REPUBLIC OF LEBANON
Council for Development and Reconstruction
CDR
Beirut

FEDERAL REPUBLIC OF GERMANY
Federal Institute for Geosciences and Natural Resources
BGR
Hannover

TECHNICAL COOPERATION

PROJECT NO.: 2008.2162.9

Protection of Jeita Spring

SPECIAL REPORT NO. 12

Stable Isotope Investigations in the Jeita Spring catchment

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Hannover
June 2014

Stable Isotope Investigations in the Jeita Spring catchment

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Commissioned by:	Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, BMZ)
Project:	Protection of Jeita Spring
BMZ-No.:	2008.2162.9
BGR-Archive No.:	
Date of issuance:	March 2014
No. of pages:	46

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List of Abbreviations

asl	above mean sea level
AUB	American University of Beirut
BGR	German Federal Institute for Geosciences and Natural Resources
DE	Deuterium Excess
CDR	Council for Development and Reconstruction
CFC	Chlorofluorocarbon, anthropogenic tracer of the hydrosphere
DOC	Dissolved organic carbon
EC	Electric conductivity
ESCWA	Economic and Social Commission for Western Asia
GMWL	Global Meteoric Water Line
GPS	Geo positioning system
GW	Groundwater
KfW	Kreditanstalt für Wiederaufbau
LMWL	Local Meteoric Water Line
MAPAS	Company operating Jeita Grotto, Jeita (Keserwan) Lebanon
MMWL	Mediterranean Meteoric Water Line
MoEW	Ministry of Energy and Water
MWL	Meteoric Water Line
SWE	Snow water equivalent
SLAP	Standard Light Antarctic Precipitation
TC	Technical cooperation
VSMOW	Vienna Standard Mean Ocean Water
WEBML	Water Establishment Beirut and Mount Lebanon

Acknowledgements

In its effort to protect the water resources in the Nahr el Kalb catchment, the project *Protection of Jeita Spring* experienced great support not only at the political and institutional level but also from many municipalities and people in the catchment area.

We are especially grateful for the backing and support of the Council for Development and Reconstruction (CDR), namely its president, Nabil Jisr, Wafaa Chafeddine (Director Funding Division) and Eng. Ismail Makki (Director Planning Division), the Ministry of Energy and Water (MoEW), namely H.E. Gebran Bassil and Dr. Fadi Comair (General Director of Water Resources and Energy), the Water Establishment Beirut and Mount Lebanon (WEBML), namely its president, Joseph Nseir, as well as George el Kadi (Technical Director), Maher Chrabieh (Director of the Dbaye treatment plant) and Dr. Paul Souaid (Director of the Water Laboratory at the Dbaye treatment plant).

Some of the technical installations could not have been achieved without the help of Jeita Grotto (MAPAS). Our sincerest thanks are extended to Dr. Nabil Haddad, Ayman Ibraheem, Najeeb Najeeb and all other staff who made it possible for us to collect our samples at Jeita.

We would like to thank Dr. Farid el Khazen (Member of Parliament) for his continuous support, promotion of the idea of groundwater protection and participation in the awareness campaigns conducted by the project.

Many mayors and staff of municipalities in the catchment saw the opportunities which the project hopes to provide in the near future as a chance for development. Among those which very actively assisted the project we would like to highlight the municipalities of Ballouneh (Dr. Pierre Mouzawak, Simon Daou), Kfar Debbiane (Jean Akiki) and Jeita (Samir Baroud).

The hydrogeological investigations were conducted together with the University of Goettingen, Department of Applied Geology. The project is thankful for the good cooperation with Dr. Joanna Doummar (now lecturer at AUB), Dr. Tobias Geyer and Prof. Martin Sauter.

We also acknowledge all help during the field sampling campaigns from our colleagues at the BGR office in Raifoun: Renata Raad, Jean Abi-Rizk, Philipp Schuler and Rony Tabet.

The project was made possible by grants of the German Government, allocated through the Ministry of Economic Cooperation and Development (BMZ). Our thanks therefore go to the staff of the BMZ, KfW and German Embassy. We experienced that this assistance is very much appreciated not only among the involved institutions and stakeholders but also the population living in the area.

List of Reports prepared by the Technical Cooperation Project Protection of Jeita Spring

Report No.	Title	Date Completed
Technical Reports		
1	Site Selection for Wastewater Facilities in the Nahr el Kalb Catchment – General Recommendations from the Perspective of Groundwater Resources Protection	January 2011
2	Best Management Practice Guideline for Wastewater Facilities in Karstic Areas of Lebanon – with special respect to the protection of ground- and surface waters	March 2011
3	Guideline for Environmental Impact Assessments for Wastewater Facilities in Lebanon – Recommendations from the Perspective of Groundwater Resources Protection	November 2011
4	Geological Map, Tectonics and Karstification in the Groundwater Contribution Zone of Jeita Spring	September 2011
5	Hydrogeology of the Groundwater Contribution Zone of Jeita Spring	July 2013
6	Water Balance for the Groundwater Contribution Zone of Jeita Spring using WEAP including Water Resources Management Options and Scenarios	August 2013
7	Groundwater Vulnerability Mapping in the Jeita Spring Catchment and Delineation of Groundwater Protection Zones using the COP Method	February 2013
7b	Vulnerability Mapping using the COP and EPIK Methods	October 2012
Special Reports		
1	Artificial Tracer Tests 1 - April 2010*	July 2010
2	Artificial Tracer Tests 2 - August 2010*	November 2010
3	Practice Guide for Tracer Tests	Version 1 January 2011
4	Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation	July 2011
5	Artificial Tracer Tests 4B - May 2011*	September 2011
6	Artificial Tracer Tests 5A - June 2011*	September 2011

Report No.	Title	Date Completed
7	Mapping of Surface Karst Features in the Jeita Spring Catchment	October 2011
8	Monitoring of Spring Discharge and Surface Water Runoff in the Groundwater Contribution Zone of Jeita Spring	May 2013
9	Soil Survey in the Groundwater Contribution Zone of Jeita Spring	First Draft November 2011
10	Mapping of the Irrigation System in the Jeita Catchment	First Draft November 2011
11	Artificial Tracer Tests 5C - September 2011*	February 2012
12	Stable Isotope Investigations in the Jeita Spring catchment	June 2014
13	Micropollutant Investigations in the Groundwater Contribution Zone of Jeita Spring*	May 2012
14	Environmental Risk Assessment of the Fuel Stations in the Jeita Spring Catchment - Guidelines from the Perspective of Groundwater Resources Protection	June 2012
15	Analysis of Helium/Tritium, CFC and SF6 Tracers in the Jeita Groundwater Catchment*	June 2013
16	Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment	October 2013
17	Artificial Tracer Tests 4C - May 2012*	October 2013
18	Meteorological Stations installed by the Project	October 2013
19	Risk estimation and management options of existing hazards to Jeita spring	October 2013
20	Project Exchange Meeting - Lessons learnt from Technical Cooperation in Jordan and Lebanon	November 2013
Advisory Service Document		
1	Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley	May 2012
1 - 1	Addendum No. 1 to Main Report [Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr	June 2012

Report No.	Title	Date Completed
	Ibrahim Valley]	
2	Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant	June 2012
3	Locating the Pollution Source of Kashkoush Spring	September 2012
4	Preliminary Assessment of Jeita Cave Stability	April 2013
5	Preliminary Assessment of the Most Critical Groundwater Hazards for Jeita Spring	June 2013
6	Handover of Water Resources Monitoring Equipment and Stations Installed by the BGR Project	November 2013
Reports with KfW Development Bank (jointly prepared and submitted to CDR)		
1	Jeita Spring Protection Project Phase I - Regional Sewage Plan	October 2011
2	Jeita Spring Protection Project - Feasibility Study - Rehabilitation of Transmission Channel Jeita Spring Intake – Dbaye WTP	May 2012
3	Jeita Spring Protection Project - Environmental Impact Assessment for the Proposed CDR/KfW Wastewater Scheme in the Lower Nahr el Kalb Catchment	Draft June 2013 (BGR contribution)

* prepared in cooperation with University of Goettingen

0 Executive Summary

This report presents the results of isotope hydrological and hydrogeological investigations of the Technical Cooperation (TC) “Project Protection of Jeita Spring” (implemented by BGR and CDR). They are part of the hydrogeological investigations carried out in the effort to determine the groundwater catchment and the water balance within this catchment for Jeita Spring, which are documented in MARGANE et al. (2013).

For the stable isotope investigations water samples of rainfall from six different elevations (104 samples), of snow (85 samples), of stalactite drips from Jeita cave (111 samples) and of six major springs in the catchment discharging from two different aquifers (665 samples) were taken. With this the stable isotope investigation in the Jeita catchment is one of the most comprehensive studies in the Middle East. It was only feasible due to the fact that BGR had the required infrastructure in place to carry out the sampling and analysis.

Based on the large number of rainfall samples from different elevations and rainfall events, the local meteoric water line (LMWL) for Mount Lebanon could be modified. It became clear that each rainfall event has a very different isotopic composition depending on the provenience of the air mass (trajectory). The correlation of $\delta^{18}O$ with elevation follows equations with parallel slope. The stable isotope content (δD, $\delta^{18}O$) of all springs behaves very similar over time, exhibiting a seasonal variation and a clear elevation effect. As already confirmed by CFC, SF_6 and $He/^3H$ analyses (GEYER & DOUMMAR, 2013), stable isotope analyses also point to a relatively short mean groundwater residence time of a few years only (MARGANE et al., 2013).

The comparison of $\delta^{18}O$ values from springs and from snow/rainfall shows that the mean catchment elevation of Jeita Spring must be higher than 1,400 m asl. However, the J4 outcrop area has a mean elevation of only 1,016 m. Therefore Jeita Spring (as Kashkoush Spring too) must have a major contribution from groundwater that was recharged at higher elevations, i.e. in the Upper Aquifer (C4). This confirms the assumption of major surface water infiltrations in the outcrop area of the uppermost C4 in Nahr Ibrahim, Nahr es Salib, Nahr es Msann and Nahr es Zirghaya and is in line with other major findings of the BGR project (MARGANE et al., 2013). Based on stable isotope analyses, it is assumed that the share of groundwater coming from the Upper Aquifer must be more than 30 %, which confirms previous assumptions based on differential surface water flow measurements (MARGANE, 2012a, 2012b).

1 Introduction

The technical cooperation project "Protection of Jeita Spring" of Federal Institute for Geosciences and Natural Resources (BGR) and Lebanon started in July 2010 and will be finished at the end of 2014. The main aim of the project was to reduce the pollution risks for the drinking water supply of the city of Beirut. The Jeita Spring in Lebanon is the main water resource for Beirut, the capital of Lebanon, with about 4 Mio inhabitants. Expanding urbanization and a strong increase in scattered residential areas with more than 200,000 inhabitants bear a high risk of water pollution in the Jeita Spring catchment.

Stable isotope values measured at the BGR isotope laboratory in Hannover were included into the scope of the project to obtain more information on groundwater catchment elevation and residence times of the major springs in the study area. BGR has a long tradition on implementing isotope methods for technical cooperation studies in the ESCWA region. See e.g. WAGNER AND GEYH (1999) for a summary of work and an introduction to isotope methods for groundwater studies. Isotope hydrological methods provide additional information for water resources management especially in karst environments (NUR OZYURT et al., 2008). Earlier isotope studies on elevation effects and Mediterranean precipitation were reported (IAEA 2005), for Syria (Anti Lebanon Mountains) (e.g. KATTAN et al., 1997; AL-CARIDEH, 2011), and Lebanon Mountains (e.g. AOUAD-RIZK et al., 2005; SAAD et al., 2005).

An interpretation of stable isotope composition, variability and relative differences monitored since March 2011 continuously in daily, weekly or monthly time series for five springs in the Jeita catchment (e.g. catchment elevation effect, seasonal effect) were conducted and are presented in this report. Detailed investigations of isotope input signals through precipitation and especially during winter snow accumulation were conducted as well.

2 Study site and methods

Jeita Spring is the main water resource for the Greater Beirut Area and provides drinking water to about 2 Mio inhabitants. Expanding urbanization and a strong increase in scattered residential areas with more than 200,000 inhabitants in the Jeita groundwater catchment bear a high risk of water pollution of Jeita Spring. Jeita Spring is located in the Nahr el Kalb valley in central Lebanon about 5 km east of the Mediterranean coast line and about 15 km north of Beirut. Prior to the hydrogeological investigations of the BGR project, the groundwater (GW) catchment of the Jeita Spring was not well investigated and the source of the water unknown. Based on a large number of tracer tests, geological mapping and long-term monitoring of physical and chemical parameters from all major springs, the GW catchment could be delineated (MARGANE et al., 2013). It has a size of 405.9 km² and is very different in shape from the surface water catchment. Elevations reach from 60 m a.s.l. at Jeita Spring to 2,628 m a.s.l. at Mount Sannine. Jeita Spring discharges from the Lower Aquifer (J4; Jurassic) but this Lower Aquifer is recharged through riverbed infiltration by water originating from the Upper Aquifer (C4; Upper Cretaceous). The main springs discharging from the Upper Aquifer and contributing to the discharge of Jeita Spring are: Assal, Labbane, Afqa and Rouaiss. Kashkoush Spring was monitored because in the beginning it was unclear whether its catchment is connected to the Jeita catchment (see Table 1). It could, however, be proven, that Kashkoush spring has no connection at all with Jeita Spring. Due to the high level of karstification the catchment is characterized by a high infiltration and relatively low retention capacities.

The climate of the study site is characterized by a Mediterranean and semiarid type close to the semiarid/arid zone (Israel/Palestine/Jordan) (VERHEYDEN et al., 2008). Long-term average rainfall in the Jeita catchment is approximately 1,450 mm/a. Rainfall distribution in the GW catchment reaches from slightly over 900 mm/a at Jeita to around 2,100 mm/a near Dome du Mzaar/Mount Sannine. Rainfall occurs mainly during the period between October to April. In the high mountains, at elevations > 1,800 m asl, mainly as snow between December and March. There are significant differences in the rainfall pattern which have a tremendous impact on the formation of snow and thus on the recharge to groundwater.

During the water year 2010/11, the main rainfall occurred during the time period between 6 December and 12 March. Due to the low temperatures in December, most of this precipitation fell as snow at higher elevations and stayed until April. Although there was a minor snowmelt at the beginning of February, snow was again accumulated due to heavy snowfall starting 16 February. This snow lasted until mid April 2011. Even though total rainfall was relatively high, discharge of Jeita Spring during this water year (3.7 m^3 s^{-1} or 115 Mio m^3) was below average (5.5 m^3 s^{-1} or 172 Mio m^3).

During water year 2011/12, the main rainfall started on 31st December and lasted until 17th February. Snowmelt started in mid February. Despite the fact that total annual rainfall in this water year was below average, spring discharge in Jeita (183 Mio m³) was above average. During water year 2012/13, there were a number of short but intensive rainfall periods during: 09th to 12th November, 05th to 11th December, 20th to 22sd December and 05th to 10th January. Rainfall almost ceased on 19th February. Snowmelt started at the beginning of March.

Table 1: Coordinates, elevation and distance to coast of precipitation samplers and springs in the Jeita catchment

Sample	station	latitude	longitude	elevation (m asl)	distance to coast (km)
Rain	Jeita Mapas	33.94311	35.64445	97	5
	Sheile WEBML	33.95552	35.65333	463	5
	Ajaltoun AIS	33.95761	35.67999	821	7
	Raifoun BGR	33.97662	35.70658	1,036	7
	Kfar-Debbiane mun.	33.98113	35.77111	1,307	12
	Chabrouh dam	34.02574	35.83447	1,591	19
Spring	Kashkoush	33.942773	35.639015	55	4
	Jeita	33.943574	35.641960	60	4
	Afqa	34.067753	35.893295	1,280	23
	Rouaiss	34.108946	35.909024	1,336	24
	Naber al Assal	34.009853	35.838548	1,540	18
	Naber al Labbane	33.994725	35.828435	1,644	17
Drip water*	JC-01 to JC-09	33.945748	35.647657	65-120	5

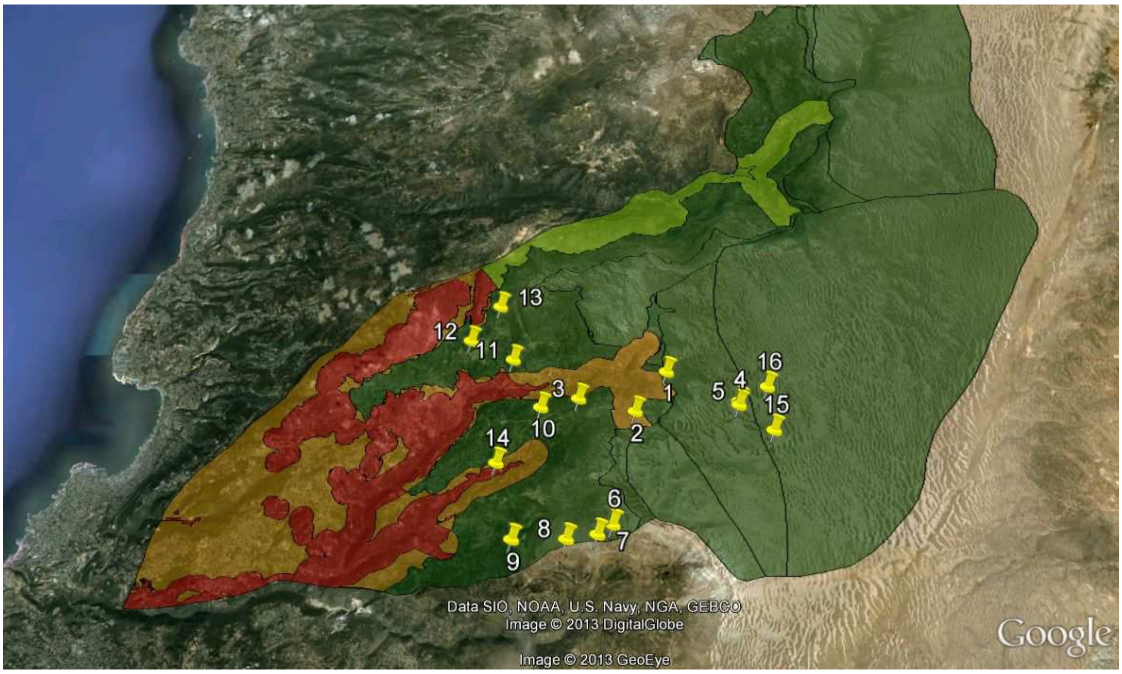
*Nine drip water samplers were installed inside Jeita cave

2.1. Field Methods

2.1.1. Isotope sampling program, sampling locations and time schedule

Field sampling for stable isotope analyses started in March 2011 at different springs in the Jeita catchments. Because first results looked promising a more intense sampling schedule of precipitation, snow, springs and wells in the catchment was developed further on. Precipitation samplers for stable isotopes that are especially designed to prevent evaporation (GRÖNING et al., 2012), where installed at six sites (Jeita Grotto, Sheile reservoir, Aajaltoun AIS, Raifoun BGR office, Kfar Debbiane municipality and Chabrouh dam) at elevations ranging between 97 and 1,591 m above sea level (asl) (see Fig. 1 and Tab. 1). Precipitation sampling started weekly in March 2012 at Raifoun. Later, starting at the beginning of rainfall events in water year 2012/13, in October 2012, the sampling program of all six stations was adjusted to be every 10 to 14 days, depending on the amount of rainfall.

