Assimilating clear-sky radiance of SSMIS humidity sounding channels in the JMA global NWP system with newly developed cloud detection algorithm

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1. Introduction

- In March 2017, JMA begun operational utilization of clear-sky radiance of SSMIS humidity sounding channel in the NWP system.
- Quality Control algorithm dedicated for SSMIS channel configuration was newly developed from a physically-based approach.
- Since SSMIS covers wide range of microwave frequency, the algorithm can discriminate liquid and frozen particles. It is useful not only for the accurate detection of cloud-precipitation affected data, but also for obtaining knowledge useful to develop all-sky assimilation.

2. Cloud detection algorithm

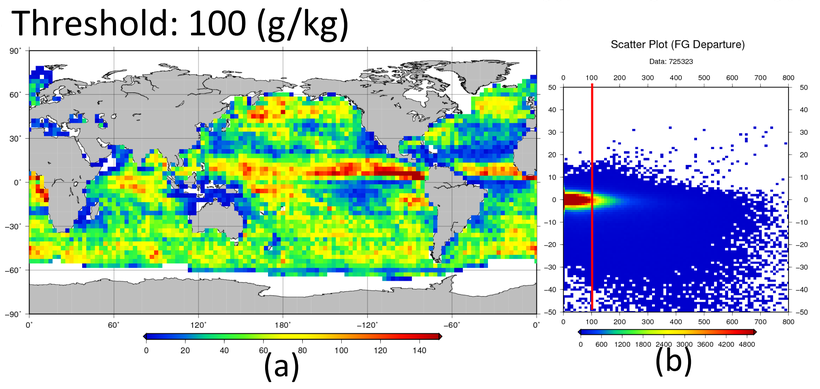
- **Clouds are classified into 3 types** based on the composing hydrometeor

(1) Cloud Liquid Water(CLW)

- Indicator: CLW calculated based on 'cloud' amount defined as follow. (Geer and Bauer, 2011)

$$cloud\ amount\ = 1 - \frac{T_b(37V)_{obs} - T_b(37H)_{obs}}{T_b(37V)_{clr} - T_b(37H)_{clr}}$$

- Threshold: 100 (g/kg)



(2) Snow Crystal

- Indicator: Polarization-corrected Temperature (PCT; Spencer et al., 1986)
- Coefficients targeting mid-latitude are adopted from Liu et al.(1998)

$$1.5 \times dT_b(91V) - 0.5 \times dT_b(91H) < -3K$$
or
$$dT_b(91V) < -5K$$

- Melting layer (CLW emission) is also considered

$$dT_b(91V) < 0K \text{ and } dT_b(37H) > 1.5K$$

where $T_b(37H)_{obs\_cor} = T_b(37H)_{obs} - 0.08 \times CLW$

$$dT_b = T_{obs} - T_{clr}$$
T_{obs} : Observed Tb
T_{clr} : Calculated clear-sky Tb

(3) Ice Crystal

- Indicator: Scattering Index (SI; Ferraro et al., 2000)
- Due to malfunction of 150 GHz onboard F18, 183±6.6 GHz (sensitive to lower troposphere) is selected as high frequency channel. This channel has the best correlation with 150GHz among 3 sounding channels.

