

# Assimilation of early FORMOSAT-7/COSMIC-2 GNSS radio occultation data with the global NWP system at Central Weather Bureau (CWB)

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## Background

### CWB's current operational global NWP system

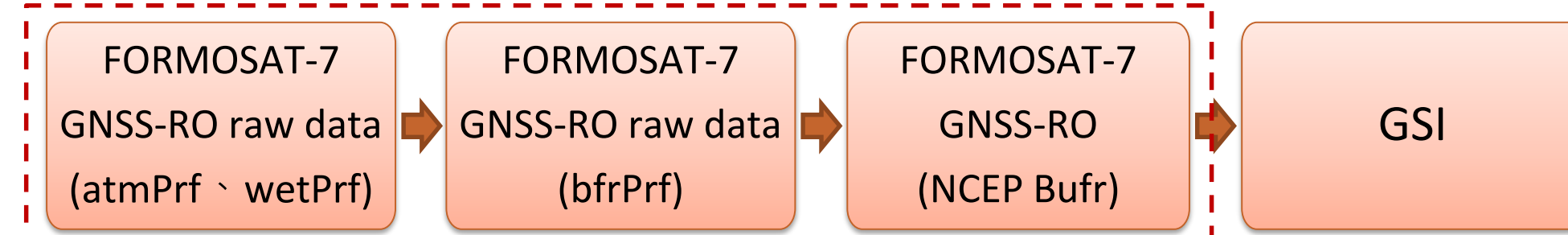
- Model: CWB Global Forecast System (CWBGFS)
  - T511L60 (~25 km)
- Data assimilation: Modified GSI (ver. 2015) for CWB GFS
  - Hybrid 3D-Var with 36 members (6-h fcst) + 36 time-lag members (12-h fcst) at T319L60.
  - Assimilate bending angle for GNSS radio occultation (RO).

### FORMOSAT-7/COSMIC-2 (FS7) satellites

- A Taiwan-U.S. collaborative space program, with a main focus of GNSS-RO observation.
  - The follow-on program to the successful FORMOSAT-3/COSMIC (FS3) program.
  - The 6 satellites were launched in June 2019, and started transmitting GNSS-RO data from July 2019.

## Experimental design

### Observation data processing



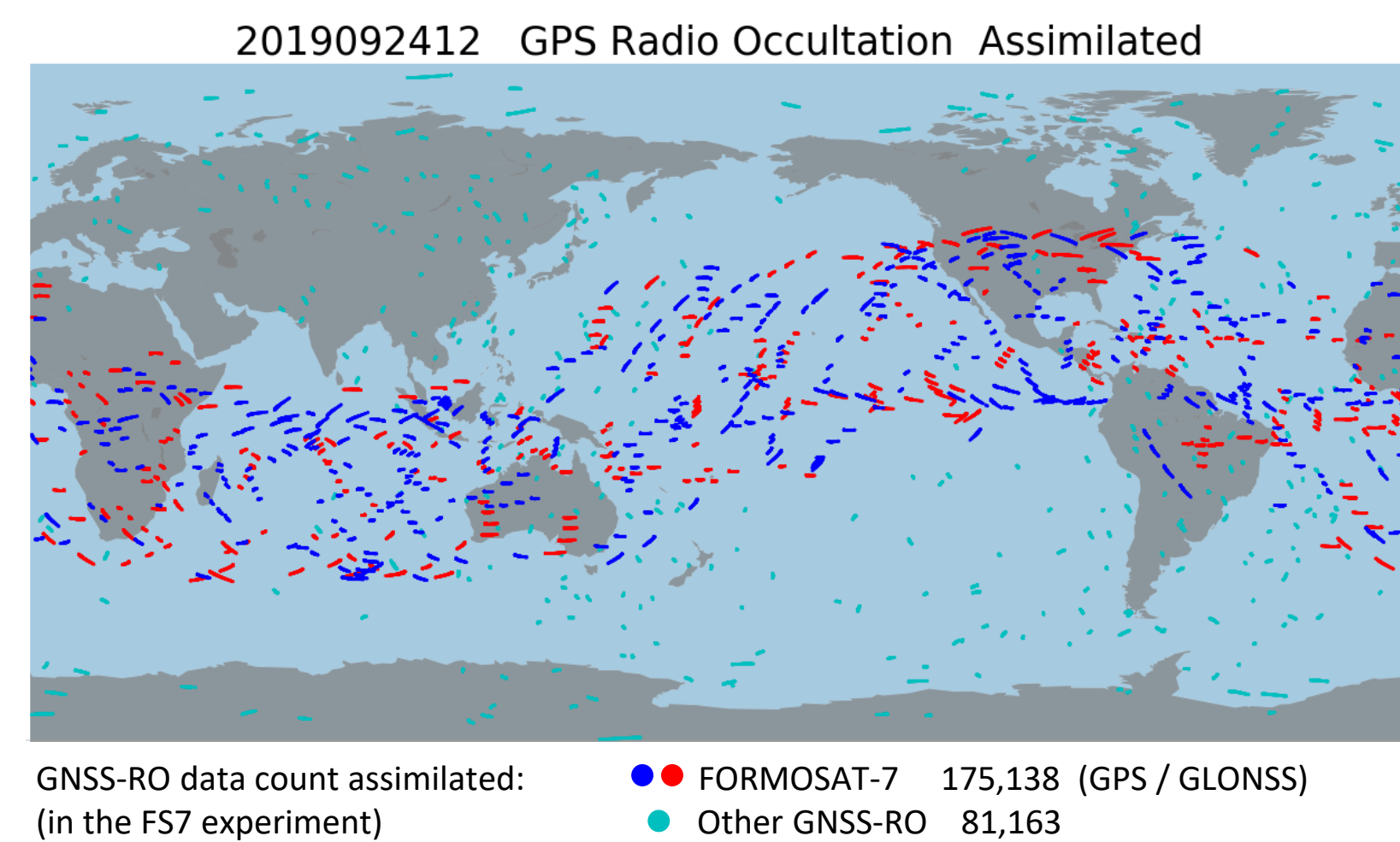
Processed by TACC (Taiwan Analysis Center for COSMIC)

