ATMOSPHERE
Observing System

National Aeronautics and Space Administration

EARTH SYSTEM OBSERVATORY

NASA Atmosphere Observing System (AOS)

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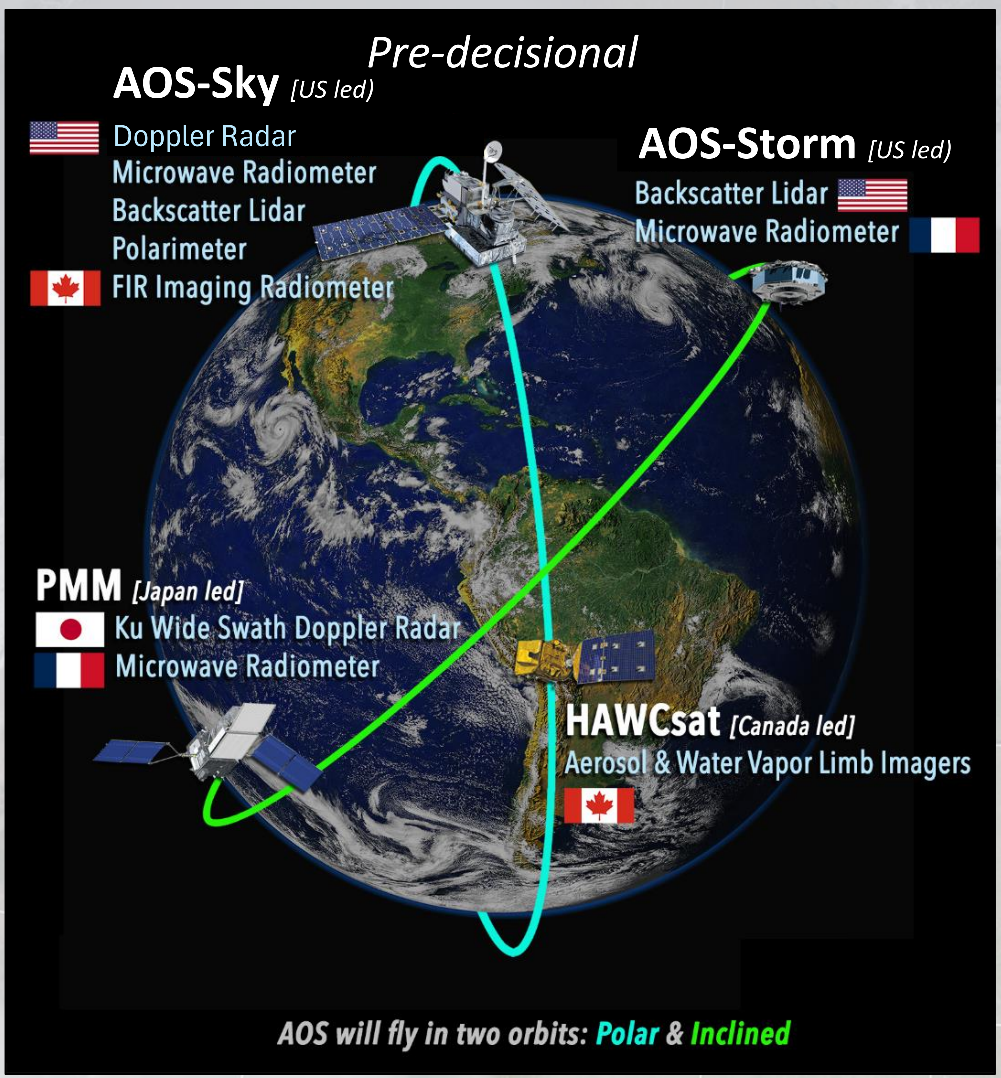
ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop
November 2023

AOS Addresses Aerosol, Cloud, Convection, and Precipitation Processes

- **AOS-Storm (Inclined orbit, 2029)**
  - **JAXA PMM Radar (Ku-band, Doppler)**
  - **CNES C2OMODO tandem radiometers (89-325 GHZ)**
  - **ALICAT backscatter lidar (532, 1064 nm)**
- **AOS-Sky (Sun-synchronous orbit, 2031)**
  - **Backscatter lidar (details TBD – *Italian partnership?*)**
  - **Doppler radar (details TBD)**
  - **Passive microwave radiometer (89-700 GHz)**
  - **Polarimeter (350-1570 nm)**
  - **CSA Thin Ice Cloud Imaging Radiometer (4-73 μm)**
  - **CSA aerosol and moisture limb imagers**
- **AOS Suborbital**
  - **Post-launch field programs**
  - **Surface-based networks, supersites**
  - **Leverage existing capabilities, more international partners**



International partnerships are very important to AOS, both in the satellite constellation and in suborbital activities.

Earth System Observatory

Atmosphere Observing System

AOS Suborbital

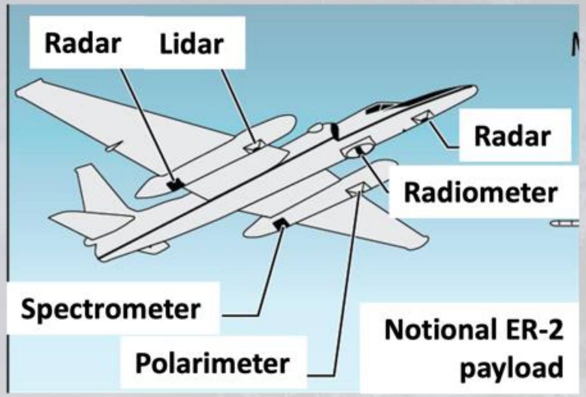
Low Clouds: *Microphysics, precipitation initiation*

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

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

Aircraft and payloads depicted are notional… instruments to be prioritized / deconflicted for each campaign.

