Dating uncertainties in layer-counted proxy records

Niklas Boers

ENS Paris, France

Time series derived from paleoclimatic proxy records exhibit substantial dating uncertainties in addition to the measurement errors of the proxy values. For radiometrically dated proxy archives, a framework rooted in Bayesian statistics was recently introduced, that successfully propagates the dating uncertainties from the time axis to the proxy axis. The resulting proxy record consists of a sequence of probability densities over the proxy values, conditioned on prescribed age values. One of the major benefits of this approach is that the proxy record is represented on an accurate, error-free time axis. Such unambiguous dating is crucial, for instance, in comparing different proxy records. This approach, however, is not directly applicable to proxy records with layer-counted chronologies, as for example ice cores, which are typically dated by counting quasi-annually deposited ice layers. Hence the nature of the chronological uncertainty in such records is fundamentally different from that in radiometrically dated ones. Here, we introduce a modification of that approach that is specifically designed for layer-counted proxy records, instead of radiometrically dated ones. We apply our method to isotope ratios and dust concentrations in the NGRIP core, using a published 60,000-year chronology. It is shown that the further one goes into the past, the more the layer-counting errors accumulate and lead to growing uncertainties in the probability density sequence for the proxy values that results from the proposed approach. For the older parts of the record, these uncertainties affect more and more a statistically sound estimation of proxy values. This difficulty implies that great care has to be exercised when comparing and in particular aligning specific events among different layer-counted proxy records.

The ecological relevance of local herbaceous biomass in climate and herbivore sedimentary reconstructions

Abraham N. Dabengwa, Lindsey Gillson, William Bond

University of Cape Town, Plant Conservation Unit Private Bag X3, Rondebosch, 7700 Cape Town, South Africa, abrahamdabengwa@gmail.com

Fire and herbivory disturbance processes in grass-dominated landscapes can complicate the interpretation of climate records from vegetation proxies. Gaps in the vegetation canopy created by disturbance alter the local climate and productivity of grassland patches. Frequently grazed areas like wetland perimeter grasslands (‘key resource areas’), which provide water and continuous grassland production for large grazing herbivores during droughts in the warm tropics can have climate and fire regimes unlike the surrounding landscape. In addition, the presence of shortgrass patches in otherwise tallgrass wetlands suggests the aggregation of large grazers in the past when they emptied out of the wider landscape to survive droughts. Several palaeoecological proxies were used alongside a regional rainfall reconstruction to assess long-term dynamics of a wetland perimeter grassland in response to drought, fire and herbivory with a wetland sedimentary core collected from a mesic grassland-savanna matrix in Vryheid, South Africa. Grassland community structure, herbivory, soil disturbance and fire were investigated using grass silica short cell phytoliths/ $\delta^{13}C$ stable isotopes, Sporormiella dung fungal spores, Zr:Rb elemental ratio, and macrocharcoal respectively. The 1250-year multiple-proxy record suggests that changes in grass tribes were driven by the combination of rainfall and herbivory. Herbivores were present throughout the sequence but increased from ca. 620 cal BP at the onset of the dry Little Ice Age as indicated by a rise in Sporormiella and the presence of Aristidoid phytoliths. Increases in herbivory coincided with more fire and soil erosion as suggested by an influx in macrocharcoal and a rise in the Zr:Rb ratio. Fire and herbivory were out of phase suggesting that the effect of soil moisture on grassland productivity affected disturbance regimes. Overall, the study demonstrates that shifting mosaic grasslands at wetland perimeter can be used to infer climate and herbivore distributions at landscape to regional spatial scales at long-timescales.

Combining age and proxy uncertainties - what is dominating the interpretability of paleo-records?

Elisabeth Dietze, Michael Dietze'*

**GFZ German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany, edietze@gfz-potsdam.de*
'GFZ German Research Centre for Geosciences, Section 5.1 Geomorphology, Potsdam, Germany, mdietze@gfz-potsdam.de

When studying past climate and environmental conditions to learn more about future global change, it is crucial to consider uncertainties, especially given an increasingly critical public. One way to show the limits of research output in paleoenvironmental research is considering age uncertainties. There have been large efforts, especially in the 14C-community in the last decades, to provide tools to calibrate "raw" 14C ages to calendar ages and to produce several thousands of Markov Chain Monte Carlo simulations of likely age depth models (from CLAM to Bacon, OxCal, Bpeat and COPRA…). With these approaches, samples from, for example, lake sediment, peat bogs or loess deposits receive individual age probability density functions (pdfs) that consider the heterogeneous 14C production in the atmosphere through time. Also, combining age information from different dating methods (Pb-Cs, 14C, OSL, tephras…) to provide reliable age-depth models is increasingly considered as standard approach.

