Recent development of NWP and EPS system in KMA

- with Korea Integrated Model (KIM) -

Seiyoung Park
& NMC colleagues

Dec. 8 2020

Numerical Modeling Center
Korea Meteorological Administration

Korea Meteorological Administration
Numerical Modeling Center

Contents

목차

Ⅰ. KMA NWP (EPS) system

Ⅱ. Korea Integrate Model

- Dynamic core, Physics,
- Data Assimilation, Operation

Ⅲ. Performance & SW Cases

Ⅳ. International Coop. (WMO SWFP)

Ⅴ. Future Plan

수치모델링센터

I. KMA NWP (EPS) system

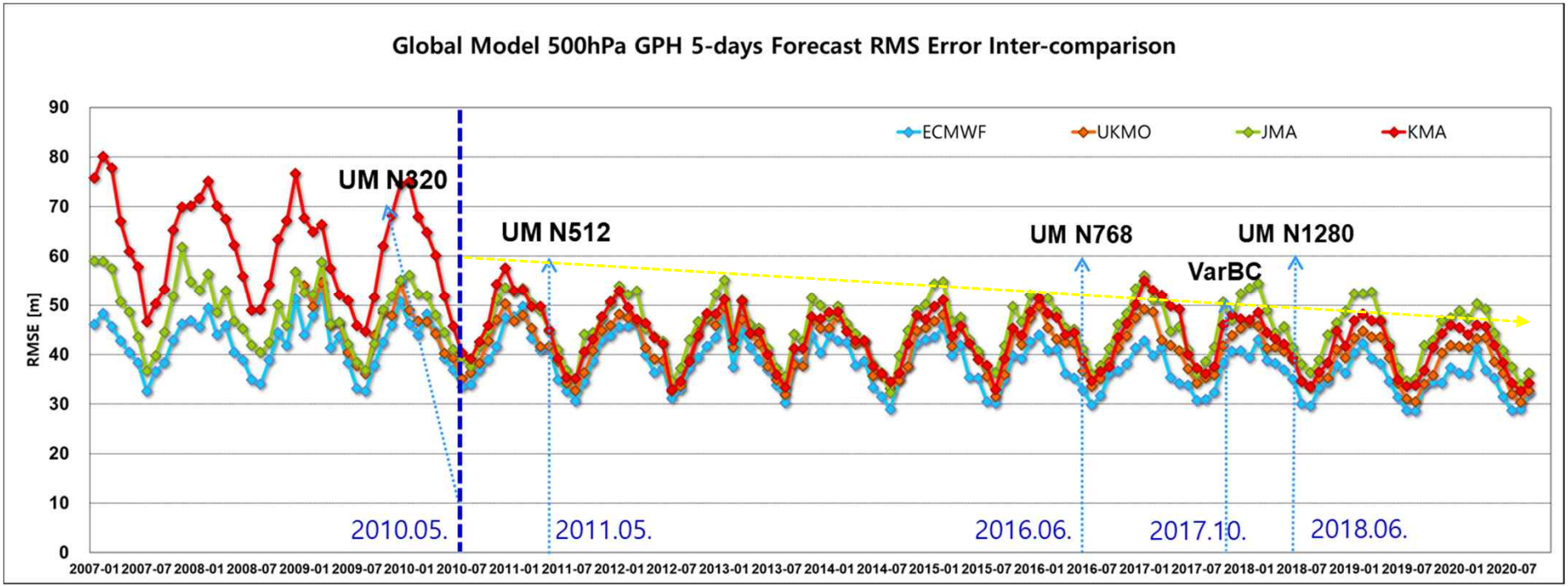
KMA Super computer with NWP system



Item	1st	2nd	3rd		4th		5th
When Installation Started	1999.2.24.	2004.4.27.	2009.9.7.		2014.6.20.		Lenovo (2020~)
When Installation Finished	2000.9.27.	2005.12.5.	2010.12.13.		2015.12 .14.		
Company	NEC SX-5/28(Japan)	CRAY X1E (US)	CRAY XE6 (US)		CRAY XC40 (US)		
Capacity(TF)	0.224 (0.128 + 0.096)	18.5 (9.75 × 2)	Initial: 37	Final: 758 (379 × 2)	Initial: 447	Final: 5,800 (2,900 × 2)	
Number of CPU	28 (16 + 12)	1,024 (512 × 2)	3,392	90,240 (45,120 × 2)	10,752	139,392 (69,696 × 2)	
Memory(TB)	0.224	4	7	60 × 2	57	372 × 2	
Storage(TB)	3.8	88	3,989		3,323	15,780	
Global Model Resolution	55km	30km	40km ➔ 25km		17km ➔ 10km		12km
Place of Installation	KMA	Seoul	Supercomputer Center (Ochang)				

JMA global model → UKMO global model (UM) → KIM

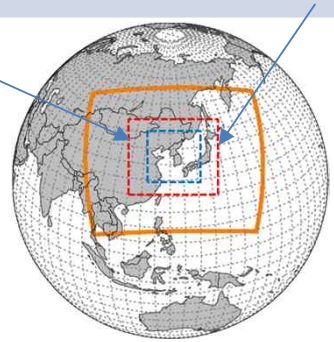
KMA global model's Annual trend



- Significant advancement in model performance since 2010 (since implementation of UM)

KMA Operational NWP System (UM based)

	Global Model	Global Ensemble	Local Model		Local Ensemble
			LDAPS	VDAPS	
Horizontal Resolution	10 km	32 km	1.5 km		2.2 km
Level	70 layers		70 layers		70 layers
Model Top	80 km		39 km		39 km
Forecast Hours	12 days		48 hours	12 hours	72 hours
Data Assimilation	Hybrid 4DVAR	25 members (49)	3DVAR		13 members
Domain	Global		Small East Asia	around Korean Peninsula	



KMA Operational NWP System (KIM based Global)

- **The Korean NWP model has been developed since 2011.**
  - A nine-year project (2011-2019)
  - **Global model & data assimilation system**

- **The best optimized model for Korean peninsular**
  - **Cubed sphere grid** system
    : Mitigation of model instability in pole area
  - Data Assimilation : **Hybrid 4DEnVAR**
  - Resolution : **12 km 91 levels**

- **Schedule for operational implementation in KMA**
  - **Parallel run** since July 2018 (v3.2)
  - **Semi-operation run** since April 2019 (v3.3a)
    upgrade in October 2019 (v3.4)
  - **Operation run** in April 28 2020 (v3.5)

KMA Operational NWP System (KIM based EPS)

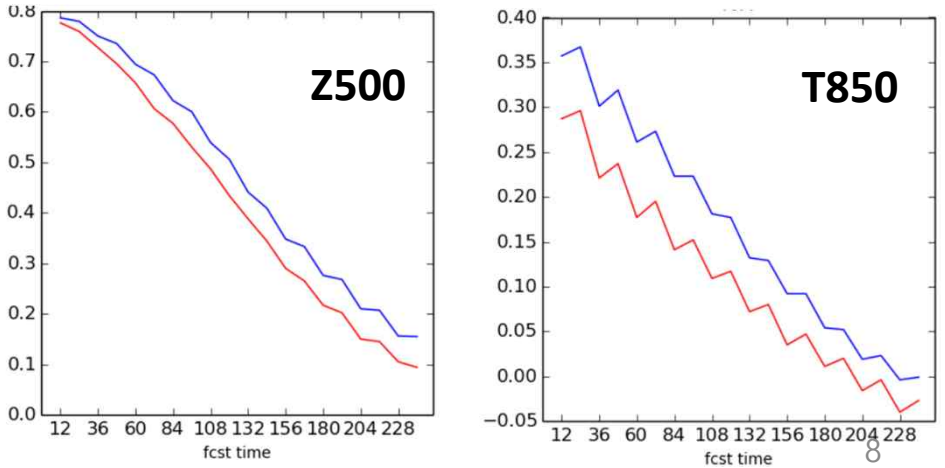
	KIM (Semi Oper)	UM (Oper)
Resolution	**50km** (ne090np3) / L90 (0.1hPa)	32km (N400) / L70 (80km)
Data Assimilation (member)	LETKF (50)	ETKF (48)
Initial Surface perturbation	-	SST, SMC, Tsoil
Stochastic Physics	SPPT, SPDT, SSST (KIM3.5)	RP2, SKEB2
Re-centering to the global analysis	u, v, t, q (50%), psfc (100%)	u, v, t, q, π (100%)
Forecast	**LATE** **12 UTC** (CTL +**13 member**)*	ERLY 00 UTC(CTL + TimeLag 24 member) 12 UTC(CTL + TimeLag 24 member)

*Efficient use of Limited Computing Resource

- Forecast time of ensemble data assimilation (50km) extended
- Semi operational run (’19.10.~)
- Operational run (’21.10.~): #25

Verification

The KIM ensemble has skill around 85% of the UM ensemble for Z500 and 70% for T850 (ref: climate)

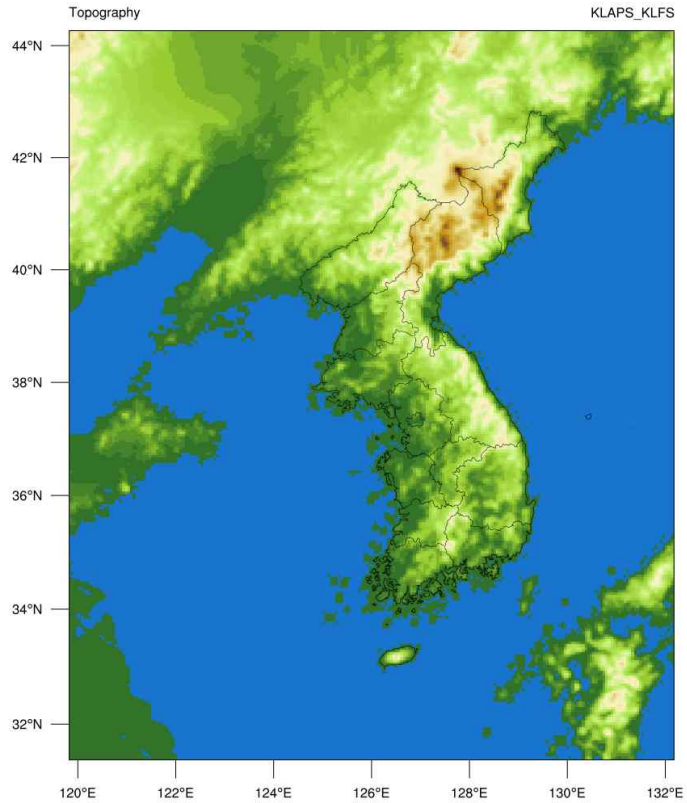


CRPSS/ Jul 2019 / Northern Hemisphere / against Obs

KMA Operational NWP System (KLAPS)

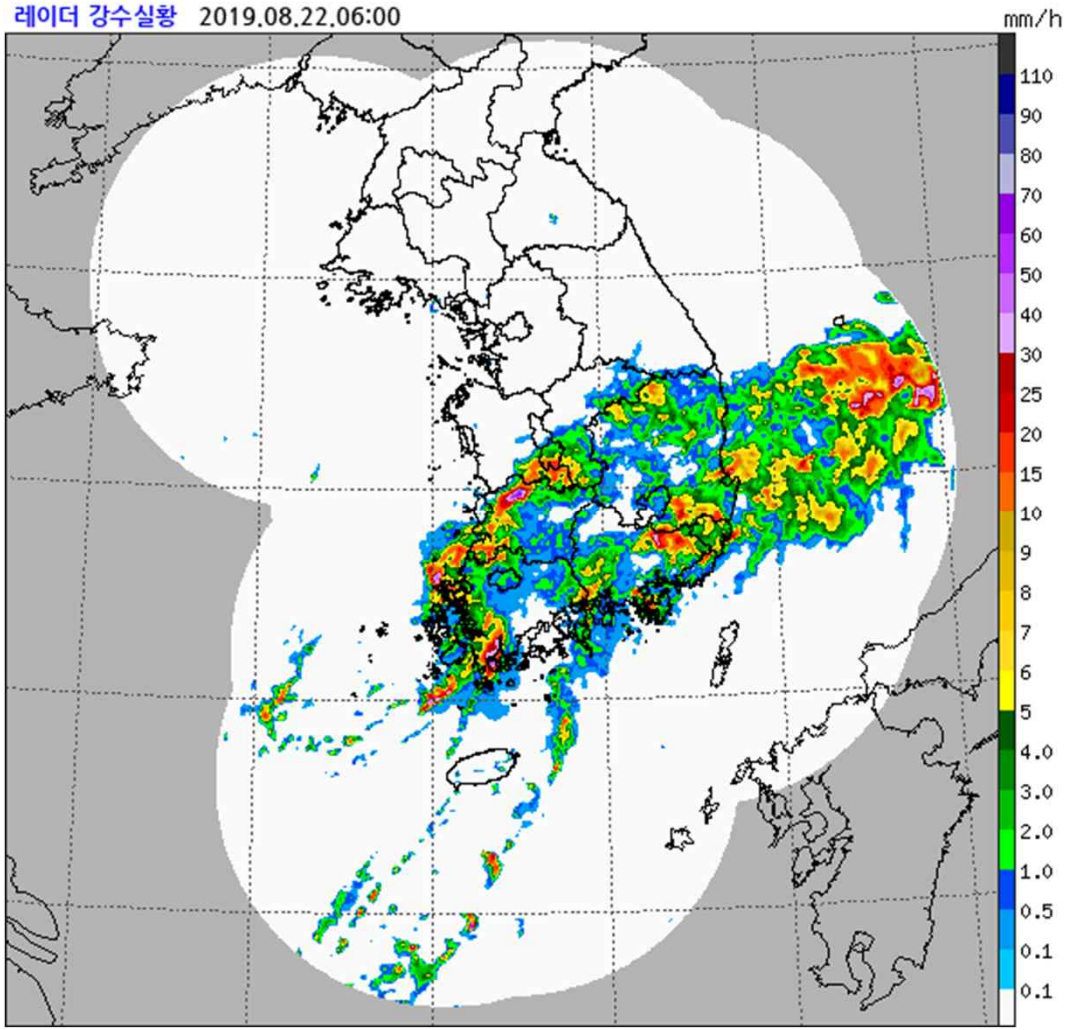
❖ **KLAPS: Very short range forecast**

- **Dynamics: WRF-ARW** 3.9.1.1
- **Physics based on KIM**
- Horizontal resolution: 5 km
- Vertical resolution (Top): 40 levels (50hPa)
- Grid number: 235 (EW) X 283 (NS)
- Update time: 1hr / 10 min. (precip.)
- Updating of background: 6 hr
- Target length: 12hrs
- Integration time: 20 sec.
- Total integration time: ~ 4min (40 nodes)



KMA Operational NWP System (KLAPS)

❖ **KMA homepage : very short range rainfall (mm/hr)** ('19.7.22~)



- Every 10 minutes rainfall
- -1 hr ~ current: rainrate of Radar
- Current ~ +6hr: blending of KLAPS & MAPLE

II. Korea Integrated Model (KIM)

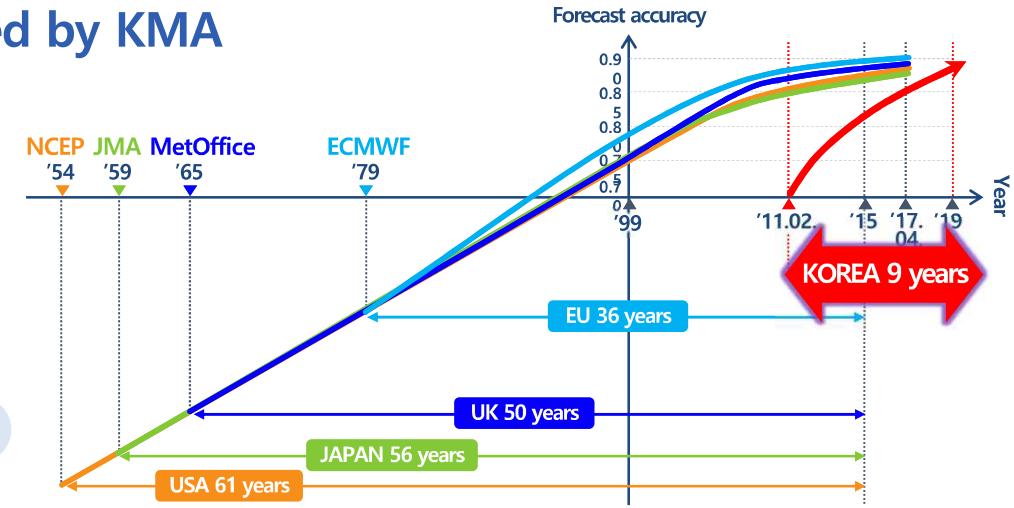
- Overview
- Dynamic Core
- Physics
- Data Assimilation
- Operation

KMA New NWP system : Korea Integrated Model (KIM)

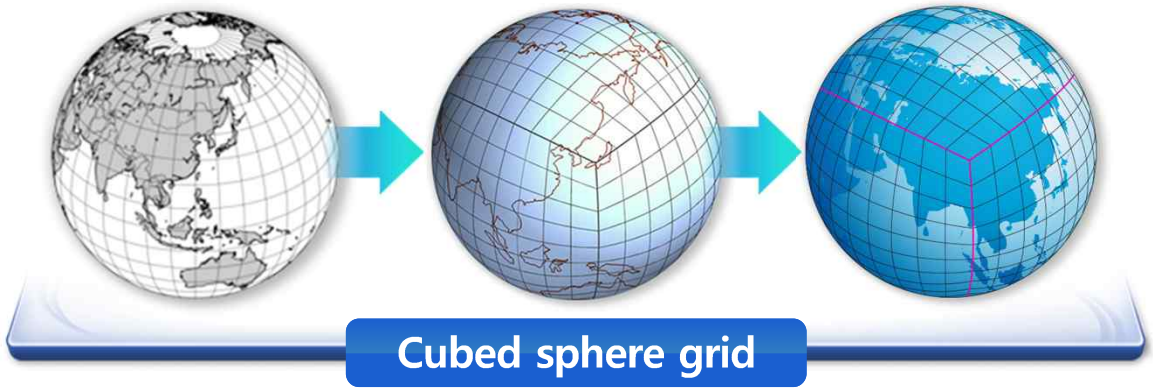
- **Next generation model developed by KMA**

- **Developed in just 9 years**
  (Operated from 2020)
  - Advanced countries spent more than 30 years in developing their models

ECMWF MetOffice NCEP JMA KMA



- **Using Cubed sphere grid system** (Next-generation grid system)
  - USA and UK are also using or plan to use this grid system
  - Solving singularity problem in Pole Area



Cubed sphere Models

- ✓ **USA**
  : GFS-FV3 (Operated in 2019)
- ✓ **KMA**
  : KIM (Operated in 2020)
- ✓ **UK**
  : LFRic (Will be operated in 2025)

KMA New NWP system : Korea Integrated Model (KIM)

❖ **KIAPS (Korea Institute of Atmospheric Prediction Systems)**
- Purpose: Developing a **next generation global operational modeling for KMA**
- Project period: **2011~2019 (total 9 years)**
- Total Budget: **$95 million**
- Man Power: **58**

step1

Foundation and basic research

- Establish the foundation of KIAPS research and development environment
- Efforts on laying out future model development – model dynamics, physics and data assimilation

2011-2013

step2

Release beta version

- Complete developing major model components based on KIAPS own research
- Release the KIAPS beta version model
- conduct semi realtime experiments with KIAPS beta version and evaluate it skills to the KMA operational model

2014-2016

step3

the operational system

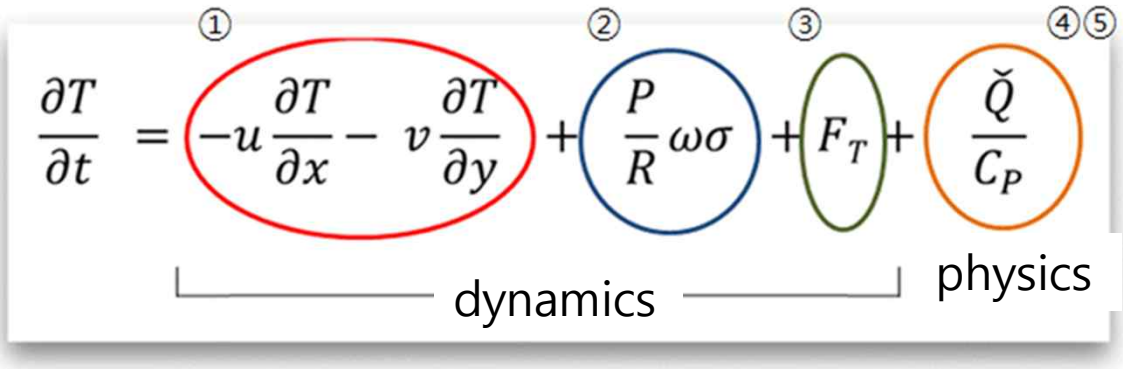
- Finalize the KIAPS operational version 1.0 and run on semi-operational basis
- Stabilize the model system by further diagnostics and verifications
- Release the KIAPS system to international users

2017-2019

❖ Numerical Weather Prediction

- A method of predicting future weather status by solving the governing equations of atmosphere with numerical method and the current atmospheric conditions.

governing eq. (e.g.): thermodynamic equation



air temperature rises in specific area:

1. warm air advect from south
2. compress of air by sinking (adiabatic)
3. turbulent mixing with warm air
4. solar radiation (diabatic)
5. condensation of water vapor (diabatic)

$$T_{future} = T_{current} + \int (dynamics + physics)dt$$

Data Assimilation

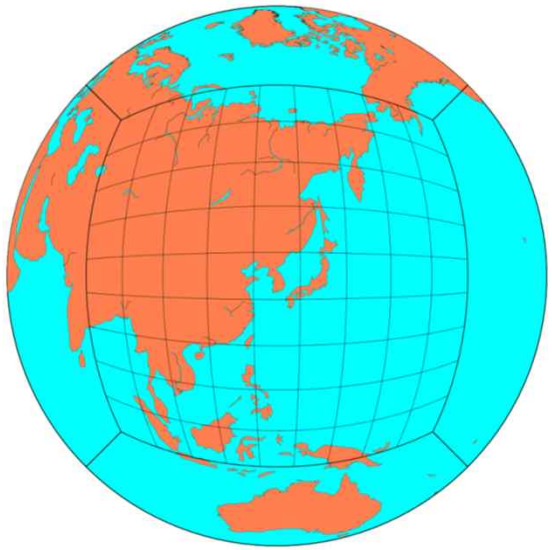
① Dynamic Core

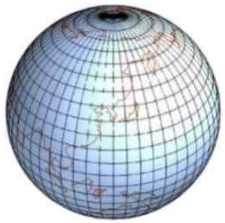
Representing **vertical/horizontal circulations of atmosphere**
e.g. advections, pressure gradient force, horizontal diffusion
(adiabatic processes)

→ no net **energy** source or sink, so **conservation is important**
spatial/temporal discretization method with grid projection

Overview of KIM dynamic core

"The first fully functional non-hydrostatic spectral element global dynamic core over cubed sphere grid" Joseph Klemp (NCAR)





horizontal discretization:

Spectral Element Method* on cubed sphere

* SEM is local in nature with a small communication stencil, we can achieve a high level of scalability.