Need a high altitude (over-storm) remote sensor…



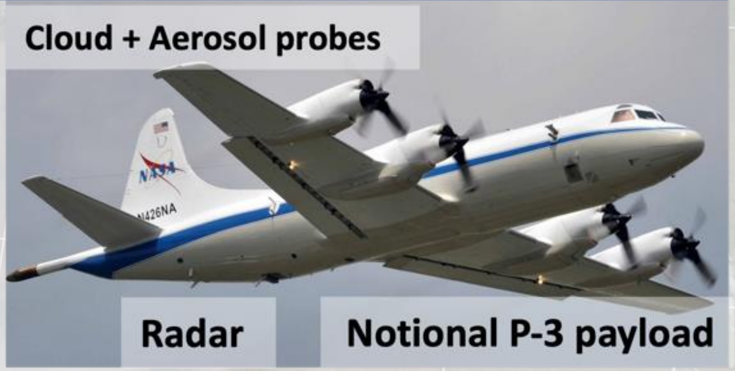
…mid/high altitude aircraft to provide both remote sensing and in situ (aerosol, cloud, precip)

Large airborne campaigns addressing *all* science themes

- **Link airborne campaigns with well-instrumented surface sites**
- **Partner with other programs / nations where practical**

Campaigns after launch to enable cal-val

…low/mid altitude aircraft to provide both remote sensing and in situ (aerosol, cloud, precip)



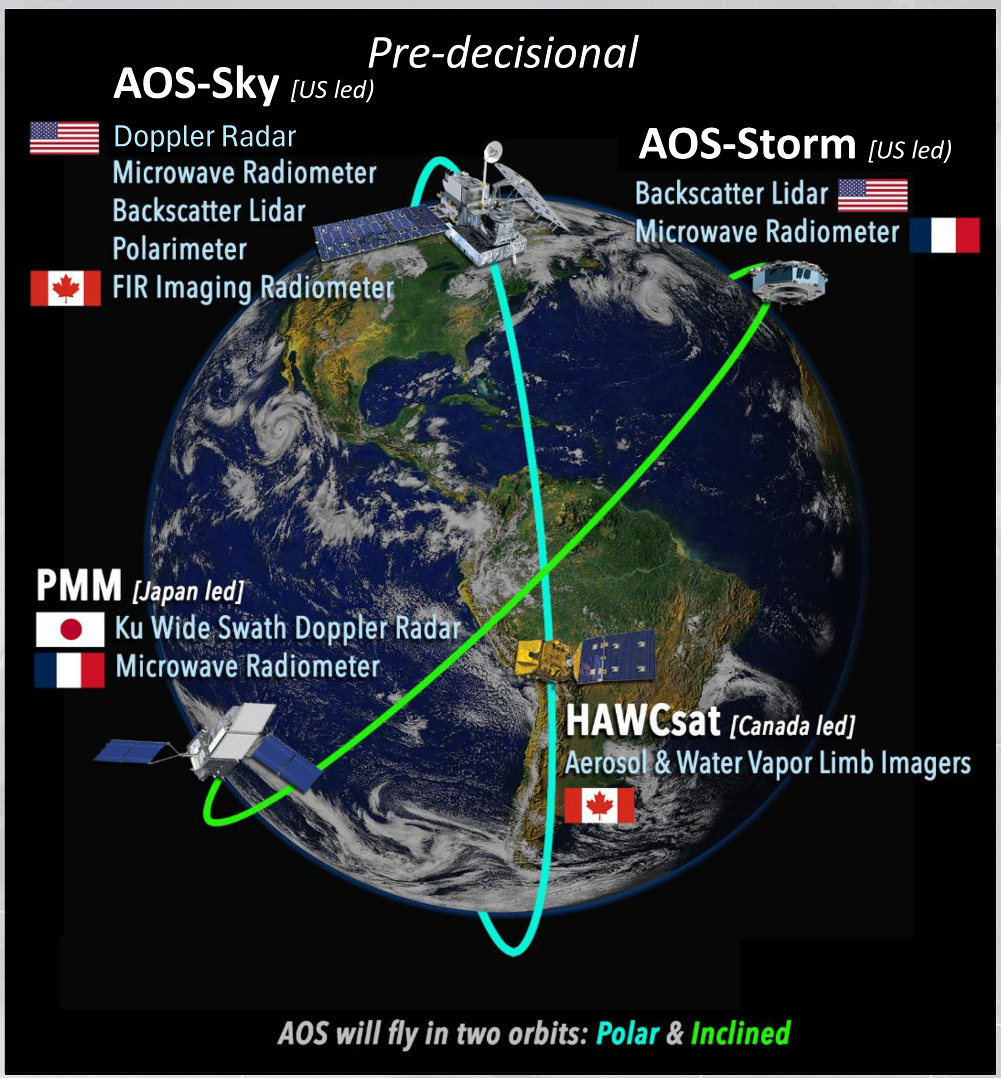
Aircraft, surface sites, and networks from partners will be especially helpful.

AOS and EarthCARE

- **AOS and EarthCARE approach cloud and aerosol profiling using similar instrument types, but different frequencies and other details**
  - **Many people / institutions aligned with both missions**

- **Some commonality in the cal-val needs**

- **Surface-based measurements, field campaigns, validation approaches used by each will be of interest to the other**
  - **Validation best-practices talk Wednesday afternoon**
  - **I'm here to discuss collaborations, match names to faces, etc.**

