A Detailed Determination of Regional Sea Level Trends in New Zealand

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Introduction

- The reliable determination of a sea level trend typically requires 50-60 yr of continuous (or semi-continuous) sea level data. In NZ, such data is only available at Auckland, New Plymouth(?), Wellington, Lyttelton and Dunedin.
- For detailed coastal hazard studies, we prefer much better spatial coverage of the trends.
- Conventional wisdom would say that there is little more that we can do on this issue.

Our Approach

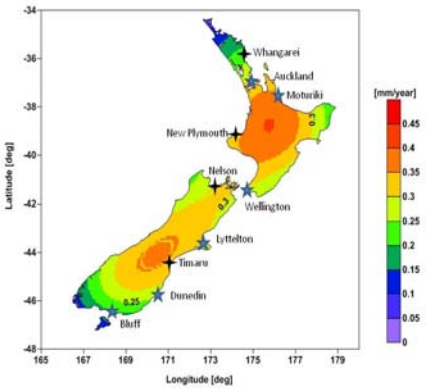
- Take a long, but broken TG record with a few years of MSL data at each end (such as are typically used for determining a height datum), and fit a straight line between the two points. The slope of the line ➔ trend.
- Assess possible bias in the result due to El Niño-Southern Oscillation (ENSO) and the Inter-decadal Pacific Oscillation (IPO), by using the long-term continuous records at the four main ports.
- Estimate errors through a formal error propagation process.

Historical Picture

Historically, NZ has 7 primary height datums and 9 secondary datums. Not all were suitable for this analysis.

Primary Datums	Definition
Auckland (1946)	7 yr data:1909,17-19,21-23
Wellington (1953)	14 yr data between 1906-46
Lyttelton (1937)	9 yr data: 1917,18,23-27,30,33
Dunedin (1958)	9 yr data: 1918,23-27,29,35,37
Bluff (1955)	**8 yr data between 1918-1934**
One Tree Point (1964) **	**4 yr 1960-63**
Moturiki (1953)	**4 yr data 7/2/49-15/12/52**

Secondary Datums	
Tararu (1952)	
Napier (1962)	
New Plymouth (1970)	**4 yr data 1918-1921**
Gisborne (1926)	
Nelson (1955)	**3.5 yr data: 12/6/1939–12/10/42**
Picton	
Westport	
Greymouth	
Timaru	**3 yr data between 1935-37**



Gauge Screening Criteria

- Good documentation on how the original MSL was determined.
- Stable TG zero or, alternatively, documentation on any movements.
- Data confirming TG stability over the years.
- At least nine years (half lunar cycle) of good, modern sea level data. We took data from 1999-2008 inclusive where available.

The Method

Example: Moturiki

MSL from 4 yr of data (01/01/1951) 4.88 ft (1.487 m) above TG zero
MSL from 10 yr of data (01/01/2004) 1.588 m above TG zero

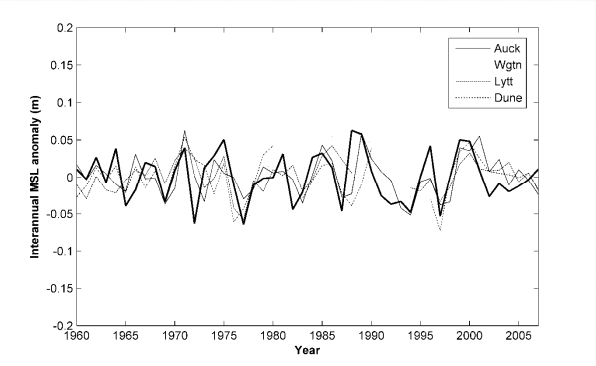
Sea level has risen 0.101 m in 53 yrs = 1.9 mm/yr

Error assessment: Assume that one year of de-trended MSL data has a σ_s = 0.025 m. Therefore 4 yr data ➔ $\sigma_m = 0.025/\sqrt{4} = 0.0125$ m
Also 10 yr data ➔ $\sigma_m = 0.025/\sqrt{10} = 0.008$ m

