Hail Day Frequency Trends and Associated Atmospheric Circulation Patterns over China during 1960-2012

Mingxin Li[1, 2] , Qinghong Zhang[1, 2*] (qzhang@pku.edu.cn) and Fuqing Zhang[2]

1Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing 100871, China

2 Department of Meteorology and Center for Advanced Data Assimilation and Predictability Techniques, The Pennsylvania State University, University Park, Pennsylvania, USA

Introduction

Hail is a type of extreme precipitation in the form of balls or irregular lumps of ice produced by convective cloud which can cause great losses.

Hail day frequency show different long-term trend among different regions over the world. How and why hail frequency has changed remain an area of active research.

Hail observations are limited both from temporal/spatial resolutions and inaccuracy of monitoring systems. But environmental conditions that favor hail-producing severe convection may be associated with a synoptic flow shift under conditions of global climate change.

Long-term trend of hail day frequency in mainland China and the associated changes in atmospheric circulation patterns were analyzed.

Data

The hail data used here are obtained from the National Meteorology Information Center (NMIC), which has a complete historical hail dataset of 753 stations over mainland China from 1951 to 2012.

If a hailstorm is recorded at one station on a particular day, we defined it as a hail day for this station.
If one station had more than 10 missing data points in a single month, that month was considered to be invalid month for that station. Stations with at least one invalid month were not used in the analysis.
Stations that were relocated are excluded.
Finally, 541 stations with complete records from 1960–2012 were selected.

NCEP/NCAR daily mean data were used for objective analyses of flow pattern changes and to calculate convective inhibition (CIN), convective available potential energy (CAPE), vertical wind shear (VWS), and freezing level height (FLH).

Results

Long-term trend and variation of hail days in China

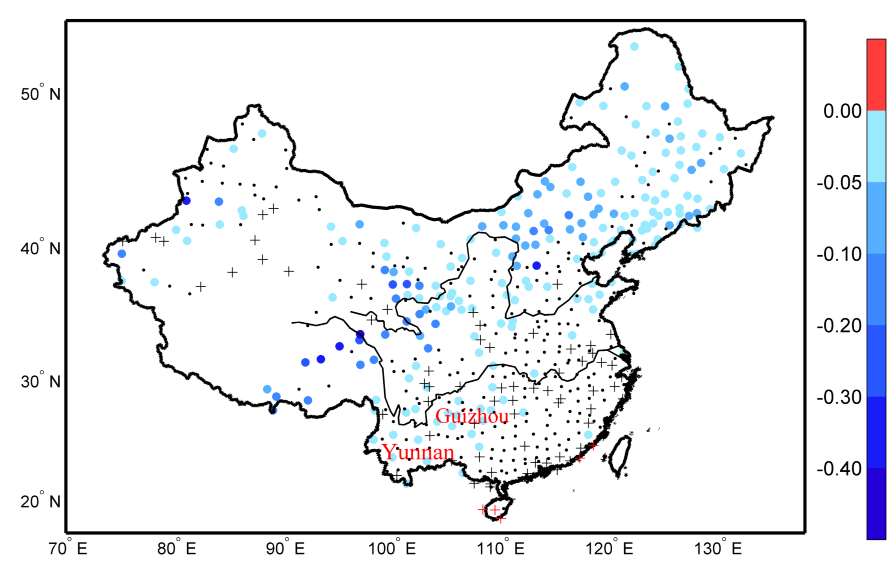

Fig.1.Annual hail day trend of 541 stations during 1960-2012 (Colored dots represent station with significant trend at 0.05 level, color represent for the trend value. Black dots and black + represent stations with down or up trend but not significant; red + represent stations that non hail day observed).

