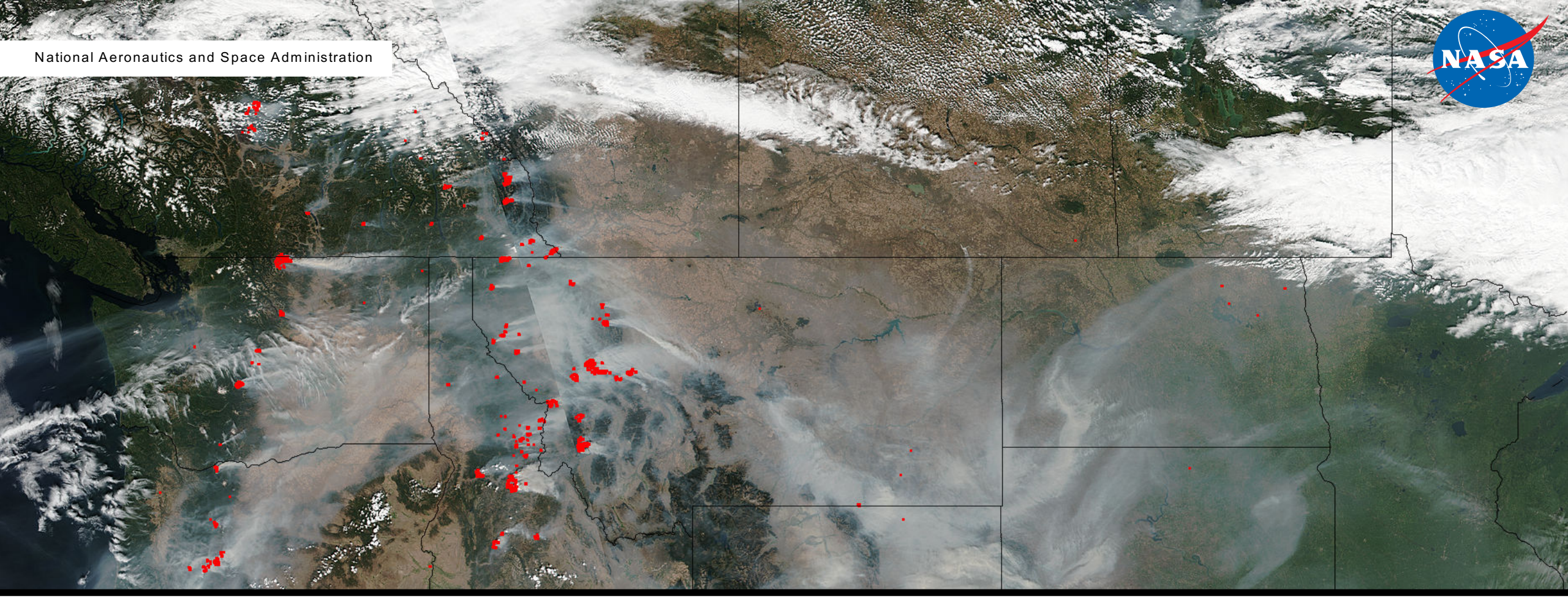


Overview of CALIPSO and CATS

Melanie Follette-Cook and Pawan Gupta

Satellite Remote Sensing of Dust, Fires, Smoke, and Air Quality, July 10-12, 2018

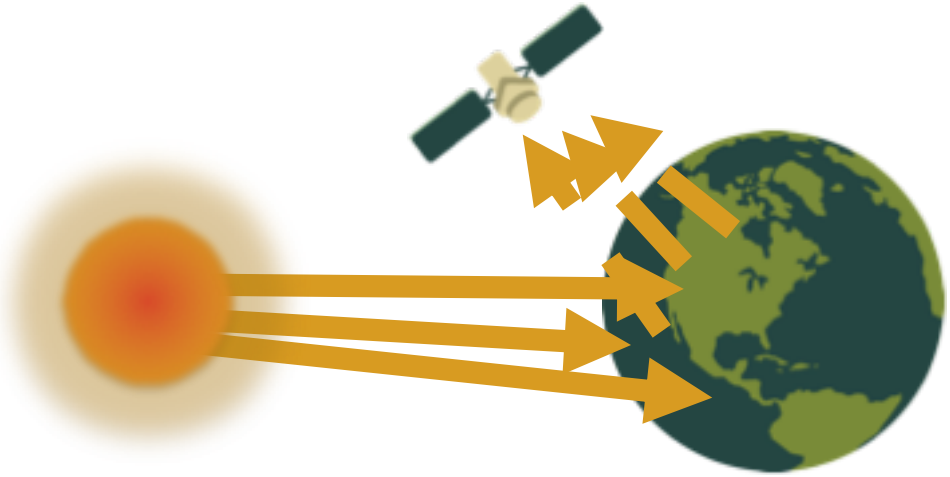
Learning Objectives

- Understand the difference between passive and active remote sensing of aerosols

- Interpret the quick-look images available from CALIPSO and CATS

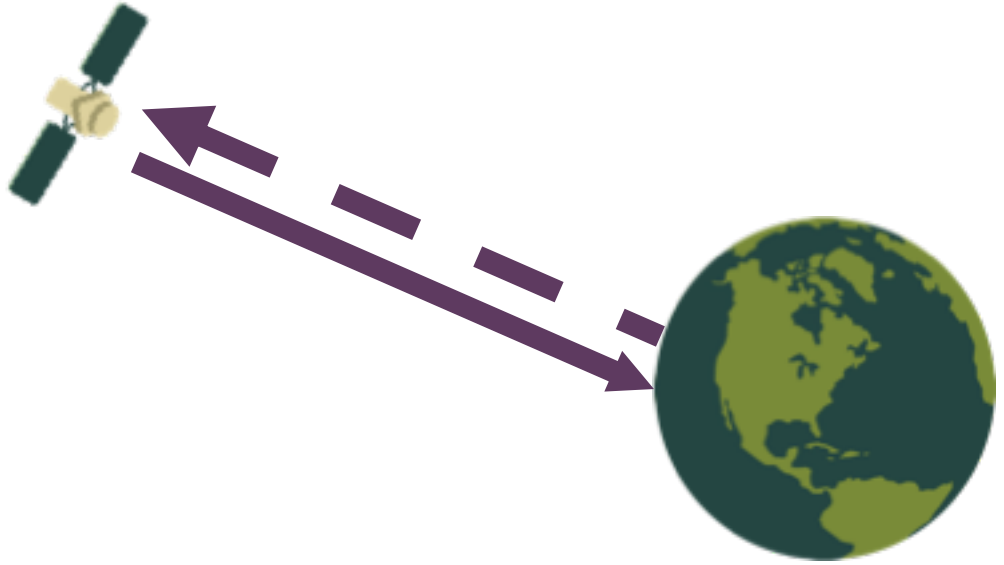
Active & Passive Sensors

Passive Sensors



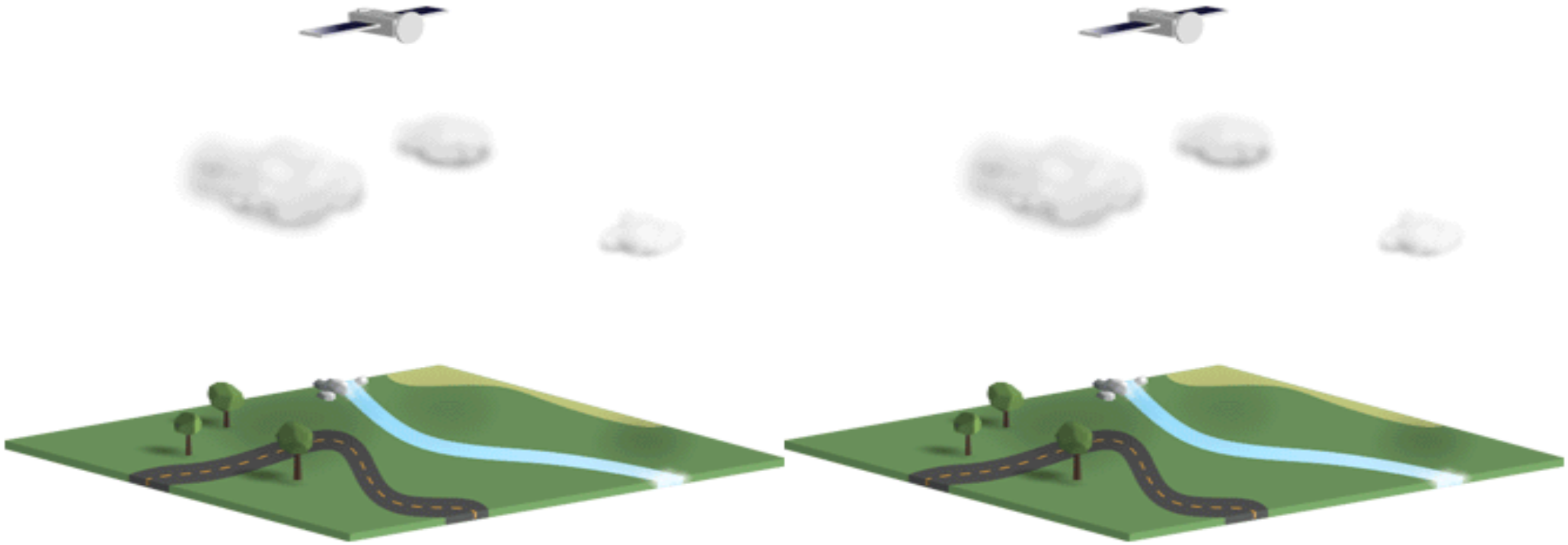
- Detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun)
- Examples: (**MODIS**, **MISR**, **OMI**, **VIIRS**)

Active Sensors



- Instruments emit their own signal and the sensor measures what is reflected back (e.g. sonar and radar)
- Example: **CALIPSO**

Active and Passive Sensors

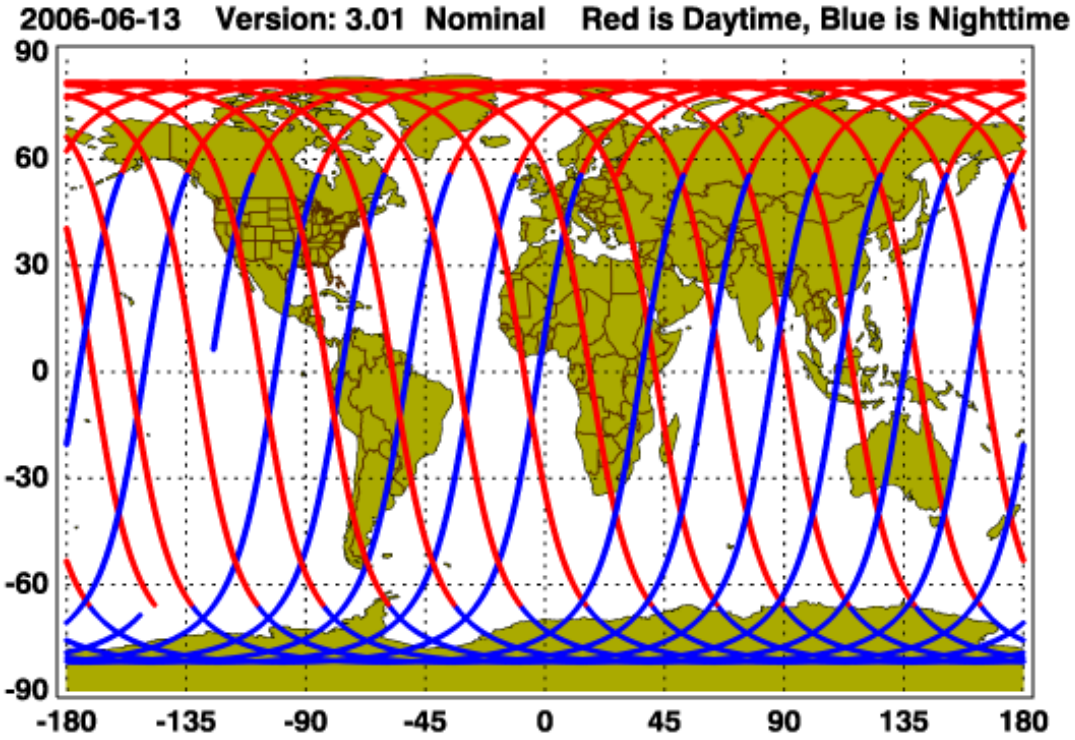


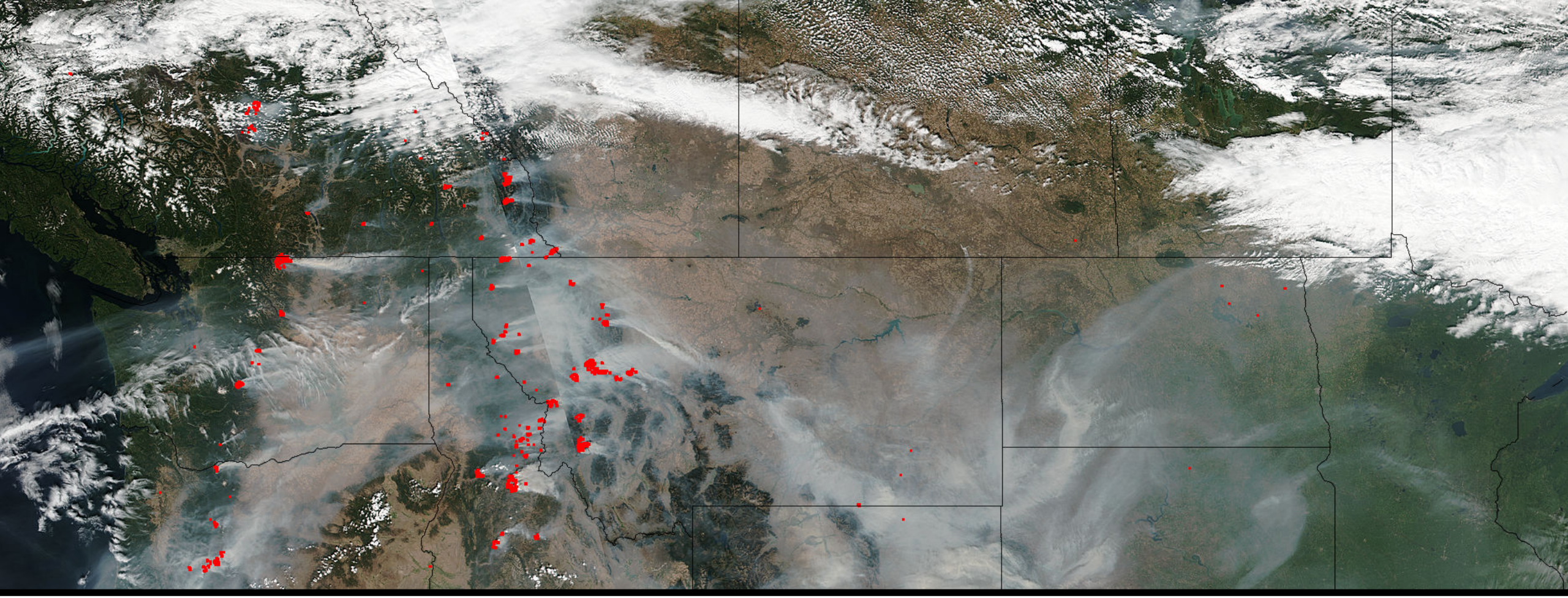
Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

