Global Data Processing System
Progress Report for 2002

HONG KONG, CHINA

1. Summary of highlights

The IBM RS/6000 SP server cluster was upgraded in 2002. It supports the trial operation of the Advanced Regional Prediction System (ARPS) at 6 km resolution commencing 2002.

Under the AMDAR programme, additional AMDAR observations are retrieved and used in a newly developed aircraft turbulence alarm for real-time monitoring and detection of low-altitude wind shear and turbulence in support of operations at the Hong Kong International Airport. The use of AMDAR data in the Operational Regional Spectral Model (ORSM) of the Hong Kong Observatory (HKO) also improved model analysis and short-range forecast of upper level winds.

2. Equipment in use at the centre

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

Machine	Quantity	Peak performance	No. of CPU	Memory	Year of Installation
IBM SP	1	66.0 GFLOPS	44	25 GB	2001
CRAY SV1-1A	1	19.2 GFLOPS	16	8 GB	1999
SGI Origin 2000	1	4.0 GFLOPS	8	2.5 GB	1998
SUN E450	2	2.4 GFLOPS	4	1 GB	1998
SGI O2	2	0.4 GFLOPS	1	1 GB	1998

The IBM SP cluster is used for the following purposes :
(i) to generate diagnostic products ;
(ii) to plot weather charts ;
(iii) to produce graphics displays for supporting the operations of the Central Forecasting Office (CFO) and the Airport Meteorological Office (AMO) ;
(iv) to run a database for keeping climatological records ;
(v) to support climatological research ;
(vi) to support the data pre-processing and graphical product generation of the ORSM ;
(vii) to support the trial operation of ARPS at 6 km resolution after 2002 enhancement ; and
(viii) to support test runs of LAPS (developed by the US Forecast Systems

Laboratory) for producing a frequently updated high-resolution local analysis for nowcasting purpose.

The SP cluster has replaced the IBM 590 servers, which become obsolete.

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

The SGI Origin 2000 serves as a backup to the data pre-processing and graphical product generation of the ORSM. It is also used to support the research work on non-hydrostatic models.

One of the SUN E450 is used for the provision of Numerical Weather Prediction (NWP) products to support aviation operations using ORSM and the verification of the model products. The other is for running the rainstorm nowcasting system to support CFO. It is planned to acquire a new computer to operate the nowcasting system with enhancement features in the following year.

Two SGI O2 are used as graphics display workstations for the visualization of nowcasting products and staging the web server for ORSM products.

3. Data and products from GTS in use

The approximate number of bulletins of observations received from GTS on a typical day in 2002 is given below:

SYNOP/SHIP	76000
TEMP/PILOT	2700
AIREP	4200
AMDAR	700
SATEM/SATOB	2400
TOVS/ATOVS	48000

Around 460 GRID bulletins of UKMO global model output and 3,200 GRIB files of JMA and ECMWF global model outputs are received daily on the GTS. On days with tropical cyclones in the region, additional GTS bulletins (e.g. RADOB) are received.

Around 18800 NCEP GSM products in GRIB format are routinely retrieved from the Internet each day starting April 2002.

The HKO started the AMDAR programme in late 2000. In 2002, there was more than 20 % of increase in the number of AMDAR bulletins as compared to that of the previous year. The HKO received about 150 additional AMDAR bulletins per day from US and Australian airlines landing or departing from the Hong Kong

International Airport via the GTS. An application tool for the aircraft turbulence alarm was developed utilizing AMDAR observations for real-time monitoring and detection of low-altitude wind shear and turbulence in support of AMO operations. The additional AMDAR observations were also ingested to the ORSM, resulting in improvements on model analysis and short-range forecast of upper level winds.

4. Data input system

Automated.

5. Quality control system

Incoming data are checked automatically for adherence to prescribed coding formats, internal consistency, and physical and climatological limits. Then, the data are checked automatically against the first guess field generated by the ORSM (external consistency check).

Quality control of outgoing observational data originating from Hong Kong is implemented to ensure conformity to WMO coding formats and to enforce checking against internal consistency, time consistency as well as physical and climatological limits.

6. Monitoring of observing system

Monitoring on the territorial level.

7. Forecasting system

The HKO operates the ORSM at 20 km and 60 km resolutions. The model was originally developed by the Japan Meteorological Agency (JMA) and was adapted for short-range weather forecasting in Hong Kong. The 60-km model is run at a 6-hourly analysis-forecast cycle with its boundary data extracted from JMA's Global Spectral Model (GSM) forecasts. The 20-km model is run at a 3-hourly analysis-forecast cycle and is one-way nested into the 60-km model.

