WEATHER DATA AS BASIS FOR CALCULATING REFERENCE EVAPOTRANSPIRATION ON AN IRRIGATION TRIAL PLOT WITHIN A VINEYARD

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Abstract
A study plot in the eastern part of Austria was equipped with a remote monitoring station composed of soil water sensors and weather instruments in order to deliver basic data for irrigation management. The weather instrument readings include air temperature, relative humidity, wind velocity, solar radiation and precipitation in 15-minute-intervals. Additionally, weather data from a nearby weather station of the Austrian Central Institute for Meteorology and Geodynamics (ZAMG) were utilized. Both datasets served for calculating reference evapotranspiration (ET_{ref}). A comparison indicated similar characteristics of the measured parameters as well as ET_{ref}. Differences could be interpreted as microclimate effects on the study plot. Generally, 2010 was a wet year; rainfall was above average, exceeding ET_{ref} most of the time.
Keywords: weather station, remote monitoring, microclimate, ET, FAO-Penman-Monteith

Introduction
In spring 2010, an irrigation trial was started in a vineyard in the eastern part of Austria, close to the Hungarian border (47°48'16" N, 17°01'57" E, and 118 m). The agricultural area is characterized by a long-term mean annual temperature of 10.6°C and an annual precipitation of about 570 mm. Irrigation may be necessary in order to guarantee high-quality grapes as basis for high-quality winemaking. Investigating the soil water status is an appropriate method for irrigation management. This aim can be achieved directly by means of soil water measurements, or indirectly by compiling a water balance. Therefore, the study plot was equipped with a remote monitoring station composed of soil water sensors and weather instruments in order to deliver basic data for managing a sophisticated subsurface drip irrigation system (hydrip®). Beside the measurements from the field plot, weather data from a nearby weather station (47°46'20" N, 17°01'59" E, and 122 m) of the Austrian Central Institute for Meteorology and Geodynamics (ZAMG) were utilized. Evapotranspiration is the main component of the water balance. In this regard, the weather data were used for calculating reference evapotranspiration (ET_{ref}) according to the recommendation of the Food and Agriculture Organization of the United Nations FAO (Allen et al., 1998).
While the measurements from the study plot primarily characterized the vineyards' microclimate, the ZAMG-data provided a more general view – especially due to long-term time series. The goal of this work was to compare both datasets in order to gain a better understanding as basis for future data interpretation.

Materials and Methods
The distance between the vineyard and the ZAMG-station was 3.6 km. The weather instrument readings on the field plot included air temperature T in °C, relative humidity RH in %, air pressure p in hPa, wind velocity u_2 at 2 m height in $m \cdot s^{-1}$, solar radiation R_s in $W \cdot m^{-2}$ and rainfall R in mm (measuring interval: 15 minutes). The measurement station was connected to a telemetry network from Adcon Telemetry GmbH, Klosterneuburg. A Remote Terminal Unit (RTU) collected data from weather sensors (Fig. 1), stored them for a short

term and then delivered data packages via GSM technology to a server. Processed data – including automatically calculated daily ET_{ref} – were provided via internet for further data interpretation.

Fig. 1: Measuring station with RTU, solar panel and weather instruments (photo: R. Nolz)

The ZAMG dataset contained T, RH, p, u_2, R_s and R in 1-hour-intervals as input parameters for ET_{ref}. Daily ET for both datasets was calculated according to FAO-Penman-Monteith (Allen et al., 1998):

$$ET_{ref} = \frac{0{,}408 \cdot \Delta \cdot (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0{,}34 \cdot u_2)} \qquad (1)$$

ET_{ref} ...reference evapotranspiration / $mm \cdot d^{-1}$
R_n ...net radiation at the crop surface / $MJ \cdot m^{-2} \cdot day^{-1}$
G ...soil heat flux density / $MJ \cdot m^{-2} \cdot day^{-1}$, (neglected for daily time steps)
T ...air temperature at 2 m height / °C
u_2 ...wind speed at 2 m height / $m \cdot s^{-1}$
e_s ...saturation vapor pressure / kPa
e_a ...actual vapor pressure / kPa
$e_s - e_a$ ...saturation vapor pressure deficit / kPa
Δ ...slope vapor pressure curve / $kPa \cdot °C^{-1}$
γ ...psychrometric constant / $kPa \cdot °C^{-1}$

Results and Discussion

Fig. 2 shows the annual rainfall and the mean annual temperature of the past 15 years. Compared to the long-term averages, this period – particularly 2010 – was relatively wet and cold.

