Global Broadband IR Surface Emissivity Computed from Combined ASTER and MODIS Emissivity over Land (CAMEL)

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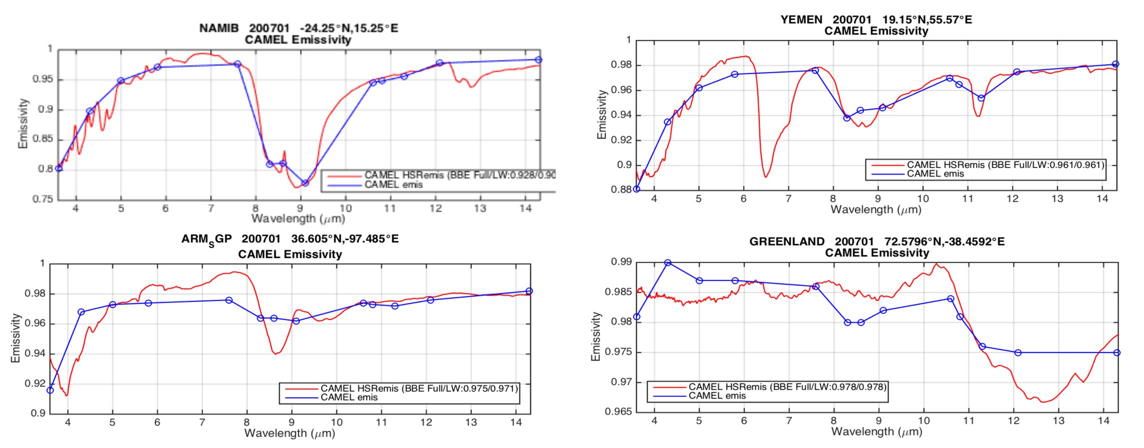
Introduction

Infrared Surface Emissivity

- Infrared surface emissivity (radiation emitted by Earth's surface, which is a non-ideal blackbody) is an important variable in the estimation of LW net radiation, a critical parameter in weather and climate models and the earth radiation budget.
- Due to a prior lack of spatially and temporally variant global broadband emissivity (BBE) measurements, it is common practice in land surface models to use a single constant BBE over the globe. This can lead to systematic biases in the estimated net radiation for any particular location and time of year.
- Several efforts have recently been put forth to develop BBE datasets using satellite measurements (e.g. Wang et al. 2005; Tang et al. 2010; Ogawa et al. 2002, 2008; Huazhong et al. 2013; Cheng et al. 2012, 2015). Such methods involve regressions of BBE to the measured narrowband emissivities.

New High Spectral Resolution Dataset

- Under the NASA MEaSUREs project a new global, high spectral resolution land surface emissivity database is being made available as part of the Unified and Coherent Land Surface Temperature and Emissivity ESDR
- This CAMEL emissivity database is created by the merging of the MODIS baseline-fit emissivity database (UWIREMIS) developed at UW-Madison and the ASTER Global Emissivity Dataset v4 produced at Jet Propulsion Laboratory
- Available for 2000-2017 at monthly mean, ~5km resolution for 13 bands within the 3.6-14.3 micron region, this dataset is extended to 417 infrared spectral channels using a principal component regression approach
- This work makes use of the recently released CAMEL beta version v0.6

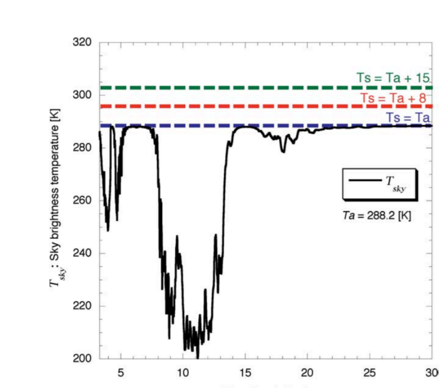


Broadband Emissivity

- BBE is calculated using the CAMEL high spectral resolution database and MODIS surface temperature as follows:

$$\varepsilon_{\rm BB} = \frac{\int_{\lambda 1}^{\lambda 2} \varepsilon_\lambda B_\lambda(T_s) d\lambda}{\int_{\lambda 1}^{\lambda 2} B_\lambda(T_s) d\lambda}$$

