Using NH_3 Retrievals from the Cross-track Infrared Sounder to Improve Emission Inventories and Models

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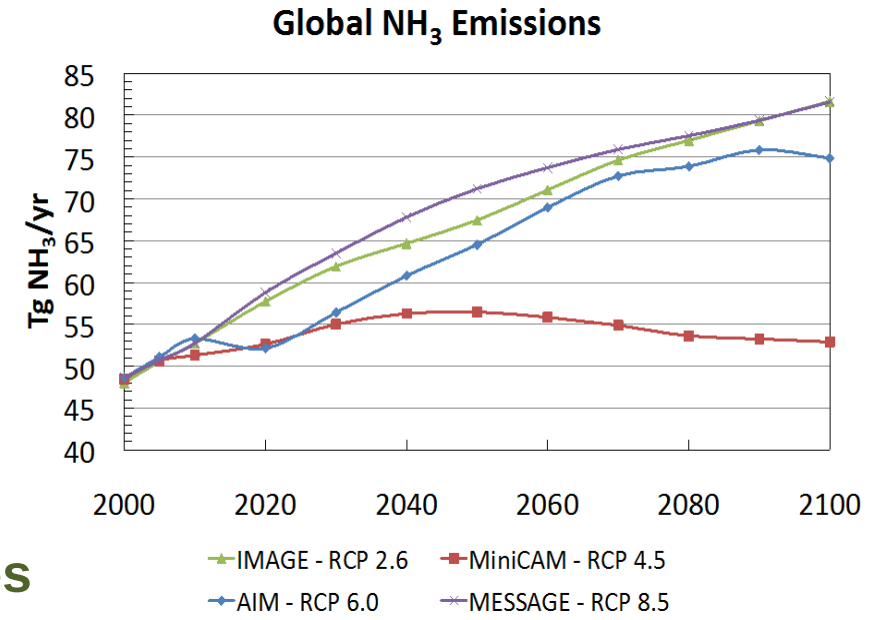
NH_3 is a $PM_{2.5}$ precursor and reactive N species

$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$

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

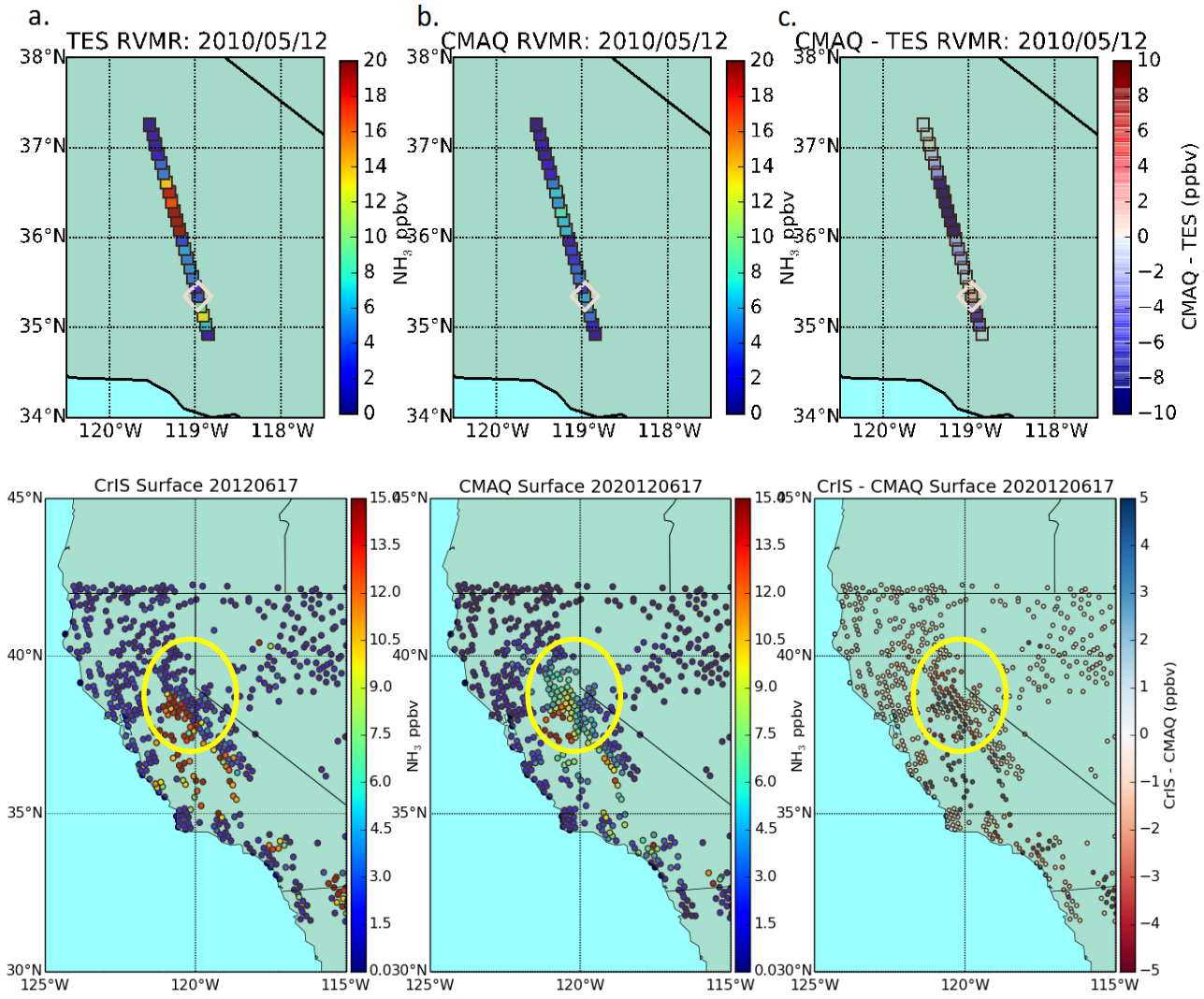
- **Increase incidence of cardiovascular and respiratory diseases**
- **Increase number of CCN**

- **NH_3 is also one of the most important reactive nitrogen species**
  - **Leads to soil acidification, water eutrophication (e.g. algal blooms)**
  - **Ammonia is the least well understood part of the nitrogen cycle**



SO_2, NO_X emissions decreasing due to controls, but NH_3 increasing!

Using Satellites to Investigate NH_3 Sources



- TES NH_3 transects over Bakersfield in CalNex suggested a x2 underestimate in afternoon due to diurnal cycle errors (Lonsdale et al., ACP, 2017)
- 2012 CrIS NH_3 is consistent with CalNex TES results.
- Some evidence of a transport error on June 17 – flow along slope not correct?

