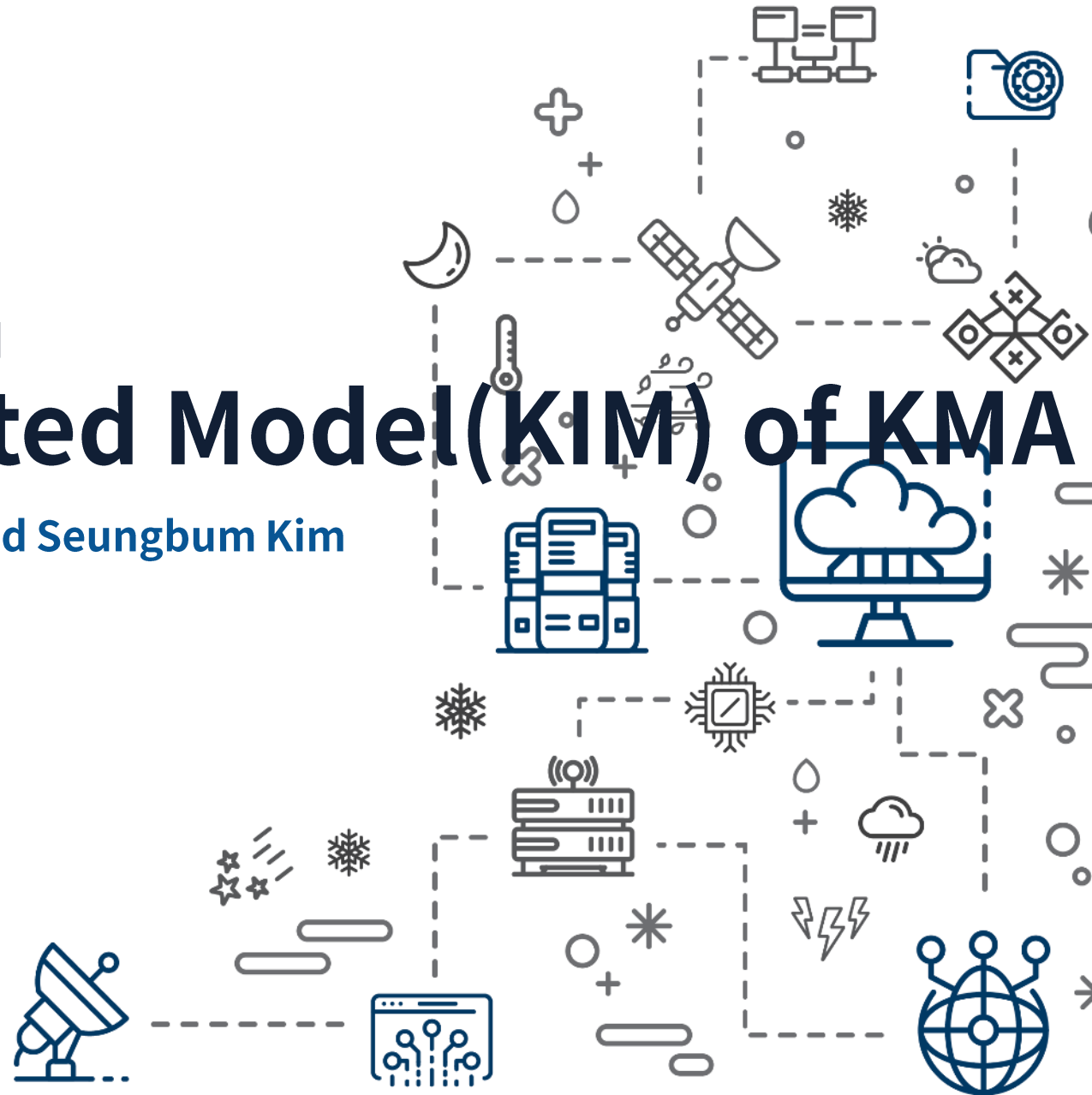


# Impact of ROMEX data on the Korean Integrated Model (KIM) of KMA

Hyung-Wook Chun, Eun-Hee Kim, Youngsoon Jo, and Seungbum Kim

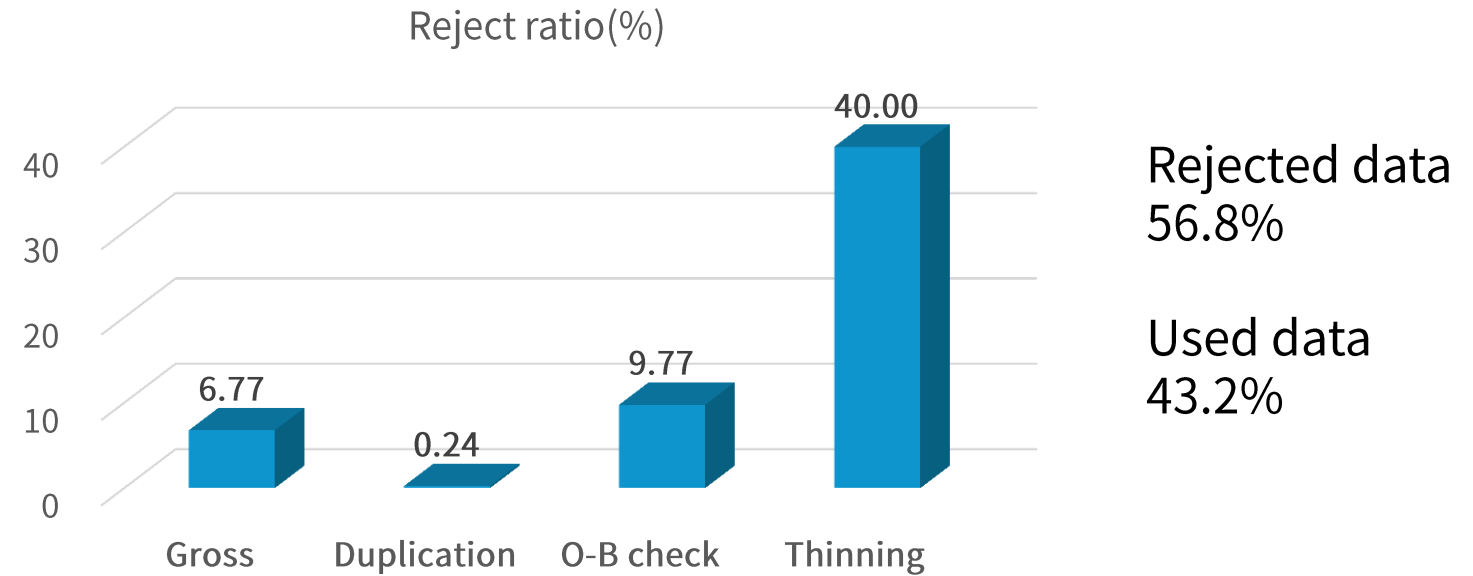
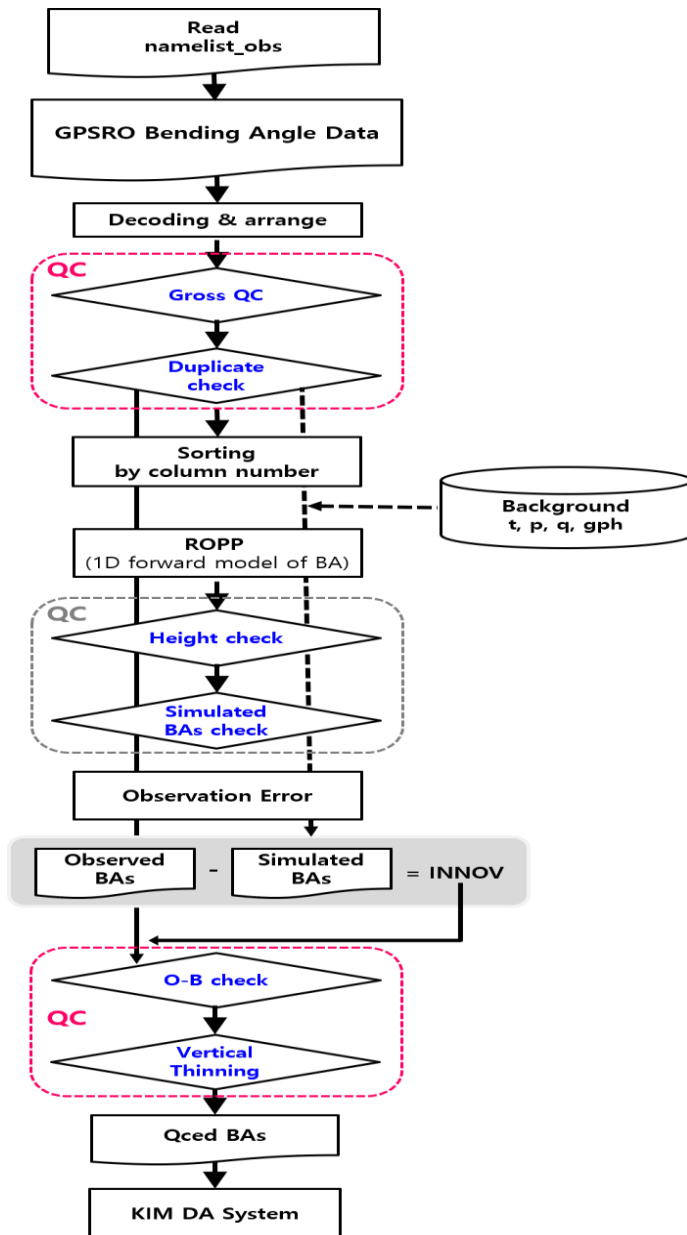
KMA, Numerical Modeling Center