where ε_λ is the CAMEL emissivity and B_λ is the Planck function at wavelength λ, and T_s is the monthly MODIS surface temperature – specifically the average of the day and night value. If no MODIS surface temperature is available a default value of 290 K is used. Studies have shown that BBE is insensitive to typical fluctuations of Earth's temperature.
- BBE over two wavelength ranges is computed—the full available MEaSUREs spectrum from 3.6-14.3 μm and 8.0-13.5 μm, which has been determined to be an optimal range for computing the most representative all wavelength, LW net radiation (Ogawa and Schmugge, 2000, 2004; Cheng et al, 2013)
- This dataset provides the advantages of being consistent with the MEaSUREs HSR emissivity and not requiring regression schemes—BBE can be calculated by simple numerical integration over the MEaSUREs high spectral resolution emissivity product



Figures 1 and 2 from Ogawa and Schmugge (2004) show for multiple surface temperatures that the 8-13.5 μm region is the most optimal wavelength range they studied (of 3-14μm, 8-12μm, and 8-13.5μm) for computing longwave net radiation.

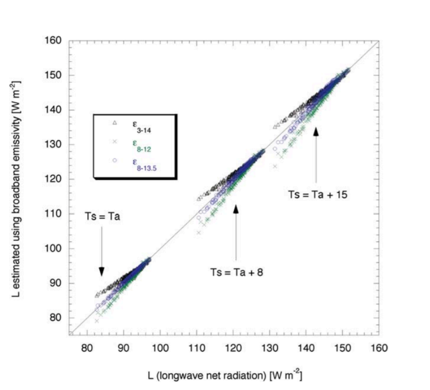


Figure 1. The effective temperature of downwelling atmospheric radiation. The difference from the surface temperature is much larger inside the atmospheric window region (8–13.5 μm) than outside.

Figure 2. The comparison of the calculated net longwave radiation (L_n) from emissivity spectra with estimated L_n from the broadband emissivity. Each point represents an emissivity spectrum from spectral libraries. Here $\varepsilon_{8-13.5}$ shows the best results for all three temperatures.

References

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Acknowledgements

We acknowledge the the NASA and United States Geological Survey (USGS) Land Processes Distributed Active Archive Center for providing MODIS skin temperature product MOD11C3 (https://lpdaac.usgs.gov/-dataset_discovery/modis) and the Global Land Cover Facility for the IGBP land cover product (http://glcf.umd.edu/data/lc/). More info on the land cover product is in Channan et al. (2013). This poster uses the NASA MEaSUREs CAMEL beta v0.6 release.
The Köppen-Geiger Climate Classifcation scheme data was accessed at http://koeppen-geiger.vu-wien.ac.at/present.htm. More information can be found in Kottek et al (2002).
This work was funded by grant number: 1498402.