Stable Isotope Investigations in the Jeita Spring catchment



Stable Isotope Investigations in the Jeita Spring catchment

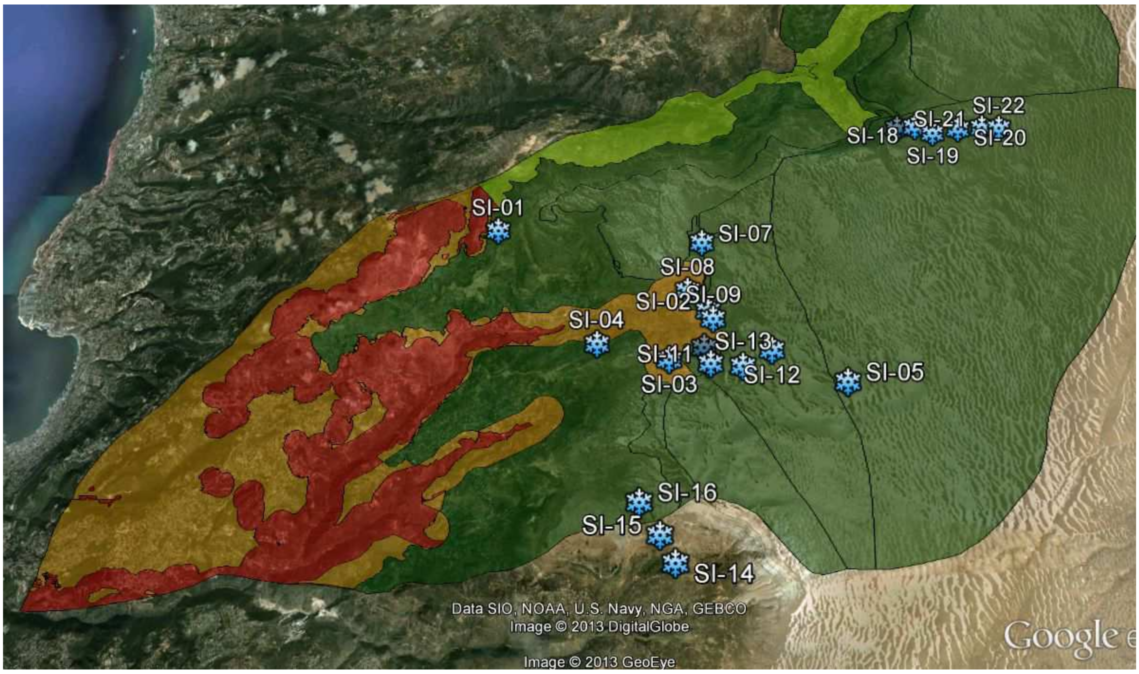
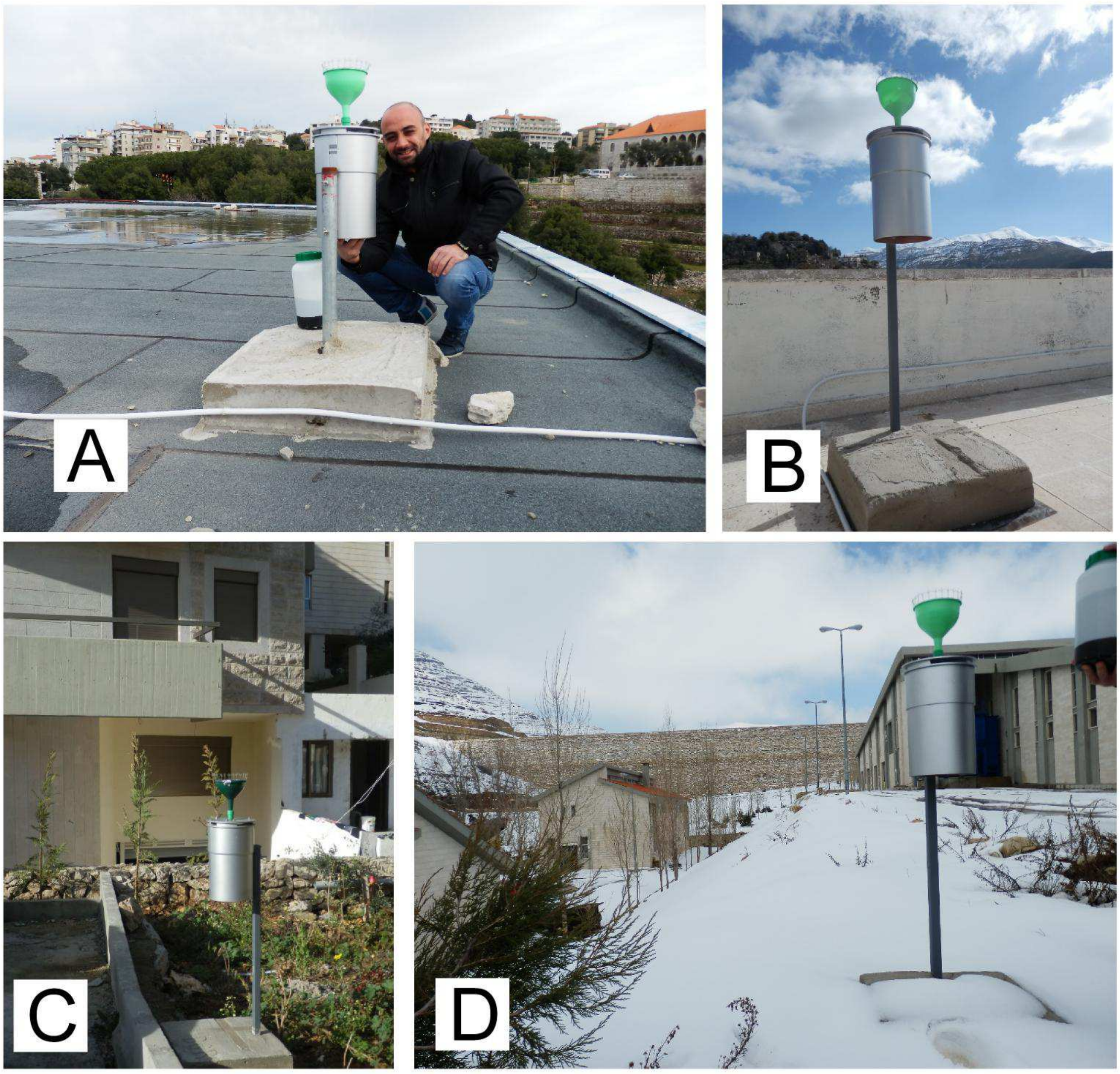


Fig. 1: Study site and location of (a) precipitation samplers, (b) snow integral sampling sites in 2012, (c) in 2013, and (d) springs.

The samples were transported to the laboratory at the BGR office in Raifoun and weighed for an estimation of the precipitation amount. Many of the rainfall samplers are in direct vicinity of meteorological stations also installed by BGR. The amount measured by the rainfall samplers closely matches that measured at the meteorological stations, even though the accuracy of the rainfall measurements by rainfall samplers is considerably less. Then aliquots of 100 ml where filled into plastic bottles, sealed and shipped to the BGR isotope laboratory in Hannover for stable isotope analyses.

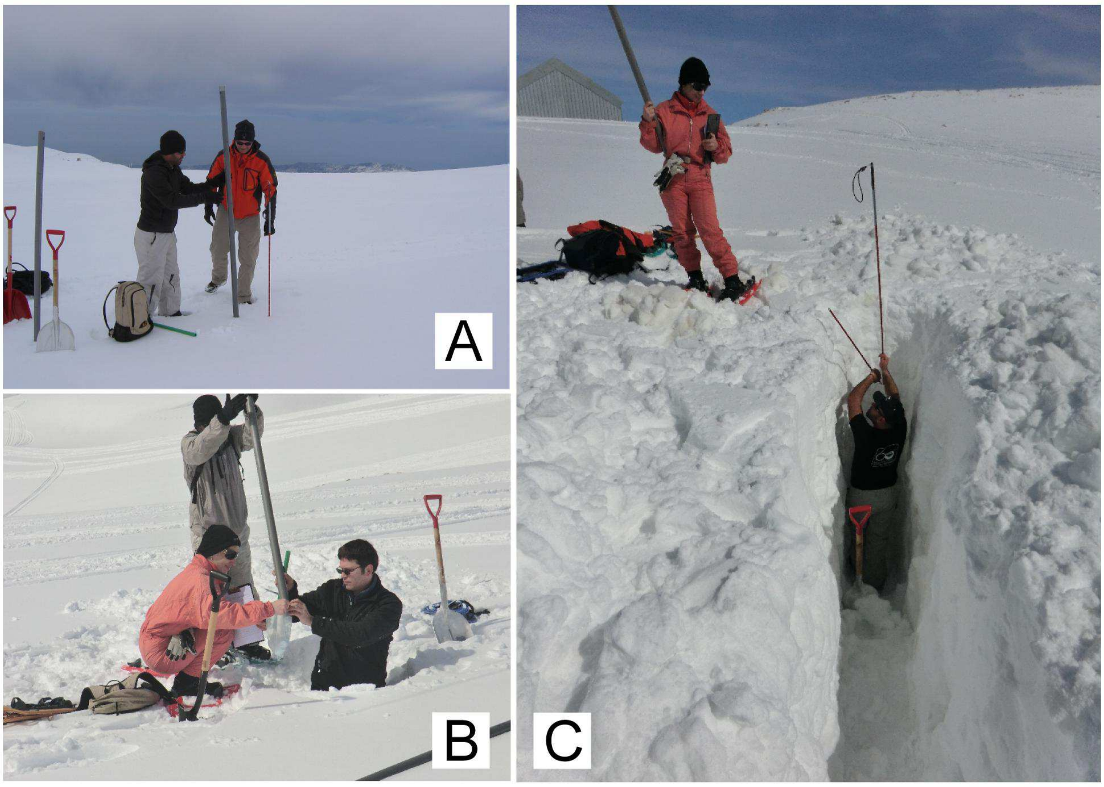


Picture 1: Precipitation samplers for stable isotopes installed at A) Ajaltoun AIS, B) Kfar-Debbiane munic. C) Raifoun BGR and D) Chabrouh dam

2.1.2. Snow sampling and snow level measurements

Snow surveys were conducted between 21st and 29th February 2012 and between 18th and 23rd February 2013. During these campaigns snow integral samples were collected at 16 sites in 2012 and 21 sites in 2013 at different elevations, ranging from 1,000 to 2,300 m asl. Additionally detailed snow profiles in 10 cm resolution over the entire profile depths were studied at the sites Wardeh (2,023 m asl) and Labbane (1,634 m asl) in 2012. During snow sampling, date, time, coordinates, elevation and snow level were recorded. Elevations and coordinates were determined with a GPS (Garmin GPS, Oregon 450t) with an x/y precision of about 3 m. Snow depth measurements were conducted with a snow level meter (Black Diamond, Quick Draw Guide Probe 300). For snow sampling 1 m, 2 m or 3 m plastic tube corers were used with a defined inner diameter of 56 mm and volume. In February 2013 the snow cover was less than in 2012. A continuous snow layer started at about 1,600 m asl and therefore sampling was not possible at lower elevations.

The snow samples were stored in 3 liter plastic bags during transportation, tightly closed to avoid evaporation, were melted overnight in the laboratory and afterwards analyzed for gravimetric, physico-chemical and isotope parameters. The snow water equivalent (SWE) was calculated from snow level, sampler volume and gravimetric weight of the melt water (A&D Company limited, type FX 3000i) with a precision of 0.01 g. Conductivity and pH-value were measured from each sample using a WTW multi parameter reader (Multi 3430).

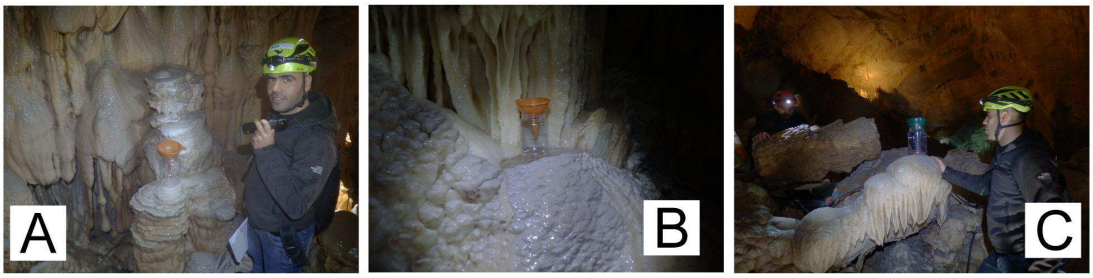


Picture 2: Snow sampling for stable isotopes using an integral snow sampler A) and B) and at a snow profile C).

Unfortunately the project could not use a standardized snow survey equipment because due to problems with the Lebanese Customs Department. Aliquots of melted snow samples were filled in 5 ml glass ampoules sealed and carried to Hannover for isotope analyses, which were conducted within two weeks after sampling.

2.1.4. Jeita Cave drip water sampling

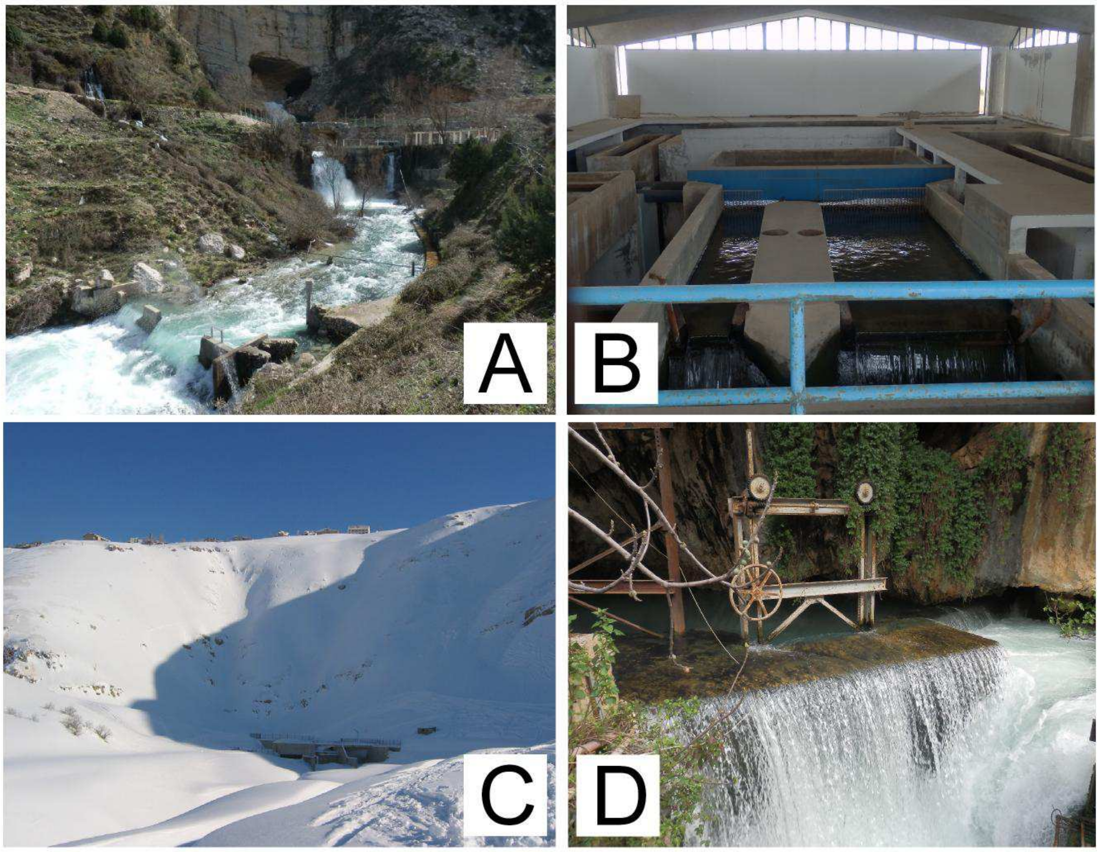
From 12th of March to 1st of August 2013 cave drip water was collected on nine sites in the upper (JC-01 to JC-06, see Picture 3) and lower (JC-07 to JC-09) part of the Jeita cave. Simple plastic collectors with a funnel and evaporation prevention were installed and emptied biweekly. Measurements were conducted for conductivity and stable isotopes later on in the laboratory.



Picture 3: Cave drip water sampling, upper part of Jeita cave with samplers designed to prevent evaporation loss at A) JC-01, B) JC-04 and C) JC-06

2.1.5. Spring sampling

Water samples from six springs in the Jeita catchment (Jeita, Kashkoush, Labbane, Assal, Rouaiss and Afqa, see Picture 4) were collected between March 2011 and December 2013 in weekly or bi-weekly time steps (Jeita Spring additionally daily from February 2012 to May 2012). Further details that characterize the sub catchments of the springs are given in Table 1. Discharge measurements from the Assal, Labbane, Jeita and Kashoush springs are available from March 2012. Chemical analyses of spring water were not conducted due to a general lack of suitable and trusted laboratories in Lebanon. The water samples were collected in sealed plastic or glass bottles avoiding evaporation and shipped for stable isotope analyses to the BGR stable isotope laboratory in Hannover. Chloride content of selected samples from snow, rainfall and springs was determined at BGR laboratory.



Picture 4: Some of the springs collected during this study A) Afqa, B) Assal, C) Labbane and D) Jeita Spring, in Lebanon

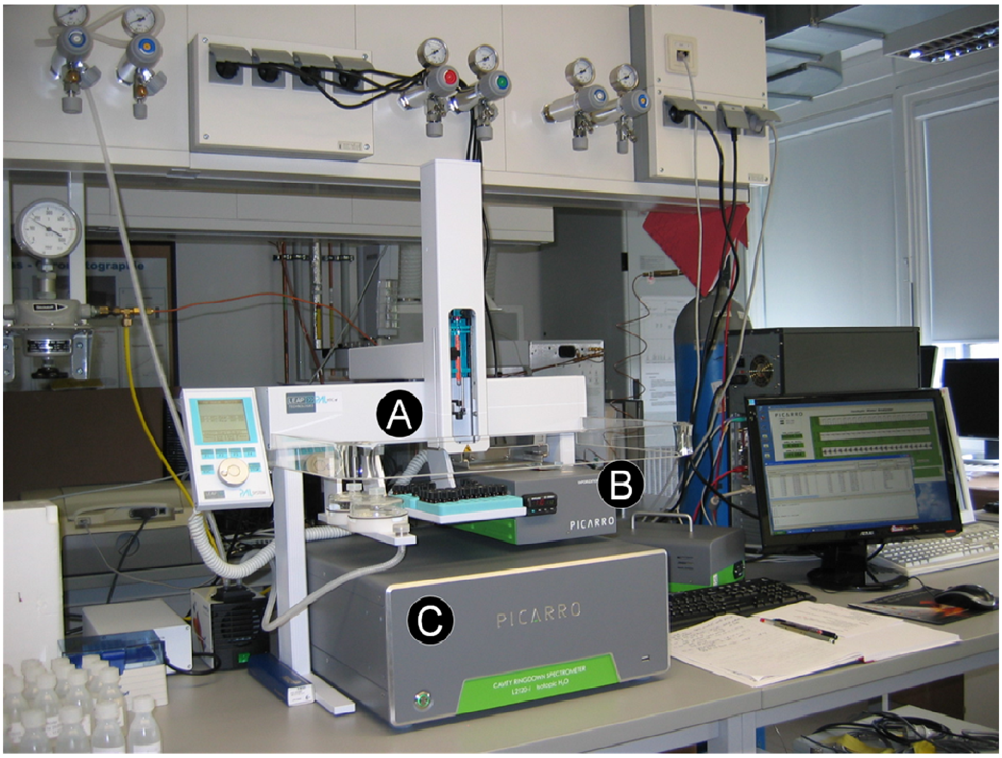
2.2. Laboratory Methods

2.2.1. Hydro chemical analyses

Hydro chemical analyses were conducted for selected samples of spring and precipitation in the hydrochemistry laboratory at the BGR in Hannover. Chloride concentration patterns were followed on precipitation transects. The methods, results and discussion of those analyses are reported separately in MARGANE et al. (2013). Hydro chemical analyzes of precipitation and springs in Lebanon can also be found in earlier studies by SAAD et al. (2004, 2005).

