Towards the assimilation of all-sky infrared radiances of Himawari-8

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Outline

- 1. Background
- 2. OB-FG statistics
- 3. Observation error
- 4. Preliminary assimilation experiments
- 5. Summary and plans

1. Background

- Cloud/rain-affected satellite data have been underused especially for infrared (IR) radiances
  - Complicated cloud/rain process in NWP and RT models, Non-linearity, Non-Gaussianity,,,
- IR radiances
  - Mostly assimilated in clear-sky condition, and in overcast conditions at some operational centers
    - Issues :: miss meteorologically important info, suffer from unexpected cloud contamination, cause dry bias,,,
  - All-sky MW radiance assimilation has been successfully implemented
  - Provide higher temporal/horizontal/vertical information, despite limited availability, compared with MW radiances
- Objective : Improve T/Q/W analysis and forecast by effectively assimilating all-sky IR radiance
  - Especially for Himawari-8

Himawari-8/AHI

- Launched in Oct. 7 2014
  - Start the operation in Jul. 7, 2015
  - Geo-sat after MTSAT2
  - Himawari-9 to be launched in 2016
- Advanced Himawari Imager (AHI)
  - 16 bands, including 3 VIS, 3 NIR, 3 humidiy, 3 window, and 1 CO2
  - 1.0/0.5 km for VIS and NIR, 2.0 km for IR and NIR
  - 10 min. for full disk, 2.5 min. for Japan regions and target regions

Himawari-8,9/AHI		
Band	Wavelength [μm]	Spatial Resolution
1	0.43 - 0.48	1km
2	0.50 - 0.52	1km
3	0.63 - 0.66	0.5km
4	0.85 - 0.87	1km
5	1.60 - 1.62	2km
6	2.25 - 2.27	2km
7	3.74 - 3.96	2km
8	6.06 - 6.43	2km
9	6.89 - 7.01	2km
10	7.26 - 7.43	2km
11	8.44 - 8.76	2km
12	9.54 - 9.72	2km
13	10.3 - 10.6	2km
14	11.1- 11.3	2km
15	12.2 - 12.5	2km
16	13.2 - 13.4	2km

2. OB-FG statistics

Models

- JMA-NHM (Non-hydrostatic model)
  - Operational meso-scale model of JMA since 2004 (Saito et al. 2006)
  - Cloud microphysics
    - Explicit three-ice bulk scheme based on Lin et al. (1983)

	Cloud water	Cloud ice	Rain	Snow	Graupel
Mix.ratio	Qc	Qi	Qr	Qs	Qg
Num.denstiy		Ni			
DSD	Mono-disperse		Exponential		

  - 5km, L50, 461x481 grids, Japan region

- RTTOV v11.3
  - Cloud scattering (Matricaldi 2005) : scaling approximation (Fu et al. 1999), cloud fraction by stream method
  - Input: 6-h forecast from JMA-NHM
    - Profiles of temperature, humidity, Liquid cloud, ice cloud, cloud fraction
    - Ice cloud : the sum of ice, snow and graupel
    - Cloud fraction is estimated by Tompkins and Janiskova (2004)

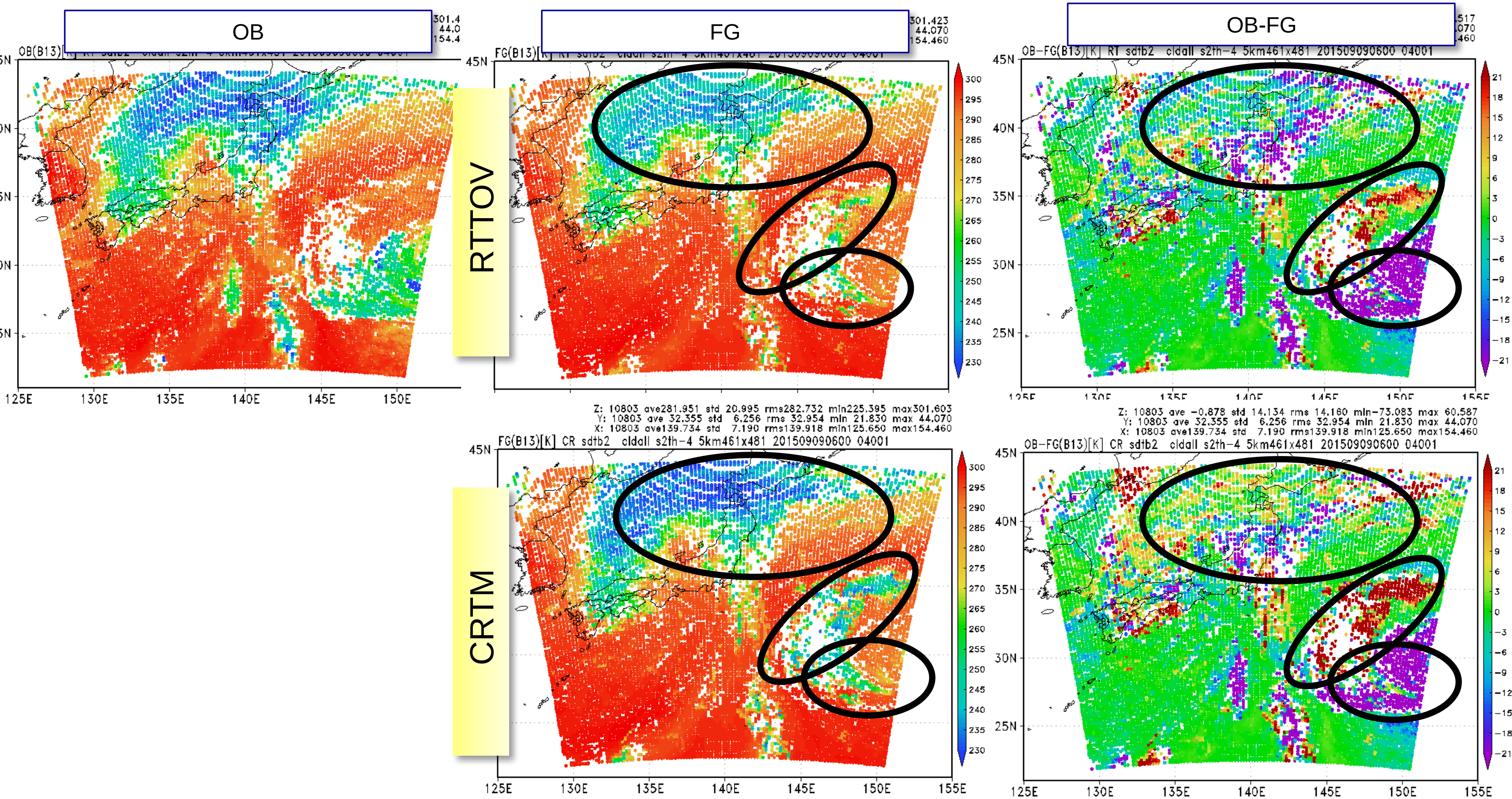
Comparison of AHI obs and simulation

- Super-ob (2x2 pixels average)
  - For better representation of 5km model
- Remove highly inhomogeneous scenes (inhomogeneity-QC)
  - Standard deviation (SD) in super-ob (SDso) at band 13 > 2.0 K
  - → Justify making IR super-ob and mitigate difficulty in partial cloud effect in RT calculation
  - SDso is estimated from original pixels inside super-ob
- Thinned in 20 km box (4 model grids)