Active vs. Passive Aerosol Observations

- Advantages
  - Yields high resolution aerosol profiles
  - Able to observe aerosols over bright surfaces (e.g., deserts, snow, bright cloud)
  - Because these observations do not rely on sunlight, daytime & nighttime measurements can be made
  - Can penetrate optically thin clouds
- Limitations
  - Narrow swath width, longer revisit times

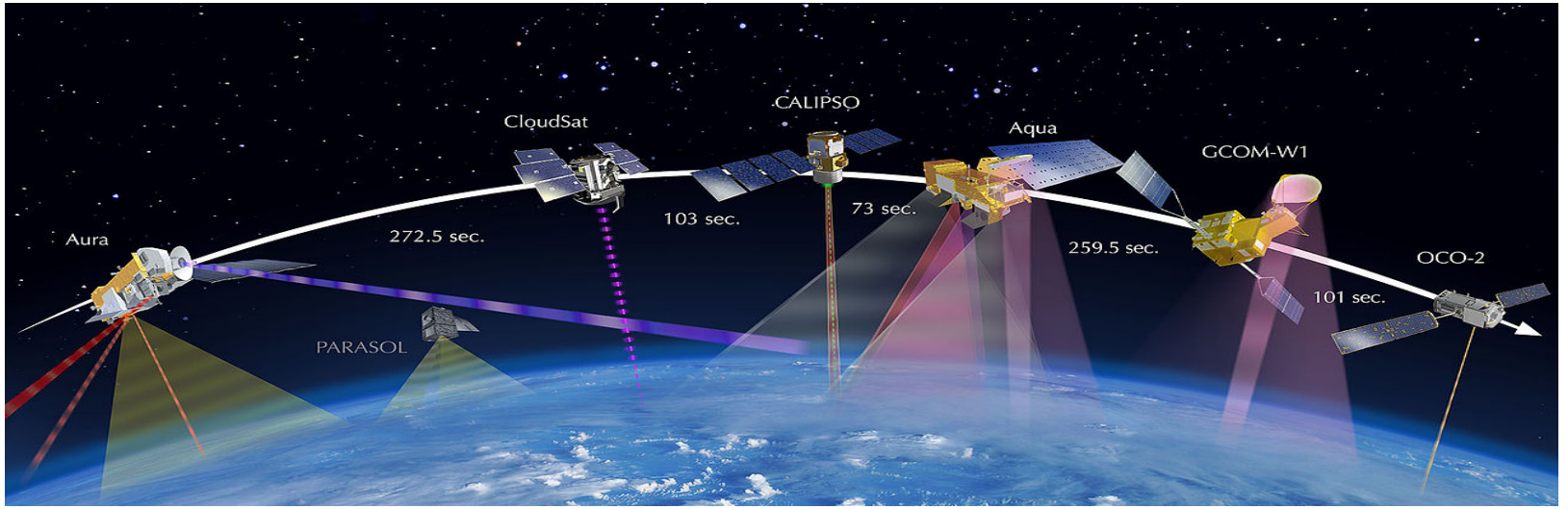




CALIPSO

CALIPSO/CALIOP

- The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite hosts three sensors
  - Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) two-wavelength polarization LIDAR (active)
  - Wide field camera (passive)
  - IR imaging radiometer (passive)
- Launched in 2006

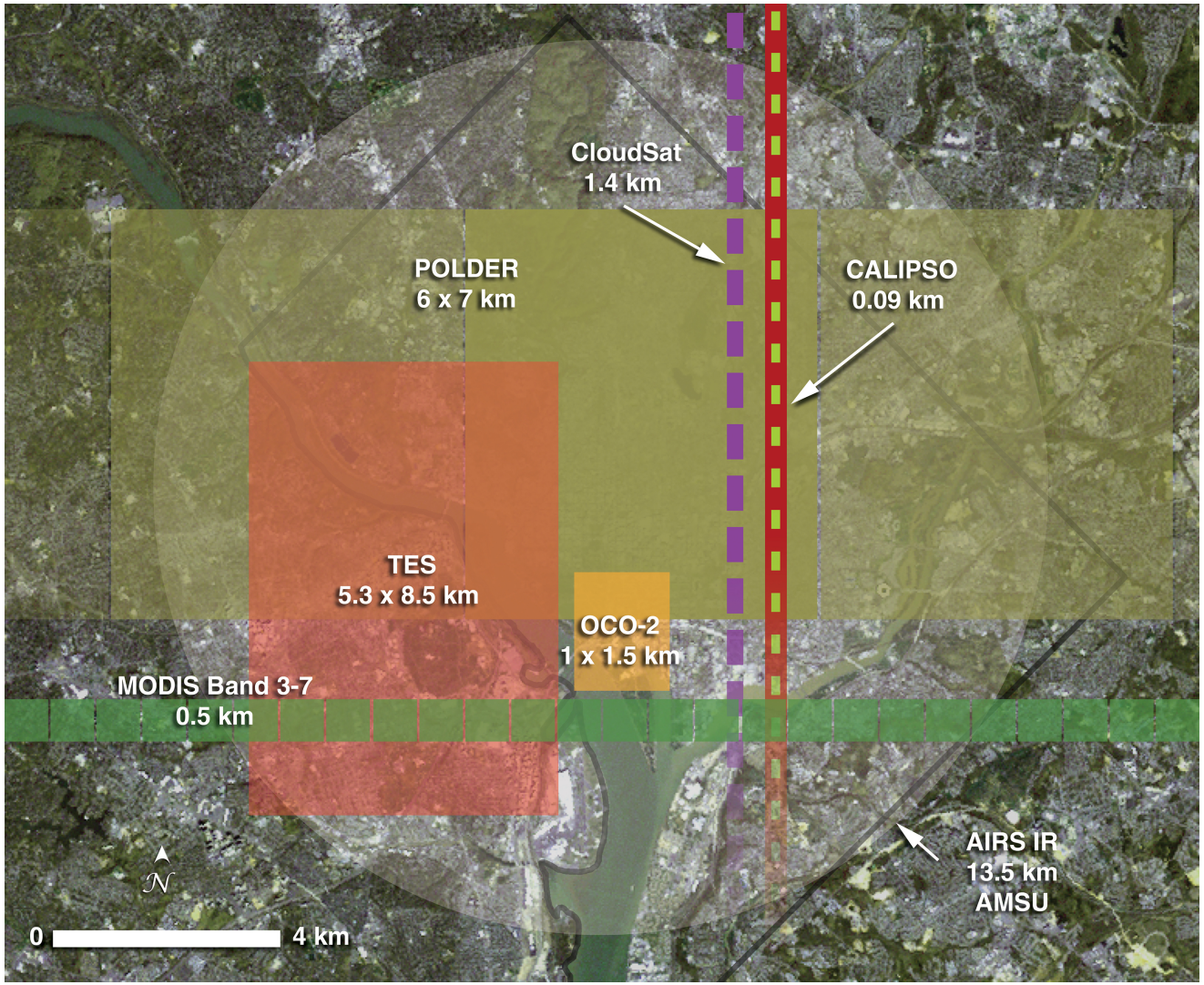


CALIOP

- 3 channels
  - 532 nm
    - Polarization beam splitter separates return signal into parallel and perpendicular
    - Measurements of signal depolarization allow the discrimination of spherical and non-spherical cloud and aerosol particles
  - 1064 nm
    - Two-wavelength signals provide qualitative information on particle size and aid in discrimination of cloud and aerosol and the identification of aerosol type
- 90 m diameter footprint every 333 m
- Revisit time, ~16 days

Source: (Winker et al. 2007)

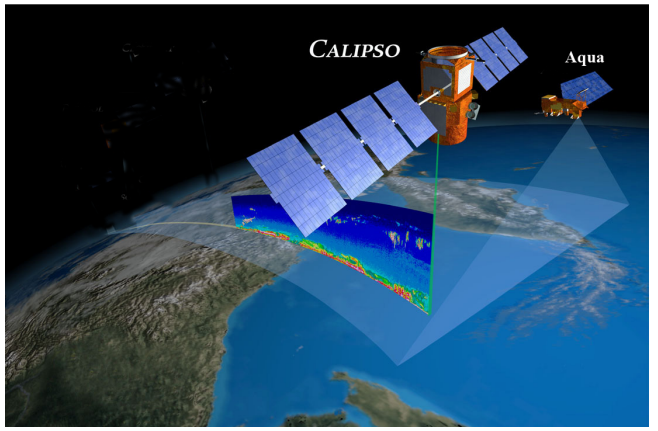
A-Train: Resolution Comparison

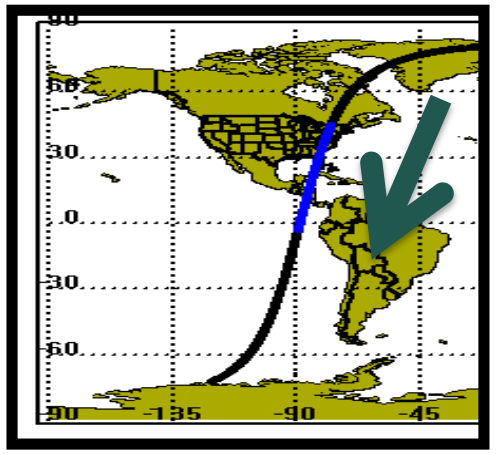


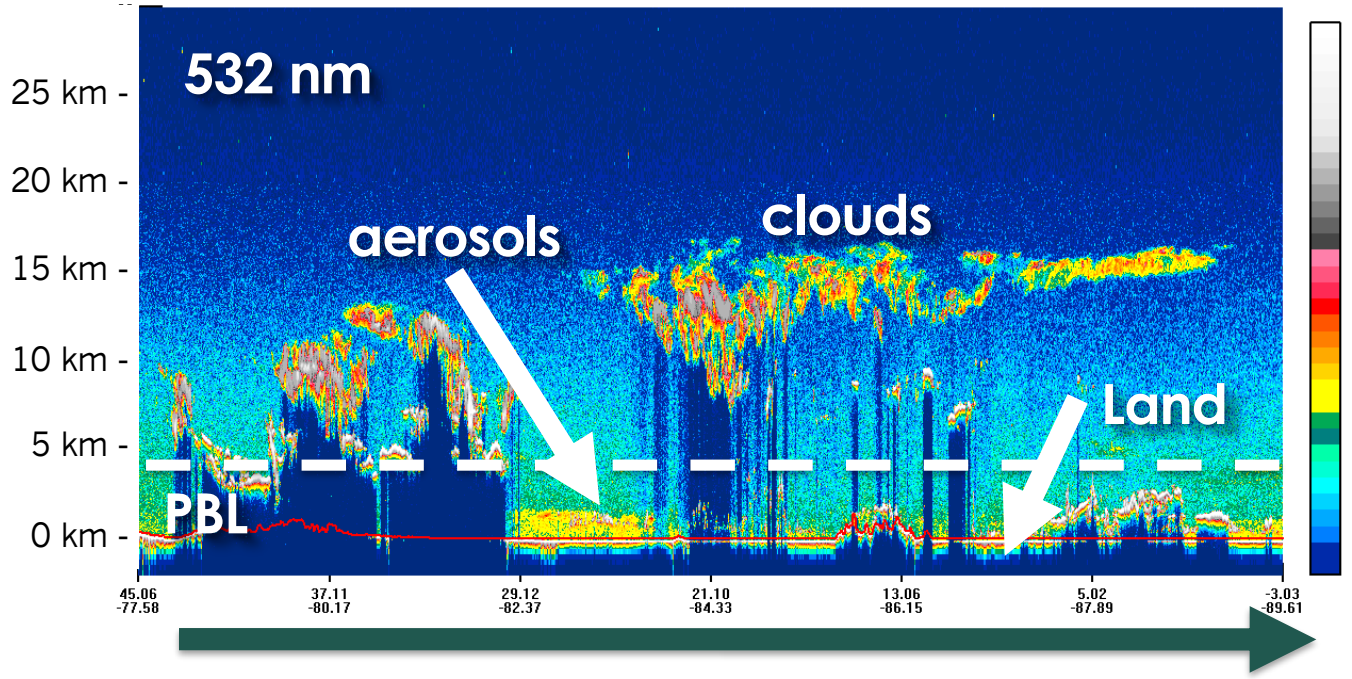
CALIPSO Products

Version 3/4 Products	Primary Parameter	Resolution Due to Averaging	
		Horizontal	Vertical (<8 km)
Level 1 **Measured**	Total_Attenuated_Backscatter_532 Perpendicular_Attenuated_Backscatter_532 Total_Attenuated_Backscatter_1064	1/3 km	30 m
Level 2 Layer **Retrieved**	Cloud Layer_Top/Base_Altitude Aerosol Layer_Top/Base_Altitude	1/3 km, 1, 5 km 5 km	30 m 30 m
Level 2 Profile **Retrieved**	Cloud and AerosolTotal_Backscatter_Coefficient_532 Extinction_Coefficient_532	5 km	60 m
Level 2 Vertical Feature Mask **Retrieved**	Feature_Clarification_Flags	5 km	30 m

