Modeling and Observing Near-Infrared Methane Surface Radiative Forcing

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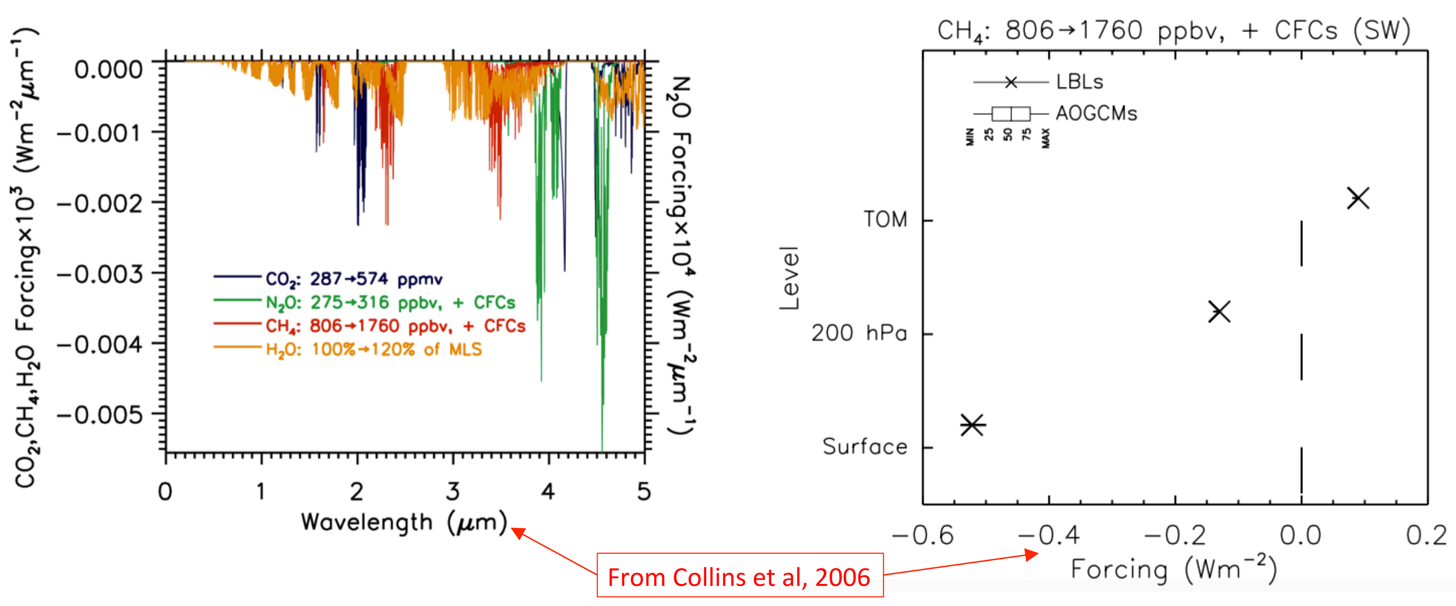
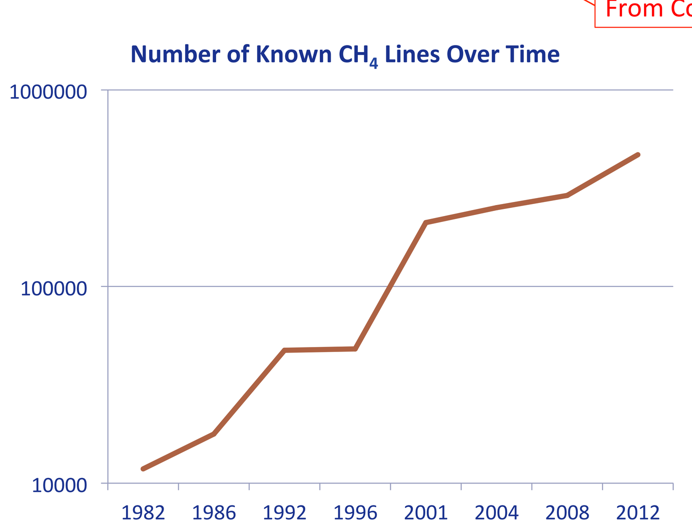
ABSTRACT

