WATER STABLE ISOTOPE SIGNATURE OF PRECIPITATION FROM SWITZERLAND RELATED TO MOISTURE SOURCES

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Summary

In Switzerland, air masses transporting moisture essentially originate from the Atlantic Ocean, the Mediterranean Sea and the Continental sector (East). Therefore, it is important to understand the regional link between the modern moisture source and the precipitation water isotopes in order to provide comprehensive records of past climate based on natural archives (Affolter et al., 2019), as for instance from speleothem (cave carbonate) fluid inclusions, which are micrometric voids filled with water originating from past rainfall, which is consequently a direct witness of past precipitation water. We collected water during three years from daily precipitation events at Le Mormont MeteoSwiss station in northwestern Switzerland (Affolter et al., 2015).

Altogether, we performed 413 precipitation water isotope analyses on precipitation samples and determined δD, $\delta^{18}O$, deuterium excess (*d*) and $^{17}O_{excess}$. In addition, we performed tritium (^3H) analyses on 228 samples (Fig. 1). We coupled these analyses with air parcel back-trajectories made for the Jura region performed at ETH Zurich. Results highlight a moisture source signature of the water isotopes as well as new insights in the $d/^{17}O_{excess}$ relationship.

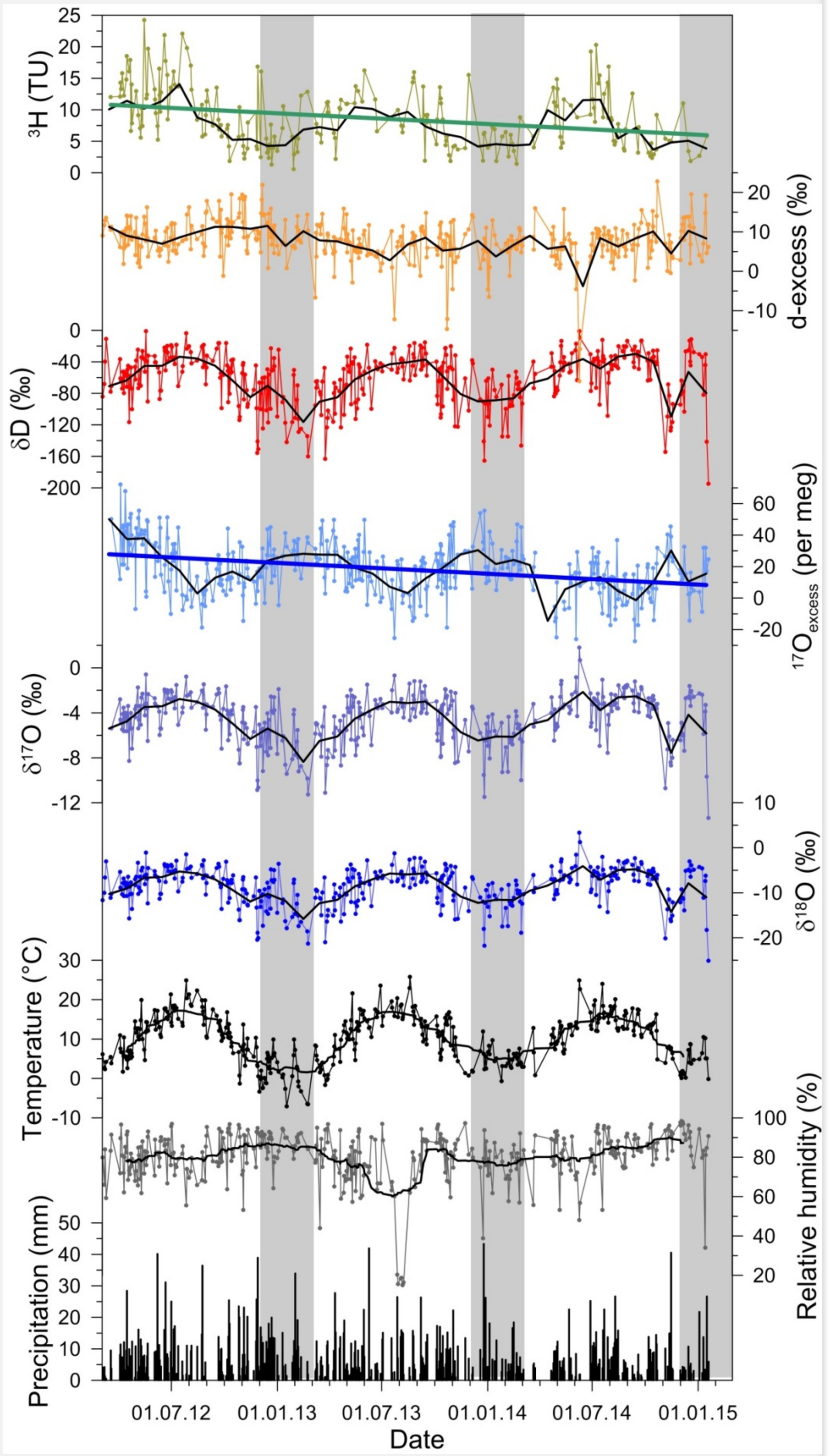


Figure 1: 3-year's record of precipitation water stable and tritium isotopes. Shown are also second order parameters *d* and ^{17}Oxs and respective monthly means (black lines). Corresponding climate parameters from Fahy station such as temperature and relative humidity (and respective 31 days running mean) as well as Mormont station precipitation are also given. Winter season (DJF) is highlighted in grey.

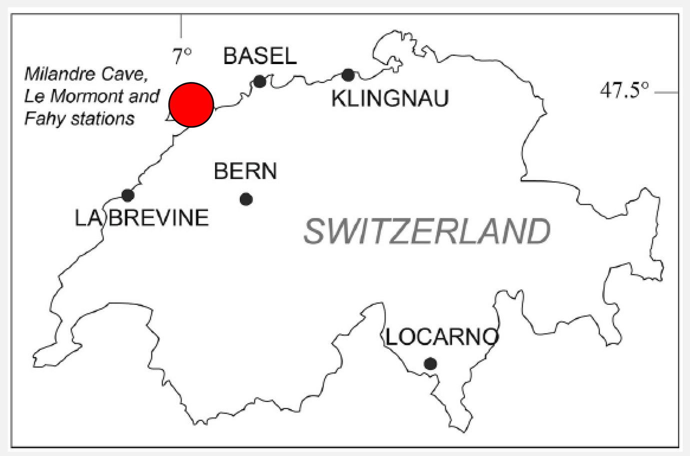


Figure 1: Location map of Switzerland. The water sampling site is shown with a red circle.

Settings

Daily precipitation water samples were collected at MeteoSwiss station n° 534 Le Mormont located in the north-western Swiss Jura Mountains (Fig. 1; 47.44 N/7.04 E, altitude 540 m a.s.l.) between 2012 and 2015. For the last five decades, meteorological observations show a mean annual temperature of ~9 °C with a pronounced seasonality, expressed by temperatures of ~17 °C in July and ~0 °C in January. Precipitation is well distributed over the year with a mean value of ~1050 mm. Modern climatic conditions correspond to a mid-latitude temperate area with moisture originating mostly from the Atlantic (~40%), especially during winter (Fig. 2). The rest is shared among the Mediterranean (~23%), eastern Europe and continental (~21%) and northern Europe (16%) (Sodemann and Zubler, 2010; Fig. 2).

