EXTRA-SEASONAL PREDICTIONS OF SUMMER RAINFALL IN CHINA AND ENSO IN 2001 BY CLIMATE MODELS*

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ABSTRACT

China is a monsoon country. The most rainfalls in China concentrate on the summer seasons. More frequent floods or droughts occur in some parts of China. Therefore, the prediction of summer rainfall in China is a significant issue. As we know, the obvious impacts of the sea surface temperature anomalies (SSTA) on the summer rainfall over China have been noticed. The predictions of the SSTA have been involved in the research.

The key project on short-term climate modeling prediction system has been finished in 2000. The system included an atmospheric general circulation model named AGCM95, a coupled atmospheric-oceanic general circulation model named AOGCM95, a regional climate model over China named RegCM95, a high-resolution Indian-Pacific OGCM named IPOGCM95, and a simplified atmosphere-ocean dynamic model system named SAOMS95. They became the operational prediction models of National Climate Center (NCC).

Extra-seasonal predictions in 2001 have been conducted by several climate models, which were the AGCM95, AOGCM95, RegCM95, IPOGCM95, AIPOGCM95, OSU/NCC, SAOMS95, IAP APOGCM and CAMS/ZS. All of those models predicted the summer precipitation over China and/or the annual SSTA over the tropical Pacific Ocean in the Modeling Prediction Workshop held in March 2001.

The assessments have shown that the most models predicted the distributions of main rain belt over Huanan and parts of Jiangnan and droughts over Huabei-Hetao and Huaihe River Valley reasonably. The most models predicted successfully that a weaker cold phase of the SSTA over the central and eastern tropical Pacific Ocean would continue in 2001.

The evaluations of extra-seasonal predictions have also indicated that the models had a certain capability of predicting the SSTA over the tropical Pacific Ocean and the summer rainfall over China. The assessment also showed that multi-model ensemble (super ensembles) predictions provided the better forecasts for both SSTA and summer rainfall in 2001, compared with the single model.

It is a preliminary assessment for the extra-seasonal predictions by the climate models. The further investigations will be carried out. The model system should be developed and improved.

Key words: extra-seasonal prediction, climate model, assessment, precipitation, super ensembles

I. INTRODUCTION

The prediction of summer rainfall in China is a significant issue. Because China is a

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monsoon country, most rainfalls concentrated on summertime. It is easy to cause floods or droughts in some parts of China. Therefore, several climate models carried on the predictions of summer rainfall in China. These models have done some extra-seasonal predictions and got some good results (Zhao et al. 2000; Yuan 2001; Zhu and Mu 2001). There were obvious impacts of sea surface temperature anomalies (SSTA) over the tropical Pacific Ocean on summer rainfall in China (Li 2001; Zhao et al. 2001). It is important to predict the SSTA over the tropical Pacific Ocean. Several dynamic models or model system have tried to predict the NINO indexes and got reasonable forecasts (Li et al. 2000; Zhao et al. 2001).

The key project on short-term climate modeling prediction system has been finished in 2000. The system included an atmospheric general circulation model named AGCM95 (Dong et al. 2001), a coupled atmospheric-oceanic general circulation model named AOGCM95 (Zhang et al. 2001; Dong et al. 2001), a regional climate model over China named RegCM95 (Ding et al. 2001), a high-resolution Indian-Pacific OGCM named IPOGCM95 (Zhao 2001a, b), and a simplified atmosphere-ocean dynamic model system named SAOMS95 (Zhao et al. 2001). They became the operational prediction models of National Climate Center (NCC) (Ding et al. 1999; Luo 2001; Ding et al. 2001).

The Modeling Prediction Workshop was held in the end of March 2001. Those climate models predicted the summer precipitation over China and/or the annual sea-surface temperature anomalies (SSTA) over the tropical Pacific Ocean (Gao 2001; Song 2001; Shi and Liu 2001; Li and Zhao 2001). Other NCC climate models such as the OSU/NCC model (Xu et al. 2001a, b) which was an old operational model of NCC and the AIPOGCM95 model which was the AGCM95 coupled with the IPOGCM95 (Zhao Qigeng 2001a) also predicted the precipitation over China in this Workshop. In the 2001 Workshop, several climate models from Institute of Atmospheric Physics (IAP) named IAP APOGCM (Zhou 2001; Lin 2001) and Chinese Academy of Meteorological Sciences named CAMS/ZS (Zheng and Song 2001) also presented their predictions.

In this paper, the second section introduces those climate models briefly, the third section indicates the evaluations of extra-seasonal predictions for the recent years, the fourth and fifth sections present the extra-seasonal predictions of the summer precipitation over China and the annual SSTA over the tropical Pacific Ocean for 2001. The sixth section indicates the assessments of those 2001 predictions by the climate models. In the last section of this paper, conclusions and discussions are given.

II. BRIEF INTRODUCTION TO CLIMATE MODELS

The characteristics of climate models which did annual prediction of SSTA over the tropical Pacific Ocean in 2001 were indicated in Table 1. The AOGCM95 is a full global atmospheric and a full global oceanic circulation coupled model, in which the AGCM95 is based on the ECMWF model and the OGCM95 is based on the IAP model (Song 2001). The IAP APOGCM is a global atmospheric model coupled with a Pacific Ocean circulation model (Zhou 2001). The IPOGCM95 based on both the HADLY and GFDL models is a high-resolution Indian-Pacific Ocean circulation model driven by a statistic atmosphere (Zhao 2001). A model system SAOMS95 based on the ZC87 and OXFORD models is a

simplified dynamic model system which included five models (Li and Zhao 2001 a, b). Those models did three or six ensemble predictions. The forecasts started from April for both AOGCM95 and IAP APOGCM, February for both SAOMS95 and IPOGCM95.

