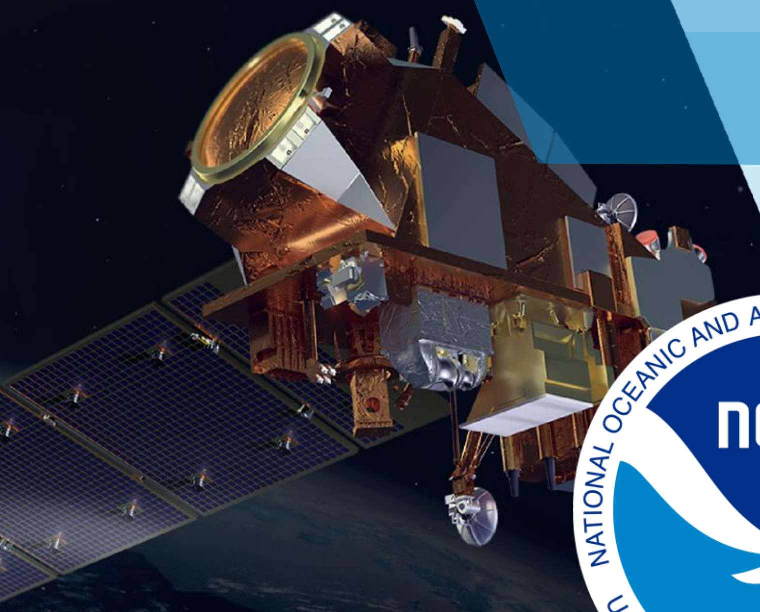

EarthCARE Applications at NOAA

Satya Kalluri, Andy Heidinger, Isaac Moradi, Shobha Kondragunta, Yoo-Jeong Noh, John Haynes

NESDIS

National Environmental Satellite, Data, and Information Service

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Background

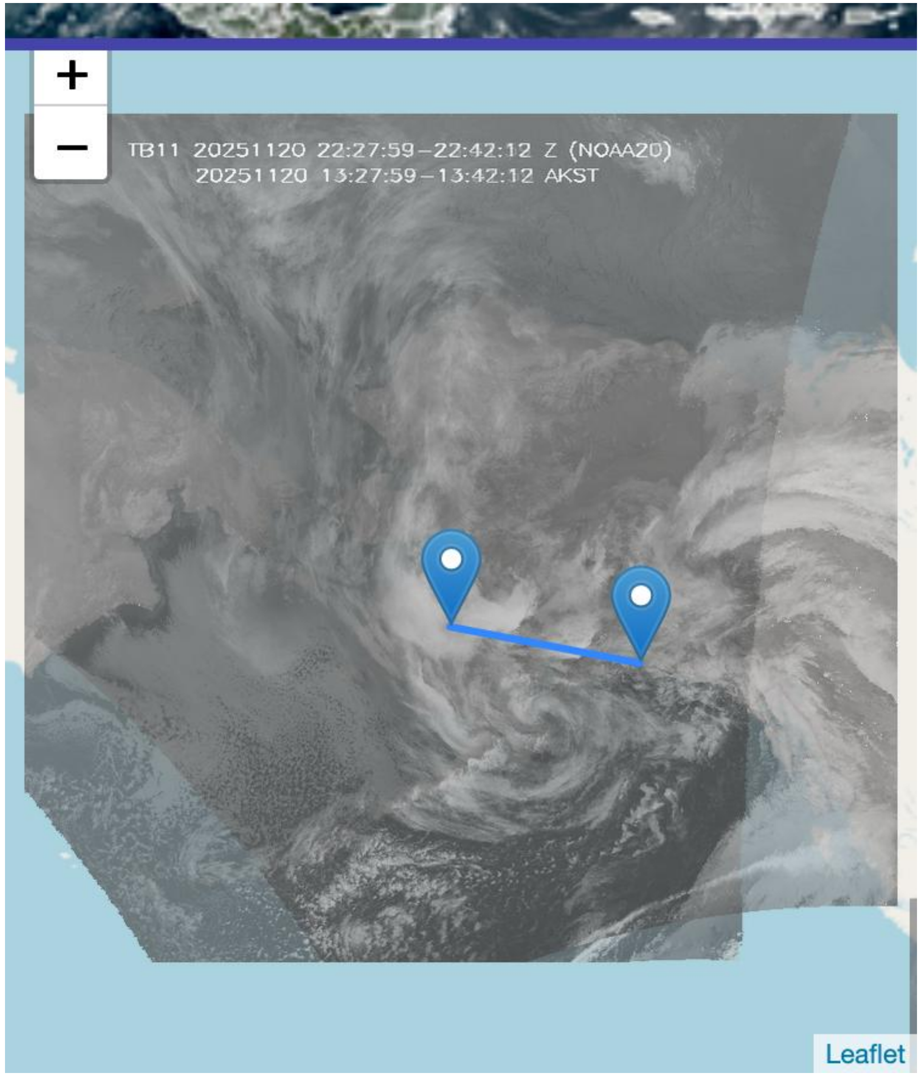
- NOAA/NESDIS provides several cloud and aerosol products from LEO and GEO imagers such as VIIRS and ABI.
- EarthCARE cloud and aerosol products provide vital calibration and validation information for these mission critical products and provides continuity of observations from CALIPSO/CloudSat.
- Development of capabilities to assimilate CPR data in NOAA NWP is ongoing.
- NASA and NOAA recently completed an intense aircraft campaign with rich suite of sensors including cloud profiling RADARs, LIDARs, hyperspectral IR and MW sounders which could be valuable to EarthCARE cal/val.

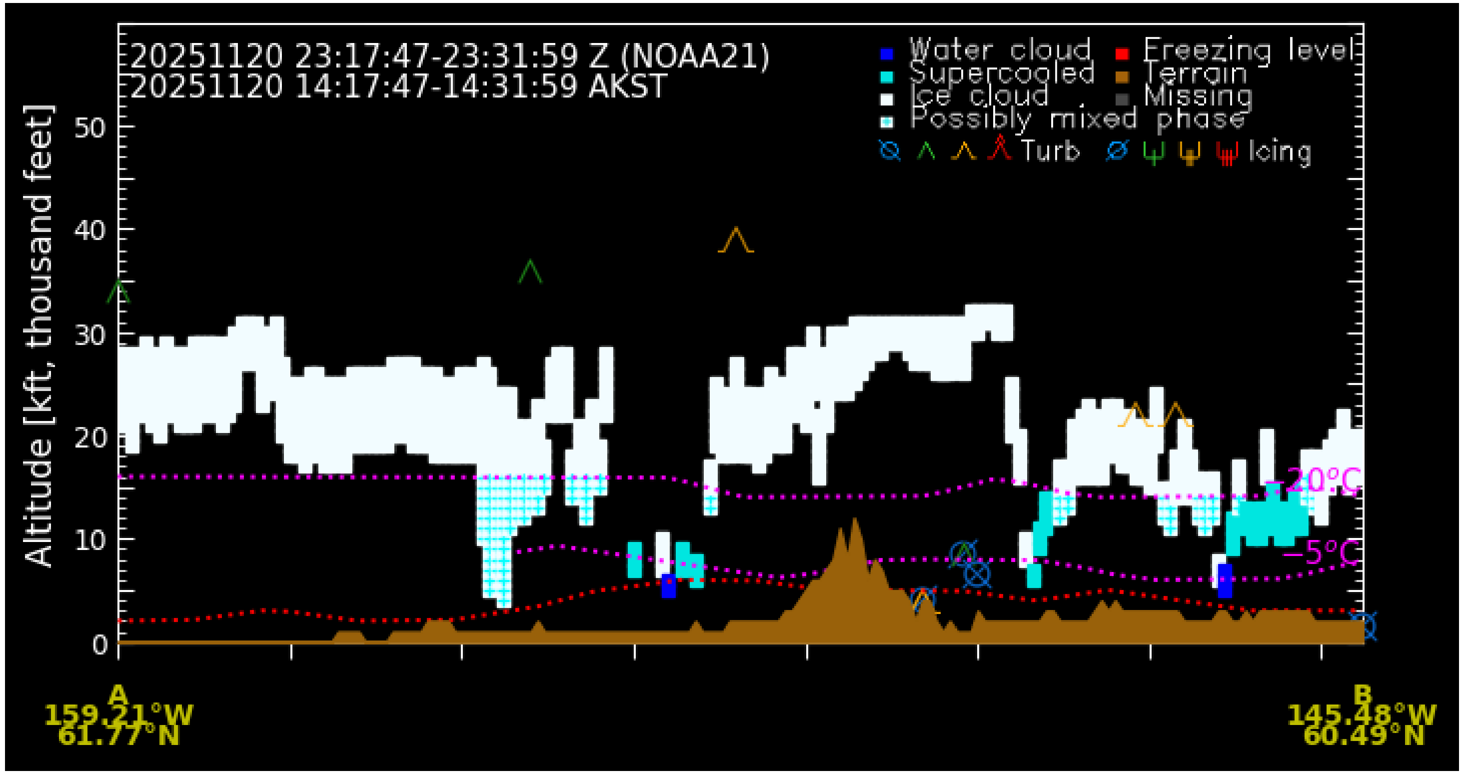
NOAA LEO (VIIRS), GEO (ABI) Cloud Products

- **Enterprise CloudAlgorithm**
- Enterprise Cloud Mask
- Enterprise Cloud Type and Cloud Phase
- Enterprise Cloud Height
  - Cloud Top Height
  - Cloud Top Pressure
  - Cloud Top Temperature
  - Cloud Cover Layers
- Enterprise Cloud Base Height Daytime/Nighttime Cloud Optical and Microphysical Properties (DCOMP/NCOMP) Cloud Optical depth
  - Cloud Effective Radius
  - Liquid Water Path
  - Ice Water Path

Importance of Cloud Vertical Cross Section in Aviation

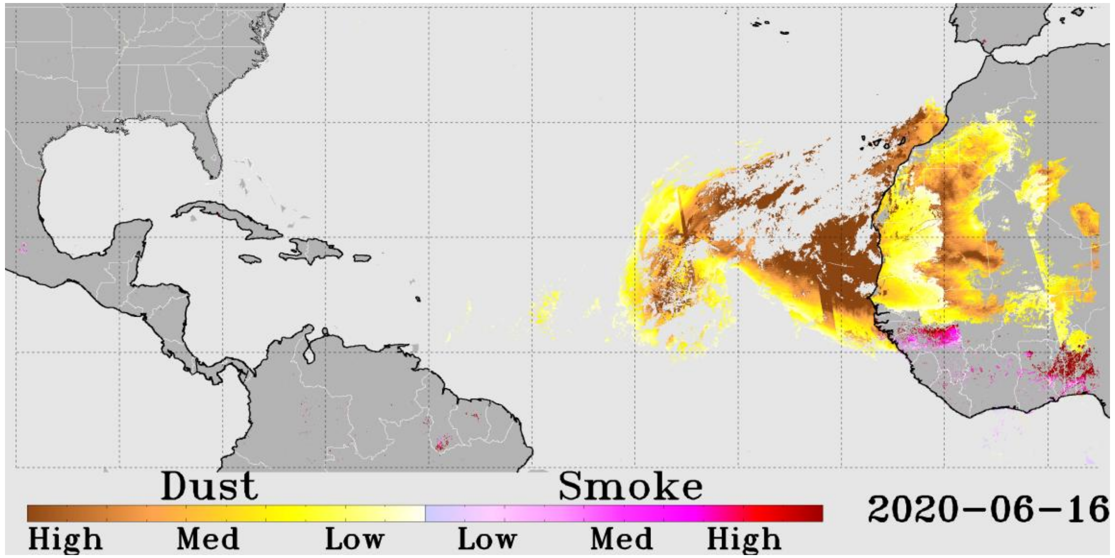
https://aviation.cira.colostate.edu/define-custom-cross-section

