POLICY BRIEF
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CENTER FOR THE STUDY OF CARBON DIOXIDE AND GLOBAL CHANGE
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Commentary and Analysis on the Whitehead & Associates 2014 NSW Sea-Level Report

by

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Kear, D., Legates, D., Mörner, N.A., Ollier C., Singer F. & Soon W.

Reference: E13.7268

The Whitehead & Associates report that is the subject of this review is available at the following web address:

> *http://esc.nsw.gov.au/inside-council/project-and-exhibitions/public-exhibition/on-exhibition/south-coast-regional-sea-level-rise-planning-and-policy-response/South-Coast-Regional-Sea-Level-Rise-Policy-and-Planning-Framework.pdf*

Summary

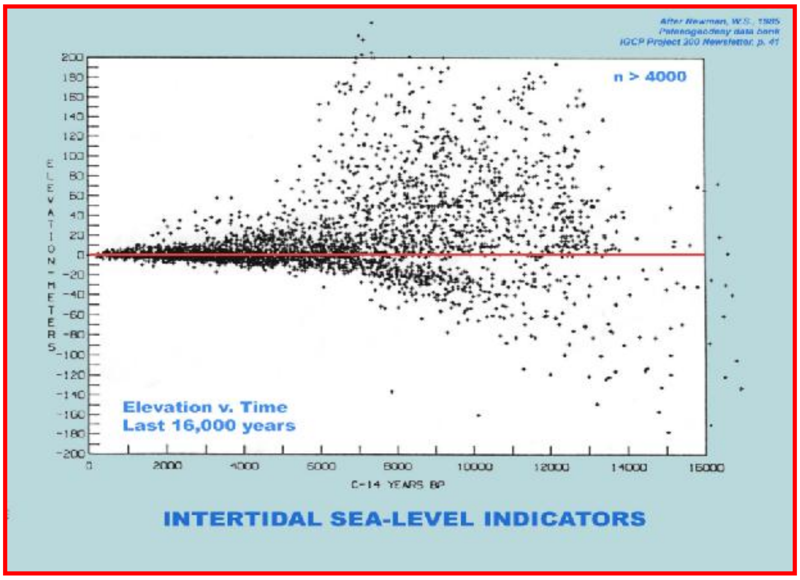
In July 2014, Whitehead & Associates Environmental Consultants, in consultation with Coastal Environment and with funding from the NSW Government, produced a report for Eurobodalla Shire Council and Shoalhaven City Council titled "South Coast Regional Sea Level Rise Policy and Planning Framework, Exhibition Draft." The conclusion of the following commentary and analysis is that this report does not provide reliable guidance to the complicated issues of measuring, forecasting, and responding to sea-level rise.

The image below presents the unmistakeable pattern of wide variations in rates of tectonic uplift (points above the red zero baseline) and subsidence (points below) in different locations around the world at particular times. In such circumstances, no effective coastal management plan can rest upon speculative computer projections regarding an idealised future *global* sea-level, such as those provided by the United Nations' Intergovernmental Panel on Climate Change (IPCC).

Coastal management must instead rest upon accurate knowledge of local geological, meteorological and oceanographical conditions, including, amongst other things, changes in *local relative sea level*.

For the central and southern New South Wales (NSW) coast of Australia, this requires basing management policies on the range of long-term rates of sea-level rise of 0.63-0.94 mm/yr that have been measured at the nearby Sydney (Fort Denison) tidal gauge.

The implied 6.3-9.4 cm of rise in the next hundred years is similar to the rise which occurred during the preceding hundred years. This did not require, nor receive, any policy formulation over and above the application of historic 20th century coastal planning regulations.



Elevation v. age plotted for individual intertidal shoreline deposits from around the world over the last 10,000 years (Holocene) (Newman, 1986).

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Main conclusions and recommendations

1. Given the widespread criticism of IPCC's reports and analyses, great caution needs to be applied in basing public policy on IPCC recommendations in the fashion urged by the Whitehead &Associates (W&A) report.
2. IPCC's Representative Concentration Pathway (RCP) 8.5 is an extreme and unlikely scenario of future greenhouse gas emissions. Model projections that are based upon this scenario, as are W&A's, are therefore exercises in speculation.
3. Best practice coastal management is not based on knowledge of past and present rates of global temperature change, nor on computer-based speculations of future rates of temperature or sea-level changes, but on empirical geological, oceanographical, meteorological and survey data collected at or nearby a coastal site of interest.
4. Because they represent a worldwide average, neither the tide-gauge nor the satellite estimates of ***global sea-level*** have any useful application to coastal management in specific locations. This key fact is obscured in W&A's analysis.
5. ***Local relative sea-level change*** is what counts for purposes of coastal planning, because even in tectonically stable areas such as eastern NSW, different rates of uplift and subsidence may apply in different locations.
6. The IPCC suite of CMIP5 computer models drawn on by W&A have repeatedly been shown to be wrong when tested against factual data. Since the models do not provide verifiable predictions, they cannot be relied upon as a tool for formulating coastal management policy.
7. The high sea-level rise figure of 3.3 mm/yr reported for the Fort Denision (Sydney) tide gauge by W&A does not represent the original data measurements (0.73 mm/yr) but results from computer modelling combined with the selection of a short and atypical section of the available sea-level record.
8. Much of W&A's analysis relies upon the presumed accuracy of satellite-borne sea-level measurements. Current research literature shows that this technique is not yet well enough established, and nor is the record long enough, to form an adequate basis for coastal planning.
9. In choosing to analyse the short 18-year period 1996-2013, W&A have selected an arbitrary length of record that encompasses a late-1990s, El

Niño-related regional increase in sea level rise. Thereby, they achieve a significantly higher rate of sea level rise than the true long-term trend at Fort Denison tide of about 0.73 mm/yr.

10. Considering the flooding and erosion risks already inherent in coastal locations, the likely 7.3 cm rise in local sea-level in NSW over the next 100 years is too small to justify a major planning response. Though other human impacts at the coast might require changes in coastal regulations, no imperative exists to change planning rules because of unproven sea-level hazard.

11. At the heart of the issue of good coastal management lies the need for an understanding of coastal processes in general, and the collection of accurate data regarding the history of those processes at any site of particular interest.

12. The study of Cairns Northern Beaches accomplished in the 1980s (Beach Protection Authority, 1984) provides an historic Australian "best practice" coastal management study of the type that has yet to be undertaken to inform the Eurobodalla and Shoalhaven Councils regarding the need, or not, for a revision of their local coastal planning regulations.

13. Three key guidelines for coastal planning are:

    - Abandonment of 'let's stop global sea-level rise' policies
    - Recognition of the local or regional nature of coastal hazard
    - Use of planning controls that are flexible and adaptive in nature

    These recommendations apply just as much to the NSW shoreline as they do to shorelines anywhere else in the world. Coastal councils that ignore or override such basic principles of good environmental management do so at the risk of their ratepayers' property and financial costs.

    To the degree that new planning regulations are based on experimental computer model projections (such as those reported by W&A, which are *not* validated predictions or forecasts), and cause financial damage to coastal property holders, legal culpability may apply.

Commentary and analysis

1. Introduction

The issue of sea-level change, and in particular the identification of a speculative human contribution to that change, is a complex topic. Given the scientific and political controversy that surrounds the matter, the Eurobodalla and Shoalhaven Councils are to be congratulated for seeking fresh advice on the topic.

The new report by Whitehead & Associates (2014; hereafter, W&A) aims to be comprehensive and contains important new information and conclusions. It nonetheless has three systemic defects.

First, the analysis provided of the science relevant to coastal management is biased towards computer modelling of the speculative effects of sea-level rise, and largely ignores other important factors such as oceanographic and meteorological variability, and sediment supply, sources and sinks. Second, not all the scientific manipulations that were undertaken have been reported transparently, i.e. in such a way that other scientists can check and replicate the calculations. And, third, the authors of the report appear to have taken the opinions of global warming lobby groups at face value. No attempt has been made to undertake the type of critical due diligence analysis of global warming, and its putative links to sea-level change, that is required.

2. Over-reliance on a single authority: Inadequacies of the IPCC

The following statement occurs on p. 3 of the W&A report:

> *In addition to the planning and legislative changes, new scientific evidence is available. The NSW sea-level rise policy, now repealed, was largely based on the Intergovernmental Panel for Climate Change (IPCC) Assessment Report 4 (AR4) from 2007 (Meehl et al., 2007). The IPCC's Assessment Report 5 (AR5) is in the process of being prepared, with the first part of the report on The Physical Science Basis released online in January, 2014. That report provides an assessment of the published scientific understanding of climate change available up to 15 March, 2013. The text for the Working Group 2 report, on Impacts, Adaptation and Vulnerability was released in March, 2014. Both documents have been reviewed as part of this study.*

The United Nations' Intergovernmental Panel on Climate Change (IPCC) is a much-criticized political (not scientific) agency whose findings are known to be influenced by an overriding agenda of establishing a link between human carbon dioxide emissions and dangerous planetary warming. One manifestation of increasing carbon dioxide emissions might be, but has not yet been demonstrated to be, an increase in the rate of global sea level rise.

Regarding sea-level change specifically, IPCC's most recent conclusion (5th Assessment Report, Summary for Policymakers, p. SPM-13; subsequently 5AR) is that:

> *It is very likely that there is a substantial anthropogenic contribution to the global mean sea level rise since the 1970s. This is based on the high confidence in an anthropogenic influence on the two largest contributions to sea level rise, that is thermal expansion and glacier mass loss*.

No empirical evidence exists in support of this statement, and the term "high confidence" refers to no statistical tests. The references to an anthropogenic influence on sea level via thermal expansion and ice loss are assertions based only on unproven assumptions and outputs of climate models. Meyssignac *et al.* (2012) analysed sea level trends for the tropical Pacific Ocean and found no signal that could be linked to greenhouse gas forcing. Instead they attributed all the observed sea level trends to natural variability. See also NIPCC (2013, Chapter 6).

In according priority to IPCC findings, W&A have overlooked the following well understood fundamental defects of the IPCC approach to policy formulation about sea-level change:

- The assumption that the rate of *global* sea-level change can be meaningfully applied to coastal management in specific *local* areas (in some of which, modern sea-level is actually falling).
- The assumption that the rate of global sea-level change can either be measured, or projected by unvalidated, speculative computer models, with sufficient accuracy for policy recommendations to be based upon any projected rate of change.
- The assumption that the measured rate of global sea-level change is materially influenced by human carbon dioxide emissions, and that such a human influence would necessarily be a universal environmental negative.

All three assumptions are demonstrably incorrect.

In making these assumptions (and noting the report publication date of July, 2014) W&A have failed to take adequate account of the many published scientific papers that provide a different, and non-alarmist, assessment of sea-level change. Many of these have been summarised by independent expert scientists in a report that parallels that of the IPCC (Idso *et al.*, 2013a), and others were published thereafter in late 2013 or early 2014 (Fu & Haines 2013; Baker & McGowan, 2014; Beenstock *et al*. 2014; Hansen 2014; Jevrejeva et al., 2014; Mörner 2014; Parker 2014a, b). Neither have W&A considered critiques that describe inadequacies in the IPCC's 5AR (e.g., Idso et al., 2013b), nor the significant recent policy briefing statement on sea level change published by the Global Warming Policy Foundation, London (de Lange & Carter, 2014).

Councillors or other readers of the W&A report who are unfamiliar with the widely reported defects of IPCC's scientific analyses can find them discussed in prestigious international reports (Interacademy Council, 2010), popular books (Laframboise 2011, 2013) and local Australian commentary (McLean 2007a, 2007b, 2008, 2009, 2014).

CONCLUSION 1

Given the widespread criticism of IPCC's reports and analyses, great caution needs to be applied in basing public policy on IPCC recommendations in the fashion urged by the Whitehead & Associates (W&A) report.

3. Deficiency of adopting IPCC emissions scenario RCP 8.5 as a basis for planning

The IPCC starts by *assuming* from first principles that sea level rise is directly related to rising concentrations of atmospheric carbon dioxide. Accordingly, and for the purposes of making speculative computer model projections of future climatic states (including sea-level), the IPCC defines a number of alternative emissions scenarios (Table 1).

In their latest manifestation in 5AR, these scenarios are termed Representative Concentration Pathways (RCPs) and range from a low rate of greenhouse gas accrual (RCP2.6) to a rate that many commentators view as extreme (RCP8.5) (W&A, p. 30, Table 2).

W&A recommend that for planning purposes Councils should adopt the highest of the three calculated RCP8.5 options, which translate to low, medium and high projections of NSW local sea level rise by 2050 of 16cm, 20cm and 26cm (W&A, Table 12). Translated into reality, however, the RCP8.5 scenario not only discounts all efforts to reduce emissions, but also assumes a total greenhouse gas forcing of 8.5 W/m^2 by the year 2100 (Table 1, columns 2 and 4). This is equivalent to a greater than 1370 ppm atmospheric CO_2 concentration in 2100 (column 3), which is more than 4-times the pre-industrial level and double the more probable 2100 level of around 500-600 ppm (cf. Tans, 2009).

