8.4 A SCALING METHODOLOGY TO COMPARE LAND SURFACE TEMPERATURE PRODUCTS DERIVED FROM THE VISIBLE INFRARED IMAGER RADIOMETER SUITE (VIIRS) AND MEASURED BY NOAA'S OBSERVATIONAL NETWORKS

Pierre C. Guillevic [a,b,*], Jeffrey L. Privette [b], Benoit Coudert [c], Egg Davis [b,d], Tilden Meyers [e], Michael A. Palecki [b], John A. Augustine [f] and Catherine Ottlé [g]

[a] Cooperative Institute for Climate and Satellites (CICS), North Carolina State University, Asheville, NC 28801, USA

[b] NOAA's National Climatic Data Center (NCDC), Asheville, NC 28801, USA

[c] Centre d'Etudes Spatiales de la Biosphère (CESBIO), 31401 Toulouse, France

[d] STG Inc., Asheville, NC 28801, USA

[e] NOAA's – Atmospheric Turbulence and Diffusion Division (ARL/ATDD), Oak Ridge, TN 37830, USA

[f] NOAA's Earth System Research Laboratory (ESRL), Boulder, CO 80305, USA

[g] LSCE – IPSL, CEA, 91191 Gif-sur-Yvette cedex, France

1. INTRODUCTION

Land Surface Temperature (LST) is a key variable that helps govern radiative, latent and sensible heat fluxes at the biosphere-atmosphere interface. Thus, understanding and monitoring the dynamics of the LST and links with the human induced changes is critical for modeling and predicting climate and environmental changes, and for many other applications such as geology, hydrology and vegetation monitoring (Kerr *et al.*, 2004). For instance, simulations with climate models show that a reduction in vegetation cover modifies the balances of latent and sensible heat fluxes, leading to an increase of LST and a decrease of evapotranspiration and precipitation over land surfaces (Meng *et al.*, 2009; Guillevic *et al.*, 2002; Guillevic and Koster, 2002; Collatz *et al.*, 2000; Shukla and Minth, 1982). Consequently, LST is an important element of the climate system that can be derived from satellite observations to monitor long-term environmental changes.

The LST Environmental Data Record (EDR) derived from the Visible Infrared Imager Radiometer Suite (VIIRS), a sensor aboard the NPOESS Preparatory Project (NPP) and future Joint Polar Satellite System (JPSS) platforms, will provide high spatial resolution images of the surface LST. The objective of this paper is to present a new validation methodology developed to monitor the quality of the VIIRS LST EDR over both homogeneous and heterogeneous surfaces (e.g., mixed vegetation classes).

* Corresponding author:
Pierre Guillevic, Cooperative Institute for Climate and Satellites (CICS), North Carolina State University,
E-mail: pierre.guillevic@noaa.gov

The approach combines point field data and fine resolution imagery in a land surface model to characterize the LST over moderate resolution scales (multiple km). The model estimates the thermal radiance for each subpixel grid cell, then integrates over the all grid cells to provide an LST estimate that is comparable with a VIIRS measurement over the same area. The approach is tested using MODIS LST collection 5 products as proxy for VIIRS products, and ground data from two collocated NOAA's micrometeorological stations from the US Climate Reference Network (USCRN) and the Surface Radiation Budget (SURFRAD) network located in Bondville, IL, USA. The site is a 14-acre area covered with a mix of prairie grass and clover surrounded by wheat and soybean crops with a different phenology.

2. VALIDATION METHODOLOGY DESCRIPTION

The LST validation scheme outlined here is anchored to ground-based observations. For most mixed vegetated landscapes, composed of various land cover types or soils, the LST measured by a station at one specific location – i.e., a point measurement – does not represent the surrounding area that is part of the coarser satellite sensor pixel. In the present work, the SETHYS land surface model model is used to estimate these components for a subpixel cell using measured surface and meteorological parameters. A cell is defined here as a 250m resolution area of homogeneous, or evenly mixed heterogeneous, vegetation cover. The model is executed for each cell, then used to estimate the aggregate LST over all subpixel cells. Here, a MODIS LST pixel is composed of 16 subpixel cells.

3. THE SETHYS LAND SURFACE MODEL

The SETHYS – for “Suivi de l’ETat HYdrique des Sols,” French acronym for soil moisture monitoring – land surface model (Coudert *et al.*, 2006) is a one dimensional soil-vegetation-atmosphere transfer model that especially represents the LST diurnal cycle and the associated response of remote sensing sensors, accounting for specific spectral domains and viewing configurations. The model needs atmospheric forcing and surface biophysical parameters as inputs, and simulates the energy and water exchanges between the surface and the atmosphere. The parameterizations of energy and water transfers used in the model are conceptual and involve a set of parameters that are usually not routinely measured at ground level. Thus, model calibration consists in the minimization of a cost function expressing the divergence between model outputs and observations. We used the multi-objective calibration iterative process (MCIP) (Demarty *et al.*, 2005), that is based on a stochastic Monte Carlo approach, and consists of the reduction of initial parameter ranges by the optimization of one or several model outputs against observations, e.g., LST bias and root mean square error (RMSE) here.

