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Recent Researches on the Short–Term Climate Prediction at IAP—A Brief Review①

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ABSTRACT

Studies on the seasonal to extraseasonal climate prediction at the Institute of Atmospheric Physics (IAP) in recent years were reviewed. The first short–term climate prediction experiment was carried out based on the atmospheric general circulation model (AGCM) coupled to a tropical Pacific oceanic general circulation model (OGCM). In 1997, an ENSO prediction system including an oceanic initialization scheme was set up. At the same time, researches on the SST–induced climate predictability over East Asia were made. Based on the biennial signal in the interannual climate variability, an effective method was proposed for correcting the model predicted results recently. In order to consider the impacts of the initial soil moisture anomalies, an empirical scheme was designed to compute the soil moisture by use of the atmospheric quantities like temperature, precipitation, and so on. Sets of prediction experiments were carried out to study the impacts of SST and the initial atmospheric conditions on the flood occurring over China in 1998.

Key words: Climate prediction, Climate model, Initialization

1. Prediction on the ENSO cycle based on the CGCM

The atmospheric part of the coupled general circulation model (CGCM) is the IAP AGCM with the resolution of $4^\circ \times 5^\circ$ L2. The oceanic part is the free surface tropical Pacific OGCM (30°S–30°N) with $1^\circ \times 2^\circ$L14 resolution. The model contains a flat–bottom of 4000m–depth and a realistic coastline. An initialization scheme was also developed for the ENSO cycle prediction (Zhou and Zeng, 1998; Zhou and Zeng, 2001). The validation data used in this work include the National Centers for Environmental Prediction / National Center for Atmospheric Research (NCEP / NCAR) atmospheric re–analysis, the observed precipitation, and the Optimum Interpolation (OI) sea surface temperature from NCEP.

By using this coupled system, a series of prediction experiments were performed. The predictions were initiated from every month of November 1981 to December 1997. The length of each prediction is 24 months. Figure 1 depicts the 6 months–lead predictions of the NINO 3 SSTA in comparison with the observation (after Zhou et al., 1998). The predicted SSTA is obtained by subtracting the model climatology from the predicted SST. The correlation coefficient between the prediction and the observation is 0.57. However, the magnitude of the prediction is systematically smaller than the observation, especially for the 1982 / 1983 and

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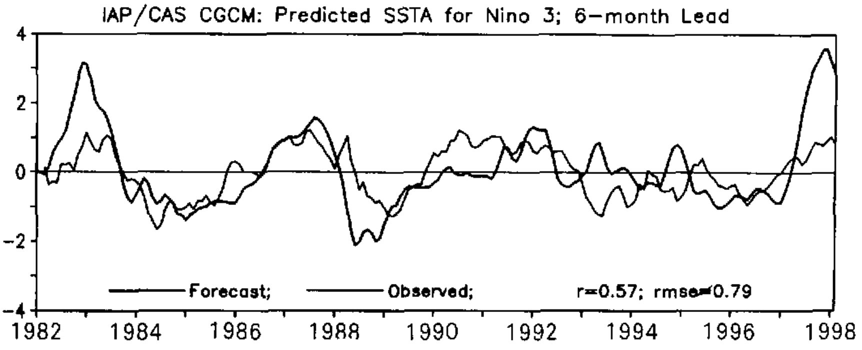

Fig. 1. The 6-month-lead predictions of NINO3 SSTA (thin line) and the observation (thick line) for January 1981-December 1998 (After Zhou et al., 1998).

1997 / 1998 El Niño events. We also note that the model failed to predict the NINO 3 sea surface temperature anomaly (SSTA) fluctuations during 1990-1996, which is the period of irregular variation of ENSO cycle.

The skill of the predictions is higher than that of the persistence prediction after 5 months of the model integrations, and can remain at about 0.57 after 12 months. This means that the prediction system could be used in the long-term prediction of ENSO cycle (up to about 16 months).

2. Prediction on the summer climate over East Asia

The first GCM-based extraseasonal prediction experiment was performed by use of the IAP AGCM coupled to coarse resolution tropical Pacific OGCM (4° × 5°L4). After that, a series of hindcast experiments and real-time predictions on the summer climate anomalies over China were carried out. The real-time predictions usually start at February of each year, and the output of the predictions contains the summer precipitation anomalies and so on (Zeng et al., 1997; Zhao and Guo, 2000; Lin et al., 2000). Figure 2 shows the ensemble simulations on the summer precipitation anomalies by use of the Center for Climate System Research at University of Tokyo (CCSR) AGCM with the resolution of T42L20 (hindcast forced by the observed monthly SST of 1998). The model could produce a reasonable degree of outlook of the summer climate anomalies over East Asia including the heavy rainfall over China. The research by using the CCSR model also suggests that the initial atmospheric anomalies in spring may play important roles in the summer atmospheric circulation at high latitudes, especially over Asia. However, it seems that summer tropical anomalies are controlled by SST anomalies, since the main observed features over the tropics are simulated only in the experiments that the observed SST anomalies are taken into account.