2.2.2. Stable isotope analyses

The water samples were analyzed for $\delta^{2}H$ and $\delta^{18}O$ simultaneously using a PICARRO L2120-i cavity ring down laser spectrometer after vaporization with a VAP 214 vaporizer at the isotope laboratory of the BGR in Hannover, Germany. All samples were measured at least four times and the reported value is the mean value. All values are given in the standard delta notation in per mill (‰) vs. VSMOW. Raw data were corrected for memory effect and excluded if necessary. The data sets were corrected for machine drift during the run and normalized to the VSMOW/SLAP scale (Vienna Standard Mean Ocean Water / Standard Light Antarctic Precipitation). An additional post correction scheme for machine drift and memory effects was applied as recommended by VAN GELDERN et al. (2012). External reproducibility, defined as standard deviation of a control standard during all runs, was better than 1.0 ‰ and 0.30 ‰ for δ^2H and $\delta^{18}O$, respectively. Deuterium excess (DE) values (DE = δ^2H - 8* $\delta^{18}O$) that are calculated from $\delta^{18}O$ and δ^2H values show more consistent values than those derived from earlier IRMS measurements, because here both isotopes are measured at the same sample at the same time. In this work standard deviations of DE-values are better than 1‰ for a continuously measured quality check sample. It has to be mentioned that high contents of dissolved organic carbons (DOC) were considered to be problematic for laser measurements because of potential interference with the used water absorption bands. Picarro Inc. provides a data correction software called ChemCorrect™ which flags samples with high DOC interference for repetition or discard. We use ChemCorrect™ with unaltered factory settings to check all samples for DOC contamination. It was not necessary to discard samples collected during this study. For notation of δ-values in Figures and Tables we follow the recommendations given by COPLEN et al. (2011).



Picture 5: Isotope laboratory in Hannover: PICARRO L2120-i cavity ringdown laser spectrometer: A) PAL autosampler, B) vaporizer, C) laser spectrometer.

3. Results

Basic meteorological and hydrological conditions in Lebanon are exemplified in the following using data collected at Beirut Airport and Jeita Spring. At Beirut Airport climate data are available from the internet at http://www.tutiempo.net/en/Climate/ Beyrouth_Aeroport/401000.htm) and a privately operated weather station in Aajaltoun of Meteo Kareh (www.meteokareh.com). Climate station Meteo Kareh in Aajaltoun reported 1,066 mm of precipitation for water year 2010/11 and 1,357 mm for water year 2011/12. The average rainfall distribution for the water years 1999/00 to 2011/12 is shown in Figure 2. The time period 2010 to 2012 is shown in Figure 3. Precipitation mainly occurs during the cooler months September to June and daily sums of precipitation at sea level show values of more than 100 mm. Snow fall is common in higher elevations of the Lebanon mountain range and occurs during winter months October to March. From the coast inlands to the Lebanon Mountains a sharp gradient exists in terms of climate conditions (e.g. temperature and precipitation amount). Generally air temperatures show a pronounced seasonal variation with lower temperatures in the winter months (Figure 5).

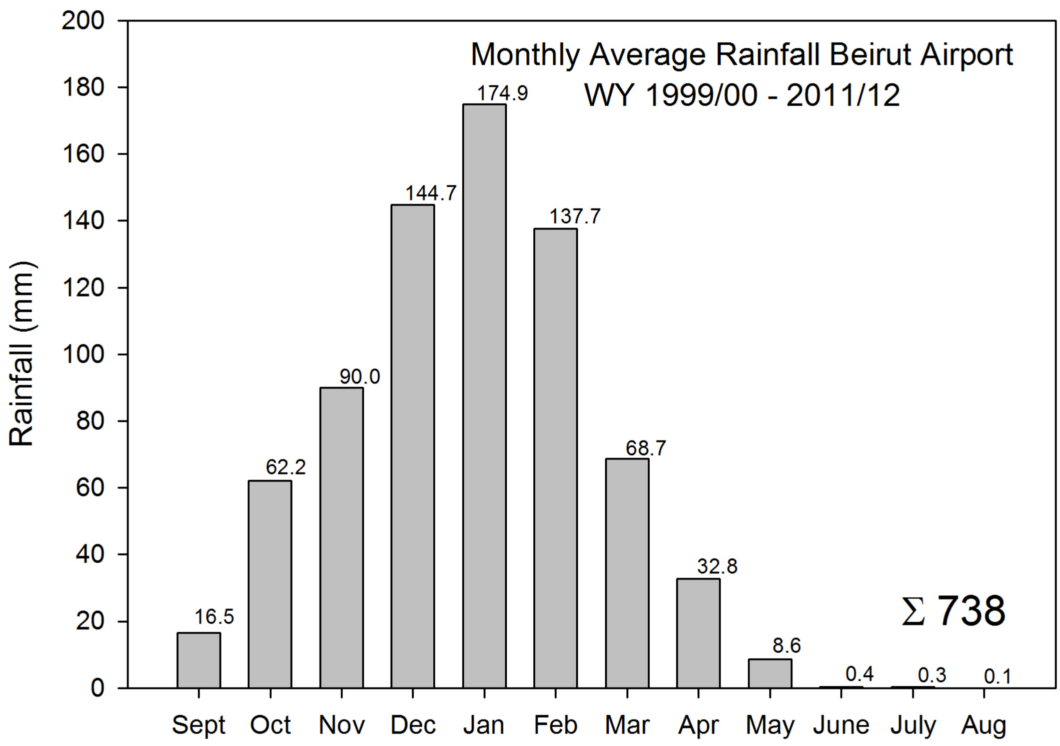


Fig. 2: Monthly average rainfall in mm year^{-1} at Beirut airport (source: tutiempo.net)

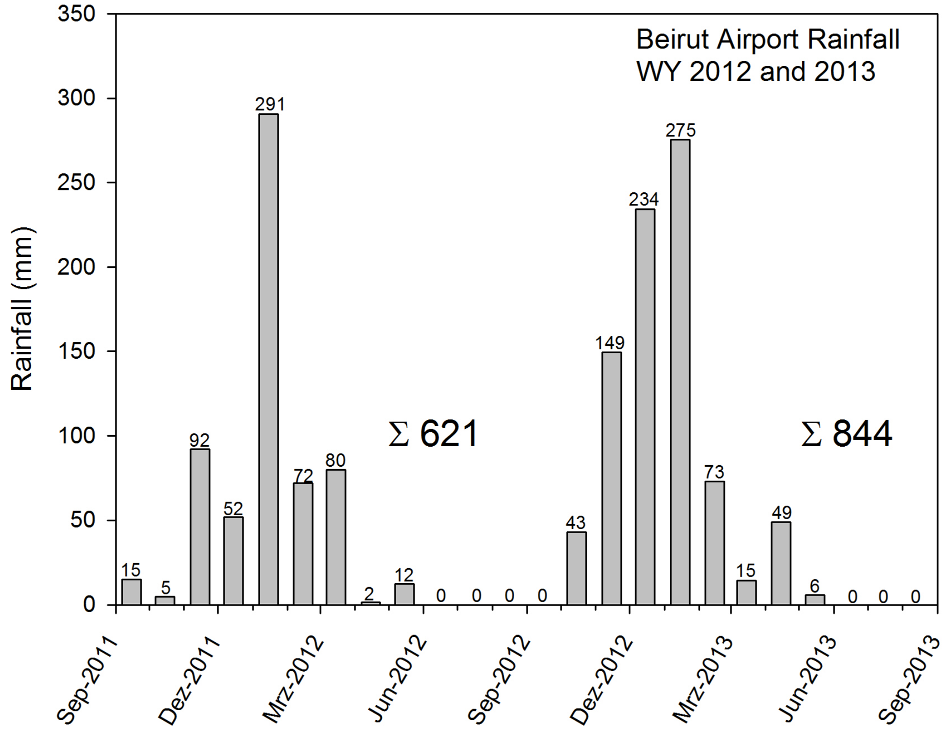


Fig. 3: Monthly rainfall at Beirut airport during water years 2011/12 and 2012/13 (source: tutiempo.net)

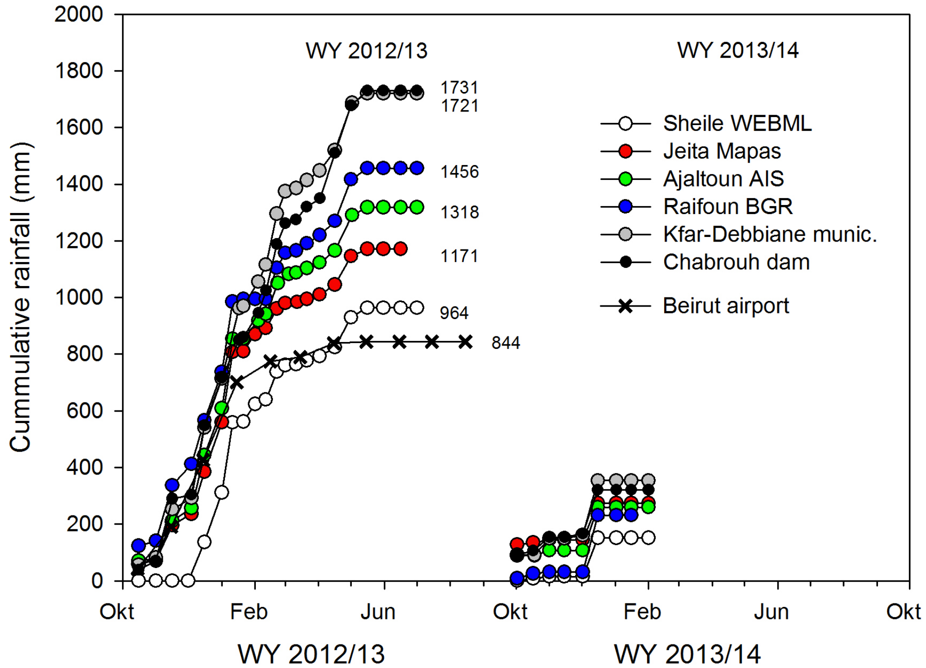


Fig. 4: Cumulative monthly rainfall at BGR rainfall samplers in the Jeita catchment and Beirut airport during water years 2012/13 and 2013/14

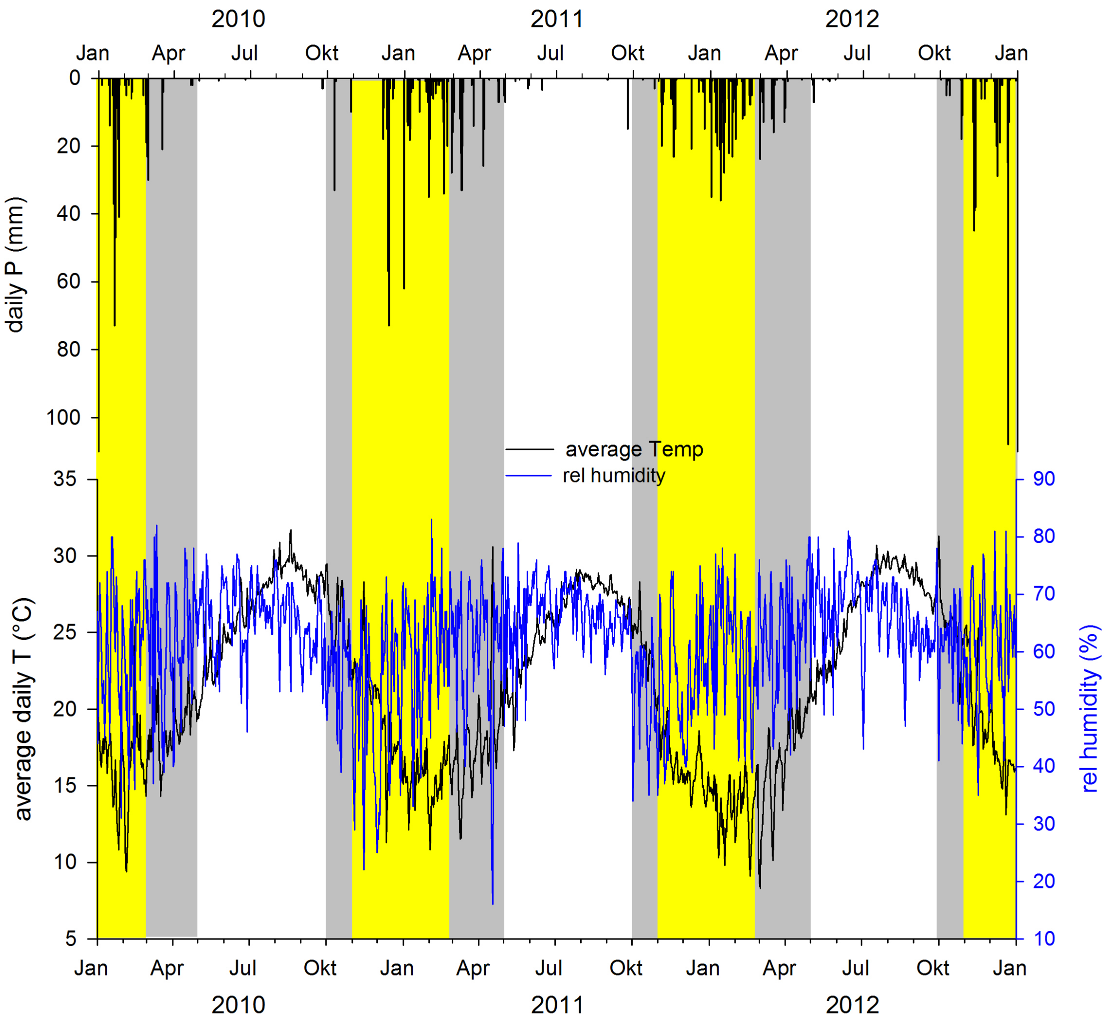


Fig. 5: Climate data at Beirut Airport measured during the period of 2010 to 2012 (source: tutiempo.net). Grey boxes indicate rainy season and yellow boxes time periods with snow layer

Since water year 2012/13, rainfall is measured by the BGR project at six stations in the Jeita groundwater catchment. The amount of rainfall measured at the climate stations is comparable to that monitored at rainfall stations (Figure 4). The precipitation sampler at Raifoun was installed first and samples were collected already since spring 2012. At the beginning of the rainy season 2012/13 in October another five rainfall samplers were installed for monitoring of the isotope composition of rain (see Fig. 1a for location), which reported weekly cumulated values of precipitation as well (summarized in Table 2). For the rainy season 2012/13 precipitation amounts increase with increasing elevation and range between 900 and 1,800 mm.

Table 2: Cumulated precipitation at six precipitation stations for the rainy season 2012/13

Station	P* (mm)
Jeita Mapas	1,170.9
Sheile WEBML	964.0
Ajaltoun AIS	1,318.1
Raifoun BGR	1,456.0
Kfar-Debbiane munic	1,720.7
Chabrouh dam	1,730.6

*Precipitation cumulated October 2012 to June 2013

Hydrological response to precipitation and snow input is best described using observations from Jeita Spring, which was continuously monitored during the study period. Jeita Spring reacts very sensitive to rainfall and snowmelt and a response within a few hours to days was observed. More detailed information on Jeita Spring discharge was already given in earlier reports (MARGANE et al., 2013; Technical Report No. 5). Long-term average discharge for Jeita Spring is about 5.4 m³/s (172 Mio m³/a). It varies between around 1 m³/s and up to 60 m³/s. Mean discharge values for the other springs in the area as well as the estimated catchment areas for all investigated springs are given in Table 3.

Table 3: Catchment area and mean discharge of the springs collected in the Jeita catchment

Spring	catchment area (km²)	mean discharge (Mio m³/a)	(m³/s)
Kashkoush	unknown	70	2.22
Jeita	406	172	5.45
Afqa	102	123	3.90
Rouaiss	66	97	3.08
Naber al Assal	15	24	0.76
Naber al Labbane	10	14	0.44

Adopted from MARGANE et al., (2013, Technical Report No. 5)

3.1. Isotopes in precipitation

In total 104 precipitation samples from six stations (see Table 1 and Figure 1a for specific location) where collected in the Jeita catchment between October 2012 and June 2013 (last rainfall events). Sampling was continued when rainfall resumed in October 2013 and will be carried out until September 2014.

Mean amount weighted isotope values for samples collected at Jeita MAPAS, Sheile, Aajaltoun AIS, Raifoun, Kfar Debbiane municipality and Chabrouh dam are -4.35‰, -5.26‰, -5.58‰, -5.82‰, -6.12‰, and -6.76‰ for $\delta^{18}O$, and -18.5‰, -24.1‰, -24.4‰, -26.0‰, -28.0‰ and -33.0‰ for $\delta^{2}H$, respectively. With increasing elevation of the precipitation collectors a progressive depletion of isotope values and an increase of deuterium excess (DE) values are visible for the overall mean as well as for the monthly values (see Table 4, Figure 6).

The amount weighted mean monthly isotope values are plotted as time series in Figure 6. During January isotope values of precipitation are most depleted in heavy isotopes, whereas DE values are highest. A presentation in $\delta^{18}O$ vs. $\delta^{2}H$ space and as DE values against $\delta^{18}O$ is given in Figure 7. Figure 8 shows the same values plotted against elevation of the precipitation samplers. All plots represent a high correlation with correlation coefficients higher than 0.8.

Table 4: Mean stable isotope ($\delta^{18}O$, $\delta^{2}H$, DE) values of precipitation for the period October 2012 to May 2013

Station	n (-)	$10^3\,\delta^{18}O$ (-)	s.d. (-)	$10^3\,\delta^{2}H$ (-)	s.d. (-)	10^3 DE (-)	s.d. (-)
Jeita Mapas	18	-4.35	1.93	-18.5	13.2	18	4
Sheile WEBML	14	-5.26	2.11	-24.1	14.1	19	5
Ajaltoun AIS	18	-5.58	1.75	-24.4	11.3	20	5
Raifoun BGR	16	-5.82	1.75	-26.0	10.7	21	5
Kfar-Debbiane munic.	18	-6.12	1.59	-28.0	9.8	21	4
Chabrouh dam	18	-6.76	1.35	-33.0	8.6	21	3

An elevation effect of isotopes in precipitation for the Jeita catchment is clearly visible from Figure 8. The monthly precipitation amount weighed isotope values which are plotted in Figure 9 in $\delta^{18}O$ vs. $\delta^{2}H$ space are additionally compared to snow and spring isotope values (Jeita Spring in red, and mean values for springs as white circles). Local regression lines (LMWL) derived from our precipitation data (bold line) and additionally from two other earlier studies (SAAD et al. 2005; AOUAD-RIZK et al. 2005) are added in comparison to the Global (GMWL) and Mediterranean (MMWL) meteoric water lines.

