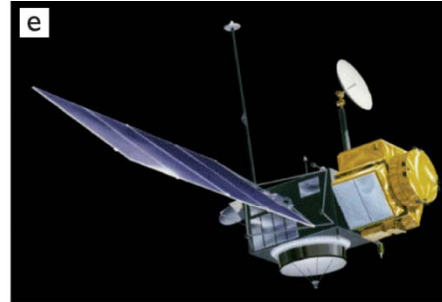
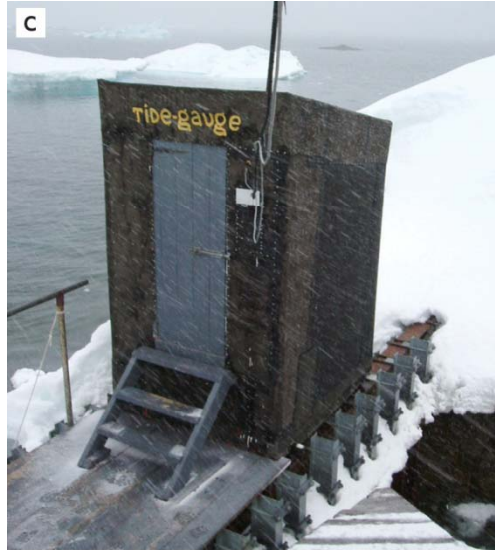


