Information Content of Lower-Tropospheric Methane Retrievals From AIRS and GOSAT data

Authors

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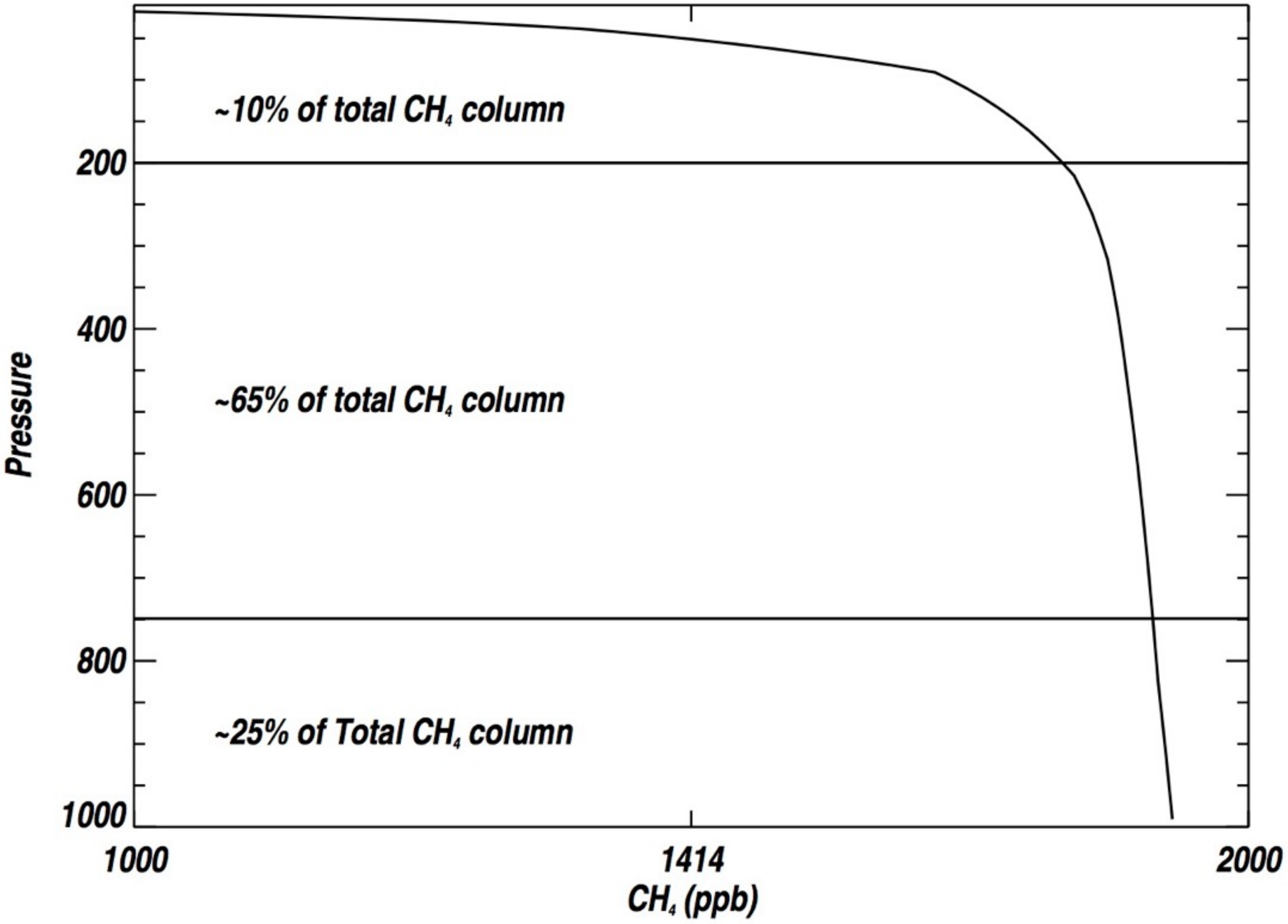
Sensitivity of Atmospheric Methane to Surface Sources

Methane profile at ~55 N in July 2006



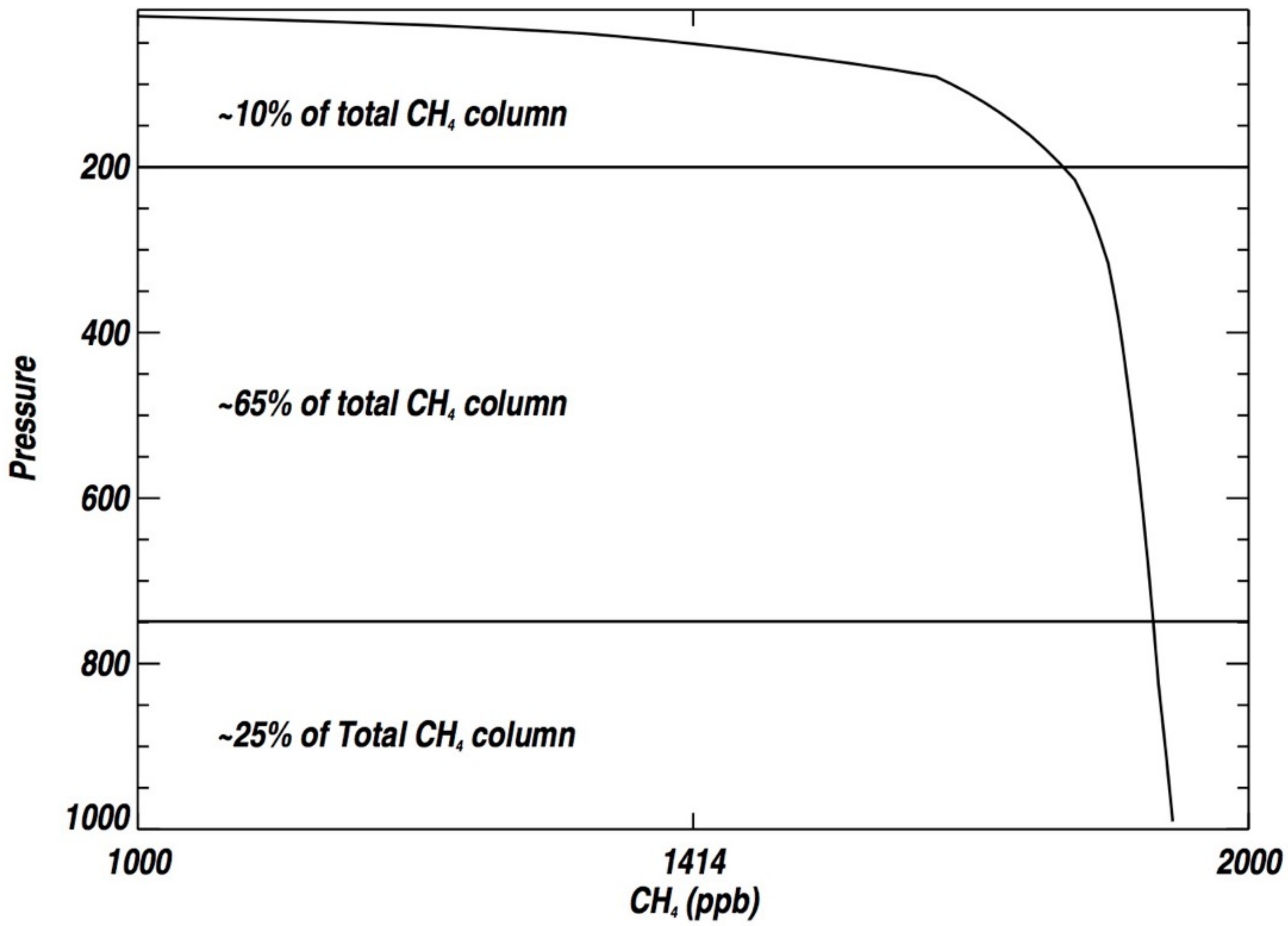
Primarily sensitive to sources really really far away from measurement

