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Submission to Joint Standing Committee on Treaties:
Inquiry into the Kyoto Protocol.

from Research School of Earth Sciences
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The Kyoto Protocol to the United Nations Framework Convention on Climate Change is an international response to concerns which arise directly from scientific observations, scientific understanding and scientific predictions. In the Inquiry into the Kyoto Protocol, the Joint Standing Committee on Treaties is concerned with the scientific basis, in particular the scientific evidence and inferences that changes in the earth's atmospheric composition due to human activities will lead to global warming which is likely to impact on physical, biological and social systems in non-trivial ways.

The Research School of Earth Sciences (RSES) is part of the international community of scientists which is undertaking research on the Earth's Climate, the global carbon cycle, sea level change, and on changes in ocean temperatures. It is from the perspective of these scientific studies that we make this submission.

The Earth's Climate has varied over the past 1000 to 5000 years (urban civilizations) and over greater extremes over the past 60,000 years (aboriginal continuity in Australia) and through earlier human evolution. The study of past climates requires a variety of dating techniques, a variety of datable records which are sensitive to climate and which retain 'frozen in' evidence of a climate-related variable, and a regional sampling which contributes to a global picture, including regional climate variations. At ANU, dating techniques include carbon-14 by scintillation and accelerator mass spectrometry methods, uranium-thorium disequilibrium series dating, electron spin resonance and optically stimulated luminescence dating, cosmogenic isotope (exposure-age) dating, and noble gas dating methods. As part of the Institute of Advanced Studies at the Australian National University, RSES is expected to conduct research at the international 'leading edge'. In development and applications of these dating techniques to quantifying global change, the publication record of the school shows that RSES is achieving this international leadership in methodologies and pioneering studies.

The inquiry, in the second dot-point of its terms of reference, appears to demand a level of certainty in the knowledge and understanding of past and future climate which may be achievable given sufficient work, but is certainly not the current situation. There are insufficient numbers of scientists and research students and insufficient project funds to provide results and 'answers' on climate change or its impacts at the rate apparently demanded by the wider community.

The statements to the JSCT Inquiry which follow are 'authoritative' in the sense that they are made by well-established scientists active in leading edge research on the natural variability of climate BUT the statements are also in the nature of 'work in progress' emphasizing how much remains to be done to achieve region-specific predictions for different regions. The following paragraphs summarise scientific research which addresses the second dot-point of the Terms of Reference for the Inquiry. They are illustrative of the scientific research that is necessary to establish "The veracity of conflicting scientific theories on global warming and any solutions proposed for it." It should also be recognised that climate processes have regional variability and scientific communities address this aspect as well as global synthesis.

On Global Warming caused by Atmospheric Change due to Human Activities (Particularly increased $CO_2$ & $CH_4$ from fossil fuels)
Firstly, the nature and methods of 'Greenhouse Science' are the same as for all other branches of natural science and technology that underpin modern society. The climate system is so complex that the development of detailed climate models must pass through many steps. Different groups address different aspects, progress and results are shared and models improved. Despite different emphases, models from all classes from simple energy balance models through to complex coupled ocean/atmosphere models agree in predicting that rising levels of atmospheric greenhouse gases lead to global warming. The average global warming predicted by newer and more comprehensive models is 2.2-3.0•C by 2100AD. We do not yet have the ability to make the confident regional predictions desirable for national adaptation responses. Historical records and geological evidence from coral growth layers, sediments, ice-cores and biological evidence from tree-rings show that global warming over the past 200 years is real and different from natural variability experienced over the past 1000 years.

On Palaeoclimate Reconstructions – the last 1000 years:
During the last decade there has been a concerted effort to produce a global set of high-resolution, chronologically controlled, palaeoclimate reconstructions to define the envelope of natural climate variability, against which anthropogenic impacts on Earth's climate may be assessed. An important focal point in palaeoclimatology is the tropics because of the potential links between tropical sea-surface temperature, atmospheric water vapour, and the global hydrological cycle. Massive corals growing in the reef ecosystems of the tropics provide rich palaeoclimate archives and geochemical records extracted from their skeletons are yielding new insights into tropical palaeoclimates. Worldwide, 10 well calibrated coral-based climate records extending back to at least the mid 1800s (and some to the 1600s) have been published in the scientific literature (Gagan et al., 2000). Eight of the records show a warming and freshening trend toward the 20th century, based on studies of the oxygen isotopic composition ($^{18}O/^{16}O$) in the coral skeletons. With the exception of one record from the tropical eastern Pacific, those spanning more than 200 years indicate that the warming / freshening trend began during the 19th century. If the shift in $^{18}O/^{16}O$ is due entirely to warming of near surface ocean water, it is equivalent to 0.3 to 2ºC (depending on the location) since the early 1800s

