# Air Quality Research for Electric/Energy Sector Applications

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Program Manager

NASA Health and Air Quality Applied Sciences Team (HAQAST) Meeting
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# About EPRI

## Core Research

- Nuclear Power
- Power Generation
- Transmission and Distribution Infrastructure
- Integrated Grid and Energy Systems
- Electrification and Sustainable Energy Strategy

## Founded in 1972

EPRI is an independent, nonprofit energy R&D organization that operates for the benefit of the public. Funding comes from various energy sector, academic, and government organizations worldwide.

## Mission

Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

## Global Collaboration

Bringing together global experts to provide scientifically rigorous and actionable R&D with a focus on solutions for a clean, sustainable, and equitable energy future.

## Innovative R&D and Application

Raising the state-of-the-art in energy research, policy analysis, and application services for more than 50 years.

## Expert Resources

Providing access to more than 1,000 experienced research professionals, three specialized labs, and EPRI training and development courses.


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# Air Quality Assessments, Multimedia Characterization, Human Health

**Mission**

Conducts detailed assessments of air quality, air quality standards, deposition, and ecosystem impacts by applying a variety of different analytical techniques, including models, data science, and risk assessment tools

Inform development of health-protective air quality policies and standards

## Recent Studies:

- Exceptional Event Screening Methods
- Background Ozone Concentrations using Machine Learning
- Nitrogen and Sulfur Critical Load Uncertainty using ML
- **Impact of Amine Emissions from Carbon Capture on Air Quality**
- Toxics Release Inventory for Power Plants (TRIPP) Software
- **SCICHEM 3.4 Photochemical Dispersion Model**
- Cumulative Impact Assessment
- Low Dose Health Effects of Particulate Matter and Ozone

## Technology Application:

- Assessment of $NO_2$/NOx Ratios at Power Plants
- Stationary Combustion Turbine Risk Assessment
- Comments on New Source Performance Standards
- Comments on Supplement to the Integrated Science Assessment for PM
- Comments on the Integrated Science Assessment for Ozone and Related Photochemical Oxidants


