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For more details please contact:
Lynda Petherick
School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand
lynda.petherick@vuw.ac.nz

Mid-latitude trans-Pacific reconstructions and comparisons of glacial advances based on soil stratigraphy of coverbeds

Alloway, B.V., [1,2], Almond, P.C., [3], Moreno, P.I., [4]; Sagredo, E., [5] Tonkin, P.J.[6]

[1] *School of Environment, The University of Auckland, Private Bag 92019, Auckland, New Zealand*

[2] *Centre for Archaeological Science (CAS), School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW 2522, Australia*

[3] *Department of Soil and Physical Sciences, Faculty of Agriculture and Life Sciences, PO Box 8084, Lincoln University, Canterbury, New Zealand.*

[4] *Instituto de Ecología y Biodiversidad, Departamento de Ciencias Ecológicas, Universidad de Chile, Casilla 653, Santiago, Chile*

[5] *Instituto de Geografía, Pontificia Universidad Católica de Chile, Av. Vicuna Mackenna 4860, Santiago, Chile*

[6] *16 Rydal Street, Christchurch 8025, New Zealand*

South Westland and Southern Chile are narrow piedmonts confined between the ocean in the west and high mountain ranges in the east, which influence regional climate. In both these southern mid-latitude regions, evidence for extensive and repeated glaciations during cold and/or cool climate phases of the Quaternary manifests as arrays of glacial drift and associated outwash plains. In South Westland, these glacial landforms are mantled by layered (multisequal) soils characterised by slow loess accretion and pedogenesis in an extreme leaching and weathering environment. These cover-bed successions have undergone repeated phases of topdown and upbuilding soil formation that have been related to fluctuating cycles of Interglacial/warm and Glacial cool-cold climate during the Quaternary. Similarly, soil cover-beds overlying glacial landforms in southern continental Chile show multisequal soils but unlike those Podzol soils of South Westland, these are of dominantly volcanigenic (andic) provenance and are very similar to multisequal soils of andic provenance in western North Island, New Zealand. In order to explain the observed occurrence of multisequal soils mantling the glacial landforms of southern continental Chile, we develop a soil-stratigraphic model based on soil genesis analogues from New Zealand. Based on proxy data from southern Chile, we propose that conditions during cold and/or cool climate episodes tended to suppress the widespread production of loess despite extensive loess sources. In the absence of a

loess flux, a constant input of Andean-sourced tephra continued to upbuild soils at the ground surface.

Wind Driven Ocean / Ice Interactions during the Ross Sea Region Deglaciation

Bertler, N.A.N.,[1,2] Conway, H.,[3] Dahl-Jensen, D.,[4] Baccolo, G.,[6] Baisden, T.,[2] Blunier, T.,[4] Brightley,H.,[1,2] Brook, E.,[5] Buizert, C.,[3] Carter, L.,[1] Ciobanu, G.,[4] Dadic, R.,[1] Delmonte, B.,[6] Dongqi, Z.,[7] Edwards, R.,[8] Eling, L.,[1,2] Emanuelsson, D.B.,[1,2] Fudge, T.J.,[3] Golledge, N.,[1,2] Hindmarsh, R.C.A.,[9] Hawley, R.L.,[10] Jiao, Y.,[7] Johnson, K.,[1,2] Keller, E.,[2] Kingslake, J.,[9] Kipfstuhl, S.,[11] Kjær, H.A.,[4] Korokikth, E.,[12] Kurbatov, A.,[12] Lee, J.,[5] Lowry, D.,[1] Mayewski, P.A.,[12] McKay, R.,[1] Menviel, L.,[14] Naish, T.,[1] Neff, P.D.,[13] Pyne, R.,[2] Scherer, R.P.,[15] Severinghaus, J.P.,[16] Simonsen, M.,[4] Steig, E.J.,[3] Venugopal, A.U.,[1,2] Vallelonga, P.T.[4] Waddington, E.D.,[3] and the RICE Science Team

[1] Victoria University of Wellington, Antarctic Research Centre, Wellington, New Zealand
[2] GNS Science-Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand [3]Univ Washington, Seattle, WA, United States
[4] Niels Bohr Institute - University of Copenhagen, Copenhagen, Denmark
[5] Oregon State University, College of Earth, Ocean and Atmospheric Sciences, Corvallis, OR, United States
[6] University of Milano-Bicocca, Department of Earth and Environmental Sciences, Milano, Italy
[7] Chinese Academy of Sciences, Key Laboratory of Cryosphere and Environment, Beijing, China
[8]Curtin University, Department of Imaging and Applied Physics, Perth, Australia
[9] NERC British Antarctic Survey, Cambridge, CB3, United Kingdom
[10] Dartmouth College, Hanover, NH, United States
[11]Alfred Wegener Institute Helmholtz-Center for Polar and Marine Research Bremerhaven, Bremerhaven, Germany
[12]University of Maine, Climate Change Institute, Orono, ME, United States
[13] University of Rochester, USA
[14] Climate Change Research Centre, University of New South Wales
[15] Northern Illinois Univ, Dekalb, IL, United States
[16] Scripps Institution of Oceanography, Solana Beach, CA, United States

Geological evidence and modelling experiments suggest that the removal of ice shelves from marine based ice sheets can lead to catastrophic collapse. Roosevelt and Ross Islands are thought to be stabilization anchors for the Ross Ice Shelf and thus the West Antarctic Ice Sheet.

The Roosevelt Island Climate Evolution (RICE) project recovered a 763m deep ice core during 2011-2013 from Roosevelt Island, at the northern edge of the Ross Ice Shelf. The ice at Roosevelt Island is grounded 210m below sea level and accumulates in situ, with the Ross Ice Shelf flowing around the rise. High resolution radar surveys show a well-developed Raymond Bump at the divide of the ice dome. The RICE age model is developed using high resolution methane data tied to the WAIS Divide ice core record, supported with annual layer count, tephra ages and a glacial flow model.

Here we show data spanning the past 30ka and discuss reconstructions of sea surface and air temperature, sea ice extent, atmospheric circulation patterns, and ice shelf grounding line retreat. An ensemble of sensitivity modelling experiments is used to determine thresholds for the removal of ice on Roosevelt Island and correlated grounding line and ice volume changes of the Ross Ice Shelf and the West Antarctic Ice Sheet.

