Evaluation and assimilation of all-sky infrared radiances of Himawari-8 in the regional and global data assimilation system

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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), Sawada et al.(2019, JGR),,,
- However the benefit of IR ASR assimilation over CSR assimilation has not been fully investigated.
  - Geer et al. (2019, QJRMS) for IASI in global DA
- Objective of this study
  1. Investigate feasibility of Himawari8 ASR in research-based regional DA system
     - Compare impact of ASR and CSR in regional DA (Okamoto et al. 2019; QJRMS)
  2. Apply to the operational global DA system

Content

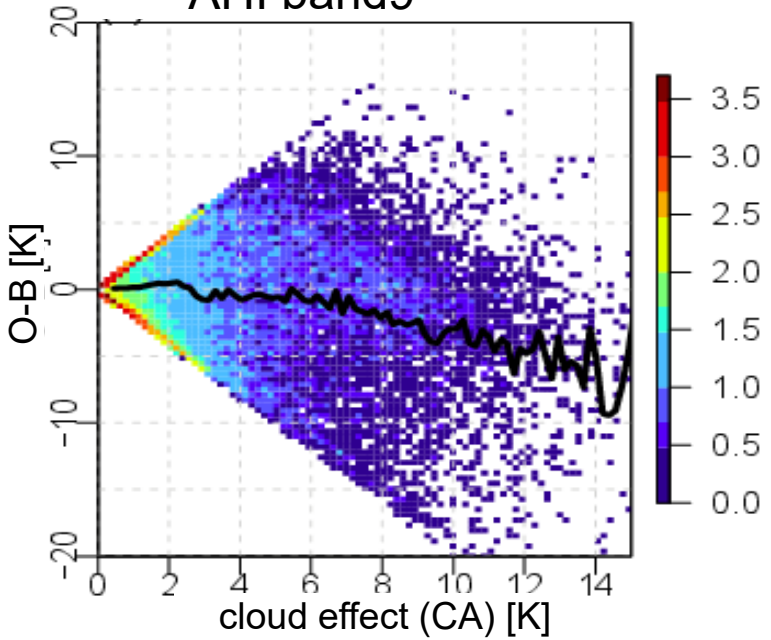
- 1. ASR assimilation in regional DA system
- 2. Apply to the operational global DA system
- 3. Summary

1. ASR assimilation in regional DA system

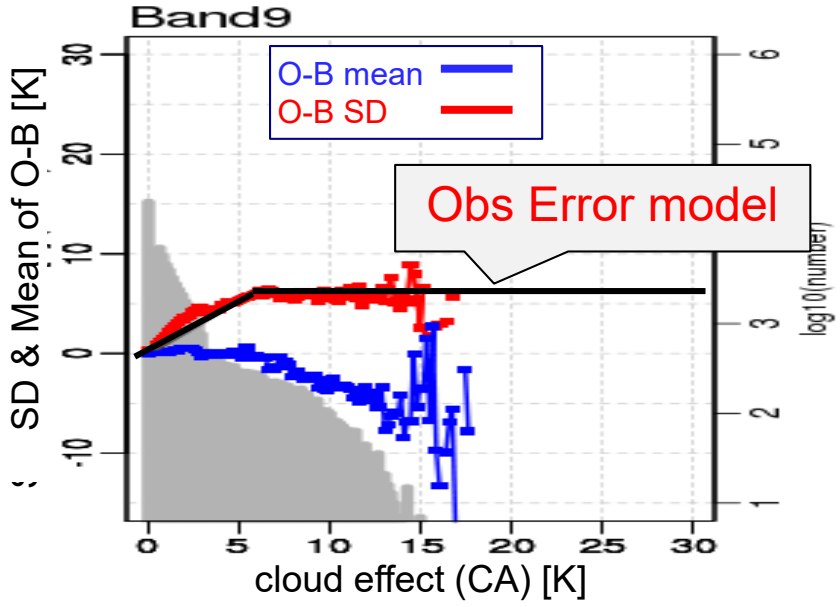
- Smaller predictability when cloud effect is large
  - O-B variability increases
- The variability can be predicted with a simple function of an appropriate cloud effect parameter (Ca)
  - Gaussian PDF of O-B normalized using Ca
  - Applied to QC, obs error assignment
  - Geer & Bauer (2011, QJRMS); Okamoto et al. (2014, QJRMS)

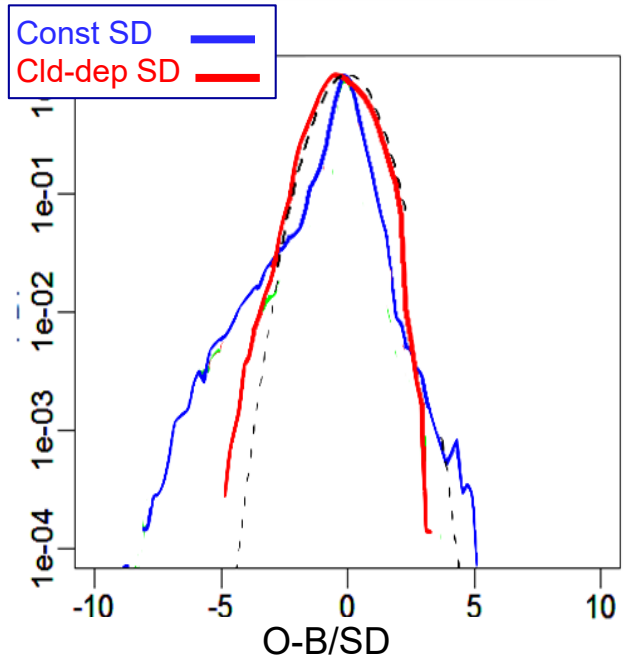
cloud effect parameter:
Ca=(|B-Bclr|+|O-Bclr|)/2,
Bclr=clear-sky first-guess

AHI band9



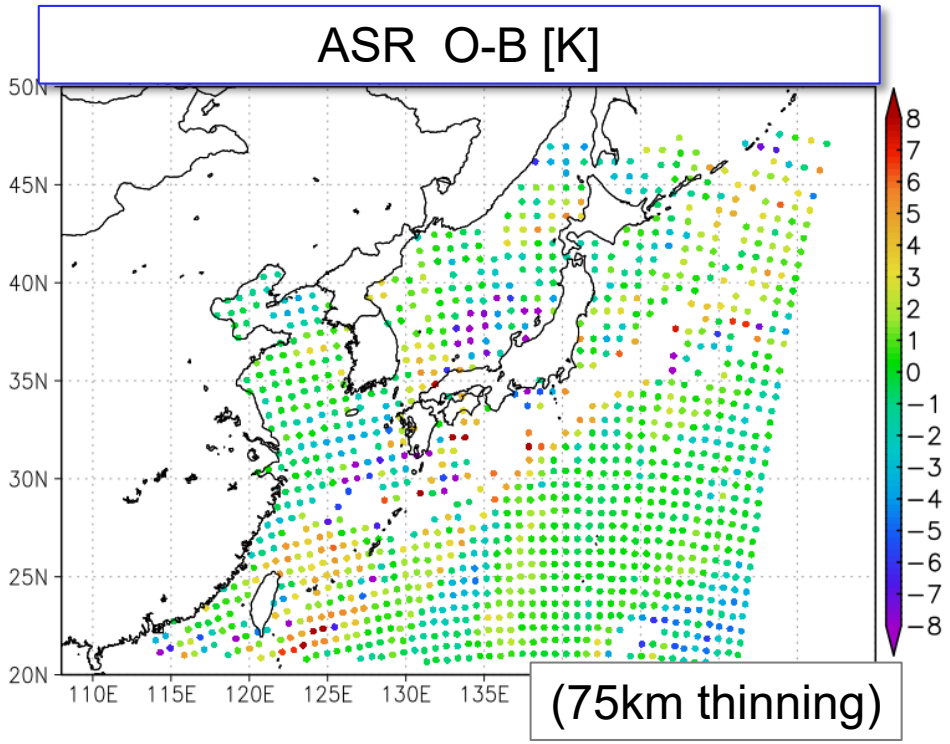
Okamoto 2017, QJRMS

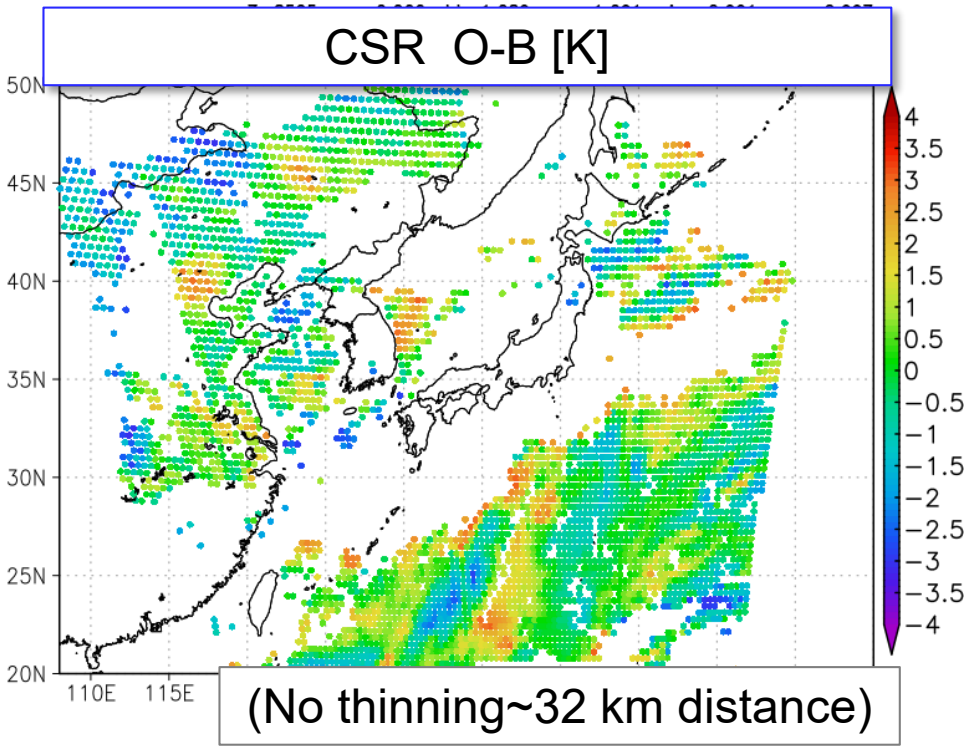




QC for ASR and CSR

- ASR
  - Reject data with large internal inhomogeneity, too low temperature, large |O-B| (cloud-dependent threshold: |O-B|<3σ(Ca)) (Okamoto 2017,QJ)
- CSR
  - Reject data with large internal inhomogeneity, low clear-pixel ratio, or large |O-B| (constant threshold: |O-B|<3σ(const)) (Kazumori 2018, JMSJ)



