

SEASONAL SURFACE SPECTRAL EMISSIVITY DERIVED FROM MODIS DATA

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Introduction

Surface emissivity is essential for many remote-sensing applications including the retrieval of surface skin temperature from satellite-based infrared measurements, the determination of cloud detection thresholds, and the estimation of the surface longwave radiation emission, an important component of the energy budget of the surface-atmosphere interface. The CERES (Clouds and the Earth's Radiant Energy System) Project is measuring broadband shortwave and longwave radiances and deriving cloud properties from the MODIS on Terra and Aqua and from the VIIRS on NOAA-19 and NOAA-20 orbiters to produce combined global radiation and cloud property data sets. Zhou et al. (*IEEE Trans. Geosci. Remote Sens.*, 49, 2011) used Infrared Atmospheric Sounding Interferometer (IASI) data to create a high spectral resolution surface emissivity atlas for remote sensing and modeling applications. The IASI measures spectral radiances between 3.62 and 15.5 μm . The VIIRS 14 channel width is from 3.55 to 3.93 μm , while MODIS Band 20 is from 3.66 to 3.84 μm . Comparisons of top-of-atmosphere (TOA) radiance calculations with MODIS and VIIRS observations for these bands relative to bands in the mid-infrared suggest that the IASI emissivity atlas near 3.7 μm may not be suitable for CERES cloud retrievals. In this poster, the IASI emissivity for the MODIS band centered near 11 μm is used to derive surface skin temperature from nighttime MODIS data. The Goddard Earth Observing System for Instrument Teams (GEOS-IT) numerical weather analyses provide temperature and water vapor profiles fused to correct the observed radiances for atmospheric absorption and emission. Global seasonal emissivity maps are then derived for the MODIS 3.7- μm band that are consistent with the derived skin temperatures and the observed TOA radiances. These seasonal climatology maps will be validated and used in CERES Edition 5 and other CERES-related cloud retrieval algorithms to provide improved clear-sky radiances and derived cloud properties.

Objectives

Develop seasonal climatology of surface emissivities at 3.7 μm (denoted channel $i = 3$), using 11 μm (channel $i = 4$) surface emissivity from IASI

Data

- Aqua MODIS: 1 km resolution, 3.7 & 11 μm , 2018
- Global Modeling and Assimilation Office (GMAO), GEOS-IT: 3 hourly, $1^\circ \times 1^\circ$ grid cell.

Methodology

The method requires observations during nighttime. For each channel i , top-of-the-atmosphere (TOA) and surface radiance can be presented as

$$B(T_i) = \epsilon_{\text{eff}} B(T_{\text{sk}}) + (1 - \epsilon_{\text{eff}}) B(T_{\text{at}}) \quad (1)$$

B - the Planck function, ϵ_{eff} - effective atmospheric emissivity, i - channel
 T_{at} - effective atmospheric temperature, T_{sk} - apparent skin radiating temperature

In the absence of solar radiation, the radiation balance at surface is

$$B(T_{\text{sk}}) = \epsilon B(T_{\text{at}}) \quad (2)$$

T_{sk} - skin temperature, T_{at} - effective radiating temperature of the surface

At night,

$$T_{\text{sk}} = B^{-1}(B(T_{\text{sk}}) / \epsilon) \quad (3)$$

B^{-1} - inverse Planck function

Knowing skin temperature T_{sk} , derived from (1) using IASI emissivity window channel ϵ_{at} , GEOS-IT profile, and Corrk to bring the observed T_{down} to surface,

$$\epsilon = [B(T_{\text{sk}})] / [B(T_{\text{at}})] \quad (4)$$

T_{sk} can be derived from (1) at night using T_{sk} . Then ϵ can be computed using (4)

$$\epsilon = [B(T_{\text{sk}})] / [B(T_{\text{at}})] \quad (5)$$

Approach

- Apply the method above (method1) to Aqua MODIS data by computing ϵ for each clear nighttime pixel over snow/ice free land and averaging the values of ϵ within every 10° latitude-longitude box for a given orbit. A mean value of ϵ was computed for each region.
- Averages were also computed for each IGBP surface type (Table 1) and used to fill in regions with no valid data. Aqua MODIS data from the 12 months in 2018 were processed in this manner.

Results

Figures 1-4 show the distributions of ϵ derived from January, April, July and October of 2018 Aqua MODIS data from method1.

Figure 1. ϵ From January 2018

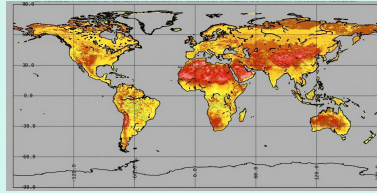


Figure 2. ϵ From April 2018

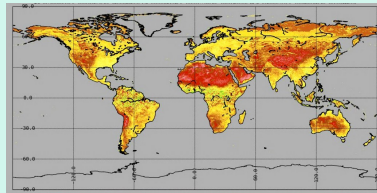


Figure 3. ϵ From July 2018

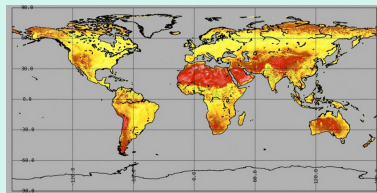
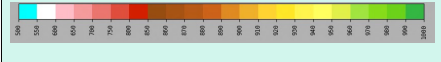
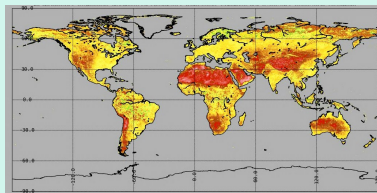


