Workshop Report

Australasia's past climate variability—strengths drawn from palaeoclimate and model data over the last 2,000 years

Australian Climate Change Science Program (ACCSP) Third Aus2k workshop

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As part of the Australian Climate Change Science Program (ACCSP) project *Variability of Australian climate over the last 1,000 years in coupled model simulations and proxy data*, a two-day multi-disciplinary workshop was held, incorporating the third Aus2k workshop. This workshop appealed to scientists from many fields and drew widespread interest, with more than 40 palaeoclimatologists, meteorologists, hydrologists and oceanographers attending the workshop. This resulted in a very constructive and stimulating cross-disciplinary meeting.

Aus2k is the Australasian component of the International Geosphere-Biosphere Programme (IGBP) Past Global changes (PAGES) 2k Network—a global network of working groups interested in reconstructing the climate of the past 2,000 years. The intention of the workshop was to engage with the wider meteorological community, with expertise in climate data–model comparison and diagnostic analyses, towards the ultimate goal of understanding the mechanisms driving Australasian climate variability in the past 2,000 years.

The research of the ACCSP aims to better understand climate processes in order to estimate the full range of natural climate variability. However, the observed record is too short to provide robust statistics on the low frequency variability of the climate system features such as the episodic El Niño–Southern Oscillation phenomenon. This is where reconstructions of the last millennium can greatly help inform our understanding. Past climate variability can be reconstructed using natural archives such as corals, tree-rings and ice cores, and can also be simulated using global climate models driven by estimates of past forcings of solar, volcanic and greenhouse gas variability.

The specific goals of the ACCSP 3rd Aus2k workshop are listed below. Sub-projects around each aim were agreed upon with co-ordinators and are listed under each point in italics.

1. Expand the Aus2k database to incorporate low-resolution material for the development of a common dataset for Australasian climate reconstructions;

Database to be frozen on 31 December 2014. Contacts: Bronwyn Dixon, Jonathan Tyler and Ben Henley.

2. Develop guidelines for the future collection of climate proxy records based on spatial and temporal gaps in the Australasian palaeoclimate record;

Nerilie Abram and Russell Drysdale will lead the testing of the number and location of records required to reconstruct specific features of Australian climate and to deal with potential biases caused by non-stationarities.

3. Discuss existing multivariate data synthesis techniques being used by Aus2k and the global community, with a post-meeting goal of running a comparison exercise using different reconstruction methods;

An inter-comparison project with Australian and New Zealand data will be coordinated by Ben Henley, Mandy Freund and Andrew Lorrey.

4. Assess the feasibility of developing Australasian climate field reconstructions (temperature, precipitation, and geopotential height) to contribute towards the global PAGES 2k Network;

To be led by Joelle Gergis, Andrew Lorrey and Steven Phipps, and;

5. Foster linkages between the palaeoclimate and climate modeling communities, with the aim of closing the loop between proxy development, data synthesis and climate modelling.

Modelling contacts: Steven Phipps and Duncan Ackerley; Modern climate: Pandora Hope

The 5th aim was the most relevant for the ACCSP, while all five were of relevance to the Aus2k working group. The outcome of Aus2k's efforts will, however, be highly informative in helping to understand the range of long-term natural climate variability in the Australian region.

Day One

The day showcased recent research developments in regional data synthesis; opportunities for the future collection of new palaeoclimate records from the region; the reconstruction of climate drivers such as El Niño–Southern Oscillation (ENSO) and the Southern Annular Mode (SAM); and climate modelling being undertaken by the *Palaeoclimate Modelling Intercomparison Project* (PMIP), the Centre for Australian Weather and Climate Research (CAWCR) and university groups.

Co-manager of the ACCSP, Robert Colman, opened the workshop by highlighting the importance of palaeoclimate data in understanding natural climate variability. He noted the untapped potential of using long-term palaeoclimate data, which extends centuries before instrumental weather observations become available around 1900, to evaluate regional climate model simulations and constrain the latest generation of Australian climate change projections.

During session 1, Joelle Gergis provided an overview of results achieved using the consolidated high-resolution dataset during Phase 1 of the Regional 2k program and outlined the global goals of Phase 2 (e.g. Neukom and Gergis, 2012). Jonathan Tyler presented progress and challenges of consolidating of Australian multi-decadal sedimentary records and their importance for understanding past hydroclimate variability in the region.

Helen McGregor shared insights from consolidating the Oceans2k group's high- and low-resolution records. She emphasised the need to establish sensible selection criteria for the inclusion of records used in regional synthesis efforts, the need to consider spatial biases present in the dataset and the value of withholding independent (in their case terrestrial) data for verification of the sea surface temperature reconstruction results.

