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# EFFECTS OF PACIFIC SSTA ON SUMMER PRECIPITATION OVER EASTERN CHINA, PART II: NUMERICAL SIMULATIONS

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**ABSTRACT:** Based on an observational analysis, seven numerical experiments are designed to study the impacts of Pacific SSTA on summer precipitation over eastern China and relevant physical mechanism by NCAR CCM3. The numerical simulation results show that preceding winter SSTA in the Kuroshio region leads to summer precipitation anomaly over the Yangtze River valleys by modifying atmospheric general circulation over eastern Asia and middle-high latitude. West Pacific subtropical high is notably affected by preceding spring SSTA over the middle and east of Equator Pacific; SSTA of the central region of middle latitude in the corresponding period causes the summer rainfall anomaly over eastern China so as to trigger the atmospheric Eurasia-Pacific teleconnection pattern.

**Key words:** Pacific; SSTA; eastern China; summer precipitation; numerical simulations

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## 1 INTRODUCTION

In the past dozen years and more, widespread persistence climate anomaly events, especially flood and drought, continually happened, which made many countries suffer from great economic loss, in such a way that the research of climate anomaly becomes a hotspot for scientific workers in the world. In the 1950s to 1960s, Namias[1-2] pointed out that SSTA was an important factor for weather and climate variance by analyzing observations. Later, scholars at home and abroad made a lot of diagnosis analyses and numerical simulations using different complicated models. Chen[3] studied the effects of key region SSTA in the Indian Ocean on summer monsoon and rainfall in China using GCM (general circulation model), showing that when SST was higher in west Indian Ocean and Arabian Sea, the Indian monsoon strengthened and Southwest monsoon weakened while Southeast monsoon strengthened in China, resulting in less (more) summer rainfall in Southwest China (East China, South China and the Yangtze River valleys). Tang et al.[4] discussed the response of July atmospheric circulation to the tropical SSTA in the Eastern Hemisphere using IAP AGCM of L9R15. Long and Li[5] discussed the atmospheric responses to positive SSTA with different durations in the eastern equatorial Pacific by using IAP-2-level AGCM and 9-level spectrum AGCM. Xu and Zhu[6] studied the effects of different stage of ENSO events under the cold and warm interdecadal background on the global precipitation, especially on Asia summer monsoon precipitation, based on the L9R15 climatic model. Yan and Xiao[7] examined the effects of the sea surface temperature anomaly in the Indian Ocean on the climate over Asian monsoon region based on IAP AGCM of L9R15. Palmer and Sun[8] discussed the effects of Newfoundland gulf SSTA on general atmospheric circulation from observation, theoretic analysis and numerical simulation, suggesting that there is positive (negative) height departure in the middle of Atlantic basin (Europe) when the middle latitude Atlantic SSTA is persistently of positive anomaly. The model results suggested that the response of middle latitude SSTA is weaker than the tropical SSTA. Palmer and Sun[8] interpreted the positive feedback process of middle latitude air-sea interaction from physical point of view. Picher et al.[9] analyzed the response of January

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atmosphere to Pacific SSTA using NCAR CCM model. The distribution of 500 hPa geopotential height anomaly in North Pacific and North America is similar to PNA teleconnection pattern. The model results show that the PNA pattern of summer geopotential height anomaly ascribes to the immediate forcing of central equatorial Pacific latent heat anomaly. Lau and Nath[10] carried out some sensitive experiments in tropical and middle latitude SSTA using GFDL-R15L9. In recent years, data analysis shows that there is a close relationship between SST of Pacific persistence anomaly region and summer rainfall in China (Huang and Li[11], Lin[12], Zhu and Xu[13], Yang and Sun[14], Yu et al.[15]), and the SSTA pattern can affect the summer rainfall by influencing summer tropical convective activity, East Asia monsoon and mid-high latitude general atmospheric circulation. In this paper, we will discuss the effects of Pacific key region SSTA on summer rainfall over eastern China and relevant physics processes by numerical simulations.

