On the regional climate simulation over SouthEast Asia using RegCM

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This paper represents some results of simulation of surface climate fields during the summer months over Southeast Asia region by using RegCM model. The numerical experiments are established based on sensitivity tests of physical parameterization schemes, such as convective precipitation and ocean fluxes. Convective precipitation and ocean flux schemes are implemented for experiments consist of 1) Grell scheme with the Arakawa and Schubert closure assumption (Grell_AS); 2) Grell scheme with the Fritsch and Chappell closure assumption (Grell_FC); 3) Ocean flux computed following BATS scheme; and 4) Ocean flux computed following Zeng scheme. Global meteorological fields used in the experiments are reanalysis data of ERA40. Monthly mean of near surface temperature, rainfall amount and atmospheric circulation fields simulated by the model have been compared to the CRU and ERA40 data. The results showed that, RegCM is capable of simulation of summer monsoon circulaion over Southeast Asia, such as cross equatorial flow, trough over gulf of Bengal, Northwest Pacific Ocean subtropical anticyclone. Overall, the simulated 2m-temperatures are underestimated about 0.5-1.0^{o}C. These values can be up to 2.0^{o}C when Grell_FC is implemented. The different ocean flux schemes seem to be not impact on simulated 2m-temperatures, but can significantly effect on amount and spacial distribution of rainfall. The simulated rainfall amount and its spacial distributions are very sensitive with physical parameterization schemes. While the simulated rainfall amounts and areas using the Grell_FC scheme exceed CRU data significantly, the Grell_AS scheme leads to an underestimate the rainfall areas. In general, the model raifalls with Grell_AS scheme fairly agree with CRU data.

1. Introduction

Southeast Asia is a region with complex topography, land surface conditions, coastlines, and with large contribution from mesoscale phenomena, such as the cold frontal systems in the winter and ITCZ, tropical cyclones in the summer. To study the regional climate in such a region, the implementaion of the Regional Climate Model (RCM) should be useful. The NCAR-RegCM (hereafter is refered to RegCM), is one of such models, has been developed at the NCAR (National Center for Atmospheric Research) in the late 1980s. Recent years, RegCM is available on the ICTP (International Centre for Theoretical Physics) website (http://users.ictp.it/~pubregcm). From this website the users can download the source code, user's guide and required data, such as meteorological fields, SST, terrain high, landuse,… for running the model.

RegCM was built upon the National Center for Atmospheric Research - Pennsylvania State University (NCAR-PSU) Mesoscale Model version MM4. The dynamical component of the model originated from that of the MM4, which is a compressible, finite difference model with hydrostatic balance and vertical σ-coordinates. An overview of the RegCM and its history can be found, for example, in (Nellie Elguindi, Xunqiang Bi, Filippo Giorgi, Badrinath Nagarajan, Jeremy Pal, and Fabien Solmon, 2004).

RegCM are run over limited-area domains and are driven by time-dependent large-scale meteorological fields specified in a buffer area adjacent to the domain's lateral boundaries. These fields can be provided either by analyses of observations or by output from general circulation model simulations.

In this paper, RegCM has been run to simulate the surface climate fields, such as circulation, temperature and rainfall, over Southeast Asia region during the summer months of the years of 1996-1998. In addition, the long term simulation for this period , from Jan 1996 to Dec 1998 was performed.

2. Model and Experiment designs

For the present simulation, the RegCM version 3 (RegCM3) is used with 18 σ-levels, in which 6 levels are under 850mb in the planetary boundary layer, the model top at 70 mb, and the normal Mercator conformal projection. The domain size covers from 80E to 130E and 5S to 40N with horizontal resolution of 54 km for both East-West and North-South directions.

Initial and time-dependent boundary conditions for the model run are the ERA40 reanalysis data with 6h time interval in the period of 1996-1998. There are two kinds of experiments are established: The seasonal simulations which focus on the summer months of June, July and August, and the long term simulations which covers overall of three years (1996-1998).

The CRU analysis data are used as observed. These data sets are corrected by update the observed data from meteorologial stations over Vietnam using objective analysis scheme. Thus, the CRU data used in this paper are not the original CRU data from ICTP.

