

Ammonia (NH₃) Distributions and Recent Trends by 14-year AIRS Measurements

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* Published in **GRL: Increased Atmospheric Ammonia over the World's Major Agricultural Areas Detected from Space**

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In the Media

NASA Satellite Identifies Global Ammonia 'Hotspots'

Global atmospheric ammonia trends measured from space from 2002 to 2016. Hot colors represent increases due to a combination of increased fertilizer application, increased burning of agricultural waste, and increased wet deposition. Cool colors show decreases due to reduced agricultural burning in some areas.

Study finds ammonia 'hotspots' of airborne ammonia over world's major agricultural areas

Global atmospheric ammonia trends measured from space from 2002 to 2016. Hot colors represent increases due to a combination of increased fertilizer application, increased burning of agricultural waste, and increased wet deposition. Cool colors show decreases due to reduced agricultural burning in some areas.

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STUDY FINDS "HOTSPOTS" OF AIRBORNE AMMONIA OVER WORLD'S MAJOR AGRICULTURAL AREAS

IN THE U.S., EFFORTS TO CURB ACID RAIN IN THE 1990S HAD THE UNINTENDED EFFECT OF INCREASING AMMONIA IN THE ATMOSPHERE

16 March 2017

John J. Worden, D.C. — The first global, independent satellite study of airborne ammonia gas has revealed "hotspots" of the pollutant over four of the world's most productive agricultural regions. Using data from NASA's Atmospheric Infrared Sounder (AIRS) satellite instrument, the research team discovered steadily increasing ammonia concentrations from 2002 to 2016 over agricultural centers in the United States, Europe, China and India. Increased atmospheric ammonia is linked to poor air and water quality.

Although the specific vary between areas, the increases in ammonia are broadly tied to crop fertilizers, livestock animal waste, changes to atmospheric chemistry and warming soils that retain less ammonia, according to the new study in *Geophysical Research Letters*, a journal of the American Geophysical Union. The results could help illuminate strategies to control pollution from ammonia and ammonia byproducts near agricultural areas, according to the authors.

"Our study reports the first global, long-term trends of atmospheric ammonia from space," said Juying Warner, a researcher in atmospheric and oceanic science at the University of Maryland and lead author of the new study. "Measuring ammonia from the ground is difficult, but the satellite-based method we have developed allows us to track ammonia efficiently and accurately. We hope that our results will help guide better management of ammonia emissions."

Gaseous ammonia is a natural part of Earth's nitrogen cycle, but excess ammonia is harmful to plants and reduces air and water quality. In the troposphere—the lowest, densest part of the atmosphere where weather takes place—ammonia reacts with nitric and sulfuric acids to form nitrate-containing particles that contribute to aerosol pollution that is damaging to human health. Ammonia gas can also fall back to Earth and enter lakes, streams and oceans, which it contributes to harmful algal blooms and "dead zones" with dangerously low oxygen levels.

"Here in Maryland, ammonia from the atmosphere contributes as much as a quarter of the nitrogen pollution in the Chesapeake Bay, causing eutrophication and leading to dead zones that make life very difficult for oysters, blue crabs and other wildlife," said Russell Dickerson, a professor of atmospheric and oceanic science at UMD and co-author of the new study.

Unintended consequences of environmental laws

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Multi-year study finds 'hotspots' of ammonia over world's major agricultural areas

Researchers: animal waste, changes to atmospheric chemistry and warming soils all tied to increased ammonia over U.S., Europe, China and India

The first global, long-term satellite study of airborne ammonia gas has revealed "hotspots" of the pollutant over four of the world's most productive agricultural regions. Using data from NASA's Atmospheric Infrared Sounder (AIRS) satellite instrument, the University of Maryland-led research team discovered steadily increasing ammonia concentrations from 2002 to 2016 over agricultural centers in the United States, Europe, China and India. Increased atmospheric ammonia is linked to poor air and water quality.

The study, published March 16, 2017 in the journal *Geophysical Research Letters*, also describes the probable causes for increased airborne ammonia in each region. Although the specific vary between areas, the increases in ammonia are broadly tied to crop fertilizers, livestock animal waste, changes to atmospheric chemistry and warming soils that retain less ammonia. The results could help illuminate strategies to control pollution from ammonia and ammonia byproducts near agricultural areas, according to the authors.

"Our study reports the first global, long-term trends of atmospheric ammonia from space," said Juying Warner, an associate research scientist in atmospheric and oceanic science at UMD. "Measuring ammonia from the ground is difficult, but the satellite-based method we have developed allows us to track ammonia efficiently and accurately. We hope that our results will help guide better management of ammonia emissions."

Gaseous ammonia is a natural part of Earth's nitrogen cycle, but excess ammonia is harmful to plants and reduces air and water quality. In the troposphere—the lowest, densest part of the atmosphere where all weather takes place and where people live—ammonia gas reacts with nitric and sulfuric acids to form nitrate-containing particles that contribute to aerosol pollution that is damaging to human health. Ammonia gas can also fall back to Earth and enter lakes, streams and oceans, which it contributes to harmful algal blooms and "dead zones" with dangerously low oxygen levels.

"Last ammonia comes from livestock or manure, it's mainly agricultural, from fertilizer and animal husbandry," said Russell Dickerson, a professor of atmospheric and oceanic science at UMD. "It has a profound effect on air and water quality—and ecosystems. Here in Maryland, ammonia from the atmosphere contributes as much as a quarter of the nitrogen pollution in the Chesapeake Bay, causing eutrophication and leading to dead zones that make life very difficult for oysters, blue crabs and other wildlife."

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Clouds of ammonia hanging over Earth's bread baskets

"As people shift from a vegetarian to a meat-based diet, ammonia emissions will continue to go up," researcher Juying Warner said.

By Brooks Hays | March 16, 2017 at 1:30 PM

Researchers at the University of Maryland found in a study that atmospheric ammonia concentrations have increased during the last decade and a half. On the map, the warmer colors show where atmospheric ammonia concentrations have increased the most. Photo by Juying Warner/GRL.

March 16 (UPI) — Researchers at the University of Maryland used data from NASA satellites to track concentrations of ammonia in Earth's atmosphere from 2002 to 2016. They found ammonia concentrations have steadily increased above regions with high agricultural productivity.

Hotspots of atmospheric ammonia were identified above parts of the United States, Europe, China and India. The colorless gas has been linked to both environmental and human health problems.

Most excess ammonia, which can degrade air and water quality, can be traced to fertilizer use and animal waste. Researchers suggest changing ammonia's conditions and warmer soils, which absorb less ammonia, are also to blame for rising ammonia concentrations.

Scientists shared their results in the journal *Geophysical Research Letters*.

Feedstuffs

Ammonia hot spots found over major global ag areas

Legislation to reduce acid rain in early 1990s most likely had unintended effect of increasing gaseous ammonia in the atmosphere.

The first global, long-term satellite study of airborne ammonia gas has revealed "hot spots" of the pollutant over four of the world's most productive agricultural regions, according to the University of Maryland.

Using data from the National Aeronautics & Space Administration's (NASA) Atmospheric Infrared Sounder (AIRS) satellite instrument, the University of Maryland-led research team discovered steadily increasing ammonia concentrations from 2002 to 2016 over agricultural centers in the United States, Europe, China and India.

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Ammonia Hot Spots Increasing Over Farmland and May Be Linked to Climate Change, Scientists Say

By Pam Wright | Mar 17 2017 12:50 AM EDT | weather.com

Ammonia hot spots are increasing in the Earth's atmosphere above regions with high agricultural productivity, according to a new study.

Using data from NASA satellites to track concentrations of ammonia in Earth's atmosphere from 2002 to 2016, scientists with the University of Maryland found high concentrations over farmlands in the United States, Europe, China and India.

