Inverse Modeling of Ammonia Emissions

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Collaborators

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Ming Luo, Kevin Bowman, TES team

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NASA JPL: SCC

Importance of studying NH_3 emissions

PM2.5

- Itself leads to NH_4^+, 10-20% of $PM_{2.5}$ mass concentration
- Governs formation of NO_3^-, which can be 20-30% in winter

PM2.5 NAAQS Regulations

- Not a presumptively regulated species, but can be very efficient (Pinder et al., 2007; Henze et al., 2008)
- Can be regulated in place of SO_2 or NO_2

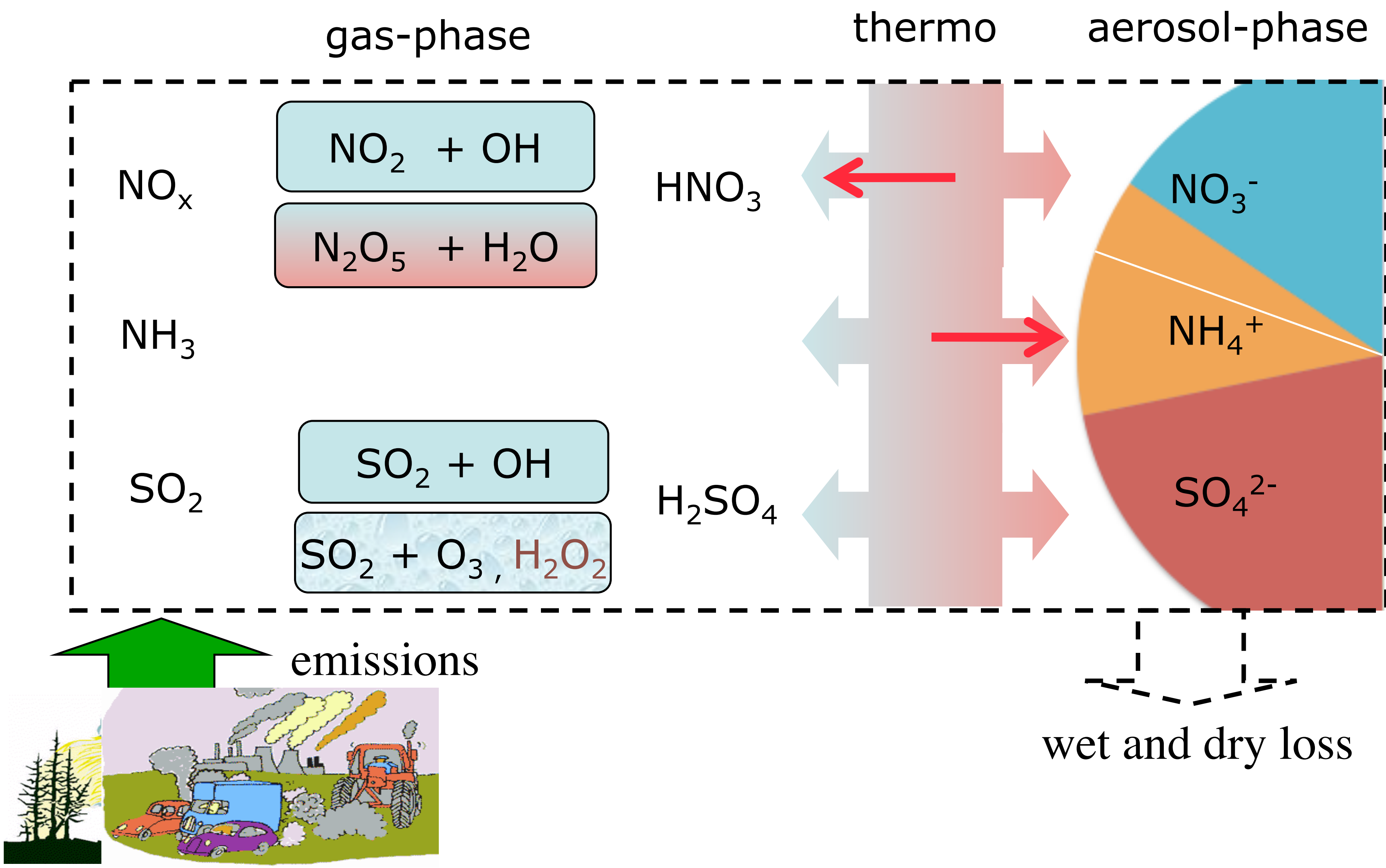
Ecosystem impacts

- 11% of worlds natural vegitation impacted by N dep (Dentener et al., 2006)
- N dep will increase 10-40% near NH_3 sources in U.S. by 2020 (Pinder et al., 2008)

