Paper EGU2010-7827

‘Major’ volcanic eruptions and climatic disasters

Wyss W.-S. Yim[1, 2*], Johnny C.L. Chan[1], Judy W.-R. Huang[1]

[1] Guy Carpenter Asia-Pacific Climate Impact Centre, School of Energy and Environment, City University of Hong Kong, Kowloon, Hong Kong

[2] Department of Earth Sciences, The University of Hong Kong, Hong Kong

* Contact author e-mail: wswyim@cityu.edu.hk

1. Introduction

Global warming has often been blamed as a probable cause for the increasing frequency of climatic disasters. However, with the exception of heat waves, it remains difficult to show whether severe-weather events related to extreme precipitation variability namely floods and droughts are caused by such a phenomenon. On the other hand cooling may be caused by volcanic eruptions. We have carried out a preliminary study of the link between 13 ‘major’ volcanic eruptions defined by a Volcanic Explosivity Index (VEI) of 5 and above and selected types of climatic disasters in the densely populated monsoonal region of southern China since the 1883 Krakatau eruption.

2. ‘Major’ volcanic eruptions

A chronological list of the 13 major volcanic eruptions investigated including their location, first eruption date, VEI, volume of tephra and ranking is shown in **Table 1** and a location map of the volcanoes and the Hong Kong Station is shown in **Figure 1**. Out of the 13 eruptions only 5 are tropical with 3 located in Southeast Asia within 4000 km of Hong Kong.

Volcano	Latitude & longitude	First eruption date	VEI	Volume of tephra	Ranking
Krakatau, Indonesia	6°6′6″S 105°25′22″E	August 27, 1883	6	$2.0 \pm 0.2 \times 10^{10}$ m^3	=2
Okataina, New Zealand	38°7′0″S 176°30′0″E	June 10, 1886	5	2.0×10^{9} m^3	10
Santa Maria, Guatemala	14°45′21″N 91°31′6″W	October 24, 1902	6?	2.0×10^{10} m^3	=2
Ksudach, Russia	51°48′0″N 157°32′0″E	March 28, 1907	5	2.4×10^{9} m^3	8
Novarupta, USA	58°16′0″N 155°9′24″W	June 6, 1912	6	2.8×10^{10} m^3	1
Cerro Azul, Chile	35°39′12″S 70°45′39″W	April 10, 1932	>5	9.5×10^{9} m^3	5
Kharimkotan, Russia	40°7′0″N 154°30′30″E	January 8, 1933	5	1.0×10^{9} m^3	13
Bezymianny, Russia	55°58′42″N 160°35′12″E	March 30, 1956	5	2.8×10^{9} m^3	7
Agung, Indonesia	8°20′30″S 115°30′30″E	February 18, 1963	5	>1.0×10^{9} m^3	12
St. Helens, USA	46°12′0″N 122°11′0″W	May 18, 1980	5	1.2×10^{9} m^3	11
El Chichón, Mexico	17°21″36″N 93°13′40″W	March 28, 1982	5	2.3×10^{9} m^3	9
Pinatubo, Philippines	15°8′0″N 120°21′0″E	June 15, 1991	6	$1.1 \pm 0.5 \times 10^{10}$ m^3	4
Cerro Hudson, Chile	45°54′0″S 72°58′0″W	August 12, 1991	5	4.3×10^{9} m^3	6

Table 1 *Chronological list of the 13 major volcanic eruptions investigated showing their location, first eruption date, VEI, volume of tephra and eruption size ranking.*

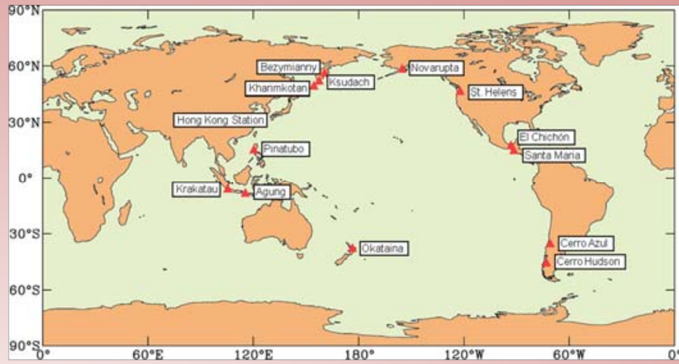

Figure 1 *Location map of the Hong Kong Station and the 13 volcanoes responsible for the eruptions investigated.*

3. Climatic effects of volcanic eruptions

The climatic effects include:
(a) Reduction of solar radiation causing cooling from lower annual mean temperatures to severe winters and ice ages.
(b) Eruption cloud interferes with the ‘normal’ atmospheric circulation.
(c) Provision of condensation nuclei.
(d) Moisture transfer from the troposphere to the stratosphere.
(f) Precipitation variability including torrential rainfall, extreme floods, landslides, droughts and salinization.
(e) Acid rain.

A simplified model of how a volcanic eruption interferes with ‘normal’ atmospheric circulation to affect both incoming solar radiation and atmospheric moisture distribution is illustrated in **Figure 2**.

