

HAWC



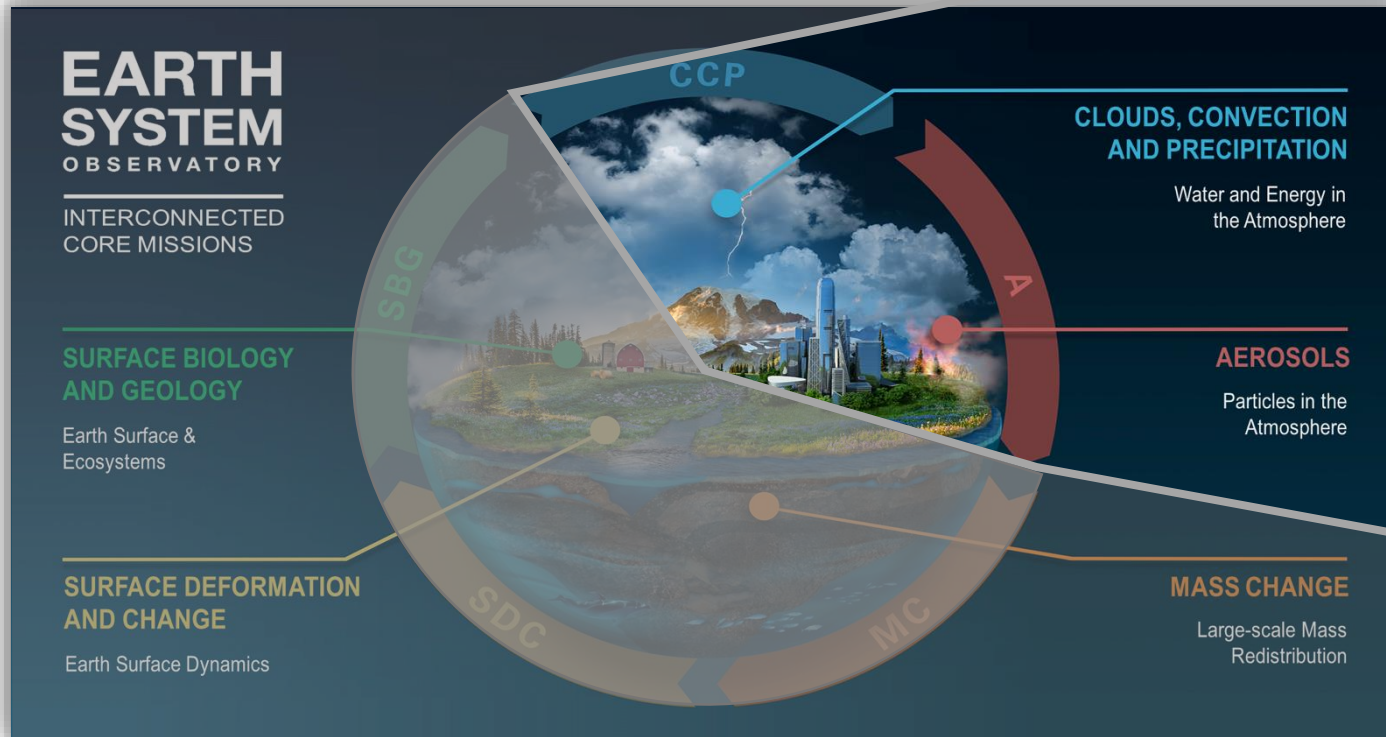
The High-altitude Aerosol, Water vapour, and Clouds (HAWC) satellite mission

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NASA ATMOSPHERE OBSERVING SYSTEM (AOS)

- Decadal Survey mission
- Coupled aerosol- cloud-precipitation processes
- Impacts on extreme 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

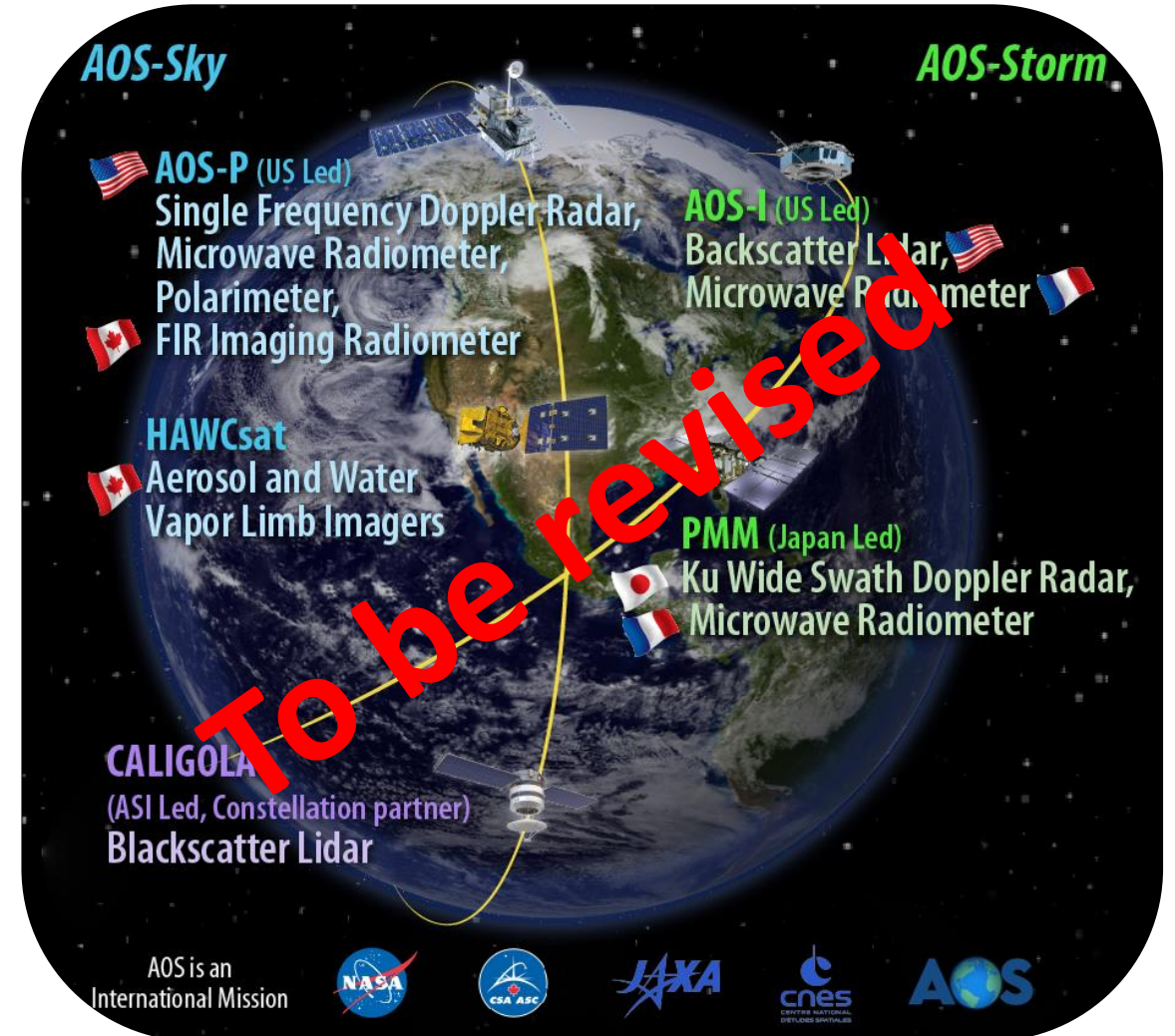
- Aerosol Direct Effect and Absorption
- Aerosol Indirect Effect

THE NASA AOS MISSION OVERVIEW

- Five satellite constellation in two orbit planes
- International contributions expand capabilities
 - JAXA, CSA, CNES, ASI

Polar orbit: AOS-Sky
2031 launch with CSA HAWC
450 km orbit, sun-sync-13:30 LTAN
3-yr mission life, 5 yr consumables

Inclined orbit: AOS-Storm
2029 launch with JAXA PMM
407km orbit, 55° inclination
2-yr mission life, 3 yr consumables

