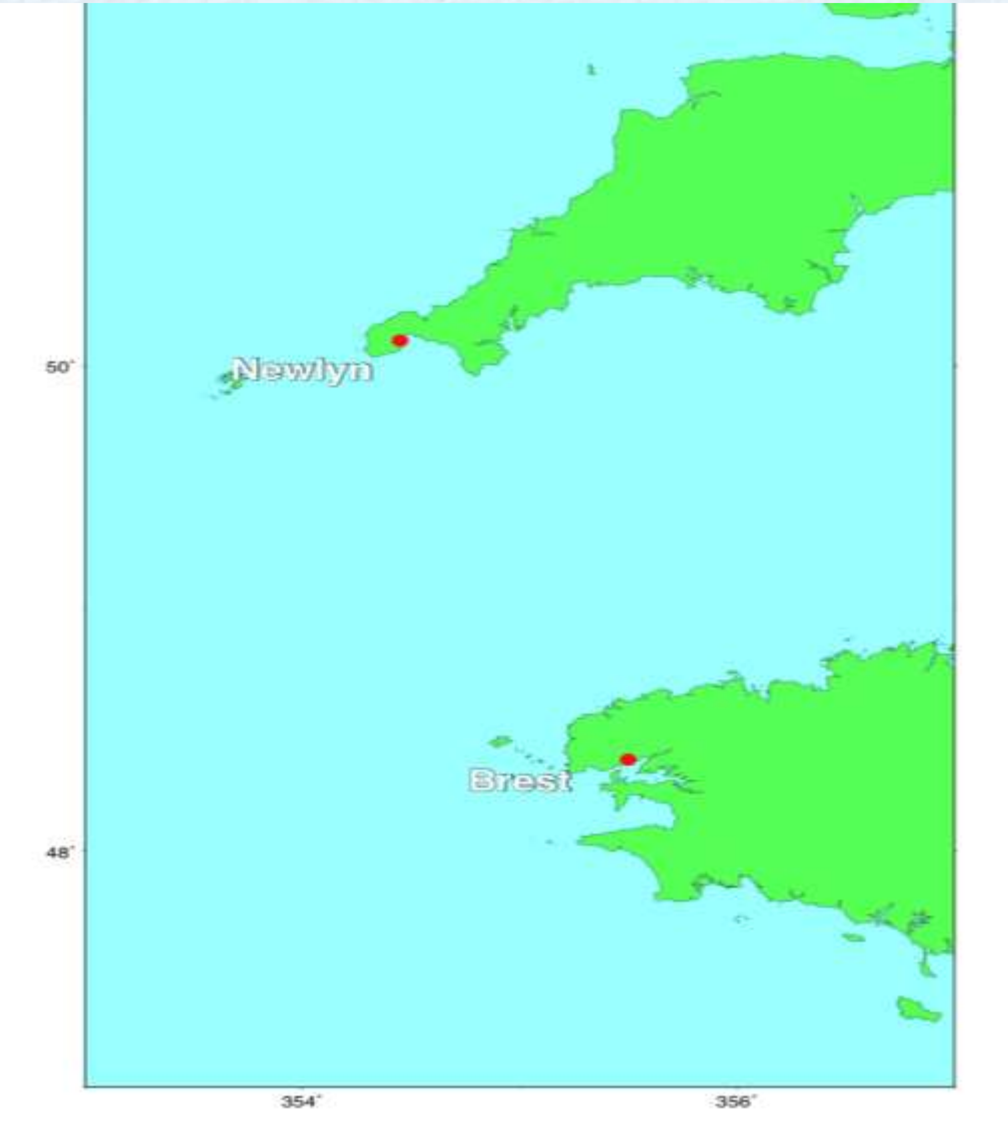
# What drives sea level variability around Europe?



- Brest and Newlyn are only ~200km apart
- Raw tide gauge rates are significantly different
- Why?
    - What are the causes of variability on timescales of years to centuries?

