# JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2013

**Korea Meteorological Administration**

**Republic of Korea**

## **Summary of highlights**

* **Major changes in the operational NWP suites in 2013**
	+ Data assimilation system is upgraded from 4DVAR to Hybrid Ensemble 4DVAR
	+ The COMS satellite Clear Sky Radiance (CSR) is being assimilated in global suite
	+ Physics package is upgraded from PS26 to PS28 : improving low troposphere temperature bias in Asia region by using aerosol climatology for radiation
	+ Global ensemble prediction system cycle is increased 4 times per day (00, 06, 12, 18UTC) to provide ensemble error covariance to new hybrid DA system
	+ Extension of forecast ranges : Global (10days→12days),

Regional & application models (72hours→87hours)

Local (24hours→36hours)

* **Operation of a new global data assimilation system – Hybrid Ensemble 4DVAR**
	+ Hybrid data assimilation system which combines 4DVAR and the ensemble forecast system was operationally launched in June 2013. Background error covariance from the ensemble forecast system was introduced into 4DVAR to correct the climatological background error, providing more realistic flow-dependent background error. Hybrid system showed the better performance generally against pure 4DVAR without ensemble background error and it showed remarkable improvement in Asia.

Table 1.1 Main operational atmospheric prediction models and application models in KMA

|  |  |  |  |
| --- | --- | --- | --- |
| Purpose | Model (domain) | Resolution  | Target Length  |
| Long-range forecast | GSM (Global) | T106L21 | seasonal |
| Medium-range forecast | UM(Global)  | Deterministic | N512 L70  | 288 hours  |
| EPS | N320 L70 M24 | 288 hours  |
| Short-range regional forecast | UM (E.Asia)  | 12km L70  | 87 hours  |
| WRF (E.Asia)  | 10km L40  | 72 hours  |
| Short-range local forecast | UM (Korea)  | 1.5km L70  | 36 hours  |
| Very short-range forecast | KLAPS (Korea)  | 5km L40 | 12 hours  |
| Ocean wave | WW3 (Global) | 55km (1/2°) | 288 hours |
| WW3 (Regional) | 8km (1/12°) | 87 hours |
| WW3 (Coastal) | 1km (1/120°) | 72 hours |
| Tide/Storm surge | POM (Regional) | 8km (1/12°) | 87 hours |
| Asian dust | ADAM2 (Regional) | 25km L47 | 72 hours |
| Tropical cyclone | DBAR (Regional) | 35km | 72 hours |

## **Equipment in use**

The supercomputer Cray XE6 is dedicated to the operation of short-, medium-range numerical weather prediction as well as long-range forecast and climate simulations.

* **Name of the model:** Cray XE6
* **CPUs and performance**
* Number of nodes: 3,760
* Number of cores: 90,240
* Core performance: AMD 2.1GHz 12-cores processor
* Peak performance: 758 TFlops (379 [operational purpose] + 379 [back-up & research purpose])
* **Operating system:** SUSE Linux 11
* **Memory**
* Memory per node : 32 GB
* Memory total : 120 TB
* **Disk storage**
* Lustre filesystem: 4 PB
* Backup filesystem (VTL, TAPE LTO-4 media): 6.5PB

## **Data and Products from GTS in use**

The number of observation data used for the operational NWP models has been gradually increased. The ATOVS, IASI and ASCAT of METOP-B were newly introduced for the operational global NWP suite. The impact of COMS[[1]](#footnote-1)-CSR data was successfully verified and so it was also added at the end of June. The ratios of assimilated observation against received observation are presented in Table 3.1.

**Table 3.1** Types and extent of observations received through GTS/FTP and assimilated in KMA’a operational global data assimilation system

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | In-situ observation | Indirect assimilation | Direct assimilation | TOTAL |
| Surface | SONDE | Aircraft | Scatwind | AMV | CSR | ATOVS | AIRS | IASI | GPSRO |
| Received | 92885 | 9847 | 294482 | 2623404 | 2022074 | 27362 | 4537568 | 168750 | 375150 | 1180 | 10152702 |
| Assimilated | 83979 | 2675 | 70323 | 48459 | 117380 | 7808 | 148853 | 23486 | 35421 | 1031 | 539415 |
| Ratio(%) | 90 | 27 | 24 | 2 | 6 | 29 | 3 | 14 | 9 | 87 | 5 |

* Surface : SYNOP, Ship, Buoy
* SONDE : TEMP, PILOT, Windprofiler, Drop-sonde
* Aircraft : ACARS, AMDAR, AIREP
* Scatwind : ASCAT, ERS
* AMV : MTSAT, GOES, METEOSAT7, MSG, COMS, MODIS, AVHRR
* CSR : COMS

## **Forecasting System**

### **4.1 System run schedule and forecast ranges**

**Short- and medium-range forecast**

Global Data Assimilation and Prediction System(GDAPS; UM N512L70) is used for 12-day forecast (00/12UTC) and 87-hour forecast(06/18UTC) with 2 hour 25 minute observation data cut-off. GDAPS is used for short-range weather forecasts, weekly forecast as well as for the provision of lateral boundary conditions of the two short-range regional NWP systems for the East Asia domain.

Regional Data Assimilation and Prediction System (RDAPS; UM 12kmL70) and KWRF (WRF 10kmL40) are operated 4 times daily(00/06/12/18UTC) for 87-hour forecast.

Local Data Assimilation and Prediction System (LDAPS; UM 1.5kmL70), which is a new operational short-range local NWP suite in 2012, runs 4 times daily(00/06/12/18UTC) to produce 36-hour forecast with 3-hourly 3DVAR cycle, and KLAPS(5km L40), a local very short-range forecasting system runs every hour analysing weather conditions around the Korean peninsula.

For typhoons originating in the north western Pacific, five track forecasts are obtained from Double Fourier Series BARotropic typhoon prediction model(DBAR), RDAPS(UM 12kmL70), KWRF(WRF 10kmL40), GDAPS(UM N512L70), and global EPS(UM N320L70M24).

**Long-range forecast**

KMA produces three types of long-range forecasts: 1-month, 3-month forecasts, and seasonal climate outlook. The 1-month forecast is issued three times a month and includes 10-day mean temperature, precipitation and characteristic pressure pattern for each 10-day period. The 3-month forecast, produced on a monthly basis, includes monthly temperature, precipitation and characteristic pressure pattern for each month. The seasonal climate outlook is issued four times a year: February for the summer climate outlook; May for the autumn climate outlook; August for the winter climate outlook; and November for the spring climate outlook. This outlook also includes special seasonal events such as Asian dust for spring and tropical cyclones for summer and autumn.

### **Medium range forecasting system (4-10 days)**

#### 4.2.1 Data assimilation, objective analysis and initialization

**4.2.1.1 In operation**

The table 4.1 shows the major characteristics of KMA’s operational global data assimilation in 2013.

