Groundwater recharge estimates with soil isotope profiles - is there a bias on coarse-grained hillslopes?

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Structure

- Introduction
- Field of study
- Sampling
- Measurement
- Analysis
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- Discussion

Introduction

- Isotope hydrology in Mediterranean areas
- Cooperative research project to efficiently design sustainable water uses
- Collaborative research on a highly innovative method of quantifying environmental flows with stable isotopes

ISOMED

Environmental Isotope Techniques for Water Flow Accounting

Lübeck University of Applied Science

Geological Survey Department of Cyprus & Cyprus Institute

German-Jordanian University

Truebner GmbH

Objectives

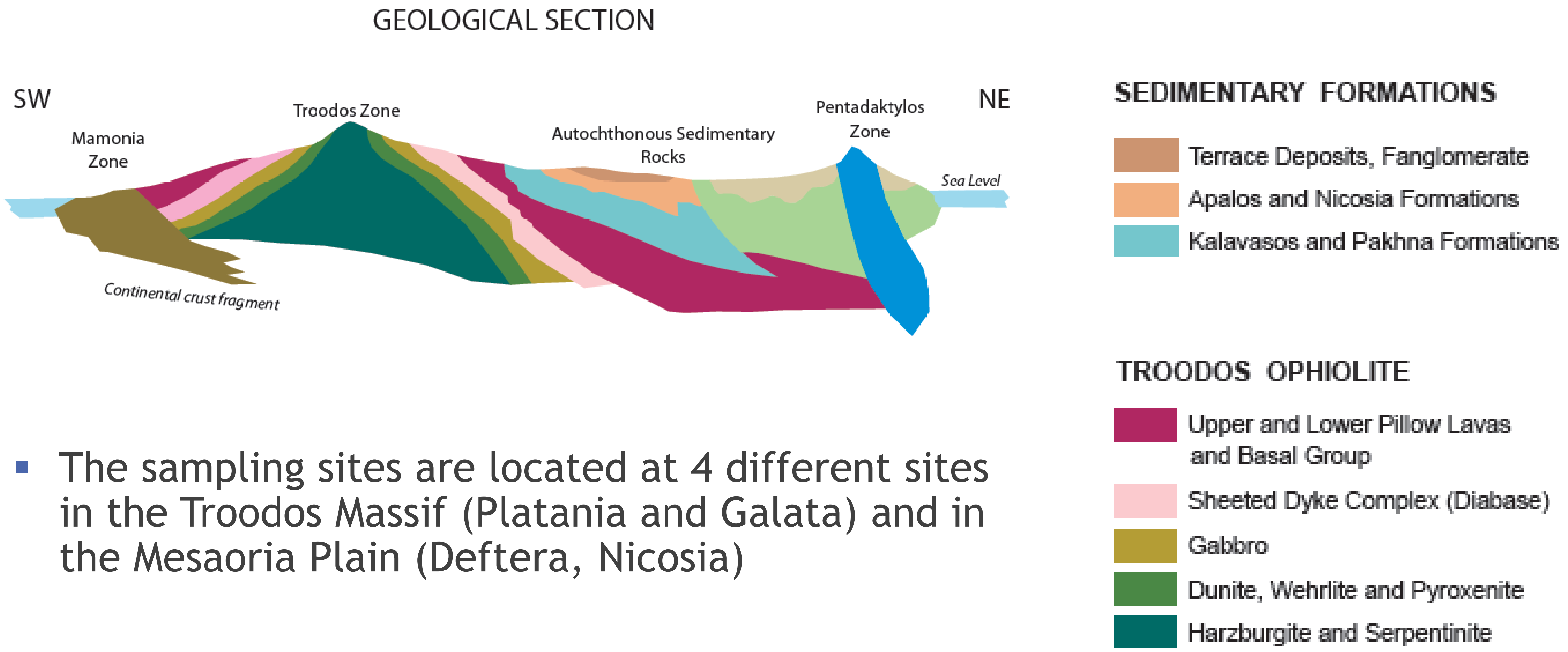
- Develop innovative, more accurate and faster methods for estimating environmental flows
- Improve mobility and improve training, education and research on the use of environmental isotopes in the Mediterranean
- Optimize water-related production
- Improve water use efficiency to secure sustainable supply of drinking water