Table 2 Characterisation of RCP's adopted in AR5
(adapted from Jubb et al. (2013))

RCP	Radiative Forcing end of 21st Century	Equivalent Peak $C0_2$ (ppm)	Description (from Jubb et al. (2013))	Comparable SRES Scenario
RCP8.5	8.5	>1370	Very high baseline scenario. Little effort to reduce emissions and warming not curbed by 2100.	A1FI
RCP6.0	6.0	850	Medium Scenario. Stabilises soon after 2100	A1B.
RCP4.5	4.5	650	Medium Scenario. Stabilises after 2100	B1 (at 2100)
RCP2.6	2.6	490	Very Low "Ambitious" scenario. Emissions peak early at 3.0 W/m^2 then fall due to active removal of $C0_2$. Also known as RCP3PD.	Lower than all SRES scenarios considered in AR4

Table 1. Representative Concentration Pathways (RCPs) for greenhouse gas emissions, as assumed by the IPCC (5AR), After W&A (2014, their Table 2).

In addition, a high value of climate sensitivity, which leads to an overestimate of warming, underlies all previous IPCC scenario estimates (including those in Table 1), in the face of new informed research that suggests a low sensitivity of less than 2^o C for a doubling of carbon dioxide (e.g., Lewis & Curry, 2014).

CONCLUSION 2

IPCC's Representative Concentration Pathway (RCP) 8.5 is an extreme and unlikely scenario of future greenhouse gas emissions. Model projections that are based upon this scenario, as are W&A's, are therefore exercises in speculation.

4. "Climate Change Science 101" (W&A, section 3.2.2)

This heading is followed in W&A by a first sentence that reads "*The Earth is warming*"; a little later in the same section we read "*Carbon dioxide is the most significant greenhouse gas*".

Both these statements are untrue, and the first is also meaningless. That such ill-informed and misleading statements are made reveals a worrisome lack of understanding of the dynamics of the climate system that the W&A authors aim to describe for their readers - and which they presume provides the controlling framework for their speculative sea-level projections.

The following statements are all true (Figs. 1, 2):

- The long-term trend of global temperature change is one of c. 2^O C *cooling* over the last 10,000 years, as revealed by high quality regional climatic datasets.
- The short-term trend of global temperature over the last 10 years, measured instrumentally, is also one of gentle *cooling*.

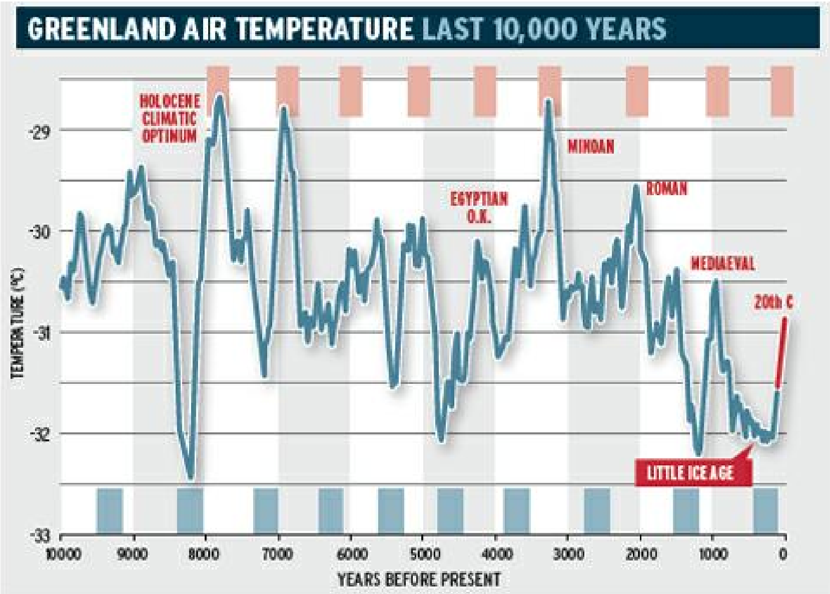

Fig. 5. Greenland surface air proxy-temperatures for the last 10,000 years (Holocene) as reflected in palaeo-temperatures derived from changes in oxygen isotope ratio in the GISP2 ice core (Alley, 2000). Short warm periods, like the Medieval Warm Period and Late 20th Century Warming, occur about every 1,000 years (pink bars, top), separated by cool periods such as the Little Ice Age (blue bars, bottom). This pattern, called the Bond Cycle and probably of solar origin, is superimposed on a cooling trend of about 0.25°C/thousand years since the Holocene Climatic Optimum (HCO). Note that the Minoan, Roman and Medieval Warm Periods, and the HCO, were all significantly warmer than the 20th century warming. Note that the short '20th C' warming plotted in red at the right side of this graph is not based upon the GISP2 isotope record, but instead represents recent global warming as measured with thermometers.

Figure 1. *Temperature record for Greenland over the last 10,000 years After Carter, Spooner et al. (2013, Fig. 5).*

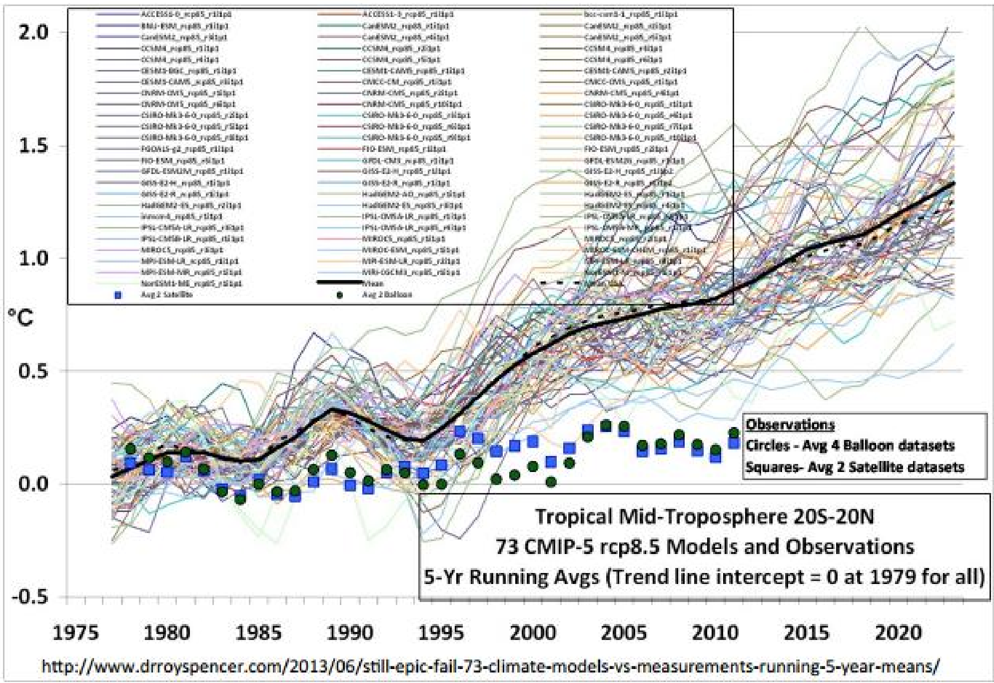

Figure 2. *Comparison of measured temperatures for 1977-2013 with IPCC computer projections for 1977-2050. After Spencer (2013).*

- A phase of global *warming* occurred between 1979 and 1997 (18 years), at a rate and to a magnitude that lie well within the envelope of known earlier natural climate changes. This warming stopped in the late 20th century, there now having been no warming for 19 years (McKitrick, 2014).
- This late 20th century phase of warming of c. 0.4^{O} C forms part of a longer and more general warming that since c. 1830 has accompanied the earth's passage from the inhospitable Little Ice Age (LIA) into the clement Late 20th Century Warm Period (L20WP).
- The passage from the LIA to the L20WP represents the most recent warming limb of a quasi-regular millennial rhythm of c. 1.5^{O} C warming and cooling recorded in many palaeoclimatic records, and that is probably of solar origin.
- Solar cycles 23 (1996-2008) and 24 (2008-) have been of extended length and reduced solar activity, a pattern that in historic time has been followed by significant cooling in succeeding cycles; accordingly, a cooling of 1^{O} C or more over the next two decades is now viewed as likely by many solar scientists (e.g., Cionco & Soon 2014; Velasco Herrera *et al.* 2014).

CONCLUSION 3

These facts notwithstanding, best practice coastal management is not based upon knowledge of past and present rates of global temperature change, nor on computer-based speculations of future rates of temperature or sea-level change, but on empirical geological, oceanographical, meteorological and survey data collected at or nearby a coastal site of interest (see Section 11).

5. Global sea-level change

Global (or eustatic) sea-level change is measured relative to an idealised reference level, the geoid, which is a mathematical model of the shape of the earth's surface. Sea-level is a function of the volume of the ocean basins and the volume of water that they contain, and global changes are brought about by three main mechanisms:

- changes in ocean basin volume caused by tectonic forces
- changes in seawater density caused by variations in ocean temperature or salinity
- changes in the volume of water caused by the melting or freezing of glaciers and ice-caps

Ocean basin volume changes occur too slowly to be significant over human lifetimes and it is therefore the other two mechanisms that drive contemporary concerns about sea-level rise. It is these mechanisms that W&A are primarily concerned with in their modelling and discussion of this issue (Section 3.2.4, p. 32 *et seq.*).

Warming temperature in itself is only a minor factor contributing to global sea-level rise, because seawater has a relatively small coefficient of expansion and because, over the timescales of interest, any warming is largely confined to the upper few hundred metres of the ocean surface.

The melting of land ice – including both mountain glaciers and the ice sheets of Greenland and Antarctica – is a more significant driver of global sea-level rise. For example, during the glacial–interglacial climatic cycling over the last half-million years, glacial sea-levels were about 120 m lower than the modern shoreline (e.g., Lambeck and Nakada, 1990). Moreover, during the most recent interglacial, about 120,000 years ago, global temperature was warmer than today, and significant extra parts of the Greenland ice sheet melted. As a consequence, global sea-level was several metres higher than today (e.g., Murray Wallace and Belperio, 1991).

Author	**Date of study**	**Period considered**	**Length (yr)**	**Rate of Rise (mm/yr)**	**Cumulative rise (cm) by 2100**
Douglas	1991	1930-1980	81	1.8	18
IPCC 3AR	2001	1900-2000	101	1.6	16
Church et al.	2006	1950-2001	52	1.4	14
Plag	2006	1950-1998	48	1.05	10.5
Hagedoorn et al.	2007	1901-2000	100	1.46	14.6
Holgate	2007	1904-2003	100	1.45	14.5
Wöppelmann et al.	2009	1997-2006	10	1.55-1.61	15.5-16.1
Burton	2010	1807-2007	200	0.5-0.6	5-6
Wenzel & Schröter	2010	1900-2007	108	1.56	15.6
Mörner	2012	1901-2000	100	0.0-0.7	0-7
Goddard	2013	1807-2007	200	0.7	7
Beenstock et al.	2014	1807-2010	203	0.39-1.03	3.9-10.3
Parker	2014b	>1950-2010	>60	0.40	4
Wenzel & Schröter	2014	1900-2009	109	1.65	16.5
Menard	2000	1992-2000	8	0.0*-1.0	0-10
Cazenave et al.	2009	2003-2008	6	-0.12	-1.2

**The asterisked value of zero results after applying a correction for an estimated ENSO effect.*

Table 2. *Recent estimates of the long-term rate of change in eustatic (global) sea-level based primarily upon selected sets of tide gauge data and (last two entries) by satellite measurement prior to applying the GIA adjustment.*

Note that all the estimates in the upper part of the table are based upon selected (and differing) sets of tide gauge site data that various authors judge will in some way provide the best, or at least a good, representation of global sea level change.

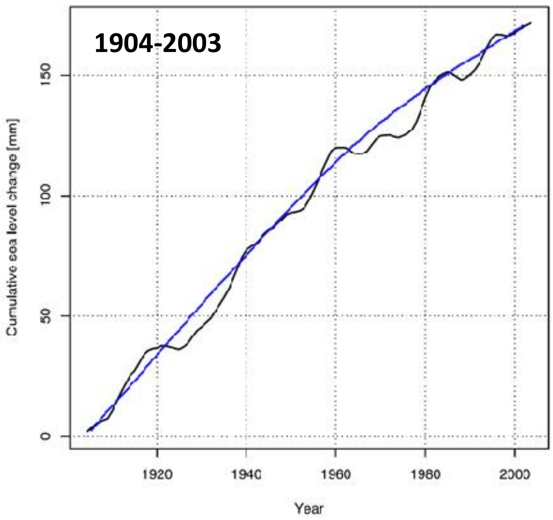

Figure 3. *Cumulative increase in mean global sea level (1904-2003) derived from nine high-quality tide gauge records from around the world. After Holgate (2007).*

Tide-gauge measurements indicate that global sea-level has been rising at rates up to about 1.8 mm/y over the 20th century (Table 2)[1], the rate decreasing somewhat over the last 50 years (Fig. 3), In contrast, the shorter satellite record indicates a higher rate of rise of 2-3 mm/y up to 2010 (Fig. 4), though also decreasing. The discrepancy between the two different rates of rise remains unexplained.

