EAML

Neural network modelling for the analysis of forcings/temperatures relationships at different scales in the climate system

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Outline

- Preliminary considerations;
- data;
- neural network model;
- global case study;
- regional case study;
- conclusions and perspectives.

Preliminary considerations

- Physical characterisation and forecasting in the climate system is a very difficult task, if we adopt an approach with complete dynamics.
- Atmosphere-Ocean General Circulation Models (AOGCMs) are the standard tools for grasping this complexity.
- They permit to recognise the role of some cause-effect relationships.

Preliminary considerations

- However, the results of AOGCMs could crucially depend on the delicate balance among the relative strength of feedbacks and the various parameterisation routines.
- Furthermore, they show limits in reconstruction and forecasting at regional and local scales.
- So, an independent analysis of influence/causality could be interesting.

Preliminary considerations

- The simplest idea: application of a multivariate linear model:

forcings (which influence temperature)

vs.

temperature itself

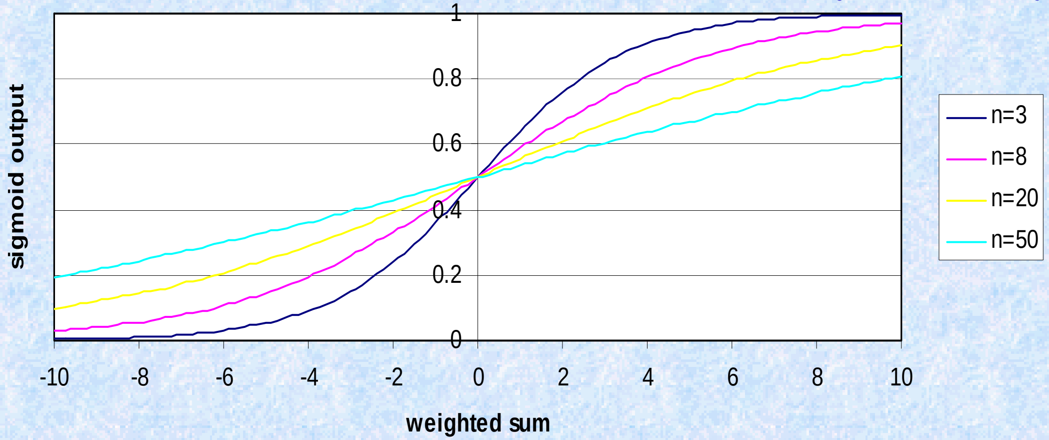
- Bad results: the linear model is too simple $\Rightarrow$ neural networks!

Data

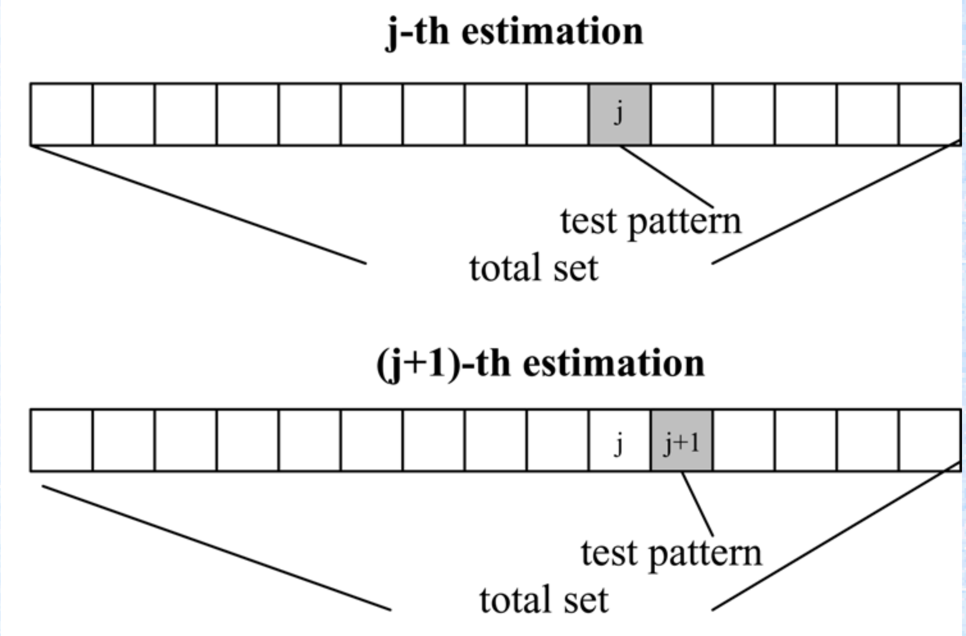
- Temperatures at both global (annual anomalies) and regional scales (Central England Temperatures - CET);
- natural forcings (solar activity and volcanism);
- anthropogenic forcings (CO_2 concentration and emissions of sulfates);
- SOI index related to El Niño (ENSO);
- North Atlantic Oscillation (NAO) index.

