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The impact of large-scale circulation on daily fine particulate matter (PM2.5) in major populated regions of China during winter

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With rapid economic growth and urbanization, air pollution episodes with high levels of particulate matter ($PM_{2.5}$) have become common in China. While emissions of pollutant precursors are important, meteorology also plays a major role in pollution episodes, especially in winter. We examine the influence of the dominant large-scale circulation and the key regional meteorological features on $PM_{2.5}$ over three major regions of China: Beijing–Tianjin–Hebei (BTH), the Yangtze River Delta (YRD), and the Pearl River Delta (PRD). The East Asian winter monsoon (EAWM) is primarily studied, including some of its main large-scale components such as the East Asian trough and the Siberian high, as it influences $PM_{2.5}$ differently in different parts of China. In the BTH region, the shallow East Asian trough curbs the invasion of northerly cold and dry air from the Siberian high which induces high relative humidity and heavy pollution, possibly via relative humidity-promoted aerosol formation and growth. A weak southerly wind in Eastern and Southern China associated with a weakened Siberian high suppresses horizontal dispersion, contributing to pollution accumulation over YRD. In addition, the El Niño-Southern Oscillation (ENSO) as the dominant mode of global ocean-atmosphere interaction has a substantial modulation on precipitation over southern China. In the PRD, weak southerly winds and precipitation deficits over southern China are conducive to atmospheric pollution possibly via reduced wet deposition. Furthermore, we construct new circulation-based indices based on the dominant large-scale circulation: a 500 hPa geopotential height-based index for BTH, a sea level pressure-based index for YRD and an 850 hPa meridional wind-based index for PRD. These three indices can effectively distinguish different levels of pollution over BTH, YRD and PRD, respectively. We also show how additional regional meteorological variables can improve the prediction of regional $PM_{2.5}$ concentrations for these three regions. These results are beneficial to understanding and forecasting the occurrence of severely polluted days for BTH, YRD and PRD from a large-scale perspective.