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Prediction of Seasonal Rainfall in Hong Kong
Using ECPC's Regional Climate Model

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Abstract

The seasonal rainfall forecast experiments conducted so far with the Experimental Climate Prediction Center's regional model indicate that the model performed reasonably well for the rainy and winter seasons in Hong Kong. The overall value of the scaled Hanssen and Kuipers score for these seasonal forecasts is 0.54.

Keywords: regional climate model, seasonal rainfall forecasts, model calibration, model performance, Hanssen Kuipers score.

1. Introduction

In collaboration with the Experimental Climate Prediction Center (ECPC) of the Scripps Institute of Oceanography, a regional climate model (RCM) was adapted by the Hong Kong Observatory in November 2000 for studying the feasibility of using the RCM as a tool to provide seasonal forecasts in Hong Kong.

Hong Kong is located in the East Asian Monsoon region at low latitudes where rainfall patterns are complex (Liang and Wu 2000, Shi et al. 2001). This paper gives an overview of RCM, documents some case studies for seasonal rainfall forecasts, states briefly the factors affecting model performance and gives an evaluation of seasonal precipitation forecasts that were made for Hong Kong.

2. Model Overview

The RCM is based on the regional spectral model described by Juang et al. (1997) and Hong and Leetma (1999). The forecasts of the RCM are treated as perturbations superimposed on the forecasts of a global model so that errors due to the difference between the climatologies of the two models and lateral boundaries are minimized. Cumulus parameterization in the regional model is implemented through the simplified Arakawa-Schubert scheme.

In the version operated by the Hong Kong Observatory, the model domain is centred on Hong Kong, with 49×50 grids covering Guangdong and the northern part of the South China Sea (19 to 26°N, 111 to 118°E). The spatial resolution is 15 km. There are 18 levels in the vertical. The initial and boundary conditions required to drive the model are provided by ECPC once a week. Details can be found in Chang (2001) and Hui et al. (2002).

The model is run on an IBM F50 server. A Linux network of 5 PII-350Mhz PCs, providing storage capacity of over 1 Terabytes, was built to support model post-processing and the compilation of model climate.

3. Data and Methodology

In order to reduce the errors induced by model and observed climatologies, in the verification process standardized anomalies of the model forecasts F' and observed values O' are used. They are defined as

$$F' = (F - C_f)/s_f \quad (1a)$$

$$O' = (O - C_o)/s_o \quad (1b)$$

where F , C_f , and s_f are respectively the model forecast rainfall, model climatological rainfall and model standard deviation of the climatological rainfall; O , C_o and s_o are respectively the observed rainfall, observed climatological rainfall and the standard deviation of the observed climatological rainfall. Model climatological rainfall and standard deviation are calculated from October 1997 to October 2001 model hindcasts. Observed climatological rainfall and standard deviation are computed from the 1961 to 1990 observations.

Following WMO (2002), rainfall forecasts are divided into the 3 categories above normal (rainfall forecasts greater than $+0.5s_f$), near normal (within $\pm 0.5s_f$) and below normal (below $-0.5s_f$). Likewise for the observed values.

To assess the overall performance of the RCM, the forecasts are then converted into the two categories viz. 'normal and above' and 'below normal' for the calculation of the scaled Hanssen and Kuipers score (K_s), which is suggested in WMO (2002) for evaluating the skill of long-range forecasts. K_s is one when the forecasts are perfect, and is zero when forecasts are totally missed.

For model forecasts on a grid size as small as 15 km, observations on a resolution finer than the 2° afforded by reanalysis data is preferred (Hui et al. 2004). Thus, for the purpose of this paper rainfall observations from 9 stations in Hong Kong and its vicinity are used instead. Such an approach is commonly used for verification of high resolution model forecasts (Bougeault 2003). In this study, the observed monthly rainfall data are extracted from the Hong Kong Observatory database, web page of Macao Meteorological and Geophysical Bureau, and the Monthly Climate Monitoring Bulletin published by the National Climate Centre of China Meteorological Administration.

4. Applications of RCM to Seasonal Rainfall Forecasting

The applications of the RCM to seasonal rainfall forecasting and its performance are illustrated with a case each for July-August-September (JAS), winter or December-January-February (DJF), and April-May-June (AMJ) periods.

Fig. 1a shows the RCM seasonal rainfall forecast for JAS 2003. It can be seen that except for northern Guangdong Province, the northeastern part of the Pearl River estuary and parts of the south China coast, the forecast is akin to the actual near-normal rainfall pattern (Fig. 1b). Of the 9 stations, the rainfall at 5 stations was correctly forecast. At 3 other stations the forecast rainfall was within 1 category of the actual and at 1 station the forecast deviated by 2 categories from the actual. The forecast accuracy was 56%. Chen et al. (2003) has noted that because of the strong convection and a high degree of variability associated with JAS rainfall, the simplified Arakawa-Schubert scheme may not always be able to successfully model the resulting rainfall.

