Using *in situ* data to better understand Chinese air pollution events

- Air pollution in China is a major health issue, resulting in over 1.3 million deaths per year.
- New emissions inventory and *in situ* datasets allow us to better understand air quality in China.

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IGC8

Jonathan M. Moch, Loretta Mickley, Hong Liao, Yuan Cheng, Meng Li

Pictures taken in Beijing during summer 2016
In situ data and GEOS-Chem can help us understand Chinese pollution events

- GEOS-Chem has previously been shown to do a bad job capturing winter PM$_{2.5}$ variability and magnitude over the North China Plain (NCP).
- A new standard simulation with MERRA2 meteorology and updated emissions inventories from Tsinghua University shows a better match with observations but now an overestimate of PM$_{2.5}$.

**DJF monthly means PM$_{2.5}$ for 6 sites in North China Plain (2012-2013)**

![Scatter plot with 1:1 line](image)

- Each point represents monthly mean from an individual site.
- Correlation coefficient ($R$) = 0.86
- Mean Bias (MB) = 38.6

**Nested China Simulation using MERRA2 DJF (2012-2013)**

![Map with PM$_{2.5}$ levels](image)

- For 29 sites across China: $R = 0.66$; MB = 4.81
Setup of new China simulation

- MERRA2 meteorology
- Nested Asia grid (0.5x0.625°)
- Multi-resolution Emissions Inventory for China (MEIC) for 2012 and 2013
  - China component of default MIX inventory for Asian emissions in GEOS-Chem v11.01
  - Individual power plant database with unit specific parameters
  - County level transportation information and digital road map

- MEIC 2012 emissions relative to 2010 MIX emissions:

<table>
<thead>
<tr>
<th></th>
<th>MEIC</th>
<th>Standard scaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NO}_x$</td>
<td>+1%</td>
<td>+5%</td>
</tr>
<tr>
<td>$\text{SO}_2$</td>
<td>+3%</td>
<td>-1%</td>
</tr>
<tr>
<td>$\text{NH}_3$</td>
<td>+8%</td>
<td>+0%</td>
</tr>
<tr>
<td>BC</td>
<td>-1%</td>
<td>+5%</td>
</tr>
<tr>
<td>OC</td>
<td>-7%</td>
<td>+4%</td>
</tr>
</tbody>
</table>

China is implementing policies such as closing coal plants in the North China Plain and attempting to reduce $\text{SO}_2$ emissions, so total emissions and spatial distributions can change rapidly.
Relatively good PM$_{2.5}$ match hides component issues

DJF monthly mean components for North China Plain

Sulfate 2012-2013

Nitrate 2012

Each point represents monthly mean from an individual site

R = 0.72
MB = -11.54

R = 0.75
MB = 21.25

During winter sulfate is underestimated and nitrate is overestimated across the North China Plain.

Hypotheses to be tested:

- Missing sulfate oxidation mechanism is leading to too little sulfate, which allows for excess nitrate in the presence of ammonia.
- Excessively high ammonia emissions allow too much nitrate to enter the aerosol phase.
- There is an issue with NO$_x$ partitioning or missing NO$_x$ sink
Comparison with Beijing daily data in 2011 shows similar bias

Comparison of GEOS-Chem with daily observations in Beijing 2011 also show an overestimate of PM$_{2.5}$ driven primarily by excess model nitrate during pollution episodes.

Component observations provided by Yuan Cheng
Switching gears to brown carbon: possibly an important absorber in China

Imaginary Refractive Index at 350 nm ($k_{OA,350}$)

- Brown carbon is the light absorbing portion of OC.
- Brown carbon and BC may play an important role in strengthening Chinese pollution episodes by absorbing radiation and stabilizing the planetary boundary layer.
- Surface measurements indicate brown carbon in China may be much more absorbing than current parameters for brown carbon in GEOS-Chem anticipate.

Reasons why $k_{OA,350}$ might be variable:
- Changing emissions
- Secondary brown carbon formation
- Photobleaching

Cheng et al., 2016; Hammer et al., 2016; Lu et al., 2015
Brown carbon may be a significant absorber at short wavelengths

Using in situ mass absorption coefficient for BrC leads to BrC making up on average 30% of total simulated AAOD over December versus 16% if using static satellite derived values.

Depending on mixing state assumptions about BC, brown carbon could make up 20-50% of total absorption over Beijing at short wavelengths.
Next steps

• Examine importance of increased nitrate removal for nitrate and ammonium overestimates.
• Examine importance of ammonia emissions for nitrate and total PM$_{2.5}$ overestimates.
• Use measurements of surface BC and BrC and aerosol optical depths to constrain GEOS-Chem simulations of BrC and BC.
• Estimate the effects of BrC and BC on regional climate.

Thanks to: Loretta Mickley, Hong Liao, Yuan Cheng, Meng Li, Shuxiao Wang, Chris Nielsen, Meng Gao, Melissa Sulprizio
Backup: 2012-2013 Monthly PM has R=0.64, with seasonal bias

DJF

R = 0.66; MB = 4.81

MAM

R = 0.59; MB = -6.63

JJA

R = 0.67; MB = -5.77

SON

R = 0.57; MB = -4.41
Sulfate underestimate is not just a problem in Beijing, but January 2013 sulfate was anomalously high.
Nitrate overestimate is largest in winter, and consistent across all of China.