JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2006

Hong Kong Observatory, Hong Kong, China

1. Summary of highlights

(i) An Intel-based blade server cluster, with a total peak performance of 432 GFLOPS, was commissioned for the enhancement of the Hong Kong Observatory's (HKO) nowcasting system as well as supporting research and development (R&D) functions of Numerical Weather Prediction (NWP) forecast and analysis systems.

(ii) The Non-Hydrostatic Model (NHM) adapted from Japan Meteorological Agency (JMA) was upgraded to include an improved radiation scheme, better land-surface characteristics and surface processes.

(iii) Clustered tropical cyclone (TC) track diagrams derived from JMA EPS TC data are generated in real-time for reference by the forecasters using an automatic clustering algorithm.

(iv) Under a WMO pilot project in Region II, city-specific NWP products, in the form of time series of weather parameters, are routinely produced based on the Operational Regional Spectral Model (ORSM) for access via the Internet by Members in the Region.

2. Equipment in use

The current computer systems at the HKO with their major characteristics are listed below:

Machine	Quantity	Peak performance	No. of CPU	Memory	Year of Installation
Galactic SuperBlade	1	432.0 GFLOPS	60	124 GB	2006
IBM p630 cluster	1	96.0 GFLOPS	20	40 GB	2004
IBM p690	1	140.8 GFLOPS	32	48 GB	2003
IBM SP	1	66.0 GFLOPS	44	31 GB	2001
CRAY SV1-1A	1	19.2 GFLOPS	16	8 GB	1999

The Galactic SuperBlade server cluster is used to support the R&D of nowcasting and NWP systems, including NHM and 4DVAR Data Assimilation System (DAS) for MPI RSM, the Message Passing Interface version of ORSM.

The IBM p630 server cluster is used to provide backup computing resources during contingencies, to operate a global-regional climate model suite and to support development of NWP systems.

The IBM p690 server is used to support the operation of the HKO nowcasting system, the trial operation of NHM and RAPIDS as well as their related R&D activities.

The IBM SP cluster is used to support various data acquisition and processing activities in support of operations of the forecasting office. Besides, it also provides a platform for the trial operations of the MPI version of the Regional Spectral Model (MPI RSM) and the Local Analysis and Prediction System (LAPS);

The CRAY SV1-1A is used to run the analysis and forecast system of the ORSM.

3. Data and Products from GTS in use

The approximate number of bulletins of observations received from GTS on a typical day in 2006 is given below:

SYNOP/SHIP	16,000
TEMP/PILOT	700
AIREP	500
AMDAR	2,000
SATEM/SATOB	200
TOVS/ATOVS	700

Other observations, such as RADOB, are also gathered through the GTS during the passage of tropical cyclones.

The approximate number of bulletins of NWP products received from GTS and through the Internet on a typical day in 2006 is given below:

Centre	Type	Number
Deutscher Wetterdienst (since December 2004)	GRIB	6,500
European Centre for Medium Range Weather Forecasts	GRIB	4,000
Japan Meteorological Agency	GRIB	3,000
US National Centers for Environmental Prediction	GRIB	18,500
United Kingdom Meteorological Office	GRIB	2,000

4. Forecasting system

4.1 System run schedule and forecast ranges

ORSM operates at 20 km and 60 km resolutions for an inner and an outer domain respectively. The model was originally developed by JMA and was adapted for short-range weather forecasting in Hong Kong. The 60-km model is run in a 6-hourly analysis-forecast cycle with boundary data extracted from JMA's Global Spectral Model (GSM) forecasts. The 20-km model is run in a 3-hourly analysis-forecast cycle and is one-way nested into the 60-km model. MPI RSM was also adapted from JMA and runs in a similar fashion as ORSM.

The forecast range of the 60-km ORSM and 20-km ORSM are 72 hours and 42 hours respectively. The outer 60-km ORSM is run 4 times a day for the area 9 °S – 59 °N, 65 – 152 °E based on 00, 06, 12 and 18 UTC analysis data, with an observation cut-off time of 3 hours. The inner 20-km ORSM is run 8 times a day for the area 10 – 35 °N, 100 – 128 °E based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC analyses, with an observation cut-off time of 2 hours. The run schedule and domain setting for MPI RSM are identical to those of ORSM.

