SUPPLEMENTARY MATERIALS

The code that generates the phenology maps with the threshold method is available at:

https://github.com/adriadescals/LandSurfacePhenology_Sentinel2.git

Estimation of the optimal *alpha* in Normalized Difference Phenology Index (NDPI)

Normalized difference phenology index (NDPI), defined as eq. 5, adjusts the snow observations to the same values of bare soil and corrects the break in the time series due to the snow-to-vegetation transition. Since the *alpha* parameter was originally set according to the spectral response of MODIS, we re-estimated the optimal *alpha* parameter for Sentinel-2.

The optimal alpha was originally set so that the NDPI estimated 32 typical spectral responses to show the maximum separability between vegetation and snow-bare soil. Here, instead of using typical spectral responses from the Aster Spectral Library, we estimated the spectral responses empirically in snow, vegetation during the dormant period, and vegetation during the peak growth (Figure S1). First, we randomly distributed 400 points covering Sentinel-2 pixels that did not present long discontinuities in the time series (maximum gap < 10 days). Then, we extracted the Red, near infrared (NIR), and shortwave-infrared (SWIR2) values of the following observations: a) The last Sentinel-2 snow observation (reflected in the scene classification layer (SCL)) before the growing season, b) the first Sentinel-2 snow-free observation of the year, and c) the observation with the maximum normalized difference vegetation index (NDVI) value. Values in a) corresponded to snow, b) corresponded to bare soil or vegetation during the dormant period, and c) corresponded to vegetation during the maximum growth activity. Finally, we searched for the *alpha* that showed the best separability between vegetation during the maximum growth, and the snow and dormant vegetation.

Table S1. Site name and coordinates of the PhenoCam sites used in the study.

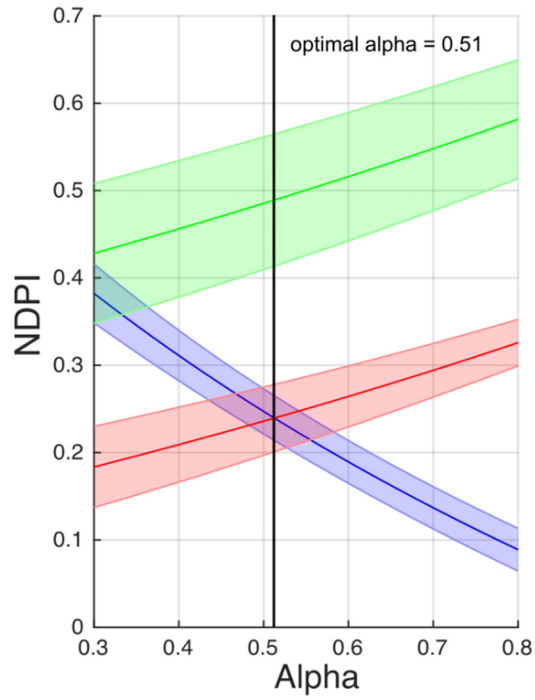| PhenoCam site name	Latitude	Longitude
imcrktussock	68.6063°N	149.3041°W
NEON.D18.TOOL.DP1.00033	68.6611°N	149.3705°W
NEON.D19.HEAL.DP1.00033	63.8757°N	149.2133°W