Very large source of uncertainty

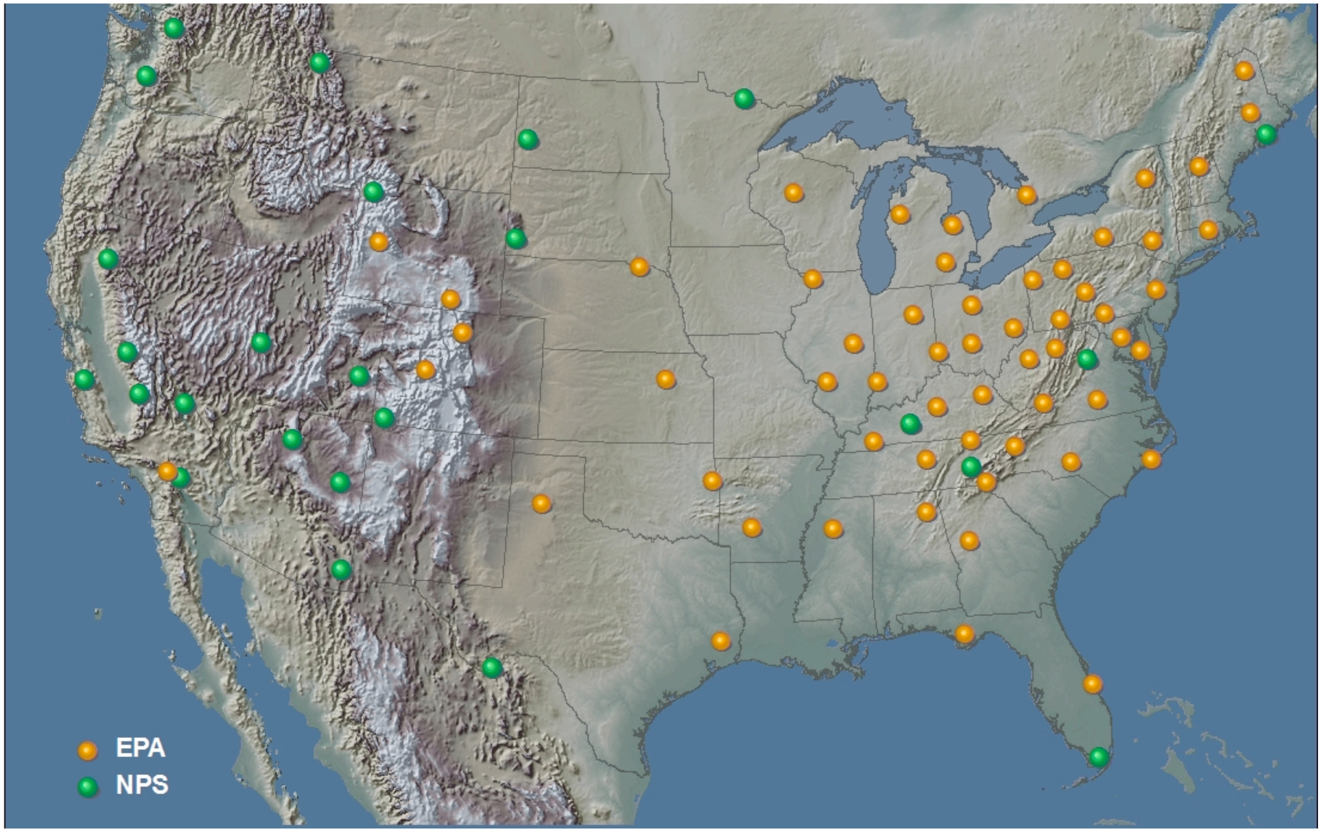
- estimating U.S. inorganic $PM_{2.5}$ levels (Yu et al., 2005; Simon et al., 2008)
- global N dep. (Sutton et al., 2007)

Secondary inorganic aerosol formation



NH_4^+ monitoring

CASTNet

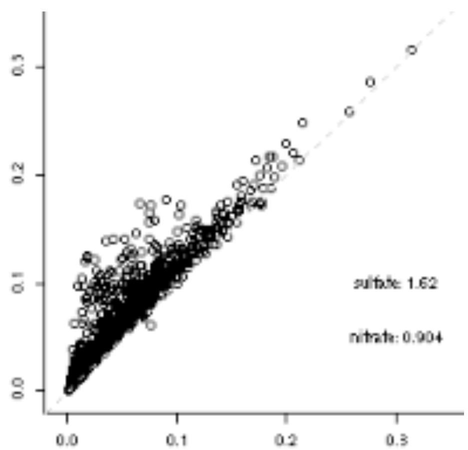


STN: another 200 sites

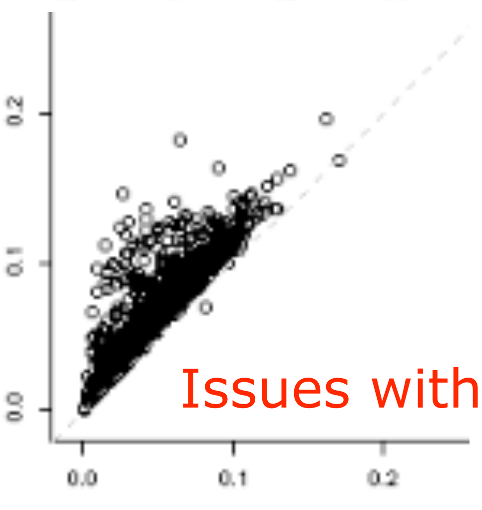
Checking ion balance:
$n(NH_4^+) : 2n(SO_4^{2-}) + n(NO_3^-)$

CASTNet, all sites,
2005-2006 (R. Pinder)

January



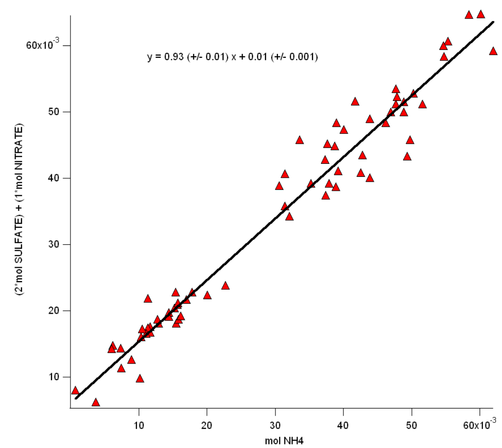
April



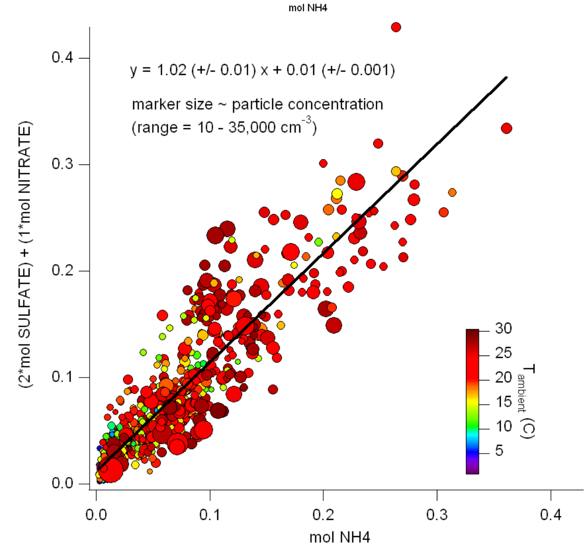
Issues with evaporation

Field campaigns
(Sorooshian et al.)