Stable Isotope Investigations in the Jeita Spring catchment

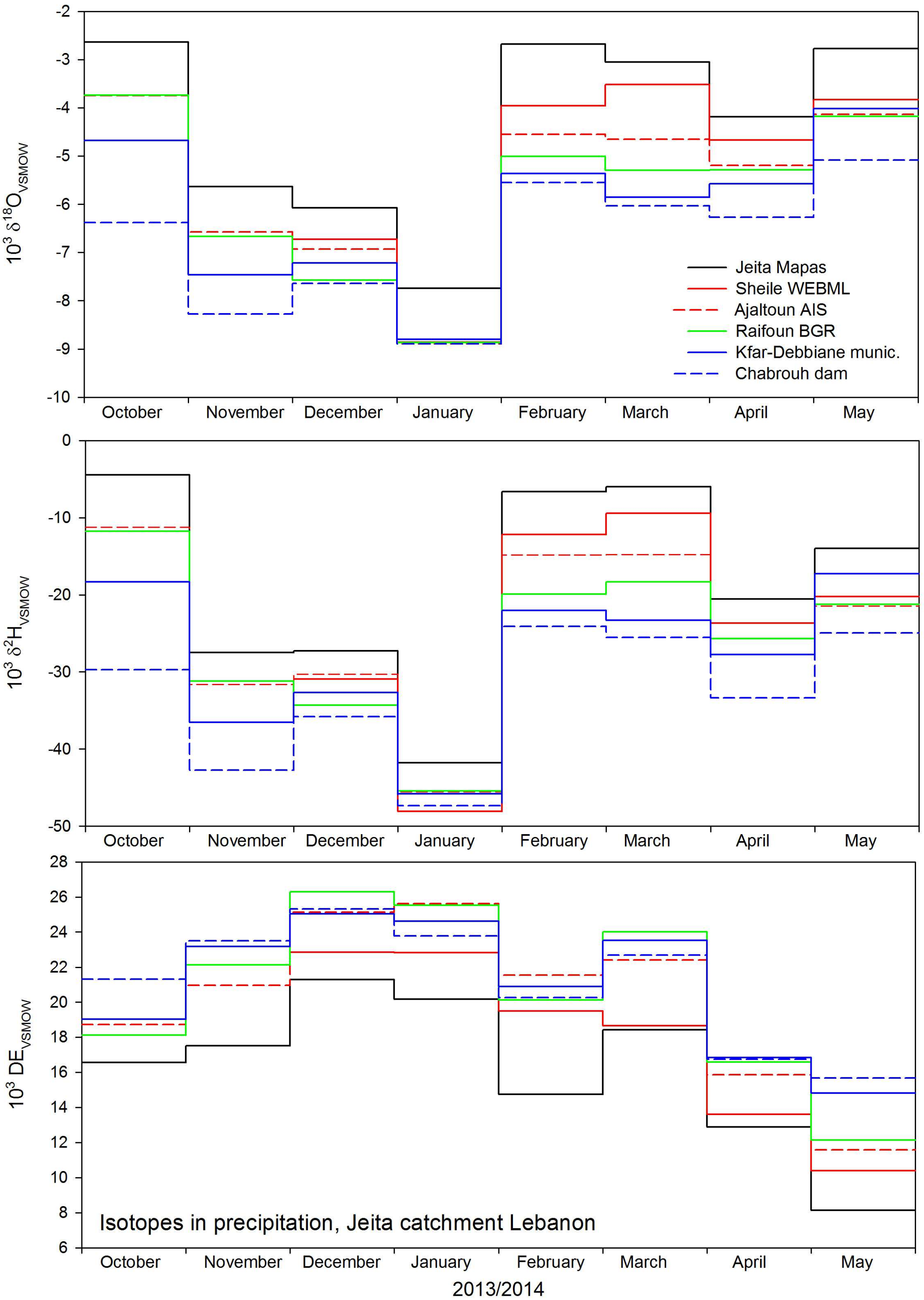


Fig. 6: Amount weighed monthly isotope values of precipitation at six stations in the Jeita catchment during the period October 2012 to May 2013

Stable Isotope Investigations in the Jeita Spring catchment

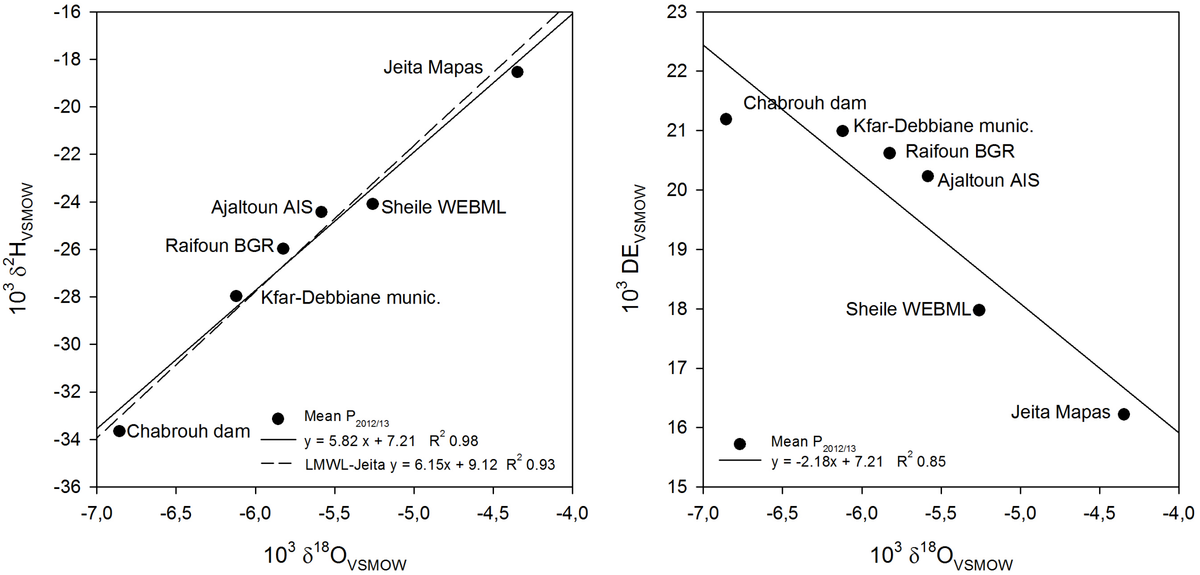


Fig. 7: $\delta^{18}O$ vs. $\delta^{2}H$ and DE vs. $\delta^{18}O$ plot of weighed mean precipitation

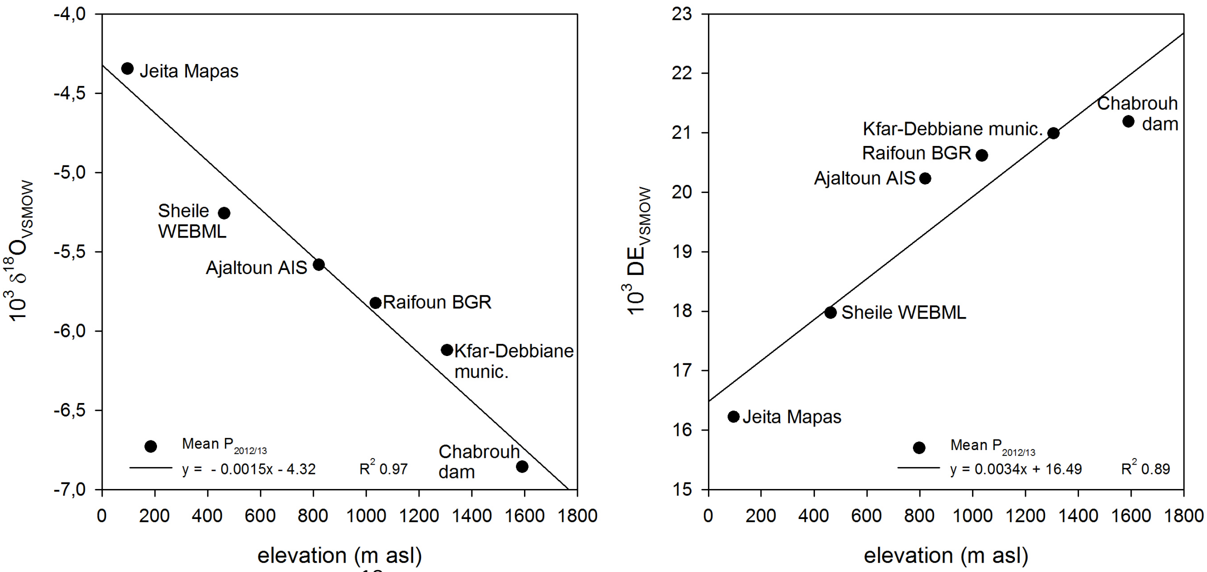


Fig. 8: Weighed mean $\delta^{18}O$ and DE values of precipitation vs. elevation of sampling site

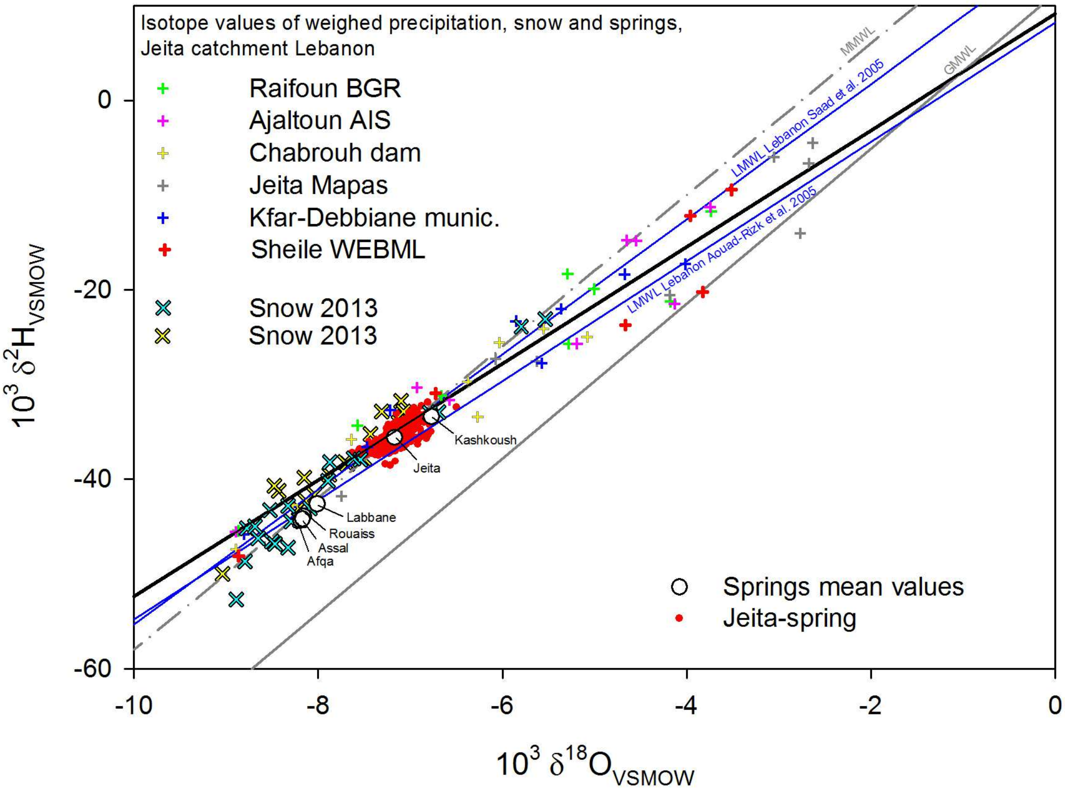


Fig. 9: $\delta^{18}O$ vs. $\delta^{2}H$ plot of collected precipitation, snow and mean spring samples in the Jeita catchment, Lebanon, with LMWLs described by SAAD et al. 2005 and AOUAD-RIZK et al. 2005

3.2. Snow integrals and profiles sampling 2012 and 2013

The results of snow sampling surveys conducted in February 2012 and February 2013 (see Fig. 1b and c for location) are summarized in Figures 10, 11 and 12. Snow depths and snow water equivalent estimated during the campaigns were different for 2012 and 2013 and during both sampling campaigns clearly correlated to elevation (Figure 10). Snow isotope values might differ significantly from year to year reflecting climatic conditions (temperature, precipitation amount). The snow layer was larger, snow depth and SWE was higher in 2012 (Figure 10) and the samples taken in 2012 were slightly more enriched in heavy isotopes in comparison to 2013 (Figure 11, Table 5). In general the overall mean values of snow samples were isotopically more depleted in heavy isotopes in comparison to the mean values of the rain samples (Table 5). This is due to the fact that snow mainly occurs at higher altitudes, where because of the altitude effect precipitation is isotopically more depleted. The DE values of snow are higher than those of the precipitation samples collected in the study site. More depleted isotope values and higher DE values in precipitation are generally expected during the winter seasons.

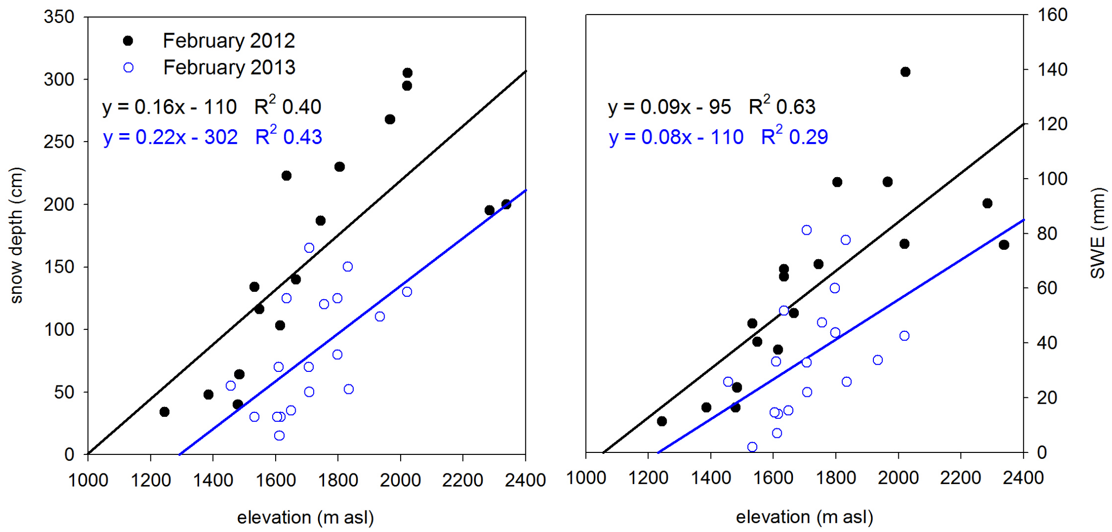


Fig. 10: Snow depth and SWE for snow integral samples during the snow survey in 2012 and 2013

An elevation effect in snow was not clearly visible for 2012 and 2013 and the derived correlation factors are rather weak in comparison to those calculated for the amount weighted precipitation samples, most likely because sampling campaigns just provide spot samplings of snow conditions in space and time.

Pronounced isotopic inhomogeneity was not only visible spatially but also within the snow layer. As shown in Figure 12, where $\delta^{18}O$ of snow is plotted against depth of samples taken at two different snow profiles in 2012, snow isotopic composition can vary significantly. This is reflecting the climatic evolution during snow accumulation and snow melt phases over the winter season.

Tab. 5: Comparison of overall mean stable isotope ($\delta^{18}O$, δ^2H, DE) values of snow and rain collected in the Jeita catchment

	n (-)	$10^3\delta^{18}O$ (-)	$10^3\delta^2H$ (-)	10^3DE (-)
Snow 2012	17	-7.79	-38.4	24
Snow 2013	21	-7.92	-41.1	22
Rain Nov. to Feb. 2013*	24	-6.77	-31.9	22
Rain 2013*	46	-5.65	-25.7	20

*Mean of all calculated monthly values; no rain isotope data was available for 2012

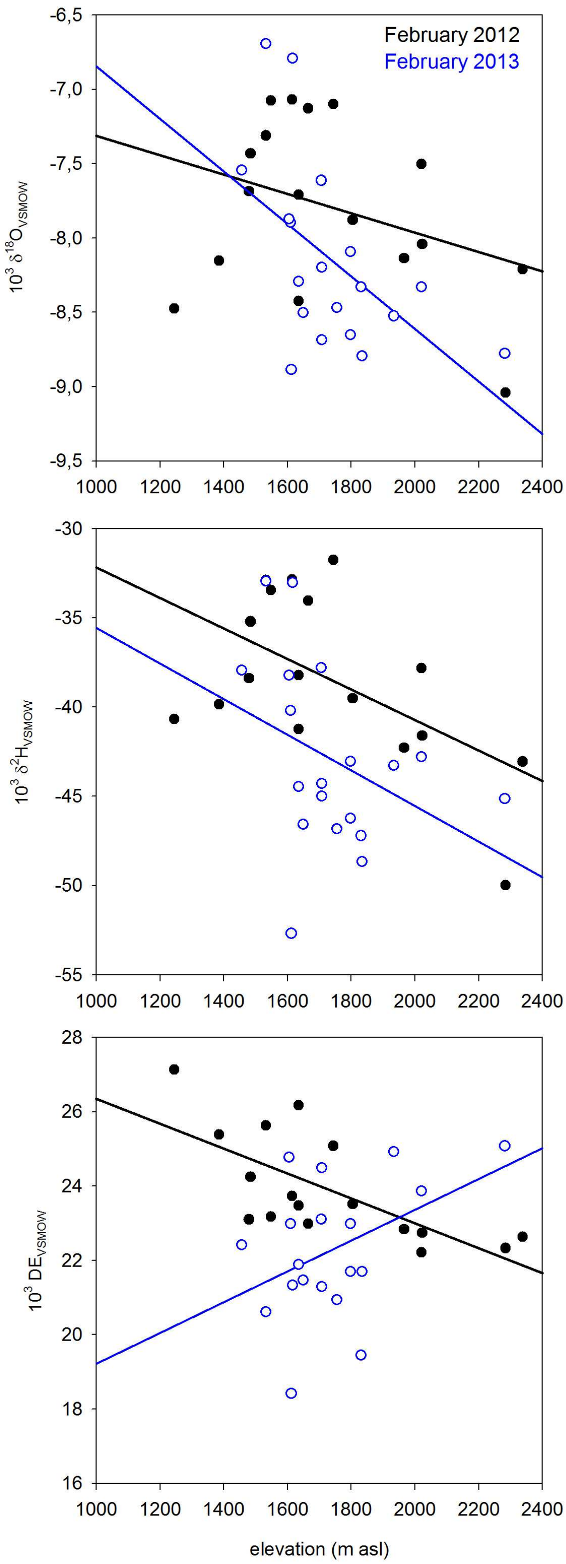


Fig. 11: $\delta^{18}O$, $\delta^{2}H$ and DE values of snow integral samples against elevation in 2012 and 2013

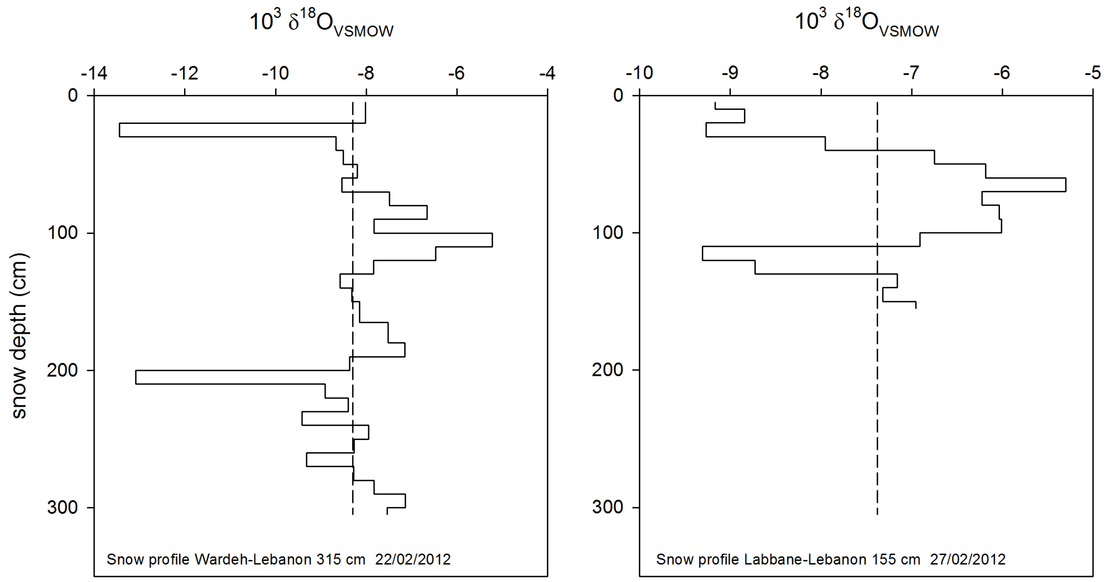


Fig. 12: Snow profiles 2012: depth vs. $\delta^{18}O$

3.3. Jeita cave drip water

For drip water within the Jeita cave we expected values similar to those of Jeita Spring water. The analysis of drop samples in Jeita cave aimed to further look into cave heterogeneities for eventual consequent studies on cave stalagmite evolutions and paleohydrological conditions in Lebanon. For the period of February to August 2013 we found mean values of isotope composition which are shown in Table 7. The time series for this season show quite different compositions of drip waters either in conductivity and isotope concentrations. This indicates that different flow pathways occur within the geological overburden of the cave. However, the relative amount of inflow from this flowpath is insignificant and has no impact on the overall stable isotope composition in Jeita waters. More details of Jeita cave drip water investigations will be reported later.

Table 7: Mean stable isotope values ($\delta^{18}O$, δ^2H, DE) of Jeita cave drip water collected at six sites bi-weekly between Feb. 2013 and Aug. 2013

Jeita	elevation (m asl)	n (-)	$10^3\ \delta^{18}O$ (-)	s.d. (-)	$10^3\ \delta^2H$ (-)	s.d. (-)	10^3 DE (-)	s.d. (-)
Cave drip water	65-120	111	-5.24	0.48	-24.0	3.3	18	1

3.4. Stable isotopes signals of springs

A continuous sampling of springs in the Jeita catchment started end of March 2011 (see Fig. 1d for location of the springs). In the beginning samples were collected biweekly. For Jeita Spring daily sampling started in March 2012 and additionally Rouaiss spring was collected since June 2012. The time series of all springs are plotted in Fig. 13 for $\delta^{18}O$, $\delta^{2}H$ and DE respectively. Snow integral samples are also included for comparison (cross symbols).

