JOURNAL OF THE GEOLOGICAL SOCIETY OF CHINA
Vol.40, No.1, P.299-311, 2 Figs., 2 Tabs., Jan., 1997

THE IMPACT OF WORLDWIDE VOLCANIC ACTIVITIES ON LOCAL PRECIPITATION
---TAIWAN AS AN EXAMPLE

LUNG-AN LI[1], CHUNG-HO WANG[2], SHUH-HAUNG LIAW[3],
YUK-LING YUNG[4], YUAN-HUI LI[5], YI-CHIEH CHEN[6] and PIIN-CHING LI[1]

1. Institute of Statistical Science, Academia Sinica, Taipei, Taiwan, R.O.C.
2. Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, R.O.C.
3. Central Weather Bureau, Ministry of Transportation and Communication, Taipei, Taiwan, R.O.C.
4. Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA, U.S.A.
5. Department of Oceanography, University of Hawaii, Honolulu, HI. U.S.A.
6. Bureau of Statistics, DGBAS, Executive Yuan, Taiwan, R.O.C.

ABSTRACT

Sulfur-rich volcanic activities are believed to disturb the hydrological cycles in addition to the anomalous temperature changes in the atmosphere. Two statistical analyses are performed to evaluate their impact on precipitation, which is determined by averaging the records from eight weather stations in Taiwan from 1897 to 1993. One analysis utilizes the so-called El Nino-Southern Oscillation (ENSO) phenomenon as a co-factor, while the other does not. It is very note-worthy that both analyses show a statistically significant drought effect on this local region's precipitation as brought on by such sulfur-rich volcanic activities. The timing of the occurrence of these volcanic events are highly correlated with the drought periods in Taiwan, and the magnitudes of their influence are found to be two to ten times greater than those by the ENSO.

Key words: volcanic activities, ENSO phenomenon, Taiwan precipitation, statistical analysis.

INTRODUCTION

Many authors have noted that climate is influenced by volcanic activities, for example, Rampino and Self (1982, 1984), Kelly and Sear (1984), Hansen *et al.* (1978, 1992), Angell (1993). Although more than 600 volcanoes are active on earth and eruptions are not uncommon each year (Tilling, 1990), only few of them are of the sulfur-rich kind. It is believed such sulfur-rich volcanic activities releases tremendous amounts of sulfur into the atmosphere, which subsequently diffuses rapidly around the world (Barry and Chorley, 1987). They not only causes optical depth, but also anomalous temperatures in the troposphere, and hydrological changes varying over different regions.

This paper studied the impact of these sulfur-rich volcanic eruptions on the precipitation of a subtropical region like Taiwan by presenting some statistical evidence confirmed from two analyses. One analysis incorporated the El Nino phenomenon, the so-called ENSO (El Nino-Southern Oscillation) phenomenon as co-explanatory factors in the model, and the other did not. Both analyses show the statistical significance of the impact of the worldwide sulfur-rich volcanic activities on Taiwan's precipitation in Taiwan.

DATA

Sulfur-rich volcanic eruptions since 1900 were considered in this paper, including those in Santa Maria located at 14.8 N, 91.6 W in October, 1902, in Katmai located at 58.3 N, 155.2 W in June, 1912, in Agung located at 8.3 S, 115.5 E in March and May, 1963, in St. Helens located at 46.2 N, 122.2 W in May, 1980, in El Chichon located at 17.3 N, 93.2 W in March and April, 1982, and in Pinatubo located at 15.1 N, 120.2 E in June, 1991. It is quite evident that some eruptions were very near to Taiwan, and some could have been as far in the other side of the earth. Some characteristics of these eruptions are discussed in greater detail in an earlier paper by Wang *et al.* (1995).

Precipitation data were collected from all of the available records of eight weather stations in Taiwan for the period covering 1897 to 1993. These stations, Pengchiayu, Taipei, Taichung, Hualien, Penghu, Tainan, Taitung and Hengchun, are located in the northern, central, western, eastern, and southern regions of Taiwan. Widely distributed around the island, these stations adequately provide information on the precipitation of the entire island. With the adoption of the superposed epoch analysis as in the Intergovernmental Panel on Climate Change (IPCC) report (1990), the precipitation data of each year were subtracted from the mean value of precipitation for the period 1951-1980 before being added up to form a composite series for study. To be specific, negative values represent precipitation conditions below the 1951-1980 norms, while positive values denote above normal conditions.

