Evaluation and assimilation of all-sky infrared radiances of Himawari-8

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Background

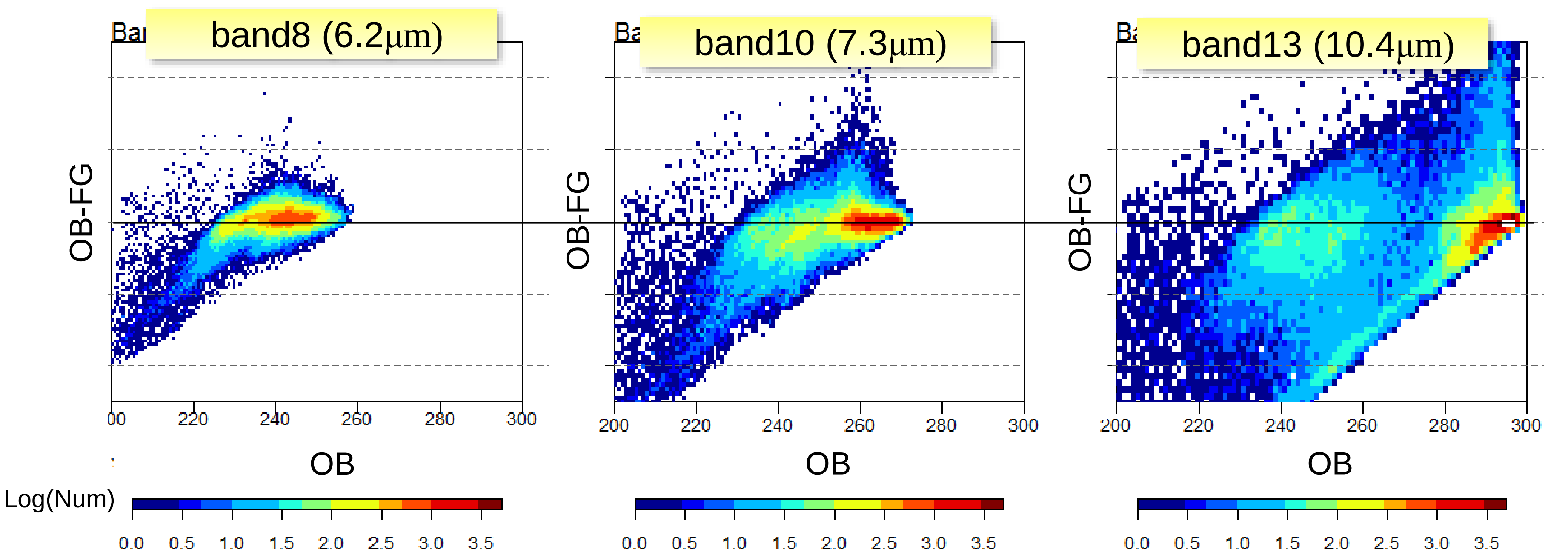
- No or few cloud-affected infrared (IR) radiances are assimilated
  - Complicated cloud process in NWP and RT models, Non-linearity, Non-Gaussianity,,,
- All-sky MW radiance assimilation has been successfully implemented
- IR radiance assimilation is expected to provide higher temporal/horizontal/vertical information

- Objective : Improve analysis and forecast by effectively assimilating all-sky IR radiance
  - Step1. Start with Himawari-8 in a research-based regional LETKF assimilation system
  - Step2. Apply the development to Himawari and other geos and hyperspectral sounders in the operational global 4DVar assimilation system

Contents

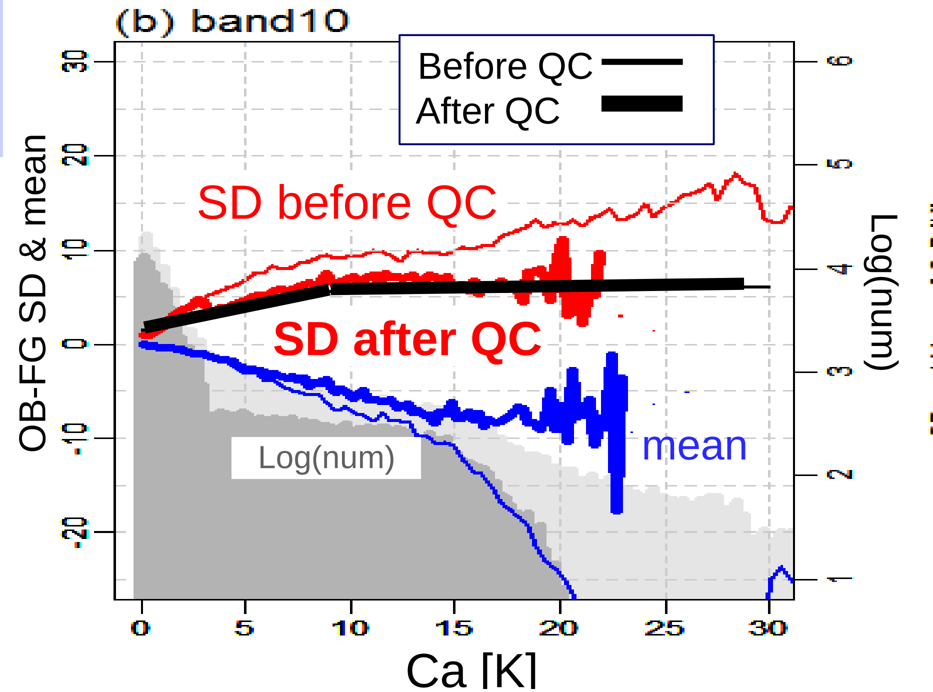
1. Evaluation of all-sky simulations

- JMA-NHM (Non-hydrostatic model) 5km-res.
  - Operational meso-scale model of JMA since 2004 (Saito et al. 2006)
  - Cloud microphysics : cloud,ice,rain,snow,graupel
- RTTOV v11.3
  - Input Ice cloud : the sum of ice, snow and graupel
  - Cloud fraction is estimated using RH (Tompkins and Janiskova (2004)
- Observations: Himawari-8/AHI
  - Super-ob (2x2 pixels average) :match scale and use inhomo information



