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Calibration of GFS model by using real time weather data for water requirement forecasting of citrus crop at the Moroccan Souss basin

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ABSTRACT
The work is about validation of Global Forecast System (GFS) model for citrus water requirement prediction in the semi-arid Moroccan region called Souss-basin. The technique consists on using real time weather data installed to calculate Evapotranspiration (ETo) and statistically compare it to forecast values. GFS model prediction was enough accurate for ETo estimated on daily basis through air temperature, relative humidity and solar radiation forecasting (89,3% for Souss Upstream and 76,1% for Souss Center). However, no logic relation could be found prediction compared to measurements of Rain and Wind. The annual predicted irrigation water needs (ETc) was 7626,5 m3/ha, when the measured one was likely 7669,1 m3/ha in Souss Upstream; and when it comes to Souss Center more closer to sea, this value is predicted to be only 5716,3 m3/ha with a good correlation to calculated measurements showing 5948,7 m3/ha Nevertheless, Calibrations must consider seasons of the year; the tested model was more accurate during cold period from 01/10/16 to 31/03/17, but in the hot period, predicted temperature and ETo become overestimated.

Keywords: Modeling; Evapotranspiration; Water requirement; Forecast; GFS.

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I. INTRODUCTION

Morocco has actually, implemented new strategy called National Green Plan 2010-2020, launched by the government to boost agriculture production and have especially given subsidies to many crops such as citrus trees at rates of 1200 USD per hectare ([1]), this have lead to implementation of new big orchards and explosion of production, which allowed the Souss Massa region to play an important role in the socio-economic development of the kingdom (Citrus plantings cover 85 000 ha with an annual production of 1.7 million tons of which 90% are used for fresh consumption. However, this situation is accompanied by more water use to meet crops irrigation requirements and a significant depletion of groundwater piezometric level to more than 2 meters per year and a decrease of water deficit varying from 100 to 370 Mm3 /year for the Souss aquifer due to over-pumping ([2]) . Indeed, the increased demand for irrigation water and the reduction in renewable water resources due to a succession of drought years are currently the major constraints in the management of groundwater resources which are considered to be the main source to satisfy water requirements ([3])

Then, The citrus production as most agricultural production suffers, now, from water scarcity enhanced by increasing demand and climate change impacts ([4]) which is expected to define food production in the coming decades ([5]). With worldwide concern about water scarcity, agriculture is under pressure to improve water management and explore available solutions to irrigation water saving ([6]) One of these solutions is Evapotranspiration forecasting applied to irrigation decision making process. Many operational Numerical Weather Prediction centres (NWP) now produce higher-resolution, limited-area, shorter-range (≤ 3 day) ensemble forecasts. These provide probabilistic guidance and early warning of the likelihood of high-impact weather. But, unfortunately the representation of near-surface and model uncertainties in ensemble systems, and the correction and filtering of forecast errors remain as significant challenges.

This is why, we decided to calibrate the data processed into the forecasting model by using real time observations/analyses, as many authors believe that, doing so, can dramatically reduce systematic errors in forecast products and improve skill and reliability ([7]).

II. MATERIALS AND METHODS

1.1 Study region

The study region is located in southern Morocco, between 30,8° - 30,4° North and between 8,2-9,1 West. The area is called Souss basin due to the name of its main river. It is characterized by an arid climate with low precipitations less the 200 mm/year. The Souss aquifer has a surface equal to 4150 km^2 mainly dominated by citrus production ([8]).

1.2 Forecasting system used

The Global Forecast System (GFS) is a global numerical weather prediction system containing a global computer model and variational analysis run by the U.S. National Weather Service (NWS). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 13 kilometer square; the mathematical model is run four times a day, and can produce forecasts for up to 16 days in advance, with decreased spatial resolution after 10 days ([9]). We used it here to predict weather out to 48 hours in advance every 3 hours. A web based script was implemented to connect automatically to servers and make spatiotemporal extrapolations with the coordinates of the real weather stations. Next table shows the used bands, units and description of the corresponding parameters.

Table 1 : List of parameters predicted using GFS model

Band Name	N° bond	description	Unité	conversion
Temperature	231	2 m above ground Temperature	[K]	T=T-273.15
Relative Humidity	234	2 m above ground Relative Humidity	[%]	
Wind component U	238	10 m above ground	m/s	
Wind component V	239	10 m above ground	m/s	
Solar radiation	285+286	Radiation at surface	W/m²	
Precipitation rate	243	Rain at surface	[kg/m^2]	

1.3 Real time weather data

The measurements are made by Twelve weather stations installed at souss basin in a way to cover most grid forecasting provided by GFS (see figure below). The basin was divided into 2 sub-basins with farmers growing mainly citrus: Souss Upstream and Souss Center; each one has 6 automatic weather stations equipped to measure hourly Temperature, relative humidity, wind speed and direction, rain and solar radiation.

- The datalogger is A753, fully integrated unit with cell modem and battery all together. Supporting analog and digital sensors, pulse counters and SDI-12 port. The Analog resolution is 16-bit and data memory is 2MB
- The Temperature and relative humidity is measured by TR1 combisensor at 2m above the ground with : Measuring Range 0 ... 100%RH (Accuracy at +20°C, ±1% rH from 0 - 90% rH ±2% rH from 90% - max. rH) and Measuring range-40°C ... +60°C (Accuracy at +20°C ±0,1°C Repeatability, Linearity, Temp. Dependence±0,1°C)
- Solar radiation is measured by CMP3 pyranometer with Sensitivity 5...20µV/Wm², Spectral Range 310 ... 2800nm and T.C. of Sensitivity +/-5% (-10°C ... 40°C)
- Wind speed and direction are measured at 2m above the ground by aluminum wind set pro10/2 with Measuring range <0.4 ... 75m/s (1.44 ... 270km/h) at Linearity < ± 0.5m/s; and Measuring range 0° - 360° at Linearity < ± 2.5°
- Rain is measured by a gauge WMO 0,2mm with orifice 200cm2 and capacity 0.2mm: 0 ... 16mm/min.

