W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N
===

ANNUAL JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM (GDPFS) INCLUDING NUMERICAL WEATHER PREDICTION (NWP) RESEARCH ACTIVITIES FOR 2014

CHINA, JULY 2015

1. Summary of highlights

1.1 Developments of operational NWP

The operational GRAPES-MESO was upgraded from V3.3 to V4.0 with 10km horizontal resolution and 50 vertical levels in June 2014. A new operational Global Ensemble Prediction System (T639-GEPS) has been operationally implemented since 7th Aug. 2014 in CMA with 15 -day forecasts and 15 ensemble members replacing the old version (T213-based GEPS). A new operational GRAPES-MESO-based Regional Ensemble Prediction System (GRAPES-MEPS) has been operationally implemented since 7 Aug. 2014 with 15km horizontal resolution, 72h forecast and 15 members.

1.2 Developments of GRAPES

A one year trial GRAPES-GFS (GRAPES Global Forecast System) was conducted with the horizontal resolution at 0.5 degree, 60 levels in vertical and the model top at about 3hPa. The performance of the trial is comparable to the current operational global spectral model of CMA.

Some research activities on GRAPES-GFS include: 1) The optimization of the code of GRAPES global 4D-Var to match the new version global model, has improved much the precision and efficiency of GRAPES-4DVAR, and its performance is very similar to GRAPES 3D-Var when only GTS data are assimilated. 2) The development of GRAPES Yin-Yang grid dynamics built in the frame of the lat-lon grid GRAPES, is almost finished. Several idealized tests are conducted with GRAEPS Yin-Yang grid dynamics and the reasonable results are shown.

An ‘on-demand’ GRAPES-3km (the horizontal resolution is 3km) was established and supported the severe weather forecast in the flood season in 2014 in China. Some results showed that this high resolution GRAPES-Meso could capture the severe rainstorm events in eastern China, and its performance was better than the operational one at 10km-resolution.

2. Equipment in use

There is no change in 2014. The total peak performance of IBM Flex System P460 is 1759 TFlops and the total storage capacity is about 6925TB. Three sets of subsystems of this HPC were installed in Beijing in 2013, in which the peak performance was more than 1PFlops. More details are showed in Table 2.1.

Table 2.1 Details of sub-systems of CMA IBM Flex System and/or P460 HPC Systems

Subsystem	SS1	SS2	SS3	SS4	SS5	SS6	SS7
Site	Beijing		Guangzhou	Shenyang	Shanghai	Wuhan	Chengdu
Peak Performance (TFlops)	527.10	527.10	391.69	77.24	51.80	77.24	26.35
Storage (TB)	2109.38	2109.38	949.22	210.94	140.63	210.94	70.31
CPU Cores （Include I/O nodes）	18560	18560	13792	2720	1824	2720	928
Memory (GB)	81792	81792	57856	10752	7168	10752	3584

3. Data and Products from GTS in use

Data from GTS in use are showed in table 3.1 according to one day data used by GRAPES-GFS in a batch experiment in December 2014.

Table 3.1 Number of observation reports in use

Data type	Mean	Data type	Mean	Data type	Mean
SYNOP	17967	AIREP/AMDAR	123782	NOAA15_AMSUA	82918
SHIP/BUOY	5166	SATOB (WIND)	86089	NOAA18_AMSUA	88896
TEMP	1335	AIRS	83200	METOPA+B-AMSUA	32400
				METOPA+B-MHS	2943000
GNSS(including COSMIC)	2447	NOAA19-AMSUA	80086	METOPA+B-IASI	64800
				METOP-A-ASCAT	589896

4. Forecasting system

4.1 System run schedule and forecast ranges

In IBM Flex Power P460, the operational schedule is shown in table 4.1.

Table 4.1 Operational Schedule of NWP system in CMA

Systems	Cut-off time (UTC)	Run time (UTC)	Computer used
Global Forecasting System (operational) (T639L60_GSI)	01:40 (18Z_ASSIM+9HR_FCST)	01:40～02:40	IBM Flex P460
	03:29 (00Z_ASSIM+240HR_FCST)	03:29～05:50	IBM Flex P460
	10:00 (00Z_ASSIM+9HR_FCST)	10:00～11:00	IBM Flex P460
	11:15(06Z_ASSIM+84HR_FCST)	11:15～13:20	IBM Flex P460
	13:40 (06Z_ASSIM+9HR_FCST)	13:40～14:40	IBM Flex P460
	15:29 (12Z_ASSIM+240HR_FCST)	15:29～17:50	IBM Flex P460
	22:00 (12Z_ASSIM+9HR_FCST)	22:00～23:00	IBM Flex P460
	23:45 (18Z_ASSIM+84HR_FCST)	23:45～02:00	IBM Flex P460
Global Forecasting System	09:10 (00Z_ASSIM+240HR_FCST)	09:10～10:25	IBM Flex P460
	12:00 (00Z_ASSIM. +6HR_.FCST)	12:00～12:25	IBM Flex P460

(GRAPES - GFS1.4)	17:30(06Z_ ASSIM +6HR_.FCST)	17:30～17:50	IBM Flex P460
	21:10(12Z_ASSIM.+240HR_FCST)	21:10～22:30	IBM Flex P460
	23:30(12Z_ASSIM.+ 6HR_.FCST)	23:30～24:00	IBM Flex P460
	3:30(18Z_ASSIM.+ 6HR_.FCST)	03:30～03:50	IBM Flex P460
Regional Forecasting System (GRAPES_MESO4.0)	03:40 (00Z_ ASSIM +60HR_.FCST)	03:40～06:40	IBM Flex P460
	16:40 (12Z_ ASSIM +60HR_.FCST)	16:40～19:40	IBM Flex P460
Ensemble Forecasts With 15 members 15 members (T639L60)	04:40 (00Z_ASSIM+240HR_FCST)	04:30～07:10	IBM Flex P460
	12:30 (06Z_ASSIM+6HR_FCST)	12:30～13:15	IBM Flex P460
	16:30 (12Z_ASSIM+240HR_FCST)	16:30～19:10	IBM Flex P460
	00:30 (18Z_ASSIM+6HR_FCST)	00:30～01:10	IBM Flex P460
Ensemble Forecasts With 15 members 15 members (GRAPES_MESO)	07:30 (00Z_ASSIM+240HR_FCST)	07:30～09:30	IBM Flex P460
	19:30 (12Z_ASSIM+240HR_FCST)	19:30～20:30	IBM Flex P460
Regional Typhoon Forecasting System (GRAPES)	05:00 (00Z_ASSIM+6HR_FCST)	05:00～07:30	IBM Flex P460
	11:00 (06Z_ASSIM+6HR_FCST)	11:00～13:30	IBM Flex P460
	17:00 (12Z_ASSIM+6HR_FCST)	17:00～19:30	IBM Flex P460
	01:00 (18Z_ASSIM+6HR_FCST))	01:00～03:30	IBM Flex P460
Sand/dust Forecasting system (T639)	05:30 (00Z_72HR_FCST)	05:30～07:00	IBM Flex P460
	18:30 (12Z_72HR_FCST)	18:30～20:00	IBM Flex P460
Sea Wave Forecasting System (WW3)	07:00 (00Z_120HR_FCST)	07:00～08:00	IBM Flex P460
	19:00 (12Z_120HR_FCST)	19:00～20:00	IBM Flex P460
HAZE Forecast System (T639)	00:10 (00Z_84HR_FCST)	00:10~04:10	IBM Flex P460
	12:00 (12Z_84HR_FCST)	12:00~16:00	IBM Flex P460
GRAPES Rapid Analysis and Forecast System(GRAPES_RAFS)	01:30 (00Z_ASSIM+24HR_FCST)	01:30～02:55	IBM Flex P460
	04:30 (03Z_ASSIM+24HR_FCST)	04:30～05:55	IBM Flex P460
	07:30 (06Z_ASSIM+24HR_FCST)	07:30～08:55	IBM Flex P460
	10:30 (09Z_ASSIM+24HR_FCST)	10:30～11:55	IBM Flex P460
	13:30 (12Z_ASSIM+24HR_FCST)	13:30～14:55	IBM Flex P460
	16:30 (15Z_ASSIM+24HR_FCST)	16:30～17:55	IBM Flex P460
	19:30 (18Z_ASSIM+24HR_FCST)	19:30～20:55	IBM Flex P460
	22:30 (21Z_ASSIM+24HR_FCST)	22:30～23:55	IBM Flex P460

