Extension of TES NH_3 and CO algorithms to CrIS

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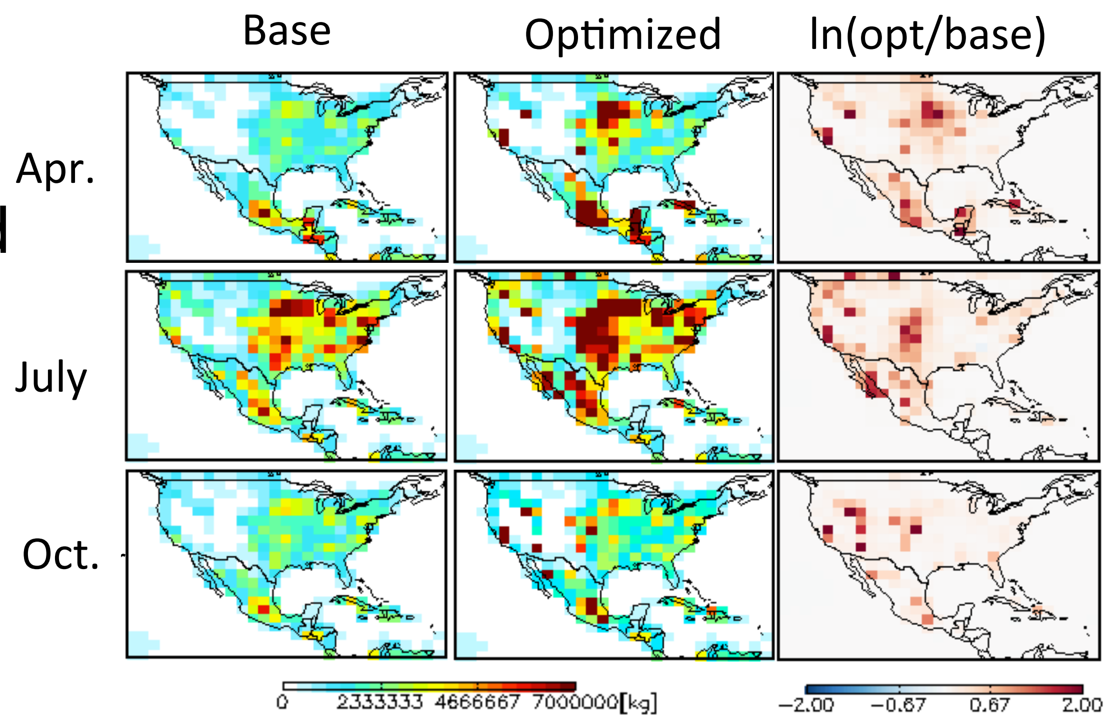
Motivation

- NH_3 and CO are important trace gases
- TES and MOPITT observations are used to optimize NH_3 and CO emissions and investigate their atmospheric impacts
- Both instruments are past their design lifetimes
- **CrIS could monitor global NH_3 and CO for many more years**



Constraining NH_3 emissions with TES:.
Zhu et al., JGR, 2013.

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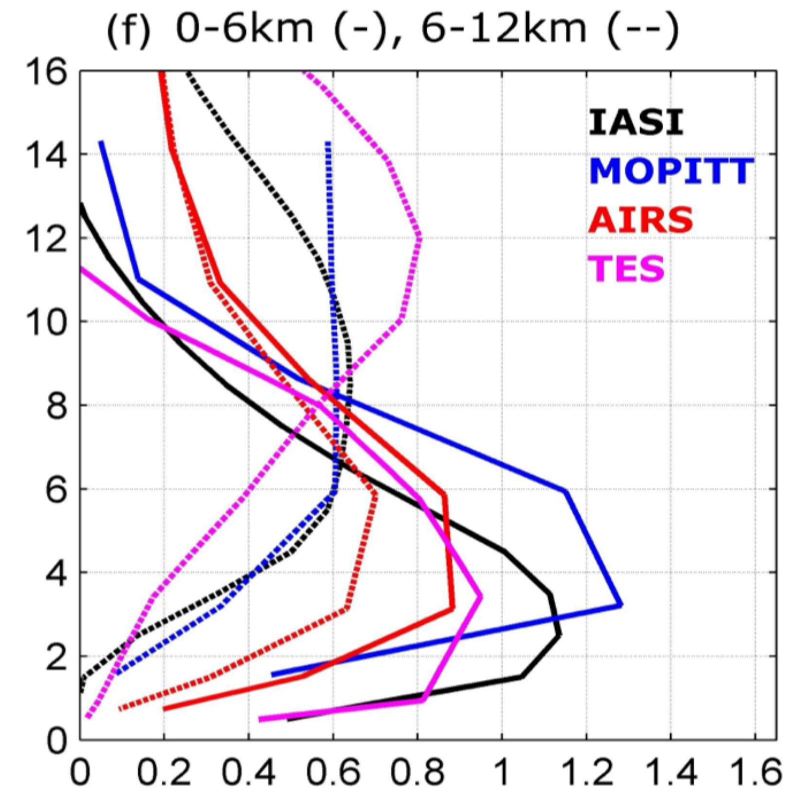
Extending the EOS NH_3 and CO Records with CrIS

