Progress Report on the Global Data Processing System in 2002

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1. Summary of Highlights

The main changes to the global and regional versions of the numerical prediction suites were the following:

15 Mar.	Use SATOB data in GDAPS (Global Data Assimilation and Prediction System) assimilation cycle
20 Mar.	Use ACARS data in GDAPS assimilation cycle
15 Apr.	Assimilation of the SATOB data from the GMS-5 and the SATEM-C data in the operational global and regional prediction system
1 Nov.	Use NCEP daily SST data in the GDAPS
15 Nov.	Assimilation of the ACARS data in the operational global and regional prediction system

2. Equipment in Use at the KMA

The supercomputer SX-5/28M is partly dedicated for the operation of the short, medium and long-range numerical weather prediction including climate simulation.

💻 Main computer: SX-5/28M2

- Peak Performance：224G Flops with 28 processors
- Memory ：224G bytes
- Single CPU performance: 8G flops
- Mass storage system ：3.0T bytes

💻 Other facilities: SX-4/2A

- Peak Performance：4G Flops
- Mass storage system ：1.4T bytes

3. Data and Products in Use

More than 5,000 synoptic observations, and various asynoptic observations, including satellite retrieval data, are used daily in the GDAPS. Table 1 presents the types and numbers received through GTS at KMA. The pre-processing procedures such as data acquisition, quality control and decoding, are fully automated.

Table 1. The types and numbers of observations received through GTS, and the percentage of data used in global data assimilation for 24 hours.

	Data type	Number of data/day	% used in assimilation
1	SYNOP/ SHIP	45,000	87
2	BUOY	8.900	73
3	TEMP/ PILOT	3,100	81
4	AIREP/ AMDAR	9,100	25
5	SATEM	27,000	73
6	SATOB	24,000	86
7	ATOVS	30,000	15
8	ACARS	135,000	7
9	AWS	11,000	-
10	PAOB	400	100

4. Data Input System

Fully automated system

5. Quality Control System

Various real-time quality control checks are performed for each observation received from GTS.

6. Monitoring of Observing System

Most of observations are monitored in terms of availability and quality.

7. Forecasting System

Along with data assimilation system having 6-hour updating cycle, the GDAPS produces 240-hour prognosis for the large-scale atmospheric variables. It provides time-dependent lateral boundary conditions for the regional models and steering flow for typhoon model.

The RDAPS runs twice a day for 48-hour forecasts, with 12-hour pre-assimilation with dynamic nudging, FDDA. Five typhoon track forecasts are obtained from BATS, RDAPS, two GDAPS(T106/L21 and T213/L30), and EPS when typhoon appears in Western Pacific. In addition, there are two types of applied models; Wave models for wave height and direction on both global and regional domain, and two statistical models of Perfect Prog Method (PPM) and Kalman Filter (KF) method for probability of precipitation and max/min temperature, respectively.

7.1 System Run Schedule

Two types of global forecasts are produced at KMA. The GDAPS for 84-hour projection runs at 00 UTC and 12 UTC with 2.5-hour data cutoff. The 84-hour projection is used for short-range weather forecasts and for the provision of lateral boundary condition for the two high-resolution(10km and 5km with 33 layers) regional models. The GDAPS for 10-day projection runs at 12 UTC with 10-hour data cutoff, in order to utilize as much observation as available. The 10-day projection used for weekly forecast. The RDAPS runs twice a day (00 and 12 UTC) for 48-hour forecasts.

7.2 Medium-range Forecasting System

7.2.1 Data assimilation, Objective Analysis and Initialization

The global analyses are prepared with the 6-hour update cycle. A 6-hour forecast from the previous run provides a first guess for the next analysis. If a typhoon exists in the Western Pacific, a typhoon bogus profile is calculated and embedded in the first guess field. The best fits of analysis are made with the 3-dimension multivariate optimal interpolation scheme for height and wind, and with the univariate scheme for relative humidity and surface pressure. The increments from the first guess are estimated at observation points, and interpolated back to grid points. The analysis is performed on the sigma levels in global model.