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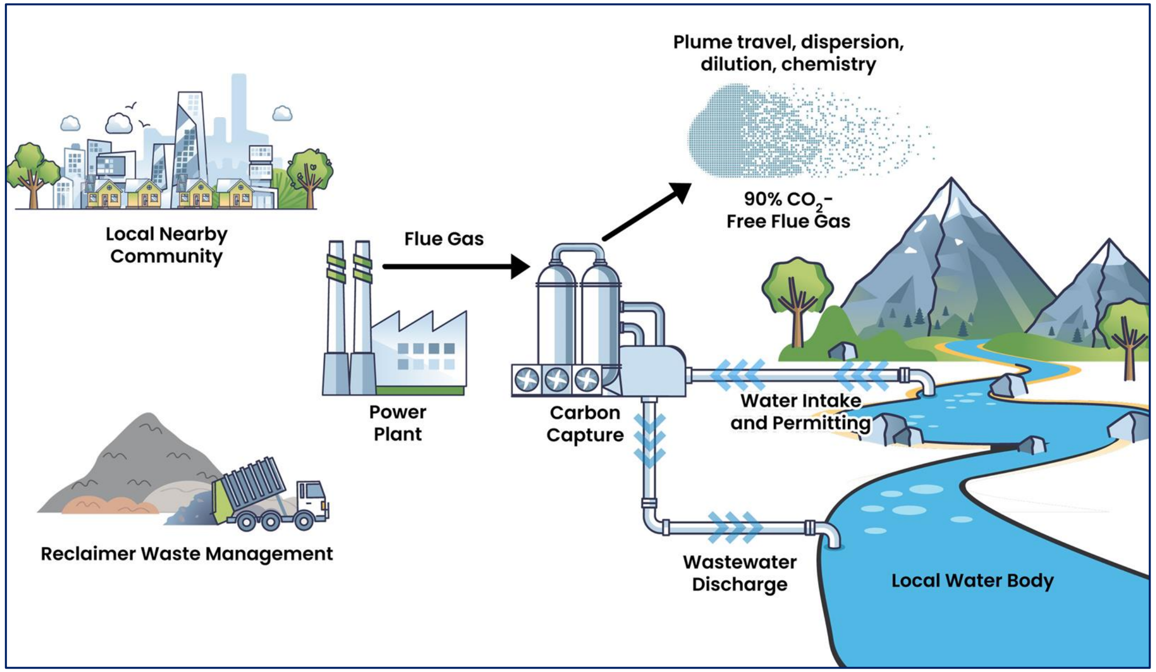
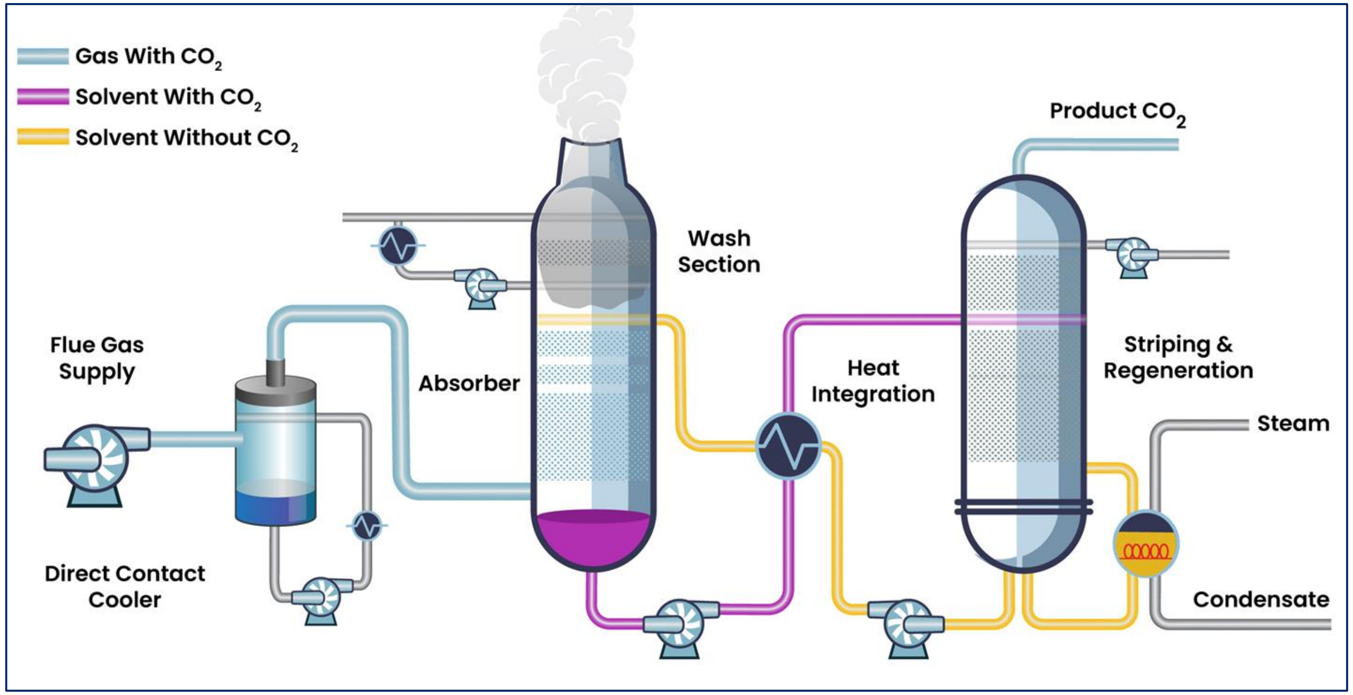
# Typical Carbon Capture Facilities




