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THE CHARACTERISTICS OF GENERAL CIRCULATION, POLAR ICE AND SNOW DAYS / COVER OF EXTREMELY SEVERE COLD MONTHS IN SOUTH CHINA WINTER

WU Shang-sen (吴尚森) , LIANG Jian-yin (梁建茵)

(*Guangzhou Institute of Tropical and Oceanic Meteorology* , *Guangzhou*, 510080 *China*)

ABSTRACT: The work has made a statistic study of the variations of extremely severe cold winter months in the south of China and general circulation and external forcing factors in preceding periods. The result shows that from the current month to the preceding March the subtropical high in the west Pacific is persistently weak or located more to the east and south. When the summer monsoon is weak in East Asia in the year before, the winter monsoon will be strong in the current year in which the extremely severe cold month occurs. The Asian polar vortex expands in the preceding July, August and September and the current winter. The Tibetan Plateau has fewer days of snow cover in the November and December before the cold month occurs. There is less snow in the Tibetan Plateau in the preceding winter / spring of each extremely severe cold month. There are more polar ice in the polar Region Ⅳ for the 11 months before the current February, especially the previous March through August, and in Region Ⅱ in January ~ November before the current cold month of December but less ice in Region Ⅲ in March ~ August.

Key words: extremely severe cold months in south China; physical factors; characteristics

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1 INTRODUCTION

In our previous work[1], definitions are given to outline what a extremely severe cold month is in the southern part of China and studies are devoted to presentation of characteristics of 500-hPa geopotential and SST fields in the current and previous 1 to 6 months. For the SST field, good persistence is shown in the extremely severe cold month winter month in south China and previous 1 to 6 months. Significant differences are also found in the 500-hPa-geopotential field over the same time. Both factors are good signs in foretelling the occurrence of the extremely severe cold month. Apart from them, other components of the general circulation system and other external forcing factors may also have some degree of influence on the wintertime air temperature in China as well as south China. Much of relevant work has proved it. Zhu and Xie[2] and Shi[3, 4] et al. have shown that the intensity of winter monsoon in East Asia is significantly closely related with the air temperature in most parts of the nation. When the winter monsoon is strong (weak), the air temperature will be low (high) in the winter of China. Huang[5] indicates that a stronger-than-normal subtropical high in the west Pacific tends to weaken the cold activity moving southward so that the cold surge would fade away in the Guangdong province. As what Li and Liu[6] have pointed out, the

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Biography: WU Shang-sen (1939 –), male, native from Qinhuangdao City Hebei Province, high-ranking researcher, undergraduate, undertaking the study of short-term climatic diagnosis and prediction and monsoon climatology in the South China Sea.

index of the polar vortex area in Asian winter displays a clear negative correlation with the air temperature in China, which shows that the expansion (shrinkage) of polar vortex area is accompanied by the fall (rise) of air temperature in China. As shown in references [7, 8], the size and distribution of the area of sea ice around the North Pole can affect the intensity of zonal and meridional circulation in the Asian region as well as the location and intensity of the polar vortex; the snow cover on the Tibetan Plateau can influence the patterns of 500-hPa geopotential field in the boreal winter. It can be drawn, therefore, that the polar ice cover and snow cover on the Tibetan Plateau are also one of the influential factors for the temperature of winter in China.

Employing statistic approach, the work studies such factors of the general circulation as the subtropical high in the west Pacific, winter / summer monsoons in East Asia and the polar vortex in Northern Hemisphere, and the relationship between the external forcing factors of snow cover on the Tibetan Plateau and polar ice and the extremely severe cold winter months in the south of China.

2 DATA AND METHODS

The National Climate Center of China is the provider of the index of the subtropical high intensity in the west Pacific, its mean ridge position and monthly snowing days recorded at the Tibetan Plateau stations. References [3, 4] are the source for the anomalies of winter / summer monsoon indexes in East Asia. The 500-hPa polar vortex area indexes in Asia are extracted from the reference [6]. The North Pole sea ice data are part of the Walsh month-to-month sea ice coverage.

The composite analysis and statistic method are used here to study the extremely severe cold months in the winter of South China and the general circulation and external forcing factors in the preceding periods.

