Progress Report on the Global Data Processing and Forecasting System in 2006

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1. Summary of highlights

In 2006, the main changes to the global and regional versions of the numerical prediction suites were the followings:

2nd Jan. The 10km resolution regional model based on WRF is in parallel run for the potential operational usage planned in 2007. The model is equipped with its own data assimilation cycle using the 3dVAR of WRF-Var system.

15th May The 3-dimensional analysis system is in operation which aims to produce analysis filed within 10m minutes at every hour. The system assimilated all the available in-suit data and remote sensing data such as satellite, radar and wind profiler. The analysis scheme is based on the LAPS and the background field is produced by the 15km MM5 system.

28th June The global ensemble prediction system improved its resolution from T106L30 to T213L40, and also increased the number of perturbed members from 16 to 32 by performing the forecast twice daily (00/12UTC).

26th Dec. The FGAT(First Guess At Appropriate Time) is in operation for the global data assimilation and prediction system(GDAPS). The first guess is picked up 3 hourly and interpolated to the observation time to calculate the innovation in the analysis.

2. Equipment in use at the KMA

The supercomputer Cray X1E-3/192-L is dedicated for the operation of the short, medium and long-range numerical weather prediction including climate simulation.

💻 Supercomputer: Cray X1E-3/192-L
-Peak Performance：15.7 T Flops

-Memory　　: 4.96T bytes

- Single CPU performance: 18.08G flops

-Direct Attached Storage : 62T bytes

-SAN Disk : 20Tbytes

3. Data and products from GTS in use

Synoptic observations, and various asynoptic observations, including satellite and wind profiler data, are used daily in the GDAPS. Table 1 presents the types and numbers of the observation that are available from the GTS and FTP. The pre-processing procedures such as data acquisition, quality control and decoding, are fully automated. The percentage of data used in data assimilation means the rate of final data used in assimilation to total input data.

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 2006.

	Data type	Number of data/day	% used in assimilation
1	SYNOP/ SHIP	45,790	45
2	BUOY+QSCAT	81,017	8
3	TEMP/ PILOT	2,277	68
4	AIREP/ AMDAR/ACARS	166,461	9
5	SATEM	25,036	38
6	SATOB	17,168	88
7	ATOVS	122,843	24
8	AWS	5,518	57
9	PAOB	400	100
10	Wind profiler	135	94

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 and FTP. Special quality control is applied to the satellite data assimilation.

6. Monitoring of the observing system

Most of observations are monitored in terms of availability and quality. The innovation, analysis increment of the horizontal distribution is monitored at every analysis time and that of histogram and time series are also monitored monthly. The satellite data monitoring system shows domain averaged time series of innovation with and without bias correction also.

7. Forecasting System

7.1 System run schedule and forecast ranges

The GDAPS for 10-day 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, weekly forecast and for the provision of lateral boundary condition for the two high-resolution (10km and 5km with 33 layers) regional models. The RDAPS runs twice a day (00 and 12 UTC) for 66-hour forecasts. Four typhoon track forecasts are obtained from DBAR, RDAPS, GDAPS (T426/L40), 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.

KMA produces three types of long-range weather forecasts: 1-month, 3-month (seasonal), and 6-month forecast. The 1-month forecasts are issued three times a month and include temperature, precipitation, and air pressure pattern for the next 30 days. The 3-month forecast which are produced at monthly basis include the trends of temperature, precipitation including special seasonal events such as Asian dust, Typhoon and Changma for the next 3 months. The 6-month forecast is issued two times a year(May and November). The system run schedule and products are listed in Table 2.

Table 2. Long range forecasting system run schedule and products.

	1-month forecast	3-month forecast	6-month forecast
Issue Date	· 3rd , 13th, and 23rd day of each month	· 23rd day of each month	· 23rd day of May and Nov.
Forecast type	Three type categories : above, below and near normal The anomalies are based on model's climatologies obtained from a 28 year database(1979 to 2006).		
Contents	· 10-day mean temperature and precipitation · 30-day mean temperature and precipitation	· 1-month mean temperature and precipitation · 3-month mean temperature and precipitation *1 *Asian dust outlook* *2 *Typhoon outlook* *3 *Changma outlook*	· 1-month mean temperature and precipitation (Jun. to Nov./Dec. to May)
Forecast area	Temperature : whole Korea Precipitation : whole Korea	Temperature : whole Korea Precipitation : whole Korea	Temperature : whole Korea Precipitation : whole Korea

*1 *Asian dust outlook* is issued in late February including frequency and density of Asian dust expected to affect Korea for the upcoming Spring.