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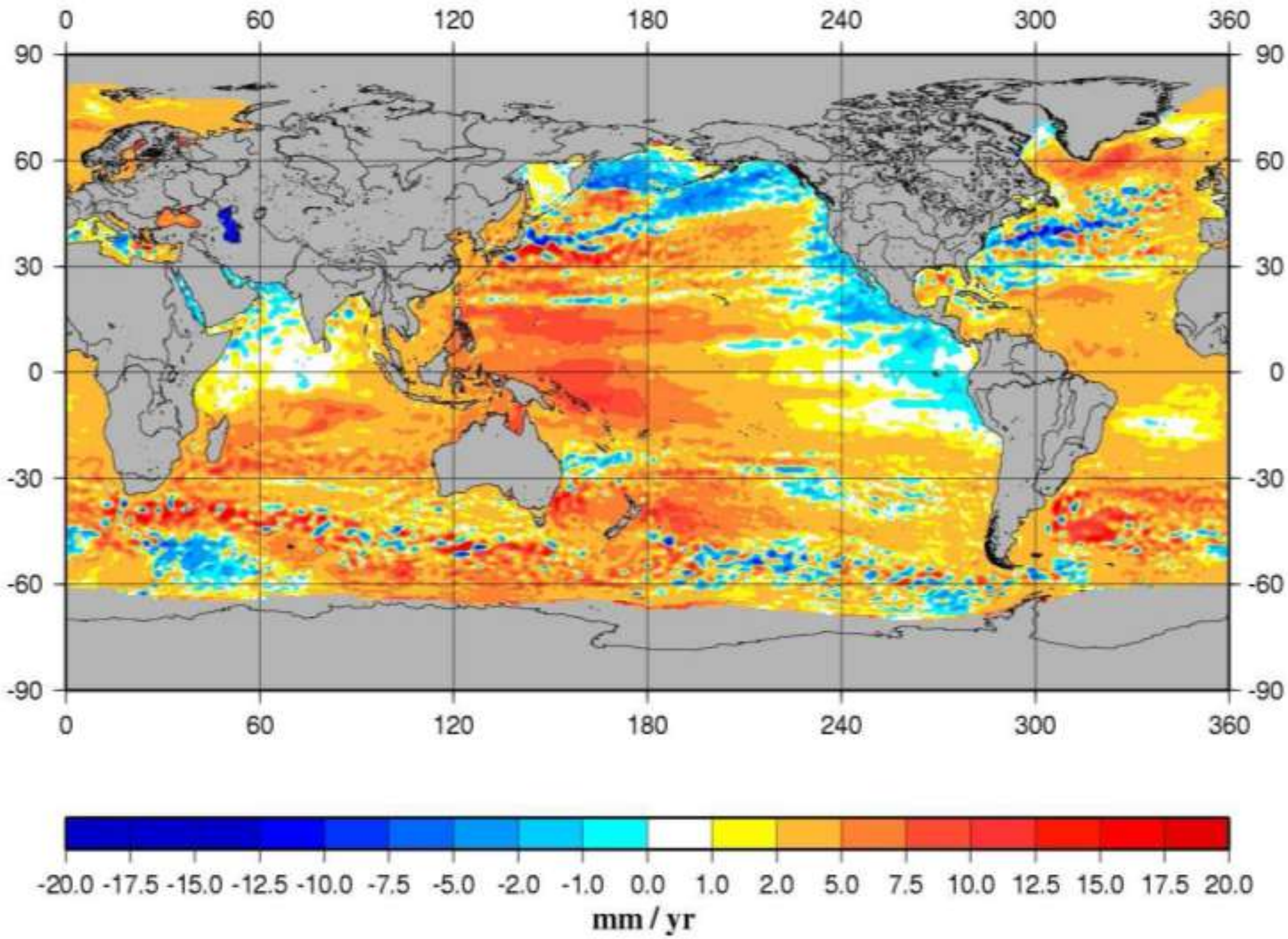
# Spatial variability in altimetry trends 1993-2008



(From Cazenave and Llovel, 2009)

# Aims

The aim of this work is to:

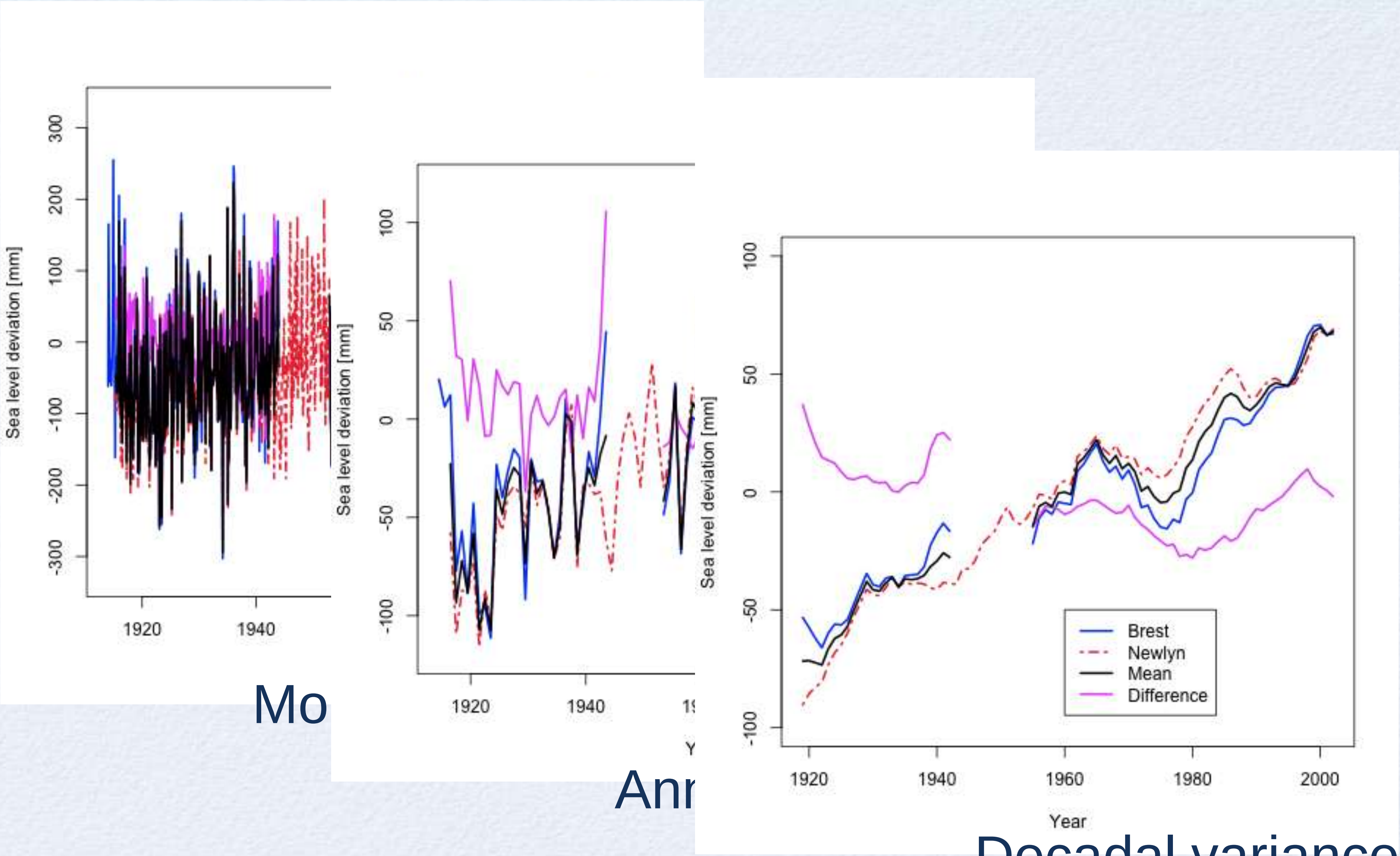
- use statistical and numerical models to understand and reduce variability in tide gauge records

  → greater confidence in estimated trends

  → ability to use shorter records

- Quantify the contribution of pressure/wind and steric changes to sea level rise in Europe

# Brest/Newlyn Difference and Mean



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Decadal variance

# Published TG Rates at Newlyn and Brest

| Author | Period | Newlyn Rate (mm/yr) | Brest Rate (mm/yr) |
|---|---|---|---|
| Woodworth et al (1996) | 1916-1996 | 1.67±0.12 | |
| Woodworth et al (2008) | 1916-2006 | 1.68±0.07 | |
| Thompson (1986) | 1950-1980 | 1.4±0.2 | |
| Rossiter (1972) | 1915-1962 | 2.2±0.1 | |
| | 1894-1961 | | 2.1±0.3 |
| Cartwright (1983) | 1916-1980 | 1.34 | |
| Douglas (1997) | 1915-1991 | 1.7 | |
| | 1880-1991 | | 1.4 |

