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

Yonghua Wu*, **Chowdhury Nazmi, Cuiya Li, Daniel Hoyos, Barry Gross, Fred Moshary**

*NOAA-CREST and Optical Remote Sensing Lab, City College of New York (CCNY), NY 10031, USA. *Email: yhwu@ccny.cuny.edu*

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).

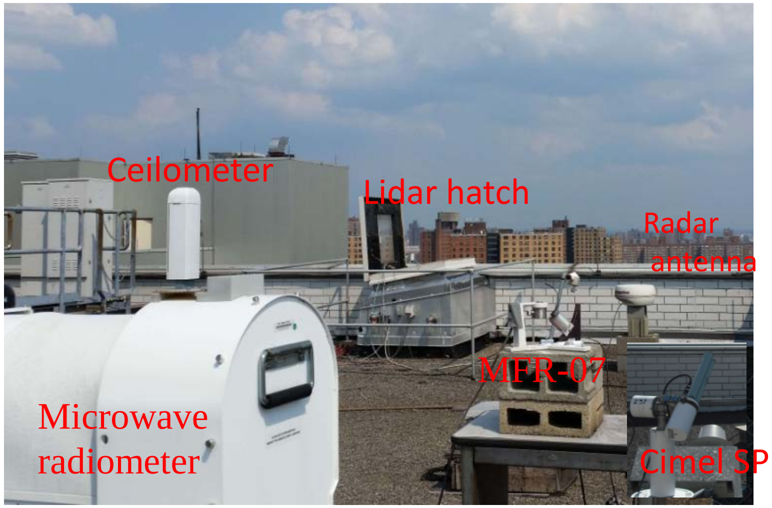
d: Air quality monitoring station