Neural network model

- Feed-forward networks with one hidden layer;
- backpropagation training (learning rate + momentum);
- our sigmoids are normalised (with reference to the number of connections converging to a single neuron of hidden and output layers);



Neural network model



- “all frame” or “hole” training;
- early stopping method.

Global case study

Inputs:

- solar irradiance and stratospheric optical thickness as indices of natural forcings coming from Sun and volcanoes;
- CO_2 concentration and sulfate emissions as anthropogenic forcings;
- SOI index (ENSO) as a circulation pattern in ocean and atmosphere which can be important for better catching the inter-annual temperature variability.

Global case study

4 case studies:

a) natural forcings only;

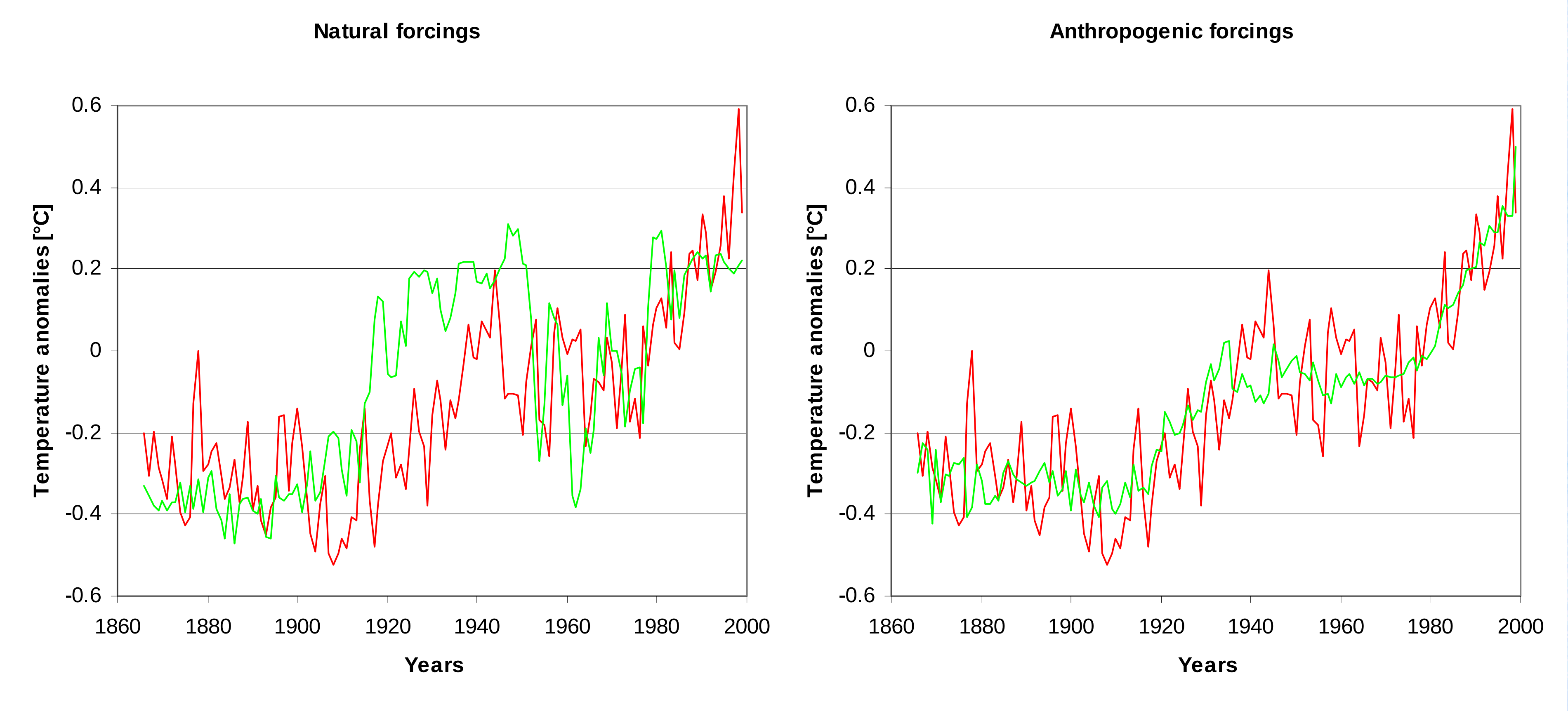
b) anthropogenic forcings only;