- Will use the same **optimal estimation approach** and **constraints** adopted for TES NH_3, TES CO, and MOPITT CO.
- This approach:
  - Allows easy comparison with model output (via AKs)
  - Provides error estimates for the retrieved profiles
  - **Builds a consistent record from 1999 for CO and from 2004 for NH_3 to beyond 2022!**
- CrIS's large coverage could provide more information for constraining sources.



Partial column averaging kernels (AK) for satellite TIR CO measurements (from George et al., 2009).

Enhanced AER CrIS/ATMS Algorithm (PI Moncet, NASA S-NPP Science Team)

- Flexible, modular software infrastructure that will:
  - Facilitate algorithm component comparisons and validation
  - Include advanced treatments of clouds, radiative transfer, surface emissivity/reflectivity, background data, and the atmospheric profile
- Primary products will include T_{atm}, T_{surf}, H_2O, cloud fraction, and cloud top T and P
- Secondary products could include O_3, NH_3, CO, LWP/IWP, and MW and IR surface emissivity/ reflectivity.

Enhanced AER CrIS/ATMS Algorithm

- Treatment of clouds adapts to conditions
  - **Cloud Clearing** as in AIRS Science Team and NUCAPS algorithm
    - Estimate clear-sky spectrum from multiple adjacent cloudy spectra
  - **Hole Hunting**
    - Identify clear-sky gaps in cloudy areas
  - **Simultaneous Cloud Property Retrieval** from EUMETSAT IASI algorithm
    - Algorithm operates on cloudy radiances while retrieving cloud parameters
- Fast and accurate radiative transfer
  - Baseline is **Optimal Spectral Sampling (OSS)**
  - Molecular absorption from **AER's MonoRTM and LBLRTM models**, including Non-LTE and Zeeman splitting of O_2 lines
  - Flexible structure allows alternative fast models, like **SARTA**

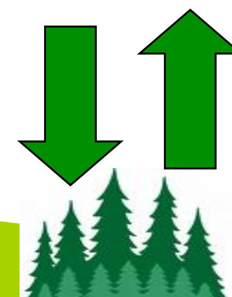
NH_3 Sources

Biomass burning

Automobiles (catalytic converters)
- Large urban centers
  - 50% of NH_3 in LA area

Industry
- Fertilizer
- Coal Mining
- Power generation

AGRICULTURE
- Animal waste (temperature dependent)
- Fertilizer application



Bi-directional Flux

NH_3 in the atmosphere

$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$
$2\ NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

Long-range export

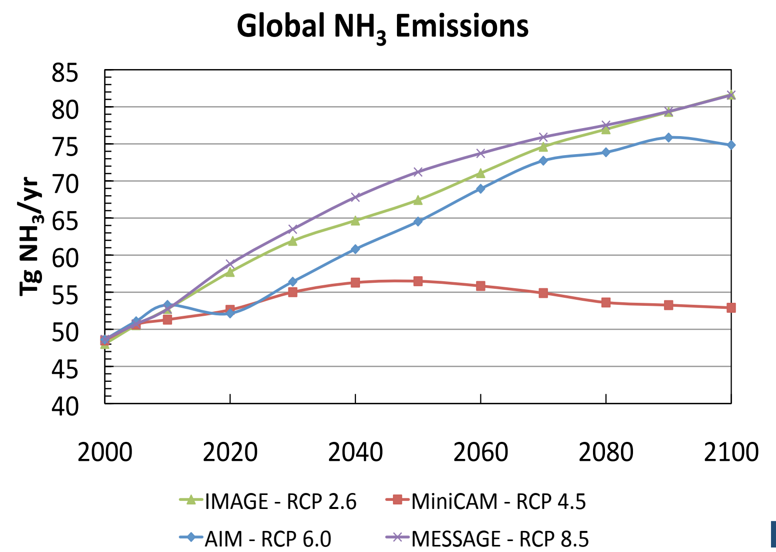
Long-range import

$PM_{2.5}$

Nitrogen Deposition

- Increase incidence of cardiovascular and respiratory diseases
- Increase number of CCN
- Alter ecosystems