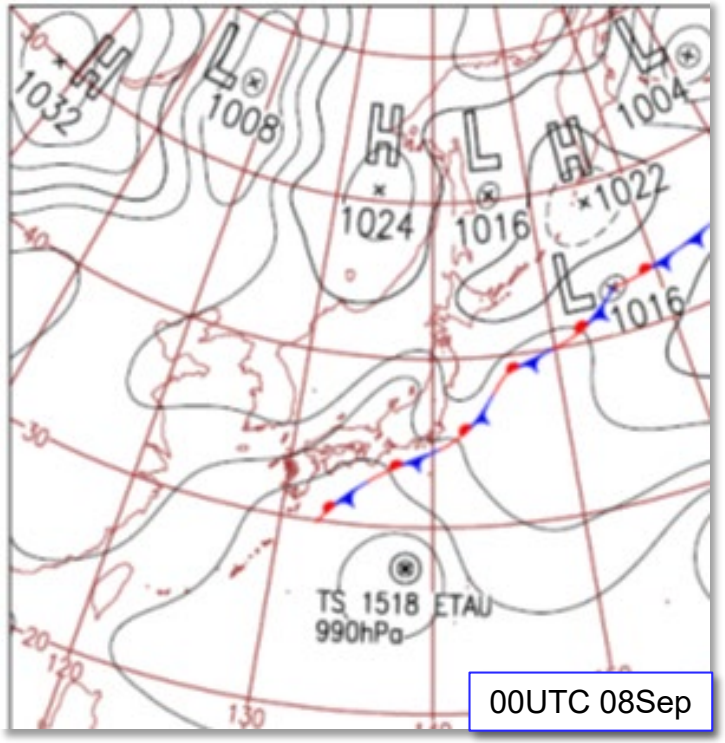


Assimilation experiment

- Assimilation system : NHM-Letkf (Kunii 2014)
  - Model: JMA-NHM (non-hydrostatic model; Saito et al. 2006, MWR)
  - Horizontal res.15km, 273x221 grids, 50 members
  - 3-h cycle, 1-h time slot

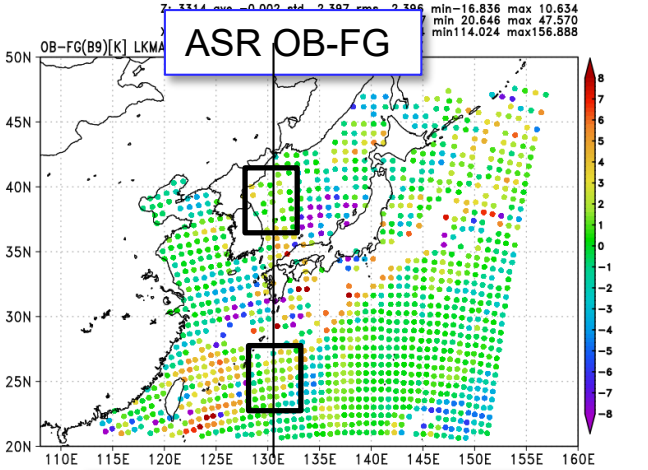
- Observation configurations
  - CNTL: Conventional data (No radiance obs)
  - ASREXP: CNTL + ASR (all-sky)
    - Band9, No over land, No bias corrected
  - CSREXP: CNTL + CSR (clear-sky)
    - Band8, include over land, bias corrected

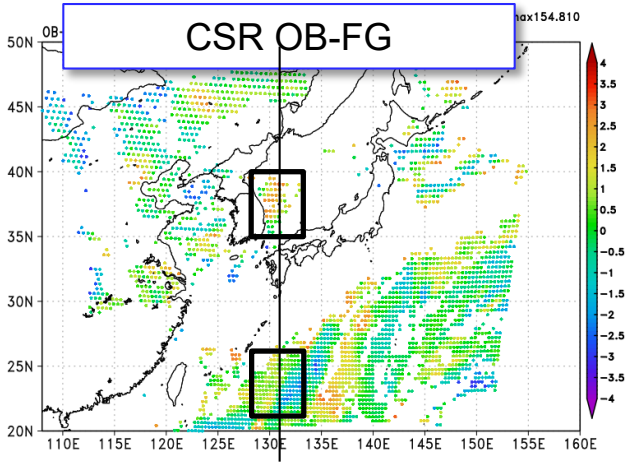
- Period
  - 10-day cycle: 1 ~ 10 Sep 2015
    (including H27 Kanto-Tohoku heavy rainfall)

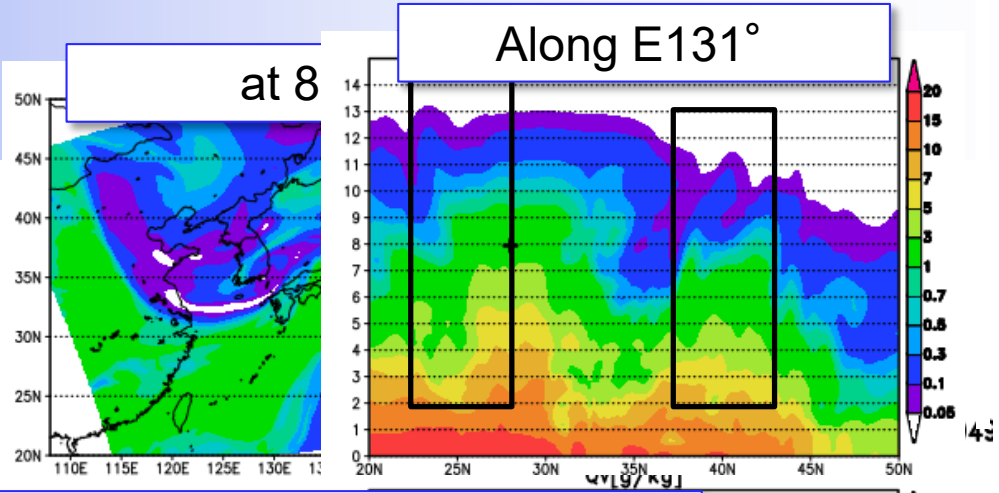


Humidity Analysis diff

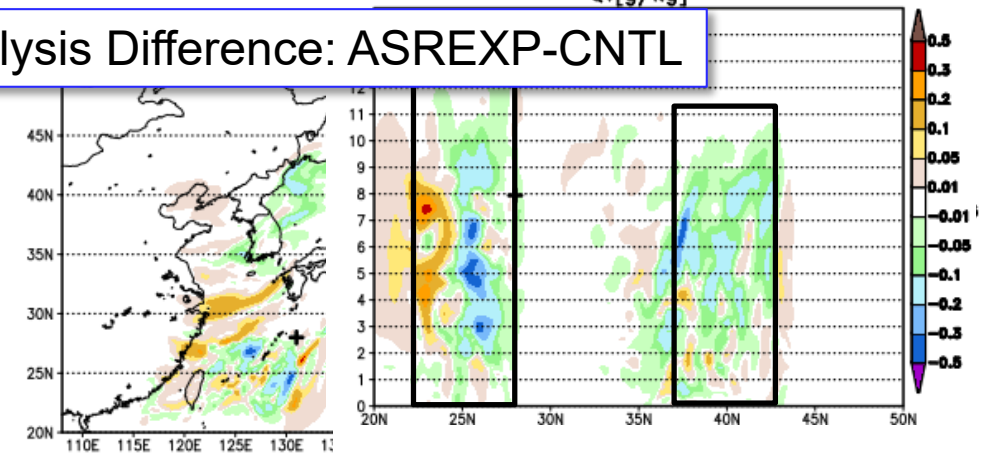
- 03UTC 3 Sep 2015
- OB-FG>0 ➔ increase FG ➔ reduce humidity & snow



