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THE IMPACT OF PRECEDING ATMOSPHERIC CIRCULATION AND SST VARIATION ON FLOOD SEASON RAINFALL IN YUNNAN

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ABSTRACT: Spatial and temporal distribution characteristics and scale range of two significant areas were obtained by analyzing the relationship among summer rainfall in Yunnan province, height field and SST field (40°S – 40°N, 30 °E – 70°W) across the North Hemisphere at 200 hPa, 500 hPa and 850 hPa for Jan. to May and correlation, and field wave structure. Remote key regions among summer rainfall in Yunnan province, height field and SST field (40°S – 40°N, 30°E – 70°W) across the North Hemisphere at 200 hPa, 500 hPa and 850 hPa were studied through further analyzing of the circulation system and its climate / weather significance. The result shows that the forecast has dependable physical basis when height and SST fields were viewed as predictors and physical models of impacts on rainy season precipitation in Yunnan are preliminarily concluded.

Key words: general circulation; SST; rainfall during the rainy season inYunnan; correlation coefficients

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1 INTRODUCTION

The forecasting of rainfall for rainy seasons has been a difficult focus in short-term operational climate prediction. Some of the previous research was on the general circulation (the geopotential height) mainly while others on the sea surface temperature mainly. By studying the impacts of general circulation variation on the rainfall of May in Yunnan and forecasting of the change, Yan et al. [1] point out that the anomalies of rainfall in May in the province may be linked with the transportation of low-latitude stationary planetary wavetrains in spherical atmosphere. Wang et al. [2] work on the impacts of mid- and lower-latitude pressure features on the May rainfall and how it is forecast. Wang[3] also note that the gradual westward movement of the mean position of longwave troughs and ridges in the westerlies from February to May is one of the important factors for the onset of the rainy season in May there. You et al. [4] studied the relationship between the onset of rainy seasons in Yunnan and seasonal variation of the general circulation. Addressing the relationship between early-summer precipitation in Yunnan and precedent general circulation, Ju et al. [5] suggest significant links between precedent 500-hPa geopotential height field and amount of precipitation in early summer in the province. Yan et al. [6] study the relationship between the rainfall of May and tropical SST and convection as well as large-scale climate background such as Asian monsoon. Achieving a lot of useful results, all of the above research has limitations of their own. In other works, Yan further sums up that inclusion of precedent evolution of the general circulation and SST field in the making of climate

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prediction of precipitation over the rainy season may solidify the physical foundation of the forecast. It is an important issue worth more discussion as how to associate raining-season precipitation with the general circulation and SST field.

Whether it rains more or not during the rainy season of Yunnan province responds to the interaction and mutual influence between cold air from the north of the country and warm and humid air stream from the south. The general circulation in the Northern Hemisphere governs how active the cold air can be while SST is the main factor that determines the transportation of water vapor and the intensity of summer monsoons. It is then necessary to probe the correlation between precedent general circulation and SST and raining-season rainfall. This work is a continuation of the previous study introduced by analyzing the correlation between the rainfall in Yunnan's rainy seasons and the geopotential height and SST fields and discussing the effects of precedent changes in the fields, in the hope that the efforts could provide effective ways of thinking and physical foundation for the climatological forecast of raining-season rainfall in Yunnan.

2 DATA AND METHODS

The mean rainfall during the rainy season at six selected weather stations in Yunnan is to be forecast, which are denoted as $\overline{R_1}$. The gridpoint fields at 200, 500 and 850 hPa in simultaneous Jan. – May in the Northern Hemisphere are used as the predictor fields with intervals of 2°×2°, which are denoted as $H_{200}^{(1)}$ – $H_{200}^{(5)}$, $H_{500}^{(1)}$ – $H_{500}^{(5)}$ and $H_{850}^{(1)}$ – $H_{850}^{(5)}$, respectively. With a 51-year sample (1951 – 2001), correlation is seek between $\overline{R_1}$ and $H_{200}^{(1)}$ – $H_{200}^{(5)}$, $H_{500}^{(1)}$ – $H_{500}^{(5)}$ and $H_{850}^{(1)}$ – $H_{850}^{(5)}$.

