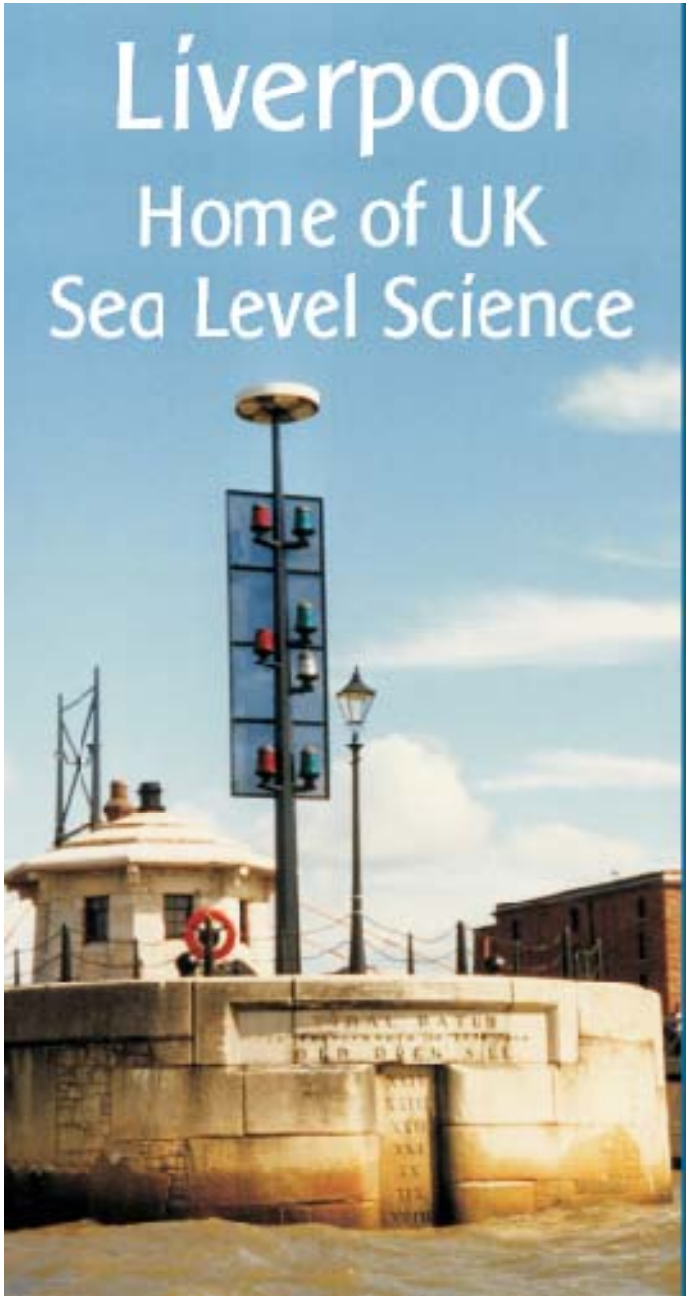


Changing Sea Level Means and Extremes and even Changing Tides

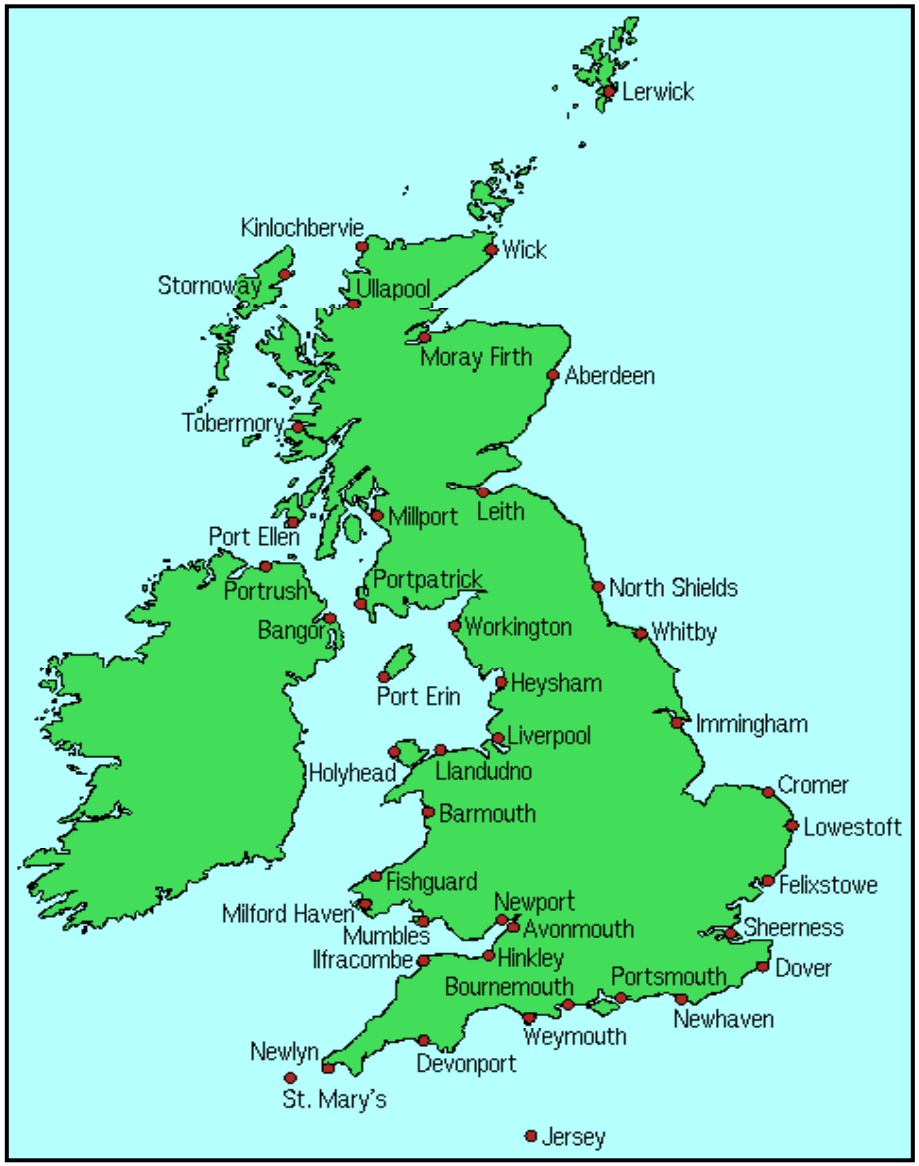
Philip Woodworth, POL

with thanks to Ivan Haigh (Southampton) and Melisa Menendez (Santander)

Liverpool
EUROPEAN
CAPITAL OF CULTURE

Contents

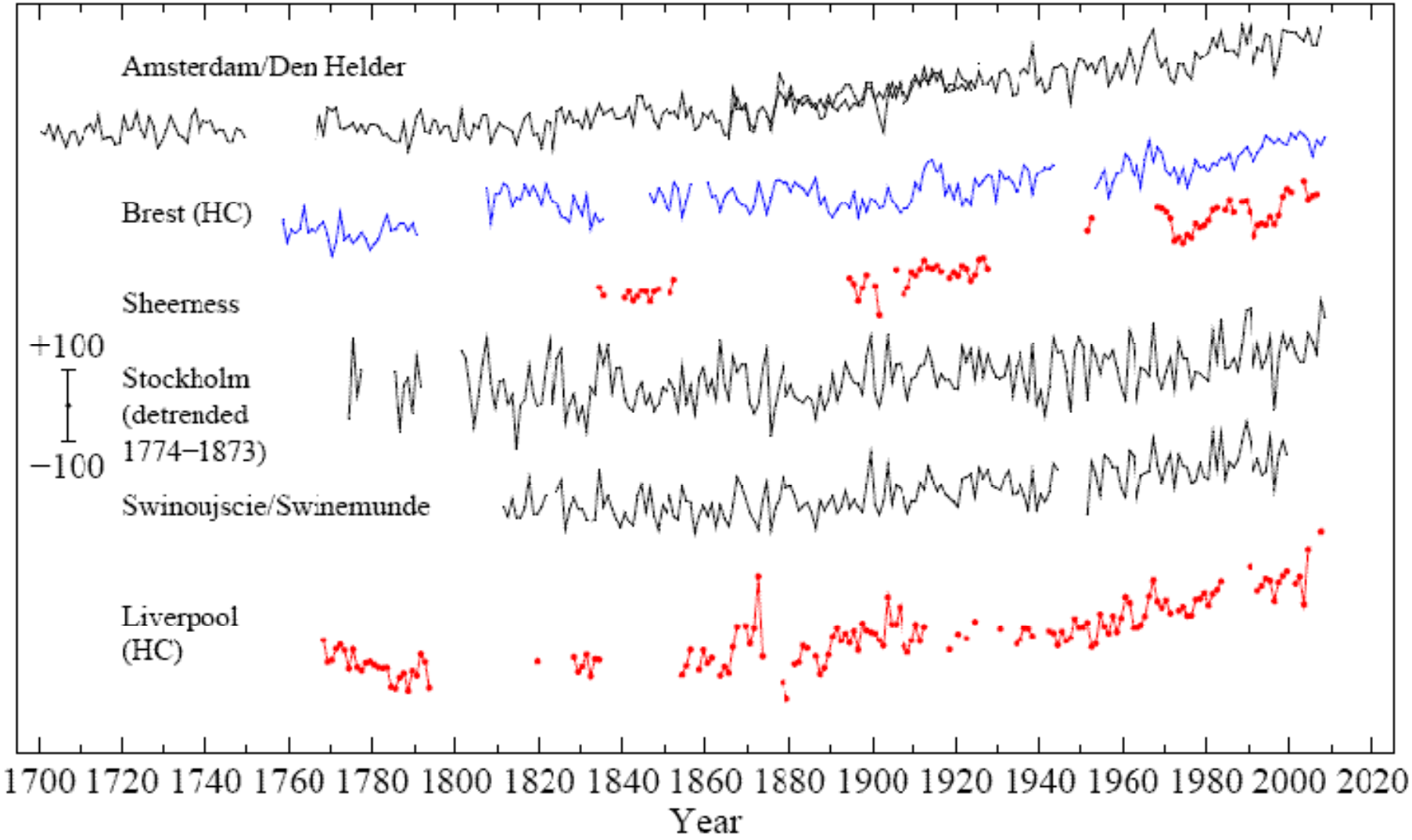
- UK Mean Sea Level change revisited
- Components of sea level change
- Global study of changes in extremes
- Global study of changes in tides
- Conclusions

