Geophysical Research Abstracts
Vol. 15, EGU2013-5900-1, 2013
EGU General Assembly 2013

Relations between large scale oscillation patterns and rising water temperatures at Lake Neusiedl

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Lake Neusiedl (Neusiedler See, Fertő tó) is a very shallow steppe lake (area 320 km^2, mean depth 1.2 m) at the border of Austria/Hungary. The low ratio of water depth to water volume accounts for dynamic, air temperature-dependent developments of water temperature with the potential of unusually warm waters that are a pillar of the touristic attractiveness of the lake. Likewise these conditions are a risk factor for water quality deterioration.
In the frame of the EULAKES-project (European Lakes under Environmental Stressors, www.eulakes.eu), financed by the Central Europe Programme of the EU, data records of water temperature at 5 monitoring stations of Lake Neusiedl (eHYD) and the nearby air temperature monitoring station Eisenstadt - Sopron (HISTALP database and ZAMG) were used to investigate the period 1976-2009. Additionally the influences of 7 teleconnection patterns, i.e. the East Atlantic pattern (EAP), the East Atlantic/West Russia pattern (EA/WR), the Eastern Mediterranean Pattern (EMP), the Mediterranean Oscillation (MO) for Algiers and Cairo, and for Israel and Gibraltar, resp., the North Atlantic Oscillation (NAO) and the Scandinavia pattern (SCA) were assessed.
The increase of temperature during the observation period was more pronounced for water than for air. Water temperatures increased significantly ($p<0.05$) for all seasons with a decadal increase of +0.81, 0.98, 0.54 and 0.41˚C, resp., for spring, summer, autumn and winter, during the last 34 years. The rise of air temperatures was significant only in spring and summer (increase per decade +0.60 and 0.70˚C, resp.). Seasonal maxima of water temperature for the period 1976-2009 all occurred in the 2000s, minima around 1980. The average increase of (surface) water temperature for Lake Neusiedl was found to be above that of other Austrian lakes.
The Neumann-test confirmed trends in water temperature data for the period 1976-2009 only for spring and summer, but not for autumn and winter and not for air temperature data. Mann-Kendall-trend test found significant trends for all seasons for water temperature and for spring and summer air temperatures.
Probable step changes (Cusum statistics) were found for water temperature in all seasons at Lake Neusiedl, which had not been detected for inneralpine Austrian lakes: spring – 1988, summer – 1991, autumn – 1986, winter – 1990. When starting regressions at the step, the regression coefficients for spring and summer were lower (0.077), those for autumn and winter higher (0.061 and 0.067, resp.).
Close relationships between air and water temperatures were confirmed. The coefficient of determination R^2 for these two parameters was between 0.9 and 0.8 for spring, summer, and autumn, but only 0.6 for winter. During winter obviously the insulation by ice and snow cover affects the link between air and water temperature.
The oscillation indices with the most distinct relationships to water temperatures of Lake Neusiedl were EAP and MO for Algiers and Cairo.