Figure S1. Relationship between the normalized difference phenology index (NDPI) derived from Sentinel-2 data and the alpha parameter (eq. 5) for three stages in the tundra time series: vegetation during the maximum growth (green), vegetation after snowmelt (red), and snow observations (blue). The central line is the mean of 400 samples and the error bar represents one standard deviation.The optimal alpha value that provides the maximum separability between productive vegetation and vegetation during the dormant period and snow is 0.51 (black line).
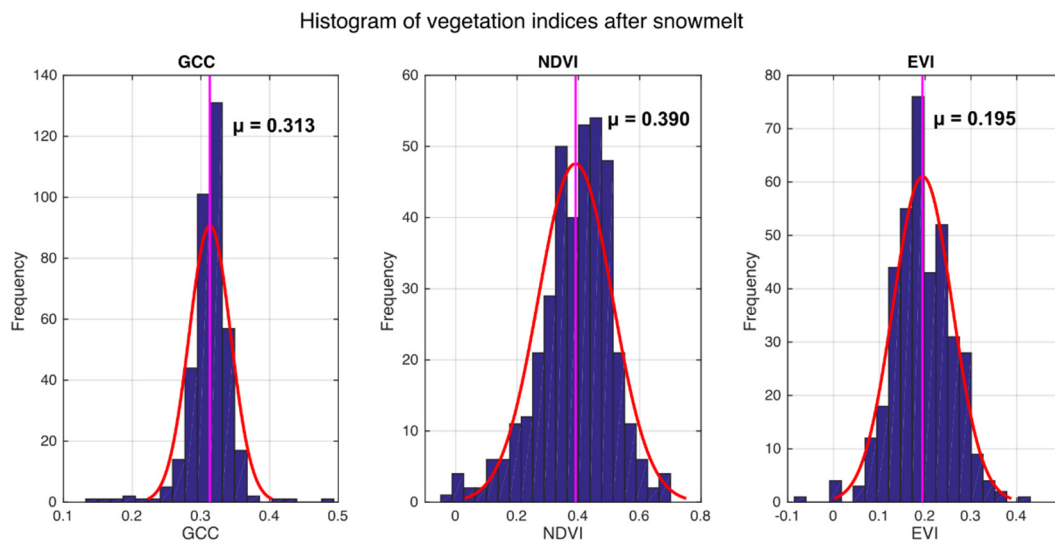
Figure S2. Histogram of Sentinel-2 green coordinate chromatic (GCC) index, normalized difference vegetation index (NDVI), and enhanced vegetation index (EVI) values observed after the last snow observation. The histogram represents the NDVI value of vegetation during the dormant period. This analysis only considers the time series with a gap that did not exceed 10 days.
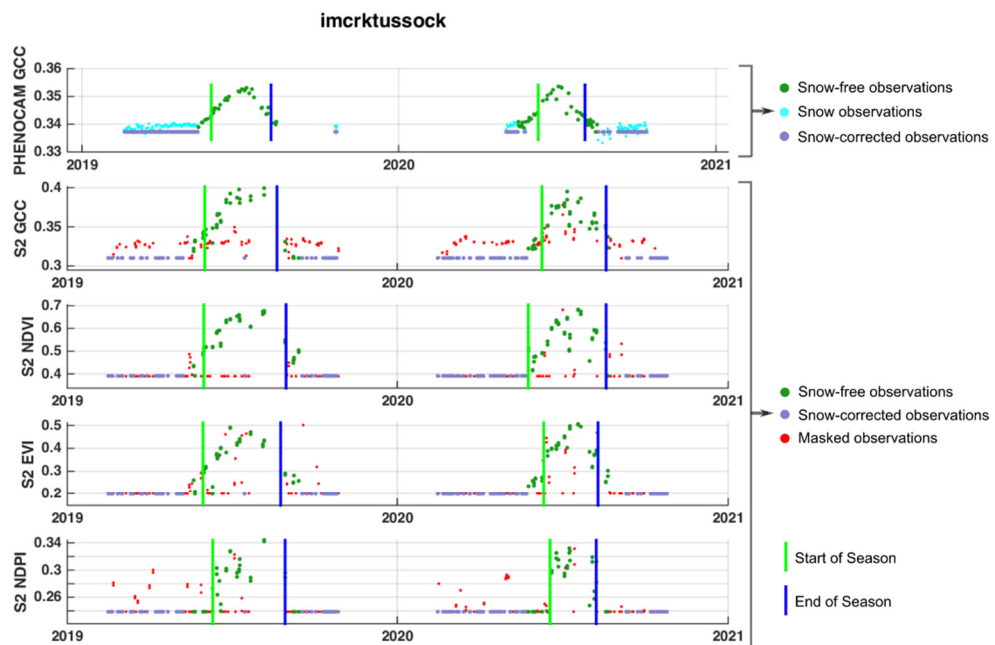
