



The Atmosphere Observing System (AOS): Future Space-Based Observations for the Study of Coupled Aerosol-Cloud- Precipitation Interactions

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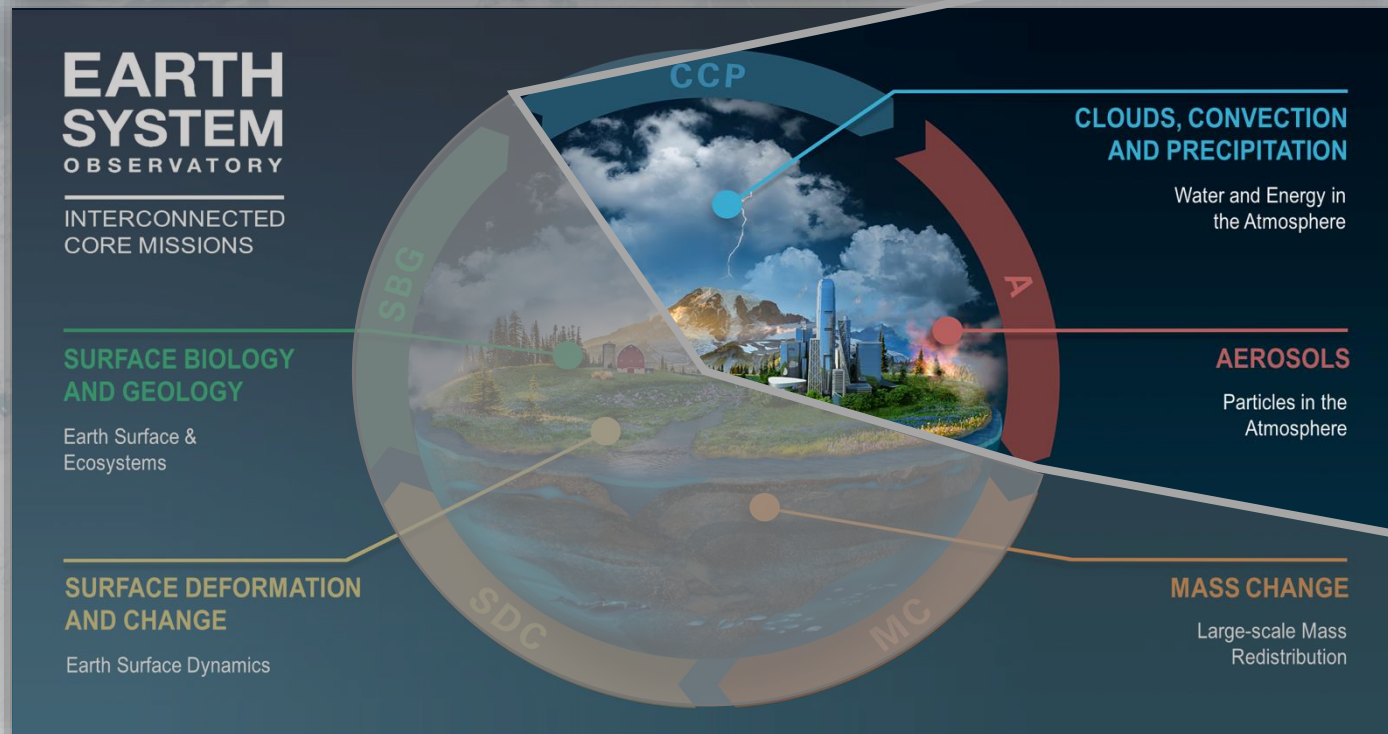
7 CNES Centre National d'Etudes Spatiales

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Sweden



What is the Atmospheric Observing System?

AOS, a key component of ESO, is a Decadal Survey mission that will deliver **transformative observations fundamental to understanding coupled aerosol-cloud-precipitation processes** that profoundly impact weather, climate, and air quality.

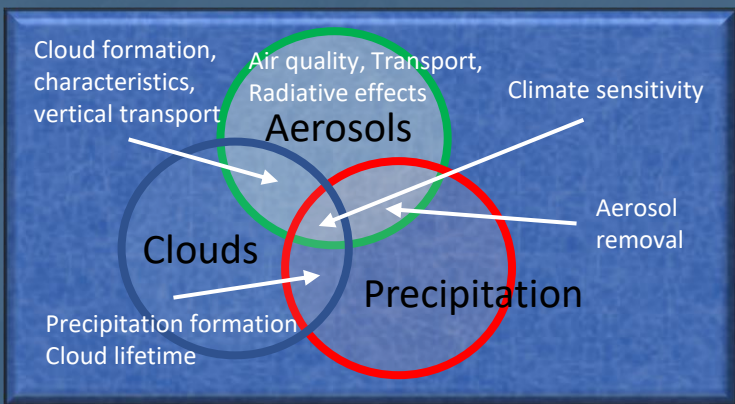


1. **Cloud Feedbacks**
 - Low Cloud and High Clouds
2. **Storm Dynamics**
3. **Cold Cloud & Precipitation Processes**