# Vertical Land Movement at Newlyn and Brest

**GPS Correction (Wöppelmann, pers. comm.)**

Newlyn: -0.27±0.12 mm/yr
Brest: -0.57±0.12 mm/yr

**AG Correction (Williams, 2006)**

Newlyn: -0.5±0.5 mm/yr

**Geological (Shennan & Horton, 2002)**

Newlyn: -1.12 mm/yr

**GIA (Peltier, 2002)**

Newlyn: -0.35 mm/yr
Brest: -0.31 mm/yr

# Methodology

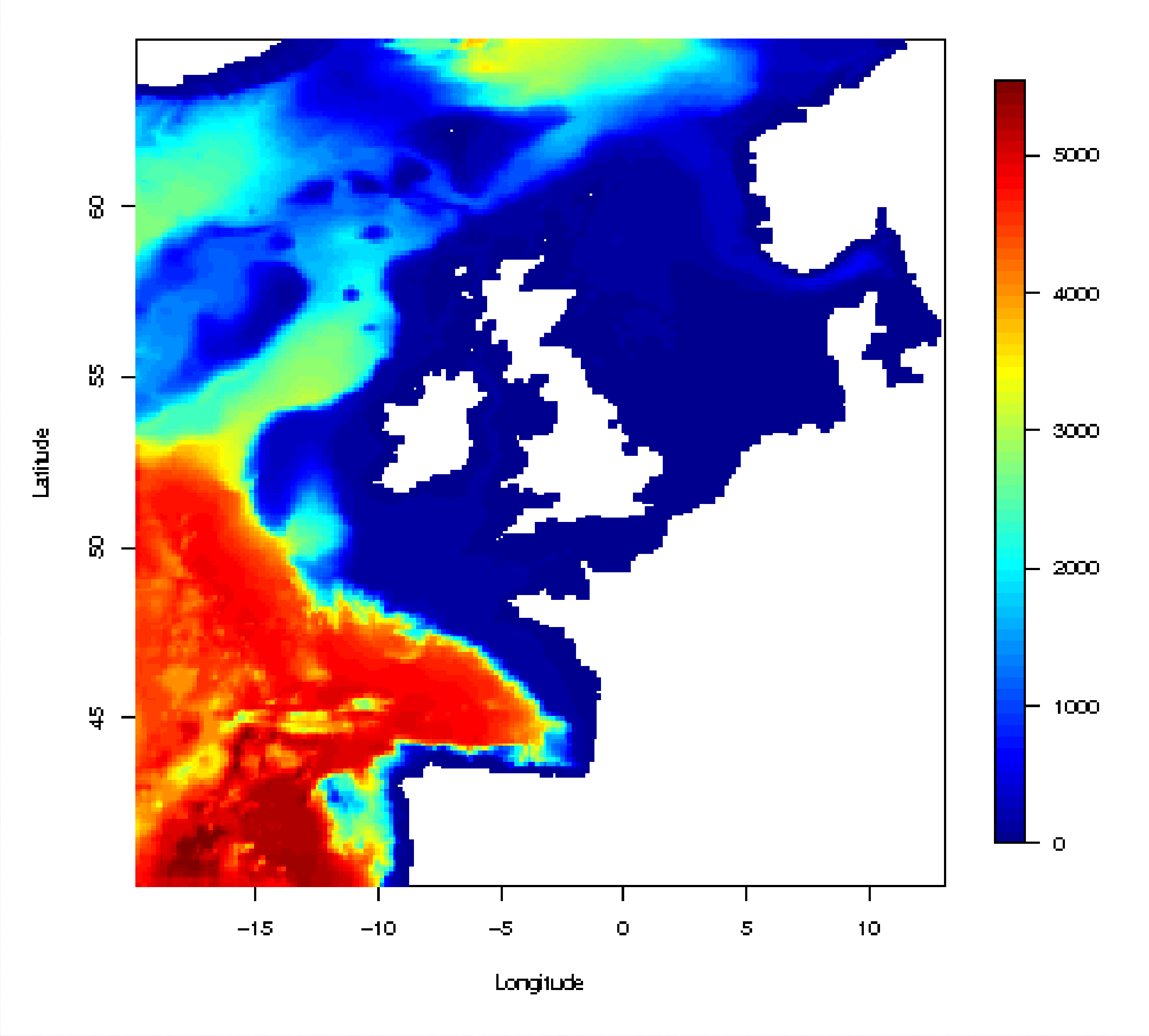
- Combine tide gauge data with numerical model (POLCOMS)
- Create statistical model (multivariate linear regression) of forcing factors
- Using the numerical model we understand all the forcing perfectly