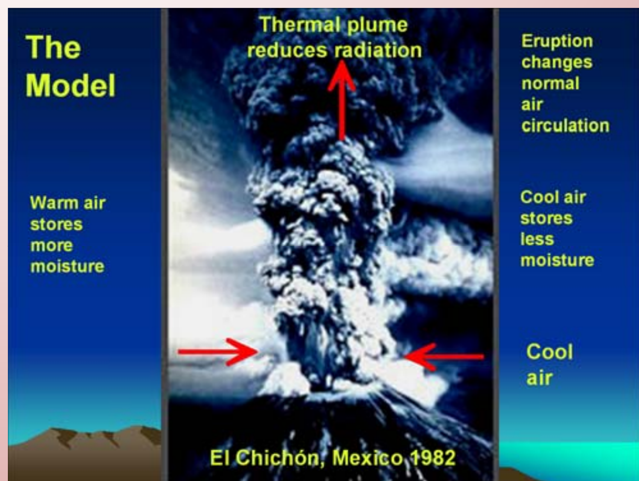

Figure 2 *Model showing how a volcanic eruption interferes with normal atmospheric circulation to affect incoming solar radiation and atmospheric moisture distribution.*

Annual mean temperatures of years immediately following the eruption year and annual precipitations during the eruption year at the Hong Kong Station and climatic observations of the 13 volcanic eruptions are shown in **Table 2**. It can be seen that some of the coldest and driest years including 5 top twenty coldest and driest years are included. Also included is the 1982 El Chichón eruption an exceptionally wet year ranked second wettest since the record began in 1884.

Volcanic eruption	AMT after eruption year (ºC)	Precipitation during year (mm)	Climatic observations
Krakatau	21.3	Not available	Coldest year
Okataina	21.7	1756.9	=5 coldest year; 20th driest year
Santa Maria	21.9	2477.2	=9 coldest year
Ksudach	22.1	2377.7	=19th coldest year
Novarupta	22.2	1625.2	9th driest year
Cerro Azul	22.5	2325.9	-
Kharimkotan	21.9	2482.9	=9 coldest year
Bezymianny	22.3	1649.3	11th driest year
Agung	22.9	901.1	Driest year
St. Helens	23.1	1710.6	17th driest year
El Chichón	23.0	3247.5	2nd wettest year
Pinatubo	22.8	1639.1	10th driest year
Cerro Hudson	22.8	1639.1	10th driest year

Table 2 *Annual mean temperatures (AMT) of years immediately following the eruption year and annual precipitations during the eruption year at the Hong Kong Station located in* **Figure 1** and their observations. *The overall annual mean temperature and the annual mean precipitation of the Hong Kong Station from 1884-2009 is 22.62ºC and 2220 mm respectively.*

The abnormally dry 1963 and 1991 may be explained by the Agung and Pinatubo eruptions respectively causing the ‘normal’ wind circulation in southern China to shift to predominantly offshore (**Figure 3**). The exceptionally wet year in 1982 is explained by the spread of the El Chichón eruption cloud across the Pacific Ocean which was tracked by satellites (**Figure 4**). This cloud reached the South China Sea by ca. 16th April 1982 causing 1041.2 mm rainfall during 22nd April to 31st May 1982 (**Figure 5**). The low surface humidity observed in Hong Kong during April 1982 is in support of the influence of the stratospheric eruption cloud.

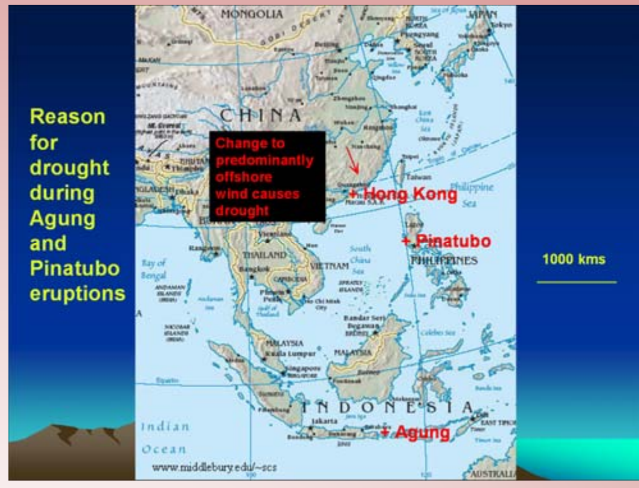

Figure 3 *Reason for drought years during the 1963 Agung and 1991 Pinatubo eruptions.*