Table 1. Characteristics of Climate Models which did Annual Predictions of SSTA in 2001

Authors	Models' name	AGCM	OGCM	Ensembles
Li & Zhao (2001)	SAOMS95	simplified dynamic	models	6×5
Song (2001)	AOGCM95	L16, T63	L30, T63	3
Zhao (2001)	IPOGCM95	statistical atmosphere	L30 1×1	3
Zhou (2001)	IAP APOGCM	L2, 4×5	P: L14, 1×2	3

Table 2 shows the characteristics of climate models that did the extra-seasonal predictions of precipitation over China. The AGCM95 based on the ECMWF model is a global atmospheric circulation model (Gao 2001). RegCM95 based on the RegCM2/NCAR is a regional climate model over China that nested into the AGCM95 (Shi and Liu 2001). The CCM3/RegCM2 is a regional climate model nested into an AGCM (NCAR CCM3) (Zheng and Song 2001). These models used the climate SSTA as their surface conditions during the forecasting. The AIPOGCM is an AGCM95 coupled to the IPOGCM (Zhao 2001). The OSU/NCC is an AGCM coupled to the global mixed-layer ocean with ice model (Xu et al. 2001a, b). Those models and the IAP APOGCM, as well as AOGCM95 predicted the SSTA. Most of the models in Table 2 did the ensemble predictions by three, six or 28 except for RegCM95 and CCM3/RegCM2. All models predicted the summer precipitation (June, July and August) over China started from February or March. The anomalies of precipitation in China were predicted except for the RegCM95 and AIPOGCM in which there were not model control runs.

Table 2. Characteristics of Climate Models that did Extra-Seasonal Prediction of Precipitation in China in 2001

Authors	Models' name	AGCM	OGCM	Ensembles
Gao (2001)	AGCM95	L16, T63	No	6
Lin (2001)	IAP APOGCM	L2, 4×5	P: L14, 4×5	28
Shi & Liu (2001)	RegCM95	L16, 60 km	No	1
Song (2001)	AOGCM95	L16, T63	L30, T63	3
Xu et al. (2001a, b)	OSU/NCC	L2, 4×5	60 m	6
Zhao (2001b)	AIPOGCM95	L16, T63	L30, 1×2	3
Zheng & Song (2001)	CCM3/RegCM2	L9, R15	L15, 160 km	1

III. EVALUATIONS OF MODELS' PREDICTIONS FOR THE RECENT YEARS

Before the predictions for 2001 are shown, the evaluations for the extra-seasonal predictions are given in this section. Several climate models (IAP APOGCM, OSU/NCC, AGCM95) have performed the predictions of summer rainfall in China for the recent years. Division of Climate Prediction of National Climate Center calculated the forecast

skills for each year (CFR. 1996—2001). Table 3 those the forecast skills for both IAP APOGCM and OSU/NCC models to compare with the Workshop of Predictions (WP) and the averaged predictions by all methods (MM) (more than 20 methods or units for each year). It is found in Table 3 that the averaged prediction skills of both IAP APOGCM and OSU/NCC are little bit higher than those of WP and MM. It means that the climate models have certain capacities in predicting the summer rainfall over China compared with WP and MM. It also indicated that it is difficult to do the extra-seasonal predictions for getting a high skill.

Table 3. Prediction Skills for Summer Rainfalls in China by the Climate Models (from CFR. 1996—2001)

Name	1995	1996	1997	1998	1999	2000	Average
IAP APOGCM	77	65	59	66	66	65	66
OSU/NCC	76	75	59	74	57	58	67
WP	84	63	58	69	44	76	66
MM	75	65	64	69	54	69	66

The evaluations of predictions for Nino3 index in the recent years have also been calculated by using the anomalous correlation coefficients (ACC) in Table 4. As comparisons. the similar models of Australia. UK and USA are listed in the left part of Table 4. SAOMS's five models (NCCo. NCCn. NCC/STI. NCC/NIM and CAMS/NJU) are listed in the right part of Table 4. It noticed from Table 4 that those models of the SAOMS system predicted Nino3 index reasonably. The ACC of those models are higher than the persistency of predictions except for NCC/NIM. It means that the SAOMS system is able to predict the trends of El Nino/La Nina events.

Table 4. ACC of Nino3 Prediction from June 1996 to March 1998 (led by 3 and 6 months) (from Li et al. 2000; Zhao et al. 2001)

Name	ACC	Names	ACC
LDEO1	−0.38	NCCo	0.88
LDEO2	−0.48	NCCn	0.89
BMRC	0.70	NCC/STI	0.85
OXF1	0.26	NCC/NIM	0.30
OXF2	0.50	CAMS/NJU	0.99
		Persistency	0.70

In recent years. the multi-model ensembles (super ensembles) have been paid more attention due to an unstable level of predictions by a single model (IPCC. WG1 2001). The evaluations of predictions of Nino3 index by a simplified dynamic model system also indicated that the five-model ensembles looked to be better than a single model (Li et al. 2001). The multi-model ensembles can be selected by several methods. such as arithmetic mean. weight mean. analyses of categories. The principles and purposes of the multi-model ensembles are to raise the level of predictions. In this research. because the evaluations of the extra-seasonal predictions for each model are not conducted yet. we use

the arithmetic mean as the first step.

IV. PREDICTIONS OF ANNUAL SSTA OVER THE TROPICAL PACIFIC OCEAN IN 2001

The climate models predicted the monthly SSTA over the tropical Pacific Ocean from February (or March) to December of 2001 (not shown). As examples, the predictions of Nino3 index are given in Figs. 1—4.

In light of above stated predictions, the AOGCM95, IPOGCM95 and four models of SAOMS95 predicted a weaker cold phase to be continued till December of 2001, but the IAP APOGCM and one model (NCC/STI) of SAOMS95 predicted that a new El Nino event might occur in May or October of 2001, respectively.