3. Correction of the model predicted results

Models alway have systematic errors in the simulation, even though models are improved all the time. In order to correct the model simulated summer climate anomalies,

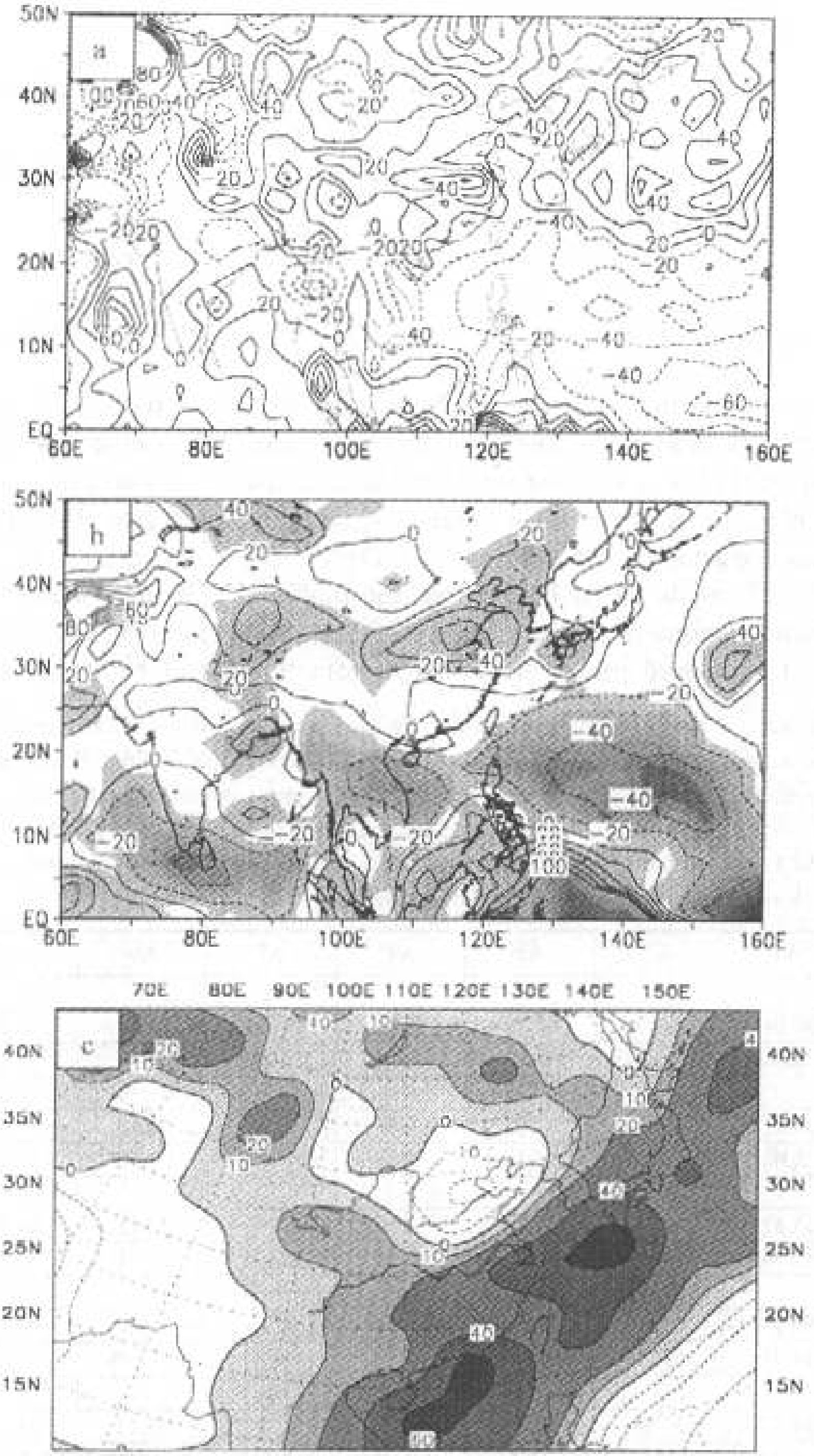

Fig. 2. The percentage of the observation (a) and ensemble predictions on the summer precipitation anomalies in 1998 by use of the CCSR AGCM (b, areas with significance higher than 95% are shaded), the IAP AGCM (c, areas with positive anomalies are shaded) (after Wang et al., 2000).

