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Variability of winter haze over the Beijing-Tianjin-Hebei region tied to wind speed in the lower troposphere and particulate sources

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This study analyzes the variability of winter haze days and visibility in the Beijing-Tianjin-Hebei (BTH) region, in relation to wind speed changes in the lower troposphere and emissions for 1961–2014. Daily surface meteorological data, NCEP/NCAR atmospheric reanalysis data, and fossil fuel emission data are used in this research. The results reveal a significant increase in winter haze days of +0.8 days decade-1 ($p<0.01$), and a subsequent decline in visibility of -1.56 km decade-1 ($p<0.01$). Most interestingly, an accelerated increase in haze days was observed for the last 11-year period (+8.3 days decade-1) of the study (2004–2014). The increase of winter haze occurrence and decrease in visibility in the study region are partly attributed to: the significant ($p<0.01$) declining trend of mean wind speed at the near-surface (-0.19 m s-1 decade-1), 925hPa (-0.23 m s-1 decade-1), and 850hPa (-0.21 m s-1 decade-1); the vertical shear of wind between 1000hPa and 850hPa (-0.07 m s-1 decade-1); and, the declining (dust storm frequency as a proxy, -0.41days dec-1) surrounding particulate sources and increasing fossil fuel emissions (total carbon emission as a proxy, +4820.6 metric tons dec-1). Specifically, wind speed changes in the lower troposphere explain 41.3% of winter haze days and 71.2% of the visibility variance. These are extended to 51.7% and 81.6% respectively when combined with natural (dust storm frequency) and anthropogenic (fossil fuel emissions) particulate sources. Therefore, the analyses show that wind speed changes in the lower troposphere, together with the varied natural and anthropogenic sources of particulates, play a key role in modulating winter haze and visibility conditions in the BTH area.