Determining Infrared Land Surface Emissivity Diurnal Variation from Satellites

Zhenglong Li#, Jun Li#, Yue Li#, Timothy J. Schmit@, Lihang Zhou@ and Mitchell D. Goldberg@

#Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison

@Center for Satellite Applications and Research, NESDIS/NOAA

Email: zhenglong.li@ssec.wisc.edu

1. Introduction and Motivation

- Infrared (IR) land surface emissivity (LSE) is important for
  - deriving other products, such as atmospheric water vapor, cloud-top pressure, land surface temperature and radiation budget etc
  - assimilating IR radiances
- IR LSE diurnal variations are poorly studied
- Laboratory measurements: emissivity increases by 1.7% to 16% with increased soil moisture content, most significantly for sandy soils in the 8.2–9.2 µm range.
- A clearly defined diurnal pattern (wave) of decreasing surface soil moisture during the day and recovery (or increased soil moisture) at night was observed.
- Expect: LSE has a diurnal wave-pattern variation with small values during daytime and larger values during nighttime.
- GOES-R ABI LSE algorithm + SEVIRI radiance measurements to demonstrate LSE diurnal variations
- Sahara Desert, sand soils
- Artifacts of algorithm? No, Evidences are provided
  - SEVIRI radiance observations
  - MODIS/Aqua radiance observations

2. SEVIRI LSE using GOES-R ABI algorithm

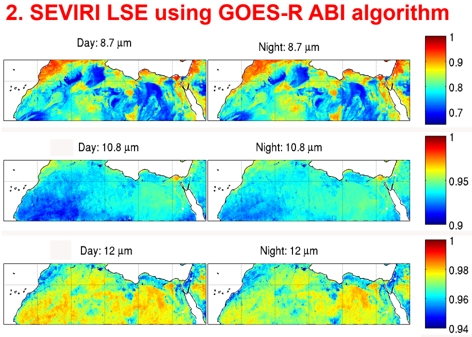

Figure 1. SEVIRI LSE one month composite for August 2006. The left panels are for Daytime at 14 UTC. And the right panels are for Nighttime at 02 UTC.

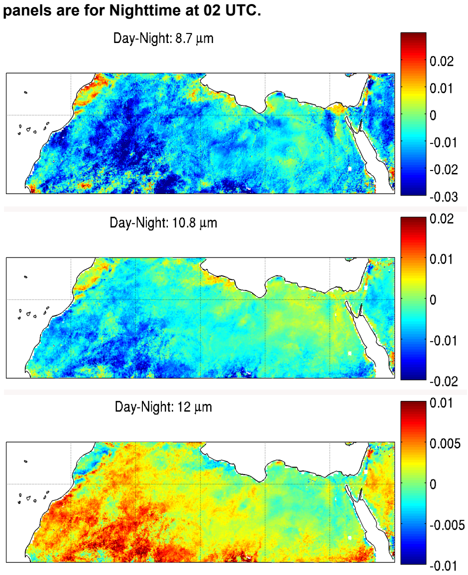

Figure 2. Day/Night difference of SEVIRI LSE for August 2006.

3. LSE diurnal variation seen by SEVIRI

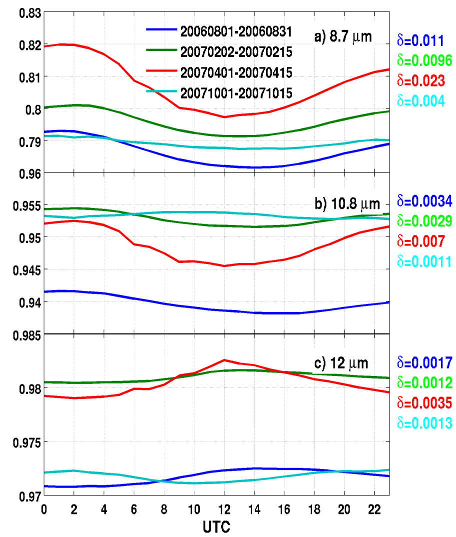

Figure 3. The mean averaged LSE diurnal variation from SEVIRI for August 2006.

4. Method to prove LSE diurnal variation

$$\delta R_{i,j} = R_i^o - R_i^c - (R_j^o - R_j^c)$$

$$= (K_i^{T_s} - K_j^{T_s})\sigma_{T_s} + K_i^{\varepsilon}\sigma_{\varepsilon_i} - K_j^{\varepsilon}\sigma_{\varepsilon_j} + \sum (K_i^T - K_j^T)\sigma_T + \sum (K_i^{\ln q} - K_j^{\ln q})\sigma_{\ln q} \quad (1)$$

Due to the similarity of the three window channels, the double difference greatly reduces the sensitivity to the errors of LST, temperature/moisture profiles, but maintains the sensitivity to errors of LSE. The relative importance of these components are: $\sigma_\varepsilon >> \sigma_{Ts} > \sigma_T \approx \sigma_{lnq}$. So Equ (1) can be simplified as

$$\delta R_{i,j} \approx \delta K_{i,j}^{T_s}\sigma_{T_s} + \overline{K_{i,j}^{\varepsilon}}(\sigma_{\varepsilon_i} - \sigma_{\varepsilon_j}) \quad (2)$$

