# Impact of microwave radiance assimilation over land using dynamic emissivity in the global NWP system of JMA

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## 1. Introduction & motivation

The Japan meteorological agency/Meteorological research institute (JMA/MRI) is working on applying a dynamic emissivity (DE, Karbou et al. 2005, 2006) method over land to the global numerical weather prediction (NWP) system of JMA. The DE is known as a good estimate method of land surface emissivity which depends on surface conditions. Therefore, we expect to improve analysis and forecast skills over land and downstream in the JMA system.

## 2. Dynamic emissivity (Karbou et al. 2005, 2006)

- The surface emissivity is used for the background brightness temperature.

$$T_b(\nu,\theta) = T_s\varepsilon(\nu,\theta)\Gamma + \{1-\varepsilon(\nu,\theta)\}\Gamma T_a^{\downarrow}(\nu,\theta) + T_a^{\uparrow}(\nu,\theta) \quad (1)$$

- The current JMA system uses the monthly mean emissivity of CNRN Atlas. But the emissivity is dynamically varied by surface conditions.

$T_b(\nu,\theta)$: brightness temperature (BT) of observation at frequency $\nu$ and at zenith angle $\theta$
$T_s$: surface temperature of background
$T_a^{\downarrow}(\nu,\theta)$: atmospheric downwelling BT of background
$T_a^{\uparrow}(\nu,\theta)$: atmospheric upwelling BT of background
$\varepsilon(\nu,\theta)$: surface emissivity
$\Gamma$: net atmospheric transmissivity of background

- We estimate such a dynamically varying emissivity from observation and background.
- The emissivity is retrieved from eq. (1) as follows,

$$\varepsilon(\nu,\theta) = \frac{T_b - T_a^{\downarrow}(\nu,\theta)\Gamma - T_a^{\uparrow}(\nu,\theta)}{(T_s - T_a^{\downarrow}(\nu,\theta))\Gamma} \quad (2)$$

## 3. Experimental settings

### Configuration of global NWP system of JMA

The 4DVar system with JMA global spectral model (GSM)

- Outer model: TL959L100 (horizontal reso. 20 km, top 0.01 hPa)
- Inner model: TL319L100 (horizontal reso. 55 km, top 0.01 hPa)
- 6-hr assimilation window, incremental 4D-Var
- Radiative transfer model: RTTOV10.2
- Used channels of AMSU-A and ATMS in the global NWP system of JMA ➔

| Temperature sounder | Sea | Land | Sea ice |
|---|---|---|---|
| AMSU-A ch. 4 | Y | N | N |
| AMSU-A ch. 5, ATMS ch.6 | Y | N | N |
| AMSU-A ch. 6-14, ATMS ch. 7-9 | Y | Y | Y |

### DE settings

The DE method is applied to surface-sensitive channels for the microwave sounders (AMSU-A and ATMS) over land.

- The dynamic emissivity is estimated at 50.30 GHz (ch.3 of AMUS-A and ATMS)
- The emissivity is used at 54.40 GHz and 54.94 GHz (chs. 6, 7 of AMSU-A and chs. 7, 8 of ATMS).

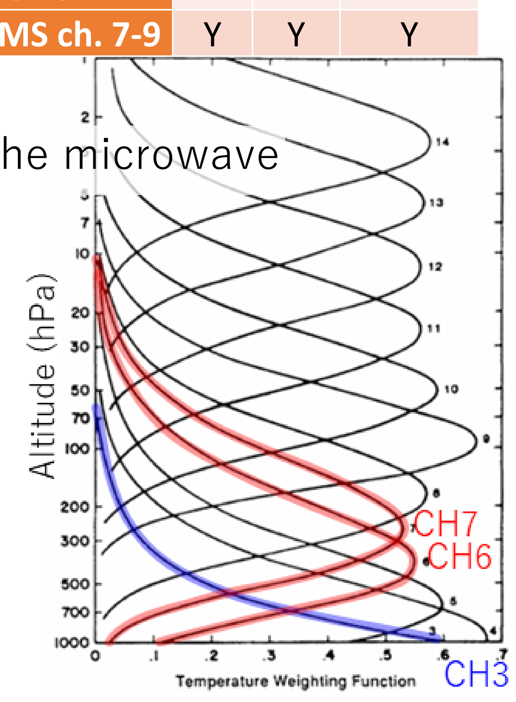


Fig. 1 Weighting functions of chs. 3-14 of AMSU-A (Janssen,1993)

### Experimental period

21 April – 11 June 2019 (verified in May 2019)

CNTL: experiment without DE (current JMA settings)
TEST: experiment with DE

## 4. Results

### Statistical verification of O-B

The DE improves brightness temperatures of the first guess because of increasing assimilated data (Fig. 2).

