An Effective Method for Correcting the Seasonal–Interannual Prediction of Summer Climate Anomaly①

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(Received September 23, 1999; revised November 8, 1999)

ABSTRACT

An effective method was proposed for correcting the seasonal–interannual prediction of the summer climate anomaly. The predictive skill can be substantially improved by applying the method to the seasonal–interannual prediction carried out by a coupled ocean–atmosphere model. Thus the method has the potential to improve the operational summer climate predictions.

Key words: Correction, Seasonal–interannual prediction, Quasi–biennial signal

1. Introduction

The seasonal and interannual prediction of summer climate anomalies by various coupled climate models is a key objective of the climate research community in the world. Studies on El Nino and Southern Oscillation (ENSO)–related climate predictability showed that predictive skill outside the tropics is generally low compared to that the in the tropics, although some predictive skills may exist in some monsoon regions (Zeng et al., 1990; Kumar and Hoerling, 1995; Brankovitch and palmer, 1997; Zeng et al., 1997; Ji et al., 1994; Webster et al., 1998). Even in the tropics, the predictive skill is quite limited. Therefore, it is a major task to seek new methods to improve the seasonal–interannual prediction.

Quasi–biennial signals were found to be presented in the variations of the general circulation, sea surface temperature (SST) and precipitation. Guo (1987) reported the existence of quasi–biennial signals in the variability of East Asian monsoon system. She also noted the quasi–3.5–year and quasi–5–6–year signals. In the tropics, especially in the tropical Asian monsoon region, the quasi–biennial signals were proved to be quite clear in the instrumental record except for period 1920–1950 (Yasunari, 1987; Yasunari, 1991; Rasmusson et al., 1990; Barnett, 1991). Such quasi–biennial variation could be reasonably simulated by the coupled ocean–atmosphere climate model.

Based on these characteristics, a method (WZZM for brief hereafter) for correcting the seasonal–interannual prediction of the summer atmospheric circulation and precipitation anomalies by the coupled ocean–atmosphere model is put forward in this paper. The effectiveness of this method will be examined in the following sections.

①This research was supported by the National Key Programme for Developing Basic Sciences under Contract G1998040905–2 and the key project "The Analytical Study on the Seasonal and Interannual Variability of the General Atmospheric Circulation (1998–2001)" of National Natural Science Foundation of China under Contract 49735160.

2. The correction method and the hindcasting experiments

The WZZM for correcting the seasonal–interannual prediction of the summer climate anomaly may be expressed as follows:

$$P_{WZZM} = (M - M_{-1})S_1 / S_2 + O_{-1} - O_A. \quad (1)$$

While the conventional method (CM) can be expressed as (Gao and Zhao, 1997):

$$P_{CM} = M - M_A. \quad (2)$$

In (1) and (2), M stands for the predicted summer time average for a quantity in a certain 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 climatology of the observation and simulation respectively, S_1 and S_2 are the interannual variations of the observation and simulation respectively, which are expressed by the standard deviation, and P_{WZZM} and P_{CM} stand for the corrected (WZZM) and uncorrected (CM) predictions respectively for the same quantity.

From the formula (1), we can easily find that factor S_1 / S_2 is the systematic correction from the model variability to the observed variability. Since the quasi–biennial oscillation is a strong signal in the atmosphere, $(M-M_{-1})S_1 / S_2$ must be very close to $O-O_{-1}$, the difference of observations between the current year and the last year. Thus we get $(M - M_{-1})S_1 / S_2 + O_{-1} - O_A \sim O - O_{-1} + O_{-1} - O_A = O - O_A$. Here " $\sim$ " means " very close to each other". Therefore, formula (1) can both correct the model variability and improve the model prediction on the climatic anomaly $(O-O_A)$ through the existing quasi–biennial oscillation.

The model used in this study is the Institute of Atmospheric Physics (IAP) coupled atmosphere–ocean model. The atmospheric part of the coupled model is the IAP 4° × 5°L2 grid–point Atmospheric General Circulation Model (AGCM) with the comprehensive physical parameterization schemes. The oceanic part is the IAP 1° × 2°L14 grid–point free–surface tropical Pacific Ocean General Circulation Model (OGCM). The coupled model was proved to have reasonable abilities to simulate and predict the ENSO cycle (Zhou et al., 1998). Figure 1 depicts the observed and 9–month lead predicted SST anomalies averaged in the Nino 3 region (90°–150°W, 5°S–5°N).