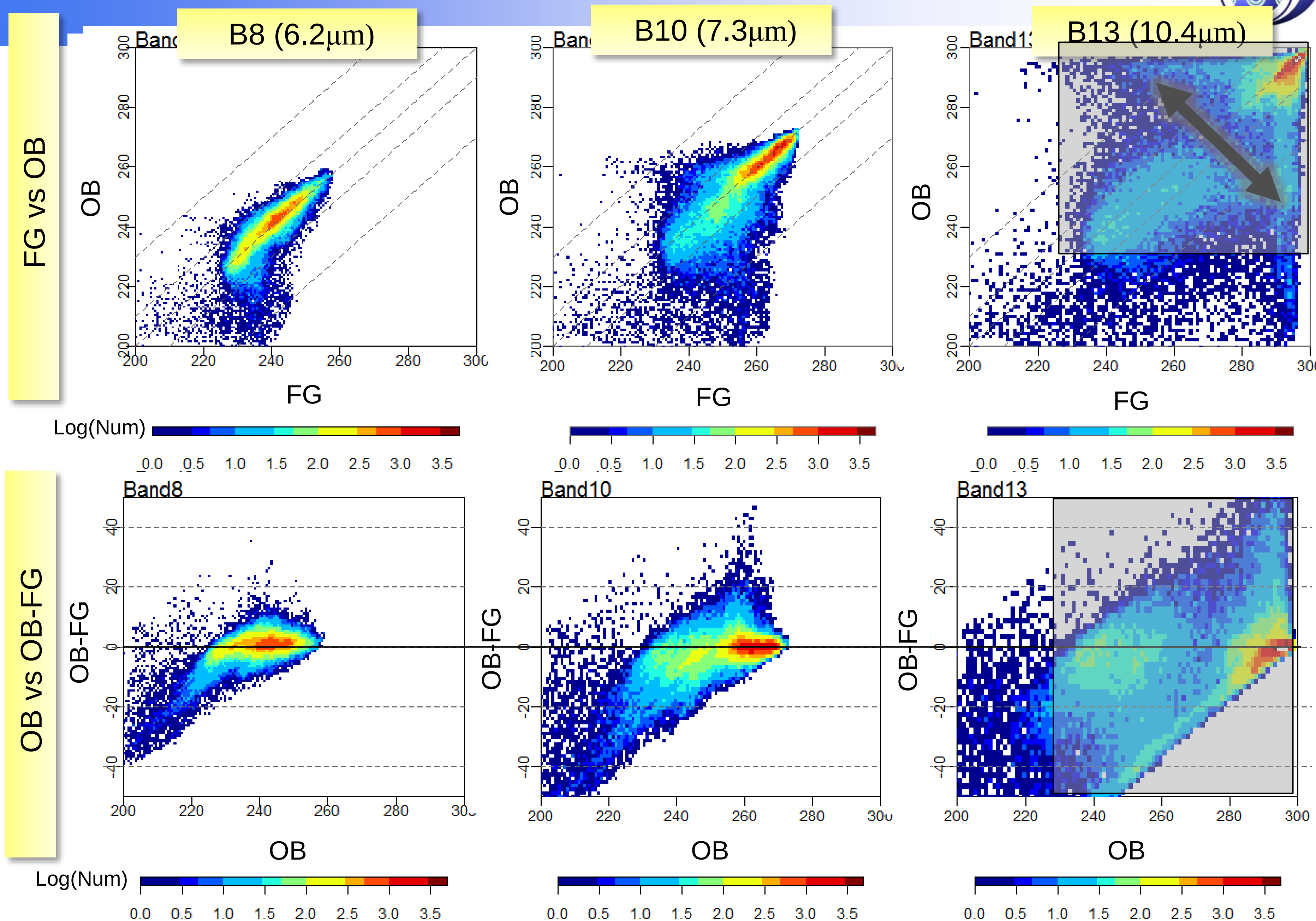
- The comparison was made for four different meteorological conditions
  - Result in a stationary rain band case is only shown : 00 UTC Sep 7~ 18 UTC Sep 9, 2015, every 6-h

OB and FG at band13 (10.4 μm)

- Insufficient simulation for low BT
- CRTM can generate more low BT but occasionally excessive



