PROJECT: Contribution towards a Solar Atlas of the Azores
TEAM: Clarisse Magarreiro master's dissertation research under the supervision of Prof. Pedro Alberto de Miranda and Prof. Miguel Centeno Brito

Context

Azores islands use mainly imported fossil fuels as primary energy source (fuel, petrol and diesel oil). Nonetheless energy provided from geothermal and wind power installations has had a positive trend.

Azores islands can also be seen as a potential privileged place for studying renewable energy by becoming, almost entirely, sustainable. The innovating MIT project *Green Islands* intends to implement this idea developing, for that purpose, new methodologies for identify options and profitable solutions of sustainable energy using endogenous natural resources.

Technical and economic viability of a given technology which use natural resources for energy harnessing are directly dependent of that same resource availability. So is therefore essential to knowledge how are characterized those resources and the factors that influence them: geographic location, season of the year, hour of the day, land use and its physiographic characteristics.

In Portugal mainland solar resource was (and is) a driving factor in development and promotion of solar systems implementation (thermal and/or photovoltaic). However, in Azores islands, due to different meteorological conditions, which are described with a major cloud cover percentage, solar resource is often defined as poor considering it energy harnessing.

The proper conception of a solar energy system, aiming it optimal performance, requires reliable *a priori* information about solar resource availability in the desired local for such system implementation. The existence probability of this required data is however short and therefore is needed to appeal upon methods of resource evaluation. The methods that can be applied differ from themselves and are mainly chosen accordingly to the meteorological data available in the local under consideration (temperature, atmosphere composition, sunshine duration, solar radiation records, cloud cover percentage, albedo). Solar radiation that reach Earth's surface is directly related to the local weather conditions.

Objectives

The Azores archipelago has not, until present, been taken into account for a proper full detail study of solar resource potential. The project research presented here was developed as a contribution to fulfill this gap within a master's dissertation scope.

The work intends to question the ability of the atmospheric numerical modelling system WRF (Weather Research and Forecast) to provide basic data for solar resource assessment model. The analysis was applied to the Azores islands Terceira and Graciosa.

Description of the project and results

The numerical weather prediction model WRF is analyzed in this study as a tool for prediction of global solar radiation values in the islands Terceira and Graciosa. Azores islands have meteorological conditions with large variability and a small network of meteorological data acquirement. To validate WRF model its output is compared with solar radiation data acquired *in situ*. Since WRF output regards only global solar radiation, three different parameterizations for decomposing it into direct and diffuse components are analyzed. Direct component of solar radiation is especially needed in the analysis of concentration systems. WRF will allow the construction of a grid with solar radiation values which will be representative of the entire islands surface. A Solar Atlas is then assembled.

Figure 1 represent the dada acquired *in situ* (shown here only one year values as example).

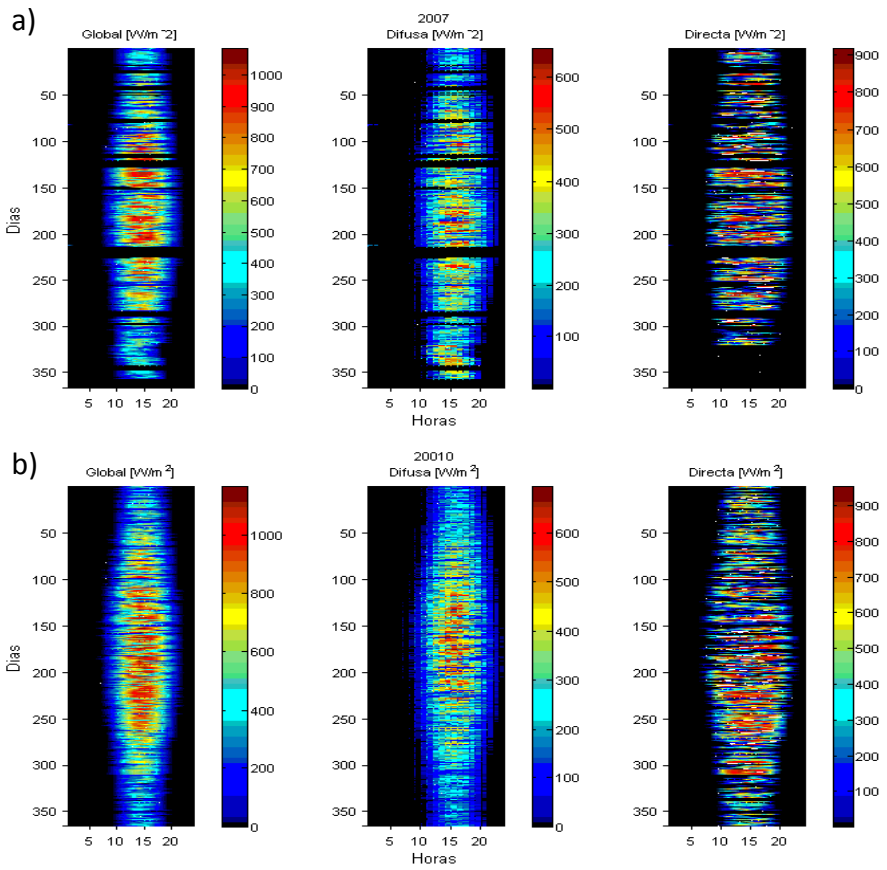

Figure 1 – Hourly means of (from left to right) global, diffuse and direct solar radiation components in Wm^{-2} for a) **Terceira 2007** and b) **Graciosa 2010**. X-axis represent hours of the day, Y-axis represent days of the year.