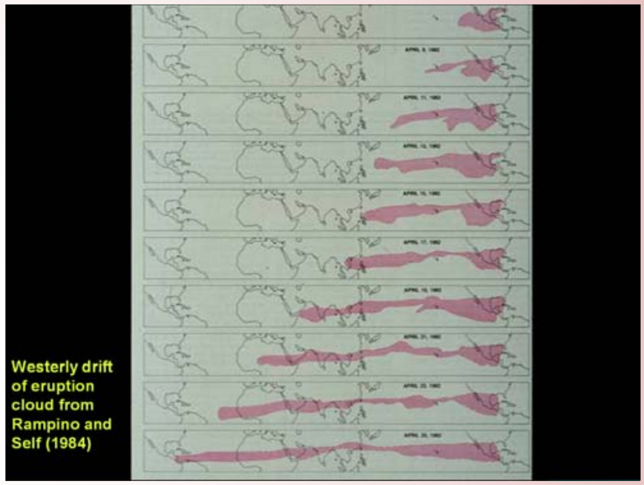

Figure 4 *Maps showing the spread of the El Chichón eruption cloud in the first 3 weeks after the eruption made by combining information from satellites. Heavy rain fell over Hong Kong 17 days after the eruption in April and May 1982.*

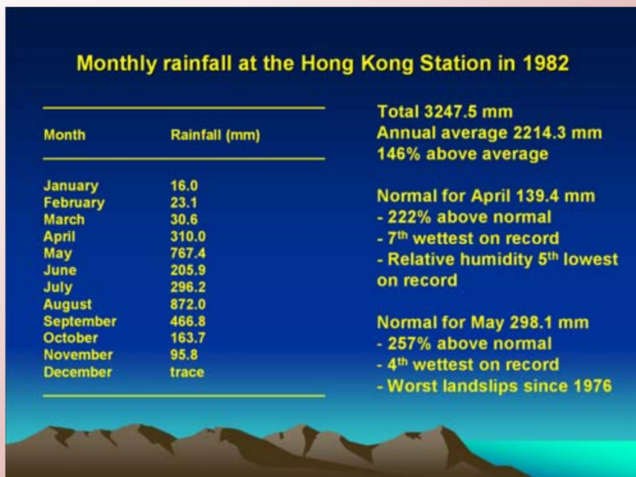

Figure 5 *Monthly rainfalls and rainfall-related statistics at the Hong Kong Station during April 1982.*

5. Disastrous events in southern China

Table 3 provides a summary of climatic disastrous events in southern China where 'major' volcanic eruptions may have played a role. The reason why southern China is prone to the disasters is explained by the coastal location which is highly sensitive to wind shifts.

Volcanic eruption	Climatic disasters in southern China
1883 Krakatau	Severe drought years with below average rainfall in 1884, 1886 and 1887
1886 Okataina	Two drought years with below average rainfall in 1886 and 1887
1902 Santa Maria	Severe drought years with below average rainfall in 1904, 1905 and 1906
1912 Novarupta	Severe drought year with poor crop yield
1933 Kharimkotan	Severe drought year with poor crop yield
1956 Bezymianny	Severe drought year with poor crop yield and salinization problems in the Pearl River Delta
1963 Agung	Exceptional drought year with poor crop yield and severe salinization problems in the Pearl River Delta
1980 St. Helens	Severe drought year with poor crop yield
1982 El Chichón	Exceptionally wet year with torrential rainfall (24 hour rainfall > 50 mm 9 occurrences, maximum 334.2 mm), severe flooding and landslides (488 reported)
1991 Pinatubo / Cerro Hudson	Severe drought with poor crop yield and severe salinization problems in the Pearl River Delta

Table 3 *Climatic disaster events in southern China linked to the 'major' volcanic eruptions since 1883. The annual mean rainfall of the Hong Kong Station since 1884 is ca. 2200 mm.*

6. Other factors exacerbating climatic disasters

These factors include:

(a) The increase in risk to climatic disaster damage through rapid population growth in southern China particularly during the twentieth century and twenty-first century.
(b) Development in the low-lying coastal regions including the Pearl River Delta.
(c) Human impact on the natural hydrological cycle through agriculture, deforestation, construction of dams and reservoirs, irrigation schemes, urbanization, etc.

7. Conclusions

Volcanic eruptions are an important but neglected cause of natural climatic variability which may result in climatic disasters. This study has shown that 'major' volcanic eruptions may be the cause of cold waves as well as extreme precipitation variability commonly in the form of severe drought years and under special conditions the occurrence of wet years associated with severe flooding and landslides in southern China. In other words volcanic eruptions are also a natural contributor to monsoon variability.

Tropical eruptions have been found to play a greater role in causing climatic disasters as compared to high latitude eruptions. This is explained by their greater impact in reducing incoming solar radiation.

Whether volcanic eruptions with VEI below 5 also result in climatic disasters should be investigated because their stratospheric eruption clouds may take only about 3 weeks to circle Earth.

8. Acknowledgements

This poster prepared with the help of Terence Lam is a contribution to UNESCO's International Year of Planet Earth under the Climate Change theme.

9. References

Rampino MR, Self S (1984) The atmospheric effects of El Chichón. *Scientific American* 250: 34-43.
Yim WW-S, Ollier CD (2009) Managing planet Earth to make future development more sustainable: climate change and Hong Kong. *Quaternary Sciences* 29: 190-198.