Quantifying Lower Tropospheric Methane Using GOSAT and TES measurements

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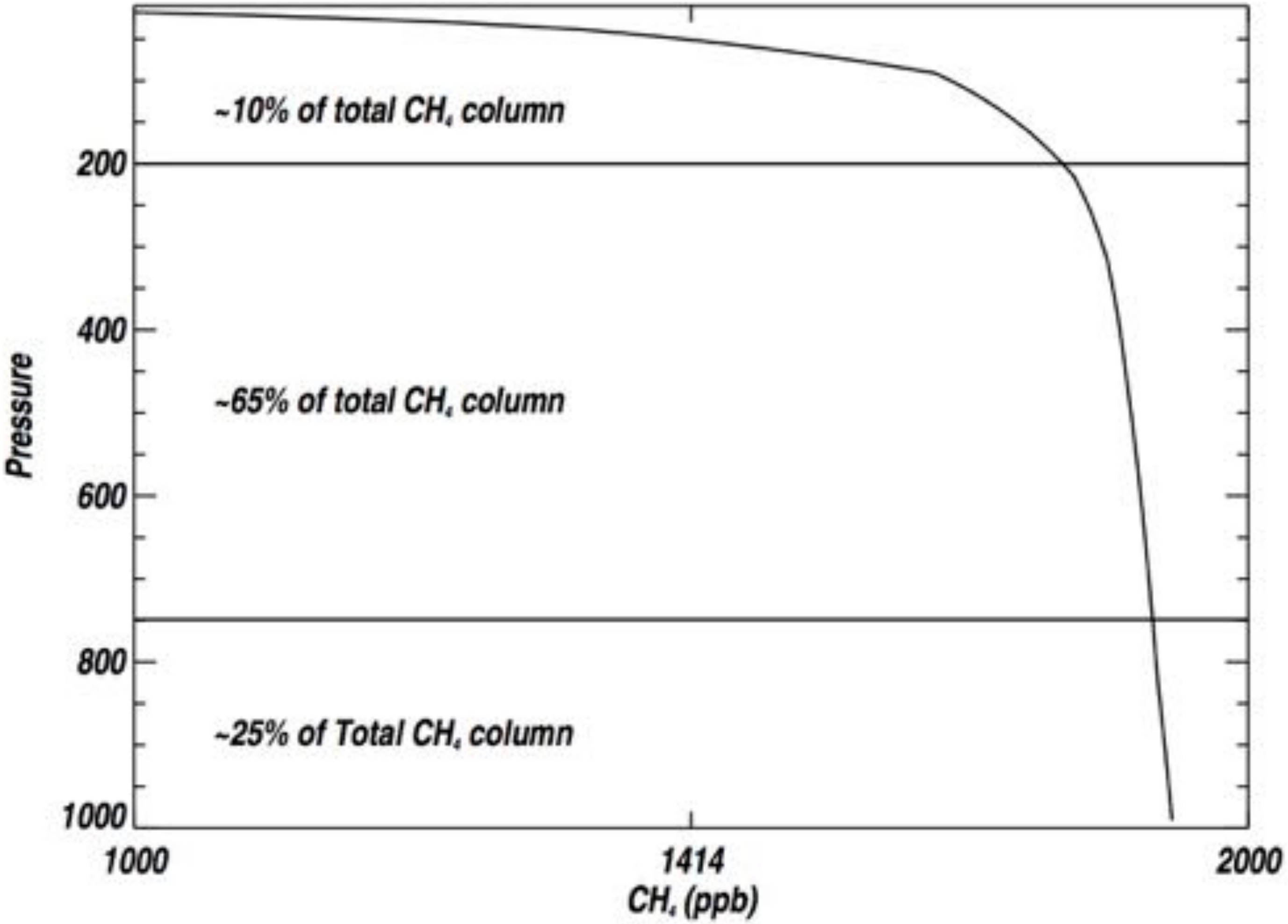
Methane profile at ~55 N in July 2006