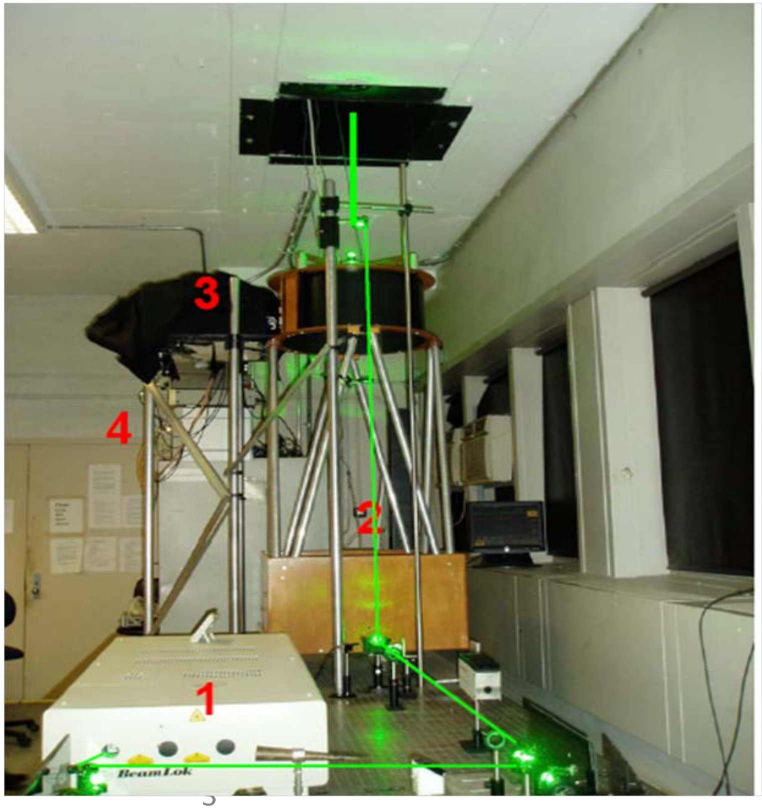
✦ **NYDEC: $PM_{2.5}$, O_3, CO**

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

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

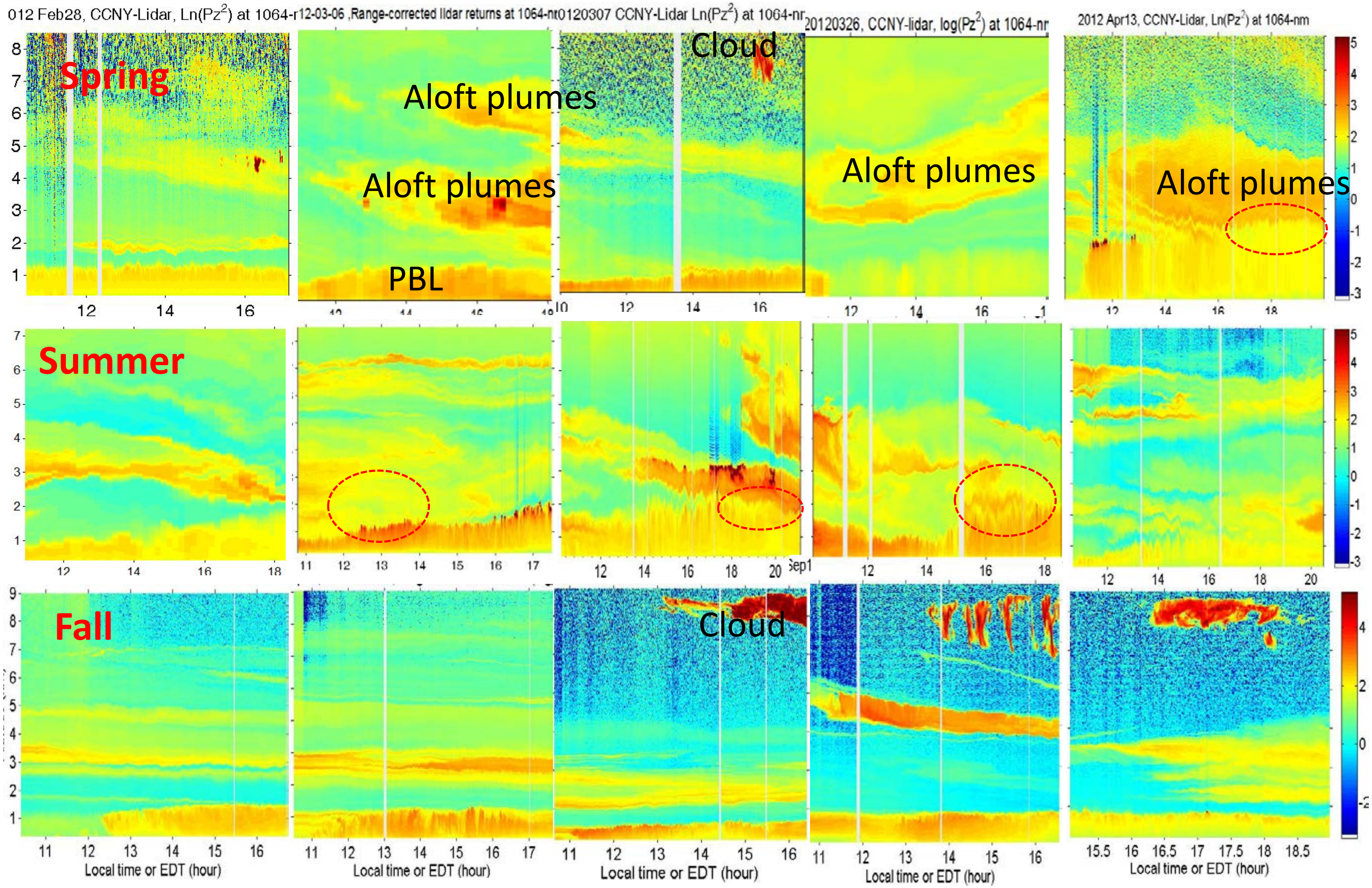
g. Wind Doppler lidar



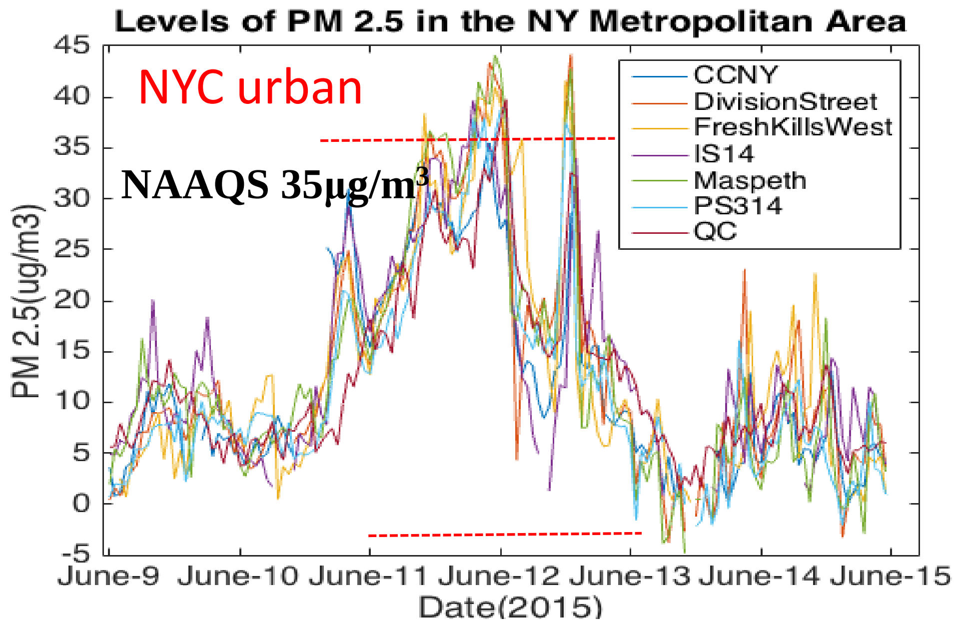


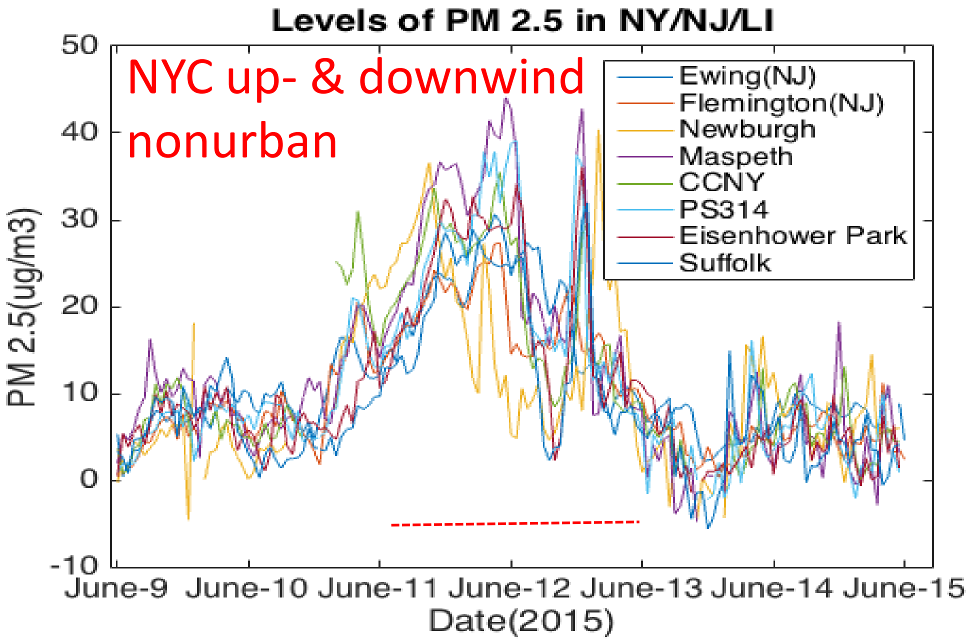
3. Results: Snapshots of aloft aerosol plumes in 2012