c) natural + anthropogenic forcings;

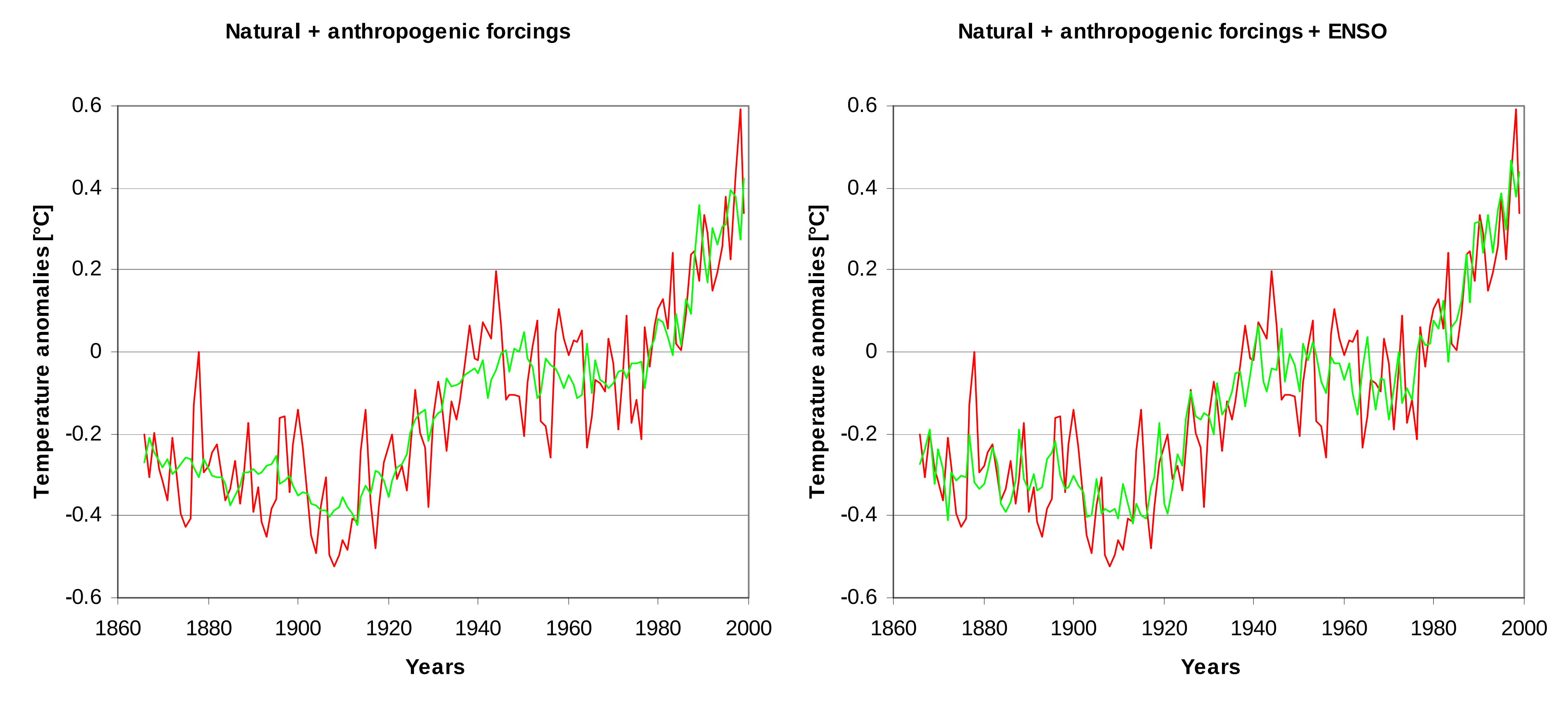
d) natural + anthropogenic forcings + ENSO.

