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Evaluation of methods to derive green-up trends based on NDVI satellite observations

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Bridging the gap between satellite derived green-up dates and in situ phenological observations has been the purpose of many studies over the last decades. Despite substantial advancements in satellite technology and data quality checks there is as yet no universally accepted method for extracting phenological metrics based on satellite derived vegetation indices. Dependent on the respective method derived green-up dates can vary up to several weeks using identical data sets. Furthermore, different NDVI products are used and validated against ground observations representing different vegetation types. The products vary spatially between 250 m - 8 km resolution and temporally between daily observations and 16-day composites. Broad resolution products are considerably affected when analysing heterogeneous landscapes while composite data might mask short term phenological changes. Consequently, trends of green-up dates relying on different methods might leave us with ambiguous results and no indication as to what the phenological response to changing temperature and precipitation patterns is.

Here, we integrated and applied most of the commonly used methods and analysed respective effects on computed green-up dates and trends thereof (Linear and Spline interpolation, Gaussian and Sigmoidal functions, Fourier and Savitzky-Golay filters). NOAA AVHRR daily NDVI observations and 8-day composites of 1 km resolution from 1989-2007 were analysed covering the area of Central and Western Europe. Daily NDVI observations were dynamically filtered using an adaptation of the Best Index Slope Extraction (BISE) algorithm, the 8-day composite values were taken 'as is'. For each method and dataset we tested a number of local and global threshold values determining green-up. Computed green-up days were related to respective budburst events observed on the ground for the area of Germany. As ground truth, observations of the extensive phenological network of the German Weather Service were used. About 1500 observations per year and the most important species (Beech, Oak and Birch) were available evenly distributed all over Germany. All methods and procedures were integrated into an R-package made available for public use.

Results reveal substantial differences between the applied methods when single years are analysed. Based on the assumption that the satellite captures predominantly the greening-up of the canopy - which occurs about one week later than observed budburst dates - interpolation, Gaussian and Sigmoidal procedures produce green-up dates which are closest to budburst ground observations. For most methods results are closer to ground observations when using local, not global thresholds (Sigmoidal functions being the exception). Differences when using the daily or composite product are only minor.

Despite diverging results for single years all methods detect a trend to an earlier greening up (between 1-5 days/year). The trend magnitude depends mostly on the applied threshold, not the method used. Again, differences in trend do not greatly differ when using the daily or composite product. Trends based on satellite data are in line with observed trends on the ground for the area of Germany.