Global radiation values from *in situ* data are compared with values from WRF output to assess the performance of the latter. Figure 2 represents the analyzed time series and comparison between WRF and *in situ* data values for the matching periods.

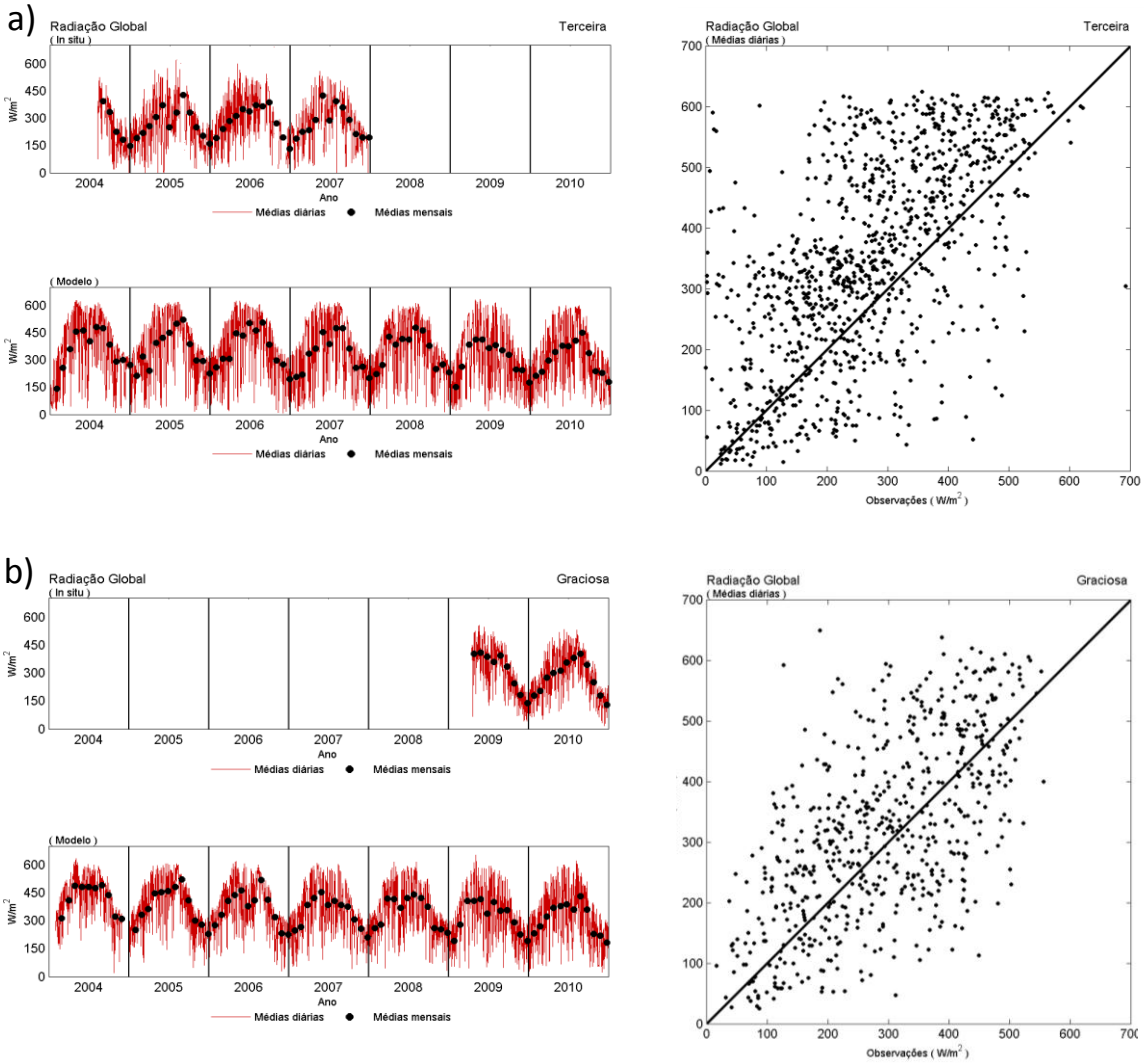

Figure 2 – Representation of the analyzed time series (panel on the left): daily means (lines) and monthly means (dots) of global solar radiation in Wm^{-2} from *in situ* measurements (top) and WRF model (bottom) for **a) Terceira** and **b) Graciosa**. X-axis represents Year.
Comparison between daily means predicted by WRF model and *in situ* measurements (panel on the right): X-axis represents values measured, Y-axis represents values predicted (Wm^{-2} both). Line 1:1 shown only as reference.

