9.04

Preliminary assimilation of all-sky IR radiances of Himawari-8 in the global data assimilation system at JMA

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1. Background & Objective

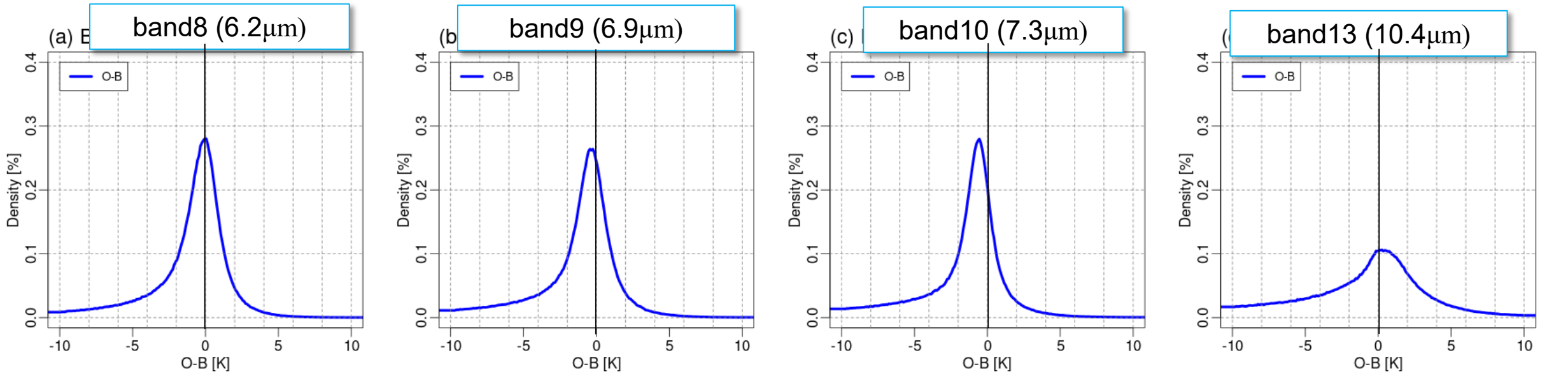
- Assimilating Infrared (IR) radiance has large impacts on NWP and has been widely implemented. But it is mostly limited to clear-sky radiances (CSRs).
- Recently IR all-sky (cloudy+clear-sky) radiance (ASR) assimilation has been significantly advanced.
  - Zhang et al. (2016, GRL), Honda et al. (2018a MWR; 2018b JGR), Minamide et al. (2019,QJRMS) , Okamoto et al. (2019, QJRMS), Sawada et al.(2019, JGR), Geer et al. (2019, QJRMS)
- However, few studies have been done about the benefit of IR ASR assimilation using the global operational DA system,
- Objective: Investigate impacts of Himawari8 ASR in the operational global DA system at JMA
  - Extend previous study in research-based regional DA system of Okamoto et al. (2019, QJRMS)

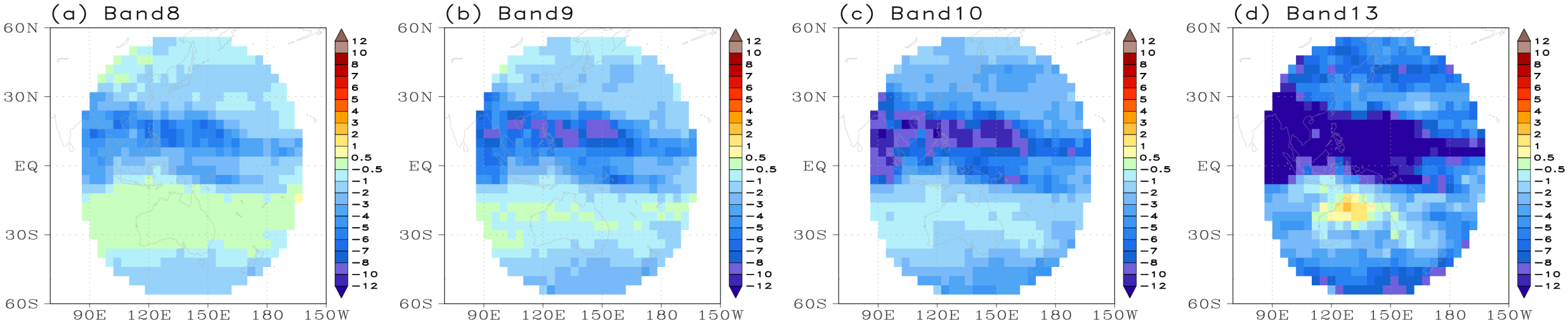
Content

1. Background and objective
2. Examination of O-B
3. Development of ASR assimilation
4. Data assimilation experiments
5. Summary and plans

O-B of all-sky radiances of Himawari-8

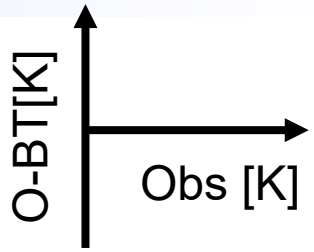
- 3 WV and window bands, no QC, no BC, 1 – 31 August 2018





O-B according to cloud type

- Dominant negative bias in thick ice cloud
- Positive bias for thin ice cloud

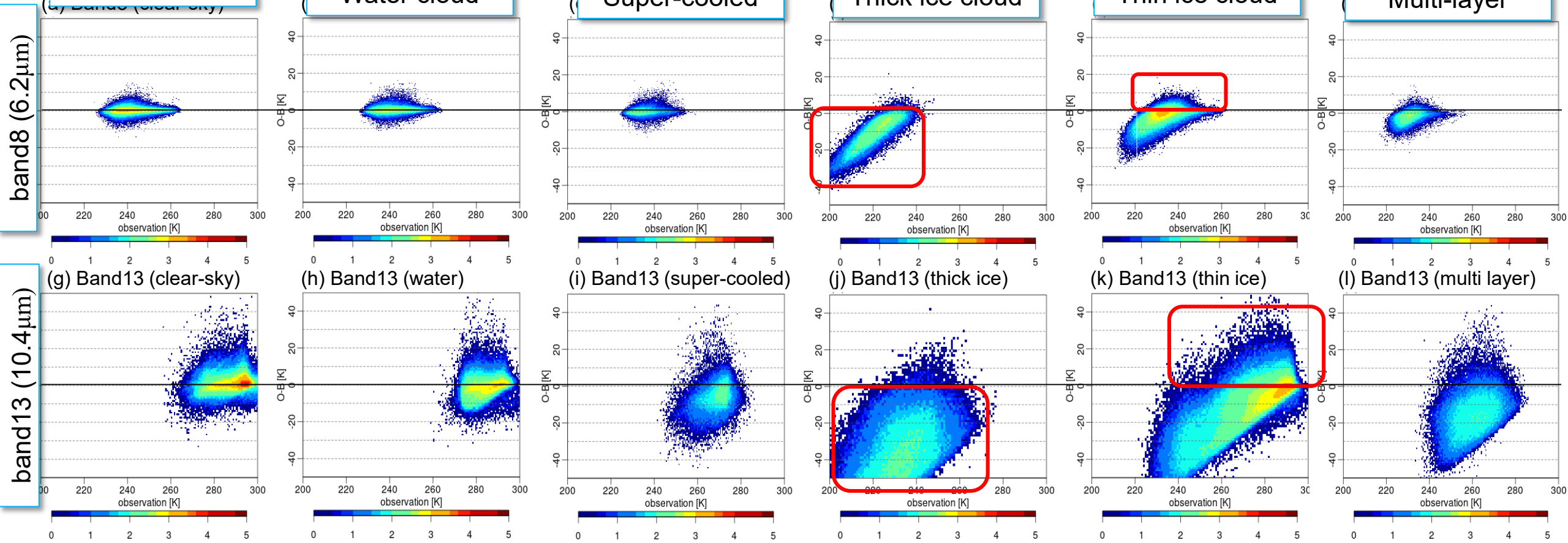


Clear-sky | Water cloud | Super-cooled | Thick ice cloud | Thin ice cloud | Multi-layer

band8 (6.2μm)

