Test of CWA's Experimental Profile-Dependent Radio Occultation Observation Error Model ~~Using the ROMEX Data~~

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Introduction

- The observation-profile-dependent nature of the observation errors of the RO data has posed challenges to their quality control (QC) and/or observation error specification.
- **Local Spectral Width (LSW)** is a measure of the RO bending angle data uncertainty. Several studies have pursued the use of the LSW information to improve the QC or to construct observation error models.
  - Liu et al. (2018): Use LSW for QC. (discarding data with large LSW values)
  - Zhang et al. (2023), Sjoberg et al. (2023), Li et al. (2024), and **this study** : Use LSW to formulate an observation error model. All of these studies share an similar concept but formulate the observation error models in different ways. ~ "continuous" (or "nonlinear") QC

Observation error model with LSW

- Assume the RO bending angle observation error variance is composed of a "dynamic" term and the other "quasi-static" term.
  The latter is not profile-dependent, but can be a function of height and latitude (or other parameters):

$$\sigma^2 = \sigma_{\mathrm{dyn}}^2 + \sigma_{\mathrm{other}}^2 \qquad (1)$$

- Take long-term average of (1) for each height and latitude bin:
  [Let $\overline{(\quad)}$ be average for each height and latitude bin]

$$\sigma_{\mathrm{static}}^2 \equiv \overline{\sigma^2} = \overline{\sigma_{\mathrm{dyn}}^2} + \sigma_{\mathrm{other}}^2 \qquad (2)$$

- (1) − (2) $\rightarrow \ \sigma^2 - \sigma_{\mathrm{static}}^2 = \sigma_{\mathrm{dyn}}^2 - \overline{\sigma_{\mathrm{dyn}}^2}$

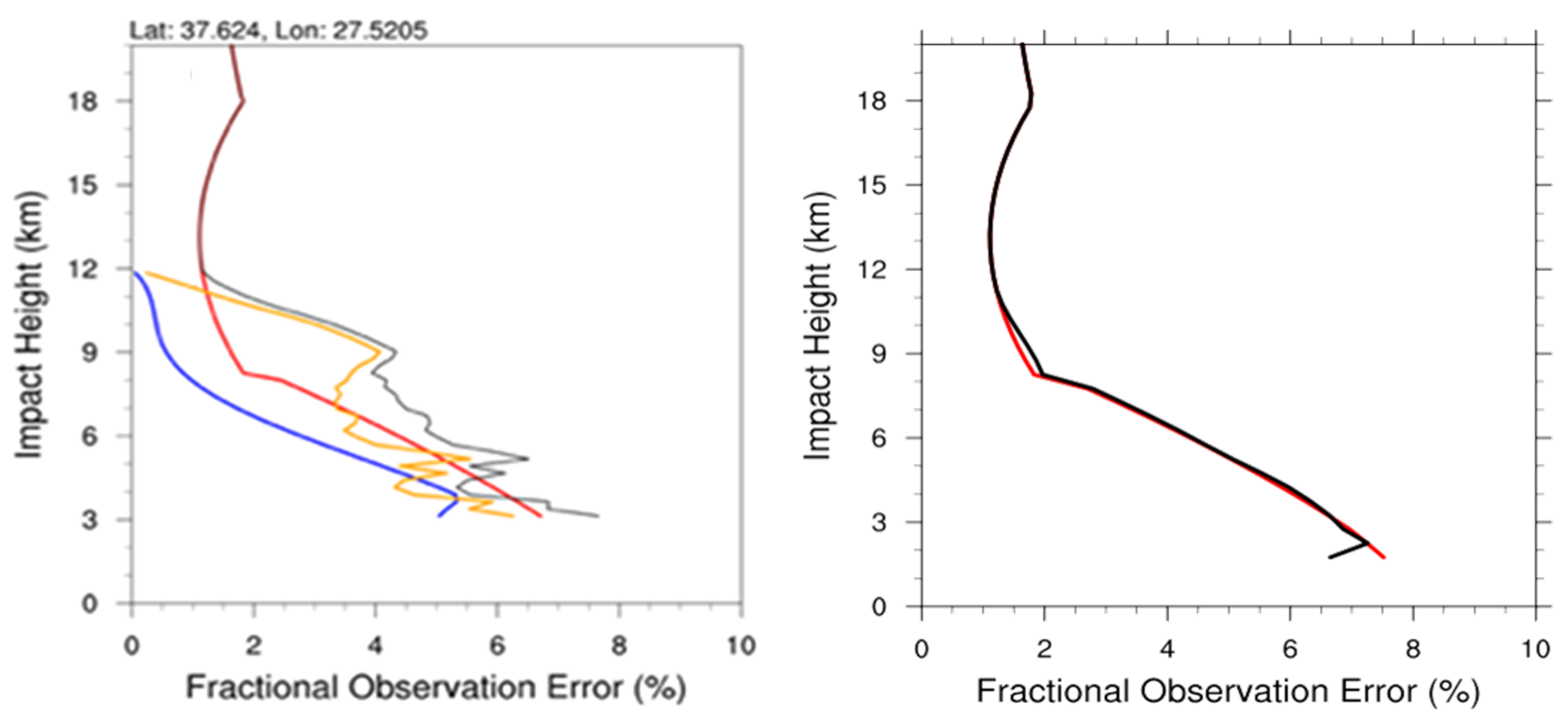
$$\rightarrow \ \sigma^2 = \sigma_{\mathrm{static}}^2 + \sigma_{\mathrm{dyn}}^2 - \overline{\sigma_{\mathrm{dyn}}^2} \qquad (3)$$