From the comparison between daily means predicted by WRF model and *in situ* measurements one is leaded to the idea that WRF model overestimates values (mainly in Terceira) of global radiation. Statistical analysis is then applied, assessing errors values. As expected was concluded that bias and mean absolute errors are smaller when comparing monthly means values (as opposed to daily means values). For Graciosa island mean absolute percentual error (MAPE) rounds 15 % and for Terceira island 25 %. Linear correlation is always higher than 0.8

for Terceira values and than 0.9 for Graciosa. Both WRF predictions, for Graciosa and Terceira islands, are overestimated in a range of [10-30] %.
It should be mentioned that the possible poor quality of the *in situ* data might be affecting the analysis, leading to faulty results.

Using parameterization for decomposing global solar radiation into direct and diffuse components are finally assembled maps for Graciosa and Terceira with solar radiation values according to WRF grid. In figure 3 is the representation of only global solar radiation (as example) for both islands.

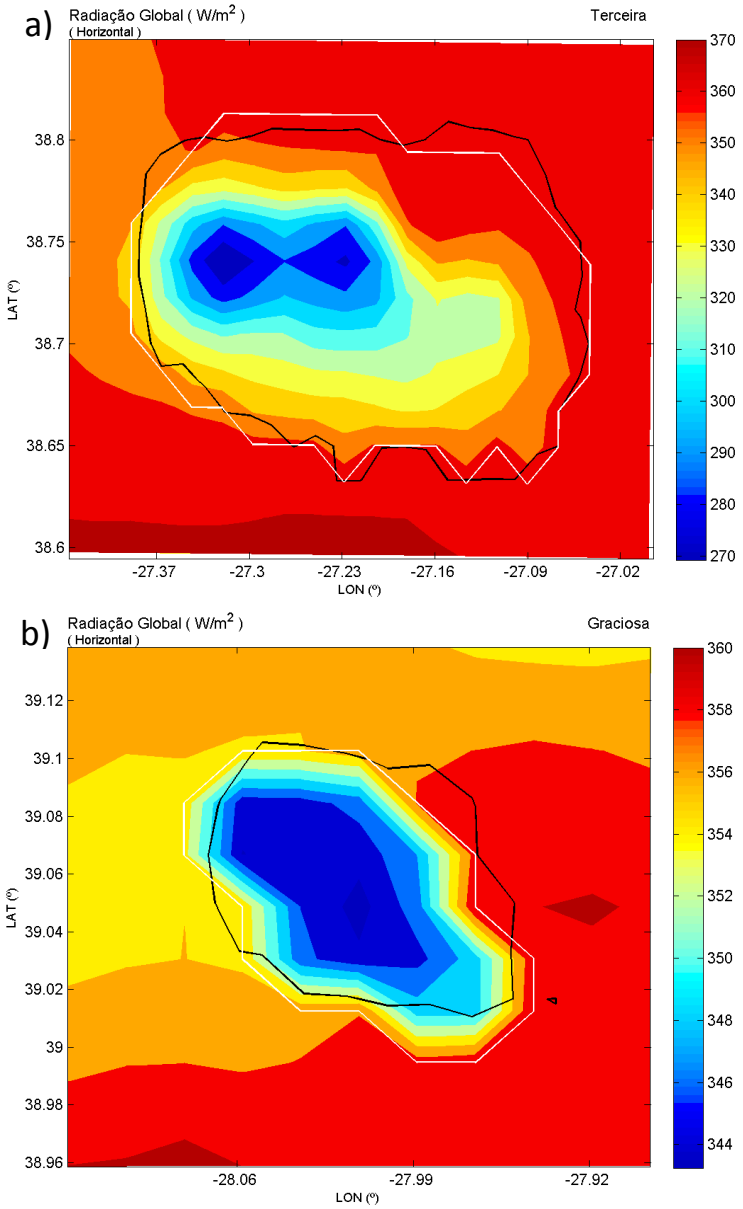

Figure 3 – Solar radiation map: global radiation [Wm^{-2}] of **a) Terceira** and **b) Graciosa**. White line represents islands (land) limits used in WRF model; black lines represents islands limits according to ETOPO1[1] model.

[1] *Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, 2009*

To provide a better insight on the solar radiation values one can assess, in a simplistic way, the mean photovoltaic (PV) potential for the solar resource characterized within this work. Taking into consideration a PV module efficiency of 12 % under a mean solar radiation of 350 Wm^{-2} (within the global radiation range of values for Terceira and Graciosa) during 7 hours/day it will get a yearly energy conversion of about 107 $kWhm^{-2}$.

Islands such as Azores are particularly interesting to be studied in order to fulfill a detailed assessment of their natural resources to favor therefore the implementation of sustainable systems which will promote the autonomy in energy sector.