Our data suggest that the delayed onset of the Ross Ice Shelf grounding line retreat during the deglaciation was driven at least in part by the early onset of deglaciation in West Antarctica as recorded in the WAIS ice core. The Ross Ice Shelf grounding line started to retreat rapidly with the initiation of an ice shelf cavity. Atmospheric circulation changes precede the onset of the Antarctic Cold Reversal (ACR) by about 200 years. Maximum sea ice extent is reached at the termination of the ACR and is maintained into the early Holocene, a time period of rapid atmospheric warming and circulation changes.

Past changes in erosion in antipodal active orogens – unsurprisingly, French and New Zealanders disagree

Carney, S.,[1,2] Wilcox, P.,[1,2] Ryan, M.T.,[3] Toucanne, S.,[4] Bayon, G.,[4] Francke, A.,[1,2] Dosseto, A.,[1,2]

[1] Wollongong Isotope Geochronology Laboratory, School of Earth and Environmental Sciences, University of Wollongong. Wollongong, NSW 2522, Australia
[2] GeoQuEST Research Centre, School of Earth and Environmental Sciences, University of Wollongong. Wollongong, NSW 2522, Australia
[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington. Wellington, New Zealand
[4] IFREMER, Unité de Recherche Géosciences Marines, F-29280 Plouzané, France

Mountains erode. A lot. And fast. But what happens in the context of Quaternary climate change is much less understood. This is mostly because of the lack of proxies for reconstructing past changes in catchment erosion. Uranium isotopes (^{234}U and ^{238}U) are sensitive to the mechanisms of hillslope erosion (shallow sheet wash vs mass wasting) and the rate of sediment transport. Thus, a high $^{234}U/^{238}U$ denotes deep hillslope erosion and rapid sediment transport. Applying this tool to sediment records could help us understand how catchment erosion responds to climate variability. We have applied this approach to two marine cores collecting sediment from two antipodal active orogens: the French and New Zealand Alps. In the Mediterranean Sea, turbidite sequences record 75 kyr of erosion in the Var River catchment, which drains a portion of the southern French Alps. Uranium isotope ratios of these sediments show higher values during the Last Glacial Maximum, followed by a decrease in the Holocene. This suggests that glacial erosion was resulting in the production and rapid export of sediments, while during pluvial conditions shallower erosion and slower sediment transport were taking place.

A marine core of the west coast of New Zealand's South Island shows contrasting results. Here, the record spans the last 200 kyr, and the lowest uranium isotope ratios correspond to glacial stadials. In this case, this suggests that erosion was shallower and/or slower, compared to interstadials. While glacial cover was more extensive during these periods, it is possible that the sediment produced was not

exported, only to be delivered to the Tasman Sea during the following interstadial. Taken together, these results show that rugby is not the only source of disagreement between French and New Zealanders. The response of mountainous catchments to Quaternary climate variability is complex, and the application of novel isotopic proxies, combined to other approaches, should shed the light on this complexity.

Records of Holocene relative sea-level change in New Zealand: current state of knowledge, future directions, and research challenges

Clement, A.J.H.

Physical Geography Group, Massey University, Palmerston North, New Zealand

Over the past 30 years studies of the New Zealand coast have focused solely on the theory that postglacial relative sea-level (RSL) change around New Zealand was spatially uniform, and that RSL had been stable at its present level for the past 6,500 years. However, recent critical analysis has shown that this theory is built upon some invalid assumptions. New reconstructions of RSL change confirm that New Zealand experienced a mid-Holocene sea-level highstand, and show demonstrable spatial and temporal variations in RSL changes around the New Zealand coast during the Holocene. Postglacial meltwater loading on the continental shelf around New Zealand is hypothesised to be a significant driver of variation in the timing and magnitude of Holocene RSL changes, but the effect in a New Zealand context remains equivocal. Variability in RSL records may also be influenced by tectonics, coastal geomorphology, sediment compaction, and the marine reservoir effect. However, these variables are currently poorly constrained. Efforts to produce reconstructions of RSL changes around New Zealand, and thereby elucidate the impacts of these drivers of variability on RSL records, are hampered by a dearth of robust palaeo sea-level indicators: only 206 in the current New Zealand dataset. There are broad gaps, both spatially and temporally, in the current coverage offered by these palaeo sea-level index points. Future efforts should seek to fill these spatial

and temporal gaps, and expand our understanding of the influence of drivers of RSL variability around New Zealand.

Temperature change in New Zealand during the last glacial termination

Eaves, S.

Antarctic Research Centre, Victoria University of Wellington. Wellington, New Zealand.

The last glacial termination (c. 19-11 ka BP) represents the most recent natural reorganisation of the global climate system. This event offers insight to the transient response of the earth system to external and internal forcing. Global climate model simulations provide opportunities to test hypothesised drivers and physical mechanisms of global deglaciation, however the veracity of these simulations requires assessment using climate proxy data.

Mountain glaciers are simple physical systems that can be well-represented by numerical models. Glacier length fluctuations are driven predominantly by temperature variability–especially in temperate mid-latitude regions such as New Zealand. Well-dated moraine deposits delineating past ice geometries thus represent useful targets for quantitative temperature reconstructions.

In this poster, we draw together new and published glacier chronologies and quantitative temperature reconstructions for the last glacial termination in New Zealand, from sites spanning the central North Island to the central Southern Alps. This dataset shows: (1) temperatures remained 6–7 °C lower than present until ~18 ka; (2) temperatures increased by 3–4 °C between 17 and 15 ka; (3) glacial stillstands/readvance occurred ~ 15–13 ka when temperatures were 2–3 °C lower than present; (4) renewed warming totalling ~ 1–1.5 °C between 13 and 11 ka.

The two-step structure and timing of glacier-derived temperature change in New Zealand shows close agreement with that predicted by transient global climate model simulations. Climate model sensitivity experiments suggest that the majority of the warming in New Zealand during the last glacial termination was the product of

CO_2 rise, atmospheric dynamics and changes in oceanic heat transport linked to the bipolar seesaw.