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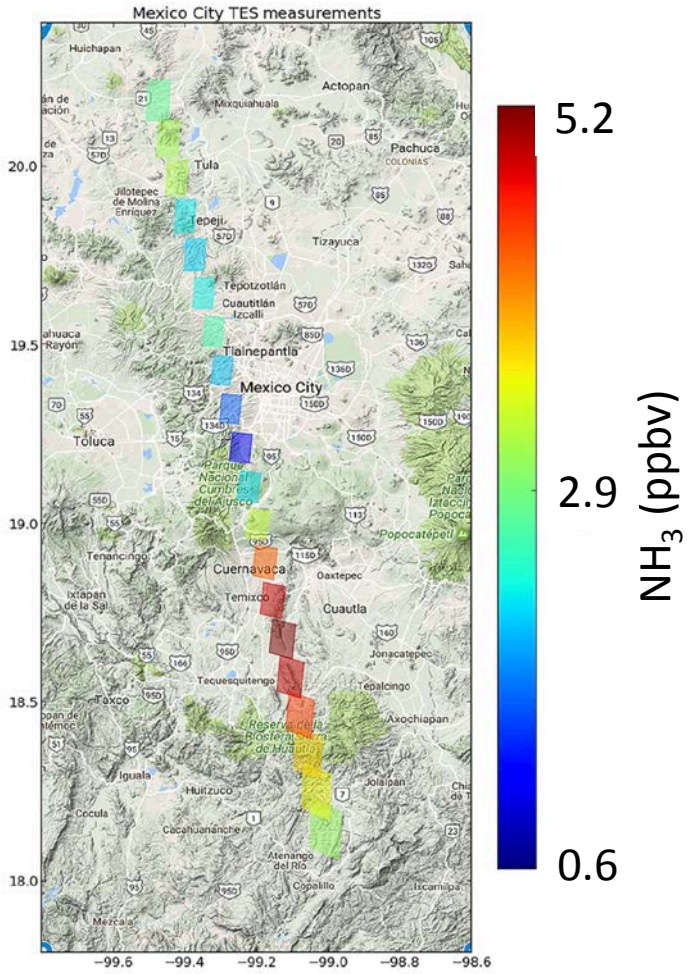
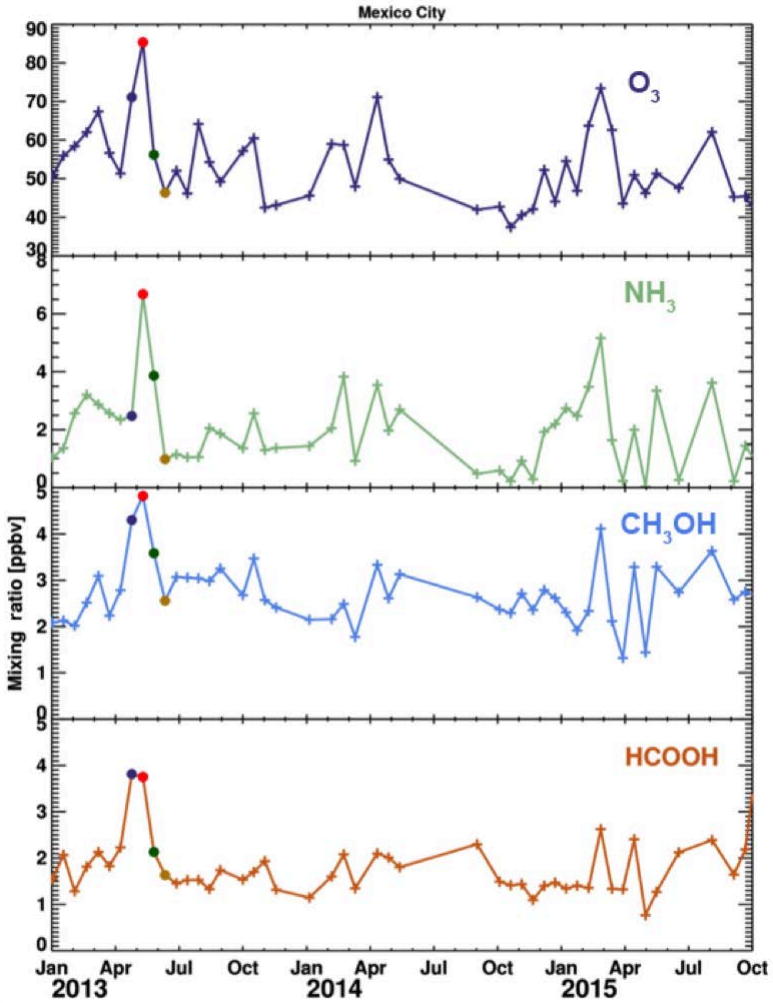
TES Long-term Megacity Records of NH_3

Mexico City Observations (Cady-Pereira, AMT, 2017)

Mar-May Mean





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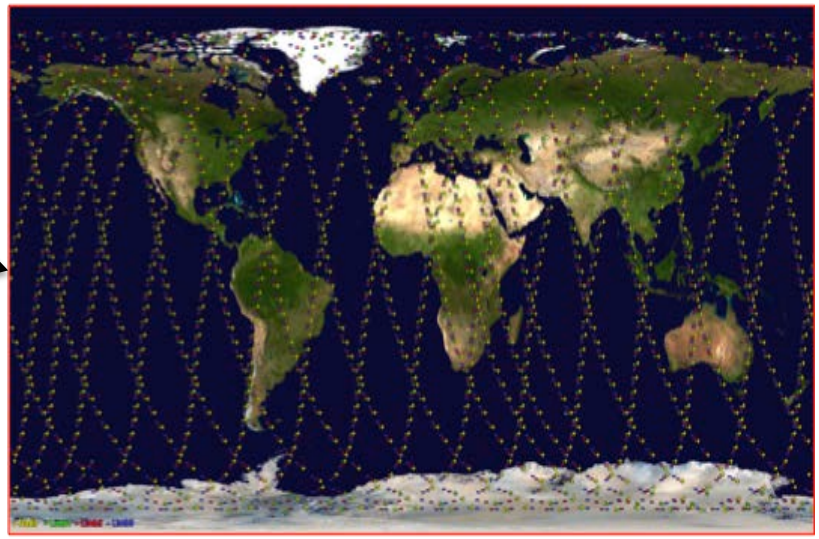
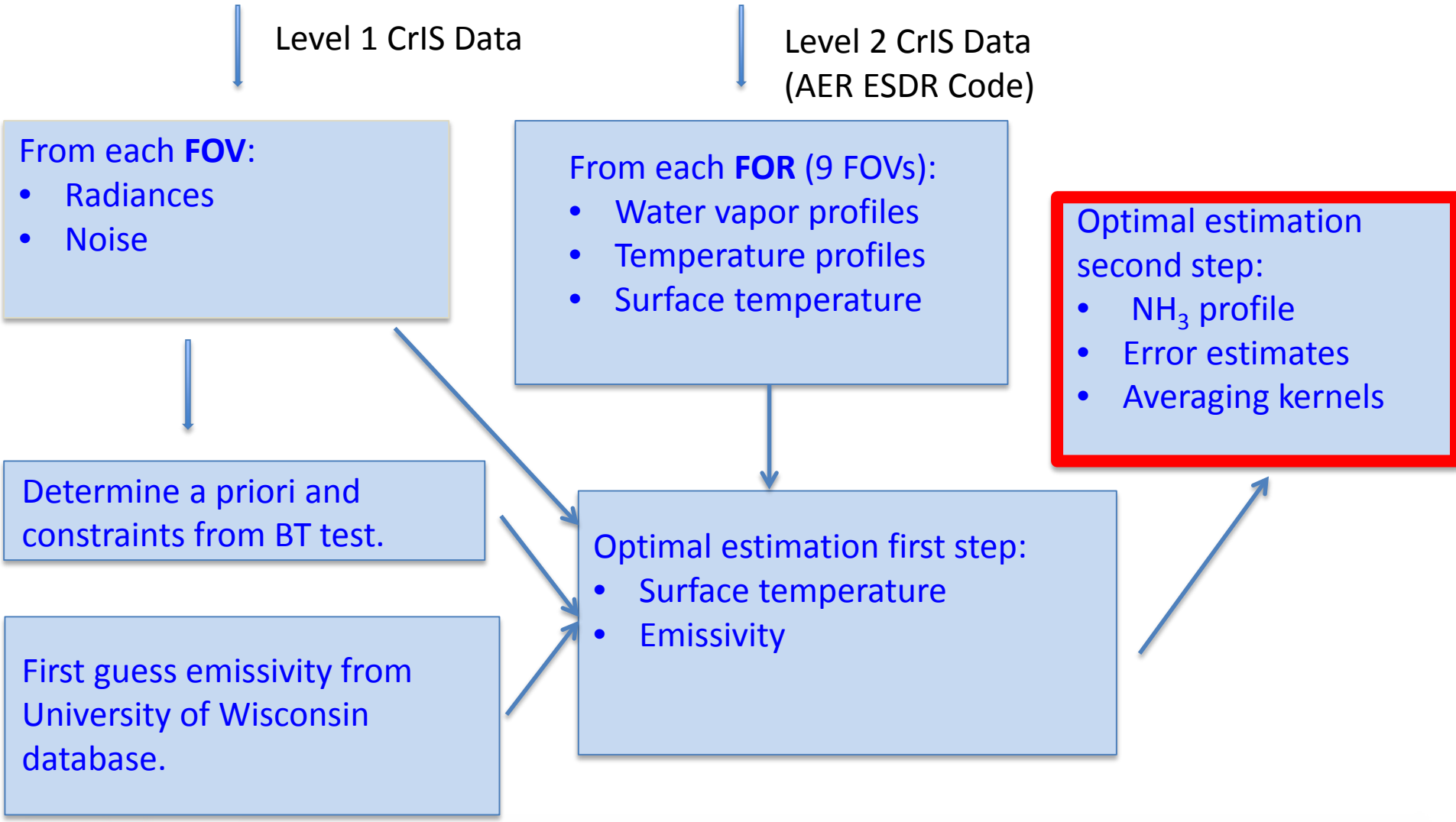
Why switch to CrIS?