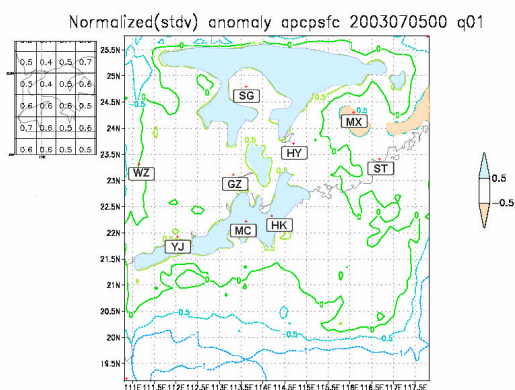


Fig. 1a. Forecast rainfall anomaly for JAS 2003. Blue, white and orange represents above normal, near normal and below normal respectively.

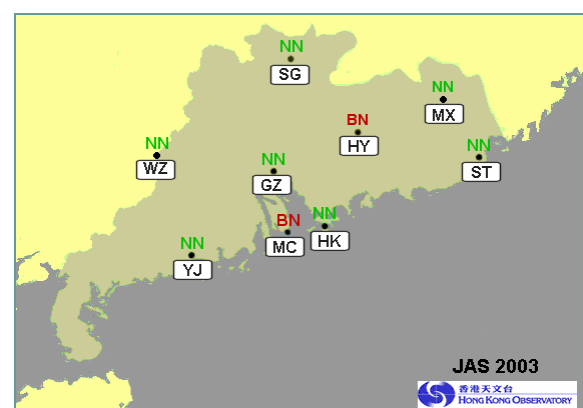


Fig. 1b. Observed rainfall for JAS 2003. NN and BN represents near normal and below normal respectively.

In the winter months, the rain over Guangdong is mainly of a frontal nature, and variability is less than the other seasons. For the winter (DJF) of

2003/04, except for the western parts of Guangdong and the southeastern coastal areas, the RCM forecast near normal rainfall (Fig. 2a). This matches quite well with the actual situation (Fig. 2b). In particular, from the data available at 7 of the 9 stations, one sees that the rainfall at 4 of them was correctly forecast, and within 1 category of the actual rainfall at the remaining 3. The accuracy was 57%.

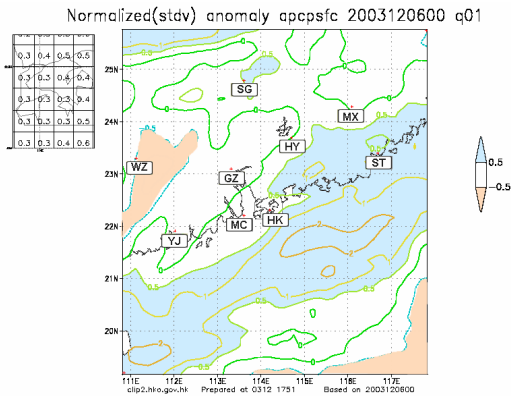


Fig. 2a Forecast rainfall anomaly for DJF 2003/04. Blue, white and orange represents above normal, near normal and below normal respectively.

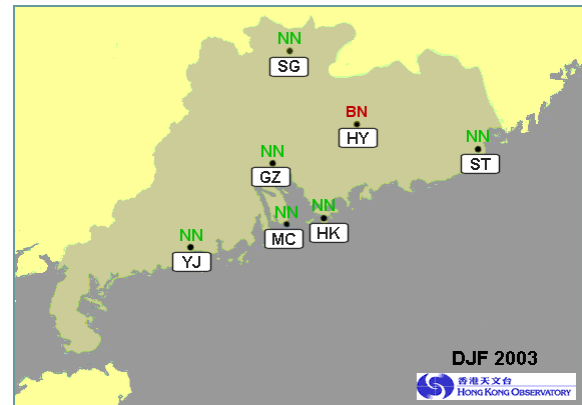


Fig. 2b. Observed rainfall for DJF 2003/04. NN and BN represents near normal and below normal respectively.

Each year, the season AMJ over the south China coast is the time when the region comes under the influence of monsoon troughs. For 2004, of the 7 stations with complete data, the negative rainfall anomalies at 4 stations in the southeastern Guangdong were correctly forecast. At the remaining 3 stations over the northern and western Guangdong, the forecast rainfall was 1 category below the actual. The forecast accuracy was 57%. Though far from perfect, the forecast did capture the pattern that negative rainfall anomalies dominated the southeastern Guangdong and the anomalies were less negative over the northern and western part of the province (Fig. 3a and 3b).

