Evaluating groundwater resources by means of global datasets

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Introduction

Climate change influences the hydrological cycle with direct effects on groundwater resources, one of the most important supply source for human consumption and irrigation. In the framework of assessing water balance and the related hydraulic works for water supply, it is crucial to correlate quantitatively climate trends, precipitation and groundwater behaviour. In a previous paper [3], data from ERA-Interim reanalysis of meteorological observations made by the European Centre for Medium-Range Weather Forecasts (ECMWF) have been compared to the local water table measurements given by the monitoring network managed by the Regional Agency for Environmental Protection of the Umbria Region (ARPA Umbria Italy). The pointed out good correlation between the trend of soil moisture – the result of precipitation over all meteorological space-time scales – and local water table data of unconfined aquifers authorizes further in-depth analyses.

In the line with such promising results, in this paper meteorological observations from ERA-INTERIM and ERA5 reanalyses are compared with the aim of evaluating the effect of:

- the different models and procedures used to obtain atmospheric global datasets,
- the characteristics of data on which reanalyses are based (e.g., their temporal and spatial resolution).

Attention is focused on the behavior of water fluxes towards water table as a preliminary phase of the water budget assessment. The ultimate goal of this research is to check whether the global atmospheric datasets – specifically the behavior of the soil moisture volumetric content – may allow estimating the available groundwater resources at a regional scale.

Data source and description

Two kinds of data have been used for evaluating the behavior of groundwater:

- soil moisture content, θ, provided by the ERA-INTERIM and ERA5 reanalysis datasets of ECMWF at four different depths, z, from the ground level (layer 1: z = 0-7 cm; layer 2: z = 7-28 cm; layer 3: z = 28-100 cm; and layer 4: z = 100-289 cm, respectively);
- water table elevation, h, given by ARPA Umbria (Italy).

ARPA Umbria has been collecting water table data at 52 sites in the region since early 2000s (Fig. 1); for each of these sites, the value of h is provided as the mean daily value [4].
In this study, attention is focused on the three sites (Riosecco, Scheggino, and Maratta) spread throughout the Umbria region [3] pointed out in Fig. 1.

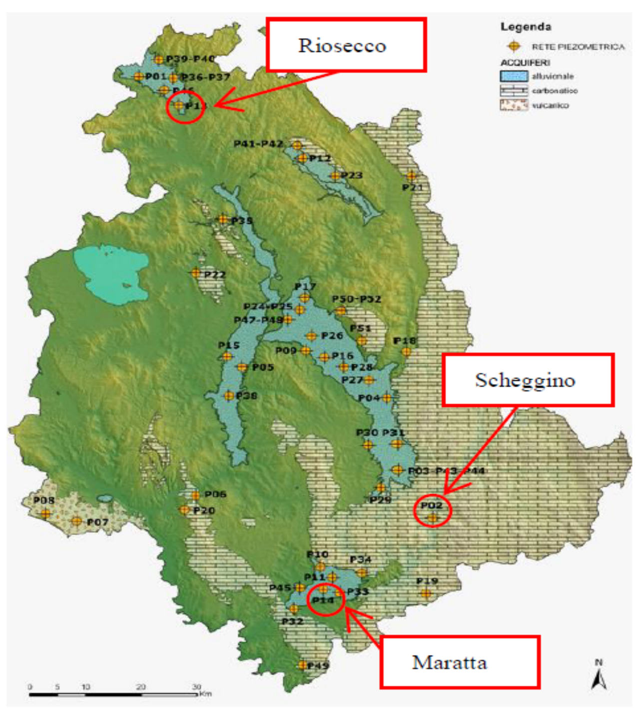

Figure 1: Water table monitoring network managed by ARPA Umbria (in red the sites considered in this study).

ECMWF soil moisture data: ERA-INTERIM vs. ERA 5

The improved modeling of the atmospheric processes and soil in ERA5 reflects clearly in a more credible dynamics of soil moisture behavior with more valuable differences between the value of θ at different depths in ERA5 with respect to ERA-INTERIM (Fig. 2).

