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Adaptation of NCEP RSM Model for Long-range Forecasting

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1. Introduction

In late November 2000, the Hong Kong Observatory (HKO) began to port the Regional Spectral Model (RSM) of the National Centre for Environmental Prediction (NCEP) to an IBM F50 computer. The objective is to operate the model to provide guidance for long-range forecasting.

The RSM was originally developed by Juang and Kanamitsu (1994) for weather prediction. Subsequently, it was modified by Juang et al. (1997) to enhance efficiency and functionality. Hong and Leetma (1999) applied the model to regional climate modelling and found it very useful for the purpose although some deficiencies were observed.

The RSM being ported is the latest version described by Juang et al. (1997). The authors understand that it is the first time that this version of the model was ported to an IBM AIX platform. The porting was essentially completed in a short time span of 6 months.

This paper describes the implementation of the RSM on the IBM F50, some of the problems that were encountered and overcome in the process, and preliminary forecasts produced by the RSM on the IBM F50.

2. Model Description

Details of the RSM can be found in Juang et al. (1997) and Hong and Leetma (1999). A brief summary is given here.

The RSM is a primitive equation model in sigma co-ordinates. It is nested in a Global Spectral Model (GSM) of NCEP which provides the RSM with the necessary initial and boundary conditions. The RSM has the same physics package and parameterizations as the GSM. This physics package includes long and short wave radiation, boundary layer processes, soil thermodynamics and soil hydrology, and cumulus parameterization based on the Arakawa-Schubert scheme.

The perturbation method is used in the RSM whereby regional forecasts are treated as perturbations on the global field. Traditionally, in regional models the influence of the global model is felt only near the lateral boundaries. In the perturbation method, the global field is allowed to permeate the whole of the regional domain. The regional forecast is then cast in the form of perturbations on top of the global field. The advantage of the perturbation method is that the climate of the regional model would not differ too much from that of the global model, the disadvantage is that a longer computing time is required. Further, at the lateral boundaries, the RSM's orography is blended into that of the GSM's via a blending technique devised by Hong and Juang (1998). The identical physics package with the GSM, the perturbation method and the orography blending all help to reduce errors due to lateral boundaries and to differences between global and regional model climatologies. These features make the RSM attractive for regional climate simulations.

3. Model Implementation

3.1 Model configuration

The RSM's inner domain has 49 x 50 grid points on Hong Kong (Fig. 1). The horizontal resolution is 15 km while there are 18 levels in the vertical. The initial and boundary data used to force the RSM come from a subset of the output of the NCEP GSM compiled by Experimental Climate Prediction Centre (ECPC). For the outer domain (Fig. 2), there are 21 x 14 grids with an effective resolution of T62 at 18 levels.

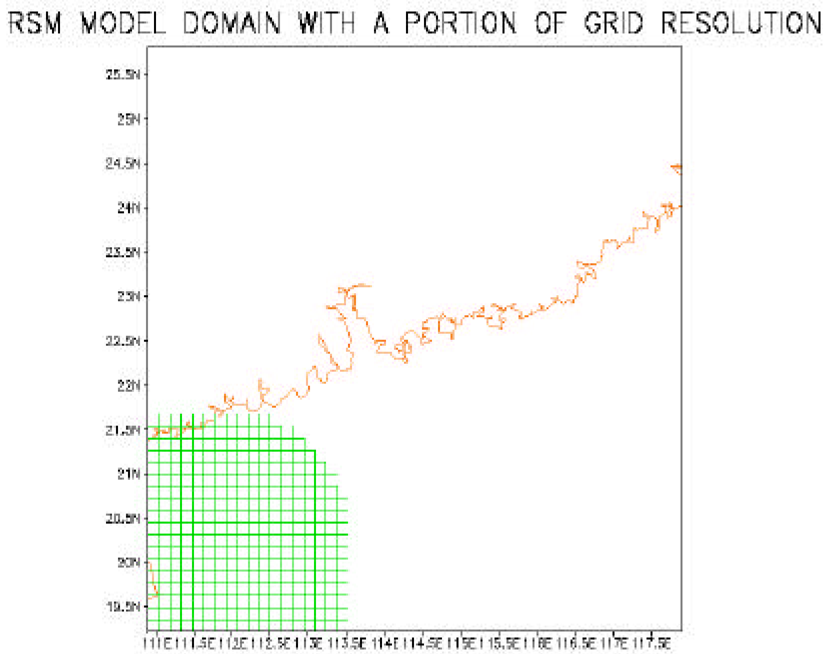


Fig. 1. Inner domain of RSM for regional long-range forecasting.

