High Resolution Ammonia Map Based On A New Oversampling Algorithm

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Introduction & Motivation

NH_3: important pollutant

- Key precursor to fine particulate matter ($PM_{2.5}$) [1]
- Unregulated in the U.S.
- Major source: agriculture (>80%) Livestock waste, fertilizers etc. [2]

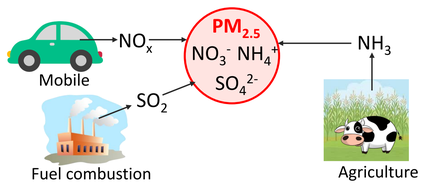

Figure 1. $PM_{2.5}$ formation

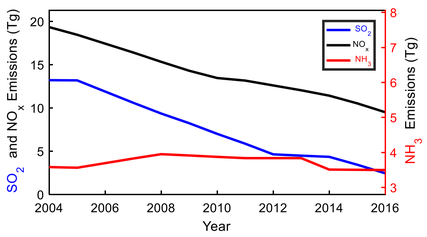

Figure 2. Pollutants emission trends [3]

Bottom-up emission inventory:

- Source specific emission factors (EFs): challenging to make representative estimates [2]
- Limited seasonality information [5]
- Model NH_3: discrepancies with observations [6]
- Large uncertainties in NH_4NO_3 simulation [7]

No significant NH_3 emission ↓

- NO_x, SO_2 (regulated in the U.S.): emissions ↓
- NH_3 emission reduction: the most cost effective $PM_{2.5}$ control strategy in some regions [4]

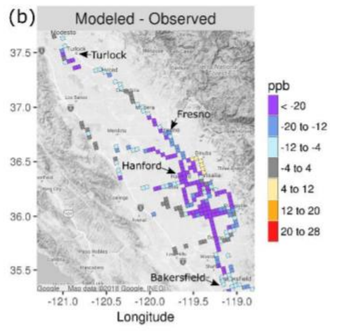

Figure 3. Difference between modeling NH_3 concentration and ground measurements [6]

Methodology

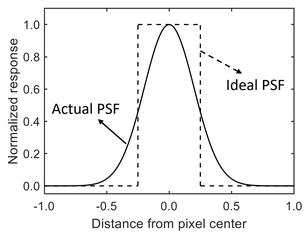

Figure 4. An example PSF

Point Spread Function (PSF)

- Ideal PFS: a uniform response to signals from within that pixel & **no response to signals from the outside**
- Actual PSF: **a significant portion** of the recorded signal of each pixel originates from the outside [8]

Spatial response function (SRF)

- The PSF projected on the ground
- Approximate the SRF: a **2-D Gaussian function** [9]

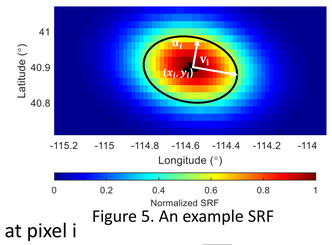

Figure 5. An example SRF

$\Omega(i)$: the vertical column density at pixel i

$\sigma(i)$: the uncertainty of vertical column density at pixel i

$$\mathrm{SRF}(u_i, v_i, t_i = 0, x_i, y_i, x_j, y_j) = \frac{\ln 2}{\pi u_i v_i} \exp\left[-\frac{\ln 2 (x_j - x_i)^2}{{v_i}^2} - \frac{\ln 2 (y_j - y_i)^2}{{u_i}^2}\right] \quad C(j) = \frac{\sum_i \frac{\mathrm{SRF}(i,j)}{\sigma(i)} \Omega(i)}{\sum_i \frac{\mathrm{SRF}(i,j)}{\sigma(i)}}$$

$\mathrm{SRF}(i,j)$+Uncertainty $\sigma(i)$→Weighted mean at grid j

Results: NH_3 map & case study

Spatial gradients

- e.g., gradient in the central U.S.

Hotspots

- San Joaquin Valley
- Central and Southern High Plains Aquifer
- Platte River Valley
- Northwest Iowa Plains

Overall seasonality:

- Low in winter, peak in spring/ summer

High variability of seasonality

Possible reason: different agricultural land use

- San Joaquin Valley (vegetation, dairy and cattle): July
- Northern Texas (beef cattle): June
- Eastern South Dakota (croplands): May
- Southeastern Kansas (croplands and cattle): May & August

