

# A climatological study on freezing rain, freezing drizzle, and freezing fog in northeastern China

Yang Bai<sup>1</sup>, \*Tetsuya Hiyama<sup>2</sup>, Hatsuki Fujinami<sup>2</sup>

1. Graduate School of Environmental Studies, Nagoya University, 2. Institute for Space-Earth Environmental Research, Nagoya University

Freezing phenomena, which derive icy ground surface over a wide area, frequently occur in cold (winter) season. Freezing phenomena, more specifically freezing precipitation, are classified into freezing rain, freezing drizzle, and freezing fog. In 2008, huge freezing rain occurred in southeastern China from early January to early February, which caused enormous economic losses and casualties. In the winter of 2010, a huge freezing rain attacked northeastern China. As a result, many airports and highways were forced to closed. Since freezing phenomena have a great influence on human activities, it is very important to explore under which weather conditions freezing phenomena will appear from a climatological point of view. Previous studies have focused on freezing rain, and explored the generation processes of freezing rain while freezing drizzle and freezing fog were not concerned. In addition, previous studies mainly focused only on the mechanism of the extreme events. None of climatological researches has been conducted based on multiple cases including freezing drizzle and freezing fog.

In this study, we investigated almost all of the freezing phenomena events which occurred at four airports of the major cities in northeastern China (Harbin, Changchun, Shenyang, and Dalian), and we analyzed atmospheric circulation pattern when freezing phenomena appeared. The aim of this study is to demonstrate the climatological features of freezing phenomena in northeastern China. The aviation meteorological reports at the above four airports is used for this study and the study period is from the 2005 to 2018 (14 years). And, the ERA-Interim atmospheric reanalysis data is also used for the analysis of large-scale atmospheric condition. The civil aviation meteorological weather reports were recorded every 30 or 60 minutes. We used meteorological data such as wind direction, wind speed, air temperature, and dew point temperature. We defined a freezing phenomenon which continued for more than three hours as one event.

We found one freezing rain and one freezing drizzle event in 14 years. On the other hand, 238 events of freezing fog in total were extracted. We found the melting process was the main reason of the freezing rain process in Shenyang airport. This was the same process as in the large-scale freezing rain event in southeastern China. In the case of the freezing drizzle event at Dalian, we found the cold air intrusion into the humid atmosphere just after a rainfall event. The sudden cold air intrusion in association with the high pressure may play a key role for the formation of freezing drizzle. Thus, it was considered that freezing drizzle could appear in case that Dalian was covered by a high-pressure system just after passing a low-pressure system.

Most of the freezing fogs were detected from nighttime to the next morning. This might be related to the surface radiative cooling. On the day of the appearance in freezing fogs, high-pressure anomalies were found around northern Japan relative to the climatological mean (for 14 years from 2005 to 2018). This made northerly winds weaker near the surface in northeastern China than those in the climatological mean of winter. Interestingly, in case of the appearance of freezing fogs in midday, stronger high-pressure anomalies were detected around Japan.

Keywords: freezing rain, freezing drizzle, freezing fog