4.2 Medium range forecasting system (4-10 days)

4.2.1 Data assimilation, objective analysis and initialization

4.2.1.1 In operation

The data assimilation system used in operation is Grid-point Statistical Interpolation (GSI) which was introduced from NCEP. The observational data include those from GTS while ATOVS

1b data from NOAA-15/18 channels are assimilated in the global data assimilation system. The background fields used for analysis are 6-hour forecasts from T639 model.

4.2.1.2 Research performed in this field

- The development of GRAPES-Var

The original GRAPES variational data assimilation system (referred to GRAPES-Var hereafter) does not match the GRAPES forecast model both in the definition of grids and atmospheric state variables (Xue and Chen, 2008). These differences may lead to quite many errors, especially when GRAPES-Var extends from the three to four dimension variational assimilation systems. Recently we have updated the GRAPES-Var, which completely employs the same grids and state variables as those in the GRAPES model. The new features of GRAPES-Var (Xue et al., 2012) include: 1) the physical characteristics and location of analysed variables are consistent with those in the forecast model; 2) the balanced constraint relationship of mass and wind fields is developed on the height-based terrain-following coordinate; 3) the preconditioned transformation allows different vertical covariance for each horizontal spectral mode, giving them more control over the variations in horizontal scale with height. 4) the observation operators are redesigned in order to match the new coordinate with the grids. The current GRAPES-Var is capable to assimilate radio sonde, synop, ship, aircraft, cloud drift wind, the global navigation satellite radio occultation observations(Liu and Xue, 2014), satellite radiances, scatterometer sea surface winds, radar observations, and so on. The satellite radiance observations used in GRAPES are Advanced Microwave Sounding Unit-A (AMSU-A) from the present polar satellites, and the hyper spectral infrared observations.

A LBE-regression hybrid balanced constraint has been developed in GRAPES-3DVAR (Wang et al., 2014). GRAPES 3D-Var resorted to the linear balance equation (LBE) to model the dynamically balanced constraint between mass and wind fields. However, the constraint implied by LBE is fallacious in the tropics where the coupling between mass and wind is overestimated. In the new hybrid scheme, after the calculation of LBE on each level, a vertical regression whose coefficients could vary at different latitudes and model levels is introduced.

The tangent linear model (TLM) and adjoint models (ADM) are rebuilt based on the new GRAPES Global model and the parallel efficiency was improved by reducing parallel halo partition and ADM’s base state using push/pop to save memory in 2014. The new TLM and ADM greatly improved the parallel efficiency of GRAEPS Global 4D-Var. GRAPES 4D-Var experimental version in 2014 needs 30 minutes using 512 CPU cores for a 6-hour time window with 0.5°*0.5°model resolution and 36 vertical levels .

- Constrained Bias Correction (CBC) for satellite radiance assimilation in GRAPES-Var

Radiance bias correction is crucial to the successful assimilation of satellite radiance observations which are typically affected by biases that arise from uncertainties in the absolute calibration, the radiative transfer modelling, or other aspects. These biases have to be removed for the successful assimilation of the data in NWP systems. Two key problems have been identified in bias correction: Firstly, bias corrections can drift towards unrealistic values in regions where there is strong model error (especially for developing models with not well tuned physics) and relatively few “anchor” observations, i.e. observations that have few systematic errors and therefore allow the separation between model and observation bias. Examples where this has been particularly problematic are channels sensitive to stratospheric temperature. Secondly, there is undesired interaction between the quality control and bias correction for observations where bias-corrected observation departures are used for quality control and where these departures show skewed distributions (e.g. in case of cloud detection). Constrained Bias Correction (CBC) scheme is proposed using priori knowledge of radiometric uncertainty information in GRAPES in order to avoid the drift of observation bias correction to the biased model background (Han, 2014). It is a kind of Tickhonov regularization techniques in inverse problems using minimum norm solution with priori information.

● The assimilation of MWTS onboard FY-3 satellites in GRAPES-Var

Fengyun-3 (FY-3) satellites are Chinese new generation polar-orbiting meteorological satellites. FY-3A was successfully launched on 27 May 2008. The Microwave Temperature Sounder (MWTS) onboard FY-3A is the first microwave temperature sounding unit in China. In 2010 and 2013, the second and third in the FY-3 series, FY-3B and FY-3Cwere launched with more advanced MWTS on board. To assimilation these MWTS radiances into NWP system, a cloud detection scheme is needed. However, the current algorithms developed for the microwave satellite measurements cannot be directly applied to the MWTS observations. A new cloud detection algorithm is proposed for the MWTS (Li and Zou, 2013). The method is based on the cloud fraction product provided by the Visible and Infrared Radiometer (VIRR) on board FY-3satellites. A MWTS field-of-view (FOV) with a cloud fraction greater than a threshold fVIRR will be identified as a cloudy radiance. The threshold fVIRR is determined by the AMSU-A cloud liquid water path products, obtained from the Microwave Surface and Precipitation Products System (MSPPS). Analysis of the test results indicates that most clouds are identifiable by applying a VIRR cloud fraction threshold of 76%. Other QC steps for FY-3A/B/C MWTS include the following: (i) two (for FY-3A/B) or eight (for FY-3C) outmost FOVs; (ii) measurements from low level channels over sea ice and land; (iii) coastal FOVs; and (v) outliers with large differences between model simulations and observations.

The impact of MWTS radiances on the prediction of Chinese NWP system-GRAPES (Global and Regional Assimilation and Prediction System) was researched. The typhoon case study shows that the assimilation of the Microwave Temperature Sounder (MWTS) data can improve the typhoon track prediction by changing the model-predicted steering flow. The impact cycle experiments conducted for 30-day periods show that the QC scheme removed the outliers efficiently. Verifications indicate that forecast skill is improved after assimilating MWTS data.

4.2.2 Model

4.2.2.1 In operation

There is no change for the operational model TL639L60 model.

