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Heat waves analysis over France in present and future climate: Application of a new method on the EURO-CORDEX ensemble

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ABSTRACT

Currently, the analysis of heat waves and the representation of such events in a comprehensible and accessible way is a crucial challenge for climate services, in particular for delivering scientific support to policy makers. In order to fulfil this need, a new method for analysing the heat waves in France has been defined. Heat wave detection is based on the high quantiles of daily temperature distributions, and can be applied on any series of temperature. The heat waves are characterised by their duration, maximal temperature and global intensity. Their characteristics are calculated for historical and future climate based on the EURO-CORDEX regional multi-model ensemble, under two different Representative Concentration Pathway scenarios: RCP4.5 and RCP8.5. The historical simulations are evaluated against the SAFRAN reanalysis data. The EURO-CORDEX ensemble simulates heat waves which characteristics are consistent with the events detected from the SAFRAN thermal indicator between 1971 and 2005. Models are able to simulate waves as intense as the 2003 outstanding event. Under future climate conditions, whatever the considered scenario, the heat waves become more frequent and have higher mean duration and intensity. Moreover, heat waves could occur during a larger part of summer. The 2003 event corresponds to a typical event at the end of the century, and its duration and intensity are much lower than the strongest waves that could occur over the last 30 years of the 21st century. However, the intensity of the evolution during the end of the century will strongly depend on climate policies.

Practical implications

Heat waves are one of the most worrying climatic extremes due to the vulnerability of our society and the expected increase in their frequency and severity in the 21st century (IPCC, 2013). France was particularly impacted by the 2003 summer heat wave which caused an excess of about 15,000 deaths from 4th to 18th August directly attributable to the heat (PoumadÉre et al., 2005). By combining peaks of extreme temperature and severe soil and hydrological droughts, this event affected numerous economical sectors at the same time (Bador et al., 2016): crop yield in agriculture, forest fires, energy production (cooling process of thermal power plants), buildings (cracks caused by shrink-swell of clay). These last years, numerous regions of the world experienced severe heat waves with comparable effects: Russia in 2010, Texas in 2011, Australia in 2012, India and Southern Pakistan in 2015. Therefore, the ability of our society for adapting to the changes of heat wave characteristics in the future is one of the biggest stakes for climate policies. At the EU level, the ‘‘climate-adapt” portal has identified heat waves as one of the four main climate threats for urban adaptation (http://climate-adapt.eea.europa.eu/tools/urban-adaptation/climatic-threats/heat-waves). In France, a national plan to better cope with heat waves has been decided after the 2003 event. More generally, a national Plan for climate adaptation (http://www.developpement-durable.gouv.fr/-Plan-national-d-adaptation-2011-.html) was defined in 2011 and took into account heat wave impacts for six sectors: fishery, urbanism, health, natural risks, energy industry and agriculture. The basic climate change scenarios for this plan, communicated through regular reports (Ouzeau et al., 2014) and through the DRIAS national web portal (www.drias-climat.fr), include a state-of-the-art of the projection of heat wave occurrence and intensity over the 21st century in France.

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According to this plan, learning from past experience of extreme events cases is crucial to compare with upcoming future events.

However, the ability of detailed analysis and past-present-future comparison of these events is today hindered by the lack of a universal definition for heat waves. They are usually identified as periods with warm temperatures above the normal observed during several consecutive days, but the parameters allowing their detection and qualification vary a lot (duration, threshold etc).

This leads in France to several climate change indices on the different national portals for climate change, without direct correlation with real heat wave events:

– the National Observatory On Effects of Climate Warming (ONERC in French) presents an index of the observed evolution of the yearly number of summer days (max temperature higher than 25 °C).
– the DRIAS portal, a French referential climate service for climate projections data dissemination, uses the Stardex definition for heat waves: 5 consecutive days with 5 degrees anomaly with respect to mean temperature in summer.

The French ministry of ecology therefore asked to define clear indices as part of the national adaptation plan (Extremoscope project).