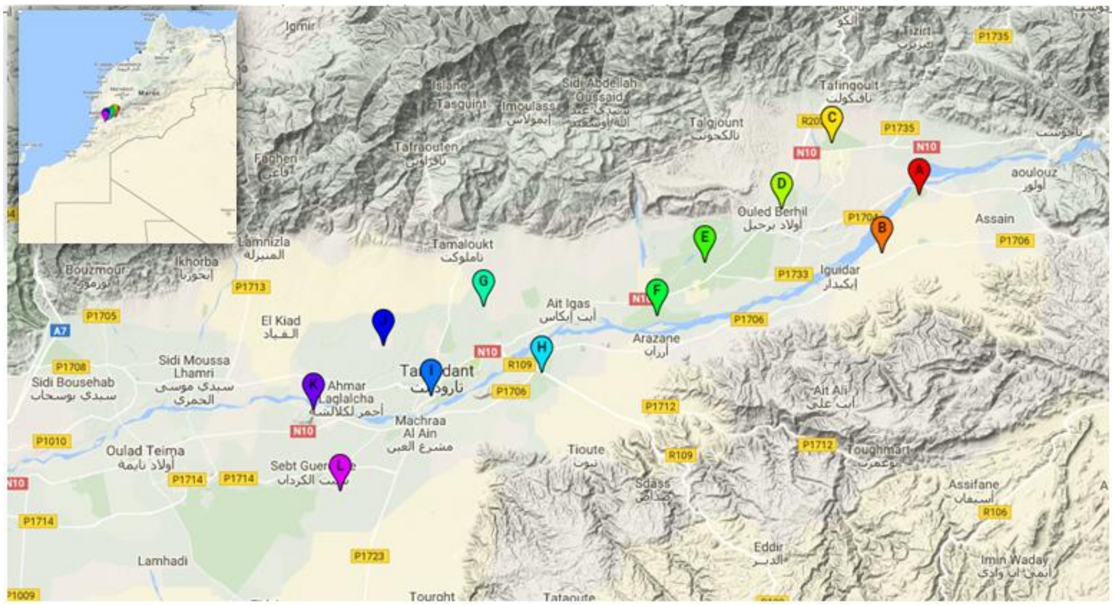


Figure 1 : Location of the different weather stations collecting real time data: Souss Upstream (A: Aoulouz, B: El Faid, C: Ouleddriss, D: Ouled Berhil, E: Igli, F: OuledAissa, G: Ait Aizza), and Souss Center (H: Fraija, I: Taroudant , J: Hmer, K: Laglalcha, L: Elguerdane)

1.4 Calculation and Statistical analysis

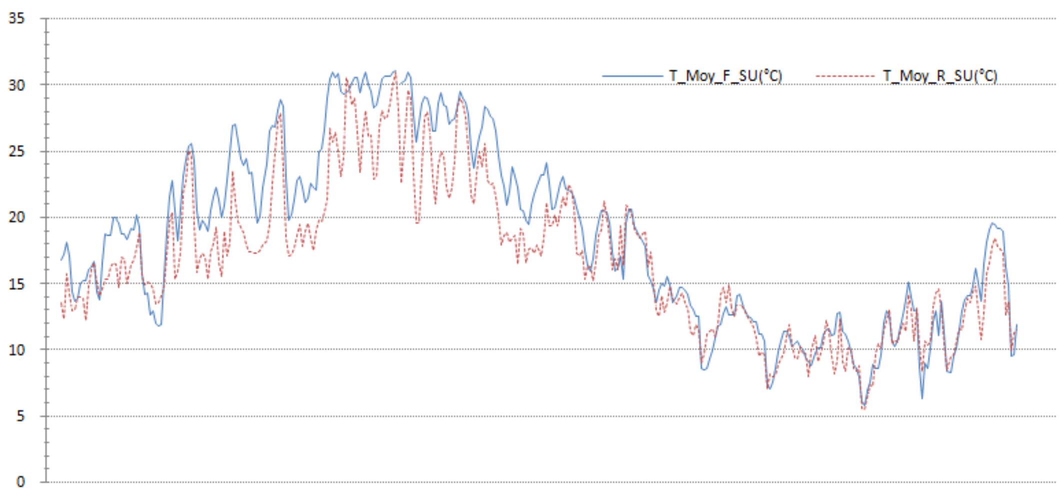
Jensen, et al. (1990) compared 20 methods of computing ETo for arid and humid locations ([10]). They found that the Penman-Monteith method as modified by Allen (1986) was the most accurate for either environment ([11]). Because of its accuracy, we used the Penman-Monteith method based on air temperature, relative humidity, wind speed, and solar radiation data predicted and measured.

Data were analyzed using MINITAB statistical software version 17.1.1.0.

Each sub-basin has got 6 repetitions, so means were calculated. Regression was made possible thanks to Pearson correlation. Treatment means were separated by Tukey's test at $P \leq 0.05$.

III. RESULTS AND DISCUSSION

As it was previously stated, the main objective of this experiment was to calibrate the forecast data from GFS model based on real data measured by weather stations in both Souss Upstream and Souss Center areas. Next four figures are showing the variations of daily forecast weather parameters and measured ones at the two sub-basins. We can distinguish a hot period from 01/04/16 to 30/09/16 and a cold period from 01/10/16 to 31/03/17 with an average temperature of 19,54°C predicted and 17,02°C measured for hot period, but only 13,49°C predicted and 13,12°C measured for cold period.