Vertical discretization:

Finite Difference Method* on hybrid sigma-P

* The FDM is beneficial for coupling the dynamical core with existing physics packages. Since most of existing physics packages are generally based on FDM formulation in the vertical discretization, easy accessibility can be guaranteed.

Temporal discretization: split-explicit RK3

Governing equations:

Flux-type non-hydrostatic

Horizontal diffusion:

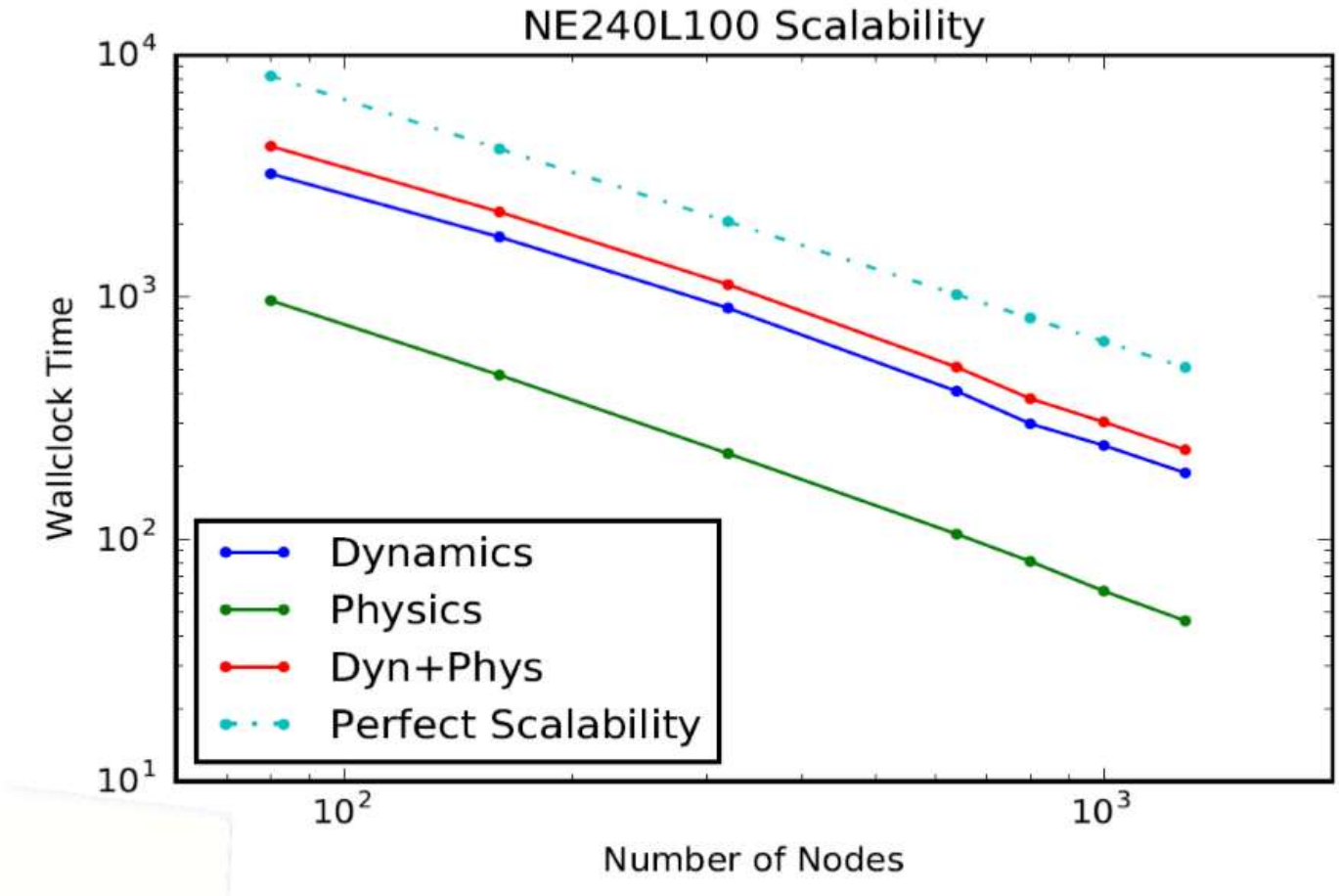
4^{th} order time-split explicit diffusion

Advantages of the cubed sphere: avoid polar singularity, scalability

Disadvantages: numerical noise along the edges, computational expensive

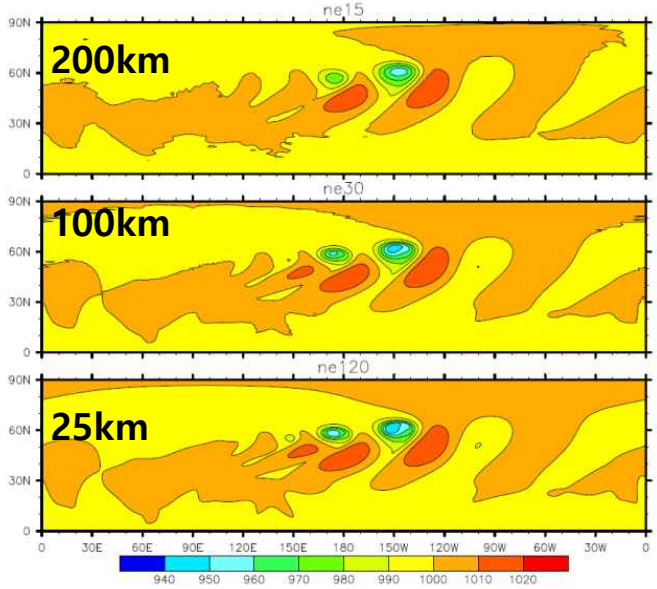
The results of KIM scalability test

- **Scalability**: the property of a system to handle a growing amount of work by adding resources to the system

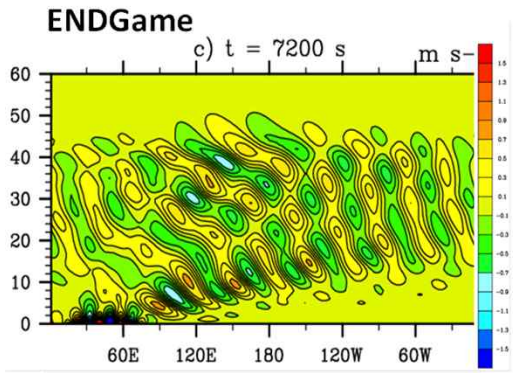


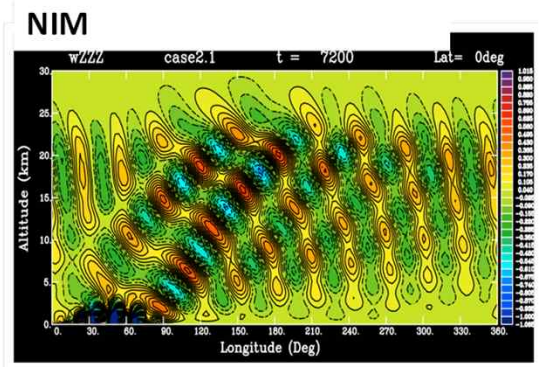
Development of Non-hydrostatic Dynamic

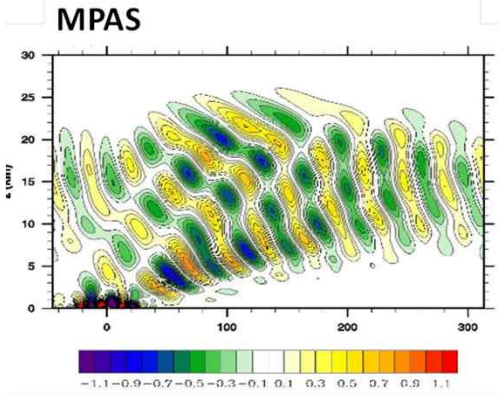
Baroclinic instability, Ps (9-days)

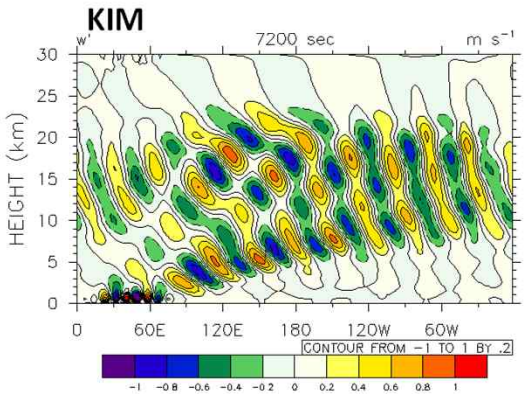


Schär mountain gravity wave in reduced Earth (X=500)



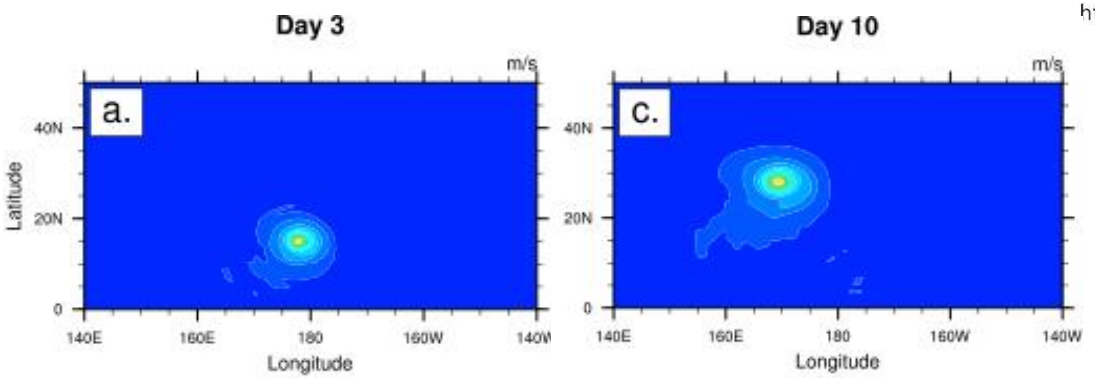






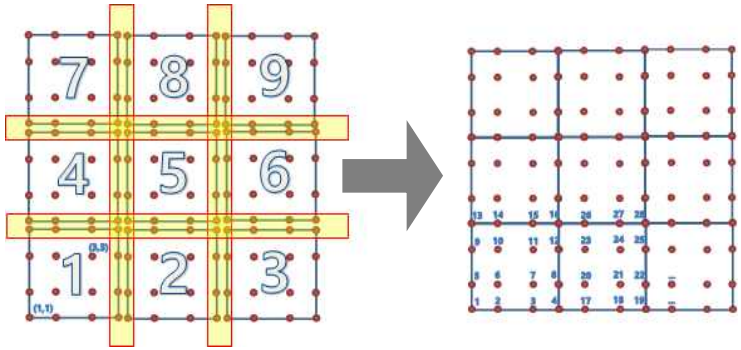
- **Idealized tropical cyclone with simplified physical forcings**

https://www.earthsystemcog.org/projects/dcmip-2012/Test_Cases/results_by_



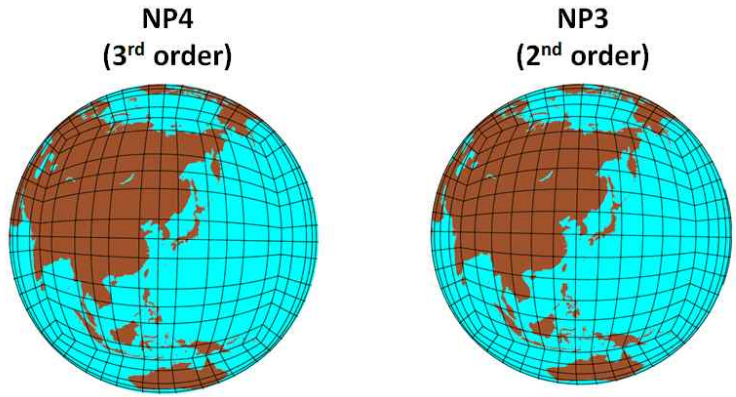
Development of Non-hydrostatic Dynamic

- **New grid system**

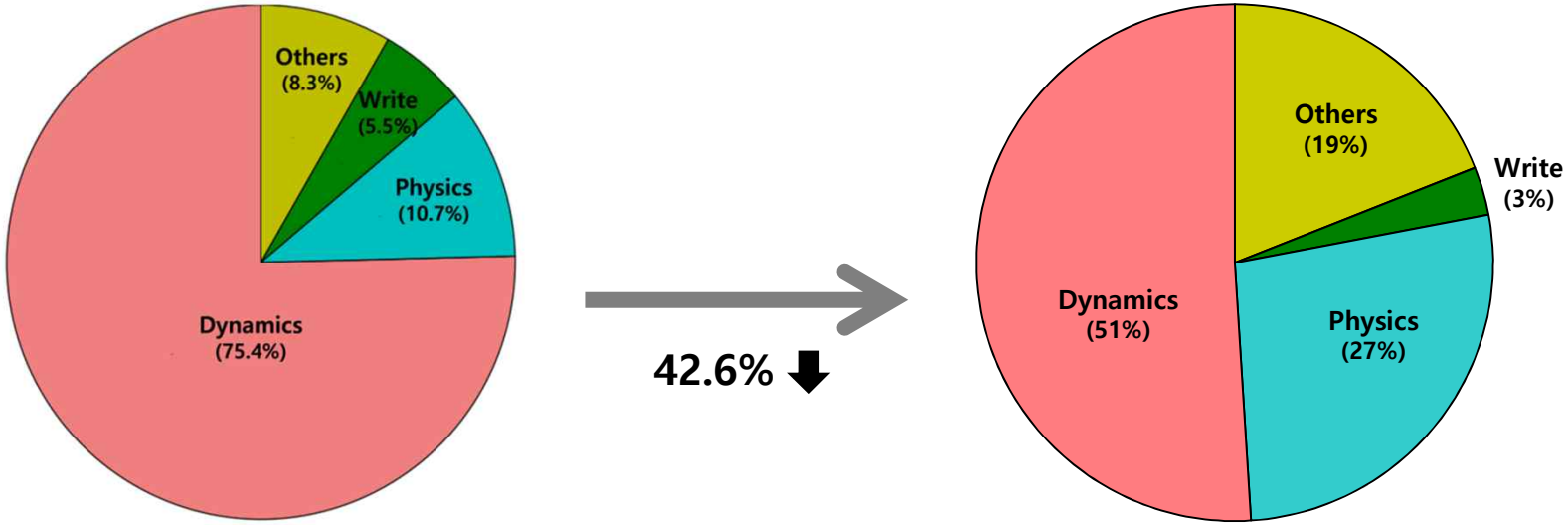


EP UP

- **Lower order basis function and diffusion** (larger time-step size)



- **Improvement of computational efficiency**

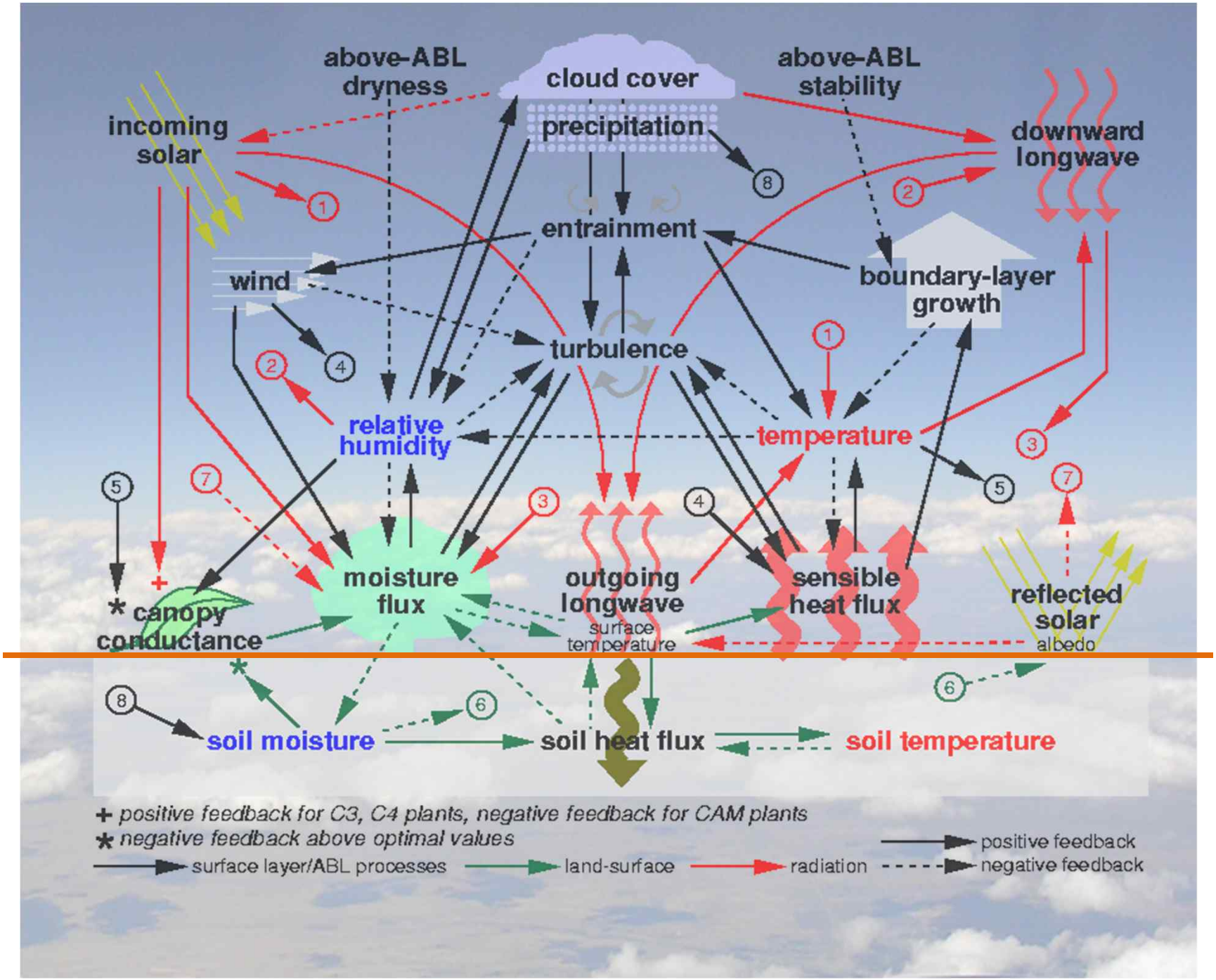


DYN/PHY = 7.1 **DYN/PHY = 1.9**

② Physics

Representing **change of atmospheric thermodynamic status**
e.g. air temperature, humidity, precipitation (diabatic processes)

→ net energy source or sink to air: causes of weather phenomenon


above-ABL dryness
cloud cover
above-ABL stability
incoming solar
precipitation
downward longwave
entrainment
wind
boundary-layer growth
turbulence
relative humidity
temperature
moisture flux
outgoing longwave
surface temperature
sensible heat flux
reflected solar
albedo
canopy conductance
soil moisture
soil heat flux
soil temperature
+ positive feedback for C3, C4 plants, negative feedback for CAM plants
* negative feedback above optimal values
surface layer/ABL processes
land-surface
radiation
positive feedback
negative feedback

Physics

	Scheme	Updated	Reference
Radiation	Revised RAD (RRTMK)	• unified RRTMG • reduced MCICA • updated ancillaries (aerosol, GMAO ozone, reflectivity, emissivity, snow albedo) • Improved two-stream approximation for shortwave radiation • Scale-awareness for sub-grid hydrometeors	Iacono et al. 2008 **Beak 2017**
Land surface	Revised LSM	• 3-layer sea-ice model • frozen processes (z0, conductivity over snow cover, flux over sea-ice) • USGS to IGBP for land data • soil moisture initialization • consistent diffusivity in LSM and RAD • Heterogeneous land-surface parametrization • Roughness length considering snow	Ek et al. 2003 **Koo et al. 2016**
Ocean surface layer	Diurnal SST OSH	• SST warming effect • Considering salinity effect	Kim and Hong 2010 **Lee and Hong 2017**
Boundary layer	Scale-aware non-local PBL	• top-down mixing • updated background diffusion & heating rate • minimum Richardson number changed • scale-aware (ShingHong PBL) • Considering dissipative heating	Hong et al. 2006 **Shin and Hong 2015** **Lee et al. 2016**
Gravity wave drag	Sub-grid orographic GWD	• flow blocking drag • orographic anisotropy • updated efficiency/intermittency factor	Hong et al., 2008 **Choi and Hong 2015**
	Non-orographic GWD	• Source-based spectral non-orographic GWD	**Choi et al. 2017**
Deep convection	Scale-aware mass-flux CPS	• revised auto-conversion & entrainment rate • moisture-based trigger threshold • Scale-aware / aerosol-aware	Han and Pan 2011 Lim et al. 2014 **Han et al. 2016** **Kwon and Hong 2017**
Shallow convection	Adjustment SCV	• improved eddy diffusivity profile (2.5) • Considering diffusion of cloud water contents	Hong et al. 2013
Microphysics	WSM5 MPS	• effective radius	**Hong et al. 2004** **Bae et al. 2016**
Cloudiness	Prognostic CLD	• revised CPS condensate • consistency (cloud-MPS-CPS-RAD) • reduced high cloud fraction at high latitude	**Park et al. 2016**

CPS (Cumulus Parameterization Scheme)

▪ The grid-size dependency is considered (scale-aware scheme)

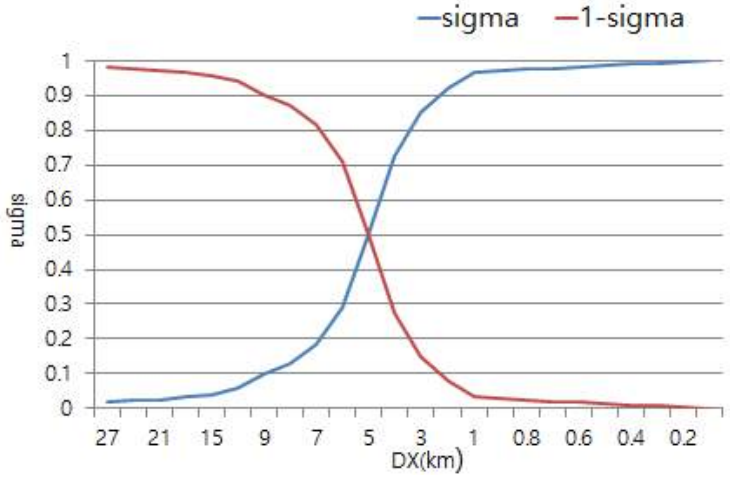
$$\sigma = 1 - \frac{1}{\pi}\left\{\tan^{-1}\left[\sigma_{con}\left(\Delta x - \Delta x_{5km}\right)\right] + \frac{\pi}{2}\right\}$$

$$\text{where } \sigma_{con} = \frac{\tan(0.4\pi)}{\Delta x_{5km} - \Delta x_{1km}}$$

Adapted from Hong and Pan (1998, MWR)

