COMMENTS ON: 'TUVALU NOT EXPERIENCING INCREASED SEA LEVEL RISE'

John R. Hunter
Antarctic Climate & Ecosystems Cooperative Research Centre,
Private Bag 80, Hobart, Tasmania 7001, Australia
john.hunter@utas.edu.au

1. INTRODUCTION

A recent paper (Eschenbach, 2004), describing observational data from Funafuti Atoll, Tuvalu, argued that Tuvalu was not experiencing increased sea-level rise. However, this paper contained a number of inconsistencies and errors, some of which are identified and discussed in this note. There are seven primary areas of concern:

- a 'best estimate' of sea-level rise that is biased low and with unrealistically low uncertainty,
- a misunderstanding concerning the meaning and use of 'asymptotic analysis',
- problems with the analysis of sea-level rise from surrounding locations,
- problems with the analysis of steric sea levels,
- a misunderstanding of the context of present sea-level rise within the late Holocene period (the last few thousand years),
- a simplistic view of the effects of sediment transport, and
- unsubstantiated and/or unreferenced claims concerning past and present temperatures and sea level.

2. A 'BEST ESTIMATE' OF SEA-LEVEL RISE THAT IS BIASED LOW AND WITH UNREALISTICALLY LOW UNCERTAINTY

Eschenbach considered that the 'true long-term rate of MSL (mean sea level) rise in Tuvalu is very likely to be between –1 and +0.5 mm/yr, with a best estimate … of +0.07 mm/year'. The latter value was apparently derived from the Australian National Tidal Facility, although no reference was cited and the record duration was not given (due to a typographic error). The figure of 0.07 mm/year most probably comes from an analysis of data from November 1977 to the end of 1998 (Hunter, 2002, p.11) by Mitchell *et al*. (2000). As indicated by Hunter (2002), this result is biased low because the record ends with unusually low sea levels associated with an El Nino Southern Oscillation (ENSO) event. The analysis of a longer record (1978–2001 inclusive) by Hunter (2002) was, however, rejected by Eschenbach on the (incorrect) belief that it did not take account of the tides (however, see IOC, 2002, pp. 39–40 and Hunter, 2002, p. 6, for discussions of how tides were treated). In fact, the trend-fitting techniques of Mitchell *et al*. (2000) and Hunter (2002), although differing in detail, would give effectively identical results, given the same data. Hunter (2002) also made an

allowance for local sinkage of one of the tide gauges at Funafuti. There is therefore no reason to reject Hunter's analysis, which was accompanied by objective estimates of the uncertainty and which involved a longer record than that used by Mitchell et al.. Hunter gave two estimates of sea-level rise: a 'cautious' estimate of **0.8 ± 1.9 mm/year** and a 'less cautious' estimate of **1.2 ± 0.8 mm/year** (which was based on a rejection of data affected by ENSO). Uncertainties are expressed as ± 1 standard deviation, which means that there is about a 68% probability that the long-term rate of rise lies between these limits. Although these estimates of *relative* sea level at Funafuti are not directly comparable with the IPCC estimates of *global average* sea-level rise during the 20th century (1 to 2 mm/year; Church et al., 2001), it is interesting to note that they are of similar magnitudes.

It should also be noted that Eschenbach's 'best estimate' for Tuvalu of 0.07 mm/year, although low, is consistent with the 'cautious' estimate of Hunter (2002) of 0.8 ± 1.9 mm/year, lying one standard deviation below Hunter's central value. As noted above, this bias is caused by an abnormally low sea level (associated with an ENSO event) occurring at the end of the period used for Eschenbach's estimate. As indicated by Hunter (2002), 'even using the full 24 years of available data, the uncertainties in estimated trend are presently undesirably large'. At least 15 more years are probably necessary to bring the uncertainty down to ± 0.3 mm/year.