# Regression model

$$\rho g \eta + p_a = a_1 t + c_{11}\cos(\omega_1 t) + c_{12}\sin(\omega_1 t)$$
$$+ c_{21}\cos(\omega_2 t) + c_{22}\sin(\omega_2 t)$$
$$+ \sum_k \sum_j b_{kj} P_j(t - K) + \varepsilon$$

After Thompson (1986)

# POLCOMS numerical model



- $1/6^o$ in Lon
- $1/9^o$ in Lat
- 3D baroclinic
- Forced by ERA40
- Run covers 1960-2004
- Ocean boundary condition from global model

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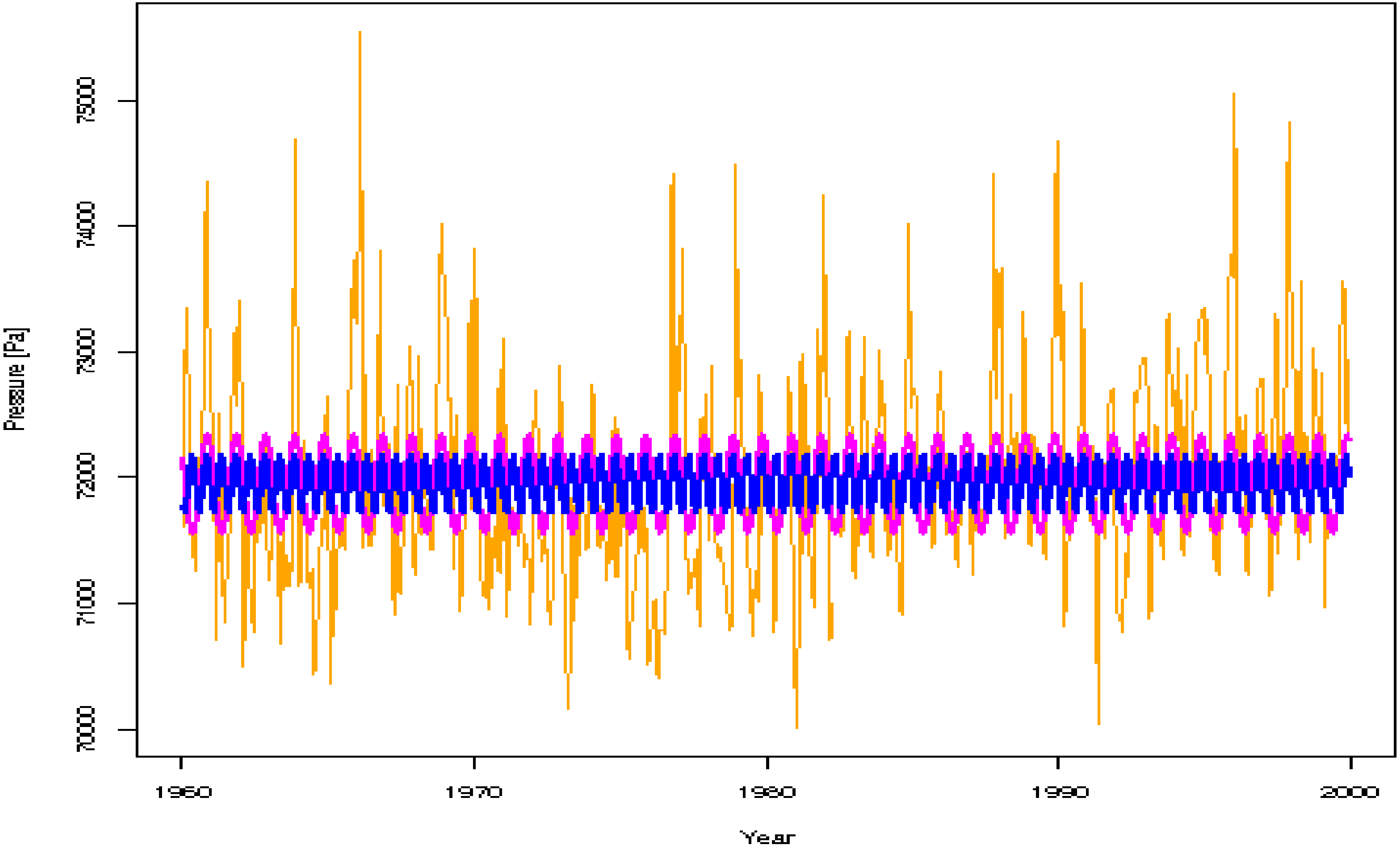
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Annual and Semi-annual Cycle at Brest



