ScienceDirect

Global and Planetary Change
Volume 79, Issues 1–2, October–November 2011, Pages 145-156

Identifying natural contributions to late Holocene climate change

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https://doi.org/10.1016/j.gloplacha.2011.09.005
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Abstract

Analytic climate models have provided the means to predict potential impacts on future climate by anthropogenic changes in atmospheric composition. However, future climate development will not only be influenced by anthropogenic changes, but also by natural variations. The knowledge on such natural variations and their detailed character, however, still remains incomplete. Here we present a new technique to identify the character of natural climate variations, and from this, to produce testable forecast of future climate. By means of Fourier and wavelet analyses climate series are decomposed into time–frequency space, to extract information on periodic signals embedded in the data series and their amplitude and variation over time. We chose to exemplify the potential of this technique by analysing two climate series, the Svalbard (78°N) surface air temperature series 1912–2010, and the last 4000years of the reconstructed GISP2 surface temperature series from central Greenland. By this we are able to identify several cyclic climate variations which appear persistent on the time scales investigated. Finally, we demonstrate how such persistent natural variations can be used for hindcasting and forecasting climate. Our main focus is on identifying the character (timing, period, amplitude) of such recurrent natural climate variations, but we also comment on the likely physical explanations for some of the identified cyclic climate variations. The causes of millennial climate changes remain poorly understood, and this issue remains important for understanding causes for natural climate variability over decadal- and decennial time scales. We argue that Fourier and wavelet approaches like ours may contribute towards improved understanding of the role of such recurrent natural climate variations in the future climate development.

Highlights

► We identified persistent cyclic variations in records from Svalbard and Greenland. ► Some identified cycles correspond to variations in the Moons' orbit around Earth. ► Some identified cycles correspond to solar variations. ► Warming since 1850 is mainly the result of natural climatic variations. ► Persistence of cycles makes climate forecasting feasible for limited time ranges.

Introduction

Here we present an empirical technique to identify natural climatic variations in climate records, and from this, to hindcast and forecast climate variations. Most meteorological series display significant decadal or multi-year periodic behaviour, which so far have not been fully included in analytic climate models (e.g., Solomon et al., 2010), mainly because of incomplete knowledge on the detailed character of such variations. For example, the Pacific Oscillation that gives rise to El Niño and La Ninã has been known for over a century, and in the North Atlantic a similar oscillation, the North Atlantic Oscillation (NAO), is known to influence the weather in this region. During the last years there has therefore been an increasing realisation of important oscillatory phenomena in the Earth's global weather system, as knowledge on such cyclic variations is important to discriminate between natural and anthropogenic influences on contemporary climate change.

This suggests that a study of cyclic natural variations is timely for improving understanding of both present and future climate variations. Most climate models are trying to solve the complex problem of climate forecasting from first principles: The Navier–Stokes equations, the thermodynamics of phase changes of atmospheric water, the detailed radiation budget of the Earth and atmosphere and ocean dynamics. Our approach is different from this, representing an empirical bottom-up approach to climate modelling. We begin our analysis on a site-specific scale, using existing climate series.

Below we demonstrate the potential importance of such a bottom-up approach by analysing two Arctic temperature series, representing different time scales: (1) the Svalbard 1912–2010 surface air temperature record, and (2) the central Greenland GISP2 reconstructed surface temperature series (Alley, 2000). The Svalbard (78°N) data series is unique by being the longest meteorological record from the High Arctic, a region usually considered very sensitive to global climate changes. The second series, the GISP2 data has merit because of the long time range represented (back to the Eemian interglacial), and because the Greenland air temperature appears to vary in overall concert with the temperature of much of the planet (Chylek and Lohmann, 2005, Brox et al., 2009). Here we chose to focus on the most recent 4000 years of the GISP2 series, as the main thrust of our investigation is on climatic variations in the recent past and their potential for forecasting the near future. In addition, this part of the GISP2 series shows an overall linear temperature trend, which simplifies the following analysis. By choosing these two data series, we want to draw attention to the usefulness of not only long proxy series, but also standard meteorological series, which are much shorter than most proxy records. Both types of data series apparently are useful for a natural cycle based climate analysis, although on different time scales. As one example, it might be difficult from a short meteorological series to characterise fully the character of a 60–65 yr oscillation, such as, e.g., the AMO. Likewise, from a long proxy data series with 20–50 yr resolution it would be impossible to resolve the character of decadal scale oscillations. However, here our main focus is the identification of natural cyclic variations, and only secondary the attribution of physical reasons for these.

Section snippets

Wavelet analyses

Visual inspection of climate data series often suggests the existence of one or several recurrent variations. However, describing the character (persistence, period and amplitude) of such cyclic patterns is difficult, as the variations quite often come and go, lasting only for a limited period at each appearance. For this reason, they may prove difficult to characterise fully from a normal Fourier power spectrum. Especially the dynamics over time of the individual cycles can be difficult to…

The Svalbard temperature record

The wavelet-based analysis approach is suitable for being applied to standard meteorological observational records, even though most of these are relatively short (<150 years). As an example of this, we here analyse the Svalbard (78°N) meteorological data series 1912–2010 (Fig. 1), which is the longest meteorological record from the High Arctic.

Special climatic interest has often been attached to the Svalbard region because of the high latitude and the fact that this part of the Arctic…

The GISP2 series

To obtain a longer time perspective, we next considered the reconstructed central Greenland surface temperatures for the past 4000years, derived from the bidecadal $\delta^{18}O$ record from the Greenland Ice Sheet Project II (GISP2) ice core (Alley, 2000, Alley, 2004). Different paleoclimatic indicators in the GISP2 ice core, and the basis for their transfer functions, have previously been reviewed by Alley (2000) and will not be discussed here. The last year in the reconstructed GISP2 temperature…

Conclusions

(1) This study has identified several persistent cyclic variations in climatic and meteorological records from Svalbard and Greenland. Some of the cycles appear to correspond to known cyclic variations in the Moons' orbit around Earth, while others may correspond to solar variations. Notwithstanding the physical explanation for such cyclic variations, which is not the main focus of the present study, wavelet analysis of climatic and meteorological records represents a potentially useful means for…

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Acknowledgements

The present study was carried out partly at the University of Oslo, and partly at the University Centre in Svalbard (UNIS). The Greenland GISP2 data were obtained from the NOAA Ice Core Gateway (http://www.ncdc.noaa.gov/paleo/icecore/greenland/greenland.html↗). The Wavelets package AutoSignal v.1.7 by SeaSolve Software Inc. was used for data analysis.…

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