Changes in West African monsoon precipitation: the competition between large-scale dynamics and local thermodynamics

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
The changes in West Africa Monsoon (WAM) precipitation are studied by the convective regimes and energetic analyses on the basis of three simulations of mid-Holocene (MH), sstClim4xCO2 and abrupt4xCO2. The atmospheric only simulation of sstClim4xCO2 shows similar changes in the pattern of WAM precipitation as that in the MH. The large-scale dynamics is found to be the main contribution to the changes in WAM precipitation, although the external forcing is completely different in these two simulations. The analyses of the moist and dry static energy (MSE and DSE, respectively) are also similar in these two simulations, showing a northward shift of the MSE and DSE maxima. However, such changes are not conclusive through models in abrupt4xCO2 simulation. Interestingly, in the very a few years when the 4xCO2 is imposed, the pattern of precipitation change is similar to those of MH and sstClim4xCO2, but the pattern reversed when the coupled system reaches an equilibrium state. The warming in the ocean tends to reduce the land-sea thermal contrast that leads to a negative contribution of large-scale dynamics, while the increase of CO2 and water vapor in the atmosphere tends to enhance the local thermodynamics. The large model spread thus result in the completion between large-scale dynamics and local thermodynamics in the models.

Mechanism of ENSO weakening during mid-Holocene

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
The mechanism of El Niño-Southern Oscillation (ENSO) amplitude change during the mid-Holocene (MH) is investigated by the Bjerknes stability (BJ) index through the model simulations from the Paleoclimate Modelling Intercomparison Project Phases (PMIP) 2 and 3. Results show that the weakening of thermocline (TH), zonal-advection (ZA) and Ekman (EK) feedback terms are the major drivers for the weakened ENSO amplitude in MH. And then we go one step further to discuss the key factors in regulating the above drivers and reveal that the weakening of TH, ZA, and EK terms are attributed to the weakened thermocline response to zonal wind stress anomaly in MH compared to PI. Such changes are due to the flattened meridional structure of ENSO-related interannual anomaly field (e.g, zonal wind stress anomaly field) in MH. The meridional structure change of ENSO-related anomaly field results from the strengthening of mean surface poleward meridional current (or mean subtropical cell). Quantitative diagnosis of PMIP simulations shows that the mean STC change might be a key factor, which plays an essential role in determining the changes of TH, ZA, and EK feedback terms, and thus the change of ENSO amplitude in MH.

The 8.2 ka cooling event caused by Laurentide ice saddle collapse

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The 8.2 ka event is a period of abrupt cooling of 1-3 °C across large parts of the Northern Hemisphere, which lasted for about 160 years. The consensus on the cause for this event has been the outburst of the proglacial Lakes Agassiz and Ojibway. These drained into the Labrador Sea in ~0.5-5 years and slowed the Atlantic Meridional Overturning Circulation (AMOC), thus cooling the North Atlantic region. However, climate models haven't been able to reproduce the duration and magnitude of the cooling with this forcing without including additional centennial-length freshwater forcings, such as rerouting of continental runoff and ice sheet melt in combination with the lake release. Here, we show that instead of being caused by the lake outburst, the event could have been caused by accelerated melt from the collapsing ice saddle that linked domes over Hudson Bay in North America. We forced a General Circulation Model with time varying meltwater pulses (100-300 year) that match observed sea level change, designed to represent the Hudson Bay ice saddle collapse. A 100 year long pulse with a peak of 0.6 Sv produces a cooling in central Greenland that matches the 160 year duration and 3 °C amplitude of the event recorded in ice cores. The simulation also reproduces the cooling pattern, amplitude and duration recorded in European Lake and North Atlantic sediment records. Such abrupt acceleration in ice melt would have been caused by surface melt feedbacks and marine ice sheet instability. These new realistic forcing scenarios provide a means to reconcile longstanding mismatches between palaeoclimate reconstructions and models. They also allow for a better understanding of both the sensitivity of the climate models and processes and feedbacks in motion during the disintegration of continental ice sheets. In addition, they provide insights into the stability of the Atlantic Multidecadal Oscillation and freshwater-driven perturbations of the AMOC resulting from the accelerating melting of the Greenland Ice Sheet.

Modelling the onset of North Atlantic Deep Water formation across the Eocene-Oligocene Transition

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Geological evidence suggests that North Atlantic Deep Water (NADW) first formed around the Eocene-Oligocene Transition (EOT; 34 Ma), coinciding with the large-scale glaciation of Antarctica. In earlier periods, deep water is thought to have formed in the Southern Ocean and possibly the North Pacific. Here we investigate possible causes of this reorganization of the deep circulation. We present novel EOT simulations using the coupled climate model GFDL CM2.1 adapted to late Eocene paleogeography. Using this paleogeography, we find that the North Atlantic becomes very fresh, which prevents NADW formation. Instead sinking occurs in the North Pacific and Southern Ocean in agreement with Eocene circulation proxies. We test the role of greenhouse forcing by varying the CO_2 to values of 400, 800 and 1600 ppmv, but the cooling alone does not substantially alter the preferred sinking regions. We further test the effect of closing the Arctic-Atlantic gateway, in light of recent evidence that the Arctic Ocean became isolated at the EOT. The gateway closure shuts off freshwater export from the Arctic to the Atlantic. This change enables a strong salinification of the North Atlantic that triggers the onset of NADW production.

Patterns of forced changes in spatiotemporal climate reconstructions of the Common Era

Session: Invited talks

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Abstract:

Spatiotemporal climate reconstructions offer opportunities to examine patterns of climate anomalies in both time and space and use these to diagnose causal mechanisms linked to radiative forcing or internal modes of ocean-atmosphere variability. Here, we use two recent Common Era temperature reconstructions to investigate the response of the climate system to volcanic eruptions as well as to radiative changes due to solar variability and greenhouse gas emissions. Our new NTREND field reconstruction of Northern Hemisphere summer temperatures shows coherent, broad-scale cooling associated with large tropical volcanic eruptions. Cooling persists in some cases for 2 or more years following eruptions and different eruptions reveal different magnitudes and spatial patterns that are not clearly associated with the estimated radiative forcing. We also detect temperature anomalies linked to centennial-scale changes in insolation and we quantify in time and space the temperature patterns linked to the Medieval Climate Anomaly, Little Ice Age, and modern warming. The PAGES2k Oceans2k High Resolution (HR) reconstruction of tropical sea surface temperatures shows cooling of the western Pacific and Indian Ocean in response to well-dated tropical eruptions but no statistically significant response in the eastern tropical Pacific, suggesting a reduction in the tropical Pacific temperature gradient but not a canonical El Nino pattern. Climate models simulate an overall larger cooling in the western Pacific and Indian Ocean than the reconstructions and produce a variety of anomalies in the eastern Pacific. New spatiotemporal climate reconstructions can provide useful benchmarks for comparing proxy reconstructions with model simulations and may help identify possible sources of disagreement.

Is the “Green Sahara” problem solved?

Session: Invited talks

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Abstract:
Palaeoclimatic theory and modelling seem to converge in the interpretation of archaeological and geological evidence of the Sahara and Arabian deserts being much greener than today during the early and mid-Holocene. Currently it is understood that the change in the Sahara and Arabian deserts was triggered by changes in insolation due to steady variations in the Earth orbit. The climate and ecosystem response to insolation changes was amplified by feedbacks between atmosphere, ocean and land. The atmosphere - land feedbacks include changes in vegetation cover, vegetation composition, lake coverage, soils and emission of mineral dust. Depending on the specific biases and the different complexity of models, some models match data better than others. Hence, it is not yet possible to quantify the efficiency of the various feedbacks involved. Likewise, the interpretation of local data is limited given the coarse spatial resolution of current climate models. The situation becomes even more challenging when addressing the question of the termination of the African Humid Period. And even if model and data converge, then it might be attributed just to a successful tuning of model parameters. Some important processes like the dynamics in plant diversity or the large uptake of mineral dust by small-scale intense convective systems are not adequately represented by current climate system models. In conclusion, we might have available most, if not all, ingredients for making the Holocene Sahara greener than today, but the precise recipe is still missing.

East Antarctic ice sheet variability during the last 3 Ma in the central & eastern Droning Maud Land

Session: Invited talks

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Abstract:
Reconstructing past variability of the Antarctic ice sheets is essential to understand their stability and to anticipate their contribution to future sea level rise. Recent studies have reported a significant decrease in thickness of the East Antarctic Ice Sheet (EAIS) during the last several million years. However, the geographical extent of this decrease and subsequent isostatic rebound remain uncertain. Recently, we reconstructed magnitude and timing of ice sheet retreat at the eastern Dronning Maud Land (DML), East Antarctica, based on geomorphological evidence and glacial isostatic adjustment modeling (GIA) (Suganuma et al., 2014). The data indicate that ice sheet thinning was estimated to be at least 500 m during the last 3 Ma. Although this study was the first attempt to estimate the absolute thickness of the EAIS thinning, local effects, such as regional ice flow and damming, to the ice sheet thickness reconstruction remain unclear. To provide a better constraint for the EAIS thickness reconstruction, we have carried out new field expeditions in wider area of the central DML. In this presentation, I will talk about preliminary results from the expeditions, which show that the significant ice sheet retreat since the Pliocene-Pleistocene boundary also occurred in the central DML.

Climate syntheses to benchmark CMIP6/PMIP4 Last Interglacial equilibrium simulations

Session: Invited talks

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Abstract:

The Last Interglacial (LIG, ~129-116 thousand years ago, ka) represents an excellent case study to investigate the response of sensitive components of the Earth System and the associated mechanisms to a climate globally warmer than preindustrial. However, a spatio-temporal representation of the LIG climatic changes remains difficult to obtain, mainly because aligning paleoclimatic records from various archives from around the globe is challenging. First, we summarize our recent studies that highlight how the coupling of HadCM3 equilibrium experiments with a synthesis of surface air and sea temperature records associated with harmonized chronologies from the appropriate time interval improved our spatio-temporal representation and understanding of the LIG high-latitude climate evolution. In particular, our integrated model-data approach shows that a freshwater input into the North Atlantic (due to the Northern Hemisphere ice sheet early melting) needs to be accounted for, in addition to the orbital and greenhouse gas concentration forcing, in 130 ka HadCM3 simulations, to explain the evolution of the early LIG climate. Second, we present a new 127 ka surface temperature time slice associated with quantitative uncertainty estimates to serve as benchmark for the upcoming CMIP6/PMIP4 127 ka equilibrium simulations. At 127 ka, summer sea surface temperatures were on average 1.1°C and 1.8°C warmer relative to preindustrial in the North Atlantic and in the Southern Ocean respectively. In Antarctica, average 127 ka annual surface air temperature was 2.2°C warmer compared to preindustrial. Finally, we provide a critical evaluation of the latest four LIG surface climate compilations and guidance on the use of these syntheses for upcoming model-data comparison exercises in the framework of the CMIP6/PMIP4 127 ka experiments. Overall, we do not recommend the use of LIG peak warmth-centered syntheses. Instead we promote the use of the most recent syntheses that are based on coherent chronologies between paleoclimatic records and provide spatio-temporal reconstruction of the LIG climate.

The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) and collaboration with PMIP

Session: Invited talks

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Abstract:

The aim of the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) is to produce process-based projections of the contribution of the ice sheets to future sea level based on the climate projections of the on-going CMIP6 activity. The project consists of three types of efforts, the analysis of simulated climate over and surrounding the ice sheets, standalone ice sheet simulations forced by AOGCM climate data and coupled ice-sheet climate experiments. ISMIP6 and PMIP have joined forces to propose a climate and ice sheet simulation of the last interglacial period as a first collaborative effort. This presentation gives an overview of ongoing and planned ISMIP6 activities and highlights current and possible future collaborations with PMIP.

AMOC response to climate forcing: Past, Present and Future.

Session: Invited talks
Author: Zhengyu Liu / liu.0722@osu.edu / Ohio State University

Abstract:
The responses of AMOC to the deglacial change of atmospheric greenhouse gases (GHG), ice sheet and meltwater forcing (MWF) is discussed using the TRACE21 simulations and the implication to the present and future AMOC is discussed. During the deglaciation, AMOC intensity is strengthened in response to the slow rise of atmospheric GHG, opposite to the weakening forced by the rapid increase of GHG in the future. In the meantime, AMOC intensity is weakened in response to the ice sheet retreat, which opposes the AMOC response to GHG such that the strength of AMOC is not changed significantly between LGM and the present. In both the AMOC responses to GHG and ice sheet, sea ice feedback plays a critical role. Furthermore, our model fails to produce the abrupt change of AMOC in response to deglacial MWF unless the MWF is prescribed to change abruptly. This may be an artifact of a model bias related to the present day freshwater budget that is common across all present coupled general circulation models (CGCMs). This overstabilization of AMOC may have underestimated the possibility of abrupt AMOC response and climate change to global warming in the future.

Palaeoclimate sensitivity, state dependence, and how well do we understand albedo changes through deglaciations

Session: Invited talks
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Abstract:
I will go through a method of palaeoclimate sensitivity reconstruction, and will highlight key assumptions. These are currently key targets for several teams aiming to capture potential state dependence of palaeoclimate sensitivity. Such work focuses on deglaciations, to see if and how climate sensitivity changed between glacial and interglacial states. But how do we assess changes in the second major slow feedback after carbon-cycle feedbacks, namely the ice-volume albedo feedback? We need well-dated, and precise sea-level reconstructions for that. For Termination I , the last deglaciation, corals and other coastal landforms have been used to make very detailed sea-level record that are well dated. But do these sufficiently represent the uncertainties? For older terminations, continuous sea-level records (e.g., Red Sea, Mediterranean Sea) offer better control, but not the absolute age control – so detailed frameworks are needed to establish both relative and absolute chronological comparisons with other key climate parameters. These introduce their own level of uncertainty. I will go through an array of issues and solutions that are being investigated. Termination II now emerges as the most promising interval of time for palaeoclimate sensitivity assessment: its sea-level history is simpler (essentially monotonic) and better understood than that for Termination II – in part this is because there is less short-term “noise” that complicates temporal comparisons than in Termination I. For other Terminations, we’re still a ways off, further than we might like, but the problem can be resolved.

Coral constraints on late Holocene tropical Pacific climate

Session: Invited talks

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Abstract:

Ocean-atmosphere interactions in the tropical Pacific drive a large spectrum of natural climate variability, and modulate the response of the global climate system to external climate forcing. Newly available datasets of past tropical Pacific climate resolve interannual to millennial-scale variability spanning from the last glacial period to the last century, and their relationship to both internal and external climate forcing. In particular, this study presents new coral-based reconstructions of central equatorial Pacific temperature and hydrology spanning the last seven millennia, with a particular focus on the last millennium. We uncover evidence for a sustained, significant reduction in El Nino-Southern Oscillation (ENSO) variability from 3-5kybp, outlining a new target for simulations of the ENSO's response to precessional forcing. We also uncover a significant response of tropical Pacific climate to volcanic forcing during the last millennium, focusing in particular on the Samalas eruption of 1258-1259AD. Our new dataset of pre-industrial ENSO activity has significantly lower variance than the ENSO activity of last decades, raising the specter that anthropogenic climate change has already altered the character of ENSO extremes. Lastly, we outline a new strategy for producing continuous, replicated reconstructions of tropical Pacific over the last 1-2 centuries for more robust comparisons with model hindcasts of historical trends in temperature and hydrology in this key region.

Modelled ocean changes at the Plio-Pleistocene transition driven by Antarctic ice advance

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

The Earth underwent a major transition from the warm climates of the Pliocene to the Pleistocene ice ages between 3.2 and 2.6 million years ago. The intensification of Northern Hemisphere Glaciation is the most obvious result of the Plio-Pleistocene transition. However, recent data show that the ocean also underwent a significant change, with the convergence of deep water mass properties in the North Pacific and North Atlantic Ocean. We show that the lack of coastal ice in the Pacific sector of Antarctica leads to major reductions in Pacific Ocean overturning and the loss of the modern North Pacific Deep Water mass in climate models of the warmest periods of the Pliocene. These results potentially explain the convergence of global deep water mass properties at the Plio-Pleistocene transition, as Circumpolar Deep Water became the common source.

Mid to late Holocene transition Holocene simulation with the IPSL Earth System Model

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

The Holocene is characterized by long term changes in seasonality induced by insolation that is punctuated by several climatic events. How different feedbacks from the surface hydrology, vegetation or dust have shaped regional trend, seasonality, variability and abrupt events is not well understood. The poster will present the first results of a small multi complexity ensemble simulation with the IPSL model. The objective is to highlight common long term characteristics in seasonal trends depending on regions, the relationship between trend and variability in Indian and African monsoon regions, as well as teleconnections between the precipitation in these regions and the long term evolution of the ENSO phenomenon in the tropics. A particular focus will be put on vegetation changes and the role they play in trends and interannual to multidecadal variability.

Simulated Last Interglacial climates with the Norwegian Earth System Model

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Following PMIP3 protocols, we performed four 1000-year long time slices of the Last Interglacial (LIG) simulations (130, 125, 120, 115 ka BP) with a recently developed efficient version of the Norwegian Earth System Model (2-degree atmosphere; 1-degree ocean). We will present large-scale features of the simulated LIG climates, with more focus on the ocean and sea ice dynamics in the North Atlantic and Arctic region. Comparison of our model results with SST proxy data shows reasonable agreement. Early LIG (130 and 125 ka) feature a stonger AMOC and less Antarctic Bottom Water (AABW), whereas late LIG feature a weaker AMOC and more ABWW. Late LIG features more Arctic sea ice in the model, which rejects more salt and leads to a higher SSS in the Arctic. More sea ice also results in higher sea ice export through the Fram Strait and the Denmark Strait. Higher SSS in the Arctic can be exported to the Nordic Seas and the North Atlantic, which counteracts the effects that more sea ice export leads to a fresher sea surface. The net effect is a freshening pattern along the Greenland coast and more saline pattern in the Baffin Bay and the North Atlantic.

Underlying causes of Eurasian mid-continental aridity in simulations of mid-Holocene climate

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Climate-model simulations uniformly show drier and warmer summers in central Eurasia during the mid-Holocene, a regional signal which is not consistent with palaeoenvironmental observations. The simulated climate results from a reduction in the zonal temperature index, which weakens westerly flow and reduces moisture flux and precipitation in the mid-continent. As a result, evaporation and latent heating are reduced and sensible heating increased, resulting in substantial surface-driven atmospheric warming. Thus, the discrepancy with the palaeoenvironmental evidence arises initially from a problem in the simulated circulation and is exacerbated by land-surface feedback. Analyses show that this region is also drier and warmer than indicated by observations in the pre-industrial control simulations, and this bias arises in the same way: zonal flow and hence moisture flux into the mid-continent is too weak and land-surface feedback results in dry conditions and surface-driven warming. These analyses pinpoint the processes underlying discrepancies between simulated and observed central Eurasian climates and suggest the need to improve aspects of the model that affect the strength of westerly circulation.

Antarctic Last Interglacial Isotope Peak in Response to Sea Ice Retreat not Ice Sheet Collapse

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Several studies have suggested that the Antarctic Ice Sheet was the primary contributor to sea level rise during the last interglacial (LIG; 130,000 to 115,000 years ago), most of which is hypothesized to have come from the unstable West Antarctic Ice Sheet (WAIS). Collapse of the WAIS would contribute ~3.5 m to the 5-9 m sea level rise reconstructed for the LIG. The prevalent hypothesis is that WAIS loss coincided with the peak Antarctic temperature and stable water isotope values from 128,000 years ago (128 ka); very early in the last interglacial. Using Bayesian multivariate linear regression and a statistical model comparison to combine isotope-enabled climate model simulations with Antarctic ice core data, we show that WAIS loss is not consistent with the isotopic evidence at 128 ka. Instead, a 65 ± 7 % retreat of Antarctic winter sea ice area best explains the 128 ka ice core evidence. This finding of a dramatic retreat of the sea ice at 128 ka demonstrates the sensitivity of Antarctic sea ice extent to climate warming. These results may also provide supporting evidence for WAIS loss and sea ice build up later during the LIG.

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Decoupling of temperatures and ice volume in the Middle Miocene: A missing piece of the puzzle?

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
The geological record documents a dynamic Antarctic ice sheet during the Middle Miocene (16 – 14 Ma) against a background of relatively low CO2. Recent bottom water temperature reconstructions indicate significant bottom water temperature changes during the Middle Miocene Climate Optimum (MMCO, 17-14.7 Ma), but no significant cooling over the major ice sheet growth of the Middle Miocene Climate Transition (MMCT, 14.7-12 Ma). This implies the increase in seawater oxygen isotopic composition at the MMCT represents growth of a larger-than-modern ice sheet. Our new modelling results indicate the mechanism by which this decoupling of temperatures and ice volume can be achieved. An ice-free Antarctic is warm and wet. Surface runoff from a very active hydrologic cycle forms a polar halocline preventing the freezing surface waters from ventilating the deep ocean. Ice sheet growth markedly reduces this precipitation and subsequent runoff, thereby making the near-freezing surface water around Antarctica saltier and able to form bottom water. Once the ice sheet has reached a continental scale, additional vertical growth does not further affect runoff significantly because precipitation has already reduced to a low level. Consequently, the polar salinity and temperatures are also little affected and hence neither is deep water production (which is in all cases produced in the south). Through orbitally paced scaling up and down of deep ocean ventilation, this mechanism is able to offer explanation for both the large amplitude variations in the MMCO benthic isotope records occurring whilst CO2 changes are no greater than 300ppm, and the lower amplitude isotopic variations following the MMCT (Holbourn et al., 2005, 2007, 2013; Kochhann et al., 2016 and references therein). Estimates of the Antarctic ice volume increase at the prior Eocene-Oligocene Transition (34-33 Ma) are equivalent to the modern ice sheet (Lear et al., 2008; Liu et al., 2009). Taken together, our new modelling results and the existing isotope, temperature, vegetation and CO2 reconstructions suggests this large Oligocene Antarctic ice sheet had collapsed by the MMCO. This implies that the dynamism during the Middle Miocene operated on a much smaller ice sheet than previously thought.

Using isotopic model emulation and ice cores to advance our understanding of Last Interglacial ice sheets

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Far-field sea level records have provided evidence that parts of the Antarctic Ice Sheet and Greenland ice sheet were likely lost during the Last Interglacial (LIG) period, 116-129 thousand years ago. Reconstructing ice sheet changes within the LIG however remains a difficult problem. Sediment cores from beneath the West Antarctic Ice Sheet (WAIS) support the view that parts were lost within the last 1.3 million years (e.g. Scherer et al., 1998), but again the timing of the loss is unknown. And set against this, proximal ice-rafted debris evidence from marine sediment cores has been interpreted to suggest that there was no major loss of the WAIS in the last 250,000 years (e.g. O'Cofaigh et al., 2001) or last 1.8 million years (Hillenbrand et al., 2002). Near field marine and sub-ice sheet sediment core data has not provided conclusive evidence of LIG changes in the WAIS, or the wider Antarctic or Greenland ice sheets. The resultant lack of agreement and knowledge about the ice sheet changes, particularly the WAIS, during the LIG hampers our ability to calibrate models of potential ice sheet loss in the future. Ice cores provide amongst the best dated proximal evidence of LIG change across the Antarctica and Greenland (e.g. Masson-Delmotte et al., 2011; Capron et al., 2014), it is therefore very helpful if we can use ice core measurements to provide constraints on the rate and timing of ice sheet change throughout the LIG. Holloway et al. (2016) thus explored the ice core signal of WAIS change; we found that ice sheet meltwater and/or ice sheet morphology changes would be recorded in Antarctic and Greenland ice cores. Here we present our recent progress on reconstructing ice sheet changes, simulating how possible LIG ice sheet and sea ice changes would be imprinted on Antarctic and Greenland ice cores using isotopically enabled climate model simulations of the LIG. We present initial results from a novel statistical approach to this problem, using isotopic model output emulation, to test the interplay of ice sheet, meltwater, and sea ice changes on the ice core record.

The role of vegetation and dust reduction in altering the West African Monsoon and the climate worldwide during the mid-Holocene Green Sahara period

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Understanding the West African monsoon (WAM) dynamics in the mid-Holocene (MH) is a crucial issue in climate modelling, because climate models typically fail to reproduce the extensive precipitation suggested by proxy evidence. We show that this discrepancy may be largely due to the assumption of both unrealistic land surface cover and airborne dust concentration, which strongly feed back into the WAM strength. However, the climate response associated to the greening of the Sahara are not limited to North Africa but affect the entire globe: the ENSO activity and mean state is significantly altered, the tropical cyclone activity is enhanced in both hemisphere in particular over the Caribbean Sea and Gulf of Mexico, the Indian Summer Monsoon is intensified, the East Asian Monsoon shifts northward and the extra-tropical is also altered. Compared to the case in which only orbital forcing are considered, all these climate responses under a green Sahara condition have better agreement with the mid-Holocene climate indicated by paleo-proxy records. Sensitivity experiments from a fully coupled ocean-atmosphere model EC-Earth show that the strengthening of the WAM induced by the orbital changes and amplified by the greening of the Sahara, shift and strengthen the Walker circulation, which triggers a chain of events that are responsible for the above-mentioned changes.

Influence of cloud radiative effects on tropical rain belts in the mid-Holocene

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
Paleoenvironmental data, in particular vegetation and lake-status in Sahara shows that at mid-Holocene (6,000 years ago) African monsoon extended much further north than today. Much of this change results from the changes in insolation driven by precession of the Earth's orbit, but in the state-of-the-art climate models, this factor alone is insufficient to explain the magnitude of the change. Previous studies showed that ocean and vegetation feedbacks affect the mid-Holocene monsoon and that the incorporation of these feedbacks in models improves the simulation of the hydrological cycle. However, it is not sufficient to reduce the discrepancies between simulated and reconstructed surface climates. In this study, we investigate the impacts of atmospheric cloud radiative effects (ACRE) on tropical rain belts during the mid-Holocene. This is done by running a general circulation model with and without cloud-radiation interactions using the IPSL model. The ACRE impacts include (1) a small northward shift of the tropical rain belts, (2) a decrease in tropical precipitation, (3) a narrowing and a strengthening of the ascending motions of the tropical overturning circulation, and (4) an intensification of the African easterly wave activity, but a contraction of tropical rain belts and decrease in precipitation over West Africa. Although the last impact in the mid-Holocene simulation is much larger than one in the control simulation, it is not enough to represent observed hydrological cycle over West Africa.

Paleoclimatic constraints on monsoon precipitation extremes over South Asia

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Knowledge about past climatic variations is critical for making reliable assessments of future changes in global and regional monsoon hydrological cycle. Paucity of long-term climate observations, limited spatio-temporal coverage of climate proxy records and complexities in modelling multi-scale variations of monsoon precipitation, pose inherent challenges in comprehending the behaviour of monsoon precipitation extremes in the past. Historical climate records for the 19th and 20th centuries provide valuable information on teleconnection linkages of the Asian monsoon precipitation with tropical and extra-tropical modes of climate variability. This study presents analyses of paleo-climate simulations for the mid-Holocene (~ 6000 years BP) and Pre-Industrial conditions (late 19th century) using a global climate model having high-resolution (

MIROC4m experiments using state-of-the art boundary conditions for the Late Pliocene and for the pre-PETM to Early Eocene

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
Warm periods of the past offer the chance to test climate models, not just through comparisons with proxy data, but also through model intercomparisons. The idea of an analogue to future global climate change, albeit with caveats, has additionally created much interest in these past periods. Two intercomparison projects have been established to utilise up-to-date paleodata to reconstruct formal boundary conditions for climate simulations. The Pliocene Model Intercomparison Project (PlioMIP), now in its second phase, focuses on the late Pliocene, approximately 3 Ma, while the Deep-Time Model Intercomparison Project (DeepMIP) looks back further to the period between the latest Paleocene and the early Eocene, approximately 55-50 Ma. Here, we present some results using the mid-resolution MIROC4m coupled atmosphere-ocean general circulation model. These results will focus on the most basic experiments specified in the projects, adhering to the protocols and using the boundary conditions provided.