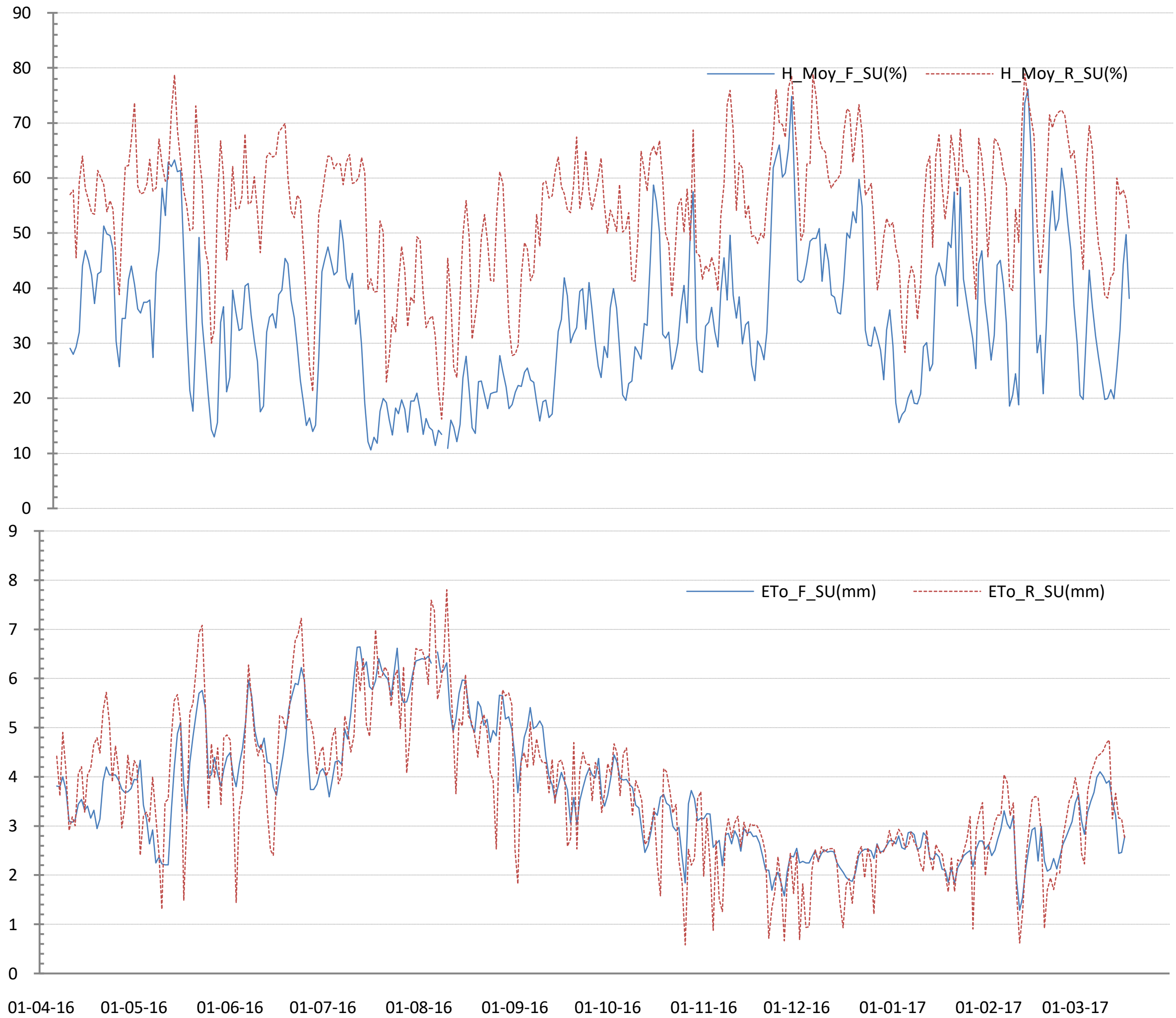
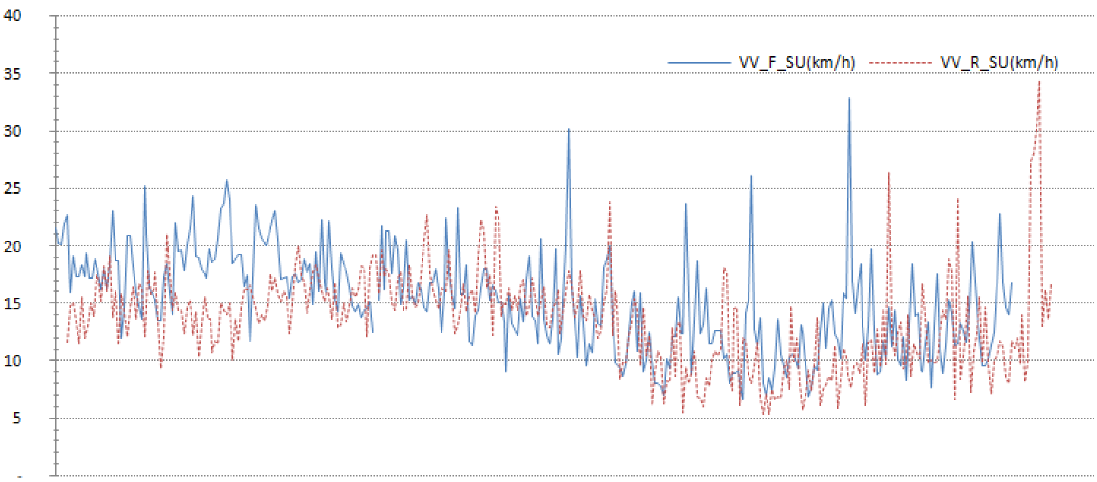


Figure 2 : Evolution of daily forecast weather parameters (continuous line) and measured one (discontinuous line) at the Souss Upstream area (SU): mean calculation of T=Temperature(°C), H=relative humidity(%) and ETo=Evapotranspiration(mm)



