A new strategy to stabilize bias correction of satellite radiance observation in data assimilation system in KIM

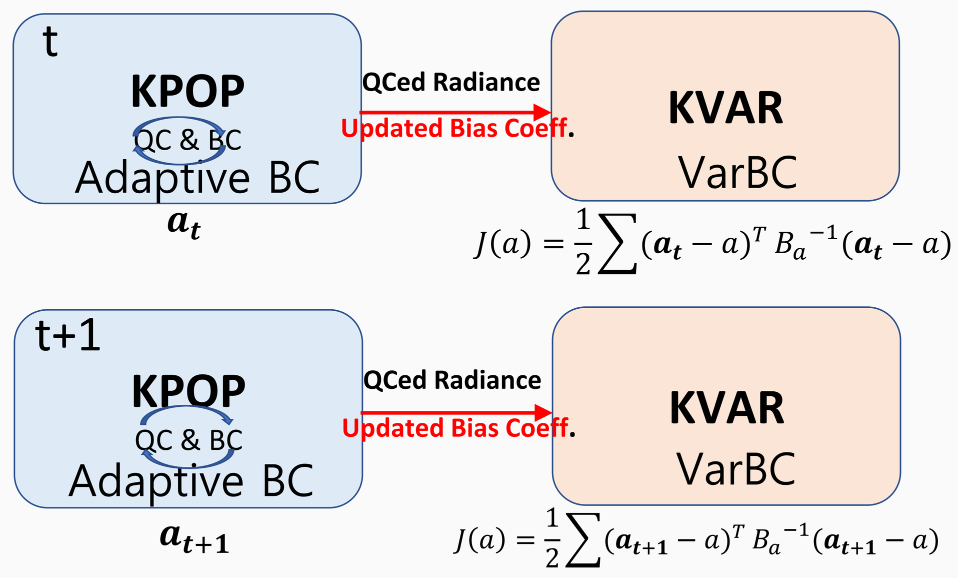
KIAPS KOREA INSTITUTE OF ATMOSPHERIC PREDICTION SYSTEMS

Hyeyoung Kim, Jeon-Ho Kang and In-Hyuk Kwon

Data Assimilation Group/KIAPS, Seoul, Korea. email: hyelong99@gmail.com

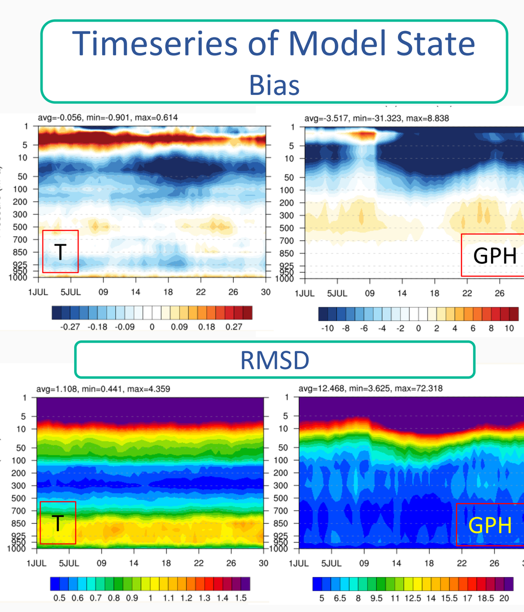
1 Background

In KPOP(KIM Package for Observation Process), the quality control and adaptive bias correction are repeatedly performed to correct the bias of satellite radiance data and then the variational bias correction scheme is applied in data assimilation process. With these methods, the bias of observation is calculated and corrected every cycle, therefore it is exposed that the bias can be strengthened if the model is biased. Comparing the analysis field of KIM with that of ECMWF, there are large biases in the upper layer(higher altitude than 100hPa) of the model, and sometimes these biases oscillate. Since adaptive bias correction is applied, the bias correction coefficients are also fluctuated with the same period shown in the biases of the KIM analysis field. It means that this bias correction method is correlated with the model field strongly. Thus, new scheme need to be designed to consider the statistics of previous observations and background model fields by giving time weights when calculating the bias correction coefficient.