The sensitivity experiments (table 1) are established based on the combination of physical parameterization scheme options, which are convection and ocean flux schemes. The chosen convective parameterization schemes consist of Grell scheme with the Arakawa-Schubert and with the Fritsch-Chappell closure assumptions (hereafter refered as Grell_AS and Grell_FC, respectively). The computation of the ocean fluxes based on BATS and Zeng schemes separately.

Table 1. The sensitivity experiments

Exp.	Convection scheme	Ocean flux scheme
Grell_FC_BATS	Grell_FC	BATS
Grell_AS_BATS	Grell_AS	BATS
Grell_AS_Zeng	Grell_AS	Zeng

3. Results and discussion

3.1. Sensitivity to Different Cumulus Parameterization

In order to test the sensitivity of cumulus parameterization in RegCM3, in this section the simulated streamline fields of the Grell_FC_BATS and Grell_AS_BATS (table 1) have been compared with that of ERA40 and CRU data (see figs.1-4). The summer monsoon circulation over Southeast Asia in August of 1996 was reproduced quite well. Figure 1 shows that a general agreement is found between ERA40 and the model cross equatorial flow, trough over Bay of Bengal, and subtropical anticyclone axis over Northwest Pacific Ocean. The model circulation with Grell_AS scheme seems to be closer to ERA40 than that with Grell_FC scheme; while the later gives some pseudo cyclones in the vicinity of Vietnam and China and over Bangladesh regions (fig.1b). The similar situations were found in other cases of simulations of 1997 and 1998.

(a) Grell_FC_BATS ***(b) Grell_AS_BATS*** ***(c) ERA40***

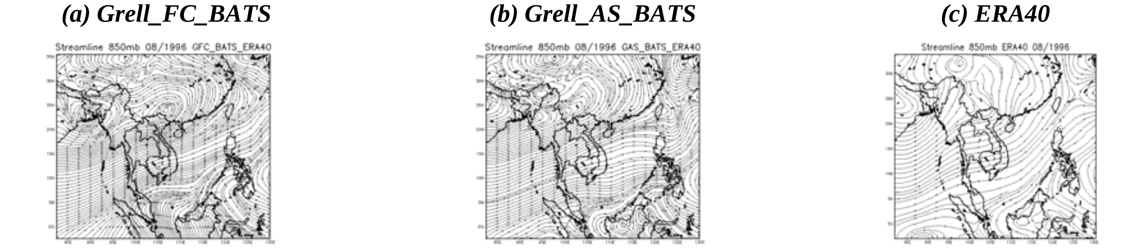


Figure 1. The averaged monthly simulated streamline of 8/1996 of (a) Grell_FC_BATS, (b) Grell_AS_BATS and (c) ERA40 data

Firgures 2 and 3 show the observed (CRU) and simulated 2m-temperature (T2m) in the two experiments. It can be seen that the model temperature is underestimated by about 2-4^{o}C over India, Thailand and Vietnam, even the model cold bias is enhanced up to 6^{o}C over the Southeast China. We can observe the generally better agreement between simulated and observed temperatures in the experiment of Grell_AS_BATS than that of Grell_FC_BATS, especially over the east China, Thailand, and the north and middle parts of Vietnam.

(a) Grell_FC_BATS *(b) Grell_AS_BATS* *(c) CRU*

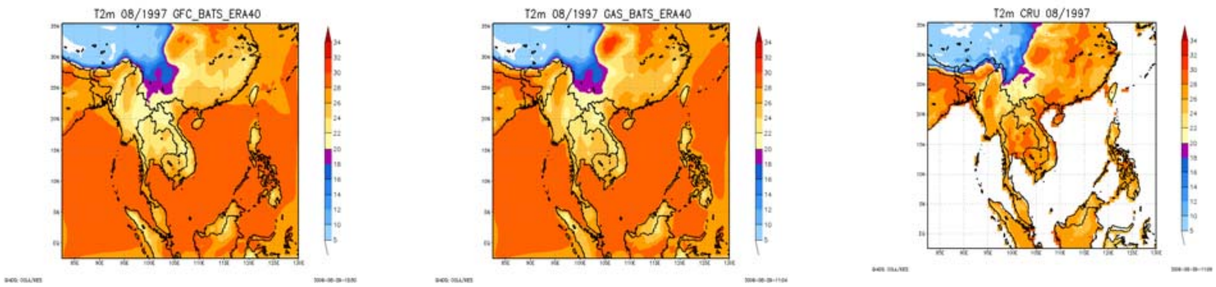


Figure 2.The averaged monthly simulated T2m of 8/1997 of (a) Grell_FC_BATS, (b) Grell_AS_BATS and (c) CRU data

