Sea level changes at Ascension Island in the last half century

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An exercise in 'data archaeology' at Ascension Island has provided an estimate of sea level change between 1955 and 2001.5 (the mid-point of a recent dataset spanning 1993-2009). That average trend of 0.93 mm y⁻¹ (SE 0.69) compares to a larger rate during 1993-2009 itself of 2.55 (SE 0.13) and 2.07 (SE 0.30) mm y⁻¹ from tide gauge and altimeter data respectively, suggesting a recent acceleration in sea level rise. An ocean model and steric height datasets have been used for comparison to the measurements, with the conclusion that the acceleration was probably at least partly due to a steric height increase. This exercise is based on only one month of historical tide gauge data and is admittedly on the useful limit for long-term sea level studies. In addition, it is unfortunate that the tide gauge benchmark installed in 1955 has disappeared, even if one can estimate its height relative to modern marks. Nevertheless, the study does provide information of interest to climate studies, enables limits to be inferred on the real changes, and provides background information for other coastal studies. Most importantly, it is intended as a demonstration of the value of similar exercises where short historical records exist.

Keywords: satellite altimetry, tide gauges, vertical land movements

Introduction

This paper reports on an exercise in 'data archaeology' in the estimation of the local sea level change since 1955 at Ascension Island in the central Atlantic Ocean. It will be seen that it results in an estimate with a large uncertainty. Nevertheless, we feel that it is of some scientific interest given the lack of information on long-term sea level change in this part of the world. In addition, one of our objectives in reporting the finding is to demonstrate what can be done with a short historical record, separated by a long period of time from more recent recording. We hope thereby to encourage similar exercises at other locations where short historical records exist.

Ascension Island is located at 8° S, 14° W, 90 km west of the Mid-Atlantic Ridge in the central South Atlantic (Figure 1a). It is a dependency of the British Overseas Territory of St Helena. Ascension is the tip of large volcano with a basal diameter of about 60 km, which rises from 3 000 m depth to the top of Green Mountain at 859 m above sea level (Nielson and Sibbett 1996). Radiometric dating suggests that lava flows exposed at the surface are less than one million years old, and there is evidence that the volcano has been active in the last few 100 years (Atkins et al. 1964, Klingelhöfer et al. 2001).

In 1955, the United States Navy Hydrographic Office (USNHO, now the US Naval Oceanographic Office, NAVOCEANO) measured sea levels every hour for one month at English Bay on the north coast of the island (Figure 1b). These measurements were made with a tide staff, and were expressed relative to the height of a benchmark on the nearby quayside, as described below. The quayside is only 280 m as the crow flies (approximately twice that by land) from a modern tide gauge installation comprising pressure and radar sensors that has been operated since 1993 by the National Oceanography Centre in Liverpool as part of its programme of sea level measurements in the South Atlantic (Spencer et al. 1993, Woodworth et al. 1996). We have used conventional levelling to determine the height of the USNHO benchmark relative to those at the modern site, thereby enabling sea level change in the intervening period to be determined.

Main datasets

The USNHO data were provided by the National Oceanic and Atmospheric Administration (NOAA) as tabulations of hourly sea levels (in feet) above the tide staff zero together with extracted values of high and low waters. Information from the modern gauge is readily available as 'delayed mode high frequency' data from the Global Sea Level Observing System (GLOSS) website (www.gloss-sealevel.org), and as monthly mean values from the Permanent Service for Mean Sea Level (PSMSL; Woodworth and Player 2003; www.psmsl.org). Daily means of surface air pressure were obtained from the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) reanalyses (Kistler et al. 2001, www.cdc.noaa.gov).

Sea surface heights from the TOPEX/Poseidon, Jason-1 and Jason-2 satellite radar altimeters were obtained from the University of Colorado global sea level change web site (sealevel.colorado.edu). The data are available in...
the form of gridded fields and have all environmental and instrumental corrections applied (Leuliette et al. 2004 and see the Release Notes documentation on the University of Colorado web site). These corrections include an adjustment for the inverse barometer (IB) effect, but do not include a term for glacial isostatic adjustment (GIA). GIA estimates for present-day relative sea level change and crustal movement for the ICE-5G VM2 L90 model were obtained from Professor Richard Peltier of the University of Toronto (Peltier 2004; www.atmospheric.physics.utoronto.ca/~peltier/data.php).