The data to reflect the ENSO phenomenon in this paper are in fact the Southern Oscillation Indices (SOI), which are the differences in sea level pressures between Stations Tahiti and Darwin. The SOI values were utilized in this analysis due to the availability of lengthier records and the advantage of providing greater simplicity than sea surface temperatures, or other means to reflect the ENSO phenomenon. The SOI values of 1897 to 1993 were also collected to coincide with the length of the precipitation data. As there are cold and warm phases in the ENSO cycles, the monthly SOI's with positive values and monthly SOI's with negative values in one year were summarized to represent the respective magnitudes of those two phases of the ENSO within the same year of this study.

STATISTICAL MODELS

Taiwan is a subtropical island located at the margin of East Asia's Continental Self with the Tropic of Cancer traversing the middle. The northeastern monsoons in the colder months and the southwestern monsoons in the warmer months alternately prevail in Taiwan each year. In addition to the rainfall regularly brought on by these monsoons, there are mei-yu (Chinese for 'plum rain', meaning it rains during the plum season) and typhoons which bring more, but various degrees precipitation to the region. Hence, rainfall from monsoons, mei-yu and typhoons are the direct sources of precipitation in Taiwan.

In this paper, the precipitation data were broken down into various components, representing the volcanic impact, or the ENSO impact, and the direct source of rainfall from monsoons, mei-yu and typhoons, respectively. The global ENSO phenomenon is related to Taiwan's precipitation in the form of the annual totals of positive monthly SOI's or the annual totals of negative ones respectively, np_t or nn_t of year t, through a transfer model. The precipitation series, p_t, and the ENSO phenomenon series np_t or nn_t, are stationary; thus, the transfer function model could be applied. In an input-output linear system, the output series, p_t, and the input series np_t or nn_t are related through a linear filter in the form of:

$$P_t = \upsilon(B)*nx_t + vr_t \quad , \tag{1}$$

where $\upsilon(B) = \sum_{j=-\infty}^{\infty} v_j B^j$ is referred to as the filter of the transfer function by Box and Jenkins (1976); nx_t denotes the input either of np_t or nn_t while vr_t represents the series of the system that is independent of the input series, nx_t.

Denote the output of the above linear filter by:

$$ENSO_t = \upsilon(B)*nx_t \quad . \tag{2}$$

$ENSO_t$ represents the effect due to the ENSO phenomenon on the regional precipitation, the first component in the precipitation series P_t, while the series vr_t corresponds to the joint effects of volcanic activities as well as typhoons, mei-yu and monsoons of the precipitation series.

The volcanic eruptions were treated as external events through Intervention Analysis to evaluate the effect. Although a volcanic eruption seems to be an abrupt event, however it may pass its effect over several years. The type of intervention applied in this study is:

$$\Psi(B)*I_t^{(T)} \quad , \tag{3}$$

where $\Psi(B)$ is a polynomial of the back operator B, and $I_t^{(T)}$ is a pulse function defined as:

$$I_t^{(T)} = \begin{cases} 1 & t = T \\ 0 & t \neq T \end{cases} \tag{4}$$

It should be noted that t = T is the time point when the intervention takes place. Therefore, the model can thus far be written as:

$$vr_t = \sum_j \Psi_j(B) * I_t^{(T_j)} + r_t \quad , \tag{5}$$

where the index j runs over the number of interventions, or the number of volcanic eruptions.

Let the output of Intervention Analysis be:

$$v_t = \sum_j \Psi_j(B) * I_t^{(T_j)} , \tag{6}$$

v_t represents the effect due to volcanic events, the second component of the precipitation series P_t, while the series r_t corresponds to the component of typhoons, mei-yu, and monsoons, which are modeled as an Autoregressive Moving Average (ARMA) model.

Hence, the precipitation series is expressed as

$$P_t = ENSO_t + v_t + r_t \ . \tag{7}$$

$ENSO_t$, v_t and r_t each represent the three major components of Taiwan precipitation P_t. All the parameter values and the orders of these three components were estimated simultaneously. The ENSO component were not considered in the first analysis; consequently, the above model can be simplified as:

$$P_t = v_t + r_t \ . \tag{8}$$

RESULTS

Table 1 presents the outcome of the analysis without the ENSO phenomenon as a co-explanatory factor. For the purposes of comparison with statistical models with the ENSO component, the five-year moving average of the composite annual precipitation series was used in the first statistical analysis in order to filter out the short-term variations, which are believed to have been principally caused by the ENSO phenomenon. It is shown that the effect of these sulfur-rich volcanic eruptions was negative on Taiwan's precipitation for several subsequent years; in other words, the precipitation of the Taiwan area decreased because of these sulfur-rich volcanic eruptions.

