Aerosol radiative forcing and heating rate by absorbing aerosol during EAST-AIRE 2005

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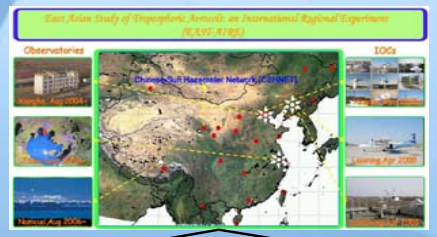
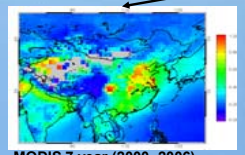
East-AIRE 2005

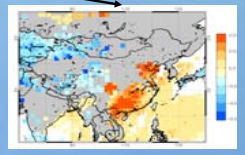
The objectives of theEast Asian Study of Tropospheric Aerosols: An International Regional Experiment (EAST-AIRE) are (Li et al., 2007) ;

(1) to acquire and understand the physical, chemical and optical properties of dominant natural and anthropogenic aerosols and their precursor gases in China and
(2) to gain insights into the direct and indirect effects of these aerosols on radiation, cloud, precipitation, atmospheric circulation and the environment.



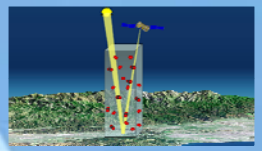


MODIS 7 year (2000~2006) mean AOT



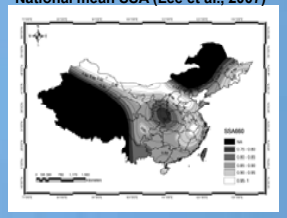
Annual AOT change rate (Δτ/yr)

The new method to retrieve the single scattering albedo;
- a combination of ground-based spectral direct transmittance and spaceborne spectral reflectance enable to find absorbed radiance by aerosol (Lee et al., 2007).



Under the clear sky condition, the difference between aerosol transmittance and reflectance is a function of SSA.

National mean SSA (Lee et al., 2007)



Aerosol loading over East Asia are relatively high (AOT≈0.69) and absorbing aerosols (SSA≈0.89) are important for climate study in this region.

Aerosol Radiative Forcing

Shortwave aerosol radiative forcing (SARF) can be determined by SBDART simulations;

$$F_{TOA,Surf} = \Delta L_{aerosol} - \Delta L_{non-aerosol}$$

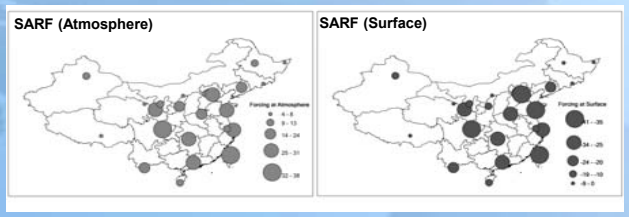
$$F_{Atmos} = \left(\Delta L_{TOA} - \Delta L_{Surf}\right)_{aerosol} - \left(\Delta L_{TOA} - \Delta L_{Surf}\right)_{non-aerosol}$$

Input data for SBDART(Ricchiazzi, 1998);

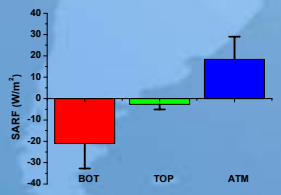
<Aerosol model>
- All AOTs and Angstrom exponents from Hazemeter (36,731 cases).
- Monthly mean SSAs from Lee et al. [2007].
- Spectral aerosol optical properties by Mie theory calculation.
- Extinction by different RH condition has been considered. Surface RH data for each station are from NCEP/NCAR reanalysis.

<Atmosphere model>
- Atmospheric profile from NCEP/NCAR reanalysis
- Ozone concentration from OMI.

<Surface model>
- MODIS spectral surface reflectance products (MOD09)



- SARF due to the aerosol absorption is very large in middle China (Yantig-Taoyuan) and east coastal area (Jiaozhou-Shanghai).
- There are large negative the national annual mean SARF in the range of -30~-40 W/m² at the surface and 25~38W/m² at the atmosphere in eastern China.

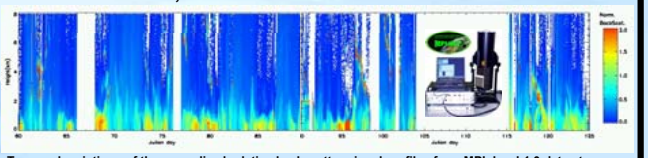


- The national mean annual SARF values are -21.1±11.6 (surface), -2.7±2.4 (TOA), and 18.4±10.6 (atmosphere), respectively.
- So does 87.2% of surface SARF according to the aerosol absorption in the atmosphere.

Obviously, large cooling (surface) and heating (atmosphere) effects are shown by absorbing aerosols.

Atmospheric Heating Rate

Heating rates by absorbing aerosol using Micro pulse LIDAR measurement data;

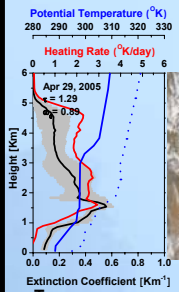


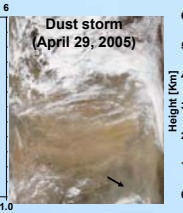
Temporal variations of the normalized relative backscatter signal profiles from MPL level 1.0 data at Xianghe, China.

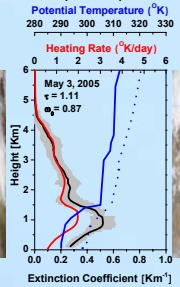
Atmospheric heating rate by the flux absorbed in the layer can be estimated with and without aerosols.

$$\frac{\partial T}{\partial t} = \frac{g}{c_p} \cdot \frac{\Delta F}{\Delta P}$$

Input data for SBDART(Ricchiazzi, 1998);
- AOT, Angstrom, SSA from AERONET.
- Spectral aerosol optical properties by best matching with OPAC.
- Aerosol vertical profile (MPL L1.5 extinction).
- RH (NCEP/NCAR), Atmospheric profile (NCEP/NCAR), Ozone (OMI), Surface reflectance (MOD09).







- Two severe aerosol event cases (Dust storm and Haze) show that the heating rate highly depends on the strength of aerosol absorption.
- Dust storm (April 29, 2005); 1~5km layer, heating rate=3.1K/day at 1.6km
- Haze (May 3, 2005); under 2km, heating rate=1.9K/day at 1.1km.

Summary

- The solar aerosol radiative forcing (SARF) and heating rate by absorbing aerosols over China is estimated during measurements made under the EAST-AIRE campaign in 2005.
- The unprecedented AOD and SSA datasets allow to determine aerosol radiative effects across China for the first time.
- Aerosols in the region exert a very large cooling effect at surface and warming in the atmosphere, but little effect at the top of the atmosphere.
- The vertical profiles of diurnal atmospheric heating rate due to aerosol absorption were also calculated using Micro Pulse Lidar (MPL) data.

Further reading
Lee, K. H. et. al. (2007), Aerosol single scattering albedo retrieval using ground-based and satellite observation data, *J. of Geophys. Res.*, 112, D22S15, doi:10.1029/2007JD009077
Li, Z., et al. (2007), Preface to special section on East Asian Studies of Tropospheric Aerosols: An International Regional Experiment (EAST-AIRE), *J. Geophys. Res.*, *112*, D22S00, doi:10.1029/2007JD008853.