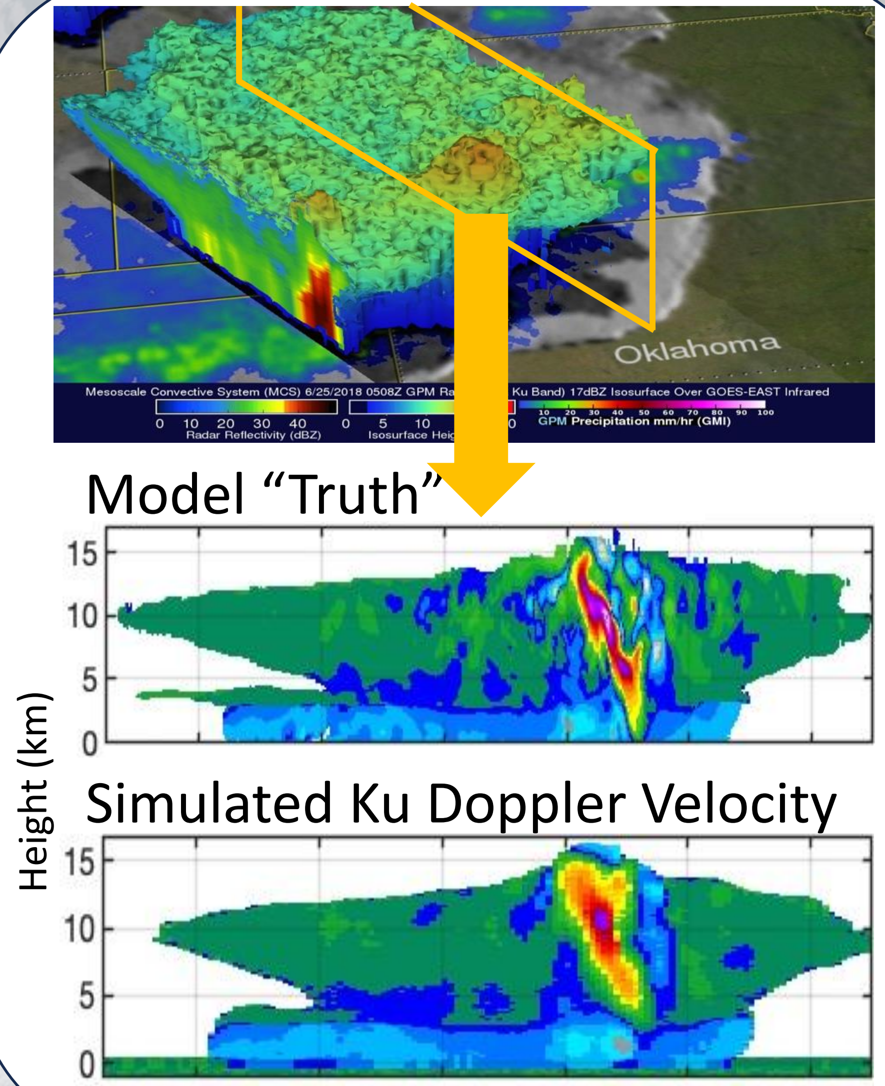


Graphic reflects initial architecture concept directed at KDP-A. Additional direction was provided to study architecture changes, which are still on-going.

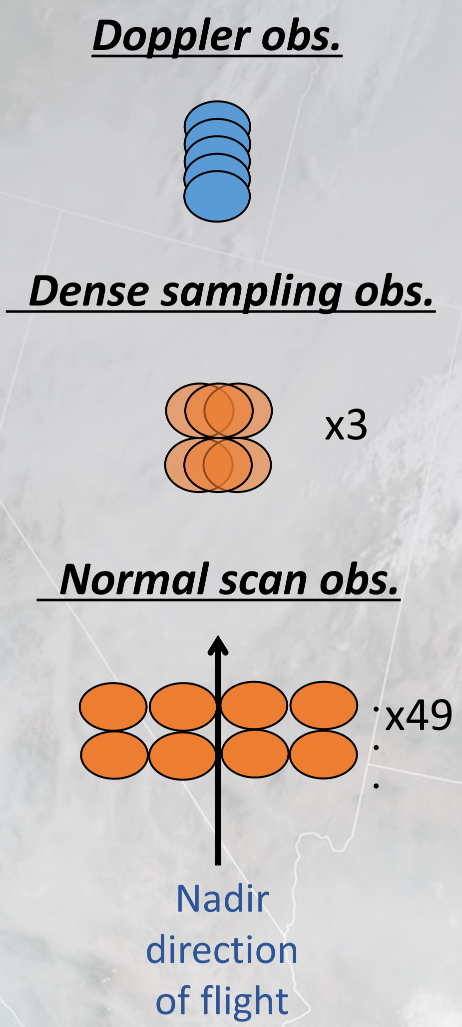
JAXA PMM Radar Capabilities

NLT March 2029 launch
430 km orbit, 55° inclination

JAXA Wide Swath Ku Doppler Radar



Courtesy of Pavlos Kollias



Baseline Requirements

Vertical sampling, resolution:
- 250, 500 m for Doppler, dense
- 125, 250 m for normal scan

