

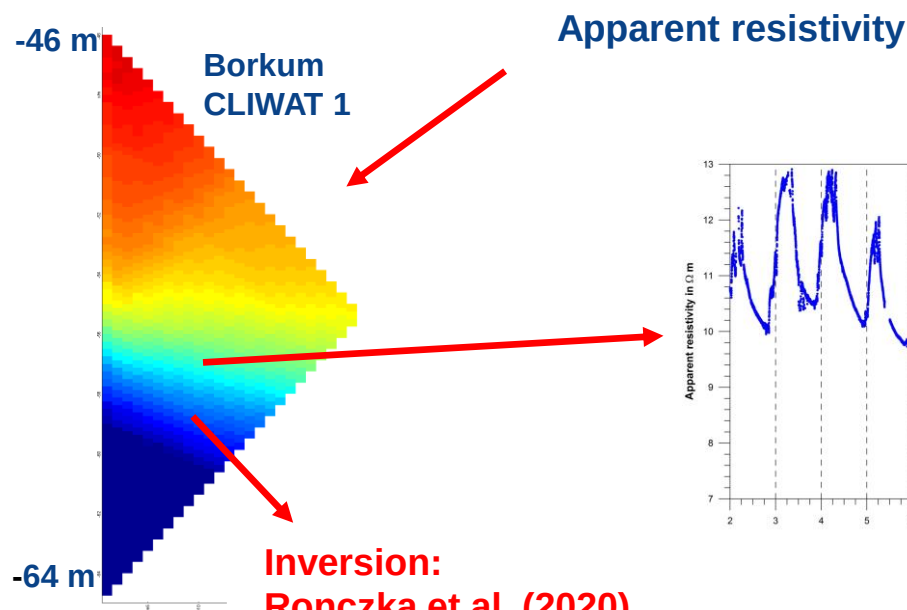
Long-term monitoring of coastal saltwater intrusion using SAMOS

M. Grinat, M. Ronczka, T. Günther, D. Epping, V. Kipke, M. Müller-Petke

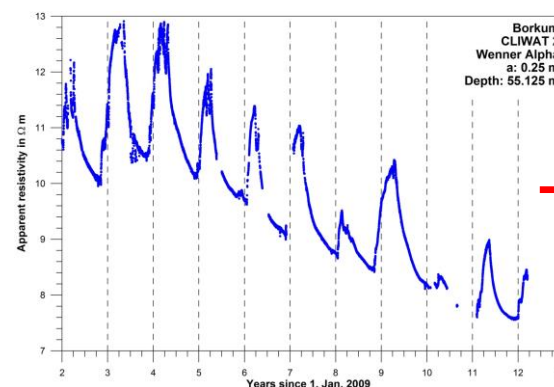
SALTwater MONitoring System SAMOS:

Automated multi-electrode resistivity measurements for

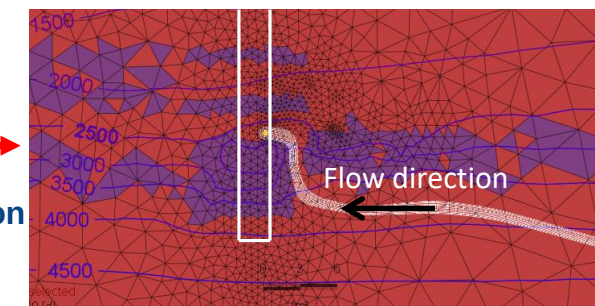
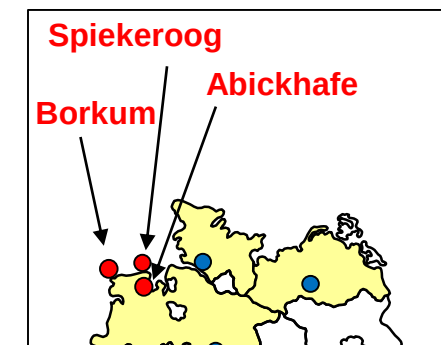
- ❑ Detailed observation of the saltwater-freshwater transition zone
- ❑ Equidistant measurements in a defined depth interval
- ❑ Long-term monitoring



Inversion:
Ronczka et al. (2020)
doi: 10.1002/nsg.12115



Input /
Validation





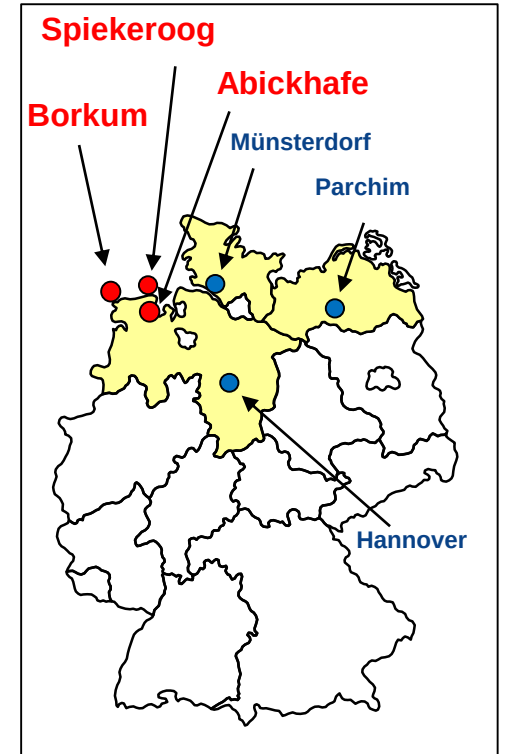
Borkum



Abickhafe



Spiekeroog



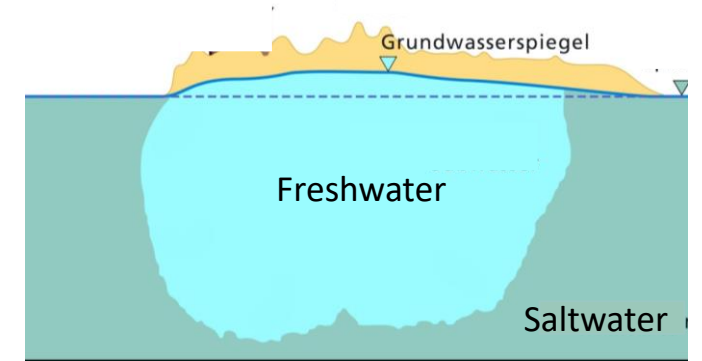
Why a new measuring system?

SAMOS is a resistivity measurement system.

SAMOS enables

- (1) Equidistant measurements in a depth interval**
 - length of vertical electrode chain depends on selected depth interval
- (2) Automated long-term monitoring**
- (3) Measurements in different distances around a borehole**
 - increase the spacing of resistivity measurements

- ❑ Detailed observation of saltwater-freshwater transition zone
- ❑ Recording of small changes
→ borehole necessary!
- ❑ Requirements for the system:
 - self-sufficient (small currents desirable), automated
 - regular data transmission to LIAG



SAMOS consists of two components:

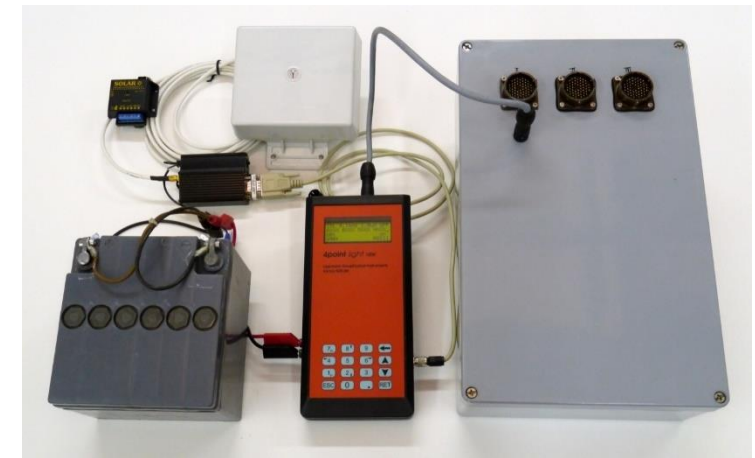
- ❑ **Vertical electrode system in transition zone between freshwater and saltwater (borehole is backfilled)**

→ no modifications possible !



- ❑ **Geoelectrical measuring system at the surface**

→ modifications possible





Running systems:

Since September 2009: Borkum (CLIWAT I & II)
(cooperation with Stadtwerke Borkum)
→ Development of SAMOS



Since December 2018: Abickhufe (go-CAM 1)
(cooperation with Oldenburgisch-Ostfriesischer Wasserverband)

Since March 2020: Spiekeroog (go-CAM 2)
(cooperation with Oldenburgisch-Ostfriesischer Wasserverband)

Vertical electrode system (installation date and installation depth)

LIAG

Borkum
CLIWAT 1 & 2



CLIWAT 1:
10/09/2009
45–65 m

CLIWAT 2:
15/09/2009
44–64 m

Abickhafe
go-CAM 1



12/12/2018
35–55 m

I
Solexperts

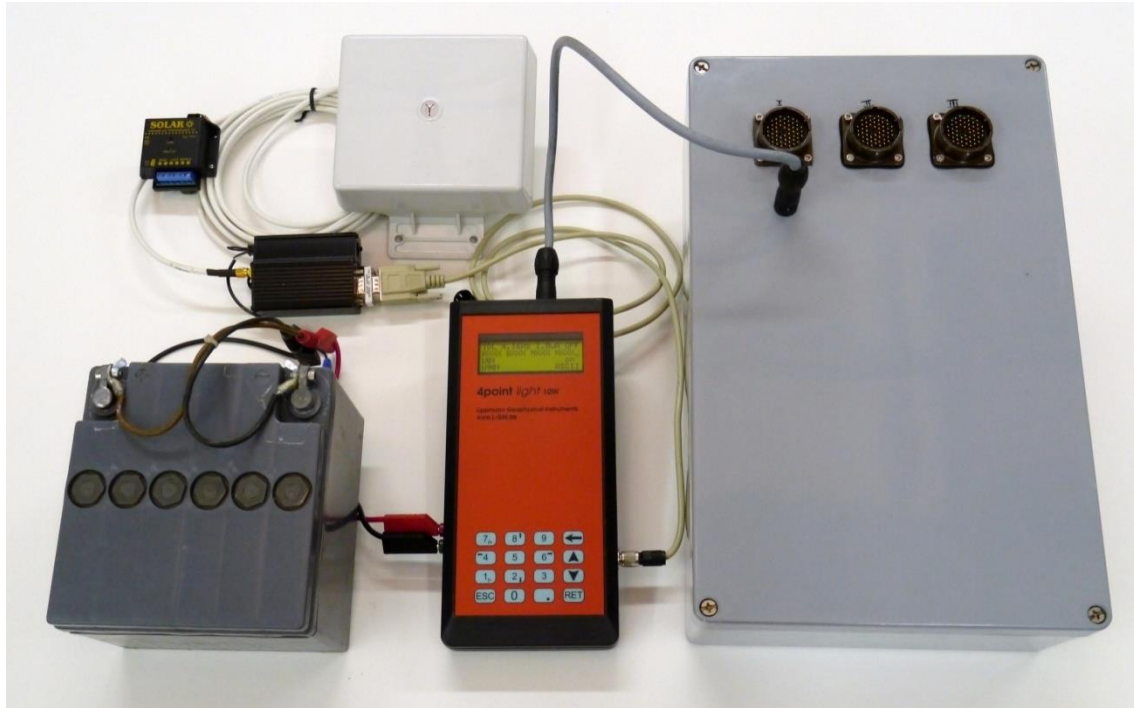
II

Spiekeroog
go-CAM 2



12/03/2020
29–53 m

Geoelectrical measuring system with scanner and data transmission



❑ Measuring system: 4point light 10W

Cooperation with **LM Lippmann**
Geophysikalische Messgeräte

❑ Scanner for ~80 electrodes

❑ GPRS for data transmission

❑ Antennae

❑ Power: batteries and solar panel

SAMOS installations at the surface



Borkum: CLIWAT 1
since 09/2009
(Photo 2019)



Borkum: CLIWAT 2
since 09/2009
(Photo 2019)

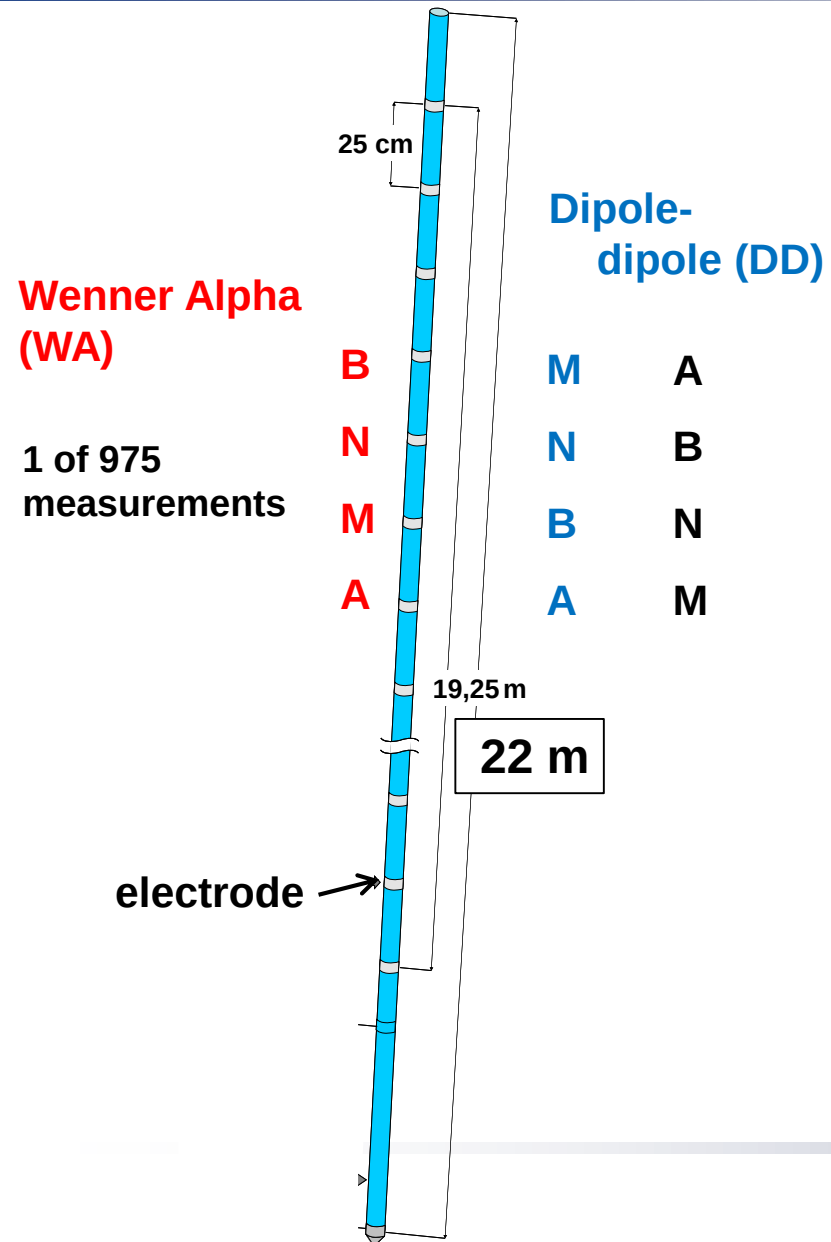


Abickhafe: go-CAM 1
since 12/2018
(Photo 2020)

