CLIMATE CHANGE – AN EMERGING ISSUE FOR KARST MANAGEMENT

– Chris Sharples

Note the lack of a question mark at the end of the title of this article. Whilst there are still a few contrarians (1) who choose to doubt the reality of present-day global climate change, or to question the by-now rather clear evidence that the present phase of climate change is being significantly driven by human factors, the clear consensus amongst climatologists and oceanographers is that we can no longer reasonably doubt that the Earth is undergoing a period of pronounced climate change. The Third Assessment Report of the Intergovernmental Panel on Climate Change(2) in 2001 (IPCC 2001) was the critical turning point in awareness of global climate change, since it was this report which made it clear that the consensus of climatological and oceanographic opinion is that renewed global climate change is no longer merely a theory, but rather is now an observed fact.

Moreover, the clear scientific consensus is that the global climatic changes now being observed cannot be accounted for by any combination of known natural forcings, but are only accounted for when human factors – notably anthropogenic changes to the composition of the atmosphere causing an "enhanced greenhouse effect" – are taken into account. In fact, the record of northern hemisphere average surface temperatures for the last millennium (derived from proxy temperature records including ice cores, tree rings and corals – not to mention speleothems!) shows a trend towards gradually decreasing temperatures over most of the last millennium, until around 1900 when average surface temperatures departed dramatically from this cooling trend and began to show the steep rise that has been a hallmark of the 20th Century (IPCC 2001, Fig. 1). It seems that the Earth was indeed heading towards a new glacial phase, until human actions triggered by the Industrial Revolution changed everything!

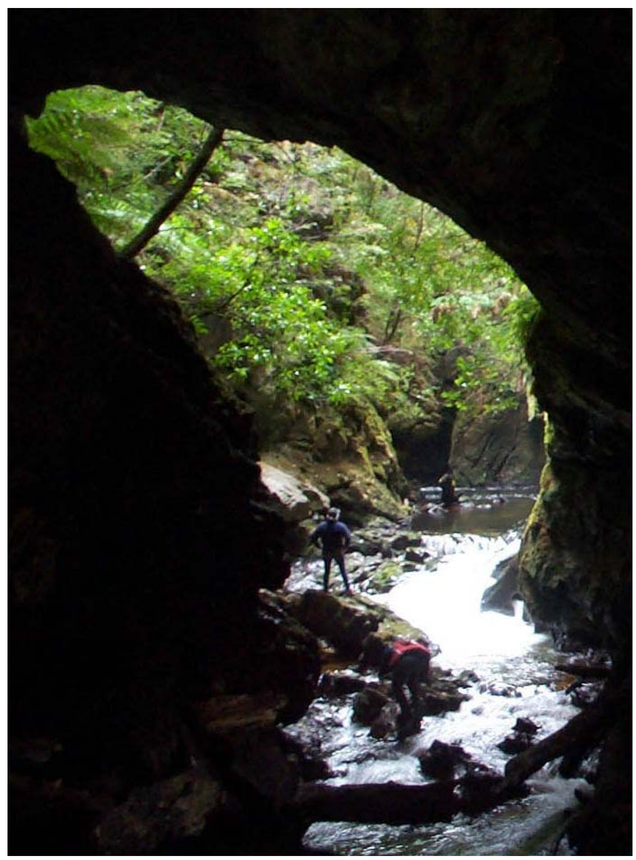
The need to start thinking seriously about climate change and its possible future effects on both natural and human systems is now widely accepted in many disciplines, notably coastal management where considerable amount of thought and effort is now being devoted to assessing the future impacts of climate change on coasts, such as increased sea level leading to accelerated coastal erosion, and increased frequencies and magnitudes of storm surges associated with tropical cyclones (e.g., Kay *et al.* 2005, Thieler 2000). Yet, it seems that awareness of the potential impacts of climate change on a wide range of other natural systems is only just beginning to register.

Karst processes, with their intimate dependence on groundwater tables and hence upon effective precipitation, are one example of a natural system that is likely to be strongly affected by climate change, yet to judge by the apparent (to me, at least!) scarcity of climate change discussion in the recent karst literature it would seem that this realisation is only just beginning to register. Hence this article, which is essentially an effort to raise awareness amongst karst managers and researchers on the key emerging issue of climate change.