### Experimental design

Experiment	Observation data assimilated
CWBGFS operational (OP)	Current operational data stream (including conventional data, satellite, GNSS-RO excluding FORMOSAT-7, ...etc.)
Parallel experiment (FS7)	Current operational data stream (as in OP) + FORMOSAT-7

The FS7 parallel experiment has been conducted for more than 3 months.

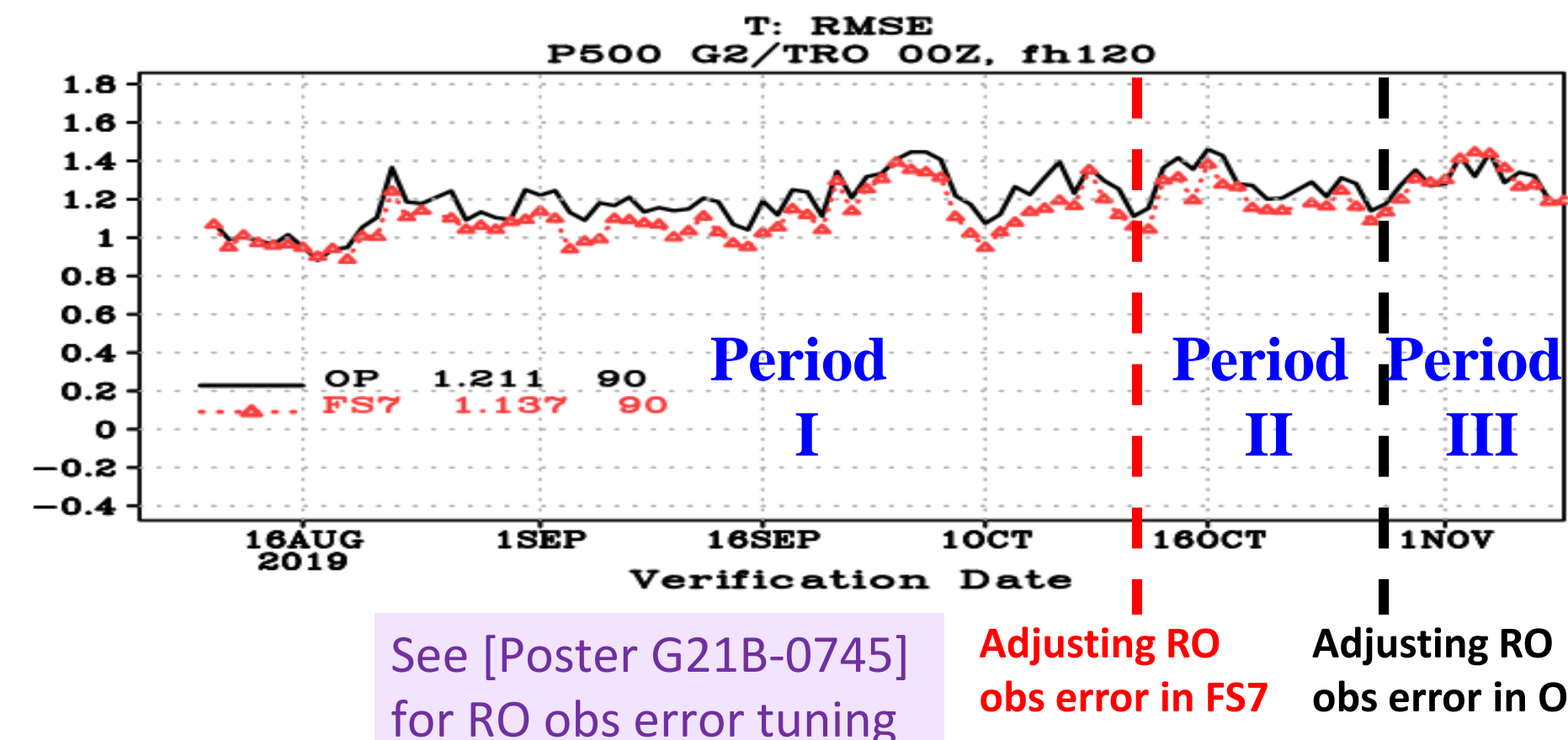
### Example of the distribution of GNSS-RO data assimilated in CWB GFS