Input forcings	Linear model	Neural model
Natural	0.661	0.622 $\pm$ 0.014
Anthropogenic	0.818	0.847 $\pm$ 0.005
Nat. + anthr.	0.828	0.852 $\pm$ 0.005
Nat. + anthr. + ENSO	0.844	0.877 $\pm$ 0.004

Global case study



Global case study



Remarks

- Strong nonlinear link between anthropogenic forcings and the temperature record;
- anthropogenic forcings appear as the main probable cause of the changes in T;
- the input related to ENSO acts as a 2nd-order corrector to the estimation obtained by anthropogenic and natural forcings (nevertheless, in a nonlinear system we cannot separate the single contributions to the final result).

A conjecture

The joint use of anthropogenic/natural forcings + ENSO leads to a very good reconstruction of our time series

⇓

we can advance the hypothesis that the variance not explained by our final model is probably due (almost completely) to a natural variability of the climate system.

How can we corroborate or falsify this last conjecture?

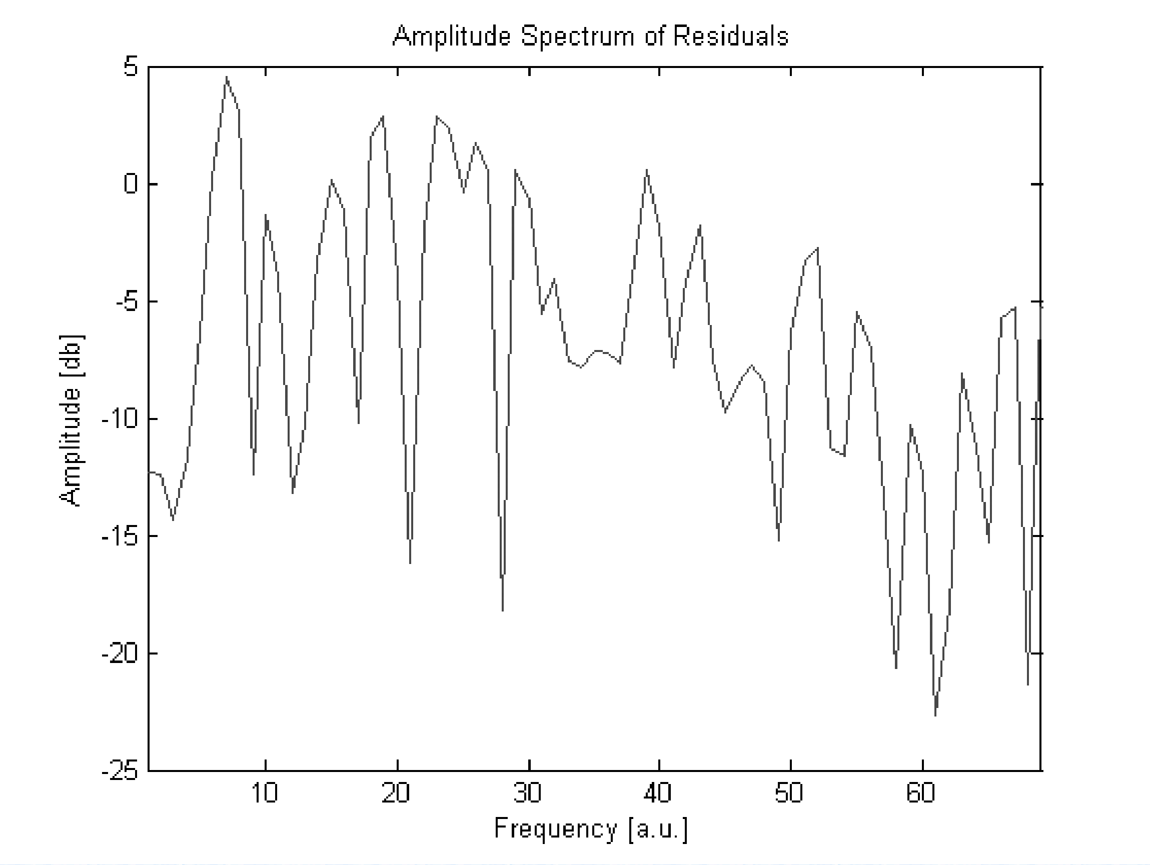
The residuals

Do the residuals appear as due to a random process or to some hidden dynamics coming from one or more neglected dynamical causes?

Two tests:

- Fourier spectrum;
- autocorrelation function.

The residuals



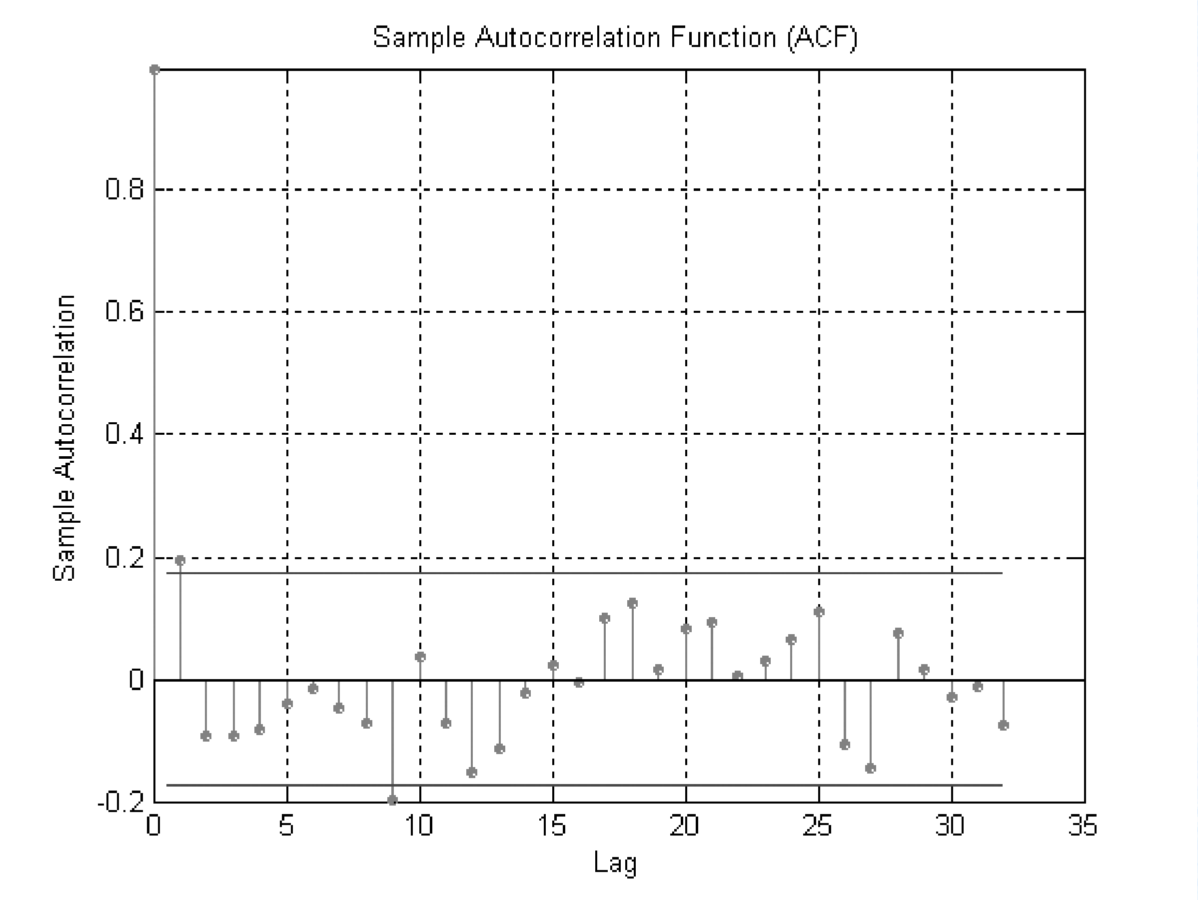
No particular peak and periodicity;

