CATS Aerosol Typing and Future Directions

CATS GSFC TEAM
Matt McGill, John Yorks, Stan Scott, Stephen Palm,
Dennis Hlavka, William Hart, Ed Nowottnick,
Patrick Selmer, Andrew Kupchock, Natalie Midzak

CATS LaRC Team
Chip Trepte, Mark Vaughan, Sharon Rodier, Tim Murray, Mike Jensen

NASA GEOS-5 Collaborators
Peter Colarco, Arlindo da Silva, Virginie Buchard-Marchant
Overview

- CATS Mode 2 Aerosol Typing Algorithm
- Case Studies
- Known Issues, Challenges and Current Efforts
- CATS Mode 1 Aerosol Typing Algorithm
- Future Plans
- Getting CATS Data
Why do we need aerosol type?

- An extinction to backscatter ratio (lidar ratio) is needed to derive extinction products from observed backscatter.
- For standard backscatter lidars like CATS, lidar ratios are assigned for aerosol types.

1. The CATS feature detection algorithm first looks for regions of enhanced attenuated scattering ratios (observed to molecular) within a 5 km averaged profile.
2. Aerosol features are discriminated from cloud features using layer integrated total attenuated backscatter, integrated depolarization ratio, temperature, thickness, and color ratio (Mode 1 only).
CATS Mode 2 Aerosol Typing Overview

- Backscatter and Depolarization Ratio at 1064 nm
- Backscatter at 532 nm is very noisy and is not used in the algorithm
- For our version 1 Mode 2 aerosol typing, we rely on heritage from CALIOP

<table>
<thead>
<tr>
<th>Aerosol Type</th>
<th>1064 nm Lidar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>45</td>
</tr>
<tr>
<td>Dust</td>
<td>55</td>
</tr>
<tr>
<td>Dust Mixture</td>
<td>45</td>
</tr>
<tr>
<td>Clean/Background</td>
<td>35</td>
</tr>
<tr>
<td>Polluted Continental</td>
<td>35</td>
</tr>
<tr>
<td>Smoke</td>
<td>40</td>
</tr>
<tr>
<td>Volcanic Sulfate</td>
<td>35</td>
</tr>
</tbody>
</table>
CATS Mode 2 Aerosol Typing Overview

- Backscatter and Depolarization Ratio at 1064 nm
- Backscatter at 532 nm is very noisy and is not used in the algorithm
- For our version 1 Mode 2 aerosol typing, we rely on heritage from CALIOP

<table>
<thead>
<tr>
<th>Aerosol Type</th>
<th>1064 nm Lidar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>45</td>
</tr>
<tr>
<td>Dust</td>
<td>55</td>
</tr>
<tr>
<td>Dust Mixture</td>
<td>45</td>
</tr>
<tr>
<td>Clean/Background</td>
<td>35</td>
</tr>
<tr>
<td>Polluted Continental</td>
<td>35</td>
</tr>
<tr>
<td>Smoke</td>
<td>40</td>
</tr>
<tr>
<td>Volcanic Sulfate</td>
<td>35</td>
</tr>
</tbody>
</table>

Opportunity for models to help
CATS Mode 2 Aerosol Typing Algorithm

Inputs:
- Feature Integrated Depolarization Ratio at 1064 nm ($\delta'_{1064}$) averaged to 5 km horizontally
- Feature Integrated Total Attenuated Backscatter at 1064 nm ($\gamma'_{1064}$) averaged to 5 km horizontally
- Surface Type (for maritime)
- Feature Altitude

* Heritage from CALIOP aerosol typing algorithm
Case Study: Saharan Dust
Case Study: Saharan Dust
Case Study: Smoke over South America
Case Study: Smoke over South America
Case Study: Calbuco Eruption
Case Study: Calbuco Eruption
March 2015 – Present Aerosol Typing [0 – 2 km]
March 2015 – Present Aerosol Typing [1 – 2 km]
March 2015 – Present Aerosol Typing [1 – 2 km]
Known Issues: High Frequency of Dust Layers
Known Issues: High Frequency of Dust Layers

Currently refining feature finding and cloud – aerosol discrimination algorithms for cloudy/marine environments.
Known Issues: “Striping” within Aerosol Layers
Known Issues: Polluted Continental vs. Smoke Typing

- Differentiation between polluted continental and smoke type depends only on layer thickness and layer base altitude
- Can also lead to “striping” due to set thresholds in algorithm
- Plan to utilize simulated aerosols from the NASA GEOS – 5 AGCM to help classify non – depolarizing aerosol types
  - Aerosol Climatology (ex. MERRA2)
  - 1-D Var Assimilation (in development)
Challenges: Depolarizing Smoke

