

## practical exercises, day 1, 11.May.2009

Questions: tlaepple@awi.de

### Exercise 1: Random numbers, mean, standard deviation and standard error of the mean

Aims:

- Learn to use the help function
  - Learn how to create random numbers. The visual comparison of random numbers and climate data is useful in “calibrating” the mind to separate signals and noise.
  - Learn the meaning of standard deviation and standard error of the mean
1. Generate 100 independent normally distributed numbers with the mean = 1 and sd = 1 and store them into a vector (Hint: ?rnorm)
  2. Plot the numbers as line plot (Hint: ?plot). Note how structured random data can look like.
  3. Plot the histogram of the numbers (Hint: ?hist)
  4. Estimate the mean and the standard deviation (Hint: help.search("standard deviation") )
  5. Estimate the standard error of the mean. This gives you a measure for the uncertainty of the mean estimate.
  6. Add vertical lines to the histogram marking the mean and standard deviation estimates (Hint: ?abline)
  7. Advanced: Repeat the above experiment 10000 times and analyze the distribution of the mean estimates. This distribution should have a standard deviation close to the standard error of the mean from the step 5.
  8. Advanced: Repeat step 7 using red noise = numbers resulting from an AR1 process instead of the independent normal distributed numbers (white noise) generated in step 1. You can use `arma.sim(list(ar="AR1 OEFFICIENT"), "NUMBER OF NUMBERS THAT YOU NEED")` to generate realizations from an AR1 process. Analyse again the distribution of the mean estimates. What do you notice ?

## Exercise 2: Analysis of a time-series of your choice

Aim:

- Learn to read in time-series into R
- Basic analysis: distribution, autocorrelation, mean, standard deviation, linear trend

Useful commands for this exercise (for details see ?command):

read.table, read.csv: Reading functions for ASCII data (comma separated, and tab separated)

ts: create a timeseries

window: choose a subset by giving the time limits

lm: fit a linear model

acf: autocorrelation function

sd, mean: estimators for the standard deviation and mean

rnorm, rpois, ppois: random normally distributed numbers, random poisson distributed numbers,

poisson distribution function

### Tasks:

- 1.) Read in a timeseries of your choice. Try it on your own. If you don't succeed you can use the reading.R file and copy the required lines from there.
- 2.) Transfer the data into a timeseries (ts) object
- 3.) Plot the data
- 4.) Perform the analysis to answer the questions given below

### Questions:

**Hurricane numbers:**

**TC\_basin.1.5.csv (number of tropical cyclones of category 1-5 in the North Atlantic basin)**

**TC\_landfall.1.5.csv (number of tropical cyclones of category 1-5 that make landfall on the US coast)**

Are the numbers of hurricanes in the Atlantic basin and in the hurricanes that make landfall increasing with time ? (Use a linear regression)

How are the hurricane numbers distributed ? Have a look at the histogram; Compare mean and standard deviation of the timeseries.

Change point analysis suggests that the timeseries of hurricane numbers can be separated into active and inactive periods that are related to the mean climate state. The last three periods were 1947-1979, 1970-1994, 1995-ongoing. Calculate the mean basin and landfall rate in the active and inactive periods.

Advanced: Under the assumption that the landfall numbers are a realization of a Poisson process with the mean equal to the observed longterm mean landfalling rate; How likely was the number of landfalls in the year 2005 ? (You can either run a Monte Carlo experiment: Simulate a large number of poisson distributed numbers and simply count how often the numbers are as high or higher than in 2005, or just use ppois = Poisson distribution)

### **Temperature data**

**GlobTemp\_GISS.txt** : global annual mean temperature from GISS based on observational data

**GlobTemp\_IPCC.txt**: simulated global annual mean temperature, ensemble mean of the CMIP3 (IPCC) models for 1900-2100

Analyze the temperature trend using a linear regression against time. Have a look at the residuals. Compare the temperature trend with the simulated trend from the IPCC models.

**Advanced: How much variance of the annual temperature is explained by a linear trend ?**

### **NAO data:**

**nao.csv**: Index of the North Atlantic Oscillation. Normalized December-February means of the pressure difference between Iceland and the Azores:

Analyse the distribution of the NAO index

Persistence: Is the NAO index in the present year useful to predict the NAO index of the next year ?

### **NorthGrip dO18 data:**

Analyze the distribution of the dO18 values: what do you see ?

Compare it to a distribution of normal distributed numbers with the same mean and standard deviation.

In the last 8000 years, a cooling trend can be observed which is related to the changes in the incoming radiation caused by the different orbital sun-earth configuration. Estimate this trend using a linear regression of dO18 against time.

Assuming a dO18 to temperature relationship of  $0.67\text{‰}/^{\circ}\text{C}$  and a polar amplification of a factor of 2 (= local temperatures at the site of the ice-core change twice as much as the global mean temperature), how does the warming rate during D/O events compare to the warming rate we observed in the last 50 years and to the warming rate we expect to have in the next century ? )