Geophysical Research Abstracts,
Vol. 11, EGU2009-10834, 2009
EGU General Assembly 2009

Impacts of Volcanic Aerosol Forcing on the ENSO Cycle

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The paleo proxy data and almost all recent significant explosive low-latitude eruptive events of the 20th century (i.e Santa Maria, Agung, El Chichon, and Pinatubo) suggest that strong tropical eruptions link to El Niños emerging in the first and second years after an eruption. A physical mechanism of this statistical link is not completely understood. To test and explain this phenomenon a comprehensive coupled climate model, CM2.1, developed recently at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) is employed to simulate the 1815 Tambora and the 1991 Pinatubo eruptions. These eruptions were the strongest equatorial explosive events in the 19th and 20th centuries, respectively. A series of ensemble 20-year runs using El Niño onset, La Niña onset, and Neutral initial conditions for each eruption were conducted. In the runs with El Niño onset initial conditions volcanic cooling decreases amplitude of El Niño but causes dynamic warming of the equatorial SST in the year following an El Niño event. In the runs with the Neutral initial conditions volcanic impact tends to produce El Niño-like response in the second year after volcanic eruption. The forced El Niño-like effect is robust and becomes stronger with increase of volcanic forcing and in the runs with weaker El Niño, reflecting nonlinearity of response of El Niño to volcanic aerosol forcing. The El Niño-like anomaly in the Eastern Equatorial Pacific is caused in part by reduction of the upwelling strength because of weakening of the trade winds as a response to the short-wave volcanic forcing according to the Ocean Dynamical Thermostat Mechanism. In the case of the El Niño onset initial conditions, volcanic forcing apparently delays arrival of the relaxing Kelvin wave that effectively prolongs El Niño-like conditions in the Eastern Equatorial Pacific. This analysis may explain the elevated frequency of El Niño events following explosive equatorial eruptions observed in paleo-reconstructions, and helps to better quantify the El Niño sensitivity to an external forcing.