BOOK OF ABSTRACTS:
ACCSP – 3rd PAGES Aus2k Workshop

Australasia's past climate variability – strengths drawn from palaeoclimate and model data over the last 2000 years

Australian Government
Department of the Environment
Bureau of Meteorology

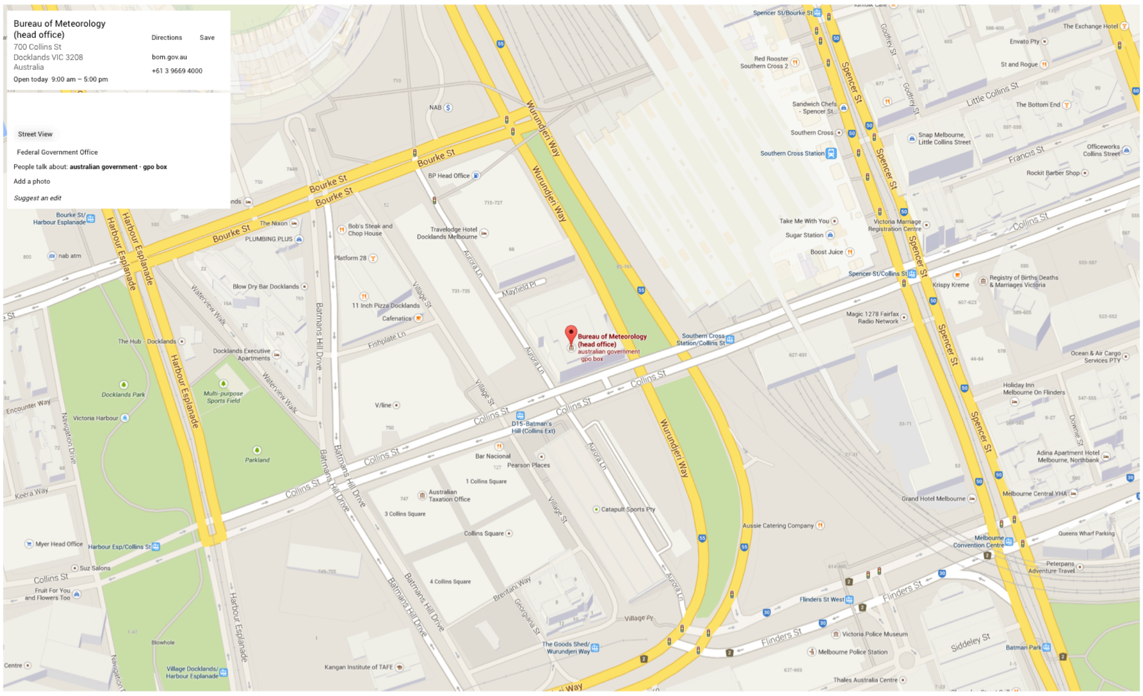
Australian Climate Change Science Programme

MEETING LOCATION

Level 6

Australian Bureau of Meteorology

700 Collins St, Melbourne, Australia



On the morning of Thursday 26th June, you can follow the signs at 700 Collins St, Docklands straight up to the 6th floor and collect your name badge.

If you are unsure about anything, do speak to the person at Bureau of Meteorology reception in the foyer, past the café, and they can help you out.

AGENDA

DAY 1 AGENDA: Thursday, June 26th, 2014

9 am Coffee, registration and poster display

Session 1: What palaeoclimate data tell us about climate variability
Chair: Steven Phipps

Speakers:

9.15-9.30 Welcome (Pandora Hope and Robert Colman)

9:30-9:40 Joelle Gergis - Introduction to PAGES Regional 2k network and the Aus2k working group

9.40-10:00 Joelle Gergis - The role of palaeoclimatology in understanding decadal variability in the Australian region – recent advances and work in progress

10:00-10:20 Jonathan Tyler - Decadally resolved records of hydroclimate variability in Australasia: why do we need them, and what can we achieve?

10:20-10:40 Helen McGregor - Ocean2k synthesis of low-resolution marine records reveals robust ocean temperature trends

10:40-11:30 BREAK - Morning tea and posters

Session 2: Australasian climate drivers and their reconstruction
Chair: Paul Holper

Speakers:

11:30-11:50 Karl Braganza - Climate drivers that influence the Australasian region

11:50-12:10 Pandora Hope - ENSO variability over the last 1000 years

12:10-12:30 Nerilie Abram - Reconstructions of the Southern Annular Mode

12:30-12:50 Ailie Gallant - Non-stationarity of climate influences on Australian rainfall (title TBC)

12:50-2:00 Lunch

Session 3: Climate modelling of the last 2,000 years
Chair: Drew Lorrey

Speakers:

2.00-2.20 Sandy Harrison - PMIP experiments and what they tell us about forced and unforced climate variability (title TBC)

2:20-2:40 Steven Phipps - The role of climate modelling in the study of the last 2000 years

2:40-3:00 Sophie Lewis - The use of palaeoclimate records for climate change detection and attribution

3:00-3:20 Tony Hirst - ACCESS model: The CAWCR group, scope for paleoclimate modelling

3:20-4:00 BREAK: Afternoon tea and posters

4:00-5:00 **Discussion: Scope for collaboration and projects.** Chair: Paul Holper
5pm finish

OPTIONAL: Informal pub-style dinner @ The Boatbuilders Yard, South Wharf (http://www.theboatbuildersyard.com/) * bring a coat!

