Ammonia measurements from the NPP Suomi Cross-Track Infrared Sounder (CrIS)

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NH_3 Sources

Biomass burning

Automobiles (catalytic converters)

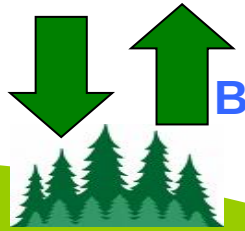
- Important in large urban centers
- 50% of NH_3 in LA area has auto source (Nowak et al., 2012)

Industry

- Fertilizer
- Coal Mining
- Power generation

AGRICULTURE

- Animal waste (temperature dependent)
- Fertilizer application



Bi-directional Flux

NH_3 Impacts

$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$

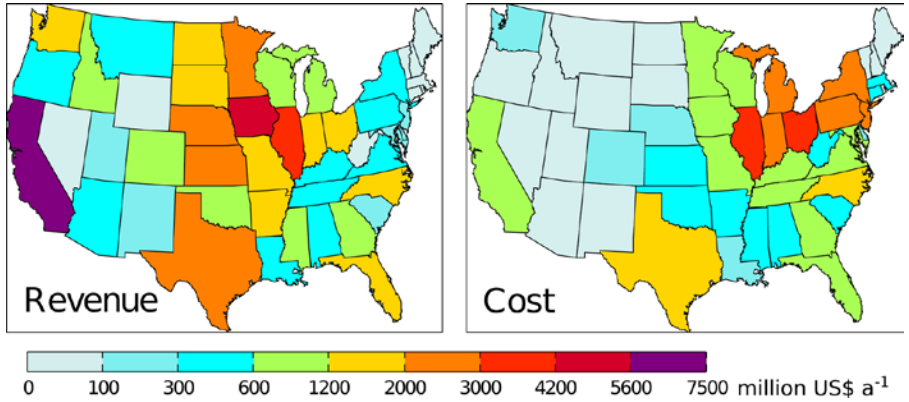
$2\ NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

↓ **Nitrogen deposition**

↓ **$PM_{2.5}$ Particles**

- **Increased incidence of cardiovascular and respiratory diseases**
  - **reducing NH_3 is often the most efficient way to reduce $PM_{2.5}$**
- **Particles impact cloud radiative properties and contribute to direct aerosol effects**
- **Deposited nitrogen leads to algal blooms and reduced species diversity**

Agricultural exports **NH_3 Health Costs**



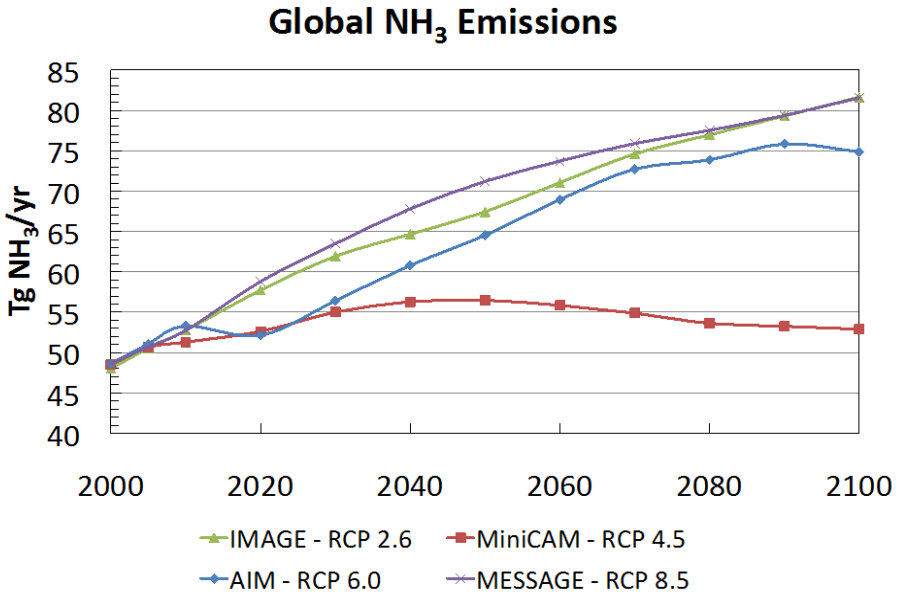
Half the revenue from exported agriculture is offset by health costs related to NH_3 emissions

(Paulot et al., 2014)

NH_3 in the Future

- SO_2, NO_X decreasing due to increased controls
- EU emissions are declining

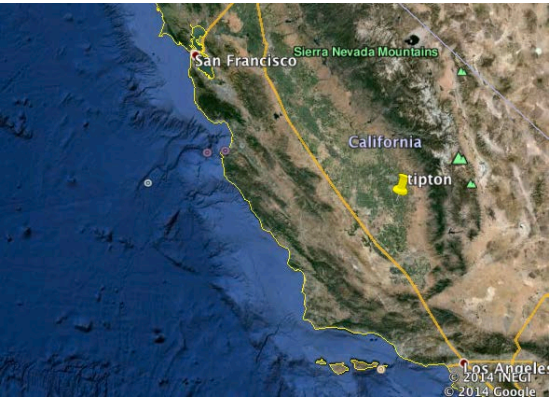
- Globally NH_3 forecast to increase:
  - Demand for more and better food in developing countries
    - More livestock raising
    - Greater use of fertilizer



Monitoring NH_3 is difficult

NH_3 is highly reactive

- ➔ **highly variable in space and time**
- ➔ **very "sticky"**



NH_3 from an Open path Quantum Cascade Laser (QCL) on a moving platform in the San Joaquin Valley during DISCOVER-AQ 2013.

(Miller et al., AMT, 2014)