*2 *Typhoon outlook* is issued in late May and Aug. regarding number of Typhoon expected to affect Korea for the upcoming Summer and Fall.

*3 *Changma outlook* is issued in late May regarding or duration and intensity of Changma .

7.2 Medium-range forecasting system

7.2.1 Data assimilation, objective analysis and initialization

The analysis resolution of global 3dVar is T426L40 and the inner loop is T106L40. The analysis top is 0.4 hPa. The climatologic constraint of zonal averaged vorticity is applied in the cost function formulation and GDPAS can produce realistic zonal wind climatology at the lower stratosphere in the Tropics. The global analysis is prepared with the 6-hour update cycle.

The FGAT is applied to all the observations to reduce the error caused by the time difference between observation and background. The background is produced 3 hourly and linearly interpolated to the observation time to get the better fit between observation and background. The FGAT helps to use more observations in the analysis and gives better performance in summer season in the Northern Hemisphere by providing the more realistic first guess at observation time.

The unified 3DVAR which can be used for the both global and region model was introduced. The unified 3DVAR, which is originated from WRF 3DVAR, is coupled with KMA global model and the next generation regional model , KWRF(KMA WRF) . The unified 3DVAR regional cycle which is built by connecting the unified 3DVAR and KWRF is being tested as the semi operational job.

The moisture profile is selected based on the cloud information derived from MTSAT-1R 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 that was newly operated at four locations over the Korean peninsula is merged to the wind profiler data over the Japan and the U.S.A. The wind profiler data are also assimilated to correct the wind background over the globe. Sea surface wind data retrieved from the QuikSCAT satellite is assimilated using the PBL operator that is based on the MRF PBL method. The assimilation of QuikSCAT reduces the bias of typhoon track forecast and improves GDPAS performance in the Southern Hemisphere and the Tropics.

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 that exceed the critical frequency. Machenhauer's iterative scheme is used for determining the non-linear balanced solution.

7.2.2 Model

Table 3. Specifications of global forecast model for 10-day forecasts

Dynamics	
Basic equation	Primitive equations in sigma-pressure hybrid vertical coordinate

Numerics	Spectral representation of horizontal variables with triangular truncation of T426, corresponding to a Gaussian grid size of 0.28125 degrees or 30km
Domain	Global
Levels	40 vertical levels ranging from surface to 0.4 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

The global ensemble prediction system (EPS), based on breeding method with global model (T106L21) was made operational in 2001. As the horizontal and vertical resolution of the operational global forecast model was enhanced from T213L30 to T426L40 in December 2005, high-resolution global ensemble prediction system (T213L40) was constructed and was made operational in June 2006.

An ensemble of 16 members is obtained from the sequence of 6-hour breeding cycle, and the EPS runs twice a day up to 10 days at 00 and 12 UTC to support weekly forecast. Transmission test of the global ensemble products is being performed in relation to the WMO GIFS-TIGGE since December 2006, and the standard verification scores of EPS will be regularly exchanged through the JMA. The main structure of the global EPS is summarized in the table below.

Table 4. Specifications of global ensemble prediction system for medium-range forecasts

Model	
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	40 vertical levels ranging from surface to 0.4 hPa
Time integration	Eulerian semi-implicit scheme

Operation	
Data Assimilation (for control analysis)	3dVar with 6hr window (wave truncation of analysis field for global forecast system T426L40)
Forecast length	10 days
Runs per day	2 (00UTC, 12UTC)
Initial perturbation strategy	Rotated Bred Vector method (Factor rotation)
Initial perturbation area	Northern Hemisphere (20N~90N)

Number of perturbed ensemble members	16 members or 32 members (using time lag) excluding control

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	66 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 Specialized numerical predictions

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). Table 3 shows the description of wave models.

Table 3. The operational wave models at KMA

	GoWAM	ReWAM
Source Code	WAM model cycle 4	WAM model cycle 4
Coordinate	Spherical coordinate	Spherical coordinate
Spatial Domain	70°S-70°N	20°N-50°N, 115°E-150°E
Spatial Resolution (Dim.)	1.25° (288 by 113)	0.25° (141 by 121)
Spectral Resolution	25 frequency 24 direction	25 frequency 24 direction
Integration Time Step	720 second	360 second
Lead Time	240 hour (12UTC)	48 hour (00/12UTC)
Elapsed Time	12 minute	2.5 minute
Initial Condition	Previous 24 hour forecast	Previous 12 hour forecast
Sea Surface Wind Input	GDAPS 12-hour interval	RDAPS 3-hour interval

3-dimensional analysis system

The 3-dimensional analysis system aims to produce analysis field within 10 minutes at every hour to give quick information of current weather to the forecasters. The system assimilated all the available in-suit data and remote sensing data such as satellite, radar and wind profiler. All the available data used in the 3-dimensional analysis system in Table 3. The analysis scheme is based on the LAPS and the background field is produced by the 15km MM5 cycling system.

