Deep learning-based data assimilation using multi-source data

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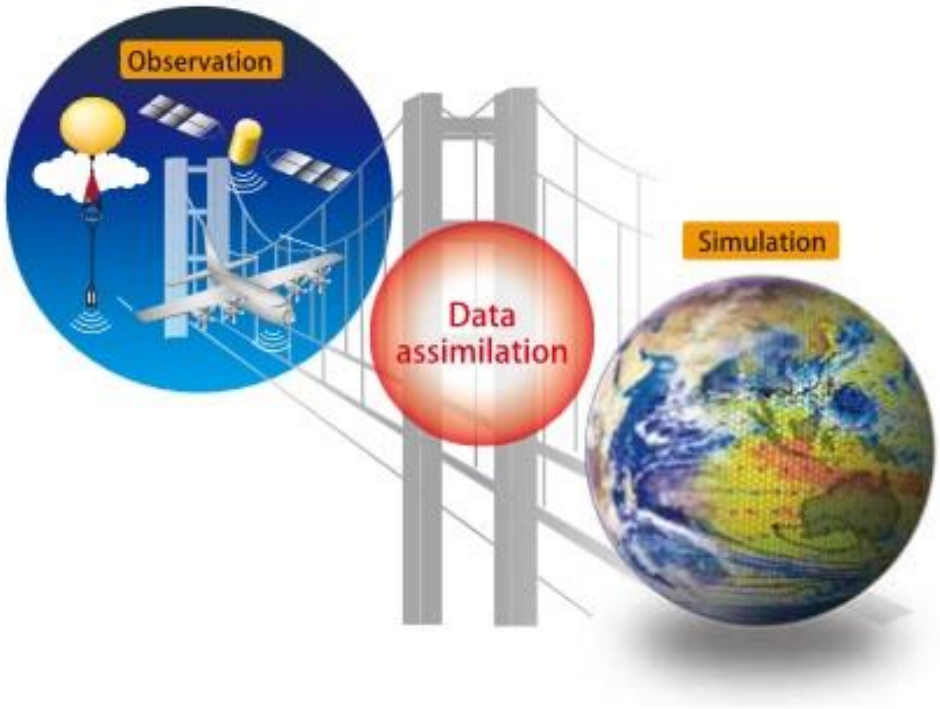
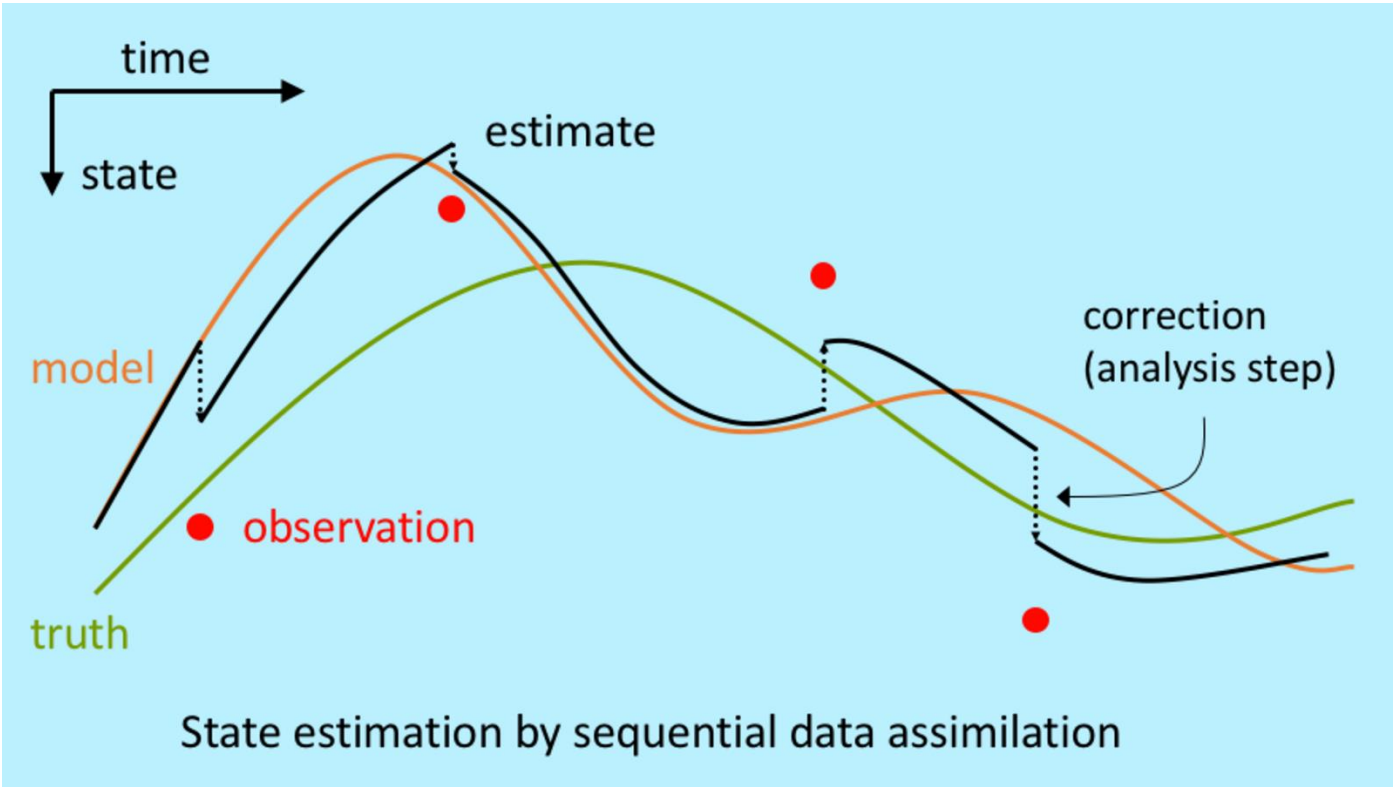
Introduction

- What is the **data assimilation** (DA)?

"Data assimilation is commonly considered as a way of keeping a model 'on the tracks' by constantly correcting it with fresh observations"



Source: RIKEN



Source: EGU19

Introduction

- Recent progresses of DA

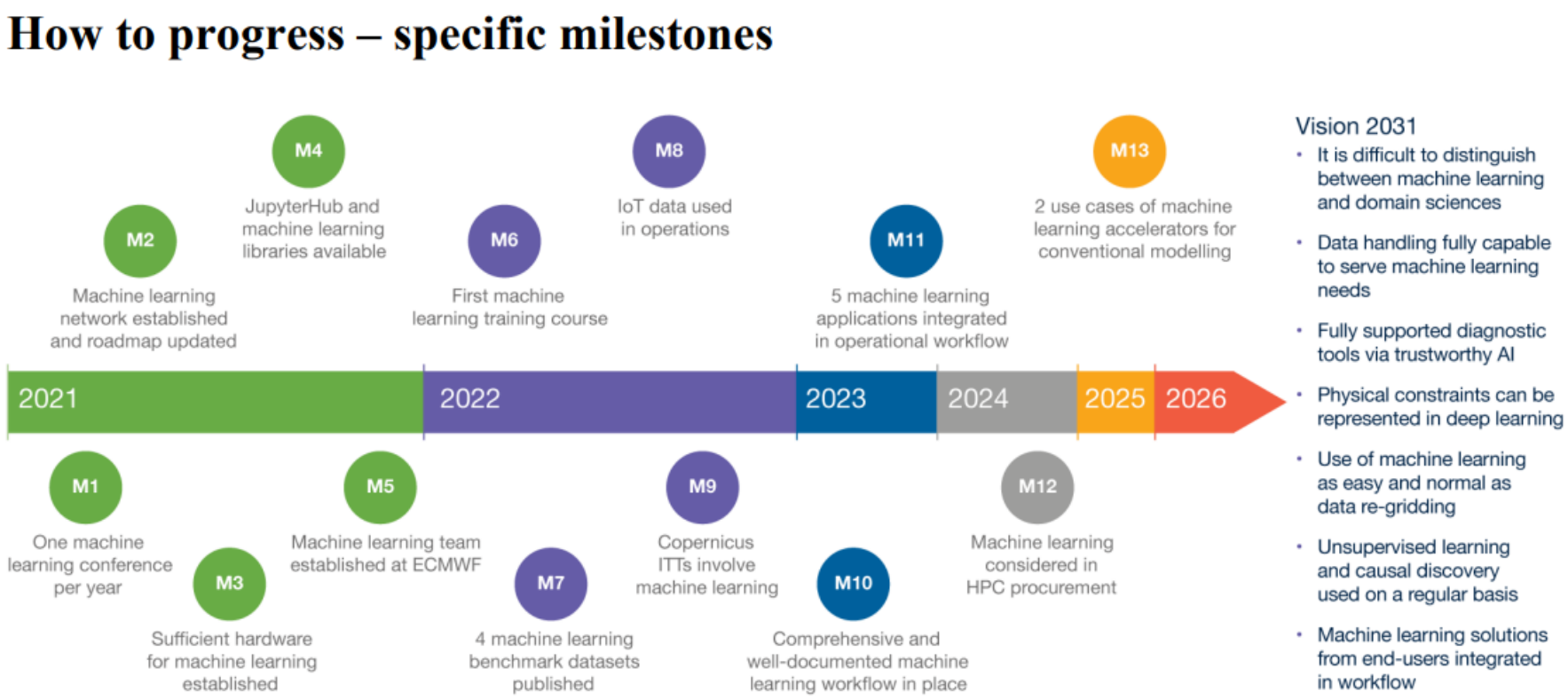
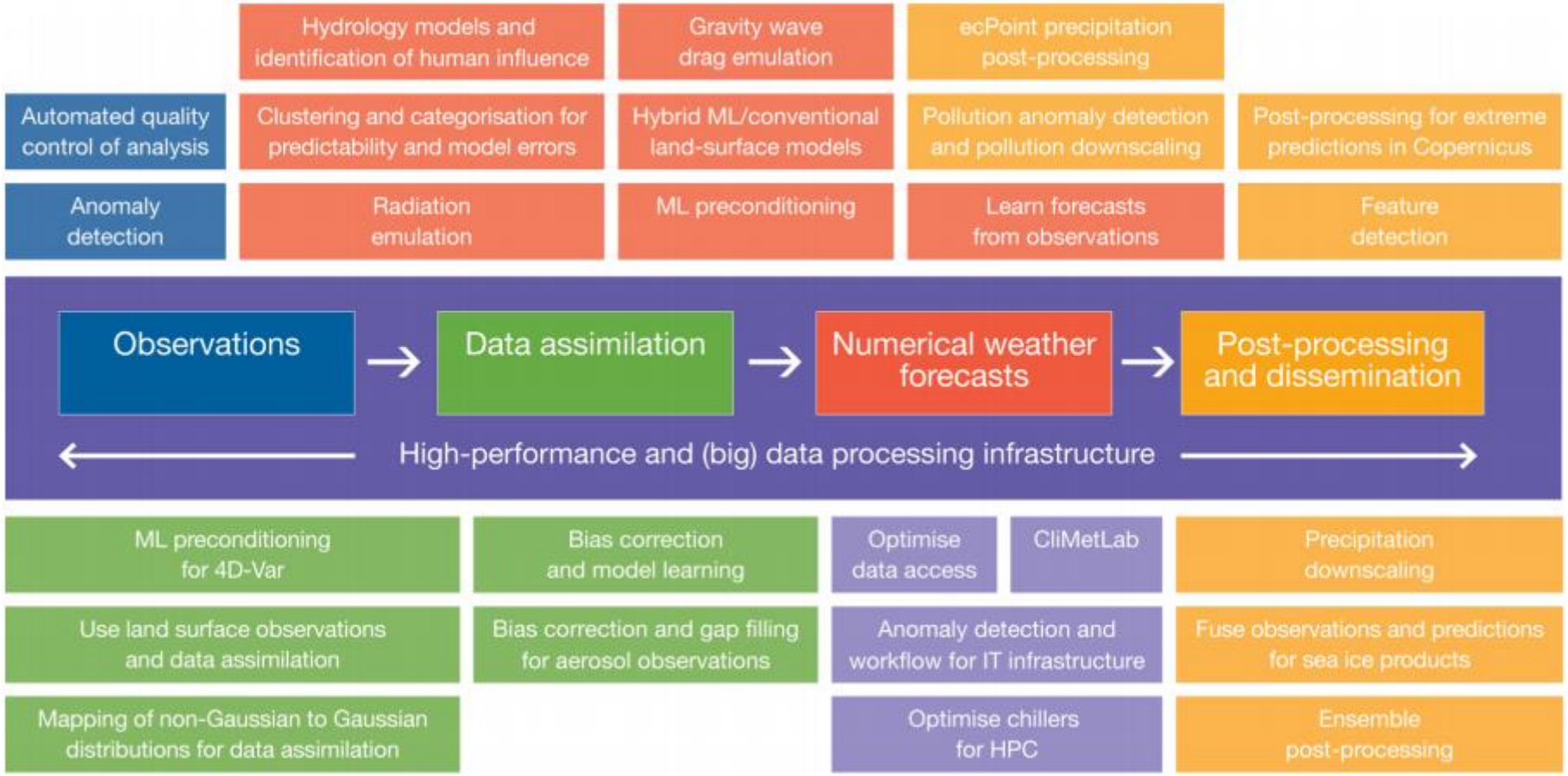


Figure 2: Timeline of machine learning developments at ECMWF with all milestones.