Blink and you'll miss it: evidence of rapid lateral variation in paleoenvironment between adjacent field sites

Elliot, J.

Victoria University of Wellington, Wellington

Within a single stratigraphic unit rapid lateral changes in paleoenvironment are often lost amidst broad, basin wide investigations. New evidence collected from the Hautawa Shellbed, Whanganui Basin, shows that small scale perturbations in depositional setting can be uncovered through focused investigation of a single stratigraphic horizon. A key aim of this research is to construct a paleogeographic map for the base of the Nukumaruan Stage at 2.40 Mya with increased resolution. The foundational work of Charles Fleming recognised the Hautawa Shellbed as a marker of major climatic change – cooling conditions expressed by the arrival of a sub-Antarctic faunal assemblage into Whanganui Basin. Often this has been linked with the magnification of Northern Hemisphere ice-sheets. However, the beginning of this amplified cryospheric activity is currently tied to the lower boundary of the Quaternary Epoch at 2.588 Mya. But when do we see this cold water influx into New Zealand? Over 150 thousand years later! The issue of correlating the base of the Quaternary into local New Zealand records is yet to be solved. As yet, the New Zealand Geological Timescale has no clear stratigraphic correlative to the global Pliocene-Pleistocene boundary.

While outcrops of the Hautawa Shellbed are known to extend over 50 kilometres laterally, the nuances in paleoenvironment are currently poorly constrained. This project aims to increase knowledge of lateral variation preserved in order to better understand a unit which has been of much historic interest and the centre of significant negotiation for the base of the Quaternary in New Zealand.

Quantitative PalaeoEnvironments from SpeleoThems (QUEST): a new approach to Australasian hydroclimate reconstruction

Fox, B.,[1] Hartland, A.,[1] Breitenbach, S.,[2] Lascu, I.,[3,4] Hoffmann, T.,[5] Hodell, D.,[3] Scholz, D.,[5] Harrison, R.,[3] Kalberer, M.,[3] Marwan, N.[6]

[1] *School of Science, University of Waikato, New Zealand*

[2] *Sediment & Isotope Geology, Institute of Geology, Mineralogy & Geophysics, Ruhr-Universität Bochum, Germany*

[3] *Department of Earth Sciences, University of Cambridge, UK*

[4] *Department of Mineral Sciences, Smithsonian Institution, USA*

[5] *Faculty of Chemistry, Pharmaceutical Sciences and Geosciences, Johannes Gutenberg University Mainz, Germany*

[6] *Potsdam Institute for Climate Impact Research, Potsdam, Germany*

Speleothems are rapidly gaining prominence as palaeoclimate archives due to their high resolution, ease of dating, and low potential for diagenetic alteration. While the Northern Hemisphere has seen a boost in speleothem-based climate studies in recent years, giving us detailed insights into past climate dynamics in Europe, Asia, and America, there is a disproportionate lack of data from the Southern Hemisphere. In recent years, Australasia's ecosystems and societies have proven highly vulnerable to regional climate change, and especially ENSO variability, with increased occurrence of heat waves, drought and floods. Rainfall projections are highly uncertain, creating stark challenges for adaptation and mitigation plans in the Australasian region. Well-dated quantitative high resolution climate reconstructions are the best means to evaluate natural climate variability in this region.

QUEST (Quantitative PalaeoEnvironments from SpeleoThems) is a new multidisciplinary project which brings together international expertise in isotope and trace-metal geochemistry, environmental magnetism, cave monitoring, cave modelling, and non-linear statistics to develop new techniques for quantitative climate reconstruction from speleothems. QUEST focuses on speleothems from Australasia (and particularly New Zealand), and aims to produce a high-resolution, quantitative reconstruction of hydroclimate and ENSO variability in this region over

the last 10,000 years. Our initial focus for palaeoenvironmental reconstruction has been Waipuna Cave (Waitomo region), with detailed precipitation and drip-water measurements and studies of the pathways for magnetic particles to enter the cave carbonate system. Here we present an overview of the QUEST project along with preliminary results.

Unravelling natural and human-accelerated erosion and weathering processes in the past using uranium and lithium isotopes applied on lake sediment records

Francke, A.,[1,2] Dosseto, A.,[1,2] Rothacker, L.[1,2]

[1] Wollongong Isotope Geochronology Laboratory, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW 2522, Australia
[2] GeoQuEST Research Centre, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW 2522, Australia

Climate change and tectonic uplift are considered to be the major control of erosional processes and landscape evolution. While tectonic uplift affects erosion on long time scales (millions of years), the recent global warming due to anthropogenic greenhouse emission might trigger a more rapid landscape evolution (years to centuries). In addition, erosional processes can be accelerated by human induced wood clearance and agricultural land-use. Therefore, it has become fundamentally important to understand and predict the response of the Earth´s surface to these changes. However, to quantify the rates and time scales of sediment formation, transport, and deposition in particular on geological time scales in which direct observations are not possible has remained challenging until today.
New, innovative analytical methods using uranium and lithium isotopes measured by means of MC-ICPMS analyses now enable a more precise assessment of past erosion and soil production rates on geological time scales. Until today, these methods have mainly been applied on fluvial and marine deposits, however, lacustrine sediment sequences probably provide even more valuable targets, as they

normally showcase highly-resolved, sensitive, and continuous archives of past environmental change for a constrained catchment. The data can be linked to traditional proxies, such as pollen, stable isotope (O, C), and sedimentological information in order to obtain a comprehensive, detailed picture of past erosion, soil production, and clastic sediment deposition in response to climatic and environmental variability. Here, we will show the results obtained from the only two studies in which uranium and lithium isotope analyses have been applied on lakes (lakes Dojran and Ohrid, Macedonia) in order to demonstrate the potential of the new methods for the application on lake sediment sequences from New Zealand.

