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Interactive comment on "Supercooled interfacial water in fine grained soils probed by dielectric spectroscopy" *by* A. Lorek and N. Wagner

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Reply to review 2 of the manuscript TDC-7-1441–1493-2013

We thank the reviewer for the report and are pleased with the positive response. We have benefited from the insightful and constructive comments and suggestions. The suggestions were considered in the revised manuscript and we appropriately responded to each comment. Moreover, the final manuscript was carefully proofread by a colleague with appropriate scientific background.

1. Abstract. The reviewer suggests writing "Water substance affects nearly all physical, chemical and biological processes on earth. . . " More detailed suggestions are provided in the pdf-file sent to the editor.

Response: Corrected: "Water substantially . . ." instead of "Water as thermodynamic state parameter . . ."

2. Abstract, Lines 7-9. What is the justification for the focus on soil dielectric properties in frequencies ranging from 10 Hz to 1.1 MHz? This is briefly discussed in page 1444, but not clearly justified. A justification should be provided in the revised article.

Response: Revised. The selected frequency range enables the detection of a freezing process due to the strong change of the permittivity of ice at frequencies <100 KHz (Hasted 1973; Ulaby et al., 1986). Moreover, the upper limit of 1.1 MHz is the limit of the used LCR-meter. However, in the response to the comments of Review 1 we highlighted the need for more broadband (<100 Hz, >1 MHz) measurements in a next step.

3. Page 1446. What is the justification for the selection of 350 kHz to determine the ice and liquid water content of Mars soil simulant?

Response: The effective complex relative permittivity of the investigated soils has the lowest dielectric losses (Fig. 4a) at the chosen frequency and therefore the real part of the permittivity at 350 kHz is sufficient to reflect the dielectric properties of the soils for the analyses of the appropriate ice- and liquid water content. We revised the appropriate paragraph (page 1459 line 13-16).

4. Pages 1451-1452. Why is the diameter of the lower plate different from that of the upper plate? What is the reason for the air-gap between the soil and the upper plate?

Response: The upper capacitor plate is embedded in a guard ring electrode, which has the same diameter as the lower capacitor plate. The useable cell surface area is defined by the diameter of the upper capacitor plate and thus the resultant measurement volume of the capacitor with parallel electrical field vectors. The air gap is preliminary used to measure powdered materials (Page 1451 line 13-18) to be able to control the atmosphere (relative humidity) above the soil by using a defined humid gas flow through the capacitor.

5. Page 1451, Eqn (12). The various terms of the equation are not defined clearly. For example, why is the subscript G used for the solid phase?

Response: The definition of the missing term was added (n). We here used the subscript G for the solid mineral phase (mineral grain).

6. Page 1453. What is an isothermal decrease of temperature? This appears to be a contradictory statement. Do the authors mean stepwise decrease in temperature? The text needs to be clarified. The reviewer suggests avoiding the term "isothermally decrease of temperature."

Response: Corrected.

7. Page 1453. What is the motivation for choosing the three water content used in the experiments with clay and JSC Mars 1 soil simulants?

Response: The measurements have started at the highest water content due to the appropriate atmospheric conditions in the laboratory. The lower water contents were achieved by using a defined gas flow through the capacitor (see response to Comment 4). In general, the presented results are the results of a "feasibility study" for the suggested method/approach. In next steps it is recommended to carry out further systematic experimental investigations at a broader water content range (see response to Review 1, Comments 9 and 12).

8. Page 1454. Is the drying of the sample for 24 hours at 105 °C enough to reduce the soil water content to negligible values? How was this tested?

Response: Yes, we agree with the reviewer, that the determination of the absolute water content of soil depends on the temperature and time. The drying of soils at 105 °C or 110 °C over 24 h is often used or recommended (Scheffer and Schachtschabel, 1989; Kutílek and Nielsen, 1994; Bittelli et al., 2004) for the removal of water in soils to enable the comparison of results of different studies. However, in further systematic

studies the general issue of the residual water content inside the dried probe needs to be addressed. First investigations on sulfate hydrates and fine grained soils show, that the measurement system WDS 400 from the Satorius AG enables the measurement of the absolute amount of the release of water during heating especially for low water contents. This allows the quantification of the different binding forms of water in soil (surface water, crystal water, capillary water) with high accuracy.

9. Page 1456. How is Eqn (18) transformed in the linear equation shown in line 12? This should be explained more carefully. What are the variables corresponding to beta and gamma?

Response: We have clarified the definition of the used transformation in the revised manuscript: "… In a representation of the natural logarithm of an appropriate relaxation time or characteristic frequency y=ln(τ_i)=-ln(2πf_(r,i)) as a function of reciprocal temperature x=Tˆ(-1) Eq. (18) transformed into a linear equation y=A_i+B_i x. This equation than was fitted to the relaxation times obtained from the characteristic frequencies f_(r,i) (T) of the maxima in the imaginary part of the complex modulus as a function of temperature …"

The appropriate relaxation processes beta or gamma become visibly in the dielectric spectrum due to characteristic features (see Fig. 4a). We added in section 4 page 1455 in point (i): "…a decrease of the real part of the effective complex relative permittivity and an increase of the corresponding real part of the complex modulus with increasing frequency as well as a maximum in the imaginary part of complex permittivity, modulus or loss factor at appropriate characteristic frequencies."

10. Page 1457. Which one is equation (GDR)? What does GDR mean?

Response: The Generalized Dielectric Response – GDR is defined at page 1447, Line 15. We revised the description accordingly.

11. Page 1457. Does the variable gamma in Eqn (19) corresponds to the same phys-

ical process as the variable gamma mentioned in line 16 of page 1456 (counter ion relaxation)? This is not clear in the text.

Response: We changed the variables in equation (19) and now use “mu” instead of “gamma”.

References

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Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/7/C1536/2013/tcd-7-C1536-2013-supplement.pdf

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