Then, the mean rainfall from the six stations, denoted as $\overline{R_2}$, is forecast. The gridpoint fields of SST (40°S – 40°N, 30°E – 70°W) in simultaneous Jan. – May are used as the predictor fields, denoted as $S^{(1)}$ – $S^{(5)}$. With a 49-year sample (1951 – 1999), correlation is sought between $\overline{R_1}$ and $S^{(1)}$ – $S^{(5)}$.

3 TEMPORAL AND SPATIAL DISTRIBUTION OF TELECONNECTION BETWEEN RAINY-SEASON RAINFALL IN YUNNAN AND PRECEDENT FIELDS OF GEOPOTENTIAL HEIGHT AND SST

3.1 *Teleconnection of the geopotential field and physical implications*

3.1.1 SPATIAL DISTRIBUTION OF TELECONNECTION OF GEOPOTENTIAL HEIGHT FIELD

From the analysis of the correlation field between the 200-hPa, 500-hPa (Fig.1) and 850-hPa geopotential height fields (figure omitted) and rainy-season rainfall in Yunnan, the spatial distribution is determined of the teleconnection of geopotential height field. On the three levels just mentioned for Jan. – May, the distribution of the correlation field tends to be consistent from low to high latitudes, with the centers of correlation generally superimposed and the area of positive correlation distributed in elongated zones. It shows well-defined wavetrain structures at planetary scale and points to important impacts of precedent ultra-longwave systems in the general circulation in the mid- and higher- latitudes on the rainfall during Yunnan's rainy seasons. The higher in the atmosphere, the better the correlation is. Comparing the correlation fields at 200, 500 and 850 hPa, we find that the correlation at 200 hPa is better than the other two levels and the correlation at 500 hPa is better than that at 850 hPa. It may be attributed to complicated and small-scale distribution synoptic systems at low levels against ultra-long and stable