## Results

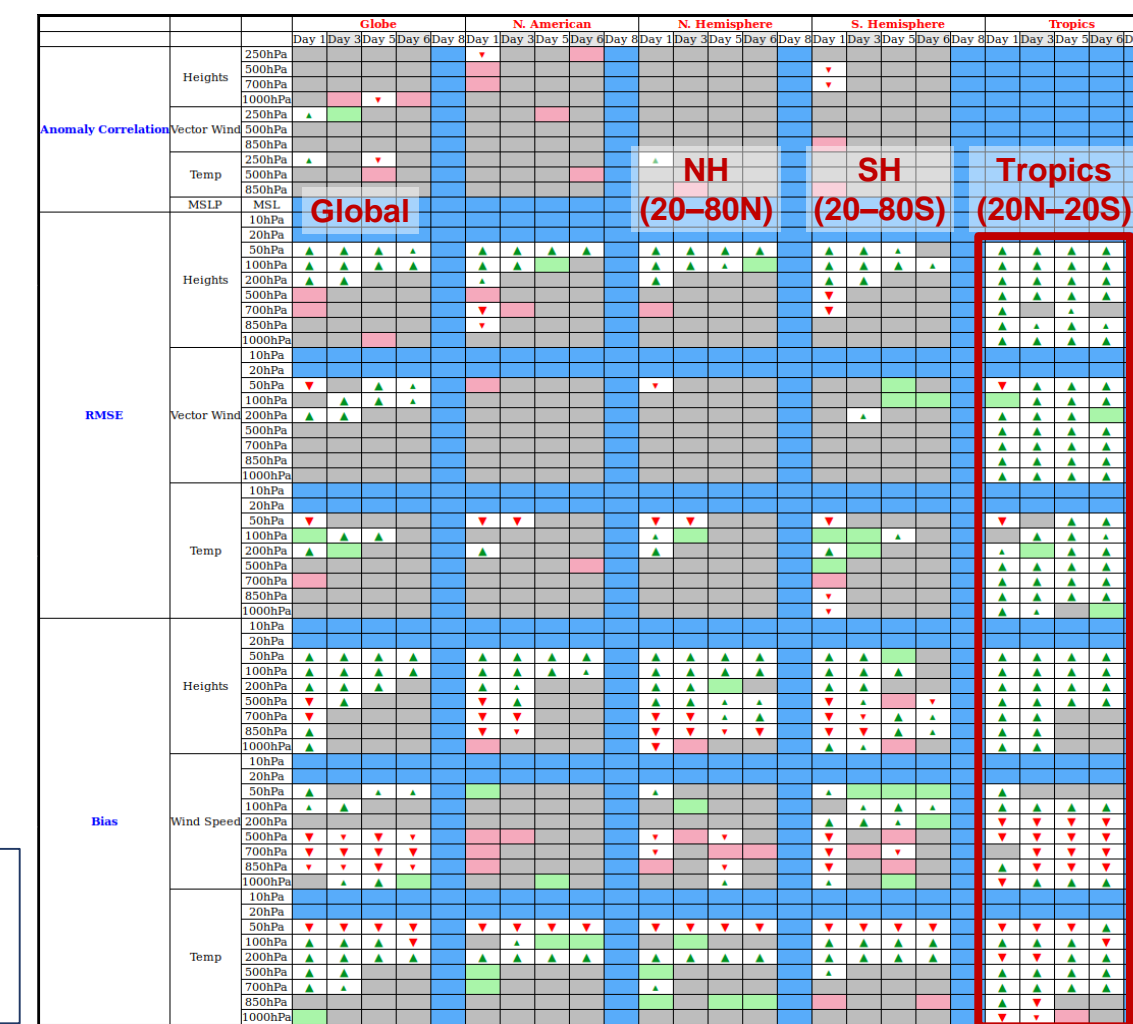
### Impact of FORMOSAT-7 data: FS7 vs. OP