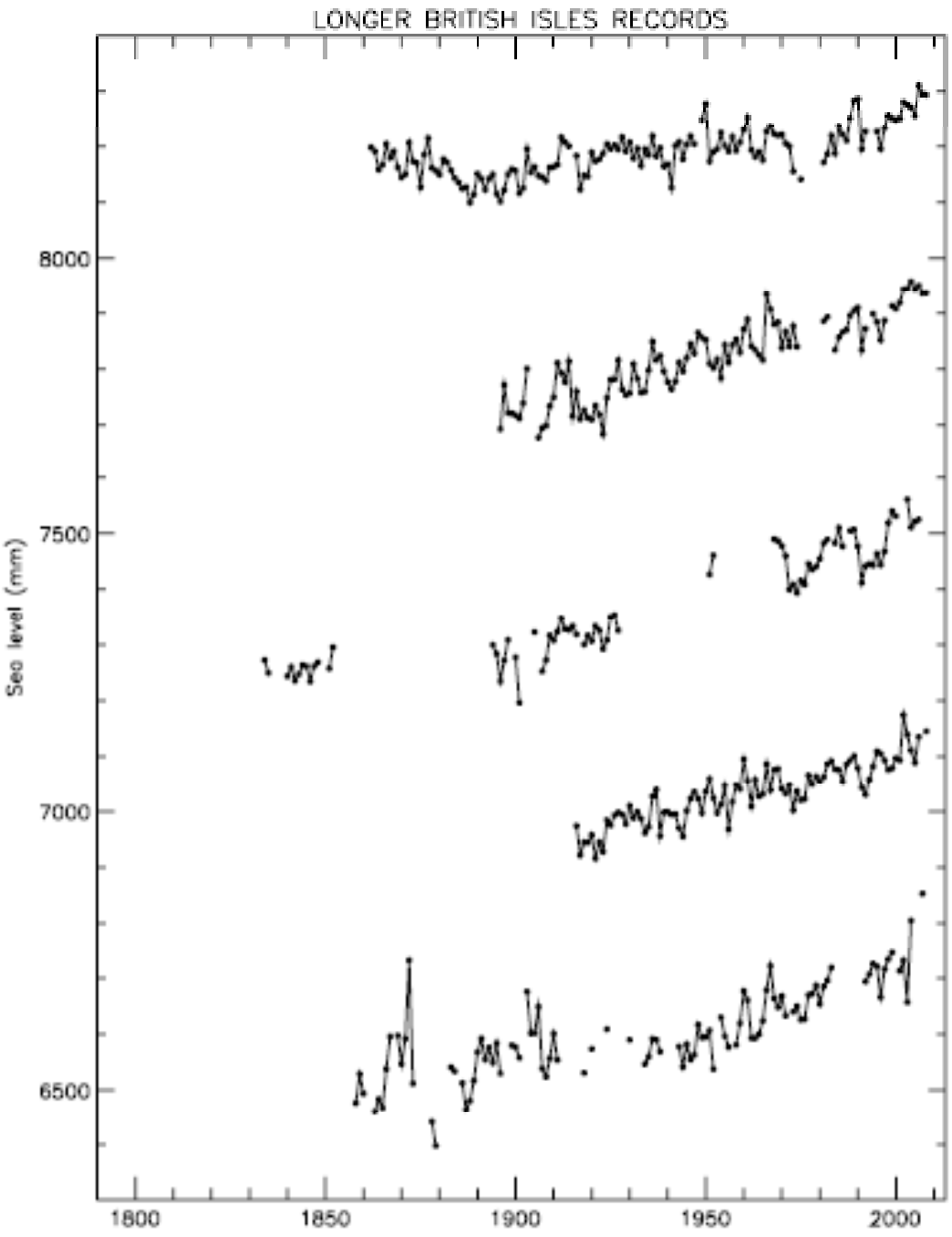


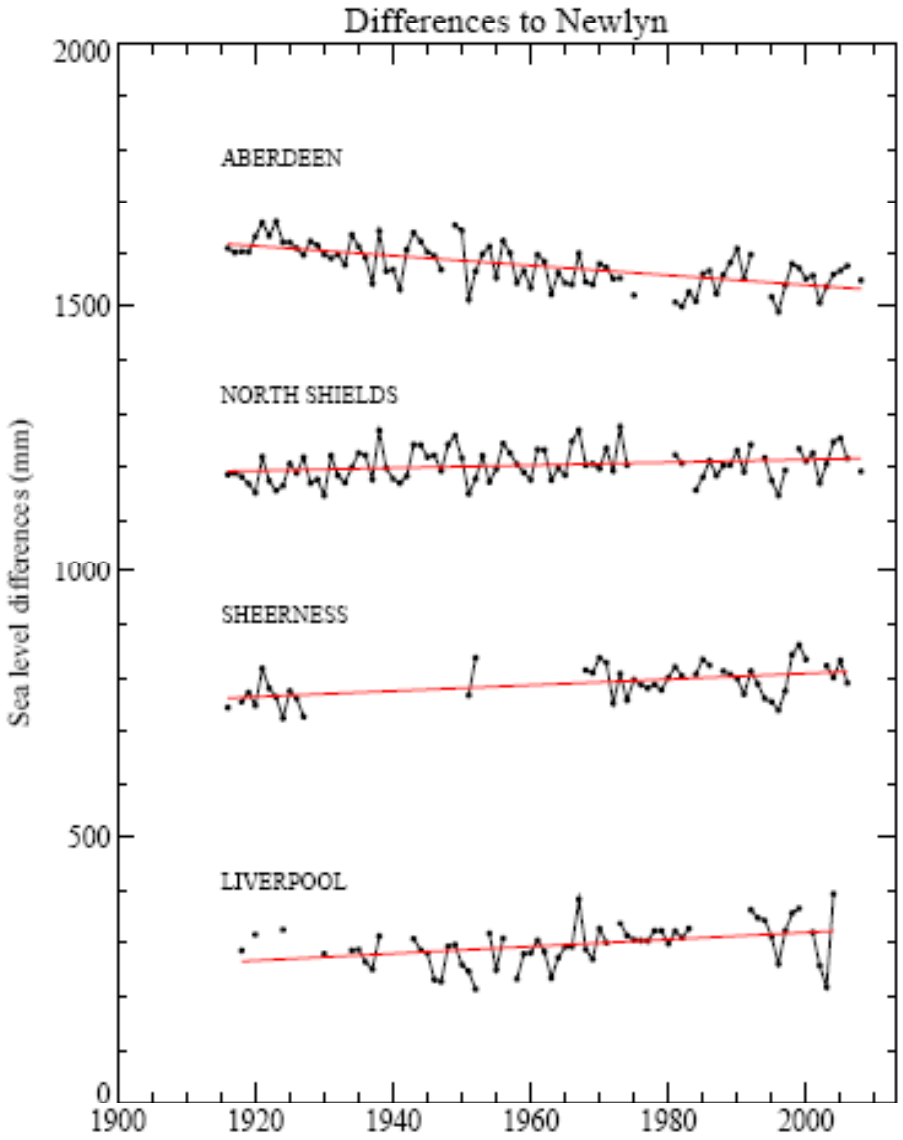
UK National Network

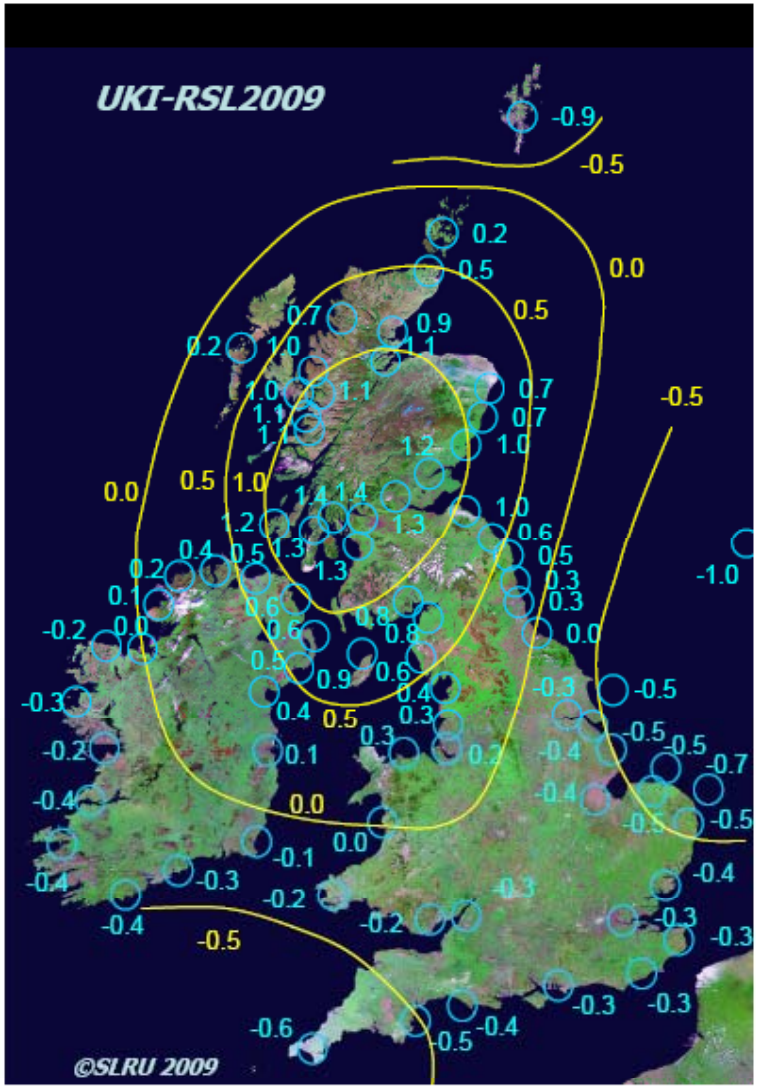
Newlyn

Float gauge 1915-1981 when replaced by Aanderaa presssure gauge then in September 1983 by an 'A Class' bubbler gauge.


Amsterdam/Den Helder
Brest (HC)
Sheerness
+100
Stockholm
(detrended
1774–1873)
−100
Swinoujscie/Swinemunde
Liverpool
(HC)
1700 1720 1740 1760 1780 1800 1820 1840 1860 1880 1900 1920 1940 1960 1980 2000 2020
Year


LONGER BRITISH ISLES RECORDS
Sea level (mm)
8000
7500
7000
6500
1800
1850
1900
1950
2000
ABERDEEN
NORTH SHIELDS
SHEERNESS
NEWLYN
LIVERPOOL

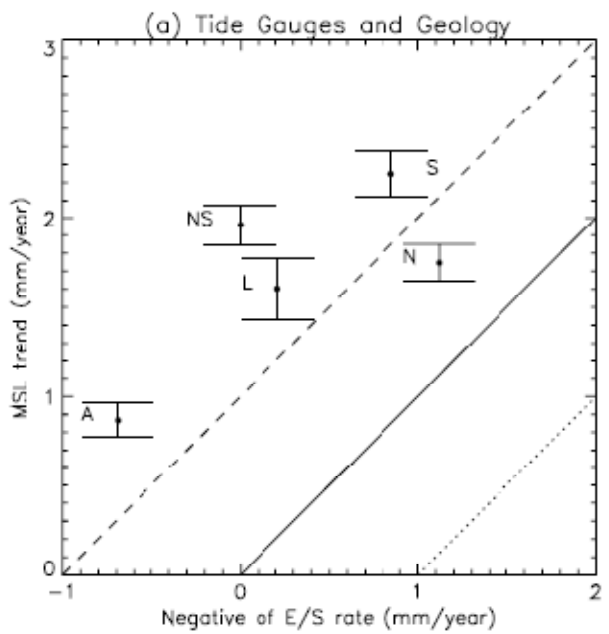




Shennan et al. 2009

20th Century Rates of UK Sea Level Change

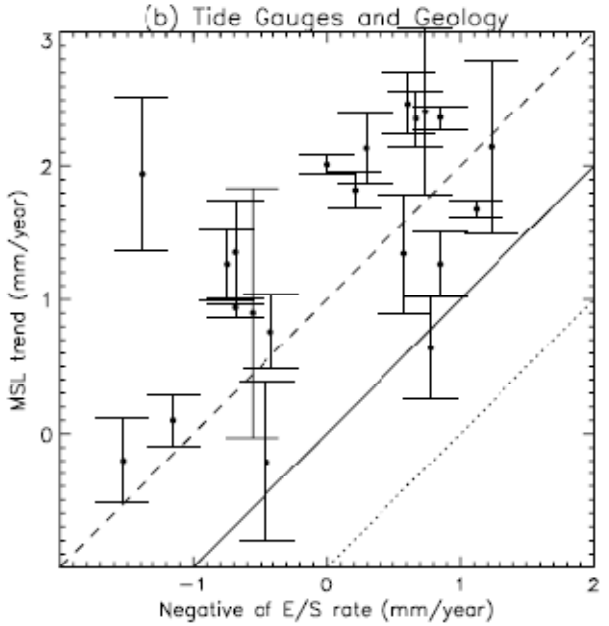
TG



Geology

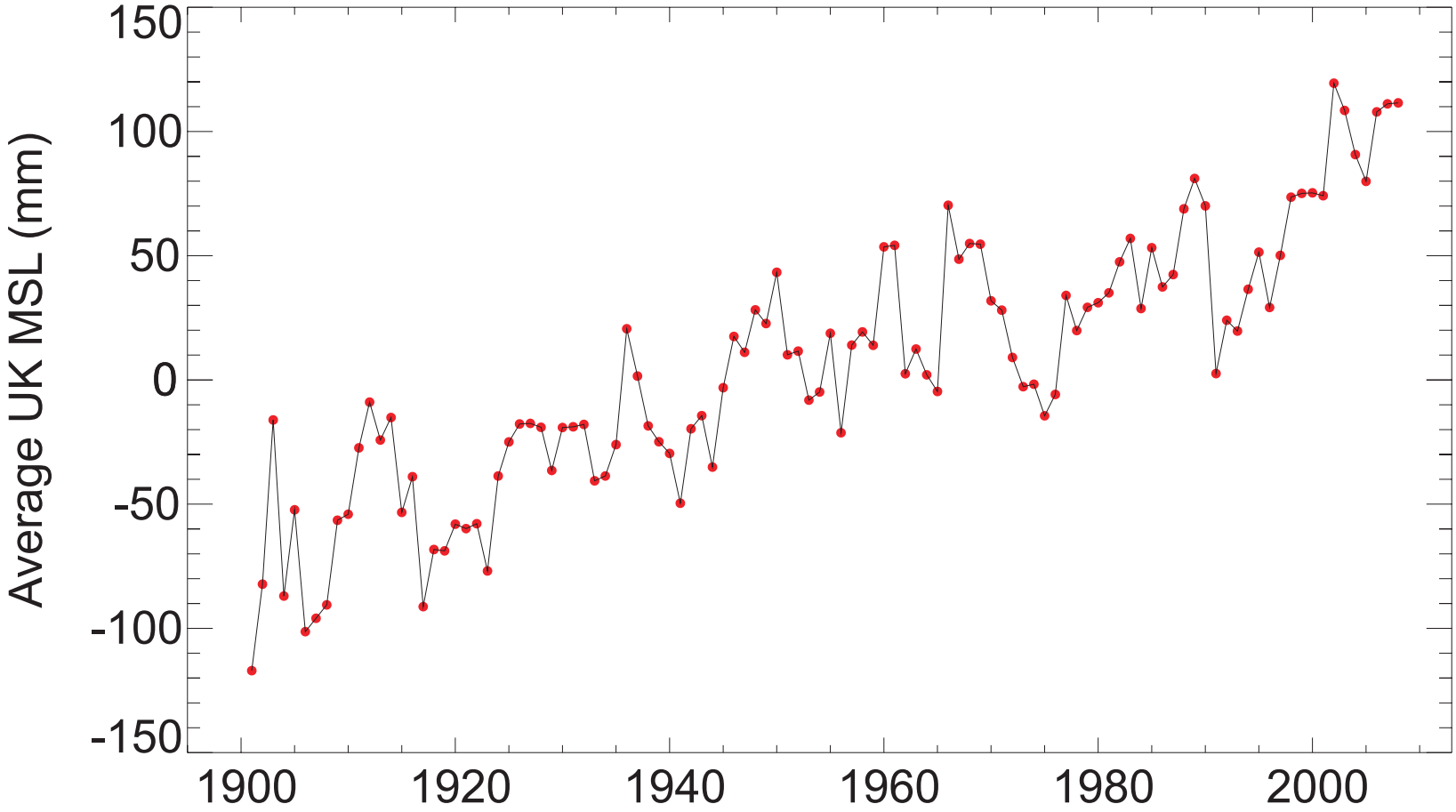
5 Long Records
(TG measured rates)