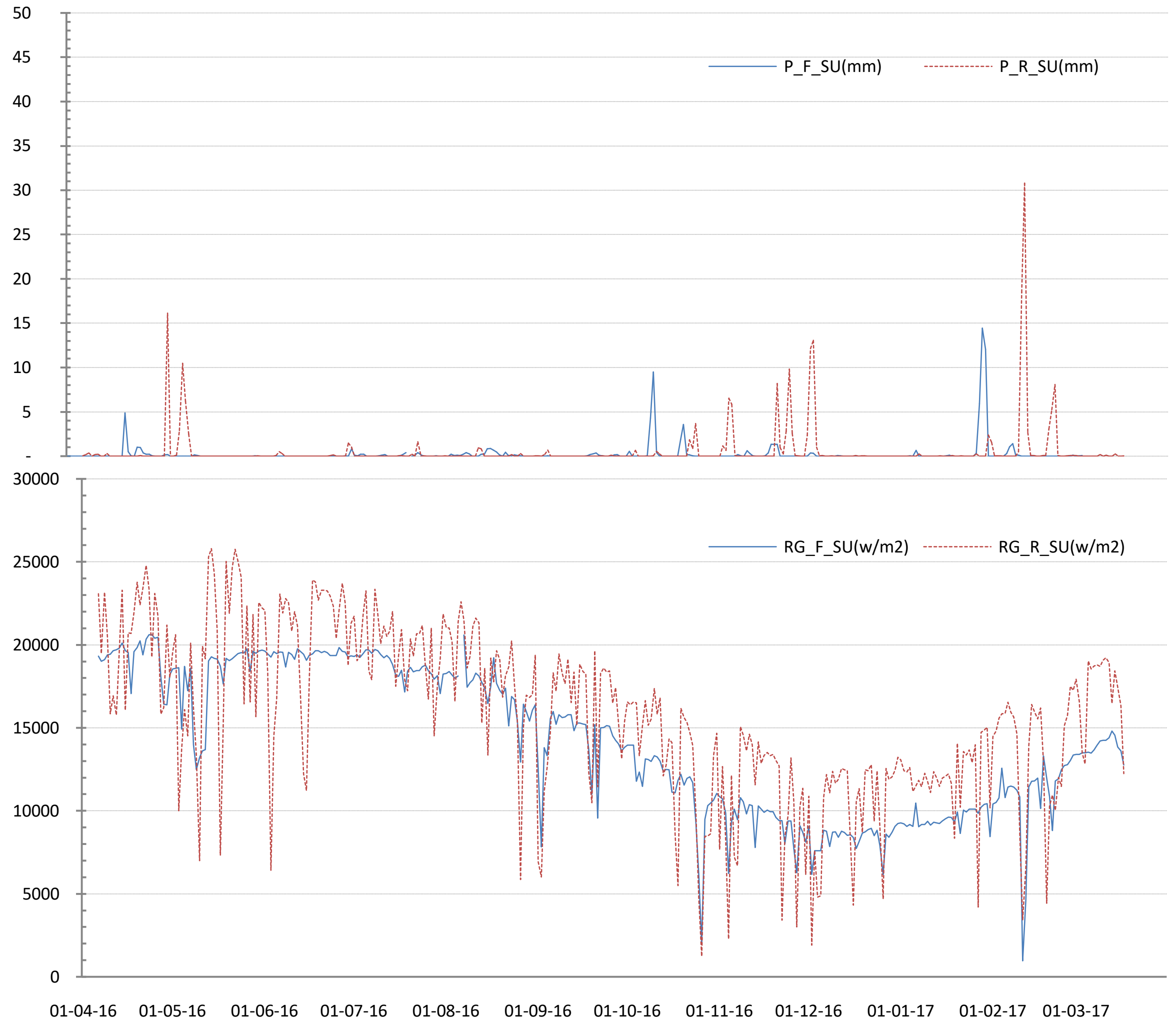
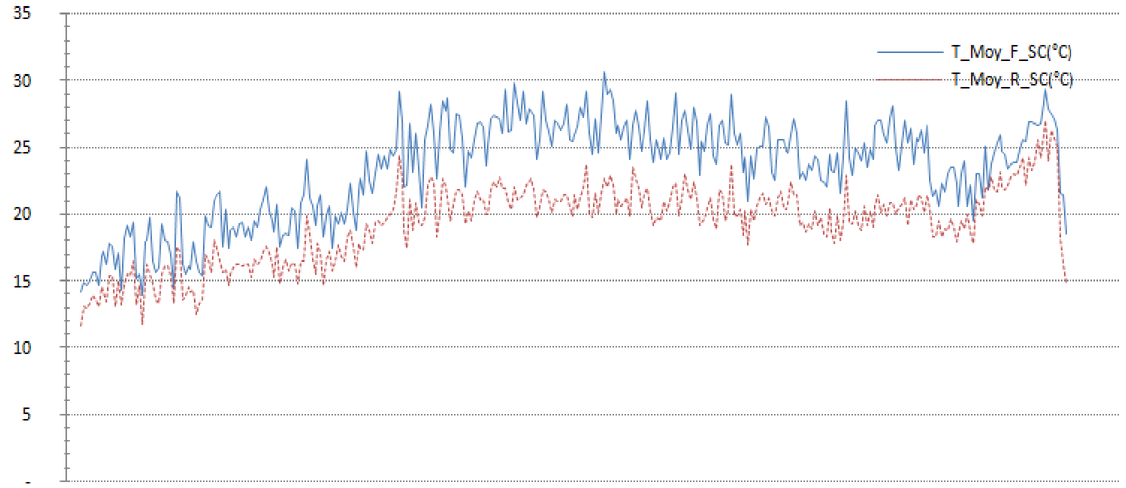


Figure 3 : Evolution of daily forecast weather parameters (continuous line) and measured one (discontinuous line) at the Souss Upstream area (SU): Mean calculation of VV=Wind speed(km/h), P=Precipitation(mm) and RG=Global radiation (w/m2)



