CALIBRATION AND VALIDATION OF ET_0 THROUGH AN R-CRAN CODE IN AGRICULTURAL LANDS OF SOUTH-EAST SPAIN

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ABSTRACT

Currently, water demands from urban and agricultural use are increasing, especially in arid and semi-arid regions, such as the Mediterranean. This situation is expected to become worse with the climate change projections for the region, increasing the pressure, in both quantity and quality, on fresh water resources. Evapotranspiration (ET_0) is a hydrologic variable with high uncertainty and considered incorrect in water balance estimations. However, its accurate assessment is essential to obtain the real value of available water to satisfy water demands, especially in extended agricultural areas such as the south-east of Spain. ET_0 can be obtained using different equations with different levels of input data requirements, among them the Penman–Monteith option is the one recommended by the FAO (PMFAO), but its input data requirements are high. On the other hand, there are simpler options, such as the Hargreaves equation ($ET_{0,HG}$), but there is not such a big agreement about its accuracy in the scientific literature. The main objection to the use of PMFAO is the lack of some of the required meteorological variables in most climate stations, forcing the use of simpler alternatives. This paper presents an R-CRAN code where the $ET_{0,HG}$, parameterized by Samani, is calibrated and validated with the Allen model considering 18 statistical contrasts. Both $ET_{0,HG}$ results (pre- and post-calibrated) are compared with daily, monthly and annual results of the PMFAO. All meteorological data was provided by the CA52 Cartagena La Aljorra weather station, managed by the Agricultural Information System of the Murcia region (SE Spain). The main results show that daily, monthly and annual $ET_{0,HG}$ results after the Allen calibration and validation are similar to the PMFAO. However, a moderate underestimation of $ET_{0,HG}$ compared to PMFAO was identified. To sum up, the presented R-CRAN code provides an alternative to apply the $ET_{0,HG}$ method with few meteorological input requirements and, once calibrated, can be applied to extended data networks in other regions.

Keywords: evapotranspiration, Hargreaves and Penman–Monteith FAO equations, Allen calibration, agricultural areas, R-CRAN code.

1 INTRODUCTION

Evapotranspiration is one of the most important processes in the water cycle; its knowledge is very important in the disciplines of hydrology, meteorology, agriculture and to carry out studies on impacts of climate change. The accurate estimation of ET_0 is especially relevant in semiarid areas where water shortages are the major obstacle to agricultural production, economic welfare and sustainable development (Hargreaves and Allen [1], Samani [2], Allen et al. [3], [5], Monteith [4]).

There are different definitions of this process, among which is the reference evapotranspiration (ET_0), which is defined as "the evapotranspiration rate of a reference surface", which occurs without water restrictions. The reference surface is a hypothetical crop with an assumed crop height (0.12 m), a fixed canopy resistance (70 s m^{-1}) and Albedo (0.23) (Allen et al. [3], Martínez-Pérez et al. [6]).

Nowadays, the Penman–Monteith FAO (PMFAO), achieved with grass crops, is the recommended method to estimate ET_0, which is considered as the reference potential evapotranspiration. However, the meteorological data required by this method are not

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available in most weather stations. In these cases, Allen et al. [7] recommended the estimation of ET_0 using the Hargreaves equation (Hargreaves and Allen [1]), which only requires maximum and minimum temperature data. The equation of Hargreaves is defined as:

$$ET_{0,HG} = C \cdot RA \cdot (Tmax - Tmin)^{0.5} \cdot (Tmed + 17.8), \quad (1)$$

where $ET_{0,HG}$ is the reference evapotranspiration (mm day^{-1}) estimated by Hargreaves; C is an empirical coefficient whose value is 0.0023; RA is the extraterrestrial radiation (mm day^{-1}) measured as ET_0 equivalent (mm day^{-1}); $Tmax$, $Tmin$ and $Tmed$ are the daily maximum, minimum and average temperature (°C). See Allen et al. [7] for details of its calculation.

