

Bridging scales with satellite and in-situ data: *from agricultural ammonia to volcanic emissions*

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NASA Health and Air Quality Applied Sciences Team #5 meeting

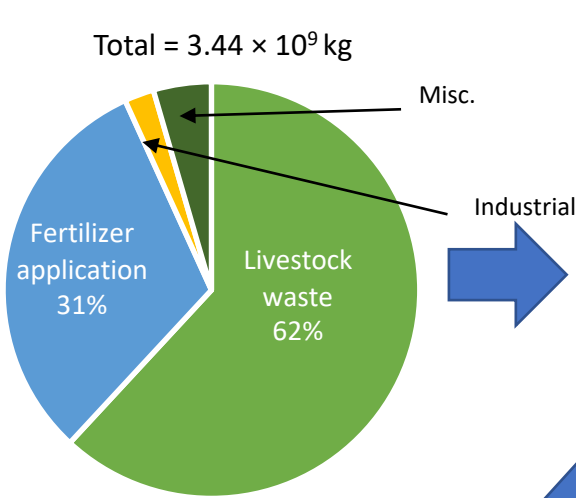
Phoenix, Arizona

January 4, 2018



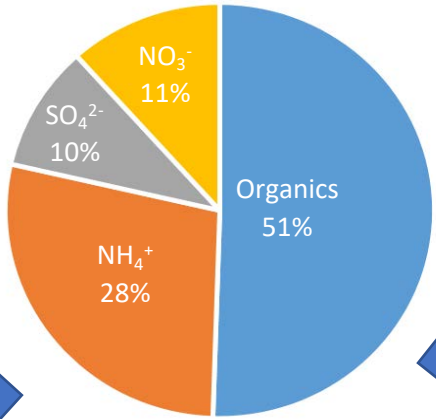
Ammonia (NH₃): air quality and ecosystem health

2011 U.S. NH₃ Emissions



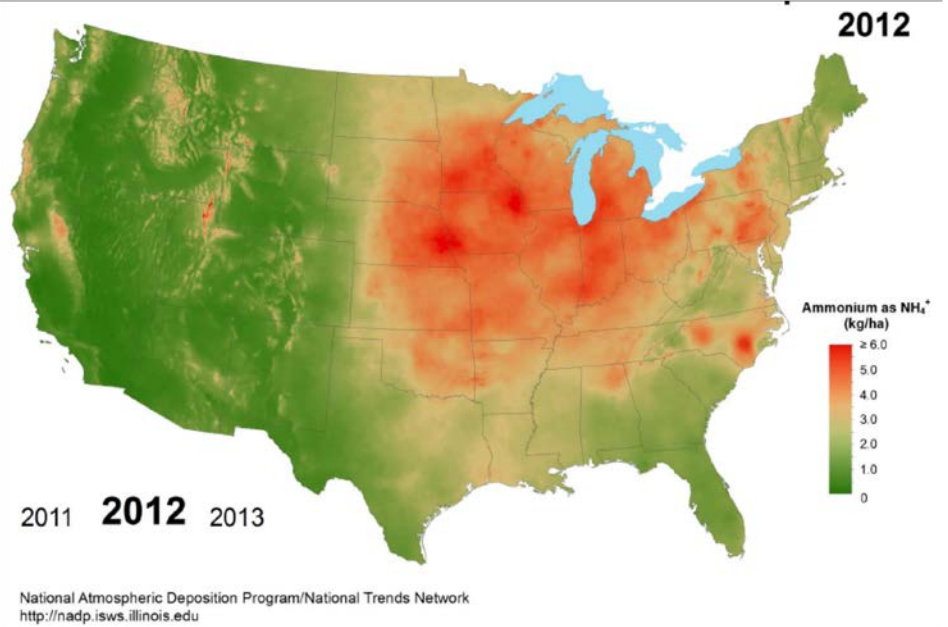
(EPA, 2011)

Aerosol composition by mole
Boulder, CO

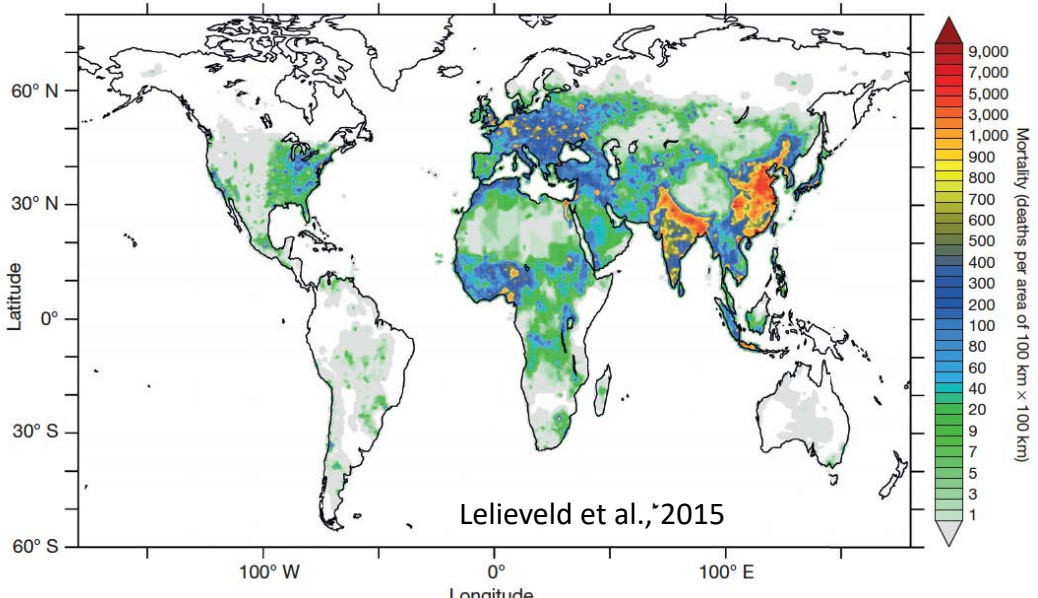


Adapted from Jimenez et al. (2009)

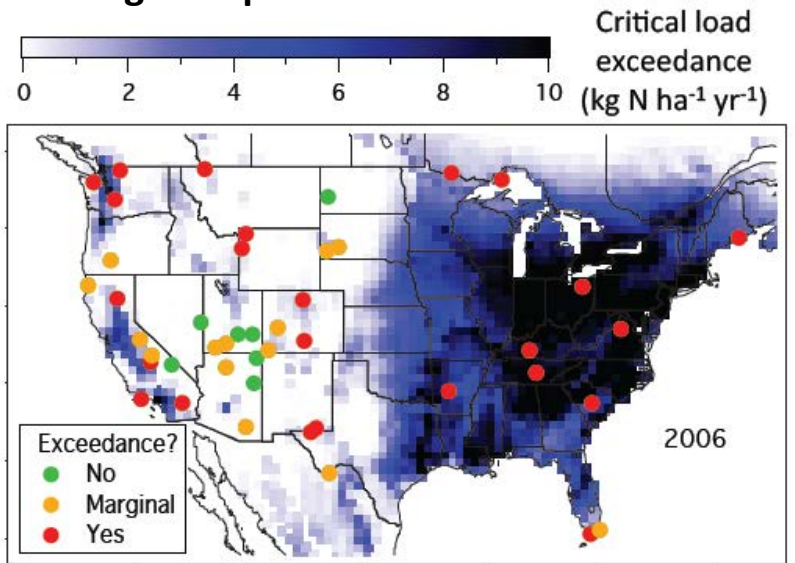
NH₄⁺ deposition in US



Deaths per year/10⁴ km² from pollution (agriculture 20%)

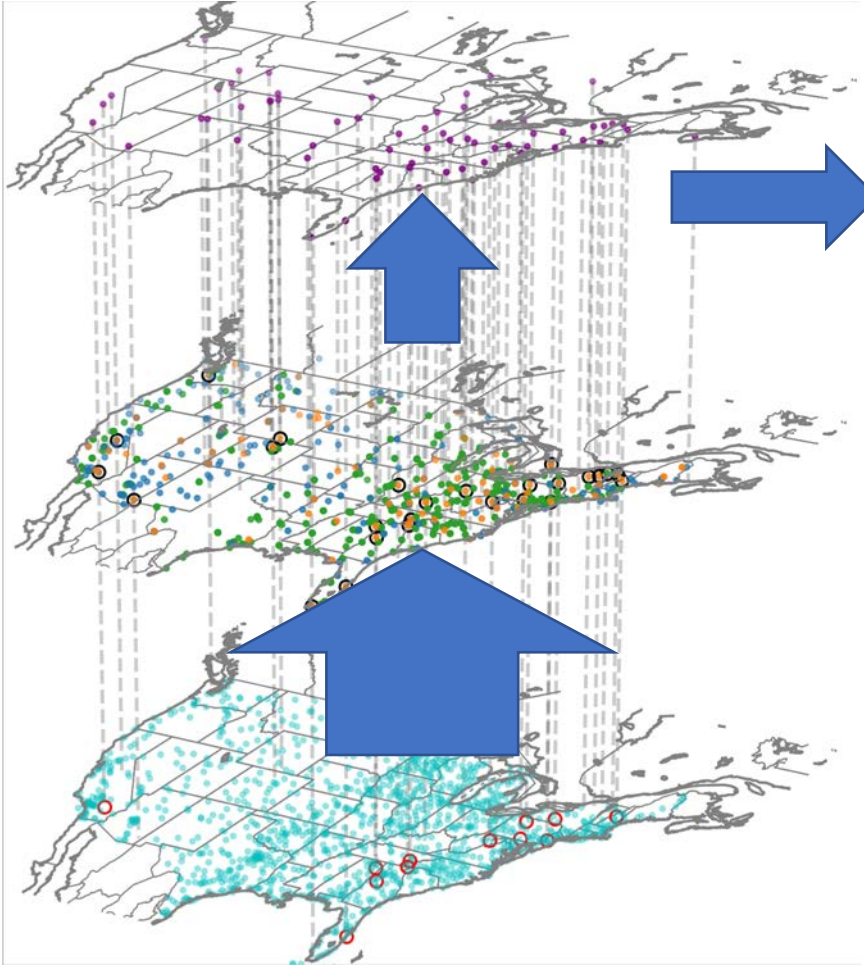


Excess nitrogen deposition in National Parks



Surface observational networks to constrain inorganic PM2.5

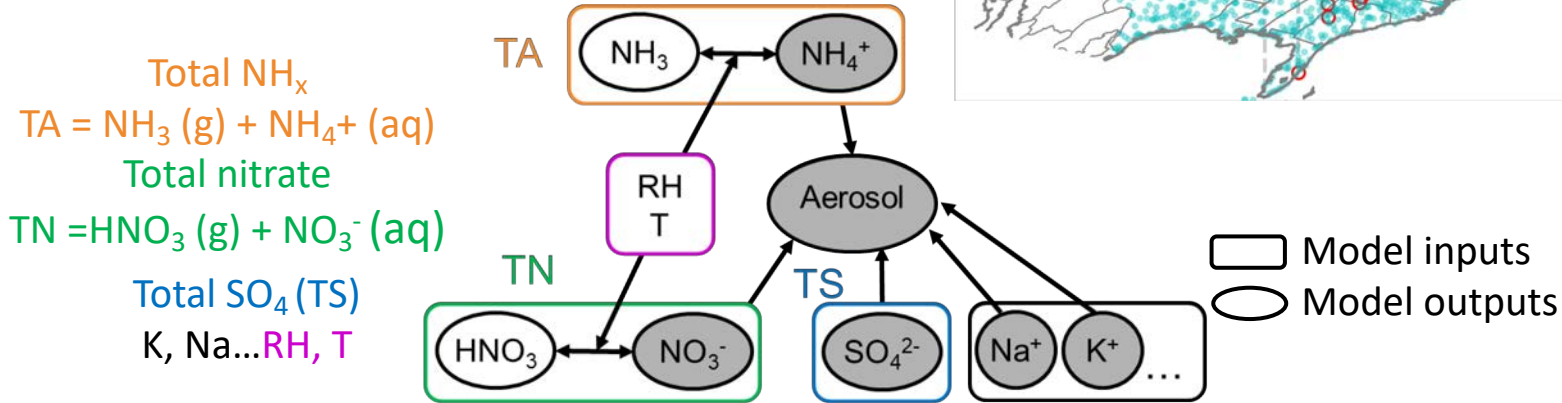
Network	Frequency	Number of sites
Gas phase NH ₃		
AMoN	Every 2 weeks	61
Aerosol composition		
CASTNET	Weekly	106
IMPROVE	Every 3 rd day	223
EPA CSN	Every 3 rd day	921
Meteorological conditions		
NOAA Integrated Surface Database	Hourly	1287