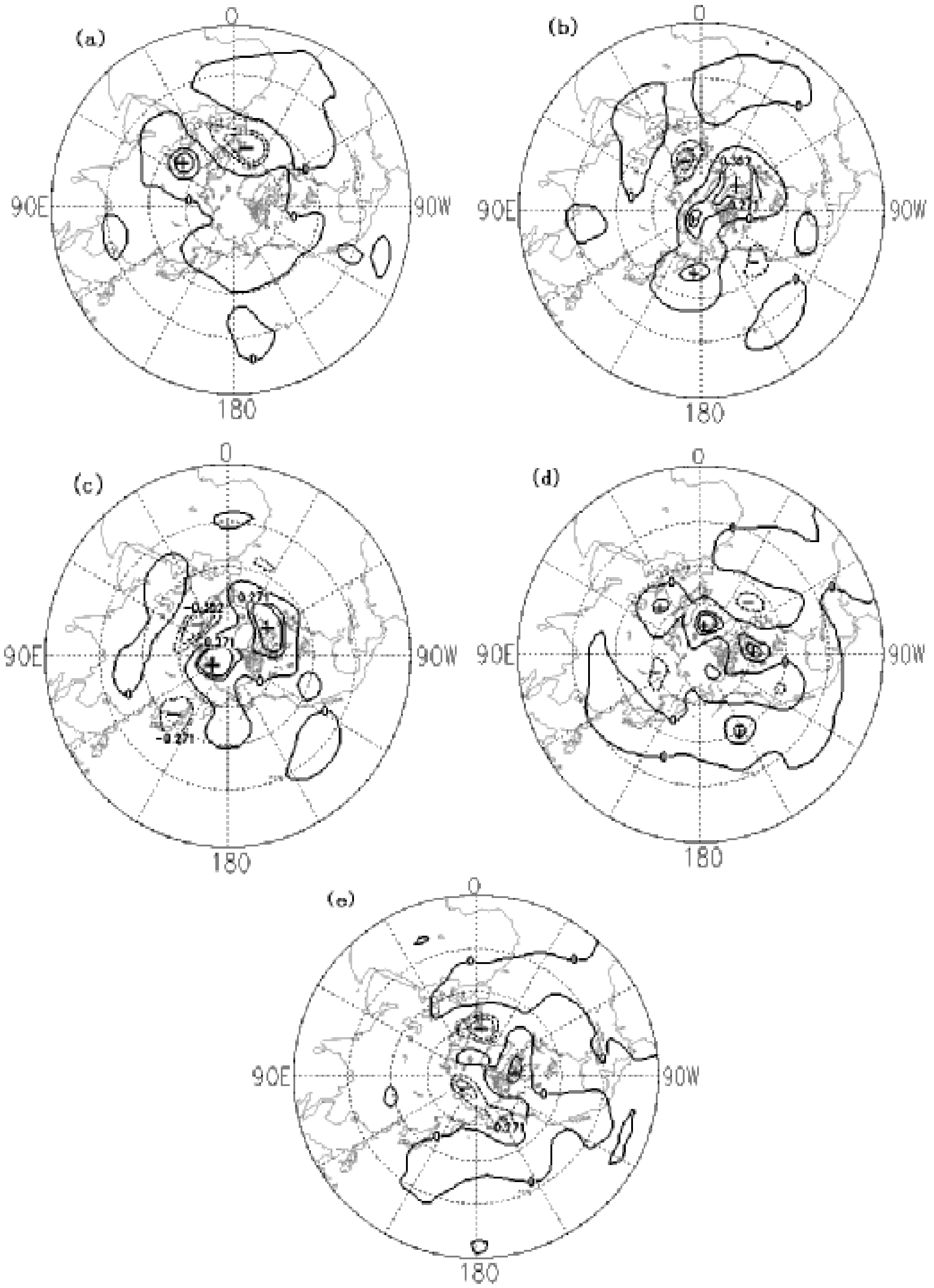

Fig.1 The fields of correlation between rainy-season rainfall in Yunnan and precedent 500-hPa geopotential altitude in Jan (a). – May (e). The dashed lines indicate areas of negative correlation that is above the 0.05 and 0.01 significance levels and the solid lines are where areas of positive correlation appear that are over the 0.05 and 0.01 significance levels.

distribution of general circulation systems that affect the correlation at higher levels. For instance, there is a well-defined maximum of the westerlies around 200 hPa, showing significant signs of ultra-long waves on the planetary scale.

3.1.2 SPATIAL AND TEMPORAL VARIATION OF TELECONNECTION OF GEOPOTENTIAL HEIGHT FIELD

Good consistence is found in the temporal variation of the correlation from Jan. to May on the levels of 200, 500 and 850 hPa. The 500-hPa case is taken for analysis.

(1) For the correlation in Jan. – Feb., the distribution varies mildly but the extent and range of significance vary remarkably. They mainly show in the following aspects. The areas of significant positive correlation weaken and significance disappears over central Europe; correlation strengthens substantially within areas of positive correlation over high-latitude polar areas, resulting in large-areas of significant positive correlation; the areas of negative correlation formerly over the Atlantic west of Europe has moved over its western coast while areas of significant negative correlation appear over eastern Pacific Ocean.

(2) For the correlation in Feb. – Mar., neither of the coverage, location and extent varies much, with the correlation at its best and the areas of correlation the largest in coverage and highest in extent from Jan. to May.

(3) For the correlation in Mar. – Apr., either of the coverage, location and extent varies much, with areas of positive correlation in eastern Pacific and positive correlation decreases in high-latitude polar regions. Areas of significant negative correlation appear in western United States.

(4) For the correlation in Apr. – May, both the coverage and location vary mildly while the extent varies drastically. Specifically, correlation weakens in areas of positive correlation in eastern Pacific and significance disappears. Positive correlation decreases sharply in mid- and high- latitudes while negative correlation strengthens considerably over most of the mid- and higher- latitude areas.