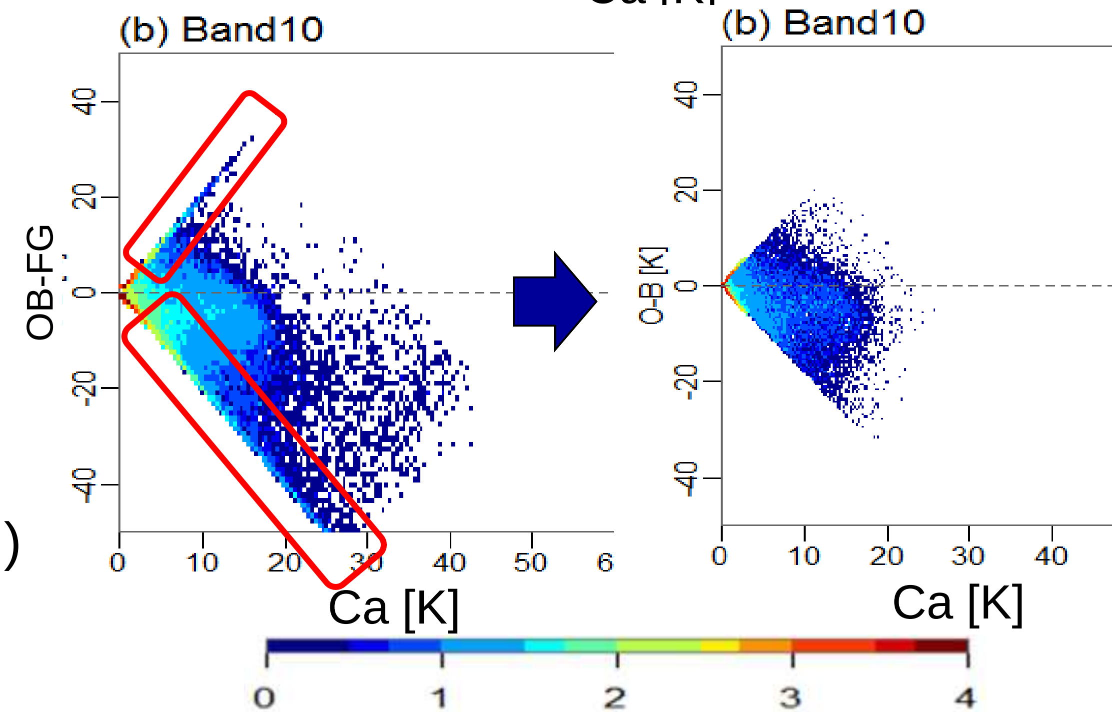
Cloud effect & QC

- Symmetric parameter to represent cloud effect on radiance : Ca
  - Ca=(|FG-FGclr|+|OB-FGclr|)/2, FGclr=clear-sky FG
  - OB-FG variability monotonically increases with Ca



- Observation error σ_r : assume linear function of Ca

- QC procedures : remove
  - ① Inhomogeneous obs
    SD > 2K (band8)
    3K(band10)
  - ② Too low BT (OB<230K)
  - ③ large FG departures
    (|OB-FG| > 1.8 Ca or 3σ_r)

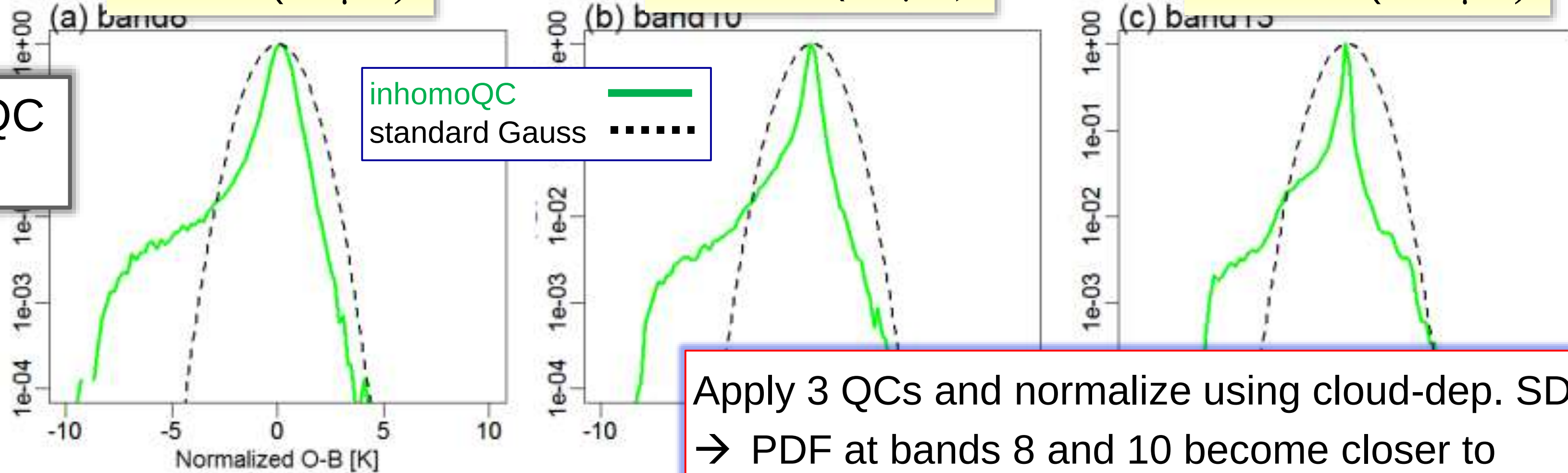


Okamoto (2017, QJRMS)