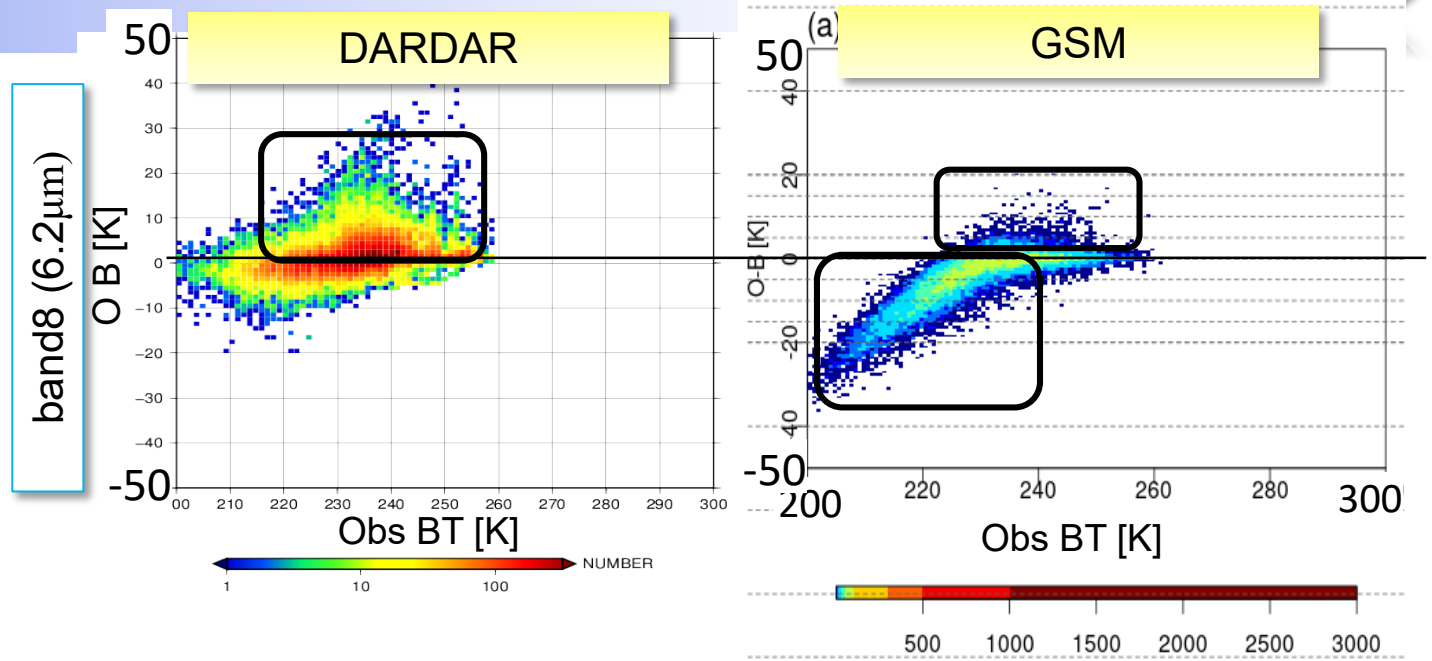
band13 (10.4μm)

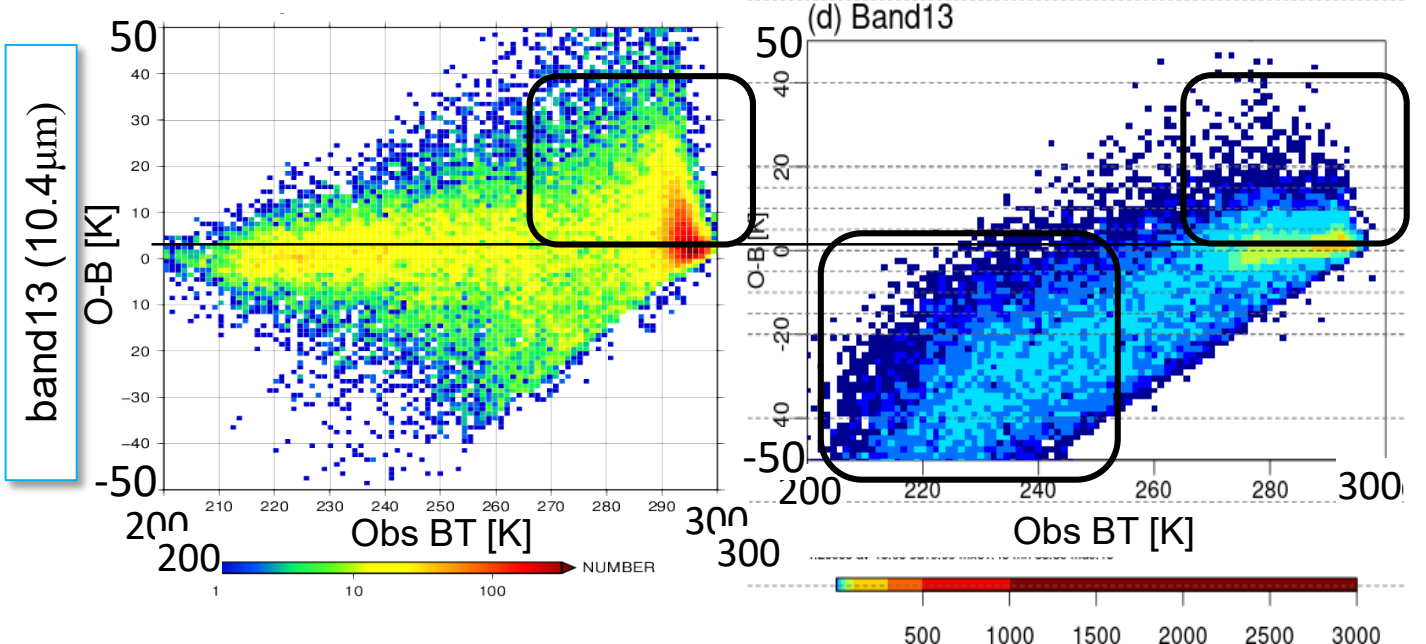
(g) Band13 (clear-sky) (h) Band13 (water) (i) Band13 (super-cooled) (j) Band13 (thick ice) (k) Band13 (thin ice) (l) Band13 (multi layer)



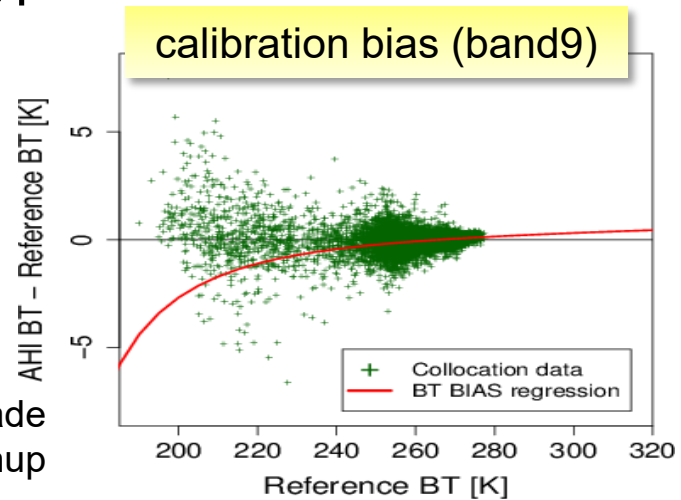
Examination of O-B bias sources

- Simulation using cloud ice from DARDAR substantially reduced –ve bias, but still have +ve bias at high BT
  - DARDAR: CALIPSO and Cloudsat combined product (Dalanoë and Hogan, 2010)
- O-B<0→ GSM underestimate cloud ice
- O-B>0 at high BT
  → overestimate thin ice cloud absorption in RTTOV
- Small effect from observation calibration bias at low BT





calibration bias (band9)



Reference BT is made from IASI matchup

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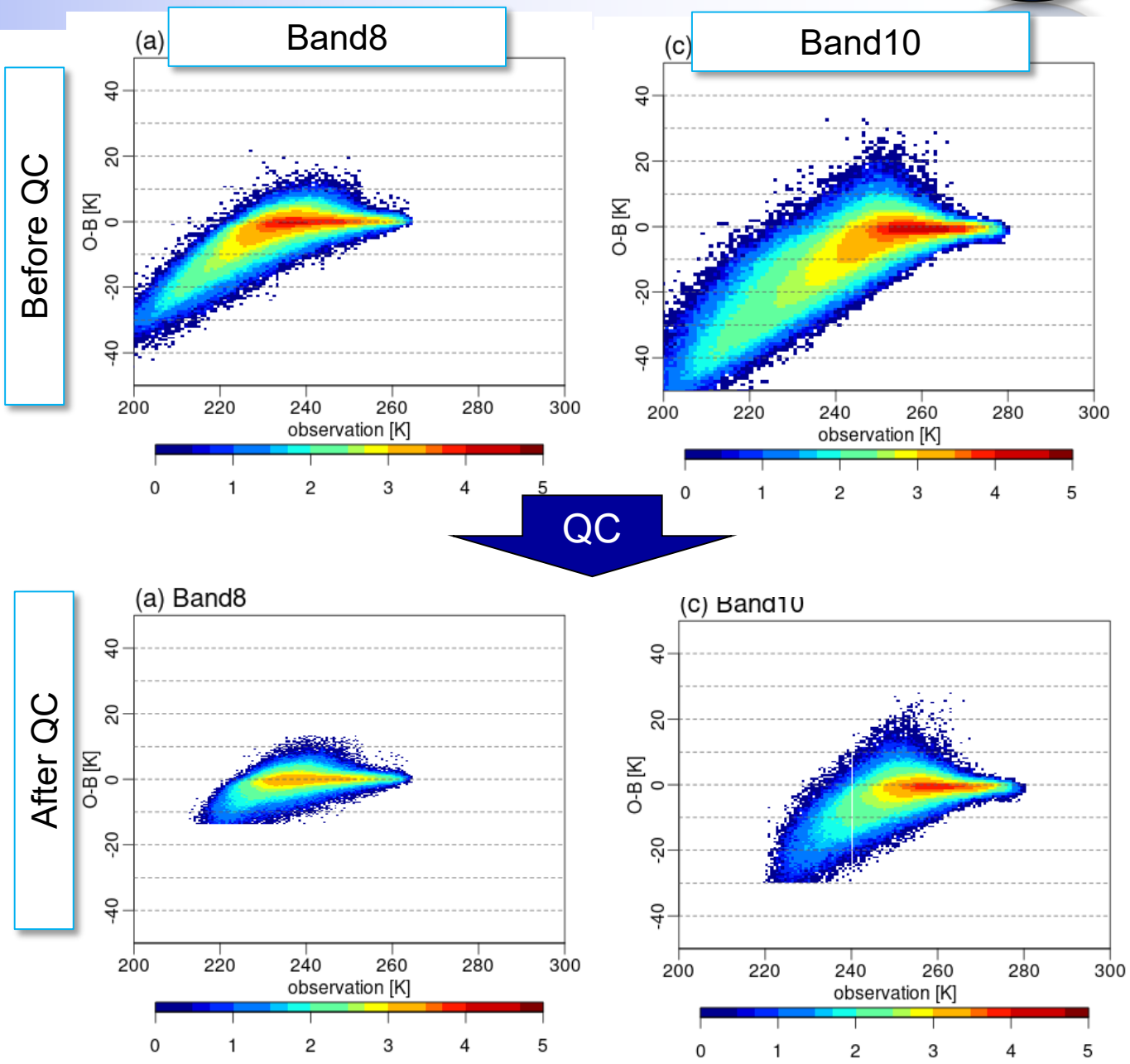
Quality Control (QC)