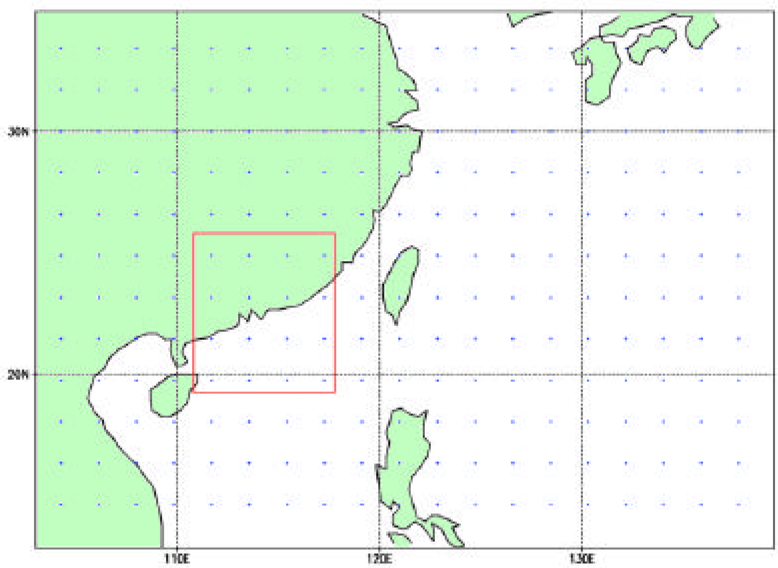


Fig. 2. Outer domain of the RSM.

3.2 Hardware set up

HKO runs the RSM on an IBM F50 computer which features 4 PowerPC 604e CPUs, 1 GB RAM, 100 GB disk storage, a 4 mm-tape drive and the AIX operating system. Currently, the model is configured to run on a single CPU which has a SPECfp_base_rate95 rating of 109. A test run of the model in December 2000 indicated that a 6-hour forecast is generated in 21 minutes. Theoretically, computations can be sped up by a factor by 3 when all 4 CPUs are used.

The IBM F50 machine is linked to the Internet by a broadband connection at 1.5Mb/s. Through this connection, initial and boundary data are downloaded from the ECPC FTP site.

A PC-based Linux server has been set up for model output post-processing, control script and utility development, and hosting a web site on the HKO Intranet for displaying the model output. The system configuration is shown in Fig. 3.

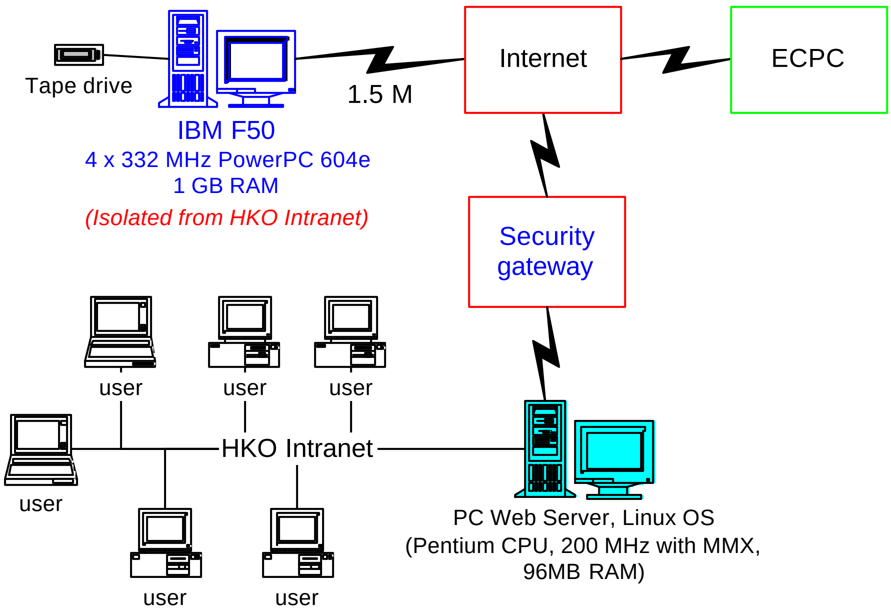


Fig. 3. Hardware set up.