$$dT_b(183 \pm 6.6) - dT_b(91V) < -10K$$

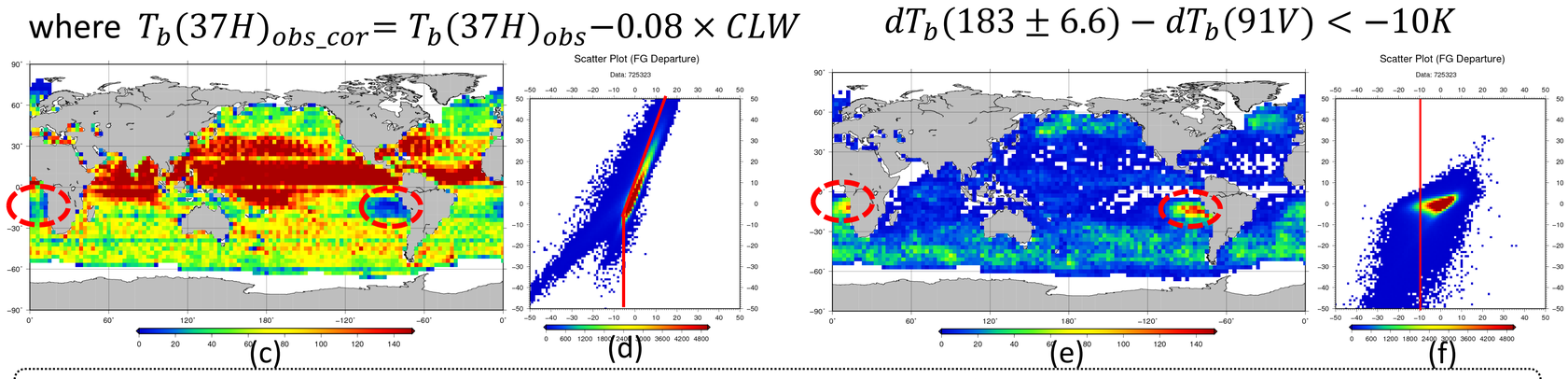
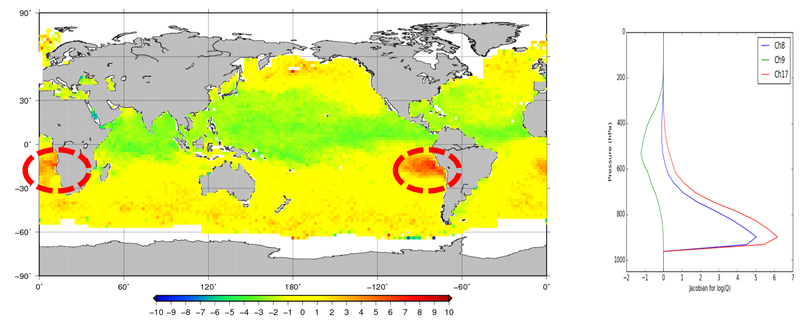


Figure1 (Data Period: Aug 2015)
(Left panel of each section)
Cloud frequency occurrence evaluated from (a) CLW, (c) SI, (e)PCT, respectively.
(Right panel of each section)
Scatterplot of (b) $dT_b(183 \pm 6.6)$ vs CLW, (d) $dT_b(183 \pm 6.6)$ vs $dT_b(183 \pm 6.6) - dT_b(91V)$, (f) $dT_b(91H)$ vs $dT_b(91V)$ respectively. Red lines indicate thresholds.

- Positive bias of $dT_b(91V)$ appears at west coast of South America and Africa.
- Suggesting negative (positive) bias of lower tropospheric humidity (temperature).

Figure2:
(Right) Mean $dT_b(91V)$ of data with $CLW < 100$
(Left) water vapor Jacobian profile for ch8/9/17.



3.Result of Quality Control

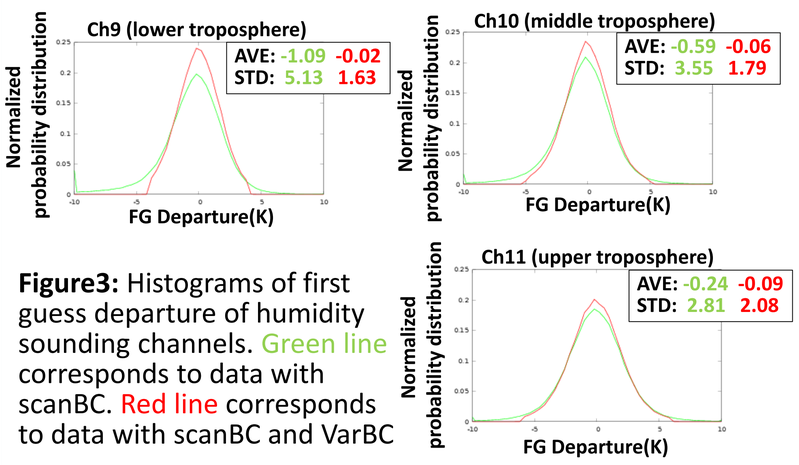


Figure3: Histograms of first guess departure of humidity sounding channels. Green line corresponds to data with scanBC. Red line corresponds to data with scanBC and VarBC

- Snow Crystal QC detects data with large variance seen around $dT_b(183 \pm 6.6) - dT_b(91V) = 0$,
- Reduce overlooking of cloud affected data mainly at relatively thick cloud (ex. cumulus, stratocumulus) area.

