**Abstract**

In recent years, complex networks have become an increasingly popular tool to analyse relationships and structures in high-dimensional data sets in a variety of research fields. They have, however, rarely been applied to paleoclimate data sets, even though the growing number of published records demands efficient tools of multivariate analysis. The few published results that combine network methods and paleoclimate proxies are often not robust or have high uncertainty levels, linked to the low dimensionality, resolution and the large uncertainties of most particulate time series.

In this thesis, I propose several ways to overcome these issues in order to obtain reliable and quantitative results from network based tools by taking the particularities of paleoclimate data into account. For this purpose, I present four case studies, focusing on two time periods, the late Holocene (last two millennia) and the transition from the last ice age to the recent warm period - the last deglaciation. These studies are all related to the North Atlantic, a key region in multi-decadal to millennial scale climate variability. I primarily use two methods, one of network based time series analysis named *visibility graphs* and one of spatial analysis, so called *climate networks*.

The first case study analyses the degree of complexity in a set of terrestrial records from Northern Europe, using the method of visibility graphs. Here, I propose an approach of both single record and ensemble based significance testing to overcome the high rate of false positives that is typical for the method. In this way, I show that during the last two millennia there were multiple time periods at which the regional climate system exhibited anomalous dynamics, possibly related to perturbations by solar and volcanic forcing.

In a second study, I propose a novel method to reconstruct integrative climate indices, in particular the North Atlantic Oscillation (NAO) for the last two millennia. In contrast to classical methods, this approach is not adversely affected by the non-stationary relationship between atmospheric patterns and paleoclimate archives, but actually utilizes it, by using network linkages between distant regions to reconstruct past multi-decadal variability.

For times beyond the Holocene, the uncertainties in paleoclimate records increase drastically, in particular due to the limitations of physical dating procedures. To be able to construct climate networks for these records, I systematically study the influences of different interpolation methods and different levels of time uncertainty in a Bayesian framework of correlation estimation. This approach is then used to construct spatial networks out of marine sediment records. In contrast to previous studies, the links in this network are probabilistic estimates, incorporating many sources of uncertainty. In this way, I am able to construct more robust and reliable networks, which still show the ocean circulation changes that accompanied the last deglaciation.

In the last case study, I turn away from proxy data to study high-dimensional climate networks obtained from a transient model simulation of the last 21,000 years. Here, abrupt transitions are clearly visible in the topology of associated climate networks, demonstrating their ability to identify patterns of changes in a complex system.

I therefore both further develop existing methods, but also propose new ways to yield reliable results when dealing with highly uncertain paleoclimate data. The case studies demonstrate the usefulness of network based data analysis to study patterns of regional climate variability. Hence, this work is another step in bringing network based approaches to a larger audience and towards a wider application of these methods.