A CALIPSO Curtain Scene



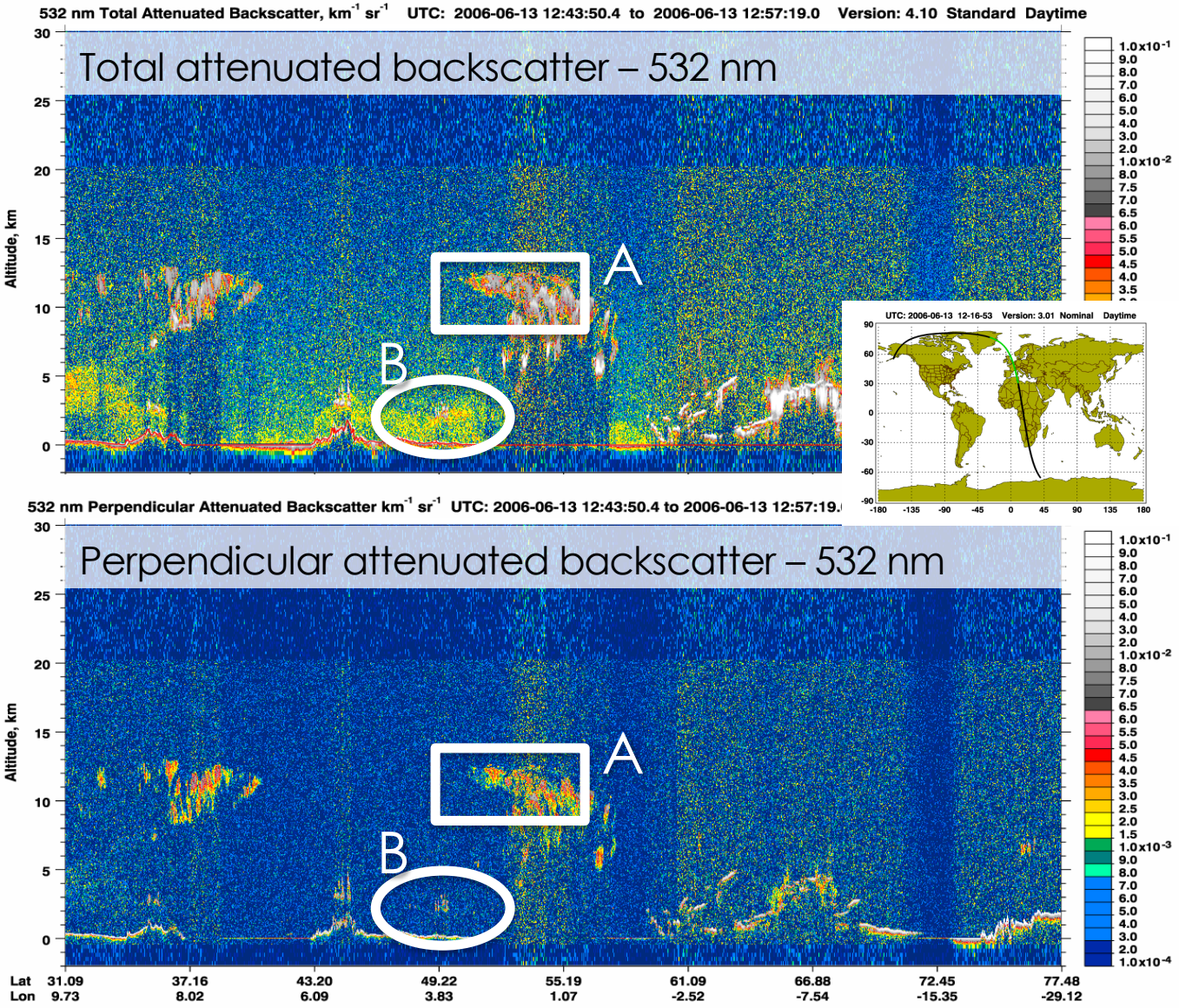




Interpreting CALIPSO Images

Level 1 Products

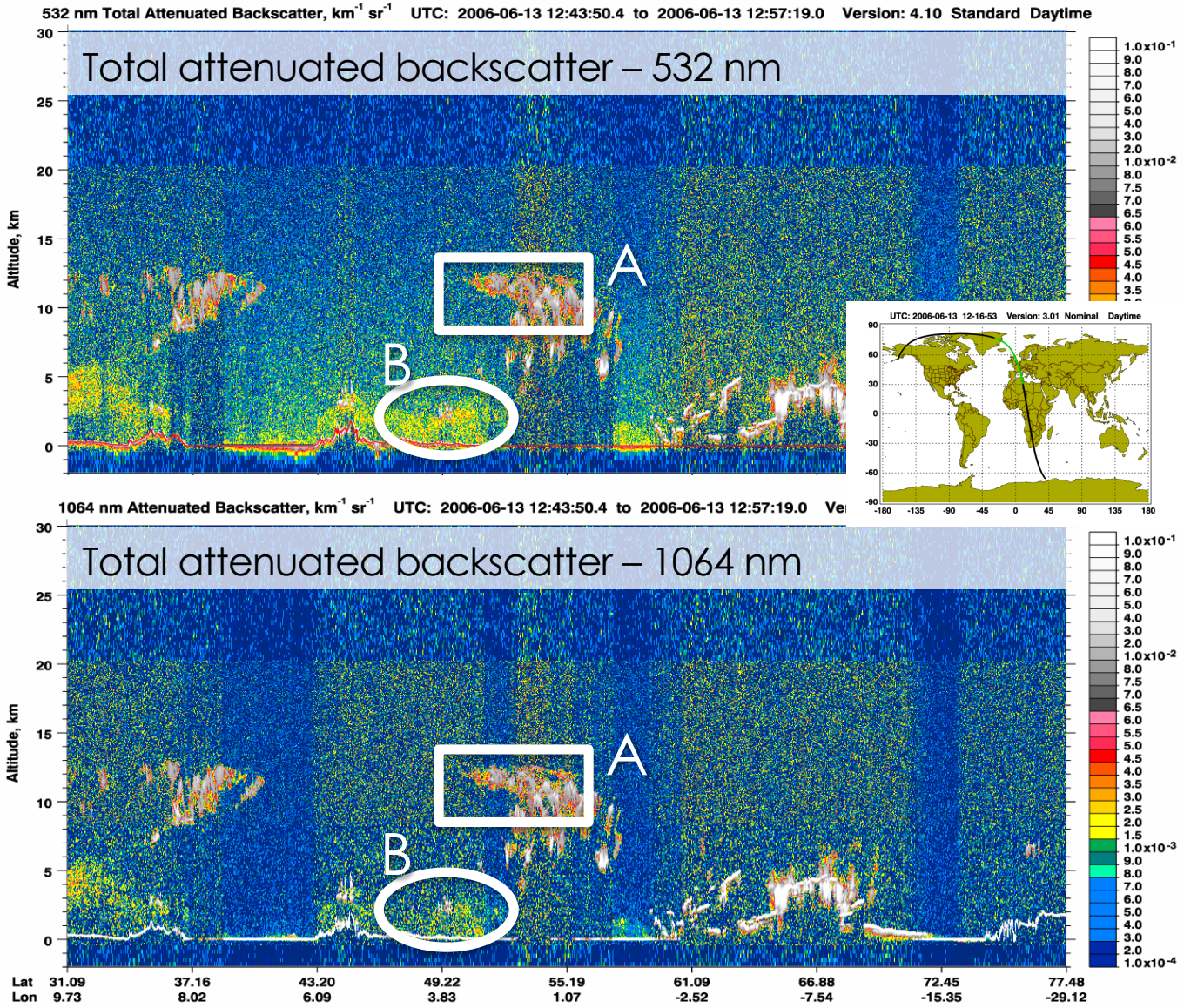
- Measurements of signal depolarization allow the discrimination of spherical and non-spherical cloud and aerosol particles (Winker et al. 2007)
- If enhanced signal in both images then non-spherical particles (Region A)
- If enhanced signal in total backscatter image but little or no enhancement in the perpendicular image, then spherical particles (Region B)



Interpreting CALIPSO Images

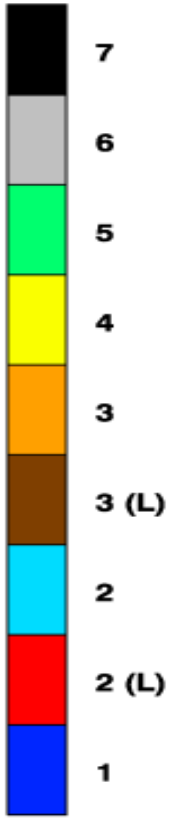
Level 1 Products

- Two-wavelength signals provide qualitative information on particle size and aid in discrimination of cloud and aerosol and the identification of aerosol type (Winker et al. 2007)
- If same intensity in both channels, coarse, larger particles
- If signal more intense in the 532 channel: fine, smaller particles
- Region A: coarse non spherical
  - cirrus cloud?
- Region B: fine spherical
  - urban pollution?



Interpreting CALIPSO Images

Level 2 Products



Totally Attenuated

Subsurface

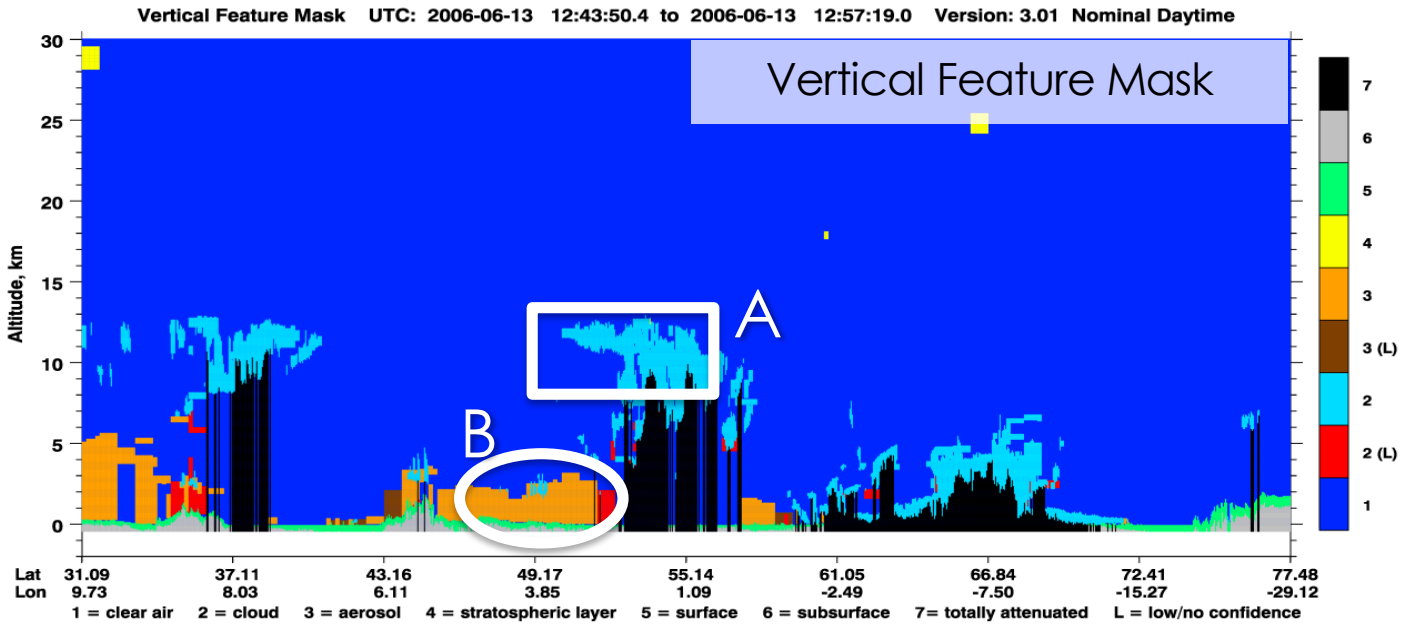
Surface

Stratospheric layer

Aerosol

Cloud

Clear air



Feature mask indicates Region A is cloud and Region B is aerosol

Aerosol Sub-Type Flowchart

Essentially a function of:

- Land surface type
  - Snow, Ice, Land, Ocean
- Attenuated backscatter
  - Identifying aerosol type over different land surface regimes in the CALIOP VFM algorithm
- Depolarization ratio
  - used to identify non-spherical particles (e.g., dust) or mixtures that contain non-spherical particles (e.g., polluted dust)
- Layer altitude
  - Elevated, Not elevated

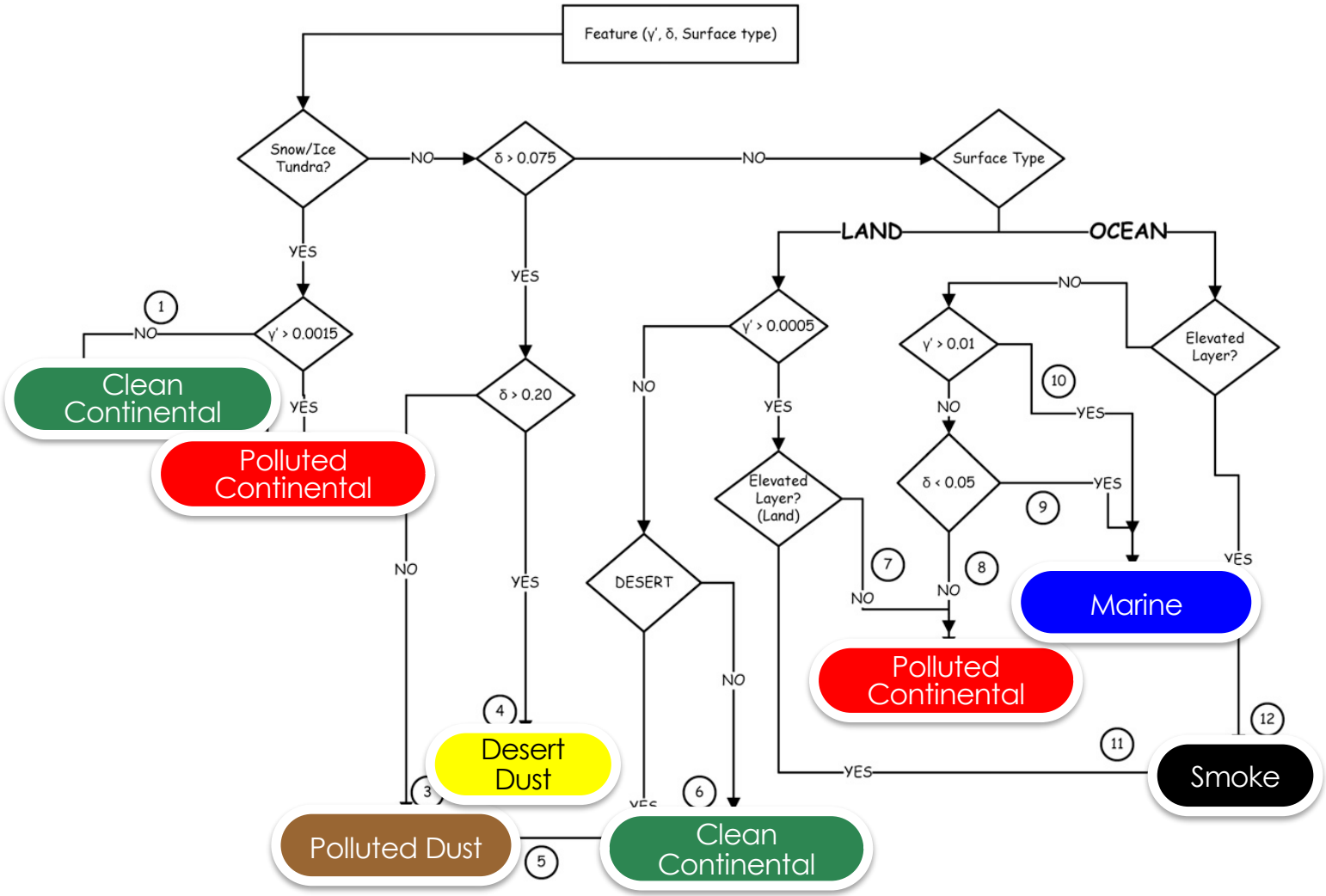


Image Credit: Figure 2, Omar et al. 2009

Interpreting CALIPSO Images

Level 2 Products

6 Smoke

5 Polluted Dust

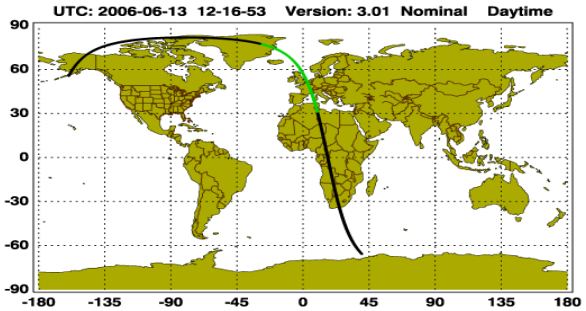
4 Clean Continental

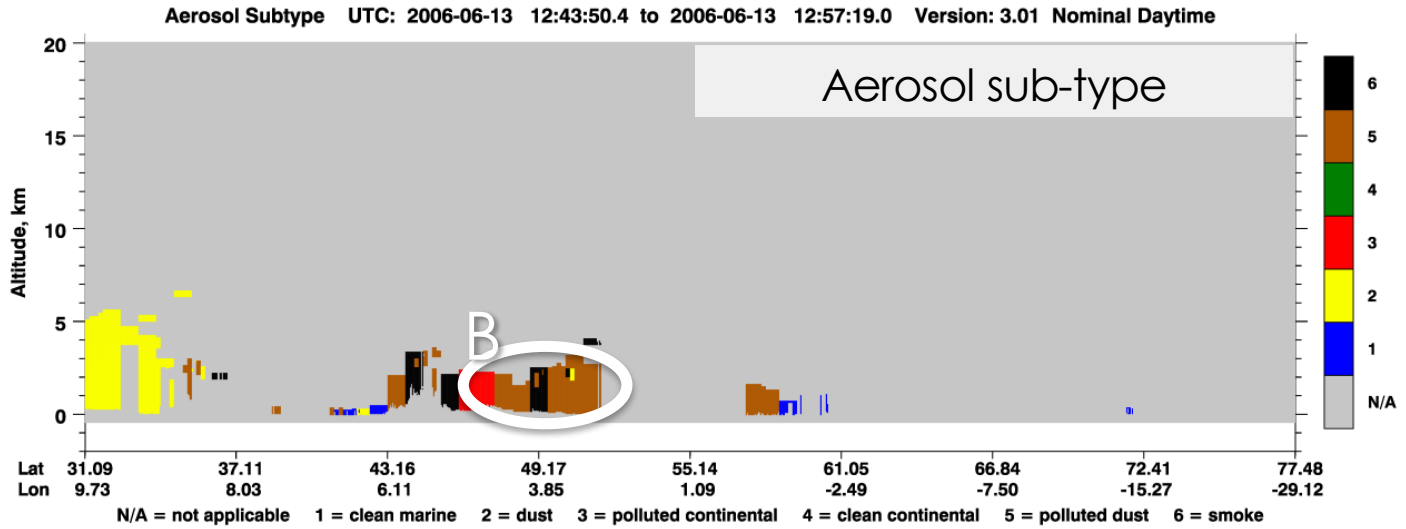
3 Polluted Continental

2 Dust

1 Clean Marine

N/A





Aerosol sub-type indicates polluted dust or smoke

Level 1 analysis indicates fine, non-spherical particles

Potentially Secondary Organic Aerosol (SOA)?