With detailed analysis, it is found that as far as positive correlation is concerned, areas of significant positive correlation for Jan. are only over central Europe on all levels, with the coverage of significance smaller than that in Feb. and Mar; areas of significant positive correlation for Feb. and Mar. are mainly over the Arctic Ocean and Baffin Is. and Greenland and nearby regions; areas of significant positive correlation for Apr. mainly concentrate over the Pacific region with smaller coverage of significance; significant positive correlation almost disappears for May. For negative correlation, areas of significant negative correlation for Jan. are over northern Atlantic and western Pacific on all levels, with the coverage of significance smaller than that in Feb.; areas of significant negative correlation for Feb. are mainly over northwestern Europe and northeastern Pacific; in Mar., areas of significant negative correlation for 500 hPa are over Japan and neighboring waters, central Europe and waters off western Europe; in Apr., areas of significant negative correlation are over central Pacific, western United States and eastern Russia; in May, areas of significant negative correlation for 500 hPa are mainly over the Arctic Ocean, Alaska, the Bering Strait, coast of western Europe and western United States. In contrast, the correlation areas for Feb. and Mar. are the largest in the coverage of significance and highest in the extent of significance.

It is known from the analysis above that Mar. and Apr. are the months in which the coverage and location of the correlation and the extent of the correlation vary the most with time, followed by Jan. and Feb. and then by Apr. and May, and Feb. and Mar. have the least variation. There is good consistency in temporal variation of correlation on individual levels, with the best correlation appearing in Feb. and Mar., which can be used as important basis for the prediction of rainfall in Yunnan’s rainy seasons.

3.1.3 SYNOPTIC AND CLIMATIC IMPLICATIONS OF TELECONNECTION KEY ZONES OF GEOPOTENTIAL HEIGHT FIELD

It is known from the above analysis of teleconnection of geopotential height fields that correlation is the best in Feb. and Mar. among the five months from Jan. to May, with the correlation centers superimposed for all levels of altitude. For this purpose, areas of significant 500-hPa correlation for Mar. (Fig.1c) are selected for analysis, together with mean geopotential height fields at 500 hPa for precedent periods (Fig.2), to probe into the synoptic and climatic implications. It is determined that in Mar., there are areas of significant positive correlation in the polar region (where there are polar vortexes), areas of significant positive correlation in front of major troughs in North America, negative correlation areas in the rear of troughs in eastern Europe and areas of significant negative correlation in the rear of major troughs in East Asia. Then, when pressure is low in both areas of positive and negative correlation in precedent geopotential height fields, the westerlies will expand to low latitudes and major troughs will be more westward in East Asia. It may result in more southward location of the westerlies and more westward location of the East-Asia major troughs during the rainy season to bring in more cold air over Yunnan so that there will be more precipitation during the time. There will be less precipitation otherwise.

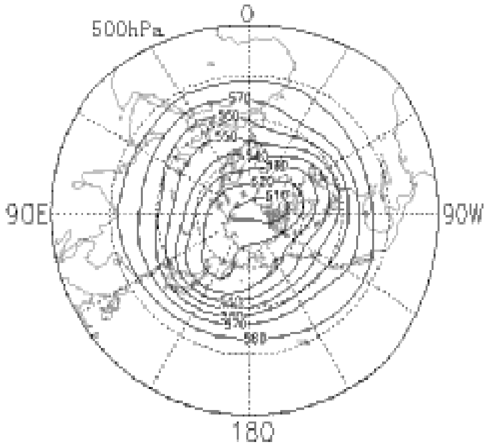

Fig.2 Mean geopotential height field at 500 hPa.

It is known from the above analysis that circulation anomalies in the key areas (where the correlation is significant) are good indicators of rainfall in Yunnan’s rainy seasons. Among the well-correlated regions with it are mainly the polar vortex, the rear part of major troughs in North America, the front part of major troughs and the rear part of major troughs in East Asia. When there are anomalies in these key regions, they can be indicators of the wetness of Yunnan’s rainy seasons.