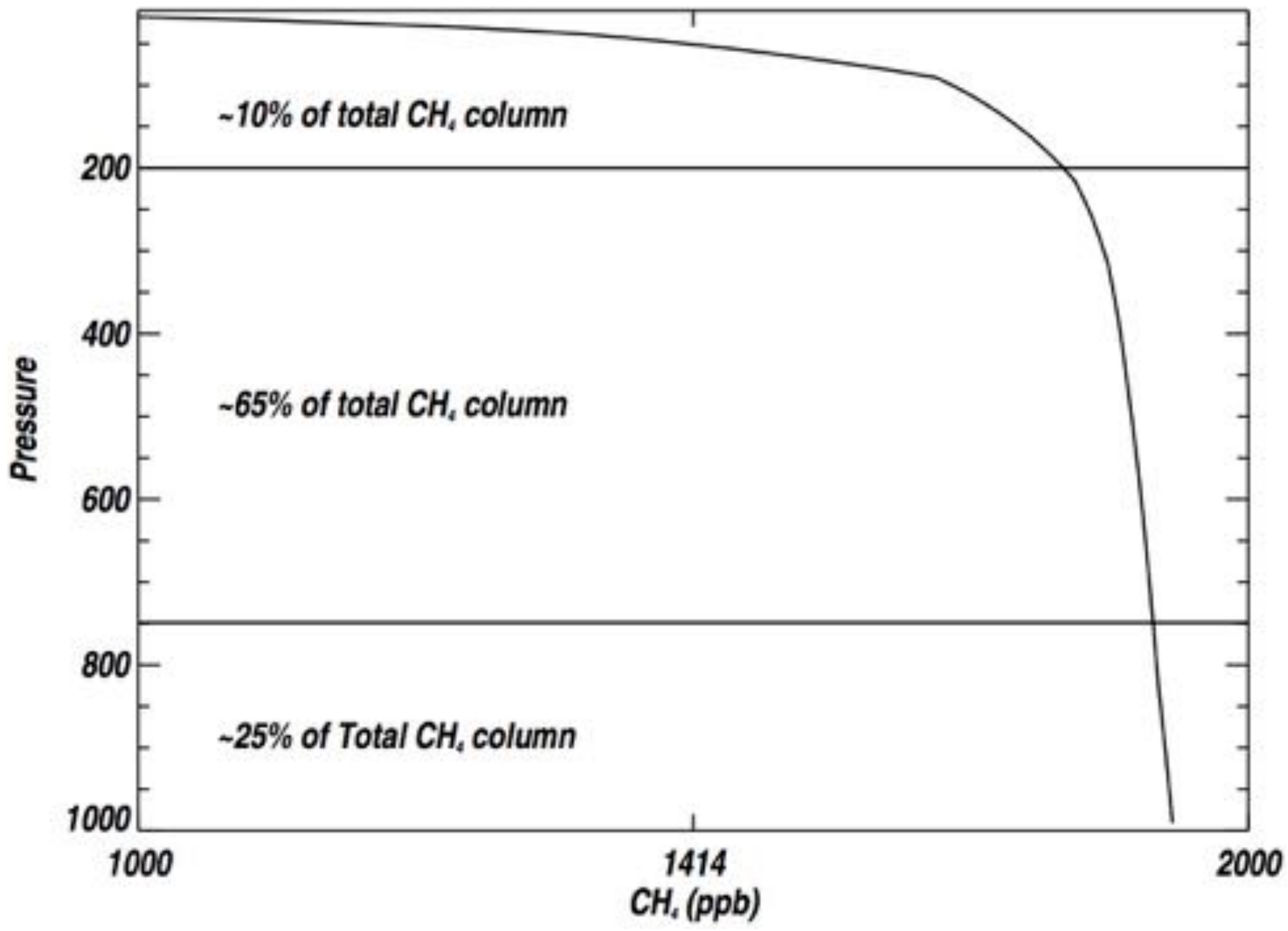


Primarily sensitive to sources really really far away from measurement

Primarily sensitive to sources ~1000's of km away

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

Methane profile at ~55 N in July 2006

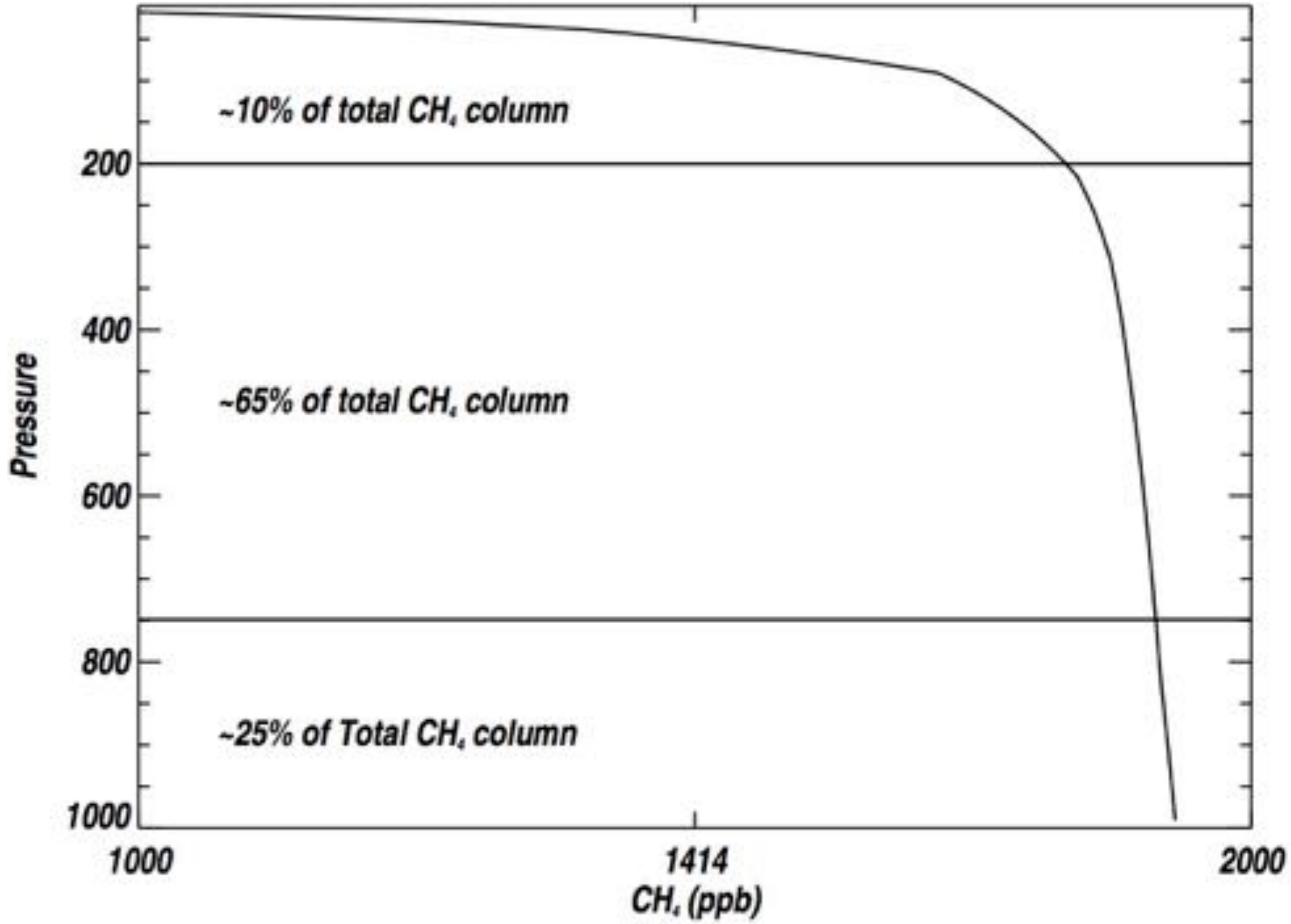


Chemistry, transport, and tropopause height