- Active Fires over Nebraska on 4/14/16
Challenges: Depolarizing Smoke

CATS Non-Spherical Smoke Detection Frequency: May-October 2015

CATS Depolarization Ratio Frequency

Depolarization <0.1
Depolarization >0.1

CATS Spherical Smoke Detection Frequency: May-October 2015

Courtesy of N. Midzak
CATS Mode 1 Overview

- Backscatter and Depolarization Ratio at 532 nm and 1064 nm
- 2 different fields of view (left + right)
- Utilize spectral depolarization ratio for aerosol typing

<table>
<thead>
<tr>
<th>Aerosol Type</th>
<th>532 nm Lidar Ratio</th>
<th>1064 nm Lidar Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>Polluted Marine</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>Dust</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Dust Mixture</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Clean/Background</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>Polluted Continental</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>Smoke</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>Volcanic</td>
<td>45</td>
<td>35</td>
</tr>
</tbody>
</table>

Mode 1: Multi-Beam

- Backscatter: 532, 1064 nm
- Depolarization: 532, 1064 nm
- L2 Products: 532, 1064 nm

CATS Mode 1
Aerosol Typing Algorithm

Inputs:
- Feature Integrated Depolarization Ratio at 1064 nm ($\delta'_{1064}$) averaged to 5 km horizontally
- Feature Integrated Total Attenuated Backscatter at 1064 nm ($\gamma'_{1064}$) averaged to 5 km horizontally
- Surface Type (for maritime)
- Feature Altitude
- Feature Integrated Spectral Depolarization Ratio
Status of CATS Level 2 and Plans for the Future:

Version 1 Aerosol Typing (ongoing):
  - Mode 1:
    - L1B data released later this summer
    - L2 data released shortly after
      - Identify algorithm biases (ex. striping, FOV biases)
  - Mode 2:
    - Processed & Released
      - Currently working on correcting algorithm issues

Version 2 Aerosol Typing (Fall, 2016):
  - Implementation of version 1 modifications
  - Integrate GEOS-5 aerosols for typing guidance for non-spherical aerosols

Version 3 Aerosol Typing (2017):
  - Implementation of 1-D Var Assimilation into GEOS-5
    - “Dynamic” lidar ratio that will evolve in conjunction with simulated aerosol mixtures
Field Campaign Support:
April – May, 2016

June 2016 - Present

Starting Fall 2016

Contacts:
John Yorks – john.e.yorks@nasa.gov
Ed Nowottnick – edward.p.nowottnick@nasa.gov
Getting CATS Data:

https://cats.gsfc.nasa.gov

Cloud-Aerosol Transport System (CATS)

The Cloud-Aerosol Transport System (CATS), launched in January of 2015, is a lidar remote sensing instrument that will provide range-resolved profile measurements of atmospheric aerosols and clouds from the International Space Station (ISS). CATS is intended to operate on-orbit for at least six months, and up to three years.

<table>
<thead>
<tr>
<th>Operation Status</th>
<th>Data &amp; Browse Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image of the Week</td>
<td>CATS Brochure [PDF]</td>
</tr>
</tbody>
</table>
Getting CATS Data:

https://cats.gsfc.nasa.gov

NRT HDF5 Files

Quick Look Images

CATS data users, please note the instrument modes and data versions below:

- Mode 7.1: data from 10 Feb. through 21 March 2015, version 2-04 (V2.06 will be released shortly)
- Mode 7.2: data from 25 Mar. 2015 through present, version 2-06
Getting CATS Data:

https://eosweb.larc.nasa.gov/project/cats/

Cloud-Aerosol Transport System (CATS)

Data and Information

The Cloud-Aerosol Transport System (CATS$^5$), is a lidar remote sensing instrument that will provide range-resolved profile measurements of atmospheric aerosols and clouds from the International Space Station (ISS).

CATS will provide vertical profiles at three wavelengths, orbiting between ~230 and ~270 miles above the Earth's surface at a 51-degree inclination with nearly a three-day repeat cycle. For the first time, it will allow scientist to study diurnal (day-to-night) changes in cloud and aerosol effects from space by observing the same spot on Earth at different times each day.

<table>
<thead>
<tr>
<th>Product Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2</td>
<td>L1B files that are run through the new operational CATS L2 algorithm, which will include new capabilities. Includes geophysical parameters, such as the vertical feature mask, profiles of cloud and aerosol properties and layer-integrated parameters.</td>
</tr>
<tr>
<td>Level 1B</td>
<td>L1A data that have been calibrated, annotated with ancillary meteorological data, and processed to sensor units.</td>
</tr>
</tbody>
</table>