



The NASA Earth System Observatory— Atmosphere Observing System (AOS): Future Space-Based and Suborbital Observations for the Study of Coupled Aerosol-Cloud-Precipitation Interactions

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John Yorks, NASA GSFC, Deputy PS for Inclined
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Daniel Cecil, NASA MSFC, Deputy for Suborbital

European Geophysical Union (EGU) Meeting
April 24, 2023, Vienna, Austria

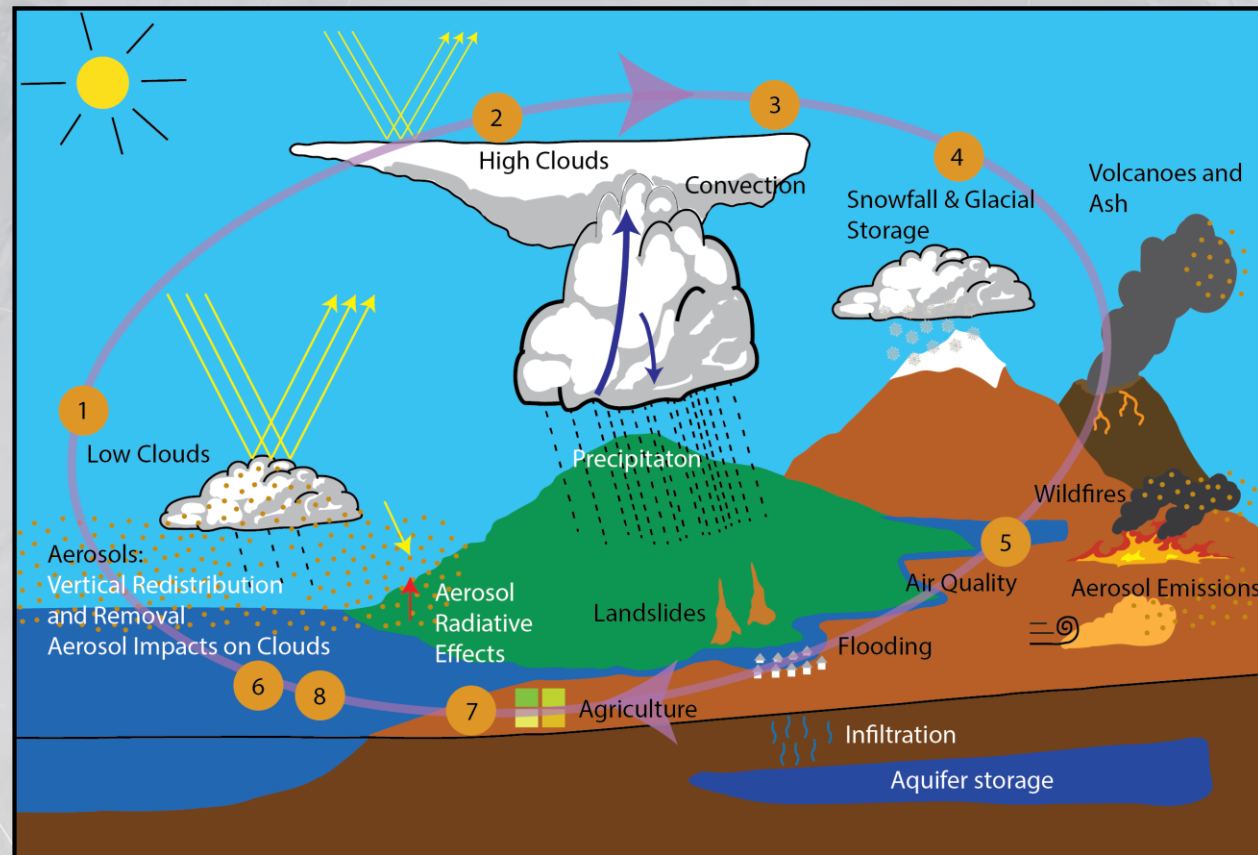


NASA Earth Science Decadal Survey and AOS Science Priorities

AOS provides an **observing system** that focuses on measurements addressing major Decadal Survey (DS) science themes tied to **coupled aerosol-cloud-precipitation processes**

AOS addresses priority science called out by *multiple* ESAS DS panels and related to *three* targeted observables

- TO-1: Aerosol & Cloud Radiative Properties
- TO-2: Aerosol Vertical Profiles
- TO-5: Clouds, Convection, & Precipitation



AOS Science Objectives

- | | |
|--------------------------------|--|
| 1. Low cloud feedbacks | 5. Aerosol attribution and air quality |
| 2. High cloud feedbacks | 6. Aerosol redistribution and removal |
| 3. Convective storm processes | 7. Aerosol direct effect |
| 4. Cold clouds & precipitation | 8. Aerosol indirect effect |

AOS Architecture Overview

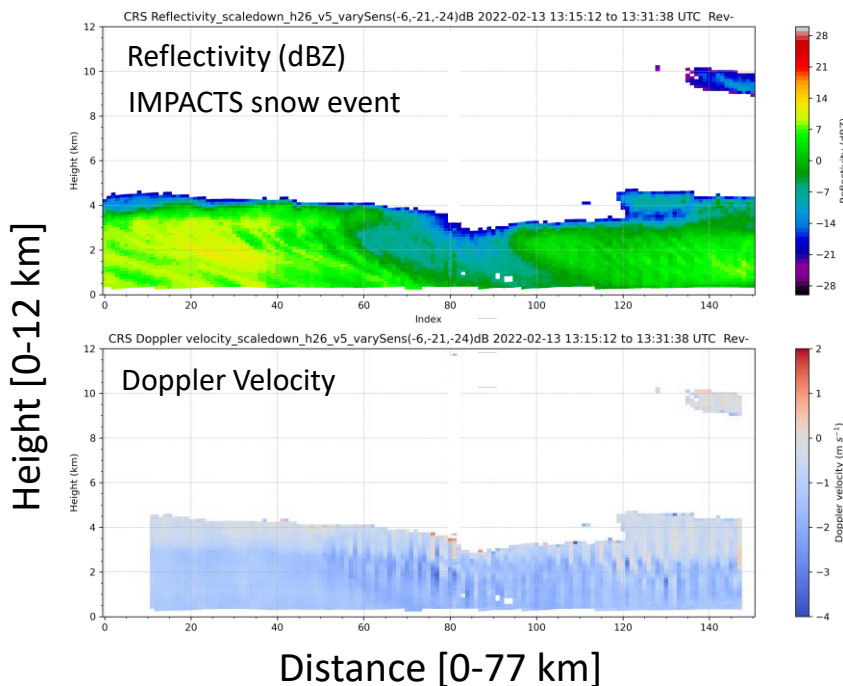
- Polar, sun-sync orbit focused on measurements for climate processes and sensor synergies
- Inclined (55°) orbit focused on weather (sub-daily) time scales with emphasis on convection, high clouds, and aerosol/PBL evolution
- Completed Mission Concept Review in May 2022
- Independent Review Board (IRB) study August-September 2022 recommended
 - Change HSRL lidar in polar to backscatter lidar
 - Change polar dual-frequency Doppler radar to single-frequency cloud-profiling capable Doppler radar
 - https://www.nasa.gov/sites/default/files/atoms/files/eo_irb_documents.pdf
- Key Decision Point A review on January 13, 2023



