Spatial distribution of long-term hail data observed in Uvurkhangai province

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Abstract. Hail is a solid precipitation that falls from cumulonimbus clouds. Hail is formed by moving updraft and downdraft through thick layers of different temperature and humidity inside the cumulonimbus cloud, and when it falls, it causes a strong impact on the surface in direct relation to the acceleration gained by the kinetic energy of the movement. It is a solid form of precipitation with a layered structure that comes from cumulonimbus clouds. In Mongolia, the frequency of hail is relatively decreasing, and the frequency of hail is relatively high in mountainous areas, while in the Gobi region, hail is relatively rare, it has been confirmed by research in recent years. Meteorological stations and weather posts observational data, from 1991 to 2020, for hail and hailstorm frequency by yearly and monthly, and spatial distribution of hail were studied in Uvurkhangai province of Mongolia. This study was conducted on the 17 meteorological stations of Uvurkhangai province, out of the total of 19 meteorological stations and weather posts, which operated continuously during the research period. A total of 135 hailstorms were observed in the territory of Uvurkhangai province for 30 years. In the territory of Uvurkhangai province, the years with the highest frequency of hail recorded 9 times in 1994, 1997, 2012, and 2016, while the lowest frequency of hail observed in 2004, 2005, and 2006, once time each. Also, no hail was in 1996 and 2015. According to the frequency of hailstorms in Uvurkhangai province, 49 hailstorms were observed in July and in April, the least number of hailstorms was observed, 3 times. In terms of daily observation, the highest rate of hail (22.2%) was observed between 15:00 and 16:00 and it is counted 30 times of repeat. Moreover, as a spatial coverage of hailstorms in Uvurkhangai province, the highest occurrence observed in Kharkhorin soum, 28 times, while the lowest frequency of hail recorded in Baruunbayan-Ulaan and Bayan-Undur soum, once time each, while no hail was observed in other soum.

Keywords: Hail, Uvurkhangai province, Yearly frequencies, Monthly frequencies, Daily frequencies, Spatial distribution

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1. Introduction

Sevel climate-related hazards such as floods, forest and steppe wildfire, droughts and hail/hailstorms occur every year in Mongolia [1]. Knowledge on the frequency, characteristics, and intensity of hail is highly desirable for several reasons. Meteorologists need climatological information for improving their understanding of atmospheric processes that lead to hail formation. Geographers want to better understand the impact of surface features and properties on hail [2]. Economists and insurers need to correctly estimate the risk they take in hail insurance of a specific portfolio. According to World Meteorological Organization's Glossary (WMO No.182, 1992), hail is "precipitation of either transparent, or partly or completely opaque particles of ice (hailstones), usually spheroidal, conical or irregular in form and of diameter very generally between 5 and 50 millimeters, which falls from cloud either separately or agglomerated into irregular lumps" [3]. In general, hail is a solid precipitation that falls from cumulonimbus clouds. Hail is formed by moving updraft and downdraft through thick layers of different temperature and humidity inside the cumulonimbus cloud, and when it falls, it causes a strong impact on the surface in direct relation to the acceleration gained by the kinetic energy of the movement [4]. It is a solid form of precipitation with a layered structure that comes from cumulonimbus clouds. Hail is a convective phenomenon that covers a small scale and is observed for a short period of time. Moreover, Jambajamts et al. (2017) highlighted that the diameter of hailstones is commonly around 10 mm, but sometimes it is observed between 100 and 150 mm [5].

Hail/hailstorms are among the most destructive and damaging weather phenomena [6]. Hail is one of the phenomena of convection, which includes heavy rain, lightning, hail, gusty winds, etc. In meteorology, convection is defined as the movement of heat and moisture in the vertical direction. It is mainly characterized by up-and-down currents of unstable nature in the atmosphere. Hail can cause great damage to crop, livestock, buildings, and people [7]. The phenomenon of convection is considered a difficult process to forecast in synoptic studies. Recent studies have confirmed that the frequency of hailstorms is decreasing yearly and slowly. Spatially, the frequency of hailstorms is relatively high in mountainous regions, and relatively low in plains and desert regions [8].

In this study, a long-term hail climatology in Uvurkhangai province is documented, presenting the temporal and spatial distributions of hail frequency. The next results imply that the temporal and spatial characteristics of hail differ, depending upon the geographical location and regional atmospheric flow/circulation features.