The method presented here is an event-based approach synthesizing all aspects of heat waves, without targeting a specific sector. A sufficiently universal index as proposed here is necessary to cover several impacted sectors, allowing comparative studies needed for a lot of policy makers and climate services such as those mentioned below. This method accounts for duration (start and end), maximum temperature and global severity. It contains an innovative multi-dimensional representation of events, based on ''bubble'' plots, synthesizing these characteristics, in a comprehensible and accessible manner for both research studies and policy makers. It is diverted from the operational method used by MÅtÅo-France for climate monitoring (http://www.meteofrance.fr/climat-passe-et-futur/bilans-climatiques/bilan-2015/bilan-climatique-de-l-ete). Its application has been recently extended for climate services into the French application Climat^{HD} (http://www.meteofrance.fr/climat-passe-et-futur/climathd), in order to represent both present-day and future heat waves. This representation has been adopted in a report about cities climate change adaptation for the Paris Urban Area (www.apc-paris.com).

Here the method is improved by using quantiles of the events or model distributions. We propose original graphical representations of both multi-dimensional and multi-model information, adapted to climate services.

This development will be used soon in an operational context for different climate services:

– For local authorities, it will be used to update the Cities Climate plans, aiming to take into account heat wave and urban heat island monitoring.
– At the national level, it will be used in on-line services as DRIAS and Climat^{HD}. An update of heat wave indices will be done shortly.

The method will be adapted in sectoral applications such as for Energy in the frame of Copernicus Climate Change Service to represent cold wave events associated to high energy demand.

Since prolonged periods of heat or cold affect the demand and generation of electricity, anticipating the energy consumption associated to these climate events is important. Furthermore, the evaluation of such events in present-day climate is crucial to adapt existing power installations. Moreover, providing expertise about the evolution of occurrence of heat and cold waves is necessary to integrate future climate conditions into the design of new installations.

The method suggested here can be applied on any series of temperature, for the needs of any country. For example in United Kingdom, the power sector works on infrastructure resilience and long-term adaptation planning. It was agreed with the government that a coordinated response to both these work streams, by the electricity sector as a whole, was an appropriate way to assess climate change risks.

1. Introduction

Instrumental observations and reconstructions of temperature evolution reveal a pronounced global warming during the past 150 years (IPCC, 2013). Several studies show that this warming is associated with changes in temperature extremes at various locations around the globe. Implications of global warming for changes in extreme weather and climate events are of major concern for society, in particular in relation to impacts on economy, ecosystems and health. One implication of global warming is the increase in the number of heat waves, which continued at a sustained rythm over the past decades (Seneviratne et al., 2014). Previous studies suggest that the change of the heat wave characteristics in future climate are linked to the changes of the extremes of the daily temperature distribution in summer (Schoetter et al. 2014) due to an increase of the interannual temperature variability in some regions (Schär et al., 2004; Cattiaux et al., 2015). A period of extremely high temperatures is generally considered as a heat wave but there is no unique definition. Many indices are constructed with a certain impact group or sector in mind, which may be impacted in a different way than another group by extremely high temperatures. Indices defined in one region or group may not be relevant in different conditions. They may not be representing all aspects of heat waves appropriately (Perkins and Alexander, 2013). However, most definitions rely on a characterization of the events by their duration, intensity or severity. Russo et al. (2014) focused on the magnitude of extreme heat waves in present and future climate that occurred worldwide, using global outputs from the Coupled Model Intercomparison Project phase 5. In particular, they proposed a Heat Wave Magnitude Index that can be compared over space and time.

France experiences a very variable summer climate, as many countries in South/Central Europe. This is essentially due to the possible influence of dry enough soils to trigger positive feedbacks between temperature and soil moisture (Zampieri et al., 2009; Seneviratne et al., 2010). However such dry conditions are only present in some summers, such as the 2003 and 2015 summers, but not in others, enhancing interannual temperature variability.

Gibelin et al. (2014) showed via a new dataset of monthly homogeneous series of temperature, that from 1959 to 2009 the mean warming over France (+0,3 °C per decade) is mainly explained by spring and summer temperature increase. Several studies have examined heat wave characteristics and their evolution in future climate in Europe (Schär et al., 2004; Beniston et al. 2007; Barriopedro et al. 2011; Lau and Nath 2014; Jacob et al., 2014). Fischer and Schär (2010) focused on summer heat