Horizontal Resolution: 5 km

Observation range (altitude):
- Doppler 17 km
- Dense 20 km
- Normal 18-20 km

Swath: 250 km

Sensitivity (min dBZ):
- Doppler 7.3 dBZ
- Dense 7.3 dBZ
- Normal 15 dBZ

Doppler uncertainty: 2 m/s @ 16 dBZ

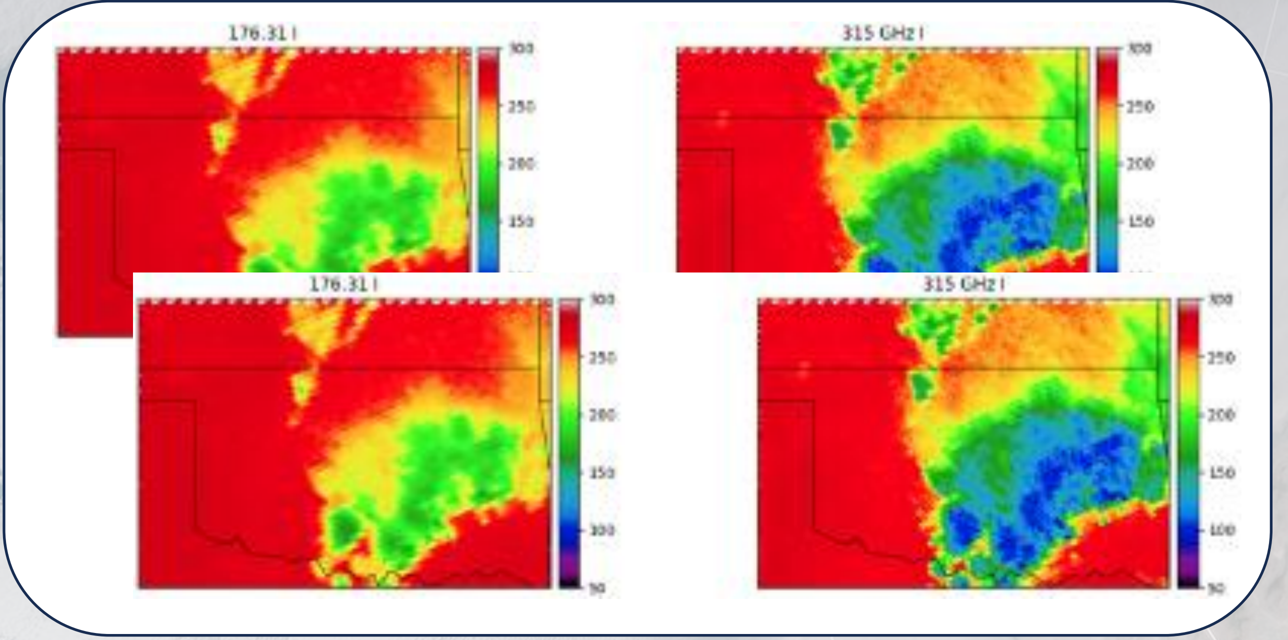
Unambiguous Doppler range: ±30 m/s

C2OMODO Radiometer Capabilities

NLT March 2029 launch
430 km orbit, 55° inclination

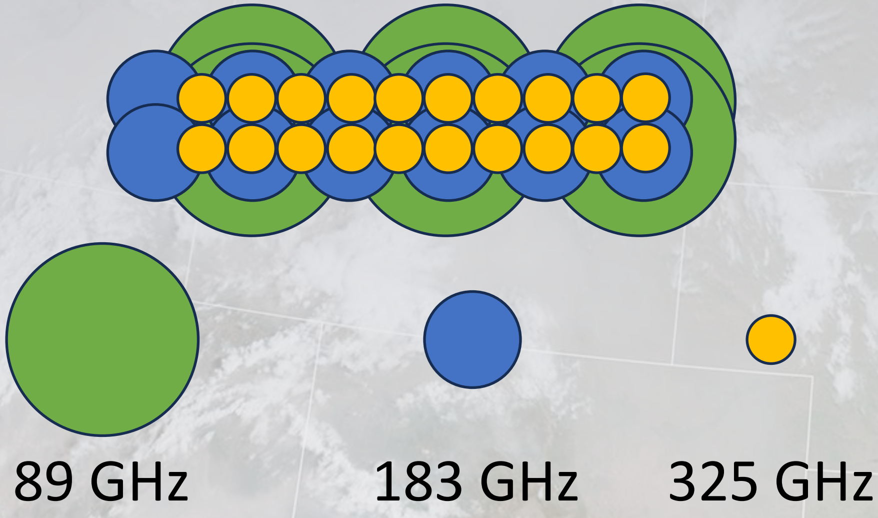
C2OMODO: Convective Core Observations through MicrOwave Derivatives in the trOpics (Brogniez et al. 2022)

CNES Microwave Radiometers (89, 183, 325 GHz)



89 GHz	10 km FOV	1 channel	Nyquist sampling
183.31 GHz	5 km FOV	6 channels	Nyquist sampling
325.15 GHz	3 km FOV	3 channels	Continuous sampling

CNES Radiometer Scan Pattern Near Nadir

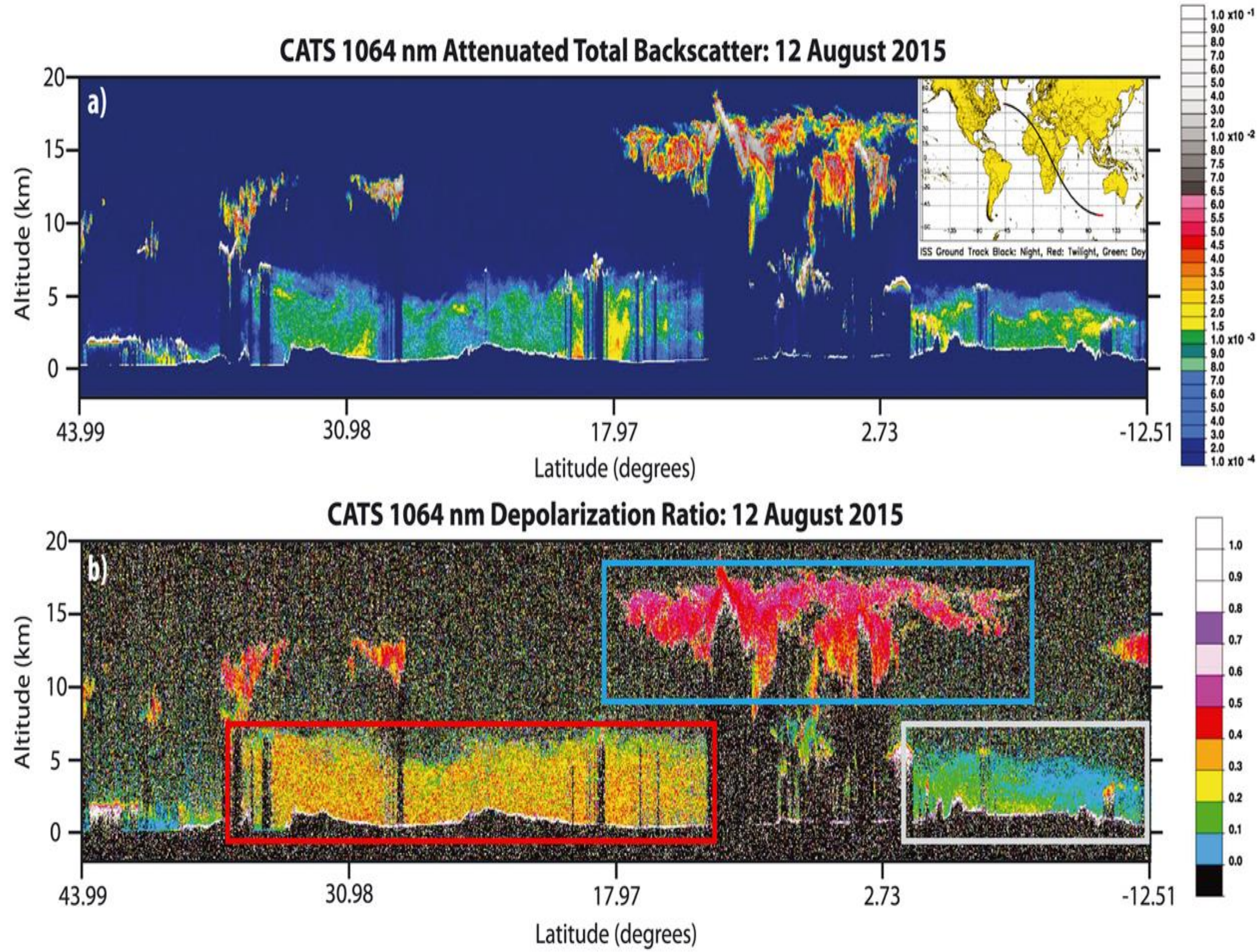


Time-differenced radiometer measurements (~1-2-minutes) contain information on convective vertical motions

ALICAT Lidar Capabilities

- NLT March 2029 launch
- 430 km orbit, 55° inclination

CATS Backscatter Lidar Example



ALICAT: Atmospheric Lidar for Cloud and Aerosol Transport

Low pulse energy, high pulse repetition frequency

Frequencies: 532, 1064 nm

Provides total attenuated backscatter and depolarization at both frequencies

Heritage: Cloud Physics Lidar, Cloud-Aerosol Transport System (CATS)