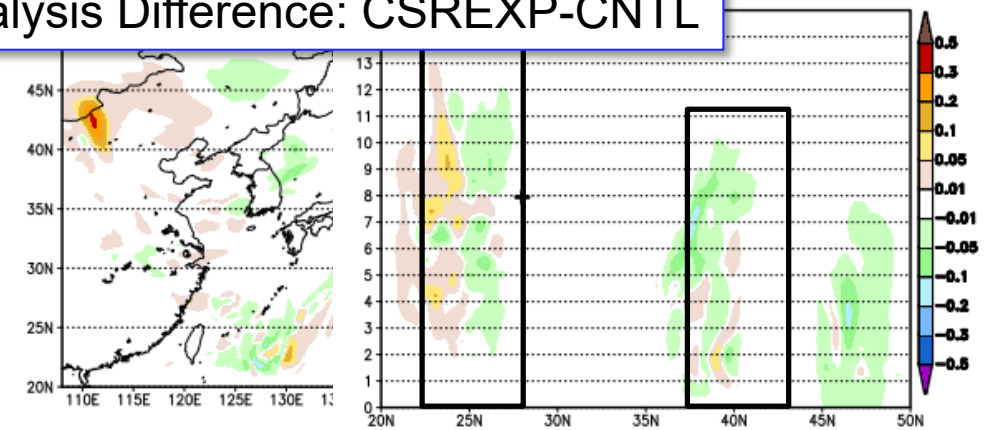




Analysis Difference: ASREXP-CNTL

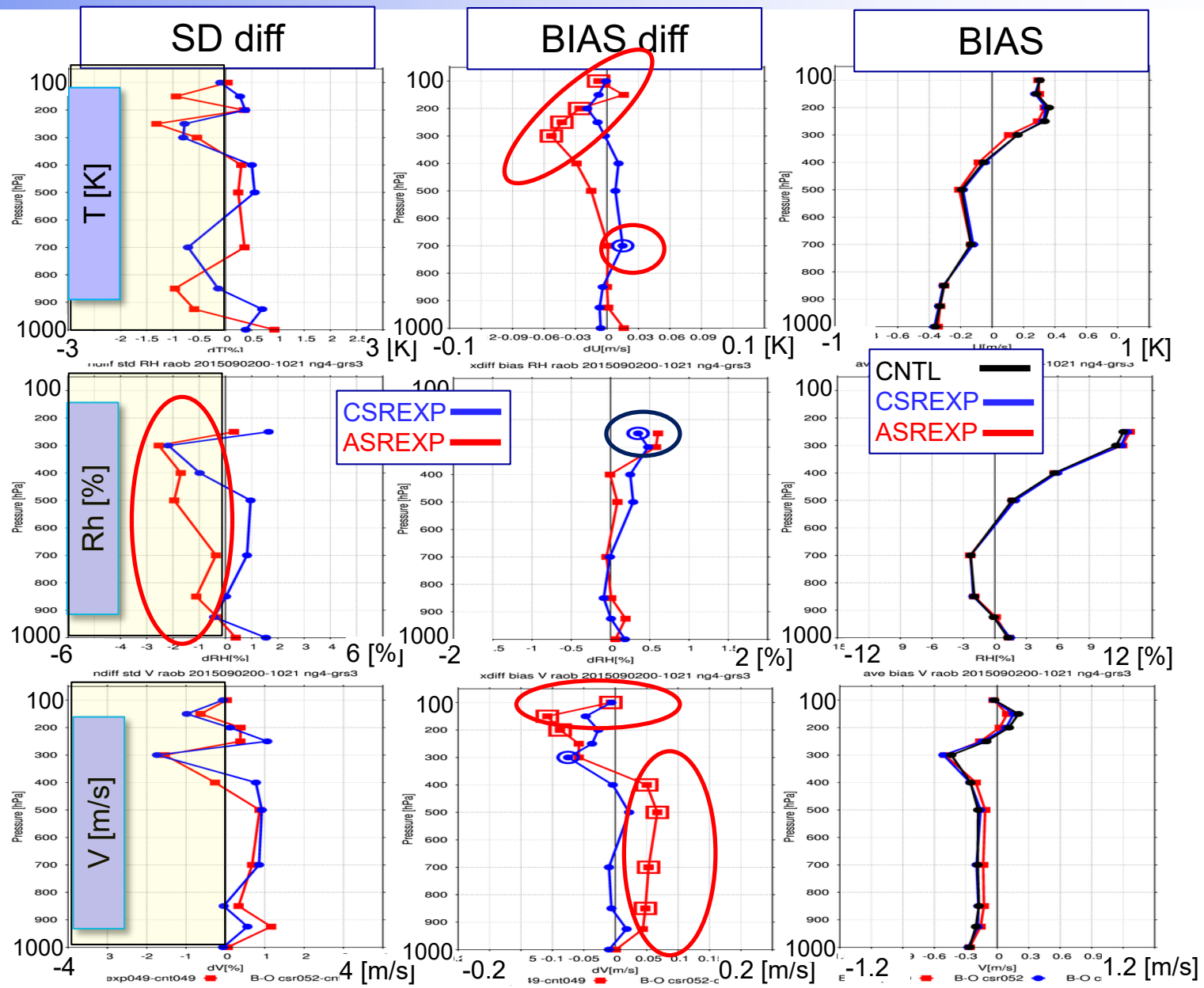


Analysis Difference: CSREXP-CNTL



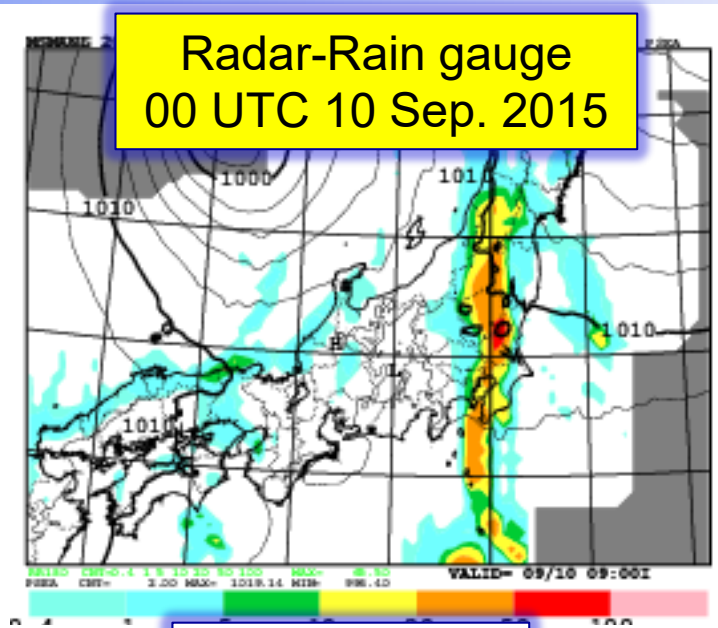
Verification (T,RH,V) : O-B SD & BIAS

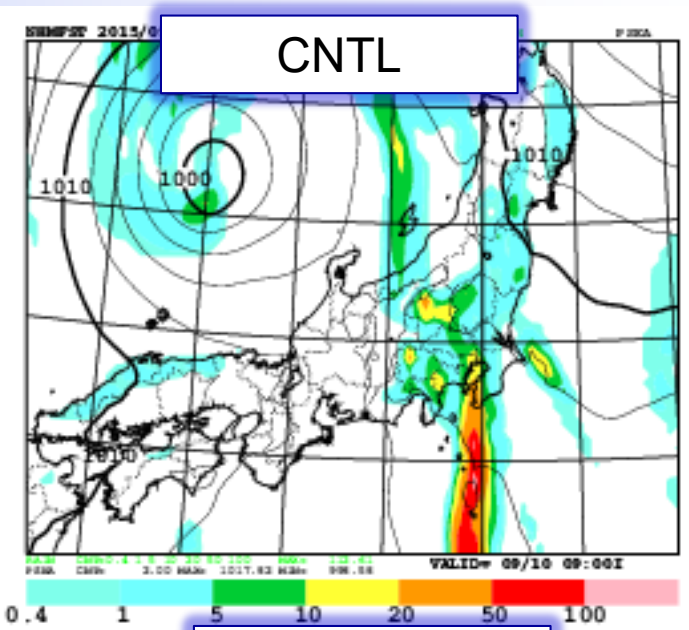
- radiosondes 2 - 10 Sep
- diff = ASREXP-CNTL, and CSREXP-CNTL
- Larger marks indicate statistical significance at 95 %

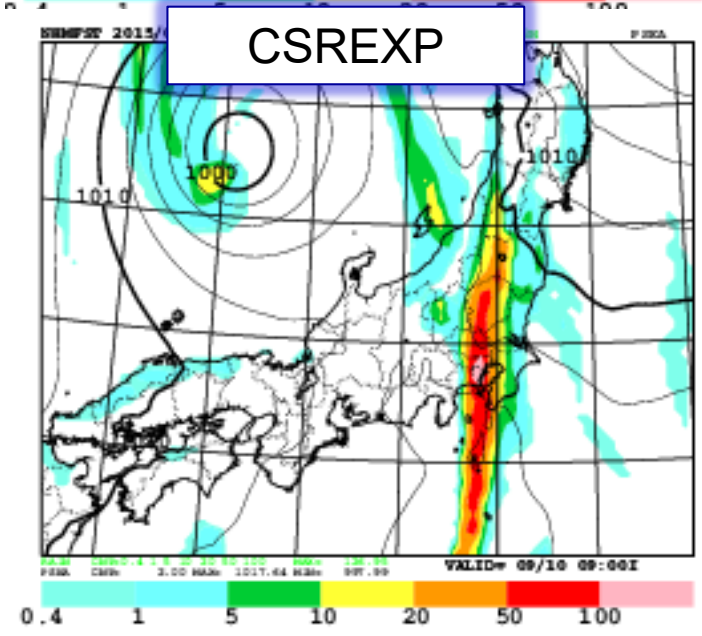


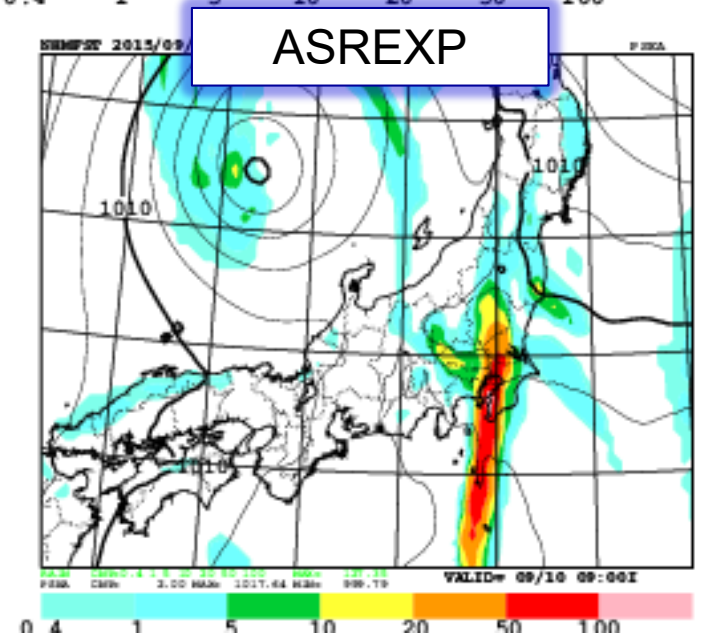
3h rainfall at 36 h fcst, initialized at 12 UTC 8 Sep

- 3h-rainfall
- Both ASR and CSR well predict the line-shaped organized convective system