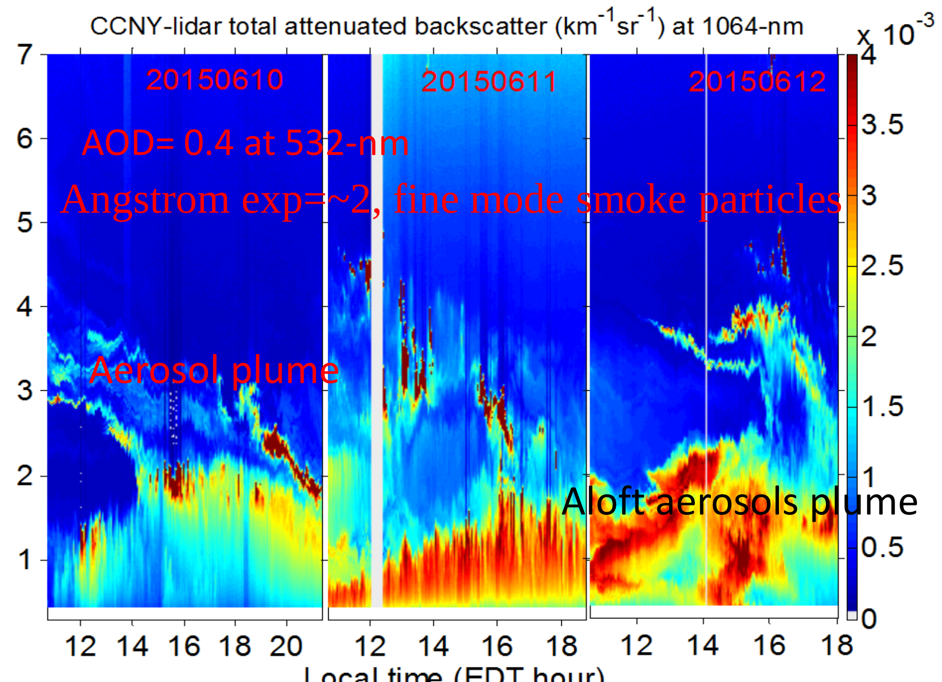
Aloft aerosol plumes (yellow) on the different days and seasons



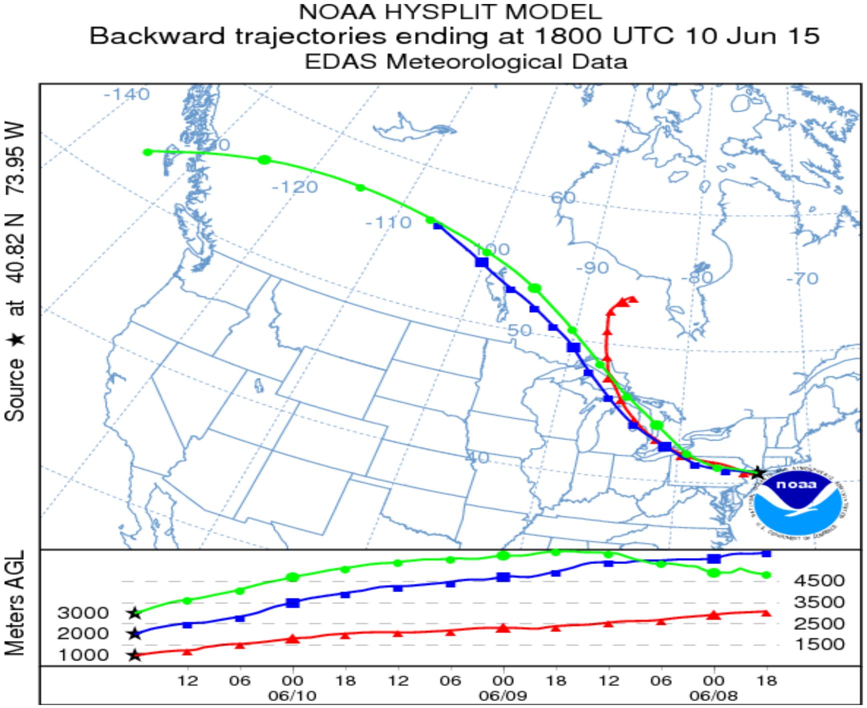
(1) Case: Summer haze related to wildfire smoke transport