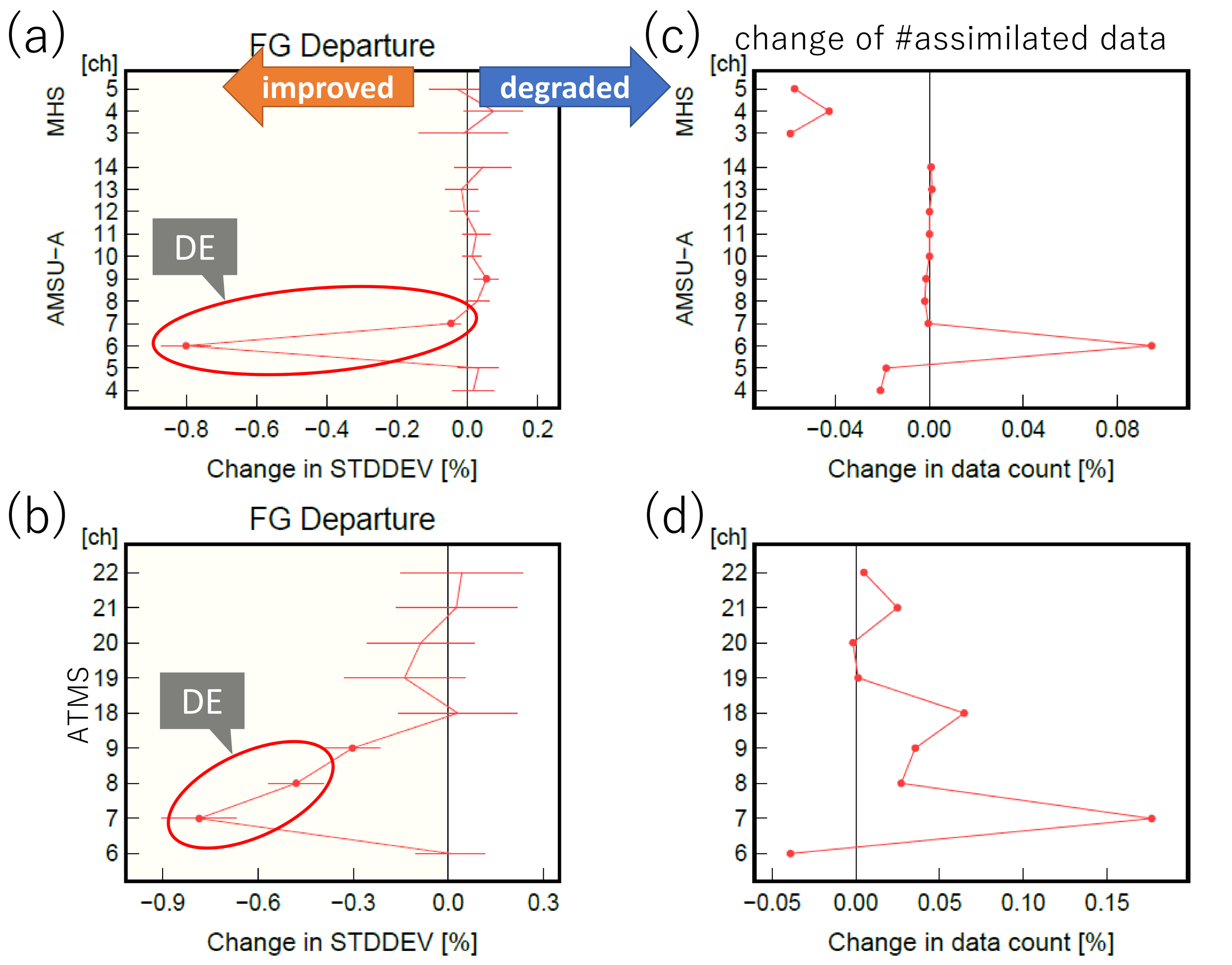


Fig. 2 Statistical verification of O-B (FG departure) in May 2019 for (a, c) AMSU-A and MHS, (b, d) ATMS. The left column (a, b) indicates improvement (%), and the right column (c, d) indicates change in a number of assimilated data.