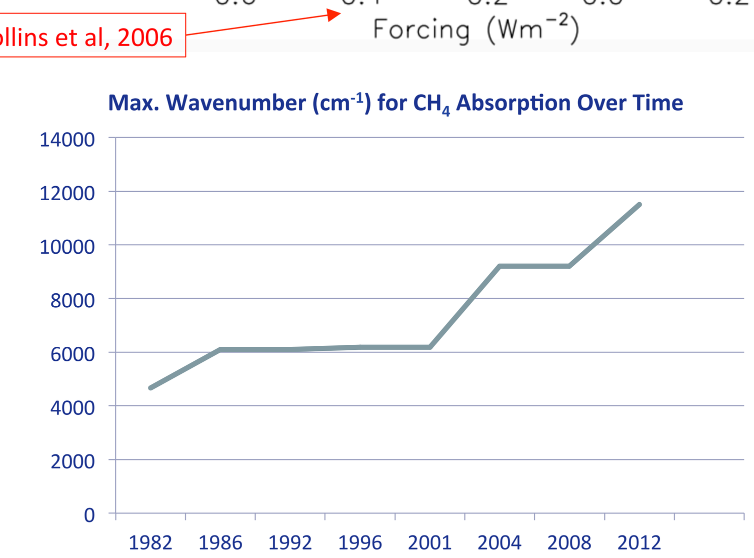
Approximately 30% of the radiative forcing from methane arises from near-infrared absorption features[1], which results in decreased solar insolation throughout the troposphere, but its impact on the surface energy budget has never been rigorously quantified. We present the first global calculation of CH4 surface forcing using massively-parallel line-by-line (LBL) radiative transfer models that include realistic atmospheric and surface boundary condition inputs. We also present techniques for using observations from the SAS-HE instrument at the ARM SGP site to detect the influence of NIR CH4 absorption on the surface energy budget.

Background

CH_4 exhibits remarkable complexity in its spectroscopic absorption[2], and has numerous IR and NIR absorption features, which means that it alters the energy balance at the surface in ***BOTH*** the LW and SW. The scientific understanding of how CH_4 affects SW radiation continues to face major revisions[3,4] and was grossly underrepresented in climate models until recently[5,6].







CH_4 Spectroscopic Uncertainty

Spectroscopic uncertainty is based on HITRAN error codes. It is derived from statistics built off of perturbations based on values corresponding to error codes[7].

