PhD position “FishSPN1”

Data fusion of information from a fish-eye camera and a global/direct/diffuse pyranometric sensor with no moving part.

About the position

Context and challenges

Surface solar irradiance (SSI) is part of the Essential Variables both for climate (ECV)[1] and for Renewable Energy (EREV)[2]. When properly maintained and quality-checked, *in-situ* pyranometric sensors are the best sources of information for assessing with accuracy different characteristics of the SSI that are needed for various applications. Besides standard measurements of the global horizontal irradiance, pyranometer can be equipped with solar tracker and shadow balls to measure the direct normal and diffuse components of the solar radiation or with a diffraction grating to decompose the solar spectrum from 250 nm to 4000 nm into finer spectral sub-bands.

However, globally, the spatial distribution of these pyranometric stations is relatively low and highly uneven across continents, countries, and regions. Sensors enabling the simultaneous measurement of total global and diffuse horizontal irradiances and direct normal irradiance are even rarer. Among the barriers to their deployment, the additional investment and maintenance costs of mechanical systems for solar angle tracking or spectral separation of incident solar radiation are particularly significant. Several alternative pyranometric systems have therefore been proposed that do not rely on precise solar tracking systems, such as the rotating shadow-band pyranometer (RSP), which resorts to a mechanical shading band rotation, or the SPN1, which has no moving parts.

This thesis will focus on the latter instrument, SPN1, which has the advantage of requiring maintenance levels equivalent to those of a simple pyranometer measuring global horizontal irradiance. This sensor is composed of seven thermopiles under a dome and a specifically determined sky mask[3]. However, comparisons with reference instruments measuring direct and diffuse components show that the SPN1 exhibits systematic measurement errors for these components on the order of 10% or more[4,5]. These errors are related to simplifying assumptions regarding the isotropy of downward radiance excluding the direct component[6] in the treatment of SPN1 raw measurements to assess the direct and diffuse components. The motivation of this thesis is to address this limitation by considering anisotropic

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[1] https://www.ncdc.noaa.gov/gosic/gcos-essential-climate-variable-ecv-data-access-matrix

[2] Thierry Ranchin, Mélodie Trolliet, Lionel Ménard & Lucien Wald (2019): Which variables are essential for renewable energies?, International Journal of Digital Earth, DOI:10.1080/17538947.2019.1679267

[3] Wood, J. G. (1999). Solar radiation sensor. In WO 99/13359. Google Patents.

[4] Vuilleumier, L., Hauser, M., Félix, C., Vignola, F., Blanc, P., Kazantzidis, A., & Calpini, B. (2014). Accuracy of ground surface broadband shortwave radiation monitoring. Journal of Geophysical Research, 119(22), 13838–13860. https://doi.org/10.1002/2014JD022335.

[5] Badosa, J., Wood, J., Blanc, P., Long, C. N., Vuilleumier, L., Demengel, D., & Haeffelin, M. (2014). Solar irradiances measured using SPN1 radiometers: uncertainties and clues for development. Atmospheric Measurement Techniques, 7(12), 4267–4283. https://doi.org/10.5194/amt-7-4267-2014

[6] https://delta-t.co.uk/spn1-resource-centre/

radiance which is expected to improve the accuracy of the sensors and at the same time characterize the anisotropy of the radiance.

In parallel, for about a decade, hemispherical cameras (fish-eye cameras) have become increasingly popular as standalone sensors for atmospheric, meteorological, and solar energy applications to acquire RGB images of the sky (and the ground). Very promising research, particularly conducted by the DLR[7], demonstrates the benefits of combining fish-eye cameras with pyranometric sensors measuring global horizontal irradiance to accurately determine global irradiance on any inclined plane. Since such cameras measure the angular distribution of the radiance, and thereby its anisotropy, they are promising to address the limitations of the SPN1.

Objectives and scientific questions:

The objective of this thesis is to study the possibility of combining a fish-eye camera with the SPN1 to enhance the overall quality of the acquired data, including hemispherical images and pyranometric measurements, and to notably improve the determination of direct and diffuse components of the incident irradiance as well as to characterize the anisotropy of the radiance.

The scientific questions will include the following:

- Can SPN1 measurements contribute to improving the determination of acquisition parameters for the hemispherical camera (HDR, exposure time, etc.), as well as the segmentation and classification of clouds in hemispherical sky images?
- Does the analysis of hemispherical images improve the quality control of SPN1 pyranometric measurements?
- What data fusion or model inversion methods should be implemented using the pyranometric measurements from the seven SPN1 thermopiles and hemispherical sky images to improve the quality of direct and diffuse irradiance measurements?

The techniques of data fusion/ model inversion will resort both on explicit physical modelling of the radiative transfer and underlying downwelling solar radiance and, if relevant, on data-driven machine learning / deep learning approaches.

About SCIDOSOL

The PhD thesis is funded by the SciDoSol chair at Mines Paris - PSL. The SciDoSol chair – "Sciences de la Donnée appliquées à l'énergie Solaire", or "Data science for solar energy" – has been launched in 2022 for 5 years and aims to tackle various challenges of the energy transition related to the characterization, forecasting, and exploitation of the solar resource. To reach its goals, the chair intends to leverage the large volume of data provided by Earth observation in combination with state-of-the-art data-science techniques.

[7] Blum, N. B., Wilbert, S., Nouri, B., Lezaca, J., Huckebrink, D., Kazantzidis, A., Heinemann, D., Zarzalejo, L. F., Jiménez, M. J., & Pitz-Paal, R. (2022). Measurement of diffuse and plane of array irradiance by a combination of a pyranometer and an all-sky imager. Solar Energy, 232(November 2021), 232–247. https://doi.org/10.1016/j.solener.2021.11.064

The PhD candidate will be located at Campus Pierre Laffitte in Sophia Antipolis (France), within the OIE (Observation, Impacts, Energy) center of Mines Paris – PSL.

Pre-requisite:

The candidate must hold an Engineering degree or a Master of Science. He/she should have a solid scientific culture and excellent analytical skills. Prior knowledge or strong interest in image and signal processing, remote sensing, atmospheric science, applied mathematics are expected.

The candidate must demonstrate good programming skills; while not strictly required, a good knowledge of Python is preferred. Prior experience with machine learning and deep learning is not necessary but would be appreciated.

Proficiency in English – scientific writing in particular – is required; French is not required but would be beneficial.

Practical information

Application: To candidate, please send the following documents to hadrien.verbois@minesparis.psl.eu (cc: yves-marie.saint-drenan@minesparis.psl.eu and philippe.blanc@minesparis.psl.eu):

- A detailed CV
- A letter of motivation
- 2 letters of recommendation

Note that the letter of motivation will be used to assess the candidate's scientific project and scientific writing.

If you have any questions regarding the position, please contact hadrien.verbois@minesparis.psl.eu.

Workplace: Sophia Antipolis

Net Monthly Salary: 2100€