Normalized OB-FG PDF

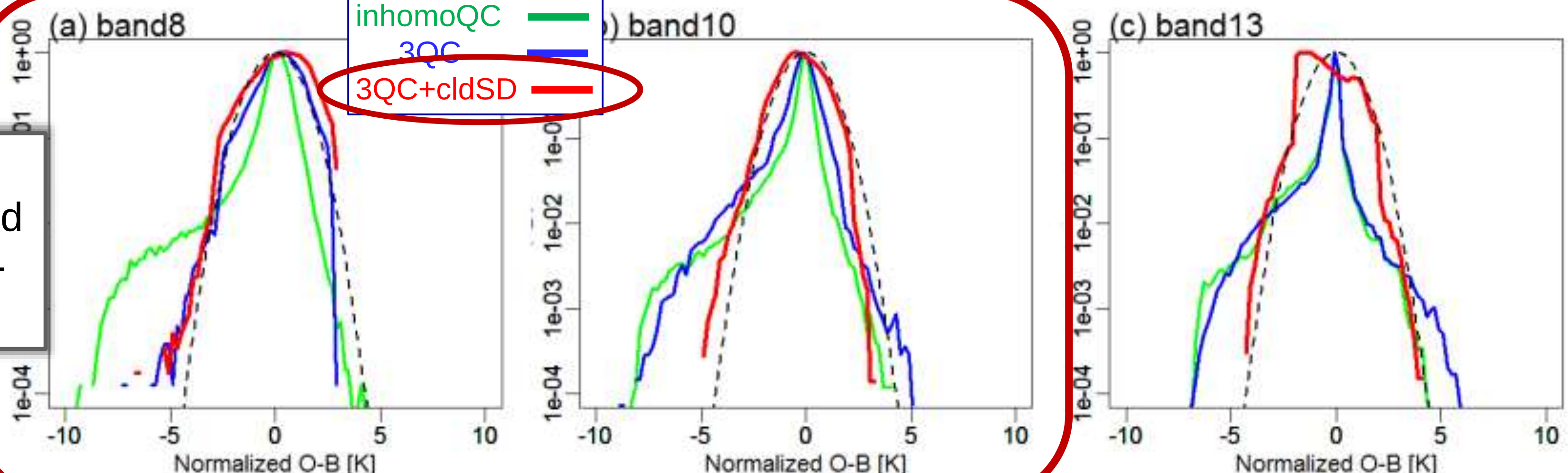
band8 (6.2μm) band10 (7.3μm) band13 (10.4μm)

inhomoQC only



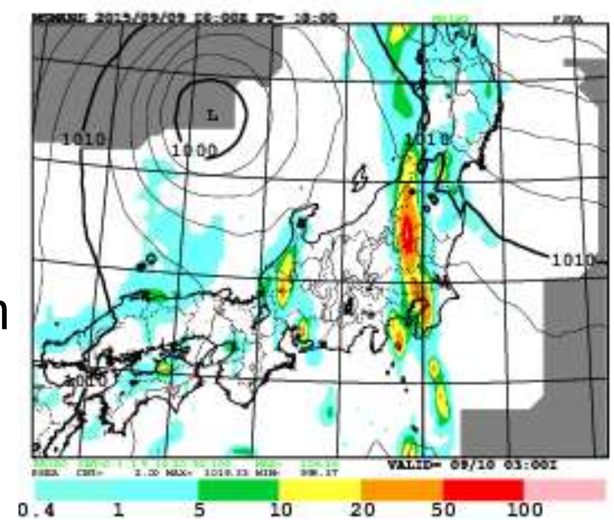
Apply 3 QCs and normalize using cloud-dep. SD
→ PDF at bands 8 and 10 become closer to Gaussian, but not at band 13

3 QCs+ normalized by cloud-dep. SD



2. Assimilation experiment

- NHM-LETKF (Kunii 2014, WF)
  - 15km, 50 members, 273x221 grids
  - 3-h cycle with 1-h slot to ingest observations
  - Inflation : RTPS (relaxation-to-prior spread)
  - H/V-localization: 100km/0.5 (BT) and 200km/0.2 (conventional)
- Period: 1 ~ 10 Sep, 2015
- Observations
  - CNTL: conventional data
    - RAOB, SYNOP, ship, aircraft, Wind Profiler, Doppler Radar, TCWV from GNSS ground, AMV from MTSAT-2
      - No clear-sky BT of AHI
  - TEST: CNTL + all-sky BT of AHI
- AHI all-sky BT
  - Super-ob (6x6 pixels)
  - Band 8 (6.9μm) + 10 (7.3μm), Thinning 75km
  - No bias correction (now developing)