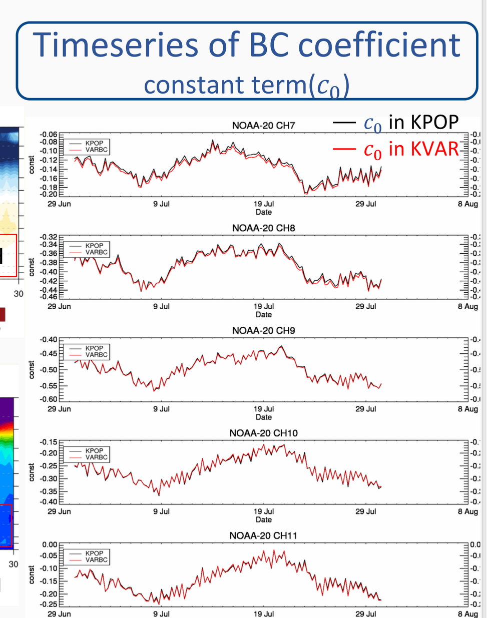


2 Issue

- Sometimes constant terms of KPOP and KVAR's bias correction are fluctuated with daily cycle and more long period cycle.
- BC coefficients are updated and the observations are fit to background field at every cycle.
- If the model becomes unstable when the model or DA is updated, this is reflected in the BC coefficients immediately.



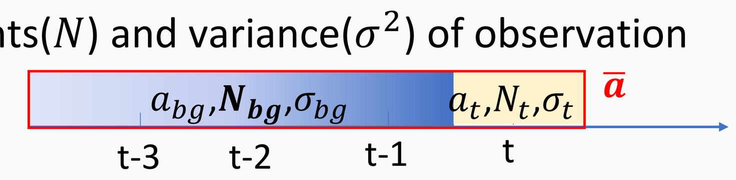
CTL's timeseries of GPH and temperature bias and root mean square errors against IFS analysis field.



Timeseries of bias correction's constant term in KPOP(black solid) and VarBC(red solid).

3 Methods-bias adaption rate

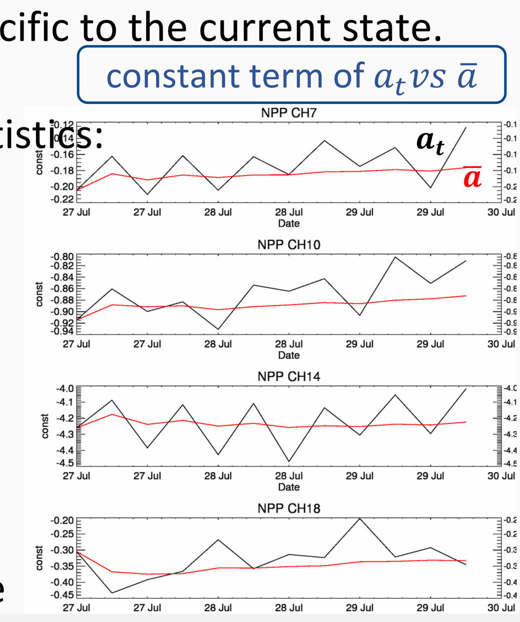
- It needs to prevent the coefficients from being made too specific to the current state.
  - Use bias adaption rate to limit the BC coefficient's range
  - Consider the current($\boldsymbol{a_t}$) and previous($\boldsymbol{a_{bg}}$) observation's statistics: counts(N) and variance(σ^2) of observation



$$\bar{\boldsymbol{a}} = w_{bg}a_{bg} + w_t a_t$$

$$= \frac{N_{bg}\sigma_{bg}^2 a_{bg} + N_t\sigma_t^2 a_t}{N_{bg}\sigma_{bg}^2 + N_t\sigma_t^2} \text{ ,where } N_{bg} = N\left(\frac{1}{2^{1/cycles}-1}\right)$$

- $\bar{\boldsymbol{a}}$ is new coefficient limited by adaption rate, which reflect the previous coefficient, and become more stable than $\boldsymbol{a_t}$



Cold run of bias correction's constant term. Current constant term($\boldsymbol{a_t}$) is black solid and the new generated constant term($\bar{\boldsymbol{a}}$)is red solid. $\bar{a}$ does not follow the daily cycle of $\boldsymbol{a_t}$.