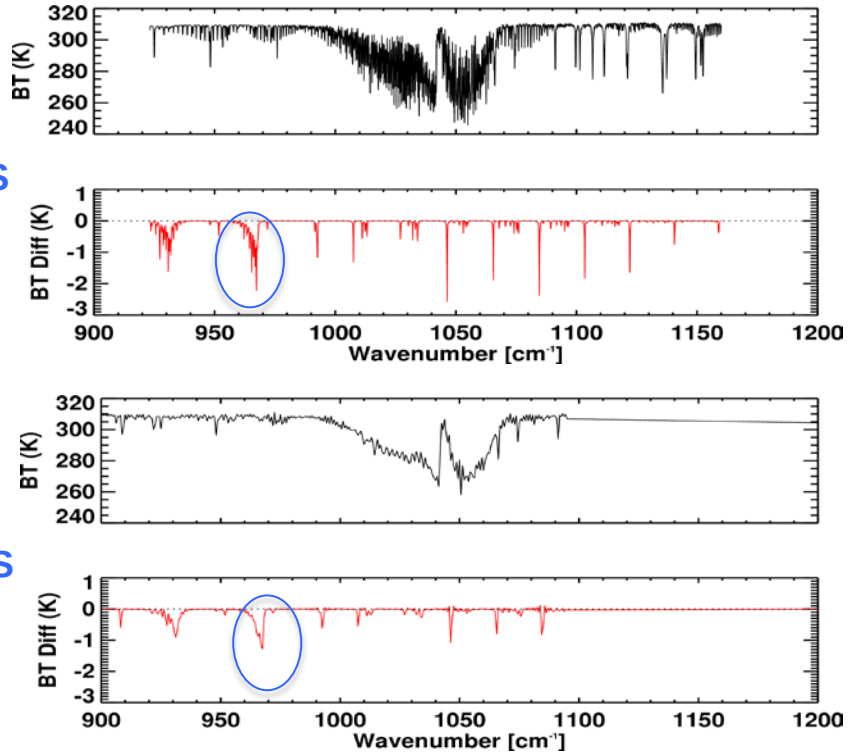
NH_3 signal from TES and CrIS

Simulated spectra and NH_3 signal

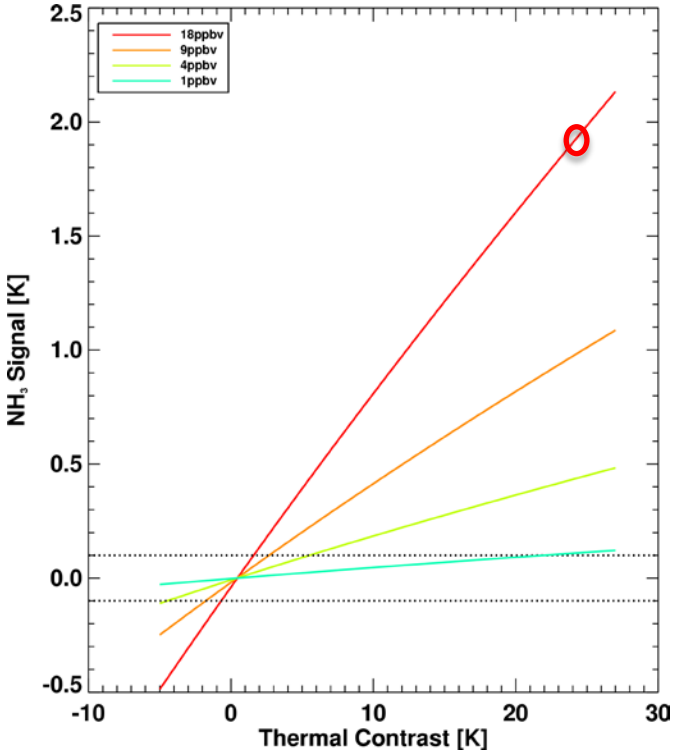
18 ppbv at surface

TES

CrIS



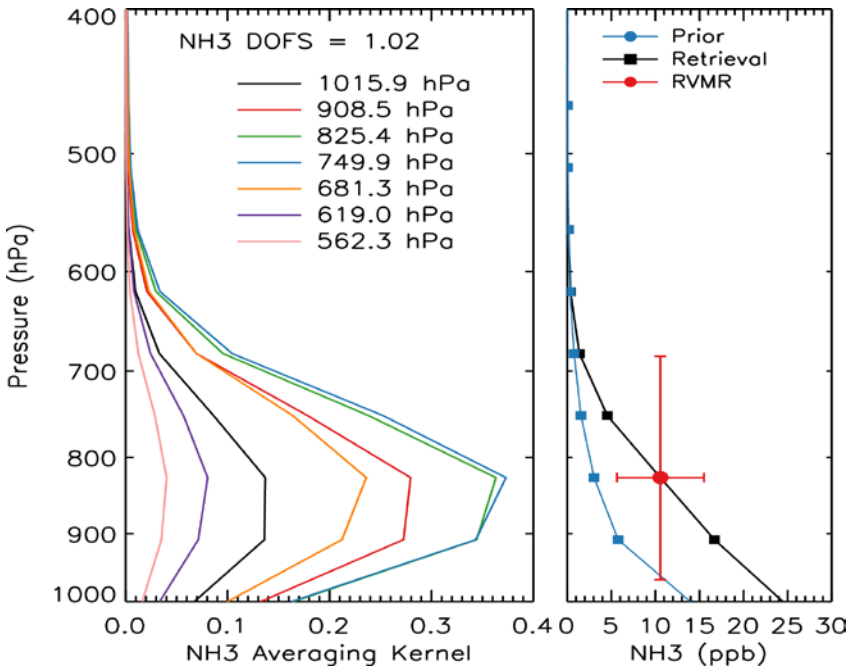
Thermal contrast is important!



Detectability is ~ 1 ppbv under ideal conditions

CrIS NH_3 Algorithm

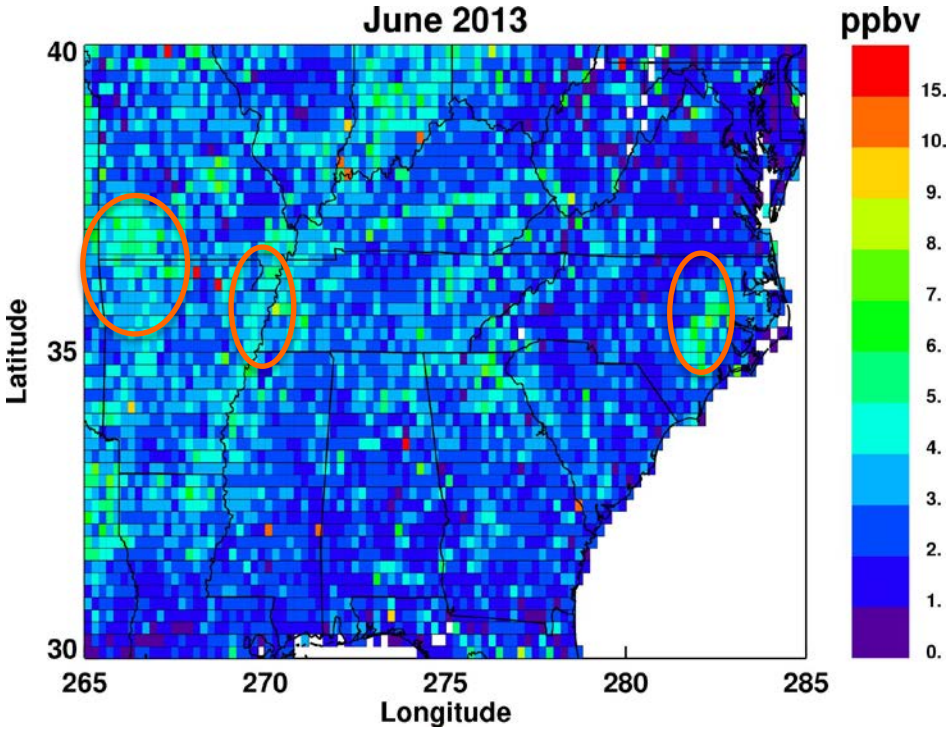
- Prototype algorithm
- TES Heritage
- Maximum Likelihood Estimation (Rodgers, 2000)
- A priori is selected from three different profiles, based on NH_3 signal
- Performed on every FOV
- Retrieval carried out in two steps:
  - Surface temperature and emissivity refinement
  - NH_3 profile



