Progress and plans for satellite data assimilation in the KMA operational NWP system

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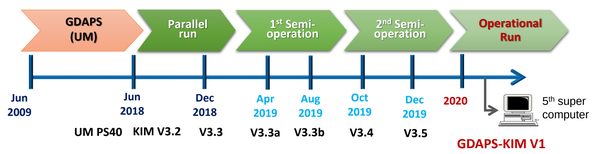
INTRODUCTION

▣ Major changes in the KMA NWP system

- ✓ KMA has carried out a project to develop a **Korean global NWP model** in order to improve the prediction accuracy of the weather phenomenon on the Korean Peninsular and to ensure the identity of meteorological technology**. The new Korean global model will be run as an operational model of the Korean Meteorological Administration from April 2020.**
- ✓ **The GK-2A, the second geostationary satellite of Korea, was launched successfully in 5 Dec. 2018.** The preliminary results from the assimilation of GK-2A CSR and AMV data show a slightly **positive impact on the middle and higher tropospheric humidity and wind fields**, significant improvements are shown in Asia region.
- ✓ Since the last ITSC, **KMA has newly assimilated Himawari-8 CSR, MT-SAPHIR, GCOM-W1/AMSR2, FY-3C/MWHS-2, LEOGEO winds and GNSS-RO from TanDem-X, TerraSAR-X, GRACE** data enhanced convective activities in middle and lower tropospheric layers over Tropics and they had an effect on increasing the initial specific humidity in the DA process. The impacts for global model showed slightly positive improvements in wind and humidity fields.

▣ R2O2R (research ↔ operation)



✓ **Major update**

UM PS05(40) : UMv10.8(**17km→10km**), RTTOV(v9 →v11.3), new BGE, topo update

KIM v3.2: Add MT-SAPHIR & ATMS upper ch., **VarBC**(AMSU-A), Ens BGE localization
KIM v3.3 : **IAU application**, RTTOV(v10.2→11.3), Add GOES-R AMV, VarBC(MHS)
KIM v3.3a/b : **bug fixes, I/O changes**, IASI/CrIS QC, code optimization
KIM v3.4 : Add AMSR2, GNSSRO QC update(obs error), BGE ens ratio/vertical mode
KIM v3.5 : Add FY-3C & all-sky radiance module, Final version from KIAPS

▣ Satellite data usage

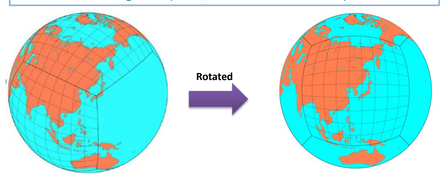
Observation type	Subtype/Satellite name	GDAPS-UM	GDAPS-KIM
ATOVS	NOAA-15/18/19, MetOp-A/B	○	○
IASI	MetOp-A/B	○	○
CrIS	Suomi-NPP	○	○
ATMS	Suomi-NPP	○	○
Satwind(AMV)	MSG, GOES, COMS, Himawari, MODIS,AVHRR,LEOGEO	○	○
Scatwind	ASCAT(MetOp-A/B)	○	○
GNSS-RO	COSMIC,GRAS,GRACE-A/B, TerraSAR-X,TanDEM-X, KOMPSAT-5(2019.12))	○	○
COMS CSR	COMS → GK-2A(2020.4)	○	○
MT-SAPHIR	Megha-Tropiques	○	○
SSMIS	F16-20	△(2020)	△(2020)
AHI CSR	Himawari-8	○	X (2020)
GOES CSR	GOES-15(16)	○	X (2020)
SEVIRI CSR	MSG	○	X (2020)
AMSR2	GCOM-W1	○	○
FY3C-MWHS	FengYun-3C	○	○
Ground GNSS	IGS, EU, UK, USA, KMA(NMSC) station	○	X (2020)
AIRS	AQUA	○	X

NEW GLOBAL MODEL (GDAPS-KIM)

▣ Development of KIM model

- Grid system : **Cubed sphere**, horizontal: **Spectral element**, vertical: **Finite difference**
- Flux-type compressible governing equations
- Time-split time integration: Slow mode → third-order Runge-Kutta
  Horizontal sound wave and gravity wave → Forward-Backward
  vertical sound wave and buoyancy → implicit
- Resolution : ne360np3(**~12 km**), **91 levels** (top = 1 Pa)

Korean (formerly KMA, KIAPS) Integrated Model (KIM) system
Hong et al. (2018, Asia-Pac. J. Atmos. Sci.)