TG

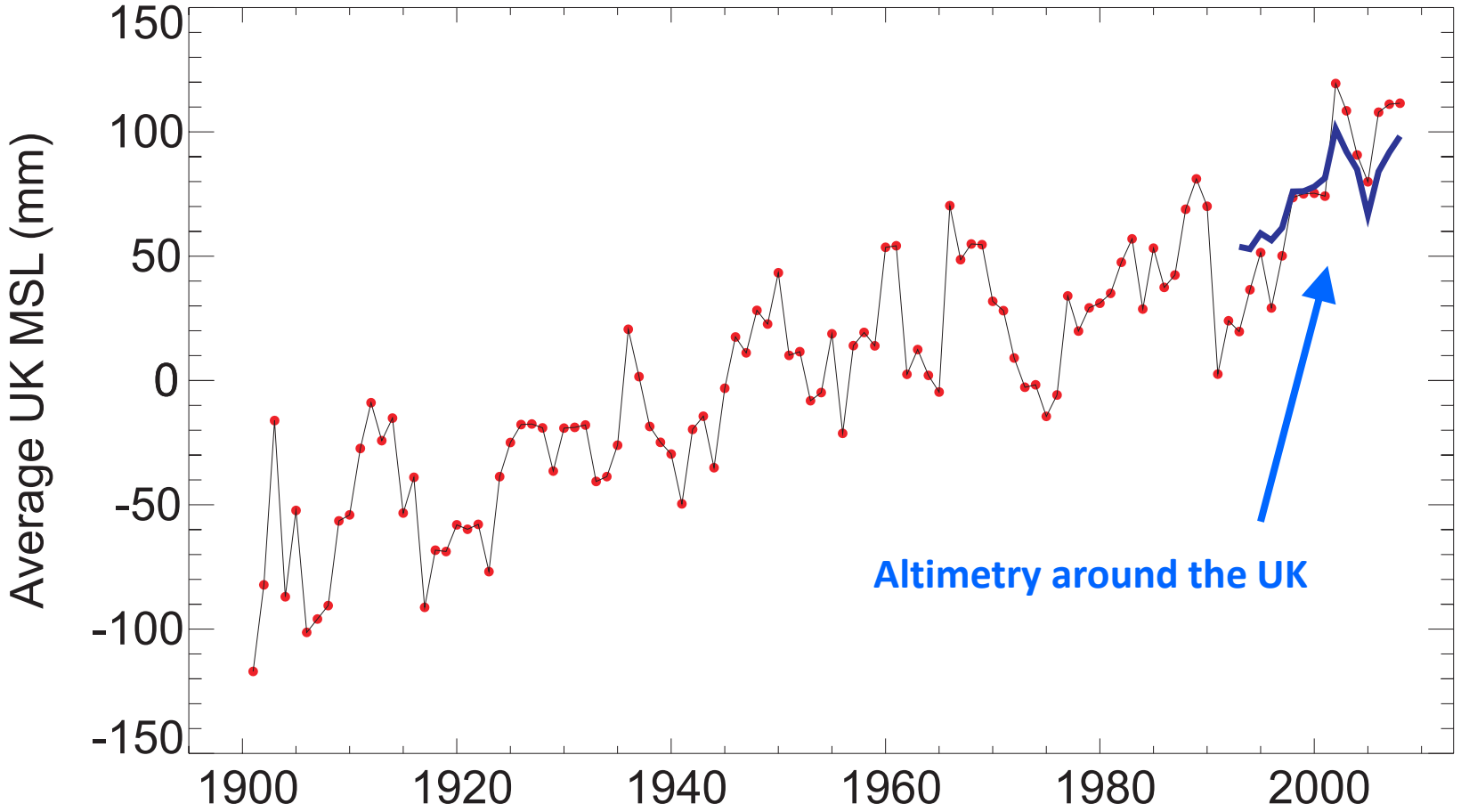


Geology

21 Short Records
(TG rates inferred by regression)

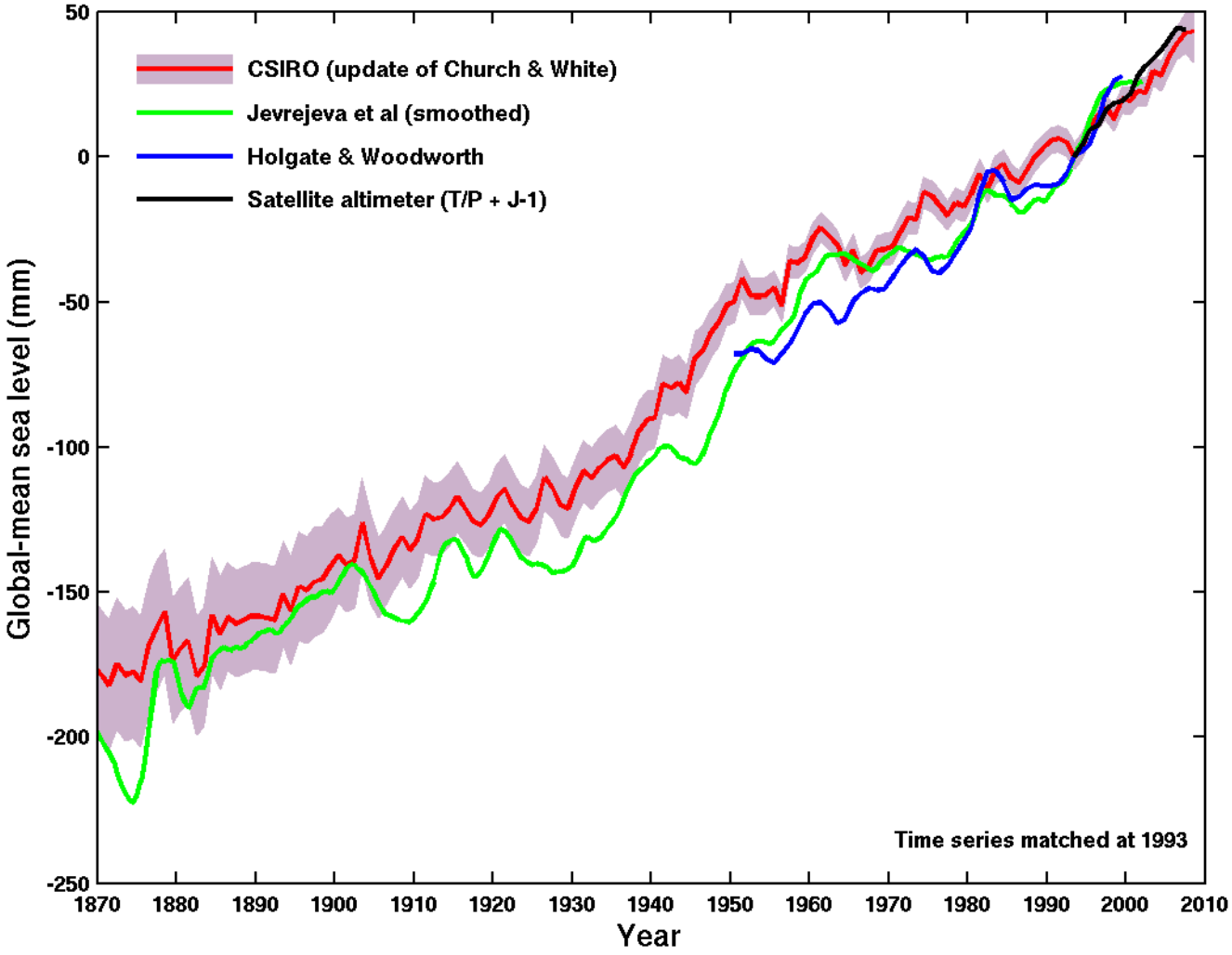


Average UK Mean Sea Level Change
1.4 mm/year for the 20th century


Average UK MSL (mm)
150
100
50
0
-50
-100
-150
1900
1920
1940
1960
1980
2000
Altimetry around the UK

Attributes of the UK Curve

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



all using PSMSL data

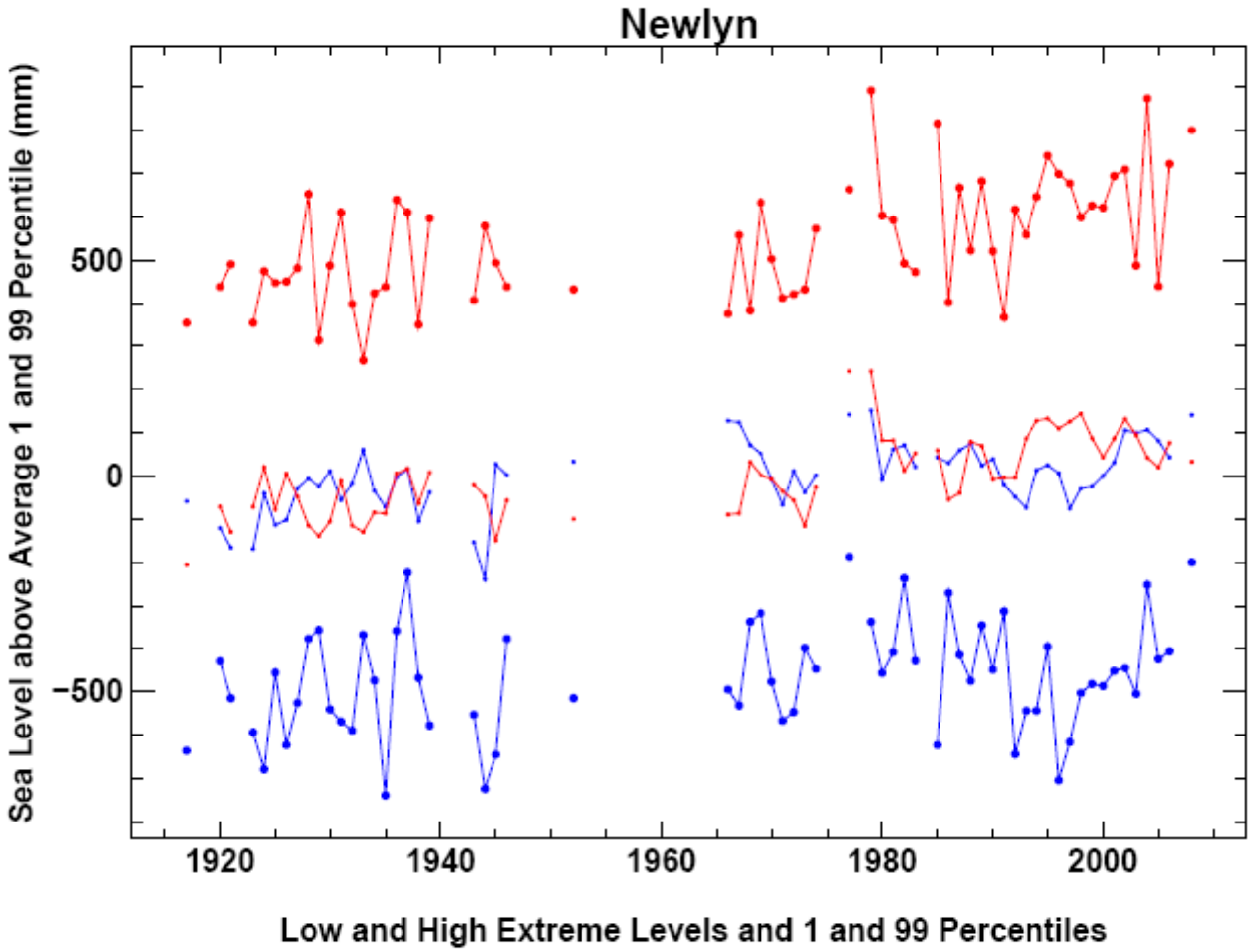
Recent Papers on UK Sea and Land Level Changes

Teferle, F.N., Bingley, R.M., Orliac, E.J., Williams, S.D.P., Woodworth, P.L., McLaughlin, D., Baker, T.F., Shennan, I., Milne, G.A., Bradley, S.L. and Hansen, D. 2009. Crustal Motions in Great Britain: evidence from continuous GPS, Absolute Gravity and Holocene sea-level data. **Geophysical Journal International,** 178(1), 23-46, doi:10.1111/j.1365-246X.2009.04185.x.

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.

Bradley, S.L., Milne, G.A., Teferle, F.N., Bingley, R.M. and Orliac, E.J., 2009. Glacial isostatic adjustment of the British Isles: new constraints from GPS measurements of crustal motion. **Geophysical Journal International,** 178(1), 14-22.