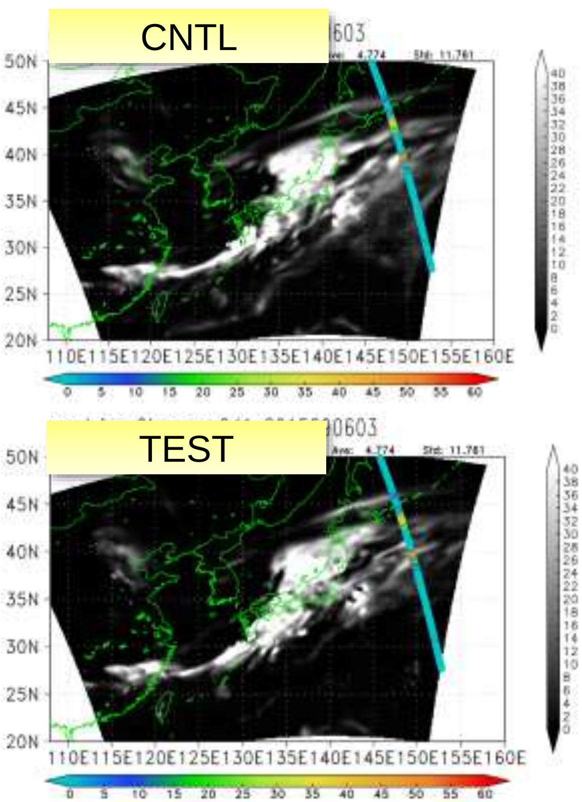


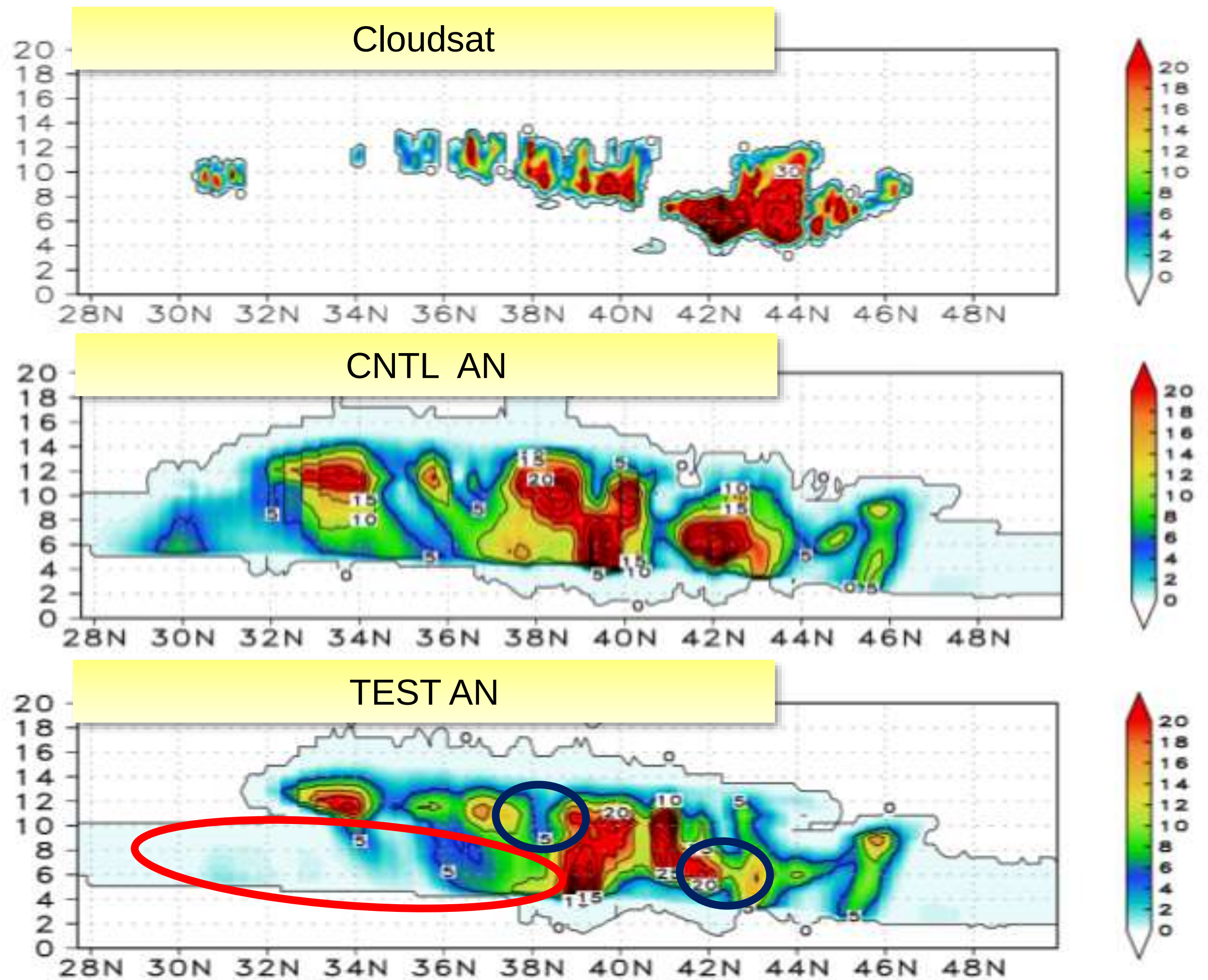
Comparison with Cloudsat

03UTC 6 Sep 2015, 48th cycle

- Frozen hydrometeors from 2B-CWC-RO
- AHI assimilation bring analysis of frozen cloud to Cloudsat observation

