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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PMIP4 participants, ;

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.

PhD Supervisor: Terrence M. Quinn (UT Austin; quinn@ig.utexas.edu) Postdoc Supervisor: Pedro N. DiNezio (UT Austin: pdn@ig.utexas.edu)

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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SISAL Working Group Members, ;

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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Modelling isotope-temperature relationships over the last deglaciation

Session: Benchmarking & cross-cutting Group 1 (Isotope modelling, COMPARE)
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Co-author: Louise Sime, British Antarctic Survey;
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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 CO2 and CH4 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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PAGES LandCover6k community, http://www.pages-igbp.org/ini/wg/landcover6k/people;

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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Iso2k Project Members, ;

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)
Author: Julia Hargreaves / jules@blueskiesresearch.org.uk / Blue Skies Research
Co-author: James Annan, Blue Skies Research;
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)
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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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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)
Author: Aradhna Tripati / atripati@g.ucla.edu / UCLA

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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