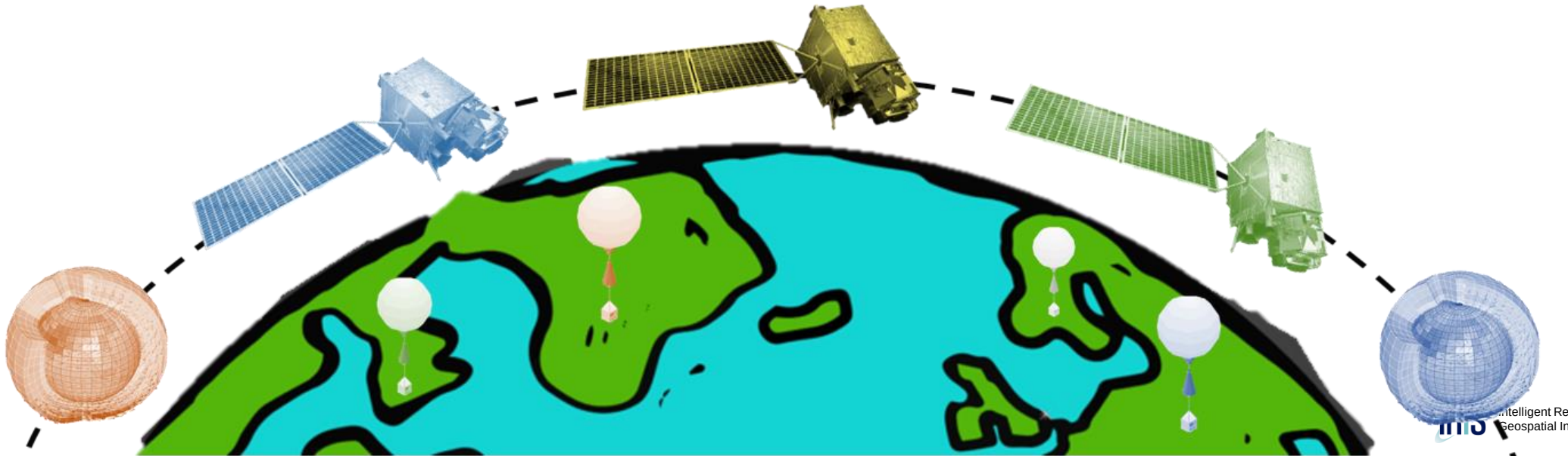
Introduction

- Recent progresses of DA



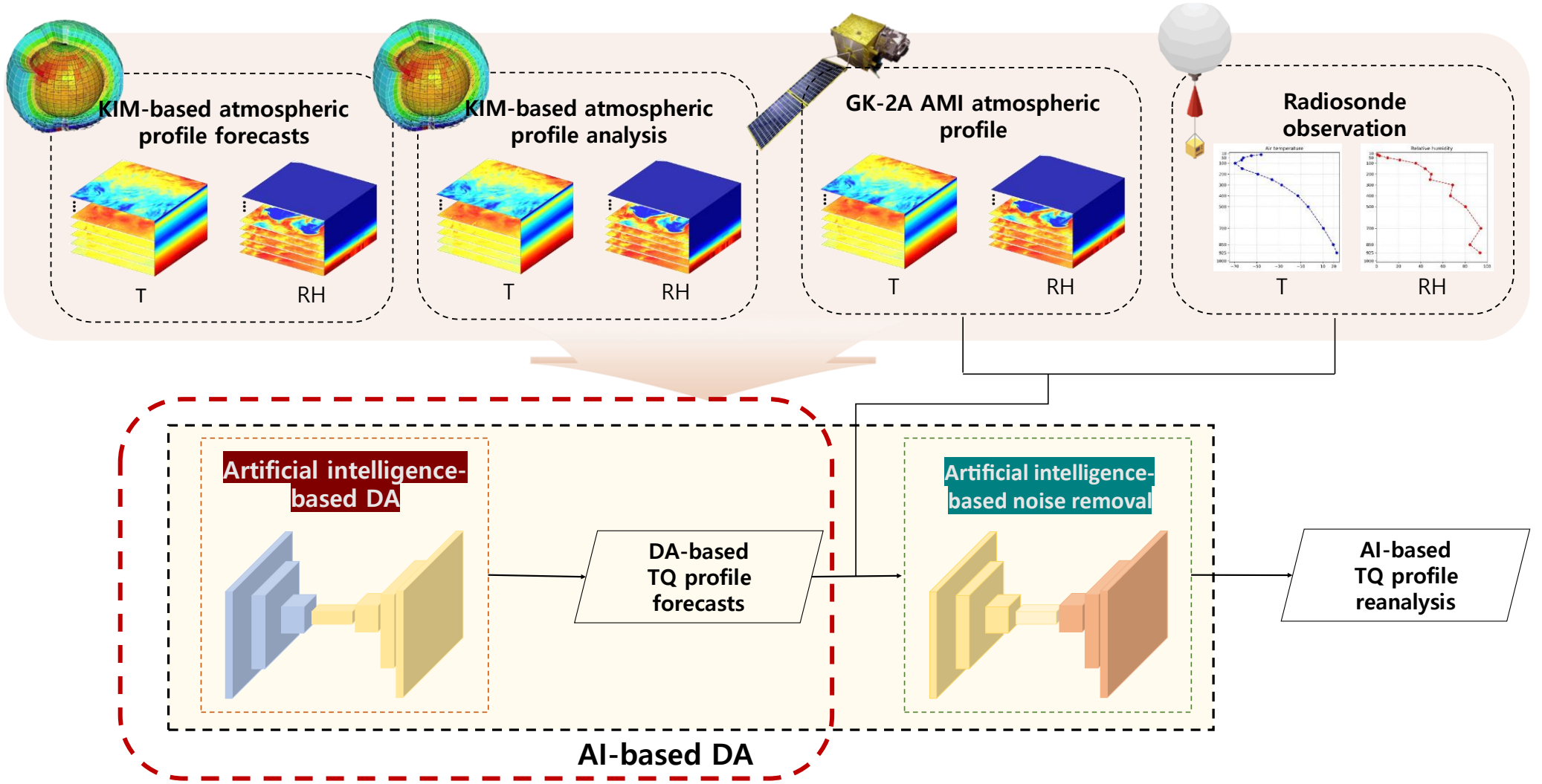
Introduction

"Propose deep learning-based data assimilation using multi-source data"

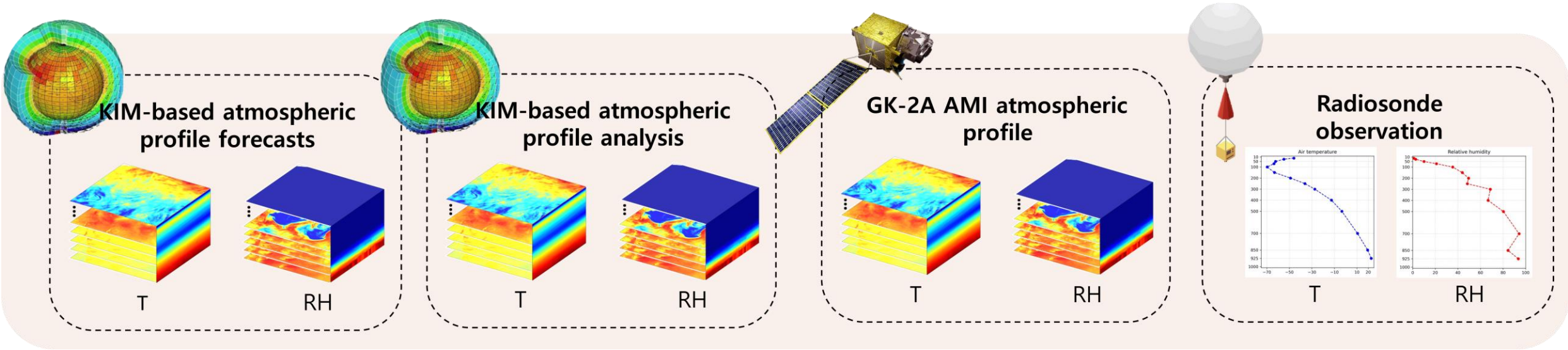


Deep learning-based data assimilation

- Overall study flow



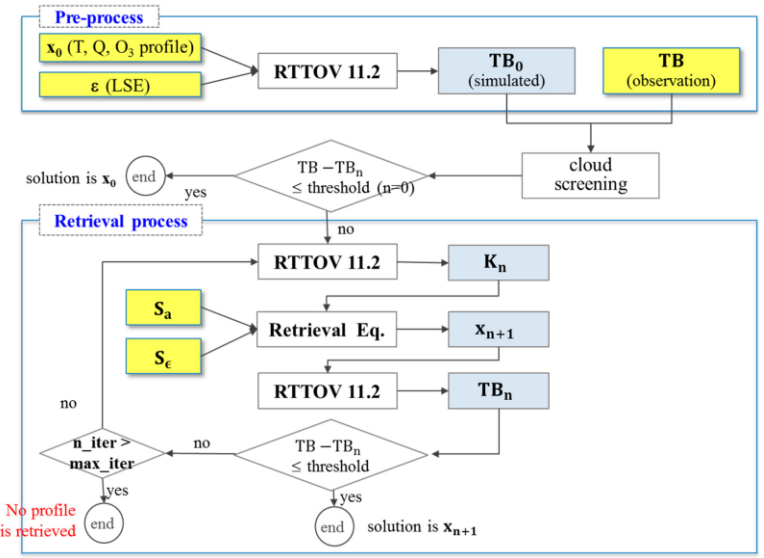
Data and method



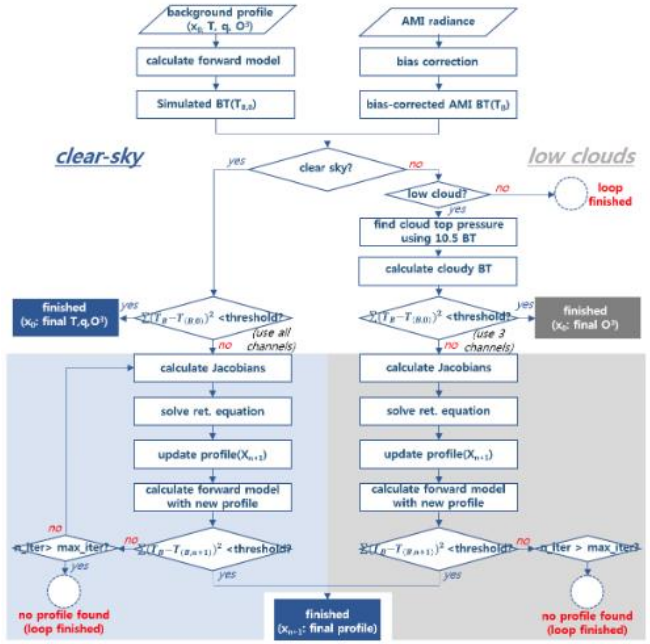
Data	Paramters	Temporal resolution	Spatial resolution	Study area	Source
KIM	**Temperature, relative humidity**	**6 hrs**	**12 km**	**East Asia**	**KMA**
GK2A AAP	**Temperature, relative humidity**	**1 hrs**	**6 km**		**NMSC**
Radio sonde	**Temperature, dew point depression**	**12 hrs**	**Point**		**NOAA ESRL**
GNSS-RO	Temperature, Relative humidity	Irregular	Point		UCAR CDAAC

Data and method

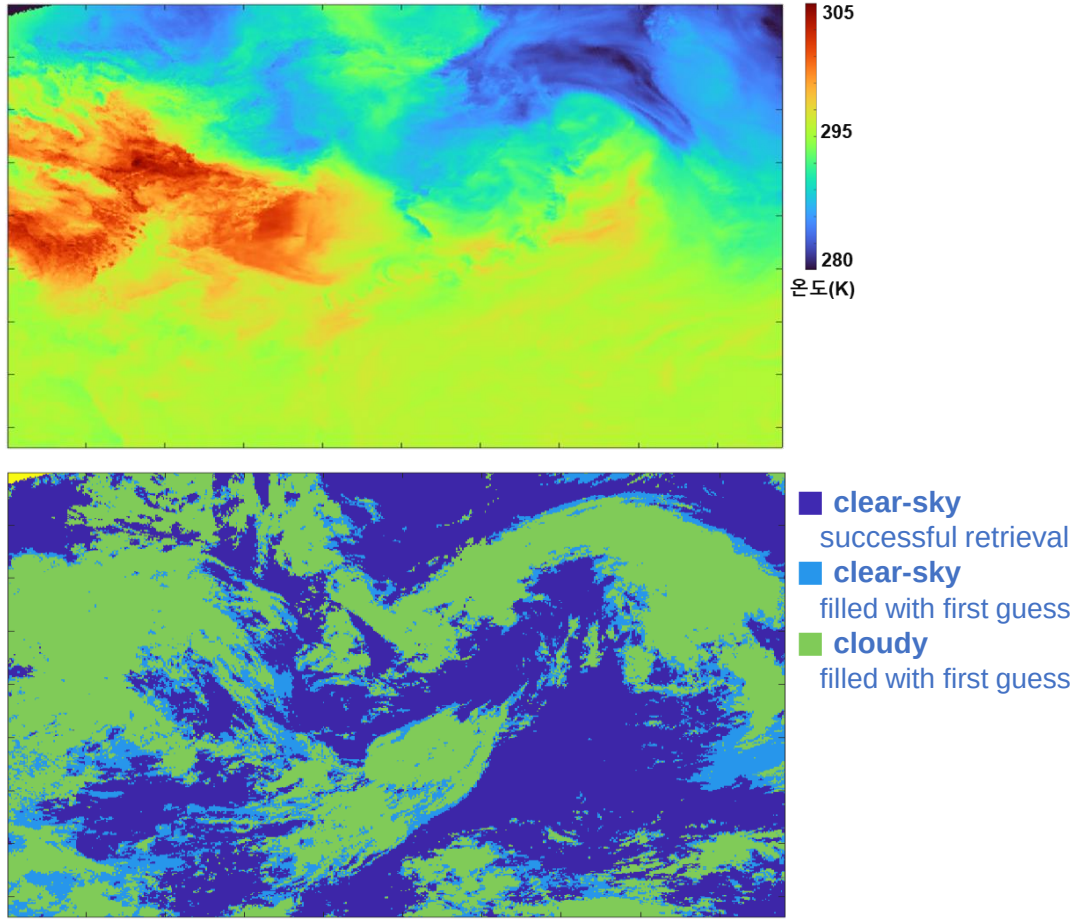
- Data – GK2A L2 AAP temperature and humidity profile