Let $\sigma_{\mathrm{dyn,\,clim}} \equiv \sqrt{\overline{\sigma_{\mathrm{dyn}}^2}}$:

$$\rightarrow \sigma = \sqrt{\sigma_{\mathrm{static}}^2 + \sigma_{\mathrm{dyn}}^2 - \sigma_{\mathrm{dyn,\,clim}}^2} \qquad (4)$$

- σ_{static} : Static observation error by traditional methods (e.g., Desroziers et al. 2005) *(for each height and latitude bin)*
- σ_{dyn} : Dynamic observation error
  ~ f (LSW) = LSW / 3
  (Zhang et al. 2023)
- $\sigma_{\mathrm{dyn,\,clim}}$: Long-term (climatological) mean of the dynamic observation error *(for each height and latitude bin)*
  $= \sqrt{\overline{\sigma_{\mathrm{dyn}}^2}}$

Static vs. Profile-dependent bending angle observation errors



A single profile

Long-term average

Red: Original static observation error
Blue: Long-term mean of the dynamic observation error
Gray: The profile-dependent observation error

Yellow: Dynamic observation error ~ LSW/3
Black: The average of the profile-dependent observation error

Main properties:

- The long-term average of the profile-dependent observation error variance always converges to traditional (statistically determined) static observation error variance.
- *[If the upper-level LSW values are zero, then]*
  Upper-level RO data use exactly the static observation errors (i.e., not profile-dependent).
- The observation errors of lower-level RO data are largely determined by their LSW values.

* Before defining the error model, the LSW values were artificially reduced to zero linearly from 9 to 12 km and set to zero above 12 km.