Figure 1: (a) Location of Ascension Island near the Mid-Atlantic Ridge in the central South Atlantic. Depths are contoured at 2 000 m (green), 3 000 m (red), 4 000 m (blue) and 5 000 m (thin black); (b) map of Ascension showing the locations of the main settlement (Georgetown, star), tide gauge at English Bay (black circle), DORIS beacon (black diamond on east coast) and GPS receiver (black diamond near Georgetown). Elevations are contoured every 100 m and are labelled at 100–500 m. They were computed from the Version 2 dataset of the Shuttle Radar Topography Mission (http://www2.jpl.nasa.gov/srtm/).
Sea level time-series

The modern tide gauge record contains a major gap but is in excellent general agreement with the altimeter measurements over the period 1993–2009 (Figure 2). This is the period for which we have not only tide gauge and altimeter data but also numerical ocean model information. The altimeter values were computed using the sea surface heights data from the University of Colorado, together with the NCEP data, to remove the IB correction which had been applied by Colorado to the measured heights. In this way, real sea level was obtained instead of the ‘IB-corrected sea level’ (akin to ‘sub-surface pressure’) often preferred by altimeter analysts. Less than the normally good agreement can be seen at the start of 2001 for which there were both tide gauge instrumental problems and high wave conditions.

Linear regressions of the tide gauge and altimeter data with time, shown by the black and red lines in Figure 2, yield rates of sea level change of 2.55 (SE 0.13) and 2.07 (SE 0.30) mm y⁻¹ respectively. These values do not have to be exactly the same, given that the former represents relative sea level change (i.e. relative to the crust), and the latter measures geocentric change. The two quantities will differ due to vertical crustal movement, see below. (The standard errors given here were determined by ordinary least-squares and their relative magnitude reflects the \( \sqrt{10} \) one might expect using daily mean sea levels for the tide gauge data and 10-day values for the altimetry, the low frequency character in the two time-series being similar. The standard error of the latter will be the more meaningful.)

The average sea level for the sections of data from the modern tide gauge is 6.956 mm, measured relative to the PSMSL revised local reference (RLR) datum for this site. RLR datum is defined by the PSMSL at each station in terms of the heights of local benchmarks, and in particular of the primary tide gauge benchmark (TGBM) (Woodworth and Player 2003). The average is formed from a similar amount of data from each month of the year.

We now turn to an important discussion of the 1955 measurements. These were expressed relative to the zero of a tide staff, which was 10.85 feet below a ‘standard USNHO benchmark disc marked ‘Tidal 1955’ set in a drill hole and flush with the surface of the concrete pier on the south-west side of English Bay. The disc is set in the centre of the pier one foot away from the dark basaltic rocks’, as described in the notes of the responsible USNHO person (L Sukman). This benchmark was almost certainly a convex brass disc approximately 90 mm in diameter, of the sort used by the US Coast and Geodetic Survey and other US groups at the time (Leigh 2009). They were several millimetres thick and were attached to a stem typically an inch in diameter and several inches long, making up a mushroom-shaped object. The stem would be concreted into a hole drilled in solid rock or existing concrete (cf. Figure 1 of Hicks et al. 1987).

The value of the measurements depends critically on knowing the height of the USNHO benchmark in 1955 and it is unfortunate that it has disappeared, as have any records of the Ascension measurements that might have been in the NAVOCEANO archives. However, from a sketch map of the quayside made by L Sukman (Figure 3a), we know exactly where it was located, and evidence for it can be clearly seen in the layer of concrete that we believe existed then (Figure 3b–c). That concrete layer must at some point after 1955 have been overlain by another layer approximately 93 mm (almost 4 inches) thick, which is now largely broken up and can be seen only at the two ends of the quayside in Figure 3b, and more clearly in Figure 3c. The bollards shown in Figure 3b are likely to have been installed at the

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**Figure 2:** Time-series of daily mean sea level from the Ascension tide gauge (black) and sea levels every 10 days from TOPEX/Poseidon and Jason altimetry (red). The black and red lines indicate linear regressions with trends discussed in the text.
same time as the additional concrete layer was applied and
the quayside extended; if they had existed in 1955, they
would most likely have been included in Sukman’s map.
The bollards are indicated on a similar sketch map drawn in
1984 by a survey team from HMS Herald. That map shows
the positions of other marks in the area but not the USNHO
mark, which we believe was by then either beneath the
additional concrete layer or had been removed.