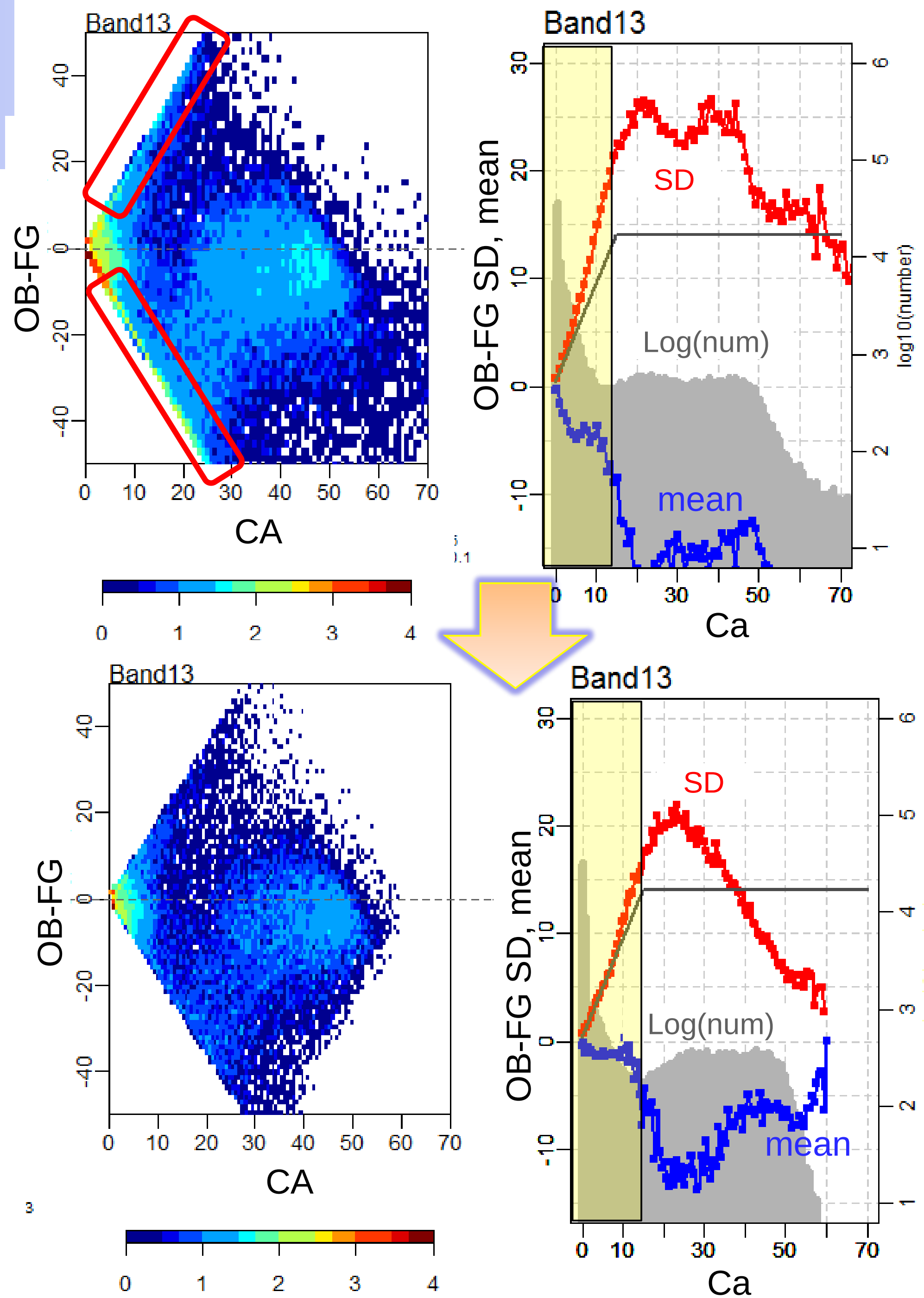
OB vs FG, OB vs OB-FG with RTTOV



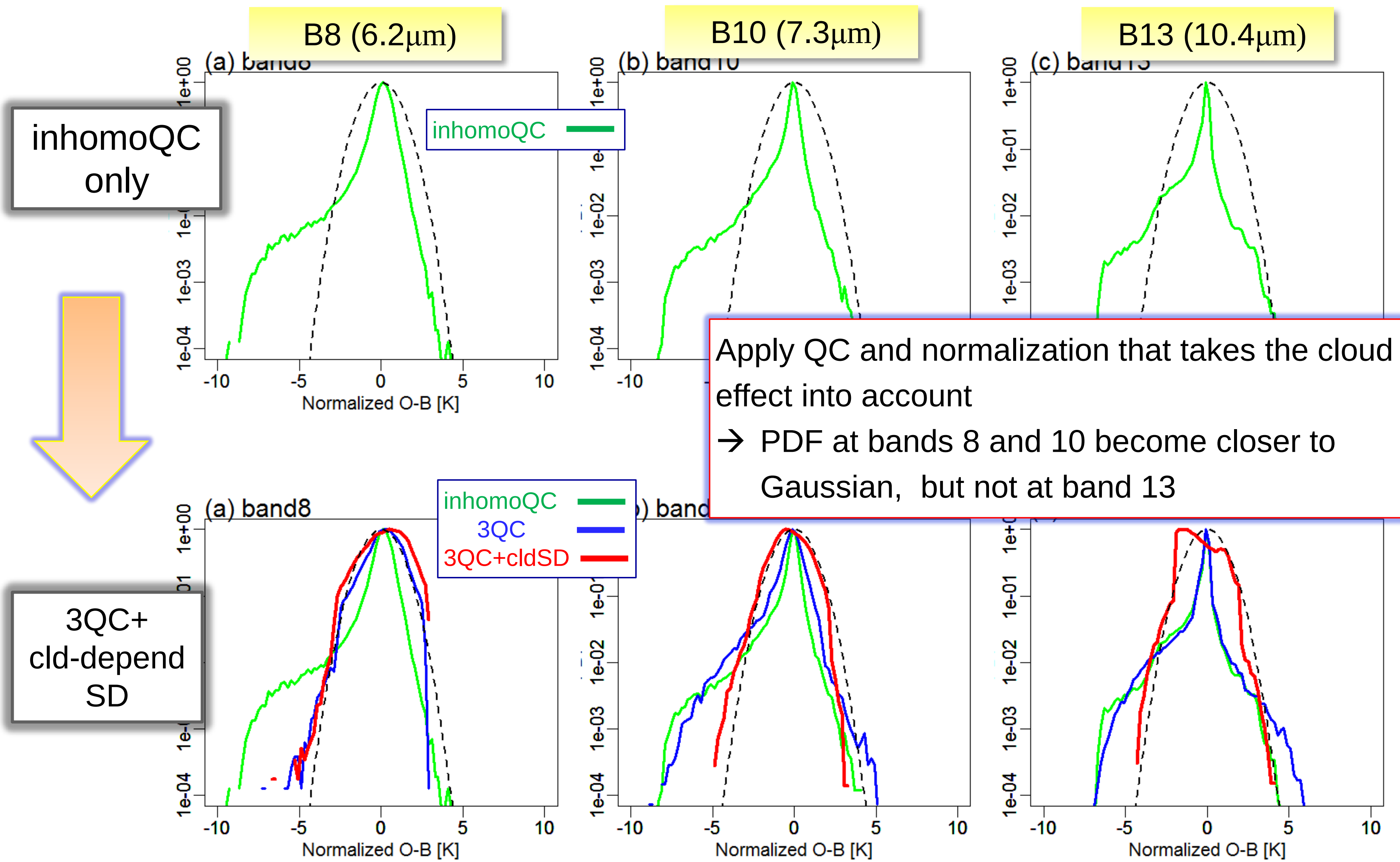
Cloud effect and QC

- A parameter to represent cloud effect on radiance : Ca
  - Ca = 0.5*(|FG-FGclr|+|OB-FGclr|), FGclr=clear-sky FG
  - OB-FG variability monotonically increases with Ca
  - → predict (cloud-dependent) OB-FG SD using Ca
  - Details in Okamoto et. al. (2014, QJRMS)

- 2 additional QCs
  - Too low TB (OB<230K)
  - Large OB-FG with Cloud-dependent criteria



Normalized OB-FG PDF



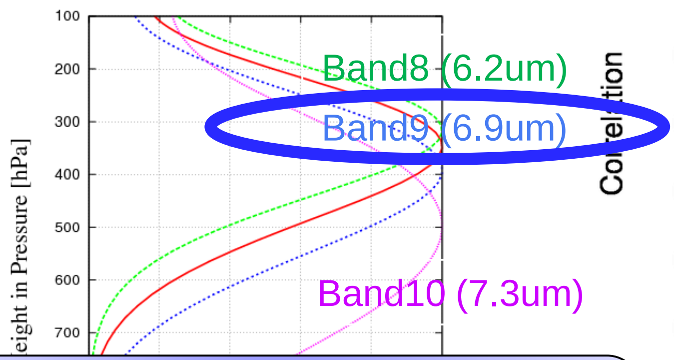
Apply QC and normalization that takes the cloud effect into account

→ PDF at bands 8 and 10 become closer to Gaussian, but not at band 13

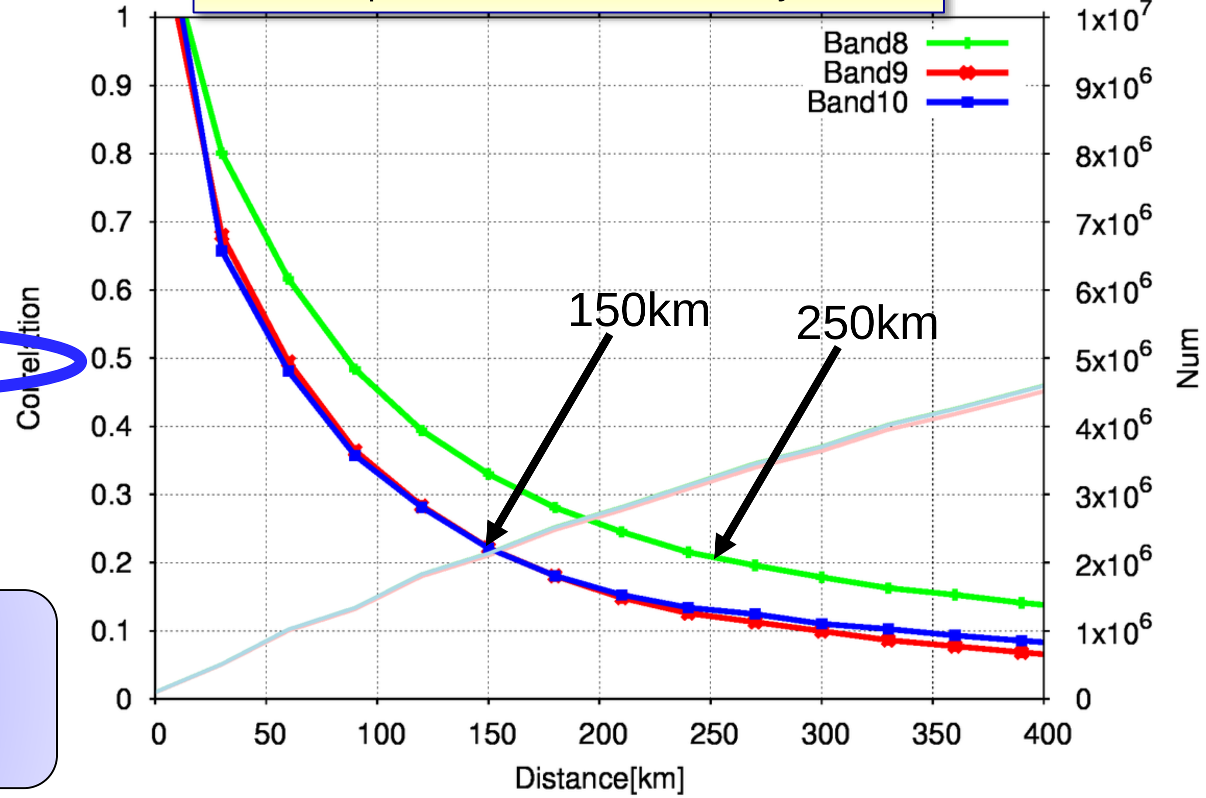
3. Observation error

Observation error statistics for all-sky rad

- Estimate obs error at humidity bands based on Desroziers diagnostics
- Obs error SD = 1.7 K (band8), 1.9 K (9) and 2.5 K (10)
- Distance at corr<0.2 = 150 km (bands 9 & 10), 250km (8)
- Strong spectral correlation
  - band8-9: 0.83, band8-10: 0.52, band9-10: 0.85