PRECIPITATION CHANGES IN AUSTRALIA

Annual rainfall in the southwest of Western Australia has declined by about 10 percent since the 1970's, with a marked trend towards drier winter conditions and higher temperatures (Pittock 2003, p. 48-50; Allen Consulting Group 2005, p. 63).

This trend has now been occurring for so long that it is difficult to attribute it solely to natural inter-decadal variation, and whilst natural factors are undoubted partly implicated in the change, many researchers consider the rainfall decrease to be associated with a change in large scale global atmospheric circulation that is consistent with changes projected by global climate models incorporating the effects of human activities on the atmosphere (IOCI 2002).



The inextricable relationship between karst and water is the key to understanding why current and projected changes to Australia's climate – especially rainfall – can be expected to have significant impacts on Australian karsts (view shows the Weld River entering Weld River Arch Cave, SW Tasmania).

The precipitation changes in southwest Western Australia are the largest and most statistically significant 20th Century rainfall changes for any region of Australia, however rainfall trends over the period 1950 to 2002 have also shown marked decreases for parts of eastern Australia, while average rainfalls in far northwest Western Australia have increased over the same period (Pittock 2003, Fig. 2.9).

While there is still some possibility that these trends are related merely to natural variability, the fact that the observed trends are similar to trends projected by global and regional climate simulation models incorporating the enhanced greenhouse effect (Pittock 2003, p. 51) is making it increasingly likely that we are seeing a long term climatic trend at least partly related to human impacts on the atmosphere.

Current climatic modelling by CSIRO, incorporating the enhanced greenhouse effect, is projecting continued decreases in rainfall over large regions of Australia during the next century, particularly in south-western and south-eastern Australia, while increased rainfall is being projected for the Kimberley region of far northwest Australia (CSIRO 2001; Pittock 2003, Fig. 2.15).

Also of significance is that fact that most climatic models for Australia are also projecting an increase in extreme rainfall events (including in areas where average total rainfall is decreasing). This of course translates to more frequent heavy downpours leading to an increased frequency of significant flooding in streams and – obviously – caves.

Large blind shrimps found in Guangxi Province, China, in 2000. Photo: Arthur Clarke.

IMPACTS OF PRECIPITATION CHANGE ON KARST

There is no need for me to rhetorically ask "What will these climatic changes mean for karst?". We all know that water is a fundamental ingredient in karst processes, such that if you change the supply of water to a karst system – as you do if rainfall changes - then you change the karst geomorphic processes operating in that system. You know this already.

Ford & Williams (1989, Ch. 10) provide a textbook account of the effects of different (and changing) climates on karst systems. This article is not the place for a detailed discussion of the effects of climate change on karst, however it is worth noting a few of the more obvious likely impacts of changing rainfall patterns on karst systems in Australia. In areas of declining rainfall, these could include:

- falling water tables, as declining rainfall recharge depletes groundwater reserves;
- consequent reduced average flows or complete drying of cave streams and pools;
- drying of speleothems and reduced rates of speleothem growth as drip water percolation declines (future karst scientists will probably be able to detect the present phase of climate change as a distinct change in speleothem growth rings!);
- in the case that the frequency of intense rainfall events increases, more frequent cave floods may result in accelerated erosion, transport and deposition of sediment within caves, despite reduced total annual water flows; and
- impacts on cave fauna, especially aquatic fauna, as reduced water availability constricts or stresses their specialised habitats.

Of course, in areas of increasing precipitation the opposite effects on karst might be expected. It is interesting to consider what effect projected increases in rainfall might have on Devonian limestone karsts in the southern Kimberley region, for example.

Given that rainfall trends have been significantly changing in parts of Australia for the last 30 – 50 years, it follows that if these sorts of impacts are likely to affect karst systems, then some of the impacts should be detectable already. Indeed, this does appear to be the case, at least in southwest Western Australia where the drying trend has been most marked.