3.3 Model adaptation and overcoming problems

Adaptation of RSM to HKO began in late November 2000. The work involved (1) development of shell scripts to download initial and boundary data from ECPC FTP site; (2) adaptation of the C2R97 (Coarse grid to Regional domain - 1997) version of the model to an IBM AIX environment; (3) implementation of seasonal regional forecast (srf) package to generate forecast up to 12-weeks ahead; and (4) development of a time-averaging utility.

3.3.1 Development of shell script for data acquisition

The model requires initial and boundary conditions at 6-hourly intervals generated by the GSM. In this connection, a shell script in KORN shell environment was developed to download data from ECPC FTP sites. A fresh set of initial and 12-week boundary data (674 files) is available every Saturday. The data volume is about 36MB.

3.3.2 Adaptation of the core modules C2R97

An attempt was made in late November 2000 to port the core modules called C2R97 of the RSM to the IBM F50 AIX platform for benchmarking the performance of the machine. The codes failed to compile on the IBM machine. The problem was traced to the inability of the IBM Fortran 90 compiler to interpret the Fortran 77 terminator in the namelist files. All the namelist files (e.g. LOCRSM, NAMLOC, NAMRIN and several others) were then modified to be compatible with the compiler of the IBM machine.

The first test run with the RSM was made based on initial and boundary data of 9 December 2000. However, this run was not successful. Examining all the log files suggested that this was probably due to computational instability. It was assessed that because of the small grid size (15 km), a time-step for integration less than the default value of 180 s should be used. In order to maintain the computational stability, the time step for integration should satisfy the following criteria:

$$\Delta t < \frac{\Delta x}{c} \text{ where c = 330m/s, the speed of sound}$$

Applying this formula, the time step for grid resolution of 15 km should be around 45 s. However, the RSM manual suggests a time step of 90 s. A set of experiments using different time steps was carried out. This solved the problem with the optimal time step determined to be 90 s.

3.3.3 Implementation of the seasonal regional forecast (srf) package

The next step was to implement the "srf" package which initiates successive 24-hour forecasts by the C2R97 to produce an extended forecast up to 12 weeks. It should be noted that this requires initial and boundary data at 6-hourly intervals from the global model for the entire 12-week period (see Fig. 4).

The original control scripts of "srf" package were developed under C shell environment and involved intensive date/time manipulation. In adapting the shell script "srf_fcst.csh" which controls the operation of "srf" package, it was found that the variable "endhr" could not rollover from 24 hours to 48 hours. The cause was identified to be the inability of IBM platform to handle the computation of string and integer variables at the same time under C shell environment. It took some time to ferret out the problem as it occurred only for particular combinations of numeric characters and integers. The solution was to convert all variables into integers for computation.

Having taken care of the above problem, a trial run of the "srf" package was made. However, the computation unexpectedly stopped at T+24 hours. To assess where the problem lay, C2R97 was isolated, run on its own and found to be able to generate forecasts beyond T+24 hours.

The premature termination of the program was due to C2R97 not being reinitiated by "srf" after 24 hours. The I/O (input and output) statements in the "srf" package were modified following which the "srf" package was successfully run.