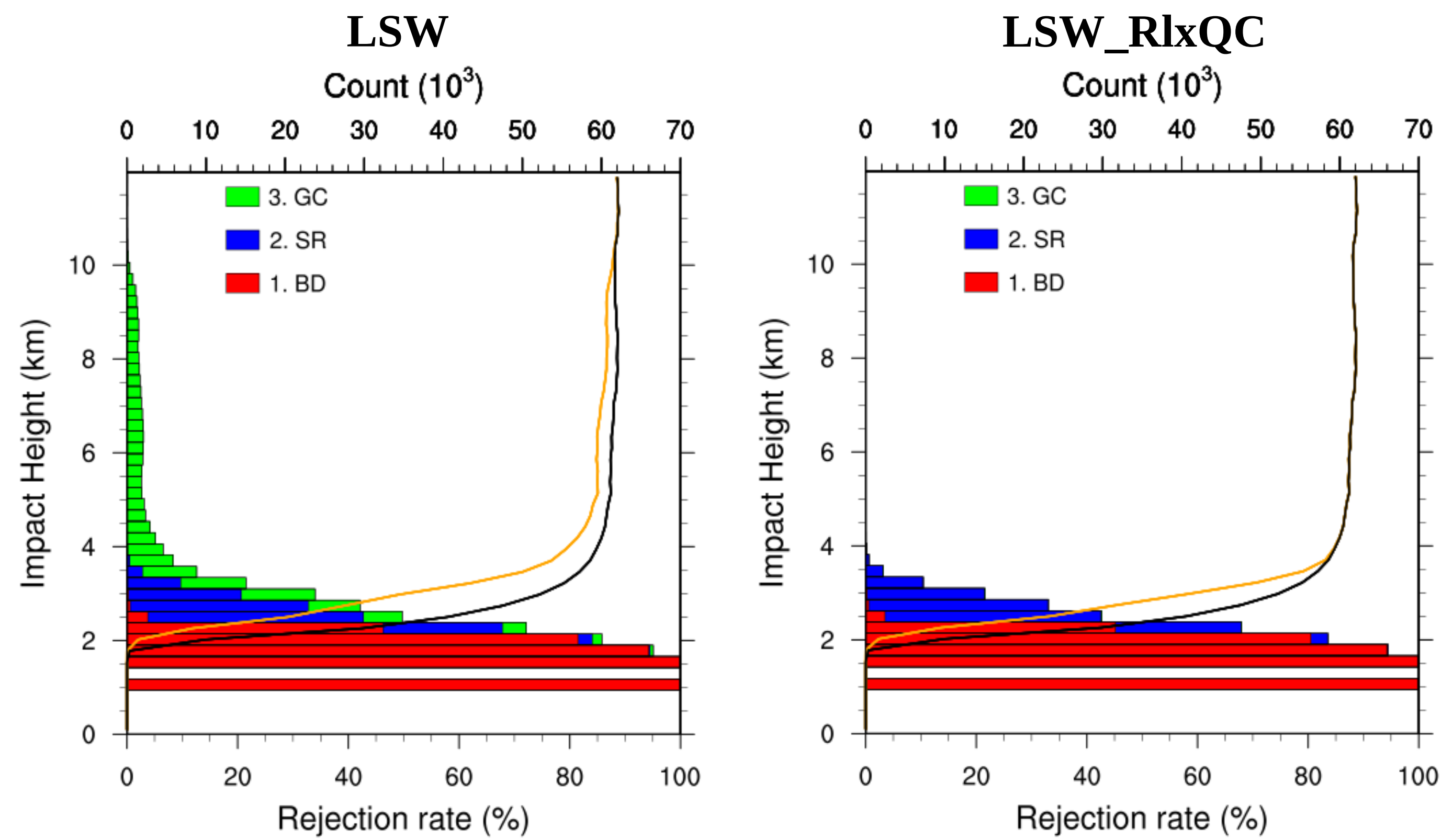
Experimental design

Model: CWA TGFS (an NCEP GFS-GSI-based system)
Period: 1 September – 15 October 2021

Experiment	LSW-based observation error model*	RO quality control
STAT	–	GSI-default QC
LSW	V	GSI-default QC
STAT_RlxQC	–	Do not use "statistical gross error check"
LSW_RlxQC	V	Do not use "statistical gross error check"

* The LSW-based observation error model is only applied to FORMOSAT-7/COSMIC-2 RO data.