3. A MISUNDERSTANDING CONCERNING THE MEANING AND USE OF 'ASYMPTOTIC ANALYSIS'

Asymptotic analysis is simply the application of linear regression to records of successively increasing length. It was used by Mitchell et al. to provide some indication of whether a sea-level record was long enough to yield a satisfactory estimate of the long-term trend. To claim, as Eschenbach did, that the trend estimated by Hunter (2002) should be rejected because it was 'marred by the lack of a proper asymptotic analysis of the data, merely a least squares regression' is nonsensical; a single estimate from an asymptotic analysis is simply the result of one application of a linear regression. Eschenbach was also incorrect in suggesting that Hunter did not use asymptotic analysis; Figure 14 of Hunter (2002) shows the results of such an analysis.

4. PROBLEMS WITH THE ANALYSIS OF SEA-LEVEL RISE FROM SURROUNDING LOCATIONS

Eschenbach estimated a rate of sea-level rise for Tuvalu by taking a distance-weighted average of the trends at 4 stations (Kanton, Pago Pago, Rabaul and Noumea). The result was given as 'about +0.3 mm/yr., with an error on the order of +0.7 to –1.5 mm/year'. It is difficult to see how this uncertainty estimate was derived, given that no uncertainties were provided for the individual trends (which were presumably extracted from Mitchell et al., 2000). Such uncertainties cannot be safely estimated simply from the spread of the trends themselves (as is common when taking the average of uncorrelated data) because the individual records have considerable overlap and so are probably significantly correlated (for example due to ENSO events). It is also strange that the uncertainties quoted by Eschenbach (+0.7 to –1.5

mm/year) are assymetrical (and biased downwards), given that, if the uncertainties of the individual trends are symmetrical (a reasonable assumption), then the uncertainty of the weighted average should also be symmetrical. Because no attempt has presumably been made to objectively quantify the uncertainties of the individual trends, the quoted uncertainty of the resultant weighted average should be discounted.

Finally, Rabaul, being in a seismically active region, is a very poor site for the estimation of the long-term trend in sea level. As noted by the (Australian) National Tidal Facility (2003) concerning tide gauges in Papua New Guinea: 'Unfortunately, tectonic activity in the Rabaul region, and the shortness of the other records, has resulted in a situation where none of these gauges add meaningful information about the interannual and longer term sea levels.'

5. PROBLEMS WITH THE ANALYSIS OF STERIC SEA LEVELS

Steric sea level is an approximation to actual sea level, calculated from the density of sea water. In the case of global warming, the density of sea water is reduced due to thermal expansion, causing a rise of sea level. This does not, however, take account of any addition of water to the oceans (e.g. due to the melting of ice on land).

Eschenbach claimed that the map of steric sea-level trends shown in his Figure 2 (from Cabanes et al., 2001) 'closely matches the records from the four stations that (he) used to make (his) initial estimate of the rate of Tuvalu MSL change'. However, a careful analysis of the figure provided by Cabanes et al. (2001) shows that this statement is quite incorrect, as shown in Table 1 (only Noumea shows any reasonable correspondence). Also shown are the trends for Tuvalu which, similarly, show poor agreement. Further, it should be recalled (previous section), that Rabaul is a very poor indicator of long-term sea-level change.

Table 1: Comparison of sea-level trends from Mitchell et al., 2000, and from Cabanes et al., 2001

Station	Sea-Level Trend from Tide Gauges (Mitchell et al., 2000; mm/year)	Steric Sea-Level Trend (Cabanes et al., 2001; mm/year)
Kanton	0.71	–0.7 – 0.0
Pago Pago	1.43	–1.4 – 0.0
Rabaul	–2.21	–2.1 – –0.7
Noumea	–0.4	–0.7 – 0.0
Tuvalu	0.07	–2.8 – –2.1

The use of the steric sea-level data of Cabanes et al., 2001, as an indicator of actual sea level is subject to two problems. Firstly, it does not include the eustatic contribution which relates to the change of mass of the oceans (e.g. due to melting ice on land). Secondly, Miller and Douglas (2004) have indicated problems that may arise from basing estimates of steric sea level on gridded data sets (as used by Cabanes *et*

al. (2001)), rather than on the original hydrographic observations. The poor agreement between the 'tide-gauge' and steric sea-level trends, shown in Table 1, suggests strongly that steric sea level is not a good indicator of actual sea level in the region around Tuvalu.

