The Effect of Vertical Land Movement Data Sets on Estimates of Sea Level Rise around the UK

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Overview

- Background and Motivation
- Updated mean sea level (MSL) trends for the UK
  - Woodworth et al. (2008) and PSMSL (2007)
- Data sets of vertical land movement (VLM) estimates for the UK
  - From measurements:
    - Geological evidence (Shennan and Horton, 2002)
    - Geodetic evidence from a combination of absolute gravity (AG) and continuous GPS (CGPS) measurements (update from Teferle et al., 2006)
  - From geodynamic models of the glacial isostatic adjustment (GIA) process:
    - Global GIA model ICE4G-VM2 (Peltier, 2001)
    - "Revised" GIA model for the British Isles (Bradley et al., 2008)
- Comparison of VLM estimates for the UK
- Effects on Average Changes of Sea Level around the UK
- Conclusions

Background and Motivation

- Sea level change is an important topic in the United Kingdom (UK) due to
  - Many low-lying areas along the North Sea coast
  - Subsidence in the London area and along the Thames Estuary
- Several studies of changes in sea level around Great Britain and the UK
  - Using tide gauges (TG) with PSMSL revised local reference (RLR) records and mean sea level (MSL) trends
  - Woodworth et al. (1999)
    - MSL trends for TG at Aberdeen, North Shields, Sheerness, Newlyn and Liverpool
    - Vertical land movement (VLM) estimates from geology (Shennan, 1989)
    - Regional average of sea level change around of Great Britain of 1.0 mm/yr
  - Teferle et al. (2006)
    - MSL trends for TG at Aberdeen, Lowestoft, Sheerness, Newlyn, Liverpool and Brest (France)
    - VLM estimates from a combination of absolute gravity and continuous GPS
    - Regional average of sea level change around of Great Britain of 1.1 ± 0.7 mm/yr, but this varies between 0.6 and 1.9 mm/yr depending on the sub-set of TG used
  - These UK estimates fit within the range of 0.7 to 1.8 mm/yr of global averages of sea level change (e.g. Church et al., 2001; Douglas, 2001; Wöppelmann et al., 2007)
- Motivation for this study:
  - Recently updated MSL trends for UK TG
  - New sets of estimates of vertical land movements for the UK

