S6-06

All-sky infrared radiance assimilation of Himawari-8 in the global data assimilation system at JMA

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Content

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1. Background

- IR radiance assimilation is significantly beneficial for NWP
  - Mostly limited to clear-sky radiances (CSR)
- IR all-sky radiance (ASR) assimilation will be more beneficial because
  - Increasing obs coverage (homogeneous spatial and temporal distribution)
  - Reducing sampling bias (e.g. dry bias)
  - Exploiting cloud and unique obs info (e.g. vertically resolved temperature at cloud top)
- Challenges of ASR assimilation (compared with CSR assimilation)
  - Poorer representation in radiative transfer model (RTM) and forecast model
  - Stronger situation-dependency of obs statistics
  - Higher non-Gaussianity and non-linearity
- Encouraging results in many recent studies
  - Zhang et al. (2016, GRL), Honda et al.(2018 MWR; 2018 MWR, JGR), Minamide & Zhang (2017 MWR; 2018 MWR), Okamoto et al. 2019, QJRMS), Sawada et al. (2019, JGR)
  - However, few studies in global DA system

1. Objective

- Improve analysis & forecast by assimilating IR ASR in JMA's global system

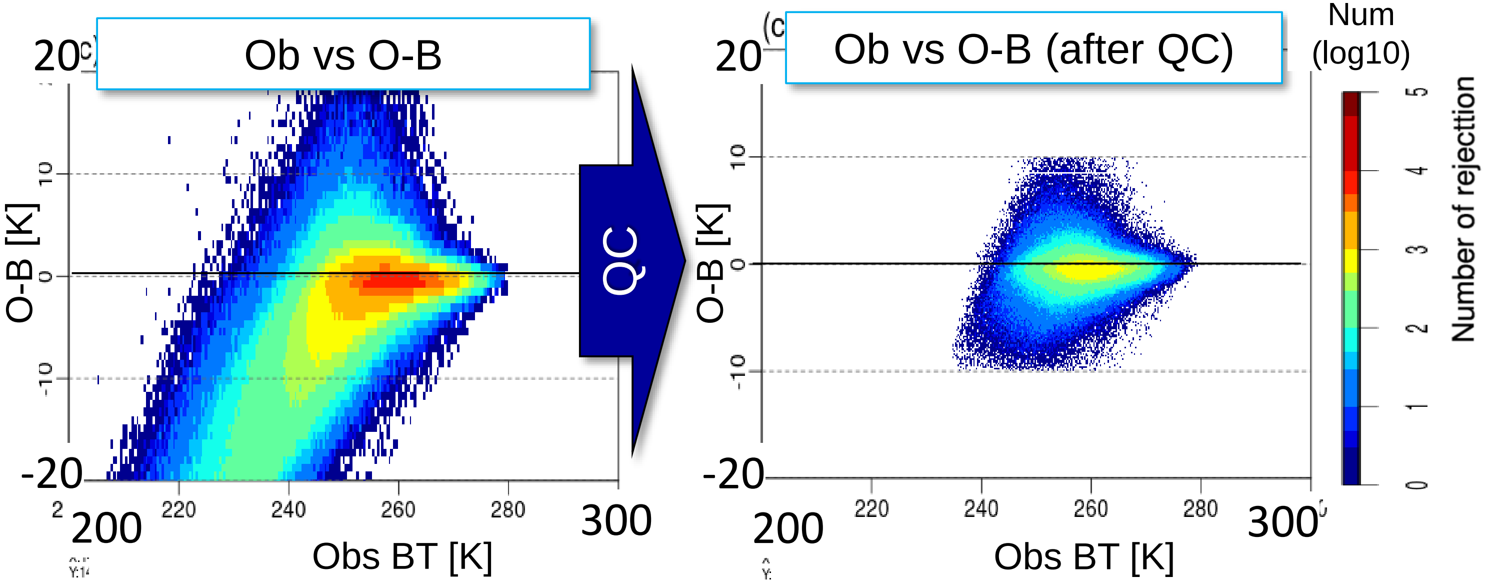
- 1. Examine the reproducibility of ASR simulations from JMA global model
  - Okamoto et al. 2021 QJRMS
- 2. Develop ASR assimilation processings
  - Handle the challenges by developing Quality Control (QC), Bias Correction (BC), obs error model,,,
- 3. Assess impacts of ASR assimilation relative to CSR assimilation