Amine-Based Carbon Capture Schematic





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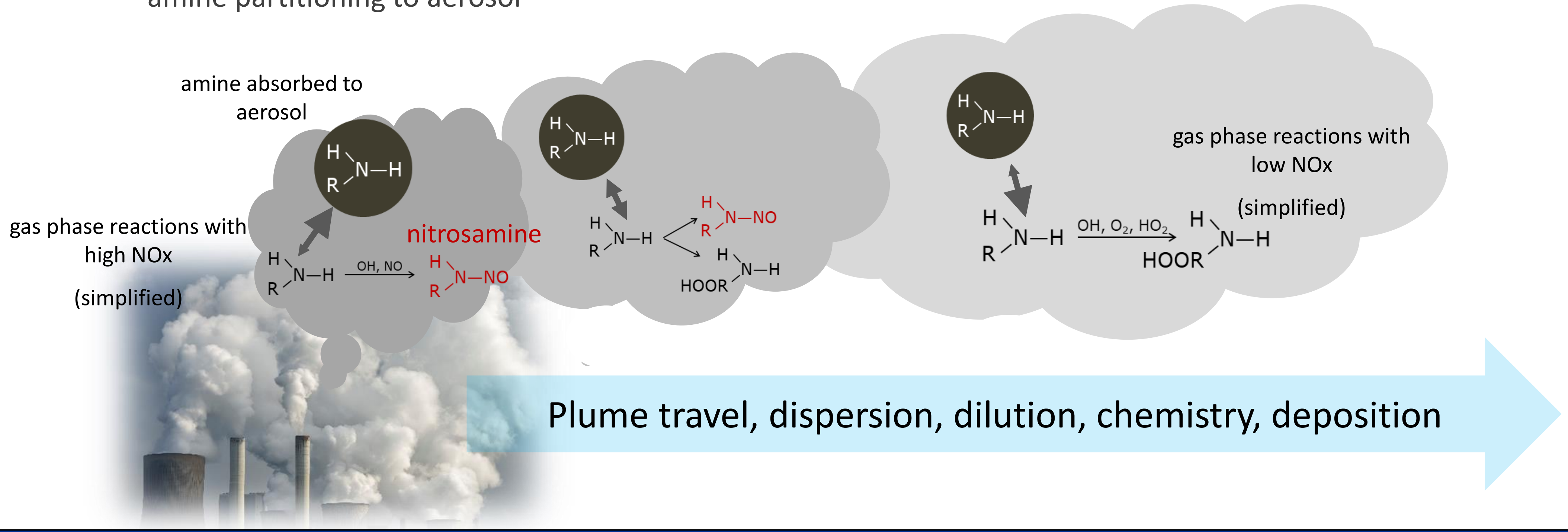
# Modeling: Atmospheric Gas and Aerosol Chemistry Reactions Form Nitrosamines and Nitramines

**Near source**

- low dilution
- "high NOx" degradation products
- amine partitioning to aerosol

**Downwind**

- high dilution
- "low NOx" degradation products
- amine evaporation from aerosol




**Preemptive understanding of air emissions, fate and transport needed**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# Nitrosamine Exposure Guidelines

- U.S. Environmental Protection Agency (EPA) and Norwegian Institute of Public Health (NIPH) estimated risk from breathing air through linear extrapolation
- Probability of developing cancer over lifetime exposure (70 years, 365 days per year)
- NIPH-Recommended total air concentration 0.0003 ug/m3

| | NDMA in air, ng/$m^3$ | Increased chance of developing cancer |
|---|---|---|
| EPA (Ref 1) | 0.07 | $10^{-6}$ |
| | 0.7 | $10^{-5}$ |
| | 7.0 | $10^{-4}$ |
| NIPH (Ref 2) | 0.3 | $10^{-5}$ |

| Nitrosamines | $TD_{50}$ for rodents, mg/kg |
|---|---|
| N-Nitrosodimethylamine | 0.096 (Ref 3) |
| N-Nitrosomorpholine | 0.11 (Ref 3) |
| N-Nitrosodiethanolamine | 3.7 (Ref 3) |
| N-Nitrosopiperazine | 8.8 (Ref 3) |


1. EPA N-Nitrosodimethylamine datasheet
2. Låg, Marit, et al. "Health effects of amines and derivatives associated with C02 capture." (2011).
3. CPDB (Carcinogenic Database, https://files.toxplanet.com/cpdb/index.html)