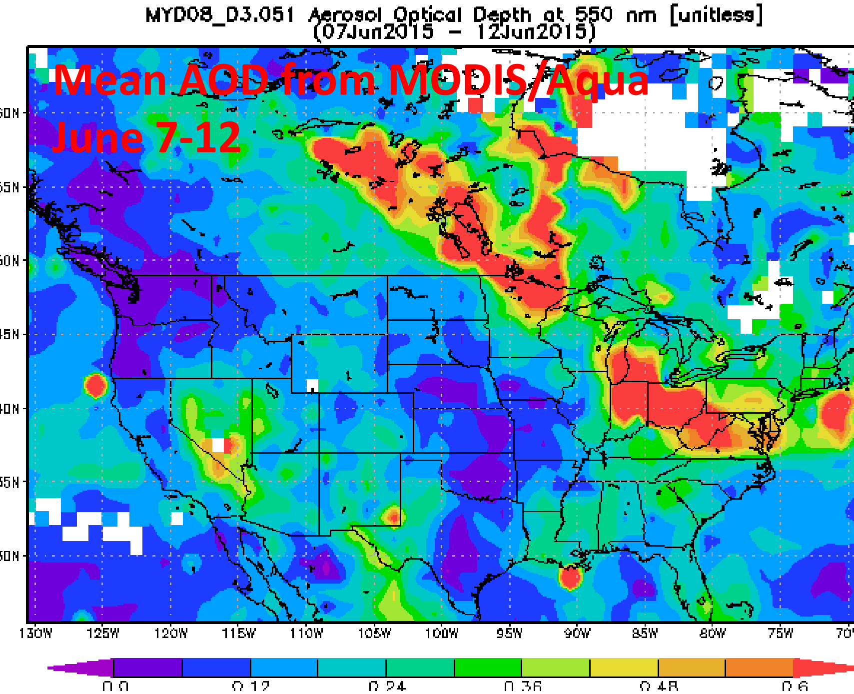


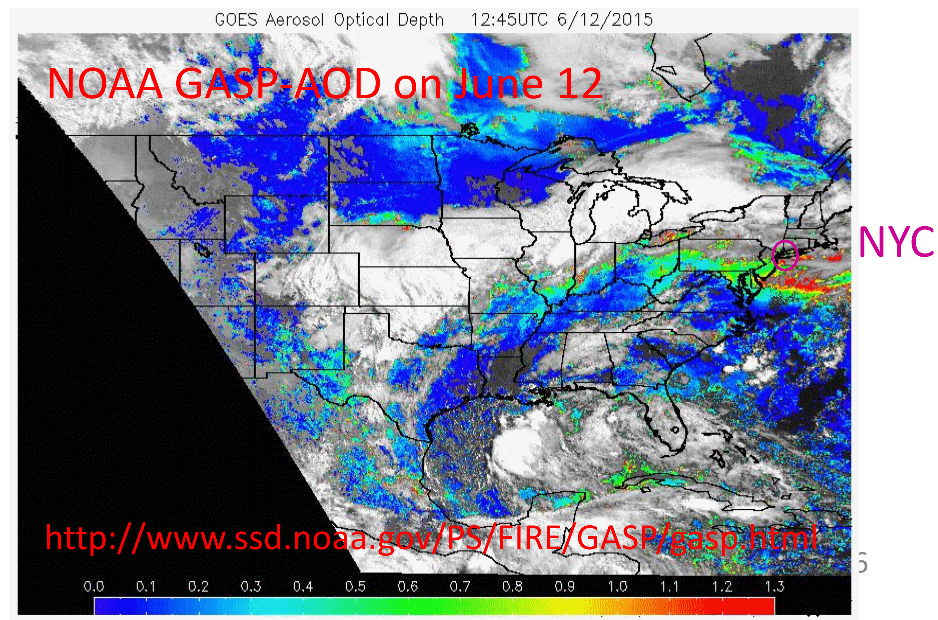




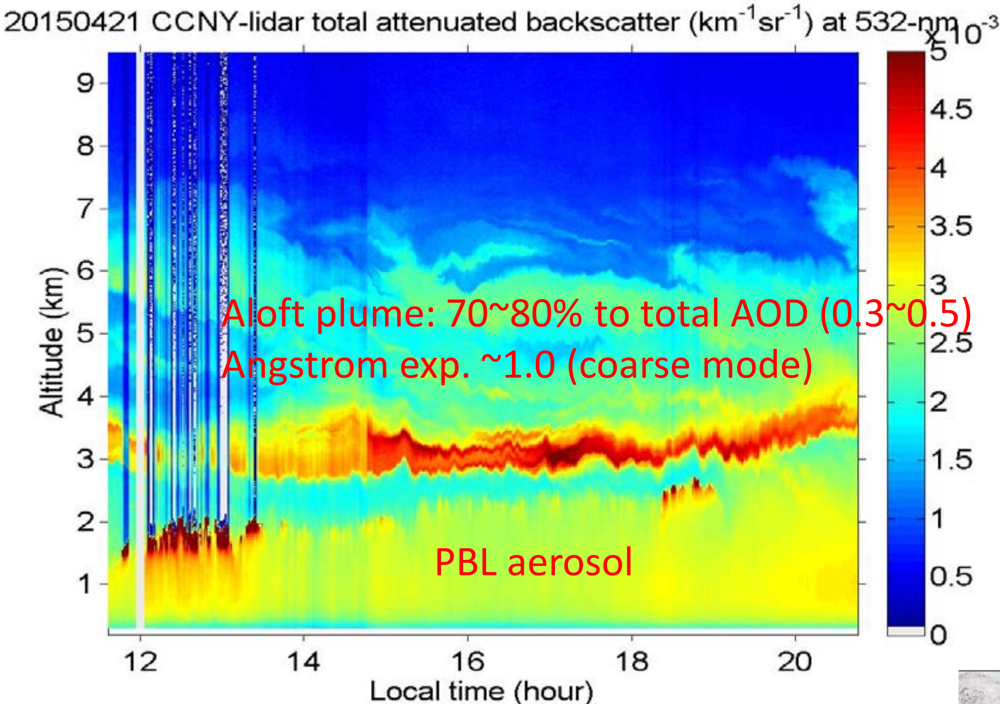
Transport path and source by model and satellite