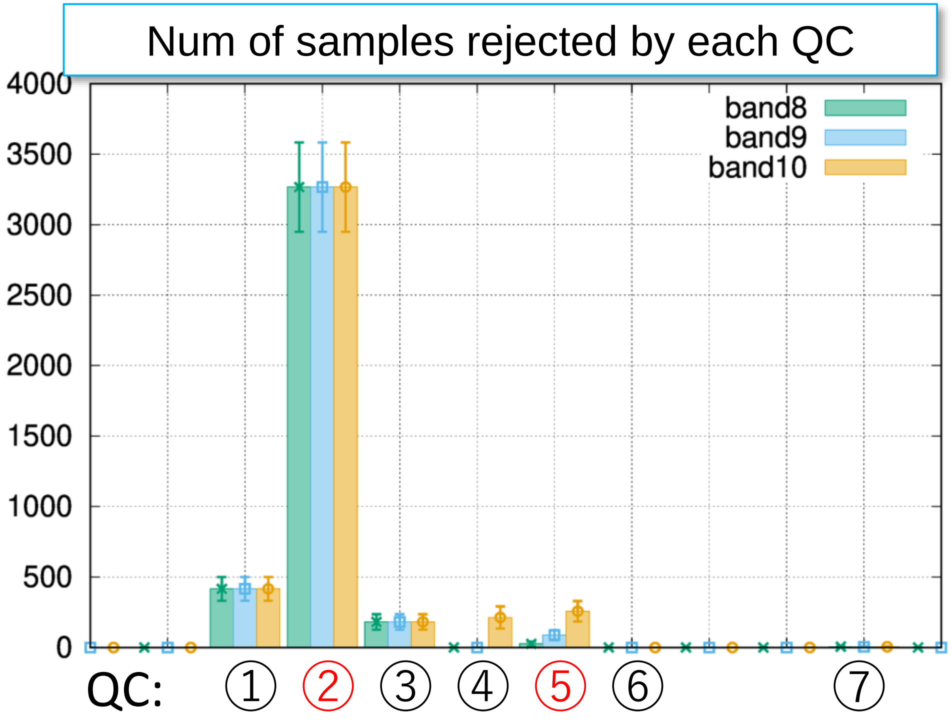
- Start with Himawari-8 (and will expand to other Geo/Leo)

2-1. Quality Control (QC)

- QC removes scenes poorly simulated:
  - ① low observed BT (BT13<230K),
  - ② high inhomogeneity (standard deviation BT13>5K),
  - ③ thick ice, ④ large land sensitivity, ⑤ large CA (CA-QC),
  - ⑥ large O-B, ⑦ large cloud Jacobian
- ➔ O-B becomes more symmetric (and Gaussian) safter QC

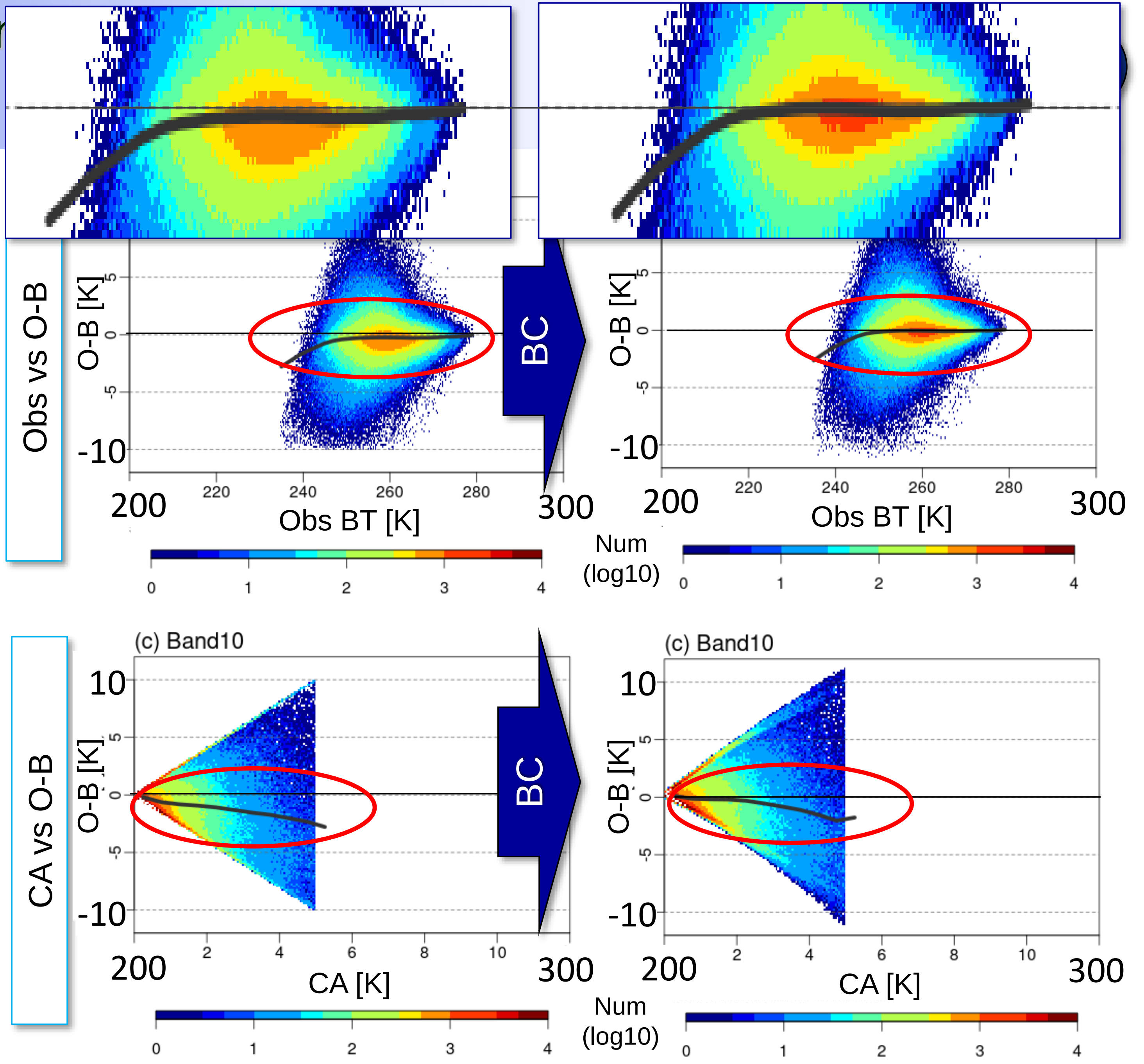
Cloud effect parameter:
CA=(|B-Bclr|+|O-Bclr|)/2,
Bclr=clear-sky first-guess
(Okamoto et al. 2014, QJRMS)