6. A MISUNDERSTANDING OF THE CONTEXT OF PRESENT SEA-LEVEL RISE WITHIN THE LATE HOLOCENE PERIOD (THE LAST FEW THOUSAND YEARS)

Eschenbach sought evidence for a sea-level rise that has accelerated during the period of the tide gauge records 'such as that predicted to occur with increasing temperature'. Mitchell et al. (2000) noted, of the Pacific region, that 'there is no clear evidence for an acceleration in sea-level trends over the course of the last century', from which Eschenbach deduced that 'there is no evidence that in the Pacific the rate of MSL rise has changed from the historical norm'. This however misses the point that, in general, sea level must have already accelerated to have arrived at the rates we observed during the 20th century. Firstly, the longest available tide gauge records indicate an acceleration around the late 19th century (Church *et al*., 2001, Figure 11.7). Secondly, as Lambeck (2002) noted: 'high resolution (geological and archaeological) records indicate that little change in sea level has occurred, over and above that which can be attributed to the isostatic factors, during the past 2000 years, such that the present-day rise must indeed have been a relatively recent phenomenon'. It is generally believed that the present rate of rise is associated with global warming (Church *et al*., 2001, Section 11.4).

7. A SIMPLISTIC VIEW OF THE EFFECTS OF SEDIMENT TRANSPORT

Eschenbach made the surprising claim that 'Tuvalu will not be bothered by a rise in the MSL even if one were to occur. If the ocean goes up a bit … the islands will grow a bit taller'. Firstly, this claim is inconsistent with his earlier statement that 'Can the ocean completely wash away a coral atoll? It certainly can and it has done so many times in the past'. Secondly, he made the assumption that, under the present rate of rise of sea level (which is probably quite different from the rate of several centuries ago; see above) the supply of sediment is sufficient to maintain the island at its present height above the sea (although he previously acknowledged that 'an atoll is … kept in place by a delicate balance of erosion and accretion'). An alternative scenario (and one for which there are ample examples worldwide) is that the supply of sediment is not able to keep up with sea-level rise. In this case, conservation of the available sediment requires that the shoreline recedes at a rate of roughly 50–100 times the rise in the sea level, as given by the Bruun Rule (e.g. Day, 2004). A sea-level rise of 1 mm/year over the 20th century would, in this case, give rise to a shoreline recession of 5 to 10 metres – a significant impact on islands which are, in places, only tens of meters across. Eschenbach's claim that 'Tuvalu will not be bothered' also ignored the rather obvious fact that, even if the land mass of Tuvalu rises due to sediment transport, the infrastructure such as buildings and metalled surfaces will not rise with it.

8. UNSUBSTANTIATED AND/OR UNREFERENCED CLAIMS CONCERNING PAST AND PRESENT TEMPERATURES AND SEA LEVEL

Eschenbach claimed that 'about 800 years ago … the MSL was some 600 mm higher than at present', based on a single data point for the Maldives Islands in the Indian Ocean, over 10000 km from Tuvalu. This claim should be discounted as it takes no account of the fact that the rate of vertical land motion at these two locations could be quite different.

Eschenbach made the further extraordinary claim, with no substantial evidence or references, that 'there is no clear evidence that humans have changed the temperature of the earth in any detectable way, and there is a lot of clear evidence to show that we haven't'. This claim, which ignores the work of thousands of climate scientists as summarised by IPCC (2001), should be discounted.

