



SWANSEA METROPOLITAN UNIVERSITY
PRIFYSGOL FETROPOLITAN ABERTAWE



An analysis of sea level trends on both sides of the Bristol Channel/Severn Estuary

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POL (2008)



Overview



- **Introduction; aims**
- **Sea level rise and climate change**
- **Erosion; Causes and Consequences**
- **Increased storminess?**
- **Methodology**
- **Results**
- **Evaluation; what would be done differently?**
- **Conclusion**
- **References**

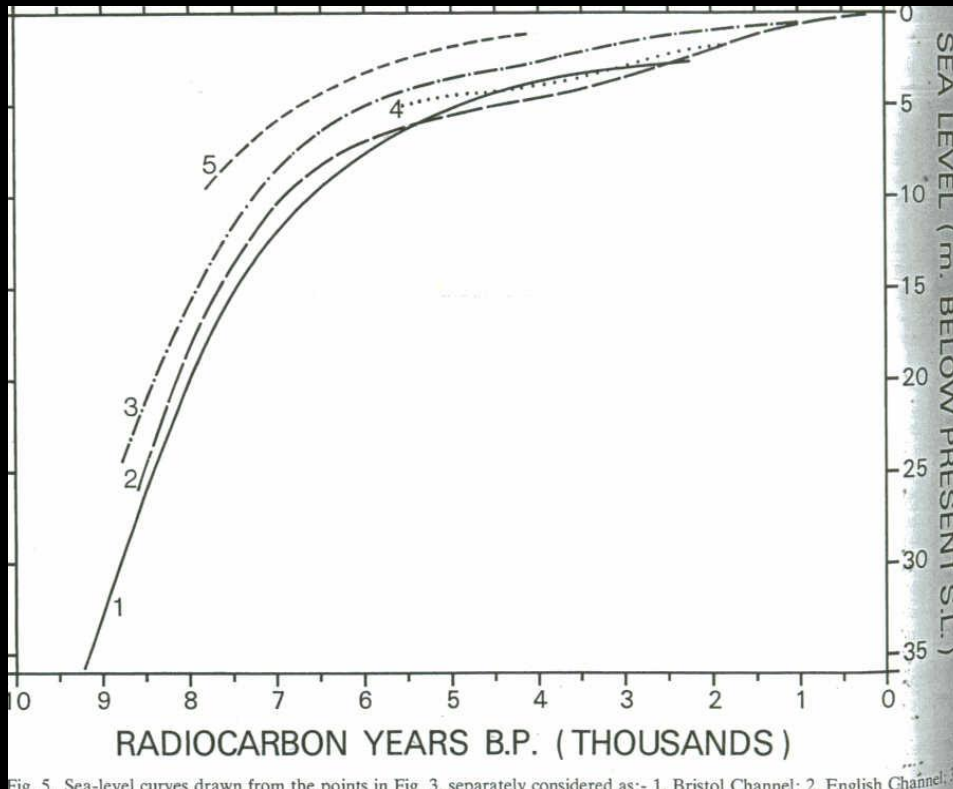


Introduction

- **The Bristol Channel / Severn Estuary: inlet of Atlantic Ocean.**
- “One of the highest semi-diurnal tidal ranges in the world” (Hashemi *et al*, 2008)
- **No studies to date comparing sea level trends using temporal tide gauge mean and extreme sea level data on the Welsh and English sides and the Bristol Channel and Severn Estuary.**
- **Mean sea level; evident issue for today’s society (Schroeder, 2000). Past events – 1607 (Haslett and Bryant, 2004).**
- **Comparisons between Northern and Southern sides of the Channel and comparisons between the Bristol Channel and Severn Estuary.**



Sea Level Rise



(Heyworth and Kidson, 1982)

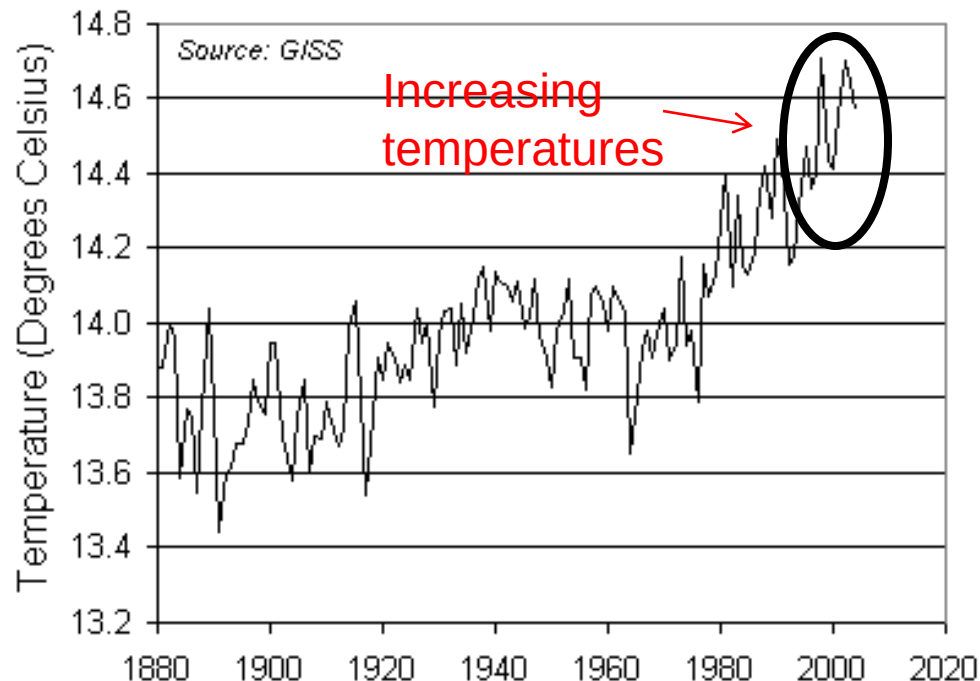
Last Glacial Maximum (20,000 years ago)
120m below present day sea level.
(Woodworth, 2000)

- Sea level is one of the principal determinants of shoreline position (Leatherman, 2001).
- Predicted annual sea level rise (6mm - Douglas, 2001; 8mm – Crawford and Thompson, 1999).
- Threatens many “low lying parts of the inhabited world” (Wunsch *et al.* 2007: 3.)
- Large population live in coastal areas (Andersen *et al.* 2002).



Climate Change

Average Global Temperature, 1880-2004



Sea level; not the same everywhere (varies by location) and adding to this, changes in sea levels globally are therefore not uniform.

Climate Change

- High tides
- Increased storm intensity and frequency (Kevin *et al*, 2004)
- Rise in sea level has been shown by historical tide gauges (Cazenave *et al*, 1998).



Erosion: Causes and Responses

- **Storms**
- **Sea level rise**
- **Coastal Infrastructure**
- **Reduction in sediment supply/dredging**
- **Advance the line (seawalls, nourishment)**
- **Hold the line (seawalls, nourishment)**
- **Retreat from the line (relocate)**
- **Do nothing**



Country	% of eroding coastline	Country	% of eroding coastline
Belgium	25.5	Italy	22.8
Cyprus	37.8	Latvia	32.8
Denmark	13.2	Lithuania	24.3
Estonia	2.0	Netherlands	10.5
Finland	0.04	Poland	55.0
France	24.9	Portugal	28.5
Germany	12.8	Spain	11.5
Greece	28.6	Sweden	2.4
Ireland	19.9	United Kingdom	17.3

Of the 875 km of European coastlines that started to erode within the past 20 years, 63% are located less than 30 km from coastal areas altered by recent engineering works (**Europa, 2007**).