Δx	σ
9 km	0.1
5 km	0.5
1 km	0.9

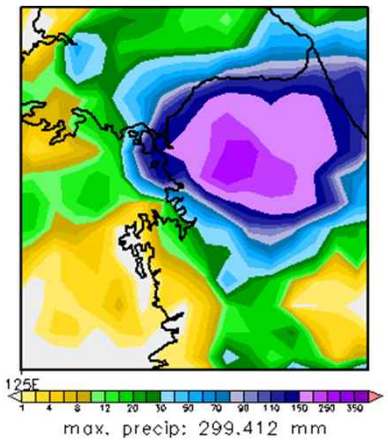
- **Cloud-base mass flux** [∝ $(1 - \sigma)^2$]
- **Convective Inhibition** (∝ (1-σ))
- **Moisture detrained to grid scale** (∝ σ)



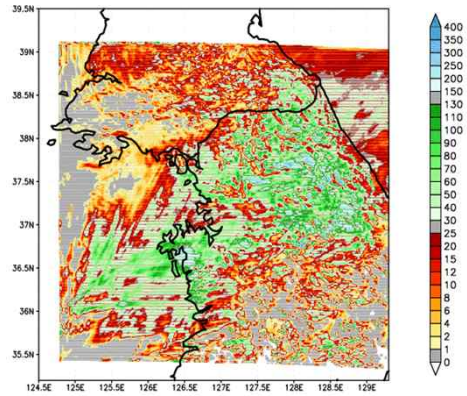
Kwon and Hong 2017

24-h accumulated precipitation

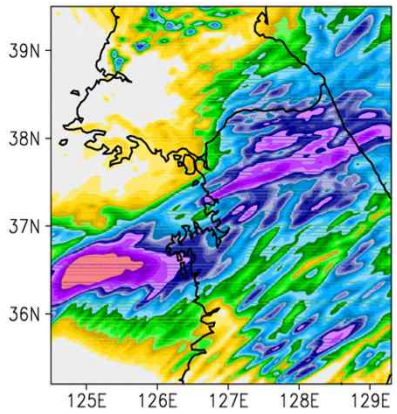
TMPA (OBS)



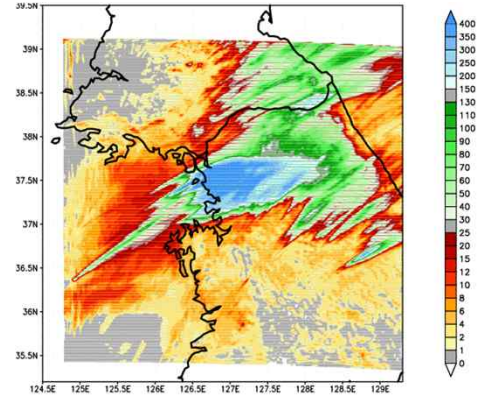
Original SAS in the domain with Δx = 3 km



No CPS in the domain with Δx = 3 km



Modified SAS in the domain with Δx = 3 km



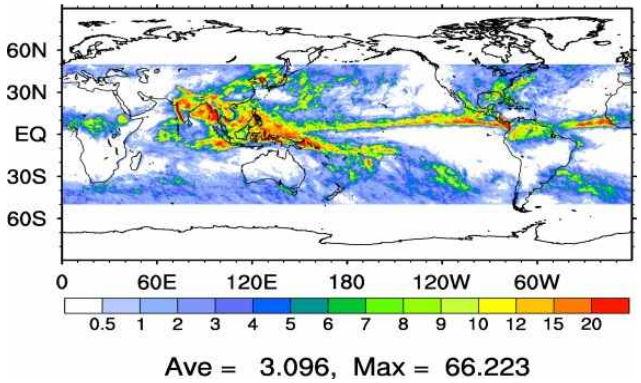
Evaporation over Ocean

- To apply the saturated vapor pressure for seawater over ocean

  Global sea surface salinity ~ 32-38 ‰

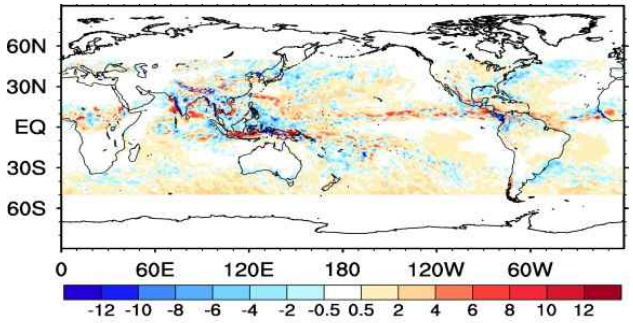
Improvement of light rain forecasting

TMPA



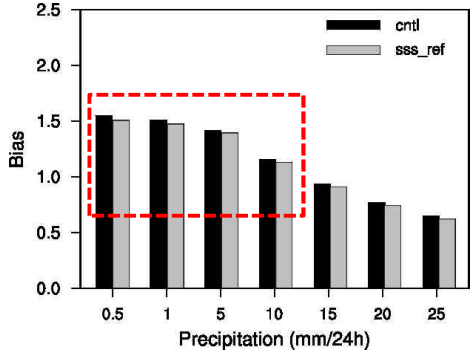
Ave = 3.096, Max = 66.223

Prcp Bias (CTL – TMPA)

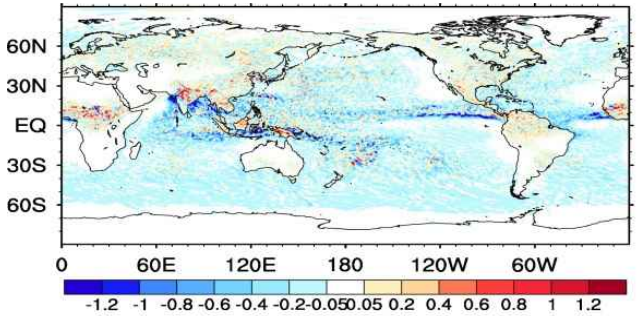


Ave = 0.244, Max = 60.354

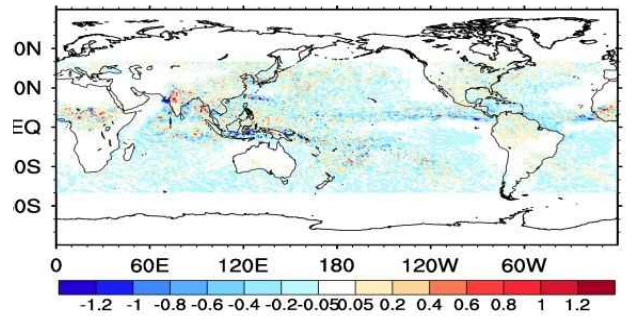
BIAS for Jul 2013



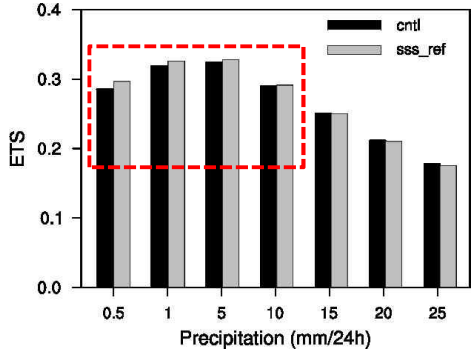
Prcp Bias Diff (SSS – CTL)



Prcp RMSE Diff (SSS – CTL)



ETS for Jul 2013



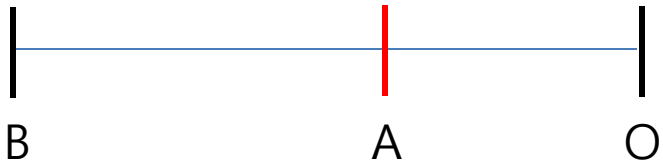
③ Data Assimilation

Describe the current atmospheric status

- Observation data preprocessing
- Optimal combination of obs and model data

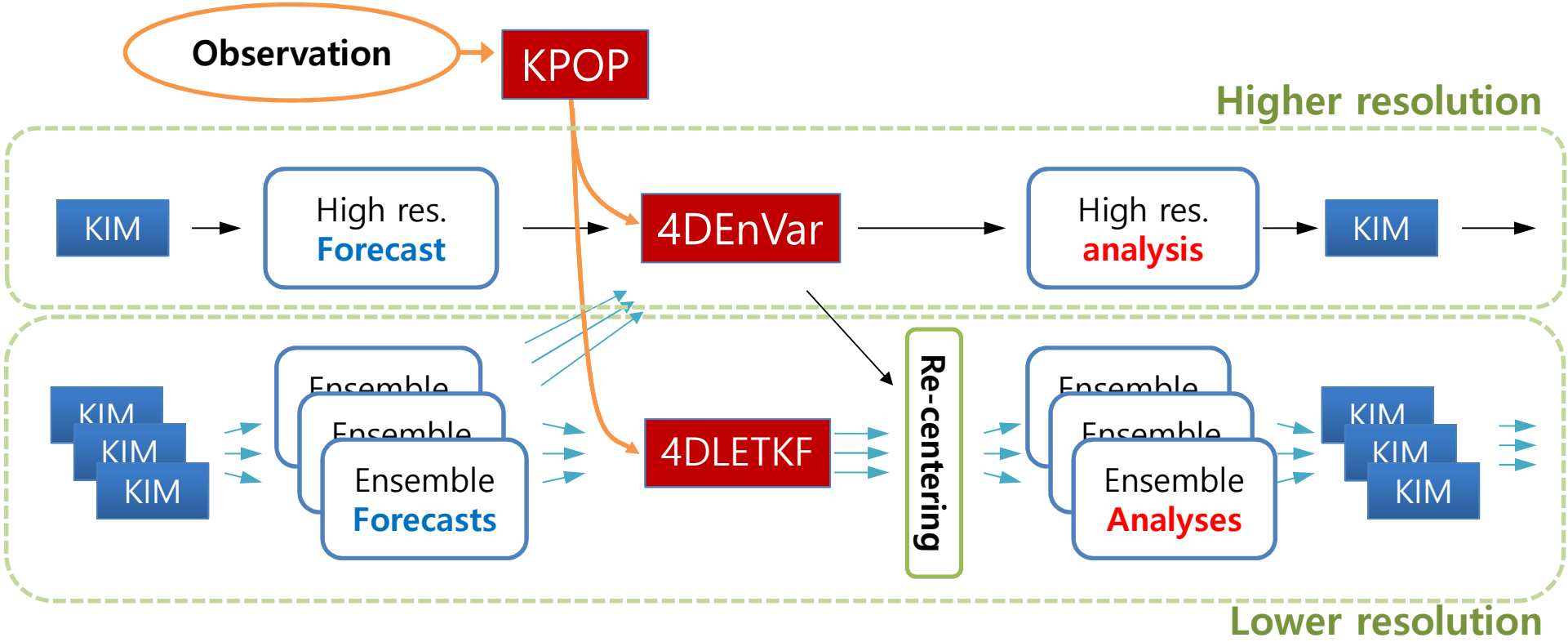
A = O x (1-Obs error) + B x (1-Model error)

- A: analysis field
- O: observation
- B: previous 6 hr forecast field



Hybrid-4DEnVar (LETKF + 3DVar)

- **Hybrid-4DEnVar Forecast System with KIM, KPOP, and 4DLETKF**



KPOP: KIM Package for Observation Processing
KIM resolution (~ 12 km)
Ensemble resolution (~ 50 km), 50 members
Analysis resolution (~ 50 km)

Observation data used in UM & KIM DA system

Observation type		UM	KIM	Observation type		UM	KIM
1	**SONDE**	○	○	9	**IASI**	○	○
2	**SURFACE**	○	○	10	**CrIS**	○	○
3	**AIRCRAFT**	○	○	11	**ATMS**	○	○
4	**SCATWIND**	○	○	12	**AMV**	○	○
5	**HIRS**	×	×	13	**GPS-RO**	○	○
6	**AMSU-A**	○	○	14	**CSR**	○	○
7	**MHS**	○	○	15	**SSMIS**	×	×
8	**AIRS**	○	×	16	**TC bogus**	○	○

※ **KMA-UM : 19 types** (+ SEVIRI CSR, GOES CSR, AHI CSR, Ground-GNSS, MT-SAPHIR, GK-2A)

SCATWIND: Scatterometer wind

HIRS: High-resolution Infrared Radiation Sounder

AMSU-A: Advanced Microwave Sounding Unit-A

MHS: Microwave Humidity Sounder

AIRS: Atmospheric Infrared Sounder

IASI: Infrared Atmospheric Sounding Interferometer

CrIS: Cross-track Infared Sounder

ATMS: Advanced Technology Microwave Sounder

AMV: Atmospheric Motion Vector

GPS-RO: GPS Radio occultation

CSR: Clear Sky Radiance

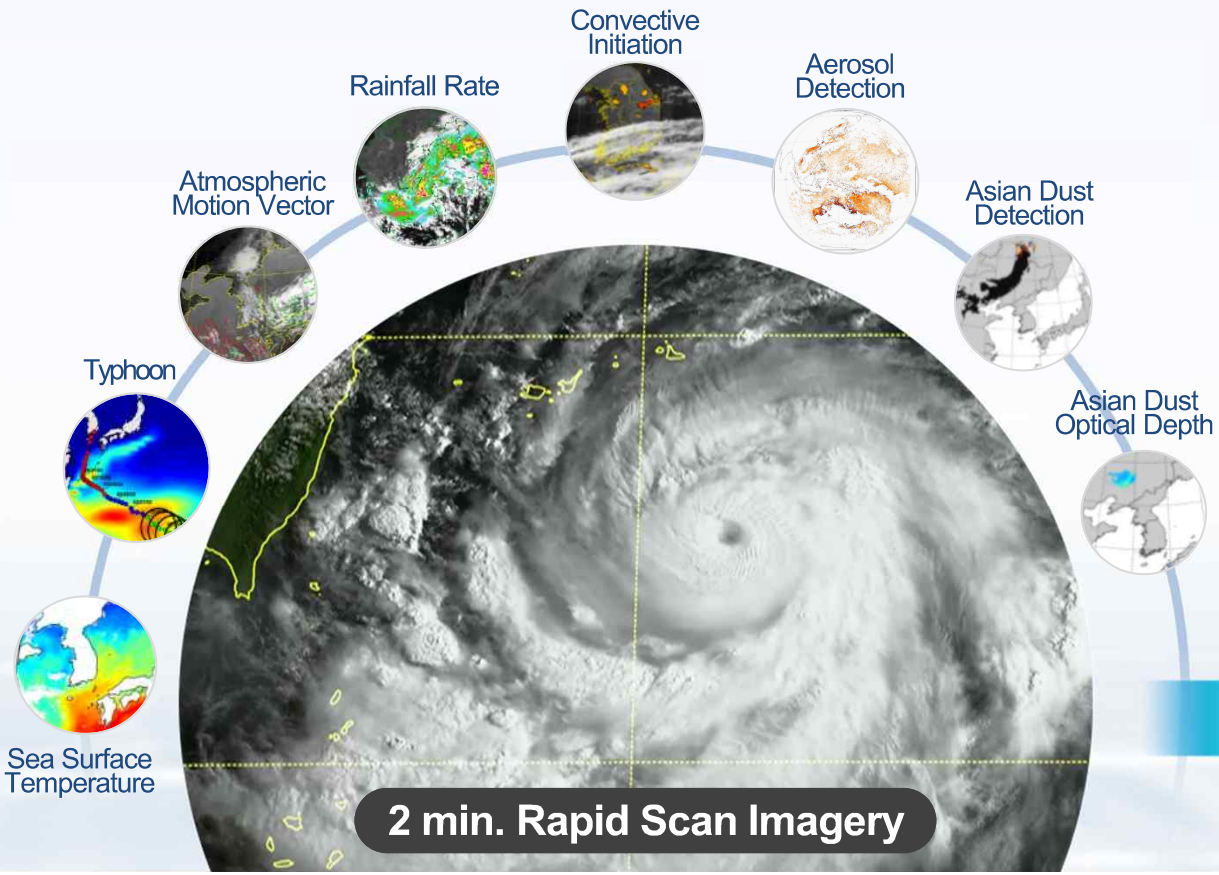
SSMIS: Special Sensor Microwave Imager Sounder

GK2A Satellite - Real-time Observation with 16 channels

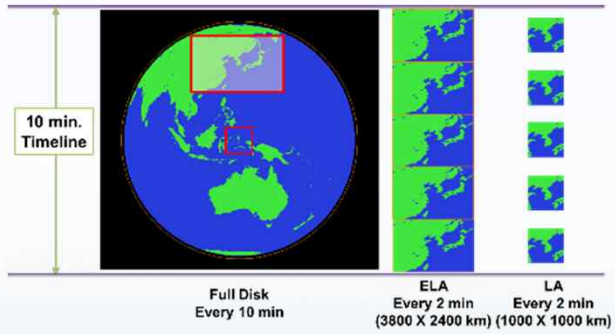
- Launched on Dec. 5, 2018 with **the World's 3rd Advanced Meteorological Imager**
- Produces **10 min. timeline** observation, **2 min. rapid scan imagery** for Target Area

Meteorological Monitoring and Analysis

Meteorological Products (52 types)



GK2A
(Dec. 2018~)
16 channels



Early Detection of Severe Weather

Observation data used in UM & KIM DA system

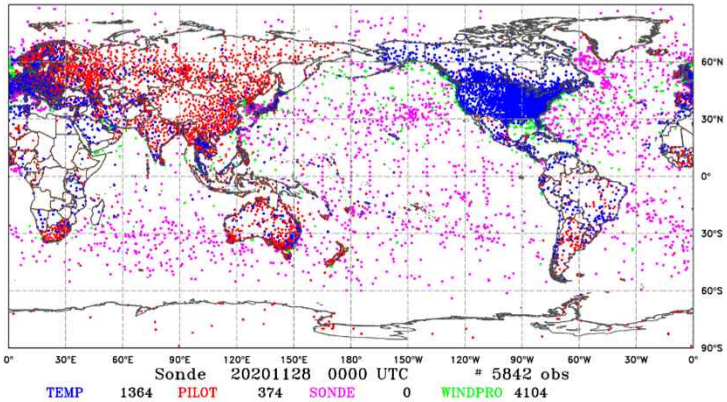
IN

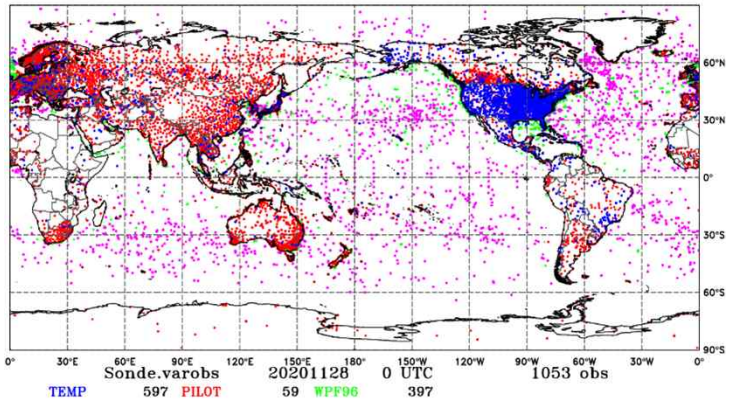
Used

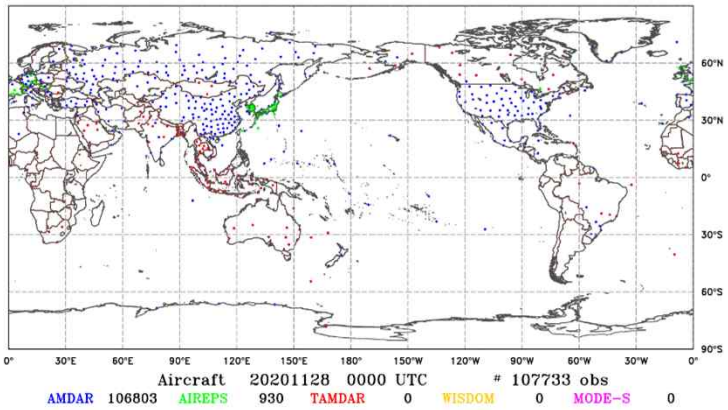
Surface

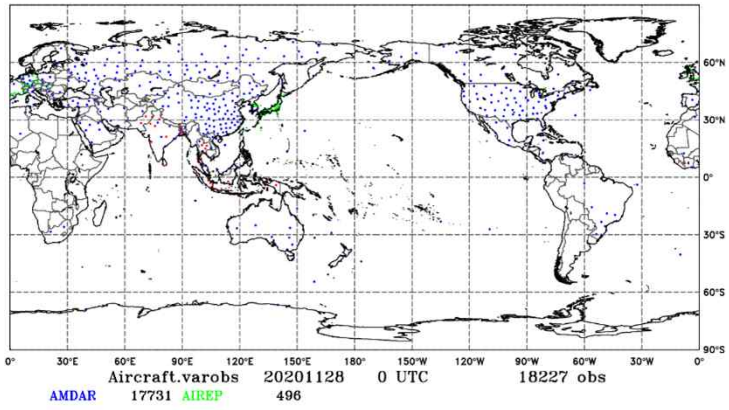
Sonde

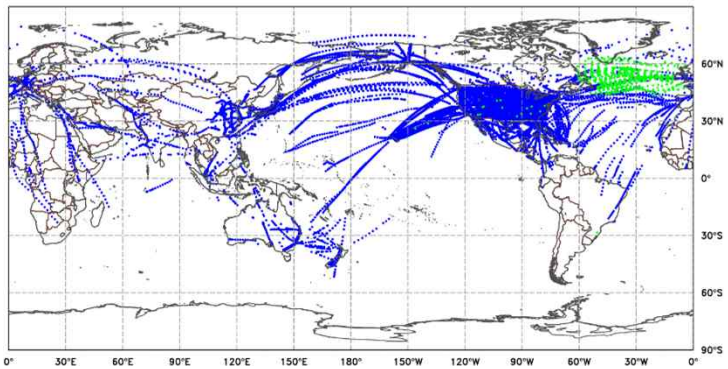
Aircraft

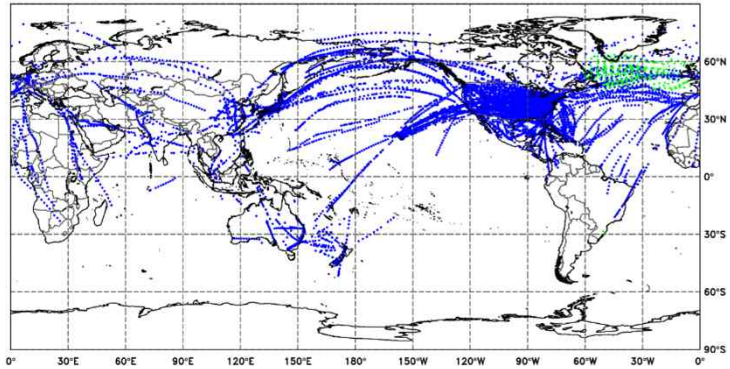










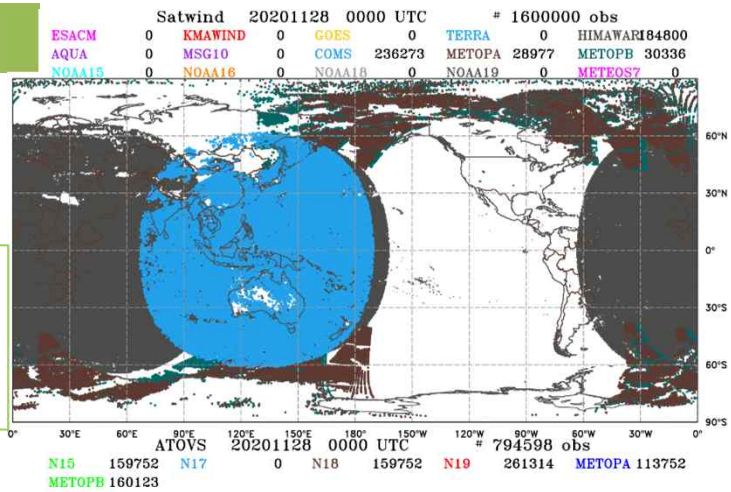


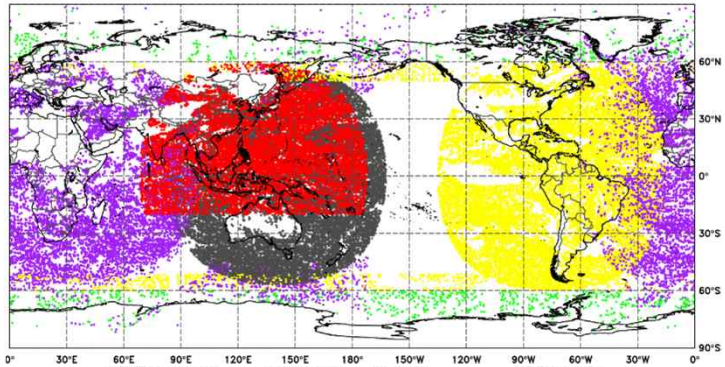
Observation data used in UM & KIM DA system