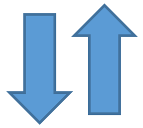
Transport and Chemistry

Boundary layer height, transport, and chemistry

Estimating Fluxes Using Surface Network



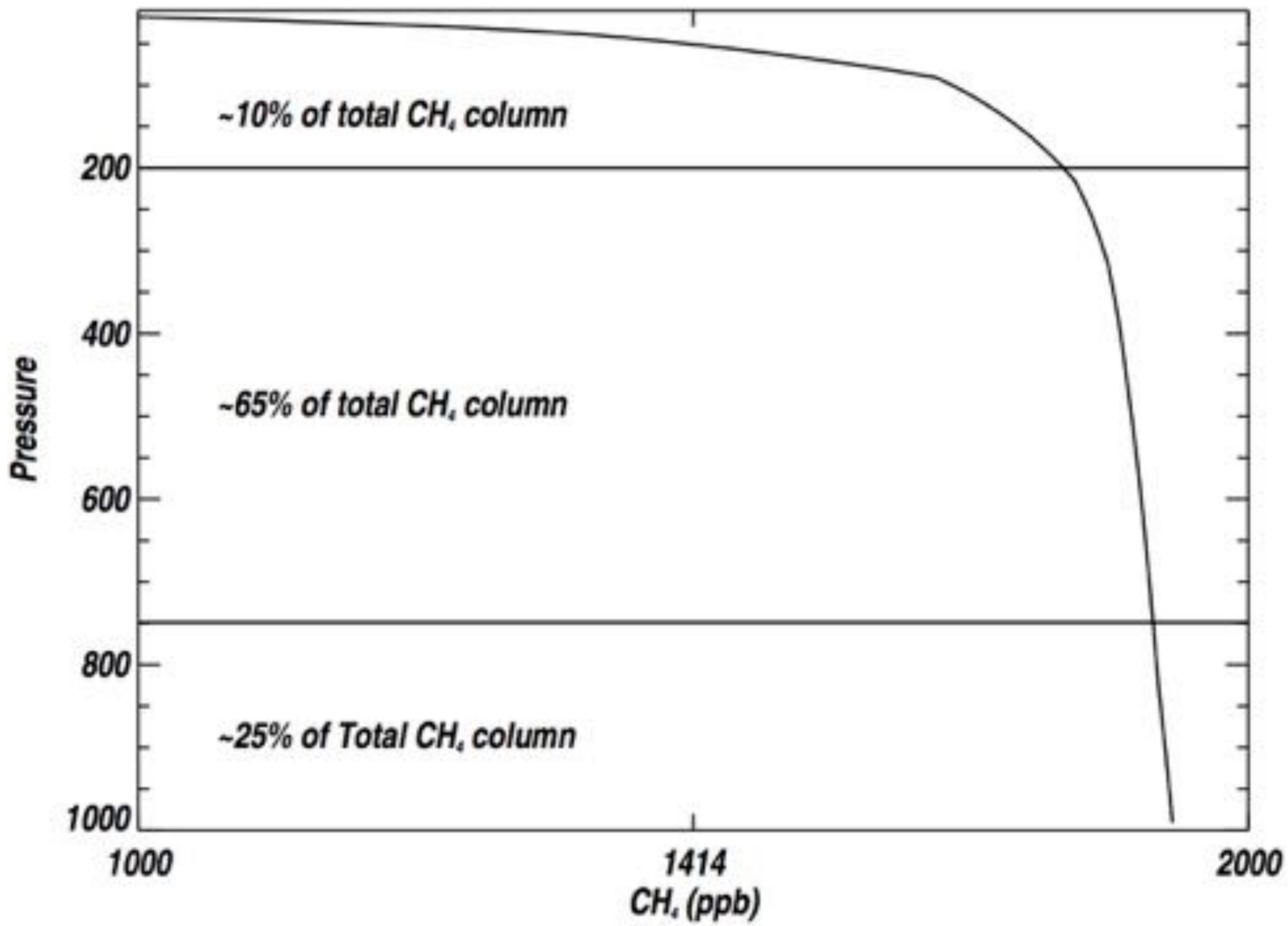
Transport and Chemistry



Boundary layer height,

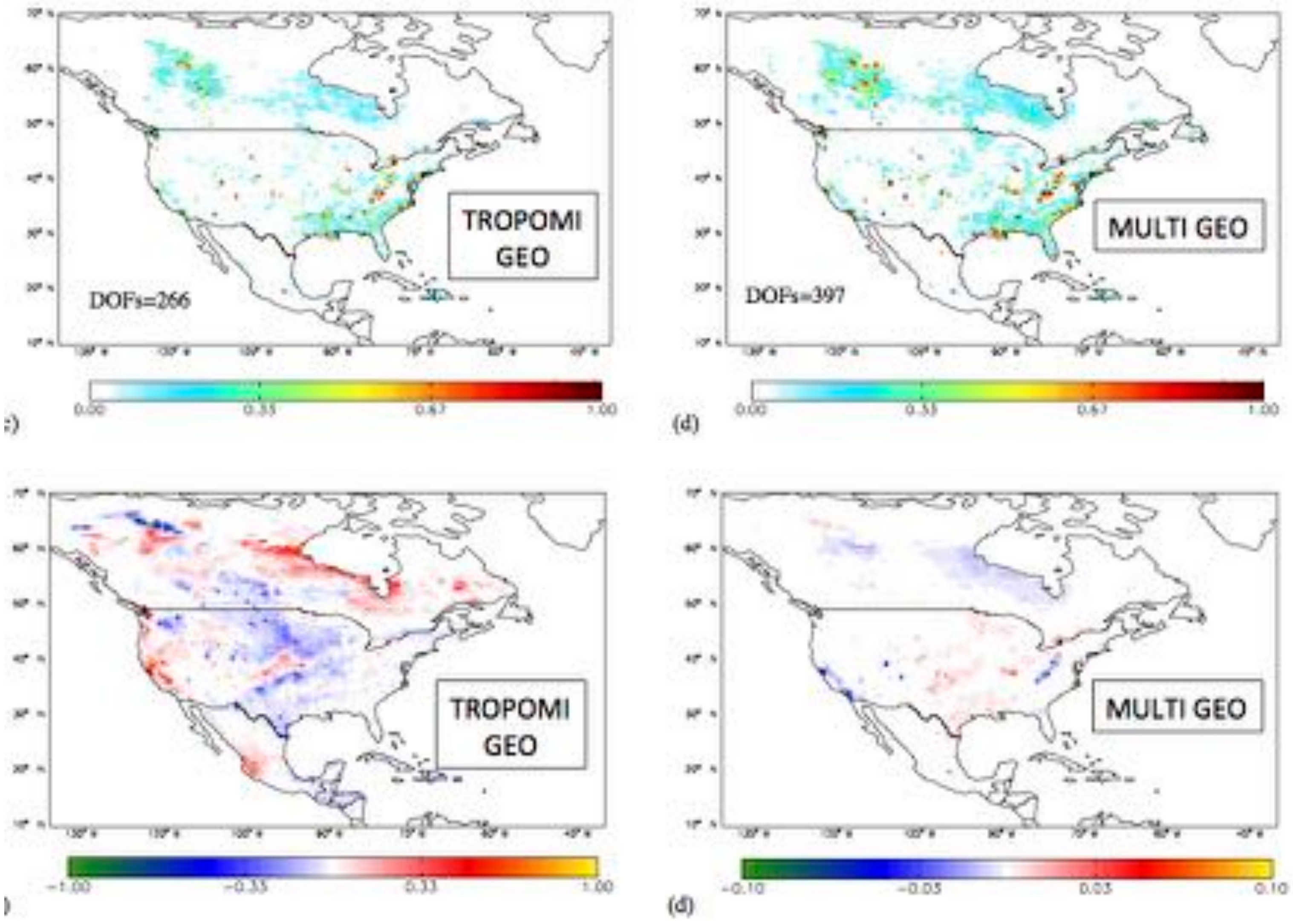
Transport, and chemistry

Estimating Fluxes Using Total Column Data