The pattern of warming / freshening in the tropical near surface ocean water indicated by the coral $^{18}O/^{16}O$ records is consistent with recent mid and high latitude temperature reconstructions suggesting that the 20th century could be the warmest of the millennium (Mann et al., 1998; Crowley, 2000). Recent reconstructions of Northern Hemisphere temperatures and climate forcing over the past 1000 years allow the warming of the 20th century to be placed in a historical context and various mechanisms of climate change to be tested. Comparisons of palaeoclimate reconstructions (corals, tree rings, ice cores) and climate model simulations indicate that about one-half of the preanthropogenic (pre-1850) temperature variation was due to changes in solar irradiance and volcanism. Removal of all climate forcing mechanisms, except greenhouse gases, from the 1000 year record results in a large residual of 20th century warming. The unique level of temperature increase in the 20th century over this time-scale provides further evidence that the greenhouse effect has already established itself above the level of natural variability in the climate system.

On Evidence for Past Climate, Warmer than the Present Climate:

The global climate change debate has led to renewed interest in analyzing corals that grew during times within the past 100,000 years when the Earth was warmer than today, or was warming rapidly. An important issue within the global climate change debate is whether the temperature of the tropical ocean is regulated, through negative feedbacks, close to the temperatures observed today. Palaeothermometry data extracted from fossil biogenic carbonates (corals, planktic foraminifera) offer the opportunity to investigate the potential of the tropical ocean to warm. Recent Sr/Ca palaeotemperature reconstructions from corals from the Australian Great Barrier Reef, Papua New Guinea, and Indonesia for a time-slice centred on ~6000 years ago all show that the tropical ocean surface was ~0.5 to 1ºC warmer than the temperatures reached by the early 1990s (Gagan et al., 1998). This result has also been inferred from Mg/Ca palaeothermometry on planktic foraminifera from deep-sea cores off northwest Australia; which indicates maximum warming of up to 1.5ºC at ~6000 to 7500 years ago. Although the exact mechanism driving the warming is not known, the result is important because it suggests that the temperature of even the warmest portion of the tropical ocean is not limited to the temperature we observe today.

The other unexpected observation is that the $^{18}O/^{16}O$ ratios in both the corals and foraminifera indicate that, together with the warming, evaporation evidently increased leading to significant drying of the northern Australian region. This is, in fact, a result predicted for the Australian sub-tropics by some general circulation models as a consequence of increased tropical temperatures. Although these climates of the past are not perfect analogues for a $CO_2$-warmed Earth, such records certainly yield perspectives on the potential for the tropics to warm, and the patterns of climate change on a regional scale. Further research will seek to establish the climate characteristics of other parts of Australia in this warm period in the expectation that the past behaviour of regional climate will act as a check against climate model predictions and an indicator of possible future scenarios for Australia.

Recent Relevant References:

Crowley, T.J. (2000). Causes of climate change over the past 1000 years. *Science*, 289, 270-277.

Gagan, M.K., Ayliffe, L.K., Hopley, D., Cali, J.A., Mortimer, G.E., Chappell, J., McCulloch, M.T. and Head, J.M. (1998). Temperature and surface-ocean water balance of the mid-Holocene tropical western Pacific. *Science*, 279, 1014-1018.

Gagan, M.K., Ayliffe, L.K., Beck, J.W., Cole, J.E., Druffel, E.R.M., Dunbar, R.B. and Schrag, D.P. (2000). New views of tropical palaeoclimates from corals. *Quaternary Science Reviews*, 19, 45-64.

Mann, M.E., Bradley, R.S. and Hughes, M.K. (1998). Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*, 392, 779-787.

On the Carbon Cycle and Potential for enhanced Carbon sinks:

The increase in greenhouse gases observed in the atmosphere and the attribution of this to industrialised human society, and particularily to burning of fossil fuels, is not seriously questioned. However the carbon ($CO_2$ and $CH_4$ principally) in the atmosphere is exchanging with major reservoirs of the terrestrial biosphere, the oceans (including marine biosphere) and the soils/lithosphere. Predictions of future greenhouse gas concentrations require knowledge of exchanges between these reservoirs and future strategies for mitigating the effects of rising CO2 concentrations include the possibility of enhancing the uptake of greenhouse gases particularily in the terrestrial biosphere (plants & soil) and marine biosphere.

