General comments

This paper is proposing and testing a new hypothesis concerning the influence of volcanic eruptions for the onset of so-called Dansgaard-Oeschger (DO) events, which corresponds to large warming events found in Greenland ice cores that takes place in a few decades. For this purpose, the authors first analyse various ice core records from Greenland and Antarctica, which provide estimate of DO variability from δ18O records and volcanic eruptions from concentrations of sulfate deposition in the ice cores. The authors use appropriate statistical approaches to show that volcanic eruptions occur more frequently than random occurrences can explain, less than five decades before the onset of some DO events. This result based on relatively high number of events and well-defined statistical tests seem robust. The authors then analyse the potential impact of such large volcanic eruptions might have on Atlantic Meridional Overturning Circulation (AMOC), a well-known tipping element of the Earth system, which is believed to be associated with DO variability. For doing so, they use an ocean-only model and find that, quite counter-intuitively, a volcanic eruption can reactivate the AMOC from an off-state, through thermally driven large increase of density in the North Atlantic, which allows the AMOC system to cross a threshold and come back to an active state.

This is a very well-presented and structured paper. The science proposed is also well thought and original. The methods are well-depicted and offer first interesting evidences to support the hypothesis presented, as well as interesting physical explanations. For all those reasons, this paper clearly deserves to be published, and fit very well with Climate of the Past main topics. This will be a very valuable input concerning the potential explanations of DO variability.

At this stage, the main weakness of the paper concerns the physical interpretation of the results obtained using ice core reconstructions and statistical analysis. This is because the model used might not be appropriate since it neglects a large number of processes (e.g. sea ice dynamics), include restoring terms at the surface that might strongly affect AMOC dynamics, and use steady state from present-day conditions, which are quite far from the ones during the glacial period. Those shortcomings are relatively well discussed at the end of the paper, but might deserve a bit more explanations for completeness.

Since the authors are honest in their presentation and already highlight relatively well the caveats of their study, I have mainly minor and specific comments to provide to them, which might be useful to further improve the quality of their manuscript.

Specific comments

- Page 6, line 9: I suggest here to also try to discuss the amplitude of the eruptions considered not only as compared to Tambora, but also as compared to Samalas eruption. From what I understand, the mean amplitude of the eruptions considered here to help triggering a DO onset is about 2-3 times larger than that of Tambora, which might correspond about to the amplitude of Samalas (e.g. Jungclaus et al., 2017). There exists a number of models that do consider this eruption in PMIP4 Last

Millennium simulations, which might be interesting to consider in follow up studies to evaluate the associated climate impacts, etc.