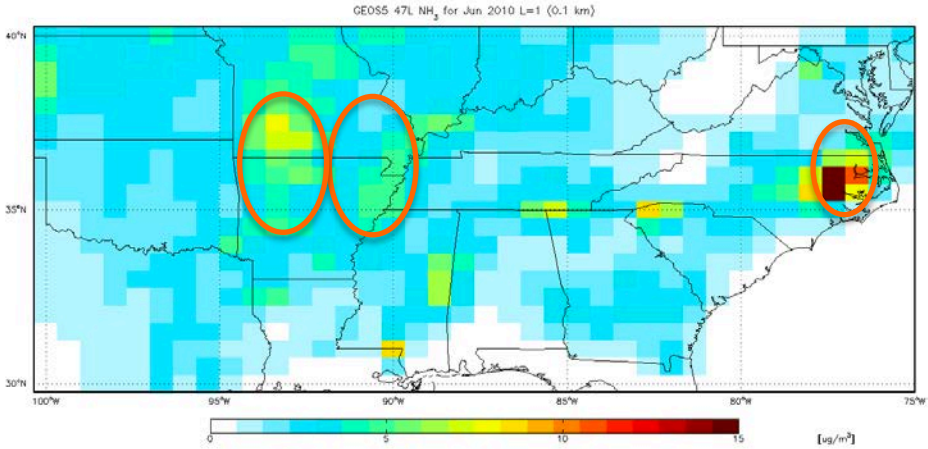
- CrIS sensitive to NH_3 between 950 and 600 mbar
- 1 piece of information or less: DOFS<1.0
- Collapse all information to a single point: RVMR
- Sensitivity weighted profile average

Average June NH_3: Southeastern US

CrIS RVMR

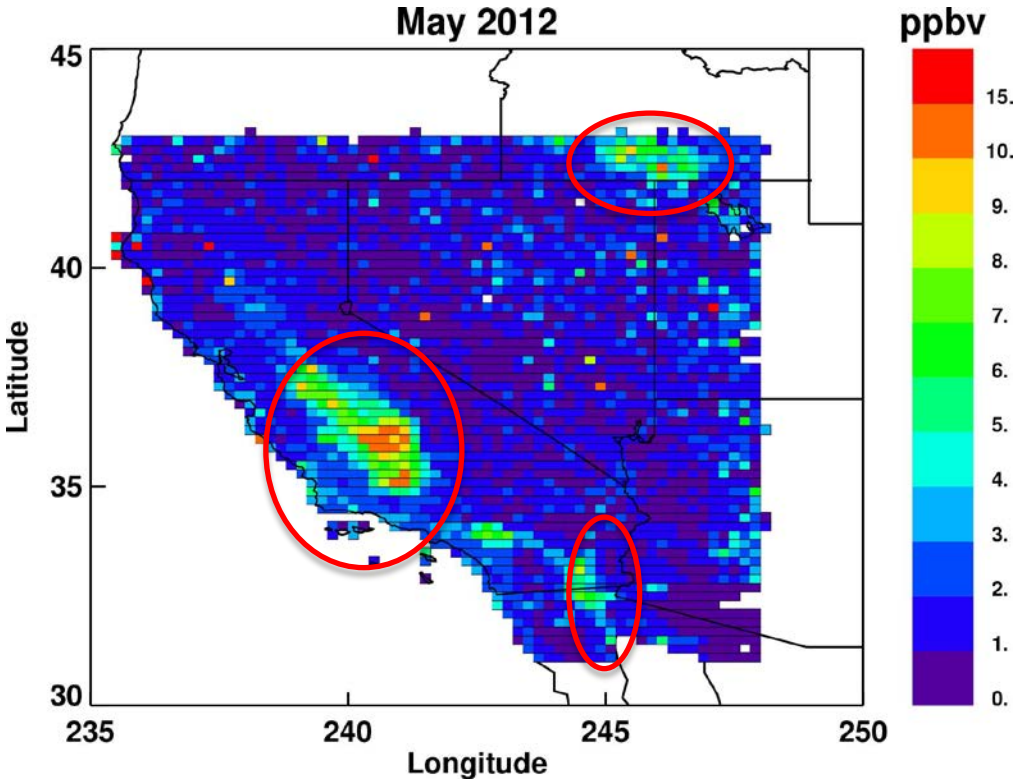


GEOS-Chem @ 0.1 km

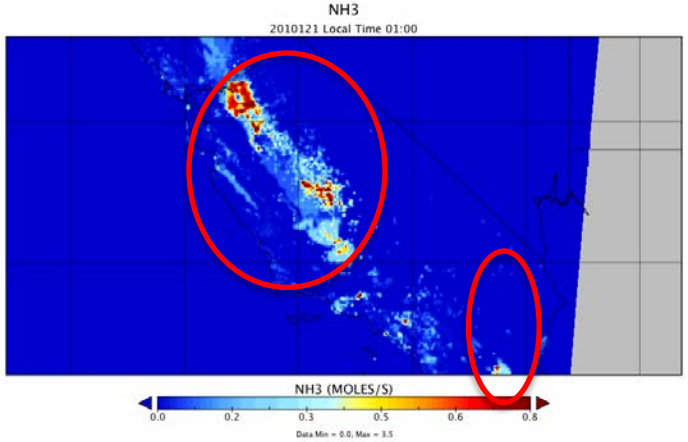


Average May NH_3: California

CrIS RVMR



CARB Emissions

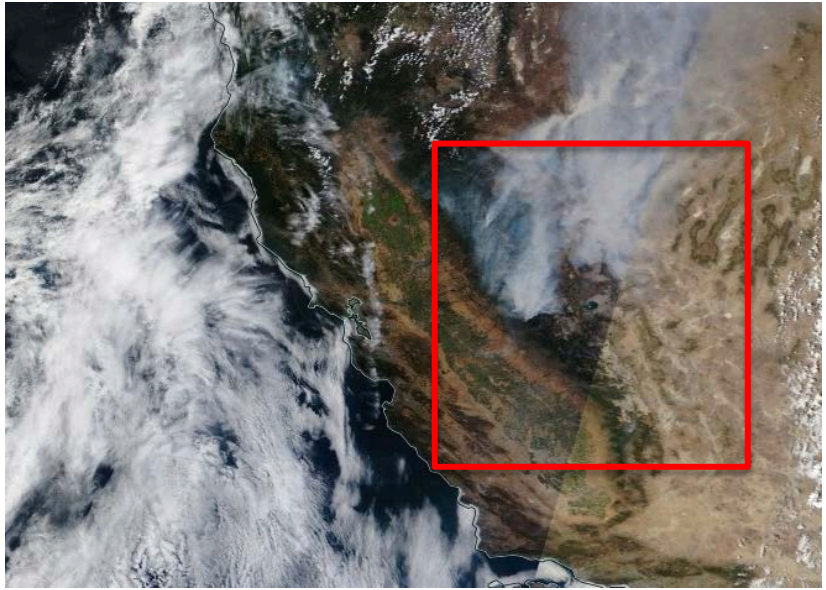


Enhanced NH_3:

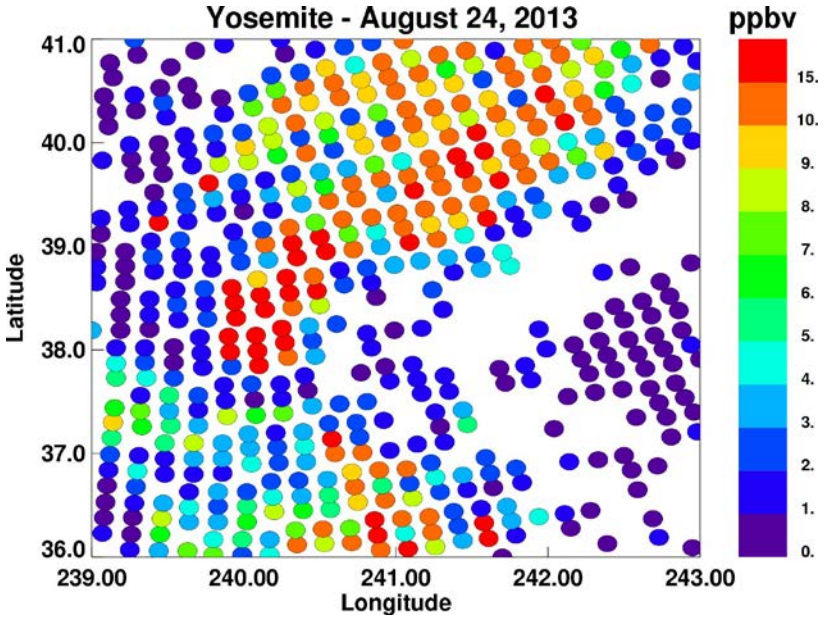
- Central Valley
- Imperial Valley
- Snake River

CrIS NH_3 in Yosemite Rim Fire

MODIS – August 24, 2013



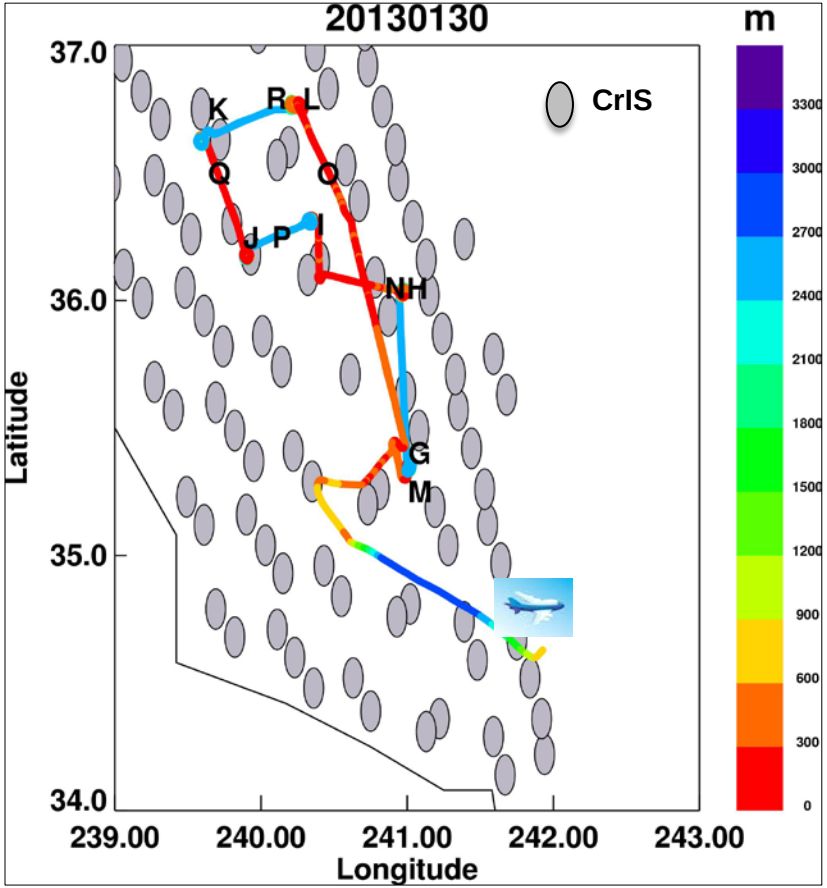
CrIS NH3 RVMR



DISCOVER-AQ

DISCOVER-AQ: Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality

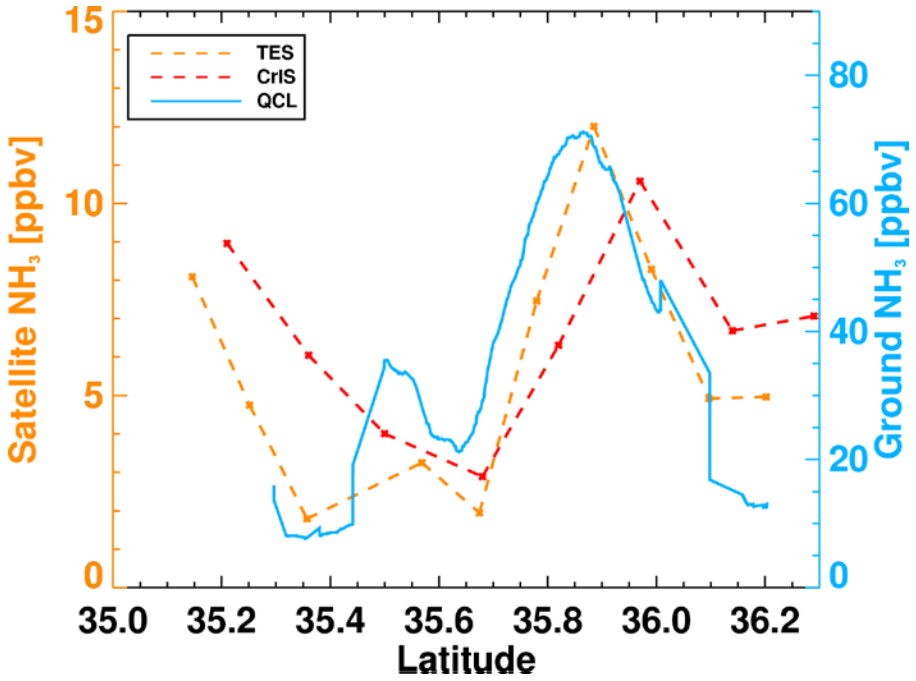
- Baltimore/DC 2011, Texas 2013, California 2013, Colorado 2014
- Four-year campaign to improve the use of satellites to monitor air quality for public health and environmental benefit
- Here we compare NH_3 from the PTR instrument aboard the P3B aircraft with CrIS profiles