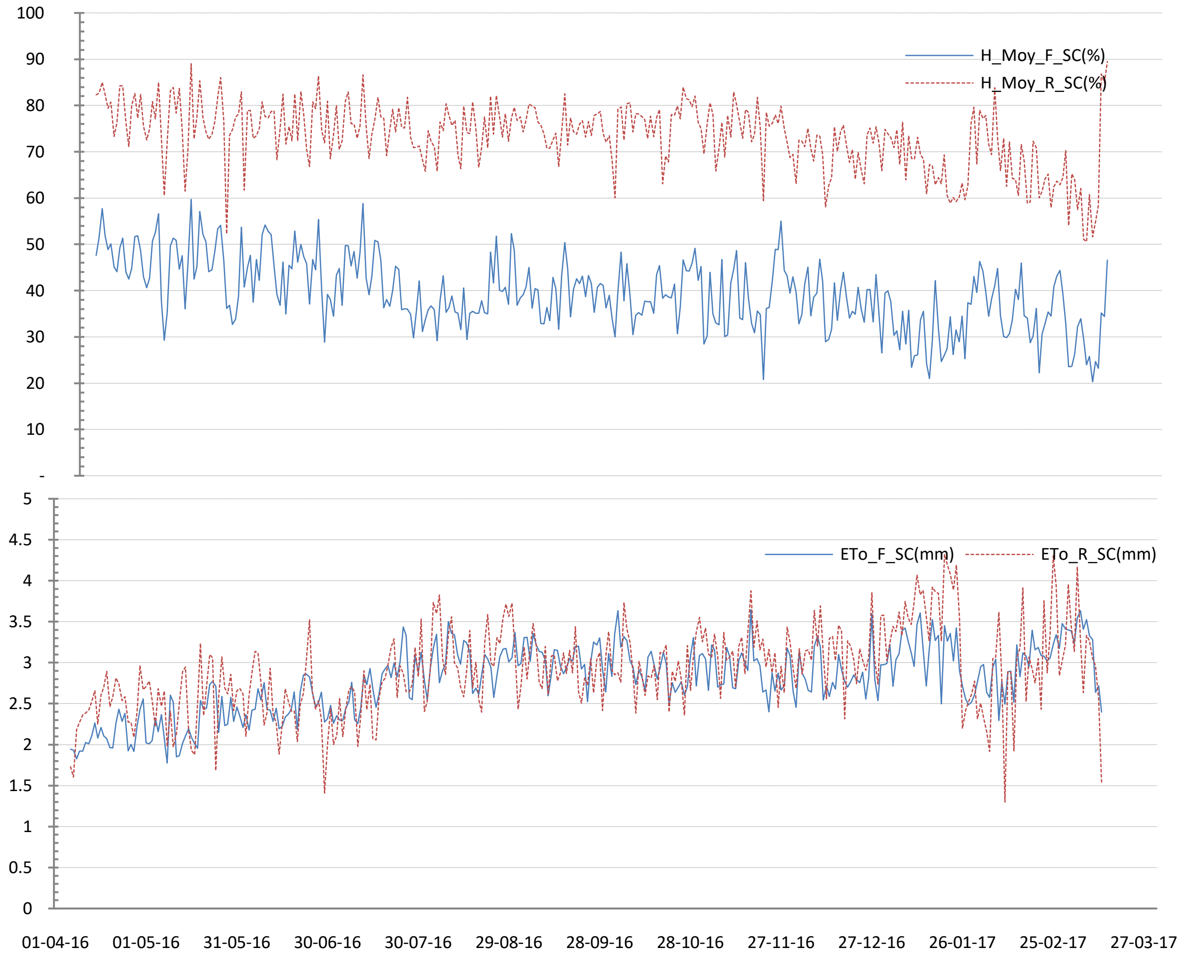
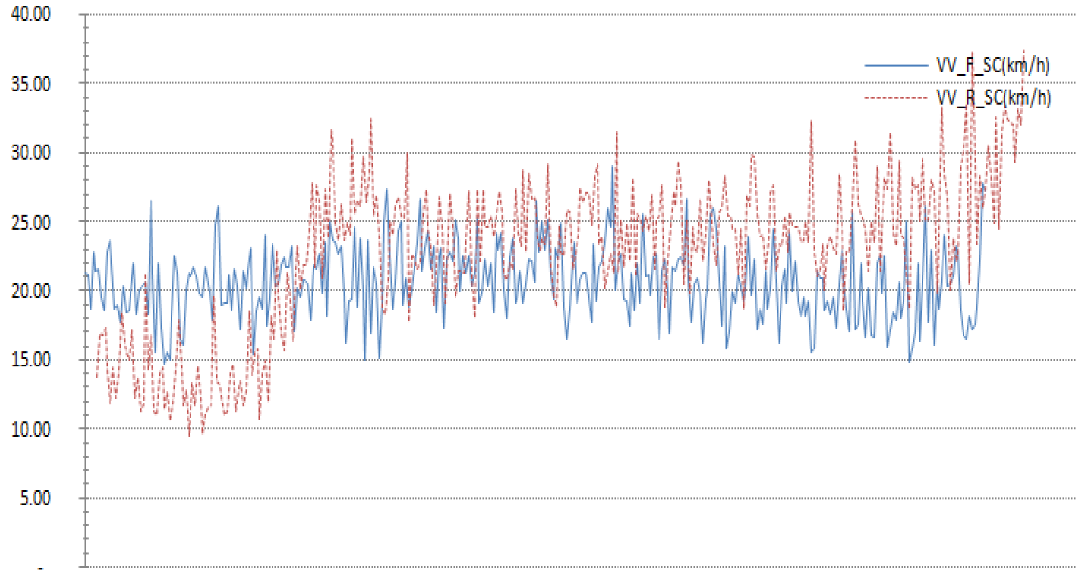


Figure 4 : Evolution of daily forecast weather parameters (continuous line) and measured one (discontinuous line) at the Souss Center area (SC): mean calculation of T=Temperature(°C), H=relative humidity(%) and ETo=Evapotranspiration(mm)