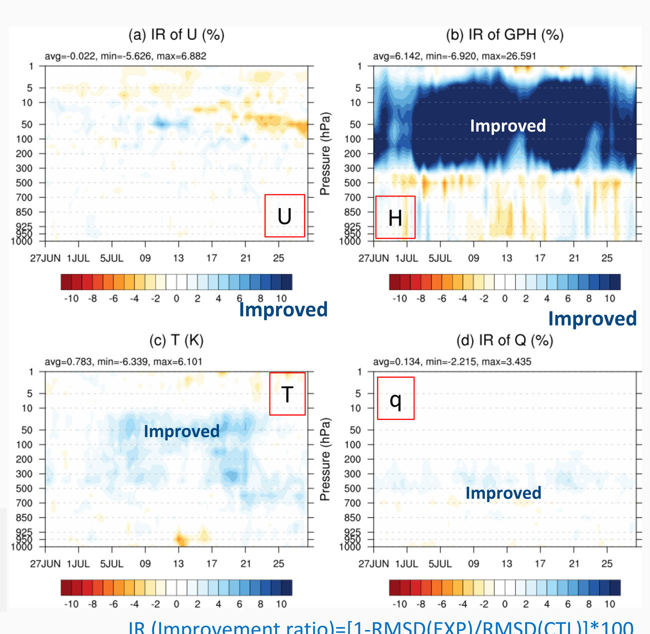
4 Results

- Experiment from 24 Jun to 31 July 2021:

CTL: KIM3.6a(ne180)+Hybrid-4DEnVAR(50km) EXP: CTL+ ATMS using adaption rate in BC

Analysis field

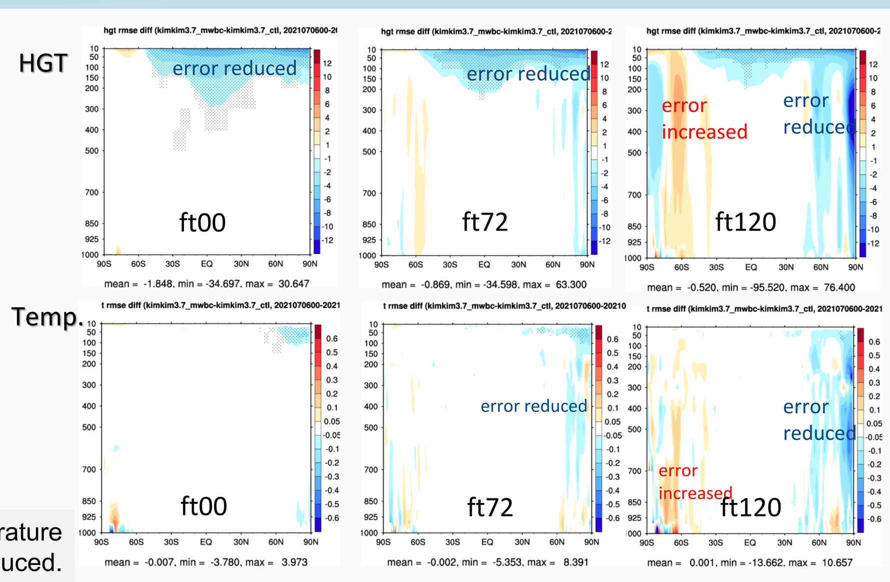
- Using adaption rate in BC process, GPH improved about 6% and temperature over 0.8% on average.
- The EXP analysis field show continuous improvement over the experiment period.
- The GPH and temperature of analysis field of EXP improved above 300hPa.
- The humidity field shows improvement above 500 hPa.



Timeseries of improvement rate(the normalized difference of root mean squared error) of wind, Geopotential Height(GPH), Temperature and humidity between the CTL and EXP's analysis field.

Verification of Forecast

- GPH with significant improvement in analysis field is shown in 5-day forecast field.
- Forecast field accuracy increases in NH(~ 6%) but decreases in SH(~ 2%).
  - It may be related to the weakened oscillation around SP.