2-2. Bias Correction (BC)

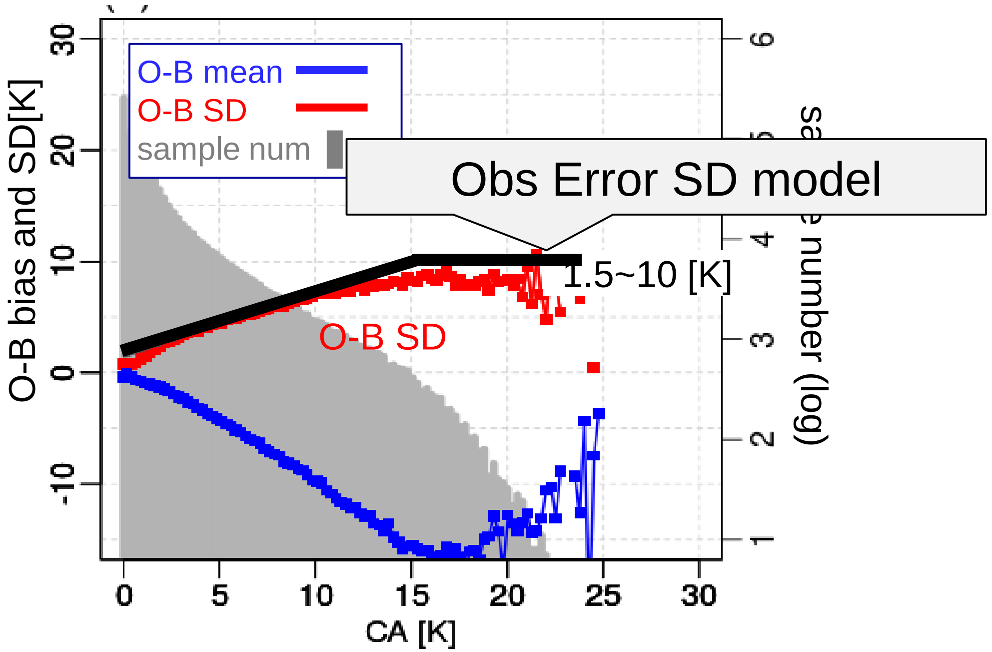
- BC: Apply variational BC (VarBC) to mainly correct the negative O-B
  - Add CA and CA^2 to CSR predictors
  - To avoid excessive correction, CA-QC excludes samples that could be substantially affected by model bias
- Remaining bias can be negligible because of large obs error assigned