Field of study - Cyprus

- In the Mediterranean region, agriculture is the largest consumer of water, and increasingly of groundwater

- Agriculture is of existential importance for rural areas

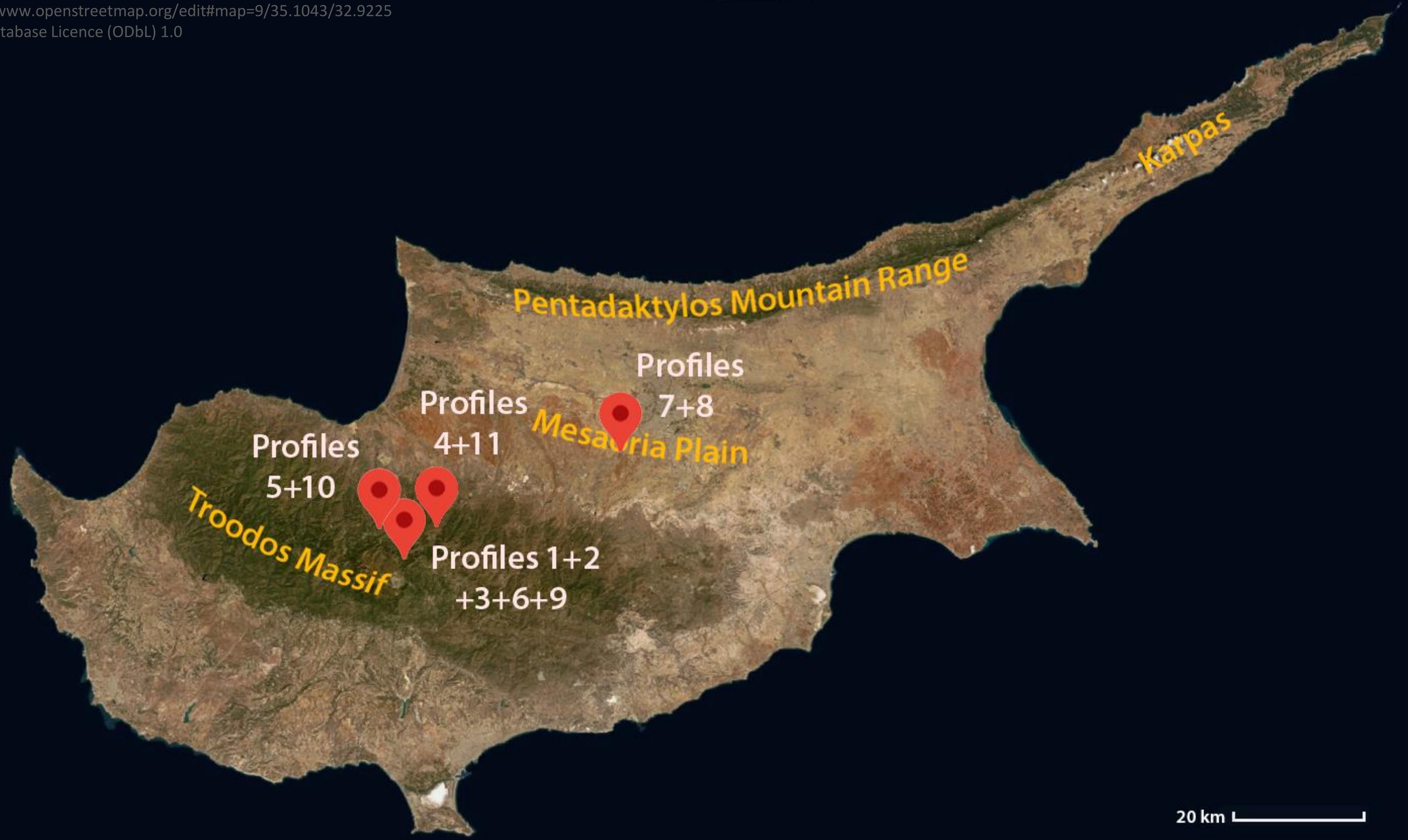
- Topographical areas of Cyprus:
  - Troodos Massif
  - Mesaoria Plain
  - Kyrenia Mountain Range



