Assessing Aerosol Data Assimilation Products Using DIAL/HSRL Measurements

Richard Ferrare¹, John Hair¹, Sharon Burton¹, Anthony Notari¹
Chris Hostetler¹, Syed Ismail¹, Amin Nehrir¹, Carolyn Butler²,
James Collins², Marta Fenn², Amy Jo Scarino², Cynthia Randles³,
Pete Colarco³, Arlindo daSilva³, James Campbell⁴,
Angela Benedetti⁵, Samuel Remy⁵

¹NASA Langley Research Center, Hampton, VA USA
²SSAI, Hampton, VA USA
³NASA Goddard Space Flight Center, Greenbelt, MD USA
⁴U.S. Naval Research Laboratory, Monterey, CA USA
⁵ECMWF, Shinfield Park, Reading Berkshire, UK
Ozone Differential Absorption Lidar (DIAL) and NASA SEAC4RS Aerosol/Cloud High Spectral Resolution Lidar (HSRL)

NASA DC-8 SEAC4RS Field Mission

Profile Measurements:
- Aerosol Extinction (532nm)
- Layer AOT, AOT at 532nm (from aircraft altitude)
- Aerosol/Cloud Backscatter (532, 1064nm)
- Backscatter Color Ratio (1064/532nm)
- Lidar Ratio (extinction/backscatter) (532nm)
- Aerosol/Cloud Depolarization (532, 1064nm)
- Spectral Depolarization Ratio (1064/532nm)
- Mixed Layer Heights
DIAL/ HSRL AOT comparison with AERONET

- AOT derived from DIAL/HSRL nadir data when DC-8 flew at or above 5 km
- AOT compared with AERONET level 2.0 AOT within 15 km, 30 min
- DIAL/HSRL AOT slightly lower than AERONET, possibly due to AOT not included above (> 5 km) or below (<150 m) profile

AERONET data – thanks to Brent Holben, Rick Wagener, Joe Shaw, Kevin Repasky, Kevin Knupp, Doug Moore
DIAL/ HSRL Comparisons with GEOS-5 During SEAC4RS
GEOS-5 Atmospheric Data Assimilation System

- GEOS-5 Earth Modeling System, GOCART aerosol module
- Five non-interactive species - dust, sea salt, BC, OC, sulfate
- Convective and large scale wet removal
- Dry deposition and sedimentation
- Optics based on OPAC model (Nonspherical Dust) from Colarco; Kim
- Fire emissions - Quick Fire Emission Dataset (QFED)
  - Based on MODIS Fire Radiative Power
  - Emission factors tuned using MODIS AOT
  - Daily mean emissions
- Aerosol Data Assimilation
  - Terra/Aqua MODIS AOT
  - MISR AOT over bright surfaces
- Resolution
  - Horizontal: 25 km
  - Vertical: 72 layers
- PBL heights defined when diffusion coefficient falls below threshold

**GEOS-5 3-hourly results from SEAC4RS reanalysis are examined here**

(more info in Randles et al. talk A52A-05 Friday AM)
SEAC4RS Aug. 19, 2013  DIAL/ HSRL Smoke flight over Midwest

DIAL/ HSRL

Backscatter Ang. Expo. (1064/532)

Aerosol Depol (532 nm)

GEOS-5

Extinction (532 nm)

Lidar Ratio

~2000 km

Aerosol Depol (532 nm)
GEOS-5 shows slightly higher backscatter and extinction in free troposphere.

SEAC4RS Aerosol Backscatter 532 nm all cases

SEAC4RS Aerosol Extinction 532 nm all cases
DIAL/ HSRL and GEOS-5 Median Intensive Parameter Profiles During SEAC4RS

- Both DIAL/HSRL and GEOS-5 intensive parameters vary with altitude suggesting aerosol type varies with altitude
- Backscatter Angstrom exponent increasing with altitude suggests decreasing particle size with height
- GOES-5 lidar ratio higher than DIAL/HSRL
- DIAL/HSRL measured more nonspherical particles (i.e. dust) near the surface than represented by GEOS-5
Comparisons of HSRL and GEOS-5 Boundary Layer Heights
Comparison of Boundary Layer Heights from HSRL-2 and GEOS-5 during DISCOVER-AQ