Spectral sums of fluxes $x_k = \int F(v)dv$

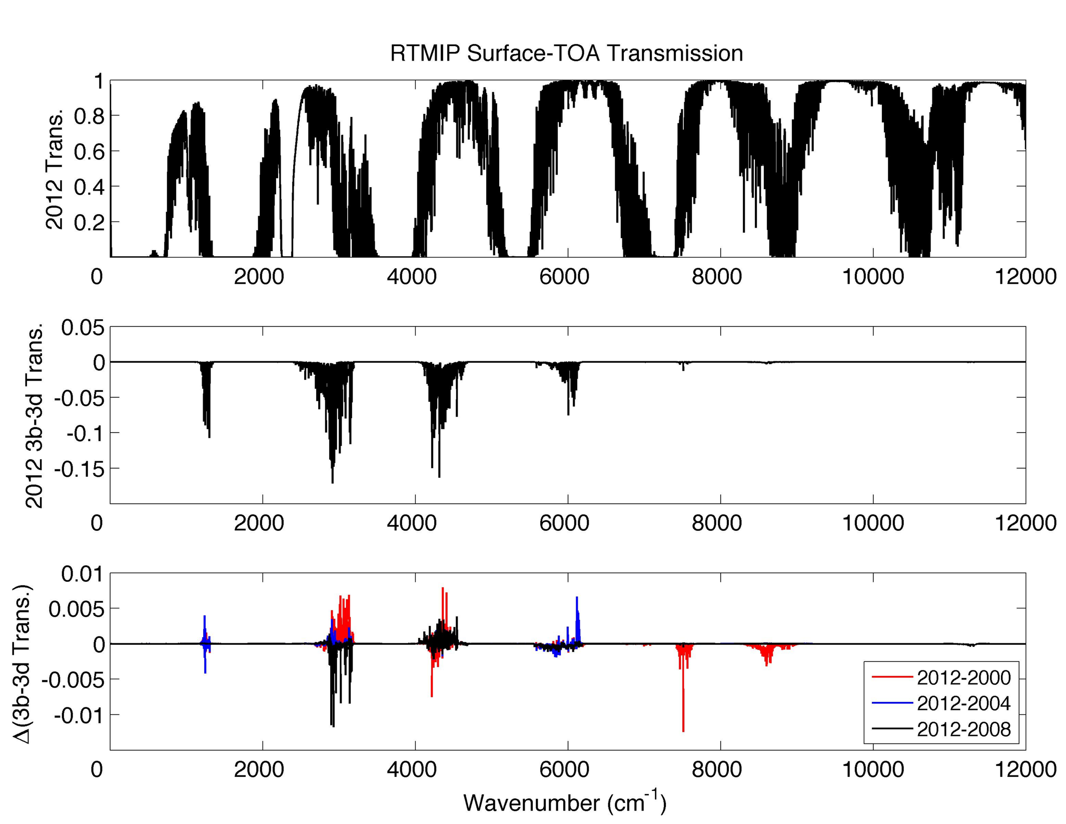
First Moments $\sigma_i^2 = \frac{1}{N}\sum_{k=1}^{N}(xi - \mu_x)$

Second Moments $\sigma_{xy}^2 = \frac{1}{NM}\sum^{N}\sum^{M}(x-\mu_x)(y-\mu_y)$

Correlated Error* (sum of 1st moments) $CE = \sigma_{D182}^2 + \sigma_{U182}^2 + \sigma_{D91}^2 + \sigma_{U91}^2$

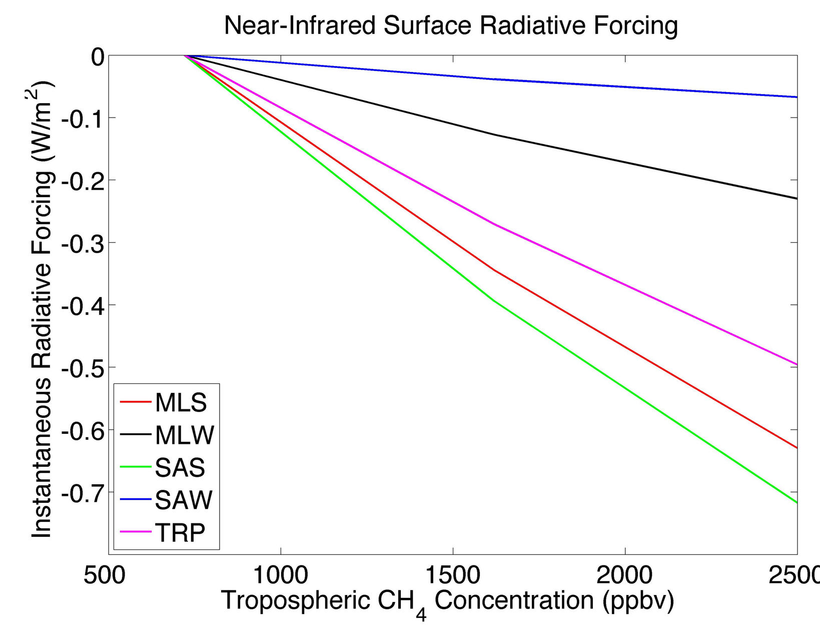
Uncorrelated Error* (sum of 2nd moments) $UCE = 2*(-\sigma_{D182U182} - \sigma_{D182D91} + \sigma_{D182U91} + \sigma_{U182D91} - \sigma_{U182U91} - \sigma_{D91U91})$

Uncertainty in NIR forcing from spectroscopy <1% of total forcing. Additionally, major updates to CH_4 line parameters associated with HITRAN2000, 2008, and 2012 yield small changes (<1%) in RF across the NIR features[8].



