Blocking circulation anomalies in the Tasman Sea region during the Medieval Climate Anomaly

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Contrasting Australasian and Antarctic proxy archive signals are being exploited to reconstruct regional- and Southern Hemisphere-scale atmospheric circulation patterns, which indicate that the frequency of blocking events across the southwest Pacific increased during the Medieval Climate Anomaly.

A recent focus on the land-sparse and data-sparse Southern Hemisphere (SH) has begun to fill critical gaps in our observational record of past climates identified by the paleoclimate research community (Jansen et al., 2007). This thrust is providing balance to Northern Hemisphere (NH) reconstructions, and is facilitating linkages between archives from the tropics through to Antarctica. Underscoring the usefulness of Australasian mid-latitude climate reconstructions are newly emerging perspectives about past extremes and mean climate state changes for the region. These new views are supplementing the general understanding of natural climate variability ranges prior to land-based instrumental records (typically less than 150 years coverage), and are expanding knowledge about tropically-based climate phenomena (El Niño-Southern Oscillation (ENSO), Interdecadal Pacific Oscillation (IPO), Indian Ocean Dipole, the Madden-Julian Oscillation, Australasian monsoon and the South Pacific Convergence Zone (SPCZ)) and other key extra-tropical components of the global climate system (e.g., the Antarctic Circumpolar Current (AAC), the Southern Annular Mode (SAM), and the mid-latitude westerlies).

Regional paleoclimate reconstructions in Australasia are being undertaken to increase natural climate variability understanding, leading to more robust validation of global climate models and improved model selection for future scenario-building. This approach is feeding into improved formulation of scenarios that are guiding mitigation and climate change adaptation strategies for Australia, New Zealand, and the small island nations of the Southwest Pacific. Observed patterns in multi-proxy paleoclimate syntheses are currently being compared to broad-scale circulation outputs from paleoclimate models (i.e., Paleoclimate Modelling Intercomparison Project (PMIP)), which will verify how well some climate models perform for the Australasian region. A key time span includes the last 2000 years, which contains the Medieval Climate Anomaly (MCA). The MCA expression in Australasia is particularly relevant to study because this period is considered as a key analogue to a future warmer-than-present world.

Approaches to integrating proxies

For New Zealand, a paleoclimate proxy integration approach called Regional Climate Regime Classification (RCRC) is being used to link paleoclimate time slices to modern circulation analogues (Lorrey et al., 2007, 2008). Uniquely, inferences about past atmospheric pressure patterns made from RCRC time slices provide a qualitative "upscaling" that can complement limited downscaled paleoclimate model information. This approach has been a boon for directly comparing proxies that are sensitive to atmospheric circulation changes and paleoclimate model outputs that lack sufficient locally downscaled precipitation or temperature results (e.g., PMIP), opening a new avenue for climate model testing and validation.

An alternative approach is employing pressure gradient and threshold detection algorithms to identify hemispheric circulation patterns associated with regional paleoclimate anomalies (Goodwin et al., 2010). The approach links modern synoptic type sets to unique climate responses at each proxy site.

With the exception of annually-resolved proxies used in the aforementioned synoptic paleoclimatology approaches, there is some uncertainty in the alignment of the archive signals that cover the MCA because of chronological uncertainties and sampling resolutions. In addition, some proxies are more susceptible to distortion than others due to geophysical and anthropogenic activity (Lorrey et al., 2010). However, careful interpretations of the records within a regionally-comprehensive network have meant multi-centennial approximations of past circulation patterns are possible using the two aforementioned approaches.

Regional synoptic circulation reconstructions for the MCA

The example RCRC time slice shown for ca. 750 to 925 AD (Fig. 1a) covering New Zealand is analogous to what occurs in a typical La Niña year, when northern and eastern regions tend to receive normal or above normal rainfall, and southern and western regions are often drier than normal. Overall the pattern is analogous to a blocking regime (Kidson, 2000), typified by more frequent northerly and easterly circulation synoptic types that block the prevailing west-to-east progression of anticyclones and troughs that characterize New Zealand's daily weather variability. Blocking patterns are generally more frequent during the warm season in La Niña years when the sub-tropical high pressure belt moves southward, conspiring with the SAM (often in a positive mode during Austral summer; L'Heureux and Thompson, 2006) to increase anticyclone presence over southern New Zealand. This pattern also has a spatially similar signature to the penultimate IPO-negative phase between 1944-1976 AD.

Time slices produced for New Zealand suggest an MCA that can be broken into at least three phases; an early (ca. 750-1075 AD), middle (ca. 1100-1300 AD), and late (ca. 1350-1550 AD) phase (Lorrey et al., 2010). Weaker precipitation anomalies in the northern and eastern regions of New Zealand in the late MCA phase indicate a slackening of the blocking strength. The middle phase is characterized by oscillations back and forth between more frequent northerly and easterly circulation (blocking) and periods of more frequent southwesterly flow (zonal regimes). The oscillatory nature of the mid-MCA phase is also suggested by at least three surface exposure age- and radiocarbon-dated glacier advances in the Southern Alps (Schaefer et al., 2009) and periods of cooler summer temperatures reconstructed from tree rings in western South Island (Cook et al., 2002).

