New Approach for $PM_{2.5}$ Retrievals using CATS Lidar and GEOS-5 Model Data Assimilation

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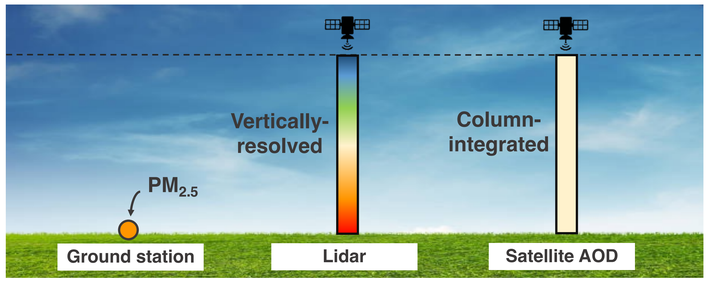
Motivation

Satellites help monitor fine particulate matter ($PM_{2.5}$) where station data are limited. However, satellite estimates using aerosol optical depth are uncertain due to a lack of vertical information.
Spaceborne lidar provides complementary vertical observations critical to fill missing data gaps and improve accuracy in $PM_{2.5}$ retrievals.



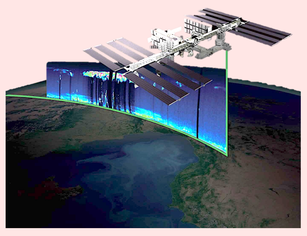
***Goal:** To improve $PM_{2.5}$ retrievals by assimilating lidar data that better constrain vertical aerosol distributions.*

Datasets

CATS Lidar

The Cloud-Aerosol Transport System (CATS) is a backscatter lidar aboard the ISS, providing vertical measurements of clouds and aerosols.

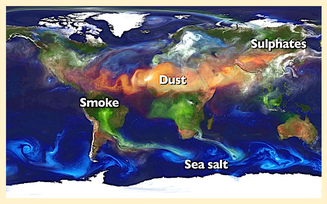
- Operational Feb 2015–Oct 2017
- Spatial coverage over ±51°
- Backscatter, depol at 1064 nm
- L1B total attenuated backscatter
- 350 m horizontal resolution
- 60 m vertical resolution



GEOS-5 Model

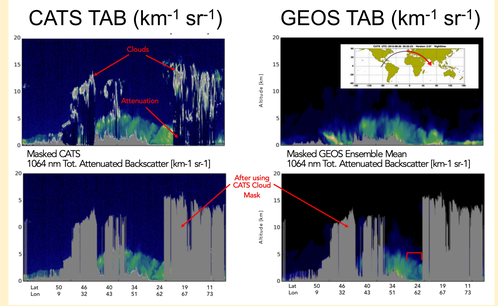
The GEOS-5 atmospheric general circulation model is developed by the NASA GMAO, providing high-resolution global simulations of weather and climate.

- Assimilates meteorology and aerosols with GOCART module
- 15 species: dust, SS, BC, OC
- 32 ensemble members
- 50 km horizontal resolution
- 72 vertical hybrid-sigma levels



Methodology

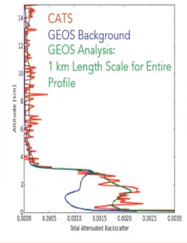
① Mask all profiles with cloud attenuation and re-grid GEOS to CATS resolution.



② Perform 1-D EnsVar assimilation to retrieve profiles of aerosol extinction.