3.2 *Temporal and spatial distribution of teleconnection of SST field and physical implications*

3.2.1 SPATIAL DISTRIBUTION OF TELECONNECTION OF SST FIELD

Fig.3 shows the coefficient field of the correlation between the SST field and the rainfall in Yunnan’s rainy seasons. From the analysis, it is known that:

(1) Areas of significant correlation generally coincide each other for Jan. – May. They show the structure of a meridional “**- + -**” wavetrain in waters of low-latitude central Indian Ocean and western and eastern Pacific Ocean.

(2) Due to the effect of factors such as seasonal variation on SST, the distribution of Jan. significant correlation areas differs from that of Feb. – May ones, in that there are areas of significant positive correlation in northern Pacific but areas of significant negative correlation in northwestern and central Pacific.

3.2.2 TEMPORAL EVOLUTION OF TELECONNECTED SST FIELDS

From the analysis of the temporal variation of the field of coefficients for the correlation between the SST field and the rainfall in Yunnan’s rainy season, it is known that:

(1) Between Jan. and May, there is little change in the location of correlation areas. Except the area of significant correlation in northern Pacific for Jan., areas of significant correlation generally coincide with each other for Jan. – May but vary much in the extent of significance and degree of correlation. In contrast, the variation is large in Feb. – Mar. and Mar. – Apr., followed by Apr. – May and Jan. – Feb.