The diameter of the circle shown in the photograph is
consistent with that of a USNHO disc and the circle itself
is evidence that the concrete layer shown was the one in
1955. If the layer in the photograph had been lower than that
in which the disc had been installed, then only the outline
of the stem hole might have been expected. If the layer
shown were to be above that in 1955, then no circle would
be expected at all as the mark would now be beneath it.

Levelling between the quayside concrete and the
benchmarks at the modern site was made in both directions.
The levelling had to be made over a route covering approxi-
mately 500 m of rough ground (about twice the ‘crow-flies’
distance). However, exactly the same level differences was
obtained in the two directions. With this information, we can
determine the mean sea level (MSL) in 1955 of 4.27 feet
above the tide staff zero to have corresponded to 6938 mm.
above RLR datum. From an estimation of uncertainties including how deep into the concrete the disc may have been inserted, its convex shape, and the likely errors in the level connections, we estimate an overall uncertainty of ±2 cm in relating sea levels between 1955 and the present day.

This MSL value of 6 938 mm was calculated as a simple arithmetic average of hourly values from 23 February–23 March 1955, whereas the modern daily means of Figure 2, and subsequently the monthly values in the PSMSL, were computed by filtering higher-frequency (usually 15-minute) values to provide daily means. This computation involves the use of a tide-killing filter (Pugh 1987). In the present case, we have estimated what the contribution of the diurnal, semi-diurnal and higher-frequency tides might have been to the MSL value in 1955 by generating a time-series of hourly tidal predictions for that period based on the known tidal constants for English Bay. The predicted ‘hourlies’ were then averaged arithmetically with the conclusion that the contribution to the MSL value from the diurnal and higher-frequency tides would have been only 0.3 mm. Meanwhile, any contribution from longer period tides with periods of a fortnight and a month could be expected to average to zero with one month of data, while a possible contribution from the nodal (18.6 year) tide is negligible, as mentioned below.

A further way of determining a MSL for a given period is to average the high- and low-water values. This quantity is usually called mean tide level (MTL) and differs from true MSL due to shallow-water tidal effects (Pugh 1987). However, such effects are small at Ascension and the MTL was calculated to be almost the same as MSL (i.e. 4.26 feet above the tide staff zero). It is difficult to assess the quality of the MSL (or MTL) value. In calm conditions, visual measurements by a tide staff can result in a precise long-term MSL (e.g. Pugh 1987). However, significant swell is often present at Ascension, with occasional major swell events due to distant storms (Vassie et al. 2004), which would make tide measurements by staff impossible at these times. The month of hourly measurements contains several short gaps, interpolated by means of a tidal analysis, which may indicate such occasions.

The 1955 average value is based on only a short record and has to be adjusted in several ways. The first adjustment is for the seasonal cycle in MSL. Figure 4 indicates that sea level during 23 February–23 March is usually higher by 12 mm than in the rest of the year. Therefore, the observed 1955 value was adjusted down by this amount. In addition, from the NCEP air pressure information, we know that air pressure in this period in 1955 was 1.3 mbar lower than in the corresponding periods in 1993–2009, implying that sea level was slightly higher than normal, even with a seasonal cycle correction. Consequently, an additional 13 mm reduction was made. An adjustment for an 18.6 year variation in MSL due to the nodal tide is unnecessary as February–March 1955 and the middle of the 1993–2009 record are both approximately at mid-points of the cycle. With these seasonal and IB corrections, we estimate mean sea level to have been 43 mm higher during 1993–2009 than in 1955, or an average rate of change of 0.93 mm y−1.