# **UK Sea Level Changes and Comparisons to Those Elsewhere**

**Philip Woodworth, POL**

# Sea Level Measurements

**POL tide gauge in Antarctica**



**TOPEX sea level satellite**



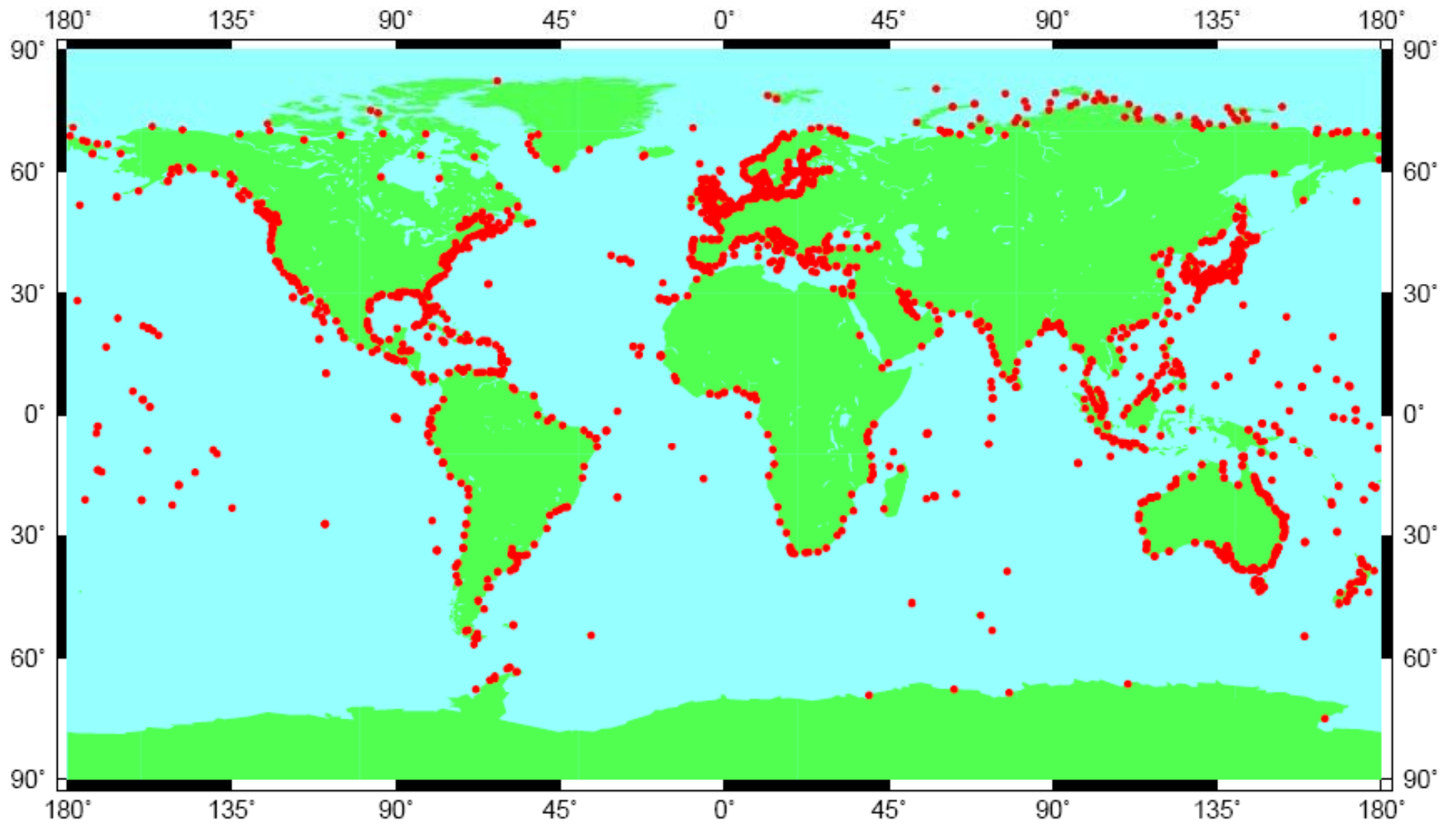
**Liverpool radar tide gauge**



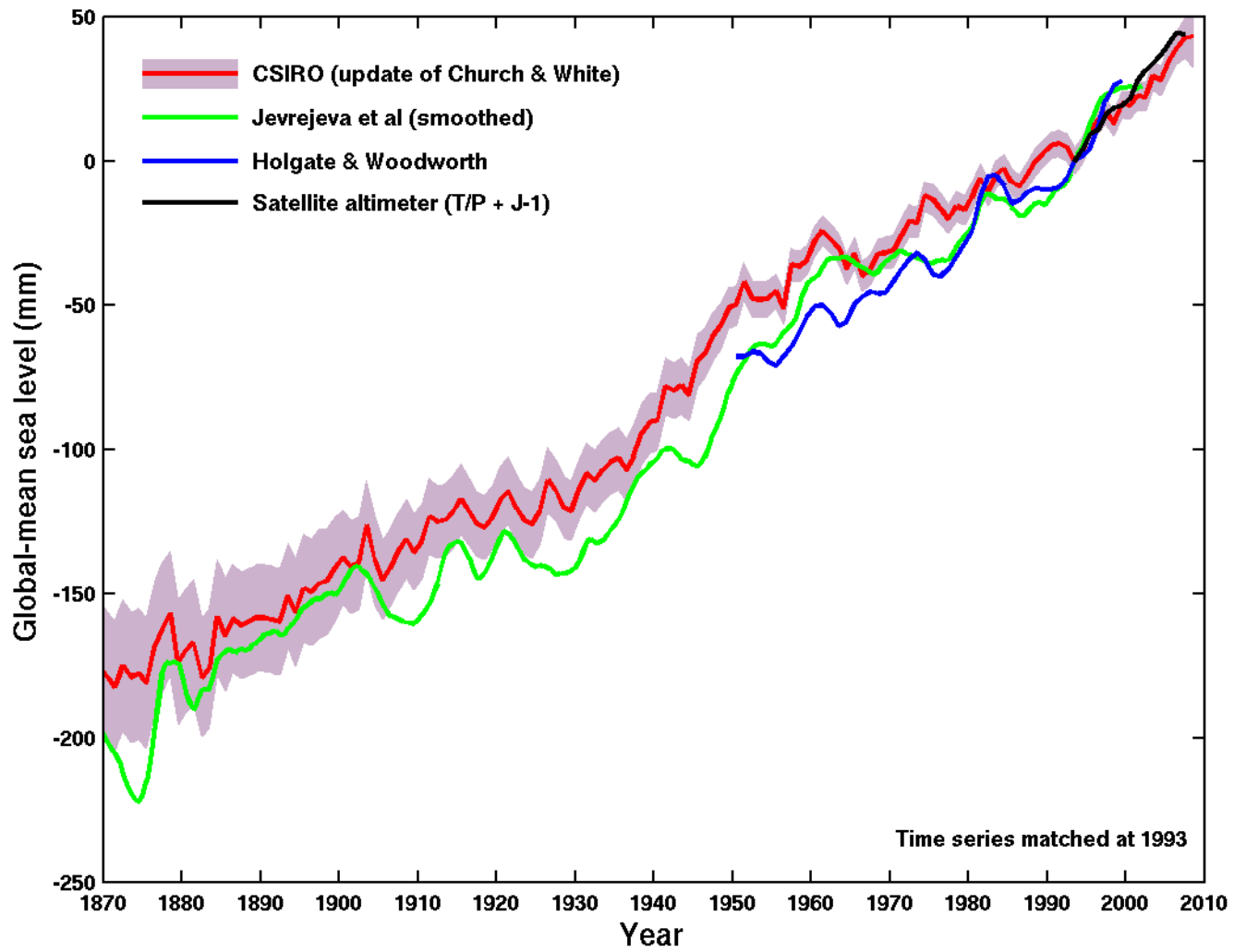
**Historical tide gauge in Venice**



**Australian acoustic tide gauge**



**Global Sea Level Data Set (PSMSL)**



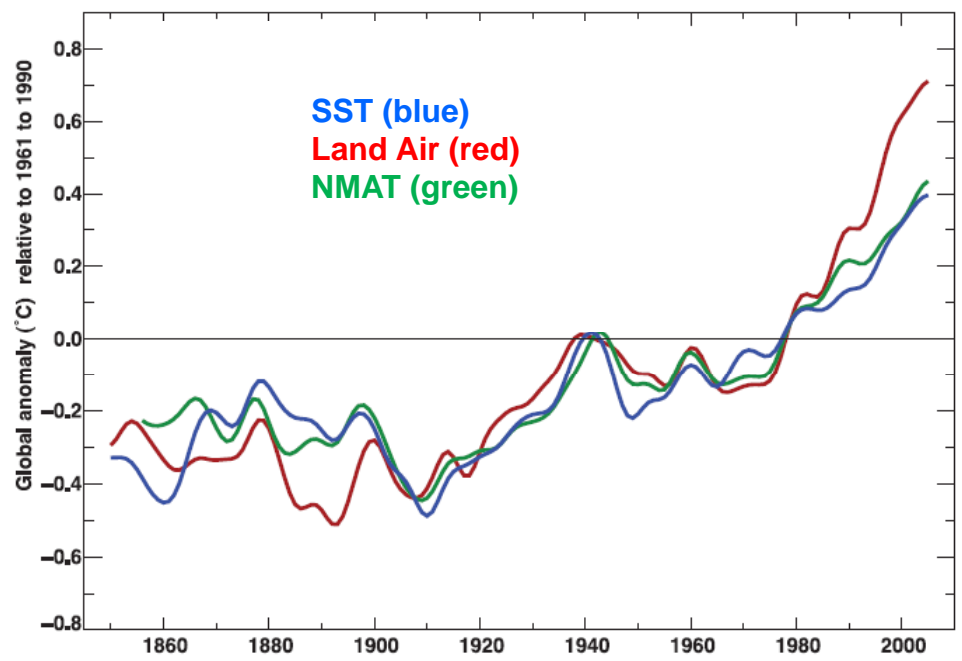
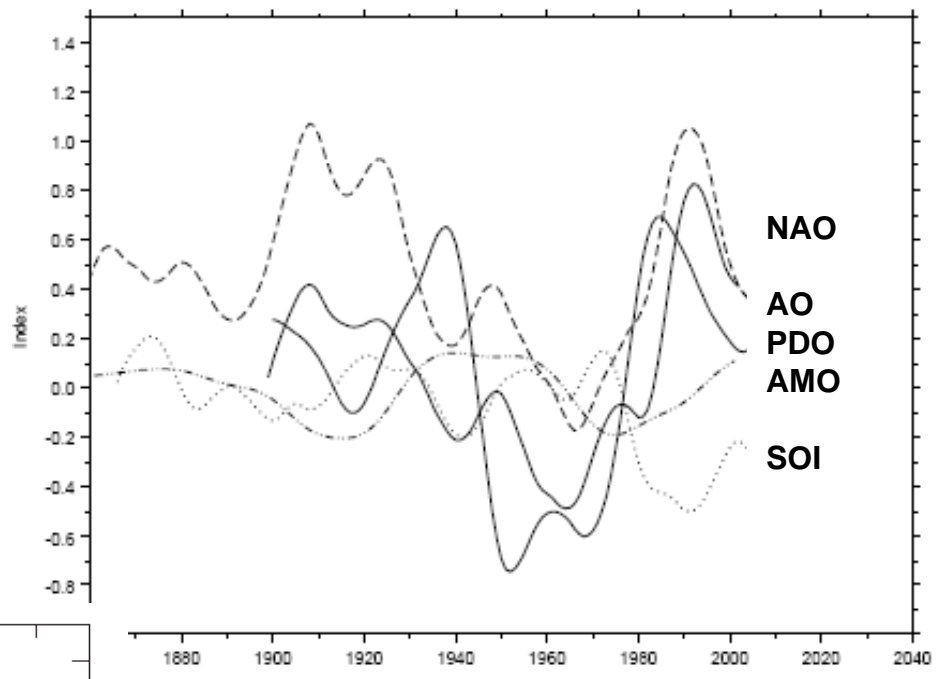
all using PSMSL data

# Attributes of the Global Curve

- Acceleration from the 19<sup>th</sup> to 20<sup>th</sup> century
- Higher rates 1920-1960
- Deceleration after 1960
- Higher rates in the 1990s

Review Paper - Woodworth, P.L., White, N.J., Jevrejeva, S., Holgate, S.J., Church, J.A. and Gehrels, W.R. 2009. Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology*, 29, 777-789, doi:10.1002/joc.1771.

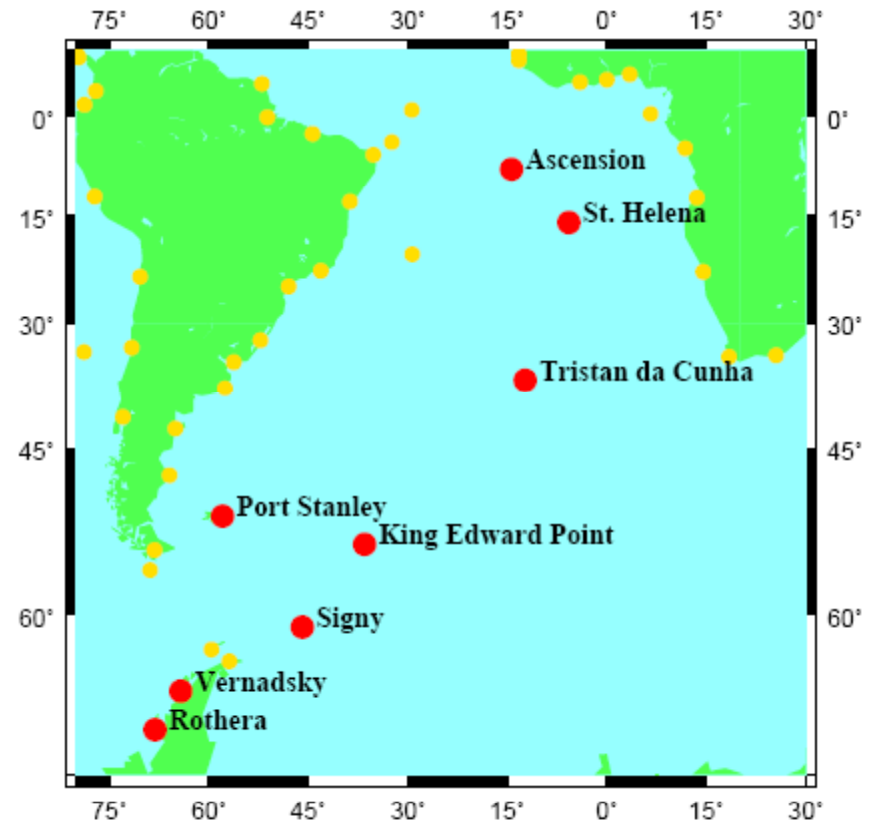
# Major Climate Indices (see also Baines and Folland, 2007)