(a) Grell_FC_BATS – CRU *(b) Grell_AS_BATS - CRU*

Figure 3. Difference of the averaged monthly simulated T2m of 8/1997 between (a) Grell_FC_BATS, (b) Grell_AS_BATS and CRU data

In general, in the tropical regions, such as Southeast Asia, the most important contribution to the total rainfall is the convective precipitation. Therefore, in the numerical models, accuracy of the rainfall simulation mainly depends on the skills of convective parameterization schemes. Figure 4 compares observed (CRU) and simulated monthly total rainfall in the Grell_FC_BATS and Grell_AS_BATS experiments. In the Grell_FC_BATS experiment the model rainfall is overestimated, while in the Grell_AS_BATS experiment, the model captures well the regional spacial distribution of rainfall over inner domain. However, in the later experiment, the area of maximum precipitation over Bay of Bengal is shifted in a eastward location compared to CRU. In both experiments, the overestimation of the simulated rainfall appears in the lateral boundary areas of the domain, such as Philippines. It can be said that the differences in the results of experiments might be caused by the different closure assumptions of convective parameterization schemes.

3.2. Sensitivity to Different Ocean Flux Parameterization

Ocean occupies a significant area in the integration domain. The water and energy fluxes between sea surface and atmosphere can significantly influence the model temperature and precipitaion. To evaluate the sensitivity of the different ocean flux parameterization schemes, two experiments of Grell_AS_BATS and Grell_AS_Zeng were performed. The simulation results of these experiments are presented in figure 5. It can be seen that the summer monsoon circulation over Southeast Asia was reproduced quite well in both experiments. Analyses of the simulated temperature at 1000mb level (T1000) in two experiments (fig. 6) show that there is no difference between them over the continent, but over India Ocean and South China Sea the model temperature in the Grell_AS_BATS experiment is warmer by 1-2^{o}C than that of Grell_AS_Zeng experiment. Compared with ERA40 data, T1000 in the Grell_AS_Zeng experiment is underestimated, especially over South China Sea and Malaysia areas, while in the Grell_AS_BATS experiment T1000 pattern is better reproduced.

