Detection of human and natural influences on the climate system: regional insights from the past Millennium

1 Summary

Understanding the mechanisms of climate variability is essential for reliable projections of future climate change and thus to develop appropriate mitigation and adaption policies. However, to understand climate variations on decadal and longer timescales, the influence of different climate forcing factors needs to be known, regionally and globally. Climate forcing factors can be external (e.g. solar irradiation, volcanic eruptions and greenhouse gas concentrations) or internal atmospheric-oceanic circulation features such as the El Niño–Southern Oscillation (ENSO). Although state-of-the-art climate models have been used to project future regional and global climate change, it is still unclear how reliable regional dynamics, spatial patterns, and sensitivities to external and internal forcing factors are captured. The main obstacle in evaluating and constraining these model simulations is the lack of globally consistent and reliable spatially explicit (gridded) multi-centennial multi-proxy reconstructions of climate variability required to validate model performance at continental and regional scales. Most of the existing reconstructions focus on the Northern Hemisphere, with very preliminary regional to hemispheric reconstructions available from the Southern Hemisphere. However, instrumental data over the last 150 years have shown significant differences in climate variability and response to forcing between the two hemispheres, demonstrating that information from the ocean dominated Southern Hemisphere is required to improve our understanding of the global climate system.

This project aims to advance the quantification and understanding of climate variability over the last Millennium through three complementary goals: i) improving the availability of reconstructions from the Southern Hemisphere, ii) formally attributing changes in past temperatures on hemispheric and global scales to external and internal forcing and iii) evaluating the influence of large-scale circulation on regional climate and the temporal stability of these spatial relationships (teleconnections).

**Aim 1:** The first phase of the proposed project will fill the existing gaps in Southern Hemisphere temperature reconstructions by developing a 1000-year gridded (5°x5° spatial resolution) reconstruction with new datasets. State-of-the-art ensemble-based statistical techniques will be applied to generate robust, annually resolved reconstructions. The results will improve our global understanding of inter-annual to multi-centennial climate dynamics.

**Aim 2:** Within the first formal “Detection and Attribution” study for the Southern Hemisphere using multi-centennial reconstructions and model simulations, key drivers of decadal to centennial temperature variability will be identified. The aim is to not only quantify the influence of human activity on climate variability, but also assess the relative importance of different natural driving factors during pre-industrial times. The results are essential for constraining estimations of the climate response to continuing anthropogenic emissions.

**Aim 3:** The outcomes of Aim 1 and 2 will then be systematically analysed during periods of anomalous temperatures over the last millennium in reconstructions and model simulations. The spatial patterns of these anomalies will be compared to important global modes of climate variability (such as ENSO) and the temporal stability of these relations will be assessed. This will allow identifying the mechanisms leading to regionally contrasting or coherent temperature patterns. The results will provide ground-breaking insights into long-term variation of the climate system, model versus proxy coherence, and help to identify the next generation of research priorities needed to reduce uncertainties associated with past and future climate variability.

The proposed project will produce a benchmark data set with very high expected impact and provide insight into regional climate variability in the global context. This is particularly relevant as regional, not global, climate data are required to quantify the direct impacts of future climate on societies, economies and the environment. This project will deliver constraints from the past, which will be a significant step towards reducing uncertainty associated with predictions of future climate change and its impacts, providing real opportunities to help inform future climate change adaptation and mitigation strategies.