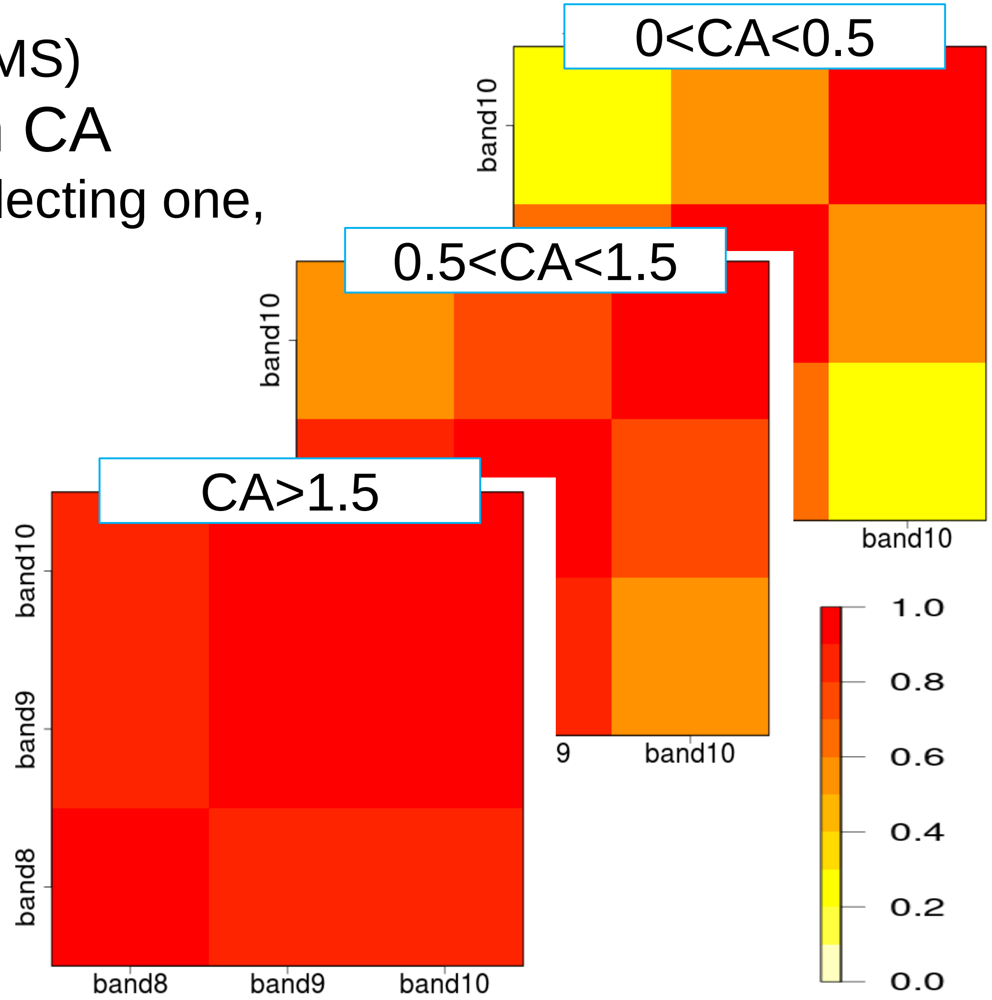
2-3. Obs error covariance model

- O-B variability can be predicted with a simple function of CA
- Obs error standard deviation (SD) is modeled with a linear stepwise function of CA
  - Geer & Bauer (2011, QJRMS); Okamoto et al. (2014, QJRMS)
- Evident inter-band error correlation, increasing with CA
  - → Account for cloud-dependent obs error correlation by selecting one, according to CA, from 3 correlation matrices precalculated