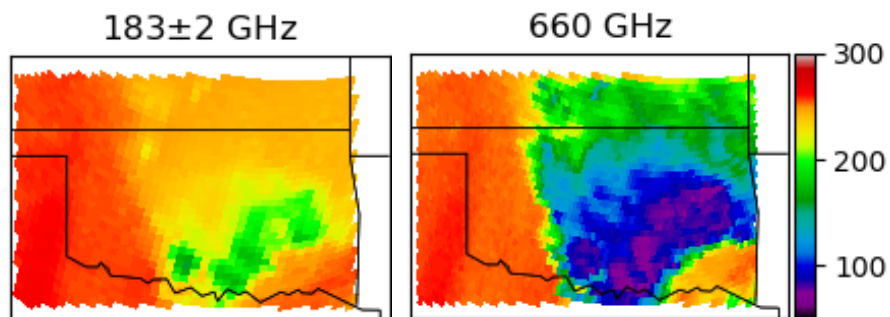
A Visual View of AOS-Polar

Launch NET December 2031

Single-Frequency Doppler Radar

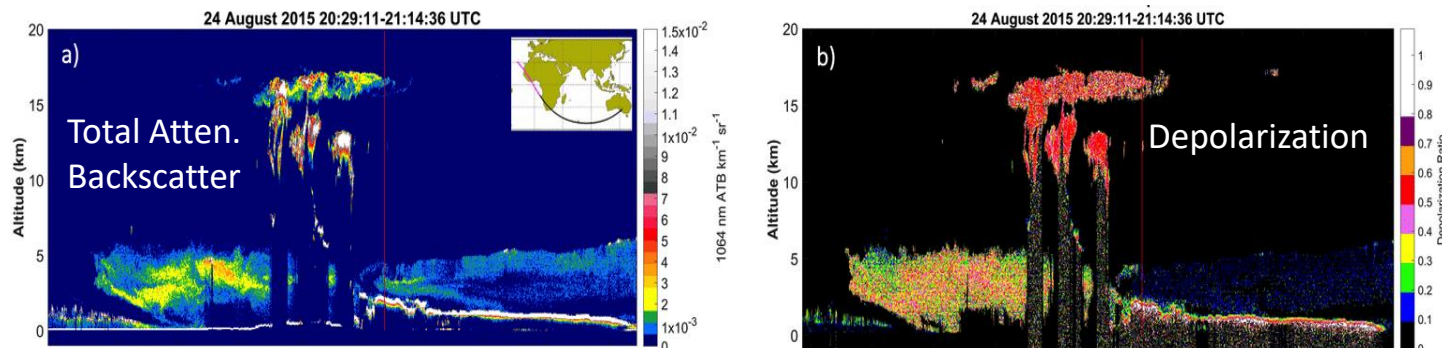


Microwave Radiometer: 89-700 GHz

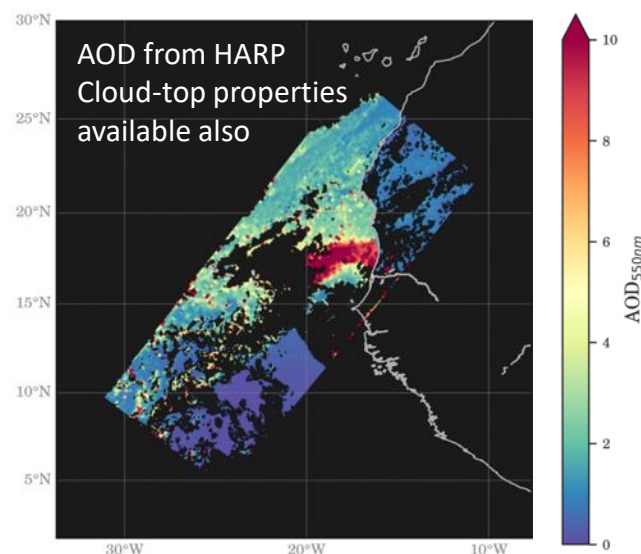


532 nm, 1064 Backscatter Lidar

Yorks et al. (2021)

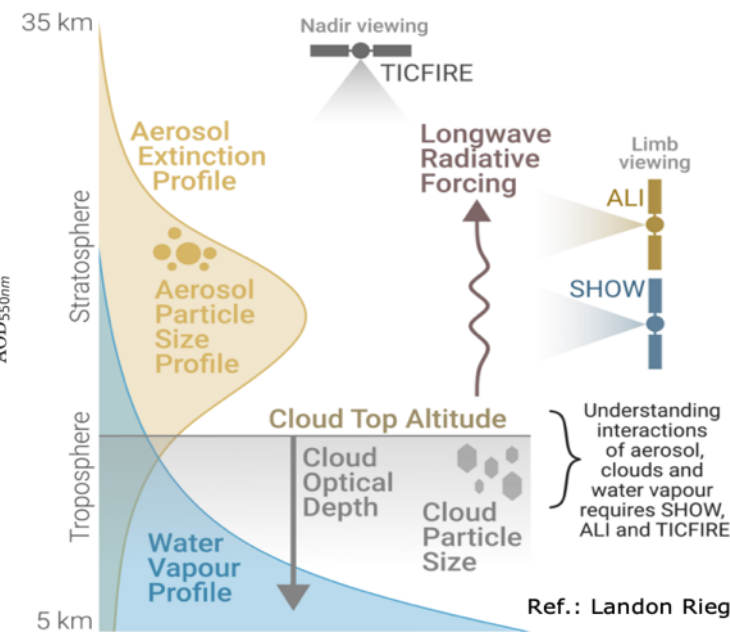


UV-VIS-NIR-SWIR Multi-angle Polarimeter



Courtesy of V. Martins

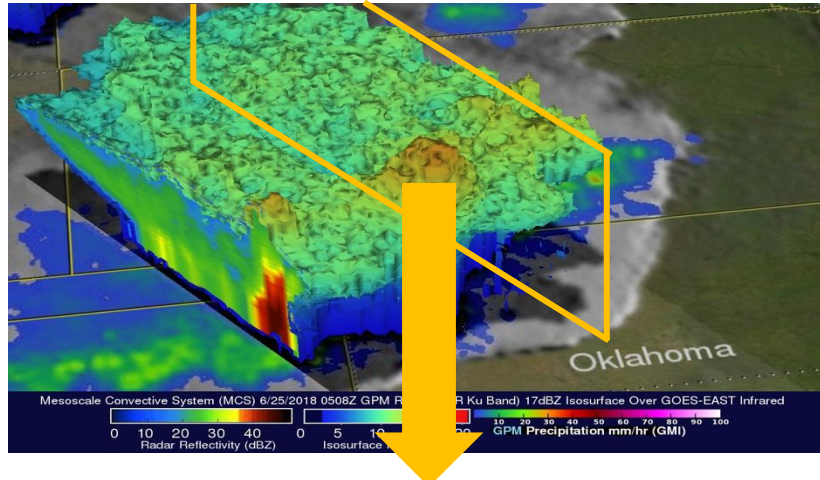
CSA LWIR-FIR Radiometer (4-73 μm), Aerosol/Moisture Limb Sounding



