Research Brief 2008/03

The January/February 2008 Persistent Low Temperatures and Snowy/Icy Weather in Southern China: Meteorological Causes and Return Periods

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1. Description of the event

From mid-January 2008, four significant rain/snow events (Jan 10-15, Jan 18-22, Jan 25-28, Jan 31-Feb 2) occurred in China south of the Yangtze River. In the provinces of Henan, Hubei, Guizhou, Anhui, Jiangsu, Hunan, northeastern Jiangxi, and northern Zhejiang, heavy snow to snowstorm was observed. The provinces of Hunan, Guizhou, southern Anhui, and Jiangxi saw freezing rain and icy weather. This disastrous weather episode, which was a very rare occasion, affected a very large area.

According to the China Meteorological Administration, the average temperature over China was -6.6°C in January, which was 0.7°C lower than the normal January average temperature of -5.9°C, and was the lowest since 1986. During the first 10 days of the month, the average temperature over China was 1.6°C above normal, but the remainder of the month saw continuous intrusions of cold air, causing the average temperature to be 1.8°C below normal. During the second 10 days, Hunan and Hubei experienced record low temperatures. In the remainder of the month, the average temperature of most of the country was below normal, with Jiangxi, Henan, Hebei, Hubei, Hunan, Guangxi, Chongqing, Guizhou, Shaanxi, Gansu, Ningxia, and Xinjiang having record low average temperatures, and Anhui actually saw its second coldest January on record.

This extremely rare event caused extensive damage and general disruption over southern China. Most of the infrastructure damages were attributed to freezing rain, which led to a huge number of broken electricity transition lines and chaotic traffic conditions for southern China. These icy/snowy weather conditions also affected severely the water and power system of China. The direct economic losses were estimated at 53.8 billion RMB Yuan, because of its scope, duration and impact. Insurance companies across the country received tens of thousands of compensation cases including half a million from the hardest hit regions. The damages are especially serious because of the coming of Chinese New year. Tens of thousands of people (on occasion as many as 500,000 to 800,000) were left stranded at several railway stations across southern China. Additionally, the chaotic road conditions affected several millions of travelers in southern China. The water shortages were also serious in southern China because of frozen and subsequently cracked water pipes. Some cities in southern China had no power or water for over two to three weeks, including government buildings and hospitals.

In this Research Brief, the meteorological conditions likely responsible for this prolonged cold event are discussed in section 2. Estimates of the return periods of the occurrence of the extreme low temperatures in southern China during this episode are then given in section 3. A summary and possible future work is presented in section 4.

2. Meteorological conditions leading to the event in January/February 2008

During the first 10 days in January 2008, the flow pattern resembled that of the climatological conditions generally observed in January. As a result, southern China, while experiencing some cool air, rapidly warmed up so that foggy weather actually occurred in some provinces. However, from 10 January, the flow pattern changed such that a much stronger southwesterly flow occurred west of the Siberian High and a much more northerly (instead of northwesterly) flow was present over the Siberian High, as illustrated in Figure 1. With such a pattern, very cold air was brought from the north, from Lake Baikal all the way to southern China. The zero-degree isotherm was displaced more than 1,000 km southward during the five-day period of January 10-15. This was the first and the strongest cold wave that hit southern China during the prolonged episode.