HadCM3 PlioMIP Phase 2 Contribution: Enhanced Boundary Condition Core Experiments.

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
We present an overview of the UK's HadCM3 climate modelling contribution to the Pliocene Model Intercomparison Project Phase 2 (PlioMIP2) as part of PMIP4. We outline the process of setting up HadCM3 with the enhanced PRISM4 boundary conditions and discuss in detail the assumptions and choices made. In particular we focus on 1) efforts to maintain modelling consistency with previous PlioMIP HadCM3 modelling, 2) efforts to minimise potential sources of residual model drift, and 3) understanding the limitations of the model when simulating palaeogeographic changes. We then proceed to outline the process of HadCM3 and vegetation model spin-up and quantify the equilibrium state. We then present data from the final climatological mean state of the two core experiments - the Pre-industrial control (E280) and Pliocene control (Eoi400) - and compare PlioMIP2 against PlioMIP HadCM3.

From PLIOMIP to PMIP-"Quaternary" climate: a coupled climate /ice sheet simulation of the Pliocene-Pleistocene transition.

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
The early to mid-Pliocene was punctuated by cold and warm phases (5.3 to 3.3 Ma) [Lisiecki et al. 2005]. This period ended up with the major MIS M2 glaciation [Tan et al. 2017] and was followed by a warm and rather stable period called the mid Piacenzian warm period (mPWP, 3.3-3.0 Ma), which was the focus of the PLIOMIP1 project [Haywood et al. 2016]. Here, our purpose is to investigate the evolution of the Greenland ice sheet (GrIS) during the 3.0-2.5 Ma interval, which embraces the commonly accepted onset of perennial Greenland glaciation. We adapted and developed a specific tool that was first used to study the Eocene-Oligocene Antarctic glaciation (34 Ma) [Ladant et al. 2014]. This physically based method uses a matrix constructed from 56 IPSL simulations with various combinations of orbital forcing, CO2 concentration and GrIS configuration and creates a continuous climatic forcing based on the temporal evolution of the insolation, CO2 and ice sheet. This method allowed us to investigate the response of the GrIS to pCO2, in a first step by keeping the CO2 temporal evolution constant and in a second time, by using published pCO2 records from the literature. The constant CO2 simulations demonstrate the existence of a threshold for perennial GrIS onset: under 280 ppm it is possible to trigger and maintain the GrIS whereas above 320ppm the building of a large GrIS is not possible. These simulations also reveal the impact of the favorable insolation at 2.7 Ma in order to build the GrIS. Next, we force our model with recent pCO2 reconstructions from the literature [e.g., Martinez et al. 2015] to discuss the consistency between model results and available data, and also compare our simulated GrIS evolution with the recent model study of Willeit et al. 2015. Finally, we propose a CO2 scenario, which produces a GrIS evolution in good agreement with SST reconstructions and IRD records.

Mean climate and ENSO changes in three typical warm periods simulated by FGOALS-s2

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
We have analyzed the basic warming patterns among three typical periods - the mid- Holocene (MH), Medieval Warm Period (MWP), and the twentieth century warming (20CW) - and carried out a comprehensive heat budget analysis using four experiments simulated by FGOALS-s2. And we found that the model simulates similar spatial warming patterns in all three warm periods, e.g. stronger warming appears in the high latitudes. However, changes in surface air temperature (SAT) over the tropical regions are different: a significant warming occurs in the 20CW and MWP but a significant cooling in the MH. The heat budget analysis suggested that SAT changes are mainly induced by the heat flux. We further investigate how the ENSO change induced by the different external forcing in the three warm periods and found that the ENSO amplitude decrease in the MH but increase in the MWP. FGOALS-s2 simulated positive skewness in three warm periods, but underestimate the simulation of ENSO asymmetry.

Tracing changes in Neogene Antarctic hydrology using a data-model approach

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

With the advancement of both isotope-enabled climate models and our understanding of water isotope proxies, the hydrological cycle is becoming an increasingly important focus of paleoclimate studies. Of particular interest are periods of warmth and reduced ice cover such as the middle Miocene or the Pliocene, where exploring changes in hydrodynamics can constrain fundamental questions around the climate system. Here, we present a data-model approach to understanding changes to the hydrological cycle. Wood fossils and terrestrial sediments in the late Neogene (3-17 Ma) Sirius Group in the Transantarctic Mountains provide a unique insight into Antarctic palaeoclimate during a period of Antarctic ice sheet retreat. We use plant compound isotopes (?18O and ?2H) to reconstruct precipitation isotopes, suggesting that ancient precipitation was significantly enriched relatively to the modern (~12‰ and 100‰ for ?18O and ?2H, respectively). This result is consistent with reconstructed Antarctic summer paleotemperatures of 5 °C and implies increased moisture delivery to the continent with a shorter vapour transport pathway relative to the modern. We then present data from atmospheric tracer experiments using isotope-enabled general circulation model (HadCM3) to explore in detail changes in moisture source and atmospheric circulation during a vital period of Antarctic climate history.

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The PMIP4-CMIP6 Simulations for the Mid-Holocene and Last Interglacial with the Community Earth System Model

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
Two interglacial epochs are included in the suite of Paleoclimate Modeling Intercomparison Project (PMIP4) simulations in the Coupled Model Intercomparison Project (CMIP6). Experimental protocols have been established for the Tier 1 simulations of the mid-Holocene [midHolocene, 6000 years before present] and the Last Interglacial [lig127k, 127,000 years before present] (Otto-Bliesner et al., Geoscientific Model Development Discussions, 2016). These equilibrium simulations are designed to examine the impact of changes in orbital forcing at times when atmospheric greenhouse gas levels were similar to those of the preindustrial period and the continental configurations were almost identical to modern. The changes in insolation are characterized by enhanced seasonal contrast in the northern hemisphere (NH) (and reduced seasonal contrast in the southern hemisphere, SH), with these changes stronger in the lig127k experiment than the midHolocene experiment. Here, we report on the lig127k and midHolocene simulations with the Community Earth System Model, version 2 (CESM2), the same model and same resolution as is being used for the CMIP6 DECK, historical, and future projection simulations. The results will be compared to the CMIP5/PMIP3 simulations with the Community Climate System Model, version 4 (CCSM4). Otto-Bliesner, B.L. et al., 2016: The PMIP4 contribution to CMIP6 - Part 2: Two Interglacials, Scientific Objective and Experimental Design for Holocene and Last Interglacial Simulations. Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-279.

A 75-Year Long Absolute SST Reconstruction Reveals Last Interglacial Variability in the Tropical Atlantic Warm Pool: Comparison of Model and Coral-Based Reconstructions

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

The Last Interglacial (LIG), when sea level was ~6 m higher than today, serves as an analog for future climate scenarios yet only a few paleoclimatic reconstructions with seasonal to decadal resolution exist from this interval. Hispaniola, in the northern Caribbean Sea, is a desirable site for producing sea surface temperature (SST) reconstructions as it is located in the northern sector of the Atlantic Warm Pool (AWP), a primary moisture source region for precipitation in Central and North America, and this location has significant correlations with SST and precipitation anomalies for much of the region. Here we present an early LIG (128.6 ka) monthly-resolved coral Sr/Ca-SST reconstruction from a well-preserved Siderastrea siderea subfossil coral spanning 75 years from the northern coast of Hispaniola (19.913ºN, 70.925ºW), which is one of the longest subfossil coral reconstructions for any interval and the longest for this region. We compare our LIG SST reconstruction with three modern S. siderea microatolls, the longest spanning 84 years (1926–2010 CE), near Port-au Prince, Haiti (18.479070°N, 72.668659°W), as well as the CCSM3 125 ka LIG model simulation spanning 300 years. We find similar SST seasonal cycles (3.7ºC) in the LIG coral and simulation that are greater than those in the modern Haitian corals, observed SST (ERSSTv4.0 and HadISSTv1.1), and CCSM3 20th century simulations. This seasonal variability is consistent with the findings of other LIG coral reconstructions in the tropical Atlantic Ocean suggesting that orbital insolation changes are driving LIG SST seasonality in this region. Furthermore, our LIG reconstruction reveals larger multidecadal (2.8ºC, ~20–30 years/cycle) and interannual variability (3.0ºC, ~3–8 years/cycle) than the modern coral reconstructions and SST records in the AWP yet similar variability is present in the LIG model simulation. This interannual and decadal variability may reflect variations in the northern extent of the AWP on these time scales, which may covary with trade wind strength, westward moisture transport to the Americas, and precipitation in the Caribbean.

Solving the enigma of Arctic amplification during the Mid-Piacenzian Warm Period using the new Community Earth System Model

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Polar amplification is key to understanding the stability of the cryosphere and sensitivity of the earth system to CO2 forcings. A potential analogue for estimating future Arctic warming is the Mid-Piacenzian Warm Period (3.264 – 3.025 Ma). During this time interval, the paleogeography and paleotopography were similar to present-day, except for a few gateway changes. The CO2 level was also similar to today, with a best estimate of 400 ppm. The MPWP shows strong Arctic amplification, which is epitomized by the existence of circum-Arctic boreal forests, a large reduction in Arctic sea ice, and absence of the western Greenland ice sheet. These findings suggest a precarious state of northern high latitude cryosphere at the 400 ppm CO2 level. However, earth system models that participated in phase one of the Pliocene Model Intercomparison Project (PlioMIP1) had limited success in simulating Arctic amplification during the MPWP, raising doubts about model sensitivity and the analogue nature of the MPWP. Since PlioMIP1, several improvements have been made to both the MPWP boundary conditions and the models' climate physics. These improvements allow us to simulate the northern high latitude warmth and Arctic low sea ice state that are broadly consistent with MPWP proxy records. Based on a series of sensitivity tests, we further identify that 1) the MPWP North Atlantic warmth is attributable to the closed Arctic Ocean gateways, 2) the Arctic low sea ice state is partly due to reduced cloud cover over circum-Arctic oceans under pristine atmospheric conditions, and 3) circum-Arctic terrestrial warming can largely be explained by a vegetation feedback from high density boreal forests. We argue that the latter two changes are relevant to future climate change at the centennial to millennial time scale. In this regard, the MPWP remains a potential analogue for the equilibrium climate state of the RCP2.6 world.

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Early Last Interglacial climate over Europe: sensitivity experiments and model-data comparisons

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
Previous simulations (e.g. PMIP3) of the early Last Interglacial (LIG) were unable to reproduce the asynchrony in temperature response between northern and southern hemisphere suggested by ocean core reconstructions (Capron et al. 2014) when solely forced with known orbital and greenhouse gas forcings. More recent sensitivity experiments with realistic freshwater forcing representing melting of northern hemisphere ice sheets (Stone et al., 2016) provided a possible mechanism to account for a colder than present North Atlantic and warmer than present Southern Ocean. Such simulations have been primarily compared to available high latitude ice core and ocean data, partly due to sparsity of terrestrial palaeodata. Here, we expand these early LIG sensitivity simulations to consider orbital, greenhouse gas, freshwater hosing, modified ice sheets, and vegetation in their impact over Europe, and compare climate changes to terrestrial palaeodata including pollen-based climatic variables.

Pliocene Climate Modes of Variability Part I: Tropical modes based on SST

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
The dominant modes of large-scale climate variability, based on sea surface temperature (SST), extend over large areas of the globe. SST-based modes have direct influence over Tropical Variability. In this work we show preliminary results for the SST-based modes of climate variability for the WAIS-free Pliocene Atlantic, Pacific and Indian oceans relative to the Pre-Industrial climate and 20th century HADISST observations. The mid-Pliocene warmer climate has been attributed to elevated CO2 concentration in the atmosphere, which makes it a perfect analogue for studying the climate at the end of the 21st century. It is the last period of Earth's history with increased concentrations of atmospheric CO2 and global mean temperatures. Here we present the Pliocene modes of variability in the Pacific and Atlantic using a simulation of the mid-Pliocene Warm Period run with the Community Climate System Model version 4 developed at the National Center for Atmospheric Research (CCSM4-NCAR). The preliminary results show the possible changes in the variability modes in an ice-free WAIS world compares to the 20th C warming.

High sea level for the Last Interglacial: Contribution of the Antarctic ice sheet

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Understanding the dynamics of warm climate states has gained increasing importance in the face of anthropogenic climate change. During the Last Interglacial (LIG, ~128 to 116 ka), greenhouse gas concentrations and high latitude insolation were higher than pre-industrial levels, causing a high-latitude warming (Turney and Jones, 2010; Pfeiffer and Lohmann, 2016). As a result of this modestly warmer climate, polar ice sheets were smaller and estimates report that the global mean sea level was 6-9 meters higher than today (Dutton et al., 2015). However, proxy reconstructions indicating a high-stand of LIG sea level are subject to uncertainties in timing and magnitude (Rovere et al. 2016). We present a suite of model results to evaluate the thresholds and feedbacks and will compare the simulations with paleoclimate reconstructions from high southern latitudes. Our atmosphere-ocean isotopic simulation of the LIG indicate that temporal and spatial gradients in ?18O do not match, adding uncertainty to the paleothermometer for past warm climates. A simulation using a reduced West Antarctic Ice Sheet (WAIS) is consistent with the isotopic signature found in ice core data (Masson-Delmotte et al., 2011). Ice sheet model simulations indicate that a pronounced subsurface oceanic warming can destabilize the WAIS, resulting in an oceanic gateway between the Ross and Weddell Seas (Sutter et al. 2016). We detect a threshold behaviour of the WAIS in the range of 2-3°C warming. A sensitivity study using the new oceanic gateway between the Atlantic and Pacific Oceans as bathymetrical boundary condition, indicates that this region would be covered by sea ice. Mixing due to sea-ice formation prevents a pronounced warming around the WAIS and would stabilize the WAIS. Thus, the sea level question of the LIG (Sutter et al. 2016; DeConto and Pollard, 2016) is uncertain. Past sea-level records located far from Antarctica and hence relatively unaffected by isostatic changes, show that it is possible that the end of the LIG was characterized by a sudden meltwater pulse (O'Leary et al., 2013), that made the sea level rise abruptly.

Impacts of boundary conditions on the simulated mid-Pliocene climate assessed using the full suite of PlioMIP2 experiments performed with the CCSM4 model

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
The Pliocene Model Intercomparison Project, Phase 2 (PlioMIP2) is an international collaboration to simulate the climate of the mid-Pliocene interglacial, marine isotope stage KM5c (3.205 Mya), using a wide selection of climate models with the objective of understanding the nature of the warming that is known to have occurred during the broader mid-Pliocene warm period. PlioMIP2 builds upon the successes of PlioMIP by shifting focus onto a specific interglacial and by using a revised set of geographic and orbital boundary conditions (BCs). Recently, we have shown [Chandan and Peltier, 2017] that with the revised BCs the CCSM4 model simulates a mid-Pliocene which is more than twice as warm as that with the BCs used for PlioMIP Phase 1. The warming is more enhanced near the high-latitudes which is where most of the changes to the PlioMIP2 BCs have been made. The elevated warming in the high-latitudes leads to a better match of the simulated climatology to proxy based reconstructions than what was possible with the previous version of BCs. We have recently completed additional PlioMIP2 sensitivity experiments using the CCSM4 model. Altogether, the nine experiments we have completed for PlioMIP2 constitute simulated model years at resolution. This is very likely the most extensive effort at any single institution, to date, to understand a specific time period of the past. Here, we present results obtained from applying a factorization methodology, that has been successfully used to understand the climate of past warm periods [Heinemann et al., 2009, Lunt et al., 2012], to investigate the impact of changes to the individual BCs (compared to present-day) in PlioMIP2 on the simulated mid-Pliocene climate. In addition to the PlioMIP2 simulations, we are currently performing simulations with an alternative set of BCs for the mid-Pliocene that we have reconstructed ourselves. These simulations allow us to assess the sensitivity of the mid-Pliocene climate to changes in global bathymetry and topography, which would not have been possible with only the PlioMIP2 experiments. References: Chandan, D. and Peltier, W. R., Clim. Past, in revision, 2017 Heinemann et al., Clim. Past, 2009 Lunt et al., EPSL, 2012

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MAGIC-DML: Combining climate and ice sheet modelling with field-based data to reconstruct the long-term glacial history of East Antarctica

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Repeated build-up and retreat events across different sectors of the Antarctic ice sheet (AIS) were tightly linked to global climate variations over glacial-interglacial cycles. However, the long-term changes in the volume of the East Antarctic ice sheet (EAIS) and its contribution to the sea-level variations remain poorly understood. The international research project MAGIC-DML aims to constrain the past vertical extents and volumes of the EAIS and shed light on the regional long-term climate evolution using a combination of direct evidence from field-based reconstructions and numerical ice-sheet and climate simulations. As part of this, we will focus on the ice sheet history since the mid-Pliocene warm period, while zooming in on the past warm interglacial intervals to provide insights into the responses of the EAIS to warmer-than-present climate and ocean conditions. In these numerical reconstructions we will employ climate fields from our in-house simulations with the Community Climate/Earth System Model and outputs of general circulation models provided by the PMIP 2-4 to drive the Antarctic ice sheet simulations. We will build upon the approach presented in our recent study where the performance of several present-day climate data sets from CMIP5 has been evaluated during the initialization of an AIS model. This initialization utilizes the observed ice elevation and thickness to derive heterogeneities in the basal sliding parameters for the grounded ice sheet sectors and melting and freezing rates under ice shelves. We have evaluated different sets of the inferred sub-glacial parameters and compared the resulting dynamical states of the AIS with observations to demonstrate that this approach can be used to identify biases in the climate model outputs across the Antarctic continent. Our results indicate that similar methods can be adopted to evaluate the skill of paleoclimate model reconstructions of the periods for which only fragmentary data on ice geometry are available.

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Characterizing the mid-Holocene tropical atmospheric hydrologic cycle using simulated water isotopes in iCAM5

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:
Despite successes in evaluating variability in precipitation patterns over the Holocene, significant uncertainties remain in interpretations of rain intensity, domain, and frequency from the diverse proxy records available. To reconcile point-wise proxies with spatially constrained circulation in the tropics, we used an AMIP-style run of the isotope-enabled Community Earth System Model (iCESM) to study the atmosphere and land components of the mid-Holocene (6.2 ka) hydrological cycle. We forced the simulation with SST and sea ice data from a fully-coupled simulation of the mid-Holocene using CCSM4, the predecessor to iCESM. All other forcings, including orbital parameters and greenhouse gas concentrations, were prescribed in accordance with PMIP4 specifications. Here, we present findings from the mid-Holocene simulation with respect to a control simulation of the pre-industrial period (PI). In agreement with previous studies, our simulation produced a wetter Sahara and Arabian Peninsula during the mid-Holocene. Using simulated water isotopes as a tracer of atmospheric transport processes, we found evidence that increased convergence of Atlantic evaporation was the primary source of increased moisture availability over the Sahara. In the maritime continent, precipitation stable isotope ratios were depleted relative to the PI, especially over land masses such as the Malaysian Peninsula, Sumatra, and Borneo. These depletions spatially correspond with lower troposphere water vapor isotope ratios more accurately than with precipitation rate. This provides evidence that moisture source was a more important factor for precipitation stable isotope ratios than, for instance, convection strength or precipitation amount. The results of this study allow for interpretations of proxy data in the context of the regional atmospheric hydrologic cycle rather than local first order variables such as precipitation amount and highlight the value of using direct simulation of isotope ratios when evaluating model performance.

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Coupled Long-Term Evolution of Climate and the Greenland Ice Sheet During Past Warm Periods: A Comparison for the Last Interglacial and the Late Pliocene

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

The Greenland Ice Sheet is expected to contribute increasingly to global sea level rise by the end of this century, and potentially several meters in this millennium, but still with considerable uncertainty. The rate of Greenland melt will impact on regional sea levels. To understand the response of the Greenland ice sheet to future warming, we are studying two warm periods in the past, from which there are relatively abundant and well-dated proxy records: e.g. the last interglacial (LIG) warm period and the late Pliocene, as potential process analogues for centuries to come. The LIG warming is primarily attributed to high boreal summer insolation. The late Pliocene is thought to represent the long-term climate response to near-current concentrations of CO2, though the North Atlantic region may also have been influenced by altered ocean heat transports in response to closed Arctic gateways. Here we examine the transient climate system response to the late Pliocene high CO2 and LIG high boreal summer insolation in two parallel multi-millennial experiments. We use the Community Earth System Model, version 2 (CESM2) fully coupled to the Community Ice Sheet Model, version 2 (CISM2), simulating the GrIS as an interactive component of the coupled climate system. The main focus of the analysis is on how the GrIS responds to differences in the imposed radiative forcing. Results will highlight the transient evolution of the ice sheet and how the surface mass balance (patterns of ablation and accumulation) and mass loss compare to data-based reconstructions of past climate states. We also discuss how these well studied past climate states may be informative in order to constrain the future evolution of the ice sheet.

Quantification of process contribution to Arctic amplification during the mid-Pliocene in EC-Earth simulation

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Co-author: Qiong Zhang, Stockholm University;
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Abstract:
Arctic amplification is becoming one of the most highlighted issues while the record of global warming and Arctic sea-ice extent minimum have been refreshed frequently over the last decade. As a potential analogue of future climate projection, the Arctic amplification in mid-Pliocene is of special interest as its magnitude is significantly greater than that of present, though the carbon dioxide concentration is comparable during the two periods. Strong Arctic amplification that comparable with PRISM reconstructions is identified in a mid-Pliocene simulation with EC-Earth. A quantification of process contribution using the Climate Feedback and Response Analysis Method (CFRAM) shows that the largest contributor to Arctic amplification is sea-ice albedo feedback and cloud feedback plays a secondary role, whereas the latent and sensible heat fluxes largely offset Arctic amplification through a negative feedback. Significant sea-ice melting is found during summer months from June to October. The large area of open-water facilitates oceanic dynamical process to store large amount of heat content in the ocean. The stored energy is discharged in winter to sea surface, heats the overlying atmosphere through turbulent heat fluxes, and thus maintains the more pronounced Arctic amplification in winter in spite of no incoming solar radiation during polar night.

Quantifying albedo and insulation effects of Arctic sea ice in the Pliocene simulation

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)

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Abstract:

Arctic sea-ice extent minimum have been refreshed frequently over the last decade. As the sea ice retreats, its reflectivity and insulation decrease. This leads to the changes in surface heat budget directly or indirectly through overlying cloud and water vapour. In this work, the Pliocene simulation with EC-Earth climate model is performed as an analogue for future climate projections. The EC-Earth Pliocene simulation shows a strong Arctic amplification featured by pronounced warming SST over North Atlantic in particular over Greenland Sea and Baffin Bays, which is comparable with geological SST reconstructions documented in Dowsett et al. (2012). In order to reveal underlying physical processes, the air-sea heat flux variation in response to Arctic sea ice change is quantitatively assessed by a climate feedback and response analysis method (CFRAM) and an equilibrium feedback assessment (EFA)-like approach. Our analyses show that the albedo effect is dominant in summer, a 1% decrease in sea ice concentration could lead to an approximate 2 Wm-2 increase in short wave solar radiation through open sea surface. The insulation effect is attributed mainly to turbulent heat flux, which releases heat from the ocean to atmosphere prominently in winter. The sea ice decline accelerates the turbulent exchange between the ocean and atmosphere. We found that insulation effect in winter is slightly stronger than albedo effect in summer, thus explains the stronger warming amplification in winter than in summer.

Understanding the enhanced aridity in Eocene Asian inland: the roles of global cooling and early Tibetan Plateau uplift

Session: Warm Climates (Mid-Holocene, Last interglacial, Deep-time, Pliocene)
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Abstract:
Evolution of the aridity in the Asian inland is now a hot topic in the study of the Cenozoic climate in Asia. Recent geological evidence has pushed the earliest Cenozoic Asian inland aridification back to the Eocene. This enhanced Eocene aridity in the Asian inland is related to combined impacts from global cooling, topography uplift and land–sea reorganization. It was widely believed that global cooling led to this aridification. Here, we carry out climate simulations to demonstrate that the early uplift of Tibetan Plateau is also important in the enhanced Asian inland aridity during Eocene. Our simulations support the observed enhanced Asian inland aridity during Eocene observed from geological evidence. Both the early uplift of Tibetan Plateau global cooling induced by decrease in atmospheric CO2 concentration contribute to the enhanced Asian inland aridity, while changes in land–sea distribution do not. The early uplift of the Tibetan Plateau contributed to the long-term Asian inland aridification during the Eocene, whilst the variations in the atmospheric CO2 concentration are more important in modulating the regional aridity on short timescale.

Searching for the deglaciation: sampling spatio-temporal climate uncertainty for simulating ice sheet evolution

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Ice sheet models fail to reproduce reconstructed patterns of Northern Hemisphere ice sheet retreat through the last deglaciation (21,000-6,000 years ago). This is the main barrier to understanding the role of ice sheets in past abrupt climate and sea level changes and constraining the post-glacial isostatic adjustment of the solid Earth. The primary reason for this failure is the large uncertainty in the boundary conditions to the ice sheet models, which are derived from global climate simulations. Simulations of the transient evolution of climate over the last 21,000 years are computationally expensive to produce and have large biases and uncertainties in their inputs (e.g. ice sheet melt input to the oceans). It is thus impossible to produce large ensembles of climate simulations that would span plausible deglaciation climates. We developed a statistical method to systematically explore the spatio-temporal uncertainty in climate (temperature and precipitation) through this period, by combining output from transient General Circulation Model (GCM) simulations of the last 21,000 years with surface air and sea surface temperature change proxy records. The method consist of producing basis vectors of climate change through single value decomposition of an ensemble of climate simulations. We then define a set of linear combinations of the basis vectors which match a compilation of proxy records of temperature changes within their uncertainty. We present a pilot application of this method using a compilation of surface temperature records from Shakun et al. (2012) and output from a perturbed physics ensemble of FAMOUS simulations as well as the Trace-21k simulation produced with CCSM3. A set of 500 plausible spatio-temporal temperature field were thus produced. With this, we ran an ensemble of 500 simulations of the North American ice sheet evolution from 21,000 to 6,000 years ago with the Glimmer-CISM ice sheet model, where climate and ice sheet parameters are varied. An evaluation of the output against reconstructed ice extent is performed to identify plausible ice sheet simulations and their corresponding climate input.

Two-stage climate response to Heinrich events

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Heinrich events are among the most prominent events of climate variability recorded in proxies. Nevertheless, their governing processes and climatic impacts are far from being fully understood. We address open questions by studying Heinrich events in transient glacial simulations with a coupled ice sheet - general circulation model framework, where Heinrich events occur as part of the model generated internal variability. The framework consists of a Northern Hemisphere setup of the modified Parallel Ice Sheet Model (mPISM) bidi- rectionally coupled to the global atmosphere-ocean-vegetation model ECHAM5/MPIOM/LPJ. The simulations were performed with transient orbital and greenhouse gas forcing. The modeled Heinrich events show a peak ice discharge of about 0.05 Sv and raise sea level by 2.3 m on average. A two-stage response in the climate system is evident. First, the freshwater release decreases the deepwater formation in the North Atlantic, resulting in a slowdown of the Atlantic Meridional Overturning Circulation and a Northern Hemispheric cooling. In the second phase, the lowered surface elevation after the surge results in a widening and zonalization of the jet stream. The experiments show that both response pathways need to be considered to understand the climatic impacts of Heinrich events.