Figure S3. Time series of green coordinate chromatic (GCC) index of the PhenoCam site *imcrkrtussock* and four vegetation indices extracted for the site location from the Sentinel-2 level 2A for the years 2019 and 2020, and the associated land surface phenology metrics estimated with the threshold method. The vegetation indices were the GCC, normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and normalized difference phenology index (NDPI).
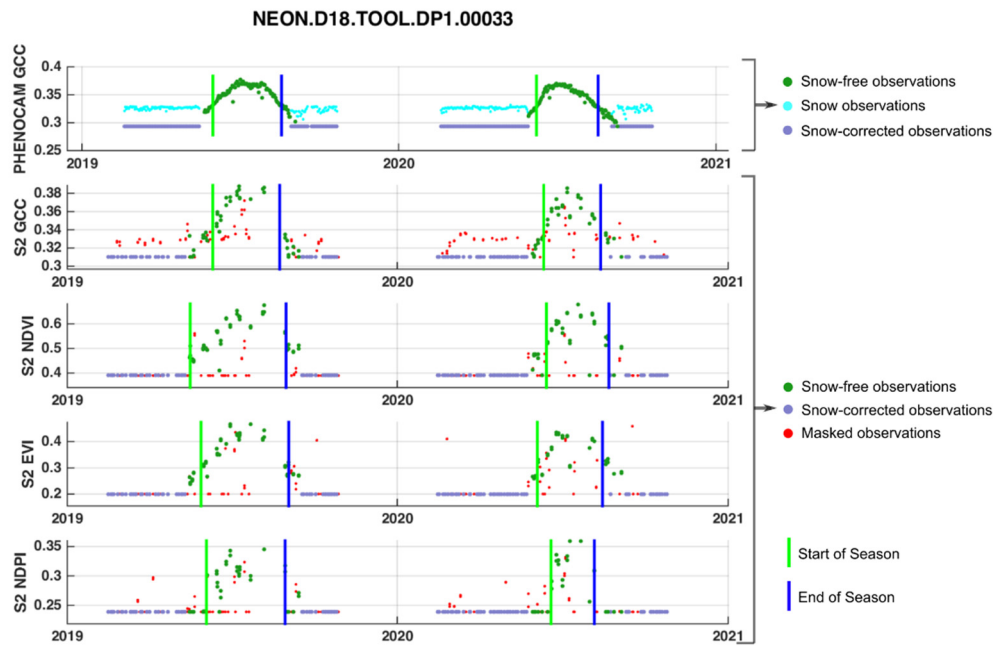
Figure S4. Time series of green coordinate chromatic (GCC) index of the PhenoCam site *NEON.D18.TOOL.DP1.00033* and four vegetation indices extracted for the site location from the Sentinel-2 level 2A for the years 2019 and 2020, and the associated land surface phenology metrics estimated with the threshold method. The vegetation indices were the GCC, normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and normalized difference phenology index (NDPI).
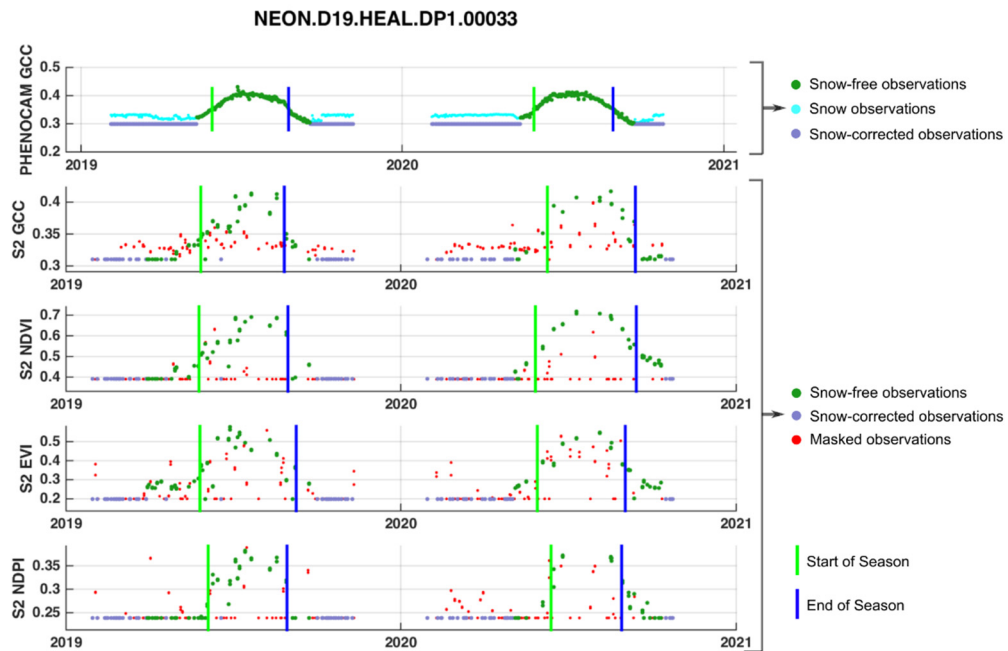
Figure S5. Time series of green coordinate chromatic (GCC) index of the PhenoCam site *NEON.D19.HEAL.DP1.00033* and four vegetation indices extracted for the site location from the Sentinel-2 level 2A for the years 2019 and 2020, and the associated land surface phenology metrics estimated with the threshold method. The vegetation indices were the GCC, normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and normalized difference phenology index (NDPI).
