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Objective definition of seasons to detect their changes based on climate data

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Seasons may really shifted parallel to the global changes. On the other hand, however, climatologists do not always use objective and flexible, climate-reflecting definitions. So, the aim of the talk is to present two candidates for definition, and to elaborate the results in the 20th and early 21th Century for the different concepts. These definitions will not incorporate the simple trend analysis of three-monthly averages, starting on the first days of November, March, etc.

A first idea to define seasons is as follows. Summer (winter) can be identified as a period including date that has highest (lowest) mean temperature, while spring and autumn can be defined by periods including dates that have highest absolute derivatives of the annual course. Season boundaries can be selected such that mean squared error of seasonal means and daily mean temperatures corresponding to actual seasons is minimal. This analysis needs daily data, of course. The annual course can also be described by cosine functions with periods of one year and one half year for every year separately. Trend of amplitudes characterizes changes of the difference between summer and winter (in case of the one year period), and changes of the asymmetry of the annual course (in case of the one half year period). Trend of phases in cosine functions show the time shift of seasons. The trends will be estimated by a nonparametric regression technique. Temporal change of the first harmonic component characterizes the difference between winter and summer. The second harmonic component is informative for the asymmetry of the annual cycle. It makes it possible to detect, among others, changes of the existing but incorrectly named "European Monsoon".

Besides this approach postulating that the annual cycle is symmetrical and regular enough to be described by just a few harmonics, another approach based on cluster analysis of the neighboring months will be applied. This needs a sequential employment of this learning algorithm performed for three subsequent years treated as one case of the analysis to delimit the seasons. Neither the number of seasons, nor the criteria for them are preliminarily settled. Limits among the seasons are varied from one year to the other (after having established for the whole set of data by the analysis) which allows to establish the possible shifts among the newly defined "seasons". Another advantage of this approach is that even distribution among the in-cluster distance between the months is surveyed, which is not the case in the traditional seasoning. Seasons will be defined by a clustering technique defining groups of months utilizing similarity among the consecutive months within groups and dissimilarity among groups. Number of seasons will not be preselected but chosen during the application of the method. This is essentially important for transitional seasons (spring and autumn) that include months with highly different properties in the case of rigid conventional season definition.

Both definitions are applied for a wide set of data. The first approach is being demonstrated on diurnal temperature and precipitation data in and around the Carpathian basin. The second approach, that requires monthly data, only, is demonstrated on wider ecological regions of Europe reflecting combined effects of thermal and hydric components of the seasonality.