The HKO started the trial operation of ARPS at 6 km and 30 km resolutions in 2002. The ARPS was originally developed by the US Center for Analysis and Prediction of Storms (CAPS) and was adapted for applications in storm-scale to mesoscale forecasting in Hong Kong. Similar to 60-km ORSM, the 30-km ARPS is also run at a 6-hourly analysis-forecast cycle with its boundary data provided by the JMA's

GSM output. The 6-km ARPS is run at 3-hourly intervals with its first guess and boundary fields extracted from the outer 30-km ARPS.

7.1 System run schedule

The outer 60-km ORSM is run 4 times a day with a cut-off time of 3 hours, to produce 48-hour forecasts for the area 9 °S – 59 °N, 65-152 °E based on 00, 06, 12 and 18 UTC analysis data. The inner 20-km ORSM is run 8 times a day for 24-hour forecasts, for the area 10–35 °N, 100-128 °E based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC analyses, with a cut-off time of 2 hours.

Similar to the ORSM system, the outer 30-km ARPS is run 4 times a day and the inner 6-km ARPS is run 8 times a day. The outer model produces 30-hour forecasts for the area 10-33 °N, 102-126 °E, based on 00, 06, 12 and 18 UTC analysis data with a cut-off time of 3.5 hours. The inner 6-km ARPS produces 12-hour forecasts for the area 19-25 °N, 111-117 °E, based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC analyses with a cut-off time of 1.25 hours.

7.2 Medium-range forecasting system (4-10 days)

Forecasts up to 5 days are formulated based on a subjective assessment of the prognostic fields disseminated by ECMWF, JMA, UKMO and NCEP.

7.3 Short-range forecasting system (0-72 hours)

7.3.1 Data assimilation, objective analysis and initialization

(i) ORSM

Meteorological data assimilated by the analysis scheme of the 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) From RSMC Data Serving System (DSS) of JMA

GMS digital data - total cloud amount, mean cloud top temperature and its standard deviation for moisture bogus

GMS cloud motion vectors during tropical cyclone situations

(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 the south China coastal region

(E) Local data

Tropical cyclone bogus data during tropical cyclone situations
Automatic weather station data
Wind profiler data
Doppler weather radar data

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 objective 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 36 vertical levels.

The horizontal domains of both inner and outer models compose of 151 x 145 model grids in Mercator projection. The first guess fields of the model analyses are provided by their respective latest forecasts.

Hourly rainfall information derived from real-time calibration of radar reflectivity with rain gauge data as well as from the GMS digital cloud data, are 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. The rainfall information in the hour preceding analysis time is used in the outer model. For the inner model, pre-runs for 3 hours preceding analysis time are performed to incorporate the rainfall information.

Non-linear normal mode initialization is performed before the forecast model is run.

(ii) ARPS

The ARPS Data Assimilation System (ADAS) assimilates SYNOP, METAR, SHIP, TEMP, PILOT, AIREP, AMDAR, SATEM, TOVS, ATOVS, SATOB, QuikSCAT sea surface winds, GMS brightness temperature and albedo, data from automatic weather stations over the south China coastal region, local wind profiler data, as well as Doppler radar reflectivity and velocity data from the local radars in Hong Kong.

In the trial operation of ARPS, objective analyses are performed for both outer 30 km and inner 6 km models at 40 vertical levels using Bratseth successive correction scheme. The scheme contains a telescoping correlation parameter that allows for the use of a variety of data sets with varying spatial resolution (Bratseth, 1986; Brewster, 1996). It also includes a method for utilizing the Doppler radar velocity data to provide increments to the horizontal wind by estimating the Cartesian component increment from the radial wind. Radar reflectivity data is also assimilated in ADAS to adjust model microphysical variables (cloud water, cloud ice, rain water, snow and hail) and relative humidity.

7.3.2 Model

(i) ORSM

Characteristics of the ORSM is shown as follows :

Basic equations	Primitive hydrostatic equations
Vertical	Sigma-P hybrid coordinate, model top at 10 hPa.
Forecast parameters	ln (surface pressure), horizontal wind components, virtual temperature, specific humidity.
Initialization	Non-linear normal mode initialization
Physical processes	
Radiation scheme	Sugi *et al.*(1990)
Short wave	Calculated every hour
Long wave	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 methods	
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.