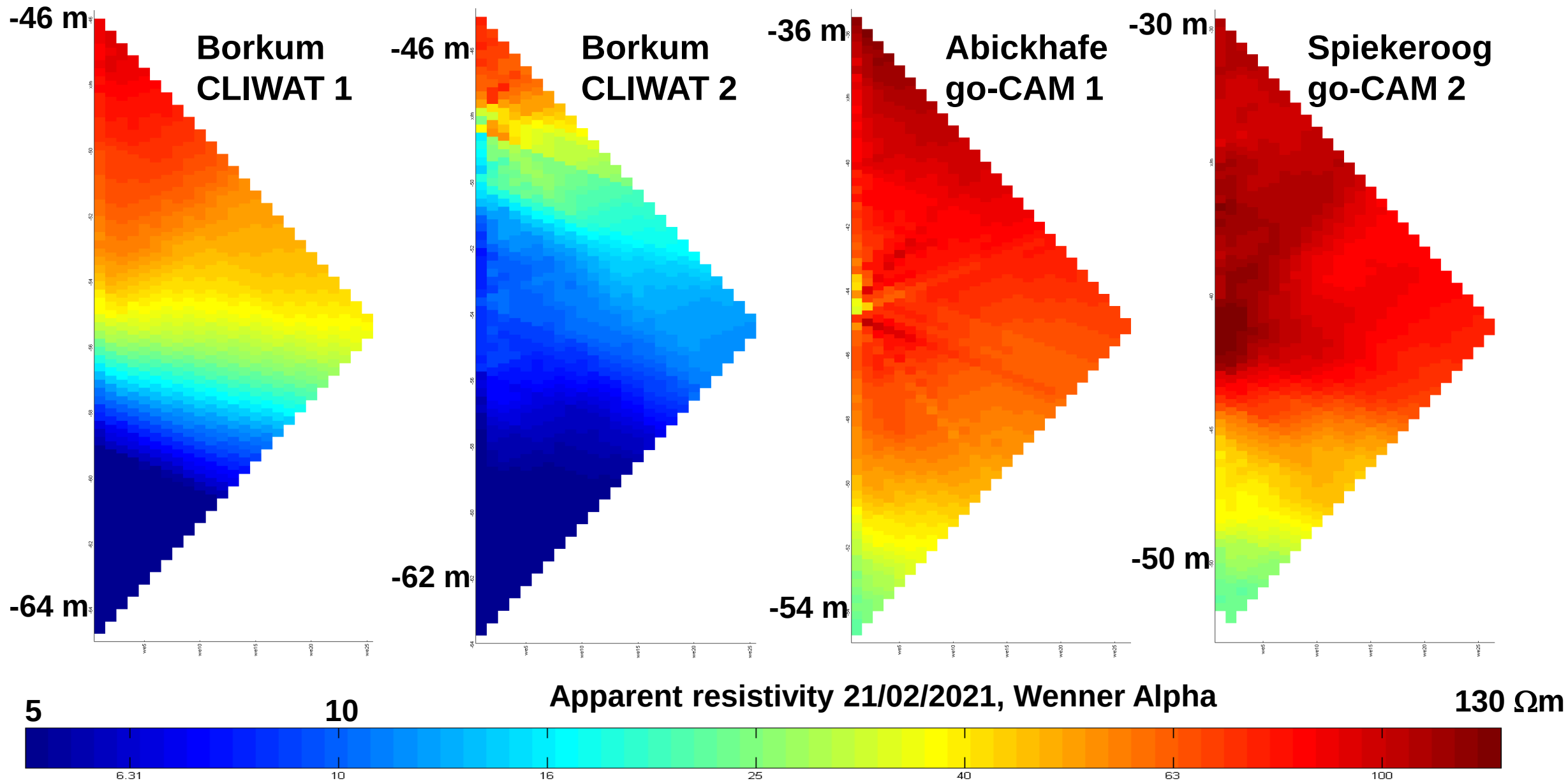


Spiekeroog: go-CAM 2
since 06/2020
(Photo 2020)

Electrode arrays used for the measurements



Data:



Ronczka et al. (2020):
Near Surface Geophysics 18, 369-383
doi: 10.1002/nsg.12115

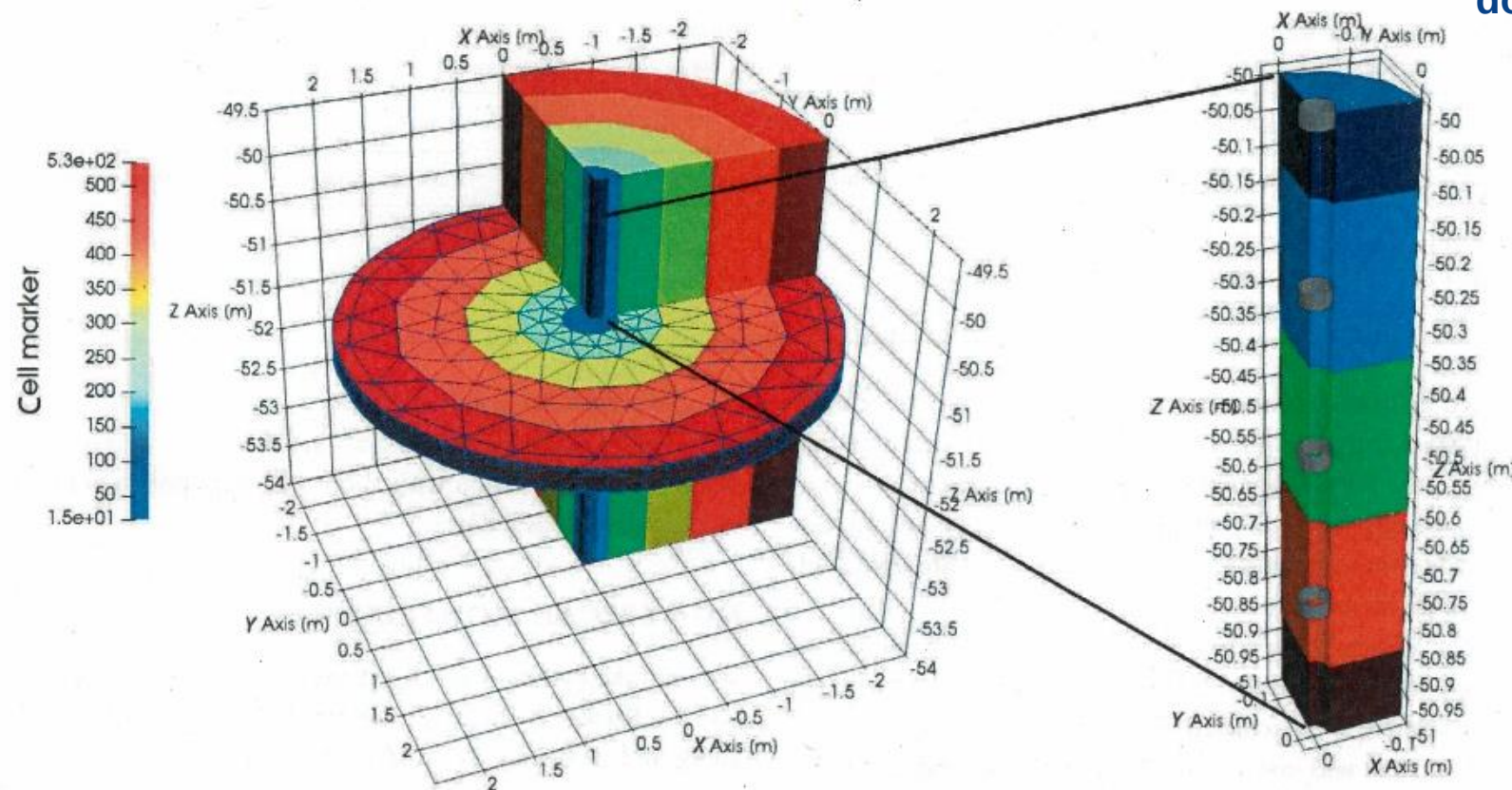
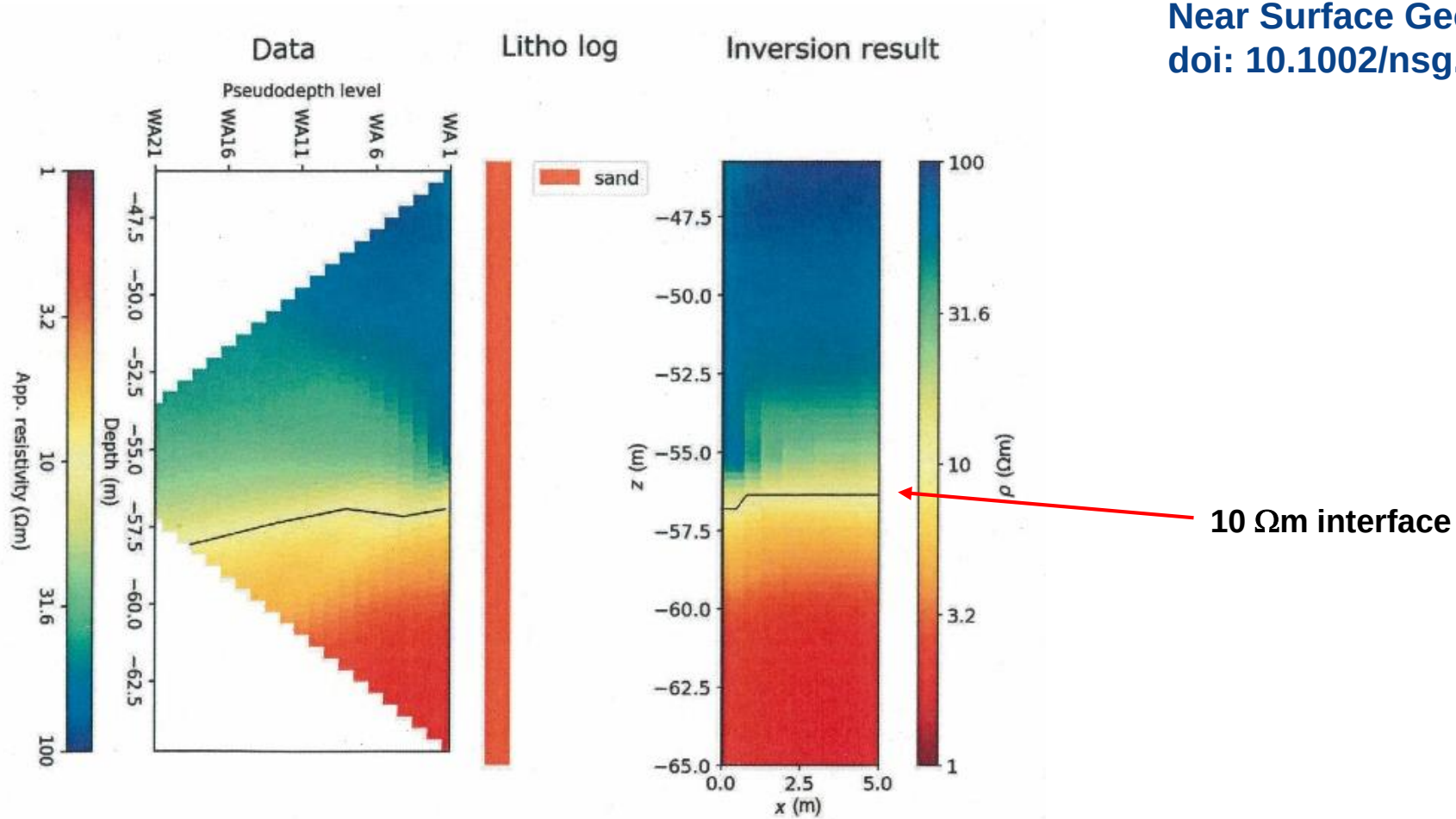


Figure 6 Cylindrically symmetric FE mesh, with a horizontal slice showing the cell marker distribution (left). The right side shows an enlarged version of the inner cylindrical segment and its vertical marker distribution including facets representing ring electrodes (grey).

Ronczka et al. (2020):
Near Surface Geophysics 18, 369-383
doi: 10.1002/nsg.12115



Ronczka et al. (2020):
Near Surface Geophysics 18, 369-383
doi: 10.1002/nsg.12115

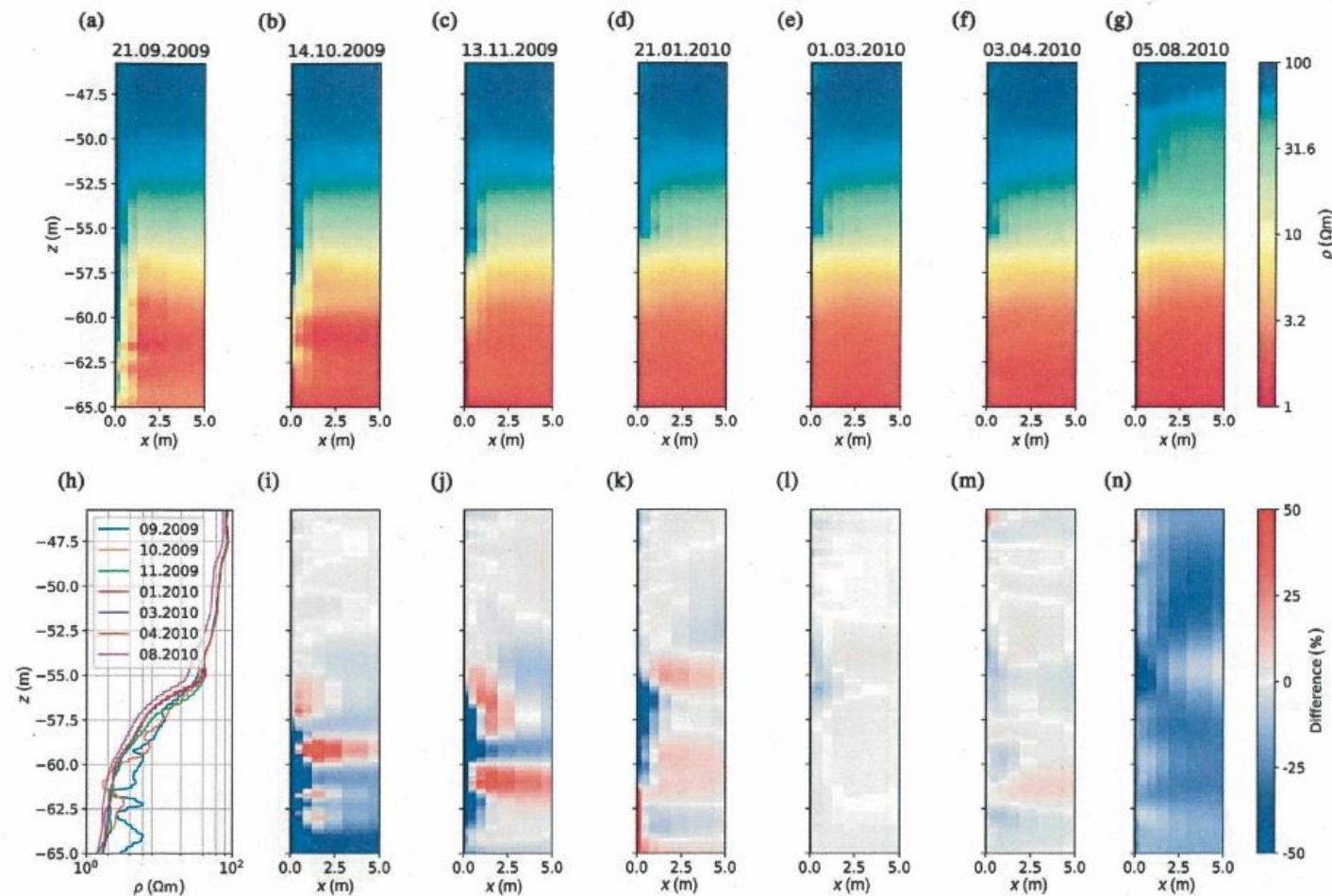


Figure 10 Dynamic inversion results from CLIWAT1, showing absolute resistivities (top) and relative differences towards the previous time step. Resistivities at 1 m distance from the electrode chain are shown in (h) for all time steps.

