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Reliability of Sentinel-1 InSAR distributed scatterer (DS) time series to estimate the temporal vertical movement of ombrotrophic bog surface

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A better understanding of the short term and seasonal peat surface vertical displacements (bog breathing) (Roulet 1991) initiated by changes in the water table is needed to improve spatial models of greenhouse gas emissions (Dise 2009). Synthetic Aperture Radar Interferometry (InSAR) is a promising tool for the task but accounting for relatively large peat surface displacements (Fritz 2006, Howie & Hebda 2018) may cause propagation of ambiguity errors and unreliability (Alshammari *et al*. 2018, Heuff & Hanssen 2021). This is usually overlooked and the absence of ground levelling data for validation is characteristic of InSAR research in peatlands (Cigna & Sowter 2017, Alshammari *et al*. 2018).

We calculated distributed scatterer (DS) time series over 2014–2020 for Sentinel-1 relative orbits number (RON) 80 (descending) and 160 (ascending). The high frequency continuous in situ ground levelling measurements cover the snow and ice-free period of 2016 (April–October). Limited by the availability of Sentinel-1 data, 13 images from both stacks were evaluated against the levelling of a hummock plot. DS points used in the comparison were located around the plot at 125–315 m. The bog points were referenced to the stable DS points from a nearby village (4 km away) to account for atmospheric effects. InSAR line of sight deformation results were projected to vertical dimension (u_{LOS}).

Concerning only the dates when we had SAR acquisitions, the largest change relative to the maximum surface level of the period is -6.6 cm and median change -2.4 cm for RON 80, and -7.5 cm and -2.4 cm for RON 160. The maximum deviation between the u_{LOS} and the levelling is 5.6 cm and median 2.11 cm for RON 80. For RON 160, the maximum deviation is 5.85 cm and median 2.81 cm. The Spearman correlation coefficient (r_s) between the u_{LOS} and the levelling is 0.84 for RON 80 and r_s = 0.81 for RON 160 (p-value < 0.001 in both cases).

To reduce the need for ambiguity resolution in the DS time series, we used relative changes between two consecutive acquisitions (baseline of 12 or 6 days) instead of accounting for the absolute change. The in situ relative surface changes between the consecutive acquisition dates of RON 80 are -2.55...2.1 cm (median -0.08 cm) and the deviation of the DS from the levelling is

-1.17…1.28 cm (median 0.38 cm). For RON 160, levelling values are -0.9…3.3 cm (median -0.3 cm) and the deviation -3.06…0.81 cm (the former is -0.45 if the 12-day image pair corresponding to the change larger than the u_{LOS} height of ambiguity is removed), median 0.23 cm. Between the levelling and DS data r_s = 0.67 (*p*-value 0.035) and 0.77 (*p*-value 0.005), respectively for RON 80 and 160. Based on the in situ levelling, we demonstrated that 1) Sentinel-1 DS time series severely underestimate real surface changes over the bog and 2) despite a serious ambiguity problem, DS time series contain the useful signal because 6-day surface changes are relatively small and usually do not need ambiguity resolution.