Recent NWP activities in CMA

Jian Sun

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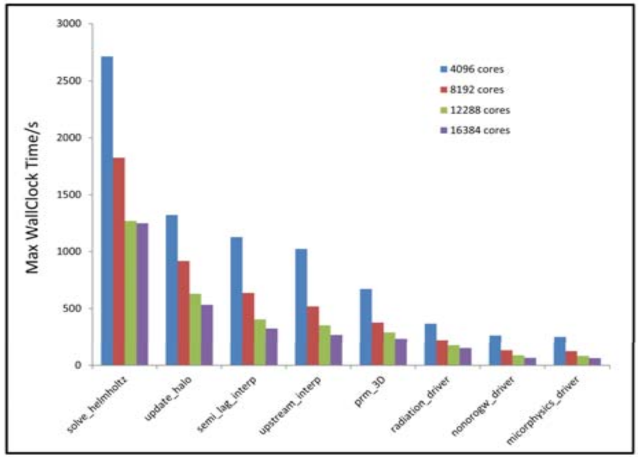
New Center — Earth System Modeling and Prediction Center

- Background
  - NWP system & climate prediction system are developed separately in CMA
    - Earth system components (ocean, waves, sea ice, land surface) will impact on the evolution of the weather.
    - Modelling the interactions between components in NWP system will improves weather forecasts.
  - Developing earth system modeling is the first and the most important task of CMA
    - Weather and climate models should be developed jointly
- How to (established at Sept 30, 2021)
  - Modelers from 5 centers, total 170+ staffs, Director: Dr. Xuexiang YAO
    - Numerical Weather Prediction Center
    - National Climate Center (Climate modeling division)
    - National Meteorological Information Center (reanalysis and parallel computing)
    - National Satellite Meteorological Center (satellite DA and satellite data preprocessing)
    - Chinese academy of Meteorological Science (dynamics, physics& earth system components, fast radiative transfer model)
- Structure of the Center
  - 3 manage divisions
  - 9 research&operation divisions
    - Model technology division, Coupling model division, Data assimilation technology division, Satellite data assimilation division, Ensemble prediction division, Diagnosis and application division, Computing technology division, Operation system division, Open laboratory (platform to contact model developers in regional centers, provinces and other units)

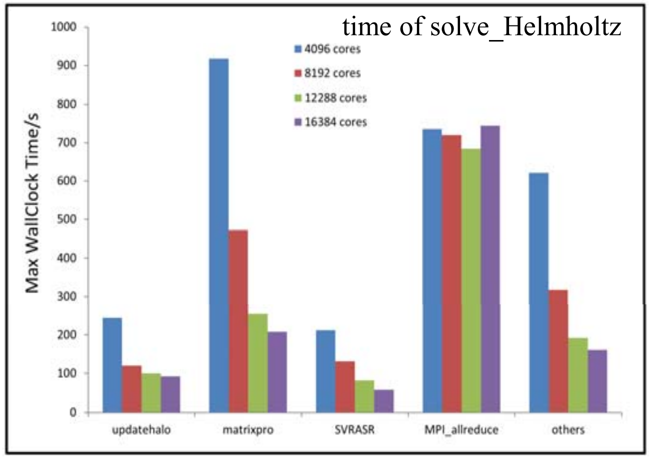
Operational NWP systems in CMA (Oct. 2021)

	GRAPES-GFS	GRAPES-GEPS	GRAPES-REPS	GRAPES-TYM	GRAPES-Meso 3km
Data assimilation **Typhoon Initialization**	4D-Var TC 1-h central pressure assimilation	4D-Var	3D-Var+Cloud analysis	3D-Var Non-linear balanced vortex intensity adjustment scheme	3D-Var+Cloud analysis
Perturbations **Members**		SVs+SPPT 31	ETKF+SPPT 15		
Domain	Global	Global	China (70-145E,15-65N)	Asia, West Pacific (40-180.14E,15S-60.06N)	China (70-145E,10-60.1N)
Hori. Res (degree)	0.25	0.5	0.1	0.09	0.03
Vertical levels **Model top (km)**	87 63	60 36.3	50 35	68 35	50 35
Forecast range	240h	360h	84h	120h	36h
Forecast times per day	4 (00, 06,12,18UTC)	2 (00, 12UTC)	2 (00, 12UTC)	4 (00, 06,12,18UTC)	8 (Every3h)