Geographically, Uvurkhangai province is located at a high altitude, 90% of the province exceeds 1,600 meters in above sea level, which are rolling plateaus that occupy a large portion of the total area of province. Particularly, mountain ranges are in the northern and western parts of the Uvurkhangai province, the Gobi Desert in the southern part [9].

2. Data and data set

Uvurkhangai province is mountainous in the northern part of the region and plain in the southern part of the region. In particular, the study area is 1,500-1,900 meters above sea level, and in the hilly areas, it is 1,200-1,500 meters above sea level [4].

Uvurkhangai province has a total of 19 soums. Each soum has meteorology or weather stations/posts, it is fully operated by WMO's standard of the stations. The first systematic meteorological observation network of Mongolia was established 1936 and Arvaikheer city, which is a capital town of Uvurkhangai province, weather station is provided and connected climate research network and program from 1940. The next table shows the height above sea level of the meteorological observation points of soums of Uvurkhangai Province (see Table 1).

Table 1. Elevation of Soums, Uvurkhangai province.

Soum	Elevation /height above sea level/	Soum	Elevation /height above sea level/
Zuunbayan-Ulaan	1840	Nariinteel	1820
Uyanga	1980	Sant	1500
Kharkhorin	1480	Arvaikheer	1813
Tugrug	1390	Bayan-Undur	1620
Baruunbayan-Ulaan	1262	Khujirt	1650
Bogd	1519	Yesunzuil	1750
Bat-Ulzii	1670	Guchin-Us	1475
Bayangol	1430	Burd	1460
Hairhandulaan	1850		

It was conducted based on the observation material of hail from 17 stations that worked continuously during that research period. In that study, data on observation points, year, month, day, time, and duration of hail were recorded manually for a total of 30 years between 1991 and 2020.

The following picture shows the location of all meteorological stations of Uvurkhangai province (see Fig 1).