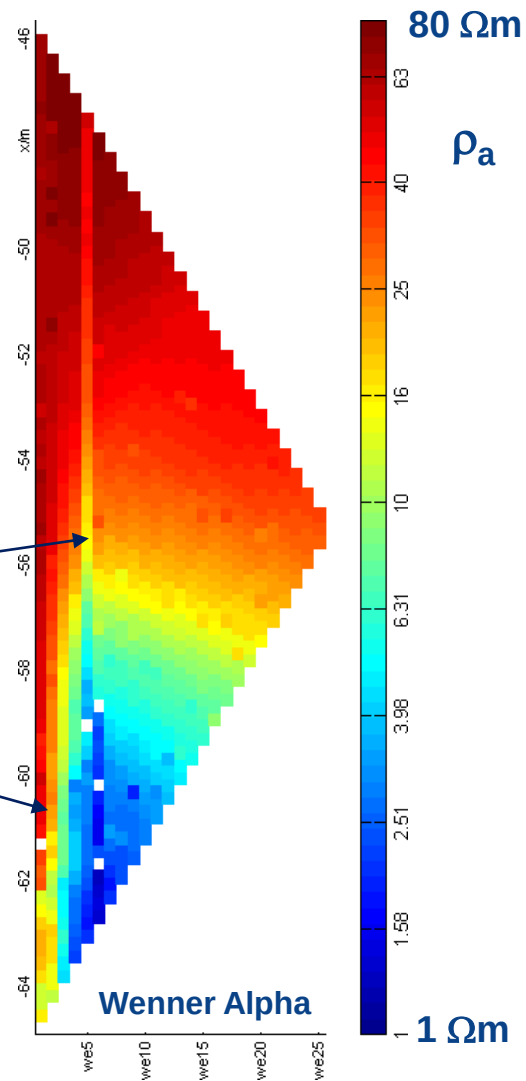
Borkum CLIWAT 1

Two effects:

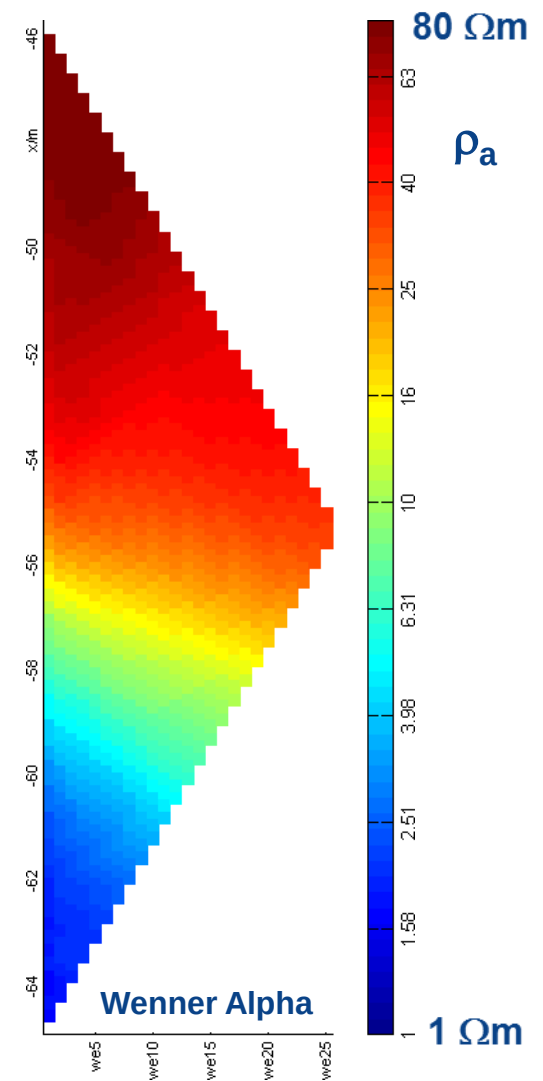
(a) Instrumental errors

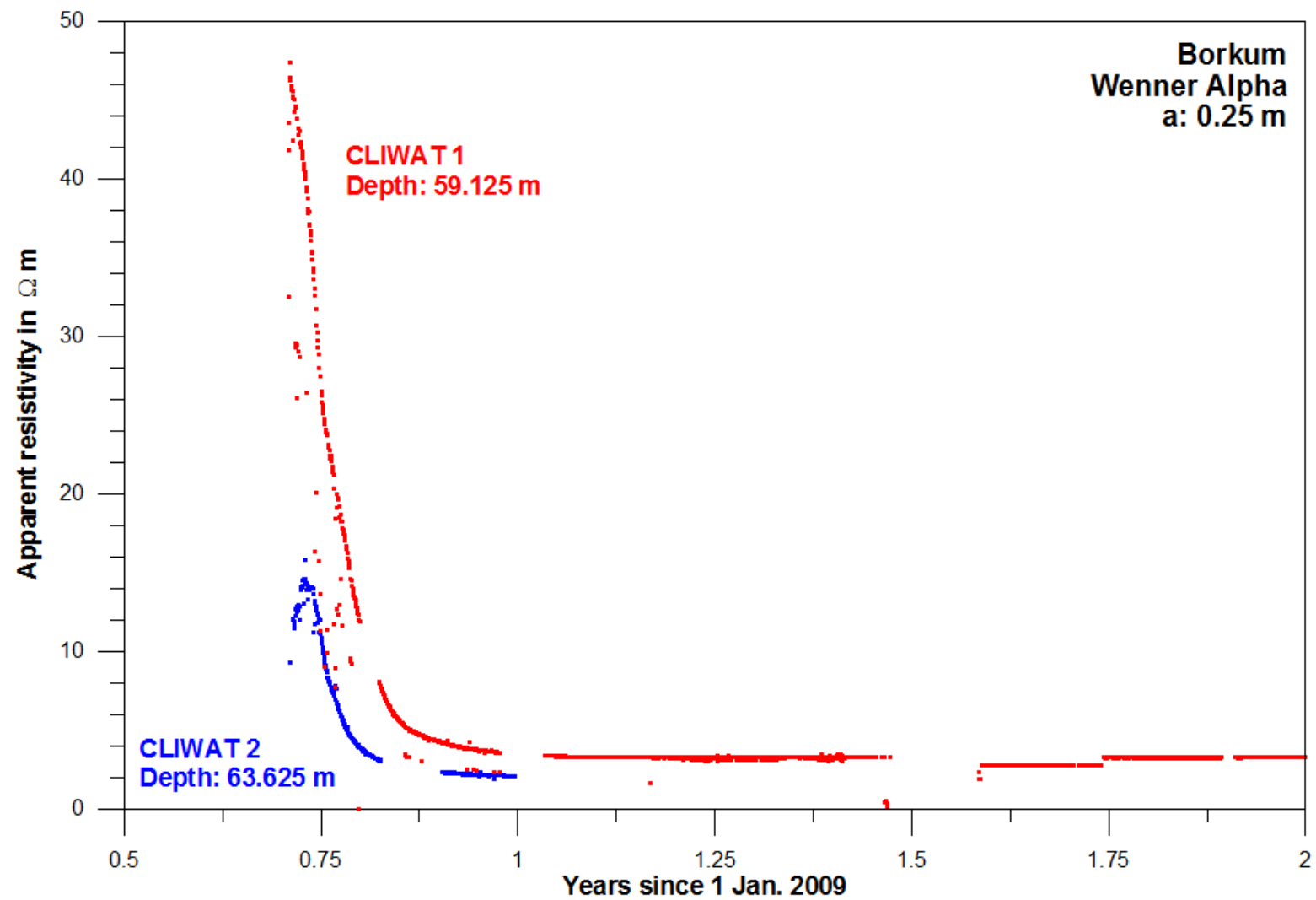
(b) Drilling influence
(small spacings)

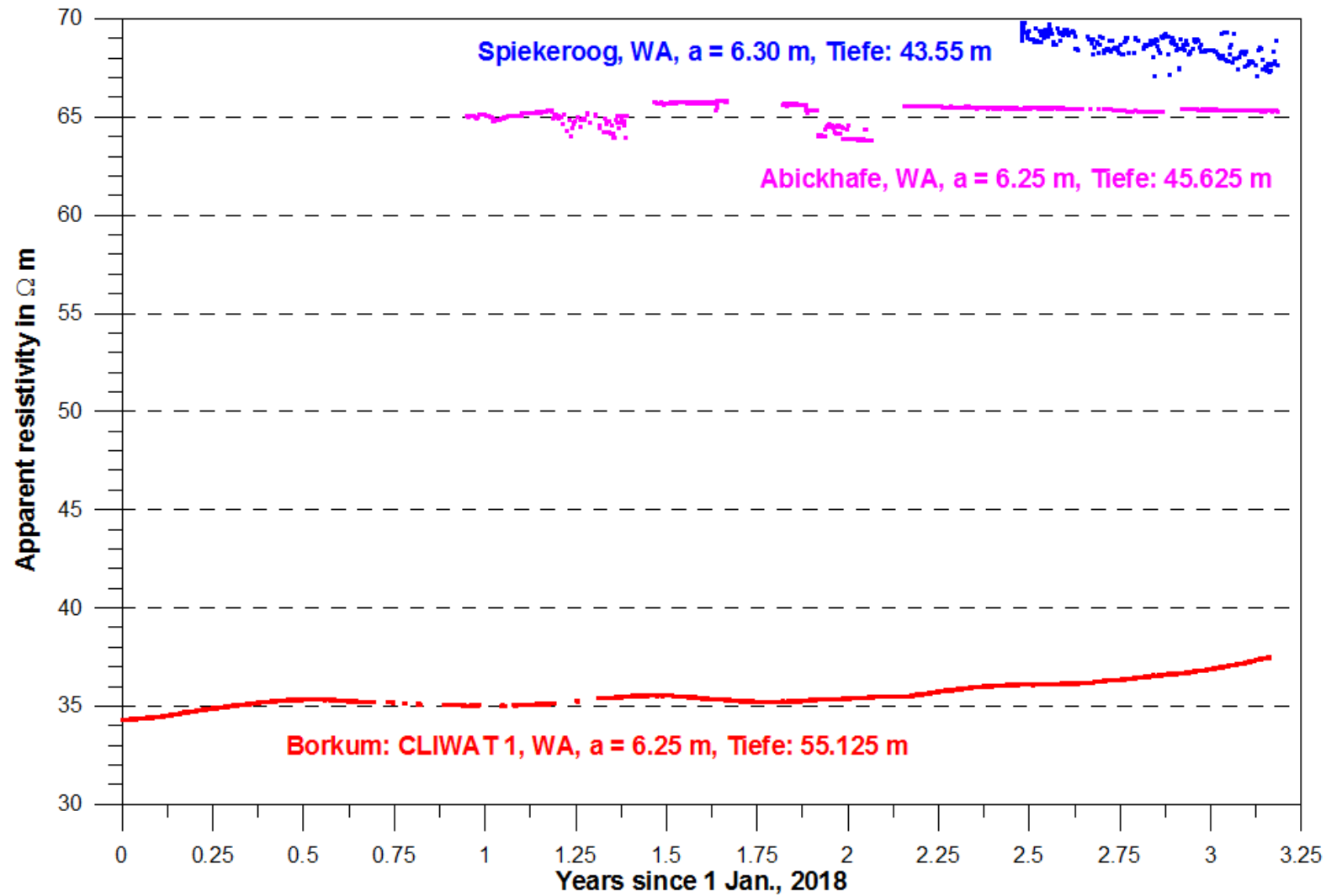
17/09/2009, 13:00 h



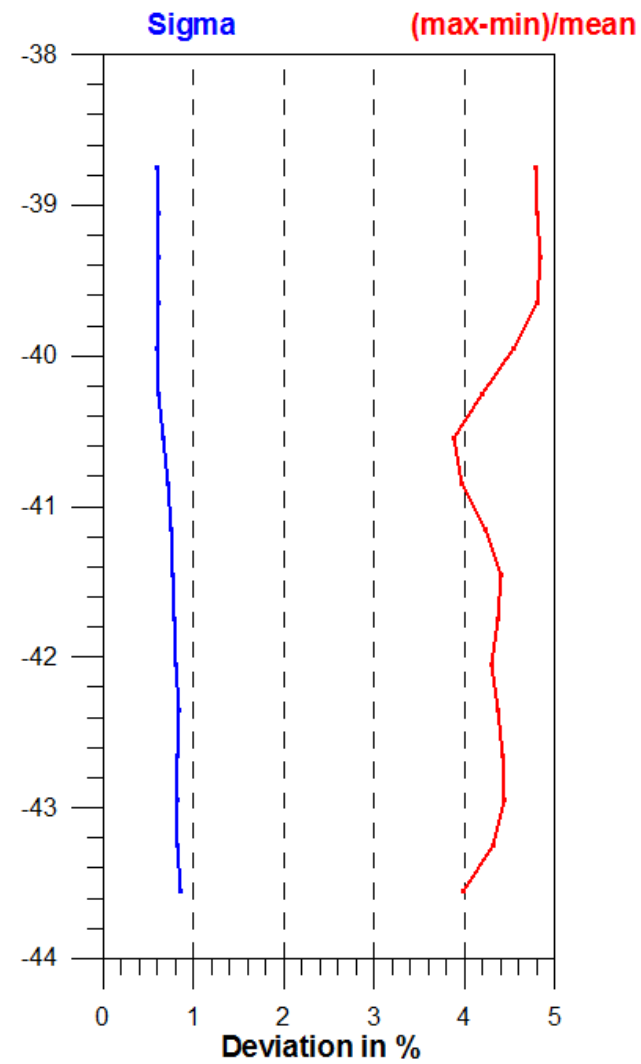
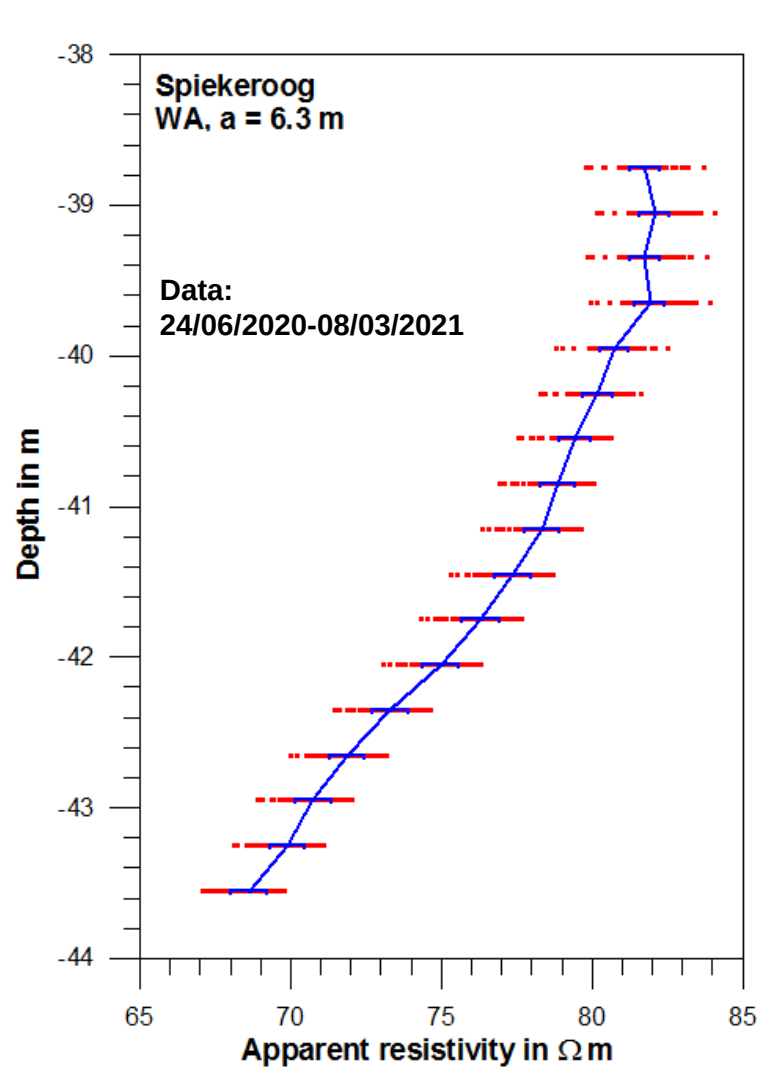
21/01/2019, 17:35 h