4.2.2.2 Research performed in this field

In GRAPES global model, a new prognostic cloud scheme is implemented to improve forecast of cloud cover, cloud water, precipitation and cloud-radiation interaction. The new scheme integrates a double-moment bulk microphysics developed by Chinese scientists, a prognostic cloud fraction scheme, which formulates the impacts of the convective detriment to grid scale cloud, and parameterizes low level cloud using shallow convective and PBL process. The vertical layers of GRAPES global model have been increased from 36 to 60, and non-interpolation of temperature in semi-Lagrangian advection has been realized to improve mass conservation.

4.2.3 Operationally available Numerical weather prediction products.

There is no change for available Numerical weather prediction products. The T639 model products generated from operational runs are 0-240h forecasts for 00UTC and 12UTC initial time and 0-72h forecasts for 06UTC and 18UTC initial one. A list of NWP Products is given in table 4.2.1.

Table 4.2.1 The List of CMA NWP Products

Variables	Unit	Layer	Level (hPa)	Forecast hours	Area
Geopotential height	Gpm (geopotential meters)	26	10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 925, 950, 975, 1000	000，003，006，009，012，015，018，021，024，027，030，033，036，039，042，045，048，051，054，057，060，063，066，069，072，075，078，081，084，087，090，093，096，099，102，105，108，111，114，117，120，126，	North-east hemisphere (0.28125*0.28125) 0°N－180°N，90°E－0°
Temperature	K	26			
U-wind	m/s	26			
V-wind	m/s	26			
Vertical velocity	Pa/s	26			
vorticity	s^{-1}	26			
divergence	s^{-1}	26			
Specific humidity	Kg/kg	26			
Relative humidity	%	26			
10m U-wind	m/s	1	10 m above ground		
10m V-wind	m/s	1	10 m above ground		
2m Temperature	K	1	2 m above ground		
Surface temperature	K	1	surface		

Sea surface pressure	Pa	1	mean sea level	132，138，144，150，156，162，168，180，192，204，216，228，240		
Surface Pressure	Pa	1	surface			
2m RH	%	1	2 m above ground			
The first layer of soil temperature	K	1	0-0.07 m below ground			
Second layer soil temperature	K	1	0.07-0.28 m below ground			
Third layer soil temperature	K	1	0.28-1 m below ground			
Fourth layer soil temperature	K	1	1-2.55 m below ground			
The first layer of soil moisture	m^3/ m^3	1	0-0.07 m below ground			
Second layer soil moisture	m^3/ m^3	1	0.07-0.28 m below ground			
Third layer soil moisture	m^3/ m^3	1	0.28-1 m below ground			
Fourth layer soil moisture	m^3/ m^3	1	1-2.55 m below ground			
Convective precipitation	mm	1				
Large scale precipitation	mm	1				
Total precipitation	mm	1				
Low-level cloud cover	%	1	cloud base			
Middle-level cloud cover	%	1	cloud base			
High-level cloud cover	%	1	cloud base			
Total cloud cover	%	1	cloud base			
Maximum 2m Temperature	K	1	2 m above ground			
Minimum 2m Temperature	K	1	2 m above ground			
Surface sensible heat flux	W m**-2 s	1	surface			
Surface latent heat flux	W m**-2 s	1	surface			
Surface solar radiation	W m**-2 s	1				
Surface heat radiation	W m**-2 s	1				
Snow	M (water equivalent)	1	snow			
Water content of Surface	m (water-e)	1				
Evaporation	m (water-e)	1				
Run-off	M	1				
Snow depth	m (water-e)	1				
Geopotential height	Gpm	1	surface			
Sea-land marks	N/A	1	surface			
Dew point temperature	K	19	200,250,300,350,400,450,500,550,600,650,700,750,800,850,900,925,950,975,1000			
Wet potential vorticity vertical component	10-6 m-2 s-1 k kg-1	19				

Wet potential vorticity horizontal component	10^{-6} m^{-2} s^{-1} k kg^{-1}	19			
Temperature Advection	10^{-6} K/s	6	200,500,700,850,925,1000		
Vorticity Advection	10^{-11} /s^{2}	6			
Dew point temperature difference	10^{-1} □C	4	500,700,850,925		
Water vapour flux	10^{-1} g/cm·hPa·s	4			
Divergence of vapour flux	10^{-7} g/cm^{2}·hPa·s	4			
Pseudo-equivalent temperature	K	4			
K index	°C	1	mean sea level		

4.2.4 Operational techniques for application of NWP products.

This item should include only a brief description of automated (formalized) procedures in use for interpretation of NWP output (MOS, PPM, Kalman filter, Expert System, etc.) for example, “the MOS from ECMWF NWP is used to derive extreme temperatures and daily precipitation”.

4.2.4.1 In operation

Station daily maximum and minimum temperatures were extended to 10-day. Gridded QPF, temperature and wind from 4-day to 7-day and maximum and minimum temperatures from 4-day to 10-day were put in quasi-operation.

4.2.4.2 Research performed in this field

Ensemble model output was used to improve forecast effect of meteorological elements from 4-day to 10-day.

4.2.5 Ensemble Prediction System (EPS) (Number of members, initial state, perturbation method, model(s) and number of models used, number of levels, main physics used, perturbation of physics, post-processing: calculation of indices, clustering)

4.2.5.1 In operation

The global operational ensemble prediction system (GEPS) based on T639 model (T639-GEPS) has been implemented. Data assimilation system for control forecast is GSI assimilation. The system configuration is as follows:

- Number of members: 15 members; 14 perturbed members (adding/subtracting perturbations from seven independent breeding cycles) plus one control run
- Initial state perturbation method: Breeding Growth Method(BGM)
- Number of models used: one model, T639L60 (about 30 km)

- Perturbation of physical process: Stochastic Physical Processes Tendency (SPPT) method
- Running cycle: 00UTC and 12UTC, running twice per day
- Integration time
  - T639L60 control run with an integration period of 15 days
  - 14 perturbed members being T639L60 with an integration period of 15 days
  - Perturbations being from 7 independent breeding cycles

4.2.5.2 Research performed in this field

The GEPS based on GRAPES_GFS model (GRAPES-GEPS) using a singular vector method as initial perturbation has been developed at CMA. The main development of GRAPES-GEPS in 2014 included: 1) the main components of SVs calculation, tangent linear and adjoint model of GRAPES_GFS, were updated, and the computation cost of SVs has been greatly reduced; 2) the forecast model in GRAPES-GEPS was updated by the latest version; 3) the experiments of increasing horizontal resolution to 50 Km and increasing ensemble size to 41 were conducted.

4.2.5.3 Operationally available EPS Products

The T639-based global ensemble prediction model products generated in operational are 0-360h forecasts for 00UTC and 12UTC initial time and 0-6h forecasts for 06UTC and 18UTC initial time. Ensemble size is 15 including 14 perturbed forecast and control run. The output interval is 6 hours. A list of NWP GEPS Products is given in table 4.2.2.