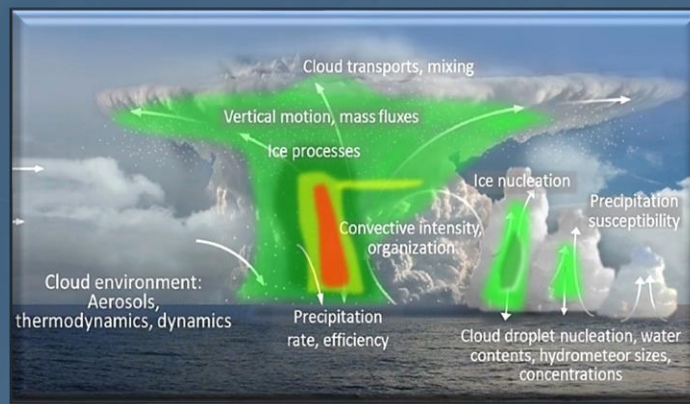
4. **Aerosol Processes**
 - Aerosol Attribution and Air Quality
 - Aerosol Removal & Redistribution
5. **Aerosol Impacts on Radiation**
 - Aerosol Direct Effect and Absorption
 - Aerosol Indirect Effect

AOS Objectives Focus on Three Themes



1. CLIMATE: How can we improve our ability to predict local and regional climate response to natural and anthropogenic forcings and reduce the uncertainty in global climate sensitivity?

- The two largest sources of future warming prediction uncertainty are (IPCC AR6 Report):
 - radiative forcing by aerosol
 - cloud feedbacks



2. CONVECTION: Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? How do microphysical properties relate to storm dynamics?

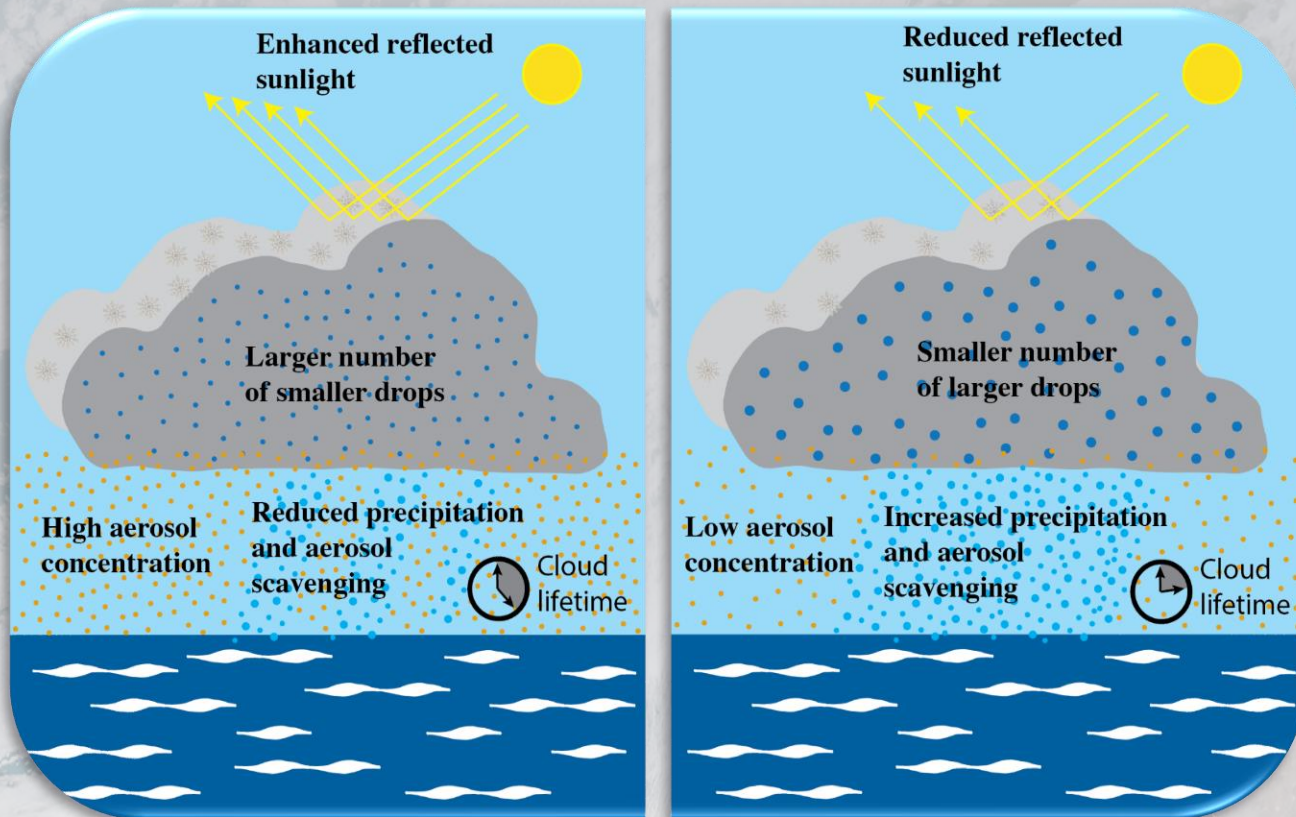
- Convective storms deliver much of the fresh water for society and are a principal source of life-threatening severe weather.