SO_2, NO_X decreasing but NH_3 forecast to increase



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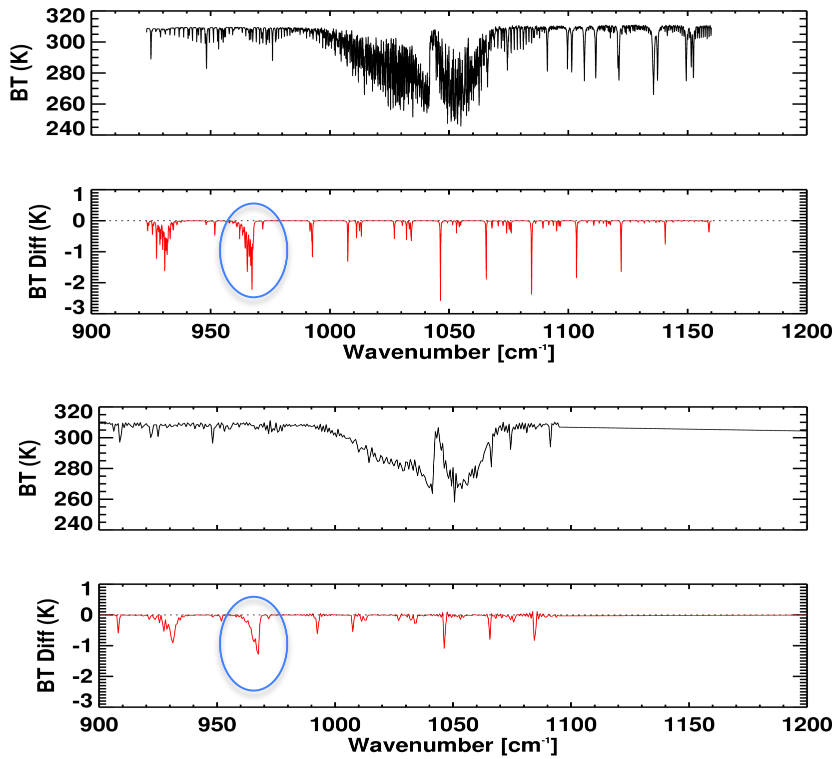
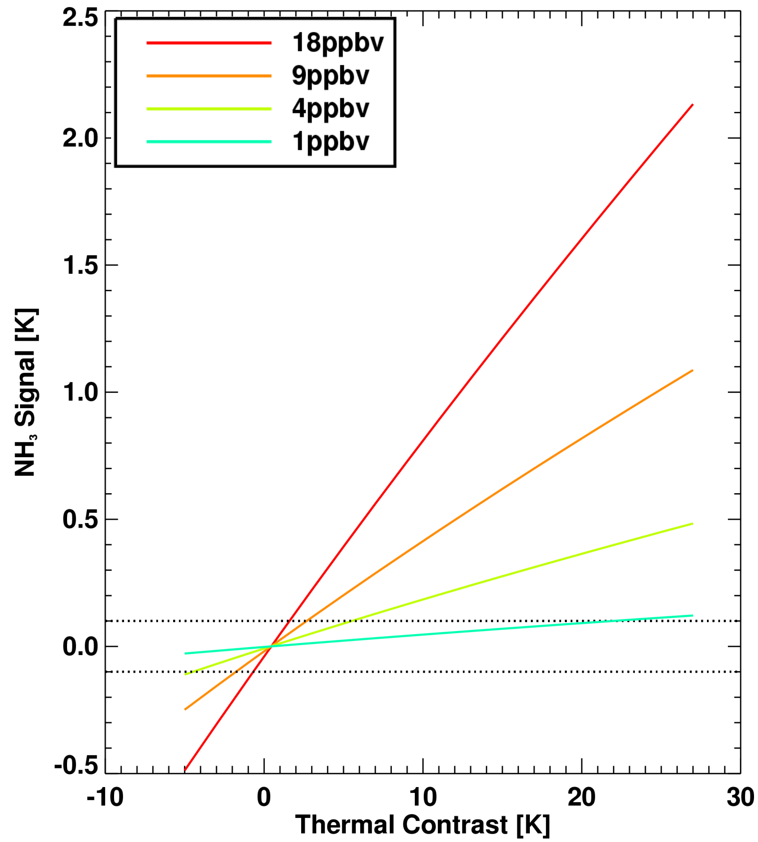
NH_3 signal from TES and CrIS

Simulated spectra and NH_3 signal
18 ppbv at surface

TES

CrIS





- Detectability is ~1 ppbv under ideal conditions
- But thermal contrast also plays a role