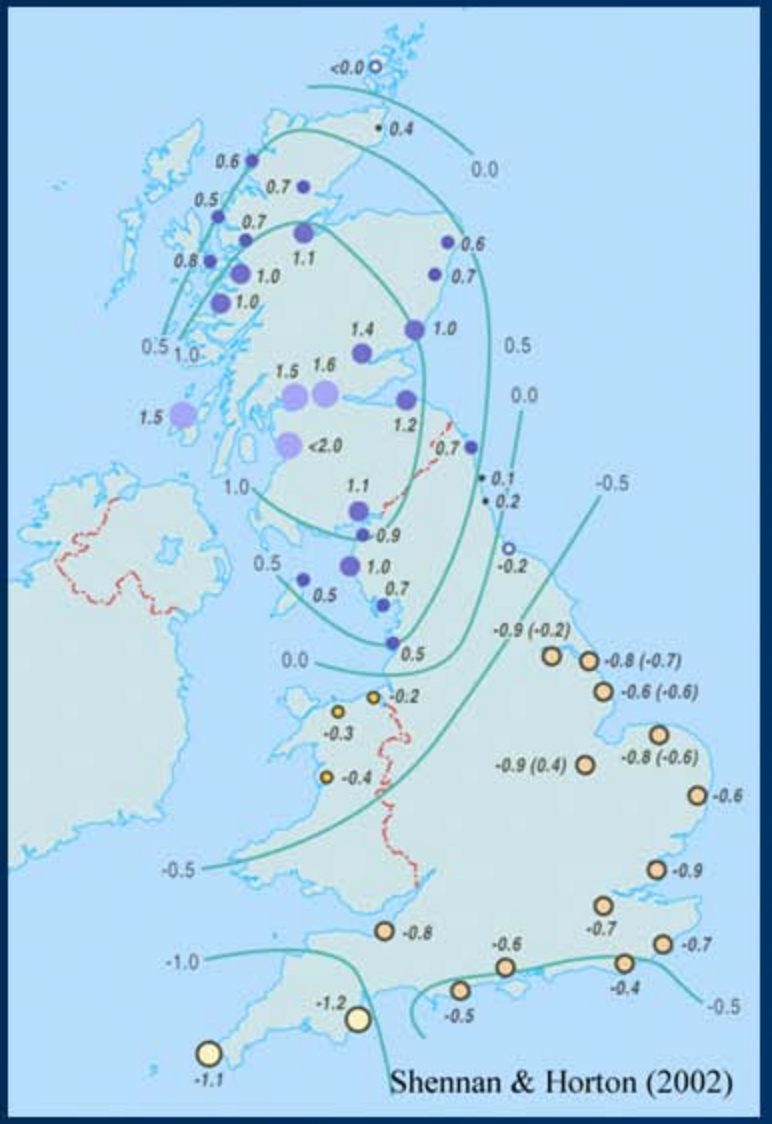
MSL trends for UK PSMSL RLR TGs

Station	No Years	Range	Trend and St. Err. [mm/yr]	S.D. [mm]
Lerwick	38	1957 - 2005	-0.68 +/- 0.34	28.5
Wick	34	1965 - 2006	1.55 +/- 0.43	30.8
Aberdeen Composite	96	1901 - 2006	0.87 +/- 0.10	28.6
Rosyth	27	1964 - 1993	1.99 +/- 0.92	41.1
Dunbar	37	1914 - 1950	0.47 +/- 0.31	20.5
North Shields	84	1901 - 2006	1.92 +/- 0.12	32.6
Lowestoft	44	1956 - 2006	2.57 +/- 0.33	31.7
Southend	44	1933 - 1983	1.22 +/- 0.24	24.1
Tilbury	22	1961 - 1983	1.58 +/- 0.91	28.5
Sheerness	58	1901 - 2006	2.23 +/- 0.13	34.0
Dover	37	1961 - 2006	2.18 +/- 0.26	22.1
Portsmouth	34	1962 - 2005	1.58 +/- 0.44	32.5
Newlyn	89	1916 - 2006	1.70 +/- 0.10	25.0
Liverpool Composite	69	1901 - 2004	1.60 +/- 0.17	40.8
Douglas	31	1938 - 1977	0.26 +/- 0.70	39.6
Portpatrick	31	1968 - 2004	1.95 +/- 0.44	25.9
Millport	20	1969 - 2006	1.20 +/- 0.53	28.0
Stornoway	18	1977 - 2006	2.22 +/- 0.90	33.9