Several statistical models were studied. Some of them were with a volcanic component, while others were not. Judged by statistical model selection criteria such as the Akaikie Information Criterion (AIC) or the Schwarz Bayesian Criterion (SBC), the models without a volcanic component is statistically worse than the ones with a volcanic component. Among those studied models with a volcanic component, the model for Table 1 is the best. The statistical model for Table 1 is represented by:

$$\begin{aligned} Y_t = {} & \alpha_{1901} I_{1901} + \alpha_{1906} I_{1906} + \alpha_{1907} I_{1907} + \alpha_{1908} I_{1908} + \alpha_{1946} I_{1946} + \alpha_{1961} I_{1961} \\ & + \alpha_{1962} I_{1962} + \alpha_{1963} I_{1963} + \alpha_{1964} I_{1964} + \alpha_{1965} I_{1965} + \alpha_{1978} I_{1978} + \alpha_{1982} I_{1982} \\ & + \alpha_{1983} I_{1983} + \frac{(1 - MA_{1,1} B^4)(1 - MA_{2,1} B^9)}{(1 - AR_{1,1} B)(1 - AR_{2,1} B^5 - AR_{2,2} B^{10})} \text{ noise} , \end{aligned} \tag{9}$$

Table 1. Analyzed results without the ENSO phenomenon as a co-explanatory factor

Parameter	**Estimate**	**Std. Error**	**T Ratio**
MA1,1	-0.9949	0.0541	-18.39
MA2,1	-0.3296	0.1249	-2.64
AR1,1	0.8864	0.0571	15.50
AR2,1	-0.8927	0.1226	-7.28
AR2,2	-0.3635	0.1315	-2.76
α-1901	-78.0496	13.3220	-5.86
α-1906	-72.5346	16.4005	-4.42
α-1907	-74.8652	22.9726	-3.26
α-1908	-123.0577	19.9883	-6.16
α-1946	-66.3911	10.7190	-6.19
α-1961	-189.2834	36.4005	-5.20
α-1962	-140.2167	33.0891	-4.24
α-1963	-202.1062	33.1124	-6.10
α-1964	-228.8412	31.0863	-7.36
α-1965	-175.5285	39.6575	-4.43
α-1978	-71.4622	39.4109	-1.81
α-1982	-32.6487	32.1651	-1.02
α-1983	-78.0990	32.7488	-2.38

Std. Error Estimate = 43.8383

AIC(Akaikie Information Criterion) = 972.6677

SBC(Schwarz Bayesian Criterion) = 1018.0599

αx;ARx,x; MAx,x = coefficients, estimated from 5-yr moving average precipitation data

I-year = Indicator of a specific year

The Model employed is:

$$Y_t = \alpha_{1901} I_{1901} + \alpha_{1906} I_{1906} + \alpha_{1907} I_{1907} + \alpha_{1908} I_{1908} + \alpha_{1946} I_{1946} + \alpha_{1961} I_{1961}$$
$$+ \alpha_{1962} I_{1962} + \alpha_{1963} I_{1963} + \alpha_{1964} I_{1964} + \alpha_{1965} I_{1965} + \alpha_{1978} I_{1978} + \alpha_{1982} I_{1982}$$
$$+ \alpha_{1983} I_{1983} + \frac{(1 - MA_{1,1} B^4)(1 - MA_{2,1} B^9)}{(1 - \mathrm{AR}_{1,1} B)(1 - AR_{2,1} B^5 - AR_{2,2} B^{10})} \text{noise}$$

where Y_t denotes the 5-yr moving average at year t; α's represent the volcanic impact of the year indicated by I's, while the direct source of rainfall due to monsoons, mei-yu, and typhoons of Taiwan's precipitation is described by an ARMA model:

$$\frac{(1-MA_{1,1}B^4)(1-MA_{2,1}B^9)}{(1-AR_{1,1}B)(1-AR_{2,1}B^5-AR_{2,2}B^{10})} \tag{10}$$

These MA's, AR's and α's computed from the data are listed in the column labeled 'Estimate' in Table 1, the estimated standard errors of these are listed in the column labeled 'Std. Error', while their divisions are shown in the column labeled 'T Ratio'. Figure 1 presents the fitting of this model, with the solid line representing the five year moving average of Taiwan's annual precipitation deviations from 1951-1980 norms, and the dotted line standing for the corresponding predicted values from this model. The model fits the data quite well.