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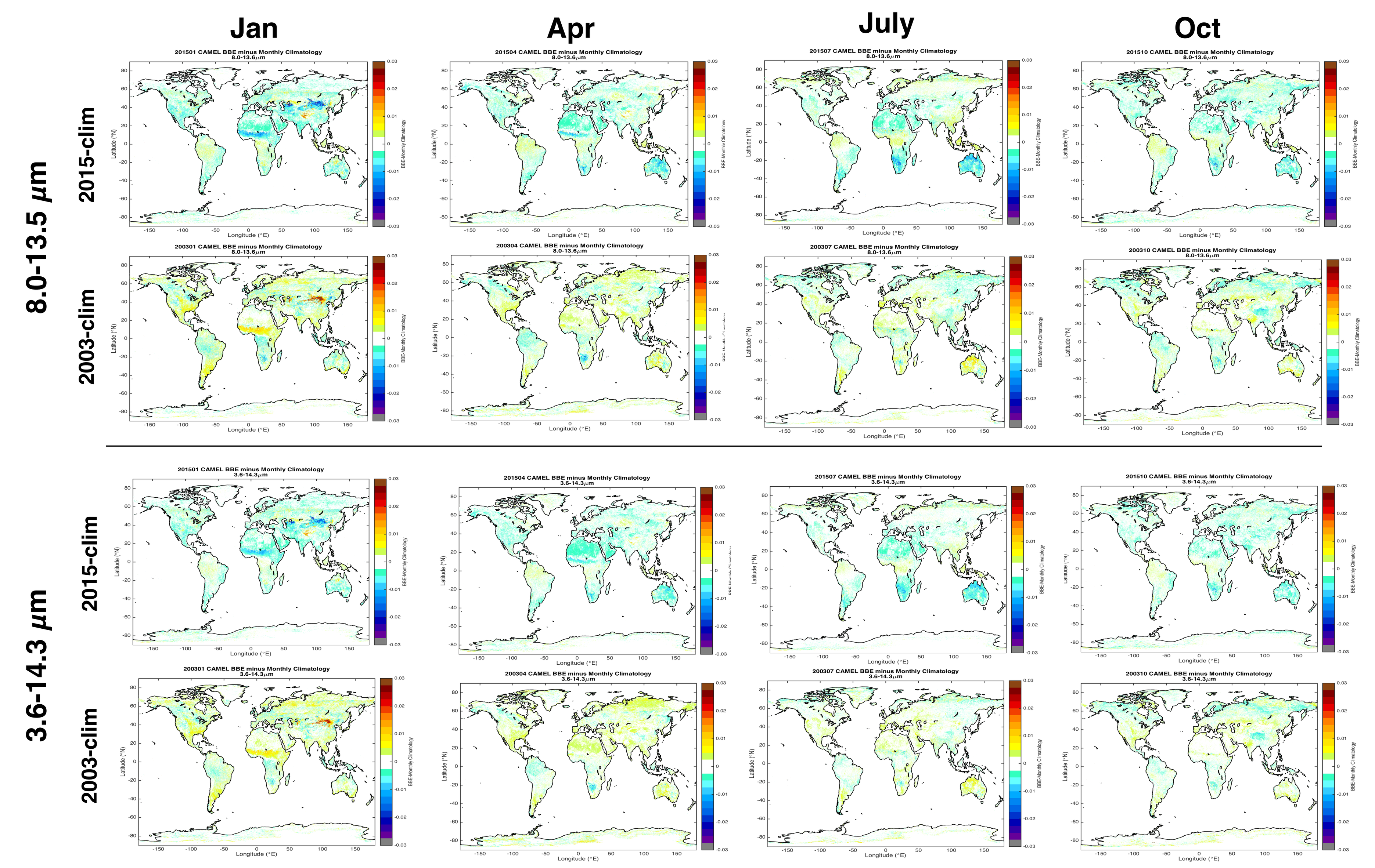
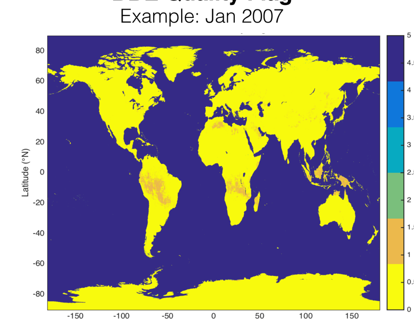
Monthly Broadband Emissivity

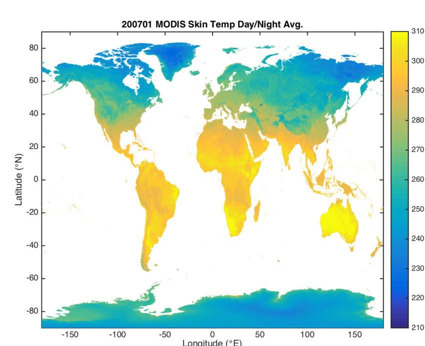


The right most vertical panel shows monthly climatologies over the CAMEL 2003-2015 record for every month. Figures to the left are differences of monthly-climatology BBE for 2 different wavelength ranges. Greater than 1% differences are common. Largest differences are seen in the month of January.