Stefan Eberhard's PhD studies of significantly lowered water tables in caves of the Margaret River region of south-western WA has implicated the regional trend of declining average rainfall as a probable key contributor, albeit Stefan has also identified a number of other contributing factors including changed firing regimes, and potentially in some cases (especially Yanchep), increased water demand of tree plantations and pumping of water for town water supplies (Eberhard 2004, Eberhard *et al.* 2005, S. Eberhard *pers. comm.*). Stefan has identified a major bioconservation problem associated with the lowering of karst water tables in the caves of southwest WA, namely the potential for the partial or complete drying of cave pools which the aquatic cave fauna depend on for survival to place those populations at risk of extinction.

Stefan Eberhard's studies of the Margaret River region karsts provide the clearest evidence yet (to my limited knowledge!) that effects related to the present phase of climate change are starting to be felt in Australian karst systems. I suspect, however, that climate change effects will be noticed in other Australian karst systems once we start seriously looking for them(3).

For example, I cannot help but wonder whether the discovery of Lake Charon (at Wolfhole Cave, Hastings karst in south-eastern Tasmania) was not aided and abetted by eastern Australia's regional drying trend, which is being strongly felt in eastern Tasmania. Lake Charon lies beyond Lake Pluto at the far end of Wolfhole Cave, and was apparently discovered around 2000 at a time of unusually low water levels in Lake Pluto (Anderson 2000, Butt 2000). Perhaps access to Lake Charon will be easier more often than not in the future?

Water erosion forming a new hole into the karst at Mole Creek, Tasmania. Photo: Kent Henderson.

OTHER POTENTIAL IMPACTS OF CLIMATE CHANGE ON KARST

Naturally, it is simplistic to assume that reduced rainfall will be the only climatic change that affects karst. It is likely that in many cases the effects of climate change on karst will be considerably more complex. For example, increasing temperatures could stimulate soil biological activity, releasing more carbon dioxide which in turn could increase the acidity of groundwater percolating into caves, perhaps resulting in a trend towards dissolution of some cave speleothems.

Another area of concern relates to the impact of global sea level rise – a well established effect of current climate change – on coastal or island karsts. Past sea level changes have had major effects on the development of coastal karsts (see Ford & Williams 1989, p. 496-506), and current sea level rise can be expected to modify coastal karsts in a variety of ways. One notable issue relates to the likelihood of additional landwards intrusion of the salty groundwater wedge that is present in all coastal regions. This may be of particular concern on small coral atolls, where the main source of fresh water for human use is contained in a karstic aquifer as a lens of rainwater – derived fresh water sitting on top of the denser wedge of salty groundwater.

However, in cases such as this a complex interaction between climate change effects may occur: whereas the effect of a rising sea level on a small coral atoll might be to reduce the size of the fresh water lens if rainfall remains constant or is decreasing, in some oceanic regions climate change may result in an increased average annual rainfall; in such cases the fresh-water lens may actually expand, at least for a period until sea level rise begins to overwhelm the whole atoll.

PAST CLIMATE CHANGE AND KARST

The Earth's climate has of course varied repeatedly and markedly over the last few million years, particularly in response to the series of glacial and interglacial climatic phases that have alternately dominated Earth’s climate system during the Pleistocene and beyond. Indeed, a significant part of our knowledge of these climate changes has been derived from dateable sediments and speleothems preserved in caves. It follows that we can seek to understand the climate-related changes that karst systems are likely to undergo in the future, by examining the record of past climate change effects preserved in karst systems .

For example, during Pleistocene glacial climatic phases, Tasmanian karsts experienced periods that were more arid than at present, yet which were characterised by frequent intense flooding events related to meltwater flows. Amongst other effects, these conditions resulted in accelerated deposition of coarse sediment, which sometimes entirely choked cave passages and resulted in re-routing of cave streams into new conduits.

However, care must be exercised in making such analogies between past and future effects of climate change on karst. While the glacial phases were indeed periods of reduced precipitation, like those predicted for the future in many Australian regions, they were also colder periods, unlike projected future climates for Australia.

The availability of large quantities of sediment to be deposited in Tasmanian caves during the last glacial phase was partly related to reduced vegetation cover and glacial or periglacial erosion resulting from the colder temperatures, and this is not going to be the case in a warmer future Tasmania!