An alternative calculation can be made using IB-corrected sea level (or subsurface pressure), the seasonal cycle of which shows almost the same value for 23 February–23 March as for the year as a whole (Figure 4). This approach yields a value of 42 mm for the rise in sea level.

One next has to estimate the uncertainty in the corrected 1955 value due to the background of ocean variability (i.e. variability other than the seasonal cycle and non-seasonal IB-related variability, which can both be parameterised adequately in the sea level time-series). This has been estimated in two ways. In the first method, a linear trend and mean seasonal cycle were removed from the time-series of IB-corrected MSL from the tide gauge, yielding a residual variability with a root-mean-square (rms) of 25 mm. In the second method, the rms of annual mean values of sea level at Ascension over the period 1950–2009 from the ocean model described below was found to be 12 mm. From these two estimates of non-seasonal and non-IB variability, we have adopted 25 mm as a conservative estimate of the rms of background variability, which when added in quadrature to the levelling uncertainty results in a long-term sea level trend of 0.93 (SE 0.69) mm y−1.

This estimate can be compared with knowledge of sea level change from other parts of the world. Sea level is understood to have risen at most locations (i.e. primarily on continental coastlines) at an average rate of 1.7 mm y−1 during the past half century (Bindoff et al. 2007) when records are corrected for GIA, the only geological process for which we have global geodynamic models that can be applied to tide gauge data. At Ascension, GIA would result in a rate of present-day sea level change of order −0.1 mm y−1 (submergence) (Peltier 2004), if there was no other geological process involved and no change in the ocean itself. In fact, the geological history of Ascension suggests that there should be an additional process considered of local submergence of the volcano of the order of several 100 m My−1 or several tenths of mm y−1 (Minshull et al. 2010). Consequently, 0.93 mm y−1 appears low compared to the reported global average, especially when any submergence terms are considered (available measurements of vertical land movement are discussed below). Nevertheless, considerable spatial variation in sea level trend over the past half century is possible as demonstrated by various ‘sea level reconstruction’ exercises (e.g. Llovel et al. 2009).

The difference in trend (or ‘acceleration’) between this long-term value (0.93 [SE 0.69] mm y−1) and that recorded by the modern tide gauge (2.55 [SE 0.13] mm y−1) is therefore 1.62 (SE 0.71) mm y−1 for which we must search for an explanation (see a summary of trends and trend-differences in Table 1). Figure 5a contains a time-series of sea level from an ocean model based on the Massachusetts Institute of Technology (MIT) general circulation model (Marshall et al. 1997a, 1997b) forced by NCEP monthly mean wind stresses and constrained by hydrographic fields provided by the UK Meteorological Office (Smith and Murphy 2007). This model has been implemented by the University of Liverpool and National Oceanography Centre, Liverpool, and has been run initially for 60 years (1950–2009), i.e. ending at the same time (2009) as the tide gauge record. The version used here has a 1° grid and 23 levels in the vertical. The model indicates that the interannual variability of sea level at Ascension is low (12 mm rms, as mentioned above), and considerably lower than at a similar latitude in the Indian
Ocean (Hughes and Williams 2010, Dunne et al. 2012). In spite of the low amplitude of variability, there is some similarity at interannual time-scales to the (IB-corrected) altimeter time-series in the period of overlap.

When using the model (and datasets of steric information discussed below) for comparison to the observations, it is not appropriate to select simply the model (or steric) value for 1955. This value will have been determined from sparse temperature and salinity information that is unlikely to fully represent real ocean conditions around Ascension, and sea level there, during that year. Instead, we have compared rates for the recent epoch (1993–2009) to those averaged over 1955–2009, which should provide more reliable estimates of long-term change. The modelling in Figure 5a suggests that the area experienced a rate of sea level rise during 1993–2009 only marginally higher (by 0.12 mm y⁻¹) than during 1955–2009 overall, which is less than the observed change of trend (Table 1).

