Interpreting the Relationship Between Ground Level Fine Particulate Matter and Total-Column Aerosol Optical Depth with SPARTAN and a Global Chemical Transport Model

Crystal Weagle
Supervisor: Dr. Randall Martin
Dalhousie University
CSC Halifax
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Tiny particles with major health implications

IARC: Outdoor air pollution a leading environmental cause of cancer deaths

Lyon/Geneva, 17 October 2013 – The specialized cancer agency of the World Health Organization, the International Agency for Research on Cancer (IARC), announced today that it has classified outdoor air pollution as carcinogenic to humans (Group 1).
Where does PM$_{2.5}$ come from?

Precursor gases:
- Nitrogen Oxides (NO$_x$)
- Sulfur Dioxide (SO$_2$)
- Ammonia (NH$_3$)
- Volatile Organic Compounds (VOCs)

Chemical reaction equations:
1. NO$_2$ (g) + OH (g) $\leftrightarrow$ HNO$_3$ (g)
2. NH$_3$ (g) + HNO$_3$ (g) $\leftrightarrow$ NH$_4^+$ (aq) + NO$_3^-$ (aq)
3. SO$_2$ (g) + OH (g) $\leftrightarrow$ HSO$_3$ (g)
4. HSO$_3$ (g) + O$_2$ (g) $\leftrightarrow$ SO$_3$ (g) + HO$_2$ (g)
5. SO$_3$ (g) + H$_2$O (g) $\leftrightarrow$ H$_2$SO$_4$ (g)
6. H$_2$SO$_4$ (g) $\leftrightarrow$ H$_2$SO$_4$ (aq)
Lack of global PM$_{2.5}$ measurements

- Field campaigns are short term
- Emerging networks only report daily values
Aerosol Optical Depth (AOD)

• Aerosols absorb and scatter visible and near-infrared light
• AOD = measure of how much light airborne particles prevent from traveling through the atmosphere
• AOD < 0.1 → clear sky
• AOD = 1 → difficulty seeing the sun, even at mid-day!
Satellite-derived estimates of PM$_{2.5}$

\[ \eta = \frac{\text{PM}_{2.5}(\text{model})}{\text{AOD}(\text{model})} \]

\[ \text{PM}_{2.5,\text{surface}} = \eta_{\text{model}} \times \text{AOD}_{\text{sat}} \]

van Donkelaar, et al., ES&T 2016, 50, 3762
Most regions lacking collocated PM$_{2.5}$ and AOD

- Ground-based AOD measurements are used to evaluate satellite AOD
Surface PARTICulate mAtter Network (SPARTAN

The GEOS-Chem Model

Aerosol Optical Depth

July

GEOS-Chem

Dust
Sea salt
Organic C
Black C
SO$_4$/NO$_3$/NH$_4$
Global $\eta$ 

$$\eta = \frac{\text{PM}_{2.5} \text{ (ground-level)}}{\text{AOD} \text{ (total atmospheric column)}}$$

Influenced by the aerosol vertical profile, aerosol properties, relative humidity
Factors affecting PM$_{2.5}$/AOD

- Aerosol vertical profile

- Aerosol properties – e.g. composition, scattering/absorbing

- Relative humidity
Contribution from Sulfate-Nitrate-Ammonium and Organic Matter (OM)
Seasonal $SO_4$ 

$SO_2 (g) + OH (g) \leftrightarrow HSO_3 (g)$
Seasonal NO$_3$

$\text{NH}_3 (g) + \text{HNO}_3 (g) \leftrightarrow \text{NH}_4^+ (aq) + \text{NO}_3^- (aq)$

Winter

Spring

Summer

Fall
Contribution from black carbon (BC), dust, sea salt (SS), and particle-bound water (PBW)
Summary

• SPARTAN has tripled the number of global sites measuring collocated PM$_{2.5}$ and AOD

• Relationship between ground-level PM$_{2.5}$ and total-column aerosol optical depth is complex

• Aerosol vertical profiles, emissions, chemistry, and seasonal changes effect contribution of major chemical species to spatial variation in PM$_{2.5}$/AOD

• Chemical transport model is powerful tool to help interpret SPARTAN measurements
Thank you!!

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