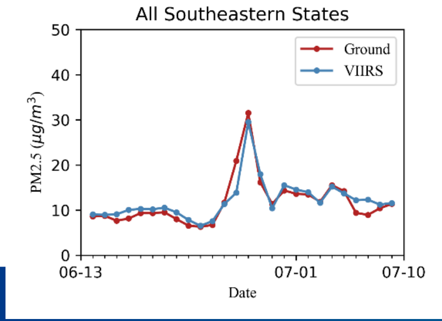


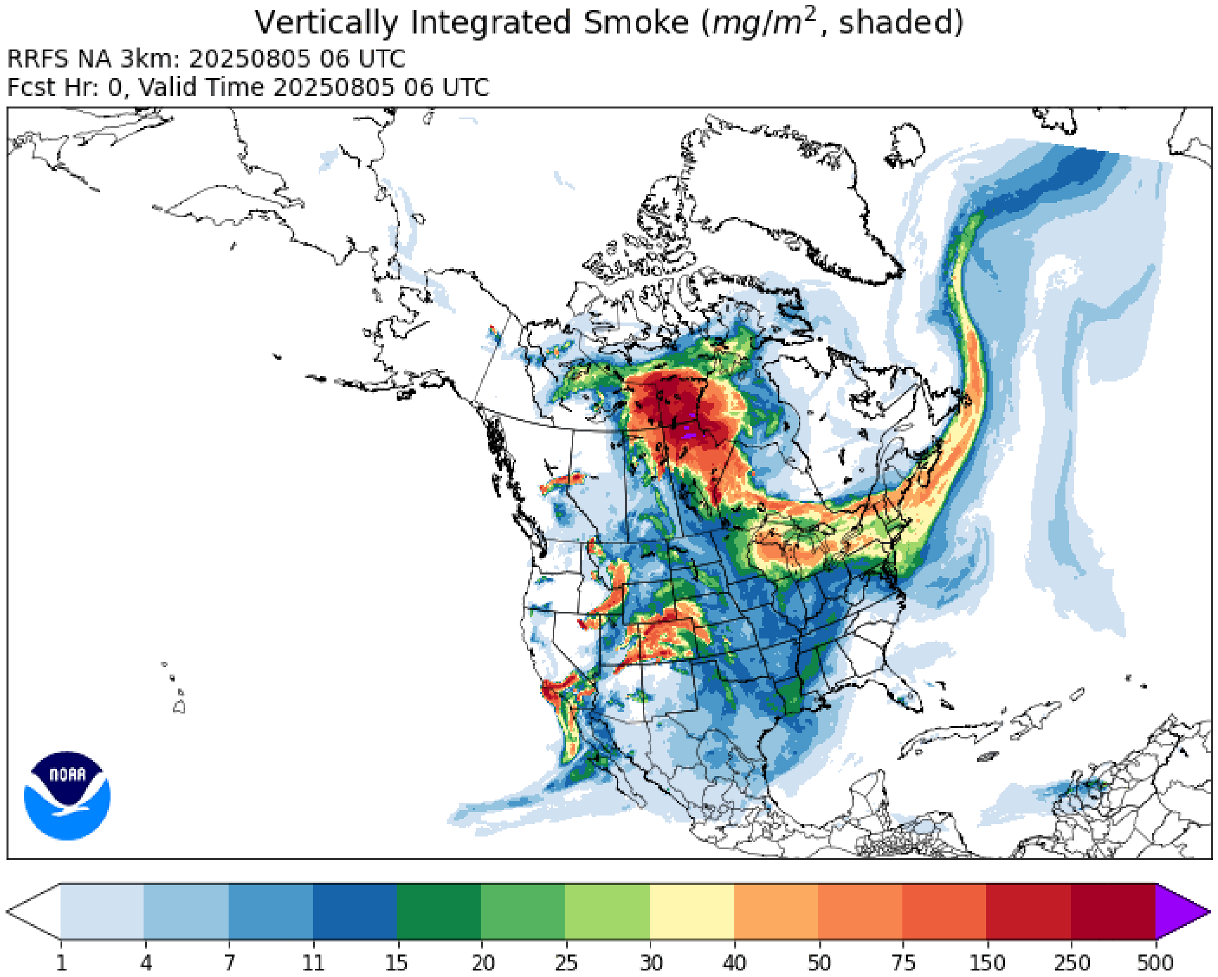


NOAA LEO (VIIRS) and GEO (ABI) Aerosol Products

- Aerosol Optical Depth (AOD)
- Aerosol type – smoke, dust
- Volcanic ash



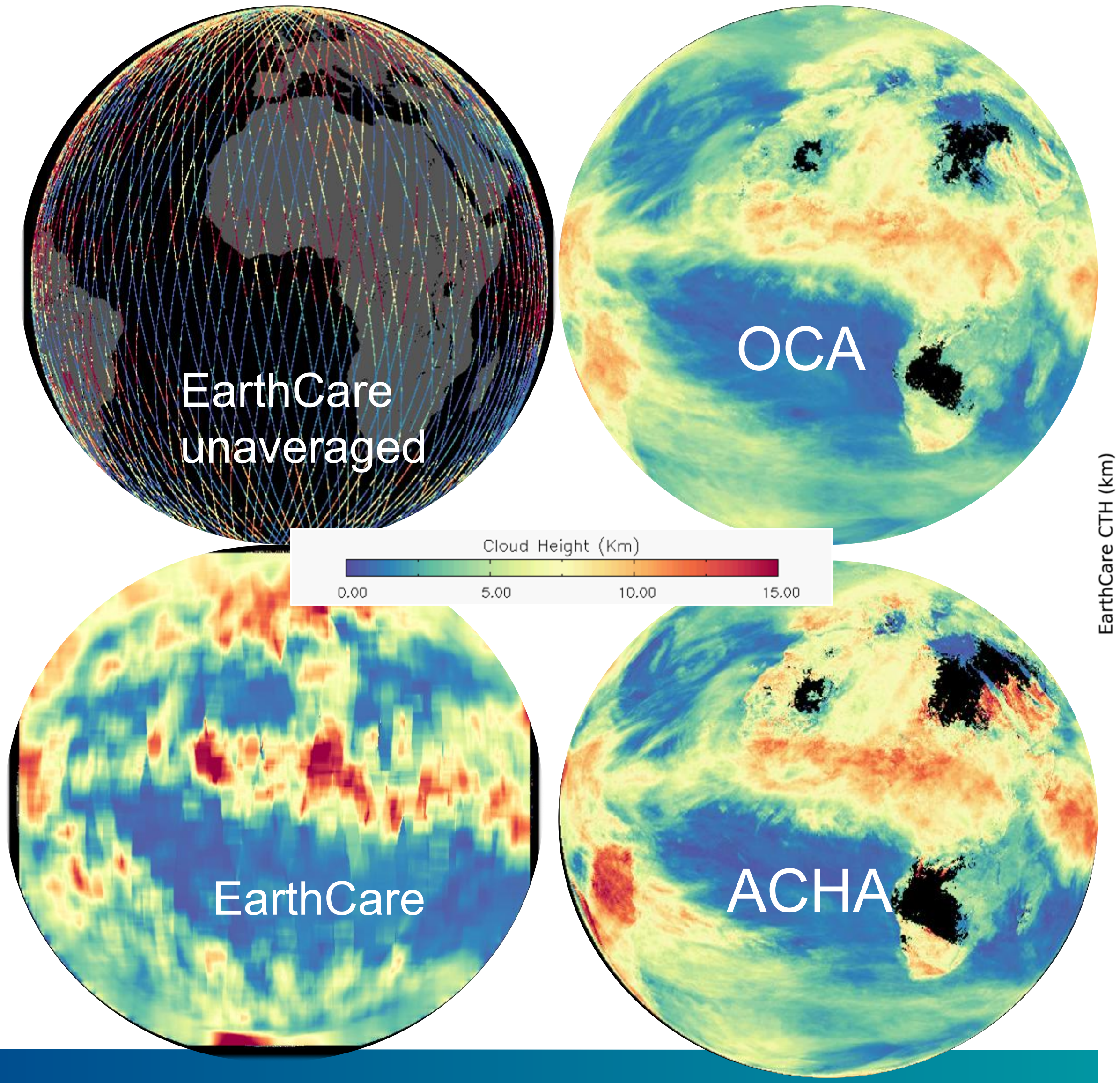




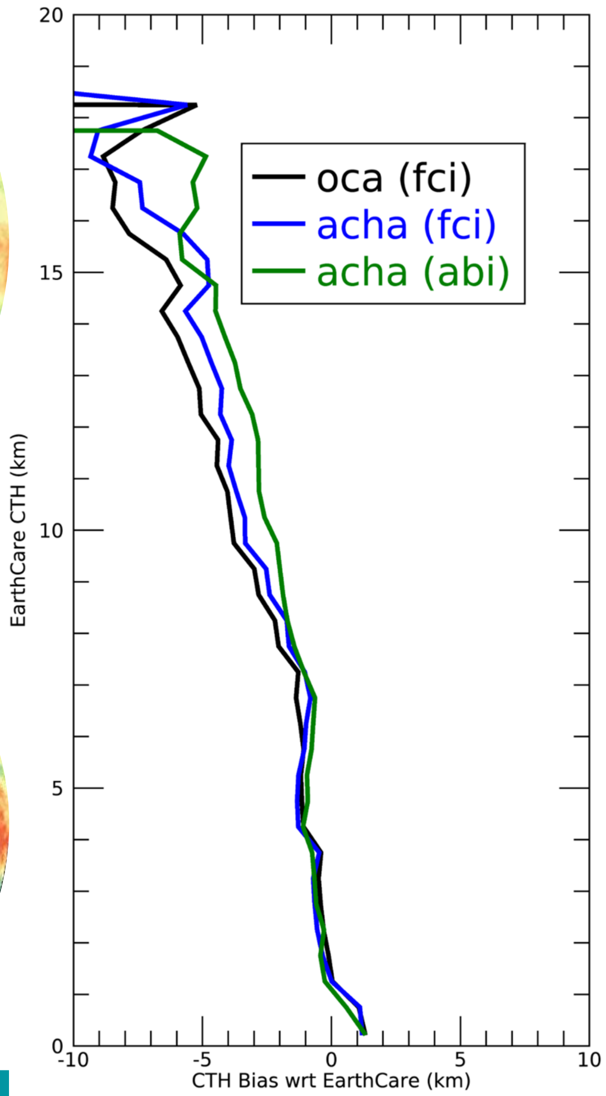
Using EarthCare ATLID to Assess FCI Cloud Heights

- The NOAA AWG Cloud Height Algorithm (ACHA) was successfully ported to the MeteoSat Third Generation (MTG) Flexible Combined Imager (FCI).
- The comparisons with the EarthCARE CTH and the EUMETSAT Optimal Cloud Analysis (OCA) showed that ACHA performed similarly to OCA and to the ACHA data on GOES-19 with respect to EarthCARE.
- This is an encouraging result between these preliminary data sets that are undergoing further development.
- Thank you EarthCare!

Cloud Height Mean Values for June 1-7, 2025

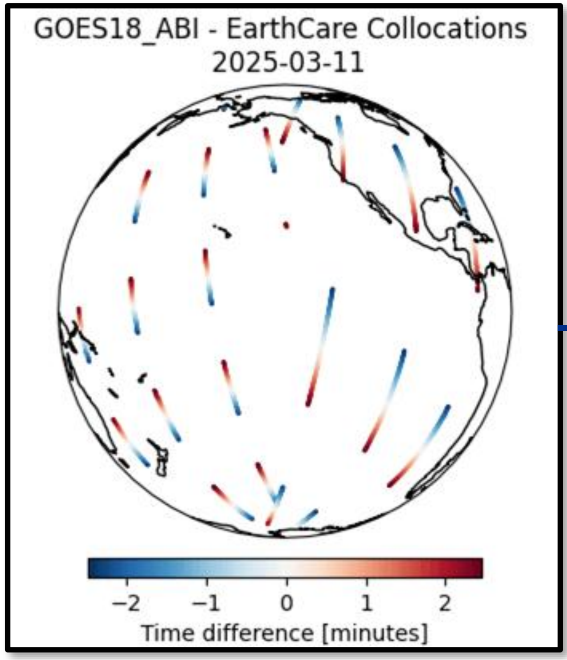


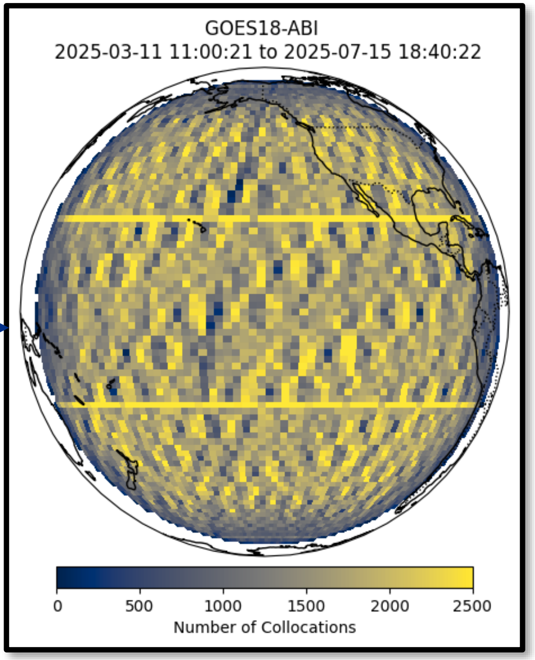
Bias wrt EarthCARE ATLID CTH June 1-7, 2025