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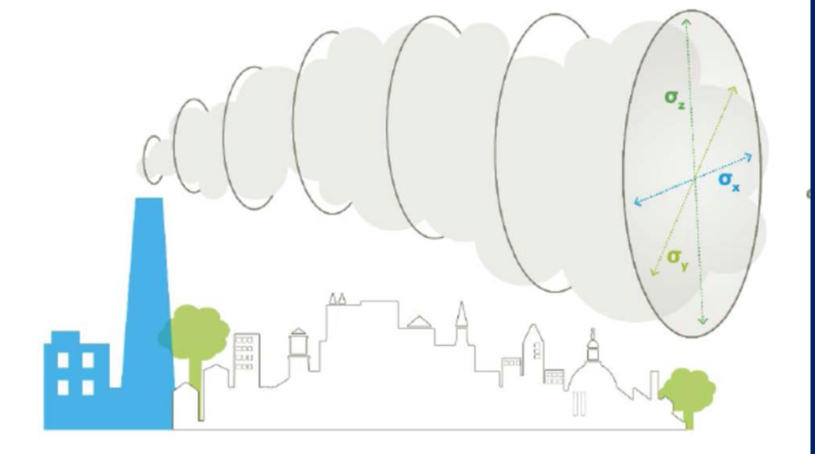
# Dispersion Model Requirements

- Simulate both near-source impacts and far-source impacts of amines and products
- Model traditional combustion pollutants (NOx, VOCs, $SO_2$, $NH_3$, particulate matter)
- Non-linear chemistry to model amine gas, including chemistry leading to $O_3$ and OH formation (NOx and VOC chemistry)
- Treatment of PM chemistry
- Efficient modeling of numerous scenarios
- Well tested and evaluated; Open-source

**SCICHEM: Second-order Closure Integrated Puff Model with Chemistry**

- Lagrangian puff dispersion model that can handle non-linear atmospheric chemistry