The Last Termination simulated with a complex ESM with interactive northern northern ice sheets

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
One of the major challenges in climate modelling is the simulation of glacial-interglacial transitions. Here we presents results from our first successful attempt to simulate a substantial part of the last glacial cycle with the ECHAM5/MPIOM AOGCM coupled interactively to a northern hemisphere set up of the dynamical ice sheet model PISM. This model is integrated from the late Glacial into the Holocene using insolation and greenhouse gas concentrations as transient forcing. The land sea mask remains fixed at the LGM state. River routing and surface elevation for the atmospheric model component are calculated interactively. To make these long simulations feasible, the atmosphere is accelerated by a factor of 10 relative to the other model components using a periodical-synchronous coupling technique. A mini-ensemble with different initial conditions is run. Additionally, one simulation is run fully synchronously without acceleration in the atmosphere. In all simulation the northern hemispheric deglaciation starts around 20 kyr BP, the warming at around 17 kyr BP. During the deglaciation the interactive river routing has a strong impact on the simulated NAMOC, which weakens in the course of the deglaciation and collapses for part of the time, before it recovers in the early Holocene.

Transient climate simulations of the deglaciation 21-9 thousand years before present (version 1): PMIP4 Core experiment design and boundary conditions

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

The last deglaciation, which marked the transition between the last glacial and present interglacial periods, was punctuated by a series of rapid (centennial and decadal) climate changes. Numerical climate models are useful for investigating mechanisms that underpin the climate change events. The last deglaciation PMIP working group coordinates transient simulations 21-0 ka, and facilitates the dissemination of expertise between modellers and those engaged with reconstructing the climate for this period. Here, we present the design of a coordinated Core experiment over the period 21–9 thousand years before present (ka) with time-varying orbital forcing, greenhouse gases, ice sheets and other geographical changes. A choice of two ice sheet reconstructions is given, and we make recommendations for prescribing ice meltwater (or not) in the Core experiment. Additional focussed simulations will also be coordinated on an ad hoc basis by the working group, for example to investigate more thoroughly the effect of ice meltwater on climate system evolution, and to examine the uncertainty in other forcings. Some of these focussed simulations will target shorter durations around specific events in order to understand them in more detail and allow for the more computationally expensive models to take part.

Collapse of the North American ice saddle 14,500 years ago caused widespread cooling and reduced ocean overturning circulation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

Collapse of ice sheets can cause significant sea level rise and widespread climate change. We examine the climatic response to meltwater generated by the collapse of the Cordilleran-Laurentide ice saddle (North America) ~14.5 thousand years ago (ka) using a high-resolution drainage model coupled to an ocean-atmosphere-vegetation general circulation model. Equivalent to 7.26 m global mean sea level rise in 340 years, the meltwater caused a 6 sverdrup weakening of Atlantic Meridional Overturning Circulation (AMOC) and widespread Northern Hemisphere cooling of 1–5°C. The greatest cooling is in the Atlantic sector high latitudes during Boreal winter (by 5–10°C), but there is also strong summer warming of 1–3°C over eastern North America. Following recent suggestions that the saddle collapse was triggered by the Bølling warming event at ~14.7–14.5 ka, we conclude that this robust submillennial mechanism may have initiated the end of the warming and/or the Older Dryas cooling through a forced AMOC weakening.

Connecting Antarctic sea ice to deep ocean circulation in modern and glacial climate simulations

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Antarctic sea ice formation plays a key role in shaping the abyssal overturning circulation and stratification in all ocean basins, by driving surface buoyancy loss through the associated brine rejection. Changes in Antarctic sea ice have, therefore, been suggested as drivers of major glacial-interglacial ocean circulation rearrangements. Here, the relationship between Antarctic sea ice, buoyancy loss, deep-ocean stratification, and overturning circulation is investigated in Last Glacial Maximum and preindustrial simulations from the Paleoclimate Modelling Intercomparison Project (PMIP). The simulations show substantial inter-model differences in their representation of the glacial deep-ocean state and circulation, which is often at odds with the geological evidence. We argue that these apparent inconsistencies can largely be attributed to differing (and likely insufficient) Antarctic sea ice formation. Discrepancies can be further amplified by short integration times. Deep-ocean equilibration and sea ice representation should, therefore, be carefully evaluated in the forthcoming PMIP4 simulations.

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Compensating effects of greenhouse gas concentrations and ice sheets on the AMOC during the Last Glacial Maximum in a coupled climate model

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

There is a large intermodel spread regarding the glacial Atlantic Meridional Overturning Circulation (AMOC) within the PMIP ensemble, and many models fail to capture the shoaling of the glacial AMOC indicated by proxy-based reconstructions. The glacial AMOC response in the coupled model MPI-ESM is the sum of two large opposing effects: the glacial ice sheets cause a deepening and a strengthening of the AMOC; the glacial greenhouse gas (GHG) concentrations cause a shoaling and a weakening. The two effects partly compensate for each other. As a result, the glacial AMOC does not shoal with respect to the modern state. The key mechanism for the GHG effect is brine release in the Southern Ocean, which increases the density of Antarctic Bottom Water; the key mechanism for the ice-sheet effect is the salt transport into the North Atlantic, which enhances the density of North Atlantic Deep Water. The magnitude of the respective effects depends on the background climate and likely also on the model-specific implementation of sea-ice dynamics and continental ice sheets. Already small differences in the magnitude of either effect can change the sign of the total AMOC response, which provides a good explanation for the spread within the PMIP ensemble.

Simulating the climate of Marine Isotope Stage 3

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
With recent model developments at the Bjerknes Centre for Climate Research (Norway), a new and efficient Norwegian Earth System Model (NorESM) version with 2-degree atmosphere and 1-degree ocean has been configured for paleo-modelling. Here we present fully coupled climate simulations of a pre-industrial control run and a MIS3 experiment at 38 ka BP, both integrated for 2000 years . We will discuss the large scale climate features of MIS3 relative to today, including ocean overturning circulation, surface temperatures, and atmospheric circulation patterns. We focus on the climatic conditions in the Arctic Ocean and Nordic Seas and discuss ocean circulation, vertical stratification and sea ice conditions. Simulated surface temperature during MIS3 is globally colder except in the periphery of the North Atlantic subpolar gyre region; AMOC is slightly stronger compared to modern day, with a deeper penetration of NADW; MIS3 also exhibits a stronger and more contracted subpolar gyre. Additional sensitivity experiments with freshwater input mimicking ice rafting events from the large land based ice sheets are also analysed. Preliminary results from these sensitivity experiments show a significant difference in ocean and sea ice response as well as Greenland temperature to freshwater input from the Laurentide versus the Fennoscandian ice sheets.

Changing topography and land-sea mask in transient simulations of the last deglaciation using CESM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The land-sea mask in Earth-system models is usually fixed. However, in the case of large changes in sea level, time-dependent ocean boundaries and bottom topography need to be considered (e.g. for simulations of the last deglaciation through which the global sea level increased by about 120 m). The aim of this project is to make the ocean component POP (Parallel Ocean Program) of the CESM (Community Earth System Model) capable of dealing automatically with those changes. A suitable algorithm was developed and tested. Manual checks were performed regarding the control of key straits, modification of through-flow depths at important sills, connection of ocean basins and determination of closed basins (where necessary, isolated points were removed). The algorithm applies changes in the land-sea mask whenever sea level change crosses a z-level of the vertical grid. The land-sea changes take place upon a restart of the model, which requires a modification of restart files. New ocean cells are initialized with nearest-neighbour values.

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North Pacific atmospheric rivers at the Last Glacial Maximum

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
Paleo-precipitation reconstructions indicate that during the Last Glacial Maximum, northwestern and southwestern North America were drier and wetter than present, respectively. These changes have been associated with southward shifts in the positions of the midlatitude jet stream and wintertime North Pacific storm track, observed in LGM simulations from a variety of models. But the source and delivery processes of water at the LGM have been recently debated. Using the ensemble of PMIP3 LGM simulations, supplemented with reanalysis and additional atmospheric simulations, we explore the role of atmospheric rivers—plumes of water vapor transport of critical importance to western North America—in delivering water to the region during the glacial. Deepened Aleutian Low and weakened North Pacific High pressure systems at the LGM concentrated water transport in atmospheric rivers into California relative to the present, enhancing moisture and precipitation in the southwest and shifting it away from the northwest. While the PMIP3 simulations were crucial for this work, uncertainties remain that will be addressable with PMIP4 results, like the effects of uncertainties in ice-sheet topography. Furthermore, the lack of daily model output and certain derived variables in the PMIP3 archives limited the range of possible analyses; PMIP4 offers opportunities to fill these gaps.

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Impacts of polar ice sheets on the East Asian monsoon during the MIS-13 interglacial

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

Among all the interglacials of the last one million years, Marine Isotope Stage (MIS) 13 has the highest ?18O value over the past 800 ka in the deep-sea sediments. This would indicate that MIS-13 is the coolest interglacial if assuming ?18O mainly represents global ice volume. The Antarctic ice core records show also that MIS-13 is the coolest interglacial over Antarctica with almost the lowest greenhouse gases concentrations (GHG). However, many proxy records from the northern hemisphere (NH) indicate that MIS-13 is at least as warm as or even warmer than the recent interglacials, with extremely strong summer monsoon and a possible melting of Greenland ice sheet. In this study, based on proxy reconstructions, different scenarios regarding the size of the Greenland and Antarctic ice sheets are made, and the response of the East Asian summer monsoon to these scenarios are tested by using the models HadCM3 and LOVECLIM as well as factor separation analysis and under the astronomical and GHG configurations of MIS-13. The results show that the influence of the disappearance of Greenland ice sheet on the surface temperature is quite localized, mainly over the northern high latitudinal regions, however, the influence of the bigger Southern Hemisphere ice sheet on the surface temperature is very global, especially in the southern hemisphere. This ice sheet condition has an impact on the precipitation pattern over tropical-subtropical regions. It causes much more summer precipitation over all the East Asian monsoon region, in consistent with the paleosol record from southern China. The scenario of melted Greenland ice sheet and of larger SH ice sheets provides one of the explanations of the strong monsoon rainfall documented by the proxy data.

Modeling the last deglaciation with an ice sheet – solid earth model system

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
Massive climate changes were evident during the last deglaciation. Melting of ice sheets resulted in about 100 m of sea level rise within 10 kyr, which on average is comparable to future projections of sea level rise. The exact location and timing of the meltwater releases is crucial for the response of the ocean circulation. To account for such processes and interactions between climate components and ice sheets it is important to integrate ice sheet models into state-of-the-art climate models. To investigate ice sheet changes throughout the last deglaciation we present results of the Parallel Ice Sheet Model PISM coupled to the solid earth model VILMA, as a first step towards a fully coupled ice sheet – climate model system. By including VILMA, we account for isostatic adjustment and gravitational sea level effects. Linear combinations of twelve stand-alone climate experiments with the Max Planck Institute Earth System Model for different orbital configurations, GHG concentrations and ice sheets are used to calculate the ice sheet surface mass balance (SMB) using an energy balance model. The SMB is then used to force the ice sheet – solid earth model setup. Ocean temperatures and salinities are used to obtain basal shelf melt rates.

The Caspian Sea during Pre- and Post-LGM as natural lab for investigation of climate changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The level fluctuations of closet lakes depend on regional-scale climate variations. Such lakes (especially such huge lake as the Caspian Sea (CS)) could be treated as natural labs, allows us to explore reaction of regional climate conditions to global climate changes. During a long part of its history, the CS was a closet lake, separating by sill from the Black Sea. Sometimes, the CS level raised so high that the CS overflowed to the Black Sea. They were so-called the Early Khvalynian transgression (age ~35-25 ka BP) and the Late Khvalynian transgression (age ~17-12 ka BP). At the time of the Early Khvalynian transgression, the level of the CS was estimated up to 50 m above the modern state and sea area spread out far to north. The Late Khvalynian transgression was modest; the level of the CS achieved +27 m above the modern state. The main question concerning these events is what was source of additional water needed to providing these anomalies? The Khvalynian phenomena did not occur due to high precipitations/river runoff over the East European Plain because model experiments (Sima et al., 2013) do not support this idea. The contribution of melting water of the Scandinavian Ice Sheet is excluded too. Indeed, its boundary was located beyond the Volga River catchment area; the ice wall was permeable and the water could drain in the north direction (Sidorchuk et al., 2006). The Khvalynian transgressions cannot be realized as the “stochastic anomaly”. Indeed, despite the CS level dynamics is represented by a system of undergoing random walk, the “super large” anomalies (like the Khvalynian transgressions) are impossible (Kislov, 2016). Water volume was proposed to be increased due to an increase of the runoff coefficient due to permafrost (Sidorchuk et al., 2006). In addition, the melting of permafrost could provide a contribution to the runoff. So far, it is unclear whether this event was sufficient to ensure the Khvalynian transgressions. Now we are faced with a paradox: «The event was, but it was inexplicable».

A transient fully coupled climate-ice-sheet simulation of the last glacial inception

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The last glacial inception occurred around 115 ka, following a relative minimum in the Northern Hemisphere summer insolation. It is believed that small and spatially separated ice caps initially formed in the high elevation regions of northern Canada, Scandinavia, and along the Siberian Arctic coast. These ice caps subsequently migrated down in the valleys where they coalesced and formed the initial seeds of the large coherent ice masses that covered the northern parts of the North American and Eurasian continents over most of the last glacial cycle. Sea level records show that the initial growth period lasted for about 10 kyrs, and the resulting ice sheets may have lowered the global sea level by as much as 30 to 50 meters. Here we examine the transient climate system response over the period between 118 and 110 ka, using the fully coupled Community Earth System Model, version 2 (CESM2). This model features a two-way coupled high-resolution (4x4 km) ice-sheet component (Community Ice Sheet model, version 2; CISM2) that simulates ice sheets as an interactive component of the climate system. We impose a transient forcing protocol where the greenhouse gas concentrations and the orbital parameters follow the nominal year in the simulation; the model topography is also dynamically evolving in order to reflect changes in ice elevation throughout the simulation. The analysis focuses on how the climate system evolves over this time interval, with a special focus on glacial inception in the high-latitude continents. Results will highlight how the evolving ice sheets compare to data and previous model based reconstructions.

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The Indian Ocean Walker circulation at the Last Glacial Maximum (revisited): Old models versus new data

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

Climate models predict a slowdown of the Walker circulation for the twenty-first century. However, historical records and observations of the Walker circulation over the twentieth century disagree on the sign of change, and thus necessitate longer climate records to test both the simulated history and fate of the Walker circulation. Here we present a suite of records of sea surface and thermocline temperatures, and of the isotopic composition of rainfall, from the eastern tropical Indian Ocean for the Last Glacial Maximum (LGM) and the late Holocene. Our results indicate an increase in both thermocline depth and rainfall suggesting a stronger-than-today Indian Ocean Walker cell during the LGM. Analysis of PMIP2 and PMIP3/CMIP5 climate model results confirms the thermocline deepening in the eastern Indian Ocean in model simulations with a stronger Walker circulation during the LGM. However, our analysis of model output also reveals a considerable scatter of model results, with some models even simulating a shoaling of the thermocline along with a weakening of the Indian Ocean Walker cell under LGM conditions. In the two models with maximum Walker circulation strengthening (CCSM3 and FGOALS-g1.0) the deepening of the thermocline is sufficiently strong to induce even warmer-than-today eastern equatorial Indian Ocean subsurface temperatures in the LGM in accordance with our new thermocline records. We conclude that during the LGM, convection and rainfall over the eastern equatorial Indian Ocean was stronger than today as a result of an intensified Indian Ocean Walker circulation, while further to the east, anomalous subsidence resulted in drier conditions over the Maritime continent, as indicated by various previous proxy studies. An intensified Walker circulation during the globally cooler last glacial period underscores the sensitivity of tropical circulation to temperature change and implies a further weakening of the Walker circulation in response to greenhouse warming.

British-Irish Ice Sheet during the LGM consistent with weakened North Atlantic heat transport

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
The British-Irish Ice Sheet of the last glacial was situated in a region that is critically sensitive to the poleward oceanic heat transport in the Atlantic. We employ the results of two Last Glacial Maximum (LGM) global climate simulations by the Community Climate System Model (CCSM) versions 3 and 4 at about 1° resolution in both the ocean and the atmosphere. The simulated North Atlantic sea-surface conditions are compared to temperature reconstructions by the Multiproxy Approach for the Reconstruction of the Glacial Ocean Surface (MARGO) project, while the atmospheric model output is used to force an ice-sheet model of the northern hemisphere. The results show that a reduced northward ocean heat transport associated with a weakened AMOC in the glacial CCSM3 simulation is consistent with extensive ice-sheet cover over the British-Irish Isles as inferred from independent geological evidence for the LGM. By contrast, a strong AMOC in the glacial CCSM4 simulation results in North Atlantic surface temperatures that are several degrees warmer than the MARGO reconstructions. As a consequence, the advection of relatively warm air from the North Atlantic towards Europe prevents the formation of a British-Irish Ice Sheet in the corresponding ice-sheet simulation. We suggest that ice-sheet modelling provides a powerful tool to evaluate paleoclimate model simulations within the framework of PMIP4.

Modelling nutrients and marine radiocarbon through the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

Ocean circulation in the high latitudes strongly influences global heat transport, ocean-atmosphere CO2 transport and biological productivity. Rapid reorganisations in ocean circulation during the last glacial cycle have been linked to millennial-scale abrupt climate events. These events had widespread impact on global carbon and nutrient cycling, and can be traced using marine radiocarbon. Here, we present results from transient model runs using the GENIE Earth System Model, simulating nutrients and marine radiocarbon for the glacial climate and stadial events. We explore links between circulation change, nutrients and carbon cycling for the Northern high latitudes, and show that overturning plays a dominant role in North Pacific nutrient budgets and CO2 release. We also demonstrate that the relationship between circulation state and ?14C can vary through time as a function of atmospheric radiocarbon history, and explore spatial and temporal variations in surface reservoir ages.

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The effect of glaciogenic dust on LGM climate

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Last Glacial Maximum (LGM) is known with the enhancement of the dust deposition from the ice/sediment core data (Winckler et al. 2008, Dome Fuji Ice Core Project members 2017), especially over the polar regions. Using an earth system model, MIROC-ESM (Watanabe et al. 2011), we investigated the impact of glaciogenic dust by Mahowald et al. (2006) on LGM climate. We have found that the effect of the enhancement of dust is less cooling in the polar regions. One of the major reason of the less cooling is that the aging of snow or ice albedo by high dust deposition mainly in the northern hemisphere. Although the net radiative forcing at the lee of high glaciogenic dust provenances are negative, warming by aging of snow overcomes the change of the radiative forcing in MIROC-ESM. The model ability of aging of snow under the glacial climate should be evaluated. On the other hand, the radiative forcing by high dust load in the troposphere acts for the surface warming surroundings of the Antarctica mainly caused by the indirect effect of dust.

Status of the IPSL simulations for PMIP4-CMIP6 and for PMIP4

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
LSCE is currently actively preparing its PMIP4-CMIP6 experiments. Our target is to model the five PMIP4-CMIP6 periods, as well as PMIP4 sensitivity and transient experiments. We will base our strategy on two models of the IPSL family: IPSLCM6, which is the main model to be used by the IPSL team for CMIP6, and IPSLCM5A2, which runs much faster than IPSLCM6 and which will be used for transient and long-term experiments. Our poster will present these models, the implementation of the experiments, and first results.

Role of Ice Sheet uncertainty on the PMIP4 Last Glacial Maximum simulations

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

An uncertainty in PMIP4 glacial simulations is the ice sheet reconstruction (height and geometry) that appears to play an important role on glacial climate (e.g the strength of Atlantic meridional overturning circulation). Here we use an isotope-enabled fully coupled AOGCM to assess the transient and equilibrium features of glacial climate in response to five available ice sheet reconstructions of the Last Glacial Maximum (Licciardi et al 1998; ANU; GLAC-1; ICE-6g; ICESHEET). Here we mainly focus on different LIS reconstructions since the Laurentide Ice Sheets (LIS) play a more important role on Atlantic meridional overturning circulation than the Fennoscandia Ice Sheets (FIS). According to the ice volume, LIS reconstructions from Licciardi and ICESHEET (Gowan et al 2016) can be classified into a low class, while the rest belongs to a high class. The initial ocean state of the experiments are identical to each other and derived from a previous PMIP3 LGM simulation. During the integrations, we find that the equilibrium timescale in ocean circulation is much shorter in the high class than in the low class. In particular, the ocean circulation experiences a pronounced weakening in its transient phase under the low ice sheets, followed by a rapid recovery to a strong ocean state. As the system gets equilibrium, the simulated climate states regarding sea surface temperature, sea ice cover and precipitation patterns are also distinguished, especially between low and high ice sheet classes. Our results suggest that various ice-sheet reconstructions will be a considerable source of uncertainty for inter-comparisons of PMIP4 LGM simulations.

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Millennial-scale climate variability, scientific objectives and experimental design for PMIP4 simulations of abrupt glacial climate changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

Various climate archives suggest that abrupt climate changes are an intrinsic characteristic over much of the last million years. Millennial-scale climate variability, known as Dansgaard-Oeschger events, has been linked to changes in the Atlantic Meridional overturning circulation (AMOC). However, whether the abrupt changes are related to the nonlinearity of climate system itself or to nonlinear forcing to a linear system remains elusive. To reproduce the abrupt transition between strong and weak circulation regimes, a common trigger mechanism in climate modelling studies is ad-hoc freshwater perturbations in the North Atlantic. This approach does not require a nonlinear climate system to trigger abrupt climate shifts because responses of ocean circulation can be just followed by the nonlinear forcing. Recently, Zhang et al (2014; 2017) find that changes in ice sheet height and atmospheric CO2 are capable of triggering abrupt circulation transitions associated with a regime of AMOC bi-stability. This indicates that climate system is intrinsic nonlinear and abrupt climate changes can be caused by gradual external forcing. Since this feature is only derived from one climate model (ECHAM5/MPIOM), it is of critical importance to evaluate its re-productivity in other climate models that are used to guide policy makers to make adaption strategy to future climate changes. Accordingly, we propose a series of simplified experiments that will provide a quantitative assessment of inter-model performances on abrupt glacial climate changes. This project will be promoted as a working subgroup within the PMIP4 framework.

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Holocene lowering of the Laurentide Ice Sheet weakens North Atlantic gyre circulation and affects climate

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
Ice sheet topography is an important control on glacial climate. The presence of the large North American Laurentide Ice Sheet (LIS) at the Last Glacial Maximum (LGM; 21 ka) produces a stronger and more zonal jet stream, modifies surface climate and storminess over the North Atlantic and affects North Atlantic gyre circulation and the Meridional Overturning Circulation. By the start of the Holocene, 9.0 ka, the size of the LIS was much reduced, yet, it has been suggested that the demise of the LIS played a role in the 8.2 ka abrupt cooling event through its topographical influence on atmospheric circulation. Here, for the first time, we evaluate how the demise of the LIS 9.5-7 ka directly influences atmospheric circulation through changing topography, and the wider implications for climate. We ran a series of 500 year-long equilibrium experiments using the HadCM3 ocean-atmosphere-vegetation General Circulation Model with LIS topographies and ice masks taken from a transient simulation of the ice sheet, using snapshots at 9.5, 9.0, 8.5 and 8.0 ka. We find that the lowering of the LIS produces a dipole pattern of surface ocean and air temperature anomalies over the North Atlantic. Between 9.5 and 8.0 ka, we model a progressive 2 °C cooling south of Iceland and 1 °C warming between 40-50° N, matching sedimentary records. This is associated with a weakening of the Subtropical and Subpolar Gyres caused by a decreasing wind stress curl over the gyres as the ice sheet lowers. However, topographical changes between 8.5 ka and 8.0 ka induce minor climatic change relative to the ~160 year-long cooling pattern of the 8.2 kyr event.

Ocean modelling with varying topographic boundaries

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

In most standard Earth System Models (ESMs) the land-sea mask is fixed throughout simulations. However, for long-term simulations with large changes in sea level, topography and ice extents, it is necessary to consider transient ocean boundaries. This is one of the main problems towards simulating a complete glacial cycle with GCM models. We present a tool to allow for an automatic computation of changes in the bathymetry used in the Max Planck Institute Ocean Model (MPIOM). As a first step, the tool remaps a high-resolution topography from ice sheet and glacial isostatic adjustment modelling to the coarse MPIOM grid. In order to avoid isolated domains, our algorithm ensures that ocean areas are connected. Then, it modifies the bathymetry at some key straits to provide for sufficient through-flow depths according to the values found in the high-resolution data. As a second step, the tool adapts MPIOM restart files to changes in bathymetry and land-sea mask. Important aspects are the conservation of mass and tracers. We present the concepts of the algorithms together with first test simulations. Once tested thoroughly the module can be used with MPI-ESM to allow for transient simulations of the last terminations with interactive land-sea mask and bathymetry.

The Last Glacial Maximum tropical oceans: impacts of paleoclimatic indicators' habitat on the recorded temperature change, potential benefits of taking this habitat into account

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The Last Glacial Maximum (LGM) tropical sea surface temperatures (SSTs) may have a high potential to constrain the climate sensitivity to CO2 (e.g. Hargreaves et al., 2007). Careful comparison of the PMIP model results to SST reconstructions (such as MARGO, 2009) could, therefore, be crucial in our evaluation of the climate models used for prediction. The MARGO reconstructions are based on several indicators including foraminifer assemblages, alkenones and Mg/Ca. These do not always yield the same SST estimates for the LGM, and collectively show larger spatial variability than the model results. Here, we examine the changes in the habitat of coccolithophores and foraminifera (in particular G. ruber) between the Last Glacial Maximum and the pre-industrial. We use the IPSL model to represent the coccolithophores, in which a representation of nanophytoplankton is included via the PISCES ocean biogeochemistry model, and the FORAMCLIM model to compute the abundance of 8 species of foraminifera. We show that coccolithophores could record temperatures at a deeper depth than G. ruber, which could help reconstruct the thermal gradients of the upper ocean. Ultimately, this could lead to an increased knowledge of the ocean circulation, and could provide additional constraints on the atmospheric circulation since it is tightly coupled to the ocean circulation in this region. This last part of the work is based on the PMIP3 results and could be extended to PMIP4 results if available at the time of the conference.

Reanalysing the deglaciation with models and data

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Using data assimilation techniques for climate reanalysis should provide the best description of how and why our climate has changed through the past and up to the present. Due to both computational and data limitations, previous paleoclimate reanalyses of the authors and others have typically focussed either on time slices (such as the Last Glacial Maximum or mid-Pliocene Warm Period) or the relatively short transient of the last millennium, using a wide variety of methods. The forthcoming PMIP6 simulations of the last deglaciation, together with recently published compilations of core data, should provide us a new opportunity to reconstruct the fully global transient evolution of the climate state over this period with more detail and accuracy than previously achieved. Here we present some initial investigations and results using transient simulations which have been produced by the FAMOUS model (low-resolution HadCM3) and CCSM3, which builds on our previous work in state (LGM) reconstruction. We show that in principle it is possible to blend the data and model simulations in order to give a realistic reconstruction of the full deglatiation. Future challenges include handling errors in the timing and magnitude of forcing time series used to drive the models, and also in the chronologies of proxy data.

High Resolution Simulations of the LGM and mid-Holocene

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The latest climate models for CMIP6/PMIP4 will generally be higher resolution than previous generations and increased resolution will often be suggested as the cause for any resulting changes. However, in the majority of cases many other aspects of the model will also have been changed and it can be difficult to rigorously attribute the changes to a specific increase of resolution. We have therefore investigated the role of resolution in simulating past climate change through a series of simulation using one particular model, HadAM3. The advantage of using this model is that high resolution versions of this model were extensively used for weather forecasting so the model physics is optimised for both low (climate) and high (weather) resolution versions. We have performed a series of atmosphere-only LGM and mid-Holocene PMIP simulations with a range of resolutions from those typical of PMIP2 and PMIP3 models (3.75 x 2.5 degrees) to much higher resolution (maximum resolution of 0.56 x 0.38) which is relatively high resolution even for CMIP6. The results show that increased resolution improves the simulation of modern precipitation patterns by better representing the detailed orographic and coastal processes, but that palaeo changes in large scale precipitation are relatively robust and insensitive to resolution scale. The exception to this is at the LGM, when the flow direction changes (causing a shift in rain shadows etc.) and when land area expands with the reduced sea level. The effects of resolution on the changes in extreme events will also be discussed. Furthermore, we will present analyses of the simulations with respect to “the wet gets wetter” paradigm. Initial work suggests that this is not especially effective at explaining the modelled changes.