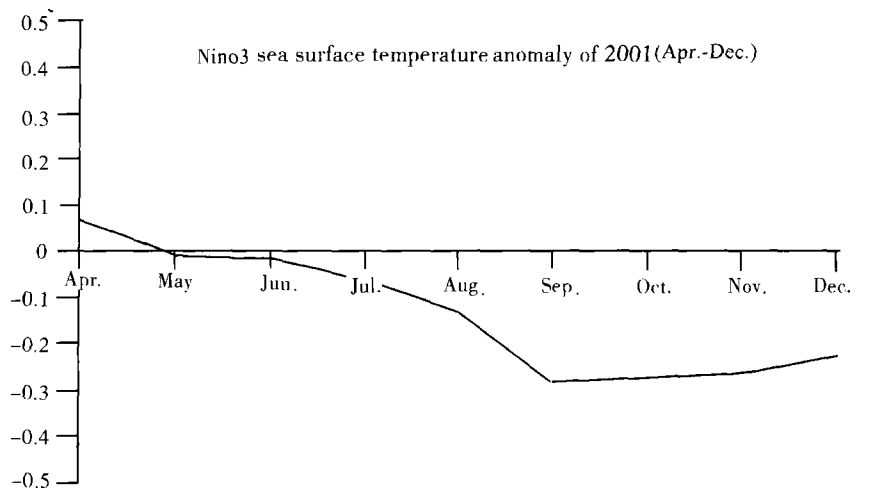

Fig. 1. Prediction of Nino3 index for 2001 by AOGCM95 (after Song 2001).

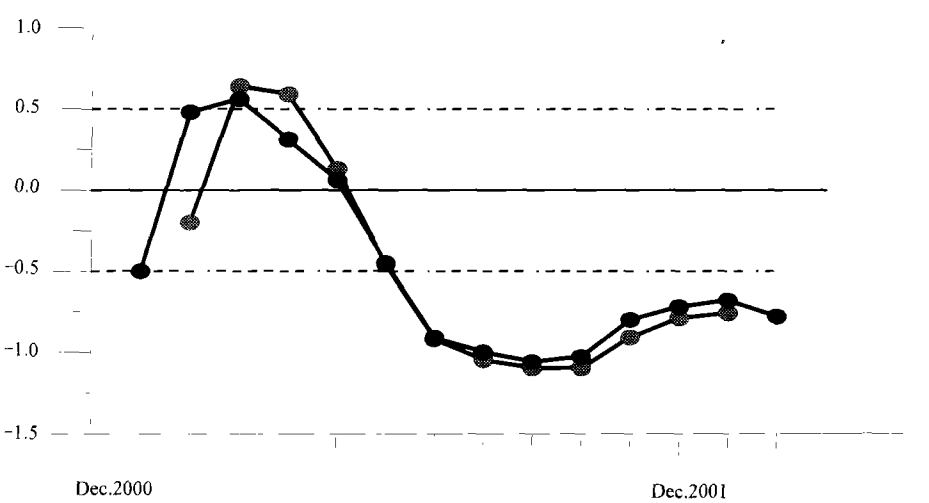

Fig. 2. Prediction of Nino3 index for 2001 by IPOGCM95 starting from January 2001 (black curve) and February 2001 (grey curve) (after Zhao 2001a).

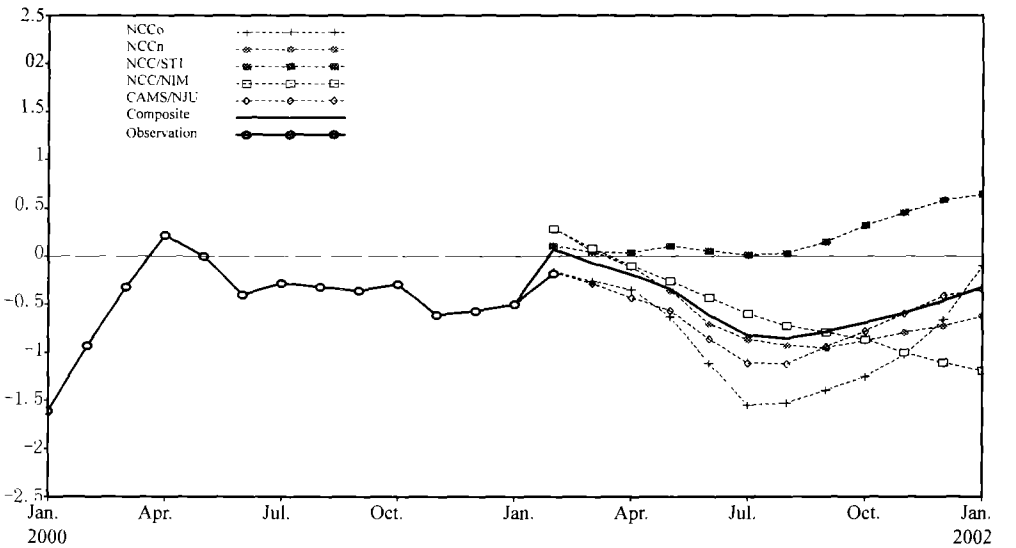

Fig. 3. Prediction of Nino3 index for 2001 by SAOMS95 (after Li and Zhao 2001).