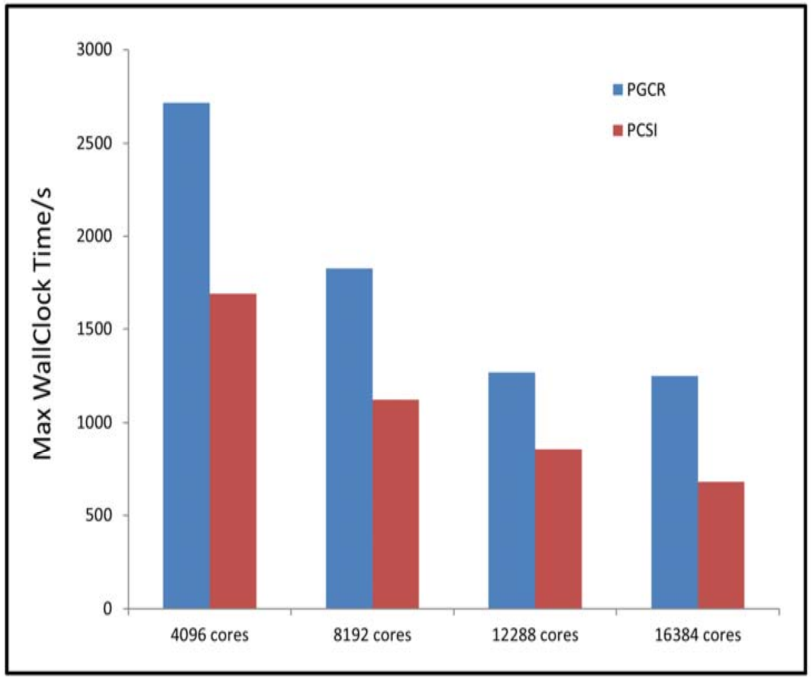
Helmholtz equation solver for GRAPES 0.125degree global model



Top eight time-consuming subroutines of solve_grapes



Time for different parts of the Preconditioned GCR algorithm



Algorithm 1. Preconditioned Generalized Conjugate Residual solver

$\mathbf{x_0}, \mathbf{r_0} = \mathbf{b} - \mathbf{A}\mathbf{x_0}, \mathbf{z_0} = \mathbf{M}^{-1}\mathbf{r_0}, \mathbf{p_0} = \mathbf{z_0}$

while not converged do

1, *for* $k = 0 : s-1$, *do*

2, $\alpha_k = \mathbf{r_k^T A p_k} / \mathbf{p_k^T A^T A p_k}$

3, $\mathbf{x_{k+1}} = \mathbf{x_k} + \alpha_k \mathbf{p_k}$

4, $\mathbf{r_{k+1}} = \mathbf{r_k} - \alpha_k \mathbf{A p_k} \Leftrightarrow \mathbf{z_{k+1}} = \mathbf{z_k} - \alpha_k \mathbf{M^{-1} A p_k}$

if converged , exit

5, $\beta_j^k = -\mathbf{z_{k+1}^T A^T A p_j} / \mathbf{p_j^T A^T A p_j} (j = 0,1,2,...,k)$

6, $\mathbf{p_{k+1}} = \mathbf{z_{k+1}} + \sum_{j=0}^{k} \beta_j^k \mathbf{p_j}$

7, *end for*

8, $\mathbf{r_0} = \mathbf{r_s}, \mathbf{p_0} = \mathbf{p_s}$

end while

Algorithm 2. Preconditioned Classical Stiefel iteration

$\mathbf{x}_0$, *estimated eigenvalue boundary* $[\nu, \mu]$

1, $\alpha = \frac{2}{\mu - \nu}, \beta = \frac{\mu + \nu}{\mu - \nu}, \gamma = \frac{\beta}{\alpha}, \omega_0 = \frac{2}{\gamma}; k = 0;$

2, $\mathbf{r}_0 = \mathbf{b} - \mathbf{A}\mathbf{x}_0;\ \mathbf{z}_0 = M^{-1}\mathbf{r}_0;\ \mathbf{x}_1 = \mathbf{x}_0 - \gamma^{-1}\mathbf{z}_0;\ \mathbf{r}_1 = \mathbf{b} - \mathbf{A}\mathbf{x}_1;\ \mathbf{z}_1 = M^{-1}\mathbf{r}_1;$

3, *while* $k \le k_{\max}$ *do*

4, $k = k + 1;\ \omega_k = 1 / \left(\gamma - \frac{1}{4\alpha^2}\omega_{k-1}\right);$

5, $\Delta\mathbf{x}_k = \omega_k \mathbf{z}_{k-1} + (\gamma\omega_k - 1)\Delta\mathbf{x}_{k-1};$