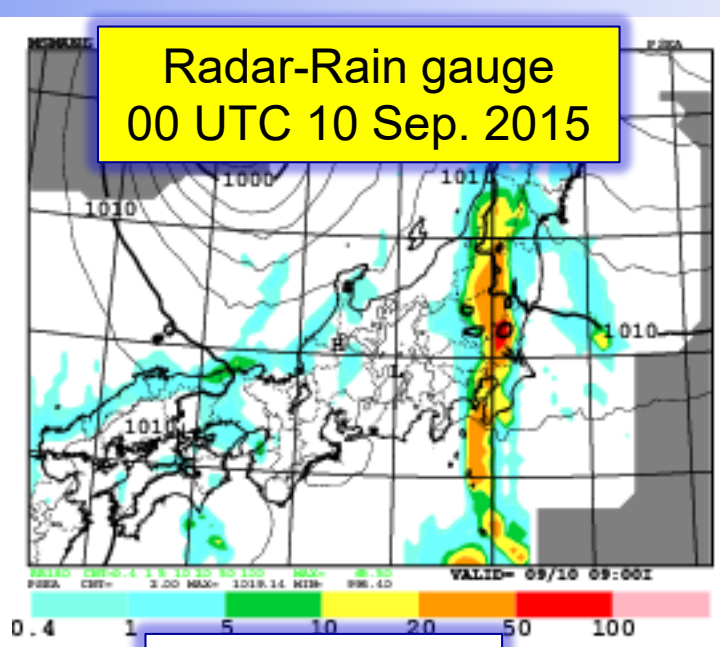


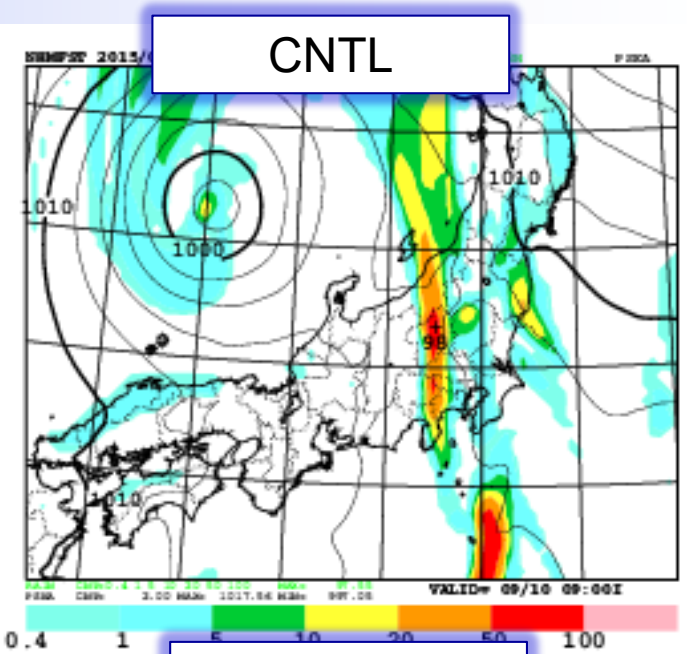


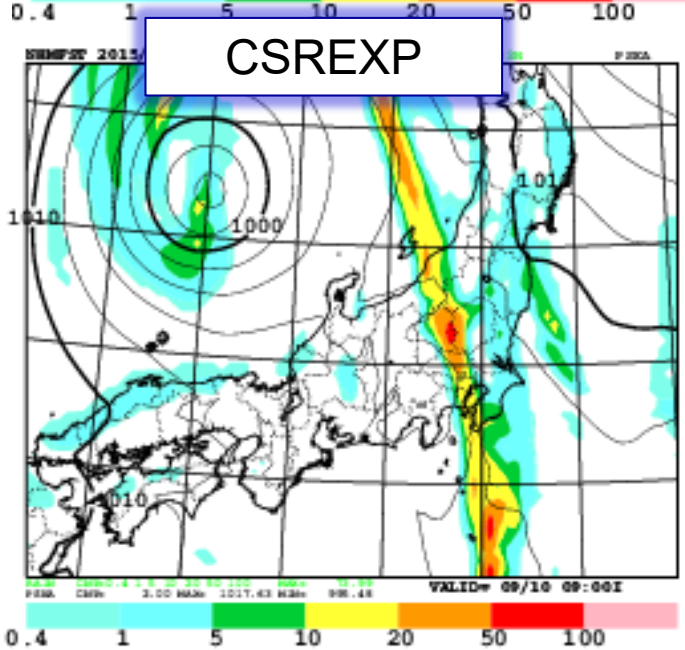


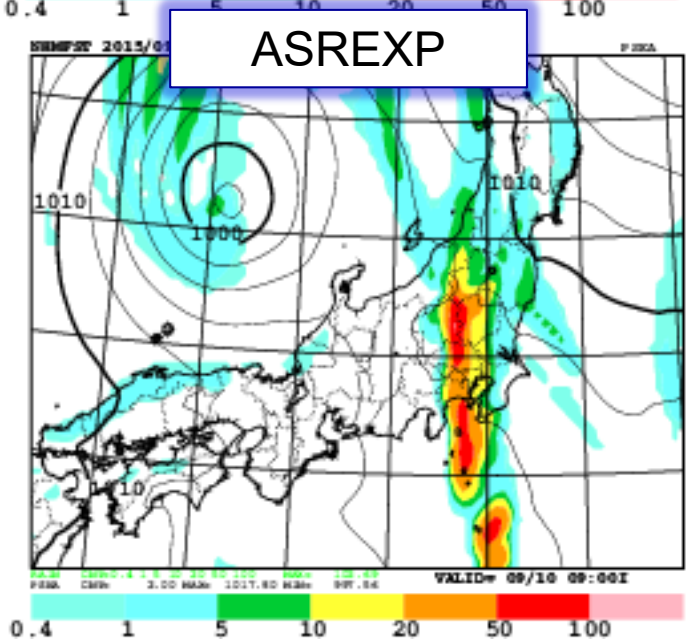
3h rainfall at 24 h fcst, initialized at 00 UTC 9 Sep

- 3-h rainfall
- CNTL and CSREXP predict the convective system shifted to the west
- ASR predicts better location