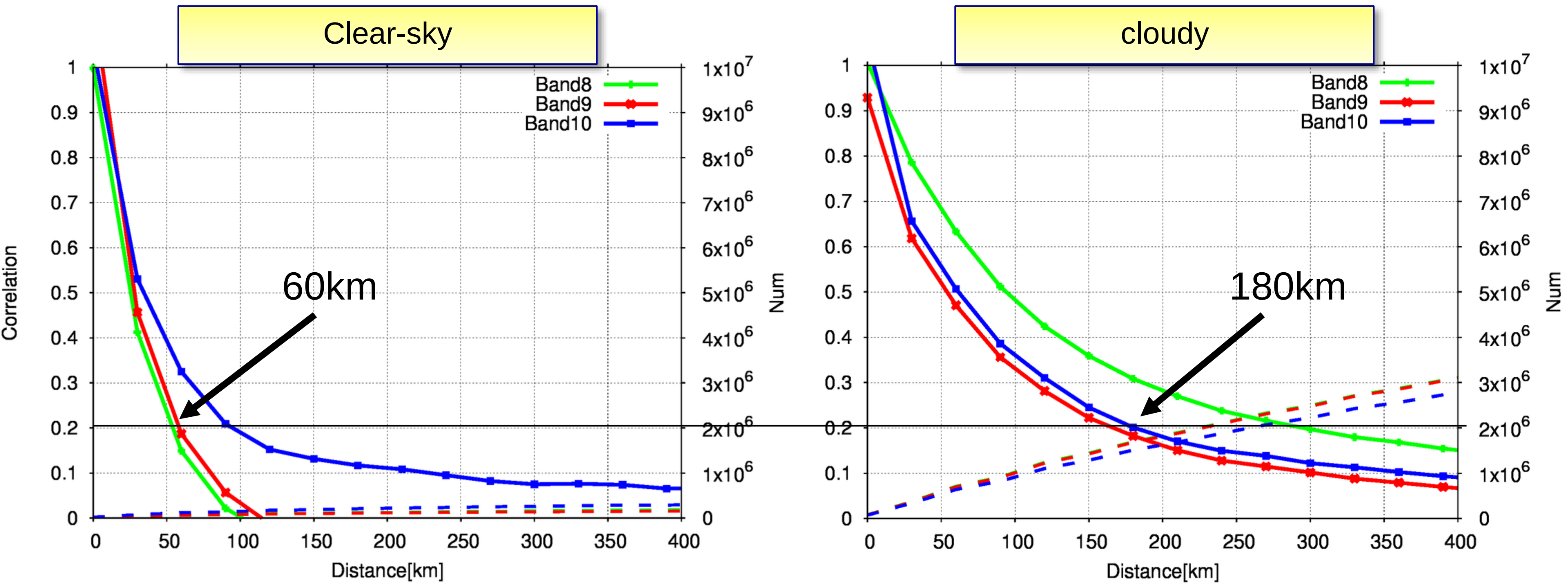
Spatial correlation in all-sky



Assimilate only band 9, Thinned to 150 km

Comparison of cloudy and clear-sky rad

- Separate cloudy (Ca>0.5) and clear-sky (Ca<0.5)
- Larger SD and spatial/spectral correlation in cloudy conditions
  - Obs error SD= 0.4,0.4,0.4(clear-sky)→ 1.9,2.3,3.0(cloudy) at bands 8,9,10
  - Dist(corr<0.2)= 60 km (clear-sky) → 180 km (cloudy) at band 9
  - Corr(band8-10)= 0.03 (clear-sky) → 0.60 (cloudy)
- Consistent to all-sky MW 85GHz statistics (Bormann et al. 2011)



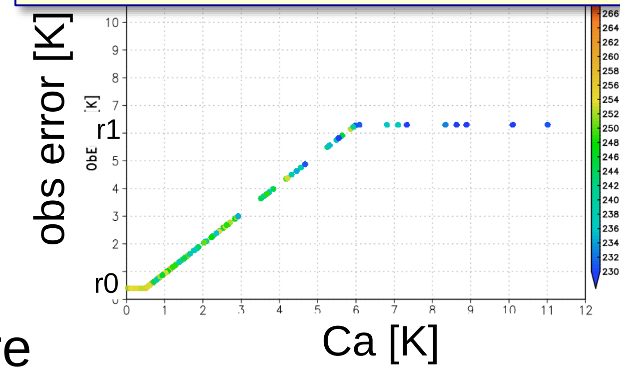
Cloud-dependent obs error

- Assume a linear model with Ca
- $r = r_0$ for $Ca < Ca_0$

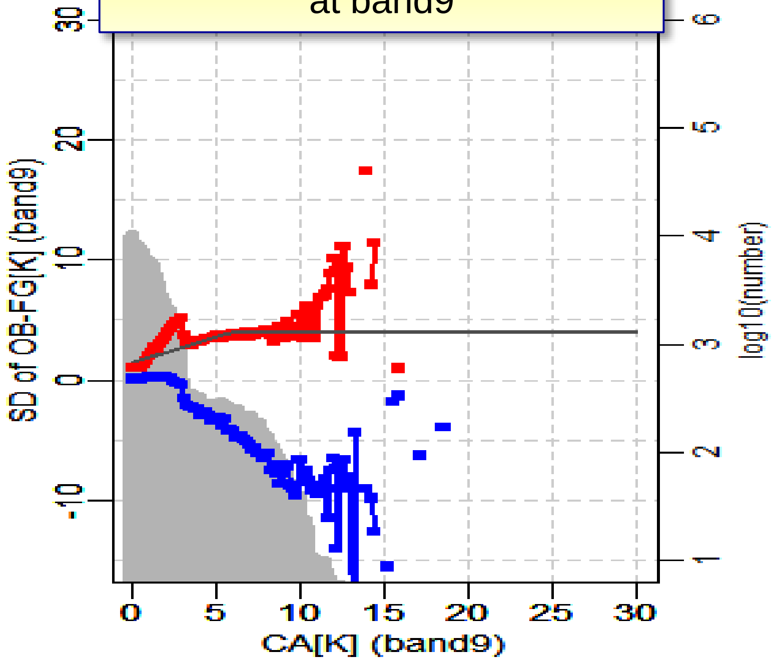
  r_1 for $Ca > Ca_1$

  $r_0 + (r_1 - r_0) * (Ca_1 - Ca)/(Ca_1 - Ca_0)$ for others
  - r_0, r_1: min,max error, estimated from Desroziers diagnostics → r_0=0.4K, r_1=6.3K
- Non-diagonal component will be included in future