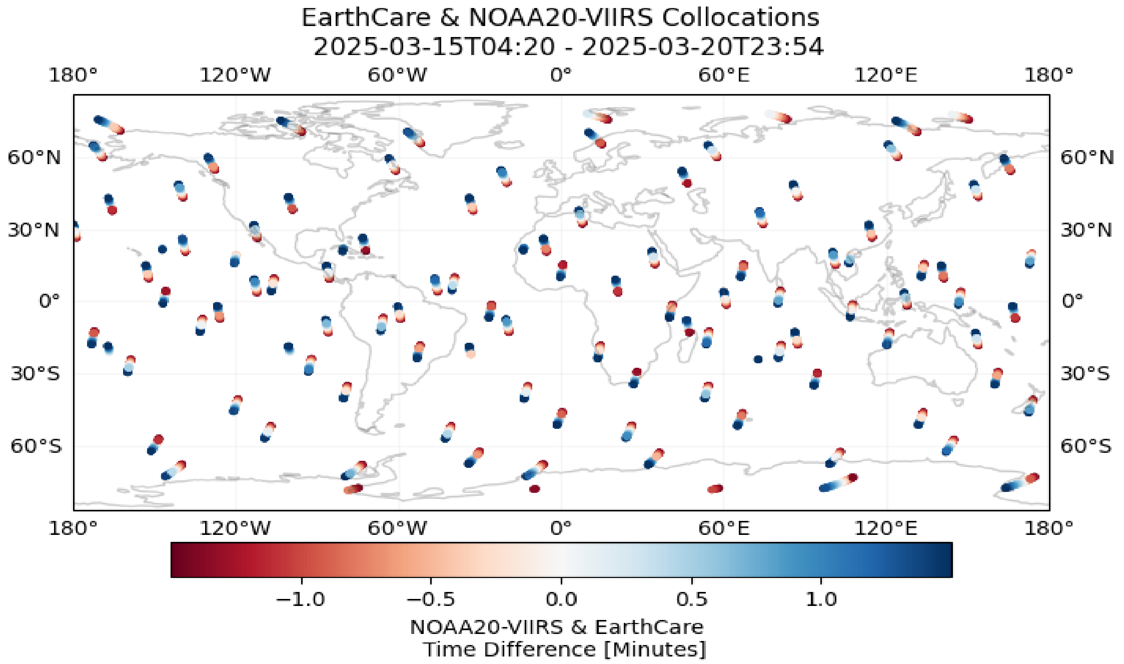
EarthCARE - GEO/LEO Imager Collocation Data

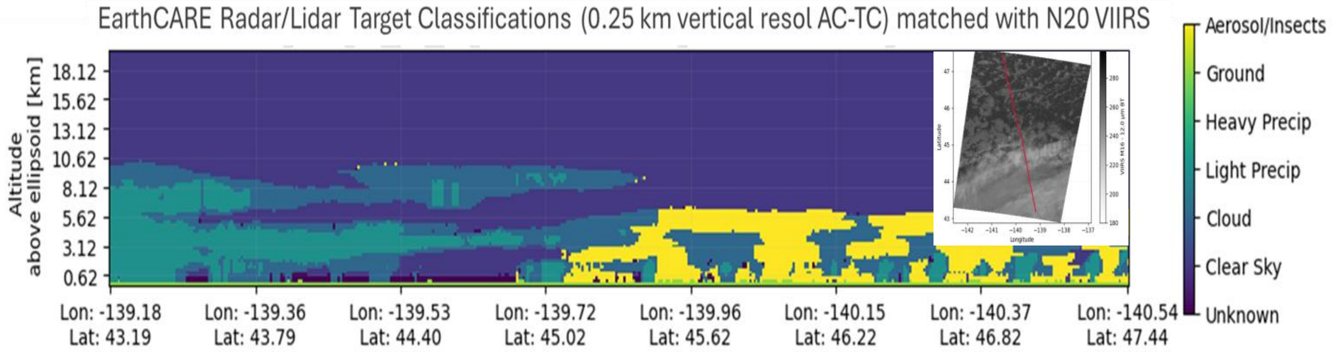
- **AI/Machine learning model training and validation for 3D cloud structures**
- Matchup processing within 2 km and 2.5 min, EarthCARE cloud-top based parallax correction





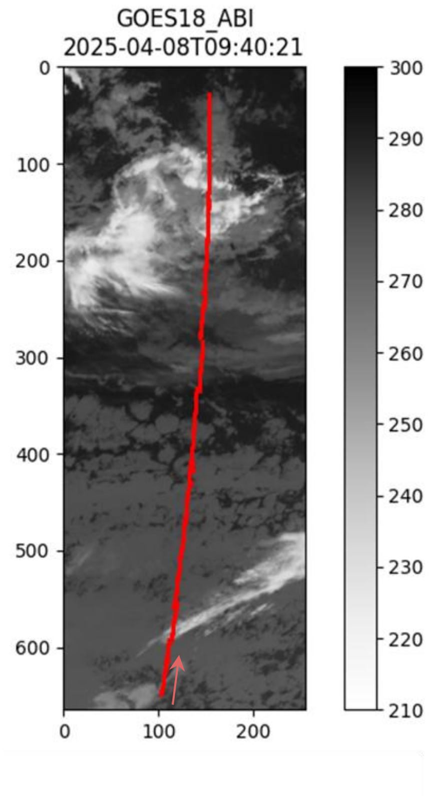
~8.2 million collocations for GOES18 - EarthCARE over 4 months

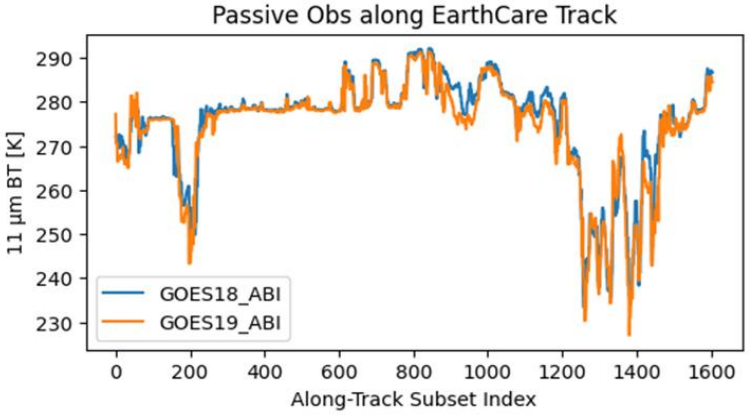


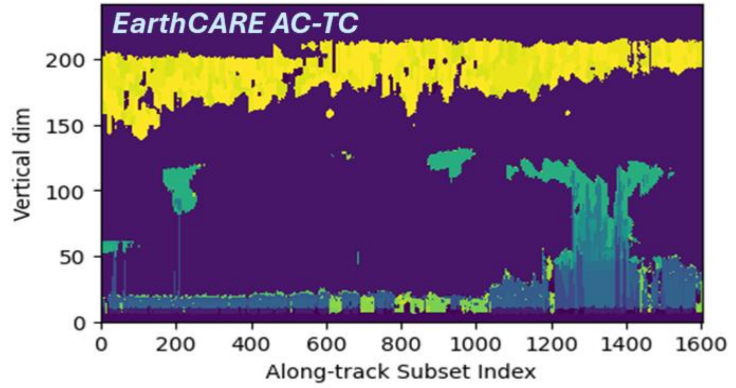


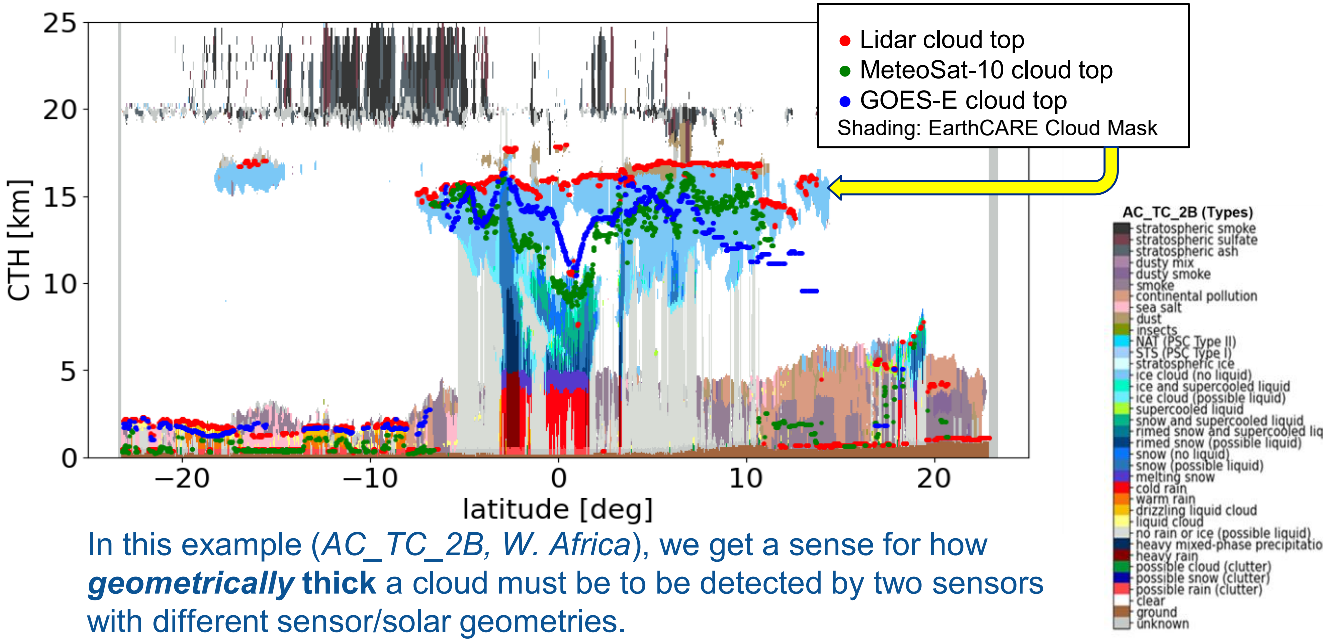
CIRA Cloud Team: Y.J. Noh, J. Haynes, C. White, C. Johnson, R. Demaria, B. Daub

Validation of Cloud Retrieval Products

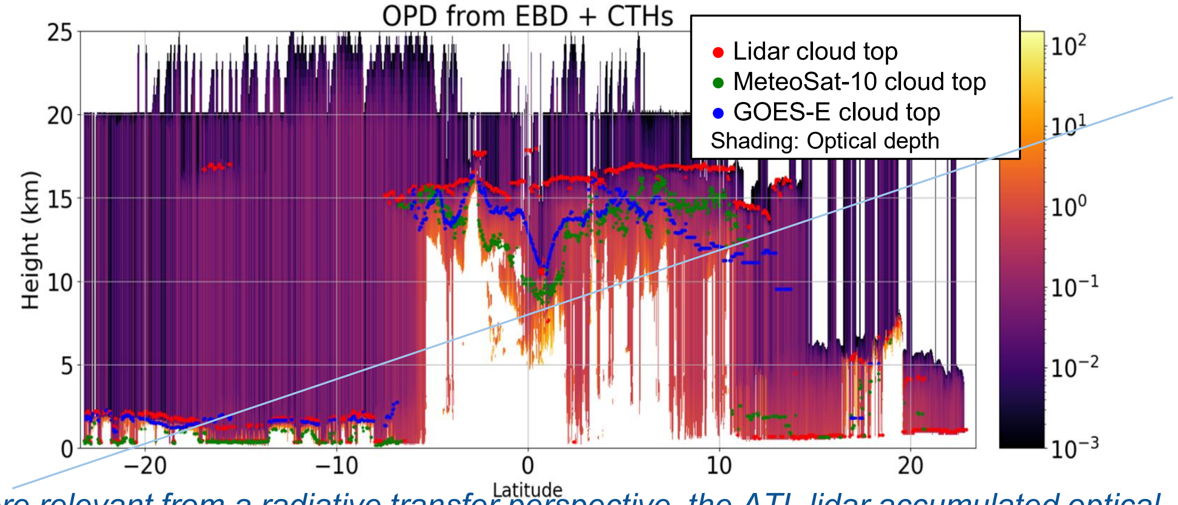








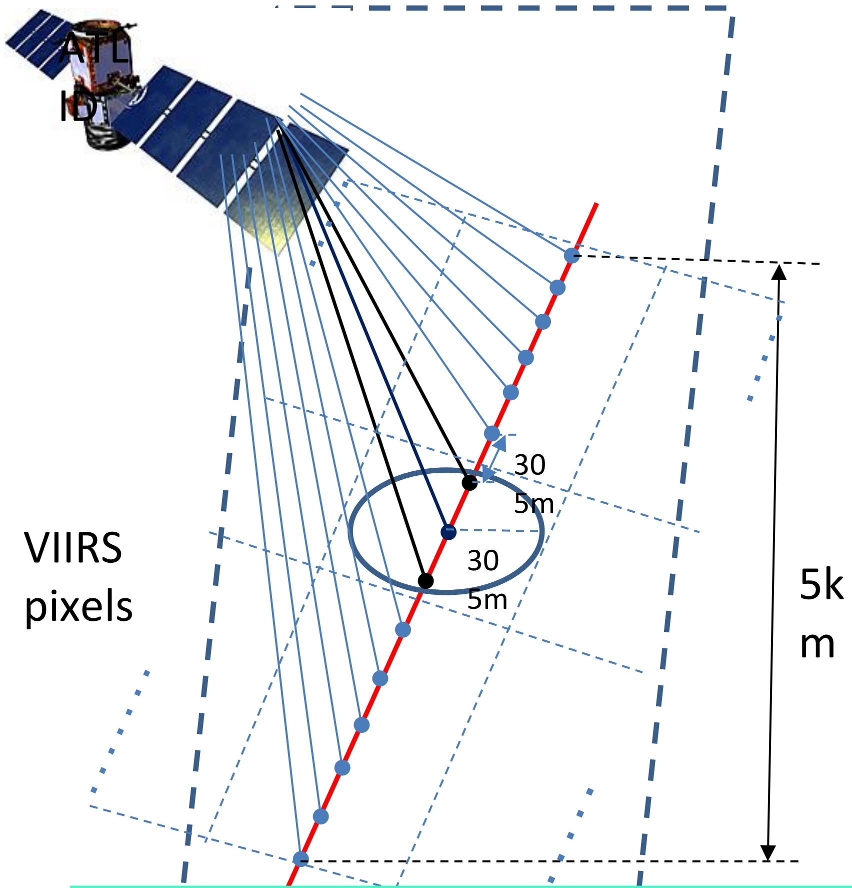
In this example (*AC_TC_2B, W. Africa*), we get a sense for how ***geometrically* thick** a cloud must be to be detected by two sensors with different sensor/solar geometries.