SJ Valley



Houston



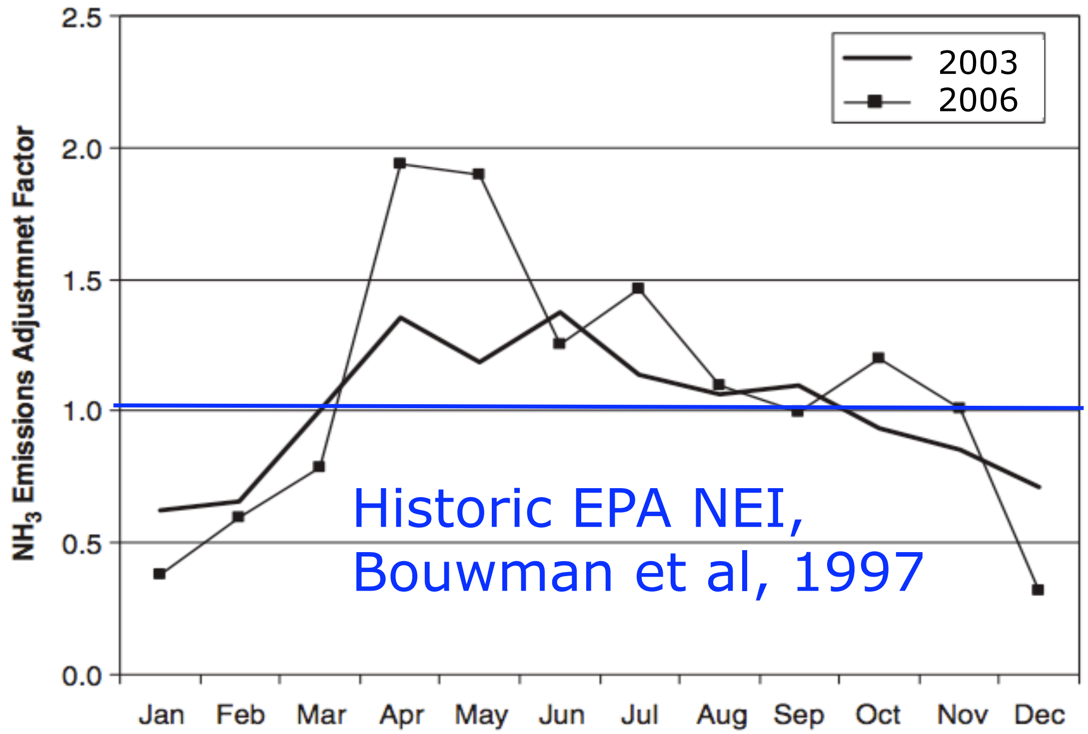
NH_3 inverse modeling: Gilliland et al.

Observations: wet NH_x = aerosol NH_4^+ + gas NH_3

Method: Kalman filter (BF) to adjust monthly nation-wide scale factors

Results:

Gilliland et al., 2003;
Gilliland et al., 2006



NH_3 emissions variability and uncertainty: Beusen et al. (2008)

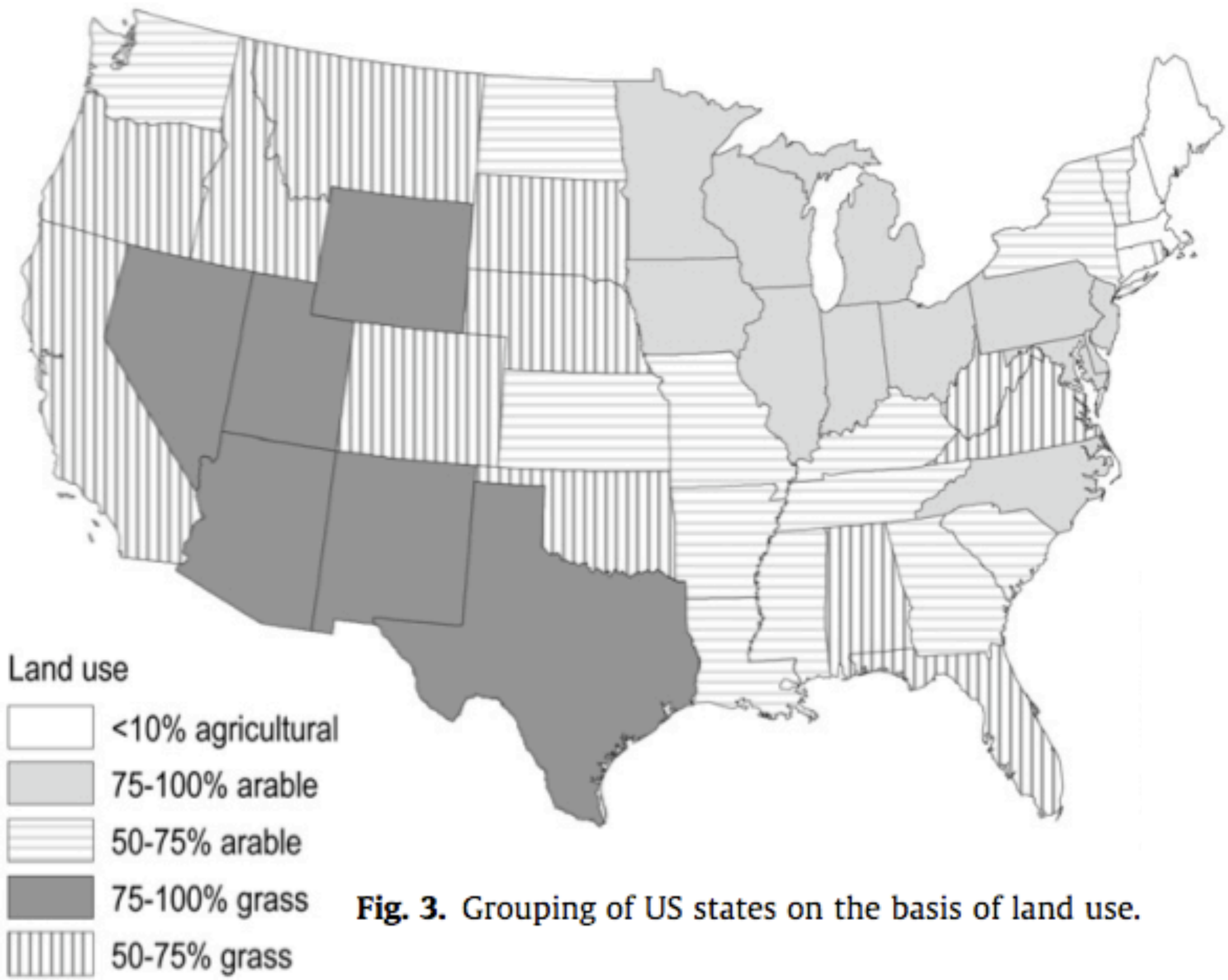
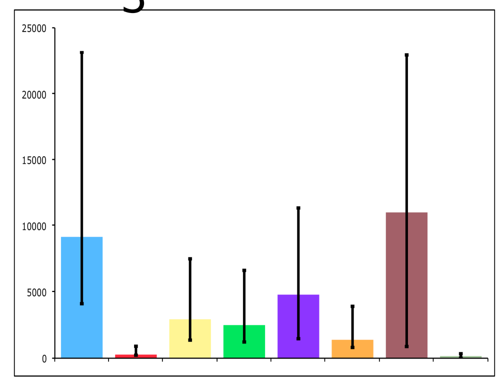