- TES is past its design lifetime and has low spatial coverage
- **CrIS could monitor global NH_3 with high spatial coverage for many more years (>2022)**

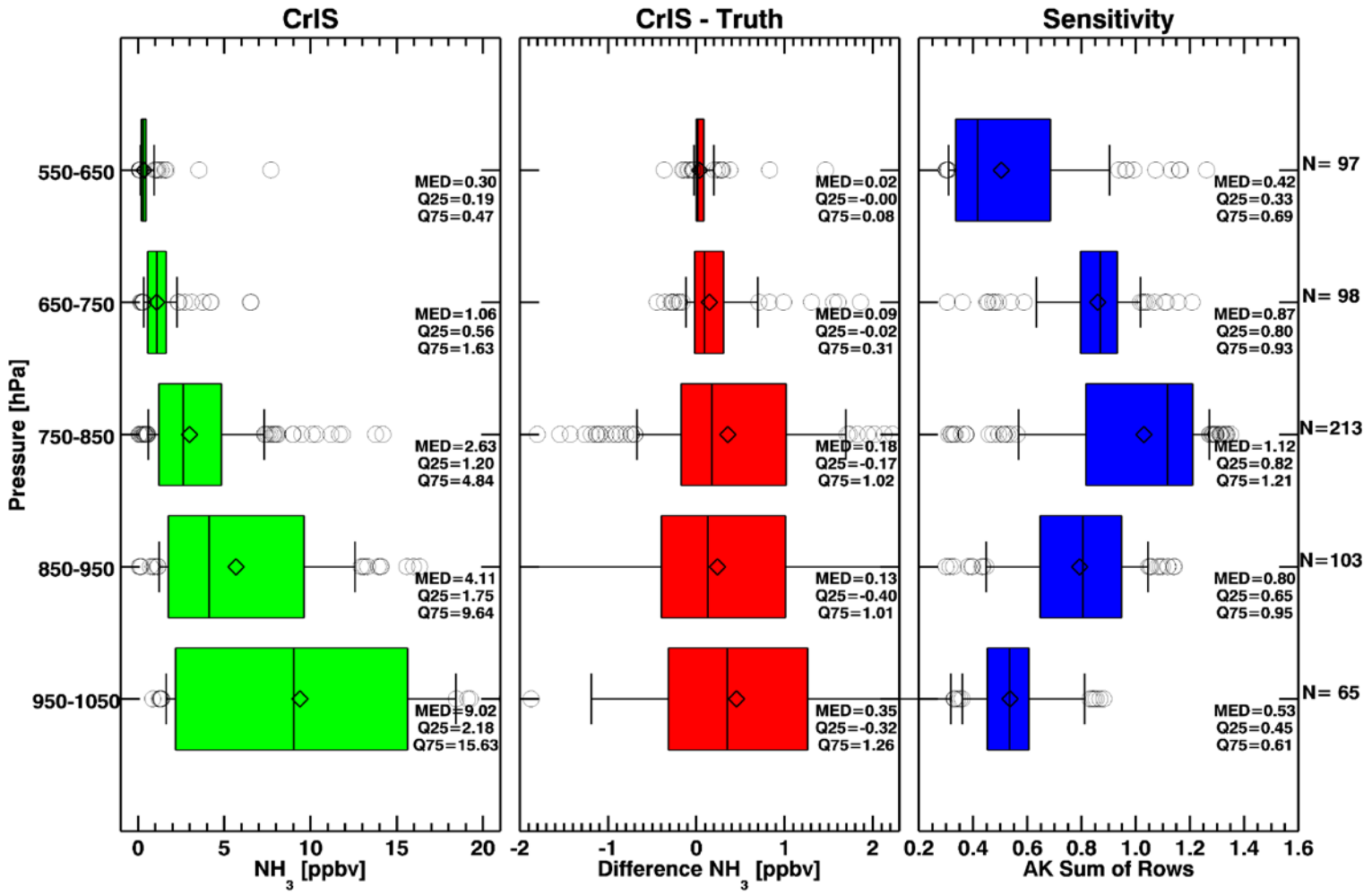


	TES	CrIS
Satellite	AURA	NPP
Available Data	July 2004-present	October 2011-present
Resolution	0.06 cm^{-1}	0.625 cm^{-1}
Footprint	5x8 km rectangle	14 km diameter circle
Repeat cycle	Once every 16 days	Daily
Equatorial crossing	1:30 am and 1:30 pm	1:30 am and 1:30 pm
Noise in NH_3 window	0.09 – 0.12 K	0.03 – 0.06 K