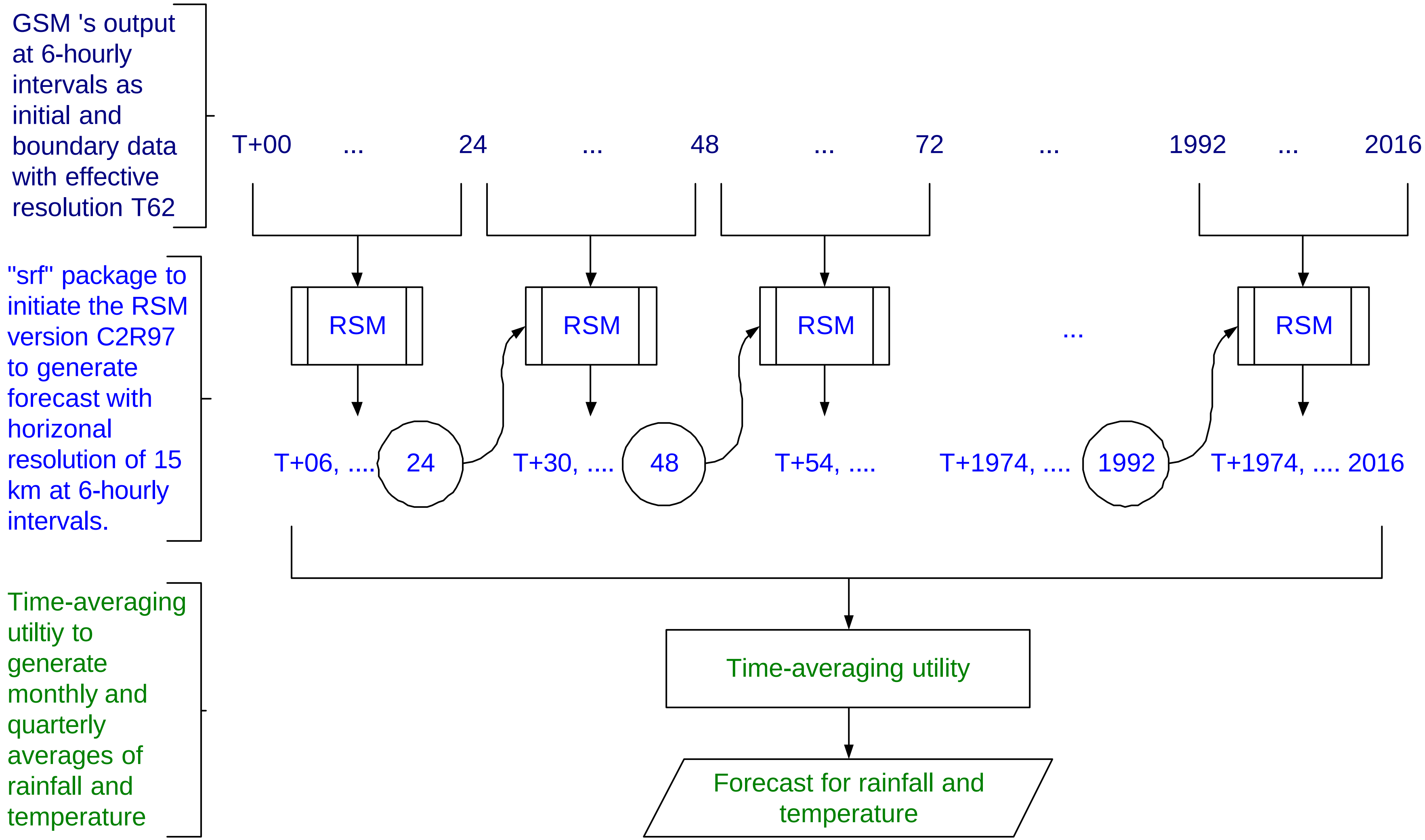


Fig. 4. Data flow of the model for long-range forecasting

3.3.4 Development of the time-averaging utility

Another difficulty encountered in the porting process was that the original time-averaging utility for generating daily, weekly, monthly and quarterly averages failed to run after compilation on the IBM F50. The source of the problem could not be identified after several weeks of debugging. It was then decided that it would be more efficient to develop a new time-averaging utility instead.

This was done with the help of a popular freeware GrADS (Grid Analysis and Display System). GrADS is chosen because it is able to read RSM's output files which are in grib format, perform arithmetic operations and produce graphic displays. A set of test data was used to ensure that the averages computed from this time-averaging utility matched those generated by ECPC. This time-averaging utility also produces time series plots of forecasts at selected grid points.

The data flow of the time-averaging utility is shown in Fig. 5. The products generated by this utility are summarized in Table 1.

Table 1. A summary of the products generated by HKO's time-averaging utility.

	Average temperature	Daily average precipitation	Time series of daily precipitation	Time series of daily temperature
Daily	✓	✓	-	-
Weekly	✓	✓	✓	✓
Monthly	✓	✓	✓	✓
Quarterly	✓	✓	✓	✓

