Properties of climate time series and implications for tree growth across Latitudes

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INTRODUCTION

Variations in climate are critical to determining the rates of biological processes and the biogeographical distribution of species around the world. However, the climate varies on all time scales, from glacial cycles to hourly temperature, each affected biologically important processes. In this work, we examined (1) the complex structure of temperature records taken on different time scales: multi-decadal and every five minutes and (2) The effect of climate on ring width at different latitudes.

1.) Analysis of temperature data series.

With the autocorrelation function, iterated function systems a Hurst exponent we calculated the correlations of the data set. We also generated a binary string of the data and we calculated the complexity of the string with the algorithm of Lempel and Ziv. Despite differences in time scale of the two temperature series, they show the same Hurst exponent, around 0.9, suggesting high autocorrelation between successive measurements of temperature. Regardless of scale, there is approximately a 90% probability of measuring the same temperate at successive time steps.

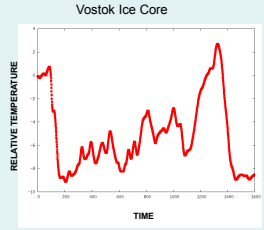

Figure 1: Time series of the relative temperature of the last 160 000 years on earth. These data was obtained from the Volstov ice core.

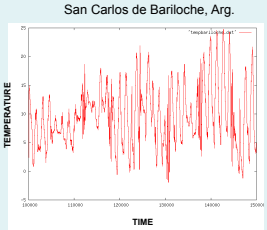

Figure 2: Time series of the temperatures measured in the last 7 years in the city of San Carlos de Bariloche.

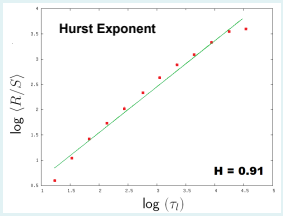

Figure 7: Hurst exponent for the time series of the relative temperatures of the earth.

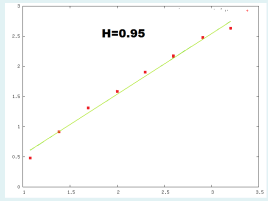

Figure 8: Hurst exponent for the time series of the temperatures measured en San Carlos de Bariloche.

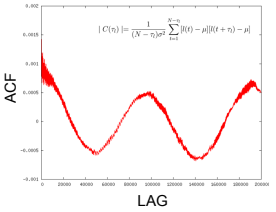

Figure 3 : Autocorrelation function of the data of the temperatures measured in San Carlos de Bariloche.

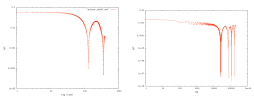
Figure 4 : Log-Log scale of the autocorrelation function for the time series of the temperatures. (Right) ACF for the time series of the temperatures measured in San Carlos de Bariloche. (Left) ACF for the time series corresponding to the relative temperature of the earth. Both cases show a periodic behavior.

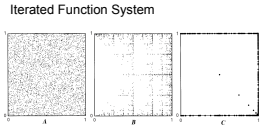

Figure 5: Iterated Function Systems generated using: a) white noise, b) pink noise and c) brownian noise. Each noise show a characteristic pattern.

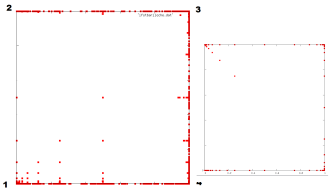
Figure 6: (Left) IFS for the time series of the temperatures measured in San Carlos de Bariloche. (Right) IFS for the time series of the realative temperatures of the earth. The points accumulated along the diagonal indicates the presence of strong short-term correlation. On the other hand, the presence of characteristic patterns in the space indicates weak long-range correlations.

2. Tree Growth

In order to determine whether variation in noise structure of temperature data affects the physiology of organisms that experience those fluctuations, we correlated the non-linear structure of annual temperature and growth of the pine tree *Psueotsuga mensiezii* (Douglas Fir, see Figure 9) across its entire latitudinal range in North America. We hypothesized that trees growing in climates where the variation in temperature is strongly autocorrelated (i.e. Brown Noise) will also show strong autocorrelation in ring width over the same time. Conversely, trees growing in locations where the variations in climate are significantly uncorrelated (i.e. white noise) should show little autocorrelation in their production of rings.

Tree ring data was obtained from the National Oceanic and Atmospheric Association's Paleoclimatology Database (www.ncdc.noaa.gov/paleo/treering.html). Mean Annual Temperature data was obtained for the nearest possible weather station for each tree ring record using NASA's database of climate data (www.data.giss.nasa/gistemp). Paired ring chronologies and temperature records were obtained for 10 locations spanning the latitudinal gradient of Douglas Fir (see Figure 10).

Figure 9: *Psuedotsuga mensiezii* and the formation of rings in conifers.

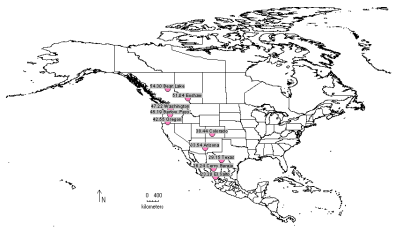
Figure 10: Map of locations of each pair of ring chronology and temperature data, spanning the latitudinal range 55N to 20N latitude.