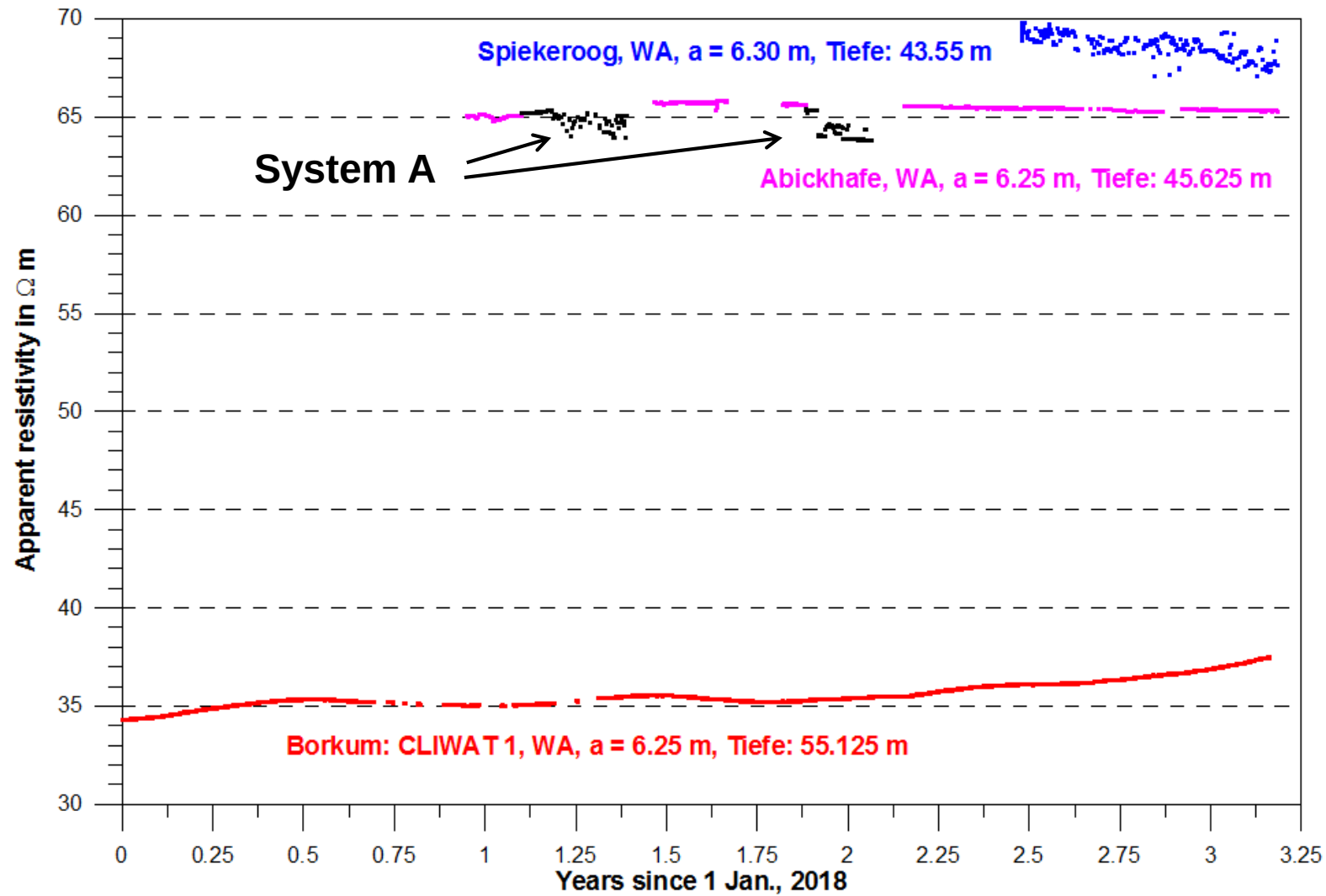




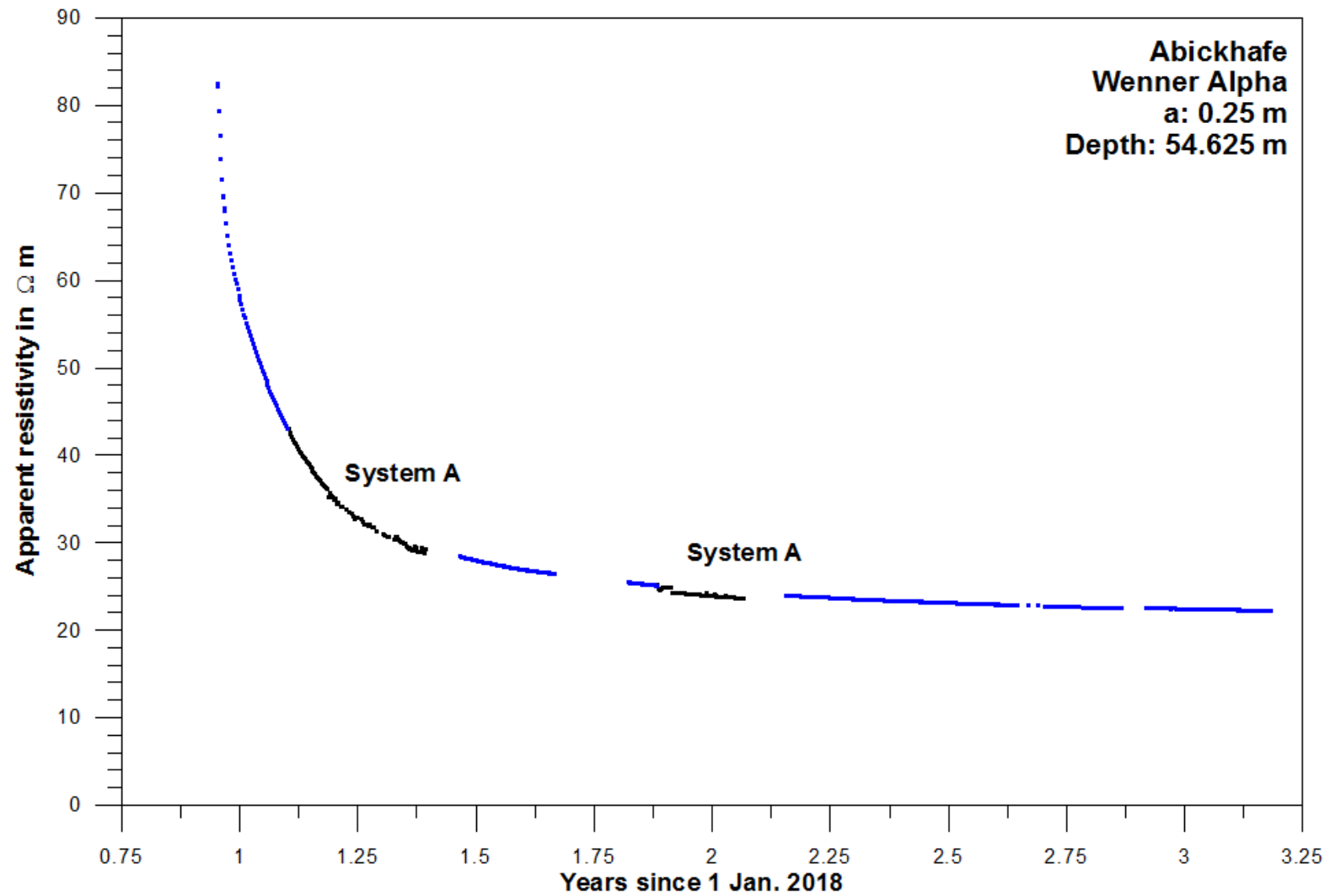


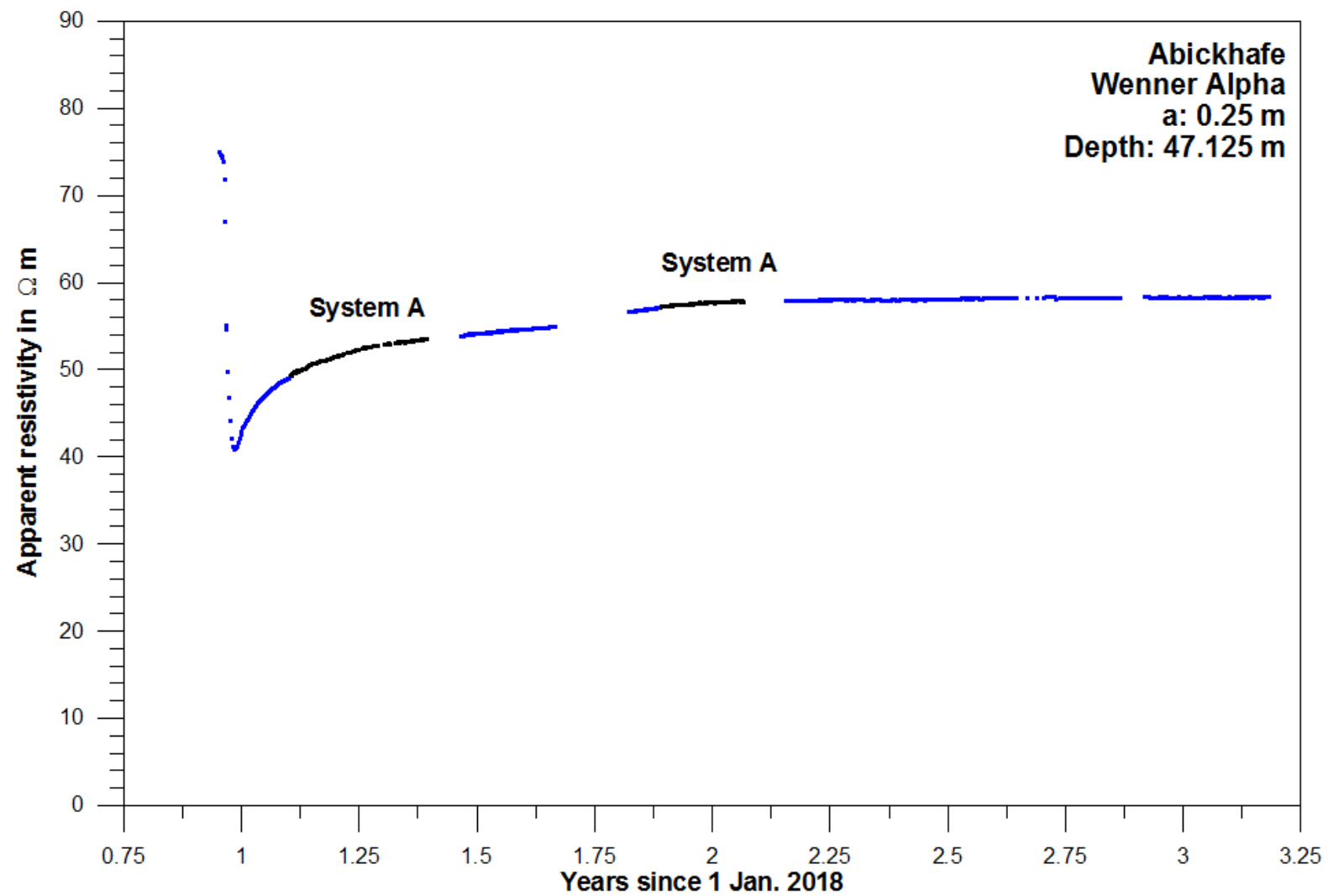
System A

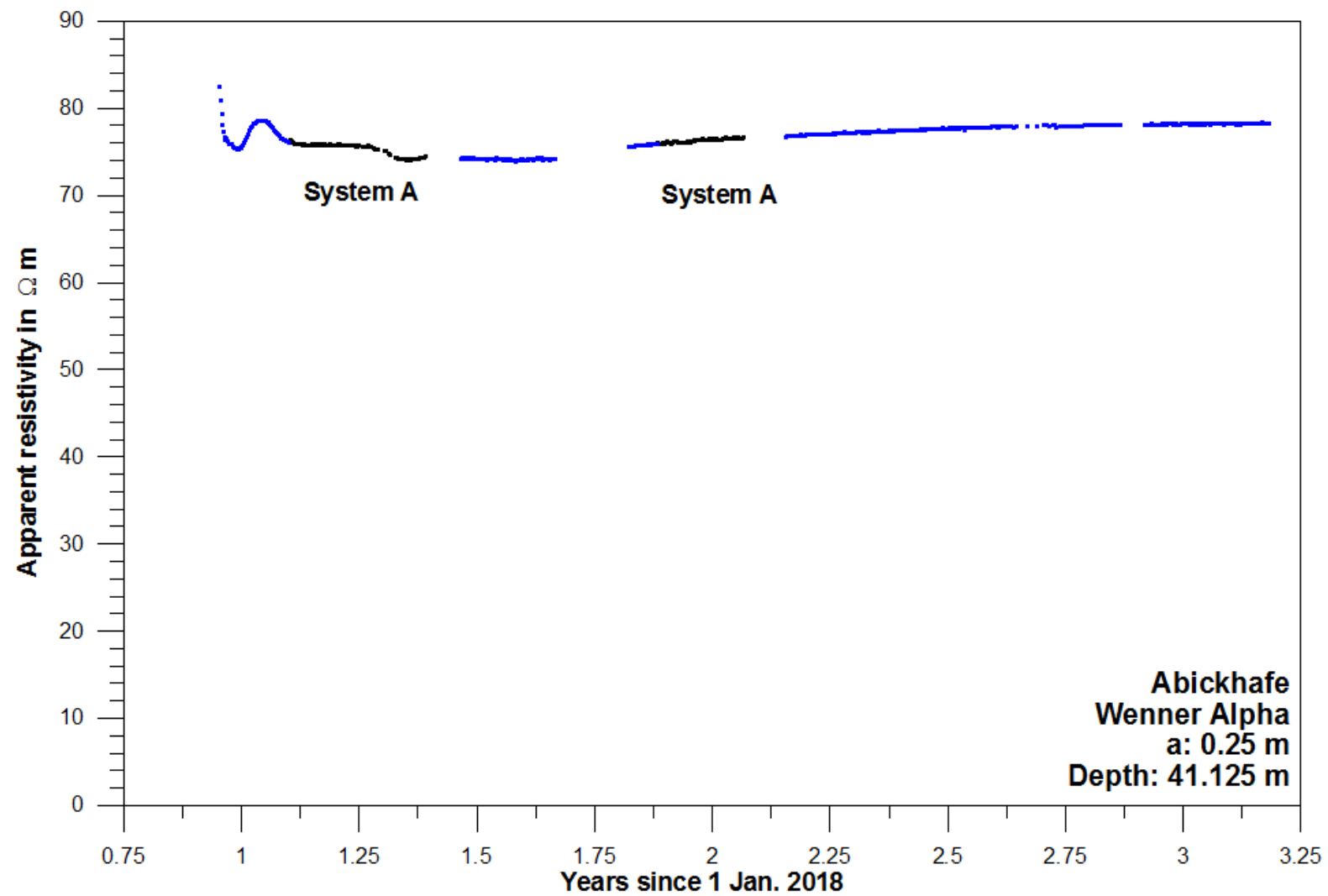


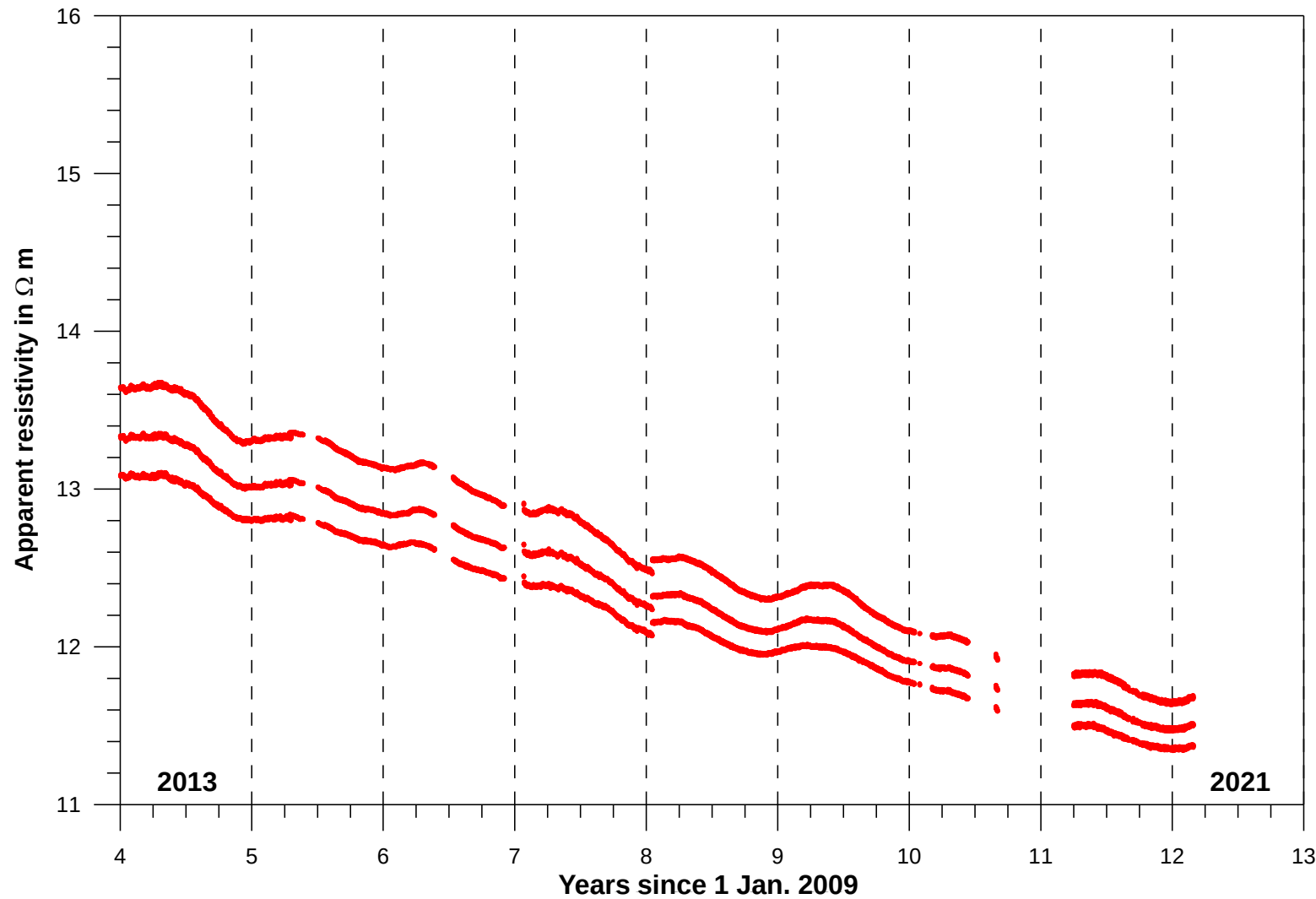