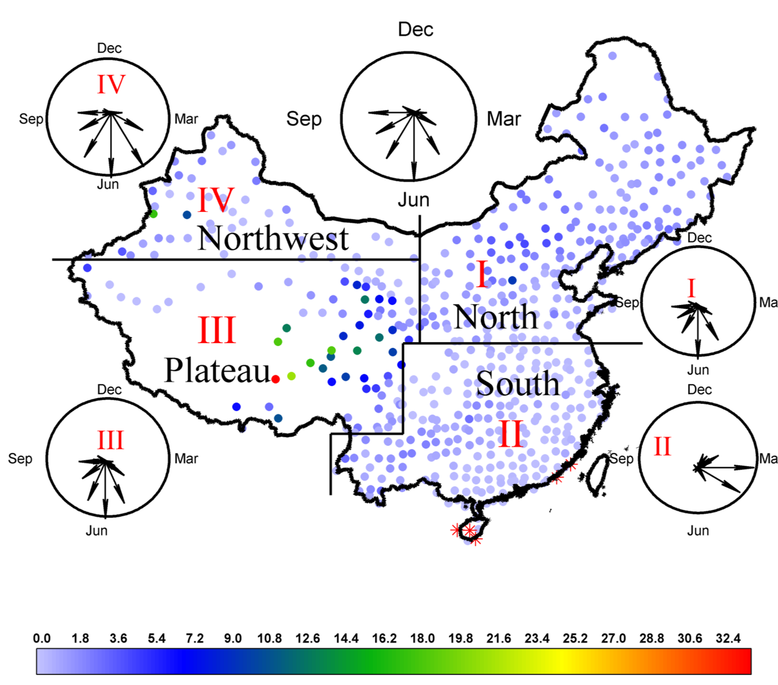

Fig.2 The distribution and annual mean hail days of 541 stations from 1960 to 2012 (color dots represent for annual mean hail day frequency). 4 subareas are divided by black line and marked with I (north), II (south), III (Plateau) and IV (northwest), circles indicate the monthly variation of hail days (length of the arrow represents for ratio of monthly hail frequency to annual hail frequency, direction of arrow show the month; the big circle on the middle top is for the whole nation and other 4 circles stand for the subareas, red * mark the stations that no hail has ever been observed).

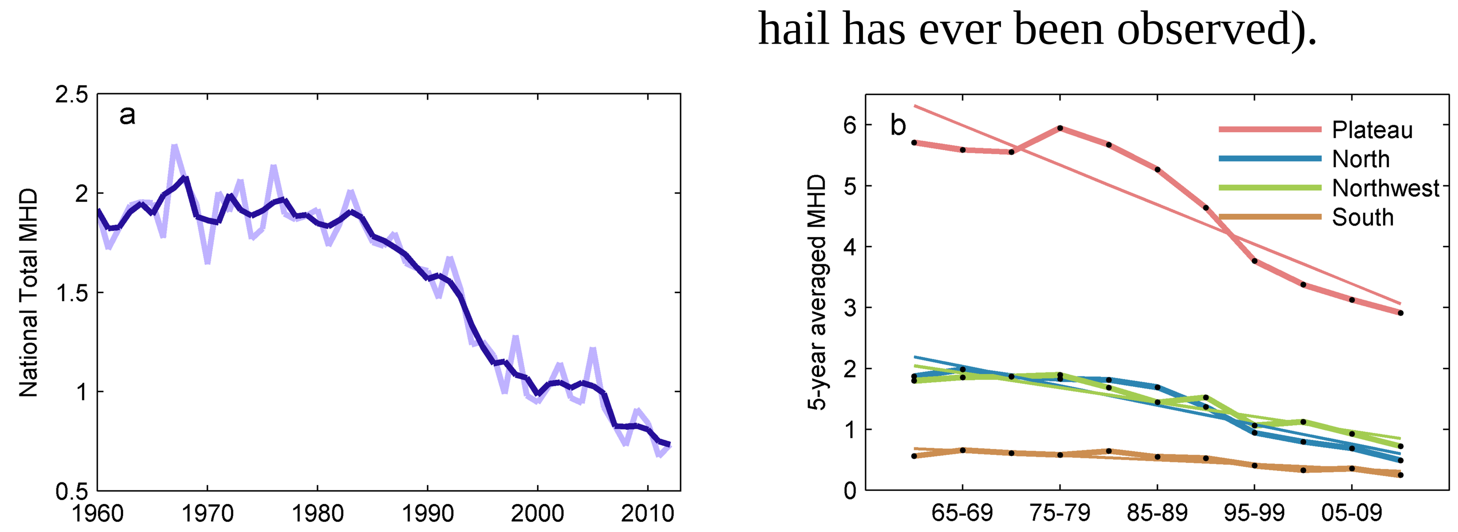

Fig.3 (a) Station-mean hail day (MHD) of China during 1960-2012 (light blue) and its moving averages (dark blue). (b) Five-year average MHD and trend line of four regions (red represent for the plateau, blue for the north, green for the northwest and yellow for the south).