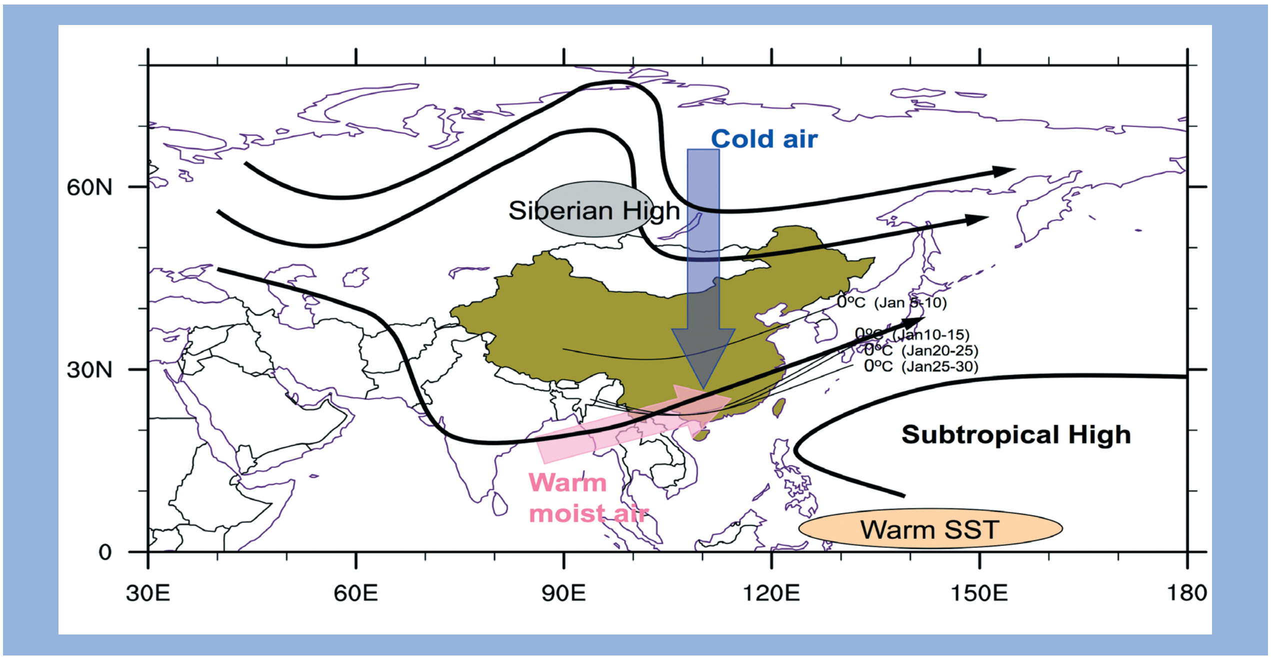

Figure 1. A schematic showing the flow pattern at around 5 km in the vertical in the Northern Hemisphere middle latitudes in January 2008. The area labeled Siberian High is the area where the sea-level pressure is generally the highest and where much of the coldest air resides. The thin lines over China represent the locations of the zero-degree isotherm during each of the periods labeled next to these lines. The thick line east of the Philippines represents the boundary of the subtropical high pressure system, and beige ellipse illustrates the area of anomalously high sea-surface temperature associated with La Niña conditions. The two wide arrows indicate the direction of the flow of warm and moist air from the south (pink arrow) and of cold air from the north (blue arrow).

Had this wave followed the climatological pattern and moved east, southern China would have warmed up after a few days. However, the pattern shown in Figure 1 persisted, forming what is referred to as a blocking pattern. Under such a pattern, the wave pattern in hardly moved. At the same time, with such a pattern, a flow also moved over the Indian Peninsula around the Tibetan Plateau (see Figure 1). This flow then moved over the Bay of Bengal and then towards the east. In normal years, this flow generally moves over the Indochina Peninsula, over the

South China Sea and into the western North Pacific Ocean. However, during 2007/08, La Niña conditions prevailed over the central equatorial Pacific, which resulted in the strengthening of the subtropical high pressure system over the western North Pacific Ocean. As a result, the flow that moved over the Bay of Bengal was forced to take on a more northeastward direction over southern China, as illustrated in Figure 1. This southwesterly flow then brought warm and moist air to southern China.

As this warm, moist air met the cold air from the north, it was forced to rise. At a higher altitude, the moisture condensed and formed clouds, which eventually led to precipitation in the form of either rain or snow. During the first cold episode of January 10-15, the air was cold through a deep layer of the atmosphere so that the precipitation was generally in the form of snow and snowstorms occurred.