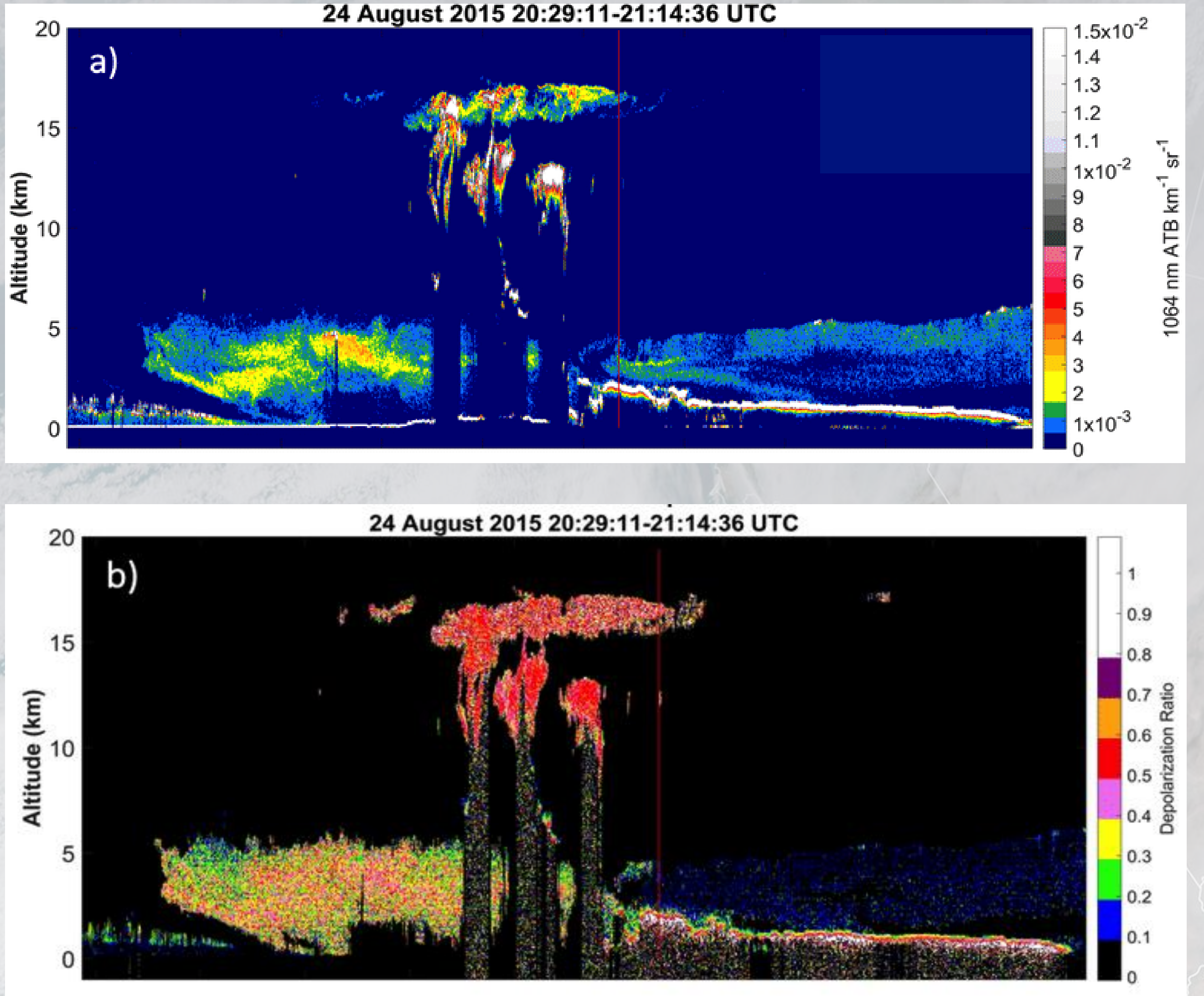
Earth System Observatory

Atmosphere Observing System

AOS-Sky Lidar

- NET December 2031 launch
- 450 km orbit, sun-sync-13:30 LTAN

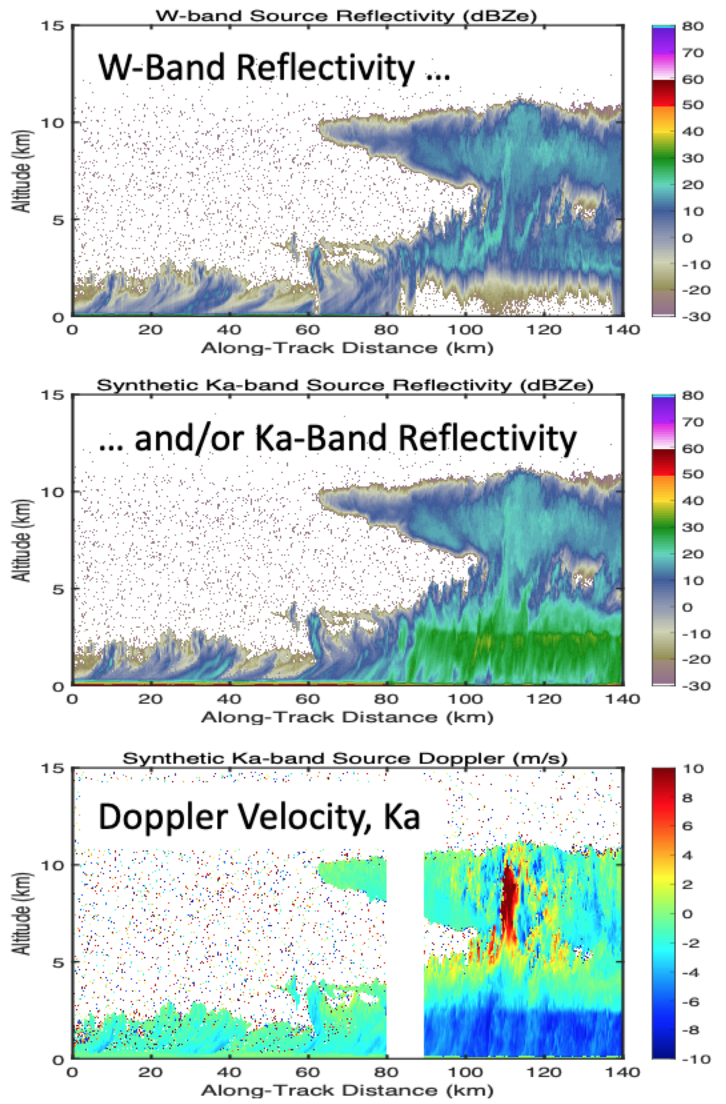
532 nm, 1064 Backscatter Lidar*



- Target requirement of daytime SNR equivalent to CALIPSO night SNR
- NASA HQ has initiated study of partnership with Italian Space Agency (ASI)
- ASI lidar:
  - 355 nm Raman (extinction)
  - 532, 1064 nm backscatter
- Requires formation flying of AOS-Sky and ASI lidar