# Global Air and Sea Temperatures (IPCC 4AR)



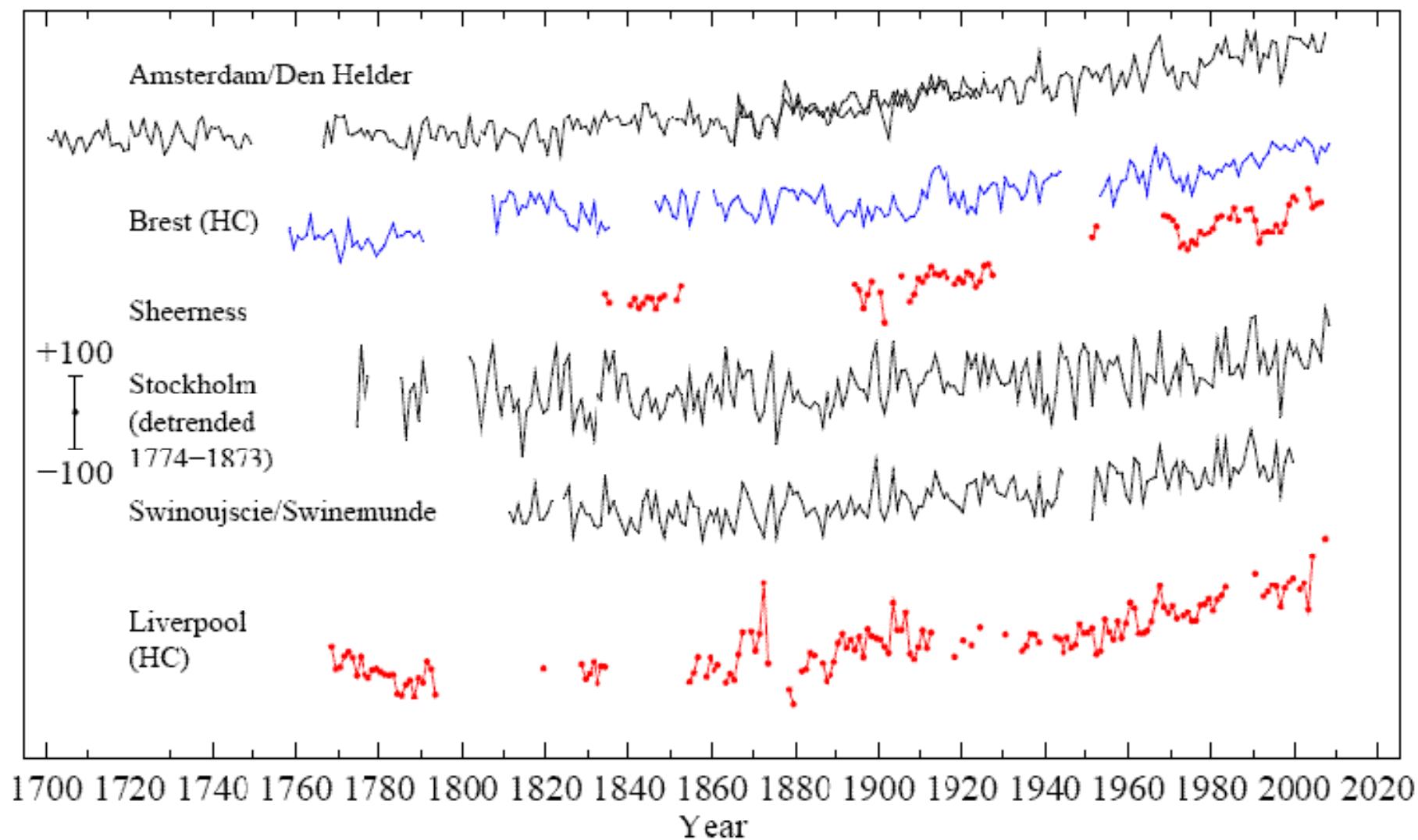
**UK National Network**

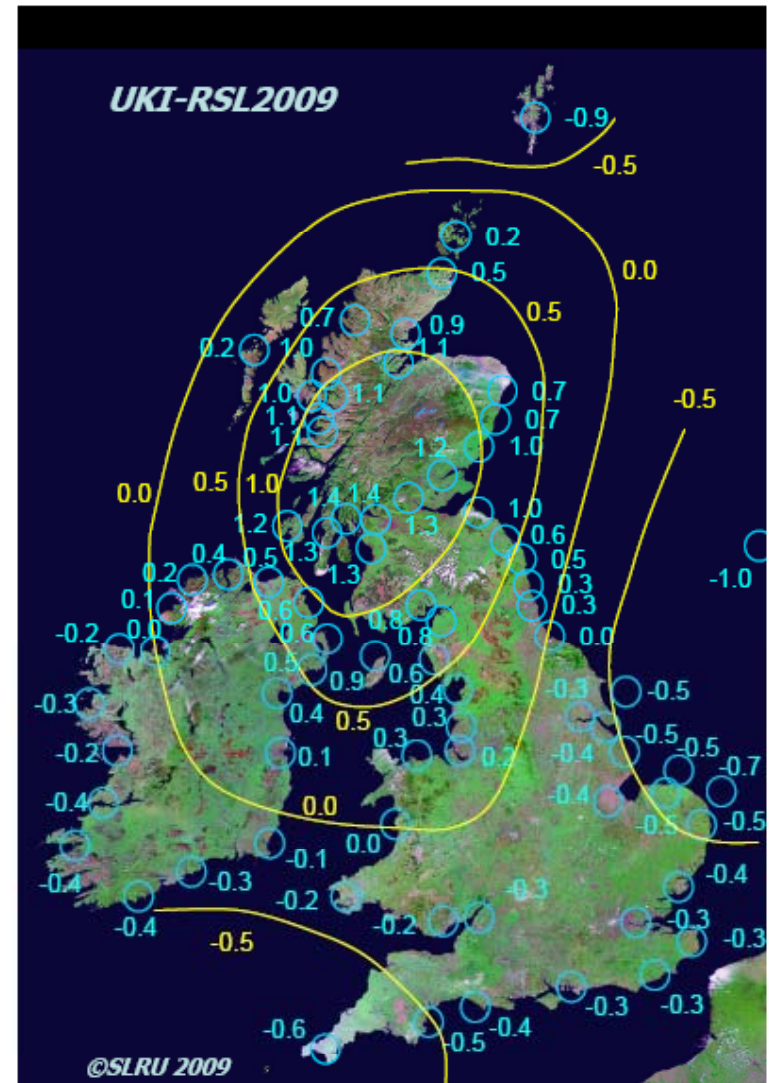
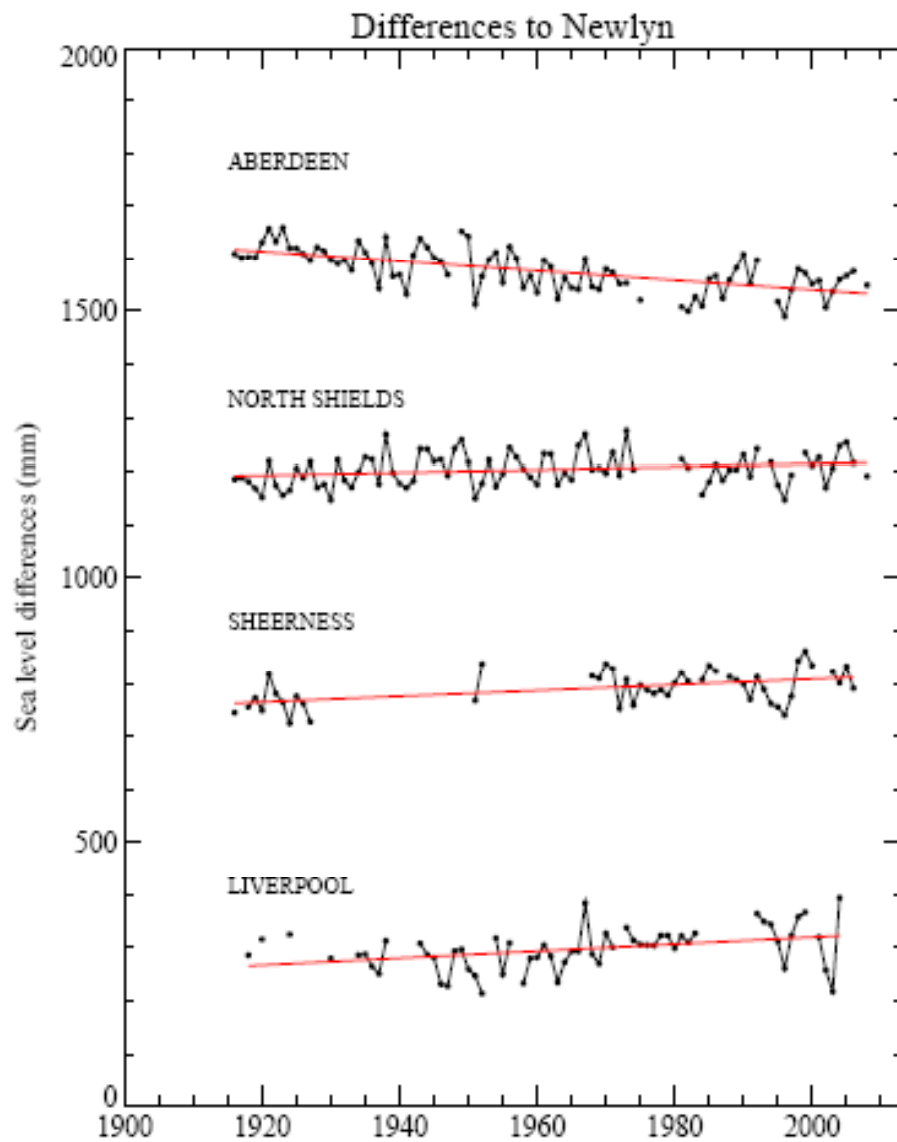