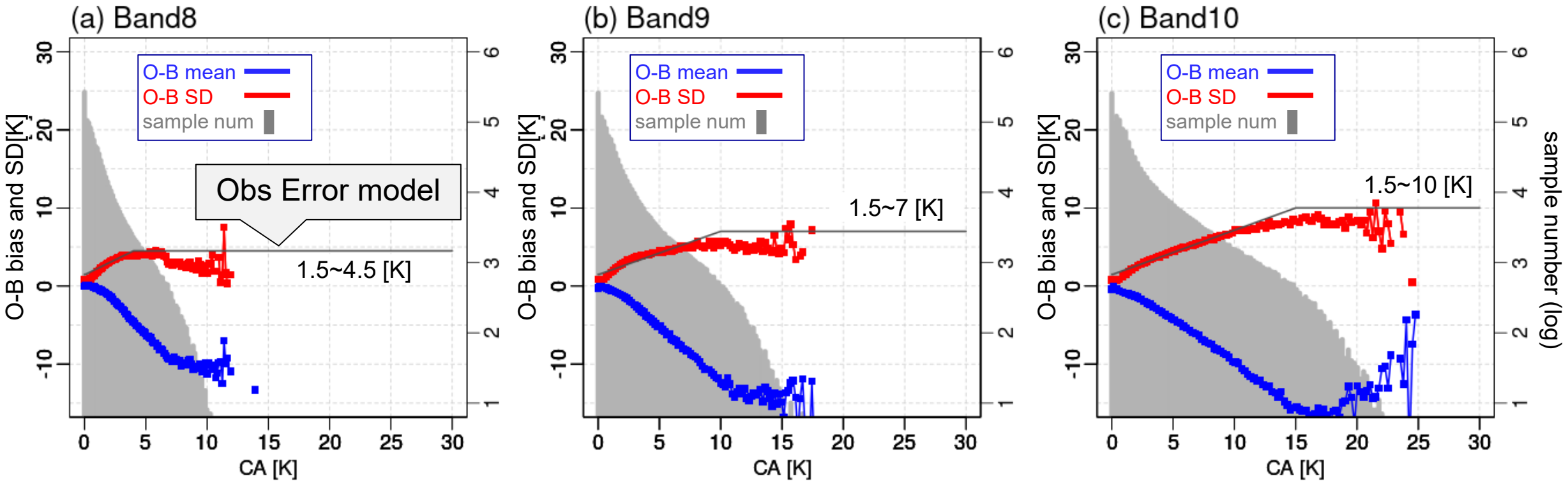
- Remove scenes with low BT (<230K), thick ice cloud, inhomogeneous (internal obs SD > 8K), large sensitivity to the land surface, or large Jacobian wrt cloud
- Cloud-dependent O-B check
  - |O-B|>3*ober
  - ober is a linear function cloud effect parameter CA
- Select only WV ch (Okamoto 2017, QJRMS)
  - Difficult to reproduce for window bands
- ➔ O-B becomes more symmetric after QC but still negative especially at band10



Observation error model (diagonal R)

- O-B variability can be predicted with a simple function of an cloud effect parameter (CA)
  - Gaussian PDF of O-B normalized using CA
- Diagonal obs error is modeled with a linear stepwise function of CA
  - Geer & Bauer (2011, QJRMS); Okamoto et al. (2014, QJRMS)

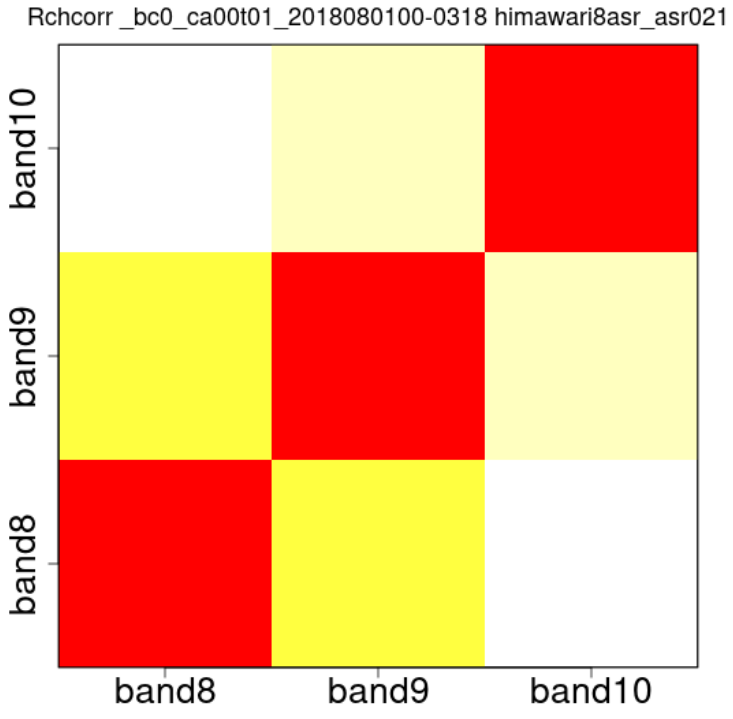
cloud effect parameter:
CA=(|B-Bclr|+|O-Bclr|)/2,
Bclr=clear-sky first-guess



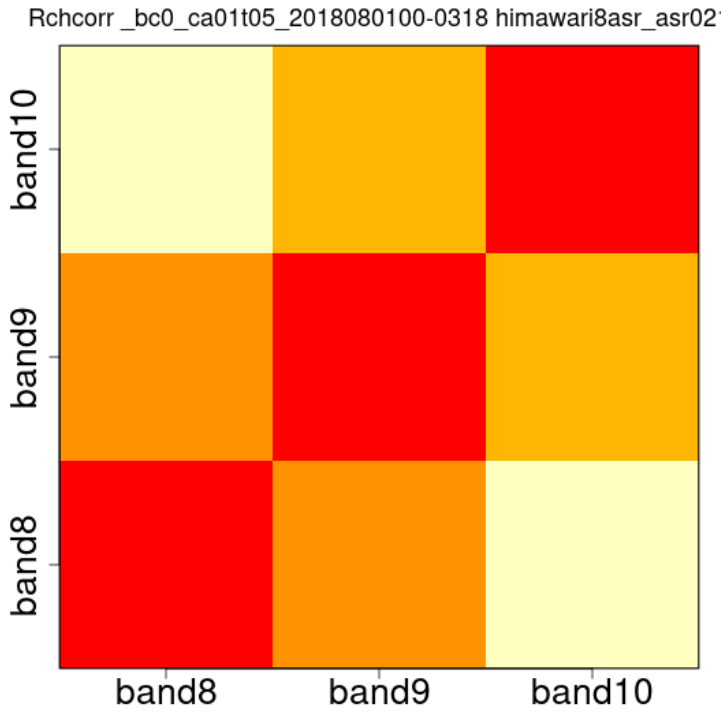
Observation error band correlation

- The correlation increases as CA (cloud effect parameter) increases
  - Less independent information from independent bands for large CA
- → Cloud dependent obs error correlation is necessary
  - Under development…