However, a reanalysis of the satellite data, using revised estimates of the respective contributions from warming and ice-melting, has indicated a rise of 1.3±0.9 mm/y for 2005–2011 (Leuliette, 2012). This result is more consistent with the tide-gauge measurements, though surprisingly this is not mentioned by W&A.

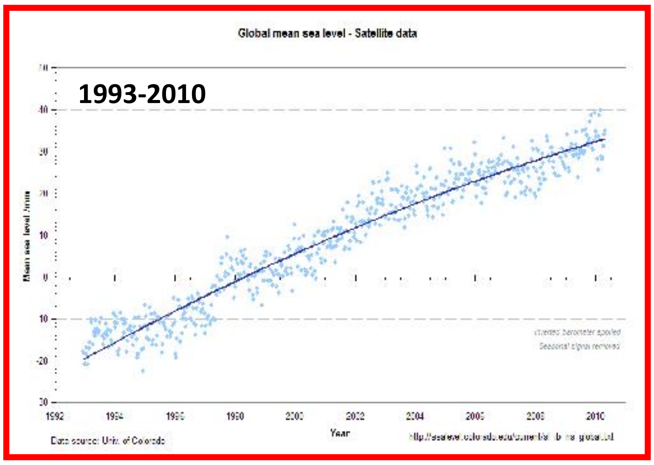

Figure 4. Satellite altimetry time series, 1993-2010 (data, University of Colorado). The linear trend from 1992 to end 2000 is 3.14 mm/yr, and from 2001 to 2010 it's 2.34 mm/yr. This represents a 25% reduction in the rate of sea level rise. After a diagram by Bob Dedekind.

Around the world, significant regional variations occur in the rate and direction of sea-level change; while some regions of the world's oceans are today rising, in other regions sea-level is falling. In part this is due to variations in the rate of warming and salinity changes between different regions, and proximity to discharges of meltwater. Mostly it reflects the influence of major ocean circulation systems that redistribute heat and mass through the oceans. The result is that at any location around or within the oceans, the observed sea-level behaviour can differ significantly from the smoothed global average.

Furthermore, when attempts are made to estimate global sea-level from studies at specific locations, it is found to vary through time. For example a recent study in the Kattegat Sea estimates that, after correction for local tectonic and other effects, rates of "eustatic" sea-level change since 5,000 years ago have varied through time by between -3.1 mm/y and +3.7 mm/y (Hansen, 2014). The same is true over shorter periods of time, such as the 20th century, and also for global data (Holgate, 2007; Gehrels et al., 2012; Jevrejeva et al., 2014; see Figs. 10, 3).

With regard to these matters, W&A state (p. v):

> *Given that* [local] *mean sea levels at all sites examined have adjusted quickly and in a similar manner in response to local ENSO related variability, we can find no reason why there would not be an almost equivalent adjustment to longer, underlying sea-level rise. Accordingly,* ***we expect that sea levels offshore of the study area will rise at a***

[1] Credible estimates of this value range between about zero up to a little less than 2.0 mm/yr. (Table 2). A widely accepted estimate in the IPCC's Third Assessment Report (2001) portrays 20th century sea-level rise occurring at a rate of 1.8 mm/yr, partitioned as 0.4 mm/yr for thermal expansion, 0.7 mm/yr for ice melt and 0.7 mm/yr for dynamic oceanographic factors.

similar rate to the global average, and that any differences between the study area and Sydney will be minimal (W&A emphasis).

It may be true that tectonic conditions are mainly "stable" along the NSW coast. But that is insufficient justification for the above statement, which not only conflates ENSO and longer time-scale phenomena but also ignores the universal reality of tectonic and dynamic oceanographic variation.

CONCLUSION 4

Because they represent a worldwide average, neither the tide-gauge nor the satellite estimates of GLOBAL sea-level have any useful application to coastal management in specific locations. This key fact is obscured in W&A's analysis.

6. Local relative sea-level change

A proper understanding of the risks associated with sea-level change can only be attained by maintaining a clear distinction between global (or eustatic) sea-level (Section 5) and local relative sea-level (discussed here). Yet it is not until p. 38 of their report that W&A attempt to recognize this distinction, arriving at the flawed conclusion that "The projections of interest to planning represent Relative Sea-Level Rise and should include GIA and Tectonic effects". Though the first half of this sentence is correct, the second part contradicts it because adjusting for GIA and other neo-tectonic and tectonic effects is part of the process of converting a local relative sea-level signal into a eustatic estimate.

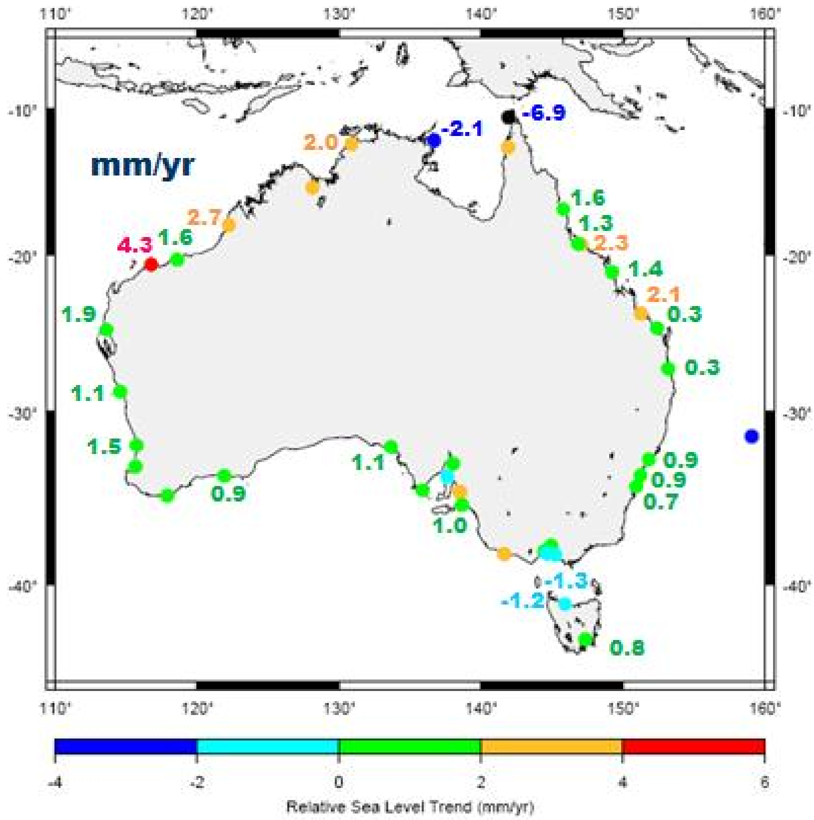

Figure 5. Averaged rates of local sea-level rise for locations around the Australian coastline. After Australian National Tidal Centre (2009).

Local relative sea-level is measured at specific coastal locations. The measurements are therefore affected by the local movement up or down of the land as well as by the notional eustatic sea-level. Local sea-level change can therefore occur at quite different rates and directions at different locations (see frontispiece graph).

In some locations the land is rising: for example, places that were depressed under the weight of the ice caps 20,000 years ago started to rise again as the ice melted. In consequence, in Scandinavia for example, the land is rising at rates of up to 9 mm/year, and local relative sea-level is therefore now *falling* through time despite the concurrent slow long-term *rise* in eustatic sea-level. Conversely, at locations distant from polar ice caps, such as Australia, no such glacial rebound is occurring, which results in local sea-level change in many places being similar to the eustatic rate of rise (Fig. 5; Table 2; cf. White et al., 2014).

Mörner & Parker (2013) analysed the same tide gauge stations as those in Fig. 5, concluding that "*the mean sea level rise from Australian tide gauges is to be found within the sector of rates ranging from 0.1 to 1.5 mm/year*" (yellow wedge; Fig. 6).

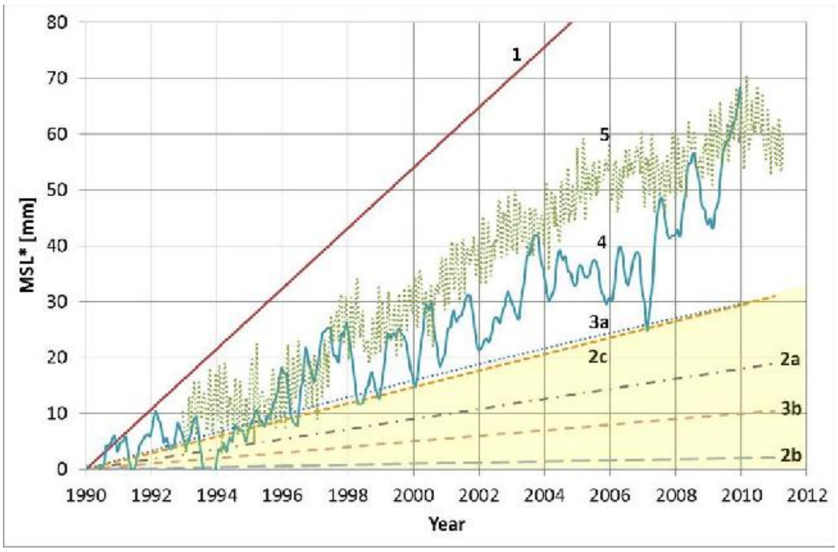

Figure 3 : Comparison among different sea level data sets; (1) the Official Australian claim (AFGCC, 2011; ABSLMP, 2011), (2a) the Australian 39 station record, (2b) the Australian 70 station record, (2c) the Australian 86 station record, (3a) the 2059 station PSMSL (2011) average, (3b) the 159 station NOAA (2011) average, (4) the reconstruction of sea level changes by Church and White (2011), and (5) the Topex/Jason satellite altimetry record (CU, 2011). All the data are shifted for a zero MSL in January 1990. The differences are far too large not to include serious errors in some of the records. The official Australian trend (1) lies far above all the other curves, indicating a strong exaggeration. The Australian (2a-c) as well as global (3a-b) curves vary between 0.1 and 1.5 mm/year. The satellite altimetry records (5) include "calibrations" previously questioned (Mörner, 2004, 2011c, 2013). The record (4) of Church and White (2011) lies between the satellite altimetry curve (5) and all the graphs representing global (3a-b) and Australian (2a-c) tide gauge records. The acceleration in curve 4 is strongly contradicted by all the other records. The same absence of acceleration is found in many other records (further discussed in the text) indicating that the concept of acceleration ought to be revised.

Figure 6. *Comparison between differing rates of sea-level rise since 1990 as indicated by Australian tidal data (yellow shaded field), the PMSL (2011) global average (blue line), satellite altimetry (green line) and by hypothetical projection of assumed Australian rates (red line). After Mörner & Parker (2013, Fig. 3).*

Alongside Mörner & Parker's (2013) estimated averages, many individual locations around the Australian coast record sea-level rises over the last century at rates between about 1 and 2 mm/y, with an absolute range between −6.9 mm/y and +4.3 mm/y (Fig. 5). Prior to this, and since the last ice age, rates of sea-level change around Australia varied in both sign and magnitude (Sloss *et al.,* 2007; Lewis *et al.,* 2012), with rates of rise perhaps greater than 10 mm/yr during sharp pulses of ice melting and shoreline advance (Larcombe *et al.,* 1995). Since the cessation of major ice-melt about 10,000 years ago, eastern Australian sea-level peaked at 1-2 m above modern sea-level about 6,000 years ago, declining thereafter due to hydro-isostatic[2] tilting (Beaman, 1994; cf. Parham *et al.,* 2014.)

A recent study by Beenstock *et al.* (2014) illustrates the variability of local relative sea-level change around the world over historic time. Using a worldwide selection of high-quality tide-gauge records from the Permanent Service for Mean Sea Level (PSMSL) for 1807 – 2010, these authors show that at 35% of locations sea levels rose at an average of 3.8mm/yr, at 61% of locations sea-level remained stable and at 4% of locations sea-levels fell on average by almost 6mm/yr.