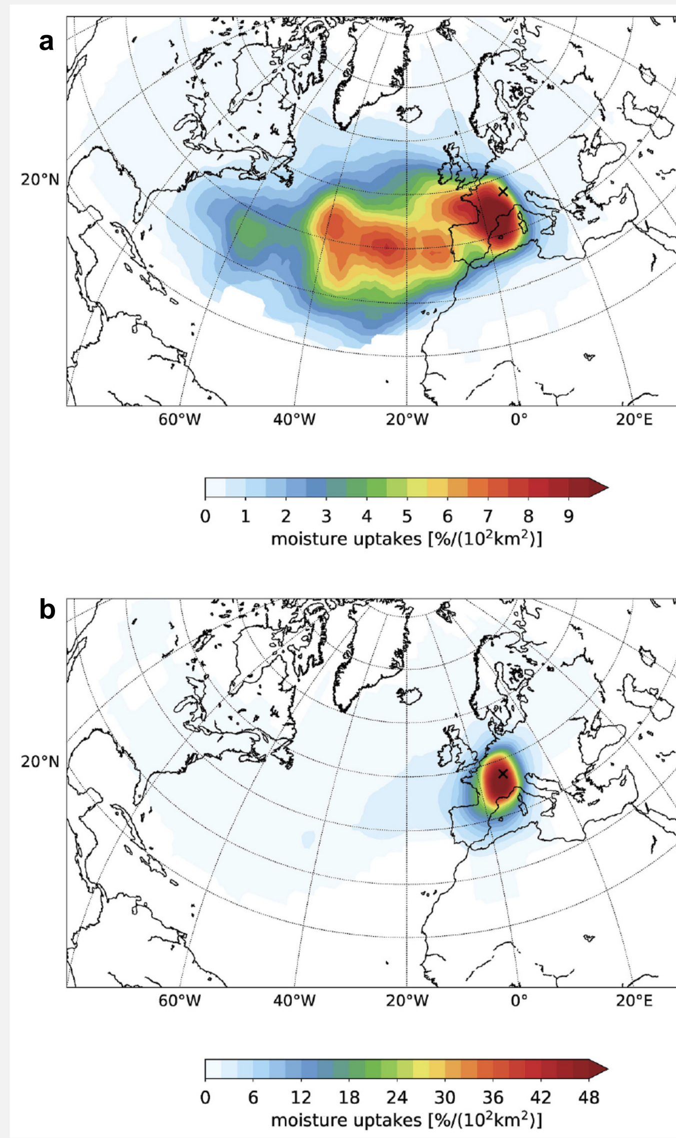


Figure 2: Location map and moisture source analysis over three years (2012 – 2015). (a) Mean moisture source region for DJF months. **(b)** Mean moisture source region for JJA months.

Hydrogen and Oxygen isotopes

Results indicate that water isotopes (δD, $\delta^{18}O$) have a different signature depending on the source (Fig. 3). For tritium, enhanced moisture contribution from the north Atlantic realm to winter precipitation brings more unpolluted marine moisture with close to Atlantic background ^3H values (Fig. 4) (Affolter et al., 2020).

