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The Cryosphere Discussions

Interactive comment on "Seasonal thaw settlement at drained thermokarst lake basins, Arctic Alaska" *by* L. Liu et al.

Anonymous Referee #3

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Review of manuscript tc-2013-192 "Seasonal thaw settlement at drained thermokarst lake basins, Arctic Alaska" by L. Liu et al.

General comments:
This manuscript investigates seasonal thaw settlement of drained thermokarst lake basins in Arctic Alaska using high-resolution InSAR data, GPR measurements, and frost probe data from several measurement locations. The high-resolution InSAR data clearly show differences in the dynamics of the various basins with some of them exhibiting larger thaw settlement compared to the others. Thaw strain, which is calculated from InSAR and GPR data, is used to quantify the strength of the settlement for different regions of one selected basin with strong seasonal settlement.

Overall this is a very interesting study showing the potential of combining remote sensing and ground based geophysical measurements. The manuscript is well written. Methods and results are well described and supported by appropriate figures of good quality.

I have some comments which I would like to have worked out before publication of the paper:

- Since the GPR measurements are a major component of the study I would like to have some radargrams included showing the reflection of the ice table from the characteristic sections (see e.g. Fig. 6). Also the related frost probe measurements may be indicated therein. The authors may also have a look at the paper of Moorman et al. (2003), PPP 14: 319–329, who discuss the identification of massive ground ice bodies using GPR. Such a discussion of the radargrams may substantiate the ground ice theory for SAC basin.
- The large textural heterogeneity of the area of investigation causes large uncertainties (20% for the basin area, 10% for the outer areas) in the estimates of volumetric water content using GPR even if ALT is known from additional frost probe measurements. Are there any options for reducing this uncertainty in future investigations, e.g. by measuring porosity from soil cores etc.? Please discuss.
- On P 5806, L 17-18 and Fig. 6 the authors observe much larger subsidence in section "BC" than in "DE". Please add some explanation for this to the discussion section as well.

Specific comments:

P 5794, L 3: Add explanation why knowing the dynamic state of DTLBs is important (cf P 5795, L 14-15).

P 5798, L 8: Replace “a few” by absolute values. This is important since we are looking at thaw settlements of also “a few” centimeters only.

P 5798, L 19: Replace “radar measurements” by “SAR measurements” to have a clear distinction to the GPR measurements discussed later on. Please check text for similar occurrences.

P 5800, L 17: Suggestion: replace “the two radar transducers” by “transmitting and receiving antenna”.

P 5801, L 19: Replace “unfrozen water” by “unfrozen water content”

P 5802, L 8; P 5805, L 5 and whole section: Replace “radar speed” by “GPR wave speed”, check text for other occurrences.

P 5802, L 14: Suggestion: call it a ...“site-specific” empirical model...

P 5803, L 19-23: From my point of view, re-arranging eq. 10 is redundant at this place. Why don’t the authors do their calculations using the dielectric permittivity values (eq. 10)? In addition, eq. 11 is only valid for saturated soils. The velocities given in Davis and Annan (1989) at least for dry silt are valid for the bulk soil (silt + air); see also comment below. In eq. 11, the velocity for the pure mineral grains would be required.

P 5805, section 3.2: The authors assume that the whole area (basin and margins) is fully saturated. I am wondering if this assumption is justified. From Fig. 1b we observe a jump in elevation of 1 to 2m between basin and margins. If the whole area was saturated the groundwater table would be a straight, maybe little inclined surface but it would not be able to follow the topography to have the complete area saturated. If the margin area would not be saturated, eq. 10 would not be valid and would have to be extended to the 3-phase CRIM formula for unsaturated soils including the air phase as well:

$$\sqrt{\varepsilon_c} = \theta\sqrt{\varepsilon_w} + [1-\phi]\sqrt{\varepsilon_s} + [\phi-\theta]\sqrt{\varepsilon_a} \tag{1}$$

$$\theta = \frac{\sqrt{\varepsilon_c} - \sqrt{\varepsilon_s}(1-\phi) - \phi}{\sqrt{\varepsilon_w} - 1}. \tag{2}$$

P 5805, L 13: please change: “The VWC of saturated pure mineral soil is...”

P 5806: Replace “detected” by “estimated” (values are not confirmed by additional measurements and velocity may change with depth)

Technical comments:

P 5797, L 1: Reference Hinkel and Nelson, 2003 missing in reference list.

P 5816, Table A1: add reference to table in Text; check for completeness (e.g v_g and v_w are missing)

P 5822, Fig. 6a: Some marks for probing locations are difficult to identify. Suggestion: use red color instead of black.

Interactive comment on The Cryosphere Discuss., 7, 5793, 2013.