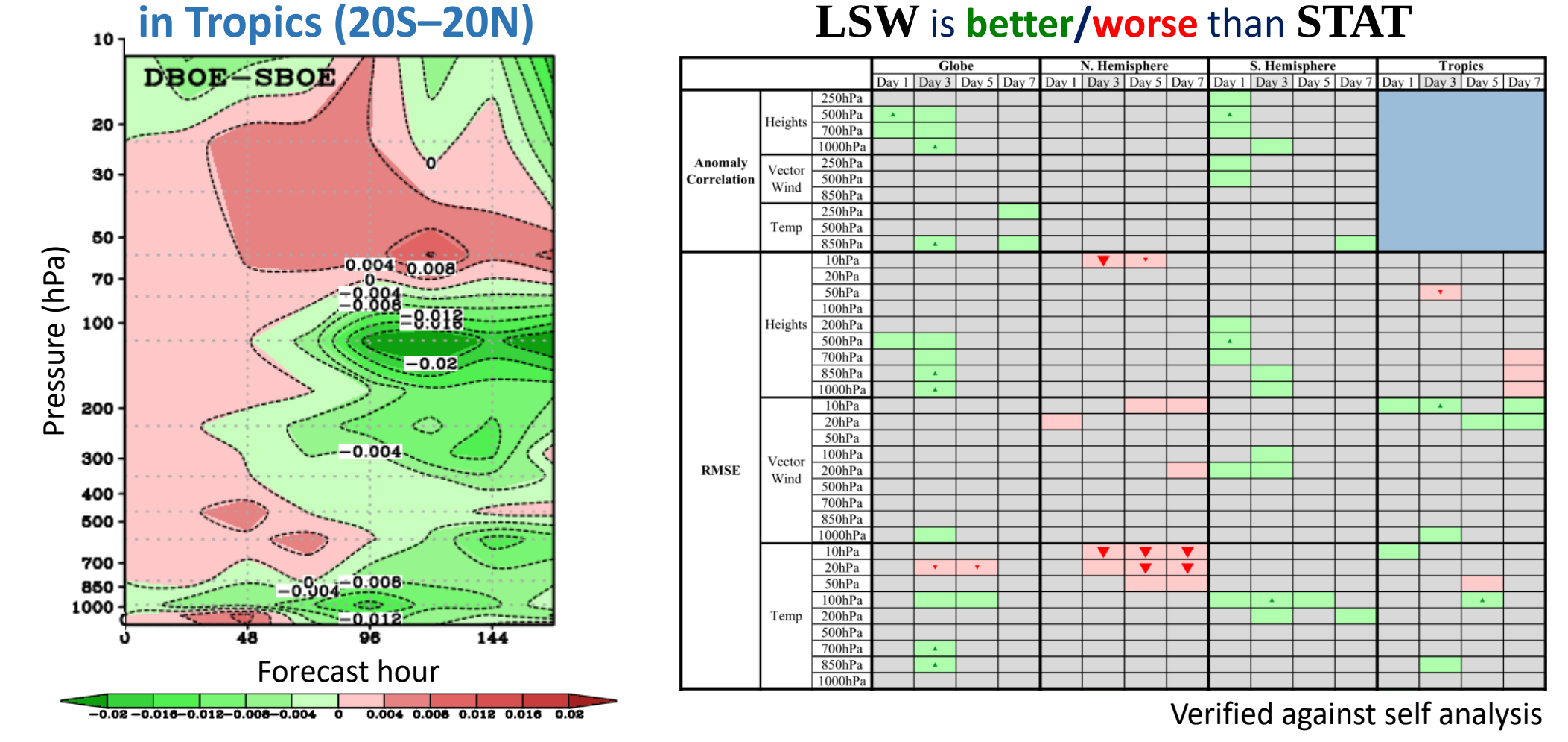
Observation counts & rejection rates



Results

LSW vs. STAT

Impact of profile-dependent RO observation errors
(Default QC in both experiments)