61 AMoN sites exist
NH₃ observations

25 AMoN sites have
NH₃ and aerosol composition

12 AMoN sites have
gas phase NH₃
aerosol composition
met. observations



Use thermodynamic aerosol chemistry model (ISORROPIA II) to predict PM2.5 sensitivities to changes in total nitrate vs. total NH_x

Sensitivity to $\text{PM}_{2.5}$ for reductions of total NH_x and nitrate

NO_3^- reduction
more effective

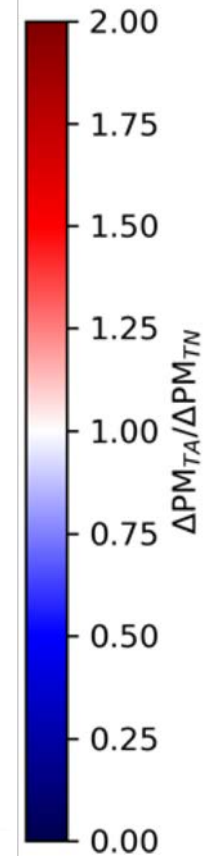
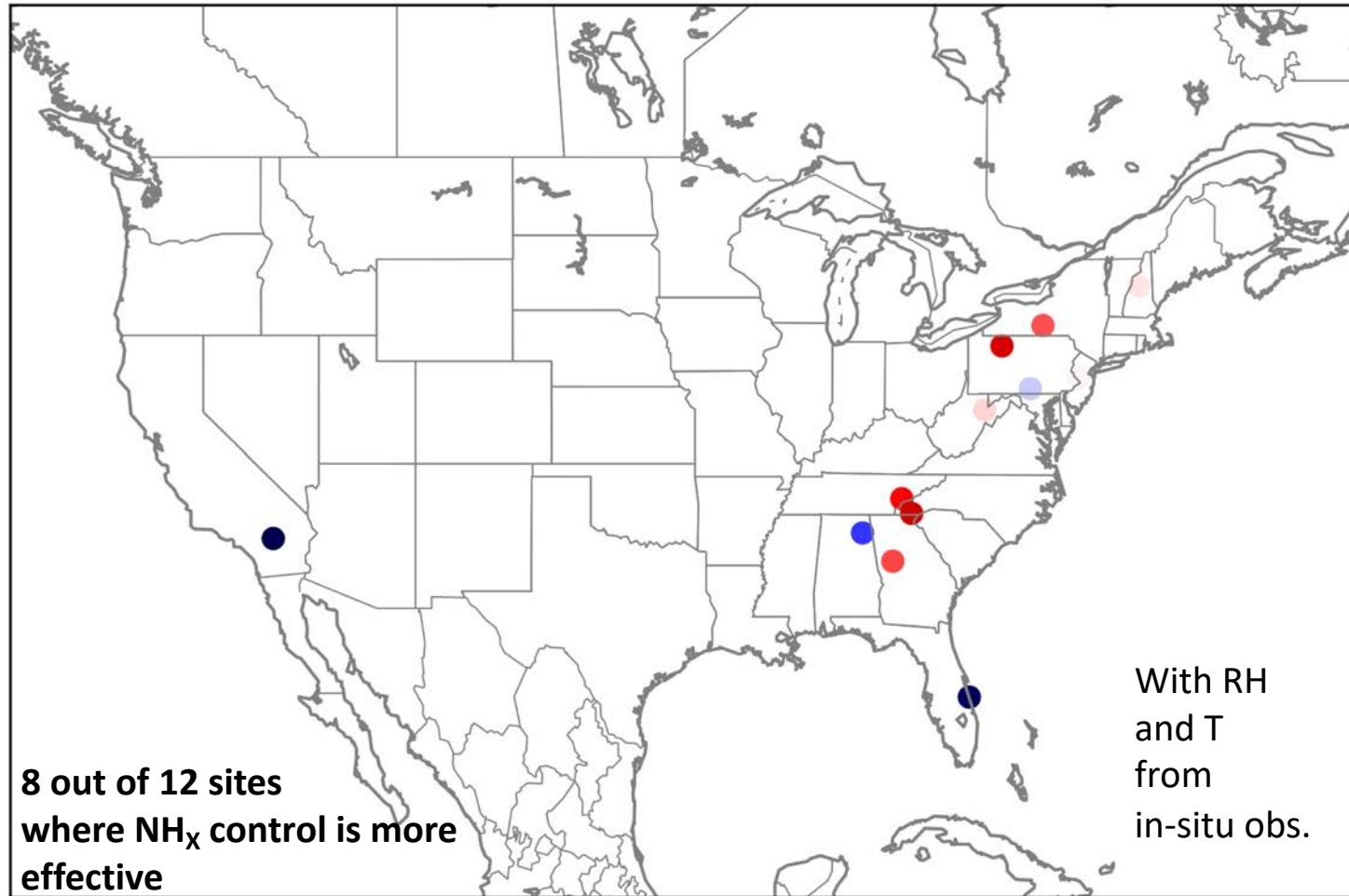
ratio < 1

$\text{PM}_{2.5}$ reduction with 50% reduction of total NH_x

$\text{PM}_{2.5}$ reduction with 50% reduction of total NO_3^-

ratio > 1

NH_3 reduction
more effective



Satellite NH_3 data can augment these types of analyses, also to constrain emission inventories

IASI satellite NH₃ measurements: oversampling for high spatial resolution

(Sun et al., AMT, 2018)

- Uses a 2-D Gaussian function to approximate the spatial response function (SRF)

(SRF determines the spatial response of the satellite pixel with respect to its center)

- Overlapping satellite pixels from different times are grid-averaged
- Weighted mean in each grid is used to plot the NH₃ map

Spatial response function SRF(i, j)

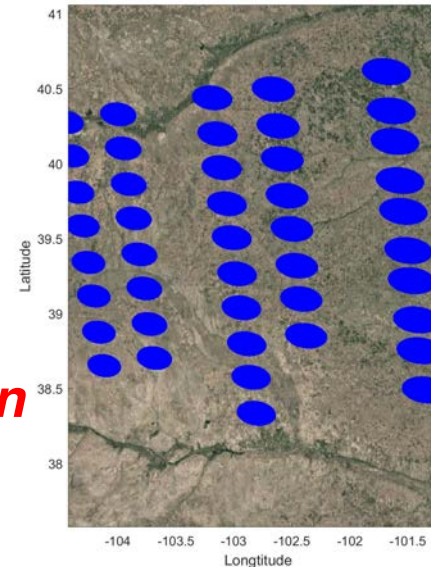
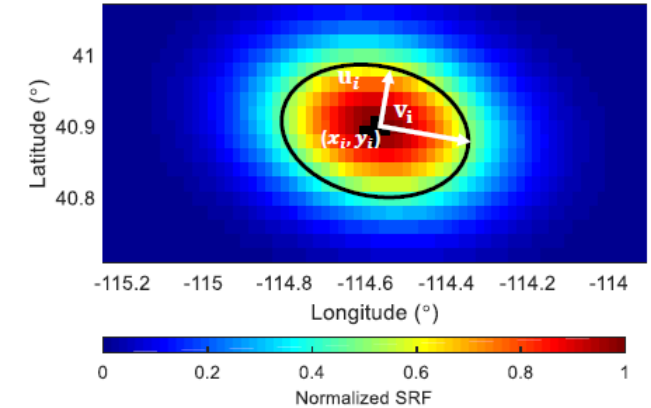
**+
Uncertainty $\sigma(i)$**

Weighted mean at grid j

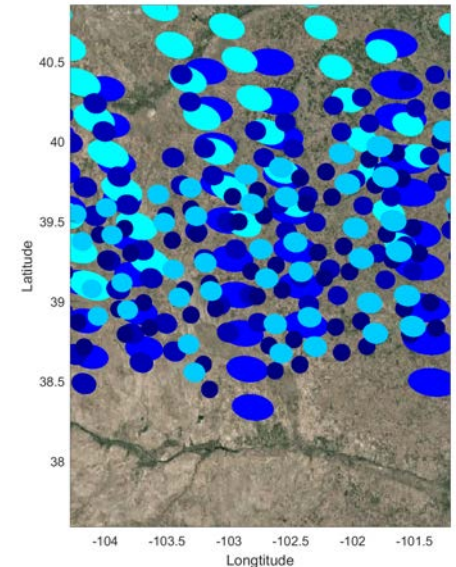
$$C(j) = \frac{\sum_i \frac{\text{SRF}(i, j)}{\sigma(i)} \Omega(i)}{\sum_i \frac{\text{SRF}(i, j)}{\sigma(i)}}$$