[Geostationary satellite-based TQ retrieval (Lee et al., 2017)]



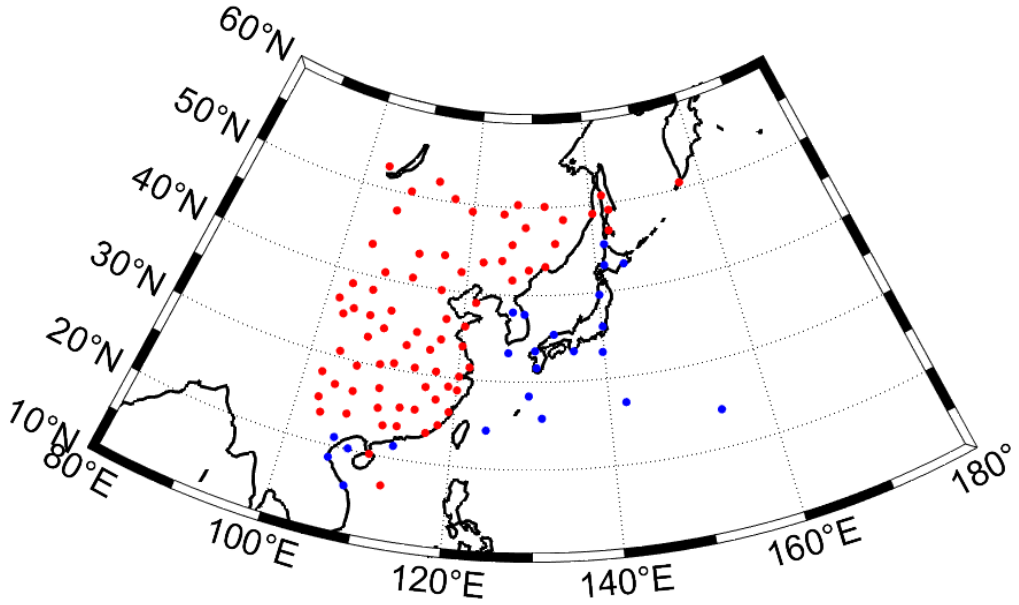
[GK2A AAP Algorithm (GK2A ATBD)]

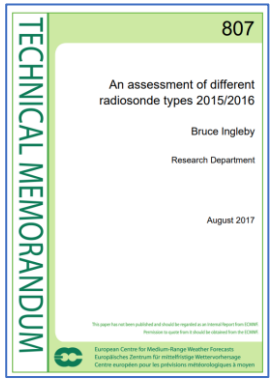


Deep learning-based data assimilation

- Data – Radiosonde observations

Earth System Research Laboratories





[ECMWF Radiosonde technical report(2017)]

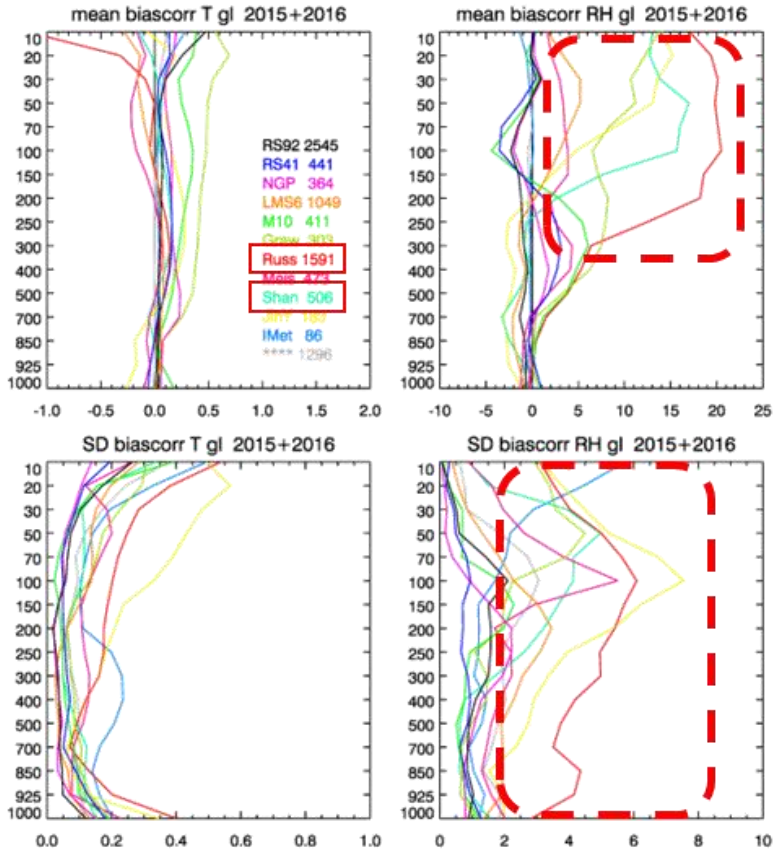


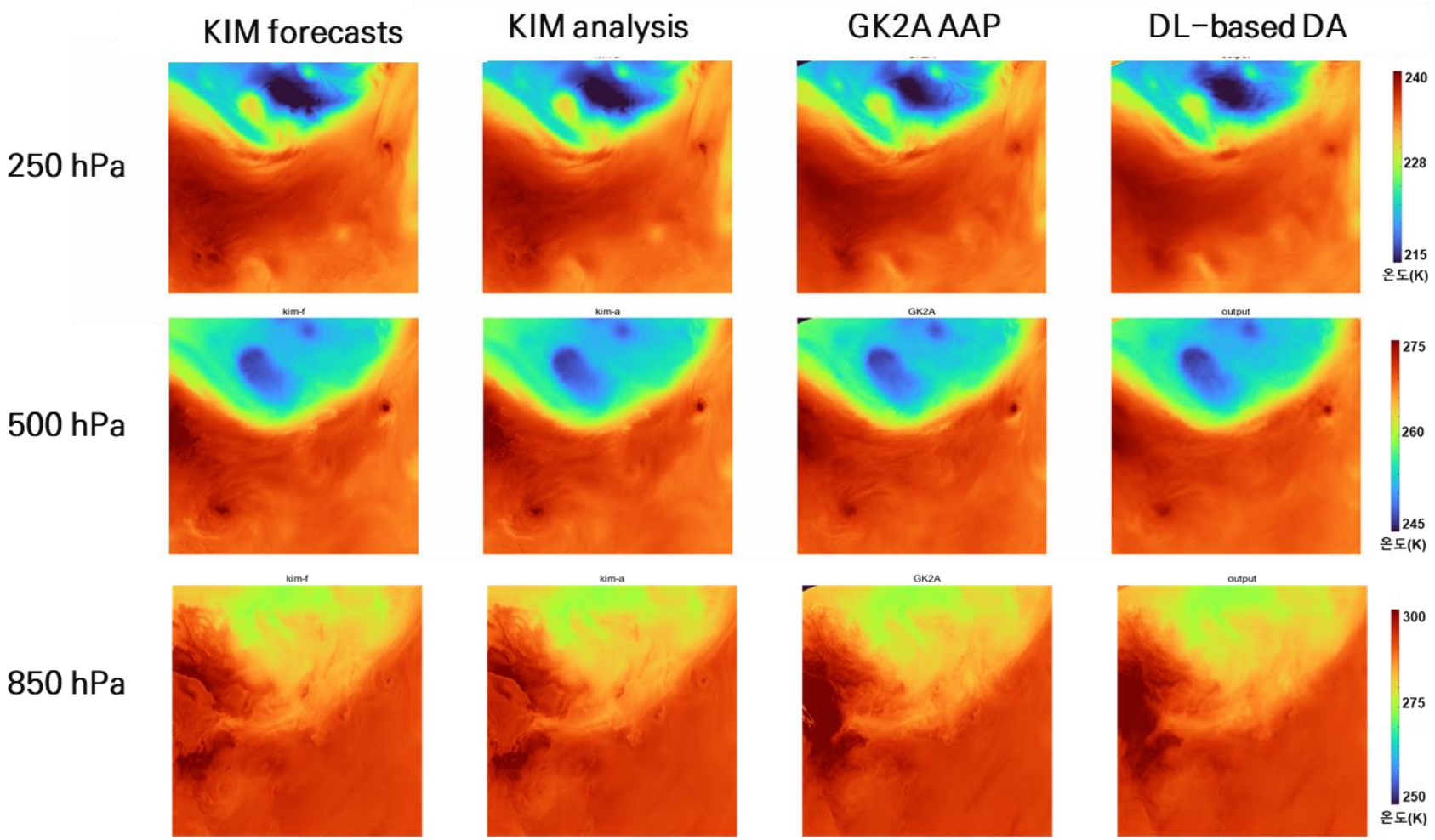
Figure 2.3. Mean and standard deviation (SD) of the bias correction applied (subtracted from reported values) at ECMWF for common types, January 2015 to December 2016, temperature and relative humidity. See key for colours, this also gives (/100) the number of reports for each category (taken as the maximum of the number of reports per standard level).

- 195 stations over the East Asia from 2021 to 2022
- Observation obtained at 00, 12 UTC
- 50% reduction over the China since September in 2021

- ✓ Large observation errors at the China and Russia stations (especially for RH)

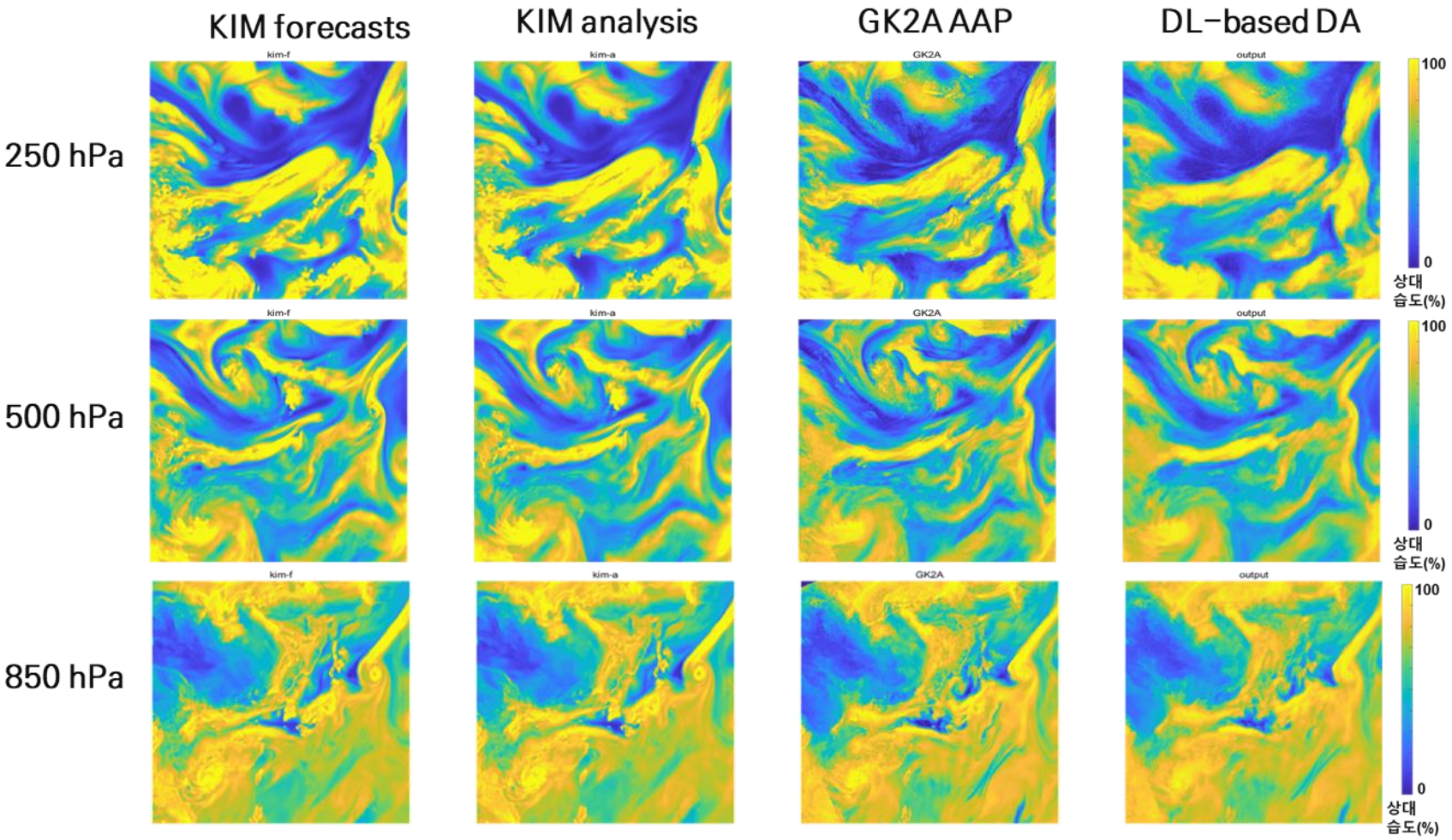
Results

- Temperature profile (08/25/2022 – 08/31/2022)