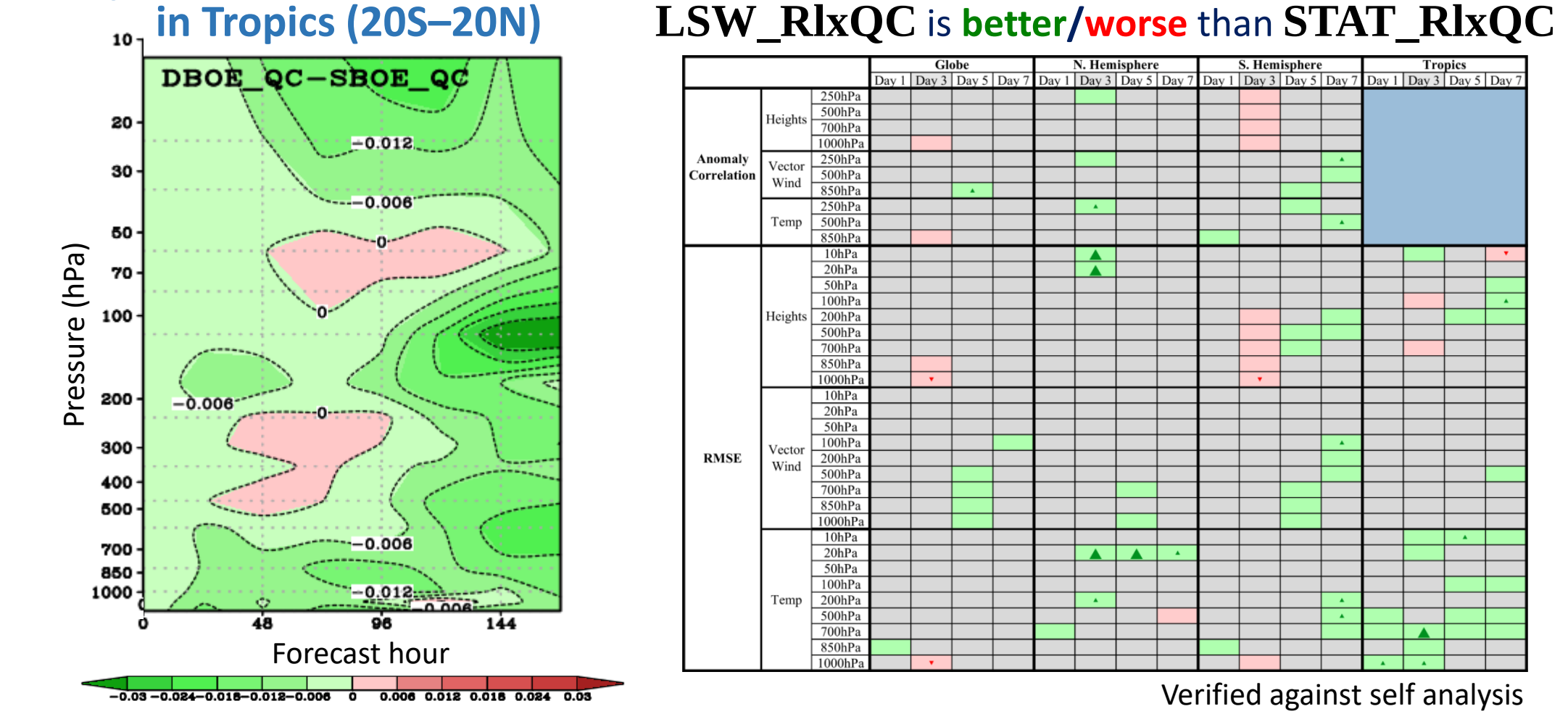
Temperature RMSE difference (K) in Tropics (20S–20N)

Scorecard – LSW is better/worse than STAT

Verified against self analysis

LSW_RlxQC vs. STAT_RlxQC

Impact of profile-dependent RO observation errors
(QC relaxed in both experiments)