DAY 2 AGENDA: Friday, June 27th, 2014

9 am Coffee

Session 1: A database of Australasian low-resolution records: data consolidation and directions for future data collection
Chair: Nerilie Abram

9:30-9:45 am Jonathan Tyler (including Bronwyn Dixon, Ben Henley and Andrew Lorrey) - Introduction to existing low-resolution Australasian databases, a brief review of data quality and quantity, and some ideas for future targeted data collection

9:45-10 am Tas Van Ommen - Examples of data collation and future data planning from the ice core community (Antarctica 2k chronology and IPICS white papers)

10:00-11:00 Group discussion:
i) Identification and inclusion of additional datasets
ii) Discussion of developing a 'high quality' Australasian database (Australia, New Zealand and Indonesia).
iii) Guidelines for strategic data collection of future records in the context of regional syntheses
iv) Future actions (intercomparison exercise, sub-working group report? paper?)

11:00-11:30 am Coffee

Session 2: Multi-archive data synthesis techniques being used by Aus2k and the global Regional 2k program
Chair: Jonathan Tyler

11:30-11:45 am Andrew Lorrey - A brief introduction to Past Interpretation of Climate Tool (PICT): http://content.niwa.co.nz/pict

11:45-12:00 pm Ben Henley - Overview of multi-archive approach to climate reconstruction: a case study of the Inter-decadal Pacific Oscillation (IPO)

12:00-1:00 pm Group discussion:

i) Discussion of multivariate climate reconstruction techniques, proxy screening methods, estimation of uncertainty and interpretational caveats
ii) Feasibility for the consolidation of the AUS2k high and low resolution data sets
iii) Possibility of trans-regional comparisons e.g. Australia/NZ, links to global 2k synthesis products
iii) Future actions (intercomparison exercise? sub-working group? paper?)

1:00-2:00 pm Lunch and Posters

Session 3: *Climate field reconstructions and climate modelling*
Chair: Pandora Hope

2:00-2:15 pm Joelle Gergis - Progress with the development of spatial field climate reconstructions for Australia

2:15-2:30 pm Steven Phipps - Climate field reconstructions and climate modelling: Towards integrated approaches

2:30-3:30 pm Group Discussion

i) Feasibility of developing Australasian spatial field reconstructions to contribute to the specific goals of the global Regional 2k program
ii) How we can integrate efforts to reconstruct and simulate past climates (e.g. detection and attribution, data assimilation, pseudoproxy studies).
iii) Discussion on how to align Aus2k activities with the global Regional 2k program
iv) Planning for future climate modelling activities (e.g. palaeoclimate runs with ACCESS)

3:30-4 pm Afternoon tea

Session 4: *Meeting wrap up*
Chair: Joelle Gergis

4:00-5:00 pm Group Discussion

i) Recap on the aims of the workshop/future work
ii) Action items

ABSTRACTS: Oral Presentations

Day 1: Thursday June 26th, 2014

9.30-9.40 am

Joelle Gergis
Introduction to PAGES Regional 2k network and the Aus2k working group

9.40-10.00 am

Joelle Gergis
The role of palaeoclimatology in understanding decadal variability in the Australian region – recent advances and work in progress

10.00-10.20 am

Jonathan Tyler
Decadally resolved records of hydroclimate variability in Australasia: why do we need them, and what can we achieve?

Understanding Southern Hemispheric climate variability on multidecadal to multicentennial timescales requires long, quantitative, sub-decadally resolved climate records. Such data provide the means to better predict future droughts, floods and fires in the region. They also shed light on globally significant patterns of low frequency climate variability in the Indo-Pacific region.

Regional climate reconstructions based on data syntheses have so far focused entirely on annually resolved palaeoclimate data. To date there are only three annually resolved records from Australasia which extend through the last 1000 years [*Neukom and Gergis*, 2012 *The Holocene*; *PAGES 2k Consortium*, 2013 *Nature Geoscience*; *Haig et al.* 2014 *Science*]. By contrast, a number of marine, lake, peat and speleothem sedimentary records exist, some of which span multiple millennia at sub-decadal resolution. Many of these records are particularly sensitive to hydroclimate variability, yet they also bring new issues, including low resolution, uncertain age constraints and indirect responses to climate forcing.

Here, I will present a new approach to synthesising sedimentary records using Empirical Orthogonal Functions, coupled with Monte Carlo iterative age modeling. The approach involves preliminary ordination of each dataset, enabling the inclusion of more information from each location and relaxing the demand for rigid climate-based calibration. The application of this methodology on a subset of Victorian lake sediment records reveals a regionally coherent pattern of change which is consistent with a growing picture of hydroclimate variability in the region.