For these and other reasons, Fu & Haines (2013, 9.1296) have recently emphasized the practical importance of local and regional sea level changes for coastal policy purposes, warning that:

> *Regional rates of sea-level change over the same (~ 20-yr) time period range from -12 to +12 mm/yr … Due to large geographic variability in the ocean currents, the time required to accurately determine the sea level trend on a regional basis varies from a minimum of 5-100 yr … These estimates do not include the contribution of systematic altimetric measurement errors, which may themselves induce spurious drifts that are*

[2] Hydro-isostasy is the effect of changing water loading due to the changing ocean volume that accompanies shoreline migration during major sea-level rises or falls. The effect is usually linked to glacio-isostasy as the changing ocean volumes are driven by changing ice volumes on land. The two terms are sometimes combined as glacio-hydro-isostasy and the term glacial isostatic adjustment (GIA) may encompass both effects (see Lambeck et al., 2003).

geographically correlated. Because the impact of sea level change is felt locally, it is the regional nature of sea level variability that is the most important factor for future adaptation and mitigation.

Quite so.

CONCLUSION 5

Local relative sea-level change is what counts for purposes of coastal planning, because even in a largely tectonically stable area such as eastern NSW, different rates of uplift and subsidence may apply in different locations.

7. Inadequacy of computer sea-level simulations using homogenized[3] data

As part of the background discussion for their NSW sea-level reconstructions, W&A (p. 36, Fig. 6; reproduced here as Fig. 7) provide a figure from IPCC 5AR which they offer as evidence that the IPCC's CMIP5 suite of computer models yield accurate projections of sea-level change. Yet at the same time, individual research publications continue to show major discrepancies between modelled and observed sea-level behaviour (e.g. Marsland *et al.,* Fig. 15).

But even should a match exist it is not necessarily evidence that the models are correct, for such correspondence can equally well result from careful and skilled curve fitting. Consider the following as an example. In 2001, IPCC 3AR authors presented a widely applauded graph that demonstrated a match between the Hadley surface temperature graph and back-predicted temperature projections from then-current computer models. Though up to 2000 the historical record and computer simulations matched (3AR), the 2007 4AR and 2013 5AR res demonstrated that subsequently a wide divergence opened up between the computer-forecast temperatures and the real-world measurements (cf. Fig. 2). This divergence relates to the cessation of warming after 1997, which falsifies the models and indicates that the pre-2000 match represented curve-fitting rather than accurate modelling.

Second, in the top panel of Fig. 7 (*Observed versus modelled sea-level height*), the indicated agreement between satellite-measured and computer-modelled sea level compares a 100-yr long simulation with an 18 yr-long set of satellite measurements. The correspondence claimed therefore rests entirely upon the baseline level chosen for the satellite measurements. What is more, and regardless of the baseline issue, the satellite data is diverging, exhibiting a higher rate of rise than present in the tide gauge data. This difference between altimetric and tide gauge-measured rates of sea-level rise, which is already widely known (e.g., Jevrejeva *et al.,* 2008; Ray & Douglas, 2011), is obscured on the middle panel of Fig. 7 (*Observed versus modelled rates of sea-level change*) by representing the altimetric curve by only a single summary point with wide error bars of unexplained origin.

[3] [3] The term homogenized "data" has come into wide circulation since government meteorological agencies replaced their former technique of reporting actual temperature measurements by publishing instead computer-generated estimates, derived from the raw data by making various corrections and modifications to it. As the W&A report demonstrates, similar techniques are now being used in the generation of sea-level "data". Though some such corrections may be justifiable, the absence of full transparency of the techniques and computer code used precludes independent checking of the homogenized "data" by disinterested third parties; as such the practice is open to subjectivity and bias, and is therefore contrary to scientific method.

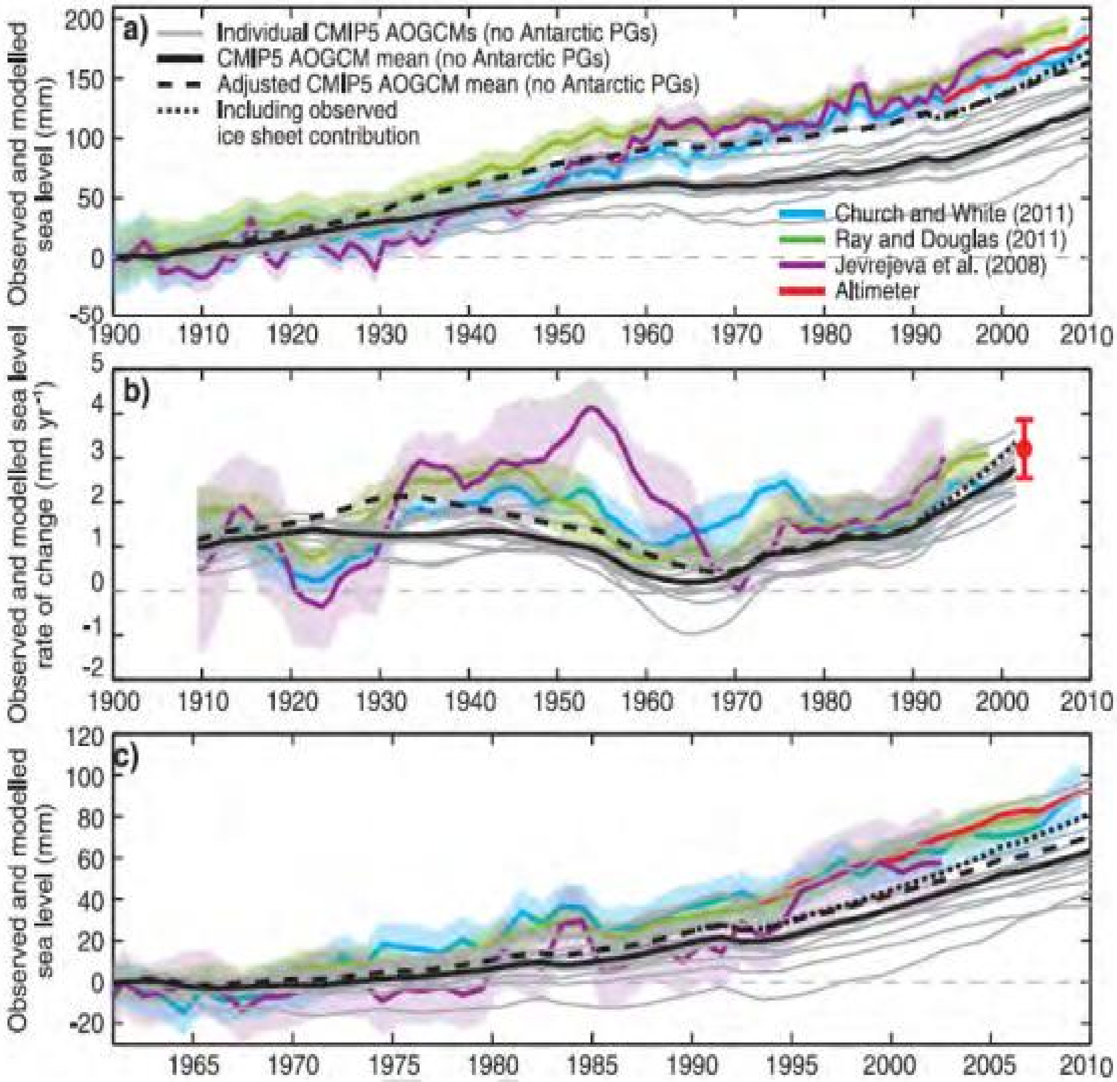

Figure 6 Performance of CMIP5 Models against estimates of Historical Global Mean Sea Level (adopted from Figure 13.7 of IPCC (2013b)).

(a) Observed and modelled sea level for 1900 to 2010
(b) The rates of sea level change for the same period, with satellite altimeter data shown as a red dot for the rate. Note that the rate (in mm/yr) has been greater than zero for all historical reconstructions since the 1920s. Conversely, some model simulations simulate a negative rate (falling sea level) during the 1960s.
(c) The observed and modelled sea level for 1961 to 2010.

Shading indicates the uncertainty estimates from different estimates of global mean sea level, (Jevrejava et al, 2008; Church and White, 2011; Ray and Douglas, 2011) to two standard deviations; Solid black line is mean of grey lines each of which represent different model simulation estimates of the summed sea-level rise from (i) thermal expansion, (ii) land water storage and (iii) glaciers excluding those peripheral to Antarctic ice sheet. The Dashed black line corrects the black line to include measured ice losses from glaciers instead of modelled values. The dotted black line adjusts the model results further by including ice sheet observations (from 1993 onwards). This last adjustment also includes the glaciers peripheral to the Antarctic ice sheet.

Figure 7. *After W&A (2014, p. 36, their Fig. 6).*

Third, the bottom panel of Fig. 7 (*Observed versus modelled sea-level since 1960 only*) represents the claim made later in the text that the tide gauge and altimetric data sets indicate similar rates of rise of 3-4 mm/yr over the last few decades. This quasi-match has been achieved by (i) adjusting the tide gauge data upward by means of additional glacial-melt and perhaps a geoidal correction (see also Section 8 below), followed by (ii) comparing only the rate of change of the two data sets and not their actual component data.

Fourth, and as W&A (section 5, p. 29) themselves point out:

> *In the context of climate change, projections are representative future scenarios for various climate related parameters.* ***They are not "predictions" with an associated likelihood.*** *Instead, the projections represent "what-if" scenarios that depend on pre-determined plausible scenarios of either economic development or concentrations of greenhouse gases (emphasis added).*

Quite so. They should therefore not be used as a basis for policy decisions, and especially not if they are based upon emissions scenarios as implausible as RCP 8.5 (see Section 2).

Fifth, the use of complex modelling of tide gauge data sets in order to yield sea-level information, such as that summarised by W&A, is in dispute even amongst those authors who participate in the practice. The prime reasons for this are the lack of independence between studies, and a failure to disclose the techniques used precisely and transparently so that other scientists can analyse them. As Mörner (2012) has noted, "If the 'corrections' applied are not clearly specified (and discussed and argued for), then the resulting corrected data cannot be objectively evaluated".

The matter is summarised by Woodworth *et al.* (2009, p. 778), who say:

> *A point to make concerning the various studies is that they cannot be independent as they are based on a single tide gauge data set, which has known spatial and temporal limitations. … A second point concerns the use in some analyses, including those of CW06* [Church & White, 2006] *and J06* [Jevrejeva *et al.,* 2006]*, of short records incorporated into an analysis in ways which are not completely transparent (in spite of outlines of analysis methods having been documented) as they depend on complex minimization techniques.*

Sixth, recent modelled global sea-level projections make correction for the vertical isostatic[4] movements that occur in response to shifting loads induced on Earth's crust by the growth and decay of ice sheets, and by parallel load oscillations induced by changes in water depths across the continental shelf (caused by falling and rising sea-level in sympathy with the glacial-interglacial fluctuations). Adding an ice or water load causes isostatic subsidence (and local relative sea-level rise), whereas removing those loads causes isostatic rebound (uplift, and local relative sea-level fall). The correction, termed a Glacial Isostatic Adjustment (GIA), is the outcome of a computer model that comprises a mathematical model of the shape of the earth (the geoid) and assumptions regarding the viscosity of the upper mantle where isostatic flow occurs. Neither the geoid (NASA JPL, 2012; Tamisiea *et al.,* 2014) nor the viscosity (Jones *et al.,* 2012) is accurately known. Accordingly, several alternative geoid models exist, the deployment of which produces differing modelled estimates of sea-level change.

[4] *Isostasy* describes the process whereby slow adjustment flowage occurs at depth in response to the addition or removal of loads at the Earth's surface. The compensating flows occur in a hot, semi-plastic layer of the mantle (asthenosphere) at depths of 70–250 km, just below Earth's rigid outer shell (lithosphere) and at rates of subsidence or rebound (uplift) up to about 1m/century.

GIA models lack independent verification, but are informed by the best available knowledge of the Earth's actual shape, as measured from space in the form of a Terrestrial Reference Frame (TRF). Recently, NASA has indicated that current TRF errors are greater than the inferred signal of sea-level change being measured, and proposed that a new satellite be launched with the specific role of measuring the TRF accurately (NASA JPL, 2012). Clearly, estimates of sea-level change made using satellite-borne altimetric data will remain problematic until the launch of NASA's new GRASP satellite, or until the development of some other mechanism for improving the accuracy of geoid models. As Wunsch et al. (2007) have reminded us, "At best, the determination and attribution of global-mean sea-level change lies at the very edge of knowledge and technology."