The moisture analysis is corrected by the cloud information at different vertical layers, including cloud top temperature derived from GMS-5 images. Both moisture and thickness fields are further refined by the 1-dimension variational data assimilation (1DVAR) of ATOVS radiance. The 1DVAR retrieves thickness and precipitable water on the layers of the SATEM data.

A Non-linear Normal Mode Initialization(NNMI) with full physics is performed to suppress the amplitude of high-frequency gravity waves. The high frequency component is filtered out for each spherical harmonic component in the five greatest vertical modes which exceed the critical frequency. Machenhauer's iterative scheme is used for determining the non-linear balanced solution.

7.2.2 Model Configuration

Dynamics	
Basic equation	Primitive equations in sigma- pressure hybrid vertical coordinate
Numerics	Spectral representation of horizontal variables with triangular truncation of T213, corresponding to a Gaussian grid size of 0.5625 degrees or 55km
Domain	Global
Levels	30 vertical levels ranging from surface to 10 hPa
Time integration	Eulerian semi-implicit scheme

Physics	
Horizontal diffusion	Second order Laplacian, and Rayleigh friction
Moist processes	Kuo scheme, large-scale condensation, and shallow convection scheme
Radiation	Long wave radiation calculated every three hours Short wave radiation calculated every hour
Gravity wave drag	Long waves (wavelength>100km) Short waves (wavelength 10km)
PBL processes	Non-local diffusion scheme and similarity theory for surface layer
Land surface	Simple biosphere model
Surface state	NCEP daily SST anomaly added to monthly changing climatological SST Climatological values are used for the soil moisture, snow depth, roughness length and albedo

7.2.3 Operational Techniques for Application of NWP Products

The 6-hour forecast of GDAPS is used for the first guess in the analyses of regional model and the steering flow of typhoon model. The surface winds predicted by GDAPS and RDAPS are used as an input for the global and regional wave model. The wind field predicted by GDAPS is also used as an input for the trajectory model for the yellow sand.

7.2.4 Ensemble Prediction System

An ensemble prediction system (EPS), based on breeding method with global model(T106/L21), has been operational since Mar. 2001. An ensemble of 16 members is obtained from the sequence of 6-hour breeding cycle. The EPS runs for 10-day projection once a day at 12 UTC to support weekly forecast.

7.3 Short-range Forecasting System

Assimilation	Four-dimensional Data Assimilation with nudging
First guess	GDAPS previous 6-hour prognosis
Observations	SYNOP, TEMP, PILOT, ACARS, SATEM, and SATOB with 12 hour interval
Method	3 Dimension Optimal Interpolation
Variables	Wind, geopotential height, and relative humidity
Vertical levels	33 model sigma levels

Dynamics	
Grids	Triply nested domain (30km for 171 x 191, 10km for 160 x 178 and 5km for 141 x 141 gird points
Numerics	Primitive equations based on the non- hydrostatic frame
Vertical resolution	33 layers with the model top of 50 hPa
Boundary condition	Time and inflow/ outflow dependent relaxation
Boundary update Frequency	30km : 12-hour interval by GDAPS forecasts 10km : 3- hour interval by 30km forecasts 5km : 1- hour interval by 10km forecasts
Time integration	72 hours for 30km mesh, and 24 hours for both 10km and 5km meshes

Physics	
Horizontal Diffusion	Fourth order diffusion
Precipitation physics	Explicit moisture scheme
Deep convection	Kain-Fritch only for 30 km and 10km mesh
Planetary layer	Non-local boundary layer
Surface physics	5-layer soil model for ground temperature
Radiation	Simple cloud scheme

7.4 Application for NWP products

Various model outputs, including the potential vorticity at isentropic surface, are available in both graphic and imagery form. Those products are also disseminated to the end users through intranet of KMA or Internet. A statistical model with KF produces 3-hourly temperature forecasts including the maximum and minimum temperature for 61 domestic stations up to 48 ~ 84 hours in advance. 10 day maximum and minimum temperatures are also provided by the KF method. The Probability of Precipitation (PoP) for 12 hour forecast of four sets up to 2 days are derived with PPM

7.5 Ocean Wave Prediction System

Two numerical wave models are currently on operation: Global WAve Model (GoWAM) and Regional WAve Model (ReWAM). Both models are adopted from the 3rd generation WAM model cycle 4 (developed by WAMDI group). The performance of GoWAM is improved by using the surface wind from the global model (T213/L30).

