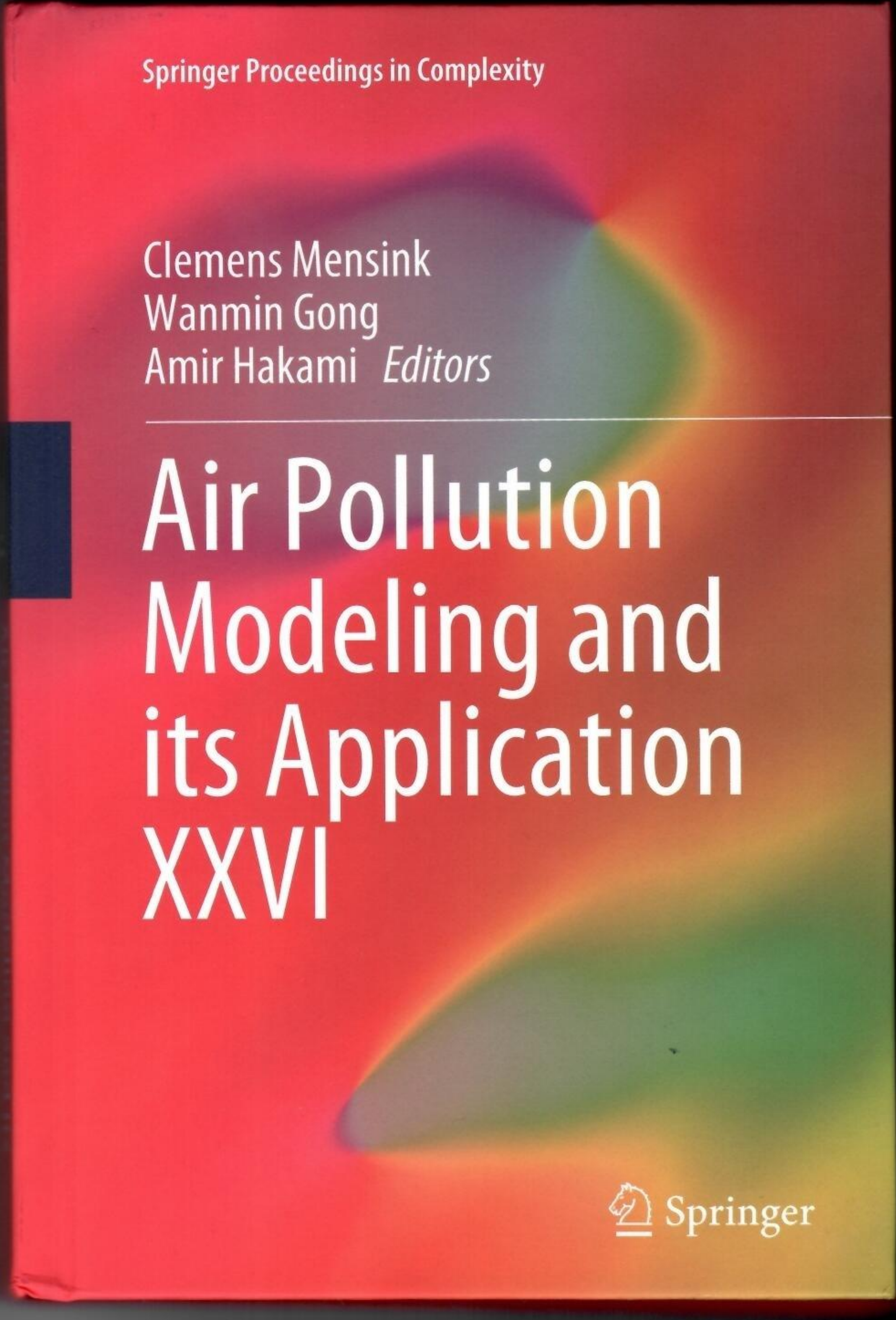

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Air Pollution Modeling and its Application XXVI