Figure 4. ϵ From October 2018



Figures 5-8 show the distributions of ϵ derived from January, April, July and October from IASI method2

Figure 5. ϵ From IASI January

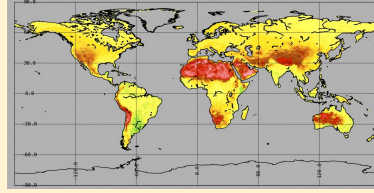


Figure 6. ϵ From IASI April

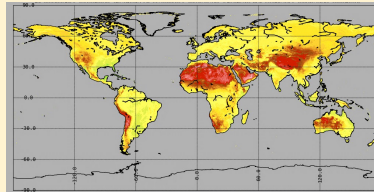


Figure 7. ϵ From IASI July

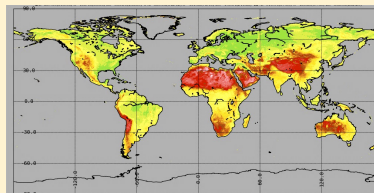


Figure 8. ϵ From IASI October

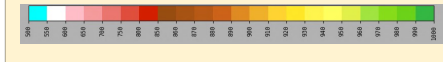
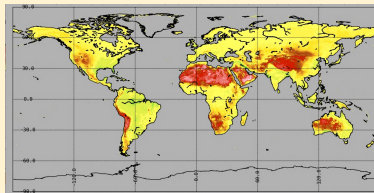


Figure 9 shows the histograms of ϵ from October 2018 Aqua MODIS data (method1) with respect to each IGBP type (Table 1).

Table 1. IGBP surface type

1. evergreen needleleaf
2. evergreen broadleaf
3. deciduous needleleaf
4. deciduous broadleaf
5. mixed forests
6. closed shrublands
7. open shrubland
8. woody savannahs
9. savannah
10. grasslands
11. permanent wetlands
12. croplands
13. urban
14. mosaic
15. snow/ice
16. desert
17. water
18. tundra
19. coastline = 10% to 90% water

Fig 9. Histogram of 3.75 μm Emissivity Oct of 2018 Histogram of 3.75 μm Emissivity

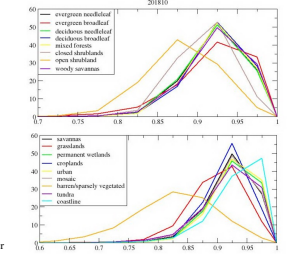
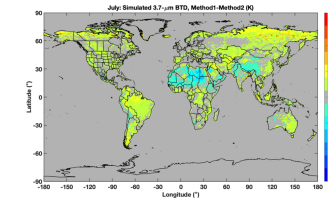


Table 2 summarizes the mean values of ϵ for each IGBP type for the four seasonal maps from method1 and method2.

Table 2. Mean ϵ from method1 and method2

IGBP	Jan		Apr		Jul		Oct	
	md1	md2	md1	md2	md1	md2	md1	md2
1	0.9109	0.9285	0.9196	0.9295	0.9232	0.9483	0.9248	0.9377
2	0.9179	0.9419	0.9210	0.9409	0.9117	0.9452	0.9241	0.9473
3	0.9125	0.9388	0.8938	0.9235	0.9157	0.9524	0.9250	0.9354
4	0.9120	0.9313	0.9205	0.9345	0.9326	0.9483	0.9280	0.9433
5	0.9093	0.9309	0.9201	0.9331	0.9371	0.9535	0.9268	0.9411
6	0.9083	0.9279	0.9074	0.9296	0.9060	0.9220	0.9105	0.9287
7	0.8748	0.9167	0.8812	0.9153	0.8762	0.9253	0.8808	0.9193
8	0.9179	0.9336	0.9195	0.9314	0.9255	0.9489	0.9271	0.9391
9	0.9175	0.9383	0.9176	0.9337	0.9210	0.9467	0.9248	0.9410
10	0.8857	0.9203	0.8920	0.9148	0.9059	0.9220	0.8998	0.9211
11	0.9291	0.9380	0.9203	0.9349	0.9420	0.9608	0.9282	0.9462
12	0.9053	0.9311	0.9125	0.9324	0.9256	0.9452	0.9201	0.9430
13	0.9207	0.9304	0.9295	0.9386	0.9299	0.9486	0.9314	0.9456
14	0.9175	0.9344	0.9203	0.9357	0.9228	0.9385	0.9236	0.9414
16	0.8125	0.8289	0.8293	0.8381	0.8253	0.8186	0.8279	0.8312
18	0.9165	0.9397	0.9084	0.9290	0.9100	0.9286	0.9232	0.9367
19	0.9313	0.9420	0.9345	0.9380	0.9352	0.9497	0.9378	0.9474

Fig 10. Simulated 3.7 μm BTD Method1 minus Method2 from July 2018



- The most barren deserts like the Sahara do not show much seasonal variation for both methods.
- Some of the IGBP types, like tundra and deciduous needleleaf forests, are not well sampled and are not reliable for method1, especially in the winter months.
- On average, the temperature bias between method1 and method2 is -0.1 to 0.4 K over land.
- The ocean and snow categories are not included in this study.

Conclusions & Future Work

- The emissivity values derived from method1 with full band width of 3.75 μm are mostly lower than the ones from method2.
- Both emissivity maps will be validated to determine which one is better for Eds CERES cloud production process.