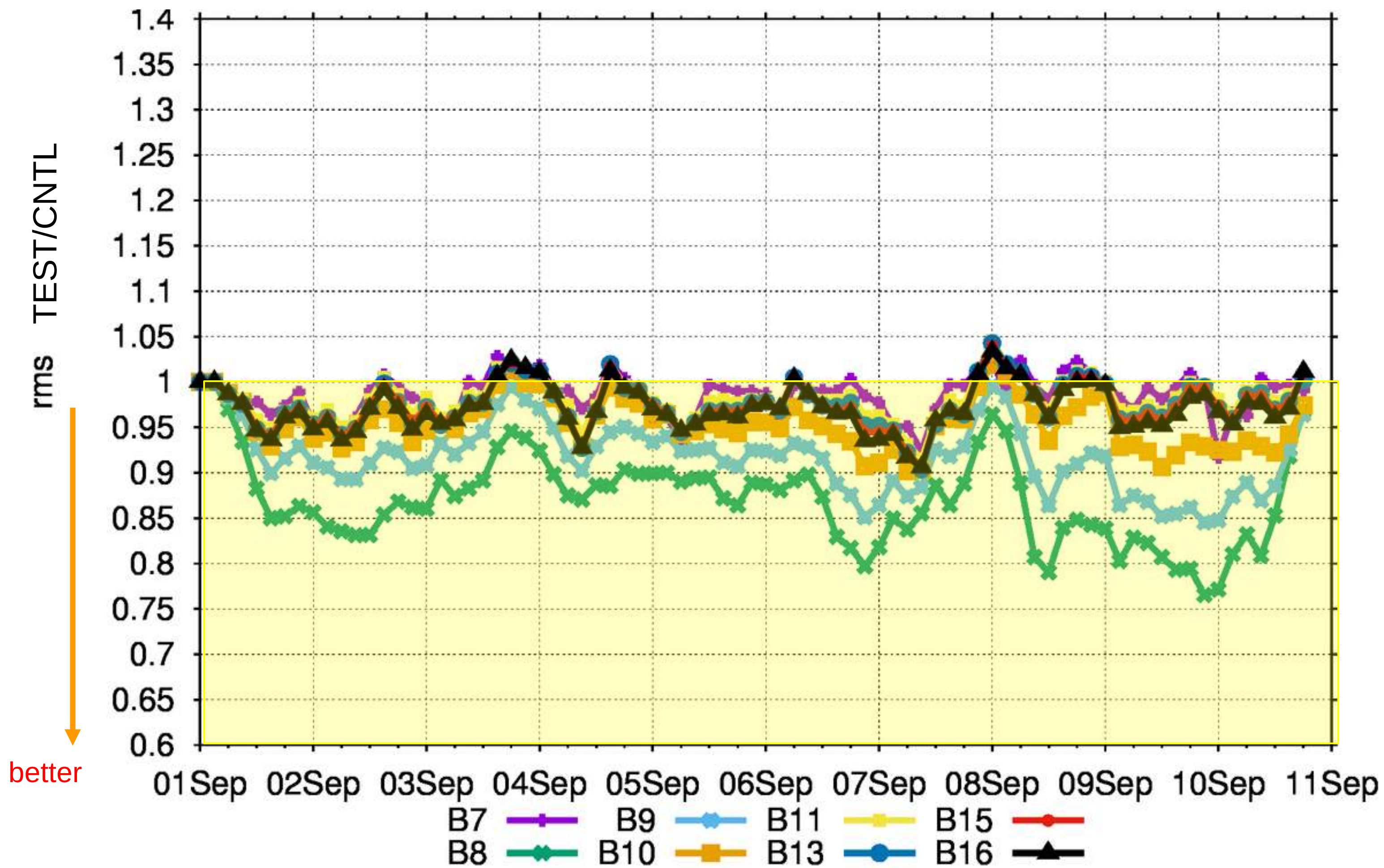
AN ice at 9km





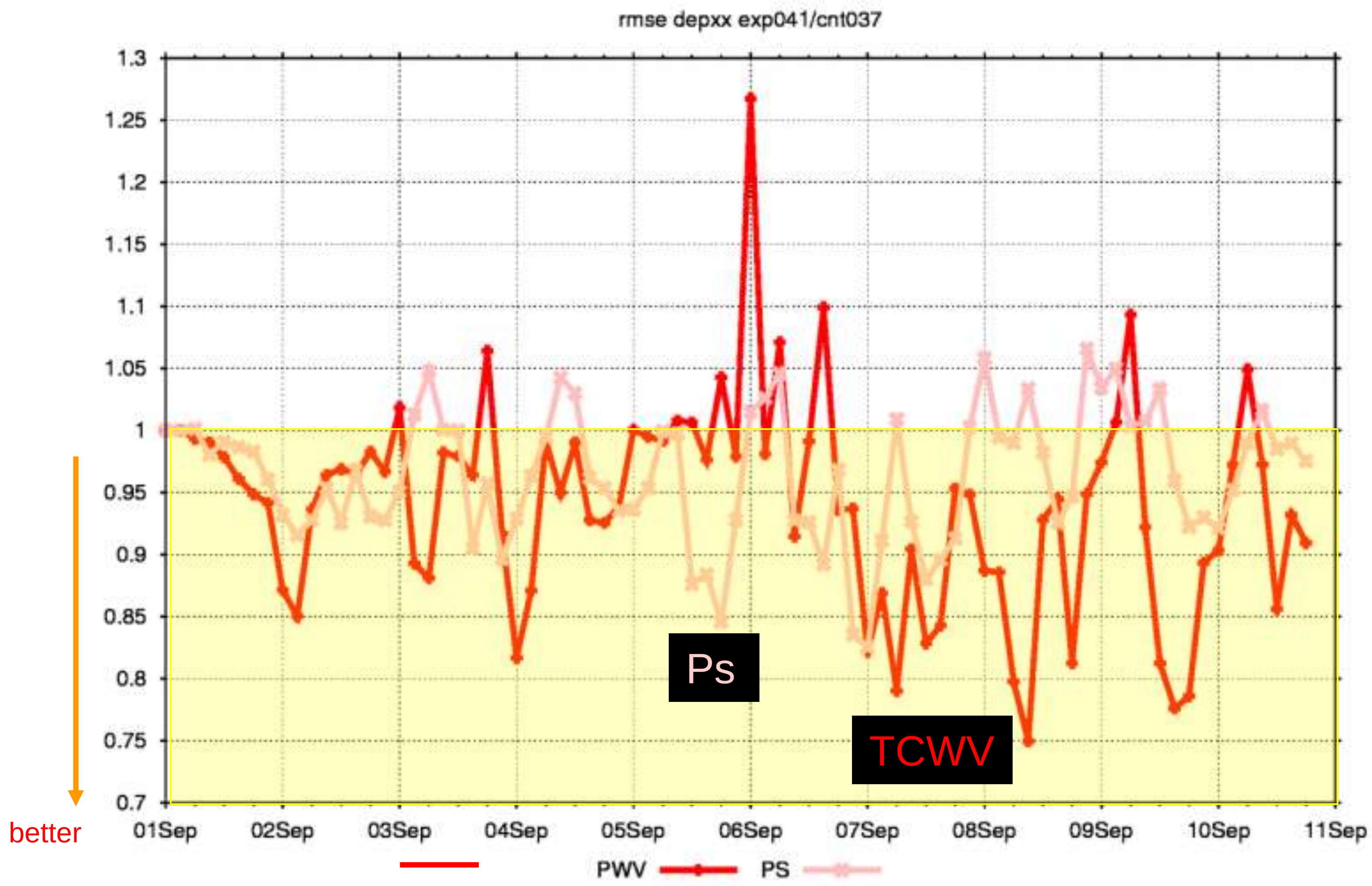
Ratio (CNTL/TEST) of OB-FG RMSE for AHI BT