## 2 THE MODEL AND EXPERIMENTS DESIGN

### 2.1 *Introduction of the model*

In this paper, the NCAR CCM3 (Community Climate Model version3) is used, which is a global spectral atmospheric general circulation model with 42 wave numbers in horizontal triangular truncation (approximately 2.8125 latitude degree×2.8125 longitude degree transform grid with 128×64 gird points on the globe) and 18 vertical levels from the model top to bottom. A semi-implicit and leapfrog time integration scheme is used as the principal algorithmic approach with a 20 minutes integration step. CCM3 incorporates many parameterized physics schemes including cloud, radiation and traction of gravity etc. CCM3 (the fourth generation in the series of NCAR CCM), compared to the preceding versions, has two major changes for model formulation, i.e. 1) modification of the serious systematic errors lying apparently in CCM2 simulations; 2) the atmospheric model more suitable for the coupling with the land, ocean and sea-ice models. The document of CCM3 has been introduced in detail in many papers (Kiehl et al.,[16], Kiehl et al.,[17]). Many studies show that CCM3 has the strong ability of simulation (Hurrel et al,[18], Tsutsui and Kasahara[19], Boville and Hurrell[20], Diedhiou et al.,[21]).

### 2.2 *The design of control experiment and sensitive experiments*

In order to examine the effects of preceding winter SSTA in Kuroshio region of Northwest Pacific, preceding spring SSTA in the eastern and central equatorial Pacific and current summer SSTA of west wind drift region in the center of middle latitude of North Pacific on summer rainfall over eastern China and general atmospheric circulation over East Asia, one control experiment and three groups of sensitive experiments are designed as follow.

a. Control experiment (CTL)

First, the model is integrated for 10 years by the use of 12-month climate mean SST as the low boundary. Second, the model is continuously integrated for 10 months from 0000Z 1 November of the ninth model year. The model results of summer (mean of June, July and August) are analyzed.

b. Sensitive experiments (EXPA)

The sensitive experiments are the same as the control experiment, but for SSTA of the key regions (Fig.1) participated in the model integration in different adding periods (Tab.1)

## 3 SIMULATION RESULTS

### 3.1 *Result of control experiment*

Results of averaged June – August in the control experiment stand for summer climate mean state. From the stream field at 850 hPa (Fig.2), CCM3 has simulated the significant systems affecting summer rainfall over East Asia, such as West Pacific subtropical high, South China Sea monsoon, Indian monsoon, Somalia Jet, Mascarene high and Australia high etc., showing that the CCM3 has a strong simulation ability to meet the need in this work.

### 3.2 *Comparison of the control experiment and the sensitive experiments of preceding winter SSTA in Kuroshio region of Northwest Pacific*

Fig.3 is the difference field of summer rainfall for EXPA minus CTL. Fig.3a shows that summer rainfall is more over the Yangtze River valleys and areas to its south with a positive center lying in the middle reaches of the Yangtze River, and rainfall is less over North China and southwest of Northeast China with a negative center standing in North China when the preceding winter SSTA in Kuroshio region of Northwest Pacific is of positive anomaly. Fig.3b shows that summer rainfall is less (more) than normal over Changjiang-Huaihe valleys (North China, western of Northeast China and Inner Mongolia) when the preceding winter SSTA in the Kuroshio region is of negative anomaly. The above results is in good accordance with the observations in Part I, suggesting again that the CCM3 has strong simulation ability.

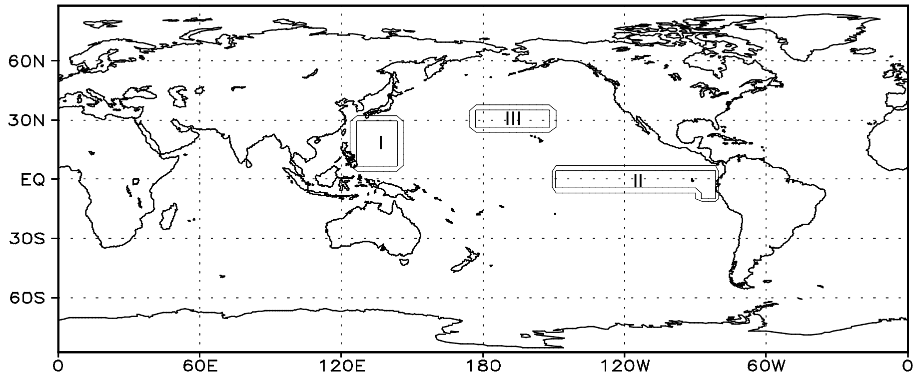


Fig.1 Sketch map of SSTA forcing areas in sensitive experiments.