AOS-Sky Radar

- NET December 2031 launch
- 450 km orbit, sun-sync-13:30 LTAN



Baseline Requirements

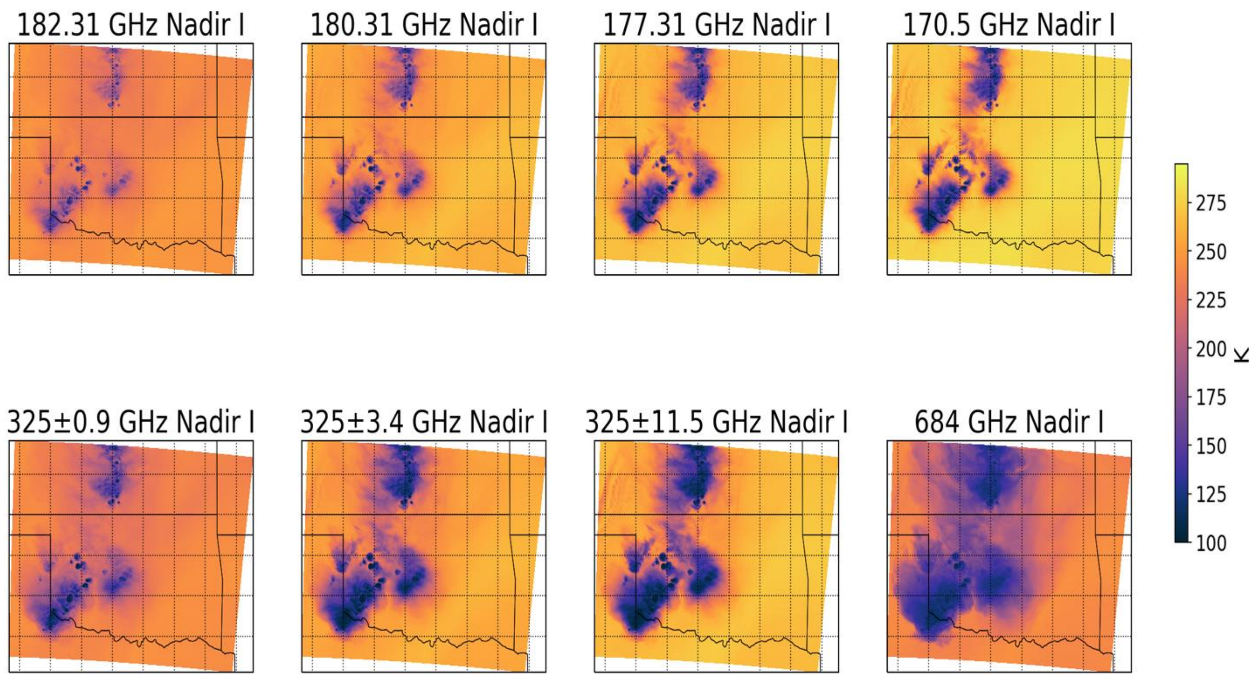
Quantity	Resolution @ altitude	Accuracy	Sensitivity @ altitude
Radar reflectivity, cloud-profiling	Horiz.: 2.0 km Vert.: 300 m @ 0.5 – 1.0 km 300 m @ 1.0 - 2.5 km 500 m @ 2.5 – 6 km 500 m @ 6 – 20 km	1.5 dB *	**≤–5 dBZ @ 0.5 km – 1 km** **≤–15 dBZ @ 1 km – 2.5 km** **≤–20 dBZ @ 2.5 km – 6 km** **≤–24 dBZ @ 6 km – 20 km**

- Requirements are frequency agnostic
- Enhancements to be studied: Second frequency, narrow swath, passive measurements if Ka band, LDR