For any two times, *t1* and *t2*, the difference is

$$\Delta\delta R_{i,j}^{t1,t2} = \delta K_{i,j}^{T_s}\Delta\sigma_{T_s}^{t1,t2} + \overline{K_{i,j}^{\varepsilon}}\Delta\delta\sigma_{\varepsilon_{i,j}}^{t1,t2} \quad (3)$$

From Equ (3), **there should exist a linear relationship between the temporal variation of *δR* and the temporal variation of LSE, and temporal variation of retrieved LST bias.**

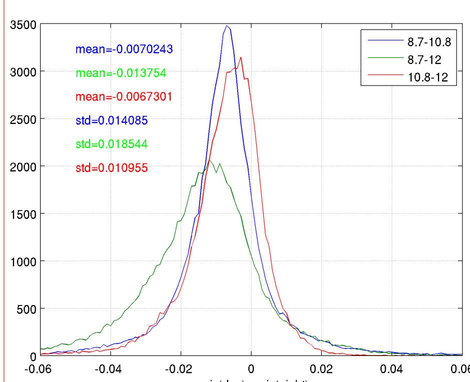

Figure 4. Histogram of the Day/Night difference of SEVIRI emissivity channel difference for 20060802-20060807.

4.1 Proof from SEVIRI observations

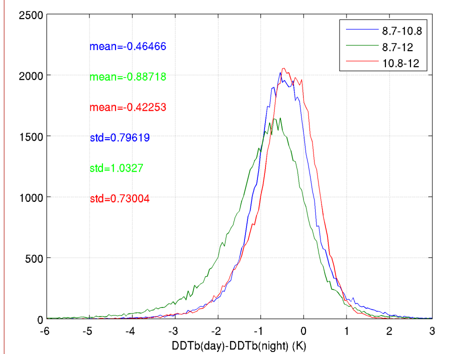

Figure 5. Histogram of the Day/Night difference of SEVIRI *δR* for 20060802-20060807.

4.2 Proof from MODIS/Aqua observations

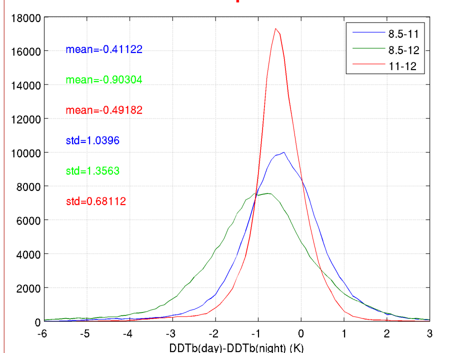

Figure 6. Histogram of the Day/Night difference of MODIS/Aqua *δR* for 20060802-20060807.

4.3 Consistency of SEVIRI and MODIS/Aqua

Sensitivity study shows

$$\delta K^{T_s} = \begin{bmatrix} -0.13 \\ -0.0636 \\ 0.0663 \end{bmatrix}$$

Equ (3) can be written as

$$\begin{bmatrix} -0.4647 & -0.4112 \\ -0.8872 & -0.9030 \\ -0.4225 & -0.4918 \end{bmatrix} = \begin{bmatrix} -0.1300 & -0.0070 \\ -0.0636 & -0.0138 \\ 0.0663 & -0.0067 \end{bmatrix} \times \begin{bmatrix} \Delta\sigma_{T_s} \\ \overline{K^{\varepsilon}} \end{bmatrix}$$

Solution is

$$\begin{bmatrix} \Delta\sigma_{T_s} \\ \overline{K^{\varepsilon}} \end{bmatrix} = \begin{bmatrix} 0.12 & -0.51 \\ 64 & 68 \end{bmatrix}$$

The estimated mean emissivity weighting functions are very close to each other, indicating both SEVIRI and MODIS/Aqua sees the LSE diurnal variations. The Daytime MYD11 LST appears to have negative bias compared to Nighttime, likely from the omission of LSE diurnal variation.

5. Summary

- Diurnal variation of LSE is seen by SEVIRI and can be proved by both SEVIRI and MODIS/Aqua observations.
- Omission of LSE diurnal variation could increase biases in
  - Deriving other products
  - Assimilating window channel radiances

6. Reference

Li, Zhenglong, J. Li, Y. Li, Y. Zhang, T. J. Schmit, L. Zhou, M. D. Goldberg, and W. P. Menzel (2012), Determining diurnal variations of land surface emissivity from geostationary satellites, J. Geophys. Res., 117, D23302, doi:10.1029/2012JD018279.

Li, Jun, Z. Li, X. Jin, T.J. Schmit, L. Zhou, and M. Goldberg (2011), Land surface emissivity from high temporal resolution geostationary infrared imager radiances: Methodology and simulation studies. J. Geophys. Res., 116, D01304, doi:10.1029/2010JD014637.