Table 4.2.2 The list of global EPS products

Abbreviations	Elements	EPS products	Probability threshold
HGT	500hPa Geopotential Height	Spaghetti	
		Ensemble Mean & Spread	
RH	700/850hPa Relative humidity	Ensemble Mean & Spread	
T	850 hPa Temperature	Ensemble Mean & Spread	
RAIN_24H	24-HR Accum. Precip.	Ensemble Mean	
		Mode & Maximum	
		PRBT	1, 10, 25, 50 ,100mm
SLP	Sea level pressure	Ensemble Mean & Spread	
T2M	Temperature at 2m	Ensemble Mean & Spread	
UV10M	Wind speed at 10m	Ensemble Mean & Spread	
		PRBT	10.8, 17.2m/s
EFIR	24-HR Accum. Precip.	Extreme forecast index	
EFIT	Temperature at 2m		
EPS METEOGRAM	Total cloud cover 6-HR Accum. Precip. Wind speed at 10m Temperature at 2m	BOX & WHISKERS	

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

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

The GRAPES regional 3DVAR system is an incremental grid-point data analysis system with 10km horizontal resolution and 50 vertical levels the same as the GRAPES_Meso model. The data assimilated include the conventional GTS data, GPS/PW and FY_2E. The analysed variables include zonal and meridonal winds, non-dimensional pressure and specific humidity. The first guess is from the operational 6-hour prediction of T639 global model with the digital filter for initialization.

4.3.1.2 Research performed in this field

Data assimilation improvements of GRAPES-MESO model included: 1) computing background errors based on T639 6h forecast fields; 2) finishing assimilation tests of intensive precipitation observation data using nudging method; 3) optimizing the thermodynamic scheme in Cloud Analysis Scheme system; 4) evaluating the effect of assimilating intensive radio-sonde data at 06UTC; 5) studying wind-profile radar data assimilation; 6) testing on partial cycle in GRAPES-Meso system.

4.3.2 Model

4.3.2.1 In operation

The operational GRAPES_Meso is a non-hydrostatic grid point model with 10km horizontal resolution and 50 levels in the vertical. The domain of the model integration covers the whole East Asia, and the forecast range is up to 72hrs. The specification of GRAPES_Meso is:

- Equations: Fully compressible and non-hydrostatical equations with shallow atmosphere approximation
- Variables: Zonal wind u, meridional wind v, vertical velocity w, potential temperature θ, specific humidity q (n) and Exner pressure π.
- Numerical technique: 2-time level semi-implicit and semi-Lagrangian method for time-space discretization; 3D vectored trajectory scheme used in computation of the Lagrangian trajectory; Piece-wise Rational Method (PRM) for scalar advection.
- Horizontal staggered grid: Arawaka C-grid.
- Time step: 60s.
- Vertical grid: Height-based terrain-following vertical coordinate with Charney-Phillipps variable arrangement in vertical.

- Physics: RRTM L W/ Fouquart & Bonnel SW, KF cumulus, WSM-6 microphysics, MRF vertical diffusion, NOAH land surface.

4.3.2.2 Research performed in this field

Research work to improve the model performance includes: W-damping scheme was introduced and tested; A diagnostic cloud scheme was introduced and tuned; optimization of forecast radar reflectivity diagnostic scheme were performed; a satellite cloud picture diagnostic module was developed; MYJ boundary layer parameterization and UWSHCU shallow convective parameterization were introduced.

4.3.3 Operationally available NWP products

More model guidance products were generated with the upgrade of GRAPES-Meso from version 3.3 to version 4.0 in 2014. The operational products of GRAPES-Meso v4.0 are listed in table 4.3.1 over China and eight climate regional areas.

Table 4.3.1 The list of GRAPES-MESO operational products

Variables	Unit	Initial time	Prediction hours	Levels (hpa)	Area
U-component of wind	m/s	00 , 12	00h~72h, every 1 hour	1000 975 950 925 900 850 800 750 700 650 600 550 500 450 400 350 300 250 200 150 100 70 50 30 20 10	70ºE - 145ºE 15ºN - 65ºN Grid (0.1°*0.1°)
V-component of wind	m/s				
Temperature	K				
Geopotential height	M				
Specific humidity	kg/kg				
Cloud mixing ratio	kg/kg				
Rain mixing ratio	kg/kg				
Snow mixing ratio	Kg/kg				
Ice water mixing ratio	Kg/kg				
Graupel	Kg/kg				
Vertical wind	m/s				
Relative humidity	%				
Dew point temperature	K				
Dew point depression	K				
Pseudo-adiabatic potential temperature	K				
Relative vorticity	s^{-1}				
Relative Divergence	s^{-1}				
Temperature advection	K/s				
Moisture flux	g/hPa.cm.s				
Moisture flux divergence	g/hPa.cm^2.s				
Surface pressure	hPa				
Sea level pressure	hPa				
Convection Precipitation	Mm				
Not Convection Precipitation	Mm				

Surface temperature	K				
Surface long wave radiation flux	W/m^2				
Surface short wave radiation flux	W/m^2				
surface heat flux	W/m^2				
surface vapour flux	kg/m^2/s				
2m relative humidity	%				
2m temperature	K				
10m U-wind	m/s				
10m V-wind	m/s				
2m specific humidity	kg/kg				
Land use					
CAPE	J/kg				
K index	K				
CIN	J/kg				
Lifted condensation level	hPa				
Parcel lifted index	K				
Sweat index					
Soil temperature	K			4 layers	
Soil moisture	Kg/m^3				

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

4.3.4.1 In operation

Gridded QPF, temperature, wind based on a subjective precipitation grade area forecast, station forecast and model output were put into quasi_ operational running. Products from 0-day to 3-day can be gotten.

4.3.4.2 Research performed in this field

A regional forecast method was used in gridded visibility, cloud cover forecast. The MOS from ECMWF NWP is used to derive extreme temperatures and daily precipitation. Gridded observational data were developed through fusing station observation and model output.

4.3.5 Ensemble Prediction System (Number of members, initial state, perturbation method, model(s) and number of models used, perturbation of physics, post-processing: calculation of indices, clustering)

4.3.5.1 In operation

The regional operational ensemble prediction system (REPS) based on GRAPES-MESO V3.3 model (GRAPES-REPS) has been running since 7th Aug 2014. The system configurations are as follows:

- Number of members: 15 members; 14 perturbed members (perturbations produced by Ensemble Transform Kalman Filter method) plus one control run
- Initial condition perturbation method: Ensemble Transform Kalman Filter (ETKF)
- Number of models used: one model (GRAPES-MESO V3.3 with 15km horizontal resolution and 31 vertical levels)
- Perturbation of physical process: Different combinations of two PBL schemes and four cumulus schemes
- Running cycle: 00UTC, 06UTC, 12UTC and 18UTC,
- Integration time: 72h for 00UTC and 12UTC and 6h for 06UTC and 18UTC.

4.3.5.2 Research performed in this field

The stochastic perturbed physical tendency (SPPT) based on first-order Markov chain has been developed for GRAPES-REPS, with the experiments using SPPT conducted, and their impacts evaluated. The preliminary results showed that the use of SPPT in the GRAPES-REPS would increase the ensemble spread of temperature and wind fields, and decrease the outlier of these fields.

A MSB IC perturbation scheme was developed. This method takes advantage of both the large-scale component of global ensemble perturbations and the small-scale component of ETKF-generated IC perturbations, with the two components obtained using a 2D-DCT filter and linearly combined with equal weight. And the main findings can be summarized as follows: The MSB method can generate IC perturbations by combining the small-scale component from the REPS and the large-scale component from the GEPS; the MSB-based REPS shows higher skill than the original system, as determined by the ensemble forecast verification. The findings of this study are useful for directing future upgrades of the current REPS.