Fig. 3. Grouping of US states on the basis of land use.

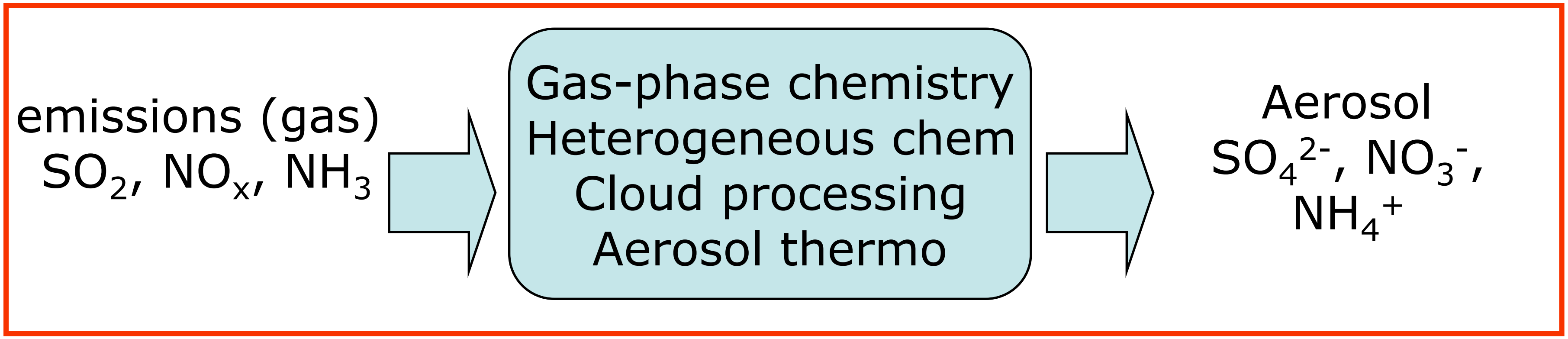
Global animal NH_3 emissions



Source types
- housing mixed
- housing pastoral
- grazing mixed
- grazing pastoral
- spreading cropland
- spreading grassland
- fertilizer cropland
- fertilizer grassland

4D-Var with GEOS-Chem Adjoint Model

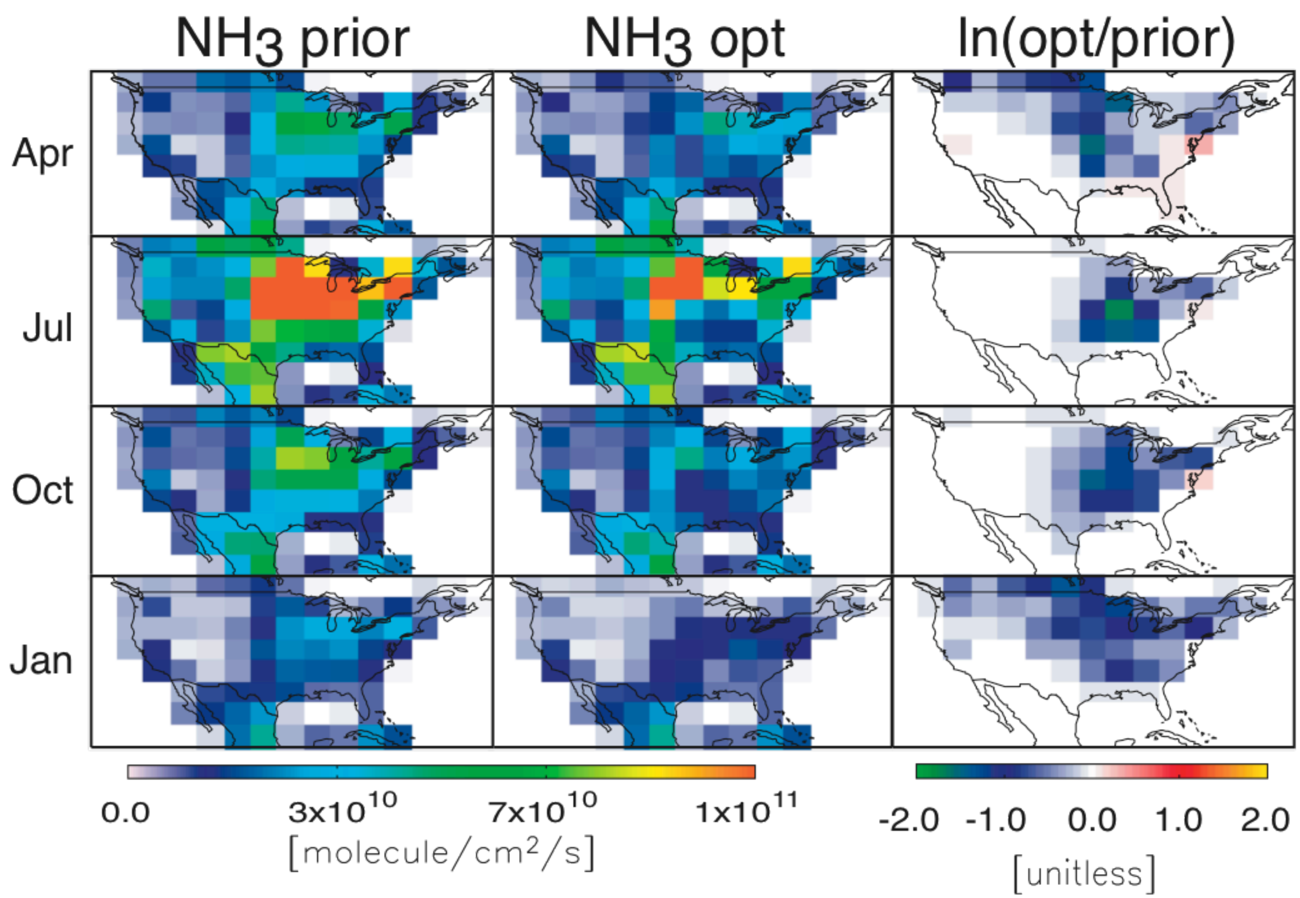
Forward model v6-02-05 (*Bey et al.*, 2001; *Park et al.*, 2004)