# Design of Observing System Experiment(OSE)

Item	Contents
Model	Operational Korean Integrated Model (KIM3.9) low-resolution (ne180, ~ 25 km)
Data Assimilation	Hybrid Variational DA (4DEnVar) (ne144, ~ 32 km / 50 ensemble members)
Experiment Period	3 months (1 Sep ~ 1 Dec 2022)
Verification period	3 months (1 Sep ~ 1 Dec 2022)
Experiment Name	Used GNSS-RO data
CTL	Operational RO data (8 types) MetOp-B, MetOp-C, TerraSAR-X, TanDEM-X, PAZ, Sentinel-6A, COSMIC-2, KOMPSAT-5
EXP	CTL (8 types) + New commercial or China RO data (8 types) SPIRE, Yunyao, GNOMES-A, FY-3C, FY-3D, FY-3E, Tianmu, CICERO-OP1
NoRO	Remove all RO data

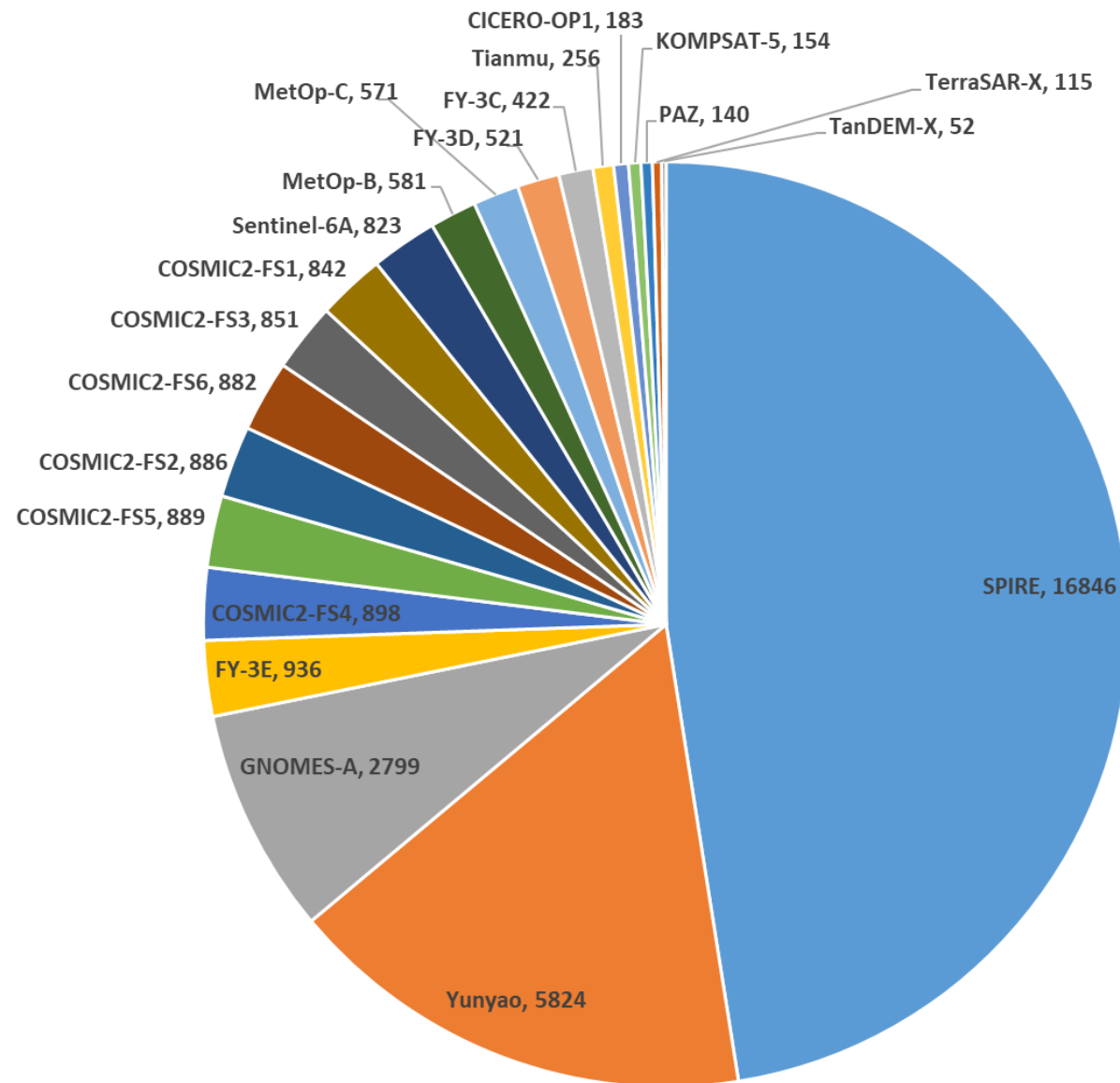
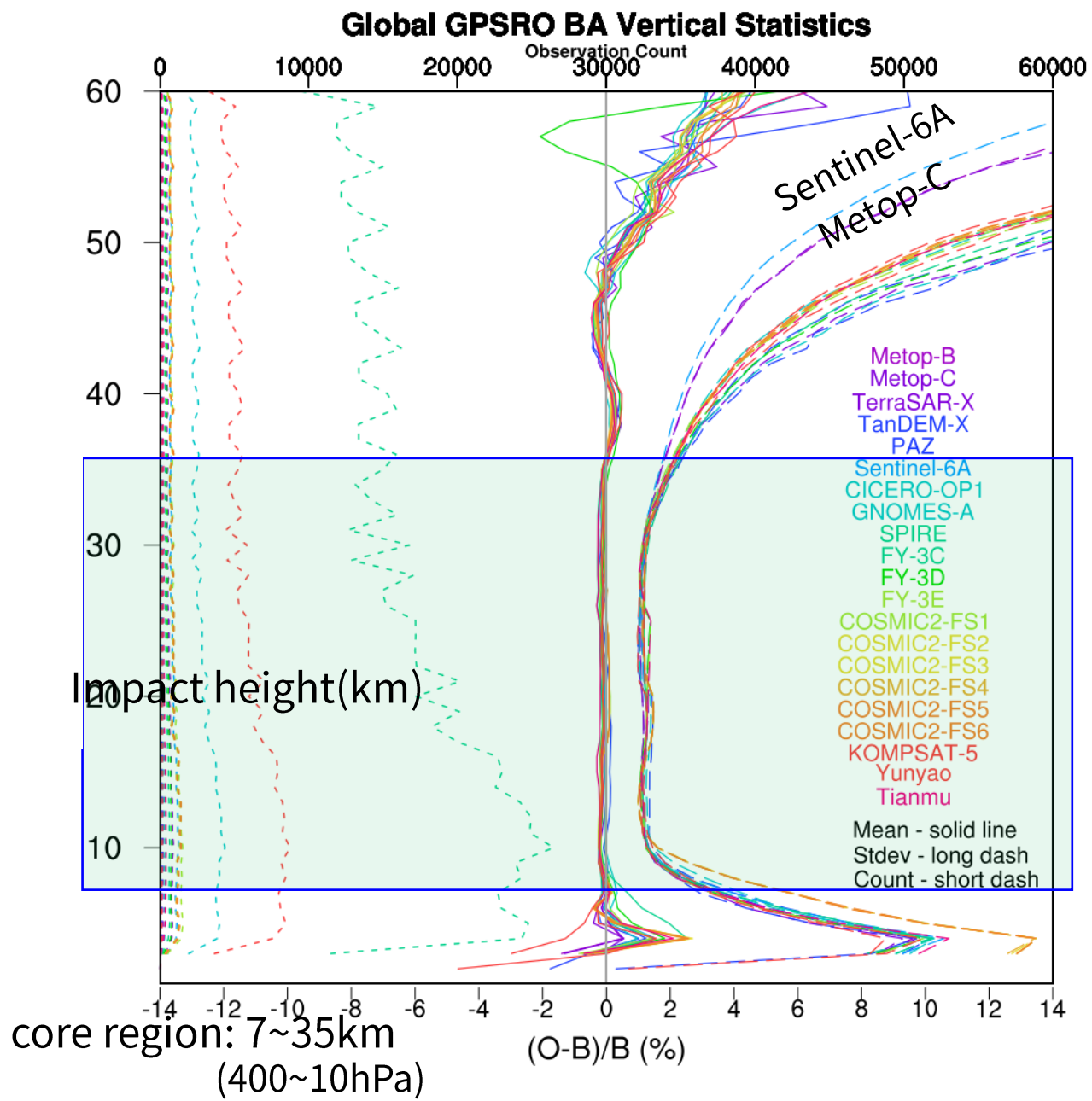
# Preprocessing of GPSRO on KIM



- ✓ **Gross check**: unphysical value check  
(earth radius of curvature, geoid undulation, average lat/lon, bending angle, impact height, etc.)
- ✓ **Duplicated check**: same profile reject
- ✓ **Height check**: impact height < model topo 🗎 warning
- ✓ **Simulated BA check**: bkg\_ba, jacobian of t, q are Nan
- ✓ **O-B check**:  $O-B > 3 \times Obserr$
- ✓ **Vertical thinning** with 400m interval

# Specs of GPSRO in ROMEX

Sep. 2022



# Distribution of GPSRO in ROMEX

CTL(8 types)