4.3.5.3 Operationally available EPS products

GRAPES-based mesoscale ensemble prediction system model products generated in operational are 0-72h forecasts for 00UTC and 12UTC initial time and 0-6h forecasts for 06UTC and 18UTC initial time. The ensemble size is 15 including 14 perturbed forecast and control run. The output interval is 3 hours. A list of NWP GEPS Products is given in table 4.3.2.

Table 4.3.2 The list of Mesoscale EPS products

Abbreviations	Elements	EPS products	Probability threshold
RAIN_24H	24-HR Accum. Precip.	Stamp	
		Ensemble Mean	

		Mode & Maximum	
		PRBT	1, 10, 25, 50 ,100mm
RAIN_12H	12-HR Accum. Precip.	Stamp	
		Ensemble Mean	
		Mode & Maximum	
		PRBT	1, 5, 15, 30 ,70mm
RAIN_6H	6-HR Accum. Precip.	Stamp	
		Ensemble Mean	
		Mode & Maximum	
		PRBT	1, 4, 13, 25 ,60mm
RAIN_3H	3-HR Accum. Precip.	Stamp	
		Ensemble Mean	
		Mode & Maximum	
		PRBT	1, 3, 10, 20 ,50mm
SLP	Sea level pressure	Ensemble Mean & Spread	
T2M	Temperature at 2m	Ensemble Mean & Spread	
UV10M	Wind speed at 10m	Ensemble Mean & Spread	
		PRBT	5.5,8,10.8,17.2, 24.5,32.7m/s
EPS METEOGRAM	3-HR Accum. Precip. Wind speed at 10m Temperature at 2m Relative humidity at 2m	BOX & WHISKERS	

4.4 Nowcasting and Very Short-range Forecasting Systems (0-12 hrs)

4.4.1 Nowcasting system

4.4.1.1 In operation

In 2014, as the main operational nowcasting system, SWAN (Severe Weather Automatic Nowcasting system) provided the continuous technical support to the nowcasting operation in CMA. Three aspects were improved, the system interface, the monitoring function and the warning dissemination function. For the new system interface, it can provide more convenient operation for the forecasters, such as the layout of the menus and the buttons, the reminder style of the warning, and so on. For the monitoring function, the auto-weather station data were added into the system, and the monitoring for different elements with different thresholds could be done automatically. For the warning dissemination function, as the warning area was finished by the forecasters, the warning text could be produced and the warning dissemination for different users could be done automatically.

4.4.1.2 Research performed in this field

To improve the ability of SWAN, some research was performed in the field of monitoring and nowcasting in 2014.

In order to realize the automatic identification of different kinds of severe weather, such as the heavy rainstorm, the convective wind and the hail, the Severe Weather Recognition Algorithm has been developed, which works by analyzing the characteristics of Doppler radar data.

To improve the accuracy of 0-1h QPF, the rainfall data of Auto-Weather Stations were used in 2014. By using the distribution and intensity of rainfall from AWS, and the moving speed and direction from TITAN algorithm and 0-1h QPF could be produced. This algorithm avoided the uncertainty of QPE and would be more accurate in the area with more rainfall data.

Moreover, to prolong the valid time of nowcasting system, 1-6h QPF technique has been developed. By blending the 0-1h QPF and the high-reso NWP products, 1-6h QPF could be produced. For this algorithm, the key factor is how to blend these two products, that is how to determine the weight of them. Much work would be done in the near future.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

GRAPES Rapid Analysis and Forecast System (RAFS) is a quasi-operational system with a horizontal resolution of 15 km and 31 vertical levels. The prediction domain is from 70°E to 145°E and from 15°N to 65°N and the grid space is 502×330. This system updates its data assimilation every 3 hours in China domain and provides 24-hour forecasting products every 3 hours. The system uses T639 real-time field database to provide its background, while the observations include real-time GTS data (radiosondes, AIREP/AMDAR reports, GMS derived winds, SHIP and SYNOP data, etc.), radar VAD data, GPS/PW, FY_2E and GPS/RO occultation retrieval of temperature profiles. The products for making an assimilation analysis of such variables as wind, temperature, pressure, humidity, and the products on severe convection weather potential forecast (CAPE, K index, etc.) were made available in such 3 formats: Grads, MICAPS, and GIF.

4.4.2.2 Research performed in this field

Research performed in this field in 2014 included:

- The flow chart of digital filter was optimized to increase stability of RAFS system in high resolution;
- Test of the moisture advection scheme was performed during the backward integration of RAFS system;
- quality control scheme for surface pressure data was developed;
- performance of assimilating intensive radio-sonde data at 12h was evaluated;
- wind-profile radar data assimilation was studied.

4.5 Specialized numerical predictions (of sea waves, storm surge, sea ice, marine pollution transport and weathering, tropical cyclones, air pollution transport and dispersion, solar ultraviolet (UV) radiation, air quality forecasting, smoke, sand and dust, etc.)

4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

4.5.1.1 In operation

- CUACE/Dust

The operational sand/dust storm prediction system in CMA is called CUACE/Dust. It is a sectional dust aerosol model with detailed microphysics of dust aerosol under a comprehension wind erosion database. It has been fully coupled with MM5. A data assimilation system has also been developed to improve the initial condition of dust aerosol. The prediction starts from 00:00 and 12:00 UTC on a routine basis, which provides 72-hour sand/dust storm predictions for both China and Asia as a whole. The overall forecasting performance of the model is good. The model provides dust load, dust concentration, dust optical depth and dry/wet deposition.

It has been selected as one of the operation models for sand and dust storm for SDS-WAS Asian Regional Centre. And all the products have been issued in the web portal for the regional centre: http://eng.weather.gov.cn/dust/.

- CUACE/haze-fog

CUACE/haze-fog has been developed for the regional haze-fog forecast in China. It is based on the CUACE which can simulate 7 types of aerosols, i.e. sea-salt, dust, OC, BC, nitrate, ammonia and sulfate. Visibility is produced based on the 7 types of aerosol concentrations and humidity condition. CAUCE/Haze-fog has been operationally run twice a day in CMA since Sept 2012. It issues 84-hrs products of visibility, PM2.5 and some gas species. It can predict the timing and distribution of the regional haze-fog over China. The current operational forecasting system is with a resolution of 54km. A CUACE/haze-fog at a higher resolution of 15-km is under testing.

4.5.1.2 Research performed in this field

The full relations of aerosol - cloud – precipitation have been developed in CUACE. Research results showed that it improves the precipitation TS scoring by 33%. Aerosol-Radiation relation has also been developed in CUACE. With the feedbacks, it increases the atmosphere stability during a haze event and hinders the vertical transport ability of the tracers in the PBL.