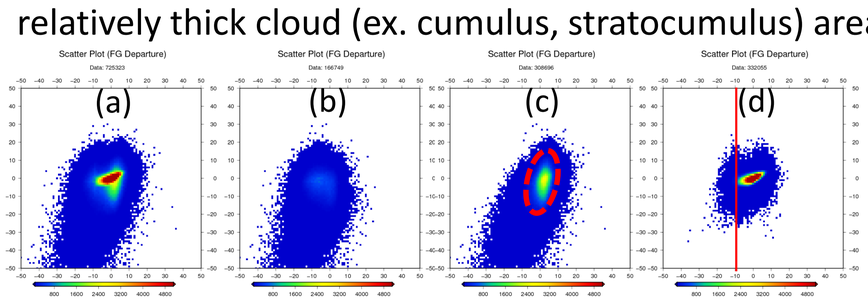


Figure4: Scatterplots of $dT_b(183 \pm 6.6)$ *vs* $dT_b(183 \pm 6.6) - dT_b(91V)$. (a) All data, data affected with (b)cloud liquid water, (c) snow crystal, and (d) remaining data passed (b) and (c). Red line indicates threshold for ice crystal QC. ScanBC is applied to the $dT_b(183 \pm 6.6)$.

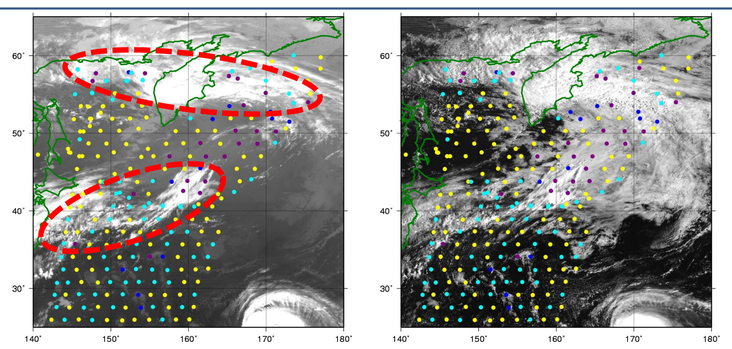


Figure5: QC result example (2015/9/6 0630 JST) (Left) IR image, (Right) Visible image.

Definition of each dot is show as the table.
✓ Identify as cloud
– Identify as clear-sky

	ICE Crystal	Snow Crystal	CLW
Purple	✓	✓ or –	
Light Blue	–	✓	✓ or –
Dark Blue	–		✓
Yellow	–		

4. Impact on the JMA NWP system

4.1 Assimilation Experiment Setup

Control:
JMA operational global DA system as of Mar. 2016 (plus minor upgrade)

Test:
Control + SSMIS-UPP radiance (3ch.(ch9/10/11), clear-sky, open-ocean)

Experiment Period:
10 Jul. to 11 Sep., 2015 (Assimilation), 21 Jul. to 11.Sep,2015 (Forecast)

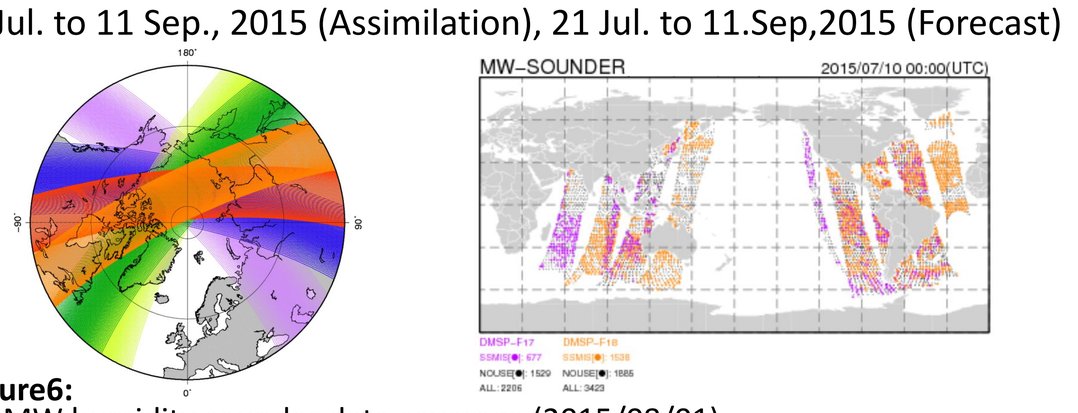


Figure6:
(a) MW humidity sounder data coverage (2015/08/01).
DMSP-F17/F18 data fill the data gap between METOP-A/B and NOAA-18/19
(b) Data coverage of SSMIS UPP
Purple and orange dots denotes used data from DMSP-F17 andF18 .
Shade dots denotes data rejected during QC process.