The hindcasting experiments were carried out each year during 1982–1997 initiated respectively from the ends of January, February, March, April, May, and the preceding

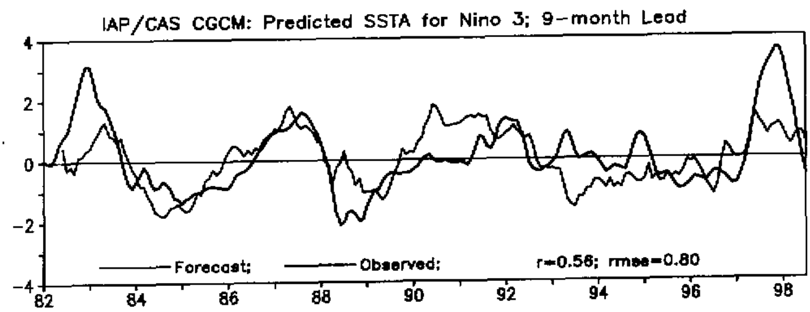

Fig. 1. The interannual variation of the observed and 9–month lead predicted Nino 3 SST anomalies (°C). Where 'r' means the correlation coefficient between the observation and the prediction, and 'rmse' stands for mean square error of the prediction.

October, November and December. All the integrations were lasted to the end of the next August.

The data sets used for validation of the prediction in this paper are the National Center for Environmental Prediction / National Center for Atmospheric Research (NCEP / NCAR) re–analysis data and the NCEP merged precipitation data.

3. The predictive skills of the correction method

The CM method has two shortcomings: one is that the magnitude of the predicted anomaly is systematically smaller than that of the observation, and the other is the low skill of the prediction. Comparatively, we can find that the predictive skill of the WZZM is substantially higher than that of CM.

The global distribution of the correlation coefficient of the observed and predicted June–July–August (JJA) mean 500 hPa geopotential height anomalies is plotted in Fig. 2. We

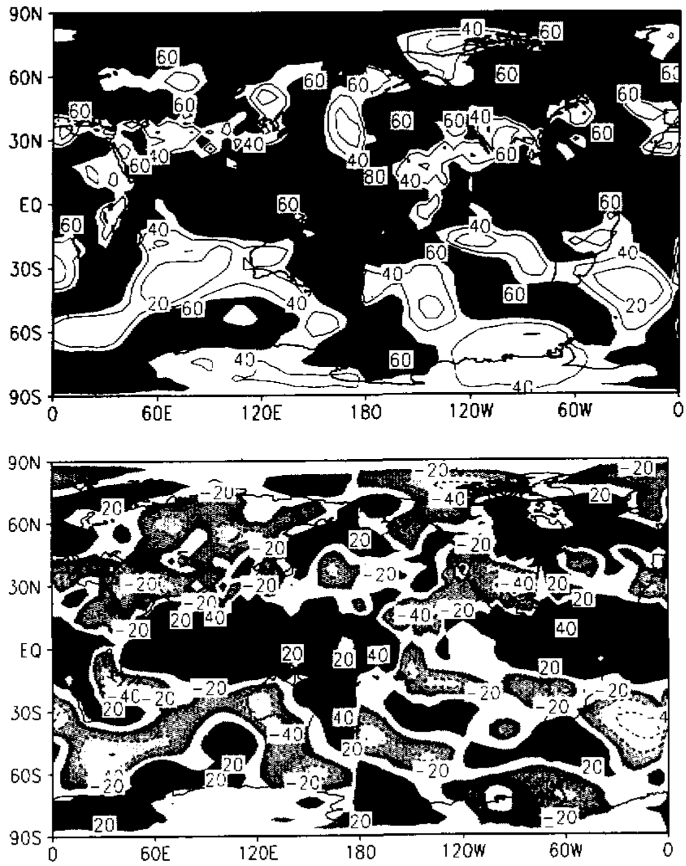

Fig. 2. The global distributions of the correlation coefficients (%) of the observed and the predicted (initiated from the end of October) JJA 500 hPa geopotential height anomalies by WZZM (top) and CM (bottom) respectively. Areas with absolute values larger than 50 are shaded.

can find that most regions in the case of the CM prediction are covered with negative values, except for regions like the southwestern tropical Pacific, indicating that the predictive skill of the CM for the 500 hPa geopotential height is low. While the WZZM could give much better prediction in most part of the globe, with more than 0.5 correlations over most middle-latitude and low-latitude areas.