The cycling of carbon through the terrestrial biosphere is currently very poorly constrained. This is due to the ecological, regional and temporal heterogeneity of the terrestrial environment under different land-use and to uncertainties in the ways in which global atmosphere and climate change will affect the carbon cycle at regional level. Over the past decade, work on carbon contents and turnover rates under different land-use practices, including forestry, have substantially reduced uncertaintities in greenhouse gas emissions and sinks. The magnitude of carbon sequestration in Australian soils remains a major question in attempting to manage land-use.

Australia's current position in international negotiations, including the Kyoto Protocol, is heavily reliant on arguments that seek to offset increased energy usage (with attendant CO2 releases) in Australia by increasing the capacity of the terrestrial biosphere to sequester carbon. The capacity to manage total greenhouse gas emissions by changes in land management, combined with changes in other sectors, must be rigorously and transparently underpinned by peer-reviewed scientific monitoring. Research methods will use sophisticated carbon extraction techniques, isotope measurements and adequately controlled experiments and significant results will come from the work of the Carbon Accounting CRC. In terms of "solutions" to the "Greenhouse Effect", there is no ready "fix" through carbon sequestration in Australia's biosphere but this approach should be one of Australia's responses to the issue.

On Sea-level Change:

Sea-level is one of the measures of climate change, dramatically evident in the contrast between Glacial and Inter-Glacial Epochs, alternating on ~10,000 to 100,000 year time scale. On these time scales, it is the growth and decay of the ice-sheets that is the dominant cause of sea-level change. With the near stabilization of the ice-sheets for the recent past, other factors become significant and the reasons for global change of sea-level today include changes in land-based ice-sheet volume, changes in terrestrial water storage (groundwater, lakes, reservoirs, permafrost etc) and warming (thermal expansion) of the upper layers of the ocean. The IPCC 2001 draft report concludes that sea-level has risen at a rate of 1.5 $\pm$ 0.5mm/year , globally, over the past 100 years. Sea-level change in the preceding century (1800-1900) was less than this. Sea-level change is not uniform across the globe, varying with extent of regional warming of near- surface ocean waters and with local or regional 'geophysical' effects due to solid-earth behaviour. On the Australian coastal margins, the background geophysical trend is of falling sea-level of 1-3m over past 6000 years, (Lambeck and Nakada, 1990) which provides the background rates against which anthropogenic effects are measured (Lambeck, 1990) The national tide-gauge network measures the combined effect of this 'natural' change and any post-industrial anthropogenically induced change. For Australia, the observed sea-level rise over the past 50 years lies below the global average.

Although the scientific understanding of causes of sea-level change is well-developed, the data-bases necessary to precisely quantify rates of sea-level change are incomplete and must have good regional coverage. Estimates of future change are based on models which are complex and incomplete – nevertheless, the models predict a sea-level rise through the 21st century as a result of atmospheric $CO_2$ increase, the predicted rise between 20 and 70cm (for the century) as a global average.

A final significant observation derived from accurate dating of past sea-level indicators, is that some changes of sea-level have been extremely rapid, for example, as a consequence of a rapid decrease in ice-volumes by about 10% over a few hundred years at the last glacial maximum (Yokoyama et al 2000) at 19000 $\pm$ 250 years before present. We do not yet know if there have been similar very large and rapid shifts in sea-level during or at the end of an interglacial period.

Reference:

Lambeck, K.(1990) Late Pleistocene, Holocene and present sea-levels : constraints or future change. Palaeogeography, Palaeoclimatology, Palaeoecology, 89, 205-217.

Lambeck, K. and Nakata, M.(1990) Late Pleistocene and Holocene sea-level change along the Australian coast. Palaeogeography, Palaeoclimatology, Palaeoecology, 89, 143-176

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Concluding Statement:

This submission to the JSCT Inquiry to the Kyoto Protocol is a summary statement of aspects of scientific research which address the scientific observations and concerns which have 'driven' the international community to formulate the Kyoto Protocol. They are presented as evidence of the scientific method, of the importance being attached to documentation and understanding of natural variability of climate and climate-related phenomena such as sea-level, sea-surface temperature, biomass etc, and of the need for scientific monitoring and research to precede and accompany measures advocated for reduction of carbon in the atmosphere.

The Research School of Earth Sciences devotes considerable resources of manpower and facilities to the measurement and understanding of global change, including climate change and the carbon cycle. From the 'authority' of our published and unpublished research at RSES on natural variability of climate, on the carbon cycle, on past sea-levels and on past fauna and flora, we are of the firm view that 20th Century global warming and sea-level rise are observed and, on scientific grounds, attributable to changes in the Earth's atmospheric composition caused by human activities..