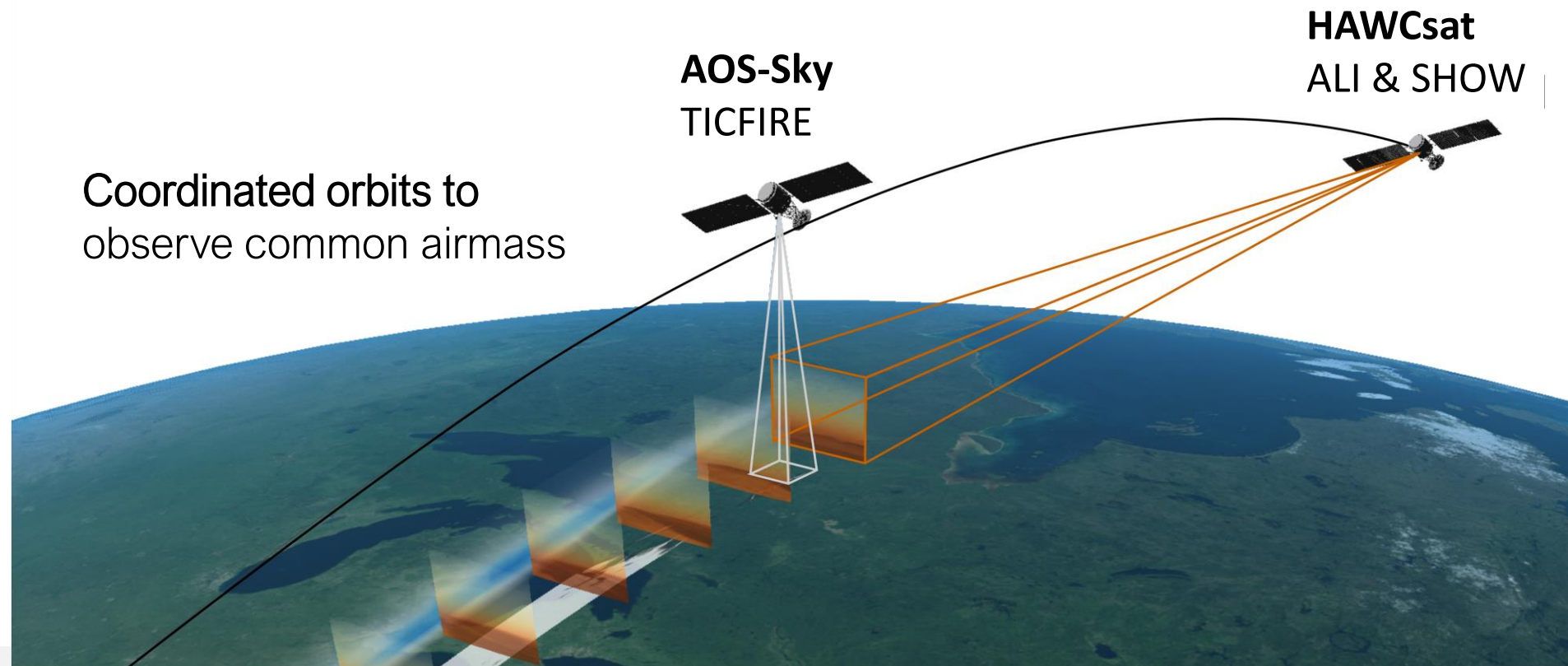


HAWC: CANADIAN CONTRIBUTION TO NASA AOS

- Two limb instruments on Canadian polar orbit satellite
 - ALI (Aerosol Limb Imager)
 - SHOW (Spatial Heterodyne Observations of Water vapor)
- Far infrared radiometric imager on AOS-Sky (polar)
 - TICFIRE (Thin Ice Clouds and Far Infrared Emissions)



Full federal
funding
announced
late 2022!



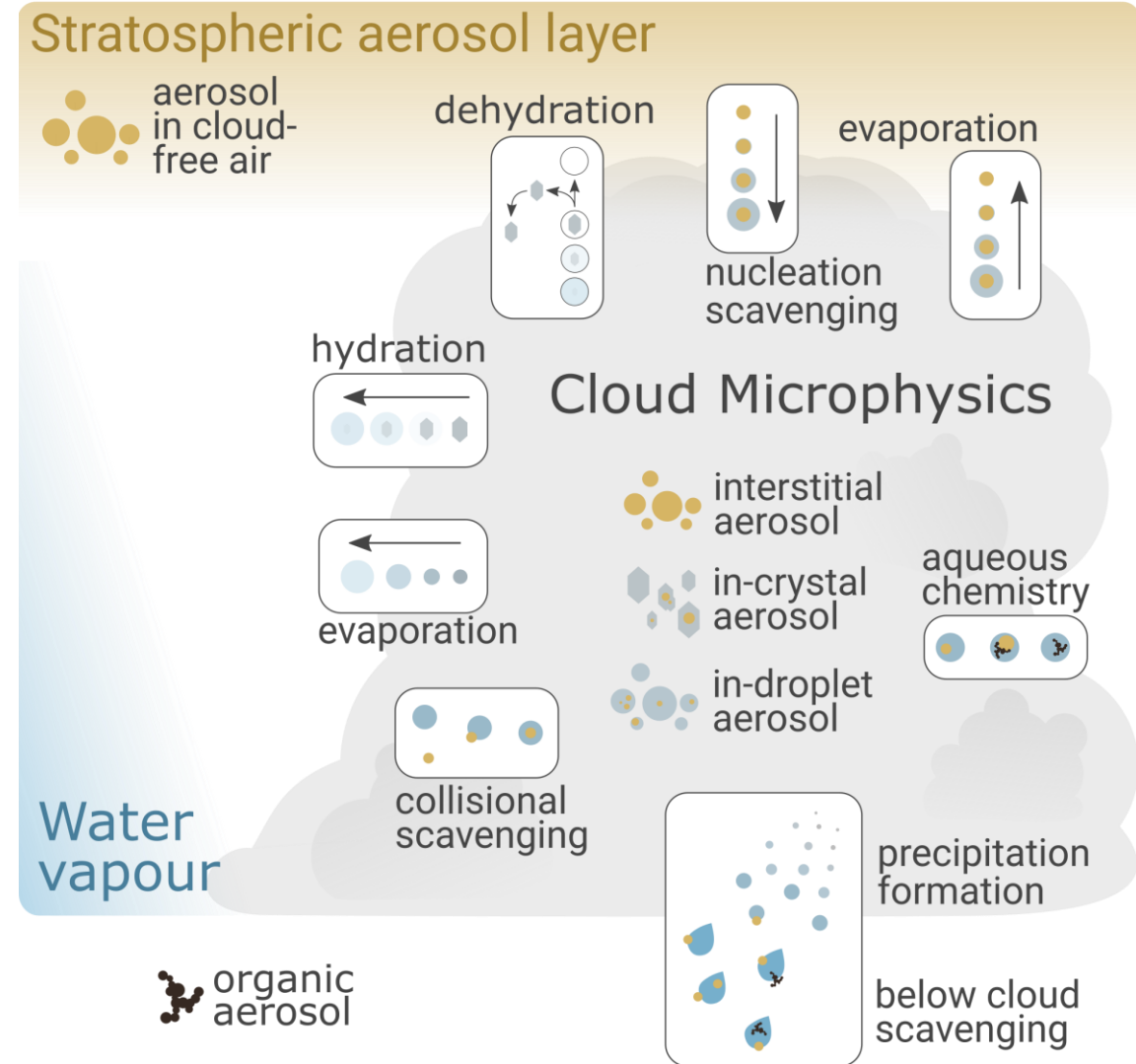
UTLS AEROSOL, WATER AND CLOUDS

UTLS **aerosol**, **water vapour** and **cloud** play an important role in climate forcing and feedbacks, but have critical knowledge gaps

- **Aerosol** measurements in the UTLS are complicated by poorly constrained microphysics and the presence of thin clouds
- Observational record shows unresolved differences in various satellite **water vapour** datasets in the UTLS.