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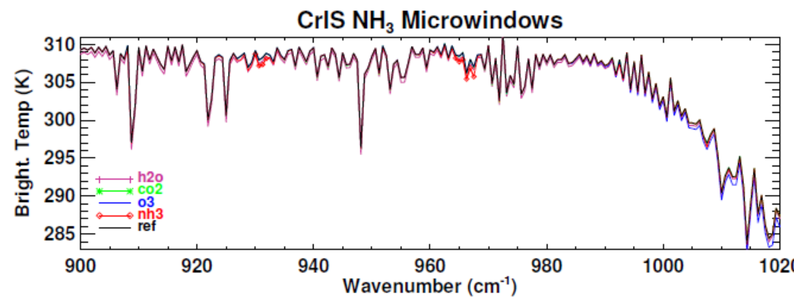
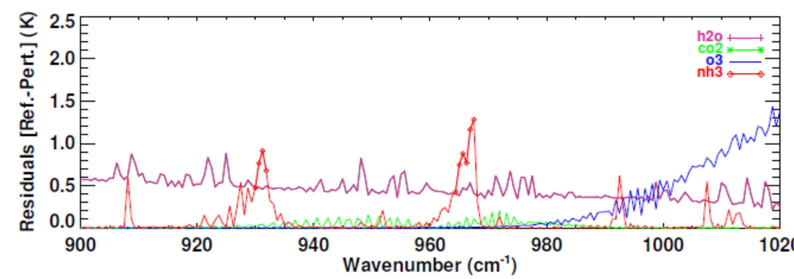
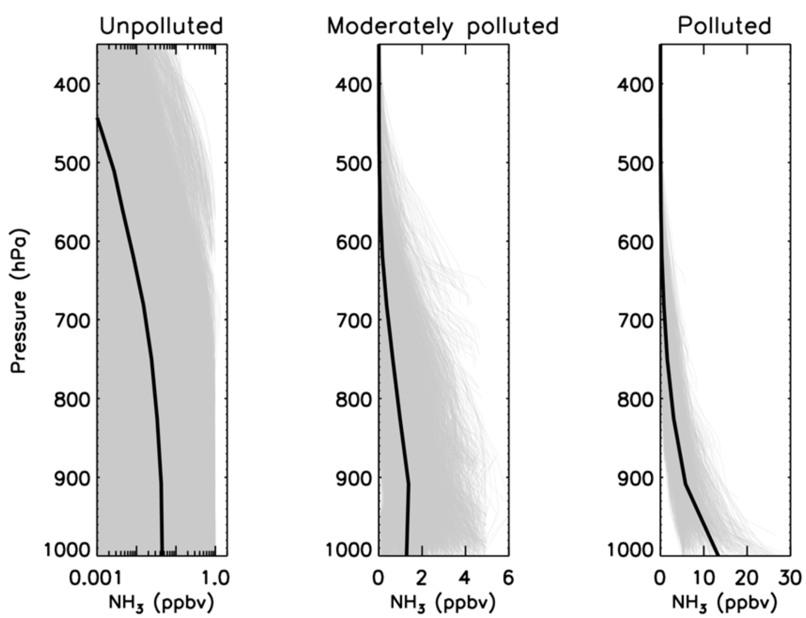
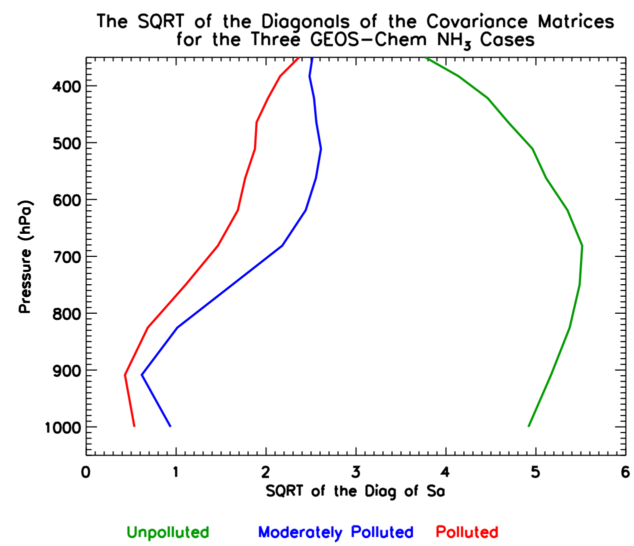
CrIS Microwindows and Constraints

- Lower spectral resolution of CrIS required different microwindows.
- *A priori* and constraints from TES (Shephard et al., 2011)
  - Polluted, Moderately polluted, and Unpolluted profiles
- *A priori* selected based on signal to noise ratio (SNR) and thermal contrast