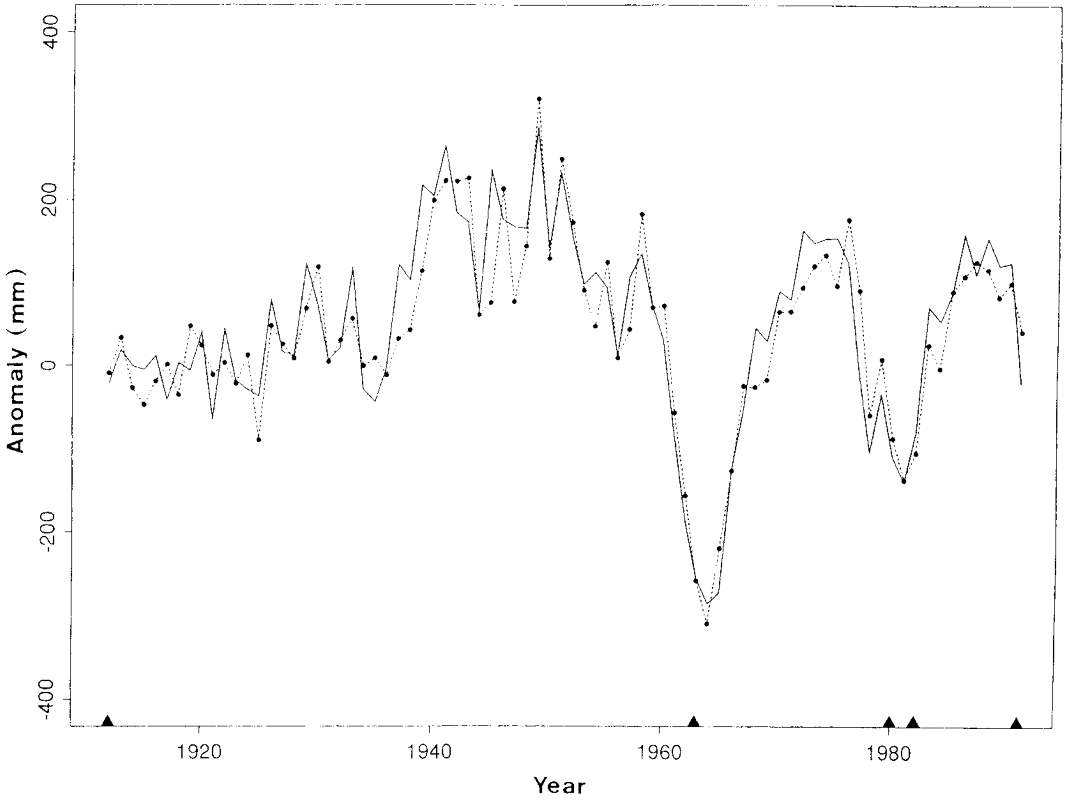


Figure 1. The 5-yr moving average of precipitation deviations from the 1951-1980 mean at eight weather stations in Taiwan (solid line), and the fitted values (dotted line) determined by a statistical model as per Table 1 without the ENSO phenomenon as a co-explanatory factor. The date indicators of sulfur-rich volcanic eruptions are indicated.

Since the dependent variable Y_t is the moving average of the original precipitation data of the years t-2, t-1, t, t+1, and t+2, Y_t could be influenced by the impact from years t+2, or t+1 if an eruption actually did occur in these years. Accordingly, the significant effect α_{1961} actually reflects the impact of the eruption of Mt. Agung in the year 1963. Table 1 also shows the eruptions of Santa Maria in the year 1902, Katmai in the year 1912, St. Helens in the year 1980 and El Chichon in the year 1982 all had negative influence on Taiwan's precipitation but to varying degrees. It is possible that Mt. Agung, which is located in the Equator region and geographically close to Taiwan, released a tremendous amount of sulfur-bearing compounds (Hansen *et al.*, 1978 and Angell, 1993), and had the greatest impact among all these sulfur-rich eruptions. It is noted that the eruption of Pinatubo in 1991 was not included in this model due to the five-year moving average process and the data in the analysis ended at 1993.