Deglacial and Holocene climate change records from subantarctic fjords

Gilmer, G.J.,[1] Moy, C.M.,[1] Riesselman, C.R.,[1] Vandergoes, M.,[2] Gadd, P.,[3] Jacobsen, G.,[3] Wilson, G.S.,[1] Visinand, C.[4]

[1] The University of Otago, Dunedin, New Zealand
[2] GNS, Lower Hutt, New Zealand
[3] ANSTO, Lucas Heights, New South Wales, Australia
[4] University of Plymouth, UK

A series of sediment cores were collected in February 2015 and 2016 from Norman Inlet, Auckland Islands, and are being used to reconstruct a high-resolution record of climate change following the Last Glacial Maximum (LGM). Sediment has been preserved in Norman Inlet due to a sill, of probable glacial origin, creating a depositional basin that was protected from the influence of sea-level rise until the early Holocene. Physical property data, ITRAX XRF and visual core descriptions indicate the cores capture several phases of sedimentation. We identify four primary sedimentary facies: 1) a deglacial facies exhibiting mm-scale laminae defined by magnetic susceptibility and density contrasts and high counts of elements associated with terrigenous deposition; 2) a lacustrine facies defined by very low density, high organic carbon concentrations and low counts of terrigenous elements; 3) a marine transgression facies with moderate density, moderate bioturbation and alternating

marine and lacustrine sedimentary components; 4) a marine facies that contains biogenic carbonate. Radiocarbon dates indicate deglacial sedimentation was underway in the basin by approximately 19,000 cal yr BP. Lacustrine deposition in an ice free watershed began around 15,600 cal yr BP and continued until the marine transgression at 9,500 cal yr BP. A low resolution *n*-alkane biomarker stratigraphy shows that marine and lacustrine facies are dominated by long chain odd number *n*-alkanes (C_{27}, C_{29}, C_{31}) and the most elevated dD values occur in the early Holocene. Bulk organic $\delta^{13}C$ values decrease down core from -24‰ to -29‰ and there are stepped changes in $\delta^{13}C$ values that suggest changes in primary productivity during the marine phase. We will place these results in a broader context by comparing the timing of reconstructed change in the Auckland Islands with established Southern Hemisphere records.

A New Zealand perspective on centennial-scale Southern Hemisphere westerly wind shifts during the last two millennia

Hinojosa, J.L.,[1] Moy, C.M.,[2] Stirling, C.H.,[3] Wilson, G.S.,[2,4] Eglinton, T.I.[5]

[1] *Dept. of Geological and Planetary Sciences, California Institute of Technology, Pasadena, USA*
[2] *Geology Dept., University of Otago, Dunedin, New Zealand*
[3] *Chemistry Dept., University of Otago, Dunedin, New Zealand*
[4] *Marine Science Dept., University of Otago, Dunedin, New Zealand*
[5] *Dept. of Earth Sciences, ETH Zürich, Zürich, Switzerland*

The strength and latitudinal position of the Southern Hemisphere westerly winds control regional climate and influence the global carbon cycle by physically regulating Southern Ocean CO_2 exchange with the atmosphere. However, the mechanisms driving interannual to millennial variability of the westerlies remain poorly understood. Here, we present an 1800-yr record of westerly wind variability recorded in New Zealand fjord sediments. Located west of the Southern Alps, fjord basins receive large amounts of westerly-driven orographic precipitation (>6 m yr^{-1}) and strong winds lead to vigorous fjord mixing. Because of these links,

reconstructing precipitation and fjord circulation provides information on westerly wind behavior over southwest New Zealand. Applying a multiproxy approach, we find several intervals of inferred regional wind variability. The intervals of 1450-1400, 825-775, 575-550, and 50-0 cal yr BP were anomalously wet, while 325-300 and 250-225 cal yr BP were anomalously dry. These interpreted intervals appear to be in phase with regional paleoclimate records. Two centennial-scale wet intervals align with a multi-centennial warm interval identified in the Pages2k Australasian temperature reconstruction, while the drier intervals generally occur during cooler times. The wet/dry intervals presented here are matched by opposite wind and/or precipitation trends reconstructed from the windfield core in Chile and the southern windfield margin in Antarctica. Such spatial patterns support the notion of centennial-scale latitudinal wind shifts or contraction/expansion of the core. Consistent with observations, all sites show wind strengthening from ~50 cal yr BP to present, indicating an overall intensification of winds that is observed in modern instrumental and reanalysis data sets.

Vegetation change, climate and volcanism in Taranaki over the last three glacial/interglacial cycles – a multi-proxy approach.

Homes, A., Ryan, M.

School of Geography, Environment and Earth Science, Victoria University of Wellington, Wellington, NZ

Previous studies of past vegetation patterns in Taranaki over the past ~250,000 years have concentrated almost entirely on palynology. While this has given considerable insight into regional vegetation patterns, particularly since the last glacial maximum, there are still some unresolved questions. We report some preliminary results from an ongoing study in which we seek to integrate pollen records with plant macrofossils to help resolve some of these problems.
Three sites in north Taranaki form the basis of the first stage of this study. Two coastal sections, at Bell Block and Airedale Reef include seams of dirty lignite that

have yielded pollen, macrofossils, tephra and charcoal. Together with a third, inland section at Colson Road, sampled for pollen alone they will allow comparison with other sites, both onshore and offshore. Initial results from this integrated approach suggest that during both MIS 7 and MIS 5, the coastal plain of northern Taranaki was covered by a complex of dunes backed by swampy podocarp/broadleaf forests, lakes and more open areas of swamp and oligotrophic restiad bog. Both volcanicity and fire seem to have affected the vegetation rather more than previous authors have suggested.

Beyond the ice: records of millennial scale climate change from the Polar Front

Liston, M.,[1] Bostock, H.,[2] Dunbar, G.[1]

[1] Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand
[2] National Institute of Water and Atmosphere, Wellington, New Zealand

The Southern Ocean (SO) plays a major role in global climate through redistributing heat and nutrients into all the major oceanic basins and regulating ocean-atmosphere CO_2 exchange. Research focusing on the mechanisms behind abrupt climate change has highlighted the degree of variability recorded in the SO. This variability can be better understood through increasing the spatial and temporal resolution of marine records, particularly in the South Pacific where data are sparse. The bipolar seesaw is a well-documented relationship that describes the out-of-phase timing of Arctic and Antarctic millennial scale climatic events evident in polar ice cores throughout Marine Isotope Stage 3 (MIS3). However, their expression in the southern mid-latitudes is poorly known. Consequently, this period may provide an important window to gauge how Earth in general and the NZ region in particular could respond to anthropogenic-induced abrupt climate changes.