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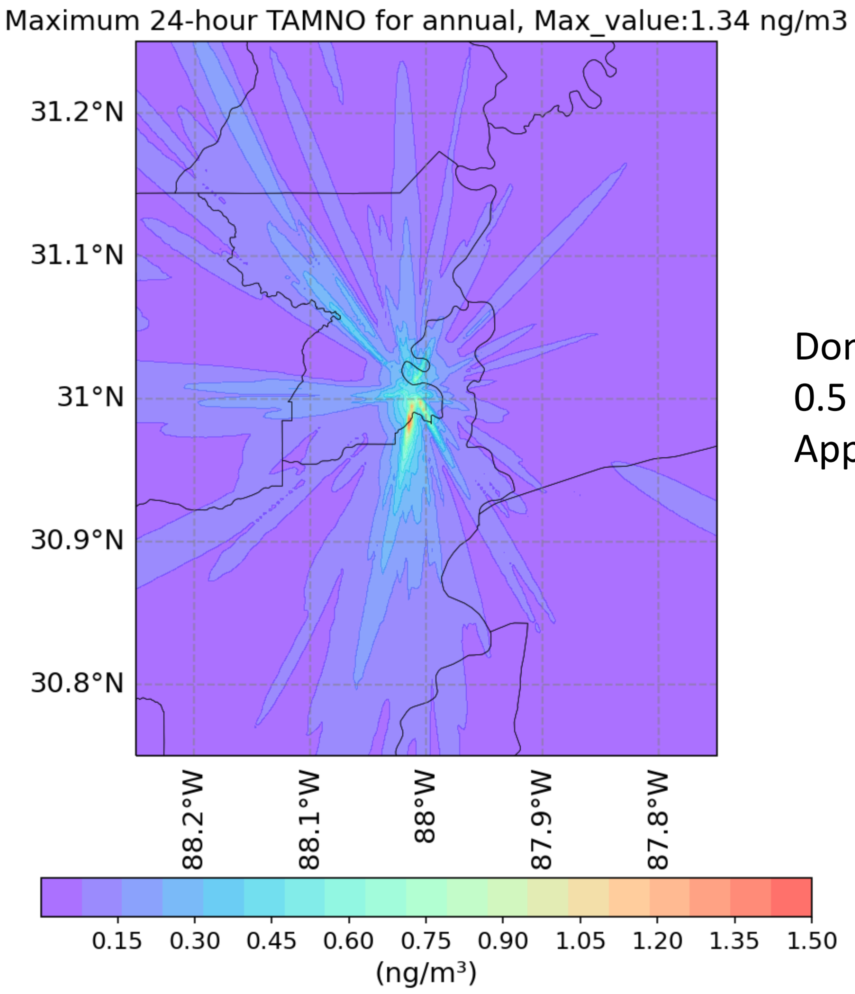
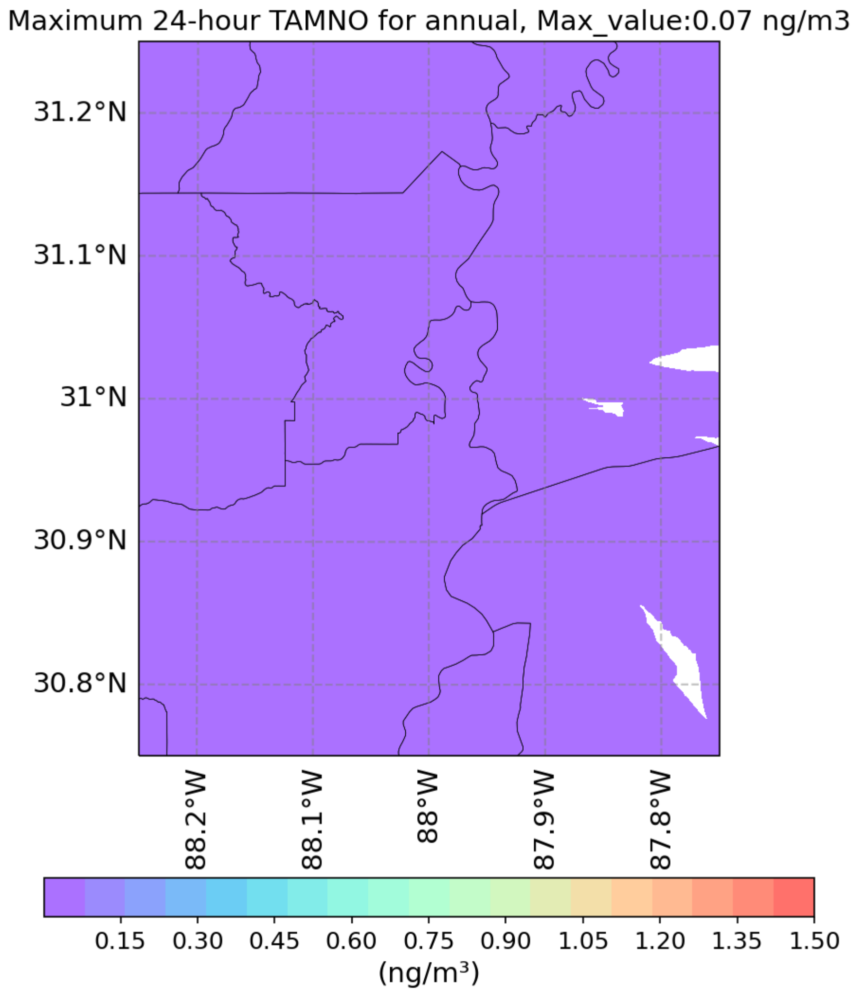
# Case Study: Annual Max 24-Hour Average Nitrosamine + Nitramine Concentrations (ng/m³) for Gulf Coast NGCC