IN

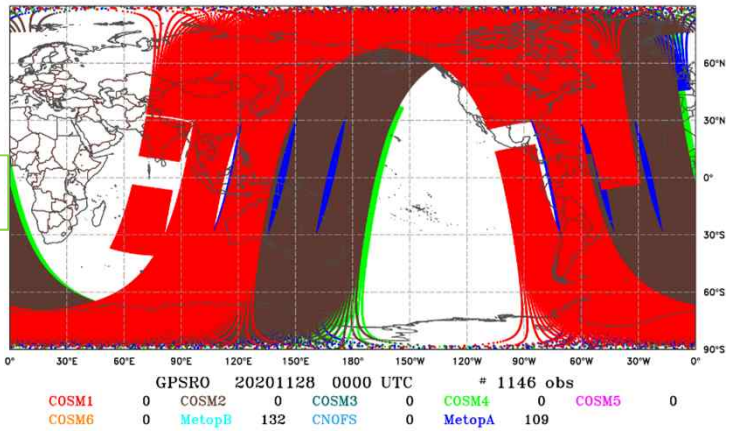
Used

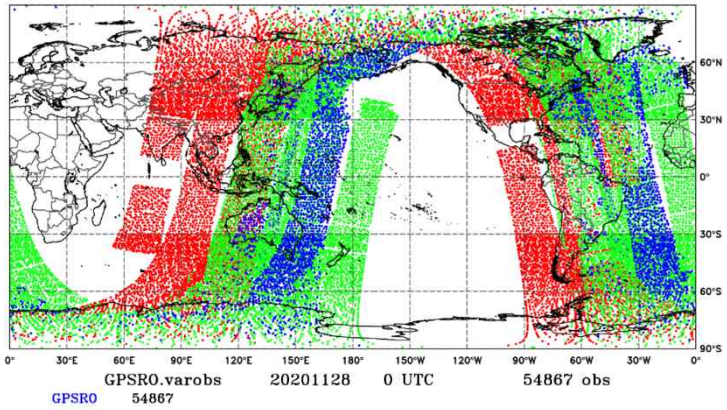
Geo-Stationary Orbit

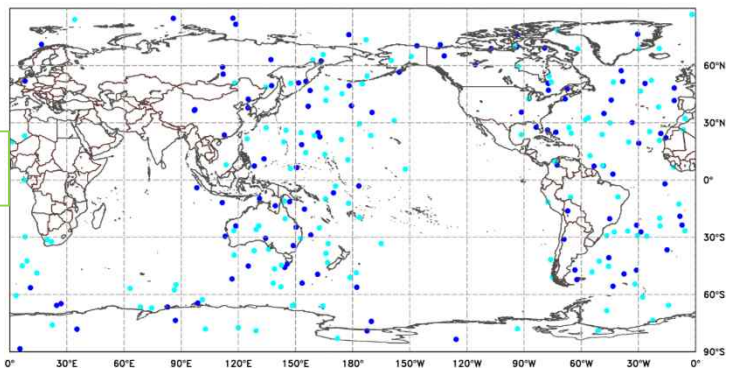


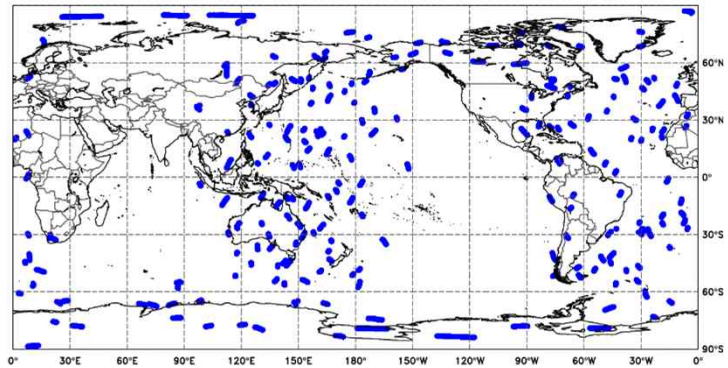


Earth Orbit





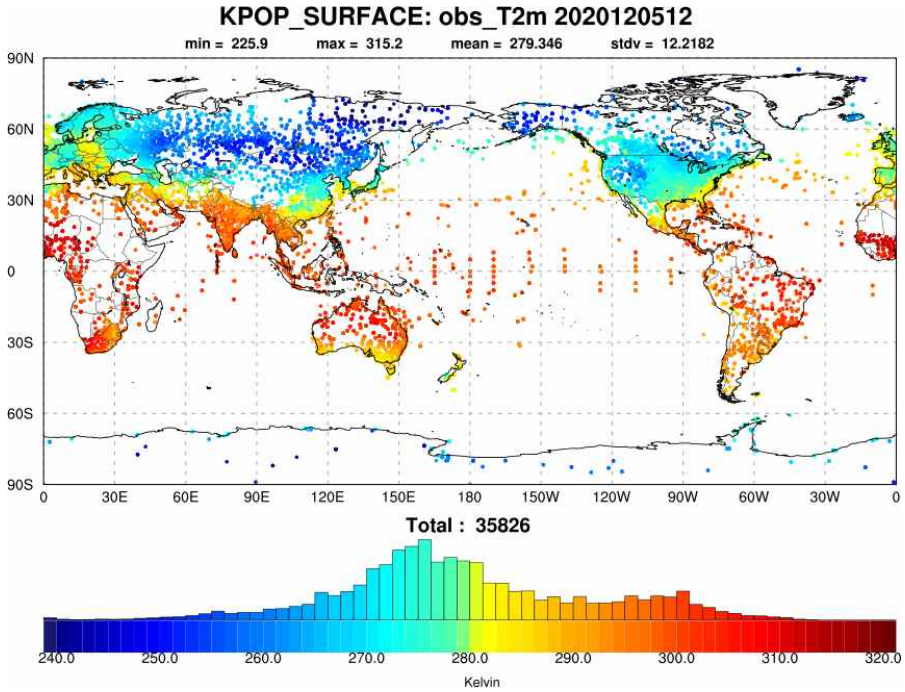




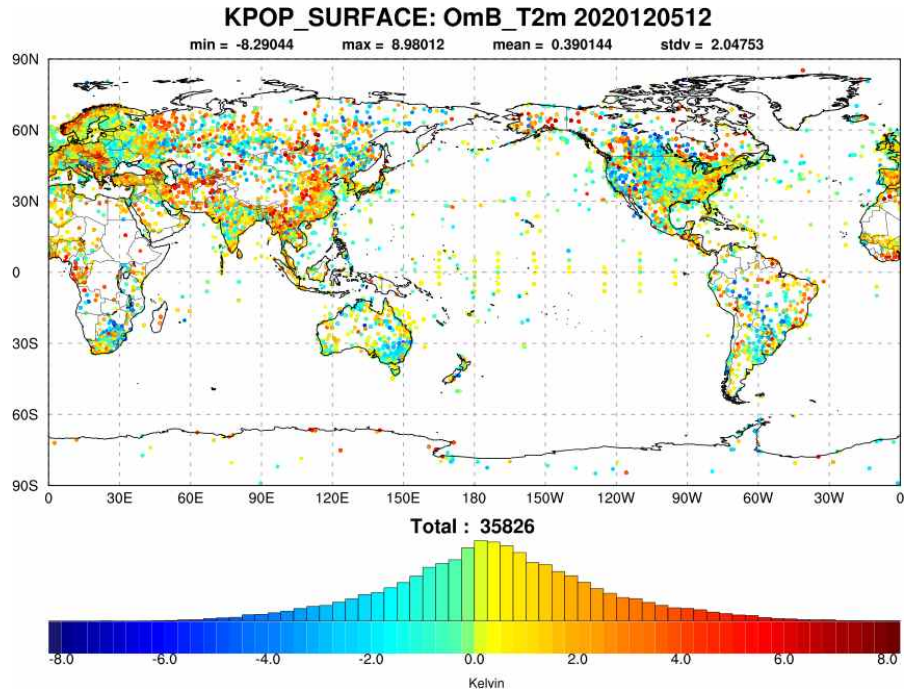
GNSS-RO

Observation data used in UM & KIM DA system

OBS



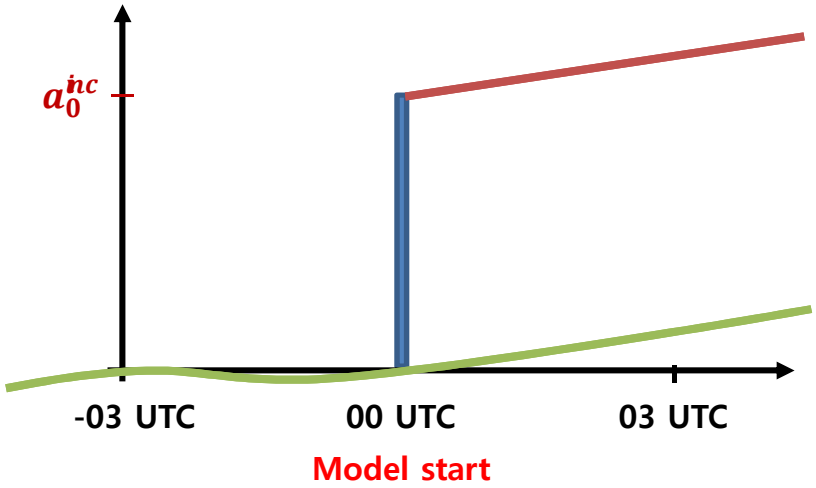
O-B



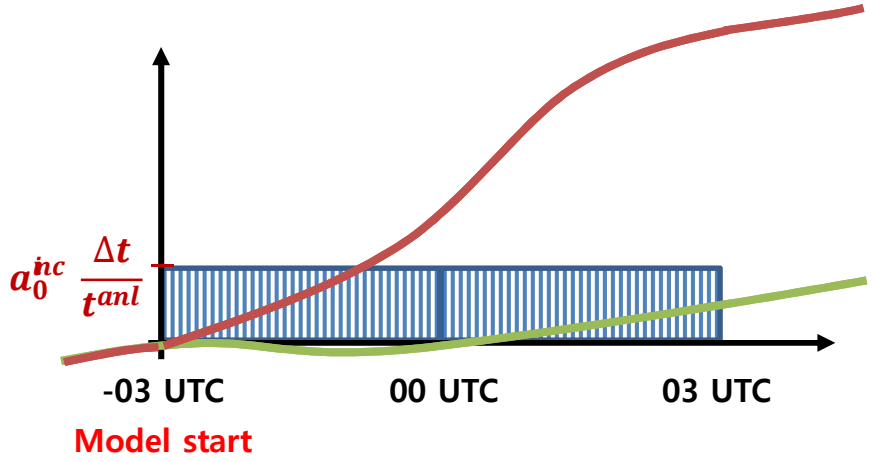
Incremental Analysis Update (IAU)

Analysis increment generates inconsistency and imbalance in the model.
The IAU introduces the increment gradually into the model to solve it.

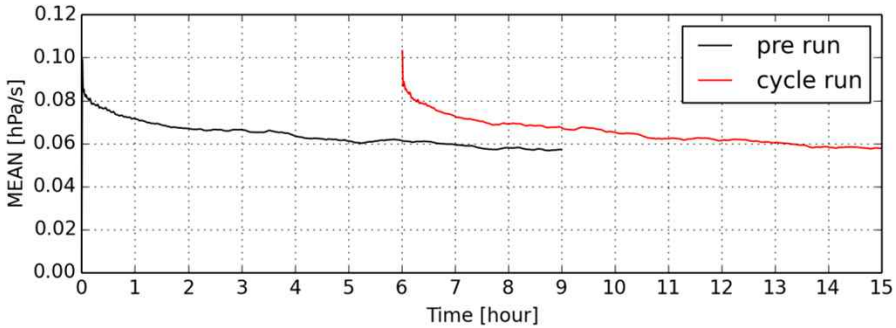
Conventional Analysis Update

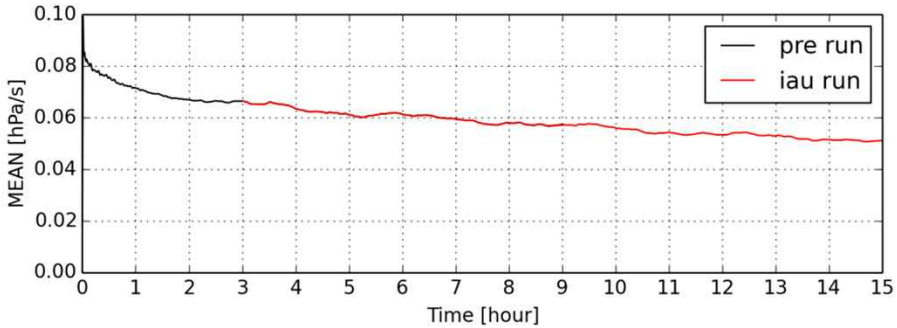


Incremental Analysis Update



Evaluation by time tendency of surface pressure

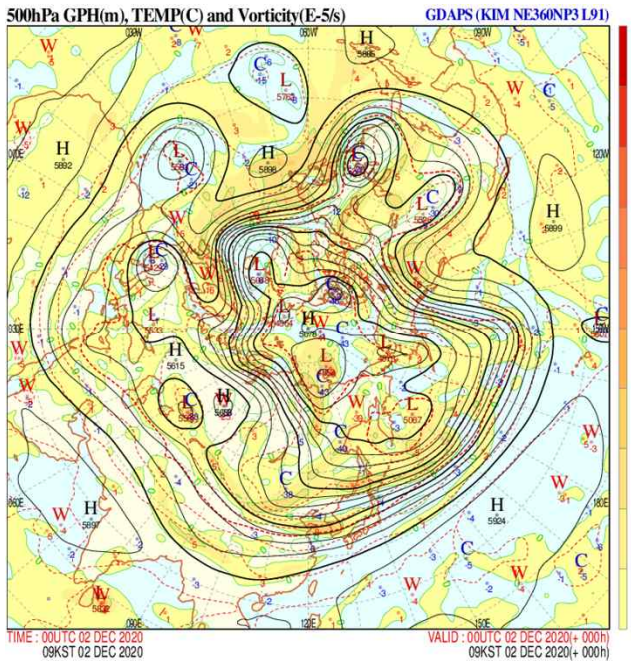




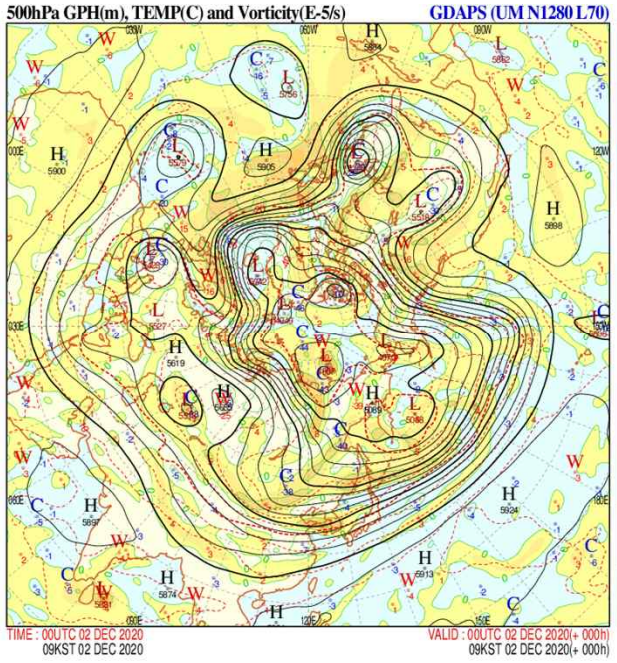
Pre-run
Model run after analysis update

- Almost identical to pre-run

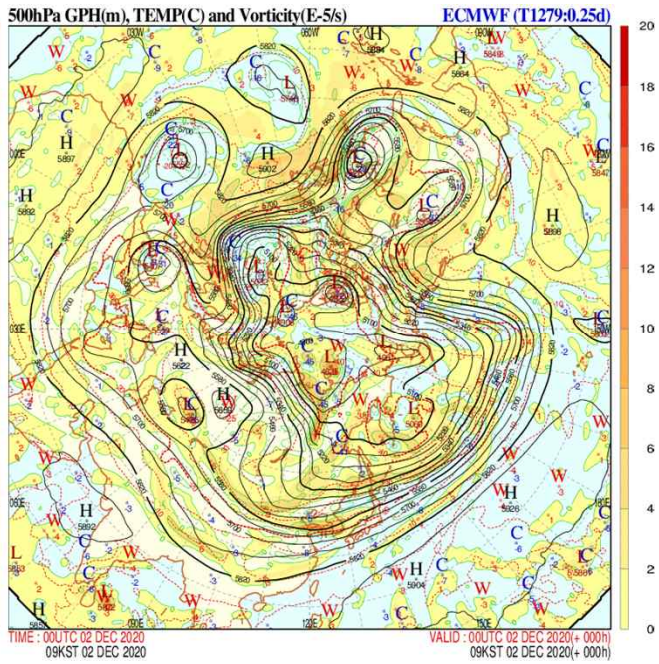
Analysis of 500hPa geopotential height
(2020.12.02.00UTC)



KIM

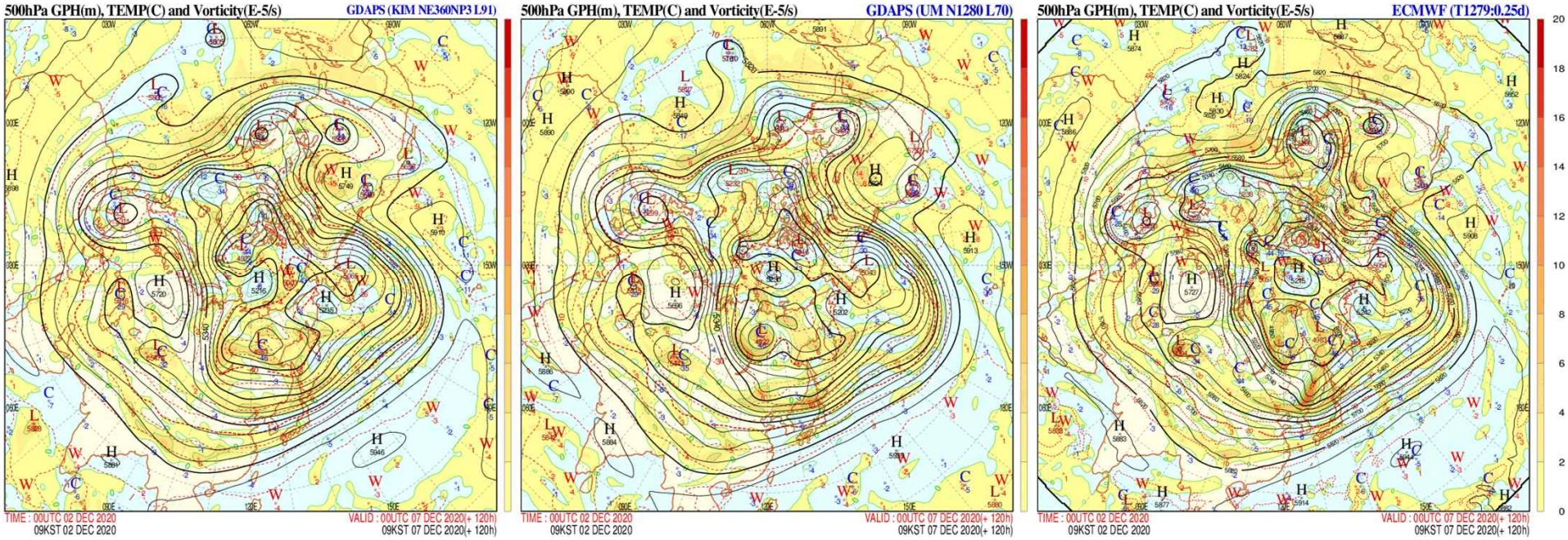


UM



IFS
(ECMWF)

5 days forecast of 500hPa geopotential height
(2020.12.02.00UTC)