# Representation of Wind and “Steric” Effects

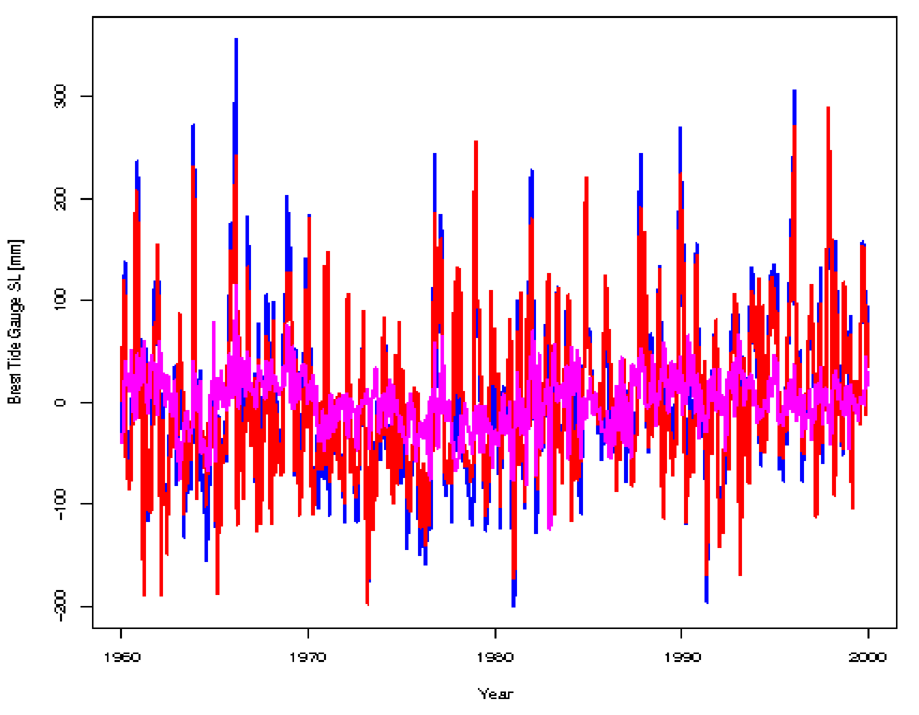
- Wind effects are included by adding surface pressures at 8 locations around the tide gauges in addition to the local surface pressure

- “”effects are implicitly accounted for by adding in sea surface height (SSH) time-series from 6 boundary locations

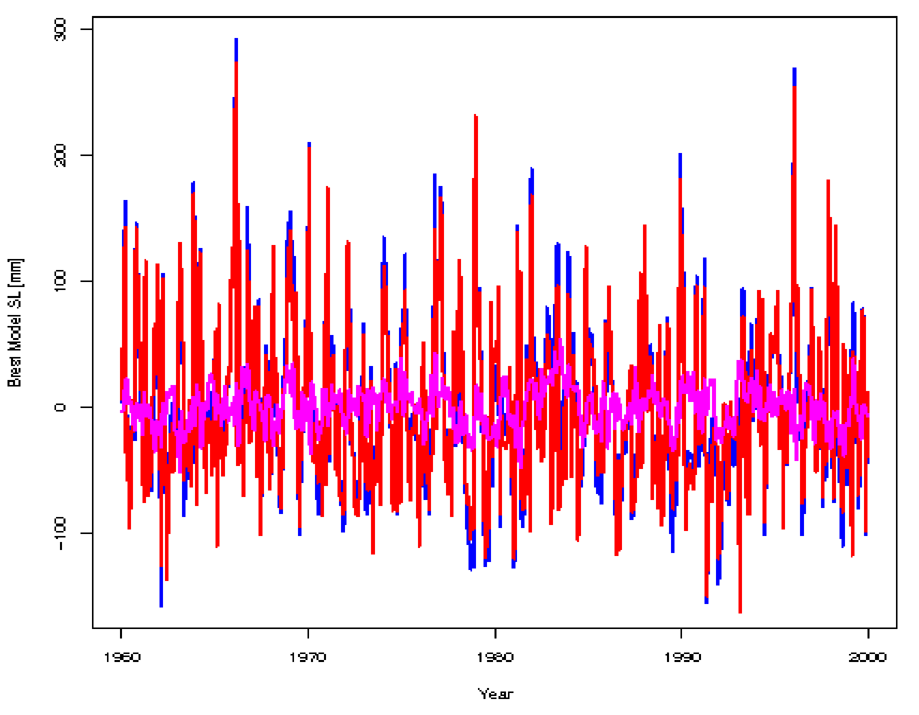
- Pressures and SSH are lagged by up to 2 months