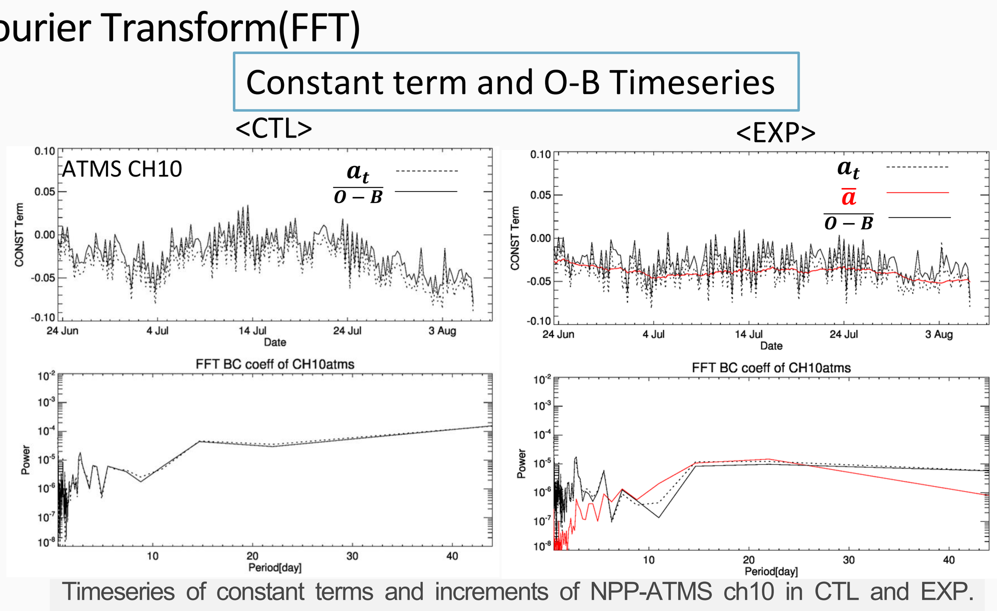


CTL and EXP's zonal mean of GPH, and temperature forecast field. Blue means that error reduced.

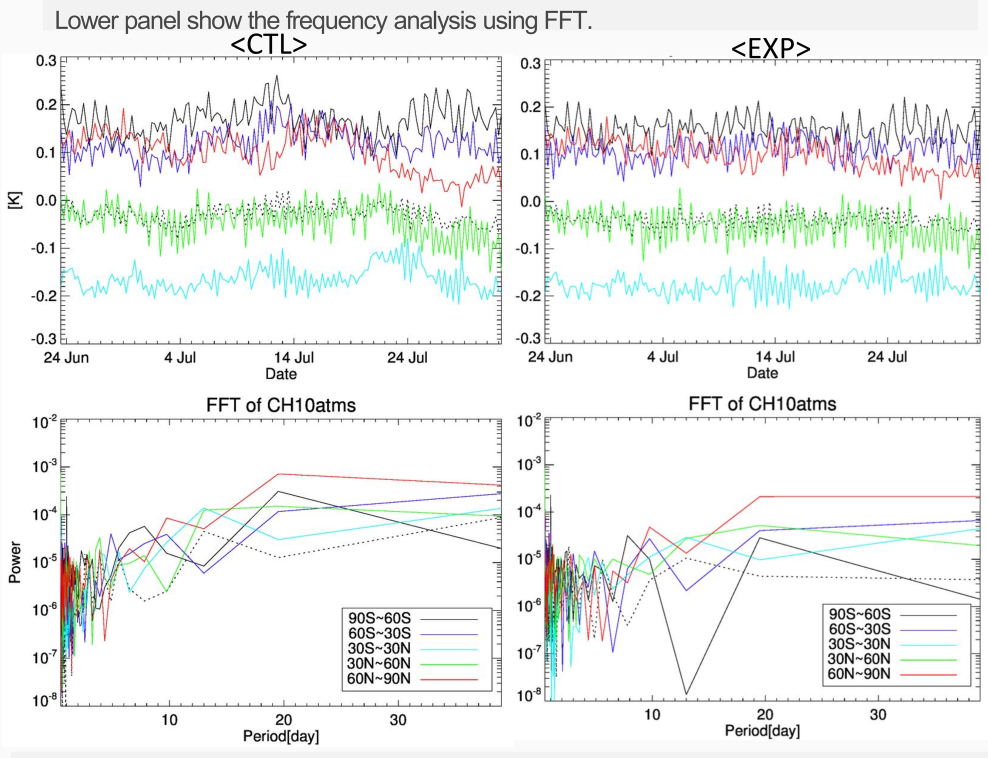
Frequency Analysis

Compare the frequency analysis of observation increments(O-B) and BC constant terms between CTL and EXP using Fast Fourier Transform(FFT)