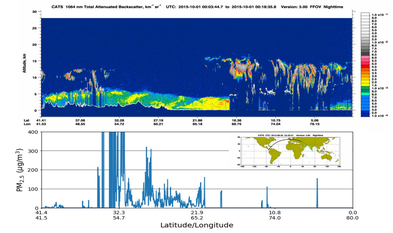
$$x = x_0 + \left(\frac{PH^T}{HPH^T + R}\right)(y - Hx_0)$$

x	= Predicted extinction
x_0	= GEOS 1064nm extinction
H	= Linear operator
P	= GEOS error covariance
R	= CATS error covariance
y	= CATS 1064nm TAB



③ Convert retrieved speciated mass to total surface concentration, $PM_{2.5}$.

$$PM_{2.5} = [DU_{2.5}] + [SS_{2.5}] + [BC] + 1.4 \times [OC] + 1.375 \times [SO_4]$$



Results

Case Studies

Observed
CATS 1064 Backscatter

Modeled
GEOS Aerosol Extinction

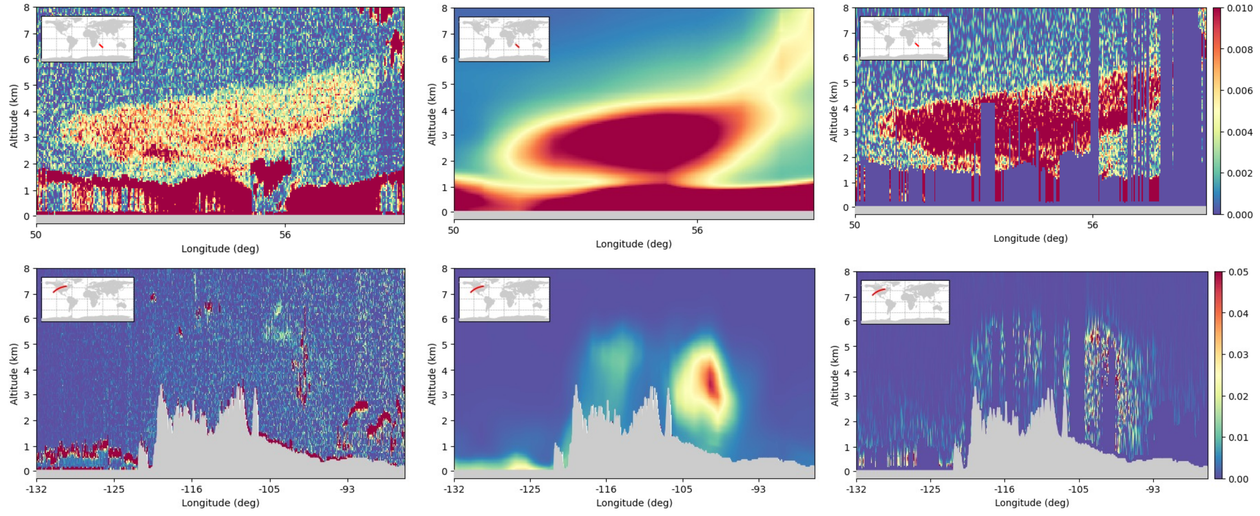
Predicted
Retrieved Aerosol Extinction

Case #1: Polluted dust

- A plume of polluted dust was detected near Madagascar
- Aerosol extinction is retrieved using data assimilation
- CATS improves height and extent in the model analysis

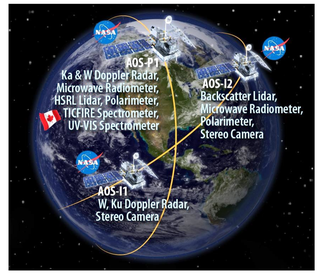
Case #2: Wildfire smoke

- CATS observed smoke layers over the western US in 2016
- Aerosol extinction profile was retrieved over cloudy skies
- Analysis show an enhanced aerosol vertical structure



Conclusions

Here, we present a new approach to retrieve fine particulate matter ($PM_{2.5}$) concentrations by assimilating CATS lidar data with the GEOS-5 global aerosol model. This study demonstrates the unique capabilities of spaceborne lidar for near real-time monitoring of surface air quality. Results presented may provide utility in other applications as well, including establishing constraints for aerosol transport models, improving passive satellite retrievals of $PM_{2.5}$, and developing data assimilation techniques for future lidar platforms.



Acknowledgements

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CATS Lidar: https://cats.gsfc.nasa.gov
GEOS Model: https://gmao.gsfc.nasa.gov/GEOS
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