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Using data from NASA satellites to track concentrations of ammonia in Earth's atmosphere from 2002 to 2016, scientists with the University of Maryland found high concentrations over farmlands in the United States, Europe, China and India.

The colorless gas has been linked to numerous environmental and human health problems, including respiratory distress. According to the study published in *Geophysical Research Letters*, most excess ammonia comes from fertilizer use and animal waste. The researchers say rising concentrations of ammonia may also be linked to climate change and warmer soils, which absorb less ammonia.

"Measuring ammonia from the ground is difficult, but the satellite-based method we have developed allows us to track ammonia efficiently and accurately," Juying Warner, atmospheric and oceanic science researcher at Maryland, said in a news release. "We hope that our results will help guide better management of ammonia emissions."

While fertilizer use has not increased in the United States in recent years, scientists believe efforts to eliminate acid rain through stricter emissions standards has had a role in the ever-increasing levels of ammonia in the atmosphere. Ironically, acid rain actually helps eliminate ammonia from the air.

ScienceDaily

IGRL: 近十几年世界主要农业区的大气NH3明显增加

2017-03-21 Warner et al.

大气化学学者论坛

Global atmospheric ammonia trends measured from space from 2002 to 2016. Hot colors represent increases due to a combination of increased fertilizer application, reduced burning of agricultural waste, and increased wet deposition. Cool colors show decreases due to reduced agricultural burning or fewer wildfires (U.S. West and India).

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• the UK: The Guardian, Indian: DownToEarth, New Zealand: Radio New Zealand Rurals

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Dr. Juying Xie Warner

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Overview



Dr. Juying Warner

Dr. Warner is a Research Scientist in the Department of Atmospheric and Oceanic Science at University of Maryland, College Park. She has been conducting research and parttime teaching at UMD and UMBC since 2004.

Click [Here](#) to view her Curriculum Vitae

Research Interests

- Remote sensing and transport study of aerosols & tropospheric trace gases (CO, NH₃, N₂O, and CH₄) from [EOS and SNPP Satellites](#)
- Retrieval Algorithm Development
- Radiative Transfer Modeling
- Airborne Remote sensing of ocean/coastal and terrestrial surface characteristics using a [Hyperspectral Imager \(Aurora\)](#)

Personal Hobbies

- Running
- Voted for Hillary Clinton for President in 2016
- Watching MSNBC; The Walking Dead; Judge Judy; RT with Bill Mahr; Listening to The Dave Ramsey Show

- FTP -



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- AIRS NH₃ data used in the publications
- NH₃ monthly means - Land and daytime
- Pursuing funds for daily products

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Research Projects

Species	Sensors	Status
N ₂ O	AIRS	
HDO	AIRS	
CO V6	AIRS	disc.sci.gsfc.nasa.gov/AIRS/data-holdings
CO	IASI	
NH ₃	AIRS	
NH ₃	CrIS	
CO	MOPITT	link

Data Links

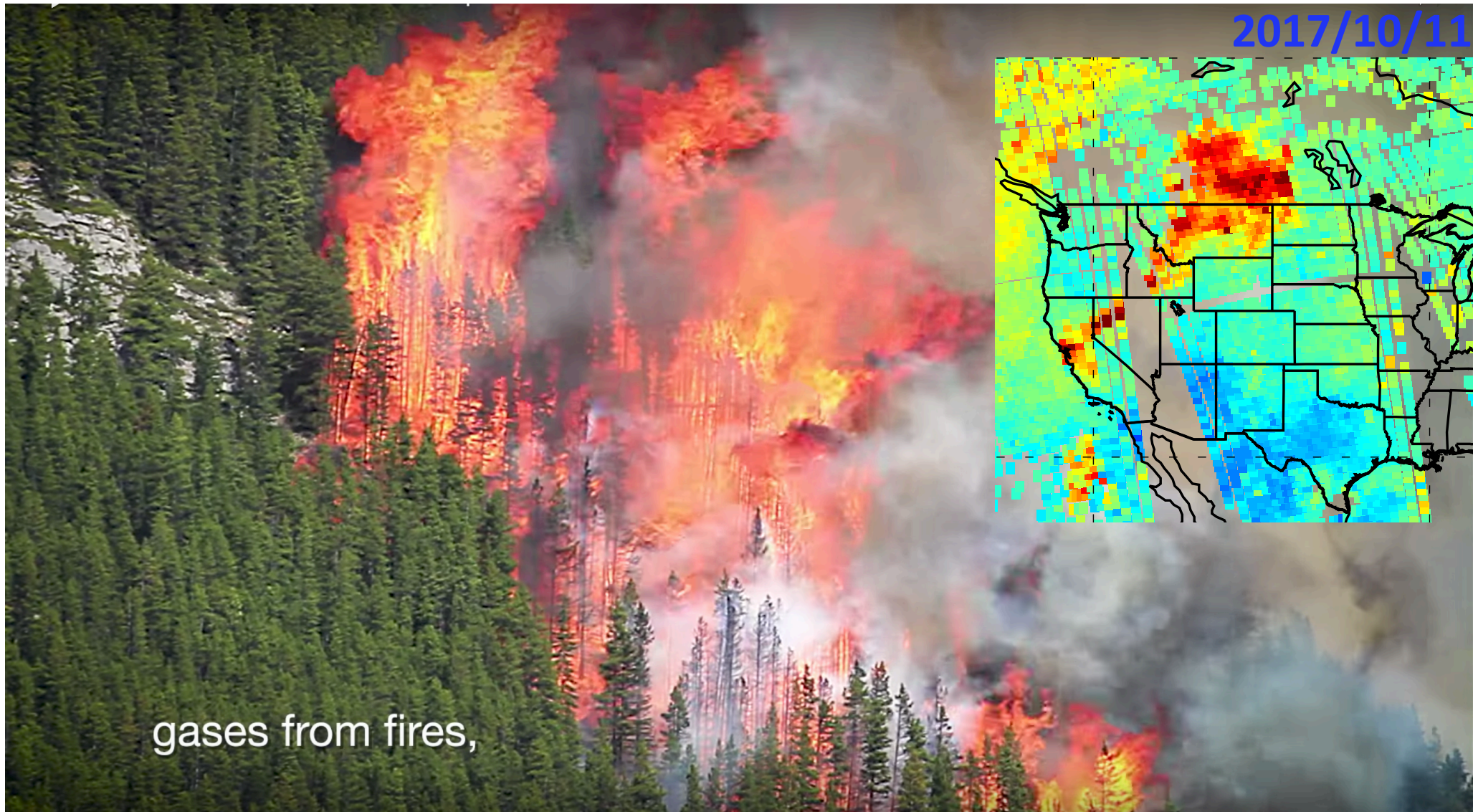
Name	Files Included
AIRS NH3 - ACP 2015	Matlab/DL/NC data formats
AIRS NH3 - GRL 2017	IDL data format
AIRS OE CO	Netcdf data format
AIRS NH3	Netcdf data format

