Supplementary Information to

GEOMORPHOLOGY AND InSAR-TRACKED SURFACE DISPLACEMENTS IN AN ICE-RICH YEDOMA LANDSCAPE.

by

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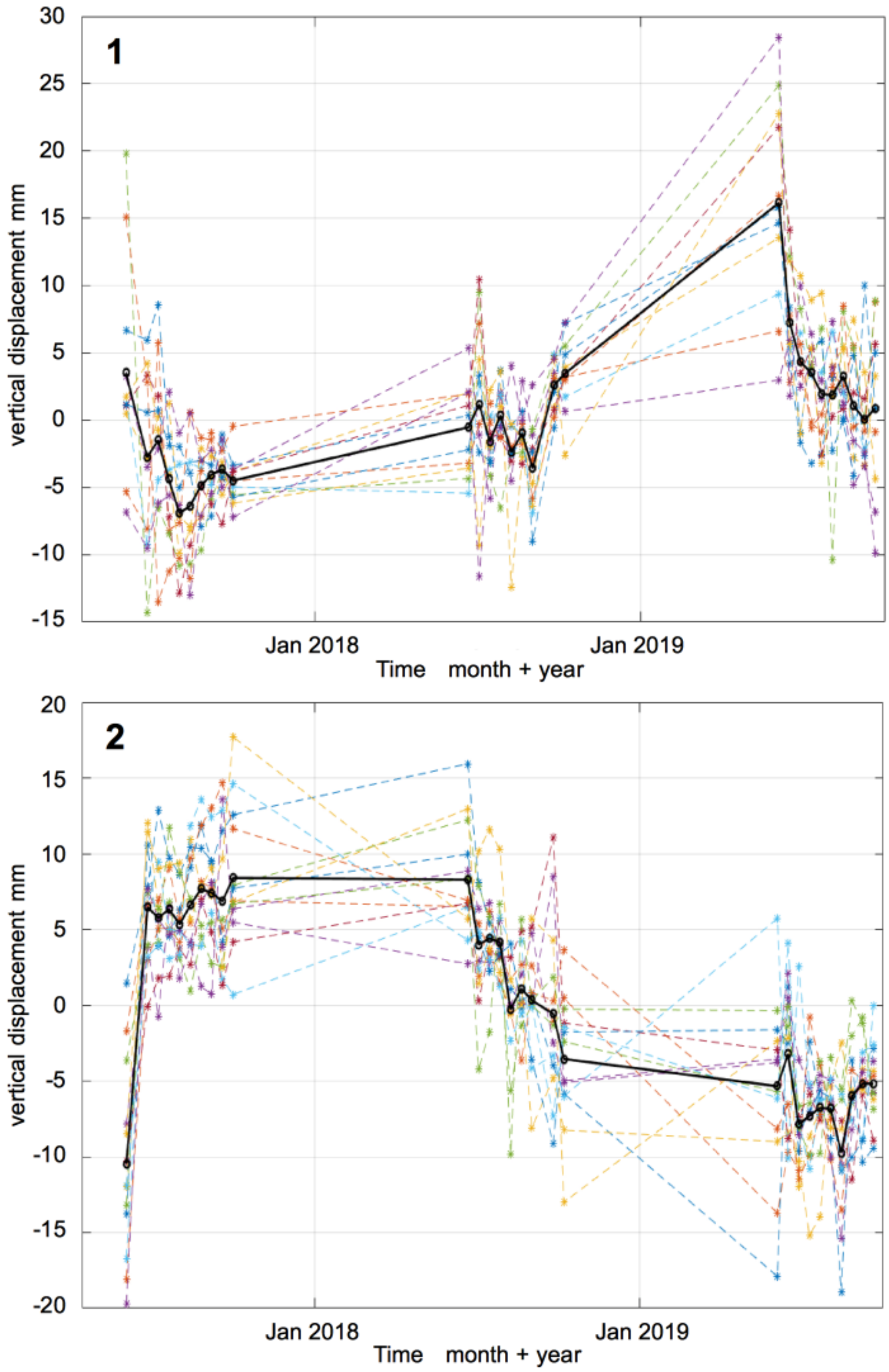
1. Additional information InSAR data.

