Surface motion at different spatial and temporal scales: measurement approaches and first results of a German-wide monitoring programme

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Introduction

Worldwide, surface motion is observed in peatlands (Howie and Hebda, 2018; Evans et al., 2021). On a long-term basis, surface heights in pristine and near-natural peatlands are increasing due to the formation of peat, while in drained peatlands surface heights are mainly decreasing due to the decomposition of peat and the concomitant emissions of carbon dioxide (CO_2).

Among other goals, the project 'Implementation of the German peatland monitoring programme for climate protection (MoMoK) - Part 1: Open Land' aims to estimate CO_2 emissions and uptake by surface motion in German peatlands. Therefore, the spatial distribution of surface heights at 198 field sites will be measured annually by elevation surveys in order to quantify the long-term trend of surface motion. At selected field sites, short-term trends of surface motion (e.g. caused by shrinkage and swelling in dependence on moisture conditions) will be measured on a higher temporal scale (hourly) with level recorders (extensometers) or pressure differences between a 'fixed' and 'moving' pressure transducer (ΔP).

Here, we show preliminary results of surface motion measurements obtained with three different measurement approaches. We (1) compare data of a level recorder with those of a 'fixed' and 'moving' pressure transducer, (2) compare surface motion data of three extensometer which are installed close to each other (distance ~3 m) with water table depths and (3) show how well different spatial and temporal scales can fit together.

Methods

Site selection

In the 'MoMoK' project, 198 sites were selected in order to represent the German-wide distribution of different organic soil types, peat substrates and thickness, land-use types and water management approaches. Organic soil types were classified into fen, bog, peat-derived organic soil, covered organic soil, and deep-ploughed organic soil following the classification scheme of Wittnebel el al. (2021). Land use types were separated into cropland, grassland and wet peatlands (paludiculture, near-natural and re-wetted). Table 1 shows the number of sites for each organic soil and land use type combination. To date (2022-08-22), 46 sites are installed.

	Fen peat soil	Bog peat soil	Peat-derived organic soil	Covered organic soil	Deep-ploughed organic soil	**Sum**
Cropland	12	3	12	6	6	**39**
Grassland	57	12	21	15	6	**111**
Wet peatland	36	12	0	0	0	**48**
Sum	**105**	**27**	**33**	**21**	**12**	**198**

Table 1 Number of 'MoMoK' sites separated into organic soil and land use types.

Measurement approaches

Surface motion is measured at different spatial and temporal scales. All measurements are performed in reference to the top of a fixed rod which is installed firmly in the mineral subsoil at all sites. The spatial distribution of surface motion is measured by a yearly repeated elevation survey (level-meter or tachymeter) on a 50 x 50 m grid with approximately 200 Points. At 12 sites, elevation surveys are performed at a higher temporal resolution of two months.

At selected sites, surface motion is measured in an hourly resolution either by level recorder (extensometer, constructed within the project by the Thünen Institute of Climate-Smart Agriculture) or by the pressure difference between a 'fixed' and 'moving' pressure transducer (ΔP) within one monitoring well for peat water levels (Frank et al., 2022). Thereby, one pressure transducer is fixed to the pipe of the monitoring well, and the second pressure transducer is attached to a pipe that is placed over the pipe of the monitoring well, free to move with the surface (op de Beek et al., 2018). Extensometers will be installed at 52 sites (to date, extensometers are installed at 26 sites) distributed proportionally to the organic soil types and land use types of the 198 'MoMoK' sites. 'Fixed' and 'moving' pressure transducer will be installed additionally at all wet peatland sites without extensometer.

Results

Hourly measurements: extensometer vs. ΔP

Figure 1 shows relative surface heights measured with an extensometer and ΔP at a deep drained bog used as grassland. Both measurement approaches showed similar results with a root mean square error (RMSE) of 0.004 m. Slight differences could be attributed to soil heterogeneity or differences in measurement technique, mostly by different contact of the measurement equipment to the moving soil surface.

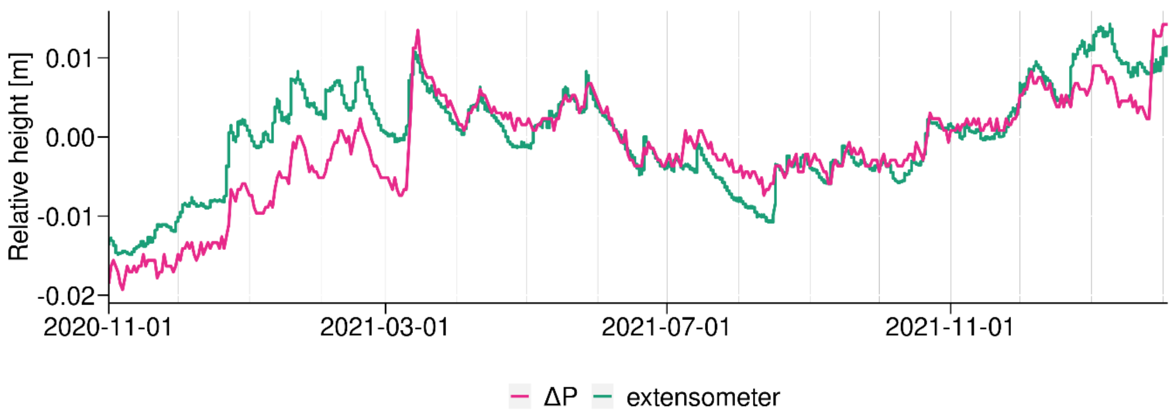

Figure 1 Relative heights measured with an extensometer and a 'fixed' and 'moving' pressure transducer (ΔP).