Northern China

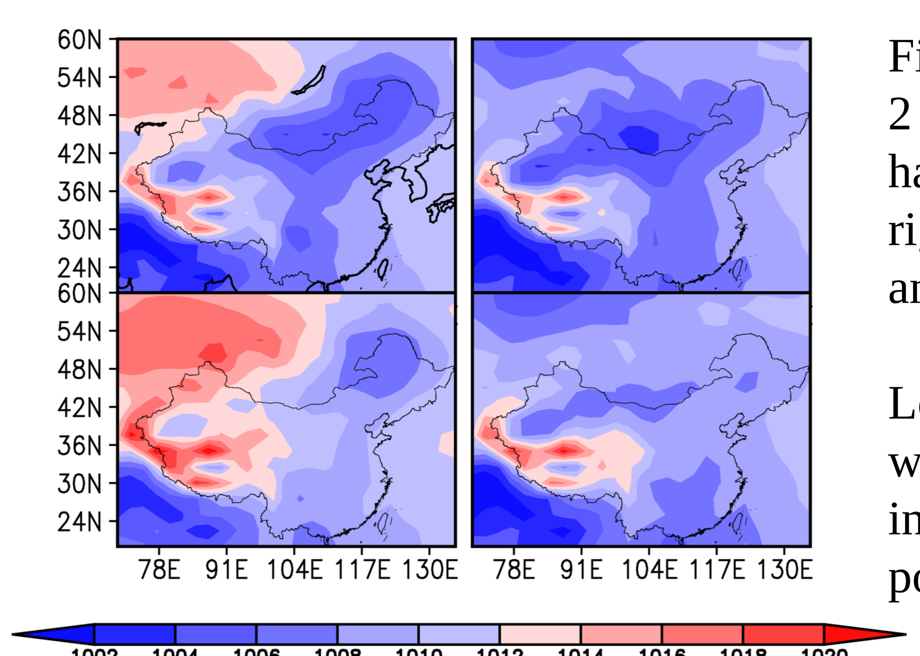

Fig. 4. Composite sea level pressure under 2 main circulation type associated with hailstorm (type 2-N: left and type 3-N: right) for the period 1960-1989 (above) and 1990-2012 (below).

Low level pattern after the 1990s became weaker than in the period before 1990, indicating weaker convergence and potential for moisture advection.

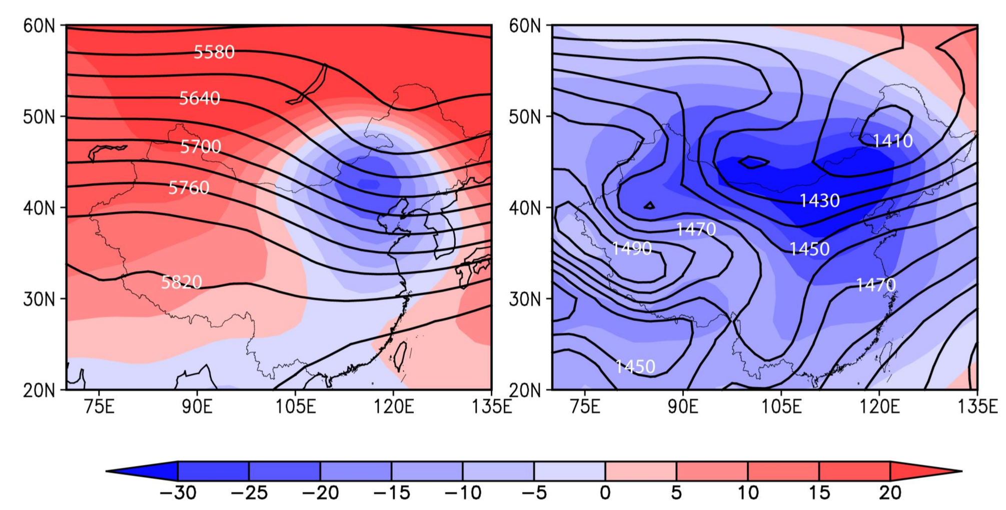

Fig. 5. Composite of 500 hPa (left) and 850 hPa (right) geopotential height of hail circulation days (black contour), shaded color shows the difference on 500 hPa and 850 hPa geopotential height of hail circulation days and no-hail-circulation days for north China in warm season from 1960 to 2012.

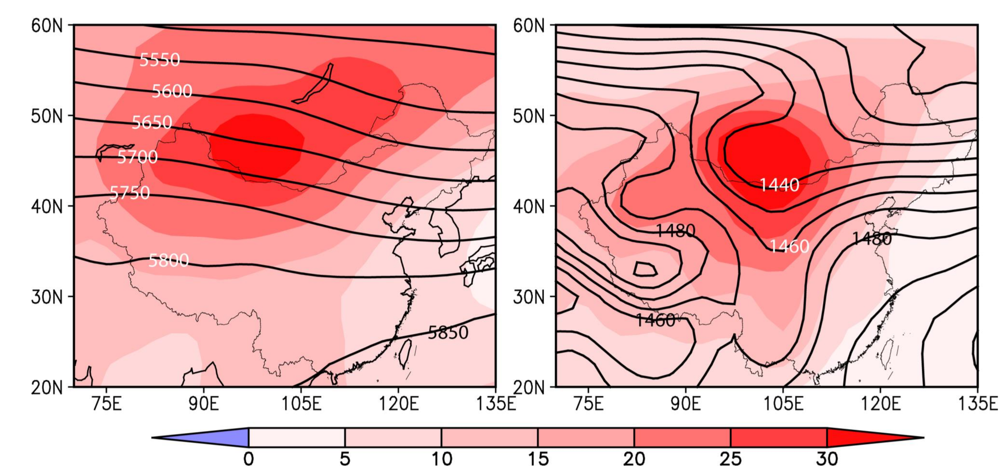

Fig. 6. Composite of warm season 500 hPa (left) and 850 hPa (right) geopotential height from 1960 to 1989 (black) and the difference between periods 1960-1989 and 1990-2012 (color shading).