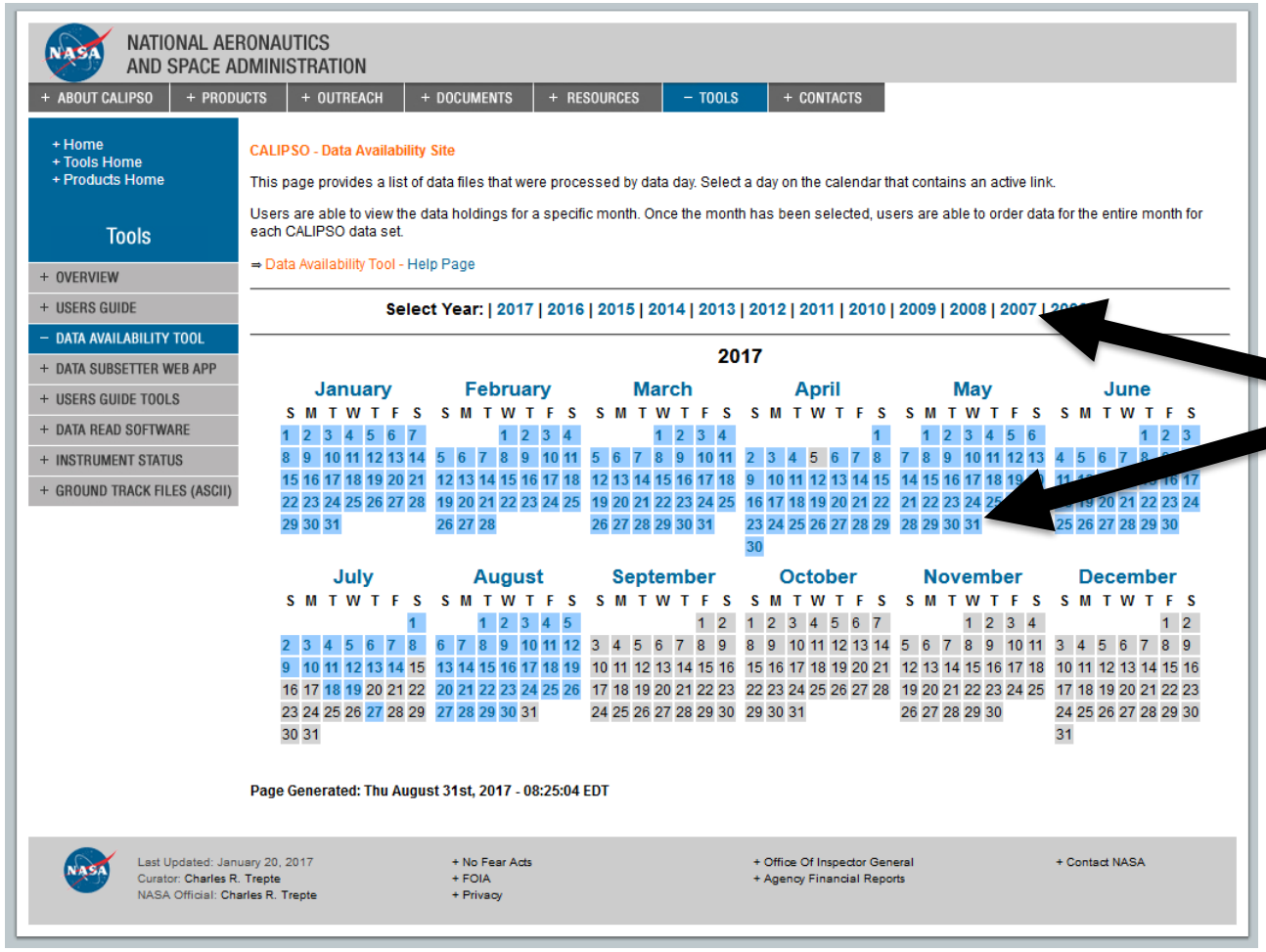
CALIPSO

Overview

- CALIOP/ CALIPSO provides aerosol vertical distribution and information on type of particle (size and shape)
- Safest use of CALIOP data:
  - Qualitative (browse lidar images online)
  - Latest version (currently V4.10)
  - Level 1 contains fewer uncertainties than level 2 data
- If using CALIOP Level 2 data,
  - Recognize the unvalidated nature of the data
  - Keep the uncertainties in mind
  - Make sure to read all quality assurance information and to apply the appropriate quality flags
- User guide: http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/
- If you have any concerns, ask the CALIPSO team

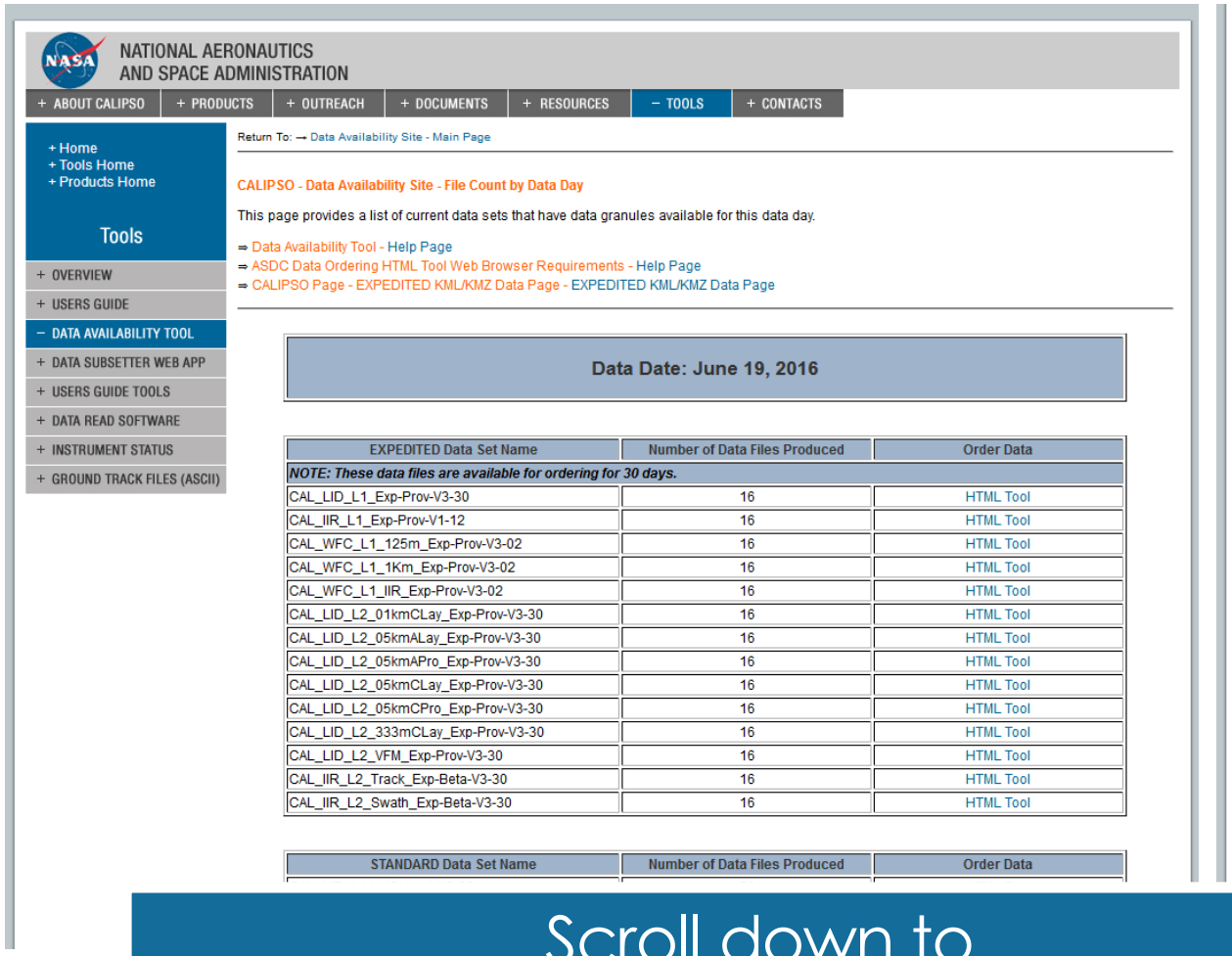
How to Access CALIPSO imagery

https://www-calipso.larc.nasa.gov/tools/data_avail/



Select a year and a day to view

How to Access CALIPSO Imagery



CAL_LID_L2_01kmCLay-ValStage1-V3-30	29	HTML Tool
CAL_LID_L2_05kmALay-Prov-V3-30	29	HTML Tool
CAL_LID_L2_05kmAPro-Prov-V3-30	29	HTML Tool
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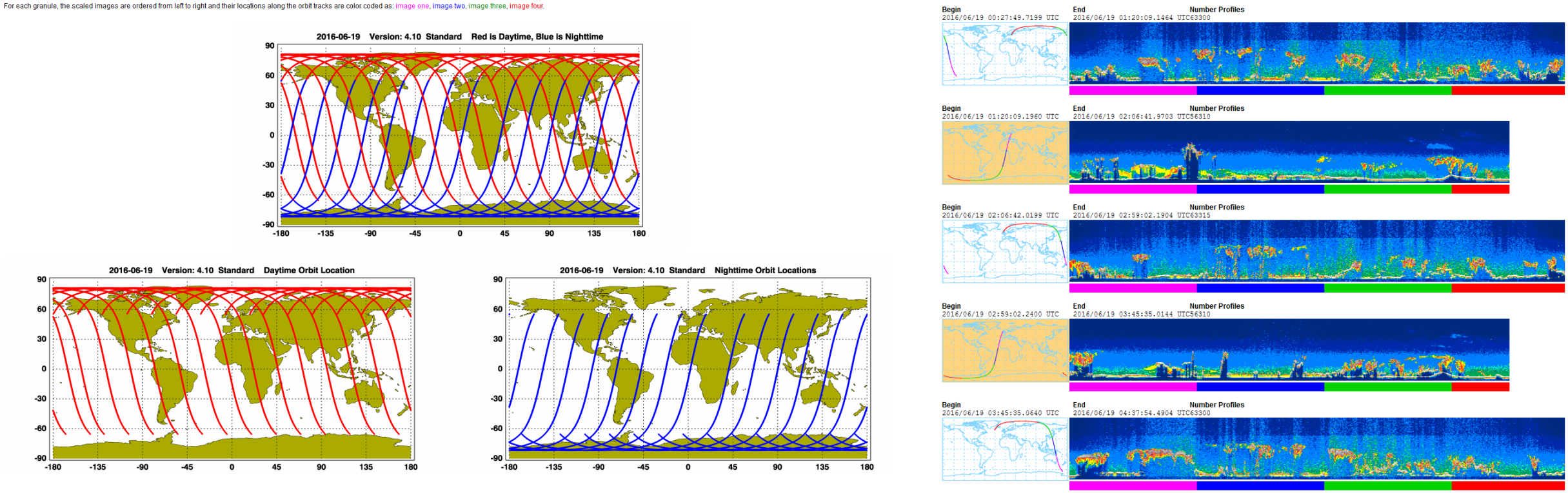
CAL_IIR_L1-Standard-V2-00	29	HTML Tool

Browse Images	
LIDAR Standard Browse Images & Other Images : Versions 3.x	YES
LIDAR Standard Browse Images & Other Images : Version 4.10	YES
Wide Field Camera Browse Images	YES
Information	
Instrument Status: *None*	
Other: *None*	
Documentation	
Data User's Guide	YES
Data Products Catalog	YES
Additional Data Tools	
Data Read IDL Software Package	YES
CALIPSO Search and Subsetting Web Application - Versions 3.x Standard Data ONLY	YES

Scroll down to
"Browse Images" and choose version

How to Access CALIPSO Imagery

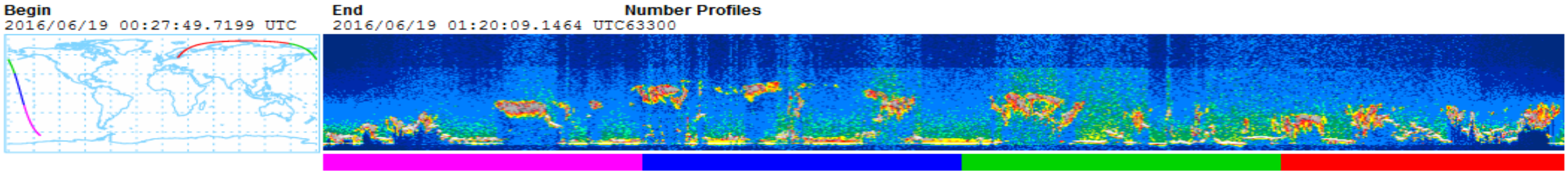
Scroll down to view that day's orbits and imagery



The images are ordered from left to right. Locations along the orbit tracks are color coded as: image one, image two, image three, image four