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

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



Satellite track on a single day



Satellite tracks on 5 continuous days

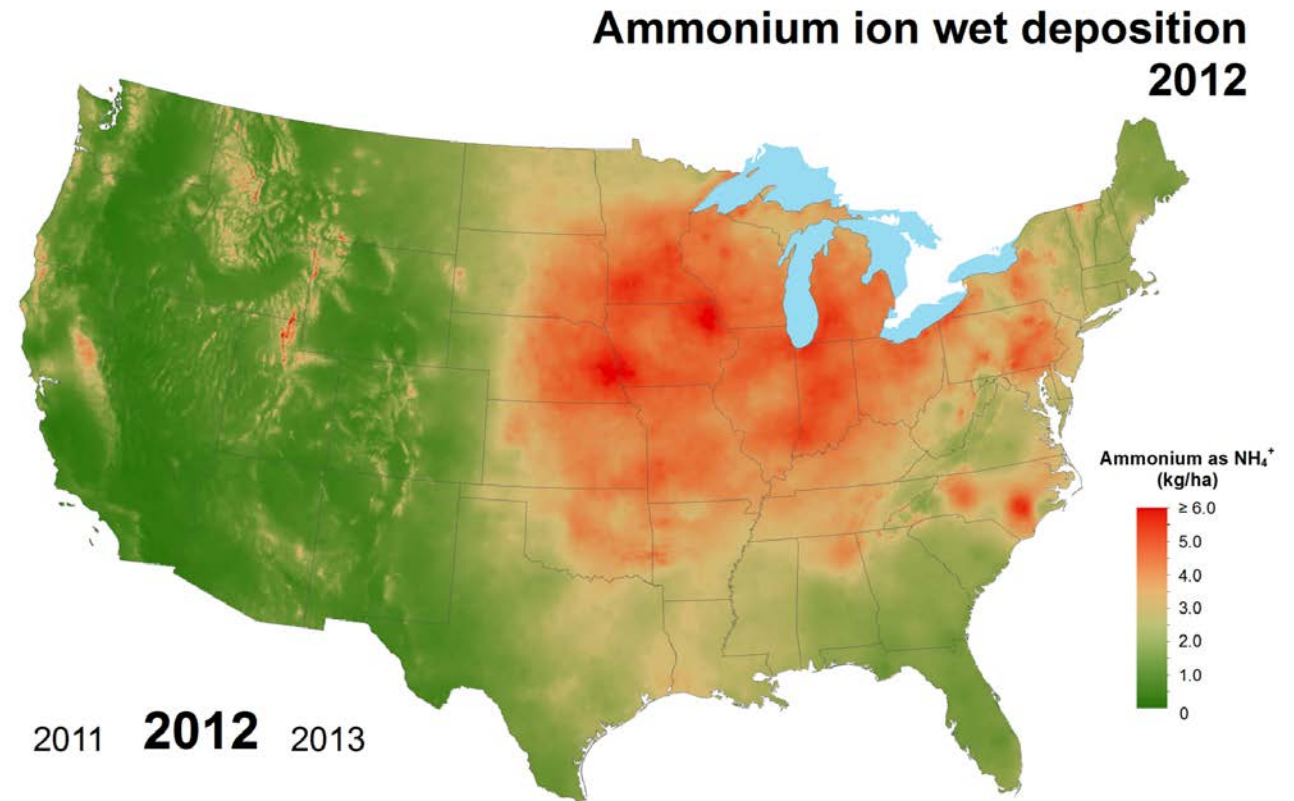
Trade temporal for spatial resolution for few km resolution

NH₃ IASI annual average and monthly changes

2008-2016, Metop/A & Metop/B, oversampling high resolution (0.02°×0.02°) maps

While NH₃ has a short lifetime and exhibits strong spatial gradients, its impact extends well beyond source regions.

Satellites can be used to identify siting requirements for next generation of ground-based networks



NH₃ IASI monthly changes: watching agriculture breathe

2008-2016, Metop/A & Metop/B, oversampling high resolution (0.02°×0.02°) maps

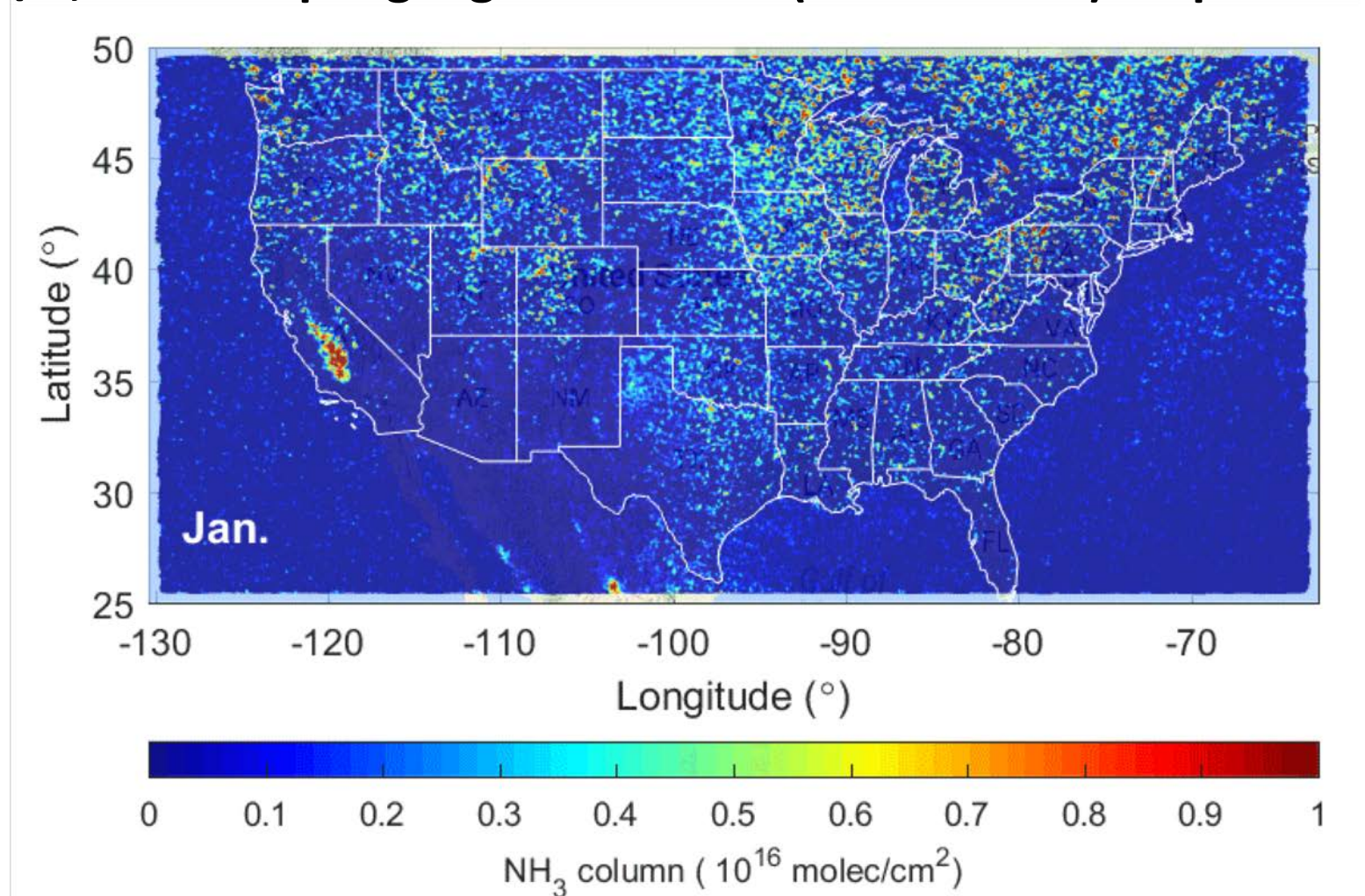
- **Overall seasonality:** low in winter, peak in spring/ summer

- **A high variability of seasonality:**

San Joaquin Valley peaks in July

Midwest in spring in May

High plains in July / August



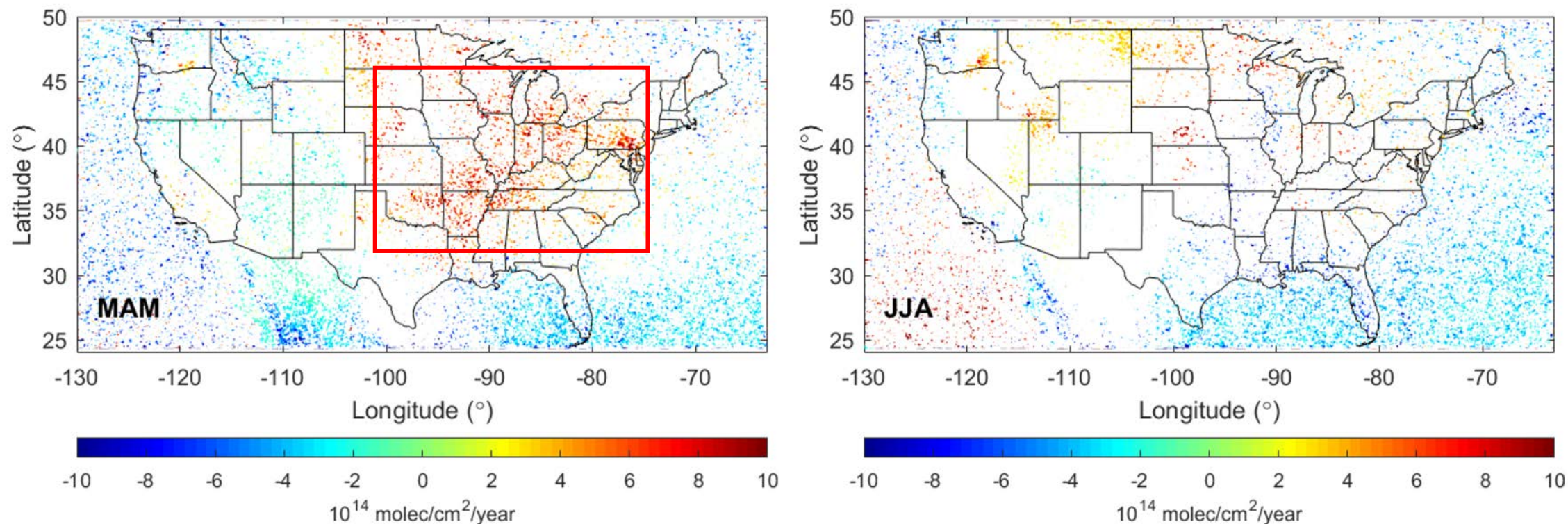
Trends in gas phase NH_3 (IASI) – Trends TT (Duncan and West)

2008-2016 seasonal oversampling, IASI NN v2.2r (removed discontinuities for trend analyses)

linear regression: slope > 0 & $p < 0.05$; decrease: slope < 0 & $p < 0.05$

NH_3 concentrations increasing over wide areas, particularly in spring (fertilizer usage)

