Hydrol. Earth Syst. Sci. Discuss., 9, C600–C604, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C600/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Evolution of spatio-temporal drought characteristics: validation, projections and effect of adaptation scenarios" *by* J.-P. Vidal et al.

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Received and published: 28 March 2012

The article analyses the future drought severity in France for the twentieth century considering three scenarios of greenhouse gasses emission (A2, A1B and B1). The authors use reanalyzed data from a model developed in METEOFRANCE and they focus on two different drought indices: the SPI and the SSWI on two different time scales with the purpose of analysing the drought severity in the twentieth-first century. I consider that the article provides novelties related to the drought science. On the one hand, the area/magnitude/duration analysis using drought indices and climate change scenarios has not been previously used. The authors show that this approach is very useful to illustrate how climate change processes may increase the severity of droughts. This approach introduces much more information than the typical analysis based on the magnitude/duration estimations based on punctual data. In addition the study is also showing the need of drought adaptation measures given future drought projections and it provides a relevant message on how drought severity may increase in the future and how drought adaptation approaches are completely necessary to reduce the possible derived impacts. Therefore, I consider that the article deserved to be published in HEES since it provides relevant results and messages, not only useful for scientists but also showing a new methodological approach with interest for managers and policymakers.

I am going to provide two main criticisms to the article, mainly conceptual. The first one is related to the drought index, SPI, used in this study. The authors use this indicator to determine future drought severity in France. Although the SPI is now considered as the reference drought index by the WMO (see Hayes et al., 2010 – authors should cite this reference in page 1627 line 10), the SPI is calculated considering precipitation data. There are several evidences that indicate that drought severity is not only related to the precipitation variability but other variables, mainly potential evapotranspiration (PET), is also having an important role, even more under the current climate warming scenario. Thus, in page 1635 the authors indicate the possible effect of upward trend in temperature (affecting PET) to increase the soil moisture droughts in the last years. Precipitation-based drought indices including the SPI rely on two assumptions: i) the variability of precipitation is much higher than that of other variables, such as temperature and potential evapotranspiration (PET), and ii) the other variables are stationary (i.e. they have no temporal trend). In this scenario the importance of these other variables is negligible, and droughts are controlled by the temporal variability in precipitation (See Vicente-Serrano et al., 2010). Nevertheless, when the authors analyse the drought projections under three different scenarios, they are using the SPI although they implicitly affirm that global warming is having a certain influence on drought severity. I think that to determine future scenarios in drought severity, it would be better the use of drought indices that consider both precipitation and potential evapotranspiration like the sc-PDSI or the SPEI, which may be also calculated on different time scales, like the SPI, but it is also sensitive to evapotranspiration changes (see Vicente-Serrano et al., 2010 and 2011). I am not requiring that authors make again the analysis using different drought indices but they should include a discussion indicating that the severity of future drought events will be probably worse than that indicated by the SPI, since the role of temperatures will be also important in the future.

The second main criticism is related to the calculation of a soil moisture drought index on different time scales (3 and 12 months). It is commonly accepted that drought is a multi-scalar phenomenon. McKee et al. (1993) illustrated this essential characteristic of drought through consideration of usable water resources including soil moisture, ground water, snowpack, river discharge, and reservoir storage. The time lag between the arrival of water inputs and the availability of a given usable resource differs considerably depending on the system under consideration. Thus, the time scale over which water deficits accumulate becomes extremely important, and functionally separates hydrological, environmental, agricultural and other droughts. For example, the response of hydrological systems to precipitation can vary markedly as a function of time. This is determined by the different frequencies of hydrologic/climatic variables. For this reason, drought indices must be associated with a specific timescale to be useful for monitoring and management of different usable water resources. For example, Vicente-Serrano and López-Moreno (2005) and Lorenzo-Lacruz et al. (2010) showed how the response of the river discharges and reservoir storages to climate droughts changes noticeably as a function of the time-scale at which the climatic drought index is calculated. Nevertheless, when the drought index refers directly to a certain usable water source (e.g., streamflows or soil moisture) the concept of time scale is less meaningful for identifying drought conditions. In other words, the severity of the streamflow or soil moisture drought will only depend on the current flow magnitude/soil moisture conditions in a given moment in time. Longer time scales can not be representative of real streamflow/soil moisture drought conditions. Therefore, although the calculation of a hydrological drought index on longer time scales than one month can be useful to be linked to large-scale climate variability or to asses the possible responses downstream (e.g., a reservoir, which storage depend on the upstream conditions during several months), this approach is not useful to detect the real drought conditions in a gauging station/crop field for a certain month, which will only depend on the streamflow/soil moisture recorded that month. Therefore, I do not see any usefulness in using SSWI3 and SSWI12, and really it should be SSWI1 to represent real drought conditions in soil moisture. The climatic drought indices like the SPI or the SPEI are calculated on different time scales to adapt the times of response of different ecological, agricultural or hydrological variables to climatic droughts (see Vicente-Serrano et al. 2011) and to monitor easily the possible drought conditions in a variety of hydrological systems (among them soil moisture). Authors should consider it in future drought analysis using the SSWI.

Minor comment: Lines 24-25. There are empirical studies that show the response of hydrological and environmental systems to the SPI on different time scales (Vicente-Serrano et al., 2011; Lorenzo-Lacruz et al., 2010; Vicente-Serrano, 2007; Vicente-Serrano and López-Moreno, 2005, and references therein).

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 1619, 2012.

HESSD

9, C600–C604, 2012

Interactive Comment