- Mean Sea Level change is only part of the information in a sea level record

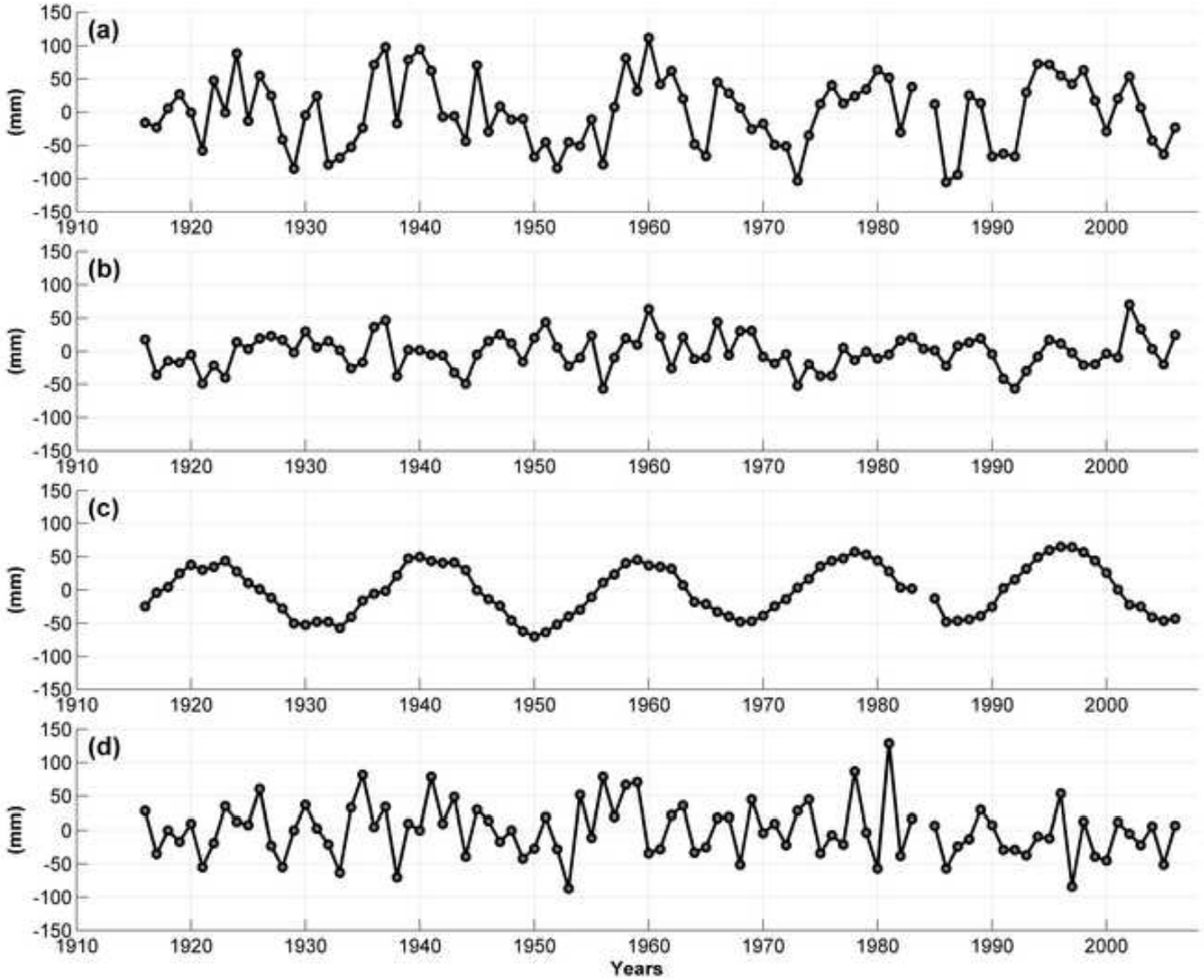


2.6

2.2
[1.9]
1.5

1.2

mm/yr



95% Water level

0.36

MSL

0.57

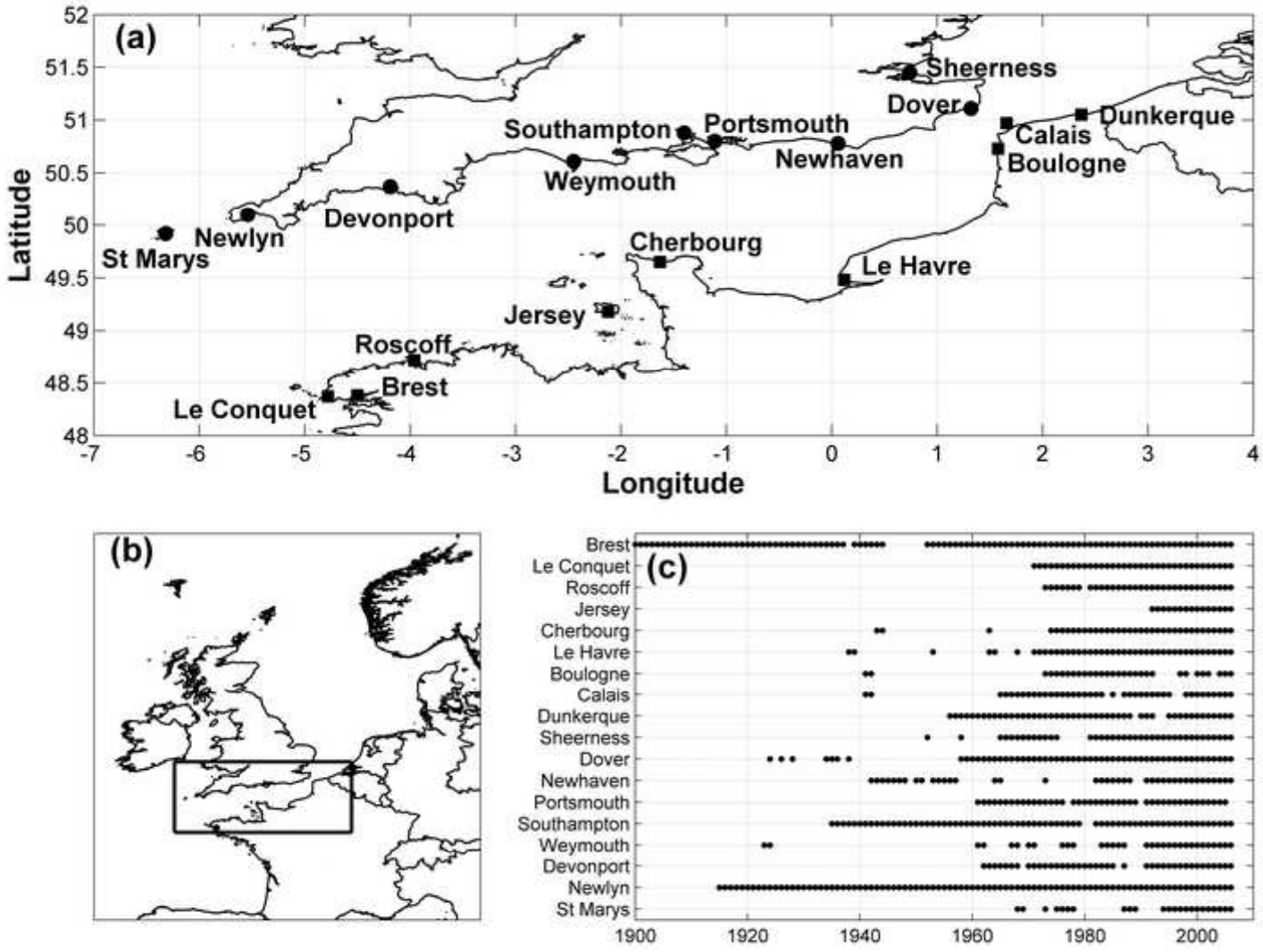
Predicted MHW

0.25

95% Skew surge

NEWLYN

Haigh et al. 2010 CSR



Haigh et al., CSR, 2010

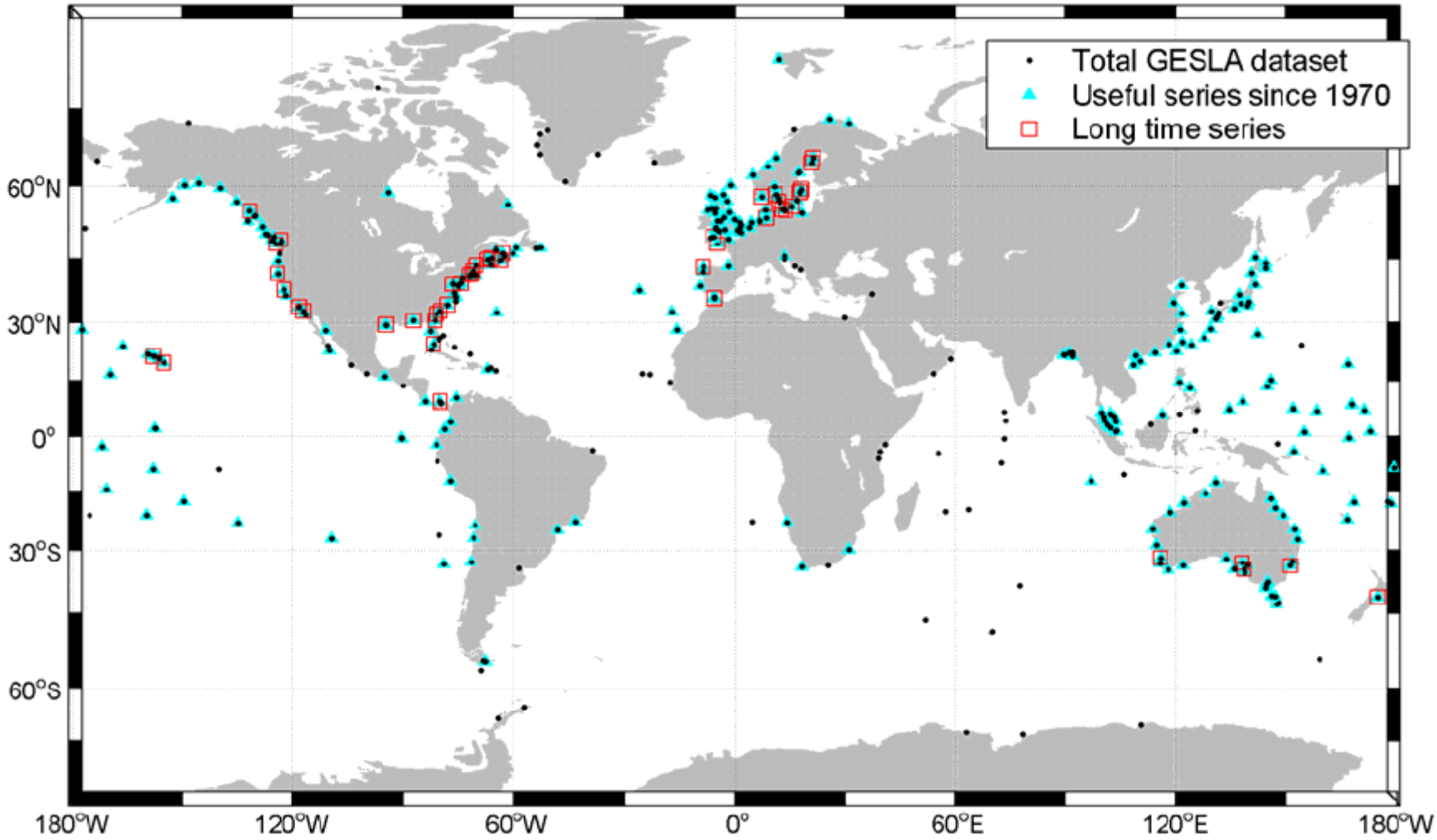
Global Extreme Sea Level Changes

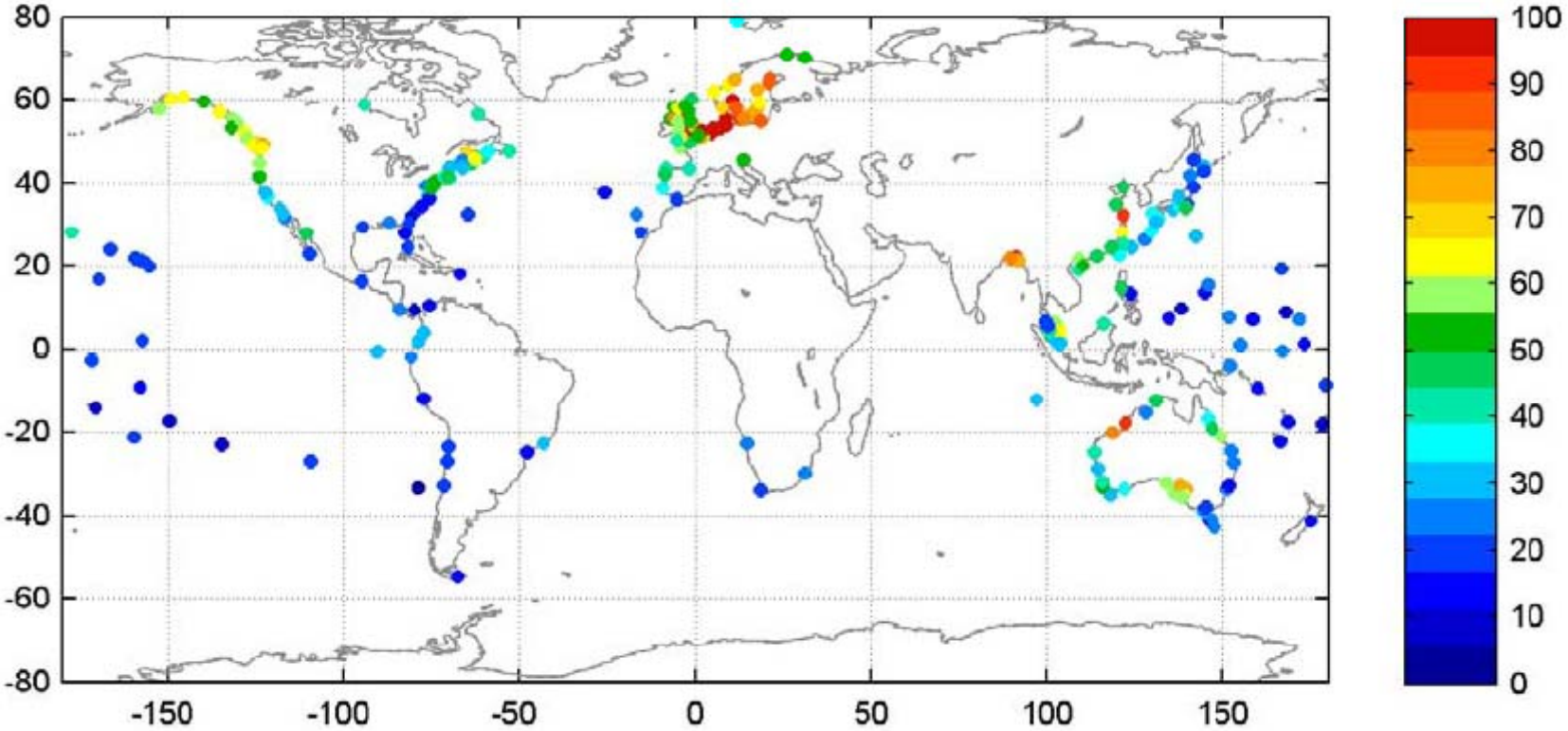
- GESLA (Global Extreme Sea Level Analysis) project developed by University of Tasmania and POL