- FTP -

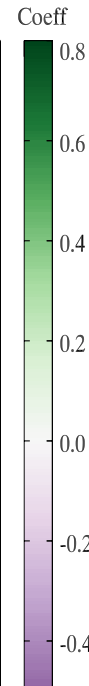
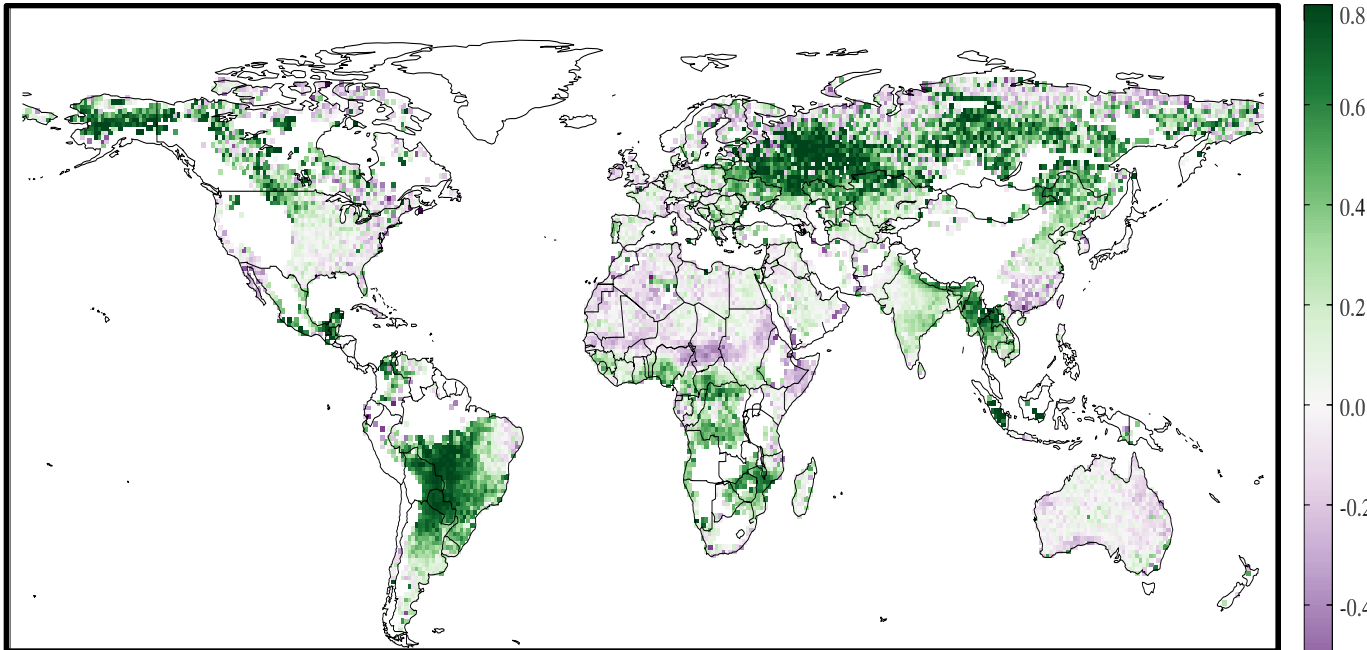


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AIRS carbon monoxide (CO) Observations of Santa Rosa Fire



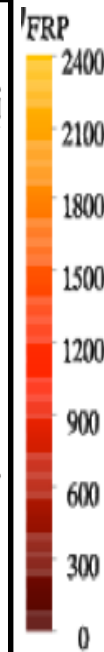
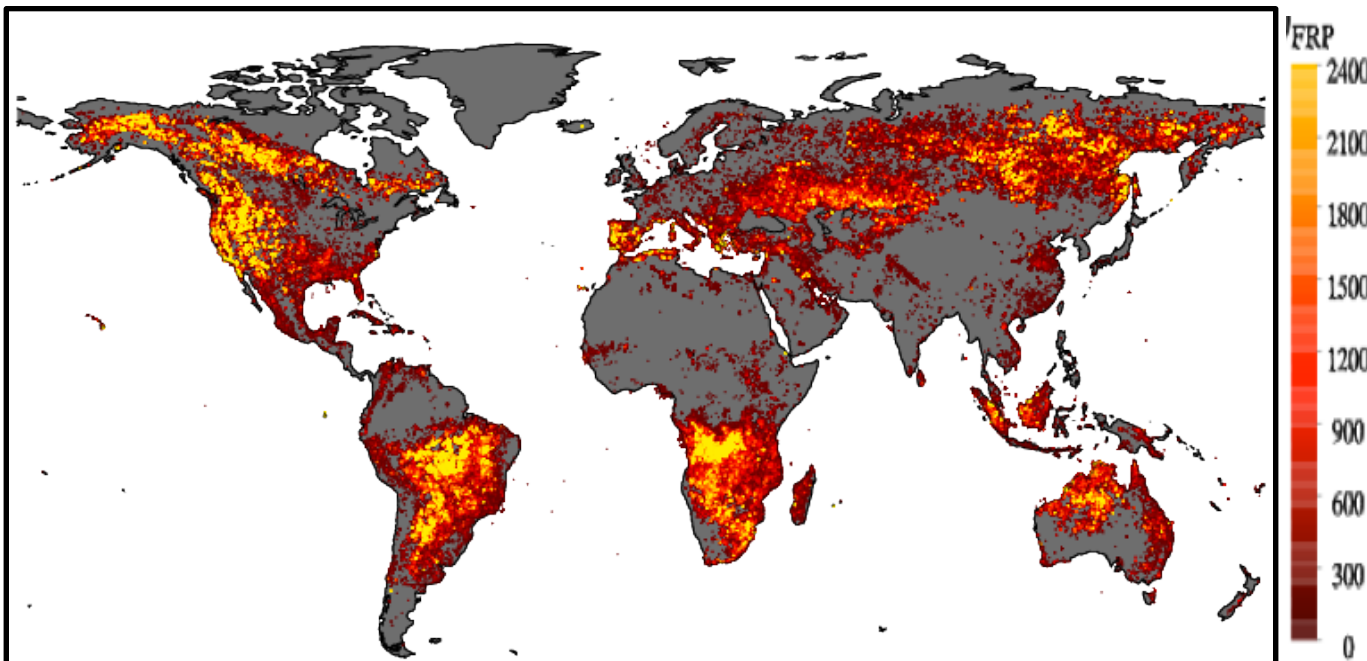
NH₃ vs CO Correlation Coefficient (1.0°x1.0°)



AIRS NH₃ and CO Emitted from Fires

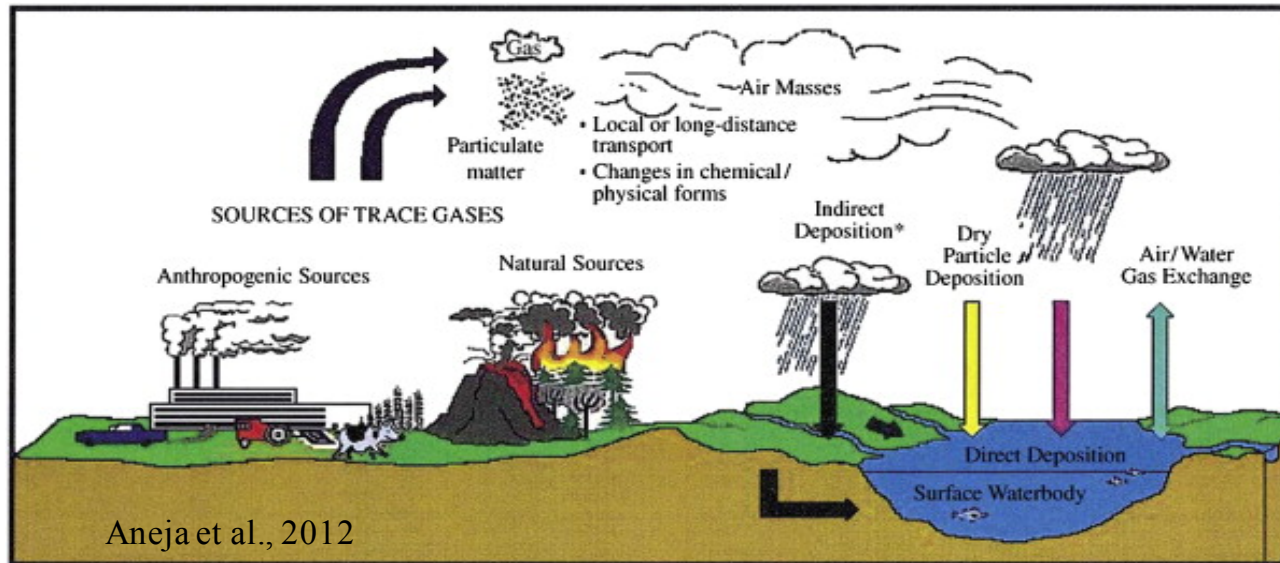
- Correlation coefficients of collocated NH₃ and CO.
- BB emissions show positive correlations;
- Agricultural emissions show negative correlations.
- Positively correlations NH₃/CO are highly agreeable with MODIS Fire Radiative Power.