Limitations and uncertainties of InSAR results are related to unwrapping and troposphere effects. The unwrapping error is mitigated by manually inspecting and discarding affected interferogram. The troposphere effect is mitigated by performing stacking (averaging). Additional error sources, related to surface properties (vegetation, moisture) may have a minor impact on accuracy. The standard deviation due to atmosphere and orbital error phase is 4-5 mm/yr. The dates of the images that were used are listed in Supplementary Table 1.

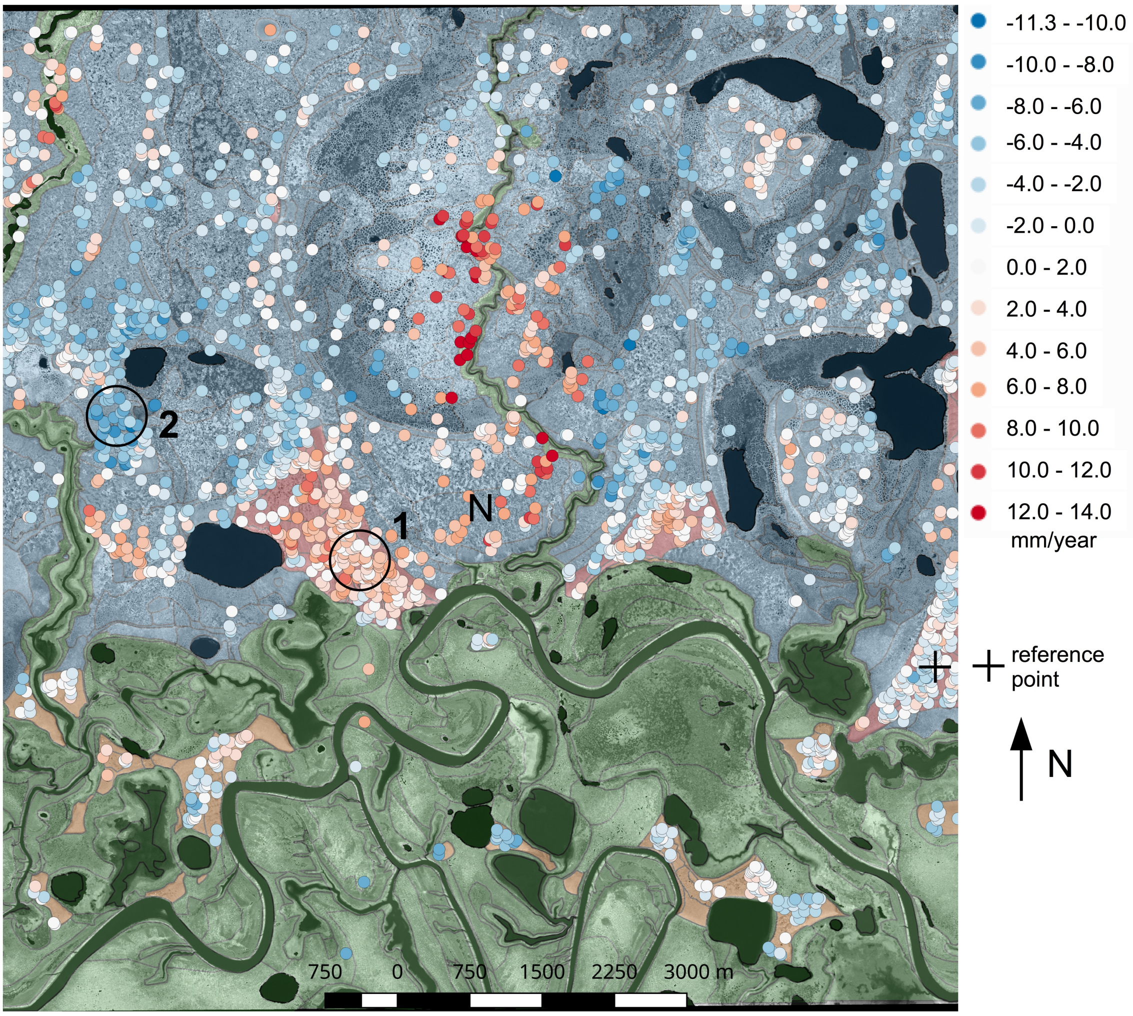
The spatial variation in surface movement occurs at short distance and is attributed to both uncertainty due to error sources in the data and spatial variation related to soil processes. Supplement Figure 1 illustrates the typical variation in the vertical displacement with respect to a reference point, of two groups of closely points within a 100 m radius, group 1 on a Yedoma plateau (1), group 2 in a drained thaw lake basin (2).