All included in adjoint (Henze et al., 2007; Singh et al., 2009)

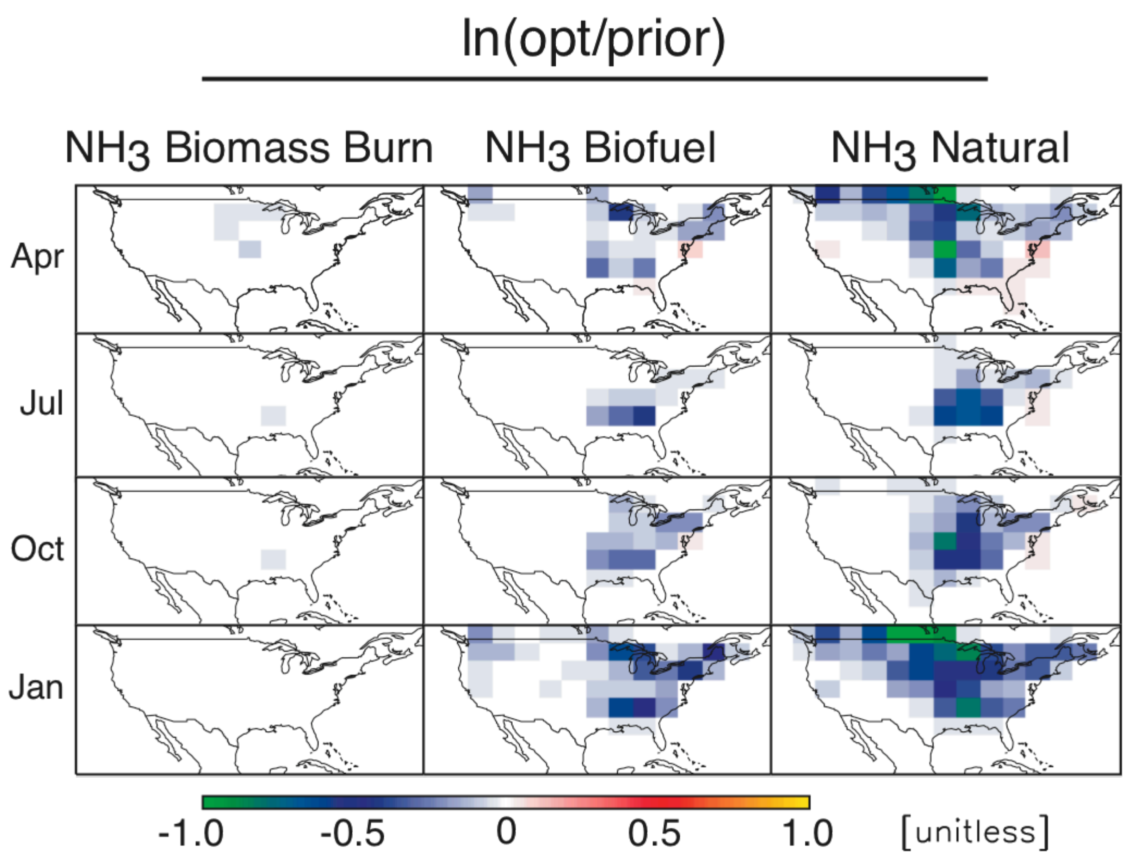
Inverse modeling (Henze et al., 2008)
- Control parameters: all NH_3, SO_2, NO_x emissions
- Sulfate and nitrate from IMRPOVE network (24h, 1in3)
- Jan, April, July, October: 4 separate inversions

Inverse modeling: anthro NH_3 emissions



- scaling is spatially variable
- scaling generally reductions
- some increases
- Each month treated separately
- reduction in RMSE ≈ 40%

Inverse modeling: other NH_3 emissions



- scaling results from product of adjoints with prior emissions estimates
- reductions affect anthropogenic sources more than natural sources
- results across sectors are correlated

Can effectively distinguish between source sectors

Inverse modeling: assessing the solution

Dependence on inverse modeling assumptions:
- error covariance matrices
- regularization