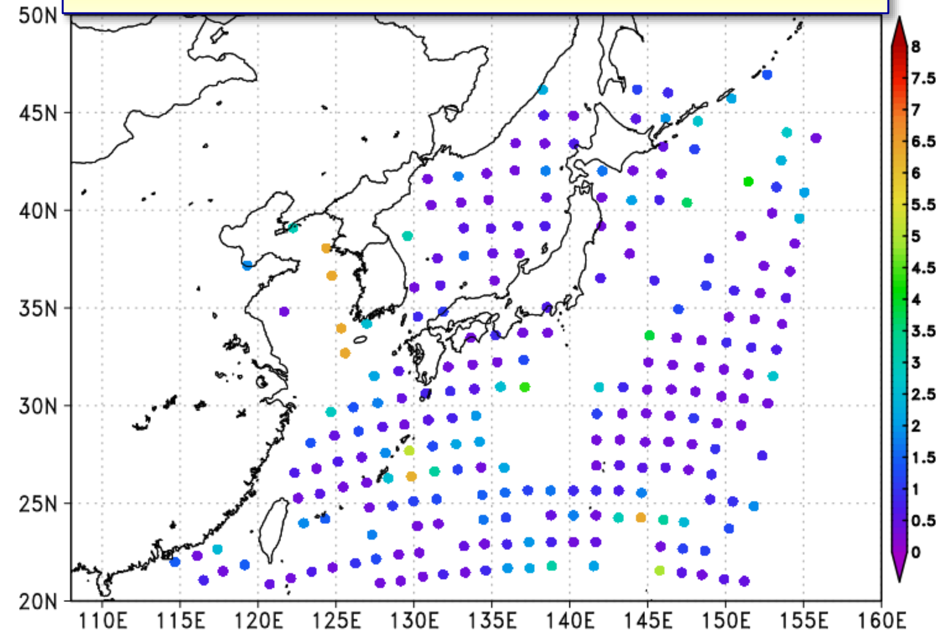
Linear function of obs error with Ca at band 9



OB-FG SD and mean with Ca at band9



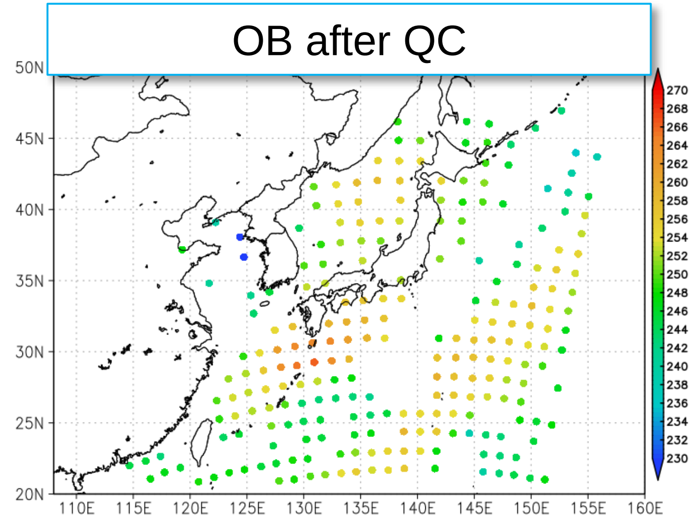
Obs error (band9)



4. Preliminary assimilation experiments

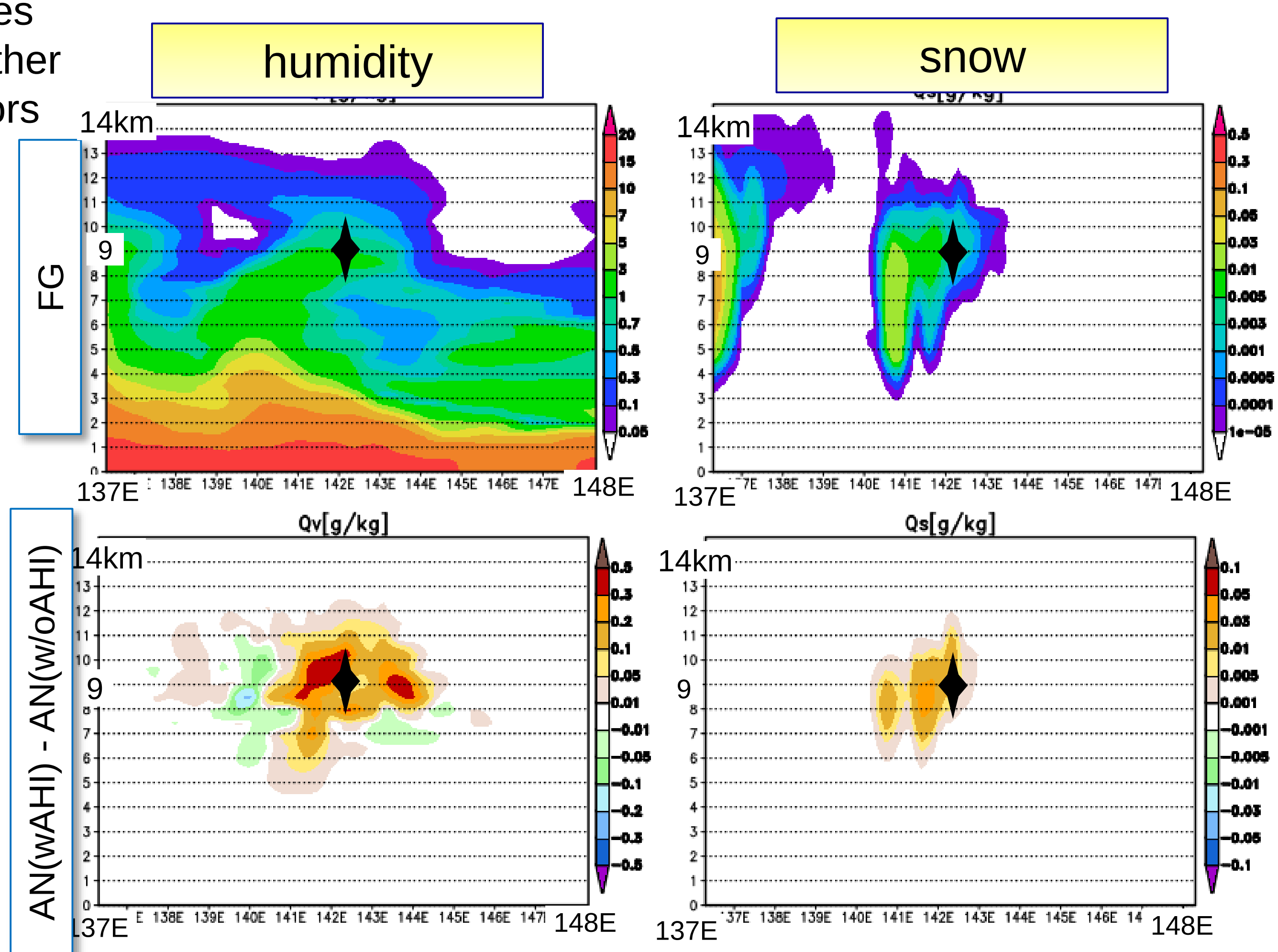
Experiment Design

- NHM-Letkf (Kunii 2014)
  - 15km, 50 members, 273x221 grids
  - 6-h cycle with 1-h slot to ingest observations
  - Inflation : RTPS (relaxation-to-prior spread)
  - Localization: 200 km and 0.2 lnP coordinates
- Period: 06 UTC 4 ~ 18 UTC 10 Sep, 2015
- Observations
  - CNTL: conventional data
    - RAOB, SYNOP, ship, aircraft, Wind Profiler, Doppler Radar, GPS ground, Atmospheric Motion Vector from MTSAT-2
  - TEST: CNTL + all-sky TB of AHI
- AHI all-sky TB
  - Super-ob (6x6 pixels)
  - Band 9 (6.9μm), Thinning 150km
  - Cloud dependent obs error (0.4~6.3K)
  - 3 QC, over sea
  - No bias correction (future work!)