The Hargreaves equation frequently overestimates ET_0 in humid regions and underestimates it in dry regions. Moreover, Hargreaves equation tends to overestimate ET_0 in low ET areas and to underestimates it in high ET areas (Droogers and Allen [8], Xu and Singh [9]). For these problems, it is necessary to carry out a regional calibration of the Hargreaves equation. In Allen et al. [3], [10] it was proposed a methodology to realize this calibration, which consists in a simple linear regression between the series of ET_0 obtained from the Penman–Monteith and Hargreaves methods, passing the regression line by the origin of coordinates and using the slope of the regression line obtained as an adjustment parameter between these two expressions:

$$ET_{0,PM} = b_0 + b_1 \cdot ET_{0,HG}, \quad (2)$$

where $ET_{0,PM}$ is the reference evapotranspiration (mm day^{-1}) estimated by Penman–Monteith equation; and b_0 and b_1 are, respectively, the y-intercept and the line slope of the above mentioned regression line.

Thus, the main purpose of this study consists on accomplish an extend R-CRAN code [11] to resolve the ET_0 Hargreaves expression (Hargreaves and Allen [1]), parameterized by Samani [2], and assess its accuracy with previously obtained series of the PMFAO-ET_0. In order to improve this accuracy, results from the Hargreaves equation are calibrated and validated with the Allen et al. [3] model considering several statistical contrasts.

2 STUDY AREA

The present study was developed with registers from the CA52 Cartagena La Aljorra weather station, located in the Cartagena municipality (province of Murcia). These areas belong to the Segura river basin district (SE Spain) which presents semiarid climate with irregular and scarce rainfalls (average precipitations of 374 mm/year, showing clear differences from NW mountain areas, around 1,000 mm/year, to coastal areas with less than 300 mm/year), high annual average temperatures (18–10°C), and a large number of hours of sun that generate high potential evapotranspiration rates (average ETP of 993 mm/year) and real evapotranspiration rates (average ETR of 335 mm/year). Detail information can be found in CHS [12], Gomariz-Castillo et al. [13] and Ruíz-Álvarez et al. [14]. Due to the mentioned climate features, irrigated agriculture developed highly in these areas especially since the 1970s (alongside the start of the Tajo-Segura interbasin transfer) and, nowadays, constitutes great water demands together with high water necessities required from the industrial zones and the extend and densely populated urban areas identified in the south-eastern Spain. In particular, the Segura river basin district showed, in 2015, a total water demand of 1762.1 hm^3/year, which 86.2% corresponded to agricultural water demands, 10.8% to urban demands, 1.7% to environmental demands, 0.7% to industrial demands do not dependent of urban supply networks, and finally 0.6% to irrigate golf courses (CHS [12], Albaladejo-García et al. [15], Grindlay-Moreno and Lizárraga-Mollinedo [16]). As a result of the recognized instability among scarce water inputs and great water demands, currently the Segura river basin district presents the highest water resources shortage of Europe (Custodio et al. [17], Melgarejo-Moreno et al. [18]), with several problems of aquifers overexploitation (227 hm^3/year estimated in 2015 by CHS [12]), political issues related with interbasin transfers from other watersheds (Molina and Melgarejo [19]), great rates of desalinated water and reused wastewaters (from desalination: 158 hm^3/year to supply agricultural and urban uses; from reused wastewaters: around 78 hm^3/year), etc. all of them as measurements to supply the large identified water demands (CHS [12], Melgarejo-Moreno and Molina-Giménez [20]). Therefore, the correct quantification of water losses, as in this case the evapotranspiration rates, result essential specially in these types of water-stressed areas.

Fig. 1 depicts the analysed weather station, CA52 Cartagena La Aljorra during the period 1 September 1999–31 December 2015, in the context of the SE Spain. This station belongs to the Agricultural Information System of the Murcia Region (in Spanish SIAM [21]), a sub-network of the Spanish Agroclimatological Information System for Irrigation (in Spanish SIAR [22]).