6, $\mathbf{x}_k = \mathbf{x}_{k-1} + \Delta\mathbf{x}_{k-1};\ \mathbf{r}_k = \mathbf{b} - \mathbf{A}\mathbf{x}_k;$

7, *update_halo*$(\mathbf{r}_k)$; $\mathbf{z}_k = M^{-1}\mathbf{r}_k;$

8, *if* $k \% n_c == 0$ *then check convergence;*

9, *end while*

The pseudo code of the Preconditioned GCR and CSI algorithm

Satellite data assimilation

- **Assimilated**

  IASI(MetOp-C)

  CrIS(SNPP, NOAA-20)

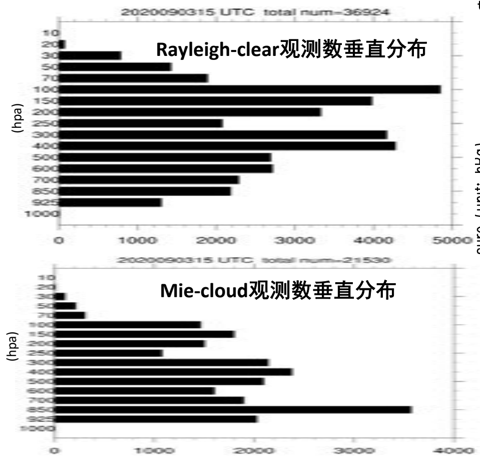
  AMSU-A (MetOp-C),

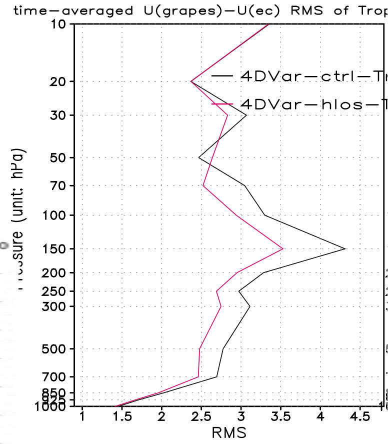
  MHS (MetOp-C),

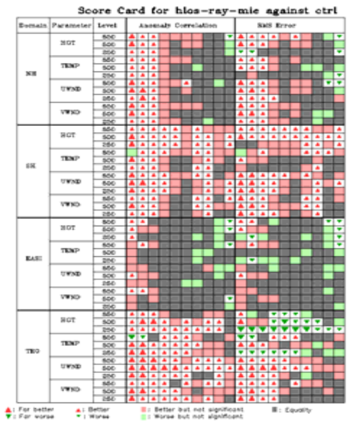
  ATMS(NOAA-20),

  AMSR2(GCOM-W)
- Aeolus
- Chinese YH and BDS RO

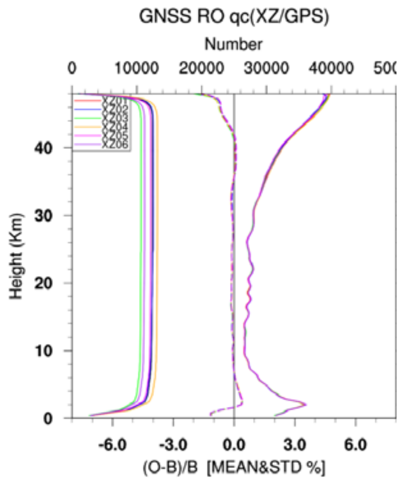