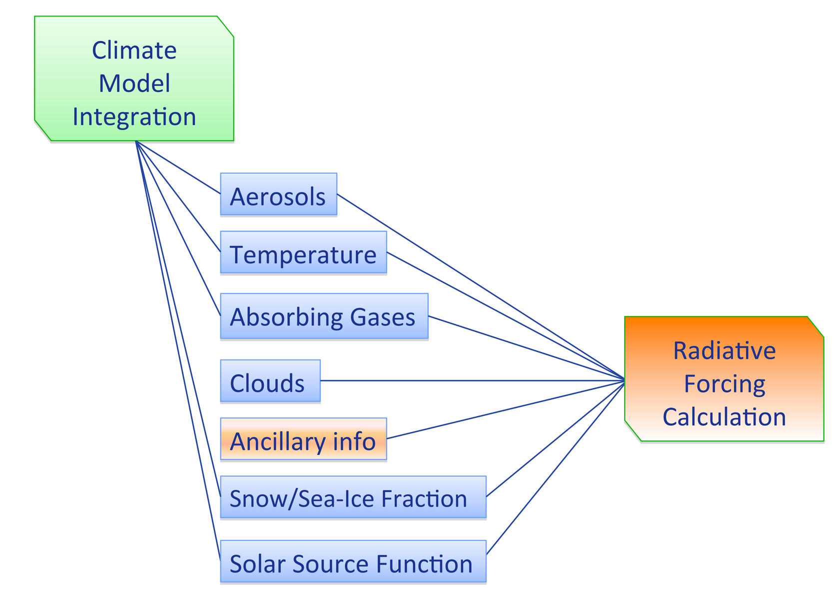
Near-Infrared Surface Forcing

Increasing concentrations of CH_4 will reduce the amount of near-IR radiation incident at the surface in the CH_4 absorption bands. The amount of this reduction depends on the length-of-day (solar zenith angle) and scattering species. Model atmospheres[9] show a range of possible CH_4 surface forcing values.