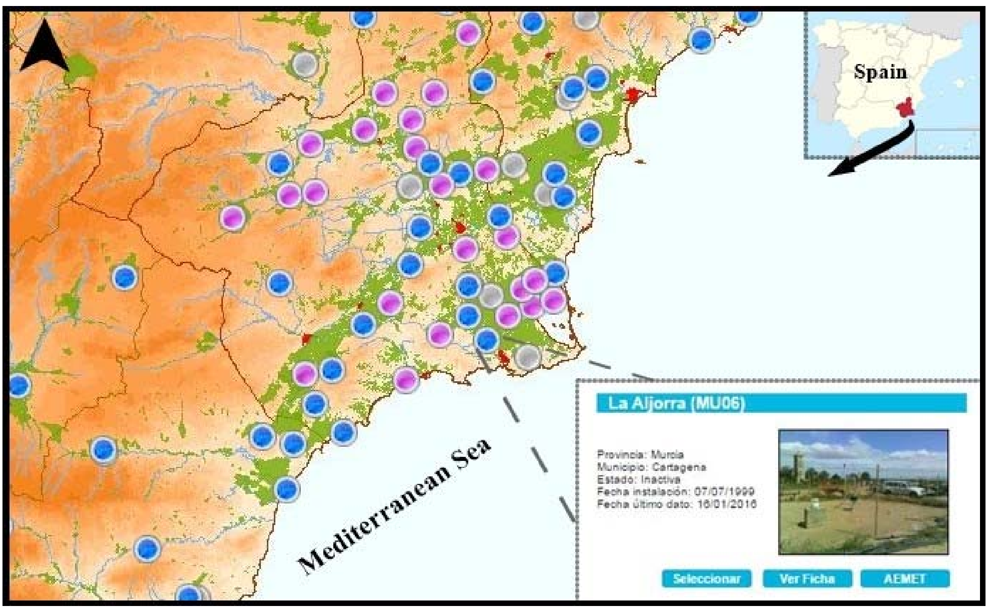

Figure 1: Study area showing the CA52 Cartagena La Aljorra weather station integrated in the SIAR network [22].

3 METHODOLOGY

In the following sections we present main items of the above mentioned R-CRAN code [11] to resolve the objectives of this study.

3.1 Previous steps

In the R-CRAN work routing, first of all, packages and libraries must be installed and loaded which depend of the study objectives. The "hydroGOF" library is necessary, among others, to perform next statistical contrasts (error estimations):

```
install.packages("hydroGOF","dep=T")
library(hydroGOF)
```

Next, daily information from CA52 Cartagena La Aljorra weather station (period 1 September 1999–31 December 2015) was imported in R-CRAN. This information contains data of Tmax, Tmin, Tmed, PMFAO-ET_0, etc:

```
dataET=read.table("data/dataorigin.csv",sep=";",dec=",",header=T,fil
l =T) # where fill=T is introduced by data gaps or NA.
```

Finally, imported daily data in R-CRAN is checked and processed before to start with the ETP equations:

```
names(dataET) # to display columns names.
dataET= dataET[,c(5,6,7,8,9)] #to conserve only columns of date, Tma
x, Tmin, Tmed, PMFAO-ET0.
names(dataET)=c("date","tmax", "tmed", "tmin","etp") # to change col
umns titles into appropriate titles (without spaces, etc.).
str(dataET) # to display the structure and type of information.
dataET$date=as.Date(dataET$date,format="%d/%m/%Y") # to convert the d
ate variable from factor or text type into date type. Expressions "%
d/%m/%Y" indicate day, month and year.
dataf2=data.frame(serie=seq(as.Date("1999-09-01"),as.Date("2015-12-3
1"),"days")) # to check the existence of all data. serie=seq to exte
nd serie from the initial date until the final date.
length(dataET$date)
## [1] 5930 # Thus, imported serie from SIAM present 5930 days with
data.
length(dataf2$serie)
## [1] 5966 #Thus, the period 01/09/1999-31/12/2015 present 5966 day
s. Therefore, imported serie from SIAM possess 36 days with data gap
s or NA.
dataf3=merge(dataf2, dataET,by.x="serie",by.y="date",all.x = T)#Thus
, we merge the matrix ''dataET'' and ''dataf2'' in a new matrix called ''
dataf3''. In the new matrix, days with data gaps are introduced with
a NA character.
length(dataf3$serie)
## [1] 5966 # to check the new matrix, called ''dataf3'', is correct.
subset(dataf3,is.na(dataf3$etp)) # to check the days with NA:
##           serie   tmax  tmed  tmin etp
## 204  2000-03-22    NA    NA    NA  NA
## 205  2000-03-23    NA    NA    NA  NA
## 206  2000-03-24    NA    NA    NA  NA
## 207  2000-03-25    NA    NA    NA  NA
## 208  2000-03-26    NA    NA    NA  NA
## 209  2000-03-27    NA    NA    NA  NA
## 210  2000-03-28    NA    NA    NA  NA
## 211  2000-03-29    NA    NA    NA  NA
## 212  2000-03-30    NA    NA    NA  NA
```

```
## 213  2000-03-31    NA     NA     NA   NA
## 214  2000-04-01    NA     NA     NA   NA
## 215  2000-04-02    NA     NA     NA   NA
## 216  2000-04-03    NA     NA     NA   NA
## 1403 2003-07-04    NA     NA     NA   NA
## (…)
```