Further details on the formulation of the ORSM are given in JMA (1997).

(ii) ARPS

Characteristics of the ARPS is shown as follows :

Basic equations	Non-hydrostatic, fully compressible
Horizontal discretization	Arakawa C-grid
Vertical coordinates	Generalized terrain-following, vertical stretching with hyperbolic tangent
Forecast parameters	x, y, z components of the Cartesian velocity, perturbation potential temperature, perturbation pressure, six categories of water substance (water vapor, cloud water, rain water, cloud ice, snow, hail)
Physical processes	Full long- and short-wave radiation including cloud interactions, cloud shadowing and terrain gradient effect. Atmospheric radiation transfer parameterization, radiation computed at staggered points. Transmission functions computed in the CO_2, O_3 and the three water vapor bands with strong absorption using table look-up in the longwave scheme.
	Moist processes include ice microphysics and Kain-Fritsch cumulus parameterization.
	Convective PBL scheme based on 1.5 TKE turbulent mixing after Sun and Chang (1986), anisotropic subgrid scale turbulence.
	In surface physics, surface fluxes calculated from the stability-dependent surface drag coefficients, and predicted surface temperature and surface volumetric water content. 2-layer diffusive soil model with surface energy budget.

Numerical methods	Finite difference
	Split-explicit time integration with vertically implicit solver.
	Fourth order in horizontal and vertical for both scalar and momentum advection.
	Vertically implicit mixing.
	Fourth order computational mixing.
	Acoustic wave anisotropic divergence damping in horizontal and vertical.
	Upper level Rayleigh damping.
	Robert-Asselin time filtering for leapfrog time
Topography	Derived from 30-second latitude/longitude resolution grid point topography data.
Boundary conditions	Similar to the ORSM, 6-hourly boundary data for the outer model are provided by JMA's GSM. For the inner 6 km model, hourly boundary data are provided by the outer 30 km model.

Further details on the formulation of the ARPS are given in Xue *et al.* (2000, 2001).

7.3.3 Numerical weather prediction products

(i) ORSM

The outer 60-km ORSM outputs 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 same forecast elements as the above are output but at hourly intervals.

(ii) ARPS

The 6-km and 30-km ARPS output pressure, temperature, horizontal wind, vertical velocity, vorticity and divergence at selected pressure levels (925, 850, 700, 500, 200 hPa) as well as surface accumulated rainfall at hourly intervals.

7.3.4 Operational techniques for application of NWP products

(i) ORSM

2D and 3D graphical model products are made available to the forecasters for reference through a web-based display. These products include forecast time cross-section and tephigrams as well as forecast rainfall distribution charts for Hong Kong. Local text forecasts based on ORSM prognostic data with warnings of thunderstorms and rainstorms, are generated automatically.

Post-processing of the model prognostic data such as application of Kalman Filtering technique and regression method are employed to generate instantaneous temperature as well as 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. The technique of pattern recognition is employed in rainfall verification with a view to identifying systematic bias of rainstorm locations and providing better interpretation guidance.

Tropical cyclone (TC) track forecasts from consecutive 6-hourly runs of 60-km ORSM are generated to facilitate forecaster's interpretation of model forecasts. Ensemble forecast of TC track derived from global model outputs is also compiled. Forecasters can modify the weightings for various model outputs and generate the ensemble forecast interactively.

(ii) ARPS

Model derived products such as vertically integrated condensate and maximum reflectivity are generated to facilitate forecasters' interpretation of model forecasts of cloudiness and rain. In addition, to assist forecasters' formulation of forecasts of local phenomena, model outputs of surface wind, pressure, temperature and dew point temperature are interpolated to observational sites, mimicking the display of local observational data from automatic weather stations. These "forecast observations" are plotted and overlaid on the top of a canvass of fine streamlines, on which warm colors suggest divergence and cold colors suggest convergence. The suggested convergence effect could be a tool for forecasting the development of heat showers later in the day during the summer time.

8. Plans for the future

Investigation will be carried out on the use of additional mesoscale observations particularly from local remote-sensing networks such as radars, wind profilers and GPS in the vicinity of Hong Kong in nowcasting and mesoscale modelling systems. Incorporation of very short-range NWP-based forecasts and satellite information into the nowcasting system will be explored. Variational techniques for assimilating asynoptic data and remote-sensing data in the development of non-hydrostatic models as well as ensemble methods using multi-analyses, multi-models and multi-model runs will also be explored in the context of mesoscale weather prediction.

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