NHM operates on an hourly basis on IBM p690 server at 5 km horizontal resolution. Model computation with initial time at T hour is started at T+50 minutes. The domain covers the area 19.5-25.0 ^{o}N, 111.2 – 117.1 ^{o}E and 12 hour forecasts are produced to give model guidance on severe weather and to support the operation of RAPIDS. The initial field of NHM is from the 20-km MPI RSM while the mixing ratios of the hydrometeors in the model cloud processes are initialised by moisture analysis output from LAPS (Albers 1995 and Albers et al. 1996). The model boundary conditions are extracted from 20-km MPI RSM.

4.2 Medium range forecasting system (4-10 days)

Operationally, forecasts up to 7 days ahead are formulated by forecasters based on a subjective assessment of the prognostic forecast products from the European Centre for Medium-range Weather Forecasts (ECMWF), JMA, the United Kingdom Meteorological Office (UKMO) and the National Centers for Environmental Prediction (NCEP) of the United States. Besides the above deterministic NWP models, ECMWF and JMA EPS data sets for four grid points nearest to Hong Kong are also acquired for forecasters' reference.

An automated medium-range forecasting system (AMFS) provides objective forecast guidance on local winds, state of sky, weather, as well as temperature and relative humidity ranges up to 7 days ahead. AMFS is run twice a day based on the 00- and 12-UTC model outputs primarily from JMA and ECMWF, supplemented with those from ORSM and the global model of NCEP. Besides the use of direct model outputs, key post-processing techniques employed in AMFS include linear regression, Kalman–filtering and poor-man ensemble averaging. The AMFS also incorporates some of the local forecasting rules used by forecasters.

An extreme wind forecast product alerts the forecasters of the possibility of occurrence of high winds in Hong Kong. The product makes reference to the ensemble maxima of the ECMWF EPS 10-metre wind data from the current and latest model runs. The possibility of high winds is assessed by tracking the highest ensemble maximum among all valid forecasts. The forecast information is presented to the forecasters in tabular form via an intranet web page.

As a product of a collaborative research project with JMA to study the utilization of the JMA EPS TC data, clustered TC track diagrams are generated in real-time for reference by the forecasters using an automatic clustering algorithm. Other post-processed products intended for operation such as weighted ensemble mean track and conditional strike probability map are also under planning.

Further study was carried out to calibrate the TC intensity forecasts derived from JMA EPS data based on the 2003-2005 dataset. An artificial neural network that could reduce the forecast errors of the

model outputs to a level with useful operational value was developed. Attempt was also made to calibrate the probabilistic TC category [tropical depression (TD), tropical storm (TS), severe tropical storm (STS) and typhoon (TY)] forecasts by means of the rank-histogram re-calibration method. It was found that the post-processing procedure developed could usefully improve the reliability of the probability forecasts for the TS, STS and TY categories.

4.3 Short-range forecasting system (0-72 hrs)

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

(i) ORSM

Meteorological data assimilated by the analysis scheme of ORSM are as follows:

(A) From GTS

SYNOP, SHIP	surface data and ship data
TEMP, PILOT	radiosonde and pilot data
AIREP, AMDAR	aircraft data
SATEM	satellite thickness data
TOVS, ATOVS	virtual temperature profiles
SATOB	satellite wind data

(B) FY-2C geostationary satellite of JMA
IR1 brightness temperature data

(C) From NCEP data server
Daily sea surface temperature analysis at 1-degree resolution

(D) Through regional data exchange
Data from automatic weather stations over southern China

(E) Local data
Tropical cyclone bogus data during tropical cyclone situations
Automatic weather station data
Wind profiler data
Doppler weather radar data

A three-dimensional multivariate optimal interpolation is performed four times a day based on 00, 06, 12 and 18 UTC data for the 60-km outer domain. For the inner domain, the same analysis scheme is performed 8 times a day based on 00, 03, 06, 09, 12, 15, 18, and 21 UTC. All analyses are applied to the 36 model levels. The first guess fields of the model analyses are provided by their respective latest forecasts.

The hourly rainfall information, derived from the real-time calibration of radar reflectivity with rain gauge data as well as from the FY-2C IR1 brightness temperature data, is incorporated into the model through a physical initialization process. In this process, the moisture of the initial field (between the lifting condensation level and the cloud top inferred from the cloud top temperature) at the point where rain is observed is adjusted to allow precipitation process to be switched on. The heating rate of the precipitation process is also adjusted to correspond to the rainfall amount observed. Rainfall information in the past hour and three hours are used in the outer and inner models' analysis respectively. A nonlinear normal mode initialization is performed before the forecast model is run.