Neverthless, detailed analysis of the model findings does suggest that the past decade at least has been anomalous at Ascension. For the entire period from 1950 to the early 2000s, the time-series of the steric component of sea surface height was very similar to that of sea level itself, but with the steric component being larger in comparison to sea level by the order of 10 mm from about 2003. This results in a larger steric trend for 1993–2009, and suggests a recent, increasingly negative, dynamical component of the model sea level. Table 1 provides a comparison of the trends for sea level and for the steric component alone. Why such a negative dynamical component should have occurred in recent years remains for further study.

We also investigated the change in steric height at Ascension implied by other oceanographic datasets. These include the World Ocean Database (WOD) (Levitus et al. 2009), the ‘Ishii’ dataset (Ishii and Kimoto 2009) and the Simple Ocean Data Assimilation (SODA) version 2.2.4 dataset (Carton et al. 2005, Carton and Giese 2008), which provide steric heights relative to reference levels of 700, 1 500 and 2 000 m respectively. Differences in the reference levels used by each dataset should not be of

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**Table 1:** Summary of observed trends in sea level and those obtained from other datasets in different periods (mm y⁻¹). The standard error of the change in trend between the two periods has been estimated by adding those of the first two columns in quadrature.

<table>
<thead>
<tr>
<th>Sea level parameter</th>
<th>Period</th>
<th>Change in trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed mean sea level</td>
<td>0.93 ± 0.69</td>
<td>2.55 ± 0.13 (tide gauge)</td>
</tr>
<tr>
<td>MIT–Liverpool model sea level</td>
<td>0.36 ± 0.10</td>
<td>0.48 ± 0.34</td>
</tr>
<tr>
<td>MIT–Liverpool model steric component</td>
<td>0.47 ± 0.11</td>
<td>1.41 ± 0.40</td>
</tr>
<tr>
<td>WOD steric height</td>
<td>0.58 ± 0.14</td>
<td>1.90 ± 0.80</td>
</tr>
<tr>
<td>Ishii steric height</td>
<td>0.35 ± 0.11</td>
<td>0.77 ± 0.75</td>
</tr>
<tr>
<td>SODA steric height</td>
<td>0.70 ± 0.21</td>
<td>0.78 ± 1.22</td>
</tr>
</tbody>
</table>

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**Figure 4:** The seasonal cycles of MSL as measured (solid line) and when corrected for air pressure (dashed line) computed from six years of data (1994, 1995, 1997, 2000, 2006 and 2008) with complete information.
The steric time-series are available for 1955–2009, 1950–2009 and 1950–2008 respectively and are shown in Figure 5b. These time-series give changes in trend (that for 1993–2009 compared to that for 1955–2009 or 1955–2008 in the case of SODA) of 1.32, 0.42 and 0.08 mm y\(^{-1}\) respectively (Table 1). The changes in trend have SEs of approximately 1 mm y\(^{-1}\) in each case, that for SODA being larger than for the others due to its time-series having a larger variance (rms values for the three time-series are 18, 14 and 26 mm respectively for 1955 onwards). Therefore, it is not possible to arrive at a useful quantitative conclusion based on these datasets as to a steric contribution to the change of sea level trend.

One reservation is that all of these datasets, and our model, will have employed similar sources of historical hydrographic information, and so it is interesting that they provide such different trends for 1993–2009. Nevertheless, in spite of the different magnitude of change in trend, they are at least of the same sign, and one concludes that variations in steric height must be at least one of the contributors to the observed change in trend in sea level. This is confirmed by studies of change in upper ocean (0–700 m) heat content.

**Figure 5:** (a) Annual mean values of I8-corrected MSL at Ascension obtained from altimetry in recent years (red) and from the MIT–Liverpool ocean model 60-year run spanning 1955–2009 (black). The two time-series are constrained to have the same average value over their common period. The black square is from an extension to the model run for the year 2010. (b) Annual mean values of steric height at Ascension from other datasets including the WOD (red), Ishii (black) and SODA (blue) steric datasets relative to 700, 1 500 and 2 000 m respectively.
that show a positive trend near Ascension equivalent to a heating of order 1 W m⁻² during 1993–2010 (Figure 3.7a of Blunden et al. 2011). Altimeter information is included in that analysis, so there is some circularity in this interpretation, but a trend of that order is consistent with that for heat content change within 0–700 m in the WOD, which is based on hydrographic information alone.

