

The authors of this manuscript argue that the large tropical eruption of Mt. Pinatubo has had little impact on Northern Hemisphere stratospheric polar vortex strength and virtually no impact on European surface temperature. With the help of large ensembles, they show that internal variability is sufficient to explain the observed temperature response after Mt. Pinatubo and possibly as well as for other large tropical eruptions. The proposed stratospheric mechanism of how volcanic eruptions dynamically influence European winter temperatures is hence called in the question by the authors.

I think the manuscript is important and of great scientific interest as it will possibly intensify the discussion about the dynamic impact of large volcanic eruptions which has been taken for granted so far. The impact of internal variability has been too much neglected so far, in this sense the manuscript offers a new, quite drastic, perspective. After addressing the few points I have, the manuscript should be suitable for publication.

### **1. General comments** (I refer to the revised version of the manuscript):

1. I feel that the authors are a little too overconfident with the conclusion that internal variability alone is sufficient to explain the surface temperature signal in the winter following tropical volcanic eruptions. There is a significant acceleration of the polar vortex of 3,5-5 m/s (see specific comment below) after Pinatubo in one particular climate model as well as in the CMIP5 ensemble (Bittner et al. 2016). I agree that even 5 m/s is small compared to SSW events (or a strong acceleration of the vortex) but even the mean acceleration might have an impact on surface climate (Kidston et al., 2015). Moreover, the change in the mean can very well represent a change of polar vortex variability, i.e. more/less SSW or more episodes of strong vortices, on smaller timescales which have been shown to have an impact on surface climate (Baldwin and Dunkerton, 1999, and many others). One would need to investigate on smaller (probably daily) timescales how the vortex changes after volcanic eruptions in a large ensemble. I am not aware such a study has been done yet and it is clearly not the scope of this manuscript, but I would ask the authors to be more careful in completely dismissing the possibility of a stratospheric influence.

2. That said, I very much agree with the authors that with the too few observations at hand one can and should be skeptical about the “stratospheric mechanism”. It might well be that the comparatively small acceleration of the NH polar vortex after volcanic eruptions are completely dwarfed by the internal variability. However, quite some observational studies show an impact of volcanic eruptions on European climate. In addition to the already cited Fischer (2007) and Shindell (2004), Christiansen (J. Clim., 2007) reports a significantly positive NAO and AO signal in the first winter after major eruptions since Krakatau (1883). Graf et al. (Clim. Dyn., 2014) show that the surface temperature signal under strong polar vortices are very different after volcanic eruptions in contrast to volcanically undisturbed winters. They note, however, the strong influence of internal variability (ENSO and QBO) and the limitation of the small sample size which prevent conclusive statements about mechanisms. Even if accounting for all the limitations of observations, especially if one goes back in time, I feel the authors are still too quick to dismiss the observational evidence. Even if Fischer (2007) reports a stronger surface influence of volcanic eruption in the second post-year eruption, it is very well possible that volcanic eruptions are partly responsible. Yes, I agree that averaging different eruptions strength can be problematic (as indicated in the manuscripts’ discussion).

However, I'd rather argue that even if one has to average many eruptions (we will never get completely comparable Pinatubo eruptions in nature) and they seem to agree on some form of continental winter warming, there is likely to be a causal, physical connection. Of course, the volcanic influence is at least strongly modified by internal variability (as mentioned in the manuscript P2, LL21-25 as "perplexing fact"), but it is possible that a still unknown process is at work. Even if the stratospheric mechanism might not be as important as always assumed (or not important at all), there might be a tropospheric mechanism, involving maybe the ocean with a much longer memory, which influence European climate. With so many observational evidences I think it is rather unlikely that "everything is internal variability", hence I would ask the authors to acknowledge this conflict (observational studies vs. "everything is internal variability") and at least discuss the possibility of a volcanic influence on European winter temperatures which climate models might not capture correctly.

## 2. Specific comments:

P2, LL21-25: As mentioned in my general comment, I do not find it "perplexing" at all that smaller eruptions as El Chichon show a larger surface response compared to Krakatau or Tambora. As the authors stress, internal variability plays a crucial role, hence the possibly volcanic forced signal might be strongly modified/superimposed by internal variability.

P3, LL13-16: I frankly do not understand where these numbers come from. Bittner et al. (2016) show in Figure 2a a polar vortex acceleration of close to 4 m/s (ensemble average) not 2 m/s to a Pinatubo forcing. And these 4 m/s is statistically different from the null hypothesis at 15(25) ensemble members at the 95%(99%) confidence level. So, 100 model runs are more than sufficient to establish that fact.

P9, LL12-13: Same issue here. Which makes the agreement to WACCM4 even "more excellent", but the number of ensemble members are more like 15-25.

P10. L15: here again.

P11., L18: and here.

Christiansen, B. (2008). Volcanic eruptions, large-scale modes in the Northern Hemisphere, and the El Niño–Southern Oscillation. *Journal of Climate*, 21(5), 910-922.

Graf, H. F., Zanchettin, D., Timmreck, C., & Bittner, M. (2014). Observational constraints on the tropospheric and near-surface winter signature of the Northern Hemisphere stratospheric polar vortex. *Climate dynamics*, 43(12), 3245-3266.

Kidston, J., Scaife, A. A., Hardiman, S. C., Mitchell, D. M., Butchart, N., Baldwin, M. P., & Gray, L. J. (2015). Stratospheric influence on tropospheric jet streams, storm tracks and surface weather. *Nature Geoscience*, 8(6), 433.