### Spatial distributions of emissivity and O-B statistics

The emissivity slightly decreases over from the northeastern Africa to the mid Asia and increases over the eastern Siberia and north America (Fig. 3c) due to the DE method, which improves the brightness temperature of the first guess (Fig. 3i).

- On the coast lines, the emissivity in the TEST is smaller because $T_b$ in eq. 2 may include influence from sea. We cannot clearly find the negative influence from the low emissivity on the coast lines.

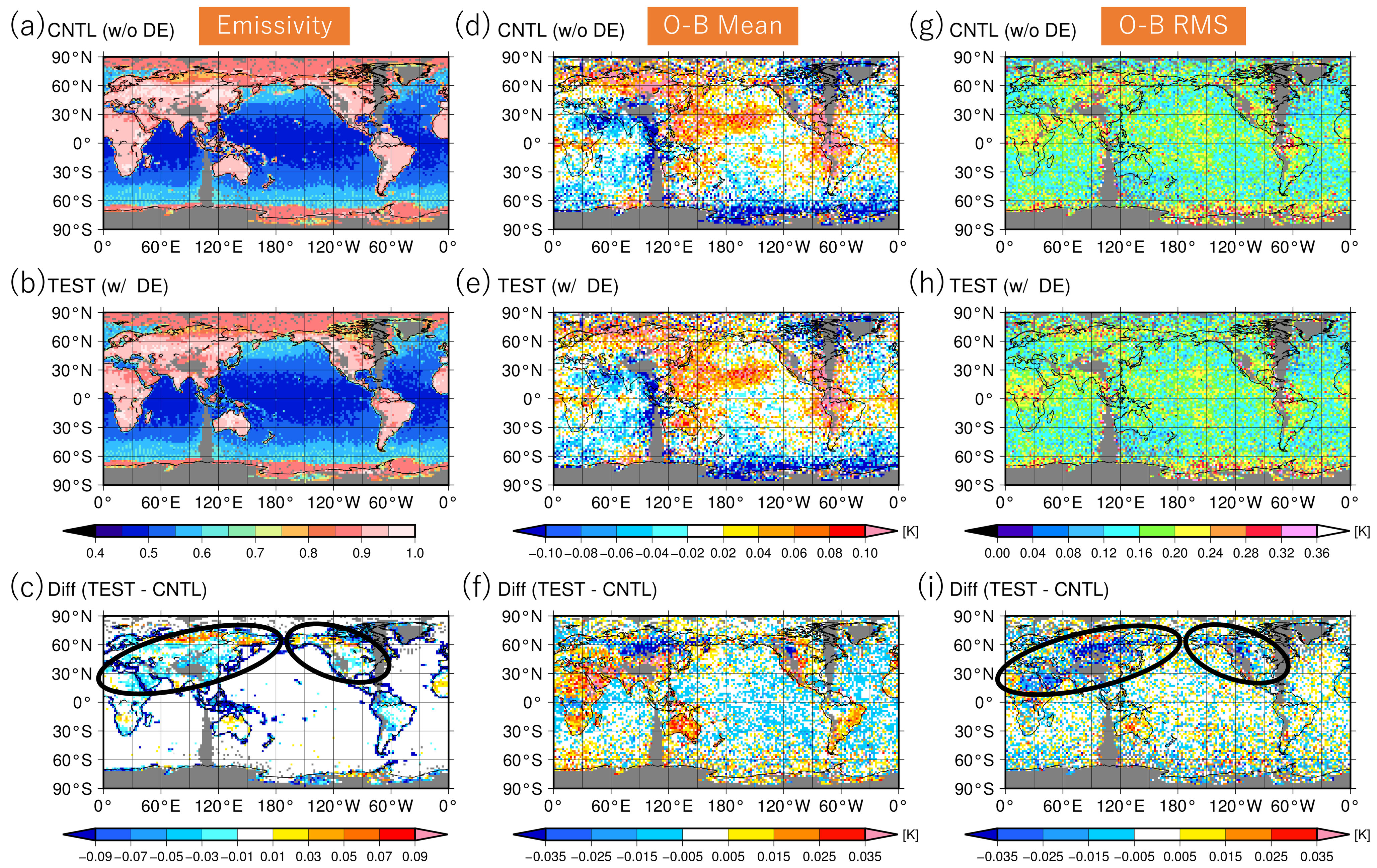


Fig. 3 Monthly mean spatial distributions at 06 UTC in May 2019 at AMSU-A ch. 6 for (a-c) emissivity, (d-f) mean of O-B, and (g-i) RMS of O-B. The top, second, third rows show CNTL, TEST, difference between CNTL and TEST, respectively.