Two marine sediment cores collected from the Polar Front, south-west of NZ, have provided a new high resolution elemental record measured by XRF. The data show a

progression of abrupt elemental changes we interpret in terms of ice-rafted debris flux and plankton productivity.
Preliminary age modelling suggests these unique marine records detail key elemental changes during MIS3. This data provides a means to understand the different components culminating in a sudden perturbation to Earth's climatic state, with the hope to better constrain the timing and spatial extent of these events in the Southern Hemisphere.

Development of palaeorecords across the last interglacial-glacial cycle from New Zealand swamp kauri tree-rings

Lorrey, A.,[1] Boswijk, G.,[2] Hogg, A.,[3] Palmer, J.,[4] Turney, C.,[5] Fowler, A.,[2] Ogden, J.[2]

[1] NIWA, New Zealand
[2] The University of Auckland, New Zealand
[3] Radiocarbon Dating Laboratory, The University of Waikato, Hamilton, New Zealand
[4] School of Biological, Earth and Environmental Sciences, University of New South Wales, Australia
[5] Climate Change Research Centre, The University of New South Wales, Australia

New Zealand swamp kauri are relic *Agathis australis* trees preserved in former northern New Zealand bogs. They are massive in proportion to other native New Zealand trees, they attain great ages, and are suitable for dendrochronology. We outline recent work on swamp kauri scientific research, and show a meta-analysis of radiocarbon data for temporally "floating" kauri chronologies and replicated sample depth to-date. At present, swamp kauri tree-ring samples are discontinuously spaced across the last interglacial-glacial, and suggest there is aperiodic preservation of wood spanning from MIS5e through late MIS3, during the Lateglacial, and the Holocene. We know of no other tree ring resource globally that has a similar coverage. We evaluate the potential to build "ultra-long" swamp kauri chronologies that are many millennia in length from our current collections. Secondary analyses (such as radiocarbon and isotopic analyses) that have potential

to add to ring-width reconstructions indicate this archive has great potential to improve our understanding of Late Quaternary changes.

Palaeoenvironmental records from tephric loess deposits aged c. 31.5 to 9.5 cal ka in the Rotorua area dated and connected to the NZ-INTIMATE climate event stratigraphy using tephrochronology

Lowe, D.J.,[1] Lanigan, K.,[2] Esler, W.,[3] Pittari, A.,[1] Newnham, R.M.[4]

[1] School of Science, University of Waikato, Private Bag 3105, Hamilton 3240
[2] Shell Todd Oil Services, Private Bag 2035, New Plymouth 4342
[3] Otonga Rd, Rotorua 3015
[4] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140

We examined tephric loess in the Rotorua area at 13 sites dating from c. 31.5 cal ka (marked by Unit L of Mangaone subgroup) through to c. 9.4 cal ka (Rotoma tephra), much later than recorded in previous studies. The loess is dominantly massive, mainly silty or very fine sand, and typically yellowish-brown, dull yellowish-brown, or dull yellow-orange. The thickest (tephra-free) loess sequence encompassing the period c. 31.5 to c. 9.4 cal ka is 4.3 m; mean accumulation rate was ~23 mm/100-yrs, ranging from ~5 mm to ~60 mm/100-yrs. In the field we divided the loess into 'packets' based on 10 bounding tephra beds. At two long sequences we measured grain-size, accumulation rate, phytoliths, magnetic susceptibility, total carbon content, carbon isotopes, and potassium content as climate proxies. Nine short climate phases (*phases P1–9*) were identified within three broad climate periods (CPs): CP-1, a warm interstadial, 31.5–25.4 cal ka (*P1*); CP-2, a cold stadial/extended LGM with interstadials, c. 25.4–18.4 cal ka (*P2–6*); CP-3, a warming/transitional period leading to an interglacial, c. 18.4−9.4 cal ka) (*P7*, *P9*), but including a late-glacial reversal c. 14.0−12.8 cal ka (*P8*). The magnetic susceptibility, potassium content, and grain-size records showed stratigraphic trends both comparable with one another and consistent with the New Zealand climate

event stratigraphy (NZces), although timings were not always well synchronised: *P1* matches events NZces-11 and -10; *P2* matches NZces-9; *P3* matches NZces-8; *P4* matches NZces-7; *P5–6* match NZces-6; *P7* matches NZces-5 and -4; *P8* matches NZces-3; and *P9* matches NZces-2 and -1.

Towards an enhanced tephra-based chronostratigraphic framework for the 60 to 30 cal ka period in New Zealand: a contribution to SHAPE

Lowe, D.J.,[1] Holt, K.A.,[2] Danisik, M.,[3] Hogg, A.G.[4]

[1] School of Science, University of Waikato, Private Bag 3105, Hamilton 3240
[2] Soil and Earth Sciences Group, Institute of Agriculture and Environment, Massey University Manawatu, Private Bag 11222, Palmerston North 4442
[3] GeoHistory Facility, John de Laeter Centre, TIGeR, Applied Geology, Curtin University, Perth, WA 6845, Australia
[4] Radiocarbon Dating Laboratory, University of Waikato, Private Bag 3105, Hamilton 3240

The NZ-INTIMATE project yielded a generally, but not entirely, well-dated tephrostratigraphic framework from 30 ka (all ages in calibrated years) to the present. As part of SHAPE, we aim to improve the chronology for the New Zealand tephra record for the period 60 to 30 ka, broadly encompassing MOIS 4 and 3. Two widespread marker beds, Rotoehu (45 ka) and Kawakawa (25.4 ka), provide key tie-points for the sequence. Our focus is on rhyolitic tephras derived from the two most active centres in central TVZ, Taupo and Okataina, but documentation of the stratigraphic interfingering of these eruptives with those from Kapenga, Maroa, and Mayor Island (Tuhua) centres is also an objective. The rhyolitic tephra record (60–30 cal ka) comprises Okataina (16 tephras), Kapenga (1), Taupo (7), Maroa (1), and Tuhua (4), with ≥5 tephras pre-dating Rotoehu. Long terrestrial and marine records and maps show that around 10 or 15 of these tephras, mineralogically and geochemically well-defined, provide a coherent stratigraphic framework of widespread markers including Rotoehu (45 ka), Tahuna (39 ka), Maketu/unit-D (37 ka), Hauparu/unit-F (35), Mangaone/unit-I (33 ka), Omataroa/unit-K (32.5), unit-L (31.5 ka), plus two from Tuhua, M3 (40.5 ka) and M4 (37.4 ka). Most tephras are

poorly dated, limited to relatively few ^{14}C dates or interpolations from sedimentation rates. Rotoehu tephra has been dated at 45 ka using U-Th-disequilibrium/U-Pb and (U-Th)/He on zircon ('zircon double dating', ZDD), and at 47 ka using Ar/Ar on K-feldspar and biotite. To maximize the potential of the tephras to help achieve SHAPE's goals, we aim to apply ZDD and ^{14}C dating (charcoal), together with Bayesian-based age-modelling of well-dated tephra-bearing sedimentary sequences such as those of Auckland maars, to obtain new dates.