Table 2 presents the outcome of the analysis treating the ENSO phenomenon as a co-explanatory factor, which has two parts representing the cold and warm phases of the ENSO cycles, respectively. There were also several statistical models analyzed with and without a volcanic component. The model selection criteria such as the AIC and the SBC also indicated the models with a volcanic component were more significant, and the best one among studied is presented in Table 2. The statistical model of Table 2 is:

$$\begin{aligned} P_t = {} & (P0 + P5B^5 + P7B^7 + P14B^{14})np_t + (N3B^3 + N7B^7 + N9B^9)nn_t \\ & + (W12)I_{1912} + (W63 + W64B + W65B^2)\,I_{1963} + (W80)I_{1980} \\ & + (W39)I_{[1939,1959]} + \frac{(1 - MA1B - MA4B^4)}{(1 - AR14B^{14})}\ \text{noise}\ , \end{aligned} \tag{11}$$

where W's denotes the impact on the years indicated by I's, P's and N's respectively represent the effect of the positive monthly SOI's and negative ones, and the direct source of rainfall due to monsoons, mei-yu, and typhoons of Taiwan's precipitation is described by a different ARMA model:

$$\frac{(1 - MA1B - MA4B^4)}{(1 - AR14B^{14})} \tag{12}$$

These W's, P's, N's, as well as MA's, AR's computed from the data are listed in the column labeled 'Estimate' in Table 2, and the estimated standard errors of these are listed in the column labeled 'Std. Error'. Their divisions are presented in the column labeled 'T Ratio'. Figure 2 presents the fitting of this model; the first three diagrams are the ENSO component, volcanic component and the ARMA component representing the rainfall by monsoons, mei-yu and typhoons. In the last diagram the solid line represents the composite series of Taiwan's annual precipitation deviations from the 1951-1980 norms, and the dashed line indicates the corresponding predicted values from this model with dotted lines as the 95% confidence interval of the predicted. This model also fits the data well.

In contrast to the finding in the first analysis, only the impact of Mt. Agung is statistically significant at the 0.05 level. However, all the coefficients related to the volcanic component

Table 2. Analyzed results with the ENSO phenomenon as a co-explanatory factor

Parameter	**Estimate**	**Std. Error**	**T Ratio**
P0	11.2076	4.2201	2.66
P5	-13.6058	4.4273	-3.07
P7	-14.2490	3.5983	-3.96
P14	7.8628	3.6525	2.15
N3	-7.1558	3.3588	-2.13
N7	-6.6662	2.9945	-2.23
N9	-10.5819	3.0321	-3.49
W12	-366.3296	318.2123	-1.15
W63	-666.8557	122.2143	-5.46
W64	-422.6425	147.0941	-2.87
W65	-431.9934	116.7040	-3.70
W80	-197.8095	153.5437	-1.29
W93	-291.1682	184.2806	-1.58
W39	31.0985	6.1651	5.04
MA1	0.5547	0.1082	5.13
MA4	-0.7866	0.1150	-6.84
AR14	-0.3658	0.1065	-3.44

Std. Error Estimate = 141.50

AIC(Akaikie Information Criterion) = 994.74

SBC(Schwarz Bayesian Criterion) = 1038.50

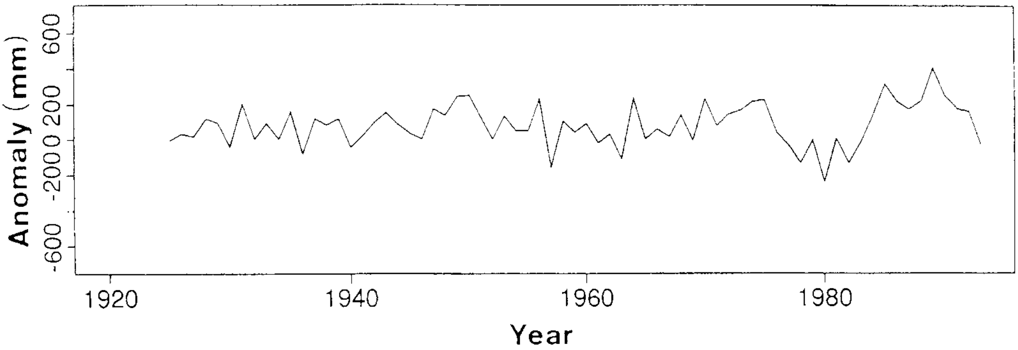
Nx;Px;Wx;ARx;MAx = coefficients, estimated from precipitation data

