Observed differences in surface radiative forcing trends from methane

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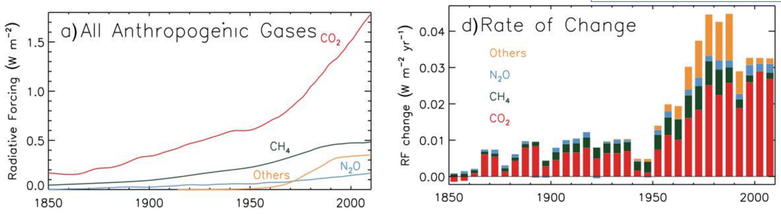
ABSTRACT

Here we measure clear-sky longwave surface radiative forcing from CH_4 using spectroscopic observations and ancillary data at Atmospheric Radiation Measurement Program (ARM) sites. From 2002-2007, the trend in forcing does not differ significantly from zero, but subsequently, the trend in forcing at the Southern Great Plains site is 0.26±0.05 W/m^2/decade which is 30% higher than the trend from CO_2. At the North Slope of Alaska site, the trend is 0.06±0.13 W/m^2/decade. The difference in observed trends at the two sites is consistent with the influence of increasing oil and natural gas production only near SGP.

Background

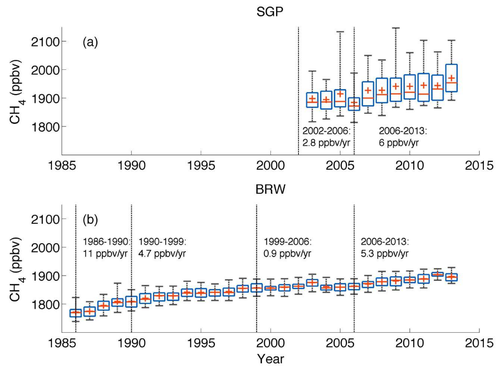
Over the past 100 years, CH_4 has been a substantial fraction of anthropogenic radiative forcing, second only to CO_2[(1)]. After a hiatus in the global increase of CH_4 mixing ratios from 1995-2006, recent studies indicate that CH_4 is once again rising[(3)] and that US emissions of CH_4 may be underestimated[(4,5)]. Using ARM measurements, we can track CH_4 concentrations and CH_4 surface forcing[(6,7)].

From IPCC AR5, Ch 8

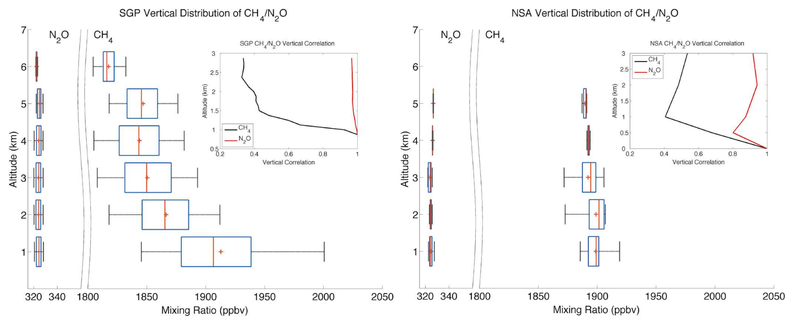


CH_4 Measurements

Ground-based measurements of CH_4 at BRW (near NSA) and SGP[(7)] indicate rising atmospheric concentrations with a hiatus in the growth of atmospheric CH_4 mixing ratios from 1995-2005. They also show positive skewed distributions at SGP and more normal distributions at BRW.

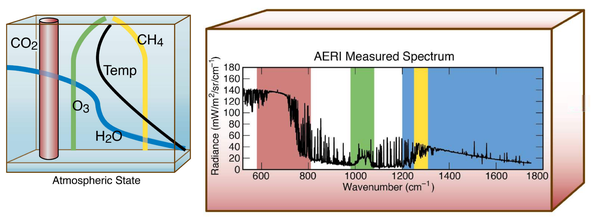


Aircraft-based flask measurements of CH_4 also indicate rising concentrations since 2005[(8)], but low correlation between the surface and free troposphere.