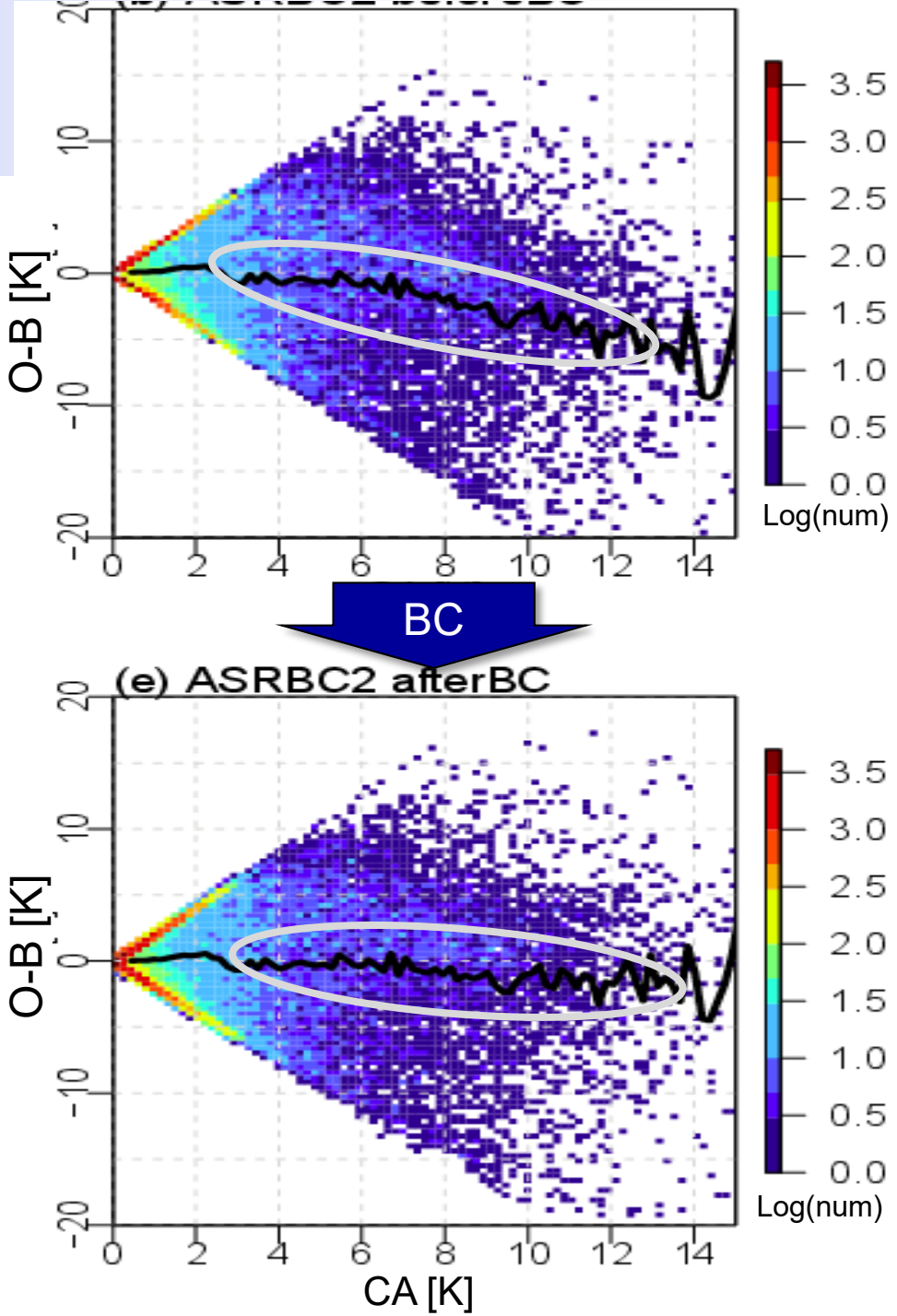






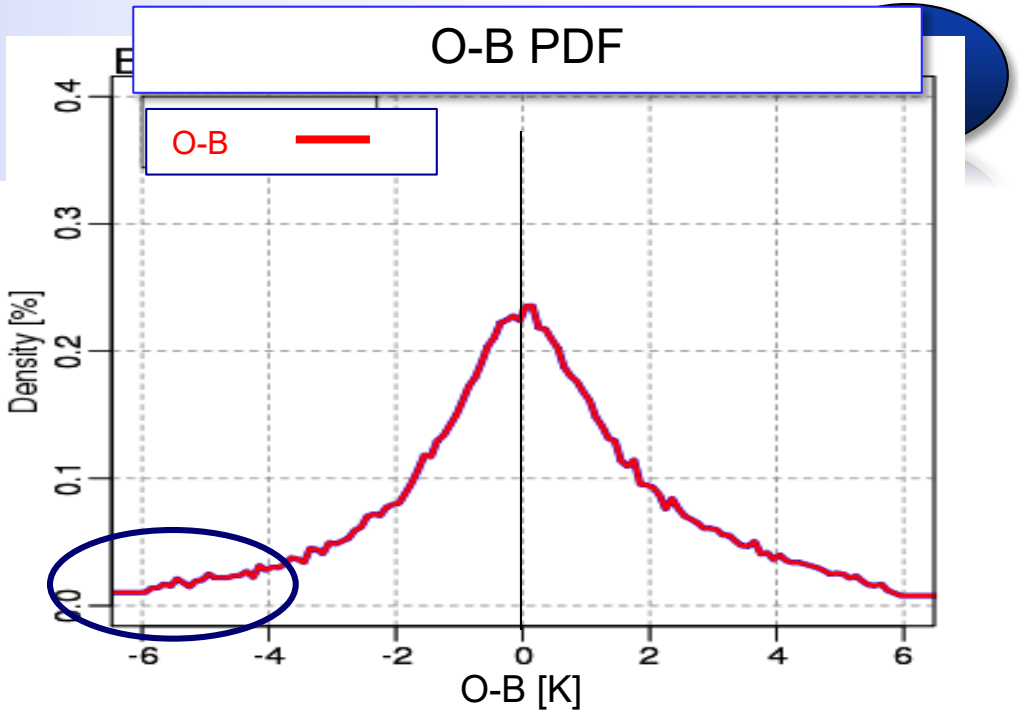
Bias correction (BC) for ASR

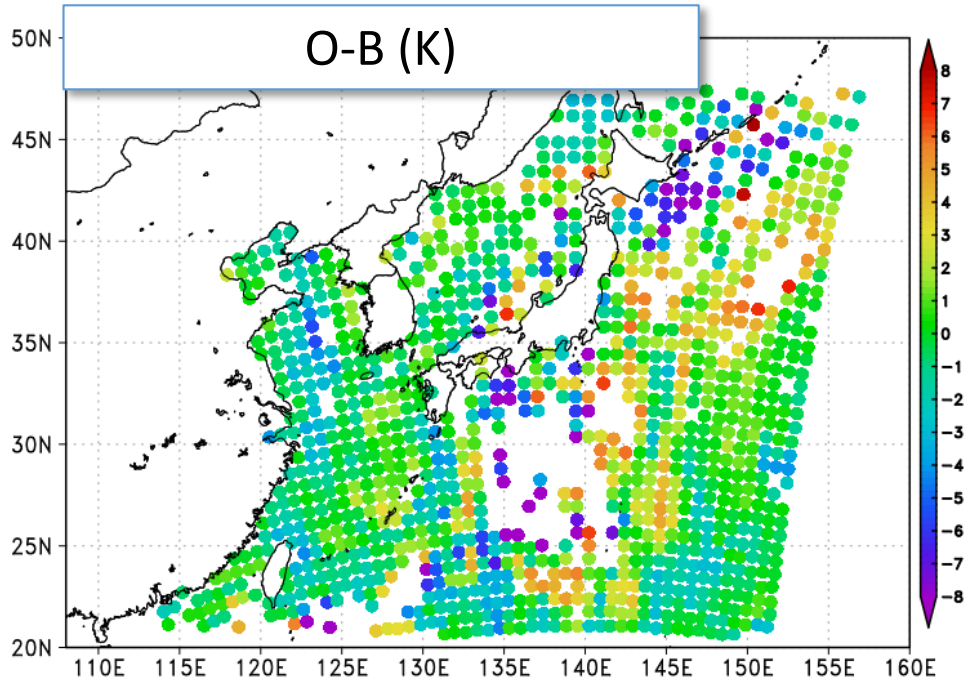
- Tested an adaptive BC in LetKF
  - Correct cloud-dependent bias: bc = $a_1Ca + a_2Ca^2 + a_3Ca^3 + a_4$
- No additional positive impact on O-B fit and rainfall forecast compared with no-BC experiments



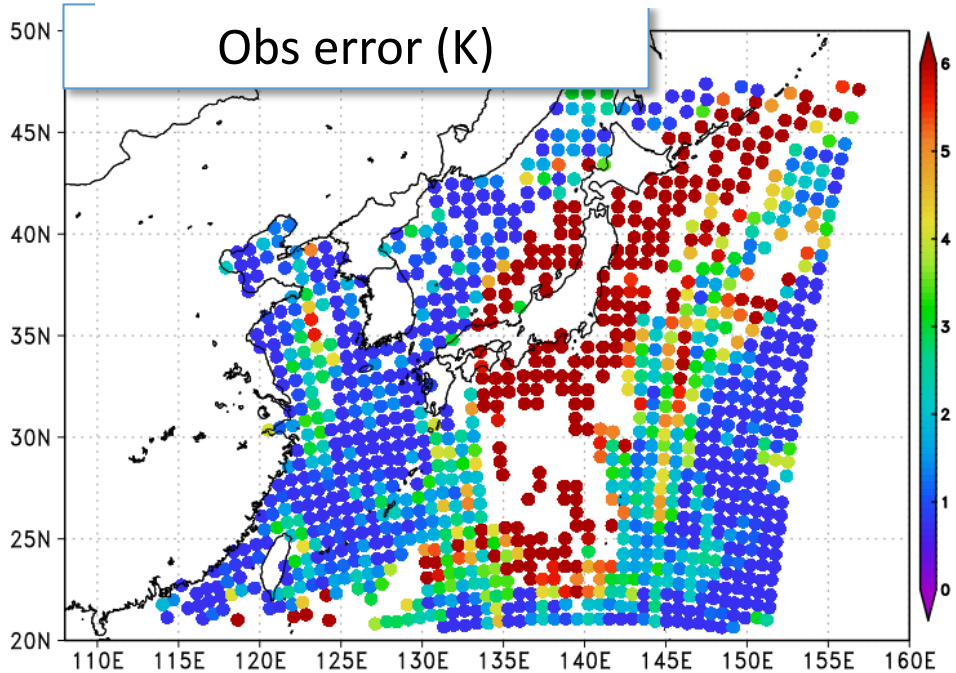
Bias correction (BC) for ASR

- Possible two reasons of no additional positive impact from BC
  - Small bias for most cases with small Ca
  - Tend to assign large ober for cases with large O-B





9/8 03UTC
AHI band9



Content

- 1. ASR assimilation in regional-DA system
- 2. Apply to the operational global DA sytem
- 3. Summary

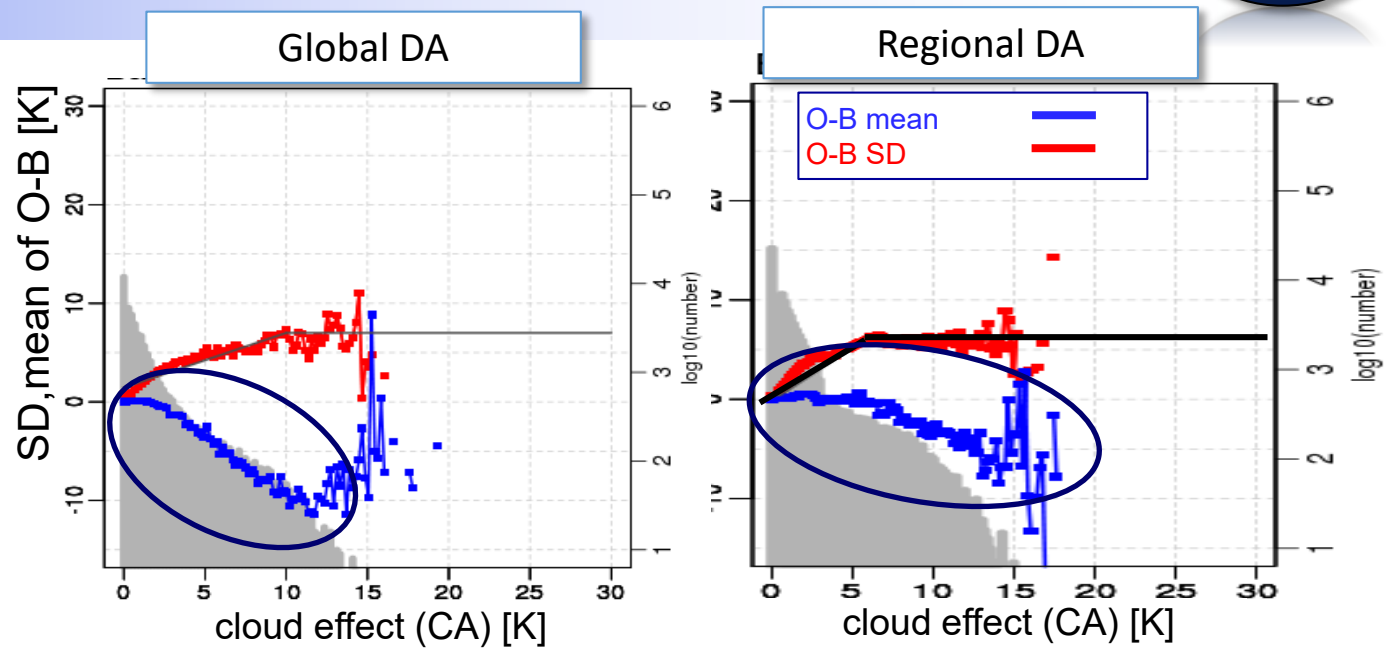
- Apply the development in the meso DA to the global DA
  - QC and obs error using cloud parameter Ca