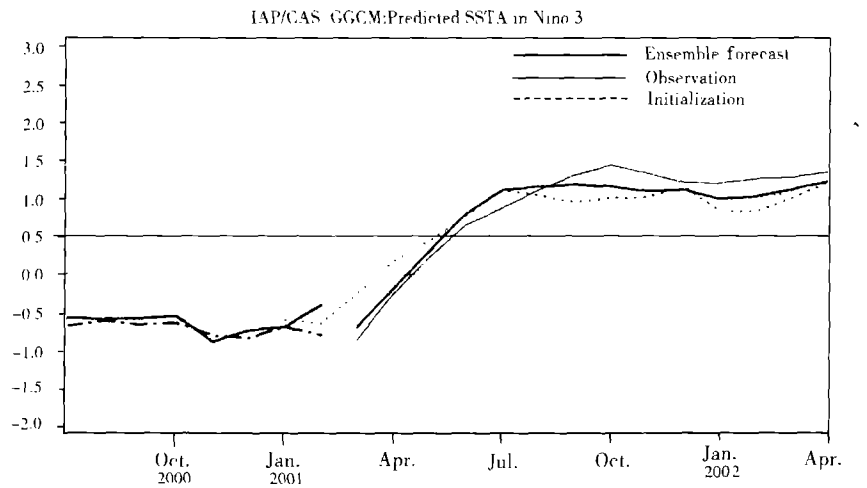

Fig. 4. Prediction of Nino3 index for 2001 by IAP APOGCM (after Zhou 2001).

V. PREDICTIONS OF SUMMER PRECIPITATION OVER CHINA IN 2001

The summer rainfalls over China in 2001 have been predicted in March or February by using six GCMs and one regional climate model. The climate models predicted the global sea-level pressure, potential height at 500 hPa, rainfall and temperature. Because summer floods and droughts in China are the significant issues, we concentrate on the predictions of summer rainfall over China. Figures 5 — 11 show the predictions of rainfall by the AOGCM95, AGCM95, CAMS/ZS, IAP, OSU/NCC, RegCM95, and AIPOGCM95, respectively.

The AOGCM95 predicted that it would be wetter than normal over South of the

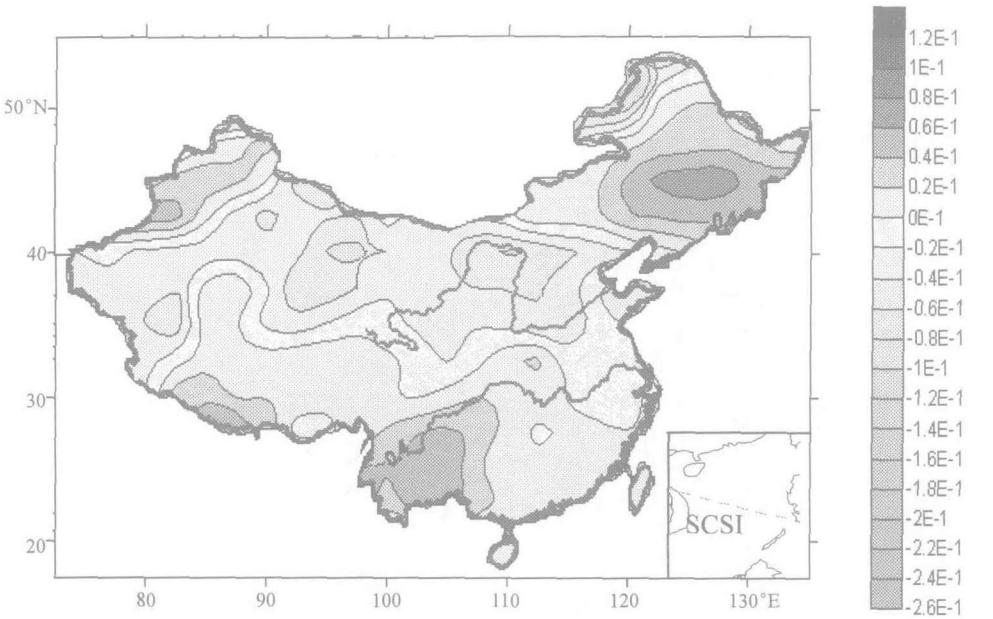

Fig. 5. Prediction of anomalous rainfall over China for summer 2001 by AOGCM95 (Song 2001).

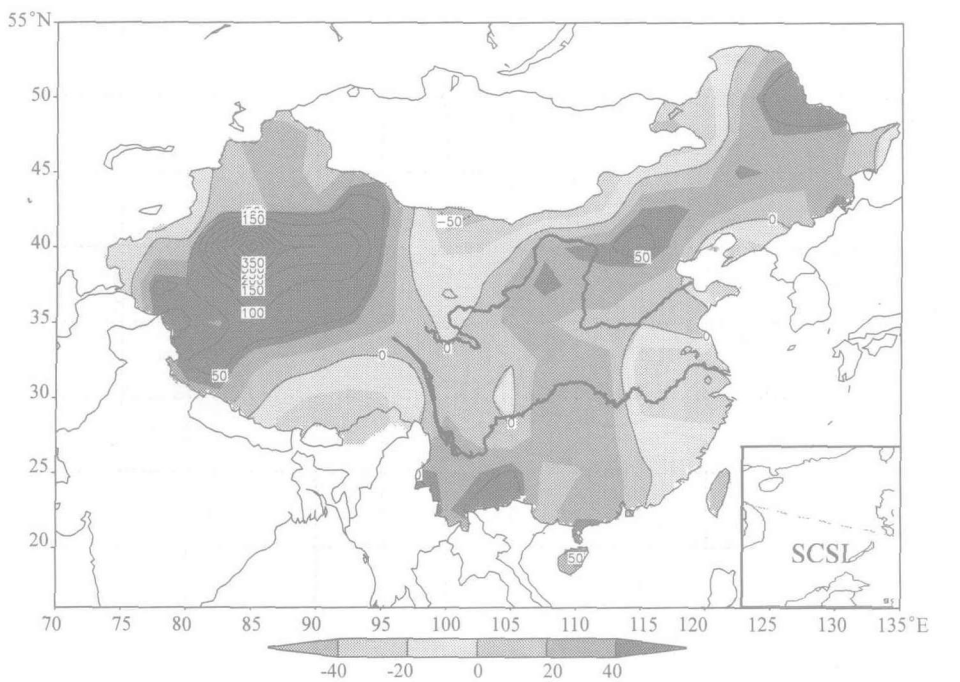

Fig. 6. Prediction of percentage of anomalous rainfall over China for summer 2001 by AGCM95 (Gao 2001).