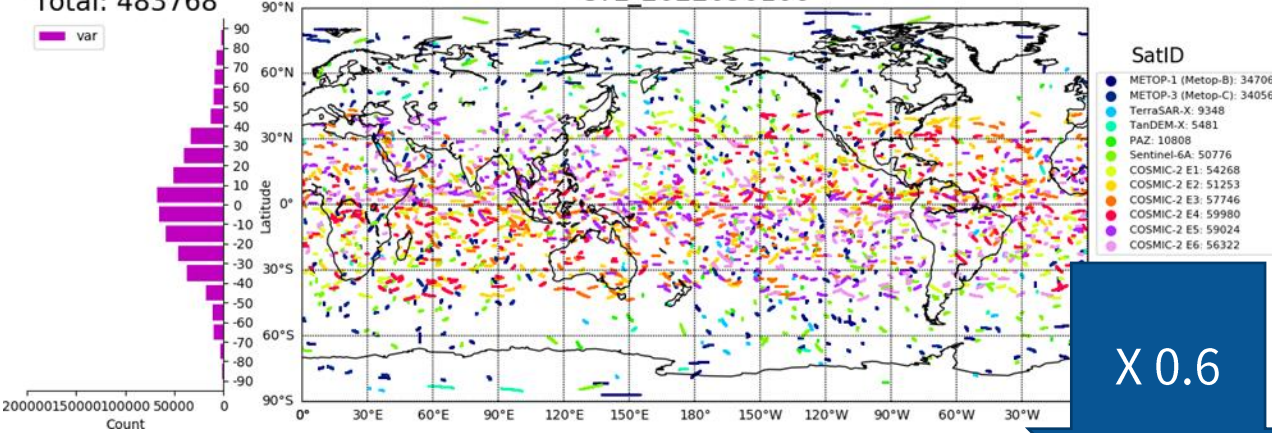
X 4.5

EXP(16 types)

Before Thinning

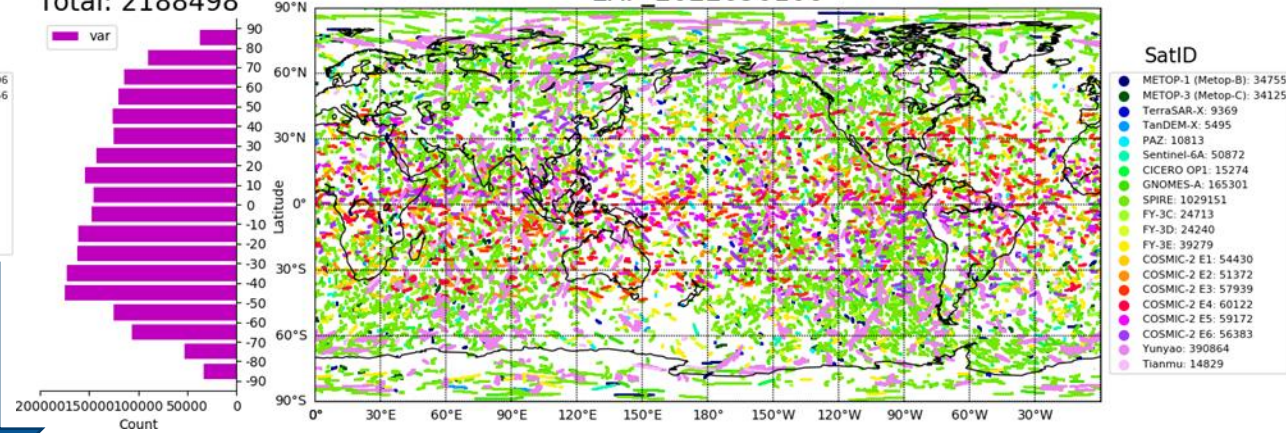
Total: 483768

CTL 2022090106



Total: 2188498

EXP 2022090106

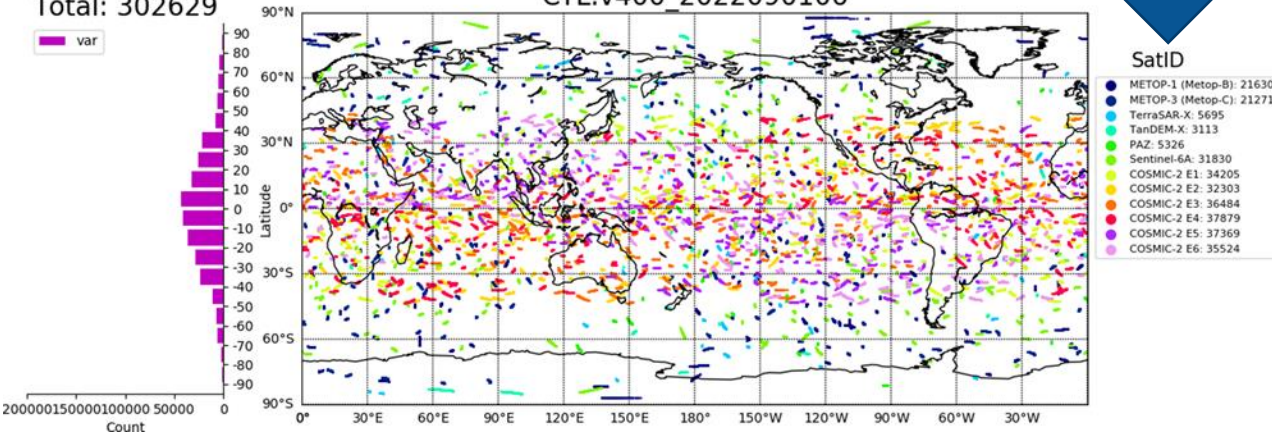


X 0.6

After Thinning

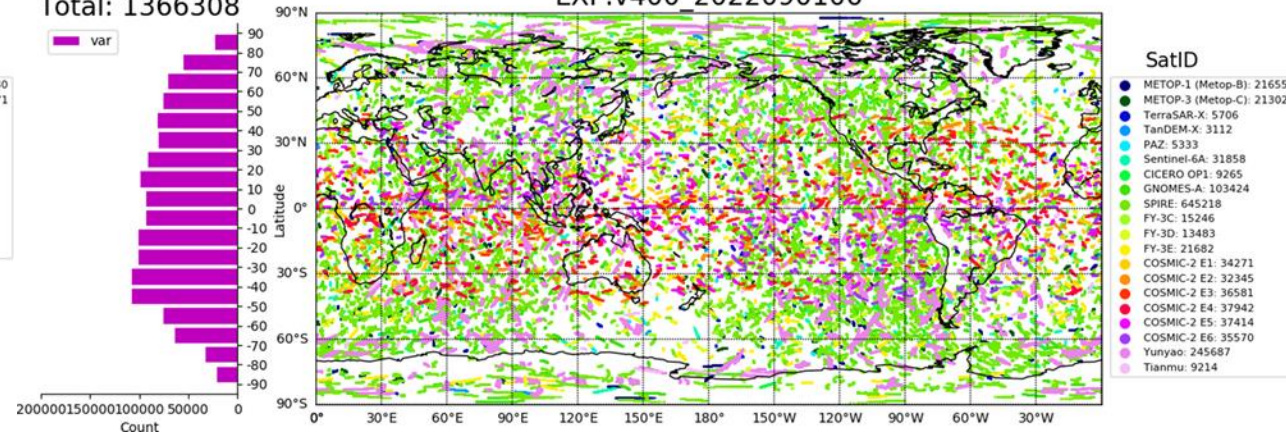
Total: 302629

CTL.v400\_2022090106



Total: 1366308

EXP.v400\_2022090106



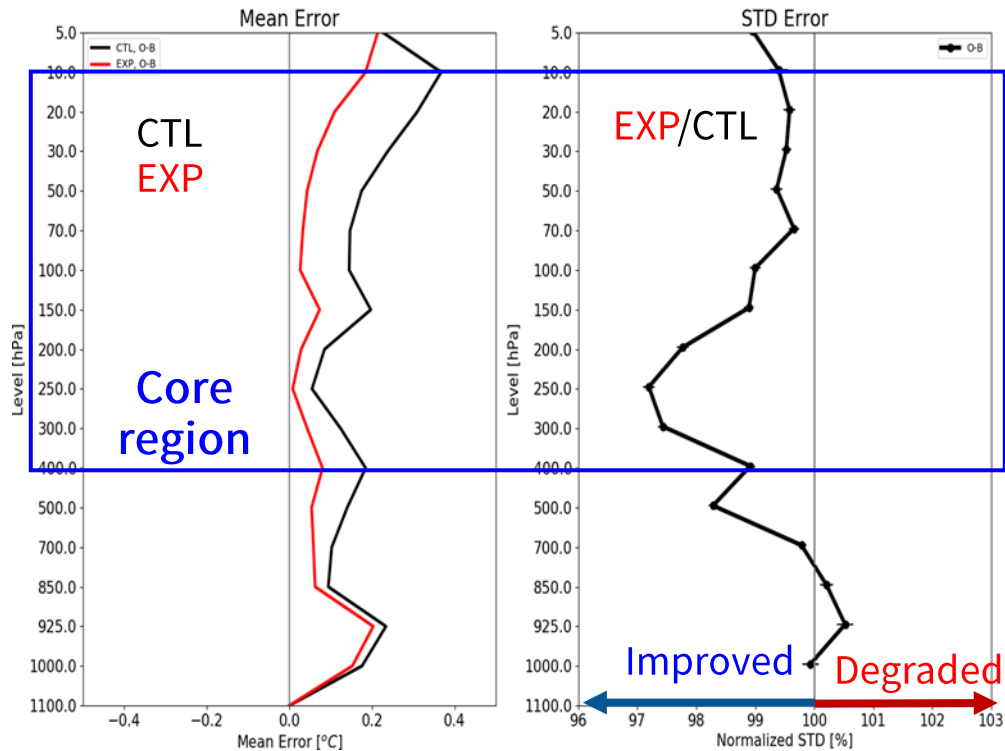
- ✓ # of EXP(CTL + New commercial RO) > **4.5 X** # of CTL(Operational RO)
- ✓ Thinning reduces data by **about 40%**.  
(Only vertical thinning with 400m interval)

- ✓ Complementing for lack of observations in **high latitude areas** by adding new data