Table 1. Image dates of 30 Sentinel-1A/B IW SLC SAR used for vertical surface displacement detection.

year	**June**	**July**	**august**	**September**	**October**
2017	3, 27	9, 21	2, 14, 26	7, 19	1
2018	22	4, 16, 28	9, 21	2, 26	8
2019	5, 17, 29	11, 23	4, 16, 28	9, 21	



Supplement Figure 1. Vertical displacement of points in two groups of points on a Yedoma plateau (1) and in a drained thaw lake basin (2), with respect to a stable reference point. The dashed lines mark trajectories of individual points within the group, the black continuous line the group average. Suppl. Fig. 2 shows the location of the groups and the reference point.



Supplement Figure 2. Location of the point groups in Suppl. Fig. 7 and the reference point. The circles at 1 and 2 are the locations of the point groups in Suppl. Fig. 1. The radius of the the circles is 100 m. Background: 2019 Worldview image overlain with landform class, see Fig. 4.

2. Details on statistical analysis.

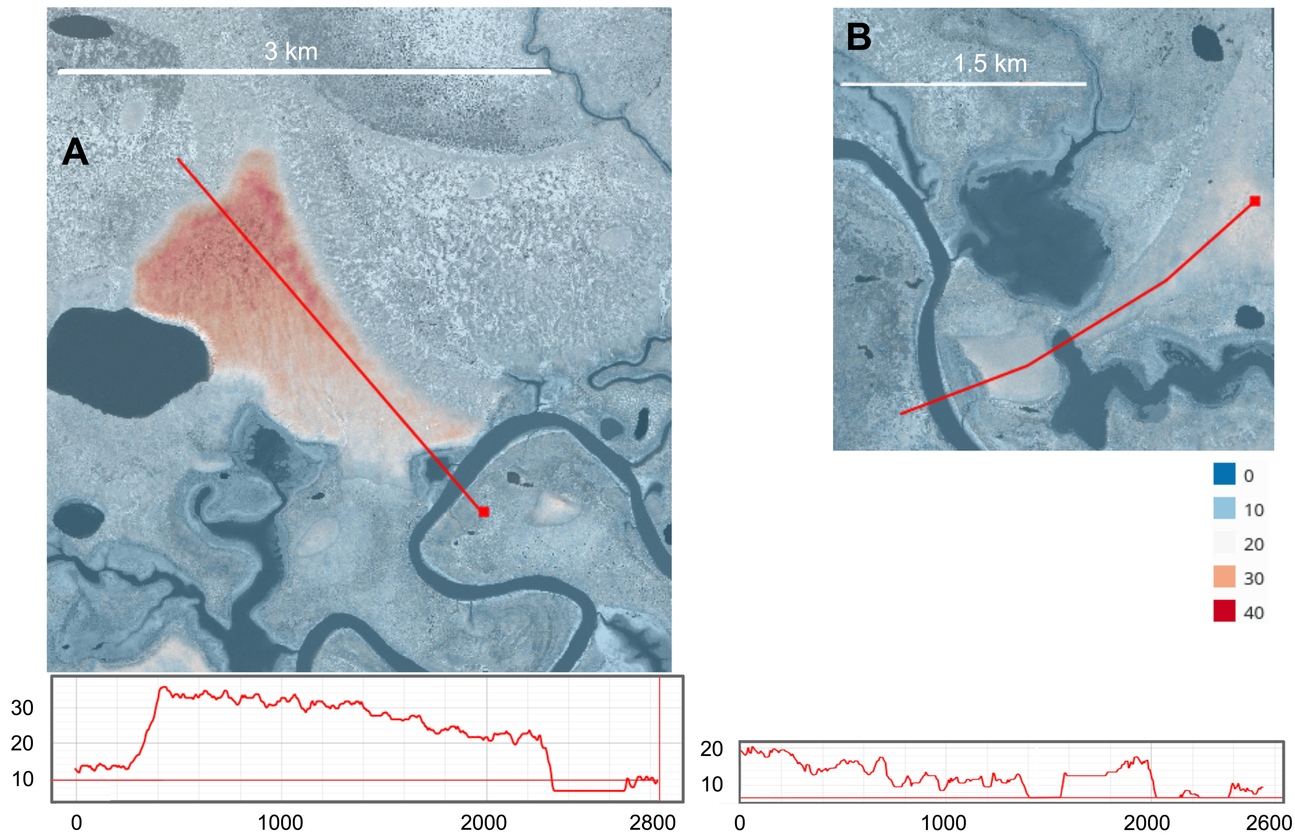
Statistical analysis has been done with the Statistics package of Matlab® version 2019a.