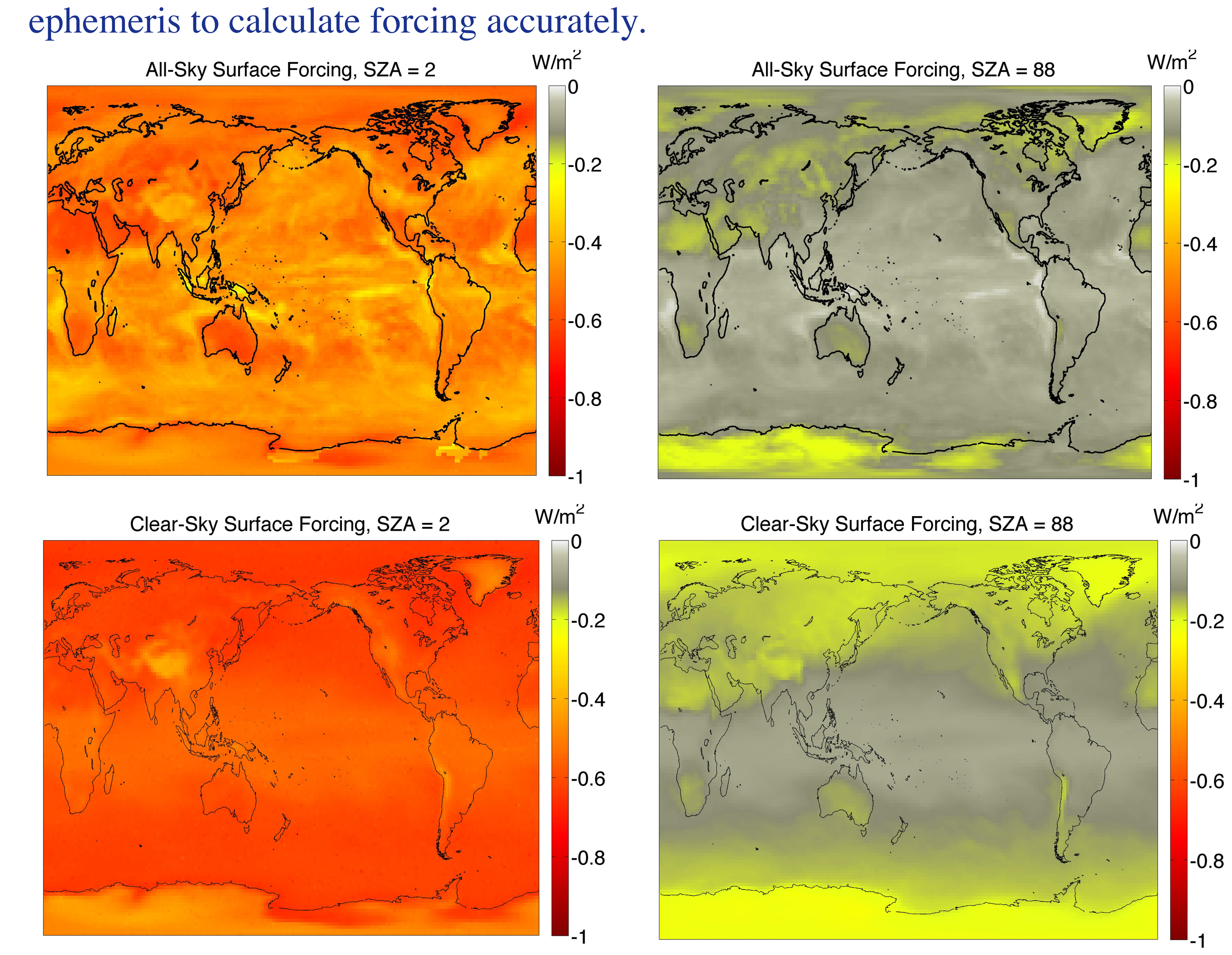
Global CH4 Forcing Calculations

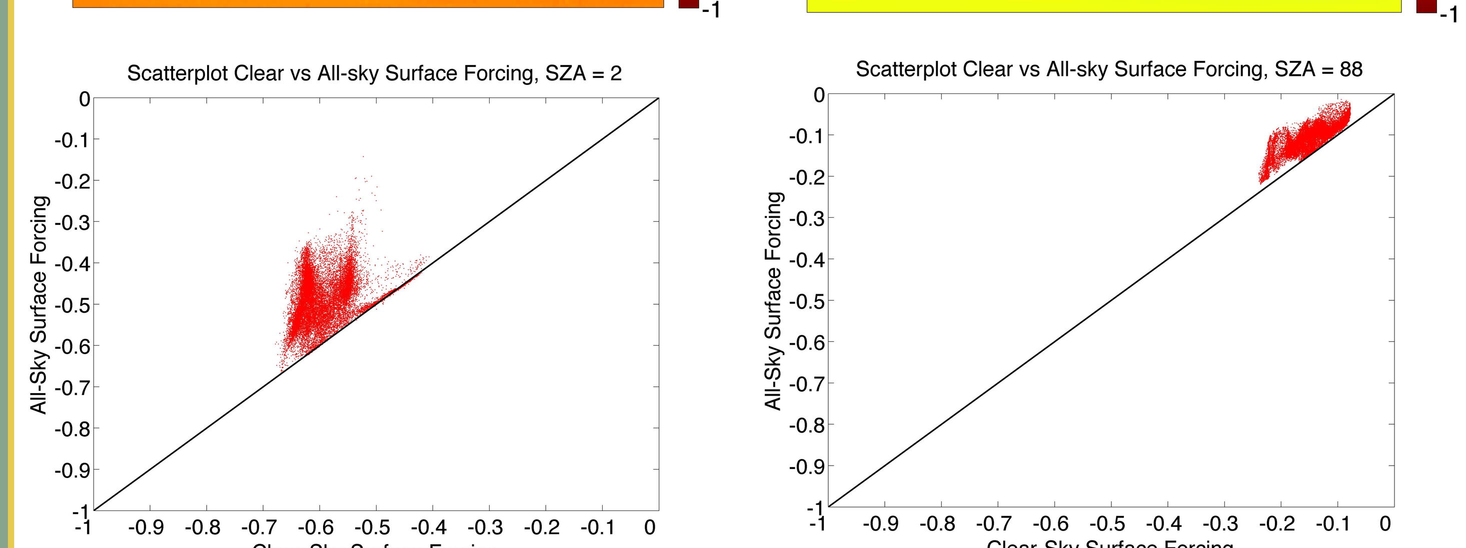
A tool has been developed[10] to calculate radiative forcing (Present-Day CH_4 at 1714 ppbv – Pre-Industrial CH_4 at 722 ppbv nominal tropospheric concentrations) at all levels using the atmospheric and condensate states, surface reflection, and solar source information from each model reporting to the CMIP5 archive.