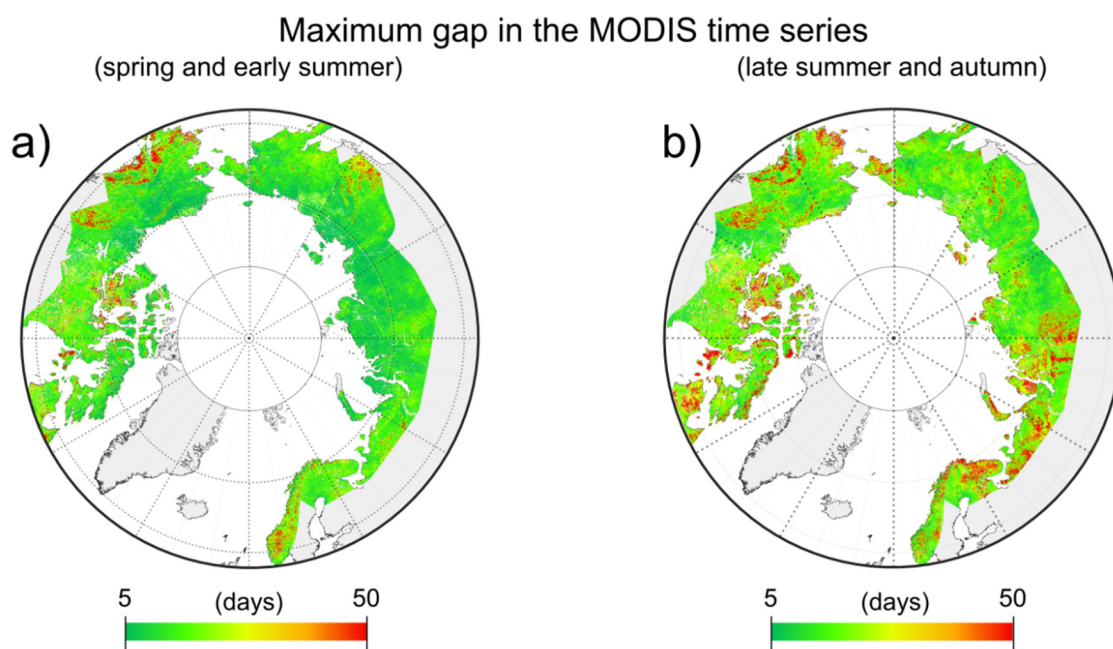
Figure S6. Maximum discontinuity in the surface spectral reflectance of Moderate Resolution Imaging Spectroradiometer (MODIS) (MOD09GAv6) time series after cloud masking for (a) spring and early summer (1 May to 15 July)and (b) late summer and autumn (15 July to 30 September) 2019.
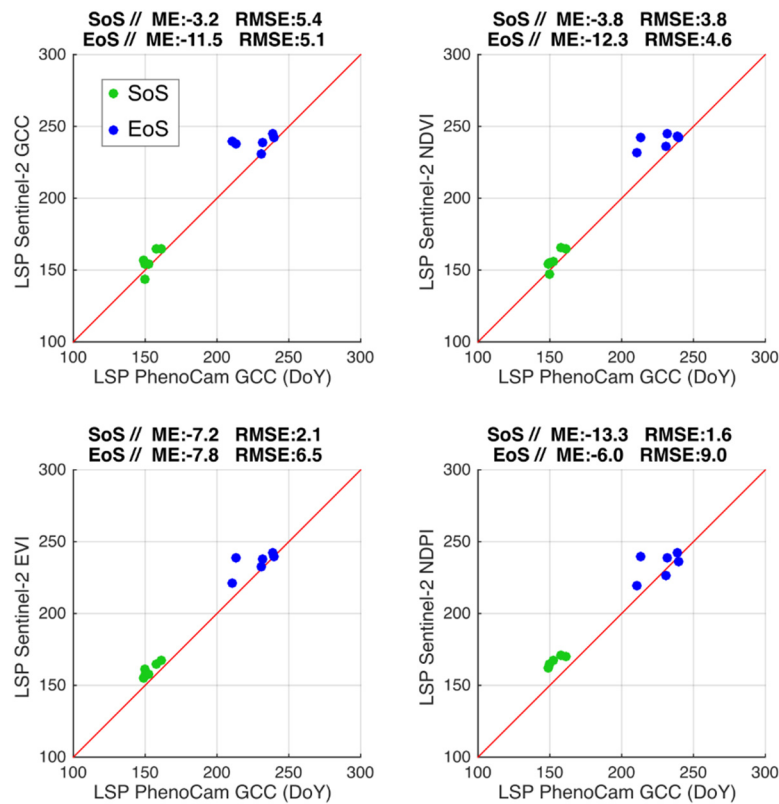
Figure S7. Comparison of start of season (SoS) and end of season (EoS) dates between PhenoCam and four vegetation indices estimated with Sentinel-2. The comparison was performed for three PhenoCam sites in the tundra biome for the years 2019 and 2020. The vegetation indices were the green chromatic coordinate (GCC) in PhenoCam and the GCC, normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and normalized difference phenology index (NDPI) for Sentinel-2. The phenology metrics were extracted with a 50% threshold method after time series smoothing. The bias between PhenoCam and Sentinel-2 is reported with the mean error (ME) and the accuracy with the root mean squared error (RMSE).