O-B SD and obs error SD model at band10



obs error orrelation



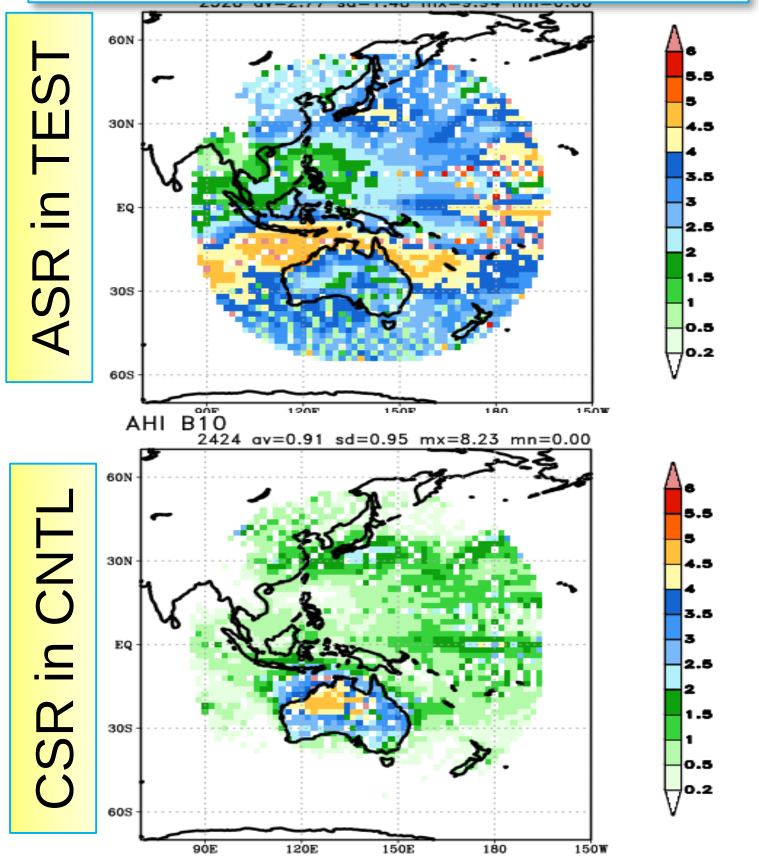
3. Data assimilation experiment

- Assimilation system
  - Operational global DA system of JMA (as of Dec. 2019)
  - Hybrid-4DVar
    - 4DVar + LETKF, TL959L100 (20km grid), MW ASR assimilation
- Obs Configuration
  - CNTL: Same as the operational configuration (Himawari-8/CSR)
  - TEST: Assimilate Himawari-8/ASR, instead of CSR
  - NoHim: Exclude Himawari-8 radiances
    - All the WV bands (8,9,10), 220km thinning
    - CSR is assimilated for GOES and MSG in all the experiments
    - RTTOV13.0
- Period
  - Analysis: 10 Jul. – 17 Sep. 2020
  - Forecast: 12UTC, 20 Jul. – 6 Sep. 2020,

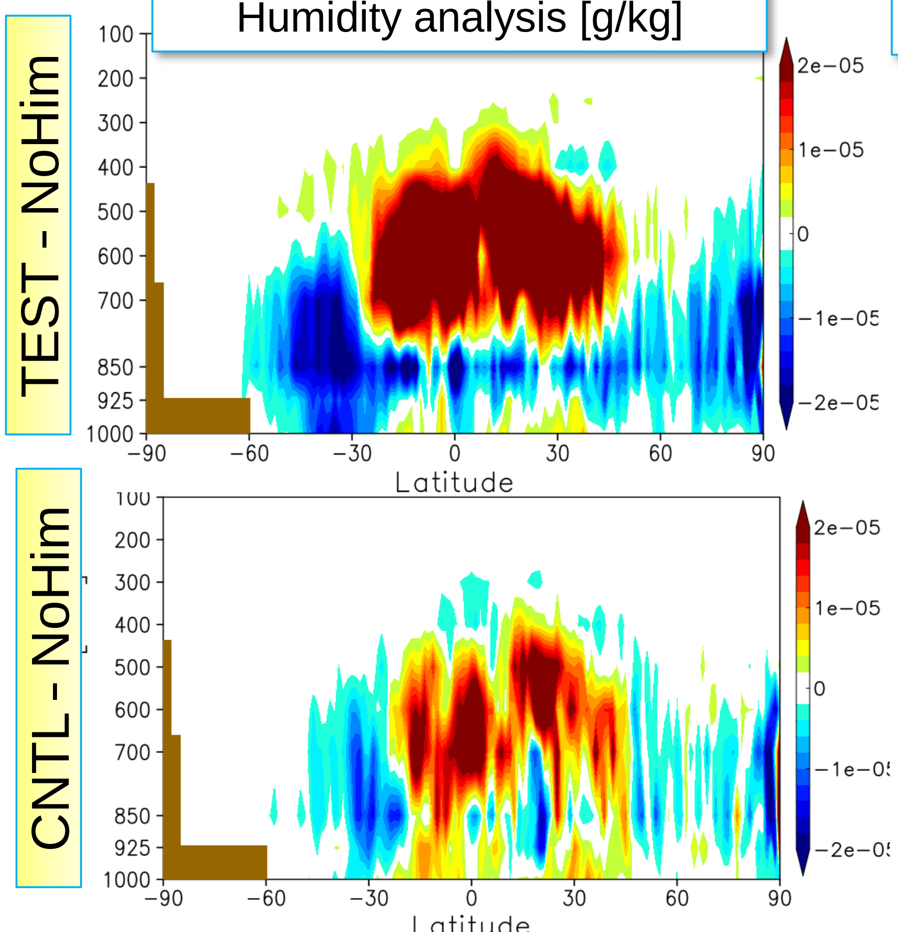
3-1. Change in number of used data and humidity analysis

- ASR is more numerous and homogenous than CSR: 21,840 vs 7,802 (2.8 times)
- ASR increase mid- and upper tropospheric humidity more than CSR
  - ➔ More effectively reduce dry bias than CSR

