Impacts of Asian Summer Monsoon on Seasonal and Interannual Variations of Aerosols over Eastern China

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Motivations

- China has high concentrations of aerosols
  - Domestic air quality
  - Outflow of air pollutants
  - Climatic effects

- China is located within a large monsoon domain
  - Seasonal variations in meteorological fields associated with Asian summer monsoon can influence transport, deposition, and chemical reactions of aerosols;
  - Asian summer monsoon has interannual and decadal variations (it has been weakening since 1970s).

- Change in Asian summer monsoon is the most important aspect of climate change in China
  - This work is the first step of our study for understanding the effect of climate change on air quality in China
Asian Monsoon

Summer monsoon
May - September

Winter monsoon
November - March
Simulated Surface-layer PM$_{2.5}$ Concentrations ($\mu g\ m^{-3}$) for ordinary monsoon year 2001

- Model version: GEOS-Chem 7.3.6
- Resolution: 4° x 5°; 30 vertical layers
- Meteorology: NASA GEOS-3 (Jan 1~Dec 31, 2001)
- David Streets 2006 emissions inventory
Simulated Seasonal Variations of Aerosols Agree with Measurements

Eastern China

110°-120°E, 20°-45°N

PM$_{2.5}$  NO$_3^-$  SO$_4^{2-}$  NH$_4^+$  BC  OC

Winter

Summer

Chao et al., 2007
Seasonal Variation in China is Opposite to That in the US

The IMPROVE Measurements of Fine Aerosol Species

Debell et al., 2006
Major Factors that Influence Seasonal Variation of Aerosols in China:

(1) Four channels of cross-equatorial flows associated with Asian summer monsoon bring clean air to China

JJA stream lines and wind velocity (colors) at 925 mb

Time-longitude distribution of meridional wind averaged over 5°S - 5°N
Correlation between $I_c$ (Wind) of Each Channel and PM$_{2.5}$
Large wet deposition starting from mid-June contributes to a sudden decrease in PM$_{2.5}$ in eastern China.
Effect of Monsoon is Much Larger than the Effect of Seasonal Variation in Emissions

**PM$_{2.5}$**

- Control run: with seasonal emissions
- JANEmis: emissions set to Jan. values
- JULEmis: emissions set to July values

**SO$_4^{2-}$**

**NO$_3^-$**

**NH$_4^+$**

$\text{PM}_{2.5}(\text{JUL}) - \text{PM}_{2.5}(\text{JAN})$ / $\text{PM}_{2.5}(\text{JAN})$

- Control run: -63.7%
- JANEmis: -59.3%
- JULEmis: -58.4%
Asian Summer Monsoon Index
(represented the strength of monsoon)

East Asia Summer Monsoon; (10°-40°N 110°-140°E)

South Asia Summer monsoon; (2.5°-20°N, 70°-110°E)

Averaged over eastern China, surface PM$_{2.5}$ concentrations in the weak monsoon year 1998 is higher than that in the strong monsoon year 2002 by 44.6%.
Differences in Meteorological Fields Between the Weak Monsoon year 1998 and Strong Monsoon Year 2002

June


925hPa meridional winds (1998-2002)

Weaker cross-equatorial flows brought less clean air to China

Abnormal winds did not favor the outflow of pollutants in weak monsoon year

Higher aerosol conc. in the weak monsoon year 1998, because of

- Weaker cross-equatorial flows brought less clean air to China
- Abnormal winds did not favor the outflow of pollutants in weak monsoon year

July

August
Factors influence seasonal variation of aerosols in eastern China:

- Cross-equatorial flows from the Southern Hemisphere bring clean air to eastern China;
- Rainfall associated with summer monsoon leads to large wet deposition of aerosols

With Asian summer monsoon, PM$_{2.5}$ concentrations in eastern China in July is lower than those in January by about 60%;

Average summer surface PM$_{2.5}$ concentration in eastern China in the weak monsoon year 1998 is higher than that in the strong monsoon year 2002 by 44.6%. The difference in concentration can mostly be explained by the difference in transport (winds).

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