BBE Quality Flag
Example: Jan 2007



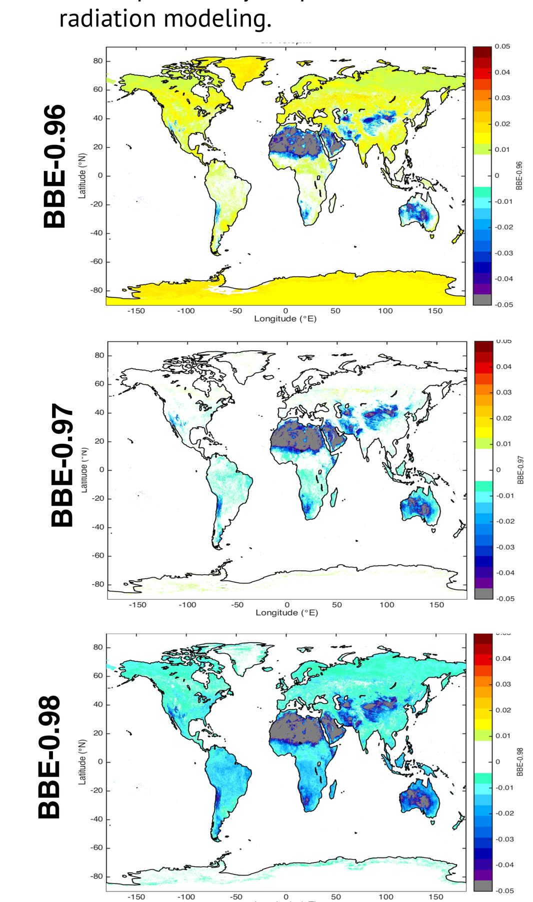
Quality Flag Description:
0: good
1: good, no MOD11 skt (default 290K used)
2: bbe outside 0.8-1.0
3: bbe calc failed
4: no bbe – no CAMEL coefs
5: no bbe – sea/inland water

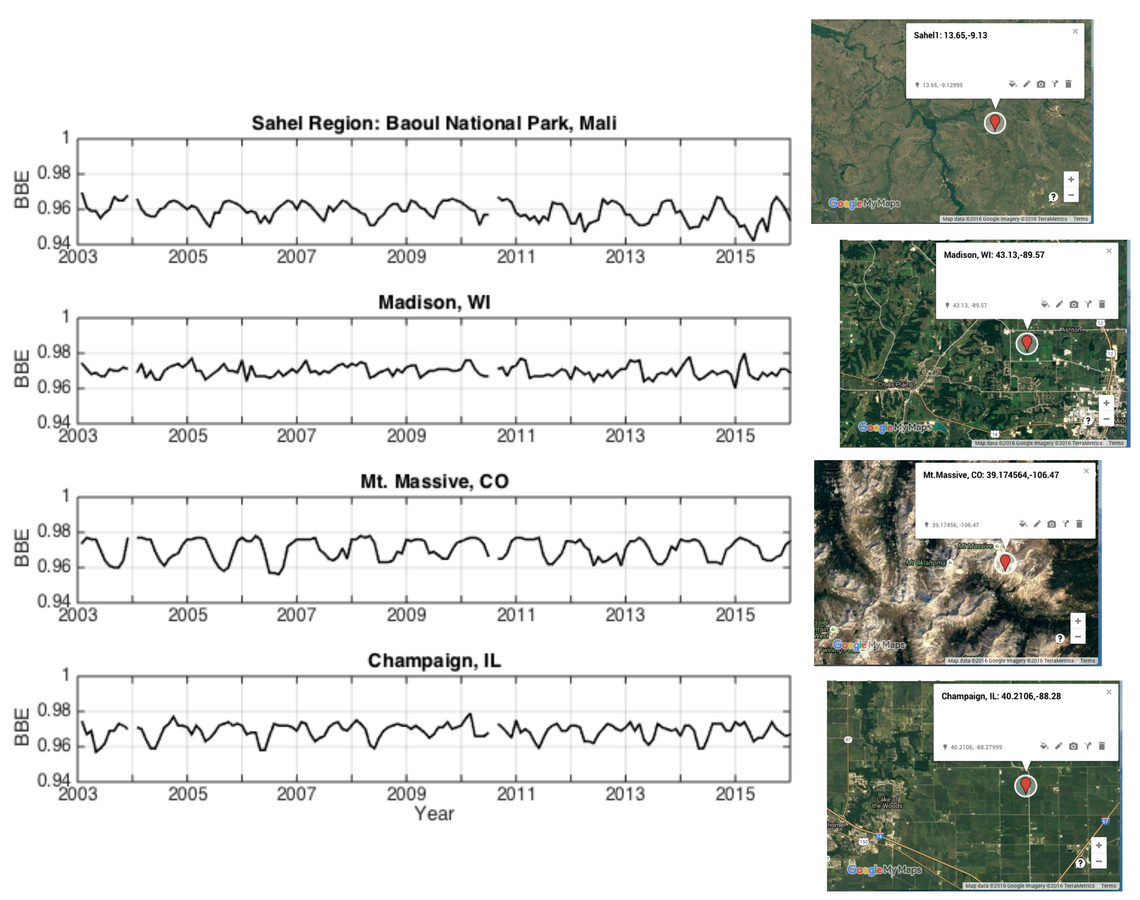


Constant BBE

8.0-13.5 μm, Jan 2007

BBE is set to a single, global constant value of 0.98 over time and space in some land surface models. The difference maps below suggest 0.97 is a more proper choice for a BBE constant for the month shown. The use of a BBE value that varies over time and land cover classifications could potentially improve such surface radiation modeling.