Aerosol and **cloud** interactions

- Thin cirrus have important interactions with aerosol, but this has been historically difficult to measure
- Aerosol influence on seeding, particle growth, and scavenging impacts cloud forcing and feedbacks
- Water vapour plays an important role in cloud dynamics and aerosol processing



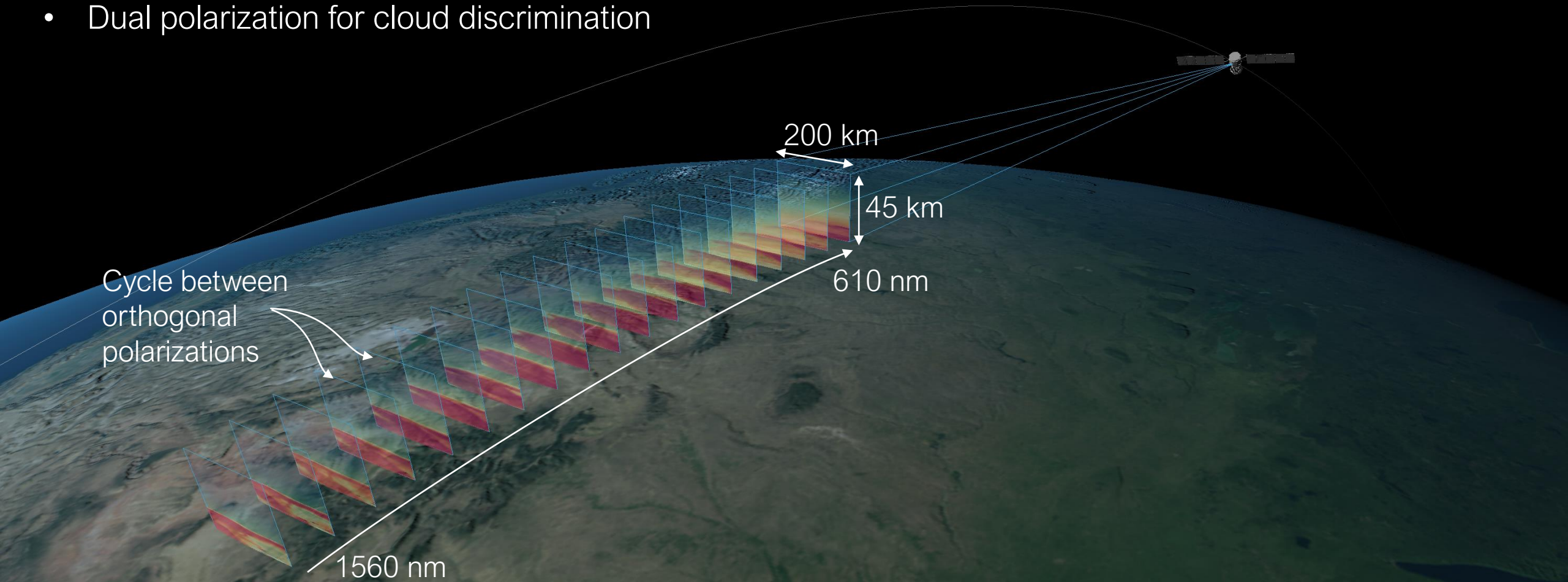
HAWC: MISSION HIGHLIGHTS

Enhance AOS Science

- High sensitivity to thin aerosol and low water concentrations extends AOS to higher altitudes and sensitive regions.
- Dense profiling capabilities with high vertical resolution provide coincident aerosol and cloud information to AOS instruments.
- FIR imagery from TICFIRE provides cloud microphysics and radiative effects
- Cloud and aerosol interactions at high altitudes and the Arctic.
- Polar orbit provides global coverage and facilitates long-term climate records

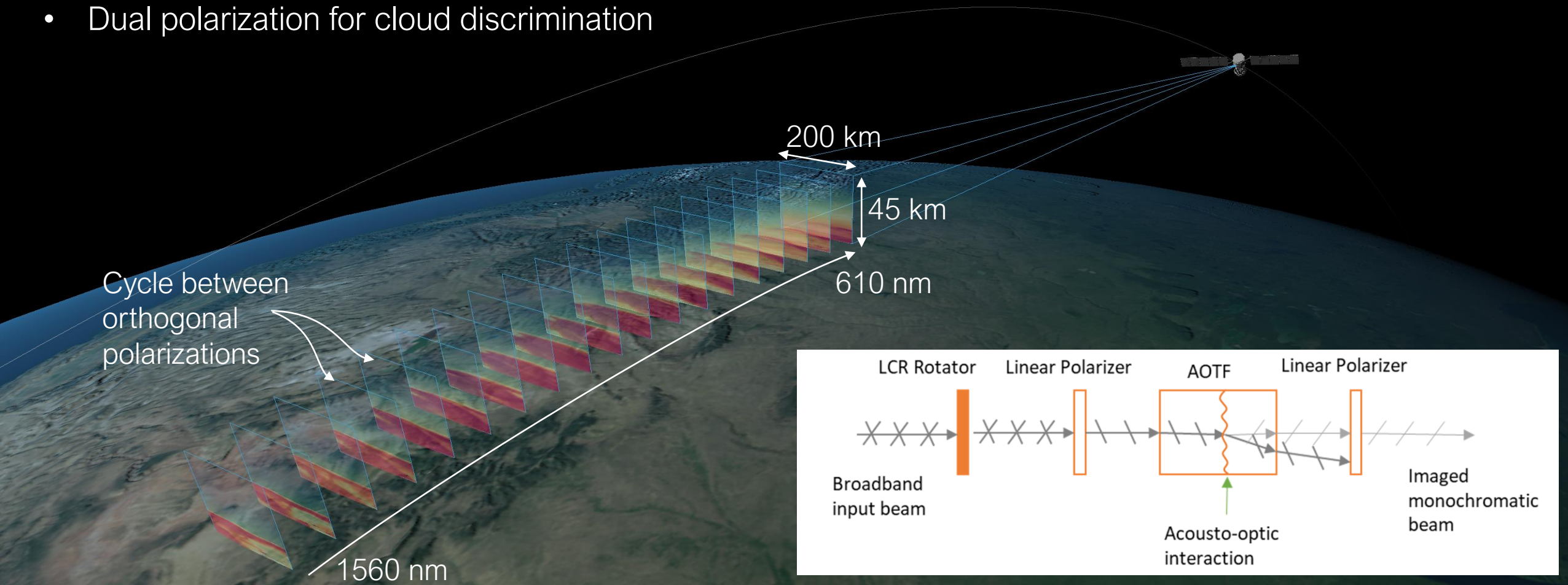
AEROSOL LIMB IMAGER (ALI)

- 2D multi-spectral images of the limb
- Spectral channels: 676, 755, 869, 950, 1022, 1080, 1225, 1360, 1450, 1560 nm
- Dual polarization for cloud discrimination