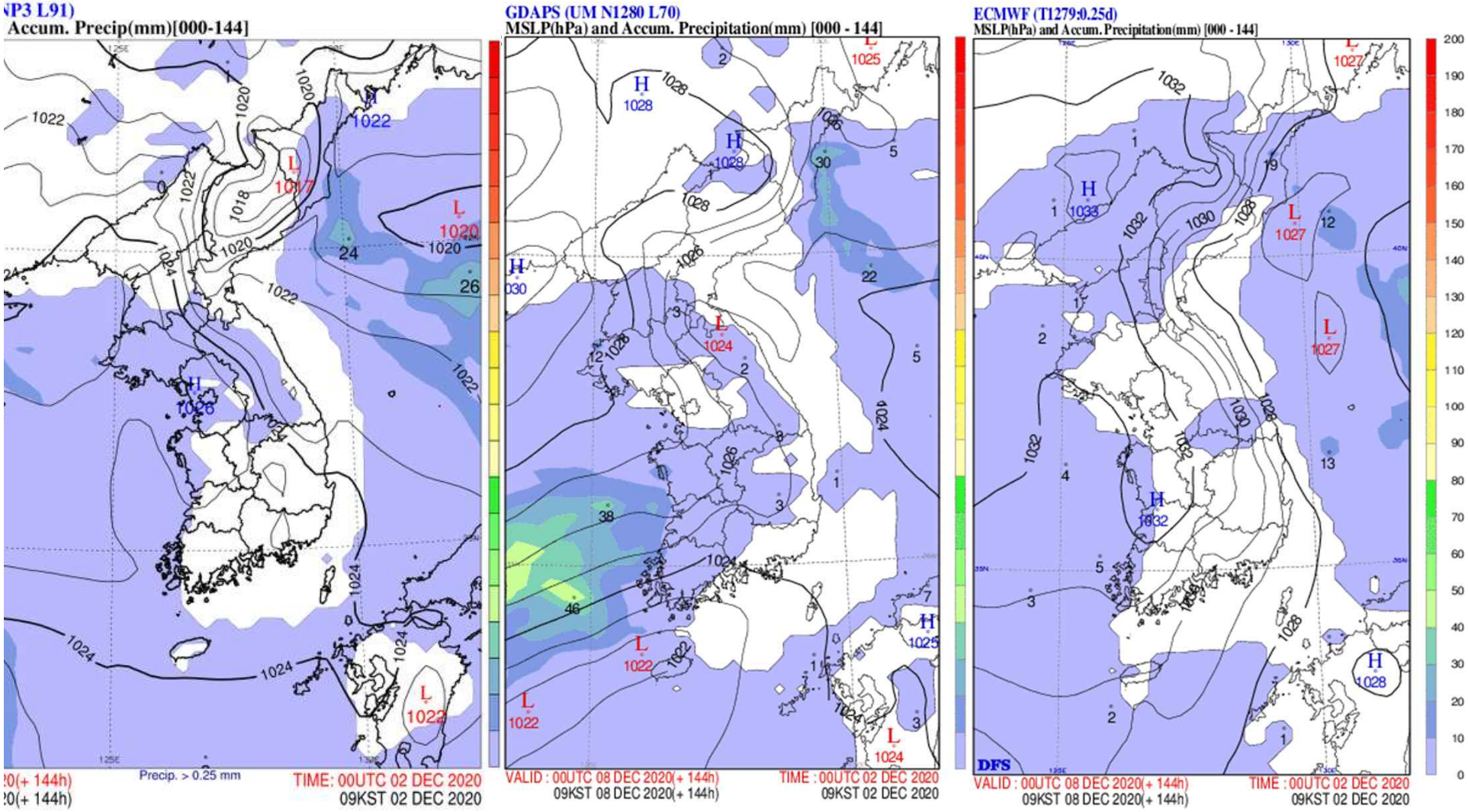
KIM

UM

IFS
(ECMWF)

Accumulated rainfall during 6 days forecast

(2020.12.02.00UTC)



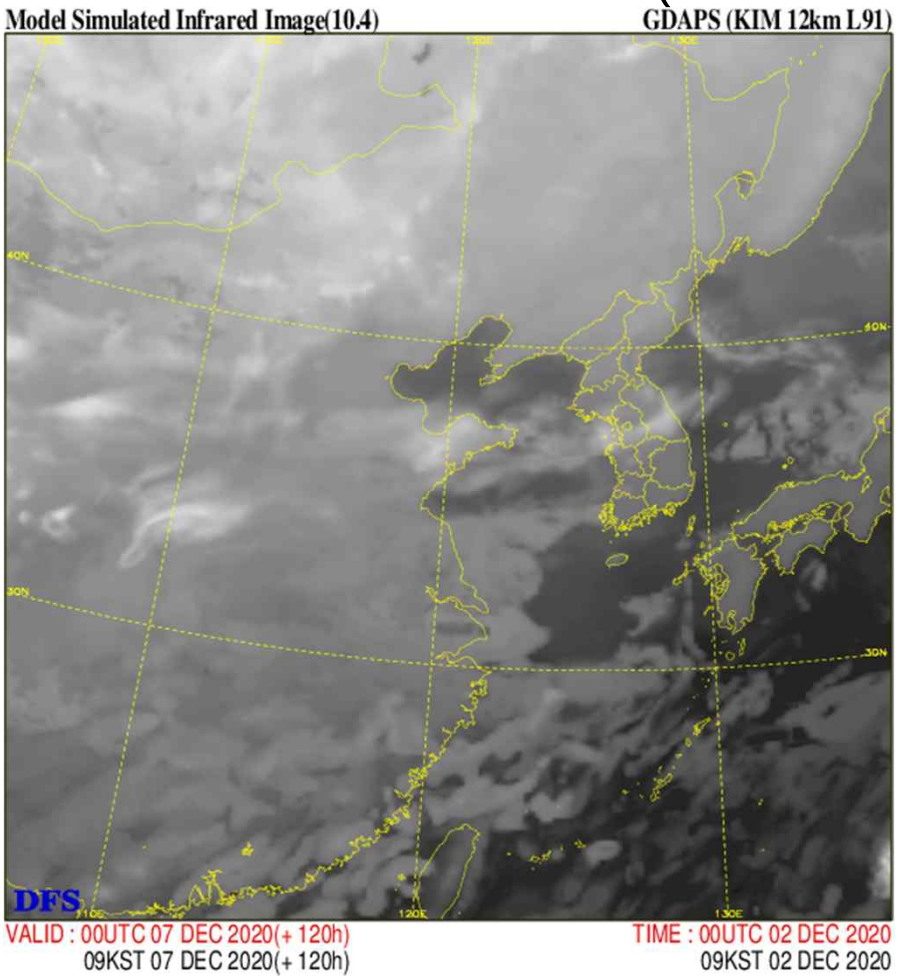
KIM

UM

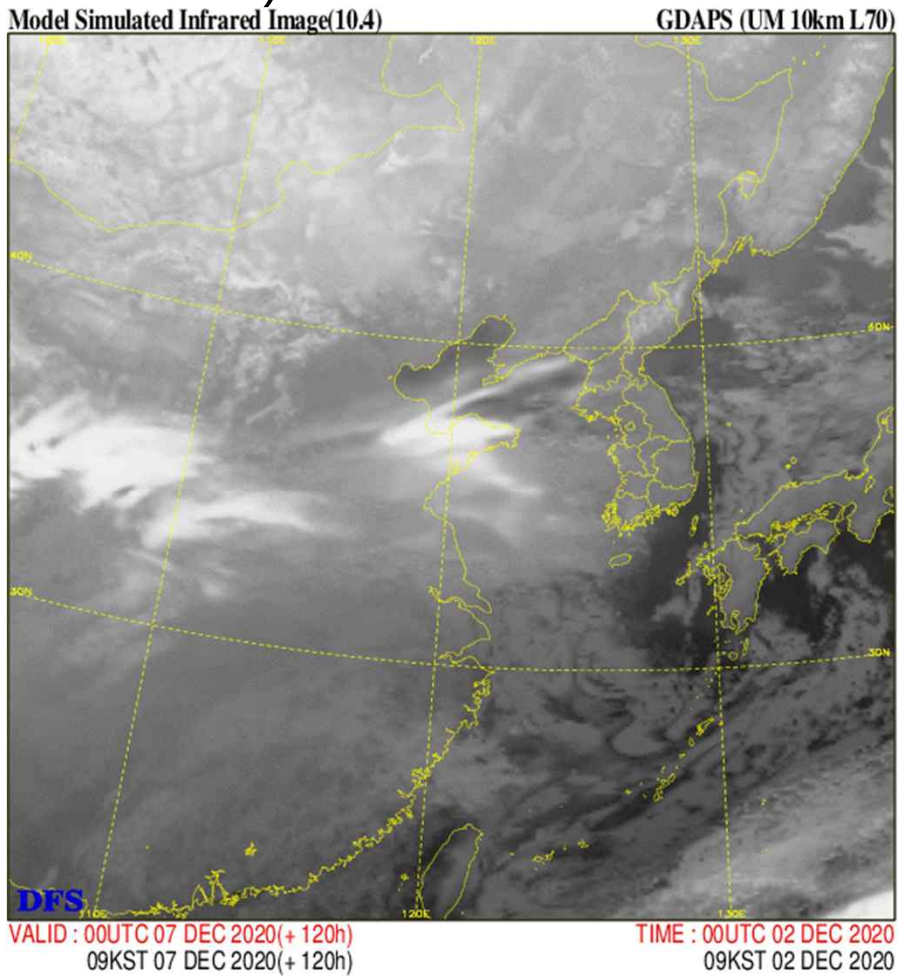
IFS
(ECMWF)

Model simulated infrared images

(2020.12.02.00UTC)



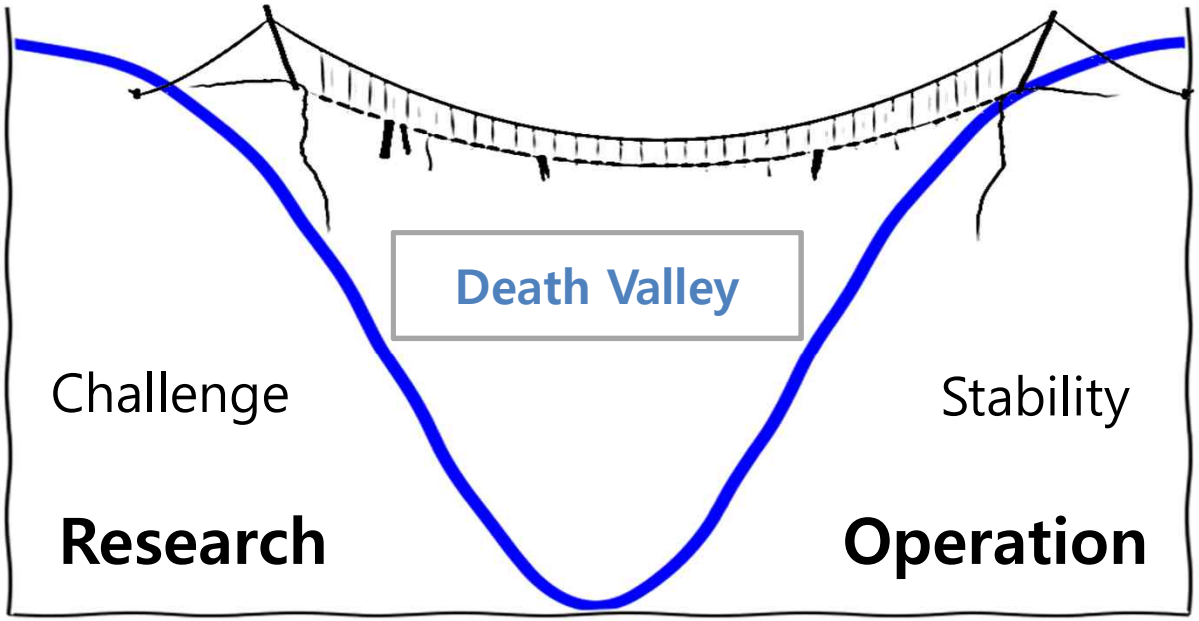
KIM



UM

④ Toward operational system & upgrade

R2O (Research to Operation)



Specific Diagnosis
and rapid update

High level
operation experience

Computational costs

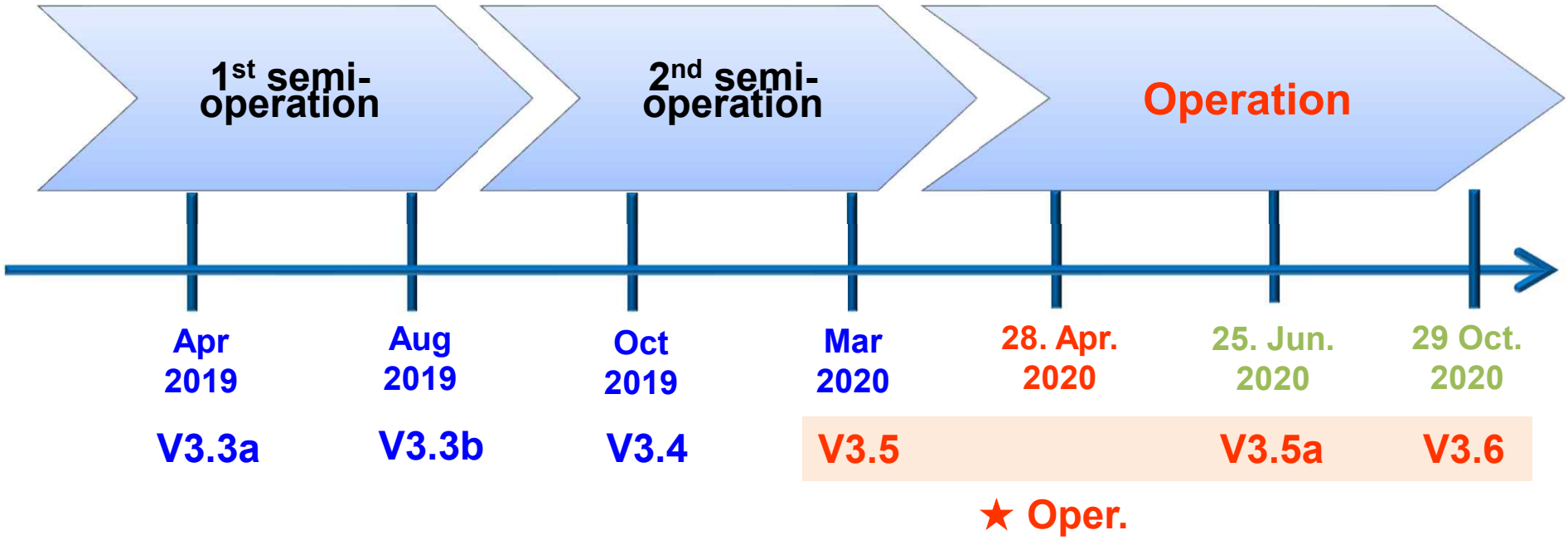
Target: 1 hr 30min in 10 days forecast for operational system

Model Version	Number of Node in 4th Supercomputer of KMA		Improvement
	820 node	1,000 node	
v3.3a	3 hr. 02 min.	2 hr. 10 min.	-
v3.3b	2 hr. 13 min.	-	Improvement of input/output system
v3.4	1 hr. 59 min.	-	Optimization of Dynamics

5th Supercomputer of KMA : within 1 hr. 30 min.

** 1 node = 24 cores*

KIM version update history



KIM main improvement (v3.3a → v3.4)

	v3.3a → v3.3b	v3.3b → v3.4
Preprocess of observation	• All sky radiance • Change of RTTOV input humidity variable • Add of South America' Aircraft • Improvement of IASI bias correction	• Improvement of GPSRO process • Thinning, QC modification of micro-channel • Modification fo IASI, CrIS, AMV, AMSR2
DA	• Use of mixing ratio for humidity • Application of TC bogussing	• Different Ensemble ratio • Modification of upper level's ensemble ratio • Add AMSR2
Model	• Improvement of radiance (zenith angle, aerosol, dust) • Improvement of surface process (emission ratio, roughness length, …) • Ocean mixed layer: remove initial SST	• Optimization of parallelization in physics • Improvement of surface process • Optimization of deep convection

KIM main improvement (v3.4 → v3.5a)

	v3.4 → v3.5	v3.5 (oper) → v3.5a
Preprocess of observation	• High resolution sonde • Improvement of wind profiler, buoy, aircraft process • Add of FY-3C MWHS2 • QC of IAIS, CrIS • Modification of AMSR2 observational error	-
DA	• New background error covariance	-
Model	• Application of new terrain data • Application of dynamic Hyper-Viscosity • Modification of Physics process • Improvement of ancillary data for sub-grid mountain drag	• Ocean mixed layer data • Optimization of Cumulus parameterization • Bug fix in radiation (minor effect)
Ensemble	• Resolution : 50 → 32km	-

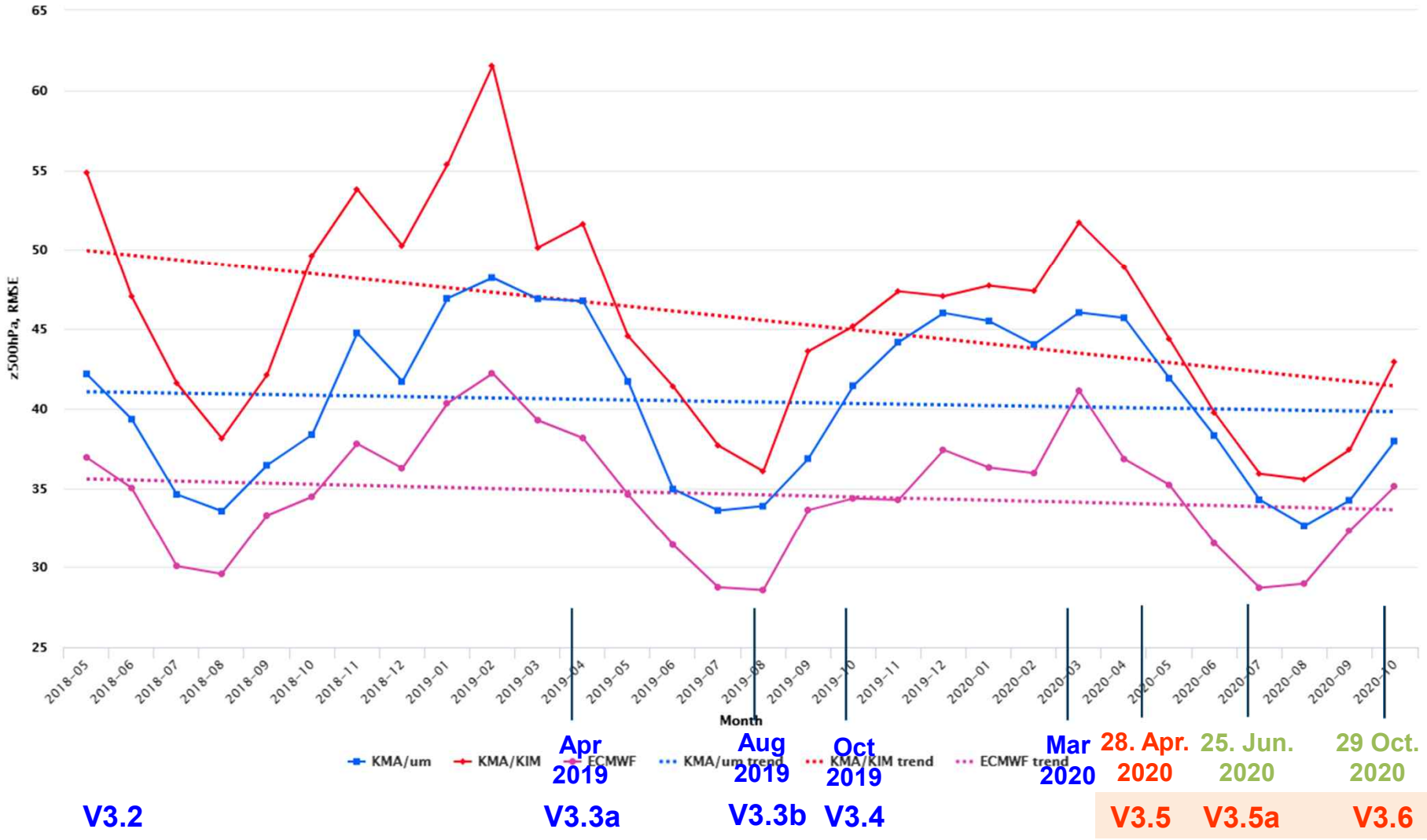
KIM main improvement (v3.5a → v3.6)

	v3.5a → v3.6	v3.6a (expecting ’21.1st quarter)
Preprocess of observation	• Downward sonde • GK2A AMV & CSR • New GNSS-RO / QC • Modification of AMV QC • MW static bias correction • Modification of Observation Error (AMSR2, AMV, GNSS-RO)	-
DA	• New background error covariance • Variational bias correction (ATMS, IASI, CrIS) • Inflation factor	-
Model	• Modification of Land surface process (inland lake)	-
Ensemble	• SST perturbation	-

III. Performance & Severe weather Cases

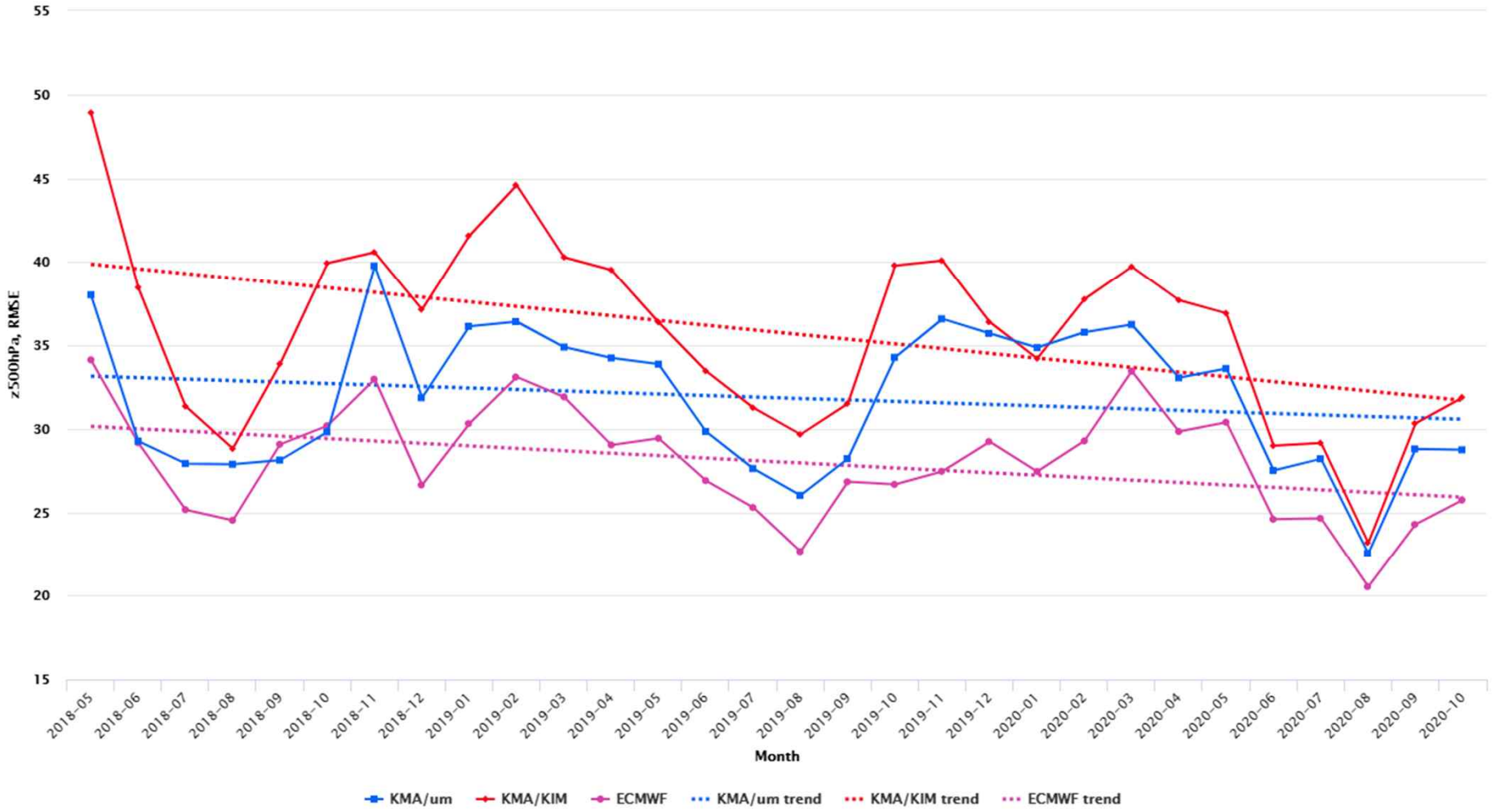
Comparison of Performance (North Hemisphere)

[Analysis verification] z500hPa 12UTC +120h ('18.05. ~ '20.10.)