4.2 Analysis and Forecast Field

- Improved fits in FG departure of water vapor field. Mean analysis field is almost unchanged.
- Positive impact for the prediction of Z and T at Southern Hemisphere.

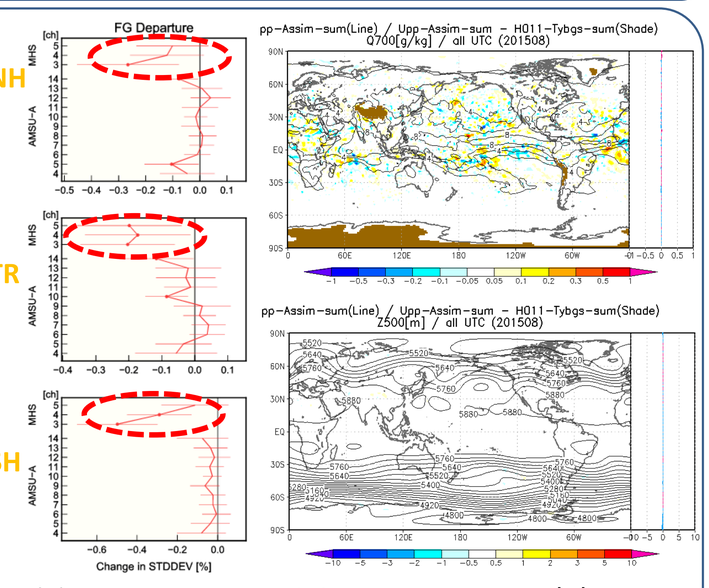


Figure5: (Left)Normalized changes in the standard deviation of first-guess departures from MW- sounding data (MHS and AMSU-A). Negative values indicates first-guess field improvement. (Upper-right)Changes in mean analysis field of Q700. (Lower-right) Upper-right)Changes in mean analysis field of Z500. Changes are defined as CNTL-TEST.

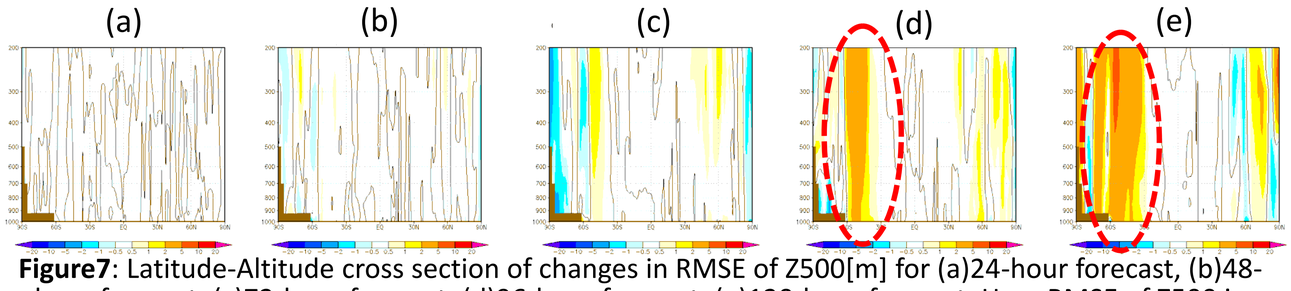


Figure7: Latitude-Altitude cross section of changes in RMSE of Z500[m] for (a)24-hour forecast, (b)48-hour forecast, (c)72-hour forecast, (d)96-hour forecast, (e)120-hour forecast. Here RMSE of Z500 is defined as RMSE(CNTL)-RMSE(TEST). Orange shade indicates improvement.

6. Summary

- Newly developed cloud detection algorithm has a wider detection area mainly at where relatively thick cloud (ex. cumulus, stratocumulus) exists.
- The algorithm is implemented to JMA global data assimilation system. Experiment results show positive impact on water vapor analysis field globally, and on temperature and geopotential height forecast field at the southern hemisphere.