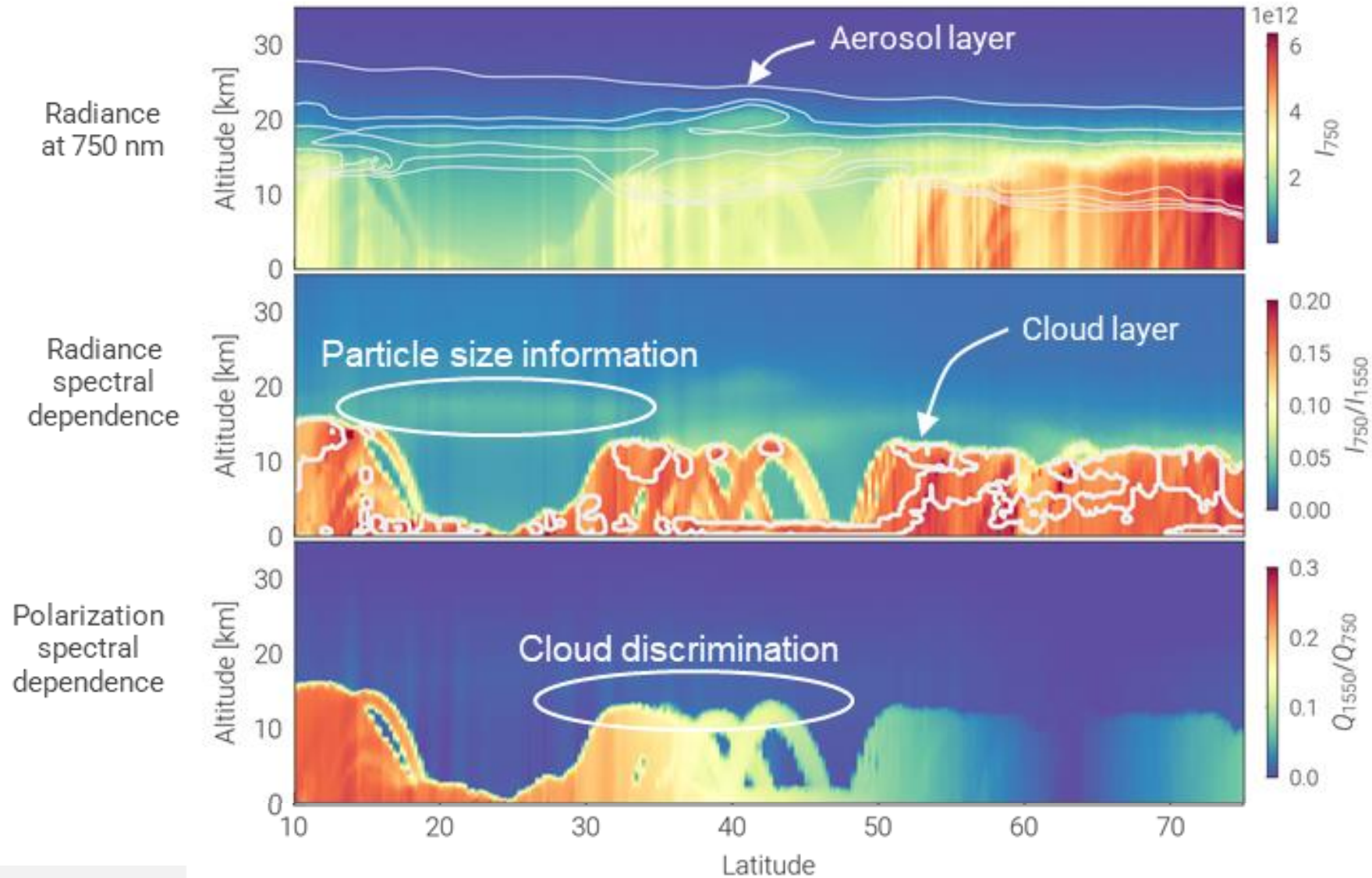


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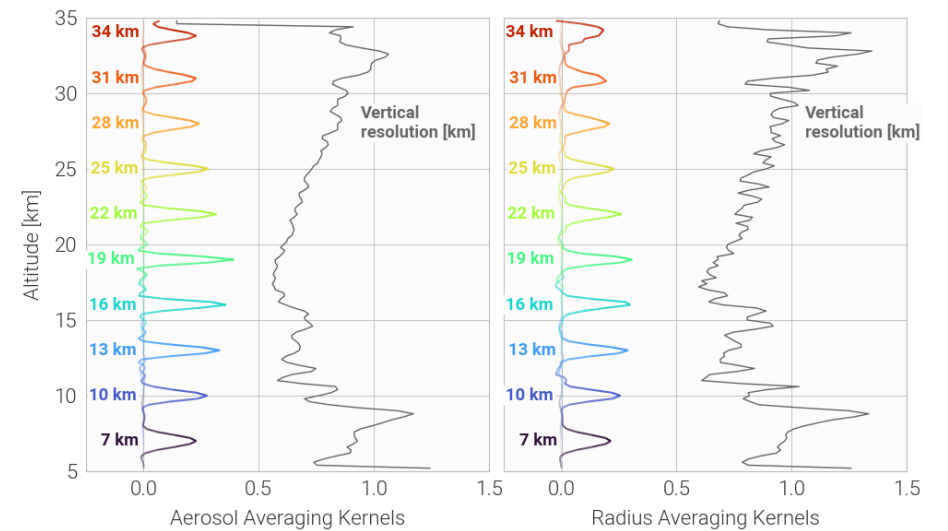
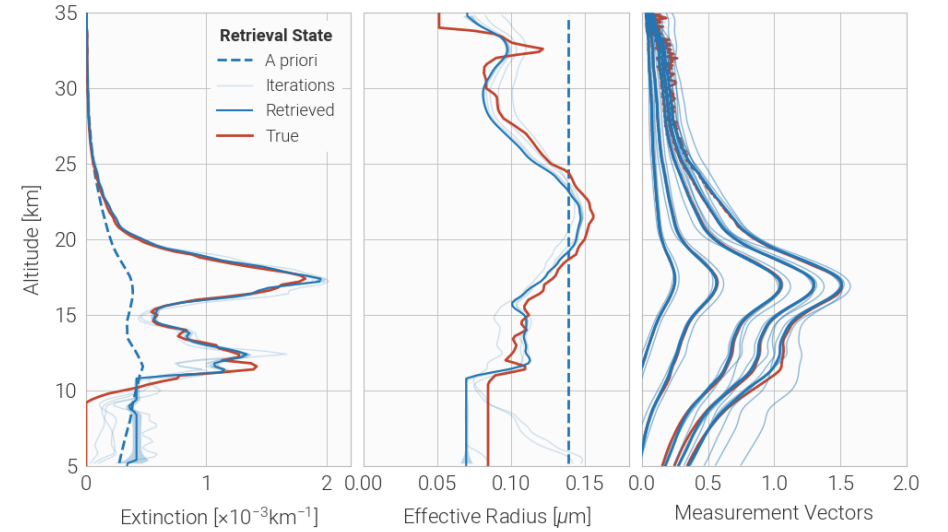


ALI MEASUREMENT SIMULATION



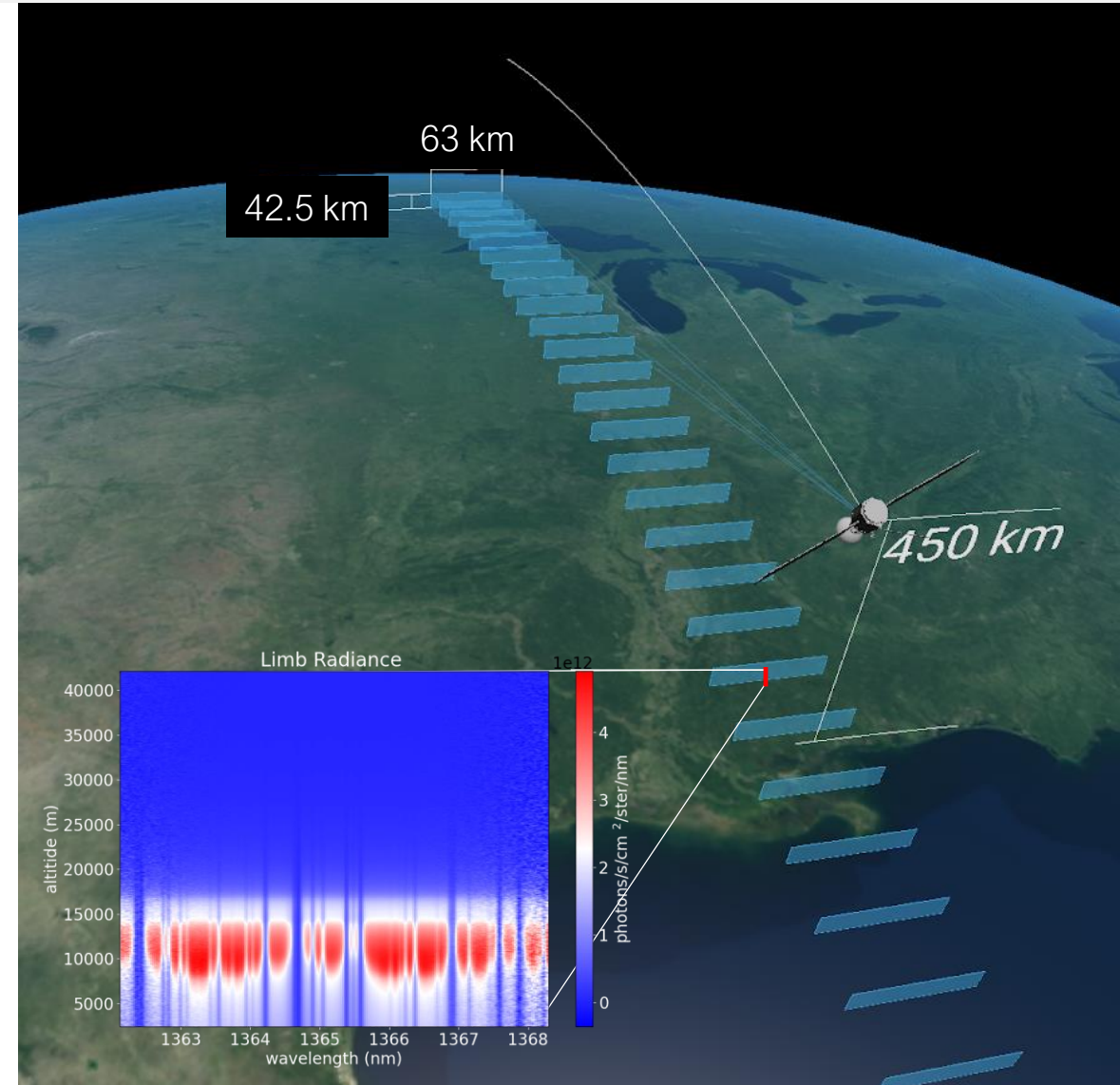
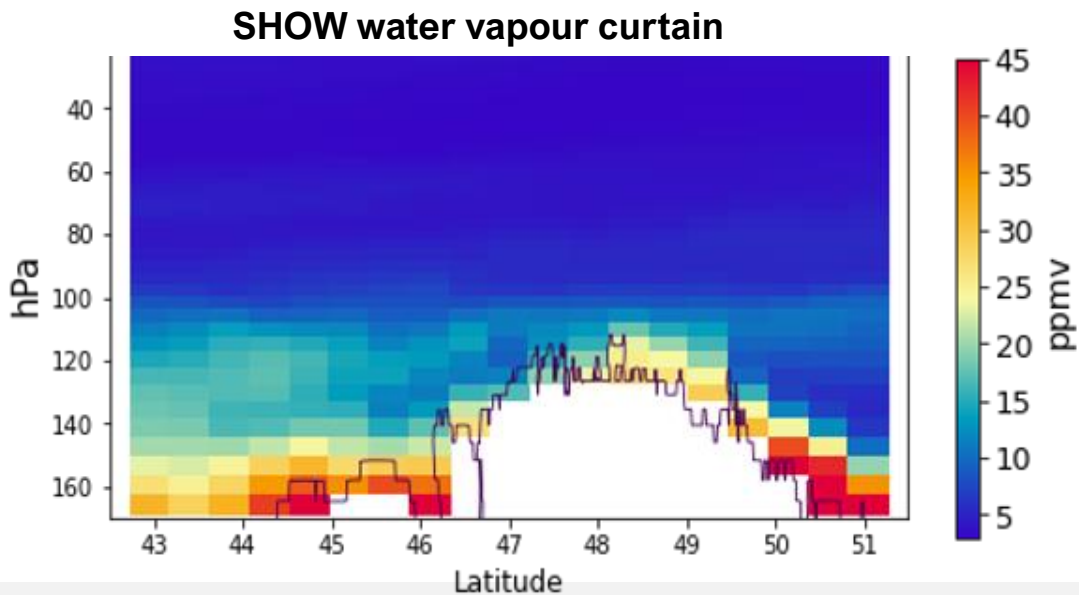
ALI DATA PRODUCTS