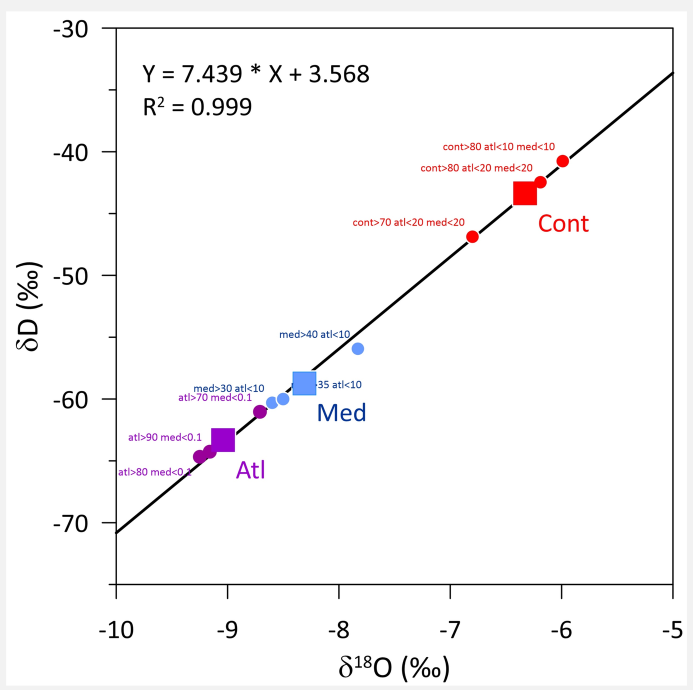


Figure 3: δD vs $\delta^{18}O$. Mean moisture source region over the three years using ETHZ software. Mean values for each source are shown with squares. Different scenarios with different moisture percentages are shown for each source. **Atl** stands for Atlantic, **Med** for Mediterranean and **Cont** for Continental.

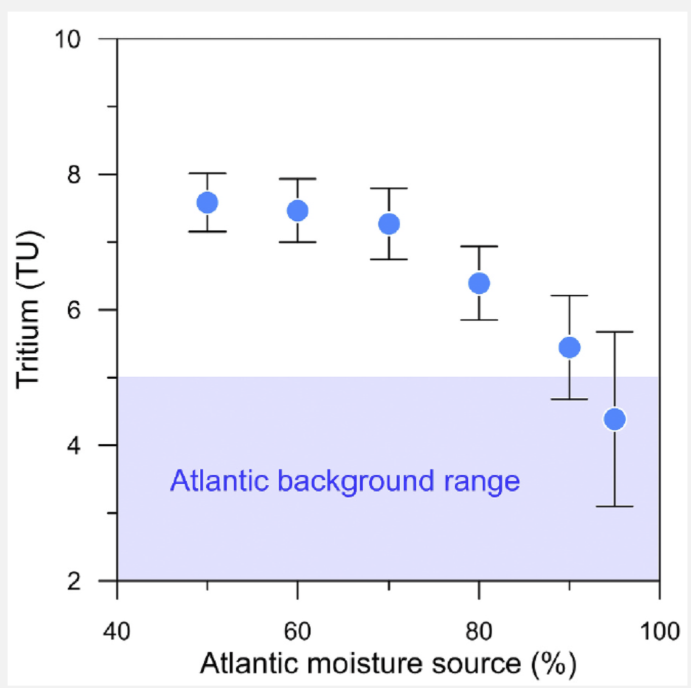


Figure 4: Mean tritium activity for samples related to the amount of precipitation forming water vapour that originates from the North Atlantic in the period 2012 to 2015. The Atlantic moisture source is based on back-trajectories determination corresponding to the water samples used for tritium measurements. The background level is ~1–5 TU (Cauquoin et al., 2015; Rozanski et al., 1991).

Deuterium excess (*d*) and $^{17}O_{excess}$

The second order parameters *d* and $^{17}O_{excess}$ also show a moisture source dependence with, in general, more positive values in both parameters for moisture coming from the Atlantic, lower values for the Mediterranean Sea and again lower for the Continental sector (Fg. 5). A $d/^{17}O_{excess}$ trend has also been observed on a global scale and suggests a potential dependence of the $d/^{17}O_{excess}$ on the water phase, i.e. vapour, liquid or solid for reasons that still need to be investigated (Fig. 6).