MODIS Fire Radiative Power (FRP) Summer 2003-2015



Why Ammonia (NH₃)

- affect air quality, ecosystem, and climate, primarily from anthropogenic sources



Sources:

- Fertilizer use for crop production;
- Anima feeding operations;
- Emission increase with:
 - Nitrogen storage and pH of soils;
 - Surface temperature exponentially;
 - Soil moisture, etc.
- Biomass burning and volcanoes.

Sinks:

- Dry and wet deposition (soil acidification and eutrophication);
- Convert to particulate ammonium by reacting with sulfuric and nitric acids, arising from SO₂ and NO_x.

Ammonia - precursor gas of PM_{2.5}

- Precursor gases for PM_{2.5} (by secondary inorganic aerosols - a large portion of PM_{2.5}):
 - ✓ Sulfur dioxide (SO₂);
 - ✓ Nitrogen oxides (NO_x);
 - ✓ Ammonic (NH₃);
- Only NH₃ is not regulated;
- Ammonia is the limiting species in PM_{2.5} formation, regulating SO₂ and NO_x alone cannot determine the fate of PM_{2.5};
- Meteorological conditions (wind, rain, temperatures, etc.) affects the concentration of ammonia gases.

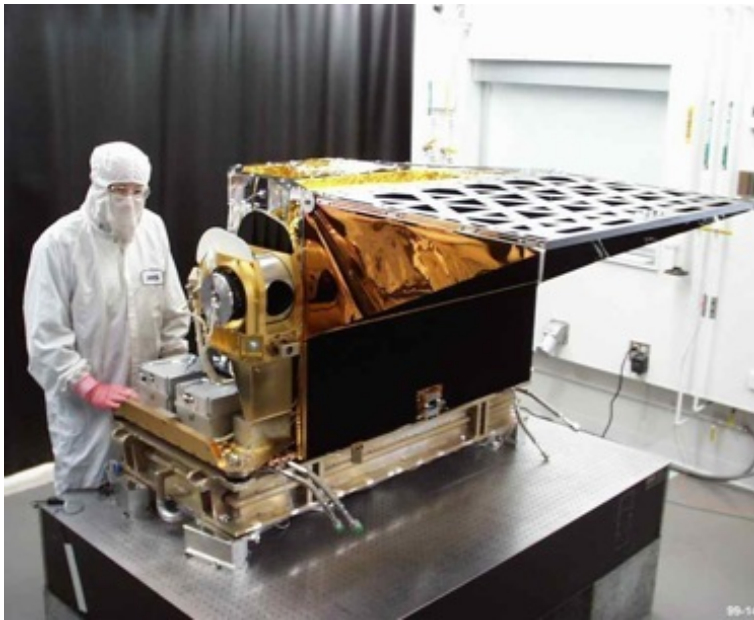


Why Satellite Remote Sensing

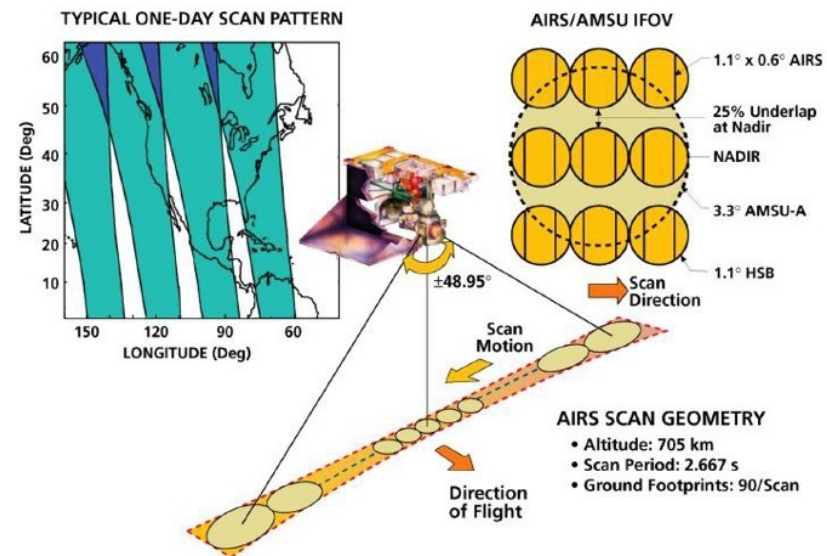
- *Ammonia in situ measurements are rare, global coverage is impossible.*
- Satellite measurements with daily and large global coverage are challenging and have been lacking partly because *the lifetime of NH₃ is relatively short* and partly because it requires high sensitivity for the retrievals that can be only obtained from areas with high thermal contrasts near the surface (Clarisse *et al.*, 2010).
- AIRS (Atmospheric InfraRed Sounder) has the advantages:
 - *afternoon overpasses (1:30pm)* are best correlated with the daily emission peak time and during the daily period with the highest thermal contrast.
 - AIRS *large coverage* with wide swaths and cloud-clearing provide *daily NH₃ maps*.
 - The *15-year data records* makes AIRS the best sensor for NH₃ trends and variability studies (to date).

Atmospheric InfraRed Sounder (AIRS)

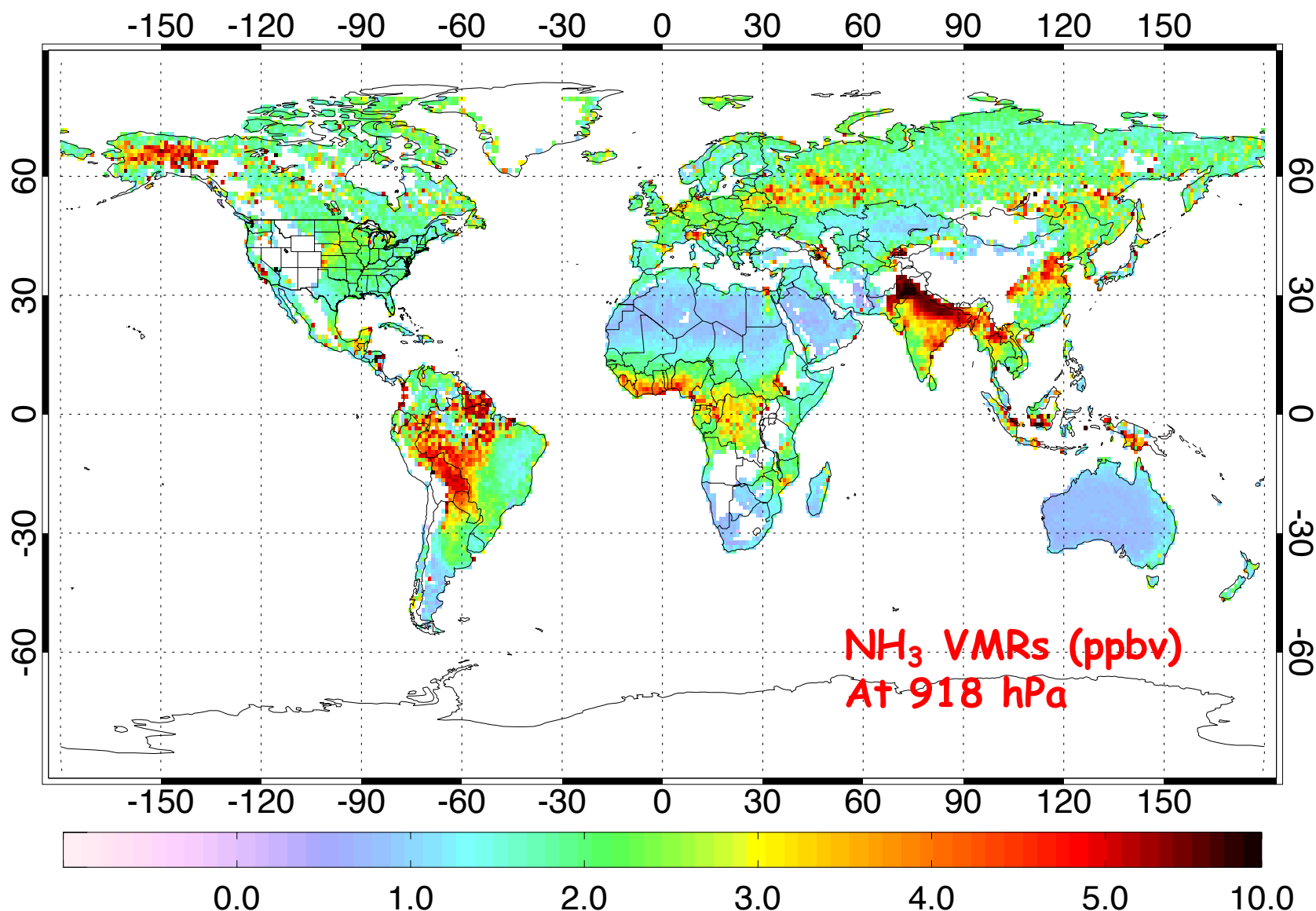
Launched May 2002; afternoon (1:30pm) overpass; daily global coverage