Single Obs Experiment (1/2)

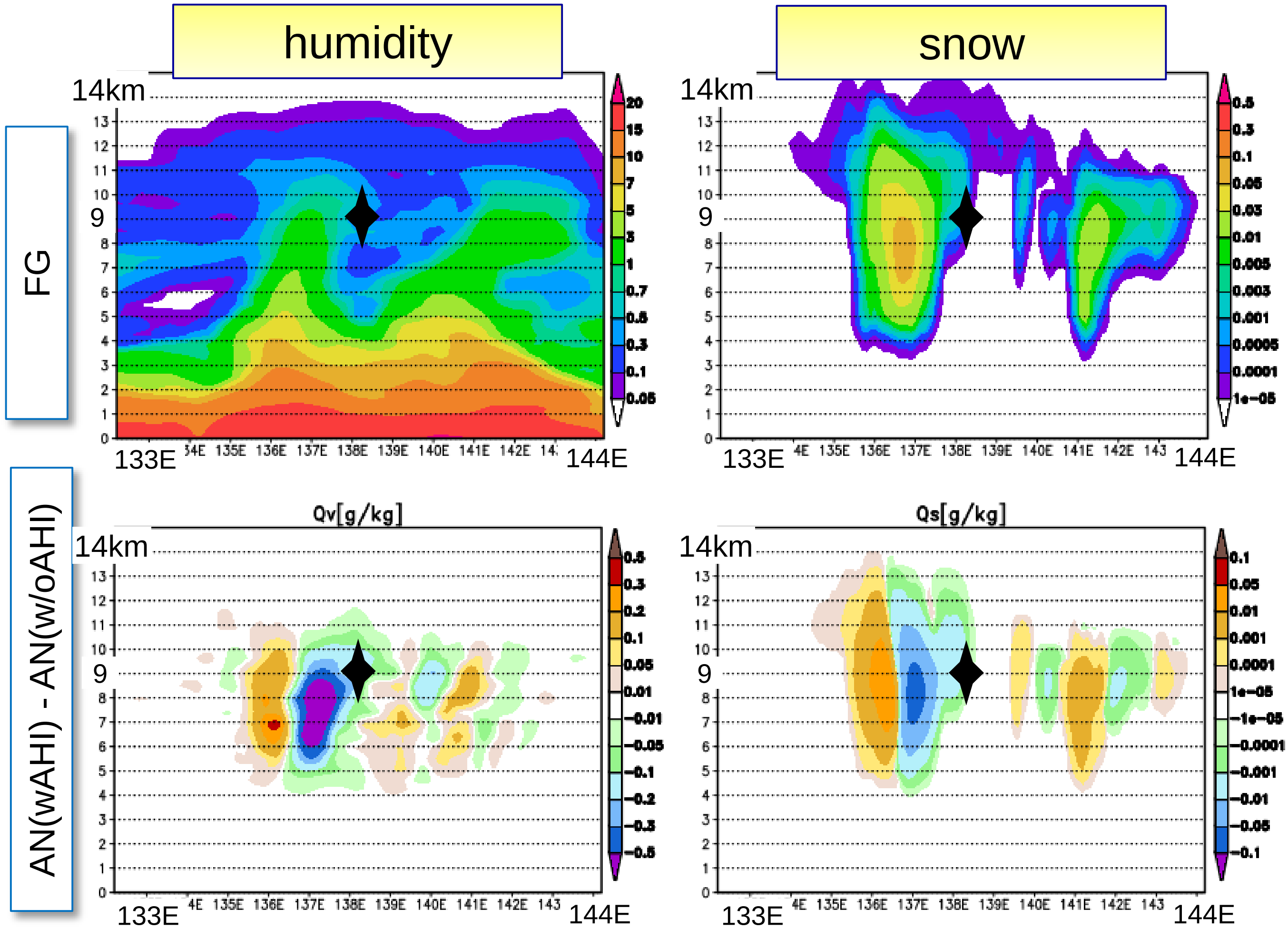
- OB=231.712, FG=248.018 at 142E, 24N ← FG underestimates cloud
- AN(w/oAHI)=247.155, AN(wAHI)=240.091
- Rad assimilation increases humidity and snow at 7~9 km around obs
  - JMA-NHM produces more snow than other frozen hydrometeors



FG & AN difference along the cross-section at 24 N

Single Obs Experiment (2/2)

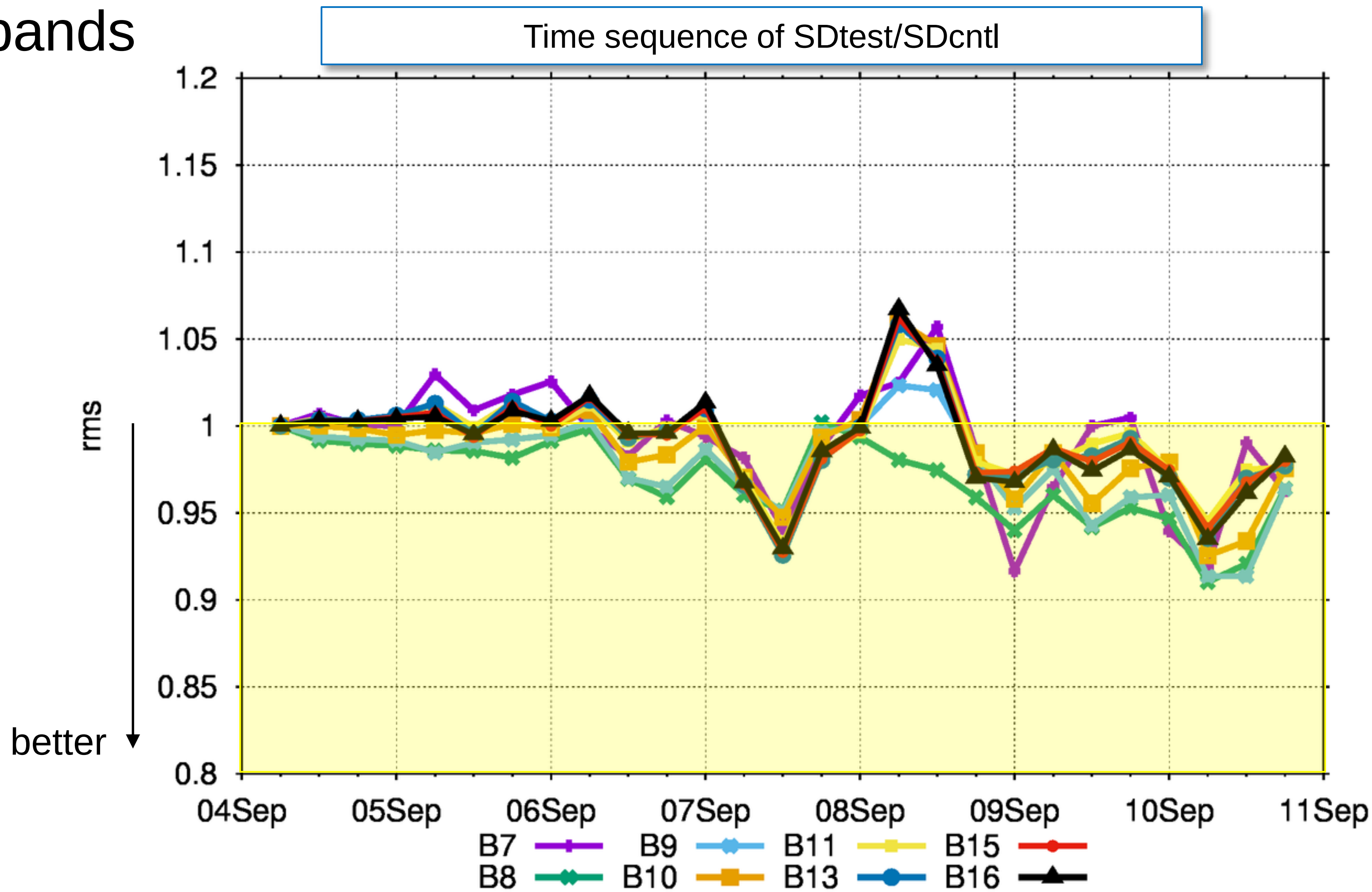
- OB=249.288, FG=243.820 at 138E,26N ← FG overestimate cloud
- AN(w/oAHI)=243.860, AN(wAHI)=251.116
- Rad assimilation reduces humidity and snow