Marine environmental changes in front of the Scandinavian Ice Sheet during the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
The Kattegat-Baltic Sea region shows evidence of strong coupling with North Atlantic climate over recent glacial-interglacial cycles, but insufficient long, continuous, high-resolution Baltic area climate records have often limited evaluating such links. New ultra-high-resolution sediment cores collected during IODP Expedition 347 allow such records to be generated, including foraminiferal geochemistry records reflecting seawater environmental changes directly adjacent to the Scandinavian Ice Sheet (SIS) during the most recent deglaciation. We present benthic foraminiferal stable isotope (d18O and d13C) and trace element (Ba/Ca, Mn/Ca and Mg/Ca) records from IODP Site M0060 (located between Sweden and Denmark in the southern Kattegat) to constrain bottom water salinity, temperature and oxygenation changes from 18-13ka (chronology is based on 14C dating). Because of the large salinity changes (fresh to near-marine) during the past 20ka in this region, we interpret d18O as reflecting salinity changes more than temperature here, while d13C reflects ventilation, productivity, and salinity. Ba/Ca, Mn/Ca, and Mg/Ca may indicate salinity, oxygenation, and temperature variations, although these proxies are less straightforward to interpret in this setting. Stable isotope results suggest fjord-like, poorly ventilated conditions during early Deglaciation, with three clear phases from 18-13ka : 1) an initial rapid, large freshening event; 2) subsequent slower, step-wise freshening (likely linked to the decay of the SIS); 3) more marine, ventilated, saline conditions after ~15.7ka. These events may be linked to regional and global climate changes during this period of global climate changes, and may help us evaluate the interplay between the SIS and climate in the North Atlantic and beyond.

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Glacial-Interglacial Fire variability in Southern Africa

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Southern Africa (south of 20°S) paleofire history reconstruction obtained from the analysis of microcharcoal preserved in a deep-sea core located off Namibia reveals changes of fire activity on orbital timescales in the precession band. In particular, increase in fire is observed during glacial periods, and reduction of fire during interglacials such as the Eemian and the Holocene. The Holocene was characterized by even lower level of fire activity than Eemian. Those results suggest the alternance of grass-fuelled fires during glacials driven by increase in moisture and the development of limited fuelled ecosystems during interglacial characterized by dryness. Those results question the simulated increase in the fire risk probability projected for this region under a warming and drying climate obtained by Pechony and Schindell (2010). To get better understanding of fire variability in South Africa we compare data of a deep sea record to model results obtained by JSBACH - the land component of the Max Planck Institute Earth System Model. Fire dynamics over the last 130.000 years is simulated in an offline mode. Climate data like precipitation and temperature as well as vegetation data like soil moisture, productivity (NPP) on plant functional type level are used to explain the trends and variability of fire activity over the last glacial cycle - trends which are driven by vegetation and climate, while vegetation itself is coupled to fire.

Paleo-ice sheet reconstructions constrained by GIA and geological data for use in climate models

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Paleo-ice sheet reconstructions are complicated by large uncertainties, particularly since it is usually only possible to infer thickness from indirect means such as the response of glacial isostatic adjustment (GIA). GIA itself has large uncertainties with respect to the rheological structure of the Earth, and it is possible to get multiple possible best fitting ice sheet configurations using different Earth models. Usually the best geological constraints for paleo-ice sheets are ice margin location, via dating methods and geomorphological features. Using the program ICESHEET (Gowan et al 2016), it is possible to exploit this knowledge and create glaciologically consistent ice sheet reconstructions for use in GIA modeling. We demonstrate this by applying them to the North American Laurentide and Innuitian ice sheets, and show that it is possible to have an ice sheet that has a much lower profile than other GIA constrained reconstructions such as ICE-6G, GLAC-1 and ANU. A lower profile ice sheet has profound implications for past climate reconstructions, including radically different atmospheric and Atlantic Ocean circulation at the Last Glacial Maximum. Such a reconstruction is better able to fit geological constraints in the near field, but are at odds with global sea level reconstructions that require much larger ice volume. We discuss possible solutions to this issue. Another benefit of ICESHEET is that it does not require climatic information, since the ice thickness is adjusted by changing a spatially and temporarily variable basal shear stress parameter. Using these reconstructions in climate models do not face the circularity of dynamic ice sheet models that require a climatic input that was often derived from a-priori ice sheet reconstructions.

The influence of the ocean circulation state on ocean carbon storage and CO2 drawdown potential in an Earth system model

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
During the four most recent glacial cycles, atmospheric CO2 during glacial maxima has been lowered by about 90-100 ppm with respect to interglacials. There is widespread consensus that most of this carbon was partitioned in the ocean. It is however still debated which processes were dominant in achieving this increased carbon storage. Here, we use an Earth system model of intermediate complexity to constrain the range in ocean carbon storage for an ensemble of ocean circulation equilibrium states. We do a set of simulations where we run the model to pre-industrial equilibrium, but where we achieve different ocean circulation by changing forcing parameters such as wind stress, ocean diffusivity and atmospheric heat diffusivity. As a consequence, the ensemble members also have different ocean carbon reservoirs, global ocean average temperatures, biological pump efficiencies and conditions for air-sea CO2 disequilibrium. We analyse changes in total ocean carbon storage and separate it into contributions by the solubility pump, the biological pump and the CO2 disequilibrium component. We also relate these contributions to differences in strength of ocean overturning circulation. In cases with weaker circulation, we see that the ocean's capacity for carbon storage is larger. Depending on which ocean forcing parameter that is tuned, the origin of the change in carbon storage is different. When wind stress or ocean vertical diffusivity is changed, the response of the biological pump gives the most important effect on ocean carbon storage, whereas when atmospheric heat diffusivity or ocean horizontal diffusivity is changed, the solubility pump and the disequilibrium component are also important and sometimes dominant. Finally, we do a drawdown experiment, where we investigate the capacity for increased carbon storage by maximising the efficiency of the biological pump in our ensemble members. We conclude that different initial states for an ocean model result in different capacities for ocean carbon storage, due to differences in the ocean circulation state. This could explain why it is difficult to achieve comparable responses of the ocean carbon pumps in model intercomparison studies, where the initial states vary between models.

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Role of dynamical ice loss during the demise of the early-Holocene Laurentide ice sheet

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
At the start of the Holocene, the Laurentide Ice Sheet (LIS) experienced rapid ice loss associated with the disintegration of the ice saddle over Hudson Bay. Constraining the early Holocene rates of ice loss is important as meltwater flux from the LIS has been identified as a likely major forcing of the abrupt 8.2 ka northern hemisphere cooling evenet, the most profound climate change event of the Holocene. Holocene LIS retreat is thought to have been largely driven by surface mass balance processes. However, the influence of Hudson strait ice stream and interactions with ocean and proglacial lakes likely provided an important feedback mechanism for surface mass balance processes in the disintegration of the ice saddle, leading to higher rates of ice loss. Simulating such processes require computationally expensive ´higher order´ ice sheet models scarcely used for past ice sheets. Now the recent BISICLES 3D ice sheet model, thanks to its unique adaptive mesh refinement is capable of accurately and efficiently resolving ice stream dynamics and grounding line migration, allowing us to accurately simulate the demise of the Laurentide Ice Sheet. We drive BISICLES (offline) with temperature and precipitation forcings from a climate model (FAMOUS) under climatic conditions 9,000 years ago. We investigate the contribution of dynamical ice loss through ice streaming and marine interactions, and combine this with changes driven by surface energy balance. This experiment provides constraints on rates of ice sheet changes and mechanisms of rapid, sub-century ice sheet changes during the early Holocene.

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Transient simulations of the last deglaciation in the framework of the PalMod project as contributions to PMIP4

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

The last deglaciation (21-9 kyr BP), which marked the transition between the last glacial and present interglacial period, was punctuated by a series of rapid (centennial and decadal) climate changes. Numerical climate models are useful for investigating mechanisms that underpin these events, especially now that – due to availability of increased computational power – some of the complex models can be run over the period of multiple millennia. In phase 1 of the Palmod project, we aim to perform transient simulations of the last deglaciation in order to quantify contributions of different climatic factors using complementary models and coupling strategies, including a setup in which the climate models are fully coupled to land-ice sheet models. In a 2nd phase also the full interaction with biogeochemical cycles is envisaged. Within PalMod continuous time series of the three greenhouse gases CO_2, CH_4, and N_2O have now been constructed, based on a state-of-the-art compilation of available ice core data, which have been carefully selected, partially corrected and spline-smoothed to an equidistant time step of 1 year. The full data sets, including uncertainty estimates, are covering the last 156 kyr and are supported by instrumental measurements until the year 2016 CE. These data might be used for the deglaciation and other PMIP4 related experiments covering parts of the last 150 kyr, We suggest that other PMIP participants use the same GHG data sets to force their models, which might then facilitate the intercomparisons. This GHG data compilation is documented here: Köhler, P., Nehrbass-Ahles, C., Schmitt, J., Stocker, T. F., and Fischer, H.: A 156 kyr smoothed history of the atmospheric greenhouse gases CO_2, CH_4, and N_2O and their radiative forcing, Earth Syst. Science Data, 2017, doi: 10.5194/essd-2017-6. The related GHG data and simplified estimates of the related radiative forcing can be accessed at doi: 10.1594/PANGAEA.871273. Link to the project: www.palmod.de

Cold ocean, warm summers? The role of atmospheric blocking

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Co-author: Arne Johansson, Royal Institute of Technology, KTH Stockholm;
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Abstract:
The late deglaciation over the Euro-Atlantic region is characterized by rapid climate shifts between warm and cold states. Proxy- and modelling-evidence suggest a consistent link between cold annual/winter climates with cold ocean states over the North Atlantic. However, it remains unclear whether and, if so, how these cold ocean states should lead to cold European summers in the presence of very high and further increasing summer insolation. Here we present results from ongoing high resolution (~100 km) time slice simulations for the late deglaciation with the Community Earth System Model (CESM1). We study the link between cold/warm ocean states and European summer temperatures under different solar and greenhouse gas forcing. In these simulations (Bølling, Older Dryas, Allerød, Younger Dryas and Early Holocene), we use a realistic paleo-topography with ice sheets and low sea-level stands. Global SSTs and sea-ice concentrations for the different warm/cold states are prescribed from a previous coarse resolution (~375 km) but fully coupled transient simulation with CCSM3 (TraCE). We show that atmospheric blocking over Europe is a dominant mechanism leading to warm summers during the late deglaciation in addition to orbital forcing. The cold ocean state of the Younger Dryas (YD, GS-1) leads to enhanced blocking. A cold-ocean-only experiment confirms that the ocean state alone leads already to warmer summers. Increased solar forcing weakens blocking over central Europe but instead leads to stronger warming over continental Eurasia. The warm but very short summers during the YD are confirmed by plant indicator species from European lakes. The strong cooling in other seasons with extreme winters may explain the dominance of cold proxy evidence. We briefly show that the summer temperature response and atmospheric blocking are model resolution dependent. In addition, we show how the positive feedback of low soil moisture, late summer heating and atmospheric blocking in response to cold SSTs in our simulation are confirmed by recent observations linking unusually cold North Atlantic SSTs with European heat waves.

Heavy impacts of climate model resolution on the simulated ice sheets at the Last Glacial Maximum

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:
Geometries and flow regimes of modeled ice sheets strongly depend on applied climate forcing. In paleoglaciological reconstructions, climate forcing is commonly derived from paleoclimate proxy data combined with present-day observations. However, such strategy fails to account for largely dissimilar patterns of the atmospheric and ocean circulation during past periods, in particular related to the effects of the ice sheets themselves. An alternative approach is to use the products of climate model intercomparison initiatives that include ice sheets as boundary conditions but often suffer from low spatial resolution. Here we present global ice sheet simulations driven by near-surface climate fields from Last Glacial Maximum (LGM) simulations, which were conducted with prescribed ice sheets and at different resolutions of the atmospheric (T31, T42 and T85) and ocean (3º and 1º) model components using the Community Climate System Model (CCSM3). Our analysis yields that ice sheet simulations forced by the highest-resolution climate fields (T85/1º) arrive at ice geometries that are largely consistent with available geomorphological constraints from end moraines. In contrast, lower-resolution fields (T31/3º and T42/1º) either inhibit the growth of the documented ice sheets or trigger ice-sheet buildup in places where the paleorecord indicates otherwise. All ice sheets exhibit high sensitivity to a decrease in the spatial resolution of the climate forcing but the response of the Eurasian Ice Sheet is most dramatic: When exposed to the low-resolution forcing, it loses its important counterpart over the British Isles, while gaining too much volume across northern Eurasia. We demonstrate that this is due to important differences between the three climate model solutions over large portions of the North Atlantic and the Arctic and conclude that such deficiencies of low-resolution climate experiments cannot be corrected using statistical down-scaling. It is therefore important to enhance the quality of climate simulations by increasing the grid resolution when setting up PMIP4 experiments with the latest generation of general circulation models. We also propose to validate the resulting climate states and examine their consistency with the prescribed ice sheet boundary conditions by flanking PMIP4 baseline simulations with a combination of global ice sheet simulations and geological evidence.

Simulating the Last Deglaciation with the isotope-enabled CESM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
A suite of four transient simulations of the last deglaciation are underway with the isotope-enabled CESM. We are using the CESM implemented with stable water isotope tracers in the atmosphere, land-surface, ocean, runoff, and sea-ice components, and new passive ocean tracers for abiotic 14C and 12C, Protactinium, Thorium, and Neodymium isotopes. These tracers are designed to improve comparison to paleoclimate proxy records and to investigate proxy-climate relationships. The baseline simulation is forced with prescribed changes in insolation, atmospheric greenhouse gas concentrations, continental ice sheet variations, and meltwater fluxes. In addition, three experiments will be performed with different sets of forcings and boundary conditions combined to factor out the relative contributions to the climate evolution of the last deglacial period. The boundary conditions and forcings are taken from the PMIP4 deglacial protocols (Ivanovic et al. 2016.) The ice sheet reconstruction used is ICE-6G (Peltier et al. 2015.) In comparison with our previous transient simulation of the deglacial period using the CCSM3, TraCE-21, run at T31 resolution in the atmosphere and nominally 3 deg. in the ocean, these simulations will be run at a higher resolution (2 deg. in the atmosphere and 1 deg. in the ocean) and with improved physical parameterizations. Preliminary results will highlight both the simulated transient climate response to different forcings in comparison to our TraCE-21, and how the isotopic signals in the water cycle vary in response to climate change globally. Ivanovic, R. F., L. J. Gregoire, M. Kageyama, D. M. Roche, P. J. Valdes, A. Burke, R. Drummond, W. R. Peltier, and L. Tarasov (2016), Transient climate simulations of the deglaciation 21–9 thousand years before present (version 1)-- PMIP4 Core experiment design and boundary conditions, Geosci. Model Dev., 9, 2563-2587, doi:10.5194/gmd-9-2563-2016. Peltier, W. R., Argus, D. F., and Drummond, R.: Space geodesy constrains ice age terminal deglaciation: The global ICE-6G_C (VM5a) model, J. Geophys. Res.-Sol. Ea., 120, 450–487, doi:10.1002/2014JB011176, 2015.

Tropical hydroclimate change during Heinrich Stadial 1 – A proxy-model synthesis

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Gerrit Lohmann, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research;
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Abstract:
We explore the response of tropical climate to abrupt cooling of the North Atlantic (NA) during Heinrich Stadial 1 (HS1) combining paleoclimate proxies with model simulations. The proxies reveal large-scale patterns of hydroclimate change relative to glacial conditions, confirming previously reported weaker Indian summer monsoon, drier Sahel and wetter south Africa, and drying over the Caribbean. Our synthesis also reveals drying over the Maritime continent as well as wetter northern Australia and southern tropical South America. We explore mechanisms driving these changes using a multi-model ensemble of so-called "hosing" simulations. We propose that ventilation of colder mid-latitude air explains the consistent reduction in the North African monsoon and Indian summer monsoon simulated by most models. The best-agreeing models indicate that cooling over the tropical NA maybe essential to drive remote tropical hydroclimate changes. Cooling of the NA also induces warming over the tropical South Atlantic (SA) via wind-evaporation-SST feedback, driving wetter conditions in South Africa and southern tropical South America. We find that the response over the warm pool is driven by El Nino-like changes in the Pacific initiated by cooling of the Caribbean. Together these results show a dominant role for altered tropical SST gradient driving changes in tropical rainfall.

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Preliminary results of the changes in ocean circulation and ocean carbon cycle during Heinrich event

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Paleoproxy records suggest that weakening of the Atlantic Meridional Overturning Circulation (AMOC) during Heinrich events was associated with the atmospheric CO2 increase of 10?20 ppm over 1000 years (Ahn and Brook, 2008). However the mechanism of CO2 increase and this linkage to the AMOC have remained unclear. In this study, the response of deep ocean circulation and ocean biogeochemical properties to glacial freshwater perturbations in the northern North Atlantic are investigated using a coupled atmosphere?ocean circulation model MIROC and offline ocean biogeochemical model. In associate with the AMOC weakening from 26 Sv to 6 Sv and the decrease in global export production by 20%, the atmospheric CO2 increases by 4.5 ppmv. Preliminary analyses show that the carbon reservoir of the upper ocean (above 2000m) except the Southern Ocean decreases resulting in atmospheric CO2 increase. On the other hand, enhanced export production in the Southern Ocean increases the carbon reservoir of the deep ocean leading to atmospheric CO2 reduction. We will also discuss the response of biological pump in the Southern Ocean and changes in carbon isotope in this presentation.

Key mechanisms for simulating glacial changes in warm pool climate: implications for the future

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

The mechanisms driving glacial-interglacial changes in the climate of the Indo-Pacific warm pool (IPWP) are unclear. We addressed this issue combining model simulations and paleoclimate reconstructions of the Last Glacial Maximum (LGM). Two drivers – the exposure of tropical shelves due to lower sea level and a monsoonal response to ice sheet albedo – explain the proxy-inferred patterns of hydroclimate change. Shelf exposure influences IPWP climate by weakening the ascending branch of the Walker circulation. This response is amplified by coupled interactions akin to the Bjerknes feedback involving a stronger sea-surface temperature (SST) gradient along the equatorial Indian Ocean (IO). Ice sheet albedo enhances the import of cold, dry air into the tropics, weakening the Afro-Asian monsoon system. This "ventilation" mechanism alters temperature contrasts between the Arabian Sea and surrounding land leading to further monsoon weakening. Additional simulations show that the altered SST patterns associated with these responses are essential for explaining the proxy-inferred changes. Our results show that ice sheets are a first order driver of tropical climate on glacial-interglacial timescales. While glacial climates are not a straightforward analogue for the future, our finding of an active Bjerknes feedback deserves further attention in the context of future climate projections.

Impact of glacial ice sheets on the duration of the stadials: Role of surface wind and surface cooling

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

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Abstract:

It has been shown from ice core reconstructions that glacial periods experienced frequent climate shifts between interstadials and stadials. The duration of these climate modes varied during glacial periods, and both the interstadials and stadials were shorter during Marine Isotope Stage 3 (MIS3) compared to MIS5. Recent studies showed that the duration of the interstadials is controlled by the Antarctic temperature, which has an impact on the stability of the Atlantic Meridional Overturning Circulation (AMOC). However, a similar relation could not be found for the stadials, suggesting that another climate factor (e.g. differences in ice sheet size, greenhouse gases and insolation) may play a role. Thus, for a better understanding of the stability of the climate, it is very important to evaluate the impact of these climate factors on the duration of the stadials. In this study, we investigate the role of glacial ice sheets. For this purpose, freshwater hosing experiments are conducted with an atmosphere-ocean general circulation model MIROC4m under several ice sheet configurations computed in an ice sheet model Icies (Abe-Ouchi et al. 2013). The impact of glacial ice sheets on the duration of the stadials is evaluated by comparing the behavior of the weak AMOC after the freshwater forcing is reduced. All experiments show a drastic weakening of the AMOC in response to the freshwater hosing, accompanied by a cooling over the North Atlantic, a southward shift of the tropical rain belt and a warming over the Antarctic. We find that experiments with smaller ice sheets take longer to recover after the freshwater hosing is reduced. Sensitivity experiments with MIROC4m reveal that differences in surface winds are important in causing the shorter stadial with larger ice sheet configurations, while differences in the surface cooling have an opposite effect.

Seasonal and latitudinal climate response to individual orbital parameters with MIROC-GCM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Orbital parameters (eccentricity, obliquity and precession) play important roles in determining glacial climate changes. We investigate the sensitivity of atmospheric GCM coupled to slab ocean and dynamical vegetation model (MIROC-LPJ; O'ishi and Abe-Ouchi, 2011) to changes in orbital parameters. We examine various orbital parameters to set eccentricity to 0, 0.01671, 0.03 and 0.0493, obliquity to 22.079, 23.439 and 24.480, and precession angles to every 30 degrees from 0 to 330 under different CO2 levels. We will discuss the dependence of seasonal and latitudinal temperature and precipitation on orbital parameters. We will also examine the role of dynamical vegetation change on temperature response to orbital parameters.

The importance of the ice sheet feedbacks over the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Co-author: D. Roche, LSCE; Earth and Climate Cluster, Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam, the Netherlands;
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Abstract:
The disintegration of the Northern Hemisphere ice sheets during the deglaciation, starting from ~ 21 kaBP, resulted in large and global modifications of the Earth climate. Multiple feedbacks are associated with the ice sheets (albedo, topography, runoff) and their importance remains debated. To further advance on this topic, we use the climate model of intermediate complexity iLOVECLIM v1.1. This coupled climate system includes atmospheric, ocean and vegetation components dynamically coupled. In its latest version, it most notably also includes an interactive ice sheet model, coupled to the atmosphere thanks to an online and conservative dynamical downscaling procedure for heat and moisture. Freshwater fluxes due to ice sheet melt and calving are transferred to the ocean in a consistent and conservative way, hence allowing for a complete closure of the water cycle. In the proposed paper, we will analyze results from multiple 21 ky long integrations of the model with both interactive and prescribed ice sheets. The importance of the corresponding ice sheet geometries and freshwater fluxes on the global climate can thus be readily evaluated together with the associated feedbacks. The simulations with prescribed ice-sheets follow the PMIP4 protocol using both provided transient reconstructions. This work is hence a contribution to the PMIP4 last glacial maximum and last deglaciation working groups.

Glacial Atlantic Overturning in CMIP/PMIP models controlled by the Southern and Northern high latitude changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
Deep Ocean circulation indicated by geochemical tracers varied during the ice age cycle with climate and the Milankovitch cycle. Multiple tracer evidence at the Last Glacial Maximum (LGM) particularly show that the water originated from the North Atlantic (NADW) was shoaler than the present day ocean and the Atlantic meridional overturning circulation (AMOC) may have been weaker. Athough it is expected to be a good test for the fully coupled atmosphere-ocean general circulation models (GCM) which are used for future climate projection, many models forced with glacial condition, however, fail to simulate the glacial AMOC, which is an obstacle to understand the response of ocean to climatic forcings. Here we analyse multi-climate models including the latest CMIP5/PMIP experiments and show that most of the climate models show a stronger and deeper AMOC associated with the insufficient cooling in the LGM Southern ocean. We further show that the models which fail to have shoeler glacial AMOC is even strengthened because of the feedback between the AMOC, sea ice and wind stress in the north Atlantic. Our additional study using MIROC AOGCM show that by eliminating the warm bias at southern ocean, which most of the climate models suffer from, the sufficiently vigorous Antarctic bottom water formation under glacial condition and proxies (MARGO and delta 13C) can be simulated. We suggest that the improvement of cloud scheme in GCM atmosphere-ocean-ice processes in the high latitude region and sufficient calculation to obtain the equilibrium state especially around Antarctica is crucial for more appropriate AMOC simulation both for the glacial and future climate change.We discuss the implication for the future climate change by analyzing the runs in the glacial and future projection using MIROC model.

Simulated abrupt recovery of overturning circulation during Bølling-Allerød using MIROC AOGCM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
During the last deglaciation, a major global warming was punctuated by several abrupt climate changes, likely related to Atlantic Meridional Overturning Curculation (AMOC). A transient simulation from the Last Glacial Maximum (21,000 years ago) to Bolling-Allerod (BA, 14,000 years ago) is conducted using an atmosphere-ocean coupled general circulation model. Changing insolation, greenhouse gas concentrations and glacial meltwater fluxes are applied based on reconstructions. An abrupt recovery of the AMOC occurred at around the period of BA, even under the glacial meltwater flux that is equivalent to a sea level rise of approximately 5 meters in 1,000 years. The simulated transition of Greenland climate occurs in approximately 100 years, which is consistent with reconstructions. The results indicate that the increasing summer insolation and greenhouse gas concentration could trigger an abrupt recovery of the AMOC without large fluctuations of glacial meltwater flux in the North Atlantic in MIROC AOGCM.

Sensitivity of the LGM climate to the uncertainty in PMIP4 ice sheet boundary conditions

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
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Abstract:
The elevation of the Last Glacial Maximum (LGM) ice sheets that covered large parts of North America and Eurasia is uncertain. This is reflected in the PMIP4 LGM protocol through the option to use either the ICE-6G or GLAC-1D ice sheet reconstructions. Previous work has shown that the climate is especially sensitive to changes in the elevation of the Laurentide Ice Sheet, with possible impacts on the strength of the Atlantic Meridional Overturning Circulation, and temperatures over the North Atlantic, northeastern Asia and the North Pacific. Here we use the CESM1.2 coupled atmosphere (CAM5 at 2°-resolution), ocean (POP2 at 1°-resolution) and sea-ice (CICE4 at 1°-resolution) general circulation model. Firstly, we force LGM simulations with these two different ice sheet reconstructions to test the sensitivity of the LGM climate to the uncertainty in the PMIP4 ice sheet boundary conditions and analyze the underlying mechanisms. Subsequently we use the simulated climate states to force an ice sheet model, which allows us to evaluate the paleoclimate simulations in terms of their consistency with the imposed boundary conditions and with the reconstructed ice-sheet extents.

The Global Monsoon Response to Volcanic Eruptions in the CMIP5 Past1000 Simulations

Session: Last Millennium & Past2K

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Abstract:

We examine the global monsoon (GM) precipitation response to volcanic eruptions in the CMIP5 past1000 simulations. The spatial patterns of precipitation exhibit drying in the monsoon regions in their respective warm season for years 1 and 2 combined following volcanic eruptions. The cooling in the western Paci?c is much stronger than that in the eastern Pacific. This zonal SST gradient across the Paci?c induces lowering SLP in the EP where the two subtropical Highs straddle the equator. This will weaken the trades which transports and converges moisture into the eastern hemisphere monsoon regions, thereby leading to the reduced GM precipitation. The ‘‘cold land-warm ocean’’ and ‘‘cold NH-warm SH’’ mechanisms can also explain why the NH monsoon has a strong reduction, while only the ‘‘cold land-warm ocean’’ lead to a weak SH monsoon. The summer monsoon rainfall shows a general decreasing anomaly across the majority of the regional monsoon regions. In contrast to a weakened global summer monsoon precipitation, most arid and semiarid desert regions, located to the west and poleward of each monsoon region, show wetting anomalies. The water budget analysis indicate that the change of the dynamic and thermodynamic terms equivalently dominate the change of precipitation.