**Table 4.1** Configuration of operational data assimilation for the global NWP suite in 2013

|  |  |
| --- | --- |
| Analysis resolution | N512L70 (horizontal resolution : ~25km) |
| Inner loop resolution | N216L70 (horizontal resolution : ~60km) |
| Analysis domain top | 80km |
| Analysis method  | Hybrid Ensemble 4DVAR |
| Observations used | SYNOP, Ship, Buoy, METAR, ERS, ASCAT, Sonde, Pilot, Windprofiler Airep, ACARS(Amdar), AMV-Meteosat7, AMV-Meteosat10, AMV-GOES, AMV-MTSAT, AMV-MODIS, AMV-AVHRR, AMV-COMS, ATOVS(global, EARS, AP-RARS, SA-RARS), IASI, AIRS, GPSRO, CSR-COMS |
| Data Base | ODB(Observation Data Base) from ECMWF |
| Pre-process | OPS(Observation Processing System) from UK Met Office : Quality control and reformation of observation data for data assimilation |

KMA’s global data assimilation system has been upgraded every year since KMA started operation of the Unified Model system (2010) introduced from the UK Met Office. The followings show major improvements in global data assimilation system in 2013.

* Hybrid data assimilation system which combines 4DVAR and the ensemble forecast system was operationally launched in June 2013. Background error covariance from the ensemble forecast system was introduced into 4DVAR to correct the climatological background error, providing more realistic flow-dependent background error. Hybrid system showed the better performance generally against pure 4DVAR without ensemble background error and it showed remarkable improvement in Asia.
* Stability of linear model(PF model) in 4DVAR was enhanced with introduction of new version of data assimilation contributing to enhancing the stability of 4DVAR calculation and model forecast.
* Clear Sky Radiance (CSR) data of COMS Water Vapour channel was newly introduced and the SSMIS data were dropped out because of its bad performance.

**4.2.1.2 Research performed in this field**

* + - * **Development of 4DEnsembleVAR**

Test version of 4DEnsembleVAR, which UKMO is developing as a next data assimilation, was installed in KMA supercomputer. 4DEnsembleVAR has similarity to hybrid system(current operational system) in that it also combines 4DVAR and ensemble system. But, 4DEnsembleVAR is considered as a better system than hybrid system in that it gives the chance to use large ensemble system by removing PF model which requires huge computing resources. The performance of 4DEnsembleVAR will be compared with hybrid system in 2014 and its possibility as a next system will be evaluated in 2015.

* + - * **Impact test of COMS high-resolution AMV**

COMS AMV data have been operationally used since December, 2011, and it is shown that the COMS AMV improves model forecast about 1 % for global and 9 % for East-Asia through FSO(Forecast Sensitivity to Observations). Recently, NMSC (National Meteorological Satellite Center), started to produce higher resolution AMV (using smaller target size with 64 km by 64 km than 96 km by 96 km target size in operation), and the cycle experiments using the new AMV data was carried out for one month during December in 2013. The slow bias of U component wind of the analysis fields and the standard deviation were decreased for the all levels against radiosonde observation. The cycle experiment results showed that the forecasting errors were reduced compared with the operation (using 96 km resolution data), especially in Northern Hemisphere. Currently, further optimization of error profiles in QC process of observation will be applied and its impact will be tested for summer period (July in 2014).

* + - * **Test using the new COMS CSR product over area of low level clouds**

COMS WV CSR data used in operational job are derived over clear pixels which are masked by IR cloud detection algorithm. For this reason, smaller data are assimilated in summer season especially. New CSR including the area of low level cloud as well was generated (it doesn’t affect WV radiance) and its impact was evaluated for one month (July 2013). The average number of data in the new CSR experiment was greatly increased from that of operational CSR data. Also, the average number of data which passed QC process and used in data assimilation was more than twice from 1,404 to 3,055. The forecast errors of geopotential height were decreased over the Asia region and Northern Hemisphere, and the temperature showed small positive impact above 700 hPa to 200 hPa. New CSR product will be tested in winter season.

#### 4.2.2 Model

**4.2.2.1 In operation**

**Table 4.2** Key model parameters of global model (GDAPS [UM N512L70]) for medium-range forecast

|  |  |
| --- | --- |
| ***Dynamics*** |  |
| Basic equation | Non-hydrostatic finite difference model with full equation. |
| Prognostic variables | Horizontal and vertical wind components, potential temperature, pressure, density, specific humidity, specific cloud water. |
| Integration domain | Global |
| Horizontal grid | Spherical latitude-longitude gird with Arakawa C-grid staggering of variables.Resolution : 0.234° latitude and 0.352° longitude. |
| Vertical grid | 70 levels (surface~80km).Hybrid-η vertical coordinate with Charney-Phillips grid staggering of variables. |
| Time integration | Two time-level semi-Lagrangian advection with a pressure correction semi-implicit time stepping method using a Helmholtz solver to include non-hydrostatic terms.Model time step = 600 sec. |
| Forecast range | 288 hours. |
|  |  |
| ***Physics*** |
| Horizontal diffusion | Second-order diffusion of winds, specific humidity and potential temperature. |
| Vertical diffusion | Second-order diffusion of winds only between 500 and 150 hPa in the tropics (equatorward of 30°). |
| Cloud | Prognostic cloud fraction and condensate cloud scheme (PC2, Wilson et al, 2008). |
| Precipitation | Wilson and Ballard (1999) single-moment bulk microphysics scheme, coupled with the PC2 cloud scheme.Prognostic rainAbel and Shipway (2007) rain fall speeds |
| Convection | Modified mass-flux convection scheme with convective available potential energy (CAPE) closure, momentum transports and convective anvils based on Gregory and Rowntree (1990). |
| Radiation | Edwards-Slingo (1996) radiation scheme with non-spherical ice spectral files.6 absorption bands in the SW, and 9 bands in the LW. |
| Boundary Layer | First order non-local boundary layer scheme of based on Lock et al. (2000) |
| Gravity wave drag | Orographic scheme including a flow blocking scheme which represents the effects of sub-grid orography.Non-orographic spectral scheme which represents the effect of gravity waves in the stratosphere and mesosphere. |
| Land surface | Joint UK Land Environment Simulator (JULES)4 layer soil model using van Genuchten (1980) soil hydrology |

**4.2.2.2 Research performed in this field**

* **Dynamics test**
* Model dynamic core of Unified Model upgrade test : New Dynamics → ENDGame[[2]](#footnote-2)
* Model horizontal resolution test : N512 (25km) → N768 (17km)
* Numerical noise test associated with orography in high altitude area
* **Physics test**
* Upgrade aerosols climatology : Direct radiative effect of aerosol species
* Refinement of surface / soil ancillaries
* Upgrade leaf area index (LAI)

#### 4.2.3 Operationally available Numerical Weather Prediction Products

Operational global products routinely available on model’s original horizontal resolution in GRIB-II format are as follow

* Pressure level data : 3-hourly up to +84 hours, 6 hourly for +90~+288 hours
	+ 3-dimensional wind components : 26 levels (1000~0.4 hPa)
	+ Geopotential height : 26 levels (1000~0.4 hPa)
	+ Temperature : 26 levels (1000~0.4 hPa)
	+ Relative humidity w.r.t. ice/water : 19 levels (1000~10 hPa)
	+ Wet bulb temperature : 850/700/500 hPa
* Single level or soil layer data
	+ 99 single level or soil layer variables are also operationally available as 3-hourly data, which are instant values or accumulated/time-averaged/maximum/minimum values.