3 EXTREMELY SEVERE COLD WINTER MONTHS IN SOUTH CHINA AND SUBTROPICAL HIGH IN WEST PACIFIC IN PRECEDING PERIODS

To have a understanding of the extremely severe cold months in the winter of south China and the subtropical high in the west Pacific (to be shortened as "the subtropical high" hereafter) in the preceding periods, we have conducted a statistic study of the anomalies of intensity index for the subtropical high for 6 extremely severe cold months and all preceding months up till the March before (Tab.1) and the anomalies of the west-extending longitude and the mean latitude of the ridge (figure omitted). The table shows that the current months of the extremely severe cold temperature all have negative anomalies of the intensity index, suggesting that these are the times

Tab.1 Index anomalies for intensity of the subtropical high in west Pacific in and before the extremely severe cold months in South China winter

e.s.c	Feb	Jan	Dec	Nov	Oct	Sep	Aug	Jul	Jun	May	Apr	Mar
Jan/77	/	-1.6	-5.8	2.2	2.8	-21.5	9.8	-17.8	-27.1	-15.0	-10.3	-12.5
Jan/84	/	-7.6	4.2	18.2	35.8	14.5	22.8	38.3	36.9	32.0	25.8	44.5
Feb/68	-9.5	-10.6	-9.8	-20.8	-4.2	-22.5	-6.2	-22.8	-24.1	-18.0	-14.3	-12.5
Feb/57	-9.5	-10.6	-12.8	-6.8	-25.2	-19.5	-16.2	-21.8	-20.1	-11.0	0.8	-7.5
Dec/67	/	/	-9.8	-20.8	-4.2	-22.5	-6.2	-22.8	-24.1	-18.0	-14.3	-12.5
Dec/75	/	/	-14.8	-23.8	-15.2	-16.5	-14.2	-12.8	-10.1	-17.0	-12.3	-12.5

*e.s.c. stands for extremely severe cold of weak subtropical high activity. It also shows that except for April 1956, all months are of negative anomaly in the intensity index preceding the current extremely severe cold month of February and all of the 9 months are of negative anomaly prior to the extremely severe cold month of January. The table also present negative anomalies for 7 out of 10 preceding months for January 1977 and positive anomalies for all the 10 months prior to January 1984. The results have one implication: the subtropical high is persistently weak in 9 ~ 11 preceding months for 5 out of 6 extremely severe cold months. Let's now look at the statistics of the location of the subtropical high. For all the 10 months prior to the extremely severe cold January 1984, the west-extending longitude of the subtropical high ridge is in negative anomaly, ranging between –11 and –30. The latitude anomaly is also negative. It shows that the subtropical high is always more eastward and southward during the 10 preceding months.

In summary, the intensity of the subtropical high in the west Pacific from the current extremely severe cold month to the preceding March has been persistently weak (5 out of 6 occasions) or has been persistently more eastward and southward (1 out of 6 occasions).

4 RELATIONSHIP BETWEEN EXTREMELY SEVERE COLD MONTHS OF SOUTH CHINA AND WINTER / SUMMER MONSOON IN EAST ASIA

It is a well-known fact that the East Asian monsoons pose an important influence on the weather and climate in China. As indicated in [1], the intensity of monsoon is negatively correlated with the air temperature in winter China and by a significant degree over large area. When the winter monsoon is strong (weak), the air temperature is low (high) in the time. The statistic correlation for temperature is particularly significant in January and February with the level of confidence as high as 0.001 or more.

Using the anomalies of the monsoon index for the month and season in the winter / summer monsoon periods as given in [3, 4], the current work studies the monsoon index during the current and preceding months. As the prime periods of winter / summer concentrate in December, January and February as well as in June, July and August, we focus on the monsoon index for these months and winter / summer seasons.

As shown in Tab.2, positive anomalies dominate both the winter monsoon indexes in all 6 current months of extremely severe cold temperature in the south China winter and the index for the season. The magnitudes are very large in 5 out of the 6 months (except for December 1975) for index of winter monsoon in the seasons in which they belong to. For the past 40 years or so, the anomalies of monsoon index in the winter of the 5 years rank the 2nd, 3rd, 3rd, 8th and 9th. It is a sufficient indicator that the winter monsoon is strong in the extremely severe cold month in the south China winter. It suggests that only when the winter monsoon is intense enough and penetrates most

Tab.2 Same as Tab.1 but for winter and summer monsoon

M.S.C. months in South China		Anomaly of winter monsoon index				Anomaly of summer monsoon index in preceding months			
year	month	current	1 month ahead	2 months ahead	winter	Aug.	Jul.	Jun.	summer
1977	1	1.45	0.32	/	1.24	0.66	0.28	0.49	0.60
1984	1	0.92	1.67	/	1.99	0.14	–0.43	0.72	0.23
1968	2	2.38	0.58	0.44	1.80	1.09	–0.19	0.60	0.86
1957	2	0.67	–0.12	2.09	1.29	1.04	0.29	0.51	0.84
1967	12	0.44	/	/	1.80	1.09	–0.19	0.60	0.86
1975	12	1.18	/	/	0.04	–0.75	0.32	–0.87	–0.71

of the region in southern China could such months occur in winter.