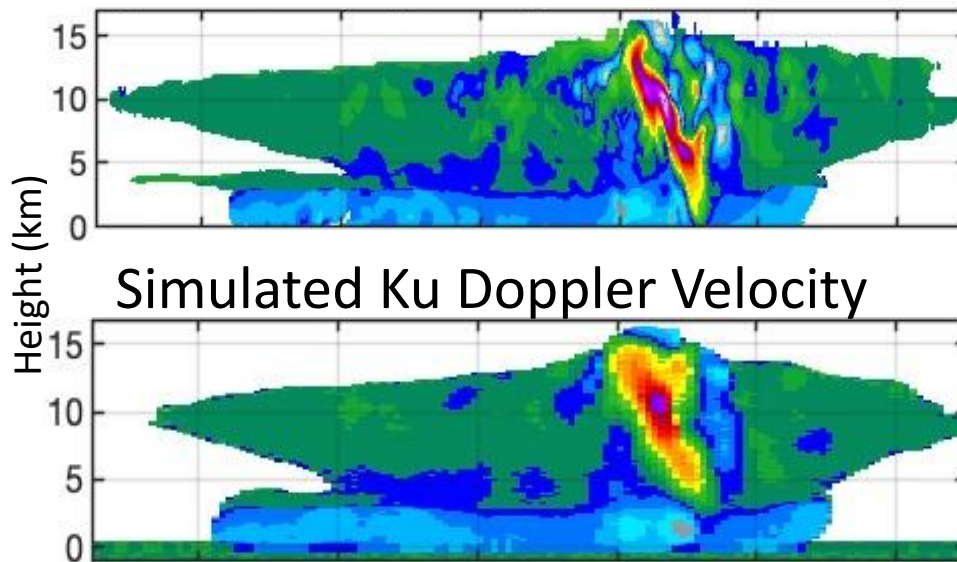
A Visual View of AOS-Inclined

Launch NET Mar 2029

JAXA Wide Swath Ku Doppler Radar

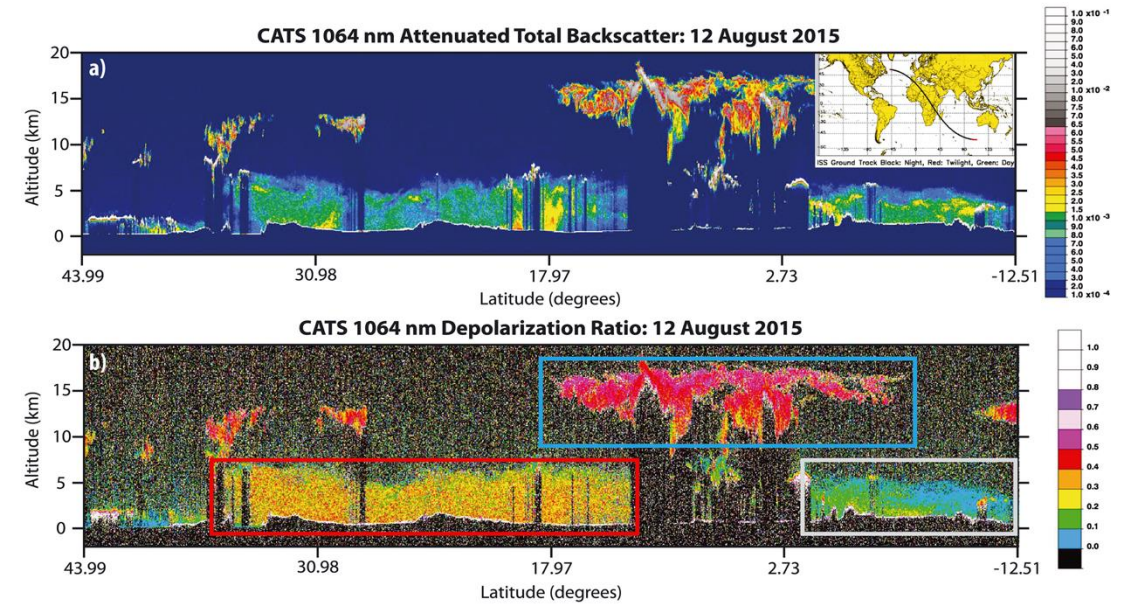


Model "Truth"

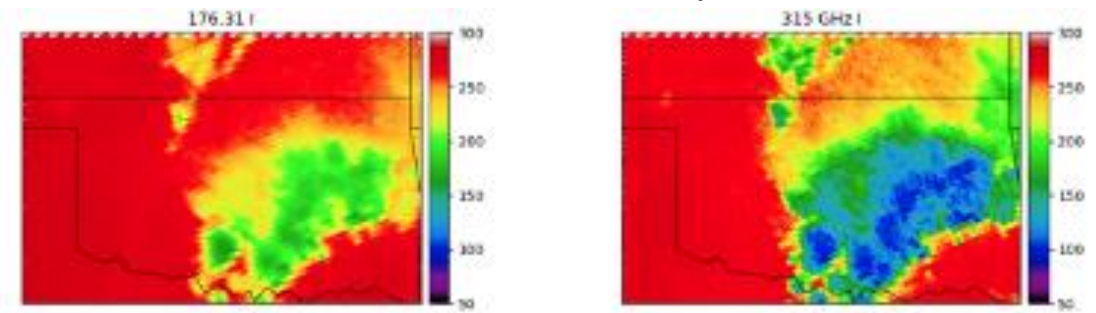


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532-, 1064-nm Backscatter Lidar



CNES Microwave Radiometers (89, 183, 325 GHz)



55° Inclination: Compromise between NASA, JAXA, CNES



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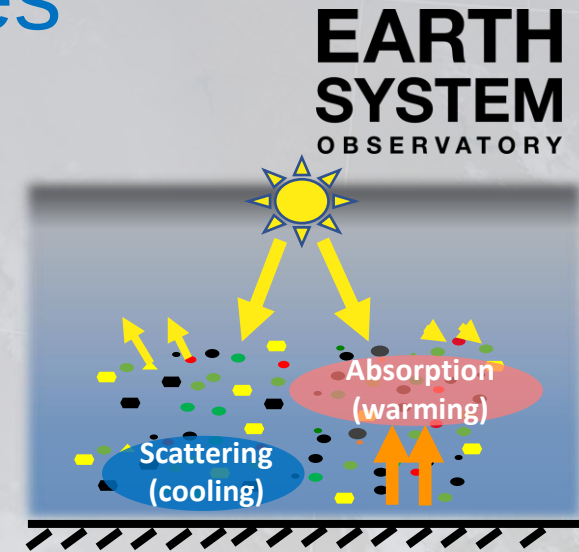
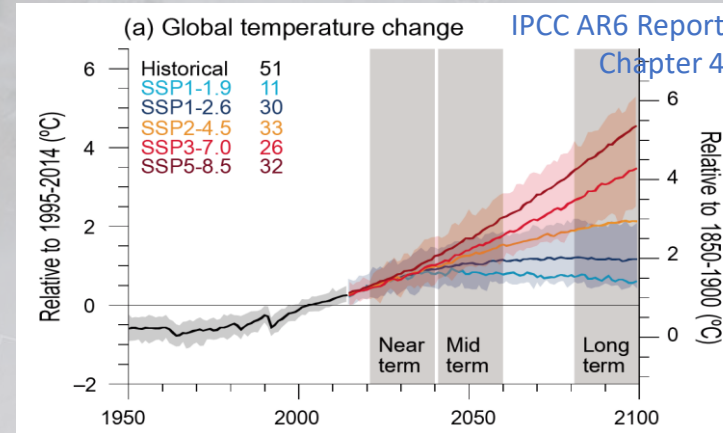
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AOS Objectives Focus on Three Themes