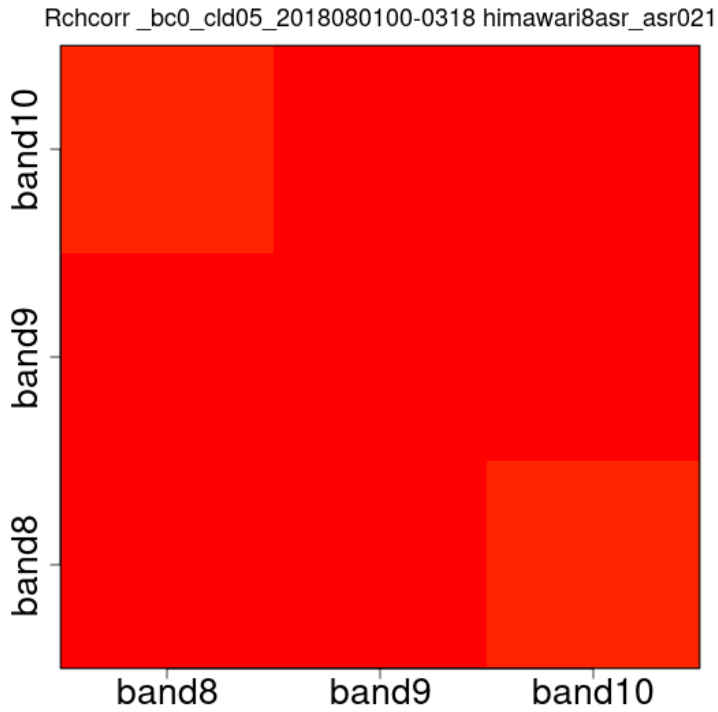
0.0<CA<0.1

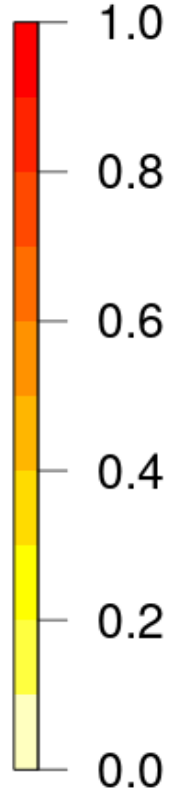


0.1<CA<0.5



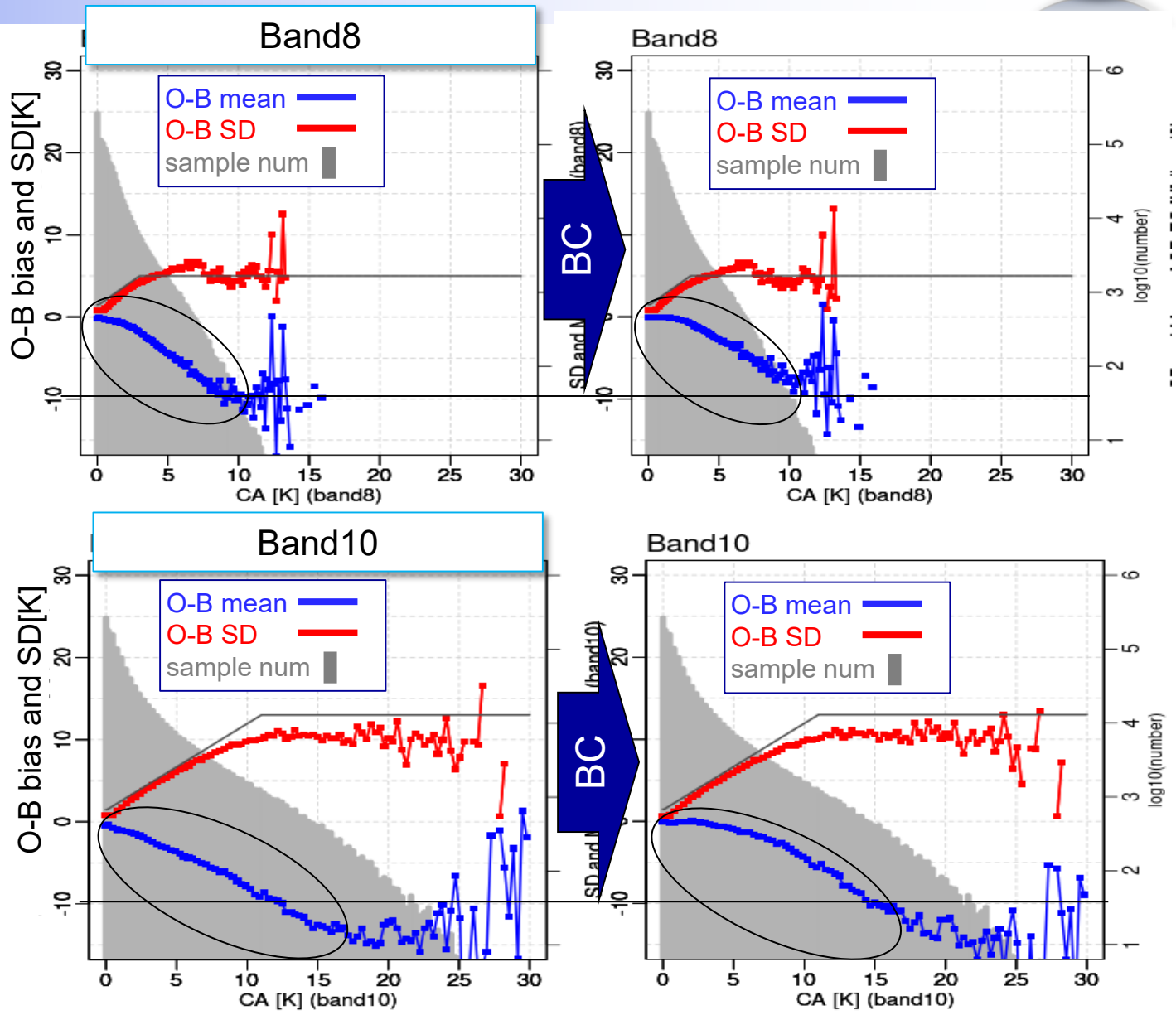
CA>0.5





Bias correction (BC)

- Experiments with No BC generated excessive positive humidity increments in the mid- and upper-troposphere
  - ← Model cloud deficit misinterpreted
- VarBC (tentative)
  - Add CA and CA^2 to CSR predictors
    - Bclear, 1/cos(zen.angle), 1.0, CA, CA^2
  - VarBC coef NOT updated for large CA to limit influence from model bias
- O-B bias is reduced, but we need to carefully examine effect of the inclusion of cloud effect



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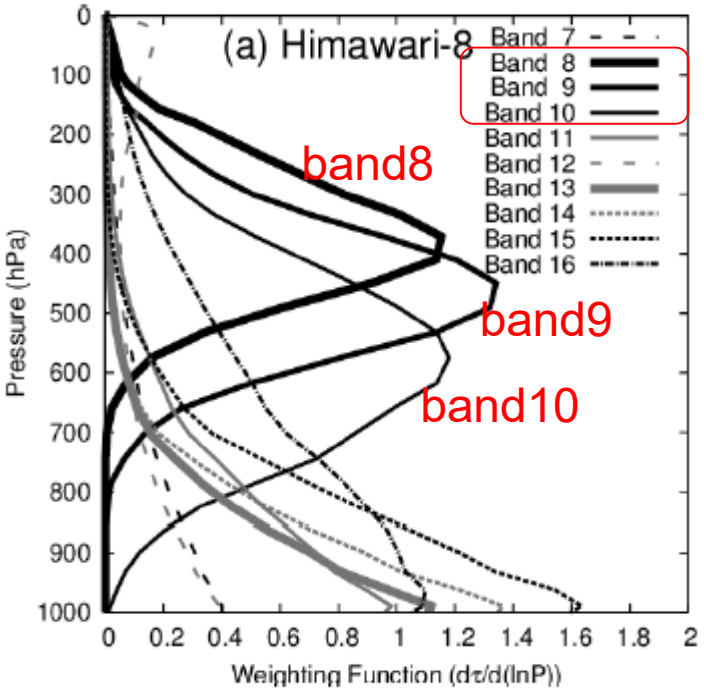
Assimilation experiment settings 1

- Compare impacts of ASR and CSR

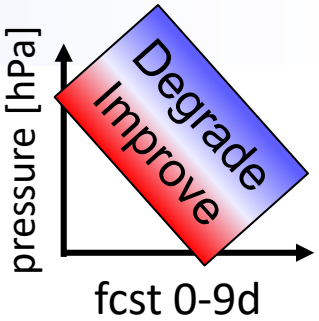
- Assimilation system
  - 4DVar with MW all-sky assimilation
  - TL959L100 (outer 20km, inner 60km, 100levels)
- Obs Configuration
  - CNTX: Operational obs as of Aug. 2018, but for no Himawari8
  - CSRX: CNTX + Himawari-8/CSR
  - ASRX1: CNTX+ Himawari-8/ASR w/o BC
  - ASRX2: CNTX + Himawari-8/ASR w BC
    - All the WV bands (8,9,10) assimilated for CSR or ASR
    - ASR thinning 220 km (same as CSR), Obs error inflation 3.0
- Period : 10 Jul. – 11 Sep. 2018