Product	Precision	Vertical Range	Resolution		
			Vertical	Horizontal	
				Along	Cross
Aerosol Extinction	10 % (10^{-2} to 10^{-5} km^{-1} at 750 nm)	8 to 35 km (or cloud top)	0.5 km	250 km	20 km
Effective Radius	20 % (10^{-2} to 10^{-5} km^{-1} at 1000 nm)	10 to 30 km (or cloud top)	0.5 km	250 km	20 km
Cloud Top Altitude	250 m	8 to 22 km	0.5 km	250 km	20 km



SPATIAL HETERODYNE OBSERVATIONS OF WATER (SHOW)

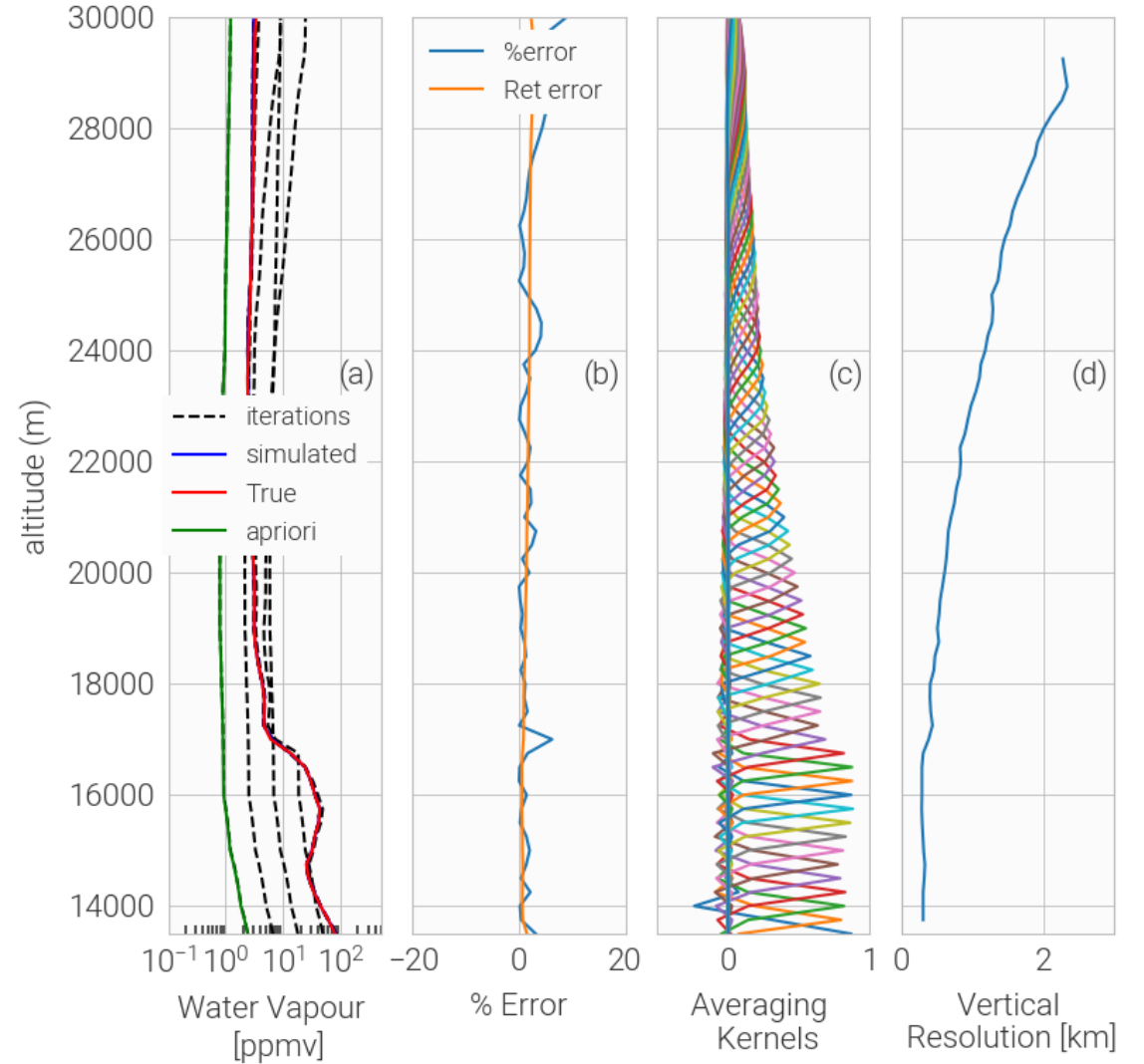
- Spatial Heterodyne: high spectral resolution within a narrow spectral window combined with a large throughput without scanning (1363-1368 nm)
- Vertically resolved images of the limb radiance are then inverted to extract the vertical water vapour profile.
- Allows for dense (vertical and along-track) sampling of the water distribution



SHOW DATA PRODUCTS

- High sensitivity to low water concentrations (0.1 – 100 ppm) in the region surrounding the tropopause
- Dense spatial sampling along the satellite track

