

Interactive comment on “Diminished greenhouse warming from Archean methane due to solar absorption lines” by B. Byrne and C. Goldblatt

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Dear Dr. Haqq-Misra,

Thank you very much for the helpful review. We have addressed your comments individually below.

COMMENT: However, the greatest discrepancy between HITRAN 2000 and 2012 occurs for CH₄ abundances that are likely to form a stratospheric organic haze layer (Fig. 4b,c), which would absorb incoming solar radiation and cool the surface. Although previous studies may have overestimated CH₄ warming at these abundances as the authors argue, the significant cooling from the formation of organic haze would lower global temperature likely by much more than the difference between the two HITRAN

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databases. Only when CO₂ abundances are high and organic haze does not form (Fig. 4a) does the difference between the HITRAN databases seem to matter. For the Archean, this suggests that the improvement in radiative transfer is most applicable to haze-free high-CO₂ environments. Possibly conditions like this may have been present in the Hadean or early Archean, which the authors may wish to discuss.

RESPONSE: We agree that an organic haze would likely have a more significant radiative impact than shortwave absorption by methane. However, we disagree that the constraints in the late Archean imply that a haze would form at low CH₄, as there is still considerable uncertainty in the CO₂ abundance in the middle and late Archean and the CH₄ abundance required for haze formation. Furthermore, there are no CO₂ constraints before 2.69 Gyr ago, thus we believe that high methane abundances are plausible without haze formation in the middle to late Archean. We have addressed these concerns in the manuscript with the following paragraph:

“Geological constraints, based on the mass balance of weathering paleosols, have suggested that the atmospheric CO₂ partial pressure was in the range 0.003–0.02 bar in the late Archean [2.69 Gyr ago, Driese et. al., 2011]. Given that an organic haze could form at CH₄/CO₂ ratios as low as 0.2–0.3, this would imply that an organic haze would form at CH₄ abundances greater than 6×10⁻⁴–6×10⁻³. In the presence of an organic haze, shortwave absorption by CH₄ would likely be of less importance. However, at the upper limit of this range, a CH₄ abundance of 6×10⁻³ results in a significant (3–4 K) difference in surface warming between HITRAN versions. Thus, given the constraints on atmospheric CO₂ and organic haze, the calculated reduction in surface warming due to improved line data may have been radiatively important throughout the Archean. Furthermore, atmospheric CO₂ constraints only exist for the latest Archean [2.69 Gyr ago, Driese et. al., 2011]. The solar luminosity used in this study (80% of today’s value) occurred 2.86 Gyr ago [equation 1, Feulner, 2012] which is 170 Myr before the earliest constraint on CO₂ [2.69 Gyr ago, Driese et. al., 2011]. Thus, CO₂ may have been significantly higher than 0.02 bar at this time, meaning atmospheric CH₄

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abundance larger than 6×10^{-3} could have existed without haze formation.”

Interactive comment on Clim. Past Discuss., 10, 4229, 2014.

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