FG & AN difference along the cross-section at 24 NC

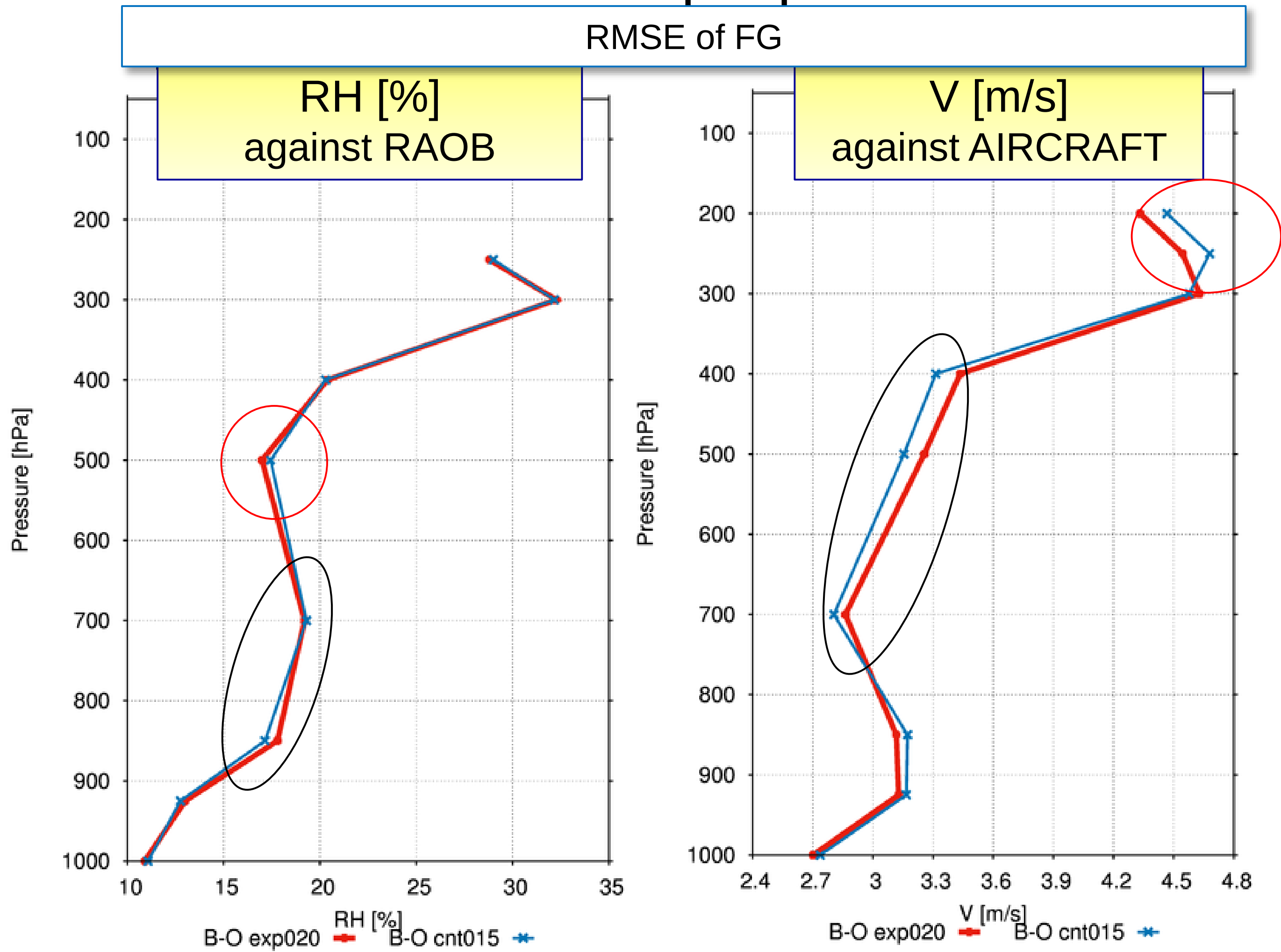
Ratio of FG RMSE against AHI rad

- $RMSE_{TEST}/RMSE_{CNTL} < 1.0$: better fitting of FG
- ➔ Improve FG fitting to rad obs at not only band 9 but other bands



FG RMSE against RH and wind

- 7 -10 September
- Improvement in V200 and RH500
- Degradation in RH850 and V in mid Troposphere

