Newsletter

Volume 15, Issue 3
March, 2016

Climate Change: Challenges and Opportunities

by Stuart Browning

Much of the popular debate surrounding global warming is framed around the unrealistic expectation that climate should not change. Yet large-scale variations on decadal or longer timescales are intrinsic characteristics of the natural climate system. In the past, these changes have provided both challenges and opportunities for humanity. Recent advancements in paleoclimatology are providing us with a clearer understanding of these changes, and allowing us to better understand societal responses.

Societal response to climate change matters because Australia's major resource and infrastructure-based investments, such as ports, mines, power generation, and agricultural systems, are vulnerable to large-scale changes in mean climate state—not to mention the effect sea level rise would have on coastal real estate. Effective planning for this variability is difficult because the full range of natural variability is not well understood. This means it is also difficult to determine the degree to which human activity might be impacting the climate system. Our lack of understanding stems primarily from a lack of data: most of the Southern Hemisphere only has observations since the advent of global weather satellite coverage in the 1970s, and this record is too brief to study large scale variability.

Records of past climate change

Fortunately, direct observations are not the only record of past weather and climate. Major weather events such as flooding, bushfire or persistent drought leave an imprint in the landscape. This might include anomalous tree-ring growth; snowfall preserved in glaciers or floodplain deposits. Climate proxies such as tree-ring growth (or density) are typically interpreted in terms of a climate variable such as temperature: for example, anomalously warm temperatures during the growing season might result in wider or denser tree rings. A great deal of information about past climates has been interpreted from these proxy climate records. The now infamous 'Mann Hockey Stick'—showing unusual recent warmth in comparison to the past 1000 years—was based mostly on tree ring data. However, climate proxies can be notoriously fickle to interpret as they are subject to a range of confounding factors. For example, tree ring growth might increase with temperature up to a certain threshold, after which the tree becomes heat stressed and ring width decreases. Proxies can also be subject to a range of non-climatic influences that must be considered. One way to account for uncertainty is to use multiple records—more confidence is given to climate signals seen across multiple records.

Traditional approaches to paleoclimatology

Proxies directly record information at their location only: if the location is well selected, climate signals can sometimes be extrapolated to cover a wider domain. For example, El Niño events influence climate throughout the world via physical mechanisms broadly described as teleconnections. Therefore, a coral based record of sea surface temperature in the central Pacific might provide some information about teleconnected regions such as Australia. A wide range of statistical methods have been developed in an attempt to spatially extrapolate climate data from multiple proxy records (Jones et al. 2009). However, directly extrapolating proxy climate signals can be complicated because teleconnection relationships often break down or reverse over time. For example, El Niño events are typically associated with dry summers in Australia—but not always. This problem has been widely acknowledged by the paleoclimate community but is rarely addressed; meaning current approaches struggle to provide information about climate states that may have differed to those of recent decades.

Climate models?

Climate models provide a partial solution to this problem: many of the newer, higher resolution models can simulate a range of mean state configurations, including climate states that have occurred relatively infrequently during recent decades. The latest Intergovernmental Panel on Climate Change (IPCC) report (AR5) contains information from a suite of different models

