SPATIAL AND TEMPORAL VARIATIONS OF ISOTOPIC COMPOSITION OF PRECIPITATION IN SLOVENIA

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Abstract
Long-term monthly and short-term monthly and daily data on isotopic composition of precipitation together with meteorological data were used to trace spatial and temporal variations of isotopic composition of precipitation in Slovenia. A spatial distribution of stable oxygen isotopic composition in precipitation over Slovenia has been generated using temperature, latitude and altitude dependences.
Keywords: Hydrology, Monitoring, Adriatic Sea

Introduction
Modern investigations of water cycle include determination of isotopic composition of precipitation, surface water and groundwater because isotopes of water molecule offer a broad range of possibilities for studying processes within the water cycle and thus became an important tool in isotope hydrology, as well as in studies related to atmospheric circulation and paleoclimatic investigations. As the recharge of groundwater is mainly due to precipitation, it is of utmost importance to know the isotopic composition of precipitation, and its seasonal and spatial variations. The Global Network of Isotopes in Precipitation (GNIP) organised jointly by the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO) in 1961 is a database that contains data on stable isotopic composition of hydrogen and oxygen, tritium activity, and relevant meteorological data on a monthly basis, and is thus extremely valuable for modelling climatic changes, as well as in hydrological and hydrogeological investigations. However, the need for a much more refined understanding of isotope variations was indicated in climatic studies and therefore the IAEA initiated a programme of collecting new data at a higher spatial density and temporal frequency in the Mediterranean basin, including the eastern Adriatic coast [1]. The aim of this paper is to present a review of isotopic results obtained since 2001.

Methodology
Monitoring of isotopic composition of oxygen and hydrogen in monthly precipitation has been performed at the continental sampling station in Ljubljana (Slovenia) since 1981 within the GNIP [2]. In the framework of an IAEA Co-ordinated Research Programme [1, 3] the monitoring programme was extended to two additional sampling stations on the coast of Northern Adriatic (Portoroz) and its near hinterland (Kozina) in the south-western, Mediterranean region of Slovenia in October 2000 during which monthly and occasionally also daily sampling was performed [1, 4]. Basic descriptive statistics, deuterium excess and local meteoric water lines were calculated. In addition, altitude effect and isotope - surface temperature relations were determined. Finally, modelling of spatial variations of isotopic composition of oxygen over Slovenia was performed.

Results and discussion
The highest precipitation amount weighted mean hydrogen and oxygen isotopic values are observed at Portoroz, while the lowest values are characteristic for the continental station of Ljubljana (Table 1). The orthogonal regression equations between the isotopic values of individual monthly samples representing local meteoric water lines (LMWLs) are:
- $\delta^2H = (8.1 \pm 0.1)\delta^{18}O + (9.8 \pm 0.7)$ for Ljubljana (1981-2006)
- $\delta^2H = (7.7 \pm 0.4)\delta^{18}O + (7.3 \pm 2.2)$ for Portoroz (2001-2003)
- $\delta^2H = (7.7 \pm 0.3)\delta^{18}O + (9.6 \pm 0.7)$ for Kozina (2001-2003)

Weighted mean d-excess values (Table 1) are close or above 10‰, showing the influence of Mediterranean air masses in south-western part of Slovenia. The altitude effect determined by vertical $\delta^{18}O$ gradient (–0.30‰ per 100 m) was calculated using the isotope data obtained for stations Portoroz and Kozina. Furthermore, the continental station Ljubljana shows higher correlation between oxygen isotopic composition and mean monthly surface temperature (r = 0.75) than the coastal station Portoroz (r = 0.36) indicating that temperature information can only be seen at continental stations and has less influence on the isotopic composition of precipitation at coastal stations.

Comparison of the monthly and daily isotopic composition of precipitation collected from October 2002 to September 2003 at Portoroz and Kozina showed profound differences between the two sets of data. It was shown that in investigated area during rain event of several days sources of air masses have changed during the course and mixing of air masses originating from the continent and from Mediterranean cyclogenesis appeared [4].

The spatial distribution of $\delta^{18}O$ in precipitation has been explained by a simple multiple regression models, based on the meteorological (temperature) and geographic factors (latitude and elevation). Continuous digital map of the $d^{18}O$ distribution over Slovenia has been generated using GIS tools (Figure 1).

Tab. 1. Weighted mean hydrogen and oxygen isotopic composition and deuterium excess values in ‰

Station	$\delta^{18}O$	δ^2H	Deuterium excess
Ljubljana (1981-2006)	-8.6	-59	9.5
Portoroz (2001-2003)	-6.3	-40	10.3
Kozina (2001-2003)	-7.8	-50	12.3

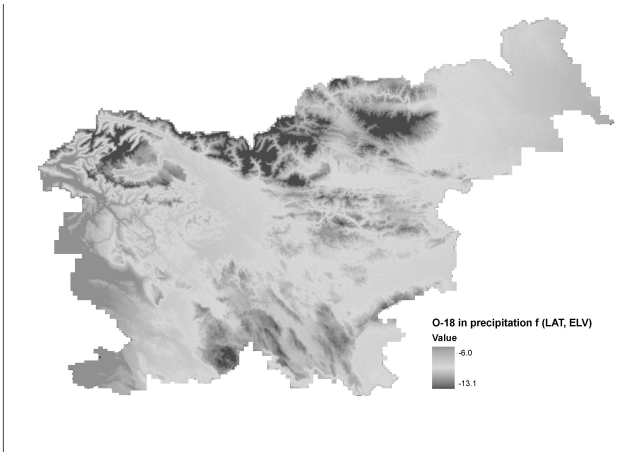

Fig. 1. Continuous digital map of the oxygen isotope distribution as a function of latitude and elevation

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