Yangtze River (Jiangnan)-Southwest China and Northeast China, and drier than normal over the middle and lower reaches of the Yangtze River, North China (Huabei)-Northwest

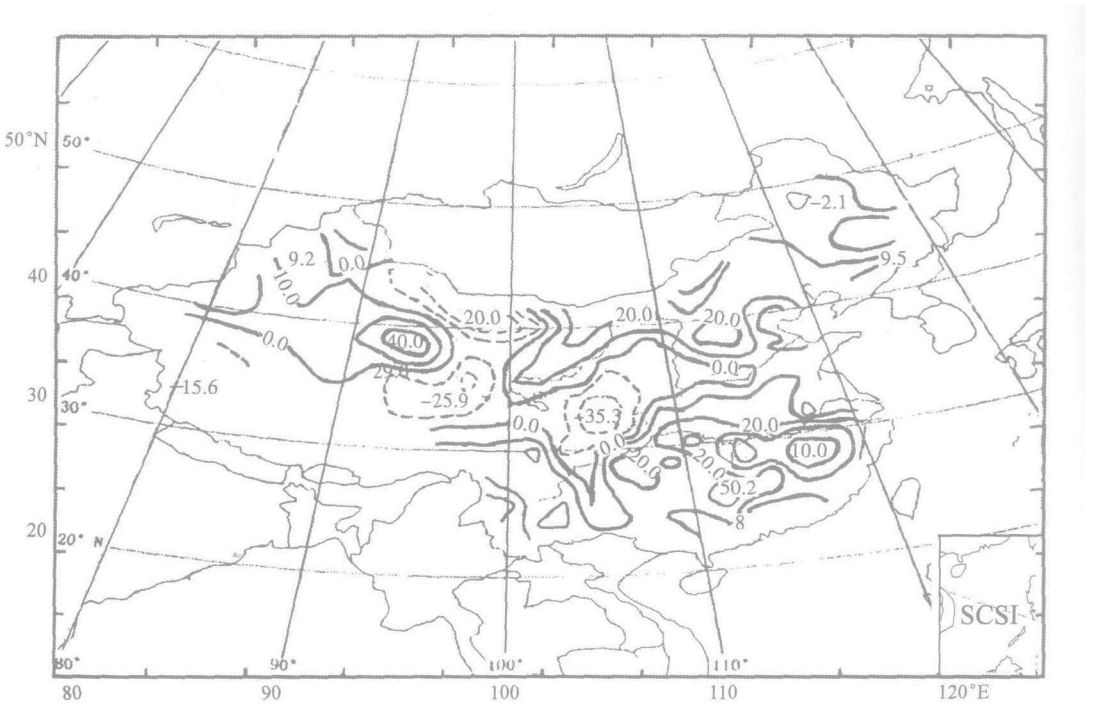

Fig. 7. Prediction of percentage of anomalous rainfall over China for summer 2001 by CCM3/RegCM2 (Zheng and Song 2001a, b).

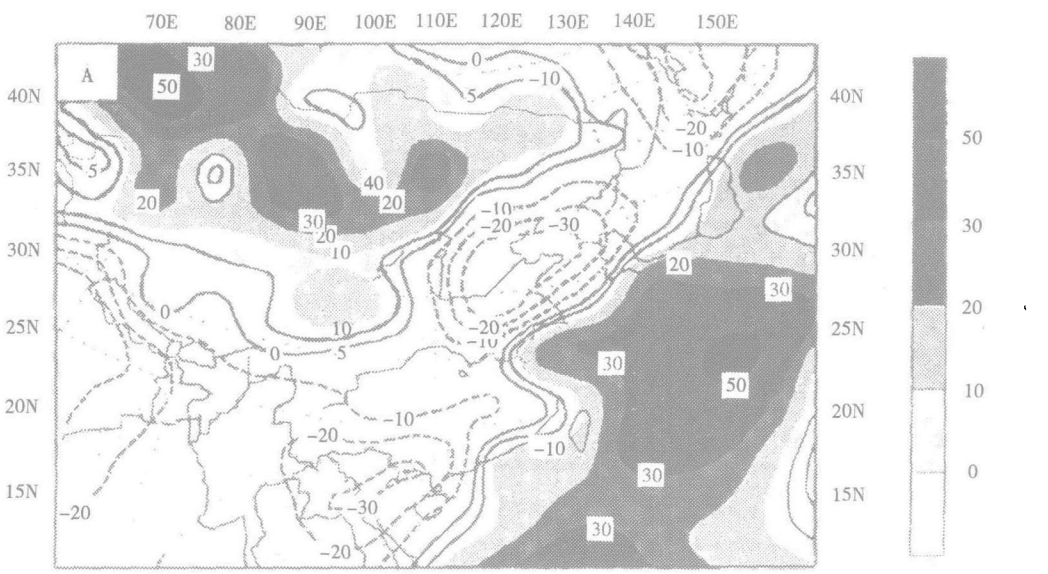

Fig. 8. Prediction of percentage of anomalous rainfall over China for summer 2001 by IAP APOGCM (Lin 2001.)