Difference Start of Season (MODIS-Sentinel-2)
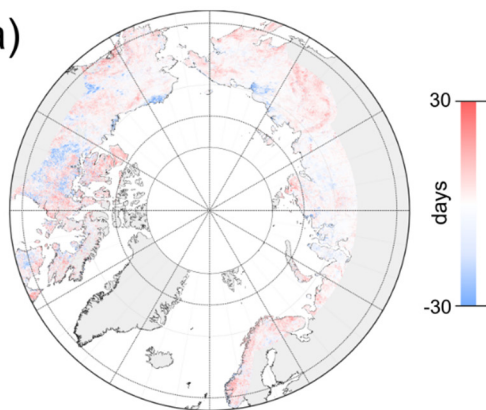
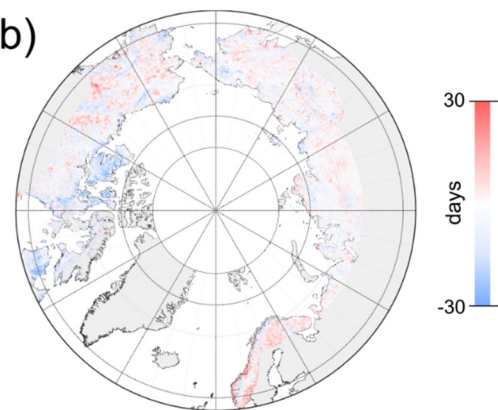**Difference End of Season (MODIS-Sentinel-2)**