- The sampling sites are located at 4 different sites in the Troodos Massif (Platania and Galata) and in the Mesaoria Plain (Deftera, Nicosia)

Source: Cyprus Geological Survey. 2016. Geology of Cyprus. http://www.moa.gov.cy/moa/gsd/gsd.nsf/All/3ED655D39943ACEDC225839400340EBE/$file/GEOLOGY%20OF%20CYPRUS%20%20WEB.pdf?OpenElement.

https://www.openstreetmap.org/edit#map=9/35.1043/32.9225
Open Database Licence (ODbL) 1.0



Sampling

- A total of 11 profiles (430 samples) were taken

- 7 profiles in November 2018, 4 repeat profiles in February 2019

Procedure:

- Ramming a probe with an impact drill hammer
- Divide profile into 2 cm sections
- Fill samples into aluminium vaporized bags
- Seal bags airtight

Measurement

- Isotopic composition of soil water derived from the isotopic composition of water vapor based on thermodynamic equilibrium fractionation according to Majoube 1971 (Klaus et. al. 2013)

- Measurement of isotope profiles possible even in desert soils (Allison et. al. 1987) and moist clay soils (Henry et. al. 2008)

- Parallel equilibration measurement with known liquid water isotope standards

Measurement procedure

- Completed using Equilibration Laser Spectroscopy according to Wassenaar et. al. (2008)

Procedure:

- Weigh all samples
- Dry the standard samples
- Add standard liquid water
- Add dry air to all samples
- Equilibration for at least 24h
- Measurement
- Dry and weigh all samples

Analysis

Isotope profiles:
- Preliminary check to detect outliers
- Calibration δ_D and $\delta^{18}O$
- Check possible sources of error (e.g. temperature consistency)

Soil moisture:
- Calculate weights to calculate the water quantity
- Consider soil skeleton parts documented in the field
- Calculate the Bulk density by considering the compression due to ramming

Percolation:
- Set Summer and Winter peaks

Results

Profile	Area			Soil	Pecolation [mm/year]
1 + 2 + 3	Troodos	Platania	natural vegatation	fine-grained	20 – 60
6 + 9	Troodos	Platania	natural vegetation	coarse-grained	~ 30
4 + 11	Troodos	Galata	natural vegetation	coarse-grained	20 – 30
5 + 10	Troodos	Galata	irrigated, orchard	fine-grained	100 – 120
7 + 8	Mesaoria	Deftera	irrigated, olive trees	fine-grained	220 – 340

