Fog and Monsoon Changes in China : Potential Impacts of Global Warming and Aerosols

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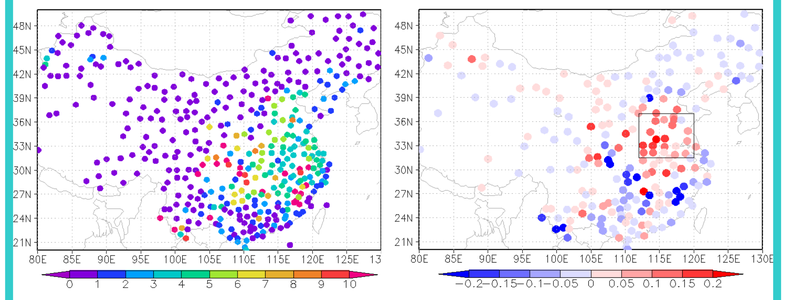
Introduction

Fog is a severe weather hazard that greatly influences traffic and daily life with potentially heavy economic loss. An increasing number of traffic accidents caused by fog have been reported in China in recent years. In this study, we show that the frequencies of fog events in wintertime over eastern-central China have doubled over the past three decades. For the same period, surface wind speeds have dropped from 3.7 m/s to about 3 m/s and the mean number of cold air outbreaks has decreased from 7 to around 5 times per winter; relative humidity and the frequency of light wind events have also increased significantly. Weakening of the East Asian winter monsoon system appears to be responsible for these changes, which is further linked to global warming and regional aerosol effects which change the regional circulation pattern, creating favorable conditions for fog occurrence.

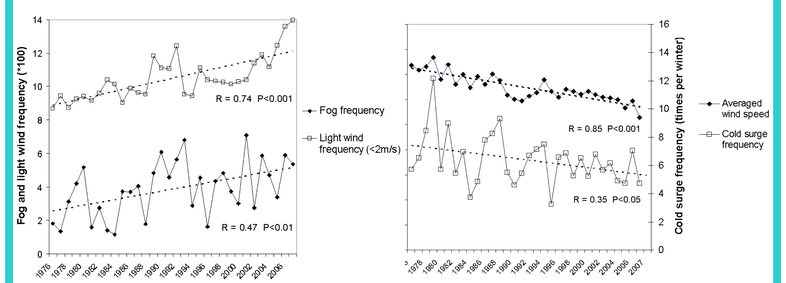
Fog frequency and its change

(a) Mean fog frequency

(b) The annual rate of changes

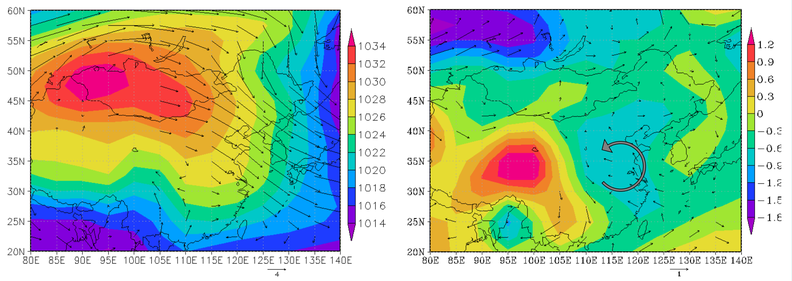


(a)The mean frequency of fog occurrence in winter (*100)
(b)The annual rate (percentage per year) of changes in the mean frequency of fog occurrence during wintertime over China at 390 sites from 1976 to 2007. Only stations with trends at the 5% significance level are shown in (b).

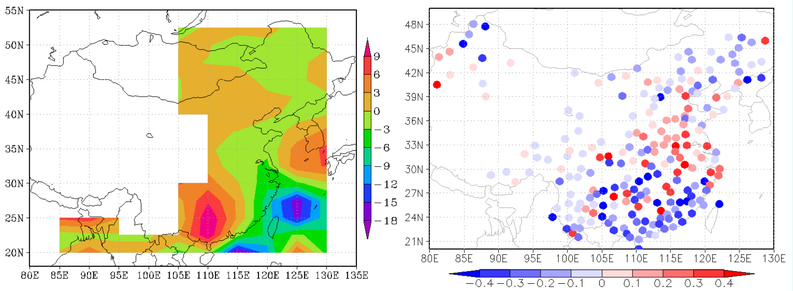


Time series of (a) mean frequencies of fog occurrence and light wind and (b) the frequencies of cold-air surges and mean wind speed over the boxed area in Figure 1b.

Changes in general circulation pattern

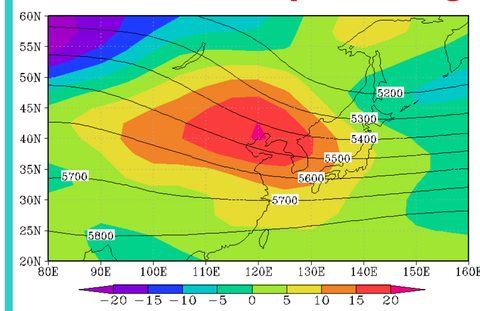


Wintertime sea level pressures (hPa) and 850hPa wind vectors (m/s) from the NCEP reanalysis: (a) mean values from 1976 to 2000, and (b) the difference (1989-2000 minus 1976-1988). Wind vectors over topography higher than 850hPa are masked out.



