Towards an improved understanding of thermal anisotropy in land surface temperature measurements

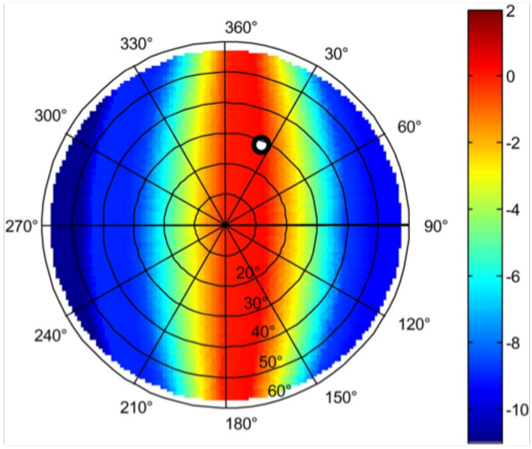

Figure 1. Left: Laboratory Goniometer System (LAGOS) instrument for directional measurements. Right: Example of thermal directionality over vineyards (Lagouarde et al 2014).

Background & Relevance:

Land Surface Temperature (LST) is one of the most important variables for understanding energy budget and fluxes at the Earth's surface, at both local and global scales. Measurements and characterisation of LST have a wide range of applications, spanning agriculture, hydrology, climate and urban environments. Remote sensing observations of LST can provide the high spatial resolution and temporal frequency needed for such applications, however these observations are affected by directional effects; when the temperature measurements differ depending on the sensor viewing angle and the sun angle. Directional anisotropy of thermal radiation is one of the main uncertainties in LST retrievals, inversions and applications, causing differences of up to 16K in vegetation and 12K in urban areas. A major gap still exists in understanding the thermal directional signature of different surfaces, and developing algorithms to correct for them. The main objective of this MSc thesis is to measure and understand the thermal anisotropy of various surface types and to build up a database of Bidirectional Temperature Distribution Function (BTDF) measurements. A variety of datasets will be used, with a primary focus on ground-based goniometer measurements in the laboratory and the field, but also UAV measurements for larger scale anisotropy characterisation. Accordingly, this thesis will provide the opportunity to gain experience in 1) acquisition of data in the laboratory and field, 2) data analysis and understanding of thermal remote sensing data, 3) contributing towards correction algorithms that reduce uncertainty of LST characterisation in surface energy balance.

Study area:

Space: Laboratory Goniometer System (LAGOS) & field observations (TBD)
Time: Fall/Winter 2022

Data Input:

- Directional Thermal Infrared (TIR) measurements
- UAV thermal infrared data
- Ancillary data collection (e.g. environmental or light conditions)

Analysis tasks (to be discussed):

- Plan and acquire directional TIR measurements over varying surface types in the laboratory
- Plan and acquire directional TIR measurements over varying surface types in the field, for example grass or concrete (TBD)
- Characterise BTDF of varying surfaces
- Compute BTDF using selected models and compare against measurements
- Analyse potential correction algorithms for thermal directionality

Objectives:

- Set up, acquisition and analysis of LAGOS thermal infrared data over varying surface types
- Build up a “BTDF database” for varying surface types
- Assess and compare retrieved BTDF models against existing directional correction models
- Development of correction algorithms

Links & References:

- Cao et al. (2019) : A review of earth surface thermal radiation directionality observing and modeling: Historical development, current status and perspectives, *Remote Sensing of Environment*, 232, 111304, https://doi.org/10.1016/j.rse.2019.111304
- Timmermans et al (2009) Automated Directional Measurement System for the Acquisition of Thermal Radiative Measurements of Vegetative Canopies, *Sensors*, 9(3): 1409-22
- Bian et al (2021) “Modeling the directional anisotropy of fine-scale TIR emissions over tree and crop canopies based on UAV measurements” *Remote Sensing of Environment*, 252: 112150, https://doi.org/10.1016/j.rse.2020.112150

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