Furthermore, proxy-inherent uncertainties become more and more important in paleoenvironmental research. These can result from distinct measurement precision and accuracy of different proxies, from aggregation of highly resolved samples or from proxy modelling and are independent of age. For example, modelling past land cover from pollen data using the REVEALS approach considers pollen productivity estimates and their standard errors as well as models of pollen dispersal. Proxy uncertainties can be described by individual pdfs that are not necessarily following classical statistical distributions.

Here, we present a generalised approach to combine age and proxy uncertainties by considering individual pdfs for discrete time-depth intervals using the open source software R. Two R-functions are illustrated by a classical case (XRF-data from a standard lake sediment sequence as proxy for lake level change) and a more complex case (fire biomarker fluxes from a varved lake). Using the classical case, we discuss what we can interpret without considering uncertainties, by considering only age or proxy uncertainties and by considering the combination of both.

Quantifying uncertainty in sediment-archived climate proxies over decadal to millennial timescales using proxy system modelling.

Andrew M. Dolman, Torben Kunz, Thomas Laepple

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany

Climate models can simulate global and local temperatures at arbitrarily fine temporal resolutions and assist in our understanding of climate variability over a broad range of timescales. For the recent past we have the instrumental record against which to compare model output, but to validate climate models on millennial scales, or for the more distant past, we have to turn to climate proxy records archived in ice sheets and sediments.

Comparing climate models and proxy reconstructions is challenging because, in addition to their low temporal resolution, many sources of bias and noise are introduced on the way from climate - to proxy - to proxy-based climate reconstruction. The (bio)chemical processes that encode climate signals, e.g. into elemental ratios in the shells of marine organisms, are influenced by multiple environmental and biological factors, making temperature calibrations uncertain. For sediment-archived biological proxies, seasonal patterns bias recorded conditions towards those found during peak development and export of biomass, and bioturbation can mix this signal over a large number of years. The process of picking, cleaning and measuring samples inevitably introduces other sources of error, and for proxies measured on a relatively small number of individuals, stochastic sampling of seasonal climate variation adds further noise to the proxy record.

Here we present a forward modelling analysis where we take a transient climate model simulation of the last 21000 years (TraCE-21ka) and simulate the encoding of the climate signal into, and climate reconstruction from, sediment-archived proxies such as foraminiferal Mg/Ca ratios and the Uk’37 alkenone unsaturation index. We examine the signal to noise ratio of the simulated proxies over a range of temporal resolutions and decompose the noise into components originating during the creation and reading of the archive.

Holocene climate variability in the North Pacific: Analysis of TraCE-21ka model simulation results and new proxy information from the Hawaiian Islands

Oliver Elison Timm[1], David Beilman[2], Siyu Li[1], Charly Massa[2]

[1]Department of Atmospheric and Environmental Sciences, University at Albany, Albany, NY
[2]Geography Department, University of Hawaii at Manoa, Honolulu, HI

Whereas a number of scientific studies have focused on the reconstruction of tropical Pacific variability in connection with ENSO variability, fewer studies have concentrated on the mid-latitude circulation changes during the Holocene. Our research aims to provide a synthesis of transient climate simulation information and paleoclimate proxy information from the North Pacific and the peripheral continents. The research presented here provides new insight into the extratropical circulation and hydroclimatic changes in Hawaii. We address the following questions:

(1) Are there significant changes in the spatiotemporal structure of the interannual/multidecadal modes of variability in response to external forcing?

(2) Can we reconstruct atmospheric circulation pattern from temperature / precipitation proxies?

(3) Do Hawaiian proxies yield results consistent with the model simulations?