Replicate measurements with three extensometers

Water table dynamics and relative surface heights at a drained bog under grassland use are shown in Figure 2. The lowest water tables (~0.6 m below surface) were observed from mid-August to mid-October (Fig. 2a). In winter, water tables were close to the surface. The relative surface heights were strongly dependent on the water table dynamics (Fig. 2). As expected, the lowest relative surface heights were measured at the driest period at the end of summer, followed by continuously increasing relative surface heights at mid-October with maximum values at the end of February. The amplitude between minimum and maximum measured values was approximately 0.06 m. All three extensometers showed similar results over the measurement period of approximately one year (Fig. 2b).

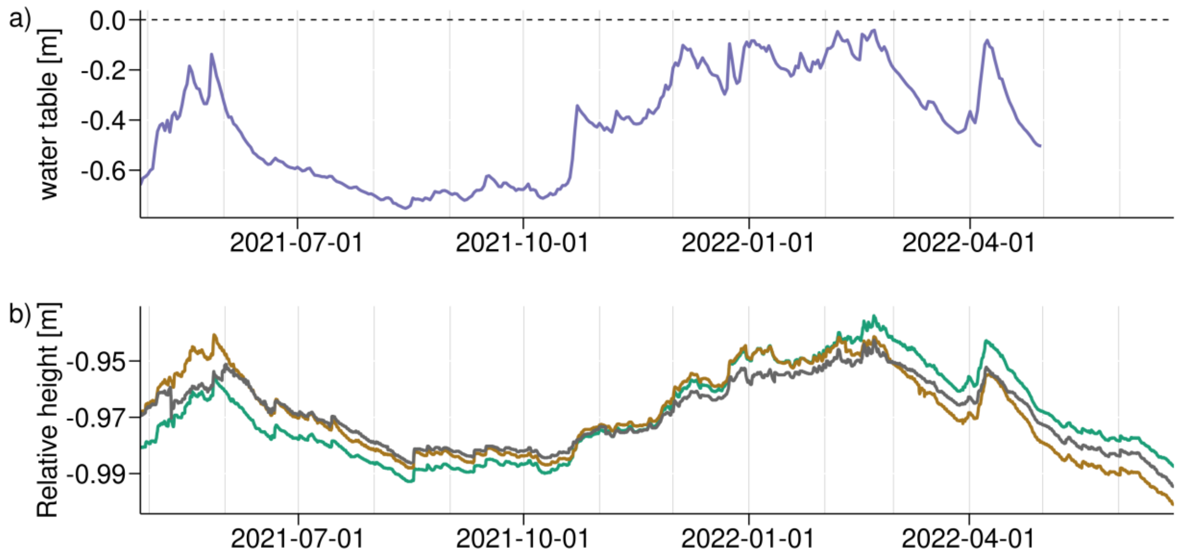

Figure 2 a) Water table and b) relative surface heights measured with three extensometers.

Elevation survey vs. extensometer

Figure 3 shows the heights of repeated elevation surveys and the mean ± standard deviation of three extensometer measurements at a deep drained bog used as grassland. Heights measured with the extensometers are in the same range as the median heights determined by the elevation survey. As the elevation survey covers a larger spatial area, a larger variability of the heights within one measurement date is to be expected and not reflecting a lower precision of the data. The quality of the data is reflected by the distributions of the elevation surveys (boxplots in Figure 3) remaining constant over the repeated measurements.

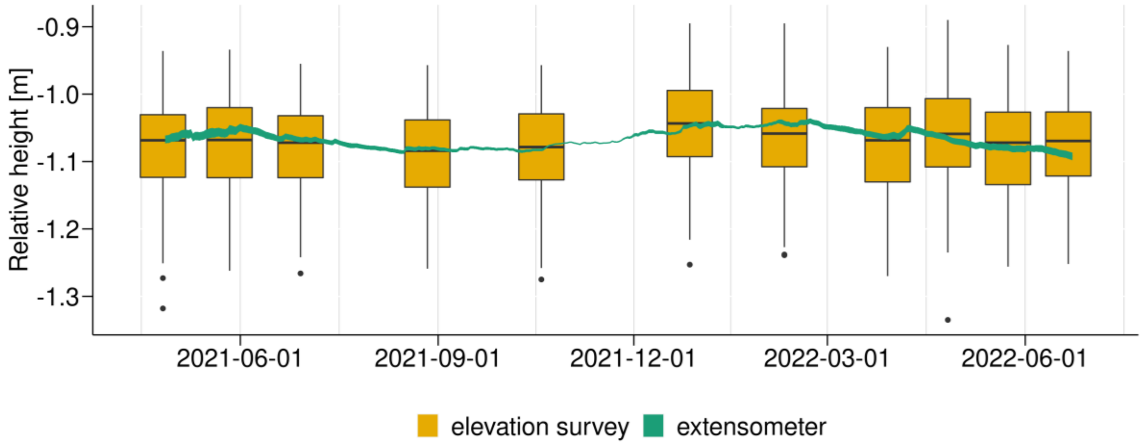

Figure 3 Extensometer measurements (standard deviation of three extensometer) and repeated elevation surveys (boxes define the 25-75% quartiles, whiskers are 1.5 times the quartile, points represent values outside this interval).

Conclusion

The results show that different measurement approaches can lead to similar results. At an hourly resolution, reliable surface heights may both be obtained by extensometer and ΔP. Data of high temporal resolution are necessary for process understanding and can support model development or parameterisation, in order to predict surface motion in dependence on different drivers (e.g. soil moisture conditions). The disadvantage is that surface motion of only a small area is measured, neglecting microtopography as well as soil and field heterogeneity. Elevation surveys are suited to capture the spatial variability of field sites, but lack on the temporal resolution. Here, we showed that surface motion measured on a small spatial, but high temporal scale (extensometer or ΔP) can be combined with elevation surveys which capture a larger spatial, but lower temporal scale.

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