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## Long-term trends and variations in haze-related stagnation intensity in North China during 1980-2018

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Recently, the climatological and environmental communities have paid significant attention to the long-term trends and variations in haze-related weather conditions in North China (NC). This study investigates the issue based on a quantified air stagnation index ( $ASI_E$ ) that combines the stagnation intensity with the background emissions, considering that haze occurrence strongly depends on the rate of emission.  $ASI_E$  shows a close spatial and temporal relationship with the observed  $PM_{2.5}$  concentrations, and a strong sensitivity to haze occurrence in NC. The change in  $ASI_E$  revealed an approximate 19% increase in the annual stagnation intensity over the period of 1980-2018, due to significant decreases in PBLH and ventilation potency. The interannual variations in stagnation intensity were very significant. The percentage change of  $ASI_E$  was as high as 50-70% in some years. However, there was an apparent drop in stagnation intensity during 2013-2018, which possibly contributed to the recently reported improvement in aerosol concentration in NC. It also shows that such low-frequency oscillation occurred twice during 1980-2018. Hence, once the current trend of decreasing stagnation intensity changes, haze events may become more common in the future. Finally, we present a quick estimate for the emission reduction ratio that can balance the variations and trend of stagnation intensity using a simple linear model, which can be used to evaluate the difficulty of the "clean air challenge" in NC. The results suggest that the enforcement of the emission reduction plan should be tailored according to the stagnation conditions in the case study year and region.