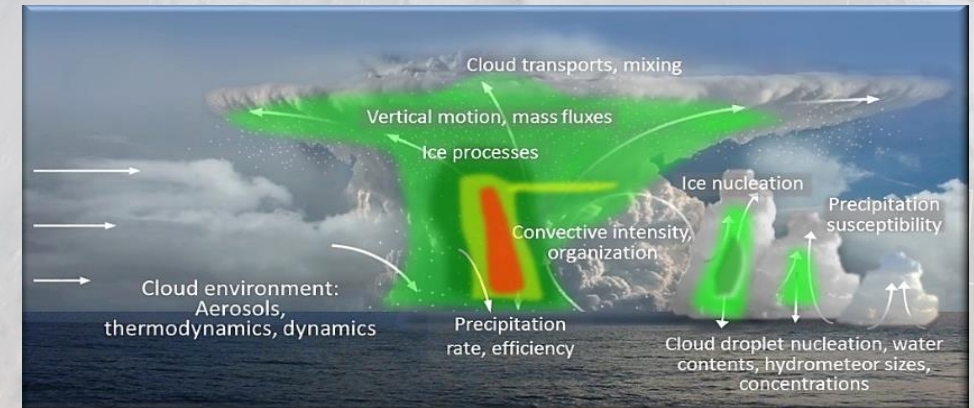
Climate sensitivity and feedbacks

- Low and high cloud feedbacks
- Aerosol direct & indirect effects
- Cold clouds and precipitation



Convective Storm Formation Processes

- Coupled storm dynamics and microphysics
- Importance of diurnal cycle
- High cloud properties



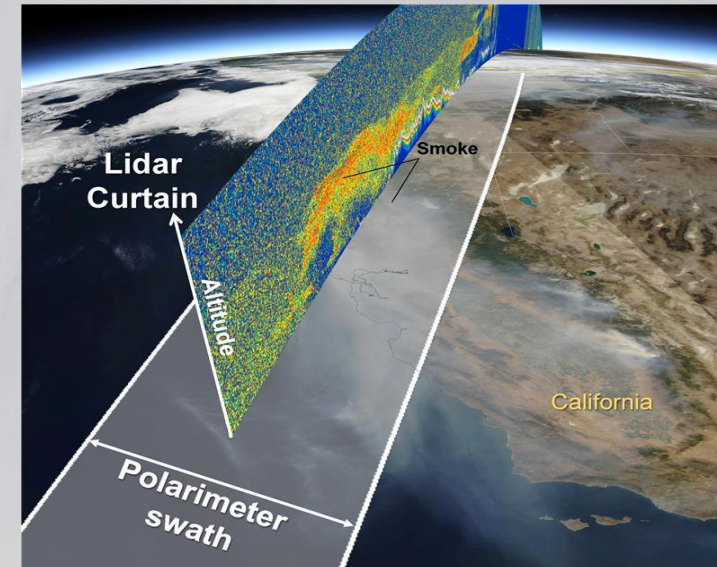
Aerosol processes and distributions

- Air quality and aerosol attribution
- Aerosol vertical redistribution and processing (from emission to removal)

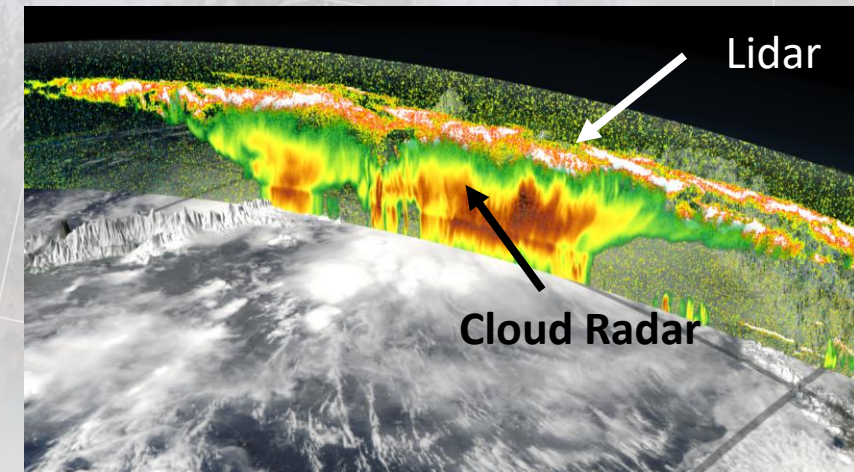


Building An Observing System

- Factors shaping the architecture
 - **Cost-capped** mission that utilizes relatively **mature** measurement capabilities
 - Microphysical understanding requires **synergistic** multi-instrument approaches for the best geophysical variable retrievals
 - **International** partnerships
 - **Continuity** desired (but not required) to the extent practical
 - **Applications** considered from early stages
- AOS still in mission concept phase with refinements likely going into formulation based on cost and technical readiness risks



Lidar+polarimeter synergy for aerosols: provides significant retrieval advances over lidar alone



Doppler radar+lidar+passive sensor synergy: adds dynamical information to cloud/precipitation profiling and passive properties

