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Quality assurance procedures for validating meteorological input variables of reference evapotranspiration in mendoza province (Argentina)

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ABSTRACT

Validated meteorological data are required to make climate assessments, related decisions and to appropriately compute other important parameters such as reference evapotranspiration (ET_0), vital to accurately estimate crops water requirements. In addition, quality meteorological datasets will increase the reliability of the results obtained by scientific or technical models that use them. In semiarid regions, with a structural water deficit as province of Mendoza (Argentina), the integrity and quality of these data are crucial to improve ET_0 estimates, ensuring an adequate irrigation water management. In this work, several quality assurance procedures were applied to meteorological data—as a pre-requisite for ET_0 computations—in order to detect erroneous and invalid data of each parameter from automated weather stations located in the three irrigated areas of province of Mendoza (Northern oasis, Western oasis and Southern oasis). Due to the lack and poor quality of solar radiation data, calibration of new based temperature solar radiation prediction models for each of the station are proposed. Results show the data flagged for each variable by range/limits, step, internal consistency and persistence tests, providing guidance of great value to end users. Finally, a simple comparison of ET_0 estimations using original and validated meteorological datasets for each irrigated area in province of Mendoza is also reported.

1. Introduction

Ensuring accurate estimations of crop water requirements is crucial for a suitable planning and efficient use of water resources, especially in semiarid and arid regions as province of Mendoza (Western Argentina). The irrigated area in this province is currently almost 270,000 ha (FAO, 2015), with an amount of 52,792 irrigators. The agricultural consumptive uses in this province are relatively high and due to lack of precipitation (average annual precipitation around 200 mm) that limits crop growth and yield, optimizing and efficiently using of water resources represent a challenge for technicians and farmers to develop the regional economy. Although snow-melt supplies water to five rivers, the use of groundwater becomes important in periods with a shortage of surface water (Querner et al., 1997). In this sense, the annual water balance is in deficit and only 75% of the annual demand can be satisfied because of an annual deficit (DGI, 2010). Being an arid province located in Cuyo region—considered as a desert—, irrigated areas are located in three characteristics extensions similar to an oasis. The three oases are: (a) the Northern Oasis, formed by the basins of the Mendoza and Lower Tunuyán Rivers, where 50% of the provincial population lives; (b) to the south, the Western (or Central) Oasis, Valle de Uco, which coincides with the basin of the Upper Tunuyán River and (c) the Southern Oasis, formed by the basins of the Diamante and Atuel Rivers. The economic activity consuming most water is the production of high value temperate fruits and vegetables for both national and international markets (Díaz-Araujo and Bertranou, 2004). Nowadays, vineyards are still the principal crop, accounting for half cultivated area, followed by olive, fruit orchards (peaches, plums, apples and walnuts) and horticulture crops (tomatoes, potatoes, garlic and onions) (Morábito et al., 2007).

In terms of computing crop water requirements, the product of K_c (crop coefficient) and ET_0 (reference evapotranspiration) is the most widely used method, providing crop evapotranspiration

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estimations (ET_c). ET_0 is the evapotranspiration rate from a hypothetical grass reference surface, not short of water and with specific characteristics, initially introduced by Doorenbos and Pruitt (1977). Factors such as canopy cover, crop type or stage of growth affect the crop coefficient. However, reference evapotranspiration represents the evaporating rate of atmosphere and it is an important component of hydrological cycle that can be computed as a function of meteorological data (Allen et al., 1998). To avoid confusion about which ET_0 estimation method should be properly used, FAO proposed Penman-Monteith model in FAO Paper No. 56 (Allen et al., 1998) using reference crop parameters such as height of 0.12 m, albedo of 0.23 and surface resistance of 70 s m^{-1}. In addition, the Task Committee of ASCE (American Society of Civil Engineers) on 'Standardization of Reference Evapotranspiration' also recommended the use of this model (Allen et al., 2000; Itenfisu et al., 2003; Walter et al., 2001). This standardized method, incorporating thermodynamic and aerodynamic aspects, has received favourable acceptance and application over much of the world and different climatic conditions (Gavilán et al., 2008; Itenfisu et al., 2003; Pereira et al., 2015).