China. The AGCM95 predicted the wet regions over Northeast China, North China (Huabei), the bend of Yellow River (Hetao), Southwest China, and Xinjiang, while dry regions over Jiang-Huai-Jiangnan (Yangtze-Huaihe Rivers and South of the Yangtze

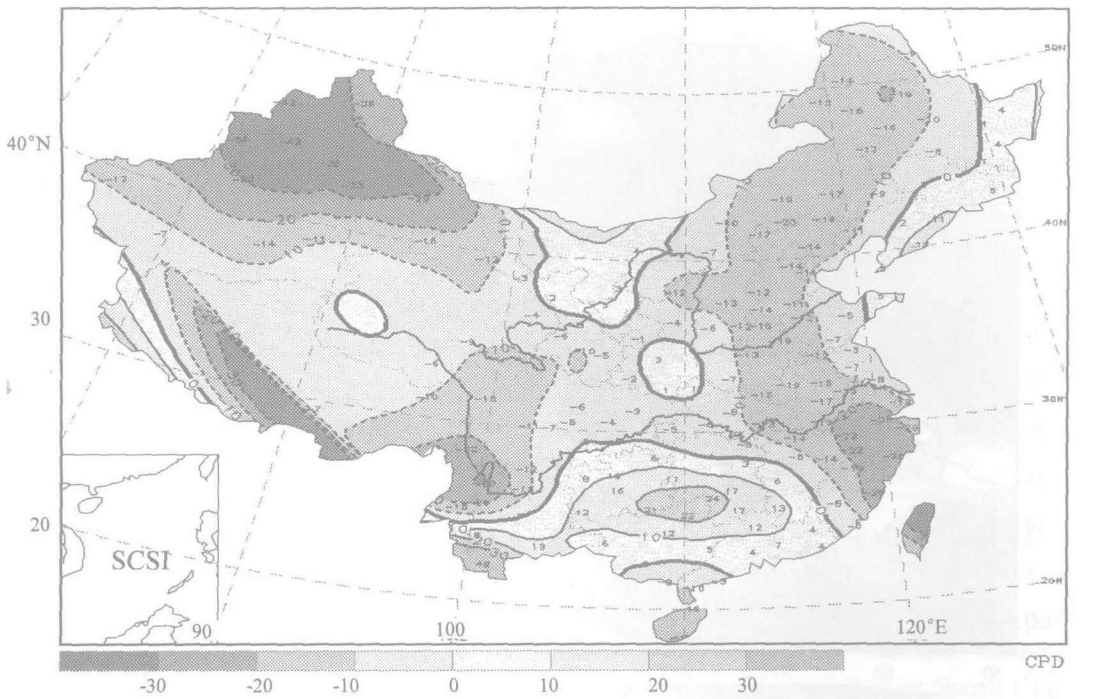

Fig. 9. Prediction of percentage of anomalous rainfall over China for summer 2001 by OSU/NCC (Xu et al. 2001a, b).

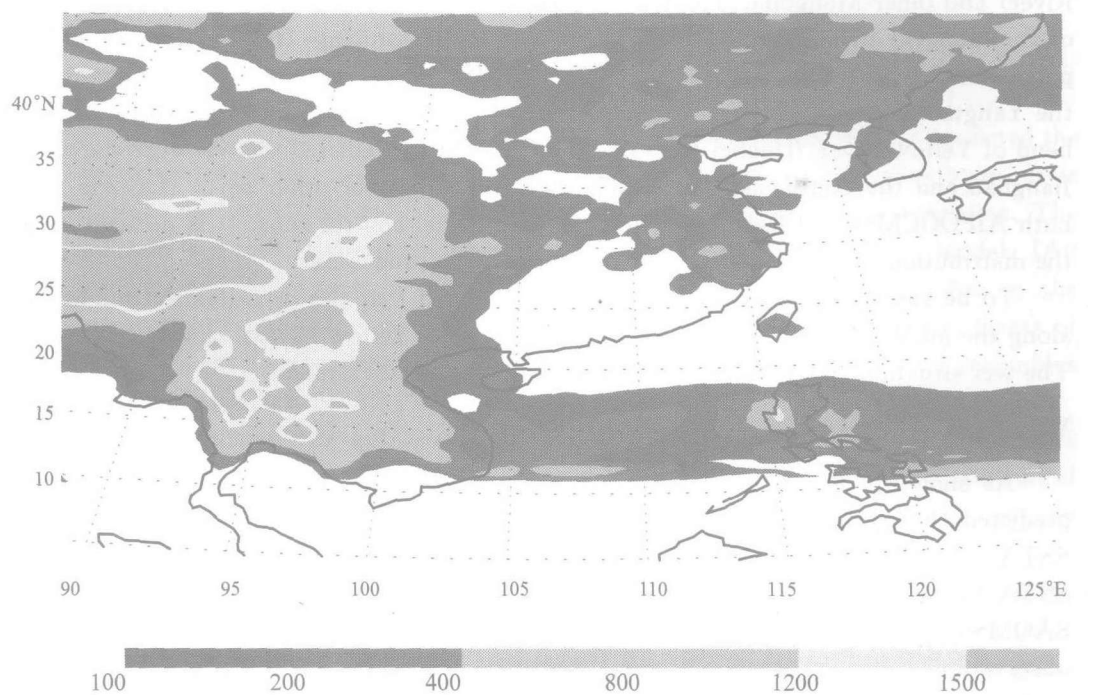

Fig. 10. Prediction of rainfall over China for summer 2001 by RegCM95 (Shi and Liu 2001).