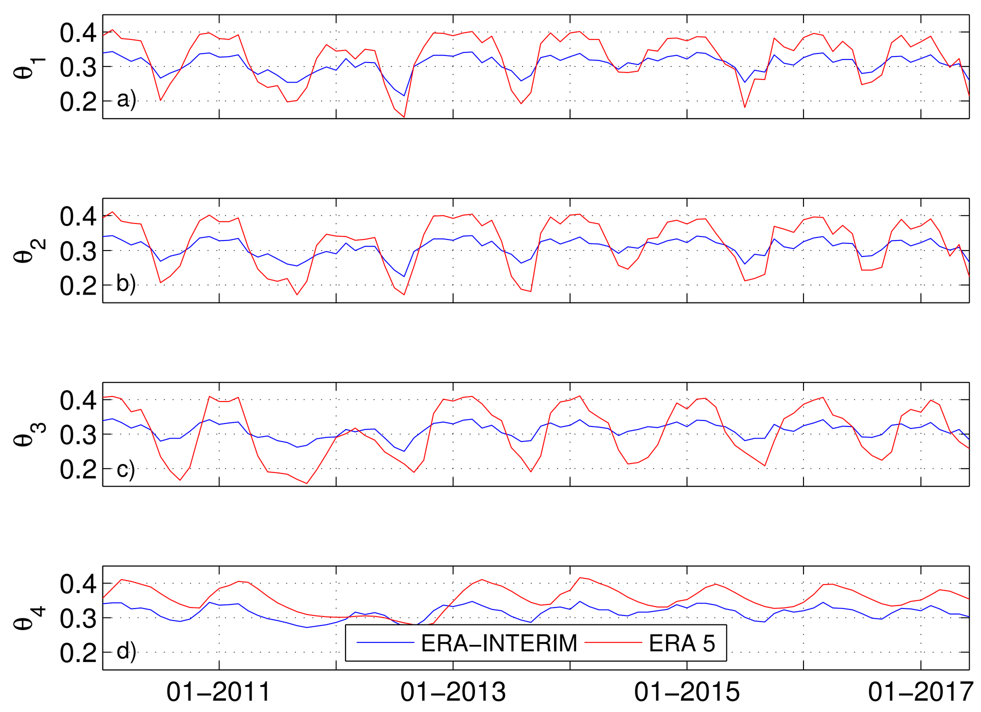

Figure 2: Riosecco site: ERA-INTERIM vs. ERA 5 – time series of the monthly-daily means of the volumetric soil water content, θ (m^3/m^3) at layer: a) 1; b) 2; c) 3; and d) 4.

One of the effects of the much larger spatial resolution of ERA5 data can be noticed in Fig. 3 where θ values at the selected sites from ERA-INTERIM do not exhibit any differences. On the contrary, ERA5 data show admissible in principle differences and make more reliable in principle ERA5 areal average values of Fig. 4.