The accurate quantification and representativeness of ET_0 estimates depends on reliability of input meteorological variables involved and it is necessary to avoid biases in data (Allen, 2008), among other problems. In this sense, validation of these meteorological data applying several quality assurance procedures ensures that the information needed has been properly generated. It identifies incorrect values, detecting problems that require immediate maintenance attention (Estévez et al., 2011). In addition, proper interpretation of meteorological data requires knowledge of its context, including its metadata (Fiebrich et al., 2010). Various network managers reported in their works that an end-to-end quality assurance system (e.g., incorporating sensor calibrations, maintenance information, automated and manual quality control procedures) is essential for producing trusted, high-quality data (Hubbard et al., 2005; McPherson, 2007; Peppler et al., 2008). The World Meteorological Organization (WMO) reported that climate change models, agricultural and meteo-hydrological scientific applications and other technical activities require the improvement and strengthening of observation networks, in order to increase the availability of climate information resources and the quality of their applications (WMO, 2006). Since early 90's, for different purposes and due to the great development of automatic data acquisition systems, meteorological information from weather stations is recorded in large databases (Miller and Barth, 2003). However, in spite of the economic effort of installing these networks, questionable results may be due to poor data quality as a consequence of non-existing quality control methods as a pre-requisite for using meteorological data (Estévez et al., 2011). Thus, the WMO has recently introduced some basic characteristics of general principles of the data quality control (WMO, 2010a) and a deep discussion about them is also reported (WMO, 2010b). The main goals of the application of quality control procedures to meteorological data are to avoid inappropriate decision-making, identifying erroneous records, and to ensure that this information is suitably measured and stored. In addition, it is crucial to detect and solve problems related to sensors calibration and an adequate maintenance of the stations and their environment (Doraiswamy et al., 2000). In the literature there are several methods that can be applied to ensure the quality of meteorological information (Feng et al., 2004; Hubbard et al., 2005; Shafer et al., 2000; Sönmez, 2013). Some of the most recent works (Estévez et al., 2015; López-Lineros et al., 2014) use 30-min or 5-min observations to validate data for ensuring their quality, but the majority of the databases from meteorological networks contain records on a daily basis. Hubbard et al. (2005) outlined that validation procedures can be divided into two categories: those that use data from a single site and those that use data from multiple sites, comparing a station's data against neighbouring stations. The set of three computer-based rules introduced by O'Brien and Keefer (1985), were applied initially by Meek and Hatfield (1994) and they are based on: fixed or dynamic high/low limits, fixed or dynamic rate of change limits and a continual temporal no-observed-change. The main purpose of any validation method is to detect data of a doubtful quality and to properly flag them, incorporating valuable information to each record but not modifying it. Flags as "good", "suspect", "corrected" or "failure" show the level of confidence of data and information about the result of tests application (Fiebrich and Crawford, 2001). It is important to note that although occasionally algorithms can be applied to correct erroneous data or to fill the gaps, both original and corrected/estimated data should always be archived (Reek et al., 1992). Finally, there is a final step in the validation process where qualified personnel should verify and manually inspect meteorological data considered as potentially erroneous. This kind of verification allows ensuring that automatic procedures are flagging data correctly.

With the aim of providing ET_0 estimations and several related meteorological parameters to improve irrigation water management and other agronomic purposes such as frost protection, Direction of Agriculture and Climatic Contingencies (DACC) of Mendoza province has installed during the last decade an automated weather stations network covering the three main cultivated areas described above (Northern Oasis, Western Oasis, Southern Oasis). Currently, some of them are not operative due to lack of funds and there is no quality control system running for validating meteorological data before ET_0 estimations are calculated and provided on the website for different end users. This paper presents the results of the development and the application of several quality assurance procedures to all available meteorological measurements from DACC (2015) according to several tests and methods described in next sections. Moreover, due to the amount of solar radiation gaps and outliers, a new calibration for solar radiation model based on temperature data (Hargreaves, 1994; Hargreaves and Samani, 1982) has been carried out for each site. Several improper estimations of ET_0 were detected, mainly due to outliers and incorrect input meteorological data. The new developed system—as a prerequisite for the ET_0 calculation—is capable of using solar radiation estimates instead of measured radiation if these observations are flagged as invalid. In this sense, Pereira et al. (2015) recently recommended still using standardized ET_0 equation (PM-FAO56) instead of other simple ET_0 computation methods, even existing missing data as solar radiation that can be estimated properly by different methods as the proposed in the present work.

The main goal of this work is to apply different procedures to compute quality ET_0 estimations before providing them to irrigators and farmers. In addition, the improvement of the integrity of long-term meteorological database, will ensure the reliability of technical and scientific models that use these records as input variables, generating screened quality hydro-meteorological datasets of great value. Finally, simple comparisons of ET_0 estimations using validated datasets instead original datasets are also reported, in order to quantify the effect of quality assurance procedures.

2. Materials and methods

2.1. Study area and weather data source

The present study was carried out in irrigated areas of Mendoza (western Argentina), located in Cuyo region—near the Andes mountains—, between the meridians 67° 50′ and 69° 50′W and the parallels 32° 30′ and 33° 50′S and occupying an extension of around 15 Mha. The region is characterized by an arid to semi-arid climate, with very dry summers and more humid winters. Its high