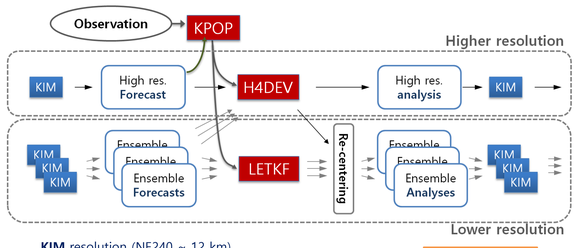


KIM Physics Packages (KIM 3.1, early 2018)

Physics schemes	KIM 3.1	Remarks
Cumulus parameterization (CPS)	Han et al. (2016) Kwon and Hong (2017)	Routed in GFS CPS of GRIMs, but with the improved cloud microphysics and the inclusion of scale-aware function, names KSAS (gray-zone SAS)
Shallow convection (SCV)	Hong and Jang (2018)	Routed in Tiedtke SCV (Tiedtke 1989) of GRIMs, but with improved diffusivity, and triggering function
Cloud microphysics (MPS)	Hong et al. (2004) Bae et al. (2018)	Routed in WSM5 (Hong et al. 2004) of WRF, but with the inclusion of cloud properties in radiation package (Bae et al. 2016)
Radiation (RAD)	Baek (2017)	Routed in RRTMG (Iacono et al. 2008) of WRF, but with a newly developed unified RAD package
Cloudiness (CLD)	Park et al. (2016)	A newly developed prognostic cloudiness package based on the Tiedtke prognostic cloudiness (Tiedtke 1993)
Vertical diffusion (PBL)	Shin and Hong (2015) Lee et al. (2018)	Routed in YSU PBL (Hong et al. 2006, Hong 2010) of WRF, but with the inclusion of scale-aware function and stratocumulus mixing
Aerosol chemistry (AER)	Choi et al. (2018)	A newly generated 3D aerosol data, based on IFS MACC 2D aerosol climatology
Orographic gravity wave drag (GWDo)	Choi and Hong (2015)	Routed in GWDo (Kim and Arakawa 1995, Hong et al. 2008) of GRIMs, but with the inclusion of orography blocking and anisotropy of mountains
No-mountain gravity wave drag (noGWDo)	Choi et al. (2018)	A newly developed source-based spectral non-orographic GWD, based on Choi and Chun (2011) and Richter et al. (2010).
Land surface layer (LSM)	Koo et al. (2017, 2018)	Routed in Noah 3.0 of GRIMs (Ek et al., 2002, Chen and Dudhia, 2000), but a revised snow physics and the inclusion of form drag
Ocean surface layer (OSM)	Kim and Hong (2010), Lee and Hong (2018)	Routed in GRIMs, but with the inclusion of salinity effect in latent heat flux computation

KIM DA system

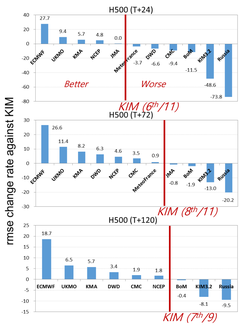
- **3DVar has been developed for cubed-sphere grid from scratch**
- Combination of **3DVar** and **LETKF**
- Error of the Day of error from **LETKF**

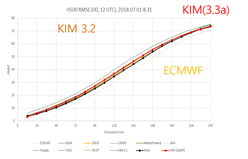


KIM resolution (NE240 ~ 12 km)
Ensemble resolution (NE060 ~ 50 km), 50 members
Analysis resolution (NE060 ~ 50 km)

Ensemble B ratio:
0.7 near tropics,
0.3 near poles

▣ Performance of KIM model

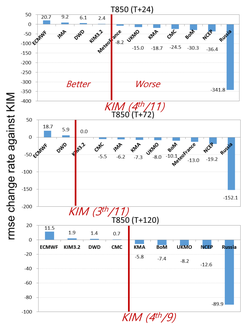


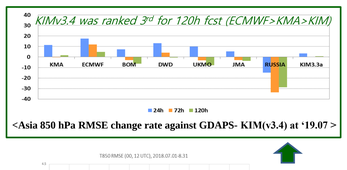


Fcst time	Ranking (in order of small RMSE)
24hrs	ECMWF > UKMO > KMA > NCEP > JMA > **KIM** > MeteoFrance > DWD > CMC > BoM > Russia
72hrs	ECMWF > UKMO > KMA > DWD > NCEP > CMC > MeteoFrance > **KIM** > JMA > BoM > Russia
120hrs	ECMWF > UKMO > KMA > DWD > CMC > NCEP > **KIM** > BoM > Russia

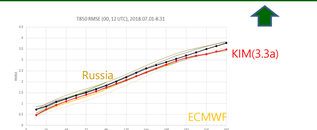
$$rmse\ change\ rate(\%) = \frac{(RMSE_{KIM} - RMSE_{others})}{RMSE_{KIM}} \times 100$$