In this presentation we show results from the TraCE-21ka model analysis. The internal modes of atmospheric circulation variability remained active through the Holocene with no significant change to the spatial structure of the leading EOF pattern. The forced response in the mean circulation pattern found in the atmospheric circulation is small compared with the internal variability. In the transition from the deglaciation time into the early Holocene we notice a reorganization of the westerly wind jet. A detailed analysis of the present-day relationship between winter circulation, storm activity and rainfall in Hawaii highlighted the strong influence of the westerly wind jet as a steering mechanism for synoptic disturbances and rainfall in the central subtropical Pacific near Hawaii. Similar relationships are found in the TraCE-21ka simulation in the preindustrial and mid-

Holocene. Overall the transient simulations shows a drying trend during the Holocene in the wet season (Nov-Apr) rainfall in Hawaii.

We present new results from a number proxies (e.g. organic carbon content, dC13, n-alkenes) retrieved from bogs and swamps on the Hawaiian Islands. The proxies indicate an increase in carbon content at the beginning of the Holocene suggesting wetter conditions started just prior to the early Holocene. During the Holocene the signals in the proxies show a trend towards drier conditions from early to late Holocene, consistent with model simulations.

Reconstructing the multidecadal variability of the NAO using functional networks for the last two millennia

Jasper Franke[1], *Johannes Werner*[2], *Reik Donner*[1]

[1]*Potsdam Institute for Climate Impact Research, Potsdam, Germany*
[2]*University of Bergen, Norway*

The North Atlantic Oscillation (NAO) is a pattern of atmospheric circulation in the North Atlantic region with considerable impact on weather and climate in both North America and Europe. On interannual timescales is is most pronounced in winter and influences temperature and precipitation in the adjunct regions. On multidecadal to centennial timescales it is thought to highly influence the Atlantic Meridional Circulation and along the temperature of the Northernn Hemisphere in general. Understanding this low-frequency variability of the NAO is crucial in understanding the natural component in multidecadal Northern Hemisphere climate dynamics.

The increasing availability of high-resolution paleoclimate proxies allows to not only study climate variations in time, but also temporal changes in spatial variability patterns. In this study we use the method of functional paleoclimate network analysis [1] to investigate changes in the statistical similarity patterns among an ensemble of high-resolution terrestrial paleoclimate records from Northern Europe. We construct complex networks capturing the mutual statistical similarity of the variability recorded by different archives during different episodes in time. These patterns of co-variability are deeply connected to the atmospheric circulation over the region and most noticeable to the NAO. Using networks based on similarity between groups of paleoclimate records we are able to extract those connections which carry information about the state of the NAO as described in a recent 1000yr long reconstruction. These cross cluster links enable us to extend the existing reconstruction of the NAO to the last two millenia. We can see changing multidecadal to centennial variability of the NOA throughout the last two millenia, with a positive phase dominating in general, but extended and pronounced intervals of negative NAO phase. The phases of rapid transitions between NAO phases are present during good known periods of history as for example the Little Ice Age, the Medieval Climate Anomaly and for the Dark Ages Little Ice Age.

[1] K. Rehfeld, N. Marwan, S.F.M. Breitenbach, J. Kurths: Late Holocene Asian summer monsoon dynamics from small but complex networks of paleoclimate data. Climate Dynamics 41, 3-19, 2013

Global surface temperature response explained by multi-box energy balance models

Hege-Beate Fredriksen and Martin Rypdal

University of Tromso, Norway

We formulate a multibox energy balance model, from which global temperature evolution can be described by convolving a linear response function and a forcing record. We estimate parameters in the response function from instrumental data and historic forcing, such that our model can produce a response to both deterministic forcing and stochastic weather forcing consistent with observations. Furthermore, if we make separate boxes for upper ocean layer and atmosphere over land, we can also make separate response functions for global land and sea surface temperature.

By describing internal variability as a linear response to white noise, we demonstrate that the power-law form of the observed temperature spectra can be described by linear dynamics, contrary to a common belief that these power-law spectra must arise from nonlinear processes. In our multi-box model, the power-law form can arise due to the multiple response times.

While one of our main points is that the climate system responds over a wide range of time scales, we cannot find one set of time scales that can be preferred compared to other choices. Hence we think the temperature response can best be characterized as something that is scale-invariant, but still possible to approximate by a set of well separated time scales.