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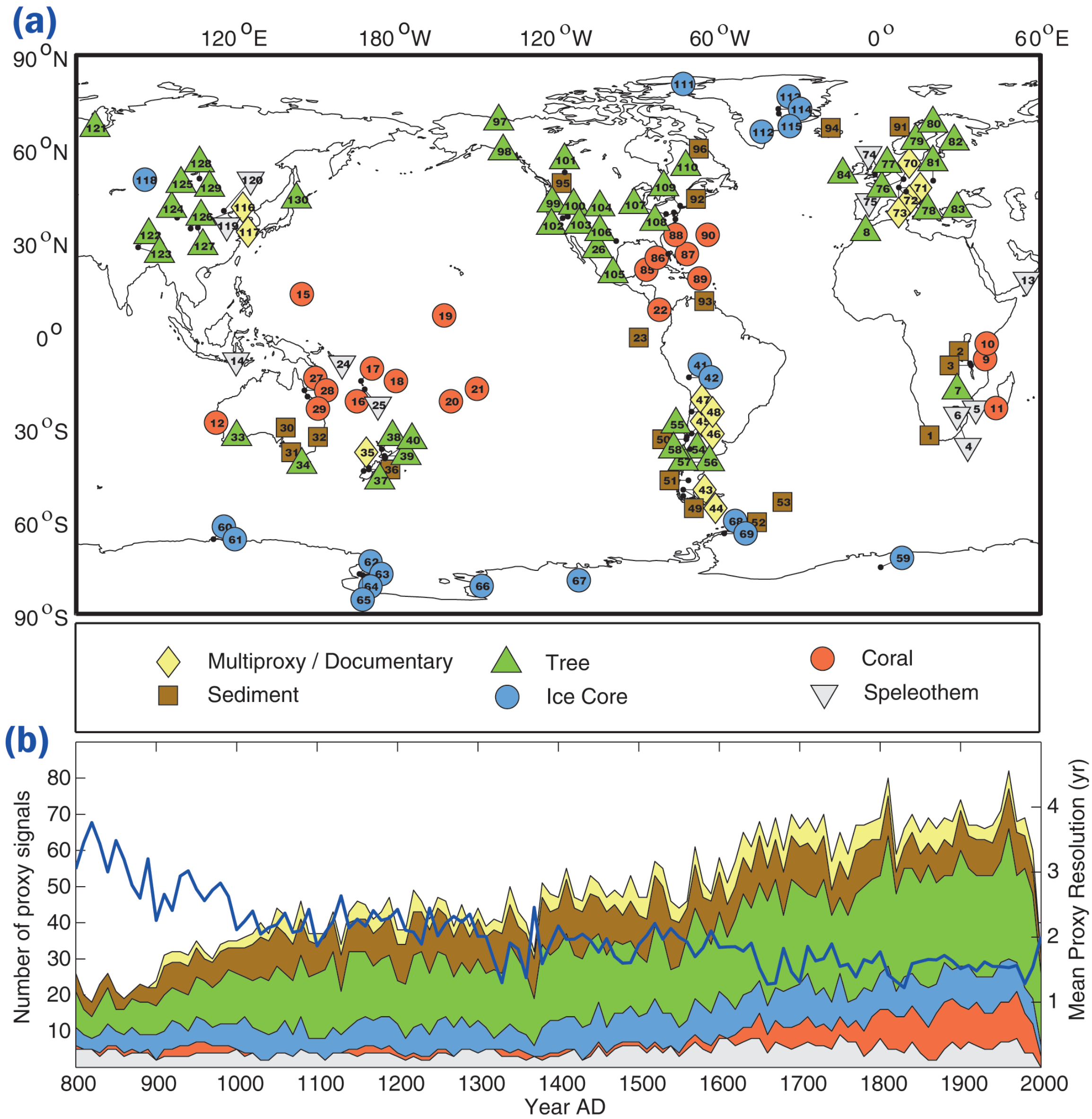

Figure 1 (a) Proxy map showing locations and types of proxy data included in the paleoclimate reanalysis (PaleoR): numbers correspond to individual records described in Browning and Goodwin (2015). (b) Density (number of individual records) of proxy data used at each timestep; blue line represents the mean temporal resolution of all proxy records at each timestep.

simulating the past 1000 years. To improve realism the models incorporate reconstructed changes in the main external climate forcings, including orbital variations, solar radiation changes and volcanic activity. Unfortunately, a large component of multidecadal variability is internally generated: it operates in addition to external forcing, so cannot be simulated by the model in a time consistent manner. This means that for any given time period, the models can tell us what might have happened, but they can't tell us what actually happened. To understand real world variability we need to also look to the proxy records.

Bring proxies and models together

There is a growing awareness in the paleoclimate research community that the best way to resolve past climate change is to use both proxy data and model simulations. Models tell us a range of potential climate states that could have occurred based on a set of physical and dynamical equations; proxies tell us what climate states actually occurred, but only at certain locations and with a high degree of uncertainty. Over the past several years we have been developing a new method to make the best use of both model and proxy data. We are now able to reconstruct climate states for any time period in the past millennium by using proxy climate information from a globally distributed dataset (Figure 1) to choose the best matching climate state analogues from an ensemble of 10 past millennium climate simulations. Conceptually, our approach is relatively simple: for example, if proxy data are indicating the decade of 1560 to 1570 was unusually warm in Tasmania and unusually wet on the south west coast of New Zealand, then we select climate states from the model that best match this information. The more proxy data we include, the more precisely we can constrain each time period of interest. To account for uncertainties in both the model and proxy data we take an ensemble average of the 50 best matching model analogues to represent each time period. The better the agreement between the 50 best matching analogues, the more confidence we have that the modeled climate states provide a realistic representation of the state of the climate system as described by the proxy data.