From Tab.2, we know that in the preceding 6 summers before the extremely severe cold months, five have positive anomalies of summer monsoon index, coinciding with the rate of 5/6 for the appearance of positive anomaly of summer monsoon in the preceding June and August.

As described in [5], the summer monsoon is defined to be weak (strong) when the index anomaly is large positive (negative); a high-index year (with weak summer monsoon) is implied when the anomaly $\geqslant$ 0.60 or a low-index year (with strong summer monsoon) is indicated when it $\leqslant$ –0.71. Comparing the definition with the actual index anomalies listed in Tab.2 for individual summer monsoons, 4 out of 6 extremely severe cold months are preceded by weak monsoon years and the remaining one by strong and the other by less weak year of summer monsoon.

It is now clear that the index is always positive for the winter monsoon anomaly in the current months and seasons of the extremely severe cold temperature in South China. In other words, the winter monsoon is strong. For comparison, the probability for weak summer monsoon to appear in the preceding summer, June and August is 5/6.

Together with the work above, statistics for the anomaly of winter / summer monsoons in the months of and before those of extremely severe cold and cold winter in the southern part of China are also obtained. The results show that neither winter monsoon nor summer monsoon in January or February with the degree of coldness is comparable with those in the extremely severe cold months. The case of December 1975 is an exception, in which the winter monsoon and preceding summer monsoon are not as strong (weak) as those in the extremely severe cold or cold months of the season. It may have something to do with less strong winter monsoon and looser correlation with air temperature in China in December.

It can be summarized in general that the index of winter monsoon for relevant months of the current years and the index of weak summer monsoon in the preceding summer, June and August can be taken as a precursory factor to predict whether any extremely severe cold months would appear in the South China winter.

5 EXTREMELY SEVERE COLD WINTER MONTHS IN SOUTH CHINA AND PRECEDING POLAR VORTEX IN ASIA

As shown in reference [6], the area index of the polar vortex in Asian winter is in significant negative correlation with the air temperature in China — as the polar vortex increases in size, the temperature falls in China; as the polar vortex shrinks, it rises. The area index of the polar vortex for February is negatively correlated with the air temperature at 160 observation stations across China, with 115 of them have a confidence level of 0.01, a share of 72%. It is obvious that the size of the vortex area in Asian winter has immediate effects on the variation and distribution of temperature for all parts of China.

With the aid of [6] for the division of 4 regions in the Northern Hemisphere, specifically, Region Ⅰ: 60°E ~ 150°E, Asia; Region Ⅱ: 150°E ~ 120°W, Pacific Ocean; Region Ⅲ: 120°W ~ 30°W, Americas and Atlantic Ocean; Region Ⅳ: 30°W ~ 60°E, we are able to study the variations of ΔS, the anomaly of area index of the polar vortex at 500 hPa in the current and preceding periods for the extremely severe cold months in the South China winter. As indicated in the result, only the anomaly ΔSI for the area index of the Asian polar vortex is well correlated with the extremely severe cold months in the south China winter.

The current work presents the statistic data of ΔSI, the area index of the Asian polar vortex in the simultaneous and preceding periods for the extremely severe cold months in the South China winter. The following points can be drawn from Tab.3.

Tab.3 Same as Table 1 but for the area index (ΔSI) of polar vortexes in Asia (unit: $10^5 km^2$)

year	month	Feb	Jan	Dec	Nov	Oct	Sep	Aug	Jul
1977	1	/	22	2	10	14	12	11	15
1984	1	/	1	3	−6	−3	10	−8	8
1968	2	15	13	6	−19	−4	11	8	14
1957	2	3	8	7	−3	−6	7	−1	15
1967	12	/	/	6	−19	−4	11	8	14
1975	12	/	/	2	4	5	−2	2	7

(1) The ΔSI of the current extremely severe cold month is always positive. It suggests that the area of the Asian polar vortex has increased over the time so that powerful cold air can travel from the polar region to the southern part of China and form extremely severe cold months there.