<NH 500 hPa GPH RMSE change rate against GDAPS- KIM(v3.3a) during 2018.7~8 >





<Asia 850 hPa RMSE change rate against GDAPS- KIM(v3.4) at '19.07 >



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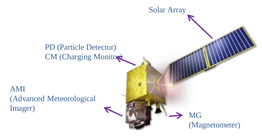
<Asia 850 hPa RMSE change rate against GDAPS- KIM(v3.3a) during 2018.7~8 >

GK-2A / KOMPSAT-5 DATA ASSIMILATION

▣ GK-2A data assimilation

✓ **GK-2A satellite data**

- Channels: 16 (COMS: 5)
- Spatial resolution(km) : 0.5, 1(VIS) / 2(IR)
- Temporal resolution : 10min(FD), 2min(KO)
- Provide 52 products
- AMV: 32km(16x16), 30min, CSR: 24km(12x12), 30min



Channels	Central channel frequency(㎛) AMI (GK-2A)	ABI (GOES-16)	AHI (Himawari-8)	MI (COMS)
1(VIS) blue	0.470	0.470	0.46	
2(VIS) green	0.511		0.51	
3(VIS) red	0.640	0.640	0.64	0.675
4(VIS)	0.856	0.865	0.86	
5(NIR)	1.380	1.378		
6(NIR)	1.610	1.610	1.6	
NIR		2.250	2.3	
7(IR)	3.830	3.90	3.9	3.75
8(WV)	6.241	6.185	6.2	
9(WV)	6.952	6.95	6.9	6.75
10(WV)	7.344	7.34	7.3	
11(IR)	8.592	8.50	8.6	
12(IR)	9.625	9.61	9.6	
13(IR)	10.403	10.35	10.4	10.8
14(IR)	11.212	11.20	11.2	
15(IR)	12.364	12.30	12.3	12.0
16(IR)	13.31	13.30	13.3	

<Channel comparison table of AMI(GK-2A), ABI(GOES-R), AHI(Himawari-8) and MI(COMS)>

✓ **Sensitivity test to find the optimal resolution of GK-2A CSR data**

- Experiments: 8x8(16km), 12x12(24km), 16x16(32km)
- Periods: 201807, Verification: against IFS analysis
- As a result, the experiment with **24km resolution** showed the best error reduction among the three resolutions.

ANAL		32km Globe	32km NH	32km ASIA	24km Globe	24km NH	24km ASIA	16km Globe	16km NH	16km ASIA
temp	250	0.0	0.2	0.0	0.2	0.2	0.6	0.4	0.0	0.4
	500	0.3	0.4	1.0	0.6	0.2	1.3	0.2	0.0	1.0
	850	-0.2	1.5	0.7	-0.2	1.0	0.7	-0.3	2.2	0.3
gph	250	0.0	1.0	0.5	0.3	0.9	1.4	-0.4	0.5	-0.4
	500	-0.4	1.8	0.2	0.1	1.5	1.1	-1.0	1.7	-0.2
	850	0.3	2.4	0.4	-0.1	0.3	0.2	-0.3	0.2	-0.5
rh	250	0.0	0.5	0.3	0.2	0.8	0.6	0.1	0.1	-0.1
	500	-0.2	0.3	0.3	0.2	0.9	0.5	-0.3	0.3	0.1
	850	0.0	1.2	0.2	0.1	1.5	0.5	-0.2	1.0	-0.1

+, green: improvement

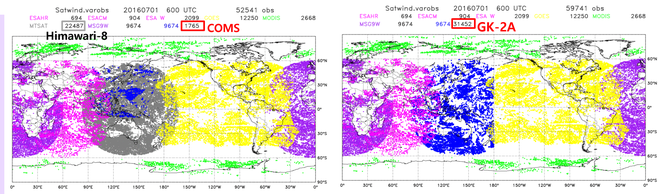
<F00 Analysis fields RMSE improvement rate(%) against IFS analysis>

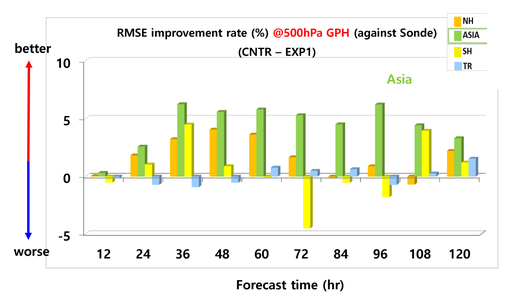
	AMI_32km Global	AMI_32km NH	AMI_32km Asia	AMI_24km Global	AMI_24km NH	AMI_24km Asia	AMI_16km Global	AMI_16km NH	AMI_16km Asia
Total	0.1	0.8	0.1	0.3	0.5	0.7	-0.1	0.5	-0.4
RH	-0.1	0.7	0.1	0.1	0.8	0.4	0.0	0.5	0.1
TEMP	0.1	0.6	0.2	0.2	0.4	0.8	0.1	0.4	-0.3
GPH	0.2	1.1	0.0	0.5	0.2	0.9	-0.4	0.5	-1.0