# Monthly RMS

## Tide Gauge



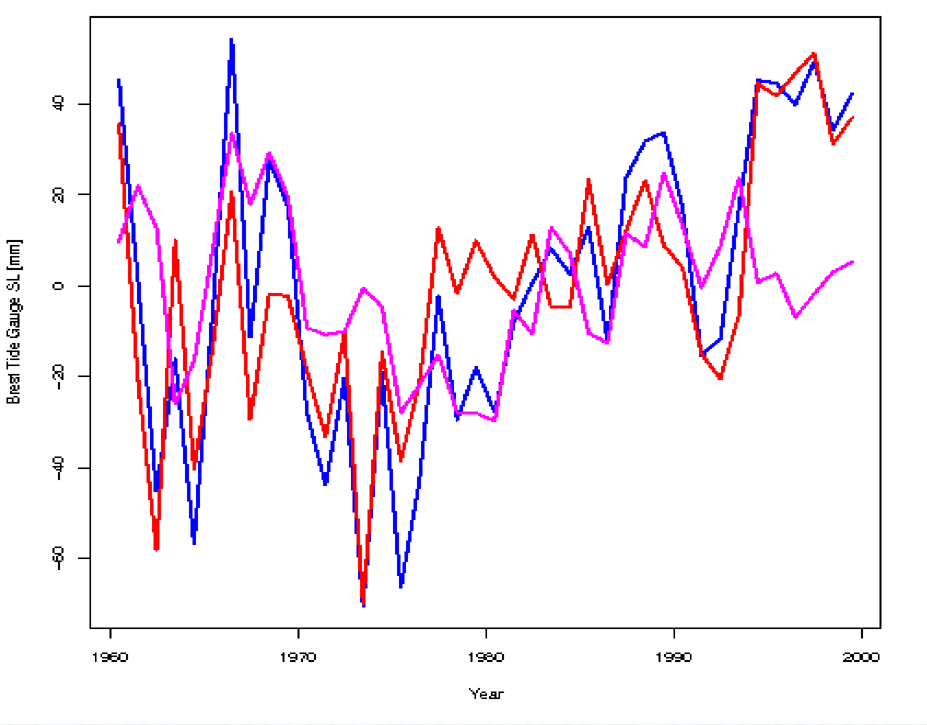
## Model



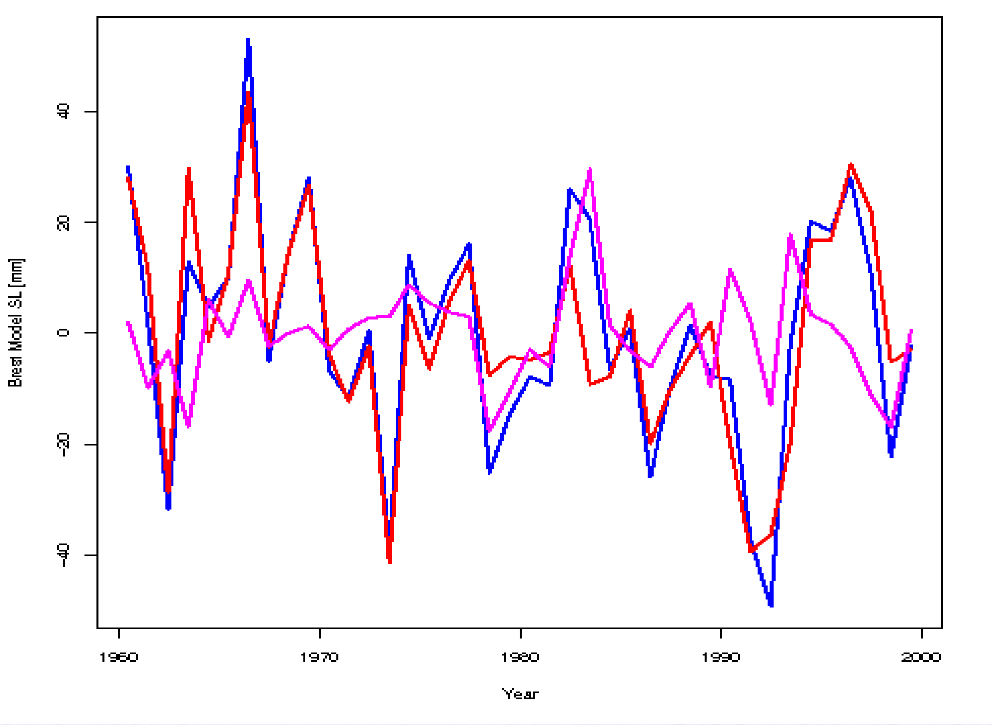
- At Brest, TG RMS reduced 66%, model RMS reduced 76%
  - What is the limit of this approach?

