New Zealand Paleoclimate

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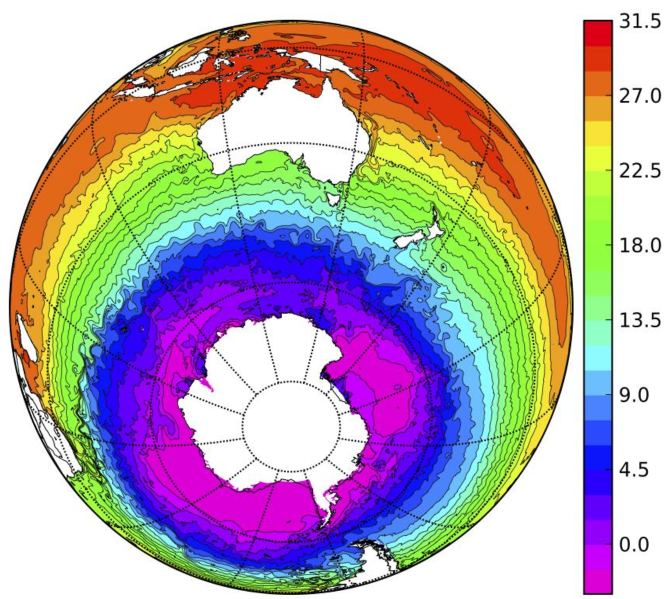
CE 394K
GIS in Water Resources
Fall 2012

INTRODUCTION

The role of southern hemisphere climate patterns in regional variability, particularly in respect to past climate and connection with northern hemisphere processes. The mid-latitudes of the southern hemisphere, particularly New Zealand, provide an ideal location for assessing changes in these large circulation patterns, both in modern climate and in the past. The NZ-INTIMATE climate project has led to creation of records of myriad types, including speleothems, lake sediments, glacial moraines, pollen assemblages, and fjord sediment flows, all geared towards creating a climate stratigraphy of the southern hemisphere. The vast majority of the evidence points to several major controls on regional climate, particularly the southern westerly winds. The community is beginning to focus more on the creation of high resolution records that will record changes in these large patterns, and allow intercomparison between both other southern records and the northern hemisphere climate system.

The mid-latitude climate of the southern hemisphere remain relatively poorly understood, in large due to the lack of major terrestrial landmass. New Zealand provides one of the best areas for the creation of paleoclimate records due to both its' position and its' myriad environments that allow for the preservation of many different types of signals. Thevolcanic crater lakes of the north island provide a unique opportunity for the creation of a long-term, high-resolution climate record.

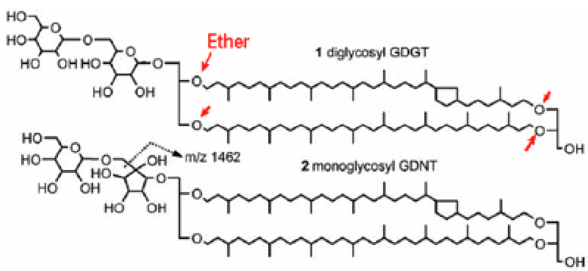
Figure 1. Southern Hemisphere Sea Surface Temperature (C) showing position of New Zealand

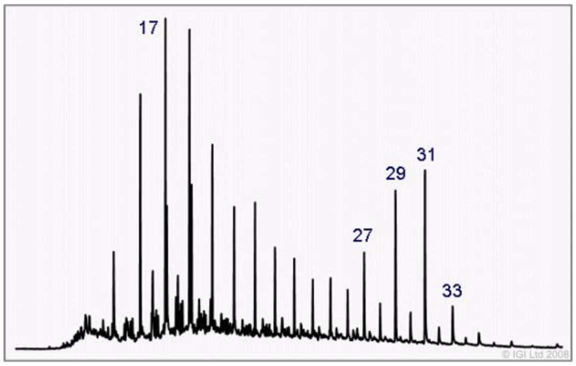


APPROACH AND RESULTS

The UT Paleoclimate research group focuses on the use of organic biomarkers to characterize past climate and environments. The New Zealand project relies on two in particular- isotopic composition of n-alkane leaf lipids and glycerol dialkyl glycerol tetraethers (GDGT). These two methods provide quantitative information about past precipitation and temperature variability, respectively (**Schouten et al, 2012)**.

