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New insights into spatio-temporal variations of trends in multiple variables by multivariate statistical methods

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The picture of long-term changes (trends) of climate is highly multivariate: the trends are detected in multiple variables, at many sites (stations or gridpoints), for different sections of year (seasons, months, or sliding seasons), for different time periods. To fully describe this picture requires either a huge pile of graphs and maps to be drawn, which would be very difficult to comprehend altogether, or an aggregation of all trend characteristics into a smaller set (that is, reduction of their dimensionality), which would be easy to look at and to interpret. The second way has rarely been attempted so far.

We suggest to use principal component analysis (PCA) for this purpose. We examine various possible settings of the input data matrix, that is, how the data are arranged into its columns and rows, and of PCA, including the choice of normalization, similarity matrix, rotation, and number of components to be rotated. This allows us to evaluate relationships among trends in multiple variables and to see, for example, how trends in temperature, daily temperature range, cloudiness, and sunshine duration are related to each other, how their relationships vary in space and during year, as well as whether they vary in the course of time. Another application of the PCA-based analysis of trends is the description of the European warming hole, that is, the region and period with the lack of warming, observed mainly in autumn in the second half of the 20th century, and its localization in space, time, and within annual cycle.