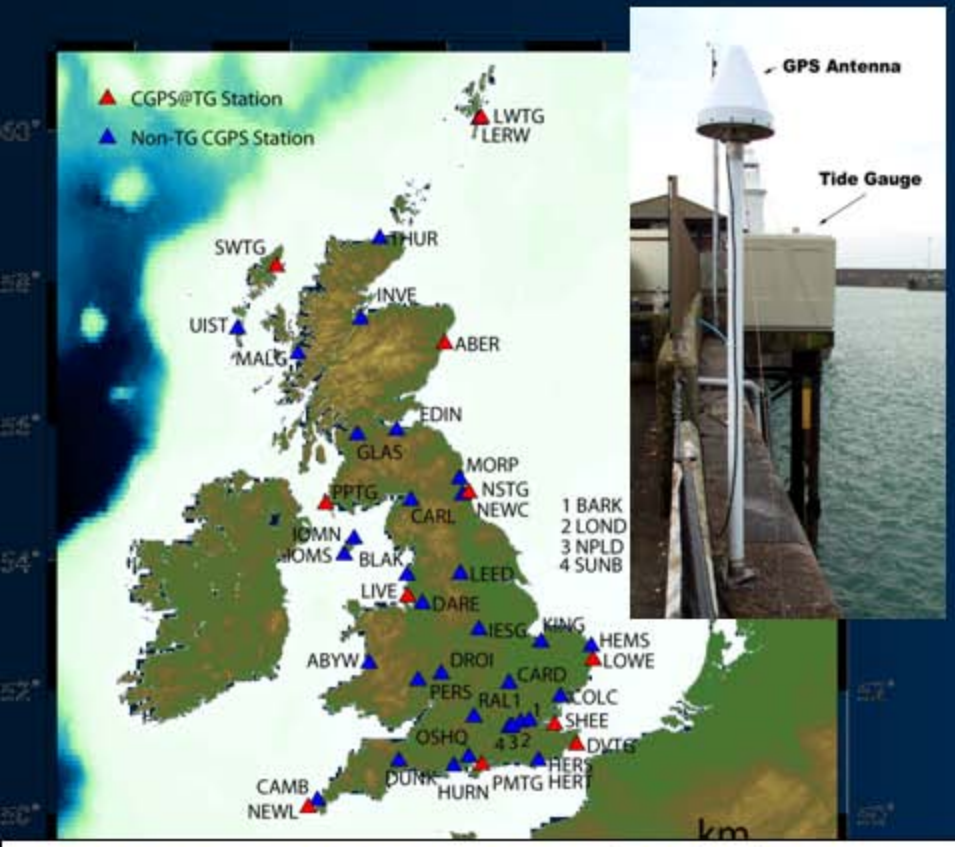
(Woodworth et al., 2008; PSMSL, 2007)

VLM from Geological Evidence: GEOL

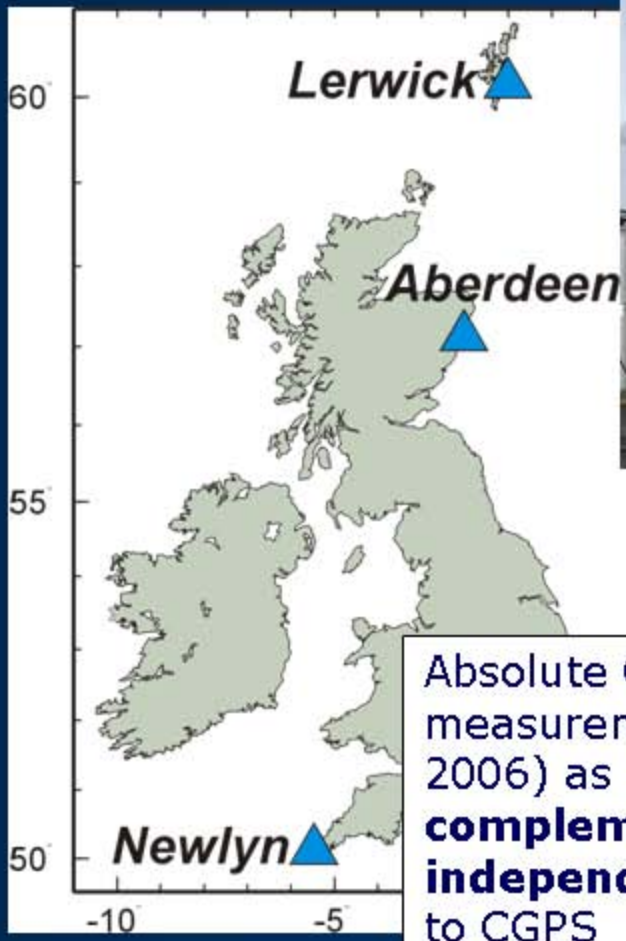
- General pattern of VLM:
  - Uplift of Scotland and Northern England
  - Subsidence in Wales, Central and Southern England
- Geological evidence from:
  - >1250 radiocarbon dated samples that constrain relative sea levels in Great Britain over the past 16,000 yr
  - Shennan & Horton (2002), Shennan et al. (2006a, b)