Primarily sensitive to sources ~1000's of km away

Primarily sensitive to sources ~100's of km away from measurement

Primary sources on uncertainty when using satellite and surface data to quantify fluxes

Methane profile at ~55 N in July 2006

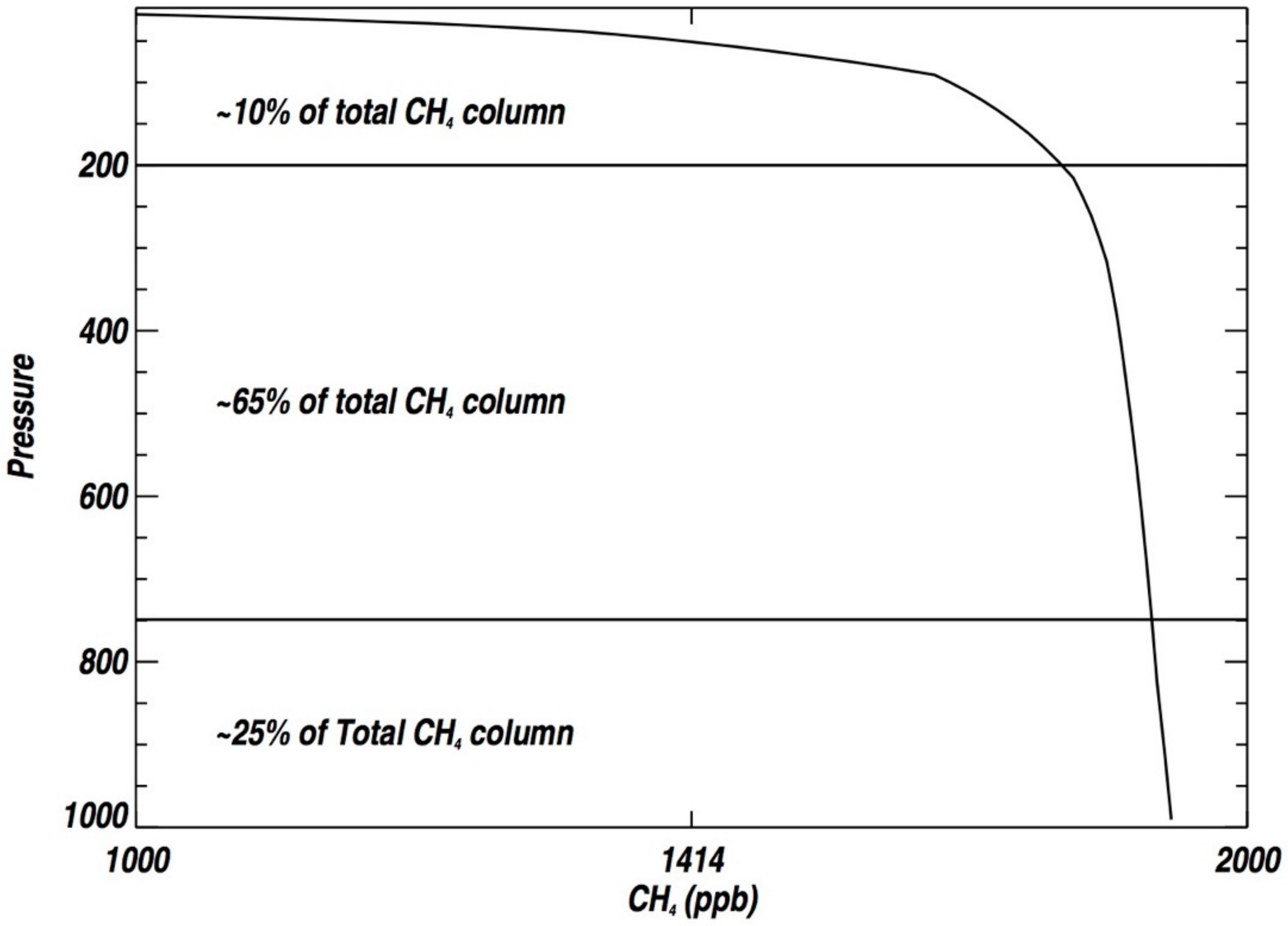


Chemistry, transport, and tropopause height

Transport and Chemistry

Boundary layer height, transport, and chemistry

Objective: Combine Total Column Measurements with Thermal IR Measurements to Quantify Lower Tropospheric Methane



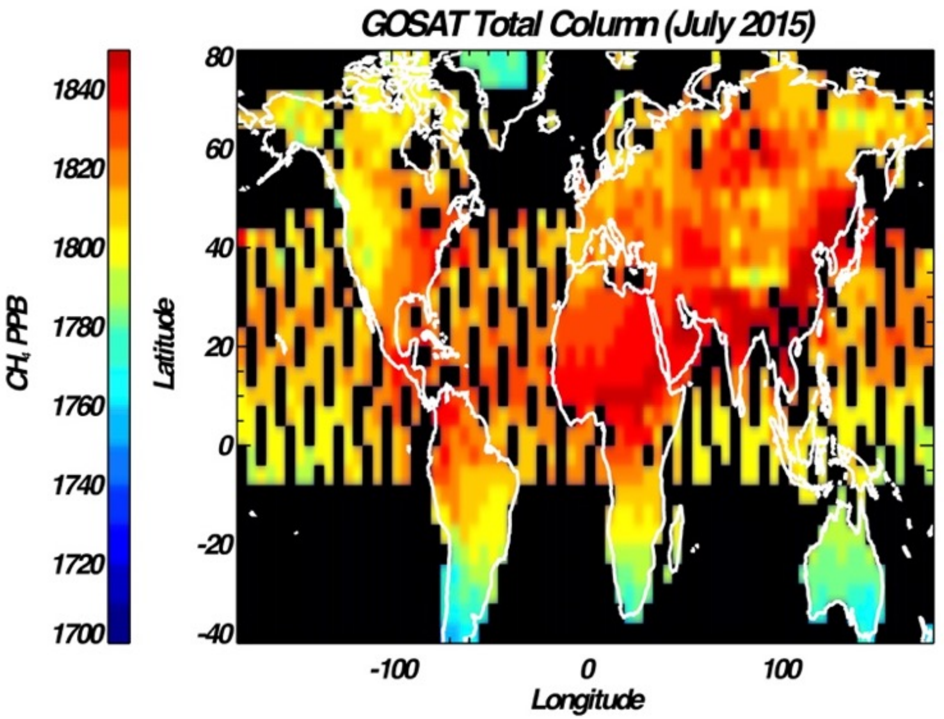
CH_4 from Thermal IR
(e.g. CRIS, TES, AIRS, IASI)