Figure 2. GDGT molecular structure and gas chromatograph of n-alkane elution





Lake Pupuke is a volcanic maar lake located north of the city of Auckland, New Zealand. Lakes of this type are relatively deep, leading to anoxic conditions and sediment preservation. The low accumulation rate has allowed for the preservation and subsequent recover of over 55,000 years of sediment, which will be analyzed at the UT Paleoclimate molecular laboratory for both n-alkanes and GDGTs. In order to help understand the drivers of past precipitation and temperature variability, the modern climate and its' drivers must be characterized.

Figure 3. Lake Pupuke, looking westward

This study consisted of multiple components: Creation of a DEM and ocean basemap, import of climate station locations and associated data, interpolation of precipitation and temperature time-series maps from station data, and calculating a qualitative deuterium/hydrogen isotope map from precipitation. Data for this project comes from several key sources: Shuttle Radar Topography Mission (SRTM) elevation data from NASA and the USGS, meteorological station data and shapefiles from New Zealand NIWA and GNS Science, and data from our collaborators at NZ-INTIMATE **(USGS, NIWA, GNS Science, Atkin 2011).**

The SRTM raw elevation data was imported to ArcGIS 10 and symbolized with an appropriate color-ramp. This was combined with ocean bathymetry data from NOAA's ETOPO2 database to create a basemap for the climate analysis and future publications involving our work **(Figure 4).** The locations of climate stations used for interpolation and analysis are given by black circles.

CLIMATE INTERPOLATION

NIWA climate stations provide monthly precipitation, temperature, humidity, and many other paramaters. For this study, only precipitation and temperature were used. The mean annual air temperature and average monthly precipitation were calculated for both the north island and south island using a Krige interpolation. The krige was set as an universal krige with semivariogram model and a point range of 12. The interpolated temperature and precipitation maps reveal an overall warming trend to the north, and a north island with little precipitation distribution but a south island with a strong precipitation trend coinciding with the highest elevations of the Southern Alps. The south island receives overall higher precipitation than the north island, but the west coast sees precipitation in excess of 300mm/month **(Figure 5 and 6).**

The monthly precipitation was then interpolated for both the north and south island, using the same krige method as described above. In order to speed the process, a model was created using ArcGIS model builder. This model moves through the z-field of the climate station attribute table (whether temperature or precipitation), and creates a krige interpolation raster for each month found (January-December). This raster

