EXPERIMENTS OF RTPS METHODS FOR THE 4D-LETKF SYSTEM IMPLEMENTED TO A GLOBAL NWP MODEL ON THE CUBED-SPHERE

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WHY INFLATE ENSEMBLE BACKGROUND ERROR COVARIANCE?

- Overly given confindence on model forecasts (Background)
  - **Limited number of ensemble and model errors can lead to underestimation of background error covariances.**

- Techniques known as covariance inflation is commonly used for practical applications of ensemble data assimilation
  - **There are three types of covariance inflation methods.**

COVARIANCE INFLATION METHODS

- Multiplicative inflation can
  - Reduce weights given to model states (e.g. Miyoshi 2011).

- Additive inflation can
  - Add perturbations missed by original ensemble (e.g. Whitaker et al. 2008).

- Relaxation to prior spread (RTPS) / perturbation (RTPP) can
  - Prevent excessive decrease of ensemble spread after data assimilation (e.g. Zhang et al., 2004; Whitaker and Hamill, 2012; Kotsuki et al., 2017).

IN THIS TALK

- Experiment 1

  Adaptive multiplicative Inflation / RTPS & A Modified RTPS

  + additive inflation as default.

  (use of AMSU- A channel 5~14 data)

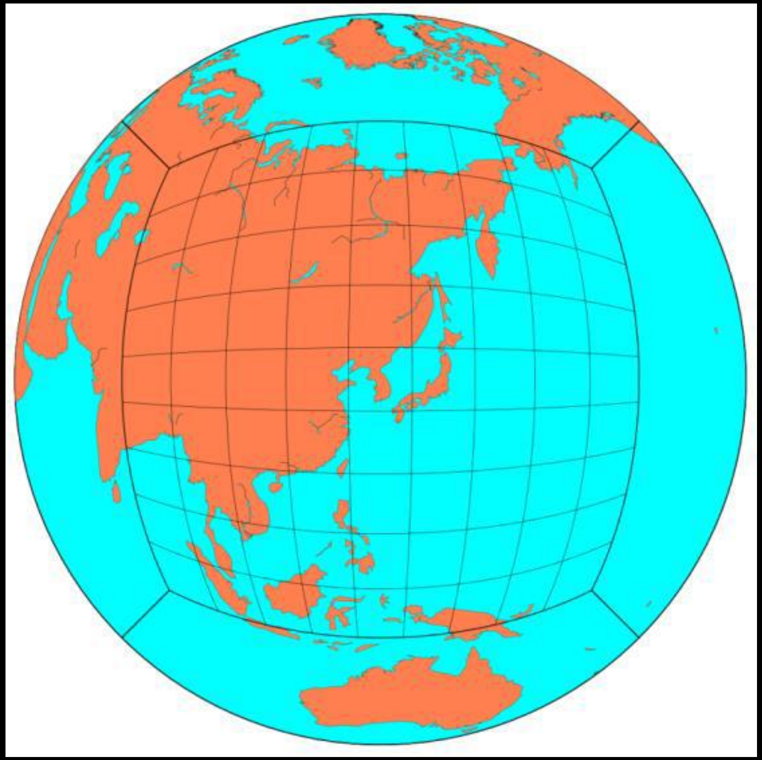
- Experiment 2

  The use of AMSU-A channel (5~14) data

  The use of AMSU-A channel (5~10) data

FORECAST MODEL

Rotated Cubed-sphere



KIM (Korean Integrated Model)

- Spectral element method on the Cubed-sphere
- Non-Hydrostatic global NWP model

Model resolution in this study

Grid length: ~50 km

- Model top: 80 km (91 model levels)

LETKF AT KIAPS

- 4-D LETKF (Hunt et al. 2007).
- 50 Ensemble Members for ca. 50 km grid.
- Adaptive multiplicative + Additive inflation.
- Analysis of U, V, T, Q .
- Horizontal localization scale: 660 km at lower levels to 1800 km at upper levels (Kleist and Ide, 2015).
- The vertical localization function for conventional data are defined by the Gaussian-like rational function.
- The vertical localization of the column-integrated radiance information into the vertical levels of the model: the direct use of weighting function defined by a gradient of transmittance of the measured radiance (Thépaut, 2003).

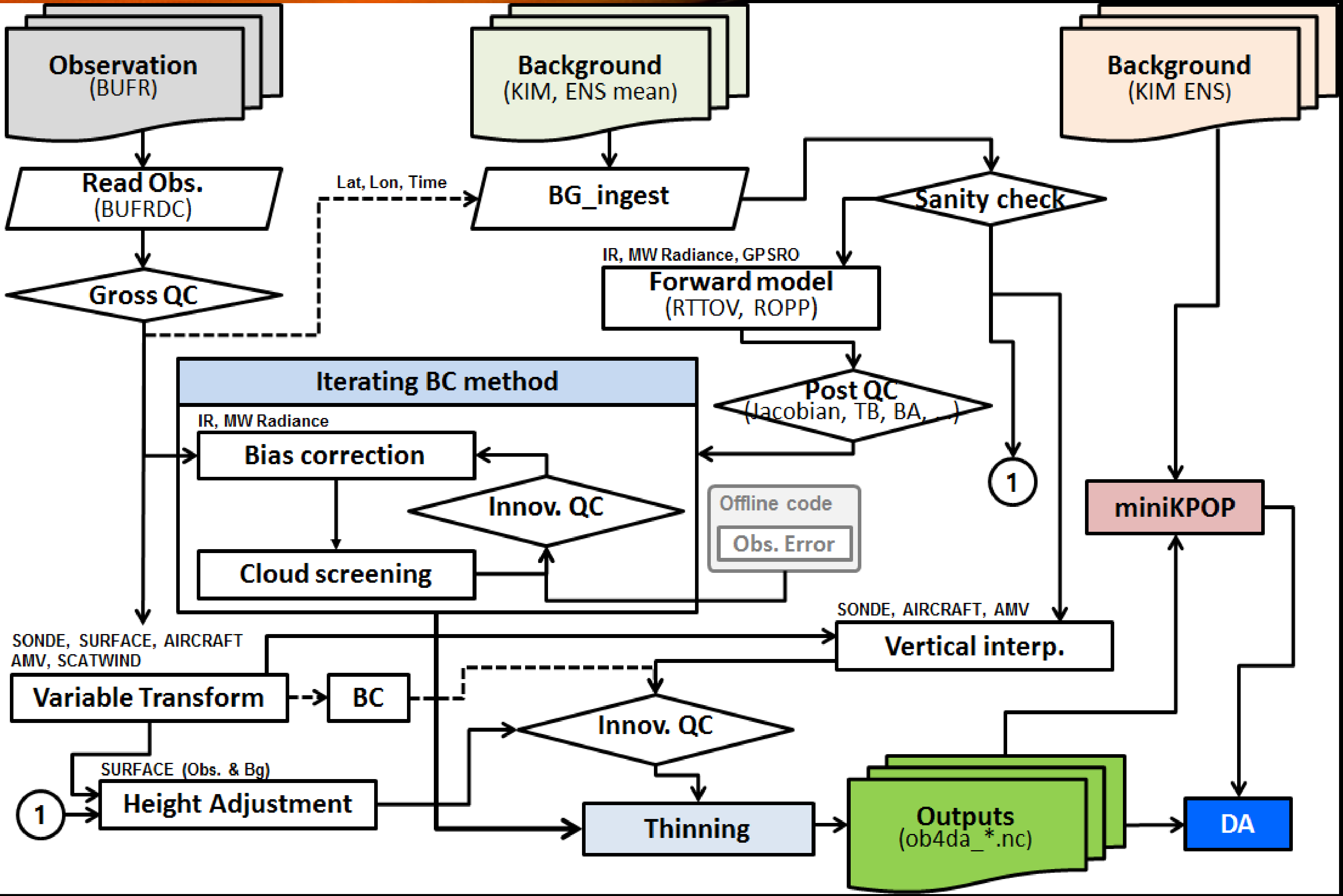
LETKF AT KIAPS

- Use of Observation Operators in KPOP (Kiaps Package For Observation Process).
- Radiance Data: AMSU-A, ATMS, IASI, MHS, CrIS, CSR,
- In addition to: Sonde, Surface, Aircraft, Scatwind, Satwind, GPSRO.

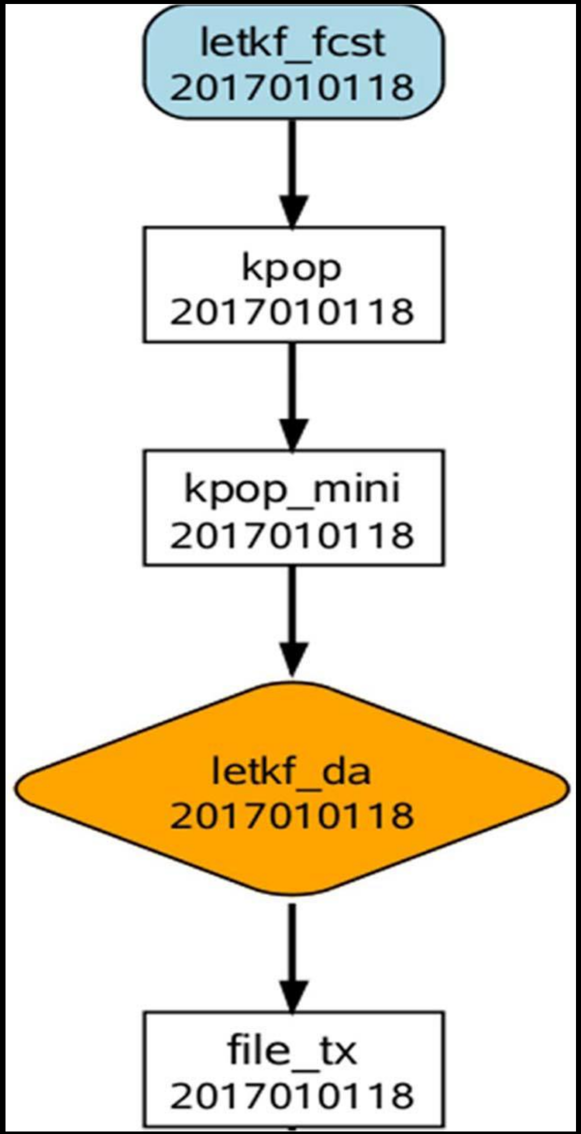
- Global Positioning System-Radio Occultation (GPS-RO),
- Infrared Atmospheric Sounding Interferometer(IASI),
- Advanced Microwave Sounding Unit-A (AMSU-A),
- Cross-track Infrared Sounder (CrIS),
- Microwave Humidity Sounder (MHS),
- Advanced Technology Microwave Sounder (ATMS),
- Atmospheric Motion Vectors (AMVs),
- Clear Sky Radiance (CSR).