- $RMSE_{TEST}/RMSE_{CNTL} < 1.0$: better fitting of FG
- ➔ Improve FG fitting to rad obs at not only bands 8 & 10 but other bands



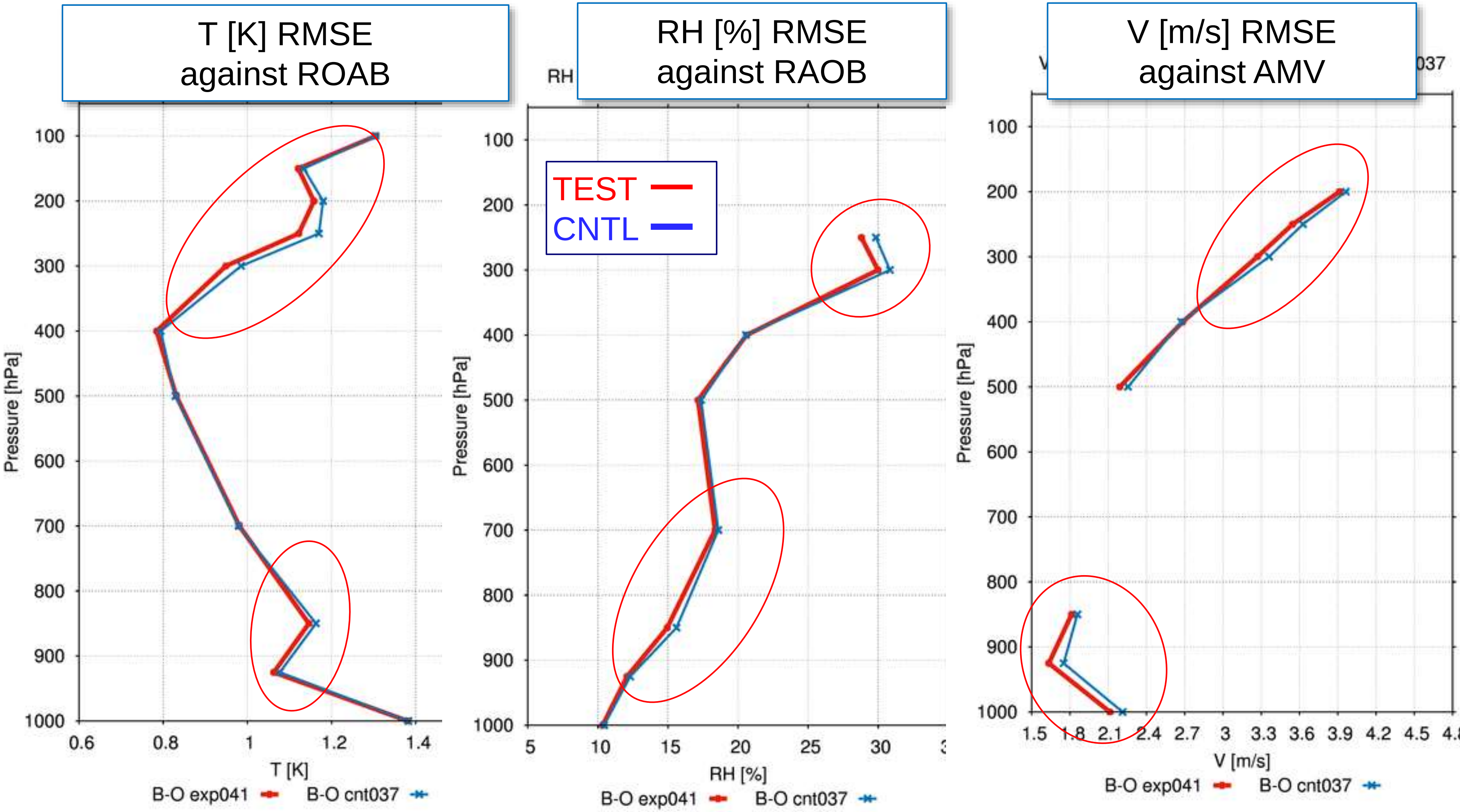
Ratio (CNTL/TEST) of OB-FG RMSE for GNSS TCWV