a method for correcting the model results was developed, which may be expressed as follows (After Wang et al., 2000):

$$P_{\mathrm{WZZM}} = (M - M_{-1})S_1 / S_2 + O_{-1} - O_{\mathrm{A}}. \tag{1}$$

While the conventional method (CM) is simply

$$P_{\mathrm{CM}} = M - M_{\mathrm{A}} \tag{2}$$

Here, M represents the predicted summer time average for a quantity in a year, O_{-1} and M_{-1} stand for the observed and predicted results respectively for the preceding year, O_{A} and M_{A} are the climatologies of the observation and simulation, respectively, S_1 and S_2 are the interannual variations of the observation and simulation, respectively, expressed by the standard deviation, and WZZM and CM stand for the corrected and uncorrected predictions, respectively, for the same quantity.

One can easily find that factor S_1 / S_2 plays the role of the systematic correction from the model variability (usually smaller than the observation) to the observed variability. The quasi–biennial oscillation is a strong signal in the atmosphere, so that $(M - M_{-1})S_1 / S_2$ must be very close to the observed difference of the current year to that of the last year $O - O_{-1}$. Thus one get $(M - M_{-1})S_1 / S_2 + O_{-1} - O_{\mathrm{A}} \sim O - O_{-1} + O_{-1} - O_{\mathrm{A}} = O - O_{\mathrm{A}}$. Therefore, formula (1) can both correct the amplitude of model climate variability and the sign the climate anomaly $(O - O_{\mathrm{A}})$ through the existing quasi–biennial oscillation. The predictions by the coupled model are initiated from the end of February, March, April,

Table 1. The correlation of predicted and observed 850 hPa zonal wind anomaly by WZZM and CM methods initiated from the end of February, NMarch, April, May, and the preceding October, November, and December respectively. Therefore, the lengths of the predictions are 6 to 10 months, respectively. A1 to A8 are the selected areas A1: (40°–110°E, 0°–20°N); A2: (110°–140°E, 0°–20°N); A3: (110°–125°E, 20°–40°N); A4: (120°–150°E, 20°–40°S); A5: (180°–90°W, 10°N–10°S); A6: (30°–90°W, 10°N–10°S); A7: (180°–90°W, 70°–90°S); and A8: (40°–70°E, 20°–50°N) (after Wang et al., 2000)

	A1	A2	A3	A4	A5	A6	A7	A8
Feb:								
WZZM	58.04	39.87	26.35	72.80	53.14	63.58	40.65	52.06
CM	−22.01	−41.10	5.63	1.67	−38.32	19.72	−25.81	−18.08
Mar:								
WZZM	54.73	47.73	52.05	18.67	68.57	28.12	50.48	82.09
CM	9.39	−26.07	18.42	−0.92	−15.07	−34.47	15.75	8.33
Apr:								
WZZM	55.87	47.35	29.80	52.80	65.97	56.51	64.83	65.22
CM	−22.40	−22.06	6.32	−5.37	−34.31	16.91	−5.65	−3.33
May:								
WZZM	90.13	89.26	86.00	25.52	68.84	20.46	43.07	86.07
CM	34.08	61.17	56.30	−30.15	−8.54	−47.76	2.07	12.40
Oct:								
WZZM	64.77	56.94	55.71	48.47	65.47	38.22	28.75	84.05
CM	−47.89	−46.37	−18.61	44.62	8.11	8.09	−25.76	26.23
Nov:								
WZZM	59.91	74.47	38.90	59.06	65.16	58.46	28.81	63.62
CM	−18.92	−9.10	0.45	−15.49	−4.26	18.57	−25.02	−8.14
Dec:								
WZZM	30.60	55.46	9.18	48.63	48.06	61.29	47.70	76.70
CM	−46.40	−10.32	−33.55	−1.25	−14.66	20.99	25.25	−11.64

May, and the preceding October, November, and December respectively. The lengths of the predictions are 6 to 10 months, respectively.