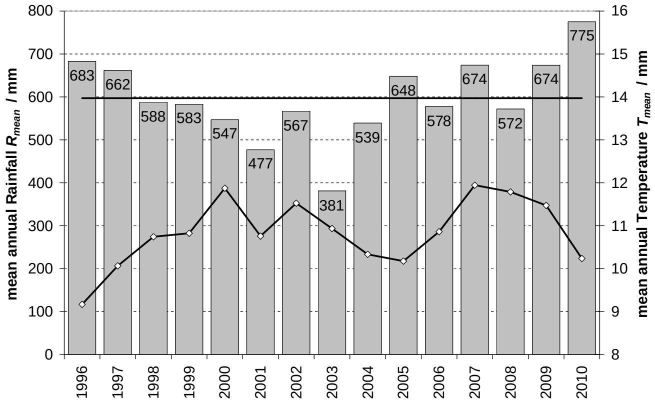

Fig. 2: Annual rainfall and mean annual temperature of the past 15 years

The investigation period of the current study started after installation of the remote weather station on July 22nd and lasted until the end of the year. The weather data of the first week of this period (23.7.-31.7.) were analyzed in detail. Tab. 1 contains the mean values of the parameters measured on the field plot (Adcon) and at the weather station of the ZAMG, respectively. ET_{ref} was calculated based on each dataset for the short- and the entire period, too.

Tab. 1: Means of the parameters from both measuring sites for the entire period (23.7.-31.12.2010) and the first week (23.7.-31.7.2010), respectively

		T	RH	p	u_2	R_s	R	ET_{ref}
		°C	%	hPa	$m \cdot s^{-2}$	$MJ \cdot m^{-2} \cdot d^{-1}$	mm	mm
23.7.-31.12.	Adcon	10.1	77	999.0	2.3	1489	335	280
	ZAMG	10.1	81	999.2	1.9	1471	375	250
23.7.-31.7.	Adcon	19.3	69	998.1	3.1	119	29	32
	ZAMG	19.5	71	998.2	3.0	137	36	35

The following figures show the field plot-data versus ZAMG-data. Both time series are based on hourly values (the ZAMG-values are displayed as a continuous line just for easier reading). The temperature curves in Fig. 3 show a good correlation (R^2=0.9769); nevertheless, some peaks seemed to be lower on the field plot. The mean values were identical in the first week, but taking into account the entire period, T was slightly lower in the vineyard (Tab. 1).

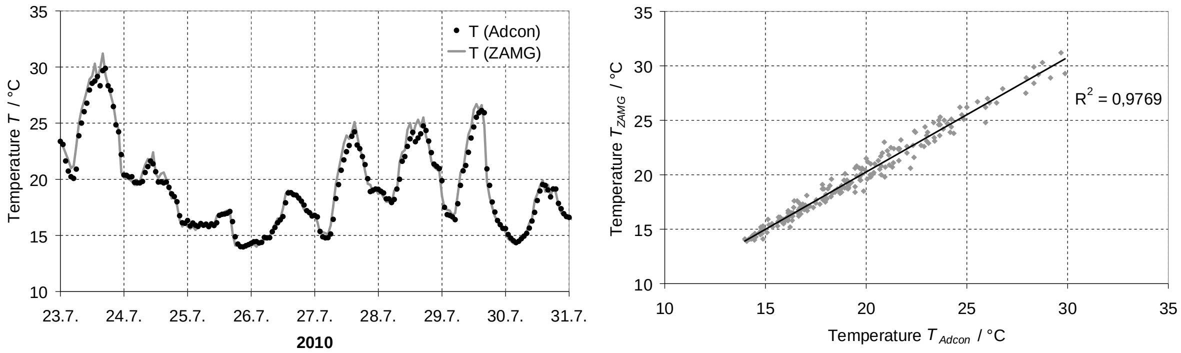

Fig. 3: Temperature T – characteristics and correlation of both measuring sites

Relative humidity measurements expressed a large variability. Fig. 4 illustrates a similar trend, but lower values at the field plot. The mean values in Tab. 1 confirm this statement. Due to a mechanical malfunction, ZAMG-data did not 90 %.