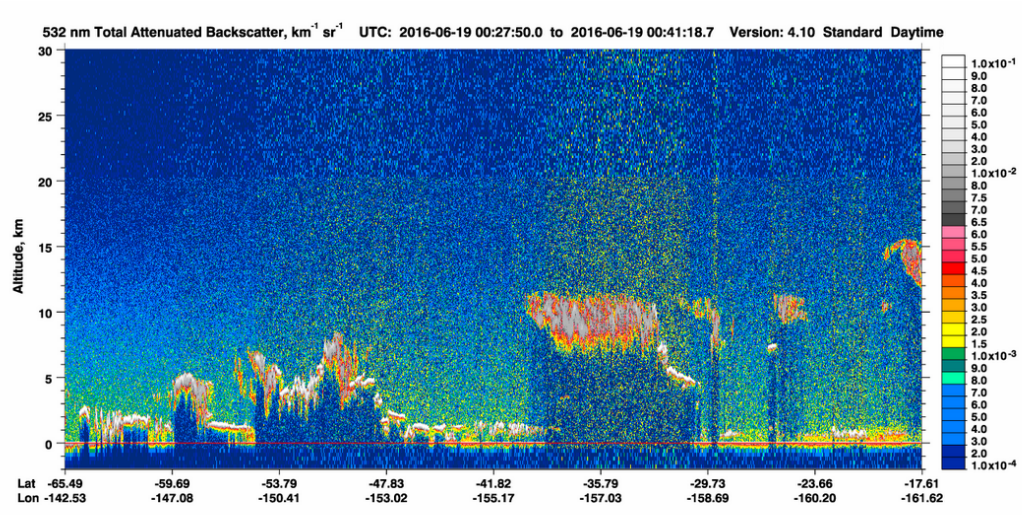
How to Access CALIPSO Imagery

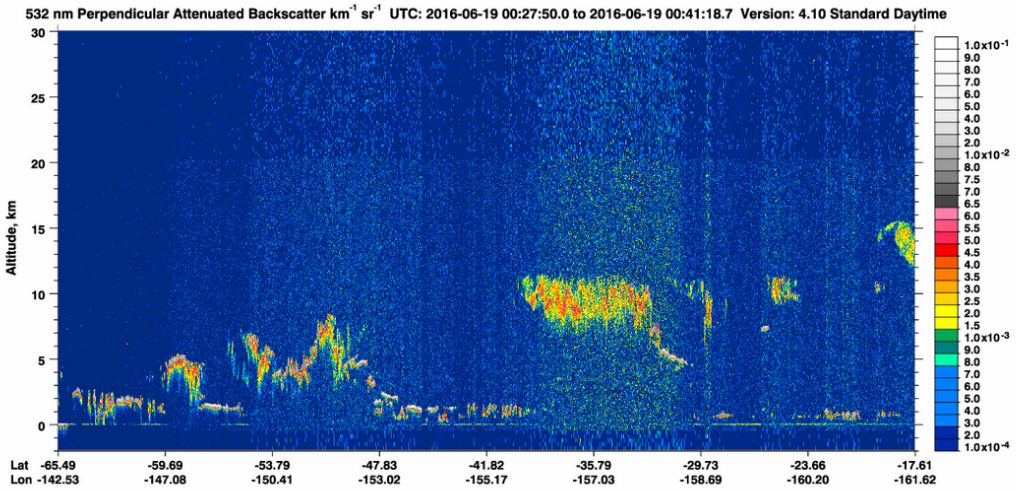
The images are ordered from left to right. Locations along the orbit tracks are color coded as: image one, image two, image three, image four



Clicking on one segment will bring up a *new window* with zoomed-in imagery

How to Access CALIPSO Imagery



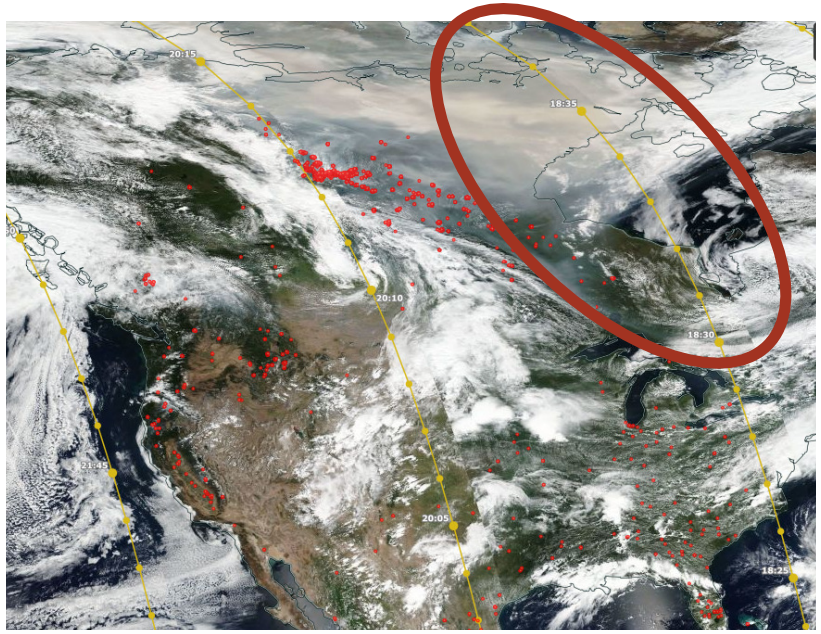


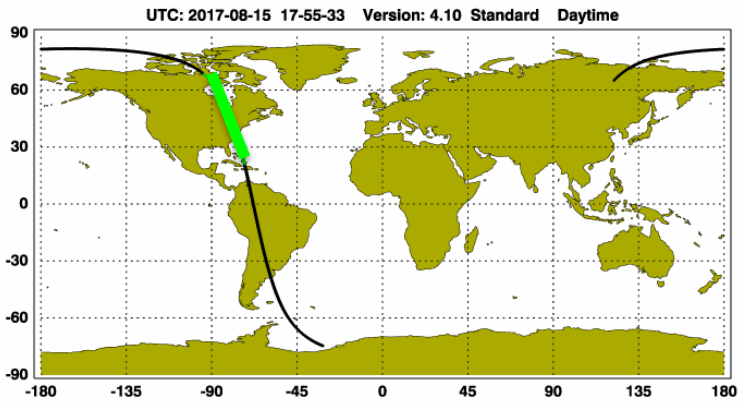
In the new window, scroll down for zoomed-in imagery:

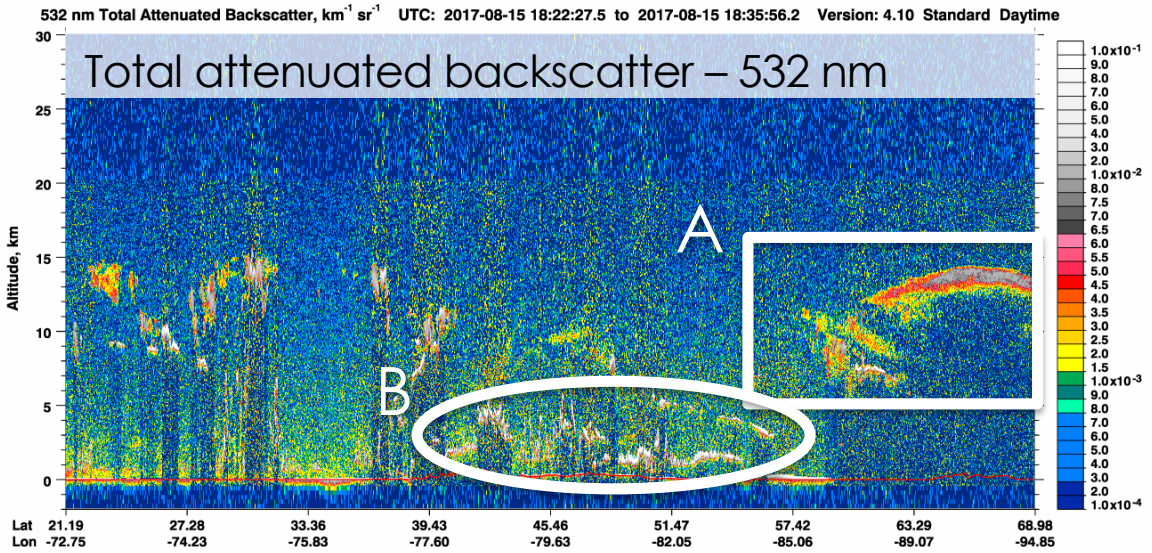
- 532 nm total attenuated backscatter
- 532 nm perpendicular attenuated backscatter
- Depolarization ratio
- 1064 nm total attenuated backscatter
- Attenuated color ratio
- Vertical feature mask
- Ice/water phase
- Aerosol sub-type
- Cloud sub-type
- Brightness temperature