Because of this blocking pattern, southern China did not warm up after this first cold episode, and the ground remained snow-covered and the air near the ground remained anomalously cold. This can be seen from the zero-degree isotherm in Figure 1 for the subsequent periods in January. At the same time, while this blocking pattern persisted, cold-air intrusions continued to occur in the western part of Europe. As these intrusions, which are referred to as "perturbations", hit the blocking pattern, they would "ride" over this latter quasi-stationary pattern and travelled from west to east. Whenever each perturbation moved to the area near the Siberian High and Lake Baikal region, it would trigger another push of cold air to the south. Three such events took place within the next three weeks: Jan 18-22, Jan 25-28, and Jan 31-Feb 2. However, these cold air intrusions were not very strong. As a result, when the warm air from the south was forced to rise, rain instead of snow actually formed, as illustrated in Figure 2. As the rain fell through the cold-air dome near the ground that has been persisting for some time, the rain water froze and became freezing rain. Upon hitting cold objects such as tree branches, power lines and the ground, ice formed. As a result, icy conditions occurred over a widespread region.

To summarize, the very rare, protracted cold event that occurred in southern China in January/February 2008 was a result of three meteorological factors:

- ***blocking pattern in the middle latitudes*** — This not only allowed cold air to persist in southern China, but also enabled each perturbation from the west to trigger a cold-air intrusion from the north. The persisting cold air also caused freezing of the rain.
- ***persisting southwesterly flow over southern China*** — This flow brought warm and moist air to the region, which then caused condensation and subsequent rain or snow.
- ***anomalously strong subtropical high*** — The prevalence of the La Niña condition in the central equatorial Pacific caused a stronger-than-normal subtropical high that forced the westerly flow from the Bay of Bengal to move northeastward over southern China.

The juxtaposition of these flow patterns thus allowed the occurrence of persistent cold and rainy/snowy/icy conditions over southern China. Among these three factors, the blocking pattern is likely to be the most important because it was responsible for maintaining the cold conditions over southern China.

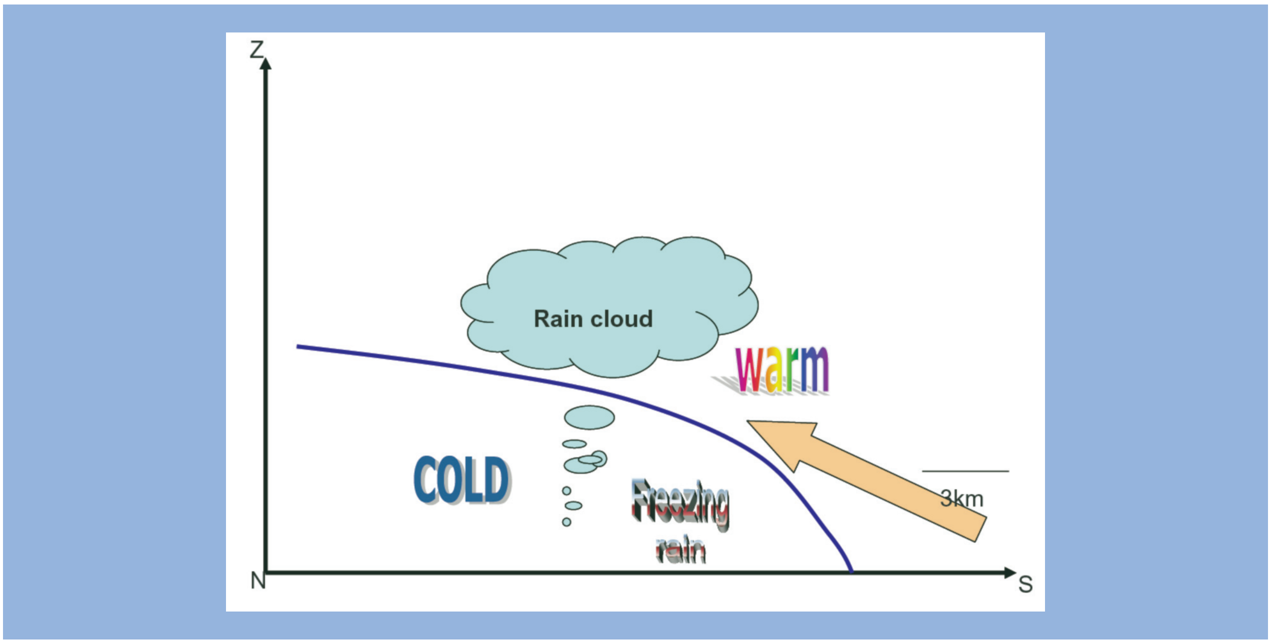

Figure 2. Schematic showing the occurrence of freezing rain. The thick blue curve indicates the boundary of the cold dome. The pink arrow represents the warm and moist air gliding over the cold dome.