the spectrum trend is almost flat…

… but, decrease in the amplitude above 50 a.u.;

not enough data to strongly support the hypothesis of white noise.

The residuals



The auto-correlation function is almost completely confined inside the white noise limits;

some oscillations are visible but more uncoupled than in previous results.

The residuals

No undoubted conclusion can be reached by this analysis: we need further statistical tools for discriminating between random and chaotic fingerprints in our signal.

Anyway, if the behaviour of our time series is quite similar to that of series due to random processes…

… we can be confident that the major causes of temperature change have been considered and only a 2nd-order dynamics has been neglected in our study.

Regional case study

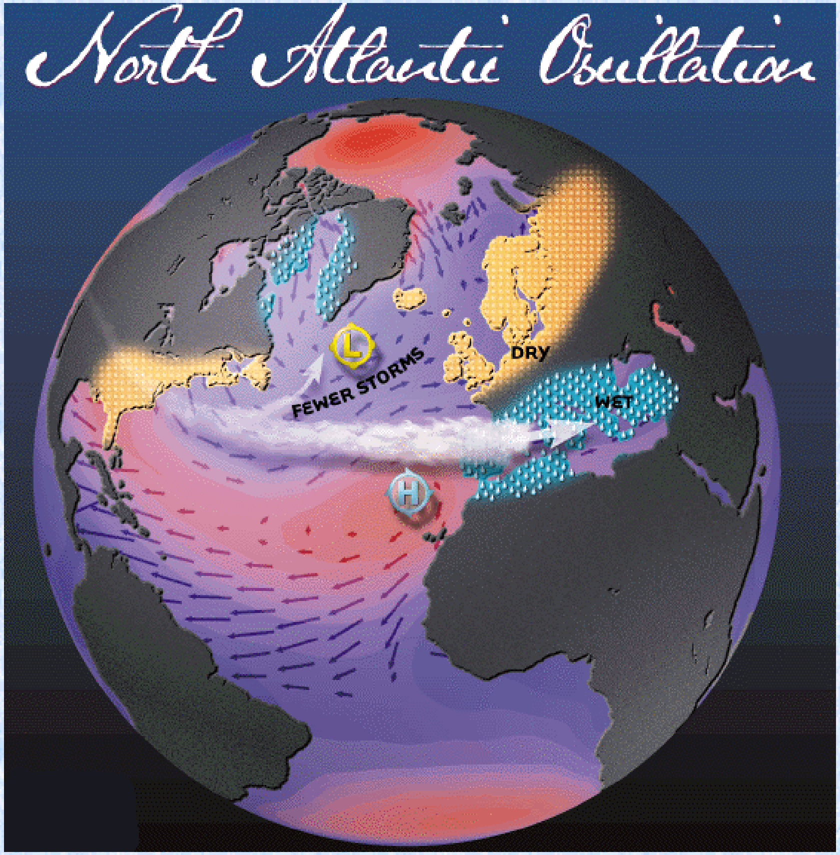
We want to analyse the fundamental elements that drive the temperature behaviour at a regional scale, with the same strategy adopted in the previous global case study.

It is well known that the North Atlantic Oscillation (NAO) correlates quite well with temperatures in a period called "extended winter" (December to March).