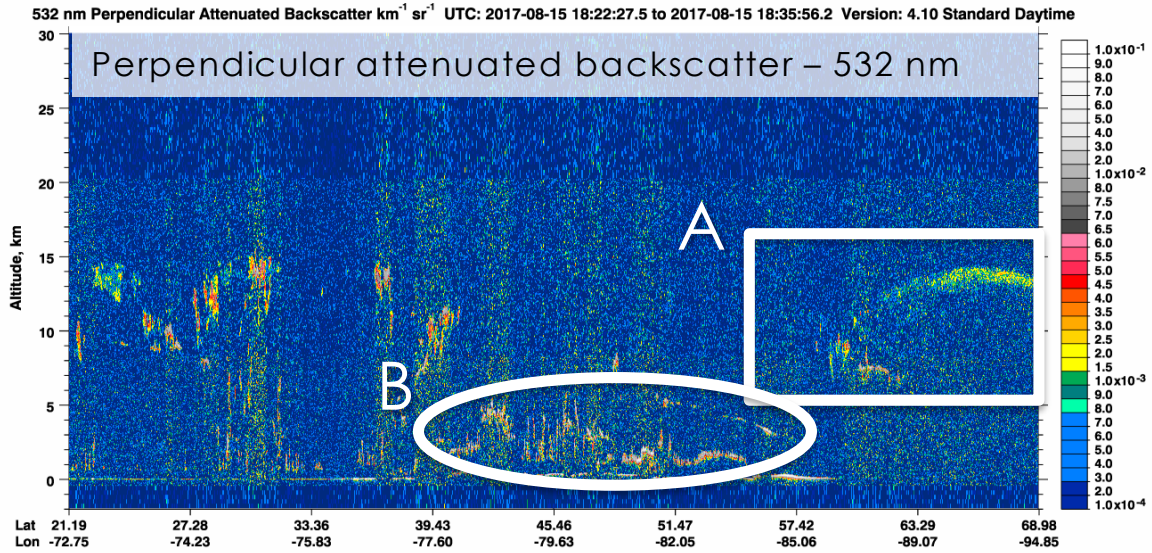
CALIPSO Curtains

Biomass Burning – 8/15/2017



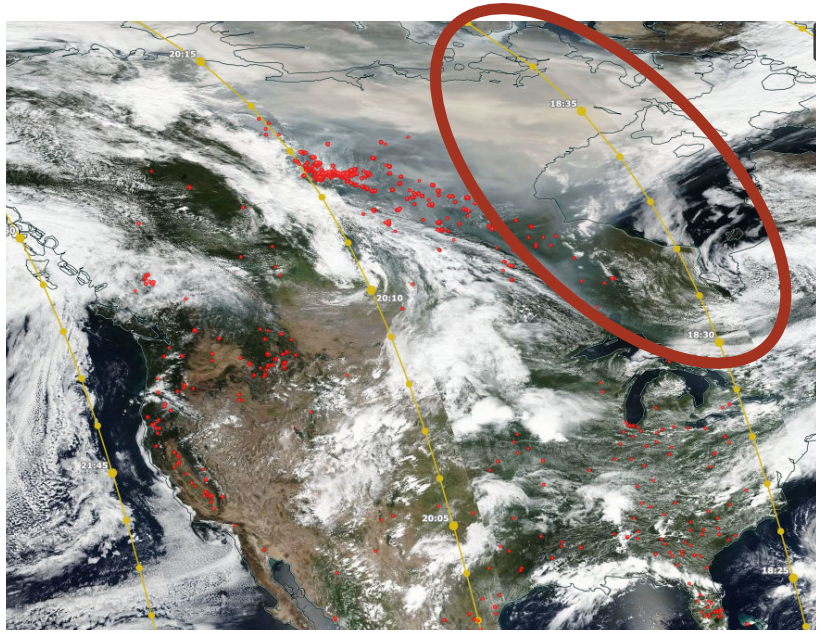


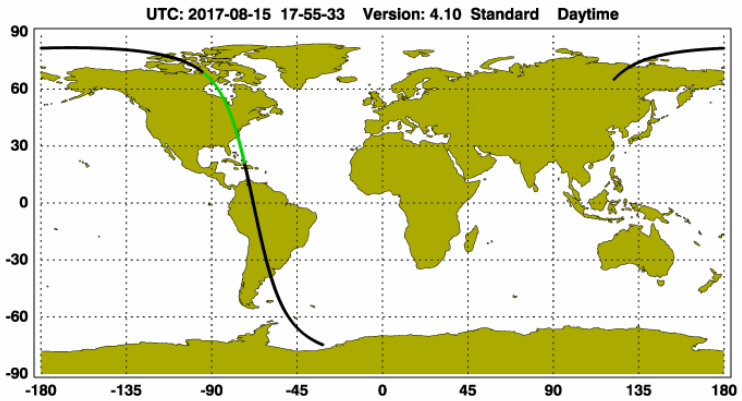


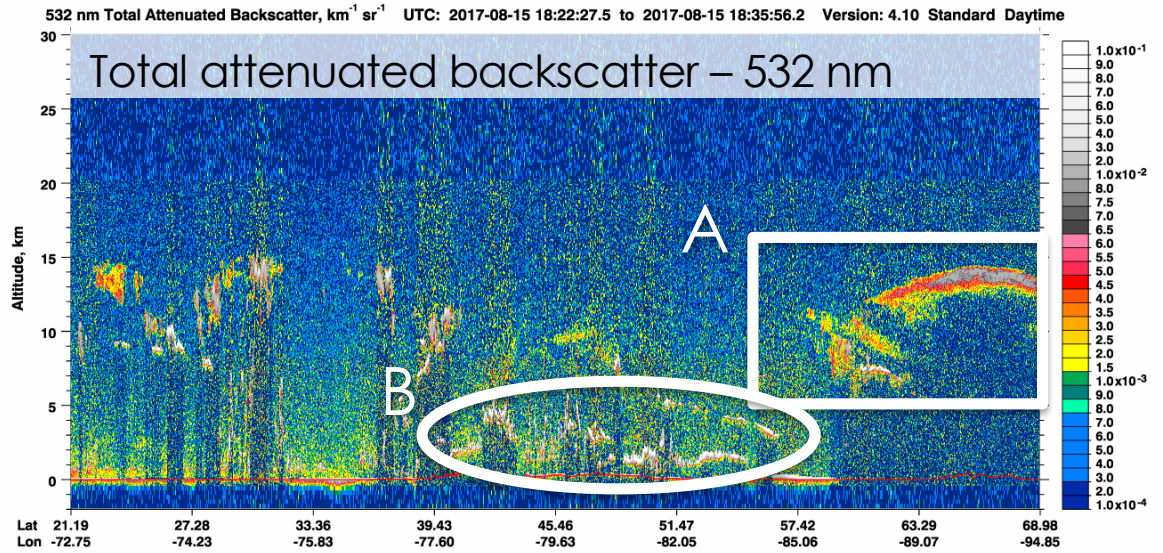


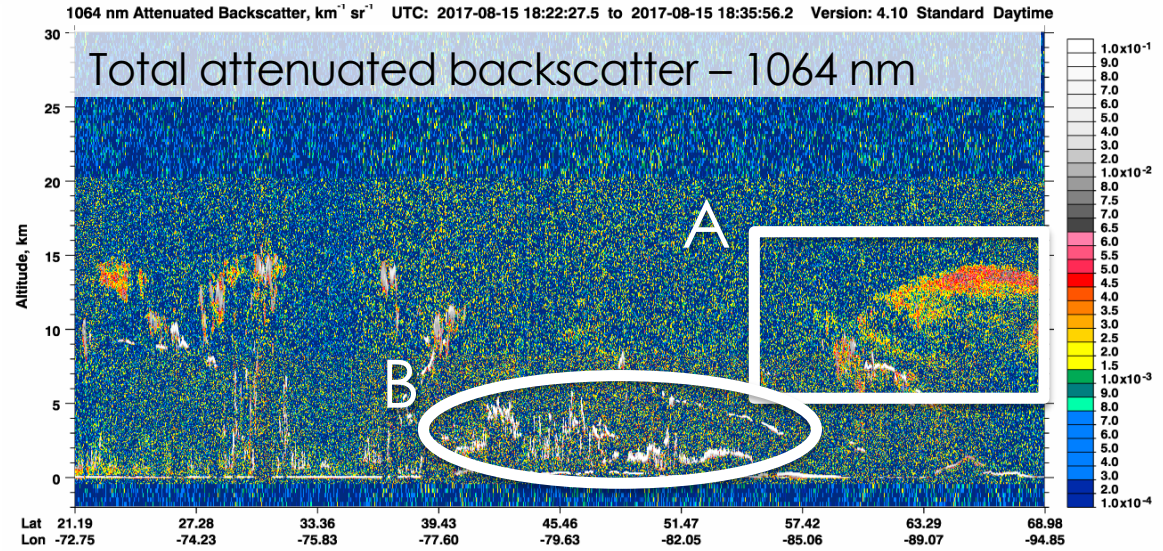
CALIPSO Curtains

Biomass Burning – 8/15/2017









CALIPSO Curtains

Biomass Burning – 10/24/2015

Totally Attenuated

Subsurface

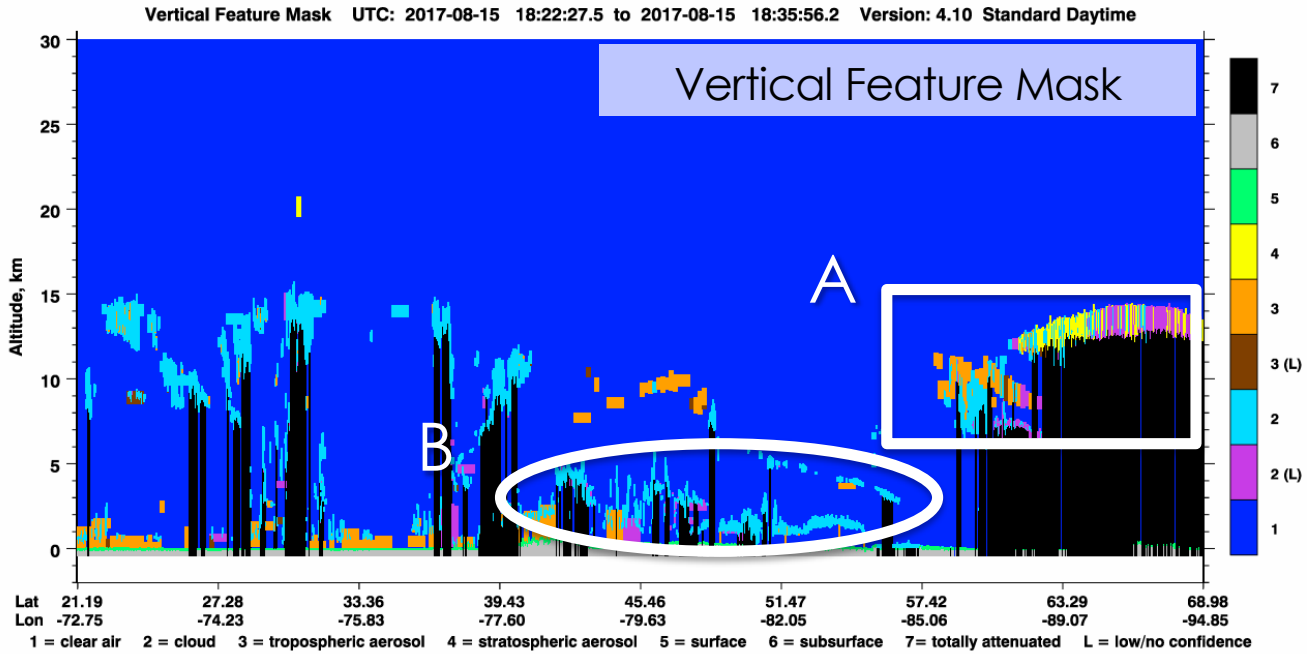
Surface

Stratospheric layer

Aerosol

Cloud

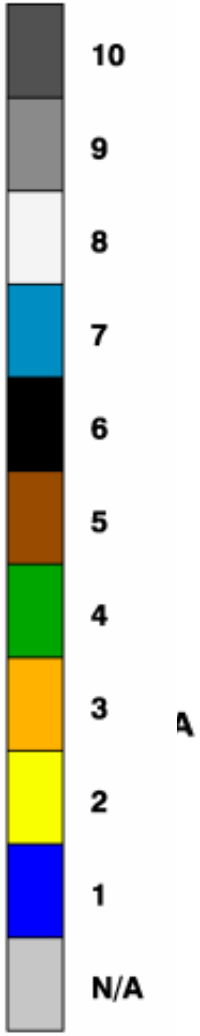
Clear air



Feature mask indicates Region A is cloud/aerosol and Region B is cloud

CALIPSO Curtains

Biomass Burning – 10/24/2015



Sulfate/Other

Volcanic Ash

PSC Aerosol

Dusty Marine

Elevated Smoke

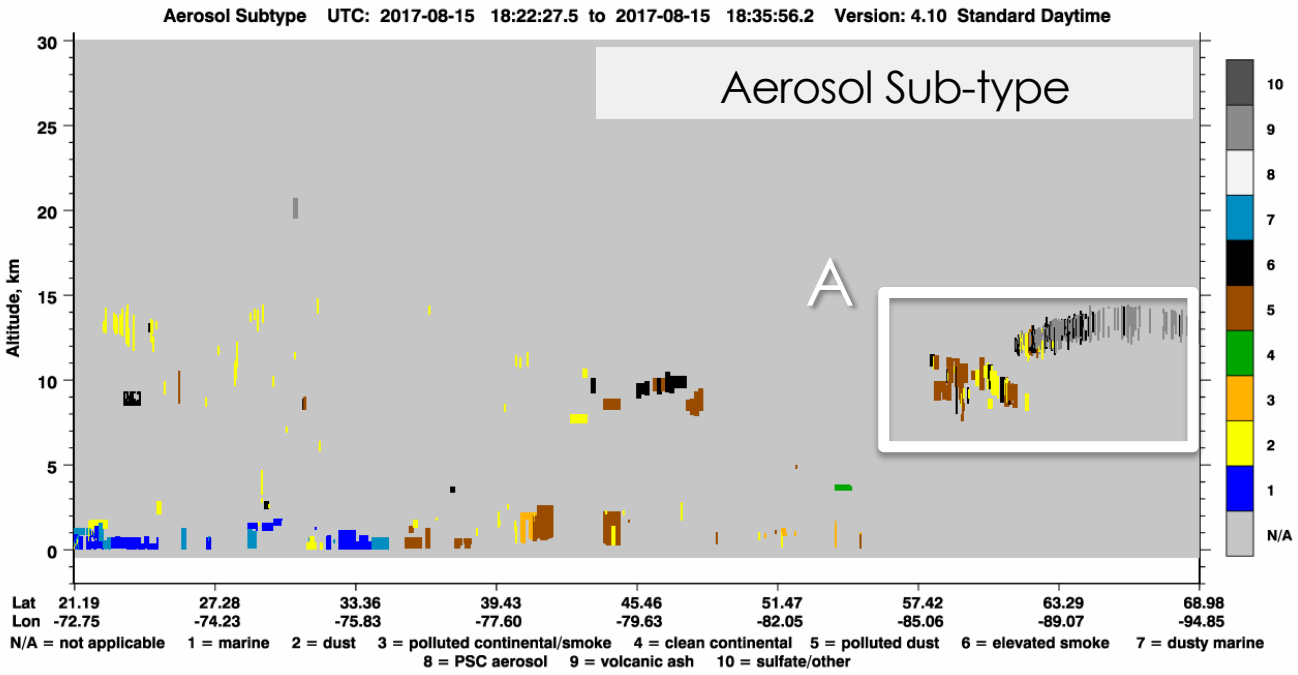
Polluted Dust

Clean Continental

Polluted Continental/smoke

Dust

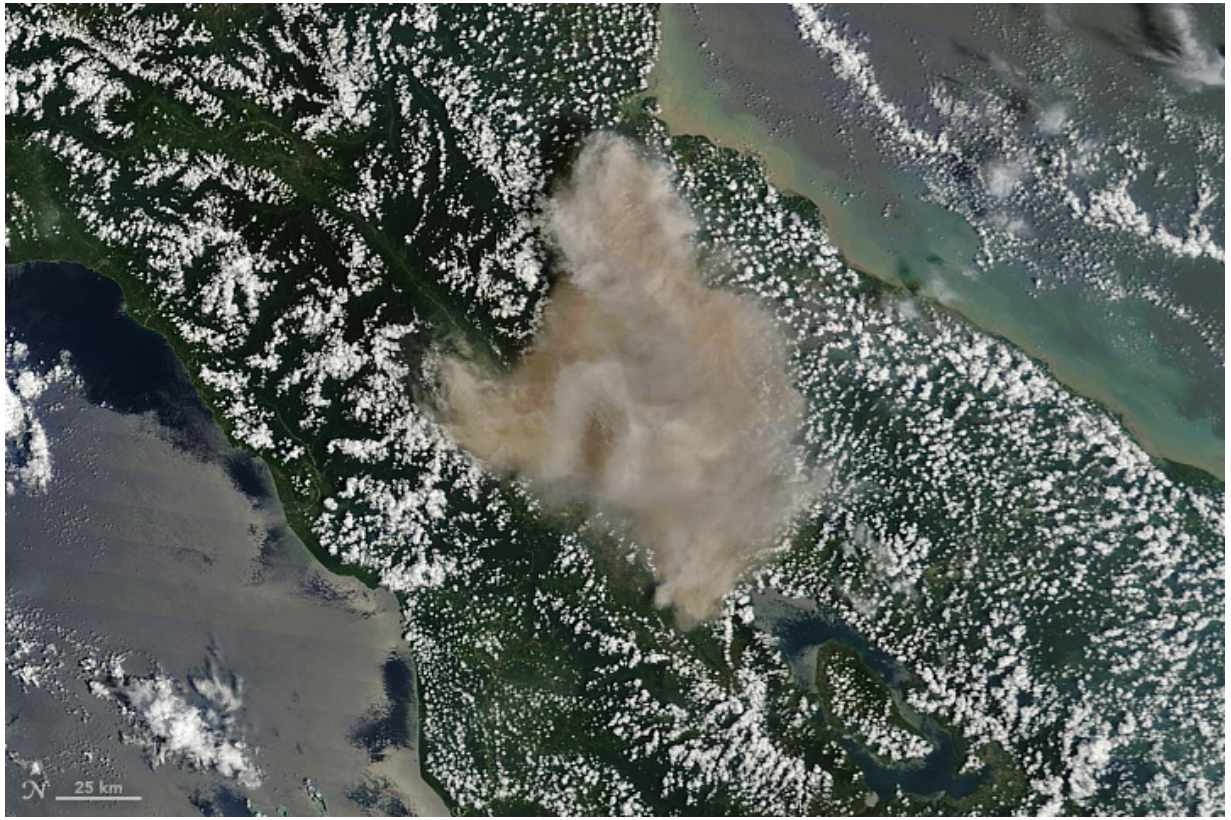
Clean Marine

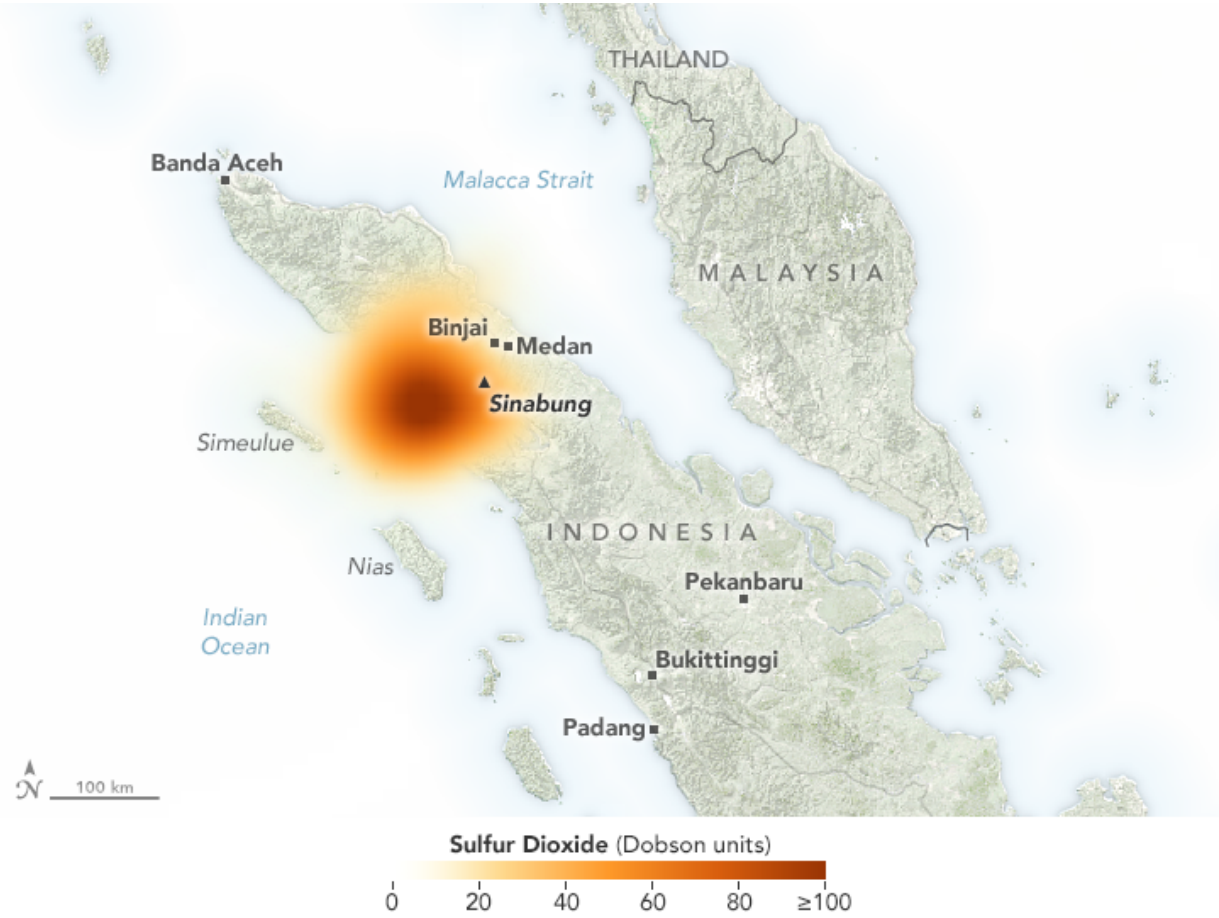


Aerosol sub-type indicates mixture of polluted dust, dust, volcanic ash, and elevated smoke