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Chapter 44

Distinguishing Between Remote and Local Air Pollution Over Taiwan: An Approach Based on Pollution Homogeneity Analysis

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Abstract An analysis of pollution homogeneity has been conducted to distinguish between remote and local pollution which contributes to month to month changes in aerosol optical depth (AOD) over the Taiwan area. This was carried out using both AERONET measurements at six monitoring sites in Taiwan and NASA MERRA-2 reanalysis, over the 15-year period from 2002 to 2017. As a measure of air pollution homogeneity we used the AOD standard deviation: the more homogeneous the spatial distribution of air pollution, the lower the AOD standard deviation is. Using this approach, we found that, over Taiwan, in autumn, inhomogeneous local air pollution is predominant, while, in spring, homogeneous remote air pollution from south-east Asia dominates. In autumn, when inhomogeneous aerosols from local sources dominate, the AOD standard deviation is essentially higher than that in spring, when homogeneous aerosols from remote sources dominate. Our approach allowed us to distinguish between homogeneous remote and inhomogeneous local sulfate air pollution of similar optical properties and chemical composition.

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44.1 Introduction

Taiwan is an island located at approximately 200 km eastward from the Pacific coast of South East Asia. Both remote air pollution from highly polluted south-east Asia (including emissions of bio-mass burning) and local air pollution from Taiwanese industries and transportation contribute to the distribution of aerosol optical depth (AOD) over the Taiwan area. Distinguishing between remote and local air pollutants is important for raising awareness about their separate effects on regional air quality, weather and climate. To this end, an approach has been developed, based on the homogeneity of both AOD data from NASA MERRA-2 aerosol reanalysis and AERONET AOD measurements [2].

44.2 Method

According to Kishcha et al. [2], AOD and its standard deviation can be used as a measure of air pollution homogeneity. To estimate month to month changes in air pollution homogeneity over Taiwan, we used AOD monthly data from six AERONET stations during the 15-year period from 2002 to 2017 (Fig. 44.1a). The analysis of AERONET AOD was complemented with the analysis of MERRA-2 reanalysis AOD data during the 15-year study period. MERRA-2 reanalysis includes AOD of the following aerosol species: black and organic carbon, sulfate, desert dust, and sea salt [1]. MERRA-2 is based on the up-to-date NASA GEOS-5 model with aerosol data assimilation. According to Randles et al. [3] and Buchard et al. [1], for the

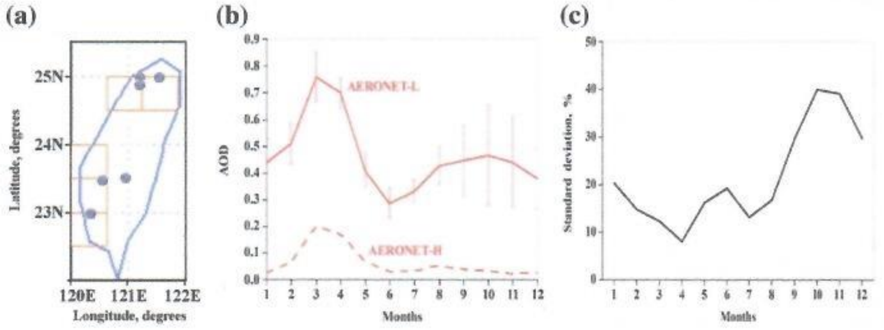

Fig. 44.1 **a** The Taiwan area, where the closed circles show the location of AERONET sites, while the orange open boxes represent GEOS-5 model grid boxes located in the vicinity of AERONET sites. Each GEOS-5 model grid box is 0.5° latitude by 0.625° longitude; **b** month to moth changes in 15-year mean AERONET AOD (2002–2017). AERONET-L designates AERONET AOD averaged over the five low-elevated AERONET sites, while AERONET-H designates AOD from the high-elevated (2800 m a.s.l.) Lulin site. The AOD standard deviation is shown by the vertical red lines; **c** month to month changes in the AERONET AOD standard deviation from the five low-elevated sites, in percentage to the 15-year mean AOD (Updated from Kishcha et al. [2])

