The estimation and tuning of GNSS-RO bending angle observation errors in the GSI hybrid data assimilation system

Zih-Mao Huang[1], Hui Shao[2], Guo-Yuan Lien[1], Chung-Han Lin[1], Daryl Kleist[3]

[1]Central Weather Bureau, Taipei, Taiwan
[2]Joint Center for Satellite Data Assimilation (JCSDA), Maryland, USA
[3]Environmental Modeling Center, National Centers for Environmental Prediction (NCEP), Maryland, USA

Outline

- Introduction
- Methodology
  - Desroziers' method and total variance method
  - Flow chart of estimating observation error
- Discussion
  - Observation error estimation and assimilation experiment results without FORMOSAT-7 data
  - Assimilation experiment results with FORMOSAT-7 data
- Summary

Introduction

- The Gridpoint Statistical Interpolation (GSI) is the operational data assimilation system of the NCEP, and it has also been operationally used with CWB's Global Forecast System.
- For GNSS radio occultation data, the bending angle data have been assimilated using the default observation error settings in GSI, which is a family of empirical piecewise quadratic equations with respect to the observation height and latitude.
- In this study, two methods, the Desroziers' method (Desroziers et al. 2005) and total variance method (Kuo et al. 2004), are used to estimate the optimal bending angle observation errors.

Methodology

- **Desroziers' Method :**
- According to Desroziers et. al. (2005), observation error can be diagnosed by

$$E[d_a^o(d_b^o)^T] = \mathrm{R} \; ; \; d_a^o = y^o - H(x^a) \; ; \; d_b^o = y^o - H\left(x^b\right)$$

We can use O – A and O – B to estimate the observation error.

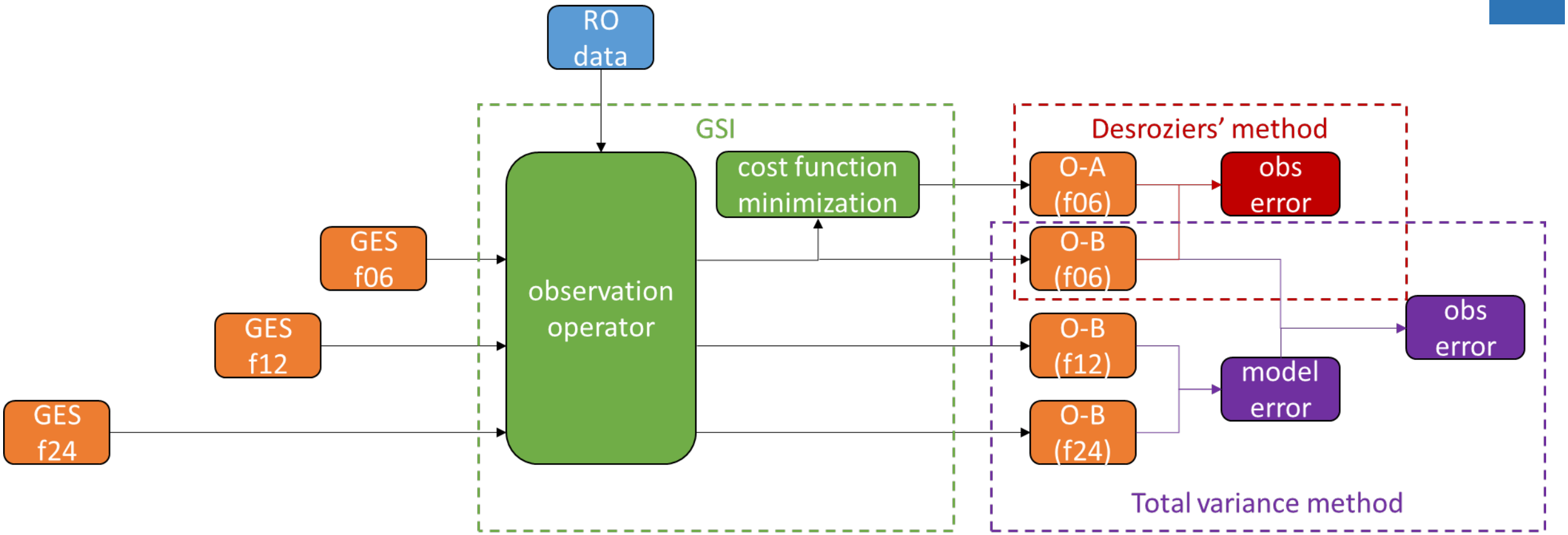
- **Total Variance Method:**
- The variance of the apparent error σ_a^2 is related to the variances of the observational and forecast errors σ_o^2 and σ_f^2 as follows:

$$\sigma_a^2 = \sigma_o^2 + \sigma_f^2$$

- The apparent error is equivalent to O − B. Forecast errors can be estimated using the NMC method based on lagged forecast differences. The differences between the forecasts at two different times, 24 h and 12 h.

Methodology

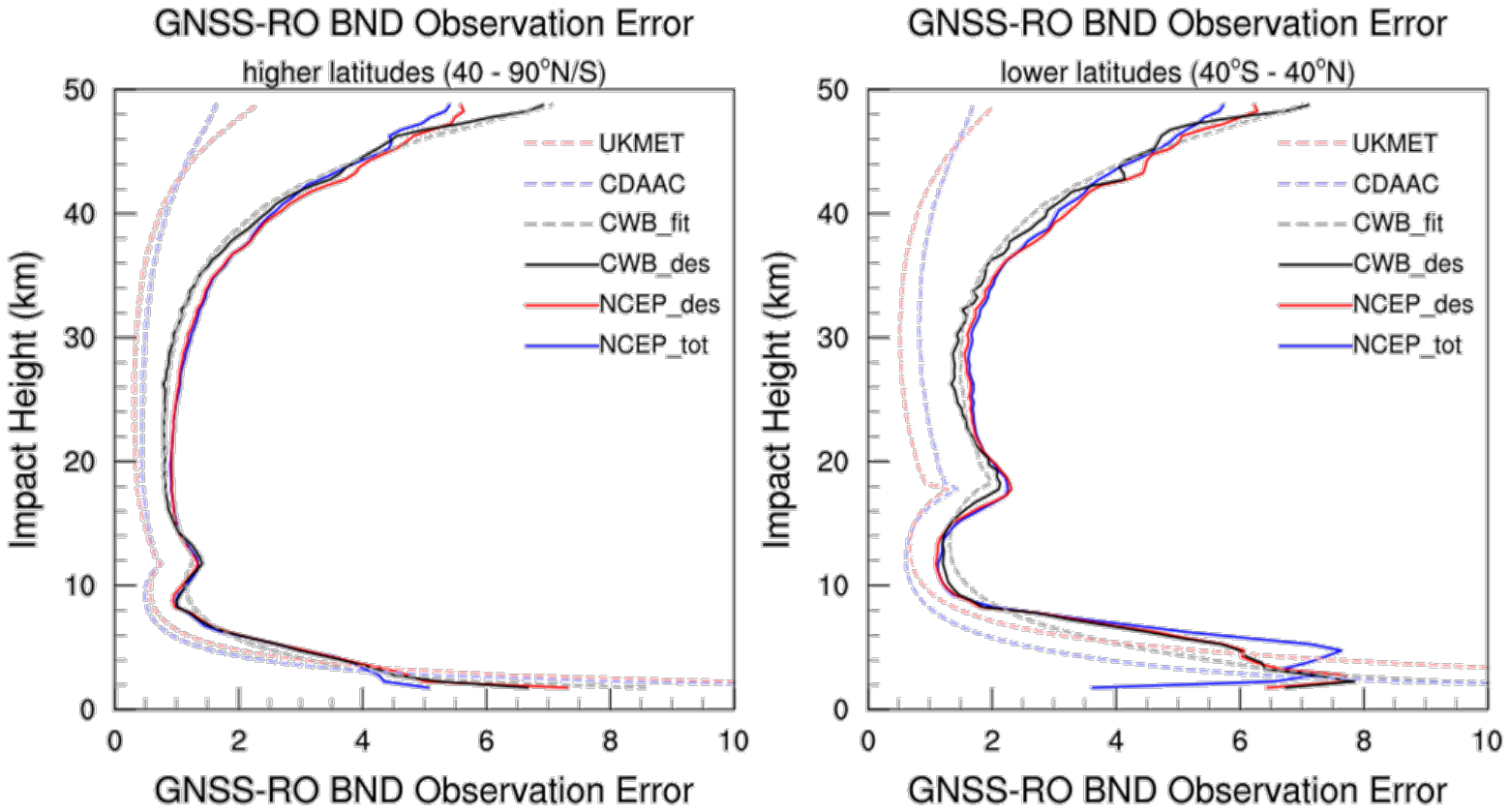
Flow chart of estimating observation error