- GESLA data set compiled from international and national databanks containing hourly or more frequent records
- 675 records but many duplicates


Norfolk, 1953

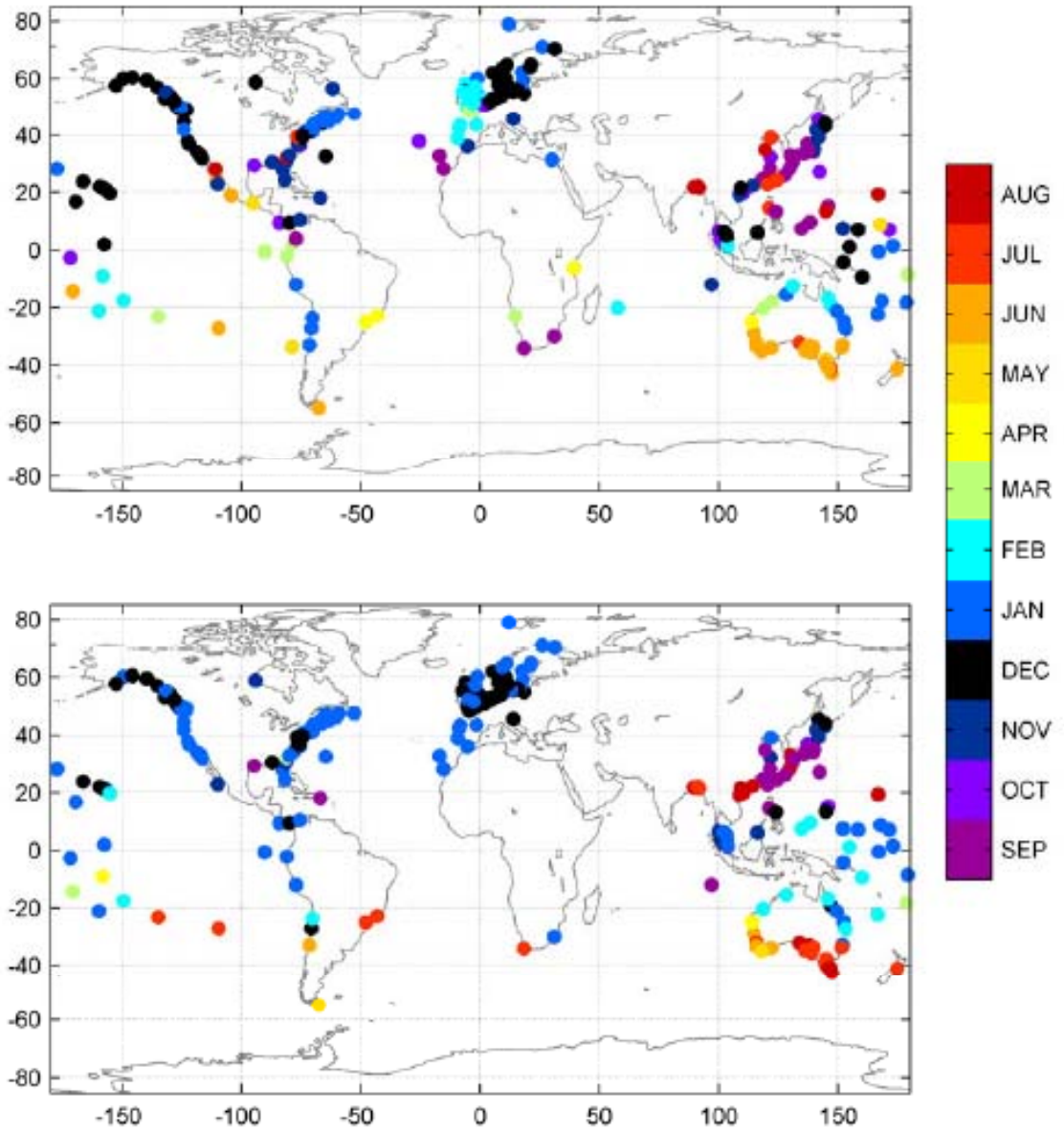

New Orleans, 2005


Bangladesh,
many times

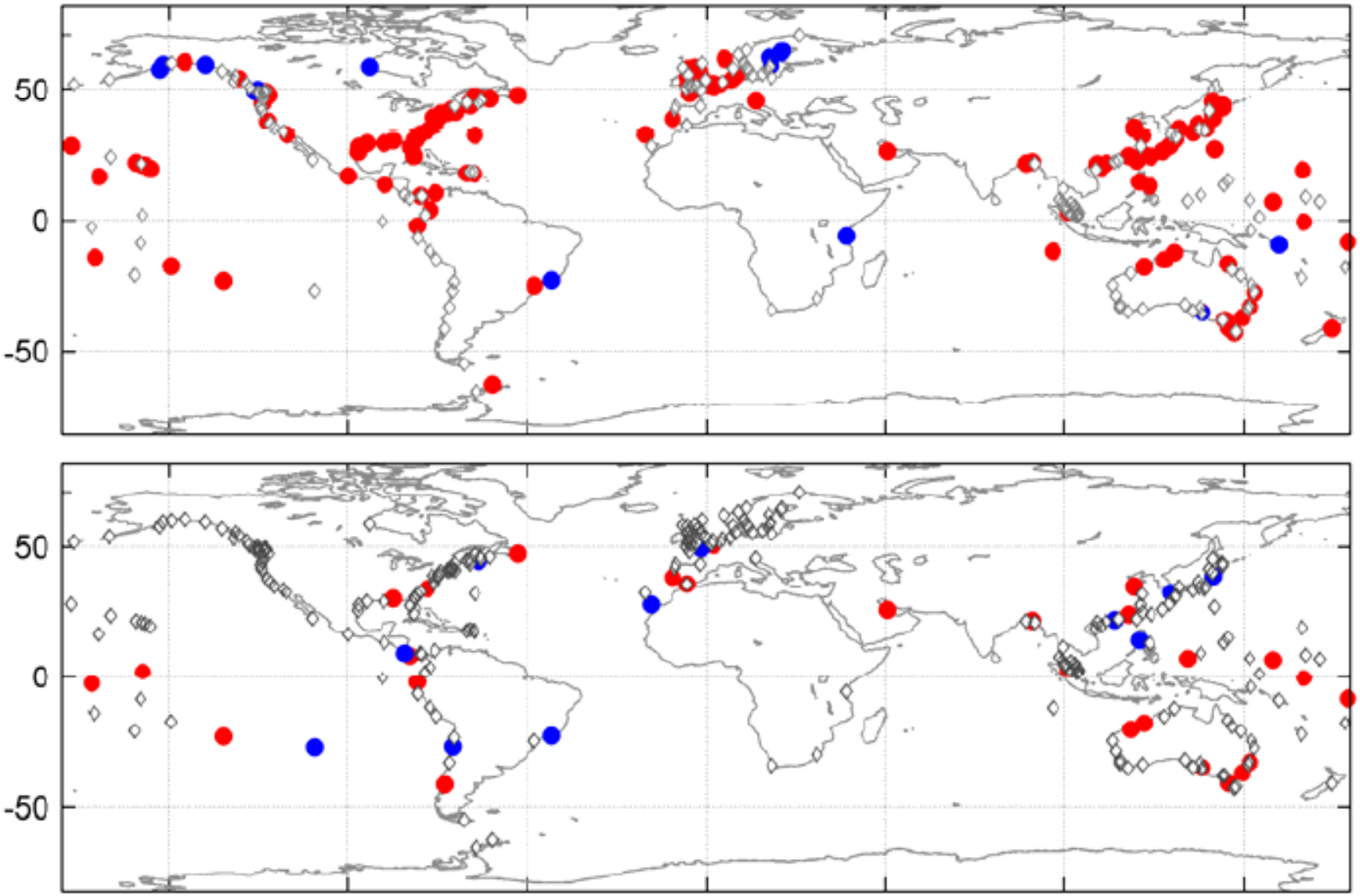

Total GESLA dataset
Useful series since 1970
Long time series
60°N
30°N
0°
30°S
60°S
180°W
120°W
60°W
0°
60°E
120°E
180°W



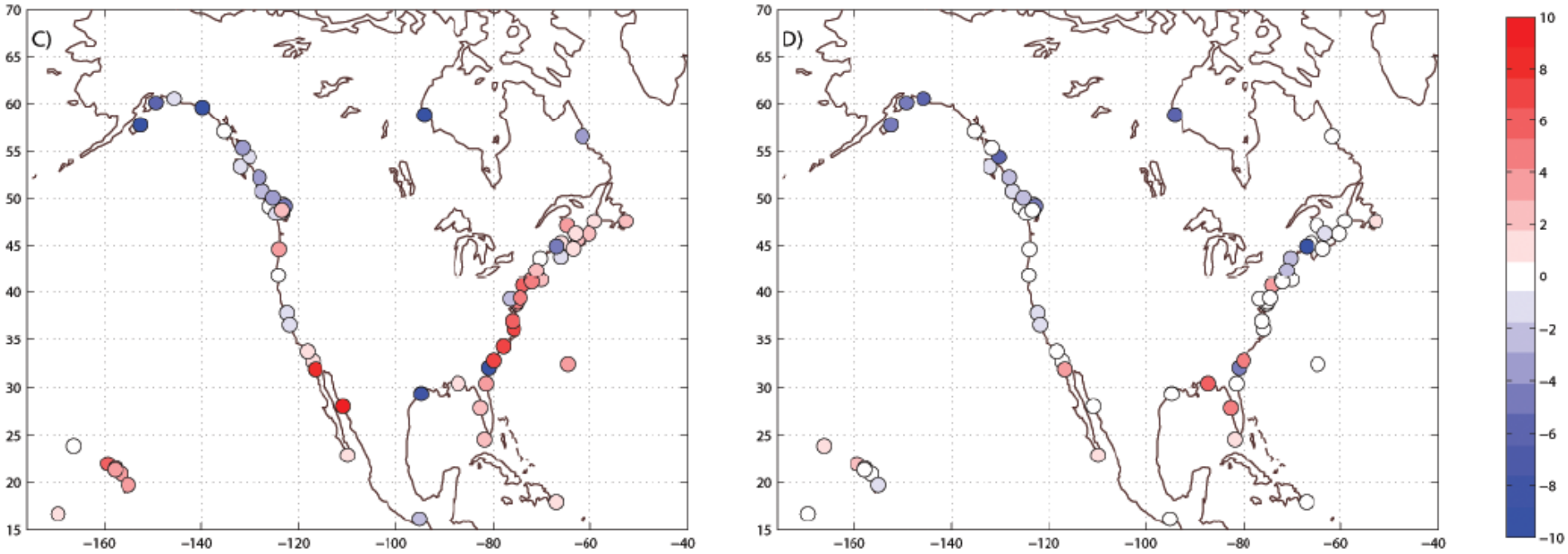
Amplitude of the annual cycle in the 50 yr return level of total water levels