**POL South Atlantic Network**



**Gibraltar**

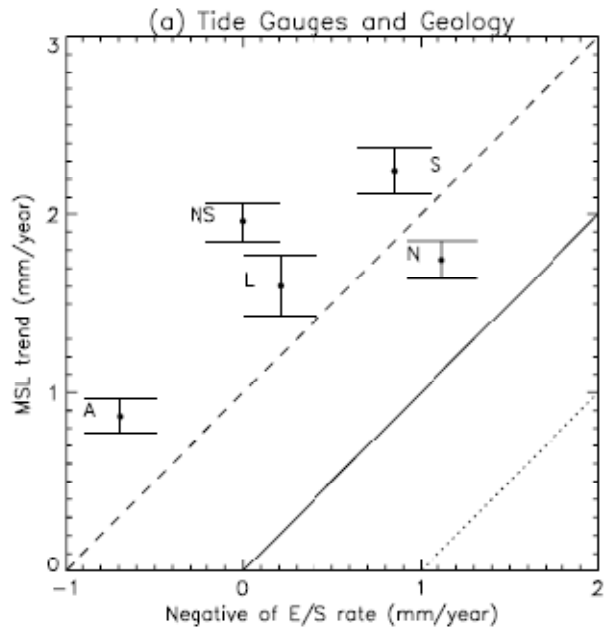




Shennan et al. 2009

## 20<sup>th</sup> Century Rates of UK Sea Level Change

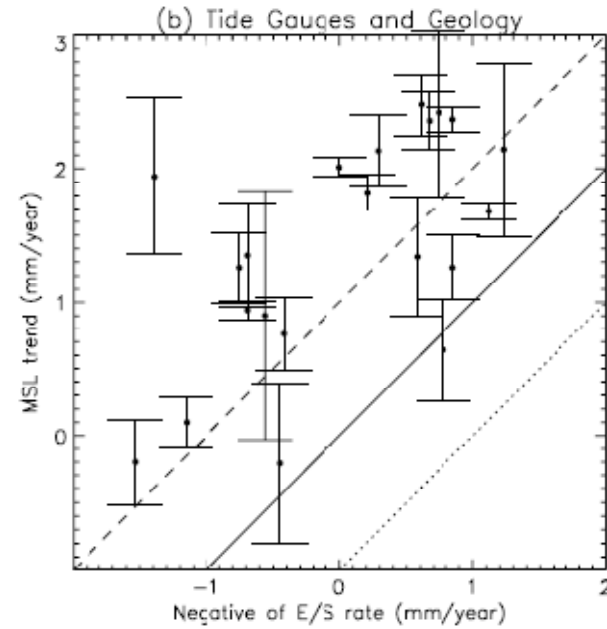
**TG**



**Geology**

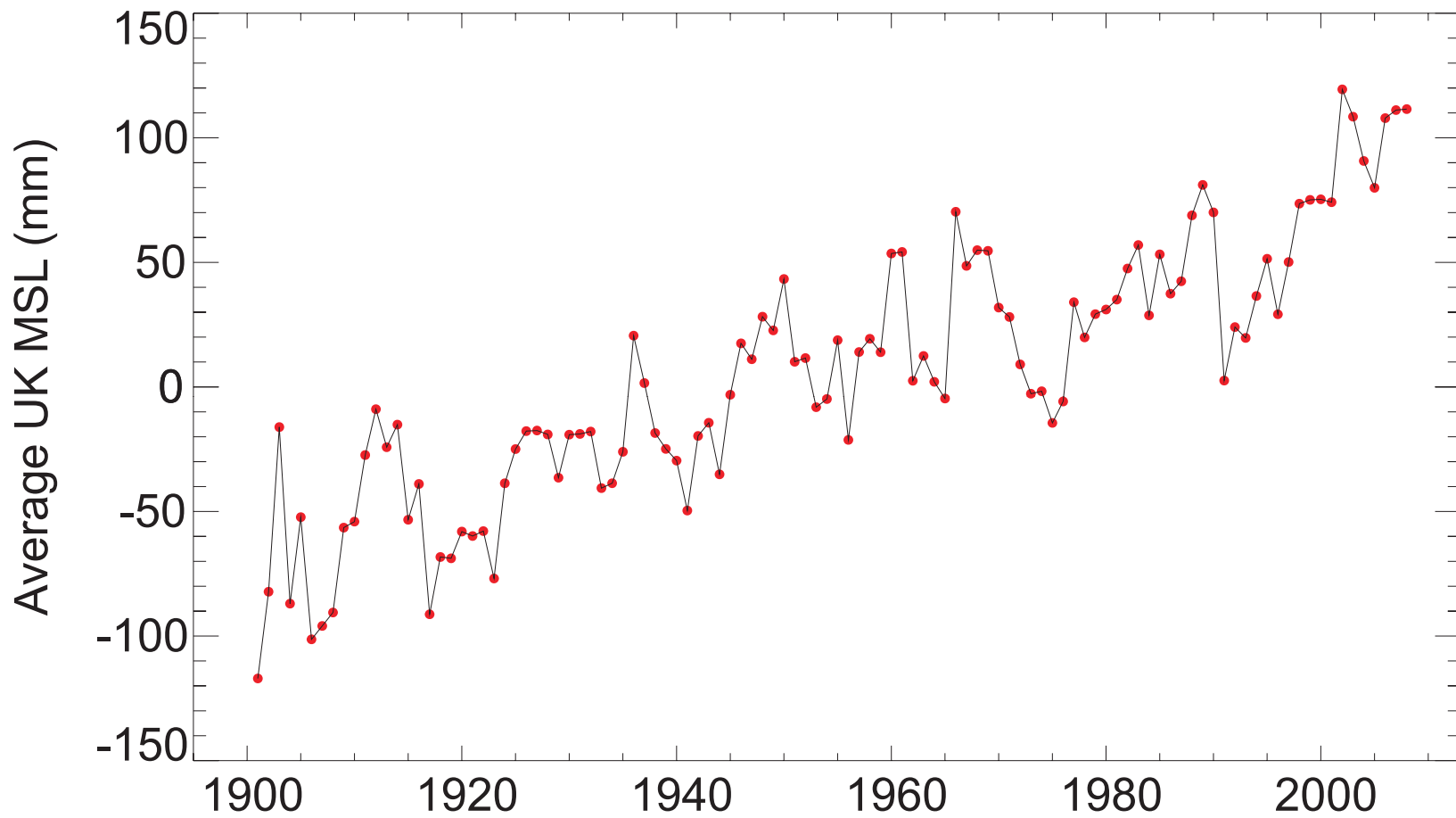
**5 Long Records  
(TG measured rates)**

**TG**

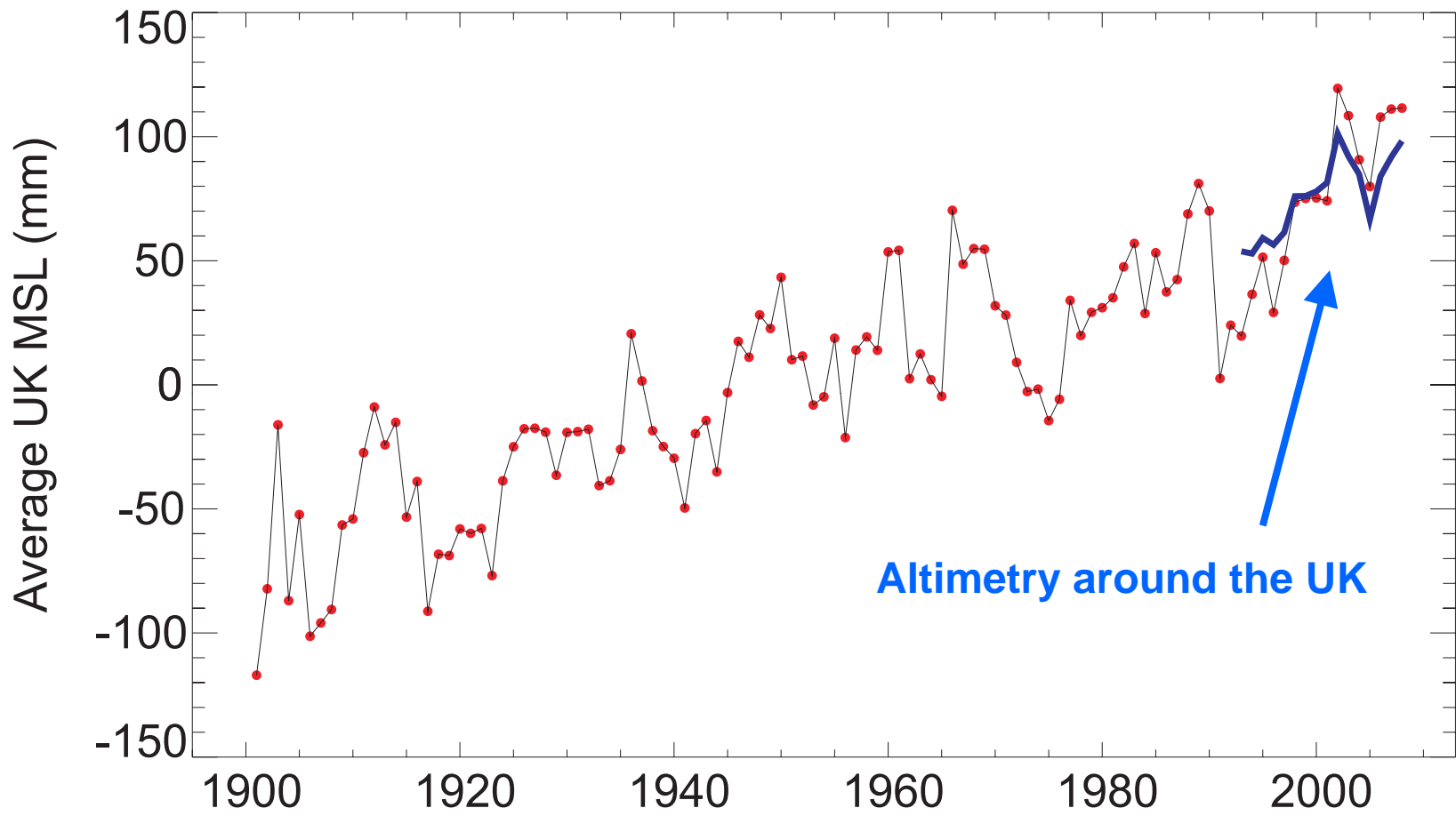


**Geology**

**21 Short Records  
(TG rates inferred by regression)**



**Average UK Mean Sea Level Change  
1.4 mm/year for the 20th century**



# Attributes of the UK Curve

- Acceleration from the 19<sup>th</sup> to 20<sup>th</sup> century
- Higher rates 1920-1960
- Deceleration after 1960
- Higher rates in the 1990s (5.3 mm/yr 1990-2008)

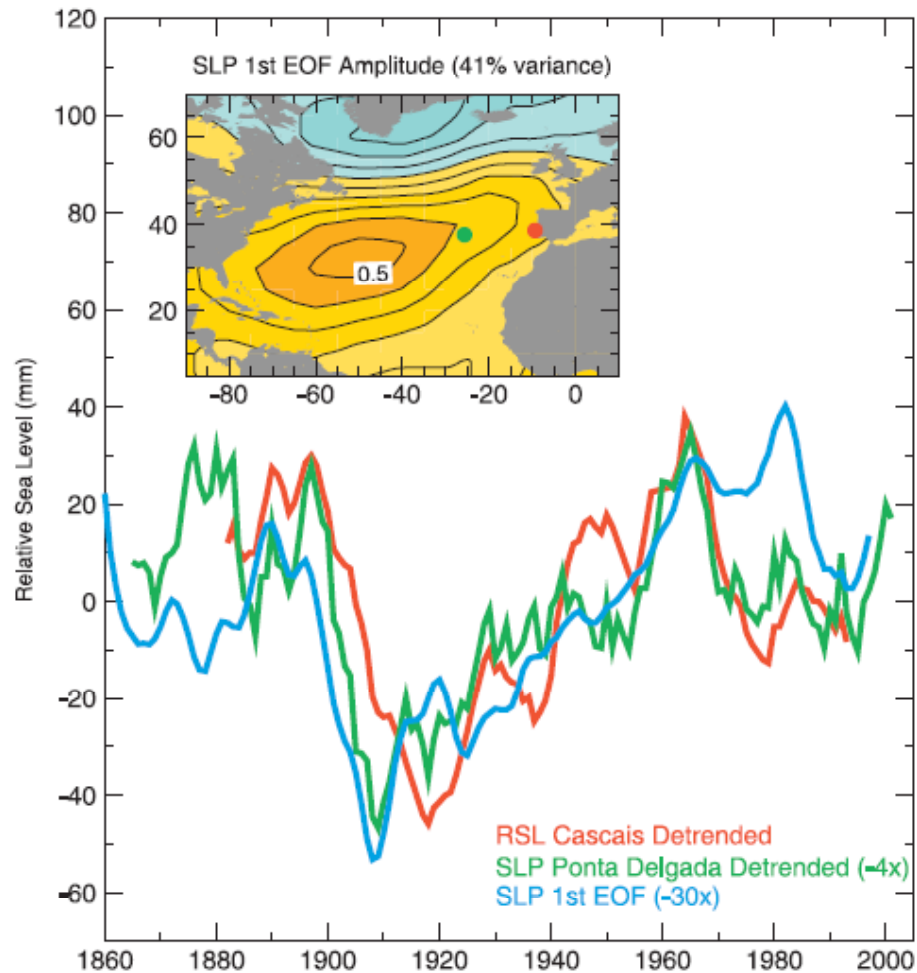
Woodworth, P.L., Teferle, N., Bingley, R., Shennan, I. and Williams, S.D.P. 2009. Trends in UK mean sea level revisited. *Geophysical Journal International*, 176, 19-30, doi:10.1111/j.1365-246X.2008.03942.x.