Similar to the predictions of the summer 500 hPa geopotential height anomaly, the predictions of summer sea level pressure and 850 hPa zonal wind anomalies are substantially improved by applying the WZZM (Fig. 3 and Fig. 4). Such high predictive skill could even satisfy the demands of the operational use.

Then, we selected 8 typical regions to check the effectiveness of the WZZM. They are the tropical Asian monsoon region defined by Webster and Yang (1992) (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°E–90°W, 10°S–10°N), mid-America (30–90°E, 10°S–10°N), the Antarctic region (180°E–90°W, 70–90°S), and the middle latitude Eurasia (40–70°E, 20–50°N). We then compare the area mean JJA zonal wind anomalies at 850 hPa for NCEP / NCAR re-analysis and the predictions. The temporal correlations of the prediction and the reanalysis are listed in Table 1. We

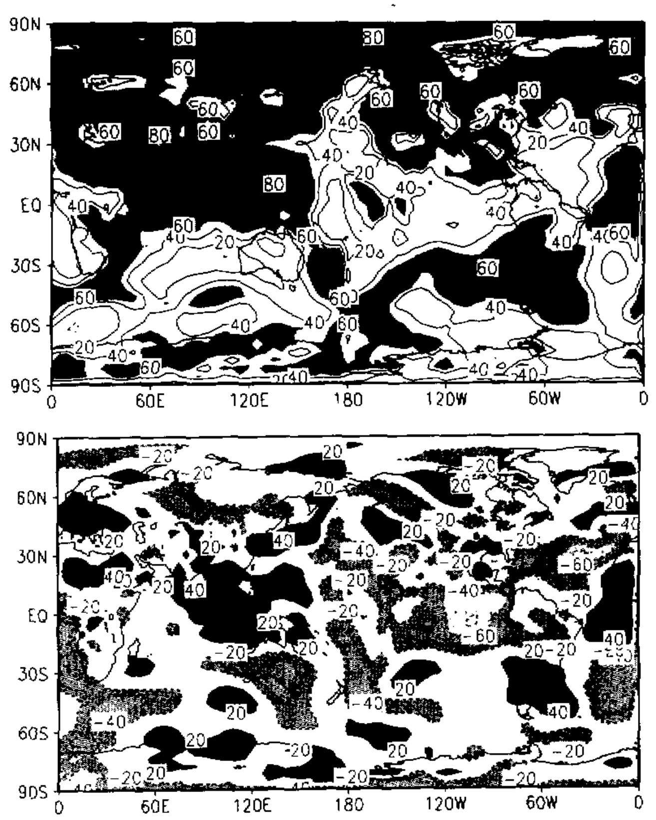

Fig. 3. Same as Fig. 2, but for the sea-level pressure.

Table 1. The correlations of predicted and observed 850 hPa zonal wind anomalies by WZZM and CM initiated from the ends of February, March, April, May, and the preceding October, November, and December 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°E–90°W, 10°N–10°S); A6: (30–90°W, 10°N –10°S); A7: (180°E–90°W, 70–90°S); and A8: (40–70°E, 20–50°N)

	A1	A2	A3	A4	A5	A6	A7	A8
February								
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
March								
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
April								
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
October								
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
November								
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
December								
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

