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PII: S0921-8181(16)30035-2
DOI: doi: 10.1016/j.gloplacha.2017.01.006
Reference: GLOBAL 2551

To appear in: *Global and Planetary Change*

Received date: 29 January 2016
Revised date: 3 January 2017
Accepted date: 21 January 2017

Please cite this article as: Didier Swingedouw, Juliette Mignot, Pablo Ortega, Myriam Khodri, Martin Menegoz, Christophe Cassou, Vincent Hanquiez , Impact of explosive volcanic eruptions on the main climate variability modes. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Global(2017), doi: 10.1016/j.gloplacha.2017.01.006

Impact of explosive volcanic eruptions on the main climate variability modes

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Abstract

Volcanic eruptions eject large amounts of materials into the atmosphere, which can have an impact on climate. In particular, the sulphur dioxide gas released in the stratosphere leads to aerosol formation that reflects part of the incoming solar radiation, thereby affecting the climate energy balance. In this review paper, we analyse the regional climate imprints of large tropical volcanic explosive eruptions. For this purpose, we focus on the impact on three major climatic modes, located in the Atlantic (the North Atlantic Oscillation: NAO and the Atlantic Multidecadal Oscillation: AMO) and Pacific (the El Niño Southern Oscillation, ENSO) sectors. We present an overview of the chain of events that contributes to modifying the temporal variability of these modes. Our literature review is complemented by new analyses based on observations of the instrumental era as well as on available proxy records and climate model simulations that cover the last millennium. We show that the impact of volcanic eruptions of the same magnitude or weaker than 1991 Mt. Pinatubo eruption on the NAO and ENSO is hard to detect, due to the noise from natural climate variability. There is however a clear impact of the direct radiative forcing resulting from tropical eruptions on the AMO index both in reconstructions and climate model simulations of the last millennium, while the impact on the ocean circulation remains model-dependent. To increase the signal to noise ratio and better evaluate the climate response to volcanic eruptions, improved reconstructions of these climatic modes and of the radiative effect of volcanic eruptions are required on a longer time frame than the instrumental era. Finally, we evaluate climate models' capabilities to reproduce the observed and anticipated impacts and mechanisms associated with volcanic forcing, and assess their potential for seasonal to decadal prediction. We find a very large spread in the simulated responses across the