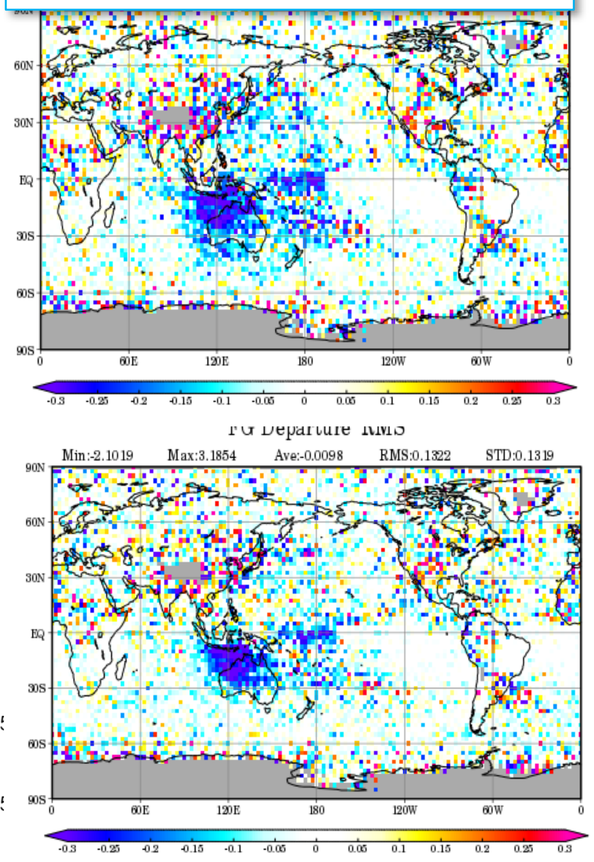
Averaged num of assimilated data



Humidity analysis [g/kg]

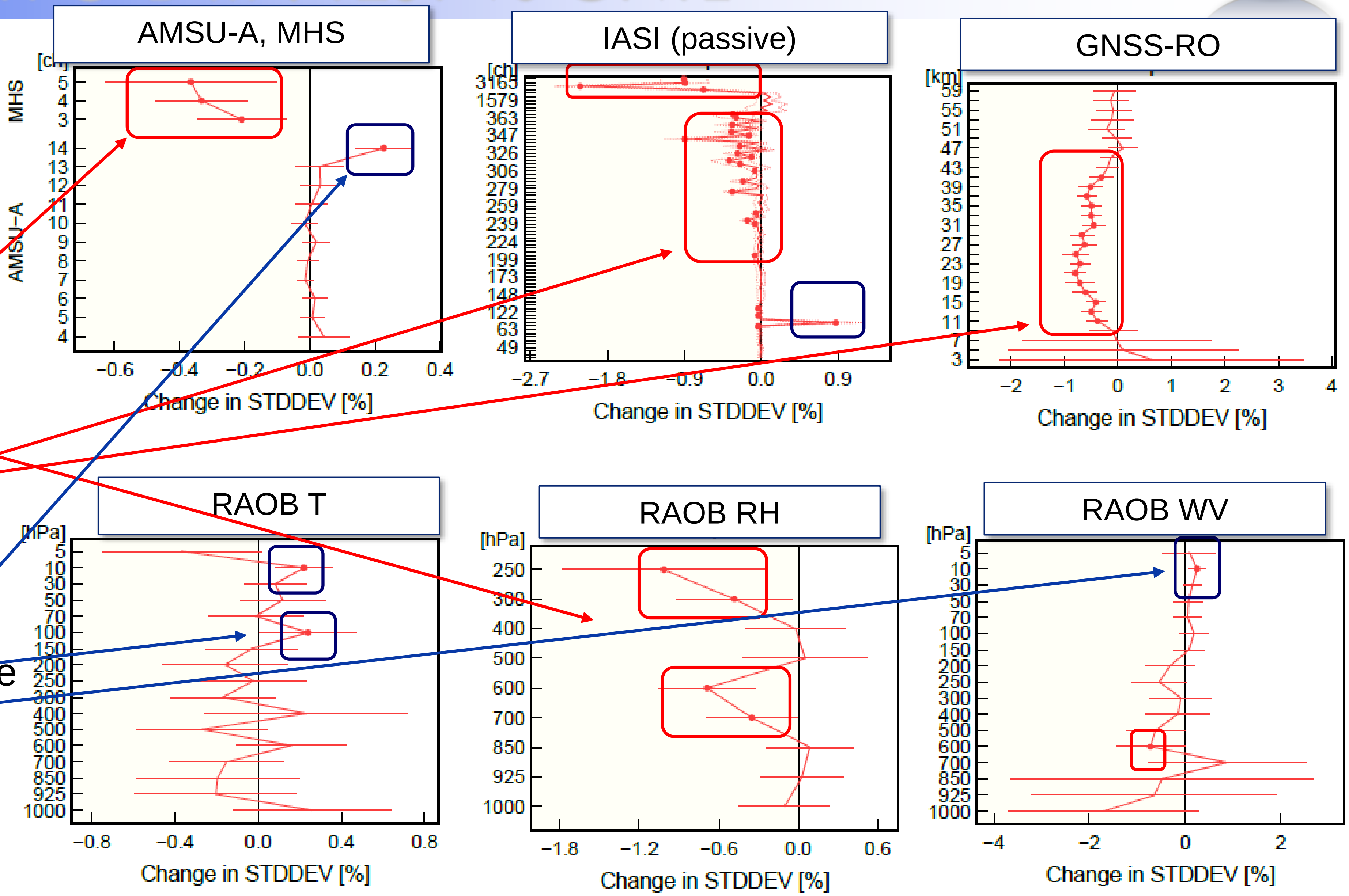


O-B SD in MHS ch4 [K]