A framework called "DaPy" is implemented using the Python script mixed with the Fortran programming language.

Shin et al. 2018



KPOP



Use of "Cylc" as a workflow engine for cycling tasks

EXPERIMENT I

- Test Period: 2018/07/05~2018/08/14.
- Evaluation using **IFS analysis as reference** and compute Root Mean Squre Difference (RMSD)
- **Experiment**:
  - Adaptive Multiplicative + Additive Inflation (**Adapt.Mult**)
  - RTPS + Additive Inflation (**RTPS**)
  - A Modified RTPS + Additive Inflation (**MRTPS**)

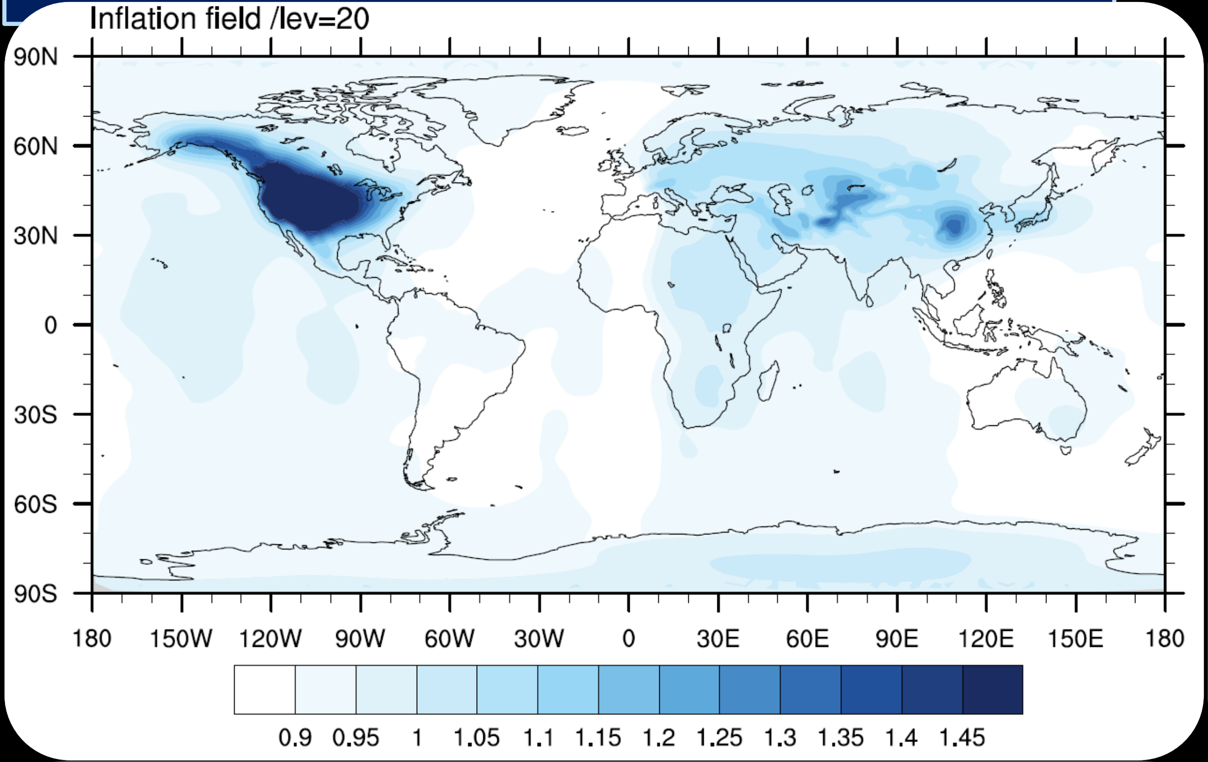
ADAPTIVE MULTIPLICATIVE INFLATION (MIYOSHI 2011)

- Kotsuki *et al*. (2017) showed that the estimation of adaptive multiplicative inflation can be dependent on the observation error settings of satellite observation.

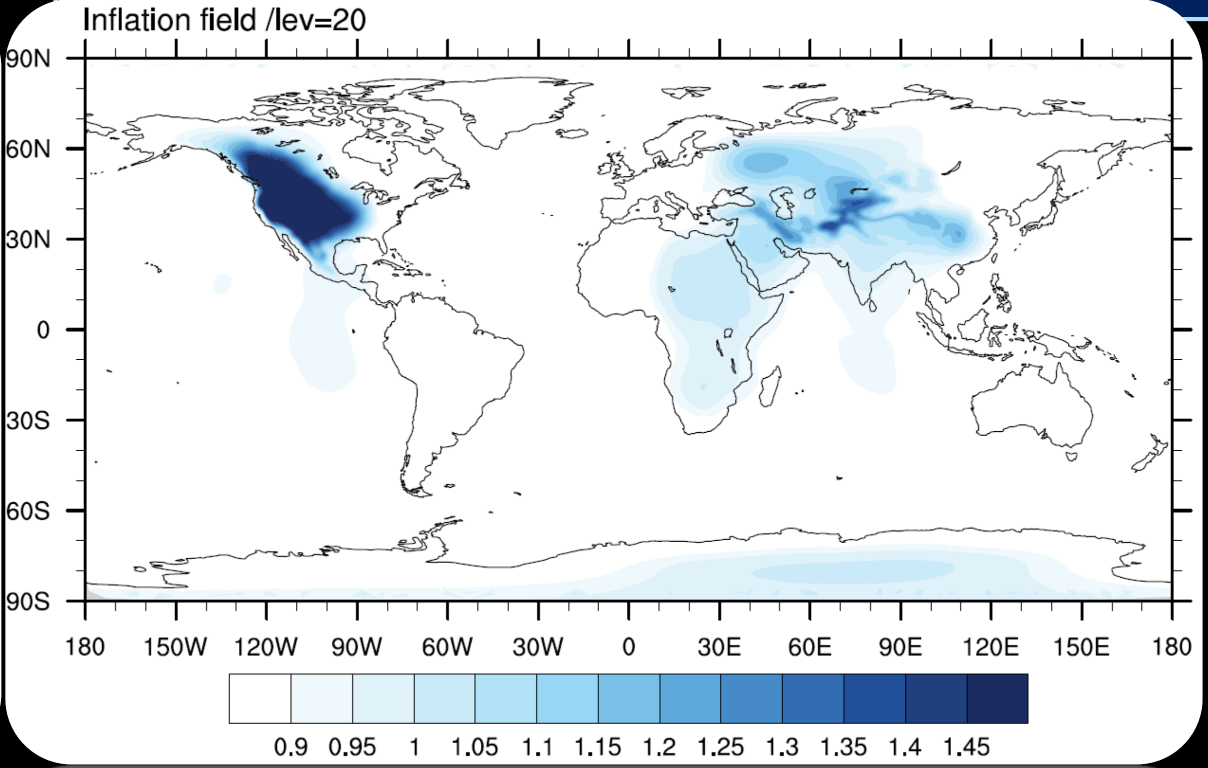
- Relaxation method can be less sensitive to the variations of observing network (e.g. Miyoshi and Kunii 2012; Bowler et al. 2017).