a)

b)

Figure S8. Difference between start of season (a) and end of season (EoS) (b) phenology metrics extracted with the 50% threshold method applied to the non-smoothed Sentinel-2 and MODIS enhanced vegetation index (EVI) time series for the Arctic in 2019. The phenology metrics estimated with Sentinel-2 were resized to the spatial resolution of MODIS (500 m).
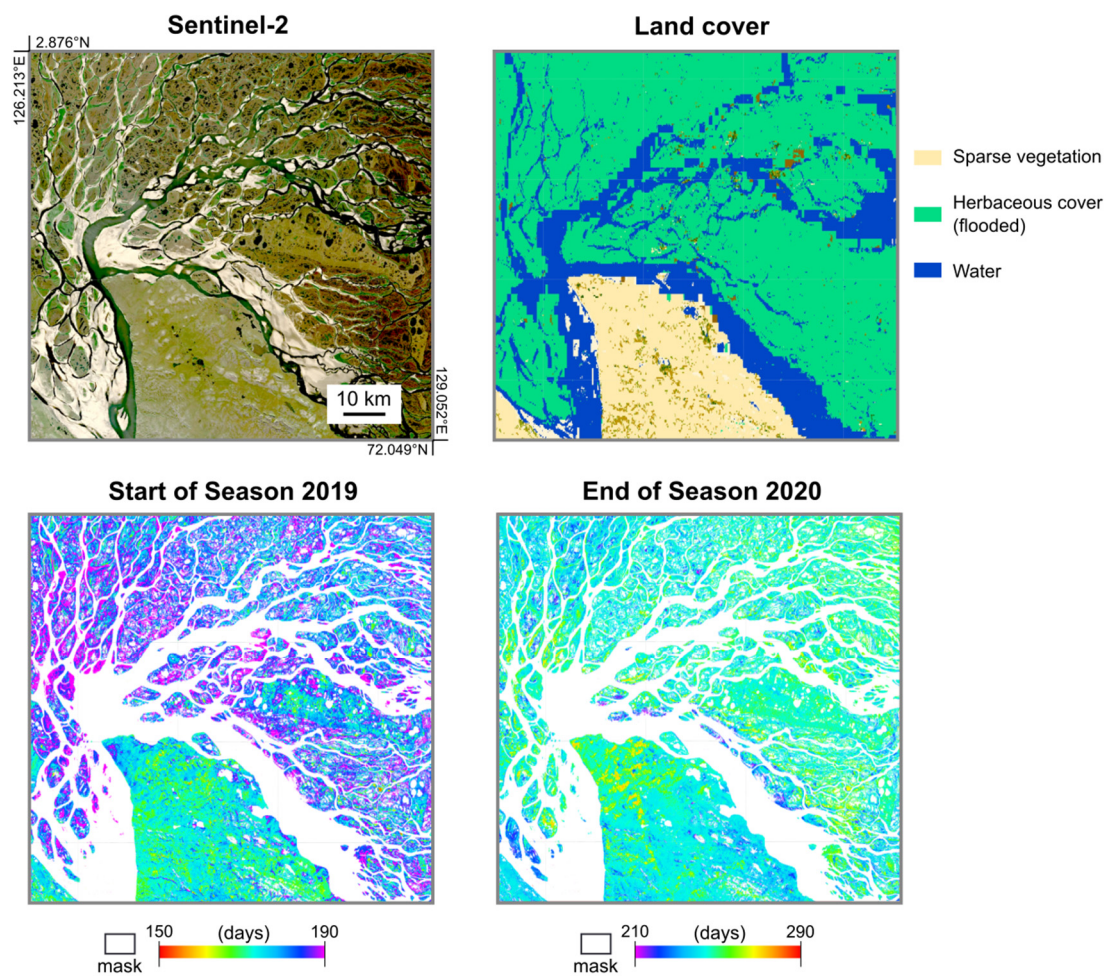
Figure S9. Differences in the vegetation dynamics in the delta of the Lena River. The Sentinel-2 image is a true composition (R: Red, G: Green, and B: blue) taken on 3 August 2019. The land cover is the GlobCover 2009.Changes in the land cover dynamics, primarily in the spring growth onset, depended on the vegetation type; greening occurs in the shrublands in the mainland earlier than the herbaceous cover in the delta.
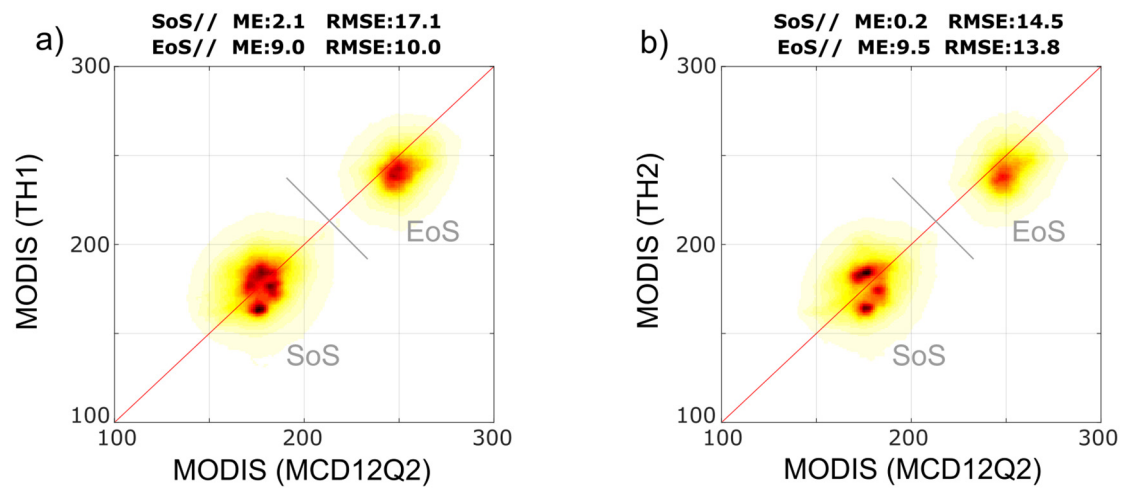
Figure S10. Comparison between the phenology metrics extracted with the 50% threshold method applied to the non-smoothed (a) and smoothed (b) enhanced vegetation index (EVI) MODIS time series derived from MOD09GAv6 surface reflectance product and the bands 'MidGreenup_1' and 'MidGreendown_1' in the MCD12Q2v6 phenology product for 2018.