I-year = Indicator of a specific year

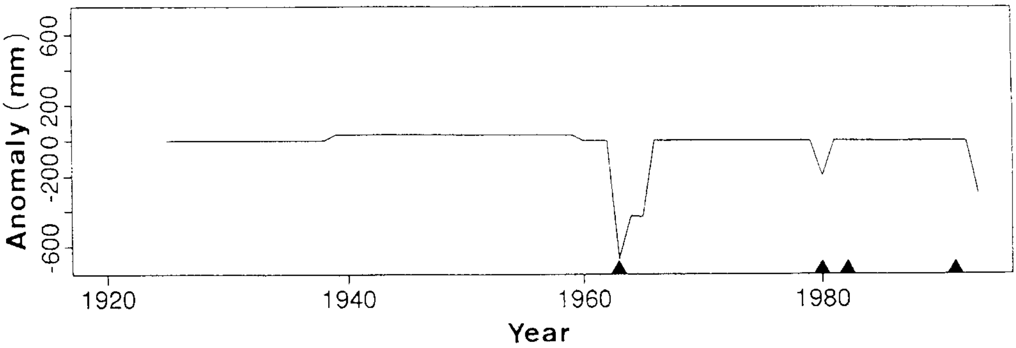
The Model employed is:

$$P_t = (P0 + P5B^5 + P7B^7 + P14B^{14})np_t + (N3B^3 + N7B^7 + N9B^9)nn_t$$
$$+ (W12)I_{1912} + (W63 + W64B + W65B^2)I_{1963} + (W80)I_{1980}$$
$$+ (\mathrm{W39})I_{[1939,1959]} + \frac{(1 - MA1B - MA4B^4)}{(1 - AR14B^{14})}\ \text{noise}$$

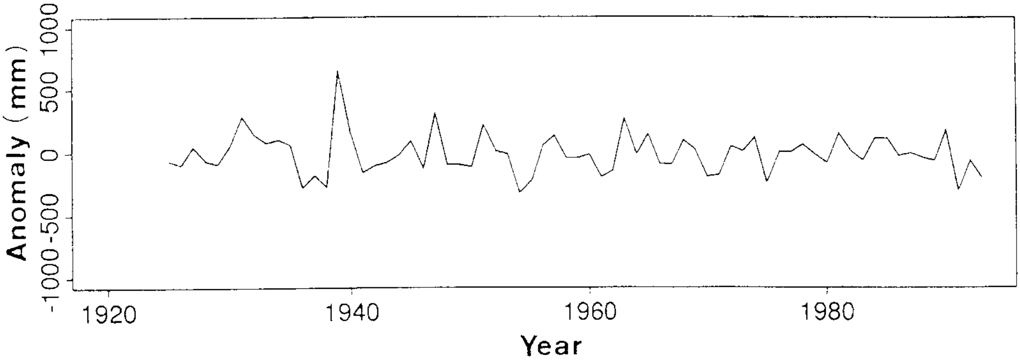
(a) THE ENSO PART



(b) THE VOLCANIC PART



(c) THE ARMA PART



(To be continued)