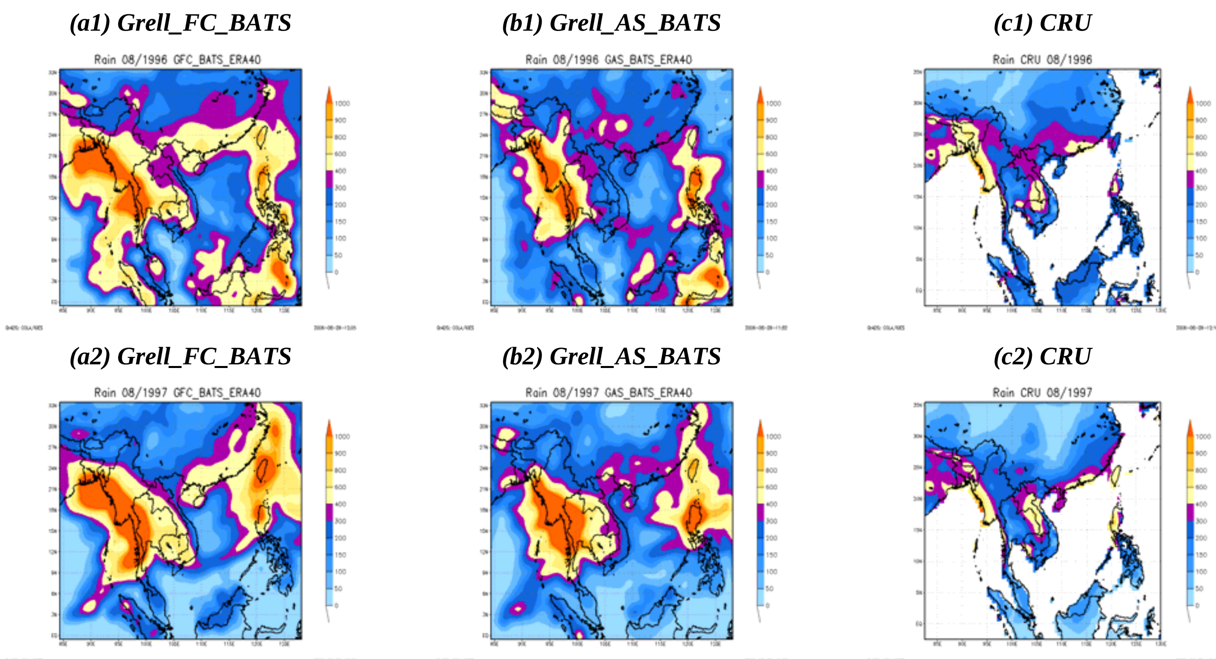


Figure 4. The monthly simulated precipitation of 8/1996 and 8/1997 of (a1,a2) Grell_FC_BATS, (b1,b2) Grell_AS_BATS and (c1,c2) CRU data

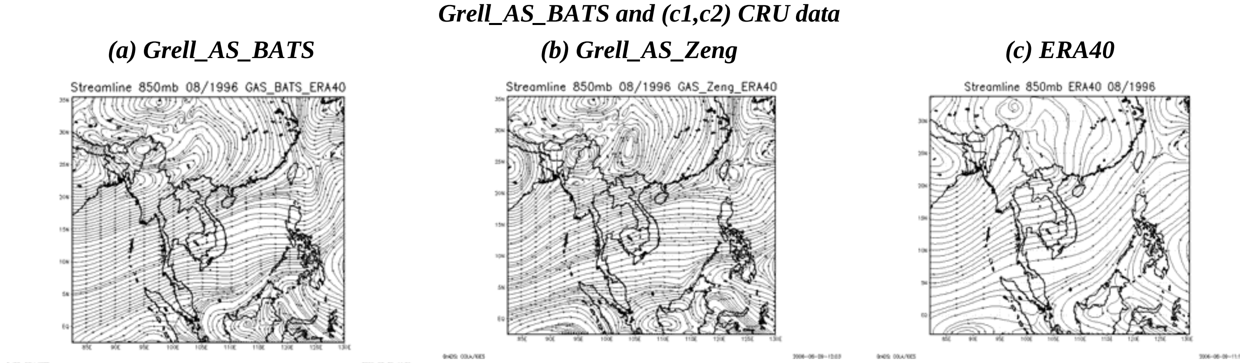


Figure 5. The averaged monthly simulated streamline of 8/1996 of (a) Grell_AS_BATS, (b) Grell_AS_Zeng and (c) ERA40 data

Unlike temperature, the model rainfall in these two experiments is rather different not only over ocean areas but also over the continent. The rainfall amount and its spacial distribution in the Grell_AS_BATS experiment are greater than that of the Grell_AS_Zeng experiment, and consequently, closer to CRU data.

In summary, among our experiments, the RegCM model with the Grell_AS convection and BATS ocean flux schemes is the best capable of simulation of circulation, temperature, and rainfall over Southeast Asia region.

3.3. Long term simulation

As mentioned above, the RegCM with Grell_AS_BATS is the best choice for climate simulation over Southeast Asia. Therefore, this "version" of RegCM is implemented for the long term simulation covering the 3 years period starting on 01 Jan 1996, and ending on 31 Dec 1998. In this section, the monthly time series of observed and simulated T2m and rainfall at meteorological stations over Vietnam are represented.

Figures 8 and 11 show the time series of observed and simulated monthly T2m and rainfall of the five subregions of Vietnam, respectively. For each subregion, the model temperature (rainfall) is interpolated onto available stations, and both observed and model values are averaged overall of stations. In addition, in the firgures 9-10 and figure 12, the time series of observed and simulated T2m and rainfall of several stations are presented.