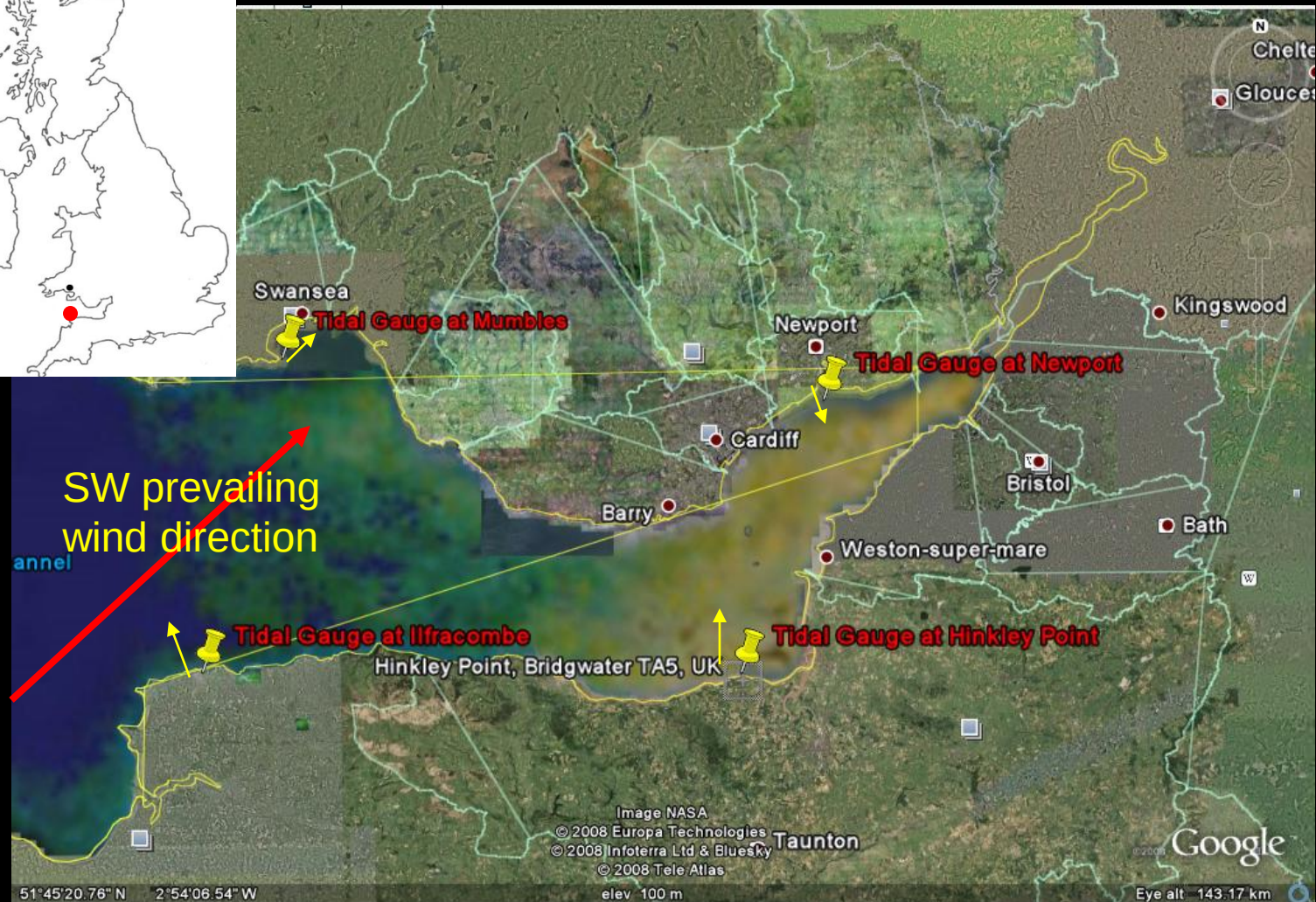
Storminess and Inundation



- Increased storminess over last 40 years on German North Sea coast (Jensen *et al*, 2001)
- Increased storminess over last 50 years in Estonia with increased inundation (Rivis *et al*, 2004)
- Flooding Venice 40x/year 2000 compared to 5x/year 1900 (Vilibic *et al*, 2000)



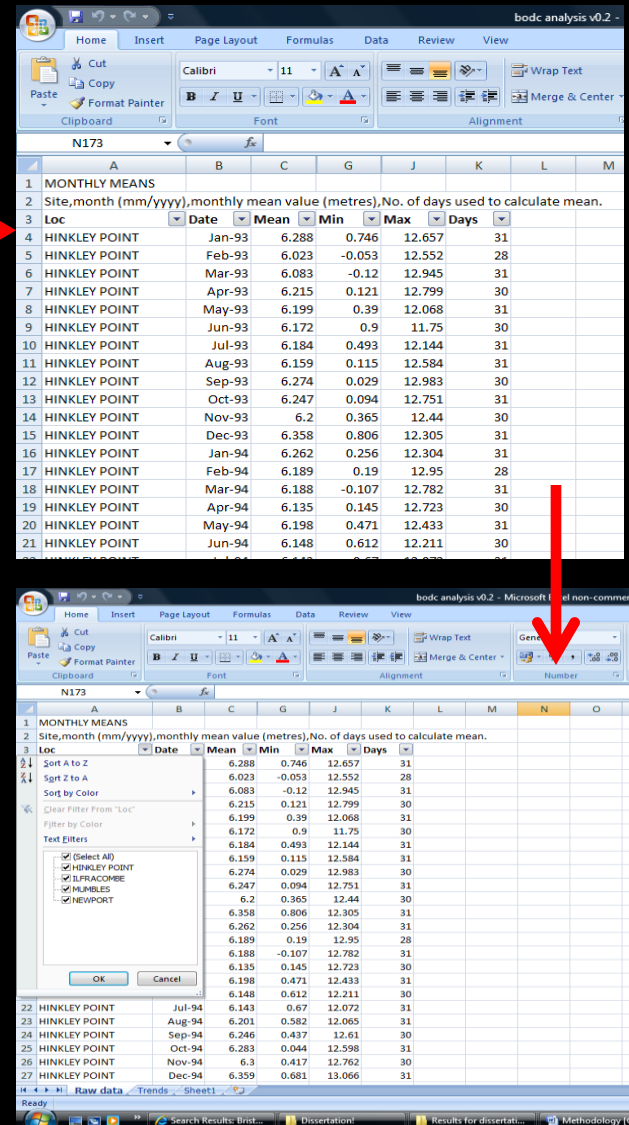
Methodology





	Latitude Measuring Point	of	Longitude Measuring Point	of	Ordnance Survey grid reference	Description of site measuring point
Ilfracombe	51° 12' 40.1" N		04° 06' 44.6" W		SS 5264 4786	Measuring points are located on the east face of the new jetty
Hinkley Point	51° 12' 54.9" N		03° 08' 04.1" W		ST 2086 4684	In underwater vented chambers, suspended from a steel pole
Mumbles	51° 34' 12.0" N		03° 58' 31.7" W		SS 6323 8756	Measuring points are mounted on the leg of the RNLI boathouse slipway
Newport	51° 33' 00.0" N		02° 59' 14.8" W		ST 3163 8392	Measuring point at Western entrance to Newport Docks