Variability and drivers during the Polynesian Warm Period

The early 2nd millennium AD heralded the arrival and permanent occupation of New Zealand by Maori (Wilmshurst et al., 2008), and it has been suggested that this interval could be termed "the Polynesian Warm Period" (PWP; Williams et al., 2009). The PWP corresponds to the mid- to late-MCA phases described above, which saw significant Polynesian voyaging episodes and cultural shifts in the southwest Pacific (Anderson et al., 2006; Allen, 2006). The "La Niña-like" blocking patterns that are strongly indicated for New Zealand prior to and during the PWP support evidence from other paleoclimate reconstructions that suggest the SH westerly wind belt and ACC shifted northward between ca. 650-1250 AD with Antarctic cooling that affected the mid-latitudes. It is proposed that high latitude changes in this interval helped set up a positive high-latitude/tropical feedback that initiated a more "La Niña-like" climate state in the equatorial Pacific (Mohtadi et al., 2007), consistent with reconstructions of a "cool" ENSO signature in the central-eastern Equatorial Pacific, expansion of the Hadley circulation, and ridging in the NH mid-latitudes (Graham et al., 2010). Under a blocking regime, there would have been enhanced anticyclonic activity in the SH mid-latitudes, including the Tasman sector. However, significant zonal regime episodes during the mid- to late-MCA/PWP suggest that blocking regimes were not exclusive at the time, but rather there were sustained, strong periods of bi-modal circulation operation. This raises the likelihood that the regional variability associated with both ENSO (and IPO) phases (including droughts, storms, SPCZ shifts, local changes in tropical cyclone incidence, prevailing wind change, and SST anomalies) were probably as significant during the MCA/PWP to Australasian and Pacific Island populations as they are at present.

The atmospheric circulation anomalies reconstructed for New Zealand during the early MCA are nested within a larger SH pattern that blankets the Australasian and southwest Pacific sectors (Fig. 1b), indicated by a multi-proxy-based pressure gradient reconstruction using Eastern Australian coastal behavior and wave climate, Southern Australian mega-lake hydrology, coral-based subtropical sea-surface temperatures, East and West Antarctic ice core glaciochemistry, and Antarctic lake hydrological balance and katabatic wind records (Goodwin et al., 2010). Composites of the conjoint archive signals for the Southern Hemisphere during the early MCA alludes to the basic structure of the Tasman region circulation anomaly suggested by the New Zealand RCRC reconstruction. More important, the synoptic reconstructions produced from