NH_3 Algorithm structure



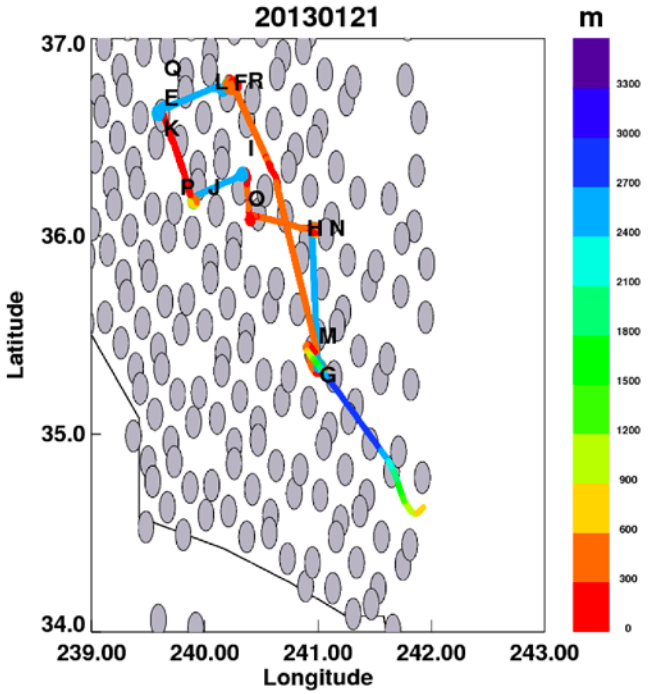
CrIS NH_3 Retrieval: Simulated Spectra

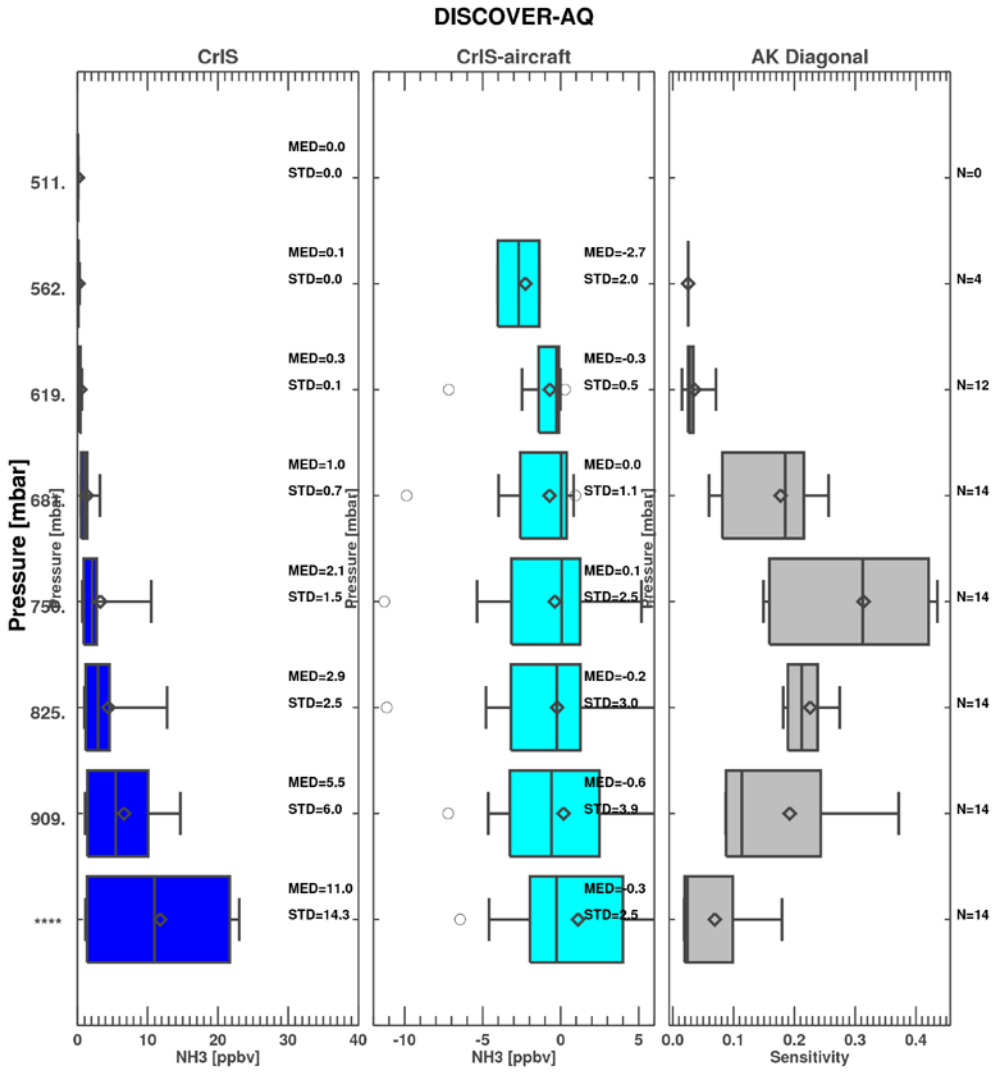


Shephard and Cady-Pereira, AMT, 2015

How CrIS compares with spirals

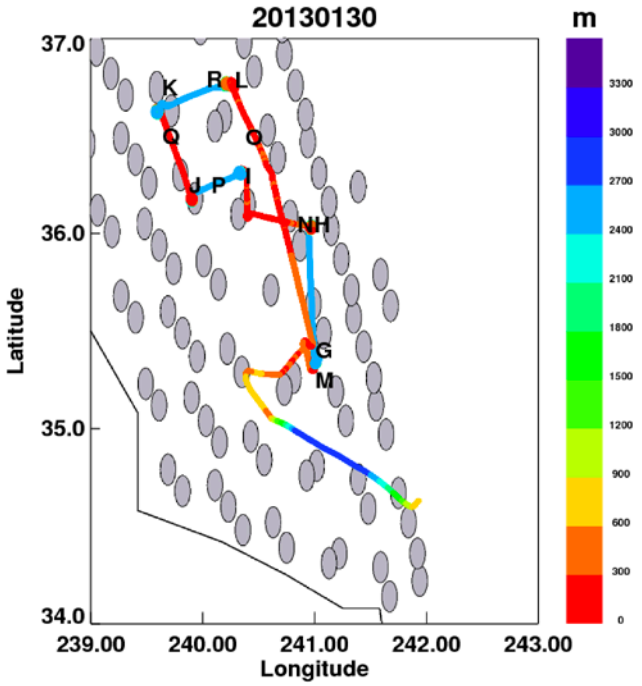
- January 21, 2013
- Matched each spiral to closest CrIS observation
- 14 spirals were compared
- Used log AK in CrIS operator