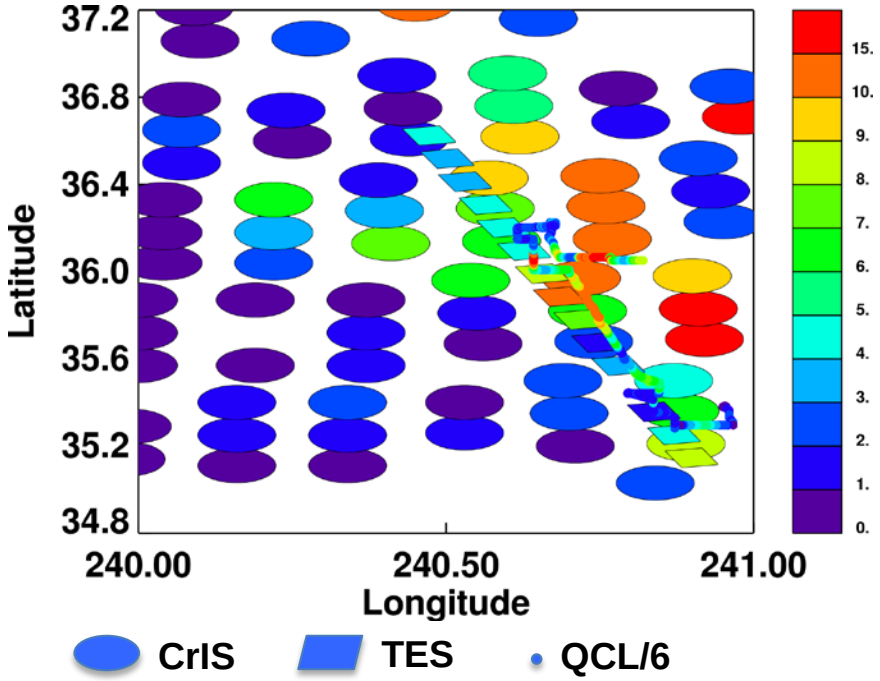


G,H,I,J,K,L,M,N,O,P,Q,R: aircraft spirals

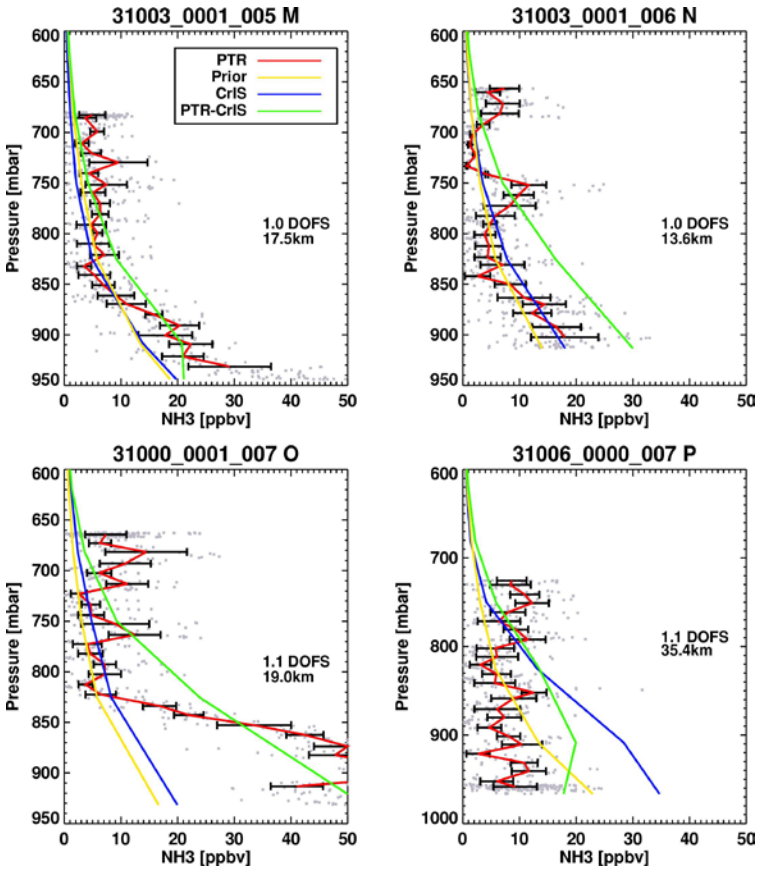
Satellite and surface NH_3 in DAQ

QCL directly under TES transect in the San Joaquin Valley on January 28, 2013

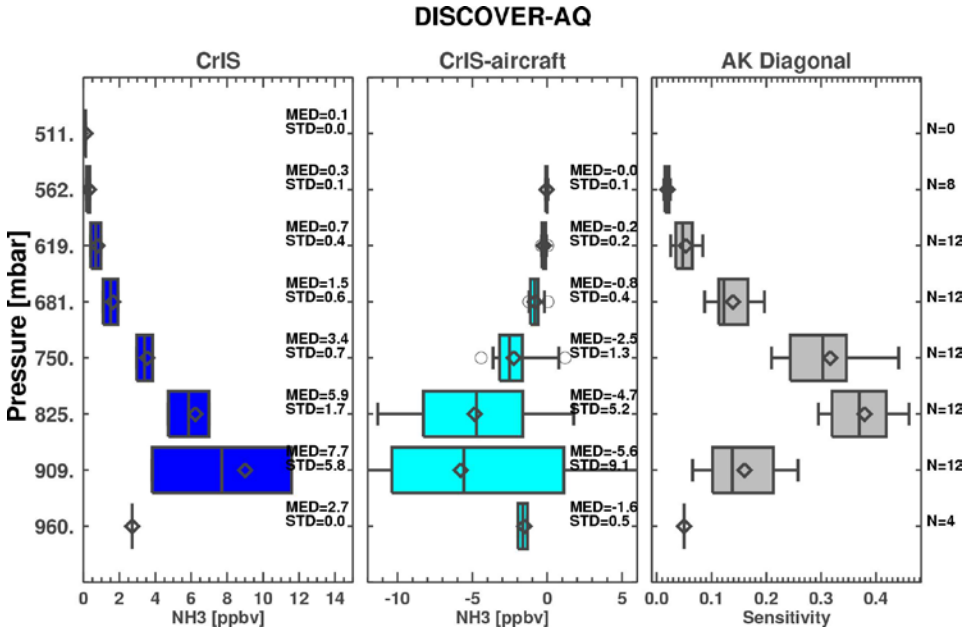




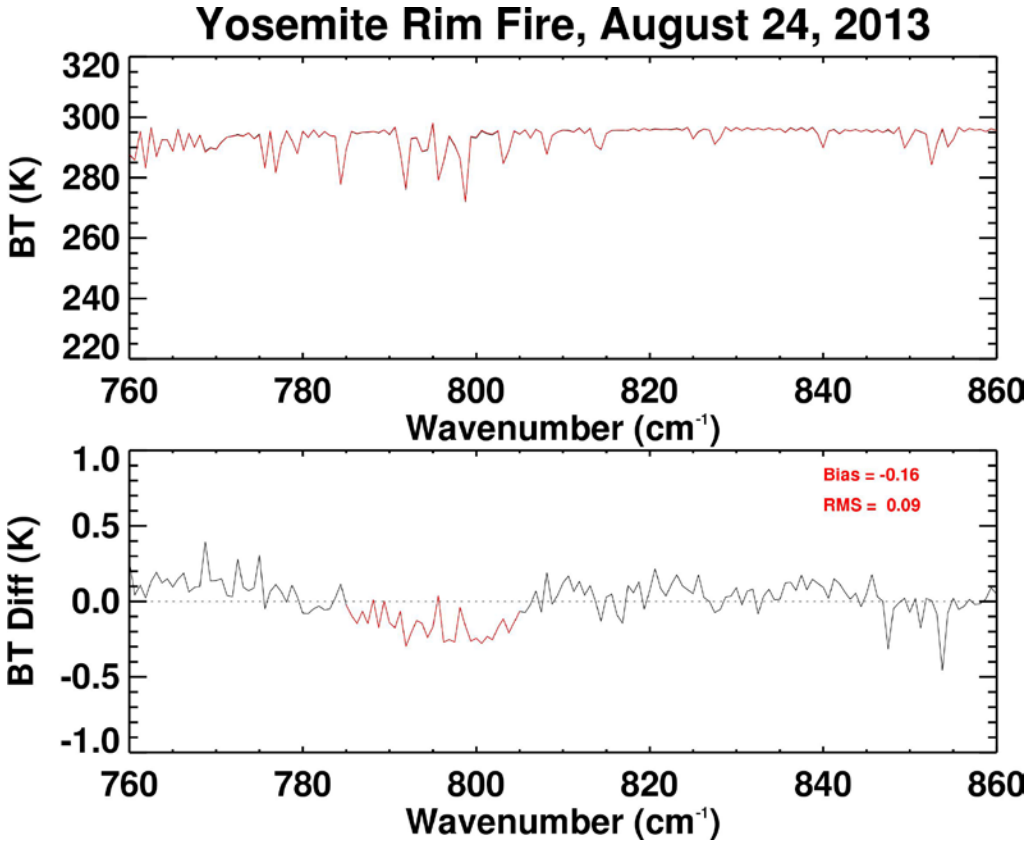
CrIS and PTR in DAQ



- Focused on January 30 – 12 spirals
- Matched each spiral with closest CrIS scan
- Averaged PTR over 10mbar intervals
- Applied CrIS operator to PTR



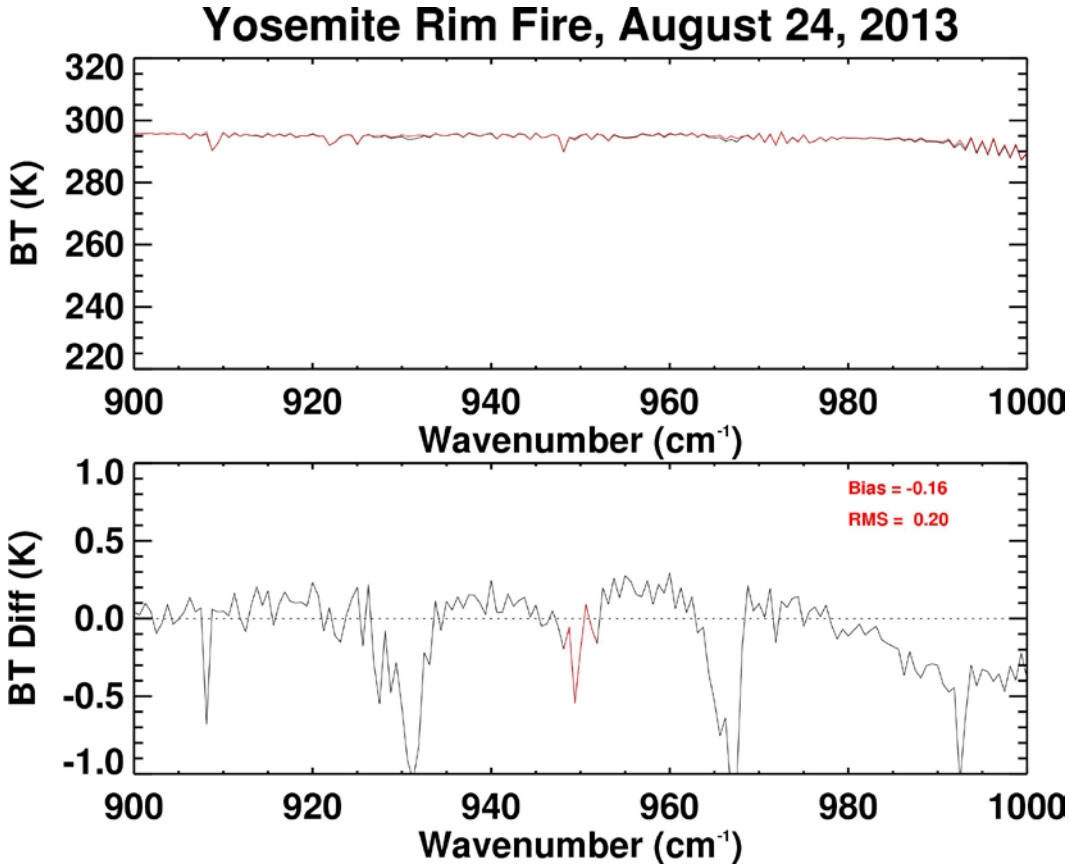
PAN in CrIS Data



PAN (Peroxy Acetyl Nitrate)

- **Reservoir for NO_X**
- **Can be transported long distances downwind (e.g., across the Pacific)**
- **Enables O_3 formation far from the original source**

C_2H_4 in CrIS data



- C_2H_4 (ethylene) is emitted by biomass burning
- Reacts very quickly

Summary

- NH_3 plays an important role in determining air quality
- Its contribution is expected to increase as other pollutants are reduced and NH_3 emissions continue to rise
- Monitoring NH_3 is difficult: highly variable, not easy to measure *in situ*
- CrIS NH_3 can provide information on temporal and spatial variability
  - Spatial variability is consistent with in situ and model data
  - During California DAQ CrIS NH_3 was biased low but within PTR variability
- PAN and C_2H_4 are candidates for future CrIS retrieval algorithms