10.20-10.40 am

Helen McGregor, on behalf of the PAGES Ocean2k LR Group
Ocean2k synthesis of low-resolution marine records reveals robust ocean temperature trends

The oceans mediate the response of global climate to natural and anthropogenic radiative forcing, yet observations of global maritime surface climate variations in the late Holocene, and the mechanisms that drive the variations, are relatively unknown. Here we synthesize 57 sea surface temperature (SST) reconstructions, sourced from all major ocean basins, and spanning at high resolution some or all of the past 2000 years. The reconstructions are derived from marine archives (Mg/Ca, alkenones, TEX86, faunal assemblages in sediment cores, and coral), and meet strict chronological control criteria. The reconstructions are geographically sparse, however analysis of multi-millennial AOGCM output and historical gridded SST observations suggest the reconstructions are spatially sufficient to resolve global mean SST.

The reconstructions were standardised into 200-year bins and the resulting Ocean2k SST synthesis reveals a robust SST cooling trend for 0-1800 years of the Common Era (CE), with the strongest cooling after 1100 CE. The cooling trend is not sensitive to localized upwelling, marine archive type, seasonality of response, chronological control, water depth, sampling resolution, sedimentation rate, basin, latitude or hemisphere.

The Ocean2k SST cooling trend is qualitatively consistent with an independent synthesis of terrestrial paleoclimate data, and with simulations from the multimodel PMIP3 ensemble, driven by the full suite of hypothesized radiative forcings. Comparison with ensembles of single and cumulative radiative forcing simulations suggests that the cooling trend arises not from orbital forcing, but from the increased frequency of explosive volcanism and/or land use change in the most recent millennium. Our Ocean2k SST synthesis and data-model comparison points to centennial-scale mediation of volcanic forcing by the ocean, and suggests that long-term regional and terrestrial climate variations are a response to global ocean change.

11.30-11.50 am

Karl Braganza
Climate drivers that influence the Australasian region

Large-scale modes of intrinsic climate variability strongly influence regional climate on interannual , multi-decadal and centennial timescales. In this way, a well-developed dynamical understanding of climate modes is essential for a range of scientific undertakings, such as seasonal climate prediction and the generation of future climate change scenarios. The potential for recent and future changes in the characteristics of intrinsic variability, associated with climate change, increases the importance of palaeo-climate reconstructions that describe how climate modes operated prior to the twentieth century.

An important aspect of palaeo-climate reconstructions is understanding how climate modes influence local climate. For example, the selection of proxy records for reconstructing variability in a given climate mode is informed by the seasonal response and spatial teleconnections across a set of climate variables. Similarly, the separation or decomposition of climate modes in a single proxy record is informed by an understanding of the various drivers of the local climate variability.

We describe the main intrinsic climate modes that influence Australian climate variability, the Indian Ocean Dipole (IOD), El Niño-Southern Oscillation (ENSO) and Southern Annular Mode (SAM) .

11.50-12.10

Pandora Hope, B. Henley, J. Gergis, H. Ye, K. Braganza, J. Brown
ENSO variability over the last 1000 years

Indicators of El Nino – Southern Oscillation (ENSO) variability have been recorded reliably via satellite and a large network of direct measurement in the Pacific Ocean for about 35 years. Other records, such as the sea level pressure at Darwin and Tahiti extend back further in time to the 1800s. Based on such records, it is clear that the signature of ENSO variability is not constant over time. Studies have shown that we may require more than 500 years of record to truly capture the range of variability due to internal variability alone. In the case of external forcing, such as greenhouse gas changes or volcanic eruptions, an even longer record may be needed to fully understand how ENSO can vary through time.

A number of proxy records of ENSO that extend back hundreds of years have been developed from various sites and using a range of methods. There are differences in the time-variance of these series of ENSO, including their spectra. Some show year-to-year variability similar to observed, while others seem to persist in La Niña-like or El Niño-like conditions for longer periods than have been observed. Is it possible that ENSO did behave in this manner at times during the last millennium?

New climate model simulations of the last 1000 years from PMIP3/CMIP5 provide an excellent testbed of the natural (internal and forced) range of variability of ENSO. In this study we examine the power spectrum of the Southern Oscillation Index (SOI) in 50 year time windows from one of the ENSO proxy series (Braganza et al. 2009) through the last 500 years and six CMIP5 climate model simulations through 1000 years from 850 to 1850 as well as the historical and control runs. The climate model simulations of the last 1000 years were forced with volcanic and solar variability as well as variations in greenhouse gas levels. One ensemble member per model from each simulation was considered.

Proxy reconstructions show epochs of up to 50 years when decadal variability dominated the ENSO spectrum (e.g. Braganza et al. 2009), and this is evident in some of the models also. However, the dominant timescale of ENSO seems to be determined more by the base model than by the forcing (albeit weak) in the historical and 1000 year simulations. The ENSO variability was close to biennial in the BCC-CSM1-1 model, while the CCSM4 and GISS-E2-R models tended to have power in the 3-8 year range, the power varied across a range of frequencies in the spectrum from the IPSL-CM5A-LR and MPI-ESM-P models. These results suggest that ENSO can have power on decadal and multi-decadal timescales, as has been evident recently in the observed series. Extended periods when La Niña or El Niño dominate can influence past and future protracted drought and flood cycles for regions such as eastern Australia, where ENSO dominates interannual and decadal climate variability.