In session 2, Karl Braganza reviewed the main climate drivers influencing Australian climate: the El Niño–Southern Oscillation, Indian Ocean Dipole and the Southern Annular Mode (SAM), calling for caution when representing coupled dynamical circulation features using simple climate indices. Pandora Hope then presented results of the ACCSP project *Variability of Australian climate over the last 1,000 years in coupled model simulations and proxy data*, focusing on ENSO and its interactions with Australian climate. She showed that the ENSO–Eastern Australian teleconnection pattern is reasonably well captured by the model simulations, and noted fluctuations in the dominance of biennial and decadal variability of ENSO over the past millennium (Hope et al. 2014).

Nerilie Abram presented a recently published SAM reconstruction–climate model comparison study (Abram et al. 2014) using data consolidated by the Long-Term Climate Reconstruction and Dynamics of South America: South American 2k (LOTRED) and Antartica2k working groups, as well as a new ice core record from the Antarctic Peninsula. She noted that the mean state of the SAM is now in its most positive phase for at least the last 1,000 years.

Ailie Gallant's presentation on the issue of non-stationarity of climate teleconnection patterns (Gallant et al. 2013) generated much discussion, highlighting the need for critical thinking around estimating uncertainty associated with palaeoclimate reconstructions. She emphasised the need to develop spatially explicit climate reconstructions to allow for the evaluation of mean state changes and their expression in regional teleconnection patterns during the pre-instrumental period.

Session 3 was dedicated to discussing the role of climate modelling of the last 2,000 years. Sandy Harrison highlighted recent progress with model evaluation of mid-Holocene and Last Glacial Maximum data, noting that the magnitude of future rainfall projections may be underestimated by up to 50% (Harrison et al. 2013). She noted that no single model is good for all variables, but some are better/worse across a suite of evaluation metrics, and that multi-model ensembles incorporating different forcings are needed to account for forcing uncertainty over the last millennium.

Steven Phipps covered some of the key roles that climate models can play in studying the climate of the last 2,000 years, including studying the roles of forced and unforced climate variability and testing dynamical hypotheses (Phipps et al. 2013). He also highlighted some of the current limitations, particularly uncertainties in our knowledge of past climate forcings. Sophie Lewis then spoke on the potential of using long-term palaeoclimate records for climate change and attribution studies. Tony Hirst gave the final talk of the session, highlighting the capabilities of the Australian global climate model ACCESS and its potential use for palaeoclimate studies. He noted that version ACCESS1.4 can run at 10 years/day on 384 cores, suggesting that a last millennium run is feasible in less than four months.

Paul Holper, the ACCSP manager, then led the discussion on the potential opportunities for collaboration between the Australasian palaeoclimate, climate modelling and meteorology communities. A range of projects including testing the assumption of teleconnection stationarity, palaeoclimate runs with the ACCESS global climate model and pseudo-proxy model exercises to test the fidelity of palaeoclimate reconstructions were discussed and collaborative contacts made.

Day Two

The second day of the workshop focused on the themes of i) Developing a database of Australasian low-resolution records: data consolidation and directions for future data collection; ii) Multi-archive data synthesis techniques being used by Aus2k and the global Regional 2k program and iii) Climate field reconstructions and climate modelling.

In session 1, Jonathan Tyler outlined recent progress in systematically screening records using PAGES guidelines and recalibrating age models for a range of "high quality" sedimentary records from Australia and Indonesia. A plan to incorporate material from New Zealand was discussed with Andrew Lorrey to consolidate the Australasian region's "low resolution" database for Phase 2 activities. It was agreed that the dataset would be frozen on 31 December 2014 to allow for consistency in subsequent climate analyses undertaken by the group.

Plans to develop guidelines for future data collection in Australasia were also discussed, including ideas around testing the number and location of records required to reconstruct specific features of the Australasian climate and to deal with potential biases caused by non-stationarites. The white papers produced by the PAGES Trieste meeting were also discussed (http://www.ncdc.noaa.gov/paleo/reports/trieste2008/trieste2008final.pdf). Nerilie Abram and Russell Drysdale agreed to take the lead on developing this initiative.

Finally, Tas van Ommen shared his experience of working in the Antarctica 2k working group and International Partnerships in Ice Core Sciences (IPICS) initiatives, highlighting the utility of using spectral analysis to classify records for high or low frequency climate analysis.

Session 2 focused on multi-archive data synthesis techniques being used by Aus2k and the global Regional 2k program. Andrew Lorrey demonstrated a synoptic type and geopotential height reconstruction technique based on modern analogs using the Past Interpretation of Climate Tool (PICT) (http://content.niwa.co.nz/node/30 e.g. Lorrey et al. 2013). Ben Henley then provided a summary of the material presented at the recent PAGES 2k Advances in Climate Field Reconstruction workshop held in Woods Hole in April 2014 and an Inter-decadal Pacific Oscillation (IPO) reconstruction that is currently under development.

The issue of incorporating records with higher time uncertainty into Climate Field Reconstructions was discussed, and it was agreed that reconstructions based on this material will form an independent means of verifying low frequency trends and variability identified from the high-resolution material. The group agreed to perform a comparison of all methods being used by the group on the regional Australasian dataset. A plan to undertake an inter-comparison project with Australian and New Zealand data was proposed and will be led by Ben Henley and Andrew Lorrey.

