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Assessing the suitability of American National Aeronautics and Space Administration (NASA) agro-climatology archive to predict daily meteorological variables and reference evapotranspiration in Sicily, Italy

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ABSTRACT

For decades, the importance of evapotranspiration processes has been recognized in many disciplines, including hydrologic and drainage studies, irrigation systems design and management.

In this research, the suitability of the Prediction Of Worldwide Energy Resource database published by the American National Aeronautics and Space Administration (POWER-NASA), to estimate daily meteorological variables and ET_0 was assessed in Sicily, Italy, for the period 2006–2014, based on ground data measured by a network of climate stations belonging to the regional Agro-meteorological Information Service (SIAS). After comparing the climate data (minimum, T_{min}, maximum, T_{max}, and average, T_{avg}, air temperature, relative air humidity, RH, global solar radiation, R_s and wind speed, u) available in both databases, a statistical comparison was carried out on ET_0 values estimated according to the Penman Monteith equation in the version proposed by the Food and Agriculture Organization (FAO-56 PM).

The analysis showed that correlations between air temperature and relative air humidity from both databases are affected by elevation of the weather stations and the distance from the sea. In addition, ET_0 values estimated with POWER-NASA database were generally comparable to those obtained by using the SIAS records, with *RMSE* values ranging between 0.68 and 1.27 mm d^{-1} and *MBE* varying between −0.39 and 0.73 mm d^{-1}. The greatest differences in ET_0 values are due to the resolution of POWER-NASA archive (1° latitude by 1° longitude), that cannot detect the actual spatial variability observed on ground, as well as to inaccurate estimations of relative air humidity occurring for the coastal weather stations as well as of the air temperature for those inland stations characterized by high elevations. However, the achieved results support the possibility of obtaining suitable estimates of daily ET_0 based on the POWER-NASA agro-climatology archive, even to other Mediterranean countries where most of the climate variables are not measured.

1. Introduction

Evapotranspiration, *ET*, is an important component of the hydrologic cycle, and its proper evaluation is important for several disciplines including agricultural water management, hydrologic and drainage studies, as well as crop growth modelling. For decades, extensive studies have been carried out to evaluate crop *ET* under different hydrological environments throughout the world (Christiansen, 1968; McMahon et al., 2013; Rallo and Provenzano, 2013; Minacapilli et al., 2016). In semi-arid Mediterranean regions, it has been recognized that *ET* represents the main hydrological loss, about 50–60% of the mean annual rainfall (Milella et al., 2010).

Actual crop *ET* is commonly estimated by considering separately the atmospheric water demand from the nature of crop surface and the soil water availability (Doorenbos and Pruitt, 1977). The former can be evaluated by means of reference evapotranspiration (ET_0) that, according to Allen et al. (1998), represents "the rate of evapotranspiration from a hypothetical reference crop, characterized by height of 0.12 m, surface resistance of 70 s m^{-1} and albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, well-watered, and completely shading the ground".

Different approaches have been adopted to measure or estimate ET_0 at plot scale. Among these approaches are pan evaporimeters that

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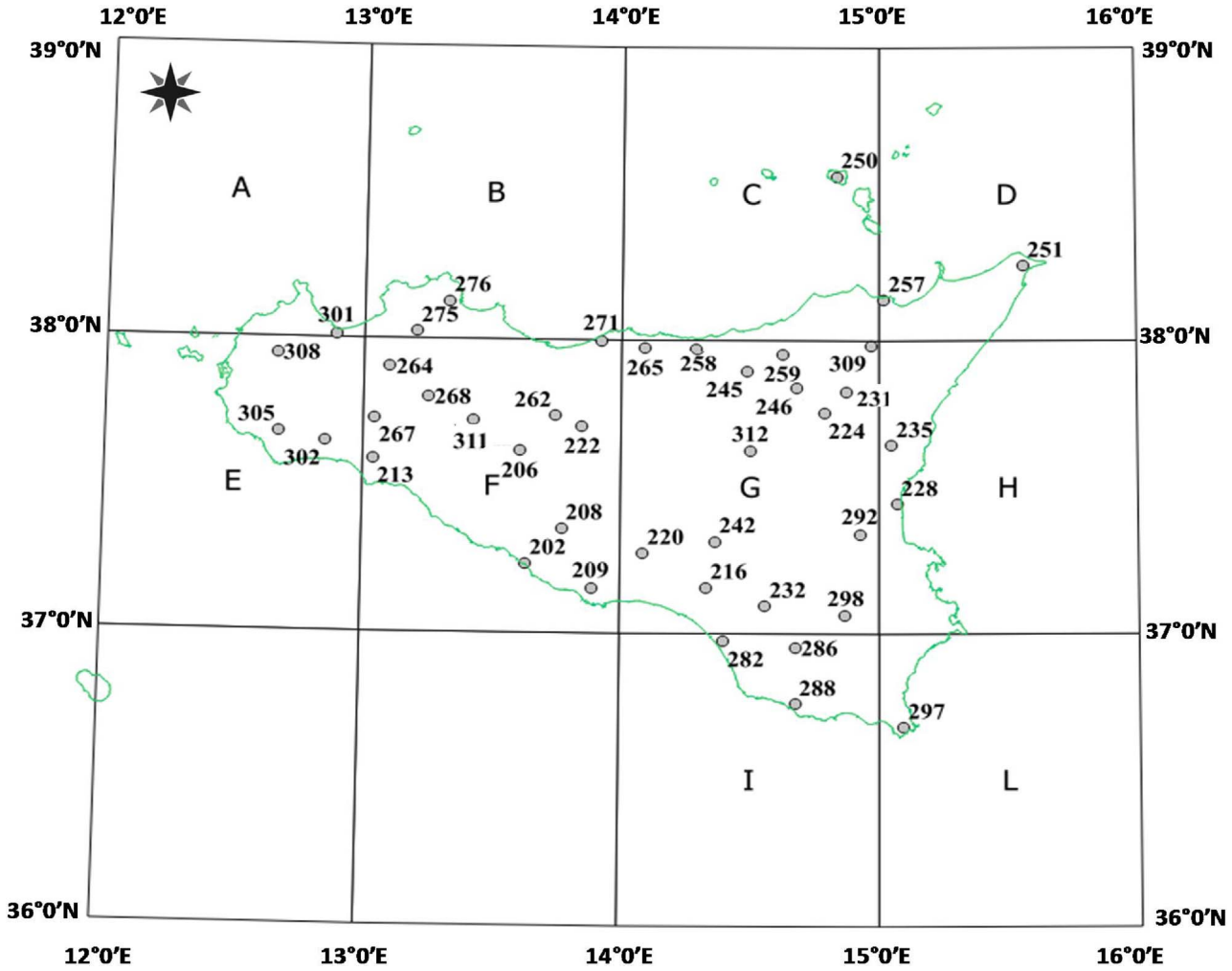