Geochemical and stratigraphic evidence for late Pleistocene and Holocene hydroclimatic change related to the Southern Hemisphere westerly winds

Moy, C.M.,[1]Nichols, J.E.,[2] Burrington, P.J.,[1] Vandergoes, M.J.,[3] Gilmer, G.J.,[1] Hinojosa, J.L.,[4] Anderson, H.J.,[1] Beltran, C.,[5] Hageman, K.J.[5]

[1] Geology Dept., University of Otago, Dunedin

[2] Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA

[3] GNS Science, Lower Hutt

[4] Div. of Geological and Planetary Sciences, Caltech, Pasadena, CA, USA

[5] Chemistry Dept., University of Otago, Dunedin

The strength and position of the Southern Hemisphere westerly winds play a fundamental role in regulating New Zealand's climate. Strong westerlies not only promote the generation of mid-latitude precipitation-bearing storms over the Southern Ocean, but the mean position of the strongest winds dictate if these systems pass over and deliver rainfall to the South Island. To provide insight into how the westerlies impact New Zealand's precipitation regime, and the broader Southern Hemisphere climate system, we evaluate past hydrologic change using sediment cores collected from lakes, fjords, and peatlands on the SW portion of the South Island and the subantarctic Auckland Islands. These localities are situated either in the core (50°S) or in the northern margin (45°S) of the modern wind belt and local catchment hydrology has demonstrated links to the westerly winds. We apply stable isotope, including compound-specific (n-alkane) H isotopes, and elemental concentration data to these records to evaluate: 1) changes in carbon cycling and delivery pathways related to organic matter provenance and water column

stratification, 2) changes in the dD of plant water related to precipitation origin and atmospheric temperature, and 3) changes in the isotopic composition of closed-basin lake water driven by evaporative processes.
During the Late Glacial and early Holocene (16 to 10 ka), we identify multiple millennial-scale reductions in lake level, elevated long-chain n-alkane dD values, and water column stratification that coincide with intervals of rapid deglacial warming identified in Antarctic ice cores. Combined, these results signal weakened westerly winds and/or southward shifts of the core away from New Zealand along millennial timescale. During the early Holocene (10 to 8 ka), we find evidence for an extended period of low and variable lake levels, combined with enhanced water column stratification, that we attribute to a combination of diminished wind strength, warmer air temperatures, and reduced seasonality. After 5.5 ka, we interpret the decline in long-chain n-alkane dD observed in peatlands (50°S) and lake sediments (45°S) to indicate enhanced SW flow over the South Island combined with cooler temperatures. Our results support the idea that climate mechanisms originating in the high latitudes and the tropics work together to influence the westerlies on millennial timescales. We will further evaluate these interpretations, and place them in a broader context, through comparison of established records throughout the Pacific Basin.

SHeMax: The Last Glacial Maximum in the Southern Hemisphere

Petherick, L.,[1] Shulmeister, J.,[2] Knight, J.,[3] Rojas, M.[4]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand
[2] School of Earth and Environmental Sciences, The University of Queensland, St Lucia, Queensland, Australia
[3] University of the Witwatersrand, Johannesburg, South Africa.
[4] Department of Geophysics, Universidad de Chile, Chile.

The SHeMax project seeks to develop a greater understanding of the timing and nature of the LGM in the Southern Hemisphere. In order to achieve this, proxy data archived in marine and terrestrial records from different settings in the Southern

Hemisphere will be analysed for the period 35-15 kyr BP, encompassing the termination of the last glacial cycle, and the traditionally-accepted timing of the global LGM (~24-18 kyr BP). Emerging evidence suggests that instead of being a relatively short event centered on 21 kyr BP, the LGM in the Southern Hemisphere may have been an extended period of time, with an early onset at 35-30 kyr BP. It has also been suggested that the LGM was not uniformly cool and dry, but may have been characterized by millennial-scale variability. In this project, records from high-resolution marine and coastal sediments, lake sediments, speleothems, ice cores, glacial moraines, dunes and fluvial systems will be compared to produce a synthesis of climatic variability and explore the premise of an extended LGM in the Southern Hemisphere. The spatial focus will be ~20-80oS, which will allow investigation into teleconnections between the mid- and high-latitudes. In addition to the synthesis of environmental conditions, we will suggest drivers and/or triggers of climatic variability. A significant component of the SHeMax project is the comparison of proxy data with model simulations for the LGM e.g. PMIP, SynTRACE-21. The project will also investigate the response of humans during the LGM to climatic variability, in terms of settlement, migration and cultural development. We welcome anyone who would like to be involved in this project.