Figure 4. SRTM 90m DEM of New Zealand

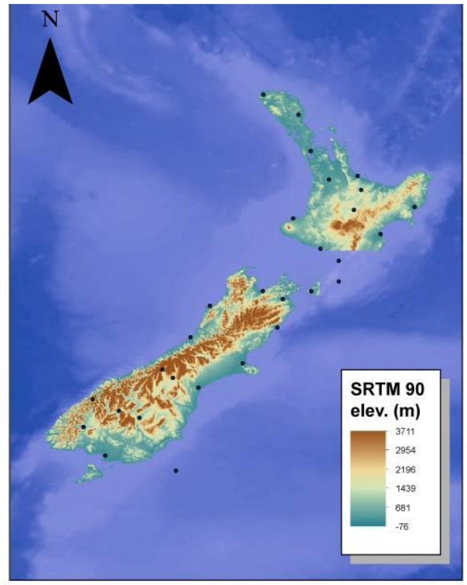


Figure 5. Mean Annual Air Temperature

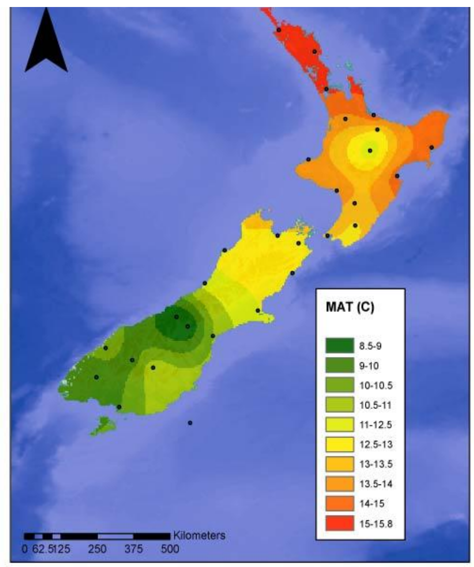
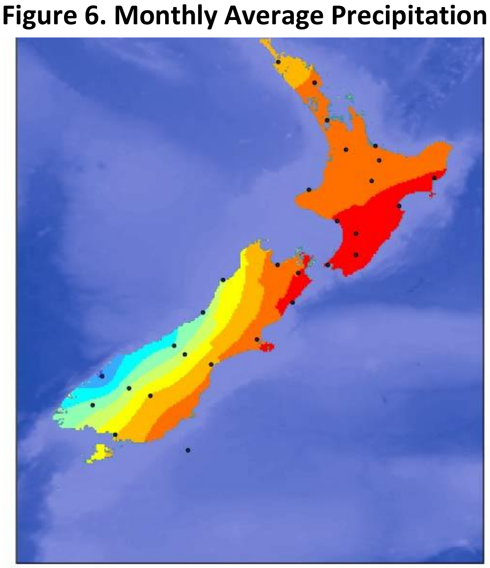


Figure 6. Monthly Average Precipitation



is then subject to an extract by shape tool, to provide the terrestrial precipitation for each month **(Figure 7 and 8).**