3. AEROSOLS: What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impacts on human health, agriculture, and ecosystems?

- Aerosol profile and amounts are key to near-surface air quality, transport & vertical redistribution
- Aerosol extinction is critical in determining the radiative effects of aerosols

Aerosol-Cloud-Precipitation Interactions



Adapted from Stephens (2021) and Mülmenstädt et al. (2021)

- Aerosols are critical to the formation and properties of clouds
 - Seeds of cloud formation
 - Impact precipitation development and cloud lifetime
 - Can change how clouds reflect or scatter radiation
- While still uncertain, aerosols may modify convection

Requires synergistic active-passive measurements to more fully observe coincident aerosol-cloud-precipitation properties

AOS Mission Overview

Current concept includes a five-satellite constellation, with complementary instruments, operating in two orbit planes

- Delivers globally distributed measurements on range of temporal scales
- Complemented by sub-orbital element (e.g., cal/val)

International contributions expand capabilities

- NASA's two spacecrafts and their instruments are enhanced by observatories and instruments provided by JAXA, CSA, CNES

AOS-Storm- Class C or D

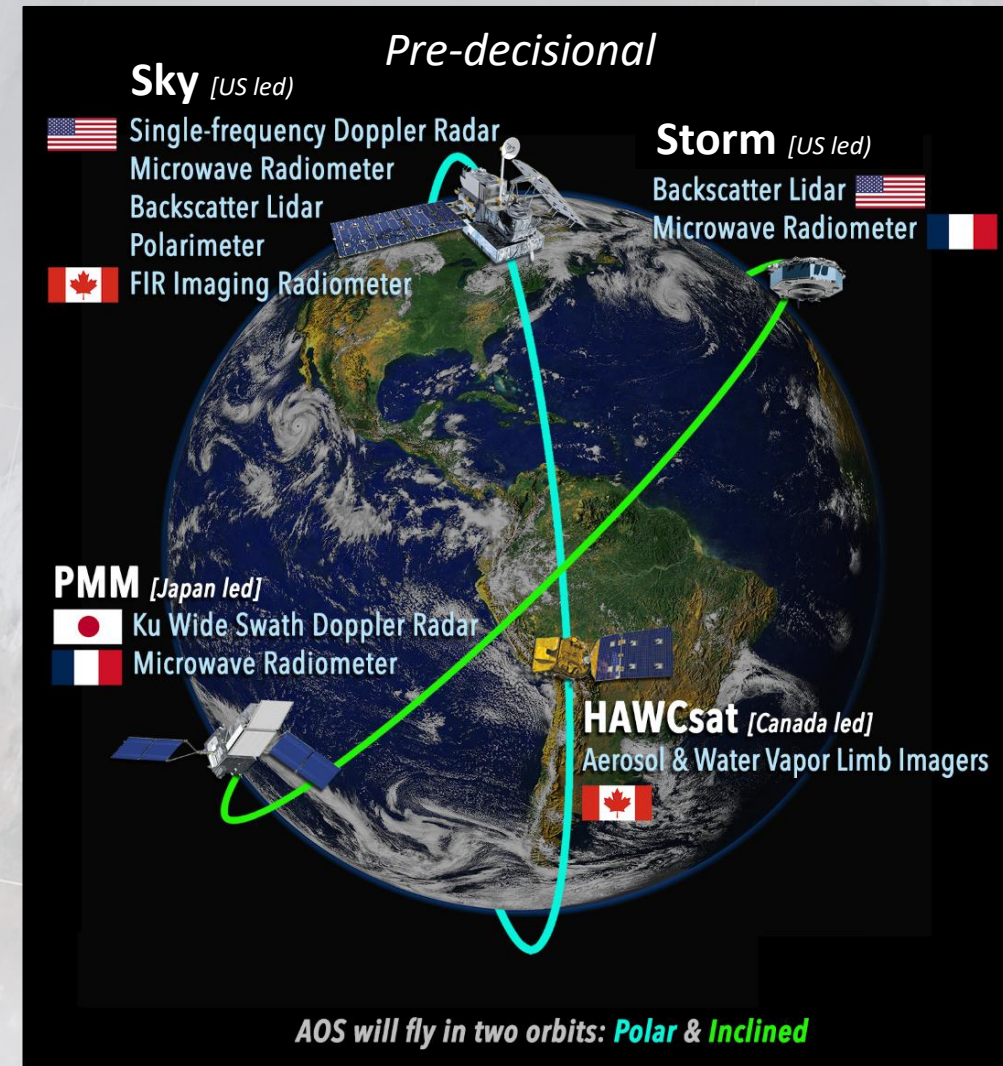


- NLT March 2029 launch
- Co-manifested launch with JAXA Precipitation Measurement Mission (PMM), 5-yr mission life
- 407-430 km orbit, 55° inclination
- 1-2-yr mission life, 3 yrs of consumables