# Background(6hr forecast) assessment against radiosonde

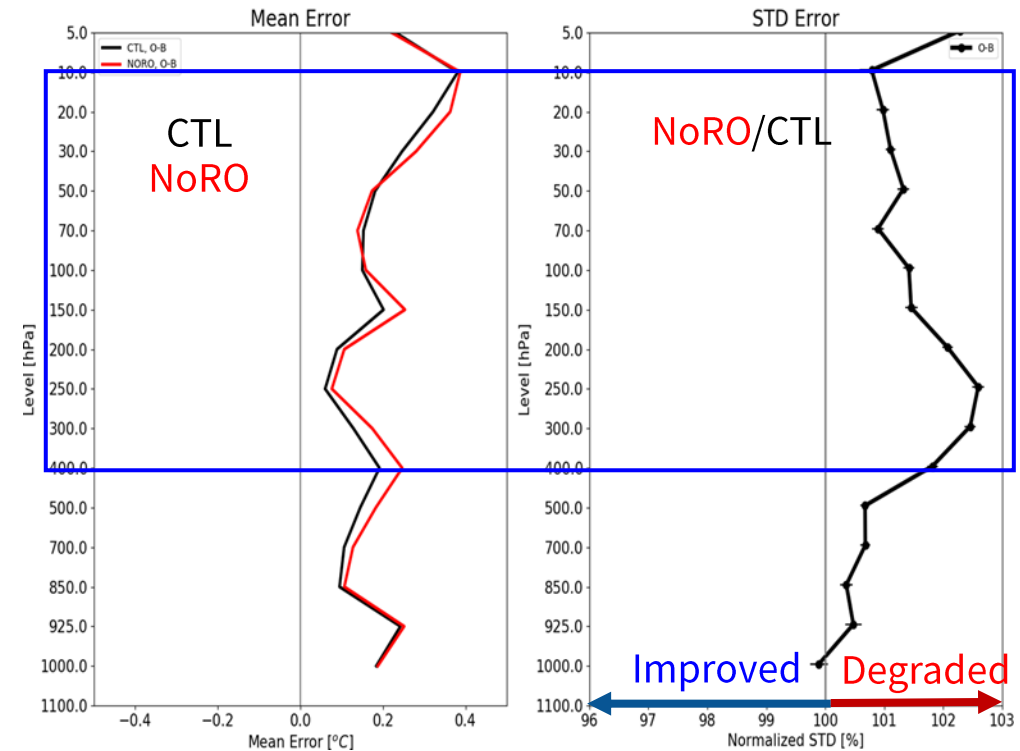
## New RO impact

T Error relative to sonde data



## Operational RO impact

T Error relative to sonde data



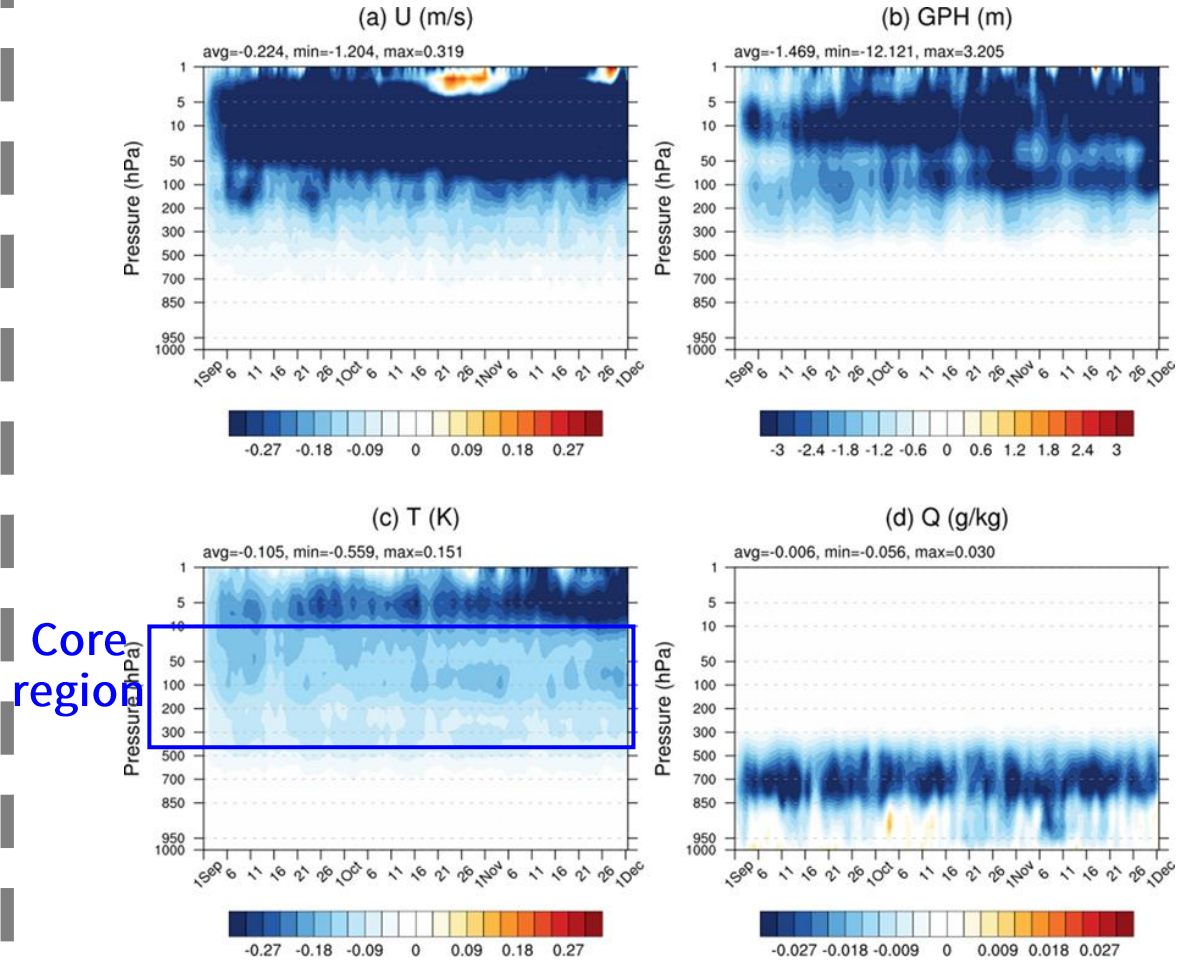
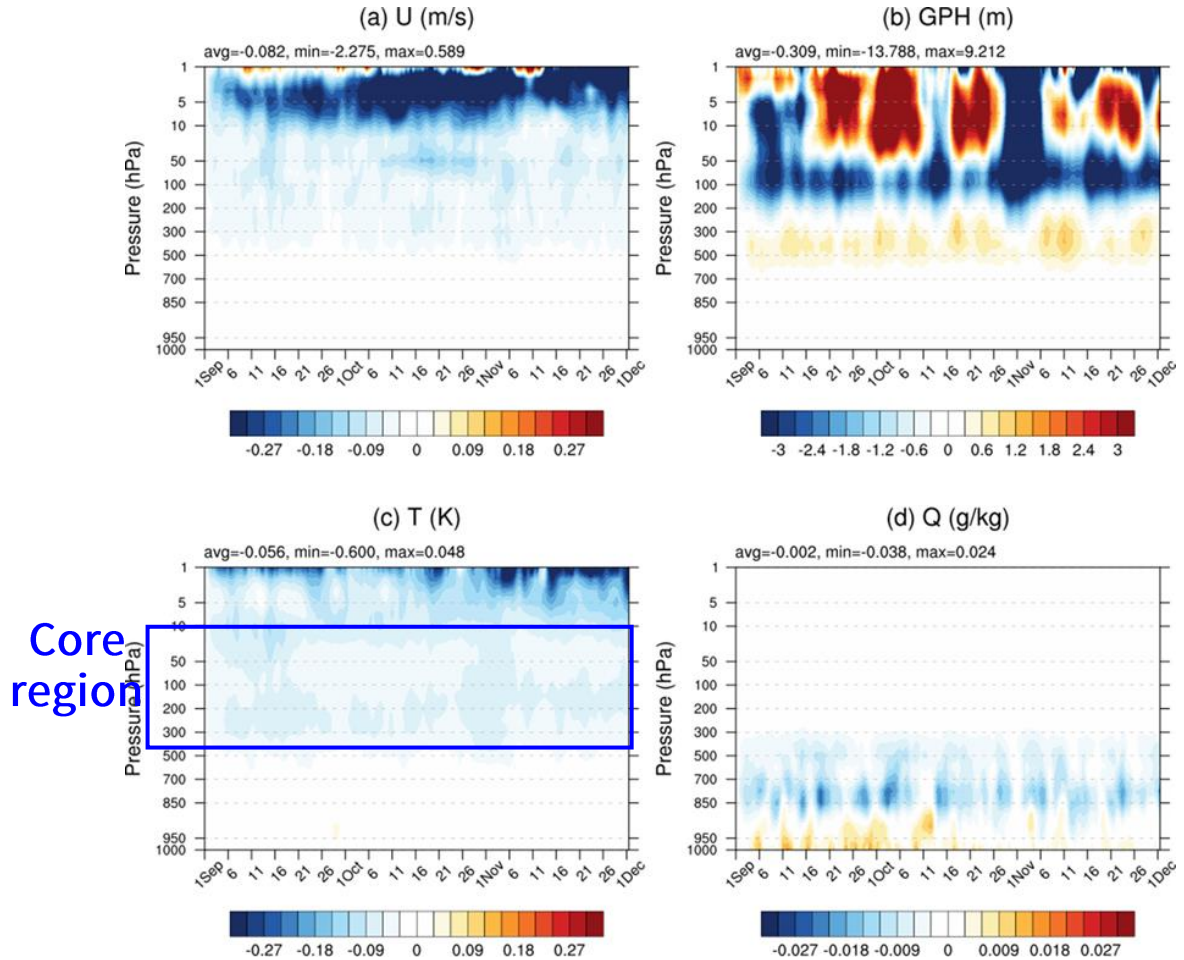
- ✓ **(Bias)** Massive new RO data improve temperature bias from -0.2 K to -0.1 K
- ✓ **(STD)** RO data mainly positive impact for core region. The impact of new data is similar to operational data