Tab.1 SST anomaly areas, strength and adding periods in sensitive experiments

| Number | Anomaly regions | Anomaly strength | Adding periods |
|---|---|---|---|
| I | 120-150°E, 0-35°N；126-144°E, 6°S-30°N | ＋0.5℃；＋1.5℃ | Dec-Feb |
| | 120-150°E, 0-35°N；126-144°E, 6°S-30°N | －0.5℃；－1.5℃ | Dec-Feb |
| II | 210-280°E, 10°S-10°N；270-279°E, 10°S-5°N；210-269°E, 5°S-5°N | ＋1℃；＋2℃；＋2℃ | Mar-May |
| | 210-280°E, 10°S-10°N；270-279°E, 10°S-5°N；210-269°E, 5°S-5°N | －1℃；－2℃；－2℃ | Mar-May |
| III | 174-210°E, 24-36°N；176-218°E, 26-34°N | ＋0.5℃；＋1.5℃ | Jun-Aug |
| | 174-210°E, 24-36°N；176-218°E, 26-34°N | －0.5℃；－1.5℃ | Jun-Aug |

Fig.4 is the 850 hPa wind difference field (EXPA minus CTL). Fig.4a shows that there is an anticyclone anomaly over Northwest Pacific, leading to the northward movement of southeast warm and humid airflow; there is a cyclone anomaly over east of Lake Baikal, beneficial to the southward steering of Siberian cold air; meanwhile Northwest wind anomaly in the westerlies is useful to guiding Balkhash cold air southward, in such a way that warm and cold air converge in the Yangtze River valleys, resulting in more rainfall over the Yangtze River valleys. Fig.4b shows that there is a cyclonic anomaly over the north of Balkhash, changing the southward-going cold air to westward or northwestward airflows, and there is a strong anticyclonic anomaly over Northeast China, Korea Peninsula and Japan Sea with the result of east wind anomaly being over south of the Yangtze River, so that warm and cold air converge over the north of North China, western of Northeast China and Inner Mongolia with the consequence of more (less) summer rainfall over these regions (Changjiang-Huaihe valleys because of useless water vapor condition).

Fig.5 is the geopotential height difference field at 500 hPa (EXPA minus CTL). Fig.5a shows that when the preceding winter SSTA in Kuroshio region is positive, the response of the two ridges and two troughs pattern at 500 hPa geopotential height field takes place with the ridges in the vicinity of Ural Mountain and Okhotsk Sea, with the result of the appearance and maintenance of Ural and Okhotsk blocking high, showing a "＋－＋" wavetrain in The Asia-Pacific region. This geopotential height anomaly pattern can cause more summer rainfall in the reaches of Yangtze according to the observed result in Part I. Different response to negative SSTA in Fig.5b shows that there is a negative height departure zone from Balkhash to Baikal as far east as Okhotsk, taking on a "－＋－" wavetrain from mid-high latitudes of Asia to the east part of East Asia. From Part I, it indicates that the pattern in Fig.5b will cause less (more) summer rainfall in the reaches of Yangtze (northern of North China, southwestern of Northeast China and Inner Mongolia).

### 3.3 *Comparison of the control experiment and the sensitive experiments of preceding spring SSTA in middle and eastern equatorial Pacific*

It is shown (figure omitted) from the summer rainfall difference field (EXPA minus CTL) that summer rainfall is less (more) over North China and Northeast China with the negative center lying in the north of North China (over the Yangtze River valleys and South China with the positive center lying in the middle reaches of Yangtze River) when the preceding spring SSTA of eastern and central equatorial Pacific

