Characteristic fluctuations in seasonal temperature curves over time

“It was a hot year”, “The summer was hot, the winter was cold”

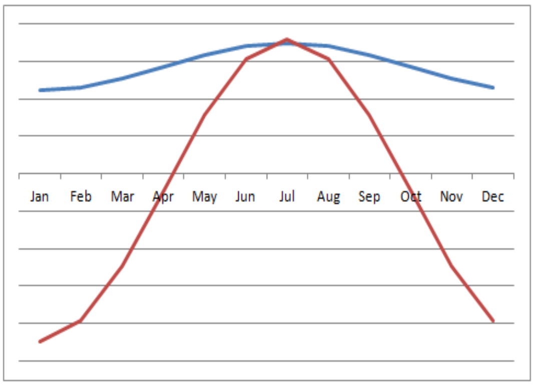
Is it meaningful to describe a particular year as being hotter than the previous year, or as having had a larger seasonal variation than the previous year? Do these statements represent underlying “characteristic fluctuations” in the seasonal temperature curve or are they simply impressions gained from essentially random fluctuations in weather?

A technique to extract such characteristic fluctuations is to calculate the principal components of the 12months x 12months covariance matrix of yearly changes in temperature. Principal components has been used in fields such as finance (to extract the characteristic fluctuations of the yield curve) and in biochemistry (to find characteristic vibrations of the DNA molecule).

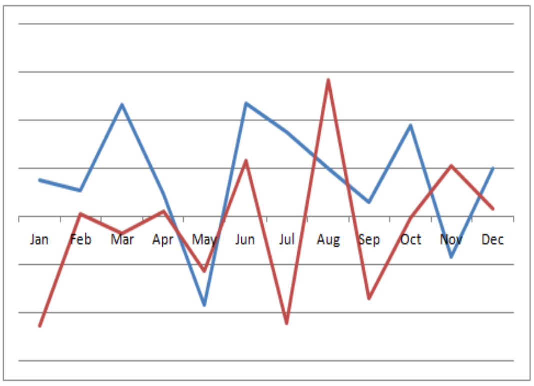
If the refrain “It was a hot year” represents a real characteristic fluctuation then we may be able to extract a major component representing parallel shifts upwards (downwards) of all temperatures throughout the year. Similarly, if the refrain “the summer was hot, the winter was cold” represents a real characteristic fluctuation then we may be able to extract a major component that shifts the curve upwards (downwards) in the summer, downwards (upwards) in the winter and leaves it unchanged in the spring and autumn.

To test the power of the technique 100 years of monthly artificial data was produced. Each year’s temperature profile was perturbed equally across all months by a vector of unit magnitude, scaled by a variable w_y, representing equal warming (cooling) in all months in year y. w_y is constructed as a normally distributed random variable with mean mu_w and standard deviation sd_w. Each month within the year was further perturbed by a sinusoidal change of unit magnitude, with peak positive amplitude in the summer and peak negative amplitude in the winter, scaled by a variable s_y, representing an exaggeration (dampening) of the seasonal curve. s_y is also constructed as a normally distributed random variable, with mean mu_s and standard deviation sd_s. mu_w and mu_s were both set at 0.01K/yr, sd_w and sd_s were both set at 0.1K.

The technique is able to extract the fluctuations (below left, blue line can be recognized as the warming (cooling) component, the red as the season exaggeration (dampening) fluctuation). However even just a 1K Gaussian noise addition to the monthly measurements makes both components unrecoverable (below right).

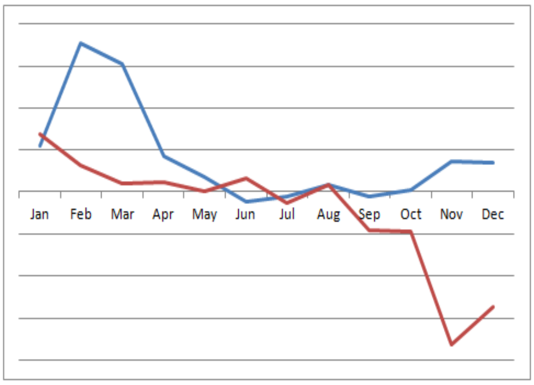


(E1=57%,E2=43%)

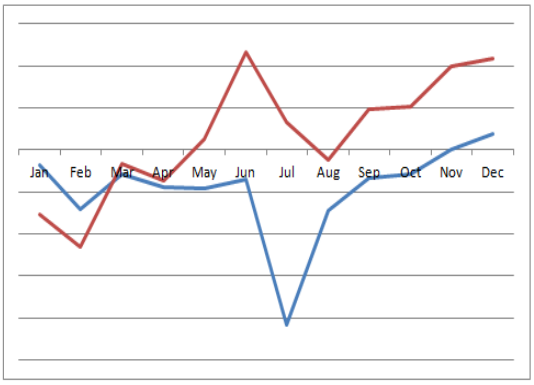


(E1=14%,E2=14%)

When applied to real data no pattern in the major characteristic fluctuations was seen (below, left is Aberdeen, right is Tokyo).



(E1=20%,E2=17%)



(E1=21%,E2=14%)

CONCLUSION

Principal components does not identify characteristic fluctuations in the seasons in the cities selected. It seems that such seasonal fluctuations either do not exist or are small and masked by other, essentially random, fluctuations.