- Mismatch between CrIS surface pressure and aircraft surface pressure: shifted aircraft profiles up.

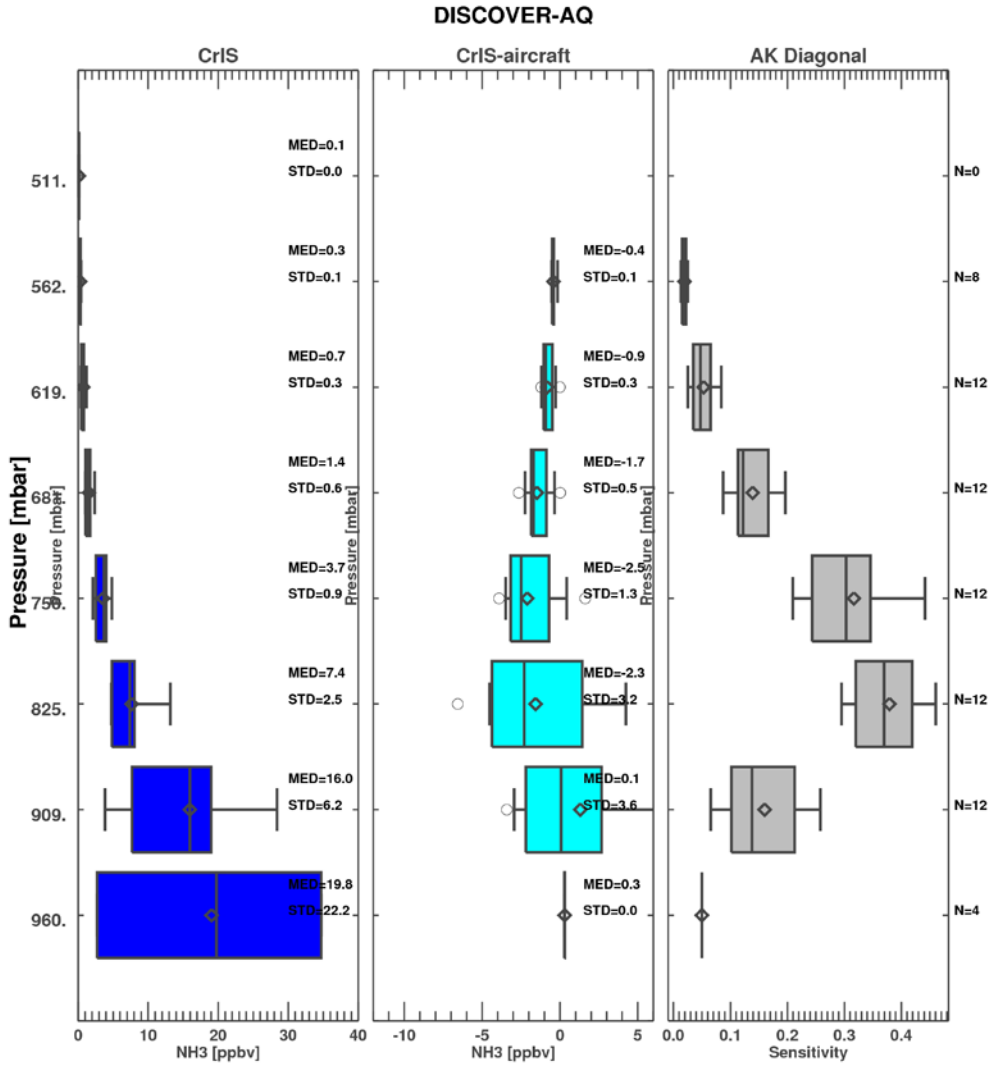




How CrIS compares with spirals

- Same as previous slide for January 30
- Rapidly growing PBL





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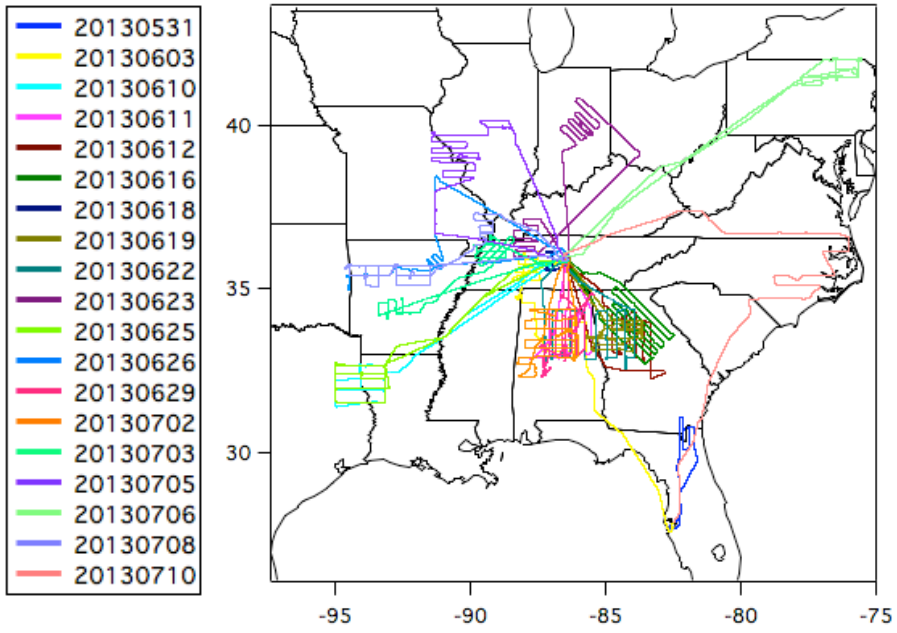
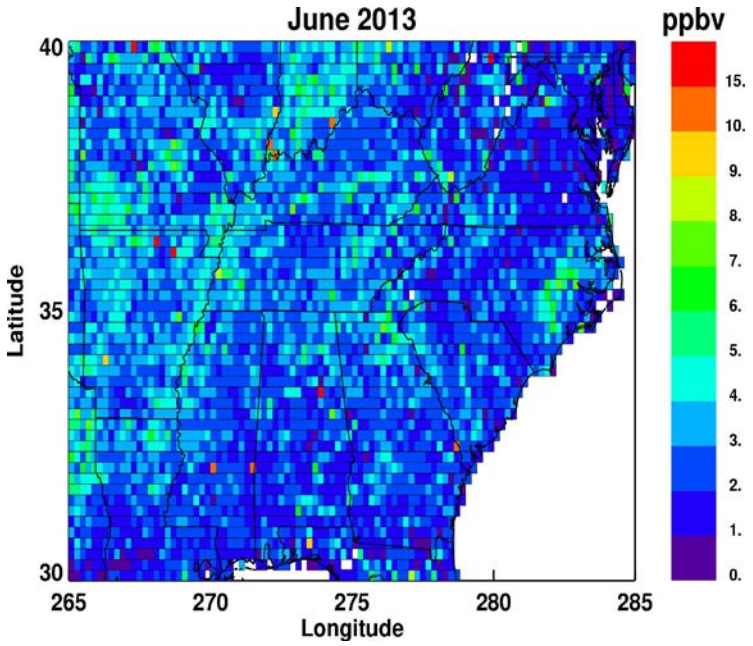
NOAA SENEX Campaign (June-July 2013)