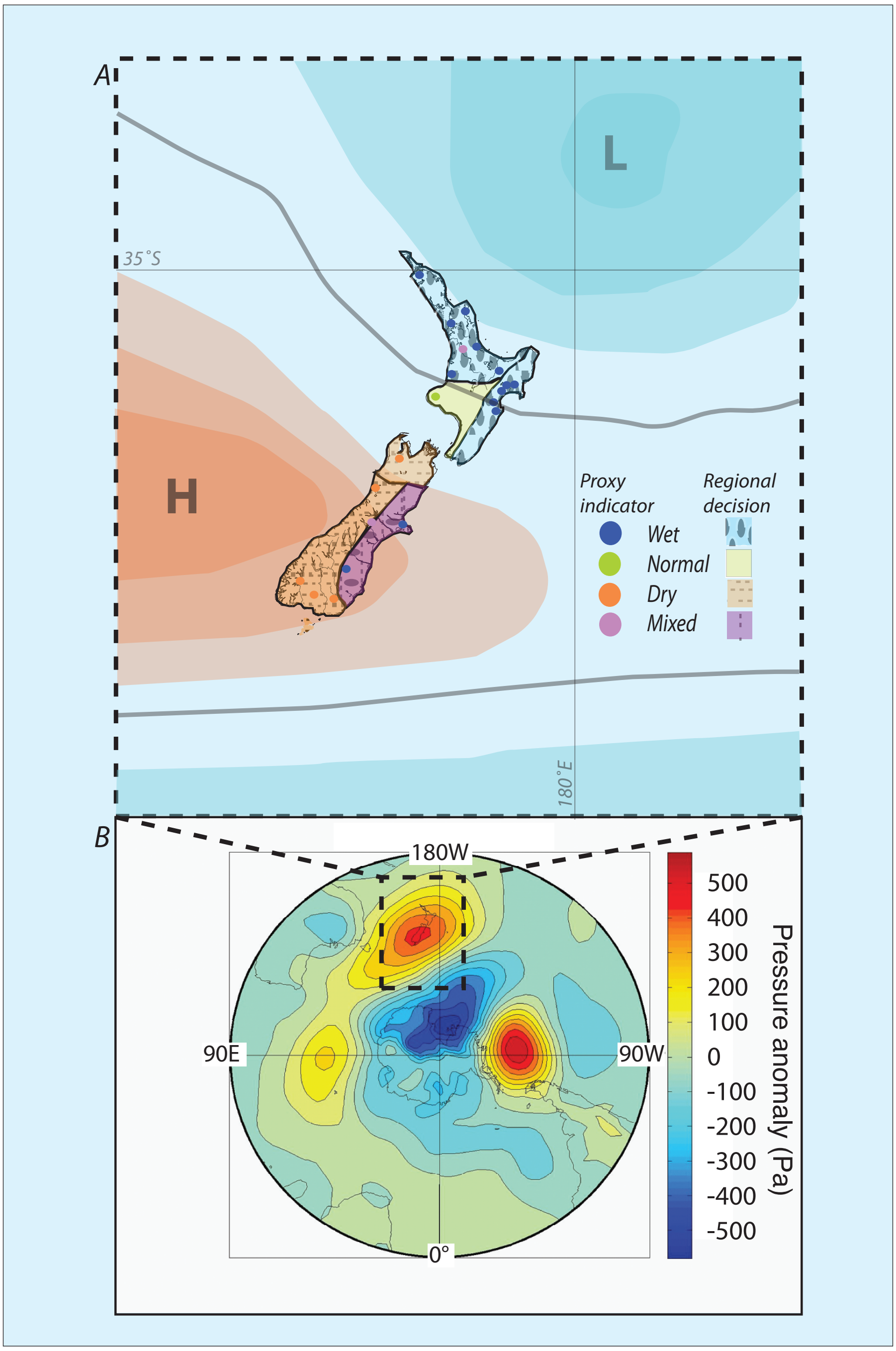

Figure 1: ***A****) RCRC paleoclimate time slice for New Zealand covering ca. 750-925 AD. Proxy sites and interpretation of paleo-precipitation signals are indicated with filled circles. The proxies used for this time slice included pollen, coastal accretion deposits, lake and alluvial sediments, and speleothems. The regional shading indicates how each of six homogenous climate districts (after Kidson, 2000) were qualified, based on a subjective assessment of the available proxy evidence in each district. The regional divisions coarsely correspond to the main axial ranges of New Zealand, which intersect the prevailing flow. The national paleoclimate anomaly pattern was compared to modern reference regimes (Kidson, 2000) to support inferences about the synoptic types that would have characterized past circulation anomalies. Synoptic types proposed for the paleoclimate time slice were then used to generate a conceptual pressure anomaly map, indicated by regions of high (H) and low (L) pressure, suggesting more frequent northerly and easterly flow.* ***B****) Distal and local proxy data used in pressure gradient / threshold detection analysis (Goodwin et al., 2010) are included, such as Law Dome (Antarctica) ice core data, Lake Frome (AUS) lake level reconstructions, and the East Coast of Australia wave climate reconstructions. These proxies were used to produce a SH pressure anomaly signature, indicating how the New Zealand regional anomalies fit within a hemispheric pattern.*

the New Zealand and wider spatial approaches have been done independently, but thus far have yielded some similar results for the characteristic patterns and also timing of circulation changes during the MCA. Both reconstructions suggest predominance of Tasman Sea region blocking during the early MCA, and easing of the anomaly pattern between ca. 1350-1550 AD (Goodwin et al., 2010; Lorrey et al., 2010).

Future direction

Comparison of different paleo-integration approaches (qualitative and quantitative) based on multi-proxy data assemblages that are aligned to reconstructing atmospheric pressure patterns are adding confidence to past change interpretations for

Australasia, and are providing a synoptic/dynamical basis for interpreting and understanding past climates. In essence, the synoptic patterns reconstructed for New Zealand, Australia, and other locations in the SH should fit together like jigsaw puzzle pieces, and the reconstructions that result commonly (but not always) appear analogous to distinct hemispheric circulation modes that are temporally fractal (self-similar). We suggest the large-scale patterns that generate distinct atmospheric pressure anomalies across the SH mid-latitudes are important to recognize for paleoclimate science, and provide a mechanism for rectifying contrasting archive signals. The patterns also provide a means to link proxies spaced by large distances, and for surmounting difficulties that arise where local climatic effects guided by orographic influences are strong. The addition of new high resolution proxy reconstructions from speleothems, lakes, tree rings, coastal and glacial deposits on land, as well as corals and other biogenic archives (like corals, shells and otoliths) are expected to enrich the chronology of changes that are emerging from the Australasian region.