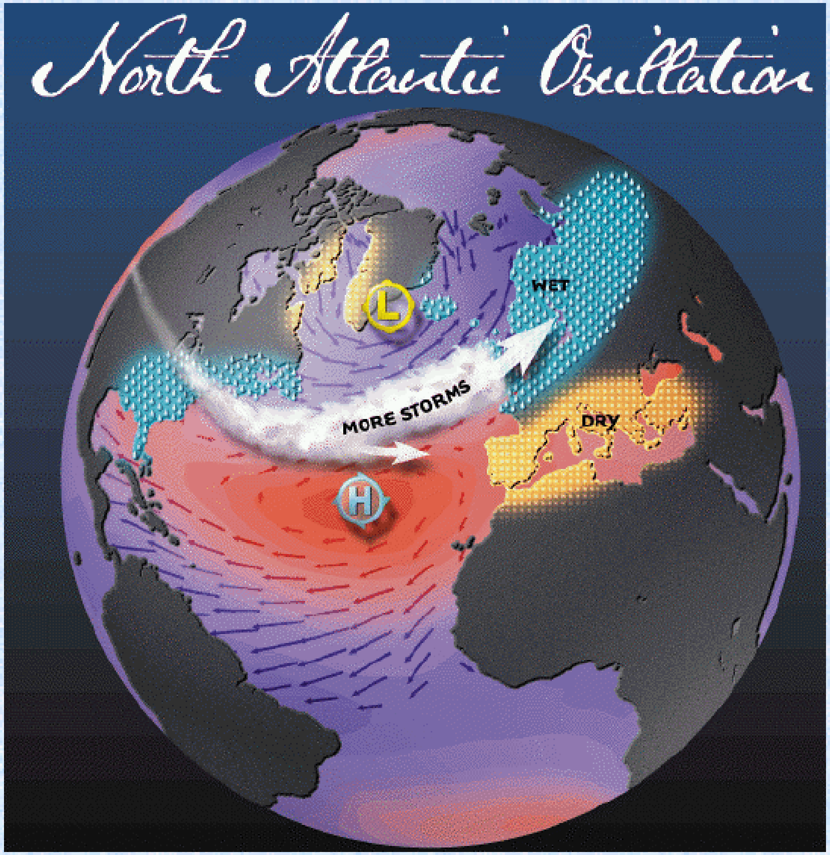
We want to assess the relative influences of global forcings and NAO on temperature in Central England.

Regional case study

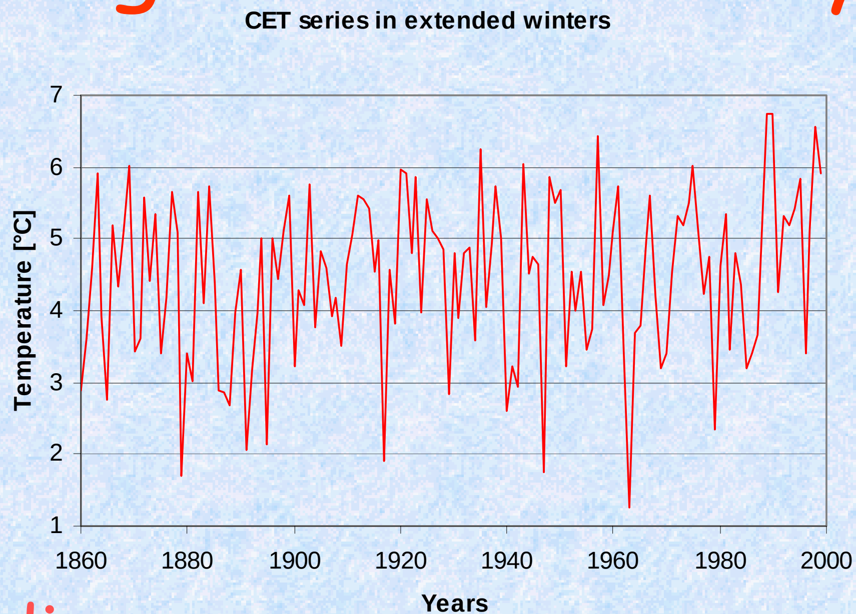
NAO -



NAO +



Regional case study



3 case studies:

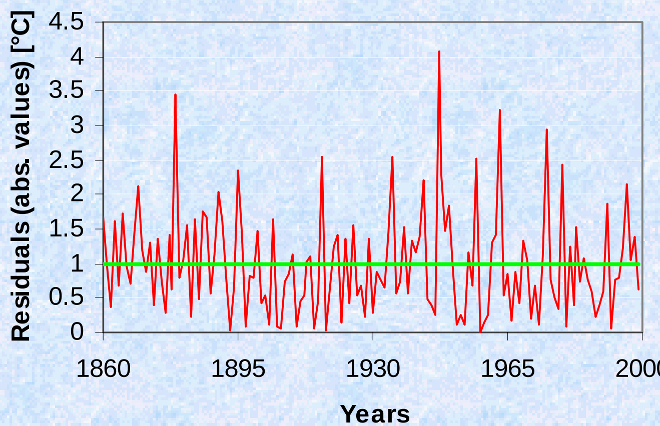
a) global (natural + anthropogenic) forcings;

b) NAO only;

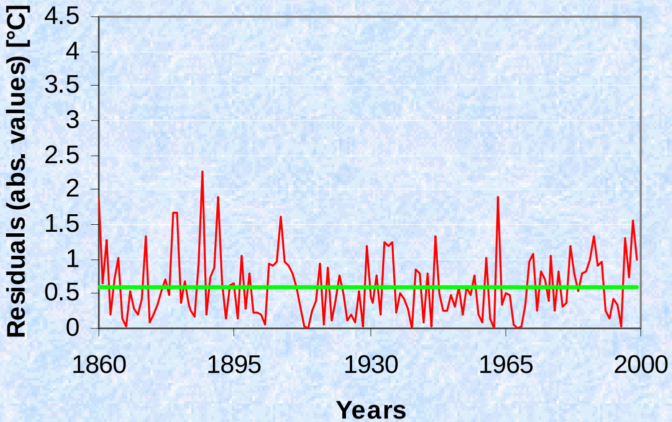
c) global forcings + NAO.

Regional case study

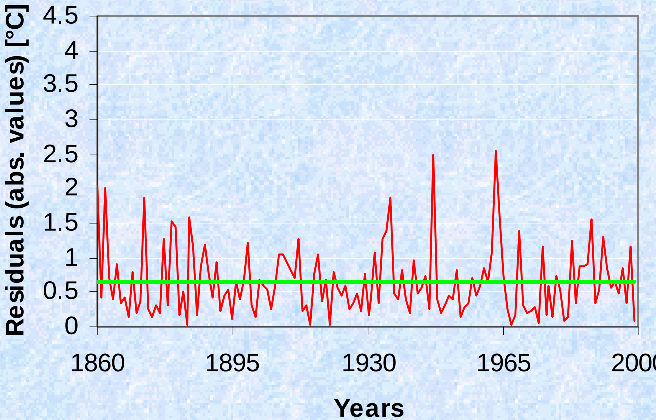
Global forcings



NAO only



Global forcings + NAO



Regional case study

Global forcings have a very little influence on the behaviour of temperatures in the central England during extended winter.

NAO - driving force: when NAO is considered, the values of linear correlation coefficients (estimated T vs. observed T) are about 0.72 ÷ 0.75 in the two cases. These values are lower than in the analogous situations of the previous global case study.

It is probably due to the enhanced inter-annual variability of climate at regional scale.

Conclusions

A non-dynamical approach allows us to obtain simple assessments in a complex system.

At a global scale we are able to reconstruct the global temperature behaviour only if we take the anthropogenic forcings into account.

Furthermore, we are able to recognise the influence of ENSO in better catching the inter-annual variability of our global time series of temperature.

Conclusions

At a regional scale, the recognition of the major influence of NAO on the CET time series appears very important.

In general, our results can be used in order to identify the fundamental elements for obtaining both:

- successful dynamical regional models
- and reliable statistical downscaling of AOGCMs in the past and for future scenarios.

Perspectives

We possess a phenomenological tool for obtaining preliminary assessments in the climate system.

In particular it is worthwhile:

- to consider an extension to inputs related to other kinds of circulation patterns and oscillations;
- to apply our method to other regions of the world;
- to extend our treatment to the reconstruction of precipitation regimes.