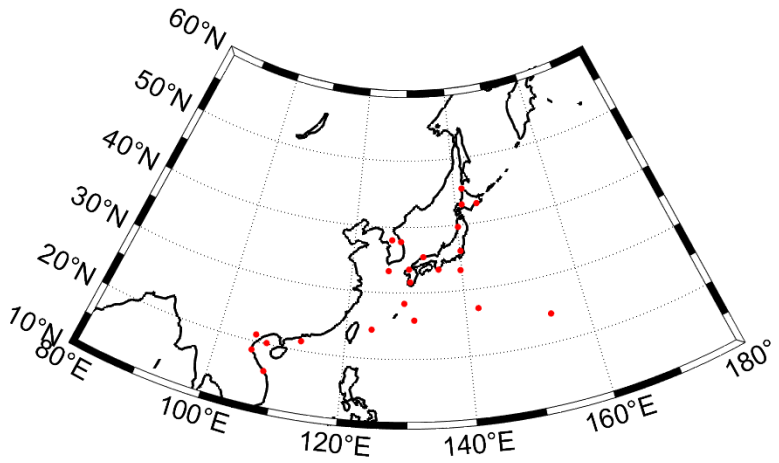
Results

- Relative humidity profile (08/25/2022 – 08/31/2022)



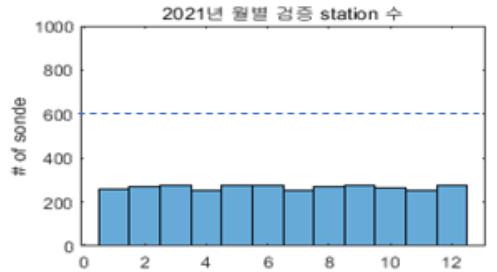
Results

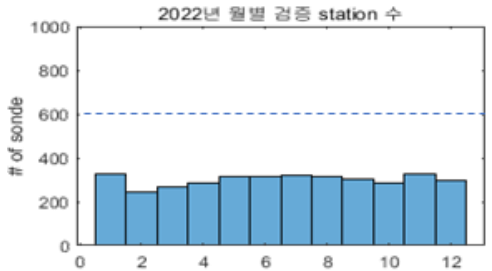
- Evaluation of T and RH profile (at 250, 500, and 850 hPa, all-sky)



Radiosonde stations

- Evaluation for last weeks in 2021-2022
- The radiosonde datasets from the China and Russia were excluded in evaluation due to the quality issues
- Number of observations for evaluations:
  - 250 hPa: 3642/168 days
  - 500 hPa: 6785/168 days
  - 850 hPa: 6828/168 days





RSME	Level (hPa)	ERA5 reanalysis	KIM analysis	KIM forecasts	GK2A AAP	DL-based DA
T (K)	250	1.3255	1.3087	1.3428	1.4535	1.3591
	500	1.3218	1.3336	1.3674	1.4078	1.3678
	850	1.6553	1.6755	1.7218	1.7658	1.6970
RH (%)	250	27.8443	30.2741	30.8899	29.1765	27.6481
	500	23.4858	24.9741	25.4216	24.4263	23.9571
	850	19.8925	21.1495	21.8662	21.0814	20.3274

Results

- Evaluation of T and RH profile (at 250, 500, and 850 hPa, clear and cloudy)

❖ Clear

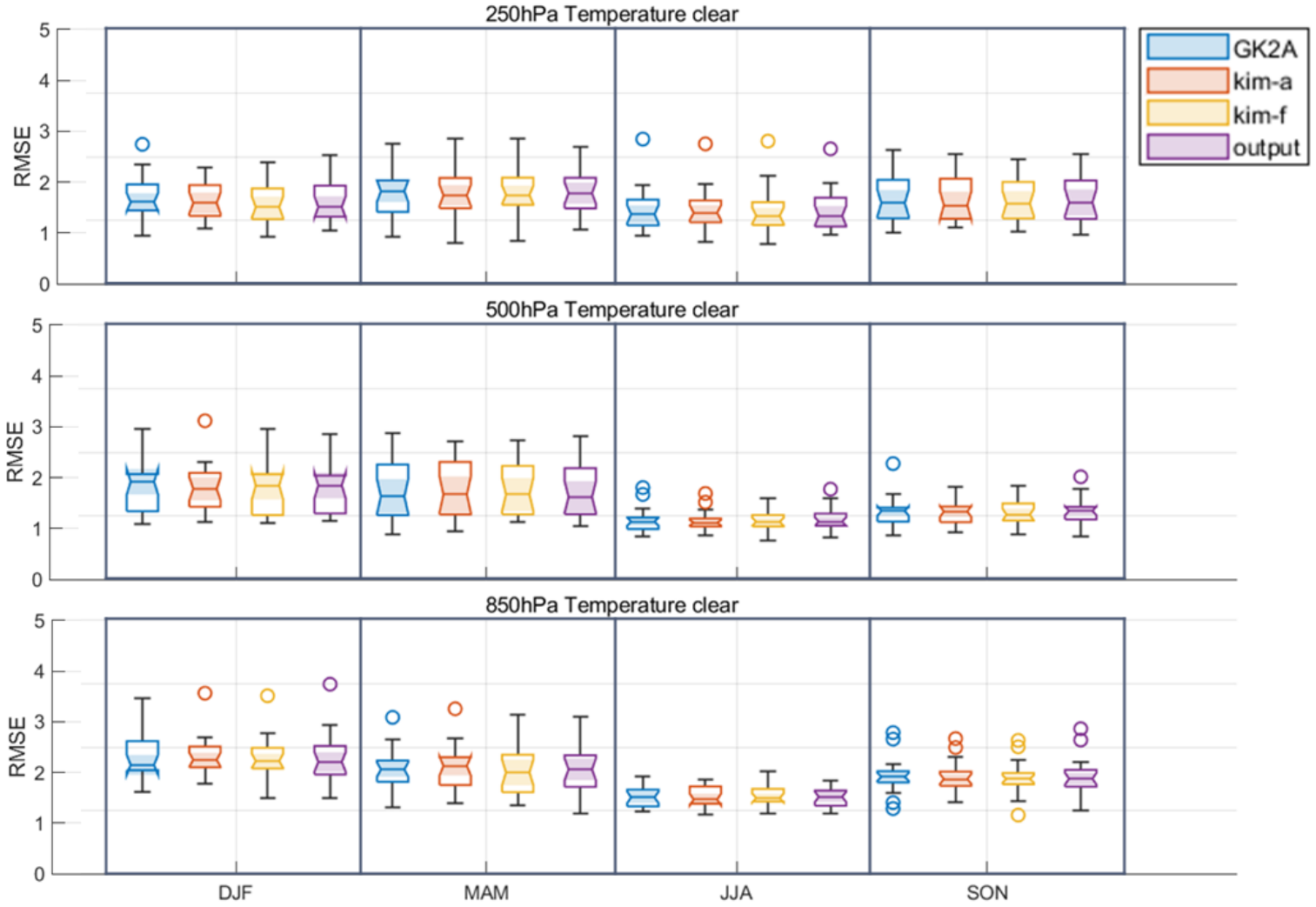
RSME	Level (hPa)	ERA5 reanalysis	KIM analysis	KIM forecasts	GK2A AAP	DL-based DA
T (K)	250	1.3102	1.2958	1.3302	1.4490	1.3583
	500	1.2115	1.2251	1.2556	1.3029	1.2785
	850	1.5517	1.5681	1.6167	1.6640	1.5927
RH (%)	250	20.7766	23.8844	24.7872	20.4925	19.5199
	500	20.1473	21.1310	21.5855	21.1695	20.5273
	850	20.8810	22.2381	22.9755	21.9673	21.2930

❖ Cloudy

RSME	Level (hPa)	ERA5 reanalysis	KIM analysis	KIM forecasts	UM forecasts GK2A AAP	DL-based DA
T (K)	250	1.3405	1.3213	1.3550	1.4579	1.3540
	500	1.4220	1.4324	1.4692	1.5039	1.4503
	850	1.7513	1.7748	1.8194	1.8606	1.7937
RH (%)	250	33.4249	35.5061	35.9458	35.7804	33.8483
	500	26.3723	28.2624	28.7127	27.2646	26.9166
	850	18.8683	20.0195	20.7157	20.2031	19.3293

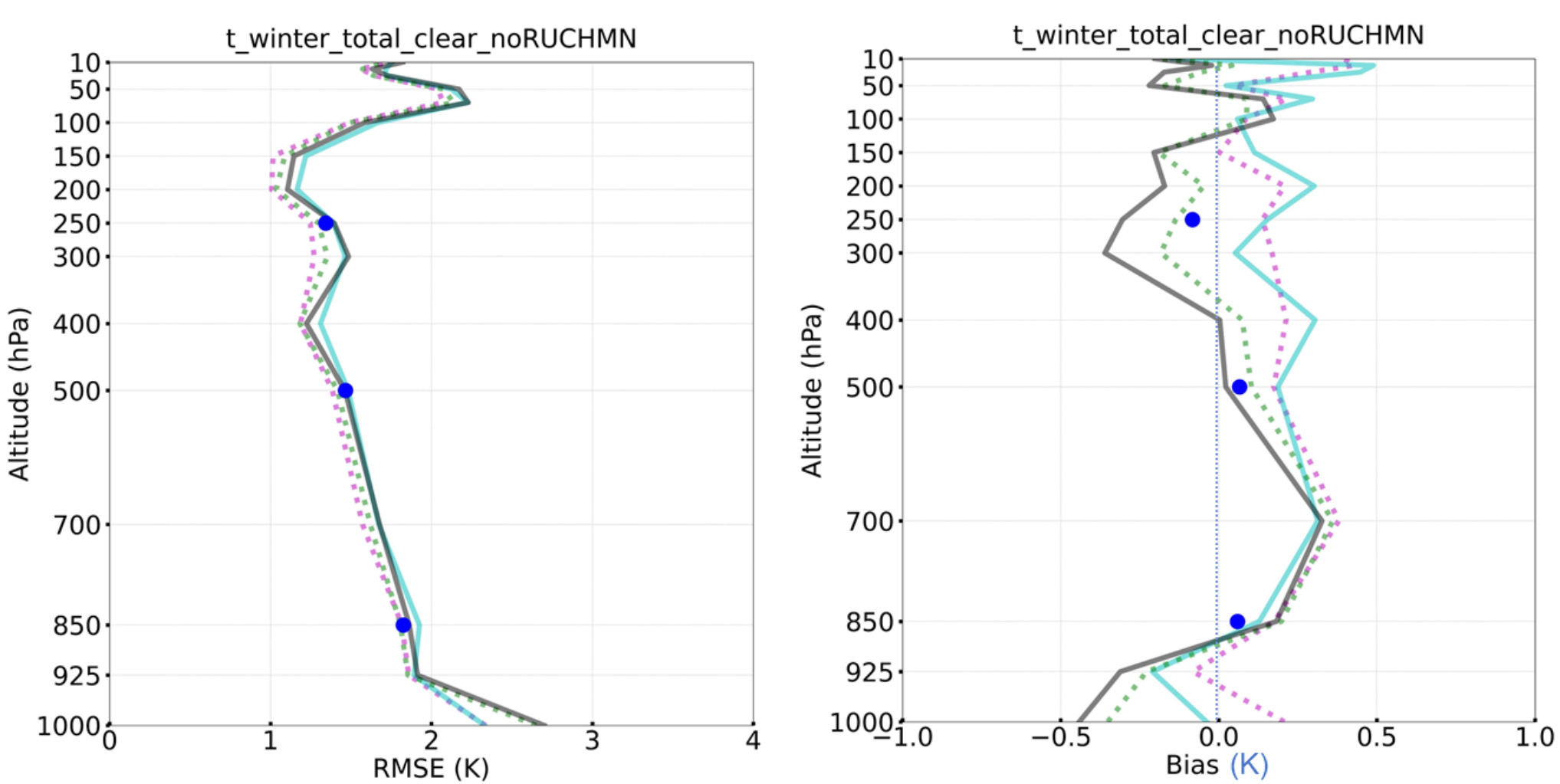
Results

- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear)



