

Historical sea level trends in the Southern Ocean from tide gauges

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The Southern Ocean as a whole is a quasi desert in terms of historical sea level measurements. Any available historical information is therefore invaluable for deriving long-term estimates of sea level change in this part of the world. We present below some results of sea level data archaeology studies undertaken at Port-Arthur, Kerguelen, Saint-Paul, Dumont d'Urville, Macquarie Island and Commonwealth Bay.

Port-Arthur (43° 08' S, 147° 51' E)



Observations of sea level at Port Arthur, Tasmania, southeastern Australia, based on a two-year record made in 1841–1842, a three-year record made in 1999–2002, and intermediate observations made in 1875–1905, 1888 and 1972, indicate an average rate of sea level rise, relative to the land, of 0.8 ± 0.2 mm/yr over the period 1841 to 2002. When combined with estimates of land uplift, this yields an estimate of average sea level rise due to an increase in the volume of the oceans of 1.0 ± 0.3 mm/yr, over the same period. These results are at the lower end of the recent estimate by the Intergovernmental Panel on Climate Change of global average rise for the 20th century. They provide an important contribution to our knowledge of past sea level rise in a region (the Southern Hemisphere) where there is a dearth of other such data (Hunter et al., 2003).

Benchmark placed in July 1841 on a small cliff on the Isle of the Dead, Port Arthur, Tasmania. It is believed to be one of the earliest benchmarks installed anywhere in the world.

Macquarie Island (54° 30' S, 158° 57' E)



Sea level observations collected at Macquarie Island during Sir Douglas Mawson's 1911-1914 Australasian Antarctic Expedition (AAE) have been used to constrain estimates of sea level and land level change at this location over the 20th Century. Nine months of 1912-1913 sea level data with intermediate observations in 1969-1971, 1982 and 1998-2007 (Watson et al., 2008) have been used to estimate sea level rise relative to the land at $+4.8 \pm 0.6$ mm/yr. This value supports the geologically surprising notion of land subsidence, corroborated by analyses of Global Positioning System (GPS) data between 1995-2007, showing an average rate of subsidence of 2.2 ± 0.4 mm/yr (i.e. downwards). Analyses of co-seismic displacements from nearby magnitude 6.4 and 8.1 earthquakes add weight to the apparent co-seismic vertical stability over recent time. The inferred absolute rate of sea level rise of $+2.6 \pm 0.7$ mm/a is within the error bounds of, yet at the upper reaches of the accepted global average. (This work is currently in preparation for Journal publication).

Cartographer Leslie Blake, standing by the AAE tide gauge installed in Garden Cove, Macquarie Island. The gauge operated between August 1912 and May 1913. (Photo by C.A. Sandell)

Kerguelen Island (49°25' S, 69°53' E)

In the 19th century, in the spirit of scientific cooperation, the Venus Transits of the 9th December 1874 was actively prepared for observation. It is estimated that there were 62 transit observations at diverse points of the globe. The British sent expeditions to the Isles of Sandwich, to Egypt, Rodriguez Island, New Zealand and to the Kerguelen Islands (Observatory Bay) where two monoliths called "Transit stones" were brought by the British astronomers to supply a stable base for their astronomical telescopes. On one of these "Transit stones" has an engraving that read "M.W. = 15. M." which is an indication on the height above the sea level made either by the British expedition in 1874 (*Mean Waters = 15 Meters*) or in 1902 by the German expedition to Antarctica lead by Drygalski (*Mittlerer Wasserstand=15 Meter*). Tide gauge monitoring, GPS, levelling and historical research are on the way to estimate the sea level change (Testut et al. 2005).

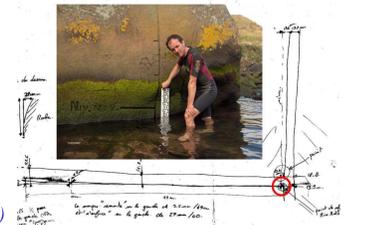
Benchmark engraved on the "Transit Stones" of the Observatory Bay at Kerguelen (Source ArchaeObs expedition => <http://www.taaf.fr/rubriques/expeditions/archaeobs/>)



Saint-Paul Island (33°42' S, 77°31'55 E)

As part of the global effort to observe the 1874 Venus Transit, the French Academy of Science organized expeditions to China, Japan, New Caledonia, New Zealand (Campbell Island) and Saint-Paul Island. The Saint-Paul expedition was led by Ernest Mouchez who set up instruments on Saint-Paul Island in September 1874. The sea level was observed with a tide pole from the 6 October until the 31 December 1874. Before the departure of the expedition a mean sea level benchmark was engraved on a rock. Both sea level measurements and benchmark were found recently on a large stone inside the crater. In November 2007 a French expedition stay for few days in Saint-Paul in order to proceed to the leveling of this benchmark and to tied it to the Saint-Paul GLOSS tide gauge (see <http://www.legos.obs-mip.fr/fr/observations/rosame/>).

Leveling of the sea level benchmark engraved on the rock at Saint-Paul Island during the NIVMER08 expedition in November 2007 (source A. Guillot DT/INSU)



Commonwealth Bay (66°54'S, 142°40'E)



The AAE expedition led by Sir Douglas Mawson that was responsible for the team of expeditioners and sea level work at Macquarie Island also explored part of the East Antarctic coast between 1911 and 1914. The AAE spent the winter of 1912 and 1913 in a station built in Commonwealth Bay, Cape Denison. During this period a mechanical float tide gauge was deployed on fast ice and observed 98 days of sea level in 1912. The sea level was tied to a benchmark on the rock, which is still present and located near Mawson's original huts. As part of a collaboration between French and Australian teams, two bottom pressure gauges have been installed in Boat Harbour (a few tens of meters from the historical gauge location) during the French NIVMER-08A expedition in January 2008. Data will be recovered in 2008 and 2009.

The engineer Robert Bage in front of the tide gauge installed at Boat Harbour (Commonwealth Bay) between June and September 1912.

Dumont d'Urville (66°40'S - 140°01'E)



In 1947 the EPF (French Polar Expedition), lead by P.E. Victor, was created and charged to organize scientific expeditions in both Arctic (Greenland) and Antarctica (Terre Adelie land). During 3 years (1950-1952) EPF made sea level measurements at Port-Martin and Dumont d'Urville station (Terre Adelie). Many of these early measurements were found in the archive of the French Hydrographic Service (SHOM). Sea level data was also observed at Dumont d'Urville during the International Geophysical Year of 1957. A preliminary estimate of sea level rise relative to the land is $+1.8$ mm/yr. This result is preliminary and a thorough check of all observations, datum connections and assessment of inter-annual variability and other error contributions is still required.

The tide gauge of Dumont d'Urville in 1950

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