### Impact of DE to the forecast

The DE also generally improves the forecast mainly over the northern hemisphere.

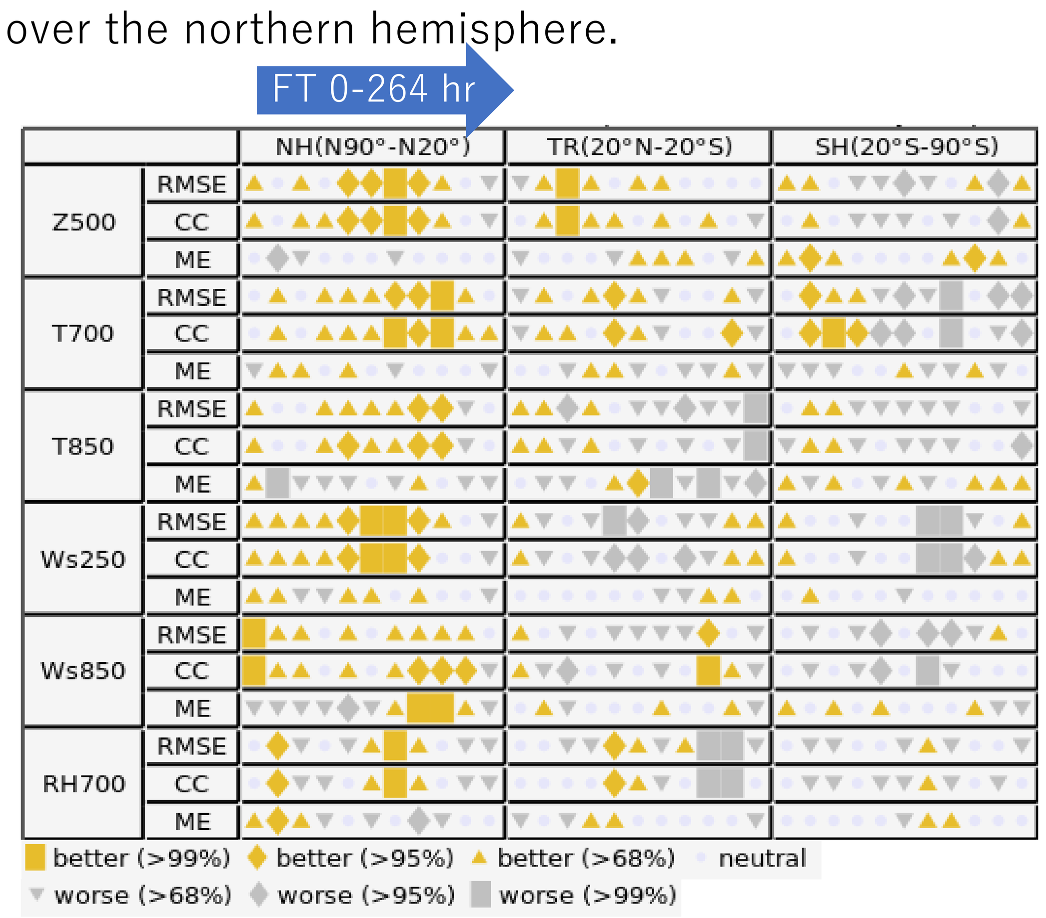


Fig. 4 Score-differences confidence over NH, TR and SH from T+0 hr to T+264 hr.

### Contamination of DE

Thick clouds/precipitations would contaminate the emissivity.

- Over the dense vegetation such as tropical rain forests, the emissivity is generally about 0.95.
- Most emissivities in the TEST are consistently estimated as around 0.95 (red dots in Fig.5a). In the case A, the emissivity is estimated under almost clear-sky condition (Fig. 5b).
- In the case B, the emissivity is estimated as 0.85, and there are thick clouds and precipitations (Fig. 5c).