Braganza, K., J.L. Gergis, S. B. Power, J S. Risbey, and A.M. Fowler (2009), A multiproxy index of the El Niño–Southern Oscillation, A.D. 1525–1982, J. Geophys. Res., 114, D05106, doi:10.1029/2008JD01

12.10-12.30

Nerilie Abram
Reconstructions of the Southern Annular Mode

The Southern Annular Mode (SAM) is the primary pattern of climate variability in the Southern Hemisphere, influencing latitudinal rainfall distribution and temperatures from the sub-tropics to Antarctica. Recent positive trends in the SAM have had a particularly pronounced impact on droughts in the southern parts of Australia. However, the brevity of climate observations from Antarctica limit our understanding of the significance of recently observed changes in the SAM.

This talk will summarise different approaches that have been employed to reconstruct changes in the SAM over the last millennium. The comparison of proxy-based SAM reconstructions with Last Millennium climate simulations will also be discussed. These proxy-model comparisons have implications for understanding the climate processes that drive changes in the SAM, and for identifying areas where future modeling studies could improve our understanding of the SAM.

12.30-12.50

Ailie Gallant
Non-stationarity of climate influences on Australian rainfall

The assumption of stationarity of relationships between local and remote climates underpins the impacts described by climatic teleconnections. However, the assumption is tenuous for many seasonal relationships between interannual variations in the El Niño–Southern Oscillation (ENSO) and the Southern Annular Mode (SAM), and Australasian precipitation and mean temperatures. Non-stationary statistical relationships between local and remote climates on the 31–71 year time scale, defined as a change in their strength and/or phase outside that expected from local climate noise, are detected on near-centennial time scales from instrumental data and climate model control simulations.

The relationships between ENSO and SAM and Australasian precipitation were non-stationary at 21%–37% of Australasian stations from 1900–2009 and strongly covaried, suggesting common modulation. Control simulations from three coupled climate models produced ENSO-like and SAM-like patterns of variability, but differed in detail to the observed patterns in Australasia. However, the model teleconnections also displayed non-stationarity, in some cases for over 50% of the domain. Therefore, non-stationary local-remote climatic relationships are inherent in environments regulated by internal variability.

2.00-2.20

Sandy Harrison
How well do models simulate climate change?

Past climates provide a test of models' ability to predict climate change. Comprehensive evaluation of state-of-the-art models against Last Glacial Maximum and mid-Holocene climates, using reconstructions of land and ocean climates and simulations from the Palaeoclimate Modelling and Coupled Modelling Intercomparison Projects, has demonstrated that multiple features of 21st century projections are characteristic of past climates and captured by models. These include: land-sea contrast, high-latitude amplification, stronger winter than summer responses, precipitation scaling with temperature, and the rich-get-richer syndrome. However, this evaluation also shows that regional climate changes are not adequately captured by state-of-the-art models. Newer models do not perform better than earlier versions despite higher resolution and complexity. Differences in climate sensitivity only weakly account for differences in model performance. Similarly, differences in modern biases cannot completely explain differences in model performance. The use of the last millennium for benchmarking is problematic because a large part of the climate and carbon cycle signal can be accounted for by internal variability. Although strong punctuate forcing helps to phase-lock the simulated responses, differences between ensemble simulations with a single model are larger than most of the observed centennial variability during the last millennium.

2.20-2.40

Steven Phipps
The role of climate modelling in the study of the last 2000 years

The climate of the last 2000 years presents a valuable opportunity to learn more about the dynamics of the climate system. Climate modelling has a crucial role to play in turning this opportunity into a reality. Through the comparison of model simulations with proxy data and climate reconstructions, we can study the relative roles of forced versus internal variability within the climate system, determine the characteristics of natural internal climate variability, derive estimates of the transient climate sensitivity, test dynamical hypotheses, and evaluate the models that are used to project future climate change.

However, the climate of the last 2000 years also presents multiple challenges. Current limitations on our ability to learn from this period include uncertainties in our knowledge of past external forcings, particularly the sun and volcanoes; the uncertainties that are inherent in climate reconstructions; and deficiencies in model physics. Internal climate variability can also hamper efforts to compare model simulations with reconstructions.

Future challenges are therefore to develop better reconstructions of past climatic forcings; to use climate modelling to test the assumptions that underlie techniques for climate reconstruction; and to continue the development of techniques that allow for more complete integration of climate modelling with proxy data, particularly forward modelling and data assimilation.

2.40-3.00

Sophie Lewis
The detection and attribution of climate change using palaeoclimate model data

The observational demonstrates that the Earth is warming, but does not by itself tell us what caused those changes. Detection and attribution studies aim to determine whether the climate is changing significantly, and if a change is detected, what has caused such changes? Detection is the process of demonstrating that climate has changed in a statistical sense and attribution is the process of establishing the most likely causes for a detected change. In this talk, I will be reviewing several approaches to detection and attribution of contemporary climate change using climate model data. As it is necessary to use proxy records to estimate temperatures prior to the instrumental record, I will also discuss detection and attribution using palaeoclimate information. Overall, palaeoclimate model data indicate that the most of the warming in the second half of the twentieth century is consistent with an anthropogenic signal.