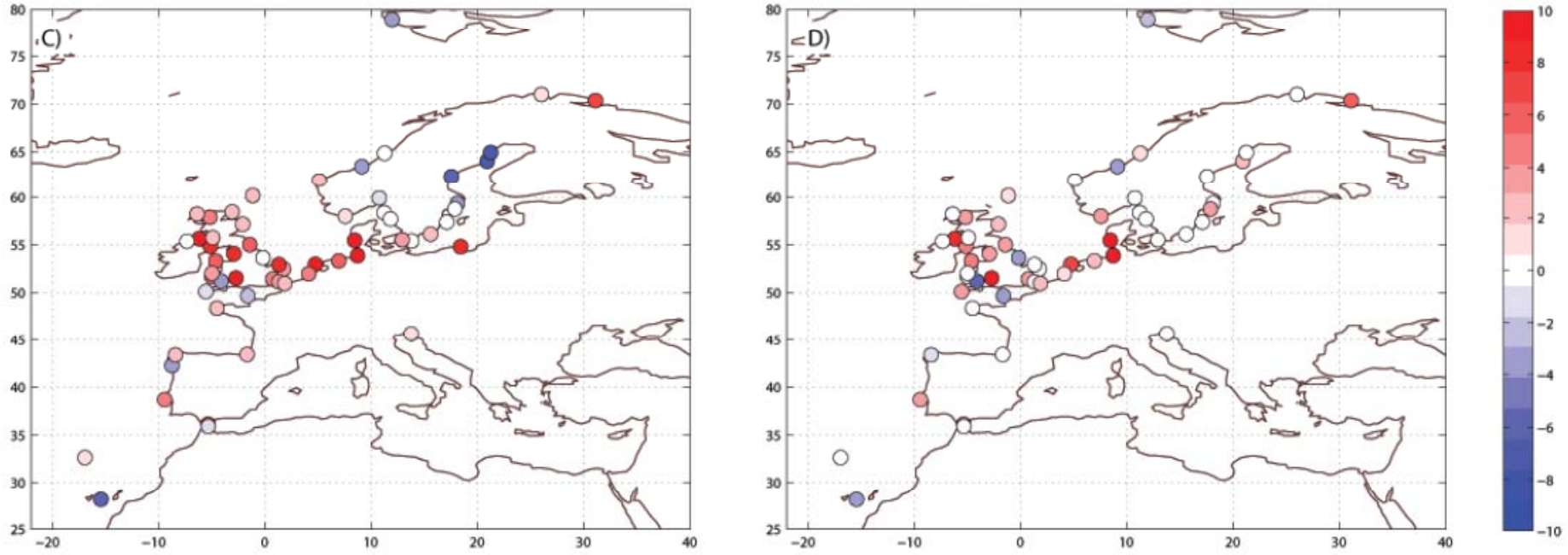
Month of highest observed water level and highest surge level



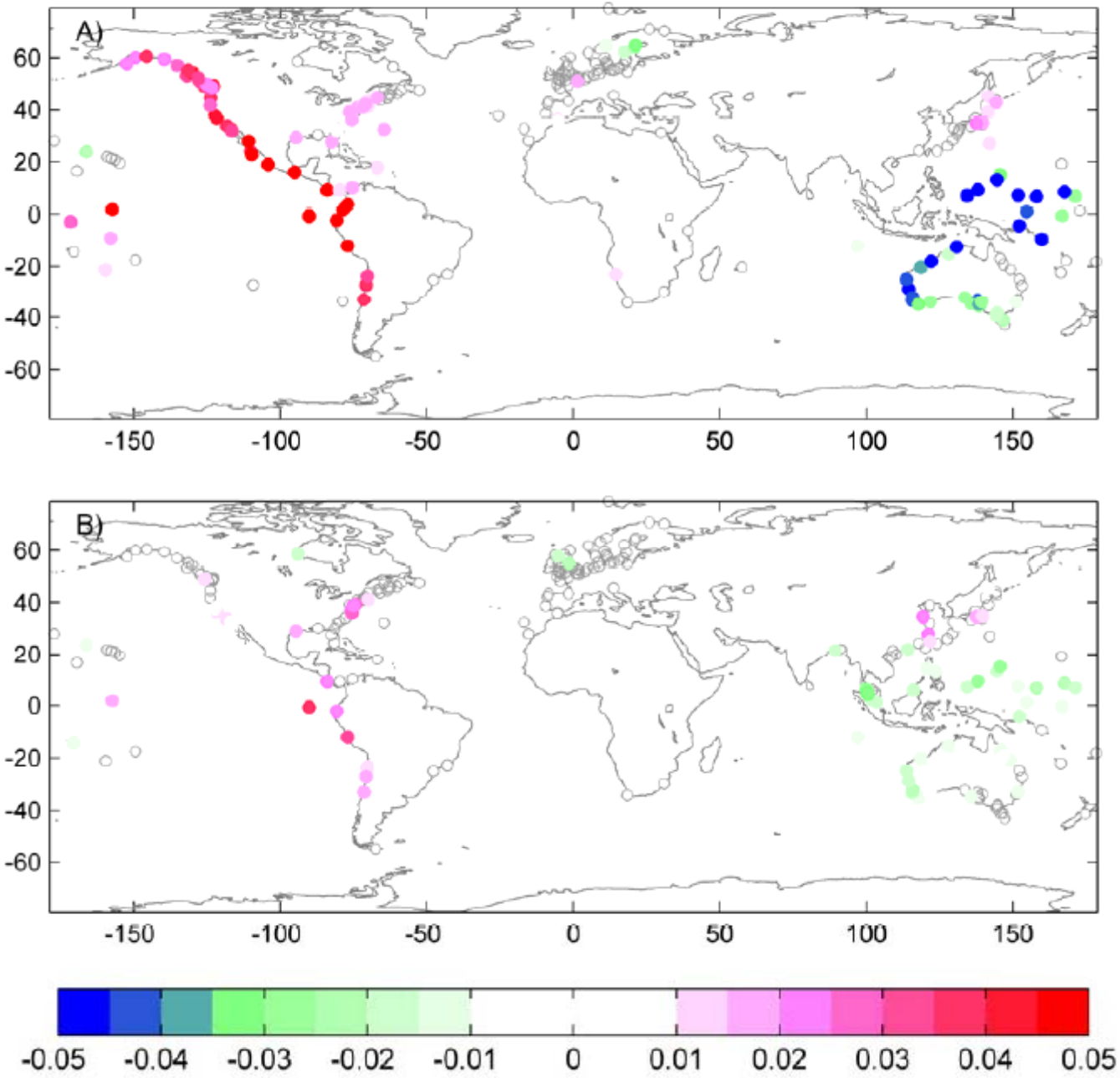
Statistically significant trends in annual 99 percentile observed sea levels and sea levels reduced to their annual medians



Trends (cm/decade) in 50 yr return sea level for recent decades for observed sea levels and with levels reduced to medians



Trends (cm/decade) in 50 yr return sea level for recent decades for observed sea levels and with levels reduced to medians



Sensitivity (m/unit index) of observed extreme sea levels to the Nino3 index

And

Sensitivity of extreme surges

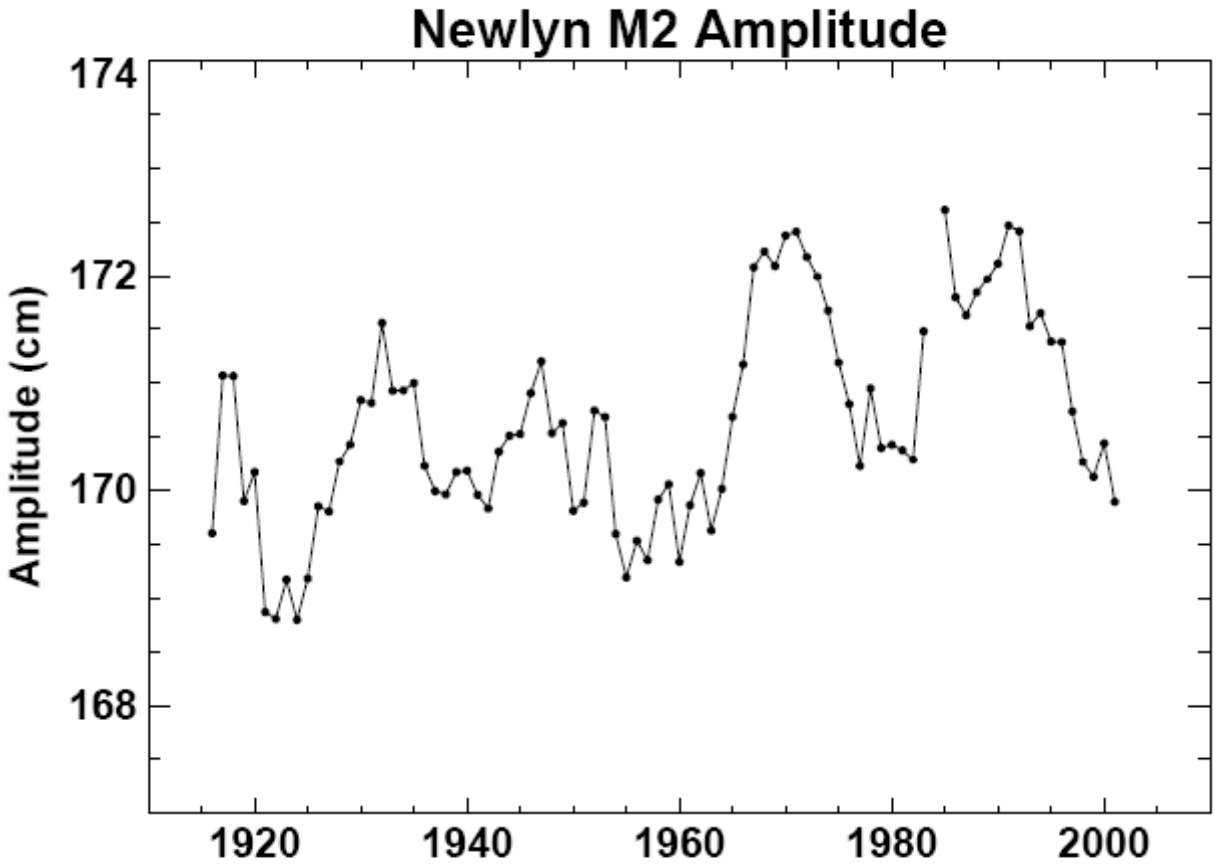
Global Tidal Changes

- Use GESLA data set again
- This study stimulated by work by Ray, Jay etc. and discussions with UKHO
- Make separate tidal analysis for every year of data
- Develop method to use shorter records (30 years or more) to determine century timescale tidal changes