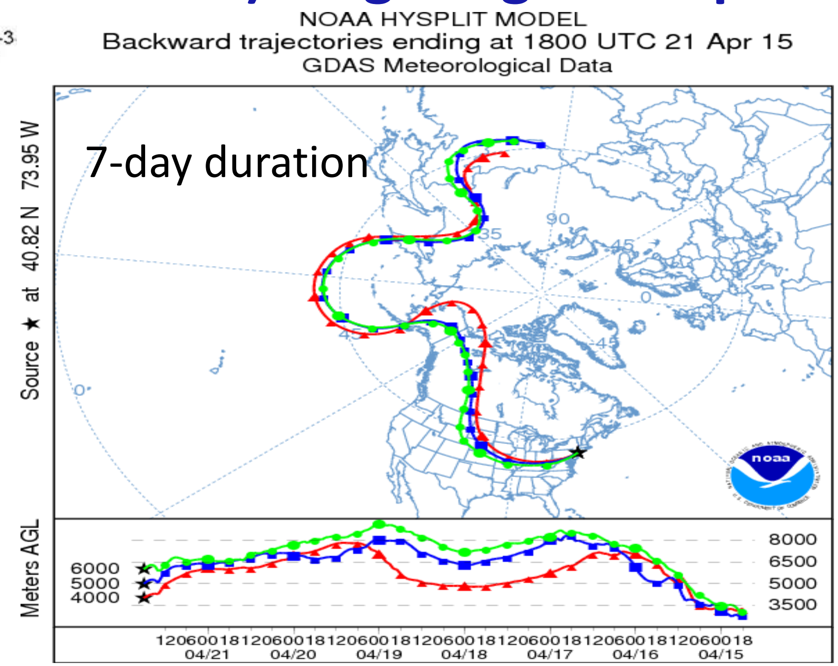




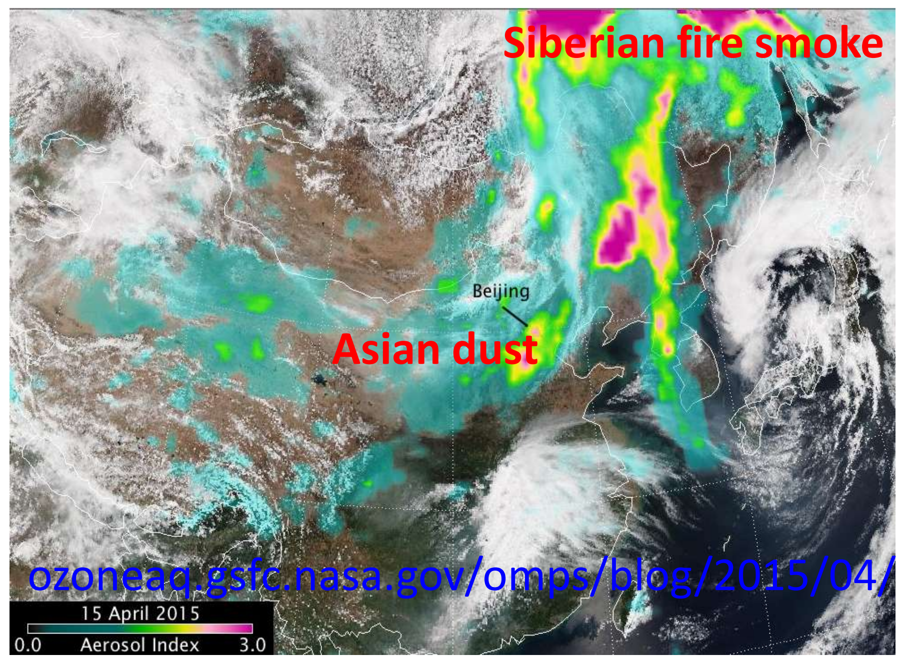


Case: Asian dust (coarse-mode dominated) long-range transport



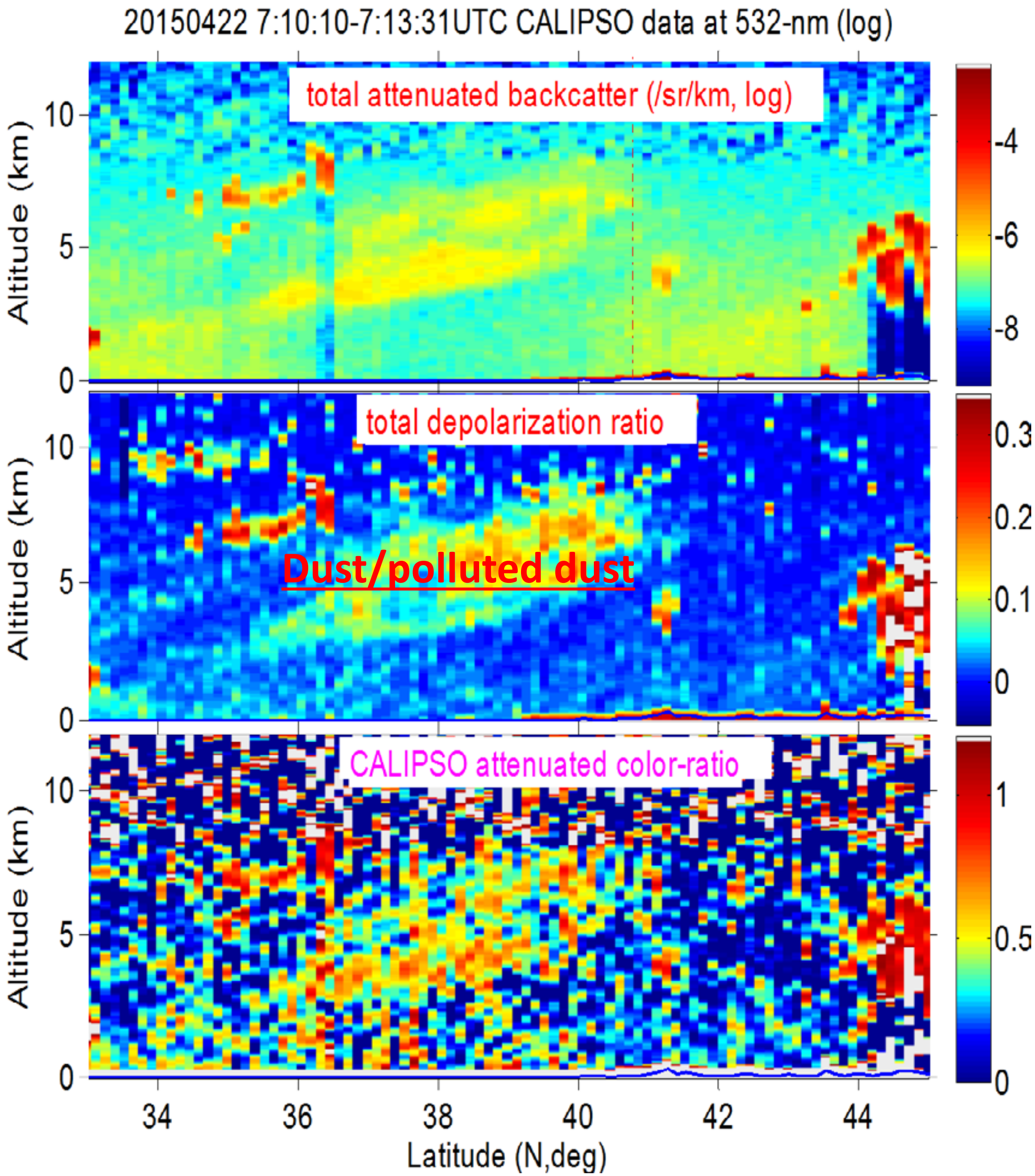


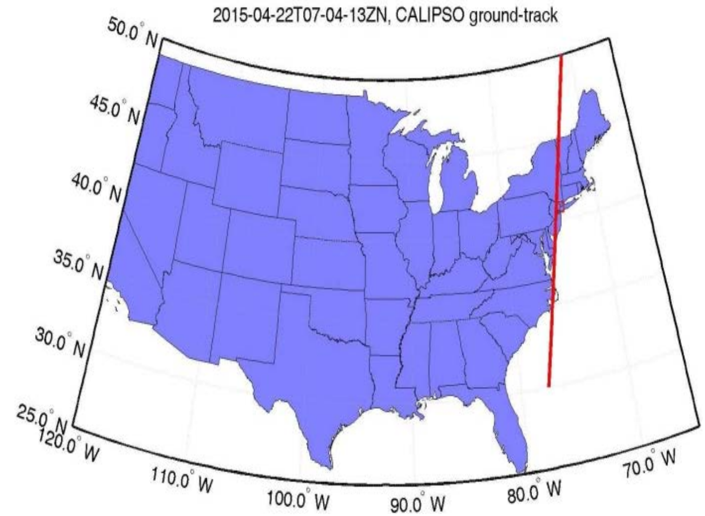
OMPS AI over VIIRS RGB image