#### RMSE of 5-day forecast 500-hPa temperature (K) in tropics

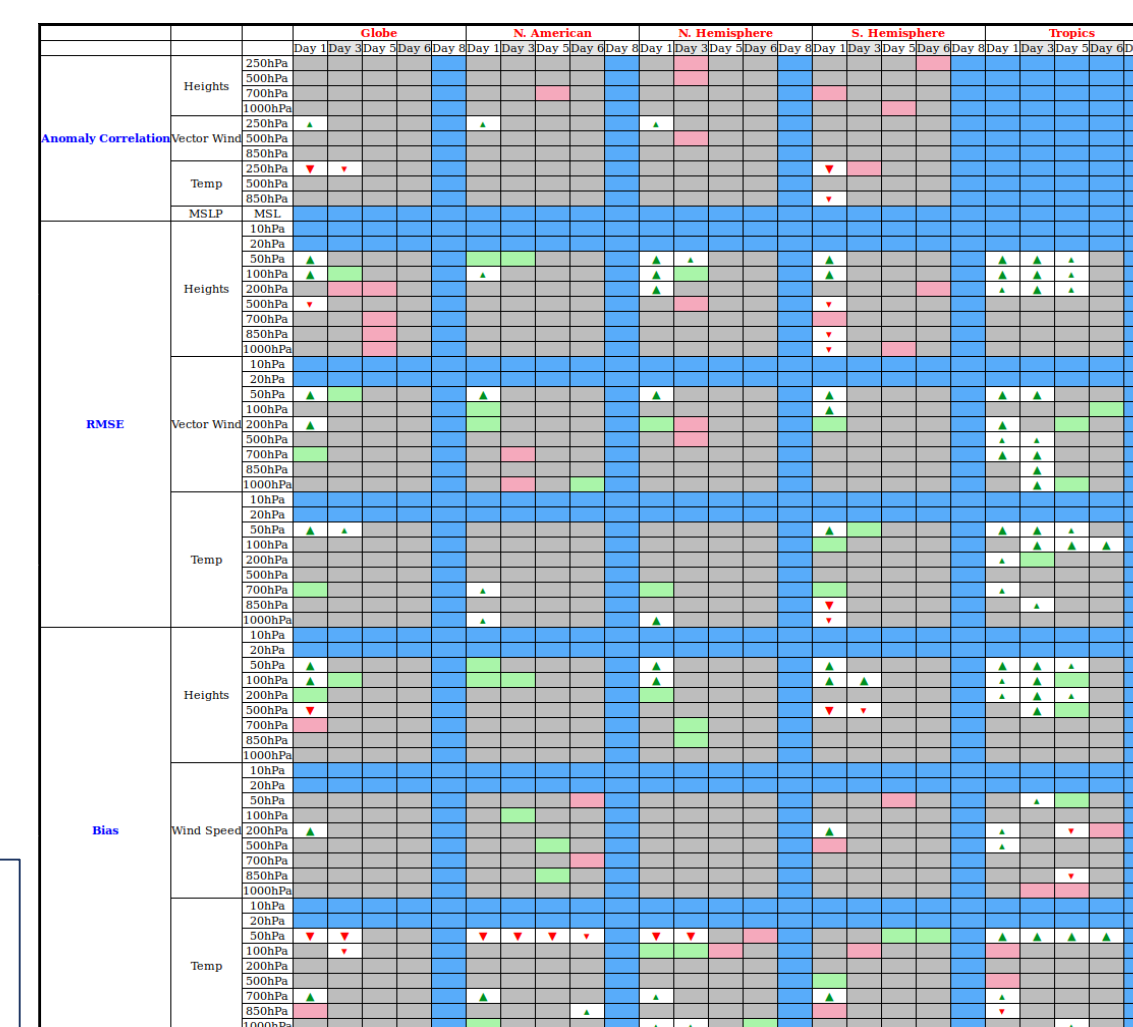


Score card – Green/Red: FS7 is better/worse than OP  
Verified against NCEP analysis