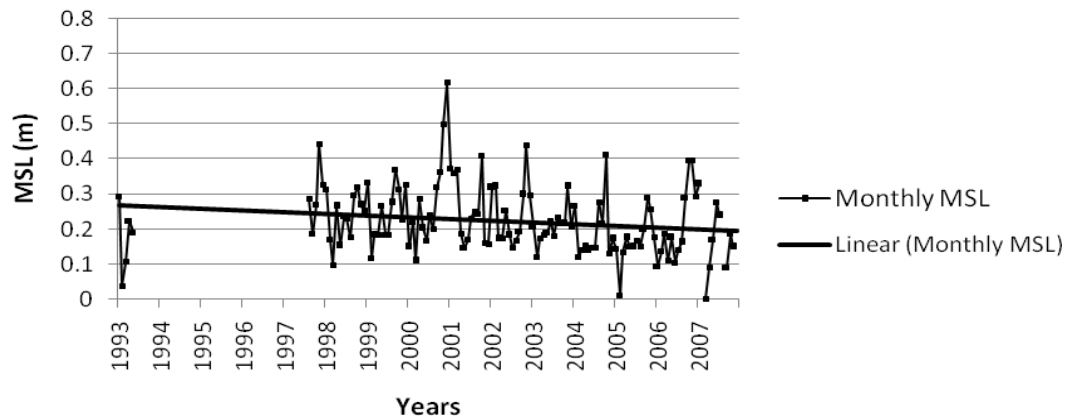
1111





Results

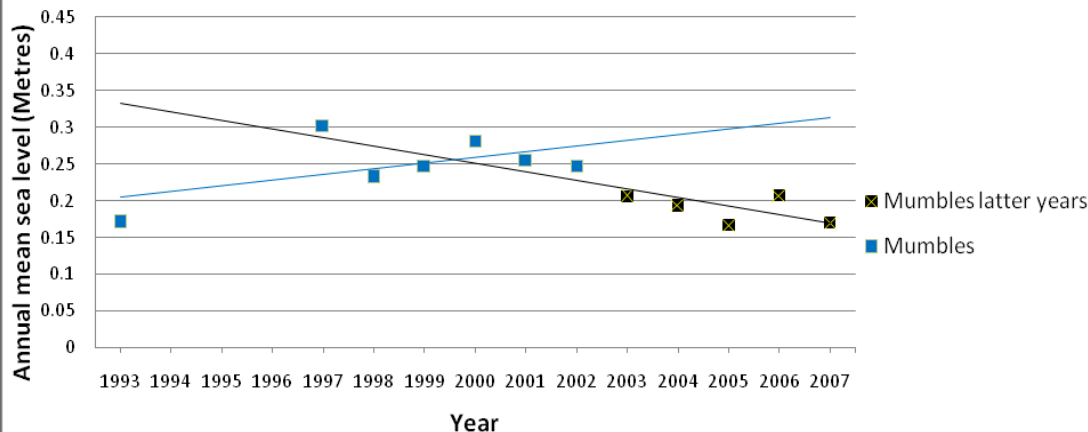
Monthly MSL at Mumbles



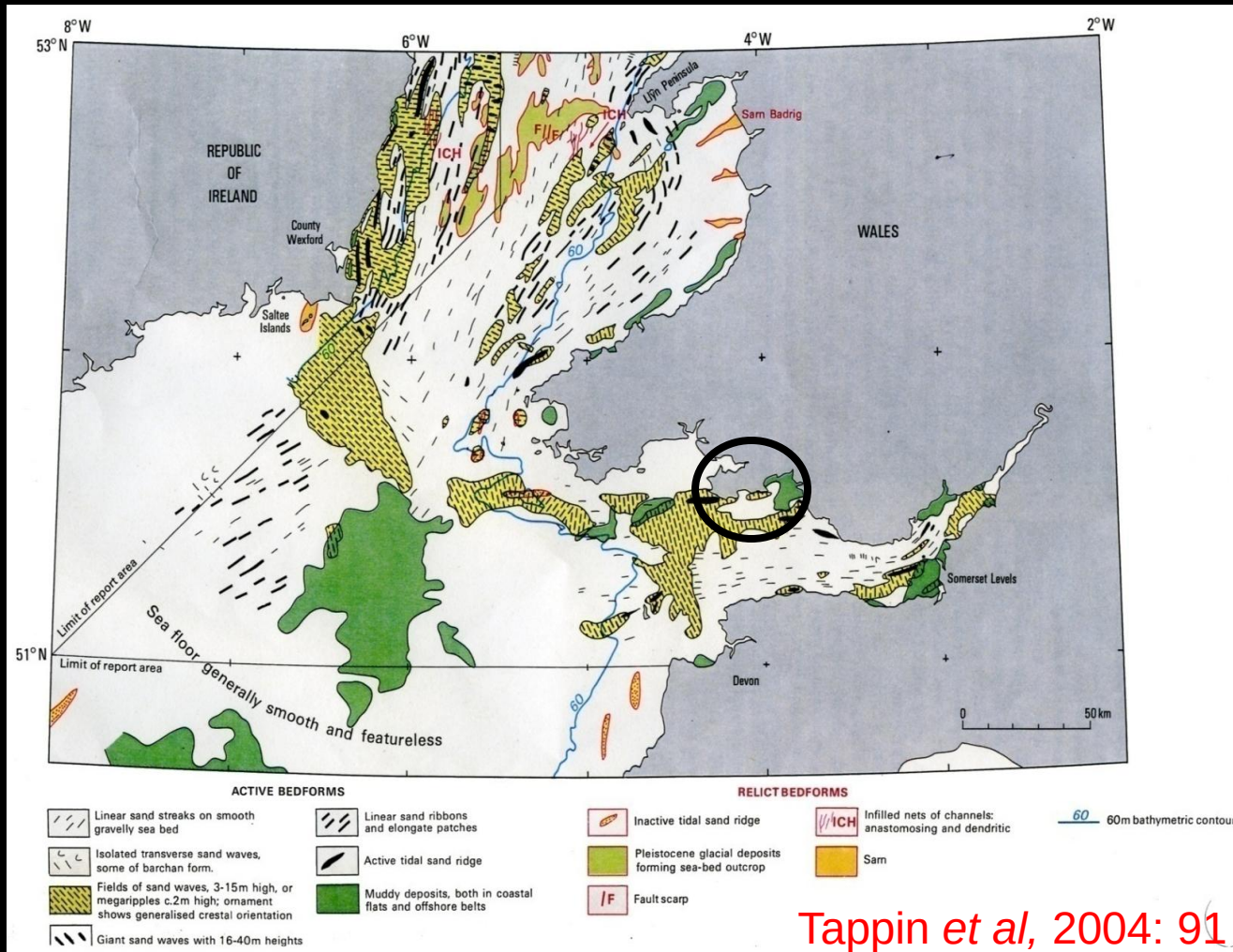
**Mumbles -0.4 mm yr^{-1}
(1993-2007)**

**Mumbles 5.4 mm yr^{-1}
(1993 – 2002)
(Phillips *et al*, 2005)**

Annual Mean Sea Level at Mumbles for 1993 to 2002 and 2002 to 2007



**Significantly lower
($t=2.673$; $df=11$;
 $p<0.05$) actual mean
sea levels than
predicted between
1993 and 2007.**



Sand waves at Mumbles between 3 – 15m offshore of the tide gauge.

Possibility for future studies?

