1. Introduction
From February 2015 through October 2017, the NASA Cloud-Aerosol Transport System (CATS) backscatter lidar operated on the International Space Station (ISS) as a technology demonstration for future Earth Science Missions, providing vertical measurements of cloud and aerosol properties. Owing to its location on the ISS, a cornerstone technology demonstration of CATS was the capability to acquire, process, and disseminate near-real-time (NRT) data within 6 hours of observation time. CATS NRT data has several applications, including providing notification of hazardous events for air traffic control and air quality advisories, field campaign flight planning, as well as for constraining cloud and aerosol distributions in via data assimilation in aerosol transport models.

Recent developments in aerosol data assimilation techniques have permitted the assimilation of aerosol optical thickness (AOT), a two-dimensional column integrated quantity that is reflective of the simulated aerosol loading in aerosol transport models. While this capability has greatly improved existing AOT forecasts, the vertical position, a key control on aerosol transport, is often not impacted when 2-D AOT is assimilated. Here, we present preliminary efforts to assimilate CATS aerosol observations into the NASA Goddard Earth Observing System version 5 (GEOS-5) atmospheric general circulation model and assimilation system using a 1-D Variational (1-D VAR) ensemble approach, demonstrating the utility of CATS for future Earth Science Missions.

4. 1-D VAR Ensemble Approach

Step 1: Use CATS level 2 observations to mask out profiles containing clouds and any profiles affected by attenuated beneath clouds. Then, regrid GEOS-5 ensemble mean and members to CATS grid.


Step 3: Perform analysis for each CATS profile.

5. Applications for Improved Aerosol Typing
For standard backscatter lidars, such as CATS, an aerosol typing algorithm is used to assign an extinction-to-backscatter or lidar ratio to an aerosol layer for converting observed backscatter to extinction products. Aerosol types are a function of observed quantities (e.g. depolarization ratio) and often other ancilla information such as surface type. Errors in defining an aerosol type can have dramatic implications for extinction, as lidar ratios can vary by as much as a factor of 3. By adapting our 1-D VAR assimilation technique to constrain the vertical distribution for each aerosol species simulated in GEOS-5, an aerosol vertical feature mask can be determined yielding a dynamic lidar ratio that is a function of the simulated mixture aerosol.

6. Considerations for Extinction
A limitation of using total attenuated backscatter is that it is impacted by attenuation effects from above, which reduces the aerosol signal and has implications for computing the background error covariance with vertical localization. Here, we construct our background error covariance matrix using aerosol extinction perturbations from GEOS-5 ensemble members with vertical localization, avoiding the effects of attenuation. This method is a more appropriate way for constructing the background error covariance matrix and still yields improved vertical aerosol structure in the GEOS-5 analysis.

7. Summary and Future Work
CATS NRT data downlinking capabilities have provided an opportunity for developing a 1-D VAR ensemble approach for assimilating spaceborne lidar profiles of total attenuated backscatter into NASA GEOS-5 aerosol forecasts:

- After performing a 1-D ensemble assimilation with vertical localization of cloud-free profiles, the GEOS-5 analysis drew the observed total attenuated backscatter from CATS.
- We explored the impacts of varying the vertical localization length scale for the aerosol mixed planetary boundary layer and the free troposphere.
- After assimilating a segment of a CATS gramine, the structure of an aerosol layer over the Arabian Sea was better resolved in the GEOS-5 analysis for both total attenuated backscatter and extinction.
- Applying our assimilation technique to vertically constrain the individual species simulated in GEOS-5 yields an aerosol feature mask that produces a dynamic lidar ratio that evolves in conjunction with simulated aerosol mixtures.
- To do:
  - Explore horizontal localization to enable assimilation in profiles impacted by clouds/attenuation
  - Address “noisy” analysis increments in the free troposphere where both CATS and GEOS-5 aerosol loadings are low.