Figures at left courtesy of Matt McLinden

AOS-Sky Radiometer Requirements

Microwave Radiometer: 89-700 GHz



Courtesy of Yuli Liu, UMBC

Cross-track scanning, ≥750 km swath

FOV ≤10 km at nadir, ≤20 km at edge of swath

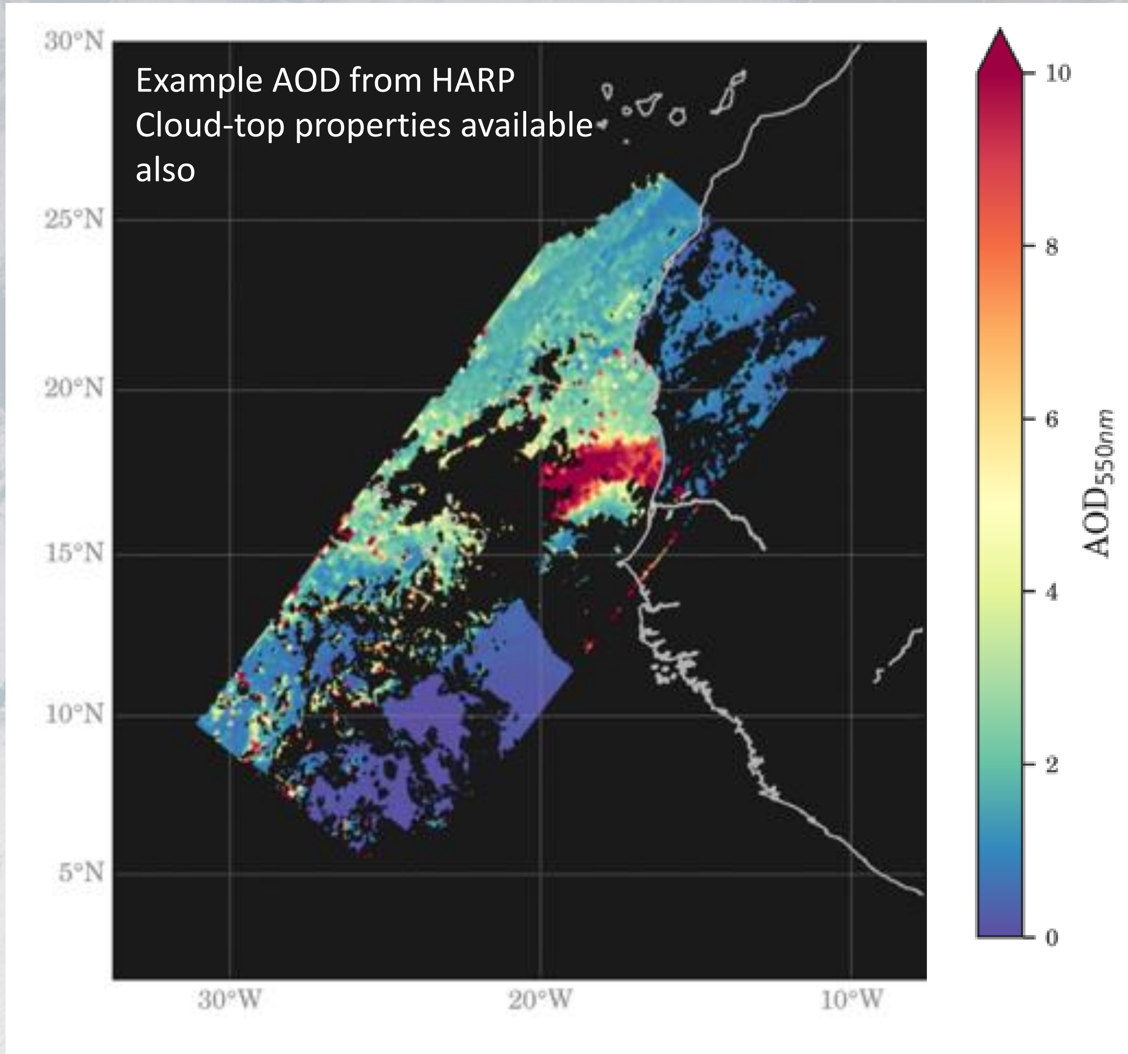
Baseline Requirements

Bands (# Channels)	Accuracy (K)	Polarization
89-113 GHz (1) 118 GHz (3)	≤ 0.5 K ≤ 0.75 K	Target: Dual Minimum: Single
183.3 GHz (3) 165/205 GHz (1)	≤0.75 K ≤0.75 K	Target: Dual Minimum: Single
310 GHz (3) 325.2 or 380.2 GHz (2)	≤ 1.5 K ≤ 1.5 K	Target: Dual Minimum: Single
640-700 GHz (1)	≤ 1.5 K	Dual

Sub-mm wavelengths bring a cloud sensitivity that is new for NASA missions

AOS Polarimeter Requirements

UV-VIS-NIR-SWIR Multi-angle Polarimeter



Baseline Requirements

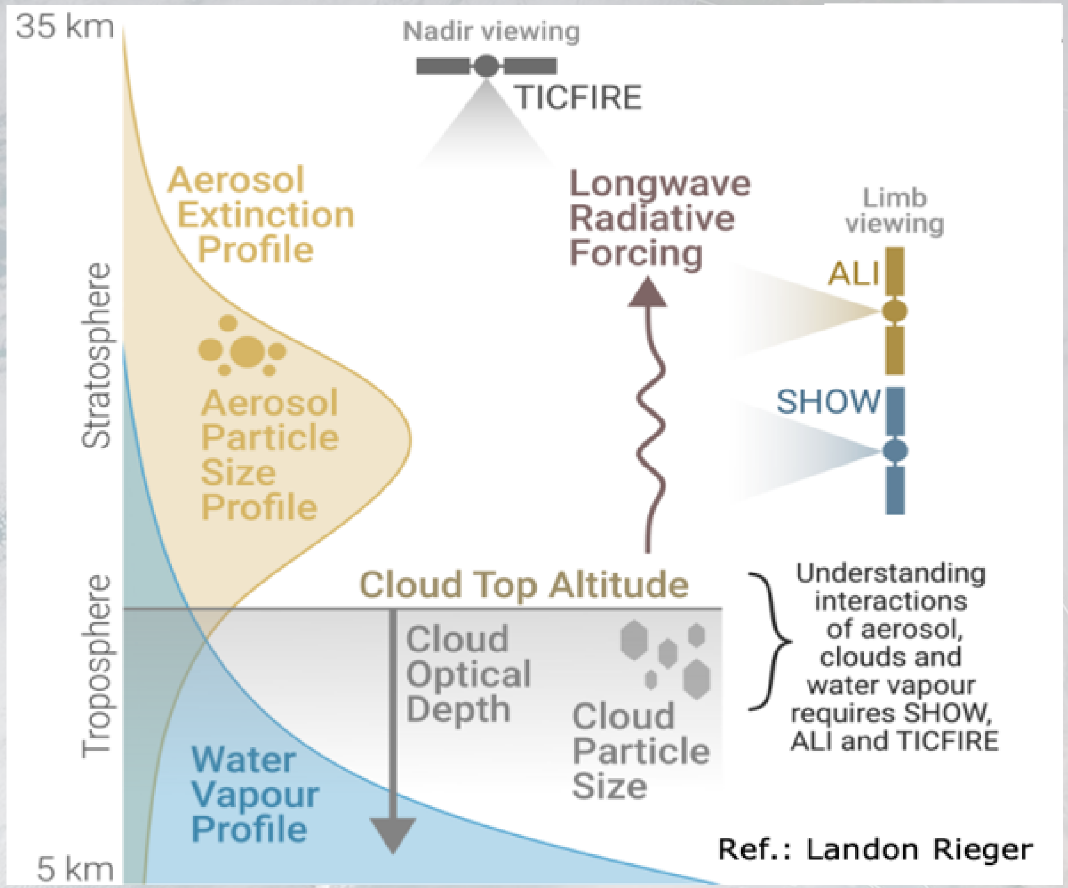
Type and/or Wavelength range (nm)	Number of spectral channels	Number of viewing angles per pixel
UV: 350 – 390 nm[1]	1	10
VIS: 410 – 750 nm	2	10
Hyperangle: 660 – 870 nm	1	60
Water Vapor: ~940nm	1	10
SWIR Cirrus: ~1380	1	10
VNIR-SWIR: 870 – 1570 nm	3	10