4.5.2 Specific models (as appropriate related to 4.5)

4.5.2.1 In operation

4.5.3 Specific Models (as appropriate related to 4.5)

4.5.3.1 peration

- Global typhoon track prediction system：This system was upgraded to T639L60 from T213L31 with a new vortex initialization scheme added in 2014
- Tropical cyclone ensemble prediction system: This system was upgraded to T639L60 from T213L31
- Regional typhoon prediction system (GRAPES_TYM): This system was upgraded in 2014 in the following aspects: 1) vortex initialization scheme; 2) cumulus convection scheme from SAS to Meso-SAS; 3) forecast length from 72h to 120h.
- Ocean wave forecasting system

The ocean wave forecasting system was updated in July 2014. The new triple nested wave numerical prediction system was on the basis of WAVEWATCH III version 3.14. The three domains of the system were global seas, the Northwest Pacific and the coastal waters of China. The resolution of the global wave model was upgraded from the original 1 × 1 degree to 0.5 × 0.5 degree; the Northwest Pacific model with a resolution of 1/6 × 1/6 degree; and the Chinese coastal waters model with a resolution of 1/15× 1/15 degree. The wave models were driven by meteorological input resulting from the operational numerical weather prediction system T639L60 and GRAPES_TYM. The upgraded system was carried out using batch tests, which showed a significant improvement over the old system.

- Environmental emergency response system (EERS):

There were no changes to this system

- Regional fine-gridded environmental emergency response system:

For regional EERS, the GRAPES_RAFS (GRAPES Rapid Assimilation Forecast System) is used to drive the HYSPLIT model, instead of WRF in order to satisfy users' demands. The resolution is upgraded from 15km to 10km; and the frequency of forecast is 8/day and forecast duration is 24 hours.

4.5.3.2 Research performed in this field

- Regional typhoon prediction system (GRAPES_TYM): Dynamic vortex initialization scheme was under development in 2014; surface layer and boundary layer schemes have been modified to improve TC intensity prediction.
- Environmental emergency response system and Regional fine-gridded environmental emergency response system (EERS):

A new source term evaluation system has been developed. This system is based on China's NPPs (Nuclear Power Plants) main operation parameters. The new system was put into operation in 2014.

4.5.4 Specific products operationally available

- Ocean wave forecasting system

Products from the ocean wave forecasts include significant wave height, mean periods and mean direction.

- Environment emergency response products:

The Atmospheric Environment emergency response system provides the following products: 1) 3D dispersion trajectories of the pollutants 0-72 hours after their detection; 2) 24-hour average pollution concentration in 0-72 hours; 3) 24-hour accumulated deposition (wet & dry) distribution accumulated in 0-72 hours; 4) the time of arrival products.

- Regional fine-gridded environmental emergency response system (EERS)

The Regional Refined Atmospheric Environment Emergency Response System provides the products superimposed with detailed geographic information, as follows: 1) 3D dispersion trajectories of the pollutants (0-12 hours after detection); 2) hourly average pollution concentration in 0-12 hours; 3) Total deposition (wet & dry) distribution accumulated in 0-12 hours. In a special emergency response procedure, the system can provide the above products in more details.

4.5.5 Operational techniques for application of specialized numerical prediction products (MOS, PPM, KF, Expert Systems, etc.) (as appropriate related to 4.5)

There are operational techniques developed for application of specialized numerical prediction products

4.5.5 Probabilistic predictions (where applicable)

There is no change in this area

4.5.5.1 In operation

4.5.5.2 Research performed in this field

4.5.5.3 Operationally available probabilistic prediction products

4.6 Extended range forecasts (10 days to 30 days) (Models, Ensemble, and Methodology)

4.6.1 In operation

The second generation Dynamical Extended Range Forecast System (DERF2.0) in Beijing Climate Centre (BCC) has become operational since 2014. DERF2.0 was developed based on

BCC atmospheric general circulation model (BCC_AGCM2.2) in 2011. The ensemble prediction generated by lagged-average-forecast (LAF) method includes 20 members of the latest five days.

4.6.2 Research performed in this field

A bias analysis of hindcast data of DERF2.0 indicates that the monthly temperature prediction performance was not good enough in operation and needs to be improved. Quantile mapping of non-parameter method is applied to correct the DERF2.0 model bias of monthly temperature. The cumulative density function (CDF) of hindcast data is calculated by deterministic output. The quantile result of model output is mapped to the CDF of observational data. The model bias can be reduced to some extent by this post-processing. Hindcast verification shows that the method can significantly reduce the Root Mean Square Errors (RMSE) of model output and improve the predictive skill of spatial distributions of monthly mean temperature anomalies during the period from 1983 to 2012. Prediction Skill (PS) and Anomaly Correlation Coefficient (ACC) scores with different lead time are improved after correction. A comparison of monthly corrections shows that the improvement in summer is greater than in winter.

4.6.3 Operationally available EPS products

Products are provided in a routine operation way, which includes surface temperature, precipitation, sea level pressure, 200hPa, 500hPa, 700hPa geopotential height, 200hPa, 700hPa wind field, as well as re-explanation of numerical forecasts such as temperature and precipitation expressed in terms of three categories including below normal, near normal and above normal. The periods of prediction are the coming 1st ten days, 2nd ten days, 3rd ten days, 4th ten days, 1-30 days and 11-40 days.

4.7 Long range forecasts (LRF) (30 days up to two years)

4.7.1 In operation

In recent years, a new generation coupled climate system model (BCC-CSM) has been developed in BCC. At present, seasonal model named BCC-CSM1.1m has been operational on a trial basis in BCC.

4.7.2 Research performed in this field

BCC/CMA is committed to carry out a series of dynamical-statistical seasonal precipitation prediction research and operational application, and establish the forecast system on dynamical and analogy skills (FODAS). The system is based on the first generation seasonal model in BCC (BCC_CM1.0) by using the 74 circulation factors of BCC, 40 circulation factors of NOAA and optimal multiple factor regression method for correcting model errors. This operational system had a rather higher prediction skill for summer precipitation anomaly percentages in 160 stations over China during the period from 2009 to 2014 than output of the model. In addition, based on the dynamical-statistical prediction principle, the outputs of the BCC_CM1.0 are used to predict 500-

hPa geopotential height at the northeast cold vortex activity area, the West Pacific subtropical high (WPSH) area and the Eurasian mid-high-latitude blocking areas in summer. The results show that this method can largely reduce the model errors and improve prediction skill.

At present, BCC is committed to carry out the improved forecast system based on dynamical and analogy capabilities (FODAS2.0) using the BCC-CSM. And the FODAS2.0 will be applied to operation in the future.

4.7.3 Operationally available EPS LRF products

No changes.

4.7.1 In operation

4.7.2 Research performed in this field

4.7.3 Operationally available EPS products

5. Verification of prognostic products

5.1 Annual verification summary

The verification against an analysis of operational numerical forecast model (T639) in 2014 is shown in the following table 5.1.