More relevant from a radiative transfer perspective, the ATL lidar accumulated optical depth gives a sense for how ***optically thick*** *the cloud must be to be detected by the passive sensors.*

CIRA Cloud Team: Y.J. Noh, J. Haynes, C. White, C. Johnson, R. Demaria, B. Daub

VIIRS ATLID Comparison Criteria



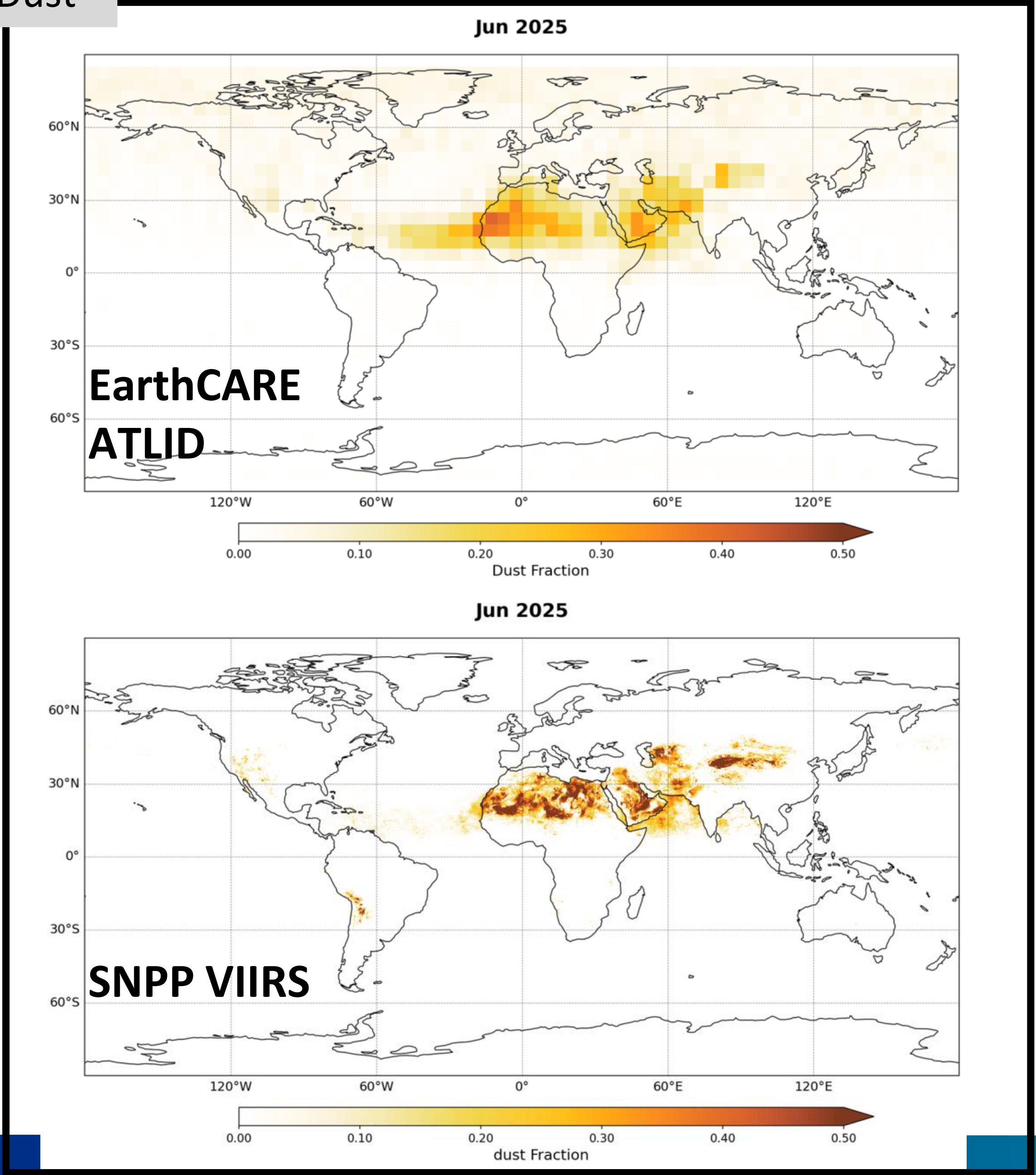
Validation example for dust
True Positive (TP): VIIRS and ATLID say dust
True Negative(TN): VIIRS and ATLID say no dust
False Negative(FN): VIIRS says no dust but ATLID says dust
False Positive(FP): VIIRS says dust when ATLID says no dust

- Time difference: ±15 minutes
- Spatially , VIIRS pixel within ± 305m of the middle ATLID profile is selected.
- Middle three profiles are used
  - all three profiles need to be cloud-free
  - dominated aerosol type is determined through the calculation of dust (or smoke) fraction (i.e., no of dust (or smoke) layer divided by the no. of aerosol layer from surface to 20 km.
- ATLID VFM column feature are grouped as :
  a. dust (including dusty_mix)
  b. smoke (including dusty_smoke)
  c. cloudy
  d. clear
  f. others (sea_salt, Continental Pollution)
- VIIRS ADP types (in 3x3 box) are grouped as :
  a. dust
  b. smoke
  c. cloudy (not produced)
  d. clear (or none/undermined)
  e. others
- Quality Control
  only smoke/dust with medium to high confidence are used

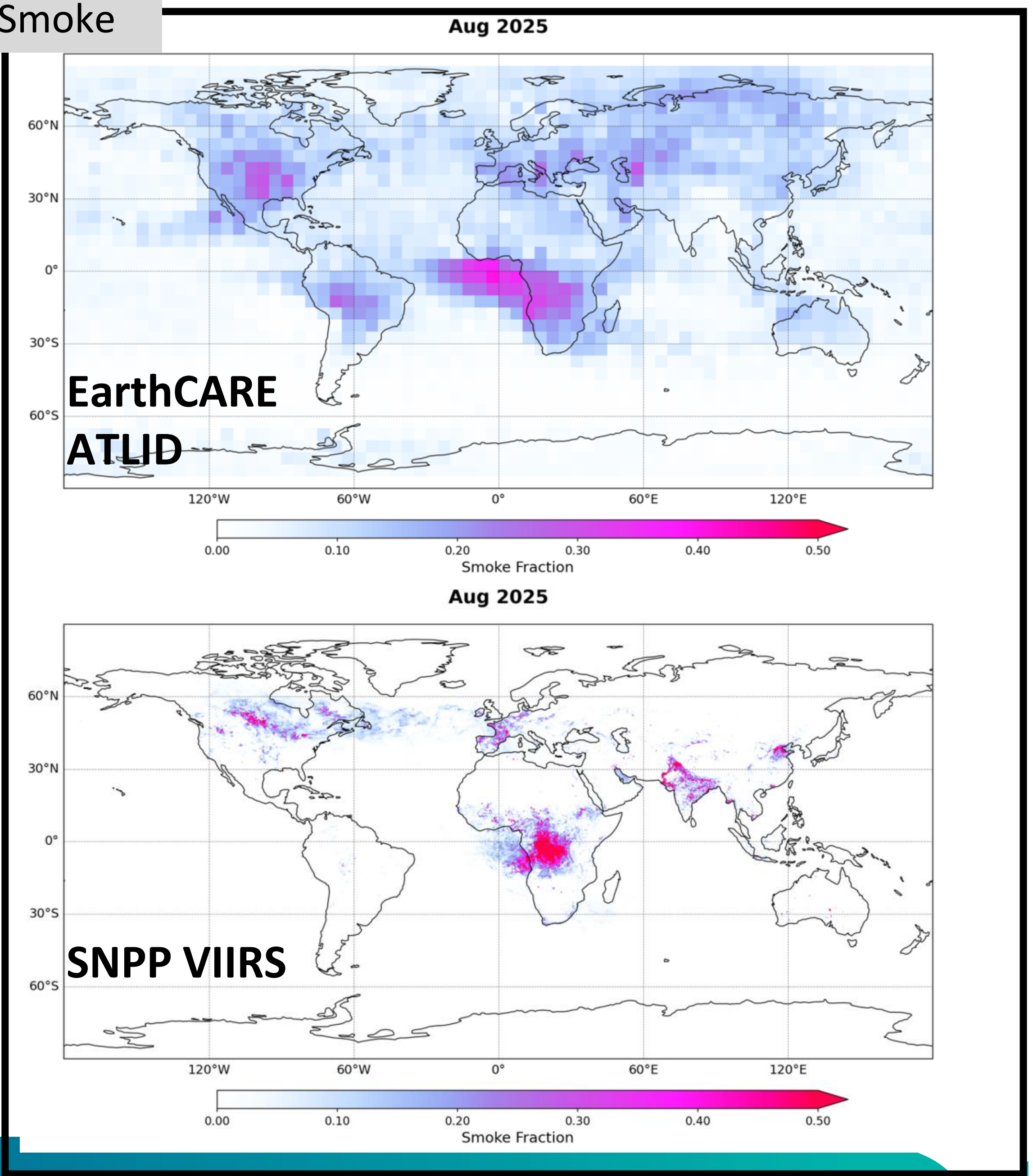
VIIRS performance metrics calculations
Correct Detections = TP/(TP+FN)
Accuracy = (TP+TN)/(TP+TN+FP+FN)
False Detections = FP/(FP+TP)