AOS-Sky- Class C



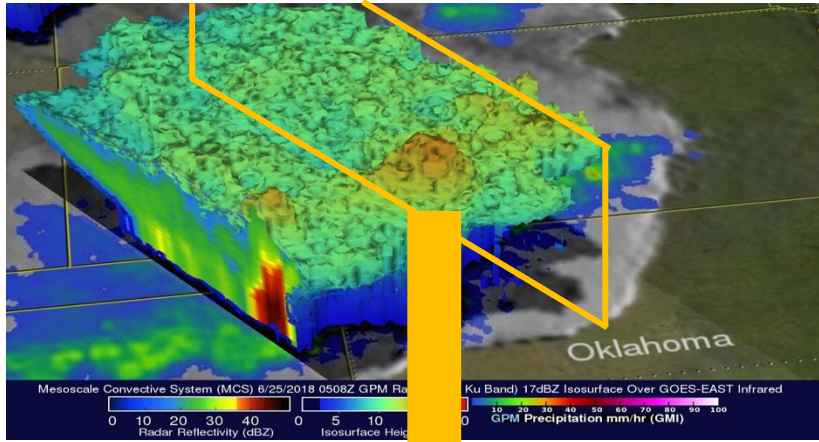
- NET December 2031 launch
- Co-manifested launch with CSA High-altitude Aerosols, Water vapor, and Clouds Satellite (HAWCsat)
- 450 km orbit, sun-sync-13:30 LTAN
- 3-yr mission life, 5 yrs of consumables



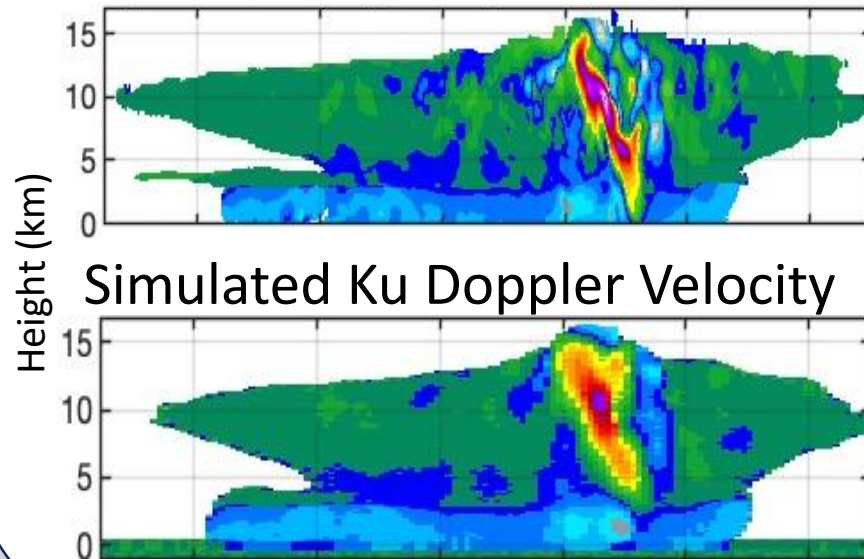
Reflects architecture revised during Phase A

A Visual View of AOS-Inclined Measurements

JAXA Wide Swath Ku Doppler Radar

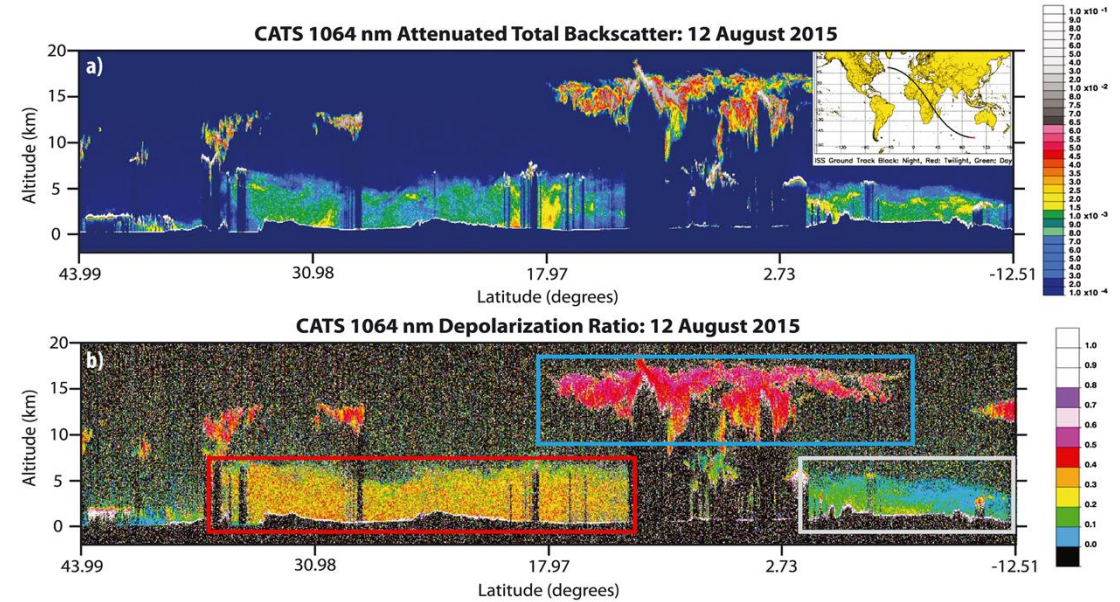


Model "Truth"

