Annual WWW Technical Progress Report

On the Global Data Processing and Forecasting System 2004

REPUBLIC OF KOREA

1. Summary of highlights

In 2004, the main changes to the global and regional versions of the numerical prediction suites were the followings:

28th January Operation of 3dVar analysis system on Regional Data Assimilation and Prediction System (RDAPS) of 10 km grid spacing

23rd August Direct Assimilation of the ATOVS Radiance with 3dVar on Global Data Assimilation and Prediction System (GDAPS)

1st September Typhoon model Barotropic Adaptive grid Typhoon System (BATS) was replaced by new Typhoon model Double Fourier Series BARotropic typhoon prediction model (DBAR).

25th November New supercomputer Cray X1-3/192-L was installed. The migration of the NWP system to new supercomputer is in progress.

2. Equipment in use at the KMA

The supercomputer SX-5/28M2 is dedicated for the operation of the short, medium and long-range numerical weather prediction including climate simulation. In 2004, KMA installed new supercomputer Cray X1-3/192-L to take high performance for computing capability. Current main supercomputer SX-5/28 will be replaced by Cray X1-3/192-L in 2005.

💻 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

💻 New supercomputer: Cray X1-3/192-L

-Peak Performance：635G Flops

-Memory ：760G bytes

- Single CPU performance: 12.8G flops

-Mass storage system ：44T bytes

3. Data and products from GTS 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 of the observation that are available from the GTS. The pre-processing procedures such as data acquisition, quality control and decoding, are fully automated. There is a little bit change in number of data in 2004 compared to in 2003.

Table 1. The types and numbers of observations received through GTS, and the percentage of data used in global data assimilation for 24 hours in 2004.

	Data type	Number of data/day	% used in assimilation
1	SYNOP/ SHIP	42,440	89
2	BUOY	8,010	73
3	TEMP/ PILOT	1,885	85
4	AIREP/ AMDAR/ACARS	218,613	27
5	SATEM	19,065	83
6	SATOB	13,539	92
7	ATOVS	71,646	15
8	AWS	5,518	53
9	PAOB	400	100
10	Wind profiler	332	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 the 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 84-hour and 240-hour prognoses 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. Four typhoon track forecasts are obtained from BATS, RDAPS, GDAPS (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 and forecast ranges

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 days 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 analysis is 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 the profiles are assimilated in 3dVar as an observation with observation error which is determined empirically. The best fits of analysis are made with the 3dVar system.

The moisture profile is selected based on the cloud information derived from GOES-9 imaginary data and the profile is assimilated in 3dVar. The direct assimilation of ATOVS radiance data (level 1D type) is embedded in the 3dVar system to refine the temperature

and moisture field especially over the ocean and stratosphere. The wind profiler data which was newly operated at three locations over the Korean peninsula is merged to the wind profiler data over the Japan and U.S.A. and the wind profiler data are also assimilated to correct the wind background over the globe.

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

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 Numerical weather prediction products

NWP products are automatically generated from NWP systems of KMA. 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 (http://www.kma.go.kr/eng/wis/wis04_nwp01.jsp).

. 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 days 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

7.2.4 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 of yellow sand.

7.2.5 Ensemble prediction system

An ensemble prediction system (EPS), based on breeding method with global model (T106/L30), has been operational since Mar. 2001. An ensemble of 16 members is obtained from the sequence of 6-hour breeding cycle. The EPS runs once a day up to 8 days at 12 UTC to support weekly forecast. The probability of gust and precipitation by EPS can be accessed at KMA homepage (http://www.kma.go.kr/eng/wis/wis04_nwp04.jsp). The standard verification scores of EPS will be regularly exchanged through the JMA.

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 Radar data for 10km grid spacing with 3-hour interval AWS for 10km and 5km grid spacing with 3-hour interval
Method	3 Dimension Optimal Interpolation/3dVar (10 km)
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 : 3- hour interval by 10km forecasts
Time integration	48 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	New Kain-Fritch only for 30 km and 10km grid spacing
Planetary layer	Non-local boundary layer
Surface physics	5-layer soil model for ground temperature
Radiation	Simple cloud scheme

7.4 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 GoWAM error statistics against Topex/Poseidon data shows improved trend by comparison with year 2003.

Specification of ocean wave prediction models

	GoWAM	ReWAM
Model Type	3rd generation spectral model	
Spectral component	25 frequencies and 24 directions	
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 four different models, the Double Fourier Series BARotropic typhoon prediction model (DBAR), GDAPS (T213/L30), RDAPS (30km grid spacing), and EPS. As a typhoon model at KMA, the Barotropic Adaptive grid Typhoon System (BATS) was replaced by DBAR in 2004. The DBAR 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.

Double Fourier Series Barotropic Typhoon Prediction Model (DBAR)

Input Data	GDAPS analysis and prognosis
Vortex Bogusing And Initialization	Geophysical Fluid Dynamics Laboratory (GFDL) bogussing
Dynamics	Spectral method using Double Fourier Series
Basic equation	Shallow water equations on the latitude-longitude coordinate
Horizontal representation	Grid distance of 0.356°
Domain	1024 x 512
Products	Central position (lat./lon.) every 6 hours up to 72 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 present detailed monthly verification statistics for GDAPS, by comparing the model forecast to the analysis.

