An Indicator of Solar Radiation Model Performances based on Fuzzy Rules

Research Institute for Industrial Crops

Gianni Bellocchi[1], Marco Acutis[2], Marcello Donatelli[1], Gianni Fila[1]

[1]ISCI – Research Institute for Industrial Crops

[2]DIAAT - Department of Agricultural Engineering and Territorial Agronomy

Introduction

Different indices or test statistics are usually computed when evaluating models, quantifying the amount of residuals, the modelling efficiency, the correlation between estimates and measurements, the presence of patterns in the residuals, etc. A clear response might not be given when such issues are not concordant. A fuzzy expert system is proposed to calculate an indicator, "I_{rad}", integrating different aspects associated to radiation model evaluation. Diverse models estimating daily radiation are available, i.e., BC, CD, DB. Evaluating and comparing such models was a complex process because of the number of statistical indices used.

Objectives

- **To develop an aggregated index for evaluating solar radiation models**
- **To use the indicator to test different models against selected case studies**

Membership functions

Two S-shaped functions (Fig. 1) describing membership to the fuzzy subsets Favourable (F) and Unfavourable (U) were defined for each index.

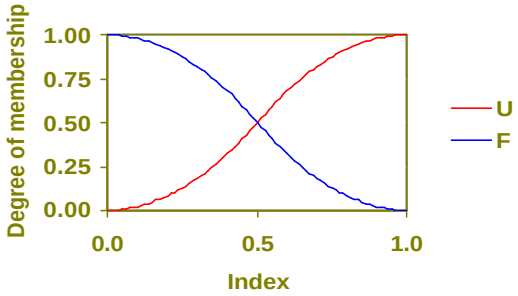

Fig. 1 - Graphical presentation of fuzzy sets. U: unfavourable; F: favourable.

The relative importance of each index was estimated by expert weights. The expert system calculates the value of modules according to both the degrees of membership of the indices to either the subsets F and U. The three modules were aggregated (again according to membership to F and U and a set of rules) into the indicator I_{rad} (scaled from 0, the best, to 1, the worst).

Modules

The indicator is composed by three modules, reflecting the magnitude of residuals ("Accuracy"), the correlation between estimates and measurements ("Correlation"), and the presence of patterns in the residuals vs. independent variables ("Pattern"). Each module depends on one or more indices (Tab. 1). The relative importance of each index was estimated by expert weights. Two S-shaped functions (Fig. 1) describing membership to the fuzzy subsets Favourable (F) and Unfavourable (U) were defined for each index. The expert system calculates the value of modules according to both the degree of membership of the indices to either the subsets F and U. The three modules were aggregated (again according to membership to F and U and a set of rules) into the indicator I_{rad} (scaled from 0, the best, to 1, the worst).

Tab. 1 - The modules "Accuracy", "Correlation" and "Pattern". RRMSE: relative root mean square error; p(t): probability of t; EF: model efficiency; r: correlation coefficient; PI_{doy}: pattern index vs. day of the year; PI_{Tmin}: pattern index vs. minimum temperature. F=favourable, U=unfavourable.

Inputs	Limits	Modules		
		Accuracy	Correlation	Pattern
RRMSE	F=20, U=40	x		
p(t)	F=0.10, U=0.05	x		
EF	F=0.90, U=0.40	x		
r	F=0.90, U=0.70		x	
PI_{doy}	F=1.0, U=2.5			x
PI_{Tmin}	F=1.0, U=2.5			x

Results

Results of the computation of indices and I_{rad} on yearly radiation data sets at six selected locations are presented in Table 2 and Figure 2.

Tab. 2 - Performance of the radiation models BC, CD and DB on six yearly data sets, quantified by a set of indices

Location	Model	RRMSE	EF	p(t)	r	PI_{doy}	PI_{Tmin}
Los Baños (Philippines) 1989	BC	19.90	0.61	0.83	0.81	1.59	1.65
	CD	19.28	0.63	0.87	0.82	2.21	1.02
	DB	19.14	0.64	0.94	0.80	0.56	0.74
Patos de Minas (Brazil) 1997	BC	16.74	0.56	0.89	0.79	2.92	5.15
	CD	15.61	0.62	0.79	0.82	2.09	3.07
	DB	17.20	0.54	0.88	0.74	0.90	2.78
Perugia (Italy) 1995	BC	21.60	0.86	0.78	0.93	1.21	1.63
	CD	20.97	0.87	0.94	0.93	1.86	1.30
	DB	21.82	0.86	0.90	0.93	1.25	1.57
Matsumoto (Japan) 1994	BC	20.67	0.79	0.90	0.78	1.74	2.23
	CD	20.25	0.80	0.89	0.89	2.39	1.25
	DB	20.83	0.79	0.89	0.92	0.88	1.56
Sadore (Niger) 1995	BC	13.42	0.23	0.96	0.57	1.01	0.74
	CD	14.21	0.14	0.84	0.52	2.24	0.97
	DB	13.03	0.28	0.99	0.53	0.66	0.51
Würzburg (Germany) 1998	BC	25.79	0.88	0.97	0.94	1.29	0.99
	CD	24.55	0.89	0.77	0.95	1.27	1.62
	DB	25.22	0.88	0.99	0.88	0.45	0.45

Fig. 2 - Performance of the radiation models BC, CD and DB on six yearly data sets, quantified by I_{rad}.