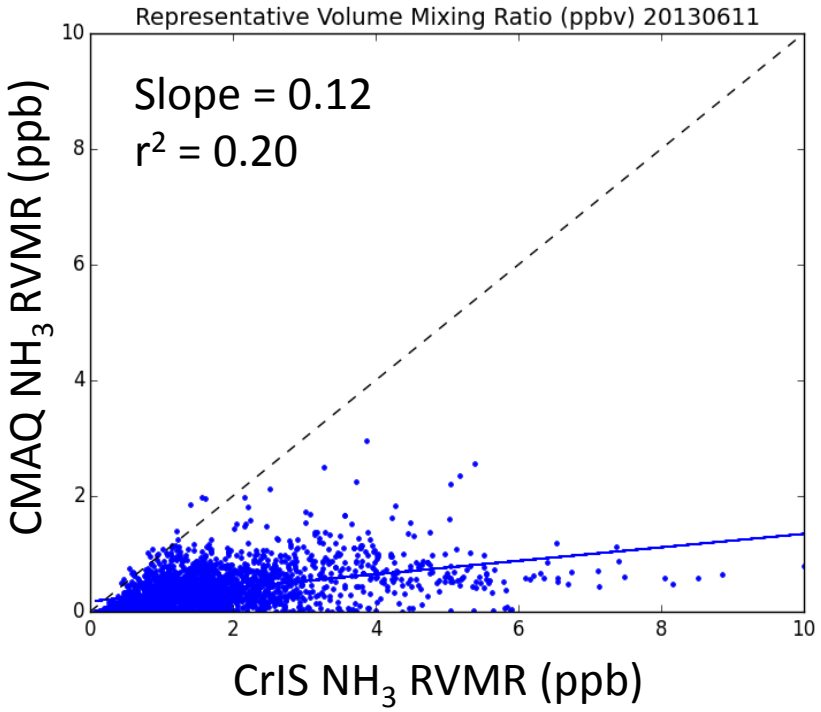
NOAA P-3 Aircraft

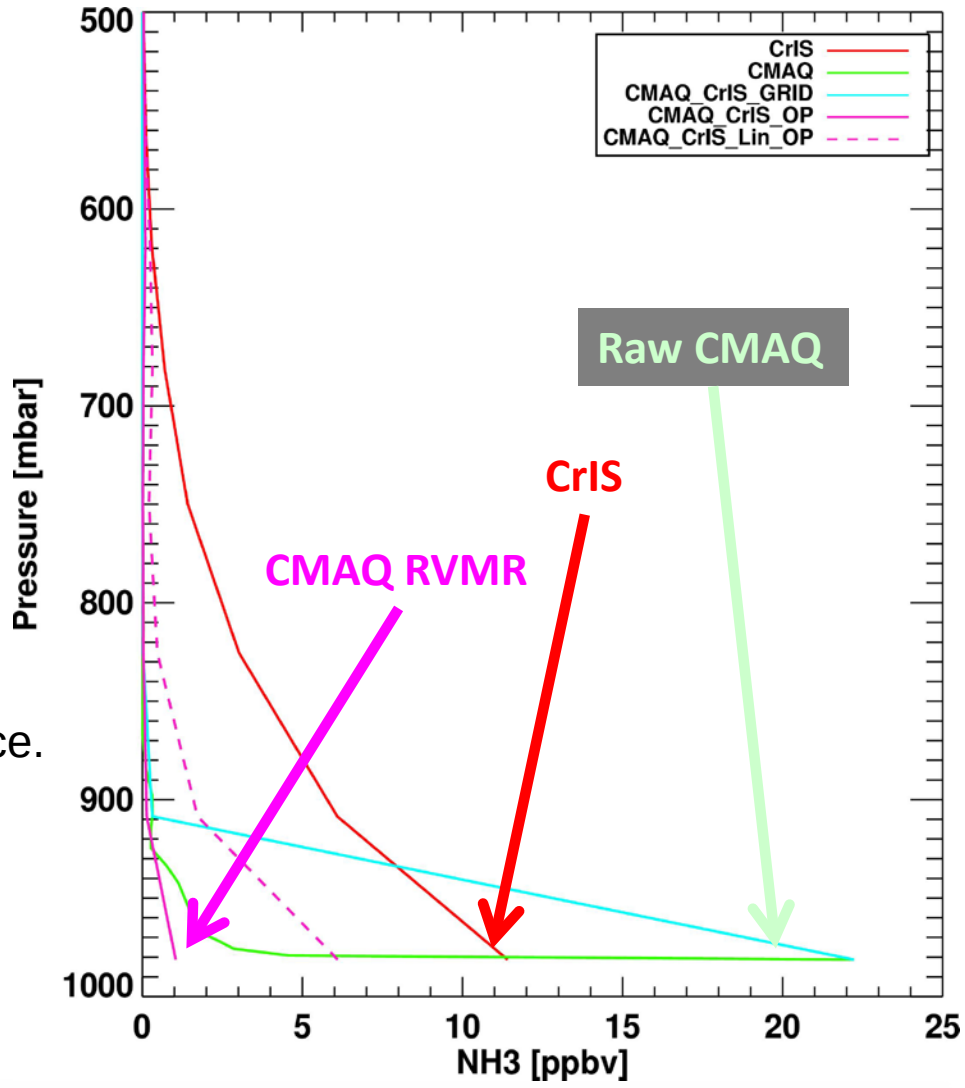


CrIS NH_3



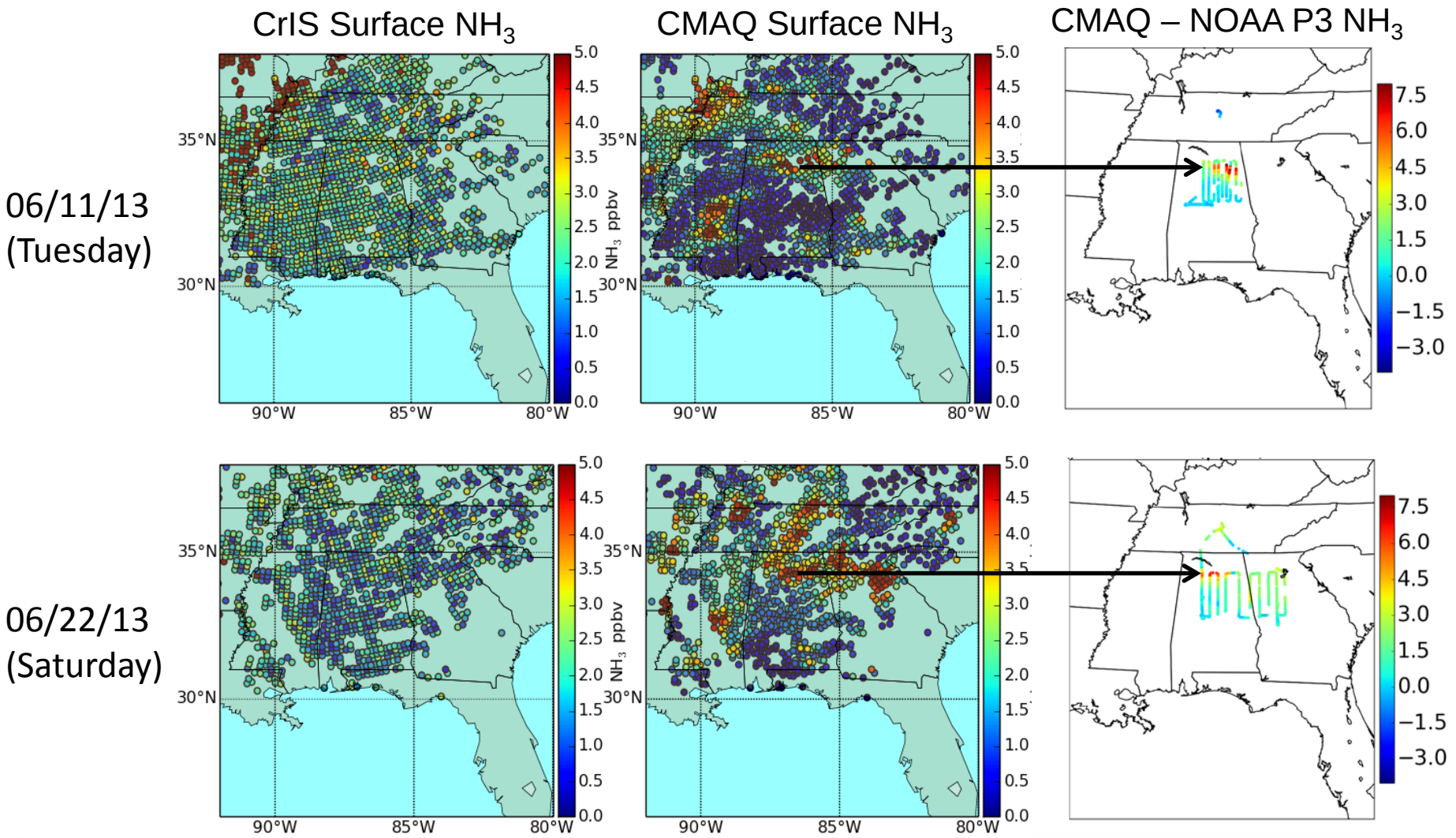
Difficulties Using NH_3 RVMR with CMAQ



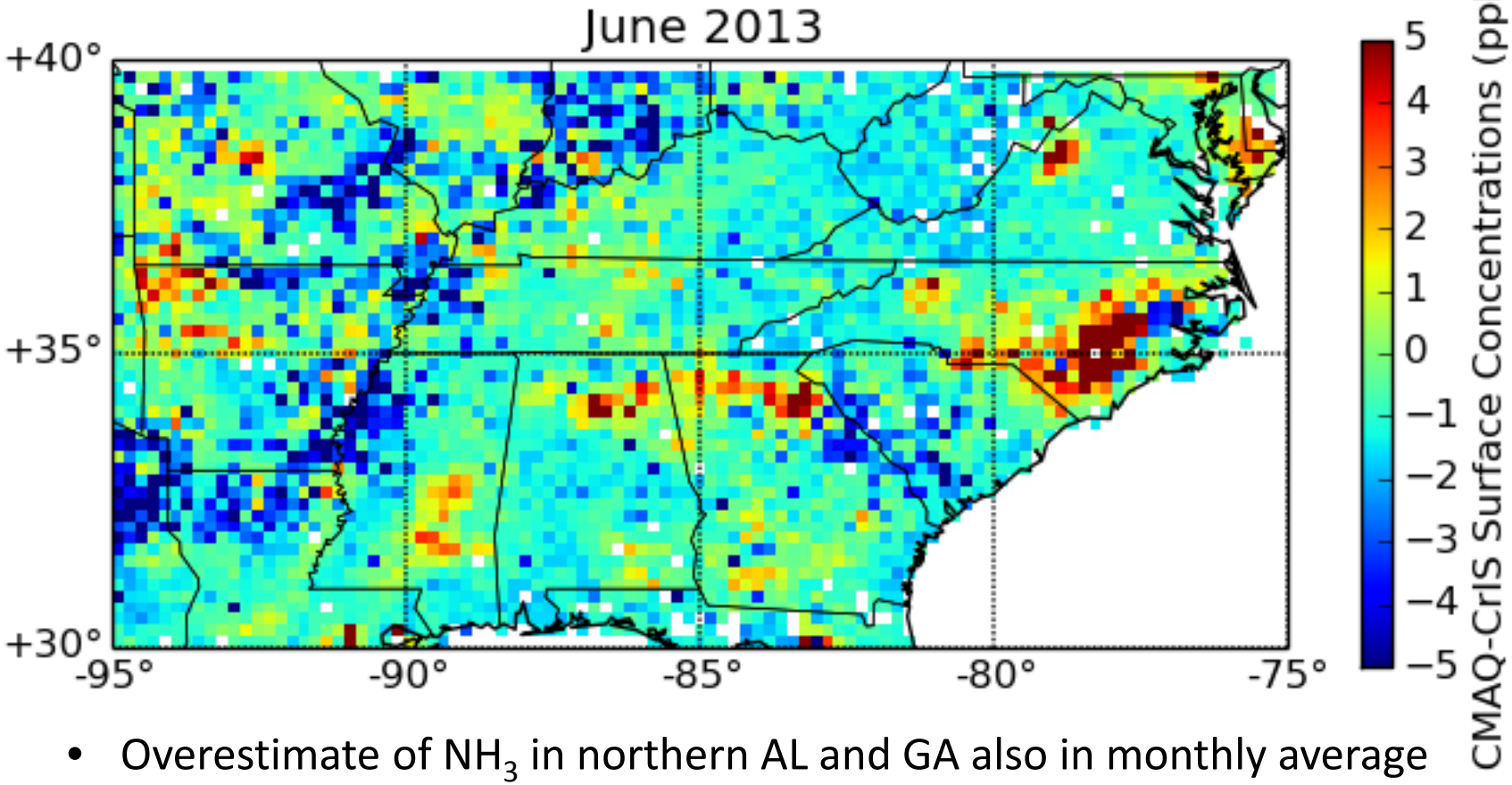


- CMAQ NH_3 profiles concentrated at surface.
- CrIS sensitivity is at higher altitudes than TES
- Using RVMR (Shephard et al., 2011) thus leads to spuriously low CMAQ values
- Instead focus on NH_3 surface gradients

