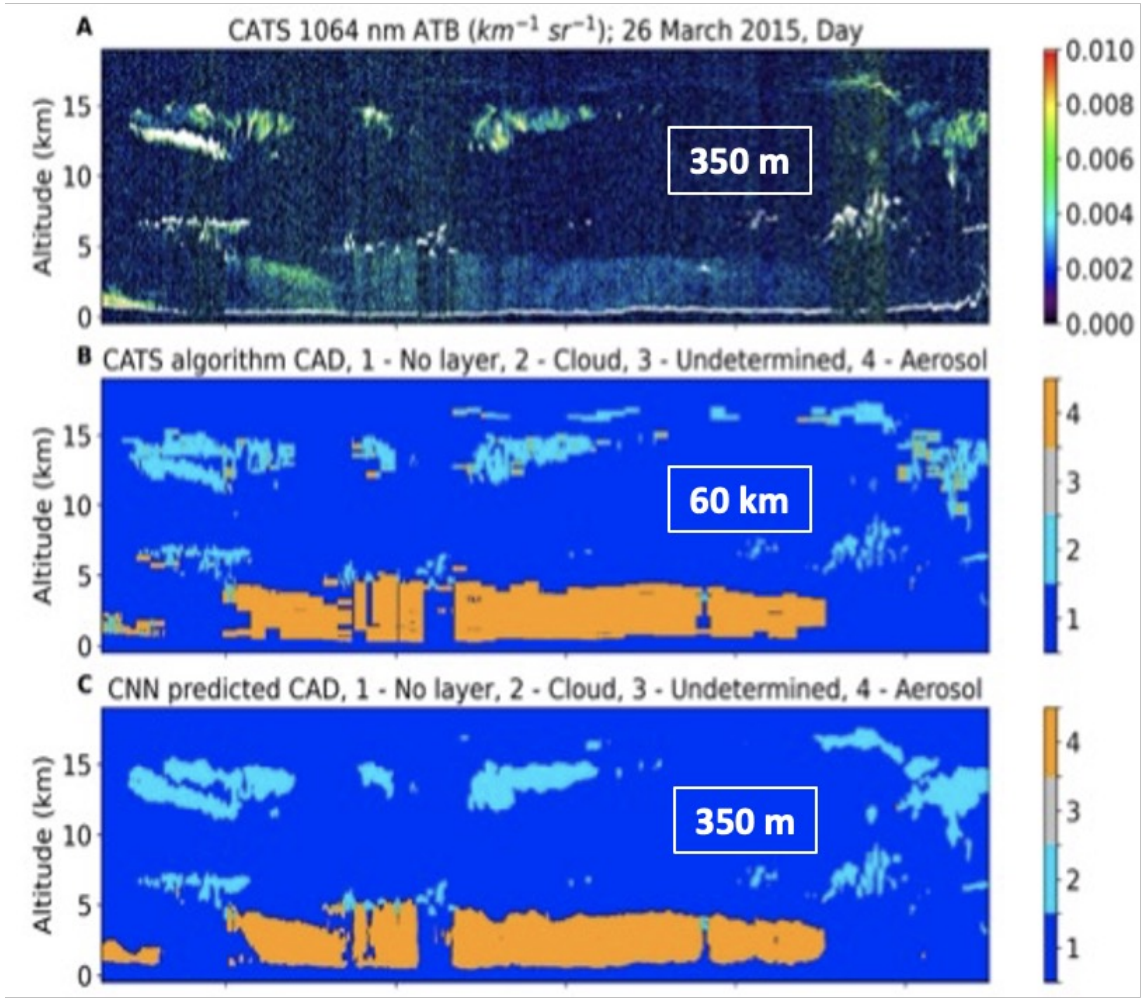
Use of CATS to Monitor Volcanic Plumes



Hughes et al., 2016

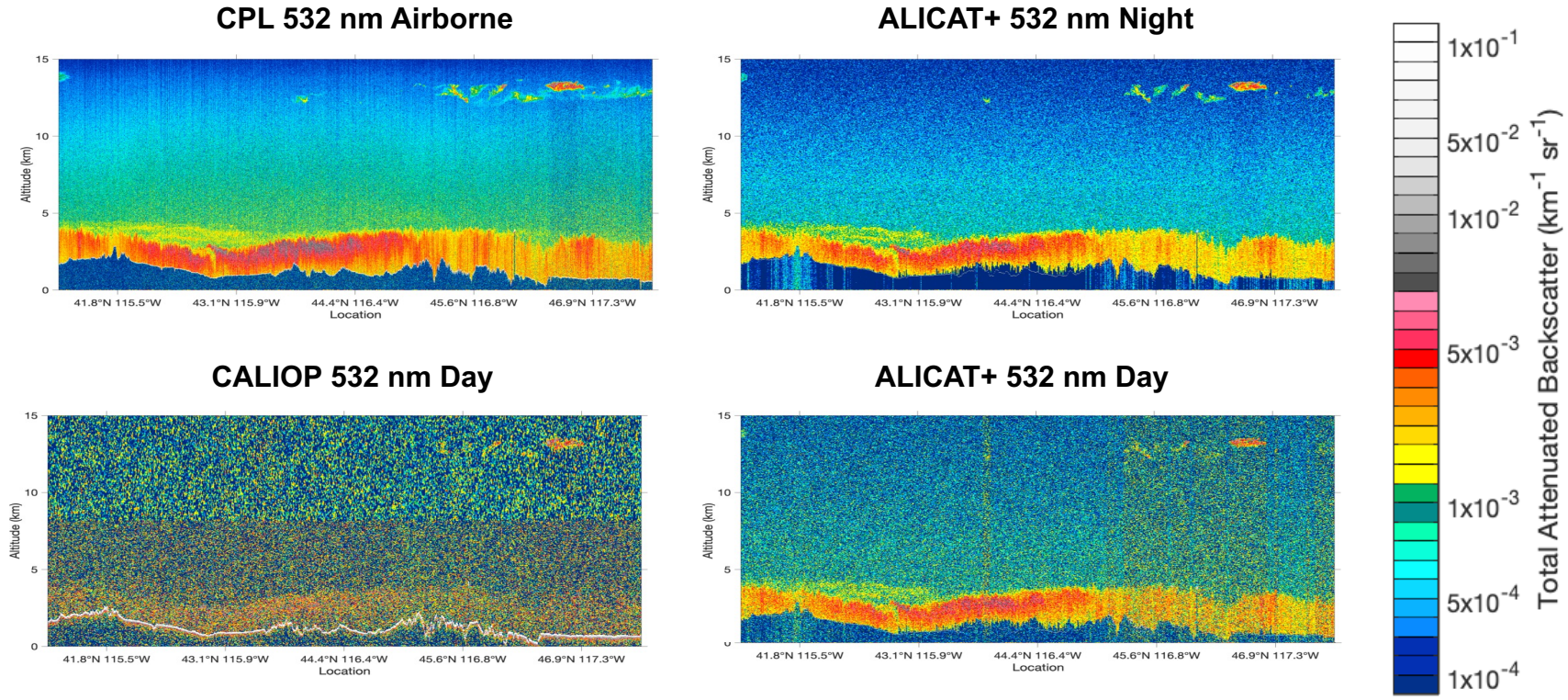
New Capability for ALICAT: Real Time Data

- A key success of CATS was the ability to provide real time data and near-real time data products
- ALICAT builds on this capability to provide data products to users ***in real time***
- ALICAT will include a Jetson TX2 GPU to deliver real-time data
- Signal de-noising and convolutional neural network (CNN) machine learning techniques have been developed and tested on CATS daytime data, which has lower SNR than ALICAT
- Machine techniques show promise for enabling L2 products such as feature detection at L1 resolution



Yorks et al., 2021

Simulated Scenes Using Airborne Data



- Airborne and ground-based scenes provide scene realism and variability not captured in global aerosol transport models
- Will be used going forward to refine and test L2 algorithms for feature detection and classification

Key Takeaways for ALICAT

- Provides critical measurements of aerosol and cloud diurnal variability for AOS and a first-ever opportunity to pair a lidar with a radar and microwave radiometers in an inclined orbit
- Provides a low-cost opportunity for early science return for AOS this decade
- Compact design enables placement options on AOS spacecraft
- Has high heritage in all key areas: hardware and design, measurements, applications, and personnel
- Led to the development of a more comprehensive simulation capability for requirement verification and future algorithm development/testing