Cluster analysis: This was applied on the raw data of velocities calculated from all Sentinel images, as variables for each data point. Ward's method (minimizing within-cluster variance) with Euclidian distance between clusters was applied, as implemented in the Matlab functions *linkage*, *cluster* and *dendrogram*. A maximum of 11 clusters was retained. This number of cluster shows spatially well defined clusters, with generally distinguishable differences between the trajectories.

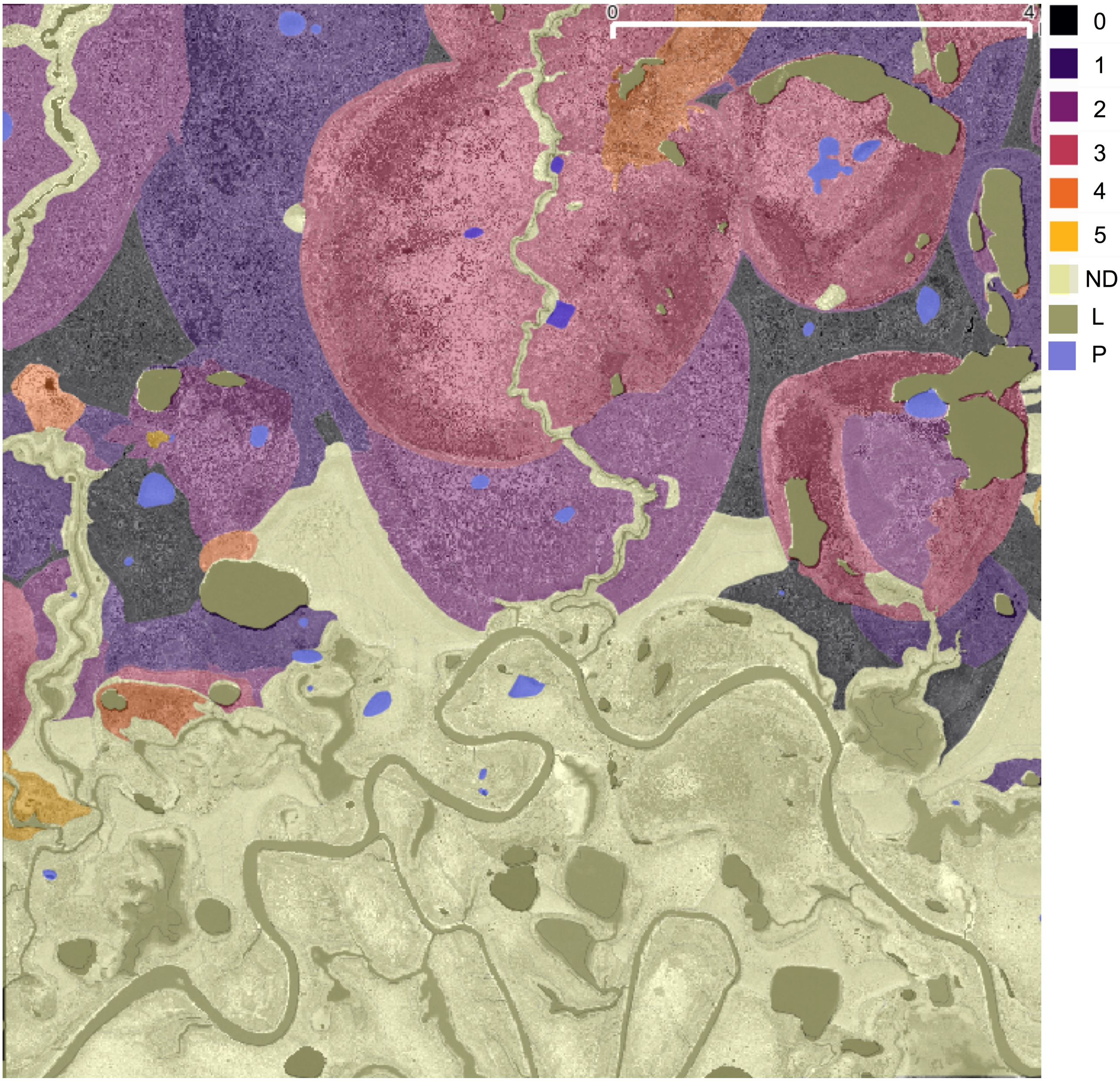
PCA: We applied principal component analysis to detect relations of InSAR-measured displacements with numerical data related to geomorphology (ALOS DEM), vegetation (panchromatic greyscale, NDVI) and ponded water presence (NDWI). Because of the differences in measurement scales, the data were standardized before analysis. The Matlab function *pca* was used.