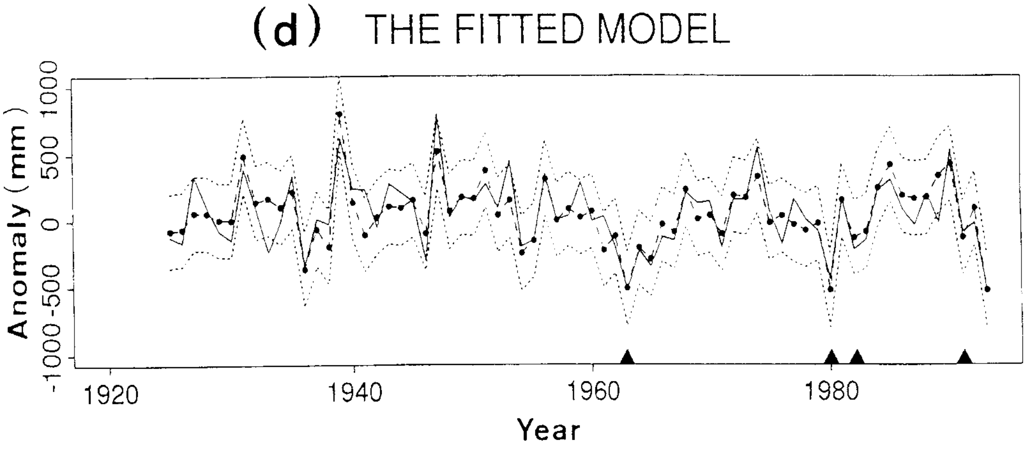


Figure 2. The average of the original precipitation deviations from the 1951-1980 mean at eight weather stations in Taiwan (solid line), and the fitted values (dashed line) together with their 95% confidence interval (dotted lines) determined by a statistical model as per Table 2 in the last diagram (d) labeled 'The Fitted Model'. This average is broken down into three components by the model in Table 2 respectively representing the impacts due to the ENSO phenomenon, volcanic eruptions and the rainfall by monsoons, mei-yu and typhoons. These three components are shown separately in the first three diagrams: (a), (b) and (c). The date indicators of sulfur-rich volcanic eruptions are indicated in the diagram (b) of the volcanic component and the last diagram (d).

were negative, consistent with the drought periods noted in Taiwan precipitation. From this analysis, it is found that the precipitation of each year in Taiwan is influenced by the global ENSO phenomenon of that year, as well as that of 3 years ago, 5 years ago, 7 years ago, 9 years ago and 14 years ago. Comparing the magnitudes of the ENSO components with the volcanic components, the impact from volcanic activities was two to ten times of that from the ENSO phenomenon. It seems the impact of the volcanic part on the precipitation of the Taiwan area was strong and negative, giving some drought periods but at shorter lags in time, while the impact of the ENSO part varied in magnitude and sign. This means that it did not necessarily decrease or increase the precipitation of the area but was characterized by longer lags in time. In addition to these components in the precipitation series, it was found during data analysis that the average precipitation from 1939 to 1959 was statistically higher than that of the 1950-1980 norm, which is considered as a standard by the IPCC indicating some discrepancy between this local precipitation and the global standard. As a matter of fact, from other findings in the Past Global Change Project of Taiwan, it seems that Taiwan is situated in a climate sensitive zone.

CONCLUSIONS

From two statistical analyses, one using the ENSO phenomenon as a co-explanatory factor, and the other not, there is sound statistical evidences that the precipitation in the subtropical region of Taiwan is strongly influenced by worldwide sulfur-rich volcanic activities. The lag of the influence is found to last two to three years, and the sign of the influence is always negative, which means the eruption is highly related to the droughts in Taiwan. The magnitudes of the impact are two to ten times that of the ENSO phenomenon, which might bring more rains to Taiwan.

ACKNOWLEDGMENTS

This work has been partially supported by the funding of the National Science Council of Taiwan and the Environmental Sciences Research of Academia Sinica, Taipei, Taiwan.

REFERENCES

Angell, J.K. (1993) Comparison of stratosphere warming following Agung, El Chichon and Pinatubo volcanic eruptions: *Geophy. Res. Lett.*, **20**, 715-718.

Barry, R.C. and Chorley, R.J. (1987) *Atmosphere, Weather & Climate*, 5th ed.: Routledge, New York, USA, 459pp.

Bernard, M.A. (1992) *Global Warning--Global Warming*: John Wiley & Sons, Inc. NY, USA, 317pp.

Bluth, G.J.S., Doiron, S.D., Schnetzler, C.C., Krueger, A.J. and Walter & Walter, L.S. (1992) Global tracking of the SO_2 clouds from the June 1991 Mount Pinatubo eruptions: *Geophys. Res. Lett.*, **19**, 151-154.

Box, G.E.P. and Jenkins (1976) *Time series analysis, forecasting and control*, revised ed.: Holden Day, San Francisco, USA.

Cheng, W.L., Berger, K.J.E. and Hsiao, L.Y. (1993) Temperature and precipitation patterns in East Asia. In: *Proc. Intl Conf. on Regional Environment and Climate Changes in East Asia*, Nov.30 - Dec.3, 1993, Taipei, Taiwan, ROC, 382-385.

Hansen, J.E., Wang, W.C. and Lacis, A.A. (1978) Mount Agung eruption provides test of a global climatic perturbation: *Science*, **199**, 1065-1067.