Need accurate model calculations of transport and chemistry over very long length scales (~1000's of km)

Estimating Fluxes Using Methane Total Column and Profiles from a GEO Orbit
Bousserez et al., ACP 2016

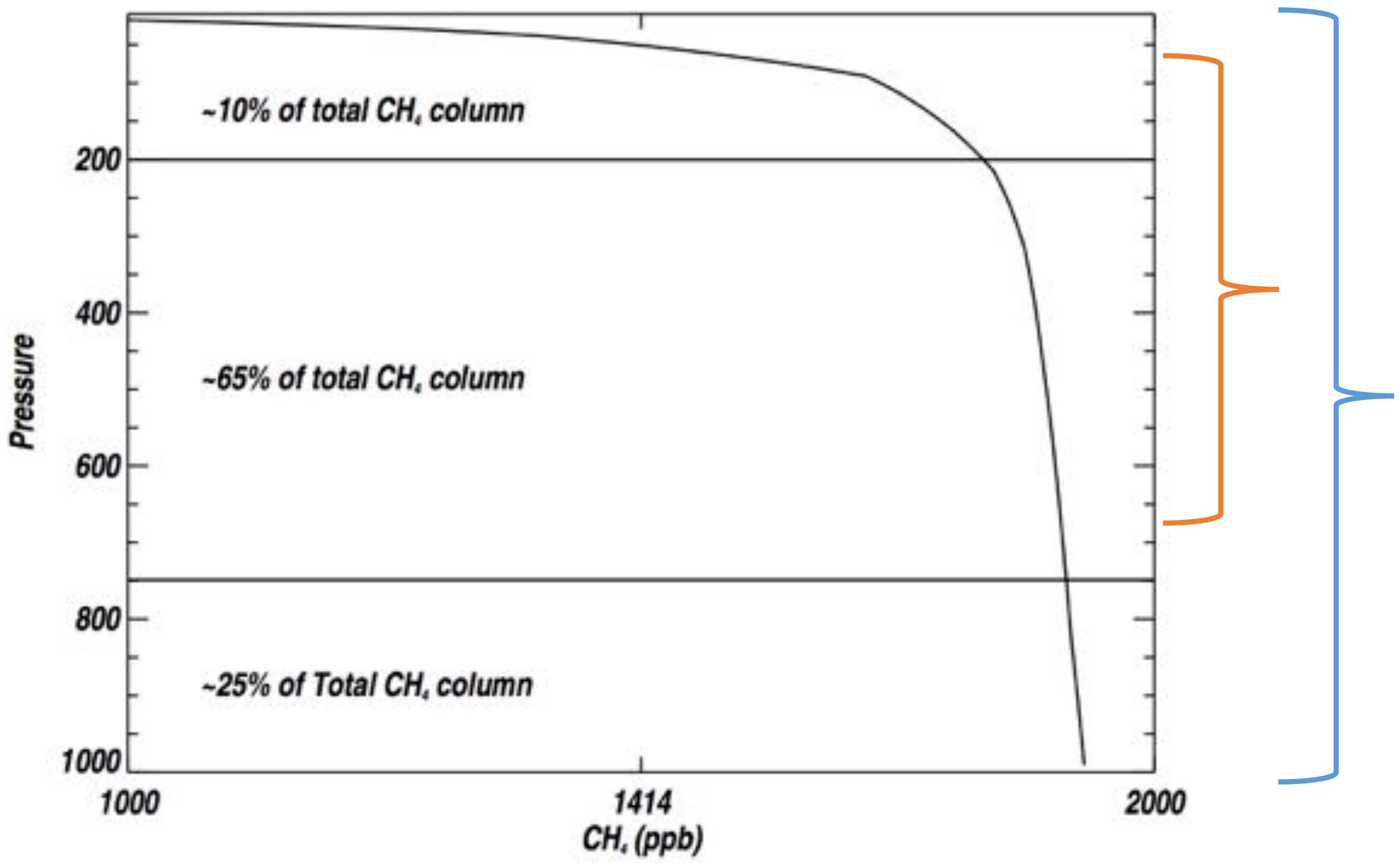


Use of Thermal IR and Near IR radiances allows for profiling of methane that can resolve the boundary layer.