Figure 7. ArcGIS Model of Precipitation Interpolation

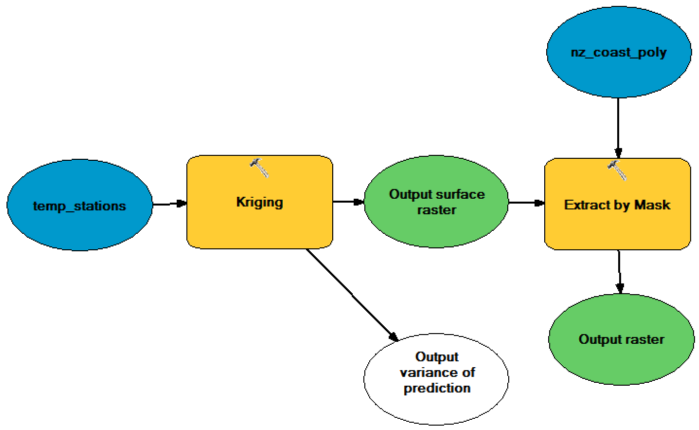


Figure 8. Precipitation Interpolation Time-Series

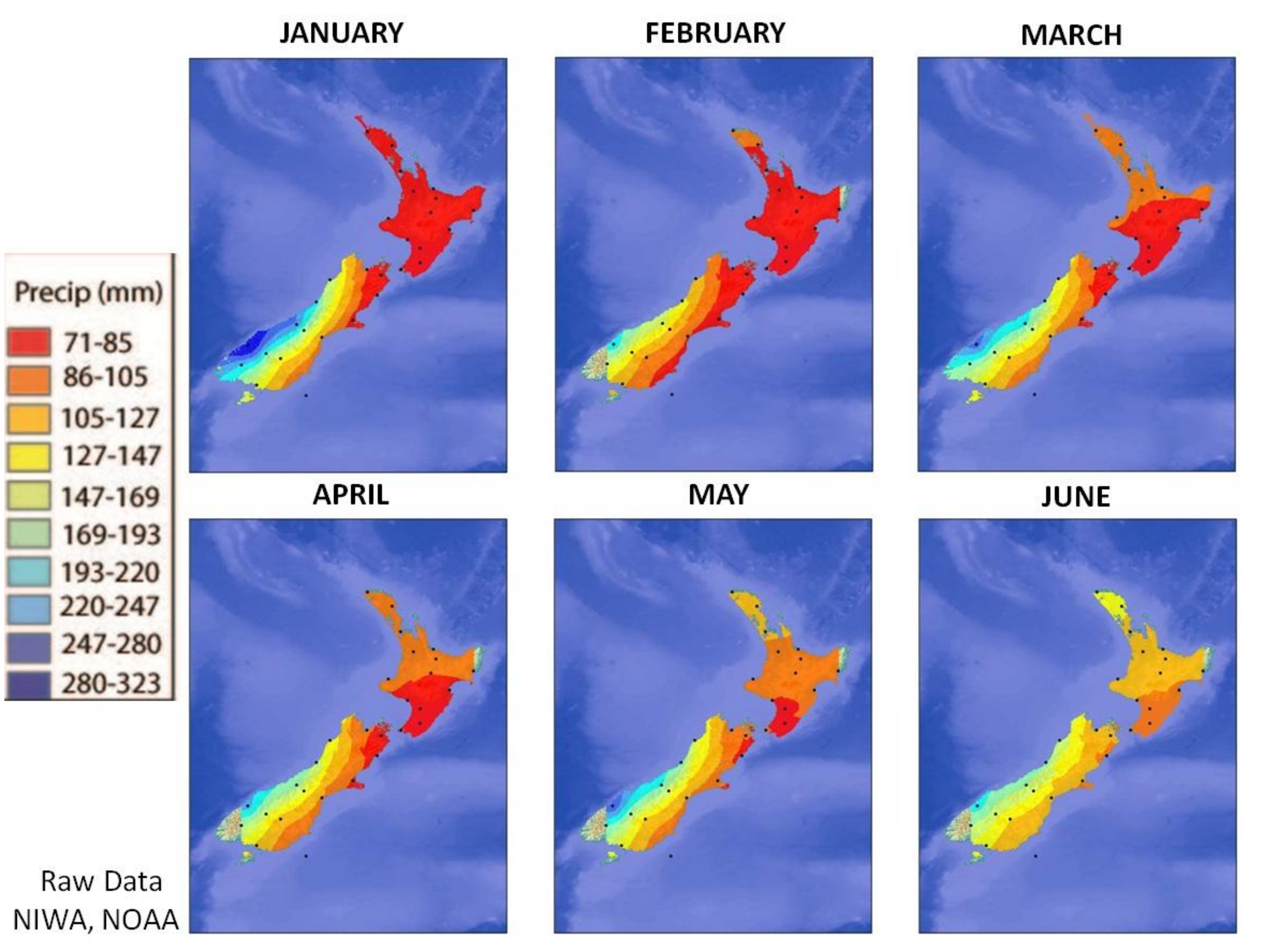
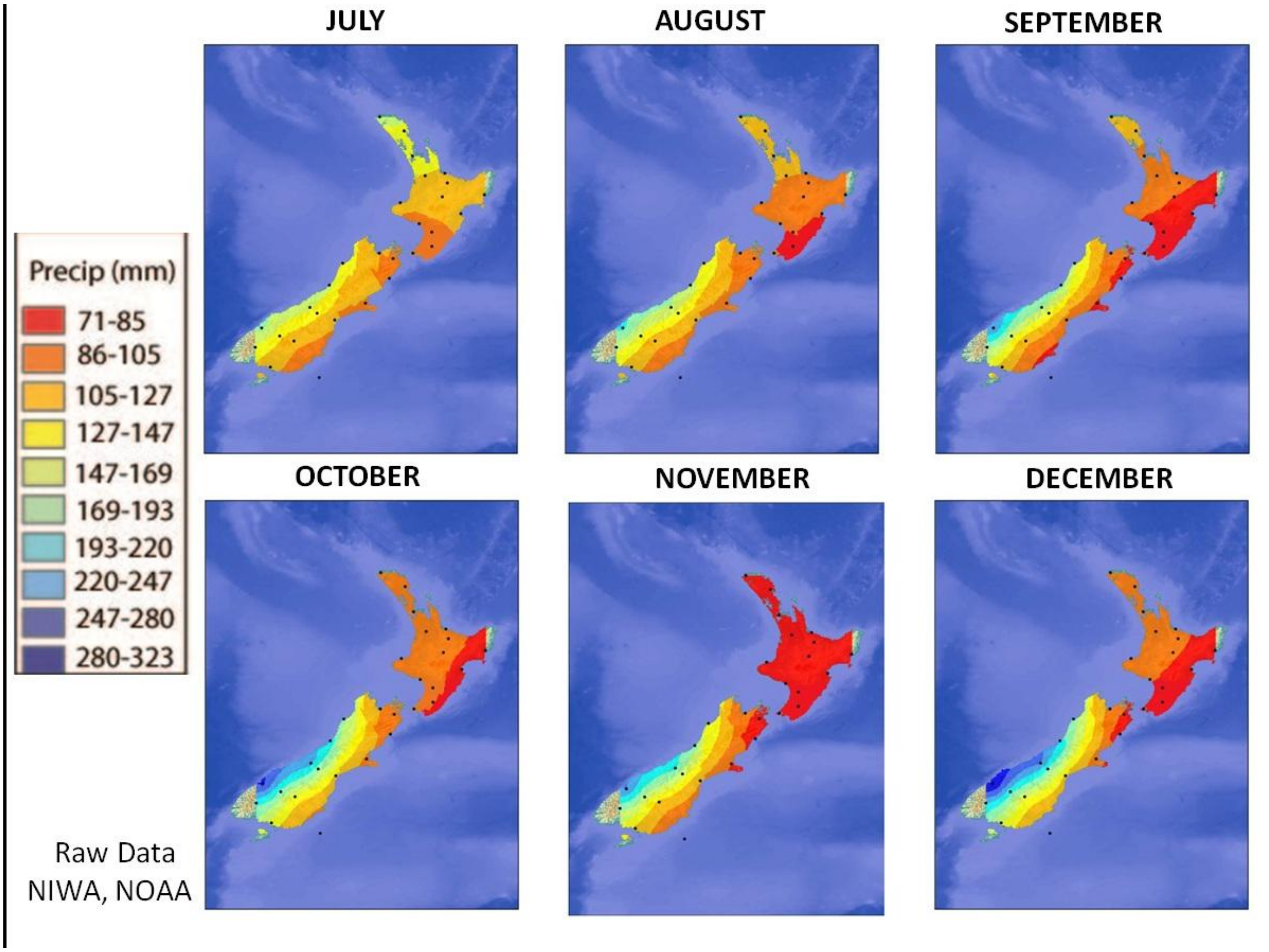