aerosol data assimilation GEOS-5 uses AOD retrievals from the Multiangle Imaging SpectroRadiometer (MISR), the Moderate Resolution Imaging Spectroradiometer (MODIS) on both NASA Terra and Aqua satellites; the Advanced Very High Resolution Radiometer (AVHRR) instruments over bright surfaces, and ground-based AERONET direct measurements. Month to month changes in MERRA AOD were analyzed over the following two areas: the open ocean area in the vicinity of Taiwan (25.5 N–29 N; 122.5E–124.5E) and the Taiwan area (22 N–25.5 N; 120E–122E). In addition, a spatial distribution of wind vectors in the 700–800 hPa layer was analyzed, using 15-year monthly mean MERRA data.

44.3 Results and Discussion

Month to month changes in AERONET AOD measurements in Taiwan show the primary maximum (AOD $\approx$ 0.75) in spring (March–April) and the secondary maximum (AOD $\approx$ 0.45) in autumn (September–October) (Fig. 44.1b). AOD from the high-elevated site in Lulin is essentially lower than AOD from the low-elevated AERONET monitoring sites. Therefore, air pollution in Taiwan is mainly vertically distributed below 2800 m a.s.l., in line with Kishcha et al. [2]. As shown in Fig. 44.1b, the standard deviation of AERONET AOD in spring is significantly lower than that in autumn, indicating the more homogeneous AOD spatial distribution in spring than in autumn. Therefore, aerosols originating from remote sources were more homogeneously distributed over Taiwan than local aerosols [2]. As a measure of air pollution homogeneity, we used the AOD standard deviation: the more homogeneous the spatial distribution of air pollution is, the lower the AOD standard deviation is. To quantify changes in aerosol homogeneity over Taiwan over the year, we analyzed month to month changes in the AERONET AOD standard deviation in percentage to the 15-year mean AOD (Fig. 44.1c). One can see that, in autumn (October), the AOD standard deviation is essentially higher than that in spring (March–April) (Fig. 44.1c): this fact points out that, in autumn, inhomogeneous aerosols from local sources are predominant, while, in spring, homogeneous aerosols from remote sources dominate.

The above mentioned finding is supported by the analysis of spatial distributions of 15-year monthly mean MERRA wind vectors in the 700–800 hPa layer [2], their Fig. 7). In particular, Kishcha et al. [2] showed that, in the spring season (March), prevailing strong west and south-west winds blow mainly from land to sea, causing transport of anthropogenic air pollution (including biomass burning) from its sources in continental Asia towards Taiwan. Therefore, in spring, aerosols from remote sources are likely to be predominant. By contrast, in autumn (October), weak east winds are observed over Taiwan, indicating insignificant transport of continental air pollution towards Taiwan [2]. Therefore, in autumn, aerosols from local sources are likely to dominate.

To support our findings about the origin of air pollution responsible for the spring and autumn AOD maxima, we conducted a comparison of month to month changes in MERRA AOD over the open ocean area in the vicinity of Taiwan (25.5 N–29 N;

122.5E–124.5E), where there are no local sources of anthropogenic aerosols, and over the Taiwan area (22 N–25.5 N; 120E–122E), where there are local sources of anthropogenic aerosols (Fig. 44.2). For sulfate aerosols, which are the major pollutant in Taiwan, MERRA AOD peaked in both spring and autumn over Taiwan, but not over the open ocean, where only the spring maximum exists (Fig. 44.2, the magenta lines). This is evidence of the contribution of local sulfate aerosols to the maximum in autumn over Taiwan. By contrast to sulfates, there are no local sources of carbonaceous aerosols (OC & BC) neither in the Taiwan area no in the open ocean area in the vicinity of Taiwan. MERRA AOD for carbonaceous aerosols (OC & BC) shows similar seasonal variations with only one maximum in spring over the two areas (Fig. 44.2, green lines). This indicates that remote carbonaceous aerosols dominate in spring over Taiwan.