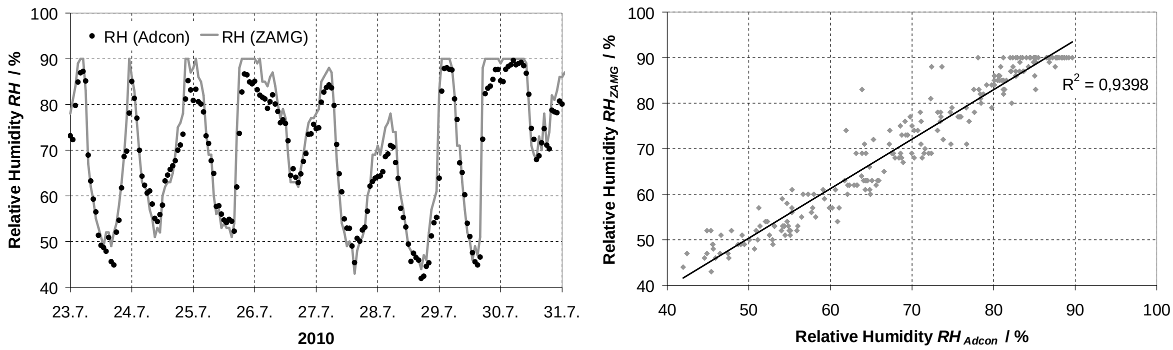

Fig. 4: Relative Humidity RH – characteristics and correlation of both measuring sites

Air pressure was almost the same at both sites (Fig. 5), this holds also for the entire investigation period (Tab. 1).

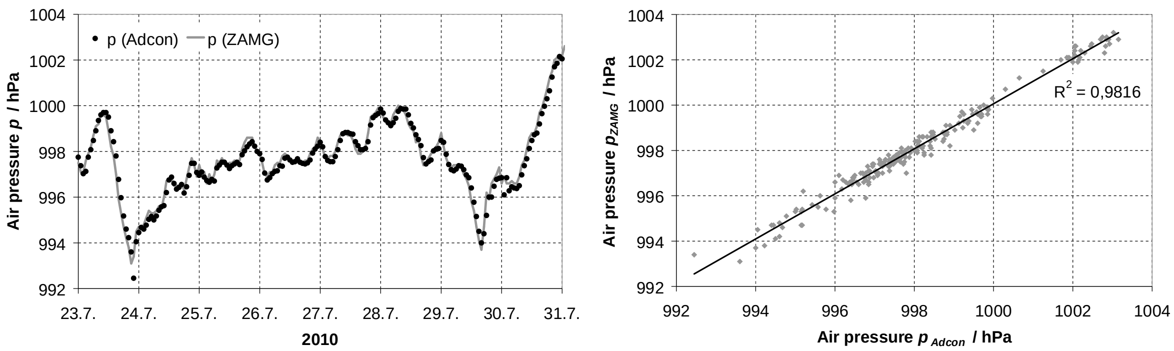

Fig. 5: Air pressure p – characteristics and correlation of both measuring sites

As expected, wind velocity fluctuations were appreciable (Fig. 6). The mean velocity was lower at the ZAMG-station (Tab. 1) – a reason may be that the weather station is situated within a village.

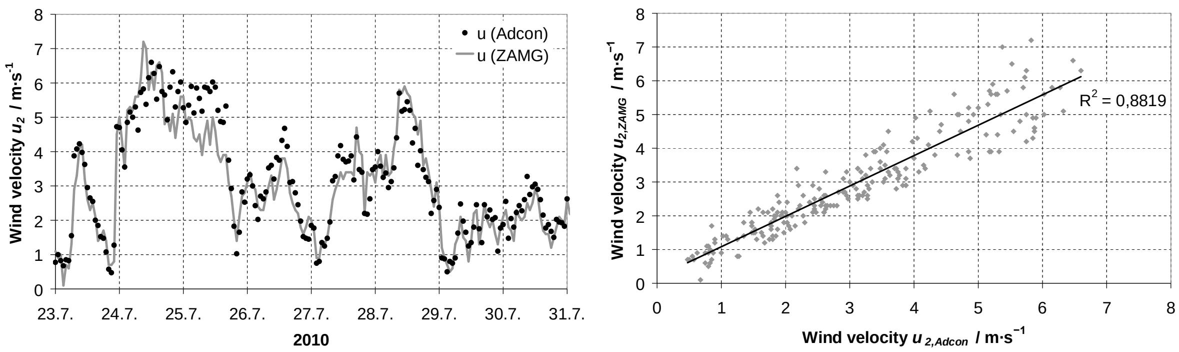

Fig. 6: Wind velocity u_2 – characteristics and correlation of both measuring sites

Local differences of solar radiation measurements generally depend on the cloudiness. The radiation sum from 23.7.-31.7.2010 was a little bit lower at the field plot, especially the peak values were lower (Fig. 7). Regarding the entire period it was the other way around (Tab. 1).