The isotope values tend to be more enriched in heavy isotopes during the winter months (grey frames in Fig. 13 indicate the rainy season and yellow boxes permanent snow layers in the mountains) and more depleted during the summer months (white frames). The lower locations (Kashoush and Jeita) are always more depleted than the springs located in the higher elevations and therefore clearly indicate an elevation effect as well for the spring samples. For the higher locations (Labbane, Assal, Afqa and Rouaiss) this is not always the case. During summer 2012 all samples indicate similar melt water concentrations. Starting in autumn precipitation dominates this effect again and therefore is visible for the springs at higher locations again. Mean values calculated from the spring samples also indicate a clear correlation with elevation for the springs (see Table 6 – mean isotope values for springs), and almost identical DE-values.

Table 6: Mean stable isotope values ($\delta^{18}O$, $\delta^{2}H$, DE) of springs collected in the vicinity of Jeita Spring, Lebanon

Spring	Elevation (m asl)	n (-)	$10^3\delta^{18}O$ (-)	s.d. (-)	$10^3\delta^{2}H$ (-)	s.d. (-)	10^3DE (-)	s.d. (-)
Kashkoush	60	46	-6.77	0.16	-33.4	1.3	21	1
Jeita	65	438	-7.17	0.15	-35.6	1.1	22	1
Afqa	1,280	45	-8.19	0.17	-44.3	1.3	21	1
Rouaiss	1,336	31	-8.16	0.21	-43.9	1.4	21	1
Naber al Assal	1,540	55	-8.17	0.18	-42.2	1.4	21	1
Naber al Labbane	1,644	50	-8.01	0.21	-42.6	1.9	21	1

Figure 14 presents a summary plot in $\delta^{18}O$ versus $\delta^{2}H$ space in comparison to the global meteoric water line (GMWL) defined by CRAIG (1961) and the Mediterranean meteoric water line (MMWL). Two lines given for isotopes of precipitation collected in Lebanon (LMWL) are also given (SAAD et al. 2005, AOUAD-RIZK et al., 2005). Kashkoush spring (blue symbols) and Jeita Spring (red symbols) at elevations of 55 and 60 m asl are clearly separated from other springs at higher elevations.

Stable Isotope Investigations in the Jeita Spring catchment

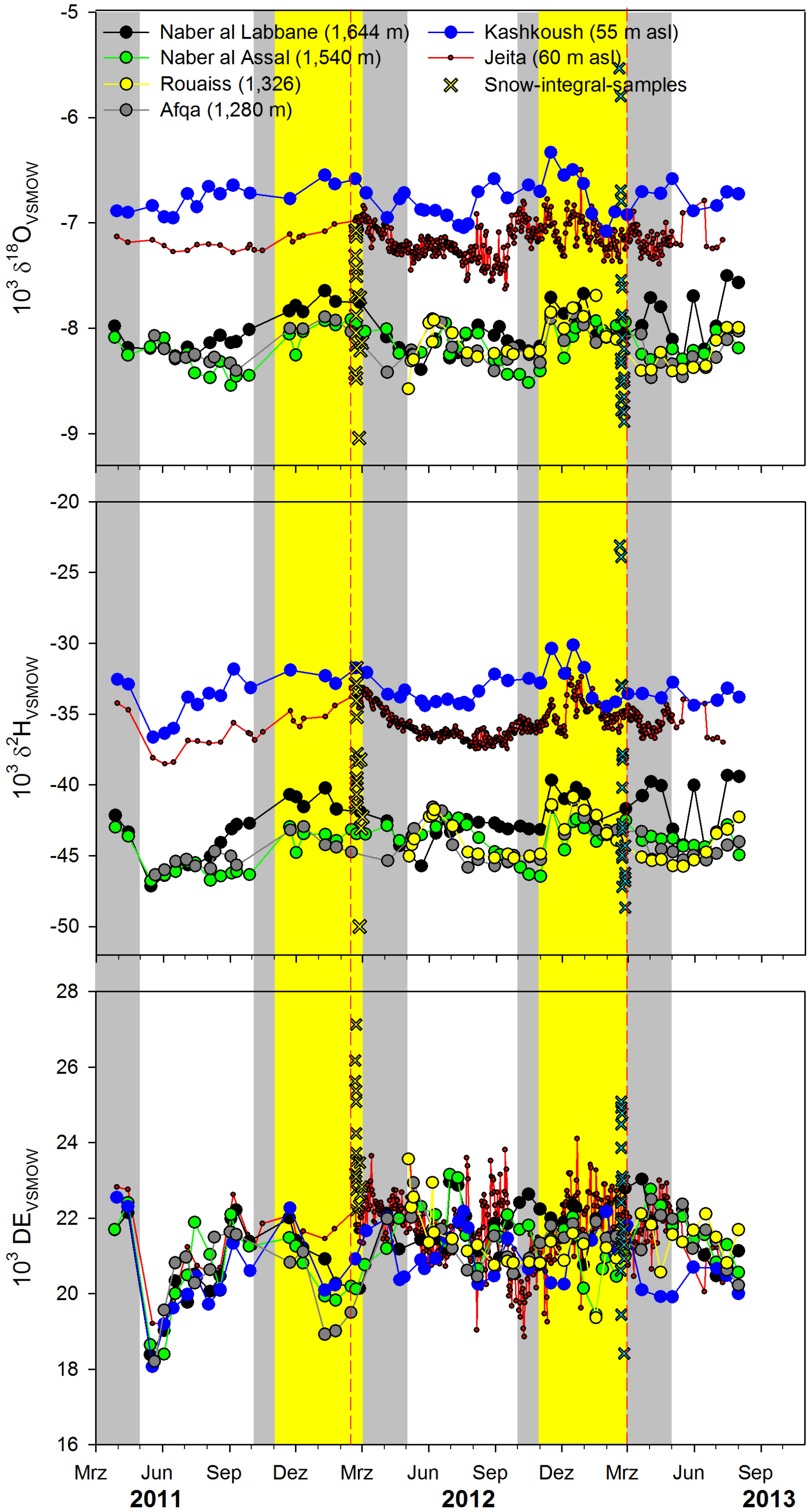


Fig. 13: Stable isotope ($\delta^{18}O$, $\delta^{2}H$, DE) time patterns of springs in the Jeita catchment and snow integral samples

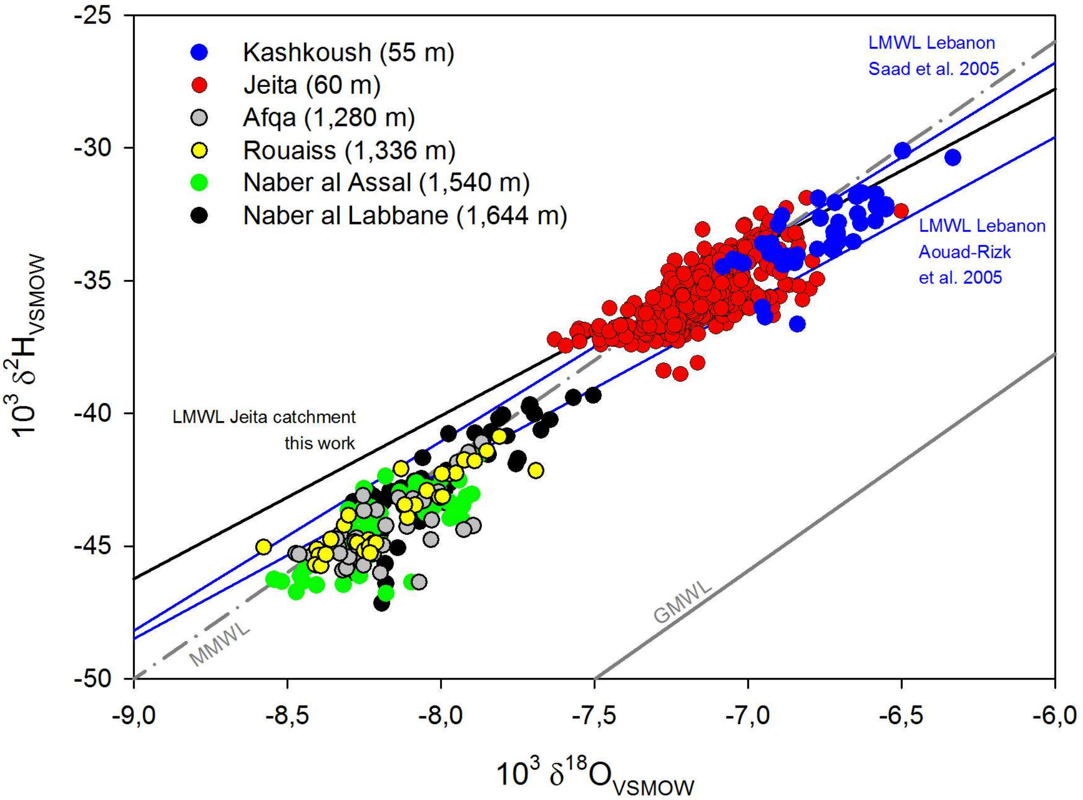


Fig. 14: $\delta^{18}O$ vs. $\delta^{2}H$ plot of all spring samples collected 2011 to 2013 in the Jeita Spring catchment, Lebanon

4. Interpretation and discussion

The knowledge of the spatial distribution of stable isotope input through precipitation is of utmost importance for all deduced interpretations. Precipitation usually has to be investigated for several years (the longer the better) to derive appropriate local meteoric water characteristics. Snow and snowmelt dominated areas might show additional unexpected characteristics. All uncertainties that are related to the isotope input (elevation effect, seasonality, snow melt) will impact all subsequent interpretations derived from stable isotopes.

Stable isotope investigations on snow samples are not as frequent as rain water studies most likely because snow surveys are more difficult to conduct. A review on snow studies in isotope hydrology was given by KOENIGER et al. (2008). In the Jeita catchment it was not possible to define a clear elevation effect with snow samples and snow isotope composition varies from one year to the other as it was found in earlier snow isotope surveys in Rocky Mountain catchments (KOENIGER et al., 2008) and in the Black Forrest in Germany (WENNINGER et al., 2011). In the Lebanon and Anti-Lebanon mountain ranges (related BGR investigations were conducted in the Figeh spring catchment; results not yet published), a pronounced stable isotope elevation effect is visible for spring water, which are related to precipitation and snow melt effects.

4.1. Local Meteoric Water Lines

A precise characterization of a local meteoric water line (LMWL) is mandatory for resources management since they describe the isotope precipitation input to groundwater that has to be evaluated. An offset from a LMWL usually describes water that has been influenced by evaporation or has undergone mixing with evaporative enriched water. For a good approximation, time series of several years are necessary with observations from several stations that adequately represent the overall catchment under consideration. Isotope values of precipitation samples in general have to be weighed by precipitation amount to prevent an unrealistic influence of outlier values, or relatively small precipitation events.

Figure 8 summarizes global (GMWL) and local meteoric water lines (LMWL) for our data in comparison to earlier published campaigns (SAAD et al., 2005, 2007, ABOU-RIZK et al., 2005). The GMWL was defined by CRAIG (1961) and modified by ROZANSKI et al (1993). A Mediterranean meteoric water line (MMWL) was introduced by GAT (1983) and GAT et al. (1972 and 1987). LMWLs for Lebanon were given for measurements conducted between 2003 and 2005 at six stations by SAAD et al. (2005) and for measurements conducted between 2001 and 2003 at four stations by AOAUD-RIZK et al. (2005). For Syria LMWLs were given by AL-CHARIDEH (2011) and ABOU ZAHKEM et al. (2010). Own observations between October 2012 and May 2013 at six stations in the Jeita catchment lead to a (preliminary) Jeita LMWL of $\delta^2H = 6.15 * \delta^{18}O + 9.12$ with a R^2 value of 0.93 (n = 46) (see Tab. 9).

Table 8: Parameters for Meteoric Water Lines (MWL) relevant to this study

	a	b	R^2	Authors
Global meteoric water line	8	10	-	Craig, 1961
Global meteoric water line	8.20	11.27	0.98	Rozanski et al., 1993
Mediterranean LMWL	8	22	-	Gat et al., 1972
Lebanon MWL	7.1	15.98	-	Saad et al. 2005
Lebanon MWL	6.3	8.2	0.96	Aouad-Rizk et al. 2005
Lebanon MWL*	7.4	14.5	0.94	Aouad-Rizk et al. 2005
Jeita MWL	6.15	9.12	0.93	This work
Syrian MWL	7.9	19.7	0.93	Al-Charideh, 2011
Syrian MWL	6.6	10.38	0.90	Zakem et al., 2010

*If samples from beginning and end of the rainy season are excluded

4.2. Mean catchment elevation

The stable isotope content of all above mentioned springs behaves very similar with time, exhibiting a seasonal variation, however, also showing a clear elevation effect (Figs. 12 and 13; KOENIGER et al., 2012). The isotope composition of Jeita (60 m asl) and Kashkoush (55 m asl) springs, discharging from the Lower Aquifer, is significantly lower than that of the springs discharging from the Upper Aquifer (C4), the Afqa (spring elevation: 1,280 m asl), Rouaiss (1,336 m asl), Assal (1,540 m asl) and Labbane (1,644 m asl) springs. Rainfall samples taken for 10 or 15 day intervals at different elevations in the GW catchment also exhibit a clear elevation effect (Fig. 6). Stable isotope composition of snow samples taken in the outcrop area of the C4 is very similar to that of the C4 springs. Stable isotope as well as CFC, SF6 and $^{3}H/^{3}He$ analyses point to a relatively short mean groundwater residence time of a few years only.

The comparison of $\delta^{18}O$ values from springs and from snow/rainfall (Fig. 6) shows that the mean catchment elevation of Jeita Spring must be higher than 1,400 m asl. However, the J4 outcrop area has a mean elevation of 1,016 m, only. Therefore Jeita Spring (as Kashkoush spring too) must have a major contribution from groundwater that was recharged at higher elevations, i.e. in the Upper Aquifer (C4). This confirms the assumption of major surface water infiltrations in the outcrop area of the uppermost C4 in Nahr Ibrahim, Nahr es Salib and other valleys. Based on stable isotope analyses, it is assumed that the share of groundwater coming from the Upper Aquifer must be more than 30%, however, concrete numbers can only be given when long-term stable isotope monitoring data of springs, rainfall, and snow are available.

The provenience of a large share of water from snowmelt on the Upper Cretaceous plateau in Jeita Spring can also be explained with long-term monitoring data of electric conductivity (EC) of springs, rainfall and snow. The EC of Jeita Spring ranges between 310 and 380 µS/cm (MARGANE & STOECKL, 2013). EC at the coast ranges between 40 and 220 µS/cm, depending on the trajectory, wind speed and temperature, and decreases with elevation to between 20 and 70 µS/cm at higher elevations (Chabrouh dam, 1,591 m asl; Margane et al., 2013). EC of snow samples taken at elevations > 1,800 m asl ranges between 10 and 50 µS/cm. The springs discharging from the Upper Aquifer have an EC of between 90 and 180 µS/cm (catchment > 1,800 m asl). If there was an inflow to the Jeita catchment from the Beka'a Valley through the Yammouneh fault (part of the Dead Sea Transform Fault), the salinity of Jeita Spring would need to be significantly higher, as it must be assumed that the salinity in the Jurassic aquifer of the Beka'a Valley must be >> 1 g/l (no boreholes have yet been drilled into the Jurassic there).

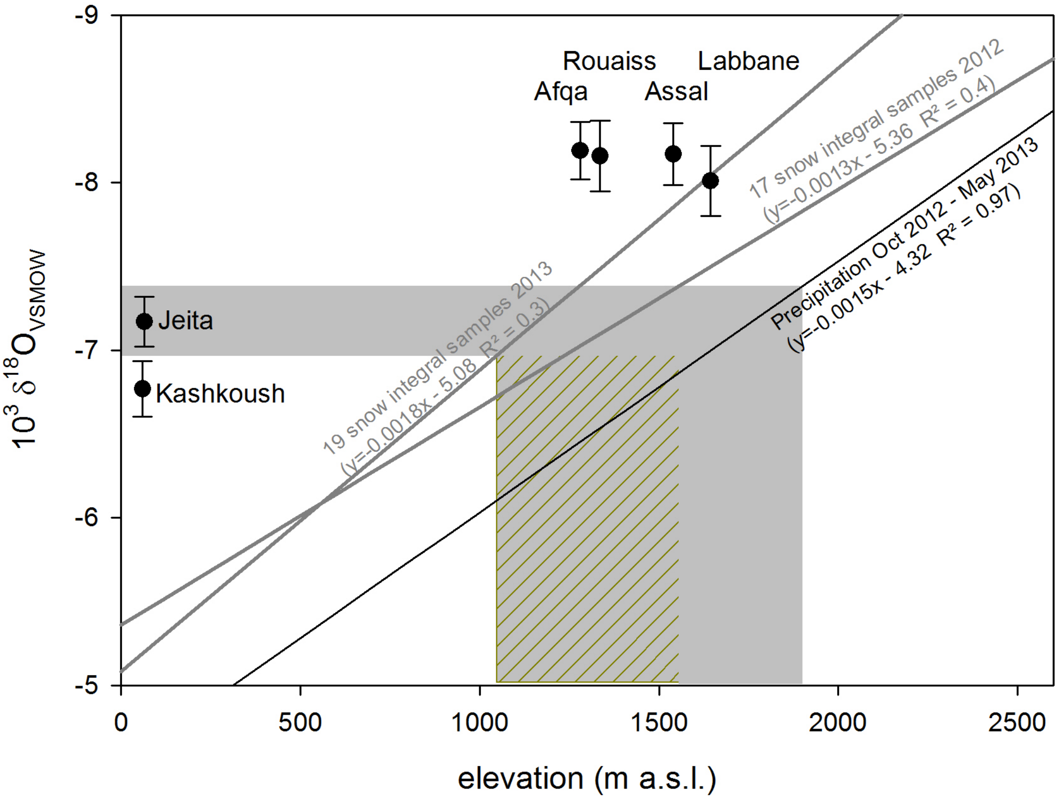


Fig. 15: Interpretation of mean catchment elevation for Jeita and Kashkoush springs

All investigations thus point towards a major contribution of water coming from snowmelt at higher elevations (>1,800 m asl) to Jeita Spring. Groundwater recharge on this plateau, where often more than 4 m of snow accumulate in winter (in winter 2011/12 snow depth was partly more than 10 m) and which is highly karstified, is believed to reach around 81%, while recharge on the Jurassic aquifer is estimated at 58% (SCHULER & MARGANE, 2013; MARGANE et al., 2013). Due to the extreme karstification, surface water drainage structures are almost non-existent on the Upper Cretaceous plateau.