3.00-3.20

Tony Hirst
ACCESS model: The CAWCR group, scope for paleoclimate modelling

The Australian Community Climate and Earth System Simulator (ACCESS) is an initiative aiming for a national approach to weather and climate modelling. Principal partners are the Bureau of Meteorology and CSIRO, through the Centre for Australian Weather and Climate Research (CAWCR), and participating universities, in particular through the ARC Centre of Excellence for Climate System Science. The initiative has recently contributed multi-century simulations from two versions of the ACCESS coupled model to the Coupled Model Intercomparison Project phase 5 (CMIP5). Comparisons with other CMIP5 models show that ACCESS is generally one of the better performing models for many metrics. The CMIP5 simulations done with ACCESS have so far not included those for paleoclimate.

This talk will discuss the potential of the ACCESS for use in paleoclimate modelling. The status of the current ACCESS model suite and plans for further model development work are summarised, with emphasis on aspects relevant to paleoclimate modelling. Some ideas concerning application to PIMP and the CMIP5 paleoclimate simulation such as for PIMP and CMIP5 are then discussed, with consideration of technical, computational and scientific aspects. The latest (post-CMIP5) version of the coupled model has some significant computational improvements over the previous CMIP5 versions, which would benefit paleoclimate application. There is also the prospect of significant improvement in the usability of the model with the advent of the Climate and Weather Simulation Laboratory developed as part of the NCRIS-funded NeCTAR program. The ACCESS partners encourage the uptake of the model for the purpose of paleoclimate research.

Day 2: Friday June 27th, 2014

9.30-9.45

Jonathan Tyler
Introduction to existing low-resolution Australasian databases, a brief review of data quality and quantity, and some ideas for future targeted data collection

A database of sedimentary archives of climate and environmental change has been compiled for the Australasian region, with a particular focus on Australia. To date, over 260 records have been identified which (a) span some part of the last 2000 years and (b) have at least one radiometric age constraint for that period. Each record was screened according to temporal resolution, duration, quality of age model and data type, and a shortlist of 25 'high quality' records was identified. These records mainly cluster around two regions: southeastern Australia and the maritime tropical region of northern Australia and southern Southeast Asia. The status of this database will be reviewed with the goal of identifying avenues for incorporating additional records and information. In addition, some suggestions will be put forward to stimulate debate on coordinating approaches to primary data collection, with the aim of improving consistency and comparability of future records.

9.45-10.00

Tas van Ommen
Update from the Ice Core Community: Antarctica2k and IPICS

The Antarctica2k group has largely completed its Phase 1 reconstruction, which went into the PAGES Consortium effort. This reconstruction relied heavily on isotope records from high resolution cores with layer counted dating, and volcanic ties to synchronise remaining cores. This still leaves the aspiration to find methods to incorporate isotope data from lower resolution cores, which poses challenges not only of synchronisation at low resolution, but calibration of heavily smoothed data. This talk will give a brief overview of the findings of the current Antarctic reconstruction, issues in deriving chronological controls, and comment on planning approaches used by IPICS.

11.30-11.45

Andrew Lorrey
A brief introduction to Past Interpretation of Climate Tool (PICT): http://content.niwa.co.nz/pict

This talk will demonstrate the PICT platform which is currently being developed at the National Institute of Water and Atmospheric Research (NZ) for use in the INQUA-supported Southern Hemisphere Assessment of PalaeoEnvironments (SHAPE) project.

PICT enables users to interpret multiproxy palaeodata of both qualitative and quantitative origin and make interpretations of past climate in terms of hemispheric atmospheric and oceanic circulation patterns. It relies on an analog based approach for matching past anomalies to similar conditions observed in the present day, and as such it can be used for Holocene data (multicentennial and better resolution). PICT could be useful for the Aus2k initiative and can be applied to proxies other than those from New Zealand, where it is currently being used to reconstruct geopotential height, changes in synoptic type frequency, climate driver indices (like SAM and the SOI/N3.4), planetary wave patterns and other climate field information. We consider that Tasmania and SE Australia are key regions that could benefit from PICT.

A demonstration of the interactive component of PICT will be shown using an recently published example, illustrating ease of use in terms of generating 'calibration' of proxy interpretations, with figures and publication ready captions. Immediate development of the tool is focused on incorporating climate field results for wind (U-, V-wind), Omega, and precipitable water to enable comparison with PMIP simulation results. In addition, calculators for solar radiation, insolation, GHG concentration changes, volcanism and global water balance changes on earth orbital time scales are moving forward as part of the tool construction.

Further questions for the Australian audience should help to identify the relevant high resolution gridded data sets that would be best to incorporate into PICT, and what types of functionality would be desired by Aus2k participants. We anticipate that this tool should be ready for the wider Aus2k community to use by 2016.