- Pages 7, line 19: it should be stated more clearly here that the model is an OGCM. This choice has strong consequences as it is not properly considering interactions with the atmosphere, and more importantly, the restoring terms might strongly affect the stability of the AMOC.
- Page 8, line 9: I assume it is 35 g/kg and not 3.5 g/kg, is that correct?
- Page 9, line 14: the citation of Fig 6a that early in text is raising an issue, since normally, the figures appear in the order of their citation of the text. Also, I have the feeling that too much result materials are presented here, while “Material and Methods” should mainly describe the tools, not the results obtained with them.
- Page 9, lines 8-10: this reference to data from Lin et al. (2021) is a bit surprising at this stage. I think it should be introduced in the section 2.1 and better compared with the other reconstruction used.
- Page 9, line 13: typo: “evidence” should be “evident”
- Figure 3: I suggest to put also estimate from Samalas eruption here.
- Figure 6: as compared to hysteresis from various EMICs shown in Rahmstorf et al. (2005), this one seems a bit different. Present-day state is in particular not bistable, contrary to what is found in a number of AMOC in Rahmstorf et al. (2005). I suggest to discuss this somewhere in the last section and compare the bifurcation figure with Rahmstorf et al. (2005).
- Page 19, line 18: the use of “likely” has a quantitative meaning in climate community due to IPCC reports. I suggest to reformulate this sentence which is not clear enough, notably the use of “some DO warming transitions” into a more quantitative IPCC-like assessment. Given the sentence just before, I would say that: “it is thus *very likely* that volcanic eruptions occurring a few decades before a DO warming contribute to this onset”. Indeed, in IPCC terminology “very likely” corresponds to above 90% confidence level. This still does not mean that all DO events are triggered by volcanic eruptions… I let the authors further improve such a formulation to be entirely in line with the high precision of their results.
- Page 20: From my understanding of the impact of large volcanic eruptions on the AMOC, I think numerous processes including sea ice and salinity might be at play. Generally speaking, I would interpret the results obtained from the ice cores a bit differently than what is proposed here using the simple OGCM. Volcanic eruptions are inducing strong excitation of the main variability modes of the North Atlantic (e.g. Swingedouw et al., 2017). In this respect, they can be considered as an exciter, an energy provider of variability of the AMOC following volcanic forcing. Here, following an eruption of the intensity of Samalas, there might large oscillations in the AMOC (e.g. Mignot et al., 2011, their Fig. 2). These oscillations can be positive ones, which clearly might increase the chance of noise-induced bifurcation highlighted here, but interpretated mainly through thermal buoyancy forcing at the surface from the volcanic eruptions, while many other processes might be at play. Thus, it is the fact that volcanic eruptions induce a strong variability (or noise) in the system that explain the shift, whatever the exact processes, which might deserve a more comprehensive climate model. This is more or less already what the authors depict, but this is not stated very clearly in my opinion. The exact mechanisms behind this excitation of larger noise are then not that essential at this stage of the hypothesis (also because

AMOC response to volcanic eruption might be model dependent…even in more comprehensive ones).

References

Jungclaus, J.H., Bard, E., Baroni, M., Braconnot, P., Cao, J., Chini, L.P., Egorova, T., Evans, M., González-Rouco, J.F., Goosse, H., Hurtt, G.C., Joos, F., Kaplan, J.O., Khodri, M., Klein Goldewijk, K., Krivova, N., LeGrande, A.N., Lorenz, S.J., Luterbacher, J., Man, W., Maycock, A.C., Meinshausen, M., Moberg, A., Muscheler, R., Nehrbass-Ahles, C., Otto-Bliesner, B.I., Phipps, S.J., Pongratz, J., Rozanov, E., Schmidt, G.A., Schmidt, H., Schmutz, W., Schurer, A., Shapiro, A.I., Sigl, M., Smerdon, J.E., Solanki, S.K., Timmreck, C., Toohey, M., Usoskin, I.G., Wagner, S., Wu, C.-J., Yeo, K.L., Zanchettin, D., Zhang, Q., Zorita, E., 2017. The PMIP4 contribution to CMIP6 – Part 3: The last millennium, scientific objective, and experimental design for the PMIP4 <i>past1000</i> simulations. Geosci. Model Dev. 10, 4005–4033. https://doi.org/10.5194/gmd-10-4005-2017

Mignot, J., Khodri, M., Frankignoul, C., Servonnat, J., 2011. Volcanic impact on the Atlantic Ocean over the last millennium. Clim. Past 7, 1439–1455. https://doi.org/10.5194/cp-7-1439-2011

Rahmstorf, S., Crucifix, M., Ganopolski, A., Goosse, H., Kamenkovich, I., Knutti, R., Lohmann, G., Marsh, R., Mysak, L.A., Wang, Z., Weaver, A.J., 2005. Thermohaline circulation hysteresis: A model intercomparison. Geophys. Res. Lett. 32, L23605. https://doi.org/10.1029/2005GL023655

Swingedouw, D., Mignot, J., Ortega, P., Khodri, M., Menegoz, M., Cassou, C., Hanquiez, V., 2017. Impact of explosive volcanic eruptions on the main climate variability modes. Glob. Planet. Change 150, 24–45. https://doi.org/10.1016/j.gloplacha.2017.01.006