- Due to Similarities between AIRS~CrIS
- NUCAPS - a heritage of AIRS algorithm
- The AIRS NH₃ codes can be a plug-in for NUCAPS!

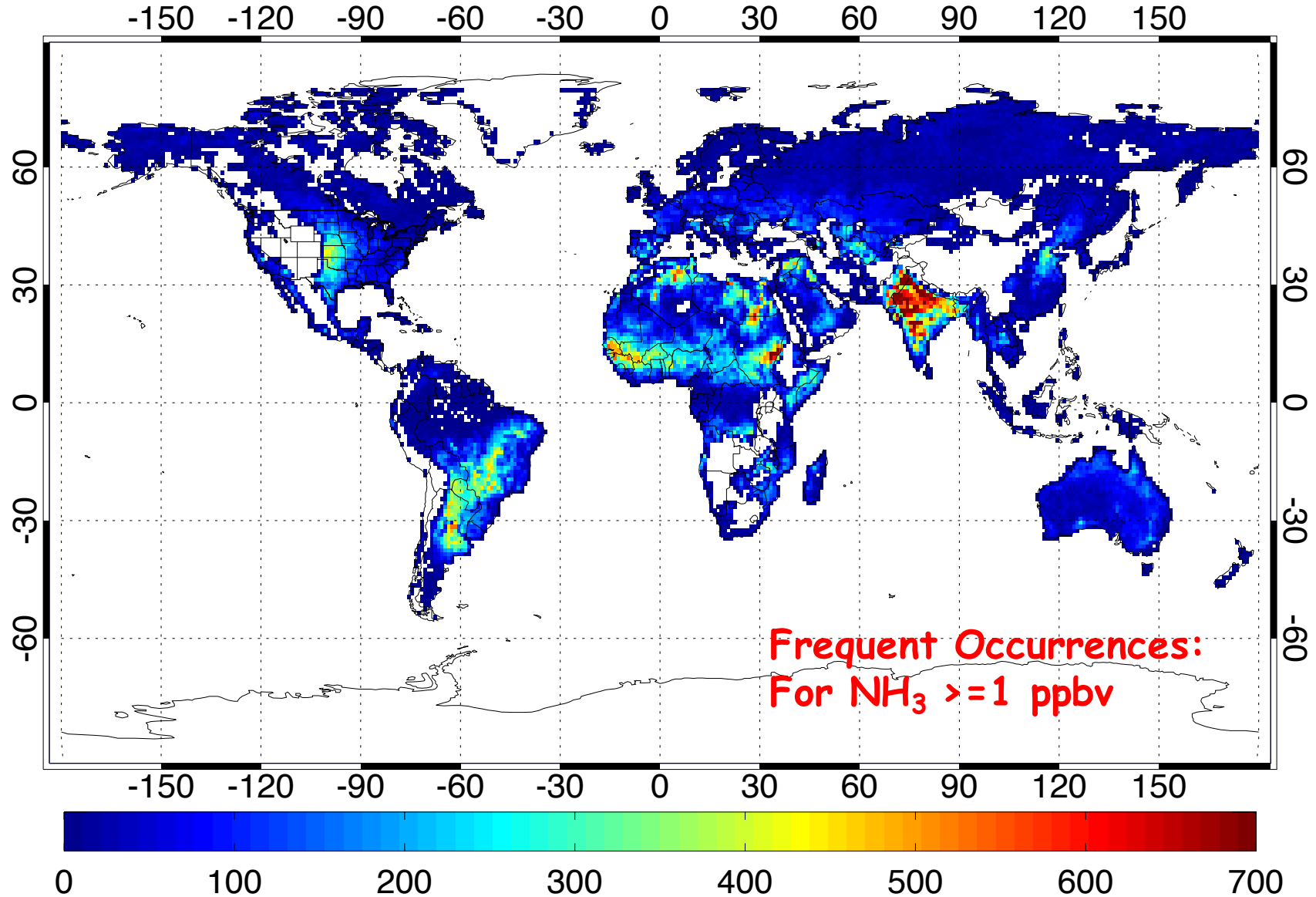


Global NH₃ in 2002-2015

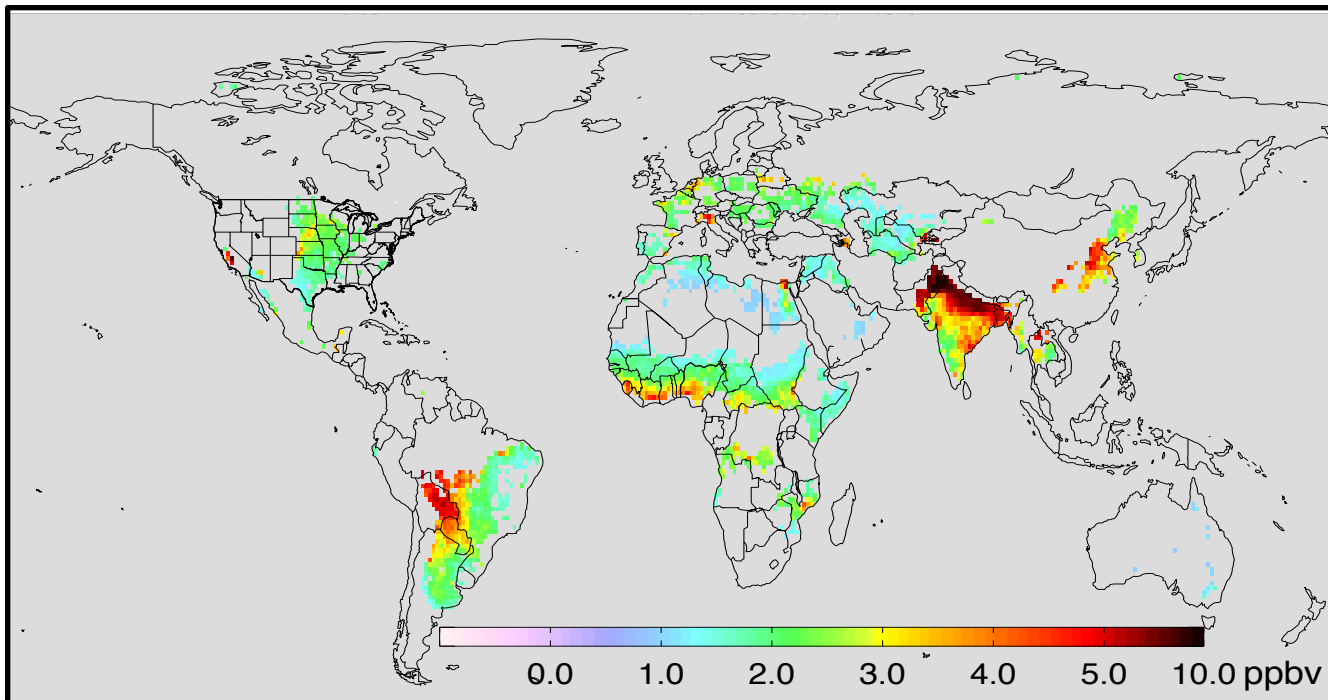


- High concentrations are mainly due to human activities and fires;
- Sources are seen in valleys (e.g., **San Joaquin Valley, California** in the U.S., the **Po Valley**, Italy, Fergana Valley, Uzbekistan, and the **Sichuan Basin** in China); Agricultural especially in irrigated lands (e.g., Azerbaijan, **Nile Delta** and near Nile River in Egypt, the Mid-West U.S., in **the Netherlands**, in Mozambique and Ethiopia, Africa, and especially the Indo-Gangetic Plain of South Asia).

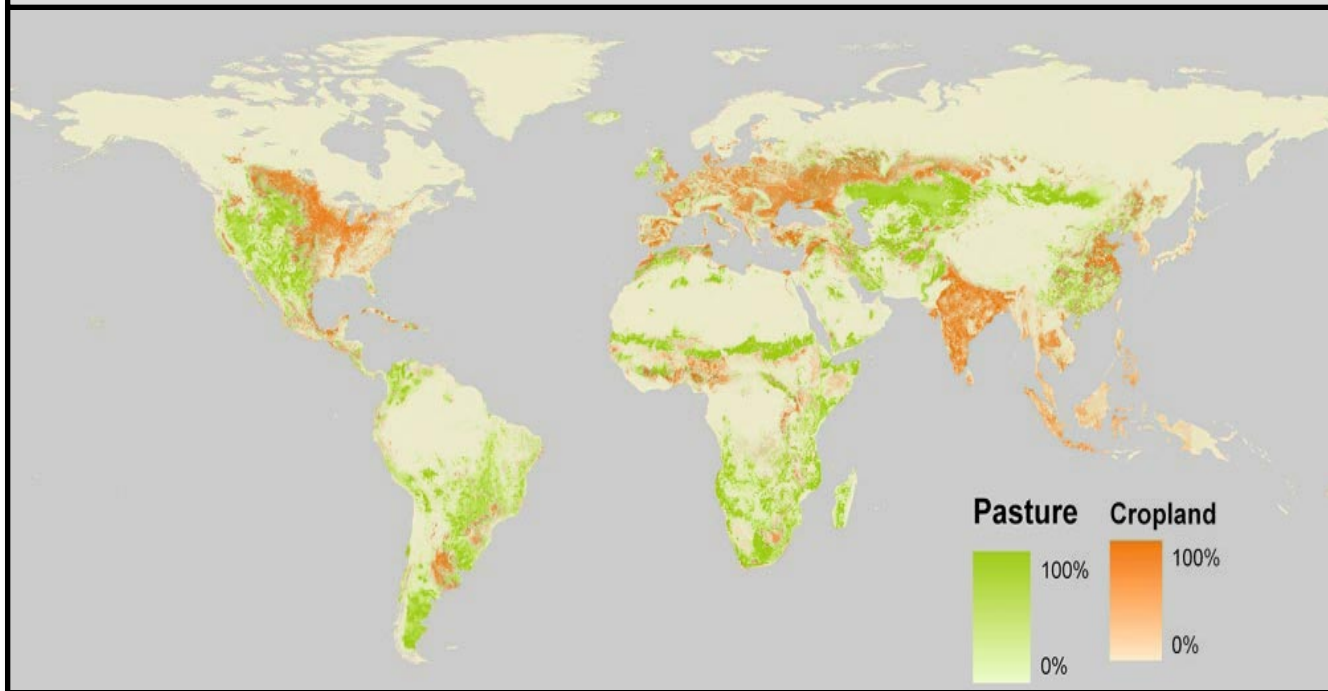
Global Frequent Occurrences in 2002-2015



Use occurrences of higher emissions (lower) to distinguish between the two major sources: agricultural (high VMRs & high frequencies); BB emissions (high VMRs & low frequencies).

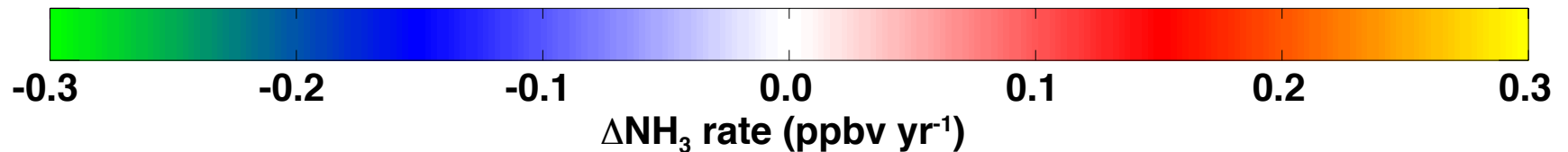
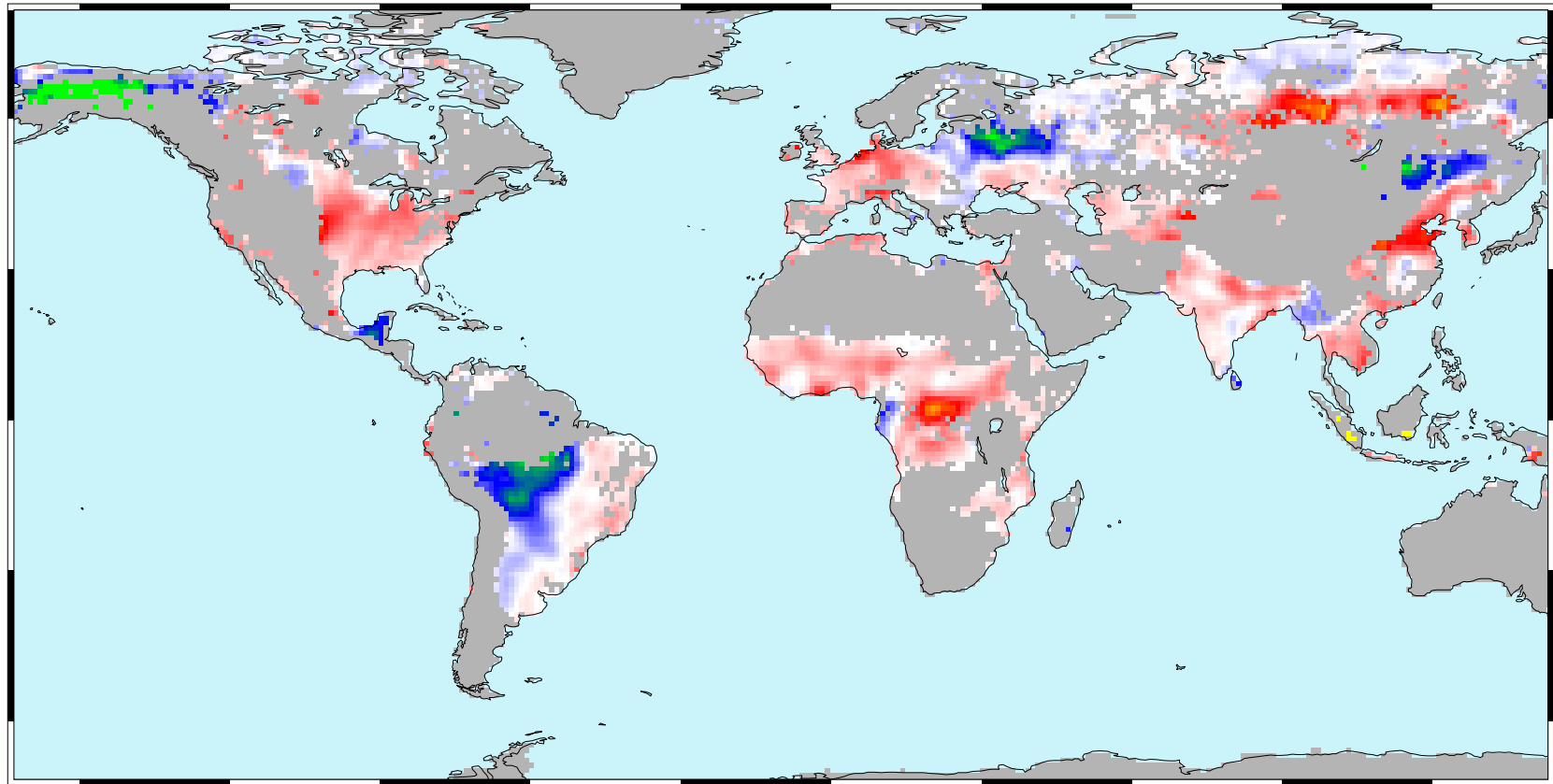