The Paleoclimate Reanalysis (PaleoR)

Over the past 10 to 20 years, meteorological data has become relatively easy to access and analyze through the advent of retrospective analyses (reanalyses) that combine past observations with forecast model simulations. Reanalysis data are published using the industry-standard netCDF format and provide values for most climate variables, such as air temperature or wind direction, at any global location as far back as the mid-19th century. Unfortunately, observational data scarcity prior to the satellite era limits their accuracy. Prior to ~1920 there are more proxy data than observations for most of the Southern Hemisphere, so it makes sense to use proxy data to develop climate reanalyses. However, traditional meteorological assimilation methods are not suitable for coarse, low-resolution proxy data. The analogue approach effectively combines information from proxy climate data and model simulations; the resulting dataset provides a range of climate variables for any global location that can be examined in much the same way as existing reanalysis datasets—it has therefore been named the paleoclimate reanalysis (PaleoR). The PaleoR dataset is published using the industry-standard netCDF format, making it relatively easy to investigate real-world climate system behavior over multidecadal to centennial timescales (Browning and Goodwin 2015). PaleoR reconstructions can be viewed online at paleor.org.

Past climatic changes in the southwest Pacific

We initially embarked on this project to improve our understanding of storm and wave climate in the Tasman Sea. Examination of coastal strand-plains revealed evidence of unusual storm erosion and coastal recession during a multi-centennial period from the 17th to 19th centuries. PaleoR independently shows that increased storm activity during this time period was the likely driver of large-scale coastal changes. To put this in perspective, storm activity during most decades of the 17th to 19th centuries was equivalent to the stormiest decades in the observational record: the 1950s and 1970s. A return to this kind of mean climate state would have major implications for the security of coastal infrastructure.

We also observed an unusual reversal in southwest pacific windfields during the 12th and 13th centuries. The timing of this windfield reversal coincided neatly with archeological evidence for the first ocean voyaging from East Polynesia to New Zealand. While Polynesians are known to have been proficient long distance voyagers, the journey from East Polynesia to New Zealand requires sailing against the prevailing winds. This sparked robust debate among the archeological community as to whether the Polynesians had upwind sailing capacity? If not then how could they have reached New Zealand? Even more confounding, why did inter-island voyaging to New Zealand cease entirely after the 14th century?

PaleoR shows that an unusual windfield reversal during the 12th and 13th centuries opened up downwind sailing routes from East Polynesia to New Zealand (Goodwin et al. 2014; Figure 2a). While this does not exclude the possibility that Polynesians could have sailed upwind, windward seafaring capacity was not essential for the colonization of New Zealand, and downwind sailing would also have been quicker and easier.

Windfield reversal and expansion of the tropics during this time would have brought milder, subtropical conditions to the Auckland Islands, which were colonized around the start of the 13th century. Unfortunately, this Polynesian settlement was short-lived: archeological evidence shows the Auckland Islands were abandoned after the 14th century, around the same time that voyaging between Polynesia and New Zealand also ceased.

PaleoR shows the 14th century cessation of voyaging coincides with a large-scale reorganisation of the global climate system. This climate change event is seen in the Northern Hemisphere as an end to the Medieval Warm Period and in the Southern Hemisphere as a strong expansion of the cold westerly wind belt into the mid-latitudes (Figure 2b).

Climate change lessons from the past?

Human expansion throughout much of the South Pacific likely occurred through opportunistic exploitation of climate change. However, what must have seemed like a stable climate state by the late 13th century abruptly changed, isolating New Zealand from the rest of Polynesia for the next approximately