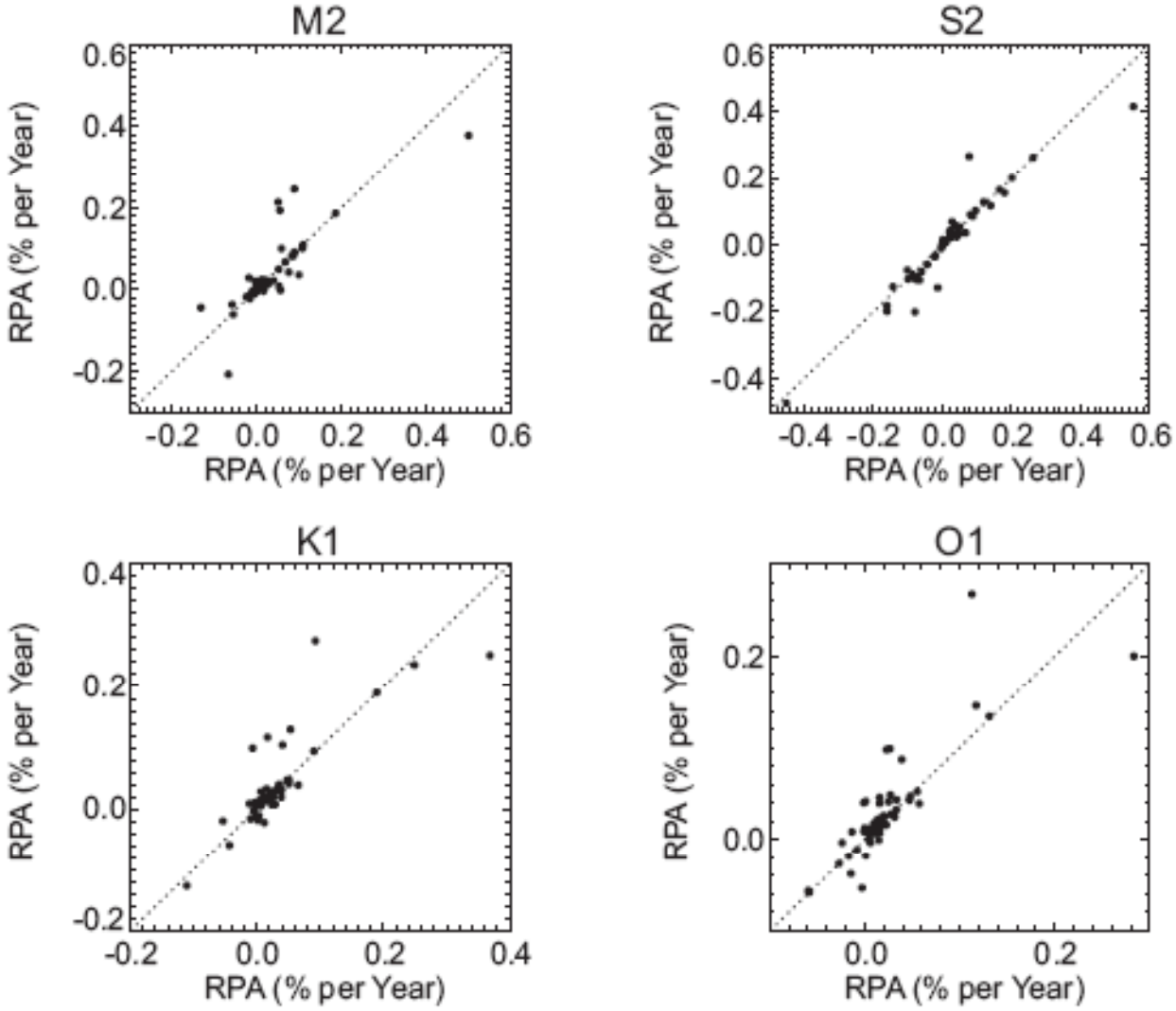
Recent Papers on Tidal Changes

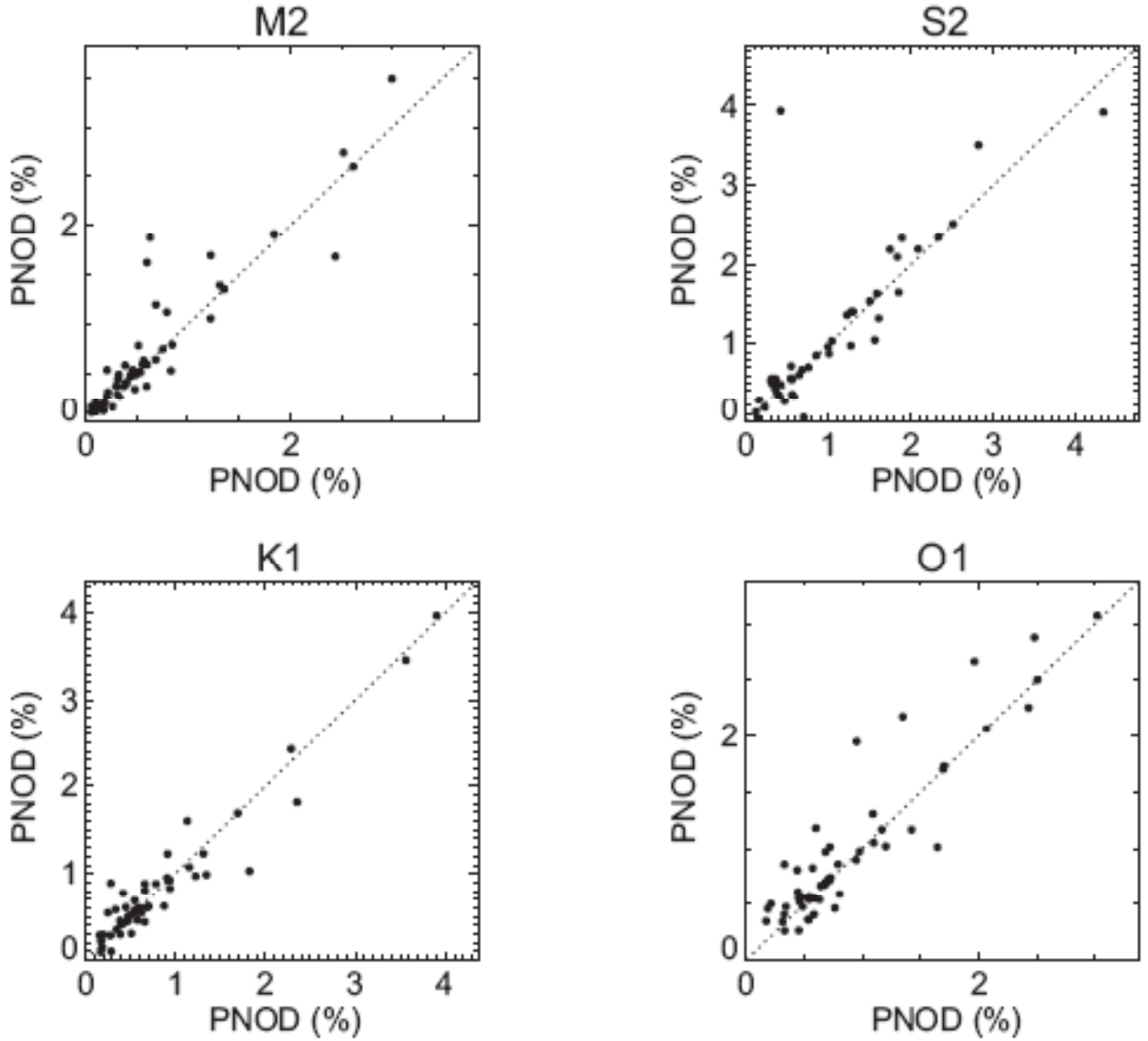
Ray, R.D. 2009. Secular changes in the solar semidiurnal tide of the western North Atlantic Ocean. **Geophysical Research Letters,** 36, L19601, doi:10.1029/2009GL040217.

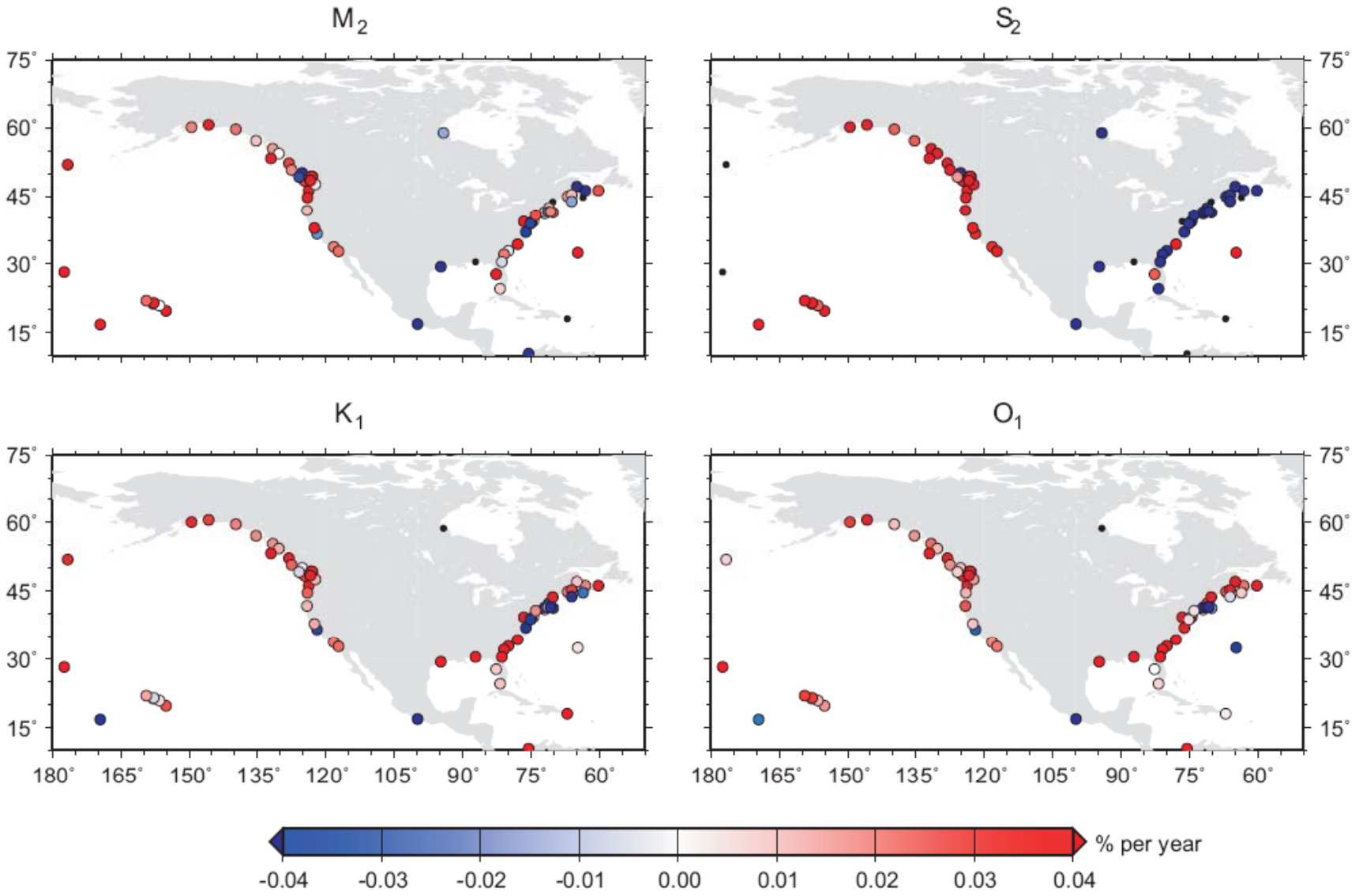
Jay, D.A. 2009. Evolution of tidal amplitudes in the eastern Pacific Ocean. **Geophysical Research Letters,** 36, L04603, doi:10.1029/2008GL036185.