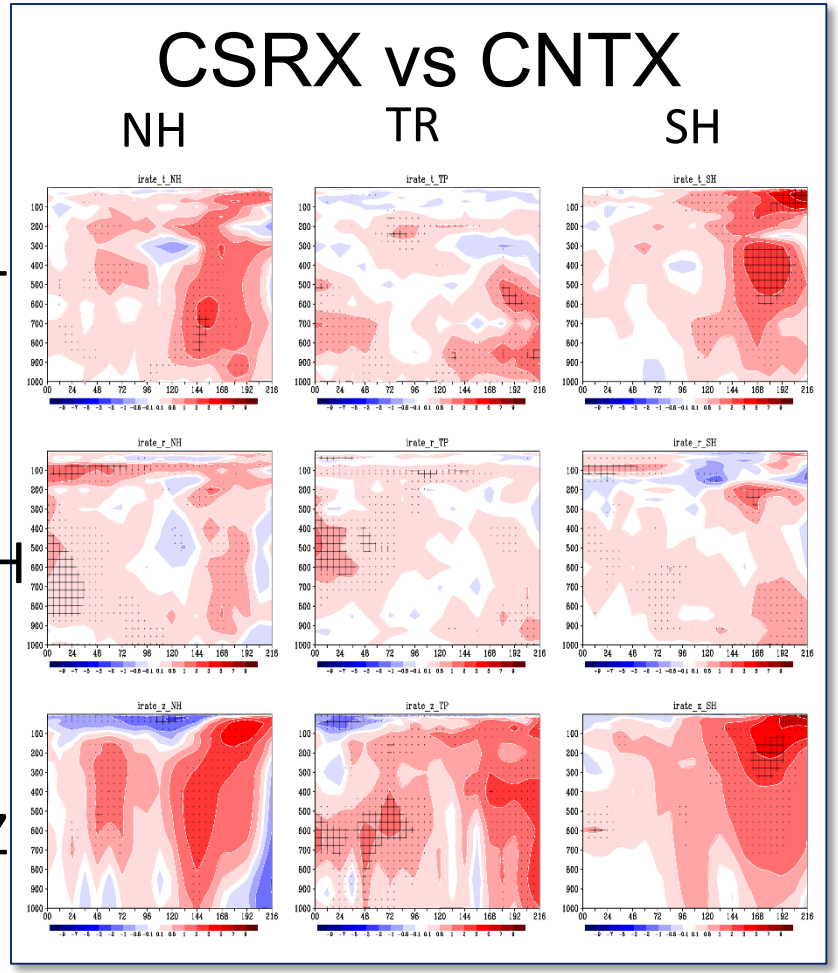
Exp	CSR	ASR
CNTX	No	No
CSRX	8,9,10	No
ASRX1	No	8,9,10 (woBC)
ASRX2	No	8,9,10 (wBC)

Impact of ASR/CSR and BC

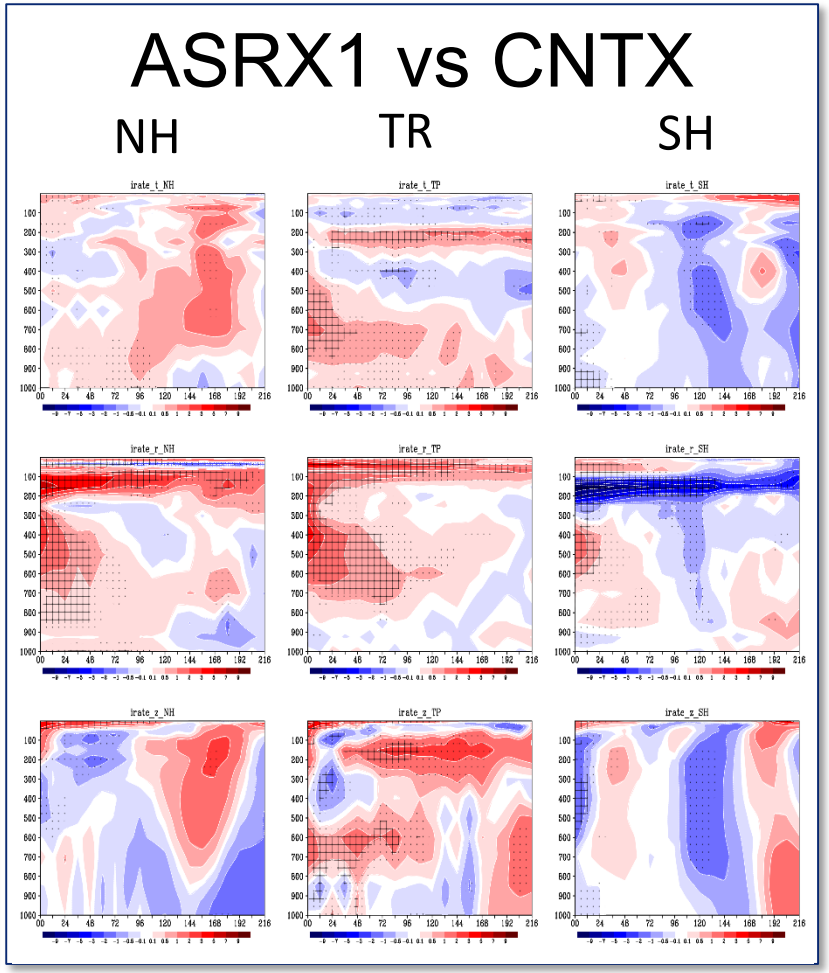
- ASR impact neutral or slightly negative while CSR is clearly positive
- Not clear benefit from BC (ASRX2 vs ASRX1)



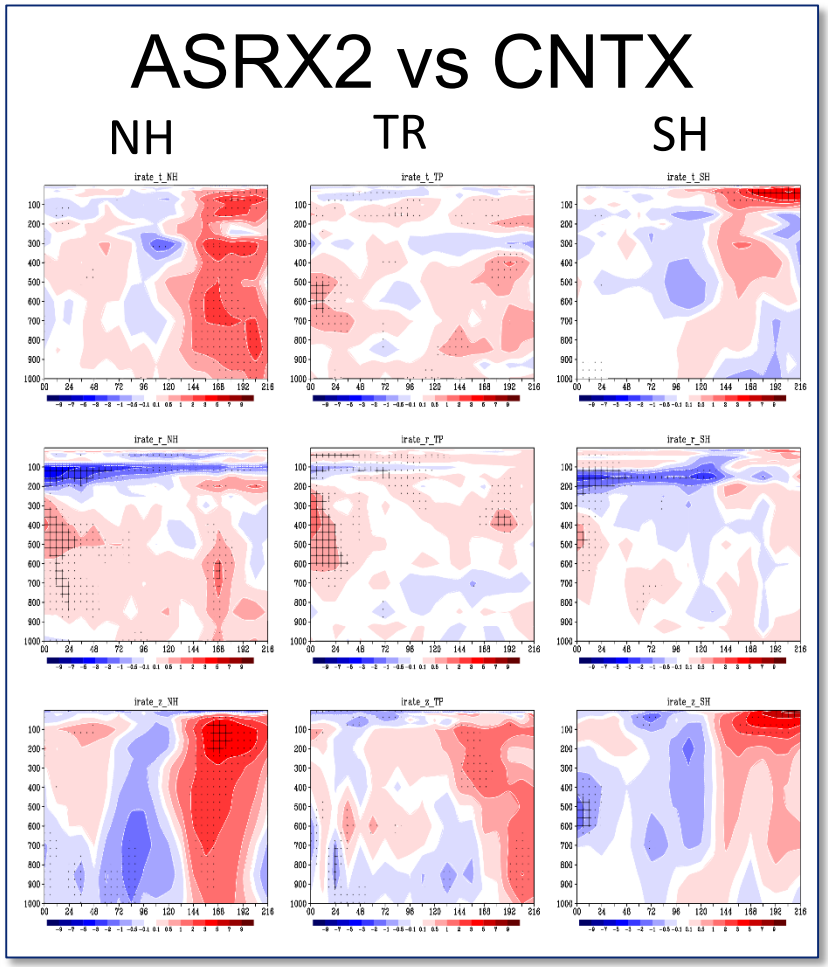
CSRX vs CNTX



ASRX1 vs CNTX



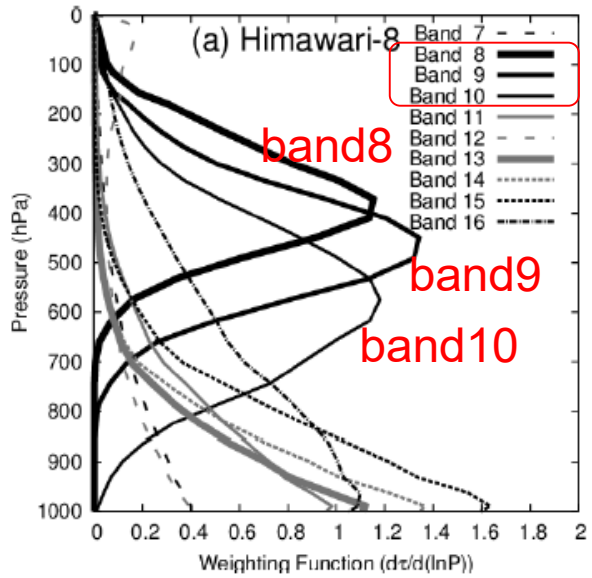
ASRX2 vs CNTX



Why is ASR impacts smaller than CSR or negative?

