PhD POSITION "deepHeliosat"

Application of convolutive networks to surface solar radiation retrieval methods for the optimal exploitation of third-generation geostationary satellites

About SCIDOSOL

The PhD thesis is financed 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 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.

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.

About the position

Context and challenges

According to IPCC report (2022), solar energy is among the mitigation options with the highest potential in the fight against climate change. To enable a reliable electricity supply with a large share of solar energy, the accurate estimation of the solar resource is critical. Several sources of data are available to provide information about the solar resource. Satellite-derived estimations of the surface solar irradiance (SSI) are among the most widely used, based notably upon geostationary meteorological satellites. The rationale of this use is that they offer a good compromise in terms of spatial coverage, time resolution, and accuracy.

The methods used to derive SSI from satellite imagery are called hereinafter retrieval methods. The Observation Impact Energy (OIE) group of MINES PARIS - PSL has a long scientific track record with such methods (Cano et al. 1986, Rigollier et al. 2004, Qu et al. 2017, Tournadre et al. 2021). In particular, the group has taken an active role in the scientific and operational developments of the Heliosat-class of methods. Two of them are now operationally exploited in widely used databases such as Helioclim3 and the CAMS Radiation service (Blanc et al. 2011, Schroedter-Homscheidt et al. 2016).

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Most existing operational satellite-derived SSI databases rely on so-called 2nd generation satellites. In the past few years, satellites from a new generation have been launched (namely GOES-R and Himawari-8) or will soon be launched in the case of European Meteosat Third Generation (MTG). These satellites have higher temporal and spatial resolutions than their predecessors, as well as more spectral channels and higher image quality in terms of luminance accuracy and geometric stability. They thus have the potential to greatly improve the quality of satellite-based cloud properties retrievals, aerosol, and water vapor retrievals, for eventually better SSI estimations. This higher resolution, however, also comes with challenges to existing retrieval methods:

1. Current retrieval methods generally disregard the contribution of the neighboring pixels in a pixel total energy. The contribution of this phenomenon – called "horizontal photon transport" – to the total pixel's energy, is growing with higher resolution (Okamura et al. 2107).
2. Furthermore, most existing operational retrieval methods ignore parallax issues, which arise from the angle of view of the satellite. The impact of this approximation is also expected to increase at higher resolution.
3. Lastly, cloud shadows, that can be observed on the ground or on other beneath clouds by the satellite, are known to cause misclassification of cloudy pixels in clear-sky ones. This is already a problem with 2nd generation, lower resolution satellites, but as the image resolution increases, they become sharper and a cloud shadow is more likely to cover a full pixel or even a cluster of pixels, leading to its complete misclassification in some situations.

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The physic underneath these phenomena is well understood and could theoretically be modelled, with so-called radiative transfer models and solvers. Fully physic-based approaches, however, are computationally expensive and relies on hard-to-gather, if not impossible, input data such as 3D structures of cloud properties. In this thesis, we propose to explore a different perspective and to investigate the potential of both data-driven and physical methods, named hybrid approach, that combine physical understanding of the problem with automatic statistical-learning.

Scientific objectives & methodology

The first scientific objective of this thesis is to understand and quantify the impact of high-resolution satellite images on existing current heliosat methods with collection of specific situations observed by the satellite. To that end, on these collected situations, the PhD candidate will first establish a baseline for SSI retrieval with operational 3rd generation satellite (GOES-R or Himawari). The PhD candidate will familiarize itself with existing satellite retrieval methods, in particular the heliostat methods developed at OIE, and implement one of them to 3rd generation satellites. The performance will be evaluated quantitively and qualitatively; notably, the impact of resolution on the performance will be studied using degraded images.

The second scientific objective of this thesis is to define and implement a hybrid satellite-retrieval method tailored to high resolution 3rd generation satellites, leveraging advances in statistical-learning. For example, deep-learning architectures such as Convolutional Neural Network – known for their efficacy in solving spatial problems, and recurrent networks, such as LSTM – to better capture the dynamic nature of the problem – could be explored. In addition, strategies to incorporate a priori physical knowledge of the problem should be investigated.

Lastly, the thesis should focus on the *explainability* of the statistical models used. In particular, the candidate will study the importance of input features – through for example ablation studies – and attempt to understand the way the model uses spatial and temporal information. In addition, standard and problematic cases (e.g. with shadowing, suspected horizontal photon transfer and parallax issue) will be identified, and the different methods will be assessed and analyzed in detail for these cases.

References

Blanc Philippe, Benoıt Gschwind, Mireille Lefevre, and Lucien Wald. The HelioClim project: Surface solar irradiance data for climate applications. Remote Sensing, 2011

Cano, D., Monget, J., Albuisson, M., Guillard, H., Regas, N. and Wald, L. : A method for the determination of the global solar radiation from meteorological satellite data. Solar Energy, 1986

Okamura R, Iwabuchi H, Schmidt KS. Feasibility study of multi-pixel retrieval of optical thickness and droplet effective radius of inhomogeneous clouds using deep learning. Atmospheric Measurement Techniques. 2017

Qu Zhipeng, Armel Oumbe, Philippe Blanc, Bella Espinar, Gerhard Gesell, et al.. Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method. Meteorologische Zeitschrift, Berlin: A. Asher & Co., 2017

Rigollier, C., Lefèvre, M. and Wald, L. The method Heliosat-2 for deriving shortwave solar radiation from satellite images. Solar Energy, 2004

Schroedter-Homscheidt Marion, Antti Arola, Niels Killius, Mireille Lefevre, Laurent Saboret, William Wandji, Lucien Wald, and Etienne Wey. The copernicus atmosphere monitoring service (cams) radiation service in a nutshell. Proc. SolarPACES16, 2016.

Tournadre, B., Gschwind, B., Saint-Drenan, Y.-M., and Blanc, P.: An improved cloud index for estimating downwelling surface solar irradiance from various satellite imagers in the framework of a Heliosat-V method, Atmos. Meas. Tech. Discuss 2021.

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 remote sensing, atmospheric science and image treatment are expected.

The candidate must demonstrate good programming skills; while not strictly required, a good knowledge of python is preferred. He/she should also have a solid basis in the field of machine learning. Prior experience with 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 statement of purpose
- Letter(s) of recommendation

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

If you have any question regarding the position, feel free to contact hadrien.verbois@minesparis.psl.eu.

Deadline: 22/08/2022, but applications will be processed as they are received

Workplace: Sophia Antipolis

Net Monthly Salary: 2100 €