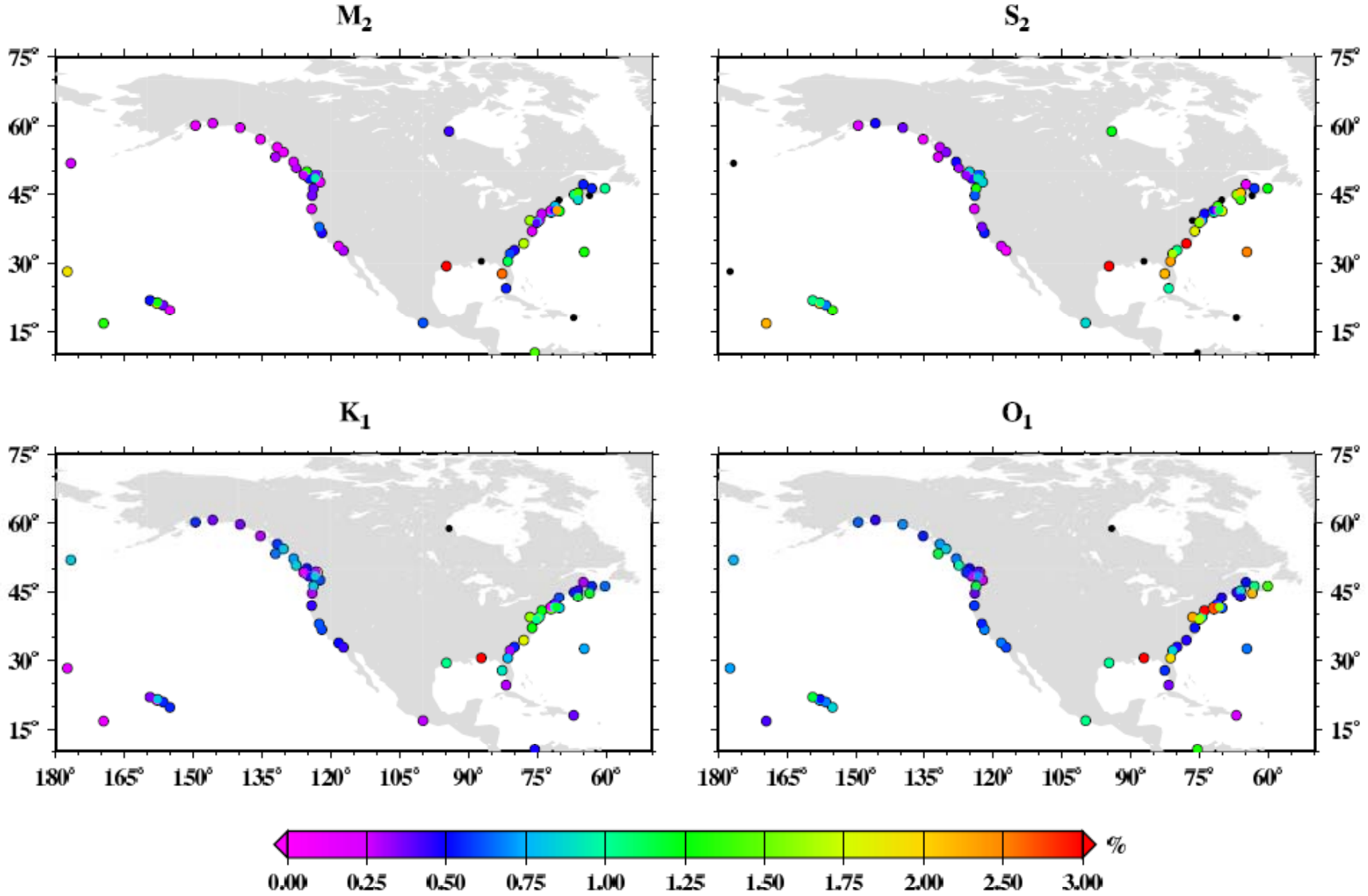


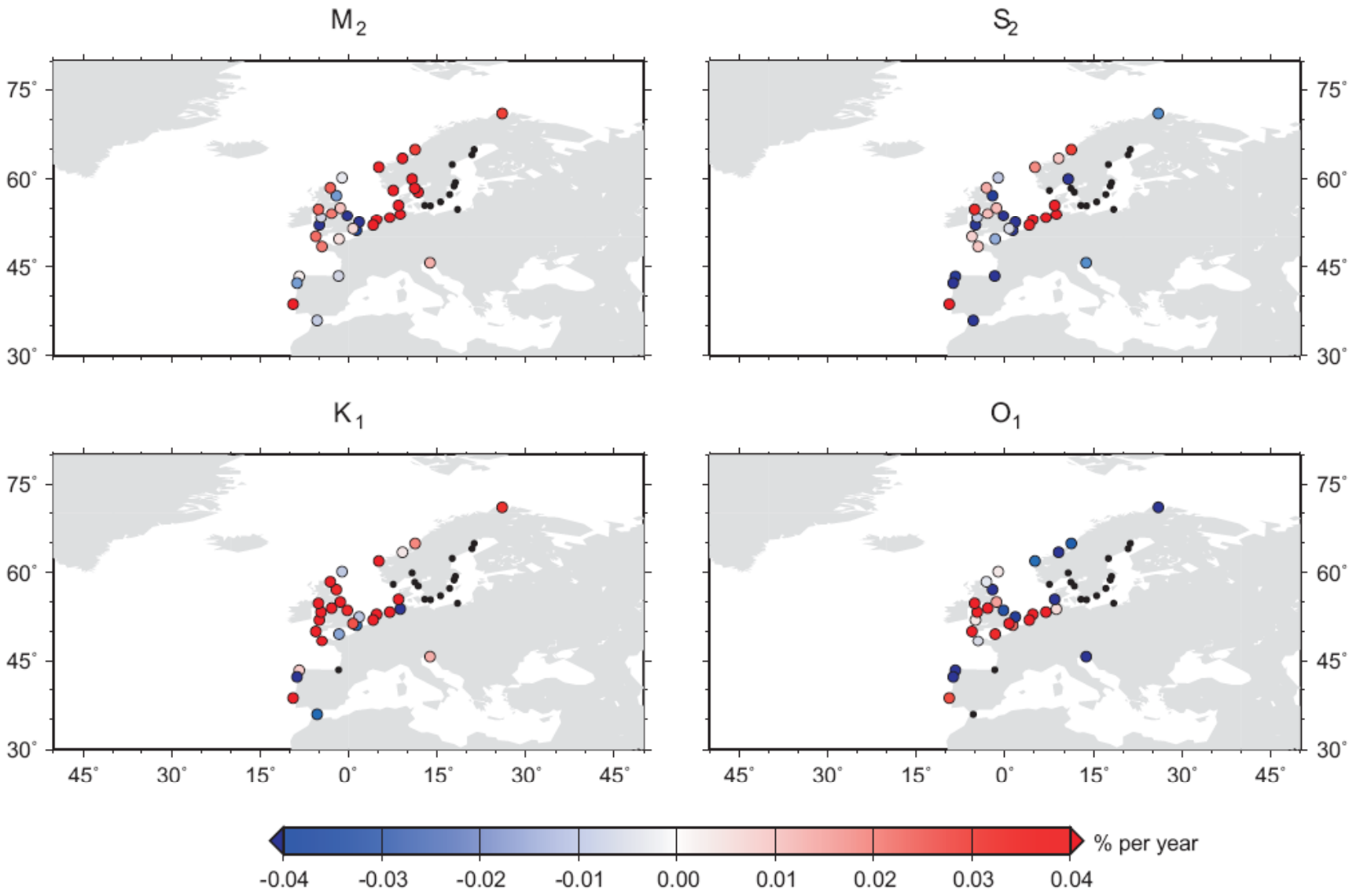
Trend in M2 = 0.20 +/- 0.03 mm/year

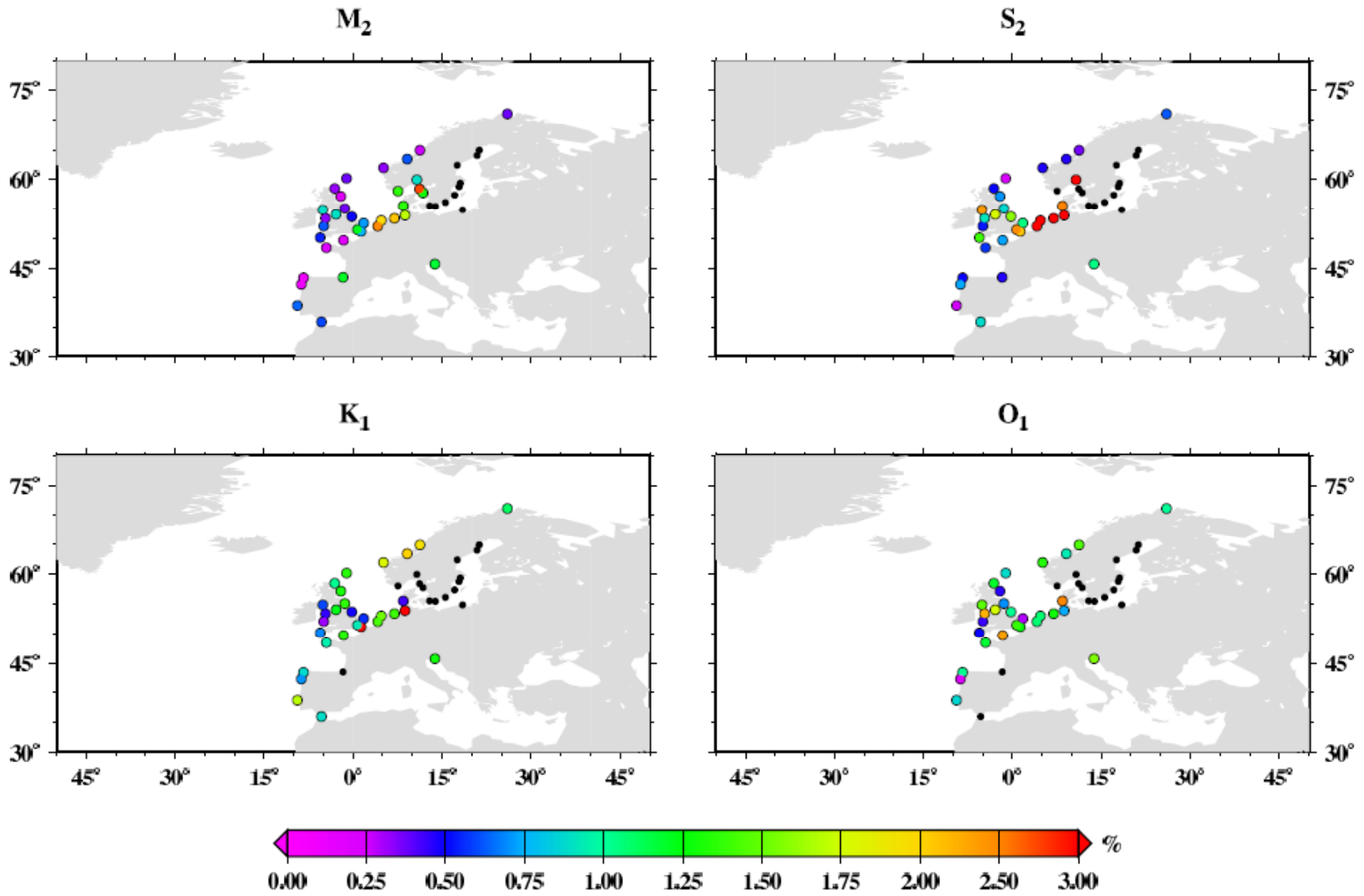

M2
S2
K1
O1
RPA (% per Year)
RPA (% per Year)
0.6
0.4
0.2
0.0
-0.2
-0.4


M2
PNOD (%)
PNOD (%)
0
2
0
2
S2
PNOD (%)
PNOD (%)
0
1
2
3
4
0
1
2
3
4
K1
PNOD (%)
PNOD (%)
0
1
2
3
4
0
1
2
3
4
O1
PNOD (%)
PNOD (%)
0
2
0
2


M2
S2
K1
O1
75°
60°
45°
30°
15°
180°
165°
150°
135°
120°
105°
90°
75°
60°
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
% per year

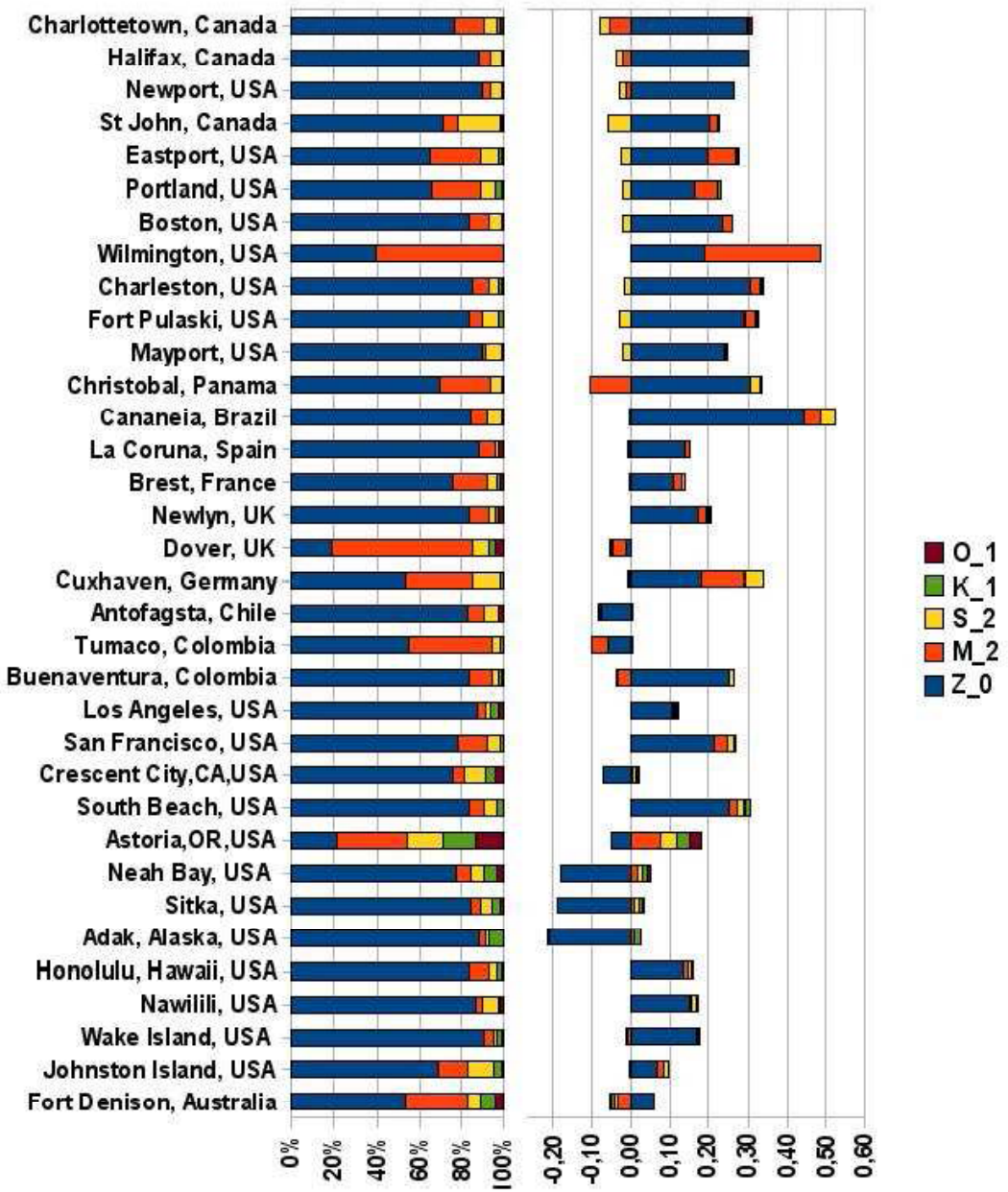

M2
S2
K1
O1
75°
60°
45°
30°
15°
180°
165°
150°
135°
120°
105°
90°
75°
60°
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.50
3.00
%


M2
S2
K1
O1
75˚
60˚
45˚
30˚
45˚
30˚
15˚
0˚
15˚
30˚
45˚
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
% per year


M2
S2
K1
O1
75°
60°
45°
30°
45°
30°
15°
0°
15°
30°
45°
%
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.50
3.00

Many Reasons for Tides to Change

- Long term changes in the tidal potential. Small on century timescales.
- Interactions between the tide and the continuum of non-tidal sea level variations. These result in changes in tidal constants from year to year, and could result in a long term trend in tidal parameters if a corresponding component exists in the non-tidal forcing.
- Increases in water depth due to MSL rise changes tidal wavelengths. However, large changes in water depth are required.
- Morphological changes in coastal waters, harbours or estuaries, either natural or anthropogenic (e.g. dredging).
- Changes in the internal tide with small changes in surface expression (e.g. Hawaii)
-
- In addition, technical reasons:
-
- Undocumented change of tide gauge location within a large estuary or harbour.
- Change in tide gauge technology.
- Timing or calibration errors or other data irregularities.



Malte Mueller,
U Vic Canada

Conclusions

- UK mean sea level (MSL) appears to have risen over the last century at a rate similar to, but a little lower than, the global amount
- Several of the ‘accelerations’ in the UK curve are similar to those in the global one
- But sea level research is more than just MSL change – many things to consider (e.g. changes in extremes and tides) if you want a complete picture of change
- Syntheses of findings are very important e.g. UK synthesis included in POL’s CLIMEX report for DEFRA (2001) and in the UKCP’09 report


SEAN CONNERY
IS JAMES BOND IN
NEVER SAY
NEVER
AGAIN