Trend analysis of river water temperatures in the Ebro River Basin (Spain)

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Water temperature is an important factor conditioning physical, biological and chemical processes in water courses. The huge changes along the last 50 years in land and water use (dam construction, urban development, nuclear power plants (NPP), riparian alteration, irrigation development, and return of agricultural lands to forests), along with climate change, call for the study of their influence on river water temperatures.

This work analyzed the trends (1973-2010) in water temperature ($T_w$) along the Ebro River (14 water quality stations) in North-East Spain and its main tributaries (6 water quality stations), as a first step to assess its possible relationships with land use changes, climate change, and other factors. Water temperature trends ($\Delta T_w$) were estimated by two different methods: (1) multiple regression incorporating year seasonality and linear trend; and (2) non-parametric Mann-Kendall seasonal trend estimator. A cluster analysis based on principal components (performed upon the variables $T_w$, $\Delta T_w$, annual $T_w$ range, lag of the $T_w$ annual cycle, coefficient of correlation between water and air temperature ($T_a$) and station altitude) allowed for grouping stations with similar behaviour in $T_w$ (along the year, seasonality, and throughout the study period, trend).

Trend analysis by the regression and Mann-Kendall methods produced similar results. They showed significant ($P<$0.05) annual upward trends in $T_w$ in all the stations but for the 2 headwater stations of the tributaries Aragón and Segre. However, there were significant differences in $\Delta T_w$ among stations and seasons. The lower reach of the Ebro River, downstream the Ascó NPP, showed the highest $\Delta T_w$ with an increase of 3.5°C in 40 years (~0.09°C/year). In contrast, the stations located on dams or on the lower reaches of the tributaries showed the lowest trends: 1.3°C in 40 years (~0.03°C/year). Generally, the $\Delta T_w$ were significant from April to June, but in the lower reach of the Ebro River (downstream from Ascó station), $\Delta T_w$ was significant from December to September.

The cluster analysis identified four kinds of stations: (i) headwaters with low $T_w$ and generally low $\Delta T_w$ and close relationship between $T_a$ and $T_w$; (ii) stations on dams, downstream the Garoña NPP, or downstream the main tributaries, with the weakest relationship between $T_a$ and $T_w$; (iii) the stations in the mean reaches of the Ebro River and outlets of the main tributaries showing the closest relationship between $T_a$ and $T_w$; and (iv) stations downstream from Ascó NPP that showed the highest $\Delta T_w$ and $T_w$ (2°C higher than contiguous stations).

Altogether, a noticeable increase in $T_w$ was observed throughout the Ebro River Basin (up to 2°C in 40 years) which may affect physical-chemical and biological in-stream processes. Although climate change should be contributing to this increase, the contribution of other anthropogenic factors (particularly related to land use, as irrigation development and reforestation) is likely to be important in this basin and its effect on $T_w$ should be studied in detail.