

GENERAL COMMENTS

The authors take a topic that is interesting scientifically and policy-wise, namely the environmental impacts of increased methane emissions from Arctic clathrate destabilization, and produce an analysis of Earth System Model simulations that covers aspects ranging broadly from atmospheric methane and ozone concentrations to temperature and precipitation. Upon closer inspection, however, I find that the whole experiment boils down to a simplistic and unrealistic methane emission perturbation scenario alongside a control simulation. Furthermore, the paper is thin in the analysis of the chemical and physical mechanisms behind the modeled changes in atmospheric composition and climate. In my view, the paper contributes little in the way of useful, new knowledge and should not be published without major additional work.

One major issue with this paper is that the selection of the two simulations is inappropriate, in my view. The authors presumably set out to evaluate the chemical and climatic impacts of an increase in methane emissions due to clathrate destabilization. However, the proper base case should be a steadily warming world rather than one at steady-state under present-day conditions, since they assume that the clathrate emissions will be driven by a warming of 5 deg C/century at 350m, 3 deg C/century at 400–600 m, etc. The climate and atmospheric chemistry of the warmer world would be quite different from that of the present world, so the evaluation of the impacts of an enhancement in clathrate emissions should use the warmer world as the baseline, minus the additional clathrate emissions. Thus, I consider the comparison between the two simulations in this paper to be of limited interest in that it is not specific to the issue of clathrate destabilization, except in that the emissions are placed in areas in the Arctic where destabilization is likely to occur.

The atmospheric chemistry and climate simulations in this study are not coupled to the ocean sediment model (TOUGH+HYDRATE) simulations reported in previous papers. Although that in and of itself is not a flaw, the lengthy description of sediment physics and simulations in the Introduction and Model, Methods, and Data section led me to believe that the simulations were indeed coupled, so I feel that these sections are misleading and should focus more on the current simulations.

The experiment thus boils down to a generic analysis of the impacts of a perturbation in CH₄ emissions relative to present-day levels. I believe other such studies already exist, although there could be new insights to be gleaned from simulations conducted using a complex Earth System Model such as the one used here. Unfortunately, this paper does not share such insights, as it neglects to analyze in detail the feedbacks between climate and chemistry changes. The only discussion of feedbacks I could find is a cursory one on page 26485, lines 19-24 : “A non-linear response is expected due to the fact that as methane reacts with the hydroxyl radical (OH) in the atmosphere the concentration of OH in the atmosphere decreases, reducing the main chemical loss of methane and thereby increasing the lifetime of

CH4 (Prather, 1996). However, our simulation is fully interactive, so our change includes temperature and water-vapor feedbacks as well.” Another example of a lack of mechanistic analysis is their lack of an explanation for what drives the increased variability in the AE scenario. Finally, statements such as "Arctic clathrate emissions increase methane concentrations non-uniformly" (Abstract, lines 16-17) do not represent new knowledge.

SPECIFIC COMMENTS

p. 26478, lines 10-12: The language in the statement “for present-day conditions with and without additional methane emissions from a plausible clathrate release scenario” is confusing—I thought this was referring to plausible "present-day" clathrate emissions. The authors actually mean future emissions.

Introduction: As I mentioned earlier, this section contains perhaps too much material on the physics of clathrate release and its climate impacts, and very little material on atmospheric processes and impacts, which is the actual focus of the current study.

p. 26482, lines 7-8: If you keep this material, please provide a bit of explanation for terms such as disperse and "saturation of 0.03".

Models, Methods, and Data section: You should explain why you are considering only Arctic emissions and not emissions that might be driven by warming oceans in other areas such as the Antarctic.

p. 26484, lines 6-7: This suggests that the OH abundance is very high in the model. What's the CH4 lifetime with respect to OH? And what are the implications?

p. 26484, lines 11-12: But doesn't the ocean warm significantly (albeit slowly) over hundreds of years in response to an increase in radiative forcing? Perhaps the increase in radiative forcing in the AE scenario is just too small for deep ocean drift to be important?

p. 26485, lines 19-24: You ought to quantify the impacts of these feedbacks and the change in CH4 lifetime.

p. 26485, lines 26-29: How realistic is the interannual variability of CH4 in the control case? And the same for temperature. If it's not simulated realistically in the control case, then it probably won't be simulated well in the AE case either; you should discuss.

p. 26486, lines 1-4: I don't understand the point here--to assess possible increases in interannual variability, one does need to consider the variability of the C simulation.

p. 26486, lines 13-16: Percentage increase in temperature isn't a meaningful quantity. This should be omitted.

p. 26486, lines 19-29: I don't think this test answers the question you pose, namely are the temperature differences at the poles significantly larger compared to lower latitudes. For that, you should consider using a two-sample t test.

p. 26491, lines 6-7: But in the real world, methane emission increases may occur in many places around the world, not just in the Arctic, so this point may not be very relevant.

Figure 3: Does “skin temperature” refer to ground temperature? Don't most studies of climate change focus on air temperature?

TECHNICAL CORRECTIONS

p. 26478, line 3: Inconsistent here--water is a compound while gas is a phase.

p. 26478, lines 15-16: Should be nitrogen oxides, not “nitrous oxide”.

p. 26478, line 21: Add the word “anthropogenic” before greenhouse gas.

p. 26478, line 26: Aren't microbial and thermogenic the only processes?

p. 26479, lines 11-13: “There are also other potentially large sources of methane in the Arctic that could impart methane to the atmosphere in a warming scenario, particularly permafrost, the East Siberian Arctic Shelf,....” You already cite continental margins and permafrost above, so how are these sources different? Please be precise.

p. 26488, line 4: The figure caption describes it as the standard deviation of the AE case, not the standard deviation of the difference between the AE and C cases. The latter quantity is preferable here.

Figure 2: I don't see the arrows referred to in the caption.