I have focused on last millennial climate modeling since I was a PhD student. My research interests are model-data comparisons of the East Asian climate variability during the last millennium. I have finished the last millennium simulation using the FGOALS-s2 climate model and released it to PMIP3. Our group also participates in the PMIP4 past1000 simulation and the VolMIP. I would be grateful if I can receive financial support as an Early Career Scientist from the conference organization. Information of reference: name: Tianjun Zhou institution: LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences email address: zhoutj@lasg.iap.ac.cn

Different global precipitation responses to solar, volcanic and greenhouse gas forcing

Session: Last Millennium & Past2K

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Abstract:
Understanding climate change caused by different external forcing is urgent for crisis management and sustainable economic development. Although previous works have demonstrated that more rainfall is generated by the natural forcing-induced global warming than by the anthropogenic greenhouse gas (GHG) forcing, it is not clear how differently the global precipitation changes in response to the global warming induced by the change of single forcing of solar radiation, volcanic activity or GHG. We address this issue using paleoclimate experiments forced by single forcing for the period of 501 to 2000 AD. The results show that the strong low-frequency variability longer than one decade can be excited by such external forcing, and that global warming can be induced by strong solar radiation, high GHG concentration or global cooling due to strong volcanic eruption. For a given temperature change, the global precipitation change is the largest under volcanic forcing, while it is the smallest under GHG forcing. The reason is that GHG forcing tends to excite stronger high-latitude warming, especially stronger Arctic amplification of global warming than the other two individual forcing does, and there is no Arctic amplification of temperature decrease under the volcanic forcing-induced global cooling. Volcanic forcing, however, causes a strong precipitation decrease in the Intertropical Convergence Zone (ITCZ) and Asian monsoon. In other words, volcanic forcing excites ITCZ and Asian monsoon amplification of precipitation decrease. It seems that a strong volcanic eruption can reduce precipitation rather than stopping the Arctic amplification of temperature increase under the GHG-induced global warming in future. The underlying mechanisms for these different climate responses are also discussed.

Multi-proxy reconstructions of May–September precipitation field in China over the past 500 years

Session: Last Millennium & Past2K

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Abstract:
The dominant modes of variability of precipitation for the whole of China over the past millennium and the mechanism governing their spatial structure remain unclear. The first reason is probably that it is difficult to reconstruct the precipitation field in western China because the published high-resolution proxy records for this region are scarce. Numerous tree-ring chronologies have recently been archived in publicly available databases through PAGES2k activities, and these provide an opportunity to refine precipitation field reconstructions for China. Based on 600 proxy records, including 491 tree-ring chronologies, 108 drought/flood indices, and a long-term instrumental precipitation record from South Korea, we revised the precipitation field reconstruction for China for the past half millennium using the optimal information extraction method. A total of 3971 of 4189 grid points in the reconstruction field passed the cross-validation process, accounting for 94.8% of the total number of grid points. The first leading mode of variability of the reconstruction shows coherent variations over most of China. The second mode, a north–south dipole in eastern China with variations of the same sign in western China and southeastern China, may be controlled by the El Niño-Southern Oscillation (ENSO) variability. The third mode, a “sandwich” triple mode in eastern China with variations of the same sign in western China and central China. Five of the six coupled ocean-atmosphere climate models (BCC-CSM1.1, CCSM4, FGOALS-s2, GISS-E2-R and MPI-ESM-P) of the Paleoclimate Modeling Intercomparison Project Phase III (PMIP3), can reproduce the south-north dipole mode of precipitation in eastern China, and its likely link with ENSO. However, there is mismatch in terms of their time development. This is consistent with an important role of the internal variability in the precipitation field changes over the past 500 years.

Solar Irradiance in the Holocene: A Consistent Multi-proxy Reconstruction

Session: Last Millennium & Past2K

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Abstract:

The Sun is the main external energy source to the Earth's system. The overall energy input and its spectral distribution are described by the total and spectral solar irradiance, respectively. The irradiance has only been measured directly for the last four decades, and thus models need to be used to reconstruct the past changes. Such models require an input proxy of solar magnetic activity. The directly observed sunspot number goes back to 1610 and covers the Maunder Minimum. To go further back in time one has to rely on indirect proxies, such as concentrations of cosmogenic isotopes 10Be or 14C in terrestrial archives. These isotopes are produced in the atmosphere by cosmic rays, whose flux is modulated by the solar magnetic field. Although the cosmogenic isotope series retrieved from the natural archives around the globe show a high degree of similarity due to their common origin, significant deviations over some periods of time can be observed due to, e.g., their differing geochemical paths in the atmosphere or local conditions. We will present the most recent total and spectral irradiance reconstruction based on a new method of consistent analysis of multi-isotope proxy series covering the last 9000 years. The record reveals the global and robust nature of solar variability in the past.

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Changes in the South Atlantic Subtropical Gyre during the Last Millennium

Session: Last Millennium & Past2K
Author: Fernanda Marcello de Oliveira / fernandamaol@gmail.com / University of São Paulo
Co-author: Ilana Wainer, University of São Paulo;
Abstract:
This study investigates changes in the circulation of the South Atlantic Subtropical Gyre (SASG) during the Last Millennium, especially in its northern boundary, represented by the bifurcation of the southern branch of the South Equatorial Current (sSEC) into the North Brazil Undercurrent/Current (NBUC/NBC) to the north and the Brazil Current (BC) to the south. The sSEC Bifurcation Latitude (SBL) marks the transition between waters flowing equatorward within the upper branch of the Atlantic Meridional Overturning Circulation (AMOC) and those flowing poleward and recirculating in the subtropical gyre. Analysis of the large-scale ocean gyre dynamics are performed using simulation results from the Last Millennium Ensemble experiment of the Community Earth System Model version 5 (CESM-CAM5 LME), for the period ranging 850-2005. Results point to an increase in the total anticyclonic circulation and a southward displacement of the subtropical gyre system. More specifically, it is found increased values of Wind Stress Curl, Sea Surface Height and Barotropic Stream Function within the dynamical rims of the subtropical gyre, together with a synchronous poleward migration of the system, which is demonstrated by displaced climatological isopleths of these fields. It is also observed a consistent southward migration of the SBL, associated with a significant increase in the equatorward advection of waters within the sSEC-SBL-NBUC system, which contributes to the AMOC upper branch. Accordingly, time series of the basin-integrated meridional transport which estimates the overturning strength displays a considerable increase in the AMOC cell, suggesting that although the governing dynamics of the subtropical gyre favors a spinned-up circulation, the bulk of the increased sSEC transport is directed to the Northern Hemisphere with the NBUC feeding the AMOC instead of heading southward with the BC and recirculating in the SASG. It is revealed that for the end of the 20th century the observed changes in the SBL and the SASG dynamics have reached levels that had rarely, if ever, been exceeded in the preceding past 1000 years.

My PhD supervisor is prof. dr. Ilana Wainer (wainer@usp.br), from University of São Paulo.

Impact of Last Millennium Volcanism for the South Atlantic Ocean

Session: Last Millennium & Past2K

Author: Laura Sobral Verona / verona.laura@usp.br / Ocenographic Institute of University of São Paulo (IO/USP)

Co-author: Ilana Wainer, Ocenographic Institute of University of São Paulo (IO/USP);

Abstract:

Quantifying how much the climate system is impacted by natural forcing is a key aspect for understanding how the Earth´s climate system is changing. Volcanism is the cause of great non-anthropogenic perturbations on the Earth climate through energy imbalance changes. Which occurs due to injection of sulfuric gases (e.g. SO2 and H2S) in the stratosphere that interacts with the incoming radiation. Thereby causing surface and low troposphere cooling. The climate effects of great volcanic eruptions have been studied mostly for the Northern Hemisphere. There is still much to be uncovered relative to the impacts on the Southern Hemisphere, even more with respect to the Southern Ocean. The South Atlantic and its Southern Ocean sector response to volcanism are examined using simulation results from the Last Millennium Ensemble Experiment of the Community Earth System Model version 5 (CESM-CAM5-LME), for the period ranging 850-2005. With a composite analysis and Wilcoxon Rank-Sum test, we evaluate significant changes in the air-sea properties due to great tropical and southern eruptions. The sea surface temperature and salinity anomaly pattern change in the first austral summer (DJF) following the eruption. North of 60S, SST gets ~0.6C colder, as expected because of the higher albedo. Contrarily, near the Antarctic Peninsula we observe a local warming of approximately 0.4C, significant at the 90% level. All surface anomalies seem to disappear after the 5th subsequent year eruptions compared to the composite average of the years before the event. The same happens with the surface salinity. There are not significant changes in the explosion year. However, from the first to the 4th subsequent DJF, a positive salinity anomaly (~0.1) is observed in the northern region off Antarctic Peninsula. On the other hand, volcanism impacts on the associated zonal wind stress are faster. The greatest anomaly is observed during the DJF of the volcano explosion year, which generates an increased zonal gradient.

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Understanding ENSO ISM teleconnectins during LM with Emphasis on MWP and LIA, a PMIP3 Approach

Session: Last Millennium & Past2K

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Abstract:
Here, using the available model simulations from the PMIP3, we study the mean summer (June-September; JJAS) climate and its variability in India during the Last Millennium (CE 850-1849; LM) for which instrumental observations are unavailable, with emphasis on the Medieval Warm Period (MWP; CE 1000-1199 as against the CE 950-AD1350 from the proxy-observations) and Little Ice Age (LIA; CE 1550-1749 as against the CE 1500-1850 from proxy observations). Out of the eight available models, by validating the corresponding simulated global and Indian mean summer temperatures and mean Indian summer monsoon rainfall (ISMR), and their respective trends, from historical simulations (CMIP5) against the various observed/reanalyzed data sets for the 1901-2005 period. From this exercise, we identify seven 'realistic' models. The models simulate higher (lower) mean summer temperatures in India as well as globally during the MWP (LIA) as compared to the corresponding LM statistics, in confirmation of several proxy data sets. Our Analysis shows a strong negative correlation between the NINO3.4 index and the ISMR and a positive correlation between NINO3.4 and summer temperature over India during the LM, as is observed in the last one-and-half centuries. The magnitude of the simulated ISMR-NINO3.4 index correlations, as seen from the multi-model mean, is found to be higher for the MWP (-0.19; significant at 0.05 level) as compared to that for the LIA (-0.09; insignificant). Our analysis also shows that the above (below) LM-mean summer temperatures during the MWP (LIA) are associated with relatively higher (lower) number of concurrent El Niños as compared to the La Niñas. Distribution of boreal summer velocity potential at 850 hPa in the central tropical pacific and a zone of anomalous convergence in the central tropical pacific, flanked by two zones of divergence in the equatorial pacific, suggesting a westward shift in Walker circulation as compared to the current day signal. The anomalous divergence center in the west also extends into the equatorial eastern Indian Ocean, which results in an anomalous convergence zone over India and therefore excess rainfall during the MWP as compared to the LM. The results are qualitative, given the inter-model spread.

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Winter amplification of the European Little Ice Age cooling by the subpolar gyre

Session: Last Millennium & Past2K

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Abstract:

Climate reconstructions reveal a strong winter amplification of the cooling over central and northern continental Europe during the Little Ice Age (LIA; here defined as c. 16th–18th centuries), via persistent, blocked atmospheric conditions. Although several potential drivers have been suggested to explain the European LIA cooling, including solar minima and/or volcanic eruptions, together with a persistent negative phase of the North Atlantic Oscillation (NAO) and/or a weakening of the Atlantic meridional overturning circulation (AMOC), no coherent mechanism has yet been proposed for the seasonal contrast in the European LIA cooling. Here we demonstrate that such exceptional wintertime conditions arose from sea ice expansion and reduced ocean heat losses in the Nordic and Barents seas, driven by a multicentennial reduction in the northward heat transport by the subpolar gyre (SPG). However, these anomalous oceanic conditions were largely decoupled from the European atmospheric variability in summer. We reject previous hypotheses that linked the European LIA cooling with a weakened AMOC or with a persistent negative NAO. Our novel dynamical explanation is derived from analysis of an ensemble of last millennium climate simulations, performed with Max Planck Institute Earth System Model, and is further supported by reconstructions of European temperature and atmospheric circulation variability and North Atlantic/Arctic paleoceanographic conditions. We conclude that SPG-related internal climate feedbacks related were responsible of the European LIA winer cooling amplification. Thus, characterization of SPG dynamics is essential for understanding multicentennial seasonal variability in the European/North Atlantic sector.

Quantifying the effects of Neotropical land use change on global carbon cycle and climate after 1492 in an Earth System Model

Session: Last Millennium & Past2K

Author: Alexander Koch / alexander.koch.14@ucl.ac.uk / University College London
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Abstract:
Agricultural activity was widespread over the American continent before Europeans arrived. Following European contact, Old World diseases, warfare and slavery led to an indigenous population loss of up to 90% and a near-cessation of agriculture. Several studies argue that the additional carbon uptake from the following reforestation event had an substantial impact on the global carbon cycle and is partially responsible for the CO_2 minimum observed around 1610 CE in Antarctic ice cores. This hypothesis is supported by a d13C-CO_2 signal pointing towards an increased terrestrial sink for this period. Modelling studies suggest that depopulation-induced land use changes could have a magnitude ranging from near-zero to accounting for the full magnitude of expected carbon sink. These results are partially down to the choice of land use datasets with different magnitudes of forcing, but may easily be model-dependent. Here we outline and present initial results from a new approach to estimate the effect of the land use change following European conquest of the Americas. We are performing an ensemble of simulations spanning the period from initial European contact until 1750 with an Earth System Model (CESM 1.2; T31 resolution, interactive carbon cycle). We compare the effects of the three available land use forcing datasets (PO10, HYDE 3.2 & KK10) and a best guess land use estimate based on available archaeological data. This approach should allow us to reliably detect variations in the carbon cycle response to different land use forcing at 1500 CE, one focus point of the Landcover6k initiative. Furthermore we should be able to constrain the contribution of land use change on the decline in atmospheric CO_2 seen at 1610 CE and address the question whether humans had an impact on the carbon cycle and climate immediately prior to the Industrial Revolution.

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Atmospheric dynamics leading to decadal droughts in the Mediterranean region

Session: Last Millennium & Past2K
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Abstract:
The land areas surrounding the Mediterranean are prone to naturally occurring multi-year and decadal droughts. Precipitation in this region is concentrated during the winter half years and its variability at inter-annual time scales is strongly controlled by the North Atlantic Oscillation, although this influence is weaker in the Eastern Mediterranean. The mechanisms is the dependence of the North Atlantic storm tracks on the intensity of the North Atlantic Oscillation pattern The analysis of past-millennium simulations of the PMIP3 model suit, however, indicates that decadal drought events are linked by pattern sea-level pressure patterns that are different, and that seem to be more associated with the anomalies of moisture advection by the seasonal mean winds. In the Mediterranean region, these patterns imprint a distinct east-west dipole of precipitation anomalies, which is not clearly present at interannual time scales. This zonal contrast of decadal precipitation variability is consistent with previous analysis of moisture sensitive dendrochronologies. The decadal drought episodes doe not show an imprint of the external climate forcing, either due to volcanic eruptions nor to the more slowly varying solar irradiance. At longer time scales than 1000 years, the sea-level-pressure trends caused by the orbital forcing may also have an influence on Mediterranean precipitation, more strongly so in the Eastern Mediterranean, and thus are appear related to trends in the South Asian Monsoon.

Simulations over the Common Era and integrated analyses of reconstructions and multi-model simulations

Session: Last Millennium & Past2K

Author: Johann Jungclaus / johann.jungclaus@mpimet.mpg.de / Max Planck Institute for Meteorology, Hamburg, Germany

Co-author: Past2k Working Group, ;

Abstract:

The working group “Past2k” aims at: • Promoting community simulations of the Late Holocene with state-of-the-art Earth System Models (ESM), such as the PMIP4/CMIP6 “past1000” experiments; coordinating the experimental design and analysis framework • Coordinating collaborative effort to asses model performance and process-based analysis • Promoting model-data comparison activities cooperating with climate reconstruction groups, statisticians, and dynamicists The WG has coordinated and initiated efforts to update the experimental protocol and reconstructions of external forcing, such as solar irradiance and volcanic aerosols as well as a data protocol. The manuscript, published in GMD as part 3 of a series of PMIP papers, discusses in detail the forcing agents: orbital, solar, volcanic, land-use/land-cover changes, and variations in greenhouse gas concentrations. The past1000 simulations covering the pre-industrial millennium from 850 Common Era (CE) to 1849 CE have to be complemented by historical simulations (1850 to 2014 CE) following the CMIP6 protocol. The external forcings for the past1000 experiments have been adapted to provide a seamless transition across these time periods. Protocols for the past1000 simulations have been divided into three tiers. A default forcing data set has been defined for the “tier-1” (the CMIP6 past1000) experiment. However, the PMIP community has maintained the flexibility to conduct coordinated sensitivity experiments to explore uncertainty in forcing reconstructions as well as parameter uncertainty in dedicated “tier-2” simulations. Additional experiments (“tier-3”) are defined to foster collaborative model experiments focusing on the early instrumental period and to extend the temporal range and the scope of the simulations. On-going efforts regarding model-data comparison have focused on regional temperature reconstructions and have extended the scope of target variables to assess hydroclimatic reconstructions. A workshop was held in Lamont in June 2016 as a joint effort of PAGES 2K and the PMIP PastK working group. The aim oft he meeting was to review CE proxy archives appropriate for hydroclimate assessment and the current ensemble of coupled model simulations. The participants discussed outstanding challenges and made recommendations for best practices for how to perform reconstruction-model intercomparisons for hydroclimate.

Planetary waves modulate summer climate variability over Europe during the Common Era

Session: Last Millennium & Past2K

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Abstract:

We investigate European summer climate variability and its tele-connections in reconstructions and model simulations covering the Common Era (CE). Simulations of summer temperature reproduce important features of recent reconstructions obtained by the EuroMed2k group of the PAGES2k framework. The model experiments have been carried out with the Max Planck Institute for Meteorology Earth System Model (MPI-ESM-P) and cover the pre-industrial millennium and (partly) the entire CE. Both in simulations and gridded field reconstructions, the first and second empirical orthogonal functions (EOF) of spatial variations are well separated. The principal component of the first EOF is an expression of a planetary-wave-like pattern that is prominent in the upper troposphere and that resembles the previously defined circumglobal wave train (CGT) pattern. The CGT mode of surface air temperature variability is accompanied by a zonally-oriented pattern in precipitation. Composites of related sea surface temperature (SST) and ocean-atmosphere heat flux fields reveal prominent anomalies in the Gulf Stream region, which might modulate the Rossby waves. The SST patterns are related to changes in the large-scale ocean gyre and overturning circulation. We also investigate the influence of external drivers (volcanic eruptions, solar modulations).

Simulated changes in gross primary productivity during the Last Millennium: a new approach to evaluating PMIP simulations

Session: Last Millennium & Past2K

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Co-author: Sandy P. Harrison, University of Reading;
I. Colin Prentice, Imperial College London;

Abstract:
Climate changes during the Last Millennium were insufficient to cause major changes in vegetation distribution, but did cause changes in vegetation productivity that are documented e.g. in peatland accumulation rates. We use a light-use efficiency model, the P model, to simulate changes in gross primary productivity driven by outputs from an ensemble of CMIP5/PMIP3 Last Millennium simulations. Temporal changes in GPP reflect changes in light (PAR) modulated by changes in cloud cover, atmospheric drought as reflected by vapour pressure deficit (VPD), growing season temperature and CO2. The relative importance of these factors varies spatially. For example, while the effect of increasing CO2 is always positive, the impact of such changes is larger in more arid regions because it enhances water-use efficiency. Although the differences in simulated climate between the Medieval Warm Anomaly (MWA: 1000-1200 CE) and the Little Ice Age (LIA: 1600-1800 CE) only resulted in moderate changes in GPP globally, regional differences can be large and thus should be discernable in palaeorecords. Despite broadscale similarities in GPP changes between members of the ensemble, there are differences between the individual simulations. Thus, comparison of the simulated temporal and spatial patterns in GPP with palaeoenvironmental records should allow discrimination between different models and different forcings. Furthermore, the impact of large volcanic events is seen in the simulated GPP, again offering the potential to evaluate the realism of alternative forcings and individual model responses.

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Spatial patterns of drought/flood over eastern China in the periods of anomalous solar activity during the past millennium

Session: Last Millennium & Past2K

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Abstract:

Based on five new reconstructions of solar irradiance, the anomalous solar activity periods during the past millennium, including 5 Solar Minimum periods, 2 Solar Maximum, were identified. Furthermore, the spatial patterns of drought/flood over eastern China for these periods were reconstructed using an index of difference between drought and flood frequency derived from a 63-site yearly drought/flood grade dataset. The simulations from CESM forced by the variation of irradiance under Solar Minimum/Maximum started with initial conditions for different phases of PDO were also performed. The reconstructions show that there are different drought/flood patterns over eastern China among 5 Solar Minimum (1010-1050, 1280-1350, 1460-1550, 1645-1715, 1795-1823), with a higher probability of drought (flood) dominating the middle and lower reaches of the Yangtze River (North China Plain). The ensemble mean patterns of drought/flood for all the 5 Solar Minimum presented a zonal distribution with flood in South China, drought in the middle and lower Yangtze River and flood in most parts of North China. Whereas in the periods of solar maximum, drought prevailed over most of eastern China during Medieval Maximum (1100-1250) and in North China Plain and southwestern China during Modern Maximum (1920-2000) respectively. While the ensemble mean for simulations started with various initial conditions show that drought (flood) prevailed over north (south) of eastern China during Solar Minimum, and flood prevailed over most of eastern China during Solar Maximum. However, the patterns varied with different initial conditions started different phases of PDO, which suggest that the anomalous hydroclimate spatial pattern may be dominated by the internal variability(e.g., phase of PDO) of climate system, rather than abnormal solar irradiance.

The Model Intercomparison Project on the climatic response to volcanic forcing (VolMIP)

Session: Last Millennium & Past2K

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Abstract:
Our understanding of the climatic response to volcanic forcing is hampered by the large uncertainties affecting the instrumental records, due to the limited number of observed events, and the available climate reconstructions, and by the non-robust dynamical responses simulated by different climate models. The lack of agreement between model results is crucially determined by differences in the model's characteristics such as resolution, complexity and implementation strategy of the forcing, and uncertainty in the eruption details including magnitude, latitude and season, input data and background climate. The multiple and varied nature of these factors prevents their contribution to uncertainty from being distinguished within existing transient simulations or non-coordinated multi-model experiments. The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP) presented here focuses on the response of the coupled ocean-atmosphere system to strong volcanic forcing. VolMIP is a CMIP6 endorsed project, which defines a common protocol to subject Earth system models and coupled general circulation models to the same volcanic forcing and under a similar range of background climate conditions. By doing so, VolMIP aims at assessing to what extent simulated responses are robust across models and at identifying the causes that limit robust behavior, especially as far as different treatment of physical processes is concerned. VolMIP provides context to the PMIP4-past1000 simulations, where volcanic forcing is among the dominant sources of climate variability. In particular, VolMIP and PMIP4 have defined a hierarchy of experiments focused on the early 19th century that will allow us to investigate the interactions between different natural forcing factors and the role of background climate conditions during one of coldest periods of the last millennium. In this contribution, we will present an overview of VolMIP and discuss how ongoing and planned coordinated activities contribute to strengthen the synergies between VolMIP and PMIP4.

The PAGES 2k Network, Phase 3: Introduction, Goals and Call for Participation

Session: Last Millennium & Past2K

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Scott St. George, University of Minnesota, USA;
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Abstract:

The past 2000 years (the “2k” interval) provides critical context for recent anthropogenic forcing of the climate, baseline information about Earth’s natural climate variability, opportunities to improve the interpretation of proxy observations, and evaluation of climate models. The PAGES 2k Network (2008-2013 Phase 1; 2014-2016 Phase 2) used peer-reviewed data from various archives at a wide range of resolutions, which met strict quality control requirements, to build regional and global surface temperature reconstructions for terrestrial regions and the oceans. Comparison with realistically-forced climate model simulations, including the PMIP3 Last Millennium ensemble, was used to identify mechanisms of climate variation on interannual to bicentennial time scales. In May 2017 Phase 3 (2017-2019) was launched, focusing on the following goals: 1) Further understand the mechanisms driving regional climate variability and change on interannual to centennial time scales (Theme: “Climate Variability, Modes and Mechanisms”) 2) Reduce uncertainties in the interpretation of observations imprinted in paleoclimatic archives by environmental sensors (Theme: “Methods and Uncertainties”) 3) Identify and analyse the extent of agreement between reconstructions and climate model simulations (Theme: “Proxy and Model Understanding”) In Phase 3, research is organized as a linked network of well-defined projects and targeted manuscripts, identified and led by 2k members in a culture of collegiality, transparency, and reciprocity. The 2k projects focus on specific scientific questions aligned with Phase 3 goals, rather than being defined along regional boundaries. Phase 3 seeks to stimulate community based projects and facilitate collaboration of researchers from different regions and career stages, drawing on breadth and depth of the global PAGES 2k community; support end-to-end workflow transparency and open data and knowledge access; and develop collaborations with other research communities and engage with stakeholders. Links with the climate modelling community, and particularly PMIP, will be critical to our success. In this contribution we illustrate some relevant applications using results from Phase 2 as a basis for working together with the PMIP4 Working Group on similar questions. If you would like to participate in PAGES 2k Phase 3 or receive updates, please join our mailing list, or speak to a coordinating committee member.

Improved volcanic forcing in PMIP4 and beyond

Session: Last Millennium & Past2K

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Rob Wilson, University of St Andrews;

Abstract:
Radiative forcing resulting from major explosive eruptions is the dominant natural driver of climate variability over the Late Holocene. Reproducing the forced component of climate variability in numerical simulations relies on accurate information regarding the timing, magnitude and location of major volcanic eruptions, the radiative properties of the resulting volcanic stratospheric aerosols, and implementation of the reconstructed volcanic forcing time series into climate models. Here, we report on recent progress on these fronts, including the construction of more accurate volcanic histories from ice cores covering the past 2500 years and new methods used in the construction and implementation of volcanic radiative forcing in climate models. Model results based on these new reconstructions, including available first results from the PMIP4 Last Millennium and Past2k experiments will be explored, including comparisons to proxy-based climate reconstructions like the Northern hemisphere TREe-Ring Network Development (N-TREND) and the Last Millennium Reanalysis. Furthermore, results will be shown from preliminary experiments utilizing "forcing ensemble" techniques, incorporating improved understanding of the uncertainties connected to the volcanic forcing reconstruction. Implications for other experiments within PMIP—e.g. the Mid-Holocene and Last Glacial Maximum experiments—will be discussed.

Last millennium regional temperatures and associated uncertainty over East Asia: a model-data analysis

Session: Last Millennium & Past2K

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Co-author: J. Fidel Gonzalez-Rouco, UCM (Madrid, Spain);
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Abstract:
A pool of existing published temperature reconstructions covering the last millennium over East Asia/China provides a suitable framework to investigate the variability of paleotemperatures at the regional scale. A sensitivity analysis based on the impact of a few methodological variants, as for instance the nature and number of proxies, the instrumental data or the method used to calibrate the reconstructions, is conducted to help constrain the uncertainty associated to the regional estimates. An ensemble of state-of-the-art simulations from various climate models following the PMIP3/CMIP5 protocol is used to evaluate the similarity between reconstructed and simulated regional temperature trajectories. Special emphasis is given to last decades warming trends in the region from the reality of models, reconstructions and simulations. New estimates of seasonal temperatures for the last thousand years over East Asia are proposed.