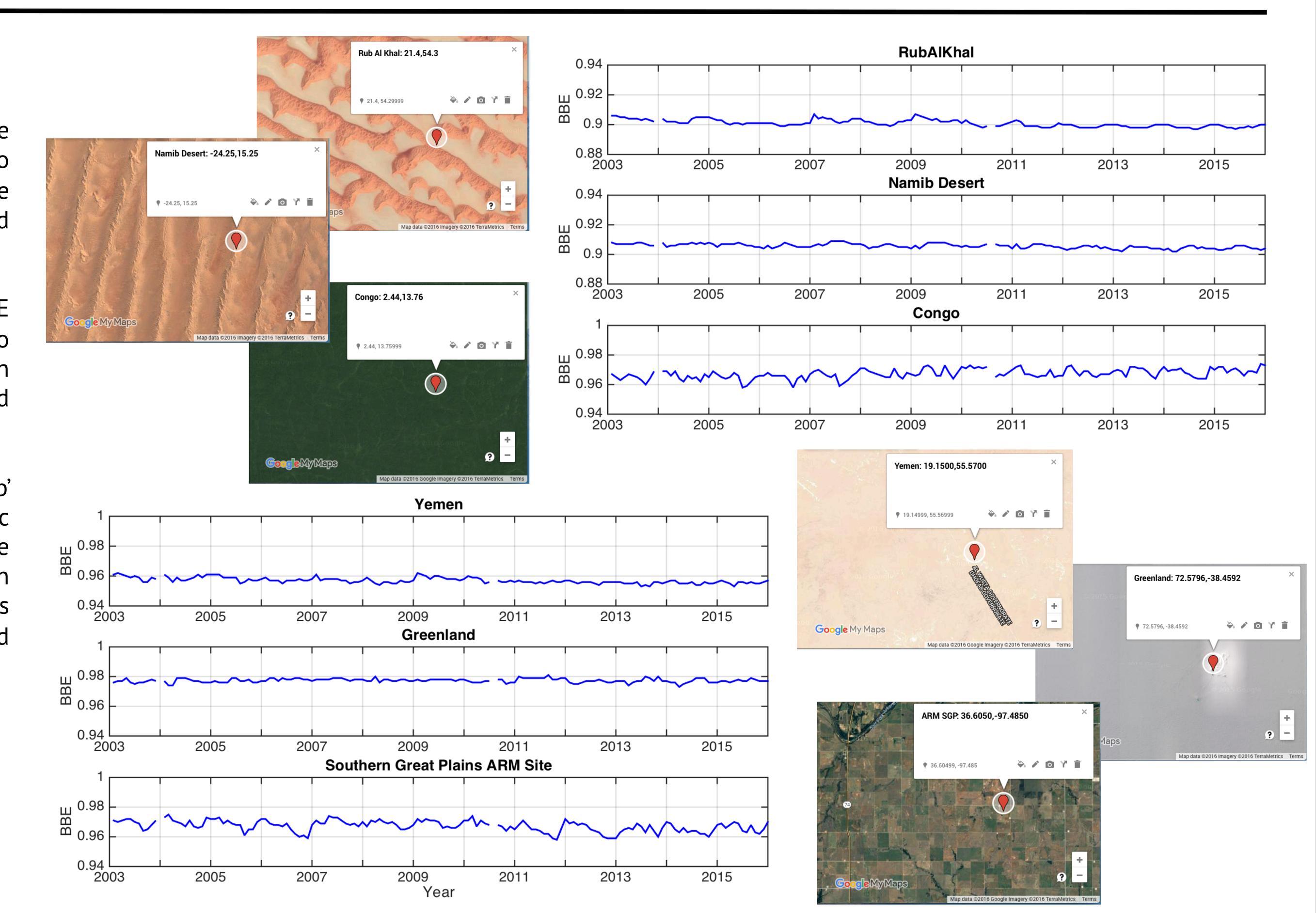
BBE Time Series

Variation of the CAMEL BBE over time is shown by time series of figures to the left and right. Time series are taken over the locations as identified in the Google Maps images.

