Observation of Smoke and Dust Plume Transport and Impact on the Air Quality Remote Sensing in New York City

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1. Motivation

- Wild fires and dust storms inject large amount of aerosols that can be transported in the long distance.
  -- Influences on air quality in the local, regional and continental scales; challenge for modeling and local emission management by EPA.

- Potential effects on cloud formation, radiation and climate.
  -- Dust as ice nuclei (IN), biomass burning aerosols as IN or CCN of clouds.

- An issue for satellite remote sensing of air quality, e.g. using aerosol optical depth (AOD) to estimate ground PM\(_{2.5}\).
  -- Aloft plumes or plumes mixing down to PBL and surface.

- This study focuses on:
  -- Cases: smoke & dust vertical distribution, optical properties and types.
  -- Climatology: monthly occurrence and transport paths.
    Quantify the influences on local aerosol optical properties, PM\(_{2.5}\), and correlation of column AOD-PM\(_{2.5}\).
2. Ground-based aerosol/cloud remote sensing testbed at CCNY

a. A multi-wavelength Mie-Raman Lidar

- 1064,532,355,387, 407-nm, 3-elastic & 2-Raman channels
- Vertical distribution of aerosol, cloud and water vapor;
- Aerosol optical properties: extinction/backscatter, Angstrom exponent, lidar-ratio, PBL-top;
- 2-3 day/week daytime run (10:00 ~ 18:00 EDT)

b. A Ceilometer (Vaisala CL31/51)

- near surface aerosol and cloud height up to 7.5km;
- 24-hr/7-day automatic run.

c. A CIMEL sunphotometer (SP) (AERONET-CCNY)

- AOD at 8-wavelength 340~1064nm, Angstrom exponent;
- Inversion data (volume size distribution, refractive index, single-scattering-albedo).

d. Air quality monitoring station

- NYDEC: PM$_{2.5}$, O$_3$, CO

e. Multi-filter shadow band radiometer (MFR-07)

f. Microwave radiometer (MWR-3000a, T, RH, liquid water)

g. Wind Doppler lidar
3. Results: Snapshots of aloft aerosol plumes in 2012

Aloft aerosol plumes (yellow) on the different days and seasons

Spring

Summer

Fall
(1) Case: Summer haze related to wildfire smoke transport

Levels of PM 2.5 in the NY Metropolitan Area

- **NYC urban**
- NAAQS $35 \mu g/m^3$

EPA-PM$_{2.5}$ stations

Levels of PM 2.5 in NY/NJ/LI

- **NYC up- & downwind nonurban**

Angstrom exp = $\sim 2$, fine mode smoke particles

$AOD=0.4$ at 532-nm

Aerosol plume

Aloft aerosols plume
Transport path and source by model and satellite

Mean AOD from MODIS/Aqua
June 7-12

NOAA GASP-AOD on June 12

http://www.ssd.noaa.gov/PS/FIRE/GASP/gasp.html
Case: Asian dust (coarse-mode dominated) long-range transport

Aloft plume: 70~80% to total AOD (0.3~0.5)
Angstrom exp. ~1.0 (coarse mode)

OMPS AI over VIIRS RGB image

Siberian fire smoke

Asian dust

NOAA HYSPLIT MODEL
Backward trajectories ending at 1800 UTC 21 Apr 15
GDAS Meteorological Data

PBL aerosol

7-day duration
Depolarization ratio and color-ratio in the East US by CALIPSO
---Coarse mode and nonspheric particles dominated (Dust-like)
(2) Climatology analysis: Range-resolved monthly occurrence

- Define an aloft-aerosol-layer event: height > PBL-top, geometric depth $\Delta z > 300$-m
- Duration time $T \geq 3$-hr

- Occurrence frequency during 2006-2013: Aloft-plume-day/tot-lidar-day
- Total days count per month > 20; plume days >10 per month

- **Main occurrence:** March to Sep., $Z < 8$-km, low in summer, high in Mar-Apr
Six clusters of transport paths at 4-km level and 72-hr long duration.

- **Cluster-2**: higher AE and SSA, but smaller $R_{\text{eff}}$. Fine mode and non-absorbing aerosol: industrial aerosols such as sulfate, nitrate.
- **Cluster-6**: Smaller AE and large $R_{\text{eff}}$, but higher SSA. Coarse-mode Asian dust.
- **Cluster 1, 3, 4**: Smaller SSA and $R_{\text{eff}}$ (fine-mode absorbing aerosols: smoke)
- **Cluster-5**: mixture of smoke and dust.
(4) Transport influence on local PM$_{2.5}$ (mixing-down vs. clear skies)

- Mean PM2.5 over the days of plume mixing down into PBL or clear/nonmixing down skies.
- Increase by 3~5 µg/m$^3$ on average during the mixing down days (2007-2013, summer).
- Similar trends at other upwind sites.
(5) Aloft plume influence on MODIS-AOD and PM$_{2.5}$ correlation

- Identify aerosol-transport events from the lidar profiles.
- Evaluate the AOD-PM$_{2.5}$ correlation in NYC during the clear sky and aloft-plume days during summer, 2006-2013.
- Linear correlation $R^2$ increases from 0.39 (aloft plume) to 0.72 (clear skies).
- Regression linear slope increases from 29.6 (aloft plume) to 40.9 (clear skies).
4. SUMMARY


- Increase of the ground PM$_{2.5}$ on those plume mixing-down into PBL. Enhance correlation and linear regression slope between the AOD-PM$_{2.5}$ when filtering out the aloft aerosols.

- Near-term plans: add a depolarized channel for discriminating dust/smoke aerosol; combine lidar-SP-LiRIC retrieving aerosol mass profiles.
Thanks for your attention!

Comments and Questions?

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