EXAMPLE OF ESTIMATED INFLATION FACTOR

When only adaptive multiplicative inflation is used



When additive as well as adaptive multiplicative inflation is used



RELAXATION TO PRIOR SPREAD (RTPS)

Spread of background

$$x_i'^a \leftarrow x_i'^a \left(\alpha \frac{\sigma^b - \sigma^a}{\sigma^a} + 1 \right)$$

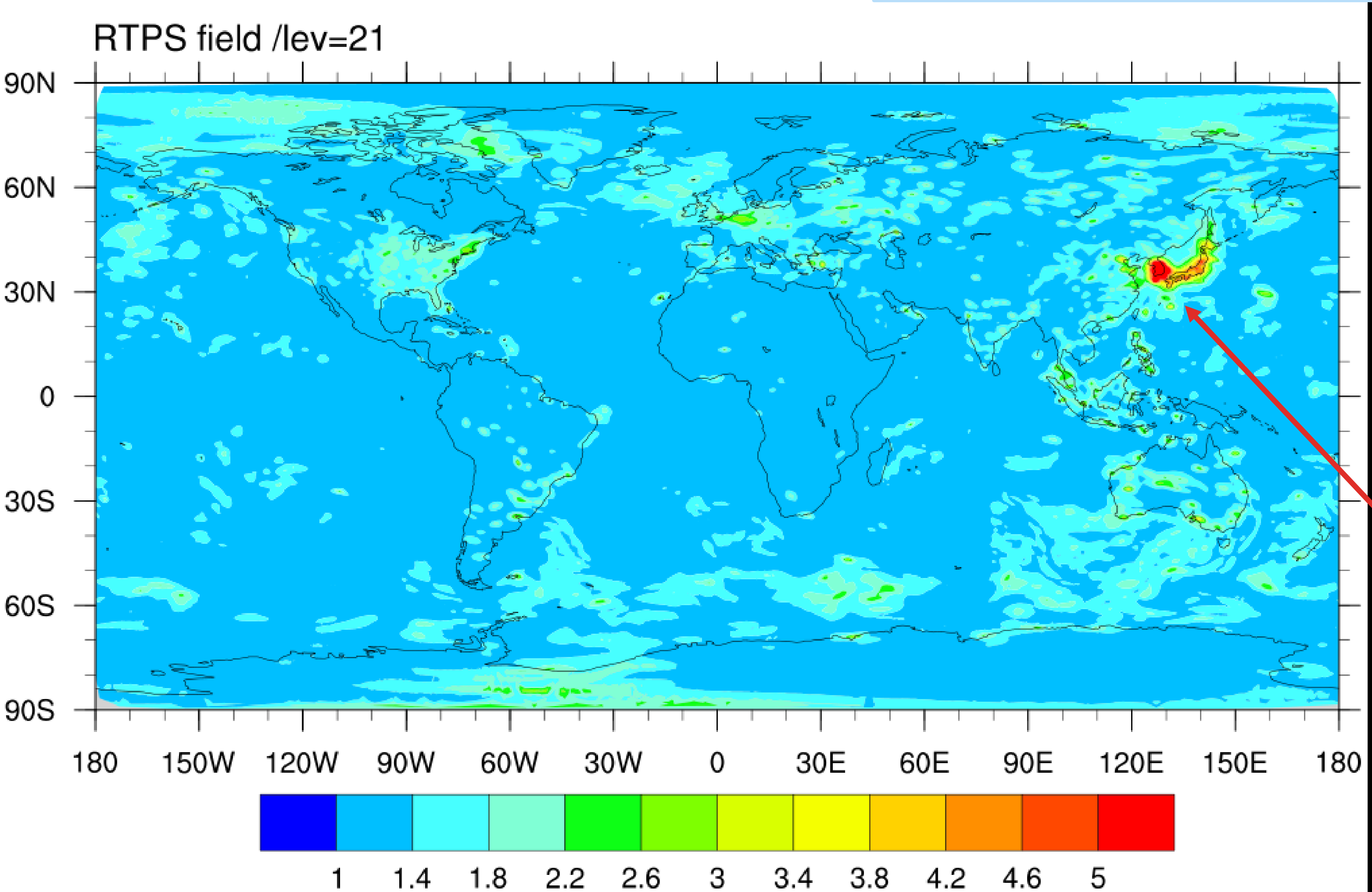
Spread of analysis

α = 0.95 in this study

Whitaker and Hamil (2012)

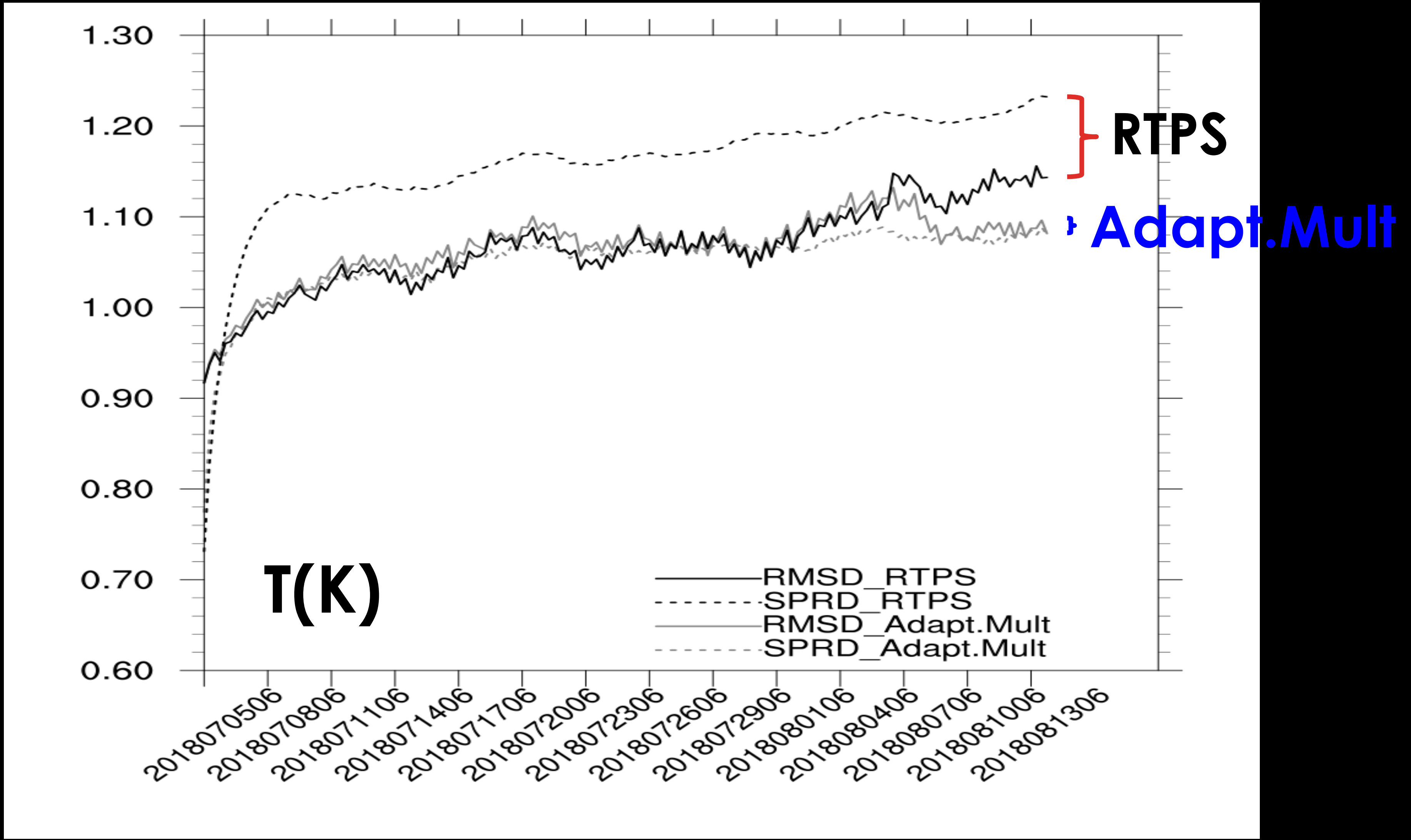
DISTRIBUTION OF RTPS

Dependent on the observation network as in adaptive multiplicative inflation.