Acknowledgements

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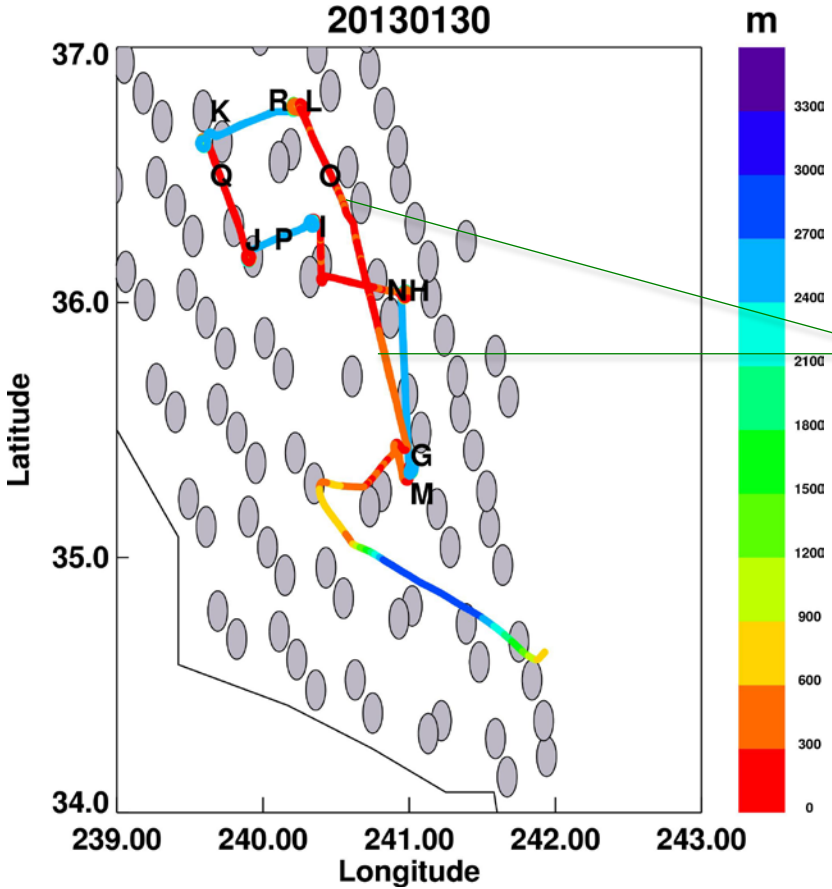
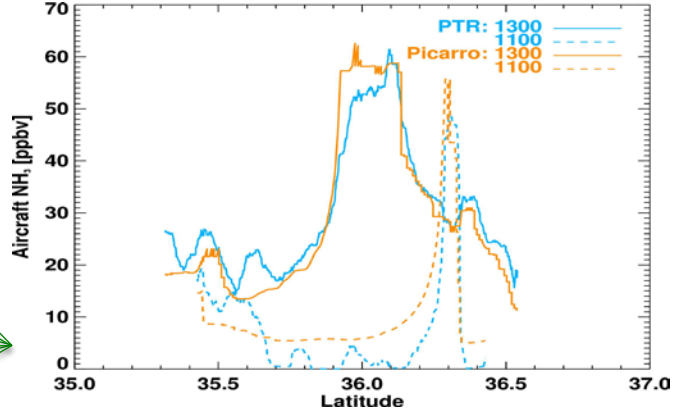
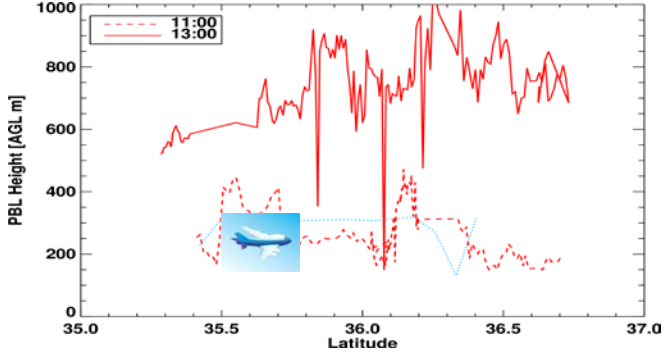
DISCOVER-AQ





NH_3 from PTR and Picarro



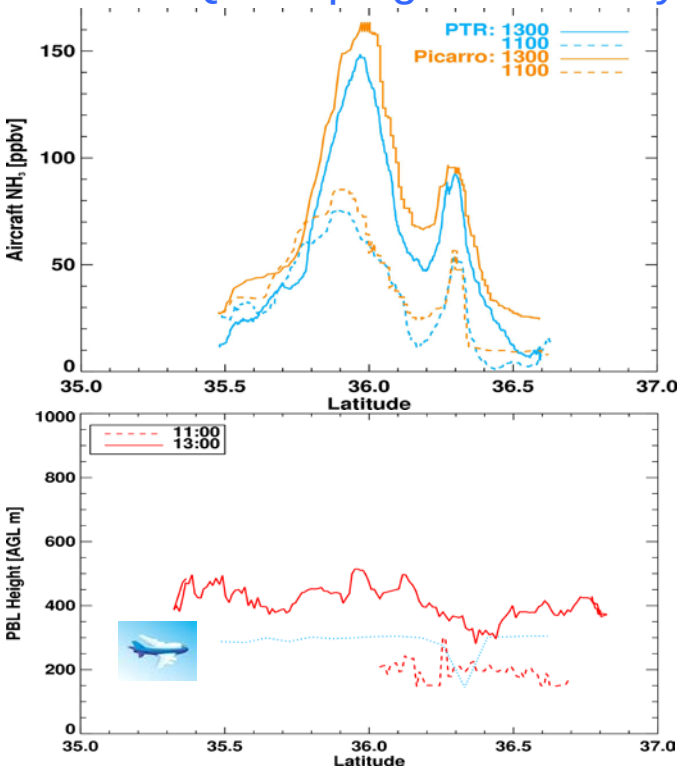
PBL from airborne HSRL backscatter

NH_3 from aircraft

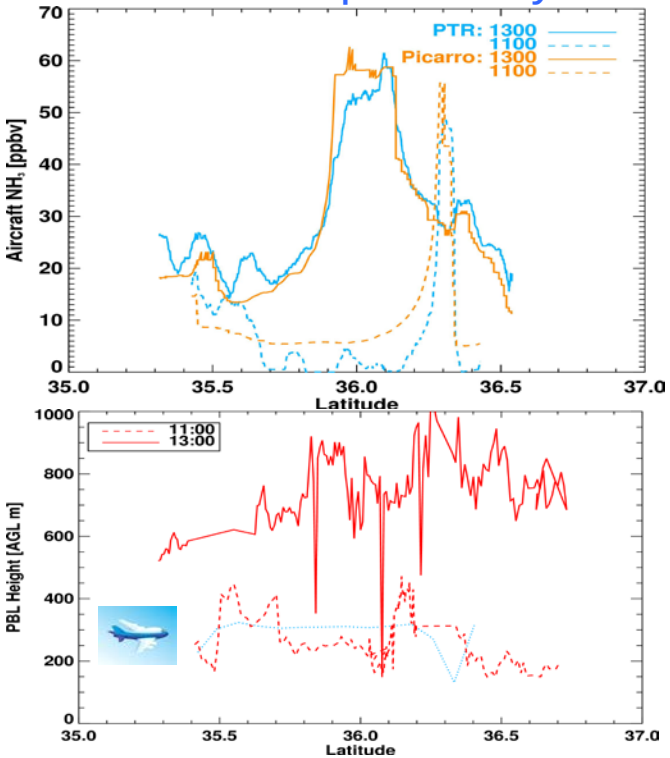
DISCOVER-AQ campaign in January 2013 in the San Joaquin Valley