Evidence for a Holocene Climatic Optimum in the Southwest Pacific: a multiproxy study

Prebble, J.G.,[1] Bostock, H. C.,[2] Cortese, G.,[1] Lorrey, A.M.,[2] Hayward, B.W.,[3] Calvo, E.C.,[4] Northcote, L.C.,[2] Scott, G.H.,[1] Neil, H.L.[2]

[1] GNS Science, P O Box 30368, Lower Hutt

[2] NIWA, Private Bag 14901, Wellington

[3] Geomarine Research, 49 Swainston Rd, St Johns, Auckland

[4] Institute of Marine Sciences, Barcelona, Spain

The early Holocene sea surface temperature (SST) gradient across the Subtropical Front (STF) to the east of New Zealand was ~2°C (measured between core sites

MD97-2121 and MD97-2120): considerably less than the ~ 6°C modern gradient between the two core sites. We document the surface ocean temperatures east and south of New Zealand during the early and middle Holocene, to test and expand upon this reconstruction. This new study samples a latitudinal transect of seven sediment cores from 37°S to 60°S in the southwest Pacific from subtropical waters north of New Zealand to polar waters in the Southern Ocean. Our compilation of SST proxies consists of 525 SST estimates from five different methods, and includes 243 new data points. We confirm that an early Holocene warm peak in this region was mostly restricted to the area immediately south of the STF, which resulted in a lower temperature gradient across the STF than in modern times. However, there is no change in Holocene SST south of the Polar Front. Faunal assemblages suggest an early Holocene meridional expansion of fauna characteristic of the modern Subtropical Front in the Bounty Gyre. We suggest that such an expansion could be achieved by a reduced inflow of Subantarctic Surface Water into the Bounty Gyre. Results from a modern-analogue matching platform called the Past Interpretation of Climate Tool (PICT) suggest that the early Holocene SST is most consistent with reduced westerly winds in the New Zealand sector of the Southern Ocean.

Investigating the Quaternary Architecture of the Lower Pohangina Valley, New Zealand.

Rees, C., Palmer, J., Palmer, A.

Massey University, Palmerston North, New Zealand.

The geology and stratigraphic architecture of the Lower Pohangina Valley, Manawatu has been documented recently by Rees (2015). A geological map has been compiled at 1:30,000 scale, allowing east-west trending cross sections to be constructed across the Pohangina valley. Data gathered from this study are used together with GIS and Leapfrog Geo modelling software to build a 3D geological model. The Quaternary geology of the Lower Pohangina Valley is dominated by regional structures including the Pohangina Faulted Monocline and underlying

shallow blind reverse faults which bound the western margin of the Ruahine Range. Basement rock is composed of highly shattered and sheared Torlesse terrane greywacke. Overlying Quaternary succession, up to 500 m thick, records marginal to shallow marine deposition within the eastern Whanganui Basin. Regional uplift and drag tilting of the overlying Plio-Pleistocene sediments has resulted in an active, young landscape with steep stream gradients, deeply incised stream channels and high erosion rates. Modelling software is a powerful tool which can be used in combination with traditional 2D mapping techniques to help visualise and refine geological interpretation. 3D geological models also create important frameworks which allow for the integration of a wide variety of datasets. A combination of stratigraphic logging, mapping and 3D modelling is used in this study to help visualise and understand the spatio-temporal distribution of geological units and structures.

Vegetation and climate reconstruction from marine cores adjacent to southwestern New Zealand, over the past 500,000 years

Ryan, M.T.,[1, 2] Newnham, R.M.,[1] Dunbar, G.B.,[2] Vandergoes, M.J.,[3] Neil, H.L.,[4] Steph, S.,[5] Alloway, B.V.,[6] Bostock, H.,[4] Sabaa, A.T.,[7] Hayward, B.W.,[7] Scott, G.H.,[3] Rees, A.B.H.,[1] Tiedemann, R.[5]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand

[2] Antarctic Research Centre, Victoria University of Wellington, New Zealand

[3] GNS Science, Wellington, New Zealand

[4] NIWA Ltd, Wellington, New Zealand

[5] Alfred Wegener Institute for Polar and Marine Research, Germany

[6] The University of Auckland, Auckland, New Zealand

[7] Geomarine Research, Auckland, New Zealand

Previous terrestrial palynological records of mid-latitude Southern Hemisphere interglacial periods are often fragmentary and poorly dated. Here, these problems are circumvented by extracting terrestrial palynomorphs from two giant piston cores

(MD06-2990 and 2991) collected from the north levee bank of the submarine Hokitika Canyon, West Coast, South Island. These terrestrially influenced, high sedimentation cores enable stronger insights than were previously possible into marine and terrestrial climate in the southern mid-latitudes across the last 4-5 glacial-interglacial cycles. Chronological constraint is provided by $\delta^{18}O$ stratigraphy, radiocarbon chronology, and the identification of two widespread silic teaphra horizons (25.6 ka Kawakawa/Oruanui Tephra; ~345 ka Rangitawa Tephra), sourced from the central North Island.

During peak warmth, MIS 11 sea surface temperatures in the East Tasman Sea were ~1.5-3°C warmer than present. This corresponds with a notable expansion and dominance of the thermophilous shrub *Ascarina lucida* at the expense of the currently dominant tall tree conifer *Dacrydium cupressinum*. The MIS 11 forest composition in this highly humid region also contrasts markedly with reconstructions of forest conditions during periods inferred to be up to 1.5°C warmer than present in the early Holocene and Last Interglacial, when *D. cupressinum* remained dominant in the region. Southern beech forest is dominant during the penultimate interglacial (MIS 7), where SSTs reach ~1°C above present. These well-resolved marine sequences of past vegetation change provide insight into the timing of sediment deposition captured in the adjacent record of vegetation-climate change from Okarito Bog, which potentially extends to at least 250,000 years.

Holocene temperature in northern New Zealand: a southern imprint on the northern mould?

van den Bos, V.,[1] Rees, A.,[1] Newnham, R.,[1] Augustinus, P.[2]

[1]School of Geography, Environment & Earth Sciences, Victoria University of Wellington, Wellington
[2]School of the Environment, University of Auckland, Auckland

The Holocene has been subdivided based on climate events best seen in the Northern Hemisphere that are thought to manifest globally (Walker et al., 2012). Due to its distal location from northern drivers, New Zealand (NZ) is ideally placed to test

this assertion. We hypothesize that Holocene climate variability in NZ is mainly influenced by ‘southern’ features, like Southern Hemisphere insolation and summer duration, El Niño Southern Oscillation (ENSO) activity and the Southern Annular Mode (SAM). We test this hypothesis by comparing new preliminary pollen and chironomid temperature reconstructions from Lake Pupuke, Auckland, representing mean annual and summer temperatures, respectively, with integrated summer insolation (Huybers, 2006) and independent proxy evidence for ENSO and SAM. Our Pupuke pollen record shows that, after an initial warming phase leading into the Holocene, mean annual temperatures remained stable. The main shift in pollen assemblages is thought to reflect a change in moisture availability, rather than temperature, with driest conditions occurring in the last ca. 5000 yr. These patterns are broadly consistent with evidence for stronger ENSO variability during the late Holocene. In contrast, summer temperatures, reconstructed using an expanded version of the Dieffenbacher-Krall et al. (2007) chironomid training set, follow integrated summer insolation with minimum values between 14,000 and 12,000 yr BP, increasing to a late Holocene maximum around 3000 yr BP. Additionally, we find preliminary evidence of a late-Holocene cold phase, which potentially coincides with the Little Ice Age period as defined in the Northern Hemisphere. Therefore, whilst the global Holocene subdivision of Walker et al. (2012) provides a broadly applicable template, southern drivers are likely to dictate the precise timing and amplitude of Holocene climate variability in the South.