#### 4.2.4 Operational techniques for application of NWP products *(MOS, PPM, KF, Expert Systems, etc..)*

**4.2.4.1 In operation**

The application techniques for both the medium- and short-range forecasting systems are described in **4.3.4.1.**

**4.2.4.2 Research performed in this field**

Nothing to report

#### 4.2.5 Ensemble Prediction System (EPS)

**4.2.5.1 In operation**

KMA medium range global ensemble forecast system which is based on the UK Met Office Global and Regional Ensemble Prediction System (MOGREPS) has been running operationally since March 2011. After the new KMA ensemble prediction system based on MOGREPS, the version of UM and physic are updated and sea surface temperature (SST) perturbations in ETKF are added. The updated KMA hybrid 4-dVAR Ensemble Prediction System has been run from 29 June 2013. It runs 4 times a day up to 12 days at 00 and 12 UTC to support weekly forecasts and runs up to 9 hours at 06 and 18UTC to provide ensemble background error statistics to hybrid ensemble-4dVar data assimilation system.

KMA participates in the WMO THORPEX TIGGE program and provides operational global ensemble products to the TIGGE archive centres. The standard verification scores of EPS are regularly exchanged through the EPS verification website hosted by JMA.

**Table 4.3** Configuration of the global ensemble prediction system for medium-range as of 2013

|  |  |  |
| --- | --- | --- |
|  | EPSG based on MOGREPS (OPER 2) | Upgraded EPSG (OPER 3) |
| Period |  24. June 2012 ~ 29 June 2013 | 29. June. 2013 ~  |
| Horizontal resolution | N320 (0.5625x0.375 degrees) | N320 (0.5625x0.375 degrees) |
| Vertical resolution (model top) | 70 levels (80km) | 70 levels (80km) |
| Forecast model | GDAPS  | GDAPS |
| Model version and physics | UM vn7.9 / PS28(GA3.1) | UM vn7.9 / PS28(GA3.1) |
| Data assimilation for control analysis | 4DVAR using Global deterministic forecast for background field | The hybrid Ensemble-4DVAR using Global deterministic forecast for background field |
| Forecast length | 10 days | 12 days |
| Number of runs per day (time) | 2 (00UTC, 12UTC) | 4 (00, 06, 12, 18UTC) |
| Initial perturbation method (area) | ETKF(Ensemble Transform Kalman Filter) | ETKF(Ensemble Transform Kalman Filter) |
| Initial SST perturbation | None | ETKF |
| Ensemble size | 24 members (1 control + 23 perturbed members) per run | 24 members (1 control + 23 perturbed members) per run |
| Perturbation of physics | RP, SKEB | RP, SKEB |
| Ancillary | CAP6.6 | CAP7.7(aerosol, ozone, soil, vegtation, etc) |

**4.2.5.2 Research performed in this field**

The upgrade in model, physics, and surface perturbations for new KMA EPS showed a slight improvement in errors and spread of geopotential height at 500hPa level. The errors and spread in the low level temperature are not significant over the Northern hemisphere and Asia area, while it showed negative performance over the Southern hemisphere and the Tropics. These negative impacts on the low level temperature are probably due to changes in model physics.

#### 4.2.5.3 Operationally available EPS Products

The following products from global EPS are available:

* Mean and Spread for MSLP, geopotential height at 500hPa, and temperature at 850hPa
* Spread and Spaghetti for geopotential height at 500hPa
* Stamp map for geopotential height at 500hPa, MSLP and precipitation
* Probability of precipitation for several thresholds
* Ensemble meteogram of temperature, total cloud amount, precipitation, wind speed at 10m, and surface air temperature for 25 major cities
* Ensemble meteogram of surface air temperature corrected bias for 20 cities
* Extreme Forecast Index(EFI) for daily rainfall, wind gust, maximum and minimum temperature
* Probability of Tropical Cyclone genesis and existence in monitoring area

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

#### 4.3.1 Data assimilation, objective analysis and initialization

**4.3.1.1 In operation**

4DVAR has been used as a main data assimilation system for the limited area model based on the Unified Model which covers the East Asia domain since it was introduced to the operational suite in 2011. Most of the observation species assimilated in the global NWP system are also available for the regional system. KMA’s another operational regional NWP system, WRF 10kmL40 is also being operated providing a different aspect of model forecast to forecasters.

**Table 4.4** Configuration of operational data assimilation for the short-range NWP suite as of 2013

|  |  |  |
| --- | --- | --- |
|  | RDAPS (UM 12kmL70) | RDAPS (WRF 10kmL40) |
| Data assimilation | 4DVAR | KWRF-3DVAR (based on WRF 3DVAR) |
| Initial condition | From regional 4DVAR | From KWRF-3DVAR |
| Boundary condition | From the Global UM | From the Global UM |
| Number of vertical layers | 70 | 40 |
| Domain top | 80km | 50hPa |
| Horizontal grids | 540 X 432 | 574X514 |
| Horizontal resolution of analysis | 12km | 10km |
| Inner loop resolution | 36km 70 layers | 10km 40 layers |
| Initialization | - | DFI |
| Domain | East Asia | East Asia |

※ DFI: Digital Filter Initialization (-2 hour backward ~ +2 hour forward)

**4.3.1.2 Research performed in this field**

Nothing to report

#### 4.3.2 Model

**4.3.2.1 In operation**

KMA has been operating two regional models, RDAPS (based on UM) and KWRF (based on WRF). KMA run operationally RDAPS based on the Unified Model with 12-km resolution in May 2010. Also, there was implementation of 4DVAR in RDAPS in May 2011. The model with 12km horizontal resolution, 70 vertical layer(top~80km) provides 87-hour prediction 4 times a day. Table 4.5 shows configuration of the two regional models.

* Major changes in the operational regional model :
* Apply Abell &Shipway(2007) rainfall speed in LS precipitation scheme
* Use the equivalent canopy snow depth in surface calculations
* Ancillary Data Set update : soil physical properties

- New soil physical properties have more sensible values and the spatial patterns are realistic

**Table 4.5** Key model parameters of regional models (UM 12kmL70 & WRF 10kmL40) for short-range forecast

|  |  |  |
| --- | --- | --- |
|  | RDAPS (UM 12km L70) | RDAPS (WRF 10km L40) |
| Base Model  | UM(Unified Model) | WRF-ARW |
| Governing Equation | Complete equation (Non-hydrostatic) | Non-hydrostatic |
| Horizontal Resolution | 12km(0.11x0.11)/540x432 | 10km/574x514 |
| Number of vertical layers | 70 | 40 |
| Model time step | 200sec | 60sec  |
| Forecast Length | 3days(87hours) | 3days(72hours) |
| Initial condition | From regional 4DVAR | From the Unified 3DVAR/ DFI |
| Time integration | Semi-implicit Semi-Lagrangian scheme | Time split by 3rd order Runge-Kuta |
| Radiation Process | Edwards-Slingo general 2-stream scheme | RRTM  |
| Surface Process | Joint UK Land Environment Simulator (JULES)4 layer soil model using van Genuchten (1980) soil hydrology | Noah LSM  |
| PBL Process | First order non-local boundary layer scheme of based on Lock et al. (2000) | YSU PBL |
| Convection Process | Mass flux convection with CAPE closure | New Kain-Fritsch |
| Microphysics | Mixed-phase precipitation | WSM6 |
| Gravity Wave Drag | G.W. drag due to orography (GWDO) | - |
| Surface B. C.  | Surface Analysis + Climatology | Surface Analysis + Climatology |
| Operation Frequency | Four times daily / 6hour D.A. cycle | Four times daily / 6hour D.A. cycle |

**4.3.2.2 Research performed in this field**

Nothing to report

#### 4.3.3 Operationally available NWP products

Operational RDAPS(Regional Data Assimilation and Prediction System) products routinely available on model’s original horizontal resolution in GRIB-II format are as follow

* Pressure level data : 3-hourly up to +87 hours
	+ 3-dimensional wind components : 24 levels (1000~50hPa)
	+ Geopotential height : 24 levels (1000~50hPa)
	+ Temperature : 24 levels (1000~50hPa)
	+ Relative humidity w.r.t. ice/water : : 24 levels (1000~50hPa)
	+ Wet bulb temperature : 850/700/500 hPa
	+ Ertel Potental Vorticity at theta surface : 330/315/300K
* Single level or soil layer data
	+ 101 single level or soil layer variables are also operationally available as 3-hourly data, which are instant values or accumulated/time-averaged/maximum/minimum values.