(2) The ΔSI over preceding months of the extremely severe cold month is also positive. It suggests that the polar vortex is also expanding in size during the time.

(3) The ΔSI over preceding July, August and September and December / January of the extremely severe cold month is positive by a rate of 5/6 and negative by 1/6, suggesting the expansion of the polar vortex.

It is therefore clear that the features of ΔSI in July, August and September prior to the extremely severe cold month and December and January in the same winter can be used as a signal to predict whether there will be an extremely severe cold month.

Statistics are also presented of the anomaly of the area index for the extremely severe cold months in terms of current and preceding periods. It shows that these months are less significant than the extremely severe cold ones, e.g. the rate of ΔSI having a positive anomaly is 5/9 over the simultaneous time, 6/9 over the previous winter and 14/27 over July, August and September.

It is apparent that the ΔSI over the simultaneous and preceding periods are different between the extremely severe cold months and extremely severe cold months. In other words, it is feasible to predict the extremely severe cold winter months in south China using ΔSI as a predictor.

6 RELATIONSHIP BETWEEN EXTREMELY SEVERE COLD WINTER MONTHS IN SOUTH CHINA AND MONTHLY SNOW DAYS IN AUTUMN & WINTER OVER TIBETAN PLATEAU

The Tibetan Plateau, "roof" of the world, is located on the upstream of the eastern part of China and poses important influence on the weather / climate in the region. As shown in a study[8], the correlation of snow days over the plateau with 500-hPa geopotential field in the Northern Hemisphere in winter is generally negative in the north and positive in the south in the Asian-Pacific area. When there is more snow over the plateau in winter, the anomaly displays a lower-north versus higher-south pattern in the Asian-Pacific region, which is featured by dominance of zonal circulation, weak winter monsoon in East Asia and high temperature in eastern China. When there is less snow, however, the anomaly pattern changes to higher-north versus lower-south distribution, with meridional circulation in dominance, strong winter monsoon in East

Asia and low temperature in eastern China. As the anomaly is quite small due to less snow during the summertime, the statistic work covers only the monthly anomaly of snow days for the autumn and winter prior to the extremely severe cold months in southern China. The result is shown in Tab.4. It indicates that for 4 out of 6 cases of extremely severe cold months, the preceding months in autumn and winter are accompanied by less snow days over the plateau by a probability of 8/12, except for the case of December 1967 ~ February 1968, which is marked by poor correlation. In November and December in the preceding year, the negative anomaly is quite significant for the number of snow days. As far as January is concerned, the probability for the extremely severe cold month to appear in south China is high if there is less snow in preceding autumn and winter over the Tibetan Plateau.

Reference [9] is the research employing the satellite data of NOAA/NECDIS of U.S. and anomalous years of snow days in winter and spring over the plateau given by a number of scientists in China. As shown in Tab.4, snow is less in the current winter / spring of the extremely severe cold January and this phenomenon is observed in 5 out of 6 cases in terms of the preceding winter/spring.

Tab.4 Anomalies of monthly snow days and snow cover over Tibetan Plateau in and before the extremely severe cold months in south China winter

M.S.C. month		February	January	December	November	October	snow cover on Tibetan Plateau	
year	month						winter/spring current year	winter/spring preceding year
1977	1	/	+0.5	–4.0	–2.0	+0.4	Less snow	Less snow
1984	1	/	+1.0	–2.0	–2.1	+0.2	Less snow	More snow
1968	2	+2.0	+3.0	+2.8	+5.4	+1.6	More snow	Less snow
1957	2	+1.5	+7.5	+1.5	–1.6	–1.0	More snow	Less snow
1967	12	/	/	+2.8	+5.4	+1.6	More snow	Less snow
1975	12	/	/	–3.0	–0.3	–1.1	Less snow	Less snow

7 RELATIONSHIP BETWEEN EXTREMELY SEVERE COLD WINTER MONTHS IN SOUTH CHINA AND SEA ICE IN THE NORTH POLE

As indicated in [7], the size of sea ice in the North Pole is related with the air temperature in China. When the area of sea ice gets larger (smaller), the air temperature will be lower (higher), especially in the northern part of China. The change in the area has the most effect on the north of China in early winter (December) but on the south of China in late winter (February ~ March).