3.2 Parameterized Hargreaves equation

In this section is shown the Hargreaves expression (Hargreaves and Allen [1]), parameterized by Samani [2], together with its parameters, partial and final equations:

```
ETHARG=function(latitude,date,tmed,tmax,tmin){
  #parameters: GSC=0.082
  #Julian day:
  djulian=as.numeric(julian(date,origin=as.Date(paste(substr(date,1,
4),"-01-01",sep=""))))
  #Partial equations:
  varpi=latitude*pi/180
  Dt=1+0.033*cos((2*pi/365)*djulian)
  delta=0.409*sin((2*pi/365)*djulian-1.39)
  omega=acos(-tan(varpi)*tan(delta))
  #Ra calculate:
  Ra=(24*60/pi)*GSC*Dt*(omega*sin(varpi)*sin(delta)+cos(varpi)*cos(d
elta)*sin(omega))
  Ra=Ra*0.408
  #ETHARG final equation:
  etharg=0.0023*(tmed+17.8)*(tmax-tmin)^0.5*Ra
  return(etharg)    }
source("FunctionHavers/FunHavers.R")
latdec=37+(40/60)+(35.9/3600) # Latitude is a variable necessary to
calculate the Hargreaves model. The CA52 Cartagena La Aljorra weathe
r station presents latitude of 37º 40´ 35.9´´ N, which was calculate
d from its UTM X and Y coordinates (SIAR [22]).
ETHARG(latitude=latdec,tmax=dataf3[1,"tmax"],tmed=dataf3[1,"tmed"],
tmin=dataf3[1,"tmin"],date=dataf3[1,"serie"])
## [1] 2.971072 # This is the Hargreaves ET0 result to the first lin
e of the ‘‘dataf3’’ data.frame.
for(i in 1:5966){
  dataf3$etharg[i]=ETHARG(latitude=latdec,tmax=dataf3[i,"tmax"],tmed
=dataf3[i,"tmed"],tmin=dataf3[i,"tmin"],date=dataf3[i,"serie"])
}# This is the Hargreaves ET0 expression to the complete ‘‘dataf3’’ da
ta.frame.
```

The complete daily serie of ET_0, obtained by the Hargreaves expression to the 5,966 days, underestimates data of PMFAO-ET_0 from the CA52 Cartagena La Aljorra weather station. Therefore, it is necessary to calibrate and validate the Hargreaves model.

3.3 Calibration and validation of the Hargreaves model

In this section the ET_0 Hargreaves expression (Hargreaves and Allen [1]), parameterized by Samani [2], is calibrated and validated with the Allen et al. [3] model considering 18 statistical contrasts:

```
modAllen=lm(dataf3$etp~dataf3$etharg) # This is the linear model of
Allen applied to the ‘‘dataf3’’ matrix in order to calibrate the ethar
g serie.
summary(modAllen) # The summary command displays important statistic
al data:
## Call:
## lm(formula = dataf3$etp ~ dataf3$etharg)
## Residuals:
##     Min      1Q    Median      3Q     Max
## -2.3380 -0.5335 -0.1595  0.3861  4.5037
## Coefficients:
##                            Estimate   Std.Error  t value Pr(>|t|)
## (Intercept)          0.32825    0.02197   14.94    <2e-16 ***
## dataf3$etharg    1.11502    0.00635  175.58    <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 0.7717 on 5908 degrees of freedom
##   (56 observations deleted due to missingness)
## Multiple R-squared:  0.8392, Adjusted R-squared:  0.8392
## F-statistic: 3.083e+04 on 1 and 5908 DF,  p-value: < 2.2e-16
```