Spectroscopic Measurements

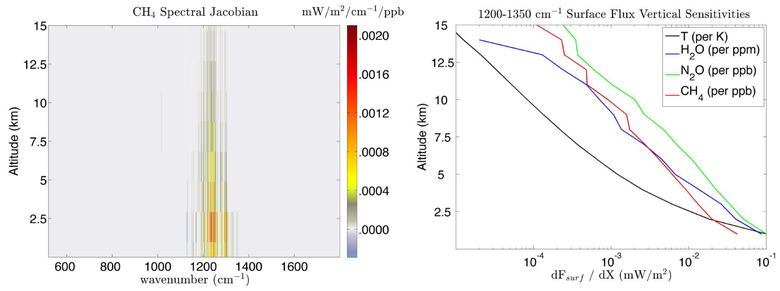
AERI spectral measurements are sensitive to CH_4 concentrations. Their change can be used to observe radiative forcing.



Forcing Determination

Using a combination of spectroscopic measurements and controlling for the atmospheric thermodynamic state with radiosondes, we can separate out the contribution of CH_4 to clear-sky downwelling radiance spectra and its infrared surface radiative forcing[(6)]. We difference measurements from a line-by-line radiative transfer calculation at pre-industrial CH_4 (722 ppbv) to produce residuals and derive this radiative forcing.

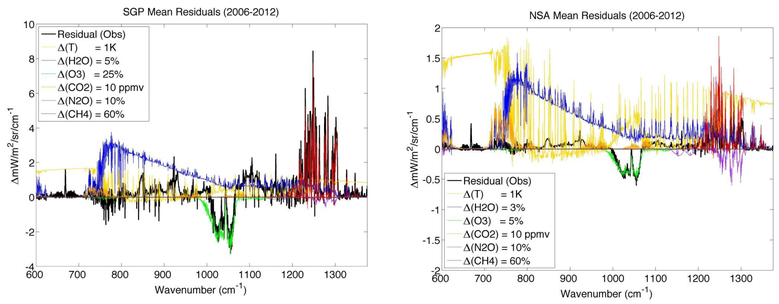
$$CH_4 \text{ forcing} = \int_{\upsilon_1}^{\upsilon_2} ADM * \left(AERI_\upsilon - LBL_\upsilon \left(T_{sonde}, H_2O_{sonde}, PI\ CH_4 \right) \right) d\upsilon$$



Spectral measurements are sensitive to CH_4 only from 1200-1350 cm^{-1}, but effects from T, H_2O, and N_2O must be considered to determine forcing. Effects of T and H_2O can be controlled through independent measurements from radiosondes. N_2O error was estimated to be insignificant because measured profiles of N_2O indicate small variability and trends less than 0.9 ppbv/yr (0 to 5.5 km)[(7)].

Spectral Residuals

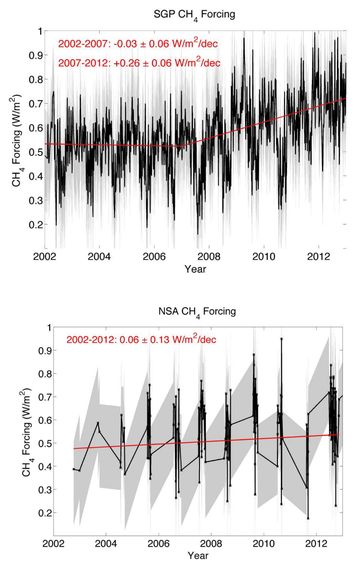
Significant residuals only between 1200 and 1350 cm^{-1} indicate our approach captures forcing from CH_4 and is not affected by errors in T, H_2O, or CO_2, though ozone is biased high in the radiative transfer calculations.