Furthermore, our approach allowed us to distinguish between homogeneous remote and inhomogeneous local sulfate air pollution of similar optical properties and chemical composition. To this end we analyzed sulfate aerosol homogeneity over Taiwan using month to month changes in MERRA sulfate AOD and its standard deviation. MERRA sulfate AOD was averaged over the five model grid boxes of 0.5° latitude by 0.625° longitude each, located in the vicinity of the low-elevated AERONET sites (Fig. 44.3). One can see that the standard deviation of MERRA sulfate AOD in autumn was higher than that in spring (Fig. 44.3). This is similar to AERONET AOD (Fig. 44.1). Therefore, inhomogeneous sulfate aerosols from local sources are predominant in autumn, while homogeneous sulfate aerosols from remote sources dominate in spring. The same approach can be applied to distinguish between remote and local air pollution over different land areas on a global scale.

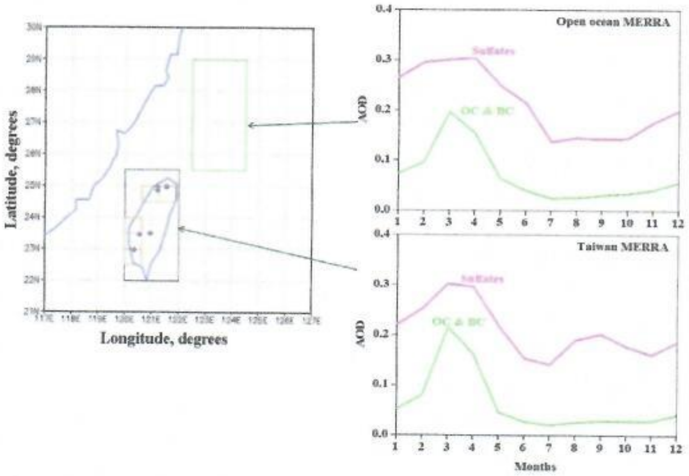

Fig. 44.2 Month to month changes in MERRA AOD over Taiwan and over the open sea area (the green open rectangle in the left panel) in the vicinity of Taiwan, over the 15-year period from 2002–2017. The green lines designate organic and black carbon (OC & BC), while the magenta lines designate sulfate aerosols (Updated from Kishcha et al. [2])

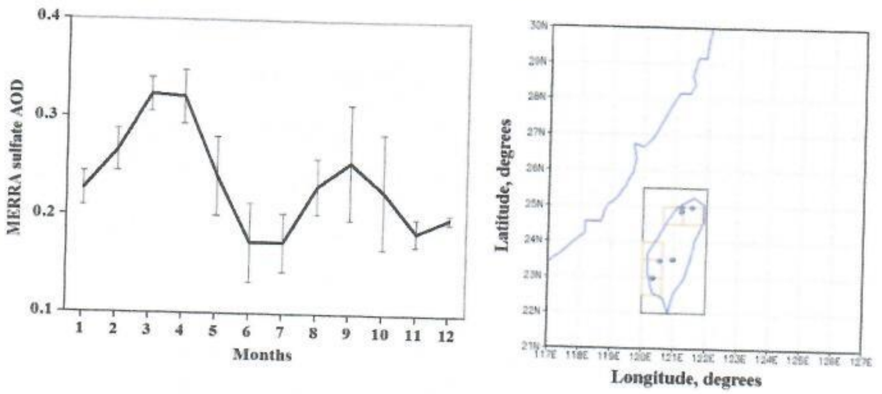

Fig. 44.3 The left panel shows month to month changes in 15-year mean MERRA sulfate AOD over Taiwan. MERRA sulfate AOD was averaged for the five specified GEOS-5 grid boxes of 0.5° latitude by 0.625° longitude each, located in the vicinity of AERONET sites (the orange open boxes on the right panel). The standard deviation of AOD is shown by the black vertical lines. The right panel represents the study area (Updated from Kishcha et al. [2])

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