...decreasing NO_x and SO_2 emissions in NE also a factor

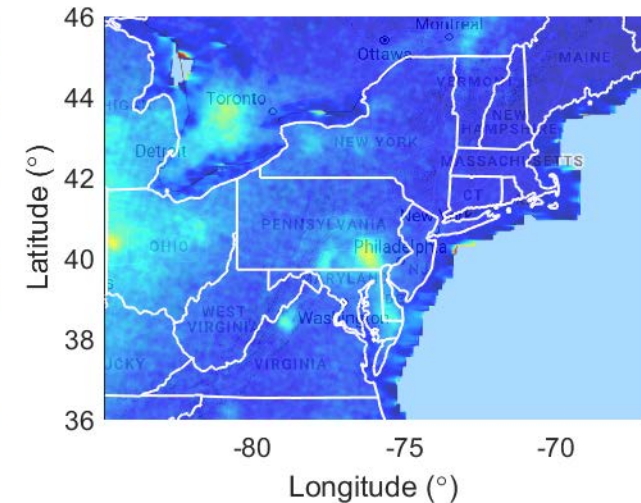
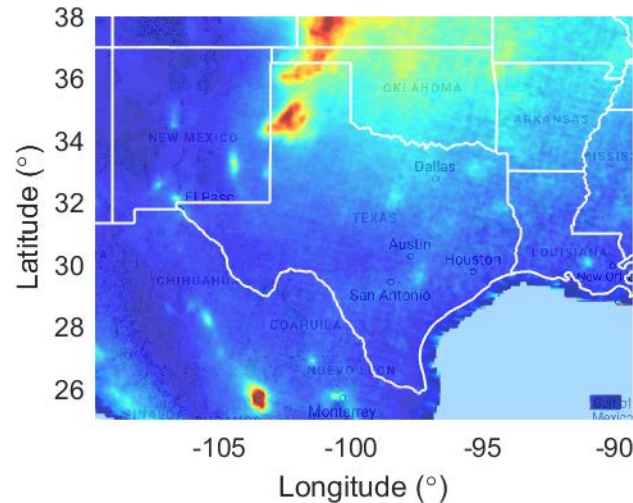
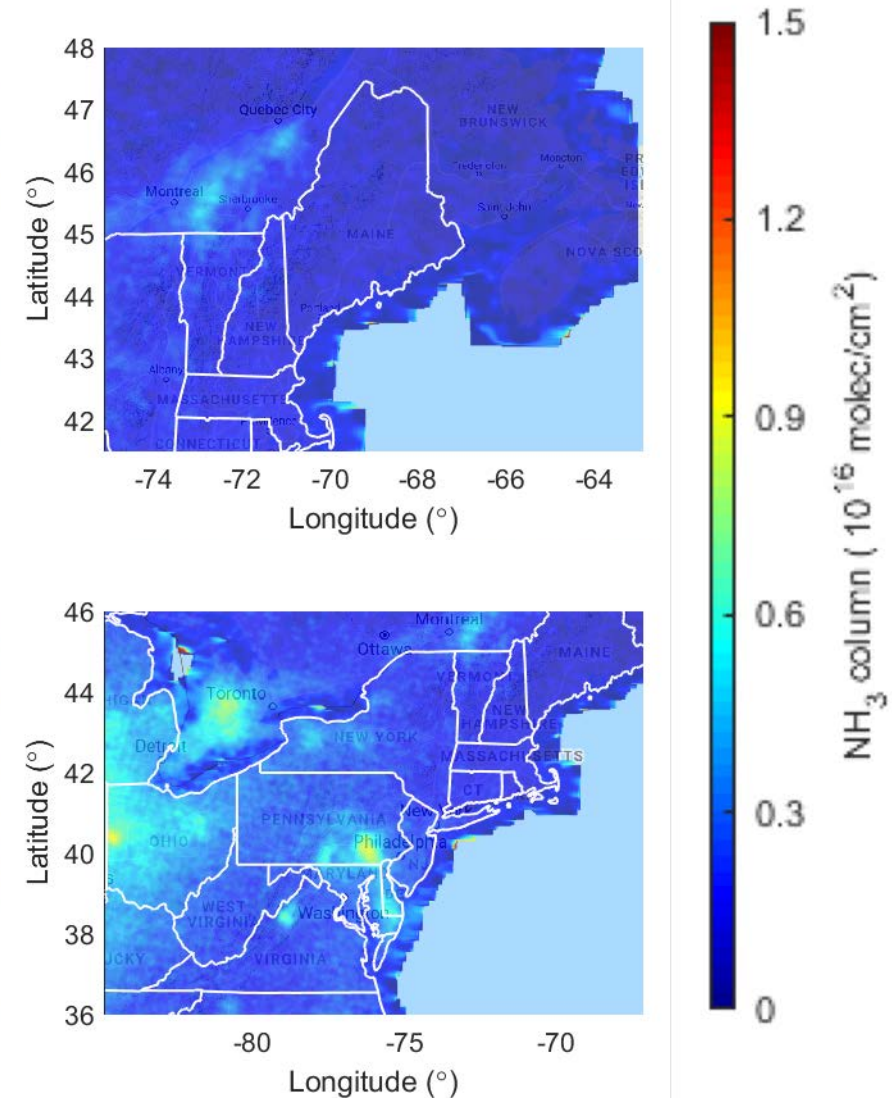
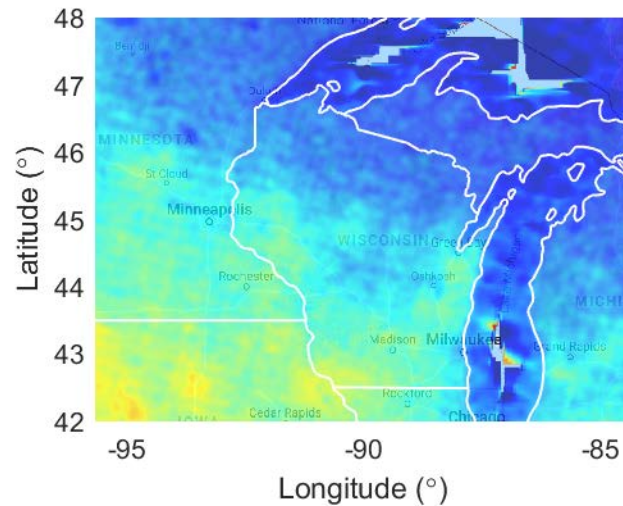
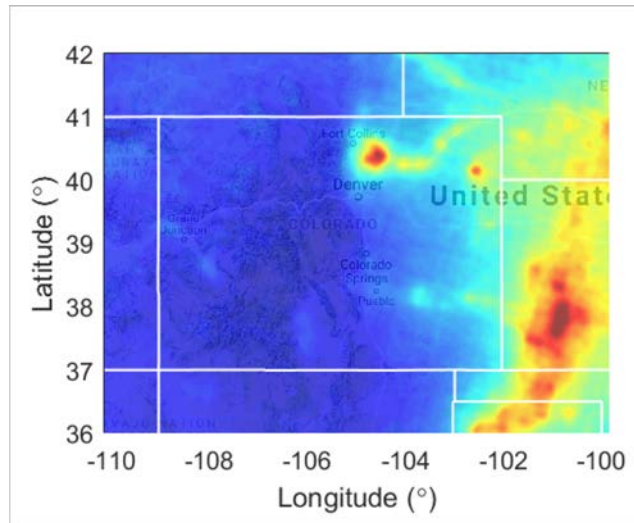


Up to 10% per year in select locations

Spatial patterns of NH₃ (IASI) – Haze TT (Fiore)

2008-2016, IASI Metopa & Metopb,
(0.02°×0.02°) maps

Stakeholders: Wisconsin, Maine,
Colorado, Texas, and Mid-Atlantic



Annual maps provide useful information on emission source locations

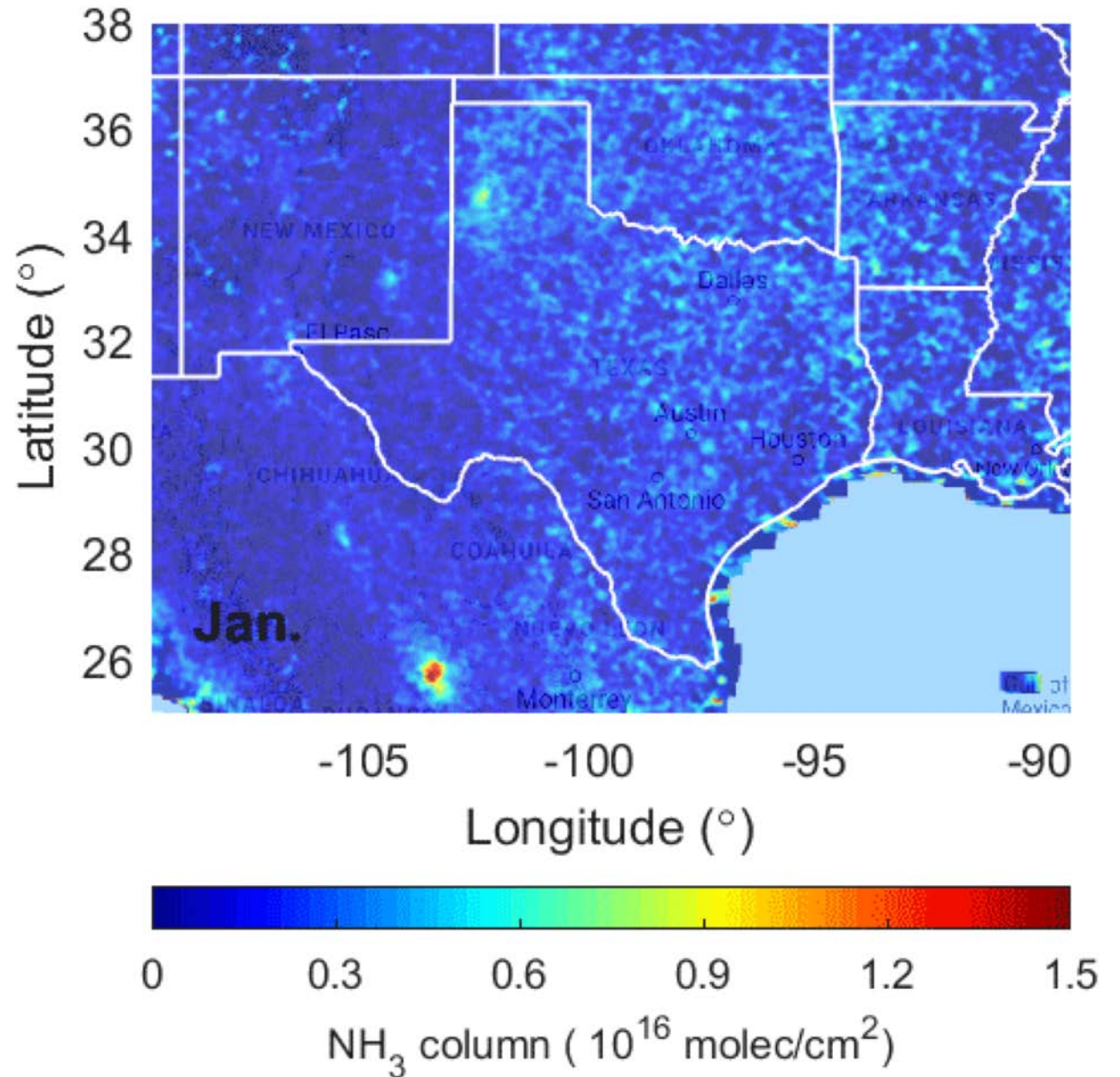
Monthly changes in NH_3 (IASI) – Haze TT (Fiore)

Texas case study:

Annual mean does not capture the hotspots change

Large month-to-month variations in both magnitudes and locations

Significant differences with various emission inventories



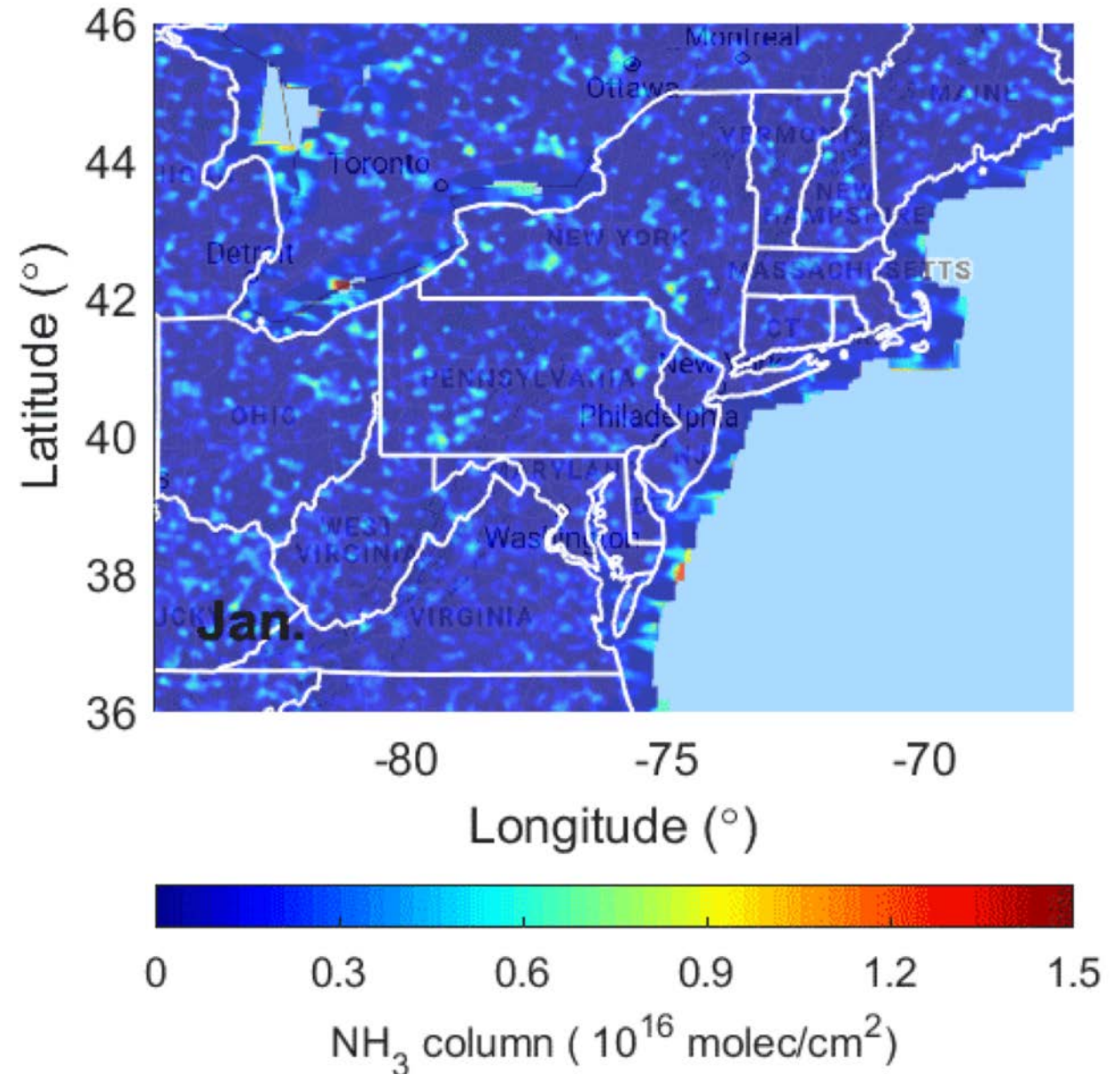
Monthly changes in NH_3 (IASI) – Haze TT (Fiore)

Mid-Atlantic case study:

Annual mean does not capture the hotspots change

Large month-to-month variations in both magnitudes and locations

Significant differences with various emission inventories



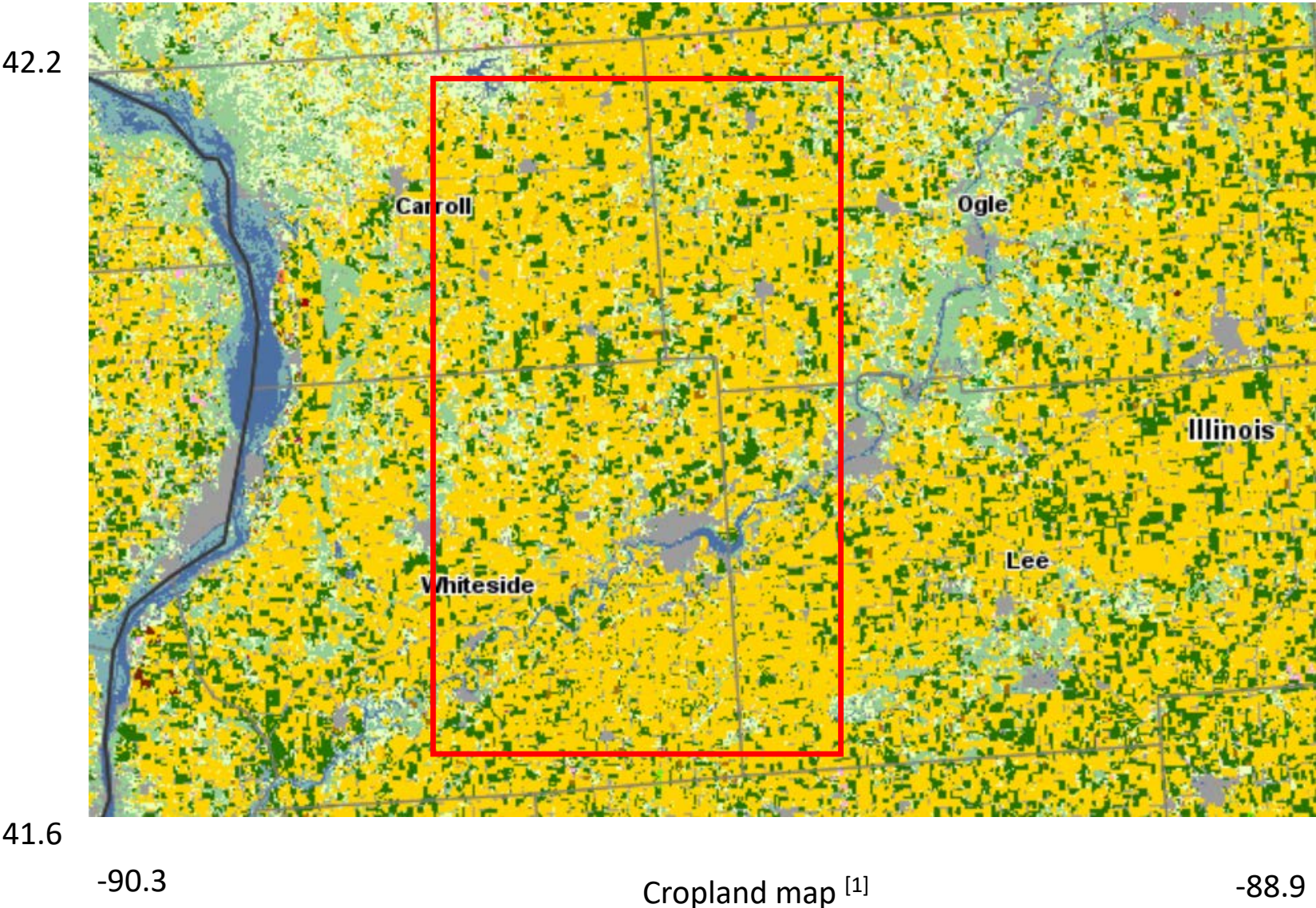
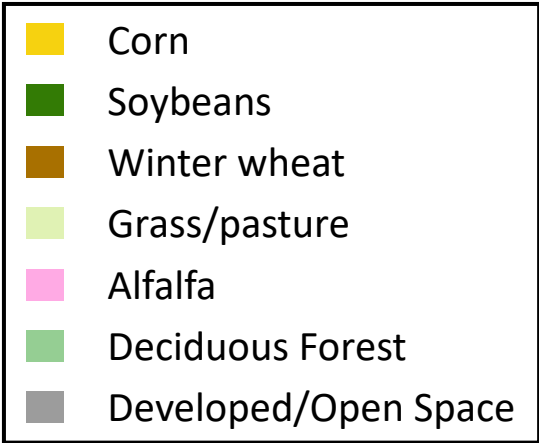
Examining NH₃ concentrations with USDA CropScape

Whiteside county, IL:

Corn dominated region [1]

$$\left(\frac{S_{\text{Corn}}}{S_{\text{Soybean}}} \approx 4\right)$$

Feedlots: limited [2, 3]

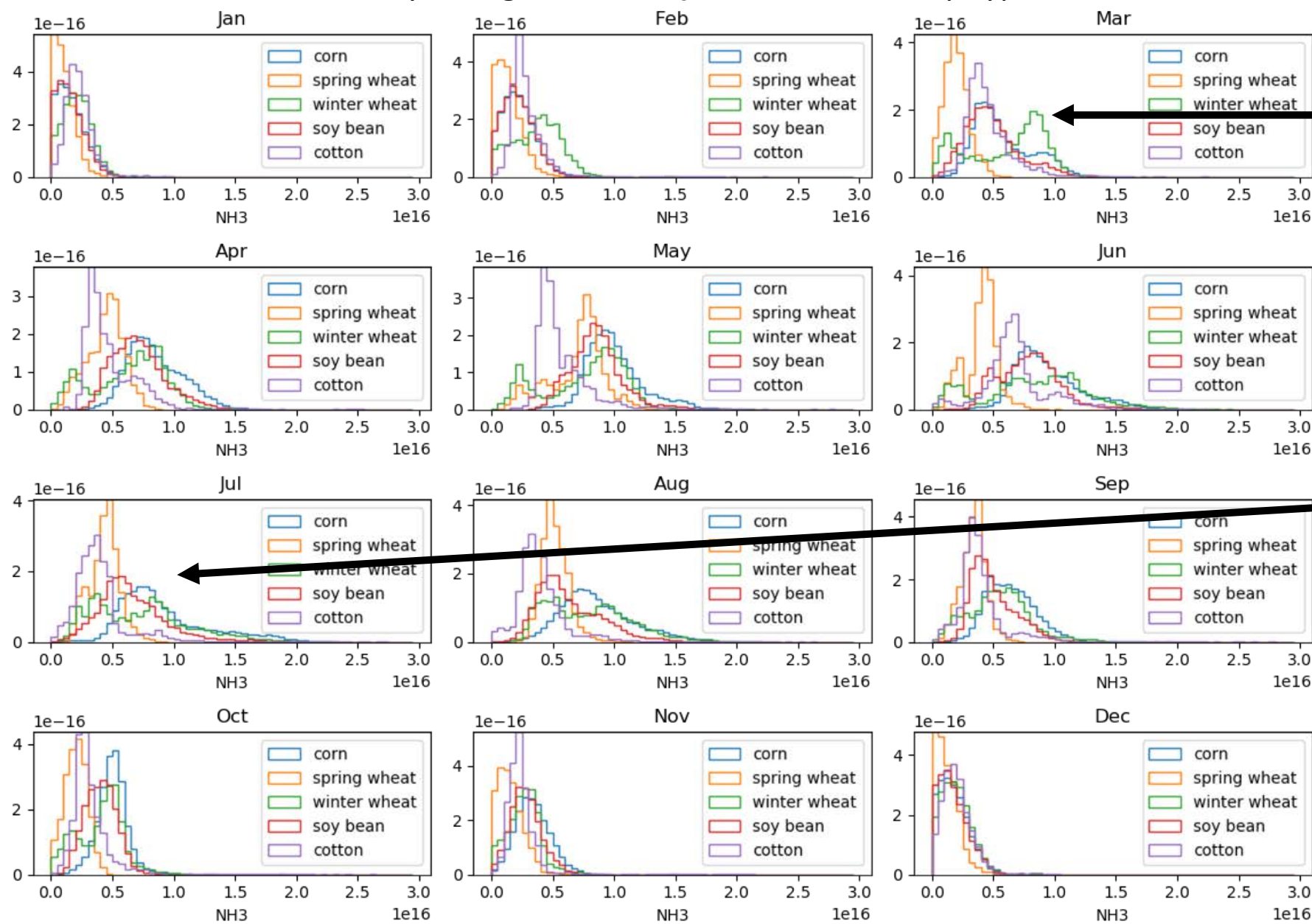


[1] USDA CropScape database [2] USDA National Agricultural Statistics Service, 2018 [3] Google earth