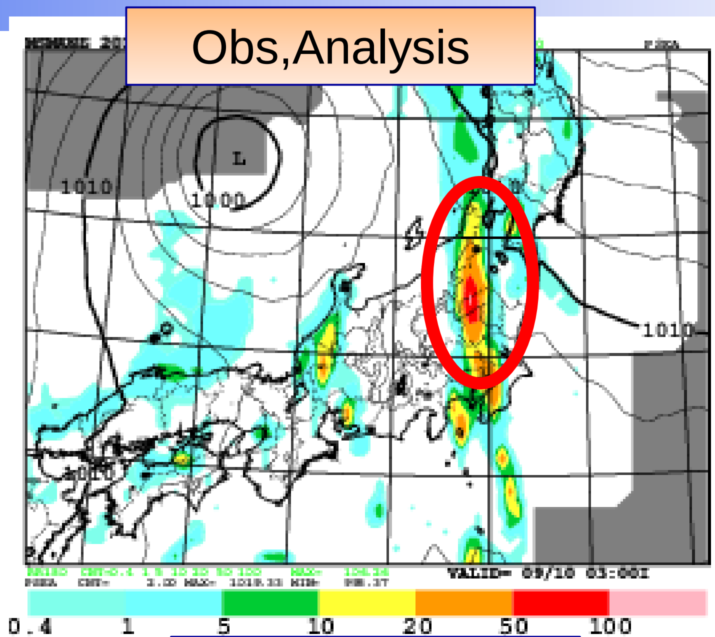


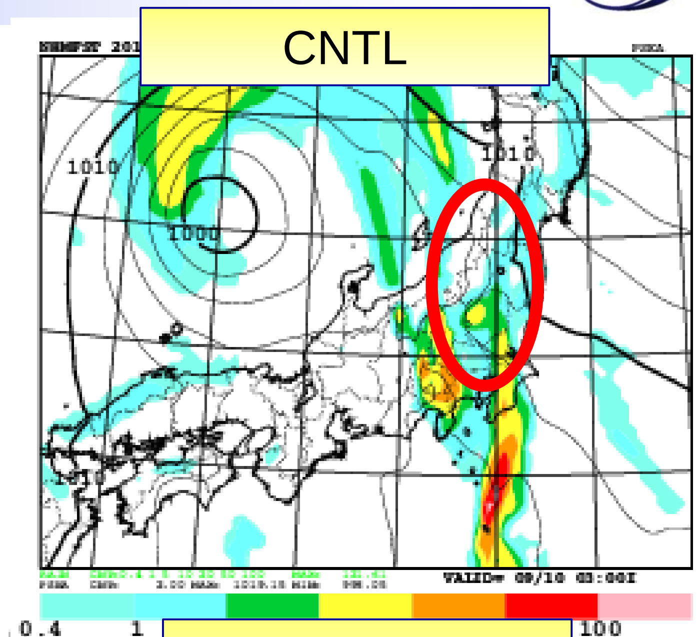
Statistics from 7 – 10 Sep 2016

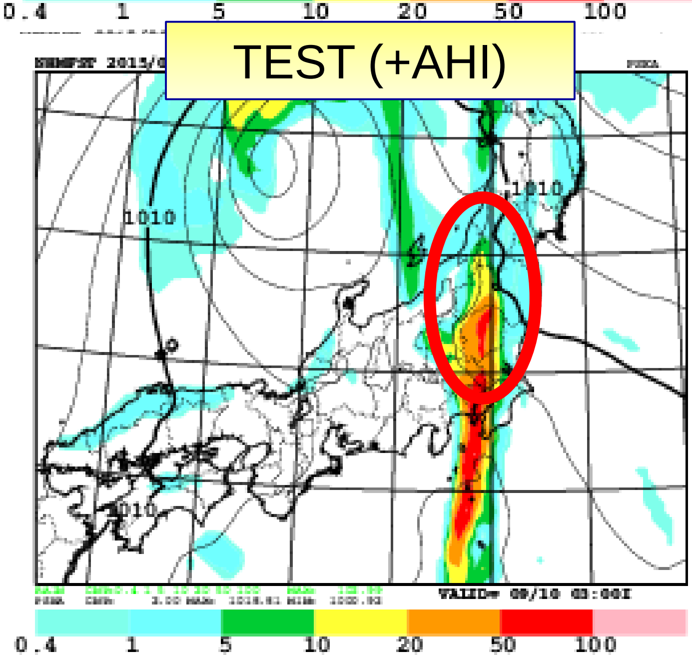
Verification of Rain and Psea forecast

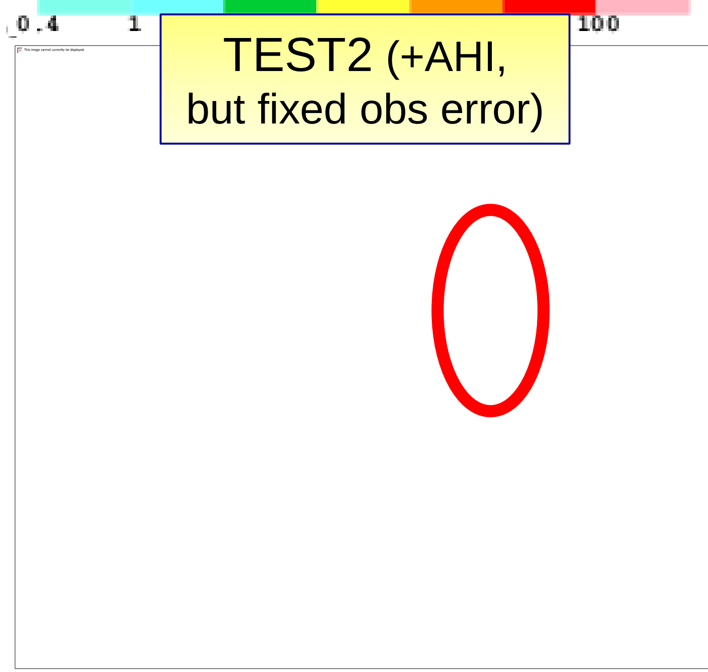
- 30-h forecast from 12 UTC 8 Sep, 2015
- rain[(mm/3h), Psea (hPa)

- TEST (AHI with cloud-dep obs err) better predicts rainband
- But the result is not robust







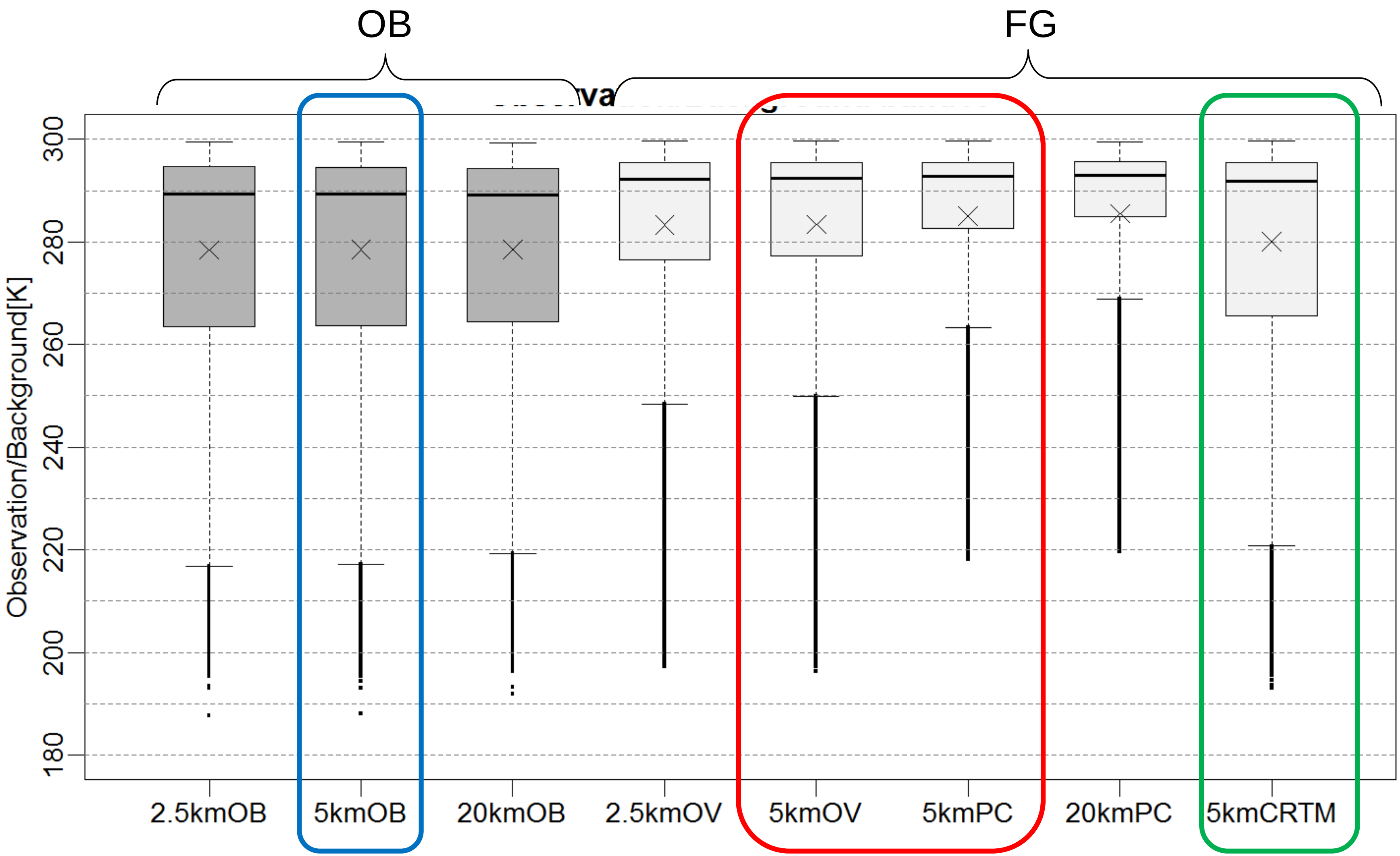


5. Summary and plans

- Models (JMA-NHM and/or RTTOV) significantly underestimate low BT, resulting in negative OB-FG bias.
- Develop 3 QCs to alleviate the discrepancy btw model and obs
  - Inhomogeneity QC, low BT QC, and cloud-dependent gross error QC
- Estimate obs error and its spatial/spectral correlation
  - Determine thinning distance and cloud-dependent obs error
  - Cloudy obs error (variance and correlation) is larger than clear-sky one
- Preliminary assimilation experiments
  - Assimilate rad at only band (at the moment)
  - Agreement of FG to obs is better for rad at IR bands, but mixed for RAOB and aircraft.
  - Better precipitation forecast can be found, but the result is not robust at the moment

- Plans
  - Develop bias correction
  - Redesign assimilation setup: longer period, cycle period, resolution,,,
  - Compare impacts of clear-sky radiance assimilation
  - Apply for the operational global data assimilation system (4D-Var)

OB and FG distribution



O-B.SD= 15.00 14.97 16.03

30-h forecast from 12 UTC 8 Sep, 2015