- Possible cause
  - [1] Obs error correlation cancel or badly affect ASR at multiple bands
    - Stronger in cloudier conditions
  - [2] BC: How (much) should we correct the biases that model bias dominates?
- Treatment with [1]
  - 1-1. Cloud-dependent obs error correlation
  - 1-2. Single band assimilation as ASR
- Treatment with [2]
  - 2-1. Improve forecast models
  - 2-2. Review VarBC: predictors, sampling conditions, constrain coef update
  - 2-3. Review QC: more strictly select data with small bias, further increase obs error according to bias
    - → Reduce model bias effect

Assimilation experiment settings 2



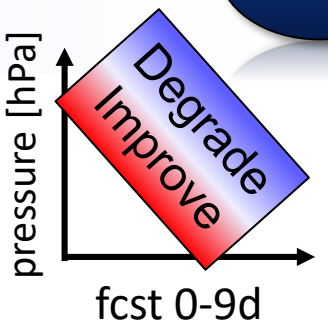
- Assimilate ASR at band8 only and CSR at bands 9 & 10
  - Band8 is least affected by clouds (or model bias)

- Obs Configuration
  - CNT: operational obs as of Aug. 2018, but for no Himawari8/CSR band8
    - Bands 9 and 10 of Himawari8/CSR assimilated
  - CSRX: CNT + Himawari-8/CSR band8
  - ASR1: CNT + Himawari-8/ASR band8 w/o BC
  - ASR2: CNT + Himawari-8/ASR band8 w BC
    - ASR (band8) + CSR (band9,10) of Himawari8
    - ASR thinning 220 km (same as CSR), Obs error inflation 2.0

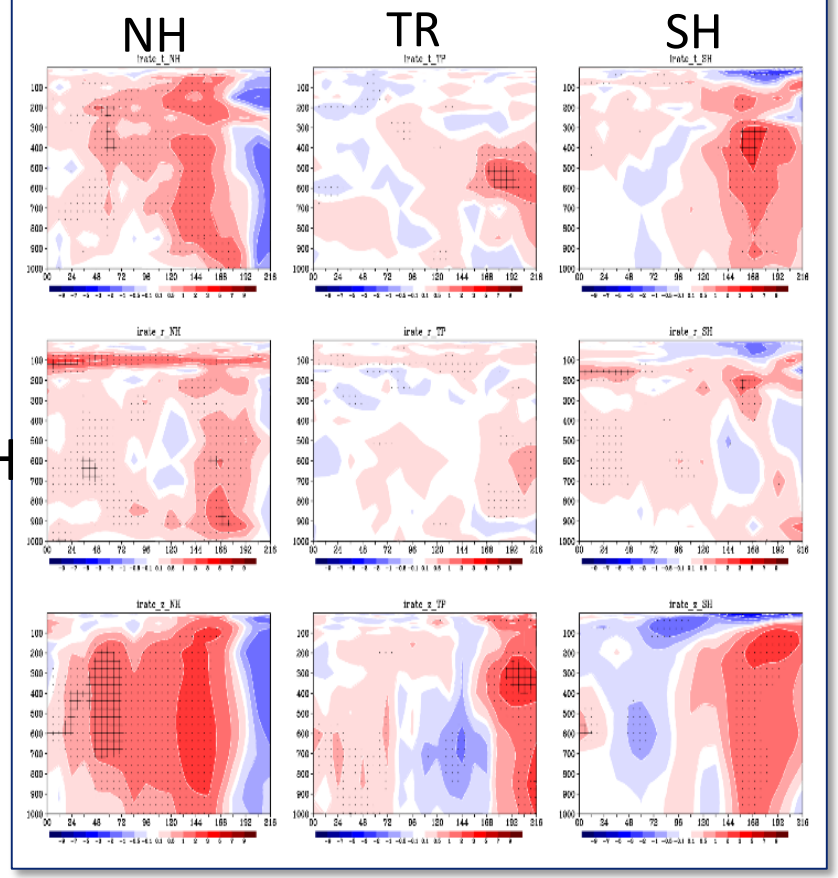
Exp	CSR	ASR
CNT	9,10	No
CSRX	8,9,10	No
ASR1	9,10	8 (w/oBC)
ASR2	9,10	8 (BC)

Impact of ASR/CSR and BC (at band8)

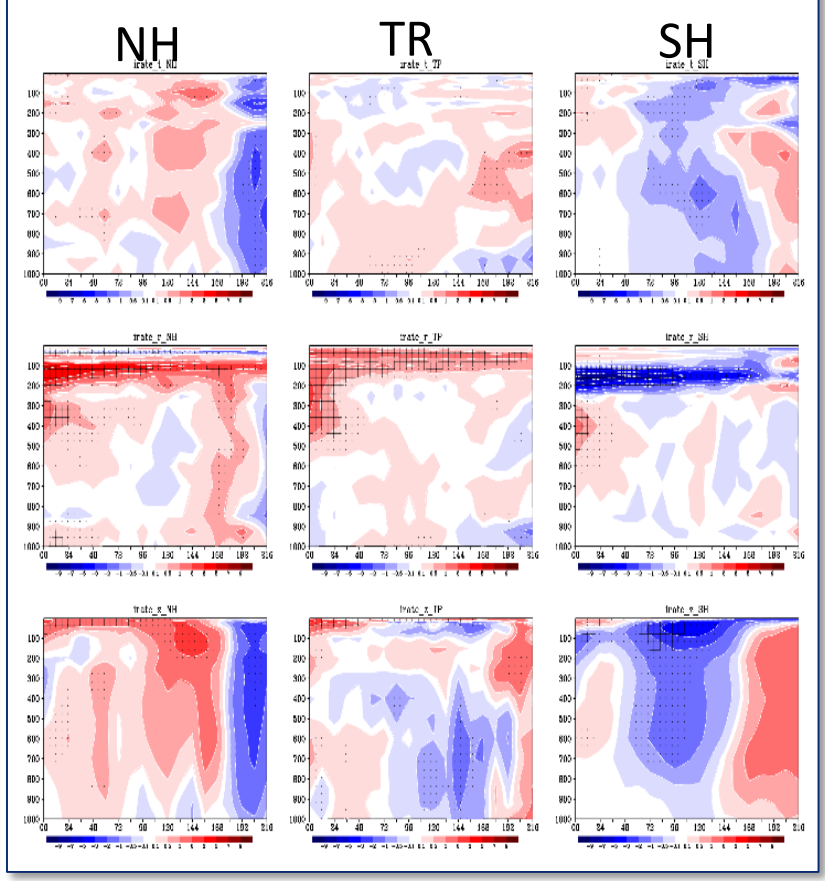
- ASR2 (ASR wBC) impact is comparably positive to CSR
- BC works well (ASR2 vs ASR1)