It can be seen that the model T2m with Grell_AS_BATS is underestimated by 2-6^oC and this tendency is obviously systematic. The simulated T2m in the early summer months (March-May) is good agreement with observed, the bias is only 0.5-1^oC. However, in the months of June-August and December-February, the simulated T2m is about 4-5^oC lower than observed data. The bias of T2m in the winter is greater than in the summer. In the South of Middle Part of Vietnam, where temperature is high and stable, T2m is always underestimated by 3^oC in the summer and 6^oC in the winter.

At some stations, such as Caobang and Tamdao, the simulated T2m is good agreement with observed data (fig. 9), bias is about 1-2^oC in the summer and 3-5^oC in the winter. However, the high cold bias of 4-8^oC can be found at Aluoi (fig. 10), especially in the winter. Compared to observed, the simulated T2m is lower in the winter but greater in the summer at Huongkhe and Kyanh stations.

Unlike temperature, except in the winter months, the simulated rainfall is too much underestimated (Fig. 11). The model values are about 200 mm/month while observed values can reach to 600-800 mm/month in summer. However, we can see the better agreement between the simulated and observed rainfall at some other stations (fig. 12).

4. Conclusions

This paper has presented the implementation of RegCM for the seasonal and long term climate simulation over Southeast Asia. The sensitivity of the physical parameterizations are performed, such as convective and ocean flux parameterization schemes. The results showed that RegCM with appropriate choice of the physical parameterization options can be used to simulate the regional climate not only for the seasonal but also for the long term simulation over Southeast Asia. However, the model values of T2m and rainfall are underestimated systematically. The model can better reproduce the T2m than the rainfall.

(a) Grell_AS_BATS *(b) Grell_AS_Zeng* *(c) ERA40*

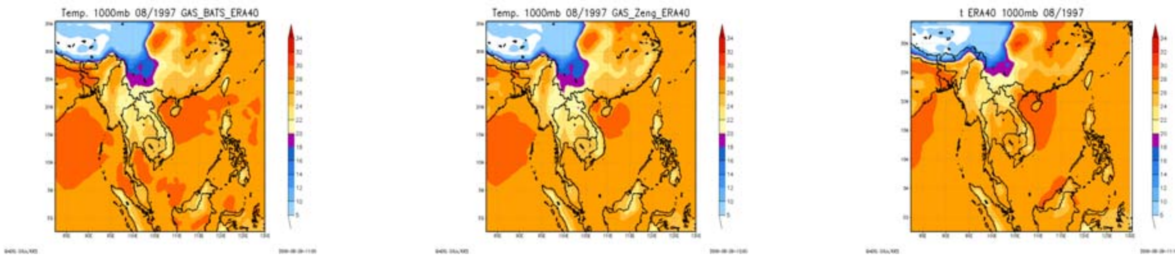
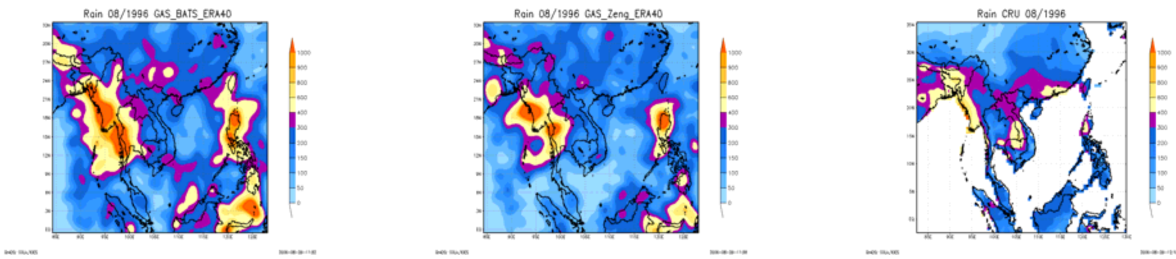


Figure 6. The averaged monthly simulated T1000 of 8/1997 of (a) Grell_AS_BATS, (b) Grell_AS_Zeng and (c) ERA40 data