Specification of ocean wave prediction models

	GoWAM	ReWAM
Model Type	3rd generation spectral model	
Spectral component	25 frequencies and 12 direction	
Grid form	Latitude-longitude grid on spherical coordinate	
Grid size	1.25deg×1.25deg(288×113)	0.25deg×0.25deg (141×121)
Domain	70°S ~ 70°N	20°N ~ 50°N, 115°E ~ 150°E
Time step	720 seconds	360 seconds
Forecast time	240 hours from 12UTC	48 hours from 00, 12UTC
Initial condition	24(12) hours forecast (spectral) from previous run	
Wind fields	from GDAPS	from RDAPS

7.6 Typhoon Track Prediction System

Typhoon track forecasts are provided from five different models, the Barotropic Adaptive grid Typhoon System (BATS), two GDAPS(T106/L20 and T213/L30), RDAPS, and EPS. The BATS is based on the continuous dynamic grid adaptation technique with the innermost grid spacing of 0.3 degrees. This model is specially designed to run with high resolution grids within little computational load. It runs four times a day by 6-hour interval.

Barotropic Adaptive-grid Typhoon System(BATS)

Input Data	GDAPS analysis and prognosis
Vortex Bogusing And Initialization	Specified vortex generated by empirical formulas Global objective analysis field with the symmetric typhoon vortex
Dynamics	
Basic equation	Shallow water equations on the latitude-longitude coordinate
Horizontal representation	Grid distance of 0.6°with the innermost grid distance of 0.3°on the continuous dynamic grid adaptation
Domain	101 grid points both in zonal and meridional directions over the domain of 60°×60°
Products	Central position (lat./lon.) every 6 hours up to 60 hours in advance.

8. Verification

The summary of annual verification statistics for GDAPS is calculated by comparing the model forecast to the analysis and radiosonde observation (see Table 2.1 and 2.2). Table 3.1 to 3.5 and Table 4.1 to 4.2 present detailed monthly verification statistics for GDAPS and RDAPS, respectively, by comparing the model forecast to the analysis.

Table 2.1 RMSE verification of KMA's global model (GDAPS) against the analysis for 2002

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500	Northern Hemisphere	16.73	42.44	71.35
Z500	Southern Hemisphere	23.34	63.48	96.56
V250	Northern Hemisphere	6.13	12.61	18.25
V250	Southern Hemisphere	6.49	15.60	21.63
V250	Tropics	5.12	9.40	11.50
V850	Tropics	2.56	4.29	5.16

Table 2.2. RMSE verification of KMA's global model (GDAPS) against observation in 2002.

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500(geopotential height)	North America	19.75	44.36	67.90
Z500	Europe	16.76	40.60	73.98
Z500	Asia	17.40	33.94	50.37
Z500	Australia/ New Zealand	17.21	29.13	41.55
V250(wind)	North America	8.70	15.54	20.52
V250	Europe	7.52	13.94	21.45
V250	Asia	8.19	12.59	16.14
V250	Australia/ New Zealand	8.97	13.30	17.53
V250	Tropics	8.14	10.28	11.83
V850	Tropics	4.69	5.53	6.18

Table 3.1. Monthly mean RMSE of 500 hPa geopotential height forecasts(m) in Northern Hemisphere (GDAPS verification against analysis).

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	20.61	19.17	18.06	16.87	16.66	14.95	14.87	14.77	14.66	15.38	16.31	18.40	16.73
72H	53.24	50.84	45.80	45.90	41.67	35.23	36.31	36.02	36.33	38.59	42.16	47.19	42.44
120H	84.79	83.03	80.75	80.32	72.01	58.06	58.18	56.81	65.23	69.29	69.68	78.09	71.35

Table 3.2. Monthly mean RMSE of 500 hPa geopotential height forecasts(m) in Southern Hemisphere (GDAPS verification against analysis).