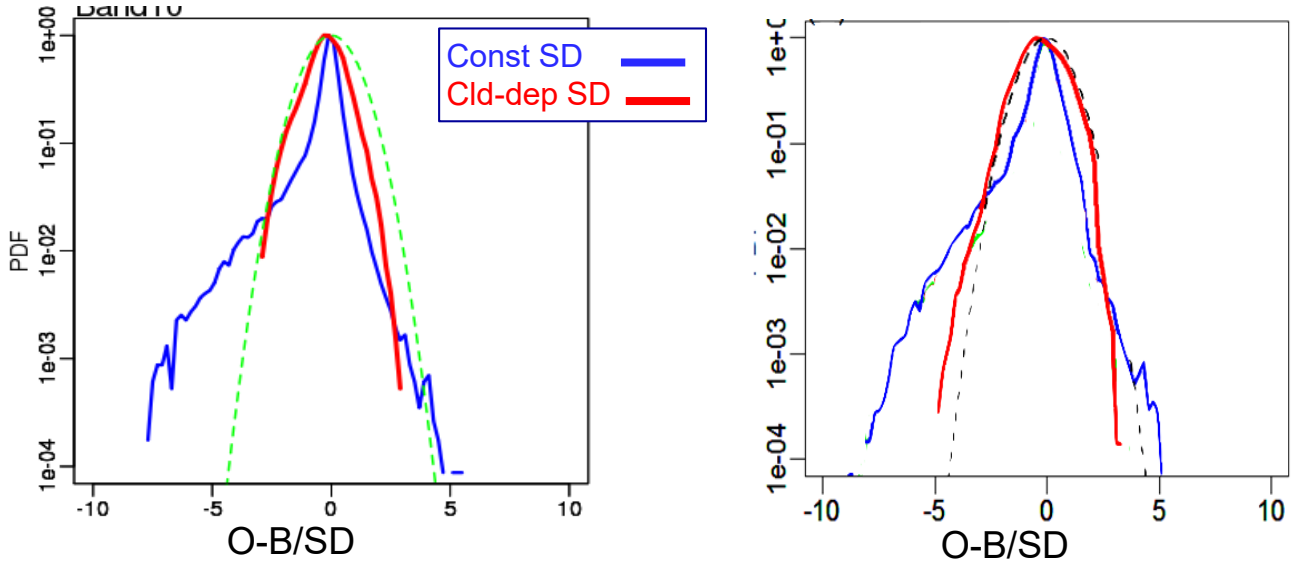
	Regional (Research)	Global (Operational)
Model	JMA-NHM (non-hydro)	GSM (hydro, spectral)
convection cloud	Kain-Fritsch 3-ice bulk, Lin	Arakawa Schubert Smith(PDF)
Forecast cloud var.	5 hydrometeor	Total cloud-water
Data Assimilation	LETKF	4DVar
Analysis cloud var.	5 hydrometeor	No cloud variables
Other sat	CSR, AMV	CSR, AMV, scatterometer, IR/MW sounders/imagers, GNSS-RO
RTM	RTTOV11.2	RTTOV10.2

Apply Ca to global DA

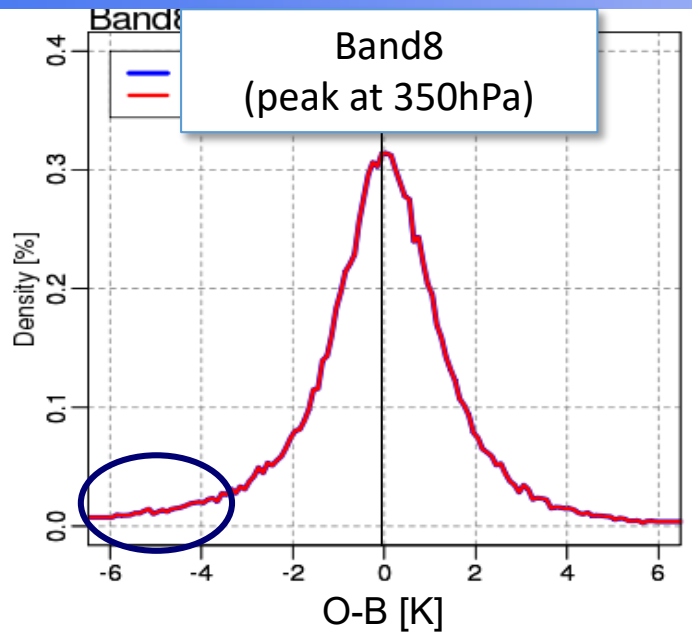
- Similar behavior in global DA
  - Linearly increase variability with Ca
  - → Similar obs error model

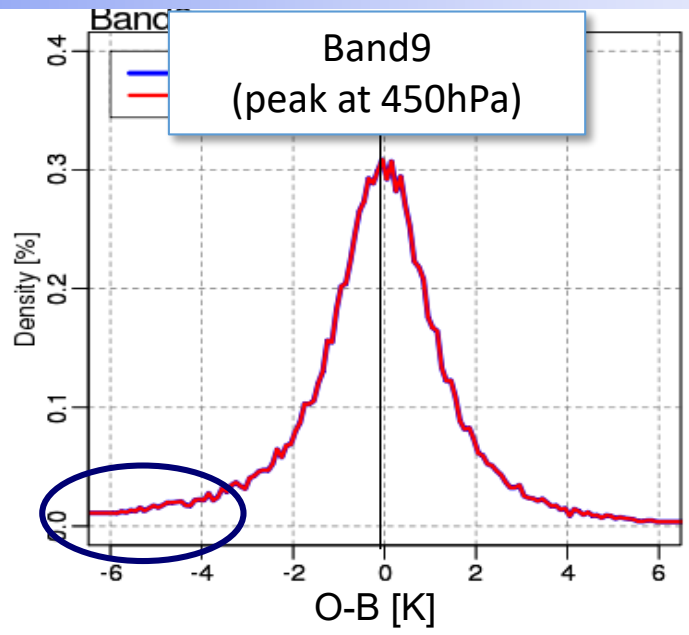
- Larger negative bias in in global DA
  - JMA global model underestimates cloud in the upper and middle troposphere

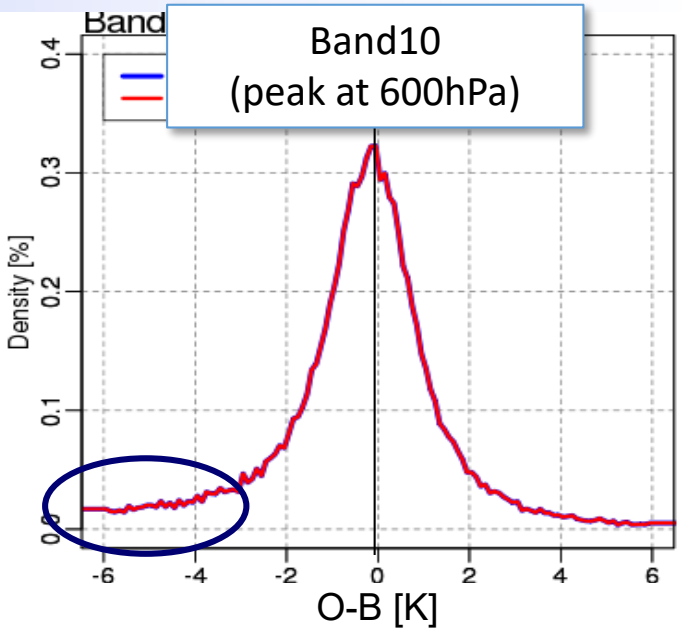




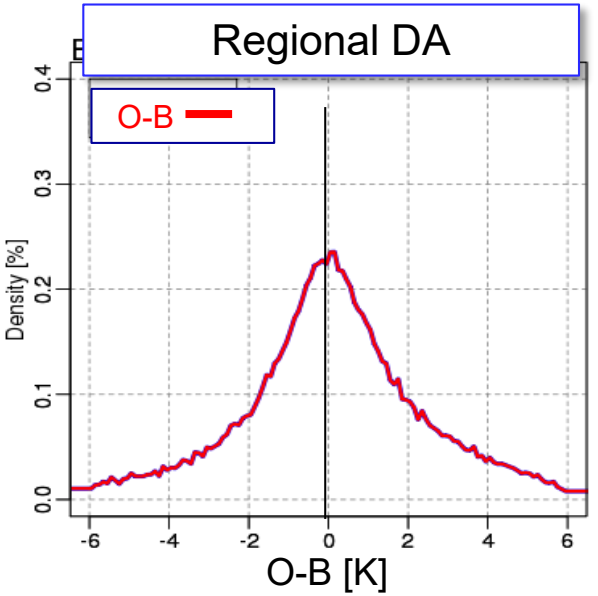
O-B bias for global DA







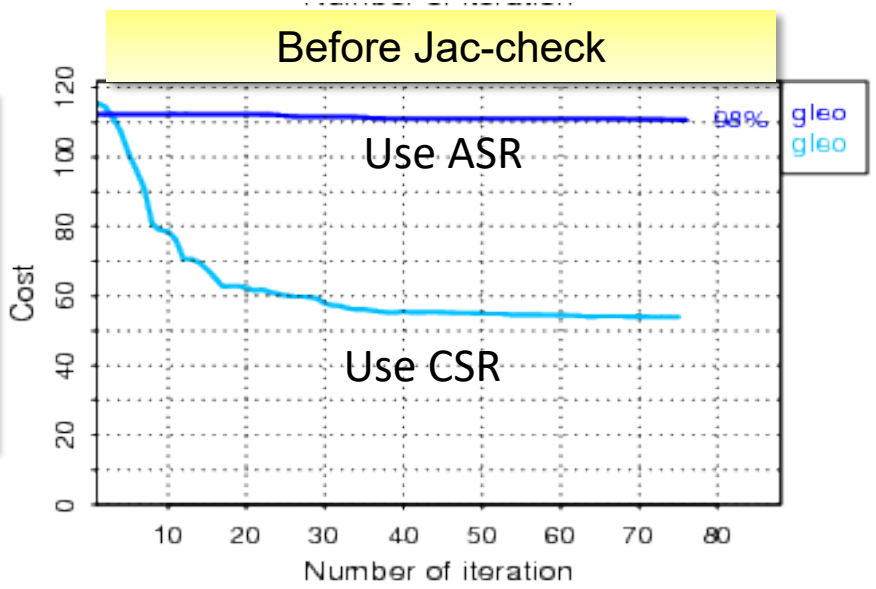
- However, the -ve bias is evident only for large Ca
  - → long tail in negative O-B
- Bad effect of the -ve bias is possibly mitigated by larger obs error assigned in large Ca
- → Initial experiment does not apply BC for ASR