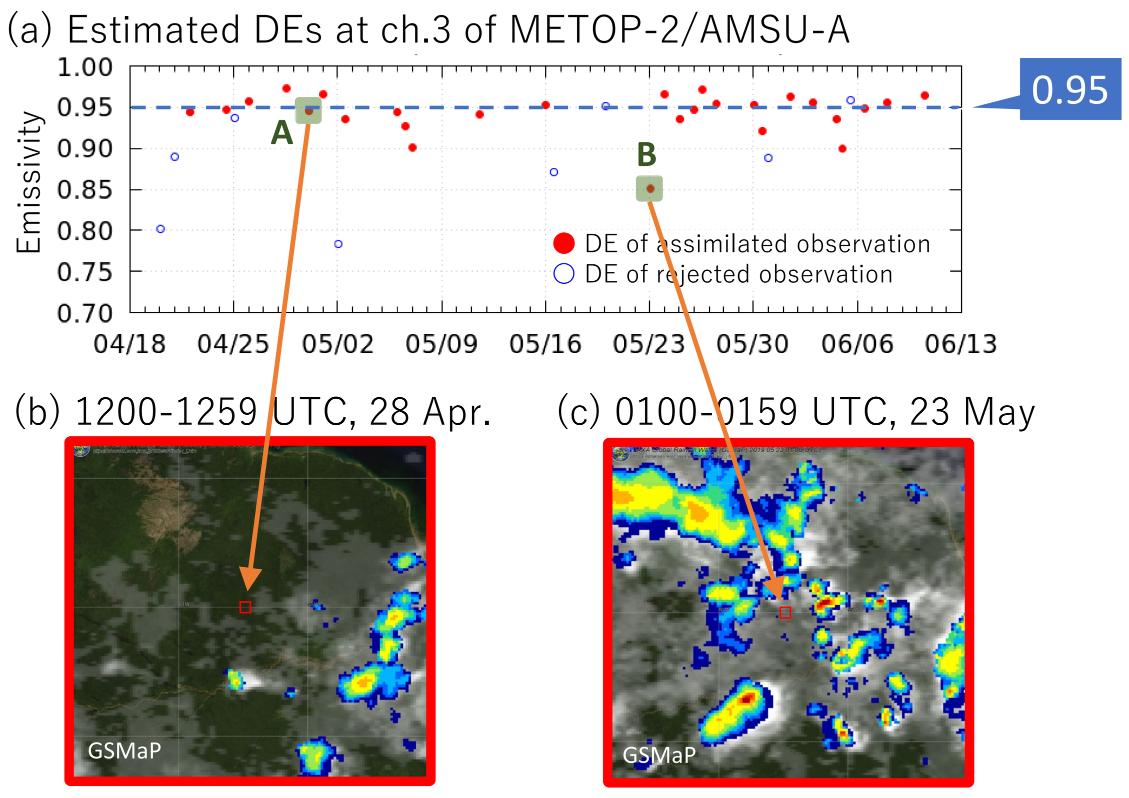


Fig. 5 (a) Estimated DEs of METOP-2/AMSU-A over amazon rain forest (0.2°N-0.2°S and 57.5°E-57.0°E). Spatial distributions of cloud/rain from GSMaP (b) in the case A at 12:00 UTC 28 Apr. 2019, and (c) in the case B at 01:00 UTC 23 May 2019.

## 5. Summary

The DE method was investigated by using the global NWP system of JMA, and we obtained some positive impacts.

- The estimated emissivity was different from the Atlas one over the northeastern Africa, mid Asia, eastern Siberia and north America.
- The background brightness temperature got closer to the observation through the estimated emissivity, and a number of assimilated brightness temperature observations was increased mainly over NH, which would improve the forecast.
- The thick clouds/precipitations would contaminate the emissivity.

### Future works

- Assimilating more surface-sensitive channels (ch. 5 of AMSU-A, and ch. 6 of ATMS) over land.
- Investigating a method detecting of the cloud/precipitation areas over land to avoid their negative influence.

## References

Janssen, M. A., 1993: *Atmospheric Remote Sensing by Microwave Radiometry*. John Wiley & Sons Inc, New York, 572pp.
Karbou, F., C. Prigent, L. Eymard, and J. R. Pardo, 2005: Microwave land emissivity calculations using AMSU measurements. *IEEE Trans. Geosci. Remote Sensing*, **43**(5), 948–959.
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