Webinar "When AI meets the sky: All sky imagers - from basic research to energy applications"

Q&A

Answers by Politecnico di Milano, Reuniwatt, and Universität Heidelberg

Solar radiation nowcasting

Q. Does your ECNN based method allow for solar radiation nowcasting on rainy days?

A. PoliMi: All the images where rain precipitation was recorded have been removed by the training set (as rain has a significant negative impact on the quality of images, and the droplets on the hemispherical mirror of the All-Sky camera could mislead the ECNN: they could be confused with little clouds) [1]. Therefore, ECNN proposed method is not employed during rainy days. This is also compliant with the solar radiation nowcasting in the power estimation by Photovoltaic plants: in rainy days the power generated by Photovoltaic plants is negligible.

[1] Ogliari, E., Sakwa, M., & Cusa, P. (2024). Enhanced convolutional neural network for solar radiation nowcasting: All-sky camera infrared images embedded with exogeneous parameters. Renewable Energy, 221, 119735. https://doi.org/10.1016/j.renene.2023.119735

Q. Do you have a PV plant close to the all-sky imager on your test site, and do you plan to assess the performance on the power output of the PV plant?

A. Yes, (please see: https://www.mg2lab.polimi.it/) we have PV plants installed nearby the All-Sky imager, and this allows to assess the relevant performances. For instance, here [2] we are adopting the solar radiation estimation for the calculation of diagnostic indicators. The single PV module performances monitored by micro-converters, are compared and assessed with the power output estimation.

[2] Leva, S., Mussetta, M., & Ogliari, E. (2019). PV module fault diagnosis based on microconverters and day-ahead forecast. IEEE Transactions on Industrial Electronics, 66(5), 3928–3937. https://doi.org/10.1109/TIE.2018.2879284

Q. Which clear sky model do you use? What is the influence of the clear sky model used on your results?

A. PoliMi: In the solar irradiance Clear Sky calculation, the Simplified Solis model by Ineichen is used [3]. However, I do not expect a significant impact on the results by changing the Clear Sky model, as it is only used to "normalize" the recorded GHI (namely, the Clearness Index ranges between 0 and 1). This is useful to reduce the computational burden related to the training of the Machine Learning based model.

[3] Ineichen, P. (2008). A broadband simplified version of the Solis clear sky model. Solar Energy, 82(8), 758–762. https://doi.org/10.1016/j.solener.2008.02.009

A. Reuniwatt: We have benchmarked several clear sky models and use the one appropriate for the target climate; you can find a reference to a recent exhaustive benchmark here [4]:

[4] Sun, X., et al. (2019). Worldwide performance assessment of 75 global clear-sky irradiance models using principal

component analysis. Renewable and Sustainable Energy Reviews, 111, 550–570. https://doi.org/10.1016/j.rser.2019.04.006

Q. Have you looked at the correlation between forecast skill and irradiance overshoot counts, i.e. how often the irradiance exceeds the clear sky irradiance in a given window?

A. PoliMi: In the presented research the Clear-Sky Index (CSI) is calculated, and it is used just as a label for model training. Therefore the "irradiance overshoot", resulting in a CSI greater than 1, were not particularly investigated: during days with "clear sky" conditions Persistence-based methods are sufficiently accurate in GHI nowcasting. Instead, one of the main focuses of the research was investigating the accuracy in those samples with very high irradiance fluctuations within the nowcasting time horizons (which is typical of "partially cloudy" days conditions). Here the proposed ECNN showed Forecast Skill greater than 20%.

Q. Have you looked at the influence of cloud types on your solar nowcasting results?

A. PoliMi: Yes, in our work [5] we presented preliminary results of a Machine Learning based method to detect the clouds which potentially obstruct the sunrays directed to a specific location, based on the cloud type. In a subsequent study [5], the same approach including a combination between a CNN with the cloud typology provided by satellite data scored positive Forecast Skill in the GHI 15-minute ahead forecast of "Clear Sky" and "Partially Cloudy" days.