ATLID vs. VIIRS: Comparison of Global Smoke and Dust Fractions

Dust

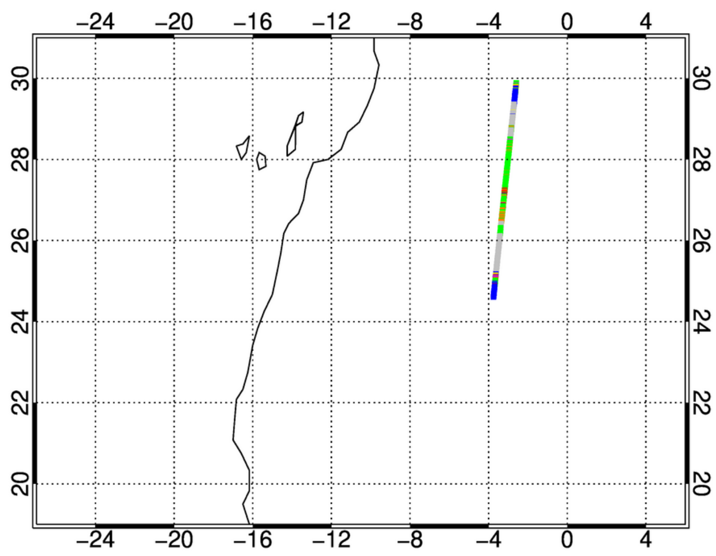


Smoke

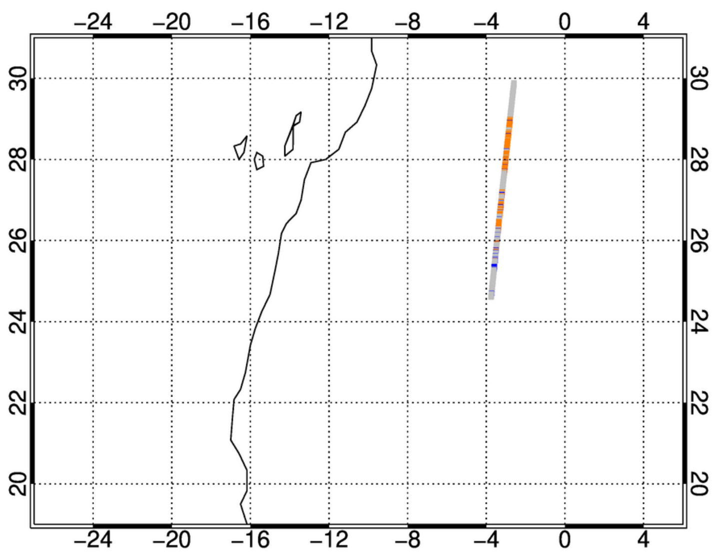


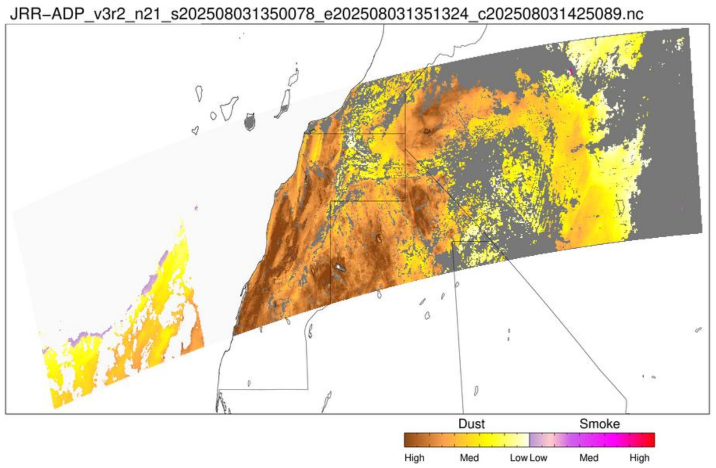
NOAA 21 VIIRS ADP 13:50 UTC, 08/03/2025

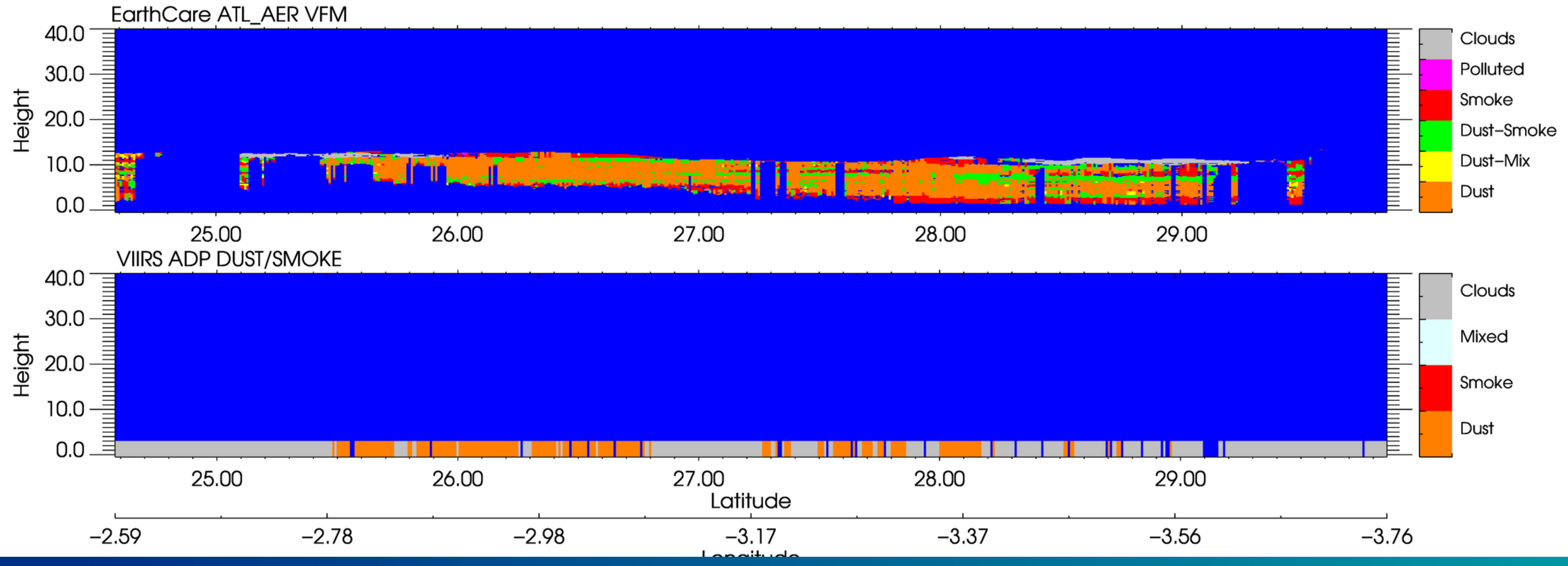
EarthCare ATL_AER VFM



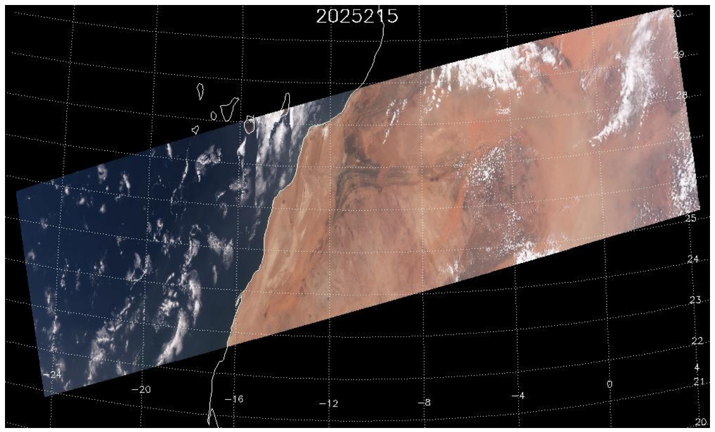
VIIRS ADP DUST/SMOKE



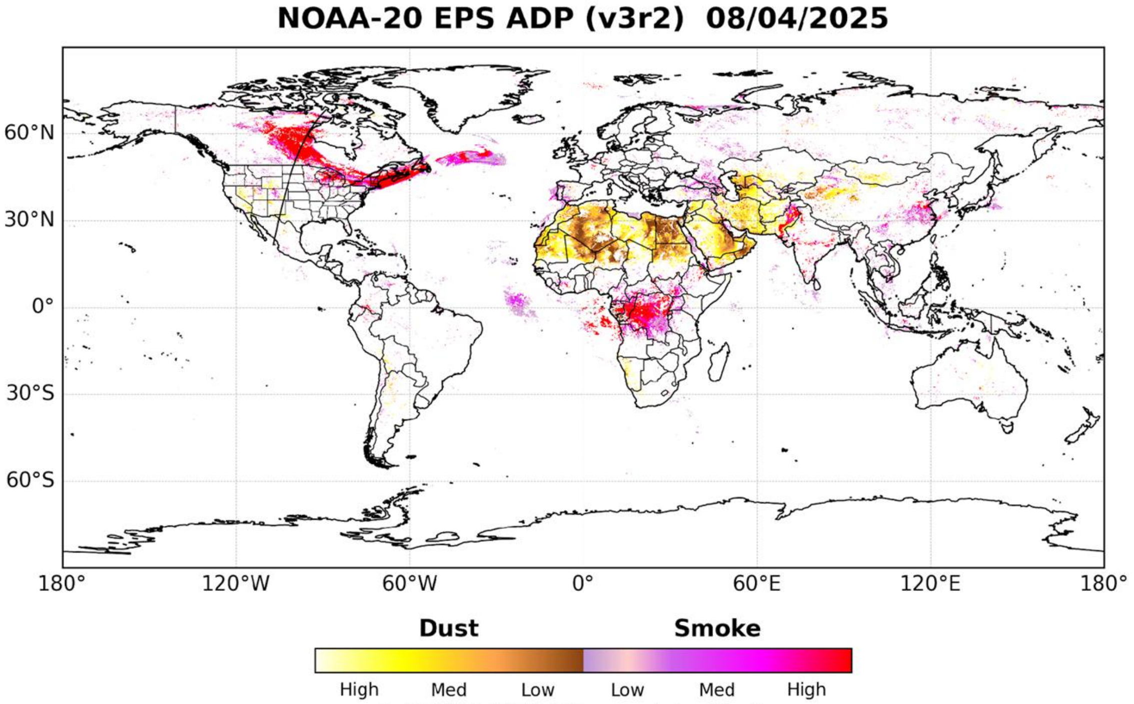


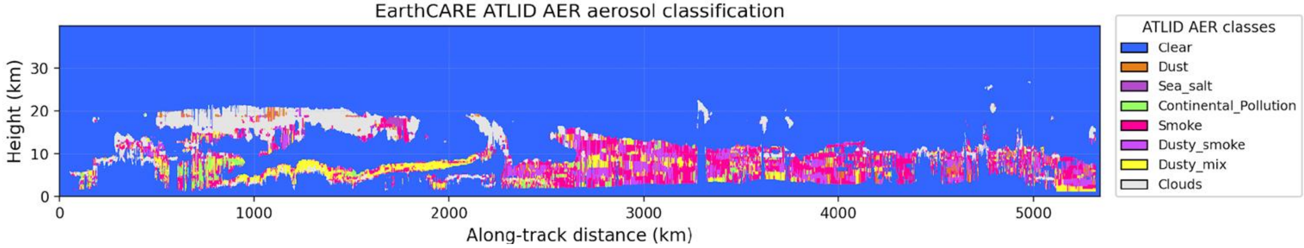


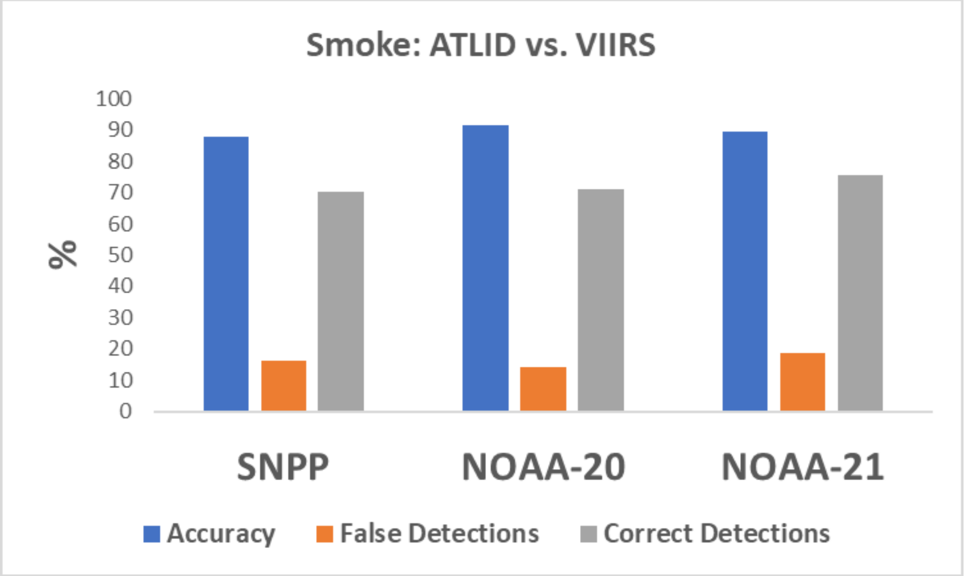
NOAA 21 VIIRS RGB image

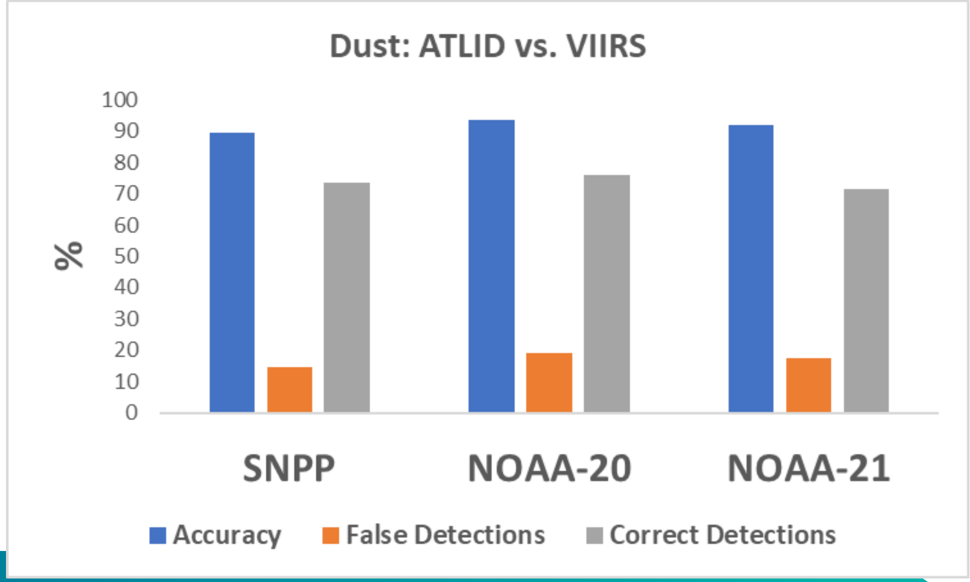


Comparison of VIIRS Smoke and Dust With ATLID
Data used: April 17 to October 30, 2025