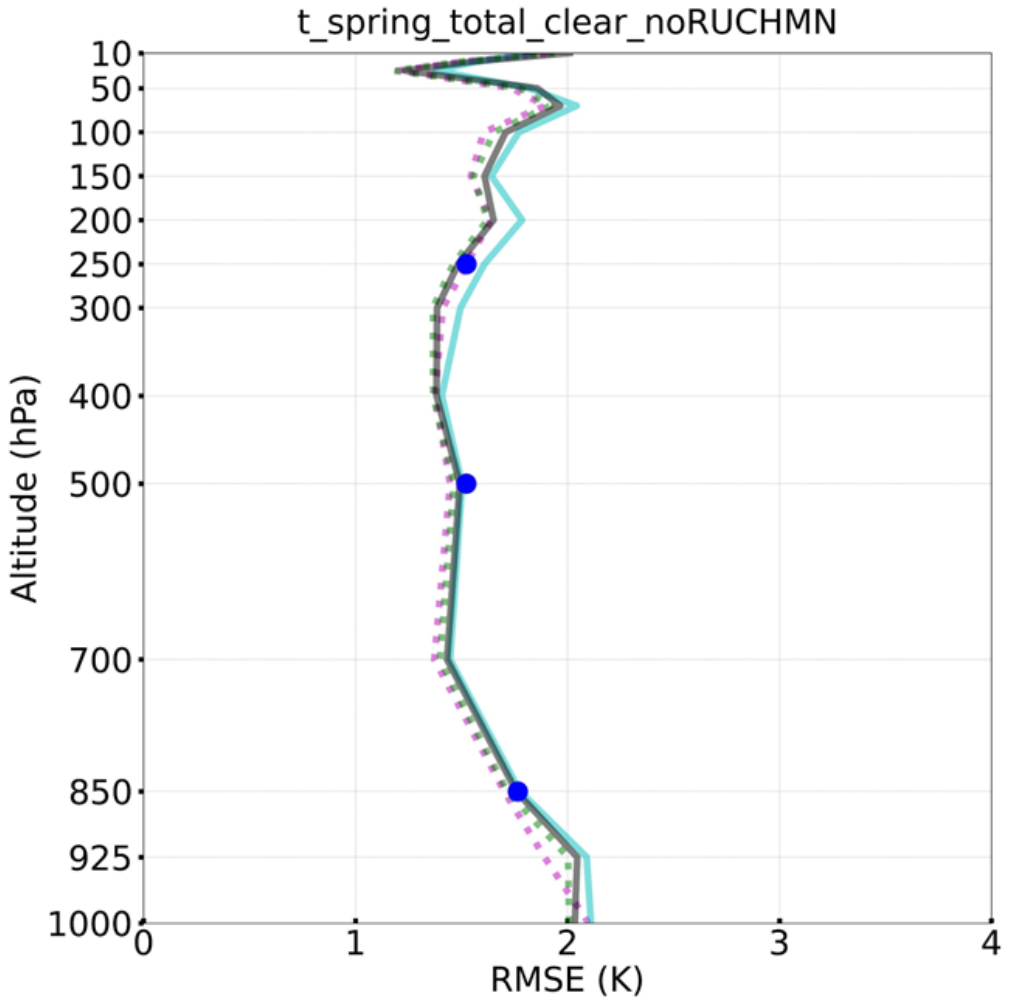
Results

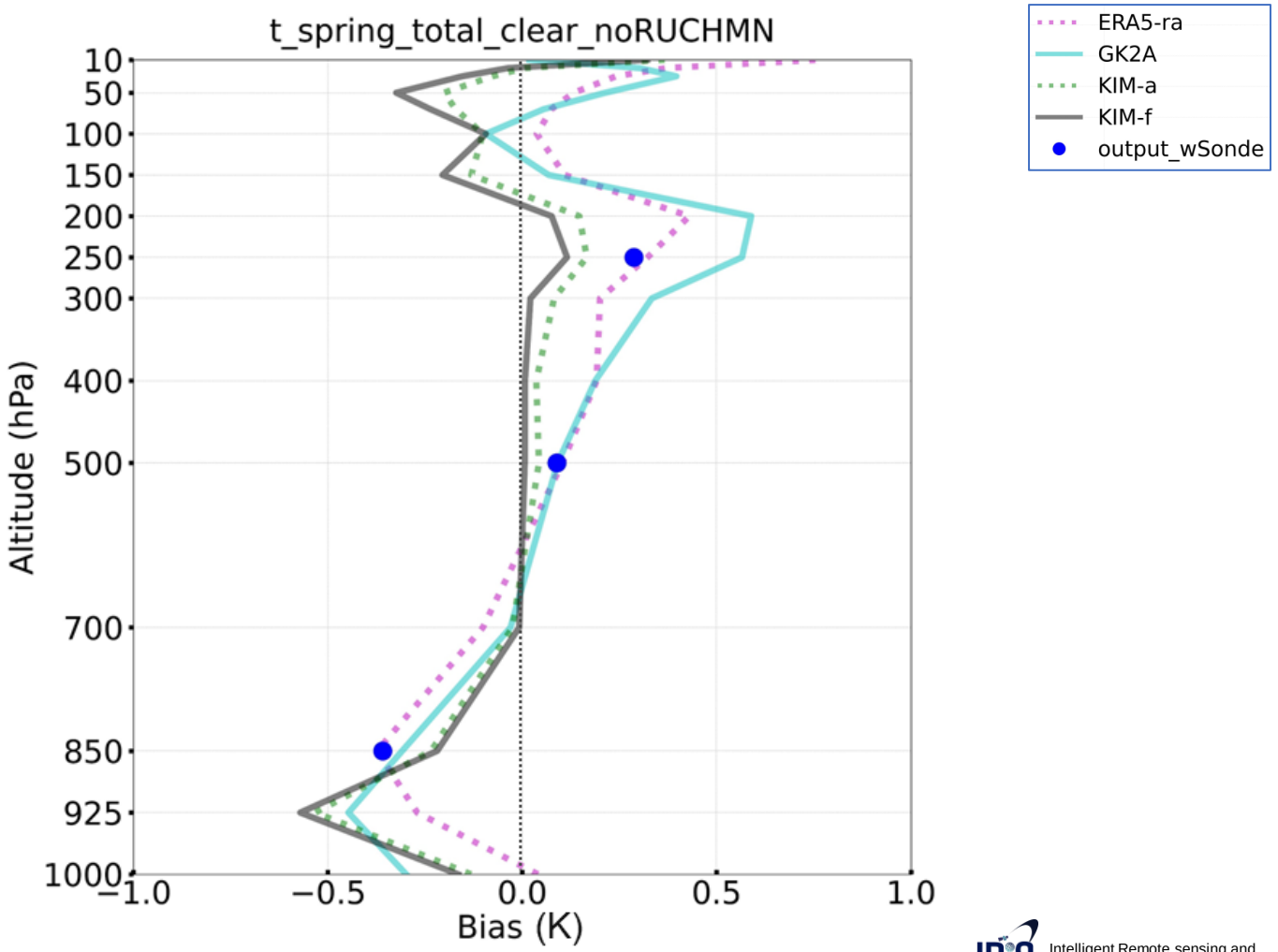
- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear, DJF)



Results

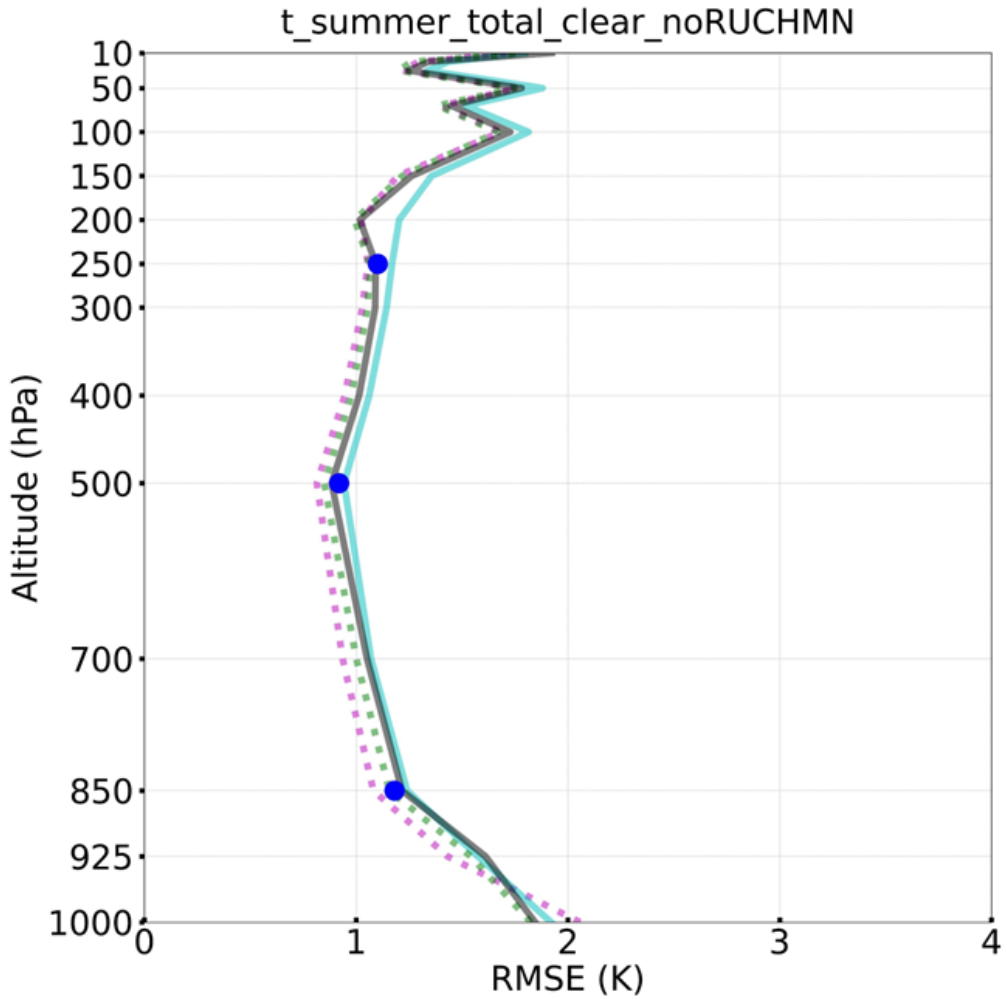
- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear, MAM)