Recent Field Campaigns

Convective Processes EXperiment

CPEX-Cabo Verde

- Improve understanding of convective cloud systems (including tropical cyclone precursors)
  - Interactions between these and large-scale forcings (e.g., African easterly waves, ITCZ, Saharan Air Layer, mid-level African easterly jet)
  - Observe how local conditions (e.g., vertical structure and variability of the marine boundary layer) relate to their initiation and lifecycle
- Investigate processes affecting Saharan dust and its transport
  - Vertical structure, boundary layer exchange processes
- Assess the impact of these observations (wind, thermodynamics, clouds, and aerosols) on prediction of tropical Atlantic weather systems and validate and interpret spaceborne remote sensors

CPEX-CV Instrumentation

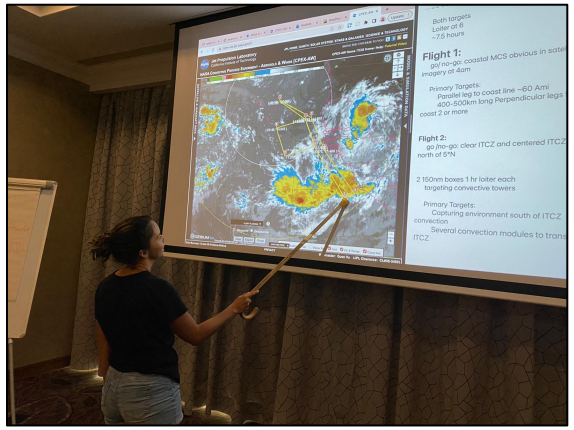
- **DAWN**: Doppler Aerosol WiNd lidar
- **HALO**: High Altitude Lidar Observatory
- **Dropsondes**
- **APR-3**: Airborne Precipitation & Cloud Radar 3rd Gen.
- **HAMSR**: High Altitude Monolithic Microwave integrated Circuit (MMIC) Sounding Radiometer
- **CAPS**: Cloud Aerosol and Precipitation Spectrometer
- **AIRO**: Aircraft In-situ and Radio Occultation
- **RDR-4000**: Weather Avoidance Radar
- **High Ice Water Content (HIWC)**

CPEX-CV

Final public data released to NASA DAACs– Global Hydrometeorology Data Center (GHRC) and the Atmospheric Science Data Center (ASDC)

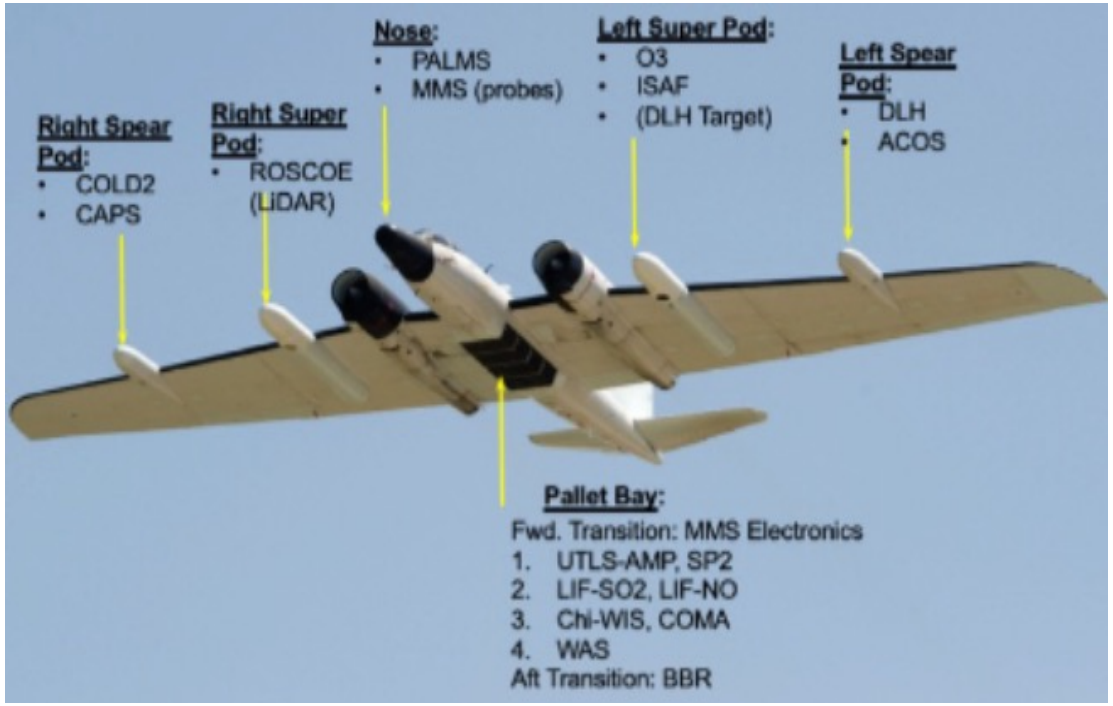
CPEX-CV provided valuable measurements of interactions between dust, clouds, and convection in a data sparse region of the East Atlantic:

- 3 science flights were primarily targeted Saharan dust outbreaks
- DC-8 sampled highest dust AOD (~4) in its history
- 2 flights (RF03 & RF10) provide the opportunity to investigate dust-convection interaction at various stages/scales



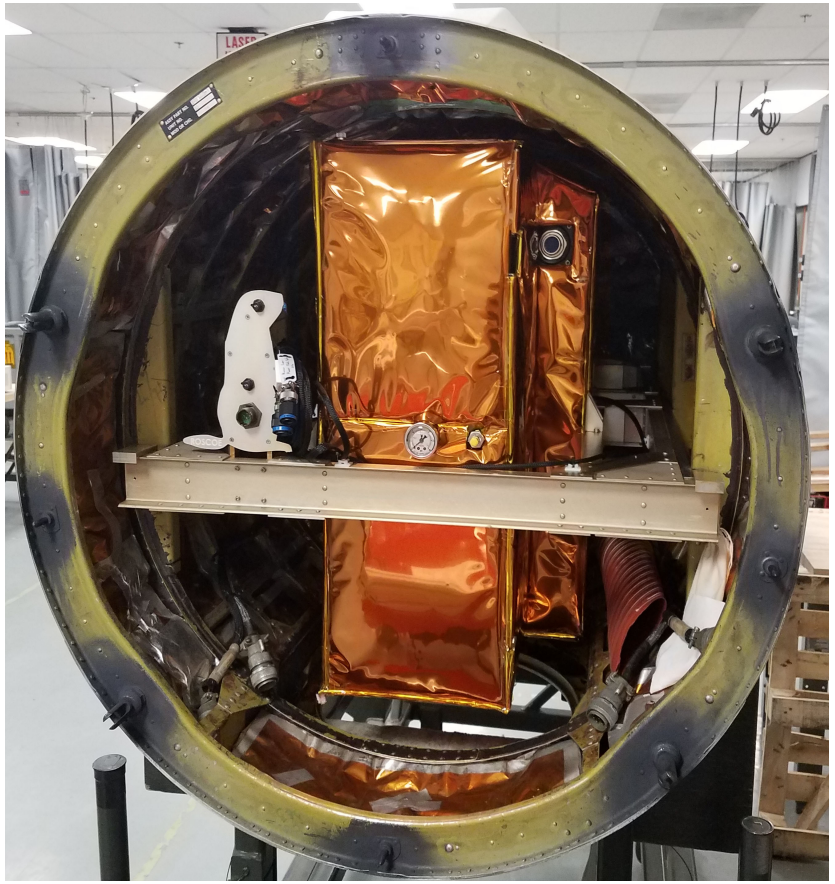
Asian Summer Monsoon Chemical and Climate Impact Project (ACCLIP)

- Based in South Korea (Summer 2022)
- Trace gas + aerosol chemistry and transport associated with the Asian Summer Monsoon, especially upper troposphere /lower stratosphere (UTLS)
- NRL's REThinC sponsored flight hours to sample cirrus