Table 1 Data used in the 3-dimensional analysis system

Type	Variable	Data Format	Numbers
Wind profiler	Wind	Burf	5 sites in Korea
MTSAT	IR image	Binary	MTSAT

	VIS image		
Radar	Reflectivity	UF	8 sites in Korea
AWS	Temp. Wind Humidity	ASCI	614 sites in Korea
Lighting	Frequency	ASCI	-
AMEDAS	Temp. Wind Humidity	GTS	222 sites
METAR	Temp. Cloudiness	ASCI	30 ~ 41sites

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.

7.5 Extended range forecasts (10 days to 30 days)

For the extended range forecast system, KMA has been operating global climate model with predicted sea surface temperature (2-Tier system). To predict the global sea surface temperature as a boundary condition for the 2-tier system, the global ocean forecasting system has been developed as a combined system of dynamical and statistical models. The global long-range forecasting system, using global climate models, is also being developed, and the SMIP2/HFP-type climatology for each model is produced for removing model bias and improving predictability. Detailed information about the model climatology is given in Table 4. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea (see Table 2).

Table 4. Description of SMIP2/HFP Experiment

SMIP2/HFP Experiment		
Experiment design		28-year integration(1979-2006) 4-month integration for each case
Ensemble member		20 ensemble members
Initial member		00, 06, 12 & 18Z of 5 days for each case
Initial condition	Atmosphere	NCEP/NCAR reanalysis(U,V,T,q,Ps)
	Land surface	Climatology
Boundary condition	SST and sea ice	Predicted SST using dynamical and statistical prediction model
	Etc.	Same as SMIP2

7.5.1 Global Climate Model

The operational extended forecasts system is based on the global spectral model, GDAPS (Global Data Assimilation and Prediction System) with horizontal resolution of T106 and 21 vertical levels of hybrid sigma-pressure coordinate. For the Ensemble forecasts, we utilize 20 ensemble members by lagged average method with about 15-day forecast lead-time (see Table 4). Detailed model description is summarized in Table 5.

Table 5. Detailed description for global climate model

		GDAPS(Operational model)
Major Physics	Cloud Convection	Kuo (1974)
	Land Surface & PBL	SiB; Yamada-Meller (1982)
	Radiation	Lacis & Hansen (1974) for SW, Roger & Walshaw (1966); Glodman & Kyle (1968); Houghton (1977) for LW
	Large scale condensation	Kanamitsu et al.(1883)
Dynamics		Three-dimensional global spectral model with hydrostatic primitive equations Hybrid sigma-pressure coordinate Semi-implicit method

Resolution	T106L21
Ensemble size	20 members
Sea Surface Temperature	Predicted SST anomaly
Land Surface Initial Condition	Observed Climatology
Model Climatology	SMIP2/HFP simulation (1979 to 2006)
Forecast range	1-month forecast 3-month forecast 6-month forecast

7.5.1 Global sea surface temperature forecasting system

The El Nino prediction system (Kang and Kug, 2000) is based on the intermediate ocean and statistical atmosphere model. The ocean model differs from the Cane and Zebiak (1987) model in the parameterization of subsurface temperature and the basic state. The statistical atmosphere model is developed based on the singular value decomposition (SVD) of wind stress and SST.

To reduce the uncertainty of initial field on the ENSO model, the breeding technique is applied. In the case of an ideal experiment, it works for better predictability, while for our El Nino prediction model, its effect is not so clear because it has weak nonlineality. Therefore, it shows some possibilities to contribute the improvement of predictability for the complicated future ENSO prediction using coupled GCM.

In order to improve the western Pacific SST prediction, KMA introduced the heat flux formula and vertical mixing parameterization to the ocean model. The initialization of the model is done by combining observed SST and wind stress. Wind stress is calculated by using the 925hPa wind of NCEP/NCAR reanalysis data. The method with calculated wind stress for initialization has a better forecast skill than that with FSU wind stress in recent predictions. (Kug et al., 2001). In addition, the present prediction is attended with random noise considered weather noise, and generates many sets of prediction. Our approach for random noise is similar to Kirtman and Schopf (1998).

