FINAL REPORT PROGRAM LEFE

Program LEFE/IMAGO	CASPER	Years 2018 – 2020

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Context

Broadband solar irradiance measurements are performed routinely with applications in atmospheric remote sensing, numerical weather prediction, satellite products validation and climate model evaluation. However this type of measurement is much less informative than spectrally resolved observations, which remain very limited.

Objectives / scientific questions

The objective of CASPER is to develop an autonomous instrument to measure spectrally resolved solar irradiance and to assess the added value of such observations for the above mentioned applications. On the one hand CASPER focuses on the retrieval of atmospheric constituents, including water vapor, ozone, aerosols and cloud characteristics. On the other hand it investigates how spectral observations could advantageously replace broadband observations for the calibration of weather and climate models.

Main results

Although the project arouses much interest at CNRM it has faced technical issues that so far have largely limited the development of the instrument. This is related both to large delays in the reception of some critical components (e.g. glass domes to protect the optical fibers sent from Asia) and to the limited availability of the technical team which was involved in 2019 in a massive high-priority field campaign not planned at the time of CASPER initiation. In addition, the mechanical facility, in charge of assembling the instrument, has been overloaded due to this campaign and human resources issues. In addition it has been mostly inoperative since the beginning of the Covid crisis. As a result, the project has not yet reached the objectives set when it was proposed, but remains active and will continue in the upcoming years. The work already achieved is detailed below.

The main components necessary for the development of the instrument, namely the spectrometer, the optical switch, the optical fibers, the cosine collectors, the embedded computer and the transport case, as well as complementary instrumentation (fan, temperature sensor, glass domes) have been purchased in 2018. The various components have been assembled in the lab (Figure 1) and the codes to control the acquisition and storage of the measurements have been developed. However the integration in the weatherproof case and the deployment in the field remain to be done.

Preliminary Monte Carlo 3D radiative transfer computations to support the design of original cosine collectors have been set up at LAPLACE early 2018. To finalize these simulations the optical properties of Spectralon (the material used for high efficiency optical diffusers) were asked to Labsphere company. Despite numerous email exchanges we could not obtain the required optical properties, and still have to estimate those from calibration curves sent by the manufacturer. However this simulation work has been suspended late 2018 to put the priority on instrument development. An experimental setup has also been developed in the radiation lab of Météo-France, to characterize the angular response of the cosine collectors. Figure 2 shows the response of the Ocean Optics commercial collector, in terms of error relative to a perfect collector. It highlights the poor capability of this collector and points to the necessity to develop a better one, as already planned. Note that the overall negative error implies that the collector will collect less light than it should for grazing angles.

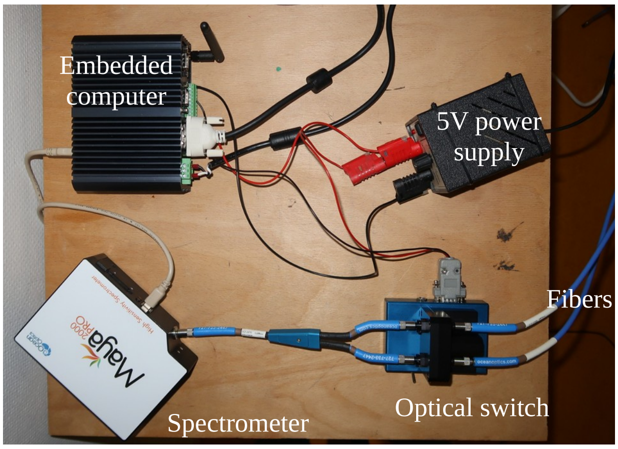

Figure 1 : CASPER main instrument

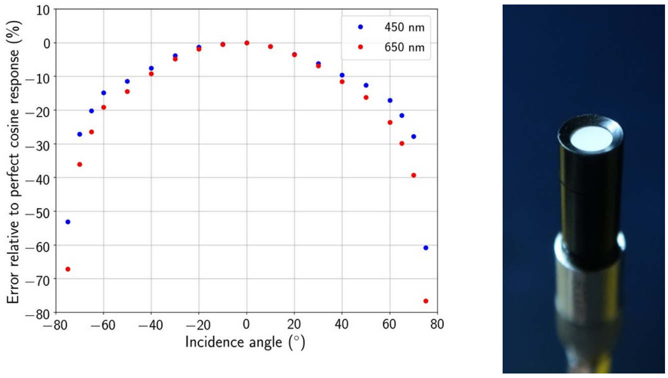

Figure 2 : Angular characterization of the commercial cosine collector (left) and picture of the collector (right)

Figure 1 *shows the main components of the instrument. Two fibers are used to measure up- and downwelling solar irradiance. An optical switch selects either channel and transmits the signal to the spectrometer (a grating) that records the irradiance at 0.5 nm resolution over the range 200-1100 nm. A computer hosts the algorithms that control both the spectrometer and the switch, and acquires and stores the spectra.*

Figure 2 *shows the deviation from the ideal cosine response of the commercial cosine collector, as determined in the lab. Deviation is negative with a very sharp decrease beyond approximately 70° there. This is due to the shape of the collector (see the sloped edges that block radiation beyond a certain angle) and to the flatness of the white diffuser which makes it non lambertian (reflectance is higher for such scattering material when the angle of incidence is larger, hence transmittance is less). Note that deviation depends on the incident wavelength. One objective of the project is to design a cosine collector with an error less than 5% for incidence angles less than 70°.*

Future of the project *:*

As of today the primary objective is to achieve what was targeted at the beginning, that is to deploy the instrument in the instrumented field of CNRM, and to have the capacity to deploy it routinely during field campaigns in which CNRM is involved. There are also internal discussions to find resources to extend the spectral measurements to the near-infrared to cover the full solar spectrum, with a strong interest for the validation of satellite observations which are often spectral. In addition we initiated an activity around the photovoltaics (PV) and acquired solar panels that are installed in the vicinity of the future location of CASPER. There are plans to study the influence of the spectral distribution of solar irradiance on solar panels performance. More generally there is a strong interest at Météo-France to refine solar irradiance forecasts. A PhD thesis started in 2019 on this topic and this could also be a topic on which to write an ANR JCJC proposal in the upcoming years.

Communication

So far CASPER experiment did not result in any dedicated publication, because it is not yet operating. However, the following publications benefited from ideas developed in the project :

- **Libois, Q.**, Lévesque-Desrosiers, F., Lambert-Girard, S., Thibault, S., & Domine, F. (2019). Optical porosimetry of weakly absorbing porous materials. *Optics express*, 27(16), 22983-22993.
- Lindsay, N., **Libois, Q.**, Badosa, J., Migan-Dubois, A., & Bourdin, V. (2020). Errors in PV power modelling due to the lack of spectral and angular details of solar irradiance inputs. *Solar Energy*, 197, 266-278.
- Sablon, J., **Libois, Q.**, Ceamanos, X, Riette, S. Impact of aerosols on the photovoltaic production over Western Europe. *In preparation*.

CASPER was mentioned in national conferences (e.g. Fédésol workshop) but not yet in international conferences

*One PhD entitled "*Improvement of solar irradiance forecasts for solar energy applications*" started in 2019 and will use CASPER data along with solar panels production as soon as available.*

One M2 internship worked on retrieval methods based on CASPER-like observations from Dome C, Antarctica. Two additional M2 internships worked on the impact of clouds and aerosols on the spectral distribution of solar irradiance for PV applications. One M2 internship just started that will use Monte Carlo 3D radiative transfer simulations and LES simulations to investigate the potential of CASPER observations for the retrieval of cloud micro- and macrophysical properties.