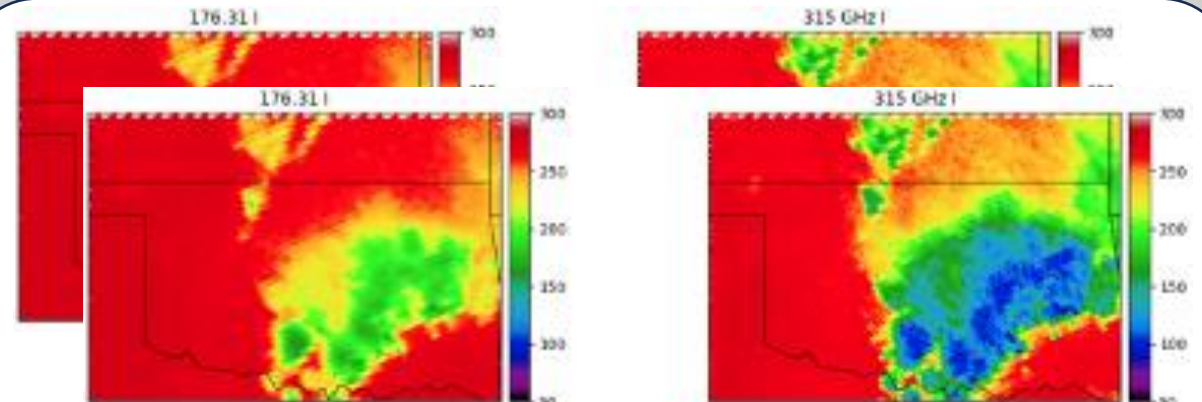


Courtesy Pavlos Kollias

532-, 1064-nm Backscatter Lidar

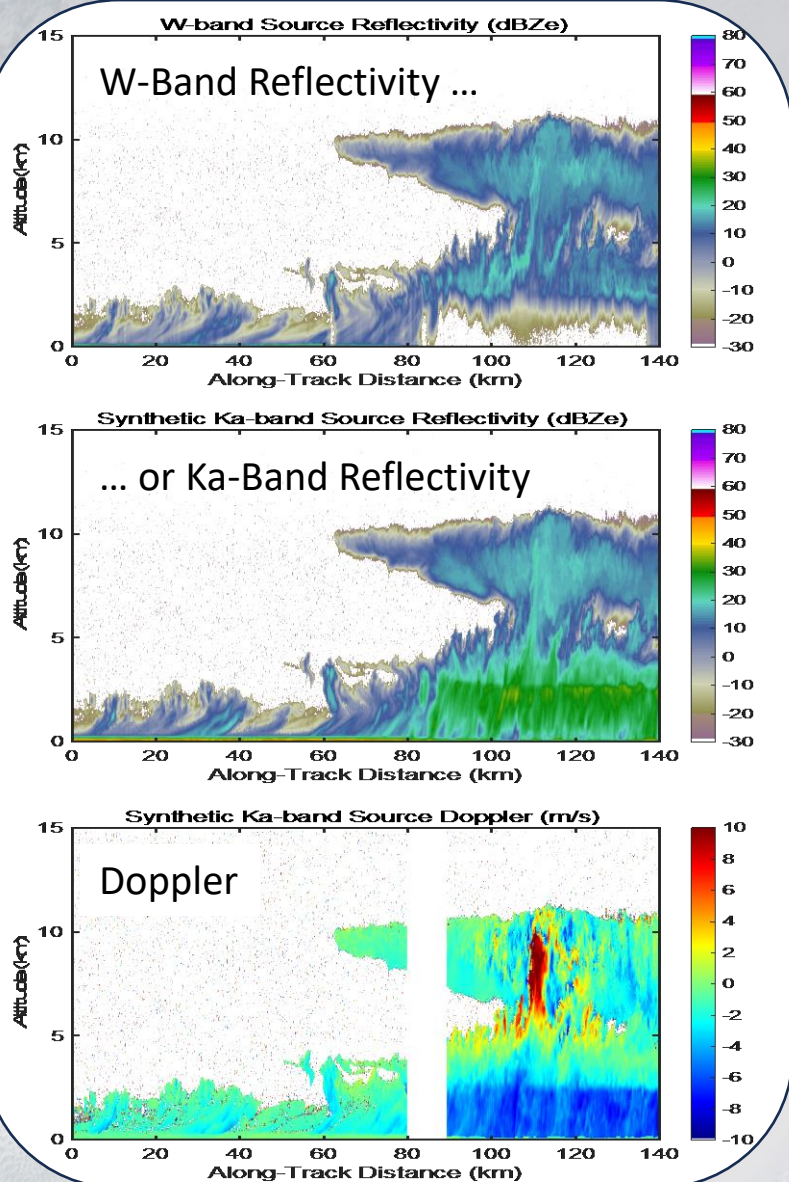


CNES Microwave Radiometers (89, 183, 325 GHz)

