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Daily temperature changes and variability in ENSEMBLES regional models predictions: Evaluation and intercomparison for the Ebro Valley (NE Iberia)

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ABSTRACT

We employ a suite of regional climate models (RCMs) to assess future changes in summer (JJA) maximum temperature (T_{max}) over the Ebro basin, the largest hydrological division in the Iberian Peninsula. Under the A1B emission scenario, future changes in both mean values and their corresponding time varying percentiles were examined by comparing the control period (1971–2000) with two future time slices: 2021–2050 and 2071–2100. Here, the rationale is to assess how lower/upper tails of temperature distributions will change in the future and whether these changes will be consistent with those of the mean. The model validation results demonstrate significant differences among the models in terms of their capability to representing the statistical characteristics (e.g., mean, skewness and asymmetry) of the observed climate. The results also indicate that the current substantial warming observed in the Ebro basin is expected to continue during the 21st century, with more intense warming occurring at higher altitudes and in areas with greater distance from coastlines. All models suggest that the region will experience significant positive changes in both the cold and warm tails of temperature distributions. However, the results emphasize that future changes in the lower and upper tails of the summer T_{max} distribution may not follow the same warming rate as the mean condition. In particular, the projected changes in the warm tail of the summer T_{max} are shown to be significantly larger than changes in both mean values and the cold tail, especially at the end of the 21st century. The finding suggests that much of the changes in the summer T_{max} percentiles will be driven by a shift in the entire distribution of temperature rather than only changes in the central tendency. Better understanding of the possible implications of future climate systems provides information useful for vulnerability assessments and the development of local adaptation strategies for multi-disciplinary investigations.

1. Introduction

Climate change has become a major focus of attention in the scientific community over the last few decades, due in part to the potential impacts on both natural systems (Burlando and Rosso, 1991; Wood et al., 2004; Ryan et al., 2008) and human environments (Patz et al., 2005). However, although climate change is a global phenomenon, the potential impacts are not homogenous over space (Trenberth, 2011). In particular, the magnitude and impacts of climate change can vary significantly from one region to another. Characterizing changes in climatic patterns and their possible future changes at finer spatial scales

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can assist in providing needed guidance and advice to local policy makers for adaption and mitigation strategies. In addition, assessing climate change and variability on local and regional scales is critical for improved management and understanding of ecosystem dynamics and human settlements.

Recently, a number of European projects have designed experiments to downscale regional climate projections from Global Climate Models (GCMs), using either dynamical or statistical approaches. Among these projects are PRUDENCE (Christensen et al., 2007), STARDEX (Goodess et al., 2005), ENSEMBLES (van der Linden and Mitchell, 2009), MISTRA-SWECIA (Kjellström, 2008) and EURO-CORDEX (Kotlarski et al., 2014). These projects allow not only for an improvement in the spatial resolution of climate simulations over Europe, but also for incorporating additional physical processes into model simulations (e.g., cloud formation, aerosol influences, radiation balance, atmospheric fronts and boundary layer processes). Improvement in the capability of these models makes them a promising tool for assessing the potential impacts of future climate change on regional scales across Europe. For this reason, these climate simulations have been investigated quite thoroughly in numerous climate studies over different regions (see for example, Olsson et al., 2009; van der Linden and Mitchell, 2009; Lorenz and Jacob, 2010; Kjellström et al., 2010; Vicente-Serrano et al., 2011; Frías et al., 2012; Sunyer et al., 2012; Nastos and Kapsomenakis, 2014).

In response to recent improvements in the capability of numerical models for predicting future climate, a number of studies have employed these high resolution climate simulations to argue that increased heat stress risk over Europe may be caused by elevated greenhouse gas concentrations (Fischer and Schär, 2009; Barriopedro et al., 2011). For example, Parry (2000) studied the future climatic trend in Europe and found that the mean temperature might increase by 2–6.3 °C at the end of this century, with the largest warming occurring over Southern Europe and the Mediterranean regions. In the same context, Schär et al. (2004) indicated that the European summers at the end of the current century will be as warm as the extraordinary 2003 summer. They estimated an increase in summer mean temperature of 10 to 15%, with a tendency for increasing temperature variability. This finding was also supported by Della-Marta et al. (2007), who found that the climate of Western Europe has become more extreme, suggesting that the increase in variance of future summer temperature has already been evident over the last 126 years. Fischer and Schär (2009) also found that changes in daily summer extreme temperatures are likely to be accompanied by changes in both the mean and the variance.