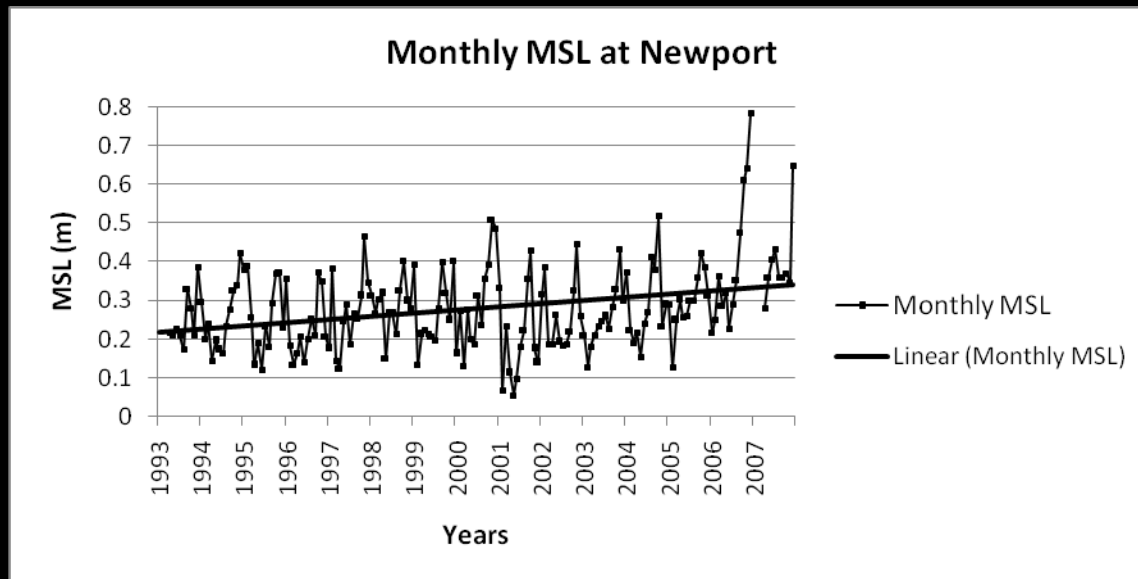
Tappin et al, 2004: 91

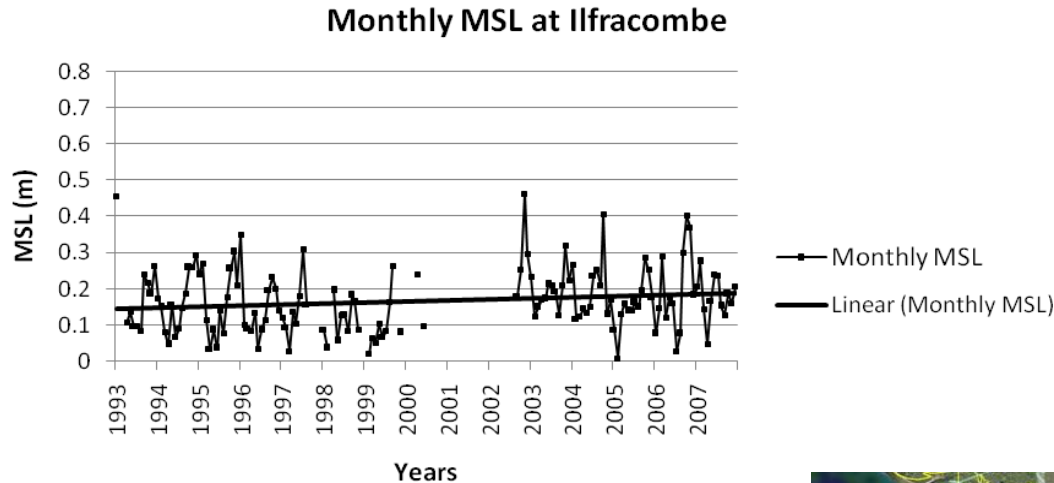


**Newport 0.7 mm yr⁻¹
(1993 – 2007)**

**Newport 0.4 mm yr⁻¹
(1993 – 2002)
(Phillips *et al*, 2005)**

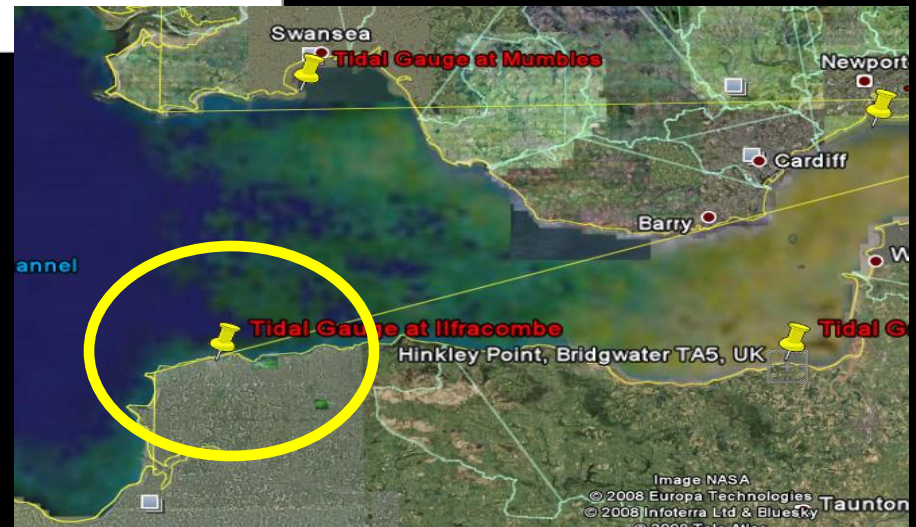
**Significantly higher
($t=2.880$; $df=14$;
 $p<0.05$) actual mean
sea levels than
predicted between
1993 and 2007.**

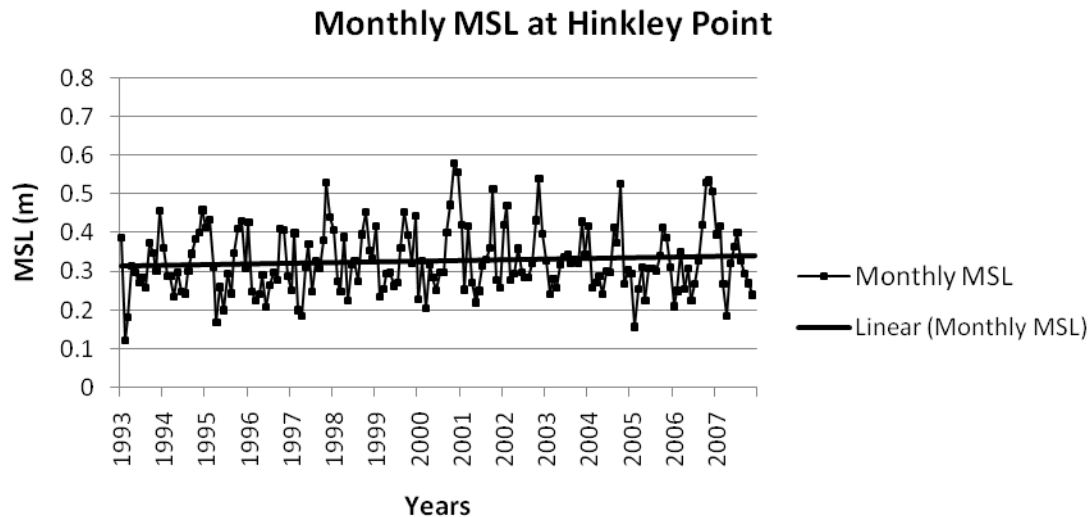




No significant difference ($t=1.989$; $df=13$; $p>0.05$) between predicted and actual mean sea levels (1993–2007).

Could be due to the location of Ilfracombe's shore at opening of the Bristol Channel (exposure).

