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行政院國家科學委員會專題研究計畫成果報告

亞洲大氣污染物之長程輸送與衝擊研究：

氣候分析與動力機制探討

The Impact and Long-Range Transport of Asian Atmospheric Pollutants: Climate Analysis and Examination of Dynamical Mechanisms

計畫編號：NSC 92-2111-M-034-002-AGC

執行期限：92 年 8 月 1 日至 93 年 7 月 31 日

主持人：余嘉裕　中國文化大學大氣科學系

1. Abstract

The Asian dust storms are well known to be one of the major aerosol sources for atmosphere in spring, and their impacts on regional air quality are also noted. Other than natural aerosol source like dust storms, the aerosols produced by the bio-mass burning in the Southeast Asia recently attract much attention from the research society. In this project, space-time characteristics of Asian aerosols are carefully examined. In particular, the background climate for long-range transport of Asian aerosols is presented.

Keywords：Asian dust storms, Bio-mass burning aerosols,

1. 摘要

亞洲沙塵暴為亞洲地區春季主要懸浮微粒之一世對於區域空氣品質有顯著衝擊。除了自然源之外，東南亞生質燃燒所產生之懸浮微粒也受到學界注意。本年度計畫將針對亞洲懸浮微粒時空分布特徵進行分析，適合長程輸送之背景大氣環流特徵將是本年度分析重點。

關鍵詞：亞洲沙塵暴、生質燃燒懸浮微粒

2、Introduction

It is well known that three conditions are necessary to induce a dust storm: (i) strong winds, (ii) unstable boundary layer, and (iii) dry and loose soils. The landscape of midlatitude Asian continent (40°N~50°N/80°E~110°E) meets condition (iii), while the active frontal movement provides the necessary conditions (i) and (ii). Asian dust storms are most active in the spring with peak month at April (Chen and Chen 1987).

Yu et al. (2002) use FGGE and TOMS data to examine the long-range transportation of dust aerosols and summarize that there are two major transportation routes for dust aerosols. One propagates eastward and the other propagates southeastward, depending on the large-scale atmospheric winds. They also note that the dust aerosols may penetrate southward to the subtropics. In this case, the air quality in Taiwan could be severely worsened (Lin et al 2001).

The FGGE surface observations not only provide the occurrence and propagation of a dust storm system but also provide its strength at each single station. Even TOMS data can capture the evolution of a dust storm system as well as the FGGE observations, the latter can provide additional information for numerical simulation purpose. For instance, the strength of the surface aerosol density is important in providing the correct initial conditions. Since most numerical models simply set the initial aerosol density arbitrarily without any observational evidence, the additional information (e.g., strength of dust storm, visibility, etc.) provided by FGGE data may be able to greatly improve the model accuracy in simulating the long-range transportation of Asian dust aerosols.

Meanwhile, recent articles published in Sciences (Menon et al. 2002; Chameides and Bergin 2002) indicate that black carbon can affect regional climate by absorbing sunlight and thereby altering the East Asian monsoon circulation. Using the NASA Goddard Institute for Space Studies climate computer model and aerosol data from 46 ground stations in China, they found that the effect of increased amounts of soot (over southern China) created a clear tendency toward the flooding scenario that has been occurring in southern China and the increasing drought over northern China that has persisted over the last several years.

The biomass burning over South Asia and Southeastern Asia during spring causes Asian brown clouds that persist for three to four months. The aerosol produced by the biomass burning has a strong impact on altering the radiative fluxes at the top of the atmosphere (Dr. Tsay, NASA, personal communication). This should further affect the Asian regional climate due to the variation of the radiative forcing.

Since Asian aerosols are much abundant in spring and their impacts on regional climate are not fully investigated and understood. It is our purpose here to use statistical analysis of various data sets and atmospheric models of various complexities to examine the impacts of aerosol variability on the regional climate through interactions of aerosol, cloud, and radiation. Detailed examination of the space-time aerosol variability and the background climate favoring long-range transportation are also carried out to provide the basis for numerical experiments.

3、Introduction

In the first-year project, FGGE[1]-type surface weather codes, NCEP grid data of atmosphere, surface weather maps, and TOMS aerosol index data are used to investigate the East Asian dust storm activity. The FGGE-type ground-station dataset provides 8 times daily observations of cloud cover, winds, visibility, weather phenomena, sea-level pressure, air temperature, precipitation, etc. Figure 1 shows the geographical distributions of some FGGE ground stations used in this study. It is noted that, except over Tibetan Plateau, ground stations are dense enough over regions of dust storm genesis and propagation.