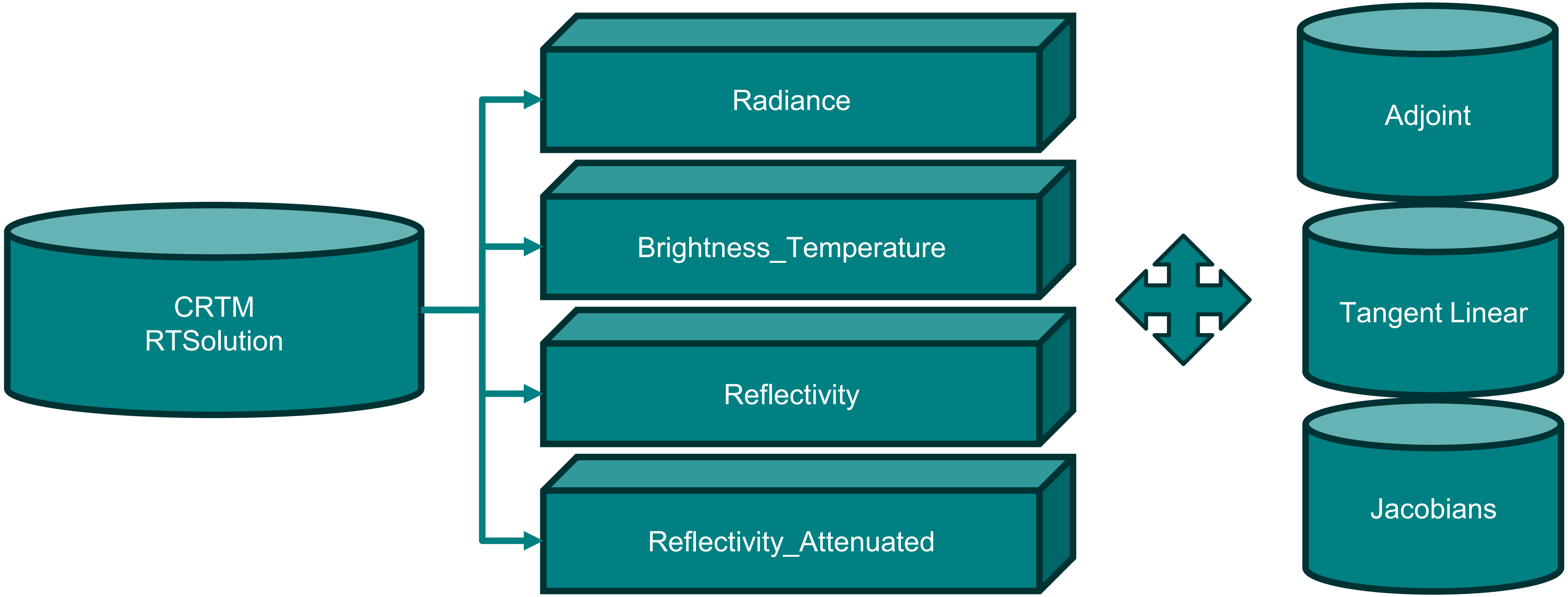




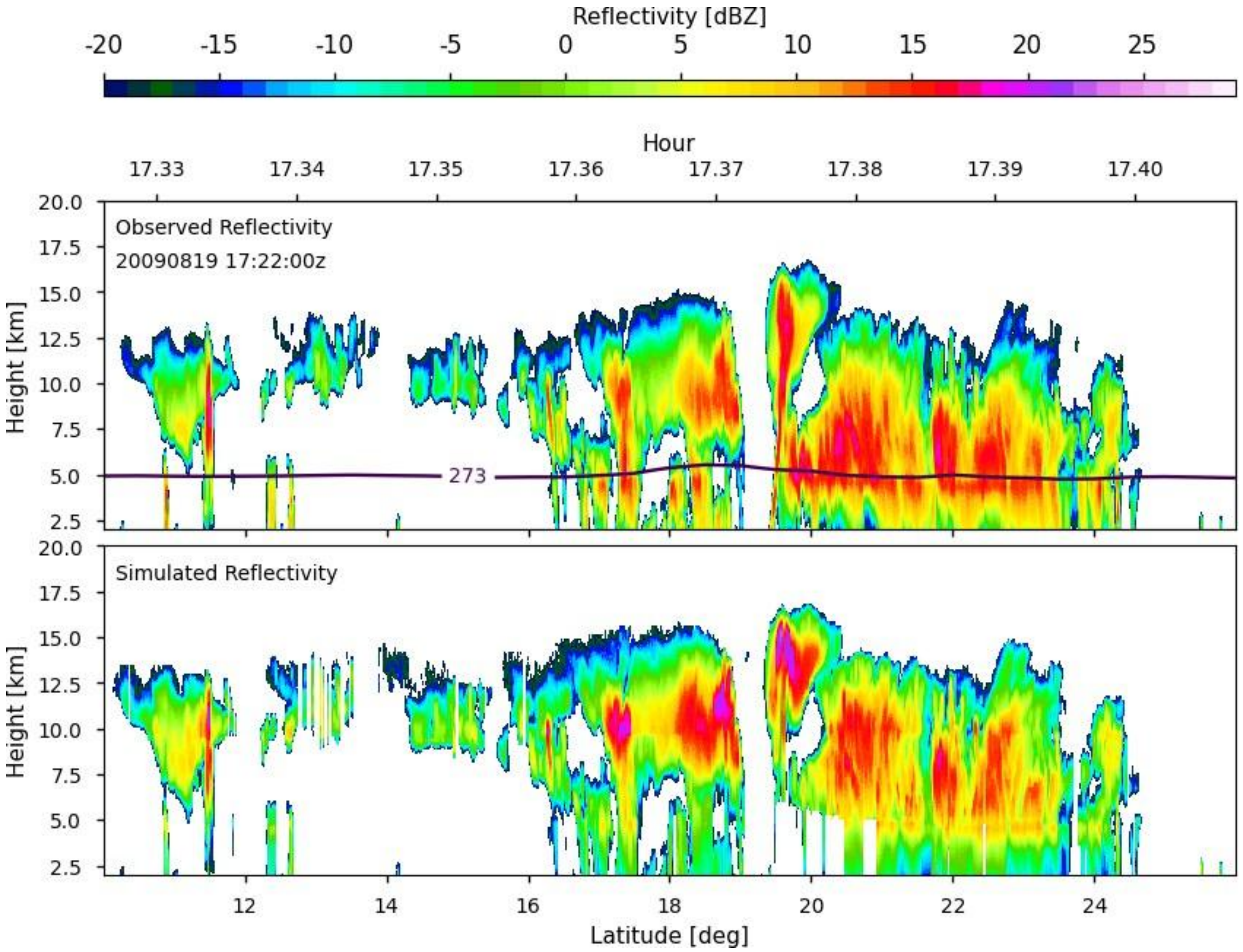
EarthCARE CPR Data Assimilation in NWP

- Cloud profiling radars (CPRs) are vital to NWP
  - They provide detailed, quantitative observations of the vertical structure and internal properties of clouds and precipitation.
  - CPRs serve as essential "anchor points" for validating and calibrating cloud retrieval data.
  - Help refine model parameters and improve understanding of atmospheric phenomena
- First step is to develop a forward RT model to simulate satellite CPR observations
  - Simulates the **radar reflectivity** (or attenuated backscatter) that the radar would measure, given a detailed, known vertical profile of atmospheric and cloud properties.
  - Approach similar to DA from CloudSat CPR (W band) and GPM DPR (Ku/Ka-band).

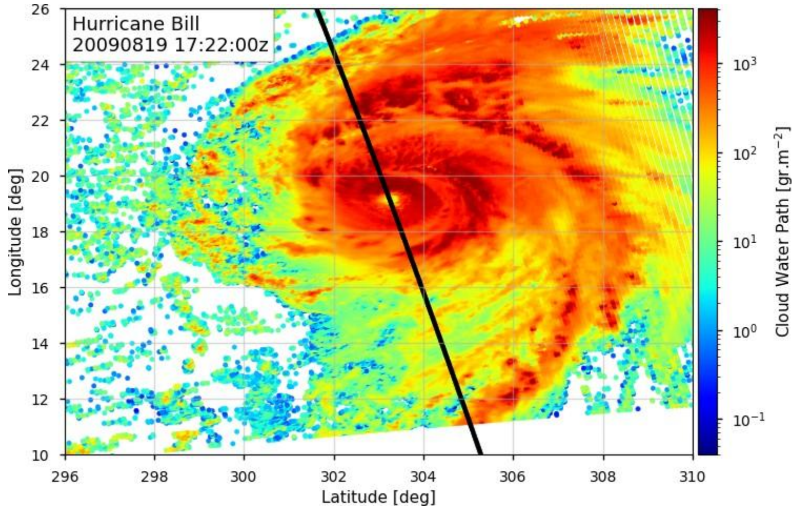
The CRTM New Variables for Radar Observations



CloudSat Cloud Profiling Radar (CPR – W-band 94 GHz)

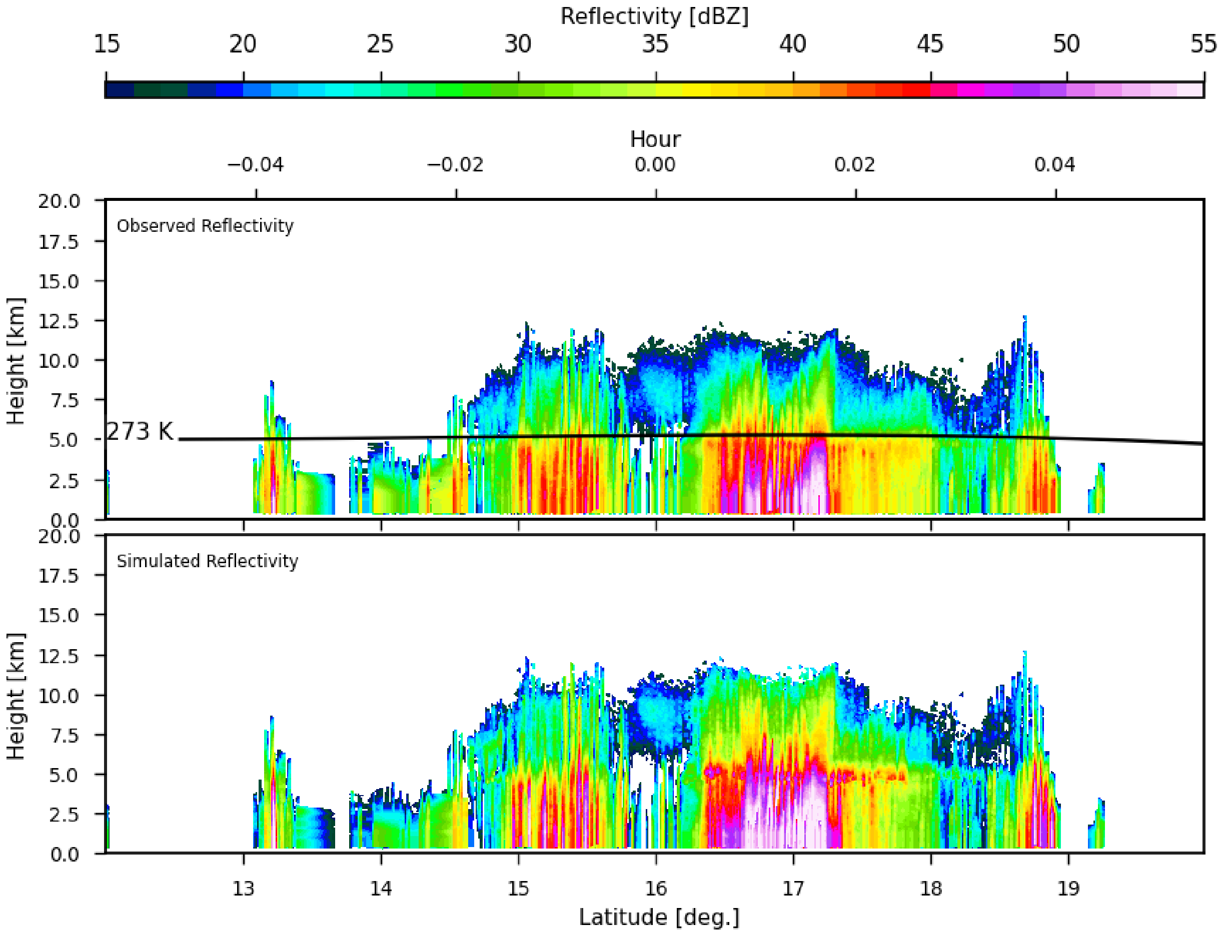


Observed and simulated reflectivities for Hurricane Bill.