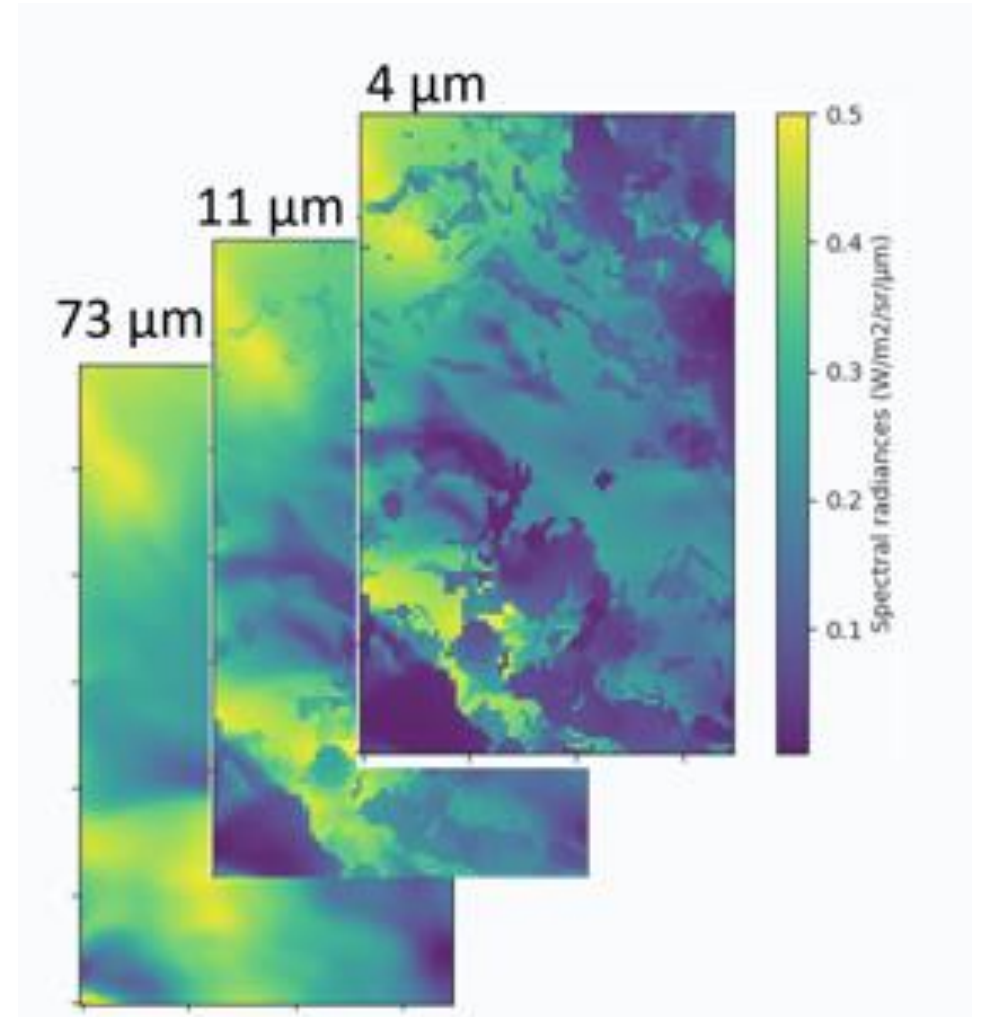
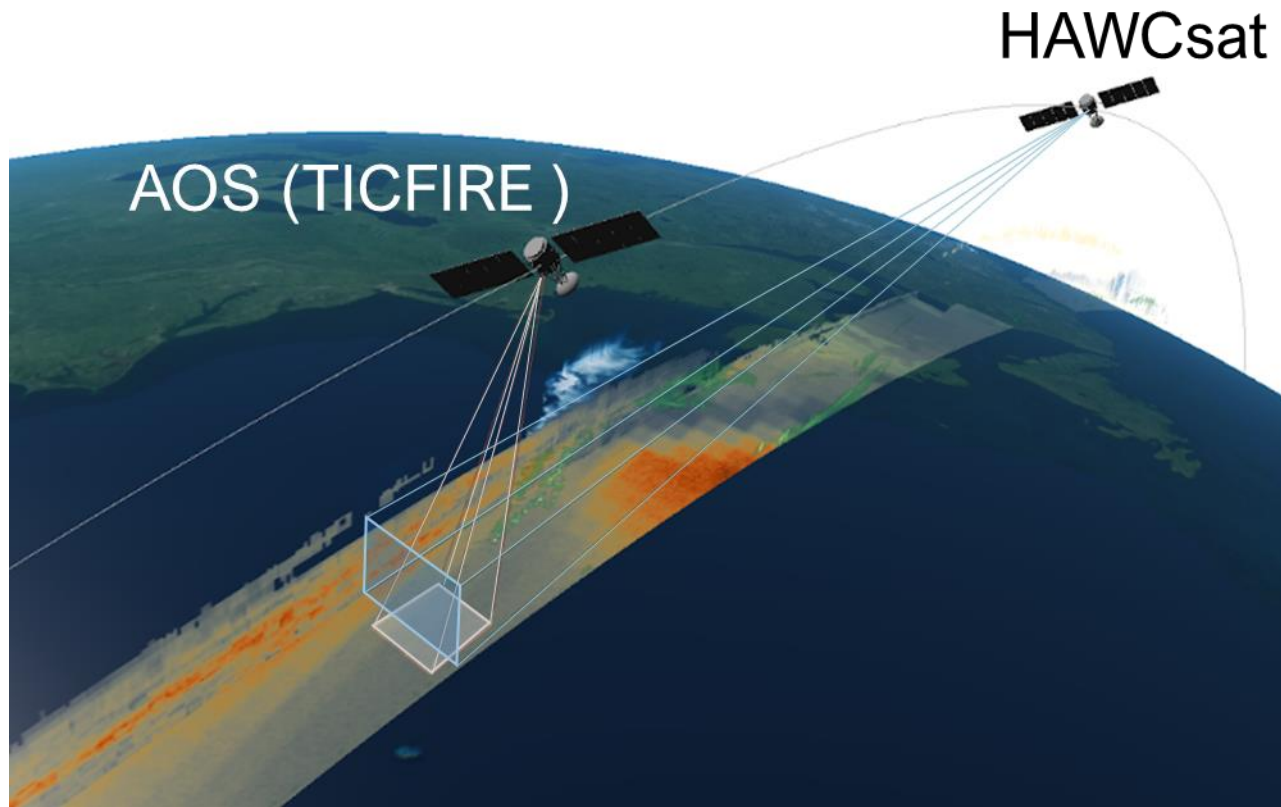
Region	Vertical Resolution	Horizontal Resolution	Precision	Accuracy
km	km	km	%	%
8-20	≤ 0.5	≤ 50	≤ 5	≤ 15
20-30	≤ 1	≤ 200	≤ 5	≤ 15