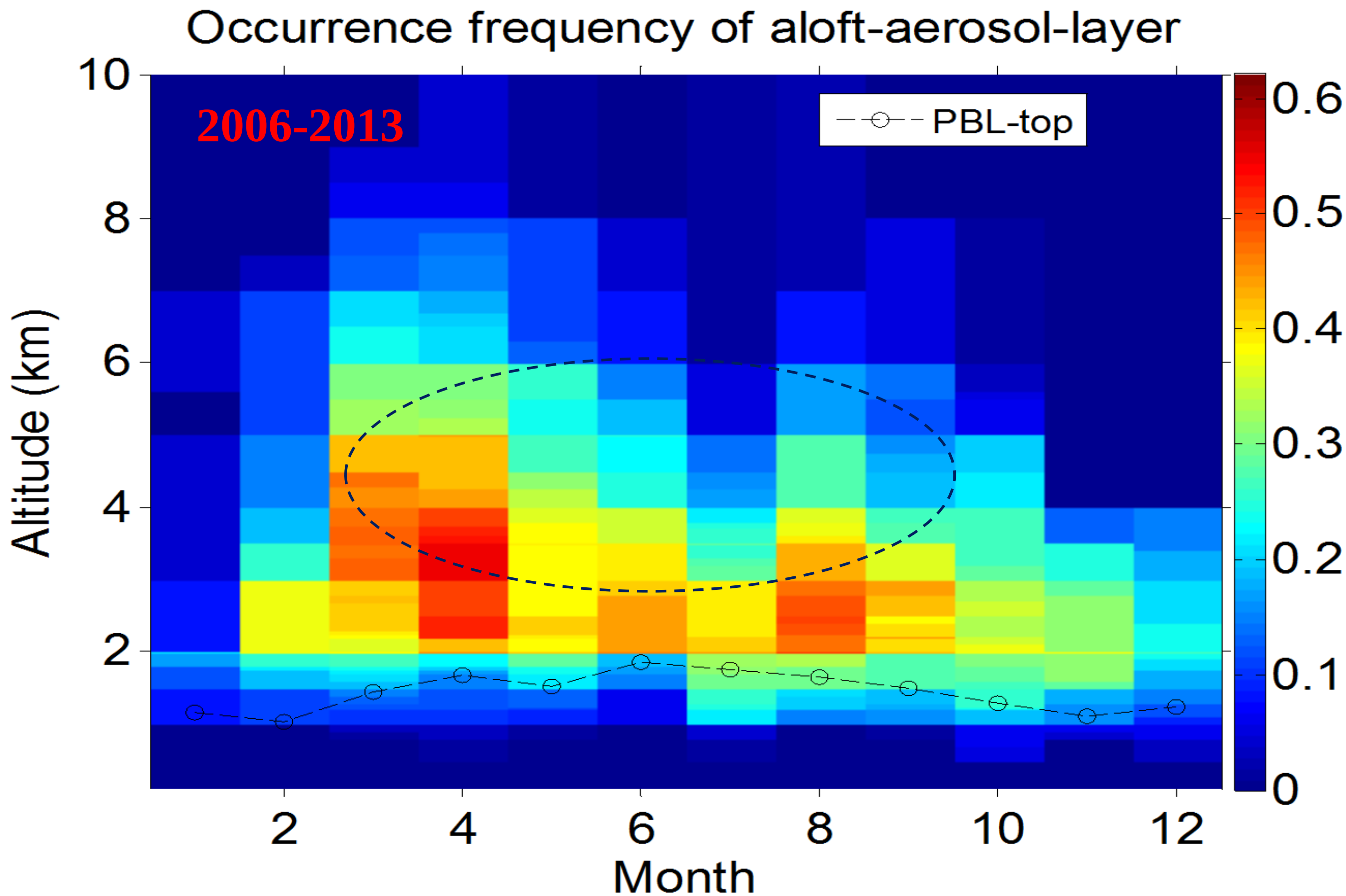
Depolarization ratio and color-ratio in the East US by CALIPSO

---Coarse mode and nonspheric particles dominated (Dust-like)





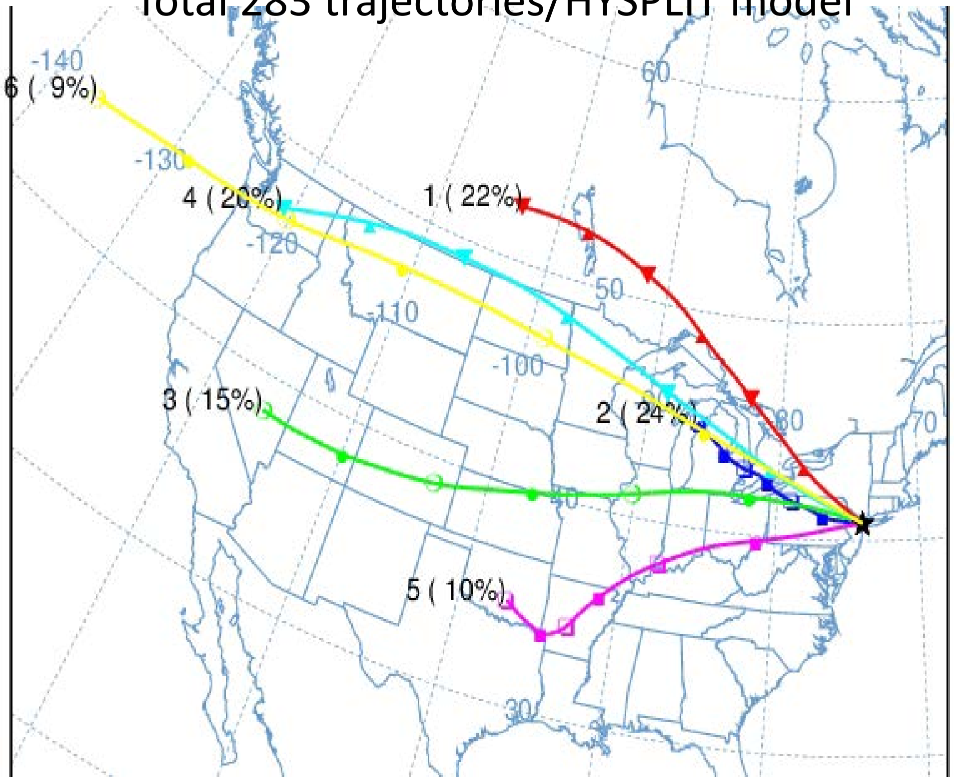
(2) Climatology analysis : Range-resolved monthly occurrence