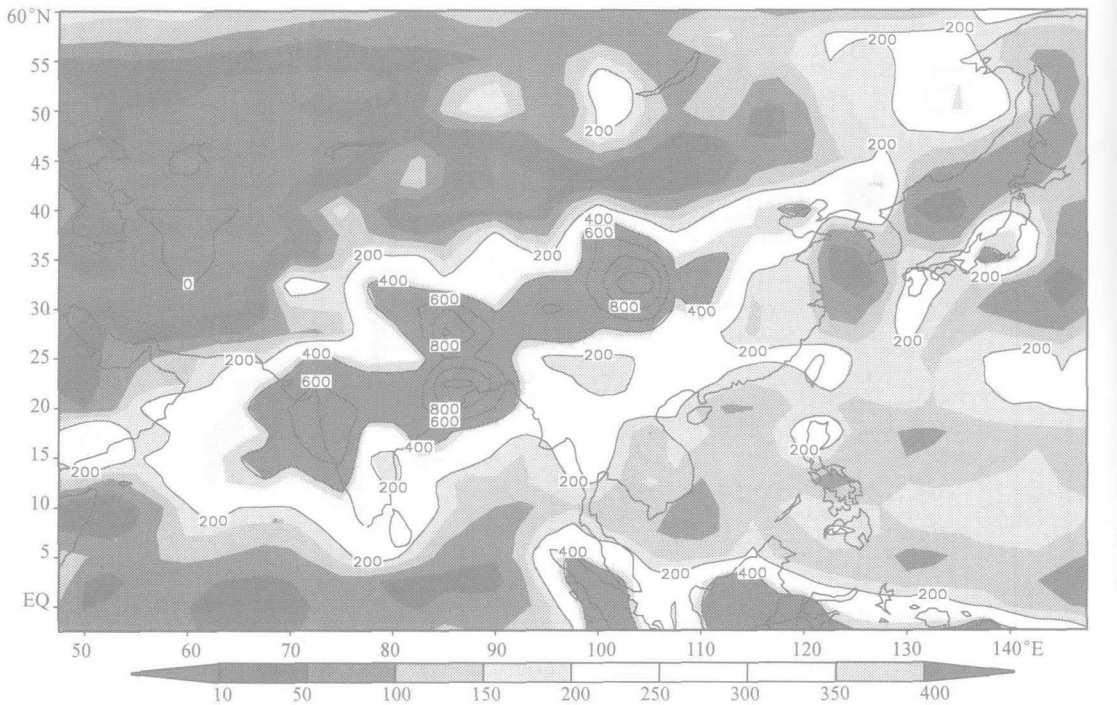

Fig. 11. Prediction of rainfall over China for summer 2001 by AIPOGCM95 (Zhao 2001).

River) and Inner-Mongolia. The IAP APOGCM predicted the wet along the lower reaches of the Yangtze River and the bend of Yellow River-Xinjiang (Hetao-Xinjiang). Other parts of China will be in dry situations. The CAMS/ZS predicted two rain belts, one along the Yangtze River and South of Yangtze River (Jiangnan), the other over North China-the bend of Yellow River (Huabei-Hetao). The OSU/NCC predicted the wet over the west of Jiangnan and the Southwest China. The dry areas are over other parts of China. Since both AIPOGCM95 and RegCM do not have the model control runs, it is difficult to give the distributions of anomalously wet and dry in their predictions.

To be summarized above, most models predicted that the dry situation might occur along the middle and lower valleys of Yangtze-Huaihe-Yellow Rivers, and Huabei-Hetao. The wet situations might appear in Huanan and Southwest China.

VI. ASSESSMENTS OF 2001 PREDICTIONS

As shown in Fig. 12, comparing with the observation from March to August, the predicted Nino3 SSTA of IAPAPOGCM model is out of phase with the observed Nino3 SSTA. The forecast of IPOGCM95 reflected the fluctuation of the observational Nino3 SSTA, but the amplitude of prediction is larger than that of observation. The prediction of SAOMS95 captured the cold phase of Nino3 SSTA, but it is about 0.5°C colder than observation. As far as April—August, 2001, the prediction of AOGCM95 is almost the same as the observation. Moreover, the composite prediction is coincident with the observation very well.

The predictions of summer rainfalls were composed based on the number that it is

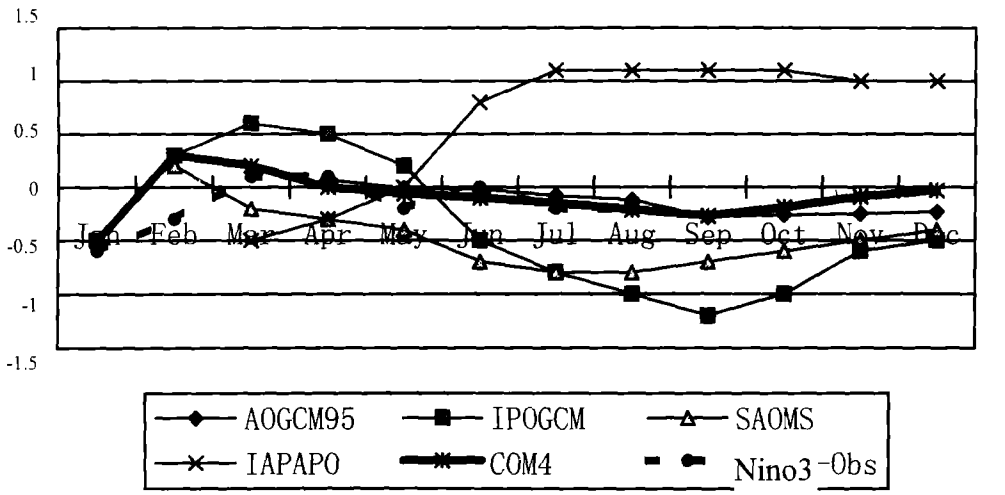

Fig. 12. Assessments of the annual predictions for the Nino3 indices (AOGCM95, IPOGCM95, SAOMS95, IAP APOGCM, composition of the above four models, and observations).

predicted wet or dry in a certain area by the five models (see Fig. 13a). Compared with the percentage of observational precipitation anomalies over China for summer (June — August) 2001 (Fig. 13b), it can be seen that more than normal rainfall over South China and the east part of East China was captured by most models, and two models predicted that it would be dry over the areas between Yangtze and Yellow Rivers, as well as Huabei, Inner-Mongolia and Hetao areas and the West China, which is consistent with observations.