THIN ICE CLOUDS AND FAR INFRARED EMISSIONS

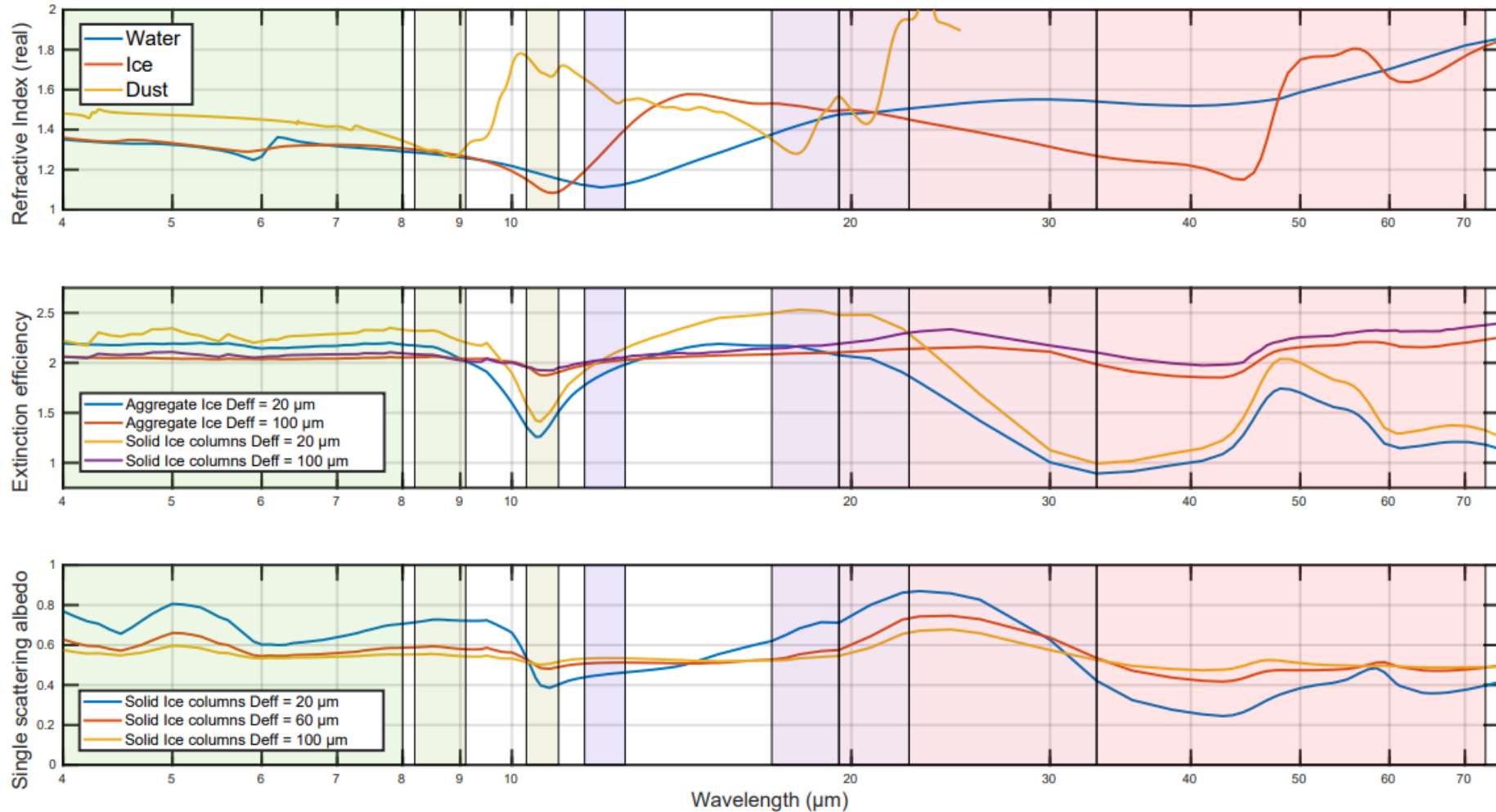
TICIFRE Instrument on AOS-Sky

- 2D nadir imaging radiometer with calibration system
- 8 spectral bands covering 4 to 73 μm



THIN ICE CLOUDS AND FAR INFRARED EMISSIONS

Spectral bands chosen for sensitivity to cloud microphysics and composition

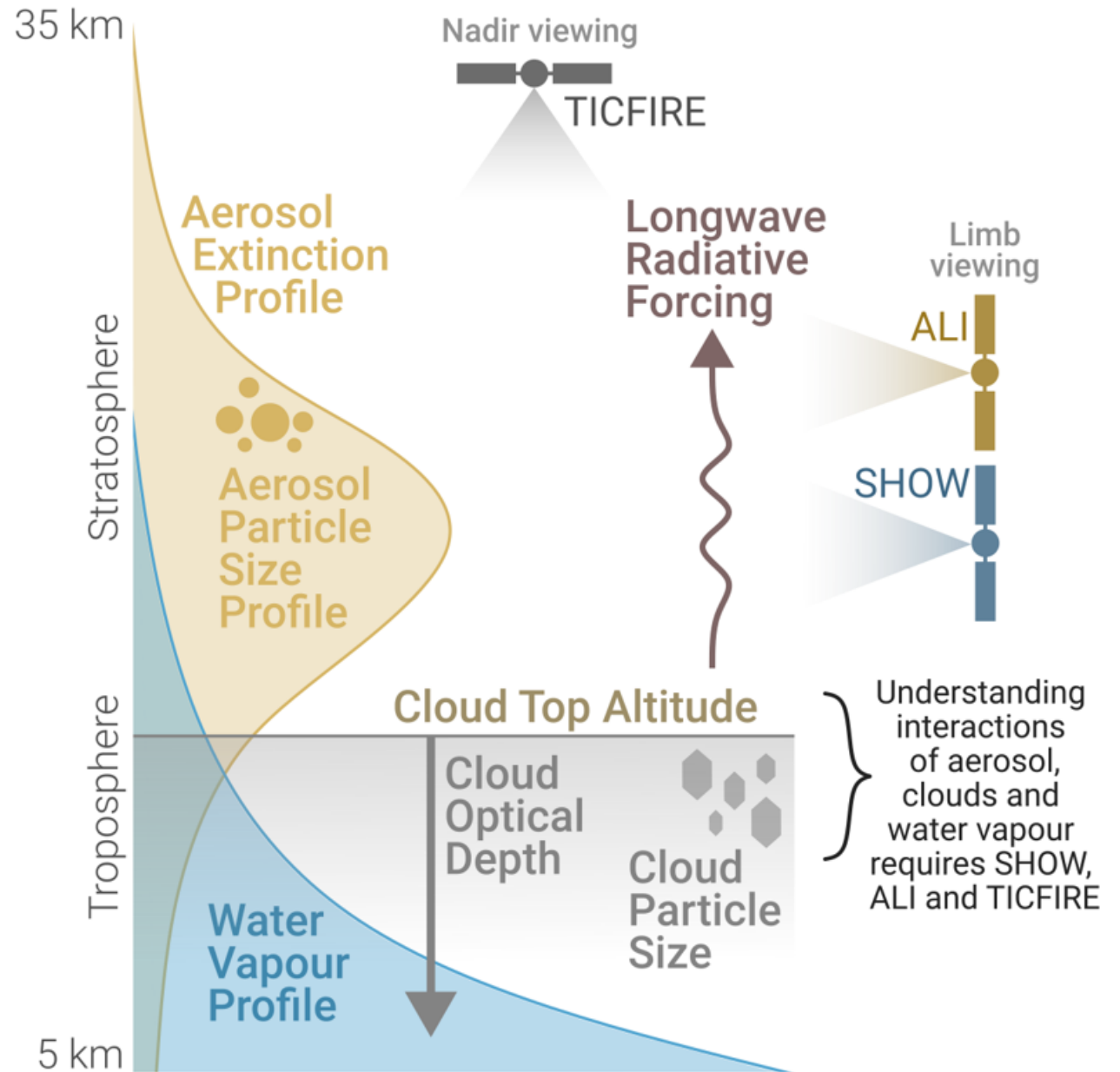


TICFIRE DATA PRODUCTS

Product	Range	Vertical Resolution	Horizontal Resolution	
Radiance in 8 channels	0 to 14 W/m ² /sr	1 to 3 km	50 to 100 km	0.02 W/m ² /sr
Broadband Radiances	20 to 120 W/m ² /sr	1 to 3 km	50 to 100 km	1.5 W/m ² /sr
Cloud Radiative Effects	0 to 200 W/m ²	1 to 3 km	50 to 100 km	5.0 W/m ²
Cloud Top Altitude	0 to 25 km	1 to 5 km	50 to 100 km	0.5 km
Ice Water Path	1 to 100 g/m ²	1 to 5 km	50 to 100 km	20%
Cloud Optical Depth	20 to 120	1 to 5 km	50 to 100 km	10%
Ice crystal size	10 to 100μm	1 to 5 km	50 to 100 km	20%
Cloud fraction	0 to 1	1 to 5 km	50 to 100 km	COD > 0.1
Cloud classification	High cloud	1 to 5 km	50 to 100 km	Precip/Non-precip
Water vapour profile	0 to 25 km	4 to 5 km	50 to 100 km	10%