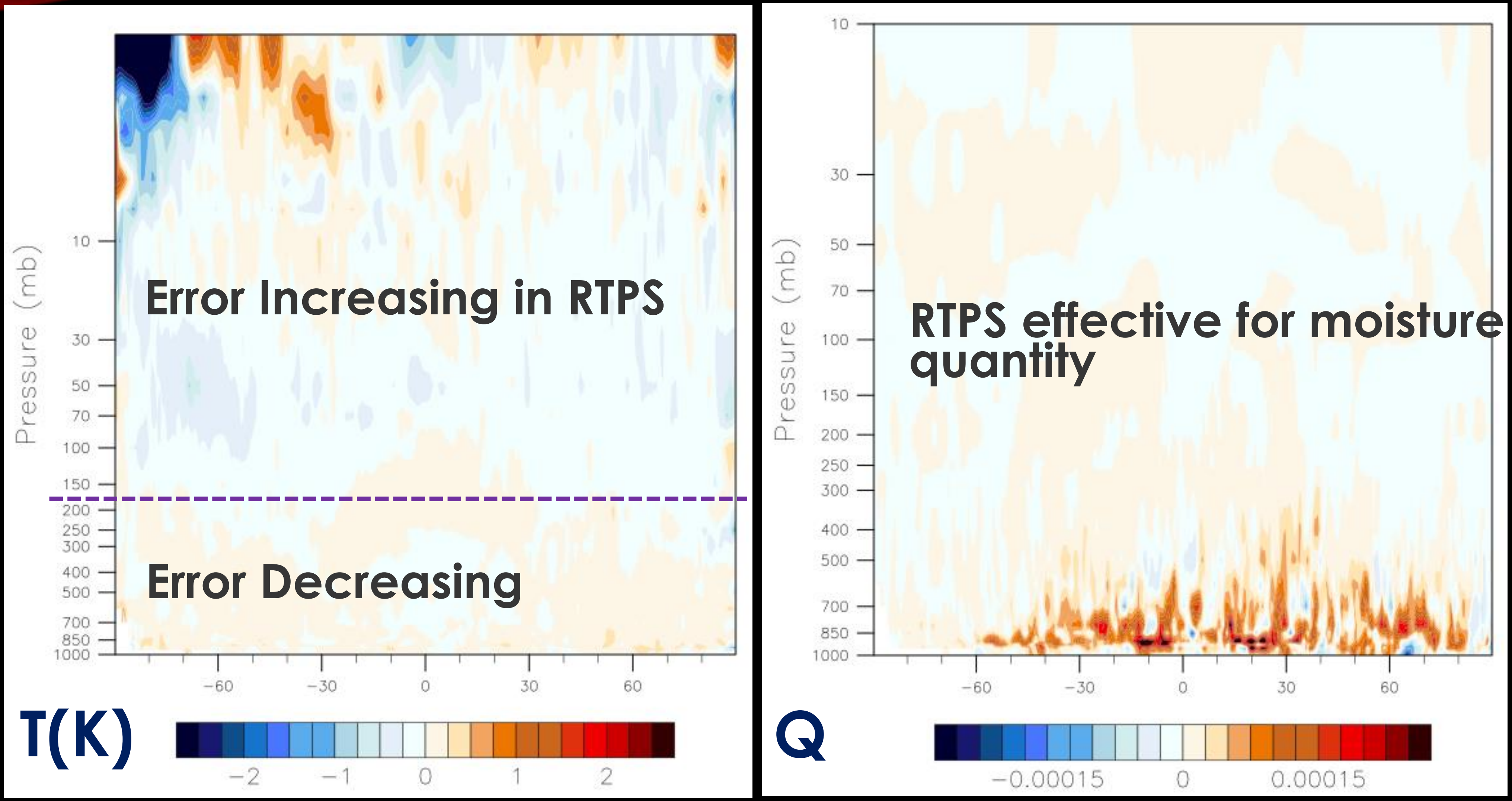


Data available from intensive observation campaign

TIME SERIES OF RMSD & SPREAD RTPS VS. ADAP.MULT



10 DAY-MEAN OF RMSD (ADAPT.MULT) – RMSD (RTPS)



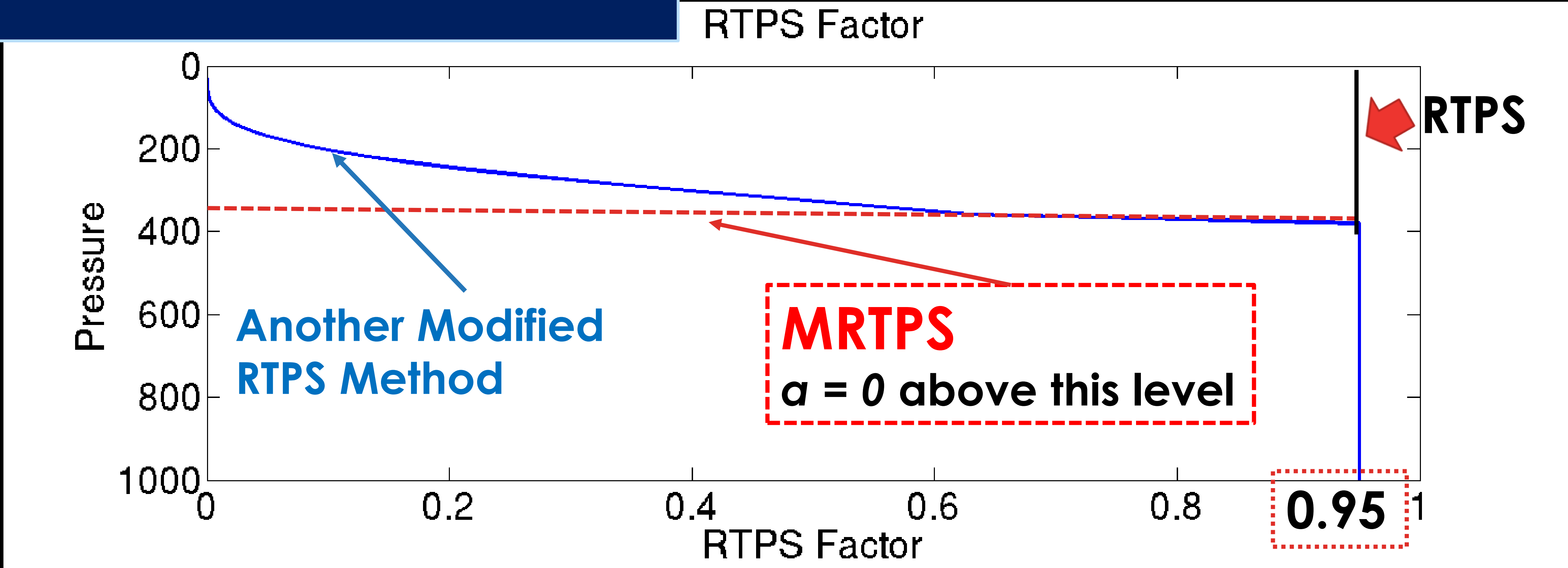
MOTIVATION FOR A MODIFICATION

"[Adaptive]-RTPS and [adaptive]-RTPP have a spatially homogeneous relaxation parameter and lead to an over-dispersive (under-dispersive) ensemble in the sparsely (densely) observed regions". (Kotsuki et al. 2017)

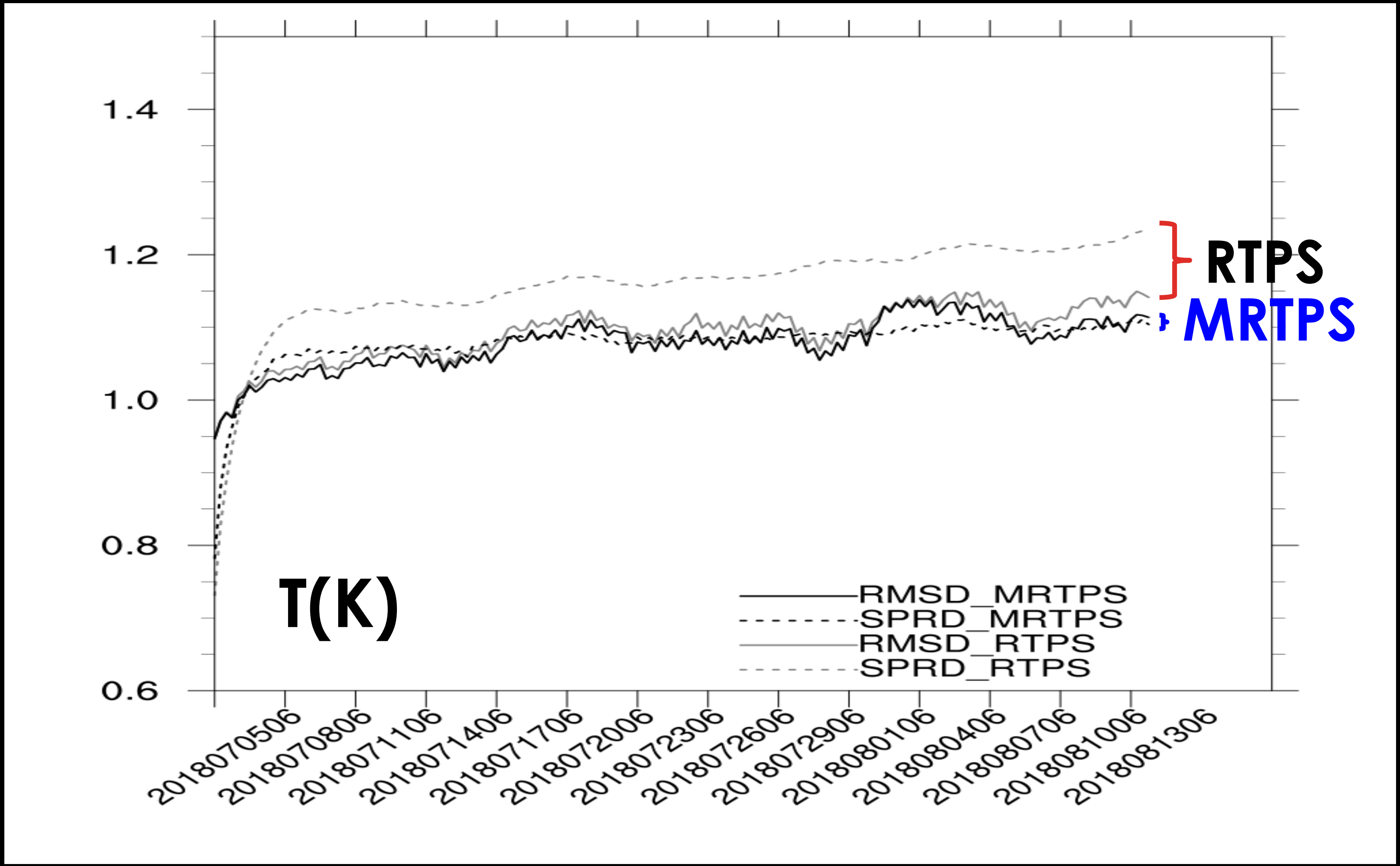
Also some experiences in the investigation of additive inflation (Shin et al. 2018) motivates a very simple test

$$x_i'^{a} \leftarrow x_i'^{a}\left(\alpha\frac{\sigma^{b}-\sigma^{a}}{\sigma^{a}}+1\right)$$