Table 2.1. RMSE verification of KMA's global model (GDAPS) against the analysis in 2004.

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500	Northern Hemisphere	16.61	41.12	69.23
Z500	Southern Hemisphere	25.37	61.66	91.45
V250	Northern Hemisphere	6.03	12.42	18.04

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
V250	Southern Hemisphere	6.70	14.54	20.15
V250	Tropics	5.68	9.77	11.51
V850	Tropics	2.80	4.62	5.40

Table 2.2. RMSE verification of KMA's global model (GDAPS) against observation in 2004.

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500(geopotential height)	North America	18.52	40.97	66.97
Z500	Europe	17.50	40.51	70.84
Z500	Asia	17.65	34.93	49.74
Z500	Australia/ New Zealand	16.78	35.75	55.20
V250(wind)	North America	8.12	14.94	20.46
V250	Europe	7.31	13.40	19.87
V250	Asia	7.94	12.51	16.35
V250	Australia/ New Zealand	8.30	13.02	17.98
V250	Tropics	7.90	10.10	11.61
V850	Tropics	4.72	5.57	6.26

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

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	18.88	18.47	17.48	16.83	15.96	15.30	14.75	15.17	15.71	16.23	16.52	18.05	16.61
72H	49.59	48.26	43.25	43.48	38.52	37.06	33.09	33.83	37.55	40.5	42.58	45.70	41.12
120H	83.18	78.86	74.47	72.21	67.87	59.91	52.74	56.86	62.12	70.18	73.21	79.17	69.23

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

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	21.91	21.29	24.03	25.53	27.98	27.25	28.60	28.50	28.20	26.59	23.03	21.56	25.37
72H	53.69	51.10	58.87	64.72	67.37	69.19	67.81	72.21	69.84	62.69	52.89	49.59	61.66
120H	78.36	75.27	90.22	99.90	99.25	100.91	99.10	105.89	101.20	92.46	80.70	74.09	91.45

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

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	6.03	6.31	5.98	6.31	6.07	5.83	5.66	5.75	5.91	6.12	6.08	6.27	6.03
72H	12.32	12.94	12.18	12.77	12.55	12.38	11.70	12.09	12.48	12.89	12.37	12.35	12.42
120H	17.74	18.13	18.05	18.36	18.85	17.40	16.23	17.06	18.3	19.00	18.35	19.02	18.04

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

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	6.58	5.88	6.22	6.38	6.99	6.79	6.74	6.54	7.51	7.30	6.76	6.74	6.70
72H	14.28	13.34	14.66	15.22	15.35	15.28	14.66	14.97	15.31	14.74	13.51	13.14	14.54
120H	18.96	18.58	20.85	21.70	21.14	20.99	20.57	20.54	20.73	20.39	18.98	18.34	20.15

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

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
24H	5.53	5.63	5.68	5.65	5.69	5.75	5.54	5.47	5.78	5.70	5.67	6.05	5.68
72H	9.73	10.01	10.33	9.88	9.51	9.84	9.39	9.42	9.44	9.51	9.77	10.36	9.77
120H	11.55	12.01	11.93	11.71	11.33	11.45	11.01	11.06	11.23	11.40	11.37	12.02	11.51

9. Future plan

Owing to installation of new supercomputer Cray X1-3/192-L, the new NWP system will be launched on Cray X1-3/192-L after the migration of NWP system on SX-5 in 2005. The high resolution global models GDAPS T426L40 and ST426L40 (T426L40 of Semi Lagrangian advection scheme) are prepared for test. As the new generation regional model at KMA, Weather Research and Forecast (WRF) of 10km grid spacing is planed for test in 2005. Additionally, Cray X1-3/192L will be upgraded to X1E-8/960L whose peak performance is 4.3TFlops.

The number of asynoptic data assimilated in the 3dVar system will intensively be increased in 2005. The WV channel TBB data observed by geostationary satellite, the sea surface wind by QUIKSCAT, and the MODIS polar winds will be assimilated in 3dVar. The global coverage ATOVS level 1C data and local direct readout ATOVS data will be merged and directly assimilated in 3dVar. Further tuning for bias correction will be followed to improve the impact of ATOVS data on GDAPS. The 3dVar will be upgraded to assimilate temperature observation and increase its outer loop resolution up to T426L40 from T213L30 and inner loop up to T106L40 from T63L30. As a first step to incorporate the time dependency of observation increment in analysis, the First Guess Appropriate Time (FGAT) technique will be introduced in the 3dVar system.

In ocean wave prediction system, the test of increasing spatial resolution of GoWAM (from 1.25deg to 0.5deg) and ReWAM (from 0.25deg to 0.083deg) will be carried out adapting Wave Watch III version 2.22 which is developed by NCEP marine modeling group.