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Effects of turbulence structure and urbanization on the heavy haze pollution episodes

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In this paper, we developed an automated algorithm to identify the spectral gap to separate pure turbulence and sub-mesoscale motions from a 30-min signal based on the arbitrary-order Hilbert spectral method. We used this automated algorithm to analyze turbulence data observed from several severe haze pollution episodes in Beijing and its nearby suburbs from 16 December 2016 to 8 January 2017. The datasets with a spectral gap accounted for approximately 30% of the total data, indicating that the eddy-correlation flux calculated using a conventional averaging time of 30 min to define perturbations is severely contaminated by poorly sampled mesoscale motions. The results of the urban site reflect are consistent with the conclusions of the suburban site. The calculations of the fluxes were also overestimated. The momentum flux, heat flux and water-vapor flux were overestimated by approximately 13%, 12%, and 15%, respectively. We can see from these comparisons that the overestimation of flux during haze events cannot be ignored. After reconstruction via the automated algorithm, pure turbulent data can be obtained. We introduce a definition to characterize the local intermittent strength of turbulence (LIST). Then, we explore the relationship between the LIST and pollution. The results indicate that when pollution is heavy, the LIST is smaller, and the intermittency is stronger; when pollution is lighter, the LIST is larger, and the intermittency is weaker. At the same time, the LIST at the city site is greater than that at the suburban site, which means that the intermittency over the complex city surface is weaker than that over the flat terrain of the suburbs. Urbanization seems to reduce the intermittency during heavy haze pollution episodes. The results were validated via the statistics on the impact of urbanization on turbulence and turbulent transport during polluted and clean periods. The sensible heat flux, latent heat flux, momentum flux, and TKE over the urban and suburban areas are all affected when pollution occurs. Due to the close distance between the two stations, the large-scale weather background is consistent, and the suburban site is locally flat, so the turbulent structure over the flat surface of the suburban area is considered as the normal state in this area under such weather and pollution source conditions, then the urban turbulent structure is influenced by urbanization. More importantly, the reduction of turbulence exchange during the pollution period in suburban sites is greater, compared to urban sites. In other words, the impact of the pollution process on the suburbs is much greater than that on the urban area. The change in the underlying surface of the urban site (the dynamic effect of complex terrain and the heat island effect caused by human activities) leads to a greater resistance to the weakening effects of turbulent exchange caused by pollution.