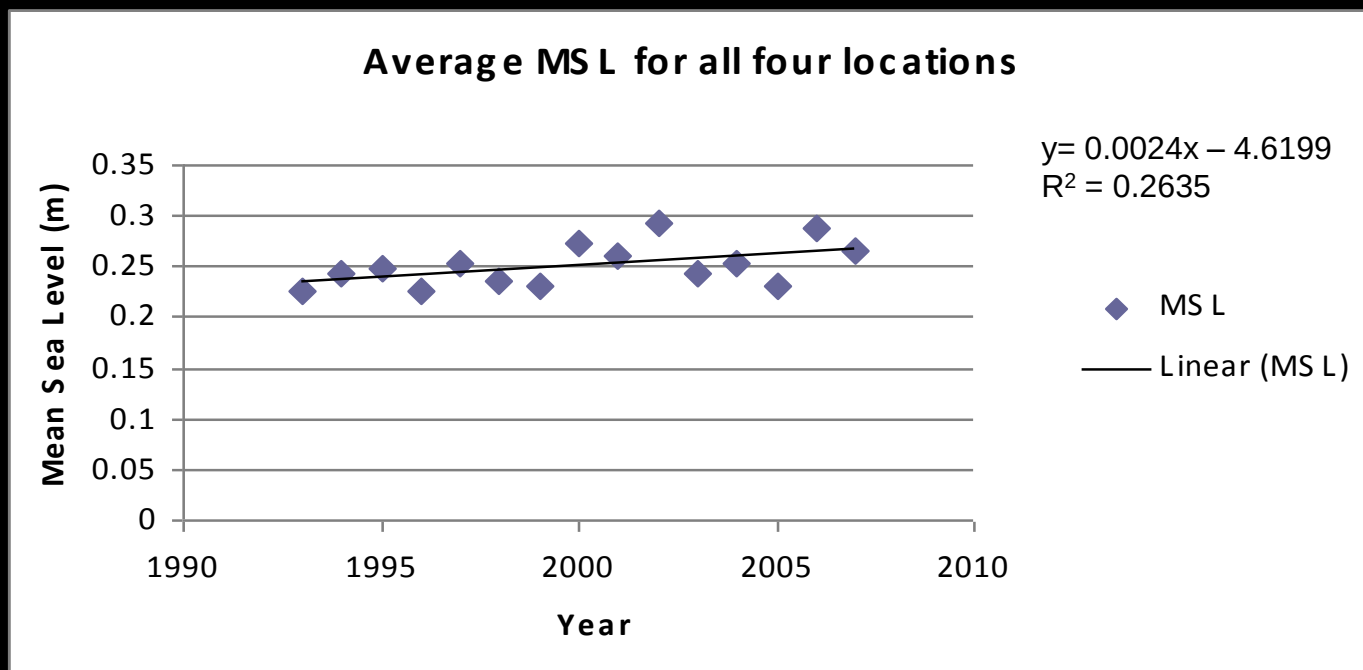


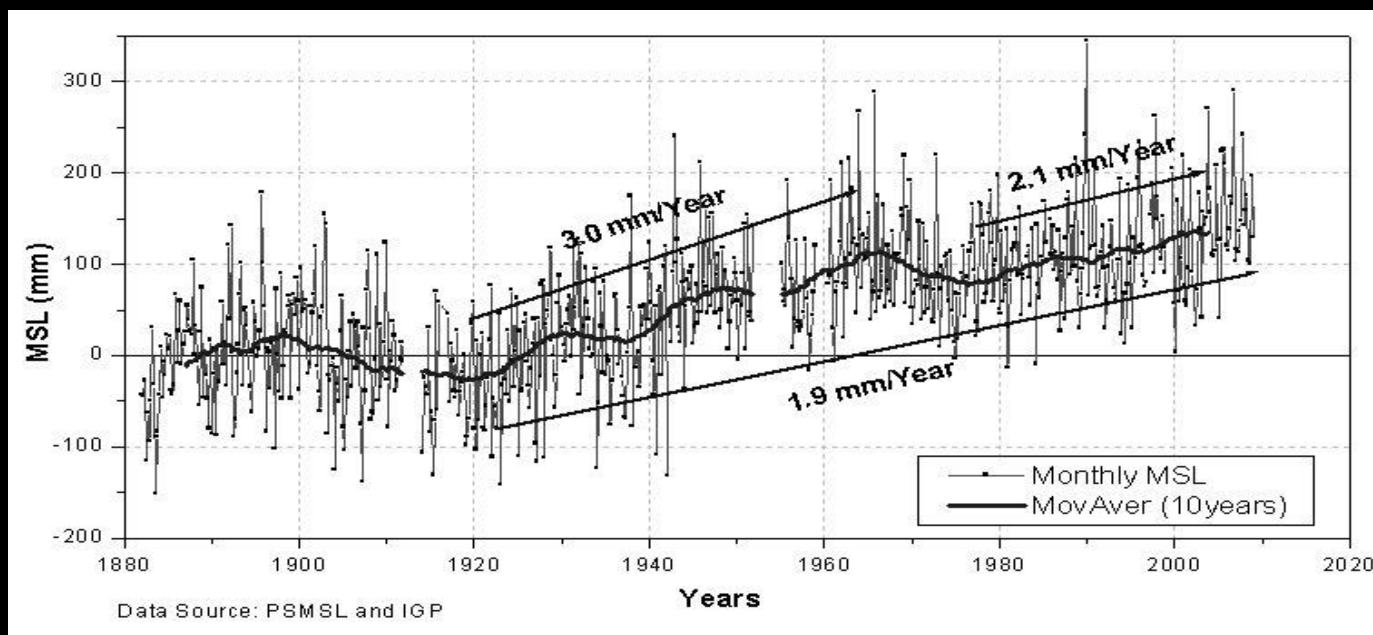


**Significantly higher
($t=5.282$; $df=14$;
 $p<0.01$) actual mean
sea levels than
predicted between
1993 and 2007.**



Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
MSL	0.227	0.244	0.248	0.226	0.253	0.235	0.232	0.274	0.260	0.293	0.244	0.253	0.231	0.288	0.266



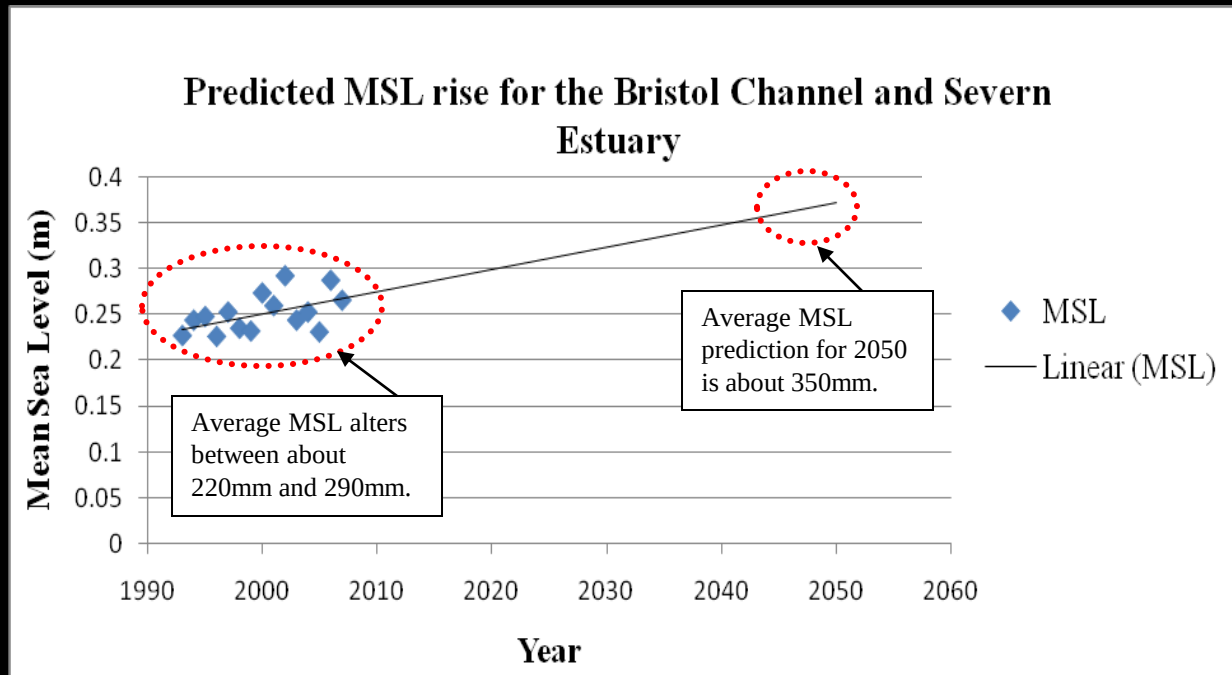


Cascais dataset (Antunis and Taborda, 2009):

2.1mm yr⁻¹

Bristol Channel and Severn Estuary:

2.4mm yr⁻¹

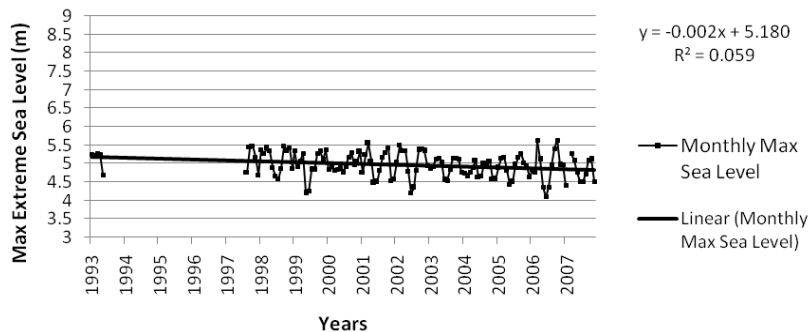


- **By 2050 average MSL will be approximately $350 \pm 35\text{mm}$, whereas currently, between 1993 and 2007 was on average 255mm.**
- **Only 15 years of data available.**

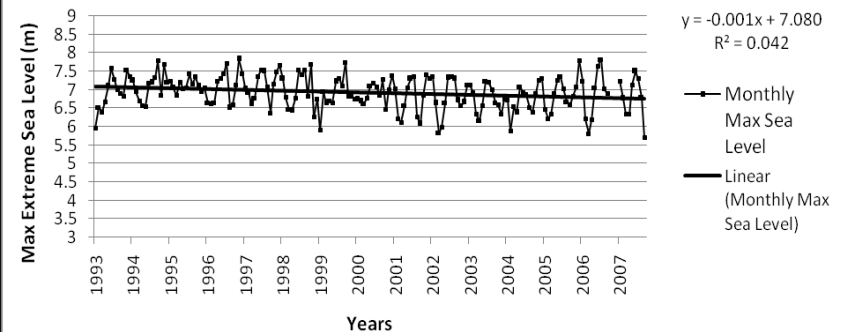


Maximum extreme sea levels show reducing trends.