In CTL, the observation increment and the constant term are almost same feature in magnitude and main frequencies. Using the adaption rate in BC process, the 7-day or longer cycle fluctuations of increments are reduced. The new coefficient($\bar{\boldsymbol{a}}$) calculated by adaption rate has smaller power for cycle of 5day or less. As a result of increment's frequency analysis by latitude, the 20-day fluctuation is strong in high latitude, and 13-day fluctuation is dominant in equator and the middle latitude of NH in CTL. The long period fluctuations are reduced except for the north pole area. The long-period fluctuation around south pole has weakened significantly in EXP.



Timeseries of constant terms and increments of NPP-ATMS ch10 in CTL and EXP. Lower panel show the frequency analysis using FFT.



The observation increment timeseries of NPP-ATMS ch10 of CTL and EXP . Lower panel show the frequency analysis using FFT. Each lines mean the increment's average for each latitude

5 Summary and Plan

- KPOP uses the (offline) adaptive bias correction to fit the observation to the background fields at every cycle.
- To prevent the coefficients being made too specific to the current cycle, the coefficient need to be limited.
- When the model fluctuates strongly, the analysis is stabilized and the Northern Hemisphere forecast is improved using bias adaption rate.
- Extend bias adaption rate to VarBC in KVAR and make it recursive to KPOP.

6 References

Atkinson, A., J. Cameron, B. Candy, and S. English, 2005: Bias correction of satellite data at the Met Office. ECMWF/EUMETSAT NWP-SAF Workshop on Bias estimation and correction in data assimilation, 9th November.
Aulighé T, and AP McNally, 2007: Interaction between bias correction and quality control. Q. J. R. Meteorol. Soc. 133: 643–653,
---------, AP McNally, and DP Dee, 2007: Adaptive bias correction for satellite data in a numerical weather prediction system. Q. J. R. Meteorol. Soc. 133: 631–642, doi: 10.1002/qj.56.
Cameron J. and William Bell, 2016: The testing and planned implementation of variational bias correction (VarBC) at the Met Office,
Dee DP, 2005: Bias and data assimilation, Q. J. Royal Met. Soc. 613, pp 3323-3343.
-------, 2004: Variational bias correction of radiance data in the ECMWF system. In Proceedings of the ECMWF Workshop on Assimilation of High Spectral Resolution Sounders in NWP, Reading, UK, 28 June to 1 July 2004. pp. 97–112.
Eyre JR., 2016: Observation bias correction schemes in data assimilation systems: a theoretical study of some of their properties Q. J. R. Meteorol. Soc. 142: 2284–2291.
--------, 1992: A bias correction scheme for simulated TOVS brightness temperatures. Technical Memorandum 176. Reading, UK: ECMWF.
Harris B. and G. Kelly, 2001: A satellite radiance bias correction scheme for radiance assimilation, Q. J. Royal Met. Soc. 127, pp 1453-1468.
Kang, J.-H., H.-W. Chun, S. Lee, J.-H. Ha, H.-J. Song, I.-H. Kwon, H.-J. Han, H.Jeong, H.-N. Kwon, and T.-H. Kim, 2018: Development of an Observation Processing Package for Data Assimilation in KIAPS. Asia-Pac. J. Atmos. Sci., 54(s), 303-31.
Rabier F, H Jarvinen, E Klinker, J-F Mahfouf, A Simmons, 2000: The ECMWF operational implementation of four-dimensional variational assimilation. I: Experimental results with simplified physics. Q. J. Royal Meteorol. Soc. 126: 1143–1170.
Rawlins F., S.P. Ballard, K.J. Bovis, A.M. Clayton, D. Li, G.W. Inverarity, A.C. Lorenc, and T.J. Patne, 2007: The Met Office global four-dimension variational data assimilation scheme. Q. J. Royal Met. Soc. 133, pp 347-362.

The 24th International TOVS Study Conference, Tromsø, Norway, 16-22, March, 2023