Observations of the High-Latitude Seasonal Cycle of WMGHG Surface Radiative Forcing

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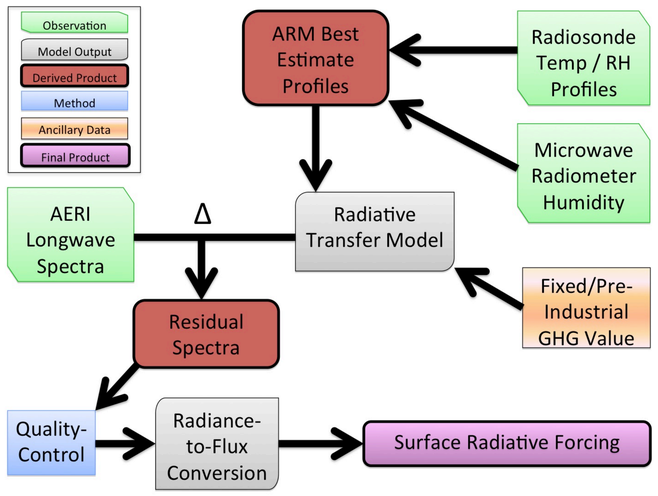
ABSTRACT

Polar amplification and its impact on ice-sheets, while largely driven by earth system feedbacks, is initiated by rising atmospheric greenhouse gas mixing ratios. We measure the seasonal-cycle of methane radiative forcing at the Summit Station in Greenland and at McMurdo Station in West Antarctica and find that the instantaneous direct radiative effect of this greenhouse gas is completely out-of-phase with its atmospheric mixing ratio. This striking finding can be explained by Planck function asymmetry which explains at least 84% of the variance in the seasonal cycle signal. From this, we find that both the amplitude and phasing of the seasonal cycle in WMGHG surface radiative forcing over the ice-sheets will depend both on changing mixing ratios of these gases and local trends in atmospheric thermodynamics.

Background

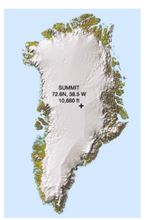
Greenhouse gas radiative forcing has traditionally been calculated with radiative transfer models. It can also be observationally determined at the surface by differencing radiometric observations from calculations with fixed or pre-industrial greenhouse gas concentrations[1,2].

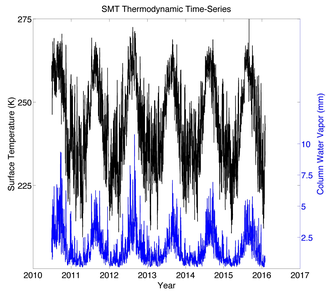


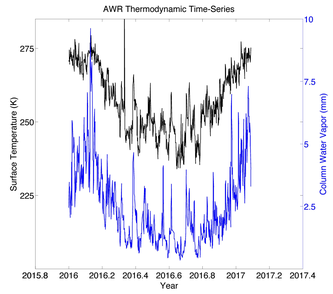
Observed surface radiative forcing trends from CH_4 have been found to depend on water vapor trends at the Southern Great Plains site[2].

Ice-Sheet Observations

Data from heavily-instrumented sites at Summit Station, Greenland, and McMurdo Station, Antarctica, enable the observation of CH_4 surface radiative forcing from 2011-Present and in 2016, respectively.