4.3. Interpretation of isotope seasonality of spring signals

Significant variability in stable isotope composition at Jeita Spring and Kaskoush spring, visible for data from high resolution sampling (Fig. 16), indicate a contribution of fast runoff components (e.g. snowmelt, precipitation events). The time series show almost identical patterns for δ^2H and $\delta^{18}O$ for each spring. However, the DE-values show trends of lower peaks during the late summer month, indicating evaporative enrichment. A dampening-out of isotope signals (KOENIGER et al., 2008) is usually assumed for mean residence times that are higher than about five years. Therefore short-term isotope signals have to be interpreted as influence of event-water with a

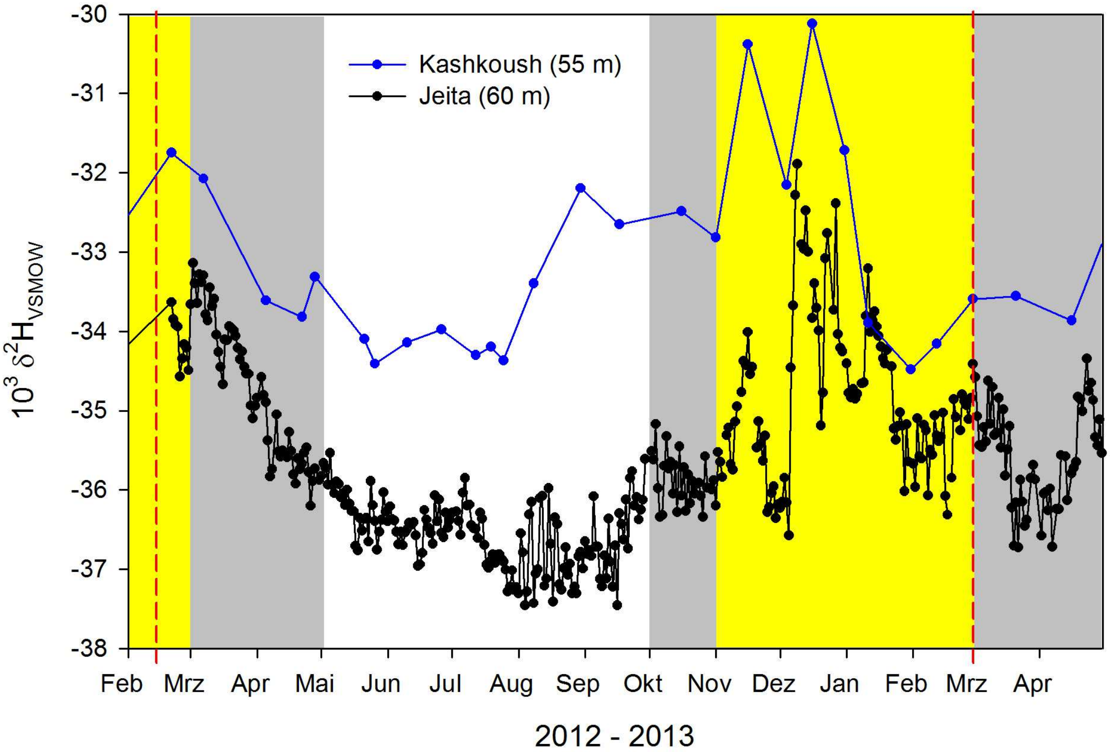


Fig. 16: High resolution seasonal δ^2H values for Jeita and Kashkoush springs

relatively short travel time. A direct comparison to precipitation or snowmelt input signals however is difficult in our case because it was not possible to collect rainfall events.

4.4. Deuterium excess and atmospheric vapor source

For all six springs relatively high mean DE-values of 22 to 21‰ (Table 6) were observed during our study. Mean DE values for snow integral samples were between 24‰ and 22‰ (Table 5) and found for rain between 21‰ and 18‰ (Table 4). Snow integral values of separate samples frequently had much higher DE-values than 24. This DE-values are much higher than those reported for areas outside the Mediterranean Sea. Precipitation samples collected in the Anti-Lebanon Mountains (Figeh catchment) showed DE-values of 19‰ and values of 23‰ (Hureireh station) for the winter season 2011/2012.

Such high values were reported earlier (GAT 1972; IAEA 1996) and explained by moisture recycling over the Mediterranean Sea (GAT et al., 1987). High DE-values usually indicate evaporative enrichment especially during the warmer periods. The time series in the Jeita catchment are not as regular as the $\delta^{18}O$ and $\delta^{2}H$ series. Lowest values appeared in June 2011 and February 2012. Additionally short term variability is visible from daily series of Jeita Spring during the early winter months in 2012. This variability is also indicated in biweekly samples. The variability of the time series mainly reflects the snow melt pattern.

5. Conclusion

A stable isotope investigation in high temporal and spatial resolution was conducted for precipitation and springs in the Jeita Spring catchment. A pronounced decrease of heavy isotopes in precipitation with increasing elevation (elevation effect) was observed. Spring water isotopic composition show a seasonal variation that indicate a strong influence of snow melt and implies very short residence times in the hydrological system. The stable isotope composition of springs show mean catchment elevations of 1,600 to 1,800 m asl for Jeita Spring and of above 2,000 m asl for Labbane, Assal, Afqua and Rouaiss springs. This stable isotope investigation adds further proof to the assumption that a large share of Jeita Spring discharge (approx. 30%) comes originally from groundwater recharged in the Upper Aquifer (C4), reaching Jeita Spring via riverbed infiltration (MARGANE et al., 2013; SCHULER & MARGANE, 2013). Elevation effects in snow samples collected in February 2012 and 2013 were not as good correlated with elevation as precipitation. A first collection of Jeita cave drip water samples was initiated and aimed to foster a more detailed study of paleo-hydrological conditions including cave stalagmite carbonate isotope composition.

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ANNEX 1: Un-weighed isotope values for rain samples

Rain station	date	amount (mm)	10^3 $\delta^{18}O$	10^3 δ^2H	10^3 DE
Raifoun BGR	16.10.2012	123	-3,40	-9,4	18
Raifoun BGR	01.11.2012	18	-6,04	-28,3	20
Raifoun BGR	16.11.2012	197	-7,16	-34,6	23
Raifoun BGR	04.12.2012	75	-5,36	-22,3	21
Raifoun BGR	16.12.2012	154	-6,25	-24,1	26
Raifoun BGR	01.01.2013	171	-8,77	-43,4	27
Raifoun BGR	11.01.2013	247	-8,87	-45,3	26
Raifoun BGR	21.01.2013	10	-8,83	-48,7	22
Raifoun BGR	01.02.2013	0			
Raifoun BGR	11.02.2013	0			
Raifoun BGR	21.02.2013	110	-5,80	-23,9	23
Raifoun BGR	01.03.2013	52	-3,32	-11,5	15
Raifoun BGR	11.03.2013	8	-3,98	-13,8	18
Raifoun BGR	21.03.2013	26	-5,71	-19,8	26
Raifoun BGR	02.04.2013	29	-3,90	-12,1	19
Raifoun BGR	16.04.2013	50	-5,25	-27,3	15
Raifoun BGR	01.05.2013	147	-5,56	-27,8	17
Raifoun BGR	16.05.2013	39	-4,17	-21,3	12
Aajaltoun AIS	16.10.2012	71	-3,59	-9,6	19
Aajaltoun AIS	01.11.2012	8	-5,10	-25,3	15
Aajaltoun AIS	16.11.2012	132	-6,99	-34,1	22
Aajaltoun AIS	04.12.2012	45	-5,35	-24,5	18
Aajaltoun AIS	16.12.2012	187	-5,72	-20,0	26
Aajaltoun AIS	01.01.2013	165	-8,29	-42,0	24
Aajaltoun AIS	11.01.2013	245	-9,33	-47,9	27
Aajaltoun AIS	21.01.2013	1	-6,48	-28,8	23
Aajaltoun AIS	04.02.2013	62	-7,21	-36,6	21
Aajaltoun AIS	11.02.2013	24	-3,00	-6,7	17
Aajaltoun AIS	22.02.2013	110	-5,35	-18,4	24
Aajaltoun AIS	04.03.2013	32	-2,92	-8,5	15
Aajaltoun AIS	11.03.2013	4	-2,47	-5,5	14
Aajaltoun AIS	21.03.2013	17	-5,22	-17,2	25
Aajaltoun AIS	02.04.2013	20	-3,44	-9,2	18
Aajaltoun AIS	16.04.2013	42	-5,67	-30,6	15
Aajaltoun AIS	02.05.2013	125	-5,31	-26,6	16
Aajaltoun AIS	16.05.2013	28	-4,13	-21,5	12

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Rain station	date	amount (mm)	10^3 $\delta^{18}O$	10^3 δ^2H	10^3 DE
Chabrouh dam	16.10.2012	38	-6,46	-30,9	21
Chabrouh dam	01.11.2012	32	-6,28	-28,3	22
Chabrouh dam	16.11.2012	220	-8,43	-43,7	24
Chabrouh dam	04.12.2012	14	-6,00	-27,3	21
Chabrouh dam	16.12.2012	245	-6,73	-27,6	26
Chabrouh dam	01.01.2013	166	-8,98	-47,9	24
Chabrouh dam	17.01.2013	134	-9,35	-48,6	26
Chabrouh dam	21.01.2013	9	-3,61	-11,6	17
Chabrouh dam	04.02.2013	87	-8,75	-49,3	21
Chabrouh dam	11.02.2013	79	-5,47	-24,0	20
Chabrouh dam	21.02.2013	165	-6,10	-26,1	23
Chabrouh dam	01.03.2013	74	-4,41	-20,0	15
Chabrouh dam	11.03.2013	13	-4,68	-18,3	19
Chabrouh dam	21.03.2013	44	-6,42	-27,7	24
Chabrouh dam	02.04.2013	30	-4,54	-14,7	22
Chabrouh dam	16.04.2013	161	-6,24	-36,0	14
Chabrouh dam	01.05.2013	168	-6,61	-34,2	19
Chabrouh dam	16.05.2013	52	-5,08	-25,0	16
Jeita Mapas	16.10.2012	61	-2,54	-2,9	17
Jeita Mapas	01.11.2012	9	-3,27	-15,1	11
Jeita Mapas	16.11.2012	126	-5,67	-27,5	18
Jeita Mapas	04.12.2012	40	-5,50	-27,6	16
Jeita Mapas	16.12.2012	149	-4,64	-15,4	22
Jeita Mapas	01.01.2013	175	-7,29	-37,5	21
Jeita Mapas	11.01.2013	248	-8,35	-45,4	21
Jeita Mapas	21.01.2013	2	-5,13	-26,6	14
Jeita Mapas	01.02.2013	61	-5,38	-27,6	15
Jeita Mapas	11.02.2013	21	-1,36	2,6	13
Jeita Mapas	21.02.2013	69	-3,23	-9,3	17
Jeita Mapas	01.03.2013	20	-2,18	-7,3	10
Jeita Mapas	12.03.2013	3	-0,97	2,4	10
Jeita Mapas	21.03.2013	11	-3,64	-8,4	21
Jeita Mapas	02.04.2013	16	-2,71	-5,8	16
Jeita Mapas	16.04.2013	35	-4,98	-27,4	12
Jeita Mapas	01.05.2013	100	-4,14	-20,5	13
Jeita Mapas	16.05.2013	25	-2,77	-14,0	8

Stable Isotope Investigations in the Jeita Spring catchment

Rain station	date	amount (mm)	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
S'haile WEBML	16.10.2012	0			
S'haile WEBML	01.11.2012	0			
S'haile WEBML	16.11.2012	0			
S'haile WEBML	01.12.2012	0			
S'haile WEBML	16.12.2012	137	-5,43	-20,1	23
S'haile WEBML	01.01.2013	174	-7,74	-39,4	23
S'haile WEBML	11.01.2013	248	-8,95	-48,5	23
S'haile WEBML	21.01.2013	2	-1,03	-1,3	7
S'haile WEBML	01.02.2013	63	-8,81	-48,2	22
S'haile WEBML	11.02.2013	16	-1,86	-1,7	13
S'haile WEBML	21.02.2013	98	-4,69	-15,5	22
S'haile WEBML	01.03.2013	23	-2,30	-5,2	13
S'haile WEBML	11.03.2013	3	-1,60	0,1	13
S'haile WEBML	21.03.2013	14	-4,98	-15,9	24
S'haile WEBML	02.04.2013	16	-2,58	-5,6	15
S'haile WEBML	16.04.2013	30	-5,01	-26,9	13
S'haile WEBML	01.05.2013	106	-4,56	-22,8	14
S'haile WEBML	16.05.2013	34	-3,83	-20,2	10
Kfar-Debbiane mu	16.10.2012	56	-4,45	-16,3	19
Kfar-Debbiane mu	01.11.2012	26	-5,17	-22,9	18
Kfar-Debbiane mu	16.11.2012	170	-7,87	-38,8	24
Kfar-Debbiane mu	04.12.2012	41	-5,79	-27,2	19
Kfar-Debbiane mu	16.12.2012	248	-6,32	-24,0	27
Kfar-Debbiane mu	01.01.2013	173	-8,50	-45,1	23
Kfar-Debbiane mu	17.01.2013	249	-9,94	-52,4	27
Kfar-Debbiane mu	21.01.2013	7	-2,09	-5,7	11
Kfar-Debbiane mu	04.02.2013	86	-6,09	-30,2	18
Kfar-Debbiane mu	11.02.2013	61	-4,59	-16,8	20
Kfar-Debbiane mu	21.02.2013	179	-6,20	-25,7	24
Kfar-Debbiane mu	01.03.2013	79	-4,07	-17,8	15
Kfar-Debbiane mu	11.03.2013	12	-4,71	-18,1	20
Kfar-Debbiane mu	21.03.2013	28	-6,33	-25,5	25
Kfar-Debbiane mu	02.04.2013	34	-4,39	-14,9	20
Kfar-Debbiane mu	16.04.2013	71	-4,94	-25,1	14
Kfar-Debbiane mu	02.05.2013	168	-6,08	-31,5	17
Kfar-Debbiane mu	16.05.2013	33	-4,01	-17,3	15

ANNEX 2: Precipitation amount weighed monthly isotope values for rain samples

	Jeita Mapas			Sheile			AIS			Raifoun			Kfar Debbiane			Chabroun		
	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
October 2012	-2,63	-4,5	17				-3,75	-11,2	19	-3,73	-11,7	18	-4,67	-18,4	19	-6,38	-29,7	21
November 2012	-5,63	-27,5	18				-6,57	-31,6	21	-6,66	-31,2	22	-7,47	-36,6	23	-8,28	-42,7	23
December 2012	-6,07	-27,3	21	-6,72	-30,9	23	-6,93	-30,3	25	-7,57	-34,3	26	-7,22	-32,7	25	-7,64	-35,8	25
January 2013	-7,75	-41,8	20	-8,86	-48,1	23	-8,89	-45,5	26	-8,87	-45,4	26	-8,80	-45,8	25	-8,89	-47,4	24
February 2013	-2,68	-6,7	15	-3,96	-12,2	20	-4,55	-14,8	22	-5,01	-19,9	20	-5,36	-22,0	21	-5,55	-24,1	20
March 2013	-3,06	-6,0	18	-3,51	-9,4	19	-4,65	-14,8	22	-5,29	-18,3	24	-5,85	-23,3	24	-6,03	-25,6	23
April 2013	-4,18	-20,6	13	-4,66	-23,7	14	-5,19	-25,7	16	-5,28	-25,7	17	-5,57	-27,7	17	-6,27	-33,4	17
May 2013	-2,77	-14,0	8	-3,83	-20,2	10	-4,13	-21,5	12	-4,17	-21,3	12	-4,01	-17,3	15	-5,08	-25,0	16

ANNEX 3: Isotope values of snow integral samples

No	date	label	place name	elevation (m asl)	snow depth (cm)	density (g/cm^3)	SWE (cm)	EC (µS/cm)	10^3 $\delta^{18}O$	10^3 δ^2H	10^3 DE
1	21.02.2012	S-1	Assal-A	1532	134	0,35	47		-7,31	-32,9	26
2	21.02.2012	S3ges	Labbane-C	1634	223	0,29	64		-8,43	-41,2	26
3	21.02.2012	S-6	Faqra_Phoeniz/F	1548	116	0,35	40		-7,08	-33,4	23
4	22.02.2012	S-7	Wardeh	2020	295	0,26	76	46	-7,50	-37,8	22
5	22.02.2012	S9ges	Wardeh	2023	305	0,46	139	34	-8,04	-41,6	23
6	22.02.2012	S-10	Bakish	1805	230	0,43	99	29	-7,88	-39,5	24
7	22.02.2012	S-11	Bakish-lower	1744	187	0,37	69	26	-7,10	-31,7	25
8	22.02.2012	S-12	Bakish-lower-2	1665	140	0,36	51	30	-7,13	-34,1	23
9	22.02.2012	S-13	Bakish-lower-3	1614	103	0,36	37	37	-7,07	-32,8	24
10	22.02.2012	S-14	Campingsite	1484	64	0,37	24	46	-7,43	-35,2	24
11	22.02.2012	S-15	Hrajel	1244	34	0,33	11	69	-8,47	-40,7	27
12	22.02.2012	S-16	Wata El Jawj	1385	48	0,34	16	71	-8,15	-39,9	25
13	22.02.2012	S-17	St. Elie	1479	40	0,41	16	32	-7,69	-38,4	23
14	26.02.2012	S-18ges	Jebel Deep	2285	195	0,47	91	19	-9,04	-50,0	22
15	28.02.2012	S-19	Wardeh peak	2338	200	0,38	76	34	-8,21	-43,1	23
16	01.03.2012	S20ges	La Cabane	1966	268	0,37	99	18	-8,14	-42,3	23
17	27.02.2012	S-21	Labbane	1634		0,39	67	35	-7,71	-38,2	23
1	18.02.2013	SI-01	13-Saint-Elie	1479	5	1,36	7	13	-5,53	-23,1	21
2	20.02.2013	SI-02	Assal	1532	30	0,06	2	60	-6,69	-32,9	21
3	20.02.2013	SI-03	Labbane	1634	125	0,41	52	19	-8,29	-44,5	22
4	20.02.2013	SI-04	Faqra	1548	7	1,00	7	5	-5,80	-23,9	22
5	21.02.2013	SI-05	Jabel Dip	2282				16	-8,78	-45,1	25
6	21.02.2013	SI-07	nn	1456	55	0,47	26	15	-7,54	-37,9	22
7	21.02.2013	SI-08	nn	1615	30	0,47	14	32	-6,79	-33,0	21
8	21.02.2013	SI-09	nn	1609	70	0,47	33	10	-7,90	-40,2	23
9	21.02.2013	SI-10	nn	1707	165	0,49	81	13	-8,68	-45,0	24
10	21.02.2013	SI-11	nn	1831	150	0,52	77	26	-8,33	-47,2	19
11	21.02.2013	SI-12	nn	2020	130	0,33	43	25	-8,33	-42,8	24
12	21.02.2013	SI-13	nn	1934	110	0,31	34	25	-8,53	-43,3	25
13	22.02.2013	SI-14	Baqeesh	1604	30	0,49	15	9	-7,87	-38,2	25
14	22.02.2013	SI-15	Baqeesh	1706	70	0,47	33	8	-7,61	-37,8	23
15	22.02.2013	SI-16	Baqeesh	1797	125	0,48	60	10	-8,09	-43,0	22
16	25.02.2013	SI-17	nn	1612	15	0,47	7	35	-8,89	-52,7	18
17	25.02.2013	SI-18	nn	1649	35	0,44	15	31	-8,50	-46,6	21
18	25.02.2013	SI-19	nn	1708	50	0,44	22	8	-8,20	-44,3	21
19	25.02.2013	SI-20	nn	1755	120	0,39	47	9	-8,47	-46,8	21
20	25.02.2013	SI-21	nn	1798	80	0,55	44	20	-8,65	-46,2	23
21	25.02.2013	SI-22	nn	1834	52	0,49	26	5	-8,80	-48,7	22

ANNEX 4: Isotope values of snow profile samples

22.02.2012 Profile 1: Wardeh 315cm			31 samples		
No	Density raw	snow depth (cm)	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
P1-1	FA	5	-8,02	-32,1	32
P1-2	FA	15	-8,02	-29,8	34
P1-3	FA	25	-13,44	-78,6	29
P1-4	3F	35	-8,67	-45,5	24
P1-5	3F	45	-8,51	-48,6	19
P1-6	3F	55	-8,20	-45,7	20
P1-7	3F	65	-8,53	-47,2	21
P1-8	3F	75	-7,49	-35,3	25
P1-9	1F	85	-6,66	-29,3	24
P1-10	S	95	-7,83	-39,5	23
P1-11	Ice	105	-5,22	-14,2	28
P1-12	3F	115	-6,47	-28,8	23
P1-13	3F	125	-7,84	-36,0	27
P1-14	3F	135	-8,57	-42,8	26
P1-15	3F	145	-8,32	-40,0	27
P1-16	3F	155	-8,15	-39,3	26
P1-17	3F	165	failed		
P1-18	3F	175	-7,52	-34,7	25
P1-19	3F	185	-7,15	-25,1	32
P1-20	3F	195	-8,37	-42,9	24
P1-21	3F	205	-13,08	-80,9	24
P1-22	3F	215	-8,90	-47,9	23
P1-23	3F	225	-8,40	-44,4	23
P1-24	3F	235	-9,41	-54,9	20
P1-25	1F	245	-7,95	-39,2	24
P1-26	1F	255	-8,27	-40,3	26
P1-27	1F	265	-9,31	-51,6	23
P1-28	1F	275	-8,27	-41,5	25
P1-29	1F	285	-7,82	-38,7	24
P1-30	1F	295	-7,14	-32,8	24
P1-31	1F	305	-7,53	-37,3	23
Mean			-8,30	-41,5	25

