SCOPE model: a tool to simulate the surface temperature directional anisotropy

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Thermal infrared (TIR) measurements are prone to directional effects. A lot of experimental studies of the TIR anisotropy, which is defined as the difference between oblique and nadir surface temperatures measurements, have been performed since the 60's and reported in literature. They reveal important hotspot effect and possible significant errors - up to 10°C - on surface temperature measurements.
Directional effects have to be characterized to correct or to normalize satellite data, particularly large swath satellites data such as MODIS or AATSR for which scan angles reach ± 55° and ± 47° from nadir, respectively. They also have to be considered for defining the mission specifications of future TIR systems. Finally they can help to improve the estimation of surface fluxes by making possible discriminating the contributions of soil and canopy. In this idea a better characterization of TIR directional anisotropy is expected to improve the assimilation of thermal satellite data in vegetation models.
A large range of approaches have been developed to simulate the anisotropy (geometric models, radiative transfer, 3D models, parametric kernels...). Nevertheless, deterministic radiative transfer modelization remains essential to generalize experimental measurements and to assess the sensitivity of surface features (vegetation structure, LAI, water status etc.) and the impact of the Sun-observer geometry impact on directional radiative temperature measurements. Moreover, new methods (such as kernel approaches or neural networks) have to be developed to correct for directional anisotropy, simple enough to be integrated in ground segments for operational satellite data processing. For this purpose another use of a deterministic model of TIR anisotropy could be the simulation of data sets from which derive operational simpler algorithms could be derived.
The deterministic SCOPE (Soil Canopy Observation, photochemistry and Energy fluxes) model, developed by Van der Tol et al. (2009) at the ITC (Nederland), is a good candidate to address the problem of the temperature anisotropy. It is a one-dimensional multilayer model coupling a radiative transfer model based on the 4SAIL (Scattering by Arbitrary Inclined Leaves designed by Verhoef et al. 2007) algorithm and an energy balance module. It has been designed to simulate radiance spectra, energy and CO_2 fluxes but it also simulates directional brightness temperatures.
After a brief description of the model, we present a validation exercise of SCOPE for fluxes and directional brightness temperatures over two original experimental data sets obtained on wheat and pine stands recorded during different years; they offer a large range of surface conditions (vegetation structure, LAI, water status). Directional radiative temperatures were measured with

several radiothermometers positioned in different zenithal and azimuthal viewing configurations

(18° towards South, 55° towards North and 27° towards West). During a few months, a radiothermometer was also mounted on a motorized platform piloted to follow the sun course during the day, so providing the temperature at the hotspot. The sites belonging to different international networks, (CarboEurope, Fluxnet) the energy (sensible and latent heat) and CO_2 fluxes were also continuously monitored.
SCOPE was calibrated using several inversion strategies which are described. The biochemical input parameters (maximal carboxylation capacity and the marginal cost of assimilation which strongly govern photosynthesis and transpiration processes) revealed to have most sensitivity on simulations and were retained to calibrate the model. The validation of SCOPE was made on cloudless days and for diurnal conditions only. Satisfactory results have been obtained on fluxes with a root mean square error (RMSE) on convective fluxes estimation of about 40 $W.m^{-2}$. The simulation of directional brightness surface temperatures revealed excellent with a 1°C RMSE over both wheat and pine data sets, and for all viewing geometries.
The use of SCOPE for generating polar plots of temperature anisotropy is finally illustrated by a qualitative comparison exercise. Simulations revealed directional anisotropy structure quite consistent with measurements available at the laboratory. The applications to evaluate the possible effects of different variables such as vegetation structure (leaf angles, LAI, etc.) and micrometeorological conditions (wind speed for instance) are discussed.

References :

Keywords :
Remote sensing ; Thermal infrared ; Surface temperaure ; Directional anisotropy ; SCOPE ;

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