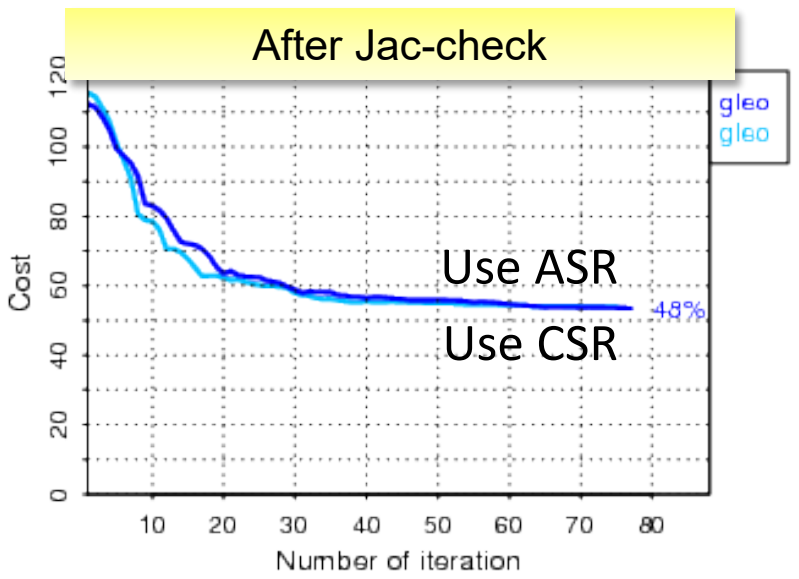


Another issue: minimization

- Anomalously large Jacobian deteriorates minimization
  - Especially for ice cloud in developed convection region
- Jacobian check
  - reject samples when |dTB/dcwc|>1.e+6 or |dTB/dcc|>10
  - → about 8 % data removed
  - Significantly improve minimization

Change in cost function of GNSS-RO with iteration



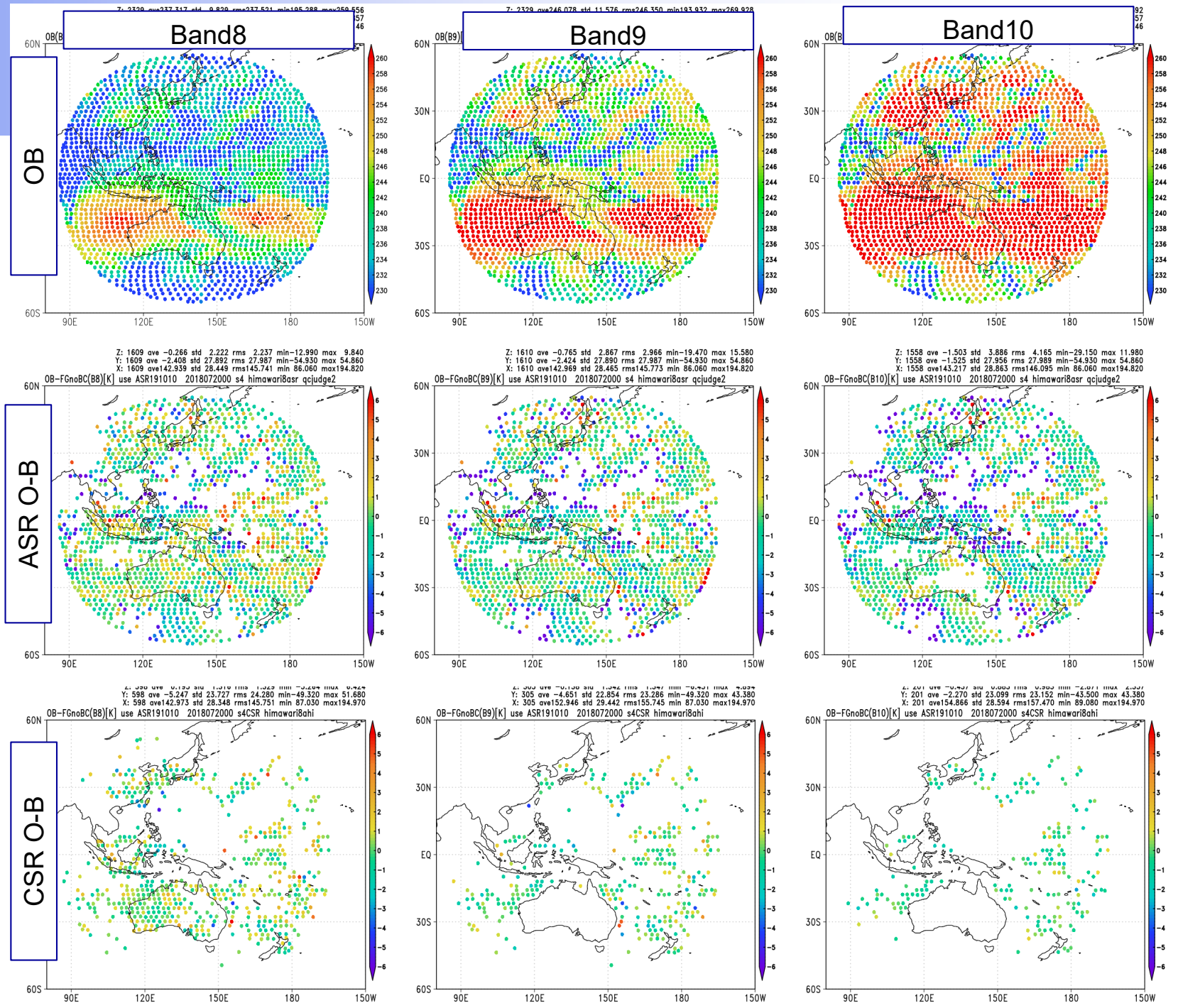


Preliminary Assimilation experiment in global DA

- Assimilation system
  - 4DVar with MW all-sky assimilation
  - TL959L100 (outer 20km, inner 60km, 100levels)
- Obs Configuration
  - CNTL: operational as of Aug. 2018
    - CSR at Band 8, 9 and 10 (all humidity bands) of Himawari8
  - TEST: CNTL + Himawari-8 ASR instead of CSR
    - Band 8, 9 and 10 (all humidity bands) of Himawari8
    - Thinning 220 km (same as CSR), Obs error inflation 2.0
    - Reject data over land when clear-sky τ>0.01 or terrain height>2500m
    - No bias correction, at the moment
- Period : 20 Jul. – 11 Sep. 2018
  - Still running. Statistics until10 Aug is shown in this talk.

Example of data distribution

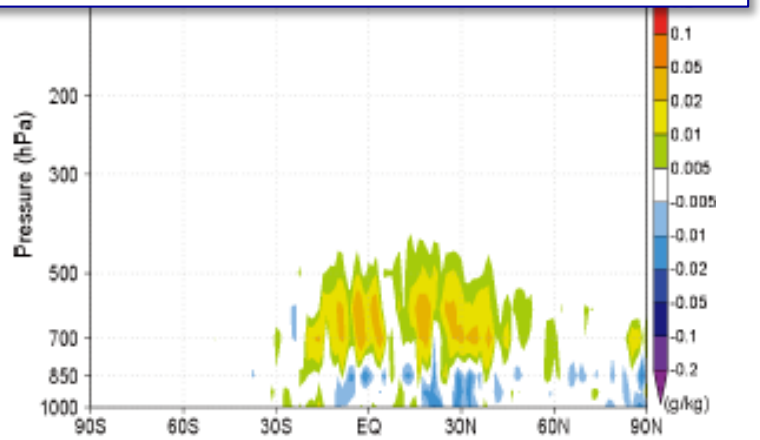
- 00UTC 20 Jul. 2018 (1h-slot)
- ASR: B8:1609, B9:1610, B10:1558
- CSR: B8:598, B9:305, B10:201



O-B of MHS ch3(183±3GHz) (7/25-8/4)

- ASR increases O-B mean → decrease B → increase UTH
- ASR decreases RMS in west pacific region → improve UTH
  - except over Australia
- Consistent change with CSR assimilation

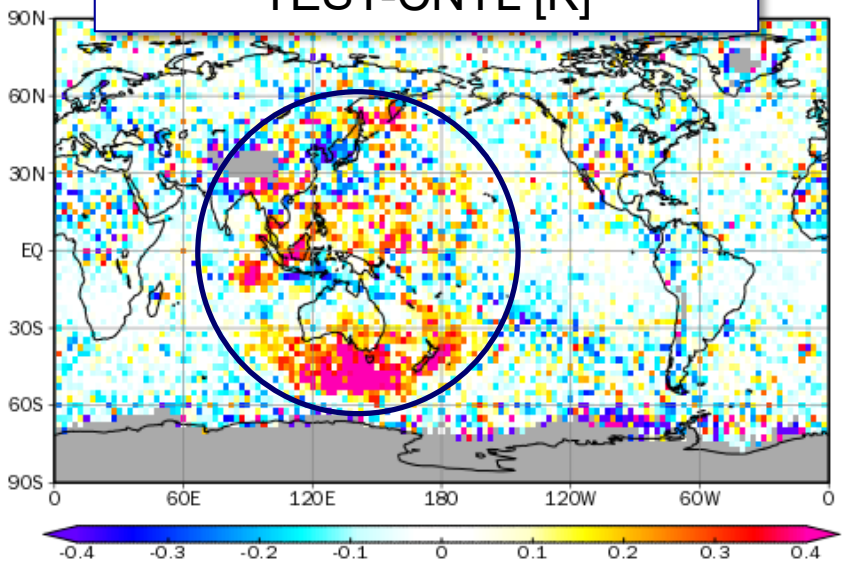
Humidity change by introducing CSR [g/kg]