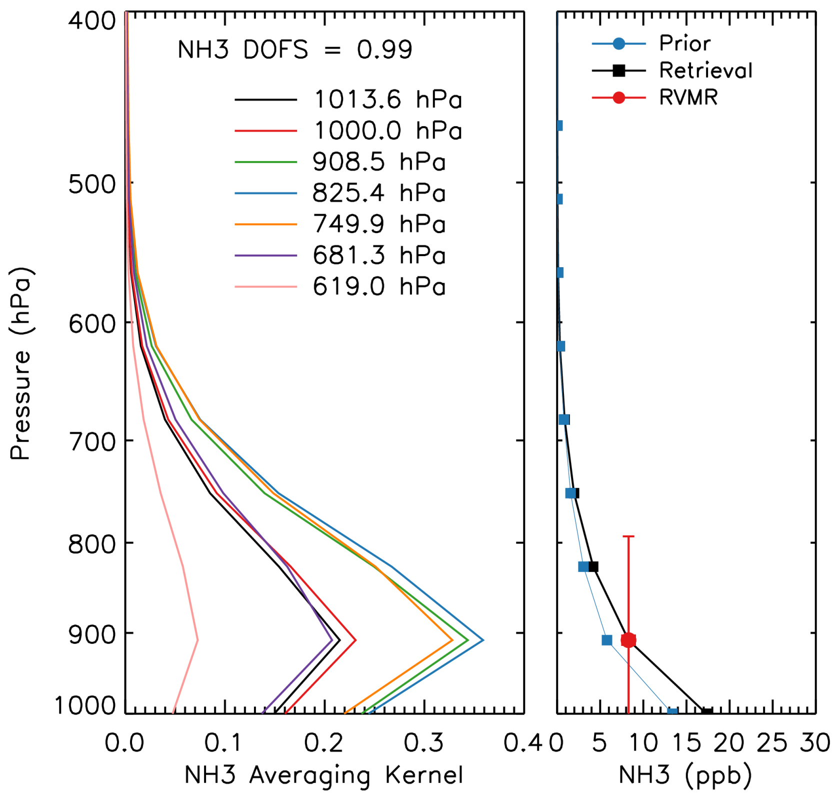




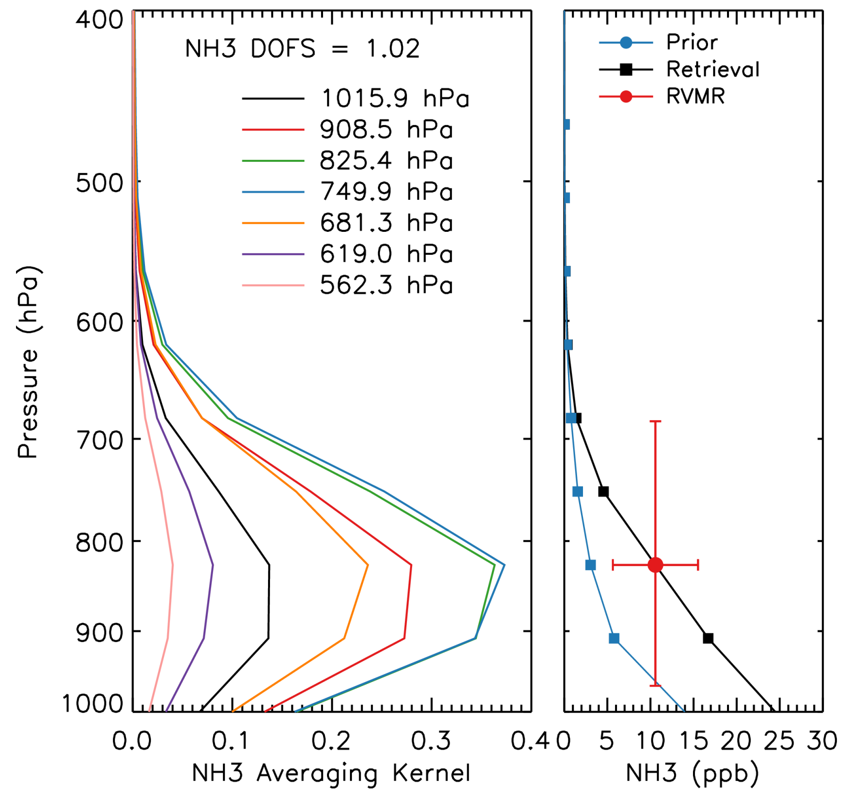


TES and CrIS Sensitivity to NH_3

TES



CrIS

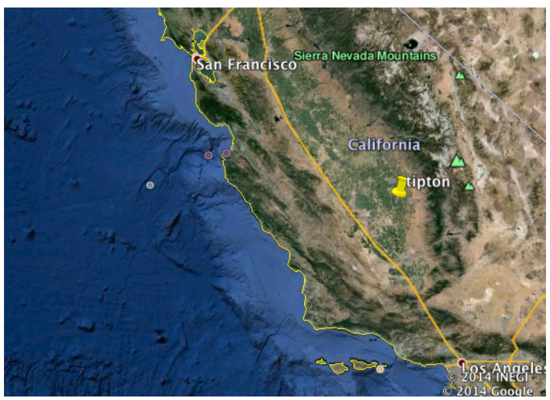


- Both instruments most sensitive to NH_3 between 950 and 600 mbar
- TES is more sensitive to amounts lower in the atmosphere
- 1 piece of information or less: DOFS<1.0