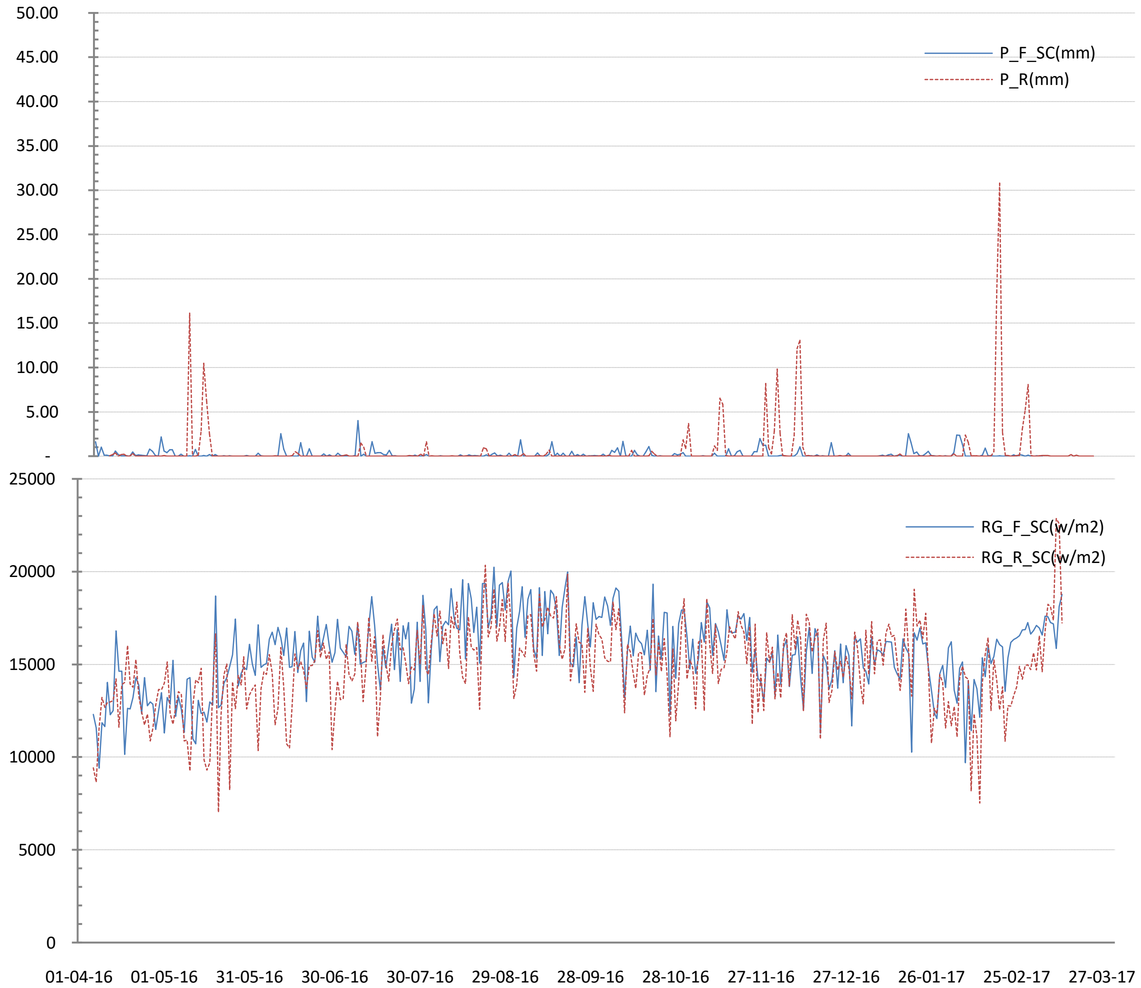
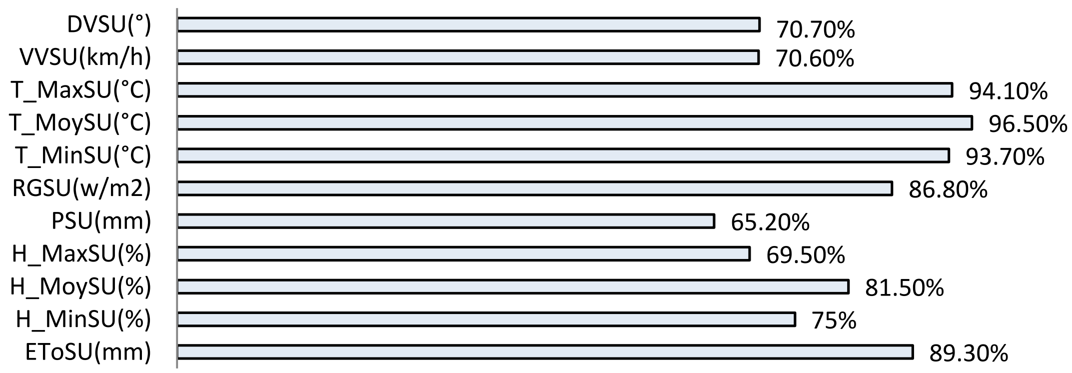


Figure 5 : Evolution of daily forecast weather parameters (continuous line) and measured one (discontinuous line) at the Souss Center area (SC): Mean calculation of VV=Wind speed(km/h), P=Precipitation(mm) and RG=Global radiation (w/m2)

However, correlation coefficient of Pearson (R^2) between forecast weather data (F) and real measured data (R) were calculated for the two sub-basins and for all repetitions (see Figure 6). It was shown that forecast data were very close to the real ones for T = Temperature (°C), H = relative humidity (%), ETo = Evapotranspiration (mm) and RG = Global radiation (w/m2) with more than 80% of correlation;

However the prediction errors for VV = Wind speed (km/h) and P = Precipitation (mm) was very high especially in Souss center area. This may be due to the level of installation of the wind sensors at 2m above the ground (the prediction concerns the level of 10m above the ground).



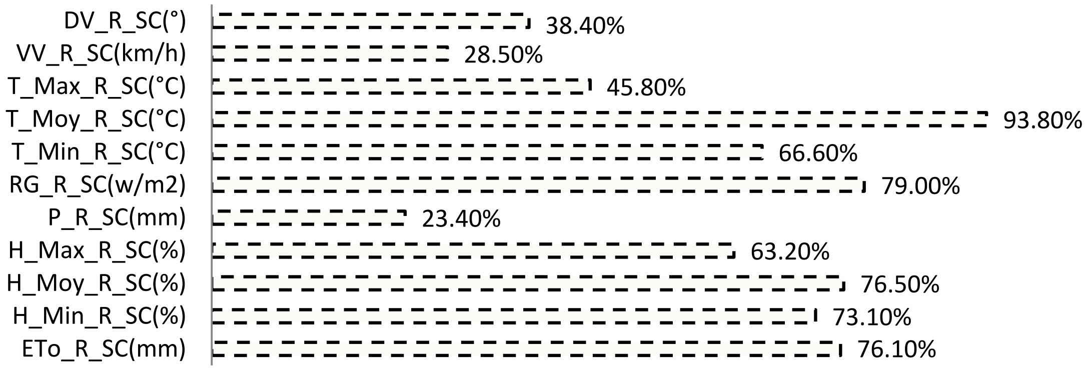
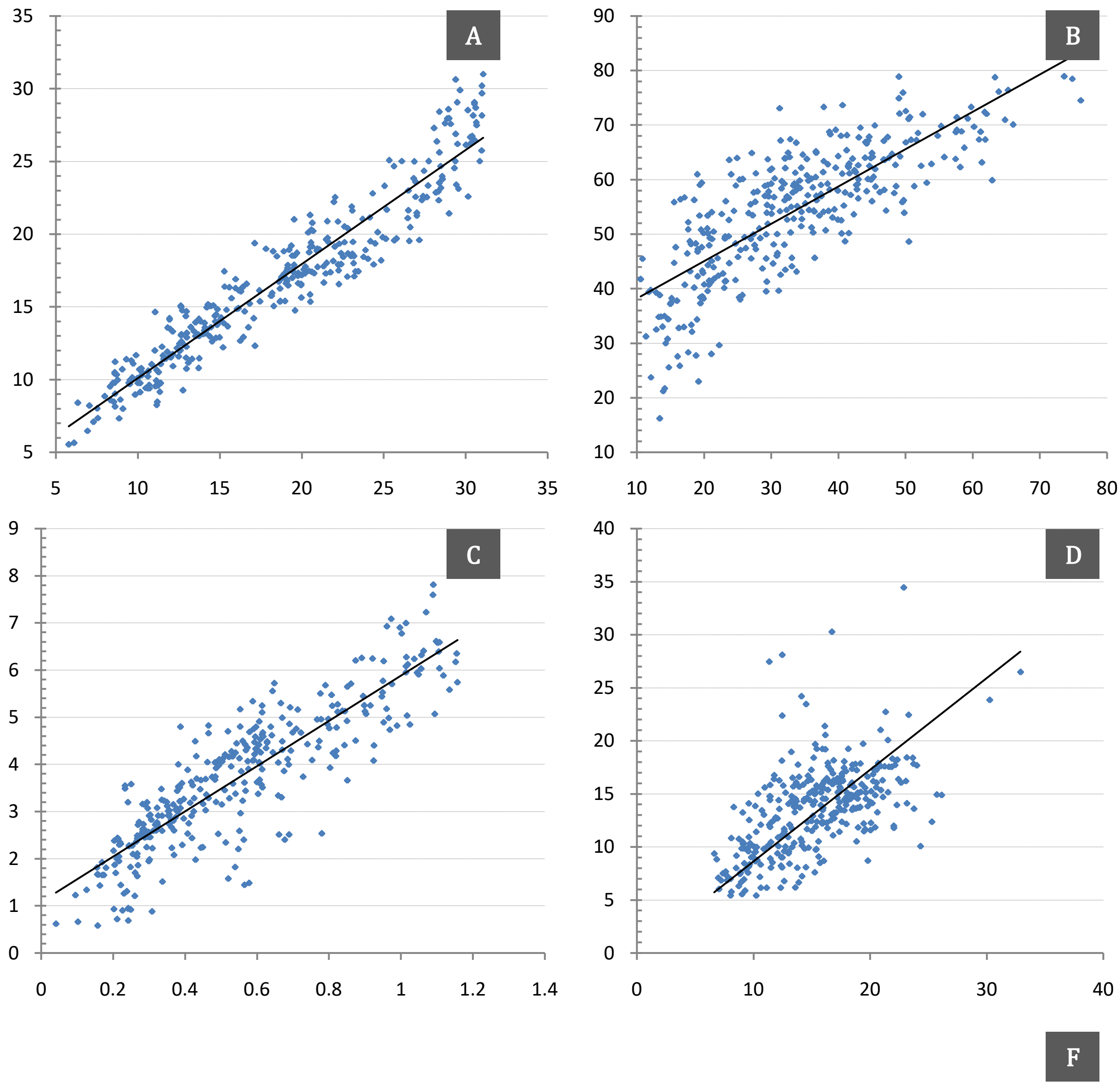