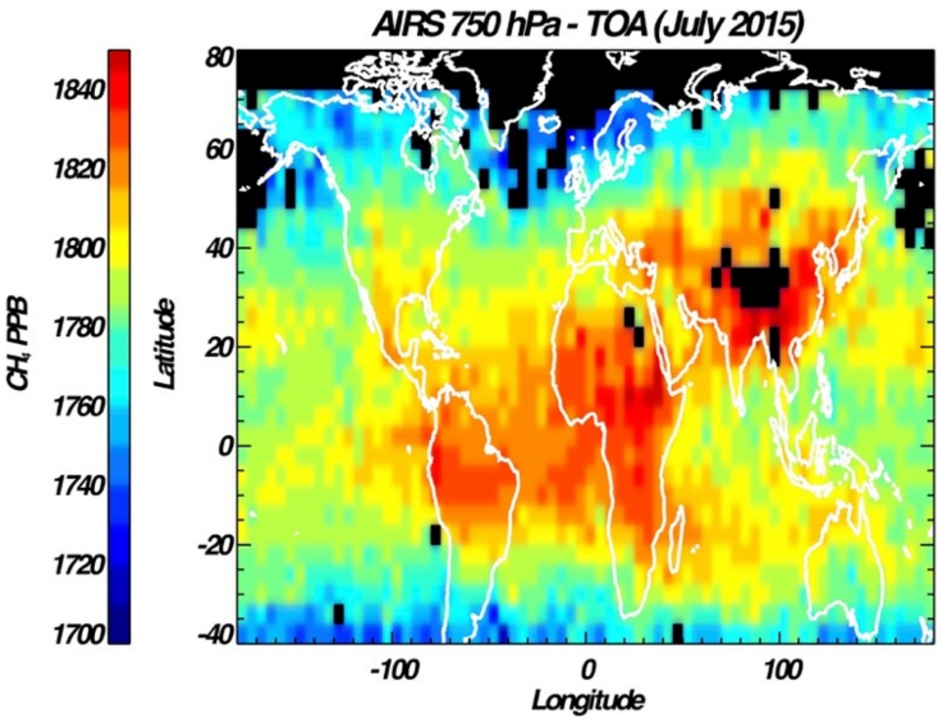
Total column CH_4 from Near IR
(e.g. TROPOMI, GOSAT, SCIAMACHY, GOME)

Lower Troposphere = Difference

Increased Sensitivity to Nearby Fluxes and Less Sensitivity to Background Errors

Comparison of GOSAT Total Column and AIRS FT/Strat Column (~750 hPa to TOA)



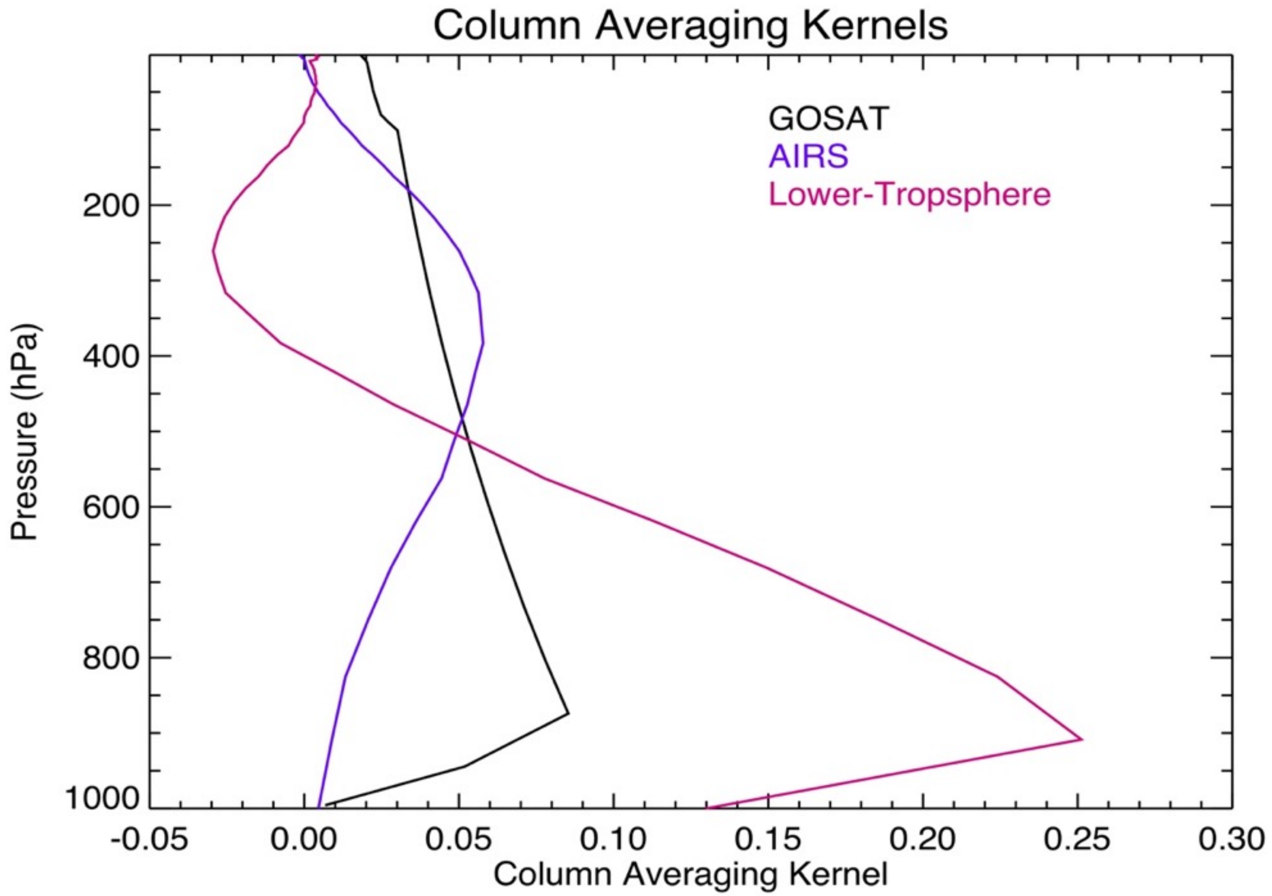


Precision ~15 ppb
Bias ~-17 to 2ppb
Parker et al., GRL 2011

Precision ~30 ppb
Bias ~-.2 ppb for latitudes between 50 S and 50 N
Worden et al., AMT 2012; Alvarado et al., 2015

Both data sets use optimal estimation → a priori, vertical sensitivity (averaging kernels), and aposteriori uncertainties for noise and interferences are provide in the product files

Example of Lower-Tropospheric Methane from GOSAT and TES: GOSAT and TES Total Column Averaging Kernels



$$\hat{C} = C^a + \boldsymbol{C_{air}} \boldsymbol{h}^T \mathbf{A}(\boldsymbol{x} - \boldsymbol{x}^a) + \boldsymbol{C_{air}} \sum_{\mathbf{i}} \boldsymbol{h}^T \boldsymbol{\delta}_i$$

$$\hat{C}_L = \hat{C}_{tot} - \hat{C}_U$$

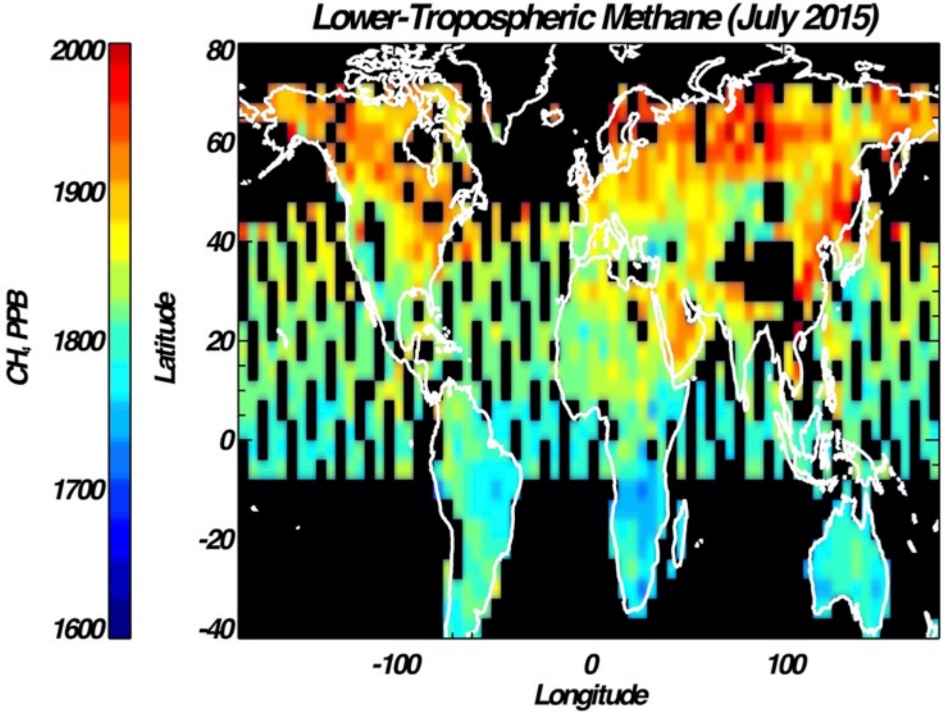
$$\hat{C}_L = C_L^a + C_{air}\, \boldsymbol{b}_L(\boldsymbol{x}_L - \boldsymbol{x}_L^a) + C_{air}\left(\boldsymbol{b}_u - \boldsymbol{h}_u \mathbf{A}_{\mathbf{UU}}^{\mathbf{TES}}\right)(\boldsymbol{x}_u - \boldsymbol{x}_u^a) + C_{air} \sum_i \boldsymbol{h\delta}_i$$