ANOVA: ANOVA was applied to each categorical variable of the geomorphological maps, to detect any significant systematic differences in surface displacements for each of these variables. This included an F-test and a Tukey-Kramer test for significance of differences. We used the Matlab functions *anova1* and *multcompare* which included these tests.

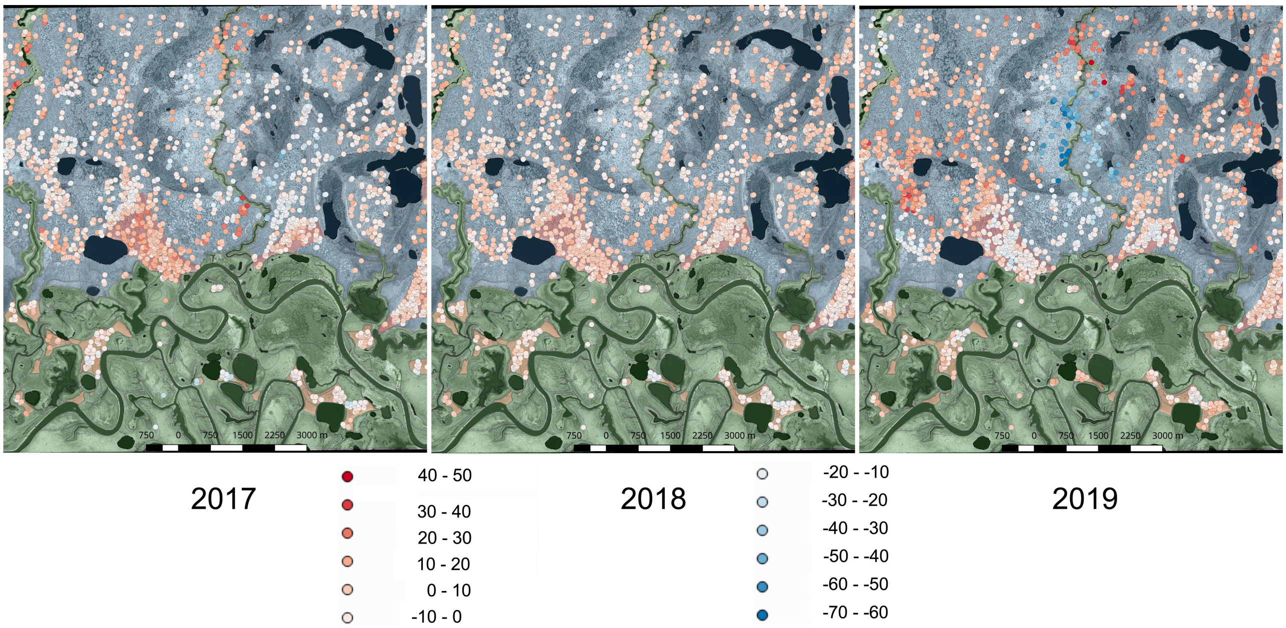
A generalized linear model was fitted to the data using the Matlab function *stepwiseglm*. This fits a generalized linear regression model to the data (numerical and categorical variables), starting with a model of constants. It adds or removes successive predictor terms based on a criterion that judges the contribution of each term to improvement of the prediction of the response variable; here the InSAR-detected surface movements, summed for each year and all years. Terms have been removed or added using Akaike's information criterion (Akaike, 1974). The significance of the regression models was tested with an F test. The only numerical variable is in the models is the ALOS DEM elevation, which was shown by PCA to be the only variable that contributes to the variability of the InSAR data. The categorical data were treated as dummy variables with an integer value, with one category in each class as reference level (value 0). We took in all classes the most widespread category as reference level. We did not include interaction terms (e.g. Landform x Flooding), since this results in many cases in interactions based on a small number of data points.