Table 5.1 RMSE of T639 model (500 hPa height, 250 hPa and 850 hPa wind speed) relative to the analysis in 2014

Month	Valid time	Z(500)		W(250)			W(850)
		NH	SH	NH	SH	Tropics	Tropics
1	24	13.1	14.5	5.6	5.4	5.8	3.3
	72	36.5	39.7	11	11.7	8.8	6.7
	120	64.1	65.7	16.1	16.8	10.6	8.9
2	24	12.8	15.6	5.5	5.3	5.5	3.2
	72	35.4	43.4	10.7	12.1	8.6	6.9
	120	59.7	70.6	15.3	17.4	10.2	9.2
3	24	11.8	17.1	5.5	5.8	5.3	3.4
	72	32.6	48.8	10.2	13.2	8.4	7.3
	120	58.4	77.9	15.2	18.7	9.9	9.7
4	24	11.2	17.9	5.6	5.5	5.3	3.3
	72	30.9	49.2	10.4	12.5	8.2	7.5
	120	57.6	80.6	15.7	18.6	9.7	10.2
5	24	10.2	18.1	0.2	0.2	4.9	3.5
	72	29.9	54.6	5.7	13.1	7.3	8.4
	120	53	94.7	15.2	20.1	8.6	11.6
6	24	10.1	17.7	0	0	5.1	3.5
	72	27.7	48.1	6.3	12.3	7.9	7.7
	120	49.3	81.4	14.9	18.4	9.4	10.9
7	24	9.9	18.3	0	0	5.3	3.5
	72	24.6	53	4	12.6	8	8.1
	120	44.1	88.4	14.6	18.7	9.4	11.1

8	24	9.1	17.5	5.4	5.2	5	3.4
	72	24.3	48.4	10.1	11.8	7.6	7.7
	120	41.7	81.8	13.9	17.4	8.9	10.5
9	24	9.4	17.3	5.1	5.3	4.9	3.5
	72	26.2	49.1	10.2	12	7.5	7.8
	120	49.7	77.5	15.3	17.8	9.1	10.4
10	24	10.2	15.8	5.1	5.2	4.9	3.3
	72	30.5	44.3	10.1	11.6	7.4	7.1
	120	57.2	71.4	15.7	16.7	8.6	9.6
11	24	11.4	13.6	5.2	5.3	4.9	3
	72	33.3	36.8	10.4	10.9	7.4	6.3
	120	60.1	61.8	16	15.8	8.9	8.5
12	24	12	13.6	5.2	5.3	5.2	3.1
	72	33.5	37.3	10.2	11.3	7.9	6.3
	120	62.1	63.7	15.6	16.3	9.6	8.5

5.1.2 The verification against observations of operational numerical forecast model (T639)

The verification against observations of operational numerical forecast model (T639) in 2014 is shown in the following table- RMSE of Z(500) and W(250).

Table 5.1.2 T639 RMSE (500 hPa height Z and 250 hPa wind speed W against observations in 2013

Month	Valid time	Z(500)				W(250)			
		N.A	Europe	Asia	Australia	N.A	Europe	Asia	Australia
1	24	18.5	18.4	15	13.9	7.8	6.3	6	6.6
	72	46.5	36.9	28.1	26.7	14.5	11.8	9.3	9.7
	120	78.7	74.4	45.1	50.6	20.5	19.2	12.9	13.2
2	24	17.6	18.5	15	17.9	7.3	7	6.3	6.8
	72	40.2	42.3	27.1	33.3	12.2	11.7	9.4	10.3
	120	62.3	71	46.3	48.7	16.6	17.8	12.9	14.4
3	24	19.4	15.7	13	21	8	6	7.2	6.8
	72	41.5	37.8	27	35	12.1	11.4	11.1	11.3
	120	59.9	68.4	45.4	49.9	16.7	19	14.2	14.7
4	24	17.5	13.6	13.7	20.2	8.1	5.8	7.4	7.1
	72	36.7	30.3	25.6	35.3	12.8	10.9	11.5	11.3
	120	55.4	65.9	41.7	54.1	17.6	18.2	14.8	16.4
5	24	14.2	11.4	14.4	13.5	7	5.9	7.4	7.2
	72	27.6	26.2	30.9	35.2	12.3	9.9	11.8	11.4
	120	46.6	49.4	46.3	61.1	16	15.2	16.1	16.6
6	24	12	10.6	14.8	17.2	7.7	5.8	7.5	7.5
	72	27.1	23.9	27.6	40	12.9	10.1	11.3	10.9
	120	43	45.8	40.2	73.7	16.9	16.3	14.6	16.4
7	24	12.3	10.7	16.1	18	6.5	6.4	6.9	7.7
	72	24.3	24.7	24.2	32.9	11.6	11.1	10.4	11.3
	120	43.9	41.4	33.8	57.2	16.1	15.8	14	16.1
8	24	10.4	9.6	14.5	16.1	6.8	6.1	7	5.9
	72	21.1	21.3	24.8	33.4	11.1	10.6	10.4	9.6
	120	33.9	39.9	36.1	54.6	15.2	14	13.9	12.9
9	24	12.7	14.6	13.1	18.3	6.5	6.1	6	6.7
	72	26.7	27	23.6	39.4	11.2	11.5	9.4	10.3

	120	38.9	50	35.4	54	14.7	18.1	13.2	15.9
10	24	15.2	22.2	12.9	20.7	7.6	6	5.6	7.1
	72	33	33.6	26.8	35.3	12.5	11.3	9.3	10.8
	120	53.8	60.5	45.7	54.8	18.7	18.3	13.5	14.9
11	24	16.4	23	13.9	18.1	7.4	6.2	5.8	7.5
	72	38.7	37.5	28.6	34.7	12.6	11.8	9.4	10.7
	120	63.7	61.3	51.2	46.1	18.5	17.9	14.3	14.4
12	24	17.3	20.4	15.9	19.7	7.2	5.9	5.5	7.2
	72	41	40.1	27.4	27.9	12.6	11.1	8.4	11.1
	120	65.4	75.1	46.2	43.6	18	19.4	12.1	14.3

5.1.3 Verification of CMA EPS

The verification against an analysis of operational Ensemble system (T213-based GEPS before September and T639-based GEPS after September 2014) is shown in the following table 5.1.3.

Table 5.1.3 Brier Score (BS) for CMA EPS (500 hPa height, 850 hPa Temperature) relative to an analysis in 2014

seasonal	**Threshold / Valid time**	**Z(500)**		**T(850)**	
		>climatology +1sd	**<climatology -1sd**	**>climatology +1sd**	**<climatology -1sd**
1-3	48	0.76	0.76	0.67	0.66
	72	0.67	0.67	0.60	0.58
	120	0.50	0.48	0.49	0.45
	168	0.32	0.29	0.37	0.33
4-6	48	0.75	0.74	0.68	0.66
	72	0.66	0.63	0.61	0.59
	120	0.46	0.45	0.49	0.45
	168	0.28	0.26	0.39	0.32
7-9	48	0.72	0.72	0.74	0.69
	72	0.61	0.57	0.67	0.62
	120	0.4	0.38	0.56	0.49
	168	0.22	0.21	0.46	0.37
10-12	48	0.8	0.79	0.68	0.69
	72	0.71	0.75	0.6	0.61
	120	0.51	0.50	0.47	0.47
	168	0.30	0.32	0.33	0.35
annual	48	0.76	0.75	0.69	0.68
	72	0.66	0.66	0.62	0.6
	120	0.47	0.45	0.50	0.47
	168	0.28	0.27	0.39	0.34

5.2 Research performed in this field

- Modify operational verification methods based on WMO new standard, the climatic data resolution was changed from 2.5°to 1.5°, and some verification areas such as northern polar and southern polar were added.
- New verification methods for precipitation, such as SEEPS for regional and global models, were added to CMA Model Unified Verification Operational Systems (MUVOS).

- The number of rainfall gauges which formed climatic data in China for SEEPS method was added from 384 to 2420. Sensitivity tests were finished and results were consistent with both climate gauges and encryption gauges and the latter reflected more regional details.