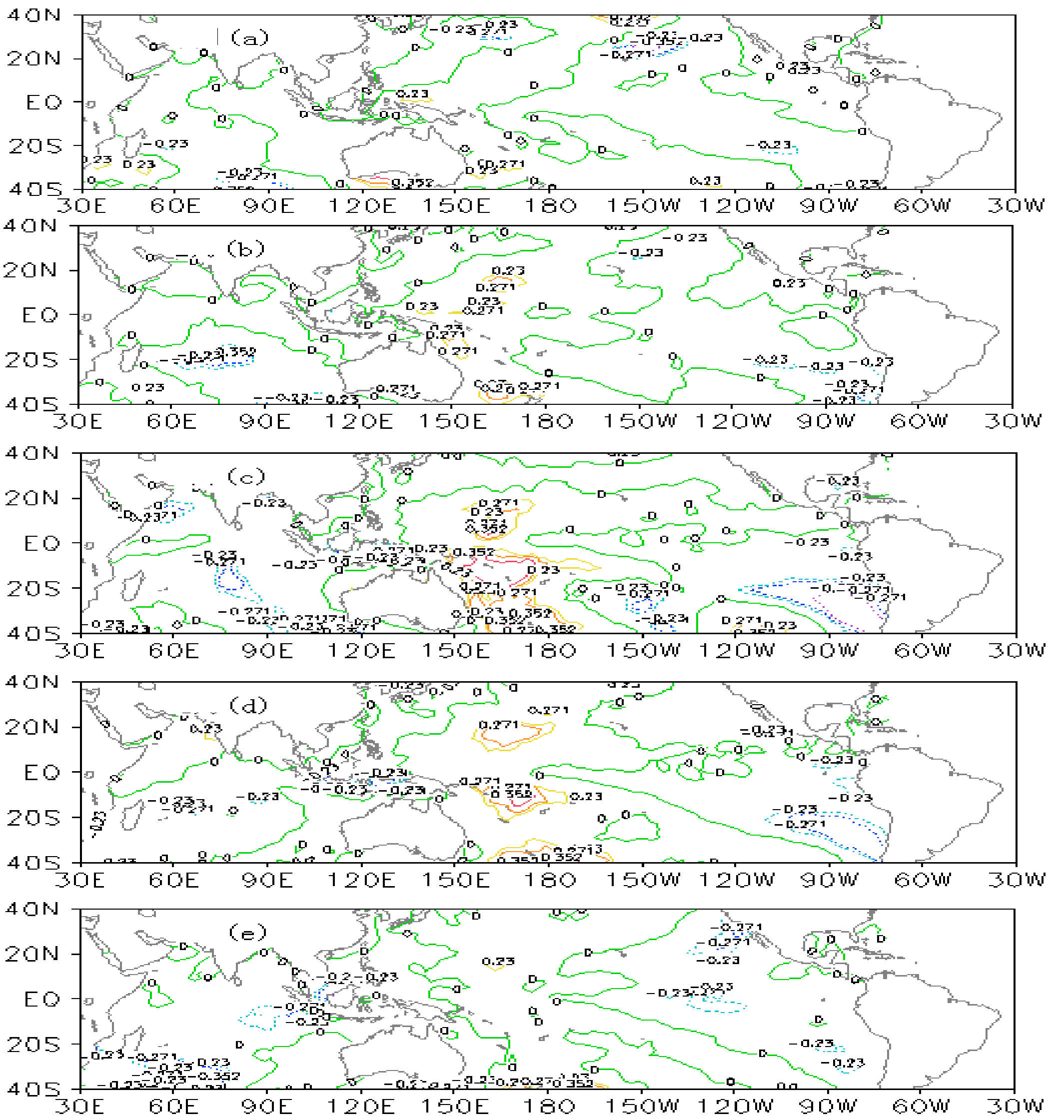

Fig.3 The field of correlation between rainfall in Yunnan’s rainy seasons and SST in precedent time (Jan. – May, as shown in a – e).

(2) For low-latitude waters, correlation is the best in March and the correlation area has the largest range and the highest degree of correlation. As far as positive correlation is concerned, there are areas of significant correlation over waters south of Australia and in northern Pacific in Jan., areas of positive correlation in northern Pacific and near New Zealand in Feb., areas of positive correlation in western Pacific, waters off the Peruvian coast in eastern Pacific in Mar., areas of positive correlation in most of the equatorial western Pacific and areas of positive correlation in southern waters of the equatorial western Pacific. For negative correlation, the areas mainly occur in most of the Indian Ocean, northwestern Pacific and eastern Pacific. By comparison, areas of significant negative correlation have the largest coverage and highest degree in Jan. in northwestern Pacific and northeastern Pacific while negative significant correlation in Mar. in the Indian Ocean and eastern Pacific has the largest coverage and highest degree of

significance.

It is known from the analysis above that the correlation is the best in Jan. – May, having the largest coverage of significant correlation and highest degree of correlation. The distribution of significantly correlated areas for Jan. differs from that for Feb. – May.

3.2.3 SYNOPTIC / CLIMATOLOGICAL IMPLICATIONS OF TELECONNECTED KEY AREAS OF SST FIELDS

It is known from the above that the Mar. correlation is the best with areas of significant correlation generally coincided for Jan. – May, except that there are areas of significant correlation in northern Pacific in Jan. Its synoptic implications are discussed in this work. In Jan. the correlation is positive in northern Pacific, indicating high (low) temperature there in the possible company of more (less) precipitation in the rainy season of Yunnan. Other positive (negative) correlation areas generally coincide with those for Mar. Comparisons of the correlation field with 500-hPa mean geopotential height field for Mar (Fig.2) shows that the areas of significant correlation in parts of northwestern Pacific are just over the southern section of a main, stationary East Asian trough and areas of significant positive correlation in northern Pacific are just over ridge in and south off Alaska. In other words, precedent low (high) SST in negative (positive) correlation areas may deepen the main trough in East Asia and strengthen the ridge over Alaska. With the evolution of troughs and ridges, waves get strengthened in the westerlies to channel large amount of cold air into the province during the season and increase the precipitation. Precipitation is less otherwise.

Studying the synoptic / climatic causation of early-summer precipitation, Yan et al. [9, 10] point out that the southeasterly trade wind by way of the Mascarene high progresses to Yunnan in the form of South Asia monsoon after it travels across the equator and over a key zone over the Bay of Bengal; the southeasterly trade wind by way of the Australian high arrives in Yunnan in the form of East Asia monsoon after it moves across the equator and over a key zone over the South China Sea. Originating from the Indian Ocean and southern Pacific, the trade winds are the main carriers of water vapor for the province. As shown in the study, most of the Indian Ocean is covered with significant negative correlation and western Pacific with significant positive correlation. It is then deduced that low (high) precedent SST over the Indian Ocean with high (low) SST in the western Pacific will have lagging impacts on the circulation cells of low-latitude monsoons to strengthen (weaken) the monsoons in East (South) Asia, consequently affecting the requirements of water vapor transportation in the province’s rainy season.