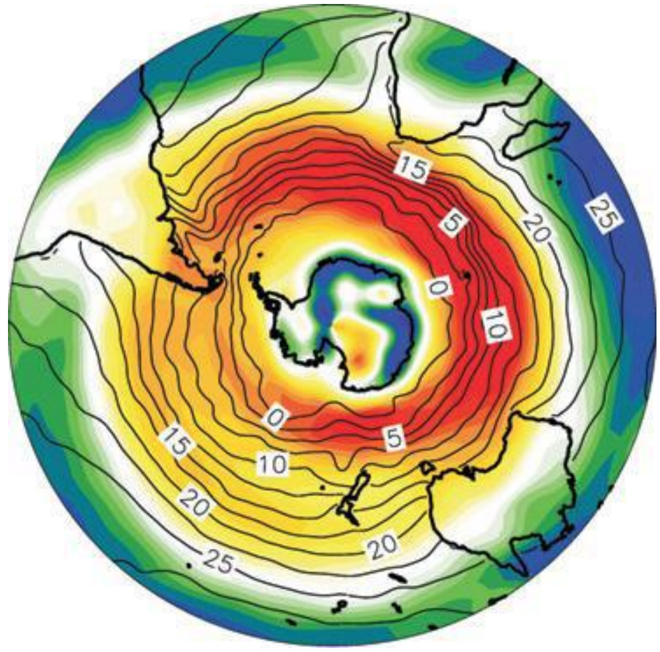
Figure 8. Precipitation Interpolation Time-Series, contd.



This series of precipitation maps indicates a distinct seasonal variability of New Zealand precipitation. During the Austral summer (December-February), the north island receives between 70-100mm/month, while precipitation maximum in the south island reach well over 300mm/month. In the Austral winter (June-August), the north island reaches almost 150mm/month, while the precipitation maximum of the south island lowers to the 160mm/month range. The precipitation patterns of the south island clearly coincide with the location of the southern alps, while the north island is much more homogenous. This provides evidence for a phasing between the two islands, when the north island receives maximum precipitation the south island reaches a minimum, and v.v.