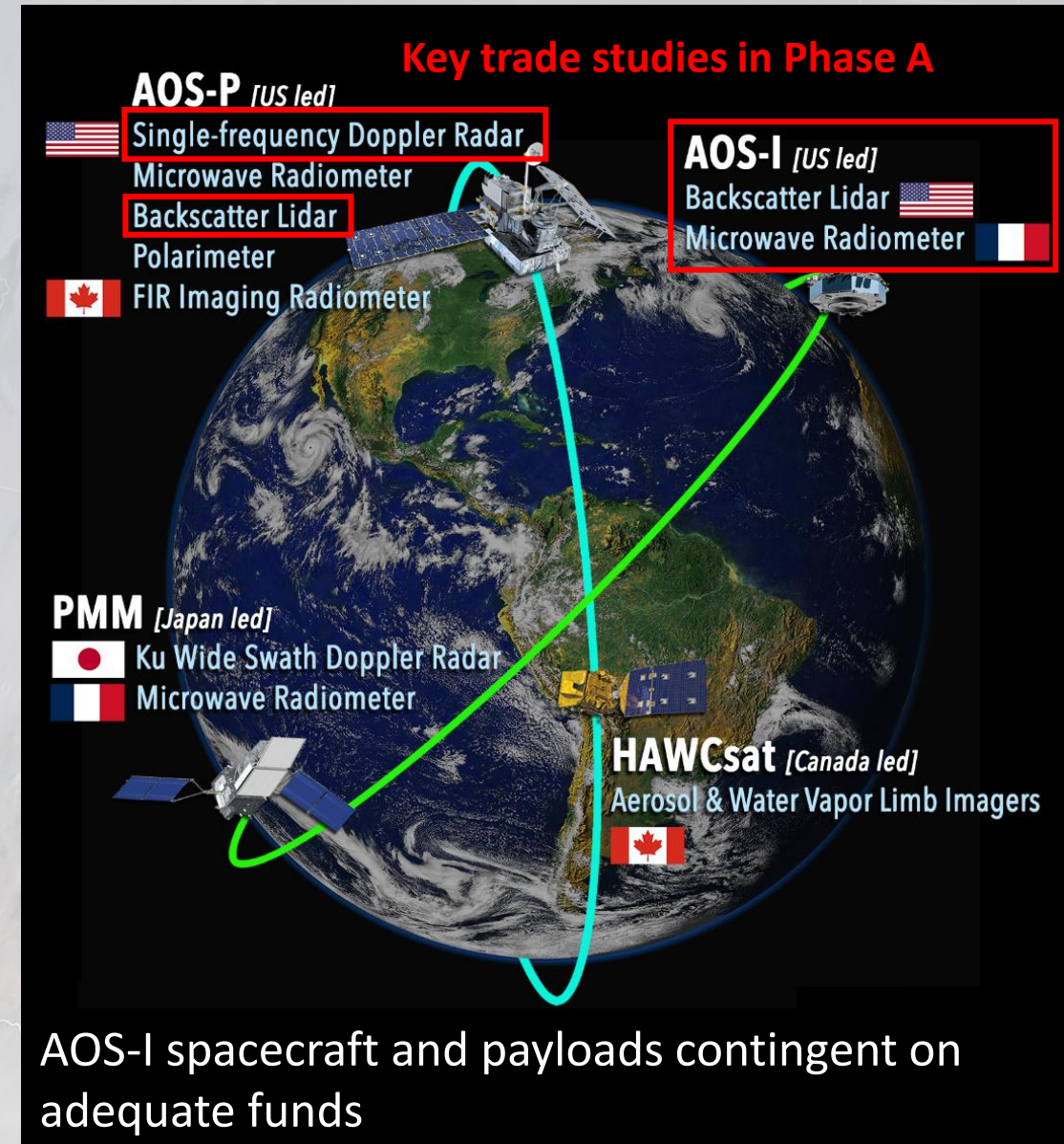
The AOS Architecture

- AOS Inclined Project

- JAXA provided spacecraft (PMM)
 - Ku wide swath radar with nadir Displaced Phase Center Antenna (DPCA) Doppler measurements
 - CNES high-frequency passive microwave radiometer (89, 183, 325 GHz) on PMM
- NASA spacecraft (AOS-I)
 - Backscatter lidar (532, 1064 nm)
 - Second identical CNES radiometer

- AOS Polar Project

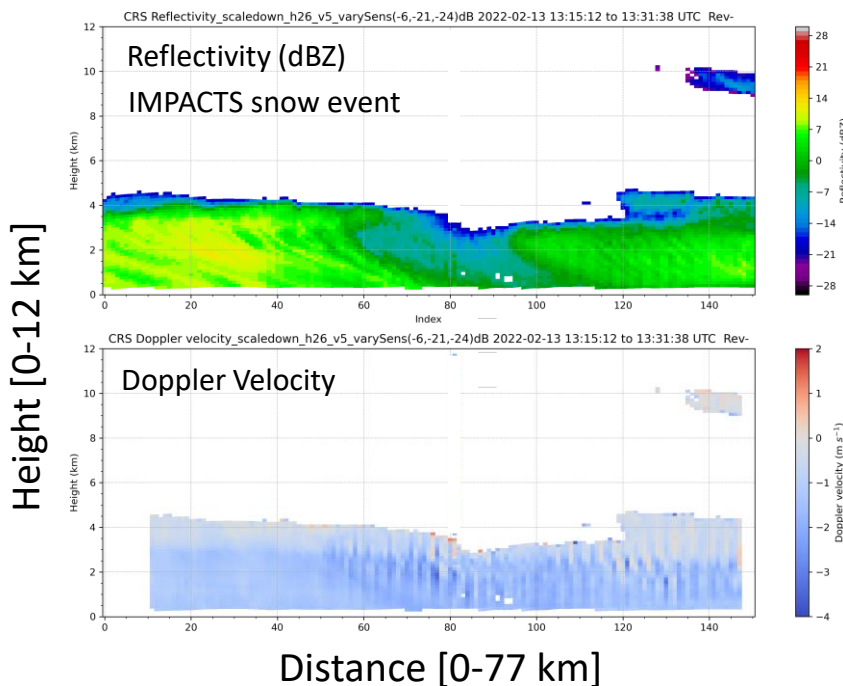
- U.S. spacecraft (AOS-P)
 - Cloud profiling (W or Ka band) Doppler radar
 - Backscatter lidar (532, 1064 nm)
 - Passive microwave radiometer (89-700 GHz)
 - Multi-wavelength (UV to SWIR), multi-angle (10 angles, 60 for cloudbow) polarimeter
 - CSA provided far infrared imaging radiometer
- CSA provided spacecraft (HAWCsat)
 - Aerosol and moisture limb sounders



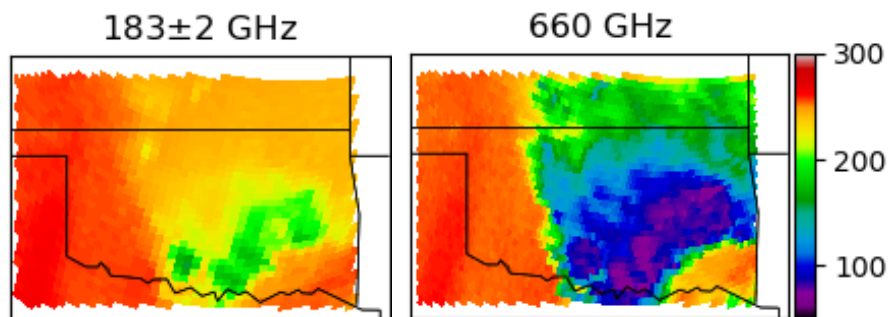
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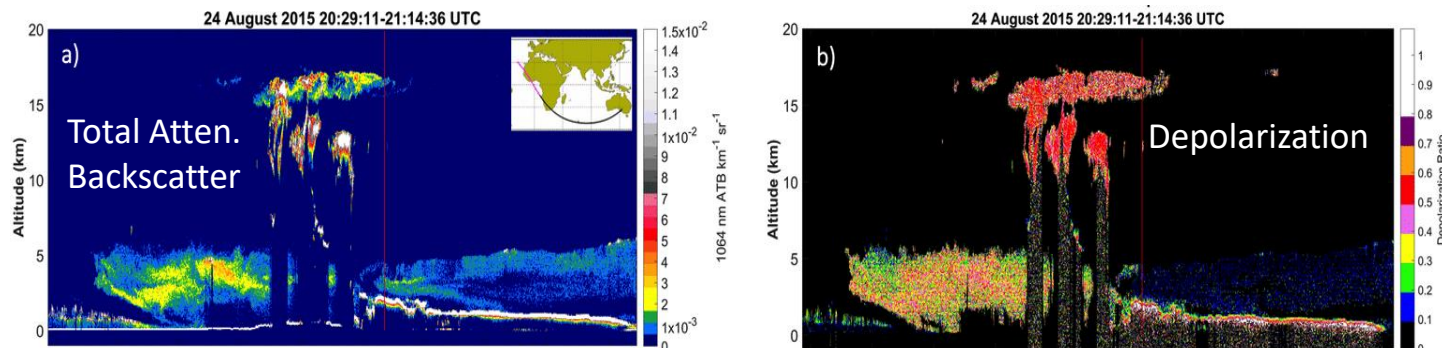


