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Groundwater supply and climate change management by means of global atmospheric datasets. Preliminary results

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Abstract

Climate change influences hydrological cycle with a direct effect on groundwater resources, one of the most important supply sources for human consumption and irrigation. In a scenario where General Circulation Models do not represent yet a usual tool for water industry managers, potentially the use of global atmospheric datasets is of great interest for evaluating groundwater resources. In this paper data from the European Centre for Medium-Range Weather Forecasts (ECMWF) are compared to local water table measurements. With particular regard to unconfined aquifers, the good correlation between the trend of soil moisture and local water table data is pointed out. Such a promising result authorizes further insights in order to refine reliable tools for evaluating available groundwater resources in a climate change scenario.

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Keywords: Water balance; soil moisture; ECMWF dataset; water table

1. Introduction

Nowadays one of the greatest concerns of the water industry managers is the potential decrease and quality of groundwater supplies, as it is the main available potable water supply source for human consumption and irrigation. In fact there are strong links between climate change and the hydrologic cycle: precipitation, evapotranspiration, and

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soil moisture depend on temperature regime [1]. In the framework of assessing the water balance, water industry managers have to address the following question [2]: how do groundwater level trends correlate with precipitation and climate behaviour? In other words, what is the influence of climate change on the volume of water that can be extracted from groundwater? Moreover, since the energy cost due to pumping stations is one of the largest components of the total system management costs [3], the analysis of the water table behaviour has also important economical implications. To solve such a paramount importance problem, a multi-disciplinary approach is needed. General Circulation Models (GCMs), which consider all relevant physical factors, must be used for understanding the aquifer response to climate change as a basis for water use policies. That said, this question arises: is the refining of a reliable GCM within the reach of any water supply company? In other words, which water company is so important that it can include all the needed capabilities in its staff? On the economical side of the problem, a further tie rises: does the dynamics of funding – in many cases resulting from a hand-to-mouth policy – allow preparing reliable management tools on time? In a world where water resources were managed according to cross-regional or, better, cross-borders criteria – some cases have been explored but for transnational river basins (e.g., [4, 5]) – a unique GCM could be used by several water companies accordingly. In the real world, water resources are not managed by means of shared criteria and each single water company has to solve its problems separately. In such a case, even if CGMs provided by research centres were used, to obtain realistic results statistical downscaling techniques should be employed to bridge the local- and synoptic-scale process by considering a number of factors including precipitation intensity and timing, topography, vegetation, and soil properties [2, 6]. In a word, a quite complex procedure which also needs an interdisciplinary approach. Moreover things are made more complicated by the fact that in many cases the water table behaviour and its links with the users – i.e., the effects of groundwater extraction and pumping criteria – is not known at a regional scale. In most cases only some local water table measurements and extracted volumes are available, often close to the most important well-fields. Situation is more critical for minor groundwater resources (i.e., those with a small withdrawn discharge) for which also the delineation of the protection areas is often a hard task [7, 8].

In the above scenario, where climate change plays a more and more critical role and, in some sense, exalts management problems, the importance of the global atmospheric datasets has to be pointed out. Particularly, for monitoring climate change, ECMWF (European Centre for Medium-Range Weather Forecasts) – as well as other global research centres – periodically uses its forecast models and data assimilation systems to reanalyse archived observations, creating global data sets describing the recent history of the atmosphere, land surface, and oceans. It is worthy of noting that such climate observations range from early in-situ surface observations made by meteorological observers to modern high-resolution satellite data sets. In this paper data from ERA-Interim – a reanalysis of meteorological observations made by ECMWF – are used for exploring if a link exists between the trend of soil moisture and local water table data. With particular regard to unconfined aquifers, such a link would represent the first stone on which a simplified – but physically based – model could be built to predict the behaviour in time of groundwater resources with the aim of refining a reliable water balance and the related investments for water supply and distribution systems in line with climate change.

2. Data source and description

Two kinds of data have been used for evaluating the behaviour of groundwater: soil moisture content provided by the ERA-INTERIM re-analysis dataset of ECMWF and water table elevation given by the monitoring network managed by the Regional Agency for Environmental Protection of the Umbria Region (ARPA Umbria, Italy).

2.1. ECMWF soil moisture data

ERA-Interim is one of the few global atmospheric datasets produced by the national agencies with the aim of monitoring climate and for research purposes. ERA-Interim is a reanalysis of meteorological observations from January 1979 to present with products gridded at T255 spectral resolution (Triangular spectral truncation at 255, about 80 km) by the ECMWF in collaboration with many institutions [9]. Gridded data products include a large variety of surface and atmospheric parameters, produced by the daily reanalysis of tens of millions of observations assimilated twice a day with a prior estimate of the atmospheric state of the ECMWF global forecast model in a statistical optimal manner. Reanalysis of data was built initially to make better use of the observations to initialize numerical weather