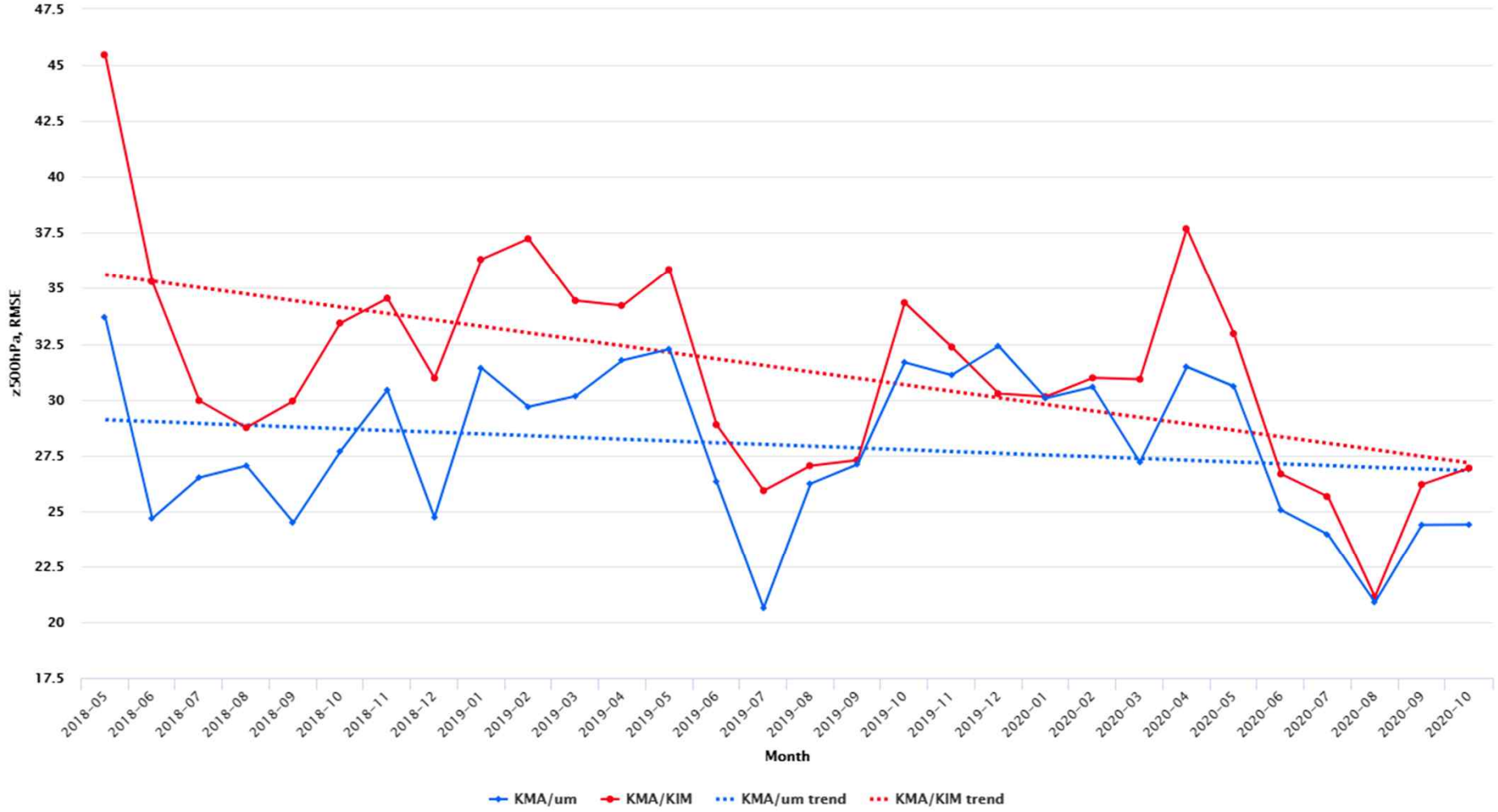
Comparison of Performance (Asia)

[Analysis verification] z500hPa 12UTC +120h ('18.05. ~ '20.10.)



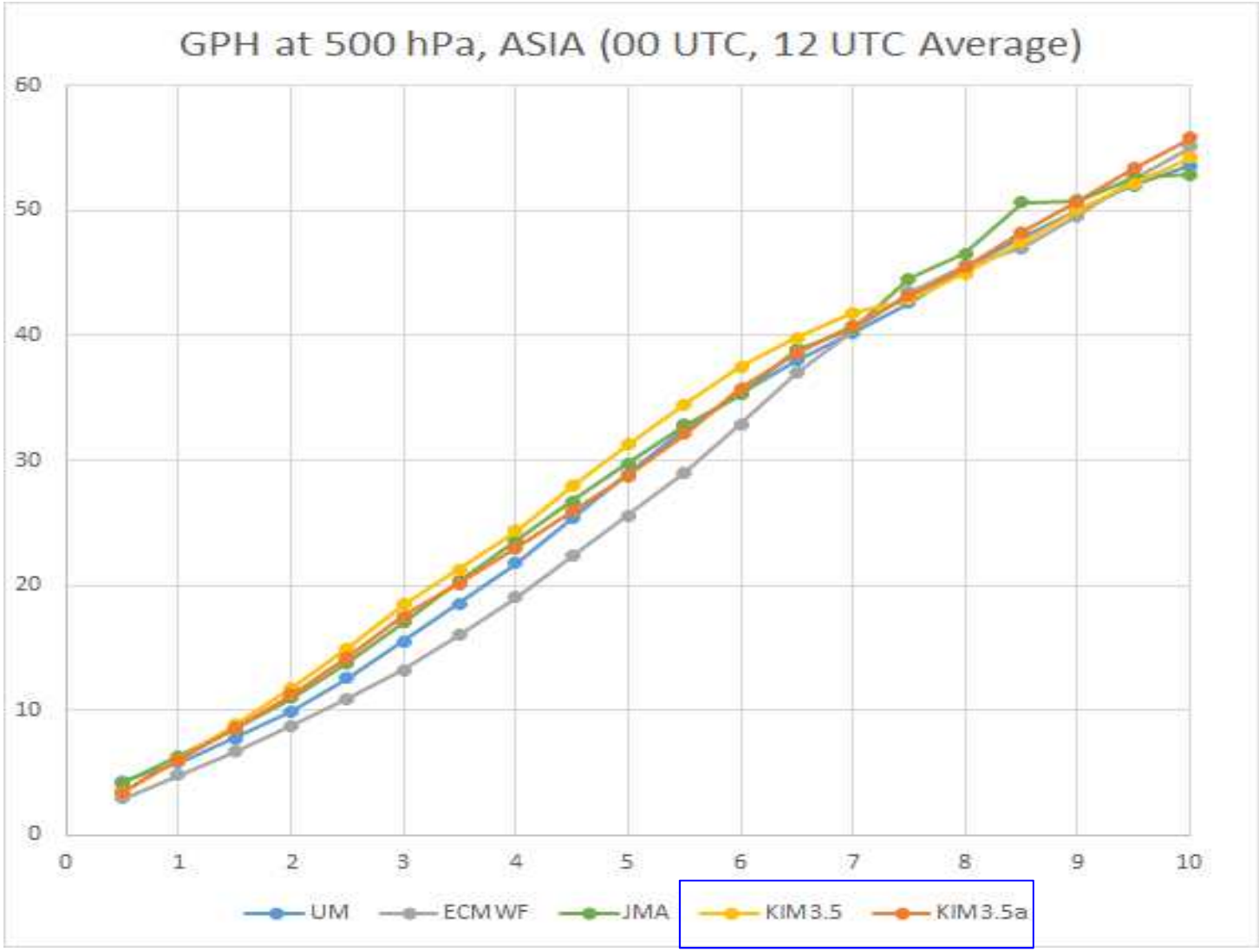
Comparison of Performance (East Asia)

[Analysis verification] z500hPa 12UTC +120h ('18.05. ~ '20.10.)



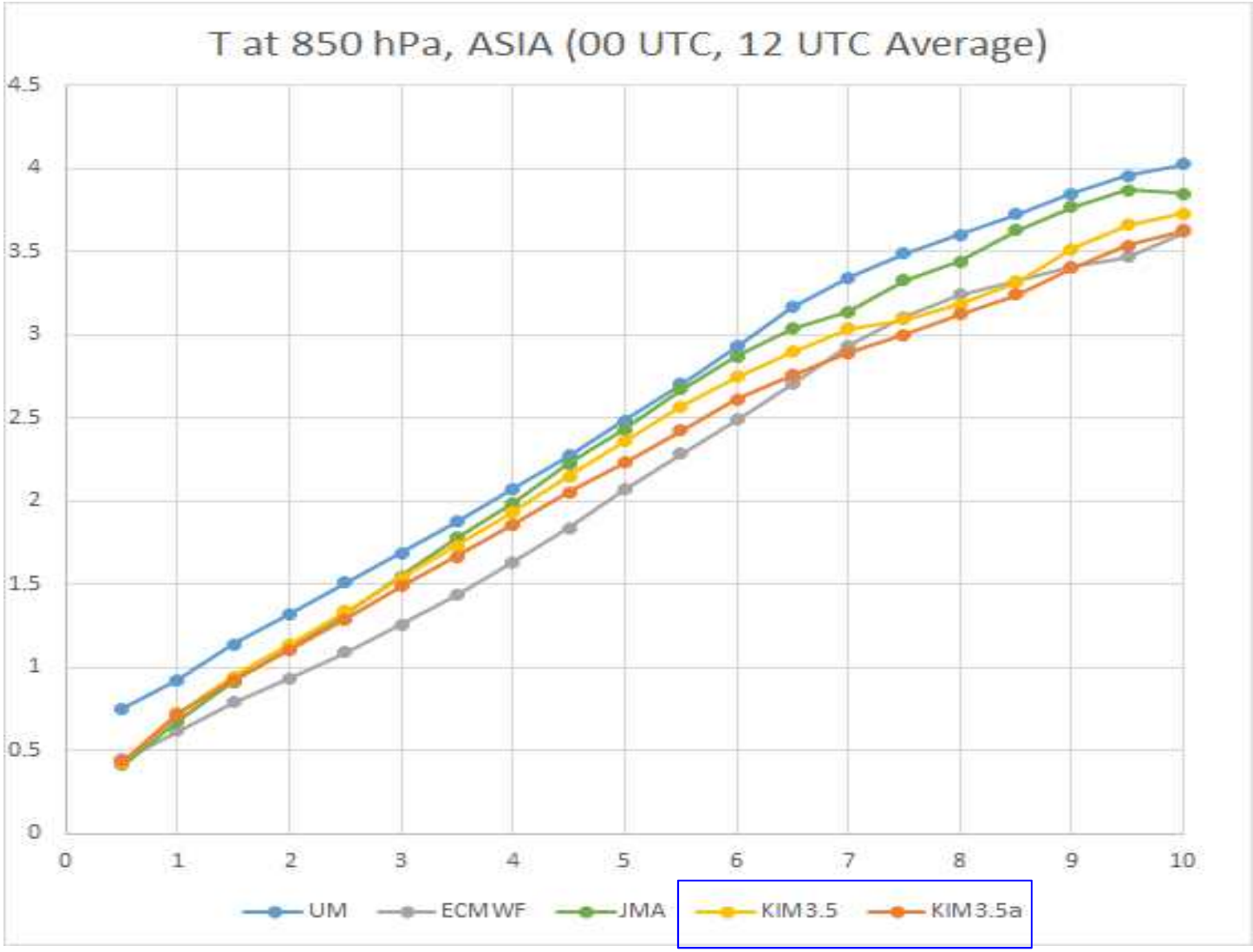
Comparison : Asia (00, 12UTC average)

500hPa geopotential height (RMSE)



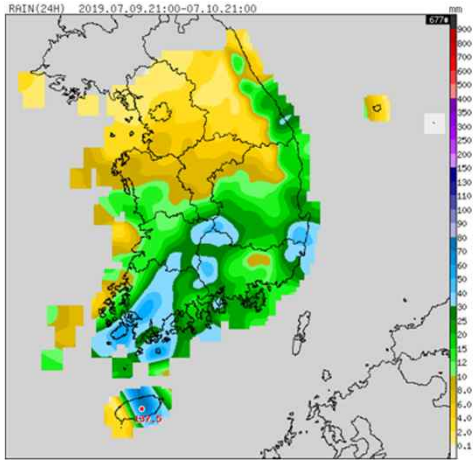
Comparison : Asia (00, 12UTC average)

850hPa temperature (RMSE)

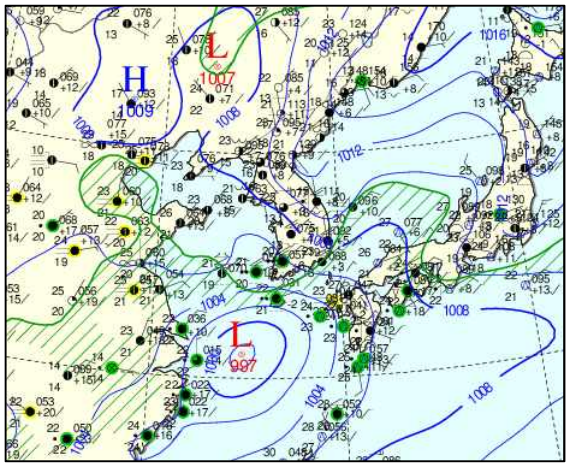


Cyclone + front (2019.07.09.21.~07.10.21LST)

[AWS] 24hr accum. Rainfall amount

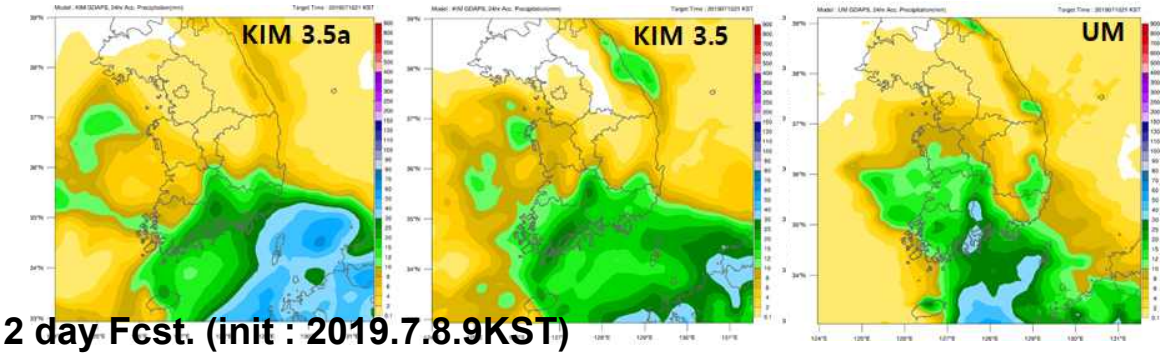


2019.7.10.9KST

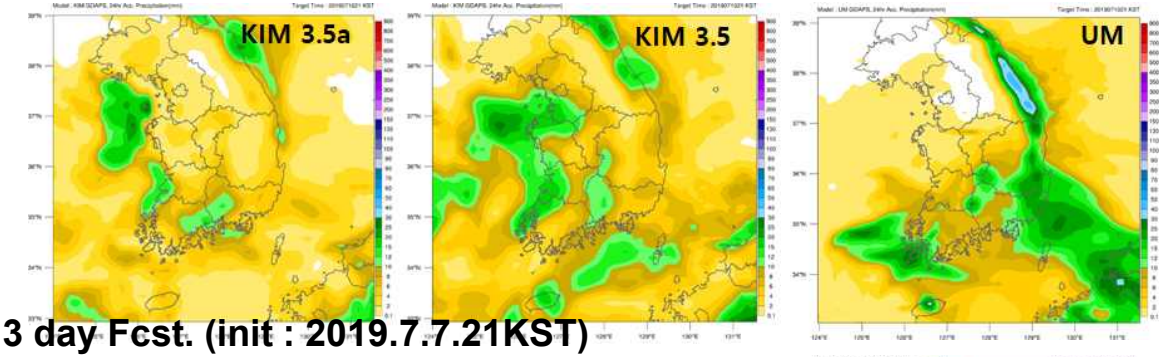


KIM3.5a KIM3.5 KMA(UM)

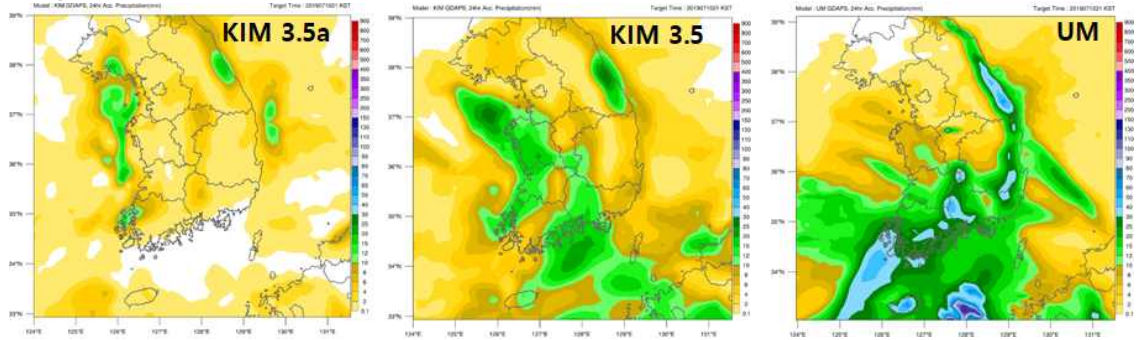
1 day Fcst. (init: 2019.7.9.9KST)



2 day Fcst. (init : 2019.7.8.9KST)

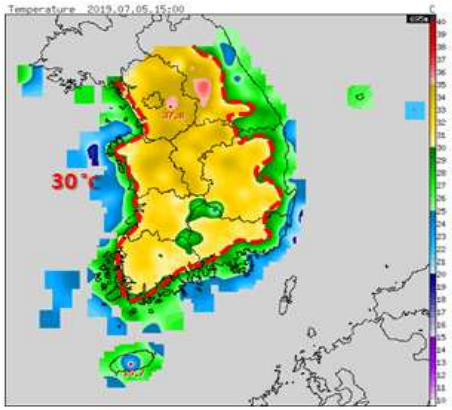


3 day Fcst. (init : 2019.7.7.21KST)



Heat wave (2019.07.05.15 LST)

AWS



KIM: similar with obs.
in the region over 30℃

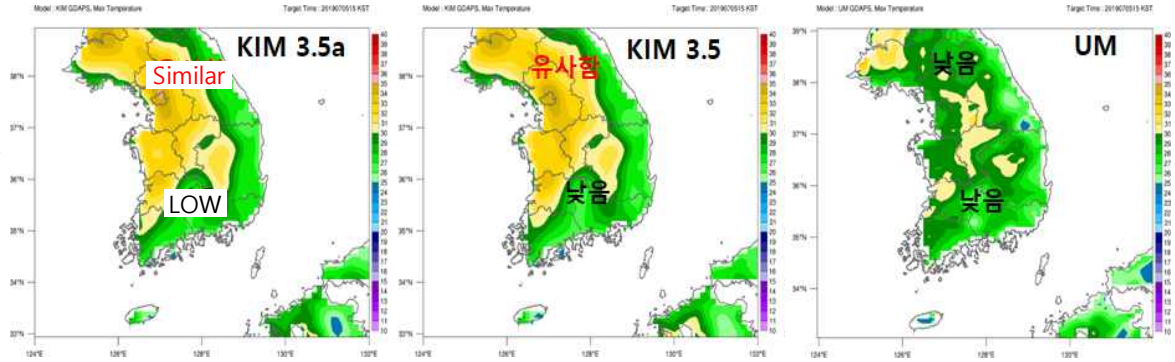
KMA-UM: colder than obs.