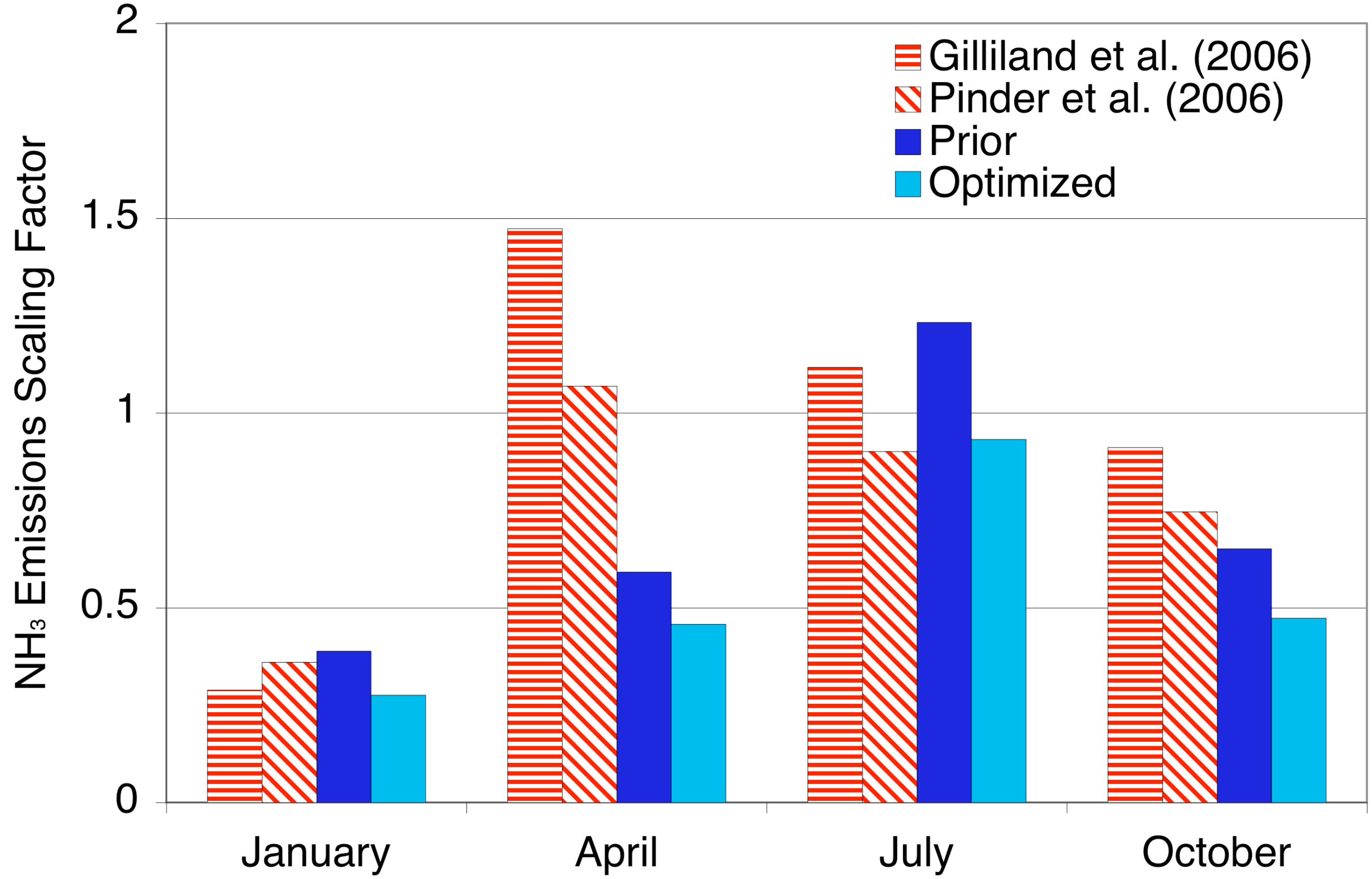
Estimated uncertainty of solution
- approximate inverse hessian
- std error and correlations

Compare to other studies
- inverse modeling
- bottom up inventories

Compare to NH_3 observations

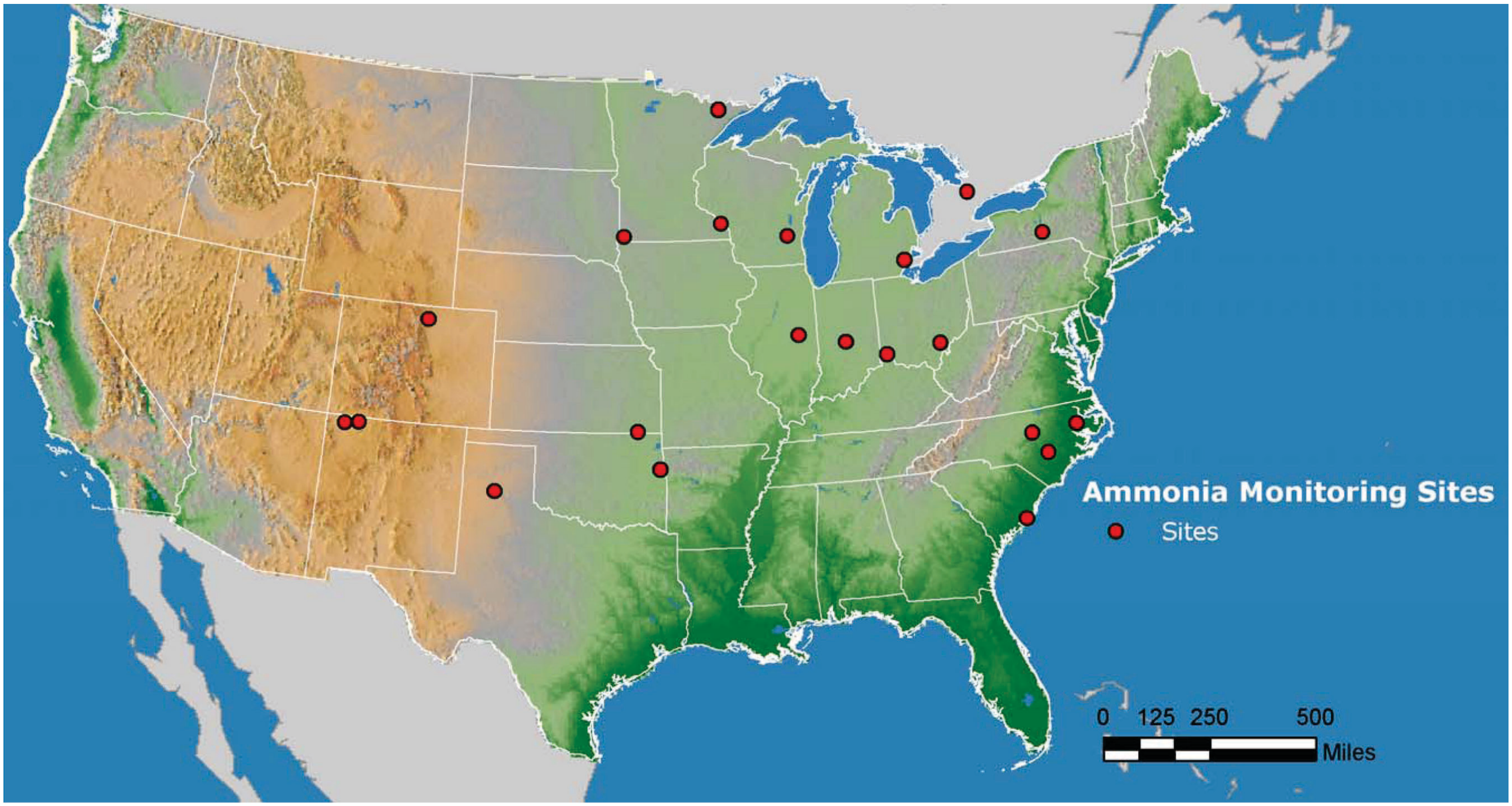
Inverse modeling: NH_3

Sum changes to NH_3 over U.S., compare to other inverse modeling (Gilliland et al., 2006) and bottom up (Pinder et al., 2006)



Seasonal peak in April or July?