- Define an aloft-aerosol-layer event: height> PBL-top, geometric depth Δz>300-m
  Duration time T>=3-hr
- Occurrence fre. 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**

(3) Climatology analysis : Cluster of transport paths

Total 283 trajectories/HYSPLIT model



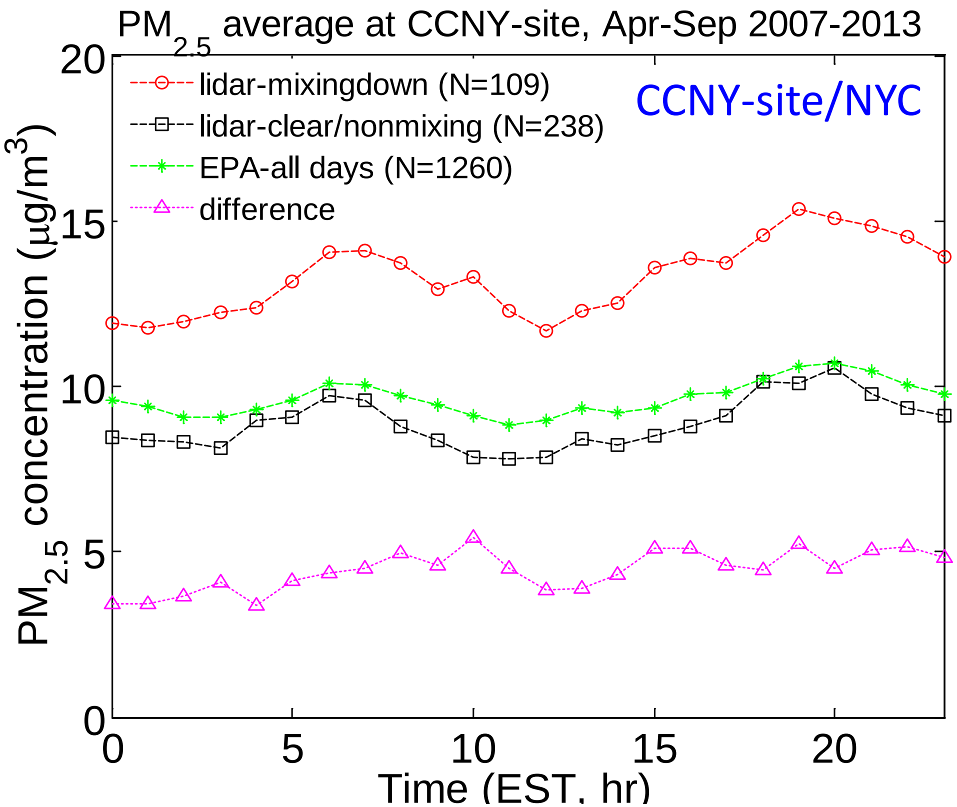
Cluster #	AOD500	AE	SSA670	R_{eff} (μm)
1	0.19	1.42	0.90	0.28
2	0.31	1.58	0.92	0.24 sulfate
3	**0.22**	**1.59**	**0.81**	**0.21** smoke
4	0.25	1.37	0.90	0.23
5	0.16	1.47	0.94	0.20
6	**0.15**	**1.32**	**0.93**	**0.31** Dust-like

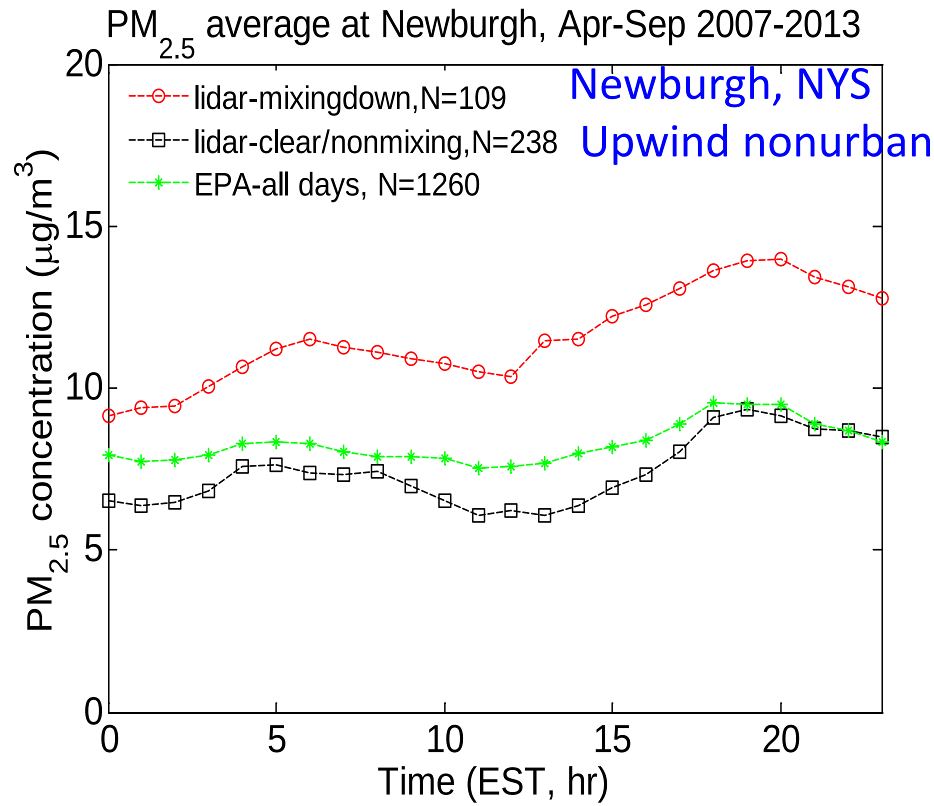
AE: Angstrom exponent at 440-870
SSA670: single-scattering albedo at 670-nm
Reff: effective radius of aerosol

- Six clusters of transport paths at 4-km level and 72-hr long duration.
- Cluster-2: higher AE and SSA, but smaller R_{eff}. Fine mode and non-absorbing aerosol: industrial aerosols such as sulfate, nitrate.