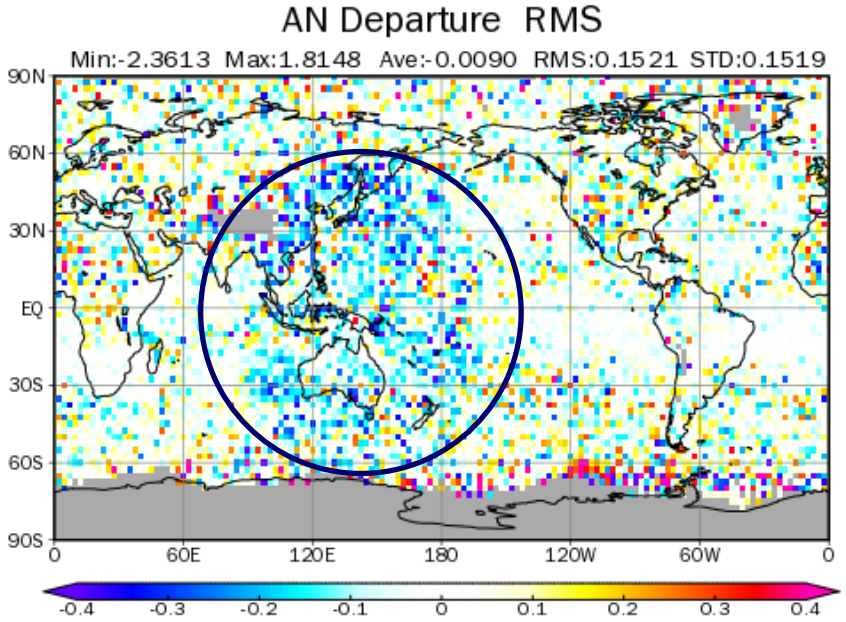
Kazumori
2018, JMSJ

TEST-CNTL [K]

O-B mean



O-B RMS



3. Summary

- Developed IR ASR assimilation for Himawari-8
  - Cloud-dependent QC & obs error model
- Regional research-based DA
  - Improve first-guess of temperature/humidity/wind
  - ASR assimilation predict better heavy rainfall at different initials
    - More secure, homogeneous obs coverage with ASR
  - → see more details in Okamoto et al. (2019, QJRMS)
- Global operational DA
  - Apply similar approach of regional DA
  - Improve the upper tropospheric humidity
  - Need further examining ASR QC and the DA experiment
    - Bias correction should be evaluated again
  - Need including obs error correlation (e.g. Geer 2019)

Acknowledgements

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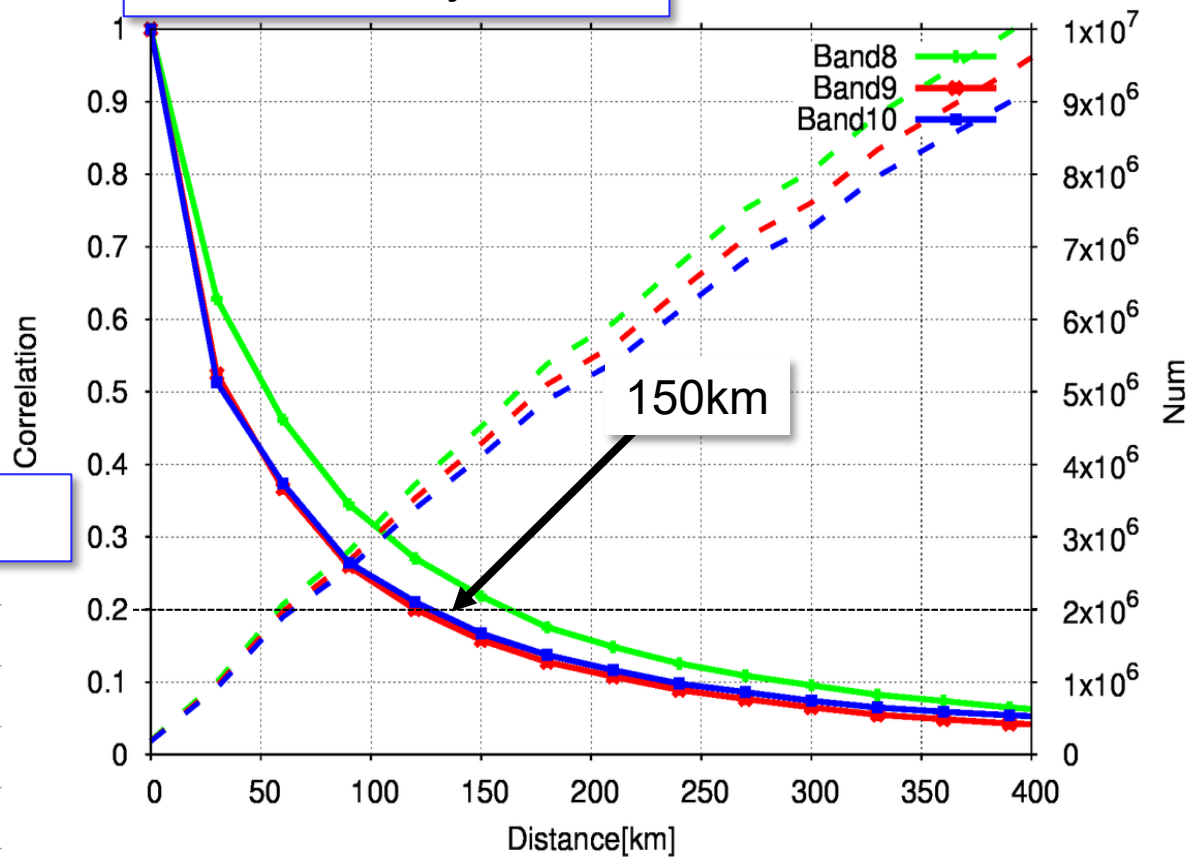
  - JAXA 2nd Research Announcement on the Earth Observations
  - CREST, Japan Science and Technology Agency (JST) .
  - The FLAGSHIP2020, MEXT, within the priority study area #4 (Advancement of meteorological and global environmental predictions utilizing observational “Big Data”)
  - JSPS KAKENHI Grant Number 19H01973

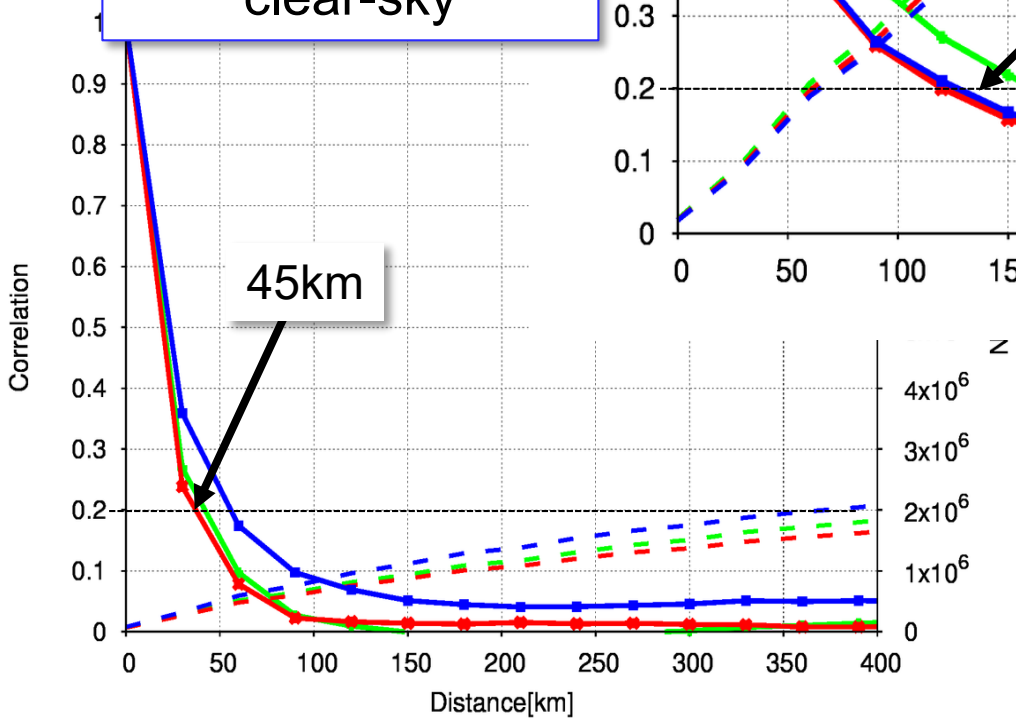
Horizontal/Inter-band obs error correlation

band8 6.2μm
band9 6.9μm
band10 7.3μm

all-sky

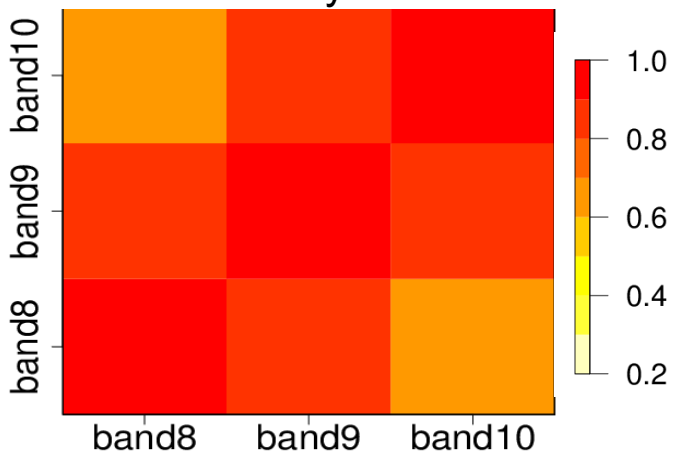


clear-sky

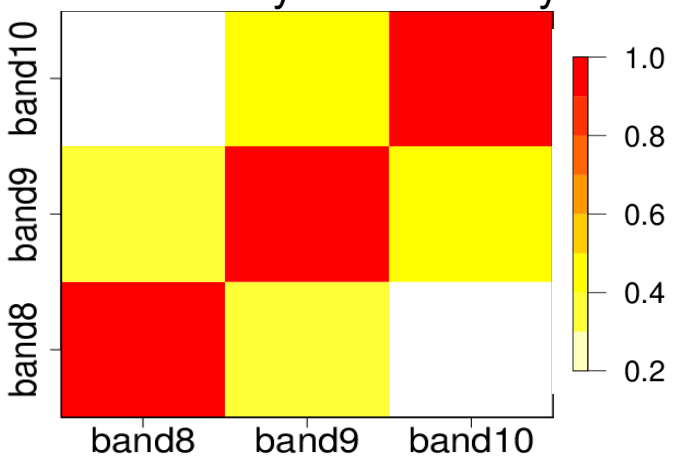


Obs error correlation estimated in meso DA

cloudy



less cloudy and clear-sky



O-B PDF and Ca dependency in global system