VLM from Geodetic Evidence: CGPS and AG



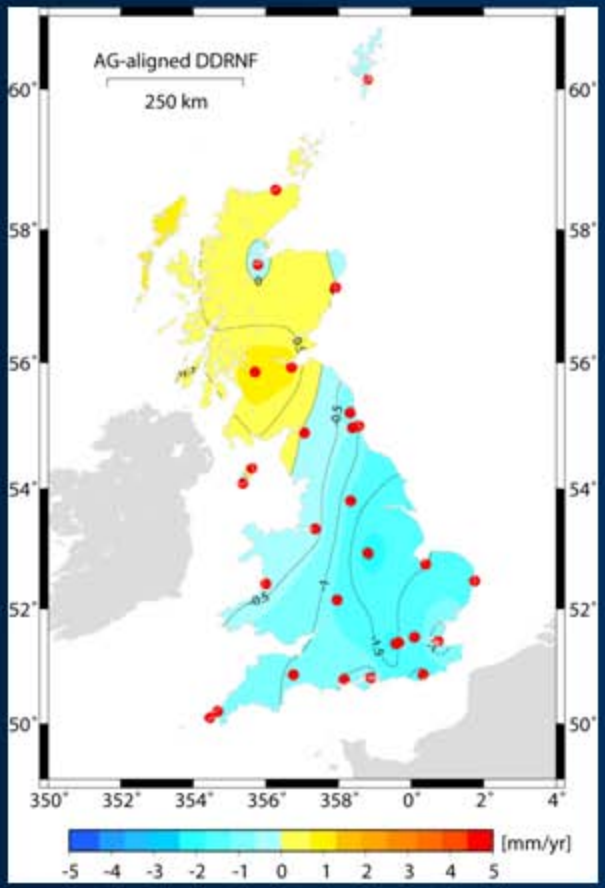
45 CGPS stations processed including 11 CGPS@TG stations and long period OSGB and Met Office stations in BIGF (1997-2005)



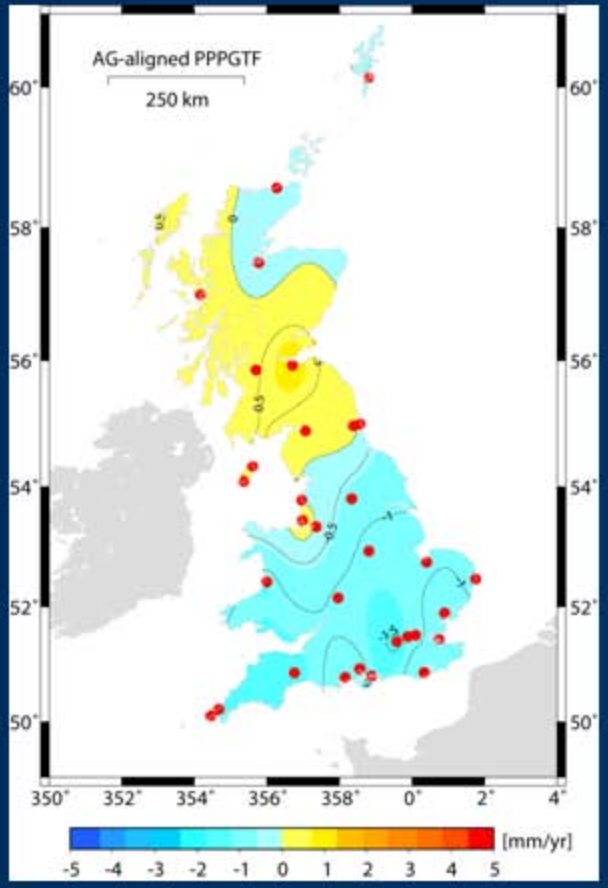
Absolute Gravity (AG) measurements (1995-2006) as a **complementary** (and **independent**) technique to CGPS

VLM from Geodetic Evidence (2)