What Causes the Accelerations  
and Decadal Variability seen in  
UK, French etc. Sea Levels on the  
eastern boundary of the North  
Atlantic?

# Miller and Douglas, GRL, 2007

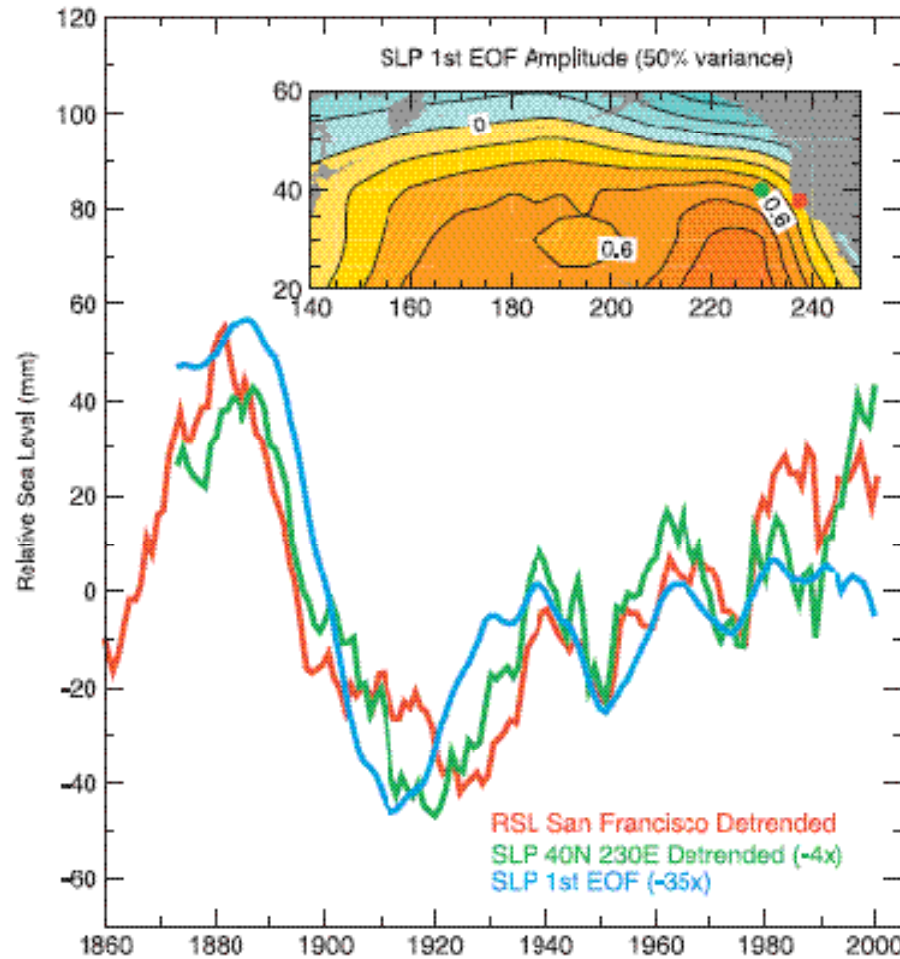
- Possibility that some of the sea level rise and acceleration seen on the European Atlantic coast could be due to spin-down of the gyre, rather than change in ocean volume
- Problem was that they were inferring multi-decadal and century timescale relationships from little more than one century of data.

Miller and Douglas, GRL, 2007



Relationship between sea level on the eastern boundary to strength of the atmospheric gyre measured by air pressure near the gyre centre.

Miller and Douglas, GRL, 2007



Similar relationship in Pacific between San Francisco and gyre air pressure although less reliable 19<sup>th</sup> century air pressure fields.

# Use Brest instead of Cascais

- Brest shows similar sea level behaviour to Cascais (used by M+D)
- Recent data archaeology by **Pouvreau** has enabled Brest MSL and MHW data to become available from mid-18<sup>th</sup> century
- Meanwhile ship logbook data from the **CORRAL** and **ACRE** projects have provided N Atlantic air pressures back to mid-18<sup>th</sup> centuries (**Küttel** et al. 2008).



## **CORRAL (UK Colonial Registers and Royal Navy Logbooks) project (JISC)**

Clim Dyn

DOI 10.1007/s00382-009-0577-9

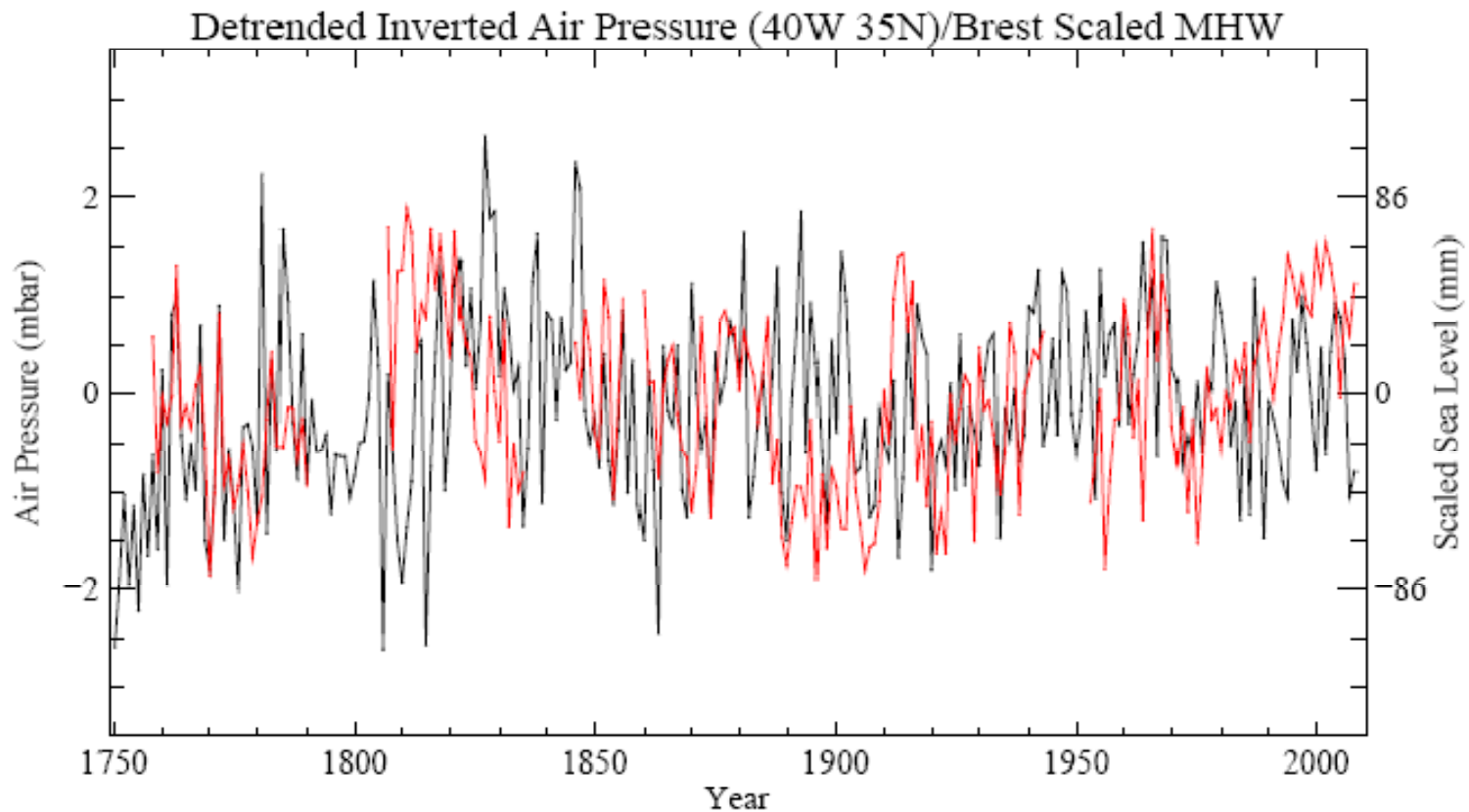
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## **The Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative**

