find that the probability of experiencing a high-impact year (defined as over 25,000 households damaged or destroyed) increases over six times by the end of the twenty-first century. Part of this increment results from the rapid expansion (urban sprawl) of major cities such as Atlanta, Chicago, Dallas, and St. Louis.

The study by Strader *et al.* considers worst-case risk and exposure scenarios to draw attention to the potential impact of disasters in the absence of mitigating policy, but also to highlight the relative importance of risk and exposure in driving disaster potential. In particular, the latter is critical for the development of effective policies for protection against natural disasters. This research represents an important first step within the context of tornado disasters, which are a costly, dangerous, and highly unpredictable threat to the US. In addition, the methods applied in this research provide a useful framework for future research, which could consider a large range of outcomes and sensitivity levels for different climate scenarios and alternative patterns of spatial development. ❒

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ATMOSPHERIC SCIENCE

Warming boosts air pollution

Atmospheric conditions play an important role in driving severe air pollution events in Beijing, China. Now research finds that global warming will enhance weather conditions favouring such events, increasing the chances of severe winter-time haze in the future.

Renhe Zhang

In recent years, the adverse economic and health impacts of air pollution in China have made the abatement of such pollution a key scientific, public, and governmental concern. However, the number of winter-time (December–February) haze days in China has significantly increased in recent decades[1], primarily attributed to greater emissions of anthropogenic pollutants associated with rapid urbanization and industrialization. Despite the occurrence of severe haze events being strongly reliant on specific weather conditions[2], weather condition changes are thought to play a minor role in the increased incidence of haze days[3]. Now, writing in *Nature Climate Change*, Wenju Cai and colleagues[4] report that conditions conducive to severe haze events in Beijing have increased in response to anthropogenic climate change, and will likely continue to do so throughout the twenty-first century.

Haze events describe times during which atmospheric concentrations of fine particles — that is, particulate matter with a diameter less than 2.5 μm ($PM_{2.5}$) — are high enough to reduce visibility to less than 10 km. When concentrations exceed 150 μg m^{-3}, conditions can be considered severe, surpassing the level the World Health Organization defines as dangerous to human health. Severe haze events are epitomized by January 2013 conditions, wherein vast haze covered over 30 cities, peak $PM_{2.5}$ concentrations reached 500 μg m^{-3} in Beijing, and economic impacts totalled US$ 3.4 billion[5].

The intensity, duration, and spatial coverage of such severe haze events have increased. In Beijing, for example, severe haze was present for 12, 18, and 25 days of

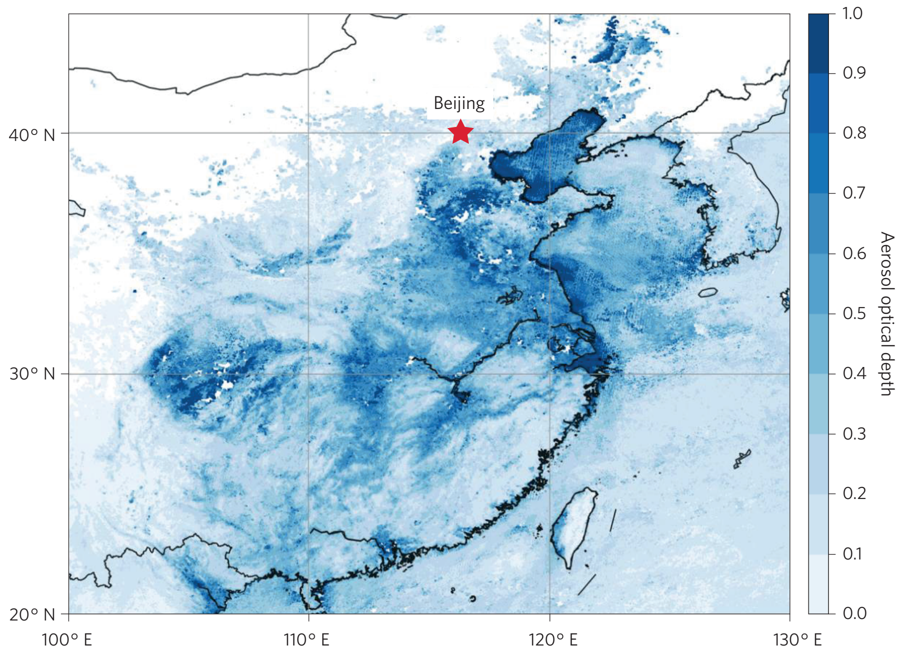

Figure 1 | Satellite-derived aerosol optical depth (AOD) over China averaged from 1 December 2016 to 31 January 2017. The AOD, ranging from non-dimensional units 0–1, is a measure of the atmospheric opacity affected by aerosols in clear sky; the higher the AOD, the more turbid the atmosphere. High pollution levels are observed throughout eastern China due to stable air and vast winter-time emissions.

the 2014–2015, 2015–2016 and 2016–2017 winter seasons, respectively. Given the grave economic and health impacts associated with haze events, it is necessary to understand what is driving apparent changes in their frequency.