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

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

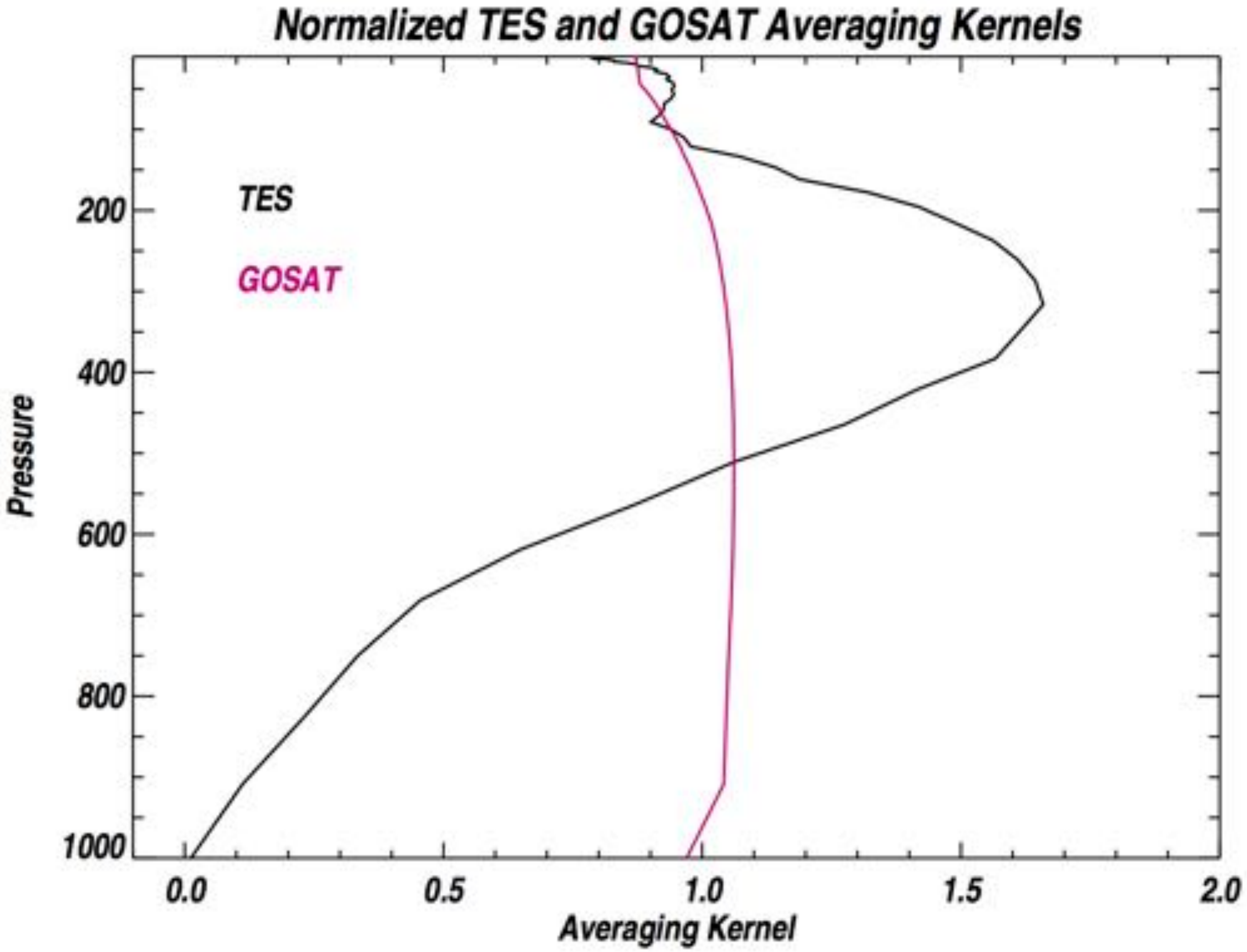
Estimating Fluxes Using Profile (or Lower Tropospheric Methane Measurements)



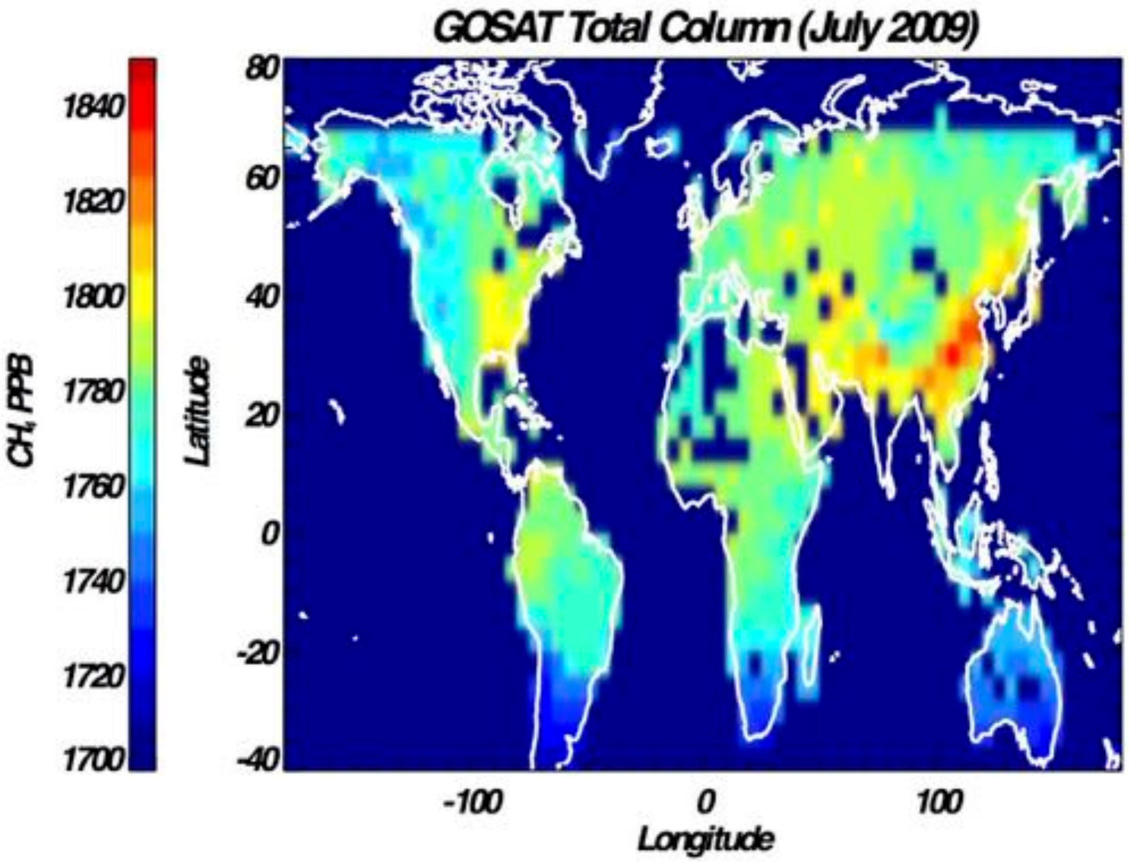
CH_4 from Thermal IR
(e.g. TES, AIRS, IASI)