The sea ice data originates from the Walsh's monthly coverage data for the North Pole sea ice area. For the 113 stations selected in the non-permanent freezing area, there are 38 stations in Region Ⅰ (160°E ~ 110°W), 23 stations in Region Ⅱ (110°W ~ 20°W), 30 stations in Region Ⅲ (70°E ~ 160°E) and Region Ⅳ (20°W ~ 70°E). The length of the data is from January 1953 to December 1984.

The analysis shows that the changes of polar ice in the preceding months of the extremely severe cold January are not applicable while those of February and December are of some statistic implication. They are illustrated in Tabs.5 and 6. As shown in Tab.5, from the preceding

Tab.5 Percentages of area anomalies for sea ice in the North Pole region in periods before the extremely severe cold February in South China winter

	Region Ⅳ		whole region	
M.S.C. month	Feb. 1968	Feb. 1957	Feb. 1968	Feb. 1957
January	0.08	–0.01	–0.04	0.21
December	0.17	0.11	0.14	0.00
November	0.31	–0.03	0.17	0.00
October	0.24	–0.11	0.01	0.09
September	0.60	–0.02	–0.04	0.07
August	0.47	0.04	–0.24	0.05
July	0.49	0.05	–0.11	–0.08
June	0.55	0.11	0.12	0.12
May	0.56	0.12	0.31	0.09
April	0.39	0.09	0.23	0.11
March	0.38	0.21	0.18	0.30
Positive sign rate preceding Mar. ~ current Jan.	11/11＝100 %	7/11＝64 %	7/11＝64 %	10/11＝91 %
Positive sign rate preceding Mar. ~ Aug.	6/6＝100 %	6/6＝100 %	4/6＝67 %	5/6＝83 %

Tab.6 Same as Tab. 5 but for periods before the extremely severe cold December

	Region Ⅱ		Region Ⅲ	
M.S.C. month	Dec. 1967	Dec. 1957	Dec. 1967	Dec. 1975
December	0.04	0.08	0.04	0.04
October	-0.04	0.30	0.05	0.05
September	0.21	0.15	0.04	0.04
August	0.38	0.04	-0.61	-0.02
July	0.08	-0.53	-0.28	-0.15
June	0.18	-0.01	-0.15	-0.11
May	0.10	-0.16	-0.16	0.07
April	0.00	0.00	-0.21	-0.05
March	-0.04	-0.15	-0.14	-0.15
February	-0.03	0.12	-0.38	0.15
January	-0.11	0.06	0.05	0.05
positive sign rate preceding Jan. ~ Nov.	7/11＝64 %	7/11＝64 %	4/11＝36 %	6/11＝55 %
negative sign rate preceding Mar. ~ Aug.			6/6＝100 %	5/6＝83 %

January back to March the previous year for the extremely severe cold February, the positive sign in Region Ⅳ appears by 64% ~ 100% for the area anomaly of polar sea ice and by 100% from March to August in the year before. For the whole region of North Pole, the rate of positive sign also takes the dominant role over the preceding 11 months (64% ~ 91%). It can be concluded that for the preceding months of the extremely severe cold February, especially in the spring / summer in the previous year, there is larger coverage of polar ice. Tab.6 shows that there is larger coverage of polar ice in Region Ⅱ in January ~ November prior to the extremely severe cold December with the positive sign appearing in 64% of the chance. For Region Ⅲ, however, the polar ice is less in March ~ August of the previous year with the negative sign appearing in the range of 83% ~ 100%.

8 CONCLUDING REMARKS

For individual extremely severe cold winter months in the southern part of China:

a. For March ~ December prior to January, the subtropical high in the west Pacific is weaker or locates more eastward and southward. The high is persistently weaker over the preceding 11 months for February and March through November before December.

b. The summer monsoon is weak in the preceding period but winter monsoon is strong in the current period.

c. The Asian polar vortex expands in the preceding July, August and September and the current winter.

d. There are fewer days of snowfall over the Tibetan Plateau in the preceding November and December for January. Snow is less on the plateau throughout winter / spring for all extremely severe cold months.

e. For February, there is more sea ice in Region Ⅳ as well as the whole North Pole region in the preceding March through January in the current year, especially in March through August. For December, the polar ice is more in Region Ⅱ from the preceding January to November but less in Region Ⅲ from the preceding March to August.

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