- Collapse all information to a single point: RVMR
  - Easier to compare with *in situ* measurements, models and other instruments

Validation with surface NH_3 data

NH_3 is highly reactive
➔ highly variable in space and time

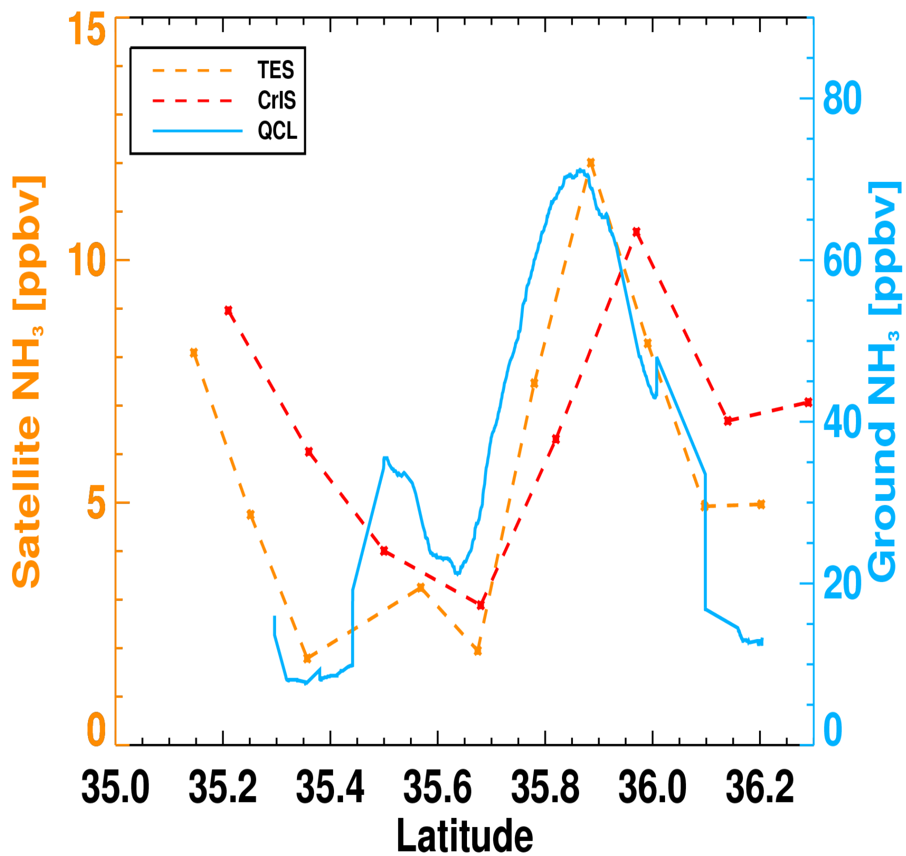
- NH_3 from an Open path Quantum Cascade Laser (QCL) on a moving platform in the San Joaquin Valley during DISCOVER-AQ 2013.