#### Period I (Aug 10 – Oct 1, 2019)

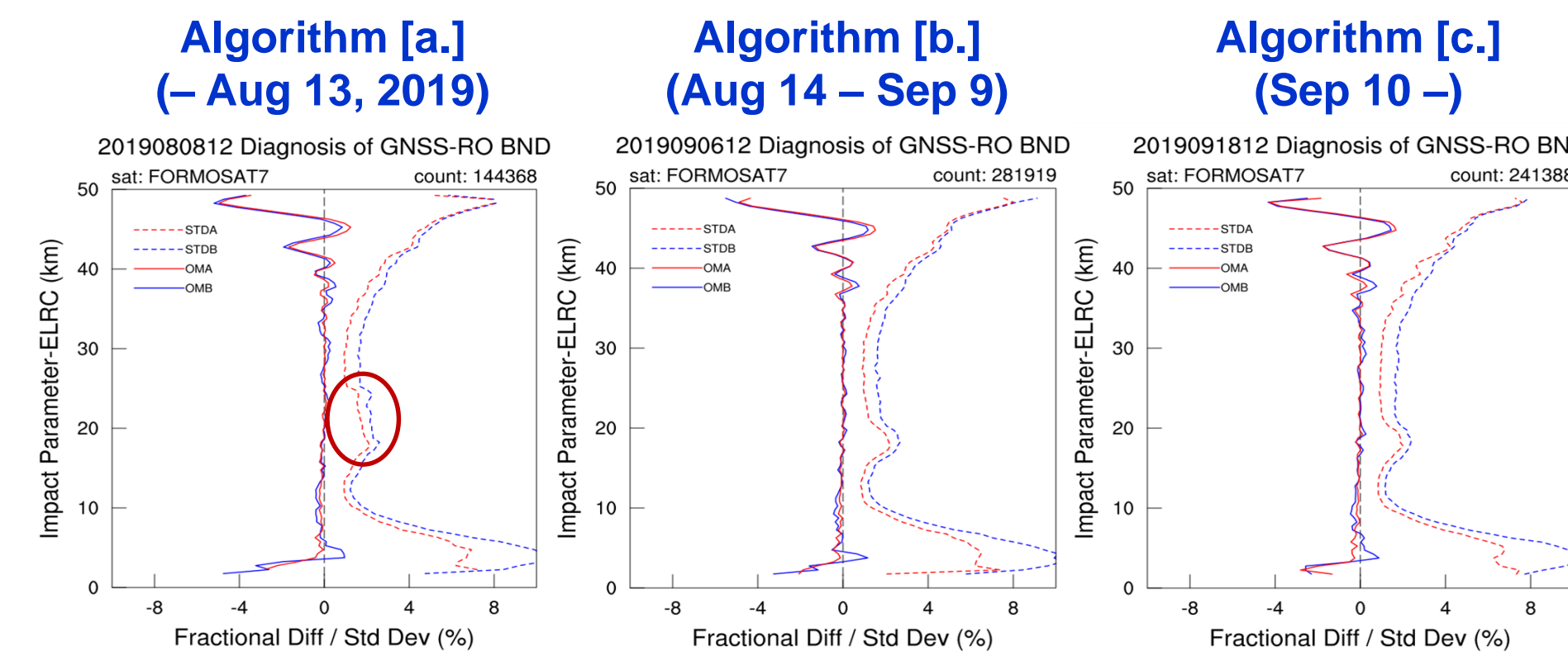


#### Period III (Oct 22 – Nov 14, 2019)



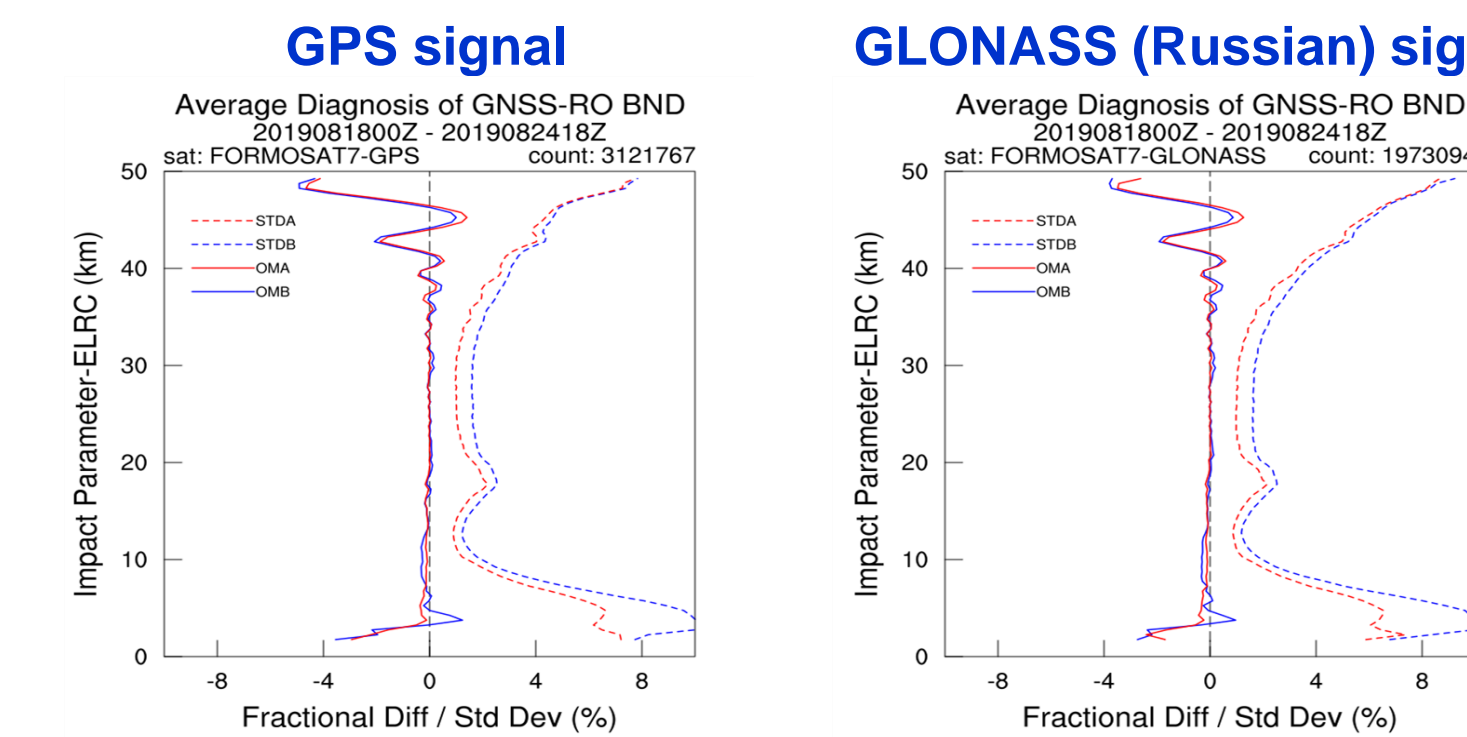
### O–B/O–A statistics

#### Comparison of different versions of data processing algorithms



- The data