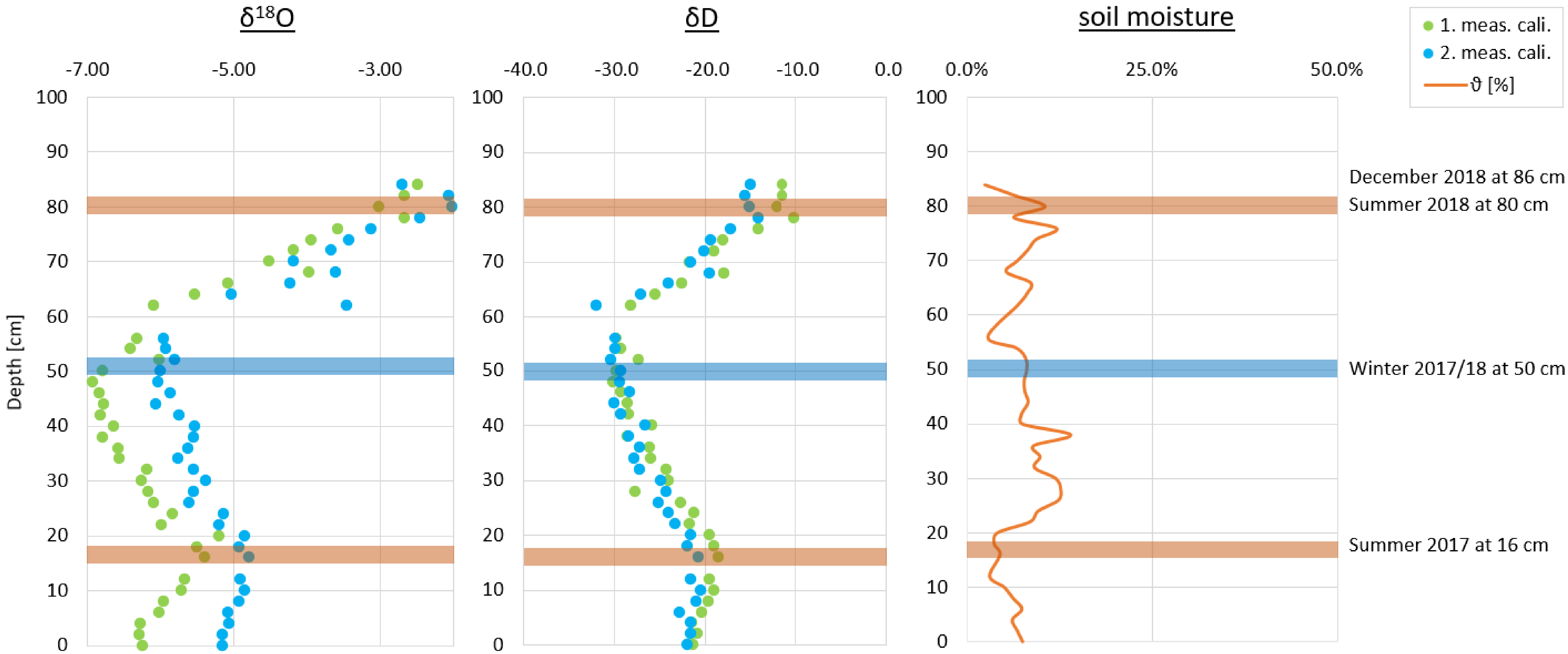
Profile 3: Platania

- Characterized by yellowish sand, gabbro and bedrock

- Seasonal fluctuations of the isotope values are visible
  - Green values: first measurement in December 2018
  - Blue values: second measurement in January 2019

- Percolation rate: ~50 mm/year (Summer 2017 to 2018)

Profile 3


δ18O
δD
soil moisture
1. meas. cali.
2. meas. cali.
ϑ [%]
-7.00
-5.00
-3.00
-40.0
-30.0
-20.0
-10.0
0.0
0.0%
25.0%
50.0%
Depth [cm]
December 2018 at 86 cm
Summer 2018 at 80 cm
Winter 2017/18 at 50 cm
Summer 2017 at 16 cm