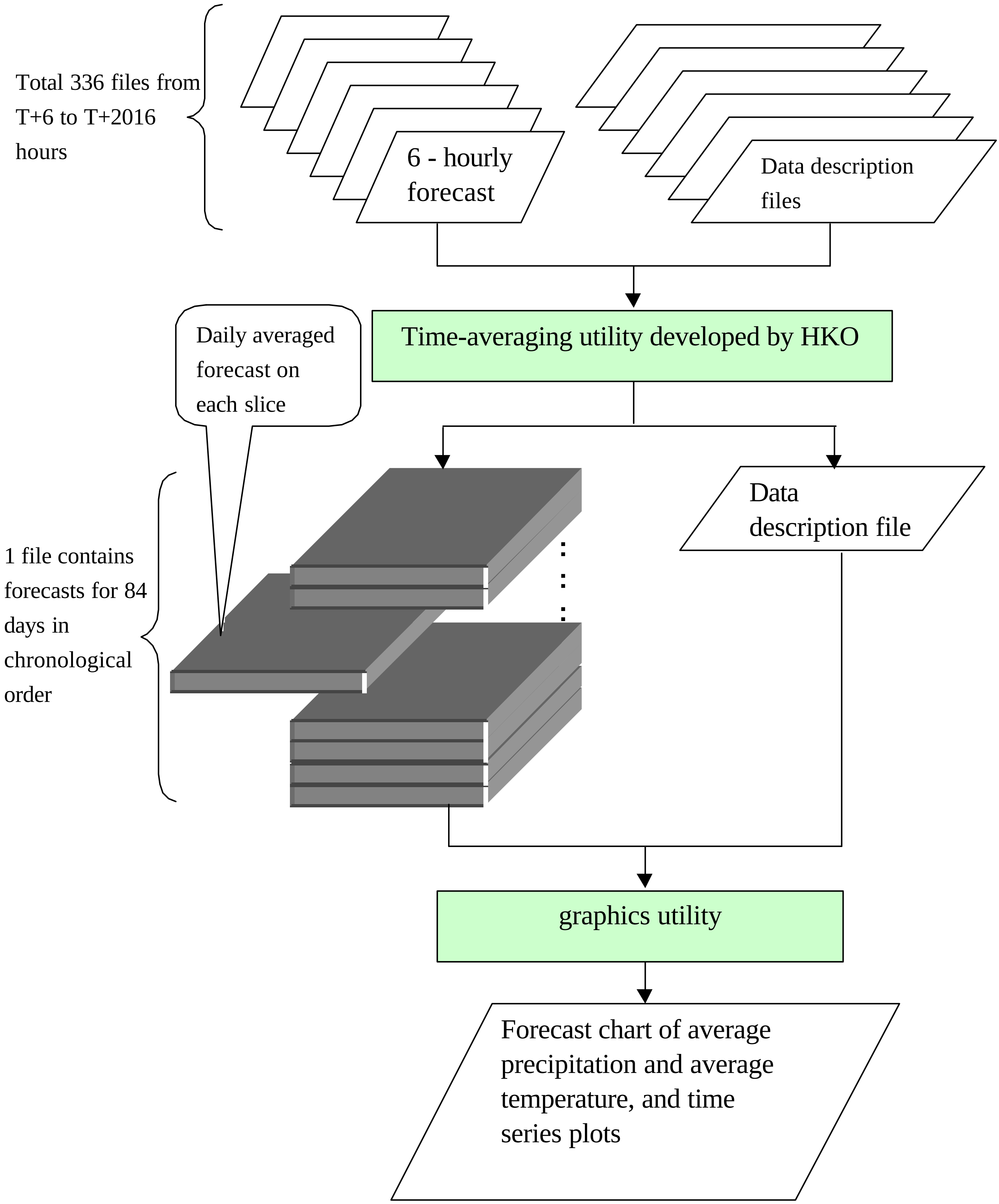


Fig. 5. Data flow of the time-averaging utility.