quality has kept improving with every upgrade of the data processing algorithms.

#### Comparison of data from GPS and GLONASS signals

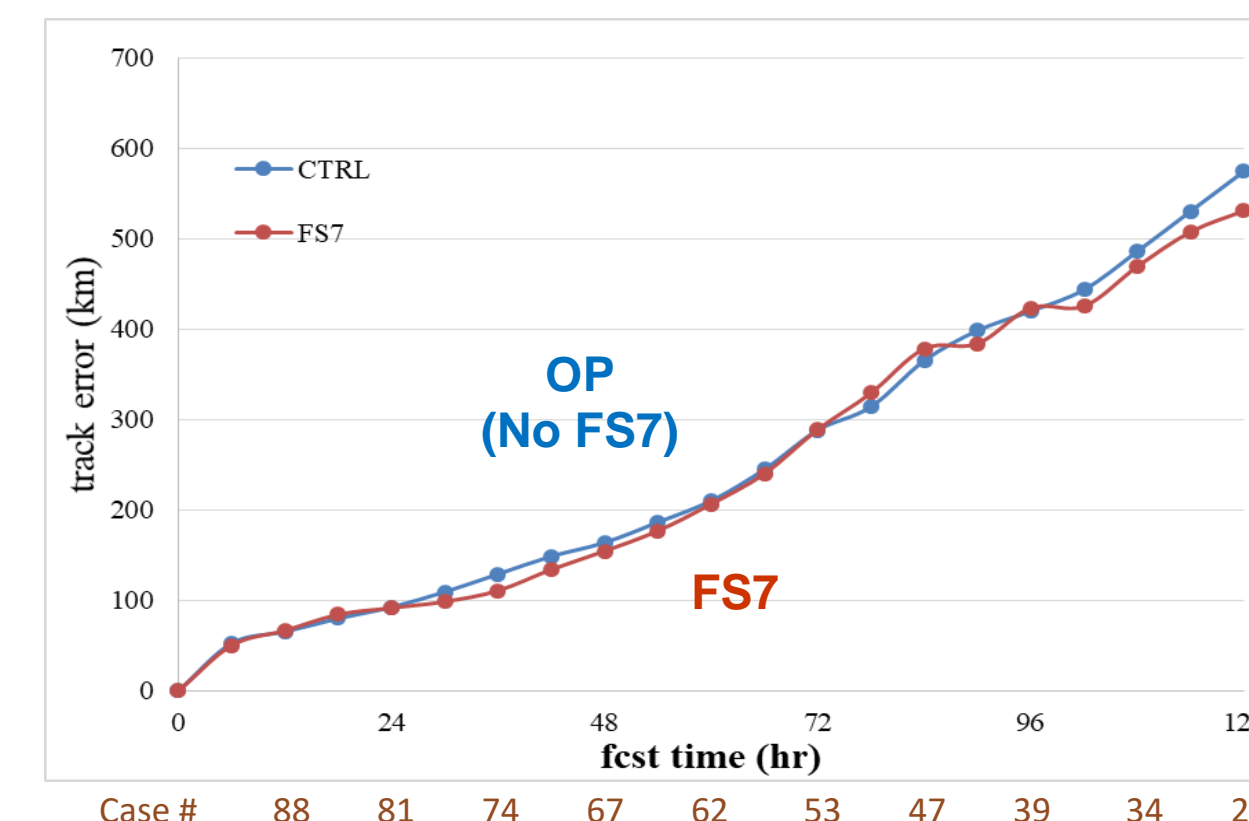


- We do not see significant differences in quality between the data from GPS and GLONASS signals.

