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Analyses of precipitation, temperature and evapotranspiration in a French Mediterranean region in the context of climate change

Analyse des variables précipitation, température et évapotranspiration en région méditerranéenne française dans un contexte de changement climatique

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ABSTRACT

This study is focused on the western part of the French Mediterranean area, namely the Pyrénées-Orientales and Aude administrative departments. The water resources (surface and groundwater) in the region are sensitive to climate change. The study addresses the question of whether any trend in the annual and monthly series of temperature, rainfall and potential evapotranspiration (PET) already appears at the scale of this region. Two data sources have been used: (a) direct local measurements using the meteorological network; and (b) spatially interpolated data from the French weather service model SAFRAN for the period 1970–2006. The non-parametric Mann–Kendall test was applied to identify significant trends at the local scale and, because of the natural spatial variability of the Mediterranean climate, regional interpretation was also performed. The trends observed in the 13 catchments of interest are consistent with those observed at a larger scale. An increase in annual mean temperature and annual PET was observed throughout the study area, whereas annual precipitation has not exhibited any trend. The monthly scale has revealed strong seasonal variability in trend. The trend for an increase in monthly PET has been observed mainly in the spring, and has not been seen in the coastal areas. A trend for an increase in monthly temperature has been observed in June and in the spring throughout the entire area. Monthly rainfall has been found to decrease in June and increase in November throughout the area. The significant trends observed in rainfall and temperature seem to be consistent between the different data sources.

Mots clés :
Détection de tendance
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RÉSUMÉ

Ce travail concerne la façade ouest de l'arc méditerranéen français, sur les départements des Pyrénées-Orientales et de l'Aude. Dans un contexte de changement climatique global, l'objectif de cette communication est de rechercher, dans des séries de mesures de température, de pluie et d'évapotranspiration à des échelles annuelles à mensuelles, si des tendances à la hausse ou à la baisse peuvent d'ores et déjà être mises en évidence sur cette zone. Diverses sources de données sont utilisées : des mesures directes à partir du réseau sol et des mesures spatialisées sur 13 bassins versants issues du système d'analyse SAFRAN

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de Météo-France, sur la période 1970–2006. Le test non paramétrique de Mann-Kendall est appliqué localement à chaque série pour détecter un changement local significatif. La variabilité spatiale « naturelle » du climat méditerranéen a conduit à mettre en œuvre une version régionale de ce test pour juger de la significativité régionale des changements identifiés localement. Les changements détectés sur les 13 bassins sont en général cohérents avec ceux observés à une échelle géographique plus étendue. L'augmentation des températures moyennes annuelles et de l'ETP annuelle affecte l'ensemble de la zone d'étude, alors que les précipitations annuelles ne montrent pas de changement. L'analyse à l'échelle mensuelle révèle une forte variabilité saisonnière des changements. L'augmentation de l'ETP concerne surtout le printemps, avec une variabilité spatiale qui semble épargner la frange littorale ; l'augmentation des températures mensuelles est généralisée sur tous les bassins en juin et au printemps. En automne, et notamment en novembre, les précipitations mensuelles enregistrent une augmentation elle aussi généralisée sur tout le secteur et une baisse en juin. Les changements identifiés sur les pluies et températures sont relativement cohérents, suivant les différentes sources des séries, mesures directes au sol ou interpolées spatialement avec SAFRAN.

1. Introduction

The conclusions of the last Intergovernmental Panel on Climate Change (IPCC) report confirm an increase in world temperature since the beginning of the industrial period and an acceleration of warming since 1975 (IPCC, 2007). Furthermore, the report stresses the now extremely probable anthropic cause of this warming. Although warming affects the whole world, regional contrasts are shown, with more marked warming in the northern hemisphere and faster warming of continents than seas, for example. One can therefore wonder about the consequences of this warming on the water cycle in general and in the Mediterranean region in particular. Indeed, this region is probably more susceptible to climate change as, geographically, it lies in a transition area between the hot, dry climate of Africa and the cold, humid air masses arriving from northern Europe (Goubanova and Li, 2007). With considerable coherence between models, climate simulations for the future display an intensification of the hydrological cycle at the scale of the planet (Planton et al., 2005). They thus forecast an increase in seasonal climatic variability (Diodato, 2004; Haas, 2002), with: (a) hotter, drier summers in the semi-arid regions (Planton et al., 2005); and (b) an increase in the duration and severity of low-flow periods and a decrease in groundwater recharge (Booij, 2005; Zhang et al., 2004). These climatic changes should be accompanied not only by a change in the average figures for the water cycle variables mentioned above but also by an increase in their variability in time. Extreme events should occur more frequently and with greater intensity (Jentsch and Beierkuhnlein, 2008). However, it is reminded that the forecasts mentioned here are subject to strong uncertainty, the reduction of which can be attempted only through a combined improvement of the spatial resolution of climate models and of their physical formulations (Le Treut et al., 2008).

The consequences of these possible changes in climate are all the more worrying in the Mediterranean region as socioeconomic scenarios indicate an increase in population and hence growing human pressure on water resources. Alcamo and Doll, 2003 and Arnel et al., 2004 consider that the consequences of increased pressure by man could be at least as great as those of climate change, at least in the short term.

The sensitivity of water resources in this region in a context of climate change and the diversity of the scenarios envisaged lead to asking questions about the already perceptible effects of modification of the climate. Our work addressing the Mediterranean zone of the South of France is focused on the Pyrénées-Orientales and Aude departments where water resources – consisting mainly of karstic and alluvial groundwater – are already a major concern today. The aim of this article is to examine if there are any signs of a change in the precipitation, temperature and potential evapotranspiration (PET) regime at different spatial scales. For brevity, these are referred to hereafter simply as climate variables. They are obtained from several types of measurements.

The study zone and the data are described in the next section. The procedure used is described in Section 3 and is followed by discussion of the results.

2. Study zone and data

2.1. Study zone

The Pyrénées-Orientales and Aude departments form a study zone of some 10,000 km^2 on the western façade of the French Mediterranean arc. The Pyrenees, culminating at an elevation of 2900 m, border them to the north and west, where the range marks the frontier with Spain. The climate is typically Mediterranean in the plain and on the coast and of a Mediterranean mountain type further west. Thirteen catchments and sub-catchments of interest have been selected (Fig. 1) on the main rivers draining the region, the Têt (1350 km^2), the Tech (750 km^2) and the Agly (1120 km^2).

2.2. Data analysed

The climate variables are defined at time scales that are relevant as regards their influence on water resources. These are cumulated values at the monthly, seasonal and annual time step.

Two sets of data were used according to the different spatial scales considered. The first consists of direct, local