Effects of Clouds and Solar Zenith Angle

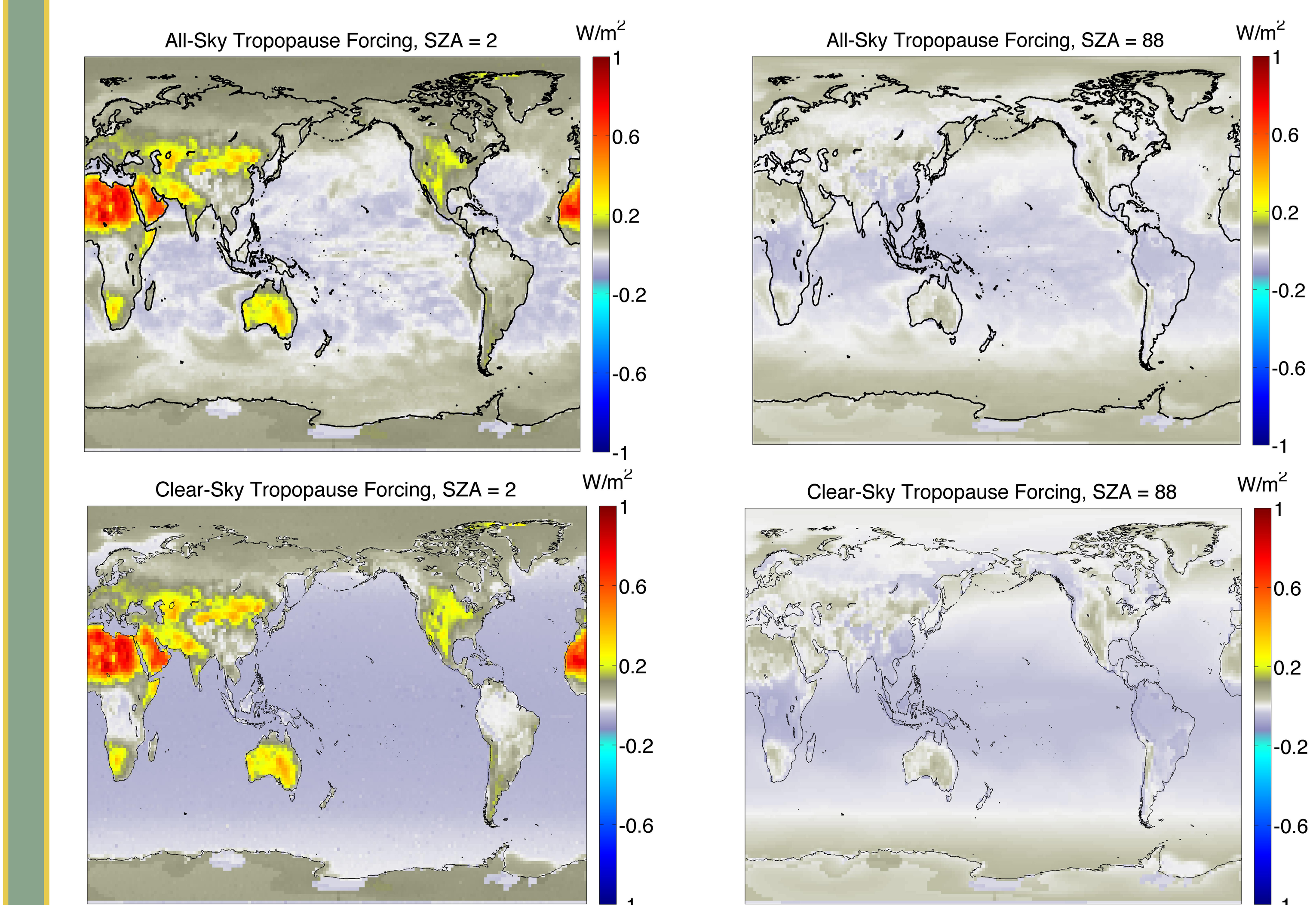
We show a sample calculation based on the INM-CM4 model for 2006, with the lowest-reported equilibrium climate sensitivity (2.08 °K/2xCO2)[11], which is the first global calculation of SW forcing by any greenhouse gas that takes into account clouds and surface reflection. We note the importance of the solar zenith angle and the need to integrate over the diurnal cycle and solar ephemeris to calculate forcing accurately.