Radiative Forcing Trends

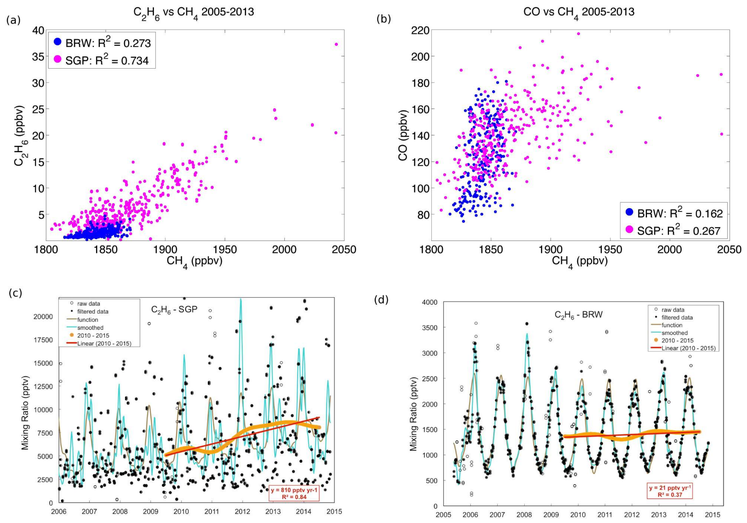
Surface radiative forcing from CH_4 at SGP does not differ significantly from zero before 2007. After 2007, it is 30% larger than the observed decadal trend for CO_2 surface radiative forcing.

Surface radiative forcing from CH_4 does not exhibit a change-point at NSA. A small, but not significant positive trend in CH4 forcing at NSA is detected, but the long integration times needed at NSA make change-detection challenging.



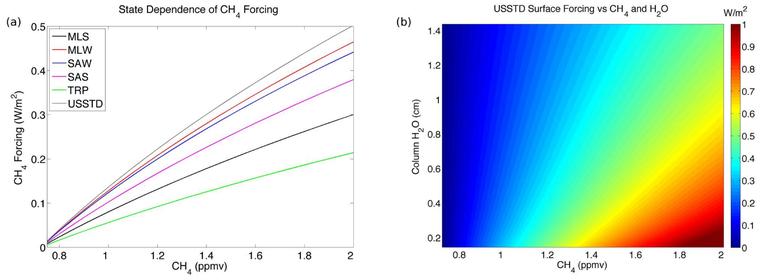
Role of Oil and Natural Gas Emissions

Inverting measured concentrations to derive CH_4 sources is challenging. However, correlated increases in atmospheric C_2H_6 and CH_4 arise almost exclusively from anthropogenic activity[(9)], and C_2H_6 is 10x higher at SGP than NSA. Correlations between C_2H_6 and CH_4 are high at SGP and low at NSA. Another possibility (combustion) is excluded by CO and AOD data (not shown). Recent positive trends in C_2H_6 at SGP are consistent with increasing influence of oil and natural gas emissions. Recent trends of C_2H_6 at BRW are flat.



Role of Atmospheric Water Vapor

CH_4 forcing at the surface and TOA depends both on CH_4 concentrations and on humidity. Decreasing trends in atmospheric water vapor at SGP[(10,11)] are also enhancing the radiative forcing from methane.



Discussion

The NSA and SGP sites have contrasting sources of CH_4. Since 2007, we find a significant forcing trend at SGP from CH_4 with a trend 30% greater than that for CO_2. The forcing trend at NSA is significantly less than SGP. Correlations between CH_4 and C_2H_6 indicate the larger trend at SGP is consistent with increased oil and natural gas extraction. Coupled with H_2O dependence, CH_4 emissions may be perturbing the surface energy balance heterogeneously.

References

1. Myhre, G., et al. (1998) *Geophys. Res. Lett.* doi:10.1029/98GL01908.
2. Myhre, G., et al. (2013) *IPCC Fifth Assessment Report, Working Group I, Chapter 8*.
3. Nisbet, E.G., et al. (2014) *Science*. doi:10.1126/science.1247828.
4. Miller, S.M., et al. (2013) *Proc. Natl. Acad. Sci.* doi:10.1073/pnas.1314392110.
5. Turner, A.J., et al. (2016) *Geophys. Res. Lett.* doi:10.1002/2016GL067987.
6. Feldman, D.R., et al. (2015) *Nature*. doi:10.1038/nature14240.
7. Dlugokencky, E.J., et al. (1995) *J. Geophys. Res.*, doi:10.1029/95JD02460.
8. Biraud, S.C., et al. (2013) *Atmos. Meas. Tech.*, doi:10.5194/amt-6-751-2013.
9. Xiao, Y., et al. (2008) *J. Geophys. Res.* doi:10.1029/2007JD009415.
10. Gero, P. J., et al. (2011). *J. Climate*, doi:10.1175/2011JCLI4210.1.
11. Jung, M., et al. (2010), *Nature*. doi:10.1038/nature09396.

Acknowledgements

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