4. FIELD DATA NETWORKS

Our validation approach is designed to be applicable over two NOAA field measurements networks:

- The U.S. Climate Reference Network (USCRN) (Leduc *et al.*, 2009) provides weather and climate measurements over 120 stations developed, deployed, managed, and maintained by the National Oceanic and Atmospheric Administration (NOAA) in the continental United States for the express purpose of detecting the signal of climate change. The USCRN data are representative of local environmental conditions (Fig. 1).

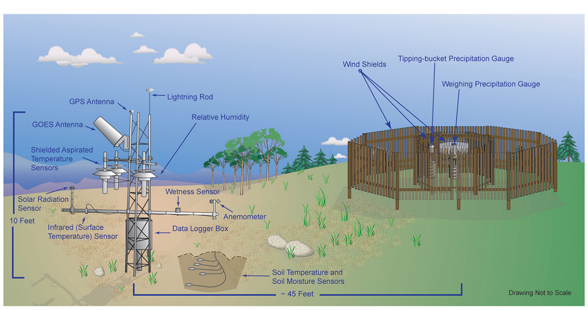

Figure 1: Schematic description of a US Climate reference Network station. Each station has the same design.

- The Surface Radiation Budget Network (SURFRAD) (Augustine *et al.*, 2005) was established in 1993 with its primary objective to support climate research with accurate, continuous, long-term measurements of the surface radiation budget over the United States. Independent measures of upwelling and downwelling, solar and infrared are the primary measurements; ancillary observations include direct and diffuse solar, photosynthetically active radiation, UVB, spectral solar, and meteorological parameters.

5. SATELLITE PRODUCTS

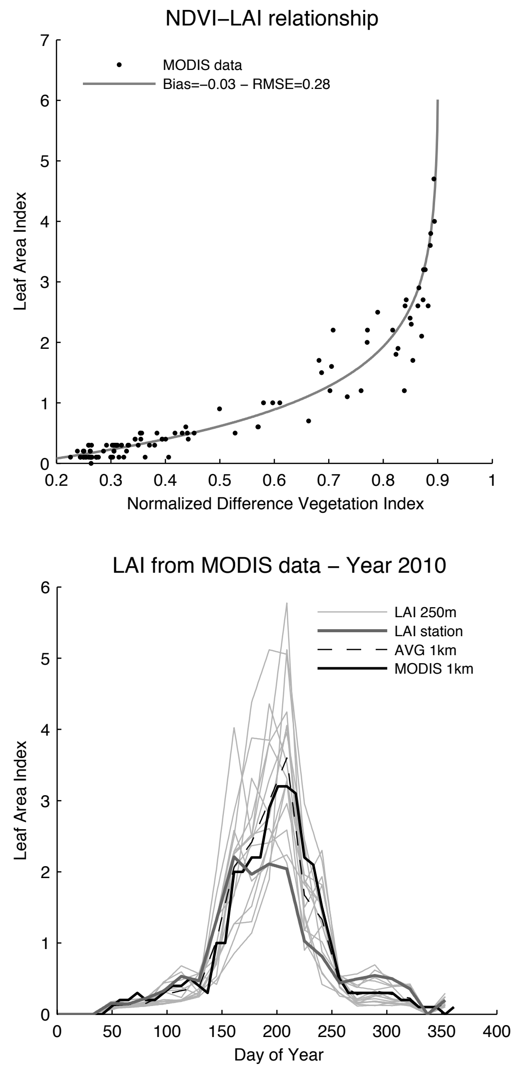

Figure 2: Relationship between NDVI and LAI MODIS standard-products at 1 km resolution (left). The relationship obtained at 1km is applied to high-resolution NDVI data to derive LAI values at 250m resolution (right). The averaged LAI value of the 16 sub-pixels included in a moderate resolution pixel and the MODIS LAI standard-product at 1 km are represented.

We use land surface products derived from the Moderate Resolution Imaging Spectroradiometers (MODIS) (Barnes *et al.*, 1998) onboard Terra and Aqua satellites to develop and evaluate the VIIRS validation methodology.

The MODIS LST Collection 5 product suite developed by Wan *et al.* (2002) is based on the local split-window technique (Becker and Li, 1990; Wan and Dozier, 1996), and is provided at ≈927m resolution. The scaling methodology requires higher resolution information about vegetation density. We use a relationship between the NDVI and the LAI of vegetation covers (Asrar *et al.*, 1984; Courault *et al.*, 2010) to estimate the LAI at 250m resolution (Fig. 2). The relation is calibrated using MODIS NDVI and LAI at 1km, and used to estimate LAI at 250m resolution using 250m MODIS NDVI product as input.