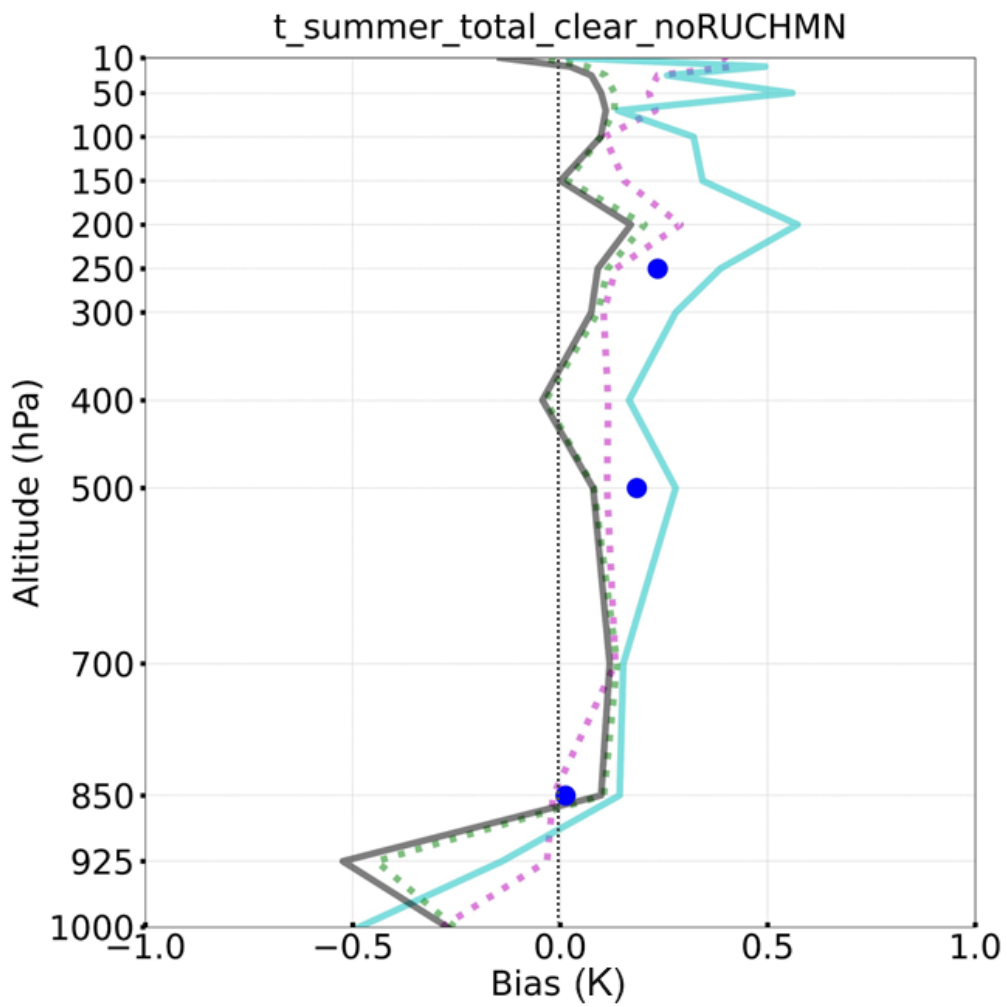




Results

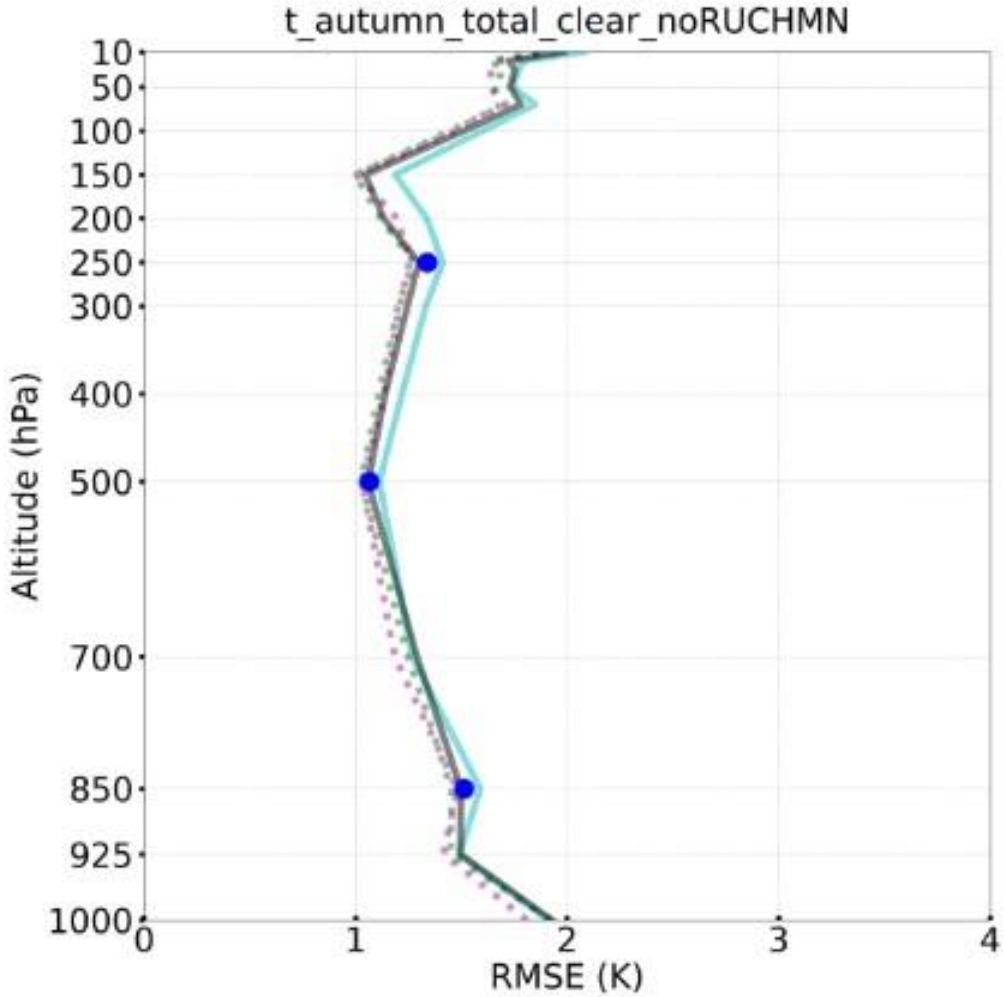
- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear, JJA)

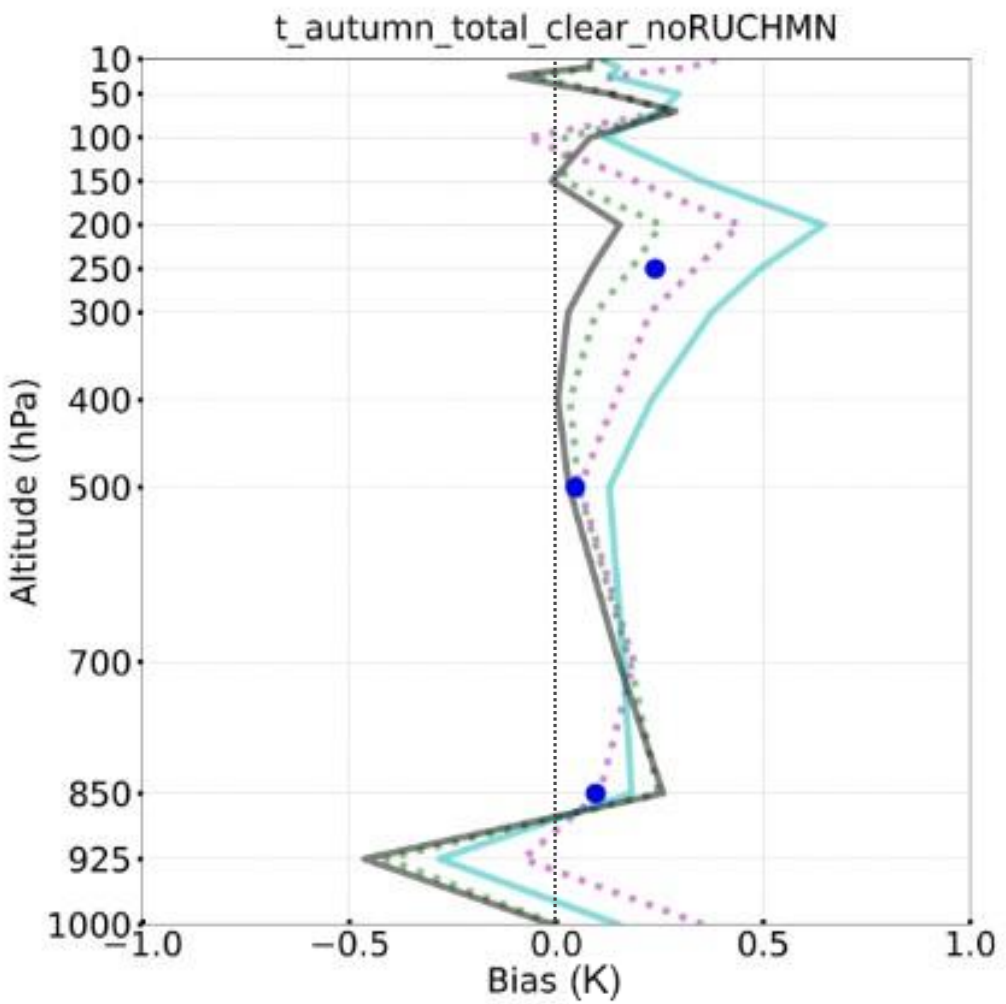


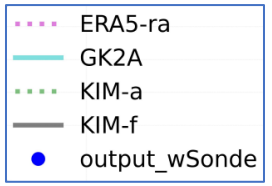


Results

- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear, SON)

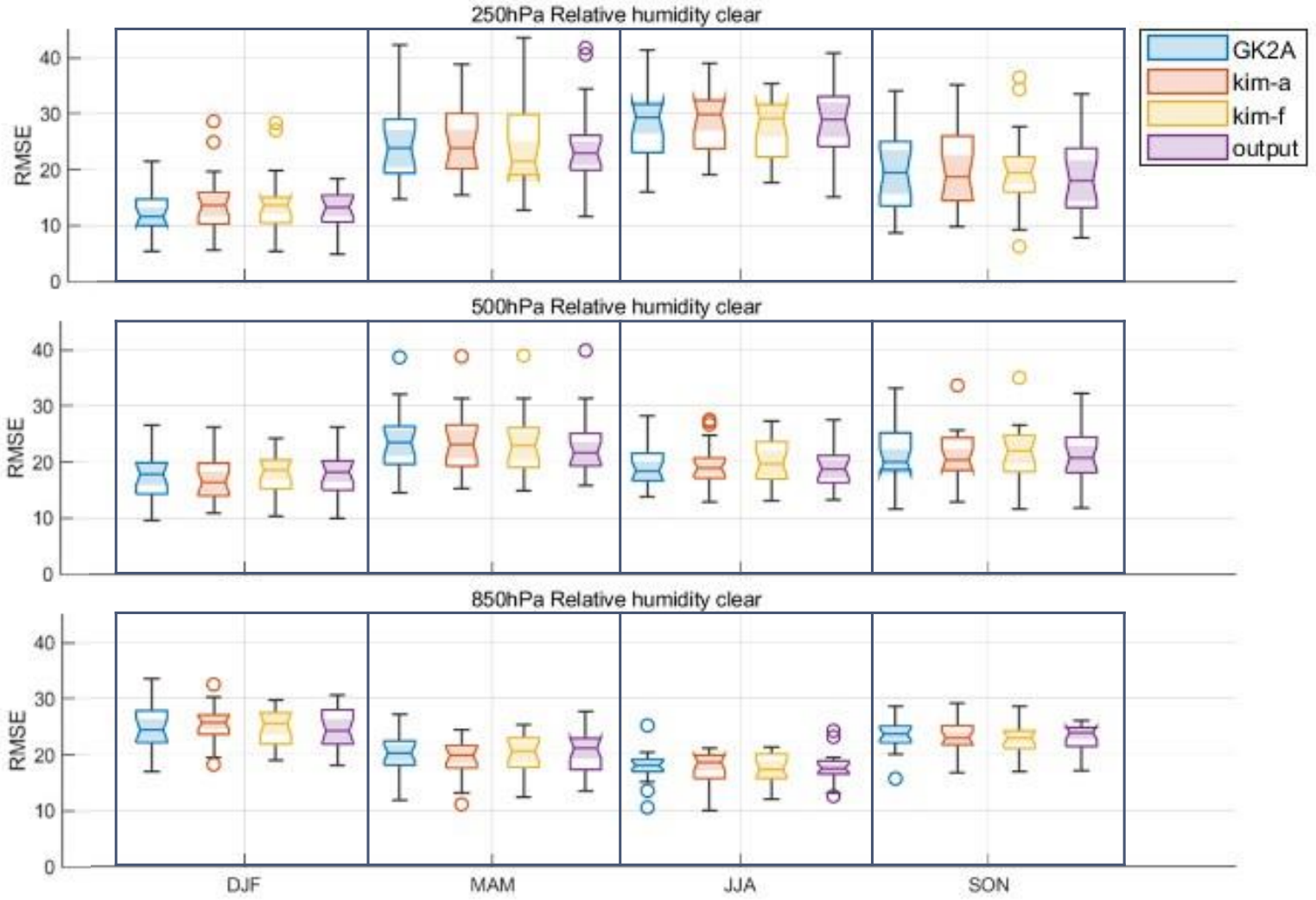






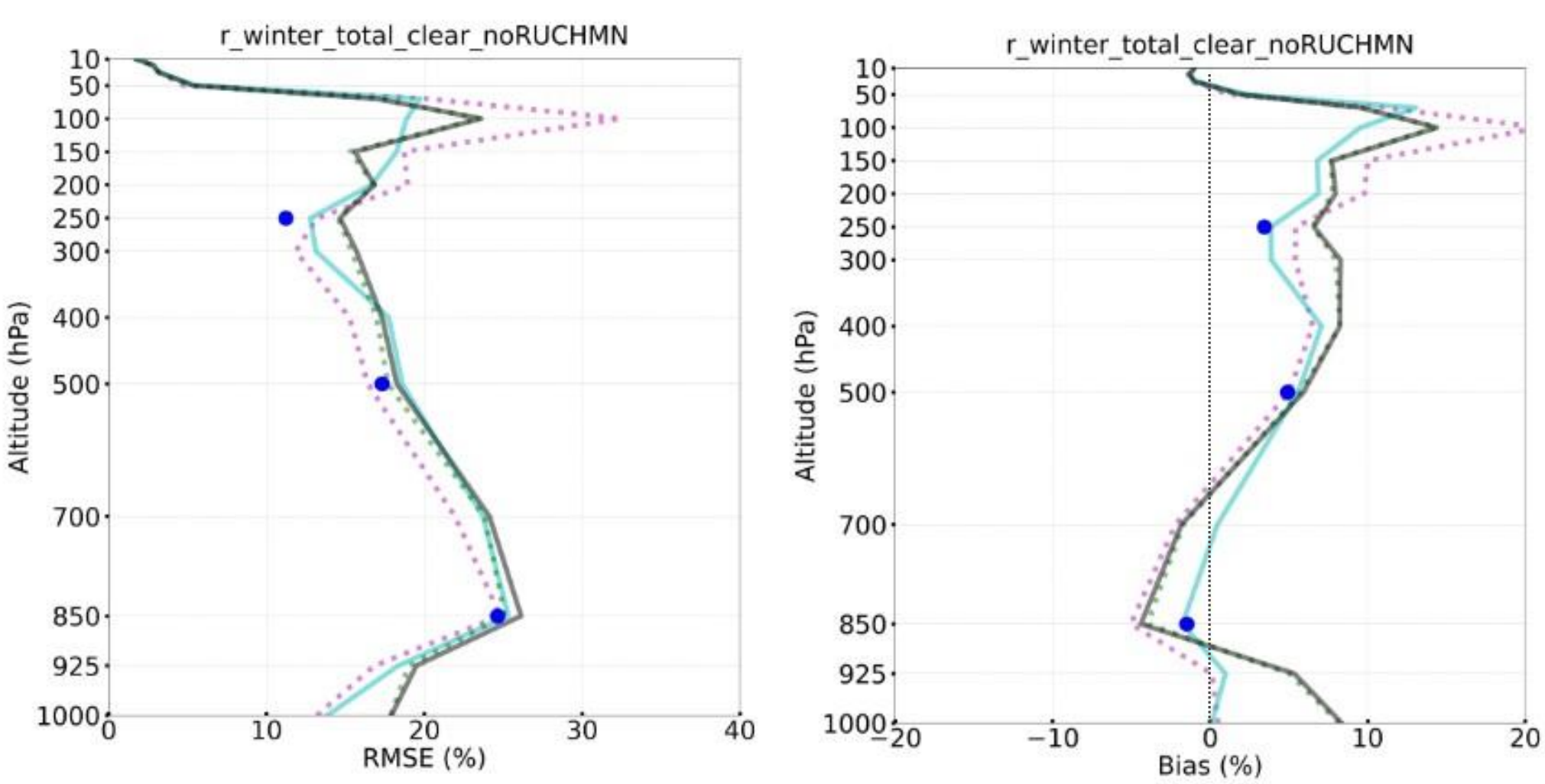
Results

- Seasonal evaluation of RH profiles (at 250, 500, and 850 hPa, clear)