[5] Nespoli, A., Niccolai, A., Ogliari, E., Perego, G., Collino, E., & Ronzio, D. (2022). Machine learning techniques for solar irradiation nowcasting: Cloud type classification forecast through satellite data and imagery. *Applied Energy, 305*, 117834. https://doi.org/10.1016/j.apenergy.2021.117834

[6] Sakwa, M., Ogliari, E., Leva, S., Betti, G., & Sgrò, D. (2024). Solar irradiation nowcasting using local cloud coverage satellite images for CNN-based method: A comprehensive methodology and a real case study. In *2024 IEEE International Conference on Artificial Intelligence for Green Energy (ICAIGE 2024)*. https://doi.org/10.1109/ICAIGE62696.2024.10776607

A. Reuniwatt: That is the next goal for our nowcasting algorithms, try to add this information as input and produce a benchmark! There is already some literature suggesting it helps.

Q. How you deal with saturated pixels on images?

A. PoliMi: I understand that by "saturated pixels" you mean either minimum or maximum value of the 1-2^16 range of 16-bit integer that each pixel is in the IR camera output. Generally, most of the clouds are in the range around 35k-45k. Therefore, it is advisable to cut the range (namely, setting a threshold) to these values bringing the stratified pixels closer to the operational range and thus increasing the general clarity of the image.

All-sky imagers

Q. Does your all-sky imager use near infrared or termal infrared?

A. Reuniwatt: The camera used is sensitive to the 8-14 microns radiance, so fully within the thermal infrared band.

Q. The mentioned IR range was 8-14 microns. There is a big gap between the lower end and the visible light. Is that spectrum any useful?

A. Reuniwatt: This spectrum is indeed very useful: there is a transparent atmospheric window between 10 and 14 microns, allowing for clouds to be observed. In addition, water in various forms (vapor, liquid, ice) is the largest emitter in this band, and so we are guaranteed to observe everything cloud related.

Q. Can you only identify cloud coverage, or is it possible to classify the vertical distribution?

A. Reuniwatt: With a single imager and no other data/instrument, it is very difficult to resolve height from a 2D image. With several imagers using stereoscopy, we can work some magic. Ceilometers can also be used in conjunction with the imager to have an estimate of the local cloud base height.

A reference for stereoscopy applications to retrieve cloud height [7]:

[7] Liandrat, O., Roussel, G., Bedoya-Velasquez, A., Ceolato, R., Cautru, A., Decroix, J., & Schmutz, N. (2022, March). A stereoscopic approach for cloud base height assessment over an optical ground station. In Free-Space Laser Communications XXXIV (Vol. 11993, pp. 150–154). SPIE. https://doi.org/10.1117/12.2632633.

Q. Can cloud type classification be done with your infrared all-sky imager? If so, what's the difference between the results from IR and VIS sky cam images?

A. Reuniwatt: It can be done using the same tools and methods (CNNs), but not with the same accuracy – although a benefit is that it works at night. We have tested the same CNN architecture used for visible imagery on the IR images instead, and accuracies drop to 70-75% down from over 90%.

Q. Do you think AOD information will help with the cloud type classification?

A. Reuniwatt: In my live webinar reply, I thought you meant Cloud Optical Depth, which helps with classification as it isolates the thinner cloud types (cirrus type clouds). Aerosol Optical Depth however is not easy to use as our instrument is blind to it, although there is likely correlation between AOD and cloud types since aerosols affect effective droplet sizes and cloud formation – I am very curious as to whether adding AOD into the model inputs would improve results. Something to try in the future!

Q. What additional information can you obtain combining an all-sky imager with a ceilometer, compared to using either of them individually?

A. Reuniwatt: The key benefit to using an imager is to obtain a detailed 2D map of the sky, which is valuable for applications where the spatial aspect is important (Solar, Satellite Optical Com, etc...). This is something that most ceilometers cannot provide, as they are pointed towards a single

direction. On the other hand, ceilometers provide extremely accurate height data along their line of sight.

Combining the two allows us to obtain a nearly full 3D overview of the sky conditions, something that neither instrument is capable of on its own.