A Scaling Model for the Anthropocene Climate Variability with Projections to 2100

Raphael Hébert, Shaun Lovejoy

Department of Physics, McGill University, Canada

The determination of the climate sensitivity to radiative forcing is a fundamental climate science problem with important policy implications. We use a scaling model, with a limited set of parameters, which can directly calculate the forced globally-average surface air temperature response to anthropogenic and natural forcings. At timescales larger than an inner scale, which we determine as the ocean-atmosphere coupling scale at around 2 years, the global system responds, approximately, linearly, so that the variability may be decomposed into additive forced and internal components. The Ruelle response theory extends the classical linear response theory for small perturbations to systems far from equilibrium. Our model thus relates radiative forcings to a forced temperature response by convolution with a suitable Green's function, or climate response function. Motivated by scaling symmetries which allow for long range dependence, we assume a general scaling form, a scaling climate response function (SCRF) which is able to produce a wide range of responses: a power-law truncated at the inner scale . This allows us to analytically calculate the climate sensitivity at different time scales, yielding a one-to-one relation from the transient climate response to the equilibrium climate sensitivity which are estimated. The model parameters are estimated within a Bayesian framework, with a fractional Gaussian noise error model as the internal variability, from forcing series, instrumental surface temperature datasets and CMIP5 GCMs Representative Concentration Pathways (RCP) scenario runs. This observation based model is robust and projections for the coming century are made following the RCP scenario 2.6, 4.5 and 8.5, for the year 2100, and compared with the associated projections from a CMIP5 multi-model ensemble(MME) (32 models).

A Scaling Model for the Forced Climate Variability over Multi-Centennial Scales

Raphael Hébert, *Shaun Lovejoy*

Department of Physics, McGill University, Canada

Separating internal variability from forced variability has become a crucial question, especially with the recent increase in anthropogenic forcing which adds complexity to comparisons of paleo and modern data. We explore new ways to characterize the forced temperature variability using a scaling model operating within the linear response framework with a power-law scaling climate response function (SCRF), the Green's function. Industrial era observations are used to estimate the best parameters of the SCRF. Using pre-industrial forcing reconstructions, we can calculate the expected forced mean temperature over the northern hemisphere and verify that it is consistent with multi-proxy temperature reconstructions over the last millenium. We assess whether the forced variability obtained is sufficient to explain low-frequency variability in the pre-industrial period, and the answer depends on the specific multi-proxy reconstruction considered for verification.

Reproducibility of Holocene proxy records: A case study from the Southwest Pacific

Sze Ling Ho[1,2], *Jeroen Groeneveld*[3], *Kira Rehfeld*[1], *Gesine Mollenhauer*[4], *Ricardo De Pol-Holz*[5], *Dirk Nürnberg*[6], *Michal Kucera*[3], *Thomas Laepple*[1]

[1]*Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.*
[2]*University of Bergen and Bjerknes Center for Climate Research, Bergen, Norway.*
[3]*MARUM and University of Bremen, Bremen, Germany.*
[4]*Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany.*
[5]*GAIA-Antarctica, Universidad de Magallanes, Punta Arenas, Chile.*
[6]*GEOMAR, Helmholtz Centre for Ocean Research, Kiel, Germany.*

Interpretation of proxy signals in marine sediments can be complicated as the signal may be altered by taphonomic processes during sedimentation, as well as by bioturbation in marine sediments which results in the mixing of proxy signals from different time intervals. These alterations can lead to a lower signal-to-noise ratio which in turns results in a skewed picture of the past environments reconstructed from proxies. Additional uncertainty also stems from sediment core chronologies typically based on radiocarbon dates.

A good handle on the various uncertainties associated with proxy records is especially critical when it comes to relatively stable periods like the Holocene where the small climate variability may be on the same order of magnitude as the proxy noise. Replicating Holocene proxy records may help to disentangle signal from noise but it is not routinely done due to limitations in sample material, resources and time.

Here we present findings from a replicate study, wherein we analyzed multiple geochemical temperature proxies (alkenone-based UK'37, d18O and Mg/Ca of foraminifera, archaeal lipid-based TEX86) on a set of short sediment cores from the same location (retrieved using a multicorer; distance < 60cm from each other). We also quantified analytical uncertainties arising from sample preparation and instruments. We find that Holocene temperature trends are reproducible within proxy type but not between proxies. The downcore variability in these proxy records is generally larger than the analytical uncertainties, suggesting that some portion of proxy variability is due to climate. In spite of the reproducibility in proxy records, there is substantial spatial variability in radiocarbon ages, with differences up to ~1000year between nearby cores. The age offset is an order of magnitude larger than the uncertainty associated with measurement and calibration of radiocarbon, indicating that the true uncertainty in radiocarbon-based age model may be larger than usually assumed.