Hansen, J., Lacis, A., Ruedy, R. and Sato, M. (1992) Potential climate impact of Mount Pinatubo eruption: *Geophy. Res. Lett.*, **19(2)**, 215-218.

IPCC (1990) *Climate Change: The IPCC Scientific Assessment,* WMO/UNEP, ed. Houghton, J.T., Jenkins, G.J. and Ehraums, J.J., Cambridge Univ. Press, Cambridge, UK, 365pp.

Kelly, P.M. and Sear, C.B. (1984) Climatic impact of explosive volcanic eruptions: *Nature*, **311**, 740-743.

Kumar, K.K., Kumar, K.R. and Pant, G.B. (1993) Long-term variations in precipitation and temperature over South Asia from instrumental records. In: *Proc. Intl Conf. on Regional Environment and Climate Changes in East Asia*, Nov.30 - Dec.3, 1993, Taipei, Taiwan, 359-363.

McCormick, M.P. (1992) Initial assessment of the stratospheric and climatic impact of the 1991 Mount Pinatubo eruption: Prologue: *Geophys. Res. Lett.*, **19**, 149pp.

Nicholson, S.E. (1989) African drought: characteristics, causal theories and global teleconnections. In: *Understanding Climate Change, Geophysical Monograph*, ed. A. Berger, R.E. Dickinson, and J.W. Kidson, Amer. Geophys. Union, **52**, 79-100.

Quinn, W.H. and Neal, V.T. (1992) The historical record of El Nino events. In: *Climate since A.D. 1500*, ed. R.S. Bradley and P.D. Jones, Routledge, London, 623-648.

Rampino, M.R. and Self, S. (1982) Historic eruptions of Tambora (1815), Krakatau (1883), and Agung (1963), their stratospheric aerosols, and climatic impact: *Quat. Res.*, **18**, 127-143.

Rampino, M.R. and Self, S. (1984) Sulphur-rich volcanic eruptions and stratospheric aerosols: *Nature*, **310**, 677-679.

Saunders, R. (1993) Radiative properties of Mount Pinatubo volcanic aerosols over the tropical Atlantic: *Geophys. Res. Lett.*, **20**, 137-140.

Schneider, S.H. (1989) *Global Warming: Are we entering the greenhouse century?*: Sierra Club Books, S.F., CA, USA, 343pp.

The SCA Statistical System (1995) The Scientific Computing Associates, Dekalb, Illinois, USA.

Tilling, R.I. (1990) Coping with volcanic hazards: A global perspective: *Earthquakes and Volcanoes*, **22(4)**, 154-160.

Wang, C.H., Li, L.A., Liaw, S.H., Yung, Y.L. and Li, Y.H. (1995) Taiwan's drought periods based on the precipitation records for the past 100 years: *The 4th Intl Conf. on the Evolution of the East Asian Environment*, Jan. 2-5, 1995, Hong Kong, in press.

W.R.P.C. (Water Resources Planning Commission) (1992) *Hydrological Year Book of Taiwan(1990)*: Republic of China. Ministry of Economic Affairs, 381pp.

Wu, M.C. (1992) Climate variation in Taiwan--temperature and precipitation: *Atmospheric Sci.*, **20(4)**, 295-318. (in Chinese)

區域雨量受到全球火山活動的影響－以台灣為例

李隆安[1]、汪中和[2]、廖述宏[3]、翁玉林[4]、李遠輝[5]、陳逸杰[6]、李品青[1]

1. 中央研究院統計科學研究所
2. 中央研究院地球科學研究所
3. 行政院交通部中央氣象局
4. 美國加州理工學院地質與行星科學系
5. 美國夏威夷大學海洋學系
6. 行政院主計處第三局

摘要

含硫火山噴發不止影響大氣溫度的劇變，也影響到全球水文的循環。這篇論文運用兩類統計分析來探討台灣地區八個雨量測站從西元1897至1993年的雨量變化，其中一類分析採用「聖嬰－南方振盪」做為分析時的共變數，另一類則沒有。兩類分析的結果都發現全球性含硫火山的噴發顯著的影響台灣地區的雨量，其噴發的時間正吻合台灣地區發生乾旱的時間，其影響的大小程度是「聖嬰－南方振盪」影響的2至10倍。

關鍵詞：火山活動、聖嬰－南方振盪、台灣地區雨量、統計分析