9. CONCLUSION

It is quite premature to claim that Tuvalu is 'not experiencing increased sea level rise'. Although tide gauge data from Tuvalu is presently not long enough to indicate the local rate of sea-level change with a certainty of better than ± 1 to ± 2 mm/year, the observations we have are comparable with estimates of global average sea-level rise for the 20th century. There is now ample evidence to support the view that, during the 20th century, global sea level rose at about 1.8 mm/year (Church et al., 2004, Holgate and Woodworth, 2004) and that this rate of rise can only have been occurring during the last one or two centuries (Lambeck, 2002). Furthermore, sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, as a result of global warming (Church et al., 2001). Although, as indicated by Eschenbach, other factors may well play a part in the flooding of Tuvalu, there is no reason for ignoring the significance of sea-level rise.

ACKNOWLEDGEMENTS

This work was supported by the Australian Government's Cooperative Research Centres Programme through the Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC).

REFERENCES

Cabanes, C., Cazenave, A and Le Provost, C., 2001. Sea Level Rise During Past 40 Years Determined from Satellite and in Situ Observations, *Science*, Vol. 294, pp. 840–842.

Church J.A., Gregory J.M., Huybrechts P., Kuhn M., Lambeck K., Nhuan M.T., Qin D., and Woodworth P.L., 2001. *Changes in Sea Level, in Climate Change 2001: The Scientific Basis*, Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and C.A. Johnson, C.A. (eds.), 639-693, Cambridge University Press, Cambridge.

Church, J.A., White, N.J., Coleman, R., Lambeck, K. and Mitrovica, J.X., 2004. Estimates of the Regional Distribution of Sea-Level Rise Over the 1950 to 2000 Period, *Journal of Climate*, Vol. 17, pp. 2609–2625.

Day, C., 2004. Sea-Level Rise Exacerbates Coastal Erosion, *Physics Today*, Vol. 57 (2), February 2004, pp. 24–26.

Eschenbach, W., 2004. Tuvalu Not Experiencing Increased Sea Level Rise, *Energy & Environment*, Vol. 15, No. 3, pp. 527-543.

Holgate, S.J. and Woodworth, P.L., 2004. Evidence for Enhanced Coastal Sea Level Rise During the 1990s, *Geophysical Research Letters*, Vol. 31, L07305, doi:10.1029/2004GL019626.

Hunter, J.R., 2002. *A Note on Relative Sea Level Change at Funafuti,* Tuvalu, report, Antarctic Cooperative Research Centre, Hobart, Australia, http://www.antcrc.utas.edu.au/~johunter/tuvalu.pdf.

IOC, 2002. *Manual on Sea Level; Measurement and Interpretation, Volume III – Reappraisals and Recommendations as of the year 2000*, Intergovernmental Oceanographic Commission, UNESCO, http://unesdoc.unesco.org/images/0012/001251/125129e.pdf.

IPCC, 2001. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (eds.), Cambridge University Press, Cambridge, 881 pp..

Lambeck, K., 2002. Sea Level Change from Mid Holocene to Recent Time: an Australian Example with Global Implications, *Ice Sheets, Sea Level and the Dynamic Earth*, American Geophysical Union, Washington DC, Geodynamics Series 29, pp. 33–50.

Michell, W., Chittleborough, J., Ronai, B. and Lennon, G.W., 2000. Sea Level Rise in Australia and the Pacific, *Quarterly Newsletter of the South Pacific Sea Level and Climate Monitoring Project*, Vol. 5, No. 1, pp. 10–19, ISSN 1026-4124, National Tidal Facility, Australia.

Miller, L. and Douglas, B.C., 2004. Mass and Volume Contributions to Twentieth-Century Global Sea Level Rise, *Nature*, Vol. 428, pp. 406-409; doi:10.1038/nature02309.

National Tidal Facility, 2003. Pacific Country Report; Sea Level & Climate: Their Present State; Papua New Guinea, National Tidal Facility Australia, June 2003, http://www.ntf.flinders.edu.au/TEXT/NEWS/PacificCountryReport_pn_2003.pdf.