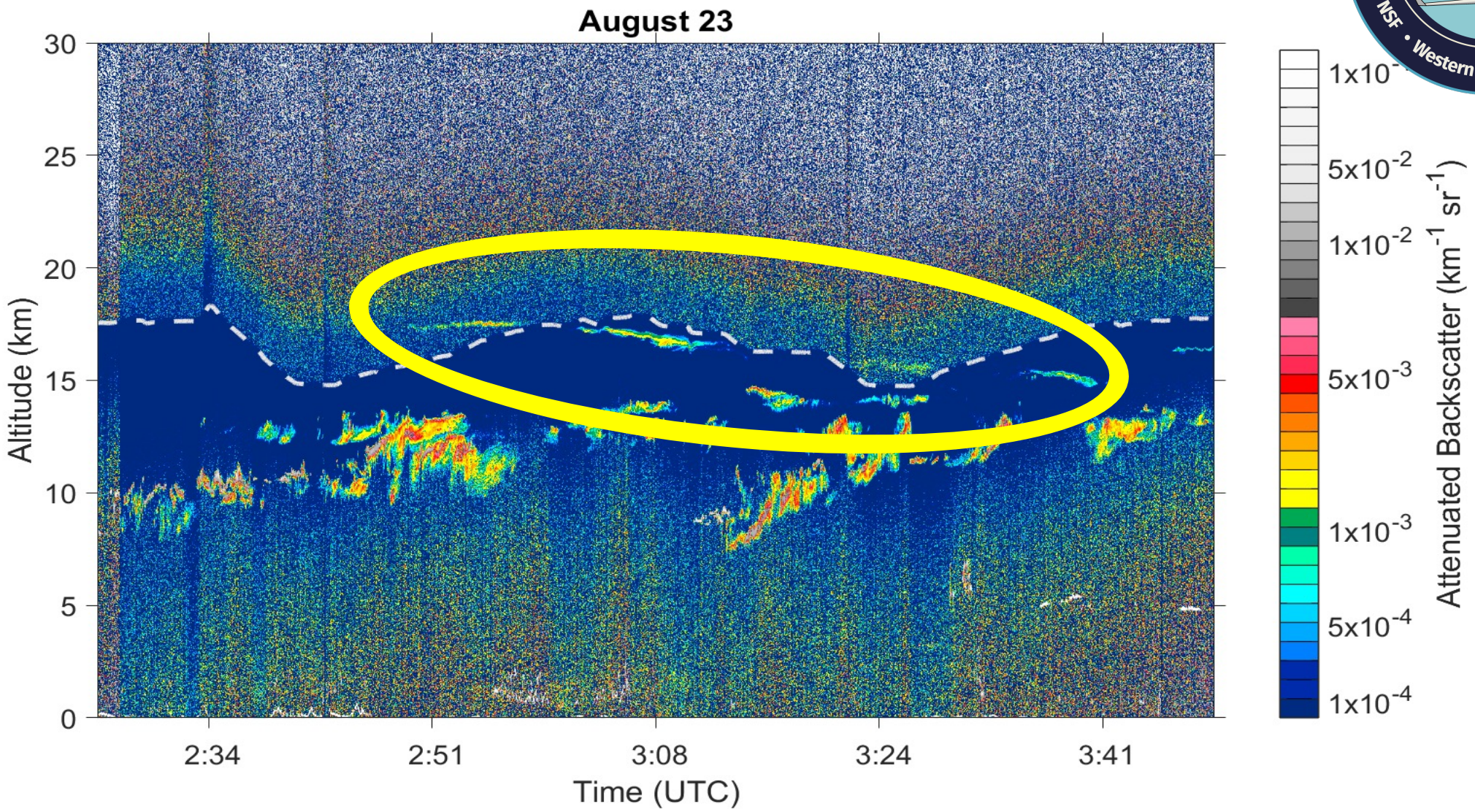


Roscoe lidar

- Next generation airborne backscatter lidar
  - Extensive heritage from CPL
  - Flown on NASA's ER-2 & WB-57
  - 2 wavelengths (1064 & 355 nm)
- Looks upward and downward!
  - Simultaneous observations above and below the plane
- Eye safe operations
  - No visible laser wavelengths (355nm & 1064nm)
- Real-time capability
  - Direct plane for optimal cloud/aerosol work