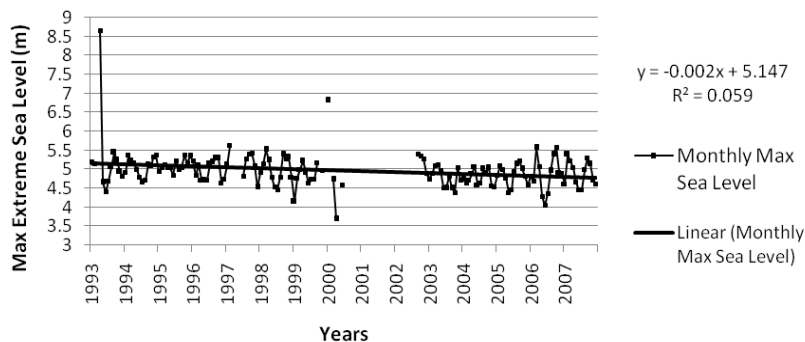
Monthly Maximum Extreme Sea Level at Mumbles



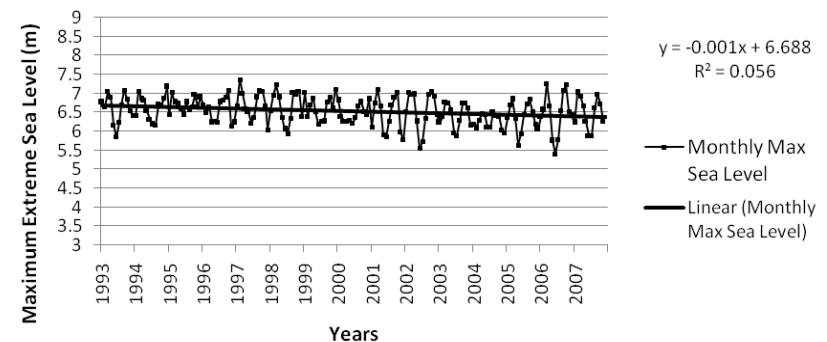
Monthly Maximum Extreme Sea Level at Newport



Monthly Maximum Extreme at Ilfracombe



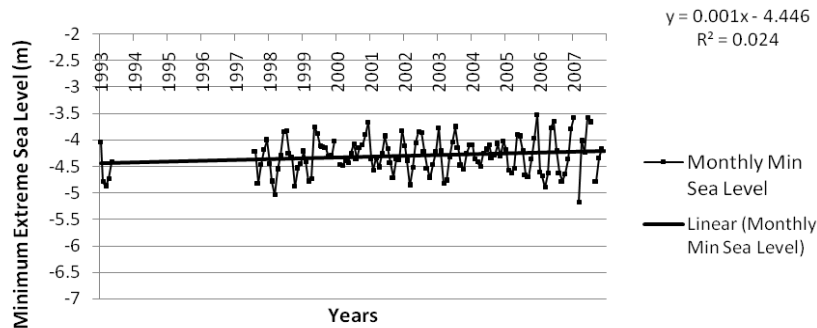
Monthly Maximum Extreme at Hinkley Point



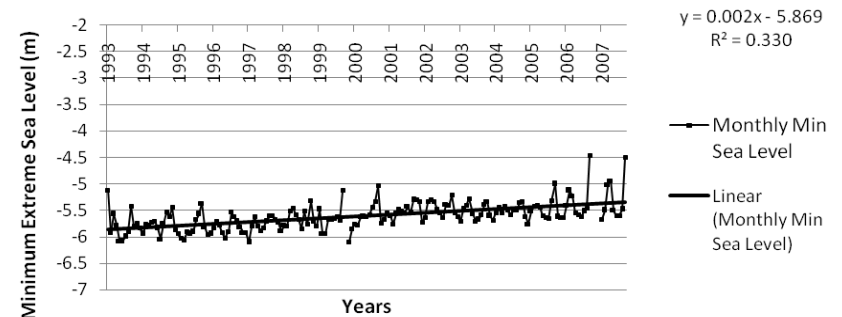


Minimum extreme sea levels show rising trends.