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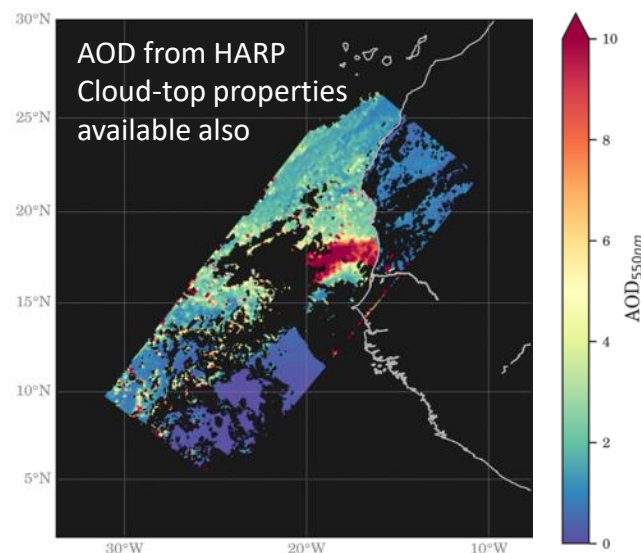


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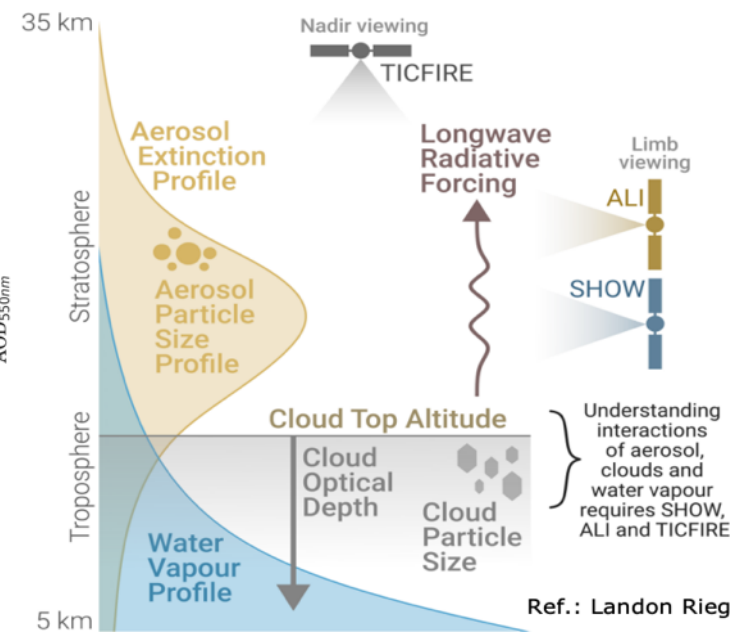


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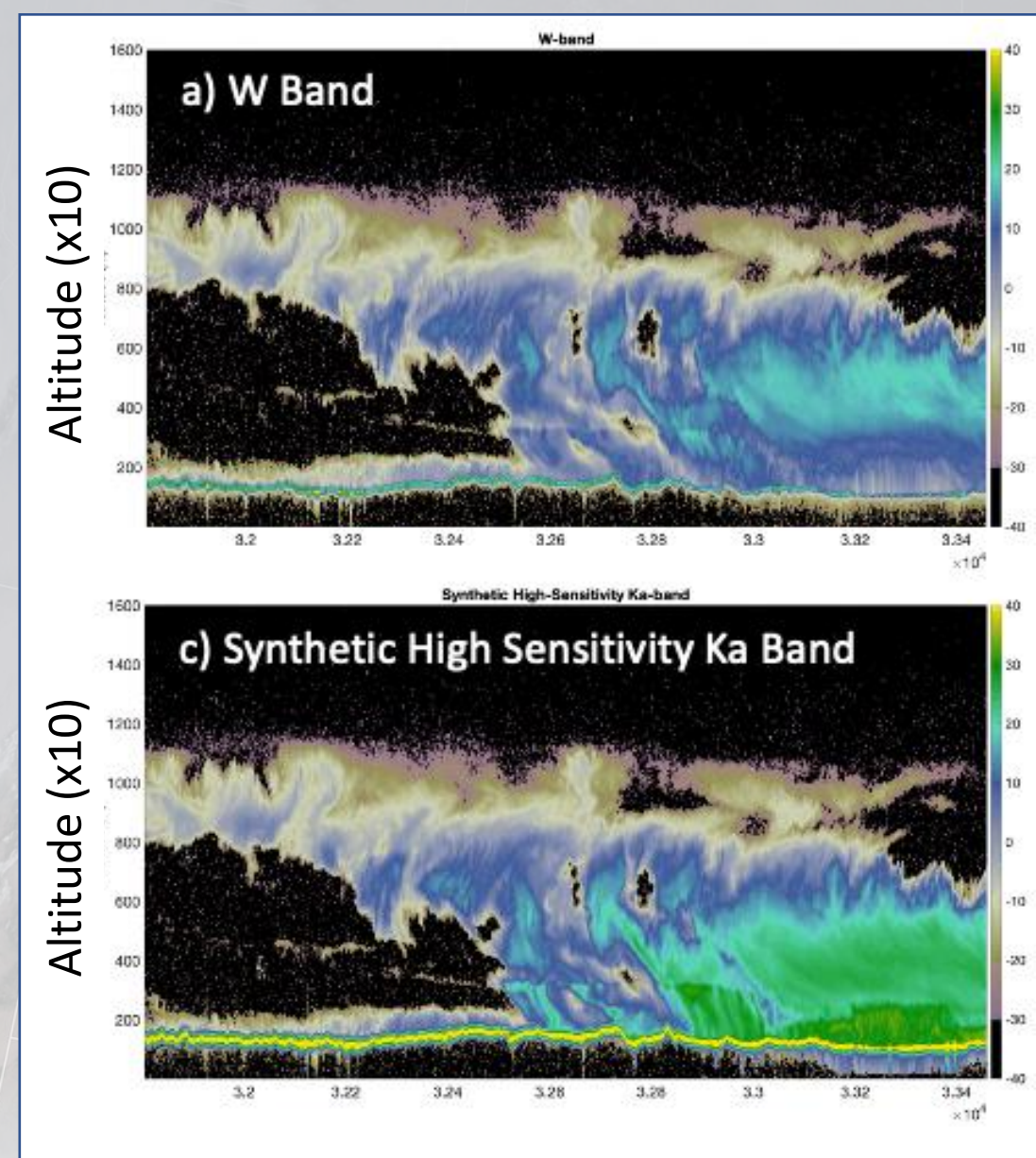
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Polar Radar Requirements

