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Analyzing phenological extreme events over the past five decades in Germany

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As climate change may alter the frequency and intensity of extreme temperatures, we analysed whether warming of the last 5 decades has already changed the statistics of phenological extreme events. In this context, two extreme value statistical concepts are discussed and applied to existing phenological datasets of German Weather Service (DWD) in order to derive probabilities of occurrence for extreme early or late phenological events.
We analyse four phenological groups; "begin of flowering, "leaf foliation", "fruit ripening" and "leaf colouring" as well as DWD indicator phases of the "phenological year". Additionally we put an emphasis on a between-species analysis; a comparison of differences in extreme onsets between three common northern conifers. Furthermore we conducted a within-species analysis with different phases of horse chestnut throughout a year.
The first statistical approach fits data to a Gaussian model using traditional statistical techniques, and then analyses the extreme quantile. The key point of this approach is the adoption of an appropriate probability density function (PDF) to the observed data and the assessment of the PDF parameters change in time. The full analytical description in terms of the estimated PDF for defined time steps of the observation period allows probability assessments of extreme values for e.g. annual or decadal time steps. Related with this approach is the possibility of counting out the onsets which fall in our defined extreme percentiles.
The estimation of the probability of extreme events on the basis of the whole data set is in contrast to analyses with the generalized extreme value distribution (GEV). The second approach deals with the extreme PDFs itself and fits the GEV distribution to annual minima of phenological series to provide useful estimates about return levels.
For flowering and leaf unfolding phases exceptionally early extremes are seen since the mid 1980s and especially for the single years 1961, 1990 and 2007 whereas exceptionally extreme late events are seen in the year 1970. Summer phases such as fruit ripening exhibit stronger shifts to early extremes than spring phases. Leaf colouring phases reveal increasing probability for late extremes.
The with GEV estimated 100-year event of Picea, Pinus and Larix amount to extreme early events of about -27, -31.48 and -32.79 days, respectively. If we assume non-stationary minimum data we get a more extreme 100-year event of about -35.40 for Picea but associated with wider confidence intervals. The GEV is simply another probability distribution but for purposes of extreme analysis in phenology it should be considered as equally important as (if not more important than) the Gaussian PDF approach.