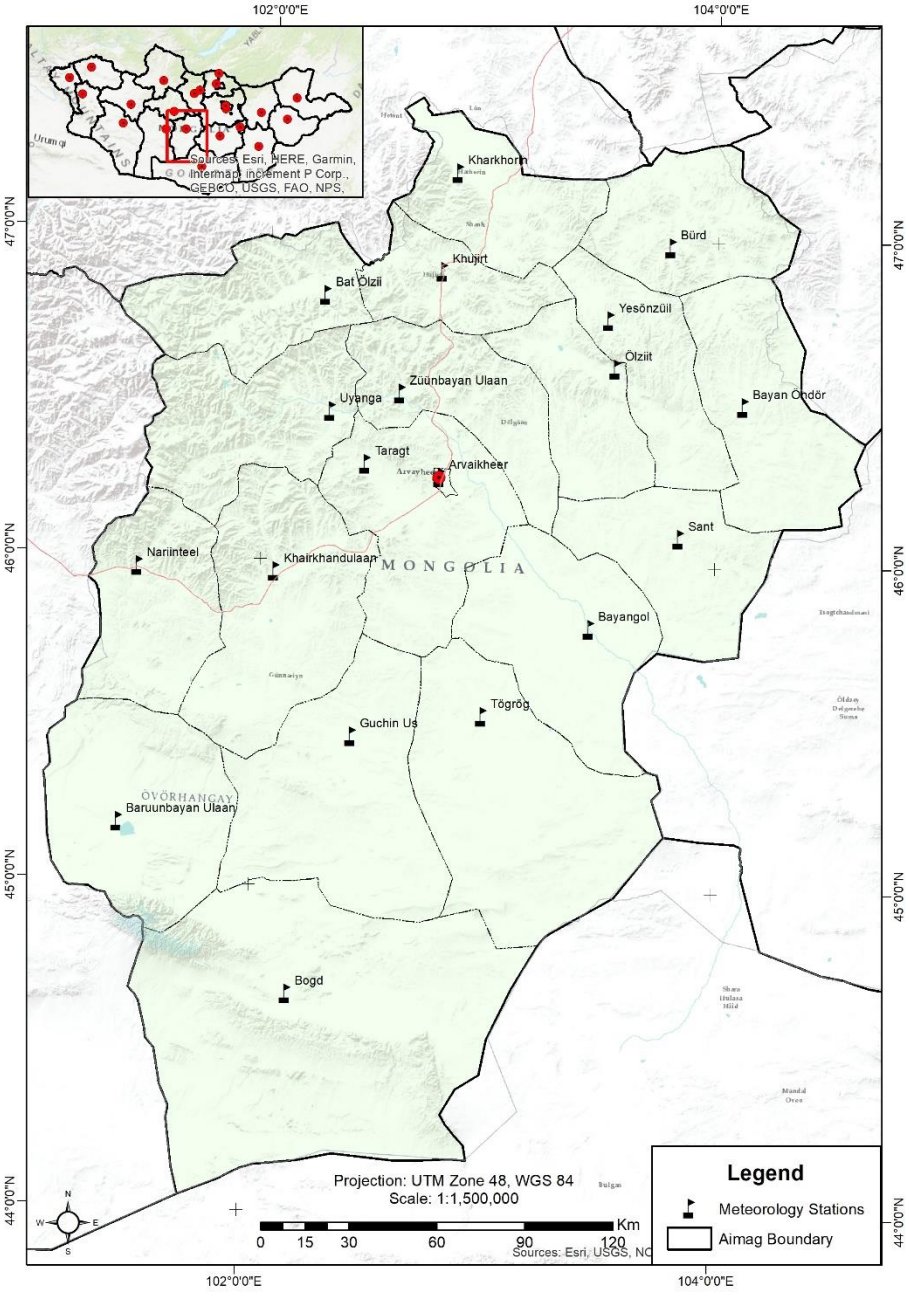

Fig 1. All stations of weather

3. Results

Using 30-year observational data between 1991 and 2020, the long-time freguencies of hail were studied in Uvurkhangai province (see Fig 2.).

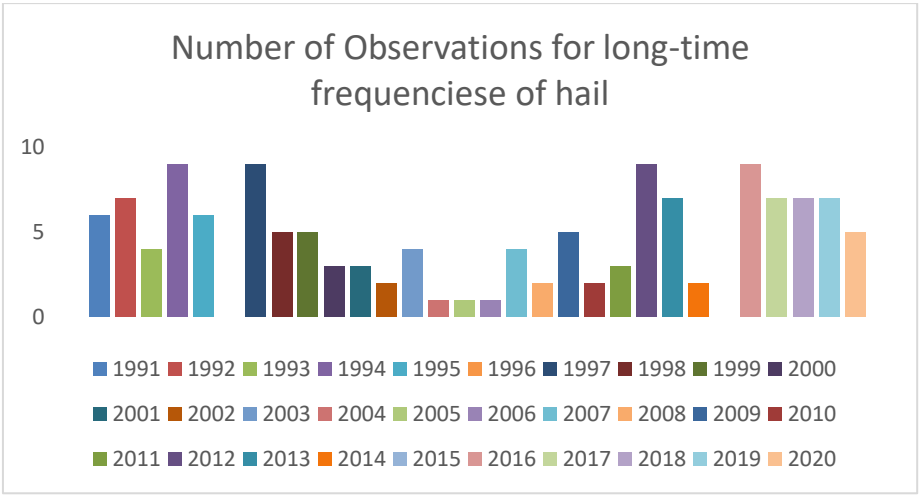

Fig 2. Numbers of hailstorms by years

During those 30 years, a total of 135 hailstorms were observed in the territory of Uvurkhangai province. In the contrast, the years with the highest frequency of hail were 9 times in 1994, 1997, 2012, and 2016, while the lowest frequency of hail was observed in 2004, 2005, and 2006, 1 time each. No hail was observed in 1996 and 2015.

Using 30-year observational data between 1991 and 2020, the frequencies of hailstorms in annually were studied in the Uvurkhangai province (Figure 3).

