Advantages and drawbacks of a statistical clear-sky model: a case study with photovoltaic power production data

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Context

Surface solar irradiance (SSI) forecast is essential to manage the massive and secure integration of photovoltaic (PV) power into the electricity network. Forecasting solar irradiance consists in predicting cloudiness and in combining it with modelled clear sky irradiance (CSI). With an inaccurate clear sky model, the SSI forecast error increases with cloudiness.

Deterministic model

Many physical clear sky models have been designed and are routinely used for a diversity of applications. The most advanced clear sky models require concentration of atmospheric components influencing atmosphere transmittance in the shortwave range, namely the aerosols, water vapour and ozone. Availability and quality of some inputs are not always guaranteed at every location. Moreover, such deterministic clear sky models cannot always represent local conditions (shading or surface effects, microclimate ...) and radiative transfer modelling at a low solar elevation.

Statistical model

Statistical clear sky models are built using a long time series of SSI (typically one year). The principle consists in computing recursively the function representing the SSI signal envelope. Local CSI is then represented for a given site only, based on real observations excluding information on atmospheric parameters.

We performed an objective comparison of both approaches by assessing a statistical model using measurements acquired by a solar reference cell. Results are compared with the performance of two deterministic clear sky models.

Statistical clear sky model building

We implemented the algorithm described in Bacher *et al.*, (2013) on a 1-year global horizontal irradiance (GHI) time series measured in Sainte-Marie, Reunion Island, France. Considering the observed GHI as samples of a random variable with a probability distribution function, which is a function of the day of year x_t and the time of day y_t, the observed clear-sky (cc) global radiation can be estimated as a quantile:

$$\widehat{G_t^{cc}} = Q_q(x_t, y_t)$$

of this distribution function, where the quantile $q \in [0, \ldots, 1]$ must be close to one ($q \lesssim 1$).

The proposed clear sky model is based on a two-dimensional second-order polynomial local quantile regression model. In this form, the local weighting is carried out with a two-dimensional multiplicative kernel function in the *day of year* and *time of day* dimensions.

Physical (deterministic) clear sky models used for comparison

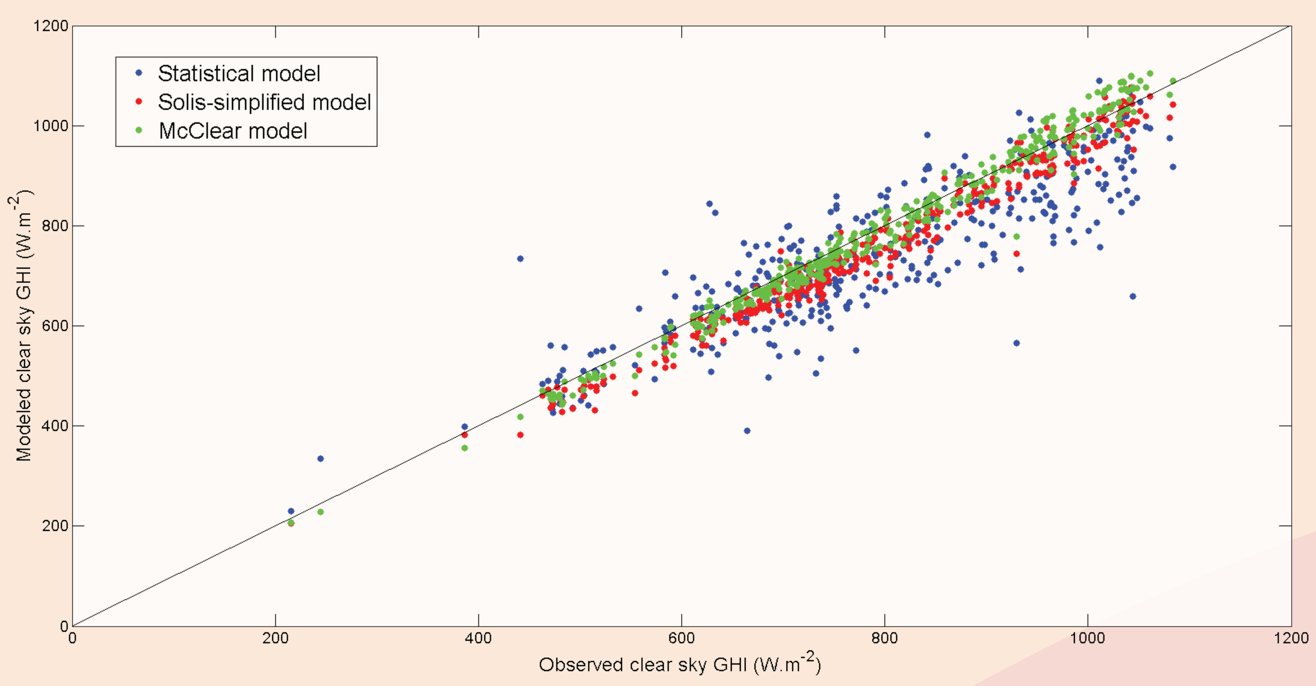
McClear

Model using detailed pre-computed abacis with the radiative transfer model (RTM). It has been designed to use the MACC atmospheric parameter datasets.