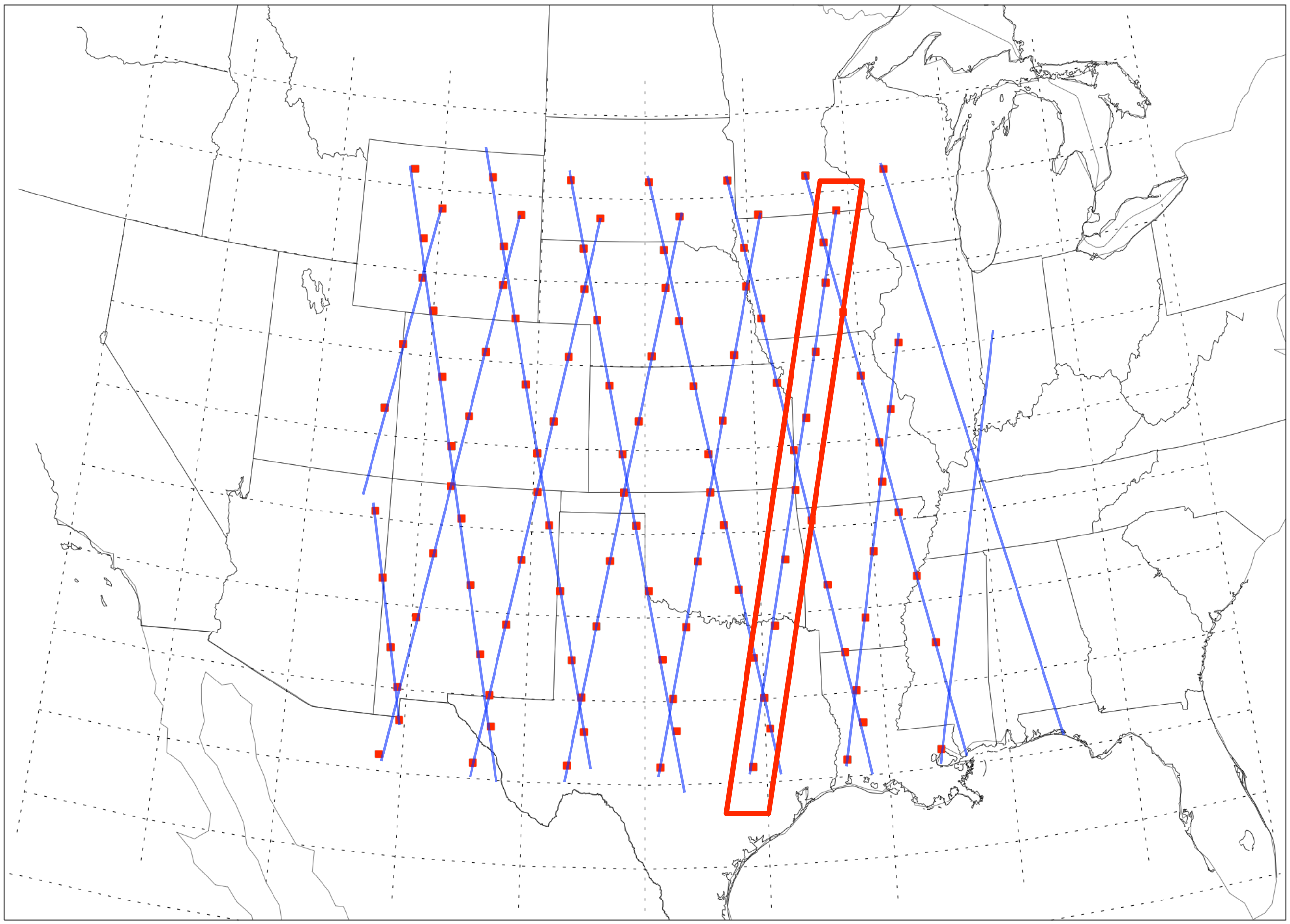
NH_3 Monitoring Sites



CAMD sites at CASTNet locations

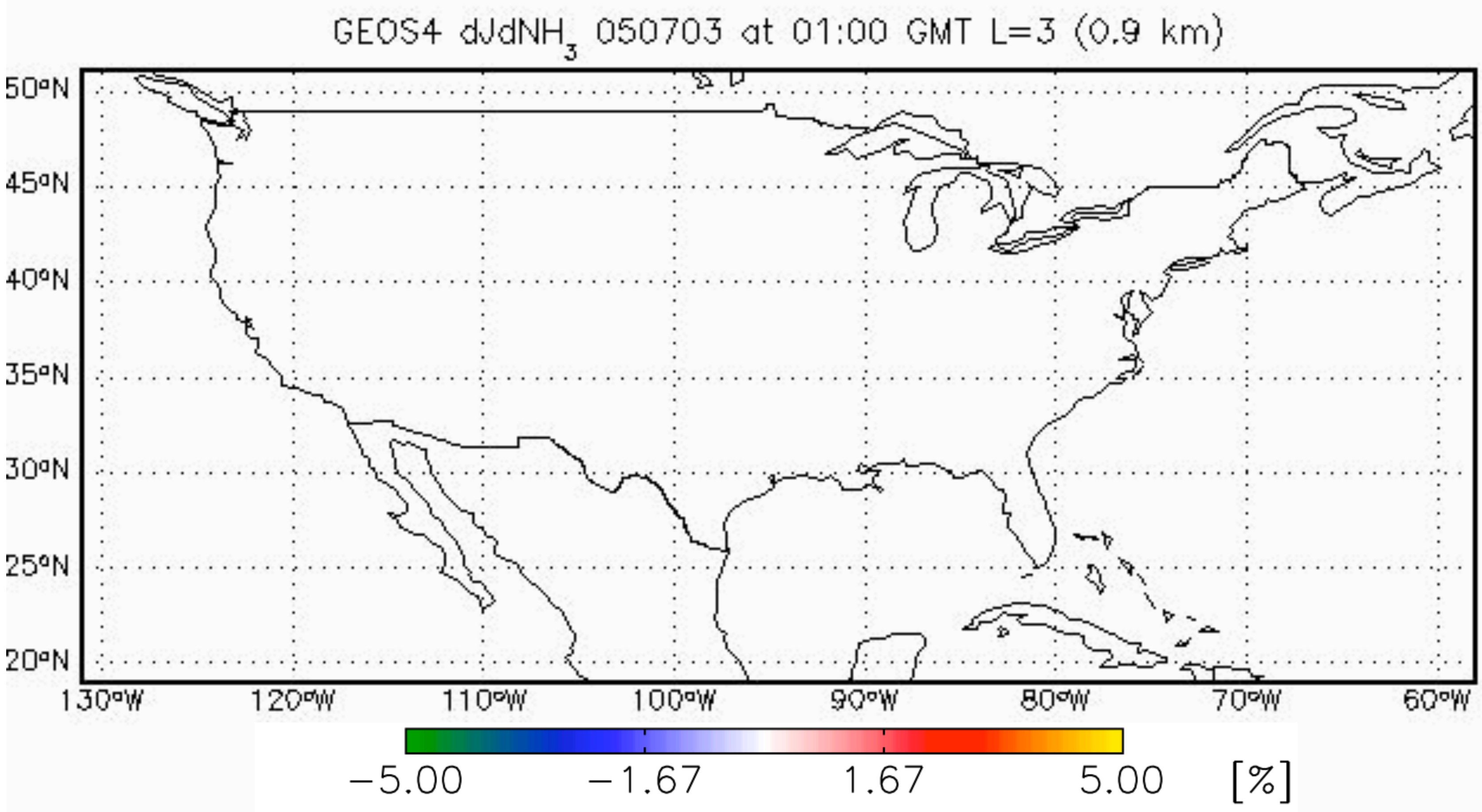
Potential for further constraints:
TES coverage for 2 weeks in July 2005

TES GS Footprints, July 4-19, 2005



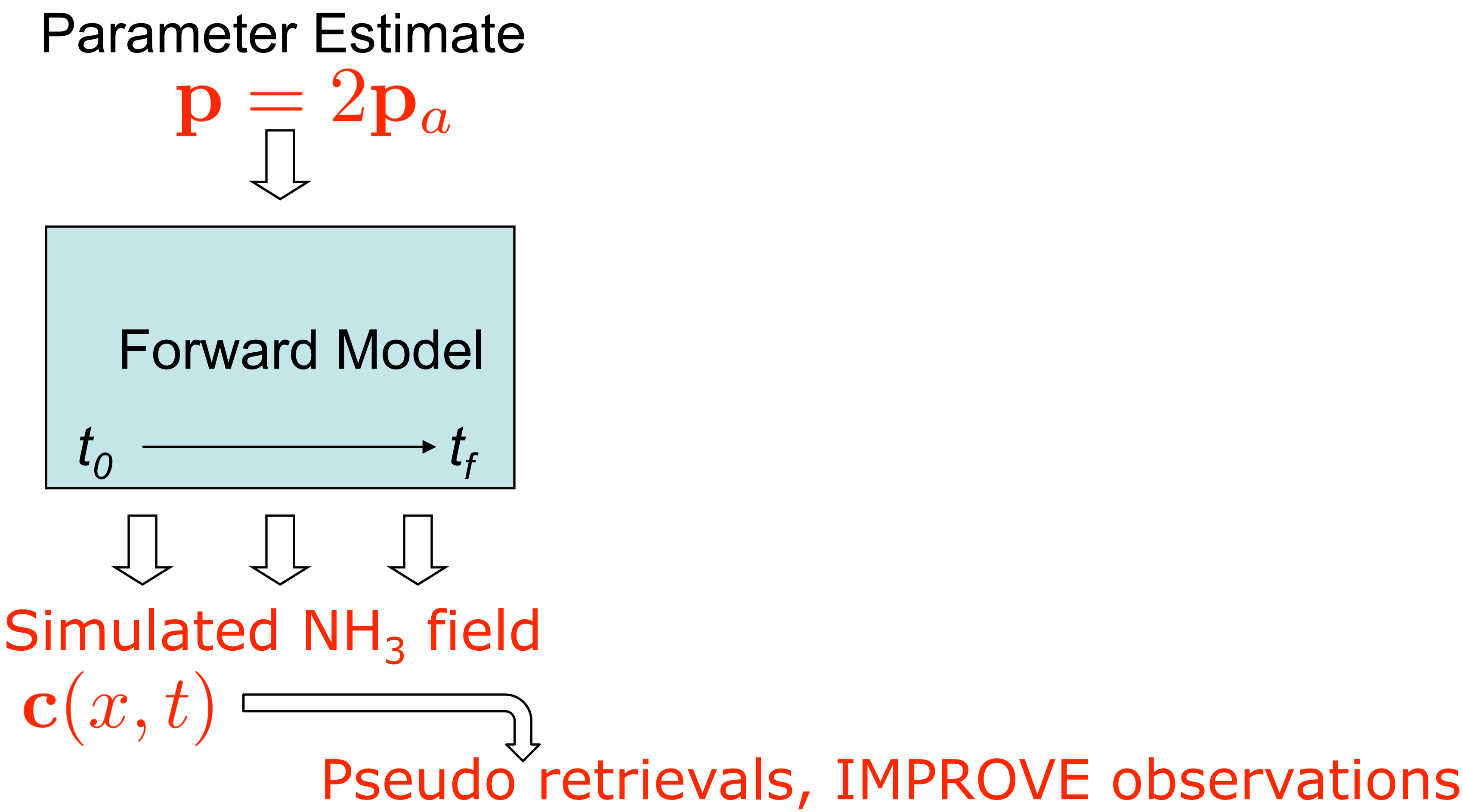
data selection: lat = [30.,45.], lon = [-110, -90.]; total number of profiles: 115

Adjoint sensitivities of modeled NH_3 retrievals



Sensitivities show the origins of the NH_3 that eventually will be "observed" by TES

Inverse Modeling: twin experiment



Inverse Modeling using Adjoint Model