#### 4.3.4 Operational techniques for application of NWP products

**4.3.4.1 In operation**

For short-range forecast, three statistical approaches, MOS, PPM and Kalman filter, have been used to objectively interpret NWP outputs. MOS and PPM based on RDAPS(UM 12kmL70) have been operated to provide initial estimation for KMA digital forecasts. PPM and Kalman filter are also applied to several KMA operational models to provide objective guidance for conventional forecasts.

KMA has operated the digital forecast system to provide village scale (5km by 5km) forecasts up to 2 days. The digital forecast system covers KMA’s short-range forecast and produces 12 weather elements in gridded base. The digital forecast system also provides various reproduced contents such as time-series forecast at specific points, worded forecast, mobile service, etc. Very short-range forecast is also provided by the digital forecast system at every hour up to 3hour.

For medium-range forecast, MOS, PPM and Kalman filter scheme based on GDAPS has been used to provide temperature guidance for 19 major cities.

KMA was extending forecast lead time 7 days to 10 days in medium range forecast and 2 days to 3days in short range forecast. According to the new requirement, the projection of MOS and PPM was extended 66 hour to 87 hour and 10 days to 12days respectively. The longest valid MOS equation was applied to the extended period and the verification showed no significant deterioration.

**Table 4.6** Operational techniques for application of NWP in KMA

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NWP Model** | **Element** | **Basis** | **Projection** | **Interval** | **Statistical Approach** |
| RDAPS(UM 12km) | 2m Temperature | 00, 12 UTC | +6 ~ +87h | 3h | MOS, KF |
| Daily Max/Min Temperature | 00, 12 UTC | +3day | 1d | MOS |
| Total Cloud Cover | 00, 12 UTC | +6 ~ +87h | 3h | MOS, PPM |
| Probability of Precipitationover 0.1mm | 00, 12 UTC | +6 ~ +87h | 3h | MOS |
| Type of precipitation | 00, 12 UTC | +6 ~ +87h | 3h | MOS, PPM |
| 2m Relative Humidity | 00, 12 UTC | +6 ~ +87h | 3h | MOS |
| 10m wind direction/speed | 00, 12 UTC | +6 ~ +87h | 3h | MOS |
| KWRF(10km) | Type of precipitation | 00, 12 UTC | +6 ~ +87h | 3h | PPM |
| Total Cloud Cover | 00, 12 UTC | +6 ~ +87h | 3h | PPM |
| Daily Max/Min Temperature | 00, 12 UTC | +3day | 1d | KF |
| 2m Temperature | 00, 12 UTC | +6 ~ +66h | 3h | KF(DLM) |
| GDAPS(UM N512) | Daily Max/Min Temperature | 00, 12 UTC | +12day | 1d | MOS,KF(DLM) |
| Type of precipitation | 00, 12 UTC | +12day | 12h | PPM |
| Total Cloud Cover | 00, 12 UTC | +12day | 12h | PPM |

**4.3.4.2 Research performed in this field**

Ensemble MOS (EMOS) based global EPS(UM N320L70M24) was developed with EPS products archived since 2011. As the initial field for EPS is generated by ETKF, one ensemble equation was derived with two year ensemble predictor database from EPS, instead of deriving 24 equations for each ensemble member. EMOS for maximum and minimum temperature was verified by 5 fold cross validation. The RMSE of median of EMOS prediction was 1°C lower than that of direct output from EPS, while the spread of EMOS being comparable to EPS.

#### 4.3.5 Ensemble Prediction System

**4.3.5.1 In operation**

No operational short-range EPS

**4.3.5.2 Research performed in this field**

KMA has been developing short-range ensemble forecasting system to provide guidance for early warning by providing a probabilistic prediction of high impact weather. The system will be designed to forecast 48 hours at every 12 hours based on enhanced KMA global ensemble prediction. We investigated the sensitivity of the performance of probabilistic precipitation forecast of local ensemble to the number of ensemble members and horizontal resolution. The sensitivity results show that 8 to 12-member 3 km ensemble is comparable or better than 12-member 2 km ensemble and even better than 16-member 1.5km ensemble for 0.1mm threat score in all spatial scale (Fig. 4.1).



 **Fig. 4.1** The fractions skill score of each members and horizontal resolution with respect to the spatial scale.

#### 4.3.5.3 Operationally available EPS Products

None

#### Short-range Local Forecasting system (0-24 hrs)

#### Data assimilation, objective analysis and initialization

**4.4.1.1 In operation**

All observations within 1 hour 30 minutes time range from analysis time are assimilated by incremental 3DVAR. The analysis increments are computed on the 3km horizontal resolution inner grid by minimizing the cost function, which measures the differences from the model forecasts and observations. The rain rate data derived from radar reflectivity and rain gauge observations with 10 minute interval is added to be assimilated via latent heat nudging. The incremental analysis update is applied to remove noises in analysis increments.

**4.4.1.2 Research performed in this field**

Impact study of reducing the data assimilation cycling from 3 hour to 1 was performed, and the results show the improvements in first 12 hour light rain forecasts. The new data assimilation and prediction system with 1km horizontal resolution with hourly cycling was developed to support the international sport event, the 2014 Incheon Asian Games.

#### 4.4.2 Model

**4.4.2.1 In operation**

KMA started running LDAPS(UM 1.5kmL70) operationally on 15 May 2012 to produce detailed short-range weather prediction for the Korean Peninsula after a successful one year trial run and stability test. The model with 1.5km horizontal resolution, 70 vertical layers (top~40km) provides 36-hour prediction 4 times a day. Table 4.7 shows configuration of the LDAPS model.

* Major changes in the operational local model(LDAPS) :
* Add ice crystal type in long wave radiation scheme
* Use unfiltered orography in short wave radiation scheme
* Change size distribution of ice particles in LS precipitation scheme
* Use murk aerosol information for visibility calculation
* Add latent heat nudging by Radar

**Table 4.7** Key model parameters LDAPS (UM 1.5kmL70) for short-range local forecast

|  |  |
| --- | --- |
| Horizontal grid | Variable grid (Inner: 1.5km, 0.0135X0.0135) |
| Vertical grid | 70 levels (surface~39km). |
| Time step | 50 sec |
| Forecast range | 36 hours. |
| I.C / Data assimilation | 3DVAR ( FGAT, IAU) |
| Boundary condition | From the global model |
| Surface B. C. | Surface analysis + Climatology |
| Operation Frequency | 8 times daily / 3-hourly D.A. cycle |
| Time integration | Semi-implicit Semi-Lagrangian scheme |
| Radiation Process | Edwards-Slingo general 2-stream scheme |
| Surface Process | Joint UK Land Environment Simulator (JULES)4 layer soil model using van Genuchten (1980) soil hydrology |
| PBL Process | First order non-local boundary layer scheme of based on Lock et al. (2000) |
| Microphysics | Mixed-phase precipitation |
| Gravity Wave Drag | G.W. drag due to orography (GWDO) |

**4.4.2.2 Research performed in this field**

Nothing to report

#### 4.4.3 Operationally available NWP products

Operational LDAPS products routinely available on model’s original horizontal resolution in GRIB-II format are as follow

* Pressure level data : 1-hourly up to +36 hours
	+ 3-dimensional wind components : 24 levels (1000~50hPa)
	+ Geopotential height : 24 levels (1000~50hPa)
	+ Temperature : 24 levels (1000~50hPa)
	+ Relative humidity w.r.t. ice/water : : 24 levels (1000~50hPa)
* Single level or soil layer data
	+ 78 single level or soil layer variables are also operationally available as 1-hourly data, which are instant values or accumulated/time-averaged/maximum/minimum values.