Profile 5: Galata

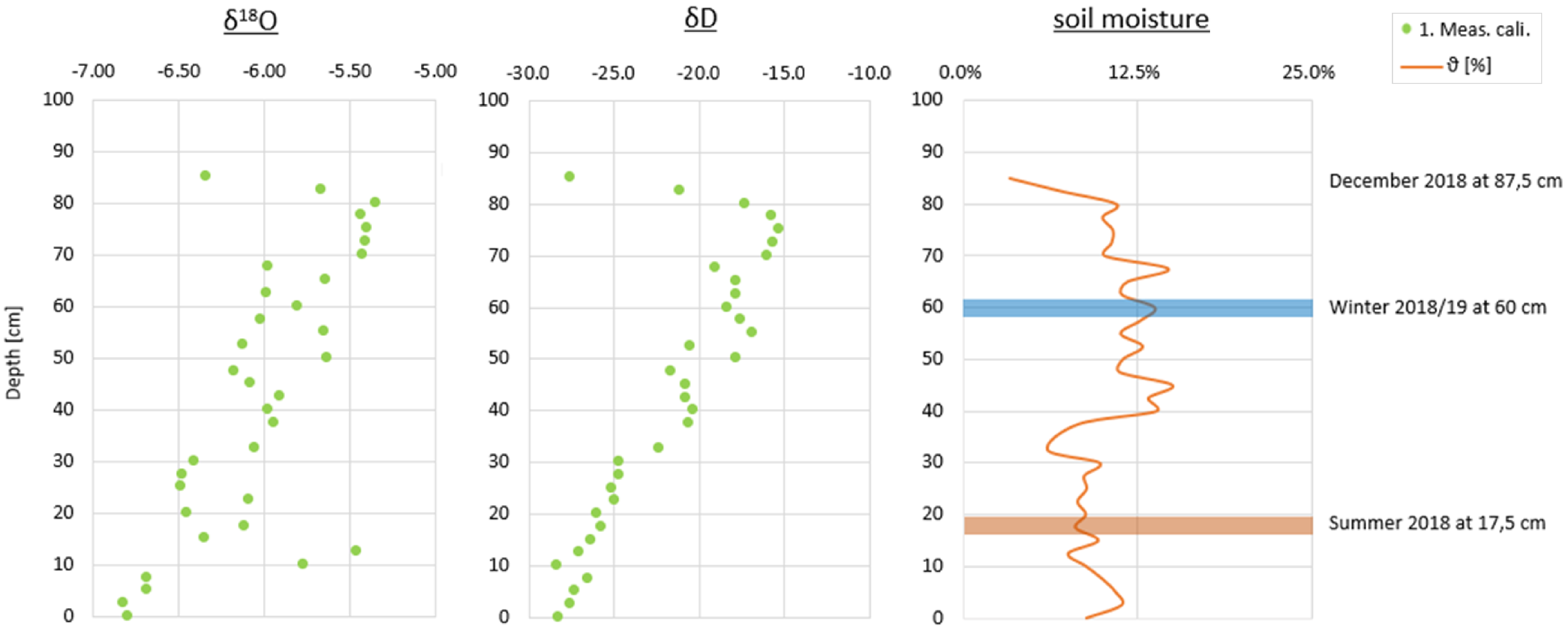
- Irrigated area, profile characterized by very clayey soil

- Fluctuations in the isotope values are visible

  - Green values: measurement in December 2018

- Percolation rate: ~50 mm/0,5*year (Summer 2018 to Winter 18/19)

Profile 5



δ18O
δD
soil moisture
1. Meas. cali.
ϑ [%]
-7.00
-6.50
-6.00
-5.50
-5.00
-30.0
-25.0
-20.0
-15.0
-10.0
0.0%
12.5%
25.0%
100
90
80
70
60
50
40
30
20
10
0
Depth [cm]
December 2018 at 87,5 cm
Winter 2018/19 at 60 cm
Summer 2018 at 17,5 cm