RED = Better

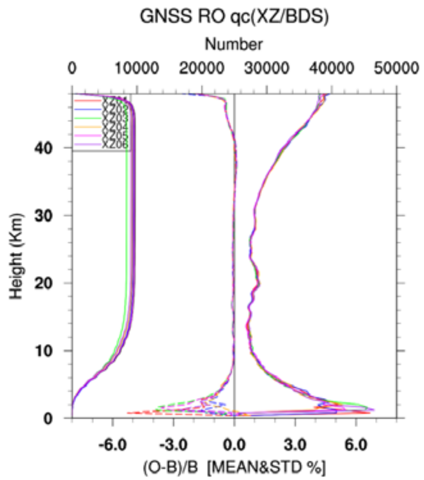


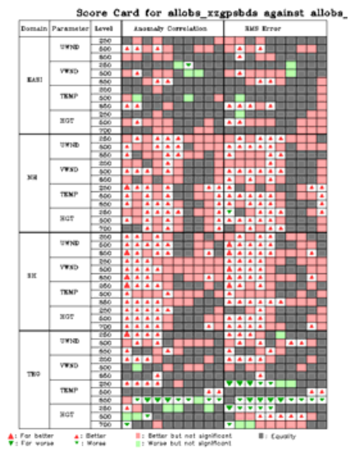




With/Without Aeolus







With/Without YH RO

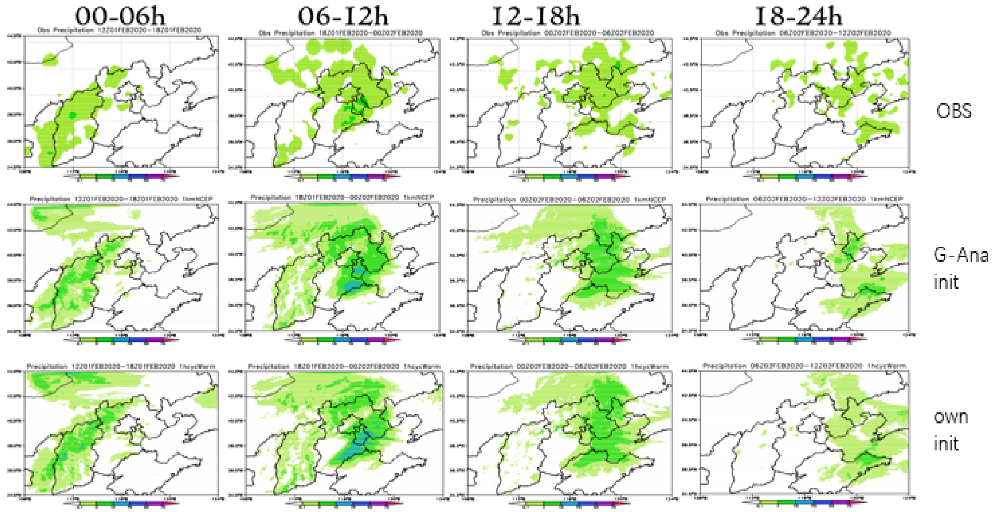
GRAPES-Meso 1km resolution with 1h cycle

GRAPES-Meso v5.1

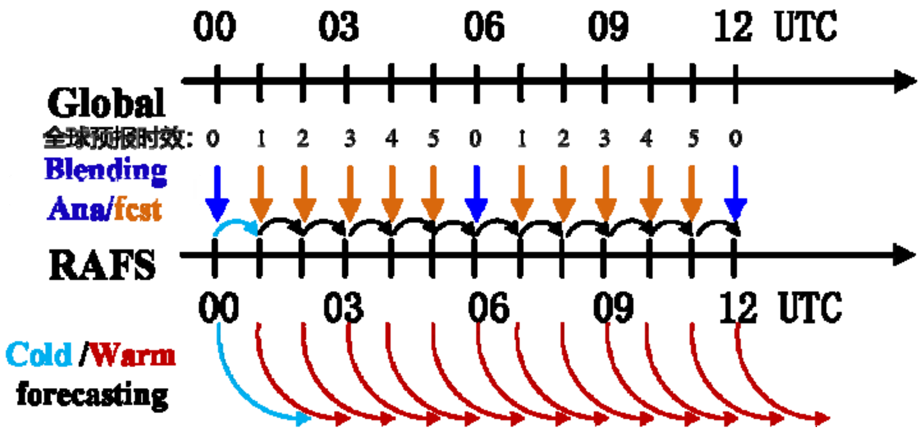
- 3km with 3h cycle
- 3DVar (U/V as control var)
- Cloud analysis
- Land sfc DA
- Data
  - Radar radial wind
  - Wind profiler
  - Surface
  - FY4-AGRI

\+

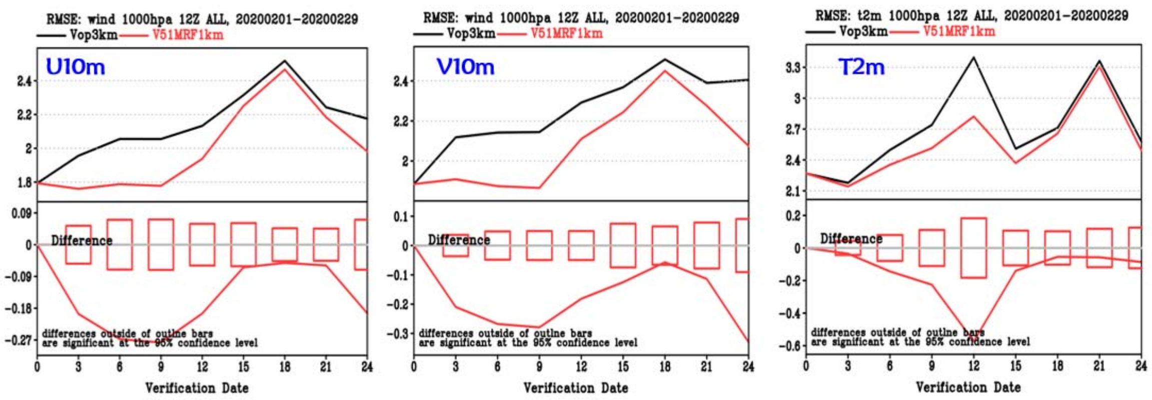
- 3D reference profile
- More precise topography and landuse
- Well-tuned microphysics with radar obs
- Blending with large-scale model
- Incremental analysis update
- Surface T2m assimilation