(a1) Grell_AS_BATS *(b1) Grell_AS_Zeng* *(c1) CRU*



(a2) Grell_AS_BATS *(b2) Grell_AS_Zeng* *(c2) CRU*

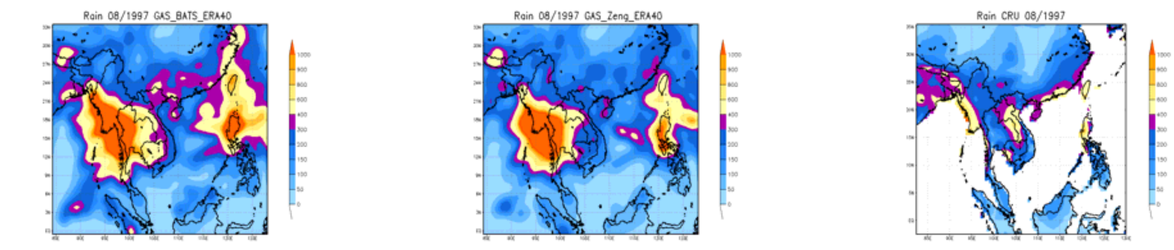


Figure 7. The monthly simulated precipitation of 8/1996 and 8/1997 of (a1,a2) Grell_AS_BATS, (b1,b2) Grell_AS_Zeng and (c1,c2) CRU data

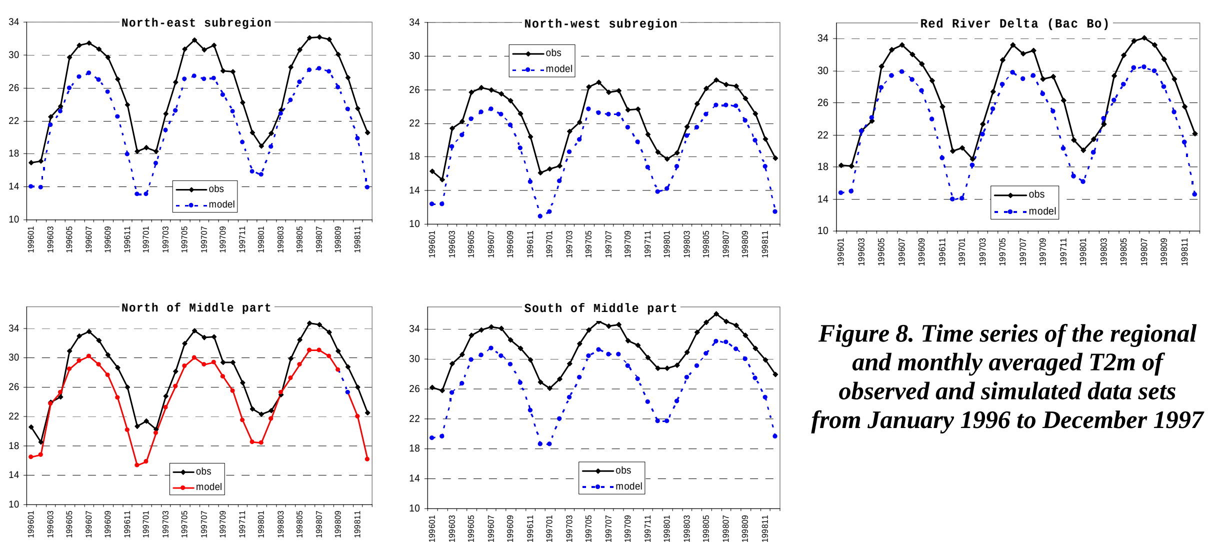
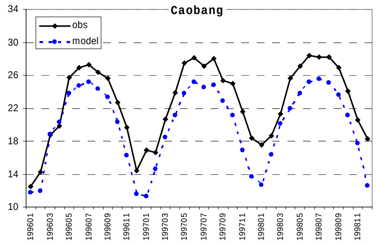


Figure 8. Time series of the regional and monthly averaged T2m of observed and simulated data sets from January 1996 to December 1997