Then, to correct the systemic error in the prediction model, the statistical model is also applied. The used Coupled Pattern Projection Model (CPPM, Lee and Kang 2003) is a kind of pointwise regression model, and the main idea of the model is to generate realization of predictions from projections of covariance patterns between the large-scale predictor field and regional predictions onto large-scale predictor field at the target year. By applying this model to the dynamic model results and compositing the results from both the dynamical and statistical models, the predictability over the tropical Pacific is improved than before.

To predict the whole global SST, a statistical global SST prediction system is being developed by combining Coupled Pattern Projection Model(CPPM), Lagged Linear Regression Method(LLRM), El Nino prediction model, and persistence method. In the tropical Pacific, predictions produced by El Nino prediction model are used, and in other regions the best results between CPPM, LLRM, and persistence are used. The LLRM is one of the point wise statistical model based on the lag relationship between the global SST and ENSO index and the optimal lag is selected by the hindcast process in the model. This is developed to determine predict the Indian SST prediction. Using this global ocean forecasting system, the boundary conditions for the global climate model are also produced.

7.6 Long range forecasts (30 days up to two years)

The long range forecast system is the same as the extended range forecast system described in section 7.5 except the forecast range. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea for the upcoming 3 months (see Table 2).

For the long range forecasts, we also utilize the multi model ensemble (MME) technique which has been developed and operated by APEC Climate Center (APCC). The APCC collects the historical and real-time forecast data of 15 different models from 8 countries and constructs the automatic MME input data producing system. The APCC has developed various MME techniques for deterministic and probabilistic seasonal predictions. For deterministic forecast, three kinds of linear MME techniques are used, namely biased and unbiased simple composite, weighted combination of multi-models based on SVD, and MME with statistical corrections. For probabilistic forecast, three ranges are determined by ranking method based on the percentage of ensemble members from all the participating models in those three categories. Moreover, regional MME system version MME I-IV has been developed for Asian Monsoon region.

8. Verification of prognostic products

The summary of annual verification statistics for GDAPS is calculated by comparing the model forecast to the analysis and radiosonde observation (see Table 6.1 and 6.2). Table 7.1 to 7.5 present detailed monthly verification statistics for

GDAPS, by comparing the model forecast to the analysis.

Table 6.1. RMSE verification of KMA's global model (GDAPS) against the analysis in 2006.

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500	Northern Hemisphere	16.32	40.74	67.42
Z500	Southern Hemisphere	26.52	65.33	95.92
V250	Northern Hemisphere	6.04	12.06	17.43
V250	Southern Hemisphere	6.95	15.21	20.83
V250	Tropics	5.89	9.96	11.98
V850	Tropics	2.94	4.72	5.43

Table 6.2. RMSE verification of KMA's global model (GDAPS) against observation in 2006.

Statistic	Area.	T+24 hr	T+72 hr	T+120 hr
Z500(geopotential height)	North America	16.74	41.79	66.11
Z500	Europe	15.53	37.14	64.78
Z500	Asia	18.75	34.13	52.42
Z500	Australia/ New Zealand	20.06	42.78	69.70
V250(wind)	North America	8.21	14.86	20.75
V250	Europe	7.02	13.07	19.18
V250	Asia	7.87	12.46	16.54
V250	Australia/ New Zealand	8.82	14.56	19.80
V250	Tropics	7.77	10.07	18.34
V850	Tropics	4.73	5.61	6.07

Table 7.1. 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	19.89	19.39	17.48	15.81	14.65	15.26	15.28	15.38	14.72	15.09	15.27	17.65	16.32

FCST	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
72H	48.83	48.12	44.99	40.77	38.57	37.34	37.24	34.58	36.33	38.28	39.89	43.89	40.74
120H	81.43	78.76	76.88	67.44	65.06	60.06	58.97	54.58	61.37	62.39	70.00	72.07	67.42

Table 7.2. 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	24.24	24.26	25.72	25.96	25.58	28.12	29.37	33.67	28.81	25.68	24.57	22.29	26.52
72H	54.81	55.14	59.93	68.39	64.65	69.98	74.33	84.43	74.34	65.51	59.28	53.23	65.33
120H	80.87	81.76	88.55	104.33	95.79	101.64	108.38	119.07	106.2	97.2	85.73	81.52	95.92

Table 7.3. 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	6.46	6.46	5.93	5.73	5.77	5.78	6.11	6.12	6.05	6.09	5.95	6.09	6.04
72H	13.23	12.75	12.21	11.9	12.58	12.42	11.73	11.25	11.61	11.73	11.66	11.66	12.06
120H	19.22	17.87	18.19	17.26	18.22	17.93	16.33	15.44	16.92	16.8	17.29	17.63	17.43