Rainfall forecast from 1km 1h cycle



Flowchart of 1km, 1h cycle

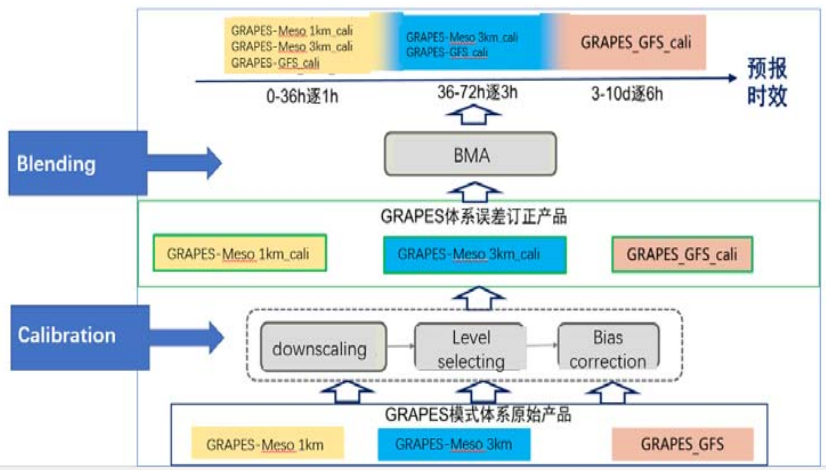


Wind-10m and T-2m

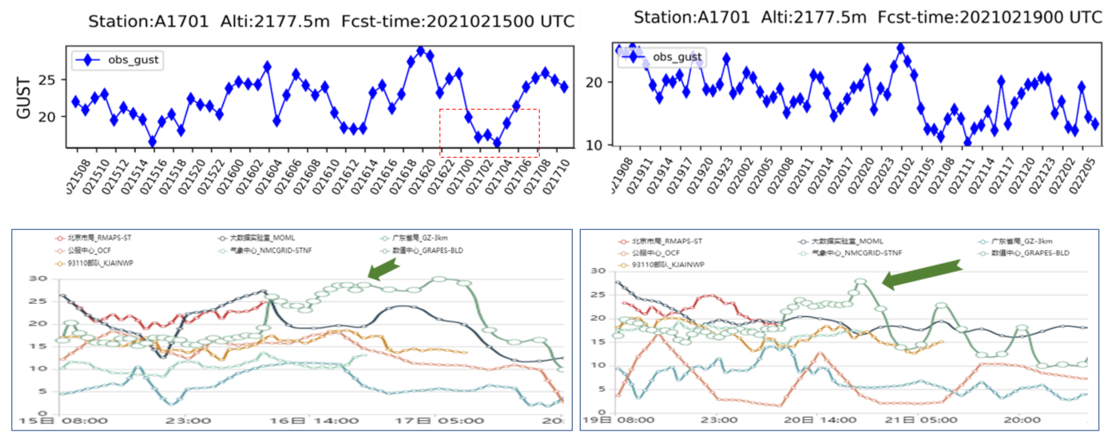
GRAPES supports the 2022 Beijing Winter Olympics

	Area	Res.	update	interval	element
Grid products	Beijing-Tianjin-Hebei	1km	6h	36h, 1h	10m U, 10m V 2m temperature, 2m relative humidity
Station products	26 sites		6h	(0-36,1h interval) (36-120h, 3h interval 120-240h, 6h interval)	2-m temperature, 2m relative humidity， 10m wind speed, 10m wind direction, total precipitation, snowfall， Gust

Flowchart of the NWP product



Wind gust forecast



100m resolution wind product

Dynamic downscaling	100m	10,30,50,80,150,250,350,500,750, 1050,1350,1650,1950,2250,2550,2 850,3150m	Update every 3h	Output every 10min	Forecst length 24h