The NCEP/NCAR (National Center for Environment Prediction/National Center for Atmospheric Research) reanalysis data used in this study use a state-of-the-art analysis/forecast system to perform data assimilation using past data from 1948 to present. This data set provides 4 times daily temporal resolution that includes air temperature, geopotential height, relative humidity, specific humidity, vertical velocity, and horizontal winds at 17 pressure levels from 1000hPa up to 10hPa, with a horizontal resolution of 2.5° × 2.5° longitude/latitude degrees. Detailed descriptions of this dataset are discussed in Kalnay et al. (1996).

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[1] FGGE experiment was held in the summer of 1979. Since then, data formats of traditional meteorological observations (e.g., ground, sounding, ship, and buoy observations) were unified and the name “FGGE-type data” was widely used or these traditional meteorological observations.

Aerosol particles are scattering and absorbing incoming sunlight, thus reducing visibility and increasing optical depth. The data from NASA's Total Ozone Mapping Spectrometer (TOMS) provides the Aerosol Index (AI) of aerosol particles in the atmosphere. The AI is determined by the UV radiometry measurements of TOMS with a property that positive values generally correspond to UV-absorbing aerosols and negative values to non-absorbing aerosols. AI is also related to aerosol optical depth, which is altitude dependent and is an indication of severity of the dust storm or aerosol. Aerosols at low altitudes tend to have a lower TOMS aerosol index than an equivalent depth of aerosol at a higher altitude.

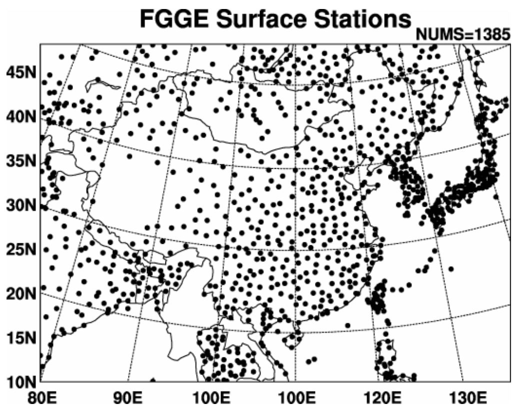

Figure 1: A horizontal distribution of land stations providing FGGE-type surface weather monitoring in East Asia.

4、Results

Figure 2 shows the seasonal activity of Asian dust storms. It is clearly that northern spring (March, April, and May) is the active season for Asian dust storms. All together, the spring accounting for nearly 70% of the total FGGE dust reports. Since the dust storms occurring to the east of 95ºE are most capable to transport dust particles eastward to affect the downstream regions, only dust activities to the east of 95ºE will be carefully examined in this project.

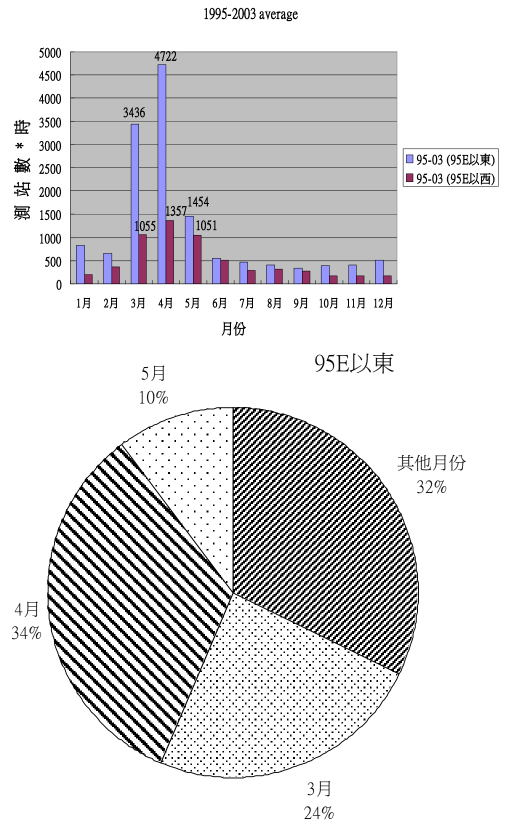

Figure 2: Monthly dust activity as measured by total FGGE dust-storm hours from 1993 to 2003 (upper) and the frequency of FGGE dust reports for March, April, May, and other month (lower).

Since the yearly activity of Asian dust storms vary significantly according to the background atmospheric climate conditions. Figure 3 compares dust storm activity between less-active and active years. In 1999, dust storms are relatively non-active. Over the dust storm source region, dust storm reports are rare. In 2001, much more active dust storms are observed over Gobi desert and over Inner Mongolia of China. The much active dust storm activity in 2001 compared to 1999 is a result of much stronger winds observed in the spring of 2001 as shown in Figure 4 which the frequency of strong winds (over 15 m/s) increases significantly compared to that in 1999.