(ii) MPI RSM

The data ingestion, objective analysis and initialization processes are identical to those of ORSM, except that the number of model levels is increased to 40.

(iii) NHM

The initial condition of NHM is obtained from interpolation of 20-km MPI RSM forecast output to the model grid at 5-km resolution.

The mixing ratios of hydrometeors (cloud liquid water, cloud ice, rain water, snow and graupel) on model levels in the initial condition are interpolated vertically from LAPS analysis on pressure levels.

(iv) LAPS

LAPS was originally developed by the Forecast Applications Branch in NOAA. The data assimilation system of LAPS is configured to ingest the 20-km ORSM output as background field. Hourly analyses are produced for a 125×105 horizontal grid of 10, 5 and 1 km resolution and on 21 constant pressure levels in vertical direction. Another domain with 121x121 horizontal grids and 37 vertical levels is set up to provide the initial condition of hydrometeors for NHM. The objective analysis scheme in LAPS is essentially a successive correction type scheme augmented by a moisture balance computation using three-dimensional variational technique.

LAPS assimilates surface observations (SYNOP, METAR, SHIP, QuikSCAT sea surface winds), upper level data (TEMP, PILOT, AIREP, AMDAR, SATOB, SATEM, ATOVS), FY2C IR brightness temperature and albedo. Observations from mesoscale observation networks are ingested in the system, including the automatic weather stations over Hong Kong and Guangdong, local wind profiler data, local GPS data, as well as Doppler radar reflectivity and velocity data from the radars in Hong Kong. In addition, derived wind products such as the TREC (Tracking Radar Echoes by Correction) winds obtained from SWIRLS are assimilated. The data cut-off time for hourly LAPS analysis at hour T for all the domains are set at T+35 minutes.

4.3.2 Model

4.3.2.1 In operation

(i) ORSM

The characteristics of ORSM are shown as follows:

Governing equations	Primitive hydrostatic equations
Prognostic variables	Natural log of surface pressure, horizontal wind components, virtual temperature, specific humidity
Horizontal coordinate, resolution, and number of grid points	Mercator projection, 20 km resolution for the inner model and 60 km for the outer, 151x145 grid points
Vertical coordinate and grid configuration	Sigma-P hybrid coordinate, 36 levels with model top at 10 hPa
Initialization	Non-linear normal mode initialization
Radiation scheme	Short wave and long wave (Sugi et al.,1990). Calculated every hour
Moisture processes	
Cumulus convection	Arakawa-Schubert (1974)
Mid-level convection	Moist convective adjustment proposed by Benwell and Bushby (1970) and Gadd and Keers (1970)
Large-scale condensation	Included
Grid-scale evaporation and Condensation	Included
Planetary boundary layer	Scheme proposed by Troen and Mahrt (1986) in which non-local specification of turbulent diffusion and counter-gradient transport in unstable boundary layer are considered
Surface	4-layer soil model
	Daily sea-surface temperature analysis (fixed in forecast)
	Climatological snow and sea ice distribution
	Climatological evaporation rate, roughness length and albedo
Numerical technique	Horizontal: Double Fourier
	Vertical : Finite difference
	Time: Euler semi-implicit time integration
Topography	Envelope topography, derived from 30-second latitude/longitude resolution grid point topography data
Horizontal diffusion	Linear, second-order Laplacian
Boundary conditions	For the outer model, 6-hourly boundary data including mean sea level pressure, wind components, temperature and dew point depression at 16 pressure levels (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 hPa) and the surface, are provided by JMA's GSM. For the inner model, hourly boundary data are provided by the outer 60km model

For further details on ORSM, please see JMA (1997).

(ii) MPI RSM

The characteristics of MPI RSM are identical to those of ORSM, except that the number of model levels is increased to 40. Further details on the formulation of MPI RSM is given in JMA (2002).