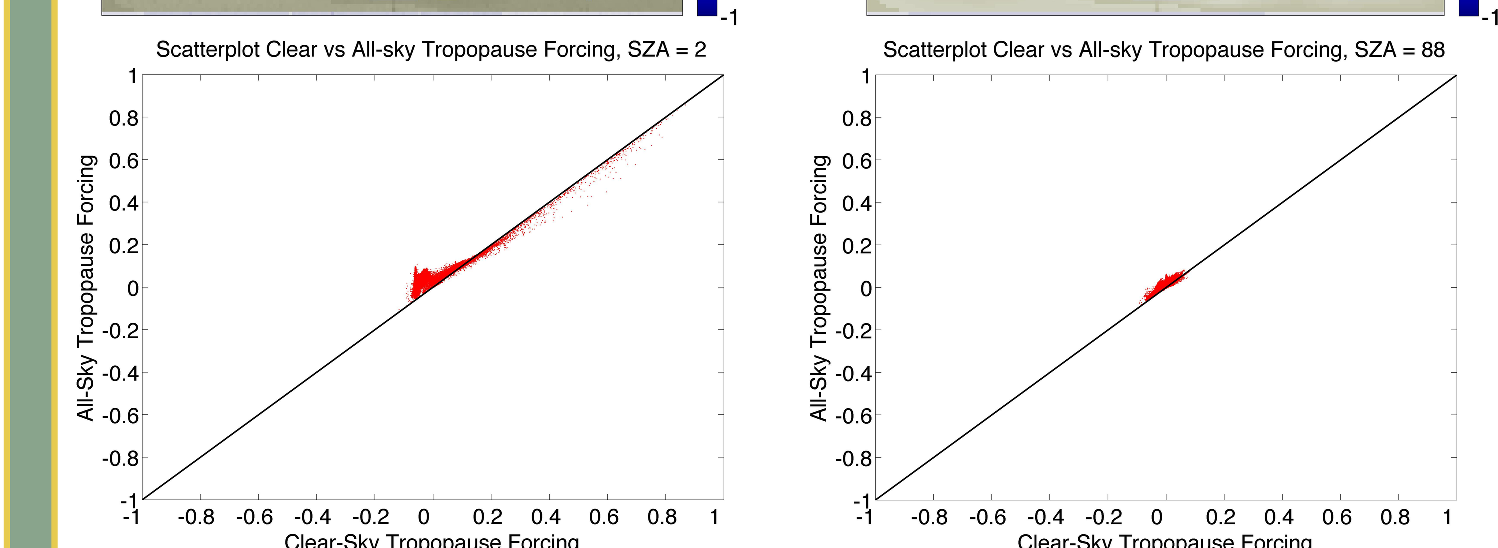




Surface vs. Tropopause Forcing

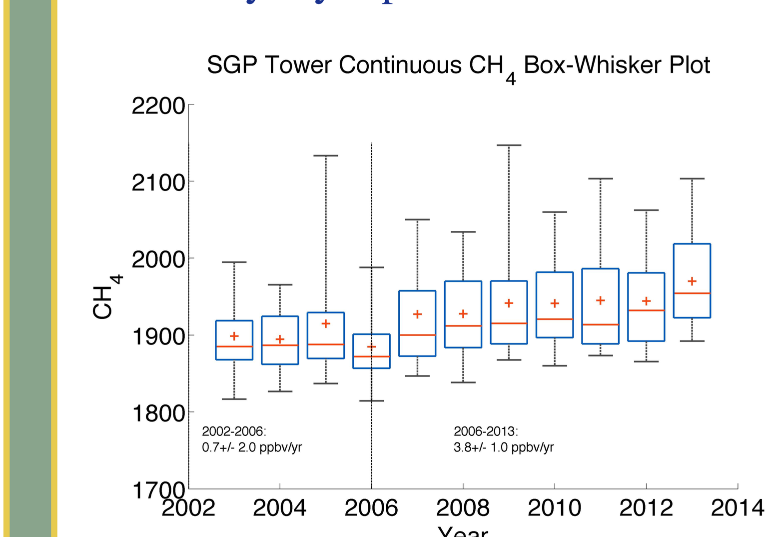
Unlike mid-IR forcing, NIR CH_4 forcing at the surface and tropopause can be of different sign, due to the lack of CH_4 absorption in the stratosphere and the larger role of photon scattering in the troposphere that affects the tropopause energy balance more than the surface energy balance.

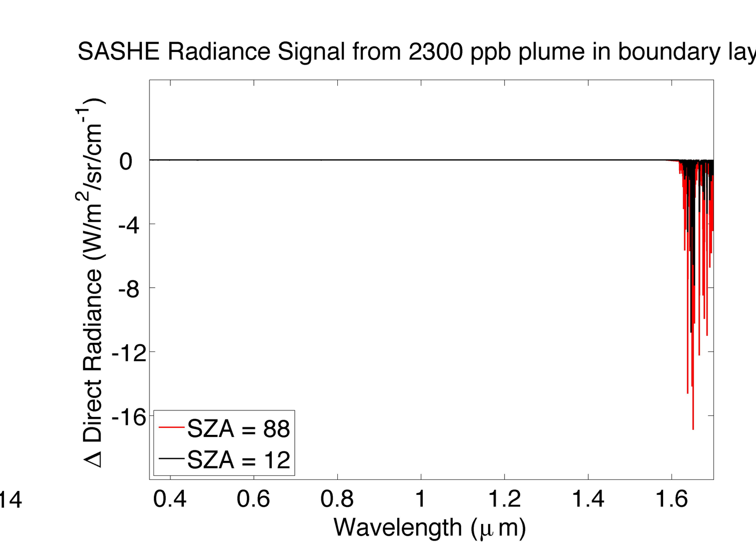




Prospects for Detection with ARM Data

The SAS-HE instrument at the ARM SGP site measures spectrally-resolved direct and diffuse radiation. We show here the radiometric signals from boundary-layer perturbations based on the 99% plume of CH_4 from tower obs.





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Acknowledgements

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