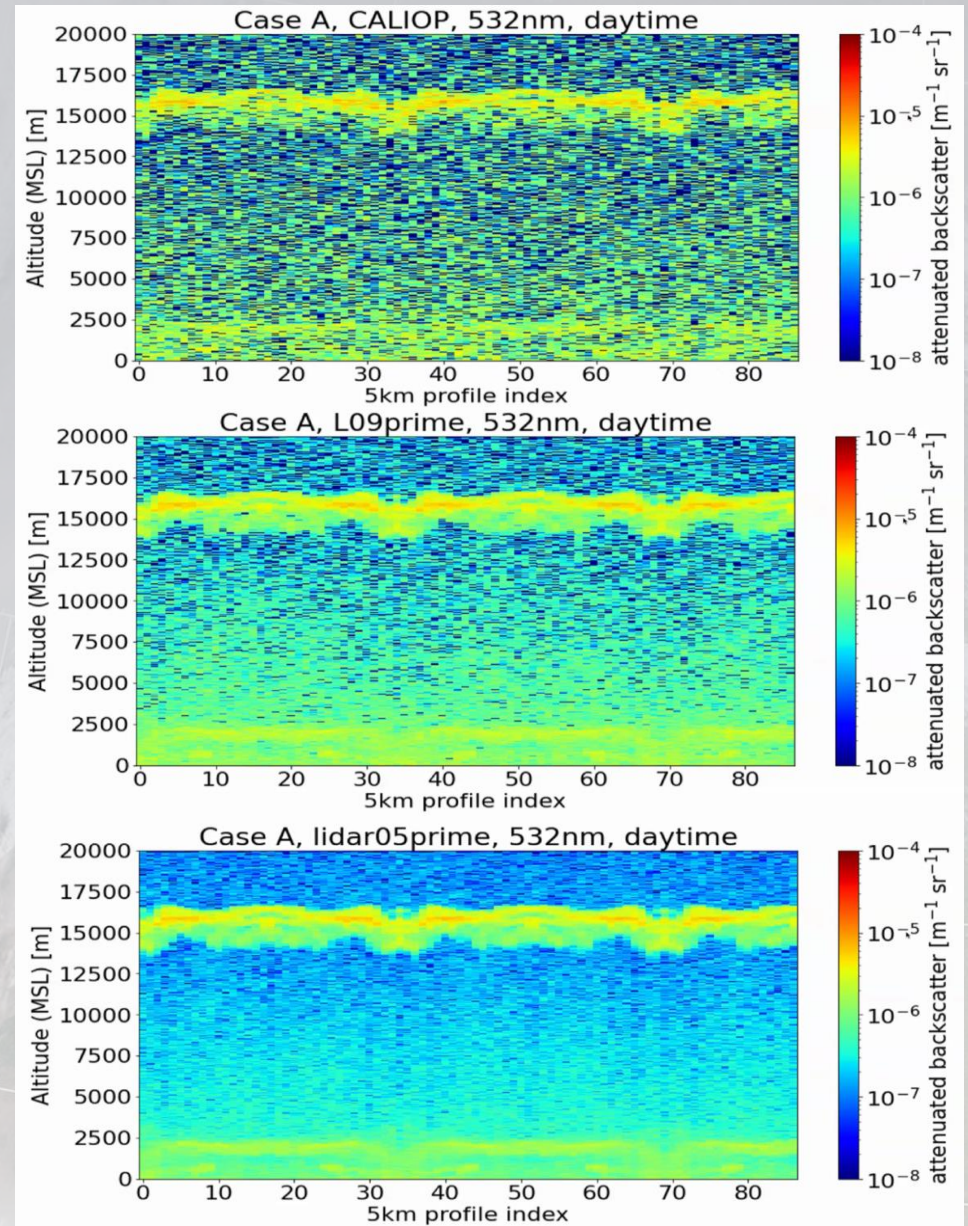
- Cloud profiling radar, either W or Ka band
- Sensitivity requirements:
 - ≤ -5 dBZ @ 0.5 km – 1 km
 - ≤ -15 dBZ @ 1 km – 2.5 km
 - ≤ -20 dBZ @ 2.5 km – 6 km
 - ≤ -24 dBZ @ 6 km – 20 km
- Doppler accuracy: 0.5 m s^{-1}
- Resolution requirements
 - 300 m (500 m) vertical resolution below (above) 2.5 km
 - ≤ 2 km horizontal resolution
- Dual-wavelength (W and Ka) to be considered if affordable



Cloud profiling radar agnostic of frequency: Radar trade studies to explore both W and Ka solutions for cloud profiling meeting sensitivity requirements

Polar Lidar Requirements

- Backscatter lidar, 532 and 1064 nm with depolarization
- Signal-to-noise ratio target:
Daytime SNR equivalent to nighttime CALIPSO SNR
- Target resolution requirements
 - 100 m horiz, 10 m vertical
- Improved dynamic range relative to CALIOP

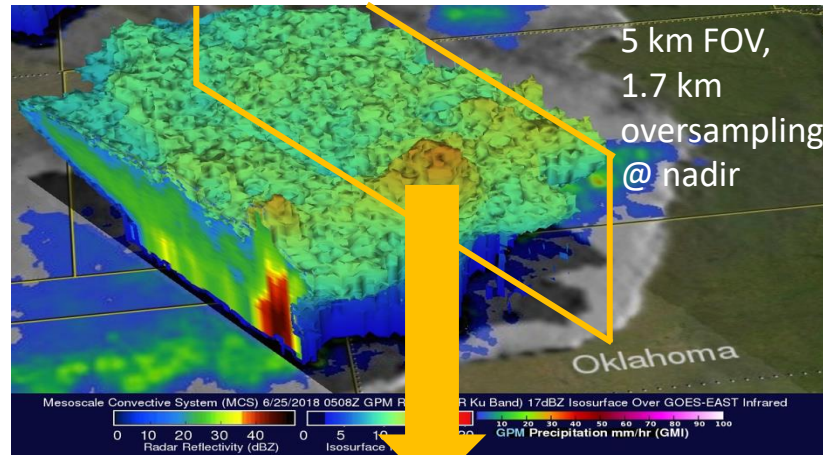


Simulated daytime lidar performance: CALIOP (top), inclined-orbit lidar (middle), and original HSRL concept (bottom)