# Time series of analysis assessment

Blue: Improved  
Red: Degraded

New RO impact  
 $RMSD_{EXP} - RMSD_{CTL}$

⊗ RMSDs are calculated against ECMWF IFS analysis  
Operational RO impact  
 $RMSD_{CTL} - RMSD_{NoRO}$



✓ (Analysis) The impact of massive new RO is less than operational RO but it is positive for T and wind

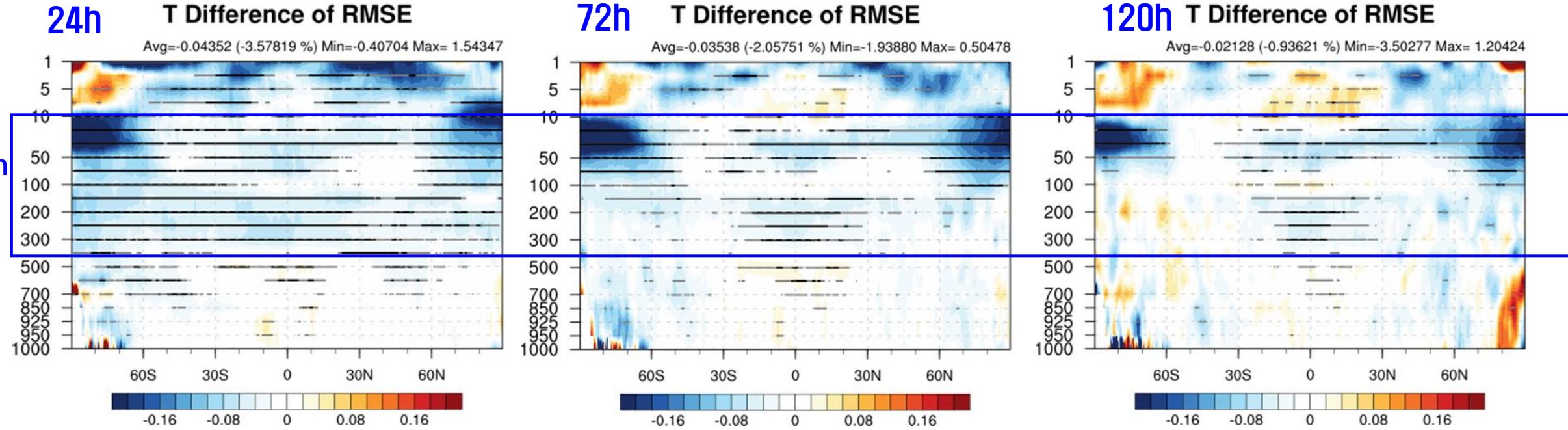
# New RO Impact of forecast for Temperature

Blue: Improved  
Red: Degraded

Difference of RMSD =  $RMSD_{EXP} - RMSD_{CTL}$

※ RMSDs are calculated against ECMWF IFS analysis

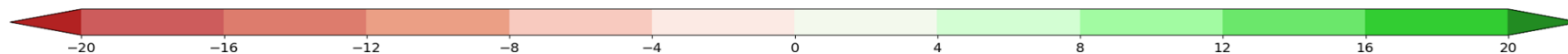
Core region



Improvement rate[%] =  $(RMSD_{CTL} - RMSD_{EXP}) / RMSD_{CTL} \times 100$

		Globe						North Hemisphere						Tropics						South Hemisphere					
		0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
T	50hPa	5.94	4.35	4.06	3.98	4.04	3.46	2.93	2.40	2.50	3.33	3.40	3.57	6.46	4.45	3.97	3.51	3.64	3.50	8.14	6.23	5.98	5.91	5.48	3.39
T	100hPa	6.77	2.11	0.72	0.09	-0.53	-0.78	6.49	2.91	1.62	1.03	0.43	0.35	4.71	0.70	-0.39	-0.78	-1.24	-1.60	11.57	5.85	3.45	1.62	0.01	-0.73
T	250hPa	12.24	6.42	3.30	1.90	1.26	0.68	9.38	4.80	2.63	1.55	1.72	0.98	16.47	8.37	5.87	4.35	4.18	3.60	11.63	6.55	2.66	1.42	-0.02	-0.23
T	500hPa	4.39	0.64	0.38	0.40	0.43	0.07	3.99	0.89	0.78	0.50	0.77	0.57	1.25	-2.99	-3.44	-3.09	-2.61	-1.53	7.52	3.39	2.07	1.48	0.82	-0.08
T	850hPa	1.05	0.92	0.52	0.44	0.39	0.26	0.86	0.75	0.51	0.74	0.92	0.68	-0.12	-0.02	-0.17	-0.51	-0.82	-1.13	2.06	1.83	1.06	0.86	0.59	0.49

Degraded



Improved

✓ The impact on high-altitude temperature is positive until the 5-day forecast, especially in polar region.

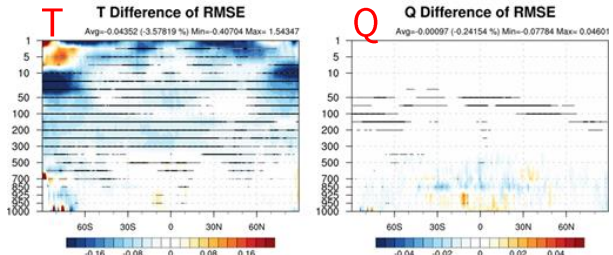
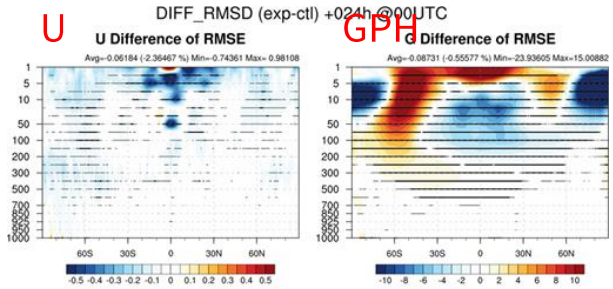


# New RO Impact of forecast for Wind, GPH, T, Q

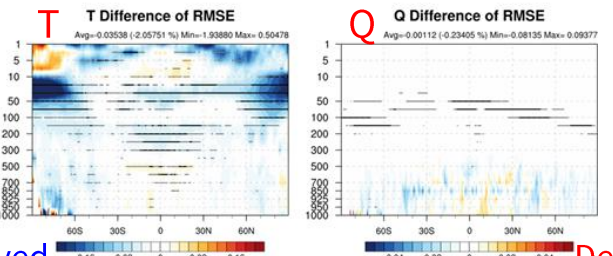
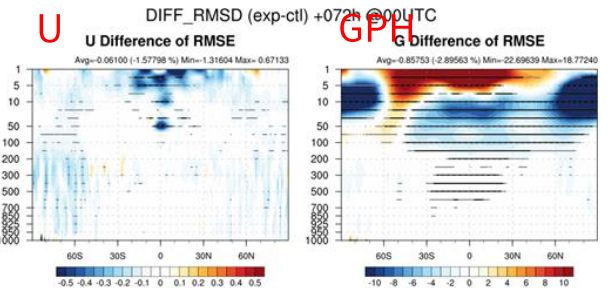
Difference of RMSD =  $RMSD_{EXP} - RMSD_{CTL}$

※ RMSDs are calculated against ECMWF IFS analysis

24h



72h



Improved

Degraded

Z score

Q

Wind Speed

GPH

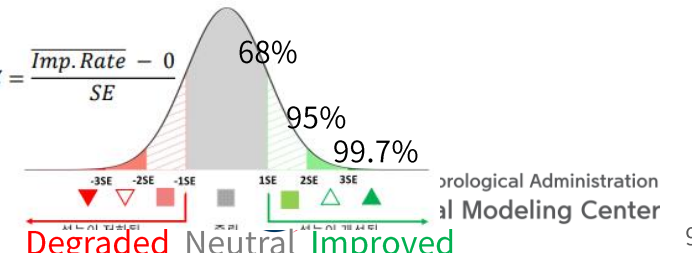
T

		Globe						North Hemisphere						Tropics						South Hemisphere										
		0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120					
Q	700hPa	▲	△							■						▲	▲							■						Improved
WS	50hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		
WS	100hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
WS	250hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	3 SE	
WS	500hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	△	
WS	850hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	2 SE	
GPH	50hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	1 SE	
GPH	100hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		
GPH	250hPa	▲	■	▲	▲	▲	▲	▼	▲	▲	▲	▲	▲	▲	▲	■	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	1 SE		
GPH	500hPa	▼	▼	▲	▲	▲	▲	▼	▼	▲	▲	▲	▲	▼	▼	▼	▼	▼	▼	▲	▲	▼	▼	▲	▲	▲	▲	2 SE		
GPH	850hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		
T	50hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	
T	100hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	■	▼	▼	▼	▲	▲	▲	▲	▲	▲	▲	▲	3 SE	
T	250hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	
T	500hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▼	▼	▼	▼	▲	▲	▲	▲	▲	▲	▲	▲		
T	850hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	■	▼	▼	▼	▲	▲	▲	▲	▲	▲	▲	▲	Degraded	