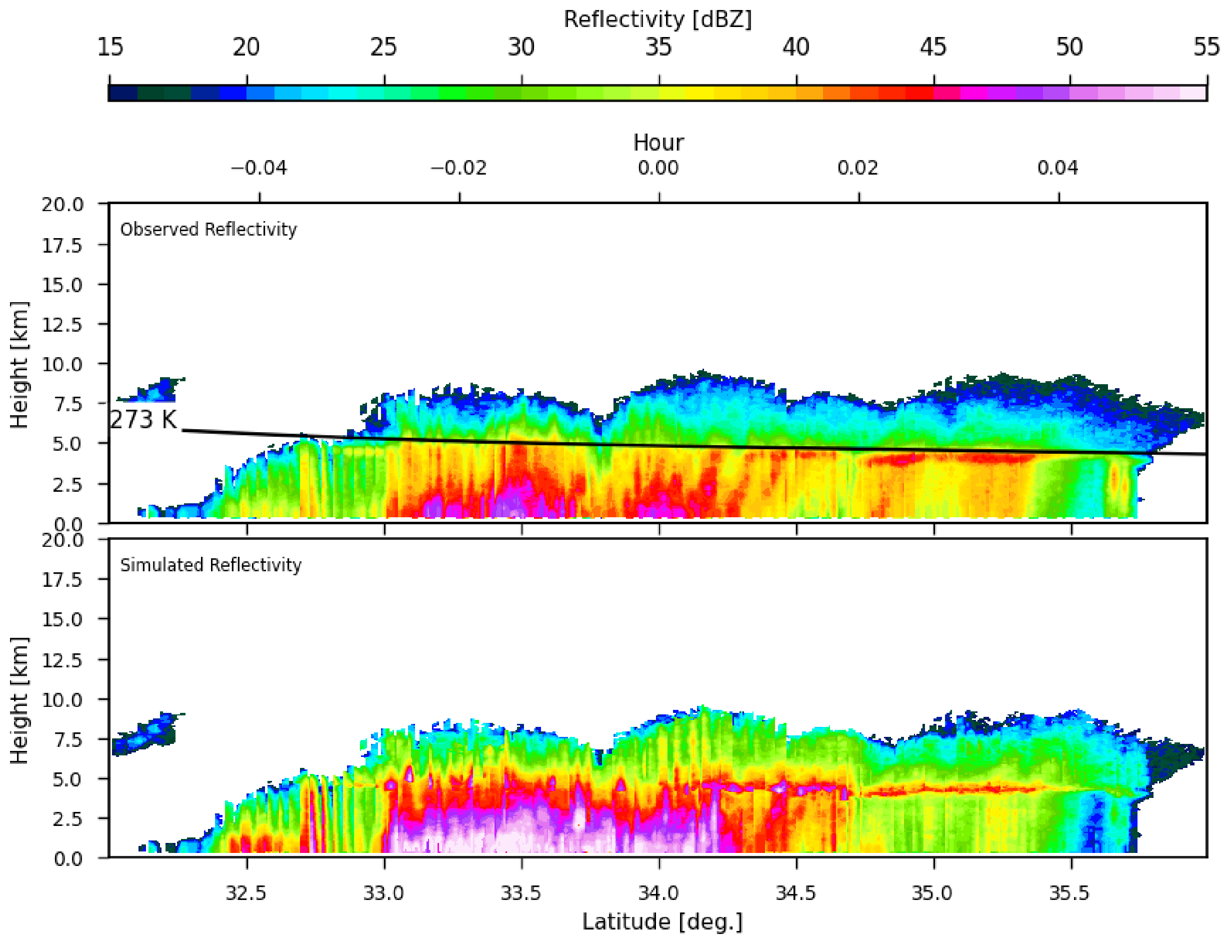


GPM DPR Chan 1: Simulations vs Observations

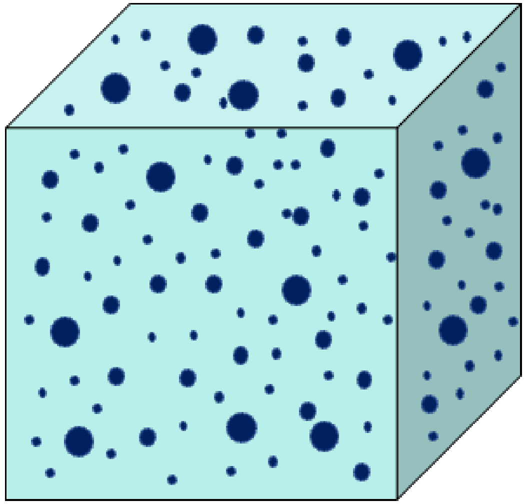
Irma

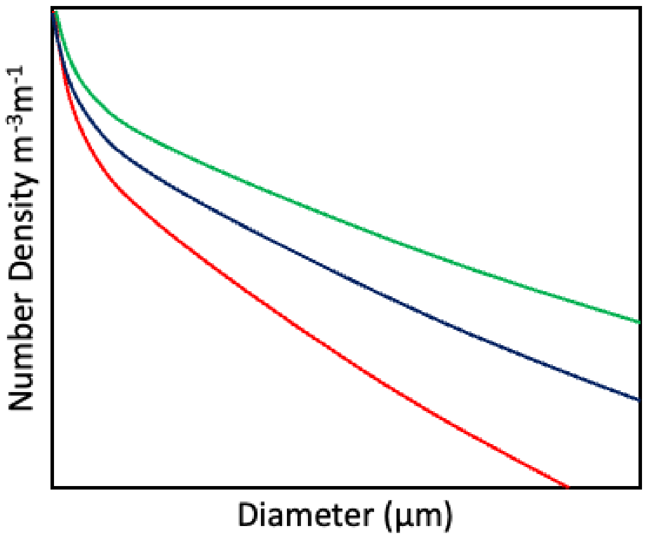


Jose

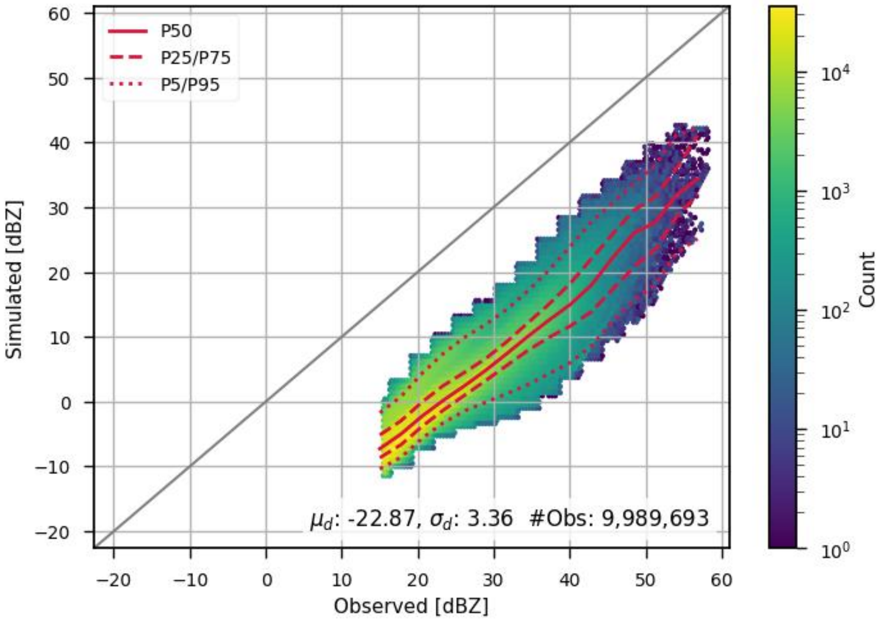


Choice of Particle Size Distribution Impacts RT Model Output for Rain

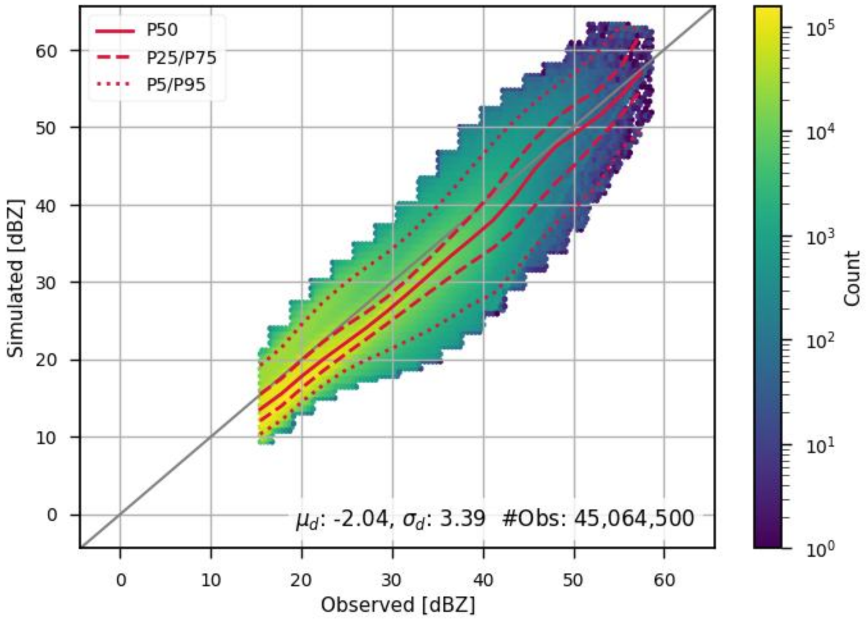




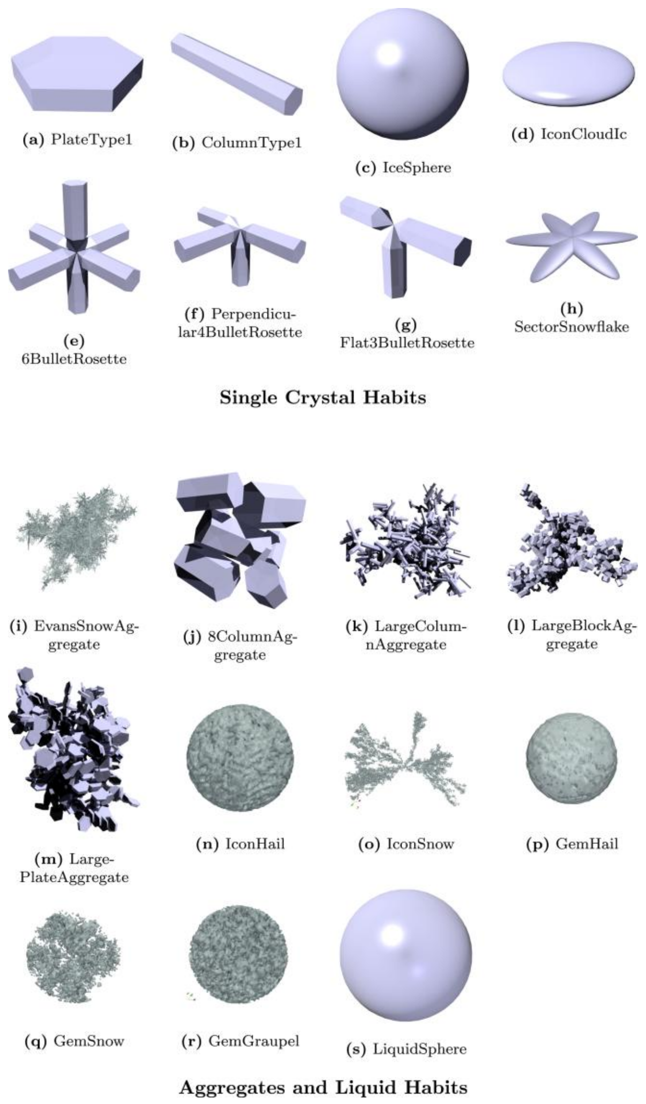
Abel 2012

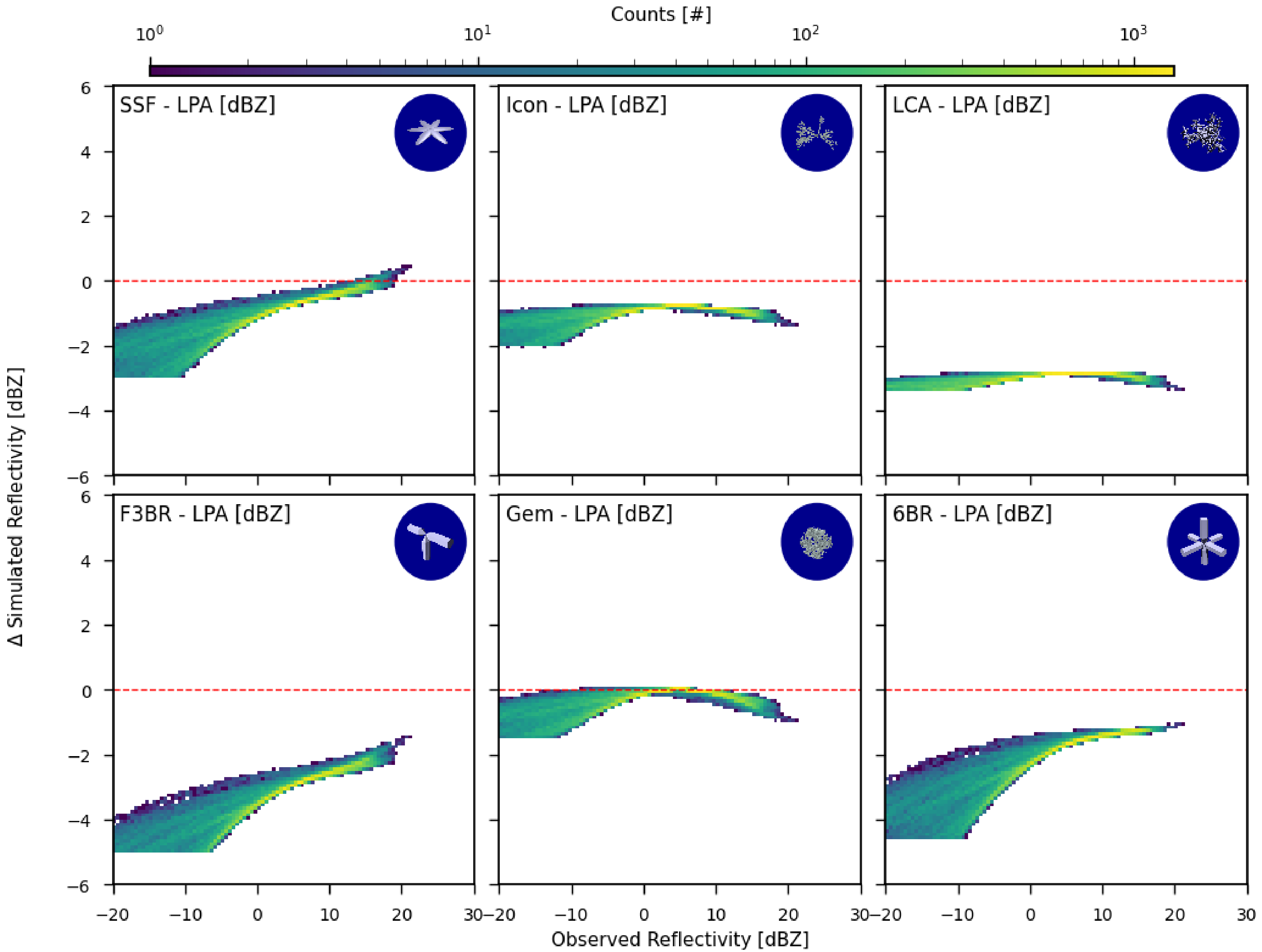


Thompson 2008



Choice of Particle Shape Impacts RT Model Output





West-coast & Heartland Hyperspectral Microwave Sensor Intensive Experiment - WH^{2}yMSIE