#### 4.4.4 Operational techniques for application of NWP products

**4.4.4.1 In operation**

Nothing to report

**4.4.4.2 Research performed in this field**

Nothing to report

#### 4.4.5 Ensemble Prediction System

**4.4.5.1 In operation**

Nothing to report

**4.4.5.2 Research performed in this field**

Nothing to report

#### 4.4.5.3 Operationally available EPS Products

None

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

#### 4.5.1 Nowcasting System

**4.5.1.1 In operation**

The precipitation nowcasting system is KONOS (KOrea NOwcasting System). The KONOS is an advanced version of MAPLE (McGill Algorithm for Precipitation Lagrangian Extrapolation) including an orographic effect, AWS-RADAR window matching, and merging with a NWP model after 3-hr forecast. KONOS extrapolates radar data from 0 to 6-hr with 1km horizontal resolution at every 10-min.

**4.5.1.2 Research performed in this field**

For developing the forecast system handling about heavy rainfall event, we realized a warning guidance of heavy rainfall by using of an observation data about 692 AWS (Automatic Weather System) stations, and performed work-site operations research for deciding an appointment on stations of actual rainfall events. The predictor of the guidance performed a predicting about a quantity of rainfall with the aid of the SVR (Support Vector Regression) model.

#### 4.5.2 Models for Very Short-range Forecasting Systems

**4.5.2.1 In operation**

The Korea Local Analysis and Prediction System (KLAPS) runs every hour with 5-km horizontal resolution in operation for the support of very short-range forecast. Mother domain runs 4 times a day with 15-km horizontal resolution.

The KLAPS has a cloud analysis and a diabatic initialization scheme for the very quick precipitation spin-up within a 1-h integration of numerical weather prediction model. The KLAPS also produces 9 current weather information (temperature, sky condition, precipitation amount, relative humidity, wind direction, speed, and precipitation types, and lightning) and 4 prediction elements (precipitation amount, sky condition, precipitation type, probability of lightning) of guidance at each grid point for the public service after the forecaster’s final decision.

**Table 4.8** Operational configuration of KLAPS as of 2013

|  |  |  |
| --- | --- | --- |
|  | Domain 1 | Domain 2 |
| Horizontal resolution | 15km | 5km |
| Number of grid-points | 251 x 251 | 235 x 283 |
| Domain distance(km) | 10,800 x 10,800 | 3,150 x 3,150 |
| Vertical layers/Model Top | 40 sigma layers / 50 hPa |
| Time step for integration | 60s | 20s |
| Cumulus Parameterization | New Kain-Fritsch | None |
| Boundary layer | YSU PBL |
| Microphysics | WDM6  |
| Radiation | Dudhia & RRTM |
| Land-surface | 5 layer thermal diffusion scheme |
| Lateral Boundary data | GDAPS(UM N512L70) forecast data |

**4.5.2.2 Research performed in this field**

KMA developed preprocessing system for back-scattering data from ceilometer and radar beam tracing model in order to utilize remote-sensing data such as ceilometer and radar. The back-scattering data play an important role in analysis for 3 dimensional cloud distribution and data assimilation for numerical model. KMA developed the technique for decoding raw data produced by ceilometer into back-scattering data in decimal digit, and besides signal processing technique was created to reduce noise in back-scattering data. The radar beam tracing model was developed to reduce weather radar propagation error due to the assumption of spherical homogeneity of refractivity. The model can calculate radar beam path under not only normal refractivity condition but also ducting condition. It is require more detail refractivity data near the surface to obtain sophisticated radar beam propagation path. KMA developed GNSS processing system to achieve precipitable water in the radial direction of the each satellite orbits.

**Table 4.9** Key model parameters of the very short-range forecasting system

|  |
| --- |
| ***Frame*** |
| Governing Eq. | Completed equation (Non-hydrostatics) |
| Spatial Discretization | Finite Difference method |
| Time integ. / Advection | Semi-implicit Semi-Lagrangian scheme |
| Horizontal resolution | 1km (0.009o X 0.009o) |
| Vertical resolution | 70 layers from surface to 39km |
| Time integration/ Operation frequency | 12 hours / every 1-hour |
| Data Assimilation | 3DVAR |
| Boundary condition | 30min interval from LDAPS(UM 1.5km L70) |
| ***Physics*** |  |
| Radiation Process | Edwards-Slingo general 2-stream scheme |
| Surface Process | JULES land-surface model |
| Deep convection | None |
| Planetary layer | Non-local scheme |
| Microphysics | Mixed-phase precipitation |
| Gravity Wave Drag | G.W. drag due to orography (GWDO) |
| Surface B. C.  | Surface Analysis + Climatology |

Data assimilation is designed to assimilate observations within 1 hour assimilation window (-30 min and +30 min of analysis time) with one-hour cycling. The observations to be assimilated are Doppler radial wind, winds from windprofiler, satellite radiances and conventional surface observations. Rainrates, derived from radar reflectivity and rain gauge data with 10 minute interval, are also assimilated by latent heat nudging.

#### Specialized Numerical Predictions

#### 4.6.1 Tropical Cyclone Prediction System

**4.6.1.1 In operation**

Centre location, maximum wind speed (Vmax), and minimum central pressure (Pmin) of the tropical cyclones are predicted from GDAPS(UM N512L70), RDAPS(UM 12kmL70), KWRF(10kmL40), EPS(UM N320L70M24) and centre location are predicted from DBAR(Double Fourier Series BARotropic Typhoon Model) systems. Configuration of DBAR is described in Table 4.10.

**Table 4.10** Key model parameters and operational specification of DBAR

|  |  |
| --- | --- |
| Basic equation | Depth integrated shallow water equation |
| Prognostic variables | Depth integrated Pressure, wind (U, V) |
| Integration domain | Global |
| Horizontal grid | Spectral model with equivalent grid spacing of 0.3516° latitude and longitude (1024 x 513) |
| Initial condition | GDAPS analysis (850, 700, 600, 500, 400, 300, 250, 200hPa mean) |
| TC vortex initialization | GFDL type bogussing |
| Forecast range | 72 hours, 4 times/day (00/06/12/18UTC) |

**4.6.1.2 Research performed in this field**

* **TWRF (Typhoon WRF)**

The WRF-based typhoon prediction model TWRF is running in real time at the National Typhoon Centre. The products from the model are sent to Typhoon Analysis and Prediction System (TAPS) for use by typhoon forecasters. The GFDL-type bogussing is applied.