Figure 6 : Correlation coefficient of Pearson (R^2) between forecast weather data (F) and real measured data (R) for Souss Upstream area (continuous line) and Souss Center area (discontinuous line): daily calculation of T = Temperature (°C), H = relative humidity (%) and ETo = Evapotranspiration (mm) VV = Wind speed (km/h), P = Precipitation (mm) and RG = Global radiation (w/m2)



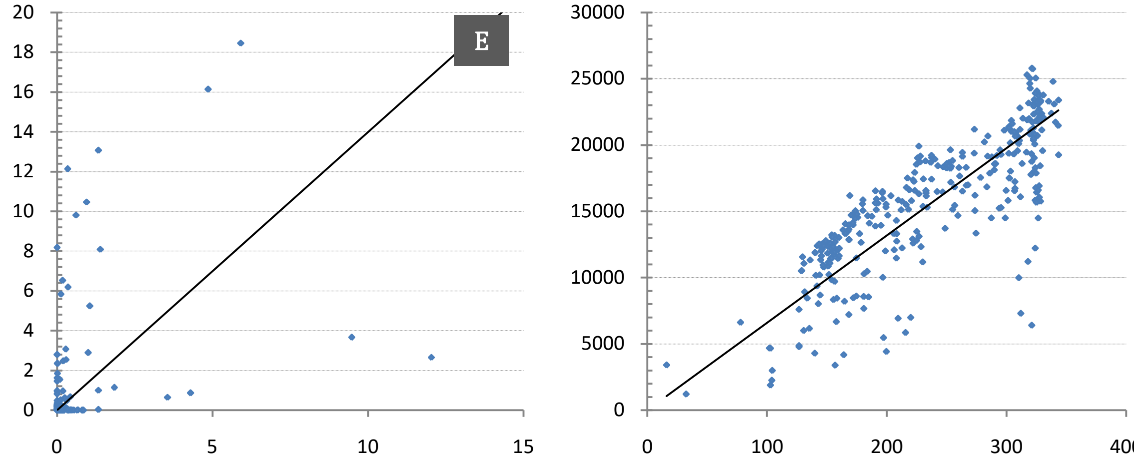
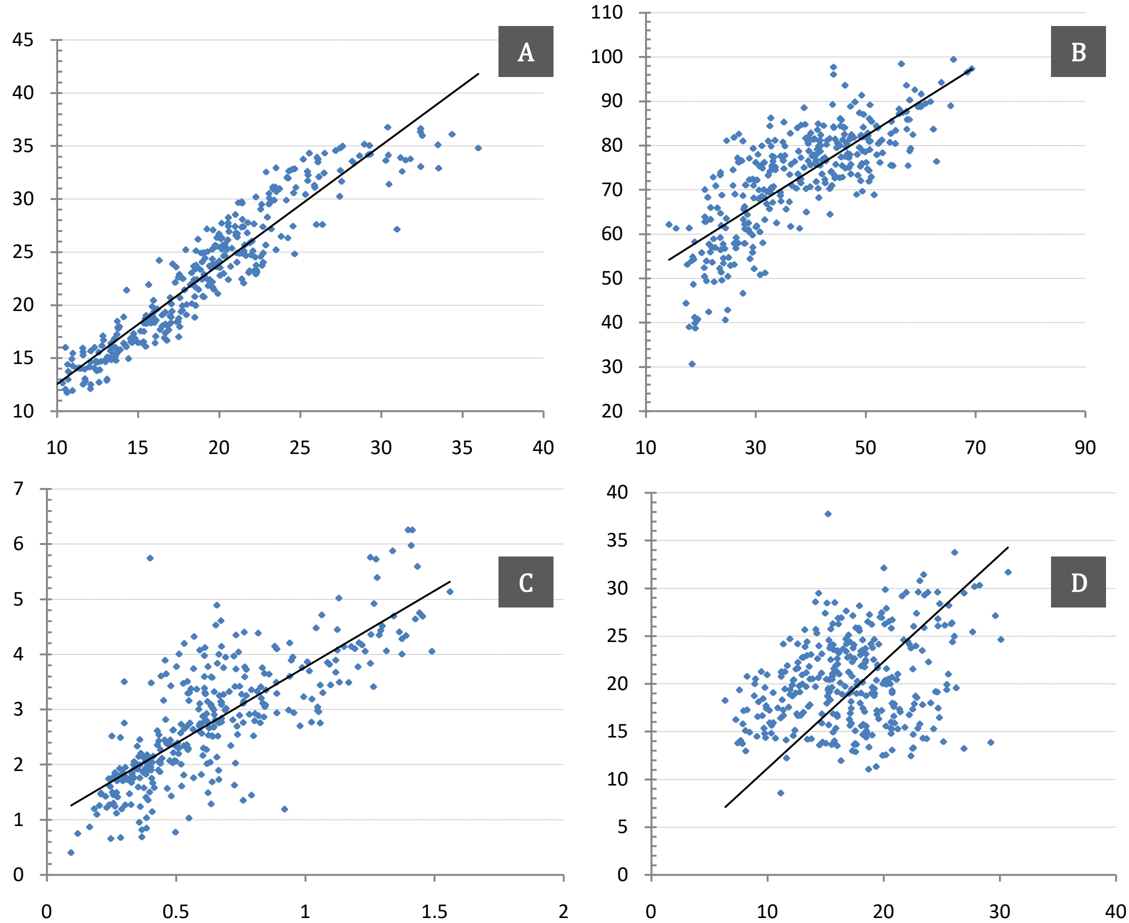