### Impact to typhoon track forecasts

#### Average typhoon track forecast errors

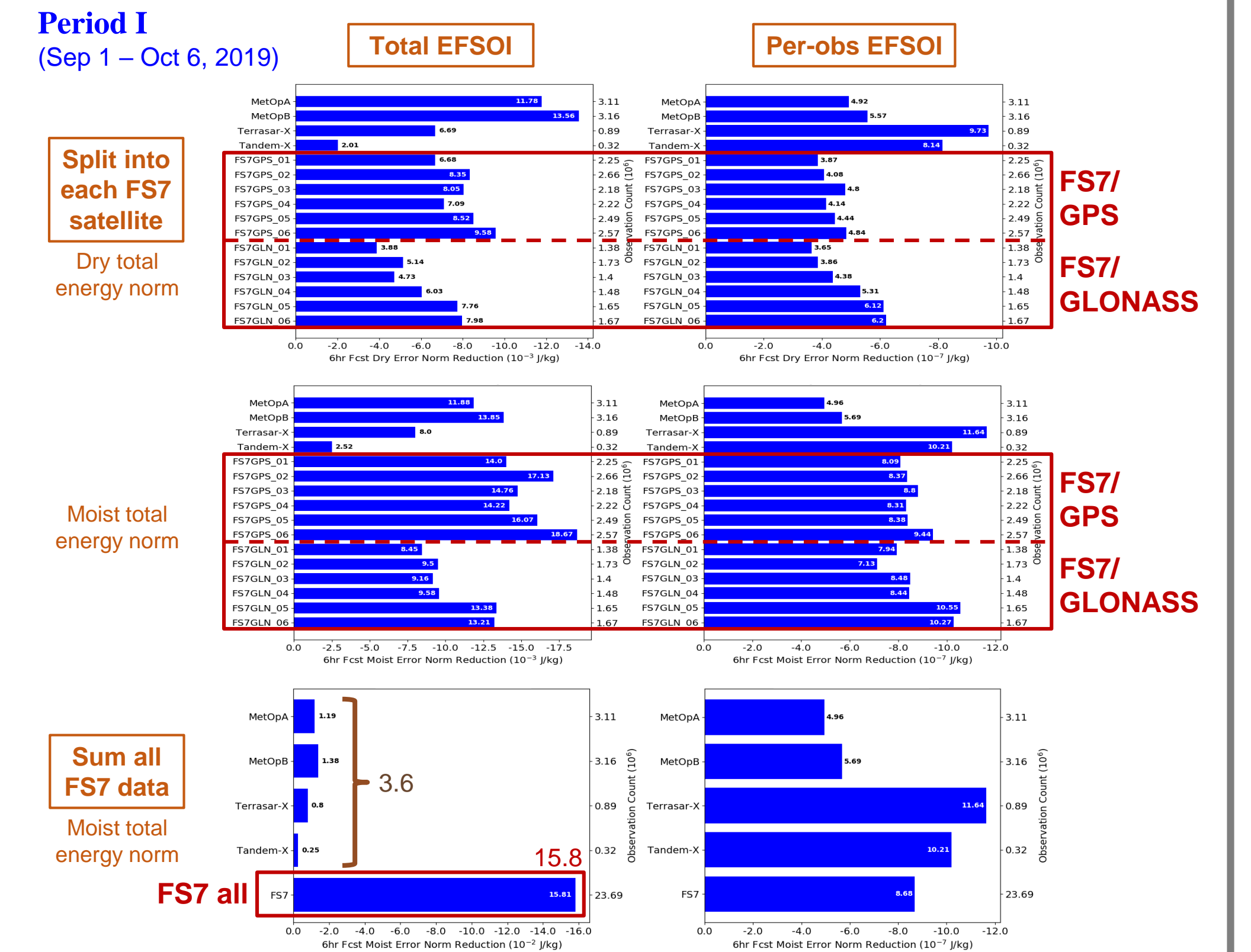
Statistics with 6 typhoons in western North Pacific during Aug – Nov 2019