The main climate driver in the mid-latitudes of the southern hemisphere is the westerly winds, which sit just to the south of the southern island (**Lamy et al, 2010).** This atmospheric

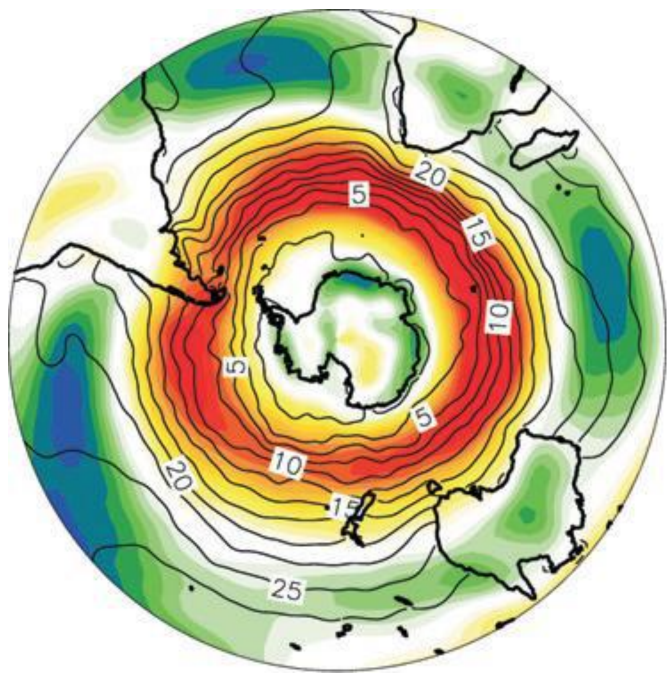
Figure 9. Austral Winter Westerly Position and Strength



circulation pattern provides the major source of moisture to this region, and fluctuations in its' position and strength appear related to the precipitation variability seen in New Zealand.

During the Austral winter, the westerly winds expand to the northward but weaken in strength, and the reverse occurs during the summer. This explains the phasing relationship seen in New Zealand precipitation. The south island is always influenced by the westerly winds, but the north island only receives moisture from this source when they expand northward in winter conditions. This expansion coincides with a weakening, however, and thus reduces precipitation in the southern island (**Figures 9, 10).**

Figure 10. Austral Summer Westerly Position and Strength



By using the modern summer and winter precipitation patterns as archtypes, this relationship can be used to interpret the molecular paleoclimate record being developed currently for Lake Pupuke. A winter-type southern hemisphere (low average temperatures) should see an expansion northward of the westerly winds, and thus increased precipitation in the north island. Conversely, a summer-type southern hemisphere (high average temperatures) would see a contraction and strengthening of the westerlies, leading to a dry climate in the north island.