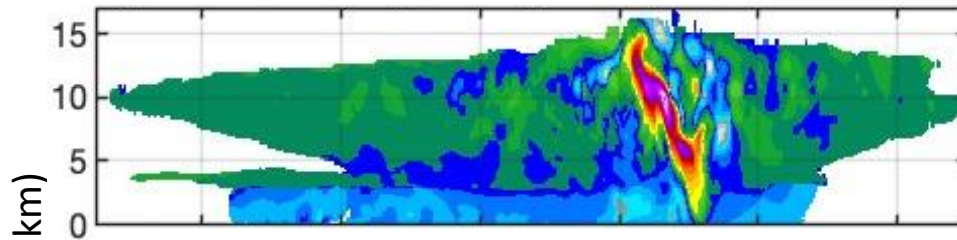
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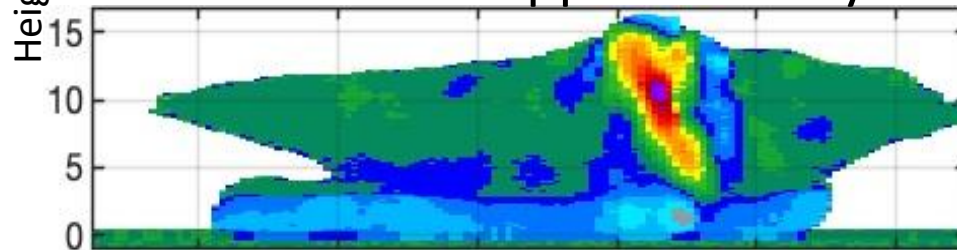
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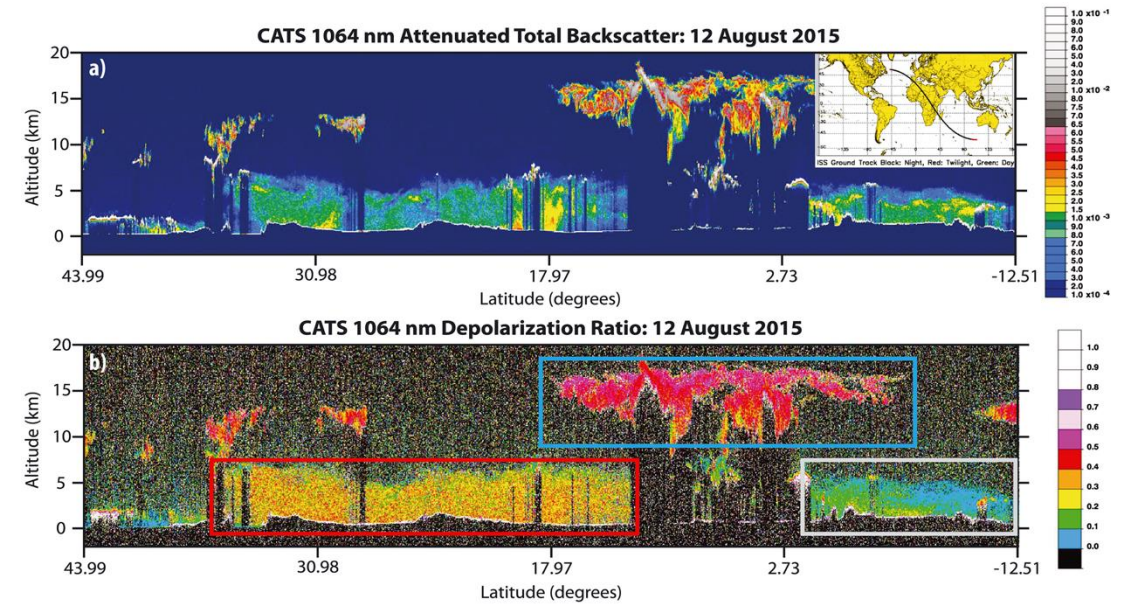


Simulated Ku Doppler Velocity

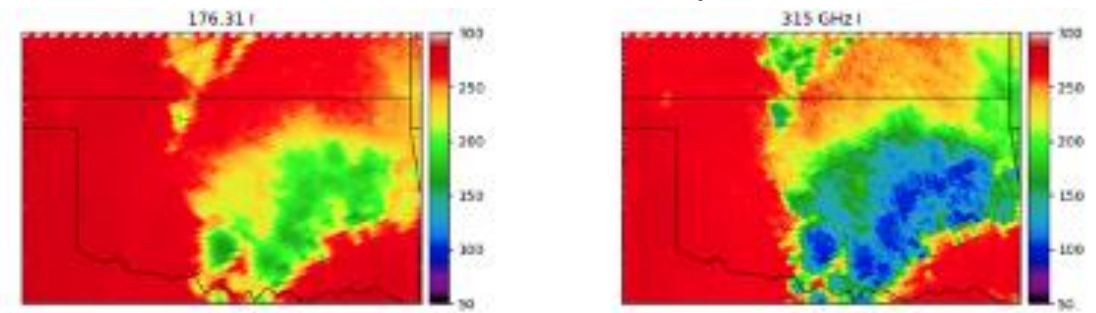


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AOS Suborbital Element: Airborne Campaign Concepts

Low Clouds: *Microphysics, precipitation initiation*

Convection/High Clouds: *Microphysics and dynamics, anvil cirrus lifecycle.*

Aerosol-Cloud-Radiation Interactions:
Vertically resolved aerosol-cloud-radiation interaction processes and lifecycle.

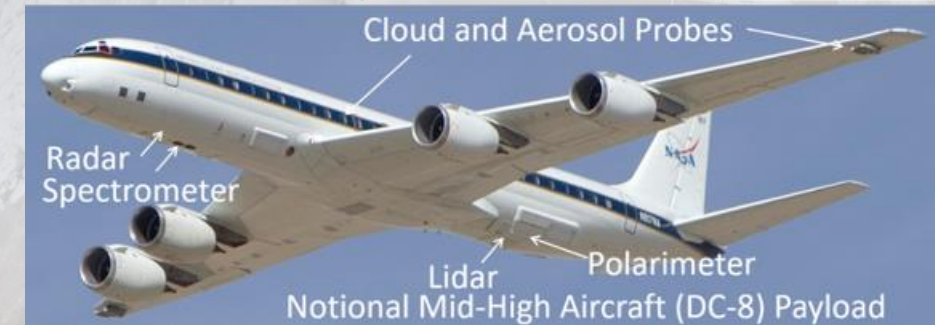
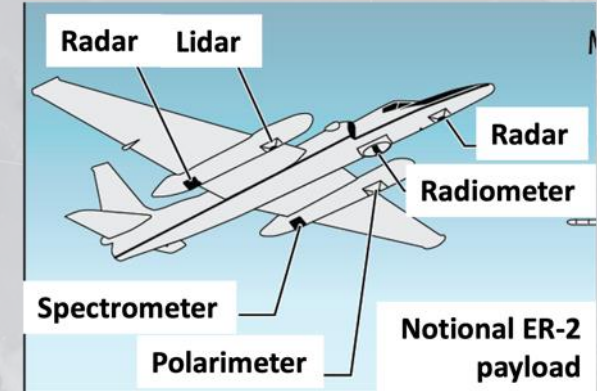
Large airborne campaigns

- Mid-latitude continental, 2029 or 2030
- Oceanic, 2032-2033

Campaigns after launch to enable cal-val

**EARTH
SYSTEM
OBSERVATORY**

Payloads depicted are notional... instruments to be prioritized / deconflicted for each campaign



Summary and Notes

- Two projects (polar and inclined orbits) for addressing aerosol-cloud-precipitation interactions:
 - Address objectives related to climate sensitivity and feedback, convective storms, and aerosol distributions and processes
 - Provide globally distributed and diurnally varying observations
 - Projects in mission concept and technology development phase
 - Responding to Independent Review Board (IRB) recommendations for project modifications to address cost and technology risks
 - Polar lidar and radar trade studies in second half of 2023
 - Targeting final architecture decisions in June 2023
 - Community Forum meeting (virtual) on May 18

AOS Website:
<https://aos.gsfc.nasa.gov>
Email: scott.a.braun@nasa.gov