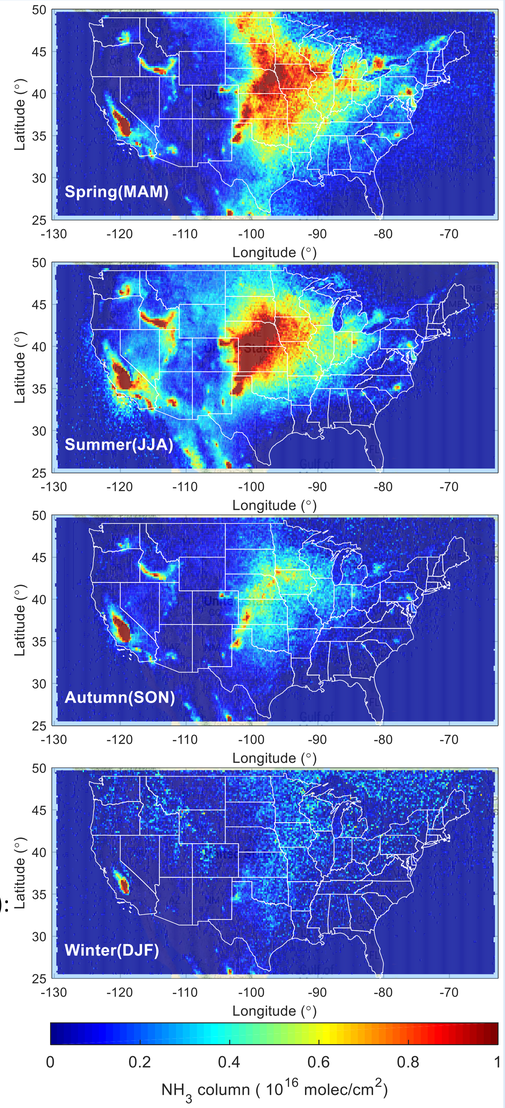

Figure 6. 2008-2016, IASI Metopa & Metopb, oversampling high resolution (0.02°×0.02°) maps

AMoN site: NC 35, NC (cropland ~ 60%, woodland~25%, pasture land~7%)

(35.0 °N, 78.3 °W)

- Peak in spring & summer
- Similar trend with AMoN ground measurements
- NH_3 hot spots in NC: co-located with pigs & hogs
- NH_3 emissions from both fertilizers and livestock

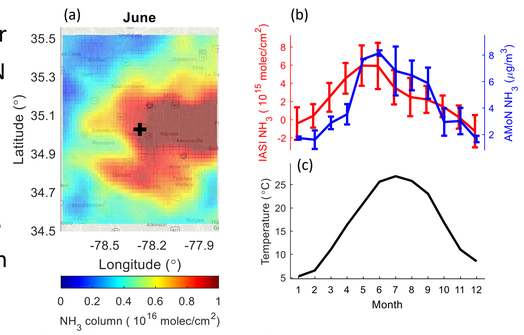

Figure 7. (a) Monthly oversampling NH_3 map (b) Monthly averaged IASI & AMoN NH3 ± 1σ (top) & (c) temperature (bottom) [10-12]

AMoN site: IL 11, IL (cropland ~ 95%)

(40.0528 °N, 88.3719 °W)

- Peak in spring: fertilizer application
- IL most active corn harvesting date: Sep. 23 – Nov. 5
- Crop burning: peaks in the afternoon
- IASI: may not be able to catch wildfire NH_3

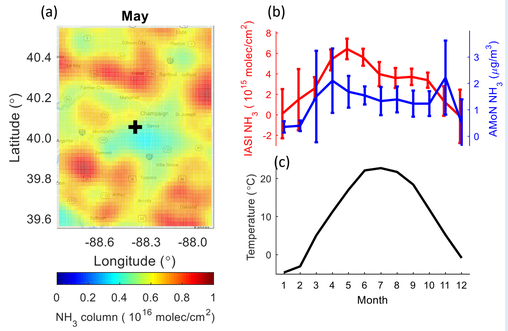

Figure 8. (a) Monthly oversampling NH_3 map (b) Monthly averaged IASI & AMoN NH3 ± 1σ (top) & (c) temperature (bottom) [10-12]

Weld County, CO (pastureland > 50%, cropland ~ 40%)

(40.5 °N, 104.5 °W)

- Cattle and calves: rank 3rd in the U.S.; sheep, goats, wool, mohair, and milk: 1st in the U.S.
- Hot spots co-located with feedlots [13]
- Peak in summer: NH_3 emission from feedlots (livestock etc.)
- Correlated well with temperature seasonality

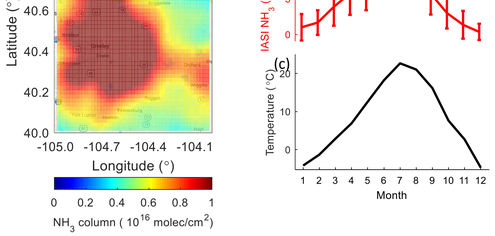

Figure 9. (a) Monthly oversampling NH_3 map (b) Monthly averaged IASI & AMoN NH3 ± 1σ (top) & (c) temperature (bottom) [10-12]

Conclusions & Future Work

- IASI is capable of providing high-resolution NH_3 map
- IASI NH_3 seasonality: agrees with AMoN. Influenced by different agricultural land use
- Further study: partitioning between NH_3 and NH_4^+; what drives the seasonality; build top-down NH_3 emission inventory

References

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[2] Paulot et al., 2014
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Acknowledgements: Special thanks to IASI team and Zondlo's group.