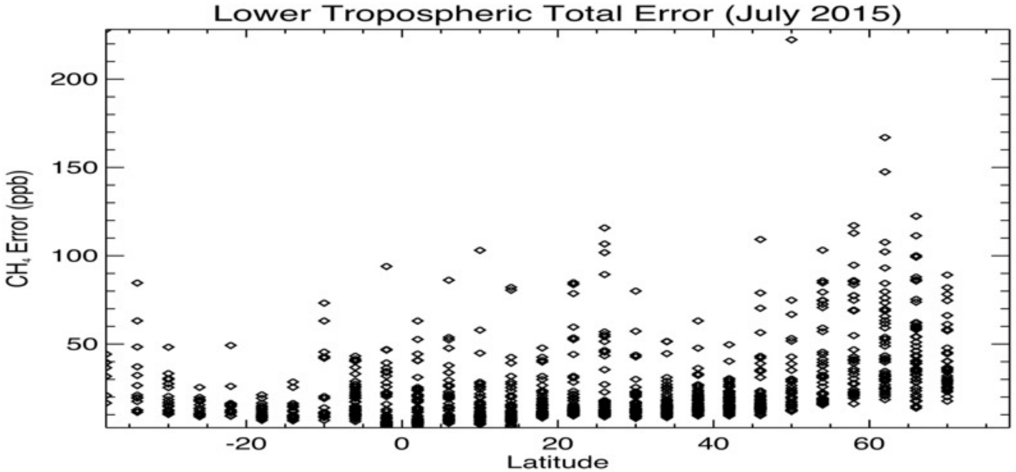
Divide above equation by the column of dry air in the lower troposphere and re-arrange and combine terms and we get:

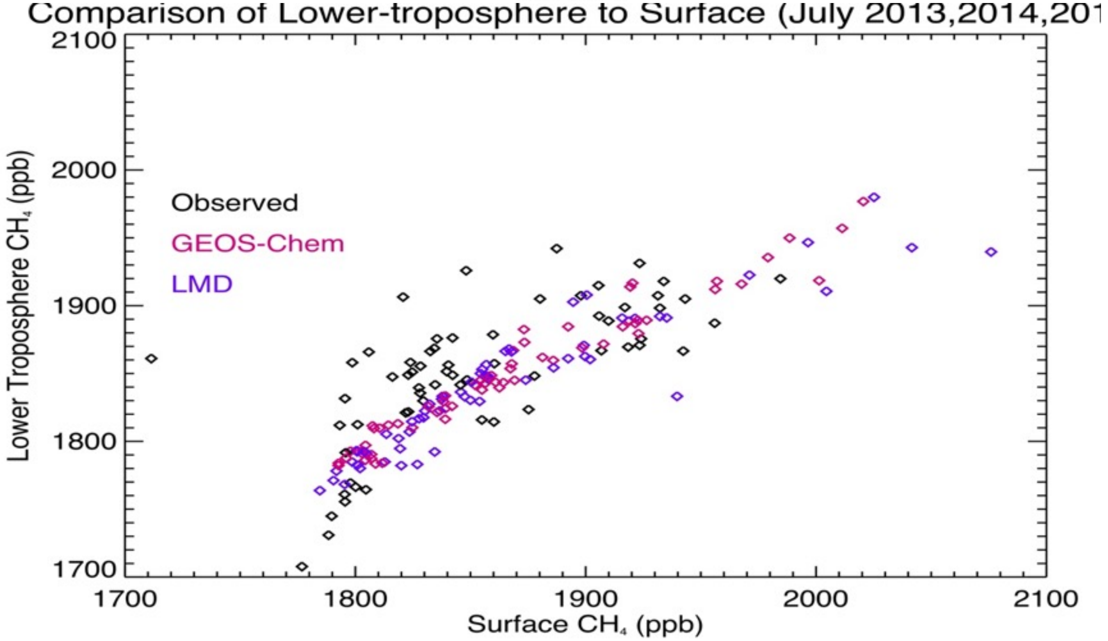
$$\hat{X}_L = X_L^a + a^T(\boldsymbol{x} - \boldsymbol{x}^a) + C_{air}/C_L^{air} \sum_i \boldsymbol{h\delta}_i$$