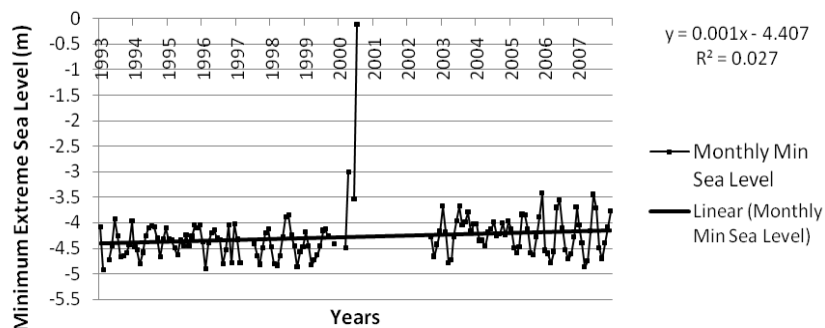
Monthly Minimum Extreme at Mumbles



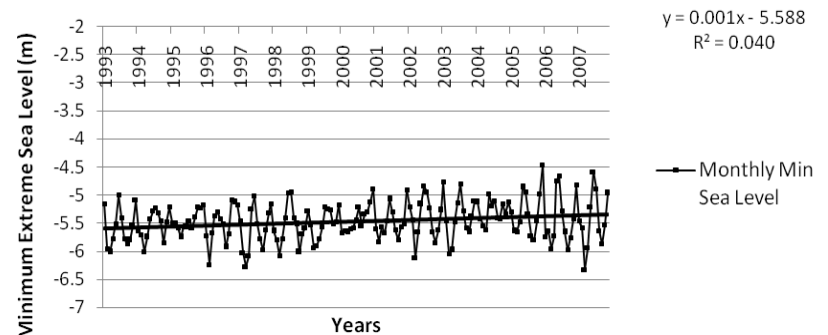
Monthly Minimum Extreme at Newport



Monthly Minimum Extreme at Ilfracombe

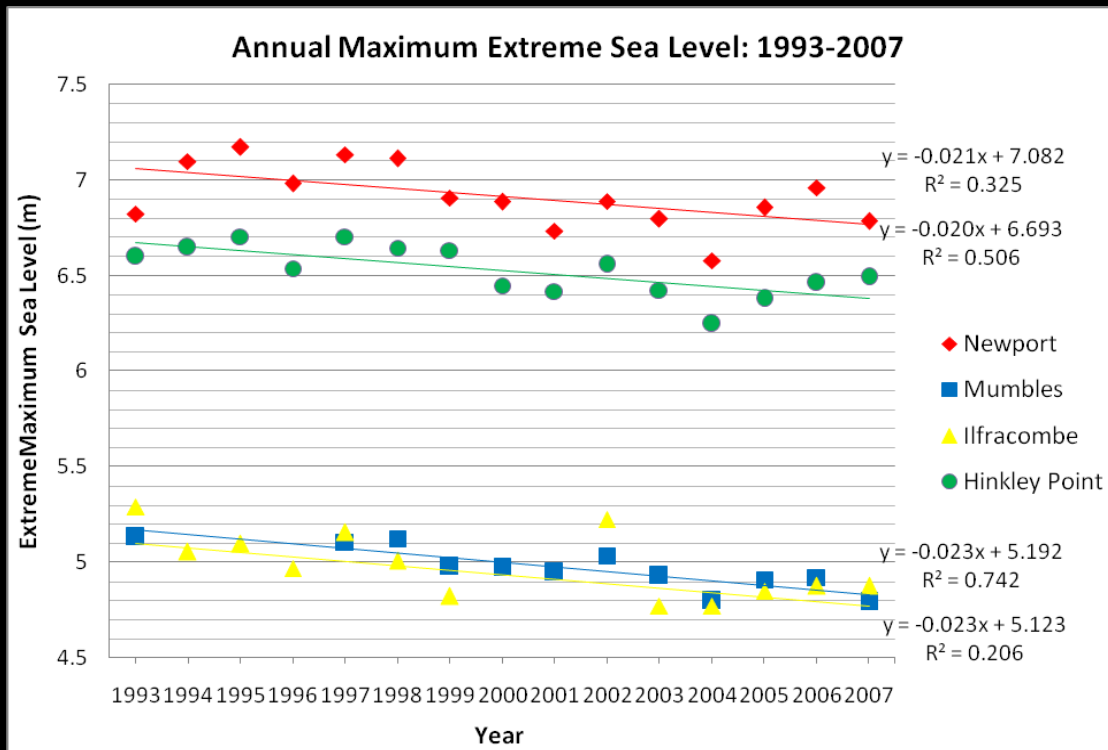


Monthly Minimum Extreme at Hinkley Point

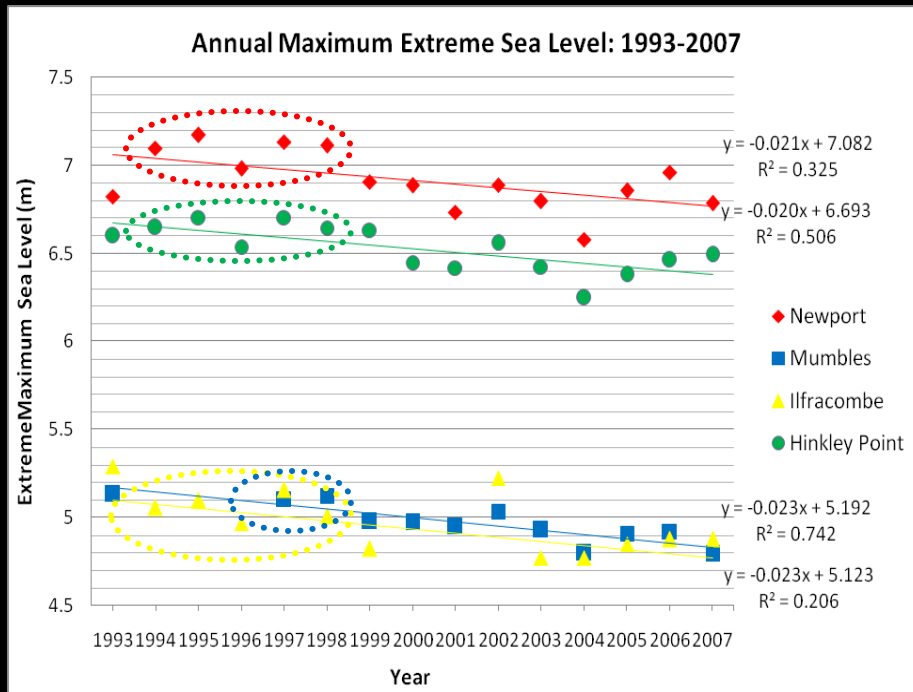




- **Annual maximum extremes display downward trends.**
- **Significantly higher maximum extreme sea levels at Newport and Hinkley Point (99% confidence) and Mumbles (95% confidence) in the years 1994, 1995, 1997 and 1998 compared with other years.**



Ilfracombe however did not demonstrate this, possibly due to tide gauge location and coastal aspect.



- Between 1994 and 1998, maximum extreme sea levels can be seen to be higher than other years.

- Correlates to findings of Phillips (2008) of critical erosion levels at Penarth.



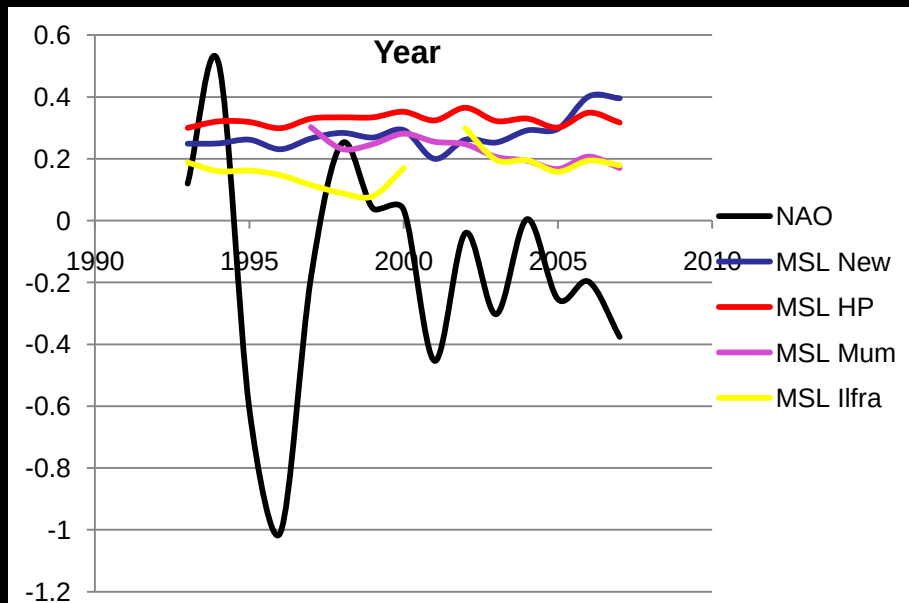
Phillips (1997)



- This was a result of a change in direction of the prevailing south-westerly winds.



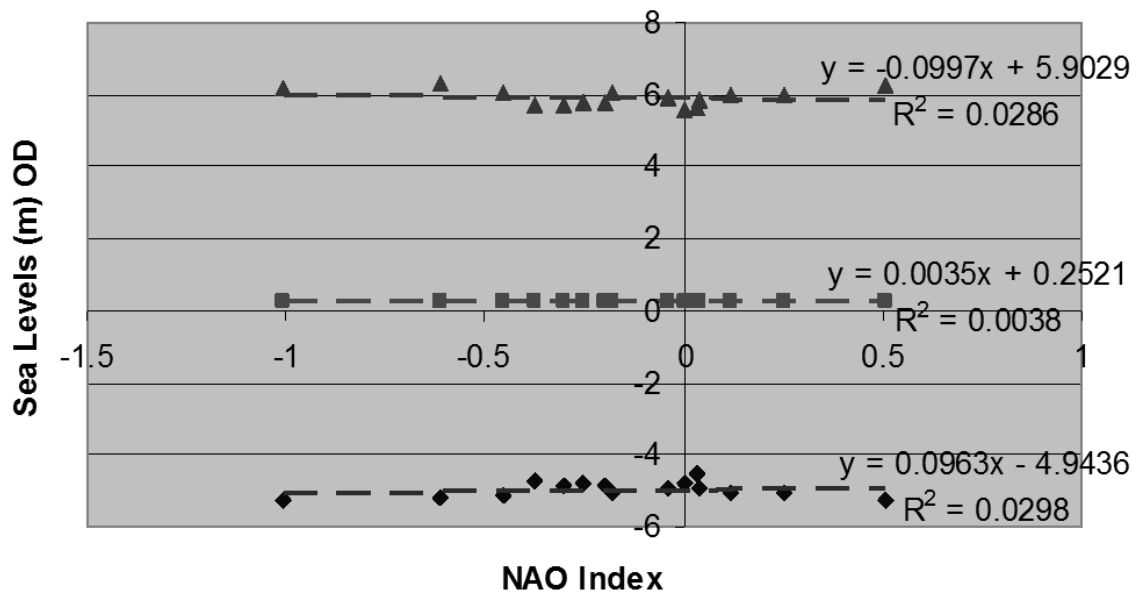
North Atlantic Oscillation



- **Plotted NAO results against mean sea levels found from this study.**
- **NAO appears to mirror mean sea levels at the four locations.**



North Atlantic Oscillation



Maximum Extreme

Mean

Minimum Extreme

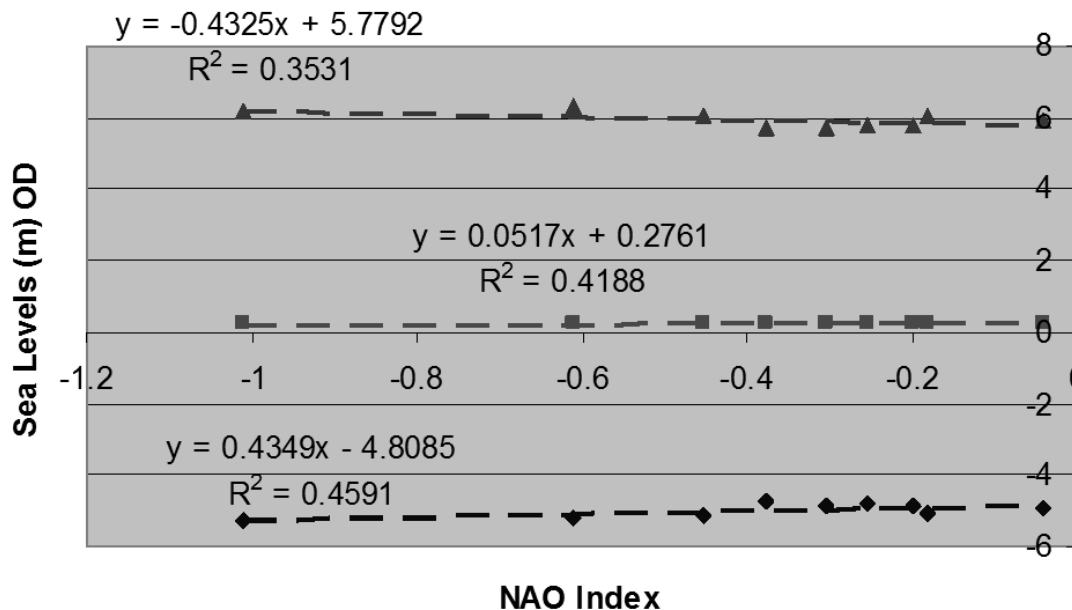
Sea Level Variations with NAO Index



North Atlantic Oscillation (Negative)

Fewer and weaker winter storms; Moist air into the Mediterranean and cold air to northern Europe; The US east coast experiences more snowy weather conditions. (Bell and Visbeck, 2009).