- TCWV (total column water vapor) and Ps (surface pressure) also improved



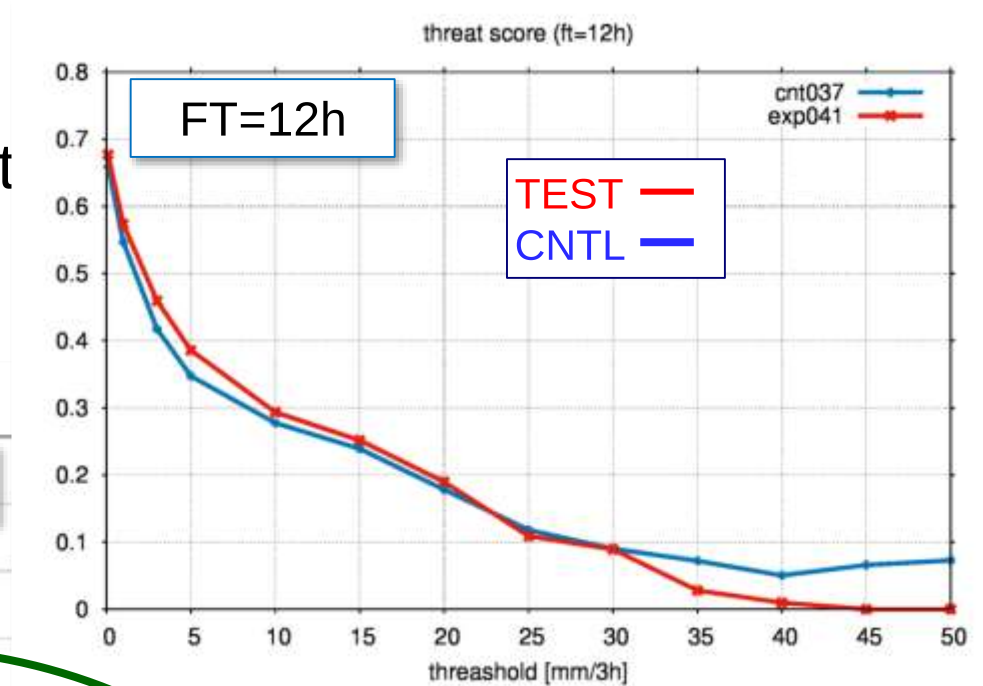
FG-OB RMSE 9/1-10

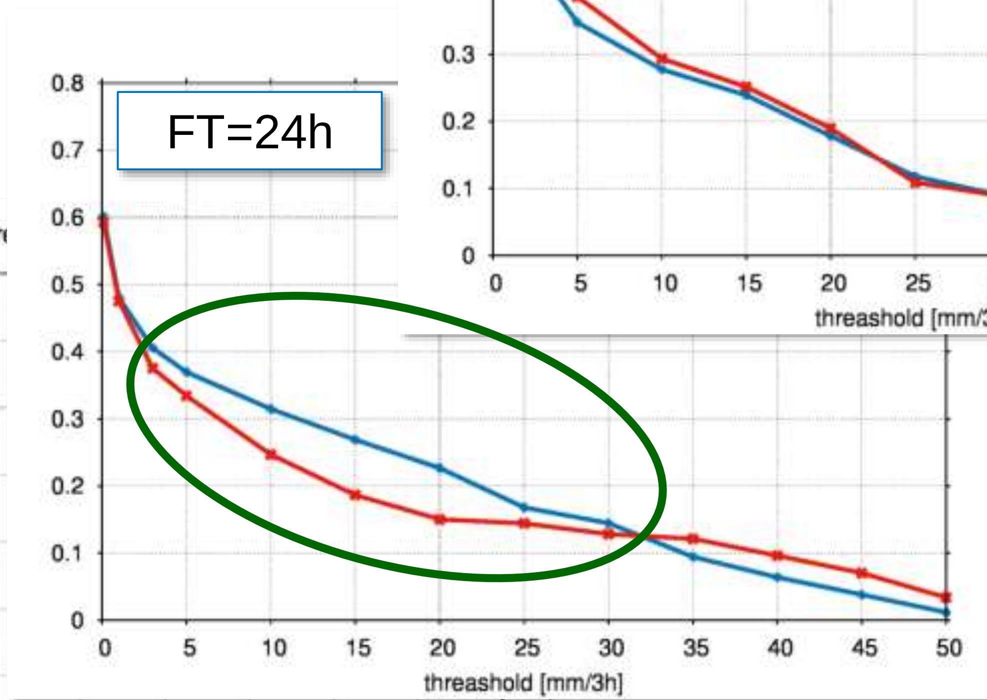
- T,RH,V improved

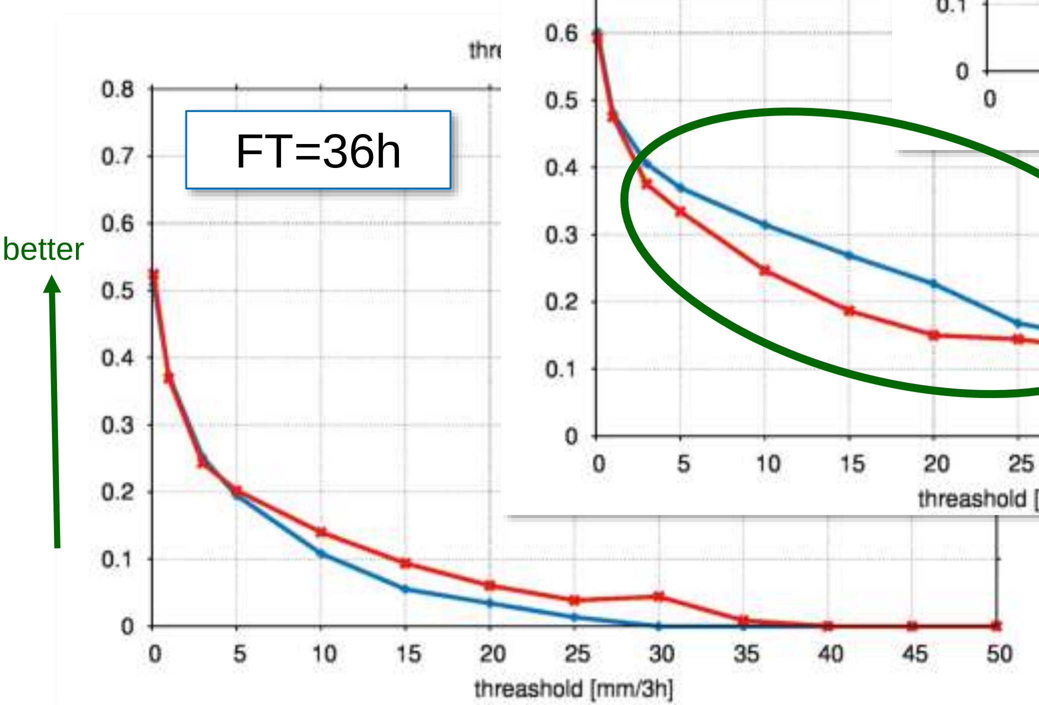


Precipitation skills

- Threat score of 3-h precipitation, verified against radar-analysis from 8 to 9 Sep.
- Mixed impact