Regarding the presented coefficients, the y-intercept (b_0 in eqn (2)) shows a value of 0.32825. To remove this value the following expression is used:

```
modAllen=lm(dataf3$etp~0+dataf3$etharg)
summary(modAllen)
```

Likewise, the period with registers from the CA52 Cartagena La Aljorra weather station (1 September 1999–31 December 2015) is divided to validate and calibrate. The first third (1 September 1999–31 December 2004) is used in validation, and the others two thirds (1 January 2005–31 December 2015) in calibration. Therefore, both series (calibration and validation) are isolated by a subset:

```
modAllen=lm(subset(dataf3$etp,dataf3$serie>="2005-01-01")~0+subset(d
ataf3$etharg,
dataf3$serie>="2005-01-01"))
summary(modAllen)
```

In this subset the "Estimate" coefficient shows a value of 1.203716. This coefficient is the line slope (b_1 in eqn (2)) of the Allen model:

$$ET_{0,PM} = b_0 + b_1 \cdot ET_{0,HG}$$
$$ET_{0,PM} = 0 + 1.203716 \cdot ET_{0,HG}$$

Thus, in the "dataf3" data.frame a new column, correspond to the calibrated $ET_{0,HG}$, is added:

```
dataf3$ethargC = 1.203716*dataf3$etharg #The next picture depicts
the first 10 days of the analysed serie (5966 days):
```

	serie	tmax	tmed	tmin	etp	etharg	ethargC
1	1999-09-01	27.80	25.47	23.19	3.78	2.9710724	3.5763274
2	1999-09-02	29.92	26.07	22.15	5.60	3.8870677	4.6789256
3	1999-09-03	35.03	28.19	21.20	7.66	5.4031067	6.5038059
4	1999-09-04	28.95	25.65	20.73	4.68	3.9109005	4.7076135
5	1999-09-05	29.38	25.50	22.42	4.98	3.5635476	4.2894993
6	1999-09-06	29.84	25.83	22.28	5.15	3.7181941	4.4756498
7	1999-09-07	30.24	24.34	20.54	5.95	4.0412823	4.8645562
8	1999-09-08	27.30	24.03	20.79	6.18	3.2645775	3.9296242
9	1999-09-09	28.47	24.46	21.05	5.92	3.4974131	4.2098922
10	1999-09-10	28.00	24.25	21.08	5.85	3.3377863	4.0177468

Therefore, new values of the calibrated $ET_{0,HG}$ (ethargC in the previous picture) are more close to the PMFAO-ET_0 serie (etp in the picture) than the uncalibrated $ET_{0,HG}$ serie (etharg). However, a moderate underestimation of PMFAO-ET_0 is observed. Thus, to assess this adjustment, in calibration and validation, 18 statistical contrasts are considered.

3.3.1 Statistical contrasts

During calibration and validation, 18 statistical contrasts were used to assess error estimations between the calculated $ET_{0,HG}$ series and the reference serie (PMFAO-ET_0). These contrasts were: Mean error (ME), mean absolute error (MAE), mean squared error (MSE), root mean square error (RMSE), Normalized root mean square error (NRMSE in %), percent bias (PBIAS in %), RMSE-observations standard deviation ratio (RSR), standard deviation ratio (rSD), Nash–Sutcliffe efficiency (NSE), modified Nash–Sutcliffe efficiency (mNSE), relative Nash–Sutcliffe efficiency (rNSE), Willmott index of agreement (d), modified Willmott index of agreement (md), relative Willmott index of agreement (rd), Pearson's correlation coefficient (r), coefficient of determination (R^2), R^2 multiplied by the linear regression coefficient between simulations and observations (bR^2) and Kling–Gupta efficiency (KGE). Detail information about these statistical analysis and their numerical expressions can be found in Nash and Sutcliffe [23], Willmott [24], Gupta et al. [25], Krause et al. [26], Moriasi et al. [27] and Gupta et al. [28]).