Tree growth and climate: an analysis of current assumptions and the advantages of forward modelling as an alternative approach for data-model comparison

Session: Last Millennium & Past2K

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Abstract:

The derivation of Last Millennium climate reconstructions from tree-ring series is based on several assumptions including that (a) ontogenetic effects on radial growth can be removed statistically, (b) tree growth at a given site is controlled by a single climate variable or at most a simple combination of two variable, (c) the statistical relationship between radial growth and climate variables is invariant through time, (d) changing CO2 concentrations [CO2] have negligible impacts on growth, and (e) carbon allocation to stem growth is a constant proportion of total productivity. Here we show that inherent temporal sampling biases mean that standard techniques to account for ontogeny still preserve the impacts of changes in long-term mean climate on growth. We also show that tree growth is always controlled by multiple climate variables, including light, atmospheric drought, soil moisture and growing season temperature. The relationship between growing season temperature and tree growth is non-monotonic, such that increasing temperature has positive effects on radial growth in cool climates but negative effects on growth in more temperate regions. The strength of the relationship between any one climate factor and growth varies spatially, but more importantly is not invariant through time. Finally, we show that while changes in [CO2] increase photosynthesis and gross primary production, this is not always reflected in increased stem growth. Tree responses to changing [CO2] involve changes in carbon allocation to leaves and rooting systems. Given that changes in [CO2] affect water-use efficiency, changes in allocation are also expected as a response to persistent drought and will therefore modulate the apparent relationship between stem growth and climate. While these analyses raise serious issues about the reliability of climate reconstructions based on tree-ring series, we propose a way forward through process-based modelling. By building on ecophysiological theory, process-based modelling avoids unrealistic assumptions about tree growth, and should allow more soundly based interpretations of tree-ring data and comparisons with palaeoclimate simulations.

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South American Monsoon System over the Last Millennium: Climate Simulations of PMIP3.

Session: Last Millennium & Past2K

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Abstract:
The natural climate variability is an important factor to be understood for exploring the predictive potential of the climate and to evaluate the role of the anthropogenic forcing. Paleoclimate records provide indications of the past variability and cover a much longer period than the instrumental era. The main purpose of this study is to evaluate the changes of the South American Monsoon System (SAMS) during the Last Millennium (LM) in the numerical simulations of PMIP3 and to verify, in general, the influence of some climatic indexes on the monsoon. Large-scale aspects associated with the SAMS are explored, as well as its relations with the indicator of the low-frequency climate variability. The analyses have been based on the Large-scale Index for South American Monsoon (LISAM) applied in the weighted average set of the climate models simulations CCSM4-M, GISS-E2-R, IPSL-CM5A-LR, MIROC-ESM, MPI-ESM-P and MRI-ESM. The LISAM is based on the analysis of combined Empirical Orthogonal Functions (EOFc) between the variables at 850 hPa: precipitation, temperature, humidity and wind. The first (second) mode of the EOFc represents the spatial patterns of the SAMS (South Atlantic Convergence Zone – SACZ). Regarding with the LISAM the patterns related of the first two modes (SAMS and SACZ, respectively) during LM were similar to those found in the historical period. The temporal variability of the expansion coefficient series of the LISAM modes showed periods of variation associated with the variability of solar cycles and sunspots, as well as the systems internal oscillations. The internal variability of the SAMS and SACZ showed strong influences of the North and South Tropical Atlantic Ocean and the Pacific Ocean. Moreover, the time series of the first mode of EOFc proved to be a good indicator of climatic transition since it was possible to determine through the application of a regime change detection test the beginning and the end years of the Climate Medieval Anomaly and the Little Ice Age. Also, it was possible to verify the influence of some of the major volcanic eruptions of the LM period.

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Long-Term Surface Temperature (LoST) Database as a Complement for GCM Control Simulations

Session: Last Millennium & Past2K

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Abstract:

Control climate simulations aim to provide a stationary state to General Circulation Models (GCMs) under constant preindustrial conditions (piControl simulations). This stationary state is then used as initial conditions in GCM simulations to provide a stable and realistic climatology, reducing the potential bias in such simulations. However, it is difficult to provide a reference to assess the climatology of piControl simulations due to the lack of long-term preindustrial observations. We explore the use of long-term ground surface temperature estimates from borehole temperature profiles as an additional reference that may be useful for the initialization procedure of GCM simulations. We compare five last millennium simulations and five preindustrial control simulations from the third phase of the Palaeoclimate Modelling Intercomparison Project (PMIP3) and the fifth phase of the Coupled Model Intercomparison Project (CMIP5) archives against estimates of long-term preindustrial ground surface temperatures from 514 borehole temperature profiles over North America. These long-term surface temperatures are retrieved from the quasi-equilibrium state of the subsurface thermal regime in each temperature profile, which is estimated from the deepest section of the profile. That is, the equilibrium state is recovered from the least affected part of the temperature profile by the recent changes in the surface energy balance. The subsurface temperatures at the bottom part of each profile depend linearly on depth, and the extrapolation of this linear behavior to the surface is interpreted as the long-term surface temperature (T0 temperature) at each borehole site. Our results suggest that the ground surface temperature estimates from borehole data could be employed as a reference within piControl simulations to enhance the quality of the initial conditions in GCM climate simulations.

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Summer temperature and drought co-variability across Europe since 850 CE

Session: Last Millennium & Past2K
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Abstract:
An increasing risk of droughts in some regions, with potentially severe consequences for agriculture and economy, entails a major challenge associated with ongoing and future global warming. However, climate model simulations do not show consistent projections as to hydroclimate changes with global warming on regional scales. We also have increasing evidence from around the world that the relationship between temperature and drought is highly timescale-dependent – thus the relationship seen in instrumental measurements over shorter time-scales might not hold true for longer time-scales. Therefore, a new PAGES2k project will study how the variations in the spatio-temporal distribution of droughts during past warm and cold periods in Europe can provide tentative information for future changes in European droughts associated with global warming. In light of recent progress in developing high-resolution European climate reconstructions it is now possible for the first time to assess the co-variability between summer temperature and drought frequency and severity over the past millennium. To realize this goal, we assess the co-variability between an updated version the Old World Drought Atlas, providing a spatially revolved tree-ring based gridded summer drought index for the European-Mediterranean area extending back two millennia, and a spatially resolved summer temperature reconstruction from tree-ring and historical documentary from 850 to 2003 CE. Additionally, we compare the high-resolution summer temperature and soil moisture simulations from the CCSM4 and MPI-ESM-P models over the same time period with the proxy-derived results. We also compare the co-variability between summer temperature and drought in the CRU TS 3.21 instrumental data for 1901–2012. We perform the comparison of the co-variability by: 1) cross-correlation calculations between gridded instrumental, proxy, and model fields, 2) sign tests of agreement between gridded instrumental, proxy, and model fields, 3) analysing the distribution of correlations in the various data series, 4) performing cross-spectral analyses of the various data series, and 5) conducting cluster analyses of the various data series. Preliminary results suggest that the co-variability between temperature and drought indeed depends on the time-scales chosen and spatial patterns of co-variability are more complex in the proxy-derived reconstructions than in the model simulations.

Impact of land model depth on long term climate variability and change.

Session: Last Millennium & Past2K

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Abstract:
The available evidence indicates that the simulation of subsurface thermodynamics in current General Circulation Models (GCMs) is not accurate enough due to the land-surface model imposing a zero heat flux boundary condition that is too close to the surface. Shallow land model components distort the amplitude and phase of the heat propagation in the subsurface with implications for energy storage and land-air interactions. Off line land surface model experiments forced with GCM climate change simulations and comparison with borehole temperature profiles indicate there is a large reduction of the energy storage of the soil using the typical shallow land models included in most GCMs. However, the impact of increasing the depth of the soil model in ‘on-line’ GCM simulations of climate variability or climate change has not yet been systematically explored. The JSBACH land surface model has been used in stand alone mode, driven by outputs of the MPIESM to assess the impacts of progressively increasing the depth of the soil model. In a first stage, preindustrial control simulations are developed increasing the lower depth of the zero flux bottom boundary condition placed for temperature at the base of the fifth model layer (9.83 m) down to 294.6 m (layer 9), thus allowing for the bottom layers to reach equilibrium. Starting from piControl conditions, historical and scenario simulations have been performed since 1850 yr. The impact of increasing depths on the subsurface layer temperatures is analysed as well as the amounts of energy involved. This is done also considering permafrost processes (freezing and thawing).

Last millennium atmosphere and soil temperature coupling in surrogate climates: Implication for borehole temperature reconstruction technique.

Session: Last Millennium & Past2K

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Abstract:
Past climate variations are known both from reconstruction methods that use proxy data as predictors and from simulations with climate models. Among them, borehole reconstruction is a well established method to reconstruct past surface air temperature (SAT) based on the assumption that SAT changes are coupled to ground surface temperature (GST) changes and transferred to the subsurface by thermal conduction. However, some physical processes can impact this hypothesis since they decouple SAT and GST. Climate model simulations from the Community Earth System Model Last Millennium Ensemble (CESM-LME) were considered for assessing the main processes that corrupt the SAT-GST coupling at local, regional and large to global scales. In addition, its implications for borehole temperature reconstruction are evaluated. The analysis of SAT-GST coupling focuses here on the covariance structure during the last millennium (850-1850 CE) and specifically on the trend changes during industrial times (1850-2005 CE). During this period the influence of different anthropogenic external forcings such as greeenhouse gases (GHG), land use land cover (LULC) and ozone/aerosols is considered . The results indicate that global long-term coupling is not significantly affected by local and regional decoupling processes although they are significant at smaller spatial scales. LULC changes play an important role in decoupling SAT-GST at local and regional scales with some implications for borehole temperature reconstructions therefore this must be considered in such type of reconstructions.

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Last Millennium Simulations using UK Met Office models: PMIP3 simulations and plans for PMIP4

Session: Last Millennium & Past2K

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Abstract:
We will run the PMIP4 past1000 simulation using the UK Met Office model HadGEM3. The model set-up and any initial results will be shown. In addition, timeseries and spatial patterns of temperature and precipitation variability from the last millennium PMIP3 simulation run using the UK Met Office model HadGEM2-ES will be presented and compared to those from a lower resolution HadCM3 model, both run with identical boundary conditions.

The role of solar and volcanic forcing in North Atlantic climate over the past 800 years

Session: Last Millennium & Past2K

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Abstract:

External climate forcings are known to affect climate and atmospheric circulation. However, the analysis of the role of external forcings based on observational data is hampered due to the short observational period, and the sensitivity and persistence of effects of external forcings are debated. On average, a positive phase of the North Atlantic Oscillation (NAO) is observed after major tropical volcanic eruptions the first following winter. Solar activity has also been suggested to influence atmospheric circulation. However, the solar link to the NAO found by modelling studies is not unequivocally supported by reconstructions, and is not consistently present in observations for the 20th century. Here we present a reconstruction of atmospheric winter circulation (DJF) for the North Atlantic region covering the period AD 1241-1970. Based on seasonally resolved Greenland ice core records and a 1200-year long climate model run, we reconstruct atmospheric pressure fields by matching the spatio-temporal variability of the modelled isotopic composition to that of the ice cores. This method allows us to capture the primary and secondary modes of atmospheric circulation in the North Atlantic region, while, contrary to previous reconstructions, preserving the amplitude of observed year-to-year atmospheric variability. We find the average response to major tropical volcanic eruptions to be a positive NAO for the five consecutive winters after eruptions, which is more persistent than previously suggested. Contrary to expectations we do not find a connection between solar activity and the NAO. Instead we find a Scandinavian blocking-type pattern in response to the 11-year solar cycle, resembling the sea level pressure response found in observations. Furthermore, the response to the longer-term deep solar minima of the last millennium is a high-pressure anomaly south of Greenland. This pattern is associated with cooling across Greenland, Iceland and western Scandinavia.

A 1,300-year moisture-balance reconstruction from the dry eastern rift valley of East Africa: the sediment record of hypersaline Lake Bogoria

Session: Last Millennium & Past2K

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Abstract:
High-quality paleoclimate records are rare in the dry eastern branch of the East African Rift System, due to frequent desiccation of lakes which form the major source of paleoenvironmental information in the region. In this study, we present a 1,300-year history of hydrological change at hypersaline, alkaline Lake Bogoria (Central Rift Valley, Kenya), which has survived more recent destructive episodes of drought. Multi-proxy analyses on sediment cores from five key positions, supplemented with seasonal sediment-trap data, resulted in a detailed characterization of lacustrine deposits in Lake Bogoria's three basins and on the two sills separating them. Variability in sedimentation dynamics at the different core sites allowed a semi-quantitative reconstruction of historical lake-level fluctuations over the past 1,300 years, constrained in time by a robust chronological framework. Moisture-balance variability throughout this period greatly exceeded the 20th-century range known from historical records. Between ca. AD 690 and 1100, drought isolated Lake Bogoria's central and southern basins as separate, shallow brine pools with intense evaporation leading to the deposition of sodium carbonates and other evaporative minerals. A pronounced highstand between ca. AD 1100 and 1350 was followed by another lake-level decline, and the northern basin was disconnected from the joint central and southern basins for most of the time until ca. AD 1800. During the last two centuries, lake level has uninterruptedly been relatively high. With the sedimentological framework in place, new stable-isotope and XRF analyses currently underway will translate the sediment archive from Lake Bogoria into a unique, high-resolution hydroclimate record of the past millennium in equatorial East Africa.

Comparing paleodust observations and models

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
Changing climate conditions affect dust emissions and the global dust cycle, which in turn affects climate and biogeochemistry. Natural archives show that the dust cycle experienced variability in the past in response to global and local climate change. The growing number of paleodust archives and the inclusion of the dust cycle in climate models has promoted synthesis efforts in the compilation of global dust datasets. In particular the DIRTMAP project formalized the compilation of dust mass accumulation rates, which is a quantitative metric that allows inter-comparison among different sites, among different kind of natural archives, and between models and paleodust observations. We review our most recent efforts in reconstructing the past global dust cycle with model simulations and the compilation of a paleodust database based on dust mass accumulation rates and particle size distributions for the Holocene. We also give a perspective on ongoing work aimed at providing adequate tools for paleoclimate model validation over the full last glacial-interglacial cycle, considering that the representation of the dust cycle will be an option in the upcoming PMIP4-CMIP6 experiments. We will analyze the potential to validate time slices over key periods (e.g. mid-Holocene, LGM) and rapid transitions such as the last deglaciation.

Latest news about the PMIP4 Database

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
We will present a summary table of which groups intend to run which PMIP4 experiments with which model, if the experiments are already running, and what the expected completion time is. The table will also give the status of the required DECK and historical experiments, and specify if some experiments are already available in the ESGF database. Just running the experiments is not enough and we will outline the steps that the groups have to follow to put their model output data in standard form with the CMOR3 library, and to make their data available in the ESGF DB, along with the appropriate documentation created with es-doc References: * PMIP4: https://pmip4.lsce.ipsl.fr/ * CMOR3: https://cmor.llnl.gov/ * ESGF: https://esgf.llnl.gov/ * es-doc: https://es-doc.org/

Pollen-based land-cover change during the Holocene in temperate China for climate modelling

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Quantification of the various effects of human-induced vegetation-cover/land-use change on past (present, and future) climate is still a subject of debate. Our understanding of these effects greatly depends on the availability of empirical reconstructions of past anthropogenic vegetation cover. PAGES LandCover6k aims at achieving such reconstructions at subcontinental to global scales for the evaluation of anthropogenic land-cover change (ALCC) scenarios and climate models (e.g. the international PMIP program). China is one of the key regions where agricultural civilizations flourished during a large part of the Holocene. But their role in vegetation-cover/land-use change is not fully understood. We present the first pollen-based reconstructions of Holocene vegetation-cover change in temperate China using Sugita's REVEALS model and 95 pollen records grouped into 35 groups/subregions. The results show that pollen percentages generally underestimate the cover of herbs, except for Artemisia that is strongly overrepresented by pollen. Human-induced deforestation is highest in eastern temperate China with 3 major phases of decreasing woodland cover at ca. 5.5-5ka, 3.5-3ka and 2ka BP. Disentangling human-induced from climate-induced vegetation-cover change still requires thorough comparison of the REVEALS reconstructions with historical and archaeological data combined with model simulations of climate-induced, natural vegetation.

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Model and proxy evidence for consistent link between Indian Ocean climate variability and zonal SST gradient

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
Models project increased year-to-year climate variability in the equatorial Indian Ocean in response to greenhouse gas warming. This response has been attributed to changes in the mean climate of the Indian Ocean associated with the zonal sea-surface temperature (SST) gradient. According to these studies, air-sea coupling is enhanced due to a stronger SST gradient driving anomalous easterlies that shoal the thermocline in the eastern Indian Ocean. We propose that this relationship between the variability and the zonal SST gradient is consistent across different mean climate states. We test this hypothesis using simulations of past and future climate performed with the Community Earth System Model Version 1 (CESM1). We constrain the realism of the model for the Last Glacial Maximum (LGM) where CESM1 simulates a mean climate consistent with a stronger SST gradient, agreeing with proxy reconstructions. CESM1 also simulates a pronounced increase in seasonal and interannual variability. We develop new estimates of seasonal-to-interannual climate variability at the LGM using ?18O analysis of individual foraminifera which indicates a marked increase in ?18O-variance during the LGM and strongly supports the simulations. This agreement further supports the dynamics linking year-to-year variability and an altered SST gradient, increasing our confidence in model projections.

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Pollen-based vegetation-cover change in space and time over the Holocene in Europe for climate model bench-marking

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Quantification of the effect of human-induced vegetation-cover/land-use change on past climate is still a subject of debate. Progress in our understanding of the effects of land-use change on climate greatly depends on the availability of reliable, empirical data on past land-use changes. We present here the achievements so far for Europe. Pollen-based reconstructions of past vegetation cover were performed using Sugita's REVEALS model for i) selected time windows of the Holocene using all available pollen records (gridded reconstructions) and ii) the entire Holocene using pollen records grouped according to biogeographical criteria and numerical classification. The gridded REVEALS reconstructions were interpolated using both a Gaussian Markov random Field (GMFR) and a Bayesian hierarchical model (BHM) for Dirichlet observations. The BHM was extended to disentangle anthropogenic from natural, climate-induced vegetation. This dataset is compared with reconstructions of land-cover changes in Europe over the Holocene from the HYDE database 3.2.

The radiocarbon fingerprint of different Meridional Overturning Circulations

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Changes in the strength and structure of the Atlantic Meridional Overturning Circulation (MOC) may have played a key role in abrupt palaeoclimatic transitions and could result in significant climatic impacts in the future. Carbon isotopes can be used to infer palaeoceanographic circulation changes. However, discrepancies exist in the interpretation of isotopes in geological archives. By directly simulating isotopic tracer fields within complex numerical models, modelled tracer concentrations can be compared to observations rather than the more uncertain climatic interpretations. We simulate the radioactive isotope 14C in the ocean component of the FAMOUS General Circulation Model to study large-scale ocean circulation, the oceanic carbon cycle and air-sea gas exchange. This abiotic tracer implementation accounts for the effects of air-sea gas exchange, advection and radioactive decay. The model was spun-up for 10,000 years to allow 14C concentrations in the deep ocean to equilibrate and evaluated by comparing simulated bomb 14C distributions with observational estimates. Here, we use the isotope-enabled model to investigate the surface climatologies and 14C fingerprint of different MOC stability regimes, as identified by net freshwater import into the Atlantic (Fov). Overall, we aim to improve our understanding of palaeoceanographic circulation at the Last Glacial Maximum and during the deglaciation.

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Using palaeodata to quantify the biomass burning contribution to climate-carbon cycle feedback

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
The recent observational record is too short to estimate the strength of fire-related carbon-cycle feedbacks unequivocally; model-based estimates are contradictory. Sedimentary charcoal records provide regional and global time series of biomass burning and show that fire has responded sensitively to climate variations over the past two millennia. Thus, they could provide an alternative constraint on this feedback. We use a single-box model of the land biosphere to quantify the biomass-burning feedback, using charcoal data from the Global Charcoal Database and the Mann et al. global palaeotemperature reconstruction for the pre-industrial Common Era. Charcoal increases with global mean temperature, and varies coherently with the stable carbon isotope composition of methane in ice cores. We estimate a centennial-scale feedback strength of 2.9 ± 1.1 ppm K–1 land temperature for pre-industrial biomass burning, with uncertainty dominated by the absolute value of the carbon flux. Satellite-based estimates of biomass burning emissions for 2000–2014 yield a feedback strength of 6.5 ± 3.4 ppm K–1 land temperature, with uncertainty dominated by the slope of the global emissions-temperature relationship. The modern relationship mainly reflects tropical deforestation and peat fires. Comparison with a consensus model estimate of the total land climate-carbon cycle feedback (13.1 ± 6.4 ppm K–1) suggests most of the contemporary climate-carbon cycle feedback is linked to anthropogenic burning.

Global patterns of ?18O and ?13C for the LGM, MH and LM from speleothem records in the SISAL database

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Speleothems can provide high-resolution records of changes in both climate and atmospheric composition. These records have the potential to be used to document regional changes in mean climate and climate variability on annual to centennial timescales. They can also be used to refine our understanding of regional changes in climate forcings, such as dust and volcanic aerosols, through time. Since many climate models now explicitly include isotopic tracers, the isotopic records from speleothems can also be used explicitly for model evaluation. Previous attempts to compile speleothem data have not provided a globally-comprehensive synthesis, nor have they provided rigorous assessments of measurement, chronological or interpretation uncertainties. SISAL (Speleothem Isotopes Synthesis and Analysis) is a new community-based working group sponsored by Past Global Changes (PAGES) to synthesise the 400+ speleothem isotopic records available globally and develop a public-access database, that can be used both to explore past climate changes and in model evaluation. In this presentation, we will showcase preliminary results of the SISAL synthesis of ?18O and ?13C records for the Last Glacial Maximum (21 ka), the mid-Holocene (6 ka) and the Last Millennium (850-1850 CE) and highlight robust signals that would be primary targets for model evaluation.

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http://www.ucd.ie/research/people/earthsciences/professorfrankmcdermott/

Modelling isotope-temperature relationships over the last deglaciation

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
The isotope thermometer method combines the observed strong linear relationship between temperature and the stable water isotopic composition (D and 18O) of surface snow with ice core records to reconstruct temperature changes over glacial-interglacial timescales. This method requires the assumption of stationarity - that the observed relationship has not changed with time. The development of isotope-enabled coupled General Circulation Models (GCMs) allows this assumption to be tested within a modelling framework. Here, we present a suite of time-slice simulations using the isotope-enabled HadCM3 GCM (iHadCM3) covering the last deglaciation, from 21,000 years ago to present. Modelled isotope-temperature relationships are validated against independent isotope and temperature constraints from Antarctica, before testing the application of spatially and time-independent relationships in the reconstruction of past temperature. Simulated isotope-temperature relationships agree well with present-day spatial distributions. However, there is considerable variability between Antarctic regions and between time periods. We identify locations that exhibit relatively constant isotope-temperature relationships across spatial and temporal scales and, therefore, might provide robust paleo-temperature reconstructions from ice cores. Finally, our methodology is applied to an ensemble of transient iHadCM3 forced historical simulations to place our results in the context of the last 150 years and the observational record.

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Holocene peatland and ice-core data constraints on the timing and magnitude of CO2 emissions from past land use

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

CO2 emissions from preindustrial land-use change (LUC) are subject to large uncertainties. Although atmospheric CO2 records suggest only a small land carbon (C) source since 5,000 y before present (5 kyBP), the concurrent C sink by peat buildup could mask large early LUC emissions. Here, we combine updated continuous peat C reconstructions with the land C balance inferred from double deconvolution analyses of atmospheric CO2 and ?13C at different temporal scales to investigate the terrestrial C budget of the Holocene and the last millennium and constrain LUC emissions. LUC emissions are estimated with transient model simu- lations for diverging published scenarios of LU area change and shifting cultivation. Our results reveal a large terrestrial nonpeat- land C source after the Mid-Holocene (66 ± 25 PgC at 7–5 kyBP and 115 ± 27 PgC at 5–3 kyBP). Despite high simulated per-capita CO2 emissions from LUC in early phases of agricultural development, humans emerge as a driver with dominant global C cycle impacts only in the most recent three millennia. Sole anthropogenic causes for particular variations in the CO2 record (?20 ppm rise after 7 kyBP and ?10 ppm fall between 1500 CE and 1600 CE) are not supported. This analysis puts a strong constraint on preindustrial vs. industrial-era LUC emissions and suggests that upper-end scenarios for the extent of agricultural expansion before 1850 CE are not compatible with the C budget thereafter.

Abrupt Dansgaard-Oeschger warming events in Greenland: d18O model-data comparison

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
Understanding of millennial-scale DO variability of the last ice-age remains limited, with no universally accepted theory of how these extremely rapid warming events occur. The Greenland ice core d180 records constitute the archetypal record of abrupt climate variability from the last glacial period. Considerable uncertainty about the relationship between local climate and the ice-core record of d180 remains. Both in terms of the contribution of seasonality changes and the relative importance of remote versus distant environmental controls. Here, we use modelling of d180 as a tool to help interpret the Greenland ice core records of DO-events. We perform an ensemble of multi-century isotope-enabled simulations with a coupled general circulation model, to investigate the nature of the signal contained in the d180 records. Experiments are set up using an isotope-enabled version of the Hadley Centre HadCM3 model. The set-up of our DO-type simulation to enable emulation of a salt oscillator type DO mechanism, whereby salt is progressively lost to the North Atlantic during stadial periods, and the onset of an abrupt warming when the oscillation occurs, and salt returns to the North Atlantic from the tropical Atlantic and wider global ocean. We run a set of 24 such simulations. Our modelled d180 increases are in agreement with the magnitude of the measured Greenland ice core abrupt rises in d180. The seasonal cycle of precipitation and d180 do both change during DO event: a substantially larger proportion of precipitation falls over the ice core sites during cold months under the warmer interstadial climate. We find however that changes in precipitation seasonality are not so important in driving the majority of the geographical variability in d180 across Greenland. We also demonstrate that DO sea ice changes have a larger impact on d180 changes, compared to site temperature control.

Water Source and Isotope changes through the Deglaciation and Holocene

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
Water Source and Isotope changes through the Deglaciation and Holocene A.N. LeGrande, A.E.Carlson, D.Ullman, J. Nusbaumer The deglacial period saw radical shifts in climate across the globe. Water isotopologues provide some of the most wide spread proxy archives of these climate changes. Here we present new analyses on a suite of 12 water isotope-enabled coupled atmosphere-ocean GCM simulations from GISS ModelE-R that span 24kya to the pre-industrial. We show how millennial scale co-variability in water isotopes and climate (temperature, precipitation, humidity, and moist-static energy) is distinct from regional scale spatial slopes, consistent with proxy archives (e.g., Cuffey et al 1995). We supplement this set of simulations with a new ensemble of deglacial simulations that contain a complementary suite of tracers that determine moisture provenance changes through the deglaciation.

Updating the Global Lake Status Data Base: overview and first regional results

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Lakes are an important source of information about changes in the hydrological budget, providing records of variability on annual to multi-millennial timescales depending on sedimentation dynamics. The Global Lake Status Data Base (GLSDB) was created in the 1990's to provide assessments of lake status changes over the past 30,000 years. This resource is now considerably out-of-date, because new approaches to reconstructing hydroclimate, improved techniques for constructing age models, and many new individual lake records have been developed since. A new consortium has been formed to update the GLSDB through creating an integrative framework to deal with the unique assets and challenges of lake-status data, which will allow ongoing regional synthesis efforts to be treated in a standardised way. We will present preliminary results addressing age modelling (specifically conversion of the GLSDB records to calendar age models), regional syntheses of new data from Africa, South America and China, and novel sources of hydroclimatic information. We will also show new ways of using the lake data for model evaluation to demonstrate possible applications of the GLSDB2 as part of the PMIP4 benchmarking and diagnosis approach.

I obtained a PhD in Geology at the Limnology Unit of Ghent University (Belgium) in June 2016. My PhD supervisor was Prof. Dr. Dirk Verschuren (dirk.verschuren@ugent.be).

