Land-atmosphere coupling in ammonia volatilization: Impacts on atmospheric chemistry

Julius Vira¹, Peter Hess¹, Jeff Melkonian² and Will Wieder³,⁴

¹ Department of Biological and Environmental Engineering, Cornell University
² Section of Soil and Crop Sciences, Cornell University
³ Climate and Global Dynamics Laboratory, NCAR
⁴ Institute of Arctic and Alpine Research, University of Colorado

Joint Chemistry Climate and Whole Atmosphere Working Group Session
CESM Workshop, 18 June 2019, NCAR, Boulder
Cycling of reduced nitrogen between land and atmosphere

\[ \text{NH}_4^+ \text{ aerosols} \rightarrow \text{NH}_3 \text{ gas} \]

~15-20% of fertilizer and manure N is volatilized as ammonia (NH3)

CESM can couple N deposition from CAM to CLM

CAM gets NH3 from emission inventories

No climate effects on NH3 emission

N not fully conserved in CAM+CLM

Can we simulate NH3 emission in CLM realistically enough for use with CAM-chem?

Is evaluating NH3 interactively useful for simulating atmospheric chemistry?

Nitrogen in agriculture

70-90 Tg N / year applied as fertilizers

110-130 Tg N / year cycled in livestock manure

N deposition

30-40 Tg NH4-N on land

30-40 Tg N volatilized as NH3

Beusen et al. (2008); Potter et al. (2010); Vet et al. (2014)
The Flow of Agricultural Nitrogen (FAN) process model

N fertilization from CLM crop model
Fertilizer types from International Fertilizer Association
Manure N production from FAO datasets

FAN
Ammonia emissions across the agricultural sector:
Manure spreading
Manure storage & handling
Grazing
Fertilizer use: urea, nitrate, others

CLM
Community Land Model

CAM
Community Atmospheric Model
Atmospheric transport partitioning between NH3 (gas) and NH4+ (aerosol) nitrate formation wet and dry deposition

N runoff
N remaining in soil
CAM simulations for 2010-2015 with FAN & other emissions

**FAN**: FAN NH₃ + HTAP2 for other species
- CLM5, 30 min coupling step, CAM4 based compset (CAM-Chem)
- prescribed dynamics with MERRA

Compared with
**EDGAR** 4.3.2 emissions for 2010
**HTAP** v2.2 emissions for 2010
**CEDS** (CMIP6) emissions for 2010

HTAP and CEDS based on EDGAR + regional inventories where available
All inventories are monthly
Ammonium wet deposition
2010-2015 mean

NH₄⁺ wet deposition (gN m⁻² yr⁻¹), FAN

NH₄⁺ wet deposition (gN m⁻² yr⁻¹), HTAP

NH₄⁺ wet deposition (gN m⁻² yr⁻¹), CEDS

NH₄⁺ wet deposition (gN m⁻² yr⁻¹), EDGAR

FAN

HTAP2

CEDS

EDGAR

R = 0.77

R = 0.79

R = 0.78

R = 0.78
Temporal profiles of NH$_4$ wet deposition

EMEP: NH$_4^+$ wet deposition (gN/m$^2$/yr)

EANET: NH$_4^+$ wet deposition (gN/m$^2$/yr)

NTN: NH$_4^+$ wet deposition (gN/m$^2$/yr)

- **Europe**
- **East Asia**
- **U.S.**

Graphs showing the temporal profiles of NH$_4$ wet deposition in different regions with specific months and values represented in gN/m$^2$/yr.
Ammonium nitrate with FAN

CASTNET: $\text{NO}_3^-$ ($\mu g \text{ m}^{-3}$)

CASTNET: $\text{NO}_3^-$ ($\mu g \text{ m}^{-3}$)

<table>
<thead>
<tr>
<th></th>
<th>1.6</th>
<th>1.5</th>
<th>1.5</th>
<th>1.1</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTAP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Does temporal resolution of NH$_3$ emissions affect mean simulated NH$_4$NO$_3$?

4 runs to test the effect of averaging NH$_3$ emission in time.

**Hot, dry**
- More NH$_3$ emitted
- NH$_4$NO$_3$ not favored

**Cold, humid**
- Less NH$_3$ emitted
- NH$_4$NO$_3$ more stable

FAN NH$_3$ emission from interactive run
- **hourly**
- **daily**
- **monthly**
- **yearly**

Each emission setup run for 2010.
Effect of temporal resolution of NH$_3$ emission on mean NH$_4$NO$_3$ for 2010

~30% reduction in NO$_3$ bias for Central & Eastern US
Summary

• FAN-driven simulations of NH4 wet deposition are comparable to those driven by global inventories
• FAN gives opportunities not possible with inventories
  • Response to climate change, effects on land biogeochemistry
• Resolving temporal variation of NH3 emissions might reduce the positive bias in nitrate aerosols over the Central and Eastern US
References