The following commands calculate the above mentioned statistical contrasts based on the setting between the PMFAO-ET_0 daily series and the $ET_{0,HG}$ daily series:

```
gof(dataf3$etharg,dataf3$etp)#uncalibrated setting (period
01/09/1999-31/12/2015)
gof(sim=subset(dataf3$etharg,dataf3$serie>="2005-01-01"),obs=subset
(dataf3$etp,dataf3$serie>="2005-01-01")) #uncalibrated setting.
Calibration period (01/01/2005-31/12/2015).
gof(sim=subset(dataf3$ethargC,dataf3$serie>="2005-01-01"),obs=subset
(dataf3$etp,dataf3$serie>="2005-01-01"))#calibrated setting.
Calibration period (01/01/2005-31/12/2015).
```

```
gof(sim=subset(dataf3$etharg,dataf3$serie<"2005-01-01"),obs=subset
(dataf3$etp,dataf3$serie<"2005-01-01"))#uncalibrated        setting.
Validation period (01/09/1999-31/12/2004).
gof(sim=subset(dataf3$ethargC,dataf3$serie<"2004-01-01"),obs=subset
(dataf3$etp,dataf3$serie<"2004-01-01"))#calibrated          setting.
Validation period (01/09/1999-31/12/2004).
```

4 RESULTS AND DISCUSSION

4.1 Uncalibrated results

In this section uncalibrated results of $ET_{0,HG}$ at daily, monthly and annual time step are shown during the study period (1 September 1999–31 December 2015, Fig. 2). The following command is used to plot these results:

```
ggof(sim=dataf3$etharg,obs=dataf3$etp,dates=dataf3$serie,ftype="dma"
,leg.cex=1.2,FUN=sum,gofs=c("MAE","RMSE", "PBIAS", "NSE","d","r", "R
2"),legend=c("ET0 Harg.","ET0 PMFAO"),main="ET0 PMFAOvsETHargreaves"
,xlab="",ylab="mm",col=c("red","blue"),cex=0.5,cal.ini="2005-01-01")
```