WEAKER WESTERLY WINDS (MetOffice, 2006)



Maximum Extreme

Mean

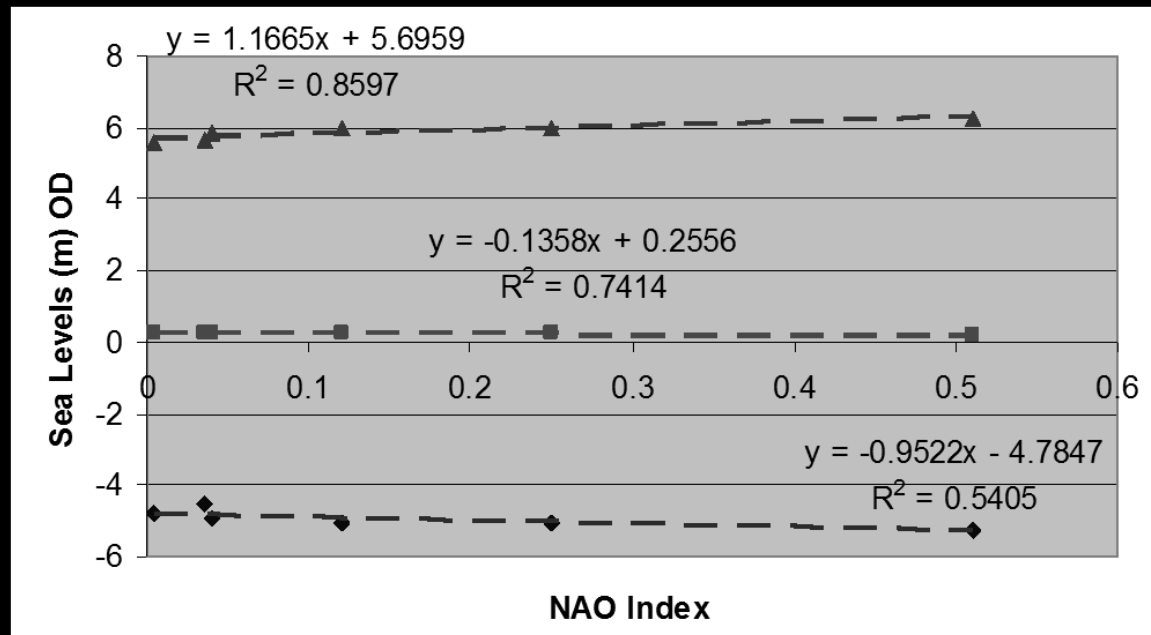
Minimum Extreme



North Atlantic Oscillation (Positive)

Strong subtropical high pressure and deeper Icelandic low; More and stronger winter storms crossing the Atlantic Ocean on a more northerly track; Warm, wet winters in Europe; cold, dry winters in Canada and Greenland; Eastern US mild and wet winters (Bell and Visbeck, 2009).

STRONGER WESTERLY WINDS (MetOffice, 2006)



Maximum Extreme

Mean

Minimum Extreme



Conclusions

- **Maximum extreme sea levels higher on northern shoreline than at corresponding locations on the south.**
- **Maximum extreme sea levels were significantly higher (1994, 1995, 1997, 1998) at Mumbles (95%), Newport (99%) and Hinkley Point (99%)**
- **Ilfracombe MSLs and max extreme sea levels showed no significant correlation – possibly due to coastal aspect and tide gauge location.**
- **MSLs indicated rising trends (except Mumbles) and significant differences between actual and predicted MSL found: Newport, 95% (Higher); Hinkley Point, 99% (Higher); Mumbles, 95% (Lower).**



- Overall annual MSL trend for the Bristol Channel and Severn Estuary shows a 2.4 mm yr⁻¹ rise (close agreement with Cascais, Portugal of 2.1 mm yr⁻¹ (exposure and aspect is similar))
- As tidal prism moved up the estuary towards Newport and Hinkley Point (Severn Estuary), tidal influences became more dominant (e.g. Da Silva and Duck, 2002).
- Convergence Max and Min Extremes (opposite Jensen et al., 2001)
- Projected 2050 (IPCC) sea level rise: 350 ± 35mm.
- Sea level variation was strongly correlated to the North Atlantic Oscillation (NAO) index, especially for maximum extreme sea levels during positive phases ($R^2 = 86\%$)



References

- Andersen, O. B., Knudsen, P., Beckley, B., (2002). Monitoring sea level and sea surface temperatures trends from ERS satellites. *Physics and Chemistry of the Earth*, 27, 1413-1417.
- Antunes, C., Taborda, R. (2009). Sea Level at Cascais tide gauge: data, analysis and results, *Journal of Coastal Research*, 1-5.
- Buckley, L., (2005). *Earth Policy Institute*. www.earth-policy.org. Date accessed 14/11/08.
- Cazenave, A., Dominh, K., Gennero, M. C., Ferret, B., (1998). Global Mean Sea Level Changes Observed by Topex-Poseidon and EKS-1. *Phys. Chem. Earth*, 23, 1069-1075.
- Crawford, W. R., Thomson, R. E., (1999). Sea level rise in British Columbia. *Canadian Coastal Conference*.
- Culver Dredging, (2005). www.culverdredging.info (accessed on 13/06/08).
- Douglas, B. C., Kearney, M. S., Leatherman, S. P., (2001). *Sea level rise: history and consequences*. Academic Press, 37-62.
- Google Maps, (2009). <http://maps.google.co.uk/maps?hl=en&tab=wl>. Date accessed 10/03/09.
- Hashemi, M. R., Abedini, M. J., Neill, S. P., Malekzadeh, P., (2008) Tidal and surge modelling using differential quadrature: A case study in the Bristol Channel. *Coastal Engineering*, 1-9.



Jensen, J., Mudersbach, C., (2004) Recent Sea Level Variations at the North Sea and Baltic Sea Coastlines. Germany, 1-6.

Kevin, B. D., Muller, R. A., Stone, G. W., (2004). Spatial and temporal variability of coastal storms in the North Atlantic Basin. *Marine Geology*, 210, 7-15.

Phillips, M.R., (2007). Beach response to a total exclusion barrage: Cardiff Bay, South Wales, UK. *Journal of Coastal Research*, 23(3), 794-805.

Proudman Oceanographic Laboratory, (2008). <http://www.pol.ac.uk/> Date accessed 05/10/08.

Schroeder, W. W., (2000). Disturbances: their role in shaping coastal environments. In: Rodriguez, G. R., Brebbia, C. A. and Perez-Martell, E. (eds), *Environmental Coastal Regions III*. WIT Press, Southampton, 431-440.

Tappin, D. R., Chadwick, R. A., Jackson, A. A., Wingfield, R. T. R., Smith, N. J. P., (1994). The geology of Cardigan Bay and the Bristol Channel. *British Geological Survey*. London, UK.

White Water Charters, (2007). *Bristol Channel tides*. <http://www.whitewatercharters.co.uk/>. Date accessed 12/12/08.

Woodworth, P. L., (2000). Monitoring and Predicting Long Term Global Sea Level Changes. *Period Biol*, 102, 665 - 671.

Wunsch, C., Ponte, R. M., Heimbach, P., (2007). Decadal Trends in Sea Level Patterns: 1993-2004. *Department of Earth, Atmospheric and Planetary Sciences*.



Thank you for listening!!!

Any Questions?