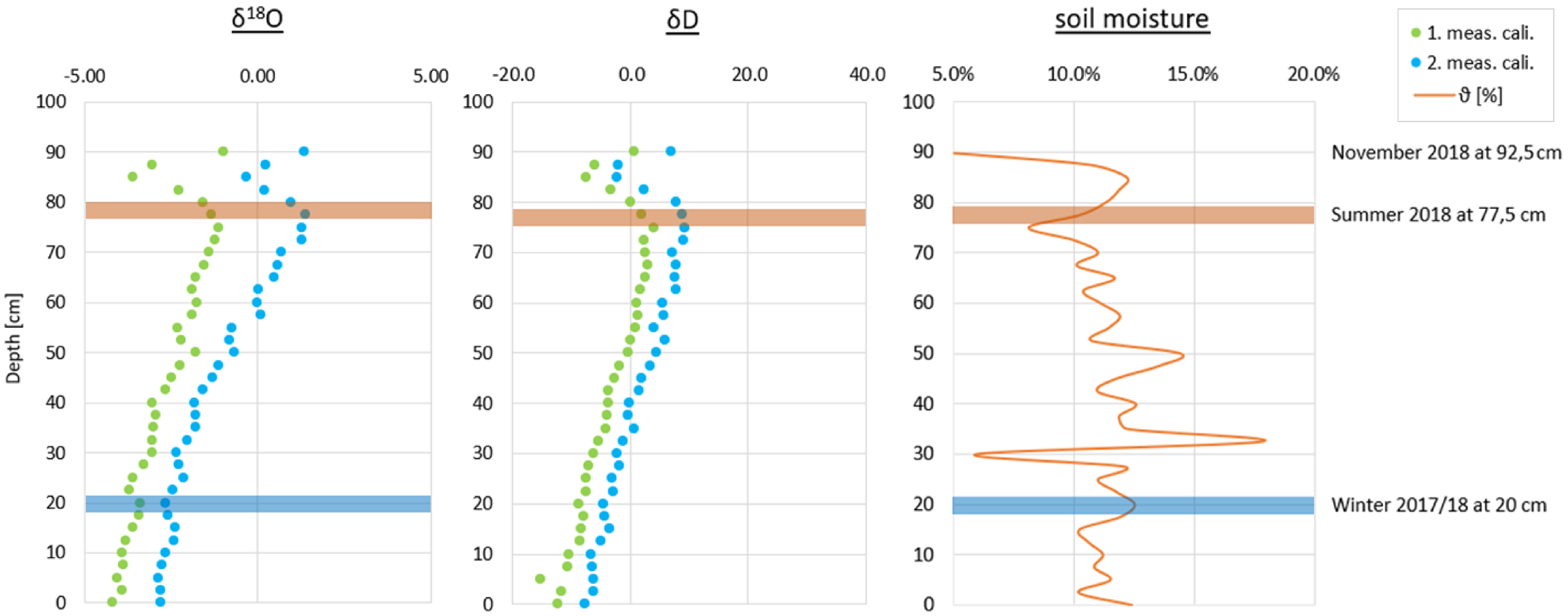
Profile 7: Deftera

- Irrigated area in the Mesaoria Plain, characterized by loam

- Isotope values are not affected by strong fluctuations
    - Green values: first measurement in December 2018
    - Blue values: second measurement in January 2019

- Percolation rate: ~ 70 mm/0,5*a (Winter 17/18 to Summer 18)

Profile 7



δ18O
-5.00
0.00
5.00
δD
-20.0
0.0
20.0
40.0
soil moisture
5.0%
10.0%
15.0%
20.0%
100
90
80
70
60
50
40
30
20
10
0
Depth [cm]
1. meas. cali.
2. meas. cali.
ϑ [%]
November 2018 at 92,5 cm
Summer 2018 at 77,5 cm
Winter 2017/18 at 20 cm