11.45-12.00

Ben Henley
Overview of multi-archive approaches to climate reconstruction: A case study of the Interdecadal Pacific Oscillation

This presentation will provide a report back from the Pages2k workshop held at the Woods Hole Oceanographic Institution in April of this year. It will provide an overview of the latest advances and approaches taken to developing climate reconstructions and the key challenges that remain. A summary of the group experiment on reconstructing the Arctic temperature field over the last 2000 years, and a discussion of the relevance to producing reconstructions in the Australian region will be given. As a case study, the presentation will provide an update on ongoing work on a multi-archive reconstruction of the Interdecadal Pacific Oscillation. The talk will conclude with a set of challenges and questions as a prompt for the group discussion that follows.

2.00-2.45

Joelle Gergis, Mandy Freund, Benjamin J. Henley and David J. Karoly.
Towards the development of spatial field climate reconstructions for Australia

During phase 1 of the PAGES Aus2k initiative, all monthly–annually resolved tree ring, coral, ice core and speleothem palaeoclimate records were assembled for the Australasian region. An area average of warm season (Sept–February) mean Australasian temperature reconstruction was developed Australasian region (50ºS–

0ºS, 110ºE–180ºE) for the A.D. 1000–2001 period using a temperature sensitive subset of the database. This reconstruction contributed to the global temperature synthesis paper published by the PAGES 2k Consortium in Nature Geoscience in 2013, and the 5th IPCC Assessment Report.

A recently funded Australian Research Council DECRA project The further back we look, the further forward we can see: 1,000 years of past climate to help predict future climate change in Australia, now aims to reconstruct spatial fields of annual climate variations for Australia suitable for direct comparison with global climate models over as much of the past 1,000 years as feasible. These multi-century temperature and rainfall reconstructions will be used to assess the performance of climate model simulations for Australia, extending the benchmarking possible from weather observations that only start in 1900. This offers real opportunity to use the region's newly consolidated past climate record to help reduce uncertainties associated with future climate change projections for Australia.

Here we present a preliminary assessment of the Australasian palaeoclimate network to resolve warm season temperature variations in AWAP data over the 1901–2012 period. The feasibility of developing multi century temperature spatial field reconstructions for comparison with climate model simulations in Australian region will be discussed.

2.15-2.30

Steven Phipps
Climate field reconstructions and climate modelling: Towards integrated approaches

To learn all that we can from the climate of the last 2000 years, we need to move beyond the simple "comparison" of climate model simulations with proxy data and climate reconstructions. Rather, we need to embrace integrated approaches, whereby the models and the proxies are employed in a unified fashion to reconstruct and understand past changes in the climate.

As part of such a paradigm shift, climate modelling needs to be seen as part of the process of palaeoclimate reconstruction itself. There are two key roles that climate modelling can play here. Firstly, the models can be used to test the assumptions that underlie techniques for palaeoclimate reconstruction, including techniques for climate field reconstruction. Secondly, the models can be used to generate climate field reconstructions by directly assimilating proxy data into a climate modelling framework.

Data assimilation is particularly promising for the study of the past 2000 years as, by constraining the evolution of climate model simulations to follow real-world data, it can avoid some of the pitfalls associated with internal climate variability. This talk will briefly cover the basics of palaeoclimate data assimilation, including the range of techniques that can be employed. It will also provide some initial proof-of-concept results for the Australasian region, demonstrating that data assimilation has the potential to generate climate field reconstructions as part of the activities of the PAGES Aus2k Working Group.

ABSTRACTS: Poster Presentations

Duncan Ackerley

Comparing RCM and GCM simulations of New Zealand climate during the Holocene

Proxy data that are used to infer past climatic conditions on land are often representative of a much smaller area than that of global general circulation models (GCMs). One way to close this gap is to undertake statistical or dynamical downscaling of the coarse-resolution GCM data to a resolution comparable with the proxies. In this study, both statistical and dynamical methods of downscaling have been employed to infer the differences in New Zealand climate between the mid-Holocene and pre-industrial (circa 1750) periods.

The frequencies of occurrence of disparate “synoptic regimes” are known to be associated with temperature and precipitation anomalies across New Zealand. A change in the frequencies of occurrence of these synoptic types between the mid-Holocene and pre-industrial simulations may therefore be used to infer differences in regional temperature and precipitation between these periods. At 6000 ybp there was a tendency for increased trough activity in summer and autumn and therefore increased rainfall. In winter and spring however, the circulation was more ‘zonal’, with drier conditions. The circulation-induced temperature changes were weak but suggested warmer (cooler) conditions prevailed in Southern New Zealand in spring (autumn).

In order to validate the synoptic regime analysis, four high-resolution (30 km) regional climate model (RCM) simulations were undertaken using data from the four PMIP2 GCMs. Surface air temperatures were consistently cooler in summer, autumn and winter and only slightly warmer over Northern New Zealand in Spring–a much stronger response than those from the synoptic classification. Moreover, the precipitation decreased (increased) in western (eastern) New Zealand in summer and autumn whereas the synoptic analysis had suggested a general increase. The differences in the results suggest that both methods require further refinement.