Without acid wash

Domain Extent:
0.5 by 0.5 degrees
Approx. 48 km by 56 km




With acid wash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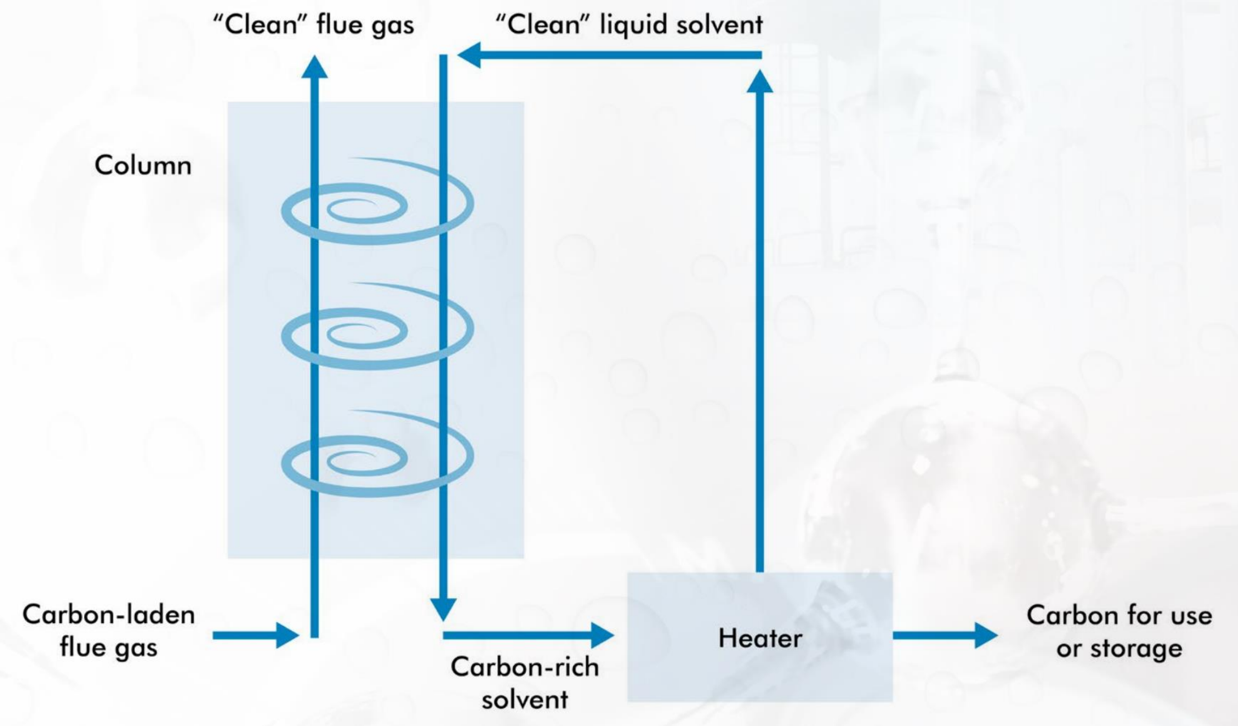
# Summary

- Important to use fine-scale modeling to resolve higher concentrations near the source
- Using acid wash and a conservative assumption of 95% removal efficiency for amine and nitrosamine results in max 24-hr concentrations of [nitrosamine + nitramine] << NIPH guideline for $10^{-5}$ risk
- Using acid wash and a conservative assumption of 99% removal efficiency for $NH_3$ results in up to factor of 4 reduction in $PM_{2.5}$ from the pilot plant







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# Satellite Data for Electric/Energy Sector Needs

- Satellite data informs air quality and health assessments, and regulatory analyses
- Several satellite data products are available with different spatial and temporal resolutions
- Many of studies cited in the latest ISA for the $PM_{2.5}$ NAAQS review include satellite data products both directly and indirectly (EPA 2022)
- Satellite data can be used to support the electric/energy sectors in environmental assessments, regulatory analyses, and implementation of standards

TEMPO Satellite

Source: https://www.warpnews.org/green-tech/satellite-to-monitor-air-pollution-in-near-real-time/


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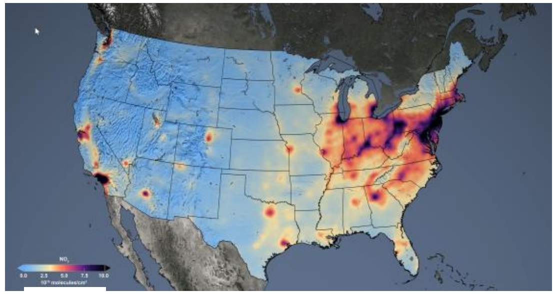
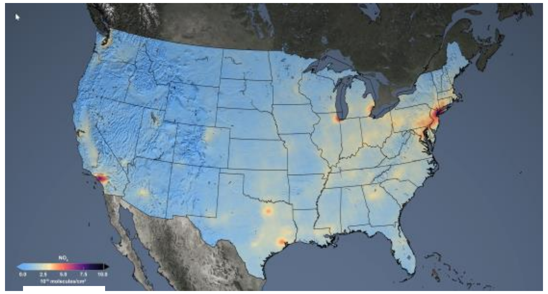
# Effectiveness of emission control strategies