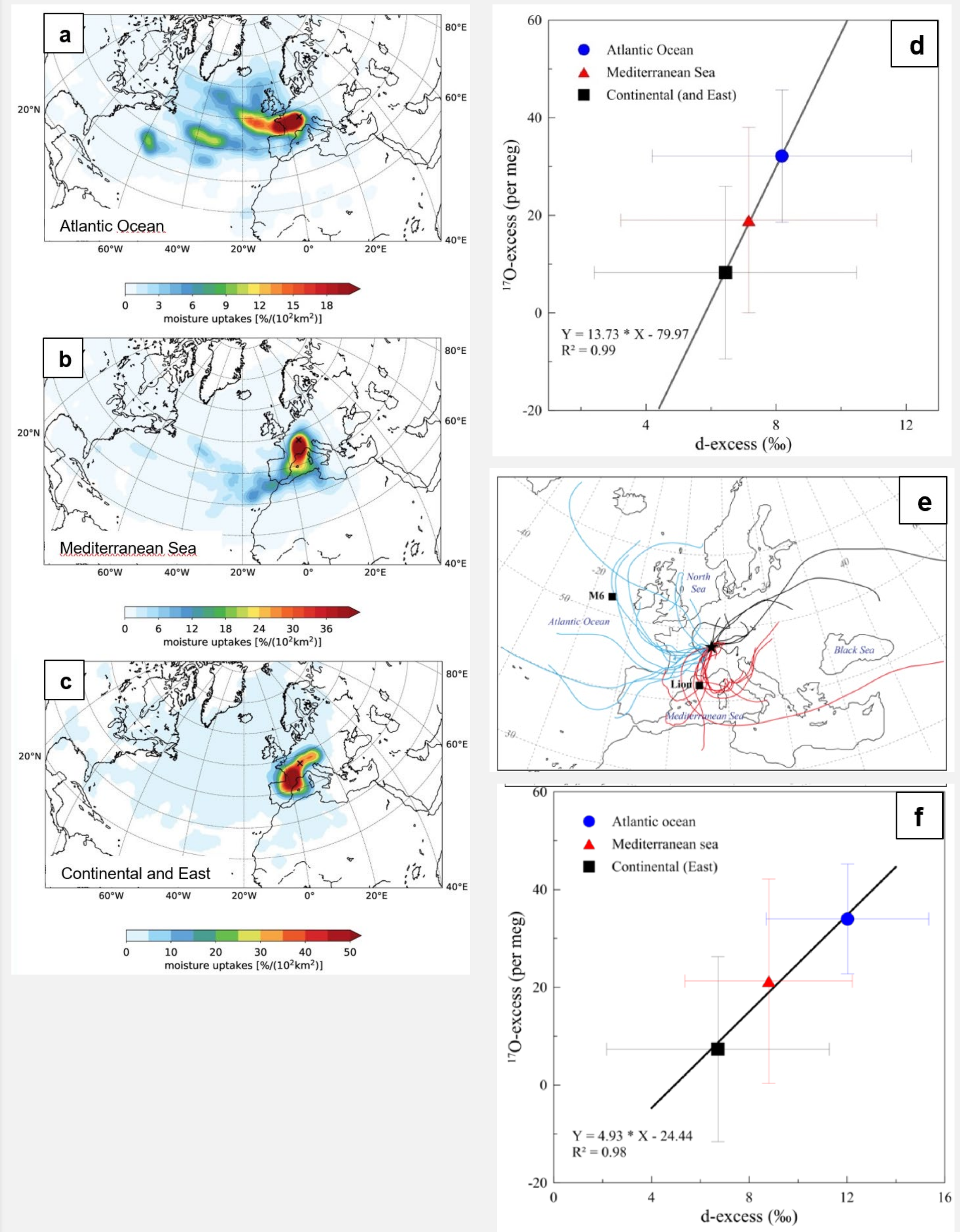


Figure 5: Moisture source analysis.