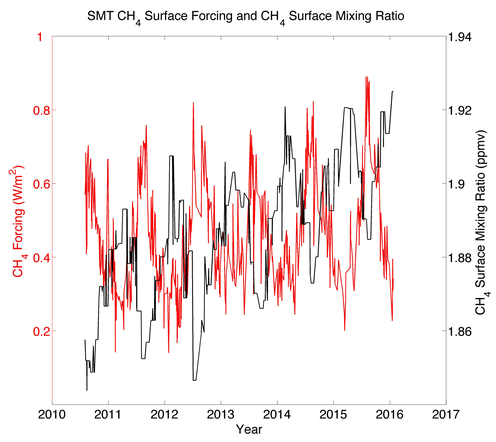




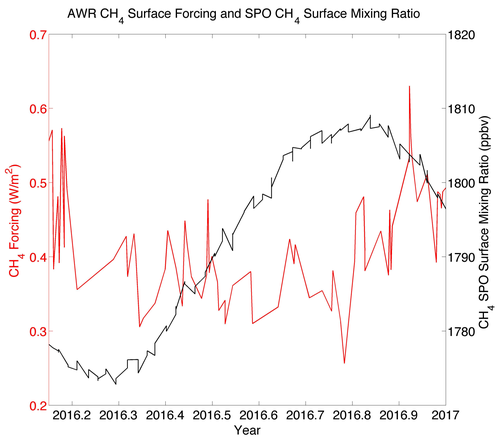


Surface Radiative Forcing Observations

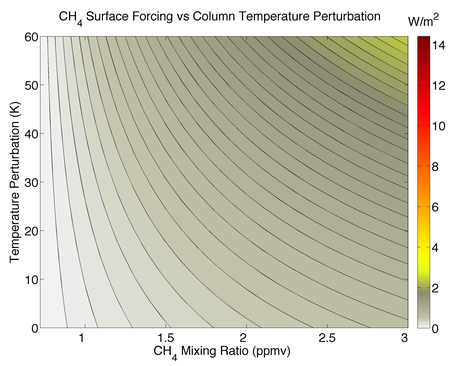
At Summit, the seasonal cycle in observed CH_4 surface radiative forcing is consistently out-of-phase with collocated CH_4 surface mixing-ratio observations.



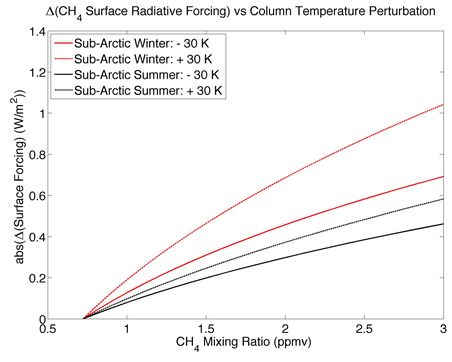
Only one seasonal cycle was observed as part of AWARE, but the seasonal cycle in observed CH_4 surface radiative forcing is also out-of-phase with CH_4 surface mixing-ratio observations at the South Pole Observatory.



Temperature Dependence



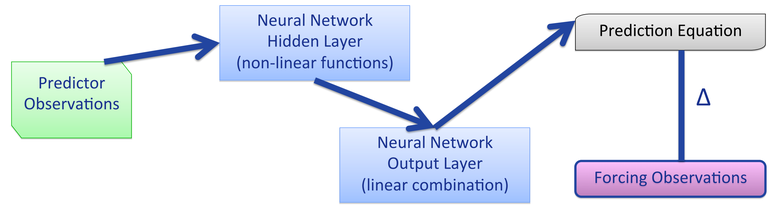
CH_4 radiative forcing depends on atmospheric mixing ratios and thermodynamics. This dependence is non-linear.



Asymmetry in the Planck function with respect to column temperature perturbations leads to an asymmetric forcing response arising from the seasonal temperature cycle over ice-sheets.

Signal Decomposition

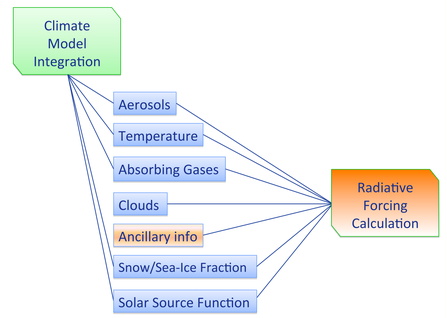
Can observed atmospheric mixing ratios of CH_4 and thermodynamics explain the observed variance in radiative forcing?



With signal decomposition analysis,
we can explain 84% of the observed variance.

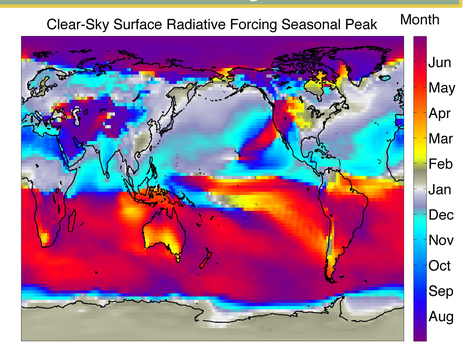
Global CH_4 Forcing Calculations

A tool has been developed[3,4] 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. Spatial variability in seasonal-cycle phase can be diagnosed with this tool.



Spatial Variability in Seasonal Cycle Phase

Comprehensive calculations reveal strong meridional gradients in seasonal cycle phase. Some zonal variability at low- and mid-latitudes also occurs.



Discussion

The direct radiative forcing of ice-sheets by methane has been observed. Its seasonal cycle is out-of-phase with mixing ratios due to forcing temperature dependence. Methane radiative forcing exhibits a spatially-variable seasonal cycle, and this variability will grow over time if the multi-model ensemble predictions of spatial patterns of trends in temperature and moisture are robust.

References

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