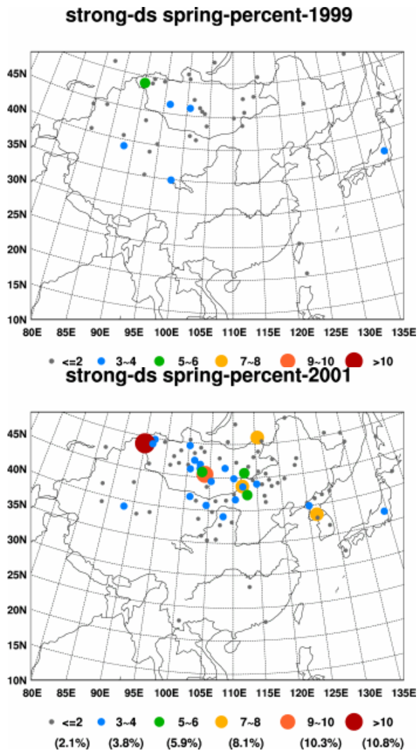

Figure 3: The dust-storm activity as measured by the numbers of dust storm day (or frequency in units of % in parenthesis) for the northern spring season in 1999 (upper panel) and 2001 (lower panel), respectively.

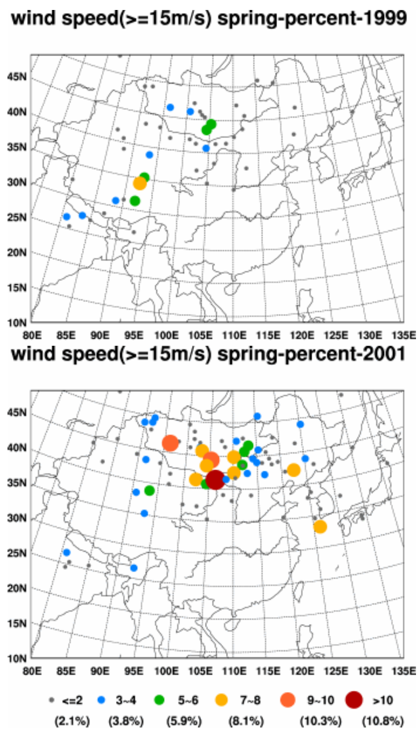

Figure 4: Same as in Fig. 3, except for the strong-wind occurrence days.

Figure 5 shows the background 1000hPa climate for spring season in East Asia. We clearly note that the existence of an east-west oriented dry zone is a common feature over the mid-latitude Asian continent in spring. Yet, we also note that the dry zone is much more intense with low humidity contours extending further eastward in 2001 compared to 1999. The prevailing winds over dust storm source region are mostly northwesterly or westerly in 2001, favoring long-range transport of dust aerosols.

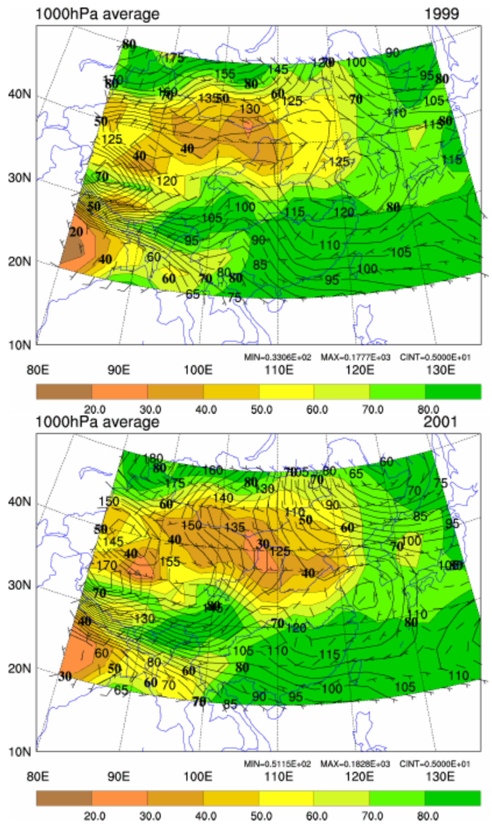

Figure 5: Horizontal distribution of the 1000hPa winds, geopotential height, and relatively in East Asia for the year 1999 (upper panel) and 2001 (lower panel), respectively.

To further understand the space-time characteristics of Asian dust aerosols, we employ the empirical orthogonal function (EOF) analysis of the TOMS aerosol index (AI). Figure 6 show the horizontal distribution of TOMS AI variability. In 1999, AI signals are mostly observed over Inner Mongolia and Hobe Province of China. These signals are the results of several minor dust activities observed in April and May as shown in the time series of principle component. In 2001, AI signals are more widespread and significant AI signals are also found over northeast China and northern Japan, as well as the surrounding oceans. These AI signals are the results of an intense dust storm event occurring in early April as shown in the time series of principle component.