Ecosystem resilience as a tool for detecting lake ecosystem response to climate driven change

Mayfield, R., *Langdon, P.G., Dearing, J.A. and Doncaster C.P.*

University of Southampton, United Kingdom

Lake ecosystems can abruptly shift from one steady state to another, sometimes crossing hysteretic tipping points and resulting in regime shifts. Past research has shown that early warning signs (EWS) can anticipate tipping points, offering ecosystem managers an opportunity to reverse the adverse lake conditions. However, the techniques used to detect EWS remain ambiguous, especially in relation to using palaeoenvironmental techniques. Our aim is to use analyses of structural changes in ecosystems, through nestedness and network approaches, to test ecological responses to climate change. To do this, we are currently working on modern data sets to identify temperature driven spatial variations in chironomid communities using nestedness and network skewness.

A centenary study case in the Paraná and the Uruguay rivers

Melanie Meis

Department of Atmospheric and Oceanic Sciences, Universidad de Buenos Aires, Argentina

In this study we analysed gauging stations in the Paraná and Uruguay Rivers, two rivers with excessive runoff which is used for energy and irrigation. We studied their statistical structure and applied spectral techniques to monthly streamflow in order to represent temporal and spatial variability. Using cross-spectrum methodology in a 105-year time series, we observed lower frequency (8- to 10-year) waves in the Paraná River. We also explored their relationship with ENSO variability. Given these conditions, climatic coherence studies between pairs of stations in the Paraná network, especially for the most frequent waves (less than two years), turned out to be redundant. Furthermore, a centenary-period analysis showed that in a hypothetical precipitation-runoff statistical model, the density distribution for the stations is not normal. The exploratory analysis for this streamflow network, and its extensive records, suggest that in order to improve hydro-climatological studies reference stations should be selected. Finally, the block maxima approach for each season considering daily discharges 1909-2013, in Corrientes station was analysed, and different return levels for 2, 5, 10, 50 y 100 years were obtained.

Using sediment and cosmogenic isotope records to reconstruct the paleomagnetic field

Sanja Panovska, *Monika Korte*

GFZ German Research Centre for Geosciences, Section 2.3 Geomagnetism, Potsdam, Germany

Paleomagnetic data from lake and marine sediments and from lava flows are typical records for reconstructing the geomagnetic field variations on millennial or longer timescales. Based on data compilation of more than 150 sediment records, a new global, time dependent, geomagnetic field model spanning the past 100 kyr has been built. Another independent source of information for the Earth's magnetic field changes are cosmogenic isotope records. We compiled more than 40 globally distributed records of 10Be from sediments, loess and ice cores. Their production rate is strongly affected by the variations of intensity and orientation of the geomagnetic field and by the solar activity. We plan to use these records as additional data for geomagnetic field reconstructions after extraction of the geomagnetic component of the signal.

The relationship between the paleomagnetic field and paleoclimate is twofold: 1) Paleomagnetic intensity measurements on sediments and isotope records may contain environmental, i.e., climate related contributions which have to be eliminated before using such records for paleomagnetic field reconstructions. For sediment intensities, normalizers that should account for changes in concentration and grain size of magnetic particles are commonly, however not always successfully, applied to achieve this. We have analysed cosmogenic isotope records with eigenanalysis techniques in order to separate the patterns of geomagnetic field and solar variability and other sources. Knowledge of past climate variations can be beneficial to understand if the signal separation was successful. 2) Tentative links have been suggested between the secular variation of the geomagnetic field and climate change over centennial time scales. Our aim is to better constrain the geomagnetic field on spatial and temporal scales, which can provide the basis for future analyses of relations between geomagnetic field, environmental and climatic variations.

Landscape dynamics in response to abrupt climate change recorded by geochemical proxies in Holocene lake sediments

Arne Ramisch

GFZ German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

Lakes form a reliable archive of paleoenvironmental change in the terrestrial realm. However, divergent proxy-records of lakes in close vicinity inhibit the reconstruction of regional climate signals. A common explanation for divergent lake records are catchment-specific sedimentary processes, which modify climate signals by autogenic fluctuation in sediment supply. However, there is no methodological framework to integrate catchment-specific sedimentary dynamics into the reconstruction of regional climate fields.