KIM3.5a

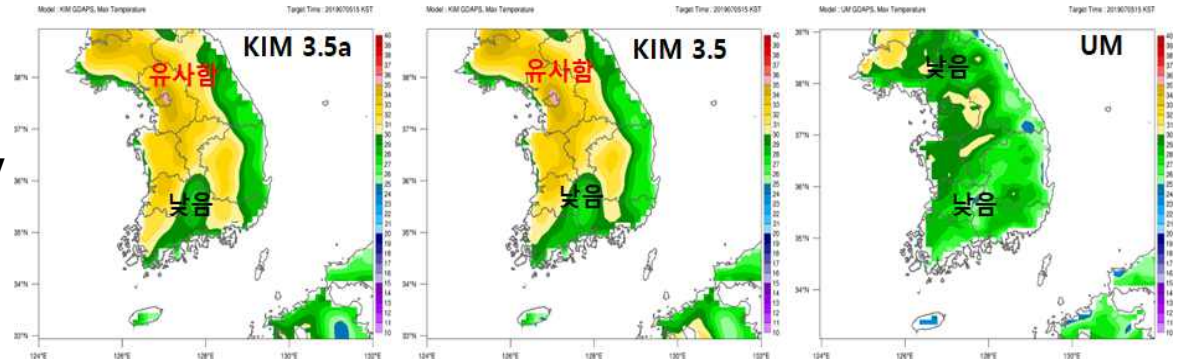
KIM3.5

KMA(UM)

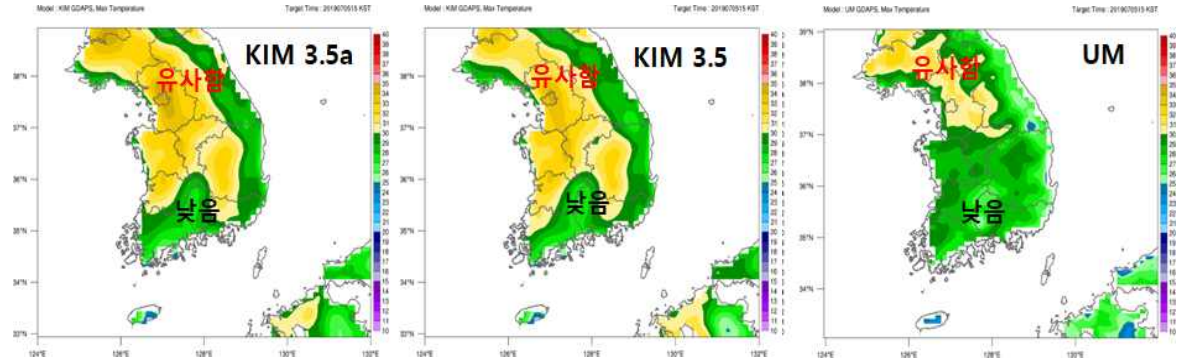
1day



3day



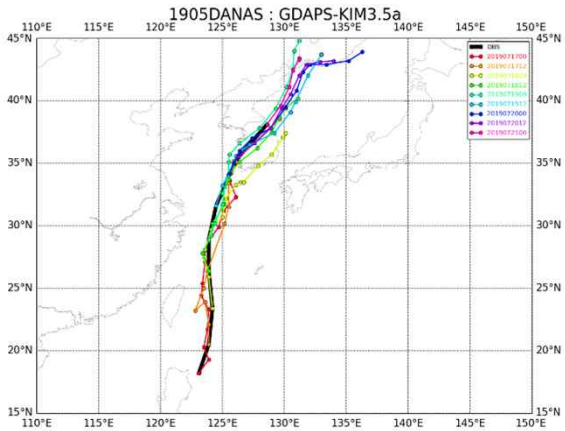
5day



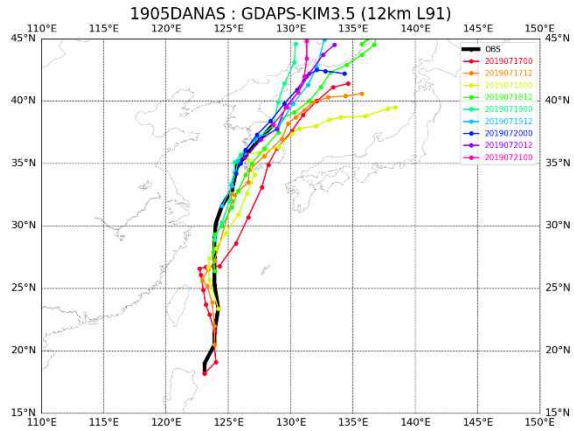
Typhoon (2019)

Danas (1905)

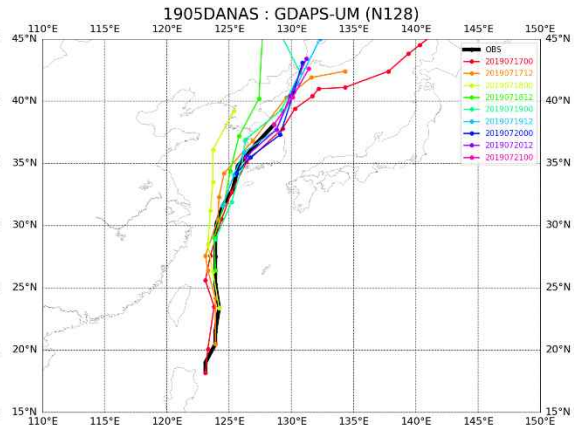
KIM3.5a



KIM3.5



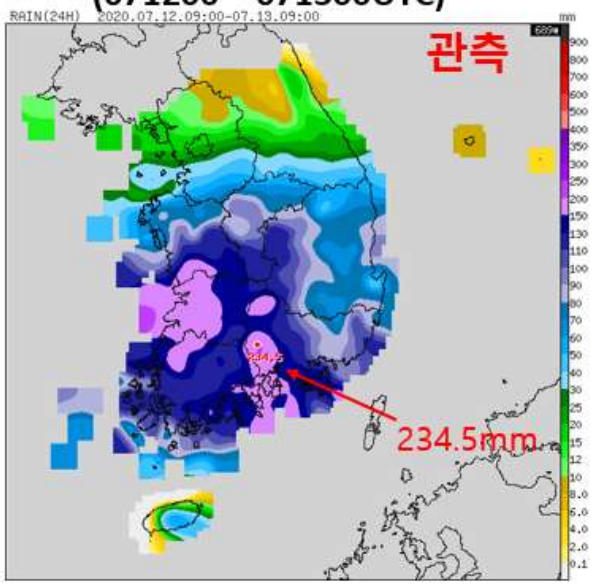
KMA(UM)

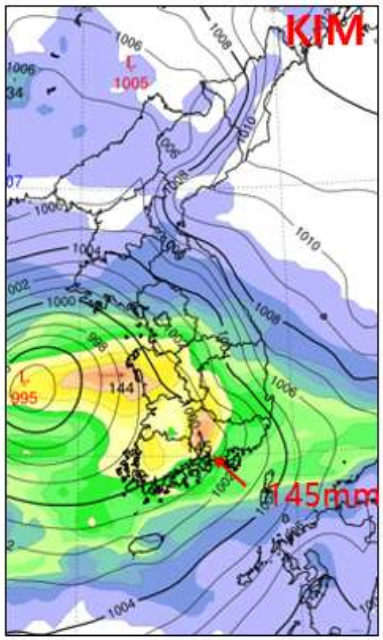


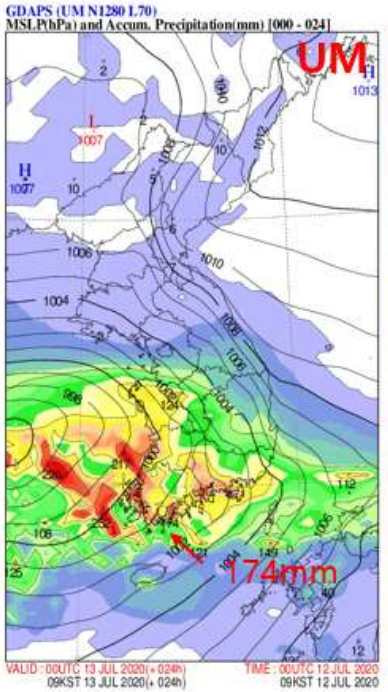
Typhoon Case	Model version	Track error (km)		
		1day	2day	3day
Danas (1905)	KIM3.5	75	134	226
	KIM3.5a	67	99	148
	KMA(UM)	65	149	192
Francisco (1908)	KIM3.5	70	158	263
	KIM3.5a	92	162	235
	KMA(UM)	81	179	271

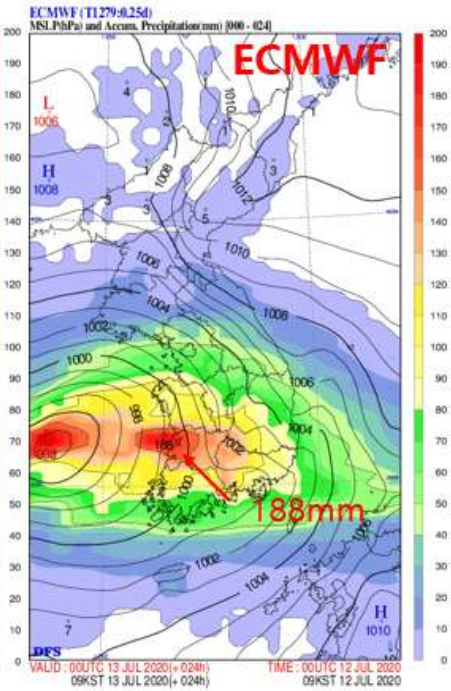
Cyclone (2020.07.12.) : Good

24hr accum.
precipitation
(071200 ~ 071300UTC)



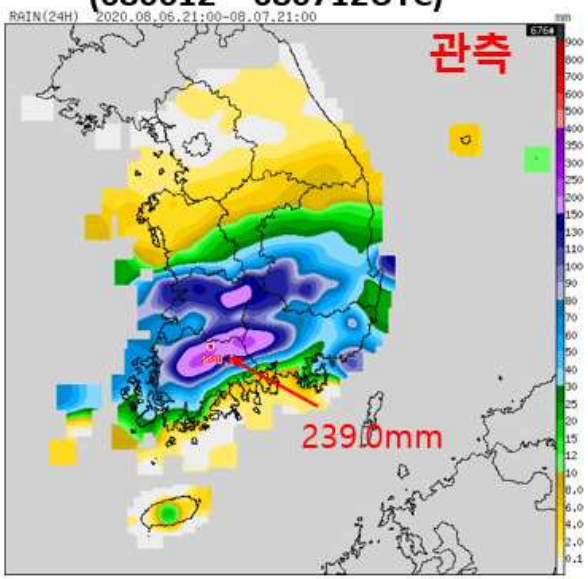


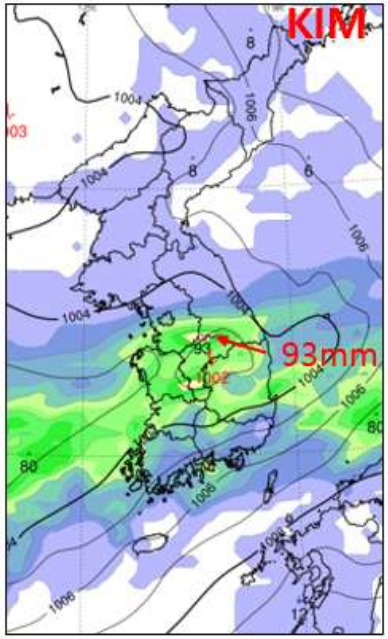


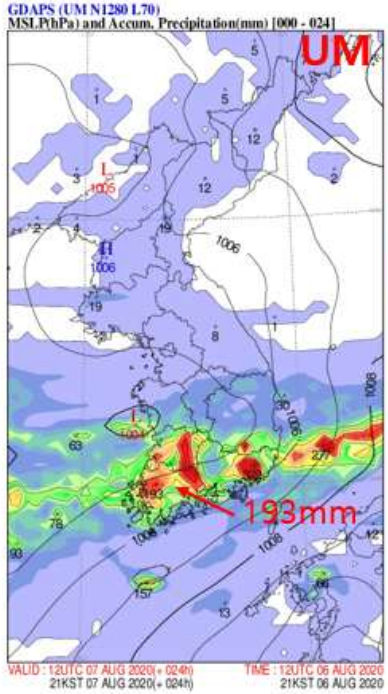


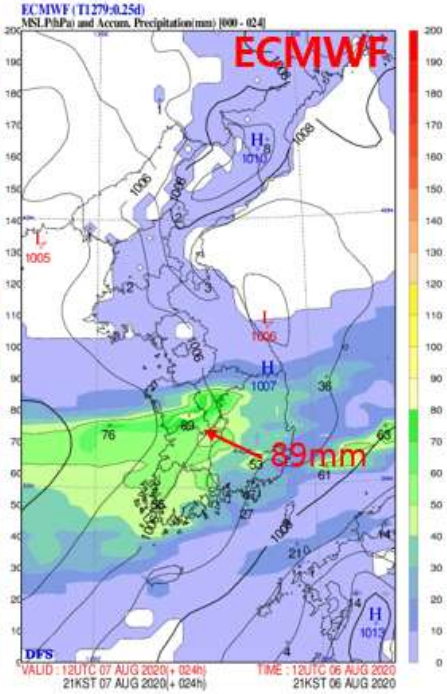
Cyclone + Front (2020.08.06.) : Bad

24hr accum.
precipitation
(080612 ~ 080712UTC)





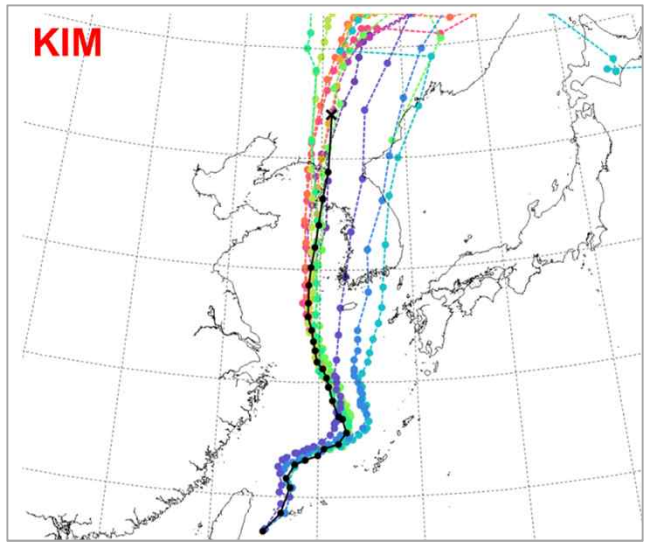


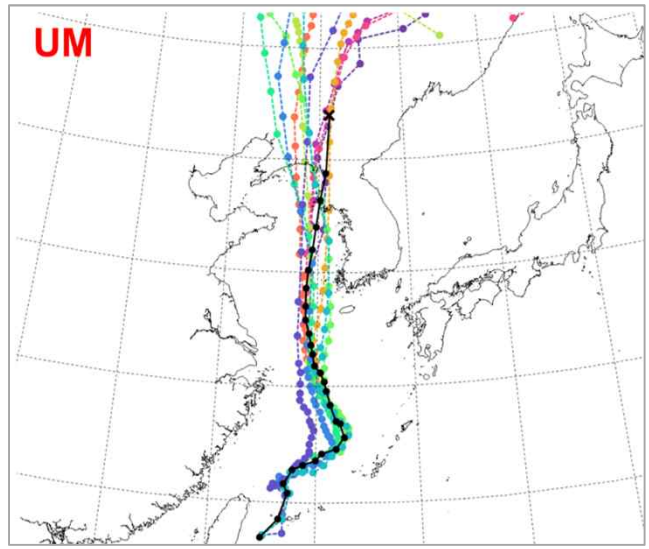


Typhoon Forecast (2008 BAVI)

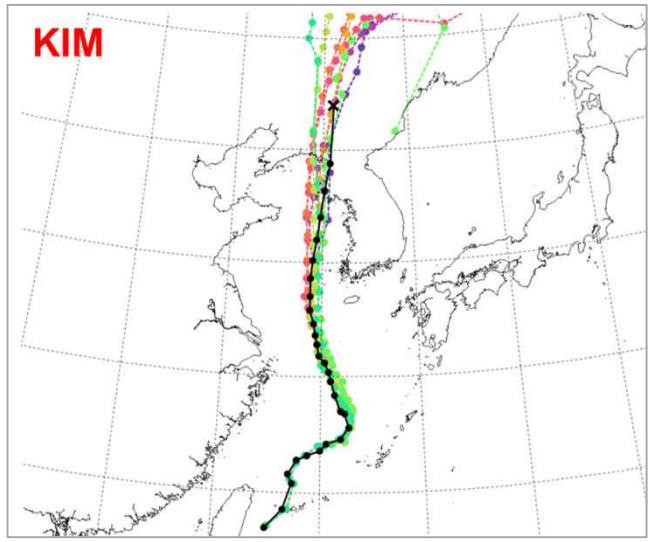
Init: 09UTC 22 Aug ~ 09UTC 27 Aug

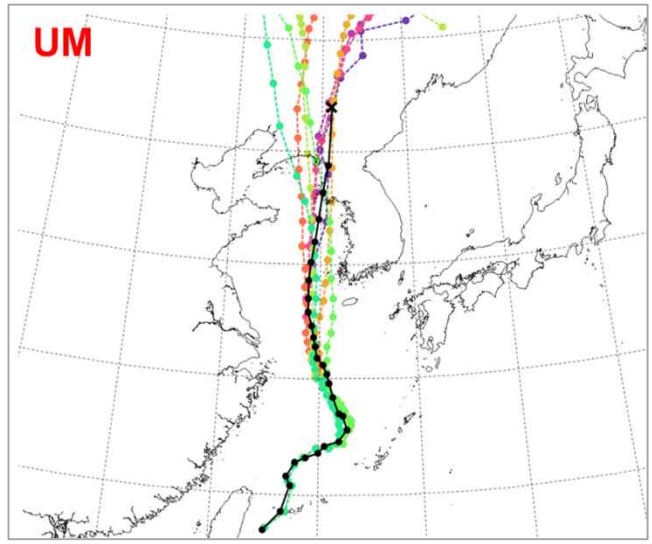
✓ KIM: not good in the TY genesis stage





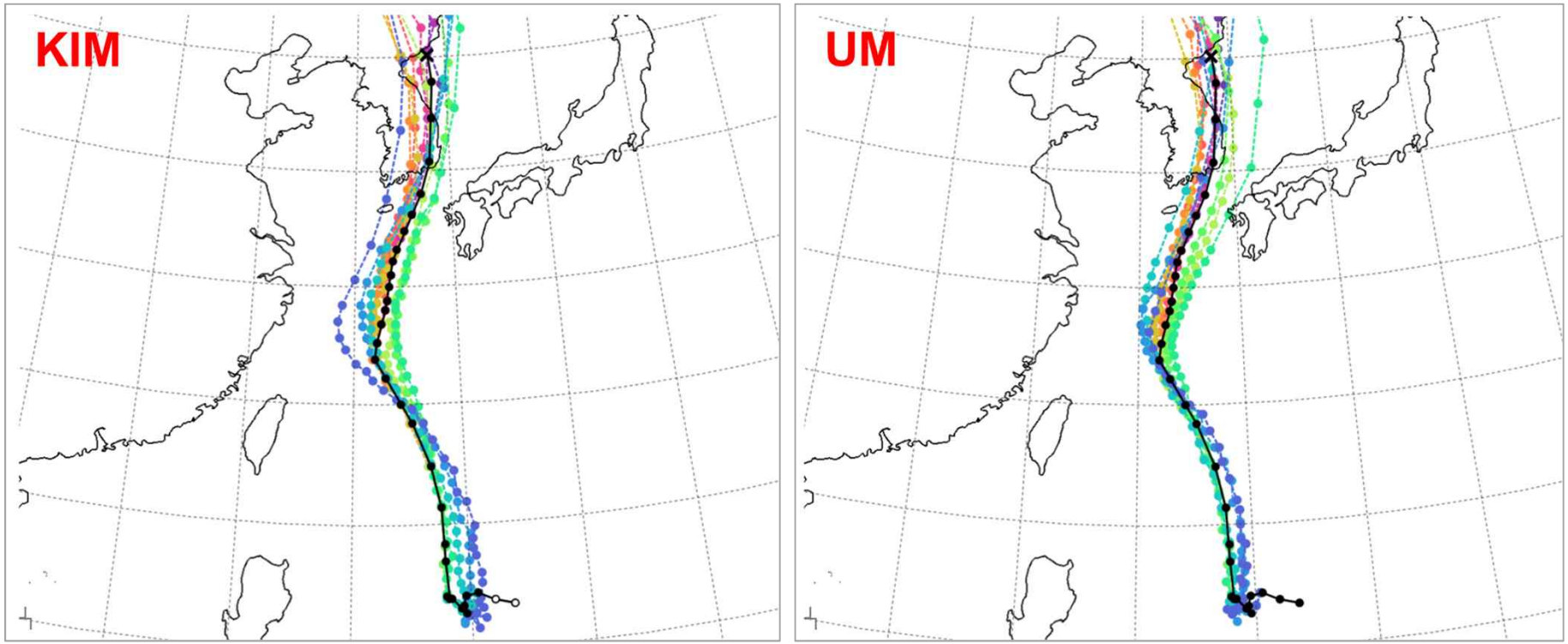
Init: 21UTC 23 Aug ~ 09UTC 27 Aug





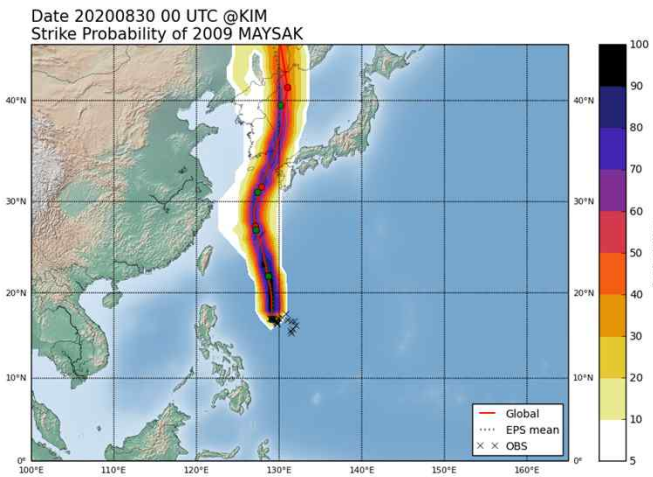
Typhoon Forecast (2009 MAYSAK)

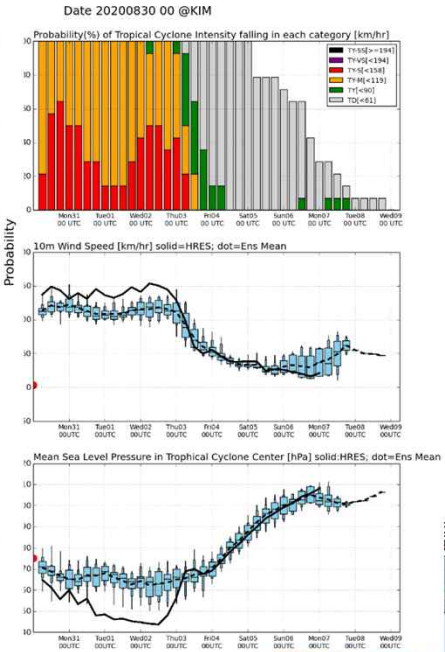
Init: 21UTC 28 Aug ~ 09UTC 03 Sep



Typhoon Forecast (2009 MAYSAK)

KIM EPS



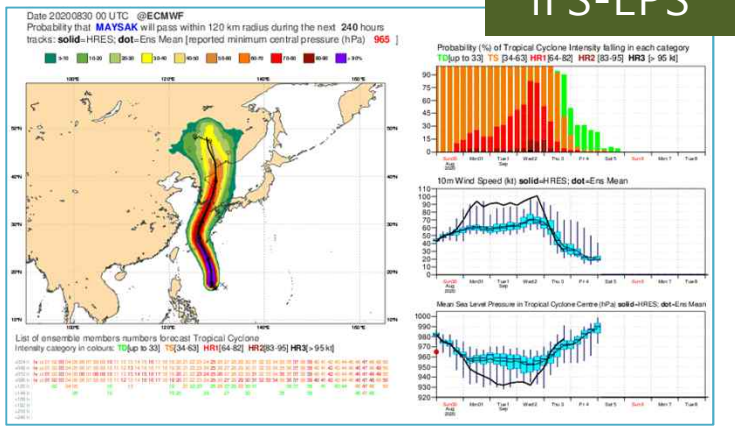


List of ensemble members numbers forecat Tropical Cyclone

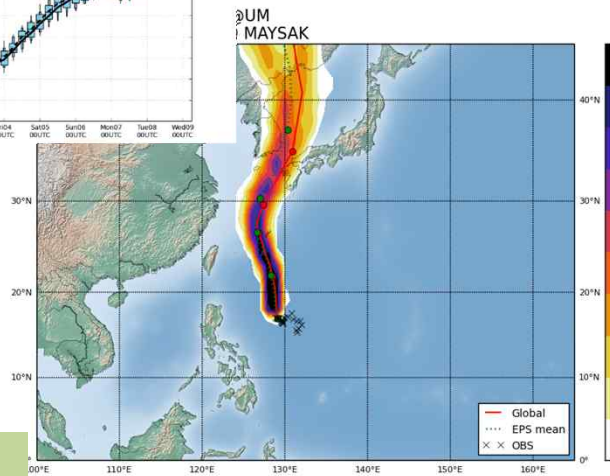
Intensity [km/hr] category in Colors: TD[<61] TY[<90] TY-M[<119] TY-S[<158] TY-VS[<194] TY-SS[>=194]