- Two independent CGPS processing streams as outlined in Teferle et al. (2006, 2007)
- Combination of AG and CGPS vertical station velocities to obtain AG-aligned CGPS estimates of vertical station velocity (Teferle et al., 2006)



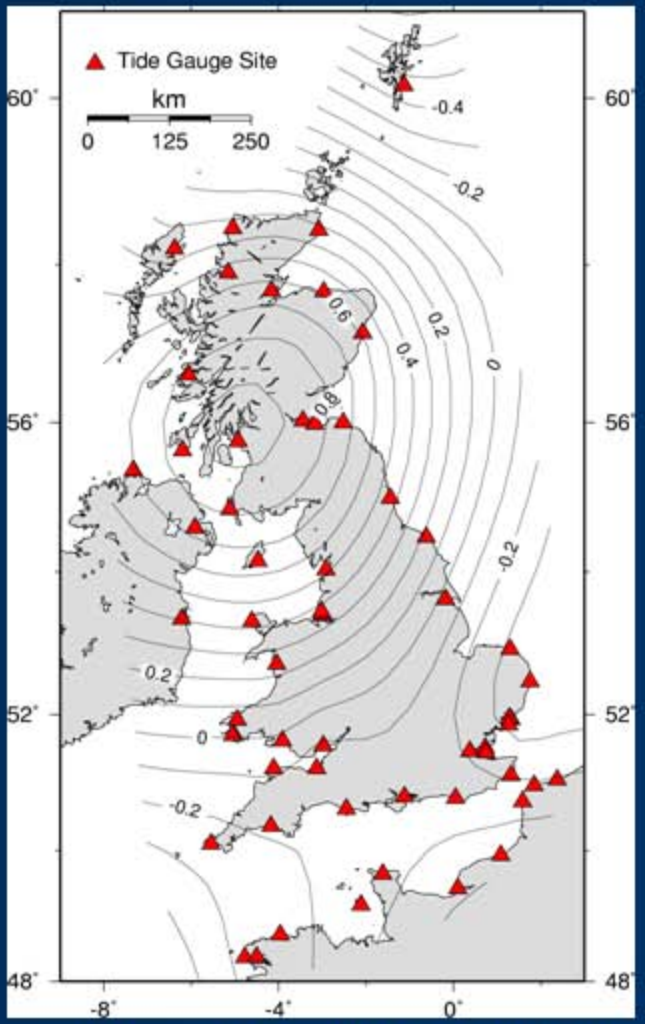
AGCGPS1



AGCGPS2

Global GIA Model: GIA1

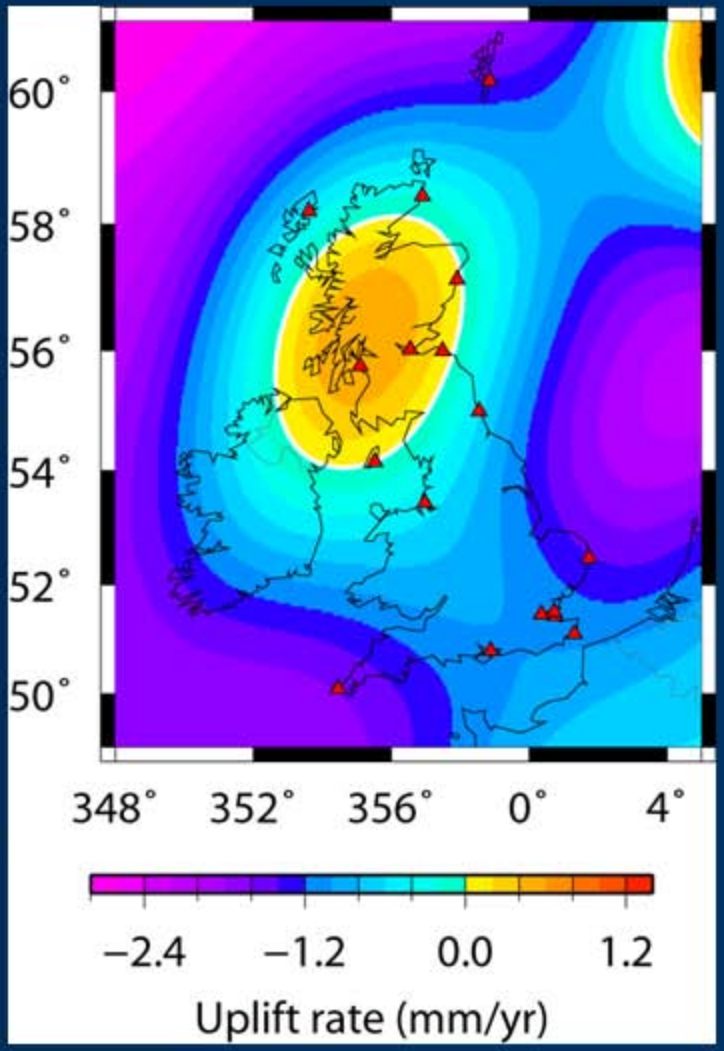
- ICE4G-VM2 model (Peltier, 2001)