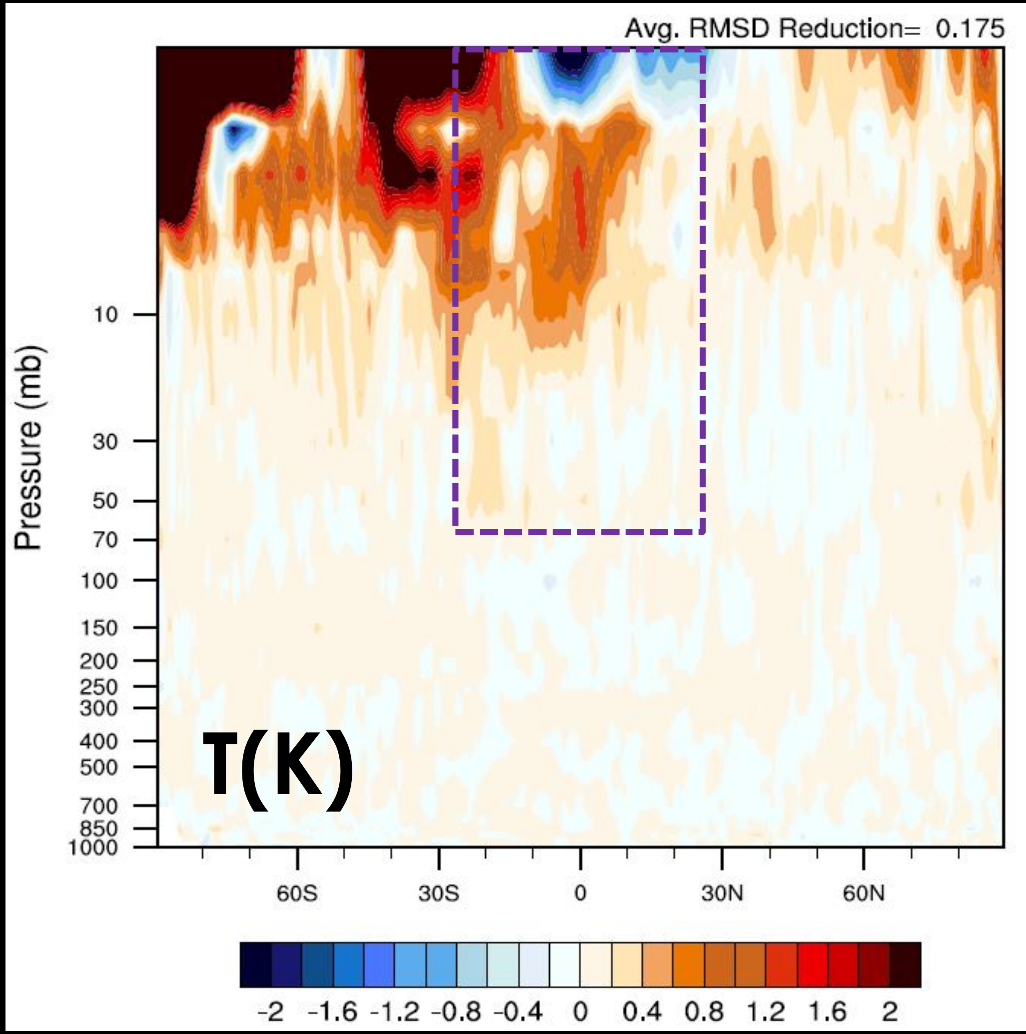
A MODFIED RTPS (MRTPS)

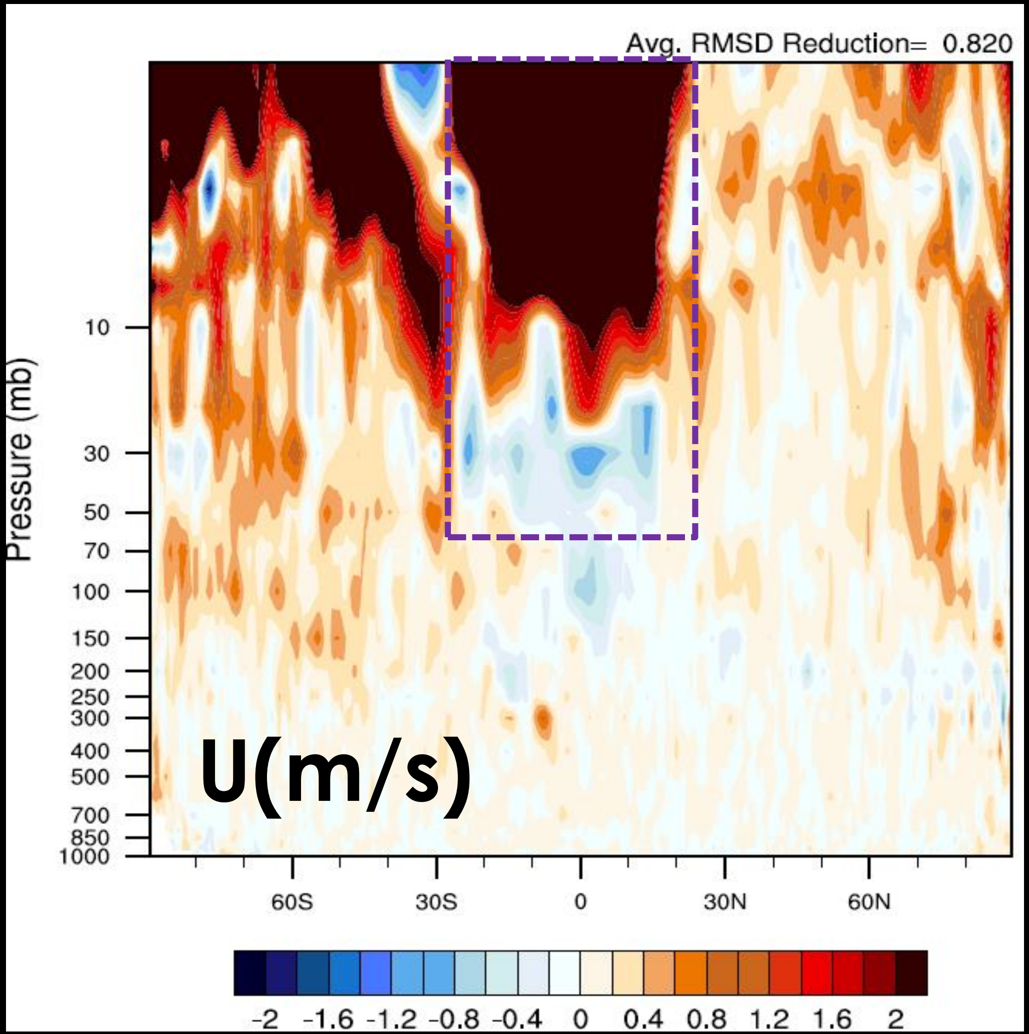


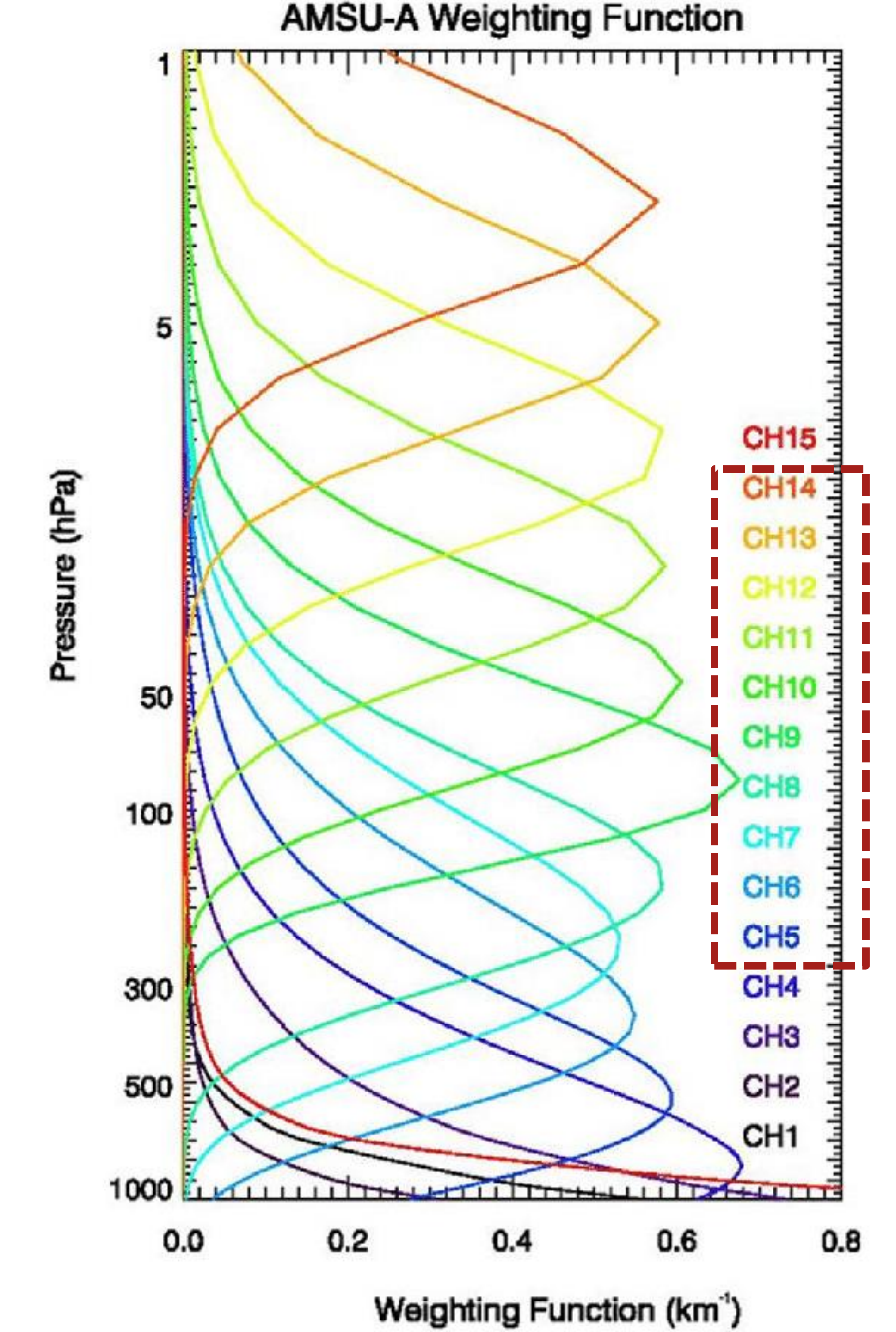
TIME SERIES OF RMSD & SPREAD RTPS VS. MRTPS