Discussion

Default vs. estimated observation errors in CWBGFS and NCEP GFS

Statistics computed based on one-month operational data



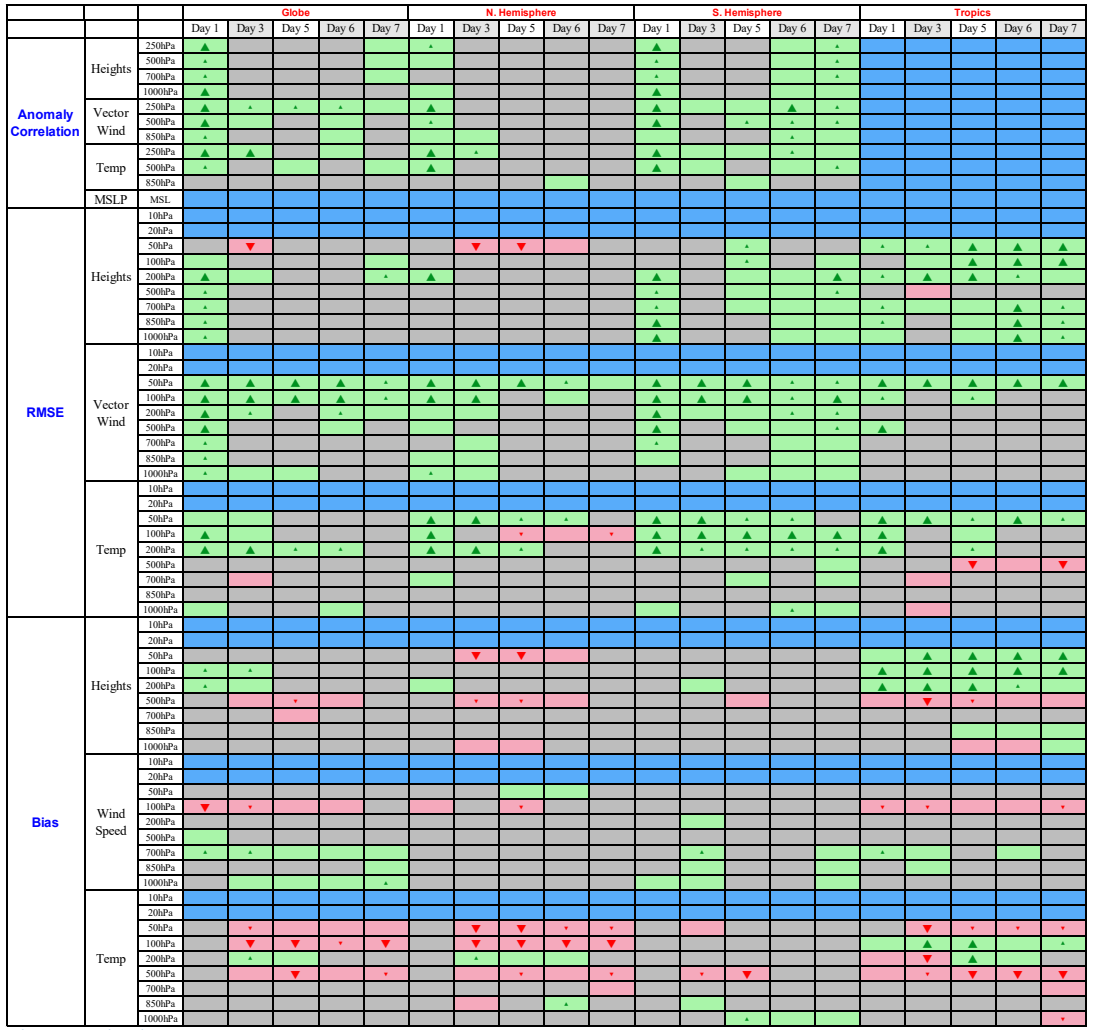
- The estimated observation error profiles show similar characteristics as the default error profiles in GSI:
  - Largest at upper stratosphere and lower troposphere with another small peak at mid-levels.
- However, the estimated error profiles are about twice larger than the default observation errors in GSI both in the FV3GFS and CWBGFS systems!
- With two NWP models and with different methods to estimate the observation errors (with NCEP GFS), all the estimated error profiles are similar.

