A New Method to Estimate Daily Global Solar Radiation

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Introduction

Global solar radiation (GSR) is one of the major determinants of evapotranspiration, hence, measured or estimated values of solar radiation are crucial for simulating the water budget of crops and cropping systems.

Given the limited availability of quality GSR, a model based on daily temperature range was proposed by Bristow and Campbell (1984). Improved versions of this model (Donatelli and Marletto, 1994; Donatelli and Campbell, 1998) better accounted for seasonality effects in temperate areas. However, all these models were not tested against data set including a wide range of latitudes, and particularly they were not tested at tropical and subtropical areas.

Objectives

- **Develop a model to be used at a variety of latitudes**
- **Test the model against an extensive dataset**

Methods

Weather data sets. The data used are from 188 stations located world-wide. In most cases each station had six years of daily values of solar radiation, maximum and minimum air temperature. In some cases the number of years was smaller (at least 3 years).

Data analysis. GSR was estimated using three models, i.e. Bristow and Campbell (BC), Campbell and Donatelli (CD), and the new model called Donatelli and Bellocchi (DB). For each location, the data available were subdivided in two groups of years, using one group for parameter calibration and the remaining for model validation. Model performance was evaluated mainly via four statistical indices, as described in table 1. Whether RMSE and CV are based on the model error, PIdoy and PITn account for patterns of residuals (estimated-measured) vs. either day of the year or daily minimum air temperature, respectively.

Parameter Optimization. Parameters were optimized minimizing RMSE with regards to the ***b*** parameter (all models), Pidoy with regards to the ***c1*** and ***c2*** parameters (DB model), and PITn with regards to the ***Tnc*** parameter (CD model).

The Model

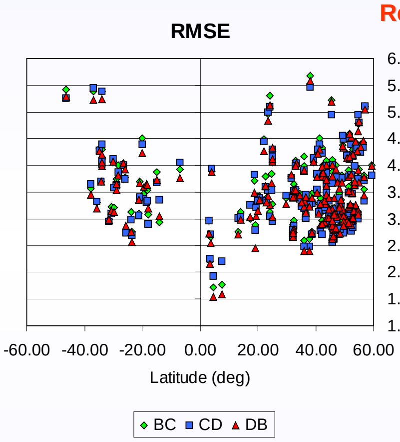
$$GSR = tt\ PotRad$$

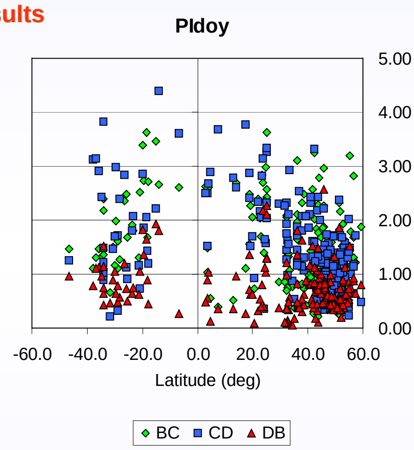
$$tt = \tau\left[1 + c1\sin\left(i\frac{\pi}{180}c2\right)\right]\left[1-\exp\left(\frac{-b\,\Delta T^2}{\Delta T_w}\right)\right]$$

PotRad	= extraterrestrial radiation
tt	= atmospheric transmissivity
τ	= clear sky transmissivity
ΔT	= daily air temperature range
ΔT_w	= weekly ΔT
i	= day of the year
b, c1, c2	= empirical parameters

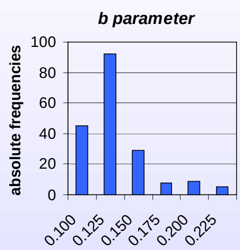
The sine function allows accounting for seasonal variation of both ΔT and τ via the parameters ***c1*** (magnitude of the correction factor) and ***c2*** (profile of the correction during the year)

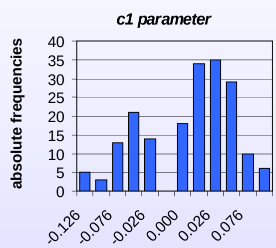
Results

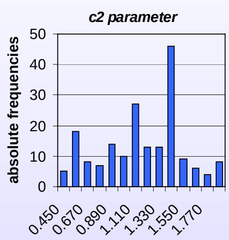




Whether the DB model shows a small improvement in terms of model error (RMSE), the same model shows a remarkable improvement in terms of the pattern of residual across the year (PIdoy). Each of the points in the graphs above is the result for more than 1000 estimates for each location.







The sign of ***c1***, which resulted always different from 0, is related to the hemisphere, although the number of southern latitude locations was too small to mirror the ***c1*** distribution of northern latitudes. The distribution of the ***c2*** parameter shows three peaks, which correspond to the most frequent pattern of correction required (due to seasonal variation of ΔT with respect to GSR) at different sites.

Conclusions

- **The new model improves remarkably the goodness of GSR estimates across the year compared to the BC and CD models**
- **Model estimates were accurate across a broad range of latitudes and environmental conditions**
- **Analysis to estimate model parameters without the support of measured radiation data is on going**

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