Reproducibility of the results - Profiles 4 and 11 - Galata

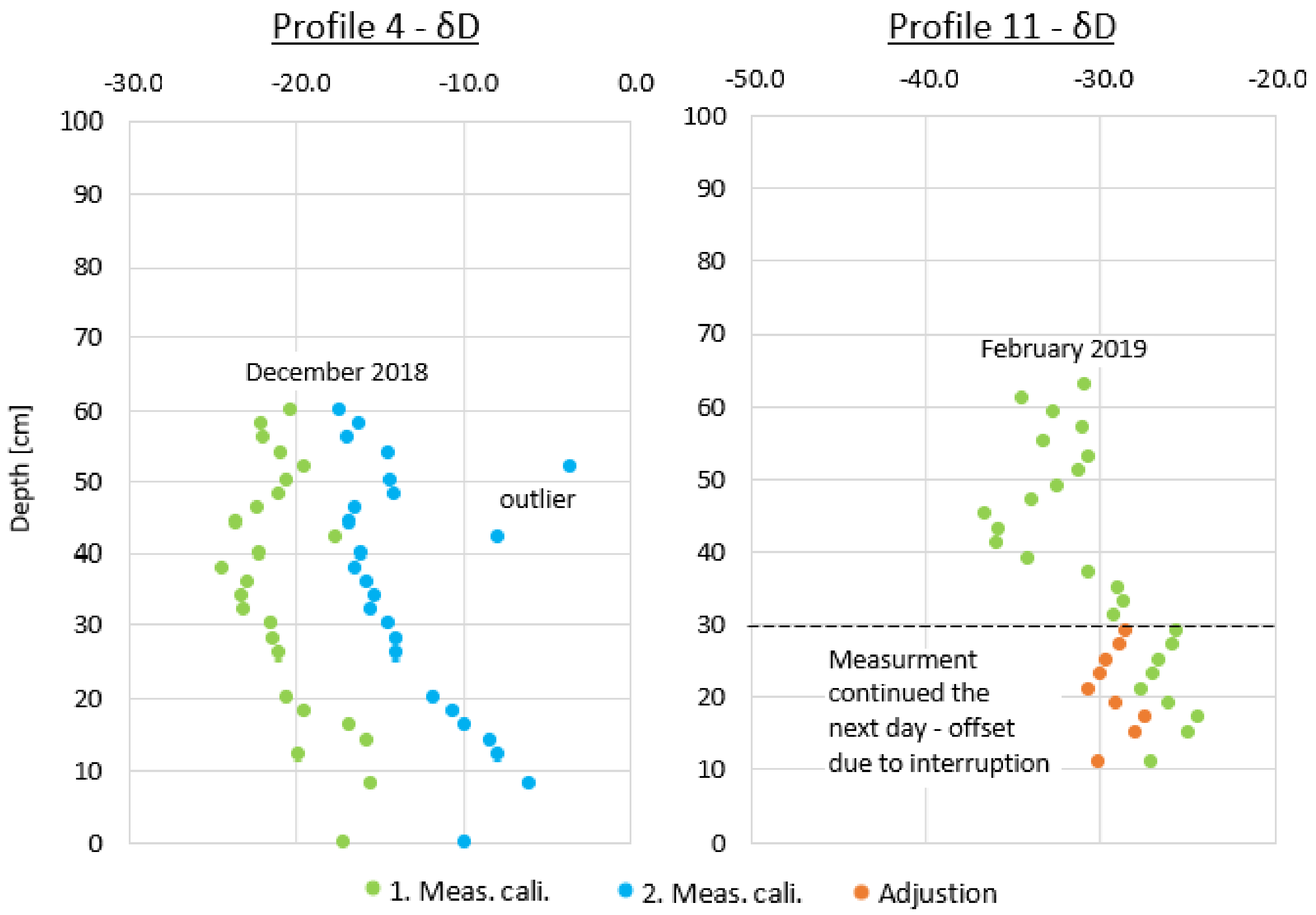
Percolation rate Summer 2017 to 2018:

November 2018:

Profile 4 17 mm/year

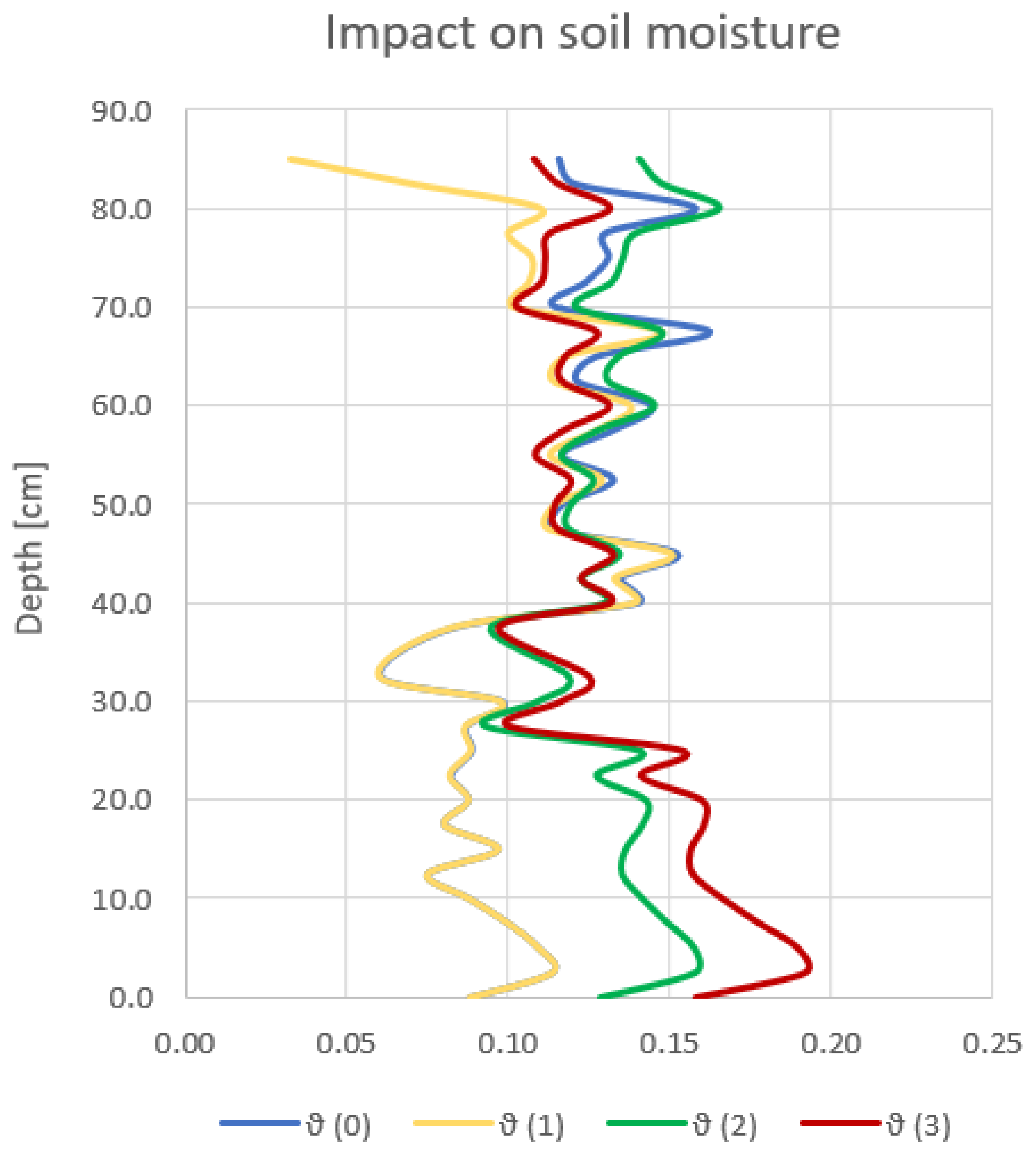
February 2019:

Profile 11 29 mm/year



Impact of different bulk densities on percolation rate

Calculation approach		Percolation
(0)	without any changes	44 mm/0,5year
(1)	with iterative corrected sample thickness	43 mm/0,5year
(2)	average bulk density: 1,3 g/cm³	52 mm/0,5year
(3)	bulk density linear increasing with depth: 1 g/cm³ to 1,6 g/cm³	53 mm/0,5year



Discussion

- According to Zagana et. al. (2007) the groundwater recharge ranges between 30 mm/year and 80 mm/year in the lowland and varies between 100 mm/year and 200 mm/year in the mountain area.

- Percolation rates correspond well to results obtained from daily soil water balance model for irrigated fine-grained soils in the plain

- Rates obtained from stable isotope methods on coarse-grained hillslopes tend to be much lower than expected

Conclusion

- Data suggest that macro-pore and preferential flow constitute a major component of percolation in coarse-grained soils of Troodos

- These components may not leave a measurable isotope trace

- Additional approaches need to be applied based on the evaluation of soil water isotope profiles

Summer School 2020!

There will be a Summer School on isotope methods in autumn 2020! Due to the current situation the Summer School may take place as an online course.

Information can be found soon at:

http://water-campus.de/

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