Session 3 was dedicated to the discussion of climate field reconstructions and climate modelling. Joelle Gergis discussed proxy selection considerations and recent progress in developing a temperature climate field reconstruction for Australia within the phase 2 timeframe. Steven Phipps then considered how climate modelling can contribute towards efforts to develop climate field reconstructions. He presented results of a proof-of-concept data assimilation analysis using proxies from the Aus2k, LOTRED and Antartica2k working group temperature reconstructions, highlighting the utility of climate model simulation ensembles in assessing climate field reconstructions developed using palaeoclimate data. He also allowed a few participants to experience the issues that modellers can face as result of natural variability and biases in their climate model (in this case, a cup of ten dice).

A number of posters were also presented. Two described ENSO reconstructions from eastern and western Australia. From the east, Cameron Barr presented a 7500-year sediment record from North Stradbroke Island. The record displays a late Holocene transition from La Niña-like conditions with lower variability, towards a more El Niño-dominated system with higher variability. From the west, Jens Zinke found that corals off western Australia provide a 215-year record of sea surface temperature. The strongest warming is associated with La Niña events and a negative zonal Western Pacific SST gradient. Shayne McGregor found that to capture ENSO variability, matching the variance from a number of sites leads to a more robust signal. The variance in all 30-year periods between 1590 and 1880 is lower than that observed between 1979 and 2009.

A number of authors described improved ways to interpret the climate signal from natural archives. Two posters by Monika Markowska, Pauline Treble and colleagues highlighted the importance of considering the drip rate when using speleothems to capture the climate signal. Guangqi Li and colleagues found that tree growth is governed by multiple factors, which need to be modelled appropriately before a true climate signal can be gleaned from tree rings. David Etheridge and his team provided an update on understanding the carbon signal in ice cores from Law Dome and Dronning Maud Land—with new factors revealing that changes in the ocean and biosphere carbon uptake have a different signature in the ice.

Finally, two posters described ways to use climate models to better understand past climates. Duncan Ackerley used a synoptic typing method and a fine resolution regional climate model over New Zealand to better interpret the broad-scale signal from global climate models at the local scale. He found that the regional model provided greater

local detail, but both methods have their place. Pandora Hope and her colleagues assessed the Coupled Model Intercomparison Project 5 (CMIP5) models for their mid- to high-latitude temperature signal across the Southern Hemisphere. Five of the six models show a steady cooling trend through the period 850 to 1850, with a consistent cool response across the globe in 1650 and a consistent warm anomaly in 1050.

The workshop wrapped up with the development of sub working groups based around the five objects of the workshop, and a clear direction forward to deliver Australasia's best available science for Phase 2 of the global 2k Network. Contacts were made across the meteorological, climate modelling and palaeoclimate communities.

The ACCSP palaeoclimate project has now ended, but interest in this field remains high.

The next Aus2k workshop will be held in Auckland, New Zealand in the austral spring 2015.

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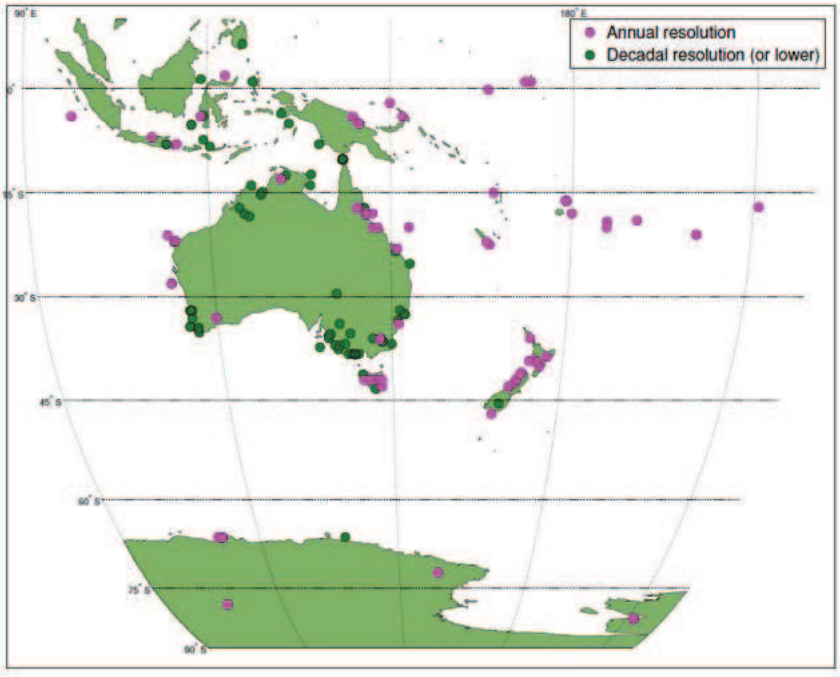

Locations of annually resolved and lower resolution palaeoclimate archives in the Australasian region.