**Table 4.11** Configuration of TWRF as of 2013

|  |  |
| --- | --- |
| Spatial resolution | 15km x 15km (361 x 361), 42 sigma vertical layer up to 50hPa |
| TC vortex initialization | GFDL-type bogussing |
| Microphysics | WSM-6 class scheme |
| Radiation | RRTM (Dudhia) |
| Land surface | 5-layer thermal diffusion |
| Cumulus parameterization | New Kain-Fritsch |
| Boundary layer | YSU PBL |
| Lateral Boundary data | GDAPS(UM N512L70) forecast data |
| Forecast range | 120 hours, 2 times/day (00/12UTC) |

#### 4.6.2 Ocean Wind Wave Prediction System

**4.6.2.1 In operation**

The current operational ocean wind wave prediction systems are the global (GoWW3, 1/2°), the regional (ReWW3, 1/12°), the coastal (CoWW3, 1/120°) systems which employs the 3rd generation community wave model WAVEWATCH-III version 2.22. The operational cycle of 3 systems are two times per day (00, 12UTC) and the lead forecast times are 12 days for global, 87hours for regional and 72hours for coastal system. The mesh size of 1km with covering 5 regional forecast offices’ marine forecast area domains nested inside the regional system. The directional wave spectra at boundaries of coastal domain are provided from 1/12° ReWW3.

* Major changes in the operational wave model :
	+ upgrading the coastal domain from six regular 2° by 3° to KMA’s 5 regional branch marine forecast domains (CoWW3).
	+ Extension of forecast ranges : GoWW3 (10days→12days), Reww3 (72hours→87hours), CoWW3 (24hours→72hours)

**Table 4.12** Configuration of operational ocean wind wave prediction systems as of 2013

|  |  |  |  |
| --- | --- | --- | --- |
|  | GoWW3 | ReWW3 | CoWW3 (5 Domains) |
| Code | WAVEWATCH-III v. 2.22 |
| Coordinate | Spherical Coordinate |
| Domain | 70°S-70°N0°E-358.75°E | 20°N-50°N115°E-150°E | Daejeon: 36.0°-39.0°N, 123.0°-127.0°E (481x361)Gwangju: 33.0°-36.5°N, 124.0°-128.0°E (481x421)Busan: 33.5°-37.0°N, 127.0°-131.0°E (481x421)Kangwon: 36.5°-40.0°N, 127.0°-132.5°E (661x421)Jeju: 31.0°-35.5°N, 123.0°-129.0°E (721x541) |
| Spatial Resolution /Dimensions | 1/2°(720 x 281) | 1/12°(421 x 361) | 1/120° |
| Spectral Resolution | Frequency: 25Direction: 24 | Frequency no. 25, Direction no.: 36 (10° interval) |
| Time Step | 720 sec | 300 sec | 30 sec |
| Forecast Length | 288 hours | 87 hours | 72 hours |
| Number of Runs | 2 times / day (00, 12 UTC) |
| Initial &Boundary Data | 12-hour forecast from the previous run | 12-hour forecast from the previous runReWW3 boundary |
| Forcing Data | GDAPS(UM N512L70)Sea SFC Winds(6-hour interval) | RDAPS(UM 12kmL70)Sea SFC Winds (3-hour interval) |

**Table 4.13** WAVEWATCH-III Grid pre-processor input information chosen for GoWW3

|  |  |
| --- | --- |
| Frequency increment factor and first frequency (Hz) | 1.1 0.04118 25 24 |
| Time steps (global / CFL for x-y / for k-theta / source) | 1440 / 720 / 1440 / 720 sec |
| Input Source Terms | Tolman and Chalikov / SIN2 SWELLF = 0.1, ZWND = 10., STABSH = 1.4 |
| Nonlinear interactions | Discrete Interaction Approximation (DIA) |
| Dissipation Source Terms & Bottom Friction | Tolman and Chalikov / JONSWAP SBT1 GAMMA = -0.019 |
| Propagation schemes | Ultimate-Quickest with averaging |
| Grid Definition | - Latitude-longitude grid (LLG): 720 (0.0) 281 (-70.0)- Bottom depth: 15m- Sub-grid information: none  |

**4.6.2.2 Research performed in this field**

The multi-grid system with WAVEWATCH-III version 3.14 which encompasses all 2-domain systems (regional-coastal) in way of double nested-multi-grid system are tested for next version of operational KMA wind wave prediction system.

#### 4.6.3 Tide and Storm Surge Prediction System

**4.6.3.1 In operation**

The Regional Tide and Storm Surge Model (RTSM) in KMA covers 115°-150°E, 20°-52°N based on POM (Princeton Ocean Model) (Blumberg and Mellor, 1987) with 1/12° horizontal resolutions including the Yellow Sea, East China Sea and the East Sea, marginal seas around Korea. In this model, the level of storm surge calculated by the difference between tide level and sea level change caused by meteorological effects. This system has same operational cycle of ocean wind wave prediction system.

* Major changes in the operational tide and storm surge model :
	+ Extension of forecast ranges : RTSM (72hours→87hours)

**Table 4.14** Configuration of RTSM system as of 2013

|  |  |
| --- | --- |
| Model | 2-D Ocean Circulation Model (POM 2D) |
| Coordinate system | Spherical coordinate |
| Model domain | 115 °E-150 °E, 20 °N-52 °N |
| Horizontal resolution | 1/12 ° by 1/12 °, (421 ×385) |
| ΔT | 200 sec |
| Prediction time | 72 H (00,12UTC) |
| Initial field | Hot start |
| Input data | RDAPS sea surface wind and MSLP, 8 tidal constituents |

**4.6.3.2 Research performed in this field**

The coastal version (CTSM) which has the same resolution and domain with coastal wave system is under development and expected to be implemented in summer season of 2014.

#### 4.6.4 Asian Dust Prediction System

**4.6.4.1 In operation**

The UM-ADAM[[3]](#footnote-3)2(N512) model is an Eulerian dust transport model which includes the specifications of the dust source regions, delineated by the statistical analysis of dust observation over the East Asian domain. The model has horizontal resolution of 25km and 47 vertical layers up to 100hPa in σ-coordinate, and the operational global model (UM N512L70) is used as an atmospheric forcing model.

Dust source regions in ADAM are defined based on the statistics of the dust report in Synoptic Observation from 1998 to 2007, which is then classified with soil types of Gobi, sand, loess, and mixed by using the Soil Atlas of China. Monthly thresholds for meteorological conditions of surface wind speed, relative humidity, precipitation, and ground temperature depending on soil type determine the onset of the dust emission process. The estimation of dust emission amount is parameterized to be proportional to the fourth power of the function of friction velocity, and is then modulated by the reduction factor of vegetation (Ri). Here, Ri is determined by Normalized Difference Vegetation Index over the source regions. Dust particles of 11 size bins with the same logarithm intervals for particles of 0.2-74 ㎛ in diameter are considered in the model. And the suspended particle-size distribution is parameterized as weighted sum of the several log-normal distributions of the soil particle-size distribution in the source regions, based on the concept of the minimally and fully dispersed particle-size distribution.

* Major changes in the operational Asian dust model :
	+ Update cycle is upgraded from 2 times (00, 12UTC) per day to 4 times (00, 06, 12, 18UTC) per day.