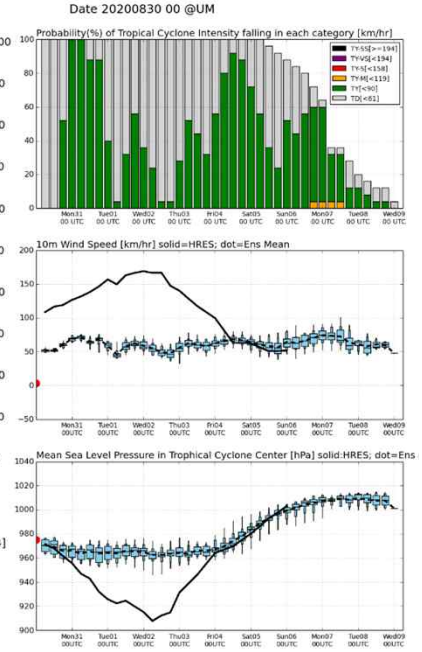
+024h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+048h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+072h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+096h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+120h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+144h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13									
+168h:	hr		1		3		5	6	7	8	9	10	11		13									
+192h:	hr				3					8		10			13									
+216h:										8														
+240h:																								

IFS-EPS



UM EPS





List of ensemble members numbers forecat Tropical Cyclone

Intensity [km/hr] category in Colors: TD[<61] TY[<90] TY-M[<119] TY-S[<158] TY-VS[<194] TY-SS[>=194]

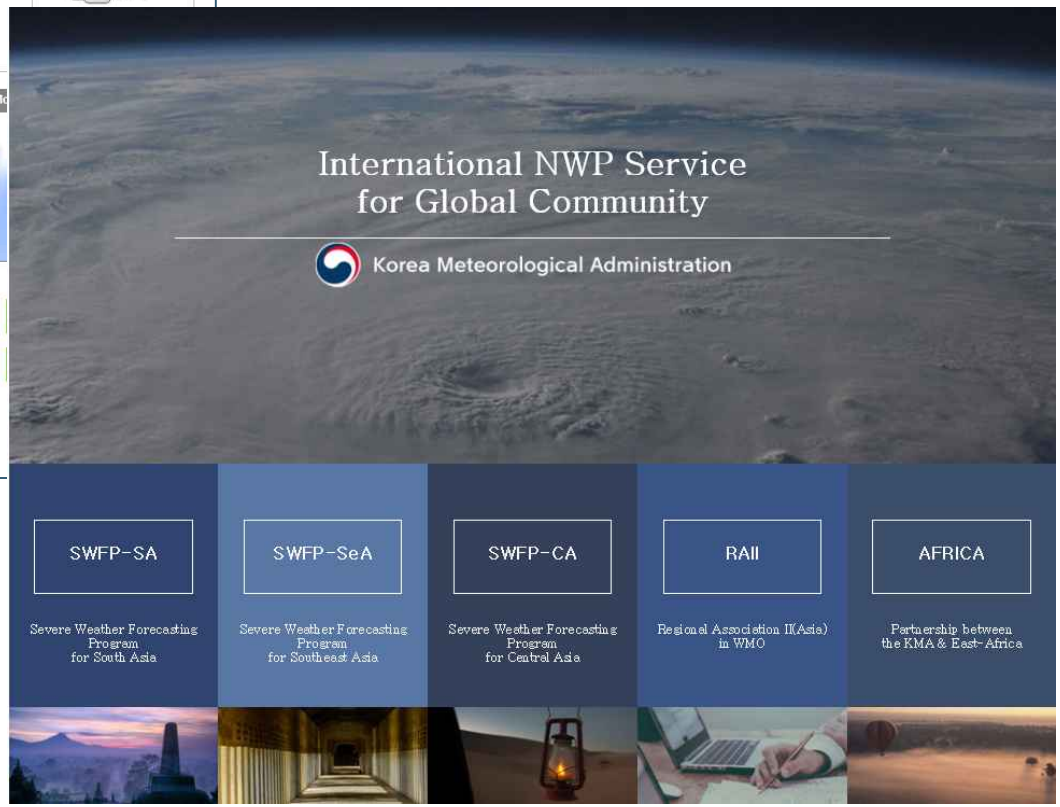
+024h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+048h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+072h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+096h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+120h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+144h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+168h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+192h:	hr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
+216h:						4					9		11			14										
+240h:											9															

IV. International Cooperation

(WMO SWFP: Severe Weather Forecast Program)

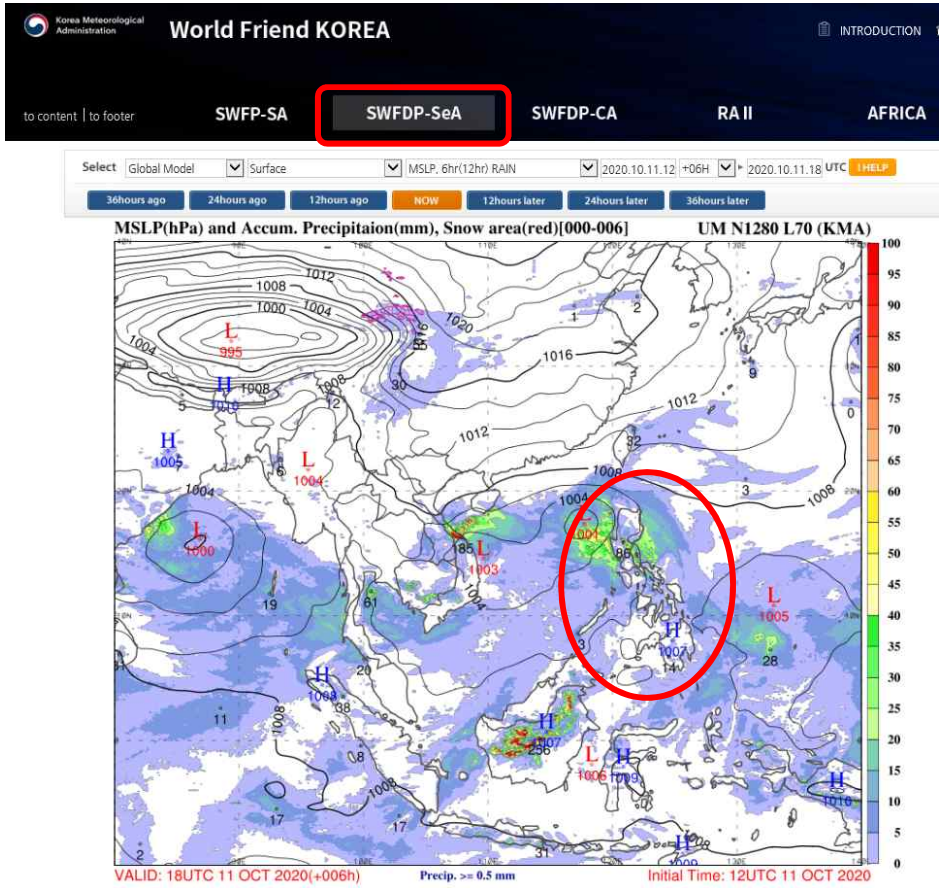
Weather charts for international cooperation

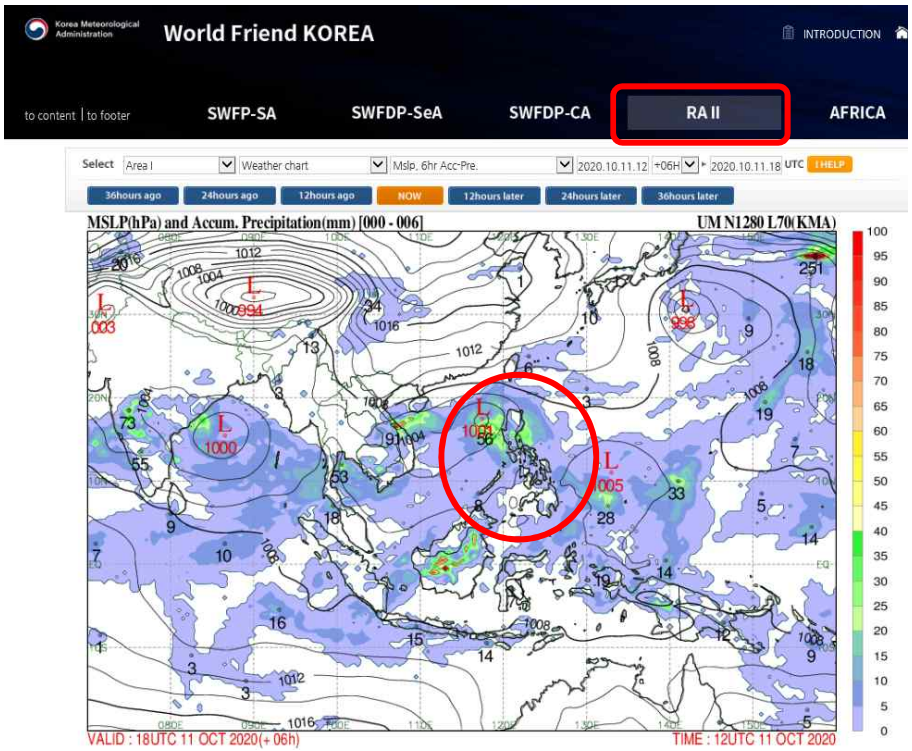
http://www.kma.go.kr/eng/index.jsp



http://www.kma.go.kr/ema/nema03/index.jsp

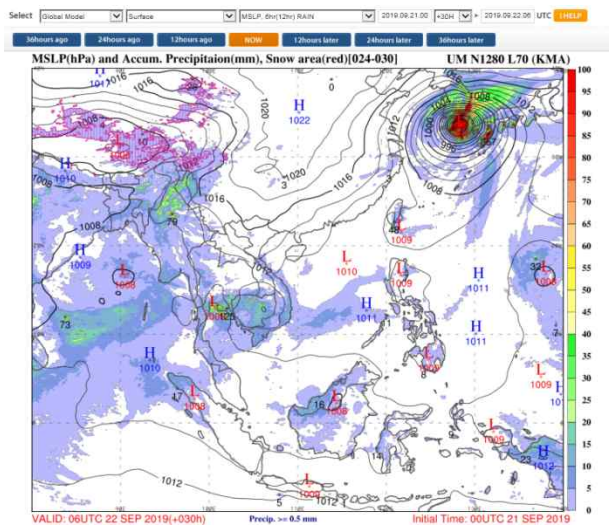
Weather charts for international cooperation



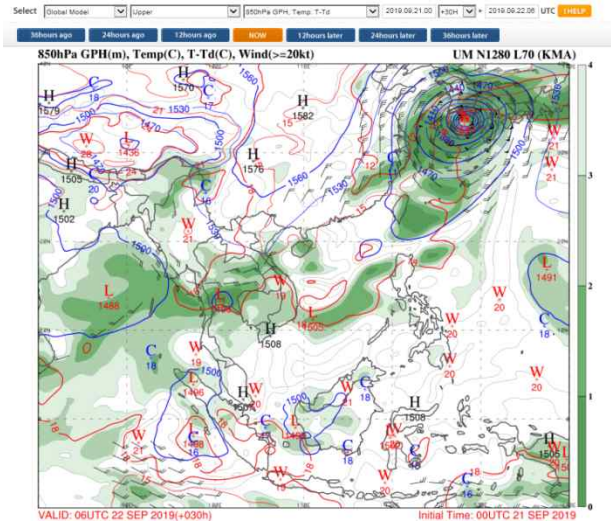


- **Rain cut-off**
  - **Summer (May~Nov.): 0.5 mm**
  - **Winter (Dec.~April): 0.25 mm**

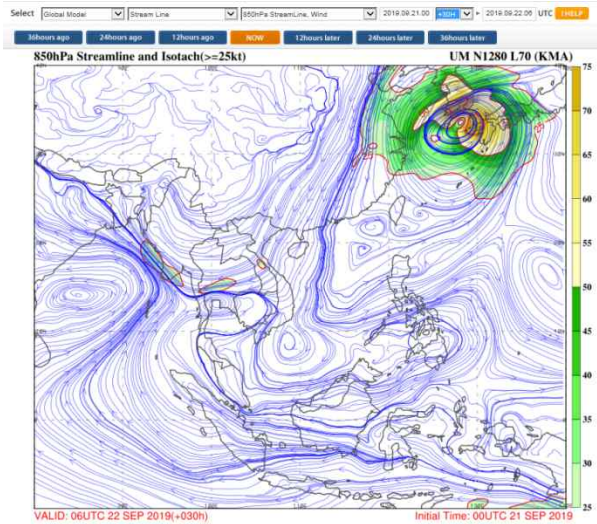
Global model based charts



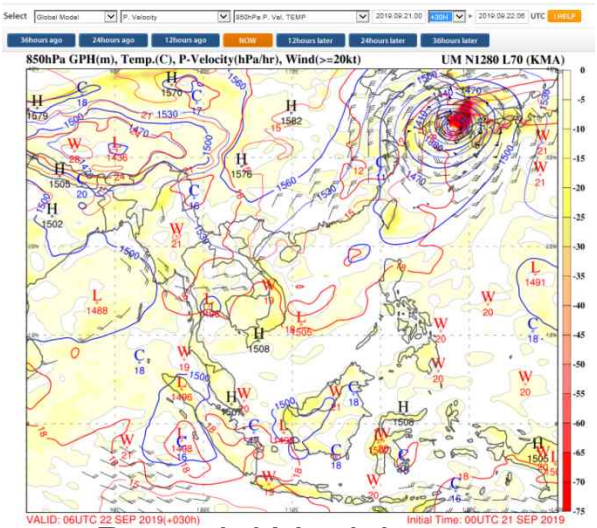
- Surface (MSLP, Rain)



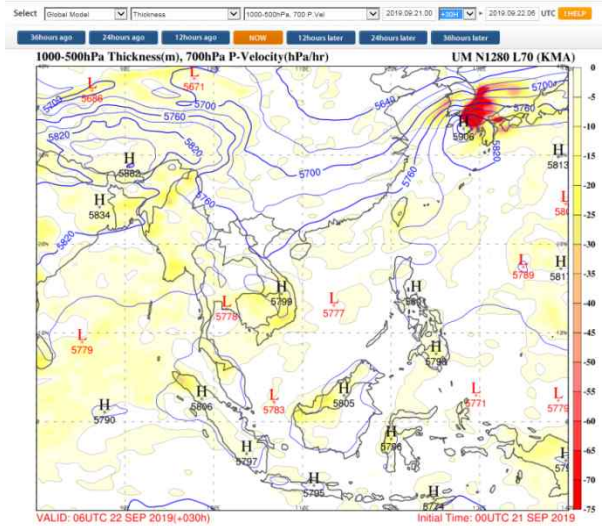
- Upper (GPH, T, T-Td)



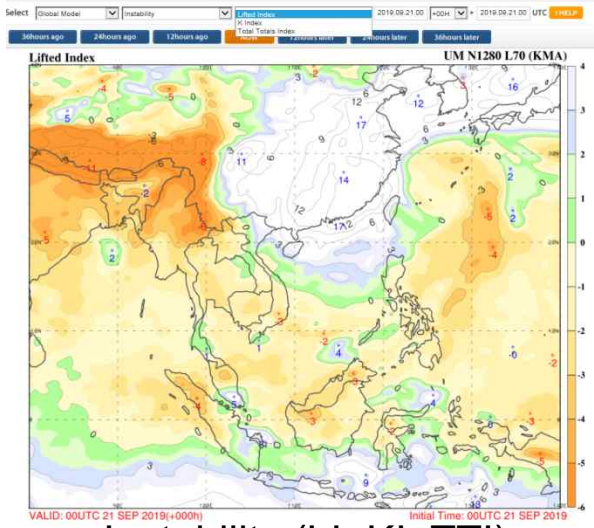
- Stream Line (Wind)



- Potential Vorticity



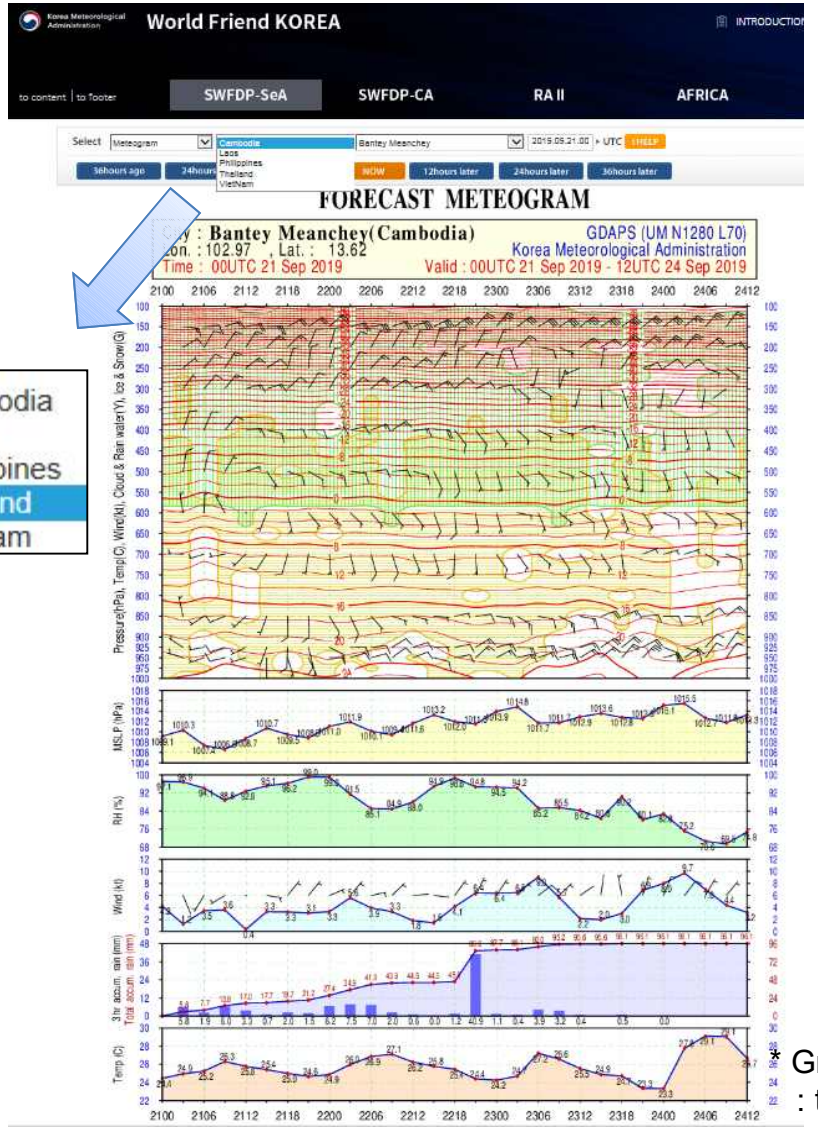
- Thickness
  (1000-500 hPa, 700 P.Vel)



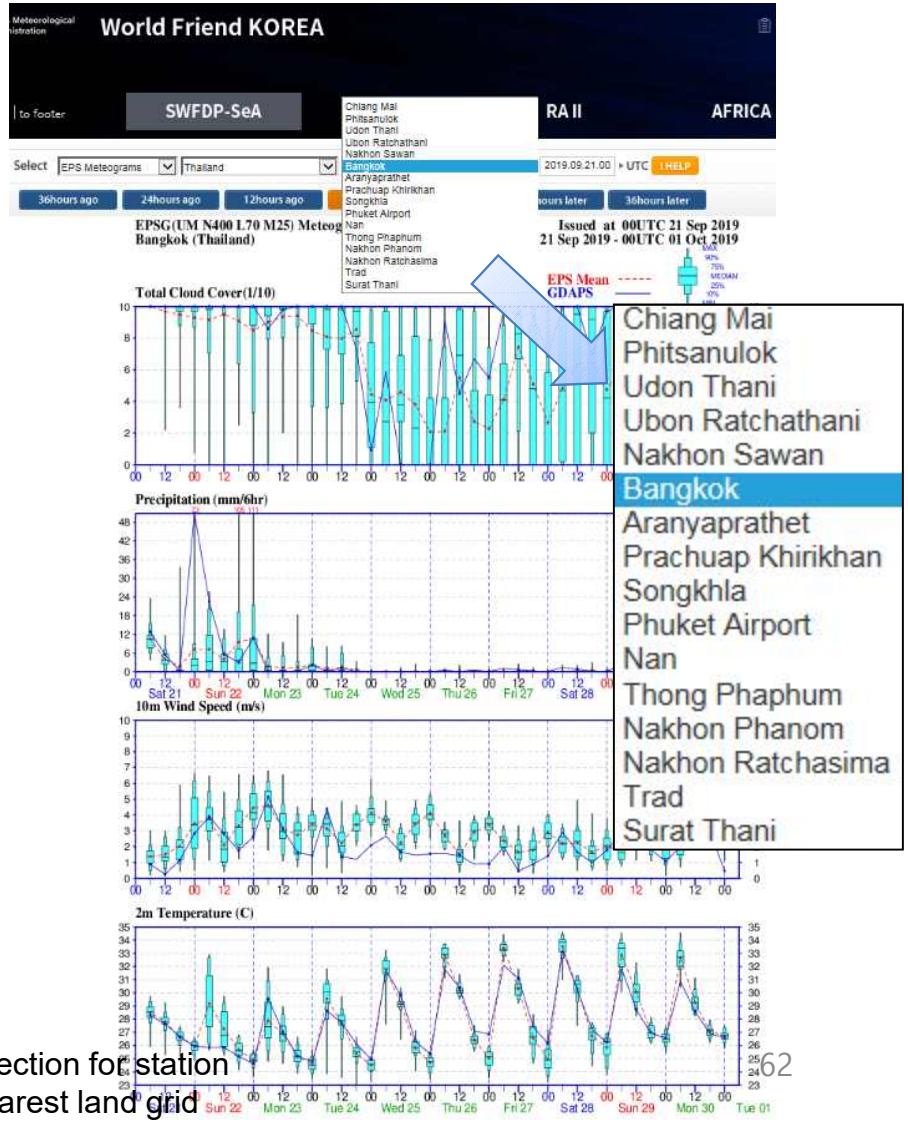
- Instability (LI, KI, TTI)

Station based charts (Meteogram)

Meteogram



EPS Meteogram



* Grid selection for station
: the nearest land grid

V. Future Plan

Future plan (~2022)

❖ **UM : Parallel run with KIM (~'22)**

❖ **KIM : Upgrade of all process** (examples)

- Ensemble: perturbation methods, multi-model ensemble, …
- Dynamics: dynamics for high resolution grid, …
- Physics: ocean mixed layer, AI based physics, …
- Data assimilation : add of observation types, upgrade of quality control, …

❖ **KIM EPS : Operation ('21.10)**

Post KIAPS project

- Period: **2020.12.1.**~2026 (7 years : 2 step = 3+4)
- Total Budget: about **$93,000,000**
- Human resources : **113 experts per year**
- Main Task
  - Adaptive grid model which covers from the very short range forecast to the extended long range forecast (30 days)
  - Ocean and land surface coupling
  - Rapid update data assimilation cycle
  - Big ensemble system

Thank you

for your attention!

Korea Meteorological Administration
Numerical Modeling Center