In this work, we provide a detailed assessment of future projections of summer maximum temperature (T_{max}) over the Ebro Valley in northeast Iberia, using a suite of regional climate models (RCMs) from the European ENSEMBLES project. The Ebro basin is the largest in the Iberian Peninsula, with a total area of nearly 85,000 km^2 and is characterized by complex topography and climate, with large regional differences (Cuadrat, 1999). The water of the Ebro is the main supply for irrigation and other agricultural activity, domestic supply, electricity production and industrial development. A comprehensive assessment of temperature change projections at fine resolution over the Ebro catchment is lacking, although numerous studies have placed an emphasis on assessing future temperature projections in other Spanish regions (e.g., Vargas et al., 2008; López-Moreno et al., 2008; Brands et al., 2011; Gimeno et al., 2011; González-Aparicio and Hidalgo, 2012; Jerez et al., 2013; Domínguez et al., 2013). To date, the majority of studies in the region were focused primarily on an assessment of future changes in precipitation (e.g., Palatella et al., 2010; García-Garizábal et al., 2014). An exception is the study of López-Moreno et al. (2014), who analyzed observed and future projections of a set of temperature extremes in the Ebro Valley during an extended winter (DJFM). Also, Domínguez et al. (2013) analyzed the capacity of five RCM simulations to represent warm days over eleven basins across Spain, including the Ebro.

In this study, we endeavor to provide a detailed assessment of future temperature changes over the Ebro catchment using simulated data from a set of high resolution RCMs. The focus will be on the summer (JJA) season, as summers in the Ebro Valley show the highest temperature changes over the last five decades (0.3 °C/decade), with a particularly strong rise in the last decade (El Kenawy et al., 2012). A prolonged warming of summer temperatures in the future may intensify the hydrological cycle in the basin, resulting in higher evaporation losses, higher irrigation water requirements, and an overall increase in water resources demands for domestic, agricultural and industrial use (El Kenawy et al., 2013a, 2013b; Vicente-Serrano et al., 2014a,b). In addition, anomalous heat events in future decades may inflict large damages and losses to the region, including human fatalities, forest fires, water deficits and crop losses.

The main objectives of this work are: (1) to evaluate the capability of a suite of nine RCMs to reproduce near present summer T_{max} variations in the Ebro Valley, (2) to assess projected changes in summer mean T_{max}, as forced by the A1B emission scenario for the 21st century, and (3) to explore future changes in summer heat events. The latter objective is undertaken by comparing changes in the lowest (pc1, pc5 and pc10) and highest (pc90, pc95 and pc99) percentiles of the summer T_{max} distribution with those of the mean state. This assessment is important to determine whether projected changes in temperature percentiles will be consistent with simulated changes in the corresponding mean climate. Indeed, changes in the warm and cold tails of temperature distribution are interesting, particularly for regional climate impact and assessment studies. Over Iberia, little research has explicitly indicated the extent to which simulated changes in mean temperature can be related to its corresponding probability distribution, particularly on a more localized scale.

2. Data and methodology

2.1. Study area

The Ebro Valley is one of the main physiographic units in the Iberian Peninsula, representing approximately 17% of Spain. The altitude varies from below 200 m to above 2500 m (Fig. 1). The Ebro extends inland along a northwest–southeast axis in a semi-enclosed basin, surrounded by mountain belts including the Pyrenees (north), the Cantabrian belt (northwest), the Catalan chain (east) and the Iberian system (south and southwest). This geographical domain is unique from a climatic perspective, as it includes the northern most semi-arid region in the European continent. Furthermore, with the latitudinal