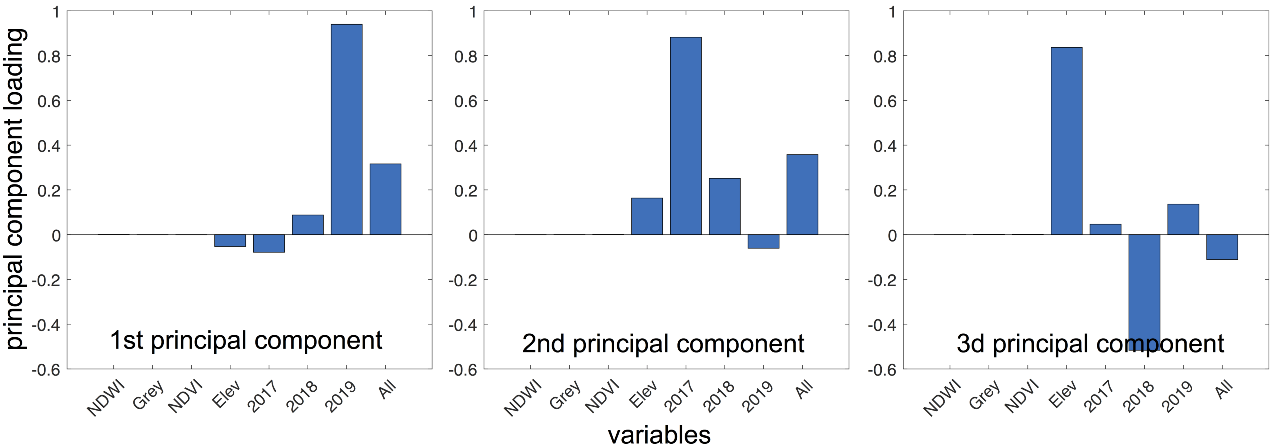
Supplement Figure 3. ALOS DEM showing sloping plateau surface of the Yedoma remnants, with elevation profiles along the length axes of the plateaus. Vertical and horizontal scales of the profiles in m. Profile B suggests continuity of the original slope of the Yedoma plateau and the river terrace (units YR and RT) for this partly eroded Yedoma remnant. Location see Fig. 4. Backdrop: 2019 Worldview image.