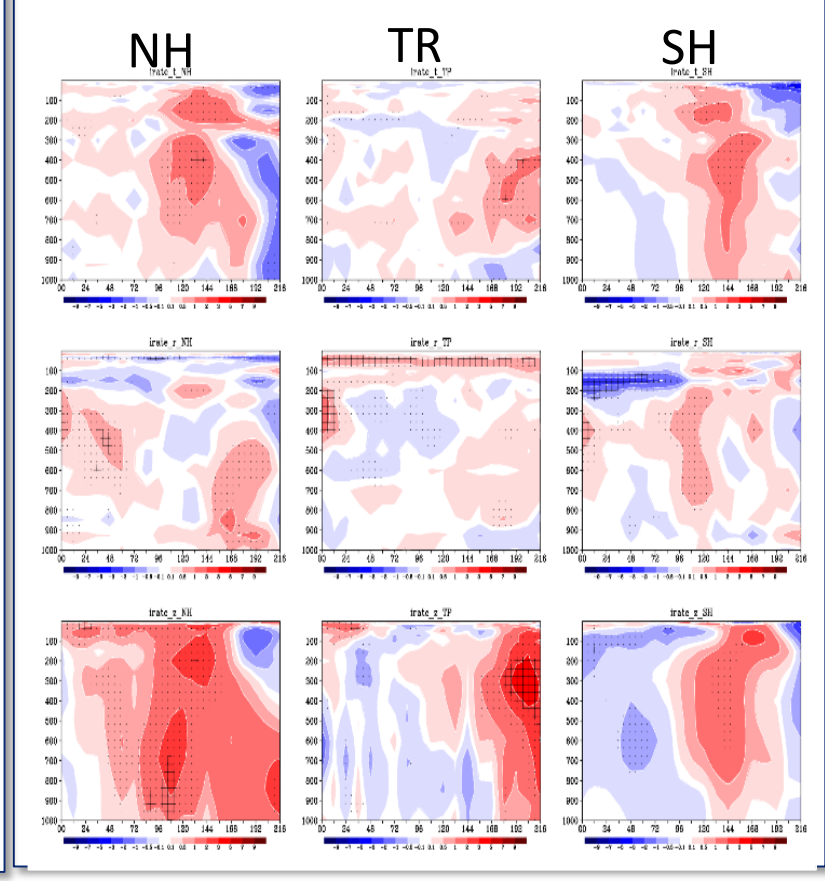
CSRX vs CNT



ASR1 vs CNT



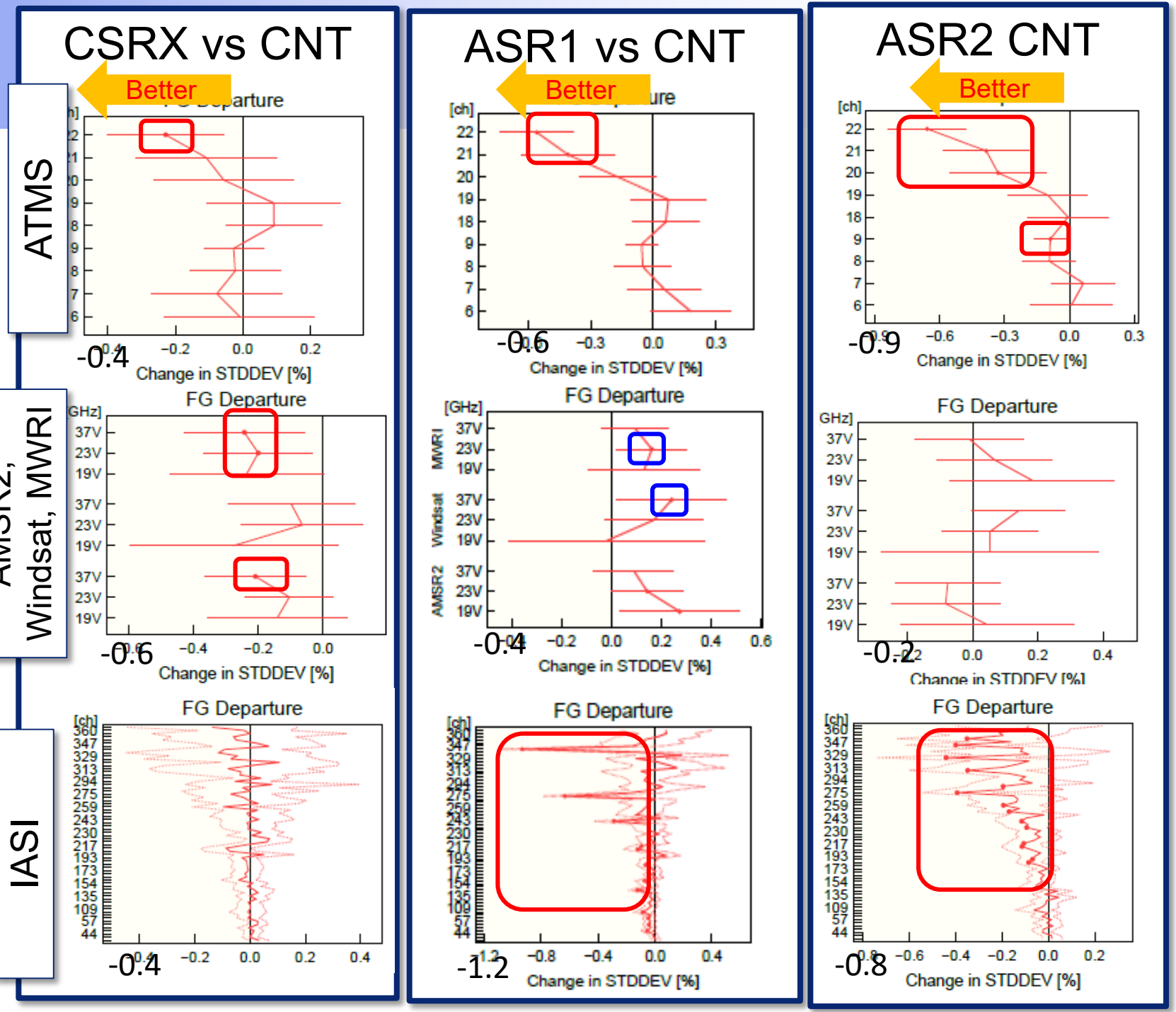
ASR2 vs CNT



Impact on short-range forecast

- Change in O-B SD
  - negative is improvement
- ASR2 is best for ATMS Q and T ch
- CSR is best for MWI
- ASR1 and 2 better than CSR for IASI temp ch
- BC improve fit for ATMS and MWI but shrink improvement for IASI

Exp	CSR	ASR
CNT	9,10	No
CSRX	8,9,10	No
ASR1	9,10	8 (w/oBC)
ASR2	9,10	8 (BC)



Summary and plans

- Investigate assimilate all-sky infrared radiance (ASR) of Himawari-8
- Examine O-B statistics and bias sources for global DA
  - insufficient model high cloud and excessive absorption of thin ice cloud in RTM
- Develop cloud-dependent QC, diagonal obs error model, and BC
- Data assimilation experiments
  - ASR at single WV band brought comparable improvement to CSR

- Ongoing development and plans
  - Cloud-dependent inter-band error correlation
  - Examine and improve bias correction
  - Extend to other Geo/LEO IR observations

Acknowledgements

- This study was partly supported by
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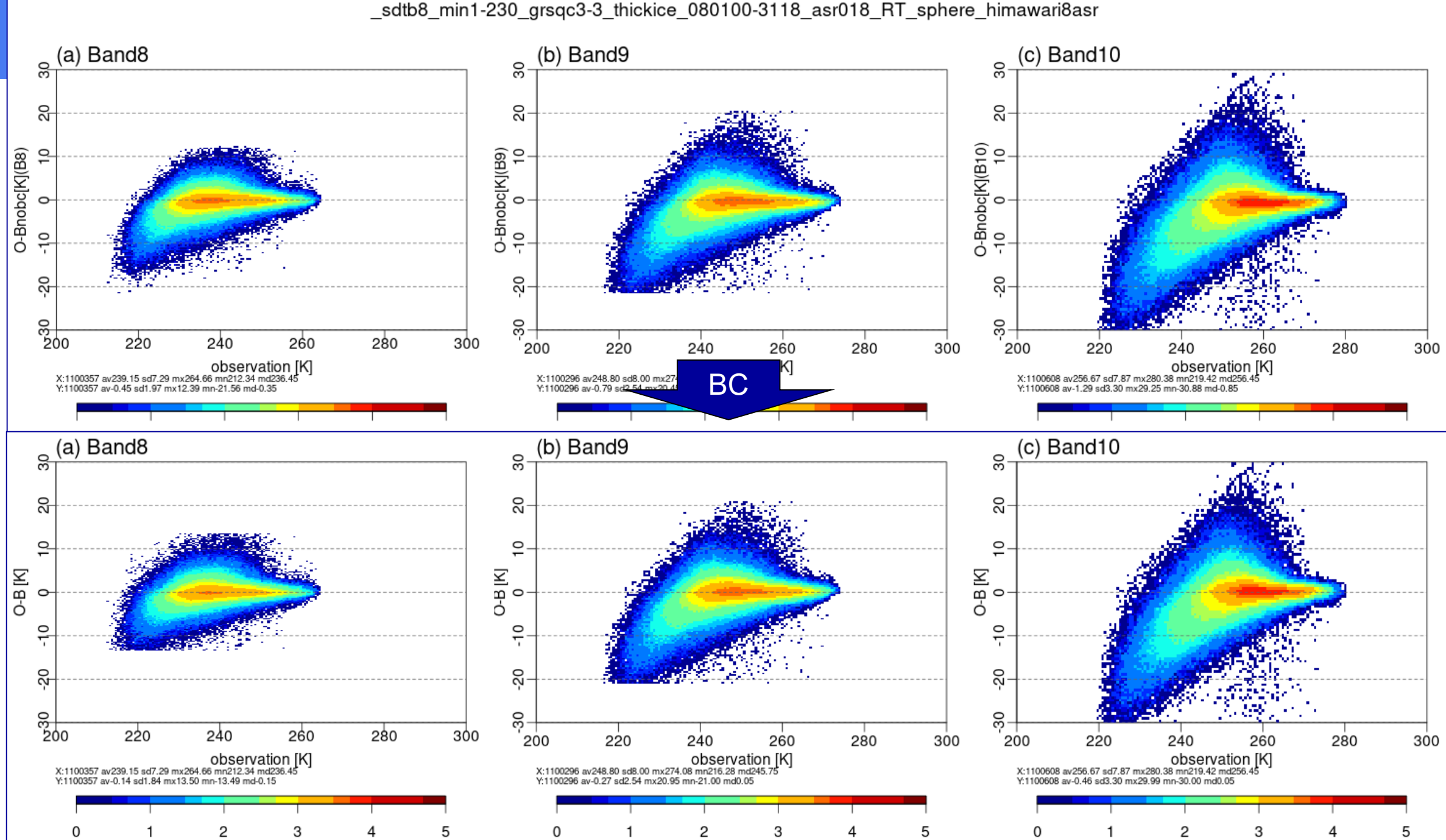
  - JSPS KAKENHI Grant Number 19H01973