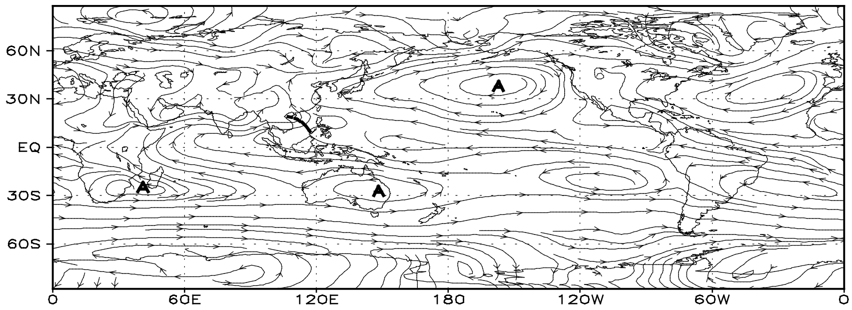


Fig.2 Stream field at 850 hPa in the control experiment.

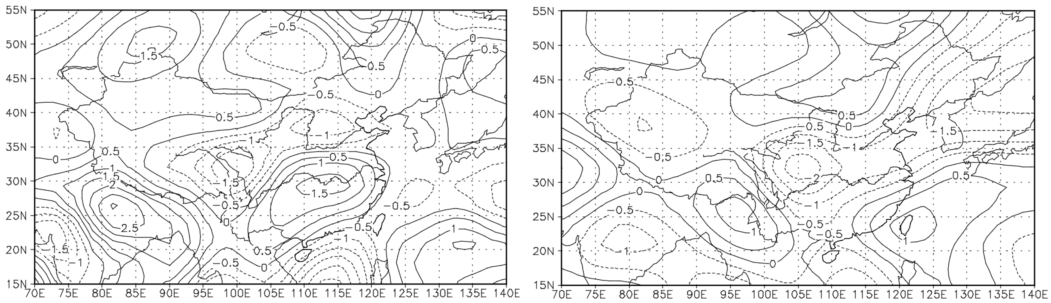


Fig.3 Summer rainfall difference fields of experiment of the preceding winter positive (a). or negative (b) SSTA in Kuroshio region minus CTL (units: mm/d).

is positive. It is also shown that the summer rainfall is less (more) in the Yangtze River valleys (North China, Northeast China and Inner Mongolia) when the preceding spring SSTA of eastern and central equatorial Pacific is negative. These results are identical with observational analysis in Part I.

It is shown (figure omitted) from the 850 hPa wind difference field (EXPA minus CTL) that there is a cyclonic anomaly over the Korea Peninsula and Sea of Japan, which helps steering cold air over Siberia southward, and there is a strong anticyclonic anomaly over the ocean south of Japan, which leads warm and humid east airflow over West Pacific northward, with the consequence that the subtropical convergence zone (i.e. Meiyu front) is stronger with more rainfall in the Yangtze River valleys. On the other hand, more rainfall occurs in South China because of the north wind anomaly over eastern Qinghai-Tibet Plateau and southwest wind anomaly from the south to South China. It is also shown that there is a cyclonic anomaly over the south of Balkhash, which leads cold air southward, and there an anticyclonic anomaly over the coastal area of eastern China with a deepened South China Sea monsoon trough, which directs east airflow from SCS and West Pacific northward to North China and Northeast China, with the consequence that warm and cold air converge in North China and Northeast China with more summer rainfall in these regions.

It is shown (figure omitted) from the 500hPa geopotential height difference field (EXPA minus CTL) that when the preceding spring SSTA is positive in the middle and eastern equatorial Pacific, the response of the negative departure at 500 hPa geopotential height field takes place over the mid-high latitude areas of Eurasia and in most parts of China and West Pacific. The northern border and axis of ridge of West Pacific subtropical high are southward and the westernmost point of the ridge is eastward of its normal position. This geopotential height anomaly pattern can cause more summer rainfall in the reaches of the Yangtze River and south of it according to the observed result in Part I. Different response of negative SSTA (figure omitted) shows that positive height anomalies distribute from the east of Baikal to Okhotsk Sea and over coastal areas of eastern China, indicating that the north border and axis of ridge of West Pacific subtropical high are northward and the westernmost point of the ridge westward is at its normal position with the result of more summer rainfall over North China and southwestern of Northeast China. These results are identical with the observational analysis in Part I.

