EGU21-12878
https://doi.org/10.5194/egusphere-egu21-12878
EGU General Assembly 2021

Influence of low-frequency variability on high and low groundwater levels: example of aquifers in northern France

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Groundwater fluctuations exhibit very often well-pronounced low-frequency variability (multi-annual to decadal timescales), linked to catchment and aquifer ability to smooth out rapid fluctuations from precipitation (low-pass filtering), especially when their characteristic time is long. This low-frequency variability, generated by large-scale climate variability and modulated by the physical properties of hydrosystems, is clearly imprinted in aquifers of northern France. Many recent researches addressed the issue of the capability of global climate models to reproduce low-frequency variability (most of the time multidecadal). For hydrological processes such as groundwater levels, which variance can be dominated by such low-frequency ranges, it may then appear crucial to provide assessment on how very high or very low levels are sensitive to such low-frequency variability. In this study, we investigate how low-frequency variability (from multi-annual to interdecadal timescales) may generate very high or very low groundwater levels (higher or lower than percentiles 80% and 20%, respectively). To test such hypotheses, our approach consists of breaking down groundwater level signals into timescale components using maximum overlap discrete wavelet transform in order to get wavelet details at different timescales. Multi-annual ~7 yr and interdecadal ~17 yr components appeared to be the dominant components of low-frequency variability of the signals. We then substracted these components (either one or both) and simply examined how many values remained over or below the selected threshold.

Results highlight that the number of events generated by low-frequency components is consistently closely linked to their contribution to groundwater level variability. Nearly 100% of high and low groundwater levels in inertial aquifers, that exhibit a large predominance of interdecadal variability, are generated by this timescale. At least 50% of high and low groundwater levels in inertial aquifers displaying a combination of interdecadal and multi-annual variabilities are generated by the combination of these two timescales. Finally, less than 50% of high and low groundwater levels in mixed aquifers (i.e. with a well pronounced low-frequency variability superimposed to annual variability) are generated by the multi-annual and interdecadal variabilities. In all studied aquifers with various dynamics, we notice a higher sensitivity of low groundwater levels to low-frequency variability than high groundwater levels.

Across aquifers of northern metropolitan France, particularly in the chalk of the Paris Basin, we observe quite a clear dependence of well-known historical high and low groundwater levels to low-

frequency variability. In particular, the 2001 high levels and the 1992 low levels are seemingly generated by concomitant multi-annual and interdecadal high levels, and concomitant multi-annual and interdecadal low levels, respectively. On the other hand, the 1995 high levels and 1998 low levels are produced by a multi-annual high level attenuated by an interdecadal low level, and a multi-annual low level attenuated by an interdecadal high level, respectively. These phasings are also observed in precipitation and effective precipitation a few time in advance (ranging from 2 months to 1.5 years). Finally, the contribution of multi-annual and interdecadal variabilities to make the groundwater levels reach or exceed one selected threshold is directly influenced by their prominence in groundwater levels variability.