(iii) NHM

A general description of NHM is summarized as follows:

Governing Equations	Fully compressible non-hydrostatic equations
Prognostic variables	Momentum in x, y and z directions, pressure, potential temperature, turbulent kinetic energy, mixing ratio of water vapour, cloud water, cloud ice, rain water, snow and graupel
Numerical technique	Finite difference method on the Arakawa-C type staggered coordinate grid system. Fourth-order horizontal finite difference operator in flux form with modified advection treatment for improved monotonicity
Horizontal coordinate, resolution, and number of grid points	Mercator projection, 5 km resolution, 121x121 grid points
Vertical coordinate and grid configuration	Terrain following height coordinates, 45 levels on Lorenz grid with model top at 27 km
Time integration and time step	Horizontal explicit and vertical implicit (HE-VI) with acoustic filter, 24 seconds
Planetary boundary layer process	Diffusion processes based on diagnosed turbulent kinetic energy using a 1.5 order turbulent closure model, non-local effect considered by adjusting mixing lengths, similarity theory adopted for surface boundary layer.
Precipitation processes	Three-ice bulk cloud microphysics + Kain-Fritsch convective parameterization. Lagrangian treatment for fall of rain and graupel
Diffusion processes	Linear, fourth-order Laplacian with non-linear damper. Targeted moisture diffusion applied to grid-points with excessive updrafts
Radiation processes	Short wave and long wave (Sugi et al, 1990); radiation scheme incorporating cloud optical properties determined by cloud water/ice contents
Upper boundary condition	Fixed wall with Rayleigh damping
Lateral boundary condition	Hourly boundary conditions from 20-km MPI RSM forecasts
Topography and land-surface characteristics	USGS global 30 second topography (GTOPO30) and (Global Land Cover Characterization) (GLCC)

Further details on NHM can be found in Saito et al. (2006).

4.3.2.2 Research performed in this field

With the use of NHM, the impact of moisture data from LAPS on TC prediction was investigated (Malano et al. 2006). Results showed that the assimilation of satellite data in the initial moisture field of NHM could produce positive impacts on the simulation of the precipitation patterns around the storm centres.

4.3.3 Operationally available NWP products

(i) ORSM

The products of the 60-km ORSM include sea level pressure / geopotential heights, wind, temperature, dew point depression at 15 pressure levels (1000, 925, 850, 700, 500, 400, 300, 250, 200, 100, 70, 50, 30, 20, 10 hPa) and the surface as well as accumulated rainfall at 3-hourly intervals. For the inner 20-km domain, the forecast elements are the same as above but the products are generated at hourly intervals.

(ii) MPI RSM

The model outputs from MPI RSM are the same as those from ORSM.

(iii) NHM

Hourly prognostic charts on surface (hourly accumulated rainfall with sea level pressure and wind) and upper levels (975, 925, 850, 700, 500, 200 hPa), time series and time cross section for grid points at the HKO and near the Hong Kong International Airport are generated.

The 60-km ORSM TC track forecast guidance is routinely generated and disseminated via the GTS. The guidance is issued and updated twice a day based on the 00 and 12 UTC model runs whenever a TC reaching tropical depression strength appears in the area of responsibility of the HKO (10-30N, 105-125E). The information provided in the guidance includes forecast TC positions and intensity changes at 6-hourly intervals out to 72 hours. The HKO analysed TC warning position and intensity at 00 and 12 UTC are also included as initial values.

The following 60-km ORSM products in GRIB format are made available twice a day on the HKO's Server for International Exchange for access by registered national meteorological services.

Table 4.3.3.1 List of 60-km ORSM model products on the HKO's Server for International Exchange

Level	Content	Initial Time	Forecast Hours	Area	Resolution
Surface	Sea level pressure	00 and 12 UTC	12, 24, 36, 48, 60 and 72	5-45 °N, 90-140 °E	0.5x0.5 Degree
	Temperature				
	Relative humidity				
	Wind				

925, 850, 700, 500 and 400hPa	Geopotential height				
	Temperature				
	Relative humidity				
	Wind				
300, 250, 200, 150 and 100hPa	Geopotential height				
	Temperature				
	Wind				

Under a WMO pilot project in Region II, the HKO has been generating city-specific NWP products based on 60-km ORSM in the form of time series of weather parameters for reference by Members in the Region since early 2006. The products, based on the direct model output of 60-km ORSM at the model land grid nearest to the corresponding cities, are made available on a password-protected web site maintained by the HKO. By end of 2006, forecasts of 82 cities are being provided by the HKO.

Table 4.3.3.2 Forecast of meteorological elements provided in the city-specific forecast time series

Content	Initial Time	Forecast Hours	Display format
Sea level pressure	00 and 12 UTC	3-hourly intervals from 3 to 72 hours	In both graphical and tabulated data formats
Surface air temperature			
Surface dew point temperature			
Surface relative humidity			
Surface wind direction and speed			
Total cloud amount			
3-hourly precipitation			

Selected model products derived from ORSM are also disseminated in graphical format via the Internet for public consumption (URL: http://www.weather.gov.hk/nwp/nwpe.htm).