Fig. 1. Map of Sicily with the location of SIAS weather stations. The identification code (ID) used to identify the agro-meteorological station is the same used by SIAS.

provides direct measurements of water surface evaporation which can be related to ET_0, even if site-specific calibrations accounting for the type and placement of pan, as well as for the climate, are required. On the other hand, despite micrometeorological measurements (Foken, 2008; Cammalleri et al., 2013; Negm et al., 2013) and weighting lysimeters (Schrader et al., 2013) can allow direct and accurate measurements of actual *ET*, these methods are expensive and demanding in terms of accuracy of evaluation, so that they can be fully exploited only by well-trained researchers.

Therefore, a wide number of empirical, semi-empirical, and physically-based equations have been proposed to estimate ET_0, based on the atmospheric variables (T_{max}, T_{min}, T_{avg}, u, R_s) affecting the process. When disposing of a complete database of weather data, the Food and Agriculture Organization (FAO) of the United Nations has recommended, as a standard method to estimate ET_0, the FAO-56 Penman-Monteith equation (FAO-56 PM, Allen et al., 1998), obtained by combining the energy and mass balances. The successful performance of FAO-56 PM has been recently assessed in Sicily at both hourly and daily scales, by using of six months of field measurements acquired with a laser scintillometer (Minacapilli et al., 2016).

The lack of complete databases of climate variables, sometimes due to the scarcity of resources for environmental monitoring (Bagarello et al., 2009; Bagarello et al., 2011), has led several researchers to propose alternative estimation methods that consider only limited weather data sets (Todorovic et al., 2013). They could be schematically classified as temperature-based (Blaney and Criddle, 1950); radiation-based (Priestley and Taylor, 1972); mass-based (Mahringer, 1970) or methods combining energy and mass balance (Penman 1948; Monteith, 1965).

The temporal and spatial observations of crop *ET* over scales higher than the plot level (i.e., from field to regional), can be monitored by means of remote sensing observations of the land surface in conjunction with energy balance algorithms. Studies from Kim et al. (2012) and Romaguera et al. (2014) have demonstrated that remote sensing (RS) is a promising and useful tool to parameterize the land surface and to quantify, between others, actual crop evapotranspiration at different spatial and temporal observation scales.

In this context, the American National Aeronautics and Space Administration (NASA), in 1990, launched the Surface meteorology and Solar Energy (SSE) project, with the aim to create an internet-accessible database of climatic parameters for renewable energy applications. The database was later extended in the frame of the Prediction of Worldwide Energy Resource (POWER) project, to create an efficient and open access agro-climatology archive, available on the web (http://power.larc.nasa.gov) and containing, on a global scale, NASA's long-series of meteorological variables and surface solar energy fluxes. This archive contains long-term estimates of meteorological variables derived from NASA's Global Model and Assimilation Office (GMAO) and the Goddard Earth Observing System assimilation model version 4 (GEOS-4) and version 5 (GEOS-5), in addition to the surface solar energy fluxes obtained by means of satellite observations. The data, available since 1983, are characterized by 3-hourly, daily and monthly time step (Zhang et al., 2010). Based on the POWER-NASA database, many investigations have been performed in industry and research

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