NH_3 from PTR and Picarro

PBL from airborne HSRL backscatter



January 21



January 30

NH_3 in the atmosphere

$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$

$2\ NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

↓

$PM_{2.5}$ Particles

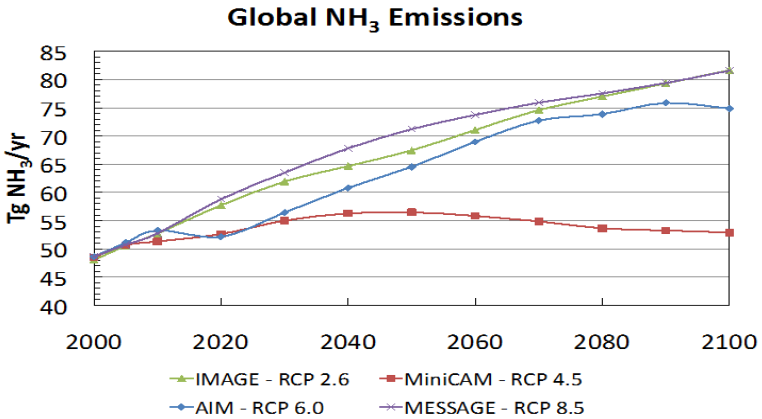
↓

- **Increase incidence of cardiovascular and respiratory diseases**
- **Increase number of CCN**
- **→Affect cloud radiative properties**
- **→Climate change**

Long-range export

Long-range import

SO2, NOX decreasing but NH_3 forecast to increase

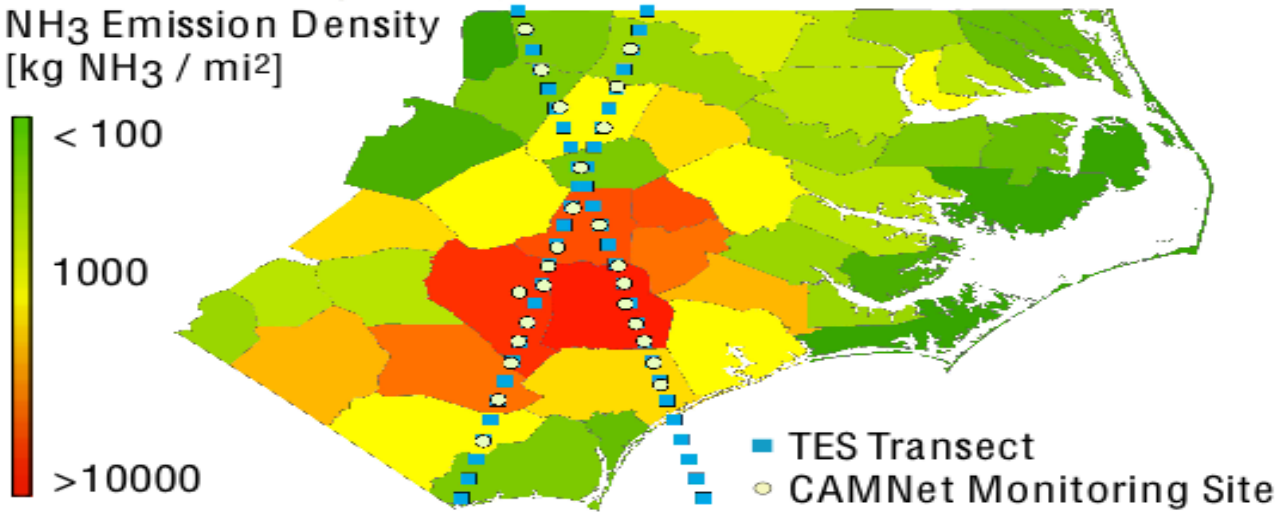


Validation in North Carolina

North Carolina

Intense livestock farming (hogs, chickens, turkeys)

- EPA CAMNet NH_3 monitoring network
- TES high spatial density observations (transects)
- Feb – Dec 2009
- Allows detection of spatial variability and seasonal trends

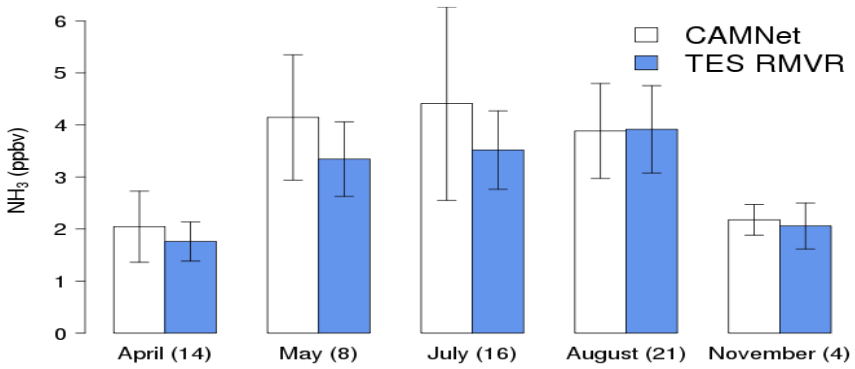


CHALLENGE

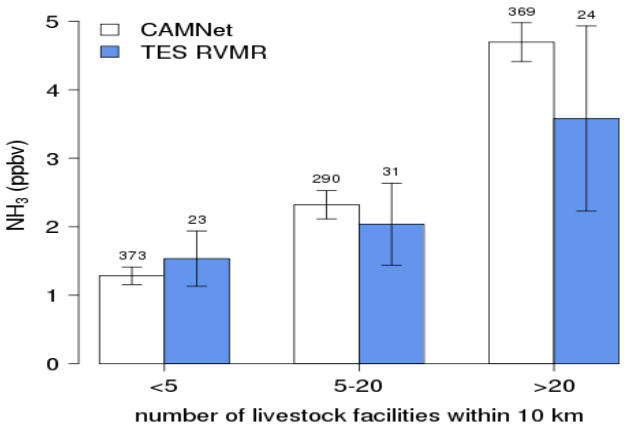
- TES: instantaneous profile over 5x8 km
- CAMNet: two week average at a surface point
- Cloudy summers!

In situ and TES in North Carolina

NH_3 vs time



NH_3 vs source concentration



TES and surface measurements are qualitatively well correlated

Pinder et al., GRL, 2011