Table 2. Same as Table 1, but for the summer precipitation anomalies

	A1	A2	A3	A4	A5	A6	A7	A8
February								
WZZM	0.20	0.55	0.58	0.37	0.39	0.25	0.92	0.57
CM	−0.31	−0.24	−0.15	0.67	−0.40	−0.01	0.17	−0.12
March								
WZZM	0.68	0.73	0.59	0.15	0.58	0.17	0.93	0.73
CM	0.17	−0.19	0.20	0.04	0.06	−0.12	−0.18	−0.25
April								
WZZM	0.22	0.71	0.50	0.24	0.61	0.21	0.93	0.52
CM	−0.29	0.14	0.00	0.19	−0.18	0.16	−0.14	−0.03
May								
WZZM	0.50	0.83	0.62	0.51	0.44	0.14	0.94	0.79
CM	0.19	0.06	−0.21	−0.09	−0.13	0.31	−0.06	0.43
October								
WZZM	0.48	0.69	0.68	0.51	0.70	0.16	0.92	0.53
CM	0.20	−0.29	−0.05	0.40	−0.20	0.10	0.03	−0.14
November								
WZZM	0.64	0.76	0.79	0.28	0.49	0.20	0.92	0.66
CM	0.25	0.14	0.19	0.47	−0.32	0.01	0.00	0.05
December								
WZZM	0.60	0.80	0.67	−0.09	0.23	0.34	0.94	0.71
CM	−0.07	−0.18	0.05	0.18	−0.53	0.41	−0.06	−0.33

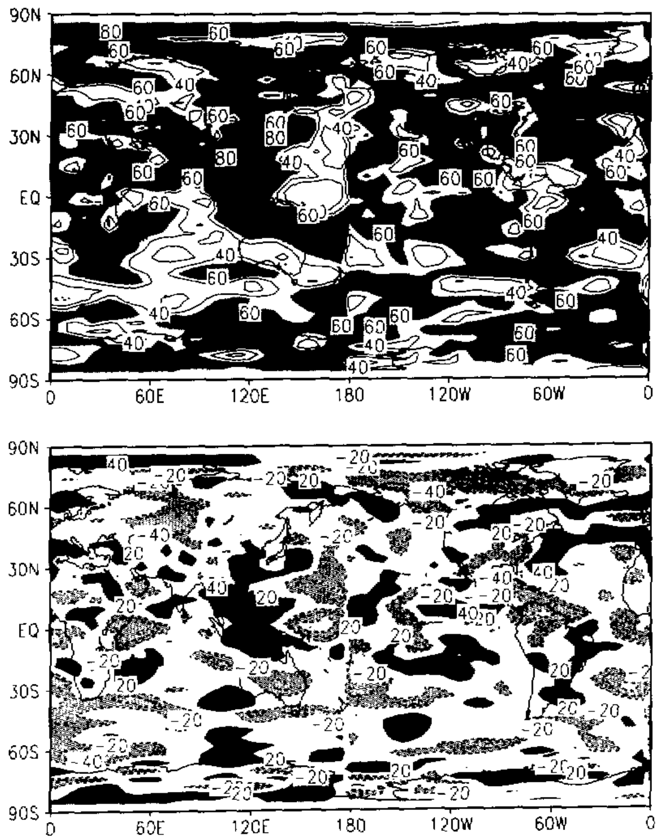

Fig. 4. Same as Fig. 2, but for the zonal wind at 850 hPa.

may conclude that the predictive skill of WZZM is much higher than that of CM at all the regions selected, and that the skill for the seasonal–lead prediction is approximately the same as that for the interannual–lead prediction. But the prediction initiated from May is better than that initiated from other dates.

Furthermore, we obtained similar results in the prediction of the summer precipitation anomaly in Table 2. The improvement of the prediction on the summer precipitation anomaly by applying WZZM is very pronounced. However, at regions A4 and A6 (Australia and mid–America) the improvement is quite limited. The weakness of the quasi–biennial oscillation of the precipitation during JJA at these regions is one of the main reasons for the above results.

4. Summary

From the above studies, the following conclusions can be obtained:

1) The substantial improvement on the seasonal–interannual prediction of the mean summer atmospheric circulation can be obtained by applying the WZZM proposed in this

paper to the model hindcasting experiments.

2) The predictive skill of the seasonal–lead forecast and that of the interannual–lead forecast are at the same level in general.

3) The WZZM does not improve the prediction of summer precipitation in some limited regions. Therefore, the combination of WZZM and CM in the operational model prediction would be more successful.

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