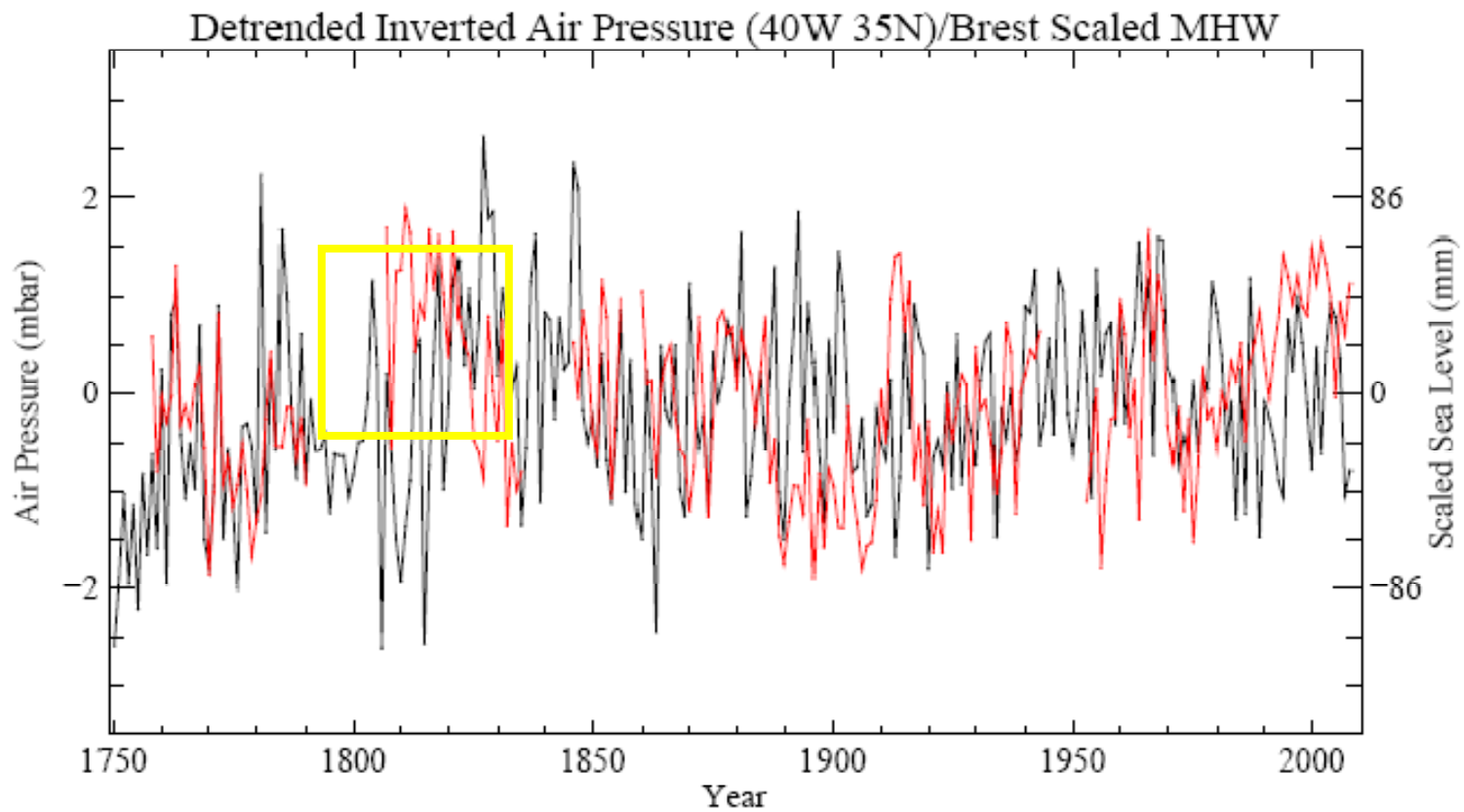
## **The importance of ship log data: reconstructing North Atlantic, European and Mediterranean sea level pressure fields back to 1750**

M. Küttel · E. Xoplaki · D. Gallego · J. Luterbacher ·  
R. García-Herrera · R. Allan · M. Barriendos ·  
P. D. Jones · D. Wheeler · H. Wanner

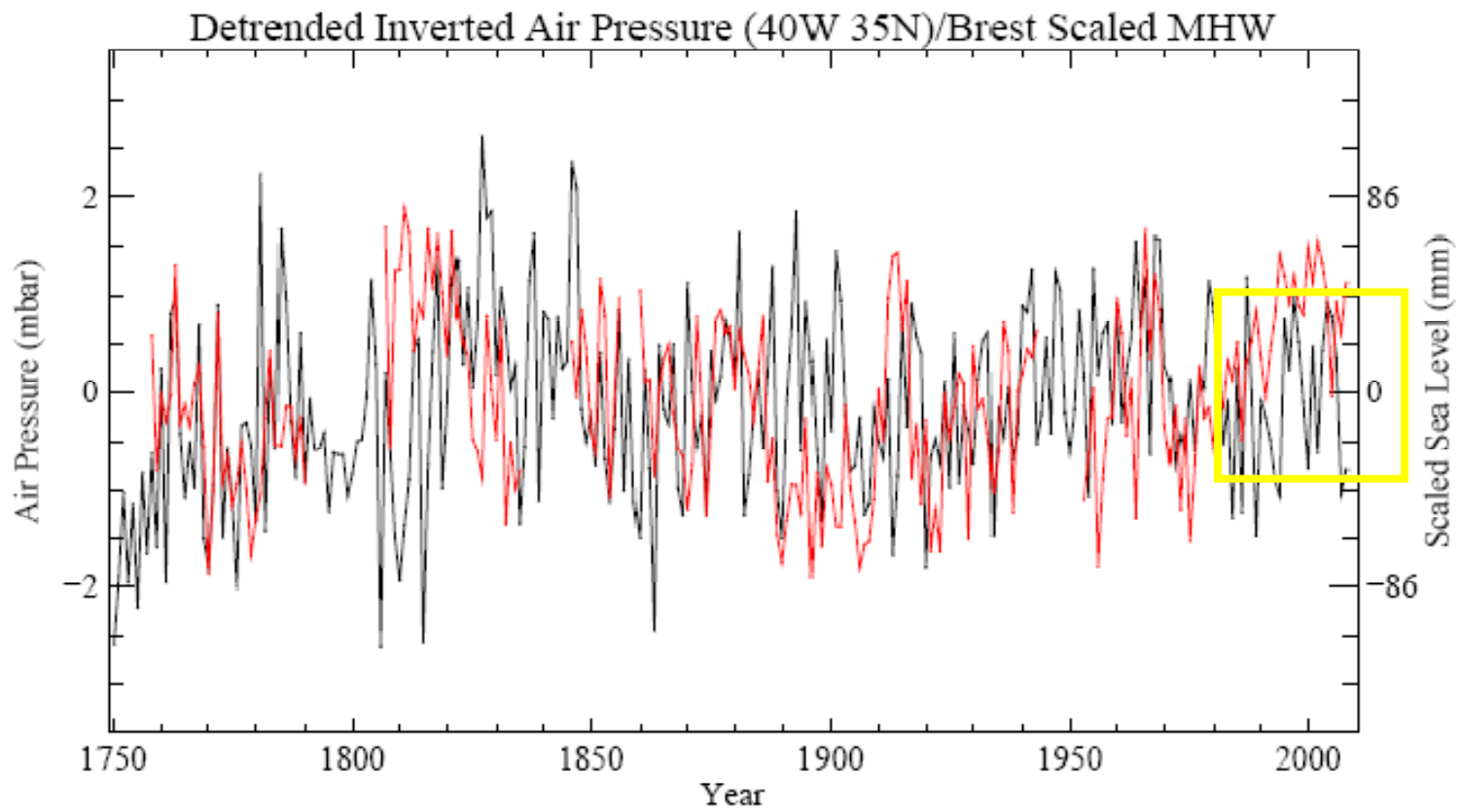


**Relationship suggested by Miller and Douglas applies over timescales twice as long as they investigated.**

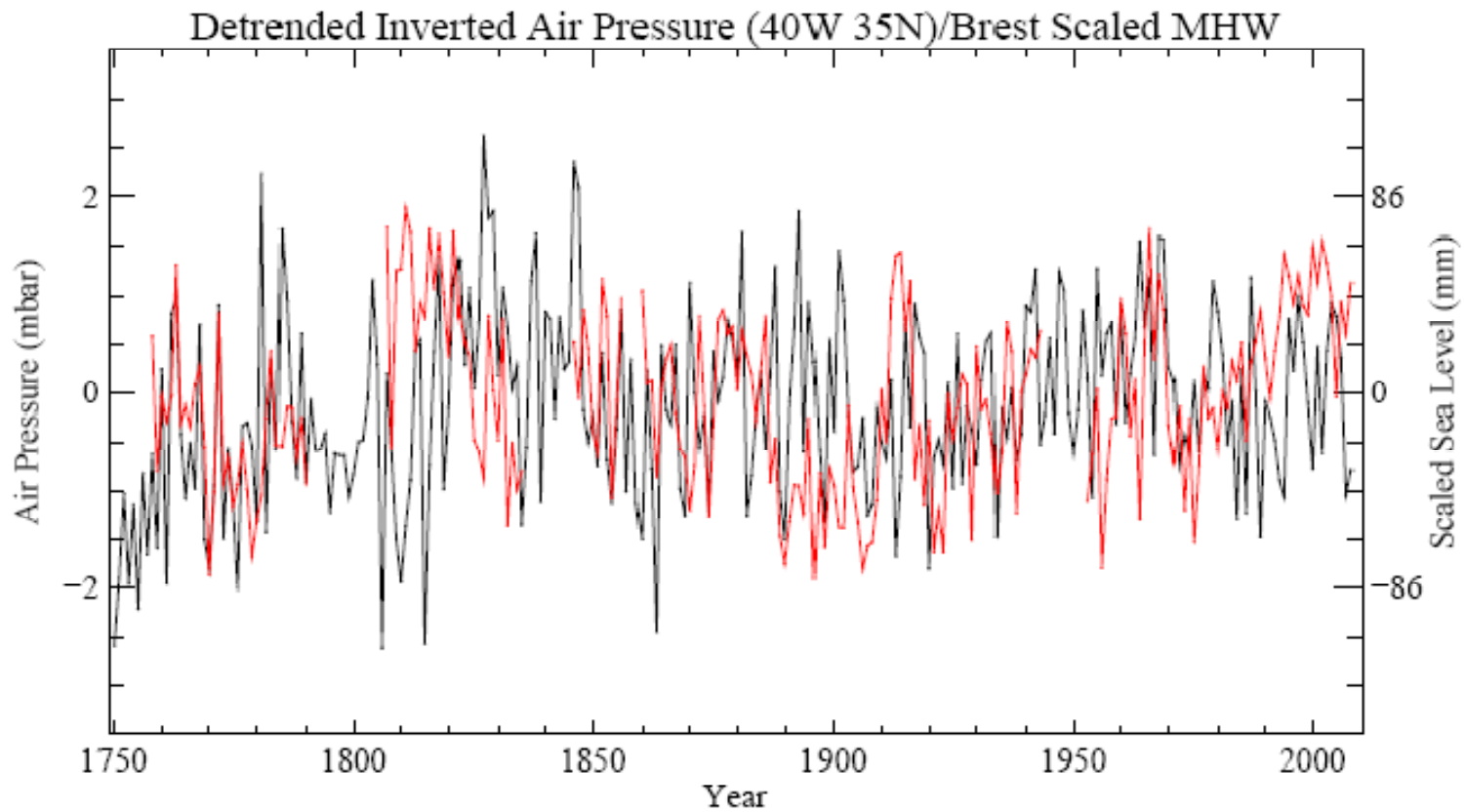
**Woodworth, Pouvreau and Wöppelman, 2009, Ocean Science**



