Kurt Lambeck

Emeritus Professor at the Australian National University

2012 Balzan Prize for Solid Earth Sciences, with emphasis on interdisciplinary research

For his exceptional contribution to the understanding of the relationship between post-glacial rebound and sea level changes. His findings have radically modified climate science.

Institution Administering Research Funds: Australian National University

Adviser for the Balzan General Prize Committee: Enric Banda

Sea-level Change during Glacial Cycles

Sea levels have changed throughout the Earth's history, and have impacted on the movements of species between land masses, including human movements over the more recent period of the past 100,000 or so years. The causes include tectonic and climate processes, and over the past million years it is the latter, with the cyclic growth and decay of the great ice sheets, that has been most important. Understanding how sea level has changed helps understand the fundamental processes that have shaped the earth through time. It is a truly interdisciplinary area of research involving the disciplines of solid-earth geophysics, geology and geochemistry, underpinned by physics and mathematics, with implications for past climates and human pre-history. The research component of the Balzan Prize addresses some important elements of this broad subject.

Research Themes

1. *Geophysical modelling of interactions between ice sheets, the solid earth and sea level*. When ice sheets melt or grow, they stress the earth and change the gravity field, which together leads to a complex spatial pattern of sea level change. Modelling of these interactions rests on a number of hypotheses that need testing, something that is now possible because of both enhanced computational facilities and observational data. Numerical modelling developments include refinement of

our models through improved characterisation of the Earth's rheological parameters and improved inversions of field data for inferring the ice sheet history. One of the goals is to develop a version of the numerical models suitable for use by 'non-experts' so as to make the methodology available to geologists and archaeologists. Another goal is to develop the next iteration of ice sheet models with a particular focus on the Antarctic ice sheet, which up to now has played a rather passive role in the discussion of past sea levels, despite it being important in assessing the future of this ice sheet in a framework of a warming planet. Other targets include an improved ice sheet model for southern Greenland and improvements in the North American ice sheet model. These models provide improved reference points for testing climate models under conditions very different from today as well as the basis for palaeogeographic reconstructions during recent glacial cycles to explore possible constraints on human migrations.

2. *Past interglacials as analogs of the present interglacial*. The past interglacials that occur about every 110,000 years are periods when climate was similar to today and sea levels were close to present-day values. The last interglacial is particularly important because its traces are best preserved in the geological record. Its climate was similar to today, but possibly a few degrees warmer, and sea levels were 4-6 meters higher than today. But the precise timing of this occurrence and any variability within the interglacial interval remains poorly constrained. Yet this information is important in the context of current climate change debate for understanding the sensitivity of ice sheets to changes in temperature. Field sites from which we have preliminary information include: Western and Northern Australia, the Seychelles and the Mediterranean. Earlier interglacials will also be examined, including the Pliocene (~ 3 million years ago), when the global glacial-interglacial cycles were markedly different from those of the past 800,000 years.

3. *The present interglacial (the Holocene)*. Ocean volumes have remained approximately constant during the past 6000 years, but periodically the argument arises that large amplitude (1-2 m) changes have occurred within relatively short time periods (a few hundred years). If correct, this has major implications for the instability of the climate system when the planet is not in an ice age. There are many reasons why this question remains debated. One is of the nature of the observational evidence. Another is land movement caused by tectonic and global dynamic processes. A third is the ongoing interaction between the past ice sheets and the solid earth and oceans. We

address these issues to arrive at what should be a definitive answer to the question of sea-level (and hence climate) stability or instability during interglacial periods.

The Research Plan

The funding has enabled a research associate to be appointed for 2 years at the Australian National University (ANU) to work on the modelling aspects of the various components of the earth-ocean-ice system. The appointee, Dr Anthony Purcell, has experience in this research area, so as to build on past work. A second appointment of a Post Doctoral Fellow, Dr Hélène Rouby, has been made together with the École Normale Supérieure (ENS) in Paris to work on the analysis of sea-level data to develop high-resolution models for sea-level change in low- and mid-latitude regions. This is part of a longer-term proposal to transfer the ANU software and experience to ENS for use by French researchers and to introduce a more complex mantle rheology into our models.

Support has also been provided to Ms Ye-Ying Sun from the University of Hong Kong (UHK) to work as a Balzan Student at the Australian National University (ANU) during 2013 compiling and analyzing sea-level data from South East Asia, from Malaysia to Japan, and learning the elements of geophysical modelling. This work is significant for both the global studies and for examining the past subsidence rates of the large east and southeast Asian river deltas. Contributions to two field projects have been made to permit students to extend their PhD work. One is a project with Ms Brigid Morrison from the University of Tasmania to collect further core samples from sites in Tasmania, and to provide radiocarbon dating to examine the rise of sea level during the past 7,000 years. The significance of this study is that it may answer questions about the role of Antarctica to the global sea level change since the last glacial maximum. The other project has provided support for PhD student Belinda Dechnik from Sydney University to participate in fieldwork in the Seychelles that examines earlier interglacial reefs that are now above sea level. These projects focus on specific scientific targets that bring together young and experienced researchers in selected field environments, in the requisite laboratory methods and in computational methods. Further field projects involving young researchers in Australia are being examined and will be gradually introduced over the next two years.

Sea level is an important component of the four-yearly Intergovernmental Panel on Climate Change assessment of the science of climate change. The Final Draft of the Working Group 1 report was delivered in May 2013. It highlights many of the important questions for which better answers are required. It is expected that through research inspired by the Balzan Foundation, the project will contribute significantly to providing useful answers.

Researchers
Belinda Dechnik
Brigid Morrison
Anthony Purcell
Hélène Rouby
Ye-Ying Sun