The Role of the Eruption of El Chichón in the Evolution of the North Pacific During the 1980s

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Introduction

The April 1982 eruption of El Chichón in Chiapas, Mexico had a volcanic explosivity index (VEI) value of 5 and resulted in the injection of 7 million metric tons of Sulpher Dioxide (SO_2) into the stratosphere, which resulted in a radiative forcing of -2.1 W m^{-2}.

Evidence has suggested the eruption of El Chichón significantly contributed to the early and mid- 1980s North Pacific ocean cooling.

Recently, a study[1] utilized a composite of multiple volcanoes in an attempt to identify the mechanism which allows the North Pacific basin to respond to a volcanic eruption.

This work uses a case-study analysis approach to identify the mechanism which generates the North Pacific basin response to the eruption of El Chichón.

Design & Methodology

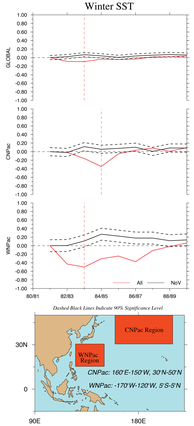
HadCM3 was used to generate two perturbed physics ensembles each containing 17 members[2].

The first ensemble contained all forcings (All) and the second ensemble did not include forcing associated with volcanic eruptions (NoV).

Anomalies for each ensemble are calculated respectively to themselves and then used to calculate an eruption anomaly, which is the difference between the years subsequent to the eruption and the year preceeding the eruption.

Finally, the eruption anomalies for the All and NoV ensembles are differenced in order to estimate the Volcanic Impact signal.

North Pacific Response



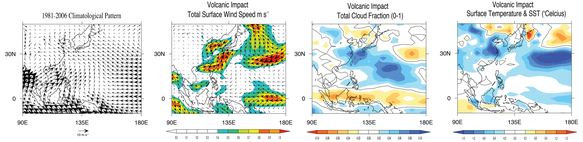
The North Pacific atmospheric response following the eruption of El Chichón was associated with a warming of the lower stratosphere, which reached a maximum during winter 1982/83, due to the presence of sulphate aerosol.

The result of the enhanced lower stratosphere temperature gradient was an equatorward shift of the Northern Hemisphere extratropical jet, which was not significantly persistent beyond winter 1982/83.

The global winter sea surface temperature (SST) response reached a minimum, approx -0.1°C, in winter 1983/84; while the central North Pacific SST lagged behind until winter 1984/85 and then reached a minimum of approx. -0.4°C.

The western North Pacific SST did not lag the global response and reached a minimum of approx. -0.5°C in winter 1983/84 following the eruption.

Summer 1982 Response

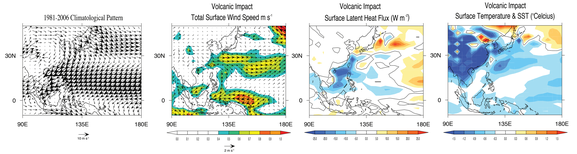


A weakened land-ocean temperature gradient between East Asia and the western North Pacific ocean modified the East Asian Summer Monsoon circulation.

The modified East Asian Summer Monsoon circulation was associated with increased cloudiness over the western North Pacific ocean.

Increased cloudiness over the western North Pacific ocean decreased the net surface shortwave radiaition (approx. 20 W m^{-2}), which cooled the western North Pacific ocean temperature.

Winter 1982/83 Response

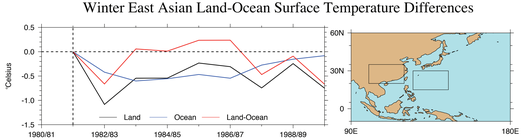


An enhanced land-ocean temperature gradient (approx. -0.5°C) between East Asia and the western North Pacific ocean modified the East Asian Winter Monsoon circulation.