Table 7.4. 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	6.39	6.34	6.85	7.19	6.79	7.2	7.30	7.58	7.26	6.89	7.05	6.53	6.95
72H	14.45	15.03	15.25	16.04	15.23	15.71	15.77	16.91	15.62	14.64	14.27	13.62	15.21
120H	19.94	19.96	20.95	22.5	21.02	21.14	21.62	23.54	20.94	20.14	18.92	19.29	20.83

Table 7.5. 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	6.39	6.57	6.08	5.89	5.71	5.48	6.16	6.07	5.5	5.78	5.4	5.71	5.89
72H	10.98	11.39	10.78	10.44	10.03	9.43	9.91	9.72	8.93	9.36	9.14	9.36	9.96
120H	13.10	13.55	12.93	12.47	12.13	11.47	11.99	11.88	10.7	11.33	11.11	11.12	11.98

The seasonal forecasts are verified in terms of global and regional (i.e. East Asia) anomaly correlation of precipitation and 850 hPa temperatures during each season spring (MAM, JJA, SON, and DJF). The anomaly correlations of the seasonal mean fields for the hindcast experiment period of 1979-2005 are listed in the Table 8.

Table 8. Anomaly correlation of 850hPa temperature and precipitation.

	MAM		JJA		SON		**DJF**	
	P	T	P	T	P	T	P	T
Global	0.062	0.231	0.040	0.189	0.086	0.167	0.122	0.221
East Asia	0.138	0.249	0.032	0.182	0.036	0.193	0.110	0.237

9. Plans for the future

9.1 Development of the GDPFS

The global EPS was constructed based on the operational global forecast model (GDAPS) and inherited its systematic biases as well. The statistical estimation and correction of the first moment biases of selected variables - 500 hPa geopotential height, 850 hPa temperature, and some surface variables - are planned for the year 2007 to remove these systematic biases. The estimation and correction of the first moment biases of ensemble products by the simple 'decaying averaging bias estimate method' are planned to be tested and implemented operationally as a statistical post-process of the global EPS in the year 2007.

The dynamic tropopause will be compared with water vapor image to monitor the performance of GDAPS. The dynamic tropopause is assumed to be the 1.5 IPV surface and the discrepancy between the dynamic tropopause and water vapor image is provided to the forecasters. In future the discrepancy will be assimilated in the assimilation cycle to fit the analysis tropopause folding to the observation.

The MODIS polar winds will be assimilated in 3dVar. The forecast performance is verified and it shows positive impact in the Northern Hemisphere at summer so far. After verifying the performance in winter, it will be in operation. The global coverage ATOVS level 1C data and local direct readout ATOVS data, namely RARS(Regional ATOVS Retransmission Services) will be merged and directly assimilated in 3dVar for global and regional also. The SSM/I data assimilation is in developing stage mainly focuses on the correction of sea surface wind for the global 3dVar system.

The 3dVar for global and regional analysis will be merged into a unified 3dVar. The unified 3dVar shares the observation operators and other possible transform operators for global and regional application to shorten the developing period of assimilating newly observed data. The vertical decouple of background error is done by the empirical orthogonal function and physical decouple is done by unbalanced velocity potential, unbalance temperature, unbalanced surface pressure to the stream function. However for the horizontal decoupling of the background error, regional application uses recursive filter while the global application uses wave decoupling because spectral global model is in operation at KMA. The unified 3dVar will be in operation in 2007 for regional system and 2009 for global system.

The WRF-ARW will be in operation as a regional model at KMA in 2007. The new regional model with horizontal resolution of 10km will be run with a 6-hour cycle 3dVAR data assimilation system. The domain will be the same as that of current regional model. In 2010, the 4dVAR of the WRF-Var will be in operation for the regional model data assimilation.

Based on the WRF-ARW and WRF-3/4dVar, KMA plans to adopt a very high-resolution regional model system with specific purpose to predict the high-impact weather event. The system is planned to be in operation in 2010. Its horizontal resolution will be less than 5km and its data assimilation will be the 4dVAR of WRF-Var with storm-scale data assimilation capability.

As for the long-range forecast plan, in order to make operational regional long range forecasts available in 2009, both statistical and dynamical downscaling methods have been developed in cooperation with APEC Climate Center (APCC) and Climate Research Lab. in the National Institute for Meteorological Research. Based on basic analysis of regional climate and topography over Korea, the regional climate sectors will be divided into 3~5 areas.

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