3. Estimates of return periods

The daily surface temperatures of nine weather stations in southern China are used. These stations are in the area most affected by the low temperatures and snowstorms (Figure 3).

To estimate the return period of the occurrence of the persistent low temperature, the Gumbel distribution (Gumbel, 1960, 1961) is used to estimate the return period of the average temperature during the second 10 days (11th-20th) and the third 10 days (21st-30th) of January 2008.

Using the Gumbel distribution, the return periods of the average temperature of the second and third 10 days in January 2008 for each of the nine southern China stations (significant at 95% confidence level) are estimated (Figures 4 and 5, with the actual numbers shown in Table 1). Most of the observations fall within a 20-50 yr return period. For the second 10 days in January 2008, only cities of Hunan province (4 out of 9 southern China stations) have a return period of > 10 yr of average temperature: 25-30 yr for Yueyang and Changde, and 10-20 yr for Hengyang and Chenzhou. However, for the third 10 days in January 2008, all the nine stations have a return period of > 20 yr, ranging between 23 and 56 yr. In particular, Yueyang, Hengyang and Chenzhou have a return period of 44, 56 and 43 yr respectively.

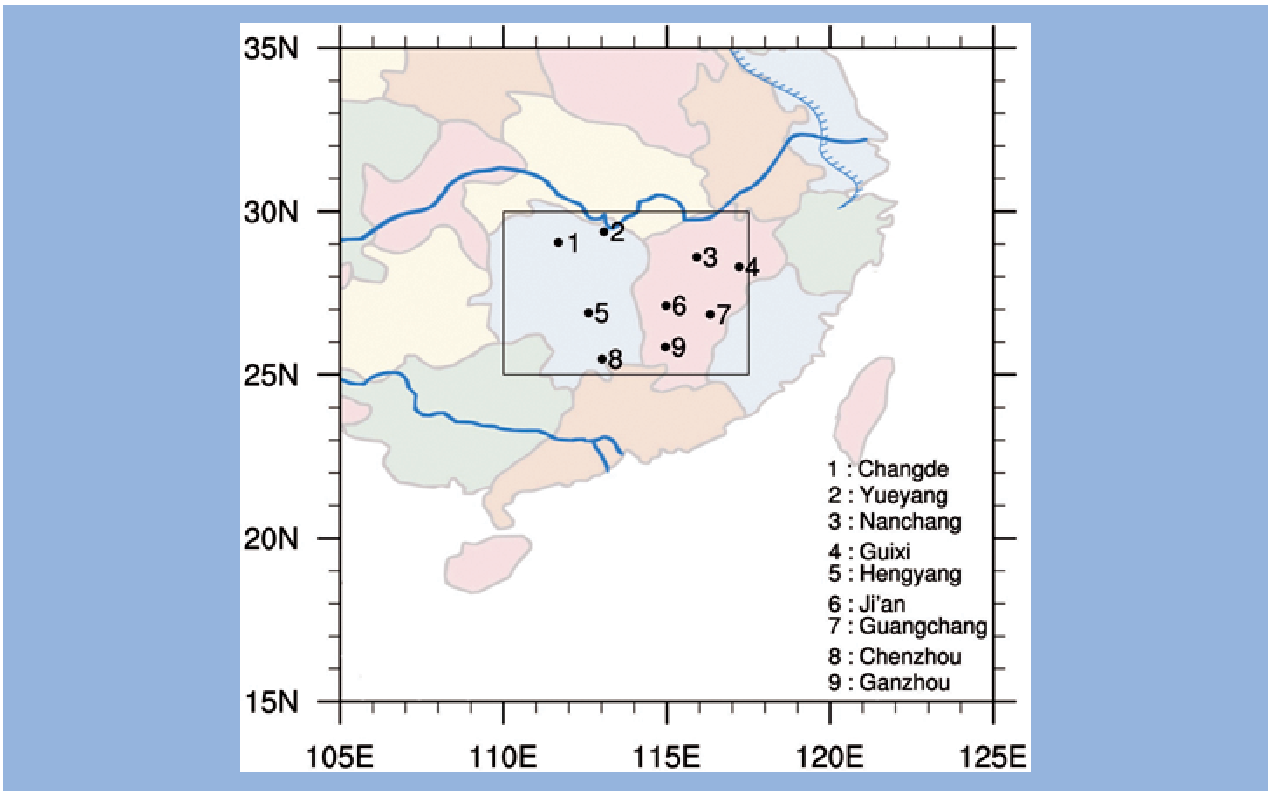

Figure 3. Location of the nine Southern China stations the data of which are used in this study.

Station	*11-20 January*			*21-30 January*		
	< T >	*DEV*	*RT*	*< T >*	*DEV*	*RT*
1 Changde	0.0	-4.6	31	-1.0	-5.6	35
2 Yueyang	-0.2	-4.7	27	-1.8	-6.5	44
3 Nanchang	2.3	-2.6	9	-0.2	-5.5	31
4 Guixi	5.4	-0.4	2	1.5	-4.8	23
5 Hengyang	1.1	-4.6	20	-1.4	-7.1	56
6 Ji'an	4.4	-1.7	5	1.2	-5.3	23
7 Guangchang	5.3	-0.9	3	1.3	-5.4	23
8 Chenzhou	2.0	-3.9	11	-0.9	-7.1	43
9 Ganzhou	6.1	-1.8	4	2.0	-6.2	27

Table 1. Mean temperature (< T >, °C), deviation from the climatological average (DEV, °C) and estimated return period (RT, years) for the second and third ten days of January 2008. The climatological reference period is 1955-2007.

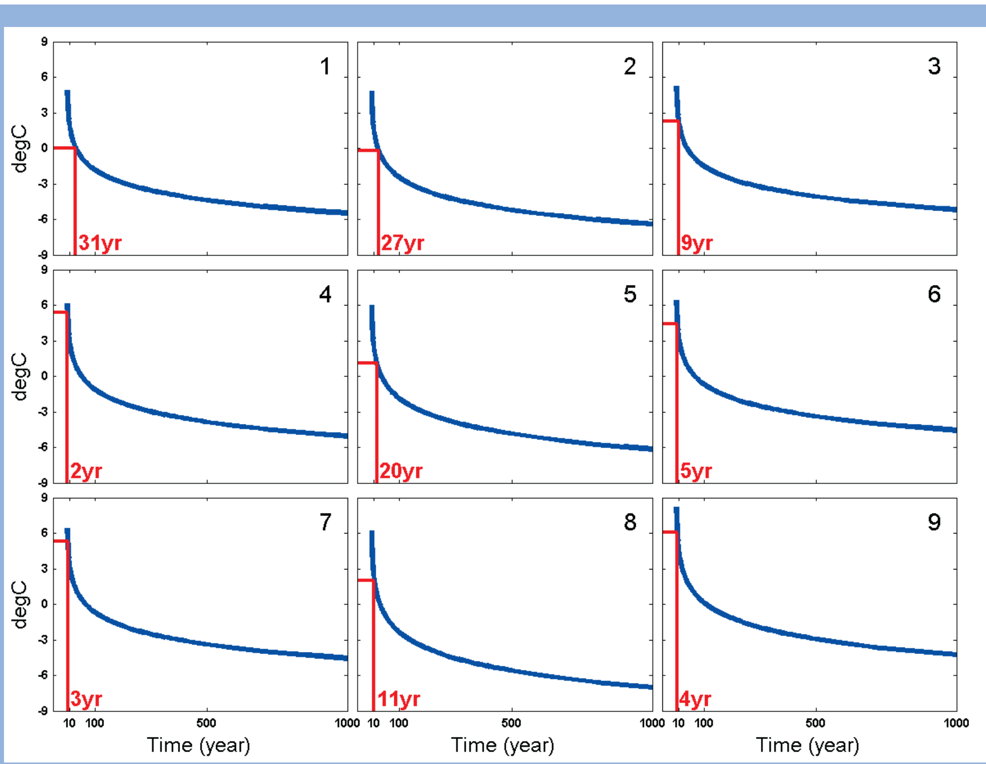

Figure 4. Return periods of 1-1000yr of averaged temperature of the second 10 days in January 2008.for the nine stations (labelled in the top right hand corner of each panel; see the name of the station in Table 1 and the location in Figure 3) in southern China (blue curves). The red horizontal line represents the average temperature observed during these 10 days and the vertical horizontal line indicating the corresponding return period (see Table 1).