# Annual RMS

## Tide Gauge



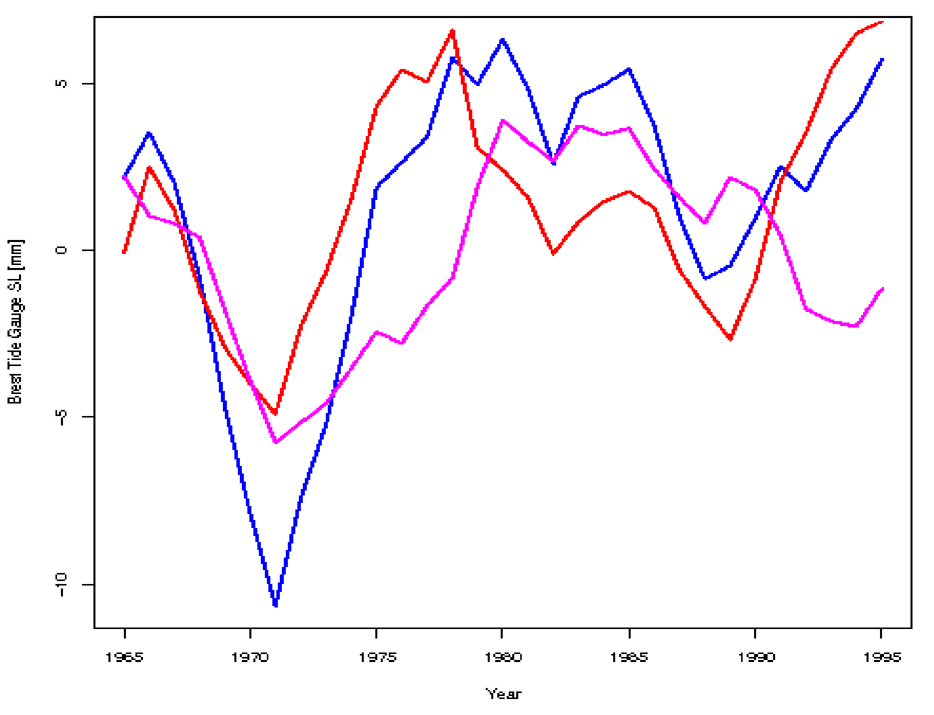
## Model



- At Brest, TG RMS reduced 75%, model RMS reduced 80%

# Decadal RMS

## Tide Gauge



## Model

- At Brest, TG RMS reduced 58%, model RMS reduced 82%

# “Corrected” Linear Rates

| 1960-2000 | Uncorrected [mm/yr] | “Wind/Pressure Corrected” [mm/yr] | “GPS+Wind/Pressure Corrected” [mm/yr] |
|---|---|---|---|
| Brest | 1.36±0.3 | 1.84±0.1 | 1.30 |
| Newlyn | 1.19±0.3 | 1.56±0.1 | 1.35 |

# Summary

- Multivariate regression greatly reduces variance at monthly to decadal timescales (58-75%)
- Dominant effect is inverted barometer (45% at Brest)
- Adding “deep sea” SSH boundary conditions improves model variance reduction much more than TGs
- Brest/Newlyn difference much reduced using “corrected” rates with GPS

Remaining variability probably comes from the deep ocean and requires better boundary conditions