With a population of more than 1.3 billion people, China has experienced considerable economic development and corresponding urbanization over the past ~50 years. The drastic increase in energy consumption associated with these developments has not only supported a rapid growth in gross domestic product, but also a rise in national and imported emissions[6]. An increase in anthropogenic pollutants can undoubtedly be connected to enhanced haze events observed across China, particularly in large cities such as Beijing.

However, severe haze events are also driven by specific meteorological conditions that encourage stagnant air. For example, winter-time air pollution is closely related to variability in East Asian winter monsoon intensity[7]. The observed monsoonal weakening over the past few decades[8] has reduced wind speeds around Beijing, subdued airflow transport for pollutants, and may therefore partially contribute to the increased incidence of extreme haze days.

Now, Cai *et al.* reveal a new perspective for understanding the increasing trend of haze events in Beijing[4], proposing that anthropogenic climate change and the associated impacts on atmospheric circulation may contribute to weather conditions being more conducive to their occurrence. Specifically, they define a haze weather index (HWI) that describes whether meteorological conditions (vertical air temperature difference between the lower and upper atmosphere, lower tropospheric wind velocity, and mid-tropospheric zonal flow) are favourable for extreme haze. Using observations, they find that positive HWI values (that is, favourable haze conditions) have increased in frequency by 10% when comparing 1948–1981 with 1982–2015. Thus, climate change over the past several decades is thought to create weather conditions more favourable for triggering haze events in Beijing.

How weather conditions conducive for winter-time haze will change in the future is an additional key concern. To address this issue, Cai *et al.* utilize the results of 15 models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) under the RCP8.5 (high emission) scenario. They demonstrate that the frequency of all positive HWI events will increase in the future, and that this will be most notable for more extreme conditions; for example, events with a HWI higher than 1 (analogous to January 2013 conditions) will increase by 50% when comparing 1950–1999 with 2050–2099. Haze events, particularly extremes, are therefore found to occur more frequently in the future.

Due to the severity of air pollution, the Chinese government introduced the Air Pollution Prevention and Control Action Plan[9] in 2013. The plan implemented extreme measures to curb emissions, including controlling current pollutant sources, optimizing industrial structures, accelerating technology transformation, and increasing clean energy supply. Although the mean winter-time concentration of atmospheric pollutants over all of China has decreased by 20% in 2015 compared to 2014 levels, it is believed that 40% of this reduction may be attributed to meteorological conditions[10]. Indeed, in spite of stringent emission controls, severe haze days in Beijing have continued to increase, as clearly seen over the past three winters.

Therefore, from the viewpoint of Cai *et al.*, aside from controlling air pollution by limiting pollutant emissions, a global effort to slow down global warming is also urgently needed to decrease the risk of heavy air pollution in Beijing. ❐

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CLIMATE VARIABILITY

Natural causes of Arctic sea-ice loss

Arctic sea-ice cover has declined precipitously in recent decades. Now research suggests that a sizeable fraction of this observed historical decline could have been caused by internal climate variability rather than by human-induced warming.

Neil Swart

Several sharp plunges in Arctic sea-ice cover over the last decade have set record lows[1], and led to dire predictions that an ice-free summer is imminent[2]. Climate models have, on average, shown a slower long-term rate of decline than observations and suggest that an ice-free Arctic should be realized in the summers around mid-century[3]. Does this mean that climate models underestimate the Arctic response to human-induced warming, or could a portion of the observed Arctic sea-ice loss be explained by other factors? Writing in *Nature Climate Change*, Qinghua Ding and colleagues illustrate that around half of the observed summer-time Arctic sea-ice loss has been driven by naturally induced changes in large-scale atmospheric circulation[4].

Recent changes in Arctic sea ice are driven by two main components: an overall long-term loss of ice in response to external forcings such as increasing greenhouse gases, and shorter term, random changes due to internal climate variability. This internal variability is generated naturally as a result of the underlying chaotic nature of the climate system. Given its random nature, in any given year natural variability can enhance or reduce the amount of sea-ice loss being driven by human-induced warming.