3-2. Impact on O-B fit : TEST vs CNTL

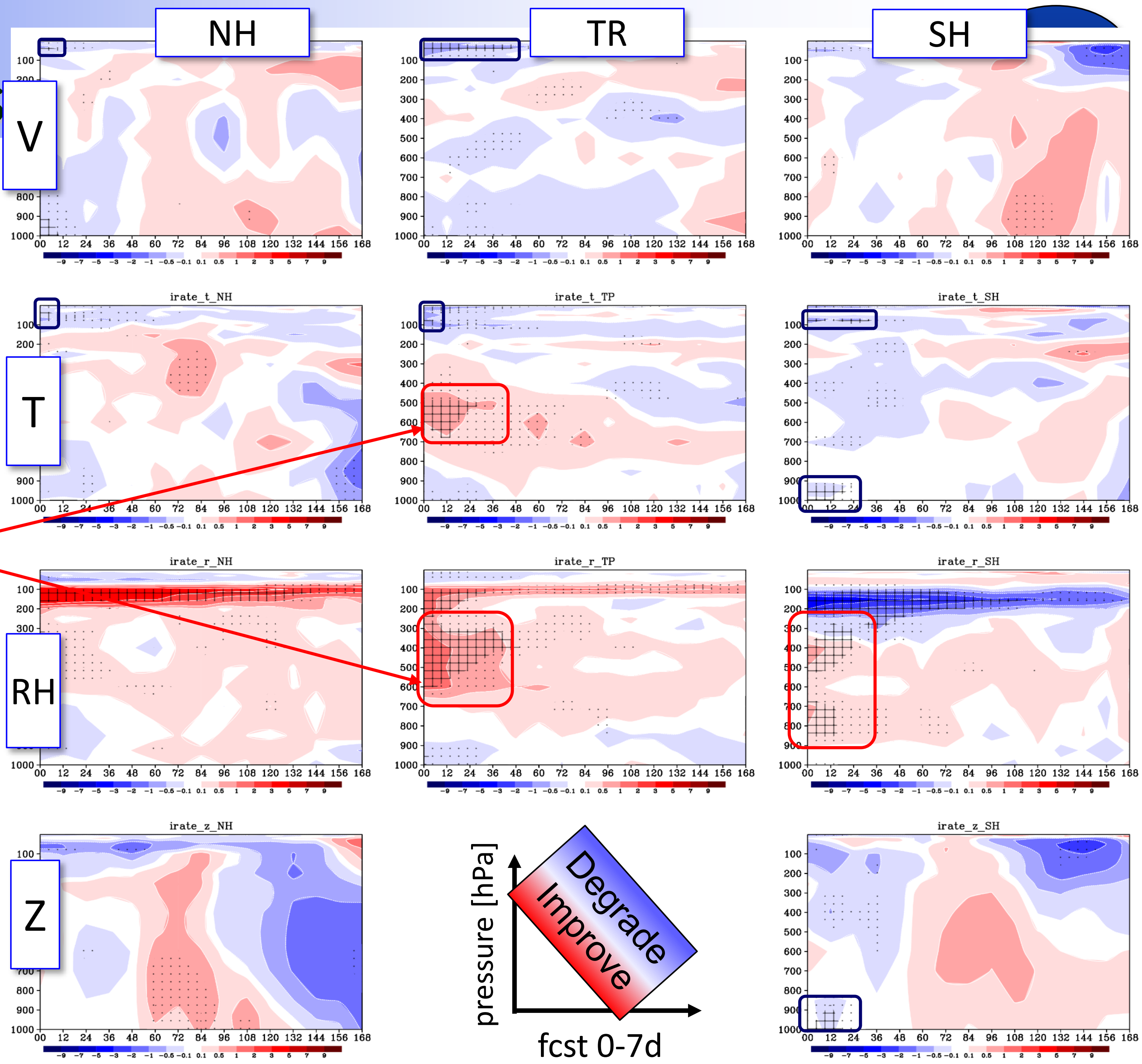
- Global O-B fit difference
  - Negative means ASR better improve background than CSR
- Significant improvement
  - Mid- and upper-tropospheric humidity
    - MHS, RAOB
  - Tropospheric Temperature IASI, GNSS-RO
- Degradation in stratospheric temperature (and wind)
  - AMSU-A, RAOB



3. DA experiment

3-3. Impact on forecasts

- Forecast improvement rate (TEST vs CNTL)
  - Warmish (Positive) shade means ASR improves forecast over CSR
- Significant improvement in upper-tropospheric humidity and temperature up to 48-h especially in Tropics
- Significant degradation in stratospheric temperature and wind