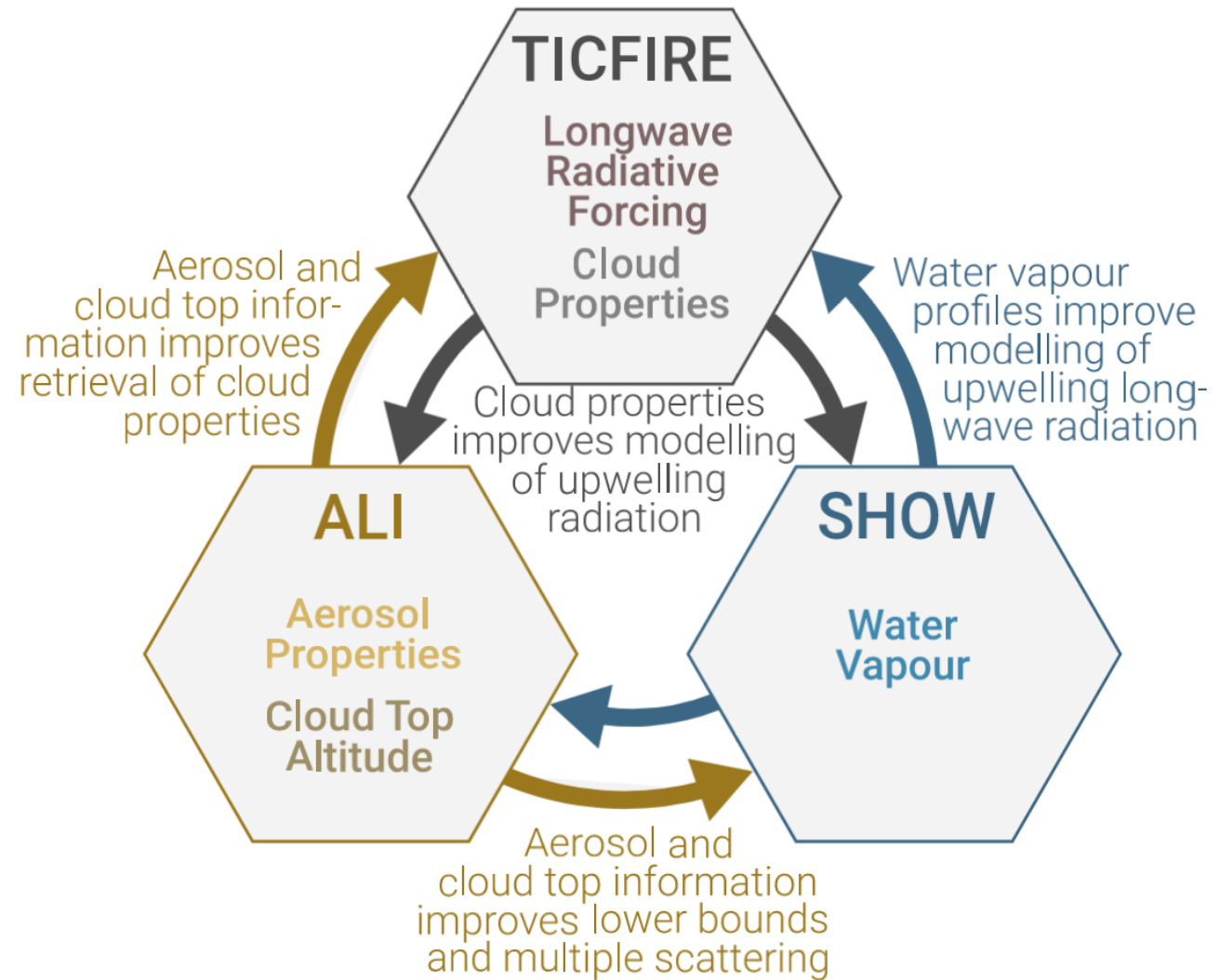
HAWC DATA PRODUCTS SUMMARY

- UTLS aerosol extinction
- UTLS aerosol particle size
- Cloud top altitude
- Cloud optical depth
- Ice particle size & shape
- Longwave spectral radiance
- UTLS water vapour
 - High vertical resolution
 - Dense along-track sampling



HAWC DATA PRODUCTS SYNERGY

- Each instrument has an independent retrieval.
- Synergistic retrievals can improve knowledge of the atmospheric state can reduce biases.
- Synergistic retrievals with AOS instruments are also being pursued.
- Data processing system integrated with NASA targeting 3-5 hours on all L2 products

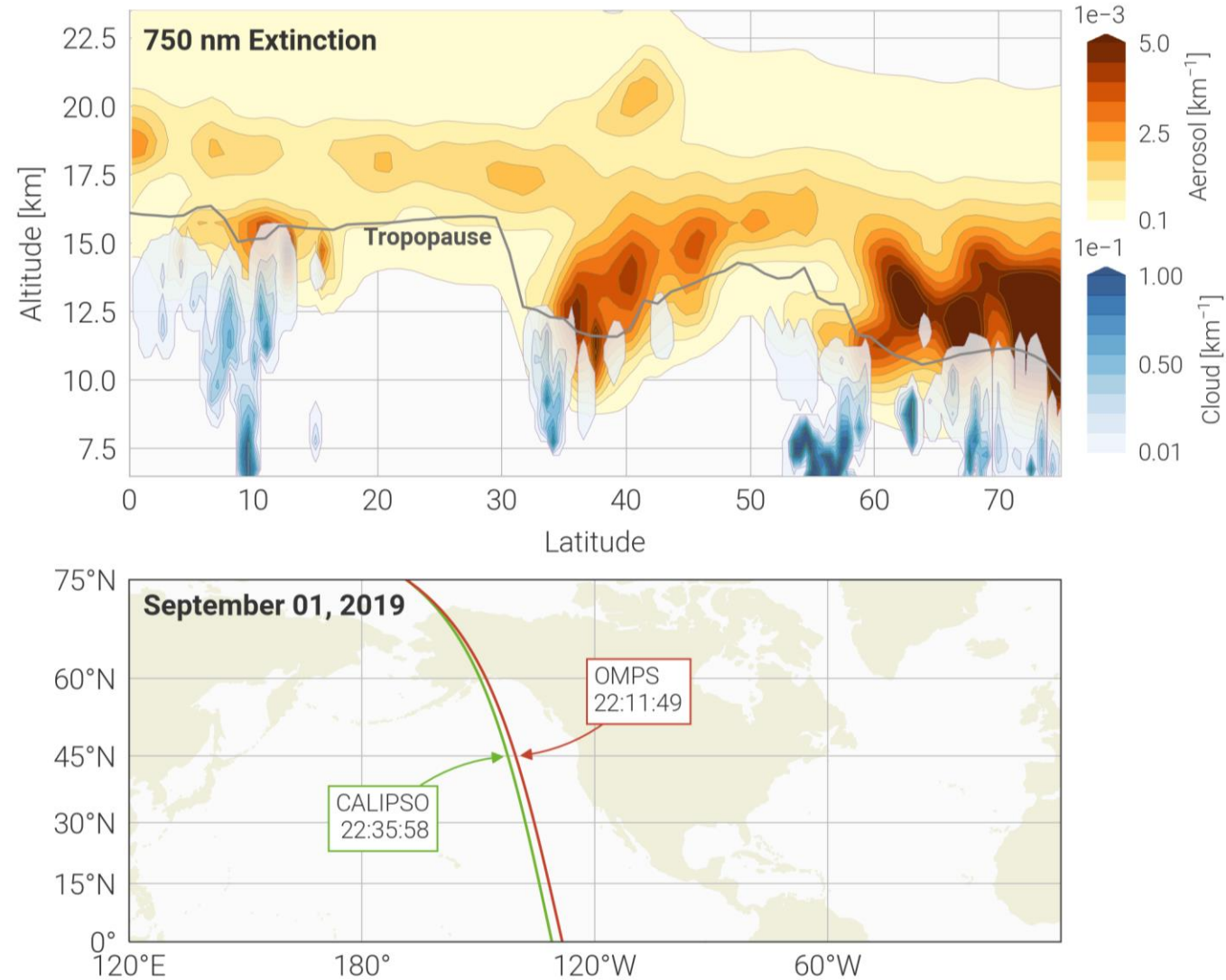


HAWC SCIENCE: UTLS AEROSOL AND CLOUDS

2019 Raikoke eruption elevated aerosol levels in the Northern Hemisphere

Mixing in the extra-tropics shows interaction between UTLS sulfate aerosols and ice clouds

UTLS aerosols at high latitudes are a substantial fraction of total loading and an important contribution to the climate impact



HAWC SUMMARY

- **HAWC is a fully funded Canadian mission contributed to NASA AOS**
 - SHOW and ALI on Canadian HAWCsat.
 - TICFIRE on the AOS Polar satellite.
- **Science firsts:**
 - Spectral infrared imagery covering essentially the entire thermal emission region
 - High res retrievals of climate-critical ice cloud characteristics and microphysical properties with a focus on the Arctic.
 - Breakthrough resolution profiles of water vapour in the UTLS, examining role in cloud dynamics and aerosol processing in evolving climate.
 - Unprecedented measurement sensitivity of high-altitude aerosol, which is highly uncertain due to the influences of forest fires and volcanic eruptions.