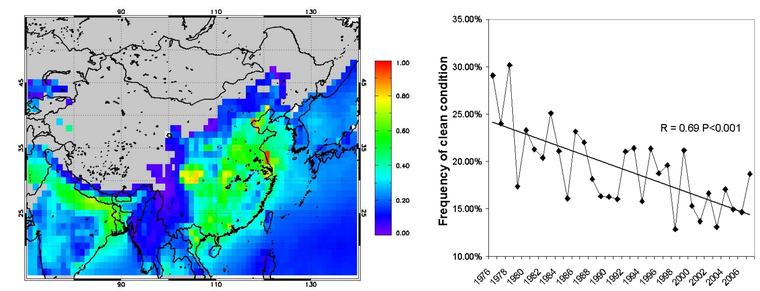
Changes in (a) water vapor transport divergence (contours, unit: kg/kg/m2/s*1E6) below 850hPa and (b) relative humidity (%). Only stations with trends at the 5% significance level are shown in (b).

Potential impact of global warming



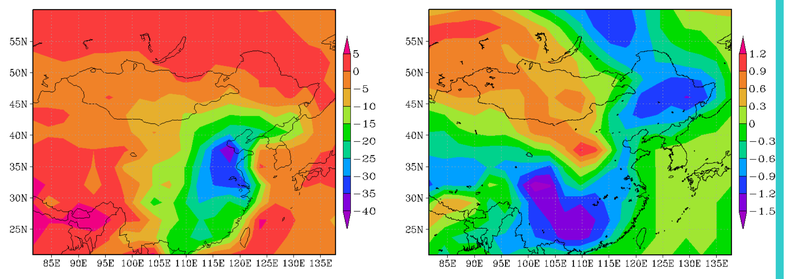
Global warming may reduce the thermal contrast between high and low latitudes and therefore weakens the 500hPa trough over Eastern Asian (left figure). The Siberian high is also weakened as shown before.

Wintertime aerosols over China

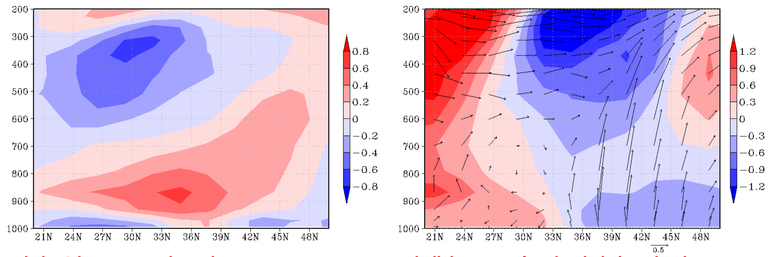


(a) Mean MODIS AOD in winter and (b) the change in the frequency of clean atmospheric conditions in eastern-central China from 1976 to 2007.

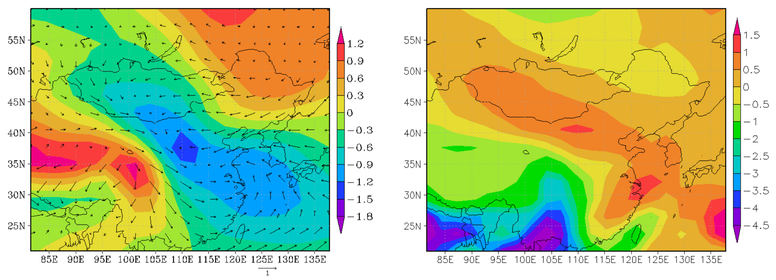
Aerosol effect



(a) Net surface shortwave forcing (W/m2) and changes in (b) surface temperature (°C) in winter caused by anthropogenic aerosols.



(a) Changes in air temperature and (b) zonal wind (shaded areas, unit: m/s) and meridional circulation (arrows, unit: 10-4 hPa/s for pressure velocity and m/s for meridional wind speed) averaged from 110oE to 120oE in winter from model simulations.



Changes in (a) sea level pressure (contours, unit: hPa) and 850hPa wind (arrows, unit: m/s) and (b) specific humidity (kg/kg*1E4) in winter.

Summary

- The increase of the frequency of fog events and the decrease of wind speed and the frequency of cold-air surges during winter over eastern-central China attest to the weakening of the East Asian winter monsoon.
- The weakening of the East Asian winter monsoon is further linked with global warming which reduces the thermal contrast between high and low latitudes.
- High loading absorbing aerosols over China reduce the radiation at the surface but heat the atmosphere, generating a cyclonic circulation anomaly over eastern-central China which also favors the formation of fog.

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