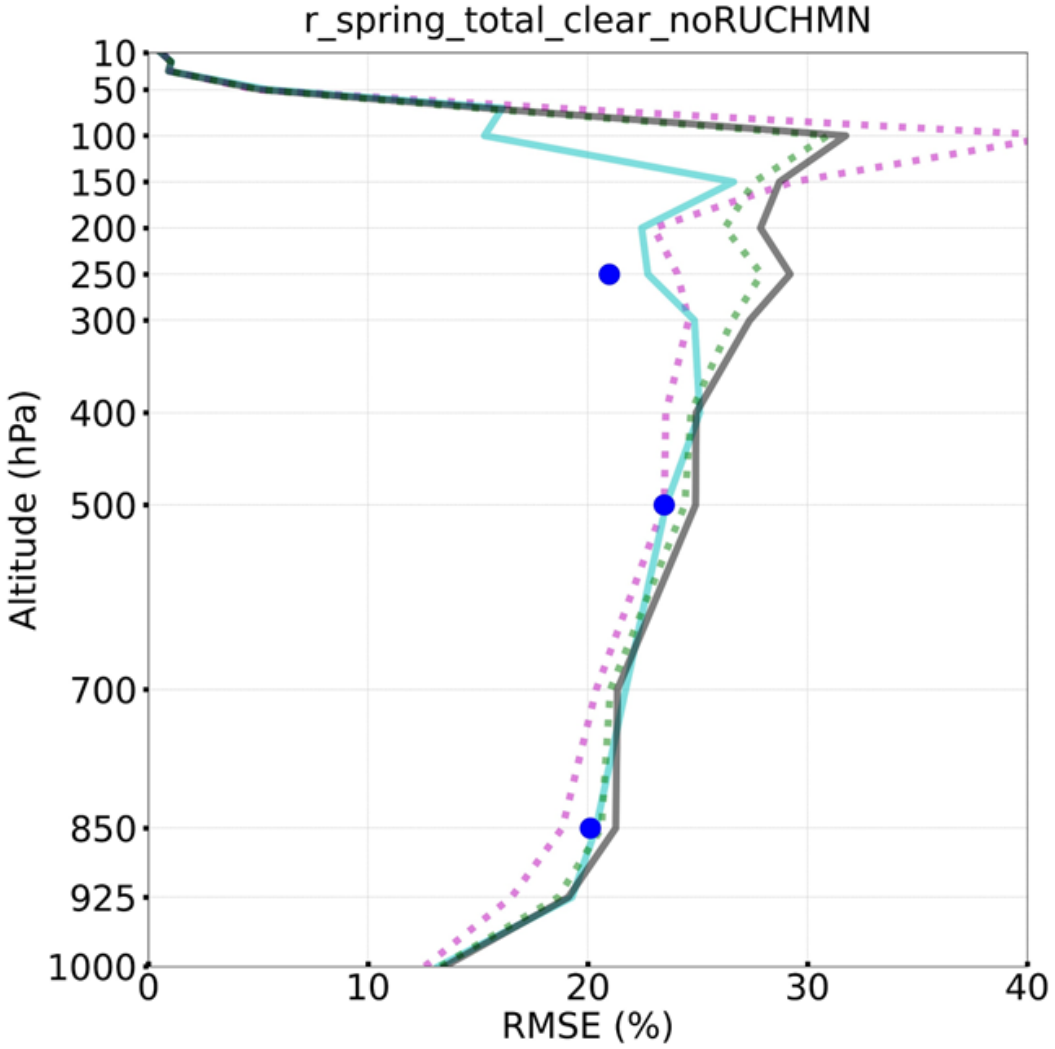
Results

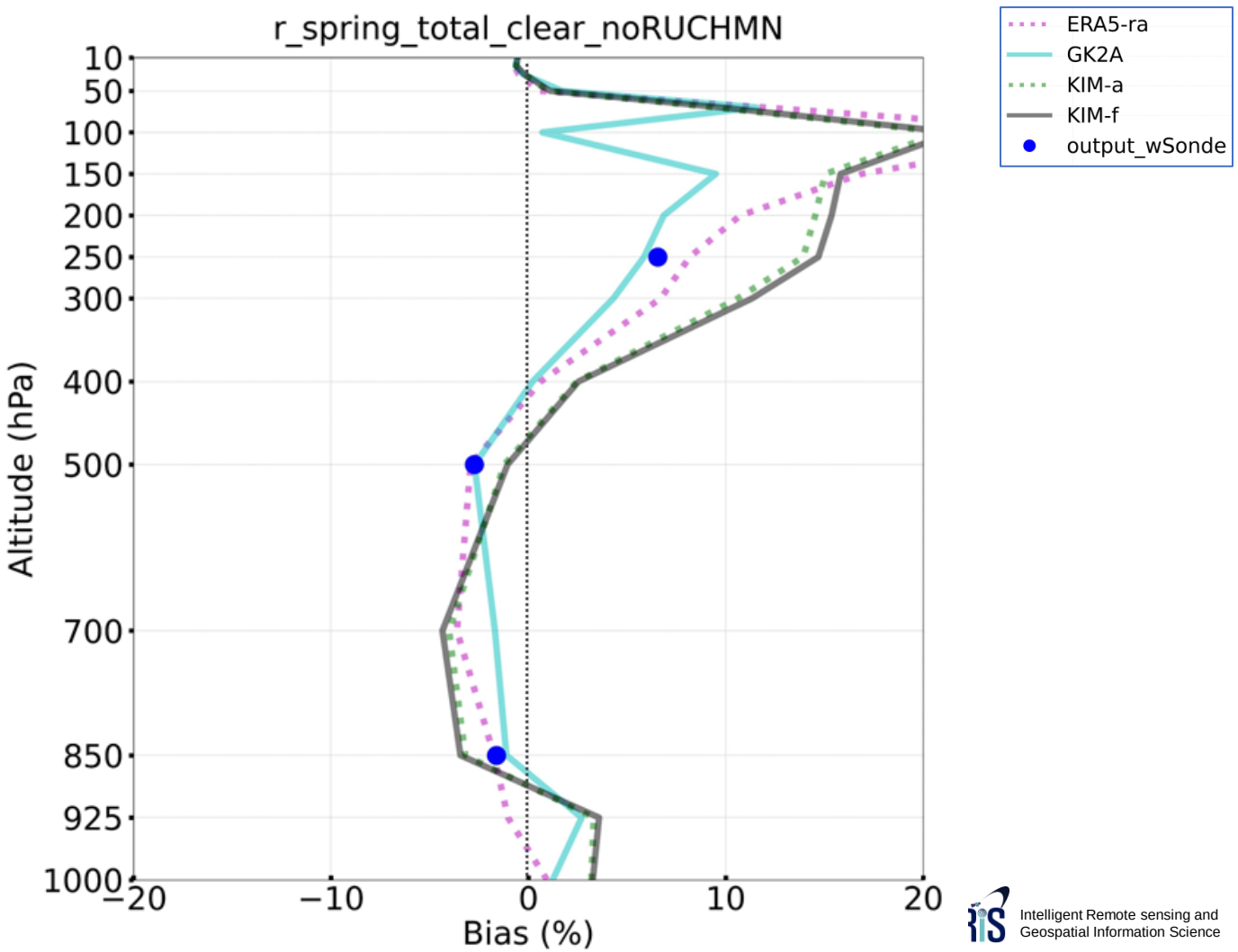
- Seasonal evaluation of T profiles (at 250, 500, and 850 hPa, clear, DJF)



Results

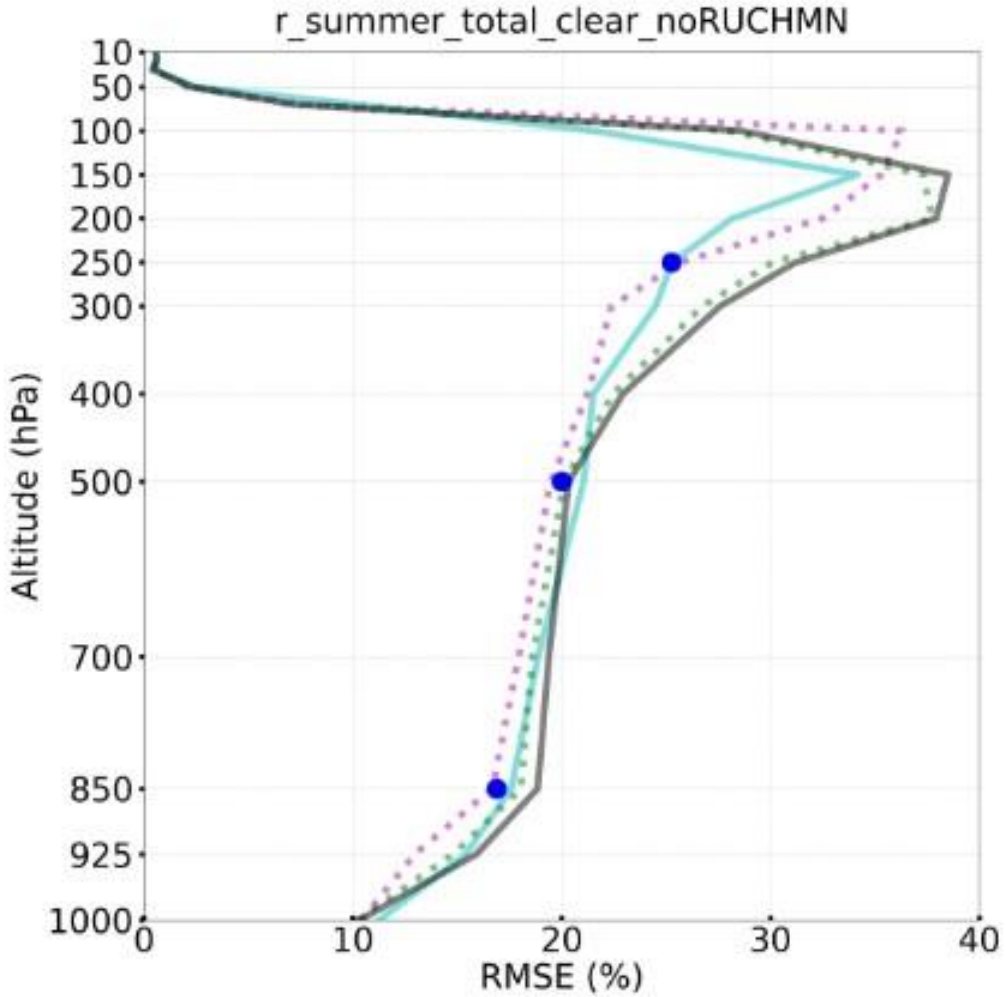
- Seasonal evaluation of RH profiles (at 250, 500, and 850 hPa, clear, MAM)