### Ensemble Forecast Sensitivity to Observation Impact (EFSOI)

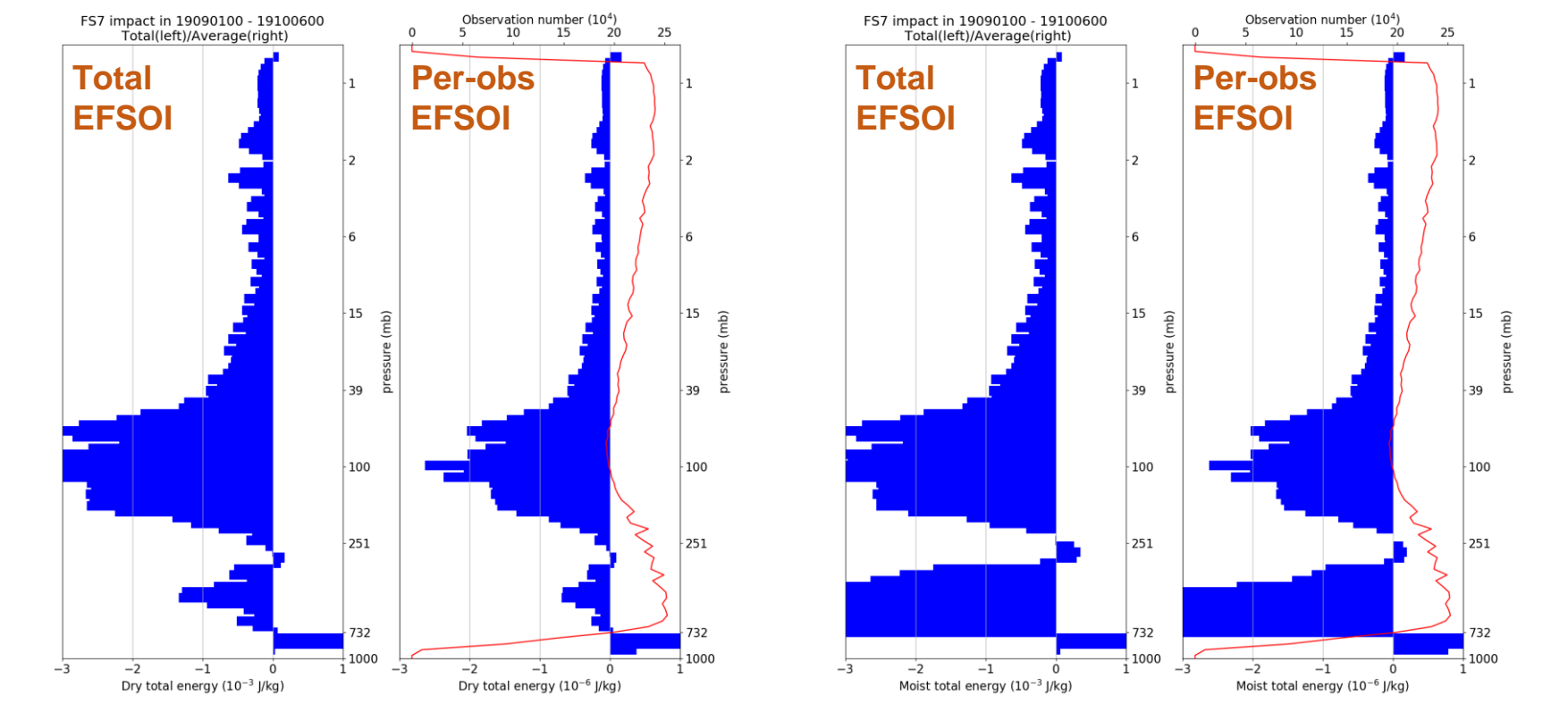
#### EFSOI by RO satellite

Estimated average forecast error reduction measured in terms of energy norms



#### EFSOI of FS7 data with respect to height

##### Dry total energy



(Negative values: beneficial impact)

- FS7 data exhibits comparable per-obs EFSOI with other GNSS-RO data.
- FS7's total EFSOI is greater than the sum of all other GNSS-RO data mainly due to its greater number.
- In troposphere (250–730 hPa), the forecast improvement by RO assimilation is mainly seen in the moisture variable.

## Summary

- CWB's global NWP team has been conducting data assimilation experiments for FORMOSAT-7/COSMIC-2 GNSS-RO data using settings similar to the operational systems.
- Preliminary forecast verification results show positive impact in tropical region, neutral impact in other regions.
- O–B/O–A and EFSOI diagnostics show that the error and forecast impact characteristics of FS7 data are similar to other GNSS-RO data such as FS3, while the great number of FS7 data should bring additional contribution.
- At this moment, the data seem ready to be released for study and use in the wide NWP community.
- We will continue to conduct our FS7 parallel experiment to monitor the data quality and impact, and to investigate the way to better use the FS7 data in NWP.