Weather conditions conducive to Beijing severe haze more frequent under climate change

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The frequency of Beijing winter severe haze has increased over past decades. In January 2013, for example, the maximum daily PM$_{2.5}$ near Beijing reached 500 μg m$^{-3}$. While the underlying cause is increased pollutant emissions, local weather conditions play a part. Further, decadal climate variability and change may have contributed. However, no long-term PM$_{2.5}$ observations are available for attribution of the increased frequency. Here we show that circulation changes induced by global greenhouse gas emissions can contribute to the increased Beijing severe haze frequency.

Linkage between severe haze events and weather conditions

To examine the weather linkage, we concatenated the seven years of winter daily PM$_{2.5}$ (the observed time series of PM$_{2.5}$ in Beijing commence in 2009 from the US Embassy). Correlation of available observed PM$_{2.5}$ over 2009–2015 with a range of ambient daily anomalies reinforces the link between PM$_{2.5}$ and weather conditions. Strong correlations are found in lower tropospheric meridional flows, midtropospheric zonal flows, and vertical temperature profiles.

Haze weather index and its observed change

Because V850, $\Delta T$ and USO are not independent, we normalized each time series by its respective standard deviation and summed the three normalized time series to construct a single index, referred to as Haze Weather Index (HWI; green, Fig. 2).

We tested the sensitivity of the HWI to the inclusion of more weather parameters, for example, a local stratification instability, and found little differences by including more parameters. The correlation between PM$_{2.5}$ and the HWI is 0.66, and the correlation between the HWI and a time series of daily visibility over Beijing is $-0.61$ over the 2014–2015 period. And 89% (146/164) of all observed severe haze events occurred with a HWI $>0$.

Future changes in the frequency of severe haze weather conditions

Under climate change, the frequency of conducive weather conditions increases markedly, manifested as a systematic shift towards higher HWI values, contributed by a similar shift towards a higher frequency of weaker northerly winds, more stable lower atmosphere conditions, and weaker East Asian troughs. Aggregated over the 15 models, there is a 20% increase in days with HWI $>0$, an 50% increase in days with HWI $>1$, the conditions under which the January 2013 events occurred.

Conclusions

- An effective index is developed to represent Beijing severe haze weather conditions.
- Future conducive weather conditions will be significantly more frequent, which is consistent with large-scale circulation changes induced by greenhouse warming.
- Global efforts in reducing GHG emissions will contribute to decreasing the risks of Beijing severe haze, as well as haze pollution over eastern China.

For further information, Cai Wenju, Ke Li, and Hong Liao et al. (2017), Weather conditions conducive to Beijing severe haze more frequent under climate change, Nature climate change 7, doi:10.1038/nclimate3249. Or scan the QR code below.