**Around 1810 -Tide gauge observer was known to be doing a bad job.**



**Last two decades – less easy to explain.**



**Relationship suggested by Miller and Douglas applies over timescales twice as long as they investigated.**

# Attributes of the Gyre Spin-Down Curve

- Acceleration from the 19<sup>th</sup> to 20<sup>th</sup> century
- Higher rates 1920-1960
- Deceleration after 1960
- Higher rates in the 1990s

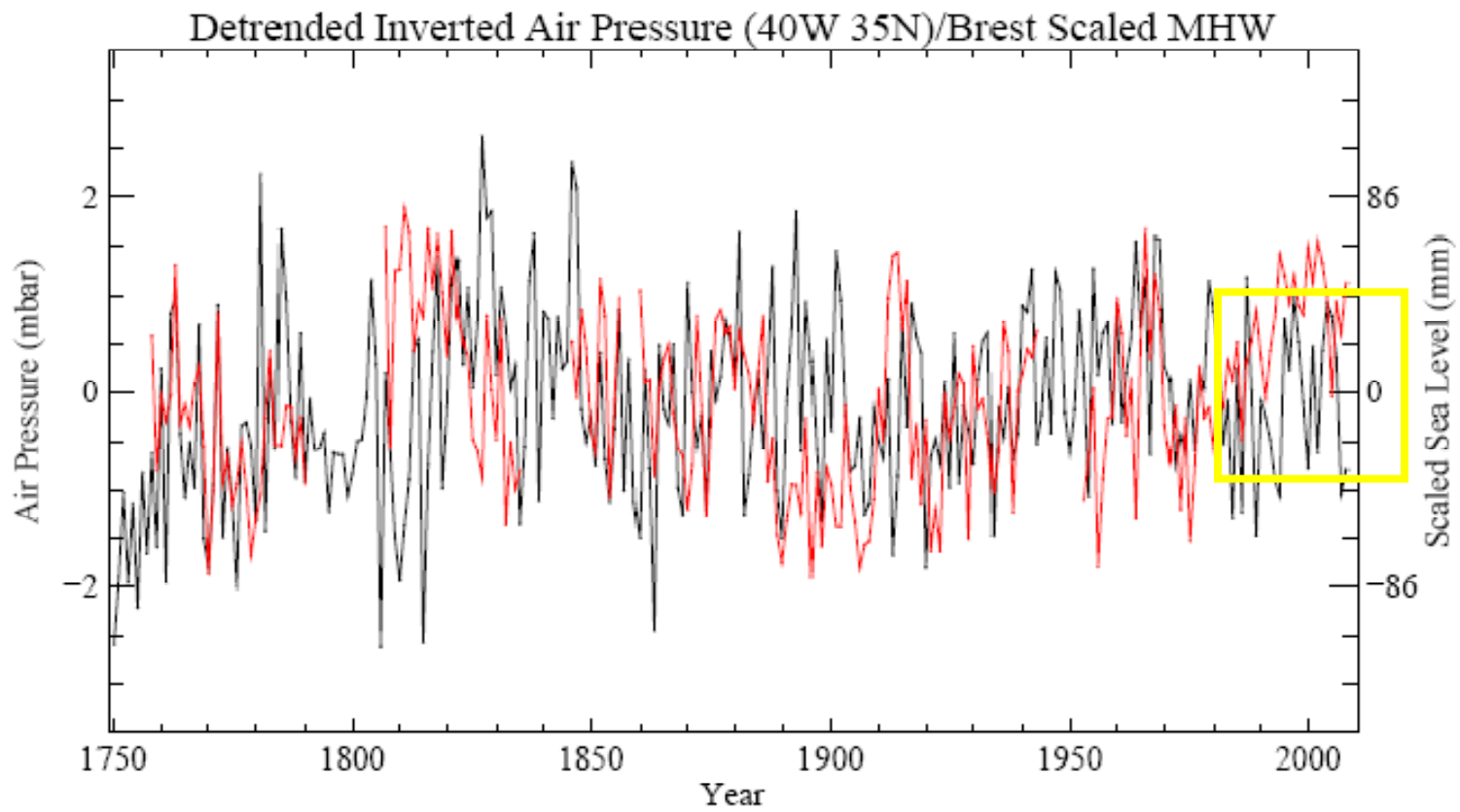
# Attributes of the Gyre Spin-Down Curve

- Acceleration from the 19<sup>th</sup> to 20<sup>th</sup> century
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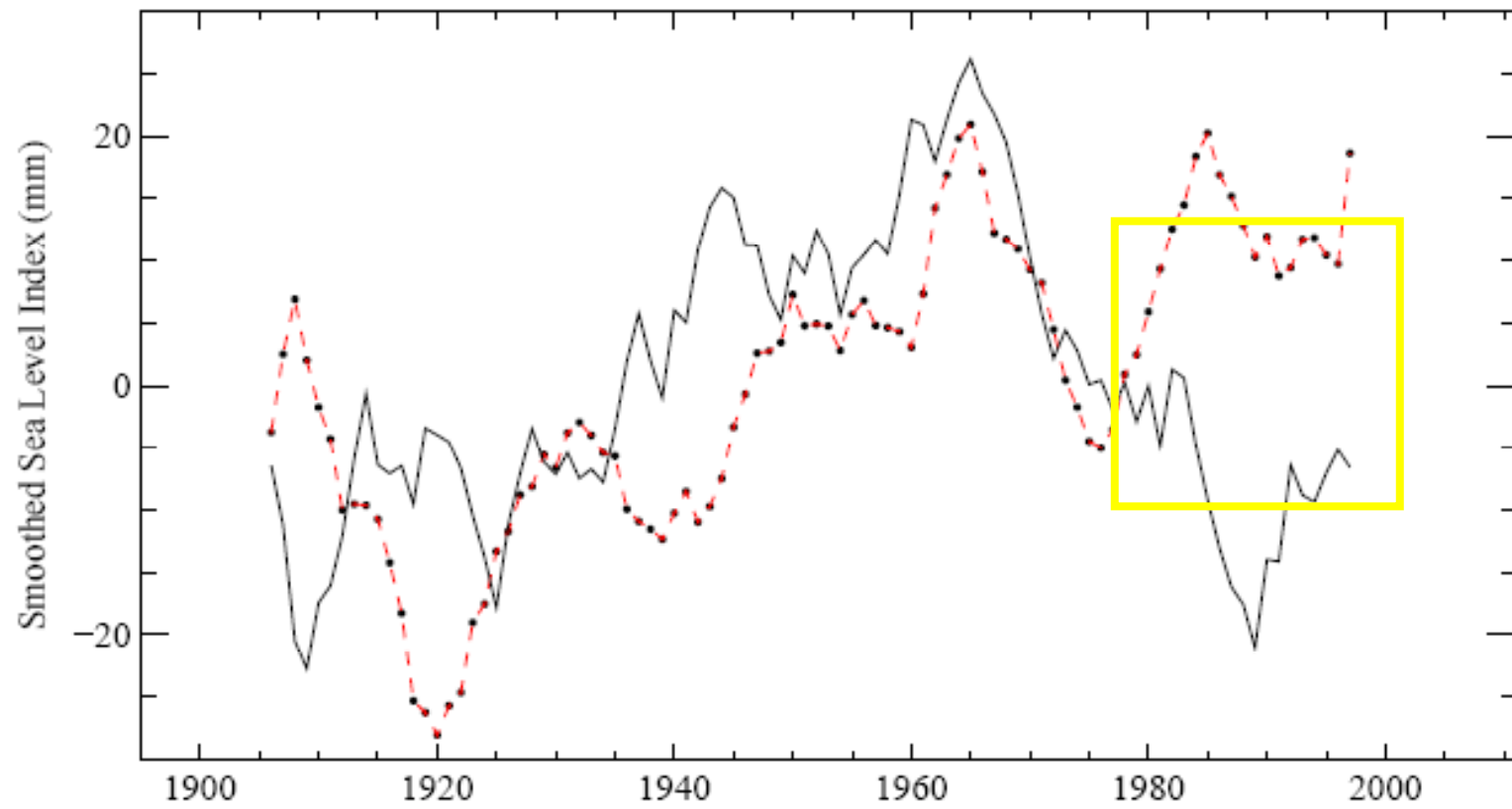
Sounds familiar?