**Table 4.15** Configuration of Asian dust prediction system as of 2013

|  |  |
| --- | --- |
| Model | UM-ADAM2(N512) |
| Meteorological model | Operational global model (UM N512L70) |
| Model domain | East Asia |
| Horizontal/Vertical resolution | Horizontally 25km (with 340 x 220 grids)Vertically 47 layers (up to 100 hPa) |
| Prediction range | 72 hours (00/06/12/18UTC) |
| Dust size range | 0.2 ~ 74 (㎛ in diameter) |
| Dust size bins | 11 bins |
| Dust density | 2600 kg m-3 |
| Dust particle size distribution | Log normal distribution |
| Vegetation data | SPOT NDVI (1km resolution) |

**4.5.4.2 Research performed in this field**

In order to evaluate the performance of the dust prediction model quantitatively, the model simulation has been tested with 72-hour forecasts for the springtime in 2013. The model results showed that the mean bias and RMSE are -21.5 and 66.3 ㎍/㎥, respectively, when compared to PM10 concentrations observed at surface stations in Korea. To deal with both dust and fine aerosols, we have developed a comprehensive aerosol model (called ADAM-Haze model). We plan to run this model operationally in order to forecast Asian dust and haze phenomena in East Asia from the year of 2015

#### Extended Range Forecasts (ERF) *(10 days to 30 days)*

#### 4.7.1 Models

**4.7.1.1 In operation**

* **Global Climate Model**

The operational extended range forecast system is based on the global spectral model, with a horizontal resolution of T106 and 21 vertical levels on the hybrid sigma-pressure coordinates. 20 ensemble members with a lagged average method with about 15-day forecast lead time are used for the ensemble extended range forecast. The specifications for the model are summarized in Table 4.16.

**Table 4.16** Configuration of global climate model as of 2013

|  |  |
| --- | --- |
| Model Name | Global Spectral Model (GSM) |
| Implementation  | Tier-2 Forecast System |
| Major Physics | Cloud Convection | Kuo scheme |
| Land Surface & PBL | SiB (Simple Biosphere)Yamada-Meller  |
| Radiation | Lacis & Hansen for SWRoger & Walshaw Glodman & Kyle Houghton for LW |
| Large scale condensation | Kanamitsu et al. |
| Dynamics | Three-dimensional global spectral model with hydrostatic primitive equationsHybrid sigma-pressure coordinateSemi-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 2012) |
| Forecast range | 1-month forecast (10-day mean)3-month forecast (1-month mean)Seasonal climate outlook |

* **Global sea surface temperature forecasting model**

The El Nino prediction system (Kang and Kug, 2000) is based on an intermediate ocean and statistical atmosphere model. The ocean model differs from the Zebiak and Cane (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. A breeding technique is applied to reduce the uncertainty of the initial field of the ENSO model.

In order to improve the western Pacific SST prediction, KMA introduced a heat flux formula and vertical mixing parameterization to its ocean model. The model is initialized by combining observed SST with wind stress. Wind stress is calculated by using the 925hPa wind of the NCEP/NCAR reanalysis data.

A statistical model is also applied to correct the systemic error in the prediction model. The Coupled Pattern Projection Model (CPPM, Kang et al. 2004) used is a point-wise 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 the large-scale predictor field of the target year. Predictability over the tropical Pacific was improved by applying this model to the dynamic model results and compositing the results from both the dynamical and statistical models.

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

**4.7.1.2 Research performed in the field**

Nothing to report

#### 4.7.2 Operationally available NWP model and EPS ERF products

See 4.8.2

#### Long Range Forecasts (LRF) *(30 days up to two years)*

#### 4.8.1 In operation

The long-range forecast system is identical to the extended range forecast system described in section 4.7. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea for the upcoming 3 months (see 4.8.2).

A multi-model ensemble (MME) technique developed and a WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME) is used for long-range forecast. The LC-LRFMME collects the historical and real-time forecast anomaly data from 12 Global Producing Centres (GPCs) for its automatic MME input data producing system. The APEC Climate Centre (APCC) and LC-LRFMME have developed various MME techniques for deterministic and probabilistic seasonal predictions. For deterministic forecast, three kinds of linear MME techniques are used, which are biased and unbiased simple composite, weighted combination of multi-models based on SVD, and MME with Regular Multiple Regression.

#### 4.8.2 Operationally available EPS LRF products

**Table 4.17** Long-range forecasts and Climate outlook as of 2013

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1-month forecast | 3-month forecast | Seasonal climate outlook |
| Issue Date | · 3rd , 13th, and 23rd day of each month | · 23rd day of each month | · 23rd day of Feb., May, Aug., and Nov. |
| Forecast type | Three-category forecast : Above, below and near normalThe anomalies are based on model’s climatology obtained from a 34 yearsdatabase (1979 to 2012). |
| Contents | · 10-day mean temperature and precipitation | · 1-month mean temperature and precipitation*\*1Asian dust outlook**\*2Typhoon outlook* | · seasonal temperature and precipitation |
| Forecast area | Korea | Korea | Korea |

\*1*Asian dustoutlook* is issued in late February including the number of Asian dust days as Asian dust is expected to affect Korea for the upcoming spring.

\*2 *Typhoon outlook* is issued in late May and Aug. regarding the number of Typhoon, which is expected to affect Korea for the upcoming summer and autumn.

## **Verification of prognostic products**

#### Annual verification summary

The summary of annual verification statistics for GDAPS is calculated by comparing the model forecast to the analysis and radiosonde observation (see Table 5.1 and 5.2). Table 5.3 to 5.7 present detailed monthly verification statistics for GDAPS, by comparing the model forecast against the analysis.

**Table 5.1** RMSE verification of KMA’s global model (GDAPS) against the analysis in 2013

| Variables | Area. | T+24 hr | T+72 hr | T+120 hr |
| --- | --- | --- | --- | --- |
| Z500 | Northern Hemisphere | 7.02 | 21.82 | 43.37 |
| Z500 | Southern Hemisphere | 8.40 | 26.22 | 51.61 |
| V250 | Northern Hemisphere | 3.89 | 8.38 | 13.31 |
| V250 | Southern Hemisphere | 3.80 | 8.62 | 13.92 |
| V250 | Tropics | 3.33 | 5.84 | 7.62 |
| V850 | Tropics | 1.93 | 3.03 | 3.75 |

**Table 5.2** RMSE verification of KMA’s global model (GDAPS) against observation in 2013

| Variables | Area. | T+24 hr | T+72 hr | T+120 hr |
| --- | --- | --- | --- | --- |
| Z500 (geopotential height) | North America | 9.81 | 22.39 | 44.45 |
| Z500 | Europe | 9.59 | 21.98 | 43.58 |
| Z500 | Asia | 12.27 | 19.58 | 30.66 |
| Z500 | Australia/New Zealand | 10.59 | 19.86 | 37.09 |
| V250 (wind) | North America | 5.51 | 9.88 | 15.28 |
| V250 | Europe | 5.01 | 8.99 | 14.66 |
| V250 | Asia | 5.29 | 8.37 | 11.79 |
| V250 | Australia/New Zealand | 5.25 | 8.26 | 12.14 |
| V250 | Tropics | 5.23 | 6.82 | 8.16 |
| V850 | Tropics | 3.67 | 4.28 | 4.84 |

**Table 5.3** Monthly mean RMSE of 500hPa geopotential height forecast (m) in the Northern Hemisphere (GDAPS verification against analysis).