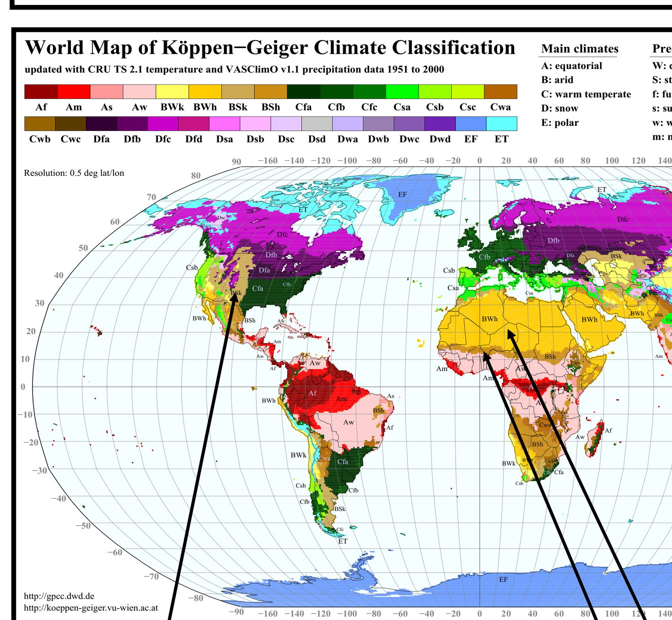
The monthly, 8.0-13.5 micron BBE averaged over an ~5 km grid is seen to change annually by up to 0.02 as seen over the Sahel and a snow covered mountain range in CO to the left.

At validation sites such as in the Rub' Al Khali Desert, quartz characteristic Namib Desert, Greenland snow/ice region, Congo forest, and Yemen carbonate region, annual variation is not seen to be large, which is a desired trait for such sites.

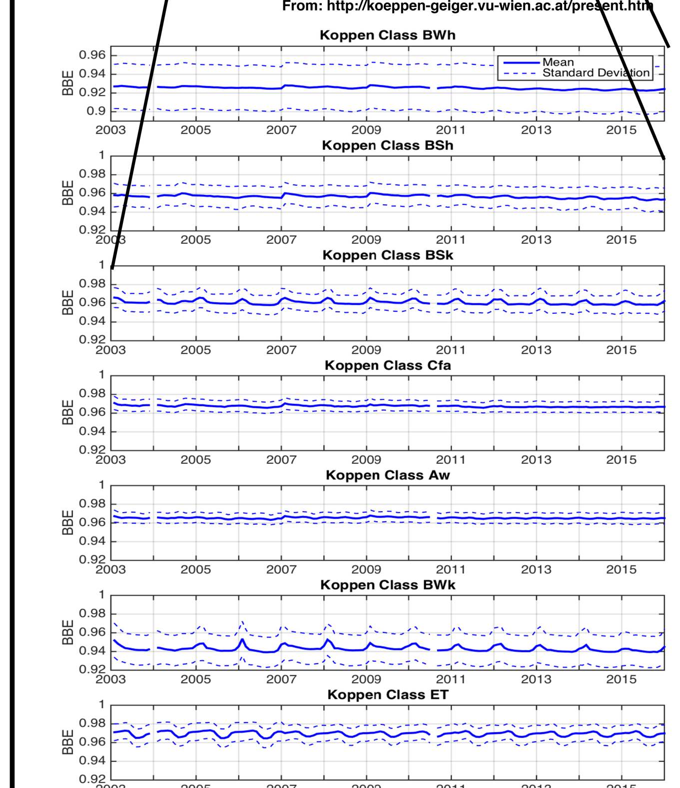
(**Note: Images of Earth's surface from Google Maps do not represent the specific ~5 km grid, but an ~9x12mile or 15x20km region)