6. Plans for the future (next 4 years)

6.1 Development of the GDPFS

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

The GRAPES Global Forecast System (GRAPES-GFS) will be put into operational run with 25km horizontal resolution and 60 levels in vertical by the end of 2015. The GRAPES-RAFS at 10km resolution will be operationally implemented, which will update its data assimilation every 3 hours in China domain and provide 36-hour forecasting products at 1h interval. The new operational short-term REPS system will be upgraded in 2015, in which the ETKF initial perturbation cycle will be changed from 6h to 12h, a blending initial perturbation method, SPPT stochastical physics perturbation and a new post processing system will be implemented.

The new operational short-term climate prediction system will be put into quasi-operation in 2015. And the prediction system for the Subseasonal to Seasonal Prediction Project (S2S) will also be put into quasi-operation in 2015 and will provide products to the archive centre.

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

It will be a main task to develop GRAPES series operational systems with GRAPES-GFS as a core system for next years, which include the operational implementation of GRAPES-GEPS in 2017, the upgrade of data assimilation system from current 3DVar to 4DVar by the end of 2017, and some new satellite data to be assimilated in GRAPES-GFS, such as FY-3C and FY-4.

The operational short-term climate prediction system will be changed from BCC_CGCM to BCC_CSM1.2, with the horizontal resolution increased to T106 in next 2 years. And then the seamless prediction system including the subseasonal to seasonal timescales will be developed in next 4 years.

6.2 Planned Research Activities in NWP, Nowcasting, Long-range Forecasting and Specialized Numerical Predictions Specialized Numerical Predictions. Indicate your planned research and development efforts in the area of understanding of physical processes, models, EPS and other techniques for the next 4 years.

6.2.1 Planned Research Activities in NWP

Further development of GRAPES and exploration of new modelling and data assimilation technology suitable for simulation on massive parallel computers are core tasks for NWP research, such as, further development of GRAPES 4DVAR, satellite data assimilation (FY -3/4, NPP and IASI etc.), model dynamics improvement focusing on the stability and the mass-conservation, and Yin-Yang grid etc. Basic research for next-generation modelling and data assimilation technology will be enhanced in terms of hybrid data assimilation techniques, and quasi-uniform grid for conserved model dynamic core.

6.2.2 Planned Research Activities in Nowcasting

More attention will be put on the following two aspects. One is the recognition of the severe convective weather, especially the storm gale, the hail, and the tornado. The other is to develop the blending algorithm for the 2-12h QPF.

Development of GRAPSES mesoscale weather prediction system at 1-km scale

6.2.3 Planned Research Activities in Long-range Forecasting

Based on the coupled sea-land-air-ice model (BCC_CSM1.0) of Beijing Climate Centre (BCC), the second generation short-term climate prediction system is being developed. It will have the ability to couple with different models describing various components of the climate system, i.e., atmospheric, land, ocean, and sea-ice models. Upon its completion, the multi-model ensemble system will be used to make operational short-term climate predictions.

To achieve this goal in the next few years, BCC is planning to:

a. increase the horizontal resolution of the atmosphere model to about 50 km and raise the model top; introduce new advection algorithm; and improve the physical processes including cloud, radiation, precipitation and PBL taking into account the climate characteristics in East Asia;

b. improve hydrological and dynamic parameterization schemes for vegetation among others based on current terrestrial model (BCC_AVIM1.0), which will be upgraded into BCC_AVIM2.0 suitable for high resolution climate system modelling;

c. improve horizontal and vertical resolutions of ocean model based on MOM4_L40, and improve mixed layers, marine biogeochemical process simulations and marine advection scheme;

d. improve the parameterization of sea ice thermodynamic processes based on CICE model; focus on interactions among sea ice-ocean-atmosphere;

e. set up the second generation high resolution climate system model (BCC_CSM2.0), with ~50km resolution for the atmospheric model and ~30km resolution for the ocean model;

f. develop the climate data assimilation system, emphasizing on the ocean and land data assimilation for the operational short-term climate prediction; upgrade the current operational ocean data assimilation system BCC_GODAS1.0 to BCC_GODAS2.0;

e. create the multi-model-based BCC_CSM1.2 super-ensemble prediction system to reduce the uncertainties in climate prediction;

h. develop the regional climate model and embed it into BCC_CSM1.2 for operational use.

6.2.4 Planned Research Activities in Specialized Numerical Predictions

Environmental Emergency Response System: The source term evaluation system will be put into operation. The dose calculation system will be developed and the relative products will be produced. The new environmental emergency response products will be improved or revised, such as the products of TOA.

CUACE: The Chinese Unified Atmospheric Chemistry Environmental System is a comprehensive aerosol and chemistry model. It is the basis for the operational forecasting systems: CUACE/Dust and CUACE/Haze-fog. Emission inventories over China have been updated with reference year of 2012. Emissions improvement research on aerosol-cloud-radiation interactions and gas chemistry updating will continue in the future.

7. Consortium *(if appropriate)*

There is no consortium in CMA

7.1 System and/or Model

7.1.1 In operation

7.1.2 Research performed in this field

7.2 System run schedule and forecast ranges

7.3 List of countries participating in the Consortium

7.4 Data assimilation, objective analysis and initialization

7.4.1 In operation

7.4.2 Research performed in this field

7.5 Operationally available Numerical Weather Prediction (NWP) Products

7.6 Verification of prognostic products

7.7 Plans for the future (next 4 years)

7.7.1 Major changes in operations

7.7.2 Planned Research Activities

8. References

Give references to the sources where more detailed descriptions of different components of the data processing and forecasting system can be found, including WEB sites addresses.

Xue, J-S. and Chen, D-H.: Scientific design and application of GRAPES (in Chinese), Science press, 2008.

Xue, J-S., Liu, Y. and Zhang, L.: Scientific documentation of GRAPES-3DVar system for the global model (in Chinese), Numerical Weather Prediction Center, China Meteorological Administration, 2012.

Liu, Y. and Xue, J-S.: Operational implementation of the assimilation of global navigation satellite radio occultation observations into the GRAPES data assimilation system, Journal of Meteorological Research DOI：10.1007/s13351-014-4028-0, 2014.

Wang Ruichun, Gong Jiandong, Zhang Lin, et al. 2014: Tropical balance characteristics between mass and wind fields and their impact on analyses and forecasts of GRAPES. Part I: Balance characteristics. Chinese Journal of Atmospheric Sciences (in Chinese), doi:10.3878/j.issn.1006-9895.1412.14233. (In Press)

Han Wei, 2014: Constrained variational bias correction for satellite radiance assimilation, 19th International TOVS Study Conference, 6 March - 1 April 2014, Jeju Island, South Korea.

Li Juan. and Zou X., 2013: A quality control procedure for FY-3A MWTS measurements with emphasis on cloud detection using VIRR cloud fraction. J. Atmos. Oceanic Technol., 30, 1704–1715.

ZHANG Hanbin, CHEN Jing, ZHI Xiefei, WANG Yi, and WANG Yanan .2015, Study on Multi-Scale Blending Initial Condition Perturbations for a Regional Ensemble Prediction System, Advances in Atmospheric Sciences, 32 (8)