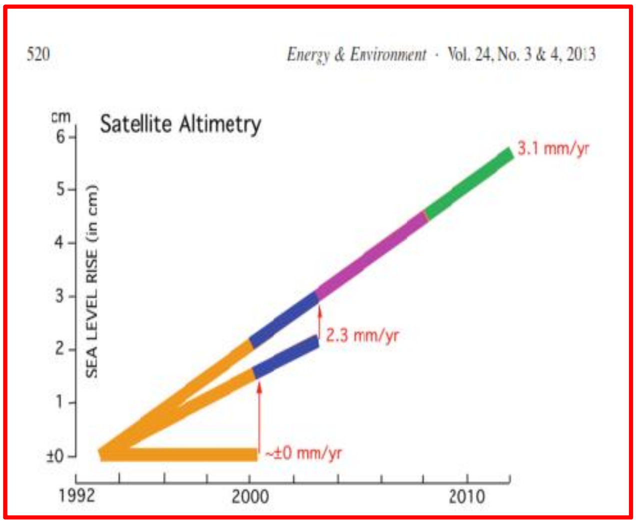

Figure 8. Changes, termed "corrections", in the mean rate of sea-level rise in satellite altimeter records. The 0 mm/yr trend of 1992-2000 (orange bar) was increased by 2.3 mm/yr in 2003 (blue bar) and by another 0.8 mm/yr in 2008 (purple bar), continuing to present (green bar). This implies that the satellite record is not a measured product but an arbitrarily "corrected" one (cf., Parker, 2014b). After Mörner, (2013, Fig. 9).

These problems notwithstanding, a GIA correction has been applied to all satellite altimeter measurements of sea-level since 2003, with the effect of changing a sea-level record that showed no trend or perhaps a gentle rise into one that now projects high rates of rise (Mörner 2004, 2013) (Fig. 8).

Lastly, and seventh, processing of all satellite altimetric data takes place against the background of known errors that at least match, if not exceed, the sea-level signal being sought. As Bar-Server *et al.* (2012) say:

> *… we assess that current state of the art reference frame errors are at roughly the mm/yr level, making observation of global signals of this size very difficult to detect and interpret. This level of error contaminates climatological data records, such as measurements of sea level height from altimetry missions, and was appropriately recognized as a limiting error source by the NRC Decadal Report and by GGOS.*

Conclusion 6

W&A (p. 33) quote George E.P. Box (1987) as saying "remember that all models are wrong; the practical question is how wrong do they have to be to not be useful". The suite of CMIP5 models drawn on by W&A have repeatedly been shown to be wrong when tested against factual data. Since the models do not provide verifiable predictions, they clearly cannot be relied upon as a tool for formulating coastal management policy.

8. What is the measured rate of sea-level rise along the central NSW coast?

It is unfortunate that apparently simple questions such as the one posed in the heading can sometimes have complex answers. It is also the case that as knowledgeable readers peruse the W&A report their attention becomes sharply riveted when they come upon page 41 and Table 6. For there it is stated that the rate of recent sea-level change as measured by the Fort Denison and Port Kembla tide gauges is 3.3 and 3.6 mm/yr rise, respectively.

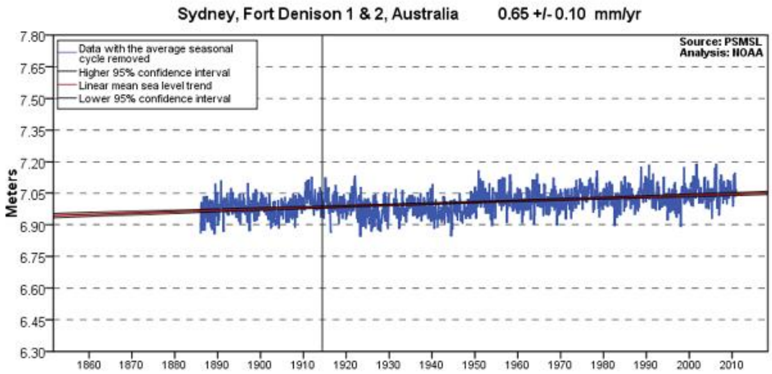

Figure 9. *Mean sea level trend for Fort Denison, Sydney for the period 1886-2010 is 0.65 millimeters/year (95% confidence interval of +/- 0.10 mm/yr). After NOAA (2014).*

How can this be? For virtually every recent official report or refereed paper on the topic has calculated rates of rise of <1 mm/yr for the long Fort Denison record (Table 3 and Fig. 9; the differing values in the table mostly representing the use of differing periods of data by different authors). Furthermore, three separate investigations have shown recently that the rate of sea-level rise on the NSW coast has been *decreasing* over the last 50 years (Watson, 2011; Boretti, 2012b; Modra & Hesse, 2011), a phenomenon that has also been noted nearby at Auckland (Hannah & Bell, 2012) and at global level by Houston & Dean (2012).

At the same time that W&A claim this almost 5-times increase in the rate of sea-level rise measured by the Fort Denison tide gauge (their Tables 6, 7), they reiterate that satellite altimeter data for the NSW coastal ocean (their Table 9, p. 47) also show rates of rise between 4.1 and 4.5 mm/yr, and assert that therefore the tide gauge and satellite records are now in agreement. Similar claims of the reconciliation of the satellite altimeter and tide gauge records have been made by Church & White (2006; 2011) and Domingues *et al.* (2008).

These assertions fly in the face of a large research literature that views the mismatch of global sea-level rise as reconstructed from tide gauges (at c. 0.0-1.8 mm/yr; Table 2) or satellite altimetry (>3 mm/yr; Fig. 6) (e.g., Munk, 2002; Houston & Dean, 2012; Houston, 2013; Jevrejeva *et al.,* 2014) as one of the biggest unsolved problems in sea-level studies (Boretti, 2012a). For example, de Lange (2010) compared the long term tide gauge record from Auckland with the nearest satellite altimeter record from the nearby Outer Hauraki Gulf (Fig. 10). His results show that the satellite data require a ~60% downscaling correction in order for them to fit with the in situ tide gauge measurements.

One reason for the mismatch is understood, though not widely taken into account. It is that the satellite measurements of sea-level yield more accurate answers when the sampling cell that they measure lies entirely within an ocean area; simplifying assumptions that are made in processing data for coastal cells, which comprise a mixture of part land and part ocean areas, introduce significant discrepancies with shoreline tide gauge measurements. A further complication, which causes a higher sea-level rise offshore than at the coast during phases of warming (as late last century), is that the amount of ocean expansion caused by warming is proportional to the depth of water below the surface measuring site, the effect thereby diminishing to zero at the shoreline (Mörner, 2013).

What then is the claim of equivalence between the tide gauge and satellite records based upon?

Author	**Date of study**	**Period considered**	**Length (yr)**	**Rate of Rise (mm/yr)**	**Cumulative rise (cm) by 2114**
Hagedoorn *et al.*	2007	1901-2000	100	0.86	8.6
Australian NTC	2009	1914-2010	106	0.9	9.0
You *et al.*	2009	1886-2007	122	0.63	6.3
You *et al.*	2009	1914-2007	93	0.93	9.3
You *et al.*	2009	1950-2007	57	0.58	5.8
Manly HL	2011	1986-2007	22	0.4	4.0
Modra & Hesse	2011	1914-2004	100	0.94	9.0
Watson	2011	1940-2000	61	0.68	6.8
NOAA	2014	1886-2010	125	0.65	6.5
Whitehead & Ass. (linear fit)	2014	1886-2014	129	0.70	7.0
NAÏVE AVERAGE				**0.73**	**7.3**
SW PACIFIC only					
Gehrels *et al.*	2012	1950-2000	50	0.7	7.0
SHORT-TERM only					
Whitehead & Ass. (homogenized)	2014	1996-2013	18	3.3	33
This commentary*	2014	1996-2012*	17	2.8	28

*Figure calculated for 1996-2012 rather than 1996-2013 because of the absence of a web-posted figure for 2013.

Table 3. *Recent estimates of the long-term rate of change in local relative sea-level at the Fort Denison tide gauge site, Sydney harbour. Note that the mean 0.73 mm/yr rise is a relative figure; when the estimated subsidence rate of -0.49 mm/yr (for 2005-2014; NASA GPL, 2014) is subtracted, the best-estimate of eustatic sea-level rise at Sydney falls to 0.24 mm/yr.*

Note also that W&A's model-adjusted short-term estimate (penultimate line) differs dramatically from all other results. It also exceeds the observational value of 2.8 mm/yr (calculated de novo *here) for the short period 1996-2012/13 by 0.5 mm, which amount presumably represents the additional excess produced by unspecified GIA and tectonic corrections.*

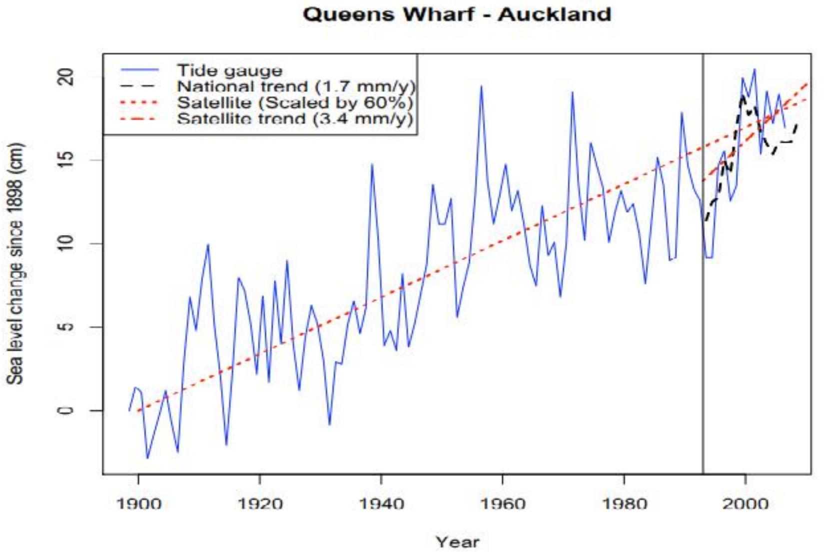

Figure 10. *Comparison of the long term Auckland sea level curve (1898-2006) and the nearest satellite altimetry observations from the outer Hauraki Gulf (1992-2009; University of Colorado). OLS regression between the tide gauge and altimetry data indicates that the altimetric data require a~60% baseline downscaling to best match the tide gauge record.*

OLS regression trends are superimposed for tide gauge and satellite (baseline shifted by 13.8 cm to allow comparison) data at the time of analysis (2010). New Zealand-wide tide gauge average for 1992-2009 indicated as black-dashed line.

Note that the GIA was not applied by the University of Colorado at the time that this analysis was performed. Inclusion of a GIA adjustment would increase the deviation between the two trends shows. After de Lange (2010).

In a 2011 study, Church & White combined measurements from discrete satellite and tide-gauge data sets into a single homogenized data set. In doing so, they noted (p. 594) that "We present results for two periods: from 1880 to 2009 and the satellite altimeter period from January 1993 to December 2009. The latter is only a partial test of the reconstruction technique because the EOFs[5] used were actually determined for this period." Exploring the matter further, Church & White (2006) acknowledged also that to represent changes in global sea-level they had included an additional spatially uniform field in their reconstruction, and that omitting this field results in a smaller rate of satellite-derived sea-level rise that is inconsistent with both individual tide gauge records, and with the various estimates of their mean; omission of the field also "results in unrealistically large regional variability in trends, because a finite number of EOFs cannot adequately represent a substantial change in mean sea-level" (Church & White, 2006).

The complexity of these unsatisfactory issues is further heightened by the practice of releasing successive sets of reprocessed (homogenized) data as the basis for "new", revised sea-level curves. In this regard, the original averaged tide gauge dataset of Church & White (2006) was supplanted by a different dataset (based on a different selection of tide gauges, and not linked to a published paper) in 2009, followed by another revised dataset in Church & White (2011). The 2006 data version shows an acceleration in the rate of sea-level rise in the late 19th and early 20th century, and a deceleration thereafter; the 2009 version shows only a deceleration in rise after 1925; and the 2011 dataset shows again a slight acceleration after 1925 (cf., Burton, 2012). How any policymaker can fashion sensible conclusions in the face of such bewildering variations in purported reality is unclear.

The key point is that a combined local tide-gauge and satellite altimetry determination of relative sea level change is based upon two incompatible sets of measurements; each of the datasets has its own

[5] Empirical orthogonal functions (EOF) represent the statistical decomposition of a data set into component functions whose weighting is determined from the data. The technique is similar to principal components analysis but identifies both time series and spatial patterns.

measurement errors and uncertainties, as well as systematic problems and errors in spatial and temporal sampling. An assertion that the two sets of measurements represent the same rate of global sea level rise is therefore a political rather than a scientific conclusion.

Deploying similar techniques to those just described, W&A arrive at their claim of matching NSW tide gauge and altimetric sea-level estimates at 3.3 mm/yr by the following route:

- Restricting the period of tide gauge data that they consider (mostly 1996-2013), and thereby discarding more than 100 years of prior data from the Fort Denison site;
- Interestingly, the selected 18 year period covers part of the time over which other authors have reported a decelerating rather than the enhanced rate of sea-level rise reported by W&A, which immediately suggests that W&A are processing the tide gauge data in a non-standard fashion; and
- Reporting the tide gauge analysis as a “Linear Fit to Annual Mean Sea Levels” (heading for Table 6, p. 42). To an innocent reader this suggests that a simple least-squares analysis has been used as the line fitting procedure, whereas discussion in the surrounding text indicates instead that the line fitted by W&A, and the rates of rise that it represents, are the outcome of a computer model.