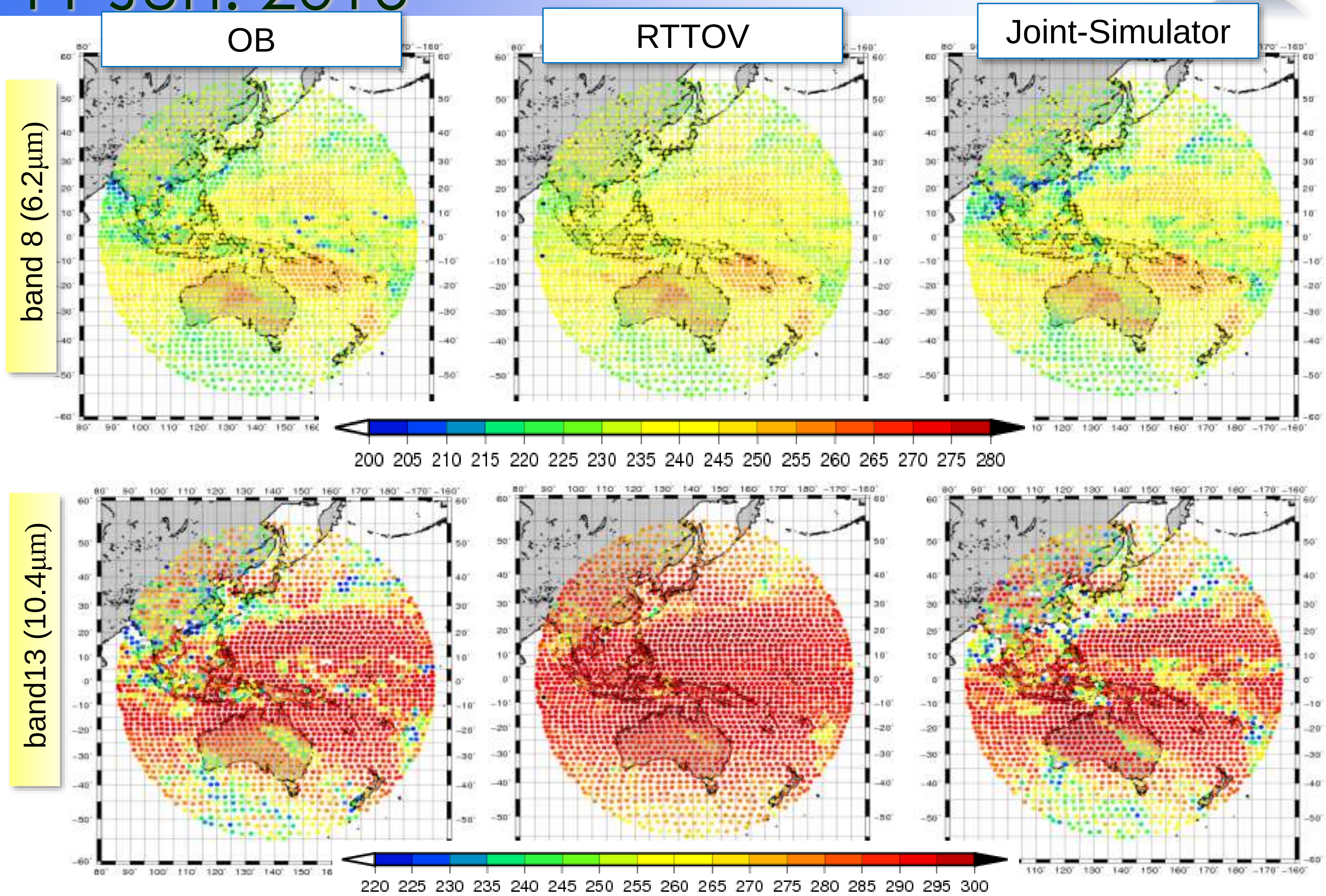




3. Comparison of simulations from global model

- Model: GSM (Global Spectral Model) of JMA: res.20 km
  - Cloud forecast variables: total cloud water (TCW = liquid + ice cloud)
- Simulators
  - RTTOV v10.2
    - Cloud input: liquid cloud and ice cloud from TCW, and cloud fraction
  - Joint-Simulator (Jsim, Hashino et. al 2013, JGR)
    - Multi-satellite sensor simulator utilizing cloud microphysical parameters consistent with input NWP models
    - Inherited from satellite data simulator unit (SDSU; Masunaga et al. 2010, BAMS) and the NASA Goddard SDSU
    - VIS/IR RTM is based on discrete-ordinate method (Nakajima & Tanaka 1986, 1988, JQSRT)
    - Cloud input: liquid/ice cloud from TCW, cloud fraction, rain flux and snow flux
- Observations: Himawari-8/AHI
  - super-ob (16x16 pixels average)

Example of simulations at 12UTC on 11 Jun. 2016



Summary and plans

- Evaluate all-sky IR rad using regional system (JMA-NHM + RTTOV v11.3)
  - Simulations overall well reproduce all-sky rad, but significantly underestimate BT depression in cloudy regions.
  - Cloud-dependent QCs and obs error model using the cloud effect parameter Ca are developed
  - OB-FG normalized by cloud-dependent SD shows Gaussian PDF for humidity bands
- Preliminary assimilation experiments in regional LETKF system
  - Assimilate rad at 2 humidity bands
  - Better fit to CloudSat (cloud), all AHI IR bands (BT), and RAOB/AMV (T,RH,V)
  - Precipitation forecast skills are not satisfactory
- Comparison of simulations from GSM suggests the need of reexamine cloud input and scattering parameters in RTTOV v10.2

- Plans
  - Test adaptive bias correction procedure
  - Apply to the operational global data assimilation system

Thank you for your attention

- Acknowledgments
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- References

  - Okamoto, K. 2017: Evaluation of IR radiance simulation for all-sky assimilation of Himawri-8/AHI in a mesoscale NWP system. Quart. J. Roy. Meteor. Soc., 143, 1517-1527
  - Okamoto, K., T. McNally and W. Bell, 2014: Progress towards the assimilation of all-sky infrared radiances: an evaluation of cloud effects. Quart. J. Roy. Meteor. Soc., 140, 1603-1614