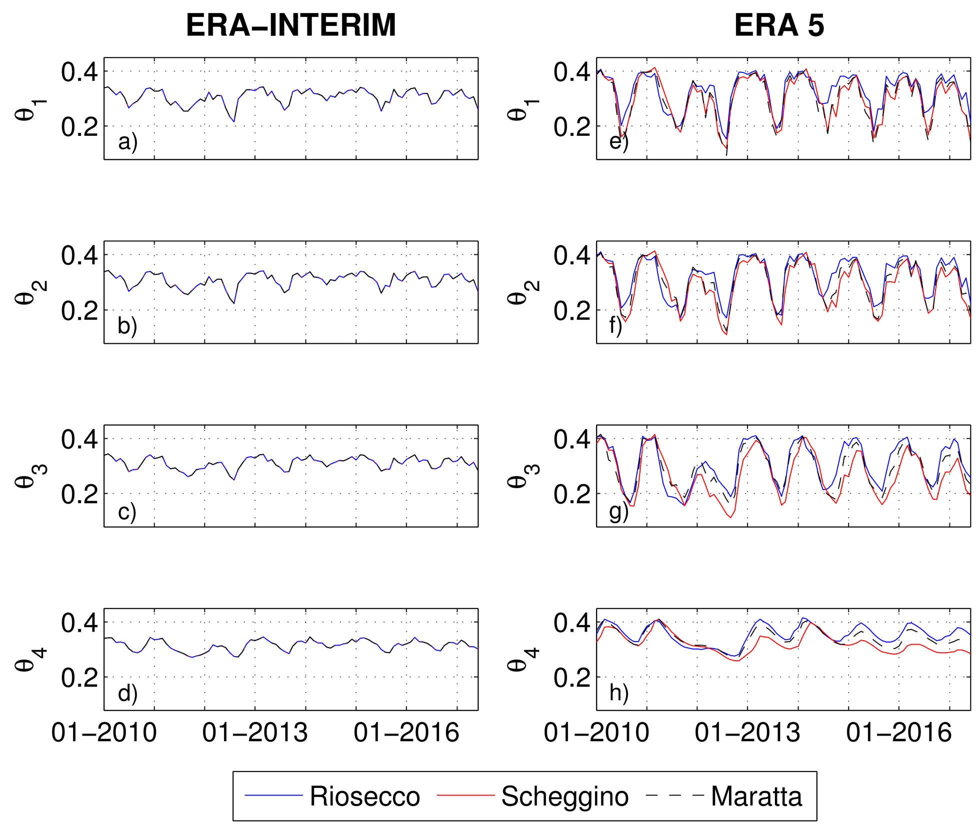

Figure 3: Comparison between the three different sites considered in this study: ERA-INTERIM vs. ERA 5 – time series of the monthly-daily means of the volumetric soil water content, θ (m^3/m^3) at layer: a), e) 1; b), f) 2; c), g) 3; and d), h) 4.

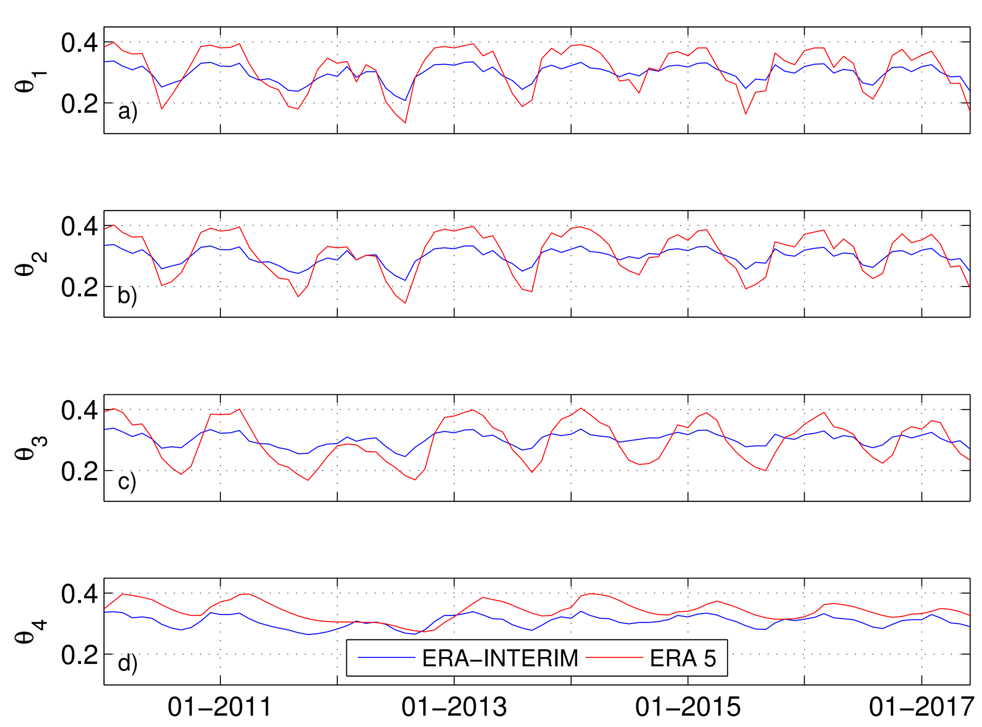

Figure 4: ERA-INTERIM vs. ERA 5 – time series of Umbria areal average of the monthly-daily means of the volumetric soil water content, θ (m^3/m^3) at layer: a) 1; b) 2; c) 3; and d) 4.