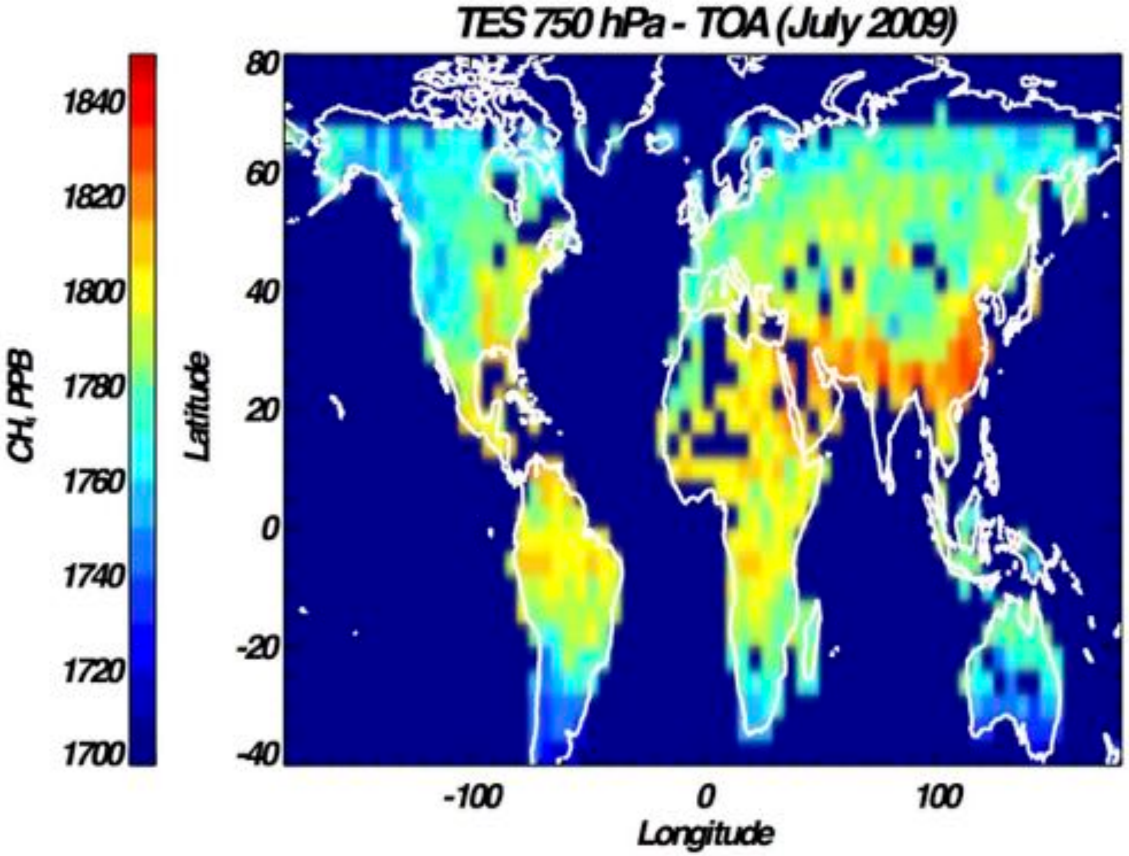
Total column CH_4 from Near IR
(e.g. GOSAT, SCIAMACHY, GOME

GOSAT and TES Total Column Averaging Kernels



Comparison of GOSAT Total Column and Aura TES FT/Strat Column (~850 hPa to TOA)





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

Precision ~15 ppb
Bias ~26 ppb
Worden et al., AMT 2012; Alvarado et al., 2015

Some Math: Derivation of Averaging Kernel and Uncertainties

$$\hat{\boldsymbol{C}} \quad = \boldsymbol{C^a} + \boldsymbol{C_{air}} \boldsymbol{h^T} \mathrm{A}(\boldsymbol{x} - \boldsymbol{x^a}) + \boldsymbol{C_{air}} \sum_{\mathrm{i}} \boldsymbol{h^T} \boldsymbol{\delta_i}$$

$$\hat{\boldsymbol{C}}_{\boldsymbol{L}} = \hat{\boldsymbol{C}}_{\boldsymbol{tot}} - \hat{\boldsymbol{C}}_{\boldsymbol{U}}$$

