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Interactive comment on "An empirical model of global climate – Part 1: Reduced impact of volcanoes upon consideration of ocean circulation" *by* T. Canty et al.

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Comment to:

T. Canty, N. R. Mascioli, M. Smarte, and R. J. Salawitch, An empirical model of global climate – Part 1: Reduced impact of volcanoes upon consideration of ocean circulation, Atmos. Chem. Phys. Discuss., 12, 23829-23911, 2012

By: Davide Zanchettin, Oliver Bothe, Johann Jungclaus, Katja Lohmann and Claudia Timmreck

This comment specifically concerns the interpretation of our paper "Bi-decadal variability excited in the coupled ocean–atmosphere system by strong tropical volcanic eruptions" (Zanchettin et al. 2012a, hereafter referred to as ZTG12). We hereby provide clarifications to this regard, hoping they positively contribute to this interesting study. While the authors cite ZTG12 correctly on page 23858 with respect to the maximum strengthening of the Atlantic Meridional Overturning Circulation (AMOC) about 10 years after a major volcanic eruption they do not cite it correctly on page 23860, where they write that the Atlantic Multidecadal Oscillation (AMO) "is at a local minimum [. . .] $\sim$ 10 yr after peak SOD (as suggested by the GCM of Zanchettin et al., 2012 [ZTG12 in our references below])". This is not correct due to the following reasons:

1) AMOC and AMO are not exchangeable

In the COSMOS Earth System Model (COSMOS-ESM) used in ZTG12, but also more generally, AMOC and AMO are not fully exchangeable descriptors of simulated North Atlantic oceanic variability.

For instance, Figure 2 in Otterå et al. (2010) shows that in the Bergen Climate Model AMOC and AMO are out of phase. The analysis by Menary et al. (2012) of (centennial-scale) AMOC variability and related processes in COSMOS-ESM and in other dynamical climate models can help further clarifying the complexity of simulated AMOC behaviors and implications.

2) In the COSMOS-Mil ensemble (ZTG12), North Atlantic SSTs do not typically respond to volcanic forcing with a $\sim$ 10-year delay

In ZTG12 we do not investigate the AMO, and we do not draw conclusions about volcanically-forced AMO variability. However, it is still possible to get an idea about the latter based on the presented material. In Figure 11 of ZTG12 post-eruption anomalies of winter upper-ocean North Atlantic potential temperatures display clearly that:

- immediately after the eruption the volcanic impact on North Atlantic upper ocean temperatures is significant over extensive regions,

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- on the multiannual scale it is mostly confined to high-latitudes, and

- on the decadal scale it is only locally significant (note, with some areas showing significantly warmer conditions).

The simulations therefore suggest that if there is a response of North Atlantic SSTs (NASSTs) to strong volcanic eruptions, it is typically confined to the first few post-eruption years.

Further, Figure 15c of ZTG12 displays the range of simulated responses of the annual average NASST to the volcanic eruptions we selected, and their dependence on background conditions. We show the signals at their expected maximum strength and, accordingly, use the average anomaly over the first five post-eruption years for the average NASST (see the reported design on top of the panel). The range of simulated responses encompasses small negative NASST anomalies as well as slightly positive NASST anomalies. Note that the selection of volcanic eruptions in ZTG12 includes events that are stronger than those during the 20th century (see point 3).

As a passing note on the variety of simulated AMOC/AMO responses to volcanic forcing, we think that the studies by Mignot et al. (2011) and Miller et al. (2012) may be worth of consideration in the paper as well.

3) 20th century volcanic eruptions may not be the best choice to constrain uncertainty of simulated NASST/AMO sensitivity to volcanic forcing based on the COSMOS-Mil ensemble

In Zanchettin et al. (2012b) we provide further information about the volcanic forcing signature on NASST variability as expressed by the COSMOS-ESM.

Figure 2 of this paper highlights the difficulty of identifying a volcanically-forced component of NASST evolution during the 20th century (as described there in our definition of the NAVI index). The five simulations we considered appear to agree on a post-Pinatubo cooling of NASSTs, but they do not agree as much for the other 20th century

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eruptions. The volcanic-relatable NAVI fluctuations in individual simulations are practically indistinguishable from fluctuations characterizing other periods of either internally-driven or externally generated variability. Thus, we think one can only weakly constrain the uncertainty of simulated NASST/AMO sensitivity to volcanic forcing based on 20th century eruptions and on this simulation ensemble.

During the last millennium (Figure 5 of the same study) a clear volcanic imprint is found only in correspondence to very strong eruptions or cluster of volcanic eruptions (note the smoothing applied on the NAVI index). Nonetheless, this does not exclude large uncertainty in simulated NASST responses even in correspondence with such a cluster of strong volcanic eruptions (see, e.g., the 17th century NAVI evolution in Figure 5).

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