Cluster-6: Smaller AE and large R_{eff} , but higher SSA. Coarse-mode Asian dust.
Cluster 1, 3, 4: Smaller SSA and R_{eff} (fine-mode absorbing aerosols: smoke)
Cluster-5: mixture of smoke and dust.

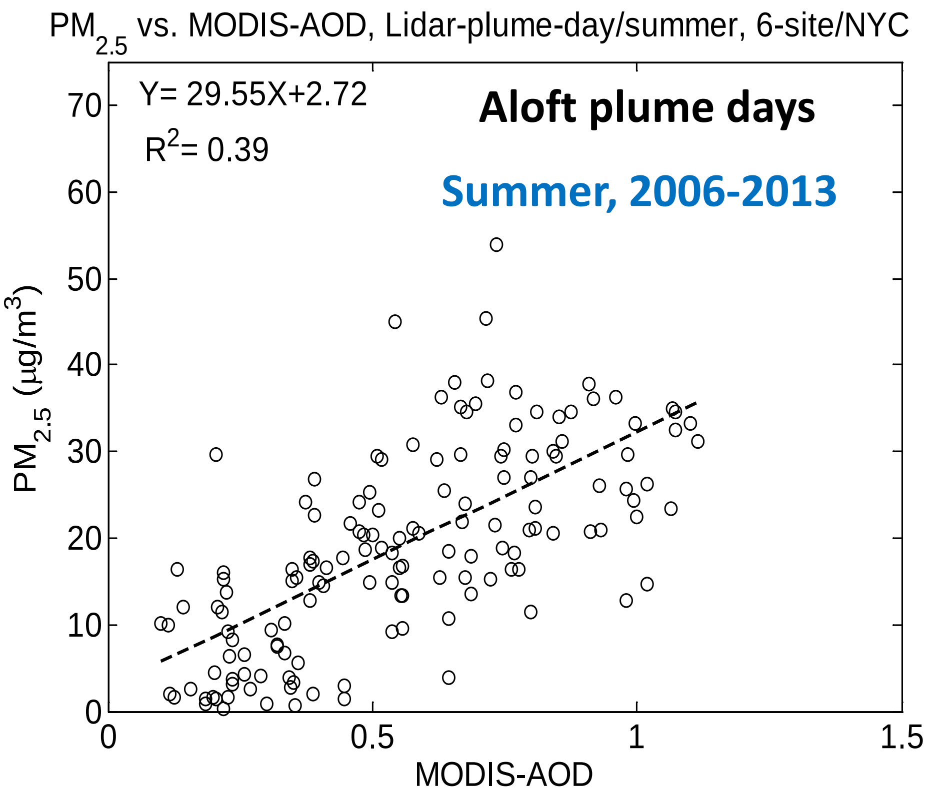
(4) Transport influence on local $PM_{2.5}$ (mixing-down vs. clear skies)

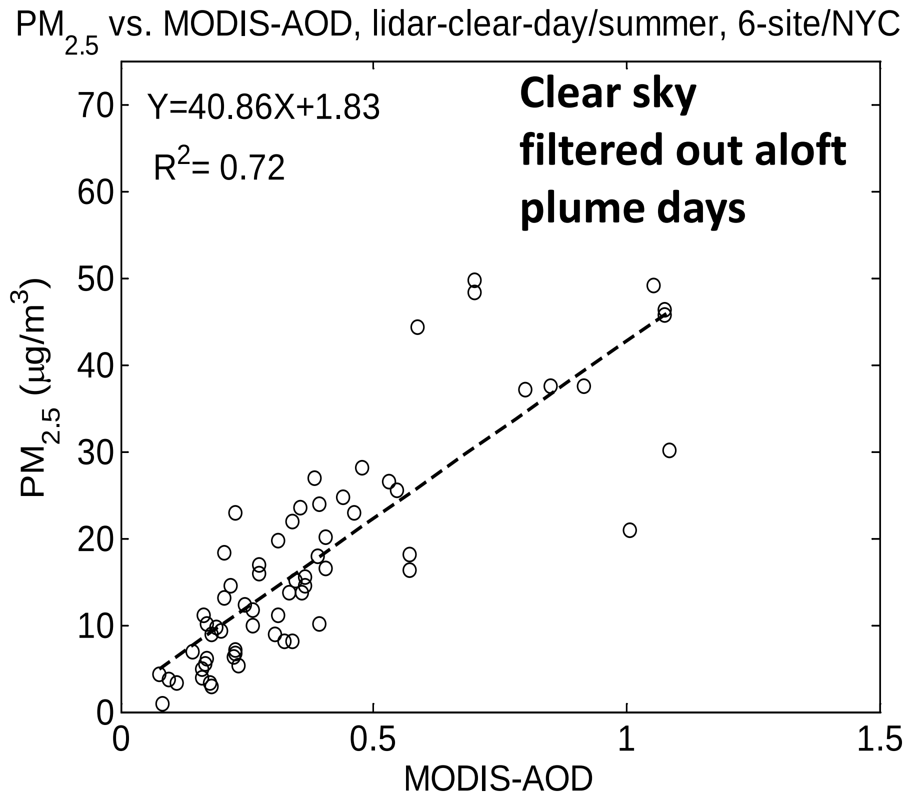




- Mean PM2.5 over the days of plume mixing down into PBL or clear/nonmixing down skies.
- Increase by 3~5 $\mu g/m^3$ on average during the mixing down days (2007-2013, summer).
- Similar trends at other upwind sites.

(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

- Lidar-ceilometer-sunphotometer measurements: time-height distribution and evolution of aerosol, optical properties and type classification.

- Climatology analysis of monthly occurrence of aloft aerosol plumes, transport path and mean optical properties.
  6 clusters of transport paths at 4-km altitude and 72hr transport.
  Cluster-2: fine-mode non-absorbing industrial aerosols.
  Cluster-6: coarse mode dust-dominated.
  Cluster-3 and other: fine-mode absorbing smoke aerosols.

- 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?

ACKNOWLEDGEMENTS. This study was supported by National Oceanic and Atmospheric Administration (NOAA) under the CREST Grant # NA11SEC4810004. Authors greatly appreciate the data from NASA-AERONET, MODIS, EPA, and NOAA-HMS, HYSPLIT and GASP products, and the partners of NOAA-CREST Lidar Network for sharing aerosol transport information.