Overview of CALIPSO and CATS

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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/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

<table>
<thead>
<tr>
<th>Version 3/4 Products</th>
<th>Primary Parameter</th>
<th>Resolution Due to Averaging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Horizontal</td>
</tr>
<tr>
<td><strong>Level 1</strong></td>
<td></td>
<td>1/3 km</td>
</tr>
<tr>
<td><strong>Measured</strong></td>
<td>Total_Attenuated_Backscatter_532</td>
<td></td>
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<tr>
<td></td>
<td>Perpendicular_Attenuated_Backscatter_532</td>
<td></td>
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<tr>
<td></td>
<td>Total_Attenuated_Backscatter_1064</td>
<td></td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td></td>
<td>1/3 km, 1, 5 km</td>
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<td><strong>Layer</strong></td>
<td>Cloud Layer_Top/Base_Altitude</td>
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<tr>
<td><strong>Retrieved</strong></td>
<td>Aerosol Layer_Top/Base_Altitude</td>
<td></td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td></td>
<td>5 km</td>
</tr>
<tr>
<td><strong>Profile</strong></td>
<td>Cloud and</td>
<td></td>
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<tr>
<td><strong>Retrieved</strong></td>
<td>AerosolTotal_Backscatter_Coefficient_532</td>
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<tr>
<td></td>
<td>Extinction_Coefficient_532</td>
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<tr>
<td><strong>Level 2</strong></td>
<td></td>
<td>5 km</td>
</tr>
<tr>
<td><strong>Vertical Feature</strong></td>
<td></td>
<td>5 km</td>
</tr>
<tr>
<td><strong>Mask</strong></td>
<td>Feature_Clarification_FLAGS</td>
<td></td>
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</tbody>
</table>
A CALIPSO Curtain Scene

- Tropopause: 12 km
- Free Troposphere: 1 km
- Planetary Boundary Layer
- Troposphere: 5 km - 10 km - 15 km - 20 km - 25 km
- 532 nm
- Clouds
- Aerosols
- Land
- PBL
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

- Smoke
- Polluted Dust
- Clean Continental
- Polluted Continental Dust
- Clean Marine

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/](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

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
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

Total attenuated backscatter – 532 nm

Perpendicular attenuated backscatter – 532 nm
CALIPSO Curtains

Biomass Burning – 8/15/2017

Total attenuated backscatter – 532 nm

Total attenuated backscatter – 1064 nm
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

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://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

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

Slides and information kindly provided by John Yorks
Forecasting Volcanic Plumes

- E. Hughes and N. Krotkov (GSFC) forecasted Etna SO2 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


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?