Table 4.3.3.3 60-km ORSM-based model forecast charts available on the Internet

Level	Content	Initial Time	Forecast Hours	Area
Surface	Weather depicting fine, cloudy and rain areas	00 and 12 UTC	12, 24, 36, 48, 60 and 72	8.5-41.7 °N, 92.1-143.8 °E
	Air temperature		00, 12, 24, 36, 48, 60 and 72	
	Sea level pressure			
	Wind			
850hPa	Wind			
	Relative vorticity and streamline			

700hPa	Wind			
	Relative humidity and streamline			
500hPa	Wind			
	Geopotential height			
200hPa	Wind			
	Jet stream and streamline			

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

(i) ORSM

Local text forecasts based on ORSM prognostic data with warnings of thunderstorms and rainstorms are generated automatically. Post-processing techniques, including Kalman Filtering and linear regression, are employed to adjust the temperature forecasts, including the daily minimum and maximum temperature forecasts in Hong Kong.

A weather map algorithm is employed to produce hourly weather map (fine and cloudy areas, accumulated rainfall contours) based on ORSM prognostic data. Rainstorm risk maps based on model-forecast rainfall rates are compiled from the latest five 20-km ORSM runs, akin to the ensemble approach. Near real-time rainfall verification results are provided to the forecasters.

TC track forecasts from consecutive runs of 60-km ORSM and 20-km ORSM are generated to facilitate forecaster's interpretation of model forecasts. The TC positions, determined as the point of minimum sea level pressure, are identified with the fitting method of overlapping parabolic interpolation (Manning & Haagenson, 1992).

(ii) MPI RSM

MPI RSM produces the same set of ORSM products for forecaster's reference. In addition, forecast satellite imageries (infrared channel) using a radiative transfer model were introduced to the product suite.

To take advantage of the vast amount of forecast information available from the two independent cycle runs of ORSM and MPI RSM, an ensemble forecasting system based on the current and time-lagged forecasts was set up. A maximum of 28 member forecasts can be obtained at any grid point in the neighbourhood of Hong Kong and the forecast information is presented in the form of standard EPS meteograms. An interactive web interface is provided for forecaster's easy control over which elements, grid points, model runs, valid times, etc., are to be included in the meteograms. An option is also provided to automatically remove any bias in the ensemble mean.

(iii) NHM

The precipitation forecast from NHM is used in the RAPIDS to blend with rainfall nowcast products generated by SWIRLS to provide quantitative precipitation forecast up to 6 hours ahead. Please refer to Section 4.4.2 below for more details.

(iv) LAPS

Based on the LAPS system, a tropical cyclone specific application called TC-LAPS is in operation. The purpose of the TC-LAPS is to provide the forecasters with rapidly updated analysis of 3-dimensional wind structure of approaching tropical cyclones. It also aims to help forecasters estimate the probability of the occurrence of strong/gale force winds over the territory. Wind field of horizontal resolution of 10, 5 and 1 km at standard pressure levels, plus vertical cross-section across the TC centre are generated hourly.

(v) TIPS

A Tropical Cyclone Information Processing System (TIPS) was developed and has been put into operational use since 2005. TIPS ingests the actual and forecast positions of TCs from NWP products of ECMWF, JMA, EGRR and NACEP as well as Observatory's own ORSM to display these tracks on screen. These forecast tracks are processed to produce an ensemble track to facilitate the forecasters to determine the subjective forecast track. Forecasters can modify the weightings for individual model outputs and generate the ensemble forecast interactively. Other meteorological information such as subjective forecasts from other warning centres, satellite pictures, radar fixes, strike probability maps, wind and rainfall forecasts are integrated into TIPS so that the duty forecasters can have all the data for dealing with tropical cyclones at their finger-tip.

(vi) Others

A forecasting tool for estimating the probability of strong and gale force winds in Hong Kong during TC situations is in operation. The probability is basically determined by regression of the spread of forecast movements from various NWP models against a Gaussian distribution. The resulting probability is then obtained from the spread and the climatological probability isopleths for occurrence of strong and gale force winds. In 2006, the tool was further enhanced to facilitate the conduct of "what-if" analyses based on user's input of alternative forecast positions of the TC.