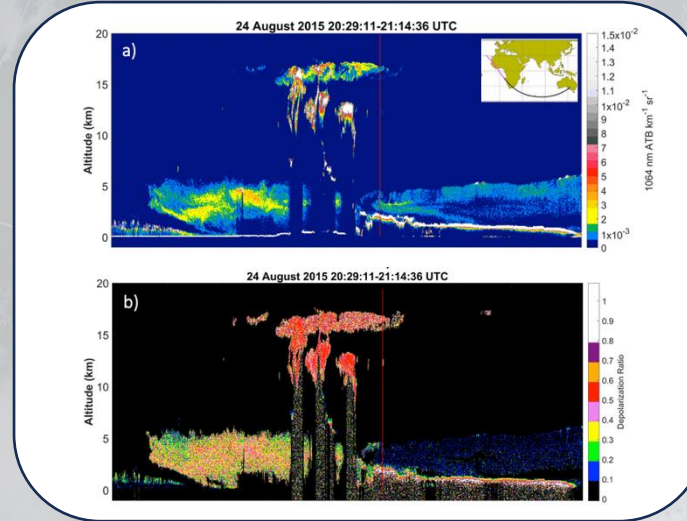


A Visual View of AOS-Polar Measurements

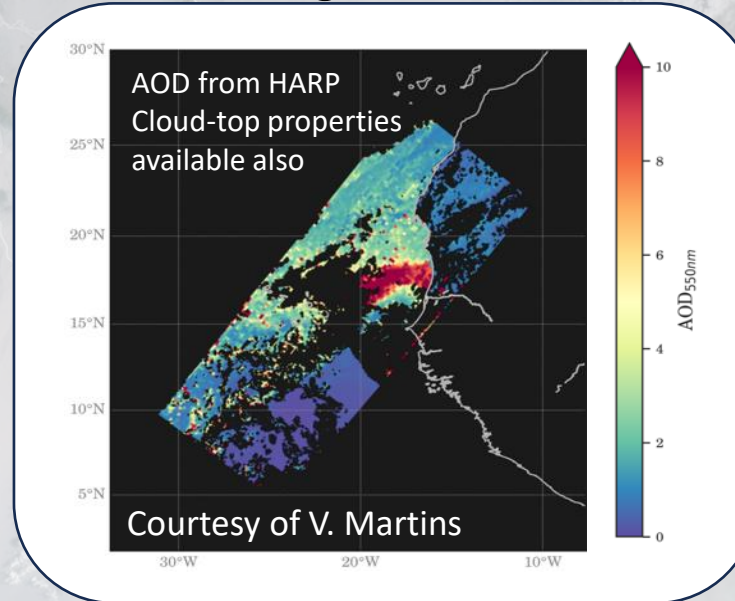
Single-Frequency Doppler Radar



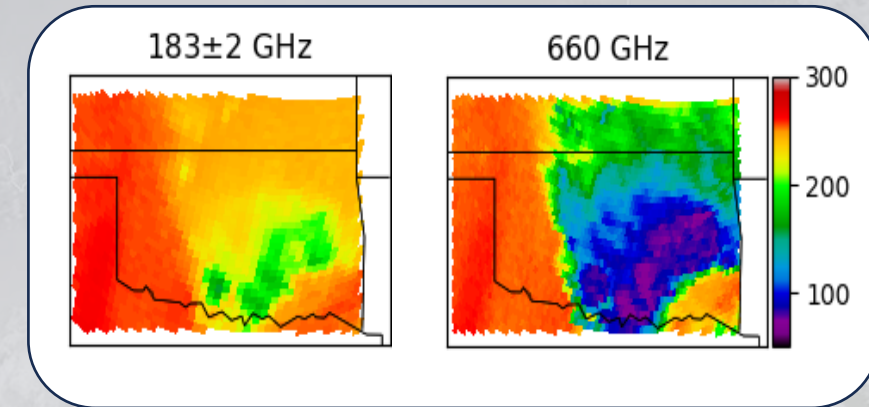
532-, 1064-nm Backscatter Lidar



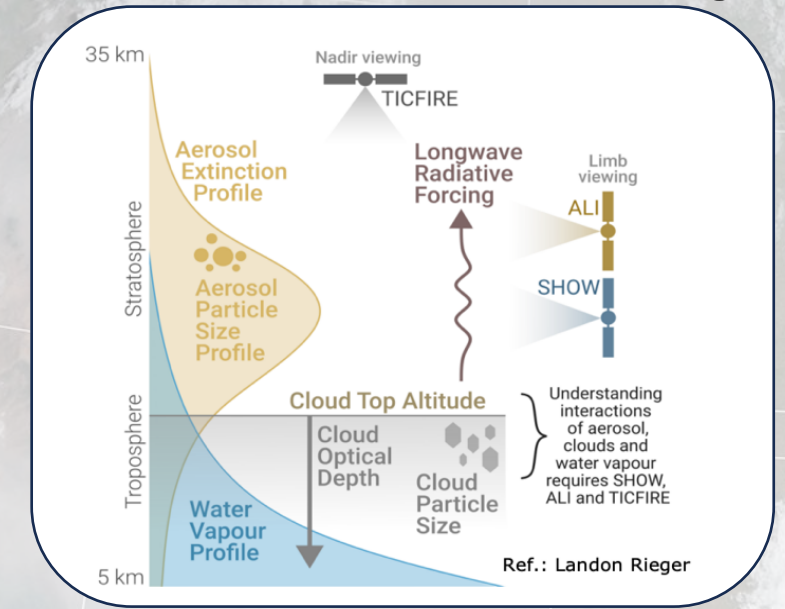
Multi-angle Polarimeter



Microwave Radiometer: 89-700 GHz



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



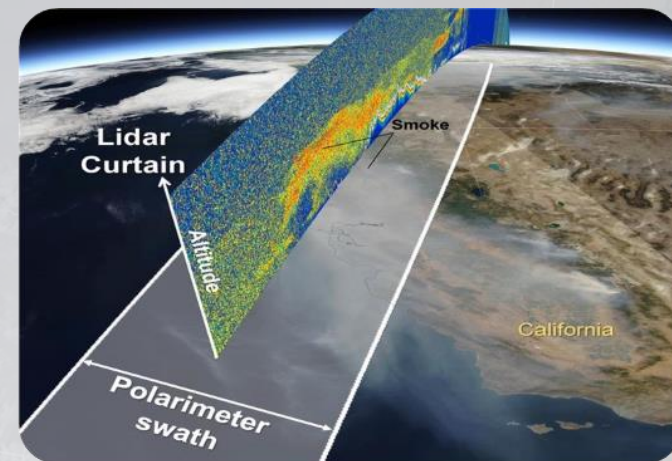
New Science and Key Synergies

- **New Science**

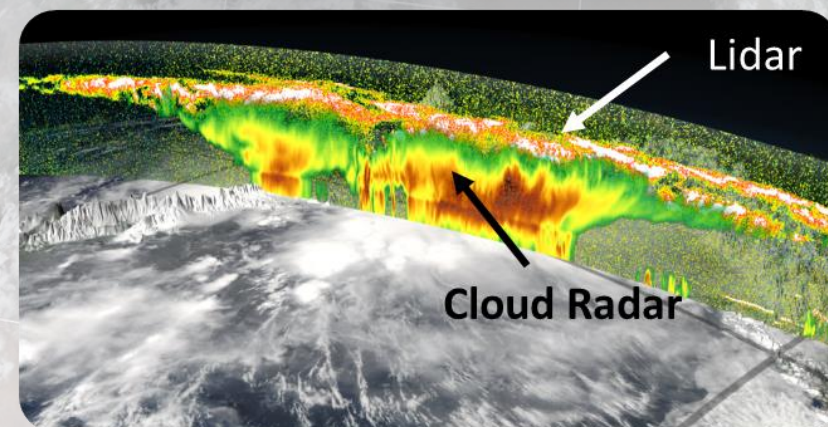
- Globally distributed and diurnally varying vertical air motions in convection
- Coupled dynamics and aerosol, cloud, and precipitation measurements, longwave radiation
- Short time-interval evolution of convective clouds
- Diurnal variability of coincident precipitation, cloud, and aerosol profiles

- **Measurement Synergies**

- A much more integrated view of Earth than possible with single measurement
- Tighter constraints on & better consistency of information retrieved
- The ability to fill gaps in Geophysical Variables
- The possibility of extracting entirely new & refined information about 'processes'