Observational constraints of crop type and emissions

F. Paulot, NOAA GFDL

Monthly histograms of NH₃ columns over crop type for US



Winter wheat fertilized early spring

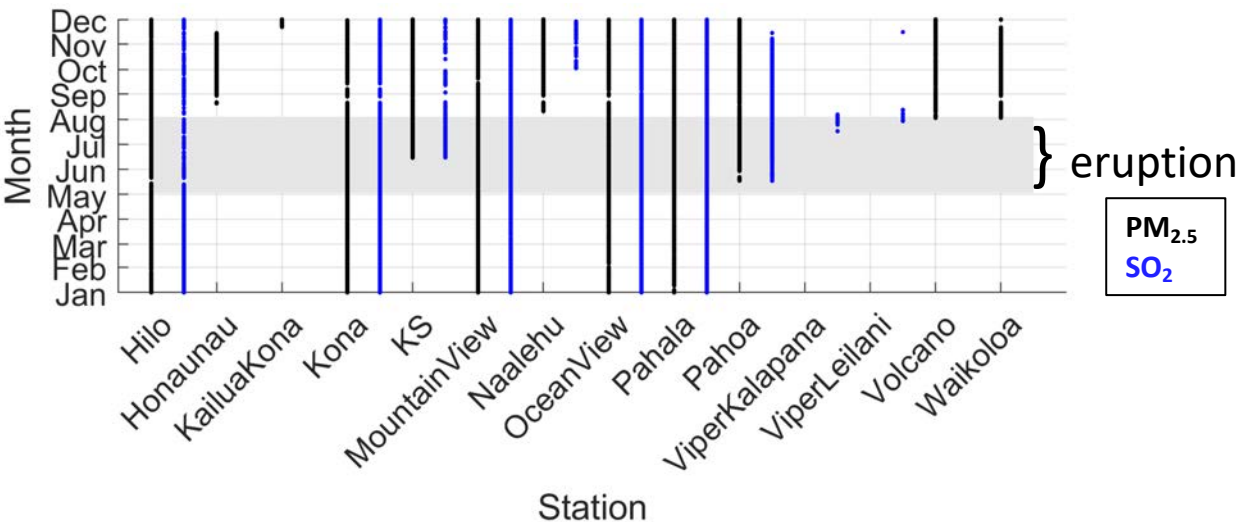
Corn higher NH₃ than soybeans

High-spatial resolution satellite maps allows for new observational constraints on agricultural emissions

Volcanic smog = vog in Hawaii

- major air quality issues on big island of Hawaii during the ~ 3 month 2018 Kilauea eruption
- excellent case study of highly-networked area (10 surface air quality networks!)
- satellite data, integrated with surface/model data, may provide more complete picture of air quality in space/time

HI Department of Health network data coverage



screenshot from
Hawaii Interagency Vog Information Dashboard

- 1. EPA eruption response air monitoring viewer**
EPA, Hawaii Department of Health (HDOH), Civil Defense, Hawaii County and State
Eruption response air quality network with independent color code advisory
- 2. Hawai'i short term SO₂ advisory**
Hawaii Department of Health (HDOH)
Current SO₂ levels across the Island of Hawai'i.
<http://www.hiso2index.info/>

Hawaii Department of Health SO₂ advisory levels
Suggested actions/activities at specific SO₂ concentrations/color codes
<http://www.hiso2index.info/assets/FinalSO2ExposureLevels.pdf>
- 3. AirNow particle data**
Federal, State and tribal consortium
Air Quality Index based on PM_{2.5} particle real-time monitoring data.
http://www.airnow.gov/index.cfm?action=airnow:local_state&stateid=12&mapcenter=0&tab=0
and <https://www.airnow.gov/index.cfm?action=pvba:aqiadvspart> for recommended actions at specific particle concentrations (AQI)/advisory levels.
- 4. Hawaii ambient air quality data**
Hawaii Department of Health (HDOH) Clean Air Branch
Maps, current, and historical data of air quality conditions (SO₂ and PM_{2.5}, plus other pollutants at some locations) in the Hawaiian Islands.
<http://enviroeb.doh.hawaii.gov/air-quality/>
Annual summaries of Hawaii air quality data can be found at: <http://health.hawaii.gov/cab/hawaii-air-quality-data-books/>
- 5. Current SO₂ and PM_{2.5} conditions in Hawai'i Volcanoes National Park**
NPS
Map showing approximate location of the Halema'uma'u and Pu'u 'Ō'ō gas plumes in HVPN. SO₂ concentrations (ppm) at nine locations, and PM_{2.5} at two locations in the park.
<http://www.hawaiiso2network.com/>
NPS webcam of plume, and current and 10-day history air quality data for SO₂ and PM_{2.5}.
<http://www.nature.nps.gov/air/webcams/parks/havoccam/havoccam.cfm>
Archived NPS HVPN air quality data can be found at: <http://nps-npqs.air-resources.com/>
- 6. Recent Kilauea eruption update and summary, information on volcanic hazards, and weekly Volcano Watch articles**
USGS
Hawaiian Volcano Observatory front page. Search the Volcano Watch archive for information about vog and volcanic gases.
<http://hvo.wr.usgs.gov/>
- 7. Webcams – Live views of Kilauea degassing vents**
USGS
Hawaiian Volcano Observatory webcams showing active degassing at Halema'uma'u and Pu'u 'Ō'ō vents.
<http://hvo.wr.usgs.gov/cams/>
- 8. SO₂ in Volcano Village**
UH Hawaii at Manoa, JABSON
Approximate SO₂ concentrations at Volcano Arts Center
<http://volcanoartscenter.org/about/current-weather-so2-in-volcano-village/>
- 9. PurpleAir Particle Data for Hawai'i Island and State**
PurpleAir air quality network
Particle concentrations for Hawai'i Island and State using low-cost sensors operated by the public. An evaluation of the accuracy of these monitors in comparison to federal reference methods can be found at: <http://www.epa.gov/oa-spc/evaluations/summary>
<https://www.purpleair.com/>
- 10. Hawai'i Island Vog Network**
MIT Hawaii Island monitoring network
Air quality equipment description (planned network - no data yet)
<http://kilaueacenter.org/research/vog-network>

Geologists say the Hawaii volcano eruption could last for months, or even years



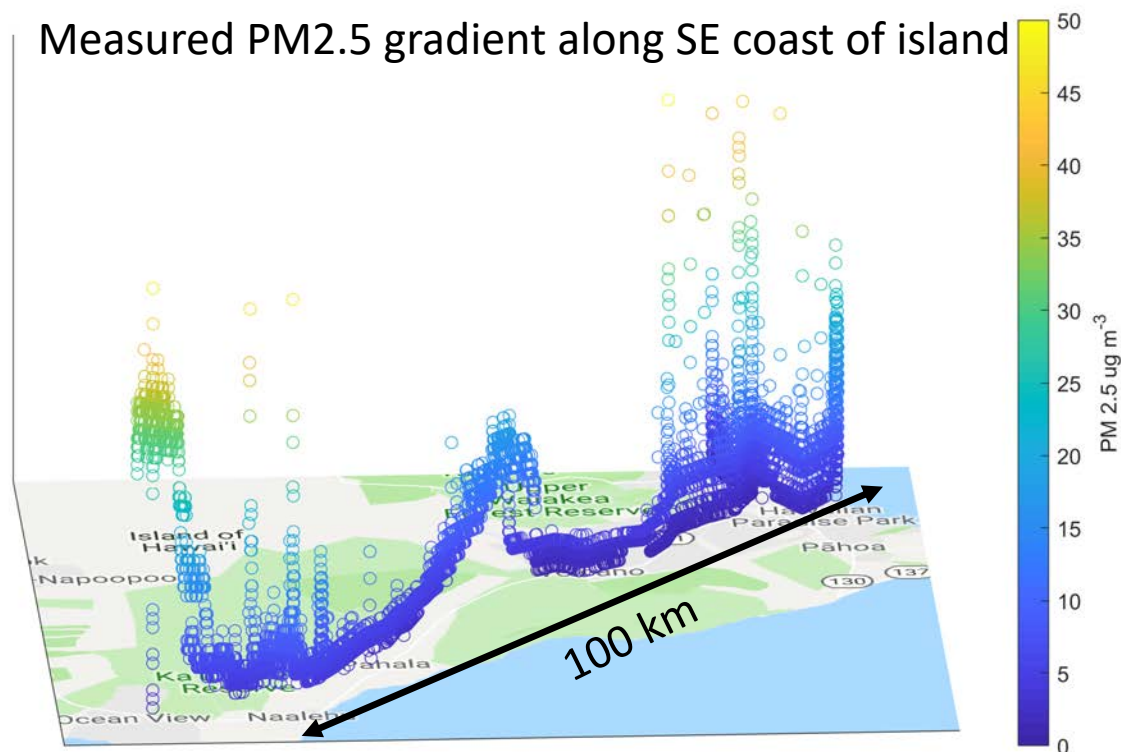
By **David Williams**, CNN

🕒 Updated 3:14 PM ET, Mon July 23, 2018



vog on Kona coast

Measured PM2.5 gradient along SE coast of island



Electric vehicle PM2.5 + trace gas measurements

Satellite data for air quality during Kilauea eruption

Original plan: synthesize surface networks, OMI/OMPS SO₂, examine spatial mobile laboratory gradients between stations, SO₂ sondes to better constrain spatiotemporal patterns of air quality in Hawaii

Photo: July 31, 2018 three miles from Fissure 8

Kilauea Volcano's Eruptions Could Continue for Months or Years, Report Says

By Sean Breslin · July 26 2018 05:00 PM EDT · weather.com

At a Glance

- A new report from the Hawaii Volcano Observatory says the eruptions at the Kilauea Volcano could continue for months or years.
 - Lava flows have been reported at the lower East Rift Zone since May 3.
 - Since the eruptions began, more than 700 homes have been destroyed on the Big Island.
-

While Hawaii's Kilauea Volcano has been erupting almost continuously since 1983, a recent spate of eruptions that have destroyed hundreds of homes could continue indefinitely, according to a new report.