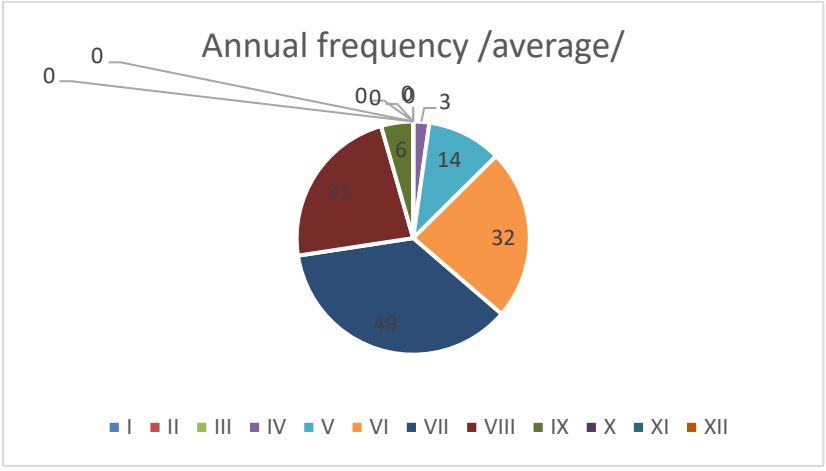

Fig 3. Histogram of hailstorms in the Uvurkhangai province

Considering the annual frequency of hail in Uvurkhangai province, it was the highest in June, July, and August, and was observed 49 times in July, 32 times in June, and 31 times in August. However, the lowest number of hailstorms was observed in April, 3 times, and 6 times in June, respectively.

According to 30 years' observational data between 1991 and 2020 of the Uvurkhangai province, the daily observations of hailstorms show in Fig 4.

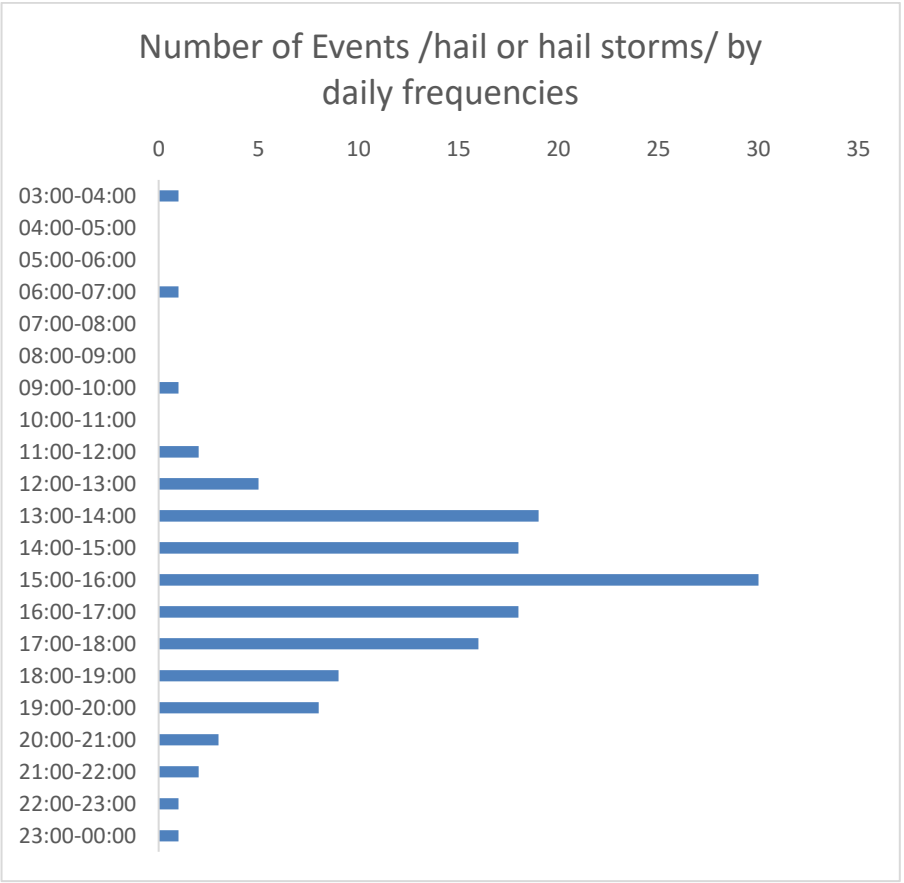

Fig 4. Frequency of hail by hours

Consequently, most hailstorms recorded between 13:00 and 18:00, especially, the maximum percentage of hail was 22.2 percent and it observed between 15:00 and 16:00. This was a total of 30 times. Moreover, 14.1 percent were recorded from 13:00 to 14:00, 13.3 percent were observed between 14:00 and 15:00, from 16:00 to 17:00, and 11.9 percent was observed between 17:00 and 18:00.