10 DAY-MEAN OF RMSD (RTPS) – RMSD (MRTPS)







Used channels: 5~14

Vertical Localisation:

the direct use of <u>weighting function</u> defined by a gradient of transmittance of the measured radiance (Thépaut, 2003)

Clear-Sky radiance

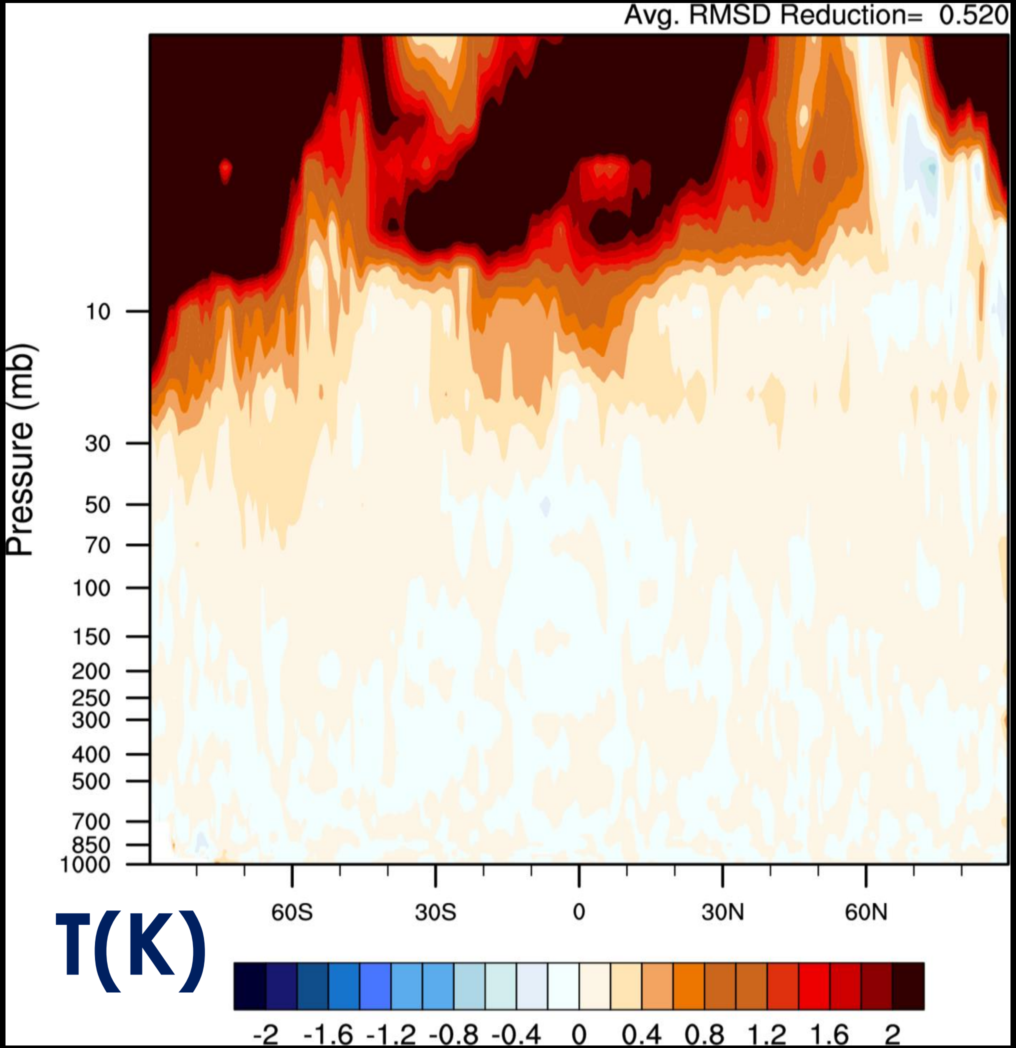
AMSU-A Weighting function for standard atmosphere (Kim et al. 2014)

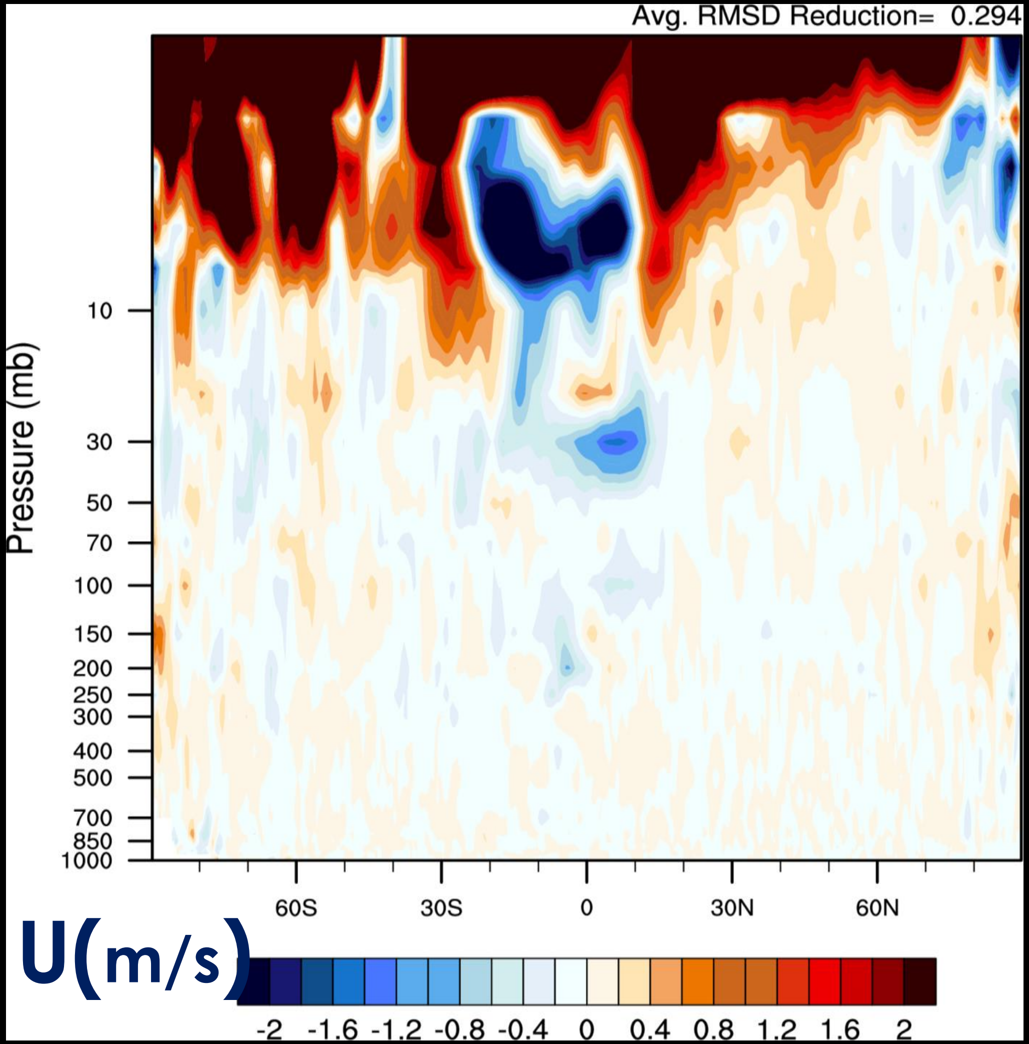
EXPERIMENT 2

Exp. AMSU-A upper-channel (5~14) [Default]
: With upper-channel radiance data (Upp.)

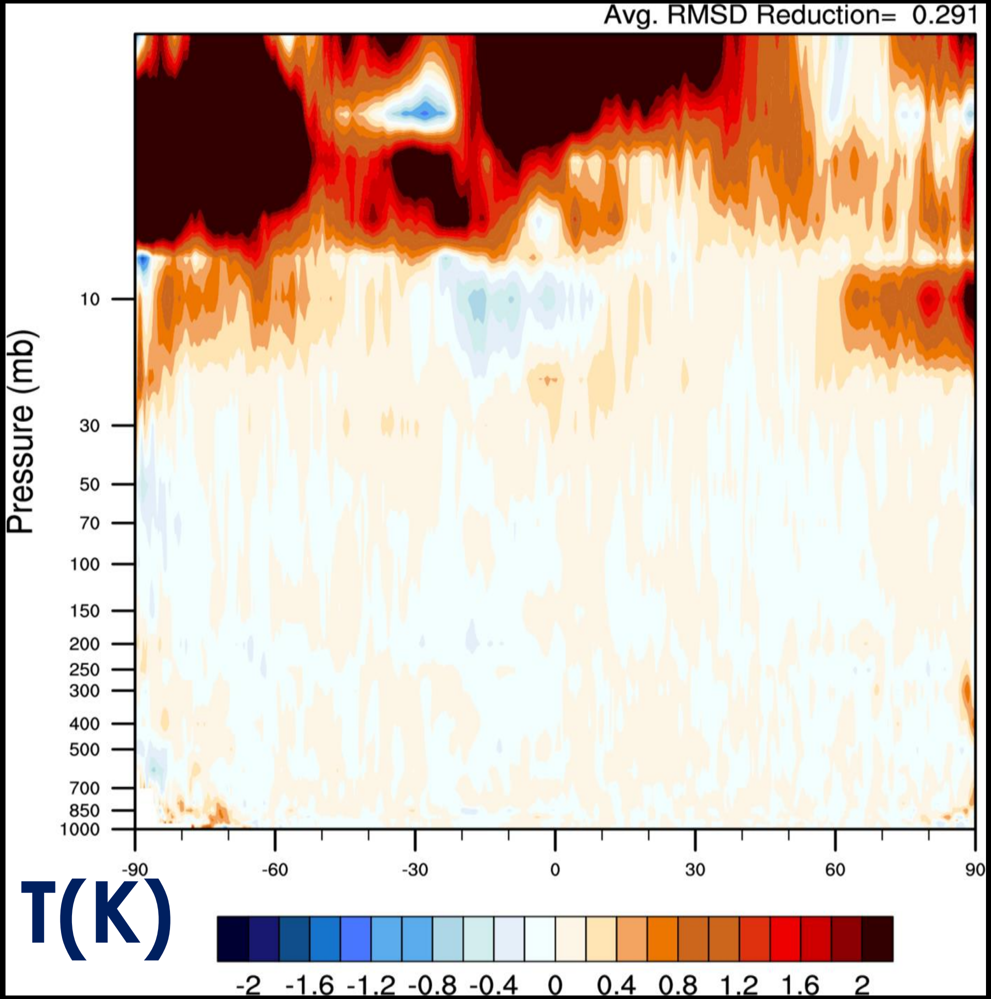
Additional Exp. AMSU-A upper-channel (5~10)
: Without upper-channel data (No Upp.)