Peat Carbon Sequestration Histories as Constraints on the Past Global Carbon Cycle

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
Peats represent a large, and often active, carbon (C) pool in the land-atmosphere system. At present, these C-rich deposits contain about 600 Pg C that has accumulated mostly since the Last Glacial Maximum -- an amount similar to the total C stocks in all living biomass or in the atmosphere. Northern (boreal and sub-Arctic) peatlands contain >90% of this C pool, followed by tropical and southern peatlands. The large size of the peat C pool and its concentration in a number of regions sensitive to climate change and human activities have promoted a heightened interest and increased research in peat C dynamics. We know that peatlands played a major role in the global carbon cycle during the Holocene as recognized by the latest IPCC report. Also, we have learned much about their distributions, histories and controls as a result of site-level, data synthesis, and modeling studies. However, we still lack understanding of climate sensitivity of these C-rich ecosystems, especially at continental and regional scales, which limits our ability to project their future trajectories. Furthermore, we have little idea about the C pool size and dynamics of peat deposits further back in time, such as during the previous interglacials, the Pliocene and beyond. The PAGES's C-PEAT Working Group aims to facilitate the interactions of international peat C researchers working on peat of all ages, including ecosystem and global modeling scientists. We continue to focus our effort on the Holocene because of the abundance of information available from northern, tropical and southern peatlands, but we also start our exploration of pre-Holocene peats using what we have learned from the studies of Holocene-age peatlands. Understanding the climate sensitivity and contribution of peat deposits to the global carbon cycle in the past, particularly their impact on atmospheric CO_2 and CH_4 concentrations, is critical to projecting their change in the future. Paleo data are essential not only for documenting carbon sequestration histories but also for evaluating and validating global climate-carbon cycle models. To that end, various available and ongoing peat C synthesis products will be useful for benchmarking PMIP4 simulations.

Holocene pollen-based land-cover reconstructions for climate model bench-marking

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

The goal of the PAGES LandCover6k initiative is to produce global maps quantifying past land-cover and land-use change based on empirical data. Changes in anthropogenic land use are inferred using archaeological and historical data, and changes in land cover from fossil pollen records, converted to vegetation cover using different model-based approaches. These empirical reconstructions are used to improve the HYDE 3.2 estimates of land-use and land-cover changes through the Holocene and can serve as inputs for climate-model simulations to examine the impact of such changes on climate. The reconstructions are also used for evaluation of model-simulated vegetation changes, since they provide quantified estimates of changes in vegetation more directly related to simulated vegetation than pollen-based biome reconstructions. We will present the REVEALS model used for pollen-based estimates of

past land-cover, which converts pollen percentage into vegetation cover accounting for differences in pollen productivity and dispersal. We will show preliminary results of gridding the REVEALS reconstructions (at 1° spatial resolution) for the northern hemisphere N of 40° at 6ka, 1850 CE and the last 100 years. We will also illustrate the use of REVEALS-based estimates for evaluation of simulated vegetation changes over the past 8000 years, as simulated by the MPI-ESM.

Holocene and LGM 3-d atmospheric dust concentration fields combining observational and model data

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
Mineral dust aerosols in the atmosphere are thought to impact on Earth's climate system directly by absorbing and scattering electromagnetic radiation, and indirectly by acting as cloud nuclei and by influencing biogeochemical cycles through micronutrient fertilization of the biosphere. Although great progress has been made in recent years in the modeling of dust mobilization, transport, and deposition, simulated atmospheric dust concentrations still feature large uncertainties and a wide model to model spread in simulation results. Here, I present a 3-d map of reconstructed atmospheric dust concentrations created by combining Holocene and LGM interpolated global dust flux fields based on observations with ensemble deposition variables from model simulations. Although not completely independent from model simulations, this observational/model hybrid still allows an assessment of individual model performance.

A model-data comparison of sea surface temperature changes during the Last Glacial Maximum

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Previous studies show considerable mismatches between MARGO SST and LGM simulations in the North Atlantic. Since MARGO SST reconstruction is a compiled ocean archive that comprises different proxies including planktonic foraminifera, diatom, radiolarian, dinocyst, alkenones and Mg/Ca, this mismatch can be potentially related to individual proxies that characterise a temperature bias and dominate in the compiled archive. Here we compare the individual SST proxies with LGM model outputs and find that there are significant data-model misfits in alkenones and dinocys. By considering potential impacts of habitats depth and growing seasons of the species on data interpretation, we can provide a better agreement of proxy data with model results. The work provides a clear reference for both proxy data and modelling communities that seek for a more reliable data-model comparison. Since MARGO data is a widely-used LGM ocean archive, our work suggests that previous conclusions directly derived from MARGO SST need to be carefully re-evaluated.

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Iso2k: A global synthesis of Common Era hydroclimate using water isotope proxies from multiple archives

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
Much of our understanding of Earth’s hydro-climate history comes from proxies for the ?18O and ?D of environmental waters (e.g., precipitation, seawater, groundwater, lake water, permafrost, ice). The ?18O and ?D of environmental waters are recorded by sensors in a wide range of natural archives, such as glacier and ground ice, speleothems, corals, lake and marine sediments, and tree rings. Despite this diversity, reconstructed ?18O and ?D can track common environmental signals such as moisture source and air mass transport history, precipitation characteristics, and temperature, and thus provide invaluable comparison targets for global climate models. However, no comprehensive synthesis of proxy ?18O or ?D timeseries yet exists in a format suitable for regional-scale climate reconstructions or for comparison with model output. The PAGES Iso2k project is creating a global database of paleo-?18O and ?D records for the Common Era based on a range of archives, with resolutions from annual to centennial, and with extensive metadata fields to facilitate interpretation and uncertainty quantification of the emergent hydroclimate signal(s). The database is being used to identify regional- and global-scale features in hydroclimate and atmospheric circulation during the past 2 kyr as well as their relationship with PAGES temperature reconstructions. As a formal project within the framework of PAGES2k Phases 2 and 3, the Iso2k effort is currently the only global, multi-archive hydroclimate database being constructed for the Common Era, with strong ties to other archive and climate target-specific groups within PAGES. Iso2k comprises the first steps towards a broader ‘Hydro2k’ synthesis. Here, we present the status of the Iso2k database, a first look at initial results, and initial targets for data-model comparison using isotope-enabled Last Millennium simulations. The goal of this presentation is to introduce Iso2k to the broader PMIP4 community and to discuss plans for synergistic activities, such as an IsoMIP project for the Last Millennium and other time periods of interest.

Seasonality and interannual variability in the tropics: A synthesis of Holocene coral and mollusk records

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

It is still unclear how climatic extremes in the tropics respond to changes in the Earth radiative budget. Whether tropical interannual variability is indeed affected by external forcing or mainly a stochastic product of the climate system internal variability is still debated. The PACMEDY project is building a database of monthly-resolved tropical Holocene marine conditions recorded by fossil corals and mollusk shells, which are the most direct and reliable observations of past changes in the oceanic high frequency variability. This synthesis will extend the previous Pacific reconstruction of Emile-Geay et al. (2016) throughout the tropics. The improved spatio-temporal coverage will allow diagnosis of past changes in the seasonality of SST and ITCZ movements, as well as the amplitude and spatial patterns of interannual variability related to El Niño Southern Oscillation and the Indian Ocean Dipole. It has been designed to assess the strength and weaknesses of climate models in their representation of tropical modes of variability, and explore the mechanisms driving tropical climate high frequency variability. The database will be made freely available to the scientific community as a target for transient or equilibrium simulations.

Evaluating the ocean circulation during the LGM using marine paleo-data

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

The quantification of model performance in simulations of past climate conditions requires both suitable paleo-data and skill assessment methods. We employ the results of multiple simulations by the NCAR Community Climate System Model version 3 (CCSM3) as well as ocean state estimates by the MIT general circulation model (MITgcm), which feature different states of the Atlantic Meridional Overturning Circulation (AMOC) during the Last Glacial Maximum (LGM): shallower and weaker, stronger and deeper, stronger but shallower. The corresponding ocean circulation and climate is compared to paleoceanographic sea-surface and deep-ocean temperature reconstructions and, in the case of the MITgcm, oxygen and carbon isotopes. We use different summary diagrams (e.g., the so-called Taylor and target diagrams) to display the degree of consistency between the models and the paleo-data and we find, for example, that a more stratified Atlantic Ocean and shallower AMOC during the LGM are consistent with most paleo-data and that the sign and magnitude of a modern model bias may strongly affect a simulation of a different climate state. Finally, we point out how our study contributes to the COMPARE (Comparing Ocean Models to Paleo-ARchivEs) working group.

Evaluating revised past land use change scenarios within global carbon cycle constraints - a roadmap for including PAGES Landcover6K products for model-intercomparison

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Timing, extent, and impacts of preindustrial land use and land use change (LUC) are uncertain, yet crucial for understanding the role of humans in the Earth's environmental history and in particular their impact on greenhouse gas concentrations during the Holocene. While the total terrestrial C balance is relatively well constrained from ice core CO2 and ?13C data, contributions from different components of the terrestrial biosphere are less well known and direct empirical data is often missing. Thus, insights into global land carbon cycle changes during the Holocene heavily rely on model simulations. CO2 emissions from LUC are commonly estimated using global dynamic vegetation models, forced by spatio-temporal scenarios of the extent of past anthropogenic land use. However, available scenarios diverge heavily by suggesting widely different extents of LUC prior to industrialisation, and land C budget constraints and archaeological evidence indicate incompatibilities in all of the available LUC scenarios. The PAGES Landcover6K initiative addresses this challenge and brings together palaeoecologists, historians, archeologists, and modellers to improve LUC scenarios. Here, we propose a roadmap for the inclusion of these improved LUC scenarios in a new set of multi-model land C cycle simulations covering the Holocene and their evaluation within given global C cycle constraints. A first special focus will be placed on the period around and after the Mid-Holocene (7-3 ka BP), to separate anthropogenic from natural impacts in a period where agriculture emerged, climatic shifts lead to large changes in biome distributions, and atmospheric CO2 gradually increased. A second focus will be placed on the extent of LUC prior to 1850 and to address the important but uncertain temporal allocation of well-constrained total present-day LUC emissions. Global C budget constraints can be used to evaluate LUC scenarios and respective cumulative CO2 emissions by 1850. This is directly relevant for the global C budget of the historical period and CMIP6 simulations with prescribed historical LUC.

The relationship between water isotope ratios and moisture source in GISS and iCESM model simulations

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Hydrogen and oxygen isotopes in various proxy records are some of the most commonly used datasets for reconstructing past climates, albeit with significant uncertainty inherent to proxy systems. Recently, isotope-enabled climate models have been used to try and reduce this uncertainty. However, climate models have their own uncertainties, and different models can produce different isotopic responses, even with the same external forcings. These discrepancies may arise from differences in model physics and isotope schemes, but may also arise because in models, as well as in nature, statistical relationships between water isotopes and local climate variables are not constant in space or time. This indicates that other, potentially non-local variables or processes may be influencing water isotope ratios, and could explain at least part of the discrepancy between different models. This study will examine a few of these non-local variables, specifically the evaporative moisture source, in the GISS model. Water tracers will be used to evaluate the relationship between water isotopes and moisture sources and transport pathways for several different climate states, such as the Last Glacial Maximum. These results will then be compared to similar results generated from NCAR’s iCESM model, to determine if they can explain the inter-model isotope differences. Finally, these moisture source and transport changes will be analyzed to determine how changes in the atmospheric circulation impact the atmospheric water cycle, and thus the water isotope ratios themselves.

Combining paleoclimate model ensembles with data to estimate climate sensitivity

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
We have investigated relationships in the PMIP ensembles between the tropical temperature changes for paleoclimate intervals and climate sensitivity for the models. The goal is to use paleoclimate observations to constrain the ensemble and thus narrow our uncertainty on our estimate of climate sensitivity. For the PMIP2 ensemble we found a correlation between tropical temperature at the Last Glacial Maximum (LGM) and climate sensitivity which is statistically significant and physically plausible (Hargreaves et al,2012). For PMIP3, however, no significant correlation is found, possibly due to the new processes in the models introducing different behaviours in different models at the LGM (Hopcroft and Valdes, 2015). For PMIP3 we additionally have an ensemble of mid-Pliocene runs (PlioMIP). We observe a correlation in the ensemble between their tropical temperature anomalies at the mid-Pliocene and their equilibrium sensitivities. If the real world fits this relationship, then the reconstructed tropical temperature anomaly at the mPWP can in principle generate a constraint on the true sensitivity. Directly applying this methodology using available data yields a range for the equilibrium sensitivity of 1.9–3.7C, but there are considerable additional uncertainties surrounding the analysis which are not included in this estimate (Hargreaves and Annan, 2016). In terms of this type of analyses, there is much to look forward to in the forthcoming PMIP4 runs: full complexity models will be integrated for the Pliocene experiment, which has been modified to more clearly represent a specific climate time slice, and there is the potential for combining estimates from both LGM and the Pliocene as the same models will (hopefully!) be used for both intervals. Hargreaves, J. C., Annan, J. D., Yoshimori, M., & Abe-Ouchi, A. (2012). Can the Last Glacial Maximum constrain climate sensitivity? Geophysical Research Letters, 39(24), L24702. http://doi.org/10.1029/2012GL053872 Hopcroft, P. O., & Valdes, P. J. (2015). How well do simulated last glacial maximum tropical temperatures constrain equilibrium climate sensitivity? Geophysical Research Letters, 42(13), 5533–5539. http://doi.org/10.1002/2015GL064903 Hargreaves, J. C., & Annan, J. D. (2016). Could the Pliocene constrain the equilibrium climate sensitivity? Climate of the Past, 12(8), 1591–1599. http://doi.org/10.5194/cp-12-1591-2016

Exploiting water isotopes for an improved modelling of past climate changes

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Atmospheric and oceanic general circulation models (GCMs) enhanced by the capability to explicitly simulate the hydrological cycle of the two stable water isotopes H218O and HDO can provide an improved understanding regarding changes of the water isotope signals in various paleoclimate archives. However, so far the number of fully coupled atmosphere-ocean GCMs with explicit water isotope diagnostics is very limited. Such coupled models are required for a more comprehensive simulation of both past climates as well as related isotope changes in the Earth's hydrological cycle. Here, we report results of a set of paleoclimate simulations performed with the ECHAM5/MPI-OM model, enhanced by explicit water isotope diagnostics. The set of simulations include the PMIP target periods of the Last Millennium, the Mid-Holocene, the Last Glacial Maximum, the Last Interglacial, as well as a series of freshwater hosing experiments, mimicking past Heinrich events. In our model analyses we focus on the relation between spatial and temporal changes of water isotopes and key climate variables, e.g. land and ocean surface temperatures, precipitation amounts, and oceanic salinity. First results indicate that the spatial relation between the isotopic composition of precipitation and surface temperatures in mid- to high-latitudinal regions has remained rather constant over time, while temporal isotope-temperature relations have varied more strongly. Based on these analyses we explore how the explicit simulation of water isotopes within GCMs may contribute to an improved data-model comparison and understanding of past climate changes within the future framework of PMIP.

A Spatial And Temporal Distribution Study Of ?13CDIC and ?18Ow In The Baltic Sea – Skagerrak Region

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
We documented the annual cycle of the stable carbon isotopic composition of dissolved inorganic carbon (?13CDIC) and the stable oxygen isotopic composition (?18Ow) in the water columns of the Skagerrak and Baltic Sea and two fjords on the Swedish west coast. The aim was to quantify the isotopic variability and provide more precise palaeoceanographic reconstructions in shelf seas. This is the first study from the region where both ?18Ow and ?13CDIC were measured concurrently, together with hydrographic and nutrient variables, from the same water samples. The lowest ?13CDIC values (-4.9 ‰) were found in the low-oxygen, brackish Baltic bottom water whereas the highest values (+1.8 ‰) were observed in the surface water of the Skagerrak during late summer. Photosynthesis drove the high ?13CDIC values (between 1.0 and 1.8‰) noted in the surface waters of both the Skagerrak and the Baltic. The ?13CDIC values below the halocline in the Baltic reflect mixing of brackish water and the more saline water from the Skagerrak, and foremost organic matter remineralization processes that release significant amounts of low-?13C CO2. Similarly, in the stagnant fjord basins, little deep water exchange and the degradation of terrestrial and marine organic matter set the ?13C composition. Deep-water renewal in the fjord basins resulted in rapid increases of the ?13CDIC on the order of 1‰, whereas remineralization processes caused a decrease in ?13CDIC of 0.1 – 0.3 ‰ per month depending on location. The combined effects of water mixing and remineralization processes (estimated using apparent oxygen utilization (AOU) values) yielded the expression: ?13CDIC =0.032*S-0.01*AOU-0.12 for the Baltic – Skagerrak region at water depths below the halocline. The ?18Ow samples the Skagerrak surface water ranged between -0.41 and 0.31‰ and displayed larger monthly variability than the Baltic surface water, which varied between -7.09 and -6.61‰ (depending on site). The very large fresh water supply to the Baltic Sea results in the low ?18Ow values. The maximum in ?18Ow (0.43‰) was noted in the Skagerrak. A mixing line was established for the region (salinity: 6-35): ?18Ow = 0.253*S-8.59 (N=263).

Tropical Pacific Variability in the Isotope-Enabled CESM

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
Author: Samantha Stevenson / samantha@ucar.edu / National Center for Atmospheric Research
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Esther Brady, National Center for Atmospheric Research;
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Abstract:
The response of climate variability in the tropical Pacific (i.e. the El Nino/Southern Oscillation, or ENSO) to external forcing is a major outstanding question. Since the instrumental record is too short to mitigate internal ENSO variability, observational targets often include multi-century oxygen isotopic records from tropical corals. However, model/proxy comparison is complicated by the fact that most climate models do not directly simulate seawater oxygen isotopic composition. Here we present first results from the newly completed Last Millennium simulation with the isotope-enabled Community Earth System Model (CESM), covering the 850-2005 period with all anthropogenic and natural forcings included. CESM simulates ENSO variability quite well, albeit with an amplitude stronger than observed, and this simulation constitutes an isotope-enabled complement to the CESM Last Millennium Ensemble (LME). The structure of seawater oxygen isotopic signals (seawater d18O) associated with ENSO variability is investigated, and compared with forward-modeled coral d18O patterns which include the effects of temperature. Unforced ENSO variability appears to dominate over much of the past millennium, but effects from volcanic eruptions and greenhouse gas forcing do appear to be detectable in some circumstances. The implications for evaluating the fidelity of Last Millennium model simulations using coral proxy records are discussed.

I am a project scientist working in Bette Otto-Bliesner's group at NCAR (ottobli@ucar.edu).

Quantitative model-data comparisons of lake level change in western North America during the Last Glacial Maximum

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

Lake level information has long offered a critical qualitative model-data comparison for past moisture conditions. We extend this comparison quantitatively, using output from coupled climate models participating in the Coupled Model Intercomparison Project (CMIP5) and forward models of lake and drainage basin water balance to simulate Last Glacial Maximum (LGM) lake levels in nine drainage basins in western North America. During the last glacial and early deglacial periods, large lakes expanded in many drainage basins across this currently-arid region. The high concentration of well-dated shoreline records here make quantitative model-data comparison feasible. The CMIP5 models achieve varying degrees of success in driving the forward models to match observed LGM lake level changes, as measured in both data and models by the ratio of lake area to drainage basin area. Those models that successfully match observations are distinguished by large decreases in lake evaporation and basin evapotranspiration at LGM due to cooling, and also yield the greatest temperature increases in future climate projections. Our results establish the important role of temperature in determining past moisture conditions over western North America and support the strong likelihood of drying in the future.

Benchmark patterns of hydroclimate change in North America since the LGM indicated by an updated lake level database

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
Changes in the water level of lakes have long provided evidence of past climate changes. Evidence of high pluvial lakes in western North America, for example, have been a key benchmark of late-Pleistocene paleoclimates for over a century. More recent work has also reconstructed changes in the surface elevations of many small lakes in humid portions of North America. Taken together, the reconstructions document the patterns of broad hydroclimate changes. A new database of data from 191 lakes across extratropical North America reveals a series of major changes that have affected the continent over the past 21,000 years. For each lake, the database includes a time series of measured or relative shoreline elevations with their measured or estimated age (e.g., the elevations of raised shorelines and their associated constraining calibrated radiocarbon ages). Histograms of the ages of all individual lake stages in the database show that more lakes than expected from chance alone reached new stages at 0.6, 2.5, 4.7, 5.5, 8.2, 10.8 ka and the beginning and end of the Younger Dryas chronozone. The clusters of ages indicate that rapid climate changes likely modified long time transgressive trends in North American hydrology. Maps document six major patterns that emerged from the combination of long-term and abrupt events: 1) following the LGM, pluvial lakes in western North America were high; 2) from 18-14 ka, the western lakes widely declined; 3) from 14-10 ka, lakes in both western and eastern North America fell as those in the mid-continent rose; 4) from 10-7 ka, southwestern lakes declined as lakes in western Canada and eastern North America rose; 5) from 5.75-5.0 ka, many lakes rapidly reversed the previous pattern; and 6) since 5 ka, most lakes trended toward their current levels. Histograms of the number of low lakes per millennium in different sub-regions of the continent show that the dominant trends may be attributable to the changing effects of the Laurentide ice sheet and seasonal insolation anomalies, but more work is need to understand episodes of rapid modification of these trends such as at ca. 5.5 ka.

How well do benthic-planktonic radiocarbon ages approximate ocean ventilation?

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Eric Delhez, Université de Liège, Aerospace and Mechanical Engineering Department, Liège, Belgium;
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Abstract:

The assessment of past ocean ventilation changes most often relies on the difference between radiocarbon ages of co-existing benthic and planktonic species (BP ages). However, several factors limit the potential of the BP ages method in this purpose. The radiocarbon distribution in the ocean results from the complex interplay between air-sea exchange, and transit pathways and rates to the ocean interior. An additional difficulty stems from varying atmospheric 14C levels over the last 40 ka. Here we examine the sensitivity of BP ages to these processes by means of experiments with 3-D OGCMs. Significant departures of the BP ages from the actual ventilation timescales (up to several hundred years) are observed., Most significantly, BP age biases, that is the difference between radiocarbon and ventilation BP ages, are far from uniform. They exhibit marked vertical and horizontal structures, even when homogeneous air-sea exchange rate is prescribed. The response of BP ages to evolving atmospheric radiocarbon levels also exhibit significant temporal and spatial variability. With the help of idealized age tracers whose properties are established in the framework of The Constituent-oriented Age and Residence time Theory (CART, www.climate.be/cart) we investigate the reasons for such significant departures. As air-sea exchange rate decreases, contributions from distant ocean regions to the local tracer age increase. This behavior explains most of the departure between the actual ventilation timescale and the apparent ventilation age derived from BP radiocarbon ages. It also appears that heterogeneity in the air-sea exchange rate only plays a secondary role in setting BP age biases.

Insights into regional patterns of climate change in the past from the comparison of clumped isotope thermometry with model simulations

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
The emergence of novel proxies enables us to develop new types of observational benchmarks and address fundamental questions about Earth's climate evolution. This presentation will discuss applications of a geothermometer that is based on the abundance of 13C-18O bonds in carbonates. We will present examples of how we are using this approach to study ocean and terrestrial temperatures and water 18O/16O ratios over timescales ranging from the Last Glacial Maximum to the early Cenozoic. We will show how we are using this approach to identify possible biases in existing reconstructions from other proxies, such as those arising from diagenesis, or from seawater Mg/Ca ratios. Finally, we will describe how we are comparing paleoclimate reconstructions using this method with results from PMIP simulations in order to probe paleoclimate dynamics.

The HORNET Project: A gridded seasonal climate reconstruction for the Northern Hemisphere extra-tropics over the last 12,000 years based on pollen-data

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:

One key aspect to understanding current data-model discrepancies during the Holocene, and for earlier time periods, is the role of atmospheric dynamics. This requires spatially and seasonally resolved reconstructions of past climate at large enough spatial scales to reveal the impact of changes in the strength and direction of the atmospheric circulation on the pattern of surface climate anomalies. The HORNET project is currently fulfilling this aim by utilizing over 3000 pollen records from across the Northern Hemisphere extra-tropics to produce a gridded record of summer and winter climate for the entire Holocene based on a standardized reconstruction and error-accounting methodology. This new reconstruction provides a basis for benchmarking both equilibrium and transient model simulations of Holocene climate, including the ability of models to reproduce the changing seasonal and spatial distribution of surface heat and moisture during Interglacial warming.

Particle filter simulations: the transition into the Anthropocene

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
Large-scale circulation patterns have been shown to have a major influence on regional and global climate on all time-scales. Here we investigate the effect of three of the most important climate modes, the El Niño-Southern Oscillation (ENSO), Southern Annular Mode (SAM) and Northern Atlantic Oscillation (NAO), on decadal-scale variability. We begin our simulations in 1780, driving the HadCM3 model using a particle filter technique so that it matches the observed states of our modes of interest. By comparing the simulated climate produced with that from a free-running ensemble (run using identical boundary conditions) the impact of ensuring that the large scale circulation states are the same as that observed can be determined.

Understanding the temporal slope of the temperature-waterisotope relation: The slope equation

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
The temporal (Dansgaard) slope relates the temperature in clouds to the 18O of precipitation 18O. In paleoclimate, the temporal slope is the critical benchmark to convert precipitation 18O to surface temperature. Previous studies have used various approaches to approximate the temporal slope, most important are two empirical approaches, one using the present day spatial slope and the other using independent borehole temperature for calibration. In these two approaches, the latter scale gives ~0.3‰°C, about half that of the former. Boyle gave an explanation why the borehole temperature slope is smaller than the spatial slope, but in a loose way. Here, we present a semi-empirical theory that relates the spatial slope with the temporal slope. We studied the relation between temporal and spatial slopes for the middle and high latitudes in a series of simulations in the isotope-enabled atmospheric model isoCAM3 for the last 21,000 years. Our model simulation suggests that both the temporal slope and spatial slope remain largely stable throughout the last deglaciation. The temporal slope can vary substantially across regions. Nevertheless, on average, and most likely, the temporal slope is about 0.3‰°C and is about half of the spatial slope. Furthermore, the relation between temporal and spatial slopes is understood using a semi-theoretical equation that is derived based on two assumptions: the Rayleigh distillation relation and a fixed spatial slope with time. The slope equation quantifies the Boyle's mechanism and suggests that the temporal slope is usually smaller than the spatial slope in the extratropics mainly because of the polar amplification feature in global climate change. Our theory is further supported by tagging experiments in isotope-enabled models. Guan, J., Z. Liu, X. Wen, E. Brady, D. Noone, J. Zhu, and J. Han (2016), Understanding the temporal slope of the temperature-water isotope relation during the deglaciation using isoCAM3: The slope equation, J. Geophys. Res. Atmos., 121, doi:10.1002/2016JD024955.

Comparing a high spatial/temporal resolution rainfall proxy dataset from southern Africa with a last millennium simulation

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)

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Abstract:
Edaphic soil moisture potential is the main determinant of leaf-level carbon isotope discrimination in savanna trees of southern Africa, and a proxy rainfall record can be obtained from radial (time series) analysis of carbon isotope ratios in trees in the region. The approach has been tested in baobab trees (Adansonia digitata, A. za, and A. grandidieri), Black Monkey Thorn (Acacia burkei) and Camelthorn (Acacia erioloba) trees. This diversity of species allows the proxy to be applied across a range of xeric conditions from the arid Namib Desert in the west, through the Kalahari Desert to Madagascar. In the mesic regions a record has been generated from Yellowwood (Afrocarpus falcatus) trees. The lack of annual rings in the stems of most of these tree species makes it necessary to generate age models using radiocarbon dates which introduces a degree of error in the age assigned to each sample. In general the sampling resolution is sub-annual, but the age error only allows decadal to centennial trends to be inferred. The outcome is a time/space matrix of rainfall variability in the region over the last 1000 years. For each sample site a composite record is generated from multiple trees. Comparison between the carbon isotope ratio proxy and the short, patchy coverage with instrumental records provides strong support for the authenticity of the proxy record. The tree record indicates synoptic scale variability in response to climate forcing. In some instances the rainfall anomalies have the same sign across the entire region, and in others there is a clear dipole response with opposite sign anomalies in different regions. The underlying forcing is attributed to north/south and east/west displacement of the main rainfall systems. These dynamics provide a tangible basis for testing model climate simulations. The EC-Earth last millennium simulation of these displacements in response to the inferred climate forcing well matches the pattern observed in the tree records. The result suggests that future climate change scenarios for southern Africa are accurately captured in the climate simulation models.