  - Global GIA model that fits US east-coast and UK geological data sets well without focus on UK area (Peltier et al., 2002)
- Ice model
  - ICE4G (Peltier, 1994; 1996)
- Earth model:
  - 1D, spherically symmetric, self gravitating, linear Maxwell viscoelastic rheology
  - VM2 viscosity profile
  - Lithosphere – 120km



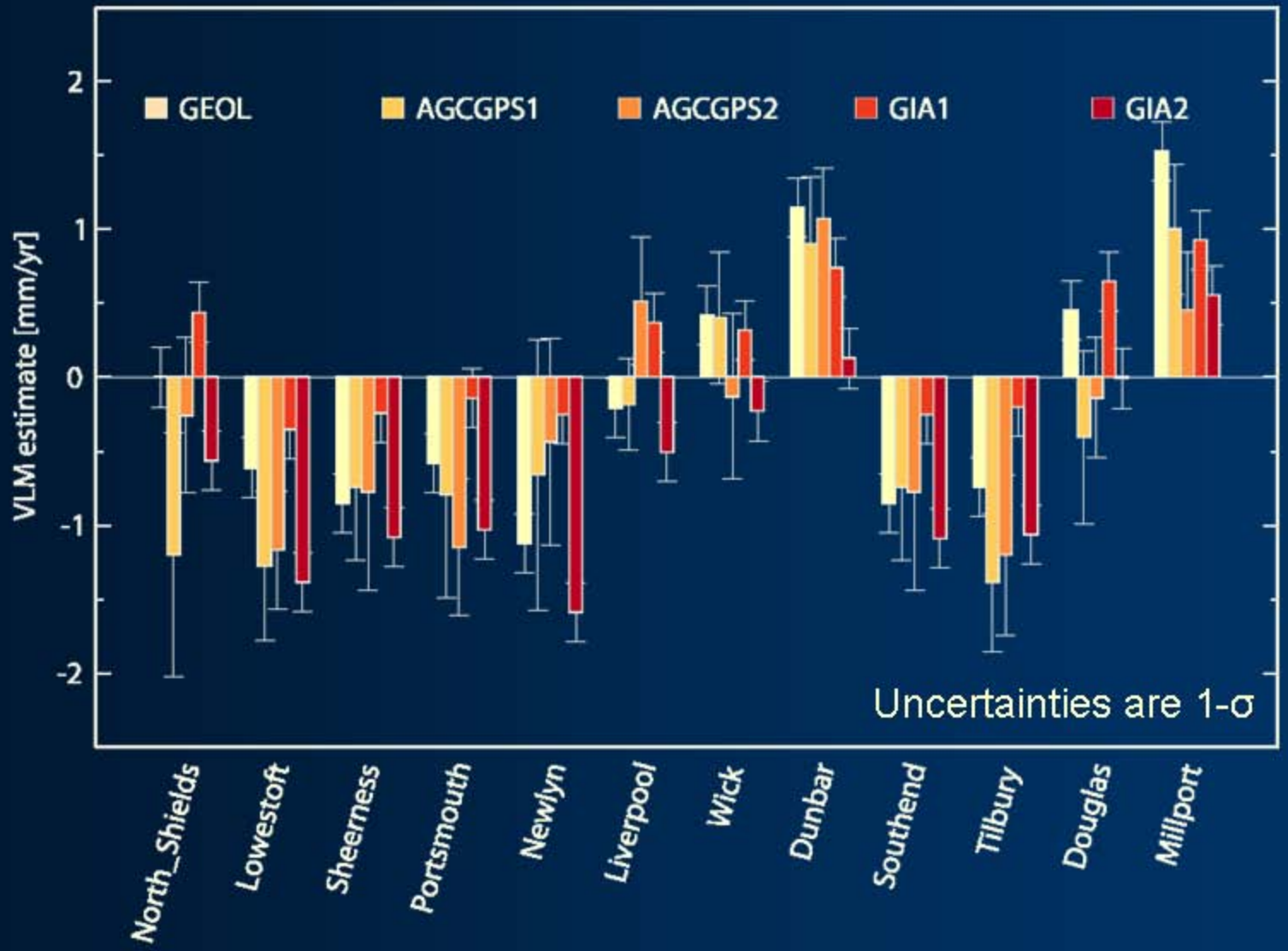
Inferred from Peltier (2001)

