Providing intraday solar irradiance forecasts before sunrise: satellite-based night cloud index retrieval and forecast

Background and objective

- Intraday solar irradiance forecasts are necessary to:
  - manage grid with photovoltaic power penetration (optimizing storage and reserve power);
  - adjust the previous day's unbalanced bids on the Day-Ahead electricity markets.
- They are often needed early in the morning, even before sunrise.
- Irradiance time-series modelling or satellite-based forecasts are generally more accurate than NWP models for short-term (up to several hours) forecasting.
- However, these techniques require observations in the daytime and cannot be delivered before sunrise.
- We implemented and assessed a satellite-based solar irradiance forecasting method usable in the nighttime using the Meteosat-10 satellite over Europe and the Meteosat-8 satellite over the Indian Ocean.

Satellite-based forecast principles

Several solar irradiance forecasting methods have been established using geostationary meteorological satellite visible images and generally present better results than NWP [1]. Reuniwatt’s HourCast method is described by the following chart. Raw images are converted into cloud index using an algorithm based on the Heliostat-2 method [2]. Then, a cloud motion vector (CMV) field is computed from two subsequent cloud index images, using an optical flow algorithm [3]. This CMV field is applied on the current image to extrapolate cloud index evolutions up to 6 hours. Extrapolated cloud index images are converted into irradiance using a clear sky model.

Early morning forecast

HourCast’s earliest forecast on a given punctual site can only be done if a large surrounding area is sufficiently illuminated by the sun. Concretely, the optical flow analysis is accurate only if the solar zenith angle (SZA) is smaller than 85° on a square of at least 1000*1000 km² centred on the given site. In some cases, country-scale forecasts cannot be delivered before one hour after sunrise. A solution to overcome this problem consists in building a nighttime cloud index to ensure an earlier delivery of HourCast. This solution has been proposed by [4]. We implemented it in our forecasting scheme.

Night cloud index computation

The principle of the night cloud index proposed by [4] consists in using infrared channels at 10.8 and 3.9 µm. Brightness temperature differences (BTD) between these channels, corrected by the satellite viewing angle permits to reproduce cloud patterns including lower warm clouds. The 10.8 µm channel is also used to detect very cold clouds (T10.8 < 232 K). Considering that the proportion of clear and cloudy pixels is stable at a continental scale between subsequent night and day times, [4] statistically computed bijective functions attributing a cloud index value for each BTD or T10.8 value for three different cloud classes.

Forecast implementation and assessment

We assessed this method by implementing HourCast using recommendations from [4]:
- a night cloud index when SZA > 89.8°
- a linear weighted combination between night and day cloud indices when 85° < SZA < 89.8°
- a day cloud index when SZA < 85°

We computed forecasts on three punctual sites and compared the results with corresponding ground measurements as summarized in the table on the right-hand side.

Results

- Scatterplots of GHI values show a linear agreement between 3-hour time horizon forecasts delivered at nighttime.
- However there is a strong underestimation for sites located in the Indian Ocean area.
- Forecasts using a combined cloud index are likely affected by the optical flow analysis in the twilight zone which can induce strong cloud pattern extrapolation errors.

Conclusion

- Nighttime assessments using early ground measurements show a reasonable accuracy confirming the interest of the satellite for applications using intraday solar irradiance forecasting.
- The high bias in Meteosat-8 IODC results confirms the necessity to adjust the cloud classification according to BTD thresholds on a particular region.
- Similar IR channels can be used on third generation meteorological satellites (Himawari-8, GOES-R, MTG...).

Bibliography