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

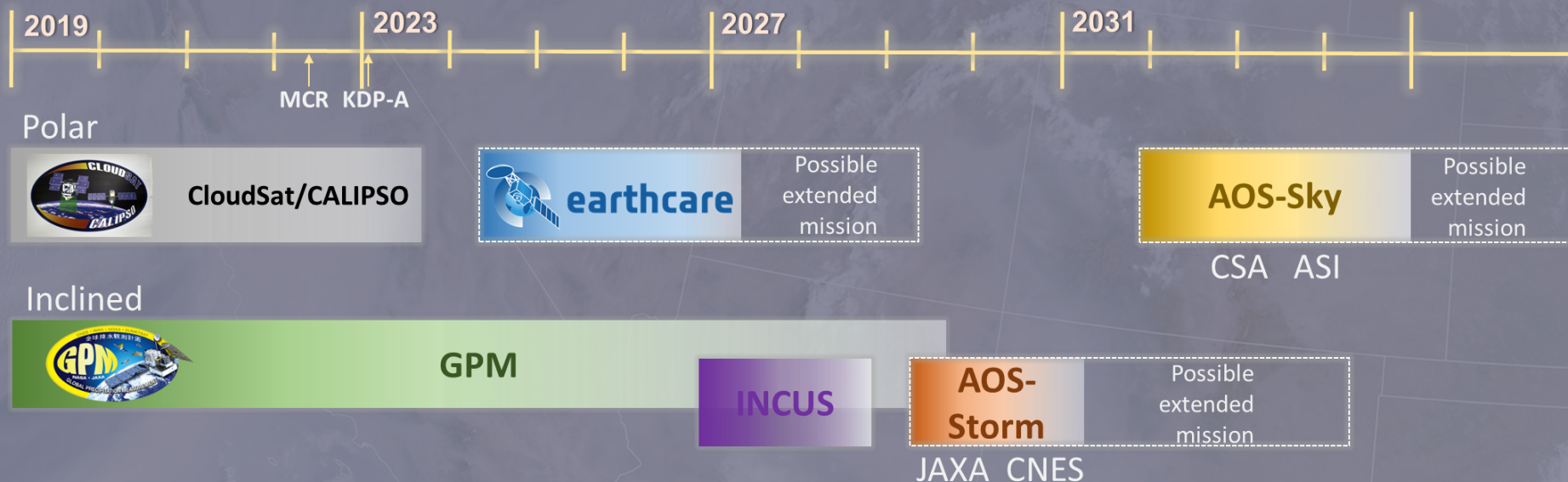


Doppler radar+lidar+passive sensor synergy: adds dynamical information to cloud/precipitation profiling and passive properties

The Urgency and Timing of AOS

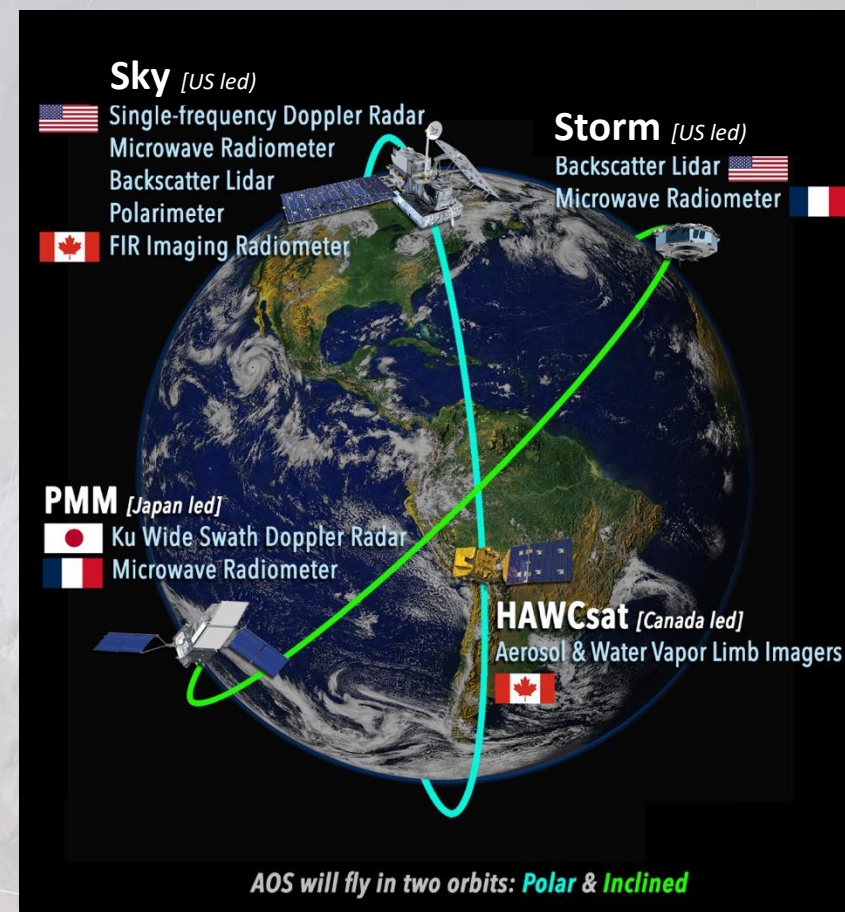
- We are feeling the **impacts from climate change now**
 - Temperature extremes, Fires & Air Quality impacts, too little and too much precipitation
 - Extreme storms – increasing in intensity and \$\$
- Planet may reach **1.5°C warming in a decade** but **projections have considerable uncertainty**
 - Need improved observations to constrain models and improve scenario modeling

Key elements of the Earth-observing system of satellites related to atmospheric measurements are **coming to an end in the very near future.**



Summary

- Two AOS projects (AOS-Sky, AOS-Storm)
 - Storm: Ku Doppler radar, microwave radiometers, backscatter lidar in 55° inclined orbit
 - Sky: Cloud-profiling Doppler radar, backscatter lidar, microwave radiometer, polarimeter, far IR radiometer, aerosol and moisture limb sounders in polar orbit
- Address objectives related to climate sensitivity and feedback, convective storms, and aerosol distributions and processes
- AOS Projects in mission concept and technology development phase (Phase A)
- Working trades for polar radar and lidar



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