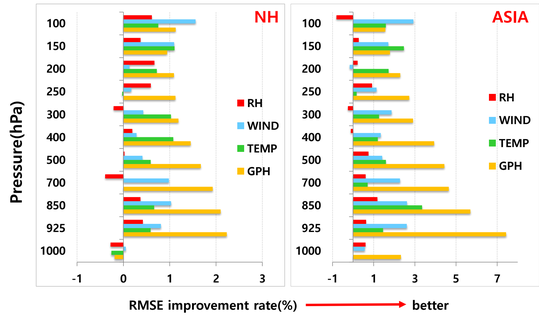
<Forecast error improvement rate averaged from F00 to F72hr >

✓ **Preliminary results of GK-2A AMV data assimilation**

- Target size(pixels): 16X16, Target search area: 54x54
- Target selection method: Dynamic critical pressure for transmittance
- Height Assignment method: EBBT, WV int, NTC, CO2 slicing
- Area of AMV generation: Full Disk
- CNTL: KMA OPER, EXP1: OPER+GK 2A AMV – H-8 AMV – COMS
- The preliminary results showed the improvement of GPH and Wind fields, especially for Asia region.

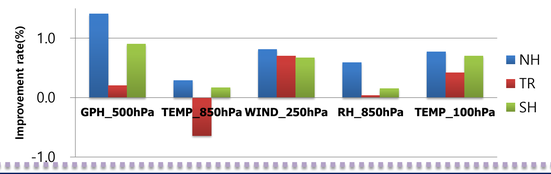


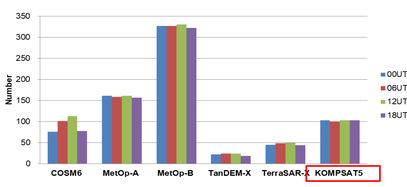




▣ KOMPSAT-5 RO data assimilation

- On average, the KOMPSAT-5 RO data are accounted for about 14% of the total RO data.
- The amount of data used in data assimilation increased 20~28% in every cycle.
- EXP shows mostly positive impact except only 850T field in the Southern Hemisphere.



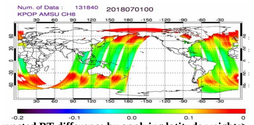


< RO data number at 00, 06, 12, 18 analysis time>

Impact of BIAS CORRECTION

▣ Application of static bias correction for QC in GDAPS-KIM

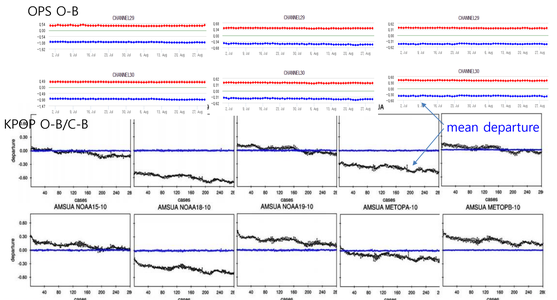
- Comparing the effect of method of obtaining BC coefficient by accumulating statistics over a period and method of calculating BC coefficient every cycle.
- Consider weight for differences in observations by latitude. Apply BC for Upper ch.

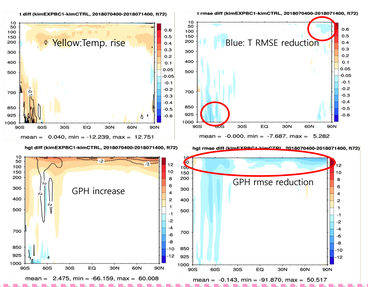


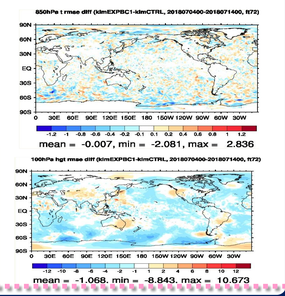
<Corrected BT difference by applying latitude weights>

	Global	NH	SH	TR	ASIA
TOTAL	0.56	1.06	0.03	1.20	0.31
TEMP	0.02	0.51	-0.18	-0.02	0.53
GPH	1.82	3.33	0.00	3.94	0.86
RH	-0.15	-0.65	0.29	-0.30	-0.46

<Forecast error improvement rate averaged from F00 to F120hr >







WORK in Progress

- ▣ **steady effort to assimilate new satellite data (GMI, NOAA 20, MetOp-C, GIIRS, VIIRS etc.)**
- ▣ **application of VARBC for all satellite data in GDAPS-KIM**
- ▣ **improved Quality Control & increased utilization of upper and surface channel for radiance data in GDAPS-KIM**