| FCST | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ave. |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24H | 8.09  | 7.14  | 7.44  | 6.95  | 7.17  | 6.84  | 6.35  | 6.02  | 6.31  | 6.70  | 7.29  | 7.91  | 7.02  |
| 72H | 26.29  | 22.14  | 24.20  | 22.34  | 21.94  | 20.36  | 18.39  | 17.26  | 20.78  | 20.56  | 23.56  | 24.04  | 21.82  |
| 120H | 51.20  | 42.92  | 50.88  | 44.29  | 44.51  | 40.04  | 35.96  | 33.32  | 41.18  | 41.22  | 47.63  | 47.24  | 43.37  |

**Table 5.4** Monthly mean RMSE of 500hPa geopotential height forecast (m) in the Southern Hemisphere (GDAPS verification against analysis)

| FCST | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ave |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24H | 7.36  | 7.17  | 7.62  | 8.24  | 9.06  | 9.55  | 9.10  | 9.22  | 9.05  | 8.58  | 8.42  | 7.38  | 8.40  |
| 72H | 22.19  | 22.25  | 24.68  | 26.96  | 29.16  | 30.45  | 27.92  | 28.76  | 27.90  | 26.16  | 25.89  | 22.32  | 26.22  |
| 120H | 43.73  | 43.89  | 47.33  | 54.93  | 58.78  | 56.35  | 57.45  | 56.64  | 54.57  | 52.66  | 50.51  | 42.53  | 51.61  |

**Table 5.5** Monthly mean RMSE of 250hPa wind forecast (m/s) in the Northern Hemisphere (GDAPS verification against analysis)

| FCST | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ave. |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24H | 3.70  | 3.62  | 3.81  | 4.01  | 3.99  | 3.99  | 4.00  | 4.08  | 4.01  | 3.76  | 3.82  | 3.87  | 3.89  |
| 72H | 8.24  | 7.66  | 8.08  | 8.64  | 8.66  | 8.67  | 8.53  | 8.44  | 8.78  | 8.06  | 8.42  | 8.35  | 8.38  |
| 120H | 13.40  | 12.18  | 13.11  | 13.53  | 13.88  | 13.37  | 12.97  | 12.75  | 13.81  | 13.29  | 14.02  | 13.46  | 13.31  |

**Table 5.6** Monthly mean RMSE of 250hPa wind forecast (m/s) in the Southern Hemisphere (GDAPS verification against analysis).

| FCST | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ave. |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24H | 3.53  | 3.62  | 3.67  | 3.81  | 3.82  | 3.85  | 3.82  | 3.80  | 3.93  | 3.83  | 3.98  | 3.95  | 3.80  |
| 72H | 8.46  | 8.39  | 8.77  | 8.92  | 9.09  | 9.00  | 8.66  | 8.37  | 8.51  | 8.39  | 8.53  | 8.39  | 8.62  |
| 120H | 13.51  | 13.31  | 13.97  | 14.48  | 15.48  | 14.54  | 14.31  | 13.42  | 13.55  | 13.77  | 13.91  | 12.84  | 13.92  |

**Table 5.7** Monthly mean RMSE of 250hPa wind forecast (m/s) in the Tropics (GDAPS verification against analysis).

| FCST | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ave. |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 24H | 3.31  | 3.25  | 3.18  | 3.12  | 3.04  | 3.20  | 3.52  | 3.46  | 3.54  | 3.38  | 3.45  | 3.52  | 3.33  |
| 72H | 6.16  | 6.03  | 5.66  | 5.90  | 5.60  | 5.70  | 5.94  | 5.71  | 5.83  | 5.66  | 5.90  | 6.03  | 5.84  |
| 120H | 8.02  | 7.89  | 7.50  | 7.71  | 7.55  | 7.61  | 7.54  | 7.32  | 7.32  | 7.43  | 7.77  | 7.74  | 7.62  |

## **Plans for the future *(next 4 years)***

#### Development of the GDPFS

#### 6.1.1 Major changes in the operational DPFS which are expected in the next year

* **Medium-range Forecasting System**
	+ Upgrade Unified Model : increase model resolution up to 17km
	+ Develop 4dEnVar (4dimensional Ensemble Variational method) for the next data assimilation system
	+ Improve large scale precipitation by including the effect of aerosol in the global model
	+ Enhance observation data utilization : COMS satellite wind and European geostationary satellite clear sky radiation data
* **Short-range Forecasting System**
	+ Refinement of surface / soil ancillaries : new soil hydraulic properties (wilting and critical points), new soil thermal conductivity
	+ Upgrade leaf area index (LAI) and model topography
	+ Upgrade regional data assimilation and observation processing software
* **Short-range Local Forecasting System**
	+ Development of Local Ensemble Prediction System
	+ Implementation of 2014 Asian Game supporting NWP guidance
	+ Develop 4dVar and incorporate more local observation such as radar reflectivity
	+ Increase model resolution up to 1km
* **Long-range Forecasting System**
	+ Implementation of a new Korea-UK joint seasonal forecasting system based on GloSea5

#### 6.1.2 Major changes in the operational DPFS which are envisaged within the next 4 years

* **Introduction of New HPC(supercomputer)**
	+ A new supercomputer, which will substitute the current Cray XE6 system will be introduced in KMA. Timeline of the major processes for the introduction of a new supercomputer is as follows;
		- ’14 : Introduction of a new supercomputer
		- ’15 : Migration of the operational NWP suite to the new system
		- ’16 : Implementation of higher resolution global NWP suite
* **NWP Models**
	+ A new dynamical core (ENDGame) of the Unified Model will be implemented and used for the operational NWP model with higher resolution (~17km) on the new supercomputer.
	+ Extended medium-range (2 weeks ~ 1 month) weather prediction system based on atmosphere-ocean couple model with ensemble approach will be developed and looked for feasibility.
	+ Short-range local ensemble prediction system with around 3km horizontal resolution will also be developed and operationally implemented.
* **Data Assimilation**
	+ 4dEnVar, which uses ensemble forecast system to keep the flow-dependency even without PF model, will be developed with the aim of its operational application in 2017
	+ Assimilation of new satellite data like NPP will be tried and various techniques to enhance the availability of the existing data like VARBC will be developed through international collaboration with the UK Met Office

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

#### 6.2.1 Planned Research Activities in NWP

* **Development of a new global NWP system**
	+ An R&D project for development of a new global NWP system in Korea started in 2011. KIAPS (Korea Institute of Atmospheric Prediction Systems) is currently developing core modules for the new NWP system – dynamical core, physics parameterization package, observation pre-processing / data assimilation and their framework, etc. – and the prototype global NWP system will be developed by 2016, targeting the development of the first operational version to be finished by 2019.

#### 6.2.2 Planned Research Activities in Nowcasting

Nothing to be reported

#### 6.2.3 Planned Research Activities in Long-range Forecasting

Nothing to be reported

## **References**

* <http://www.wmolc.org/~GPC_Seoul> : WMO LRF MME web site – contains information on KMA’s LRF system and produces
* <http://web.kma.go.kr/eng/biz/forecast_02.jsp> : Brief introduction of KMA’s NWP system
* <http://super.kma.go.kr/eng/index.jsp> : National Center for Meteorological Supercomputer web site – contains information on KMA’s supercomputer
* <http://www.kiaps.org> : KIAPS(Korea Institute of Atmospheric Prediction Systems) web site
1. Communication, Ocean and Meteorological Satellite (COMS, also known as Chollian); Korea’s first geostationary satellite launched in 2010. [↑](#footnote-ref-1)
2. ENDGame : Even Newer Dynamics for General atmospheric modelling of environment [↑](#footnote-ref-2)
3. ADAM : Asian Dust and Aerosol Model [↑](#footnote-ref-3)