The influence of internal climate variability on synoptically-driven poor air quality in Beijing

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Beijing has recently suffered a series of poor air quality episodes, which have severely impacted human health and economic growth in Northeast China. Because pollution emissions have been relatively constant in the region, poor air quality in Beijing is generally driven by pollutant-trapping meteorological conditions (e.g. anomalous southerly winds, atmospheric stability, high relative humidity, and weak surface winds). Irrespective of pollutant emissions trends, existing research differs considerably on the risk that anthropogenic forcing poses to poor air quality in Beijing. Differences in such risk assessments are driven in part by disagreements over: (1) which meteorological ingredients most strongly influence Beijing's poor air quality in the present day; (2) the appropriateness of using spatially-coarse coupled models to project changes in such meteorological processes; and (3) the accounting of how internal variability materially shapes such risks in the present and future. Using both observations and the CESM Large Ensemble (CESM-LE), we address each of the above, showing that the observational occurrence of favorable pollutant-trapping meteorology is consistently linked to synoptic-scale anticyclonic circulation over the region, thereby placing each ingredient in the context of a larger set of physical processes. The skill of synoptic-scale circulation in accounting for observed air quality variability provides the grounds on which we evaluate historical CESM representations of such circulation and its association with poor air quality meteorology in the wider context of internal variability. Based on our evaluation of CESM's representation of the historical connections between synoptic circulation and local meteorology in Beijing, we use the CESM-LE to quantify the relative roles of anthropogenic forcing and internal variability in projected poor air quality risks for the region. The potentially significant role of internal variability in shaping these risks emphasizes the importance of fully constraining the geophysical sources of uncertainty to better assess the risks of future human health hazards.