Cameron Barr

Variability in large climate processes, such as the El Niño-Southern Oscillation, Indian Ocean Dipole and the Southern Annular Mode, impact regional precipitation. However, palaeo-precipitation records, which can provide insight into the behaviour of these processes over time, are uncommon. We present a quantitative record of precipitation variability inferred from the stable carbon isotope ($\delta^{13}C$) composition of Melaleuca quinquenervia leaves retrieved from the Holocene sediments of Swallow Lagoon, North Stradbroke Island, in the sub-tropics of Queensland; a region strongly affected by ENSO, particularly the La Niña mode. The modern relationship between rainfall and $\delta^{13}C$ was quantified using a collection of monthly M. quinquenervia leaf falls collected between 1992 and 2003 and climate data. The 7500 year record is reminiscent of other Holocene ENSO records, displaying a late-Holocene transition from a La Niña-like system with low variability to a more El Niño-dominated system with enhanced variability. The little ice age is clearly evident as a period of high rainfall and reduced variability.

David Etheridge

Greenhouse gas changes during the last 2000 years: climate forcing and carbon cycle- climate interactions

Pandora Hope, J. Brown, K. Braganza and H. Ye

Southern Hemisphere climate as modelled by the PMIP3/CMIP5 last millennium simulations

The palaeo-proxy records of past temperatures in the mid- and high- Northern Hemisphere (NH) far out-number those in the Southern Hemisphere (SH) over the last 1000 years. The NH records show periods described as the 'Medieval Climate Anomaly, which was relatively warm, and the 'Little Ice Age', when an extended period of cooling occurred. Did these same climate anomalies also occur in the SH? Ice and firn records from Antarctica and tree rings from mid-latitude continents go some way to describing high-latitude SH temperature variability. Climate model simulations of the last 1000 years from the PMIP3/CMIP5 data base may also shed some light on how the global climate varied through the last millennia.

The NH and SH spatially averaged time series of surface temperature poleward of the tropics from six climate model simulations of the last 1000 years associated with PMIP3/CMIP5 were assessed. The models were forced with volcanic, solar and greenhouse gas variability. In general the NH temperatures have greater year-to-year variability than their SH counterparts. The temperatures from all models show strong short-term (1-3 year) cooling in response to the major volcanic eruptions; in some models that response is primarily in the NH. Five of the six models show a steady cooling trend through the millenium in the SH. These five models show consistency in the long-term (a running mean of 50 years)temperature response across each hemisphere and in the tropics around 1050 (warm) and 1650 (cool). The cool period around 1650 was likely due to a series of volcanic eruptions and a downturn in greenhouse gas levels, but this would need further experiments to be tested fully.

Guangqi Li, Sandy Harrison and Colin Prentice

Multiple climate factors control analysis of Callitris columellaris tree ring width in the last 150 years — application of T-model in Great Western Woodland, Western Australia

We developed a simple, generic model of annual tree growth, called 'T'. This model accepts input from a first-principles light-use efficiency model (the P model). The P model provides values for Gross Primary Production (GPP) per unit of absorbed photosynthetically active radiation (PAR). Absorbed PAR is estimated from the current leaf area. GPP is allocated to foliage, transport-tissue, and fine root production and respiration, in such a way as to satisfy well-understood dimensional and functional relationships. Our approach thereby integrates two modelling approaches separately developed in the global carbon-cycle and forest-science literature. The T model can represent both ontogenetic effects (impact of ageing) and the effects of environmental variations and trends (climate and CO2) on growth. Driven by local climate records, the model has been successfully applied to simulate ring widths during 1958~2006 for multiple trees of Pinus koraiensis from the Changbai Mountain, northeastern China. The simulated and observed interannual variability and response to the climate are consistent.

We have applied the T-model to Callitris columellaris in the Great Western Woodland (GWW), Western Australia. Measured ring-width series (46 cores, 10 trees) cover the last 150 years; meteorological observations are available for this period. Ring width is positively correlated with precipitation, especially autumn and winter rainfall, and negatively correlated to temperature and sunshine percentage. The strength of the positive effect of precipitation has increased during the last 50 years, while the negative relationship between temperature and ring width is also stronger. Changes in the strength of climate relationships with ring width reflects the fact that tree growth is controlled by multiple factors, and suggests that reconstructions based on single-factor correlations over limited observation periods may not reflect the real controls on growth over longer timeframes. Integrated modelling can help to address this problem. There are around 200 tree ring records from Australia and New Zealand. These records could be used as targets for T-model simulations driven by climate-model outputs (forward modeling) while Bayesian inversion of the T-model (inverse modelling) could provide climate reconstructions based on these records that take into account changing strengths of climate controls through time.