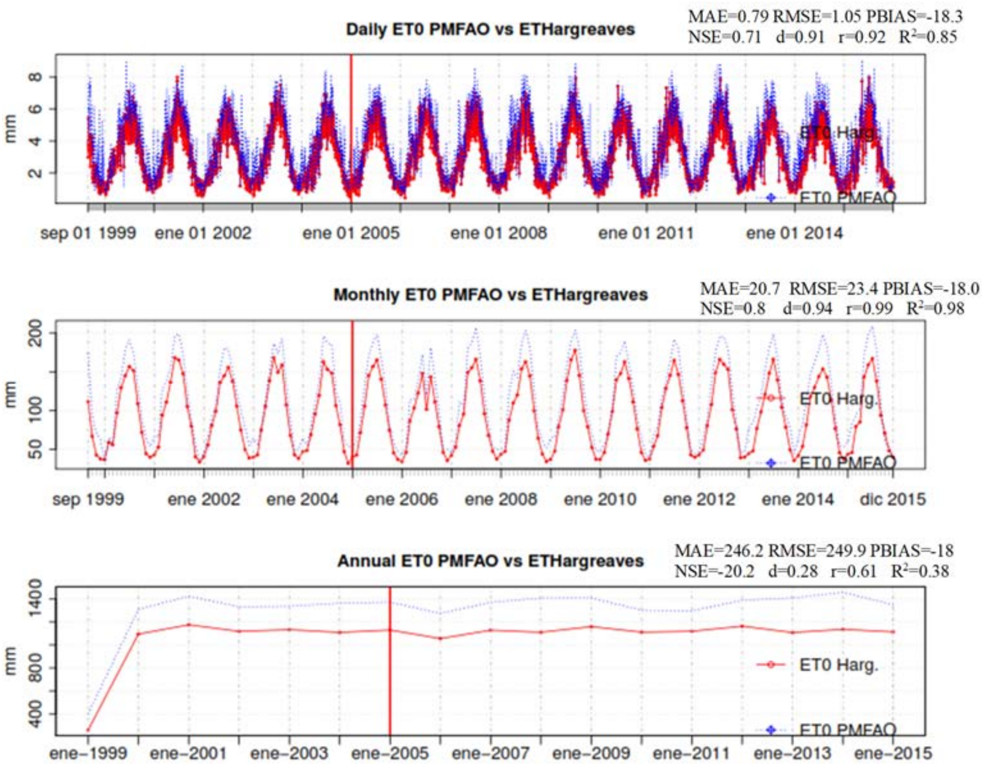

Figure 2: Uncalibrated results of $ET_{0,HG}$ Vs the reference serie (PMFAO-ET_0) at daily, monthly and annual time step during the study period (1 September 1999–31 December 2015).

As can be observed in Fig. 2, obtained series of $ET_{0,HG}$ depict a clear underestimation regarding the reference serie (PMFAO-ET_0). This circumstance can be verified trough the PBIAS statistic which results show values around -18% in the three time steps (daily, monthly and annual).

4.2 Calibrated results

In this section calibrated results of $ET_{0,HG}$ at daily, monthly and annual time step are shown during the study period (1 September 1999–31 December 2015, Fig. 3). The calibration and validation were carried out with the Allen et al. [3] model. The following command is used to plot these results:

```
ggof(sim=dataf3$ethargC,obs=dataf3$etp,dates=dataf3$serie,ftype="dma
",leg.cex=1.2,FUN=sum,gofs=c("MAE","RMSE", "PBIAS", "NSE","d","r", "
R2"),legend=c("ET0 Harg.Allen99","ET0 PMFAO"),main="ET0 PMFAO vs ETH
argreaves.Allen99",xlab="",ylab="mm",col=c("red","blue"),cex=0.5,cal
.ini="2005-01-01")
```

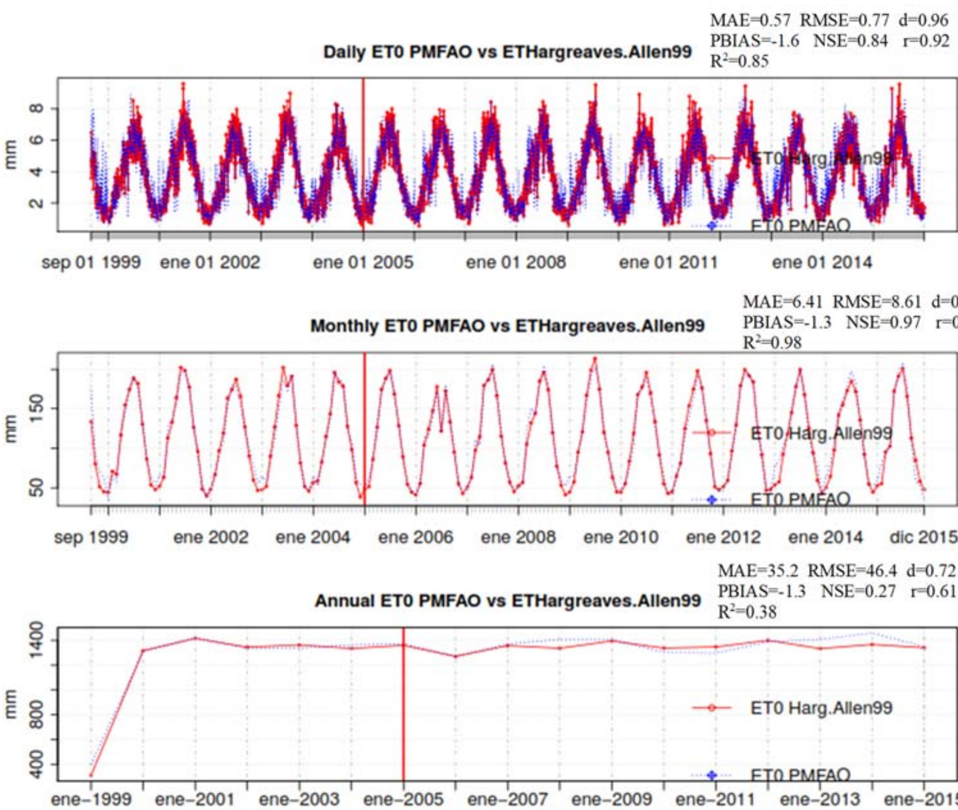

Figure 3: Calibrated results of $ET_{0,HG}$ Vs the reference serie (PMFAO-ET_0) at daily, monthly and annual time step during the study period (1 September 1999–31 December 2015).