2005



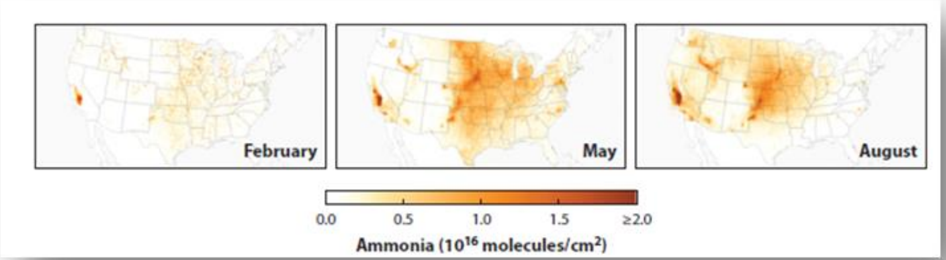
2022

NASA SVS | Nitrogen Dioxide Over the United States, 2005-2022

**Visualizer :** Trent L. Schindler (USRA)

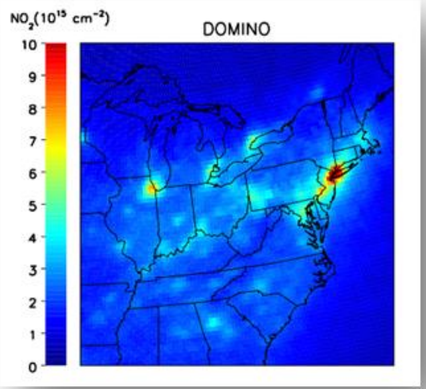
**Scientists :** Bryan Duncan (NASA/GSFC), Lok Lamsal (University of Maryland, Baltimore County)

# Contribution of other sector emissions



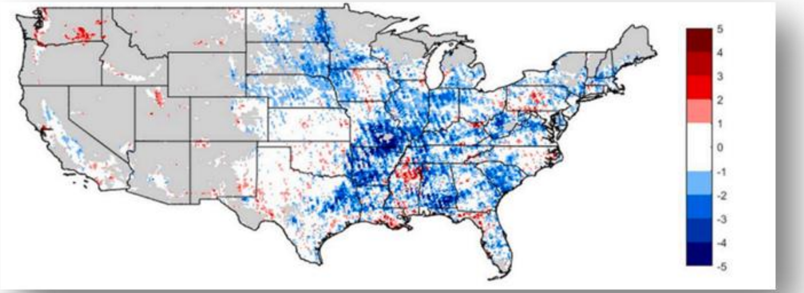

**Seasonal Contribution of Agricultural $NH_3$ emissions (MetOp Satellite)**
**Source:** https://earthobservatory.nasa.gov/images/144351/the-seasonal-rhythms-of-ammonia

# Evaluation of pollutant trends, contributions, and sensitivities




**July-August 2007 $NO_2$ column (OMI)**
**Source: Canty et al., 2015.**

# Contribution of biogenic/soil emissions



**Difference between 2011 and 2017 OMI $HCHO/NO_2$ ratios**
**Source: Jung et al., 2017**

# Changes in $O_3$ chemical regime



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# Some Potential Future Applications

Enhance characterization of global, regional pollutant contributions to background levels to inform NAAQS

Leverage cutting-edge ML and AI satellite data processing methods to improve estimates of sector contributions to emissions inventories

Advance characterization of biogenic and soil emissions role in ozone and $PM_{2.5}$ formation through data assimilation into models, trends assessment, and regional analyses

Assess cross-state pollution contributions, including source apportionment of different emission sources

Continue building improved tools for rapid and effective exceptional event demonstrations


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