abstract

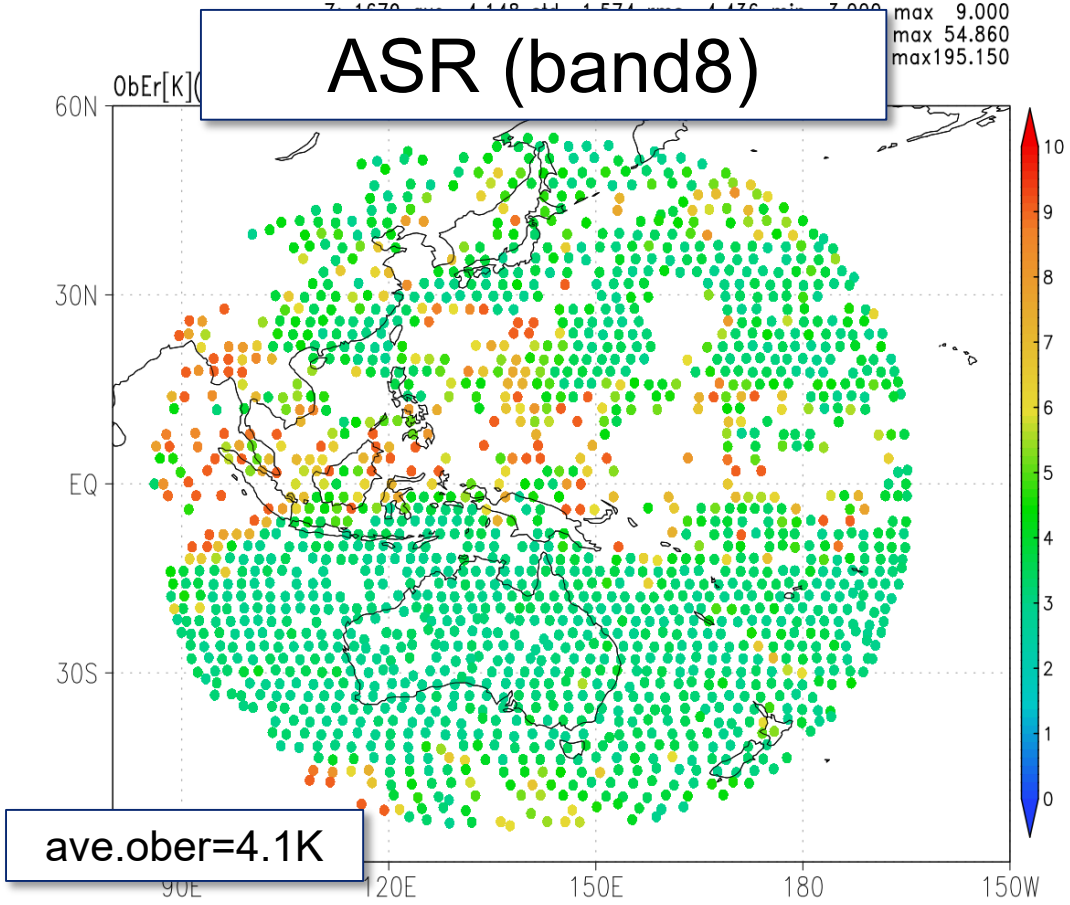
- All-sky infrared radiance (ASR) assimilation has been developed for Himawari-8 in the global data assimilation system of JMA.
- The representation of ASR simulations from the global forecast model and radiative transfer model were carefully examined. The poor representation of simulations was found especially for thick high-altitude clouds. The systematic differences between observations and simulations were caused by considerable deficit of high cloud in the forecast model and overestimated absorption of thin ice cloud in radiative transfer calculation.
- This examination results helped to develop quality control (QC) procedures and bias correction (BC).

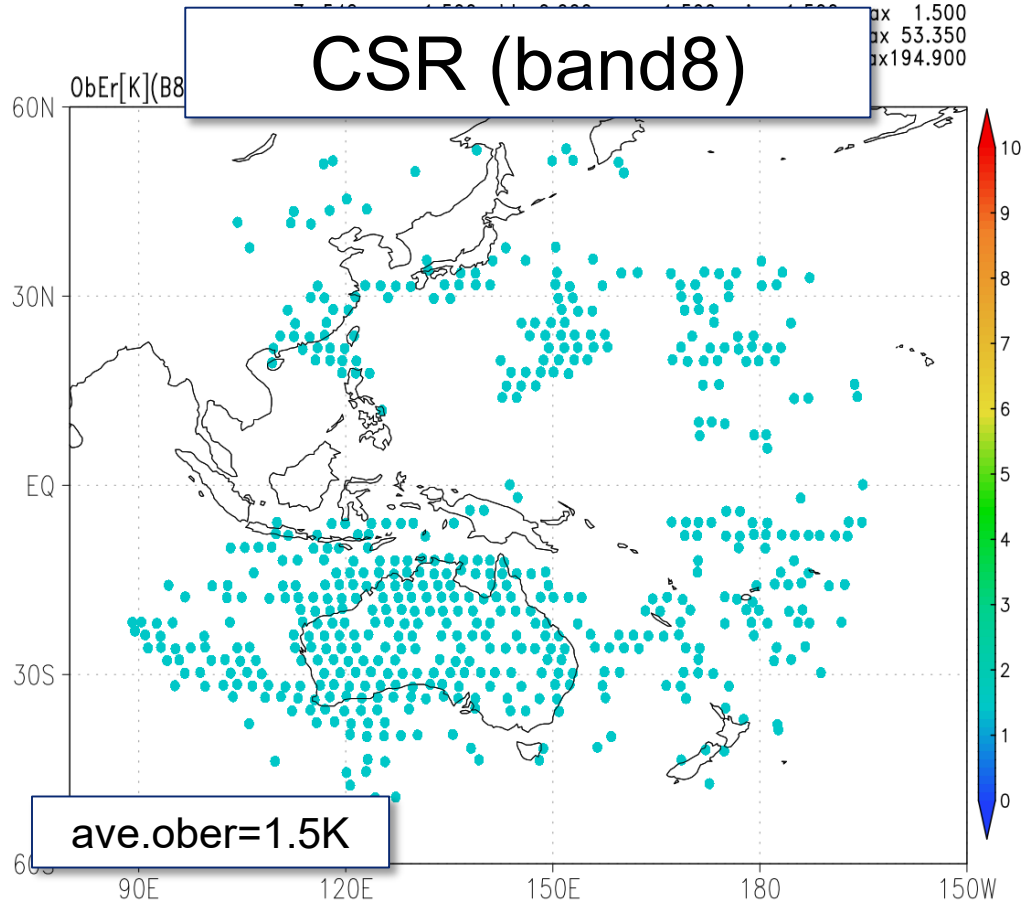
- We assessed impacts of Himawari-8 ASR through data assimilation cycle experiments in comparison with the operational clear-sky radiances assimilation.
- The assimilation experiments without BC showed positive impacts in temperature but negative in water vapor with respect to first-guess departure fit, and overall neutral or negative impacts on medium range forecasts.
- We speculate that the negative impacts were associated with the significant model biases. Several different BC predictors and sampling conditions to compute BC coefficients in the VarBC scheme are being tested.
- The preliminary results for these assimilation experiments with BC will be presented.


_sdtb8_min1-230_grsqc3-3_thickice_080100-3118_asr018_RT_sphere_himawari8asr
(a) Band8
(b) Band9
(c) Band10
O-Bnobc[K](B8)
O-Bnobc[K](B9)
O-Bnobc[K](B10)
observation [K]
X:1100357 av239.15 sd7.29 mx264.66 mn212.34 md236.45
Y:1100357 av-0.45 sd1.97 mx12.39 mn-21.56 md-0.35
X:1100608 av256.67 sd7.87 mx280.38 mn219.42 md256.45
Y:1100608 av-1.29 sd3.30 mx29.25 mn-30.88 md-0.85
BC
(a) Band8
(b) Band9
(c) Band10
O-B [K]
observation [K]
X:1100357 av239.15 sd7.29 mx264.66 mn212.34 md236.45
Y:1100357 av-0.14 sd1.84 mx13.50 mn-13.49 md-0.15
X:1100296 av248.80 sd8.00 mx274.08 mn216.28 md245.75
Y:1100296 av-0.27 sd2.54 mx20.95 mn-21.00 md0.05
X:1100608 av256.67 sd7.87 mx280.38 mn219.42 md256.45
Y:1100608 av-0.46 sd3.30 mx29.99 mn-30.00 md0.05

Examples of ASR and CSR distribution

- Obs error, after QC at 00 UTC 10 July 2018
- More widespread, except thick cloud regions, and larger observation errors





Change in O-B SD

- WVch in ATMS improved in either exp
- ASR is degraded for MWI, ASRX2 being worst
- asr better than csr for IASI, ASRX1 being best