In reporting their inflated estimate of rate of sea-level rise in NSW, W&A (p. 41) comment that for the tide gauge records analysed “erroneous data were removed, the annual average mean sea level was calculated, and that value was adjusted to Australian Height Datum”, which again might suggest that simple least-squares analysis was used. However, the elevated magnitude of the rate of rise compared with all earlier estimates (Table 3) demonstrates that this result must reflect some combination of use of an inadequately short time period (1996-2013; which in itself increases the long-term rate of 0.73 to ~2.8 mm/yr; cf. Table 3) and computer adjustment (the remaining ~0.5 mm/yr, which includes the GIA correction).

Therefore, and as Dr Howard Brady has pointed out (submission to Shoalhaven Council on regional plan DCP 2014; Sept. 18, 2014), the claimed rate of sea-level rise of 3.3 mm/yr in Sydney Harbour is not based upon “the 'actual regional data' but the homogenised[6] data that calculates Fort Denison sea level rise as currently 33 cm/century (over three times the local regional rate)".

CONCLUSION 7

The high sea-level rise figure of 3.3 mm/yr reported for the Fort Denison (Sydney) tide gauge by W&A does not represent the original data measurements (0.73 mm/yr) but instead results from computer modelling combined with the selection of a short and atypical section of sea-level record.

Some of the detailed steps in the data homogenization process are discussed further under the next heading. Suffice it for the moment to note that, irrespective of any modelling problem, estimates of sea-level change made using satellite-collected data remain problematic, because of the many uncertainties that exist with their collection and processing. In particular, there is inconsistency

[6] The term homogenized “data” has come into wide circulation since government meteorological agencies replaced their former technique of reporting actual temperature measurements by publishing instead computer-generated estimates, derived from the raw data by making various corrections and modifications to it. As the W&A report demonstrates, similar techniques are now being used in the generation of sea-level “data”. Though some such corrections may be justifiable, the absence of full transparency of the techniques and computer code used precludes independent checking of the homogenized “data” by disinterested third parties; as such, the practice is open to subjectivity and bias, and contrary to scientific method.

between the results derived by different research groups, with all results depending upon the accuracy of complex adjustments some of which lack independent verification (Houston and Dean, 2012), plus the related problem that the signal being sought may well lie below the noise level of the data being used (Morner, 2013; Parker, 2014b).

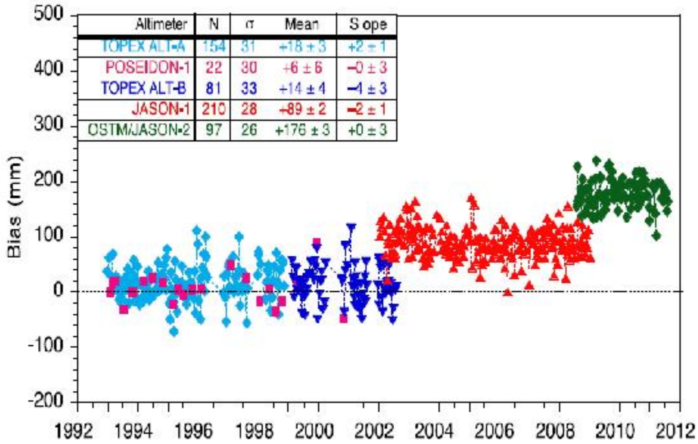

Figure 11. *Long-term sea surface height (SSH) calibration time series for three satellite altimeter missions (Topex/Poseidon), Jason-1 and Jason-2). The two latter missions measured SSH too high by +9 and +18 cm, respectively. The bias represents errors in altimeter characterization data and misattribution of the mechanical reference point for the spacecrafts' altimeter antennae. After Fu & Haines, 2014.*

One of these problems was highlighted in the recent study of the satellite altimetry data records by Fu & Haines (2013, p. 1291). These authors highlighted that:

> *[S]ignificant biases* [have] *existed for years, and must be accounted for in constructing the combined sea-level record* [their Fig. 7, re-shown here as Fig. 11]. *The sources of these biases have only been recently discovered, and relate to errors in the altimeter characterization of data as well as inconsistency in the interpretation of mechanical reference point for the altimeter antennas on the spacecraft … .*

As concluded by Wunsch *et al*. (2007) with respect to satellite altimeter measurements of sea-level:

> *At best, the determination and attribution of global-mean sea-level change lies at the very edge of knowledge and technology…Both systematic and random errors are of concern, the former particularly, because of the changes in technology and sampling methods over the many decades, the latter from the very great spatial and temporal variability…It remains possible that the database is insufficient to compute mean sea-level trends with the accuracy necessary to discuss the impact of global warming – as disappointing as this conclusion may be. The priority has to be to make such calculations possible in the future.*

CONCLUSION 8

Despite these and other similar warnings and caveats, much of W&A's analysis relies upon the presumed accuracy of satellite-borne sea-level measurements. Current research literature shows that this technique is not yet well enough established, and nor is the record long enough, to form an adequate basis for coastal planning.

9. Inadequacy of using an 18 year (1996-2013) baseline as a planning template

Significant sections of the W&A report are concerned with presenting results about, and discussing, sea-level change over the 18 year period 1996-2013. In a footnote to Table 6, W&A (p. 42) warn that rates calculated over this period "are unsuitable for long term estimation of sea-level rise, refer to text". They are entirely right, and therefore the policy advice that they give predicated upon analysis of 1996-2013 data should be rejected outright.

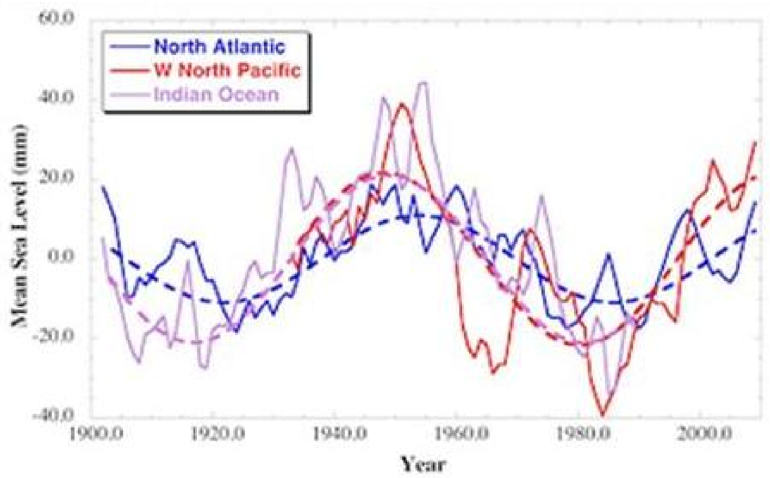

Figure 12*. 60-year long, 40-cm amplitude rhythmicity associated with 20th century sea-level records from the North Atlantic, North Pacific and Indian Oceans. After Chambers et al. (2012).*

Climate-related phenomena, including changes in sea-level, change through time in a non-stationary[7] way, and exhibit repetitive (though not exactly regular) patterns of behaviour over decadal and multi-decadal periods (Fig. 12).

Changes in the rate of global sea-level are, for example, known to be influenced by a 50-60 year rhythm related to oceanic internal variability (e.g., Pacific Decadal Oscillation, PDO; Atlantic Meridional Oscillation, AMO) (Holgate, 2007; Chambers *et al.,* 2012; Marcos *et al.,* 2012; Soon & Legates, 2013). Long period tidal constituents (the 18.6 lunar nodal cycle, for example) also exert an influence on sea-level height (e.g., Pugh, 2004; Yndestad *et al.,* 2008).

It follows that sea-level records longer than 60 years, and even better longer than 120 years, are required to identify any long-term trends that might, or might not, occur in the data. On the eastern NSW seaboard, only the tide gauge record from Sydney Harbour (Fort Denison) meets these criteria (Fig. 9). This record indicates a long-term rate of rise since 1886 of just 0.73 mm/yr (Table 2). This is almost 5-times slower than the rates of rise adopted by W&A in formulating their policy advice.

W&A use 1983-2013 as their longest sea-level record and arbitrarily discard the earlier measurements, which extend back to the 19th century (cf., Fig. 13). The available tide gauge records from the Tasman Sea and Southwest Pacific Ocean that are greater than 100 years long all exhibit a similar and significant multi-decadal PDO-related sea level signal, marked by an upward step every 50-60 years with a relatively flat signal in between these steps (e.g., Auckland; Fig. 14). As W&A (p. 49) themselves note, this behaviour reflects changes in the magnitude and frequency of El Niño and La Nina events over time, in line with a changing PDO.

Note that the PDO effect does not appear strongly in *global* sea level data, because the precise timing of the oscillation differs in different parts of the ocean basins, and thereby tends to average the effect out (cf., Fig. 12).

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[7] i.e., do not consist simply of random oscillations about a fixed long-term mean, but display steps, trends and baseline-shifting rhythmicities in their behaviour.

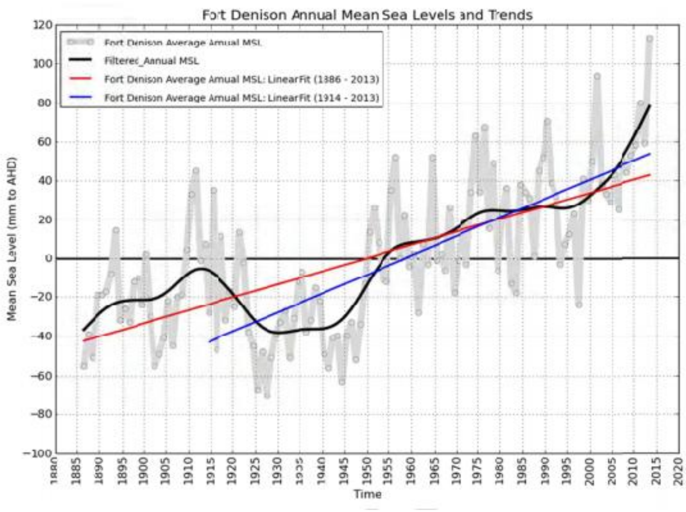
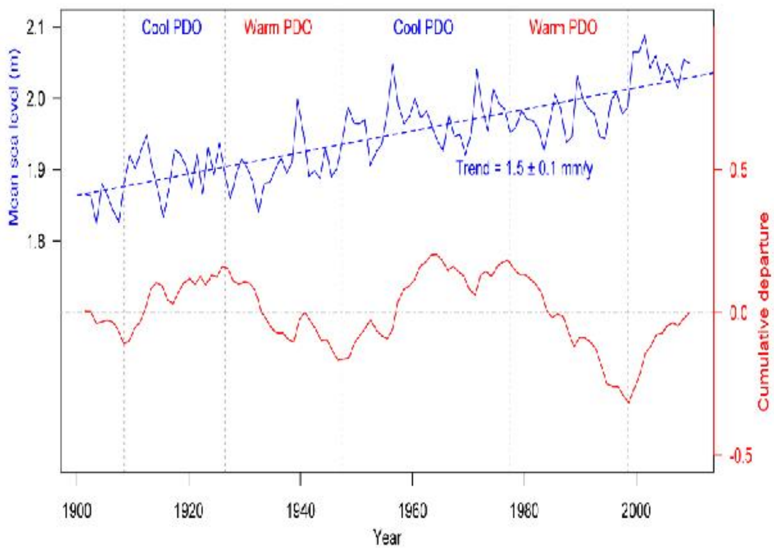


Figure 13. *Fort Denison average annual sea-level record, 1866-2013. After W&A (2014, their Fig. 13).*

Notwithstanding this, the PDO-related pattern can be coherent over *wide regions* such as the Tasman-Southwest Pacific, as can be seen by comparing the Fort Denison and Auckland tide gauge records (Figs. 12, 13; and compare W&A, Figs. 9, 10). Further analysis of the Auckland record yields long-term trend rates of sea-level rise of 1.4-1.8 mm/yr, the exact trend depending upon what time period is considered and where the analysis starts and finishes in relation to the PDO-related jumps (cf. W&A's similar alternative trend analyses of the Fort Denison record, Fig. 12).

Figure 14. *1899-2009 tide gauge record from Auckland harbour. Note the progressive long-term sea-level rise at a rate of 1.5 mm/yr, superimposed on which are irregular variations that correspond to El Nina-La Niño (ENSO) cycling and the phases of the Pacific Decadal Oscillation (PDO). Auckland gauge data (blue, above) after Hannah et al. (2010). Red line (below) is the cumulative sum of the residuals in the sea-level curve (differences between the blue dashed and solid lines). PDO phases added after* http://jisao.washington.edu/pdo/



CONCLUSION 9

In choosing to analyse the short 18-year period 1993—2013 and 1996-2013, W&A have selected an arbitrary length of record that encompasses a late-1990s, El Niño-related regional jump in the rate of sea level change. Thereby, they achieve a significantly higher rate of sea level rise than the true long-term trend at Fort Denison of about 0.73 mm/yr.