Is a cold planet Earth's climate more sensitive to volcanic forcing than a warm one?

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Abstract:
The paleoclimate record is crucial to establish the role of natural forcing in generating climate variability in states that are very different from today. It is clear that small and large volcanic eruptions occurred throughout the last Glacial cycle and the Holocene, although possibly at a lower rate than during the last millennium. Yet, most climate model experiments for these periods are performed with constant solar and no volcanic forcing. This biases model estimates in model-data comparisons for past climate variability. Here we present first results from an ensemble of long (>1000a) paleoclimate model experiments. Simulations for the Last Glacial Maximum, the mid-Holocene, the Preindustrial and the past millennium were performed under PMIP3 boundary conditions, and with/without solar variability and volcanic forcing. We evaluate, to what extent regional and global climate impacts of this natural forcing is dependent on the mean climate state. As the model includes water isotope diagnostics, we further determine to what extent the variability is consistent with the paleoclimate proxy evidence from ice cores.

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Process oriented analyses to better infer precipitation changes in West Africa

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:

The representation of future precipitation changes in West Africa show little agreement between model simulations. In addition, PMIP mid-Holocene simulation underestimate the northward extend of the monsoon rain. Here we propose a convective regime sorted analyses to estimate the relative part of the changes in boreal summer precipitation resulting from changes in large scale pattern or more local thermodynamically factors. For this we consider three periods: Last Glacial Maximum (LGM), mid-Holocene (MH) and abrupt4xCO2 (4X). The first part of the analyses shows that there is more analogy between model results when using this classification, compared to ensemble model mean. It tells us that part of the model spread in the change in total precipitation results from differences in the relative effect of large scale versus more local thermodynamics. Model agreement is however dependent on the analyses period, the largest agreement being found for the changes in the distribution of the convective regimes. In order to show detailed regional changes in WAM precipitation, an attempt is made to modify the precipitation regime of the ERA-interim reanalysis data by the changes of regimes from model results, and to apply a correction on precipitation that takes into account the information gained from the distribution and the efficiency of precipitation of the different convective regimes. For 4X and LGM it is however difficult fully assess regional changes given the regional spread of the results.

Comparing simulations of last millennium AMOC with reconstructions

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
Author: Chris Brierley / c.brierley@ucl.ac.uk / University College London
Co-author: David Thornalley, University College London;
Abstract:
The Atlantic meridional overturning circulation has large amplitude variations on decadal timescales. Although models show this variability, a quantitative evaluation of it is hard because of a lack of observational records. Recent developments in paleoceanography now allow us to estimate the temporal behaviour of the AMOC over the last millennium. Here we will present three recent reconstructions (Rahmstorf et al, 2015; Thornalley et al, submitted). Here these are compared with the output of the PMIP3 past1000 simulations and the CESM last millennium ensemble. We explore the relevant approaches to perform such a data-model comparison. From a logistical viewpoint, this analysis will highlight the importance of both extending the past1000 simulations through the historical period and uploading the msftmyz diagnostic to the Earth System Grid.

The PMIP Paleovariability Working Group and NCAR's Climate Variability Diagnostics Package

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The Paleovariability working group aims to foster and facilitate research into looking at how climate variability changed in the past. The majority of its focus so far has been on ENSO. Partly this is due to ENSO's global dominance at interannual timescales. But we feel that this is also partly down to the effort required to download and compute standard climate variability indices from the PMIP simulations. However substantial effort has recently been expended in developing a software stack to automate Earth System Model validation (ESMval; Eyring et al, 2015). Like PMIP's own benchmarking activity, this has predominantly been focused on analysing the mean state of the climate. Nonetheless, significant progress has been made towards the standardised and routine calculation of multiple modes of climate variability (Phillips et al, 2014). On behalf of the Paleovariability working group, University College London is undertaking the computation of these modes and diagnostics. The intention of this effort is to (a) provide a first look at variability in PMIP4 (b) permit quick assessment of the potential of future research studies (c) provide pre-computed time series/patterns to allow studies to compare to climate variability, without needing to the download simulation data itself. Here we would like to demonstrate the utility of this effort, by showing results of the diagnostic package from PMIP3 simulations.

East Asian summer monsoon dynamics in the past and future warmer climates: mid-Pliocene and RCP4.5 scenario comparison perspective

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:

In this study, moisture budget analysis and moist static energy (MSE) are applied to investigate the drivers and mechanisms of East Asian summer monsoon (EASM) precipitation in the mid-Pliocene and RCP4.5 scenario. The enhancement of EASM precipitation is a common feature in both warmer climates. By diagnosing moisture budget analysis, it was found that thermodynamic component contributes more than dynamical contribution to EASM precipitation in both warmer climates, which essentially represents the increasing response of EASM precipitation to the past and future warming. MSE is used to reveal the dynamical mechanism responsible for the EASM precipitation enhancement. One mechanism identified by MSE is zonal thermal contrast enhancement and the other is stationary meridional velocity. The former can affect EASM precipitation via strengthening of large-scale circulation associated moisture transport into EASM domain. while the latter can exert EASM precipitation through modulating the local physical processes associated with moisture convergence in mid-Pliocene and divergence in RCP4.5 scenario, which is possible reason to explain why projected EASM precipitation with higher than mid-Pliocene CO2 level but precipitation increase less than mid-Pliocene. Nevertheless, mid-Pliocene offers an analogue to understand the EASM dynamics in the future scenario.

Yong Sun 1. Institute of Atmospheric Physics, Chinese Academy of Sciences 2. Laboratoire des Sciences du Climat et de l'Environnement, France Education Background: 09.2005 – 07.2009 Atmospheric science, Yunnan University, Bachelor 09.2009 – 07.2014 meteorology, university of Chinese Academy of Sciences, PhD 04.2012– 03.2013 exchange PhD student, Laboratoire des Sciences du Climat et de l'Environnement, supervisor: Gilles Ramstein Work Experience: 07.2014 – research associate, LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, Supervisor Tianjun Zhou 09.2016 –09.2018 Postdoctoral researcher, Laboratoire des Sciences du Climat et de l'Environnement, France, Supervisor Gilles Ramstein Research interested areas: Tropical dynamics and Paleo-monsoon dynamics during past and future warmer climates Publication: 1. Sun Y., G. Ramstein, Laurent Z. X. Li, T. Zhou, N. Tan, S. Y. Wang and M. Kageyama 2017: Regional meridonal cells governing the interannual variability of Hadley circulation in boreal winter. Climate Dynamics (under review) 2. Sun Y., T. Zhou, G. Ramstein, C. Contoux and Z. Zhang, 2016: Drivers and mechanisms for enhanced summer monsoon precipitation over East Asia during the mid-Pliocene in the IPSL-CM5A. Climate Dynamics, 46,1437-1457 DOI: 10.1007/s00382-015-2656-4 3. Sun Y. and T. Zhou, 2014: How Does El Niño Affect the Interannual Variability of the Boreal Summer Hadley Circulation?. J.Climate, 27, 2622–2642. 4. Sun Y., G. Ramstein, C. Contoux, and T. Zhou, 2013: A comparative study of large-scale atmospheric circulation in the context of a future scenario (RCP4.5) and past warmth (mid-Pliocene), Clim. Past, 9, 1613-1627, doi:10.5194/cp-9-1613-2013. 5. Sun Y., T. Zhou, and L. Zhang,

2012: Observational analysis and numerical simulation of the interannual variability of the boreal winter Hadley circulation over the recent 30 years. Sci China Earth Sci, 55, 1–15, doi: 10.1007/s11430-012-4497-x.

A comparison of the Arctic warming mechanism between the mid-Holocene and the future

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:

There remain substantial uncertainties in the future projections of Arctic climate change. Schmidt et al. (2013) advocated potential of constraining the uncertainties by making use of both paleoclimate simulations and archives. Indeed, they found a statistical correlation in sea ice changes between the mid-Holocene (MH) and the future with respect to the modern period. It was unclear, however, why such a relation emerges and what the mechanism behind the relation is. We conducted a surface energy balance analysis on 10 CMIP5/PMIP3 atmosphere-ocean general circulation models for climate changes under MH forcing and future RCP4.5 scenario forcing. We found that many common dominant processes that amplify the Arctic warming from late autumn to winter exist between the two periods, despite of the completely different external forcing (insolation vs. GHGs). We also quantified the contribution of individual processes to the inter-model variance of the surface temperature changes. The controlling term varies with seasons, and the details will be presented. Based on the understanding of Arctic warming mechanism from this study, we conclude that paleo-archive recording the Arctic warming at the MH must contain the useful information relevant to the future Arctic climate change.

large-scale Climate And VegetatIon Changes OveR the last Deglaciation (CLAVICHORD)

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The last deglaciation (from 21,000 to 9,000 years ago), during which the huge ice sheets over the North America and Scandinavia melted, is a period of tremendous climate and environmental changes. These changes are documented by physically based paleoenvironmental indicators (such as oxygen or carbon isotopes in ice cores and marine cores) and by biologically based data (such as paleo-vegetation). This study aims, for this period of the last deglaciation, at 1) building a comprehensive documentation of climate changes over terrestrial areas from widely available pollen data, 2) assessing the impact of both climate and atmospheric CO_2 changes on vegetation change, and 3) investigating the changes in large-scale atmosphere circulation and the hydrological cycle responsible for these surface climate and vegetation changes. This study will provide new benchmarking data for understanding environmental changes and evaluating climate models that are used for climate projections. Then, these results will contribute to quantifying the range of possible changes in these circulations in the future. Here, we develop pollen/biome-based global climate reconstructions with an inverse (equilibrium) vegetation modeling approach over the last deglaciation. The approach is implemented by searching for a set of climate values which, when input to a vegetation model, simulates vegetation that is consistent with the paleovegetation reconstructed from fossil pollen data. The approach allows us to avoid both no-analog and wrong-analog problems and to assess the potential bias in reconstructions that may result from varying atmospheric CO_2 concentrations.

Reconstructing the East African rainfall and Indian Ocean sea surface temperatures over the last centuries using data assimilation

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:
The relationship between the East African rainfall and Indian Ocean sea-surface temperatures (SSTs) is well established. The potential interest of this covariance to improve reconstructions of both variables over the last centuries is examined here. This is achieved through an off-line method of data assimilation based on a particle filter, using hydroclimate-related records at four East African sites (Lake Naivasha, Lake Challa, Lake Malawi and Lake Masoko) and SSTs-related records at 12 oceanic sites spread over the Indian Ocean to constrain the Last Millennium Ensemble of simulations performed by CESM1. Skillful reconstructions of the Indian SSTs and of the East African rainfall can be obtained based on the assimilation of only one of these variables, when assimilating pseudo-proxy data deduced from the model CESM1. The skill of these reconstructions increases with the number of particles selected in the particle filter, although the improvement becomes modest beyond 99 particles. When considering a more realistic framework, the skill of the reconstructions is strongly deteriorated because of the model biases and the uncertainties of the real proxy-based reconstructions. However, it is still possible to obtain a skillful reconstruction of the whole Indian Ocean SSTs based only on the assimilation of the the 12 SST-related proxy records selected, as far as a local calibration is applied at all individual sites. This underlines once more the critical role of an adequate integration of the signal inferred from proxy records into the climate models for reconstructions based on data assimilation.

Orbital modulation of ENSO seasonal phase locking

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
Modern El Niño-Southern Oscillation (ENSO) events are characterized by their phase locking of variability to the seasonal cycle and tend to peak at the end of calendar year. However, in an idealized CCSM3 simulation of the climate of the last 300 thousand years, ENSO seasonal phase locking is shifted periodically following the precessional forcing: ENSO tends to peak in boreal winter when perihelion is near vernal equinox, but peak in boreal summer when perihelion ranges between autumnal equinox and winter solstice. The mechanism for the change of ENSO's phase locking is proposed to be caused by the change of seasonality of the growth rate, or the intensity of ocean-atmosphere feedbacks, of ENSO. It is found that the December peak of 'winter ENSO' is caused by the continuous growth of ENSO anomaly from June to November, while the June peak of 'summer ENSO' appears to be caused jointly by the seasonal shift of positive growth rate in spring and relatively stronger stochastic noise in the first half of the year. Furthermore, the change of the seasonal cycle of feedbacks is contributed predominantly by that of the Ekman upwelling feedback (EK) with the thermodynamic damping playing a secondary role. The summer peak of ENSO is proposed to be caused by the following mechanism. A perihelion in the late fall to early winter forces spring cooling of SST in the eastern equatorial Pacific (EEP) due to reduced insolation, which, reinforced by an oceanic process, leads to weakened thermodynamic damping. The EEP thus becomes more sensitive and favors the growth of the eastern Pacific-like ENSO (opposing to the central Pacific-like ENSO). This generates more uniform basin-wide wind response (quantified as a component of EK), in turn, increased instability in spring, ultimately benefiting the subsequent summer ENSO peak.

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The calendar effect in PMIP4 time-slice and transient simulations: overall impact and strategies for data analysis

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The “calendar effect” is the common expression for the impact that the known changes in the length of months or seasons over time, related to changes in the eccentricity of Earth’s orbit and precession, have on summarization of model output. Even if daily data are available, the calendar effect must still be considered when summarizing data by months or seasons, or when calculating climatic indices such as the temperature of the warmest or coldest month—values that are required for comparisons with paleoclimatic observations. The impact arises not only from the changing length of months or seasons, but more importantly, from advancement or delay in the starting and ending dates of months or seasons relative to the solstices. The impact of the calendar effect is large and spatially variable, and can produce apparent spatial patterns that might otherwise be interpreted as evidence of, for example, high-latitude amplification of temperature changes, continental/marine temperature contrasts, or variations in strength of the global monsoon. Calendar effects must also be considered in the analysis of transient climate-model simulations (even if data are available on the daily time step). Time series of data aggregated using a fixed modern calendar as opposed to an appropriately changing one can differ not only in the shape of long-term trends, but also in the timing of Holocene “thermal maxima” by several thousand years, depending on the time of year. There are a number of approaches for adjusting monthly data that were averaged using present-day calendar definitions to a “paleo calendar”. A simple one involves a) determining the appropriate fixed-angular month lengths for a paleo experiment (e.g., Kutzbach and Gallimore, 1988, JGR 98:803-821), b) interpolating the data to a daily time step using a mean-preserving interpolation method (e.g., Epstein, 1991, J. Climate 4:365-368) or using archived daily data directly, and then c) averaging or accumulating the interpolated daily data using the appropriate paleo month starting and ending days (i.e., month lengths). We present examples of the calendar effect and discuss their implications for interpretation of paleoclimate data.

PaCMEDy - Palaeoclimate Constraints on Monsoon Evolution and Dynamics

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:
PaCMEDy aims to identify emerging constraints on monsoon evolution and dynamics, linking modelling of past climates to future projections. The evaluation of the variability and the strength of monsoons in palaeoclimate simulations through past records provides the opportunity to assess the credibility of future climate projections. The project will use annually-resolved palaeoenvironmental records of past 6000 years from corals, molluscs, speleothems and tree rings, together with global climate-model transient (from mid-to-late Holocene) and high resolution simulations of Indian, African and South-American monsoons to provide a better understanding of the monsoon dynamics. The project will also use forward models, including models of terrestrial productivity, tree growth and speleothem development to relate simulated climate changes more directly to observations. PaCMEDy is organised around four themes: (1) the impact of external forcing and extratropical climates on intertropical convergence and the hydrological cycle in the tropics; (2) characterization of interannual to multidecadal monsoon variability to determine the extent to which the stochastic component is modulated by external forcing or changes in mean climate; (3) the influence of local (vegetation, dust) and remote factors on the duration, intensity and pattern of the Indian, African and South American monsoons; and (4) the identification of paleo-constraints that can be used to assess the reliability of future monsoon evolution. The poster will present the objectives of the project and a synthesis of the results obtained during the first year.

The role of vegetation change upon polar amplification in warm climate by feedback analysis

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:

Past warm periods are induced by both higher atmospheric CO2 concentration and the change of Earth’s orbit through different temporal and spatial pattern of downward shortwave radiation. Previous studies revealed that vegetation change in high latitude (e.g. from tundra to forest) in warm climate strengthens a polar amplification. This is due to lower vegetation albedo of forest than tundra, snow-albedo feedback caused by early snow melt due to forest coverage and ocean heat release in autumn and winter. To reveal the mechanisms of orbit-induced warming case (6ka) and CO2-induced warming cases (2xCO2 and 4xCO2), we apply a feedback analysis method (Yoshimori et al. 2014) on several climate simulations by a GCM with vegetation feedback. We also discuss the difference of feedback mechanisms in the orbit induced case and CO2-induced case, especially focusing on interseasonal warming mechanisms caused by vegetation feedback in the high latitude and its contribution to the polar amplification.

Proxy system modeling and data assimilation in paleoclimatology

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
Optimally using data assimilation techniques to combine paleoclimate observations and model results requires addressing several challenges. First, the variables measured in environmental archives collected in the field (such as tree ring width or pollen assemblage) are often not directly simulated by climate or Earth system models and may be a complex and nonlinear function of several environmental factors. An objective comparison between the measured variables and simulation results may be improved by modeling the mechanisms by which a paleoclimatic archive is imprinted with an environmental signal, i.e., by using a “proxy system model”. Second, specific data assimilation techniques are needed to handle sparse data, represent temporal averaging, spatial downscaling and chronological uncertainty. In this framework, the goal of the new PAGES working group on Data Assimilation and Proxy System modeling (DAPS; http://pastglobalchanges.org/ini/wg/daps/intro) is to stimulate the application of proxy system models and data assimilation in paleoclimatology. Among the initiatives proposed at the first DAPS meeting in Louvain la Neuve, Belgium, were “proxy system model intercomparison projects” for important paleoclimatic archives and observations, which will lead to improved assessments of proxy system model uncertainty; and application of data assimilation methods to construct a last century product, whose skill and error characteristics may be examined relative to historical and modern reanalyses within the data assimilation framework. These efforts will benefit from close collaboration with the PMIP4 initiative.

WCRP Assessment on Climate Sensitivity - the paleo angle.

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The aims of the WCRP Assessment on Climate Sensitivity are: to make a thorough assessment of climate sensitivity; to clarify the nature and limitations of key evidence; to assess the likelihood of very low or high climate sensitivity and provide robust 5-95% confidence ranges for it; and to highlight future research directions most likely to yield stronger constraints. Towards these goals, a review paper is currently in progress, to be submitted for publication in 2018. As part of this we hope to make available some simple code to allow the community to reproduce, test and build on the results. There are three groups involved, focussing on: process modelling/present day constraints; the Historical Record; and the Paleoclimate Record; plus a subgroup focussing on synthesising the different lines of evidence. Here we will overview progress to date, particularly highlighting the constraints on climate sensitivity from the paleoclimate record.

The PMIP Past to Future (P2F) Working Group

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The Past to Future working group provides a focus for scientists interested in using paleoclimate information to improve predictions of climate change. The group website (https://wiki.lsce.ipsl.fr/pmip3/doku.php/pmip3:wg:p2f:index) contains information for those interested in learning about this area of research, with an outline of common methodologies, suggested targets for research, information on how to find model output and paleoclimate observations, and summaries of relevant papers over recent years. There is also a subgroup focussed on the Last Glacial Maximum which aims to keep track of model experiments which segregate the different forcings for that climate interval, with the aim of diagnosing the effect of the different feedbacks. As well as overviewing these activities, we will show some highlights of recent research in the P2F area.

Assessing reconstructions of temperature changes over the past millennium in Antarctica using pseudo-proxy experiments and data assimilation

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Barbara Stenni, Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Italy;
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Abstract:

Reconstructions of temperature changes in Antarctica over the past millennia are still relatively uncertain. This can have several origins: 1) The number of high resolution ice cores is small, in particular on the Antarctic Plateau; 2) The instrumental records are too short to adequately calibrate the reconstructions and test the methodologies; 3) The link between isotope records measured in the ice core and local climate are usually complex and dependent on the spatial and time scales investigated. In order to estimate the potential biases of the standard reconstruction methods, their skills are first assessed in a pseudo-proxy framework. To do so, the surface temperature and stable oxygen isotopes results of a long simulation of an isotope-enabled model are sampled at the same temporal and spatial resolution as the real data synthesized by the working group Antarctica2K. This provides temperature series covering the last decades corresponding to instrumental data and isotopes values over the last centuries at the locations where ice core data are available. Those pseudo-data are used to make reconstructions of temperature over the last millennium using standard statistical methods that can then be compared to the simulated temperature to evaluate the performance of each of these methods. In a second step, using the same pseudo-proxy framework, a data assimilation method based on a particle filtering is applied and the resulting reconstructions of temperature changes are compared to the ones of the statistical methods. Finally, the data assimilation implementation method tested and improved in this idealized framework is applied to the real data and the results compared to available reconstructions based on statistical methods.

Experiments for ensemble-based joint state-parameter estimation in past climate reconstructions

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
Within model-data comparison under a data assimilation (DA) perspective in paleoclimate we may have two main objectives: a) to conduct climate field reconstructions (CFR), and b) to constrain (or calibrate) the model parameters with the alternative/additional goal of improving model projections of future climates. One can well approach the problem of CFR for past climates without explicitly accounting for parameter estimation, and in fact this has allowed the use of the so-called offline (possibly multi-model) DA approaches for CFR in recent studies. However, in general, for long-term past climate reanalyses, inaccurate parameters in the climate model have a predominant role in the growth of prediction errors. Although DA is most often used for state estimation, combining observational data with model predictions to produce an updated model state that most accurately approximates the true system state whilst keeping the model parameters fixed, it is also possible to use DA techniques for the joint state-parameter estimation problem. Unfortunately, it is not possible, in general, to use offline approaches for this, as the background ensemble has not been explicitly designed with the joint estimation problem in mind. This leads to the problem that one needs to resort to new paleo-simulations if we want to attempt both (a,b) goals, with the attached computing cost. Here we explore some ensemble strategies for the joint state-parameter estimation problem with a synthetic study using the global Community Earth System Model (CESM v2.1) and MARGO-like sparse pseudo-proxy SST observations.

Improving coupled vegetation dynamics in an Earth System model with palaeo-environment evaluation

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:
Paleoclimate simulations are usually performed using coupled general circulation models or Earth System models that have released to the academic community. This can often mean that the performance of a given model for a given palaeo-epoch does not have much influence on the development of that model, and does not therefore influence decisions about model structure, parameterisations or tuning. Here we report work on palaeoclimate simulations of the last glacial maximum and mid-Holocene that have been performed in parallel with the development of the United Kingdom Earth System Model (UKESM). This model will form a major part of the UK's contribution to CMIP6 and is being developed jointly by the UK Met Office and UK academic community. We present the first palaeoclimate simulations with the UK Met Office's Global Atmosphere model version 7 (GA7) in an Earth System configuration that includes dynamic vegetation, aerosols and chemistry. GA7 is a 3D semi-Lagrangian, non-hydrostatic, fully compressible general circulation model with a horizontal resolution of 1.875x1.25 degrees and with 85 vertical levels, 35 of which are in the stratosphere. GA7 includes a prognostic rather than diagnostic cloud scheme, and a new dynamical core which has improved the simulation of climate variability. A size-resolving aerosol scheme allows for a more realistic simulation of the indirect aerosol-cloud interactions. The land surface scheme (JULES) uses 9 natural plant functional types and simulates vegetation interactively using an updated version of TRIFFID. In comparison with the most recent pollen-based LGM vegetation reconstructions for northern Eurasia, GA7 significantly overestimates bare soil coverage. Results from a parallel 100-member perturbed parameter ensemble of land surface-only LGM simulations together with a statistical emulator, allow us to identify underlying reasons for this bias and to make suitable parameter changes that lead to improved vegetation coverage, thereby potentially improving the fully coupled Earth System model. Together with previous work using an older version of the UK Met Office Earth System model (HadGEM2-ES), vegetation coverage in mid- to high-latitudes at the LGM appears to provide effective bounds on the temperature dependence of vegetation productivity, and the associated surface feedbacks from snow cover.

Spatial paleoclimate reconstructions using model simulations and proxy data

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
The German research programme “Our way to Europe“ (CRC 806) studies the history of the Modern Man in an interdisciplinary framework by using geoscientific and archaeological methods. One aim of the climatological group is the spatial climate reconstruction for Europe by including all available proxy and model data. This contribution looks at the comparison between model simulations, which are taken from the PMIP3 database, and statistical climate reconstructions based on pollen data. The aim is to optimize the model data by including the probabilistic information of the occurring taxa. This concept will be presented and discussed. For the Mid-Holocene (6 ka BP), especially summer temperatures change clearly when assimilating the PMIP3 multi-model ensemble to the observed pollen data. In this case, the original PMIP3 simulated temperature data are increased through the inclusion of the paleo pollen data. This happens especially over land. The added value can be detected by the predominantly positive Brier skill scores.

Pre-monsoon precipitation inferred from Himalayan Birch from the Central Himalaya

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)
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Abstract:
Based on Himalayan birch collected from the Sagarmtha National park and Langtang National park of central Nepal, we developed 460-year chronology, currently this is the longest chronology of this species from High Asia. Himalayan birch showed strong and direct relationship with spring (March-May) precipitation thus, used to reconstruct spring precipitation back to 1552AD. This is the first precipitation reconstruction using this species. The reconstruction captured 37% of the variance in the calibration model over the period 1960-2009. Reconstruction (2011-1552) shows annual, multiannual to decadal variation. The year 1999, 1813 and 1954 respectively experienced the driest spring where as 1775, 1557 and 1988. The reconstructed series showed AD1811- 1821 and 1995-2005 are the driest decades where as AD 1926-1936 and 1640-1650 the wettest in the whole reconstruction (1552-2011). The most interesting feature of this reconstruction is a decrease in precipitation between 1 to 5 years following the eruption of volcanic eruption depending upon the strength of the volcano. The MTM spectral analysis showed significant spectral peaks at 3.4, 3.6, 3.9, 26.2, 30, 42.7, 53.8 years. The reconstructed precipitation also showed significant correlation with the Kathmandu precipitation and other larger-scale regional indices used to represent the South Asian monsoon rainfall. Thus, the result here indicates a great potential to extend the tree-ring series in length using Himalayan birch that could provide high-resolution palaeoclimatic records that span the last several centuries and fill the gaps from the data scare region of central Himalaya.

Proxy data “Pollen” assimilation to reconstruct climate for Holocene (10kyr BP) in the Euro-Mediterranean region

Session: Cross-cutting Group 2 (Paleovar, Past to future, Data assimilation)

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Abstract:
The Mediterranean area is a hotspot of climatic change and during the Holocene, it has known important climatic changes which has deeply influenced its socio-economic development. We present a new approach to reconstruct these climatic changes, based on an off-line pollen data assimilation in the earth system model. Pollen data have been extracted from the European Pollen Database (286 sites). The earth system model, LOVECLIM, is run to simulate at a annual time-step the last 10kyr Holocene climate with appropriate boundary conditions and realistic forcing. To match data and model simulations, a simple downscaling scheme is used to the 10’ resolution. Simulated climate variables (temperature, precipitation and sunshine) are averaged over an interval of 10 years and are used as the forcing parameters to a vegetation model, BIOME4, that calculates the equilibrium distribution of vegetation types and associated phenological, hydrological and biogeochemical properties. A canonical analysis is applied to optimise the correlation between the pollen aggregated plant functional types (pft) and the model simulated pfts. BIOME4 output, constrained with the pollen observations, are off-line coupled using a particle filter based data assimilation method. The observations are assimilated at every 100 year step using 1000 ensembles at each step. A Bayesian likelihood function provides the best particles taken from the 1000 candidates (10 yr model averages). The results are compared with previous reconstructions and are available for data-model comparison exercises.