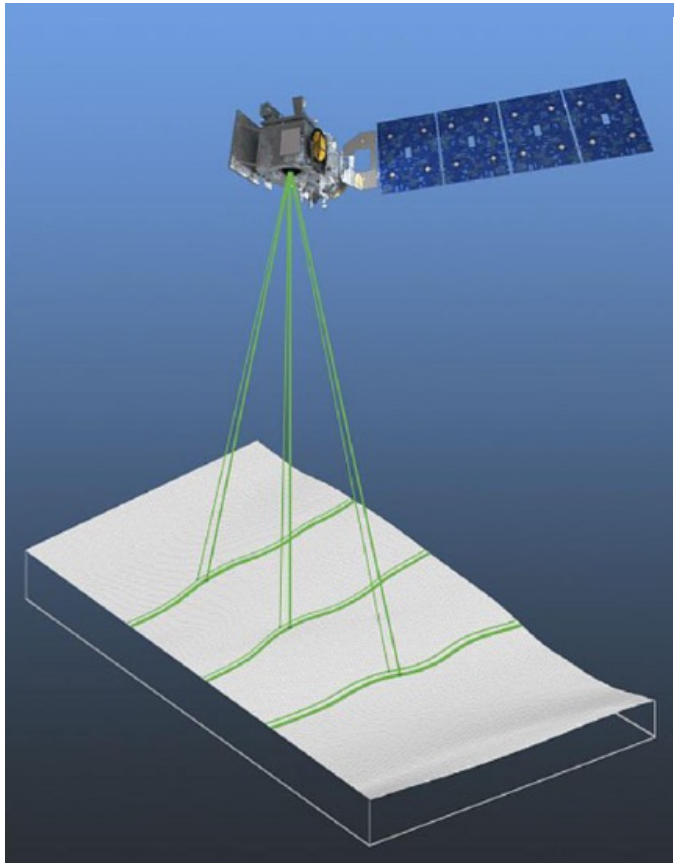


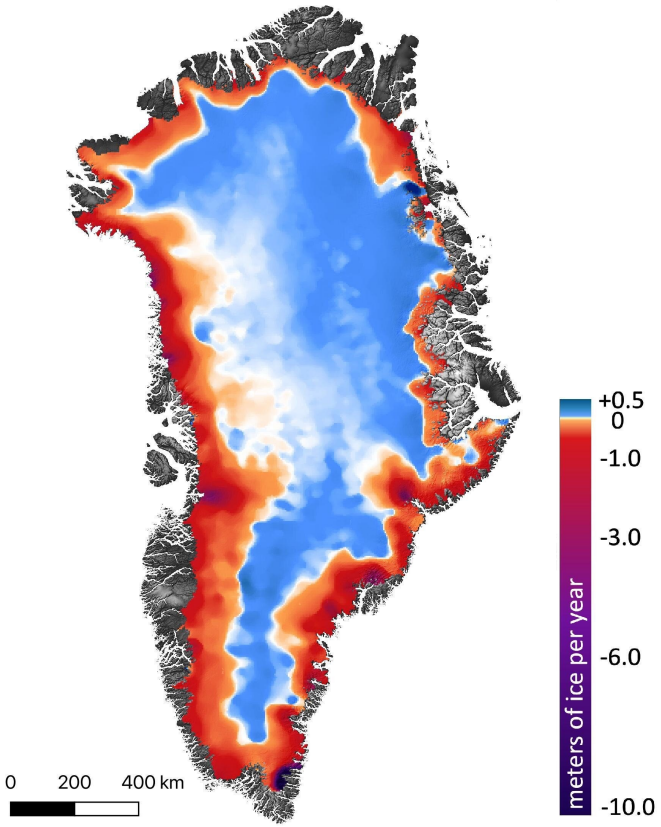
Roscoe lidar



ICESat-2

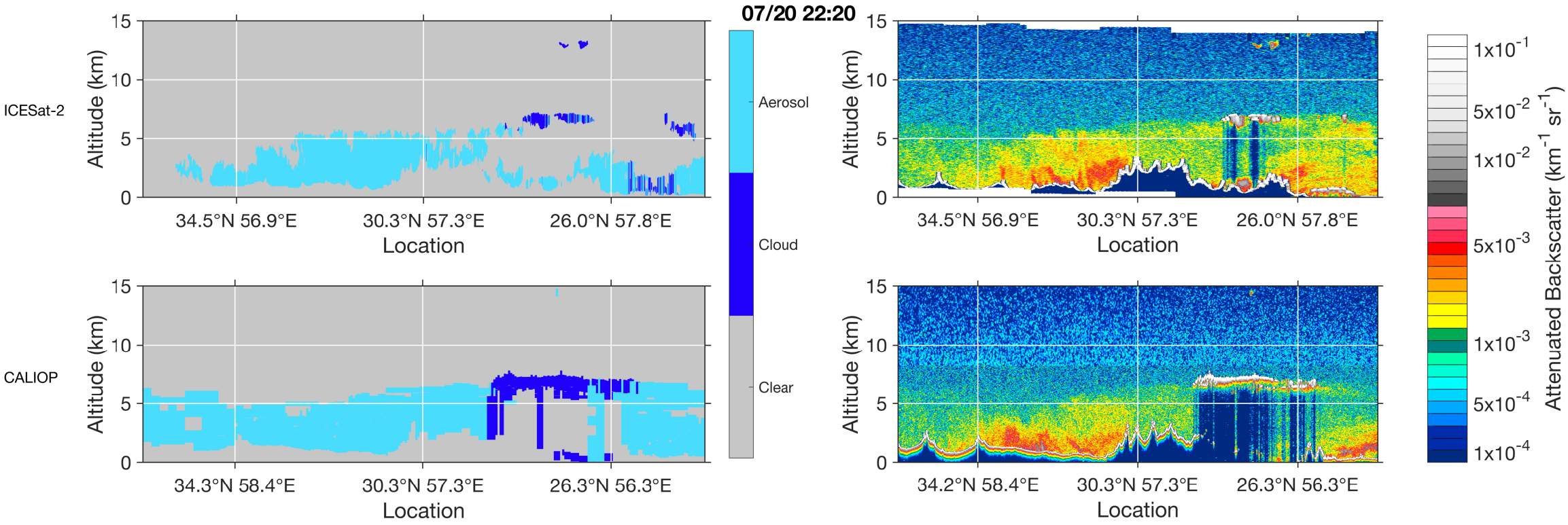
- Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) was launched September 2018
- Primarily for cryosphere
  - ice sheet altimetry
  - blowing snow
- Atmospheric products exist and compliment the altimetry products





Smith et al., 2020

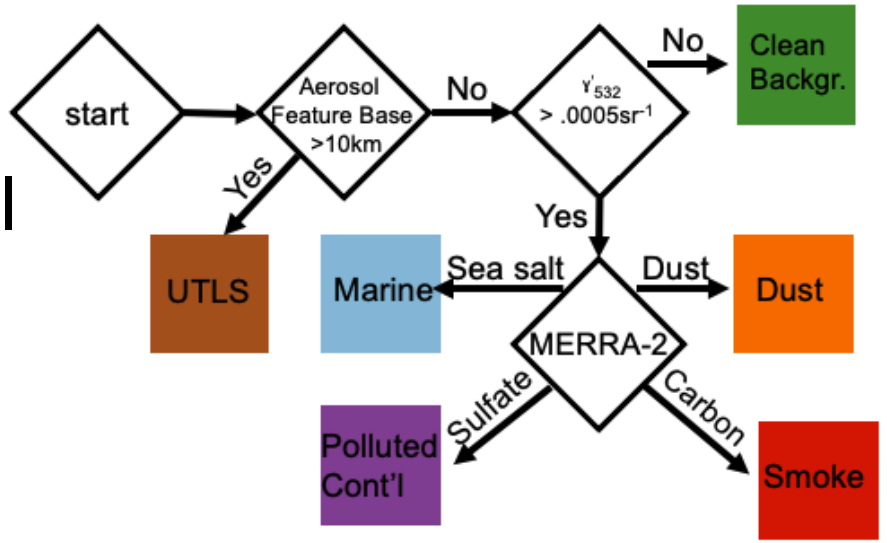
ICESat-2



Nighttime ICESat-2 backscatter profiles and feature detection agree well with CALIOP

ICESat-2

- Use MERRA-2 model reanalysis for cloud phase/aerosol typing
- Use lidar ratios to determine layer optical depths/extinction profiles
- Explore machine learning techniques to combat daytime SNR & aid feature typing



Thank you!

Instrument Specs

Parameter	Value
Laser Type	Nd:YVO_4
Laser Wavelengths	1064 and 532 nm
Depolarization	1064 and 532 nm
Laser Repetition Rate	4 kHz
Laser Pulse Energy	3 mJ at 1064 nm; 2 mJ at 532 nm
Laser Pulse Length	~10 ns
Transmitted Beam Divergence	70 µrad (1064 nm)/35 µrad (532 nm)
Telescope Diameter	60 cm
Telescope Field of View	115 µrad (1064 nm)/85 µrad (532 nm)
Vertical Resolution	30 m or 60 m
Horizontal Resolution	70 Hz or 100 m along-track