Monika Markowska, P. Treble, A. Baker, M.S. Andersen, C. Jex, C. Tadros, R. Roach and S. Hankin

Unsaturated zone hydrology and implications for paleo-climate speleothem reconstructions

Speleothem growth relies on the supply of water which percolates from the surface, through the unsaturated zone and discharges into cavernous voids. The flow path of water feeding individual speleothems varies considerably depending on the karst architecture e.g. micro-fractures, solution pipes, structural voids in the karst, storage reservoirs, etc., all of which may alter the composition of drip waters over the flow route. By monitoring drip waters, we can determine: 1) unsaturated zone flow regimes; 2) connectivity between the surface and cave discharge zone; and 3) thresholds for groundwater recharge. This information can be used to identify suitable speleothems in caves for reconstruction of past climatic and hydrologic variability, at least over the last few thousand years of similar mean climate state.

High-frequency, spatially-dense monitoring was conducted in Harrie Wood Cave, Yarrangobilly, Snowy Mountains over a 15 month period to characterise the flow regimes at 14 sites along a depth profile within the cave. Sites were monitored using acoustic drip loggers (stalagmates®). Discharge rates and response to significant rainfall events were highly variable between sites. A moderate relationship was found between decreasing discharge rates and increasing depth ($r2 = 0.40$). We suggest unsaturated zone storage and mixing, unrelated to depth, also have a significant impact on flow regimes. Using a statistical approach, five different drip types, which often had no spatial commonality, were identified. This information was used to inform the choice of speleothems for paleo-climate reconstruction, using stalagmites with differing hydrological regimes feeding growth, of which the preliminary data will be presented here. The study highlights the need to understand unsaturated zone hydrology at the individual drip discharge level, prior to any speleothem study for paleo-climate, to truly appreciate the drip water signal it is recording.

Shayne McGregor

It is vital to understand how the El Niño–Southern Oscillation (ENSO) has responded to past changes in natural and anthropogenic forcings, in order to better understand and predict its response to future greenhouse warming. To date, however, the instrumental record is too brief to fully characterize natural ENSO variability, while large discrepancies exist amongst paleo-proxy reconstructions of ENSO. These paleo-proxy reconstructions have typically attempted to reconstruct ENSO's temporal evolution, rather than the variance of these temporal changes. Here a new approach is developed that synthesizes the variance changes from various proxy data sets to provide a unified and updated estimate of past ENSO variance. The method is tested using surrogate data from two coupled general circulation model (CGCM) simulations. It is shown that in the presence of dating uncertainties, synthesizing variance information provides a more robust estimate of ENSO variance than synthesizing the raw data and then identifying its running variance. We also examine whether good temporal correspondence between proxy data and instrumental ENSO records implies a good representation of ENSO variance. In the climate modeling framework we show that a significant improvement in reconstructing ENSO variance changes is found when combining information from diverse ENSO-teleconnected source regions, rather than by relying on a single well-correlated location. This suggests that ENSO variance estimates derived from a single site should be viewed with caution. Finally, synthesizing existing ENSO reconstructions to arrive at a better estimate of past ENSO variance changes, we find robust evidence that the ENSO variance for any 30 yr period during the interval 1590–1880 was considerably lower than that observed during 1979–2009.

Pauline Treble and the Golgotha Cave speleothem team
Southwest Australian speleothem records – an update

Southwest Western Australia (SWWA) experienced a clear climatic change during the late 20thC and has been identified as highly vulnerable to future climate change (Hope et al., 2010). Paleoclimate records could assist in understanding SWWA climate but very few exist for this region. Early investigations into speleothems were very promising, demonstrating that speleothem-based proxies record the multi-decadal reduction in rainfall since the 1970s (Treble et al., 2003, 2005; Fischer and Treble, 2008). Subsequent efforts to build a paleoclimate record revealed that the climate-speleothem signal was poorly understood in our studied cave e.g. disagreement between coeval records; non-linear response in the speleothem-climate signal. To address this, a cave monitoring program was launched in 2005 involving instrumentation of Golgotha Cave and monthly drip water collection. We present a summary of these findings during 2005-2013 from two contrasting high and low-flow drip sites, as well as our progress on building a high-resolution climate record spanning the last ~600 years.

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Jens Zinke

Recent La Niña events have been associated with mass coral bleaching on both fringing and isolated atoll reefs along the west coast of Australia, and in the western and southwestern Pacific islands. Long-term temperature records, with which to establish the influence of past El Niño/ Southern Oscillation (ENSO) events on these isolated reefs, are limited. Here, we use strontium/calcium and stable isotope sea surface temperature (SST) proxies from ten coral cores from three reef complexes (17-28S, 113-119E) to reconstruct a robust 215 year (1795-2010) annual SST anomaly record for the western Australian (WA) shelf. The record suggests SST anomalies along the western shelf of Australia are tightly associated with Western Pacific Warm Pool (WPWP) temperatures during several multi-decadal time periods over the past 215 years, and the association has strengthened since 1980. On the WA shelf, the strongest warming signals are associated with strong La Niña's and a negative zonal Western Pacific (WP) SST gradient. Our reconstruction shows that recent extreme events were exacerbated by a strong WP warming trend after 1980, and the negative WP SST gradient since mid-1990s. These findings point to an uncertain future for the southeastern Indian Ocean coral reefs, living close to their upper thermal threshold.