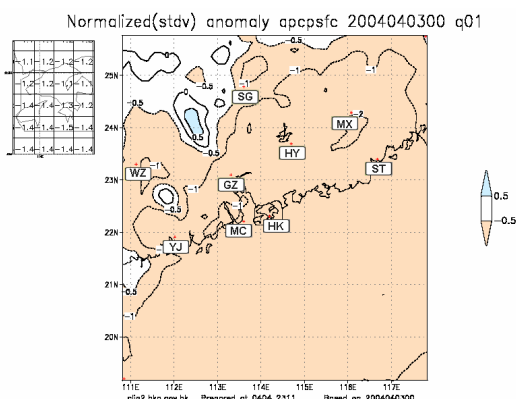


Fig. 3a. Forecast rainfall for AMJ 2004. Blue, white and orange represents above normal, near normal and below normal respectively.

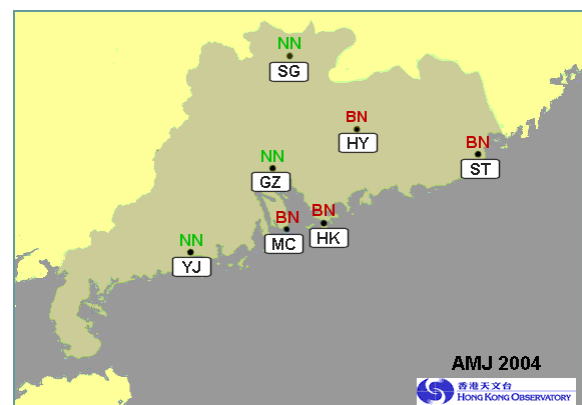


Fig. 3b. Observed rainfall for AMJ 2004. NN and BN represents near normal and below normal respectively.

The three cases above represented different synoptic features at work. Yet in all cases the RCM forecasts was able to reflect the rainfall tendencies, and the accuracies were above 56%. This suggests that the RCM has a definite measure of skill. It also suggests that the combination of time step (90 s) and diffusion coefficient (6, dimensionless) adopted in the model was more or less correct, explosive development in model rainfall induced by computational instability being successfully avoided.

5. Overall Performance of RCM

Some 30 sets of seasonal rainfall forecasts for the rain and dry seasons in Hong Kong between 1997 and 2004 had been generated. Verification against rainfall observed at 9 different stations gave an overall Hanssen and Kuipers score (Ks) of 0.54. This indicates that the model has reasonable skill in forecasting seasonal rainfall in a monsoon climate where many systems of different spatial and temporal scales are at play. In this study, Ks ranges between the lowest of 0.30 for AMJ and the highest of 0.69 for DJF (Table 1). The forecast is less skillful in summertime during which precipitation is convective in nature. This, to certain extent, reflects the difficulty in representing the convective precipitation using the existing model physics. This observation is consistent with the finding of Hong and Leetma (1999).

Table 1. Values of Ks for different seasons

Season	Ks
April-May-June (AMJ)	0.30
June-July-August (JJA)	0.51
July-August-September (JAS)	0.48
October-November-December (OND)	0.52
December-January-February (DJF)	0.69
1997-2004	0.54

6. Regional model against global model

The case for AMJ 2004 is a good example to demonstrate the advantage of using regional model for forecasting seasonal rainfall. It was anomalously dry over southern China during these 3 months. The regional model was able to forecast the widespread dry conditions over most part of Guangdong in AMJ 2004 (Fig. 4a) which turned out to be correct vis-a-vis the wet conditions forecast by global models (Fig. 4b). This can be attributed in part to better resolution of the wet-dry boundary in the regional climate model compared to that in the global model.

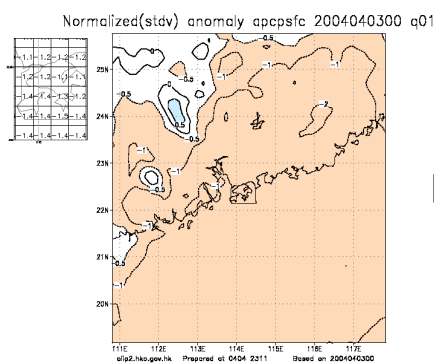


Fig. 4a. RCM forecast for AMJ 2004.

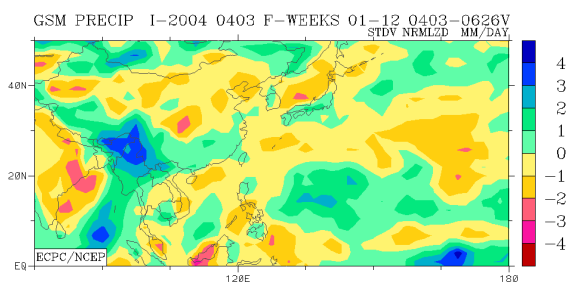


Fig. 4b. GSM rainfall forecast for AMJ 2004.

7. Conclusions

Verification indicates that the regional model adapted by the Observatory possesses skill in forecasting seasonal rainfall for the south China coastal area. The overall Hanssen-Kuipers score was 0.54. More experiments are required to further evaluate the skill of the regional model.

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