A TC forecast guidance tool is also in use to forecast the TC intensity up to 72 hours ahead using JMA global model output. Based on regression of model forecast on central pressure against the best-track data in the past few years, a set of best-estimated parameters is derived and then applied to the real-time NWP forecasts to calculate the probability of particular class of intensity, maximum wind and central pressure of the TCs.

4.3.4.2 Research performed in this field

An evaluation study was conducted on the application of multi-model super-ensemble technique to temperature forecasting. Results showed that the new technique could generate more accurate forecasts than other post-processing methods currently in use (Kalman filtering, regression method). Software would be developed to generate real-time super-ensemble temperature forecasts for forecaster's reference.

Much research work has gone into determining the probability and timing for the occurrence of strong or gale force winds caused by a given tropical cyclone on a certain track. A statistical approach is used for the calculation and a set of probability isopleths are integrated into TIPS for reference by forecasters. Other research topics include use of different weighting for generating the ensemble tropical cyclone track and a vector motion consensus method for extending the working track for a longer time frame are in the pipeline.

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

4.4.1 Nowcasting system

4.4.1.1 In operation

SWIRLS is a radar-based nowcasting system with output updated every 6 minutes. It has been put into operation since 1999, with an original objective for short-range rainfall forecasting in support of rainstorm warning operation in Hong Kong. It has since evolved into a multi-function system with a wide spectrum of applications, including flood warning and landslip warning. Major components of SWIRLS include: (i) TREC which derives the multi-scale "wind" fields at multi-altitude levels by tracking the movement of individual radar reflectivity cells using the TREC technique; (ii) GTrack which tracks and predicts the movement of clusters of radar echoes using an object-oriented approach; (iii) Dynamic radar-raingauge analysis which updates the Z-R relation dynamically using radar reflectivity and rain-gauge data in order to re-calibrate the radar rainfall in real-time; (iv) QPF which extrapolates the rainfall re-calibrated radar echoes along the TREC wind direction using a semi-Lagrangian advection scheme to produce rainfall accumulations out to 6 hours over Hong Kong and nearby areas; (v) Landslip Alert which predicts the number of landslides in the next 3 hours based on a rainfall-landslide correlation model developed by geotechnical engineers; (vi) Flood Alert which predicts flash floods over low-lying areas based on the 1-hour QPF of SWIRLS; and (vii) TephiViewer which calculates a number of thermodynamical instability indices based on upper-air observations and various NWP model outputs to alert forecasters of the potential of severe weather.

4.4.1.2 Research performed in this field

(i) Lightning – An algorithm to predict the onset and intensity of cloud-to-ground lightning is being developed based on radar reflectivity data and 3-dimensional temperature analysis fields of LAPS.

(ii) Downburst / Wind gust – A physically-based algorithm to predict the maximum possible wind gust due to downburst associated with thunderstorms is under development. Major inputs include radar-estimated vertically integrated liquid water and ascent data.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

RAPIDS

RAPIDS has been put in trial operation since April 2005 to provide quantitative precipitation forecasts for 1-6 hour forecasts at 2 km resolution on an hourly update basis (Li et al. 2005, Wong and Lai 2006). The system blends the output from SWIRLS and NHM with their respective weightings based on real-time verification results of precipitation predictions. To correct for spatial errors in the location of forecast precipitation field in NHM, a spatial uniform phase correction is applied to shift the pattern of model rainfall output before merging with the SWIRLS products.

4.4.2.2 Research performed in this field

Studies on the performance of RAPIDS in heavy rain and tropical cyclone cases showed that the blending technique could produce improved precipitation predictions. Studies such as regional phase correction and incorporation of their uncertainties in blending are underway.

4.5 Specialized numerical predictions

No specialized numerical model is being operated at the moment.

4.6 Extended range forecasts (ERF) *(10 days to 30 days)*

No ERF model is being operated at the moment.

4.7 Long range forecasts (LRF) *(30 days up to two years)*

4.7.1 In operation

The Observatory operates a Regional Climate Model (RCM) adapted from the Experimental Climate Prediction Center (ECPC) of the University California at San Diego, USA, and generates seasonal temperature and rainfall forecasts for Hong Kong and its neighbouring areas. Starting from March 2006, the forecast products of RCM are made available to the general public via the Observatory's Internet website.