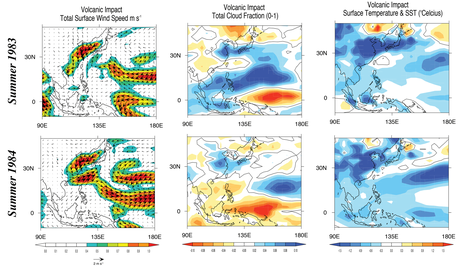
The modified East Asian Winter Monsoon circulation was associated with anomalous northerly flow off the continent.

Anomalous northerly flow enhanced the surface latent heat flux over the western North Pacific ocean by approximately -20 W m^{-2}, which cooled the western North Pacific ocean surface.

The enhanced land-ocean temperature gradient did not persist beyond the winter 1982/83 due to continued cooling of the ocean surface and a relative warming of the East Asian land surface.



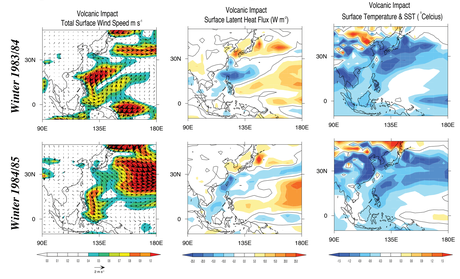
Subsequent Summer Response



Evolution of the western North Pacific ocean cooling during summer 1983 and summer 1984 was associated with a coupled air-sea response.

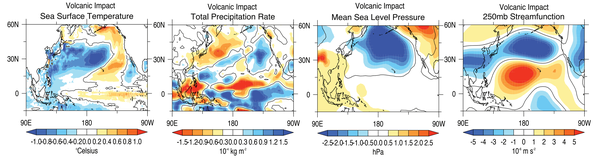
The maximum summer time cooling occured during summer 1984 and was located in the west-central North Pacific ocean.

Subsequent Winter Response

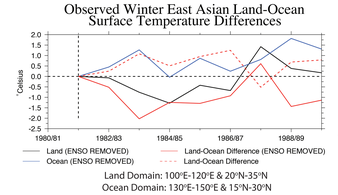


Evolution of the western North Pacific ocean cooling during the winter 1983/84 and 1984/85 was associated with a coupled air-sea response.

The maximum central North Pacific ocean cooling during winter 1984/85 was associated with both the local coupled air-sea response and the extra-tropical North Pacific ocean response to the mild El Niño like SST pattern in the tropical Pacific ocean.



Comparison to Observations

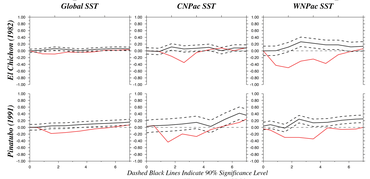


An increase in the winter East Asian land-ocean temperature difference was found in observational records[3] after removing the climate signal associated with the El Niño-Southern Oscillation.

The land-ocean temperature gradient from the observations without ENSO was approx. -2.1°C.

The observational results suggested the occurence of the 1982 El Niño, the second largest on record, masked the direct impact of the eruption of El Chichón.

Comparison to Other Eruptions



Analysis of the eruption of Pinatubo in June 1991 (VEI 6) revealed a similiar land-ocean temperature gradient response over East Asia, which modified the summer and winter monsoon circulations in the first winter following the eruption.

The maximum cooling subsequent to the eruption of Pinatubo in the central North Pacific ocean was approx. -0.45°C and occured in the second year; while the western North Pacific ocean cooling lagged until the fourth year and reached a minimum of approx. -0.35°C.

Comparing the Volcanic Impact signals from El Chichón and Pinatubo suggested the East Asian land-ocean temperature gradient was sensative to the strength of the eruption and was not simply a linear response.

Future Work

Investigate the relationship between the location and strength of a volcanic eruption and the East-Asian land-ocean temperature gradient response.

Identify the strength of the ocean gyre response to the eruption of El Chichón.

Verify the Volcanic Impact signal using a model with active chemistry instead of prescribed optical depth.

References

1) Wang, T. et al., The response of the North Pacific decadal variability to tropical volcanic eruptions, Climate Dynamics, 2012.
2) Collins, M., et al., Towards quantifying uncertainty in climate change, Climate Dynamics, 2006.
3) 20th Century Reanalysis V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/

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