Lower Tropospheric CH_4 Estimates are for a Monthly Average on a 4x5 degree bin

Calculated uncertainty
~10-30 in tropics ~20-60 ppb at high latitudes

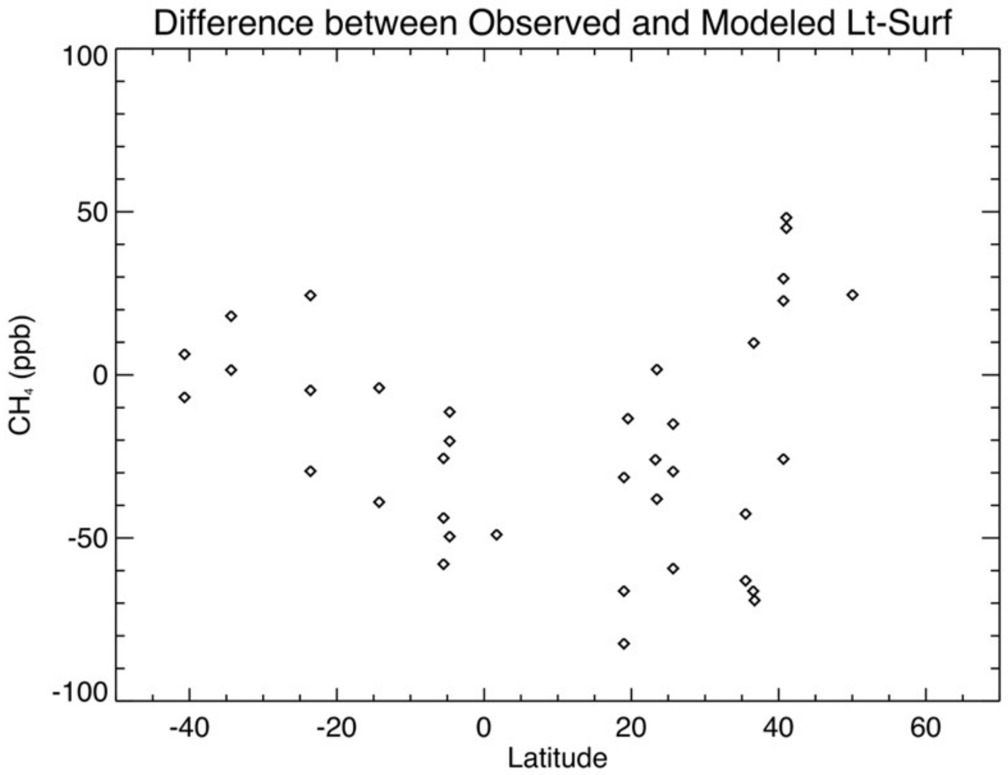




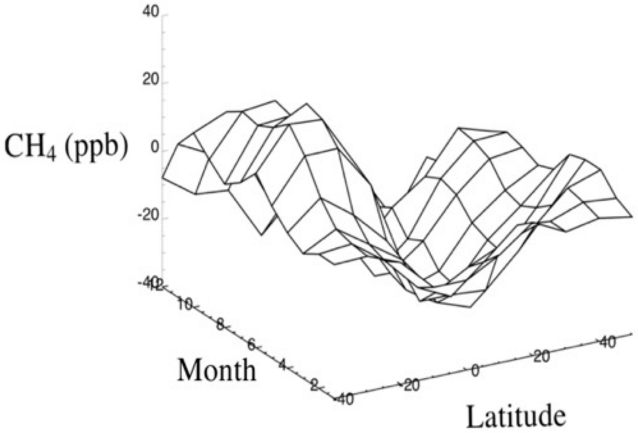


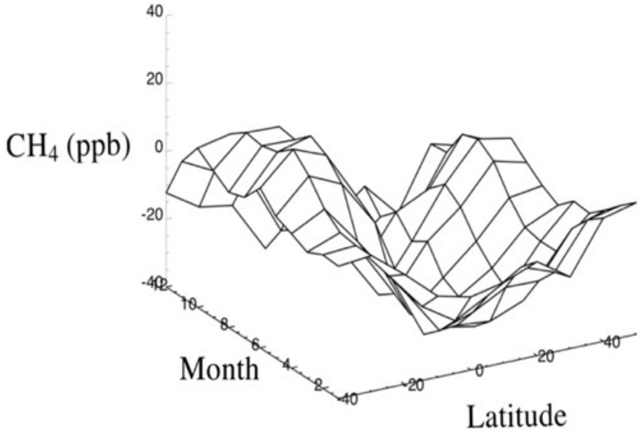
RMS difference between lower-troposphere and surface data ~30 ppb
Use Surface data comparison, transferred through GEOS-Chem model, to calibrate data

Comparison Using GEOS-Chem (and LMDz) models with Surface Network Suggests Seasonal Variability in Bias at High Latitudes → Likely Because of Tropopause Variations



However Comparisons between Surface Network (Via





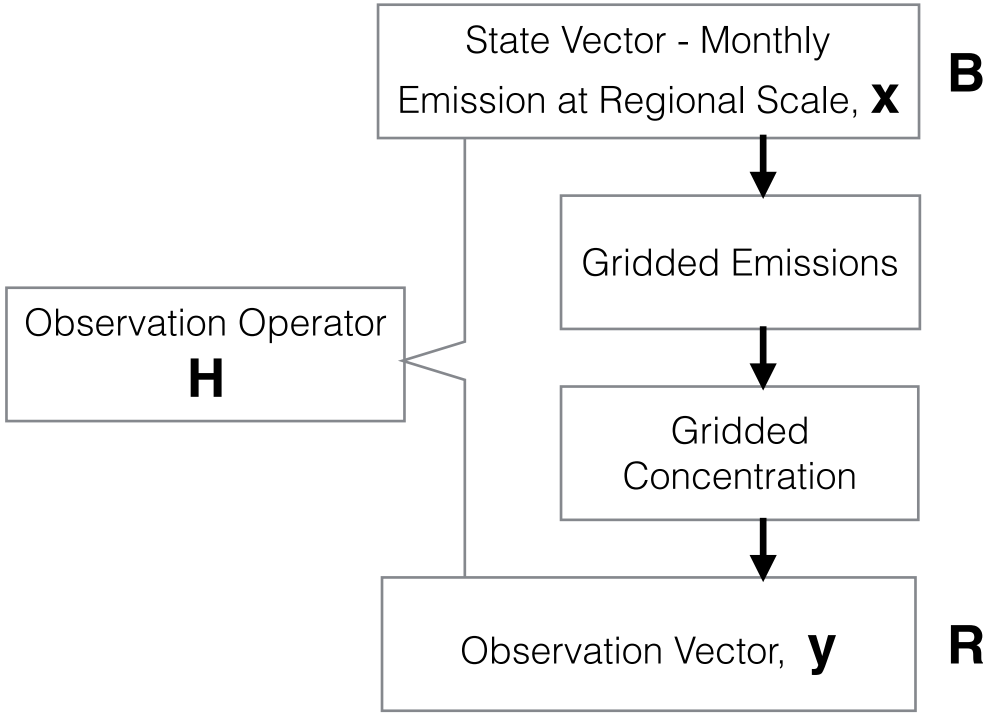
Assume that difference between the lower-troposphere and surface in the model is well understood

Comparison between two different chemistry / transport models support this assumption

$$\boldsymbol{C} = \left(\widehat{X}_L - X_s\right) - \left(\widehat{X}_L^M - X_S^M\right)$$

Conclusion: For Now just use tropical data where seasonal variability in bias is < 5 ppb

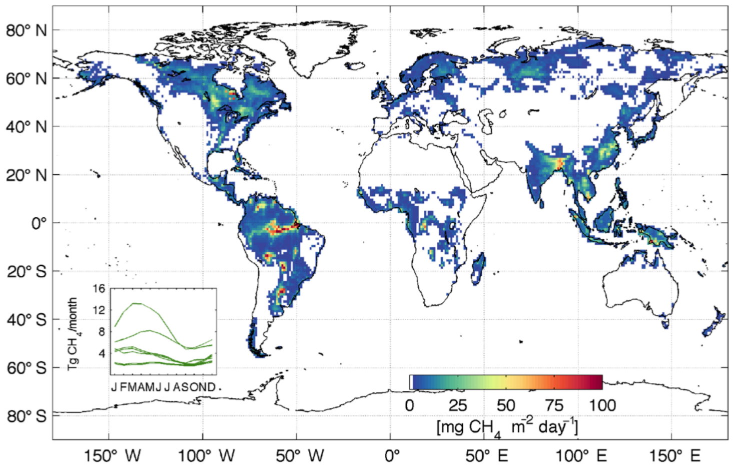
Analytical Inversion System



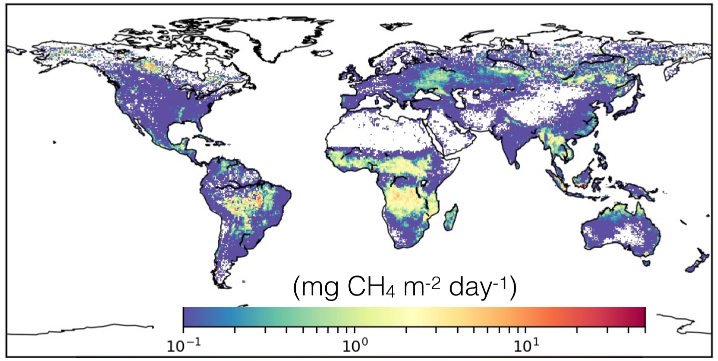
$$A = (B^{-1} + H^T R^{-1} H)^{-1}$$

$$x^a = x^b + A H^T R^{-1} (y - H x^b)$$

Wetland CH_4 emissions, WetCHARTs, Bloom *et al.*, (2017)

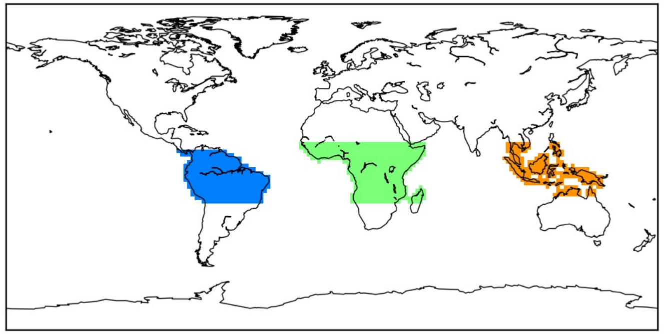


Fire CH_4 emissions, GFED4.1, van der Werf *et al.*, (2017)