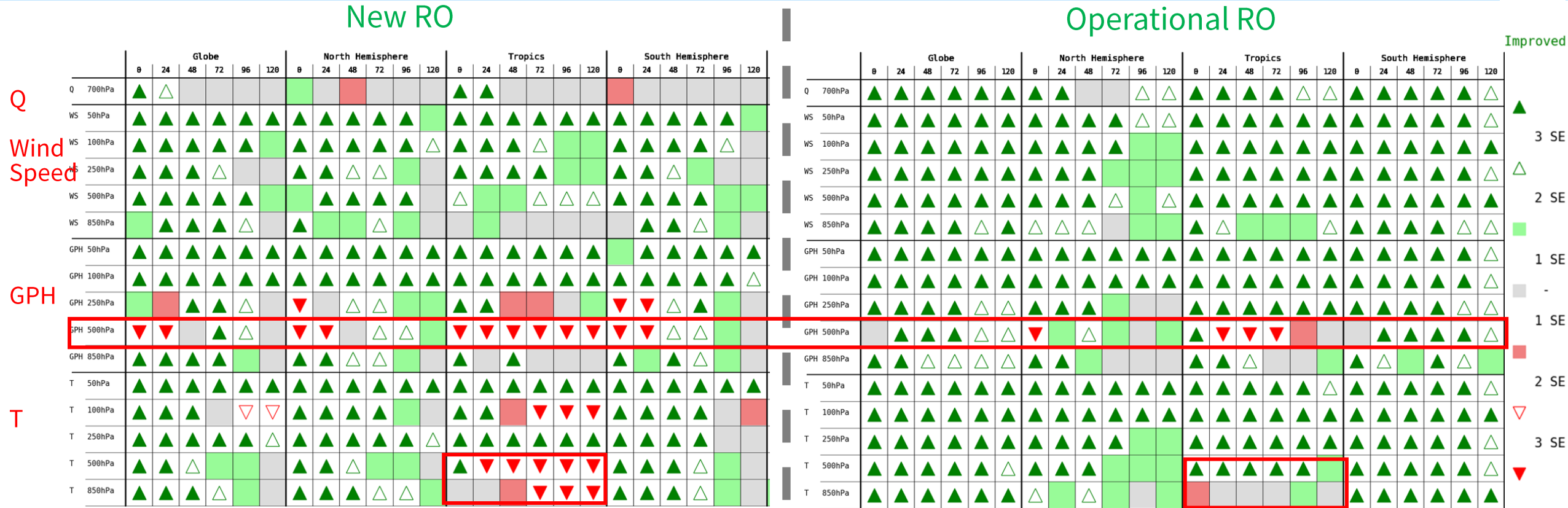
$$Imp. Rate = \frac{RMSD_{EXP} - RMSD_{CTL}}{RMSD_{CTL}}$$

at each time

$$SE = \frac{\sigma_{Imp.Rate}}{\sqrt{N}} \quad Z = \frac{Imp.Rate - 0}{SE}$$



# Impact of forecast: Z core (New RO vs. Operational RO)



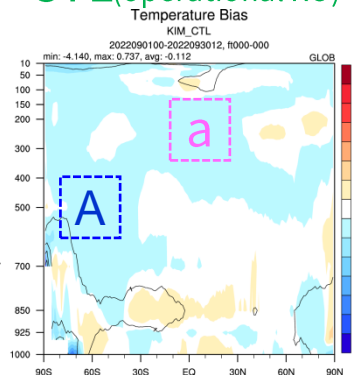
✓ The impact of massive new RO is less than operational RO, but it has positive potential for T

✓ There are some side effects in GPH for short-term forecast

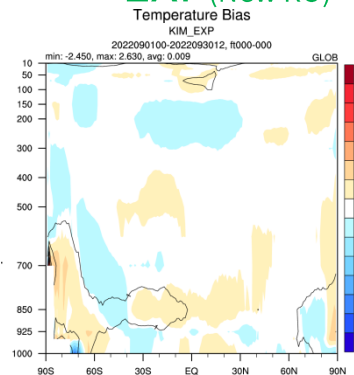
Variable	New RO	Operational RO
T	Positive impact at the higher altitude than 250hPa Negative impact at 850~500hPa of Tropics	Globally Positive impact at whole levels and all forecast time except for GPH 500hPa at NH and tropics on some forecast time
GPH	Negative impact at 500hPa until 1 day forecast	
WS	Positive impact on 0~3 day forecast	
Q	Neutral	

Bias

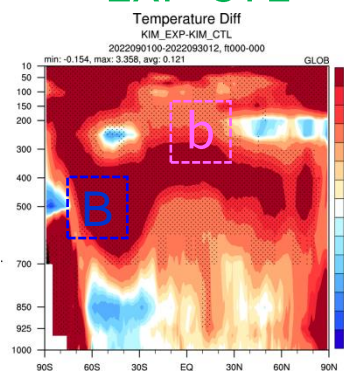
CTL<sub>(operational RO)</sub>



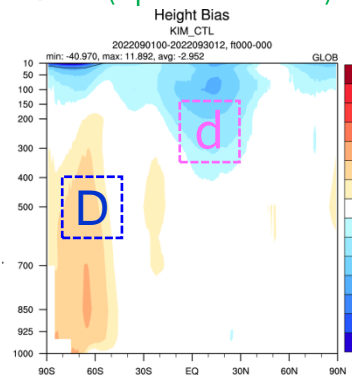
EXP<sub>(New RO)</sub>



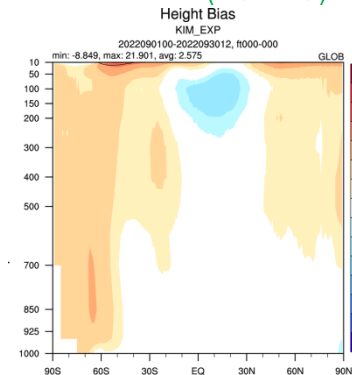
EXP-CTL



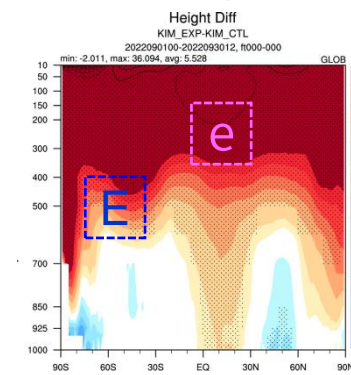
CTL<sub>(operational RO)</sub>



EXP<sub>(New RO)</sub>

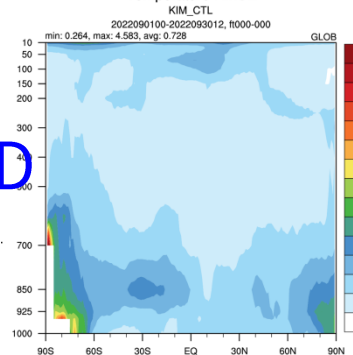


EXP-CTL

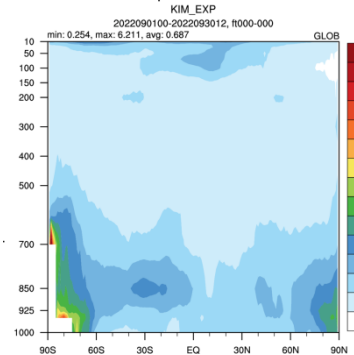


RMSD

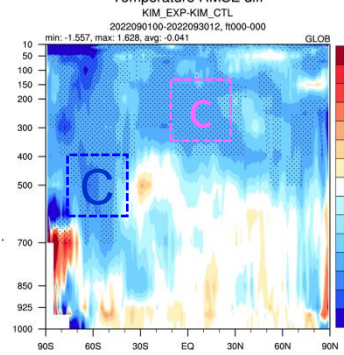
Temperature RMSE



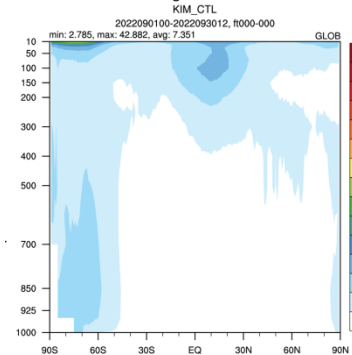
Temperature RMSE



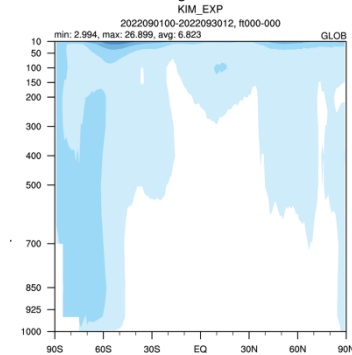
Temperature RMSE diff



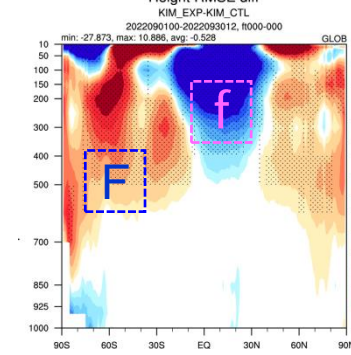
Height RMSE



Height RMSE



Height RMSE diff



- The adding of new RO generally leads to an increase in T (B,b). Consequently, this results in an elevation in GPH (E,e).
- The determination of RMSD improvement is dependent on the pattern of biases in T and GPH.