Now use standard error propagation techniques to propagate errors into the trend model ➔ $\sigma_{Trend} = \pm 0.2$ mm/yr

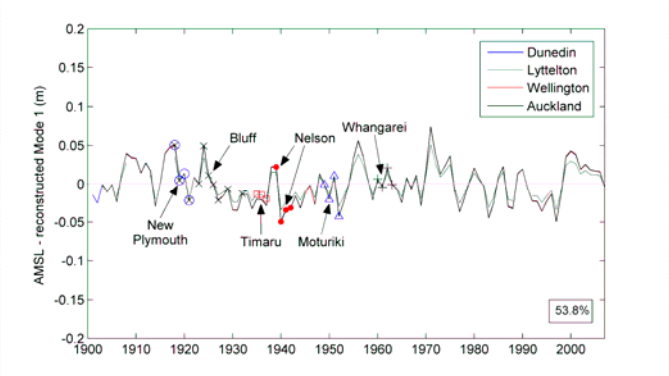
Possible Bias in the Results. ENSO & IPO?

In NZ waters, ENSO (2-5 yr period) can induce ± 0.06 m in variations in annual MSL. High during La Niña, low during El Niño.



IPO effects (12-14 yr period) are much smaller but cause a step in sea level when it shifts from a warm phase to a cool phase.

Dominant Mode Variability at the Four Main Ports from EOF Analysis

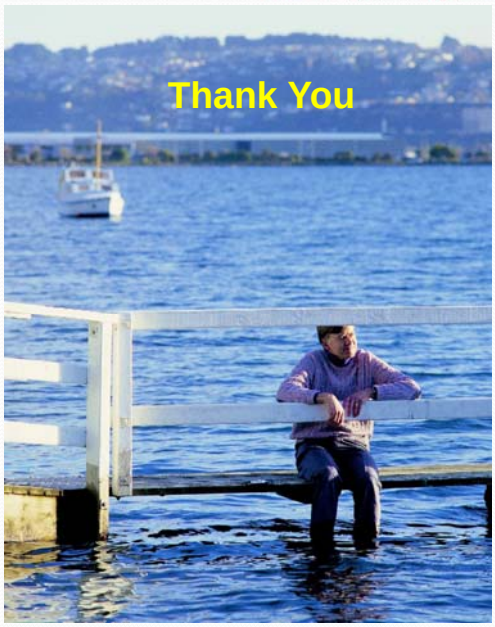


Results

Port	Inferred Linear Sea Level Rise (mm/yr) This analysis	Linear sea level rise (all TG data) Best Estimate	Comment
Auckland	1.7 ±0.14	1.5 ± 0.1	
Wellington	2.2 ±0.13	2.0 ± 0.2	GPS data suggests regional subsidence since 2000.
Lyttelton	2.0 ±0.15	1.9 ± 0.1	
Dunedin	1.3 ±0.15	1.3 ± 0.1	
Whangarei	2.2 ±0.6		Weakest data set. Trend under-estimated. Note +0.02 m anomaly
Moturiki	1.9 ±0.2		Trend over-estimated by ~ 0.2 due to sea level anomaly.
New Plymth.	1.5 ±0.2	1.7 ± 0.3	
Nelson	1.3 ±0.25		
Timaru	1.7 ±0.25		
Bluff	1.8 ±0.15		

Conclusions

- Results from this analysis are very consistent with best estimates at all five ports where long-term tide gauge records exist. This not only suggests that the technique is robust but also that the accuracy estimates are appropriate.
- Variations in the accuracy estimates reflect the number of years of data in the original datum definition and the elapsed time to 1/1/2004 (the epoch of the new datum).
- When taken together, the weighted mean relative sea level trend from the six new estimates = 1.7 ± 0.1 mm/yr – a result that is EXACTLY the same as the mean of the long term trends as determined at Auckland, Wellington, Lyttelton and Dunedin.


Thank You