WHY DOES CLIMATE CHANGE MATTER IF ITS ALL HAPPENED BEFORE?

Nevertheless, it is clear that Australian karsts (and their biota) have experienced and adapted to wide climatic variations in the past. For example, Eberhard *et al.* (2005) note that cave invertebrates in Jewel Cave (SW Western Australia) survived significantly lowered water tables associated with a period of regional aridity around 11,000 to 13,000 years ago.

So if karst systems and their biota have adapted to past climatic variations, then it is reasonable to ask whether the present phase of renewed climate change should be of any particular concern, beyond a simple interest in observing the changes that occur? The answer to that question must be yes!

There is considerable reason for concern about the impacts of renewed climate change on karst systems. The reason is that the climate changes being experienced today, and their likely impacts, are different in a number of significant ways from those which have occurred in the past – and those differences are all to do with present day human activities that were not occurring during previous phases of Pleistocene climate change.

Firstly, the climate changes occurring today are being driven not only by natural variations, as in the past, but also by humanly induced factors, particularly the enhanced greenhouse effect.

This means that the climate changes that occur over the next few centuries are like to differ in both degree and type from those which have occurred in the past, and consequently may affect karst systems in ways not directly comparable to changes that have happened in the past.

Secondly, many of the karst systems likely to be affected by current and projected future climate changes have already been significantly affected by a variety of other human impacts unrelated to climate change.

For example, water tables in some karsts are already un-naturally low as a result of ground water pumping, tree plantation development, agriculture, or other causes.

The effect of climate change on such already-stressed karst systems may be to push the changes that occur in them beyond the natural rates and magnitudes of change, such that, for example, cave fauna which could cope with past climatic variations are unable to cope with the greater and/or different changes associated with the current phase of climate change. This is the fear articulated by Eberhard *et al.* (2005) for invertebrate populations in caves of southwest Western Australia.

SO WE DO NEED TO START THINKING ABOUT IT!

There are clearly reasons for karst managers to be concerned about potential impacts of climate change on karst systems, both for reasons of nature conservation (loss of important karst-related phenomena), and also for entirely utilitarian reasons (e.g., karst aquifers already under stress because of over-exploitation may become practically unusable for human purposes if reduced rainfalls lower their water tables even further).

The time has come for karst managers to add climate change to their already lengthy list of concerns! Whereas the possibility of climate change impacting on karst has been virtually ignored in most discussions of climate change to date (e.g., IPCC 2001, Pittock 2003, Allen Consulting Group 2005), karst specialists need to begin thinking about the linkages between the current phase of global climate change and their own speciality.

I am happy to predict that when more karst geomorphologists and hydrologists begin focussing their attention on the issue, evidence of incipient climate change impacts on karst will begin to become apparent not only in southwest Western Australia, but in many other places as well.

In tandem with research into and monitoring of the impacts of climate change on karst, I believe that karst managers need to start considering the means by which they can hope to mitigate impacts on karst in an effort to at least maintain changes within the natural range of past changes.

This will primarily mean focussing on reducing other human stresses on karst systems in order to give those systems greater capacity to adapt to unavoidable climate change impacts.

NOTES

(1). Although some contrarians present themselves as "skeptics", there is a clear distinction: a skeptic is not a "dis-believer", but rather is somebody who demands clear evidence before tentatively accepting a proposition; a contrarian is one who simply ignores the weight of evidence in order to maintain a favoured idea.

(2) The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Program (UNEP). The IPCC co-ordinates a global network of hundreds of leading experts in climatology, oceanography and related fields. The IPCC does not conduct research in its own right, rather its function is to review and synthesise the current state of scientific understanding of the Earth's climate.

(3) It is a common pattern in the history of science, that important phenomena can stare us in the face but go un-noticed for years (did anybody think of gravity before Newton recognised it as an actual force?). Then one day somebody recognises an example of the new phenomenon for what it is – and suddenly we start seeing the same thing in numerous other places that we had looked at previously without twigging to what we were actually seeing!

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The entrance to Mangawhitikau Glowworm Cave, Waitomo. Photo: Kent Henderson.