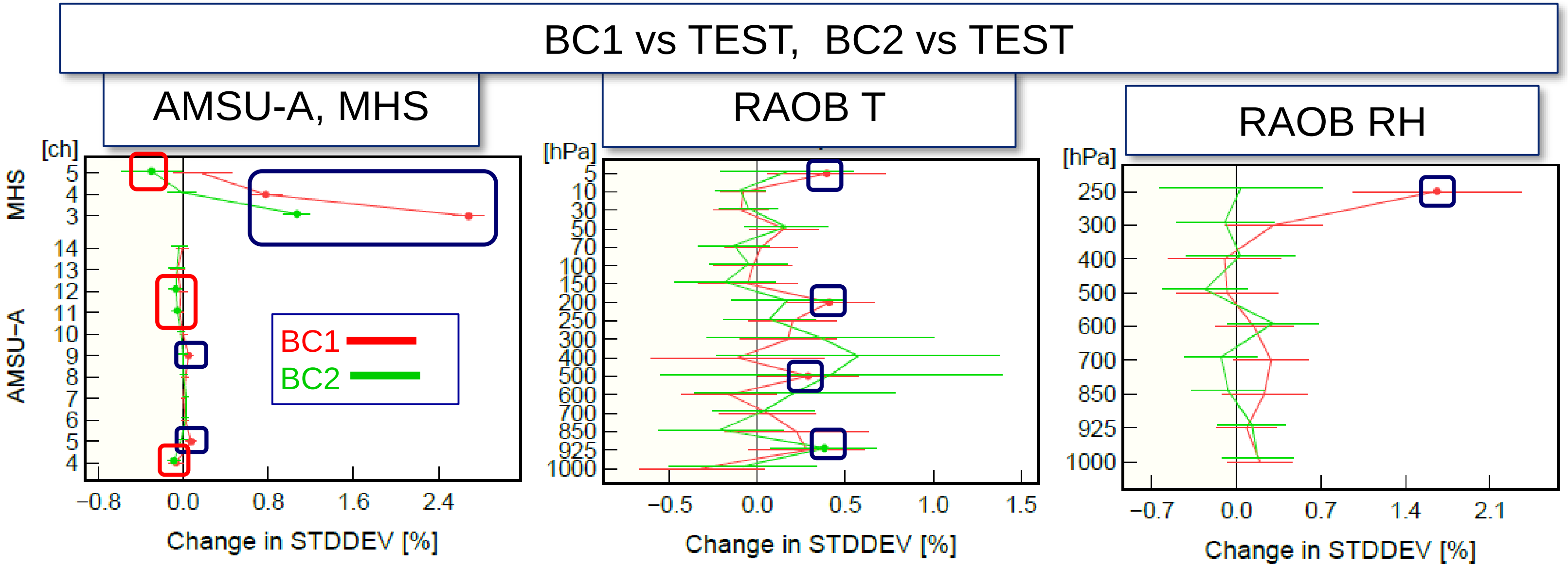
4. Additional impact studies

cloud-dependency of BC

- Examine how to represent bias in VarBC
  - Ref: CSR BC = c_1*Oclr + c_2*1/cos(θ) + c_3
  - TEST: BC = BC1 + c_4*CA + c_5*CA^2
- BC1: Equivalent to CSR: BC = c_1*Bclr+c_2*1/cos(θ)+c_3
  - Coefficients calculated from samples with O-Bclr > 1K
  - → Significant degradation
- BC2: Obs-based predictors (Otkin & Potthast 2019): BC=c_1*O+c_2*O^2+c_3*O^3+c_4*1/cos(θ)+c_5
  - → Equivalent skills as TEST

Oclr: clear-sky obs BT
Bclr: clear-sky background BT
O: all-sky obs BT

Cloud-dep predictors are important in the presence of significant O-B bias



4. Summary and plans

- Developed IR all-sky radiance assimilation in global data assimilation system
  - Cloud-dependent QC, BC and obs error covariance model
- ASR assimilation, relative to CSR assimilation
  - Significantly increase observations assimilated by 2.8 times
  - Increase mid- and upper tropospheric humidity to better alleviate dry bias than CSR assimilation does
  - Improve short-range forecast (~48h) of Q, T and W in the mid- and upper troposphere, especially in Tropics
  - Degrades stratospheric T and W
- Sensitivity experiments
  - Cloud-dep BC predictors are essential in the presence of large (negative) O-B bias
  - Obs error correlation and cloud-dep SD are important, but cloud-dependency of correlation is not so much.

- Ongoing studies and Plans
  - Investigate the degradation in upper stratospheric T and W
  - Assess impacts of ASR from GOES and MSG
  - Extend the development to hyperspectral IR sounders