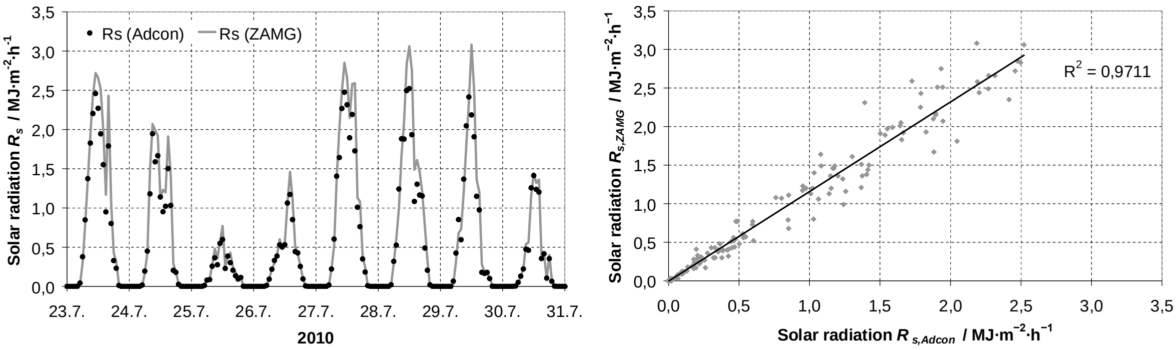

Fig. 7: Solar radiation R_s – characteristics and correlation of both measuring sites

The rainfall sum measured at the ZAMG-station exceeded the amount at the field plot by 5 mm (Fig. 8 & Tab. 1). Fig. 9 shows the cumulated rainfall in the entire period. Although the cumulated curves display differences, they equalize at beginning of November. From the end of November until the end of the year snow was falling, causing a difference of about 50 mm (snow was not measured at the field station).

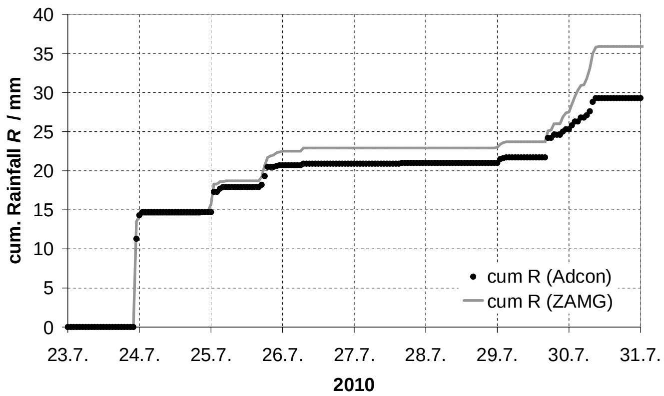

Fig. 8: Cumulated rainfall of both measuring sites

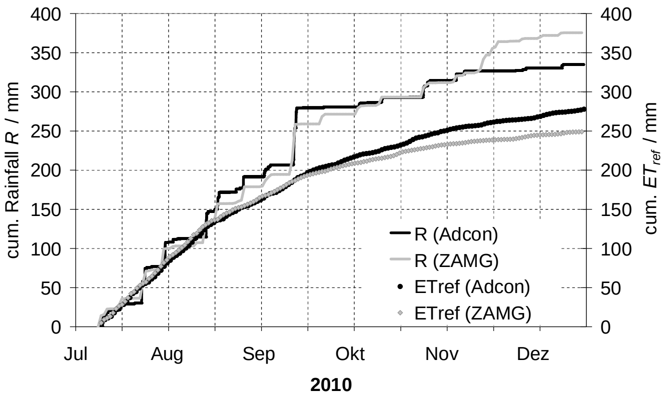

Fig. 9: Cumulated rainfall and ET_{ref} for the entire study period (23.7.-31.12.2010)

In the period from 23.7.-31.7.2010 air temperature, relative humidity and solar radiation were lower, and wind velocity was slightly higher at the study plot (Fig. 9 & Tab. 1). Comparing both datasets for the entire study period, relative humidity was lower at the study plot, but wind velocity and solar radiation were higher than the ZAMG values. Thus, calculated ET_{ref} for the whole period was higher at the vineyard, exceeded by rainfall from end of August to the end of the year (Fig. 9).

Conclusion

Both datasets provided a proper basis for calculating ET_{ref} on hourly basis. Additionally, time series from the weather station of the ZAMG gave an overview about the past years. The remote station on the field plot delivered continuous data, anytime available via internet. Several characteristics of the measured parameters were similar; on the other hand, differences could be detected through detailed study. ET_{ref} based on both datasets delivered feasible results. Nevertheless, the calculation procedures should be compared in detail in order to verify if the different results occur only due to different input data. Since the vineyard was recently planted, the grape-vines and the leaves were rather small. However, the plants will soon influence the microclimate within the vineyard. The results of this study will serve as reference for future data interpretation.

Dedication

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