Feed lot NH_3 emissions overestimated in AL

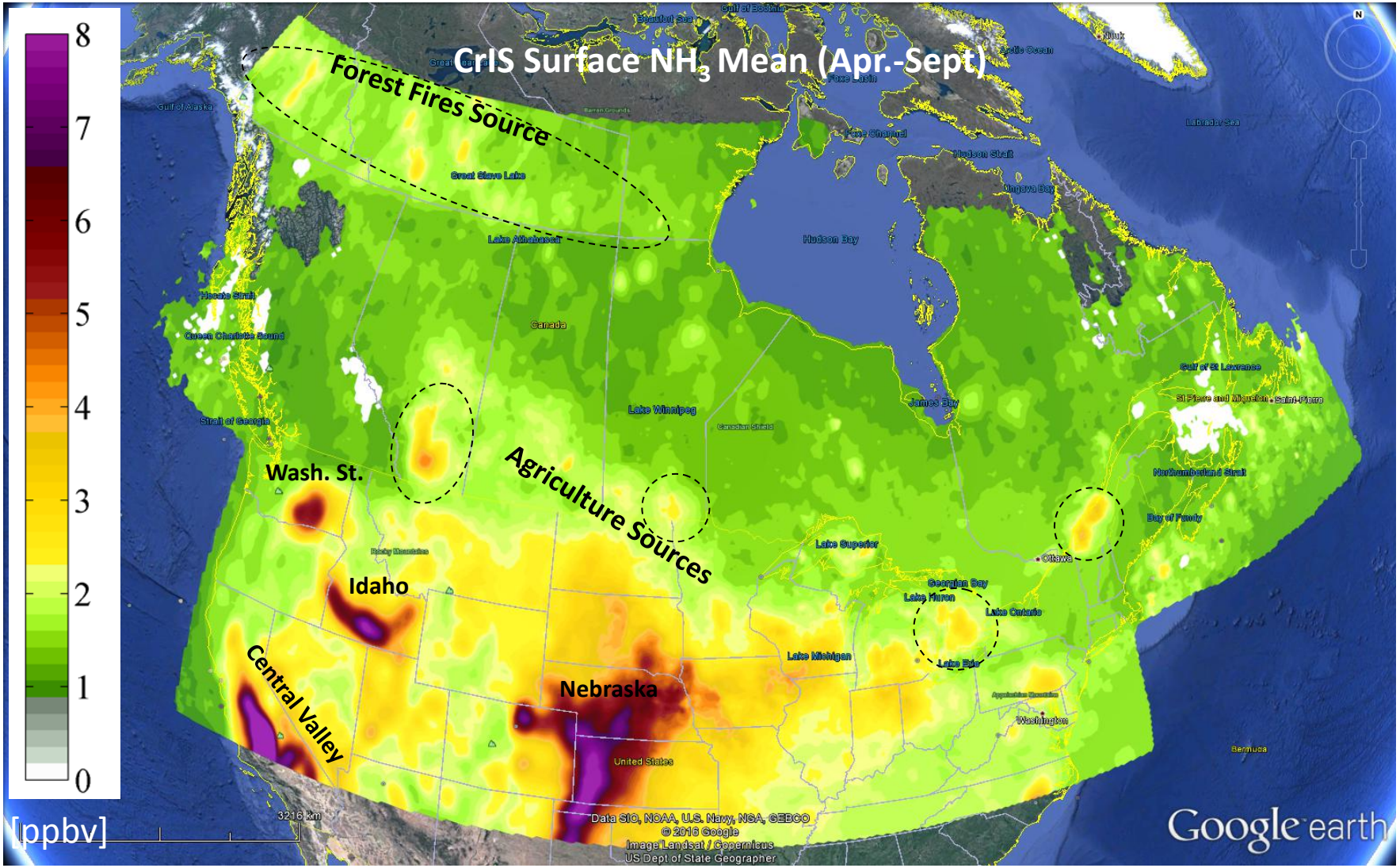


CrIS shows other errors in monthly-average NH_3 from CMAQ



- Overestimate of NH_3 in northern AL and GA also in monthly average
- Similar overestimates in NC, MI, VA
- Underestimate along Mississippi River?

CrIS NH_3: N. America Warm Season Average 2013



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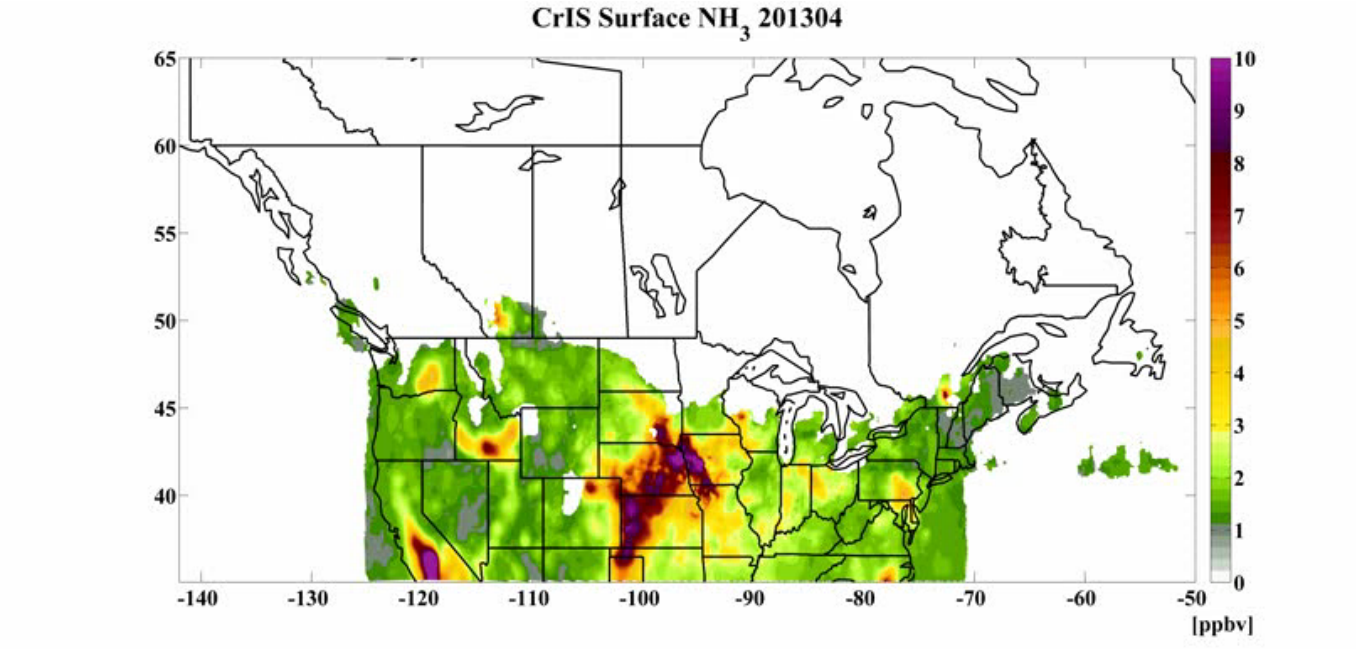
CrIS NH_3: North America Monthly Averages April to October, 2013



Captures expected temporal and spatial distributions of ammonia

- Spring fertilizer applications (May over Canada)
- Episodic events (e.g. Northern forest fires in middle of summer)

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CrIS NH_3: Example of Daily Spatial Variability of Surface NH_3 over North America on August 10 2013

MODIS

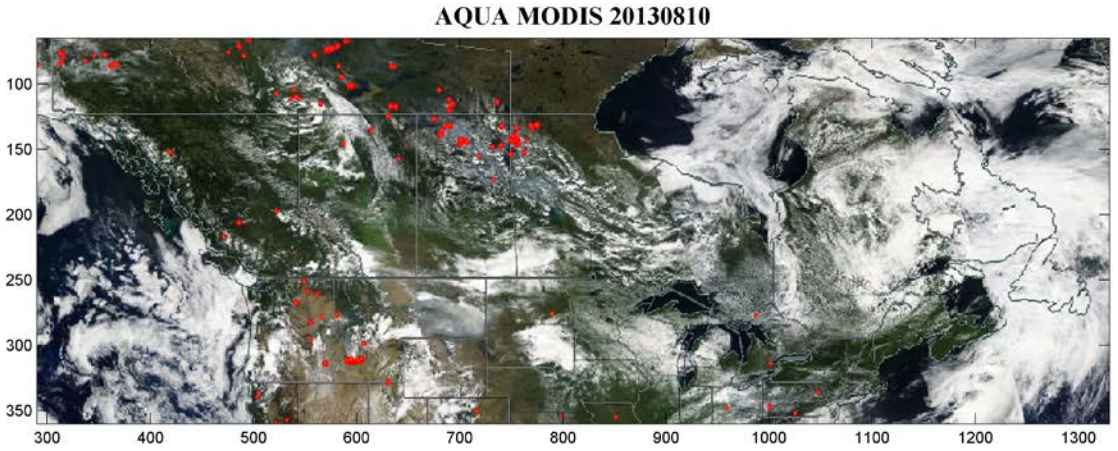
Infrared:

Fire Detection (red)

Visible:

Cloud (White)

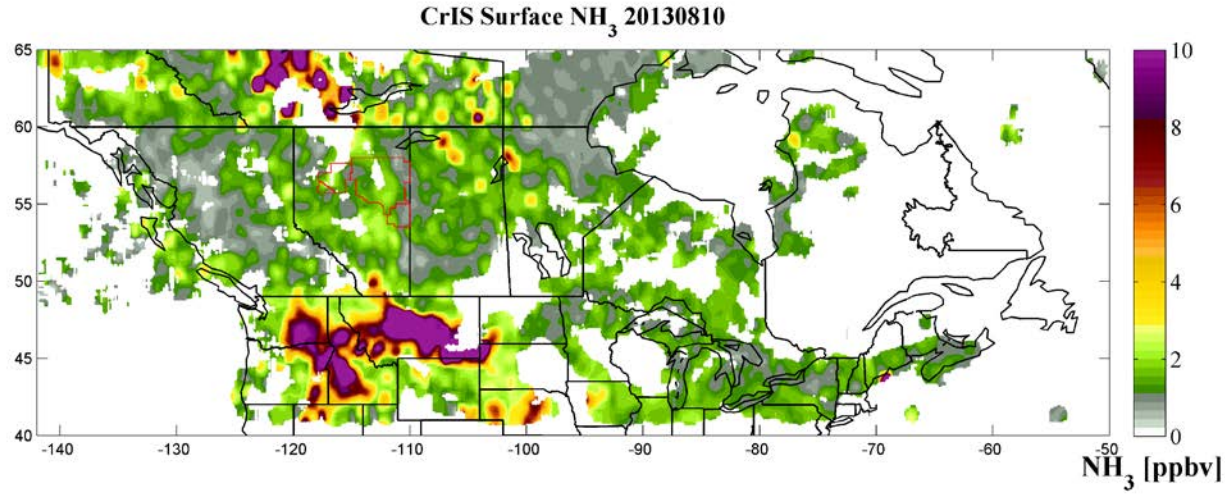
Smoke (blue/gray)