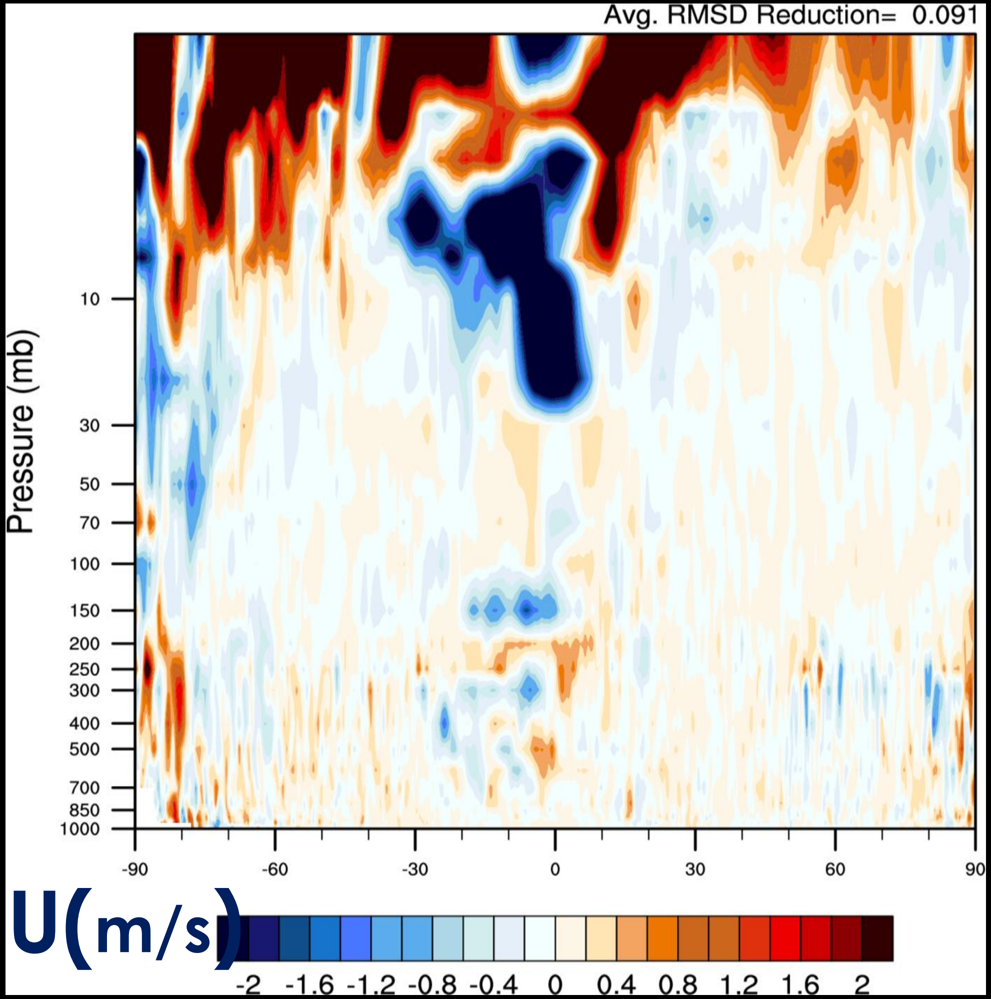
10-DAY MEAN
RMSD NO UPP. – RMSD UPP. (IN MRTPS)



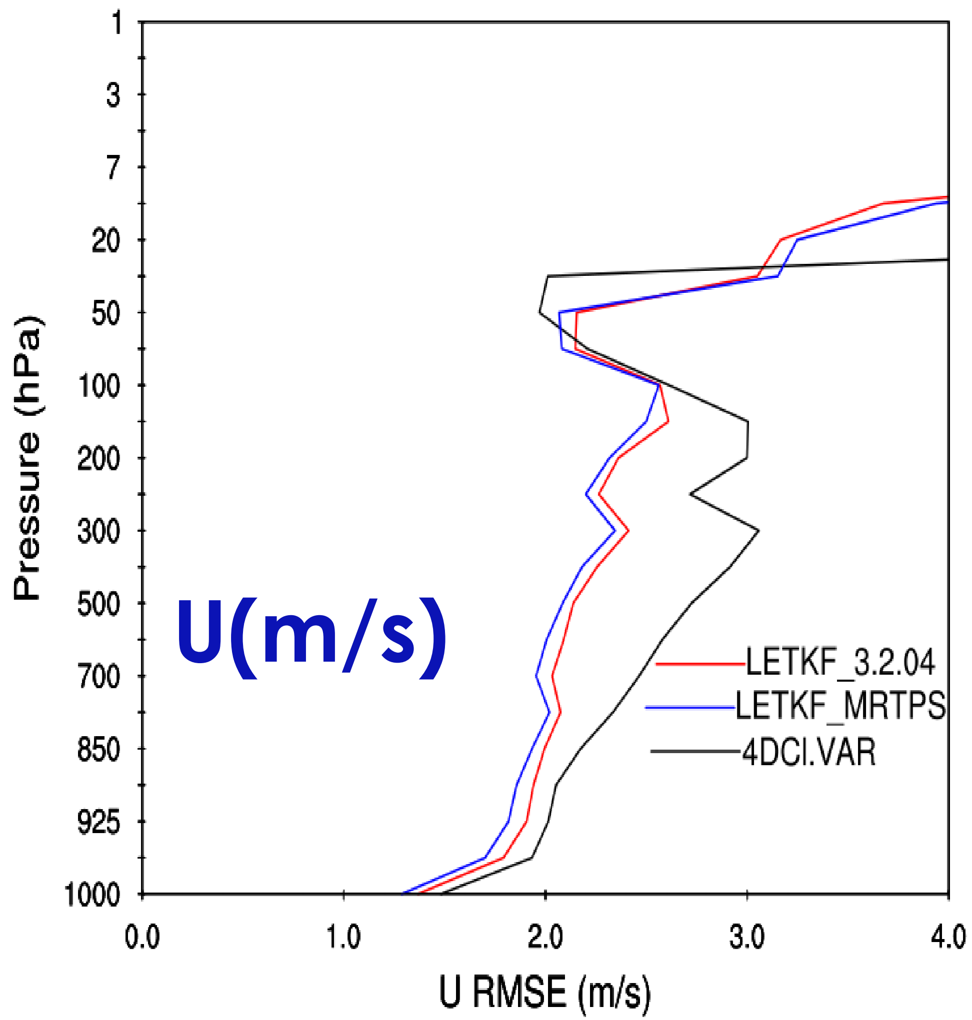


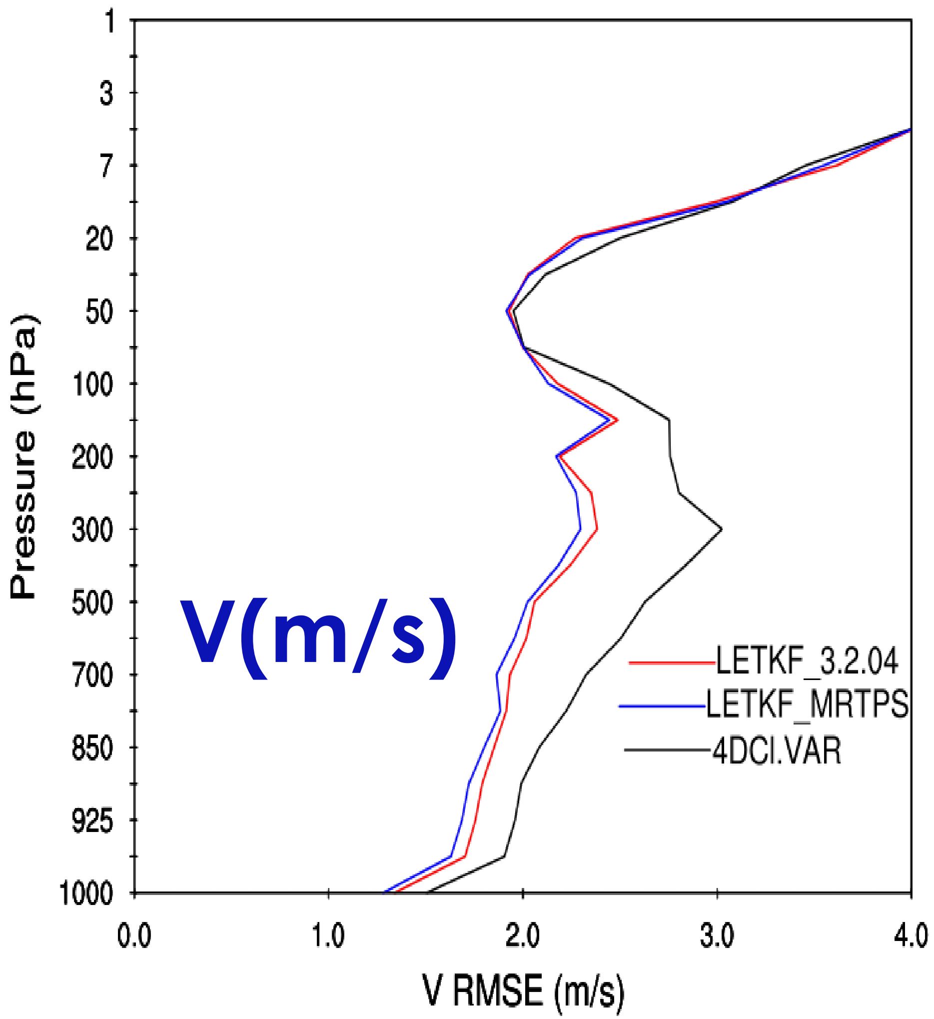
10-DAY MEAN [3D-VAR RESULT] RMSD NO UPP. – RMSD UPP.