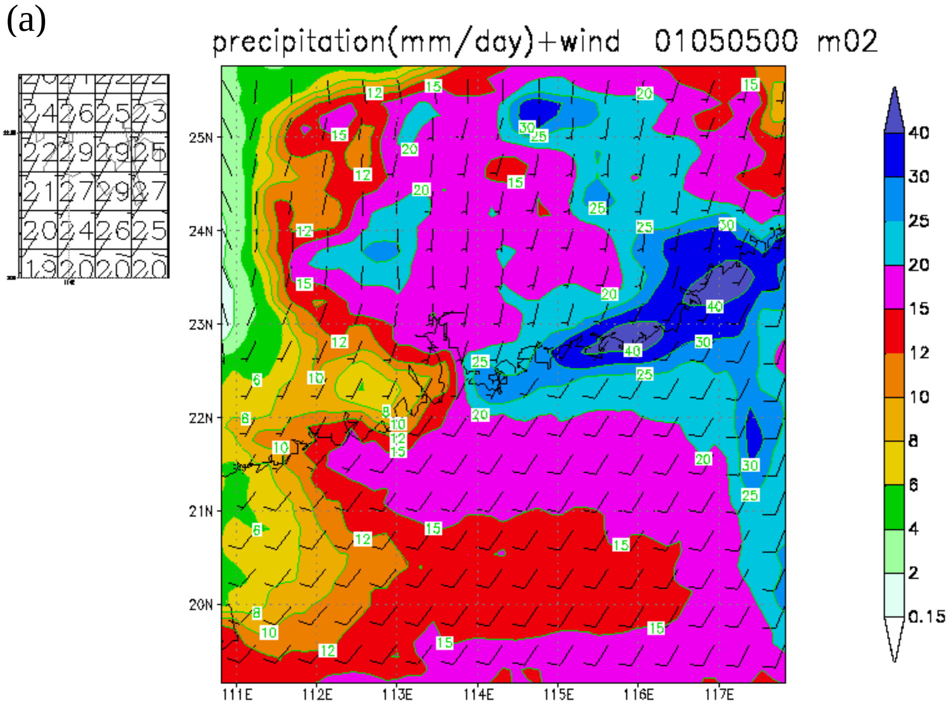
4. Some simulation results

Fig. 6a shows the forecast mean precipitation field for June 2001 as calculated by the time-averaging utility from the 6-hourly forecasts generated by the RSM on the IBM F50. The starting time of the simulation is 00Z on 5 May 2001. Fig. 6b shows the actual June 2001 precipitation field derived from NCEP's re-analysis data.

Comparison of the two patterns shows that the rainfall maxima along the south China coast is well forecast by the RSM. The small panel on the upper left corner of Fig. 6a shows that the forecast mean daily rainfall rate at Hong Kong's grid point is about 29 mm/day. This translates into a total rainfall of some 870 mm for the month. This forecast can be considered to be quite remarkable given that the actual rainfall recorded at the Hong Kong Observatory in June 2001 was 1083 mm. This was about 3 times the normal for June and making June 2001 the wettest on record.

Such agreement although remarkable is the result of an isolated run and could be fortuitous. It does provide some encouragement to the team.

(a)



(b)

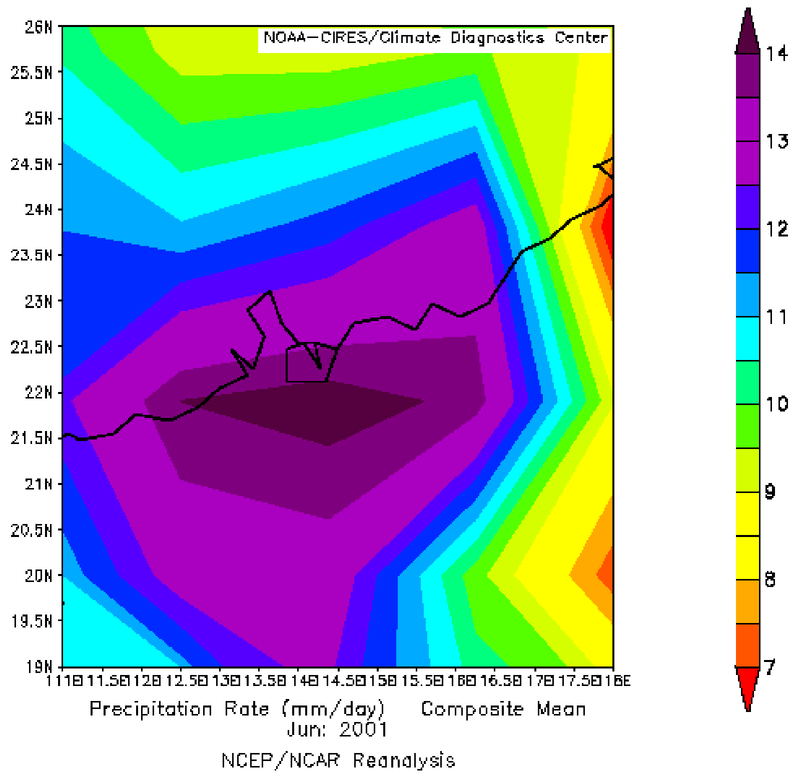


Fig. 6. Outputs based on the model run with initial time of 00Z on 5 May 2001: (a) monthly average rainfall forecast for June 2001. The small panel at the upper left corner shows the forecast rainfall rate in the 16 grid points around Hong Kong, and (b) actual June 2001 precipitation field derived from NCEP's re-analysis data.

5. Outlook

Routine run of the model will soon commence, and model evaluation will proceed in parallel. In time, the model climate will be generated based on the data 1999 and 2000 and used to correct systematic bias in the forecast.

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