State Vector:

- Monthly wetland/fire emissions from three tropical regions
- The rest of the world (boundary conditions)
- Initial conditions (four latitudinal bands)



Transport model:

- GEOS-Chem (4x5, 47 levels)

Observations:

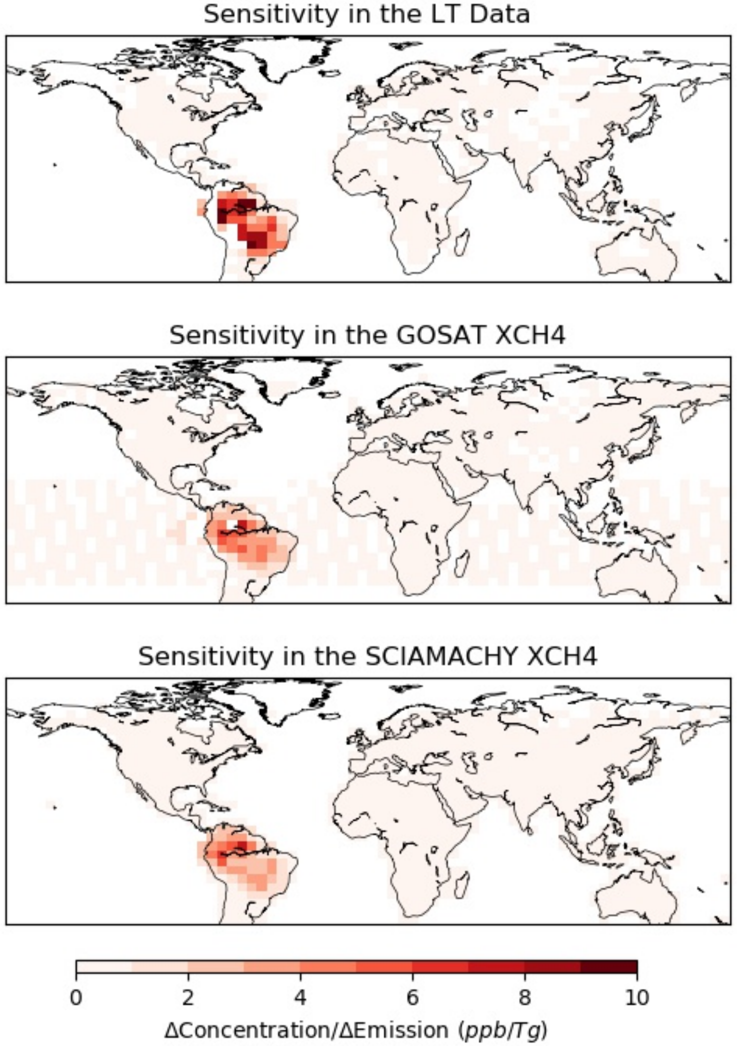
- Monthly LT retrievals 30S-N

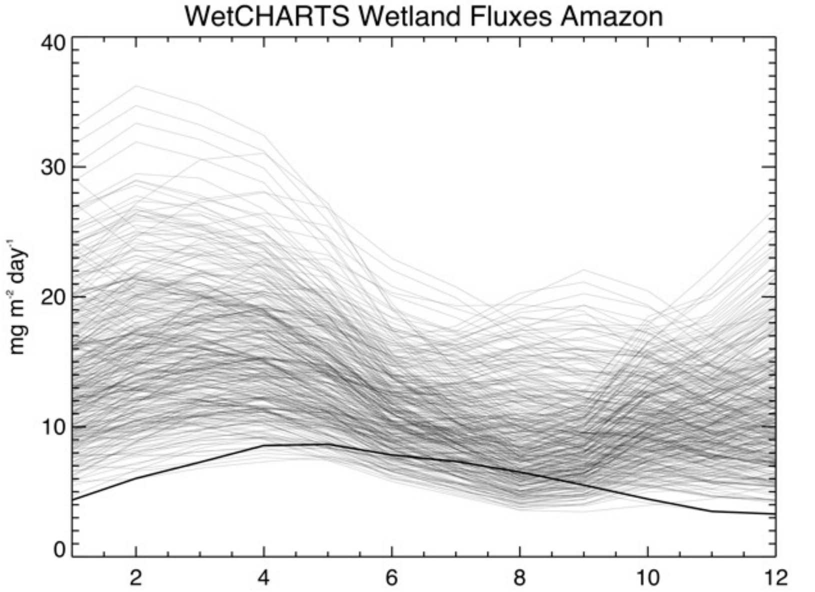
Sensitivity of Lower-Troposphere Data to Amazon wetland Emissions Show Lower-Troposphere Concentrations Are Sensitivity to Seasonal Cycle of Wetlands (~10 Tg Emissions ~ 15 ppb change)

