Volcanic Forcing of Monsoonal Precipitation Variability in Selected Modern Eruptions

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1. Introduction

Volcanic eruptions affect climate by injecting gases and aerosol particles into the stratosphere (Robock, 2003). While temperature decline has been observed in the northern hemisphere after major eruptions e.g. Francis (1993), little is known about their regional-scale forcing of precipitation. In the present investigation, three modern major eruptions within the past fifty years have been selected for study. They are the February 1963 Agung eruption in Indonesia, the March 1982 El Chichón eruption in Mexico and the June 1991 Pinatubo eruption in the Philippines located in Fig. 1.

There are two main reasons for choosing the three volcanic eruptions. Firstly, they have the greatest influence on reducing solar radiation over the past fifty years (Fig. 2). Secondly, the three eruption years are associated with the occurrence of either abnormally dry or abnormally wet years in southern China (Table 1).

2. Precipitation connection

Volcanic eruptions occurring within Southeast Asia may be regarded as ‘near-field’ due to their relative short distances from southern China. During major eruptions, the rising thermal plumes generated cause the surrounding cool air to be drawn in (Fig. 3). Because of the coastal location of Hong Kong at the margin of the largest continental land mass in the world, the change from the ‘normal’ wind pattern to predominantly offshore would be conducive to drought (Fig. 4). The low annual precipitation in 1963 and 1991 at the Hong Kong Station may therefore be accounted for by the Agung eruption and the Pinatubo eruption respectively.

Abnormally low annual precipitation was found in southern China during 1963 and 1991 respectively. Based on the total annual precipitation recorded at the Hong Kong Station, the precipitation was the driest and the tenth driest since record began in 1884 respectively. In contrast, abnormally high annual precipitation was found in southern China in 1982 with the Hong Kong Station recording the second wettest year since record began.
The 1991 Pinatubo eruption is probably the best monitored major volcanic eruption within the past fifty years. A ground level view of the eruption is shown in Fig. 6. Thermal images taken immediately after the eruption and the tracking of the volcanic cloud via satellites are shown in Figs. 7 and 8 respectively.

Fossil fuel-consuming power stations and nuclear tests also generate thermal plumes differing in time and scale. The former are relatively ‘long’ term while the latter are relatively ‘short’ term. Both may also impact the natural hydrological cycle to cause precipitation variability. Two examples of how droughts are made worse by nuclear testing are shown in Fig. 9.

Volcanic eruptions in Central and South America may be regarded as ‘far-field’ due to their great distances from Hong Kong. The El Chichón eruption in 1982 at latitude 17°N in Mexico is a trans-Pacific Ocean event. By combining imagery from the geostationary GOES East and GOES West satellites which is received every 30 minutes, the volcanic cloud of the eruption spreading across the Pacific Ocean was tracked and found to have reached the South China Sea by 16th April 1982 (Robock and Matson, 1983). The abnormally heavy precipitation of 1041.2 mm from 22nd April to 31st May, 1982 may be attributed to the volcanic cloud providing condensation nucleus for this period and the remainder of the year making 1982 the second wettest year since record began in 1884.

Fig. 9 Two examples of how nuclear testing may lead to abnormally dry years at the Hong Kong Station.

What makes droughts worse in HK?

Two examples:

1962 Annual precipitation at Hong Kong Station 1741.0 mm (41.3 % of average)
1963 Annual precipitation at Hong Kong Station 901.1 mm (79.7 % of average)
Nuclear testing – 31/10/1961 USSR explodes the world’s largest nuclear bomb
Nuclear testing – 24/9/1966 France explodes atomic bomb at Mururoa Atoll

Monthly precipitation at the Hong Kong Station in 1982

Fig. 11 Summary of precipitation statistics at the Hong Kong Station in 1982. Both the timing and the intensity are indicative of a role for volcanic forcing.

Fig. 12 shows the time series of annual precipitation in China from 1958 to 1988 after Prieler 1999). It can be seen that the normally wetter southeastern China was affected by abnormally lower precipitation in 1963 while the opposite was found during 1982.
3. Conclusions

(a) Major volcanic eruptions are a natural forcing of climate change including monsoonal variability and have been shown to cause extremely dry and wet years regionally.

(b) Because volcanic forcing is a natural phenomenon, it is dangerous to attribute the occurrence of floods and droughts to global change through the production of man-made greenhouse gases only.

(c) Volcanic eruptions, nuclear tests, fossil fuel-consuming power stations and urban heat islands caused by mega-cities generate thermal plumes differing in time and space. Unlike volcanoes all are caused by human impacts on the natural hydrological cycle.

(d) The volcanic forcing on regional precipitation should be investigated using the instrumental record to assist water resources management and precipitation variability studies.

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5. References