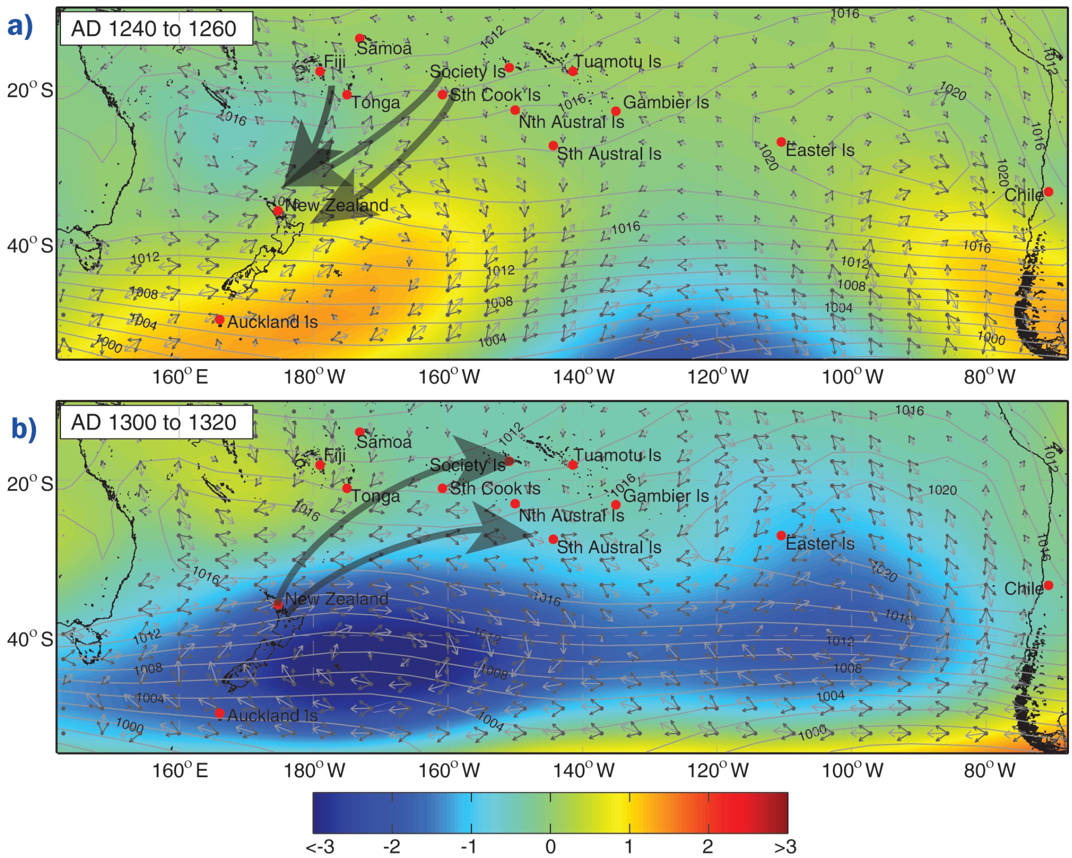

Figure 2 Reconstructed bidecadal mean sea level pressure (black lines), sea level pressure anomalies (colour, hectopascals), and the associated wind field anomaly vectors (gray) for the periods (A) A.D. 1240–1260, and (B) A.D. 1300–1320. Also shown, for each wind direction vector, is the ±30° limit of off-wind sailing vectors (solid black) for Polynesian canoe voyaging. The length of the wind anomaly and associated off-wind sailing vectors depict the relative difference in wind speed across the Pacific and are proportional to the reconstructed atmospheric pressure gradients. The potential downwind voyaging routes for each climate window are denoted by the large gray arrows. Figure reproduced from Goodwin et al. (2014).

500 years. These changes were especially disastrous for the Auckland Islanders, who were plunged into sub-arctic climate conditions resulting in abandonment of settlements.

As for Australia's eastern seaboard, we now have evidence that high impact storms such as East Coast Lows have, in the past, been more frequent and intense, resulting in rapid changes to the coastal margin. Managing future risk to coastal infrastructure should consider the full range of potential climate states, irrespective of projected human influence on the climate system.

Past civilizations have not had the benefit of advanced knowledge and in some cases, such as the Mayan and Khmer empires (and Polynesian settlers on Auckland Island), appear to have failed to adapt. In the modern context, anthropogenic CO_2 emissions have set the climate system on a warming trajectory. As history has shown, climate change will provide challenges and opportunities. While there are still many unknowns, our understanding of the climatic impacts associated with increasing greenhouse gas concentrations provides us with a certain element of predictability for future climate changes—potentially more-so than if the climate system were left in its 'natural state'. Advanced knowledge provides the potential to turn challenges into opportunities, whether we take advantage of this predictability is optional.

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Risk Frontiers' suite of *Catastrophe* Loss Models

Risk Frontiers' NAT CAT models combine the science of natural perils together with building vulnerabilities, insured values and their spatial distribution, in order to estimate the insurance risk from natural perils.

Risk Frontiers' Multi-Peril Workbench integrates loss analysis for multiple NAT CAT models. It can combine losses in reinsurance structures and output event tables and insurance-relevant statistics suitable for pricing insurance premiums, informing reinsurance and capital management decisions and for communicating with APRA over regulatory concerns.

The latest release of the Workbench - Version 2.3 - includes the following major enhancements:

- Full integration of latest post-Christchurch NZ Earthquake model
- Exposure input at latitude-longitude
- International currency options

All the models listed below are now fully integrated into the Workbench.

- Tropical Cyclone (Australia) - CyclAUS 3.1
- Earthquake (Australia and New Zealand) - QuakeAUS 5.1, QuakeNZ 2.0
- Bushfire (Australia) - FireAUS 2.1
- Hail (Australia) - HailAUS 6.2
- Flood (Australia) - FloodAUS 3.1

Risk Frontiers also has the following models as in-house capability which will be rolled into the Multi-Peril platform in the future:

- Typhoon (South Korea)
- Volcano (Tokyo and New Zealand)
- Severe Convective Storm Wind (Australia)
- Tropical Cyclone Storm Surge (Australia)
- Post-event demand surge (Australia and NZ)

Risk Frontiers maintains national databases of key natural perils and its PerilAUS is a database of events that have resulted in loss of life or material damage to property and is considered complete since 1900.

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