There is significant negative correlation off the Peruvian coast in the eastern Pacific but significant negative correlation in the western Pacific (it is seen from Feb. to Apr. in the warm pool in the equatorial Pacific). With the El Niño (La Niña) episodes in effect, the SST is low (high) in the western part of the equatorial Pacific versus high (low) SST off the Peruvian coast to weaken (strengthen) the Walker (Hadley) cells. In their study on the impacts of ENSO on the precipitation in Yunnan, Ju et al. [11] report negative correlation between precipitation in early summer and precedent SST. Zhang et al. [12] suggest good corresponding links between precipitation in May – Jun. And the El Niño episode. With the presence of El Niño (La Niña) episodes, precipitation is usually less (more) during the two months in Yunnan. The El Niño episode is accompanied by normal or late onset of the rainy season while the La Niña episode appears with generally early onset. The rainy season starts late and brings less precipitation in May and Jun. when the El Niño is strong. In fact, the onset of El Niño (La Niña) episodes is just the time when tropical atmospheric circulation is affected to cause abnormalities in summer monsoon, and summer monsoons are systems at the planetary scale, whose continuity in both time and space inevitably affect the rainfall in Yunnan’s rainy seasons.

It is known from the analysis above that the transportation of water vapor is well correlated with precedent changes in SST inside the key zones, especially so during the El Niño or La Niña