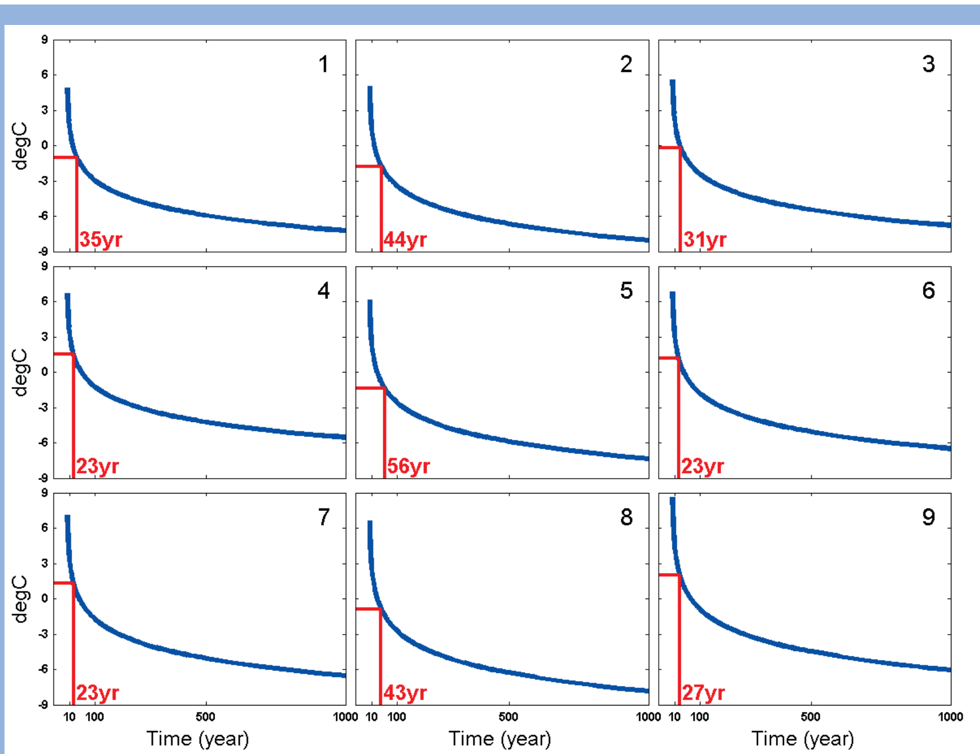

Figure 5. As in Figure 4 except for the third 10 days in January 2008.

4. Summary

This Research Brief presents a preliminary analysis on the meteorological conditions that are likely to be responsible for the extremely low temperatures and icy/snowy weather that occurred during January/February 2008 in southern China, and estimates of the possible return periods of such an event. Three factors have been identified to be responsible: a blocking high pressure system, a warm and moist airstream from the Bay of Bengal and the anomalously strong subtropical high pressure system that is likely related to the La Niña. It is obvious that because all the three factors need to be present simultaneously, such cold episodes cannot occur on a regular basis, and hence the relatively long return periods. For the third 10 days in January during which the temperatures were about 4 to 7°C below the climatological average, the return period of such occurrence ranges between 23 to 56 years.

It should be pointed out that the return periods presented here are based solely on the daily average temperatures and data on snowfall, snow depth or snow cover have not been used as these data are not available. If such data are available, it would be useful to make similar estimates of the return periods and the joint probabilities of the occurrence of both low temperatures and heavy snowfall. Further analyses of the meteorological conditions are also necessary to determine why such conditions occurred simultaneously. Such analyses will be useful in future predictions of similar events. A detailed study of similar events in the past is also necessary to determine whether any periodicities exist in such occurrences or whether such events have become more frequent under global warming.

References

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