Solis

Based on RTM calculations and a modified Beer-Lambert law. It is routinely used to derive solar irradiance from GOES american satellite. MACC data have been used as Solis inputs.

Comparison with ground GHI measurements



θ: *solar zenith angle*

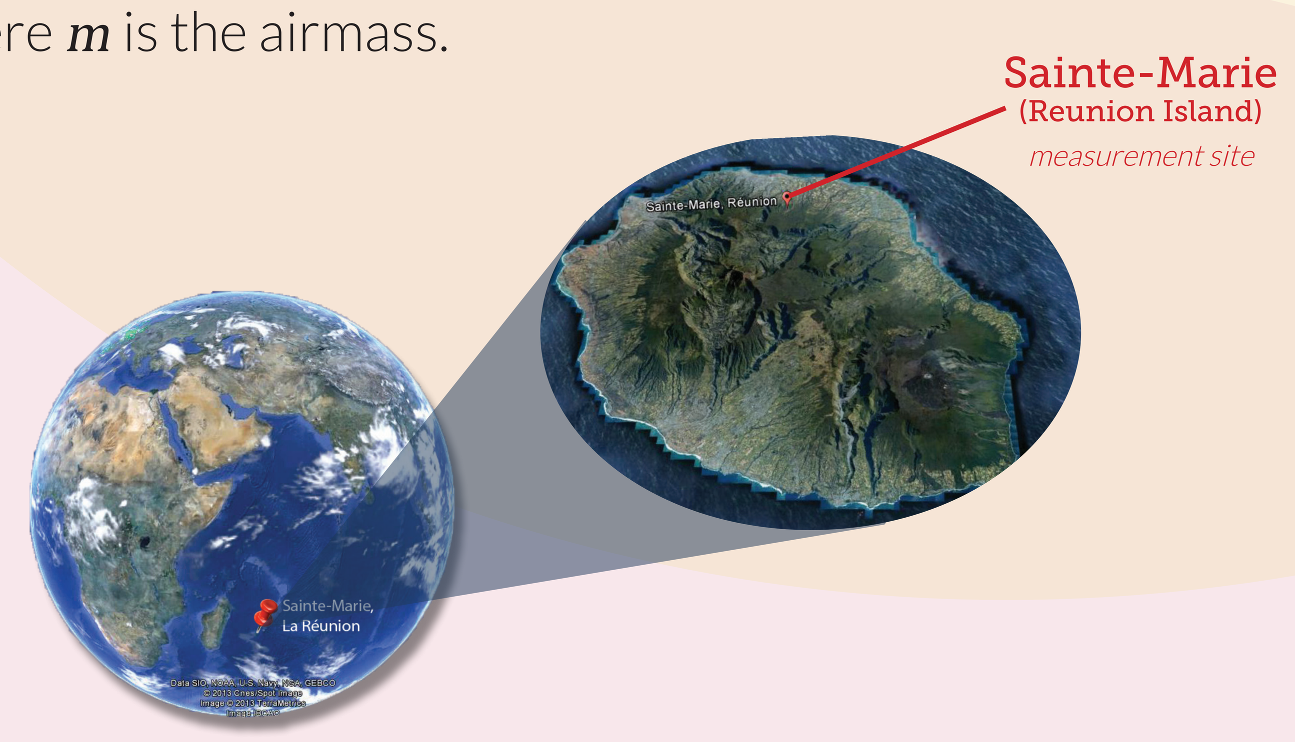
0°< θ <90°	RMSE (%)	BIAS (%)	Correlation coefficient
Statistical	12.0	-6.1	0.86
Mc Clear	3.2	-0.6	0.98
Solis	5	-4.1	0.97

60°< θ <90°	RMSE (%)	BIAS (%)	Correlation coefficient
Statistical	19.2	5.4	0.63
Mc Clear	5.1	-4.3	0.98
Solis	7.2	-5.6	0.97

Modelled clear sky hourly irradiance has been compared with PV power outputs from a reference cell from Sainte-Marie for the whole year 2011. Hourly clear sky instants have been selected if at least one hour before and after the given instant the modified clearness index *KT'* is superior to 0.75.

$$KT' = KT/[1.031.\exp(-1.4/(0.9+9.4/m))+0.1]$$

where m is the airmass.



Conclusion

A statistical clear sky model has been implemented and assessed using ground measurements. Identical comparisons have been performed for the two deterministic models McClear and Solis. These physical models show a much better representation of clear sky surface irradiance even for high solar zenith angles. The statistical model has been built from GHI data acquired in Reunion Island where cloudiness presents a high variability. This fact might be a major difficulty to retrieve an accurate signal envelop over a 1-year dataset.

Further studies must be undertaken with GHI observations available at 1-minute time step. However, physical models showed very accurate results without using an historical dataset. They present a great advantage for GHI assessment and forecasting in operational conditions.

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