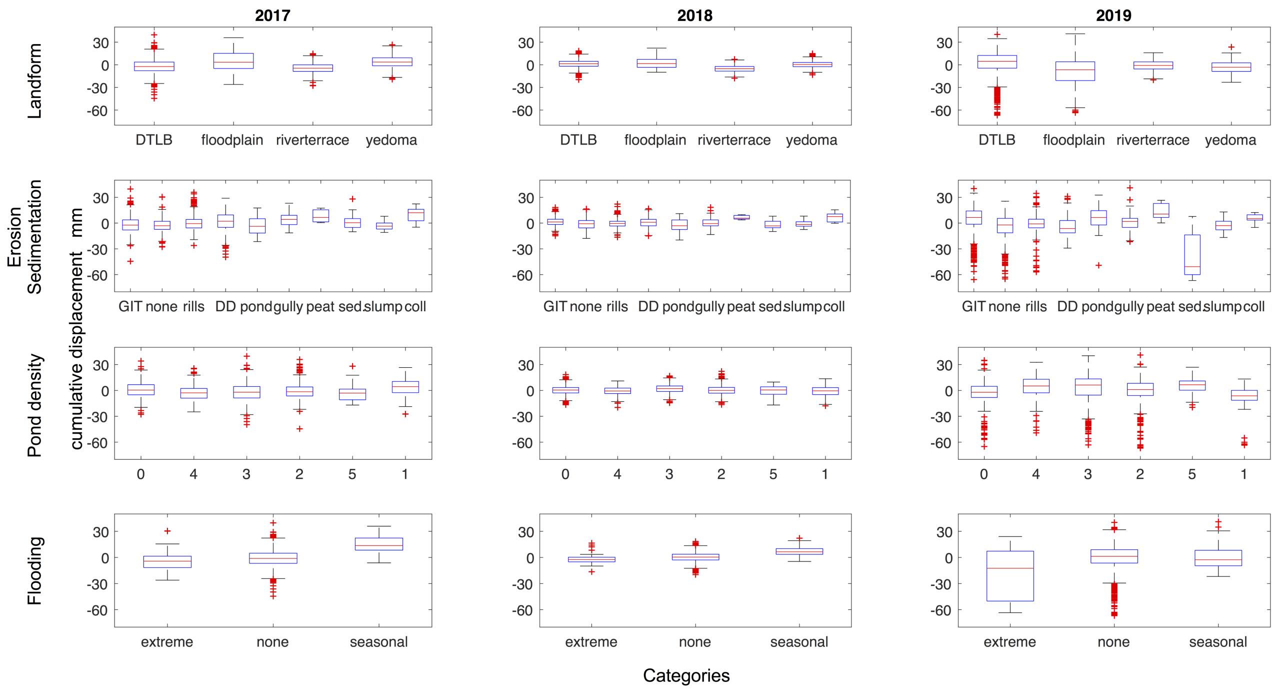
Supplement Figure 4. Age relations of DTLB derived from overlap relations and surface characteristics of the lake basins. Numbers indicate relative ages from 0 (oldest) to 5 (youngest). ND: Non-DTLB areas and pingos. L: present lakes and river channels. P: Pingos. Backdrop: 2019 Worldview image. NB: Overlapping relations with other lake beds are not necessarily synchronous at different parts of the shoreline of a lake; therefore these overlapping relations can only be tentatively translated in relative age relations.



Supplement Figure 5. Cumulative thaw season surface subsidence (-) and heave (+) velocities in mm. Background: 2019 Worldview image overlain with landform class, see Fig. 4. Scale bar 3 km. Point legend from red (heave) to blue (subsidence).



Supplement Figure 6. Principle component loadings on NDWI, panchromatic greyscale, NDVI, Elevation, ∑2017, ∑2018, ∑2019, ∑all years.



Supplement Figure 7. Box plot of summed vertical movement per year per categorical variable (vertical axes). Classes for each variable are indicated on the horizontal axes of the plots. The boxes indicate the 75th and 25th percentile of the data, the red line the median. The whiskers indicate the 99% range of the data assuming a normal distribution; the red stars outliers in the data.