Issued by the U.S. Geological Survey's Hawaii Volcano Observatory, the report says the eruptions in Kilauea's lower East Rift Zone could become the longest ever recorded at the volcano, as the lava flows **show no sign of slowing down.**

That could mean more homes in danger, and with more than 700 dwellings



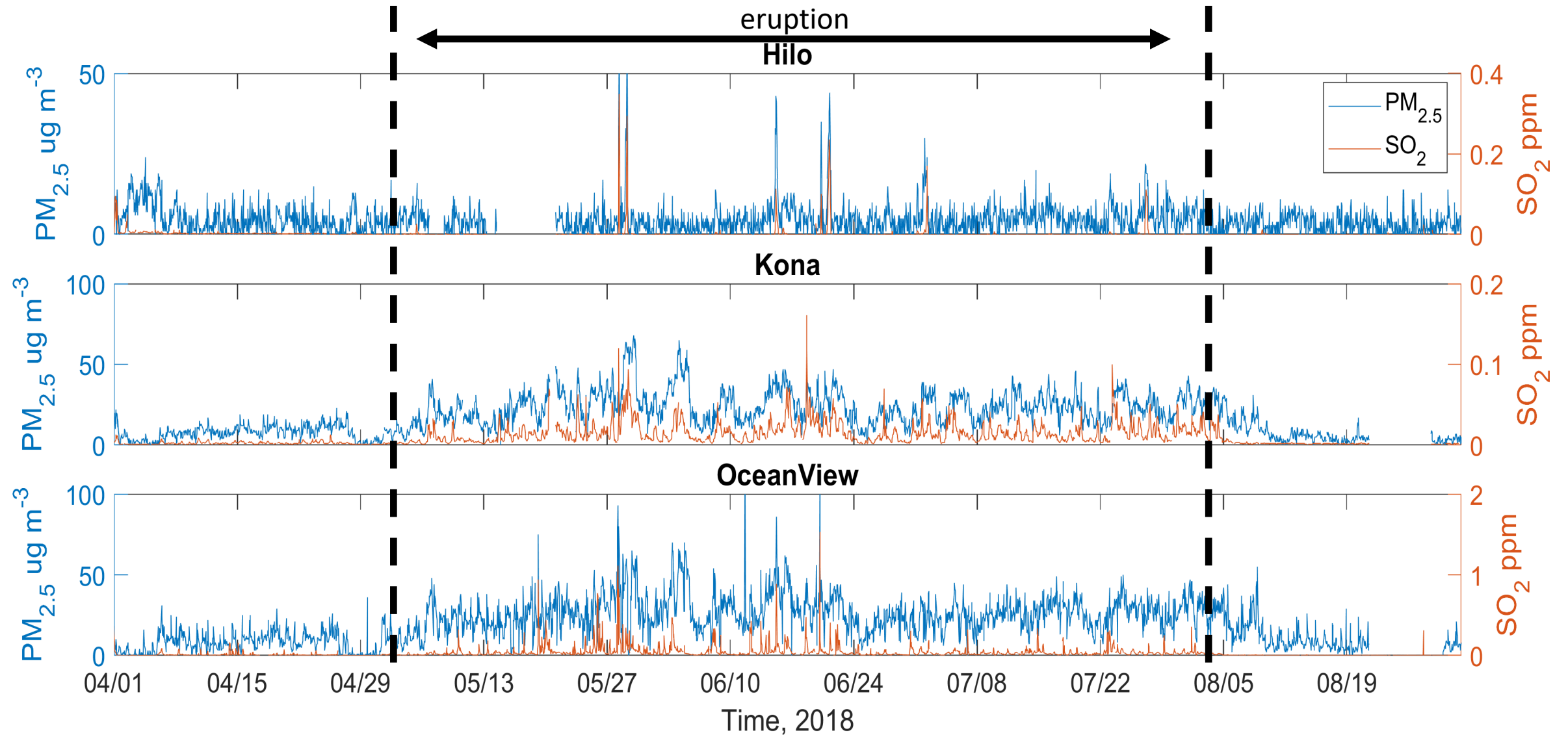
Kīlauea Eruption Abruptly Slows Down

Volcanologists say it's too soon to know whether the sudden drop in activity signals the end of the eruption or just a pause.

Signs of a Slowdown

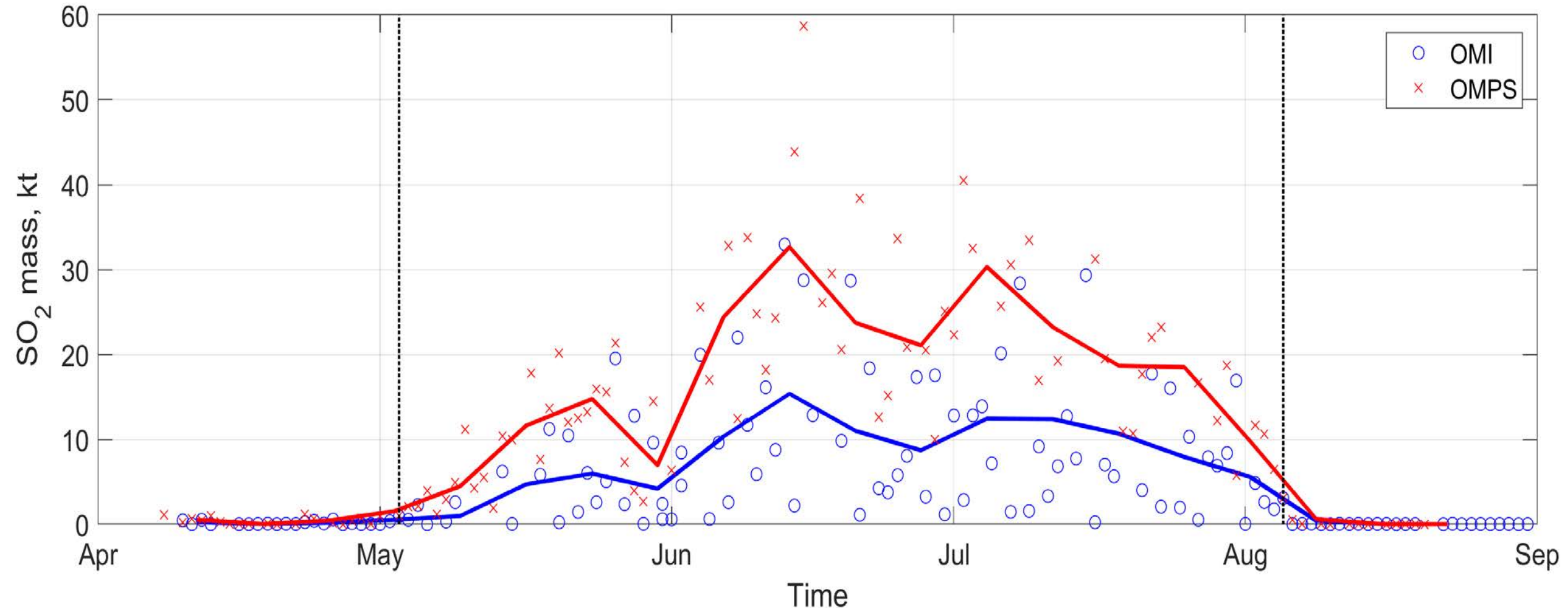
Although they were not obvious at the time, Neal says scientists now recognize that the volcano may have been giving signs since mid-July that the eruption was going to change.

Surface PM_{2.5} and SO₂ datasets



PM_{2.5} and SO₂ surface data showed no obvious trends during July into early August

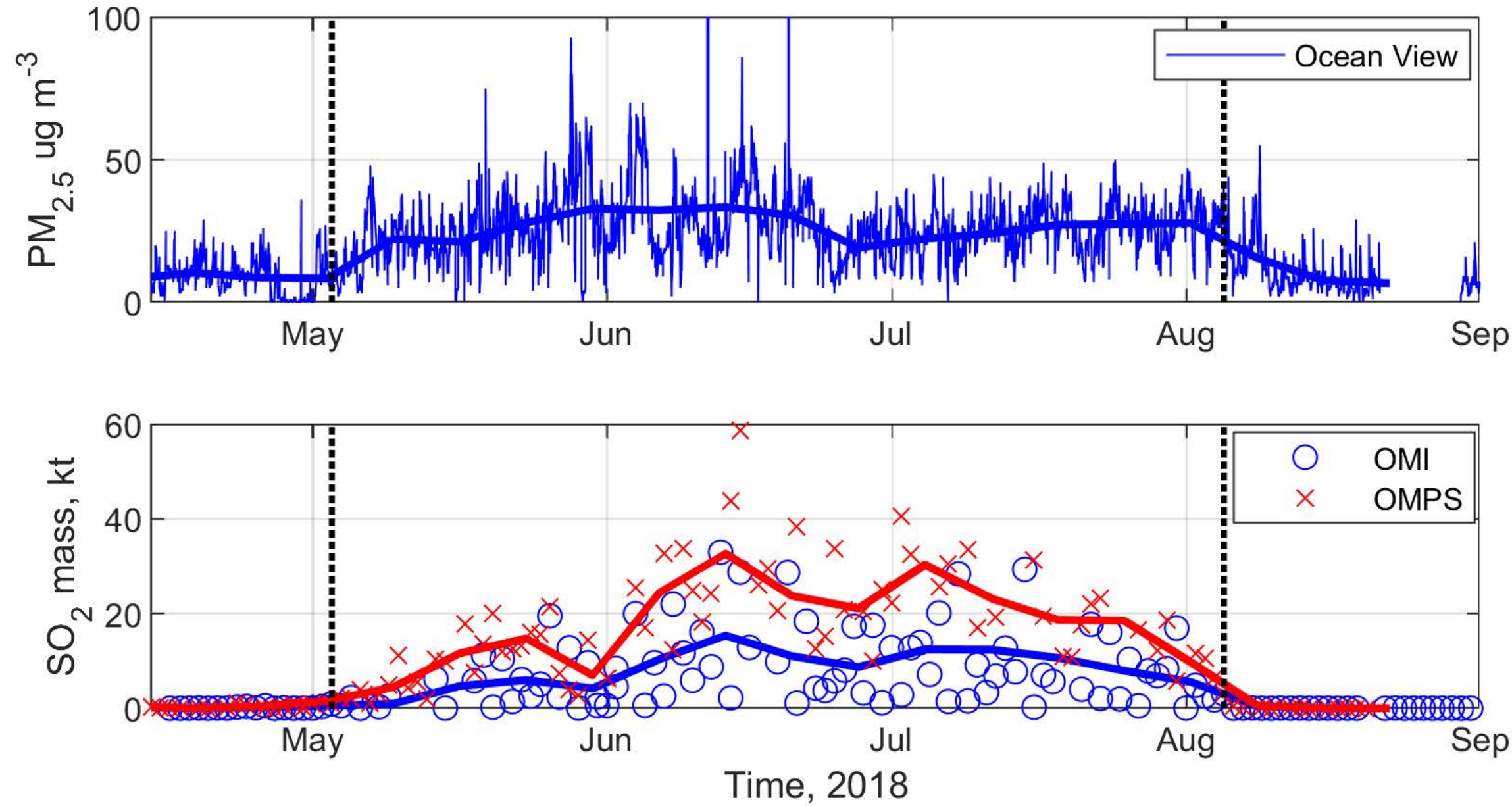
What did SO₂ mass from OMI and OMPS suggest?