6. RESULTS AND DISCUSSION

The experiment is based on one year of data collected in 2010 (table 1). We had selected six periods of time with significant clear days and good quality satellite data.

Table 1: Periods of time selected to evaluate the validation scheme. Quality flags associated with MODIS data are used to define six periods with no obvious and persistent clouds over the area. Number of quality-controlled MODIS data available for each period is indicated.

Period	First day	Last day	Number of "clear sky" MODIS data		
			Daytime	Nighttime	Total
1	98	108	8	12	20
2	165	179	6	3	9
3	218	228	8	4	12
4	239	249	10	7	17
5	272	282	15	17	32
6	285	295	8	14	22
		TOTAL	**55**	**58**	**113**

The model has been calibrated for the six selected validation periods (table 1), by adjusting twenty-three model parameters using the iterative MCIP algorithm. Ten algorithm iterations are processed to reduce the parameter ranges and minimize two predefined cost functions: the bias and root mean square error (RMSE) calculated between simulated and ground-based LST. The bias, RMSE and correlation coefficient calculated between observed and simulated LST are in averaged around 0K, lower than 1.5K and higher than 0.99, respectively. For most of validation periods, the ground truth is well included in the look-up table of simulations (Fig. 3).

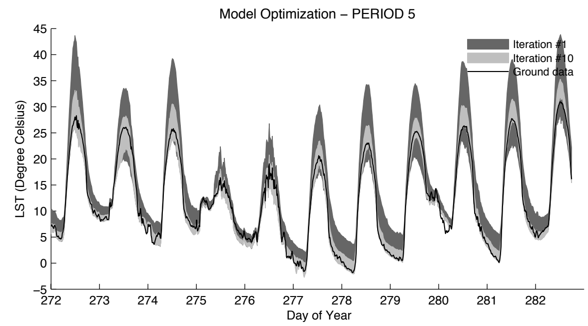

Figure 3: Look-up table of model simulations (LST values) generated by the calibration methodology. Every iteration of the MCIP algorithm represents an ensemble of 6,000 simulations. Ten iterations are used to minimize the bias and RMSE between observed (black line) and simulated LST. Results are for period 5.

A collection of 110 MODIS clear-sky images collected over 2010 (table 1) are used to evaluate the scaling methodology by comparing satellite-derived data with ground-based LST acounting for scaling process or not (Fig. 4). Whichever validation period, MODIS LST products agree better with scaled-up field data than with non-scaled field observations. Globally, over all periods, the scaled-up field data are more comparable with satellite products: the standard deviation of the difference between satellite LST and ground-based data – that represents the precision of the satellite product – is about 2.2K with scaling and higher than 3K without scaling.

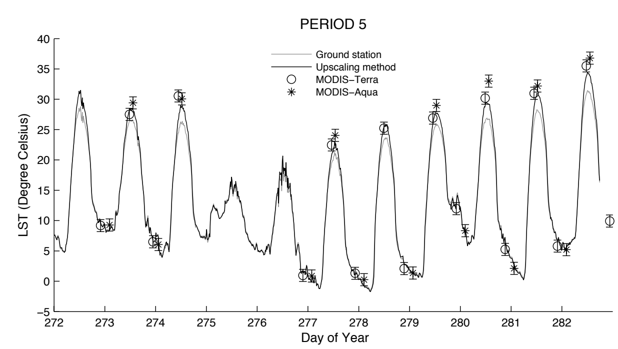

Figure 4: LST measured by a SURFRAD station (gray line) and by MODIS satellites (circles and stars), and assessed using the upscaling methodology (black line) over Bondville, IL. Error bars represent the possible errors associated with MODIS data – from MODIS quality flags.

7. CONCLUSION

Users of satellite products put a high priority on providing statements of products accuracy – and a product will be used only if it is reliable and therefore fully validated. In this context, we have developed a new validation methodology to monitor the quality of satellite LST products at moderate spatial resolution and evaluate retrieval algorithms performance. Using ground-based data without scaling, we found that MODIS LST product – used here as VIIRS proxy – does not verify NPP/VIIRS specifications. However, the product precision calculated using scaled-up ground data is around 2.0K and lower than VIIRS requirements (=2.5K). The ro utine VIIRS LST validation will be mainly based on ground data from the USCRN network that represents around 120 stations over the continental US.

Acknowledgments

The MODIS data used in this study are distributed by the Land Processes Distributed Active Archive Center (LPDAAC), located at USGS/EROS, Sioux Falls, SD, http://lpdaac.usgs.gov. The authors used the Earth Observing System ClearingHOuse (ECHO) / Warehouse Inventory Search Tool (WIST) interface developed by the Earth Observing System Data and Information System (EOSDIS), NASA GSFC - URL: https://wist.echo.nasa.gov/api/. The authors thank Deb Mish and Sara Veasey from NOAA/NCDC's graphic team for providing useful graphic support.

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