### 3.4 *Comparison of the control experiment and the sensitive experiments of current summer SSTA in the center region of middle latitude*

It is shown (figure omitted) from the summer rainfall difference field (EXPA minus CTL) that

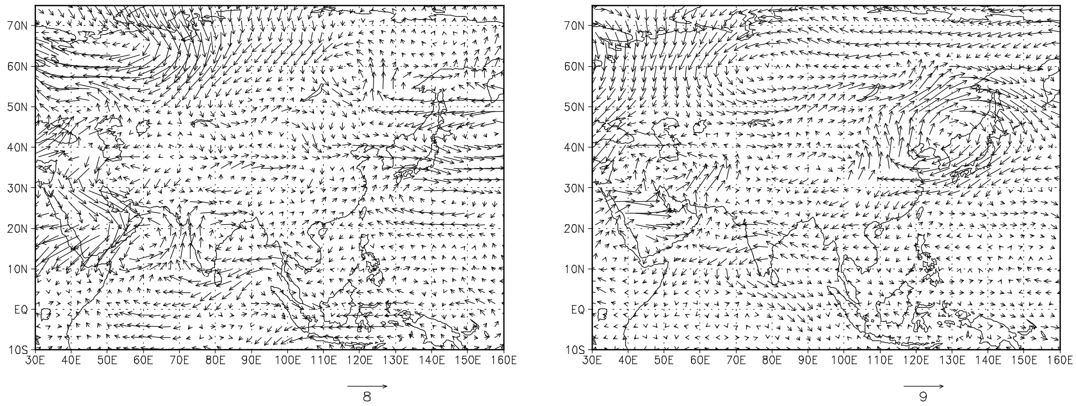


Fig.4 850 hPa summer wind difference field experiment of the preceding winter positive (a) or negative (b) SSTA in Kuroshio region minus CTL (units: m/s).

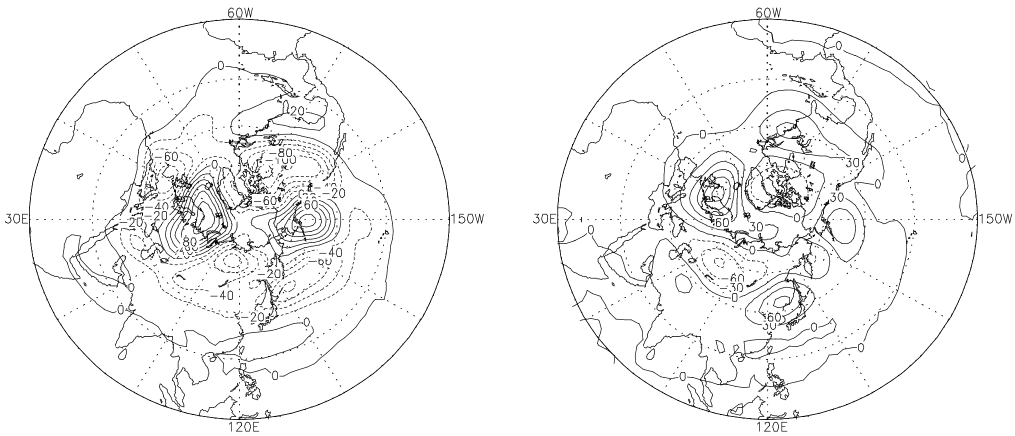


Fig.5 500 hPa summer geopotential height difference field of experiment of the preceding winter positive (a) or negative (b) SSTA in Kuroshio region minus CTL (units: dagpm).

summer rainfall is more (less) over north of North China and west of Northeast China with the maximum in north of Hetao (over Changjiang-Huaihe valleys, Southwest China and South China with the minimum in the middle reach of the Yangtze River) when the current summer SSTA is positive in the west wind drift region. It is also shown that summer rainfall is more (less) over the Yangtze River valleys, South China and Southwest China (over Hetao) when current summer SSTA is negative in the region. These results are identical with the observational analysis in Part I.