Cycling assimilation experiments for one-month period

CTRL: with the default observation errors in GSI

NEWOE: with the newly estimated observation errors

Score card – Green/Red: NEWOE is better/worse than CTRL



00Z			
▲	Better at 99.9% significance level	▼	Worse at 99.9% significance level
▲	Better at 99% significance level	▼	Worse at 99% significance level
	Better at 95% significance level		Worse at 95% significance level
	Not statistically significant		Not applicable

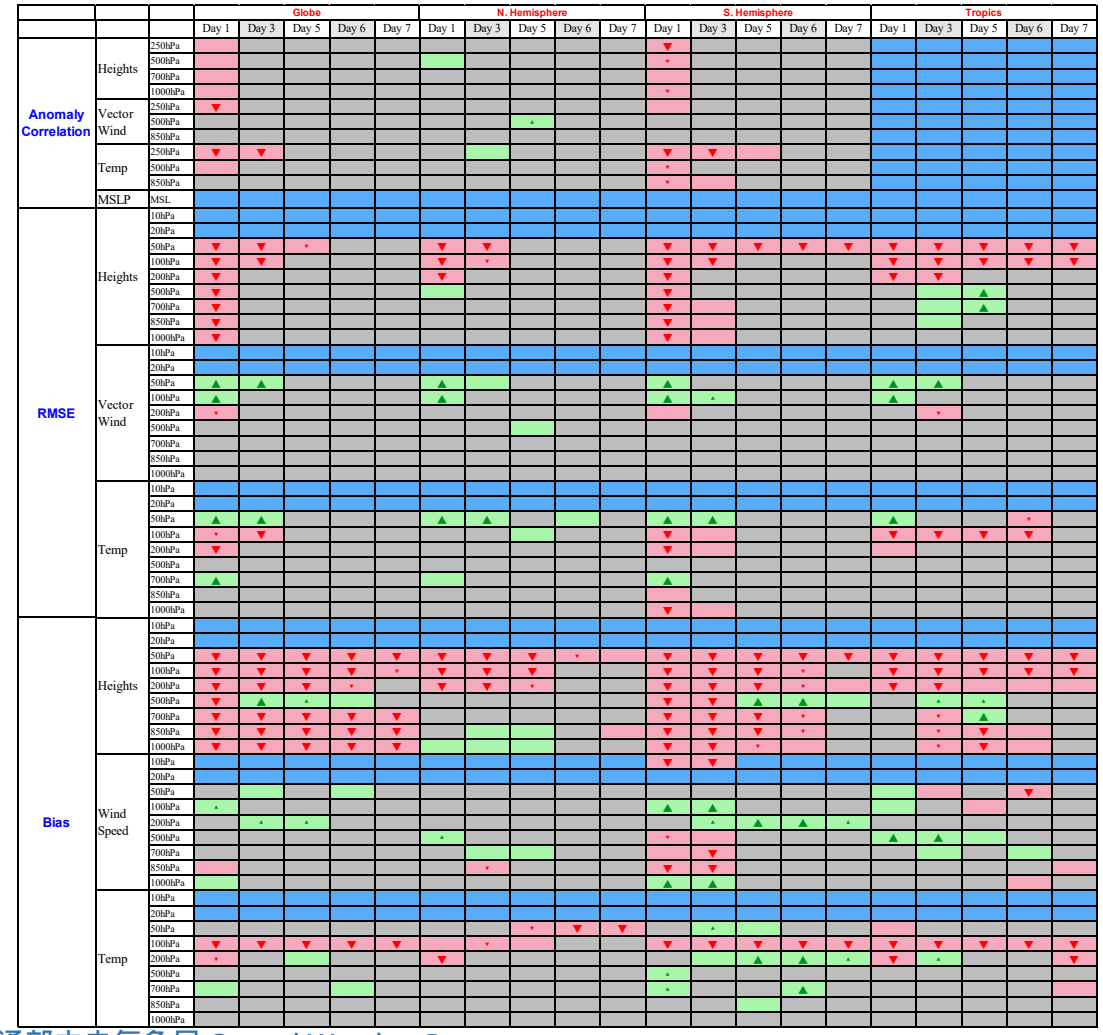
- The experimental results show that using the newly estimated observation errors of GNSS-RO data can actually lead to generally positive impacts on the forecast scores.
- We note that the FORMOSAT-7 data are not available in this period, and this conclusion would only be valid when using GSI for the CWBGFS model.