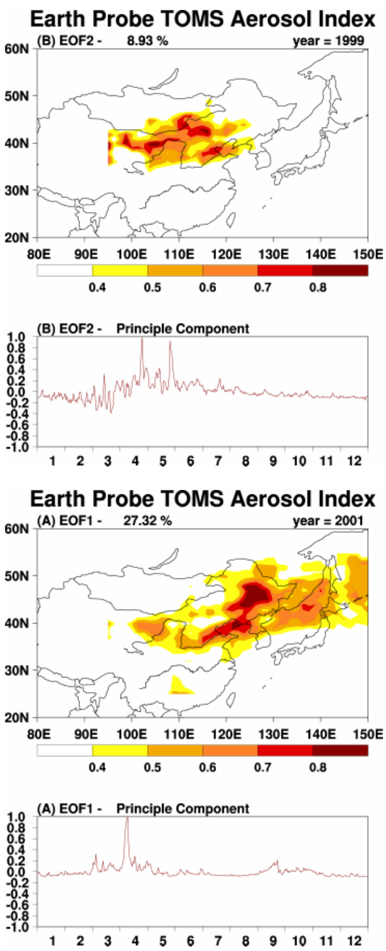

Figure 6: EOF analysis of the TOMS aerosol index for the year 1999 (upper panel) and 2001 (lower panel), respectively.

5. Concluding remarks

In the first-year project, statistic methods such as the EOF (Empirical Orthogonal Function) Analysis, SVD (Singular Value Decomposition) analysis, and composite analysis are used to examine i) the space-time characteristics of Asian aerosols resulted from either the Asian dust storms or the bio-mass burning processes. ii) the background climatology that favors long-range aerosol transport that is important for forecast purpose.

The preliminary results indicate that the Asian dust storms are much more active in spring (March, April, and May), with nearly 70% of the dust storms observed in the spring season. However, the dust activity also exhibits large inetrannual variability as a result of changing large-scale atmospheric circulation over Asian continent. We choose 1999 (2001) as an example of less-active (active) dust year. By comparing the background climate between 1999 and 2001, we note the prevailing northeasterly winds observed over Gobi desert and Inner Mongolia in the spring of 2001 are pretty much responsible for the intense and widespread dry zone, which may result in the enhancement of dust storm activity over East Asia.

6、References

Chameides, W. L. and M. Bergin, 2002: Soot takes center stage. *Sciences*, **297**, 2214-2215.

Chen, G. T.-J., and H.-J. Chen, 1987: Study on large-scale features of dustorm system in East Asia. *Papers in Meteor. Res.*, **10**, 57-80.

Chen, J.-P., and coauthors, 2002: The weather condition of Mainland dustorm and the establishment of warning system. EPA final report (EPA-91-U1L1-02-108)

Dickinson, R. E., 1984: Modeling evapo-transpiration for three-dimensional global climate models. In *Climate processes and climate sensitivity*, J. E. Hanson and T. Takahashi, eds., Geophysical Monograph 29, Maurice Ewing Volume **5**, *Amer. Geophys. Union*, 58-72.

Dickinson, R. E., A. Henderson-Sellers, P. J. Kennedy, and M. Wilson, 1986: Biosphere-Atmosphere Transfer Scheme (BATS) for the NCAR Community Climate Model. NCAR *Tech. Note TN-275+STR*, NCAR, Boulder, CO, 1986.

Entekhabi, D., and P. S. Eagleson, 1989: Land surface hydrology parameterization for atmospheric general circulation models including subgrid scale spatial variability. *J. Climate*, **2**, 816-831.

Hansen, J., I. Fung, A. Lacis, D. Rind, S. Lenedeff, et al., 1988: Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model. *J. Geophys. Res.*, **93D**, 9341-9364.

Lin, N.-H., J.-Y. Yu, G.-S. Huang, C.-M. Peng, and S.-T. Lai, 2001: The impact of long-range dust storm transportation on air quality over Taiwan. EPA final report (EPA-90-FA17-03-90B023).

Lin, N.-H., and coauthors, 2002: Intensive observations in atmospheric boundary layer of highly polluted area and study of the dispersion of air pollutants. EPA final reports (EPA-91U1L1-02-109).

Menon, S., J. Hansen, L. Nazarenko, and Y. Luo, 2002: Climate effects of black carbon aerosols in China and India. *Sciences*, **297**, 2250-2253.

Shuttleworth, W. J., 1988: Evaporation from Amazonian rain forest. *Phil. Trans. Roy. Soc. London B*, **233**, 321-346.

Yu, J.-Y., Y.-M. Cho, and J.-Y. Tu, 2002: On the space-time characteristics of East Asian dust storms. Submitted to *Environmental Protection*.