Blue box	Bias of CTL	RO effect on bias	Bias of EXP	RMSD
T	⊖⊖ (A)	⊕ (B)	⊖ Improved	Improved (C)
GPH	⊕⊕ (D)	⊕ (E)	⊕⊕⊕ Degraded	Degraded (F)

Pink box	Bias of CTL	RO effect on bias	Bias of EXP	RMSD
T	⊖⊖ (a)	⊕ (b)	⊖ Improved	Improved (c)
GPH	⊖⊖ (d)	⊕ (e)	⊖ Improved	Improved (f)

# Adjustment of Observation error inflation

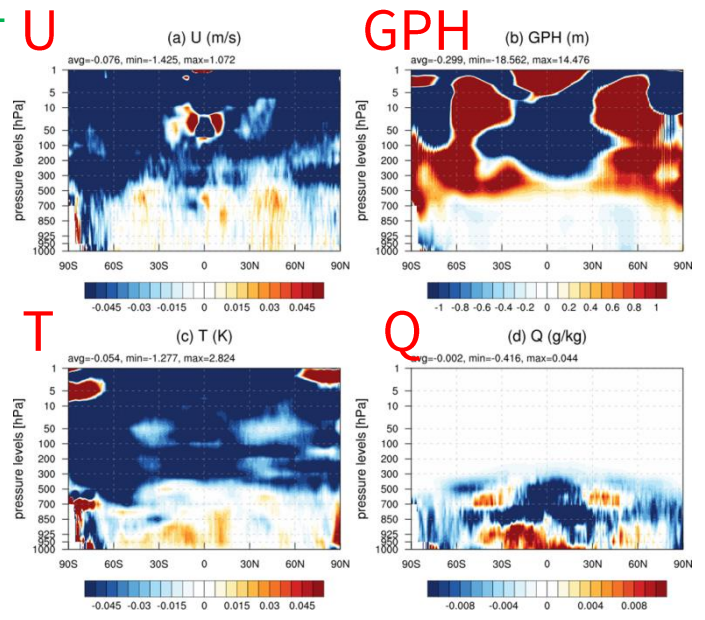
Blue: Improved  
Red: Degraded

Difference of RMSD =  $\text{RMSD}_{\text{EXP}} - \text{RMSD}_{\text{CTL}}$

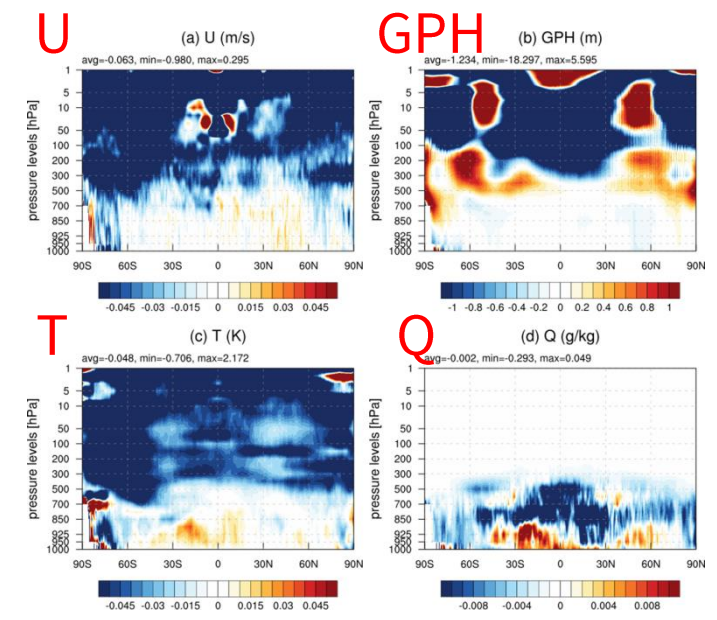
※ RMSDs are calculated against ECMWF IFS analysis

$\sigma_o$  : observation error of CTL

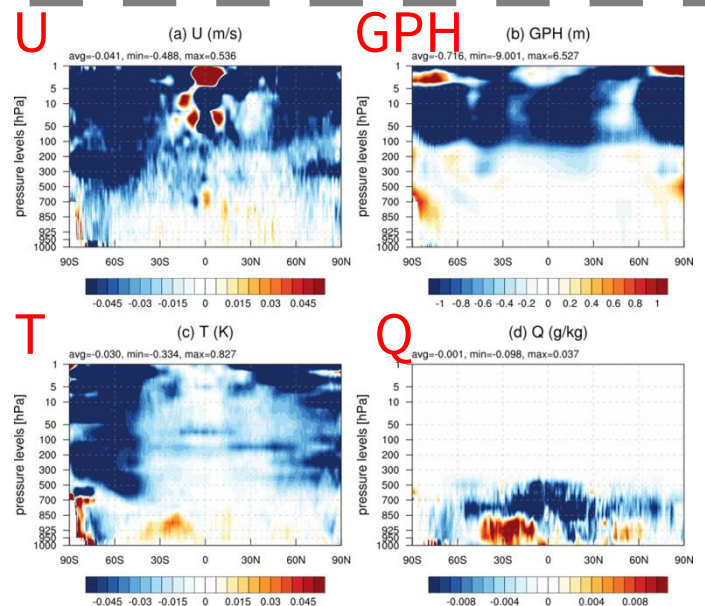
$\sigma_o \times \sqrt{1}$



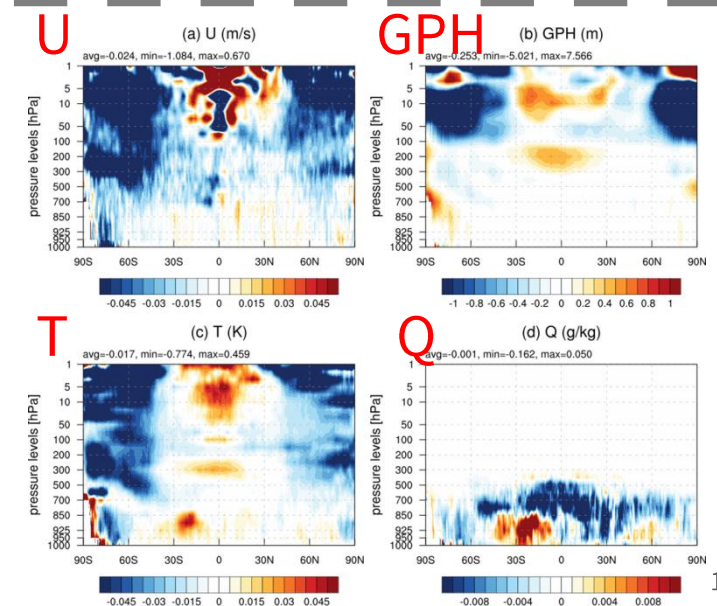
$\sigma_o \times \sqrt{1.5}$



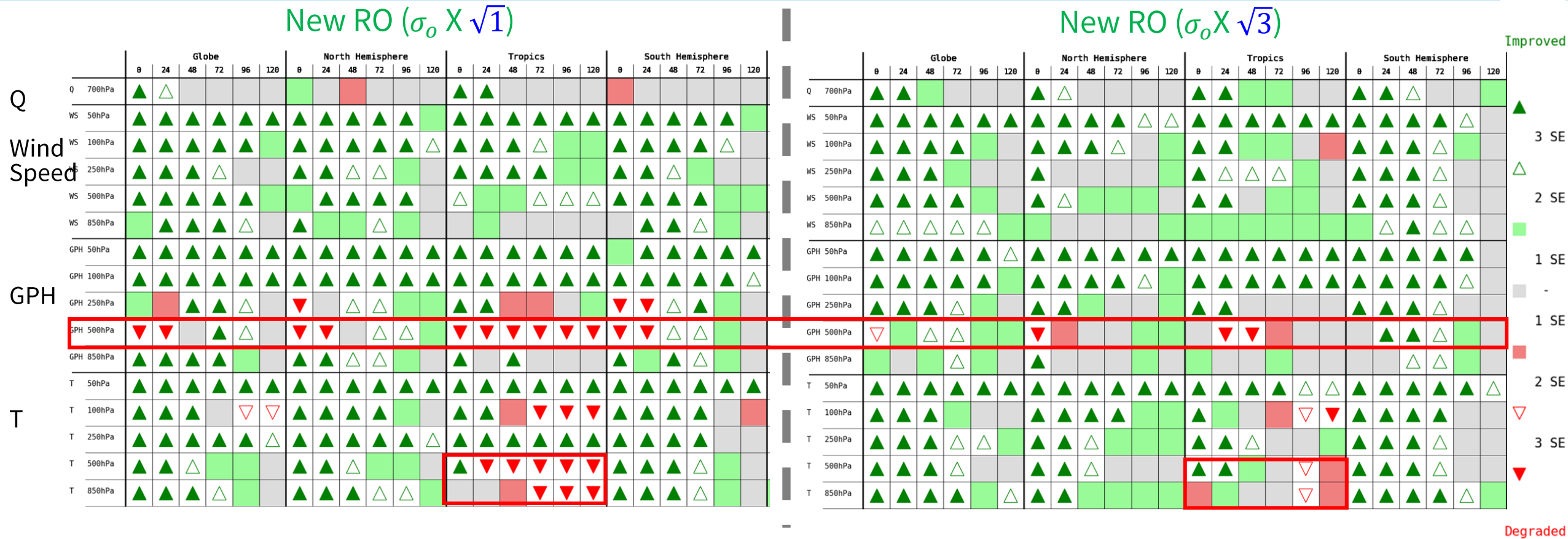
$\sigma_o \times \sqrt{3}$



$\sigma_o \times \sqrt{4.5}$



# Impact of forecast: Z core (New RO vs. Obs. error Adjust)



✓ After inflation of the observation error, the side effects in the red boxes were greatly reduced.

Variable	New RO ( $\sigma_0 \times \sqrt{1}$ )	New RO ( $\sigma_0 \times \sqrt{3}$ )
T	Positive impact at the higher altitude than 250hPa Negative impact at 850~500hPa of Tropics	The negative impact seen in the Tropics are greatly reduced.
GPH	Negative impact at 500hPa until 1 day forecast	The negative effects seen at 500 hPa are greatly reduced.
WS	Positive impact on 0~3 day forecast	Positive impact is slightly reduced in the Northern Hemisphere.
Q	Neutral	The positive impact is improved slightly.