4.7.2 Research performed in this field

In 2006, efforts were devoted to adapt the Global Spectral Model (GSM) and the latest version of RCM from ECPC. Adaptation of the global-regional suite of models was successfully carried out. Using NCEP/NCAR re-analysis data to initialize the GSM, the HKO is now capable of generating boundary conditions required to operate the RCM at much finer resolution. The performance of the Global-regional suite over the South China coastal region was evaluated and compared with that of the existing RCM and the global-regional suite was found to have slightly better skill than the existing RCM.

4.7.3 Operationally available EPS LRF products

No EPS LRF system is being operated at the moment.

5. Verification of prognostic products

5.1 Verification of forecasts generated by ORSM is conducted on a routine basis. Forecast parameters including zonal and meridional winds, temperature, pressure/geopotential heights and relative humidity at a number of model levels are verified against ORSM analysis and rawinsonde observations for the area 10 - 40°N, 95 – 135 °E. The monthly verification results of 60-km ORSM 12 UTC runs for 2006 are presented in Appendix I.

6. Plans for the future *(next 4 years)*

6.1 Development of the GDPFS

6.1.1 No significant change to the operational DPFS is expected in 2007.

6.1.2 The CRAY SV1-1A will be replaced by an enhanced high performance computing system with a peak performance of around 5 TFLOPS in 2008 to support the development and operation of a new suite of high resolution NWP models. The new suite of NWP models, comprising meso-scale models with horizontal resolutions ranging from 20 to 2 km, is expected to be fully commissioned in mid-2009.

6.2 Planned research Activities in NWP, Nowcasting and Long-range Forecasting

6.2.1 Planned Research Activities in NWP

(i) Study on running NHM in higher horizontal resolution (e.g. 2 km) in support of RAPIDS will continue. The development of NHM applications to provide guidance on severe weather prediction in the very-short-range will be explored.

(ii) The development of a 4DVAR DAS for future operation with MPI RSM will continue.

(iii) More forecasting tools and products based on research studies on EPS TC data will be developed for operational use. The detailed results of the studies will be reported.

6.2.2 Planned Research Activities in Nowcasting

(i) Continue development and testing on the nowcasting algorithms for lightning and wind gust associated with thunderstorms;

(ii) Development and testing of SWIRLS for participation in the WWRP B08FDP project.

6.2.3 Planned Research Activities in Long-range Forecasting

The new suite of global-regional models will be put into operation soon. The possibility of generating monthly forecast using this model suite will be explored.

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Appendix I — Summary of Verification of Prognostic Products Generated by 60-km ORSM 12 UTC Runs for 2006 (Verification Area: 10 – 40 °N, 95 – 135 °E)

Table 1. RMS error of geopotential height at 500 hPa against analysis (in m)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
24	10.2	9.9	9.3	11.9	10.3	9.1	12.9	9.2	10.0	9.5	10.4	11.1	10.3
72	18.2	24.9	18.3	21.0	22.9	16.6	22.2	15.5	18.0	17.9	21.4	21.7	19.9

Table 2. RMS error of geopotential height at 500 hPa against observations (in m)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
24	15.8	16.5	16.0	16.4	14.2	13.0	15.0	13.0	13.4	12.5	14.7	14.7	14.6
72	23.8	27.9	23.5	25.4	24.7	19.8	24.1	18.3	19.7	19.9	26.1	26.5	23.3

Table 3. RMS of vector wind errors at 250 hPa against analysis (in m/s)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
24	6.7	7.1	7.4	8.4	8.0	7.1	7.1	6.4	6.9	7.1	6.9	6.1	7.1
72	9.7	10.9	10.8	13.4	13.1	11.2	11.0	9.6	10.9	12.3	11.0	9.7	11.1

Table 4. RMS of vector wind error at 850 hPa against analysis (in m/s)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
24	3.8	3.9	3.8	4.7	4.7	4.4	5.3	4.4	4.4	4.0	4.5	4.7	4.4
72	6.1	6.3	6.0	7.2	8.1	7.4	9.7	7.9	8.4	6.3	6.6	6.7	7.2

Table 5. RMS of vector wind errors at 850 hPa against observations (in m/s)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
24	10.1	10.0	10.1	10.2	9.8	9.1	9.6	8.1	8.3	7.8	9.6	9.8	9.4
72	12.2	12.1	12.6	13.1	12.7	12.8	13.3	11.4	11.4	10.1	12.0	12.5	12.2