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In Fig. 3, calibrated series of $ET_{0,HG}$ depict closer to the PMFAO-ET_0 at the three time steps (daily, monthly and annual) than the uncalibrated $ET_{0,HG}$ series presented in Fig. 2. This circumstance can be verified through the statistic results closer to their optimal values (Moriasi et al. [27], Gupta et al. [28], Fig. 3). A good example is given by the percent bias (PBIAS) which show values between -1.3% and -1.6% (Fig. 3). Therefore, the PMFAO-ET_0 underestimation, previously identified in the uncalibrated $ET_{0,HG}$ series, has reduced considerably.

4.3 Statistic summary

This section depicts statistic results obtained during validation and calibration of the $ET_{0,HG}$ daily series and the contrast with their optimal values (Table 1).

Table 1: Results of the considered statistical contrasts during daily validation and calibration ($ET_{0,HG}$ Vs PMFAO-ET_0).

Statistical contrasts			Validation (1 September 1999– 31 December 2004)		Calibration (1 January 2005– 31 December 2015)	
Acronym	Range	Opt. value	Uncalibrated $ET_{0,HG}$	Calibrated $ET_{0,HG}$	Uncalibrated $ET_{0,HG}$	Calibrated $ET_{0,HG}$
ME	-∞...+∞	0	-0.66	-0.03	-0.69	-0.06
MAE	0...-∞	0	0.75	0.60	0.79	0.57
MSE	0…-∞	0	1.09	0.69	1.10	0.60
RMSE	0…-∞	0	1.04	0.83	1.05	0.77
NRMSE	-100%...100%	0	55.10	44.00	54.00	39.90
PBIAS	-100%...100%	0	-17.90	-0.90	-18.30	-1.60
RSR	0...+∞	0	0.55	0.44	0.54	0.40
rSD	0…+∞	0	0.83	1.01	0.82	0.98
NSE	-∞…1	1	0.70	0.81	0.71	0.84
mNSE	-∞…1	1	0.54	0.63	0.54	0.66
rNSE	-∞…1	1	0.74	0.73	0.75	0.74
d	0…1	1	0.91	0.95	0.91	0.96
md	0…1	1	0.76	0.82	0.75	0.83
rd	0…1	1	0.92	0.93	0.92	0.93
r	-1…1	-1&1	0.91	0.90	0.92	0.92
R^2	0…1	1	0.82	0.82	0.85	0.85
bR^2	0…1	1	0.67	0.80	0.68	0.82
KGE	0…1	1	0.74	0.90	0.73	0.92

As can be observed in Table 1, generally statistic contrasts achieved better results in the calibrated $ET_{0,HG}$ daily series, and even better in the calibrated $ET_{0,HG}$ to the period 1 January

2005–31 December 2015 (Table 1). It is considered that this finding is mainly due to the measure improvement often identified in meteorological stations during current periods.

5 CONCLUSIONS

Main conclusions of the present work are listed below:

- In the CA52 Cartagena La Aljorra weather station (SE Spain), the ET_0 Hargreaves series, parameterized by Samani [2] and simulated during the period with available data (1 September 1999–31 December 2015), showed initially a great underestimation of the Penman–Monteith FAO reference evapotranspiration at three time steps (daily, monthly and annual).
- After the $ET_{0,HG}$ validation (1 September 1999–31 December 2004) and calibration (1 January 2005–31 December 2015), with the Allen et al. [3] model, this variable enhanced its setting to the PMFAO-ET_0 reducing notoriously the above identified underestimation. Thus, results of the considered statistic contrast verified this improvement.
- Therefore, the presented R-CRAN code, to estimates the evapotranspiration variable, can be applied in extend areas over the world thanks to the high capability of R-CRAN to manage massive information (data).

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