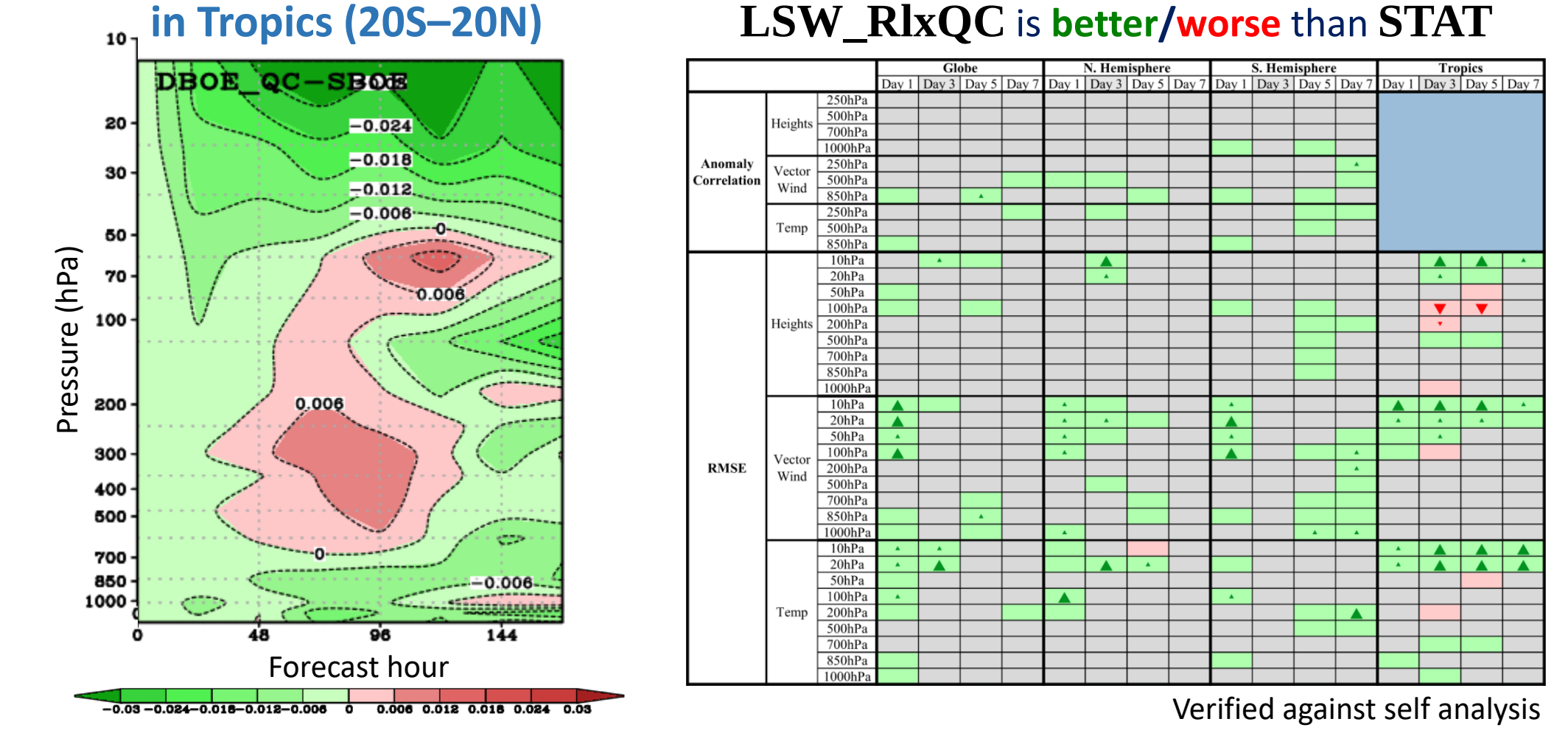
Temperature RMSE difference (K) in Tropics (20S–20N)

Scorecard – LSW_RlxQC is better/worse than STAT_RlxQC

Verified against self analysis

LSW_RlxQC vs. STAT

Impact of profile-dependent RO observation errors
(QC relaxed only in the LSW experiment)



Temperature RMSE difference (K) in Tropics (20S–20N)

Scorecard – LSW_RlxQC is better/worse than STAT

Verified against self analysis

Conclusion and future work

- We propose a new approach to formulate a bending angle observation error model, which considers both the traditional (statistically determined) static observation errors and the LSW-determined dynamic observation errors.
- We test this new profile-dependent RO observation error model in CWA TGFS global NWP system:
  - When QC is unchanged, it improves slightly some forecast skills.
  - When it is combined with a relaxation of the GSI-default QC, a larger positive impact is found.
- This approach provides a general procedure to develop profile-dependent RO observation error models upon any statistically determined RO observation error formula.
- In the current study, we apply this profile-dependent RO observation error model only to FORMOSAT-7/COSMIC-2 RO data. We will apply this observation error model to ALL ROMEX data once the UCAR-processed ROMEX data (with LSW values included) are released.

References

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Liu et al., 2018, *J. Atmos. Oceanic Technol.*, **35**, 2117–2131, https://doi.org/10.1175/JTECH-D-17-0224.1.
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