Hydrol. Earth Syst. Sci. Discuss., 12, C3629–C3632, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C3629/2015/

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Nonstationarity of low flows and their timing in the eastern United States" *by* S. Sadri et al.

S. Sadri et al.

justin@princeton.edu

Received and published: 12 September 2015

We appreciate the comments by Dr. Serinaldi, which are pertinent and useful. Our goal with this study was to develop practical tools for identifying non-stationary behavior over large-scales. The eventual goal is to move towards understanding the footprint of climate variability and human influences (whether direct management of water or indirect influences such as land use change) on the hydrological cycle at large-scales (regional and larger) as manifested in observations such as streamflow, and do this in the context of real-world applications such as flood and drought risk assessment, monitoring and prediction. This paper represents initial work to do that based on the high availability of data in the eastern US and the large-scale human influences. Our

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

goal is motivated by the need to understand changes in regions with less data and potentially less (by amount or accessibility) information on how flows are influenced by human activities, such as in many parts of the developing world. We believe that the approach that we have presented shows promise in achieving this being based on simple and straightforward methods. Having said that, we do agree that there are elements of the approach (and the use of terminology) that need to be revisited in the context of this paper.

Stationarity/non-stationarity does indeed refer to the processes driving the changes and the models that are used to characterize those processes. We have reflected on the title of the paper and the terminology used in the paper in light of these comments and those of the referees. We think that the title is appropriate as it conveys the essence of the paper, but have tweaked the language at various points to be more appropriate, including rewriting the methodology section to better reflect the hydrological literature, also in response to the referee comments.

We are interested in understanding the processes that are driving changes in low flows. Our approach has therefore been not to only fit statistical models of changes, but to do so with regard to possible documented influences on changes. We hypothesized that step changes may be related to human influences and gradual changes are related to climatic influences, and we test this by looking at site notes that provide information on potential influences. We recognize that this does not account for climatic drivers of step changes, but make the further stricture that step changes have to be large enough (visually and statistically) to be likely due to human influence. Many studies, including Dr. Serinaldi's own work, have emphasized the importance of exploratory data analysis, particularly visual inspection of the time series, to look for clues as to the possible processes driving changes and therefore appropriate models. We have also focused on this aspect, attempting to align what we see in the time series with appropriate models that can detect changes in a systematic and automated manner. This has perhaps not been emphasized as clearly in the original manuscript. The key question here in the

HESSD
12, C3629–C3632, 2015

context of our goals, is how can we make judgments on the variations in data for multiple sites across a region with little knowledge of the processes (in particular human influences) driving these variations? Of course, further tests could be carried out to (1) confirm the results or (2) test alternative hypotheses of the type of change, but we have focused here on a simple methodology that we think captures the main elements.

In response to the referee comments, we have changed the methodology somewhat to better account for autocorrelation in the low flow time series when applying the tests. Originally, autocorrelation in the series was tested for and sites with significant overall autocorrelation were removed from further analysis, based on the simplification (supported by visual analysis) that this was indicative of human influences (although natural processes could also drive autocorrelation, such as a strong groundwater influence). Instead, we now pre-whiten the time series before applying the tests, among other changes to the methodology. More details are provided in the referee responses.

We think that we have taken an appropriate approach to attributing changes. Firstly, the comparison with site notes, whilst not a perfect comparison, instills some confidence in our approach for detecting human influences. Secondly, the comparison of low flows at sites with no or little influence, with time series of precipitation and potential evaporation indicates that any changes are generally consistent with changes in these physical drivers, which adds confidence that these drivers are in fact realistic.

At a single site, confidence in the identification of human influence or the attribution to physical drivers will be low, of course, given that there are multiple influences and the data record is often not very long. Serinaldi and Kilsby (2015a) show how different interpretations of change can easily be justified by fitting different models, but robust attribution requires examination of the metadata and understanding of the physical drivers and feedbacks. However, at the large-scale of this study, we show that there are multiple lines of evidence that suggest the existence of human influences or the dominance of certain physical drivers. This pooling of information gives us greater confidence that we have identified the main drivers.

HESSD

12, C3629–C3632, 2015

Indeed, the dominance of the large-scale patterns of increases and decreases is suggestive of a climatic influence. These changes may be an effect of longer-term variability associated with quasi-periodic climate variability such as the PDO or AMO. However, such “oscillations” are not necessarily well defined because of the short record lengths that in some cases can only, at best, capture one cycle. We are therefore cautious about attributing these trends to climate change or climate variability, but are confident that these are mainly driven by climate. At small scale, further exploration of alternative causes (groundwater pumping, surface water extraction) and more detailed evaluation (e.g. timing of dam construction) is needed, as well as potential experiments with physically based hydrological models. For example, there are spatially contiguous areas along the eastern coast that show declines in low flows that are inconsistent with increasing precipitation, but are consistent with increasing pumping in regions of active groundwater contributions to low flows, although this is somewhat speculative.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 2761, 2015.