Then, they selected 8 typical regions to verify the effectiveness of WZZM method. They are the tropical Asian monsoon region (40°–110°E, 0°–20°N), the Southeastern Asia (110°–125°E, 0°–20°N), the East Asian monsoon region (110°–125°E, 20°–40°N), Australia (120°–150°E, 20°–40°S), the tropical eastern Pacific (180–90°W, 10°S–10°N), mid–America (30°–90°E, 10°S–10°N), the Antarctic region (180–90°W, 70°–90°S), and the mid–latitude Eurasia (40°–70°E, 20°–50°N). The anomaly correlation coefficient for the area mean JJA zonal wind anomalies at 850 hPa between the NCEP / NCAR re–analysis and the predictions is listed in Table 1. The results show that the predictive skill of WZZM method is much higher than that of CM method at all the selected regions, and that the skill for seasonal–lead prediction is approximately the same as that for interannual–lead prediction. But the prediction initiated from May is better than the prediction initiated from other dates.

4. The decadal scale variation of the East Asian summer monsoon

As known before, the meridinal wind component is comparable to the zonal wind component in the lower troposphere over East Asia, and the East Asian summer monsoon system

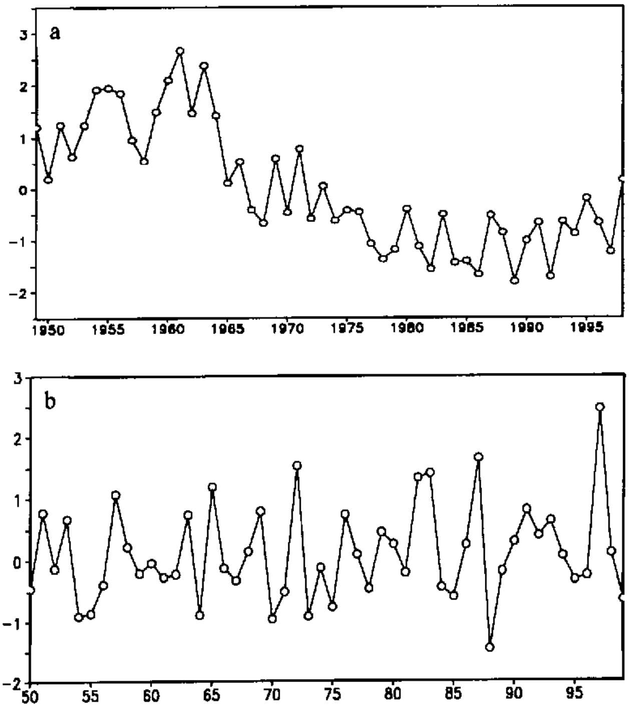

Fig. 3. The interannual variation of the East Asian summer monsoon index in m / s (a) and Nino3 SSTA in °C (b) during 1994–1998 (after Wang, 2001).