CrIS

Infrared:

NH_3



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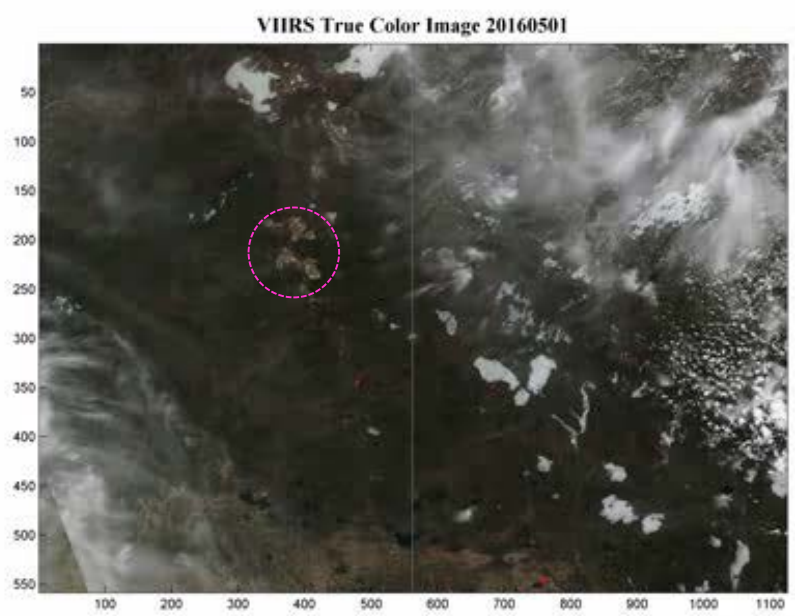
CrIS NH_3: Fort McMurray forest fires Daily values in May 2016

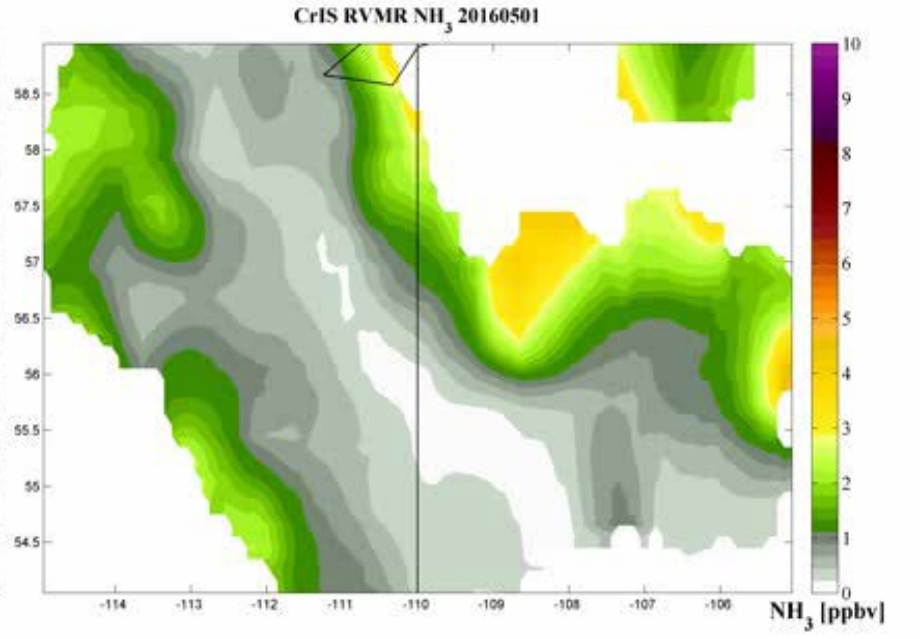
VIIRS

Infrared: Fire Detection (red)
Visible : Cloud (White), Smoke (blue/gray)

CrIS

Infrared: Ammonia (NH_3)



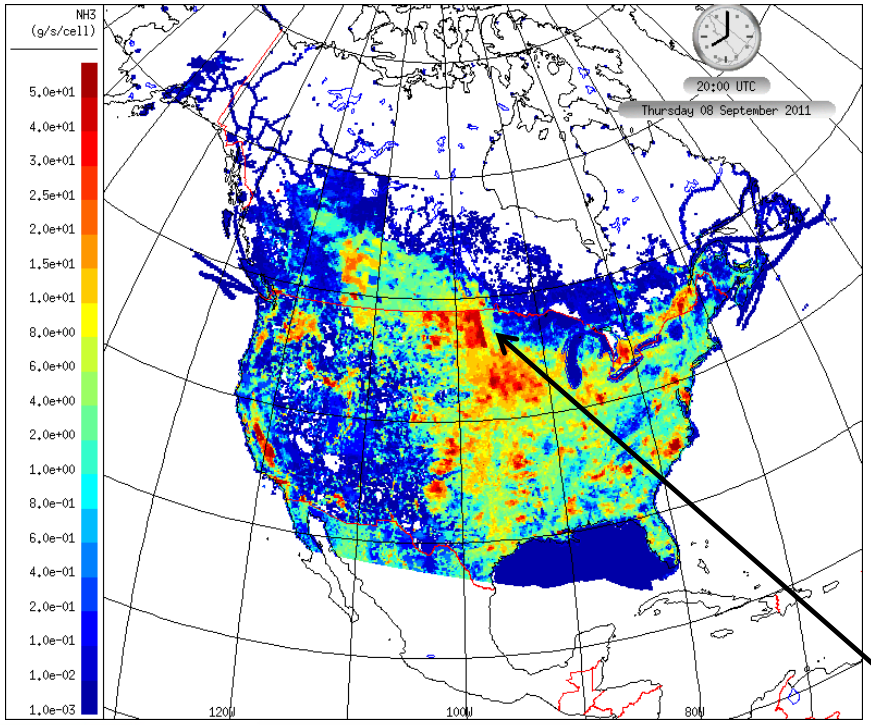


Click image to view Movie

Model Evaluation: GEM-MACH Spatiotemporal Emissions

GEM-MACH Emissions

- 15-km emissions from annual/monthly inventory using monthly/weekly/diurnal activity-based temporal profiles
- 20:00UTC hourly snapshot corresponding to satellite overpass
- No forest fire emission included

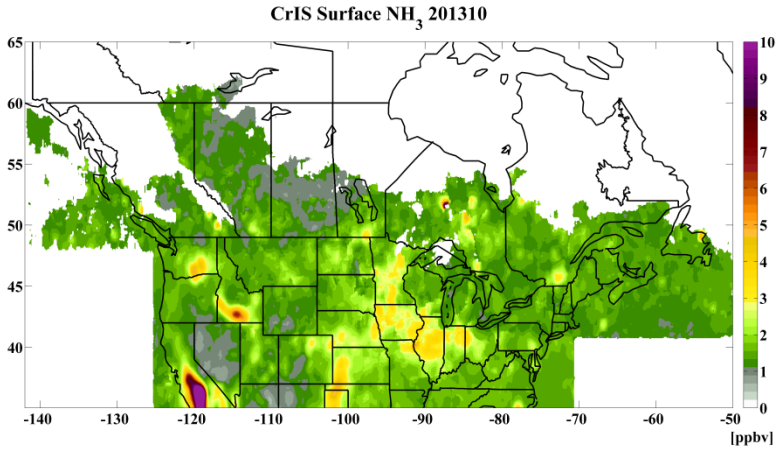


Model emission improvement study led by Junhua Zhang

CrIS Surface Concentrations

- Monthly Mean
- Satellite overpass (~1:30 local time)
- Includes contributions from forest fire

Sept 2013



Spatial and temporal distributions are generally consistent

- **some regions need improvement**
  - North Dakota (spring/fall)
- **use satellite to improve model spatial and temporal emissions**

Summary

- CrIS is able to retrieve NH_3 with similar skill to TES, but much higher spatial coverage.
- CrIS NH_3 retrievals compared well with spirals made during DISCOVER-AQ in California.
- CrIS and NOAA P-3 observations show NH_3 emissions from feed lots in northern Alabama are lower than in the 2011 NEI.
- CrIS is able to measure seasonal and spatial patterns of NH_3 from fertilizer applications and fires over US and Canada.
- Ongoing work is being done to use this data to improve NH_3 emission inventories for models.

Acknowledgements

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