It is shown from the wind difference field at 850 hPa (EXPA minus CTL) that there is a strong anticyclonic anomaly over Northeast China, Korea Peninsula and Japan Sea, which helps to lead east warm and humid airflow over East China Sea and Yellow Sea to the north of North China and west of Northeast China, and there is a cyclonic anomaly over Baikal, which leads the cold air over Siberia southward to the north of North China and west of Northeast China, with the consequence that warm and cold air converge over North China, western of Northeast China and Inner Mongolia with more rainfall over these regions. The weaker Indian southwest Monsoon and South China Sea monsoon cause less summer rainfall over Changjiang-Huaihe valleys, Southwest China and South China. It is also shown that there is a strong cyclonic anomaly over Northeast China, Korea Peninsula and Sea of Japan, which helps to lead cold air southward to the Yangtze River valleys and South China, and there is an anticyclonic anomaly over the ocean south of Japan, which leads warm and humid airflow of Northwest Pacific to the Yangtze River valleys and South China, with the consequence that warm and cold air converge in the Yangtze River valleys, Southwest China and South China with more summer rainfall in these regions.

It is shown (figure omitted) from the geopotential height difference field at 500hPa (EXPA minus CTL) that when the current summer SSTA is positive in west wind drift region of North Pacific, the response of the geopotential height anomaly field takes on a "＋－＋" EUP teleconnection pattern in the high-mid latitude of Eurasia. Different response of the summer negative SSTA (figure omitted) shows that negative (positive) height departures distribute in Baikal (Balkhash and

Okhotsk). According to Part I, it is known that positive geopotential height anomaly around Okhotsk gives rise to the building and maintenance of Okhotsk blocking high with the result of more summer rainfall in the reaches of Yangtze River and South China.

## 4 CONCLUDING REMARKS

(1) When the preceding winter SSTA in Kuroshio region of West Pacific is positive, the response of the two ridges and two troughs pattern at 500 hPa geopotential height field takes place with the ridge area in the vicinity of Ural Mountain and Okhotsk, with the result of the appearance and maintenance of Ural and Okhotsk blocking high, showing a "＋－＋" wavetrain in the Asia-Pacific region. The ascending movement is strengthened (weakened) in summer over the reaches of the Yangtze River (North China and southwestern of Northeast China) with more (less) summer rainfall in the reaches of Yangtze River (North China and southwestern of Northeast China), and vice versa.

(2) When the preceding spring SSTA is positive in the central and eastern equatorial Pacific, the north border and axis of ridge of West Pacific subtropical high are southward and westernmost point of the ridge eastward of its normal position, and the ascending motion is strengthened (weakened) over the reaches of Yangtze River and South China (North China and Northeast China), resulting in more (less) summer rainfall in the reaches of Yangtze River and South China (North China and Northeast China), and vice versa.

(3) When the current summer SSTA is positive in the west wind drift region of North Pacific, the response of the geopotential height anomaly field takes on a "＋－＋" EUP teleconnection pattern in the high-mid latitude of Eurasia with more (less) summer rainfall in northern of North China and western of Northeast China (the Yangtze-Huaihe reaches, Southwest and South China). When the current summer SSTA is negative, the negative (positive) height departures distribute in Baikal (Balkhash and Okhotsk), which gives rise to the building and maintenance of Okhotsk blocking high with the result of more (less) summer rainfall in the reaches of Yangtze River, Southwest and South China (northern of North China, western of Northeast China and Inner Mongolia).

The influencing mechanism of North Pacific SSTA on summer rainfall over eastern China is very complicated. In this paper, the allocating effects of SSTA in the several key regions of North Pacific on summer rainfall are not discussed. Chen and Wu[22] suggested that the different kinds of joint effects in SST anomaly structures in the northwest and tropical regions of the Pacific are the important factors resulting in various summer rainbelt patterns in eastern China, so it is necessary to design some experiments using SSTA in these key regions during different phases to discuss the role of SSTA nonlinear in general atmospheric circulation. Besides, the feedback role of general atmospheric circulation is not considered because the CCM3 model only supplies one-way oceanic information to general atmospheric circulation. In the future, the interaction relationship between North Pacific SSTA and East Asia general atmospheric circulation should be further studied by CGCM (Coupling General Circulation Model).

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