However, neither the model nor the steric height datasets include the changes in ocean mass, which are known to have taken place during the second half of the 20th century due to exchanges between the ocean and cryosphere or terrestrial hydrosphere. Such mass contributions could include the 0.98 (SE 0.33) mm y⁻¹ global MSL-equivalent change in mass added to the ocean from land ice (1.09 mm y⁻¹) and removed by terrestrial storage (0.11 mm y⁻¹) in the period 1972–2008 calculated by Church et al. (2011), a combined rate which the authors claim increased to 1.68 (SE 0.33) mm y⁻¹ during 1993–2008. The change in sea level trend at Ascension could then have contained a contribution of the order of 0.7 mm y⁻¹ from mass change.

Unfortunately, our tide gauge data extend only to the end of 2009. However, at the time of writing the altimeter information is available up to the third quarter of 2011. This allows approximate annual means to be computed for 2010 and 2011, which have been added to Figure 5a. It is evident that these recent values are higher than at any time in the two decades of the altimetry record, or even the last half century if the model information is a guide. The altimetry already exceeded the model value in 2009, the last year of our initial model run. An extension to the run to include 2010 (Figure 5a) indeed supports an increase, although to a lesser extent than as observed in the altimetry; this increase of model sea level is primarily of steric origin.

This increase in the last couple of years remains for further study but some observations can be made. One is that the anomalous rise is not an artifact of the University of Colorado processing. A time-series constructed from altimeter data processed by AVISO (Archivage, Validaition et Interprétation de données des Satellites Océanographiques, www.aviso.oceanobs.com) gives a sea level trend of 1.96 (SE 0.43) mm y⁻¹ for 1993–2009, consistent with the Colorado information, and shows similarly large values for the last few years. A second observation is that the tropical Atlantic (especially the northern tropics) experienced historically high sea surface temperatures during 2010 (Blunden et al. 2011). Therefore, it is plausible that the last two years have seen even further increases in steric height and heat content. However, a time-series of dynamic height relative to 500 m depth at the Prediction and Research Moored Array in the Atlantic (PIRATA) mooring near to Ascension at 10°W, 10°S (www.pmel.noaa.gov/pirata/10s10w.html) suggests a larger seasonal cycle but no significant increase in the mean during the last few years. It will be of great interest to see whether these anomalously high sea level values persist.

**Vertical crustal movements**

Vertical crustal movement is one component of a sea level change observed by a tide gauge. In this section, we simply document the small number of measurements of vertical crustal movement at Ascension that have been reported in the literature. On balance, they suggest overall negative movement, but with differences between rates that are larger than the stated SEs. Of course, the possibility of differential land movement on an island like Ascension cannot be excluded.

A Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) beacon is maintained at the European Space Agency tracking station in the north-east of Ascension (Figure 1b). Analysis of 492 weekly solutions of its station coordinates by Ray et al. (2010) suggested a high rate of crustal movement (−2.2 [SE 0.5] mm y⁻¹). An analysis of data for 1999 to 2009 by the Institut Géographique National, France, (available from ids-doris.org/network/ids-station-series.html) suggested a lower rate of −0.4 (SE 0.3) mm y⁻¹; analyses by other centres given on that web site suggest rates more like that reported by Ray et al. (2010). A global positioning system (GPS) receiver was operated near to the airfield in the west of the island by the Jet Propulsion Laboratory, USA (Figure 1b). Analysis of its data for 1996–2007 by the Système d’Observation du Niveau des Eaux Littorales (SONEL) at the University of La Rochelle, France, (www.sonel.org) gave a rate of −0.51 (SE 0.38) mm y⁻¹, which is consistent with the difference between tide gauge and altimeter trends mentioned above. That estimate was obtained using the ULR4 velocity fields employing the 2005 implementation of the International Terrestrial Reference Frame (ITRF) (Santamaria-Gomez et al. 2012). A more recent estimate of +0.44 (SE 0.17) mm y⁻¹ was obtained using the newer ULR5 velocity fields and ITRF-2008 implementation (Santamaria-Gomez et al. in press), opposite in sign to the earlier finding. For reference, it is noteworthy that the same model of GIA as above, GIA which it has to be remembered being only one of several possible geological processes, gives a value of approximately −0.17 mm y⁻¹ for present-day vertical crustal movement (Peltier 2004).