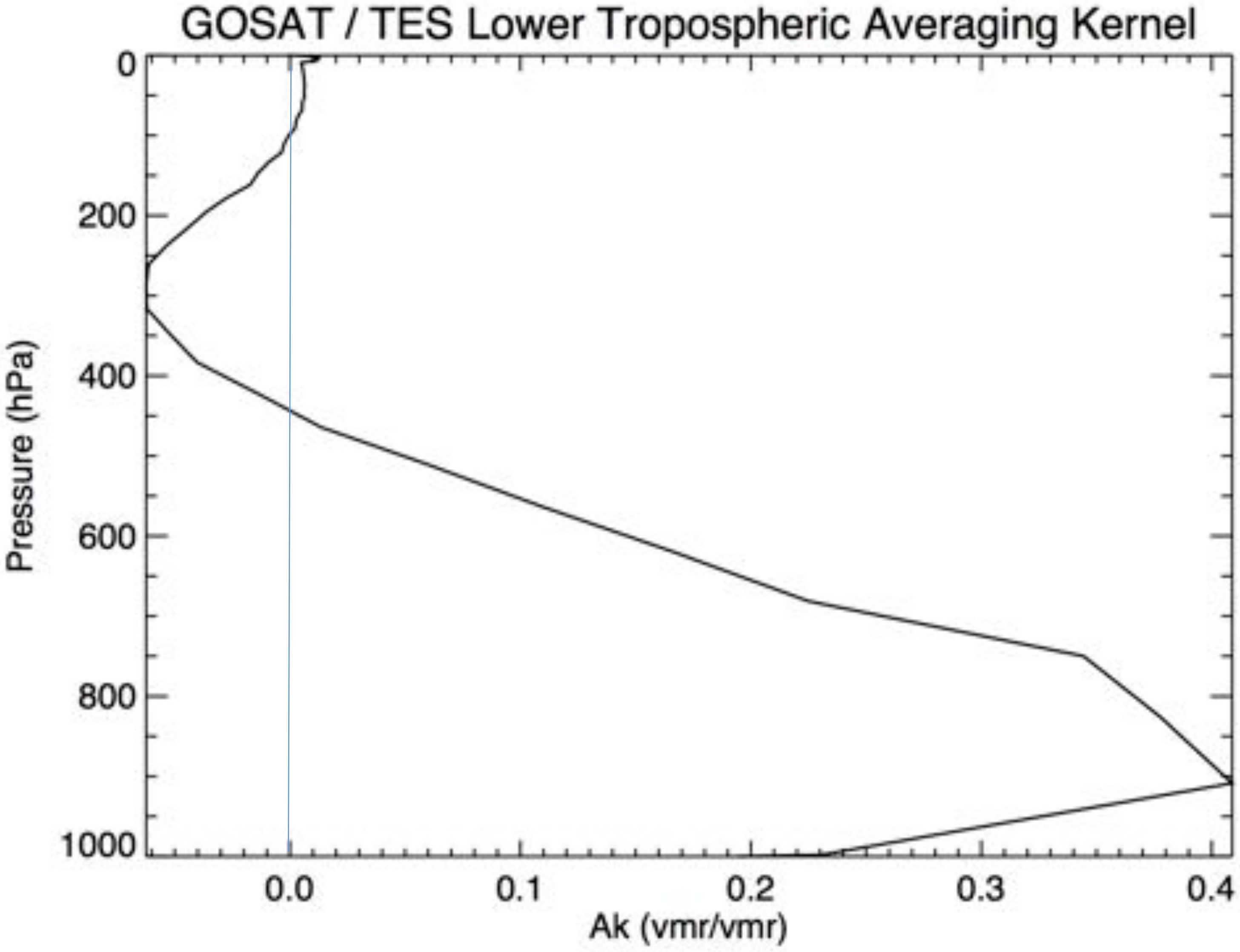
$$\hat{C}_L = C_L^a + C_{air}\, \boldsymbol{b_L}(\boldsymbol{x_L} - \boldsymbol{x_L^a}) + C_{air}(\, \boldsymbol{b_u} \; - \boldsymbol{h_u} \mathbf{A}_{\mathbf{UU}}^{\mathbf{TES}})(\boldsymbol{x_u} - \boldsymbol{x_u^a}) + C_{air} \sum_{\boldsymbol{i}} \boldsymbol{h\delta_i}$$

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

$$\hat{X}_L = X_L^a + a^T(\boldsymbol{x} \quad - \boldsymbol{x^a}) + C_{air}/C_L^{air} \sum_{\boldsymbol{i}} \boldsymbol{h\delta_i}$$

Now we have an equation that is similar to that described in Rodgers (2000).
Note amplification of uncertainties by about a factor of 4 due to $\boldsymbol{C_{air}}/\boldsymbol{C_L^{air}}$ term

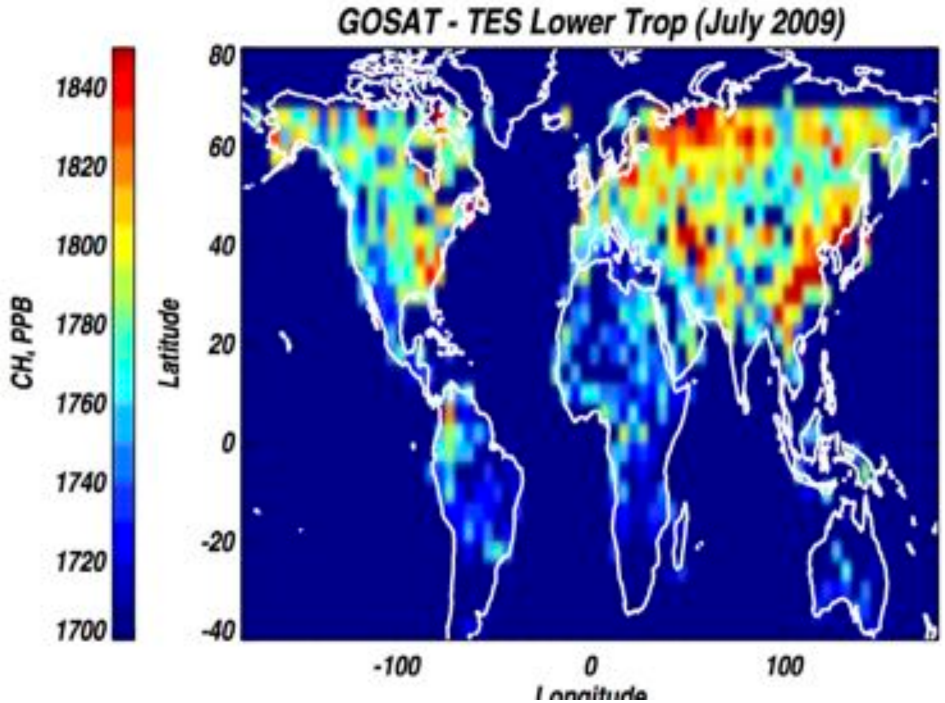
Worden et al., AMT 2015



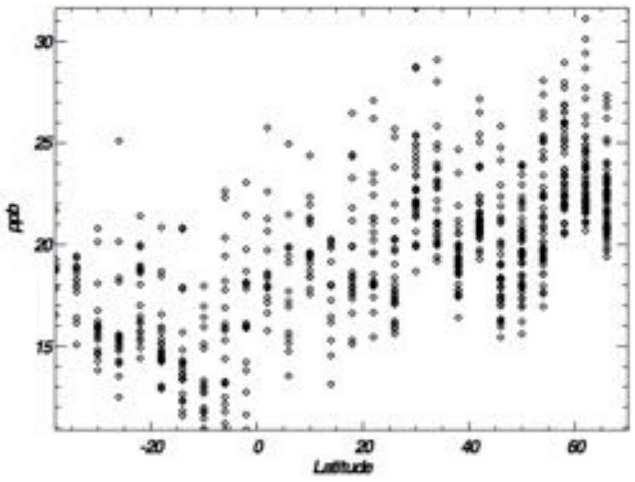
Reduced sensitivity of lower tropospheric estimate to stratosphere and upper tropospere