CALIPSO Curtains

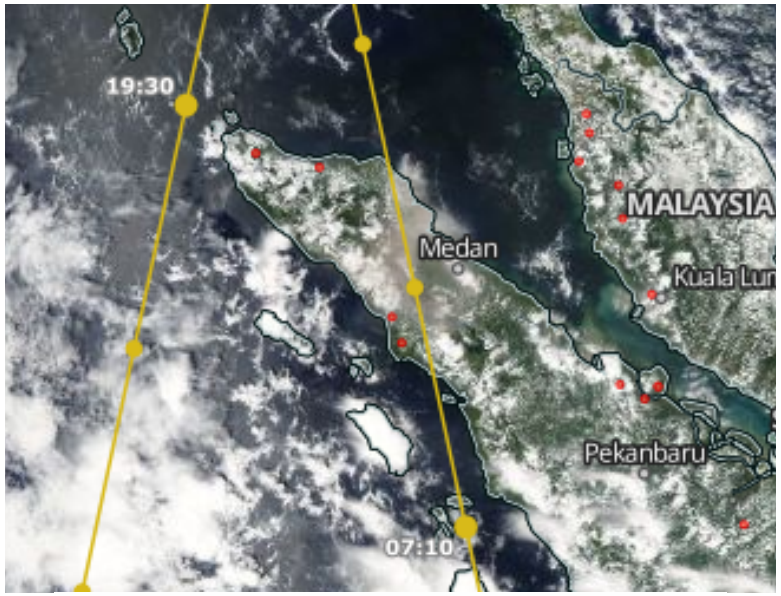
Mount Sinabung – 2/19/2018

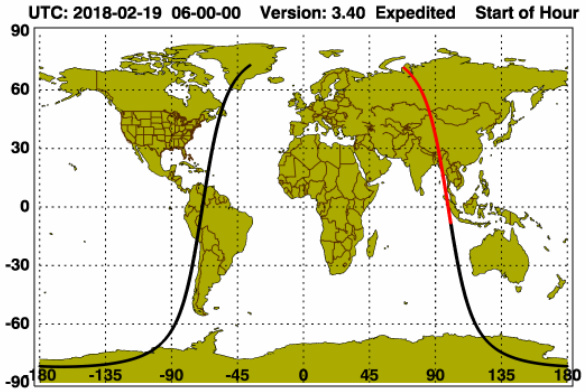


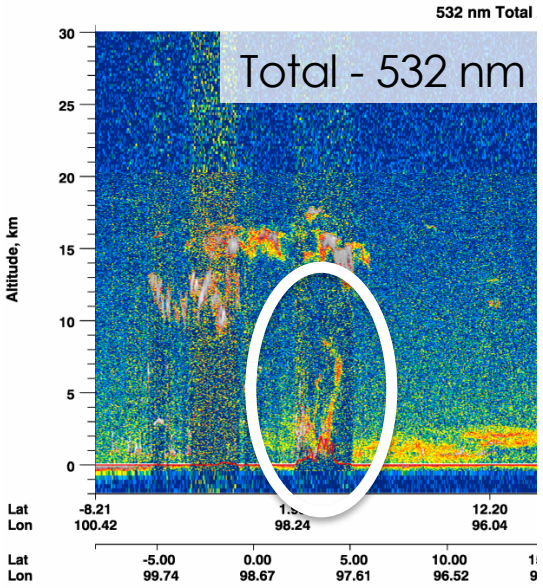


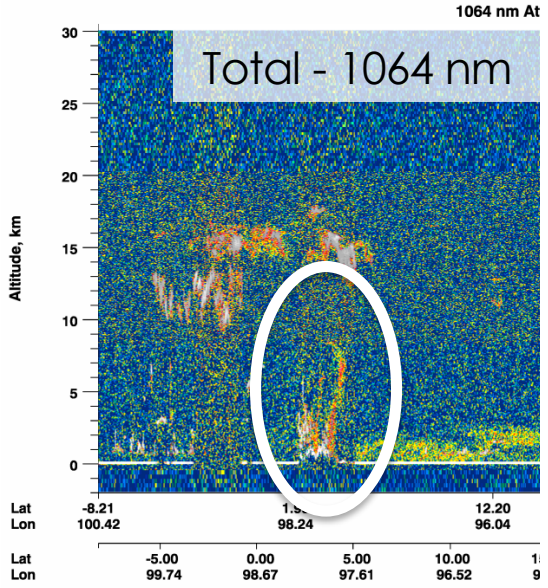
CALIPSO Curtains

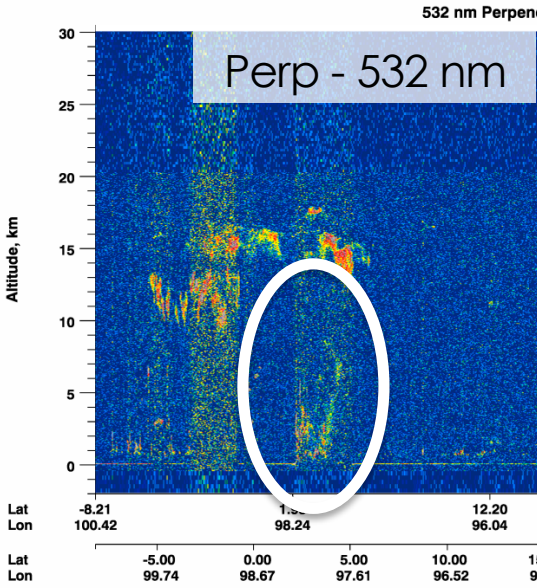
Mount Sinabung – 2/19/2018











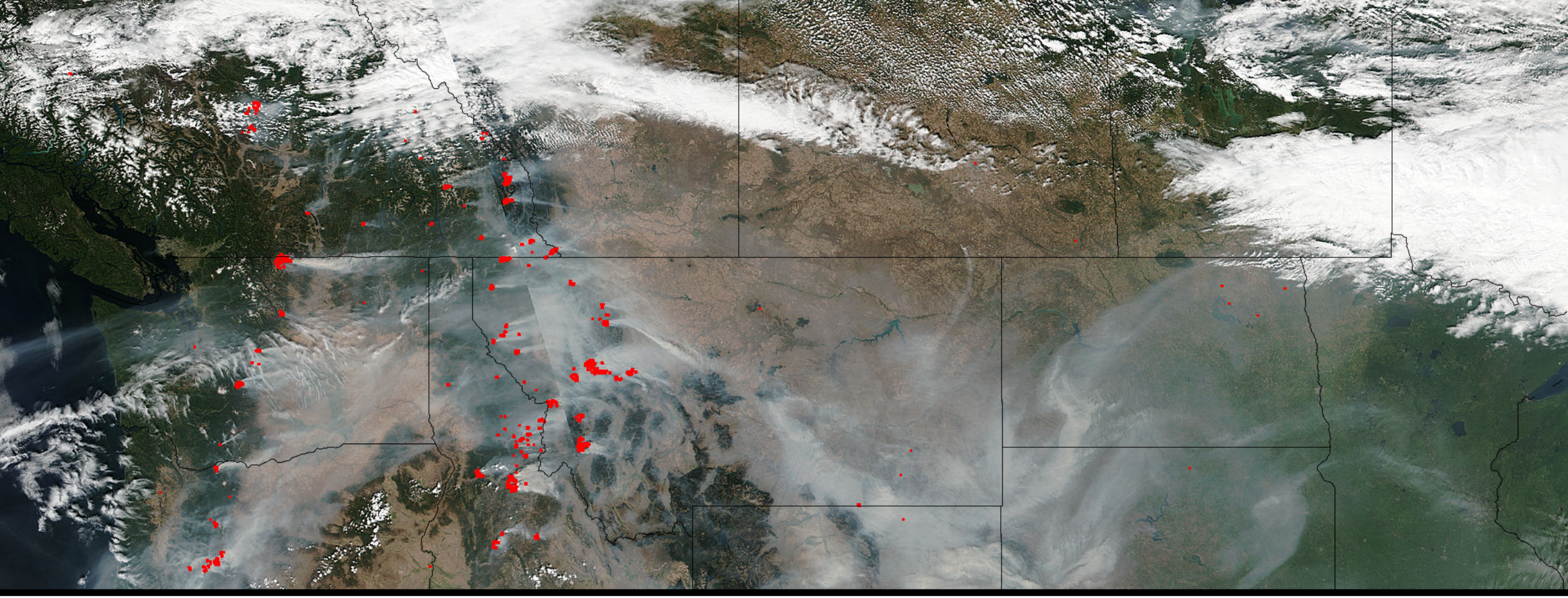
CALIPSO sees the volcanic plume:

- Larger particles
- Depolarizing (non-spherical)

Note: These are expedited release images

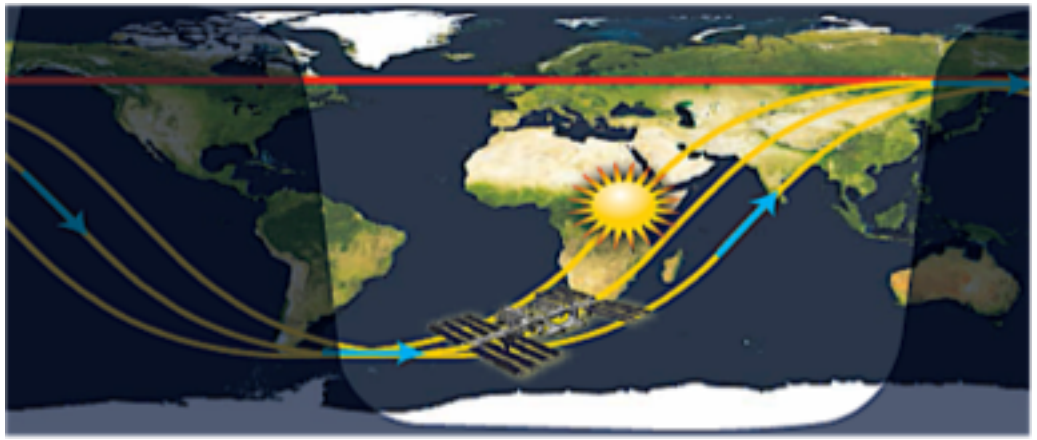
Further Information

- User Guide:
  - http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/
  - FAQ, Essential reading, Data Product Descriptions, Data quality summaries (V3.01), Example and tools, Order Data, Publications
- Data download:
  - http://eosweb.larc.nasa.gov/HBDOCS/langley_web_tool.html
  - http://www-calipso.larc.nasa.gov/search/ for subset files
  - For NRT data, there is expedited imagery released within 12 hrs: https://www-calipso.larc.nasa.gov/products/lidar/browse_images/show_calendar.php
  - Also contains Google Earth kmz files
  - When available, standard products should be used for detailed science analysis



CATS

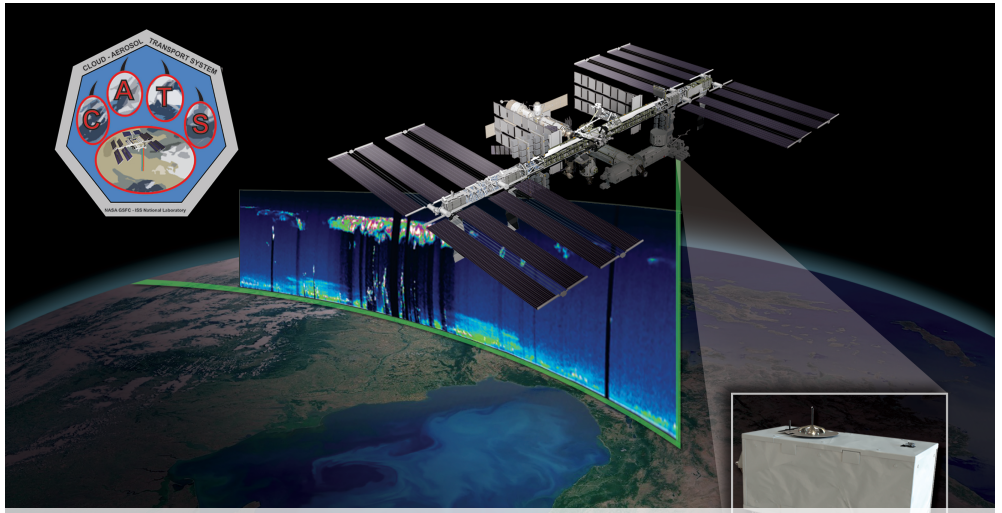
CATS Overview



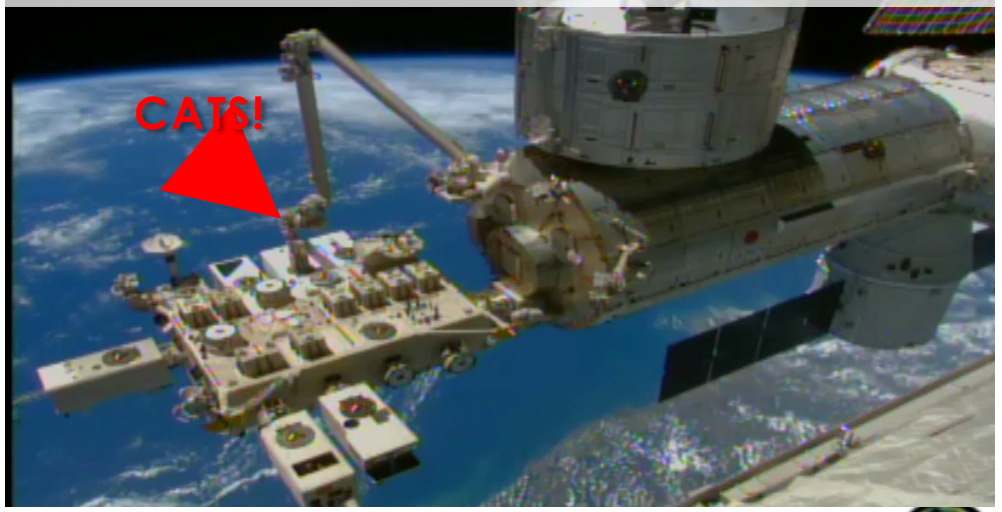
- Jan 2015 – 10/30/17
- Channels and wavelengths similar to CALIPSO (532, 1064 nm)
- CATS has operated in 2 modes
  - Mode 1: total attenuated backscatter & depolarization ratio at 532 & 1064 nm
  - Only operated from 2/11/15-3/21/15
  - Mode 2: total attenuated backscatter & depolarization ratio at 1064 nm
  - Mode of operation from 3/25/15 to present
- 14.38 m diameter footprint
- Due to lower orbit, revisit time, ~3 days

CATS Overview

- CATS - LIDAR using the ISS as an Earth Science platform designed to:
  - Complement the CALIPSO data record with diurnally varying cloud and aerosol vertical profiles
  - Monitor dynamic events such as wildfires and volcanic eruptions
  - Provide demonstration of technologies for future satellite missions



