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Inter-annual variation of aerosol pollution in East Asia and its relation with strong/weak East Asian winter monsoon

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Abstract

Aerosol has become one of the major air pollutants in East Asia, and its spatial distribution can be affected by the East Asian monsoon circulation. By means of the observational analysis and the numerical simulation, the inter-annual variation of wintertime aerosol pollution in East Asia and its association with strong/weak East Asian winter monsoon (EAWM) are investigated in this study. Firstly, the MODIS/AOD records during 2000-2013 are analysed to reveal the inter-annual variation characteristics of aerosols. It is found that there is an increasing trend of AOD in East Asia over the last decade. The areas with obvious increasing AOD cover the Sichuan Basin (SCB), the North China Plain, and most of the Middle-Lower Yangtze River Plain in China. Secondly, the EAWM index (EAWMI) based on the characteristic of circulation are calculated to investigate the inter-annual variations of EAWM. The NCEP reanalysis data are used in EAWMI calculation and meteorological analysis. Nine strong and thirteen weak EAWM years are identified from 1979 to 2014. Finally, the effects of strong/weak EAWM on the distribution of aerosols in East Asia are discussed. It is found that the northerly wind strengthens (weakens) and transports more (less) aerosols southward in strong (weak) EAWM years, resulting in higher (lower) AOD in the north and lower (higher) AOD in the south. The long-term weakening trend of EAWM may potentially increase the aerosol loading. The weakening of EAWM should be another cause that results in the increase of AOD over the Yangtze River Delta (YRD) region, the BeijingTianjin-Hebei (BTH) region and SCB but the decrease of AOD over the Pearl River Delta (PRD) region. Using the Regional Climate-Chemistry coupled Model System (RegCCMS), we further prove that the intensity of EAWM has great impacts on the spatial distribution of aerosols. More obvious changes occur in lower atmosphere, and the change pattern of aerosol column content in different EAWM years is mainly decided by the change of aerosols in lower troposphere. This chapter mainly focuses on the characteristics of the East Asia winter monsoon (EAWM). An examination of the climatology of the boreal winter in Asia shows that the EAWM results from the development of a cold-core high over the Siberia-Mongolia region. The movement of this cold air southward produces pressure surges and temperature drops across the Asian continent. Two types of such surges can be identified: the northerly surge (NS) and the easterly surge (ES). The initiation of the NS begins with the eastward passage of a polar jet streak west of Lake Balkhash. The eastward migration of this jet streak over the Siberia-Mongolia region intensifies a cold high there, which eventually leads to a southward outpour of the cold air in the lower troposphere. Such a push of the cold air then excites gravity waves that propagate across the South China Sea, which results in convection over the maritime continent. On the other hand, an ES is apparently the consequence of an initially eastward and then south-eastward migration of a cold pool that splits off from a quasi-stationary high-pressure system over the Siberia-Mongolia region due to the passage of a 500-hPa ridge over the region. As the low-level anticyclone moves to the east coast of China, it initiates a southward surge of cool air and strong winds along the coast, resembling a coastal Kelvin wave. Its strength is usually much less than that of the NS. Other than these surges, a significant effect of the EAWM is the explosive development of low-pressure systems over the East China Sea as the cold air moves off the continent and over the warm water, which results from the strong baroclinity between the cold air from the continent and warm air over the ocean, and the subsequent potential instability, rising motion and latent heat release. The last section of the chapter discusses intrapersonal, internal and interdecadal variations of the EAWM, which can be related to similar oscillations in other planetary-scale circulation features. These include the 10-20-day oscillation, the Madden-Julian Oscillation, the polar vortex, the El Niño/Southern Oscillation, sea-surface temperature anomalies in the North Pacific, the North Atlantic Oscillation, and the East Asia summer monsoon. Furthermore, “two-way” interactions between the EAWM and some of these oscillations have also been found.

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