Typical Averaging Lower Trop "column" averaging kernel peaks at 900 hPa

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

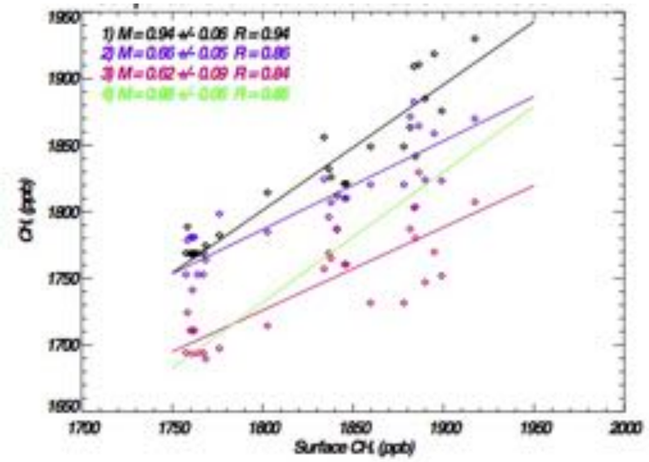


Precision



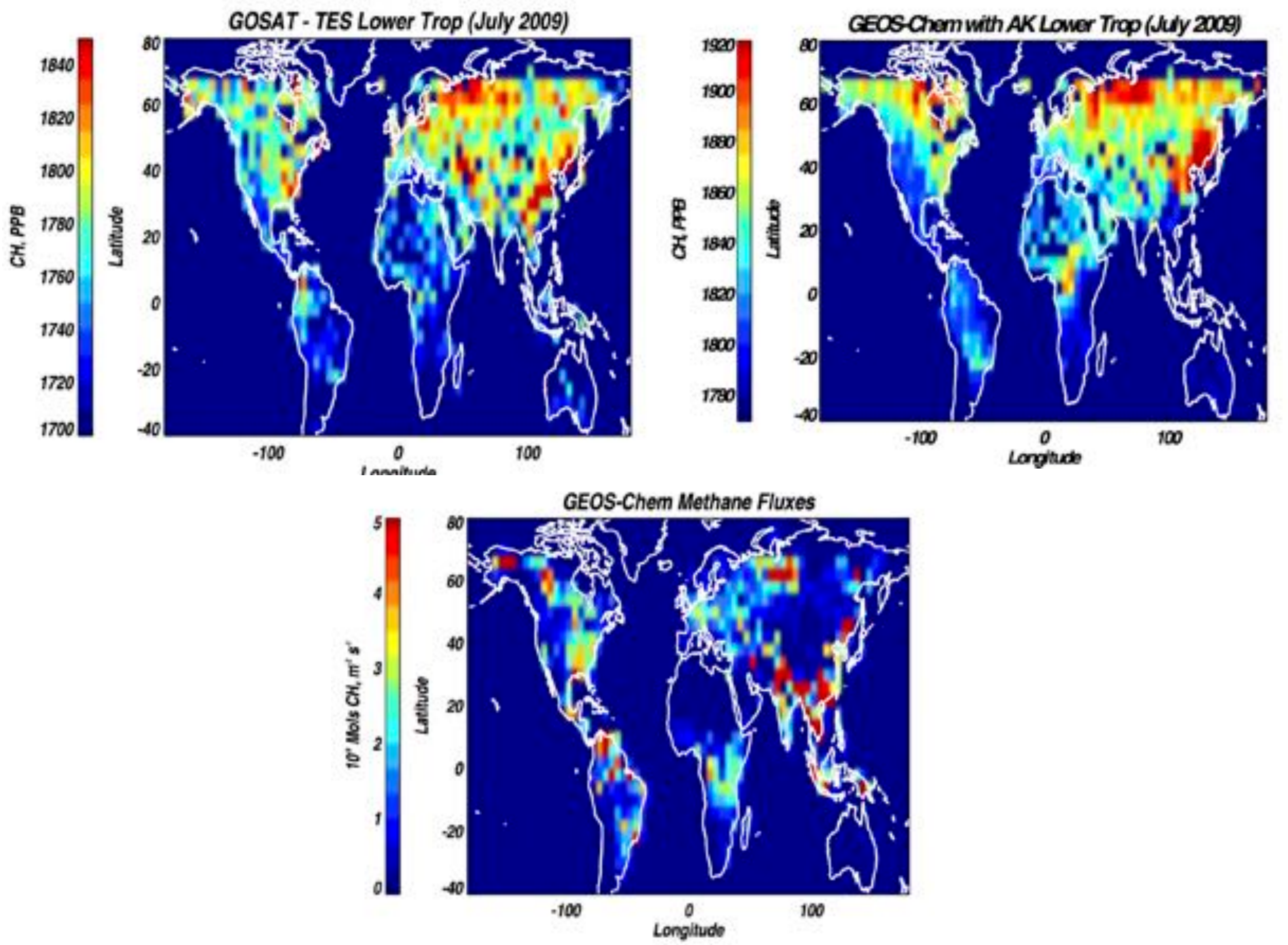
Precision depends on (1) noise, (2)sampling differences between GOSAT and TES, (3) cross-state error in TES free-tropospheric methane

Comparison to Surface Network



Comparison to surface data (via GEOS-Chem model) suggests that data are biased low by ~65 ppb)

Comparison between data and model reveal regional enhancements over methane sources



Summary

Lower tropospheric methane can be quantified from "Level 2" CH_4 estimates from separate near IR and thermal IR measurements.

For GOSAT / TES combination the precision is ~30 ppb, accuracy is ~6 ppb for a monthly averaged estimate on a 4x5 bin. These data are biased low by ~65 ppb based on comparison with the surface network.

GOSAT / TES Lower tropospheric estimates can resolve the boundary layer → potentially large reduction of uncertainty in methane fluxes from model transport and chemistry error using these data