VII. CONCLUSIONS AND DISCUSSIONS

After the assessments of 2001 predictions, it is noticed that some models predicted the Nino3 index and summer rainfall well, but some models' predictions were poor. It is noticed that both the IAP and NCC/OSU models did the predictions for a longer time. The evaluations showed that in the recent three years, compared with NCC/OSU model, IAP model predicted the distribution of rainfall well. The reasons might be due to the development of physical processes in IAP model over East Asia and 14 vertical layers of the OGCM over the Pacific Ocean. On the other hand, the IAP model did 28 ensembles and corrected the predictions.

The evaluations of the extra-seasonal predictions by the climate models for 2001 indicated that the super ensembles of climate models predicted the SSTA over the tropical Pacific Ocean and Nino3 index well. The super ensembles of most climate models predicted the dry and wet situations over China more reasonably.

The workshops on extra-seasonal predictions of climate models have been held for several years. The evaluations of predictions showed that the assimilations of initial fields are important for the climate models, especially for the oceanic data. The physical processes of climate models need to be improved, especially over East Asia and China. The methods of both the single model ensembles and the multi-model ensembles, as well as the corrected methods for the biases of prediction should be studied. For this purpose, it is

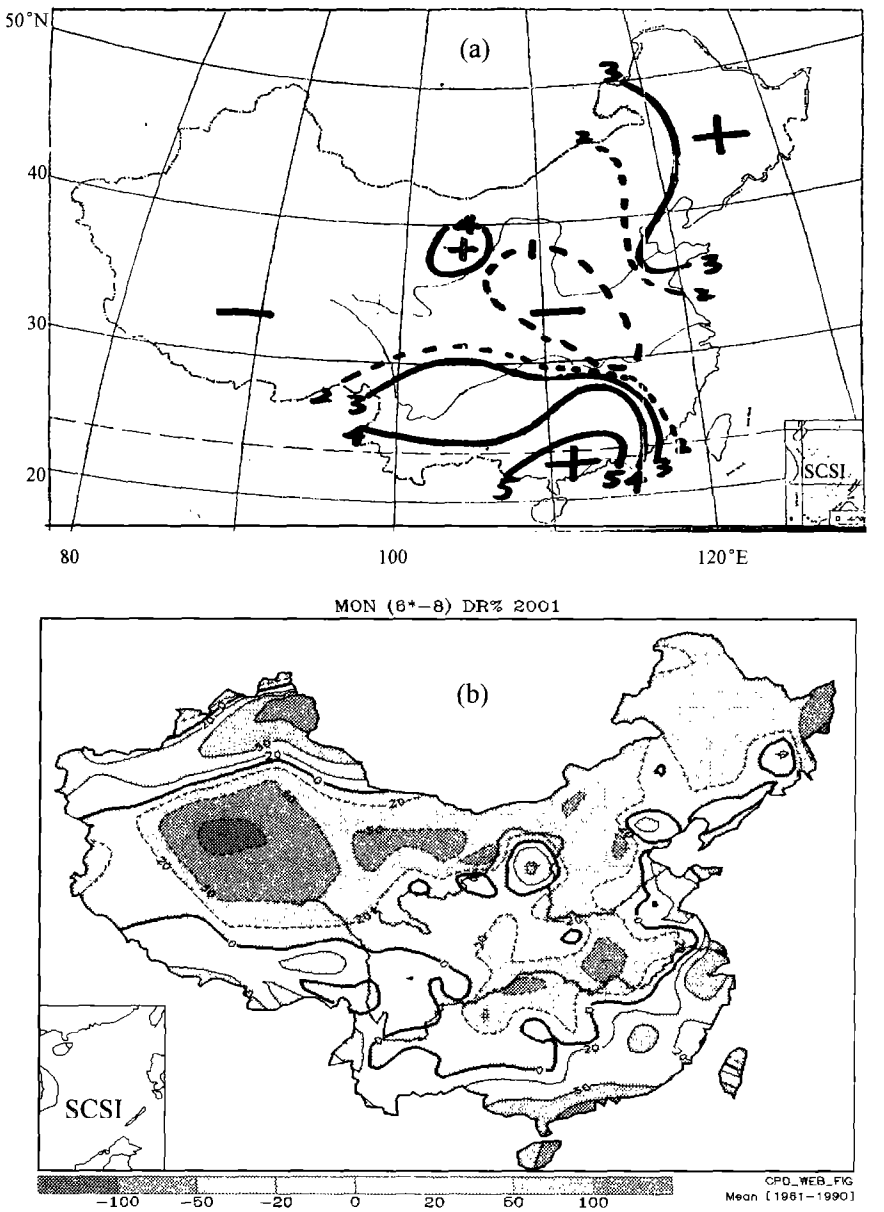

Fig. 13. (a) Composite prediction for summer rainfall of 2001 on the basis of the predictions of AOGCM95, AGCM95, IAP APOGCM, CAMS/ZS, OSU/NCC models, (b) percentage of observational precipitation anomalies over China for summer (June—August) 2001.

better to carry out the intercomparisons of the Chinese extra-seasonal forecast models, such as CHINA-CMIP.

It is the first time to predict the SSTA and summer rainfall by using about nine or ten climate dynamic models (or model system). We are going to evaluate the extra-seasonal predictions for each year in future. After those evaluations, the model system of short-term climate prediction will be improved and developed.

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