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27.02.2012 Profile 2: Labbane 155 16 samples											
No	snow depth (cm)	net weigt (g)	density (g/cm³)	SWE (cm)	EC (µS/cm)	T(EC) (°c)	Ph	T(pH) (°c)	10^3 δ¹⁸O	10^3 δ²H	10^3 DE
P2-1	5	182,7	0,3	3	13	18,6	7,9	18,5	-9,16	-44,3	29
P2-2	15	278,5	0,4	4	30	18,2	8,0	18,1	-8,84	-42,8	28
P2-3	25	335,4	0,5	5	37	18,0	7,9	17,9	-9,27	-53,1	21
P2-4	35	266,4	0,4	4	36	18,0	7,3	17,9	-7,95	-40,3	23
P2-5	45	271,9	0,4	4	29	18,1	6,8	18,0	-6,75	-29,7	24
P2-6	55	327,1	0,5	5	16	18,7	6,8	18,6	-6,18	-27,3	22
P2-7	65	329,1	0,5	5	23	18,2	6,8	18,1	-5,30	-16,0	26
P2-8	75	328,6	0,5	5	37	17,9	7,3	17,8	-6,23	-25,8	24
P2-9	85	322,4	0,5	5	11	17,9	7,3	17,8	-6,04	-24,7	24
P2-10	95	313,8	0,5	5	17	17,8	7,3	17,8	-6,01	-24,6	23
P2-11	105	306,8	0,4	4	11	18,1	7,2	18,0	-6,91	-32,8	22
P2-12	115	320,7	0,5	5	10	18,2	7,2	18,1	-9,31	-51,8	23
P2-13	125	313,3	0,5	5	10	18,1	7,3	18,1	-8,73	-47,5	22
P2-14	135	323,0	0,5	5	8	18,0	7,3	18,0	-7,16	-35,0	22
P2-15	145	311,9	0,4	4	7	18,8	7,2	18,6	-7,32	-37,7	21
P2-16	155	312,6	0,5	5	8	18,8	7,3	18,7	-6,95	-34,5	21
Mean				4	19	18,2	7,3	18,1	-7,38	-35,5	24

ANNEX 5: Jeita cave drip water samples

		Cond. µS/cm	T °C	10³ d18O	10³ d2H	10³ DE
JC-01	22.02.2013	376	20,0	-5,19	-23,8	18
	28.02.2013	377	20,0	-5,30	-23,5	19
	12.03.2013			-5,38	-23,7	19
	21.03.2013			-5,22	-23,4	18
	02.04.2013			-5,31	-23,2	19
	11.04.2013			-5,27	-22,7	19
	01.05.2013	335		-5,20	-21,7	20
	16.05.2013	299		-5,05	-21,2	19
	31.05.2013	291		-4,99	-21,6	18
	16.06.2013	292		-5,16	-23,4	18
	01.07.2013	296		-5,27	-23,8	18
	15.07.2013	306		-4,99	-22,2	18
	01.08.2013	307		-4,95	-21,0	19
JC-02	22.02.2013	567	19,9	-5,49	-25,7	18
	28.02.2013	520	20,3	-5,29	-24,8	18
	12.03.2013			-5,35	-25,5	17
	21.03.2013			-4,50	-17,0	19
	02.04.2013			-5,19	-23,3	18
	11.04.2013			-5,20	-23,5	18
	01.05.2013	382		-5,37	-23,7	19
	16.05.2013	402		-5,04	-23,0	17
	31.05.2013	392		-5,15	-23,1	18
	16.06.2013	364		-4,92	-22,6	17
	01.07.2013	361		-4,94	-22,1	17
	15.07.2013	379		-5,19	-24,0	18
	01.08.2013	362		-5,04	-22,4	18
JC-03	22.02.2013	463	19,5	-5,06	-24,6	16
	28.02.2013	529	18,9	-5,09	-24,6	16
	12.03.2013			-5,33	-25,0	18
	21.03.2013			-5,15	-24,1	17
	02.04.2013			-4,82	-20,8	18
	11.04.2013			-5,16	-23,8	17
	01.05.2013	380		-5,41	-24,6	19
	16.05.2013	370		-4,81	-22,3	16
	31.05.2013	346		-4,95	-22,4	17
	16.06.2013	344		-4,91	-23,3	16
	01.07.2013	353		-5,00	-23,1	17
	15.07.2013	338		-4,88	-22,8	16
	01.08.2013	366		-4,83	-21,9	17

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		Cond. µS/cm	T °C	10³ d18O	10³ d2H	10³ DE
JC-04	28.02.2013	453	20,2	-4,81	-20,0	19
	12.03.2013			-5,41	-26,2	17
	21.03.2013			-5,32	-25,5	17
	02.04.2013			-5,24	-25,1	17
	11.04.2013			-5,31	-25,9	17
	01.05.2013	388		-5,41	-24,8	19
	16.05.2013	390		-5,18	-24,1	17
	31.05.2013	356		-5,06	-23,9	17
	16.06.2013	350		-5,11	-24,8	16
	01.07.2013	356		-5,13	-24,5	17
	15.07.2013	361		-5,06	-23,8	17
	01.08.2013	361		-5,04	-22,6	18
JC-05	22.02.2013	482	19,5	-4,68	-19,8	18
	28.02.2013	488	19,1	-4,81	-20,0	19
	12.03.2013			-4,78	-20,0	18
	21.03.2013			-4,50	-18,7	17
	02.04.2013			-4,57	-18,4	18
	11.04.2013			-4,48	-18,0	18
	01.05.2013	451		-4,87	-18,6	20
	16.05.2013	426		-4,31	-15,8	19
	31.05.2013	417		-4,08	-16,0	17
	16.06.2013	417		-4,09	-15,9	17
	01.07.2013	408		-3,97	-14,9	17
	15.07.2013	408		-3,89	-14,5	17
	01.08.2013	406		-3,79	-13,6	17
JC-06	22.02.2013	667	19,6	-5,25	-24,6	17
	28.02.2013	589	20,1	-5,20	-24,7	17
	12.03.2013			-5,22	-24,9	17
	21.03.2013			-5,23	-25,3	17
	02.04.2013			-5,16	-24,9	16
	11.04.2013			-5,31	-25,1	17
	01.05.2013	518		-5,26	-24,8	17
	16.05.2013	524		-5,22	-24,4	17
	31.05.2013	522		-5,22	-24,3	17
	16.06.2013	641		-5,33	-26,0	17
	01.07.2013	619		-5,27	-25,4	17
	15.07.2013	588		-5,39	-25,6	18
	01.08.2013	648		-5,41	-24,8	19

Stable Isotope Investigations in the Jeita Spring catchment

		Cond µS/cm	T °C	10³ d18O	10³ d2H	10³ DE
JC-07	12.03.2013			-6,09	-28,5	20
	21.03.2013			-5,84	-26,3	20
	02.04.2013			-5,73	-24,5	21
	11.04.2013			-5,69	-25,8	20
	01.05.2013	455		-5,92	-27,9	20
	16.05.2013	467		-5,88	-27,1	20
	31.05.2013	468		-5,98	-28,0	20
	16.06.2013	454		-6,11	-29,8	19
	01.07.2013	441		-6,36	-30,5	20
	15.07.2013	389		-6,43	-30,6	21
	01.08.2013	396		-6,27	-29,1	21
JC-08	12.03.2013			-5,54	-26,7	18
	21.03.2013			-5,65	-27,0	18
	02.04.2013			-5,49	-26,5	17
	11.04.2013			-5,61	-27,1	18
	01.05.2013	555		-5,56	-26,7	18
	16.05.2013	556		-5,62	-26,7	18
	31.05.2013	540		-5,64	-27,4	18
	16.06.2013	537		-5,52	-26,6	18
	01.07.2013	520		-5,69	-26,9	19
	15.07.2013	510		-5,67	-26,8	19
	01.08.2013	518		-5,63	-25,5	20
JC-09	12.03.2013			-5,03	-26,0	14
	21.03.2013			-5,59	-26,9	18
	02.04.2013			-5,59	-26,8	18
	11.04.2013			-5,55	-26,9	18
	01.05.2013	400		-5,63	-26,5	19
	16.05.2013	405		-5,79	-26,8	20
	31.05.2013	391		-5,69	-27,2	18
	16.06.2013	387		-5,60	-27,2	18
	01.07.2013	380		-5,73	-27,3	18
	15.07.2013	384		-5,77	-27,3	19
	01.08.2013	388		-5,58	-25,7	19

Stable Isotope Investigations in the Jeita Spring catchment

ANNEX 6: Isotope values for spring samples

Jeita spring (65 m)												Jeita spring (65 m)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
30.03.2011	-7,13	-34,2	23	27.03.2012	-7,12	-34,5	22	24.05.2012	-7,26	-35,9	22	19.07.2012	-7,31	-36,9	22
14.04.2011	-7,18	-34,7	23	28.03.2012	-7,11	-34,5	22	25.05.2012	-7,16	-36,2	21	20.07.2012	-7,35	-36,8	22
18.05.2011	-7,16	-38,1	19	29.03.2012	-7,15	-34,9	22	26.05.2012	-7,31	-36,4	22	21.07.2012	-7,29	-36,9	21
03.06.2011	-7,22	-38,5	19	30.03.2012	-7,07	-35,1	21	27.05.2012	-7,30	-36,8	22	22.07.2012	-7,38	-36,8	22
15.06.2011	-7,27	-38,4	20	31.03.2012	-7,02	-34,9	21	28.05.2012	-7,27	-36,5	22	23.07.2012	-7,55	-36,8	24
05.07.2011	-7,26	-36,9	21	01.04.2012	-7,11	-34,8	22	29.05.2012	-7,22	-36,4	21	24.07.2012	-7,53	-36,9	23
18.07.2011	-7,21	-36,9	21	03.04.2012	-7,02	-34,6	22	30.05.2012	-7,16	-36,0	21	25.07.2012	-7,49	-36,9	23
03.08.2011	-7,21	-37,1	21	04.04.2012	-7,03	-34,8	21	31.05.2012	-7,13	-36,3	21	26.07.2012	-7,28	-37,0	21
19.08.2011	-7,21	-37,0	21	05.04.2012	-7,04	-34,9	21	01.06.2012	-7,15	-36,4	21	27.07.2012	-7,36	-37,3	22
06.09.2011	-7,28	-35,6	23	06.04.2012	-7,18	-35,4	22	02.06.2012	-7,16	-36,2	21	28.07.2012	-7,27	-37,2	21
26.09.2011	-7,24	-36,3	22	07.04.2012	-7,24	-35,8	22	03.06.2012	-7,24	-36,4	22	29.07.2012	-7,23	-37,0	21
29.09.2011	-7,21	-36,4	21	08.04.2012	-7,28	-35,7	22	04.06.2012	-7,22	-36,4	21	30.07.2012	-7,36	-37,3	22
05.10.2011	-7,26	-36,8	21	10.04.2012	-7,05	-35,1	21	05.06.2012	-7,16	-36,5	21	31.07.2012	-7,35	-37,2	22
16.10.2011	-7,26	-36,3	22	11.04.2012	-7,17	-35,5	22	06.06.2012	-7,32	-36,7	22	01.08.2012	-7,30	-37,3	21
23.11.2011	-7,11	-34,8	22	12.04.2012	-7,27	-35,6	23	07.06.2012	-7,19	-36,5	21	02.08.2012	-7,26	-36,5	22
27.11.2011	-7,18	-35,5	22	13.04.2012	-7,23	-35,5	22	08.06.2012	-7,26	-36,7	21	03.08.2012	-7,23	-36,8	21
06.12.2011	-7,14	-35,9	21	14.04.2012	-7,28	-35,5	23	09.06.2012	-7,24	-36,5	21	04.08.2012	-7,34	-37,5	21
11.12.2011	-7,12	-35,3	22	15.04.2012	-7,23	-35,6	22	10.06.2012	-7,27	-36,5	22	05.08.2012	-7,23	-37,3	21
10.01.2012	-7,08	-35,2	21	16.04.2012	-7,20	-35,3	22	11.06.2012	-7,32	-36,4	22	06.08.2012	-6,92	-36,3	19
23.01.2012	-7,01	-34,4	22	17.04.2012	-7,28	-35,5	23	12.06.2012	-7,17	-36,4	21	07.08.2012	-7,04	-36,2	20
21.02.2012	-6,98	-33,6	22	18.04.2012	-7,29	-35,8	22	13.06.2012	-7,19	-36,4	21	08.08.2012	-7,38	-37,4	22
22.02.2012	-6,96	-33,8	22	19.04.2012	-7,30	-35,9	22	14.06.2012	-7,27	-36,6	22	09.08.2012	-7,33	-37,1	22
23.02.2012	-6,95	-33,9	22	20.04.2012	-7,22	-35,6	22	15.06.2012	-7,29	-37,0	21	10.08.2012	-7,33	-37,0	22
24.02.2012	-6,95	-33,9	22	21.04.2012	-7,26	-35,7	22	16.06.2012	-7,22	-36,9	21	11.08.2012	-7,04	-36,1	20
25.02.2012	-7,05	-34,6	22	22.04.2012	-7,23	-35,7	22	17.06.2012	-7,23	-36,8	21	12.08.2012	-7,03	-36,1	20
26.02.2012	-7,00	-34,3	22	23.04.2012	-7,23	-35,5	22	18.06.2012	-7,15	-36,3	21	13.08.2012	-7,46	-37,2	22
27.02.2012	-6,94	-34,2	21	24.04.2012	-7,21	-35,5	22	19.06.2012	-7,21	-36,4	21	14.08.2012	-7,43	-37,1	22
28.02.2012	-7,03	-34,2	22	25.04.2012	-7,31	-35,8	23	20.06.2012	-7,22	-36,5	21	15.08.2012	-7,22	-36,0	22
29.02.2012	-7,06	-34,5	22	26.04.2012	-7,26	-36,2	22	21.06.2012	-7,24	-36,5	21	16.08.2012	-7,41	-36,7	23
01.03.2012	-6,98	-33,7	22	27.04.2012	-7,21	-35,9	22	22.06.2012	-7,32	-36,7	22	17.08.2012	-7,48	-37,4	22
02.03.2012	-6,92	-33,1	22	28.04.2012	-7,21	-35,7	22	23.06.2012	-7,14	-36,1	21	18.08.2012	-7,12	-36,4	21
03.03.2012	-6,84	-33,4	21	30.04.2012	-7,27	-35,9	22	24.06.2012	-7,14	-36,4	21	19.08.2012	-7,09	-36,4	20
04.03.2012	-6,93	-33,6	22	01.05.2012	-7,18	-35,8	22	25.06.2012	-7,18	-36,1	21	20.08.2012	-7,44	-37,2	22
05.03.2012	-6,87	-33,3	22	02.05.2012	-7,21	-35,7	22	26.06.2012	-7,19	-36,5	21	21.08.2012	-7,42	-37,3	22
06.03.2012	-6,99	-33,4	23	03.05.2012	-7,29	-35,7	23	27.06.2012	-7,23	-36,6	21	22.08.2012	-7,26	-37,0	21
07.03.2012	-6,97	-33,3	22	04.05.2012	-7,25	-35,9	22	28.06.2012	-7,19	-36,3	21	23.08.2012	-7,28	-36,7	22
08.03.2012	-6,94	-33,8	22	05.05.2012	-7,20	-35,5	22	29.06.2012	-7,19	-36,5	21	24.08.2012	-7,25	-37,1	21
09.03.2012	-7,09	-33,9	23	06.05.2012	-7,21	-35,9	22	30.06.2012	-7,24	-36,4	22	25.08.2012	-7,56	-36,9	24
10.03.2012	-6,96	-33,5	22	07.05.2012	-7,45	-36,0	24	01.07.2012	-7,26	-36,3	22	26.08.2012	-7,55	-37,3	23
11.03.2012	-7,05	-33,7	23	08.05.2012	-7,29	-35,9	22	03.07.2012	-7,20	-36,3	21	27.08.2012	-7,48	-37,2	23
12.03.2012	-6,99	-33,6	22	09.05.2012	-7,28	-35,9	22	04.07.2012	-7,22	-36,4	21	28.08.2012	-7,55	-37,3	23
13.03.2012	-7,13	-34,0	23	10.05.2012	-7,28	-36,1	22	05.07.2012	-7,21	-36,6	21	29.08.2012	-7,48	-36,8	23
14.03.2012	-7,24	-34,3	24	11.05.2012	-7,38	-36,0	23	06.07.2012	-7,28	-36,0	22	30.08.2012	-7,43	-36,8	23
15.03.2012	-7,15	-34,5	23	12.05.2012	-7,34	-36,2	23	07.07.2012	-7,21	-35,9	22	31.08.2012	-7,42	-37,0	22
16.03.2012	-7,16	-34,7	23	13.05.2012	-7,29	-36,0	22	08.07.2012	-7,28	-36,2	22	01.09.2012	-7,34	-36,7	22
17.03.2012	-7,00	-34,1	22	14.05.2012	-7,23	-36,2	22	09.07.2012	-7,25	-36,2	22	02.09.2012	-7,32	-36,8	22
18.03.2012	-7,03	-34,1	22	15.05.2012	-7,33	-36,3	22	10.07.2012	-7,28	-36,4	22	03.09.2012	-7,43	-36,8	23
19.03.2012	-6,98	-33,9	22	16.05.2012	-7,23	-36,3	22	11.07.2012	-7,28	-36,5	22	04.09.2012	-7,35	-36,8	22
20.03.2012	-7,05	-34,0	22	17.05.2012	-7,29	-36,7	22	12.07.2012	-7,28	-36,5	22	05.09.2012	-7,09	-36,1	21
21.03.2012	-7,04	-34,0	22	18.05.2012	-7,34	-36,8	22	13.07.2012	-7,31	-36,6	22	06.09.2012	-7,39	-36,7	22
22.03.2012	-7,05	-34,1	22	19.05.2012	-7,27	-36,4	22	14.07.2012	-7,28	-36,3	22	07.09.2012	-7,48	-36,7	23
23.03.2012	-7,05	-34,2	22	20.05.2012	-7,32	-36,5	22	15.07.2012	-7,31	-36,4	22	08.09.2012	-7,44	-37,1	22
24.03.2012	-7,09	-34,4	22	21.05.2012	-7,16	-36,4	21	16.07.2012	-7,30	-36,7	22	09.09.2012	-7,44	-37,2	22
25.03.2012	-7,07	-34,3	22	22.05.2012	-7,13	-36,4	21	17.07.2012	-7,37	-36,9	22	10.09.2012	-7,41	-36,8	22
26.03.2012	-7,07	-34,4	22	23.05.2012	-7,29	-36,7	22	18.07.2012	-7,41	-37,0	22	11.09.2012	-7,40	-37,1	22