Figure 7 : Regression formula of calibrated weather data (y) and forecast from GFS model (x) for Souss Upstream area: A = Temperature (°C), B = relative humidity (%) C = ETo Evapotranspiration (mm) D = Wind speed (km/h), E = Precipitation (mm) and F = Global radiation (w/m2)



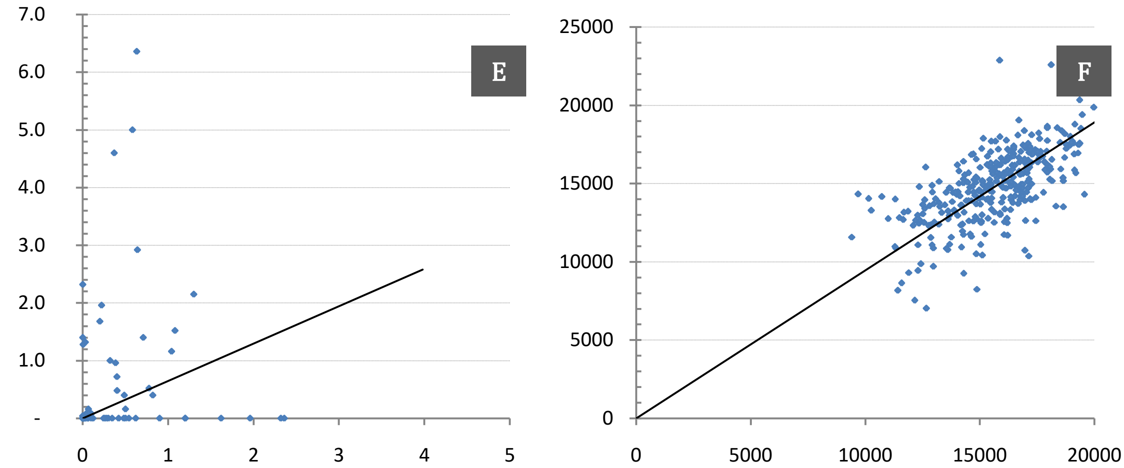


Figure 8 : Regression formula of calibrated weather data (y) and forecast from GFS model (x) for Souss Center area: A = Temperature (°C), B = relative humidity (%) C = ETo Evapotranspiration (mm) D = Wind speed (km/h), E = Precipitation (mm) and F = Global radiation (w/m2)

Advanced data analysis considering seasons of the year says that prediction in cold period was closer to reality, but it needs more calibrations during the hot period. : List of parameters predicted using GFS model

Table 1 shows calibration formula for forecast provided by GFS model (F) for Souss Center and souss upsetream areas considering the four parameters that do correlate (T, H, ETo, RG).

Table 2 : Calibration formula for forecast provided by GFS model (F) for Souss Center and souss upsetream areas for the four parameters that correlate: T = Temperature (°C), H = relative humidity (%) C = ETo Evapotranspiration (mm) RG = Global radiation (w/m2)

	Cold period		**Hot period**	
	Eq	R2	Eq	R2
Souss	T_Moy_R_SU(°C) = 0,842	92,	T_Moy_R_SU(°C) = 0,660	79,
	H_Moy_R_SU(%) = 18,62	74,	H_Moy_R_SU(%) = 30,05	54,
	ETo_R_SU(mm) = 0,3462	77,	ETo_R_SU(mm) = 1,342 + 4,413 ETo_F_SU	59,
	RG_R_SU(w/m2) = 984	78,	RG_R_SU(w/m2) = -817	38,
Souss Center	T_Moy_R_SC(°C) = 4,95	50,	T_Moy_R_SC(°C) = 2,992	95,
	H_Moy_R_SC(%) = 46,31	36,	H_Moy_R_SC(%) = 53,47	44,
	ETo_R_SC(mm) = 1,244	31,	ETo_R_SC(mm) = 1,597	41,
	RG_R_SC(w/m2) = 2247 + 0,8186 RG_F_SC(w/m2)	41,3	RG_R_SC(w/m2) = 4317 + 0,6612 RG_F_SC(w/m2)	42,0

In Souss Upstream area, using a citrus crop coefficient (Kc) of 0,6 as an annual average value (ETc = Kc x ETo) ([12]), The predicted irrigation water needs (ETc) processed by the model from 01/04/16 to 31/03/17 was 7626,5 m3/ha, however, calculated ETc based on weather measurements was 7669,1 m3/ha.

When it comes to Souss center area which is closer to the sea, this value was predicted to be only 5716,3 m3/ha and measured equal to 5948,7 m3/ha at the same annual basis.

IV. CONCLUSION

According to the previous results, we can say that GFS model is a good tool to predict citrus water needs on a daily basis through air temperature, relative humidity and solar radiation forecasting. Nevertheless, results must be calibrated by local weather measurements installed at two sub-basin areas, but in a seasonal basis, at least, we have to distinguish between Cold and Hot period.

However, the tested model may cause consequent errors when predicting Rain and wind speed or direction.

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