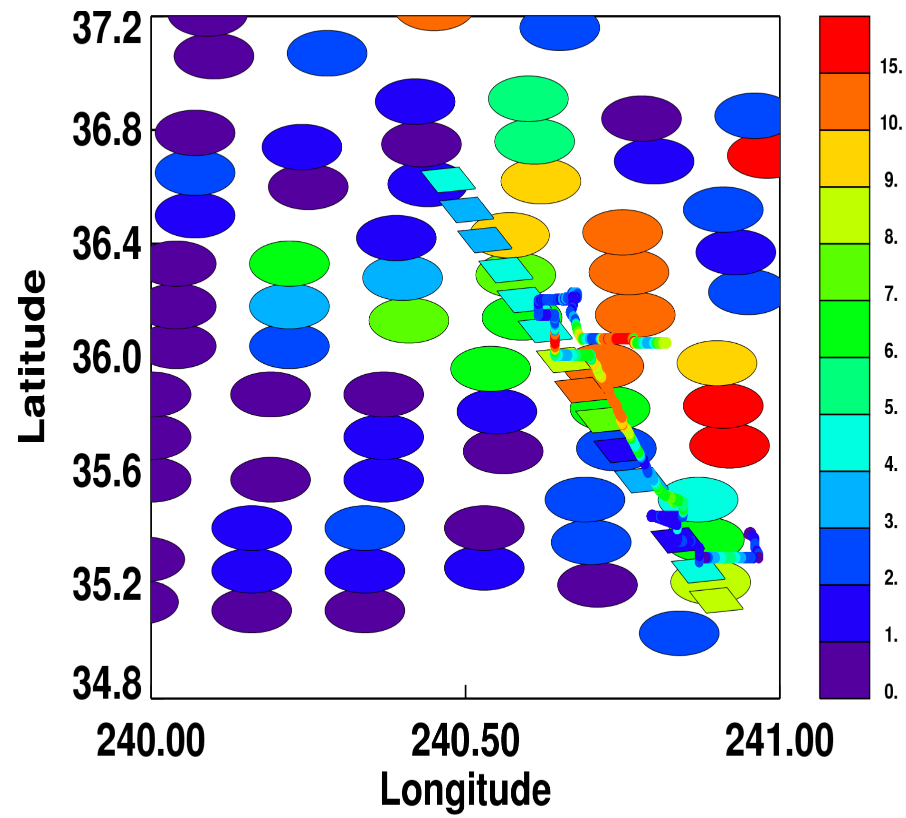


Miller et al., AMT, 2014

TES and CrIS versus surface NH_3

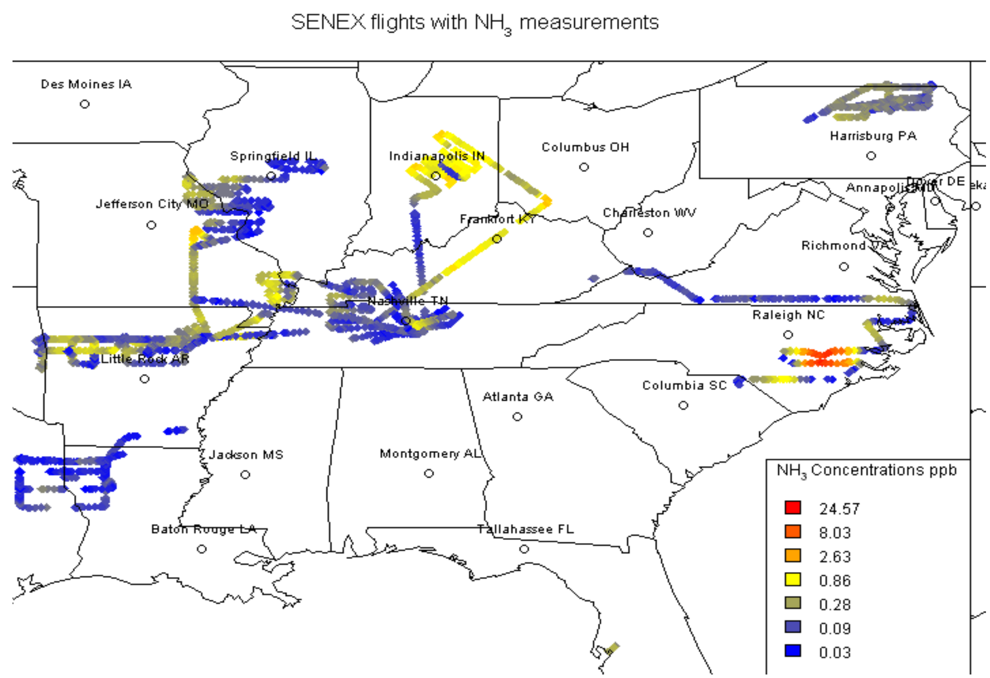
- QCL directly under TES transect in the San Joaquin Valley on January 28, 2013





Future Work on CrIS NH_3 Retrieval

- Validate against SENEX, FRAPPE, and other field NH_3 measurements.
- Use CMAQ adjoint to test ability of CrIS to optimize NH_3 emissions.
- Incorporate NH_3 into AER CrIS/ATMS algorithm and deliver to NASA SIPS
- Incorporate into NUCAPS?



NH_3 mixing ratios (ppbv) measured by the NOAA WP-3 aircraft during SENEX 2013. (Figure courtesy of Jesse Bash, US EPA NERL.)