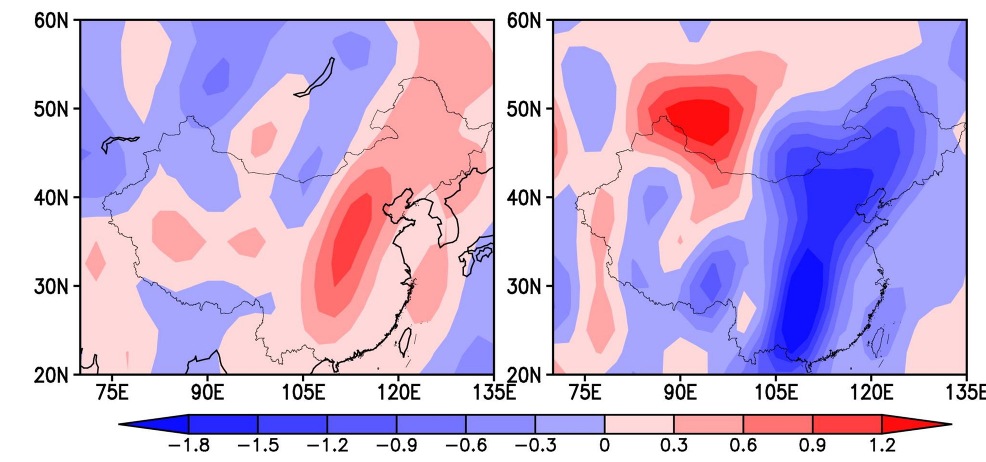

Fig. 7 Meridional wind difference of warm season at 850 hPa geopotential height between hail circulation day and non-hail circulation days (left) and between periods 1960-1989 and 1990-2012 (right)

The Tibetan Plateau region

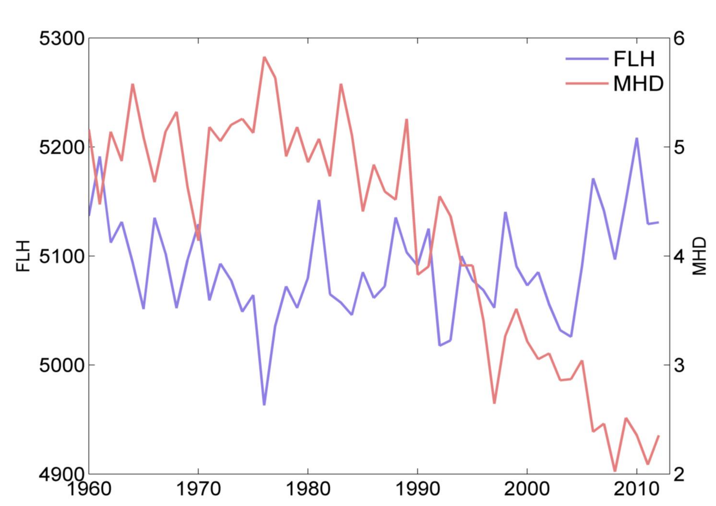

Fig.8. Variation of mean freezing level height (dark blue) and MHD (pink) of Plateau in warm season from 1960 to 2012.

The frequency of hail day in the plateau region was high under all circulation patterns (not shown here) and was largely related to changes in the FLH.

Conclusions

There was no detectable trend in hail frequency from 1960 to the early 1980s, but a significant decreasing trend was apparent in later periods throughout most of China, and in particular over the Tibetan Plateau from the early 1980s and over northern and northwestern China from the early 1990s. Hail frequency in southern China did not decrease as significantly as in other regions over the last couple of decades.
51.85% of the hail days occurred during two major circulation types, both of which were associated with cold frontal systems in northern China.
The synoptic trough in East Asia, signified by the meridional circulation at 850 hPa, became considerably weaker after 1990. This change in the synoptic pattern is consistent with a weakening trend in the East-Asian summer monsoon, the primary dynamic forcing of moisture transport that contributes to the generation of severe convection in northern China.
The long-term variability of hail day frequency over the Tibetan Plateau was more strongly correlated with the change in mean freezing level height (FLH) than the strength of the East-Asian Monsoon.

Reference

Li, M., Q. Zhang, and F. Zhang, 2016: Hail Day Frequency Trends and Associated Atmospheric Circulation Patterns over China during 1960-2012. *J. Climate*, (2016).