LT data

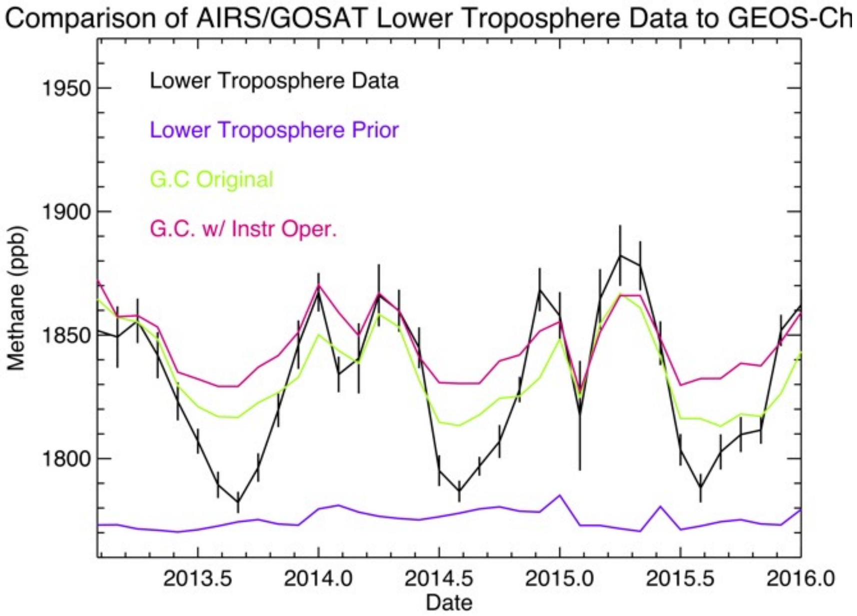
GOSAT

SCIA

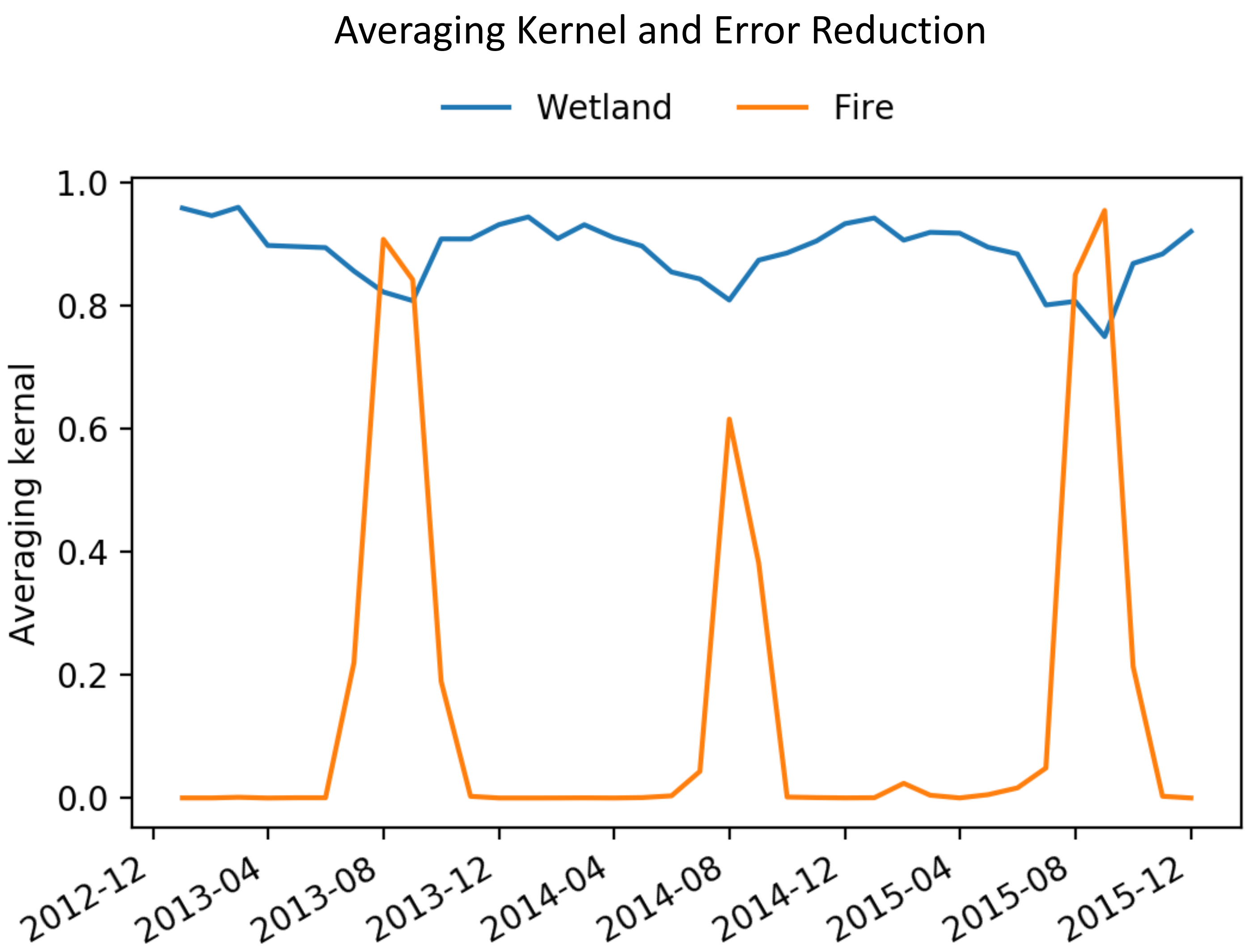




Amazon Wetlands Peaks in Early Fall (rainfall) and Late Winter (Inundation)



Lower troposphere data has same seasonality as G.C. but different magnitude



1 DOF means that the emissions estimate is entirely dependent on the wetland fluxes

DOFS ranges from 0.8 to 0.95 for Amazon

Using the Hessian we calculate a 60% error reduction from the prior

Prior assumes ~50% uncertainty

No estimate on the emissions yet.. Could not get tha working before meeting ☹

Summary

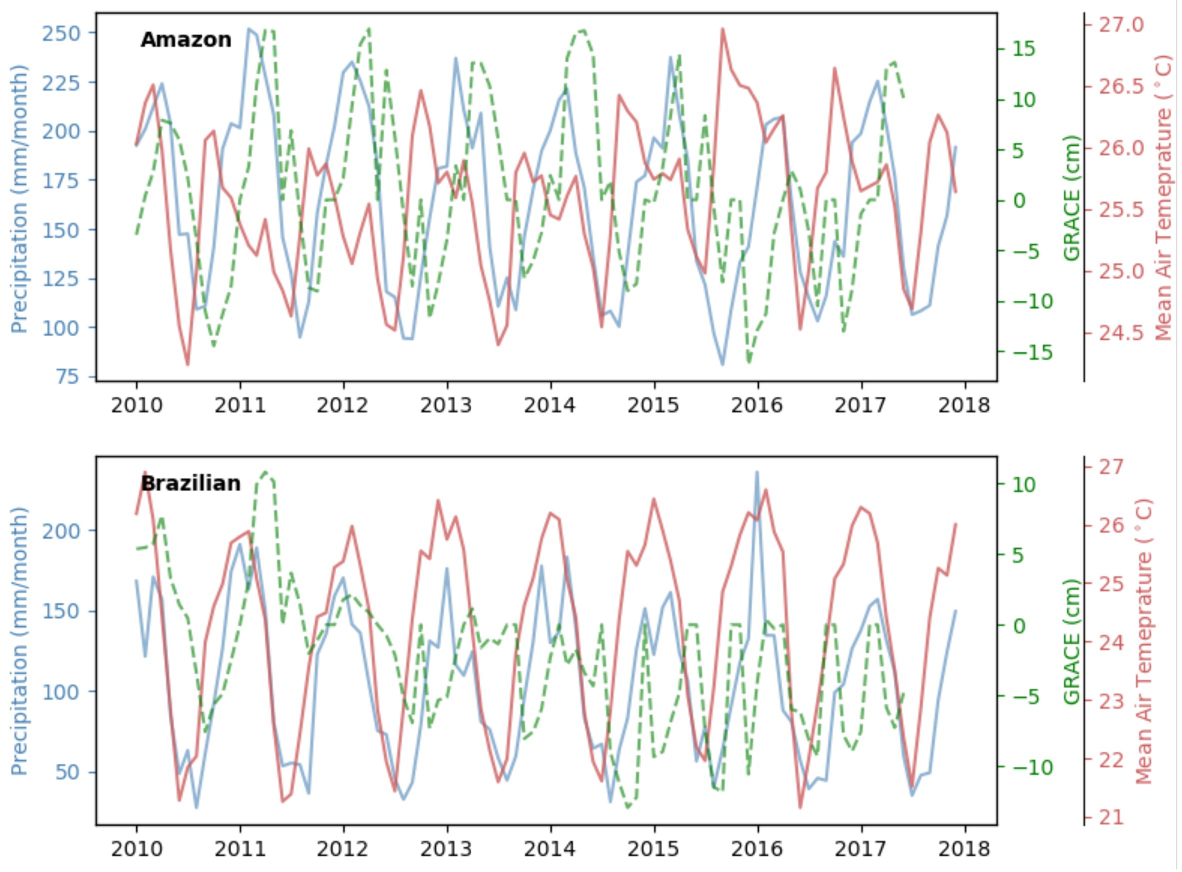
Lower-troposphere methane data from GOSAT/AIRS combination have ~15 ppb calculated / actual uncertainty in tropics for a 5x4 lon/lat average with peak sensitivity at ~900 hpa

Three approaches to cal/val:
1) GOSAT is validated using TCCON, 2) AIRS is validated using HIPPO, 3)Lower troposphere product is evaluated against surface network. Comparison against surface network (with GEOS-Chem) reveals latitudinal variation in bias with higher latitude data also showing a significant seasonal bias (~10 ppb¥), likely due to changes in the tropopause.