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References

Goodwin, I.D., Cohen, T., Mayewski, P., Lorrey, A., Browning, S., Curran, M., van Ommen, T. and Renwick, J., 2010: *The Medieval Climate Anomaly – A view from down under*. Abstract PP34B-06 presented 2010 Fall meeting, American Geophysical Union, San Fransisco, Dec. 13-17.

Graham, N.E., Ammann, C.M., Fleitmann, D., Cobb, K.M. and Luterbacher, J., 2010: Support for global climate reorganization during the "Medieval Climate Anomaly", *Climate Dynamics*, doi: 10.1007/s00382-010-0914-z.

Lorrey, A.M., Fowler A.M. and Salinger, J., 2007: Regional climate regime classification as a qualitative tool for interpreting multi-proxy palaeoclimate data spatial patterns: A New Zealand case study, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **253**: 407-433.

Mohtadi, M., Romero, O.E., Kaiser, J. and Hebbeln, D., 2007: Cooling of the southern high latitudes during the Medieval Period and its effect on ENSO, *Quaternary Science Reviews*, **26**(7-8): 1055-1066.

Schaefer, J.M., et al., 2009. High-frequency Holocene glacier fluctuations in New Zealand differ from the northern signature, *Science*, **324**: 622-625.

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Climate during the Medieval Climate Anomaly in China

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Various climate archives reveal a heterogeneous occurrence of the Medieval Climate Anomaly in China in terms of timing, amplitude and duration. Uncertainty analyses indicate that it is difficult to assess whether the medieval warmth exceeded that of the late 20th century.

During the past few decades, the Medieval Climate Anomaly (MCA), a supposed interval of elevated temperatures between approximately AD 900 and 1300, has generated considerable interest due to its potential value as a "natural" analogue of 20th century "greenhouse" warming. Recently published National Research Council (2006) and IPCC (2007) reports have placed a high priority on identifying the confidence level in regional to hemispherical temperature changes during the past 2000 years, including the putative MCA.

China is one of the few regions in the world with almost all types of climate archives that could provide high-resolution proxy data, including the world's longest continuous written historical records. Temperature time series of the last 500 to 2000 years have been reconstructed based on historical documents and natural archives (e.g., tree rings, ice cores, stalagmites, lake sediments) from China. In this paper, the results of regional proxy-based reconstructions are reviewed and the associated reconstruction uncertainty is assessed.

Regional reconstructions

Five climate regions of China have been selected (Northeast, Northwest, Central East, Tibet, and Southeast) to conduct the uncertainty assessment of the regional reconstructions (Ge et al., 2010). However, the Southeast has been excluded from the regional reconstructions assessment because the time series from that region are too short to cover the MCA. Examples of regional reconstructions from the climate zones are shown in Figure 1.

For the Northeast region temperature proxy data from lake sediments, peats and stalagmites cover the last 2000 years. The MCA is heterogeneously expressed in all three series in terms of timing, amplitude and variation patterns. The annually resolved 2650-year warm season (May, June, July and August: MJJA) temperature series reconstructed by a stalagmite layer thickness record from the Shihua Cave (115°56'E, 39°47'N), Beijing, indicates a pronounced warmth occurring from the 9th to 13th centuries (Fig. 1e) (Tan et al., 2003). The $\delta^{18}O$ proxy record from peat cellulose with a 20-year resolution from the Jinchuan peat (126°22'E, 42°20'N), Jilin Province, reveals a pronounced warm period at around AD 1100-1200 (Hong et al., 2000). However, the MCA is not visible in the quantitatively reconstructed mean July temperature from the Daihai Lake sediment (Xu et al., 2003).

The Tibet region has four reconstructed temperature series covering more than 950 years. One is a composite of the ice cores Dasuopu, Dunde, Guliya and Puruogangri (Fig. 1c), one is based on tree rings and two are individual lake sedimentary records. The MCA is discernable in form of a $\delta^{18}O$ maximum in Dunde and Guliya ice records, invisible in Puruogangri ice record, and shows a negative trend in the Dasupu record (Thompson et al., 2006a). When the four ice cores are composed as one series, the MCA is not discernable (Thompson et al., 2006b) (Fig. 1c). The temperature reconstruction based on tree-ring widths of *Qilian juniper* from Wulan (Fig. 1b), Qinghai Province, indicates a moderate warming around AD 1144-1264 (Zhu et al., 2008). A lower resolution Total Organic Carbon (TOC) record form Qinhai Lake sediment in the Qinghai Province reveals warm and dry conditions from AD 1160-1290 (Shen et al., 2001); while the sediment record of Sugan lake in the same province shows a pronounced warm period from AD 500-1200 (Qiang et al., 2005).

In Central East China, Ge et al. (2003) reconstructed winter (October to April) temperatures at a 10- to 30-year resolution from phenological observations recorded in Chinese historical documents