Statistics by Land Surface Types

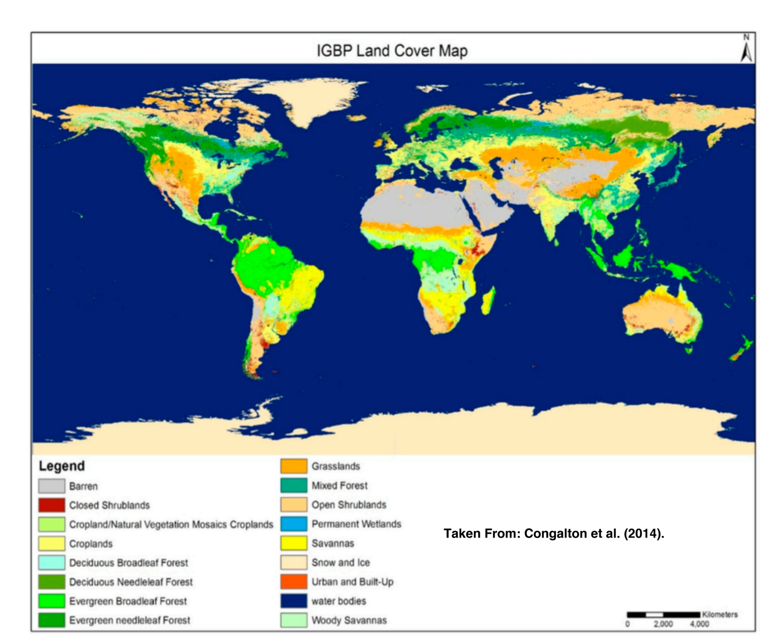


From: http://koeppen-geiger.vu-wien.ac.at/present.htm



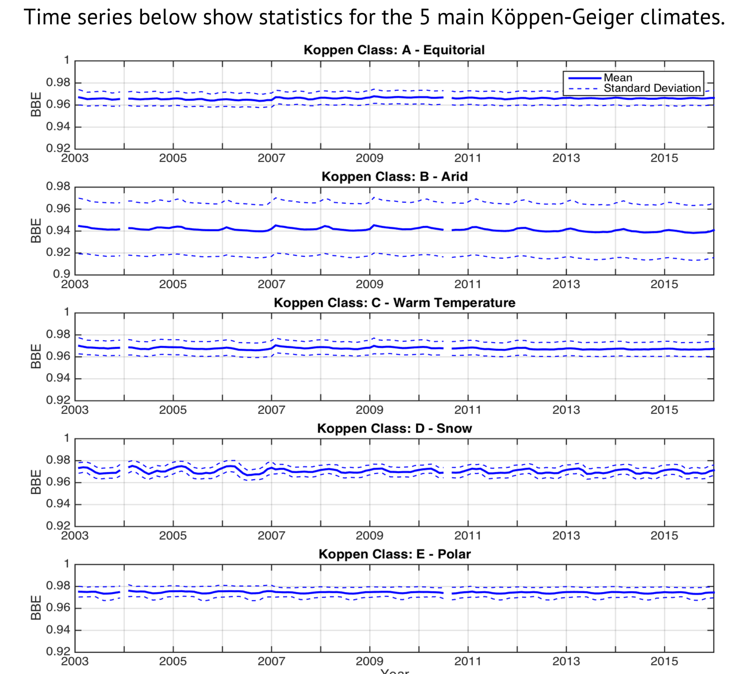
Statistics for monthly, 8.0-13.5 micron BBE were calculated according to IGBP land cover categories (map to right) and Köppen-Geiger Climate Classifcations (map to left).

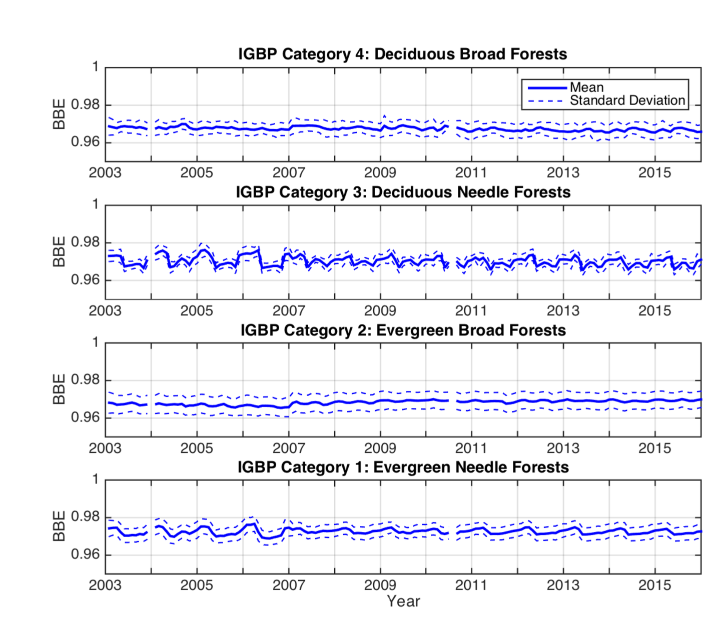
Time series of monthly mean BBE overlaid with the monthly mean +/- monthly standard deviations are shown for IGBP categories in the right two columns and for Köppen-Geiger classifications in the left two columns. Uncertainty of the mean was found to be negligible.
Larger standard deviations highlight the land cover types that are not as well represented by a single, constant BBE value.