10. What rate of sea-level rise should be used to inform Councils' coastal planning?

Two things are clear from the previous discussion. First, and as also recommended by the NSW Chief Scientist (O'Kane, 2012), coastal Councils should use the closest available long term tide gauge measurements of local relative sea-level change to inform their policy making. Second, the current generation of deterministic computer models are flawed when measured against empirical data, and are therefore not reliable for policy setting.

Regarding the first point, the nearest long term, high-quality tide gauge to the central NSW coast is Fort Denison, Sydney harbour (Fig. 9). In which regard we agree with W&A, who say (p. 74):

> "*We advise that monitoring and analysis of the contemporary mean sea level at Fort Denison will provide results that are directly applicable to the study area*";
>
> and (p. 53) that:
>
> "*In future, sea-level rise within the study area can be adequately assessed by examining behaviour at the Fort Denison gauge and adopting this gauge as a proxy. While Port Kembla may be equally suitable, Fort Denison has the advantage of a much longer record for teasing out longer term variability*".

But having conceded the essential point that local long-term NSW sea-level data should be used for planning, W&A strangely then turn to providing reasons for not applying their own conclusion, saying (p. 27):

> *The following sections detail a relatively simplistic approach, applying linear fits to the available data, to determine trends over the past two decades. The values calculated by this method are not suitable for the projection of future sea levels.*

That no reason is given for the claimed lack of suitability of simple empirical projections is odd, given that such projections have informed coastal decision making for more than 100 years.

A little later (p. 35), and after extended discussion regarding the use of computer model projections, W&A add:

> *"In conclusion, we consider that the process based models and their projections are useful for planning. No model is perfect, and this needs to be considered in making policy decisions. The execution of a number of independent models as part of the CMIP5 project provides confidence that the actual sea-level rise that will be realised for a future scenario is within the ranges of projected values provided".*

In reality, the CMIP5 intercomparison provides no such justification for model accuracy, and mostly serves to show that the model projections fail when tested against reality (Fig. 2). Furthermore, regarding the probability estimates, IPCC claim (5AR, Summary for Policy Makers, p. SPM-2):

> *"Probabilistic estimates of quantified measures of uncertainty in a finding are based on statistical analysis of observations or model results, or both, and expert judgment".*

In other words, even the IPCC concedes that its probability estimates are NOT rigorously statistical. As Idso et al. (2013) point out:

> *"Weather forecasting methods make successful use of probabilistic ensemble averaging to provide a numerical range of uncertainties for individual forecasts. IPCC's climate models, however, are not run in this mode, and their ensemble averages are based upon a statistically inadequate and inconsistent number of runs, generally less than five. As discussed by Singer (2013), the chaoticity of modeling can only be overcome by using a large number of runs.*

Given their commitment to the usefulness of model projections, it is perhaps not surprising that W&A chose to deploy for their policy discussion NOT the long term rate of rise measured at Fort Denison (0.73 mm/yr) but instead the almost 5-times higher short-term (1996-2013) figure of 3.3 mm/yr (their Table 6). In justification of this recommendation, W&A remark (p. 35):

"*Although the inclusion of results from many models generates uncertainty, the overall projection of an accelerating future sea-level rise is clear, even if that acceleration cannot yet be unequivocally proven based on the presently available measured record*."

Paraphrased, this says: "measurements do not show an acceleration in sea-level rise but our models do; therefore the models must be right".

The choice to use many GCM models (none empirically proven), was W&A's alone, and we agree with their statement that all it does is to introduce uncertainty; what is needed, after all, is one validated model rather than a pot-pourri of speculative ones. That all the models project acceleration in the rate of rise of sea-level is scarcely surprising, for that is what they are designed to do, and this is certainly no argument for trusting their speculative projections. We also welcome W&A's admission that no empirical evidence exists in support of their preferred model outcome.

The key issue here is the lack of any justification given by W&A for preferring to adopt a high rate of rise of 3.3 mm/yr, based on modelling homogenized data over an inadequately short period, rather than the established long term empirical trend at Fort Denison of ~0.73 mm/yr. Experienced sea-level researchers understand both that "*records under 40 years* (long*) cannot correctly represent sea level rise*" (Modra & Hess, 2011), and that "*the best prediction for sea level in the future is simply a linear projection of the [tide gauge measured] history of sea level at the same location in the past*" (Burton, 2012).

In the absence of reasons for doubting the accuracy of the long-term tide gauge record from Fort Denison, policy decisions should be formulated using the long term rates measured there, i.e. an average rate of rise of sea-level of 0.73 mm/yr (Table 2), 7.3 cm/century or 3.7 cm by 2050.

Finally, it should be noted that although the NSW coastline was subjected to a similar amount of sea-level rise as this in the 20th century, no deleterious effects are known to have resulted. This is doubtless because a change of <10 cm in a century is at least an order of magnitude less than the natural variations in local coastal sea-level caused by daily, seasonal and extreme meteorological and oceanographic events.

CONCLUSION 10

Considering the flooding and erosion risks already inherent in coastal locations, the likely 7.3 cm rise in local sea-level in NSW over the next 100 years is too small to justify a major planning response. Though other human impacts at the coast might require changes in coastal regulations, no imperative exists to change planning rules because of unproven sea-level hazard.

11. Good coastal management is not only about sea-level change

Societal concern about sea-level change rests upon the shoreline erosion, harbour or channel siltation and other negative coastal effects that sometimes result from a rising sea-level, but often do not. Fears of sea-level rise are easy to generate, and are often driven by two main factors. The first is the misidentification of what causes coastal flooding today, and the second is the use of the rudimentary computer models that project unrealistic estimates of future temperature and sea-level rise (Fig. 2 and Section 7, above).

The position of a shoreline and the stability of that position depend upon a number of factors besides local mean sea-level. Other important natural processes involved include subsidence or uplift of the land, rate of supply of sediment (gravel, sand, mud), tidal regime, oceanographic regime and meteorology (especially storm magnitude and periodicity, and rainfall).

As summarised by de Lange & Carter (2014, p. 17):

> *Modern coastal flooding is driven by the occurrence of rare natural events, most notably high spring tides, heavy rainfall over the interior and large storm surges, each of which can add a transitory metre or so to local sea-level height, or even 2–3 metres if combined – a height which can then be doubled for the storm surge associated with a very large hurricane. Over the last 100 years, the majority of locations (though not all) around the world's coastlines have experienced a sea-level change of between about −50 cm and +50 cm. This amount is too small to have effected noticeable changes in shorelines that are subject to daily and seasonal variations in weather and sediment supply. When, from time to time, beach erosion, river outlet clogging or cliff fall has made the media headlines, mostly the cause has been a storm event, or natural or human interference with the flow of sediment: sea-level changes that might have occurred over previous decades are rarely identifiable as a significant hazard contributor, although of course they may have slightly enhanced or diminished the precise level reached by a flood peak.*

Shorelines, then, are dynamic geographic features. The average position of a sedimentary shoreline may shift landwards or seawards by distances of metres to many tens of metres over periods between days and years, in response to variations in the amount of sediment supply, the occurrence of calms and major storms, and variations in local mean sea-level. In the past, coastal inhabitants have adapted to such changes.

CONCLUSION 11

At the heart of the issue of good coastal management lies the need for an understanding of coastal processes in general, and the collection of accurate data regarding the history of those processes at any site of particular interest.

The data required include measurements of coastal oceanography, historic information regarding weather variability (especially storm, hinterland rainfall, runoff and sediment discharge records), geomorphic information regarding historic changes in coastal and beach-bay landforms, stratigraphic information regarding changing pre-Recent (Holocene) sediment configurations, surveying information that includes measurement of tectonic change (i.e., land elevation or depression) and tide gauge measurements of local relative sea-level change.

CONCLUSION 12

The study of Cairns Northern Beaches accomplished in the 1980s (Beach Protection Authority, 1984) provides an historic Australian "best practice" coastal management study of the type that has yet to be undertaken to inform the Eurobodalla and Shoalhaven Councils regarding the need, or not, for a revision of their local coastal planning regulations.

12. Conclusions and recommendations

We reiterate here the policy guidelines that de Lange & Carter (2014) recommended for application by councils and other public bodies responsible for coastal hazard, including sea-level change. The three key guidelines are:

- **Abandonment of 'let's stop global sea-level rise' policies**

No justification exists for continuing to base sea-level policy and coastal management regulation upon the outcomes of speculative sea-level modelling. And even if the rate of global sea level change could be known accurately, the practice of using a notional global rate of change to manage specific coastal locations world- wide is irrational, and should be abandoned.

- **Recognition of the local or regional nature of coastal hazard**

Most coastal hazard is intrinsically local in nature. Other than periodic tsunami and exceptional storms, it is the regular and repetitive local processes of wind, waves, tides and sediment supply that fashion the location and shape of the shorelines of the world. Local relative sea-level change may be an important determinant in places, but in some localities it is rising and in others falling. Accordingly, there is no 'one size fits all' sea-level curve or policy that can be applied everywhere. Crucially, coastal hazard needs to be managed in the context of regional and local knowledge, using data gathered by site-specific tide-gauges and other relevant instrumentation.

- **Use of planning controls that are flexible and adaptive in nature**

Many planning regulations already recognize the dynamic nature of shorelines, for example by applying minimum building set back distances or heights from the tide mark. In addition, engineering solutions (groynes, breakwaters, sea-defence walls) are often used in attempts to stabilize a shoreline. To the degree that they are both effective and environmentally acceptable, such solutions should be encouraged. Nevertheless, occasional damage will continue to be imposed from time to time by large storms or other extreme - though natural - events, and that no matter how excellent the pre-existing coastal engineering and planning controls may be. In these circumstances, the appropriate policy should be one of careful preparation for, and adaptation to, hazardous events as and when they occur.

These recommendations apply just as much to the NSW shoreline as they do to shorelines anywhere else in the world. Coastal councils that ignore or override such basic principles of good environmental management do so at the risk of their ratepayers' properties and financial costs.

To the degree that new planning regulations are based on experimental computer model projections (such as those reported by W&A, which are *not* validatd predictions or forecasts), and cause financial damage to coastal property holders, legal culpability may apply.

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About the Authors

Robert M. Carter, Ph.D.

Carter is a palaeontologist, stratigrapher, marine geologist and environmental scientist with more than 40 years professional experience, and holds degrees from the University of Otago (New Zealand) and the University of Cambridge (England). He has held tenured academic staff positions at the University of Otago (Dunedin), James Cook University (Townsville) - where he was Professor and Head of School of Earth Sciences between 1981 and 1999 – and a research position at the University of Adelaide (South Australia).

Dr. Carter's professional service has included acting as Chair of the Earth Sciences Discipline Panel of the Australian Research Council, Chair of the national Marine Science and Technologies Committee, Director of the Australian Office of the Ocean Drilling Program, and Co-Chief Scientist on ODP Leg 181 (Southwest Pacific Gateways). He has testified as an expert witness on climate change in the Australian, New Zealand and Swedish parliaments and the US Senate, and gave evidence in the London High Court case that ruled that Mr Al Gore's film, *An Inconvenient Truth*, contained at least 9 basic scientific errors.

Dr. Carter contributes regularly to public education and debate on scientific issues which relate to his areas of knowledge. His public commentaries draw on his knowledge of the scientific literature and a personal publication list of more than 100 papers in international science journals. His current research on climate change, sea-level change and stratigraphy is based on field studies of Cenozoic sediments (last 65 million years) from the Southwest Pacific region, especially the Great Barrier Reef and New Zealand.

Willem de Lange, D.Phil.

de Lange is a coastal oceanographer with degrees in computer and earth sciences and who specialises in prediction and mitigation of coastal hazards. He currently lectures and supervises research students in the School of Science, University of Waikato, including teaching courses in coastal management.

Dr de Lange's research, as well as his students, mostly focusses on the assessment of coastal hazards and developing tools for predicting and mitigating hazard. This included the first research in NZ linking shoreline changes and coastal processes to climatic variations associated with the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), and research into the impacts of human activities on shoreline changes in the Southwest Pacific and Southeast Asia.

Dr de Lange has been involved in advising the NZ government about sea level rise as part of periodic climate change impact assessments, and has also been involved in setting legal precedents for coastal hazard management since 1984. He was involved in the IPCC second assessment report published in 1995, and more recently, the NIPCC second assessment report published in 2013.

Jens Morten Hansen, Ph.D.

Hansen was born in 1947 and took a masters degree (1975) and PhD (1983) from Copenhagen University. During 1975-1991 he worked as a researcher on a wide range of geological topics, including biostratigraphy, structural geology, sea-level change, glacio-isostasy and geological mapping in Denmark and Greenland.

