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The Characteristics of the Real-time Land Surface Emissivity of ATMS

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Introduction

◆ Background

- Utilization of satellite observation to numerical weather prediction models improves the forecast skill.
- **However,** assimilation of microwave observations over land and near-surface channels is restricted due to uncertainties in land surface emissivity and surface temperature.
- Ɛ(emissivity) = $\frac{E_{R(T)}}{E_{BB}(T)}$, $(E_{BB} = \sigma T^4)$
- **MW emissivity** is depending on scan angle, frequency and the surface characteristics (i.e. vegetation types, soil moisture contents)
- Difficulties in estimating MW land surface emissivity: High variability

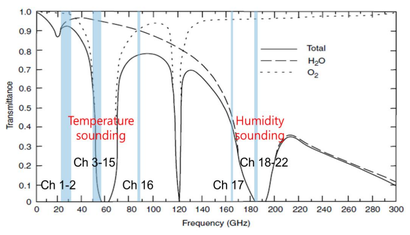
◆Objective

- To better estimate the MW land surface emissivity using ATMS observation
  - ➢ To better utilize the MW observations over land.
  - ➢ To improve NWP skills.

Data

◆ The Advanced Technology Microwave Sounder (ATMS)

- A cross-track scanning MW sounder with 22 channels onboard the Suomi-NPP.*
- To estimate the atmospheric temperature/humidity vertical profiles.



Atmospheric transmittances as a function of frequency. (Liou et al., 2002)

*NPP: National Polar-orbiting Partnership

ATMS (SDR)	Brightness Temperature (TB) Satellite Zenith/Azimuth Angle Solar Zenith/Azimuth Angle
UM model of KMA	Temperature/Humidity profile Surface Temperature/Pressure/Humidity 2m Temperature/Pressure/Humidity 10m wind (u, v components)
Period	201410, 201501, 201504, 201516 (each 15 days)

Method

◆ Method

$$R_{obs} = R(\uparrow) + R(\downarrow) \times (1-\varepsilon) \times \tau + R_{sfc} \times \varepsilon \times \tau \quad (1)$$

$$\varepsilon = \frac{R_{obs} - R(\uparrow) - R(\downarrow) \times \tau}{(Rsurf - R(\downarrow)) \times \tau} \quad (2)$$

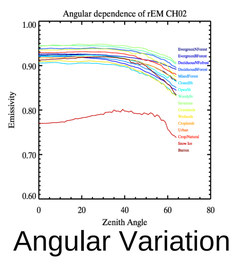
R_{obs}: Observed Radiance
$R^{\uparrow}$: Atmospheric upwelling Radiance
$R^{\downarrow}$: Atmospheric downwelling Radiance
τ : Transmittance

- Real-time emissivity retrieval
  - Up-welling, down-welling radiances and transmittance are estimated with RTTOV using the spatio-temporally collocated analysis data.
  - The real-time emissivity at window channels can be calculated with the equation [2].
  - The emissivity at temperature sounding channels is estimated by interpolating the emissivity of the window channels.
  - The emissivity of the window channel (Ch16 or 17) is directly assigned to humidity sounding channels.
- Comparison with TELSEM*

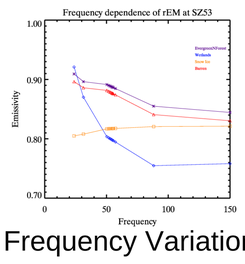
*TELSEM: A Tool to Estimate Land Surface Emissivities at Microwave frequencies

Results & Discussion

◆ Angular and Frequency Variation (31.4 GHz)



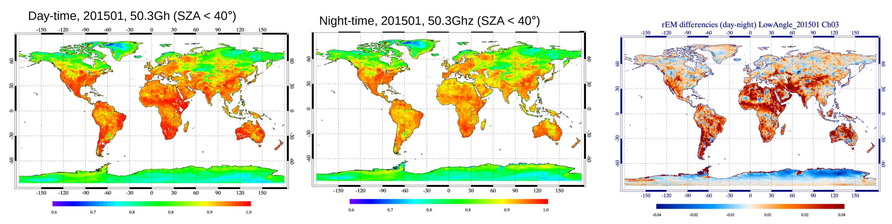
Angular Variation



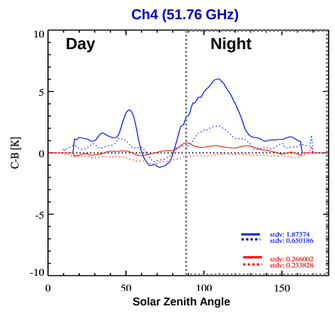
Frequency Variation

- As the satellite zenith angle increases, the decrement of the real-time emissivity increases.
- The emissivity over each vegetation types shows different variation with regard to satellite zenith angle and the channel frequency.
- These variations correspond with other microwave emissivities.