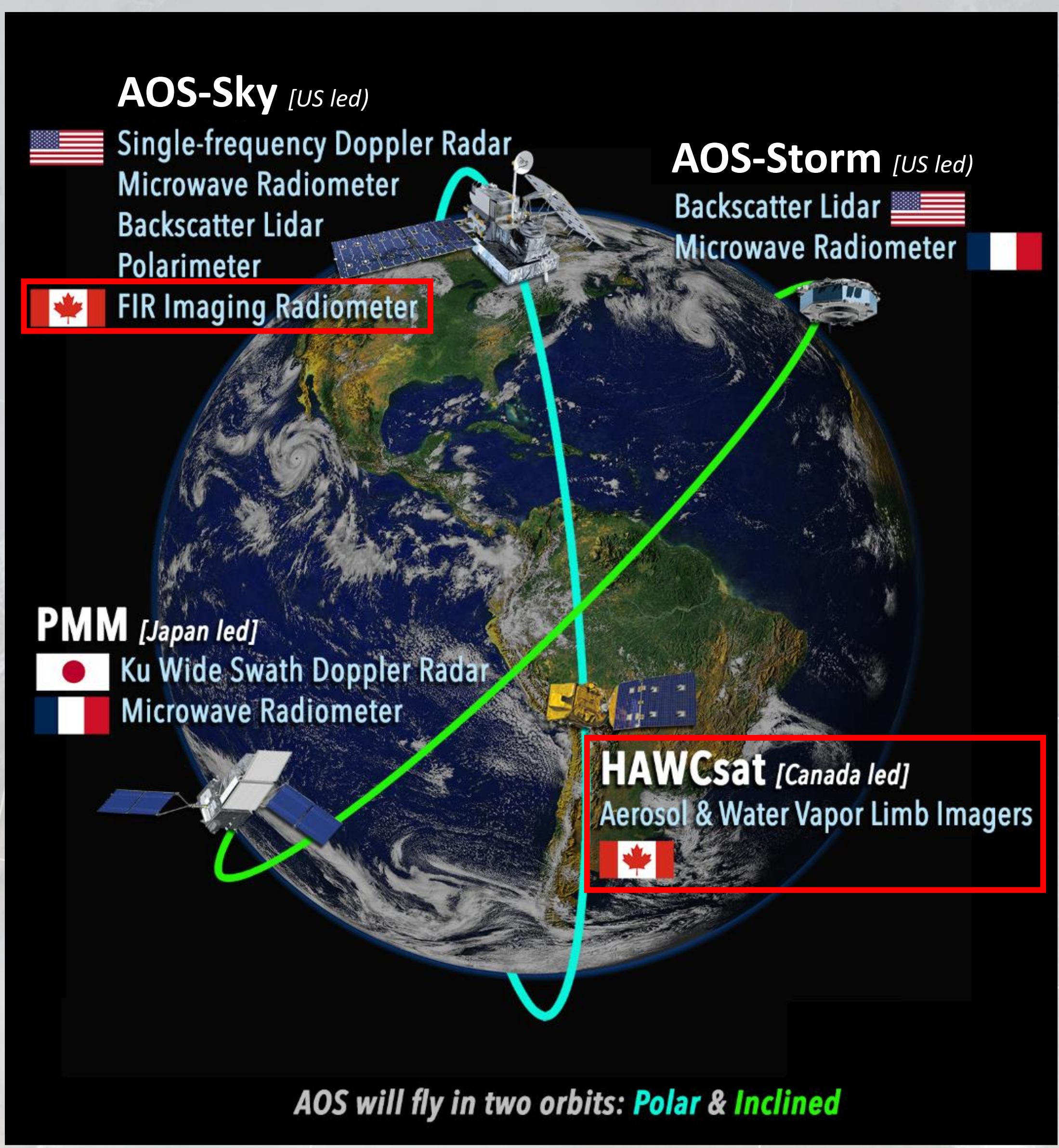
300 km swath width

0.5 km IFOV (at nadir)

CSA Contributions

Canadian Space Agency Longwave-Far Infrared Imaging Radiometer (4-73 µm), Aerosol/Moisture Limb Sounding



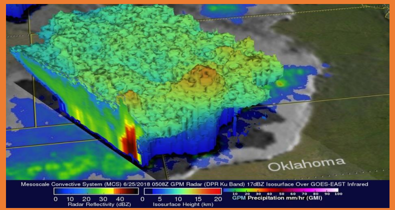


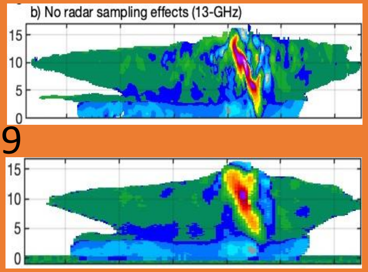
Summary of AOS Measurements & Timeline

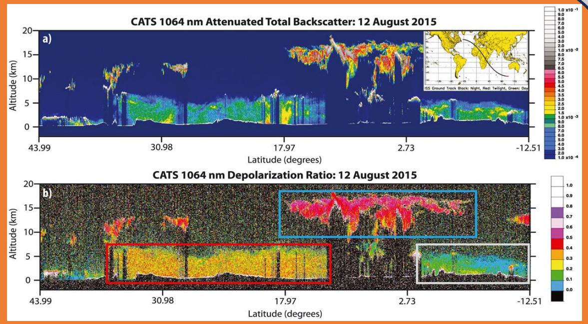
Earth System Observatory
Atmosphere Observing System

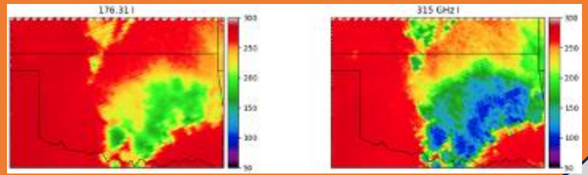
Inclined orbit (diurnal variations)

55° inclination
NLT March 2029



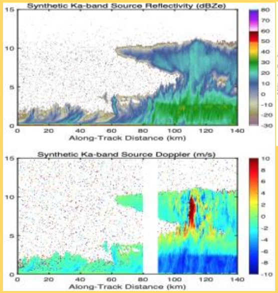


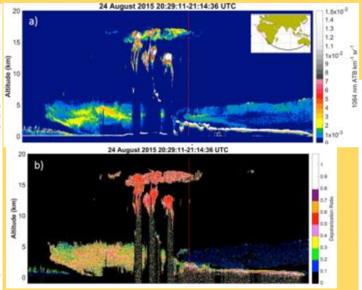


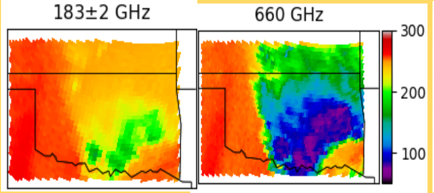


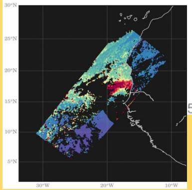
Polar orbit

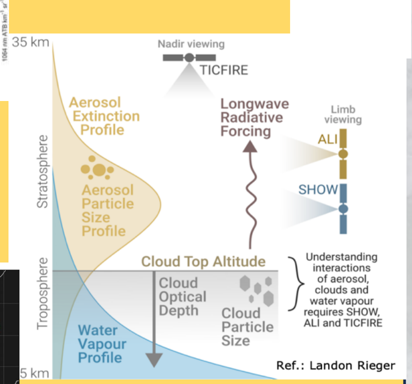
Sun-synch
1330 LTAN
NET Dec 2031











AOS-Storm, JAXA PMM, and CNES C2OMODO:

- Ku-Doppler radar
- dTB/dt (~mm-wavelength)
- Backscatter lidar

AOS-Sky, CSA HAWCsat:

- Cloud-profiling Doppler radar
- Backscatter lidar
- sub-mm radiometer
- Polarimeter
- Longwave radiometer
- Limb sounder (aerosol+moisture)