Top panel: The NH₃ VMRs from the persistent sources, i.e., ≥ 1.4 ppbv for more than 40 days;



Bottom panel: Pasture and Cropland Map (<http://OurWorldInData.org>)

NH₃ Trends - Last 14 years



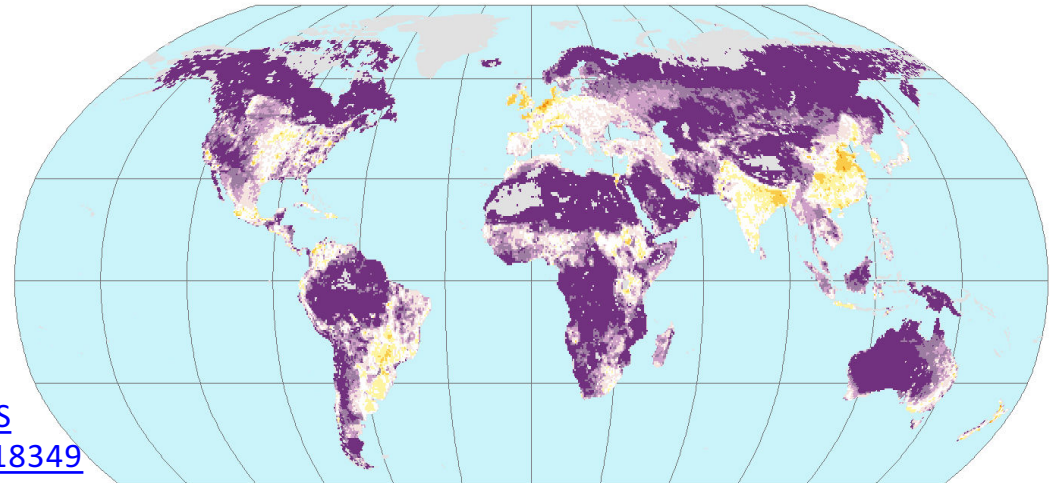
- Global trends in atmospheric NH₃ (i.e., VMRs at 918hPa for each 1x1 grid)
- Red-yellow colors represent increases due to agriculture emission increases and reduced scavenging by acid aerosols
- Blue-green colors represent decreases due to possibly reduced agricultural burning and fewer wild fires

NH₃ Increase - Fertilizer Applications

Global Nitrogen Fertilizer Application

Global Fertilizer and Manure, Version 1

Country /Region	Mean fertilizer use (TgN yr ⁻¹) [trend] 2002-2013
US	11.5 [+0.7% yr ⁻¹]
EU	11.0 [-0.3% yr ⁻¹]
China	31.2 [+2.7% yr ⁻¹]
S. Asia	18.8 [+3.6% yr ⁻¹]

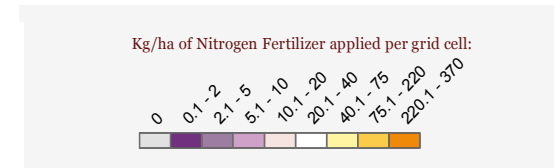
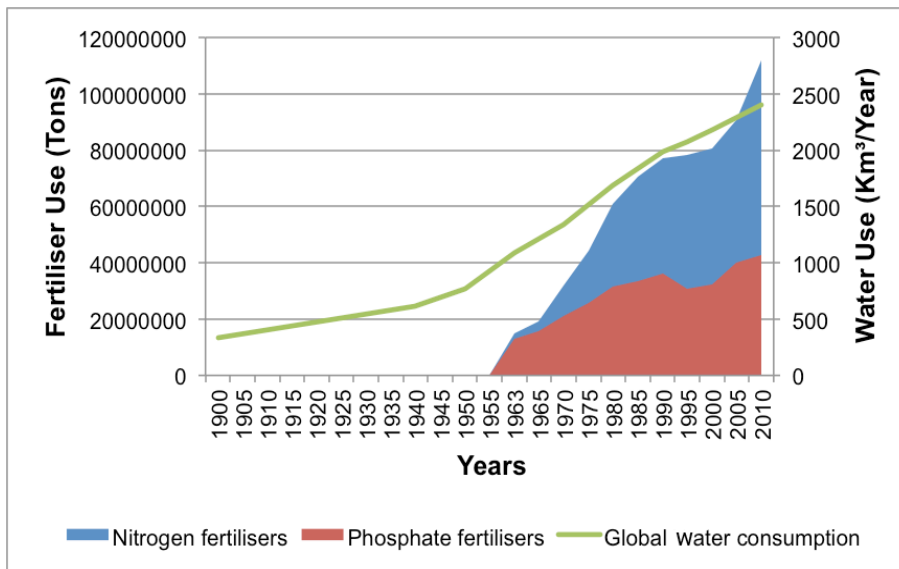