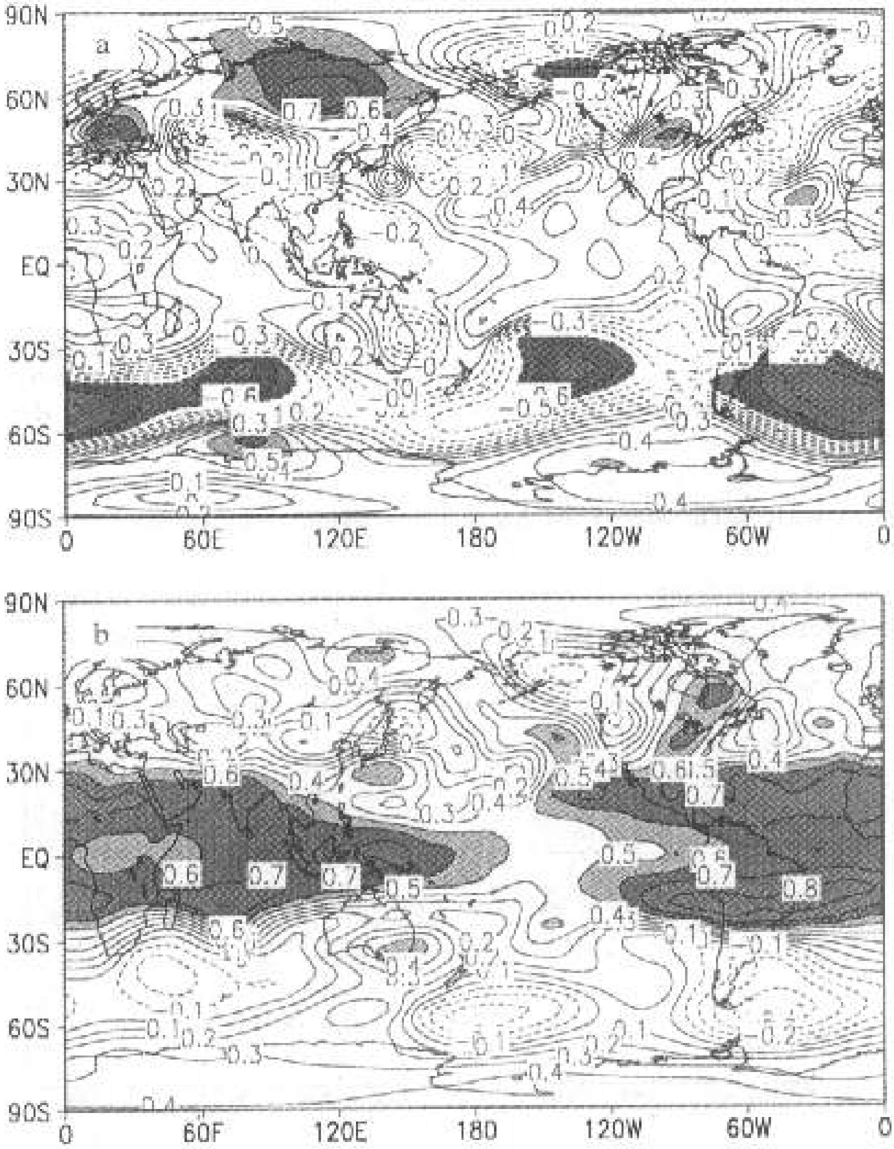

Fig. 4. The geographical distribution of the correlation coefficient of EAMI and 200 hPa geopotential height for JJA in two 20–year periods, 1959–1978 (a) and 1979–1998 (b).

includes both the subtropical monsoon component that is highly influenced by the subtropical high–pressure system over the western Pacific and the tropical monsoon component originated from the Indian Ocean. In order to describe the strength of the East Asian summer monsoon directly, the area mean (110°–125°E, 20°–40°N) velocity at 850 hPa is used as the East Asian summer monsoon index (EAMI for brief). In the figure of the interannual variability of EAMI and the Nino3 SSTA (Fig. 3), there exists a clear transition for EAMI at the end of the 1970's, which was indicated by Wang (2001) elsewhere. After the transition, the EAM becomes significantly weaker. At the same time the averaged JJA SST in the Nino3 region is higher after the transition at the end of the 1970's.

The variation of the correlation of the EAMI and the Nino3 SSTA was studied by the cross wavelet spectra (figures not shown). The change of the inter–relation is very clear. Tight correlation appears in the 1964–1974 and 1983–1990 periods and sparse correlation exists in

1975–1983 and 1991–1995 periods.

In order to provide more evidence of the decadal scale variation of the atmospheric circulation related to EAM, we depict the correlation coefficient of EAMI and 200hPa geopotential height in JJA in two 20–year periods, 1959–1978 and 1979–1998 (Fig. 4). We can find that the patterns between the two periods are substantially different. During 1959–1978, the larger correlation appears in the high–latitude Eurasia. While in 1979–1998 period the region with significant correlation is located in the tropics.

5. Initialization of the soil moisture

Possible impacts of the soil moisture anomalies in Spring on the summer climate have been studied by some researchers since the 1980's (Shukla and Mintz, 1982, Yeh et al., 1984) and by Lin et al. (2000) recently. In order to take account the role of the initial soil moisture anomalies in the summer climate anomalies, Ma and Fu (personal communication) developed a scheme to compute the soil moisture empirically by use of some meteorological quantities. From the computed and observed soil moisture for the last 10 days mean of July, 1981 over China, it can be seen that the scheme reasonably reproduces the soil moisture distribution over the eastern China, especially for the deep soil layers (90–100 cm and 50–60 cm).

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中国科学院大气物理研究所近年来的短期气候预测研究——简要回顾

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摘　要

回顾了近年来在中国科学院大气物理研究所开展的有关短期气候预测研究的进展．第一个短期气候数值预测是曾庆存等利用一个耦合了热带太平洋海洋环流模式的全球大气环流模式作出的．1997年，一个基于海气耦合模式的ENSO预测系统，包括一个海洋初始化方案被建立起来，同时也开展了基于海温异常的东亚气候可预测性研究．利用气候变动的准两年信号，王会军等提出了一个可以显著改进模式预测准确率的模式结果修正方案．为了考虑土壤湿度的初始异常对夏季气候的影响，一个利用大气资料如温度、降水等经验地反演土壤湿度的方法也被建立起来．还通过一系列的数值试验研究了1998年夏季大水发生当中海温异常和大气环流初始异常的作用．

关键词：气候预测，气候模式，初始化