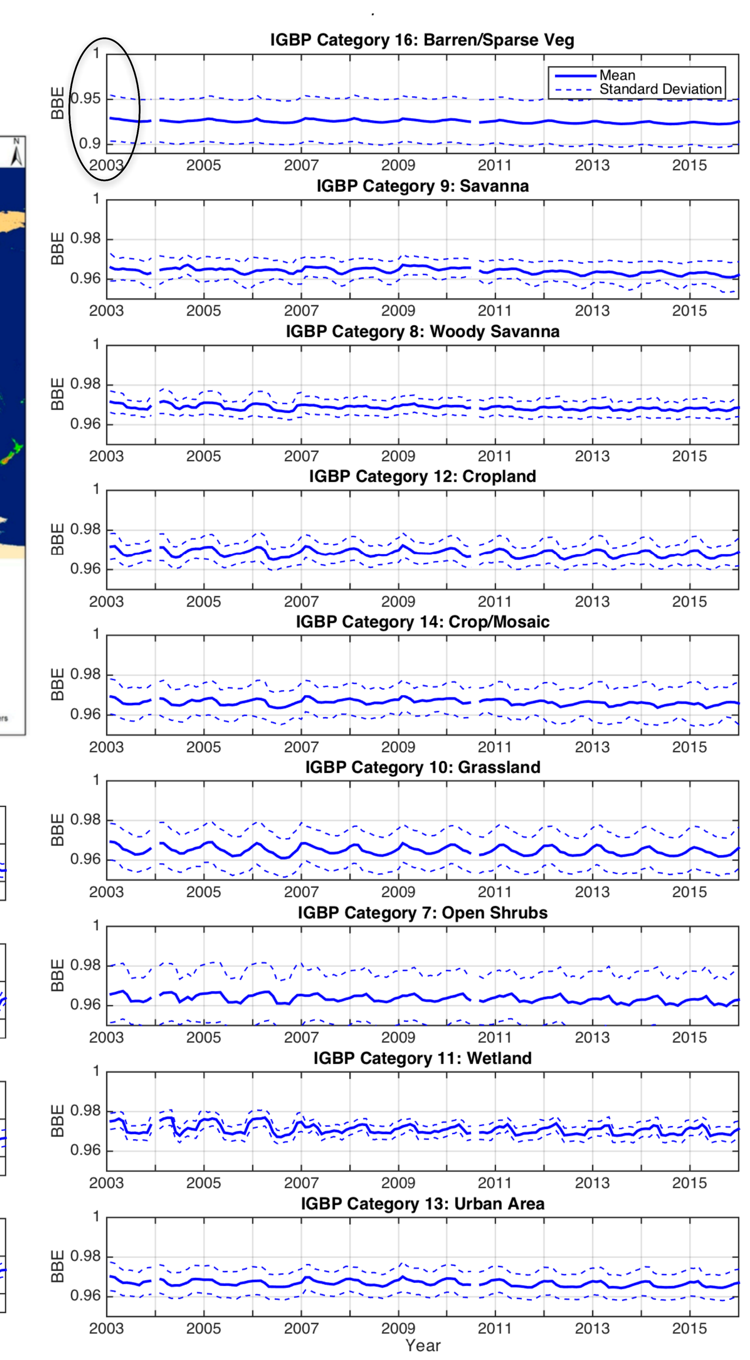


Taken From: Congalton et al. (2014).

Time series below show statistics for the 5 main Köppen-Geiger climates.







Climatology

2003-2015

8.0-13.5 μm