ERA 5 water flow vs. water table measurements

As a first taste of a possible use of the global atmospheric datasets as a reliable tool for water resources management, water flow towards water table, F_w, has been evaluated by means of the Richards equation:

$$F_w = k(\frac{\psi_{i+1} - \psi_i}{\Delta z} - 1) \tag{1}$$

by assuming free drainage as bottom boundary condition [2]; in Eq. (1), the hydraulic conductivity, k, assumed as spatially variable according to the global soil texture map reported in [1], is given by the van Genuchten equation [5], and the pressure head ψ has been evaluated by assuming $\theta = \theta_4$. As a reference, in Fig. 5a) and 5b) the time-history of F_w for Riosecco site are compared with the relevant water table measurements. As pointed out in Fig. 5c), the yearly periodicity can be observed as well as a one or two months time shift between the maximum values of F_w and h.

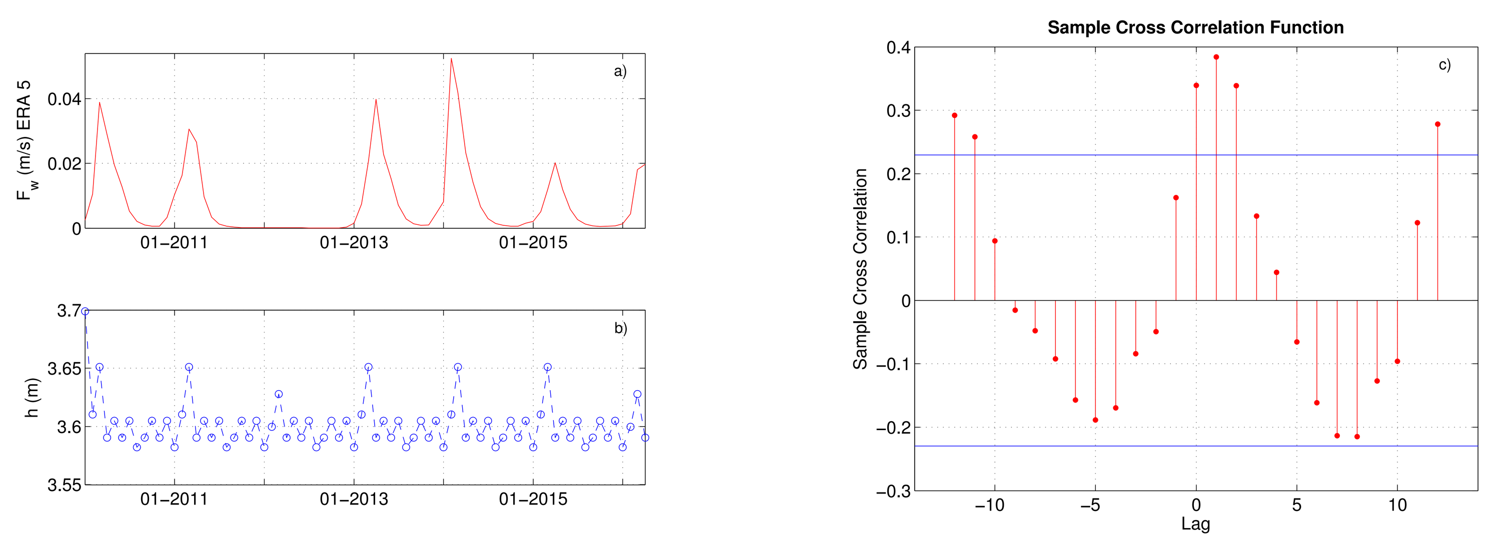

Figure 5: Riosecco site: monthly-daily mean time series of the: a) water flow from layer 4 to the aquifer, F_w; b) water table elevation, h; c) sample cross correlation between F_w and h.

References

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Acknowledgments

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