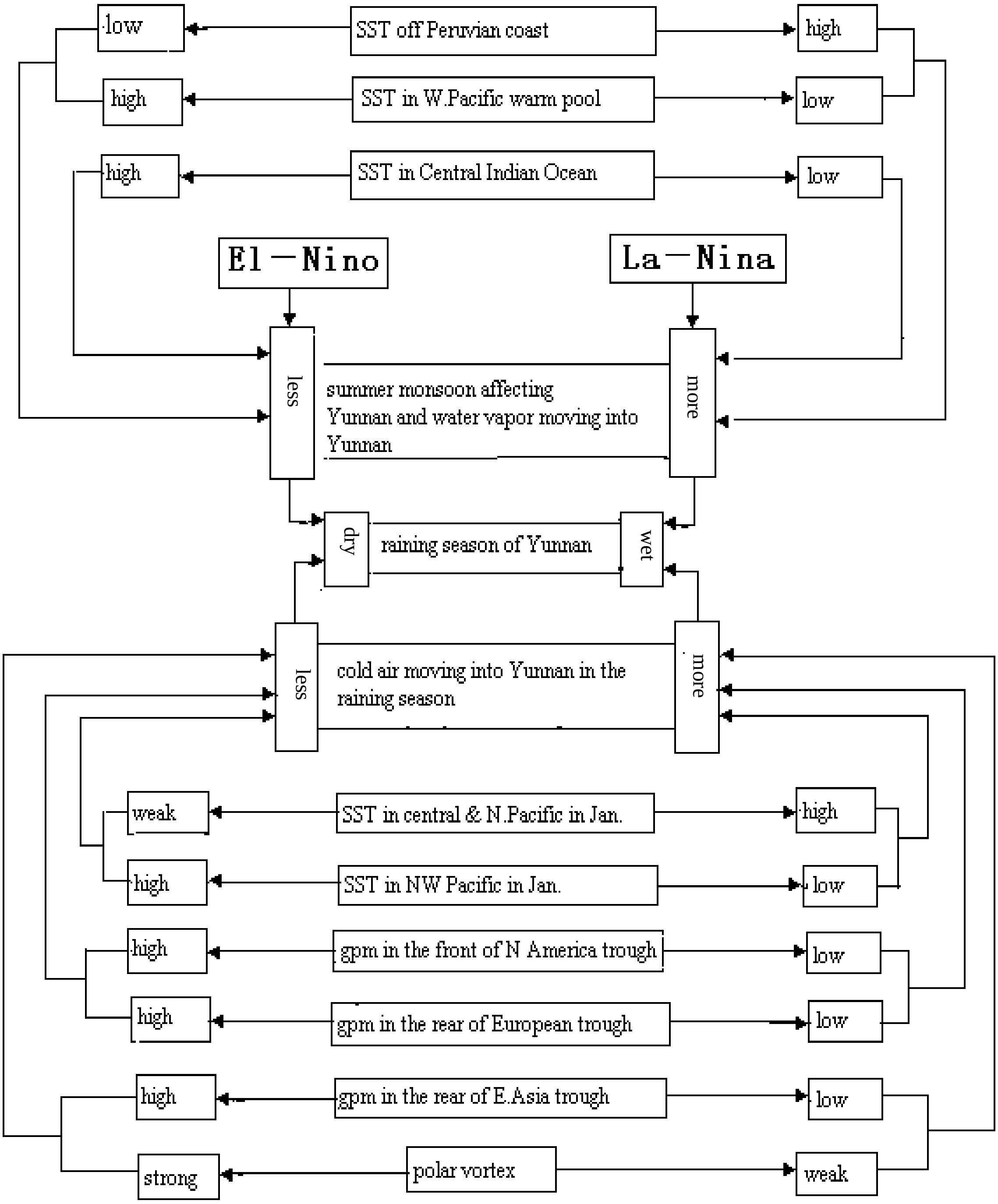

Fig.4 A concept model for precedent physics affecting the rainfall in Yunnan’s rainy seasons.

years. Low-latitude general circulation systems, closely correlating with SST impacts, show themselves as planetary-scale summer monsoons. The SST in the key zones over the central

Indian Ocean, western Pacific warm pool and waters off the Peruvian coast in the eastern Pacific, have important effect on the rainfall during the season.

3.3 *Models of physical concepts*

In summary, precedent geopotential height and SST fields correlate well with the rainfall in Yunnan's rainy seasons. Circulation systems in the westerlies in the Northern Hemisphere, which are described with geopotential height field, foretell how active cold air is while SST mainly affects the intensity of summer monsoons and the transportation of water vapor towards Yunnan. In their study on the weather / climatic causation for the May rainfall, Yan et al. [9] noted an intercorrelation between circulation systems and pointed out that their allocation and interaction determine the amount of precipitation. In the meantime, Huang et al. [13] pointed out that the rainfall in question is the result of combined action of atmospheric circulation systems and the combined action of anomalous circulation systems resulted from anomalous geopotential height and SST fields. The two fields for Mar. and the SST for Jan. are used as basic factors to determine a schematic chart of physical concept model for indicating the effect of precedent changes in circulation and SST on the precipitation in Yunnan's rainy season (Fig.4, see the previous page).

4 CONCLUDING REMARKS

a. Positive correlation for the 200, 500 and 850 hPa geopotential fields is mainly seen in the middle and higher latitudes. The fact that the structure of large-scale belt-shaped, wavetrains and positive and negative correlation centers shows high consistency on these levels indicates that large-scale circulation systems are mainly responsible for the rainfall in the season. The higher in the upper levels, the better the correlation. It indicates that these systems are mainly active at the middle and high levels.

b. During the variation of the correlation field from Jan. to May, circulation patterns of precedent areas of significant correlation such as the polar vortex, the front part of the stationary North America trough and the rear parts of the stationary European and East Asian troughs are anomalous and can be used to predict the wetness of the rainy season in Yunnan.

c. For the SST field, there is little change in the location of correlation from Jan. to May and areas of significant correlation generally coincide in the first five months of the year except the area of significant correlation in northern Pacific in Jan. Meridional "- + -" wave train structure is observed in the low-latitude parts of the central Indian Ocean, western and eastern Pacific Ocean.

d. The geopotential height and SST fields in precedent periods best correlate with the rainfall in the rainy season of Yunna in Mar. It is then seen that the general circulation systems and their variation as well as the variation of SST in the month best correlate with the rainfall in Yunnan's rainy season, being very useful in the prediction of rainfall in Yunnan's rainy season.

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