Robinson Projection

<http://data.worldbank.org/indicator/AG.CON.FERT.ZS>

<http://www.ars.usda.gov/Services/docs.htm?docid=18349>

Courtesy of Russ Dickerson

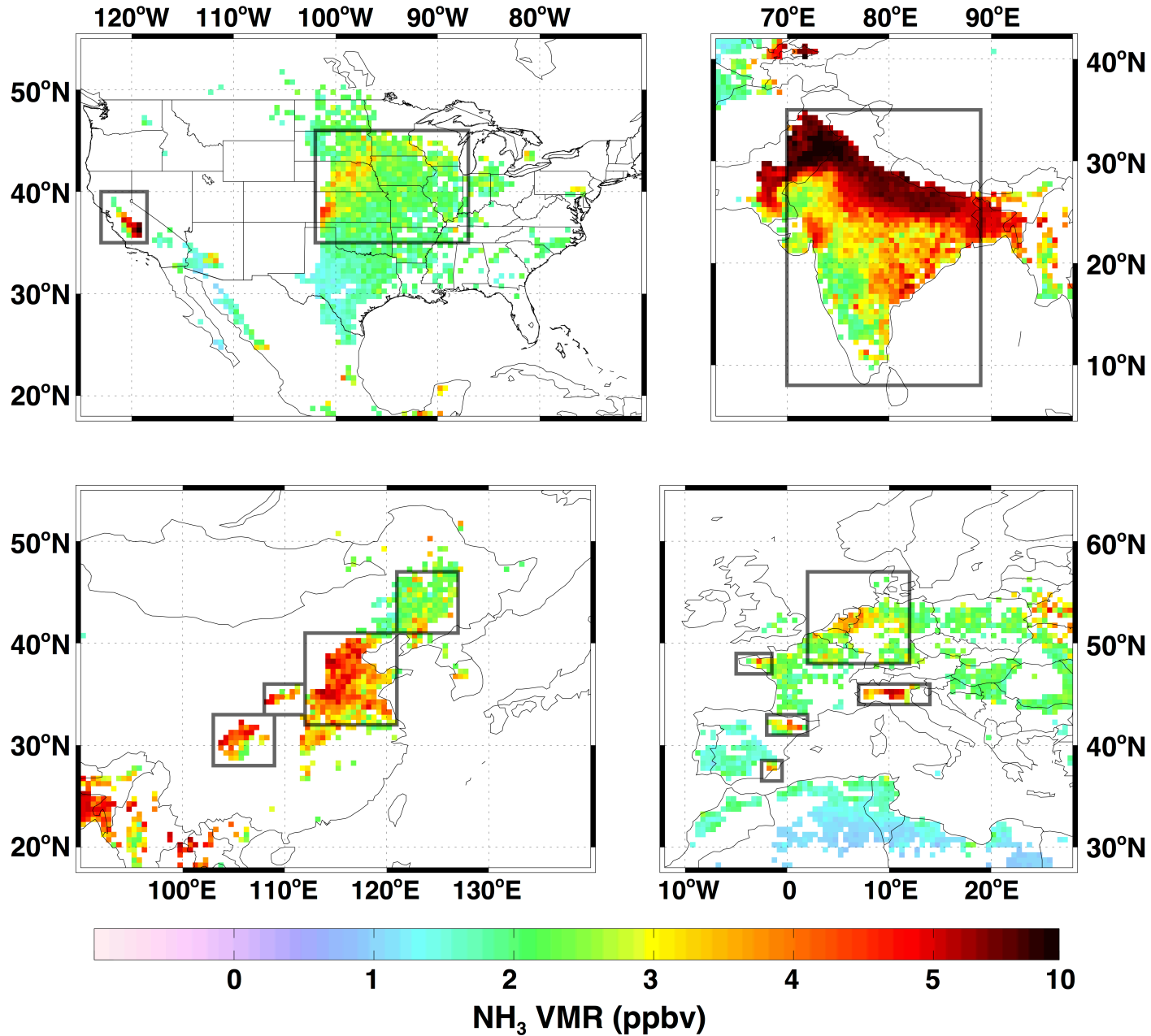


<http://sedac.ciesin.columbia.edu/>

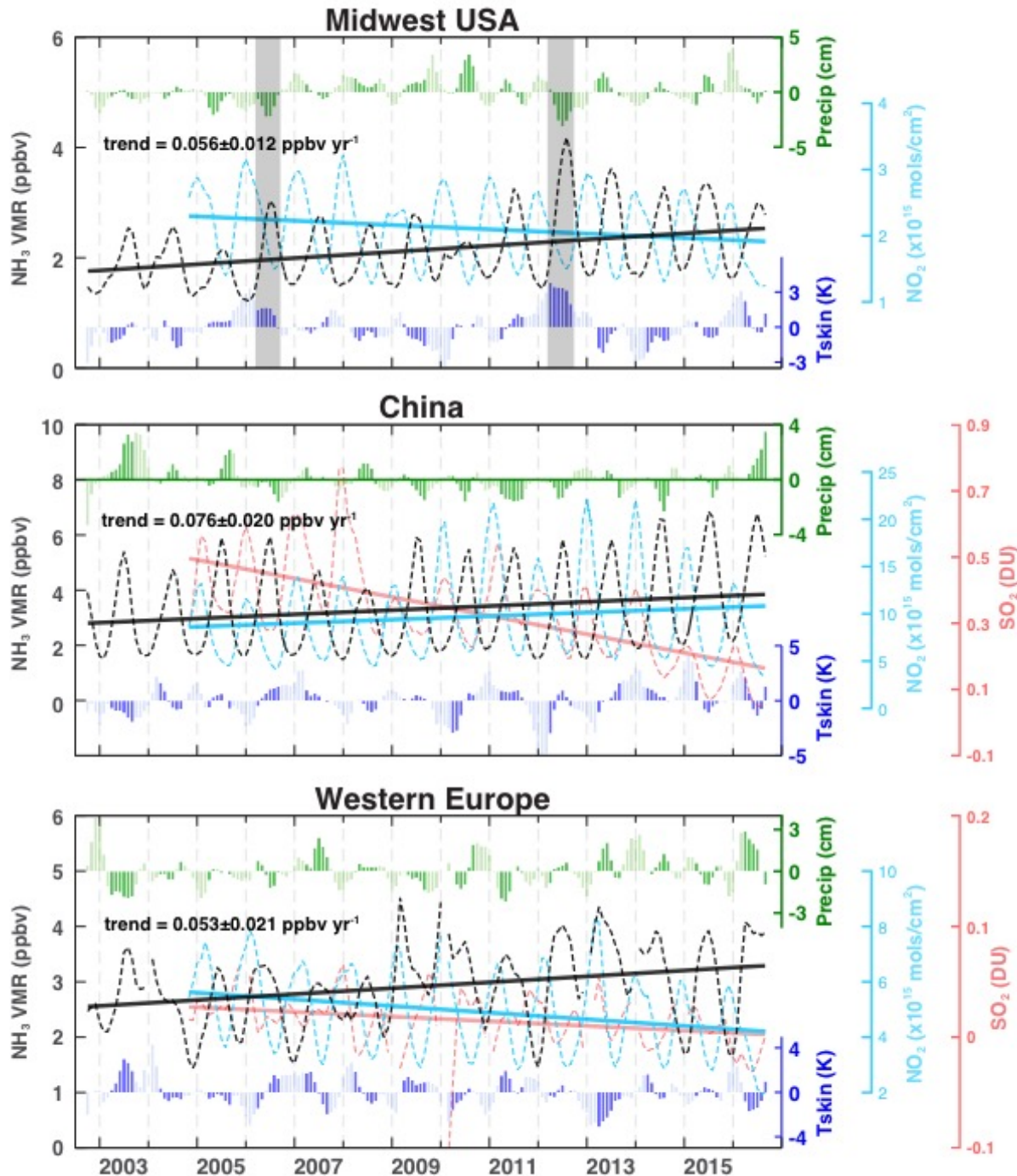
<https://freshwaterwatch.thewaterhub.org/>

NH₃ over USA, China, India, and Europe

Using high concentration and high frequencies



AIRS NH₃ vs OMI NO₂ for US (top), SO₂ for China (middle) and NO₂ for Western Europe (lower)



All show increasing NH₃ trends (black) 2002-2016.

Decreased SO₂ largely explains the NH₃ increases in Midwest U.S. (not shown), China, and Europe.

OMI NO₂ decreasing explains winter NH₃ increasing over the US and Europe.

Meteorological conditions also affect NH₃ concentrations (high surface temperatures and low precipitation), see shaded anomalies in the top panel.

ECMWF surface skin temperatures show increases over the US and China can possibly link climate change to the increased NH₃ emissions.

Summary

- AIRS NH_3 products not only include 14 years data record, it also provide daily maps!
- AIRS retrieved vertical profiles show good agreement (~5 - 15%) with in situ profiles from the 2013 DISCOVER-AQ field campaign in central California.
- AIRS daily measurements captures the strong continuous NH_3 emission sources from the anthropogenic (agricultural) source regions, as well as emissions from biomass burning (BB).
- Ammonia trends increase over agriculture regions, where fertilizers are used as routine practice, decrease over BB regions (with insufficient records).
- Ammonia concentrations increase resulted primarily from decreases in concentrations of acidic aerosols (sulfate and nitrate), an unintended consequence of effective controls of NO_x and SO_2 emissions.