Cycling assimilation experiments with FORMOSAT-7 data

CTRL_FS7: assimilated FORMOSAT-7 data with the default observation errors

NEWOE_FS7: assimilated FORMOSAT-7 data with the estimated observation errors

Score card – Green/Red: NEWOE_FS7 is better/worse than CTRL_FS7



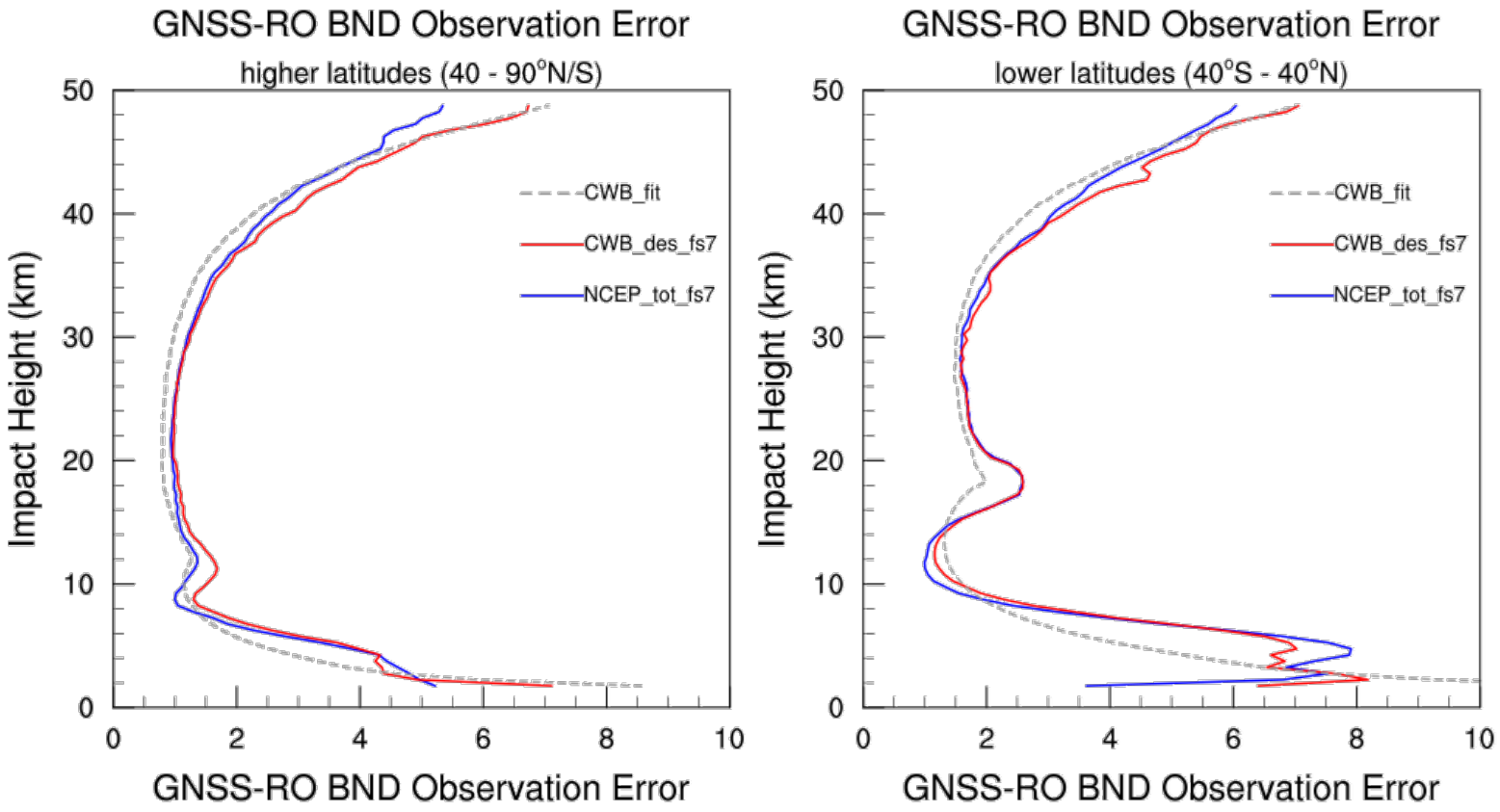
00Z			
▲	Better at 99.9% significance level	▼	Worse at 99.9% significance level
▲	Better at 99% significance level	▼	Worse at 99% significance level
	Better at 95% significance level		Worse at 95% significance level
	Not statistically significant		Not applicable

- These experiments with the FORMOSAT-7 data with the new observation errors would lead to slightly detrimental impacts on the forecast skills.
- The new observation errors of GNSS-RO data may not be suitable for assimilating the FORMOSAT-7 data.

Discussion

Estimated observation errors with FORMOSAT-7 data

Statistics computed based on one-month data



- The estimated observation errors of FORMOSAT-7 data are generally similar to those of other existing RO data, except for the data near the tropopause (~18 km) and below ~8 km in the lower latitudes.
- Therefore, why the new observation errors seem to not work well with the FORMOSAT-7 data remains unexplained; we need more investigations to find out the best setting for assimilating GNSS-RO data with FORMOSAT-7.

Summary

- The diagnosed observation errors are roughly two times as large as the default values consistently in both the FV3GFS and CWBGFS systems.
- Replacing the GSI-default RO observation errors with the newly estimated (larger) one, we obtain a positive assimilation impact with the CWBGFS system in a period without FORMOSAT-7 data, but negative impact in another period with FORMOSAT-7 data.
- We suggest that more investigations are needed to improve the forecast skills with the FORMOSAT-7 data.

Thanks for your listening