# Summary

## ■ New RO characteristics

- ▶ **(Quality)** Similar to operational RO: standard deviations are similar at core region(7-35km, 400-10hPa)
  - Apply the same quality control process to new RO as well as operational RO
- ▶ **(Quantity)** 4.5 times of the number of operational RO, especially adding observation in polar region

## ■ Impact assessment with new RO compared to operational RO

- ▶ **(O-B, Radiosonde temperature)** The impact of new RO is similar to operational RO
- ▶ **(Analysis)** The impact of massive new RO is less than operational RO but it is **positive for T and wind**
- ▶ **(1-5day Forecast)** The impact on **high-altitude T** is positive until the 5-day forecast, especially in polar region

There are some side effect in GPH

→ By inflating the observation error by a factor of  $\sqrt{3}$ , the side effects that appeared in GPH are reduced.

# Thank you!!



# Backup slides

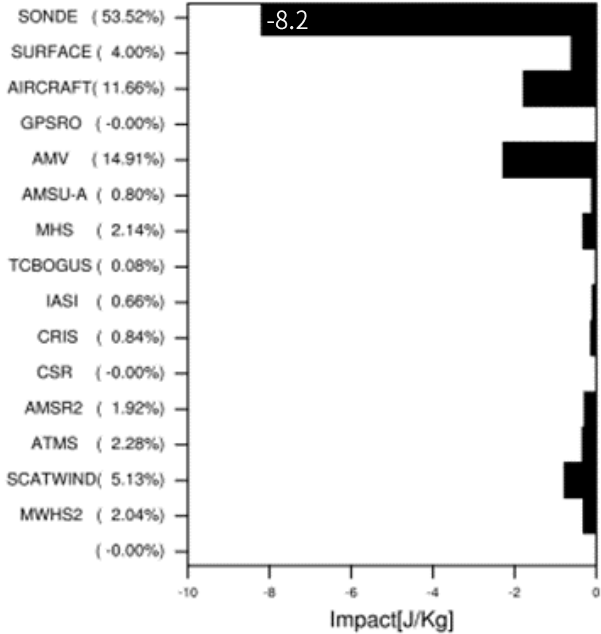




# EFSO with LETKF of KIM

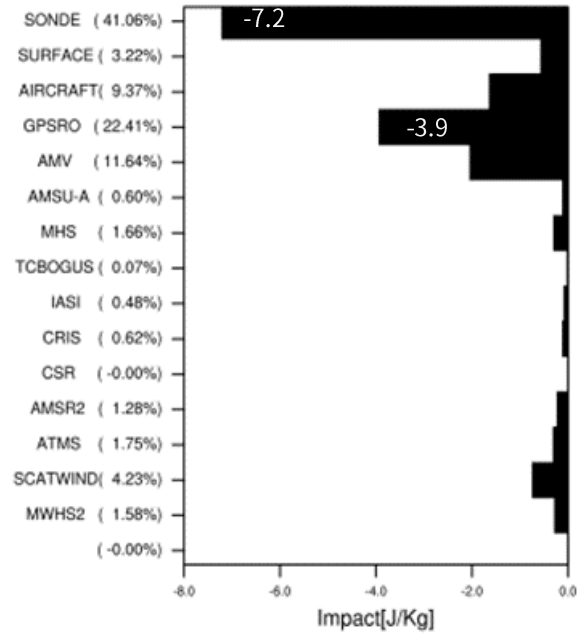
NoRO

Total obs. impact



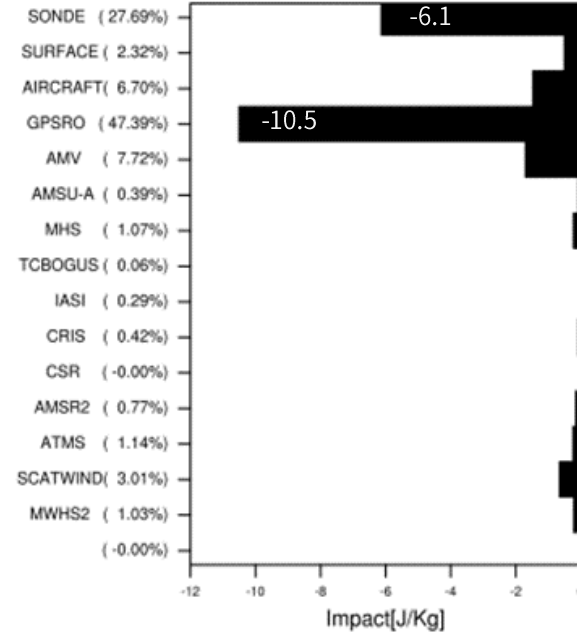
CTL

Total obs. impact



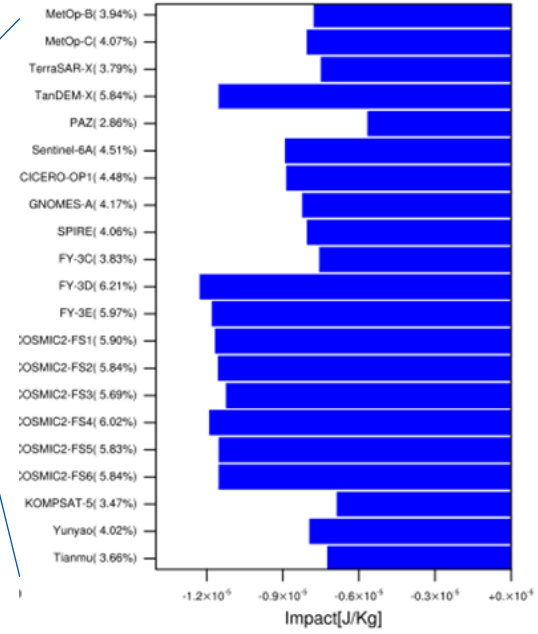
EXP

Total obs. impact



Each RO

Normalized obs. impact(EXP)



Sum of obs. Impact in Energy norm

-15.31 J/Kg

-17.55 J/Kg

-22.20 J/Kg

-2.24 J/Kg  
Operational RO impact

-4.65 J/Kg  
New RO impact

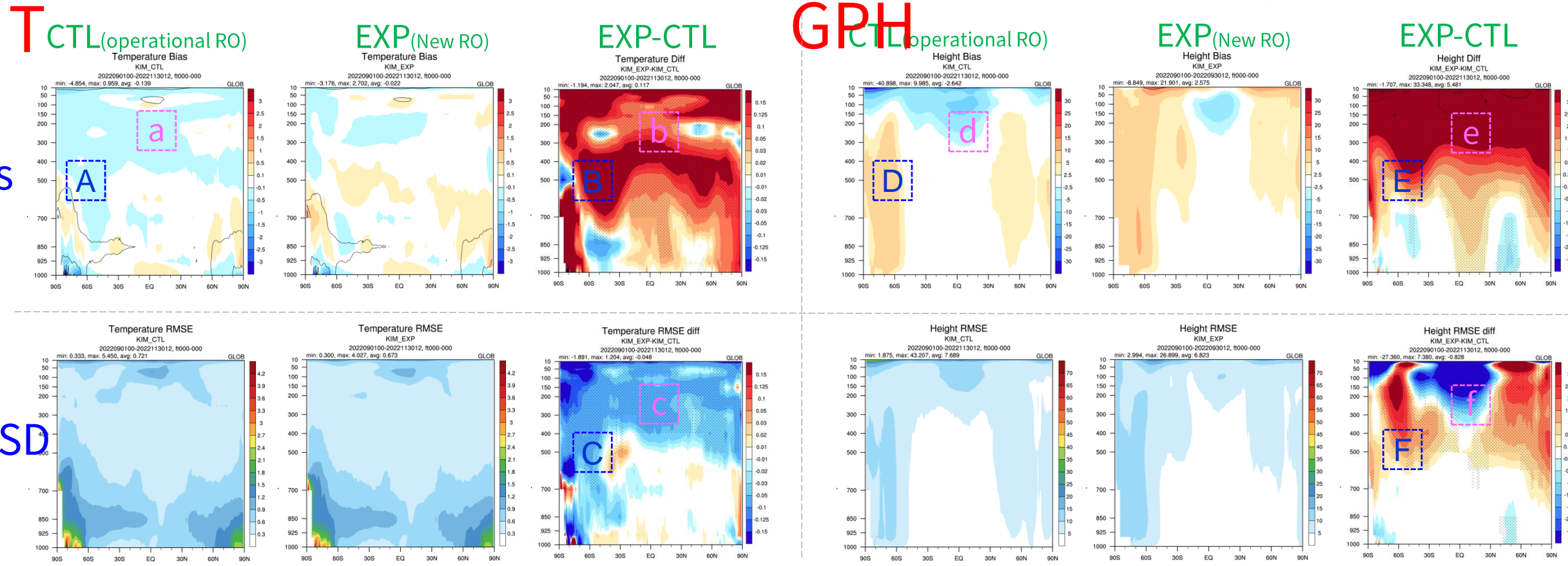
✓ The impacts normalized by the number of obs. are at a similar level regardless of satellites

✓ EFSO impact is double by adding 3.5 times more new RO than operational RO  
 → Even if the efficiency of new RO is slightly lower than operational RO, New RO is still valid

# Forecast time 000h

# CTL<sub>(operational RO)</sub> VS. EXP<sub>(New RO)</sub>

※ Bias and RMSD are calculated against ERA5 analysis



Bias

RMSD

- The adding of new RO generally leads to an increase in T (B, b). Consequently, this results in an elevation in GPH (E, e).
- The determination of RMSD improvement is dependent on the pattern of biases in T and GPH.

Blue box	Bias of CTL	RO effect on bias	Bias of EXP	RMSD
T	⊖⊖ (A)	⊕ (B)	⊖ Improved	Improved (C)
GPH	⊕⊕ (D)	⊕ (E)	⊕⊕⊕ Degraded	Degraded (F)

Pink box	Bias of CTL	RO effect on bias	Bias of EXP	RMSD
T	⊖⊖ (a)	⊕ (b)	⊖ Improved	Improved (c)
GPH	⊖⊖ (d)	⊕ (e)	⊖ Improved	Improved (f)