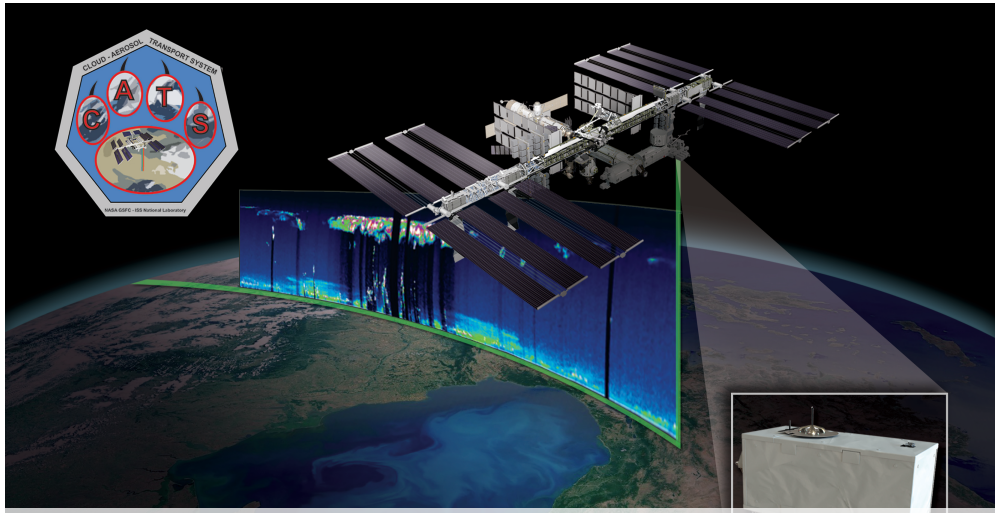
Cloud-Aerosol Transport System



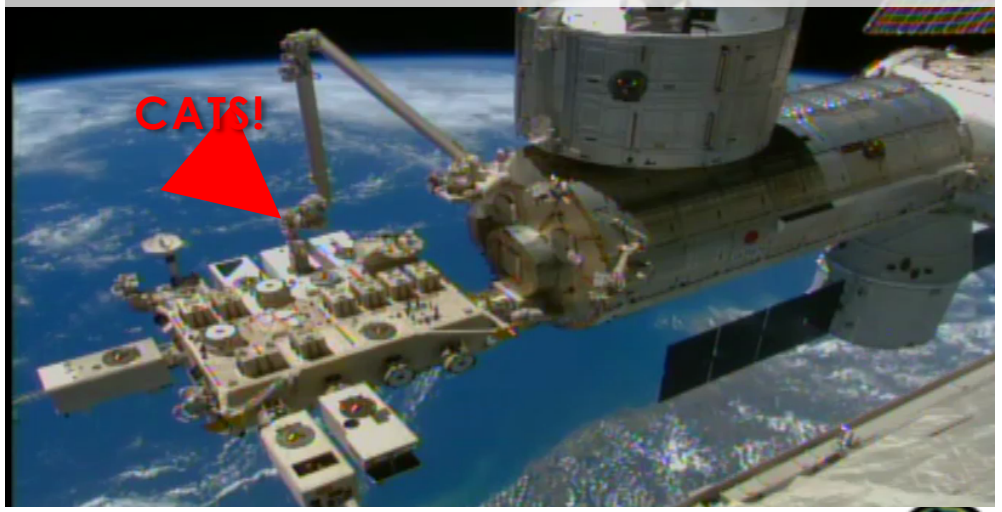
Slides and information kindly provided by John Yorks

CATS Overview

- CATS operated on the ISS for 2+ years and fired 150+ billion laser shots
- CATS near real-time data
  (6 hr latency) enabled applications such as:
  - Predicting/monitoring air quality during hazardous events (i.e. wildfires)
  - Forecasting volcanic plume transport that cost the airline industry billions of dollars



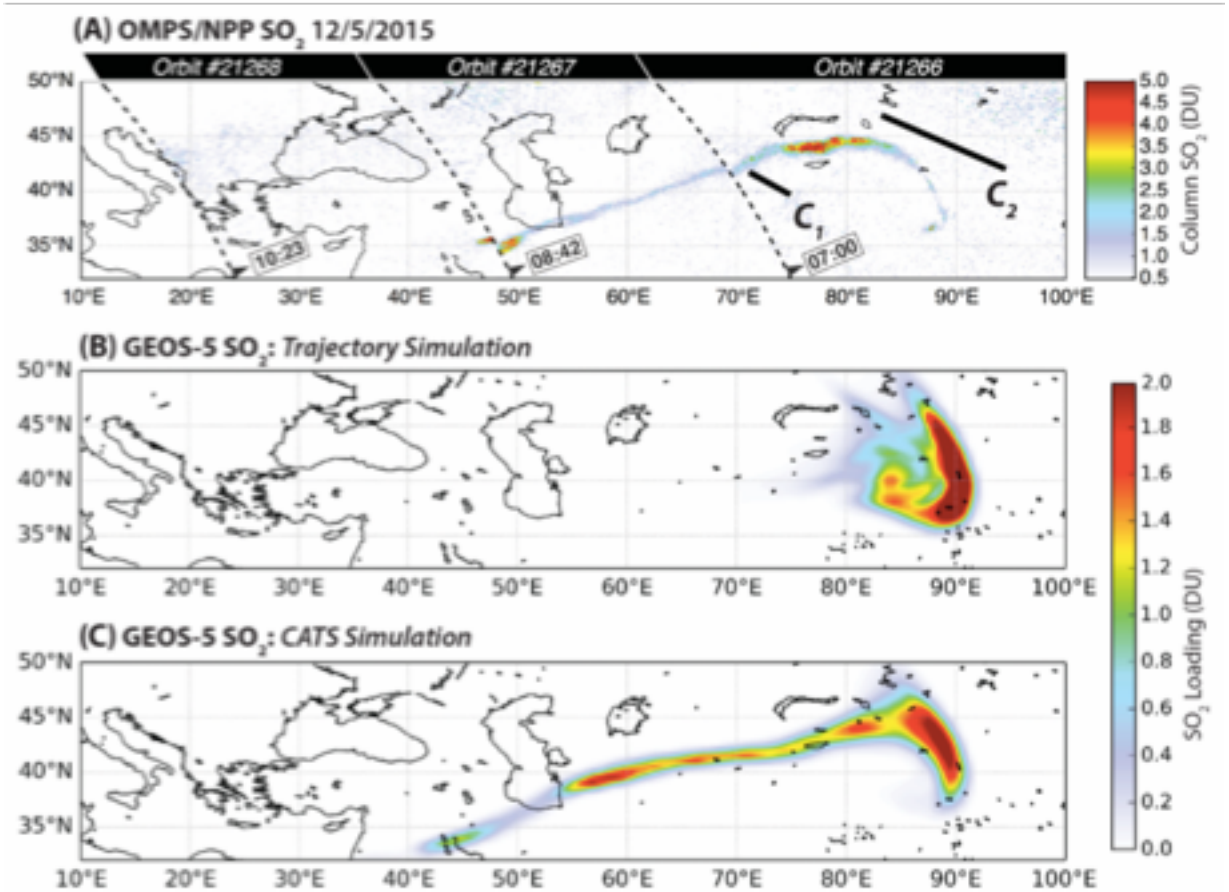
Cloud-Aerosol Transport System



Slides and information kindly provided by John Yorks

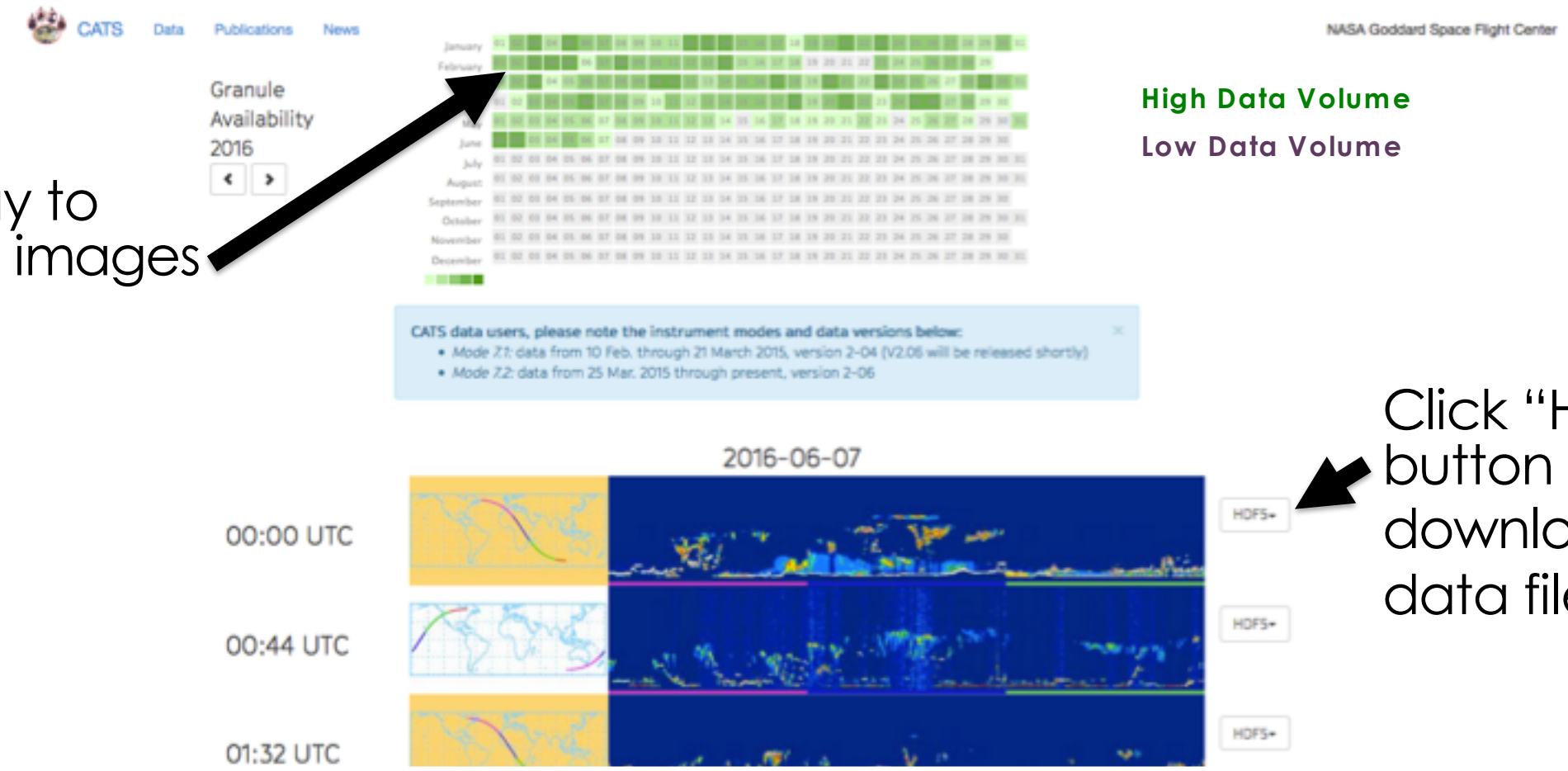
Forecasting Volcanic Plumes

- E. Hughes and N. Krotkov (GSFC) forecasted Etna SO_2 plume transport using GEOS-5/GOCART
- Forecast using CATS data to initiate volcanic plume injection height (C) agrees better with observations (A) than forecast using trajectory analysis (B)
- CATS NRT data provided an unprecedented opportunity to assimilate global lidar data into aerosol forecast models



CATS Data Availability

http://cats.gsfc.nasa.gov/data/browse



Pick day to browse images

Click "HDF5" button to download data file

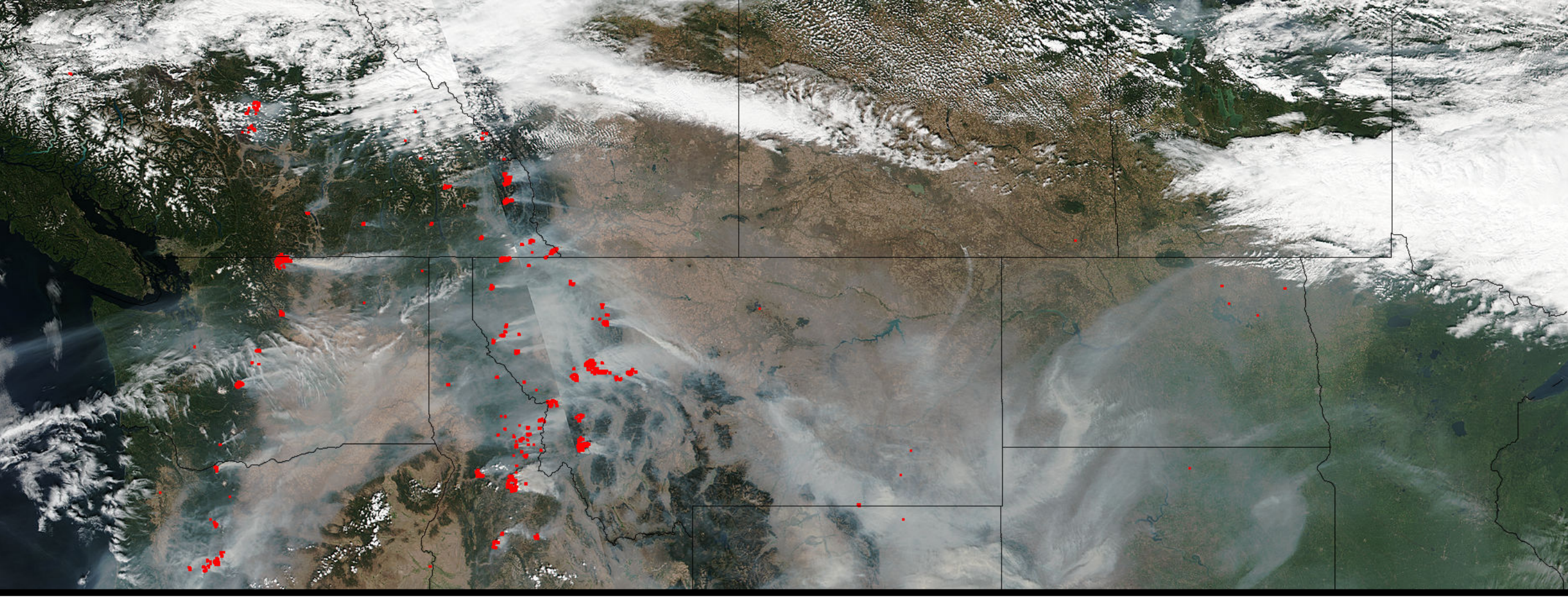
For CATS questions and data, contact John Yorks: john.e.yorks@nasa.gov

References

- Winker, D. M., W. H. Hunt, M. J. McGill, 2007. Initial performance assessment of CALIOP. Geophy. Res. Lett., 34, L19803, doi:10.1029/2007GL030135.
- Winker, D. M., M. A. Vaughn, A. Omar, Y. Hu, K. Powell, Z. Liu, W. Hunt, S. Young, 2009. Overview of the CALIPSO Mission and CALIOP Data Processing Algorithms. J. Atmos. Ocean. Technol., 26, 2310-2323, DOI: 10.1175/2009JTECHA1281.1.

Questions & Discussion Prompts

- What is an advantage of active remote sensing of aerosols?
- What information about aerosols can you learn when you have retrievals from multiple channels?
- Name an application of NRT active remote sensing of aerosols.



Questions?