After a combined scientific and administrative career as vice-managing Director for the Geological Survey of Denmark and Greenland (1991-1998), and Director General of the Danish Research Councils

(1998-2006), he reengaged as a full time researcher in a position as 'statsgeolog'. This is a public scientific position from which Hansen gives advice to Danish governmental and other public authorities on matters in the field of geology.

Hansen's present research is concentrated on sea-level changes of the North Sea and Baltic regions including analyzing the region's many long tide-gauge records, as well as studying the region's large number of palaeo-shorelines. After his reengagement in 2006 as a full-time researcher Hansen has published many scientific papers, and currently holds several research grants. Hansen participates in working out official Danish sea-level prognoses.

Hansen is currently Chairman of Danish universities' censors in geology, and Secretary of the Board of Directors for public research institutions.

Ole Humlum, Ph.D.

Humlum is a physical geographer, geomorphologist and environmental scientist with 37 years professional experience, and holds MSc and PhD degrees from the University of Copenhagen (Denmark). In 1976 he was awarded the Prize Essay Gold Medal of the University of Copenhagen. He has since held tenured academic staff positions at the University of Copenhagen (Denmark; 1976-1983 and 1986-1999), University of Oslo (Norway, since 2003), and at the University Centre in Svalbard (UNIS, Svalbard, Norway, since 1999), and has been a visiting scientist at the University of St. Andrews (Scotland) and at the Faroese Museum of Natural History (Tórshavn, Faroe Islands).

Dr. Humlum's professional service has included a position as Scientific Director at the Arctic Research Station (Qeqertarsuaq, Greenland, 1983-1986), and a position as Special Consultant at the Danish Polar Center (Copenhagen) to initiate a monitoring programme within Earth Science in NE-Greenland (Zackenberg, 1995). He has been Editor for the Greenland Home Rule Office, Pilersuiffik, Denmark, and Secretary for the INQUA Working Group on Geospatial Analysis of Glaciated Environments (GAGE, 1994-1999). He was Co-chair for the Working Group on Periglacial Processes and Environments, International Permafrost Association (IPA, 1998-2003). Dr. Humlum's own numerous research contributions have been published in many leading peer-reviewed journals.

Craig D. Idso, Ph.D.

Idso is a climatologist and agronomist, is the founder, former president, and currently chairman of the Center for the Study of Carbon Dioxide and Global Change. The Center was founded in 1998 as a non-profit public charity dedicated to discovering and disseminating scientific information pertaining to the effects of atmospheric carbon dioxide enrichment on climate and the biosphere. The Center produces a weekly online newsletter, *CO2 Science*, and maintains a massive online collection of editorials on and reviews of peer-reviewed scientific journal articles relating to global climate change. Dr. Idso has published his research contributions in many professional, peer-reviewed science journals.

Dr. Idso received a B.S. in Geography from Arizona State University, an M.S. in Agronomy from the University of Nebraska – Lincoln, and a Ph.D. in Geography from Arizona State University, where he also studied as one of a small group of University Graduate Scholars. He was a faculty researcher in the Office of Climatology at Arizona State University and has lectured in Meteorology at Arizona State University.

David Kear, Ph.D.

Kear received his training in geology and mining engineering at the University of London (Imperial College), completing a BSc (Engineering, 1st Hons) London in Mining Engineering and a BSc in Mining Geology. He also holds an Associateship of the Royal School of Mines (ARSM, Ist Hons). Kear's 1963 PhD degree, also awarded by London University, was based upon field studies of a Plio-Pleistocene succession near Auckland that contained fossil evidence for sharp climatic and sea-level changes – these studies acting to arouse a lifelong interest in climate change.

Moving permanently to New Zealand, Kear lectured at the Huntly School of Mines, and acted as Director of the New Zealand Administrative Staff College. After joining the New Zealand Geological Survey, he rose to the position of Director General of the Department of Scientific and Industrial Research (DSIR). He is a Fellow of the Royal Society of New Zealand, and served a term as Vice-President of the Society. During his active research career, Kear published more than 100 research papers on New Zealand and Pacific geology, volcanology and mineral resources, and served a term as President of the New Zealand Geological Society. Throughout his career he also acted as a member or Chairman of numerous national and international committees and working parties on matters related to geology (including sea-level change), minerals, engineering and general science policy.

David R. Legates, Ph.D.

Legates received a B.A. in Mathematics and Geography (double major) in 1982, a M.S. in Geography-Climatology in 1985, and a Ph.D. in Climatology in 1988, all from the University of Delaware. His expertise lies in hydroclimatology/surface water hydrology, precipitation and climate change, spatial analysis and spatial statistics, and statistical/numerical methods. Legates' dissertation was entitled "A Climatology of Global Precipitation" and focused on obtaining a better picture of global precipitation by incorporating a high-resolution precipitation gage database that was adjusted for changes in instrumentation and biases associated with the precipitation gauge measurement process. His climatology of precipitation continues to be widely used as it is still the only global climatology available that addresses the gauge measurement bias problem.

Legates became an Assistant Professor in the College of Geosciences at the University of Oklahoma, being granted tenure and promoted to Associate Professor in 1994. He became the Chief Research Scientist for the Center for Computational Geosciences at the University of Oklahoma in 1995. In 1998, Legates moved to the Louisiana State University and became an Associate Professor in the Department of Geography and Anthropology as well as a research scientist with the Southern Regional Climate Center. Legates then returned to the University of Delaware in 1999 as an Associate Professor and was promoted to Full Professor in 2010. While at Delaware, Legates has served as the Delaware State Climatologist (2005-2011), Director of the Center for Climatic Research (2001-2007), and founder and co-Director of the Delaware Environmental Observing System (2003-2011).

Legates has been invited to speak to the US Senate Committee on the Environment and Public Works on three separate occasions. He has received over $7M USD in grants over his career and has published more than 60 refereed articles. He has made more than 200 professional presentations.

Nils-Axel Mörner, Ph.D.

Mörner took his Ph.D.-thesis in 1968 in Geology at Stockholm University. In his thesis he was able to separate the isostatic and eustatic components behind the relative sea-level changes observed. His eustatic curve recorded a low-amplitude oscillating sea-level rise after the Last Ice Age – contrary to the high-amplitude curve of Fairbridge (1961) and the smooth curve of Shepard (1963). In 1976, Mörner introduced the concept of geoid changes, and by implication redefined the concept of eustasy. In 1984, he introduced the concept of Super-ENSO events and horizontal redistribution of oceanic water masses.

Mörner has published more than 200 peer-reviewed papers on sea-level change and related questions, and has direct field experience in 59 countries. He has acted as president of the INQUA Commission of Sea Level Changes and Coastal Evolution, leader of the Maldives Sea level Project and co-ordinator of the INTAS project on Geomagnetism & Climate. Mörner has also edited books like: “Earth Rheology, Isostasy and Eustasy” (Wiley, 1980), “Climate Change on a Yearly to Millennial Basis” (Kluwer, 1984), “The Tsunami Threat: research and technology (InTech, 2011).

Mörner was the head of Paleogeophysics & Geodynamics at Stockholm University between 1991 and 2005. In 2008, he was awarded “The Golden Condrite of Merits: for his irreverence and contribution to our understanding of sea level change”.

Cliff Ollier, D.Sc.

Ollier is a geologist and geomorphologist who is an Emeritus Professor from the University of New England, Armidale, and currently an Honorary Research Fellow at the School of Earth and Environment, University of Western Australia, Perth.

Dr Ollier is the author of over 300 scientific papers and ten books, including *Tectonics and Landforms* which has chapters on oceans and sea level changes. He has worked on every continent, lectured at over a hundred different universities around the world, and been employed by seven. He has carried out research on coasts around Australia and on several Pacific islands, studying the practical problems associated with shoreline erosion and sea level change.

S. Fred Singer, Ph.D.

Singer is an atmospheric and space physicist, is one of the world’s most respected and widely published experts on climate. Dr. Singer served as professor of environmental sciences at the University of Virginia, and is currently professor emeritus of environmental sciences at the University of Virginia. He directs the non-profit Science and Environmental Policy Project, which he founded in 1990 and incorporated in 1992.

Charlottesville, VA (1971-94); distinguished research professor at the Institute for Space Science and Technology, Gainesville, FL, where he was principal investigator for the Cosmic Dust/Orbital Debris Project (1989-94); chief scientist, U.S. Department of Transportation (1987- 89); vice chairman of the National Advisory Committee for Oceans and Atmosphere (NACOA) (1981-86); deputy assistant administrator for policy, U.S. Environmental Protection Agency (1970-71); deputy assistant secretary for water quality and research, U.S. Department of the Interior (1967- 70); founding dean of the School of Environmental and Planetary Sciences, University of Miami (1964-67); first director of the National Weather Satellite Service (1962-64); and director of the Center for Atmospheric and Space Physics, University of Maryland (1953-62).

Dr. Singer did his undergraduate work in electrical engineering at Ohio State University and holds a Ph.D. in physics from Princeton University.

Willie H. Soon, Ph.D.

Soon is an astrophysicist and geoscientist. Since 1992, Dr. Soon has been an astronomer at the Mount Wilson Observatory. He is also receiving editor in the area of solar and stellar physics for *New Astronomy*. He writes and lectures both professionally and publicly on important issues related to the sun, other stars, and the Earth, as well as general science topics in astronomy and physics.

Dr. Soon's honors include a 1989 IEEE Nuclear and Plasma Sciences Society Graduate Scholastic Award and a Rockwell Dennis Hunt Scholastic Award from the University of Southern California for "the most representative Ph.D. research thesis" of 1991. In 2003, he was invited to testify to the U.S. Senate, and in 2014 he was awarded the Courage in Defence of Science award at the 9th International Conference on Climate Change in Las Vegas.

Dr. Soon is the author of *The Maunder Minimum and the Variable Sun-Earth Connection* (World Scientific Publishing Company 2004). His research has appeared many times in peer-reviewed journals, including *Climate Research, Geophysical Research Letters, Energy & Environment, Eos,* and *Journal of Climate.*

Dr. Soon earned his bachelor's and master's degrees in science from the University of Southern California and his Ph.D. in aerospace engineering from the University of Southern California.

About the NIPCC

The Nongovernmental International Panel on Climate Change, or NIPCC, is an international panel of scientists and scholars who came together to understand the causes and consequences of climate change. NIPCC has no formal attachment to or sponsorship from any government or governmental agency. It is wholly independent of political pressures and influences and therefore is not predisposed to produce politically motivated conclusions or policy recommendations.

NIPCC traces its beginnings to an informal meeting held in Milan, Italy in 2003 organized by Dr. S. Fred Singer and the Science & Environmental Policy Project (SEPP). The purpose was to produce an independent evaluation of the available scientific evidence for carbon dioxide-induced global warming, in anticipation of the release of the IPCC's Fourth Assessment Report (AR4). NIPCC scientists concluded the IPCC was biased with respect to making future projections of climate change, and overemphasized the human influence on current and past climatic trends.

To highlight such deficiencies in the IPCC's AR4, in 2008 SEPP partnered with The Heartland Institute to produce *Nature, Not Human Activity, Rules the Climate,* a summary of research for policymakers that has been widely distributed and translated into six languages. In 2009, the Center for the Study of Carbon Dioxide and Global Change joined the original two sponsors to help produce *Climate Change Reconsidered: The 2009 Report of the Nongovernmental International Panel on Climate Change (NIPCC),* the first comprehensive alternative to the alarmist reports of the IPCC.

In 2010, a Web site (www.nipccreport.org) was created to highlight scientific studies NIPCC scientists believed would likely be downplayed or ignored by the IPCC during preparation of its next assessment report. In 2011, the three sponsoring organizations produced *Climate Change Reconsidered: The 2011 Interim Report of the Nongovernmental International Panel on Climate Change (NIPCC),* a review and analysis of new research released since the 2009 report or overlooked by the authors of that report.

In 2013, the Information Center for Global Change Studies, a division of the Chinese Academy of Sciences, translated and published an abridged edition of the 2009 and 2011 NIPCC reports in a single volume. On June 15, the Chinese Academy of Sciences organized a NIPCC Workshop in Beijing to allow the NIPCC principal authors to present summaries of their conclusions.

In April 2014, NIPCC released *Climate Change Reconsidered II: Impacts, Adaptation, and Vulnerability*, the second of two volumes bringing the original 2009 report up to date with research from the *2011 Interim Report* plus research as current as the first quarter of 2014. In September 2013, NIPCC released *Climate Change Reconsidered II: Physical Science,* the first of these update volumes. A new Web site was created (www.ClimateChangeReconsidered.org) to feature the new report and news about its release. One more volume in the CCR-II series, subtitled *Human Welfare, Energy, and Policies*, is planned.

For more info about NIPCC, visit www.climatechangereconsidered.org or www.nipccreport.org.