Campaign Period: October 18, 2024 - November 15, 2024

Objectives

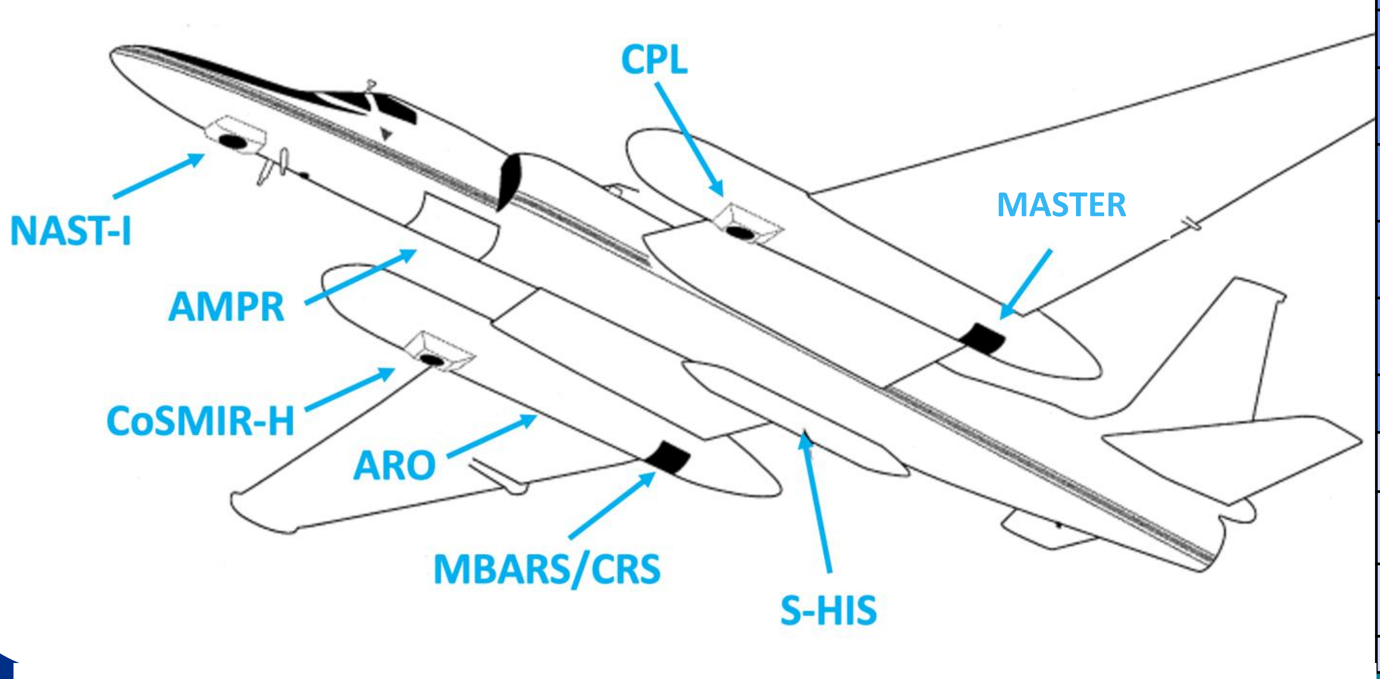
Demonstrate the capabilities of CoSMIR-H

- Maximize sampling of ocean clear sky environments and under fly various POR satellites equipped with microwave instruments (ATMS, AMSU/MHS)

Capture a wide variety of atmospheric states that contribute to variability in PBL and surface emissivity over land (e.g. convective/non-convective)

- Maximize validation opportunities and overflights of ground based PBL-focused networks (e.g. SGP, NCAR Boulder, G-III dropsondes)

Challenge the capability of the combined remote sensing payloads (ER-2 + G-III) by sampling baroclinic zones (T/q gradients) and cloudy environments (e.g. marine stratocumulus)



ER-2		
Instrument	**Measurement Type**	**Spatial Scale**
Conical Scanning Millimeter-wave Imaging Radiometer - Hyperspectral (CoSMIR-H)	Hyperspectral Microwave	1 km
Microwave Barometric Radar and Sounder (MBARS)	Doppler Radar	1-4 km
Cloud Radar System (CRS)	Doppler Radar	300 m
Cloud Physics Lidar (CPL)	Backscatter Lidar	125 m
Scanning High-resolution Interferometer Sounder (S-HIS)	Infrared	2 km
National Airborne Sounder Testbed – Interferometer (NAST-I)	Infrared	2.5 km
Advanced Microwave Precipitation Radiometer (AMPR)	Microwave	0.64 – 2.78 km
MODIS/ASTER Airborne Simulator (MASTER)	Visible-Infrared	50 m
Airborne Radio Occultation (ARO)	GPS Radio Occultation	~125 km
G-III		
High Altitude Lidar Observatory (HALO)	Differential Absorption Lidar	6-12 km x 315 m
Aerosol Doppler Wind Lidar (AWP)	Doppler Lidar	~ 2 km
Dropsondes	In Situ	~ 20 km

WH^{2}yMSIE Over Land Objectives and Ground-Based Support

- Capture wide range a surface types to develop improved surface emissivity models critical for future PBL-relevant microwave retrievals of temperature and water vapor
- Observe PBL dynamics over different surface types (dessert, grasslands, etc.) at different times of day to capture diurnal variability

Land Flight Overview

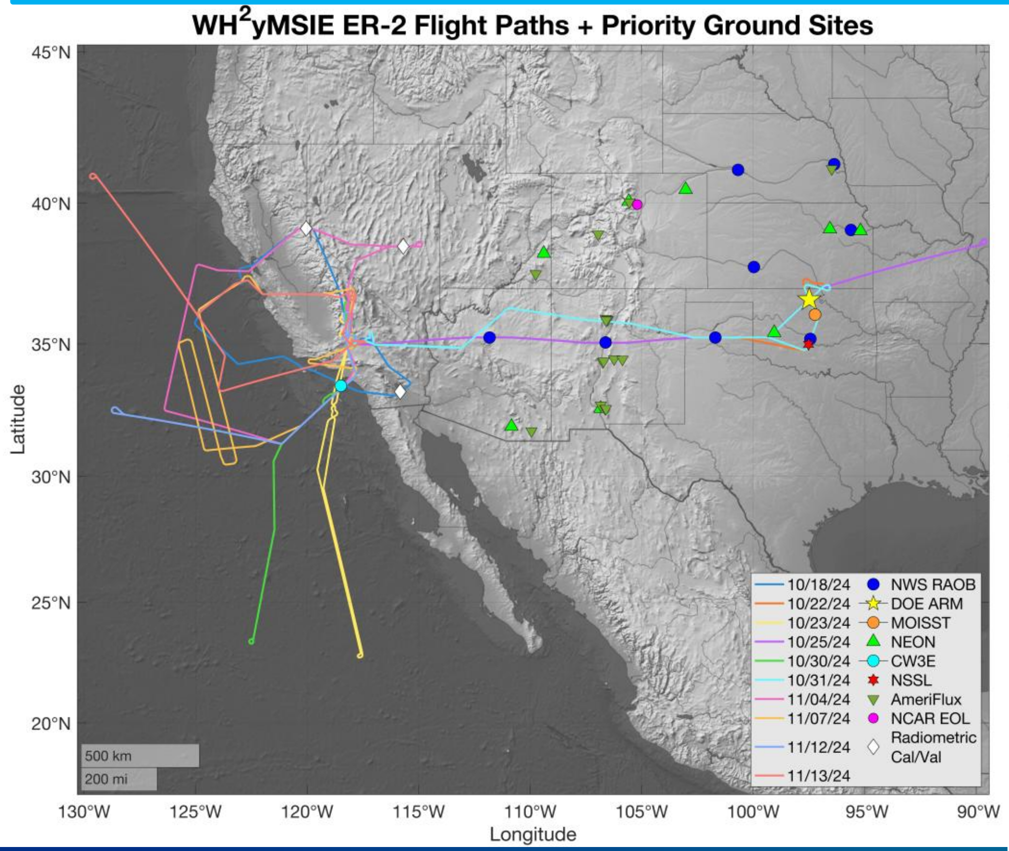
- 4 science flights
- 27 radiosondes
- Clear sky
- NOAA-21, **EarthCare**

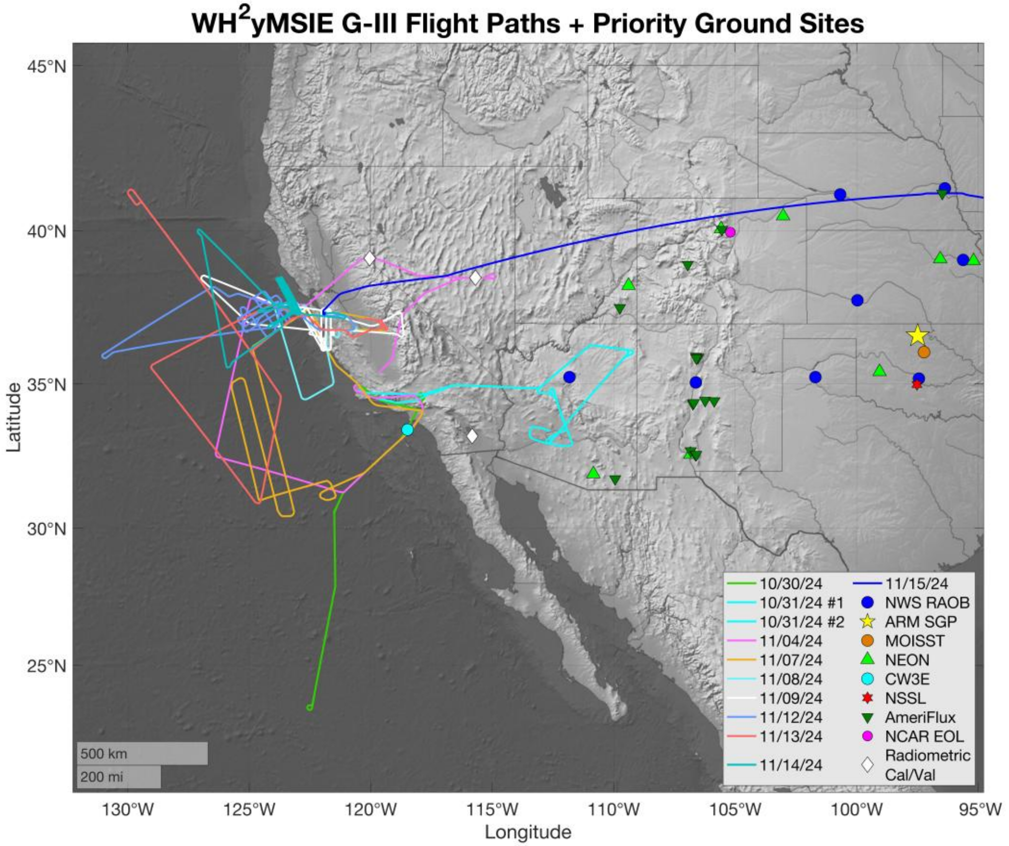
WH^{2}yMSIE Over Water Objectives and In Situ Validation Support

- Maximize clear sky data points and under fly POR satellite instruments for future MW and IR cal/val comparisons
- Observe a variety of marine PBL environments in clear and cloudy conditions

Ocean Flight Overview

- 6 science flights
- 40 dropsondes
- Mix of clear and cloudy scenes
- NOAA-21, Arctic Weather Satellite (AWS), **EarthCare**





WH^{2}yMSIE Data Archive is located at https://www-air.larc.nasa.gov/

Summary

- EarthCARE data are actively being used within NESDIS for verification and validation of LEO and GEO cloud products and aerosols.
- Development of CRTM forward model for NWP verification and data assimilation is ongoing.
- In-situ data from the WHyMSIE field campaign data are available for EarthCARE cal/val.