A "Revised" GIA Model for the British Isles: GIA2

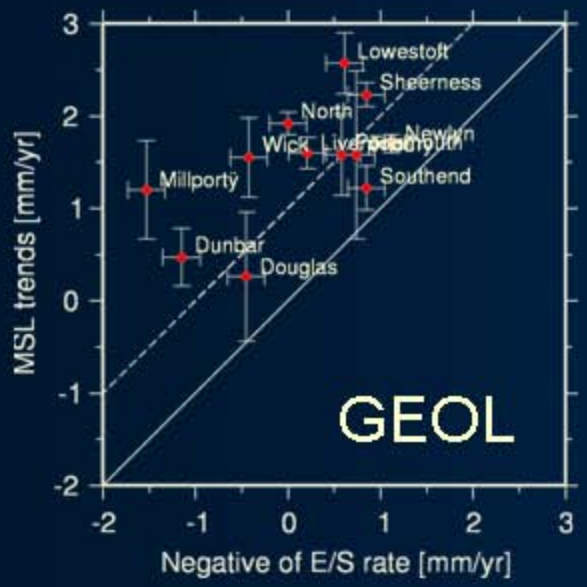
- **Ice model:**
  - Global Background model (Basset et al., 2005)
  - Regional Model (Shennan et al., 2002)
  - Terrain correction
  - Rapid glaciation begin at 34k yr BP with no isostatic equilibrium at Last Glacial Maximum
- **Earth model:**
  - 1D, spherically symmetric, self gravitating. linear Maxwell viscoelastic rheology
  - Lower mantle - 4*10^22 Pa s - (Basset et al., 2005)
  - Upper mantle - 5*10^20 Pa s - (Peltier et al., 2002)
  - Lithosphere – 71km (10^43 Pa s) – (Shennan et al., 2006)