SO₂ decreasing significantly during July prior to the shutdown on Aug. 4, 2018

Future work: TROPOMI SO₂ (?), integration of surface/satellite/model products

Comparison of surface PM2.5 and satellite SO₂



Using satellites to bridge scales: ongoing work and future directions

Agriculture

- Satellite NH_3 provides excellent constraints on the spatial pattern of NH_3 emissions
 - relevant for siting of next generation of ground-based network locations (N deposition, background trends, etc.)
- Because NH_3 emissions vary strongly with time, annual means not be representative of their importance
- NH_3 levels trending upwards up to 3-5%/year in Midwest, particularly in agricultural regions
- High-resolution NH_3 and land use provide observational constraints on crop-type emissions and potentially fertilizer usage

Volcanoes

- Satellite SO_2 was a useful indicator of the 2018 Kilauea eruption intensity, not well recognized by some stakeholders (opportunity!)
- Synthesized satellite datasets in Hawaii have promise of improved maps of air quality



Year 2.5 Progress Update, PI Mark Zondlo

SPATIOTEMPORAL VARIABILITY OF AMMONIA THROUGH SYNTHESSES OF IN-SITU-, GROUND-BASED, AND REMOTE SENSING MEASUREMENTS

- Validation of satellite NH_3 at pixel scale
 - Zondlo et al., JGR paper in prep. for IASI
- Spatial variability of NH_3
 - Paper published on oversampling algorithm (Sun et al., *Atmos. Meas. Tech.*, 2018)
 - Paper published with EPA on San Joaquin Valley ammonium nitrate formation (Kelly et al., *JGR-A*, 2018)
- Temporal variability of NH_3
 - 1 paper in prep. on monthly US emissions at high spatial resolution
 - NASA Earth Observatory Image of the Day on Dec. 10, 2018 with IASI NH_3
 - 1 paper in prep. on ammonia dry deposition in North Carolina with EPA
 - 1 paper in prep. on the effectiveness of NH_x control for $\text{PM}_{2.5}$ from observational datasets
- Integrating satellite/surface data for Kilauea eruption (new)
 - Examining how satellite data can help fill in gaps of the existing surface network and be an indicator for volcanic activity
- Stakeholder talks to Western Regional Air Partnership Regional Technical Operations Working Group, Colorado Dept. of Public Health and the Environment, California Air Resources Board, EPA ORD, New Jersey DEP + 8 academic talks in 2018

Tiger Team Participation

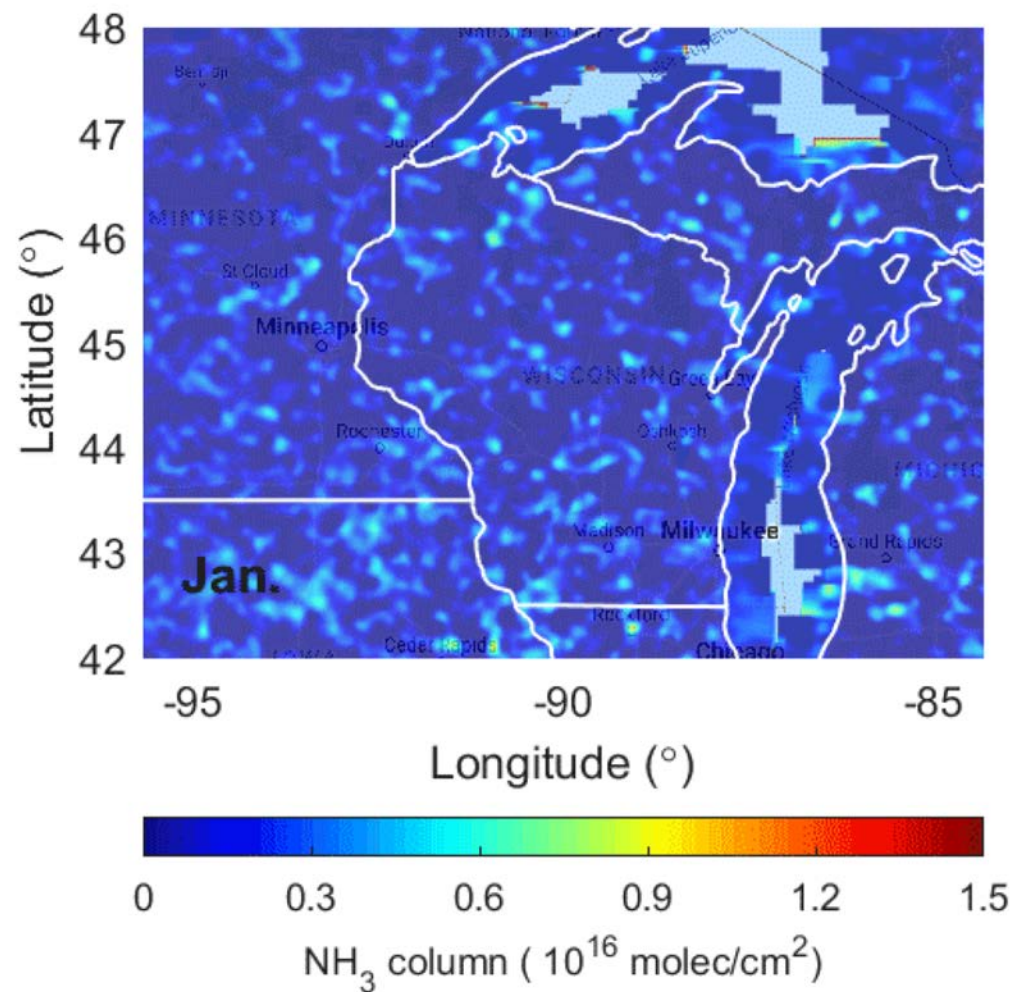
- TT Trends (Duncan/West)
 - Ammonia trends for eastern US from satellite
 - Monthly trends in Mid-Atlantic region
- TT SIP (Fiore)
 - 2-page primer on the availability and use of satellite ammonia to stakeholders written for archival
- TT High-resolution (Kinney)
 - Measured 50 transects of $\text{PM}_{2.5}$ across Central Park to compare to maps from satellite and low-cost sensor network gradients across this part of Manhattan
- TT Regional Haze (Fiore)
 - Delivering ammonia spatial maps monthly to four regional stakeholders for constraining ammonia emission inventories
- TT 2017 Fires (O'Neill)
 - Examining NH_3/CO enhancement ratios from CrIS satellite observations to examine precursor $\text{PM}_{2.5}$ emissions from fires

2 papers published

4 papers in preparation

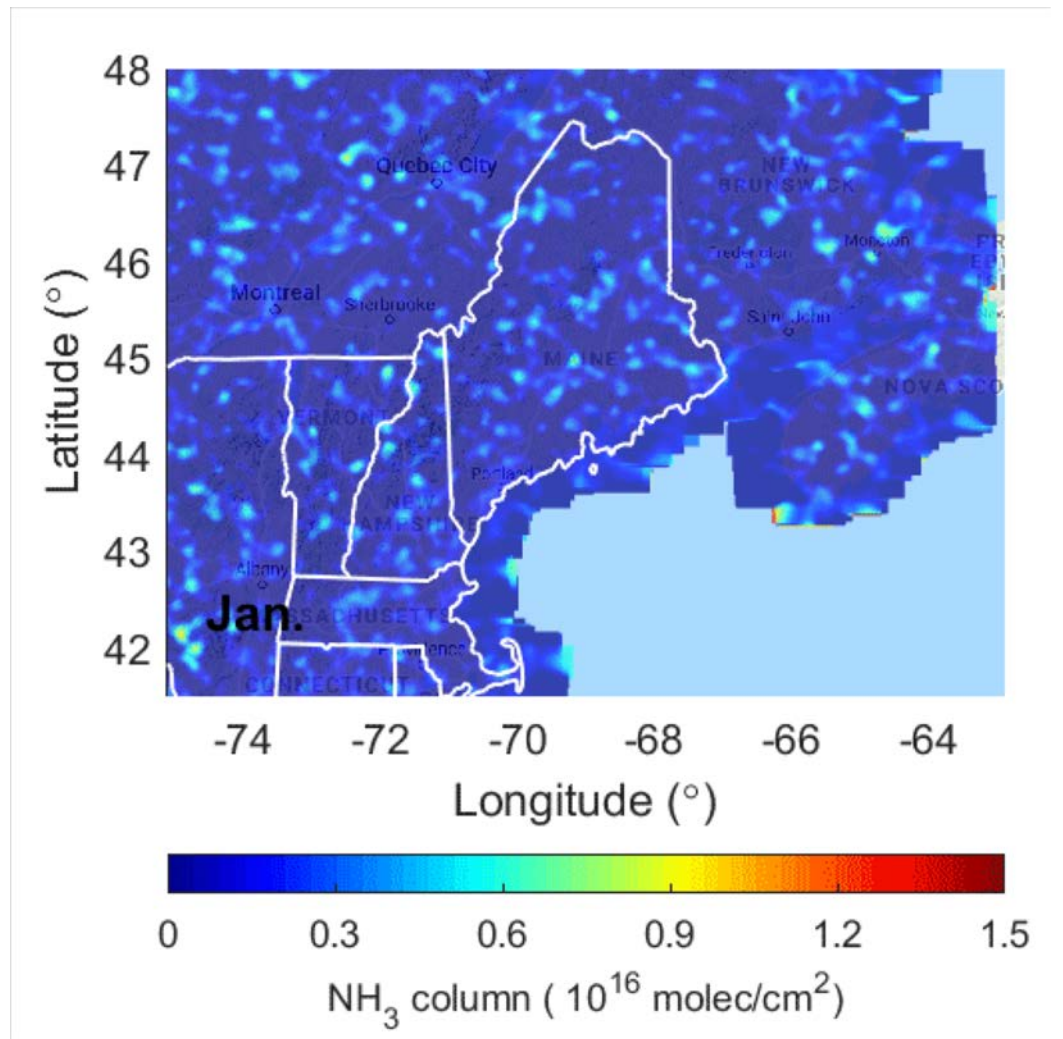
2008-2016, IASI Metopa & Metopb,
oversampling high resolution ($0.02^\circ \times 0.02^\circ$)
maps

Seasonal variation



**2008-2016, IASI Metopa & Metopb,
oversampling high resolution ($0.02^\circ \times 0.02^\circ$)
maps**

Seasonal variation



**2008-2016, IASI Metopa & Metopb,
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