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	19.99	20.62	23.93	22.62	25.17	26.90	24.63	24.53	26.09	23.33	22.37	19.91	23.34
72H	50.79	54.39	63.94	64.34	70.05	72.28	69.73	64.95	70.67	64.67	62.19	53.81	63.48
120H	77.21	85.72	92.58	101.47	110.96	107.17	104.42	93.22	109.51	100.82	94.25	81.33	96.56

Table 3.3. Monthly mean RMSE of 250 hPa wind forecasts(m/s) in Northern Hemisphere (GDAPS verification against analysis).

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	6.63	6.17	6.27	6.46	6.35	5.92	5.84	5.76	5.87	5.83	6.10	6.31	6.13
72H	13.32	12.55	12.55	13.43	12.84	12.26	12.43	12.55	12.39	12.00	12.55	12.40	12.61
120H	18.80	18.45	18.67	19.73	18.77	17.48	17.18	17.23	18.33	18.22	18.26	17.84	18.25

Table 3.4. Monthly mean RMSE of 250 hPa wind forecasts(m/s) in Southern Hemisphere (GDAPS verification against analysis).

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	5.68	5.80	6.18	6.12	6.34	7.31	6.65	6.79	6.95	6.80	6.84	6.43	6.49
72H	13.65	14.22	15.20	15.42	16.10	17.67	15.87	15.76	16.10	16.28	16.07	14.86	15.60
120H	19.18	20.34	21.44	22.49	23.04	24.18	22.13	20.47	21.92	22.34	21.90	20.14	21.63

Table 3.5. Monthly mean RMSE of 250 hPa wind forecasts(m/s) in Tropic (GDAPS verification against analysis).

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	4.84	4.96	4.93	4.69	4.71	5.20	5.59	5.27	5.11	5.19	5.38	5.59	5.12
72H	8.94	9.44	9.24	9.01	9.18	9.63	9.84	9.36	9.23	9.72	9.61	9.60	9.40
120H	11.06	11.74	11.29	11.34	12.04	11.78	11.75	11.20	11.29	11.85	11.49	11.16	11.50

Table 4.1. Monthly mean RMSE of 500hPa geopotential height forecasts in 30km RDAPS (verification against analysis).

FCST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12H	11.64	10.31	10.62	9.40	8.58	8.86	9.63	9.39	9.10	9.49	10.27	10.18
24H	14.25	12.06	13.89	12.44	10.57	10.65	13.31	12.99	10.88	12.10	11.97	12.37
36H	18.30	17.04	19.12	17.22	13.86	13.73	18.15	17.19	13.82	16.26	15.35	16.97
48H	23.00	23.56	24.76	22.44	17.68	17.12	21.65	19.09	16.82	21.00	20.91	22.02

Table 4.2. Monthly mean RMSE at 850hPa Temperature forecasts in 30km RDAPS (verification against analysis).

FCST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12H	1.29	1.17	1.23	1.22	1.06	1.18	1.08	1.07	1.03	1.21	1.31	1.30
24H	1.62	1.43	1.60	1.55	1.34	1.41	1.28	1.25	1.26	1.47	1.65	1.54
36H	1.90	1.70	2.03	1.85	1.65	1.63	1.49	1.44	1.51	1.69	1.93	1.73
48H	2.14	1.93	2.41	2.13	1.98	1.82	1.65	1.62	1.71	1.91	2.20	1.94

9. Future Plan

The 6-hour cycling data assimilation system of 3DOI with the Incremental Analysis Update (IAU) technique will be implemented in the RDAPS in 2003 for a better initialization. The data assimilation (3DVAR) of the asynoptic observations, such as radar velocity and reflectivity observations, AWS (Automatic Weather Station) observations, satellite radiances, is under test operation and will be fully operational in 2004.

Especially AWS and radar data will be applied to make the good regional analysis field of 10km RDAPS for the improvement of local heavy rainfall prediction. The ATOVS satellite data will directly be assimilated in the 3DVAR to get more balanced initial field and to maximize the impact of satellite data in NWP system. The regional and global 3DVAR systems will be unified in 2004.