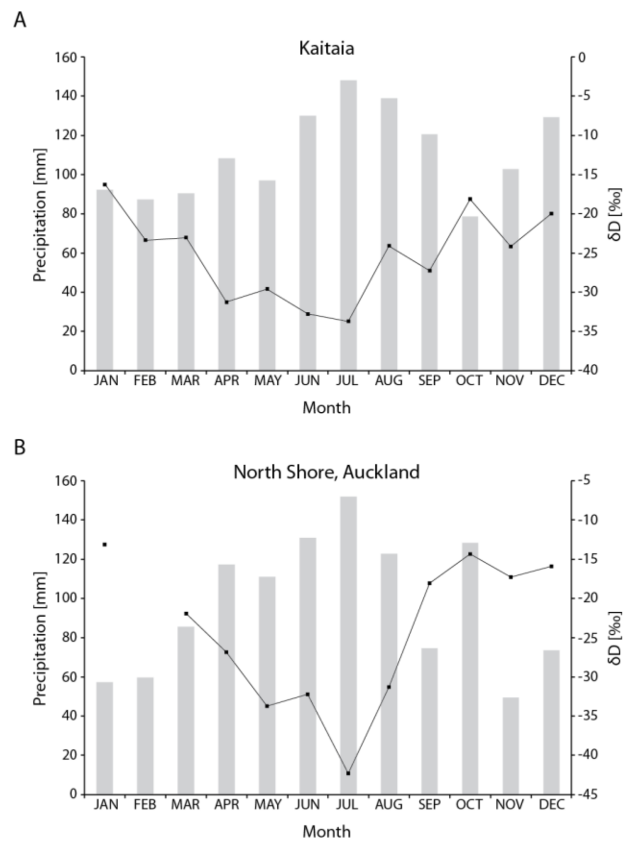
ISOTOPE INTERPOLATION

As mentioned before, past precipitation variability can be determined by analysis of the isotopic composition of n-alkane compounds, particularly their deuterium isotopic ratio (dD). dD can vary based on either temperature or precipitation (kinetic fractionation or the amount effect) and so it is important to understand the nature of the control in the modern system. Using precipitation station data combined with isotopic analysis of water collected at that exact point, a dD/precipitation relationship can be developed (**Figure 11, Frew unpublished).**

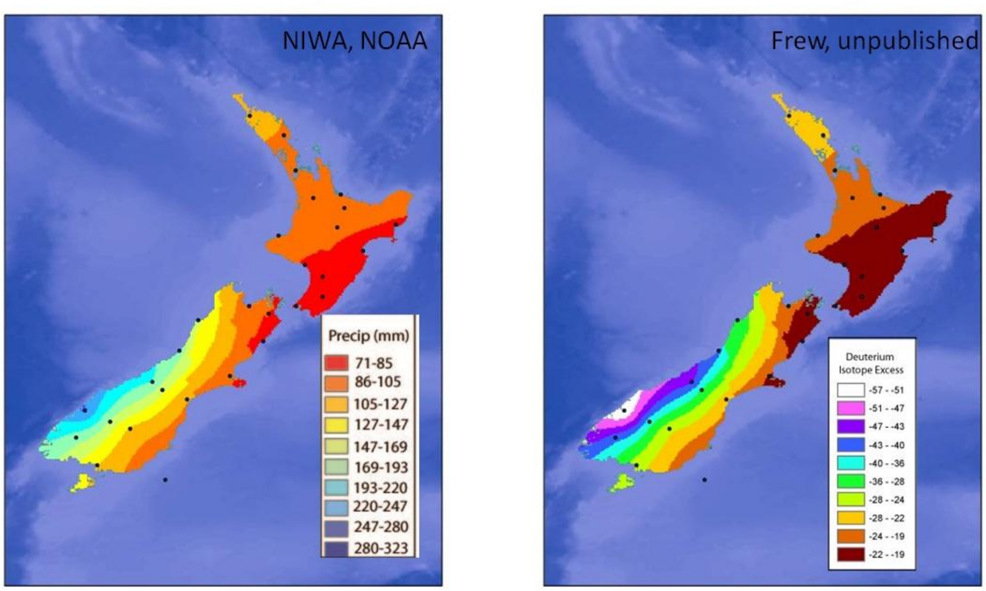
The results of this analysis is an precipitation control, or "amount effect". As precipitation increases dD becomes more negative, or more depleted. This relationship will allow analysis of the downcore record as it is completed.

This relationship can be used in conjunction with the previously described precipitation maps to interpolate a predicted dD map of New Zealand, which may aid in future climate studies. By first developing a polynomial equation using MATLAB, the equation can then be applied to the precipitation raster using Raster Math to create an interpolated dD map (**Figure 12).**

Figure 11. dD and Precipitation relationship from North Island station



Precipitation and dD relation



Monthly Average Precipitation

Interpolated dD

CONCLUSIONS AND FUTURE WORK

The New Zealand basemap will provide the basis for future paleoclimatic reconstructions in New Zealand, such as landscape analysis and dominant vegetaton types. The interpolated climate maps provide compelling evidence for the westerly winds as the major driver of precipitation over New Zealand, and using these maps in conjunction with statistical analysis will allow a climatic "fingerprint" to be created and applied in the interpretation of our downcore record. Both precipitation and temperature will be reconstructed, using n-alkanes and GDGTs, for the last 55,000 years at approximately 100 year resolution. This will allow for large-scale climate fluctuations of the type significant enough to shift westerly wind position to be seen and interpreted in the context of global climate. Major future GIS work to be completed includes a re-interpolation of the precipitation data, using a PRISM-type method that uses topography to inform the analysis and produce more realistic results.

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