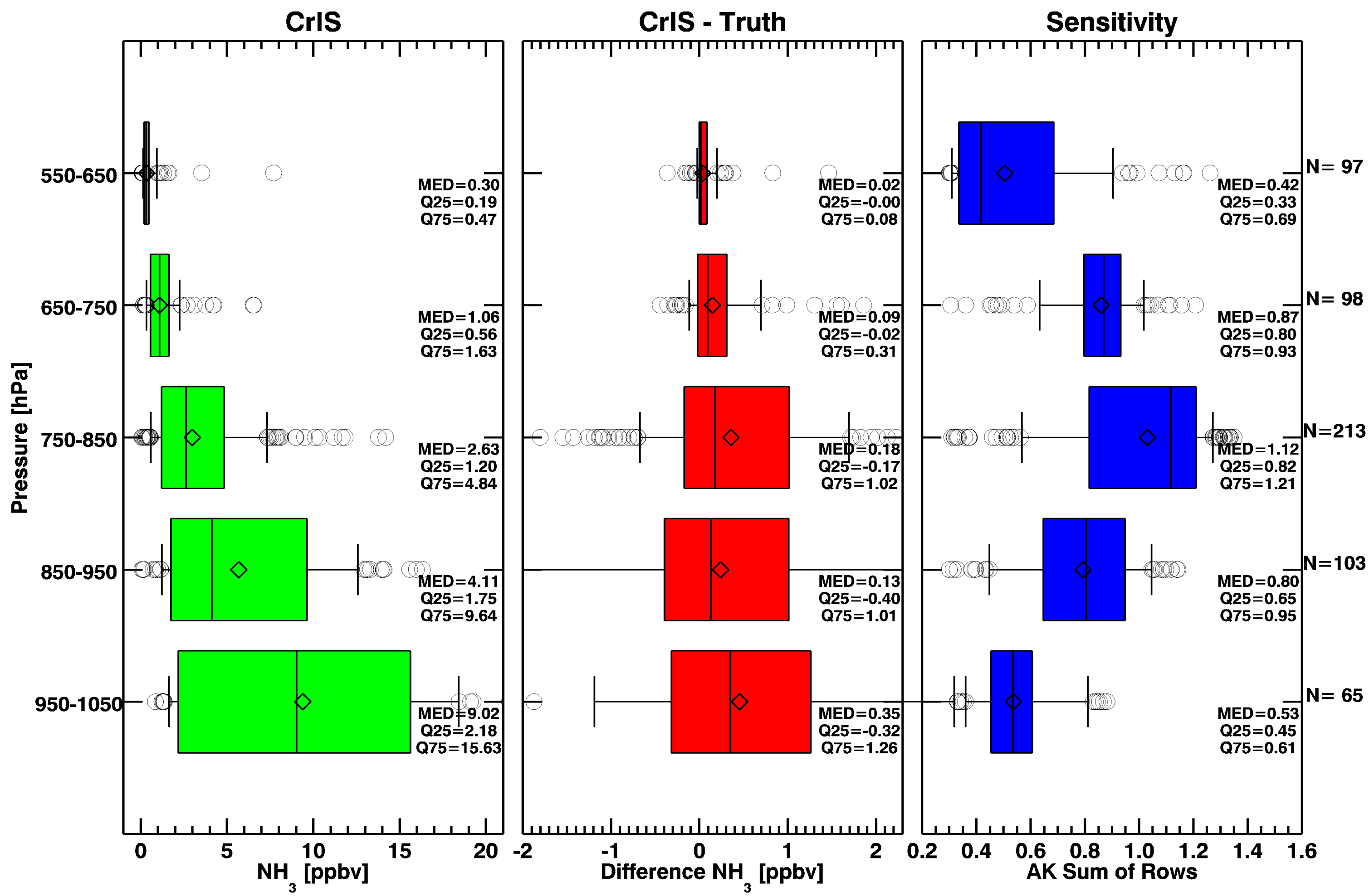
Summary

- A prototype NH_3 retrieval for CrIS, based on the TES algorithm, has been built and tested
  - LOD ~ 1 ppb, DOFS < 1.0, sensitive slightly higher in atmosphere than TES
  - Algorithm performs well for simulated spectra
  - Qualitatively similar to surface data from DISCOVER-AQ
  - Further validation needed (e.g., SENEX and FRAPPE)
- A similar CrIS CO algorithm, based on the MOPITT and TES approaches, is planned
- Both algorithms will be incorporated into the enhanced AER CrIS/ATMS algorithm for delivery to NASA SIPS

Acknowledgements

- NOAA CPO AC4 Program
- TES Science Team
- NASA Suomi-NPP Science Team

CrIS NH_3 Retrieval: Simulated Spectra



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