As a spatial coverage in the Uvurkhangai province, in the dataset of study, the summaries of hailstorms are shown the following chart (see Fig 5.).

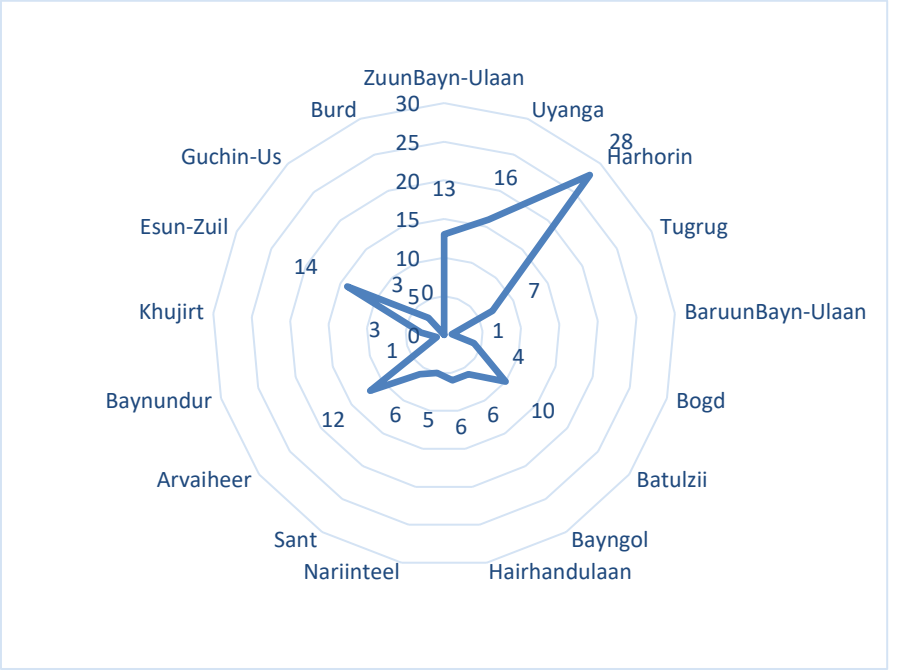

Fig 5. Spatial distribution of hail

It analyses, geographically, that it is the highest records of hailstorms in mountainous areas. It was monitored 28 times in Kharkhorin soum, 16 times in Uyanga soum, and 14 times in Yesunzuil soum. However, the frequency of hailstorms was the lowest, once in Baruunbayan-Ulaan and Bayan-Undur soum, while no hail was observed in other soum.

4. Conclusions

Using 30-year observational data between 1991 and 2020, the multi-year recurrence, monthly recurrence, daily recurrence, and spatial recurrence of hail were studied in Uvurkhangai province. In the dataset of study, a total of 135 hailstorms were observed in the territory of Uvurkhangai province. In the territory of Uvurkhangai province, the years with the highest frequency of hail were 9 times in 1994, 1997, 2012, and 2016, while the lowest frequency of hail was observed in 2004, 2005, and 2006, 1 time each. No hail was observed in 1996 and 2015. Considering the annual event of hail in Uvurkhangai province, it was the highest in June, July, and August, and recorded 49 times in July, 32 times in June, and 31 times in August.

However, the lowest number of hailstorms was observed in April, 3 times, and 6 times in June, respectively. In terms of daily frequency, it is most recorded between 13:00 and 18:00. The maximum (22.2%) percentage of hail was logged between 15:00 and 16:00. This was a total of 30 times. Also, 14.1 percent were observed between

13:00 and 14:00, 13.3 percent were monitored between 14:00 and 15:00 and from 16:00 to 17:00, and 11.9 percent was monitored between 17:00 and 18:00. However, the hail is recorded highest occurrences in mountainous areas. It was surveyed 28 times in Kharkhorin soum, 16 times in Uyanga soum, and 14 times in Yesunzuil soum. However, the frequency of hailstorms was the lowest, once in Baruunbayan-Ulaan and Bayan-Undur soum, while no hail was observed in other soum.

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