System A





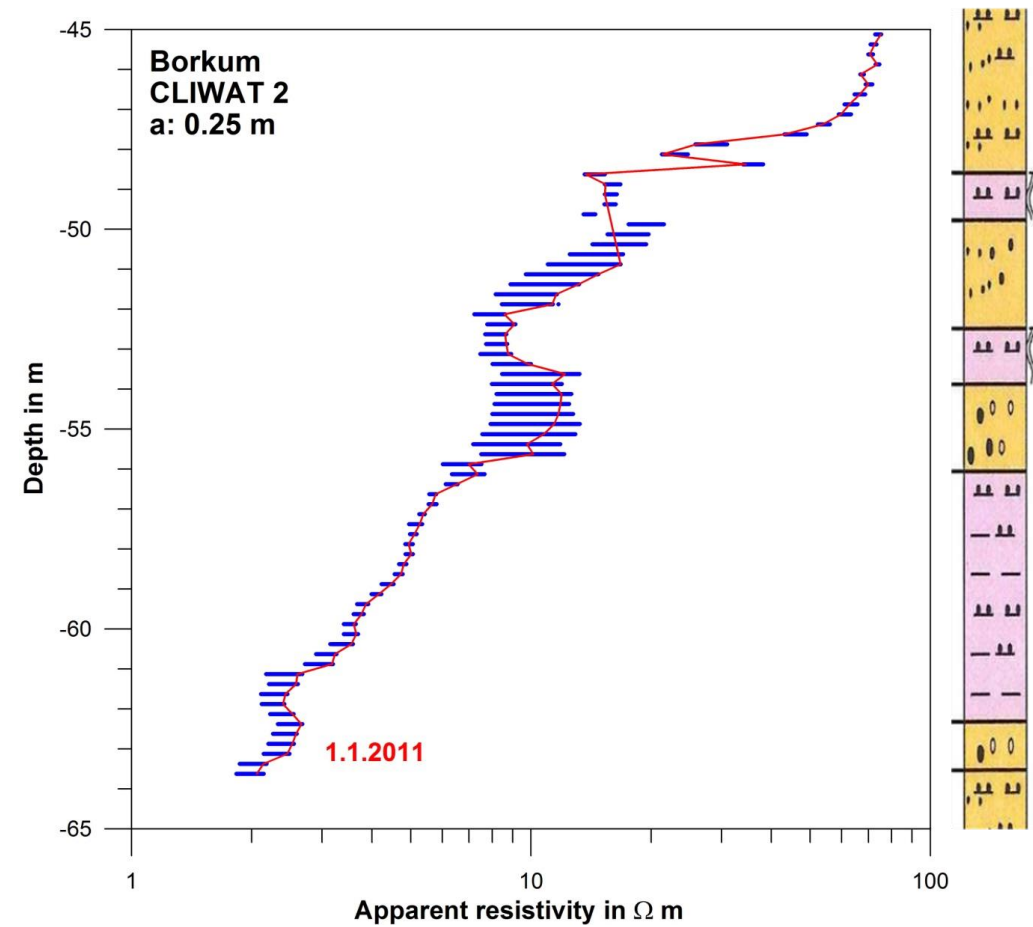
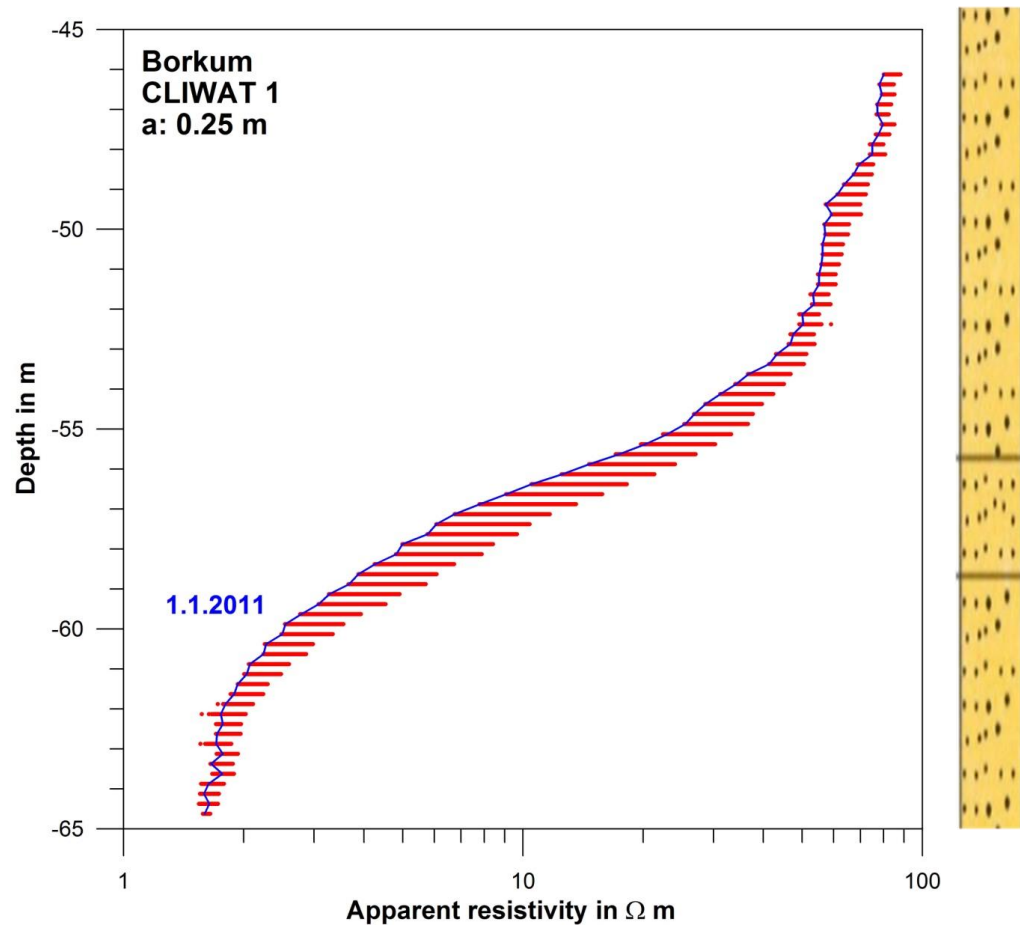




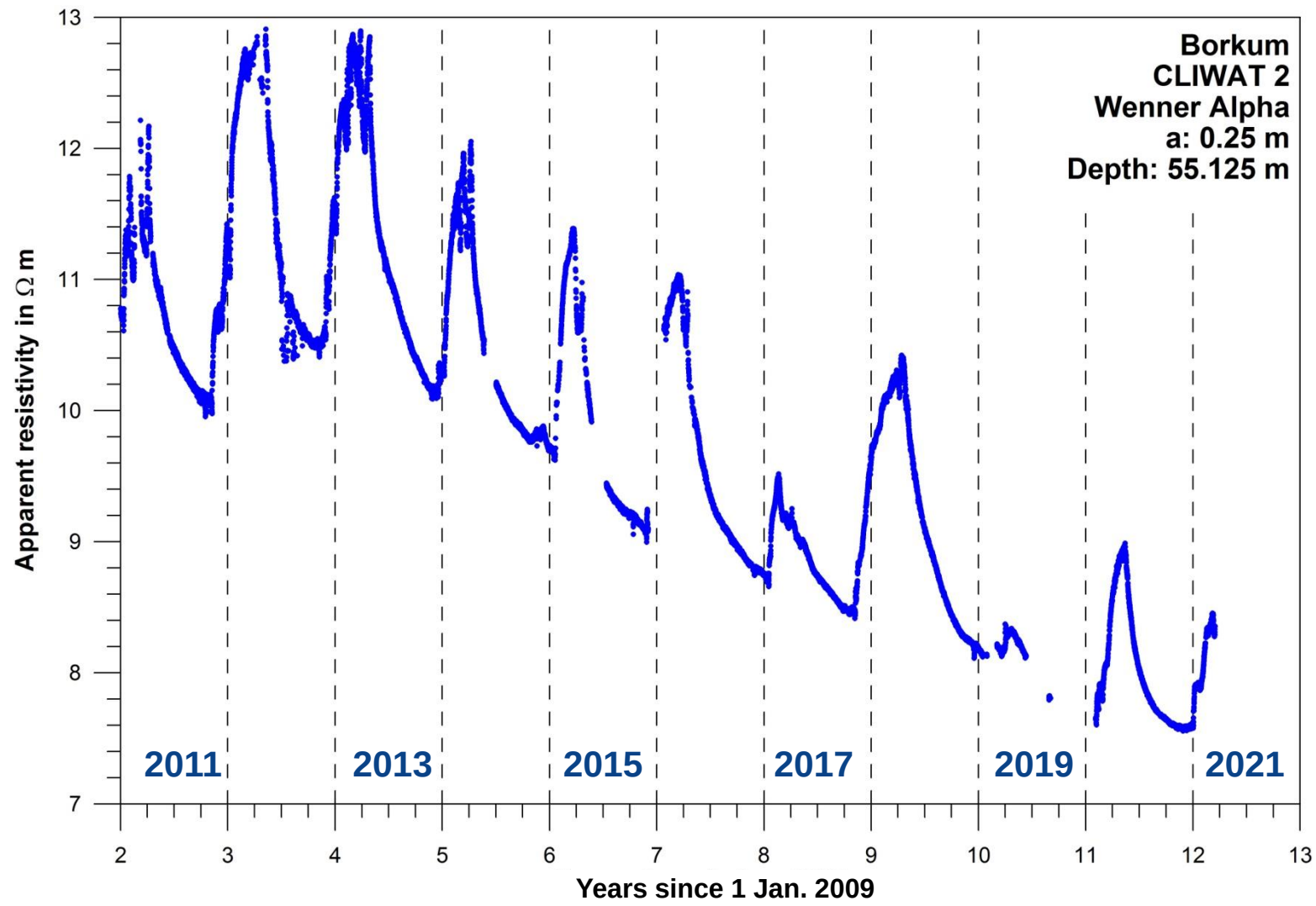
Borkum CLIWAT 2

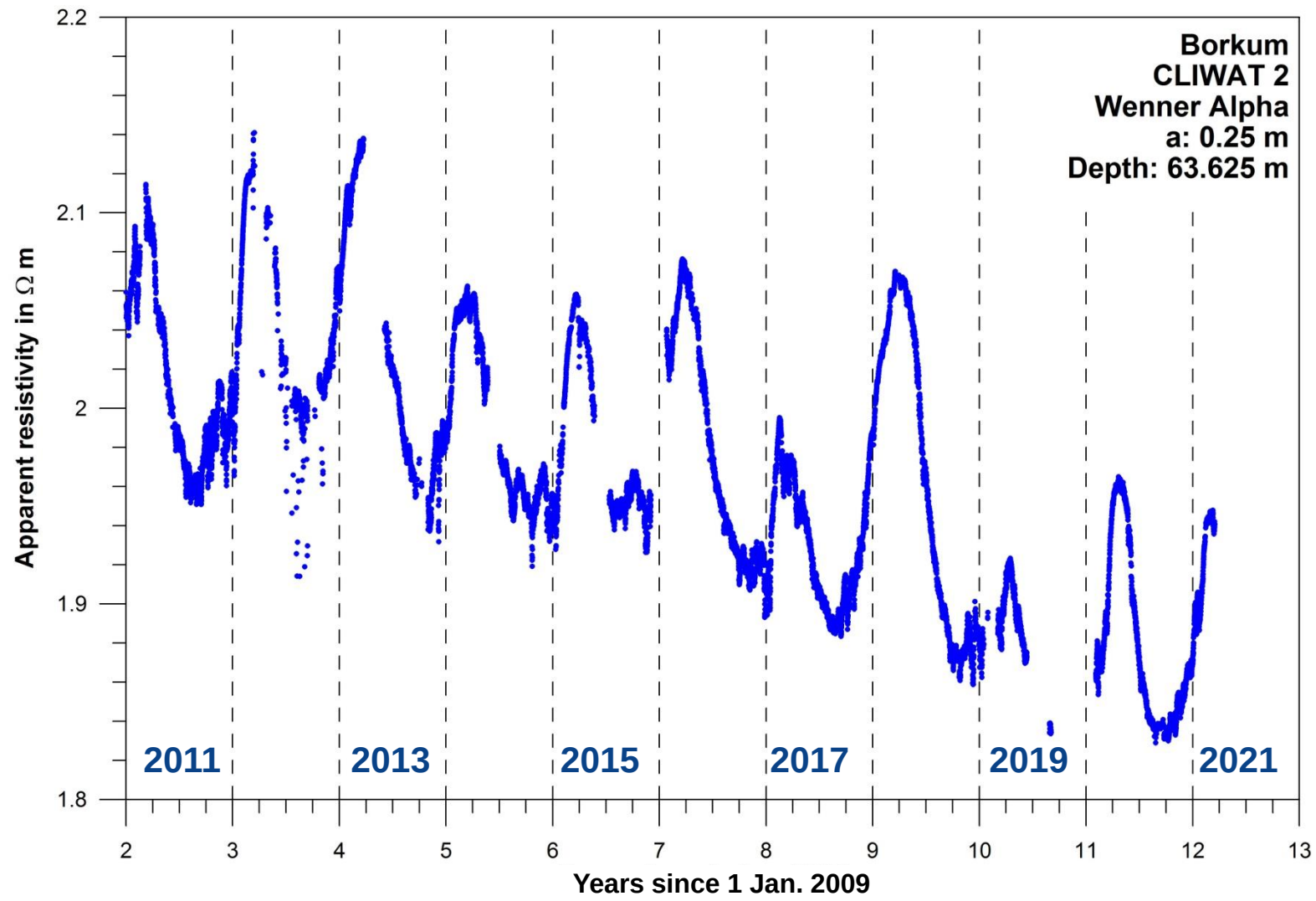
a: 6.25 m
(max. spacing)

