Improvements to Infrared Land Surface Emissivity for the Community Radiative Transfer Model

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Abstract

A new infrared land surface emissivity look-up table (LUT) has been developed for the Community Radiative Transfer Model (CRTM). It is designed to match the GFS Vegetation Type classification scheme (13 classes). The emissivities are based on spectral reflectances of various materials from the JPL Spectral Library. Comparisons of CRTM simulation to satellite observation were used to select vegetation and soil blends from the JPL Spectral Library that minimize brightness temperature bias. Weekly climatological green vegetation fraction adds a temporal component to the emissivity. Corrected surface temperature from the EMC-Land Group was used to ensure that emissivity is not compensating for biases in surface temperature. A time series of comparisons shows consistent improvement in CRTM-to-satellite bias and RMSE when using the new emissivity.

Methodology

1) Establish varying proportions of vegetation and soil reflectances from JPL Spectral Library in a "Test Matrix". Blends of vegetation and soil are specific for each of the 13 GFS Vegetation Types. Over 400 combinations of veg & soil reflectances were tested.
2) Run CRTM for all tests in Test Matrix and compare CRTM simulation to GOES-Imager satellite observation on a single day.
3) Calculate bias for each test in Test Matrix and select the blended veg & soil proportion for which the bias is the smallest. The new emissivity LUT represents the best blended proportion (smallest bias) for each of the 13 GFS Vegetation Types.
4) Verify CRTM-to-satellite bias remains small on independent days (seasonal time series).

By choosing proportions where the difference between the CRTM simulation and satellite observation are minimized, we know the emissivity is improved.

CAVEAT: Ts bias must also be small, because Ts and emissivity are correlated.

- Use of nighttime data (small Ts bias) and new corrected Ts (Exp_70) from EMC-Land Group (for daytime) prevents correcting of Ts bias along with emissivity.

Example Test Matrix: GFS Veg Type #6: broadleaf tree w/groundcover (Savanna)

$Refl_{broadleaf}$ = %Veg * (Veg blend) + %Soil * (Soil blend)

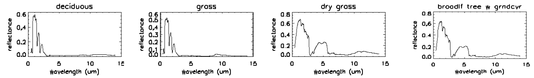
% Veg	Veg blend	% Soil	Soil blend
0.7	0.3 decid + 0.7 grass	0.3	0.1 clay + 0.3 silt + 0.6 sand
0.5	0.5 decid + 0.5 grass	0.5	0.6 clay + 0.3 silt + 0.1 sand
0.3	0.4 decid + 0.4 grass + 0.2 dry grass	0.7	0.1 clay + 0.6 silt + 0.3 sand
	0.3 decid + 0.3 grass + 0.4 dry grass		0.3 clay + 0.4 silt + 0.3 sand
	0.1 decid + 0.1 grass + 0.8 dry grass		

Emissivity

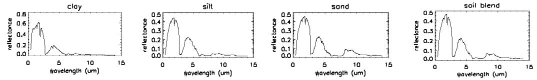
CRTM-to-satellite comparisons resulted in selection of "best" bias from all tests for each of 13 GFS Vegetation Types and satellite band. A new IR emissivity LUT was constructed using the veg & soil blend from "best" bias, for example:

JPL Spectral Library reflectance — CRTM Emis LUT

.1 deciduous + .1 grass + .8 dry grass = Type #6 Savanna



.1 clay + .3 silt + .6 sand = Soil Reflectance



Seasonality

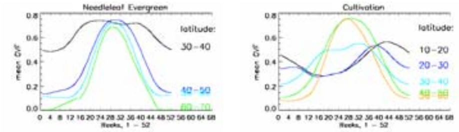
Emissivity was given a temporal component by adding green vegetation fraction (GVF) to emissivity. GVF proportionally adds soil reflectance $R_{Soilblend}$ where surface is not green (more soil added as vegetation decreases in winter):

$$Refl_{type,t,\lambda} = (GVF_t \times Refl_{Vegblend,type,\lambda}) + ((1-GVF_t) \times Refl_{Soilblend,\lambda})$$
$$Emis_{type,t,\lambda} = 1 - Refl_{type,t,\lambda}$$

1) Green vegetation fraction (Jiang et al., 2008): weekly GVF climatology from 25 years of AVHRR data (1982 – 2006)

2) LUT created for CRTM that averages GVF for each of the 13 GFS vegetation types by latitude (10-degree latitude bands) and time: 3-dimensional GVF LUT (52 weeks x 13 surface types x 18 latitude bands). GVF dynamics are preserved in the LUT, for example:

GVF Look-up Table for CRTM for 2 GFS Vegetation Types:



CRTM-to-Satellite Comparison

CRTM (forward model) was run with current (NPOESS) and new (JPL-based) emissivity LUTs and compared to GOES-East (GOES-12) channel 2 (3.9μm) and channel 4 (10.7μm). CRTM inputs: GDAS atmospheric profiles and surface parameters, interpolated to pixel using GSI interpolation.

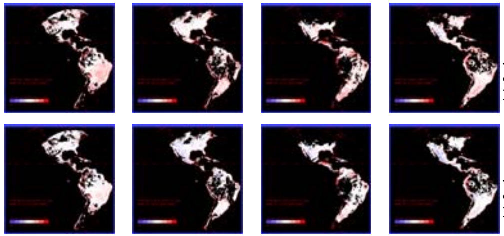
Time Series of CRTM Tb minus GOES Tb (K), Channel 2 (3.9μm), Nighttime.

New emissivity shows improvement over current emissivity:

2008-07-21 | 2008-10-19 | 2009-01-14 | 2009-04-17

Current Emissivity (NPOESS)

New Emissivity (JPL-based)



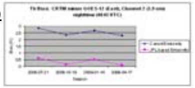
Tb Difference (K) color bar: -20 (CRTM higher) – +20 (GOES higher)

Tb Difference (K) color bar: -20 (CRTM higher) – +20 (GOES higher)

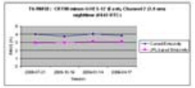
Tb Bias and RMSE time series, CRTM minus GOES: new emissivity improved over current emissivity

Ch 2 (3.9 μm)

Bias (K)

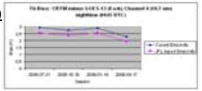


RMSE (K)

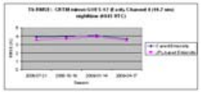


Ch 4 (10.7 μm)

Bias (K)



RMSE (K)



Conclusion

- The new infrared land surface emissivity look-up table (LUT) based on JPL Spectral Library reflectances improves CRTM-to-satellite comparisons in both bias and RMSE for window channels.
- Green vegetation fraction (GVF) is used to create a temporal component to the emissivity. The CRTM-to-satellite comparisons show consistent bias and RMSE reduction across seasons.
- The new IR emissivity LUT matches the GFS Vegetation Types (13 classes).