# Attributes of the Gyre Spin-Down Curve

- Acceleration from the 19<sup>th</sup> to 20<sup>th</sup> century
- Higher rates 1920-1960
- Deceleration after 1960
- Higher rates in the 1990s
- Deceleration from 18<sup>th</sup> to 19<sup>th</sup> century



**Last two decades – less easy to explain.**



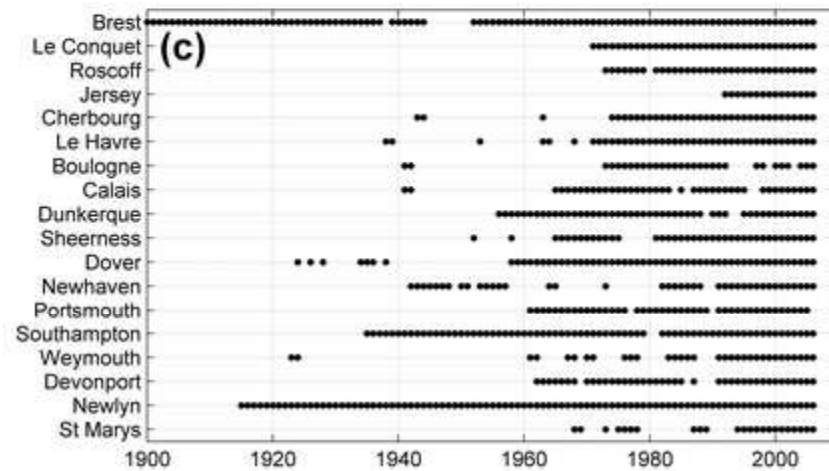
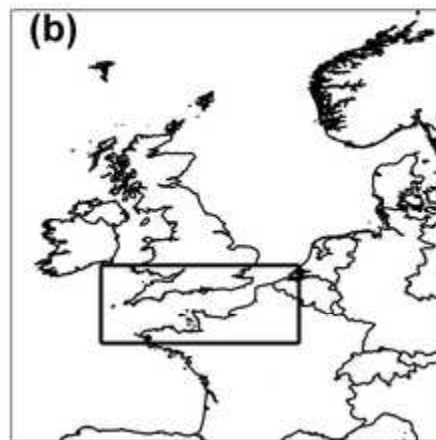
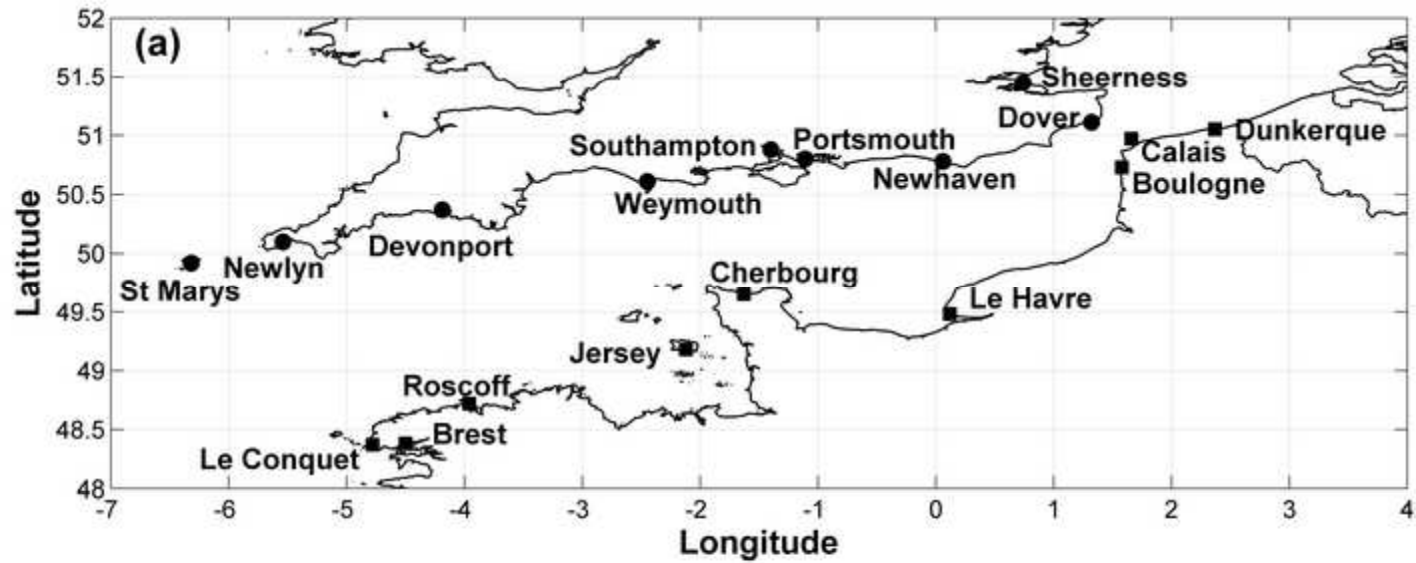
**UK Sea Level Index (red dotted) and Air Pressure at the Gyre Centre**

# Disturbing Questions

- Are the eastern boundary data over-represented in the 'global' sea level curves?
  - If so then part of the observed 'global sea level rise' could have been due to redistribution of water.
- ➔ Data analysis and ocean modelling tasks that we are addressing at POL and LU

# Improvements in the Sea Level Data Set

- UK – Ivan Haigh (S'ton) extension of 6 south coast records
- More UK data archaeology in progress e.g. Belfast
- Sea Level 500 project - saltmarsh data from the North Atlantic to complement and extend tide gauge records



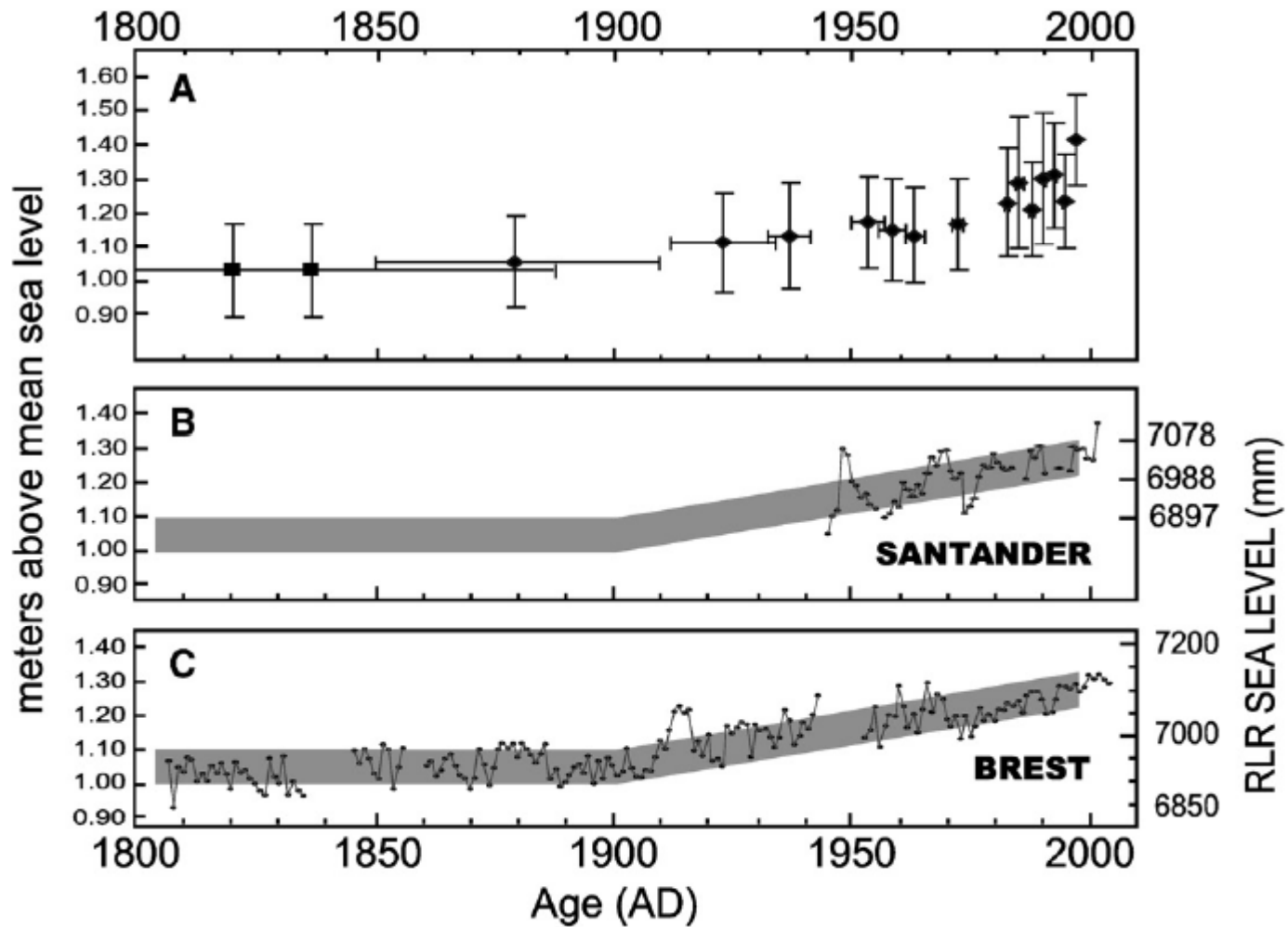
Haigh et al., CSR, 2009

# Sea Level 500



**Plymouth – Durham – POL/L'pool Saltmarsh and TG Studies (NERC)**

**also Univ. Pennsylvania Measurements in Bermuda (NSF)**



Leorri et al., Marine Geology, 2008. Northern Spain saltmarsh data.

# Conclusions

- UK sea level appears to have risen over the last century at a rate similar to, or a little less than, the global rate
- Variations in the rate around the UK broadly consistent with geology (and also GPS and Absolute Gravity measurements)
- Several of the main 'accelerations' within the UK record are similar to that in the global curve
- UK, Brest and other eastern boundary sea levels have low-frequency components similar to that of gyre spin-up/down as proposed by Miller and Douglas which must be investigated in more detail.

## **Advertisement**

### **Understanding Sea-Level Rise and Variability**

**eds. John Church, Stan Wilson, Thorkild Aarup and  
Philip Woodworth**

**Wiley-Blackwell, Early 2010**

# Liverpool

## Home of UK Sea Level Science



