PhD POSITION "SSI Variability"

Modeling, characterization and prediction of solar radiation variability

About SCIDOSOL

The PhD thesis is financed by the SciDoSol chair at Mines Paris – PSL; it is also supported by the geoscience center of Mines Paris. 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 in Sophia-Antipolis (France), within the OIE (Observation, Impacts, Energy) center of Mines Paris – PSL. He/she will be brought to collaborate closely with researchers in the geoscience center, located in Fontainebleau, close to Paris.

About the position

Context and challenges

In a context of fight against climate change, the share of renewable energy sources (RES) in the energy-mix is expected to increase considerably. This will lead to significant changes in the management of the electricity supply system, notably because of the strong weather dependence of most RES. Thanks to energy forecast systems, the variability of renewable energies can be accounted for in the planning and management of energy systems. However, to anticipate the massive deployment of RES expected for the future, it is very important to improve the performance of current forecasting methods. The objective of this thesis is to propose solutions to manage the spatial and temporal variability of large amount of RES using stochastic approaches.

In the case of solar energy, surface solar irradiance (SSI) is commonly characterized using geostationary meteorological satellite images (Cano et al. 1986, Rigollier et al. 2004, Qu et al. 2017, Tournadre et al. 2021), because of their availability and accuracy. However, SSI estimations derived from geostationary satellites have spatial and temporal resolutions limited by the the characteristics of the spaceborne sensors. With currently operating satellites, this resolution is not as fine as that required by energy systems. Indeed, the time scale required for ramp forecasts is 1 min and a few decameters. It is thus necessary to downscale satellite-derived estimations, i.e. to perform spatial and temporal disaggregation/interpolation.

Downscaling of satellite-derived SSI estimations can be approached from several angles.

1- *Smart* interpolation is one approach, where temporal oversampling is achieved using cloud motion vectors (CMV) and intra-pixel variability is done using bilinear interpolation and adapted convoluted Gaussian noises (Inoue, 2012).

2- Using methods based on Stochastic Partial Derivative Equations (SPDE - Lindgren et al., 2011, Carrizo-Vergara et al. 2018) is another possible answer to this problem. In addition to downscaling the estimations, such geostatistics methods provide an estimate of the likelihood – or uncertainty – of their output.
3- Finally, conditional Generative adversarial networks (GAN) have recently been adapted to the problem of hyper-resolution of satellite images (Leinonen et al. 2021).

The goal of this thesis is to evaluate the potential of these different approaches to downscale satellite-derived estimations at the desired resolution and to assess how the resulting information can be efficiently in the energy system.

Scientific objectives & methodology

The first objective of this thesis is to understand and define the metrics to be used to assess the quality of downscaling methods of SSI. In particular, quantitative measures of the spatio-temporal structure of SSI estimations at different scales should be defined. In addition to classical precision/accuracy metrics, the concept of plausibility will be explored.

The second objective of this thesis is to implement the downscaling methods mentioned above in order to evaluate and compare them on real use-cases. To that end, the candidate will rely on solar radiation data with a high spatial and temporal resolution, such as:

- Very high spatial and temporal resolution measurement networks (HOPE-Jülich, HOPE-Melpitz, NREL-Oahu, UCAR/ARM...)
- High spatial resolution images from polar satellites (Sentinel 2)

The implementation will be designed to exploit the spatial and temporal dimensions at their best. The different metrics identified in the first part of the thesis will be exploited to evaluate the different methods. Depending on the results of the comparison, the candidate may propose an alternative or hybrid approach.

Lastly, the candidate will evaluate the added value and fit-for-use of the selected methodology in a number of selected applications (e.g. forecast uncertainty, ramp forecast, prediction of spatial smoothing…). Different possibilities will be explored to share the stochastic information with the targeted end-users: uncertainty metric, ensemble of multiple scenarii, probabilistic information…

References

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Carrizo-Vergara, R., Allard, D., & Desassis, N. (2018). A general framework for SPDE-based stationary random fields. arXiv preprint arXiv:1806.04999.
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Inoue, T. (2012). Spatio-temporal Kriging of solar radiation incorporating direction and speed of cloud movement. 14–17.
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Lindgren F., Rue H., Lindström J. (2011) An explicit link between Gaussian fields and Gaussian Markov random fields : the stochastic partial differential equation approach. Journal of the Royal Statistical Society : Series B, 73(4) :423-498
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Rigollier, C., Lefèvre, M. and Wald, L. The method Heliosat-2 for deriving shortwave solar radiation from satellite images. Solar Energy*, 2004, 77, n°2, 159-169.*
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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 solar forecast, atmospheric science and stochastic model 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 and appetence in the field of machine learning and more generally in Data Science, comprising notably image processing, spatial and temporal stochastic modelling. 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 : yves-marie.saint-drenan@minesparis.psl.eu , hadrien.verbois@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 yves-marie.saint-drenan@minesparis.psl.eu.

Applications will be processed as they are received

Workplace: Sophia Antipolis

Net Monthly Salary: 2100 €