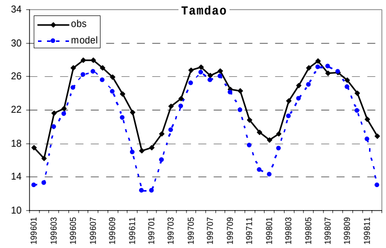
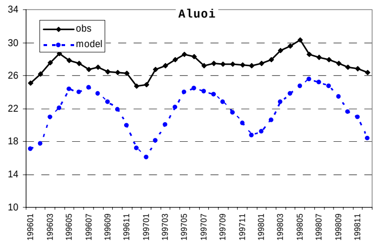
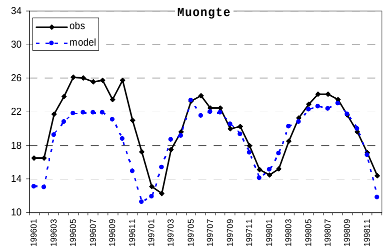
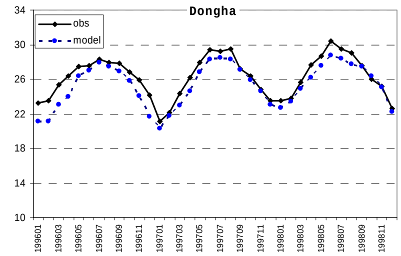


Figure 9. Time series of the monthly averaged T2m of observed and simulated data sets from January 1996 to December 1997 of some stations in the North Vietnam







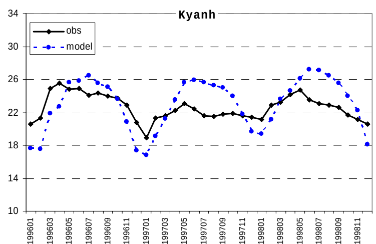
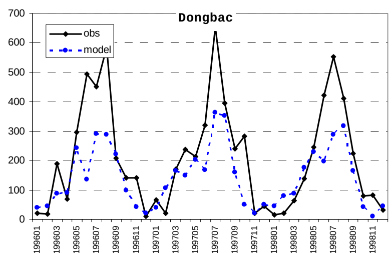
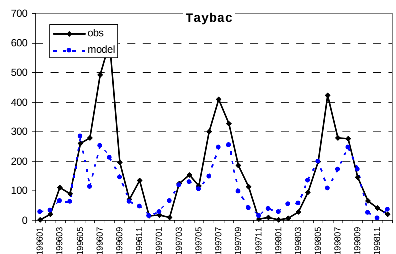
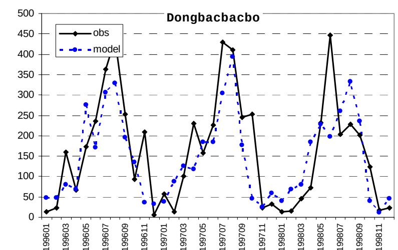
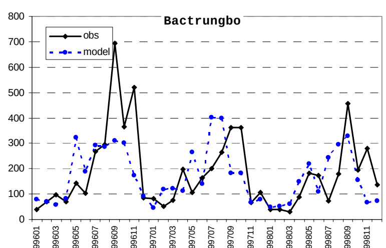


Figure 10. Time series of the monthly averaged T2m of observed and simulated data sets from January 1996 to December 1997 of some stations in the Middle Part of Vietnam









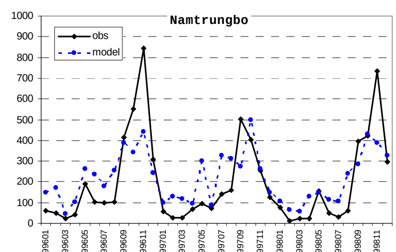
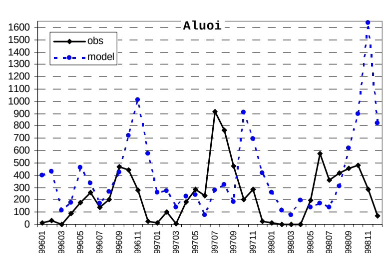


Figure 11. Time series of the regional and monthly averaged precipitation of observed and simulated data sets from January 1996 to December 1997



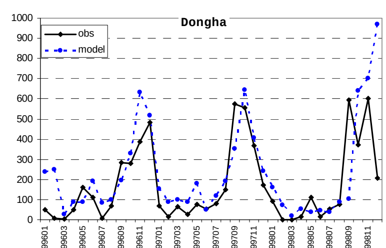


Figure 12. Time series of the monthly averaged precipitation of observed and simulated data sets from January 1996 to December 1997 of some stations in the Middle Part of Vietnam

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