Unravelling possible climatic and/or seismic signals preserved in coastal sand dunes and around modern Lake Wairarapa, North Island, New Zealand

Veitch, J.C., Clement, A.J.H., Fuller, I.C., Holt, K.A., McColl, S.T.

Physical Geography Group, Massey University, Palmerston North, New Zealand

Coastal sand dunes evolve in response to environmental changes such as fluctuations in sea (or lake) level, sediment availability, climate, and human disturbances of the environment. Sand dunes in New Zealand have previously been found to record large-magnitude earthquakes producing pulses of sediment

delivered to the coast, and changes in sea-level and climatic conditions (Goff and McFadgen, 2002). This ongoing research project is the first to investigate and unlock the archive of palaeo-environmental changes preserved in a sequence of dune ridges located along the south-eastern shore of Lake Wairarapa. We explore the formation and timing of these dunes and test two alternative hypotheses. The first hypothesis is that the dunes record earthquake-triggered sediment pulses delivered to Lake Wairarapa ('Wairarpa Bay' during higher sea-levels) by rivers draining the surrounding ranges. Lake Wairarapa lies immediately adjacent to the Wairarapa Fault that is capable of producing earthquakes of considerable magnitude approximately every 2,200 years. The second hypothesis is that the dunes record climatic signals expressed through changes in the level of Lake Wairarapa, or changes in the wind regime of the area, that result in periodic phases of dune-building activity. Sedimentological and XRF analysis of alluvial and dune deposits collected in cores will be used to explore the wind regime and climate responsible for the formation and evolution of dune ridges. A chronology of dune development will be established using a combination of luminescence and radiocarbon dating. Synthesis from these lines of inquiry will be compared with existing records of seismic activity and past climate to elucidate the environmental drivers responsible for the formation of the dunes and the geomorphic evolution of the lower Wairarapa Valley.

Glacial chronology and Holocene environmental history of Lake Tennyson, North Canterbury, New Zealand

Woolley, J-M.,[1] Lorrey, A.M.,[1] Augustinus, P.C.,[2] Barrows, T.,[3] Almond, P.,[4] Shanhun, F.[5]

[1] NIWA, Auckland, New Zealand

[2] The University of Auckland, New Zealand

[3] The University of Exeter, United Kingdom

[4] Lincoln University, Canterbury, New Zealand

[5] New Zealand Antarctic Research Institute, New Zealand

Lake Tennyson lies at the boundary between regional climate districts and is sensitive to atmospheric circulation changes. This site can provide evidence to help test hypotheses about what drives glacier activity. However, few detailed studies on the late-glacial and post-glacial history exist there, despite well-defined end moraines marking the southern margin of the basin. We addressed this knowledge gap by establishing the timing of the glacial sequence emplacement at Lake Tennyson. Our work employed geophysical, stratigraphic and geomorphic approaches that included pedology, tephrostratigraphy, cosmogenic analysis and radiocarbon dating. The most recent maximum ice extent was achieved close to ~18.6 ka at Lake Tennyson. However, an older advance of similar extent, limited by local accommodation space, is likely for MIS4 at ~64 ka. Kawakawa/Oruanui Tephra is also inferred as a cryptotephra within a well-developed podzolised soil capping the moraine that marks maximum local ice extent at Lake Tennyson. Inboard recessional moraines mark glacier (and presumably climate) variations during the early part of the last termination through to ~17.1 ka. Replicated cosmogenic ages on the cirque sill of Princess Bath suggest ice had mostly evacuated the catchment by 11.2 ka. Sediment cores change from inorganic to organic sedimentation following small tree and shrub expansion at the expense of herbs prior to 10.5 ka cal BP. Beech (*Fuscospora*) pollen has been present since prior to 10.5 ka, and has been elevated for at least the last 1000 years. Relatively high sedimentation over the last millennium suggests a bi-decadally resolved record could be obtained at this site.

Lake Ohau Climate History (LOCH) project: A 17,000 year-long annually-resolved paleoclimate record to decipher high frequency climate change in Southern New Zealand.

Vandergoes, M.,[1] Dunbar,G.,[2] Levy, R.,[1] Howarth, J.,[3] and the LOCH team

[1] GNS Science, Lower Hutt, New Zealand

[2] Antarctic Research Centre, Victoria University of Wellington, New Zealand

[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand

https://geodiscovery.gns.cri.nz/Geodiscovery/On-Land/In-Lakes/Lake-Ohau-Climate-History

Geological records that span millennia yet still capture paleo-environmental information at seasonal-annual resolution can make an important contribution to understanding the spatial and temporal variability of climate processes that vary at high frequency, such as the Southern Annular Mode (SAM), El Niño Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO). However, such records are scarce and are particularly rare in the southern hemisphere. Sediment cores up to 80m long recovered from Lake Ohau, New Zealand as part of Lake Ohau Climate History (LOCH) project yield mm-scale laminated sediments representing annually-resolved accumulation in the lake basin from ~17,000 years before present to today.

We outline continuing developments from the LOCH project, including radiocarbon and layer count chronology, the results of physical properties core scanning and the development of biological indicators of lake productivity, as well as palynological reconstructions of temperature change. We highlight the potential of the complete 17,000 year long record to decipher annual to centennial-scale climate variability in southern New Zealand and the mid-latitudes of the Southern Hemisphere.