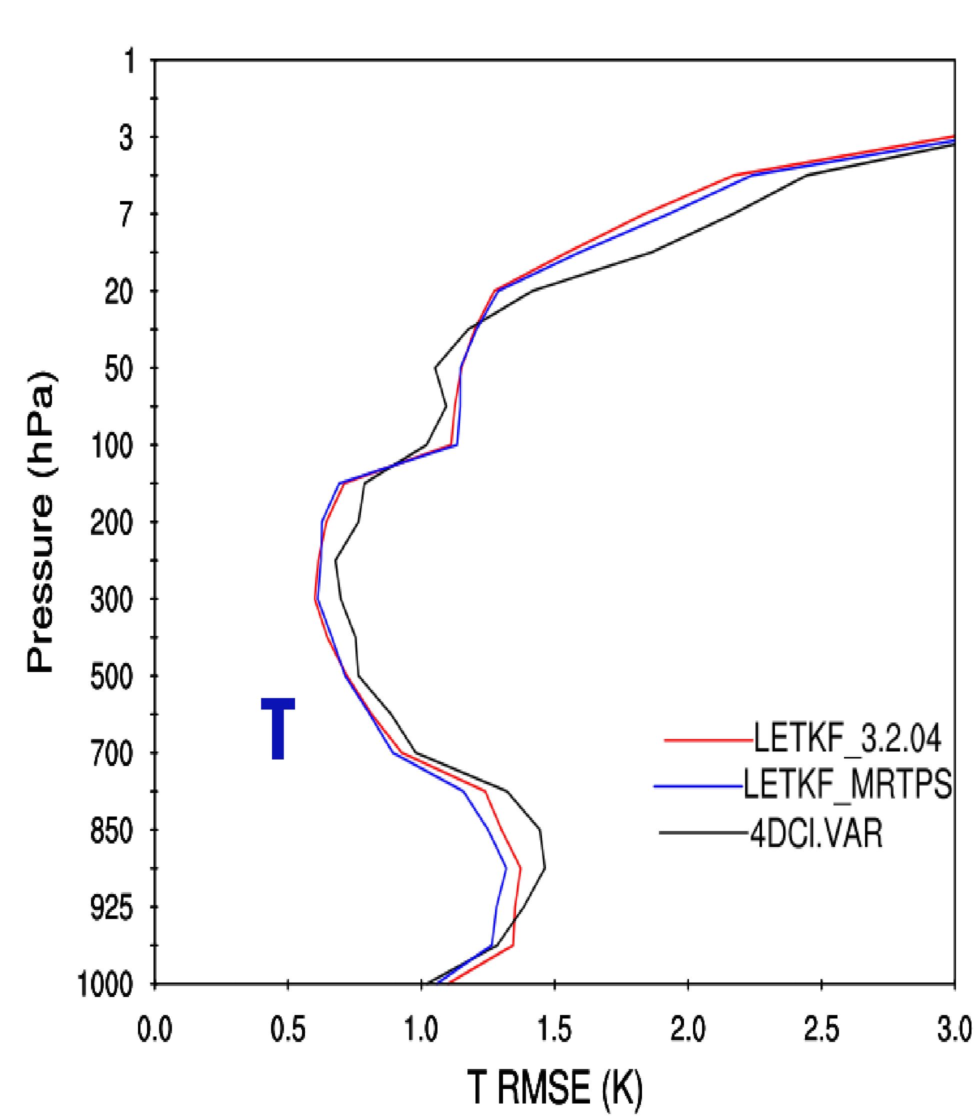


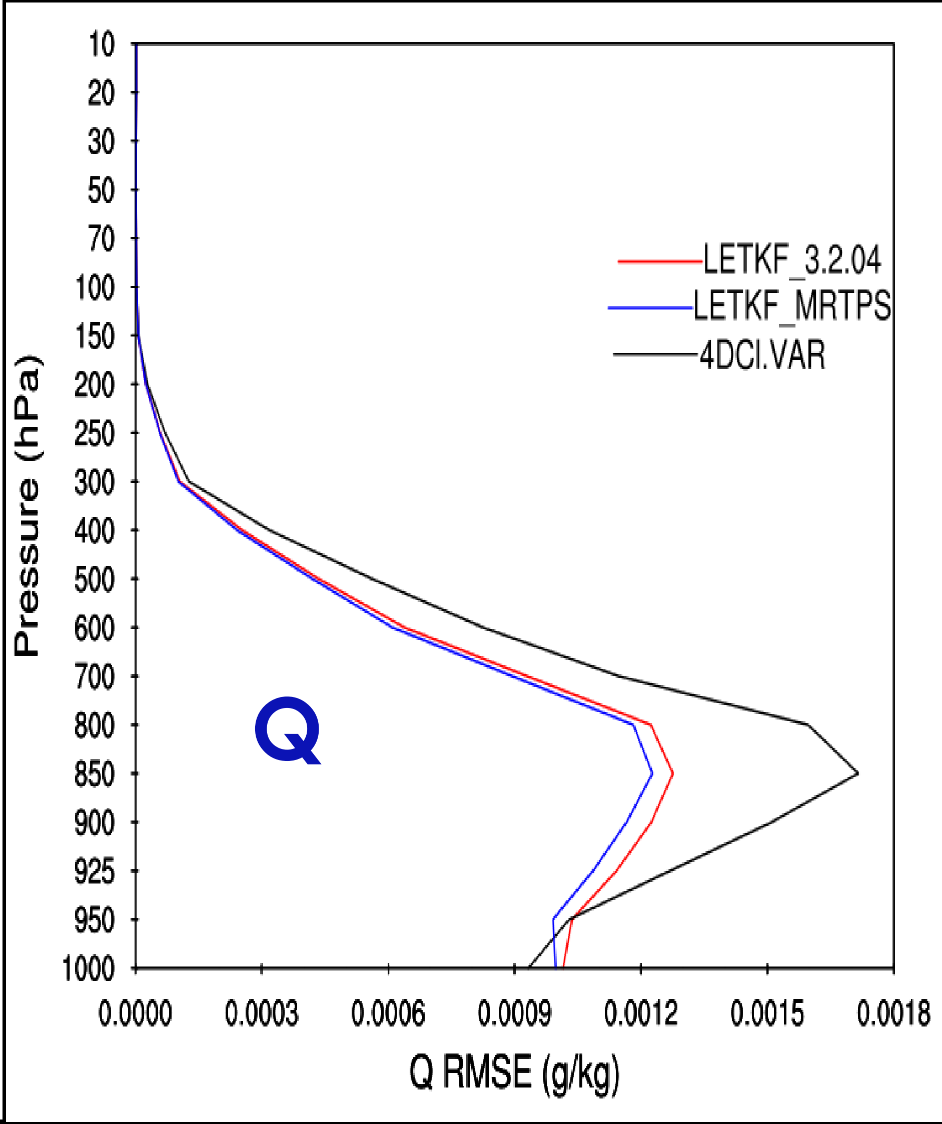
3D-Var (black) / Adapt.Mult (Red) / MRTPS (Blue)
RMSD PRFILE





3D-Var (black) / Adapt.Mult (Red) / MRTPS (Blue)
RMSD PRFILE





"A key missing component of the global observing system (GOS) is measurement of the three-dimensional global wind (World Meteorological Organization, 2000),…. particularly in the tropics, Southern Ocean, and in most of the stratosphere and mesosphere". (Allen et al. 2015)

Moreover, winds are not well constrained by temperature observation due to the lack of geostrophy in tropics.

A potential for ozone assimilation has been suggested for the wind analysis, particularly in the tropics in a global shallow-water model (Allen et al. 2015).

Also in this study, it is shown that the tropical winds are not well constrained by radiance observation alone in the stratosphere.

Appropriate covariance inflation as well as wind or highly correlated observation would be required for tropical stratosphere.

SUMMARY AND OUTLOOK

RTPS effectively inflates background covariances, especially in the troposphere where observation is dense.

A modified RTPS method is suggested here to avoid excessively enhanced perturbations above the troposphere and thereby reduce unnecessary analysis increments in the region where observation is rather sparse.

There are difficulties in the wind analysis in the tropical stratosphere, especially in the ozone layer. A remedy can be the ozone data assimilation, which can be examined in the future.

Toward a less tuning and more adaptive way:
(e.g. Further improvement of MRTPS and other combinations