								Jeita spring (65 m)							
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE	date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
12.09.2012	-7,24	-36,4	22	09.11.2012	-7,09	-35,7	21	11.01.2013	-6,85	-33,2	22	11.03.2013	-7,12	-35,3	22
13.09.2012	-7,45	-36,9	23	10.11.2012	-6,88	-35,1	20	12.01.2013	-6,96	-34,0	22	12.03.2013	-7,08	-35,3	21
14.09.2012	-7,63	-37,2	24	11.11.2012	-6,78	-35,0	19	13.01.2013	-6,93	-33,9	22	13.03.2013	-7,02	-34,8	21
15.09.2012	-7,41	-36,7	23	13.11.2012	-6,96	-34,8	21	14.01.2013	-7,01	-33,7	22	14.03.2013	-7,08	-35,5	21
16.09.2012	-7,59	-37,5	23	14.11.2012	-6,92	-34,4	21	15.01.2013	-7,07	-33,9	23	15.03.2013	-7,02	-35,0	21
17.09.2012	-7,34	-36,3	22	15.11.2012	-7,03	-34,4	22	16.01.2013	-6,97	-34,1	22	16.03.2013	-7,18	-35,8	22
18.09.2012	-7,22	-36,4	21	16.11.2012	-6,85	-34,0	21	17.01.2013	-7,18	-34,2	23	17.03.2013	-7,09	-35,5	21
19.09.2012	-7,07	-36,6	20	17.11.2012	-7,02	-34,5	22	18.01.2013	-7,12	-34,3	23	18.03.2013	-7,11	-35,2	22
20.09.2012	-7,04	-36,1	20	18.11.2012	-7,01	-34,4	22	19.01.2013	-7,09	-34,4	22	19.03.2013	-7,24	-36,2	22
21.09.2012	-7,10	-36,7	20	20.11.2012	-7,12	-35,5	21	20.01.2013	-7,09	-34,2	23	20.03.2013	-7,34	-36,7	22
22.09.2012	-7,03	-35,9	20	21.11.2012	-7,00	-35,1	21	22.01.2013	-7,03	-34,4	22	21.03.2013	-7,28	-36,2	22
23.09.2012	-6,93	-35,8	20	22.11.2012	-7,08	-35,4	21	23.01.2013	-7,17	-35,2	22	22.03.2013	-7,29	-36,7	22
24.09.2012	-7,13	-36,2	21	23.11.2012	-7,18	-35,6	22	24.01.2013	-7,20	-35,4	22	23.03.2013	-7,24	-35,9	22
25.09.2012	-7,14	-36,1	21	24.11.2012	-7,09	-35,3	21	25.01.2013	-7,21	-35,2	22	24.03.2013	-7,18	-36,2	21
26.09.2012	-7,19	-36,4	21	25.11.2012	-7,17	-36,3	21	26.01.2013	-7,06	-35,0	21	25.03.2013	-7,22	-36,5	21
27.09.2012	-7,14	-36,3	21	26.11.2012	-7,18	-36,2	21	27.01.2013	-7,06	-35,2	21	26.03.2013	-7,26	-36,4	22
28.09.2012	-7,07	-36,1	20	27.11.2012	-7,15	-36,0	21	28.01.2013	-7,36	-36,0	23	28.03.2013	-7,21	-35,9	22
29.09.2012	-6,93	-35,6	20	28.11.2012	-7,23	-36,0	22	29.01.2013	-7,26	-35,2	23	29.03.2013	-7,13	-35,7	21
02.10.2012	-7,00	-35,5	20	29.11.2012	-7,22	-36,4	21	30.01.2013	-7,23	-35,6	22	30.03.2013	-7,29	-35,9	22
03.10.2012	-6,90	-35,6	20	30.11.2012	-7,26	-36,2	22	01.02.2013	-7,25	-35,7	22	02.04.2013	-7,33	-36,6	22
04.10.2012	-6,87	-35,2	20	01.12.2012	-7,24	-36,2	22	02.02.2013	-7,31	-36,0	23	03.04.2013	-7,09	-36,0	21
05.10.2012	-6,92	-36,0	19	02.12.2012	-7,31	-36,2	22	03.02.2013	-7,09	-35,1	22	04.04.2013	-7,19	-36,0	22
06.10.2012	-7,08	-36,3	20	03.12.2012	-7,24	-35,8	22	04.02.2013	-7,22	-35,6	22	05.04.2013	-7,34	-36,3	22
07.10.2012	-7,04	-36,3	20	04.12.2012	-7,31	-36,2	22	05.02.2013	-7,25	-35,6	22	06.04.2013	-7,15	-36,0	21
08.10.2012	-6,98	-35,7	20	05.12.2012	-7,32	-36,6	22	06.02.2013	-7,24	-35,2	23	07.04.2013	-7,32	-36,7	22
09.10.2012	-6,80	-35,3	19	06.12.2012	-7,10	-34,5	22	07.02.2013	-7,20	-35,3	22	09.04.2013	-7,25	-36,2	22
10.10.2012	-6,82	-35,7	19	07.12.2012	-7,01	-33,7	22	08.02.2013	-7,36	-36,1	23	10.04.2013	-7,33	-36,2	22
11.10.2012	-6,93	-35,6	20	08.12.2012	-6,88	-32,3	23	09.02.2013	-7,14	-35,5	22	11.04.2013	-7,11	-35,6	21
12.10.2012	-7,00	-36,0	20	09.12.2012	-6,81	-31,9	23	10.02.2013	-7,16	-35,6	22	13.04.2013	-7,21	-35,6	22
13.10.2012	-6,95	-35,7	20	11.12.2012	-7,01	-32,9	23	11.02.2013	-7,07	-35,1	21	14.04.2013	-7,39	-36,1	23
14.10.2012	-7,14	-36,3	21	12.12.2012	-7,01	-33,0	23	12.02.2013	-7,08	-35,3	21	16.04.2013	-7,27	-35,8	22
15.10.2012	-6,98	-35,5	20	13.12.2012	-6,96	-32,5	23	13.02.2013	-7,24	-35,4	22	17.04.2013	-7,21	-35,7	22
16.10.2012	-7,08	-36,1	21	14.12.2012	-6,94	-33,0	22	14.02.2013	-7,26	-35,3	23	18.04.2013	-7,31	-35,6	23
17.10.2012	-6,96	-35,7	20	16.12.2012	-6,90	-33,8	21	15.02.2013	-7,18	-35,0	22	19.04.2013	-7,09	-34,8	22
18.10.2012	-7,16	-36,3	21	17.12.2012	-6,94	-33,4	22	16.02.2013	-7,32	-36,1	23	20.04.2013	-7,16	-34,9	22
19.10.2012	-7,17	-35,8	22	18.12.2012	-6,84	-33,7	21	17.02.2013	-7,30	-36,3	22	21.04.2013	-7,20	-35,0	23
20.10.2012	-7,25	-36,2	22	19.12.2012	-6,92	-34,0	21	19.02.2013	-7,37	-35,8	23	23.04.2013	-7,00	-34,3	22
21.10.2012	-7,13	-35,9	21	20.12.2012	-7,22	-35,2	23	20.02.2013	-7,12	-34,9	22	24.04.2013	-7,21	-34,8	23
22.10.2012	-7,10	-36,0	21	21.12.2012	-7,22	-34,8	23	21.02.2013	-7,07	-35,1	21	25.04.2013	-7,15	-34,6	23
23.10.2012	-7,05	-35,9	20	22.12.2012	-7,15	-33,1	24	23.02.2013	-7,16	-35,2	22	26.04.2013	-7,16	-34,9	22
24.10.2012	-7,14	-35,9	21	23.12.2012	-6,93	-32,8	23	24.02.2013	-7,15	-34,8	22	27.04.2013	-7,14	-35,3	22
25.10.2012	-7,08	-36,1	21	26.12.2012	-6,99	-33,7	22	25.02.2013	-7,13	-34,9	22	28.04.2013	-7,22	-35,4	22
26.10.2012	-7,15	-36,3	21	27.12.2012	-6,50	-32,4	20	26.02.2013	-7,25	-34,9	23	29.04.2013	-7,14	-35,1	22
27.10.2012	-6,97	-35,6	20	28.12.2012	-6,95	-34,0	22	27.02.2013	-7,24	-35,1	23	30.04.2013	-7,21	-35,5	22
28.10.2012	-7,08	-36,0	21	29.12.2012	-6,95	-34,2	21	28.02.2013	-7,12	-34,8	22	01.05.2013	-7,08	-35,1	22
29.10.2012	-7,18	-36,0	21	30.12.2012	-6,99	-34,3	22	01.03.2013	-6,94	-34,4	21	07.05.2013	-7,20	-36,0	22
30.10.2012	-7,17	-36,0	21	01.01.2013	-7,06	-34,4	22	02.03.2013	-6,92	-34,6	21	14.05.2013	-7,21	-35,6	22
31.10.2012	-7,07	-35,9	21	02.01.2013	-7,12	-34,8	22	03.03.2013	-7,09	-35,1	22	16.05.2013	-6,91	-34,0	21
01.11.2012	-7,16	-36,2	21	03.01.2013	-7,13	-34,8	22	04.03.2013	-7,18	-35,4	22	15.06.2013	-6,79	-34,3	20
02.11.2012	-7,03	-35,5	21	04.01.2013	-7,02	-34,7	21	05.03.2013	-7,16	-35,5	22	18.06.2013	-7,23	-36,7	21
03.11.2012	-7,05	-35,6	21	05.01.2013	-7,14	-34,9	22	06.03.2013	-7,07	-35,2	21	26.06.2013	-7,25	-36,8	21
04.11.2012	-7,16	-35,8	21	06.01.2013	-7,18	-34,8	23	07.03.2013	-7,09	-35,4	21	02.07.2013	-7,24	-36,7	21
06.11.2012	-7,08	-35,3	21	08.01.2013	-7,16	-34,7	23	08.03.2013	-7,03	-34,6	22	10.07.2013	-7,16	-37,0	20
07.11.2012	-6,83	-35,2	19	09.01.2013	-7,26	-34,6	23	09.03.2013	-7,05	-35,2	21	17.09.2013			
08.11.2012	-7,03	-35,7	21	10.01.2013	-7,14	-33,8	23	10.03.2013	-6,89	-34,7	20	24.09.2013			

Stable Isotope Investigations in the Jeita Spring catchment

Naber al Labbane (1644 m)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
27.03.2011	-7,98	-42,2	22
14.04.2011	-8,19	-43,3	22
15.05.2011	-8,19	-47,2	18
03.06.2011	-8,18	-46,4	19
18.06.2011	-8,29	-46,0	20
05.07.2011	-8,18	-45,7	20
15.07.2011	-8,26	-45,6	21
05.08.2011	-8,14	-45,1	20
19.08.2011	-8,07	-44,1	20
03.09.2011	-8,14	-43,1	22
10.09.2011	-8,13	-42,8	22
28.09.2011	-8,01	-42,7	21
22.11.2011	-7,84	-40,7	22
01.12.2011	-7,78	-40,9	21
11.12.2011	-7,85	-41,6	21
10.01.2012	-7,65	-40,2	21
25.01.2012	-7,75	-41,7	20
27.02.2012	-7,76	-41,9	20
04.04.2012	-8,09	-42,6	22
21.04.2012	-8,19	-44,3	21
21.05.2012	-8,39	-45,7	21
10.06.2012	-8,11	-43,4	21
24.06.2012	-7,95	-42,4	21
30.06.2012	-8,28	-43,3	23
11.07.2012	-8,23	-43,0	23
22.07.2012	-8,06	-42,5	22
08.08.2012	-7,97	-42,6	21
30.08.2012	-8,07	-42,7	22
06.09.2012	-7,99	-42,9	21
17.09.2012	-8,12	-43,1	22
04.10.2012	-8,17	-42,9	22
16.10.2012	-8,22	-43,1	23
01.11.2012	-8,17	-43,2	22
16.11.2012	-7,71	-39,7	22
04.12.2012	-7,86	-41,0	22
16.12.2012	-7,89	-40,8	22
20.12.2012	-7,81	-40,2	22
31.12.2012	-7,67	-40,6	21
17.01.2013	-8,07	-42,6	22
26.02.2013	-8,06	-41,7	23
21.03.2013	-7,98	-40,8	23
02.04.2013	-7,71	-39,8	22
16.04.2013	-7,80	-40,1	22
02.05.2013	-8,11	-43,1	22
16.05.2013	-8,31	-44,2	22
31.05.2013	-7,69	-40,0	22
15.06.2013	-8,20	-44,6	21
01.07.2013	-7,98	-43,4	20
16.07.2013	-7,50	-39,3	21
01.08.2013	-7,57	-39,4	21
29.09.2013			

Naber al Assal (1540 m)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
27.03.2011	-8,09	-43,0	22
14.04.2011	-8,26	-43,6	22
15.05.2011	-8,18	-46,8	19
03.06.2011	-8,09	-46,4	18
18.06.2011	-8,26	-46,1	20
05.07.2011	-8,24	-45,5	20
15.07.2011	-8,43	-45,5	22
05.08.2011	-8,47	-46,7	21
19.08.2011	-8,32	-46,5	20
03.09.2011	-8,54	-46,3	22
10.09.2011	-8,46	-46,1	22
28.09.2011	-8,45	-46,3	21
22.11.2011	-8,06	-43,0	21
01.12.2011	-8,25	-44,8	21
11.12.2011	-8,03	-43,5	21
10.01.2012	-7,93	-43,5	20
25.01.2012	-7,97	-44,0	20
15.02.2012	-7,92	-43,2	20
22.02.2012	-7,95	-43,5	20
05.03.2012	-8,03	-43,5	21
04.04.2012	-8,01	-42,9	21
21.04.2012	-8,24	-43,9	22
21.05.2012	-8,23	-43,5	22
10.06.2012	-8,13	-43,0	22
24.06.2012	-7,95	-42,3	21
30.06.2012	-8,25	-42,9	23
11.07.2012	-8,18	-42,4	23
22.07.2012	-8,05	-42,8	22
08.08.2012	-8,05	-43,7	21
30.08.2012	-8,30	-44,7	22
06.09.2012	-8,30	-44,9	22
17.09.2012	-8,44	-45,4	22
04.10.2012	-8,44	-45,8	22
16.10.2012	-8,52	-46,3	22
01.11.2012	-8,40	-46,5	21
16.11.2012	-7,88	-41,6	21
04.12.2012	-8,29	-44,6	22
16.12.2012	-8,08	-42,6	22
20.12.2012	-8,00	-42,4	22
31.12.2012	-7,90	-43,0	20
17.01.2013	-7,93	-44,0	19
26.01.2013	-8,02	-43,5	21
31.01.2013	-8,06	-43,5	21
14.02.2013	-7,97	-43,3	20
26.02.2013	-7,94	-42,5	21
21.03.2013	-8,25	-43,9	22
02.04.2013	-8,30	-43,7	23
16.04.2013	-8,27	-43,8	22
02.05.2013	-8,20	-43,8	22
16.05.2013	-8,29	-44,3	22
31.05.2013	-8,21	-44,3	21
15.06.2013	-8,24	-44,4	22
01.07.2013	-8,02	-43,3	21
16.07.2013	-8,02	-42,8	21
01.08.2013	-8,19	-45,0	21

Kashkoush (60 m)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
30.03.2011	-6,89	-32,6	23
14.04.2011	-6,90	-32,9	22
18.05.2011	-6,84	-36,6	18
03.06.2011	-6,94	-36,4	19
15.06.2011	-6,95	-36,0	20
05.07.2011	-6,72	-33,8	20
18.07.2011	-6,85	-34,3	20
03.08.2011	-6,66	-33,5	20
19.08.2011	-6,73	-33,7	20
06.09.2011	-6,65	-31,8	21
29.09.2011	-6,72	-33,2	21
23.11.2011	-6,77	-31,9	22
10.01.2012	-6,55	-32,3	20
24.01.2012	-6,63	-32,8	20
21.02.2012	-6,58	-31,7	21
07.03.2012	-6,72	-32,1	22
05.04.2012	-6,95	-33,6	22
22.04.2012	-6,77	-33,8	20
28.04.2012	-6,72	-33,3	20
21.05.2012	-6,87	-34,1	21
26.05.2012	-6,88	-34,4	21
10.06.2012	-6,88	-34,1	21
26.06.2012	-6,93	-34,0	21
12.07.2012	-7,03	-34,3	22
19.07.2012	-7,05	-34,2	22
25.07.2012	-7,01	-34,4	22
08.08.2012	-6,71	-33,4	20
30.08.2012	-6,58	-32,2	20
17.09.2012	-6,76	-32,7	21
16.10.2012	-6,64	-32,5	21
01.11.2012	-6,70	-32,8	21
16.11.2012	-6,33	-30,4	20
04.12.2012	-6,55	-32,2	20
16.12.2012	-6,50	-30,1	22
31.12.2012	-6,63	-31,7	21
11.01.2013	-6,91	-33,9	21
31.01.2013	-7,08	-34,5	22
12.02.2013	-6,90	-34,2	21
01.03.2013	-6,92	-33,6	22
21.03.2013	-6,71	-33,6	20
16.04.2013	-6,72	-33,9	20
02.05.2013	-6,58	-32,8	20
31.05.2013	-6,89	-34,4	21
02.07.2013	-6,84	-34,0	21
16.07.2013	-6,71	-33,2	20
01.08.2013	-6,73	-33,8	20
08.10.2013			

Afqa (1280 m)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
21.05.2011	-8,07	-46,4	18
03.06.2011	-8,20	-46,0	20
18.06.2011	-8,28	-45,4	21
03.07.2011	-8,28	-45,3	21
15.07.2011	-8,25	-45,7	20
05.08.2011	-8,32	-45,9	21
11.08.2011	-8,27	-44,7	21
02.09.2011	-8,33	-45,0	22
10.09.2011	-8,40	-45,7	22
23.11.2011	-8,00	-43,2	21
11.12.2011	-8,01	-43,0	21
10.01.2012	-7,90	-44,2	19
25.01.2012	-7,93	-44,4	19
15.02.2012	-8,03	-44,8	19
05.04.2012	-8,42	-45,4	22
08.05.2012	-8,21	-43,6	22
09.05.2012	-8,25	-43,7	22
11.05.2012	-8,25	-43,1	23
06.06.2012	-7,91	-41,6	22
18.06.2012	-7,95	-41,9	22
03.07.2012	-8,18	-44,2	21
24.07.2012	-8,31	-45,8	21
07.08.2012	-8,22	-45,3	20
30.08.2012	-8,41	-45,7	22
17.09.2012	-8,30	-45,4	21
25.09.2012	-8,19	-45,0	21
17.10.2012	-8,25	-45,1	21
01.11.2012	-8,33	-45,3	21
16.11.2012	-7,91	-41,5	22
04.12.2012	-8,12	-43,5	21
16.12.2012	-7,87	-41,1	22
31.12.2012	-7,97	-42,3	21
17.01.2013	-8,14	-43,2	22
31.01.2013	-8,09	-43,2	21
14.02.2013	-8,09	-43,2	22
20.03.2013	-8,06	-43,3	21
03.04.2013	-8,47	-45,3	22
16.04.2013	-8,33	-44,5	22
02.05.2013	-8,34	-44,7	22
16.05.2013	-8,46	-45,3	22
30.05.2013	-8,27	-45,0	21
17.06.2013	-8,37	-45,3	22
01.07.2013	-8,28	-44,8	21
16.07.2013	-8,11	-44,3	21
01.08.2013	-8,03	-44,0	20
28.09.2013			

Rouaiss (1326)			
date	$10^3\ \delta^{18}O$	$10^3\ \delta^2H$	10^3 DE
04.05.2012	-8,58	-45,0	24
08.05.2012	-8,31	-44,2	22
11.05.2012	-8,30	-43,9	23
01.06.2012	-7,95	-42,3	21
06.06.2012	-8,13	-42,1	23
08.06.2012	-7,92	-41,8	22
03.07.2012	-8,05	-42,9	21
24.07.2012	-8,24	-44,8	21
07.08.2012	-8,27	-44,9	21
30.08.2012	-8,24	-45,2	21
17.09.2012	-8,22	-44,9	21
25.09.2012	-8,25	-45,2	21
17.10.2012	-8,23	-45,0	21
01.11.2012	-8,21	-44,9	21
16.11.2012	-7,85	-41,4	21
04.12.2012	-8,00	-43,2	21
16.12.2012	-7,81	-40,9	22
31.12.2012	-7,89	-41,8	21
17.01.2013	-7,69	-42,2	19
31.01.2013	-8,08	-43,5	21
14.02.2013	-8,11	-43,9	21
20.03.2013	-8,40	-45,1	22
03.04.2013	-8,40	-45,4	22
16.04.2013	-8,23	-45,3	21
02.05.2013	-8,41	-45,7	22
16.05.2013	-8,39	-45,8	21
31.05.2013	-8,37	-45,3	22
17.06.2013	-8,36	-44,8	22
01.07.2013	-8,12	-43,4	21
16.07.2013	-7,99	-43,1	21
01.08.2013	-8,00	-42,3	22
28.09.2013			