The Variation of Extreme Low Temperature Events in the Northwest Pacific under the Global Warming

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Abstract: Under the background of global warming, the variation of extreme low temperature events in the Northwest Pacific are undergoing significant changes. The extreme low temperature events have obvious monthly, inter-annual and inter-decadal characteristics. Extreme low temperature events were mainly concentrated in January-March. It showed an increasing trend from 1982 to 1991, a downward trend from 1992 to 2011 and an upward trend from 2012 onwards. The frequency of extreme low temperature events has significantly reduced. The number of days and the duration of a single event have significantly reduced. The average temperature and the minimum temperature of a single extreme low temperature event show a linear upward trend. The extreme low temperature events have two time scales cycles, with a large cycle of 13-20a and small cycle of 4-10a. Over the past 33 years, extreme low temperature events have changed from small time-scale cycle to large time-scale cycle.

1. Introduction
Changes in the frequency and intensity of extreme weather events are likely to have a huge impact on human society, economy and environment, which has attracted more and more attention from the international community [1-2]. Extreme events are referred to the value of a weather or climatic variable, which is higher than (or below) the threshold near the upper limit (or lower limit) on the range of the observed variable[3].

On November 18, 2011, the Intergovernmental Panel on Climate Change (IPCC) issued a special report –Managing extreme events and disaster risks and promoting climate change adaptation[3]. This report pointed that extreme weather and climate events have changed since 1950. The number of cold days and cold nights is likely to decrease, while the number of warm days and warm nights is likely to increase in the world. In Asia, the rising trend of daily extreme temperature is moderate. Trends in daily extreme temperatures in Africa and South America generally show low to moderate confidence. But globally, the duration or number of warm events, including heat waves, has increased in many regions with adequate information.

What is certain is that on a global scale, it has been observed that the coldest days and nights on most of the land are decreasing while the warmer days and nights are increasing[4]. However, what happened to the extreme temperature events on the oceans has not been observed and studied detailly so far.
2. Purpose
Utilizing the NOAA Optimum Interpolation 1/4 Degree Daily Sea Surface Temperature Analysis data for the period 1982–2014, on the basis of determining the threshold of extreme temperature, the temporal and spatial variation characteristics of extreme low temperature events in the Northwest Pacific during the last 33 years were discussed by a variety of statistical diagnostic methods, which laid the foundation for monitoring and forecasting extreme weather and climate events.

3. Study Areas
In this research, study areas are located between 0° and 30°N along the longitude from 105° to 155°E (Figure 1). The Northwestern Pacific is a key area that affects China's climate change.

4. Data and Methods
Sea Surface Temperature (SST) data comes from the NOAA Optimum Interpolation 1/4 Degree Daily SST Analysis Data V2.0. The time range covers 1982.01–2014.12, at a spatial resolution of 0.25°×0.25°, including SST and SST anomalies. The sea surface temperature anomaly index comes from the ERSSTv4 Climate Prediction Centre Extended Bureau America reconstruction of sea surface temperature data[5-6]. Based on the probability distribution of the meteorological elements, the fourth report of the IPCC defines an event less than or equal to the 10th percentile (greater than or equal to 90th percentile) as an extreme case [7]. Some scholars have pointed out that in the study of climate change, they usually take 5% / 95% or 10% / 90% as the extreme value threshold in order to reflecting the variation trend of extreme events [8-10]. Taking into account the temperature data in this paper over a short time span, we use the 10% / 90% percentile as the threshold for extreme events and use the definition of extreme events proposed in the IPCC Fourth Report.

5. Results and Discussions
The daily average temperature of Northwest Pacific from 1982 to 2014 are arranged in ascending order, with the 10th percentile as the extreme low temperature threshold, which is 25.79°C. Extreme low temperature ranged from 24.86-25.79°C, and the minimum sea surface temperature appeared in March 5, 1986, which is 2.73°C lower than the average daily temperature over many years. Extreme cold events mainly concentrated in the January-March, with the highest occurring in February, accounting for 47.96%, followed by 26.06% and 25.98% respectively in January and March. In the recent 33 years, the number of extreme cold days in the Northwest Pacific were 1202, corresponding to an average of 36.4 per year. According to the fitted curve, the annual variation of extreme low temperature events was great, with the most number of days in 1993 (81 days) and the least (2 days) in 2007, showing a rapid linear decrease trend with a reduction rate of 27d / 10a and also an obvious stage fluctuation. It showed an increasing trend from 1982 to 1991, a downward trend from
1992 to 2011 and an upward trend from 2012 onwards. The frequency of extreme low temperature events in the western North Pacific has decreased significantly. During 1982 to 2014, 41 extreme low temperature events occurred in the North-western Pacific, with an average duration of 29.3 days. The longest and shortest durations of single extreme low temperatures were 81 days and 2 days respectively (Figure 2). The duration of a single extreme low temperatures in recent 33 years showed an overall linear decrease trend with a decrease rate of 1.6 days / time. The average temperature and minimum temperature of a single extreme low temperature event also showed a linear upward trend with the average temperature rising rate of 0.0087 ℃ / time and the minimum temperature rising rate of 0.017 ℃ / time.

**Figure 2.** The duration and mean (minimum) temperature of extreme low temperature events

Figure 3 shows the change cycle of extreme low temperature events throughout the year (Fig. 3a) and from January to March (Fig. 3b-3d) during 1982-2014 in the North-western Pacific. It can be seen that in the past 33 years, there were two time-scale cycles of extreme low temperature events. In the large-scale period of 13-20a, there were six stages of multi-little-multi-little-multi-little-multi-little-multi-little. In 1982-1987, 1993-1997 and 2002-2007, there were relatively more extreme low temperature events. While there were less extreme low temperature events with the main period of 15 years in 1988-1992, 1998-2001 and 2008-2014. Before 2000, there were both medium time-scale cycle of 4-10a and large time-scale cycle, and then medium time-scale cycle had weakened and disappeared. It can be concluded from the above analysis that during the past 33 years, the extremely low temperature events in the North-western Pacific have undergone a transition from small-scale cycles to large-scale cycles.

**Figure 3.** The cycle variation of extreme low temperature events

6. Conclusions
Analyzing and discussing the extreme low temperature events that occurred in the Northwest Pacific from 1982 to 2014, and the following conclusions are as follows:
(1) The extreme low temperature events in Northwest Pacific from 1982 to 2014 have obvious monthly, inter-annual and inter-decadal characteristics. Extreme low temperature events were mainly
concentrated in January-March. It showed an increasing trend from 1982 to 1991, a downward trend from 1992 to 2011 and an upward trend from 2012 onwards.

(2) The frequency of extreme low temperature events has significantly reduced. The number of days and the duration of a single event have significantly reduced, and the average temperature and the minimum temperature of a single extreme low temperature event show a linear upward trend.

(3) There are two time-scale cycles of extreme low temperature events, which is the large cycle (13-20a) and the small cycle (4-10a). In the past 33 years, the extremely low temperature events in the North-western Pacific have undergone a transition from small-scale cycles to large-scale cycles.

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