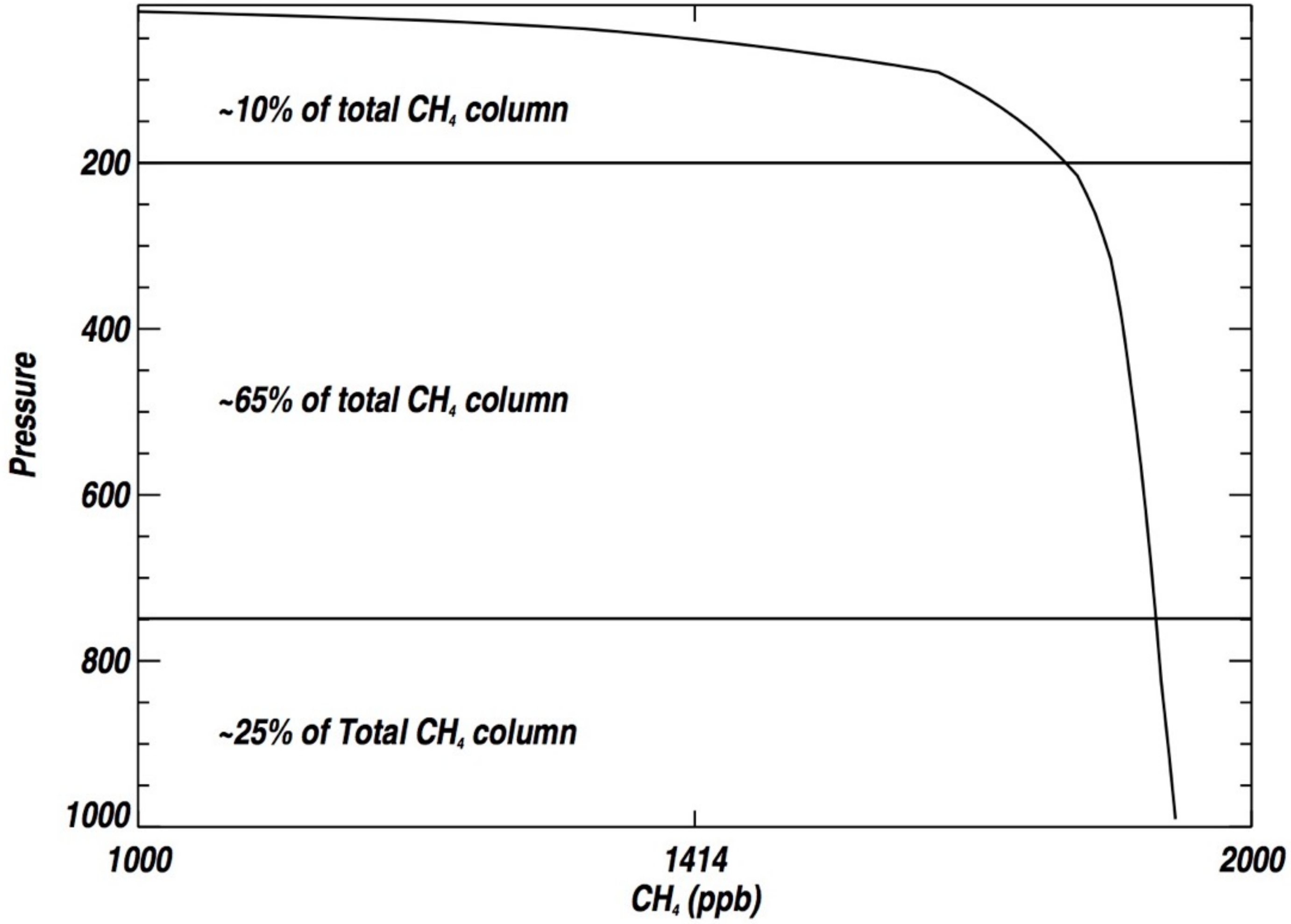
Use of Lower-troposphere data product provides ~0.9 DOF for Amazon wetland emissions for all seasons with ~60% error reduction from the prior

At least for the Amazon, the seasonal variability of lower-troposphere is consistent with wetlands and suggest inundation is primary driver for emissions but with possible contribution from precipitation

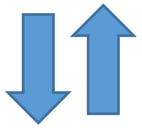
Monthly timeseries of T, P, and GRACE



Primary sources on uncertainty when using surface data to quantify fluxes



Transport and Chemistry

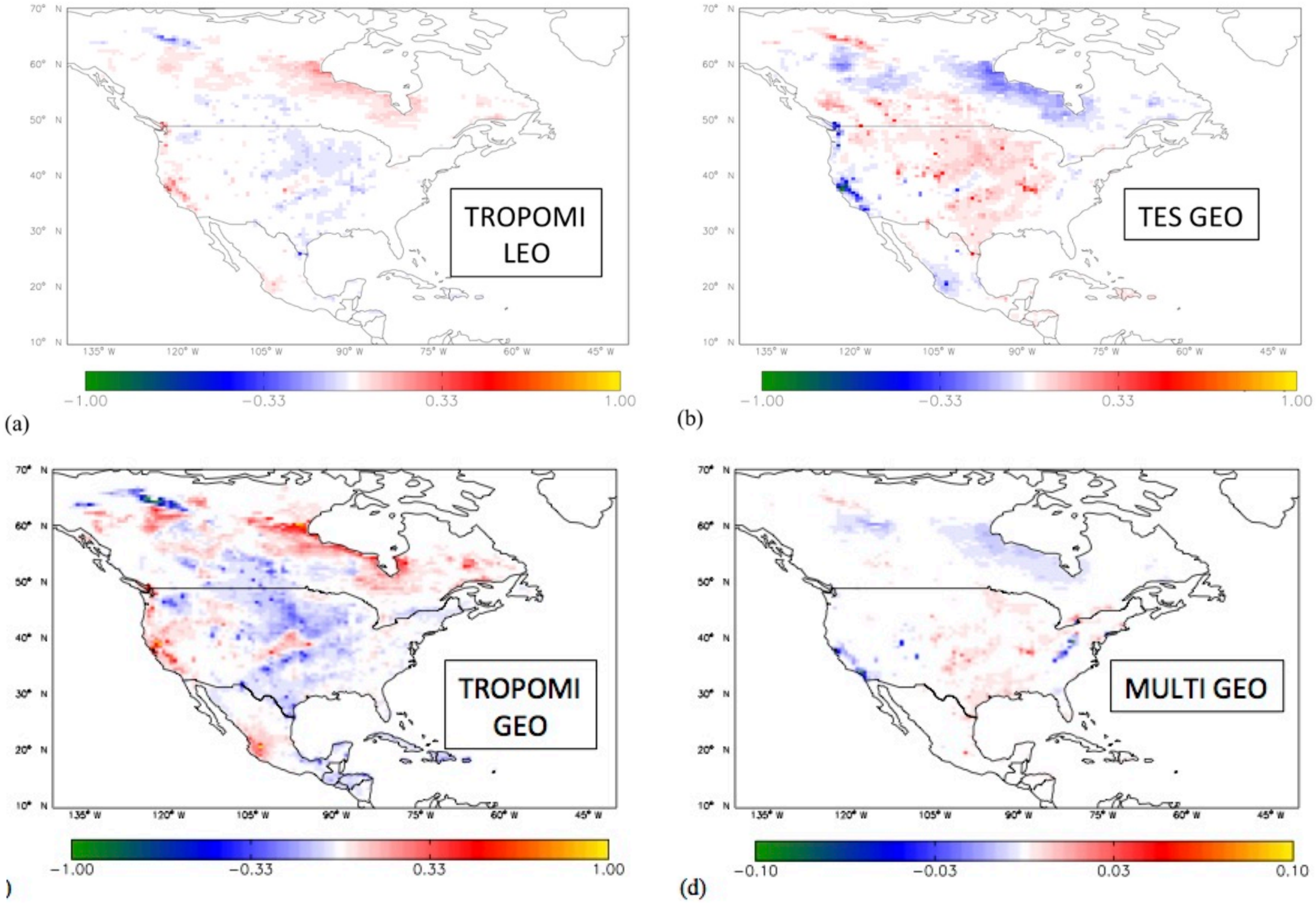


Boundary layer height,

Transport, and chemistry

Estimates of Methane Fluxes Using Methane Profile Information Reduces Sensitivity to Background (transport/chemistry) Uncertainties

Bousserez et al., ACP 2016



Use of Thermal IR and Near IR radiances allows for profiling of methane that can resolve the boundary layer.

Use of profiles (instead of columns) to quantify fluxes results in a:
~50% increase in sensitivity to surface fluxes

Substantial reduction (> 10x reduction) in sensitivity to background errors (e.g. transport and chemistry)