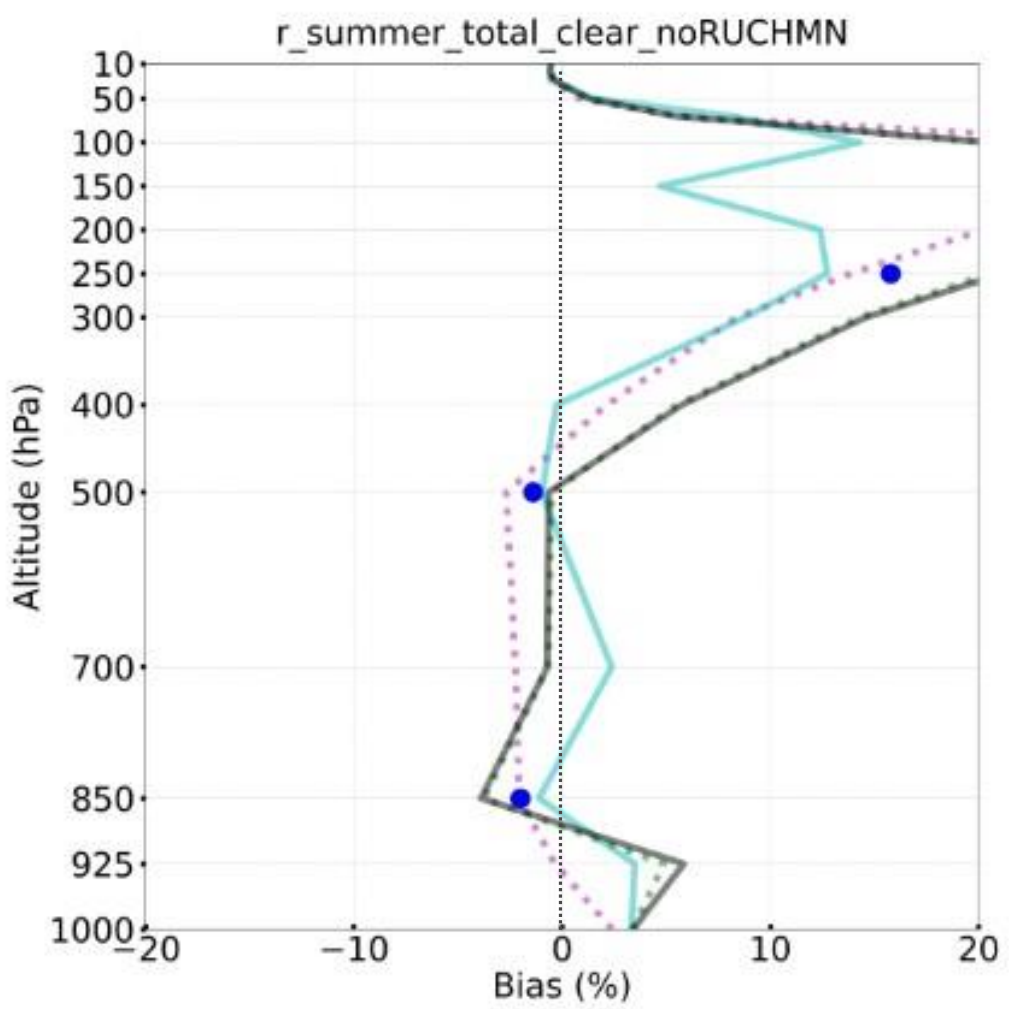


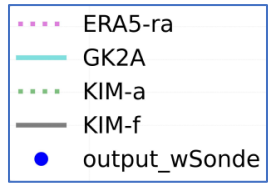


Results

- Seasonal evaluation of RH profiles (at 250, 500, and 850 hPa, clear, JJA)

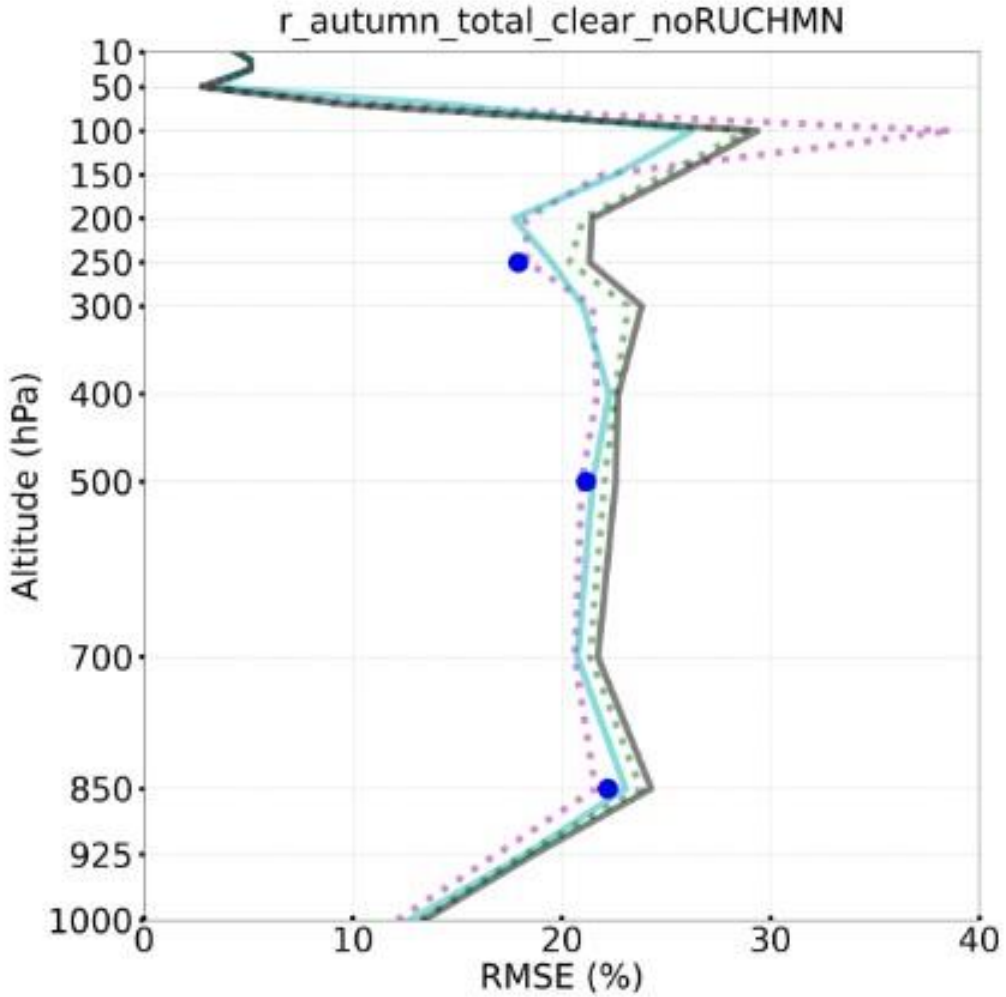


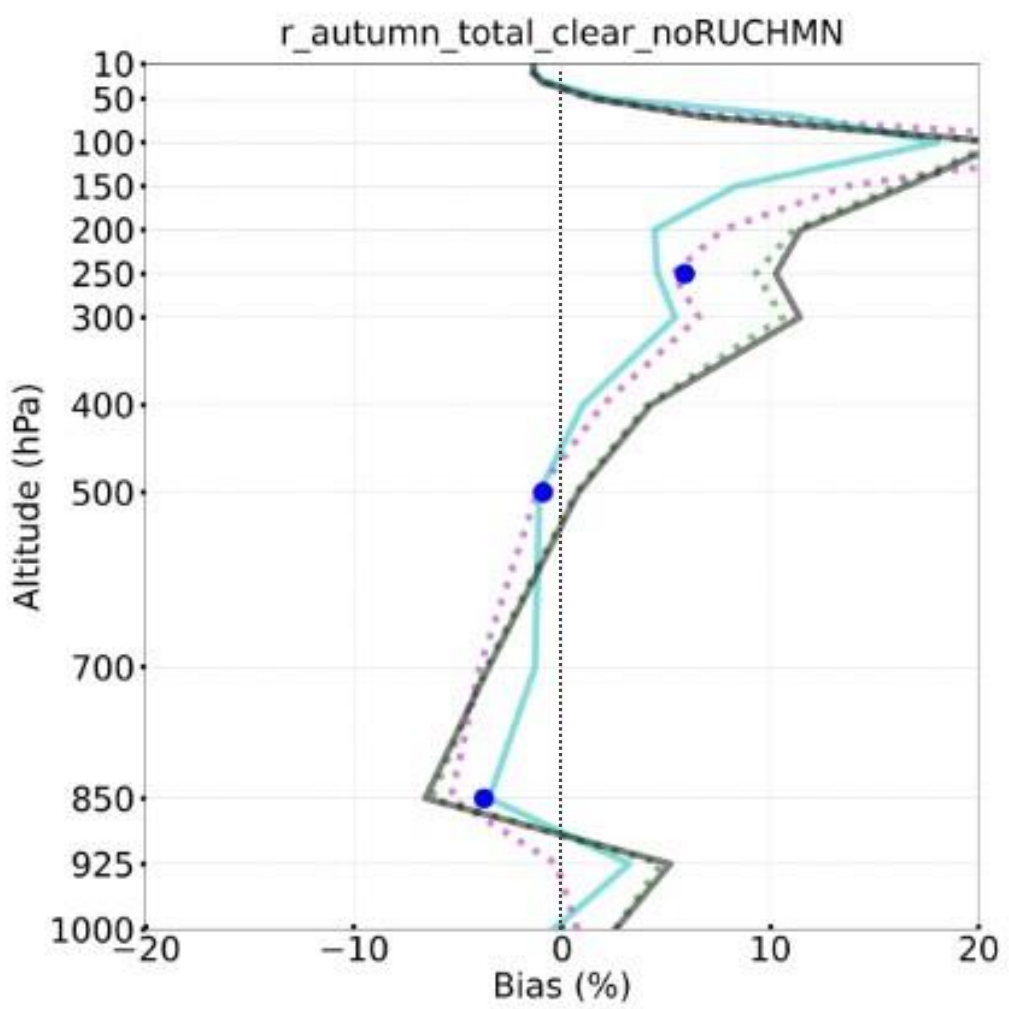




Results

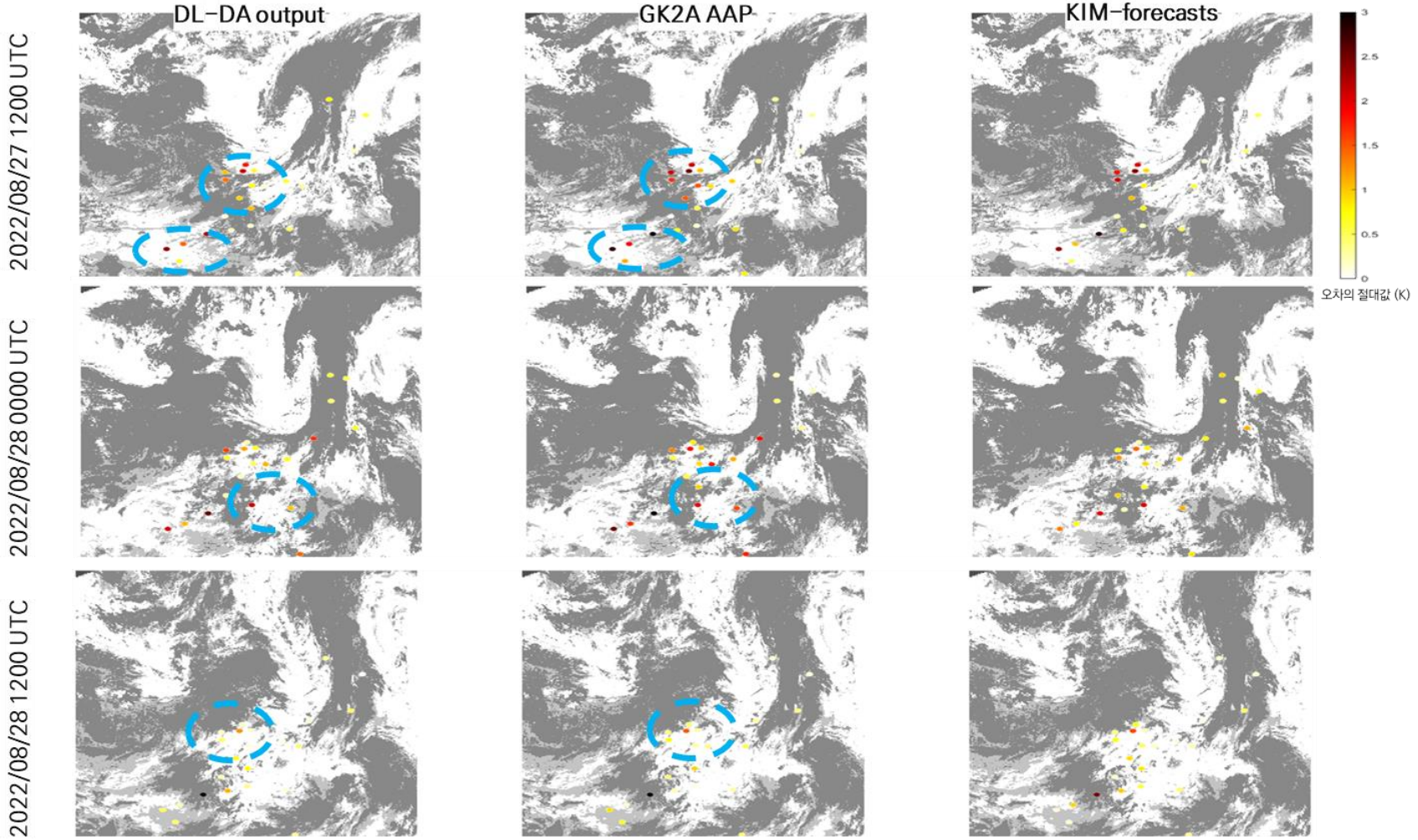
- Seasonal evaluation of RH profiles (at 250, 500, and 850 hPa, clear, SON)





Results

- Difference between observations and model-based results (temperature at 250 hPa, background image: GK2A cloud mask)



Conclusion

- Propose deep learning-based data assimilation approach using geostationary satellite observations and radiosonde observations
- Test on atmospheric parameters of temperature and relative humidity at 850, 500, and 250 hPa
- At clear sky, deep learning-based DA results achieved improvement compared to GK2A AAP algorithm, and comparable performance with KIM-based forecasts
  - Improvement from GK2A AAP (GK2A RMSE – DL-based DA RMSE)

△RSME	Temperature (T, K)	Relative humidity (RH, %)
250 hPa	0.0907	0.9726
500 hPa	0.0244	0.6422
850 hPa	0.0713	0.6743

- This research was supported by “The Technical Development on Weather Forecast Support and Convergence Service using Meteorological Satellites” of the NMSC/KMA (KMA2020-00121)

Thank you

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