**Discussion and conclusions**

Ascension has been an excellent source of information on many aspects of sea level variability. Data from tide gauges there have been used in studies of ocean tides (Cartwright et al. 1988), the inverse barometer effect (Mathers and Woodworth 2001), 5-day waves in the atmosphere and ocean (Woodworth et al. 1995, Mathers and Woodworth 2004), tropical Atlantic circulation (Andrew et al. 2006) and the long distance propagation of ocean swell (Vasse et al. 2004). Ascension gauges have contributed regional information to the global sea level network for the calibration of satellite altimeters (Mitchum 2000). The island has also provided a test site for the development of tide gauge and telemetry hardware (e.g. Woodworth et al. 1996, Holgate et al. 2008).

However, until now there has been no study of sea level change at the island during the past century, either from tide gauge or, to our knowledge, geological perspectives. The present exercise in ‘data archaeology’ (which at times has verged on archaeology itself as seen in Figure 3b–c) follows from other recent studies around the world that have attempted to make use of historical datasets to learn more of long-term sea level changes (Woodworth 1999, Hunter et al. 2003, Wöppelmann et al. 2008, Testut et al. 2010, Watson et al. 2010, Woodworth et al. 2010). In the present case, we
realise that without the survival of the 1955 benchmark, the scientific value of the study is reduced, although we have shown that there is good evidence on where the benchmark was located and its height relative to modern marks. (In this respect, our study has some similarities to that of Watson et al. 2010.) In addition, it must be acknowledged that one month of historical information is a bare minimum, and that it results in an estimate of sea level change with a large uncertainty (0.93 [SE 0.69] mm y⁻¹) between 1955 and the recent period of 1993–2009. However, even this approximate value provides limits on possible changes in the past (e.g. a value of several mm y⁻¹ can be excluded) and one notes that there is no other source of long-term sea level information in this region, the longest record nearby being from Takoradi in Ghana (Woodworth et al. 2009).

We hope that this exercise encourages others to make similar investigations in other parts of the world, especially where the essential historical benchmark information has been fully preserved. Even if such estimates are as approximate as ours have been, they may well be of practical use to coastal studies. In the case of Ascension, for example, the green turtle Chelonia mydas populations on the island’s beaches are of particular interest and their sensitivity to climate change, including sea level change, is an important research topic (e.g. Godley et al. 2001, Hays et al. 2003).

Our most important finding has been the apparent high rate of sea level rise during the last two decades compared to that previously (and also an increase in the last couple of years, which remains for further study). A difference of the order of 1.6 mm y⁻¹ was found between the average rate for the last half century and that for 1993–2009. This difference in trend is consistent with being at least partly due to an increase in steric height, although the different model and steric height datasets do not result in a useful quantitative conclusion. A similar increase in trend has been reported elsewhere in the South Atlantic. Woodworth et al. (2010) compared MSL changes between the mid-19th century and the present day at Port Louis in the Falkland Islands, and found the rate of change in the last two decades to be approximately 2 mm y⁻¹ larger than that averaged over one and a half centuries.

In fact, it is known that many regions around the world experienced higher rates of sea level rise in the 1990s (e.g. Holgate and Woodworth 2004), although whether that rate of rise was unprecedented in the instrumental record is a matter of debate. Merrifield et al. (2009) suggested that the 1990s acceleration was indeed unusual in that it took place in most ocean basins, with particular contributions from the tropics and from higher southern latitudes. Analyses such as the present one at other locations would be welcome in order to confirm how spatially representative the recent acceleration may have been, while an important question for ocean and climate modellers is to determine whether any acceleration might persist into the 21st century.

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References