◆ Diurnal Variation



Monthly averaged real-time emissivity.
Day (Left), Night (Middle), Day-Night (Right)

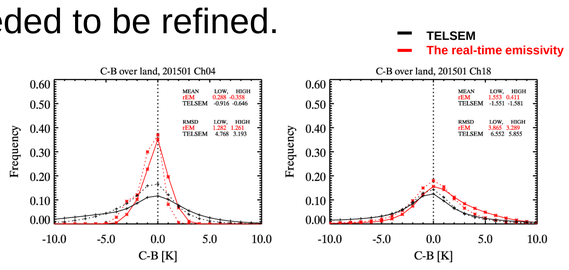


- (Left) The real-time emissivity describes the diurnal/seasonal variation of surface states and atmospheric condition better.
- (Right) As a result, the variation of O-B with regard to solar zenith angle decreased. Solid line(SZA ≥ 40°), dashed line(SZA < 40°)

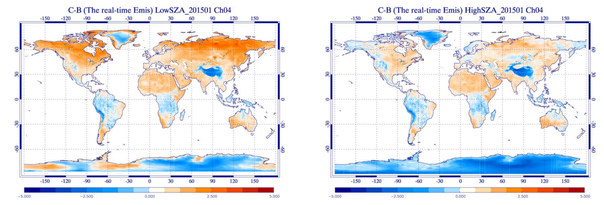
*O-B: Observed TB – Background TB

◆ Improvement in C-B values (FG departure)

- RMSD of C-B decreased at the surface affected channels (CH 4 – 7 and CH 18 – 22).
- Increasing number of observation data that can pass the QC.
- **However,** the biases over the high altitude, high latitude and moist area are still needed to be refined.



Histogram of C-B at CH4 (left), and CH18 (right)



C-B Map at CH4. (Left) SZA ≥ 40°, (right) SZA < 40°

*C-B: Bias Corrected observation TB – Background TB

◆ Emissivity sensitivity to errors in the parameters

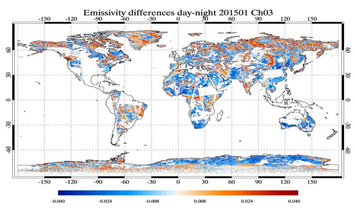
- The emissivity estimation is most sensitive to the surface temperature errors (followed by observation errors) at CH3.

- R_{obs} error: NEdT
- $R^{\uparrow}$, $R^{\downarrow}$ error: RTM model error (0.2 K)
- R_{surf} error: UM error covariance

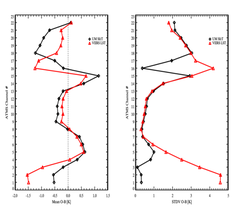
$$error\ [\%] = \frac{\varepsilon_{err} - \varepsilon}{\varepsilon} \times 100$$

Emissvity sensitivity [%]		Low Angle (SZA < 40°)			
		Ch01	**ch02**	**ch03**	**Ch16**
Obs	**Mean(STDV)**	0.39(0.34)	0.36(0.30)	0.89(0.75)	0.30(1.11)
T_{sfc}	**Mean(STDV)**	-0.53(0.40)	-0.50(0.38)	-0.74(0.58)	-0.60(0.45)
Tb_{up}	**Mean(STDV)**	-0.11(0.10)	-0.09(0.07)	-0.20(0.17)	-0.12 (0.44)
TB_{dn}	**Mean(STDV)**	-0.04(0.05)	-0.03(0.04)	-0.04(0.04)	-0.03(0.15)

◆ Estimation with VIIRS land surface temperature



real-time emissivity estimated with VIIRS LST: Day-Night



Mean bias and STDV of C-B at each channels

- The diurnal variation of emissivity decreased.
- UM T_{sfc} induced the diurnal variation of emissivity (actual emissivity value doesn't show diurnal variation).
- Mean bias and STDV of C-B at sounding channels decreased.

Conclusion

- By utilizing the real-time emissivity estimated with ATMS observations to pre-processing process, mean bias and STDV of O-B improved especially for near-surface channels over land.
- Thereby, we expect more land observations to be assimilated for data assimilation system.
- However, relatively high biases are shown over high altitude and arctic regions.
- These can be refined by improved pre-processing method (cloud screening and bias-correction) or by more accurate land surface temperature data.

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