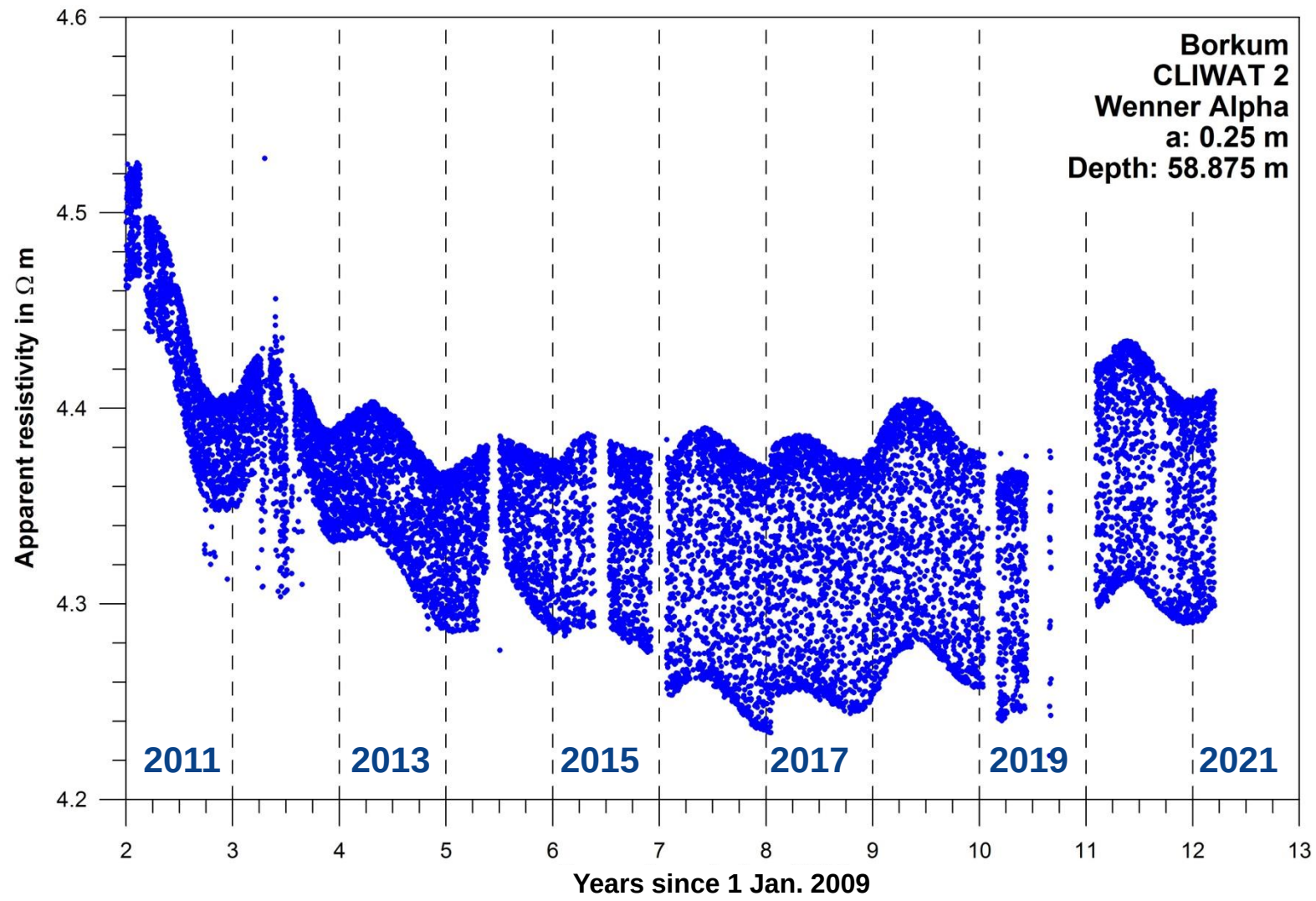
Depths:
54.125 m
54.375 m
54.625 m

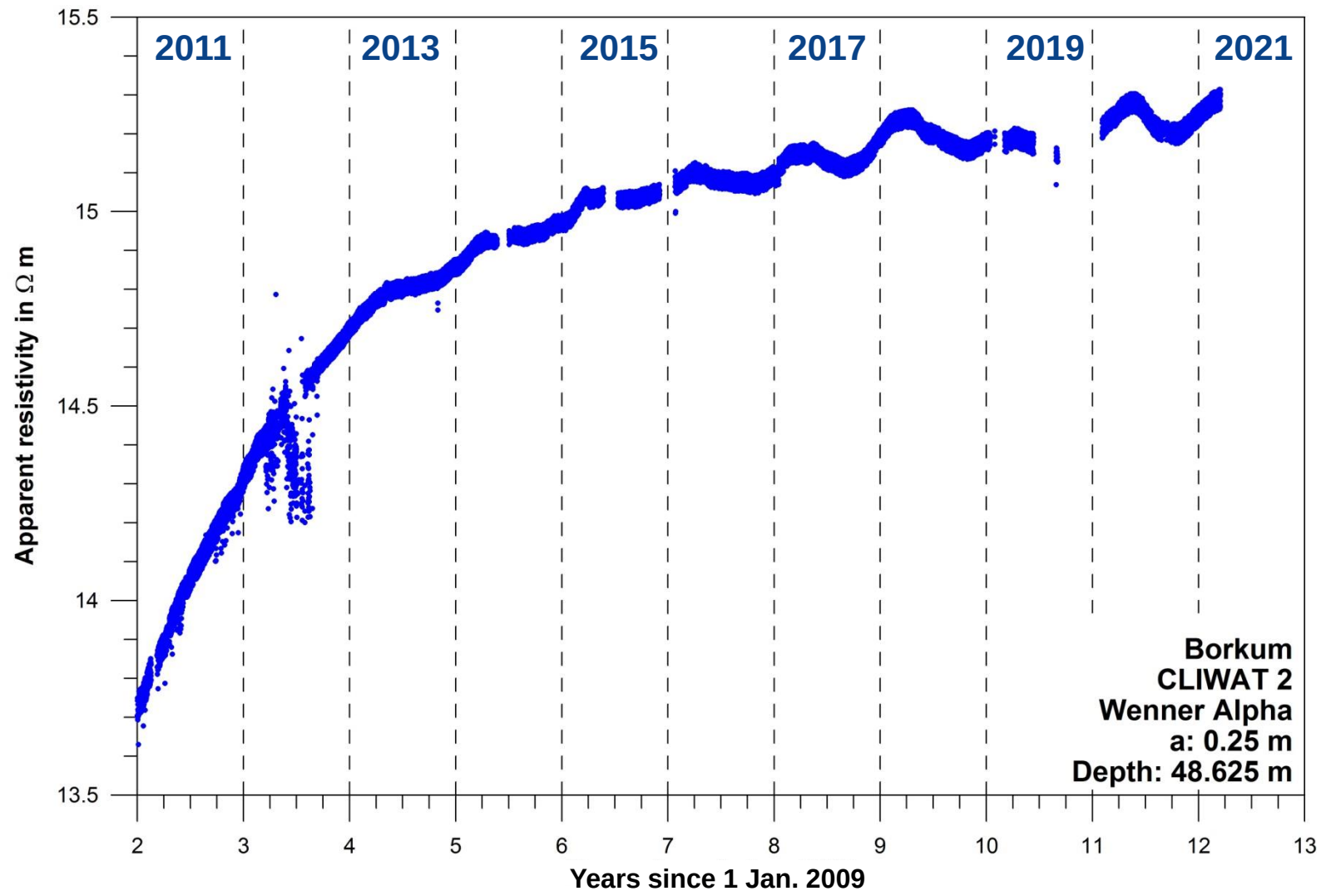


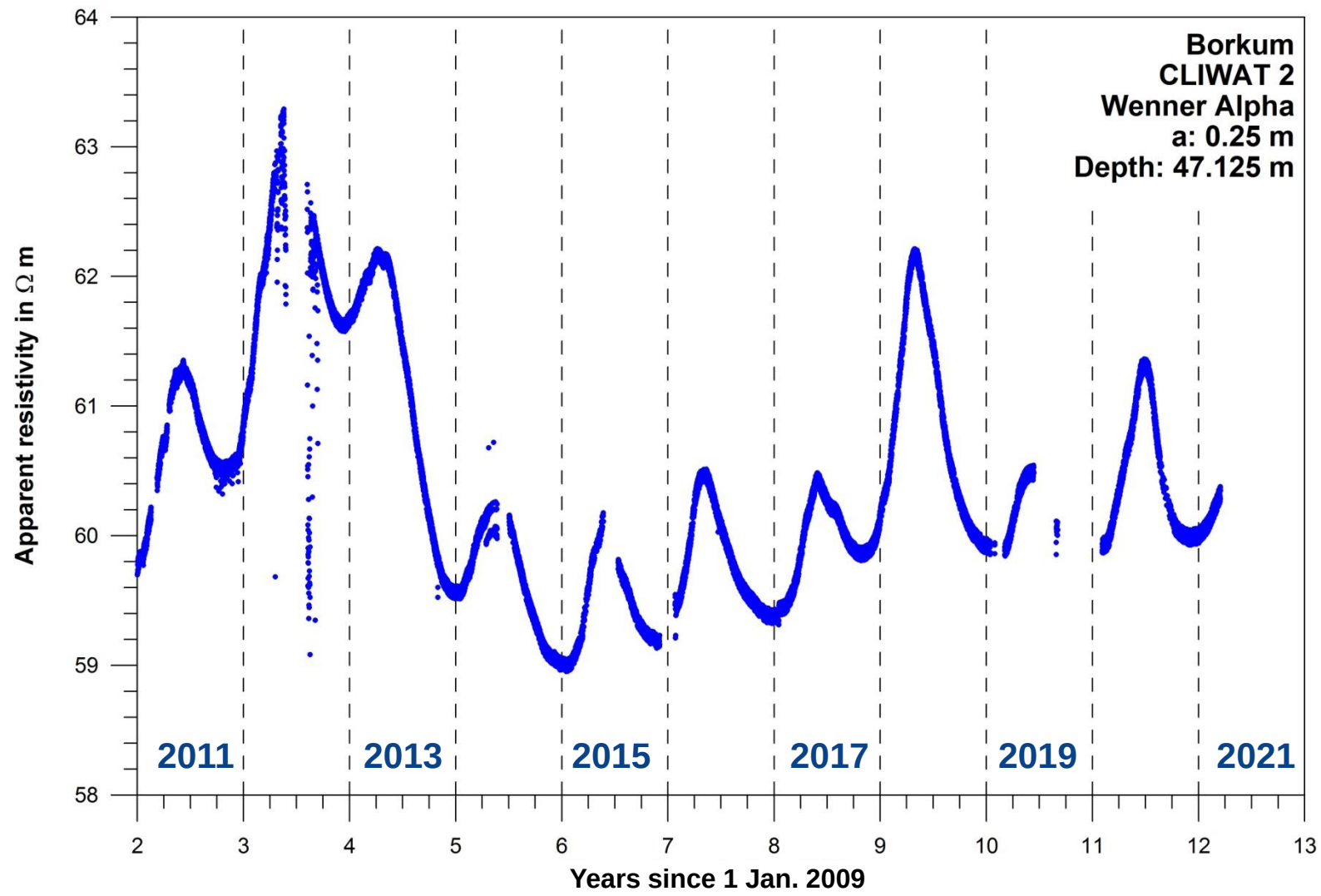
Wenner Alpha, data: 01/01/2011 – 17/03/2021

