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# Impacts of drought on vegetation phenology as observed from microwave observations.

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Vegetation is a highly dynamic land surface parameter, and plays an important role in regional and global hydrological, energy and carbon cycles. Phenological metrics, such as start and length of season, are highly affected by climate variability, where for example increases in temperature can lead to an earlier onset of vegetation activity in spring. Droughts have also been found to impact vegetation through a loss in the photosynthetic capacity of vegetation. Vegetation studies are traditionally based on optical based satellite products, e.g. Normalized Difference Vegetation Index (NDVI) or Leaf Area Index (LAI). However, unlike optical sensors, microwave remote sensing instruments have the advantage that they are not hindered by cloud cover, smoke, aerosol contamination and low solar illumination. In addition, the longer wavelength of microwaves allows to penetrate the canopy deeper and are sensitive to the total water content in both the crown as well as the woody part of the vegetation. Previous studies have shown the potential of both backscatter and Vegetation Optical Depth (VOD) to estimate phenological metrics and monitor drought effects on vegetation.

We build upon these studies with the aim to quantify shifts in phenological metrics and relate them to climate variability, focusing in particular on soil water deficits. We analyzed ten years (2007-2017) of VOD data obtained from the Advanced Scatterometer on-board a series of Metop satellites. Start and Peak of Season (SOS and POS) were calculated on a global basis for each year. First, as a quality assessment, spatial patterns of SOS and POS obtained from VOD were compared to those from MODIS LAI. Although small differences in the timing between optical based and microwave based SOS and POS were observed, spatial patterns were found to be similar. This demonstrates the capacity of VOD to monitor phenological metrics. The small temporal disagreements can be explained by the fact that the two different sensing methods are sensitive to different parts of the vegetation, where microwaves are sensitive to the canopy and woody part of the vegetation. Anomalies in the timing of phenological metrics were further related to antecedent soil moisture conditions from before and during the onset of the growing season. Soil moisture data was obtained from ESA's Climate Change Initiative soil moisture dataset (ESA CCI SM) and long-term anomalies were calculated based on the period 2007-2017. The presented work demonstrates the benefit of novel vegetation monitoring methods and will increase our understanding of the impacts of climate variability on vegetation dynamics.