Here we present XRF records from several Asian lake archives, which indicate asynchronous variations of similar geochemical records since the late glacial/early Holocene. All XRF time series are characterized by damped harmonic oscillations of relative element concentrations throughout the Holocene. We present a numerical model, which accurately simulates major Holocene variations in the element concentration of lake records and discuss implications for the reconstruction of environmental signals from lake sediments.

Spatial variability and signal content of Holocene temperature proxy records

Maria Reschke, *Kira Rehfeld, Thomas Laepple*

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany

Analyzing the natural climate variability of the Holocene is necessary to improve predictions of future climate due to human-made climate change. Unfortunately, the climate signal which is contained in proxy records is affected by noise, time uncertainty and seasonal recording which hinders detailed climate reconstructions as well as the analysis of natural forcing and dynamical processes leading to climate change.

To improve proxy-based temperature reconstructions and estimations of past climate variability, we analyze a global set of marine and terrestrial Holocene temperature proxy records by estimating its signal content. For this, we compare the spatial correlation of proxy records and model simulations in dependence of data resolution, proxy type and seasonality, as well as the effects of noise and time uncertainty. This allows an improvement of further reconstructions of the Holocene temperature evolution and variability by knowing the properties of proxy records.

Lakes of southwestern Siberia and Northern Mongolia like high resolution palaeoarchives for climate and vegetation reconstruction

Natalia Rudaya

Alfred Wegener Institute, Potsdam, Germany

High-resolution palaeoarchives of vegetation and climate from the southern part of Siberia and northern part of Mongolia are still rare but necessary for evaluating the role of vegetation in interglacial climate variations, for validating climate models and for better understanding of past and future environmental dynamics in a region that hosts more than 50% of Siberian population. This are provides a paramount connection between the Central Asian steppes and the North Asian forest-steppe. Holocene environmental changes might have had a significant influence on the development of the human societies in this region.To address past linkages between humans and climate in NW Asia, we collected a suite of lake sediment archives in the geographic key area mostly covering entire Holocene (lakes B. Toroki, Chany, Kuchuk, M. Yarovoe, Teletskoye, Hoton-Nur, and Bayan-Nur).

Pollen records as proxy for vegetation and climate are one of the most powerful tools to understand past environments. Beside taxonomy, newly developed statistical approaches strengthen the use of pollen data and allow numerical reconstructions of climate parameters such as air temperature and precipitation commonly used in climate modelling. Besides pollen we used other bio- and geoproxies to reconstruct lake level fluctuations and lake conditions; content of organic materials and carbon stable isotopes etc. Radiocarbon dating and content of 210Pb support the precise chronology.

Combining proxy data and climate simulations for spatial reconstructions of paleoclimate

Nils Weitzel

Meteorological Institute, University of Bonn, Germany

Reconstructions of past climate are important for the understanding of the long term behavior of the climate system and the sensitivity to forcing changes. Unfortunately, they are subject to large uncertainties, have to deal with a complex proxy-climate structure, and a physically reasonable interpolation between the sparse proxy observations is difficult. As Bayesian models can include multiple sources of information (e.g. different proxy types, physical models for interpolation, output from climate simulations) and quantify uncertainties in a statistically rigorous way, they are in theory a good method to approach these problems.

We present a Bayesian framework that combines a network of pollen records with a spatial prior distribution estimated from an ensemble of climate simulations. The use of climate simulation output aims at a physically reasonable spatial interpolation on a regional scale. To transfer the pollen data into (local) climate information, we use a forward version of the probabilistic indicator taxa model. In addition, we can include Gaussian distributed data from preprocessed proxy records. The Bayesian inference is performed using MCMC methods following a Metropolis-within-Gibbs strategy.

As applications of our framework, we show reconstructions of European temperature for the Mid Holocene and the Last Glacial Maximum using an ensemble of climate simulations from the PMIP3 project and pollen syntheses from Bartlein et al. (2011) and Simonis et al. (2012).

Climate variability in the mid-Holocene control simulation by AWI-CM

Hu Yang

Alfred Wegener Institute, Bremerhaven, Germany

Three hundred years' Mid-Holocene and Pre-Industrial control runs are carried out by AWI-CM. The climate variabilities, e.g., ENSO, AAO, AO, AMO, PDO and NAO are analyzed. Moreover, the background climate states are compared between the Mid-Holocene and the Pre-Industrial. In the near future, a 6000 years transient simulation from mid-Holocene to Pre-Industrial will be presented.