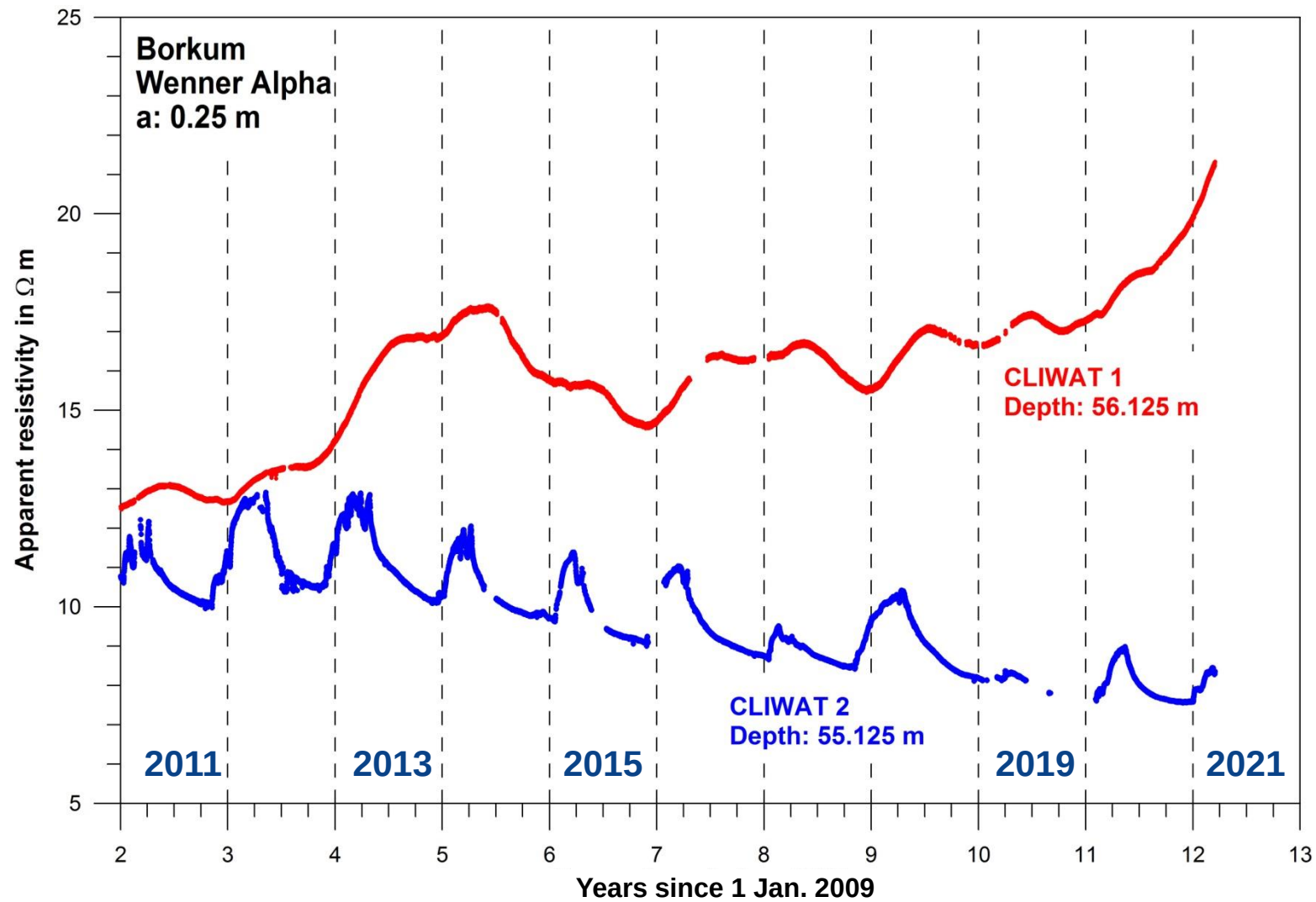


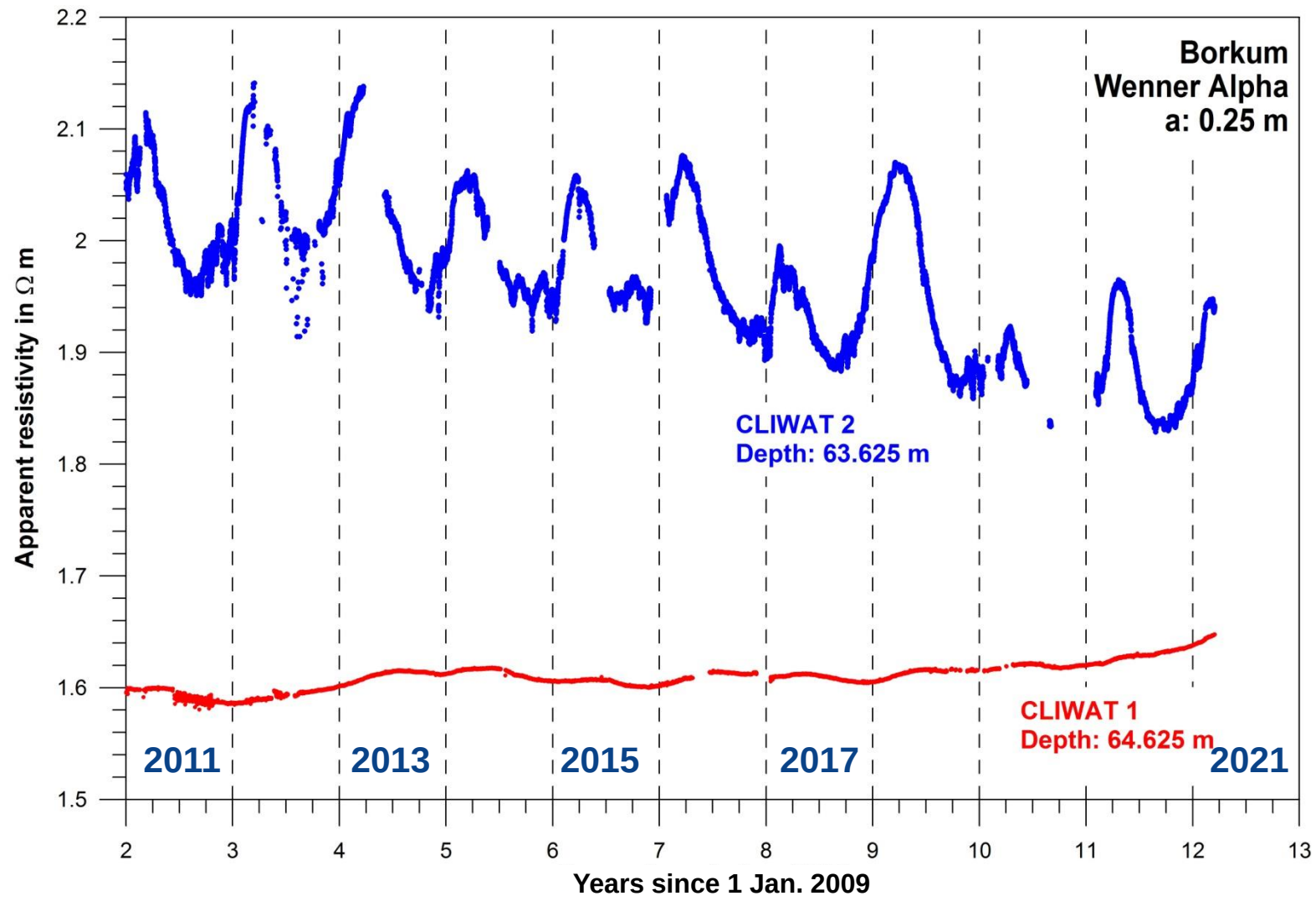


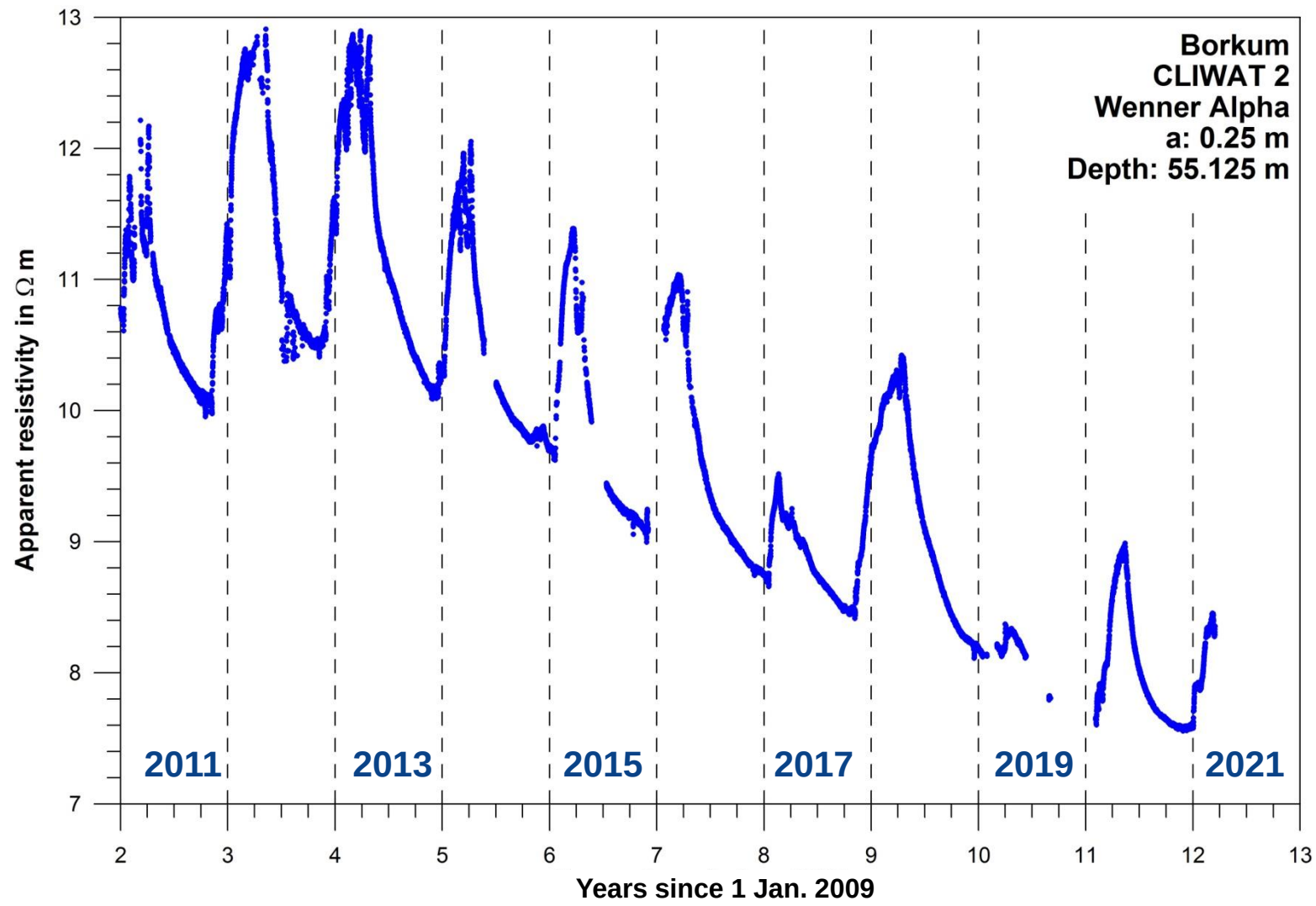






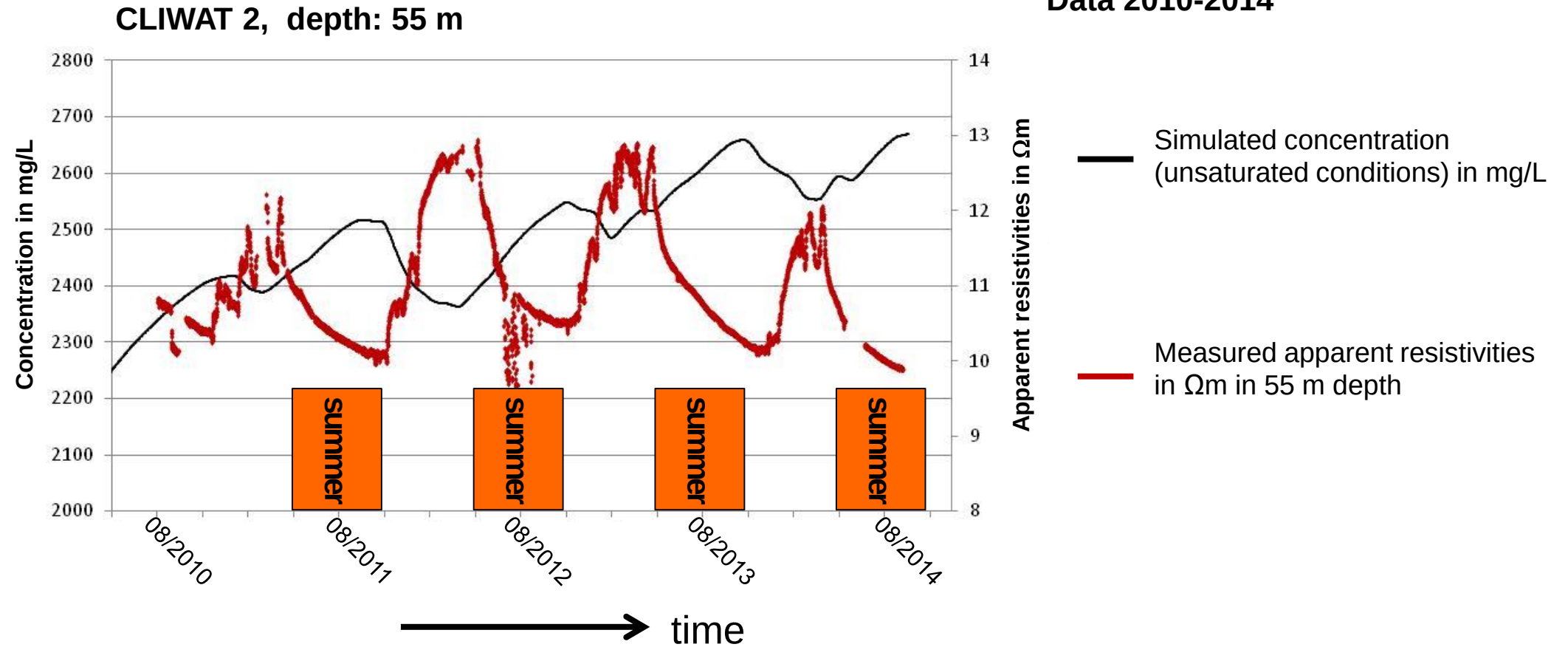






Results of 2-D density dependent groundwater flow model

Master Thesis M. Ibenthal (2015):
Data 2010-2014



Concentrations inverse proportional to resistivities

Results of 2-D density dependent groundwater flow model

Input parameters:

- Monthly groundwater recharge rates
- Monthly pumping rates

Low pumping capacity:

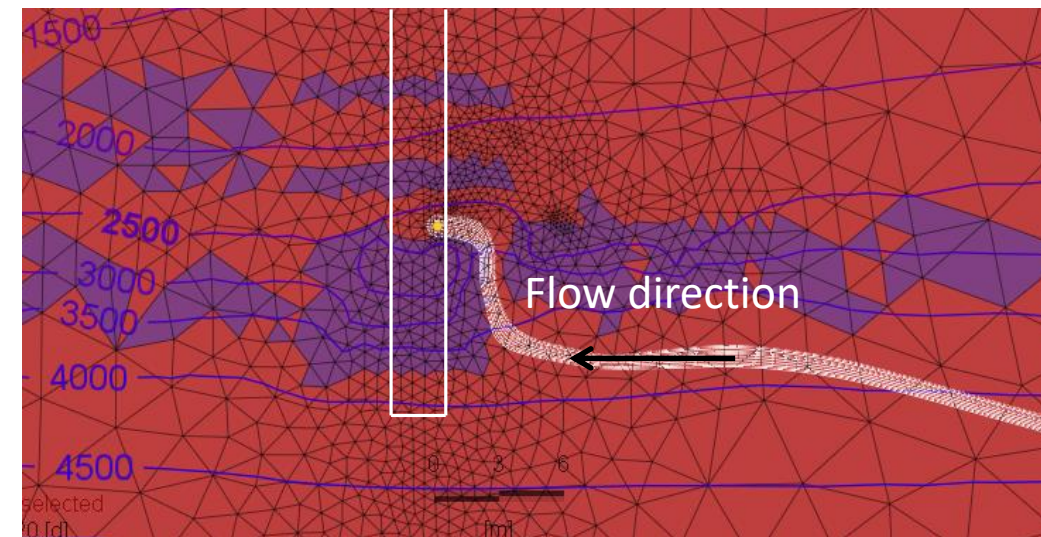
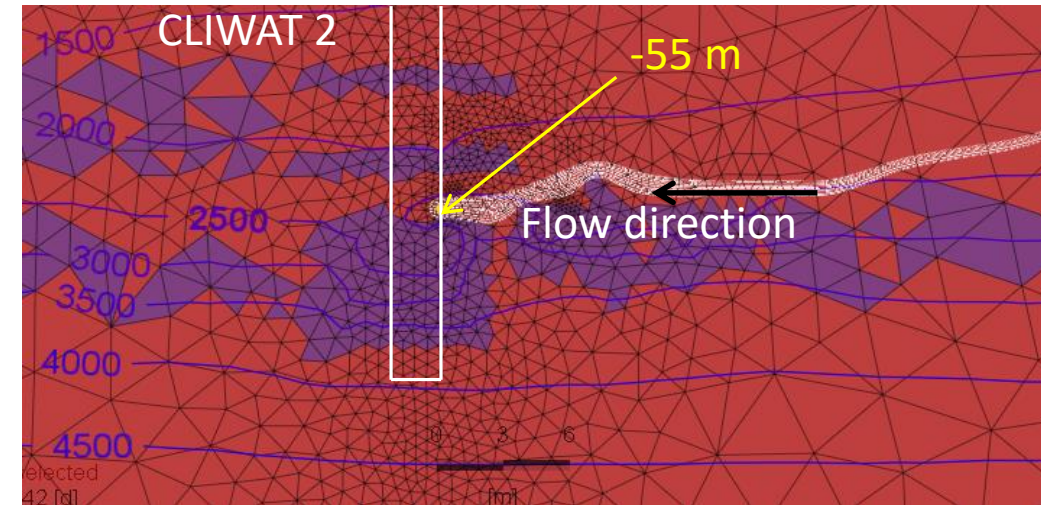
Only water with low salt concentrations extracted

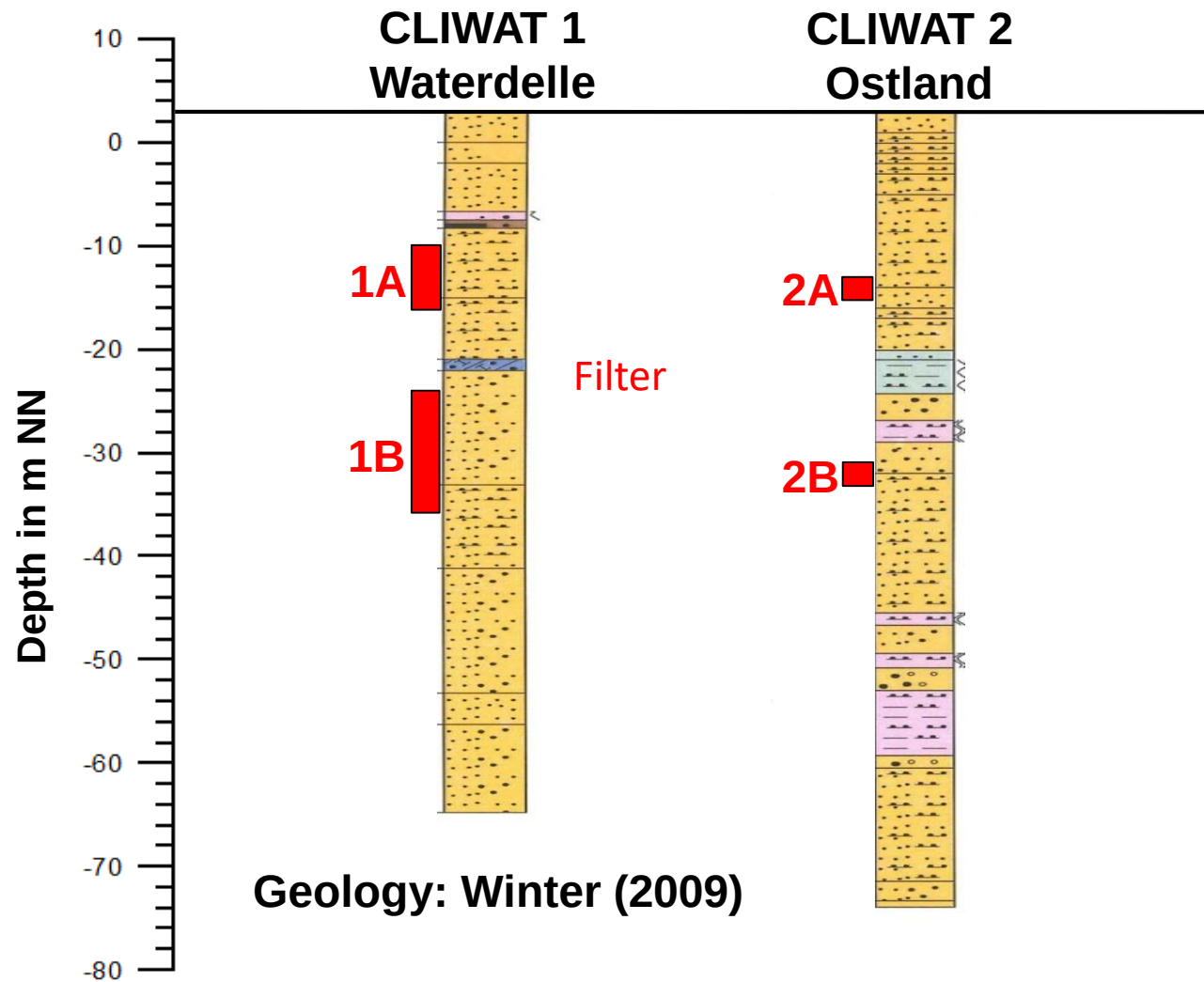
→ Higher resistivities

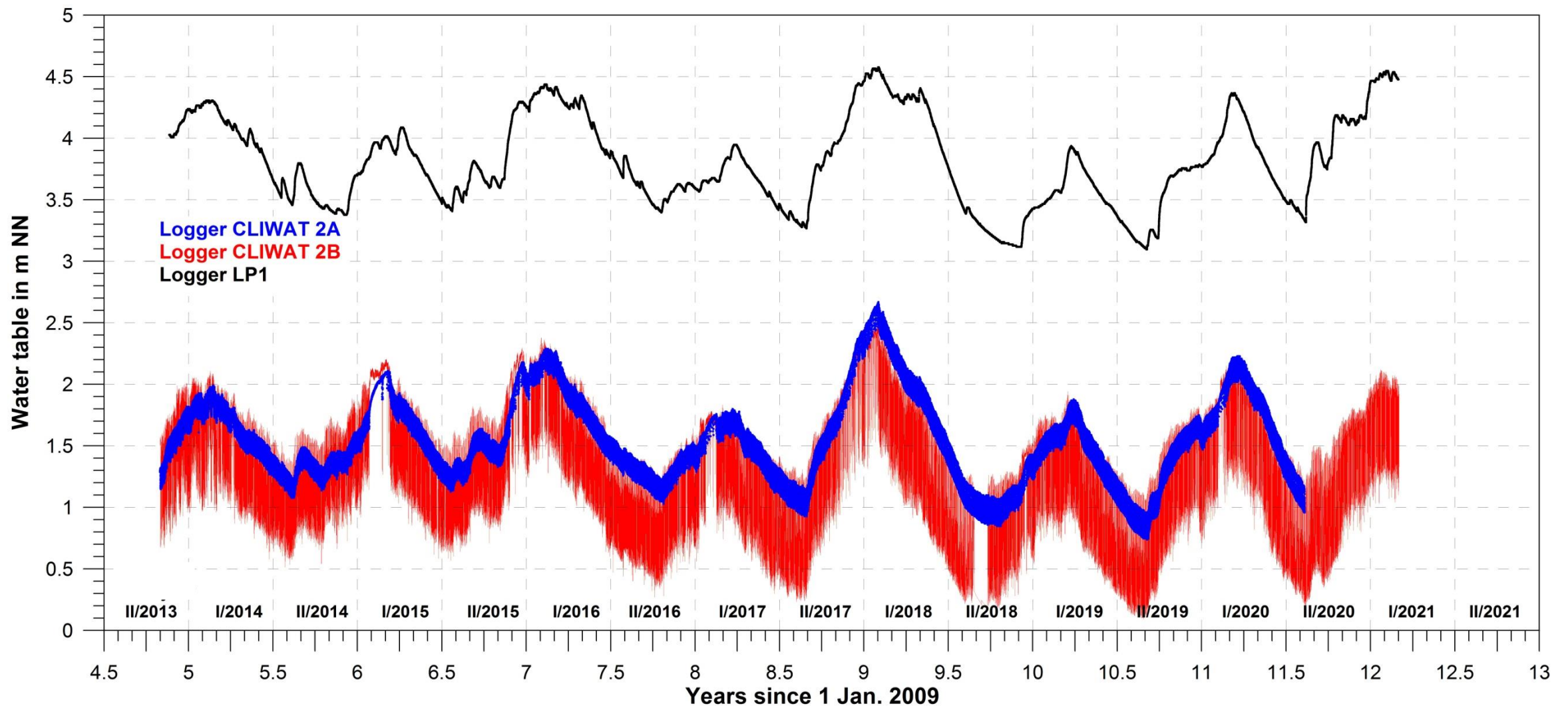
High pumping capacity:

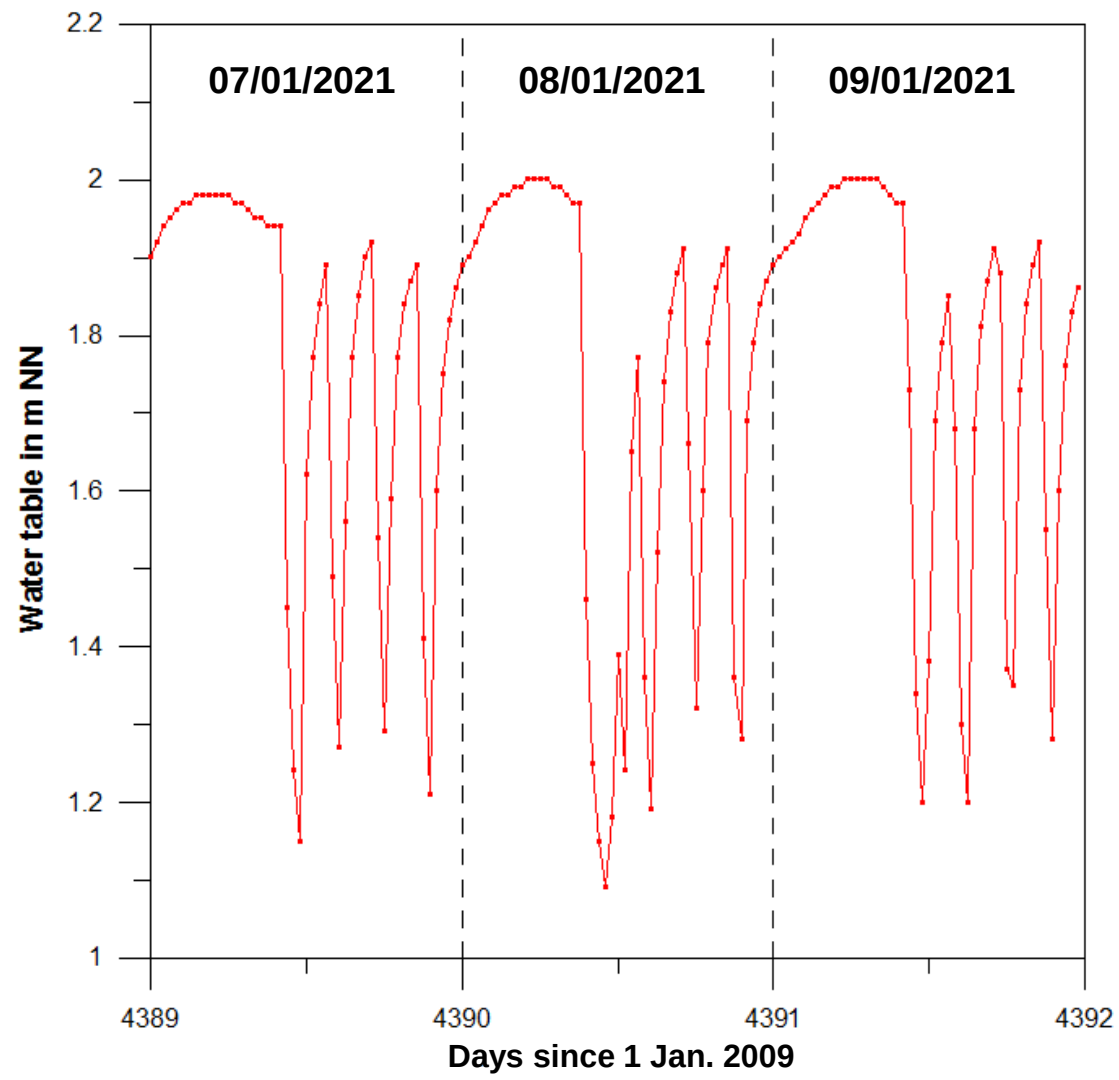
Water from greater depths with higher salt concentrations is also extracted.

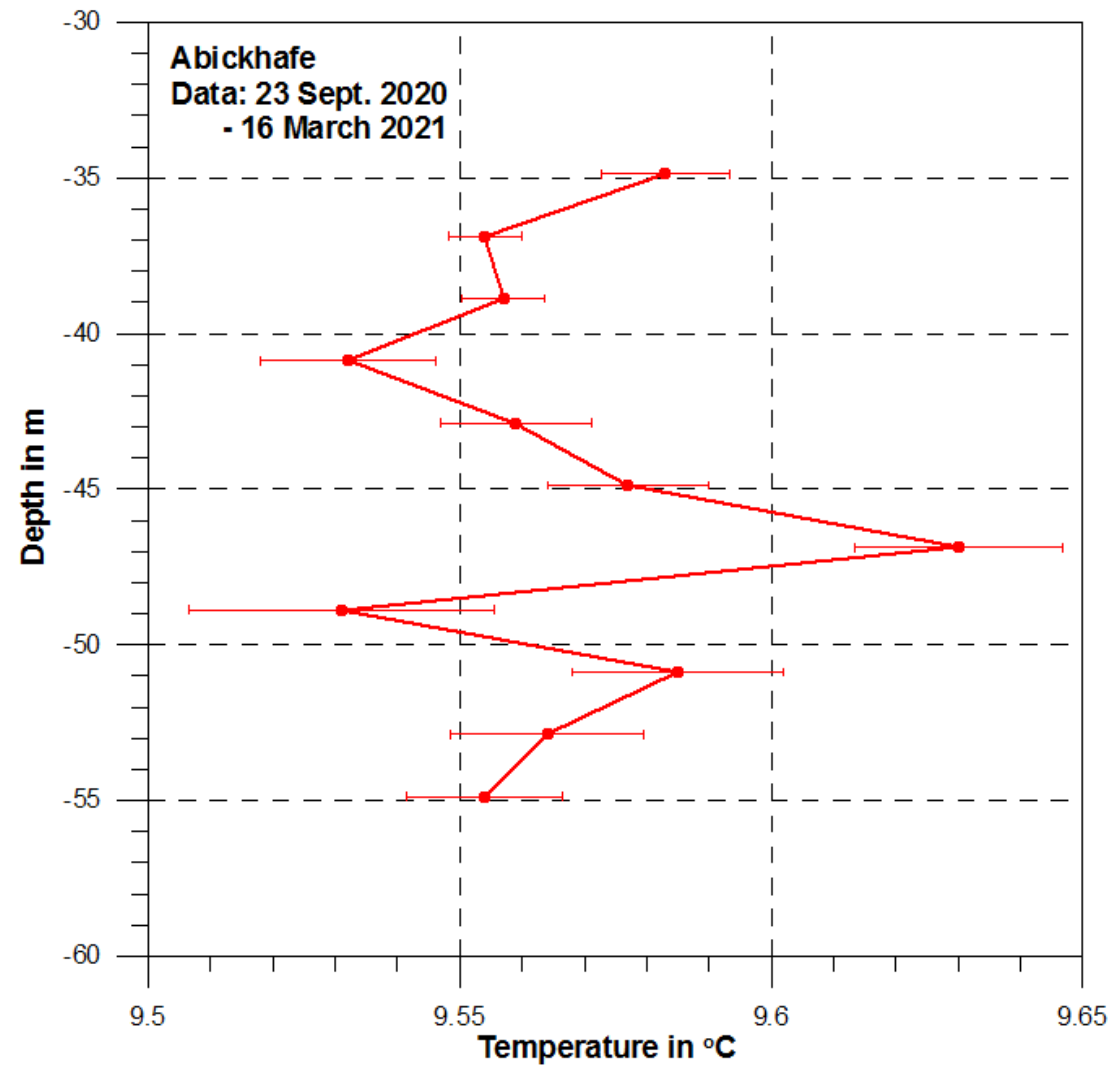
→ Lower resistivities



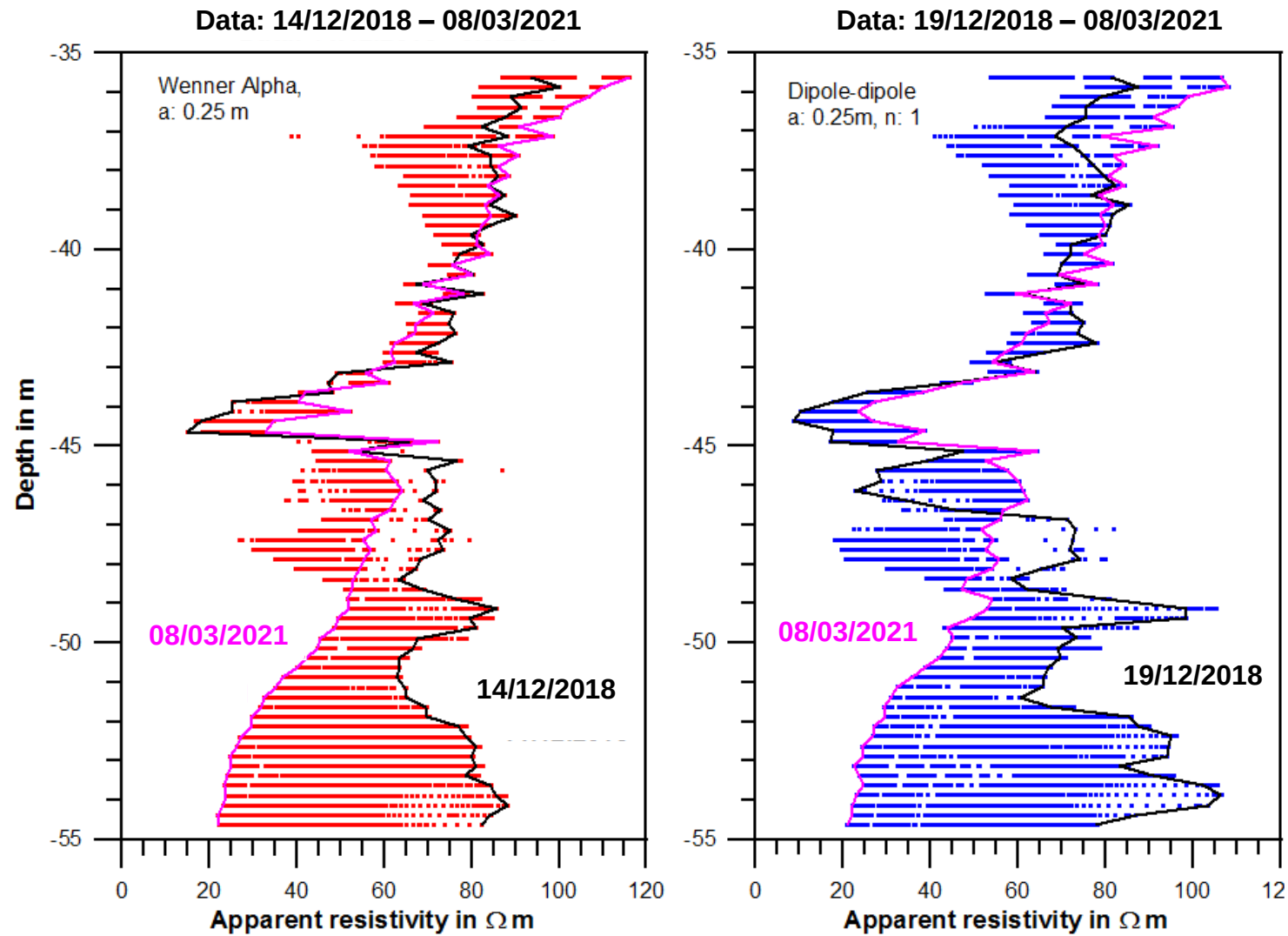




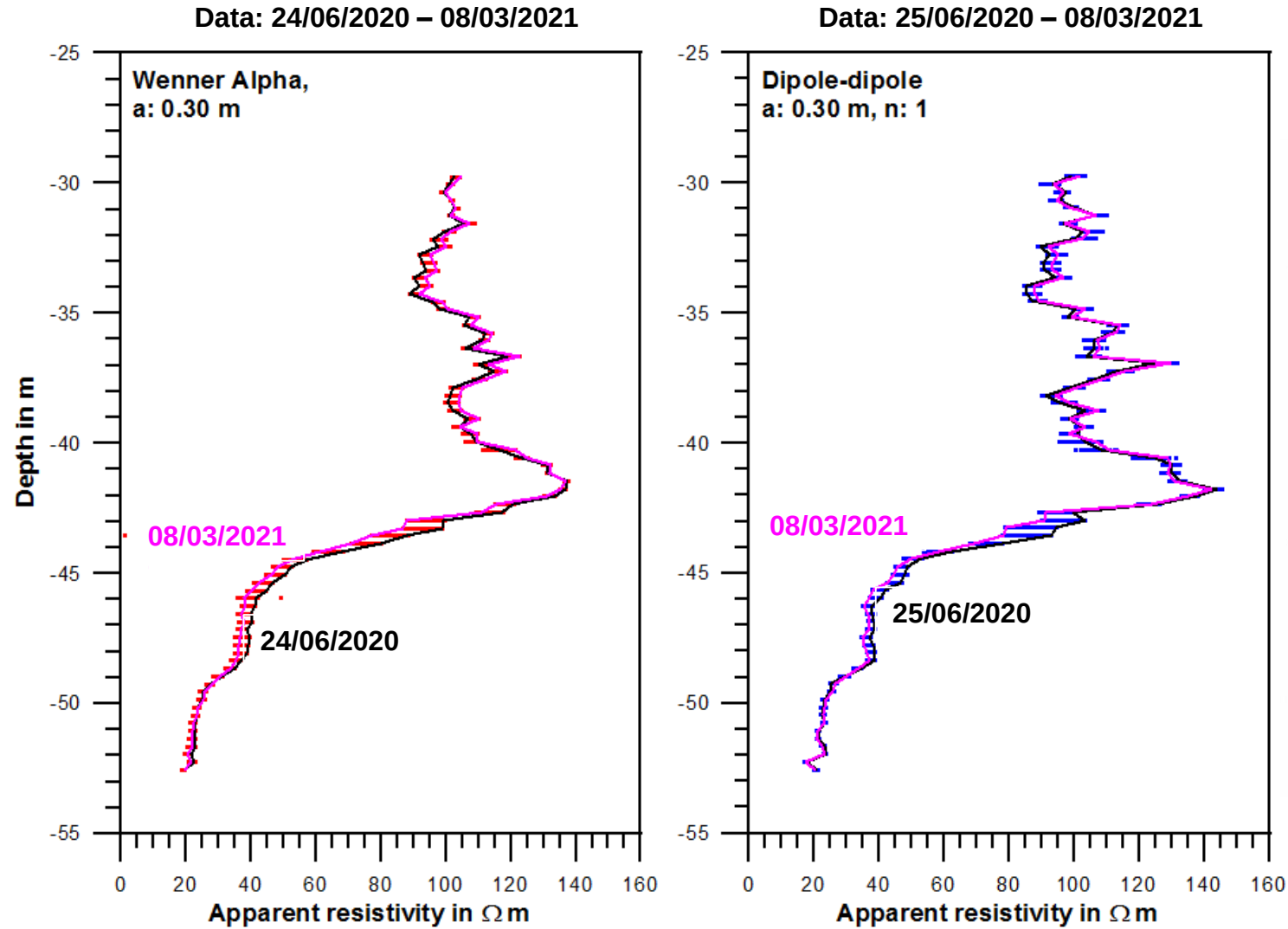




Abickhafe



Spiekeroog



Summary

- ❑ SAMOS: working at four sites (fifth site: Münsterdorf together with TU Berlin)
- ❑ Vertical electrode systems in the subsurface:
 - are working well
 - Construction in cooperation with companies
- ❑ Measuring systems at the surface:
 - Challenges and troubles in monitoring different from single resistivity measurements
 - Modifications and repairing possible
- ❑ Raw data:
 - Accuracy very high (differences between systems detectable, device effects must be considered)
 - Fading of drilling influences recorded
 - Seasonal influences as well as long-term changes recorded
- ❑ Inversion software (M. Ronczka)