- HSRL-2 boundary layer heights from aerosol backscatter gradients
- GEOS-5 boundary layer heights from thermal diffusivity and aerosol backscatter gradients were about 450-500 m higher than those derived from HSRL-2 and DIAL/HSRL

(see Scarino et al., poster A31C-3040 Wed. AM for more details)
Comparison of Boundary Layer Heights from HSRL-2 and GEOS-5 during SEAC4RS

- DIAL/HSRL boundary layer heights from aerosol backscatter gradients
- GEOS-5 boundary layer heights from thermal diffusivity and aerosol backscatter gradients were about 500-600 m higher than those derived from HSRL-2 and DIAL/HSRL
DIAL/ HSRL Comparisons with ECMWF/ MACC During SEAC4RS
ECMWF/ MACC-II Model

- Monitoring Atmospheric Composition and Climate-Interim Implementation (MACC-II) Model
  - Provides information regarding air quality, global atmospheric composition, climate forcing, solar energy
  - Consumers include WMO, EPA and European Centers, weather services, solar irradiance forecast groups, field campaigns
- Aerosol model has components for dust, sea salt, organic matter, black carbon, sulfate
- Eleven prognostic aerosol variables and one for SO₂
- Aerosol sources taken from
  - Quick Fire Emission Dataset (QFED)
  - Speciated Particulate Emission Wizard (SPEW)
  - Emission Database for Global Atmospheric Research (EDGAR)
- Resolution
  - Horizontal: T255 (~80 km)
  - Vertical: 60 layers
- Aerosol Data Assimilation
  - Terra/Aqua MODIS AOT
  - Working towards assimilation of CALIOP aerosol profiles
- MACC-II 3-hourly results from reanalysis are examined here

SEAC4RS DIAL/ HSRL data used to examine impacts of:
  - Assimilation of CALIOP data
  - Increased model resolution
  - Plume rise model impact on smoke injection heights
Example: Comparison of Aerosol Extinction Profiles for August 19 Flight

DIAL/HSRL

MACC-II
MODIS assimilation only

MACC-II
MODIS and CALIOP assimilation
Comparison of Median Profiles with and without CALIOP assimilation

- Only small effects on median profiles
- Tend to lower the AOT with respect to runs that assimilate only MODIS AOT
Impact of plume rise model smoke injection heights

- Injection heights for smoke emissions are estimated using Plume rise model (Paugam et al., 2015, in preparation, based on Freitas et al., 2007), and Sofiev's parameterization (Sofiev et al., 2012).
- This plume rise model uses MODIS FRP and modelled atmospheric profiles with a shallow convection scheme to represent detrainment from fire plume.
- Initial comparisons show that both aerosol extinction and AOT increase throughout the profile, not necessarily at smoke height shown in DIAL/HSRL profile.
Impact of MODIS assimilation

- Assimilation of MODIS AOT significantly reduces aerosol extinction profiles in some sections of these flights.
- Reductions in aerosol extinction vary with altitude.
Impact of Higher Model Resolution

- Model resolution increased from T255 (80 km) to T1279 (16 km)
- Higher resolution seems to do better at representing smoke altitude than MODIS assimilation or plume rise model
Summary

- HSRL measurements of aerosol extensive and intensive parameters provide additional constraints for developing and assessing models
  - On average, GEOS-5 profiles of aerosol extinction and backscatter are in good agreement with HSRL measurements
  - GEOS-5 simulations of aerosol depolarization are biased low
  - Both GEOS-5 and airborne HSRL data show aerosol intensive properties vary with altitude during SEAC4RS
  - GEOS-5 Boundary layer heights during DISCOVER-AQ Houston are biased 500 m high relative to boundary layer heights derived from airborne lidar data
  - Median ECMWF/MACC model extinction profile in agreement with median DIAL/HSRL profile
  - Initial comparisons show increased model resolution does a better in representing smoke heights