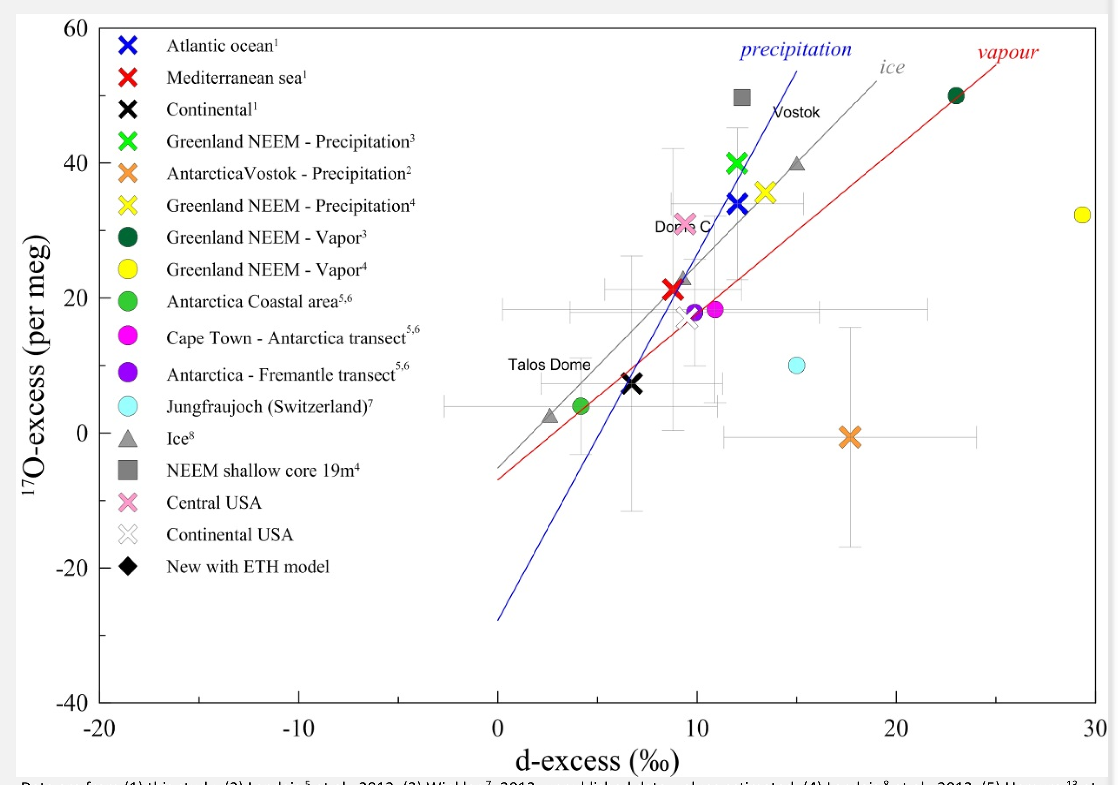
(a, b, c) Moisture source region for the selected days over the three years used to establish the means shown in panel (d).

(d) $^{17}O_{excess}$ versus *d* for precipitation in NW Switzerland for moisture sources coming from three distinct source regions using ETHZ software.

(e) Similar as (a) to (d) but using HYSPLIT on selected distinct daily events for moisture source coming from Atlantic region (blue lines), the Mediterranean area (red) and from continental sources (East, black). Air masses back trajectories were generated at 500 meters elevation above ground for selected days for a duration of 84 hours. Study site (star), buoys (squares). **(f)** ^{17}O-excess versus *d* for precipitation in NW Switzerland for moisture sources coming from three distinct source regions.

Number of days used is 13 (Mediterranean), 9 (Continental) and 14 (Atlantic).

Figure 6: Relationship between *d* and ^{17}O-excess in worldwide precipitation (crosses), water vapour (circles) and ice (triangles and squares). Correlation is high for each water phase, i.e. vapour (R2 = 0.99), liquid (R2 = 0.96) and ice (R2 = 1). Associated with these trends are also present values that are significantly shifted (Greenland NEEM, yellow dot, and Jungfraujoch station) for the vapour or the precipitation (Antarctica). For the vapour, Greenland NEEM (Landais et al., 2012, yellow dot) values were measured on a short interval only (3 days, 6 measurements) and differ from the other Greenland NEEM (Winkler, 2012) record that fits the regression line.



Data are from (1) this study, (2) Landais 5 et al., 2012, (3) Winkler 7, 2012, unpublished data, values estimated, (4) Landais 8 et al., 2012, (5) Uemura 13 et al. 2008, (6) Uemura 3 et al., 2010, (7) this study, (8) Winkler 6et al., 2012.

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