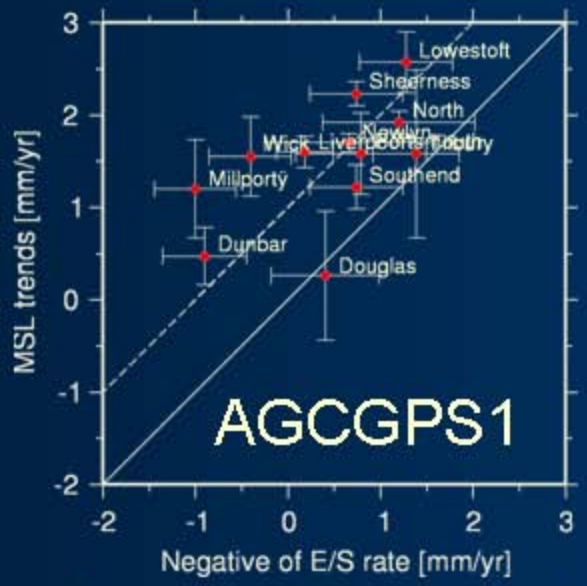


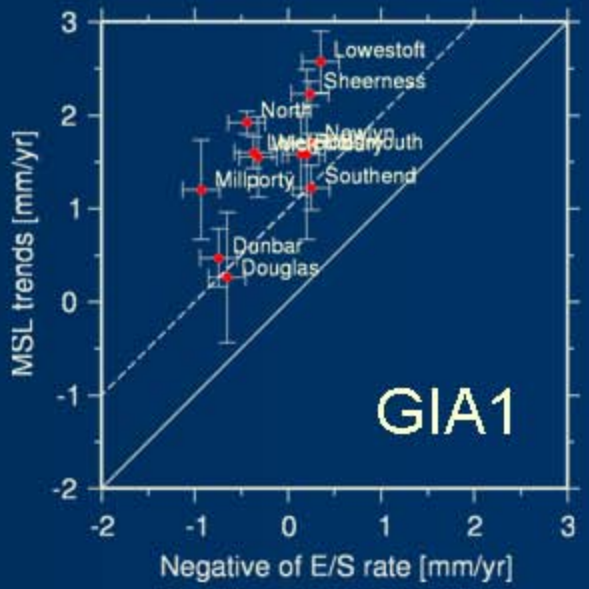
VLM Estimates for Selected TG Stations

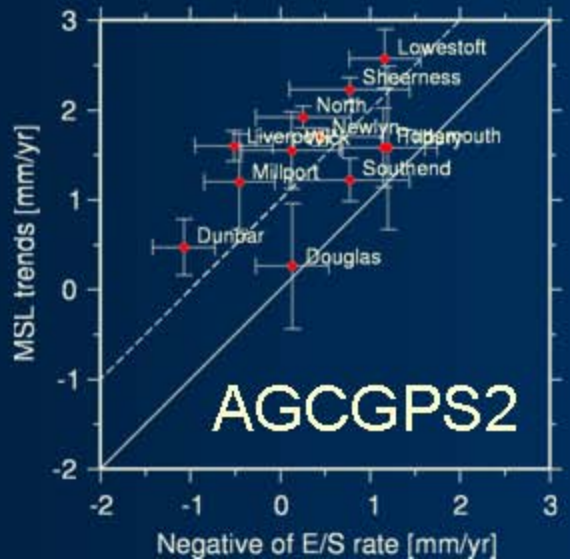


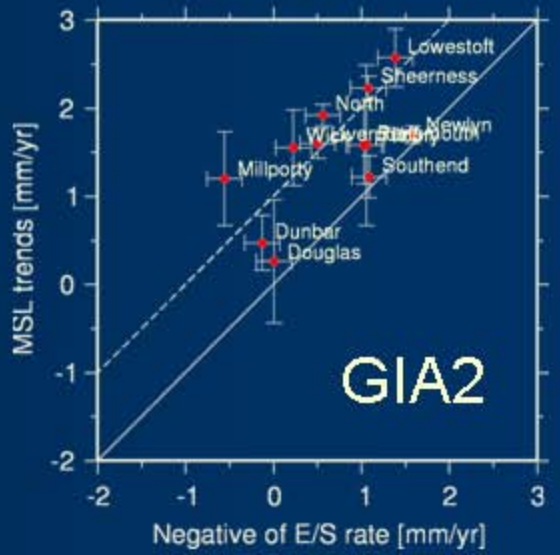
MSL trends vs. Negative Emergence/Submergence Rate





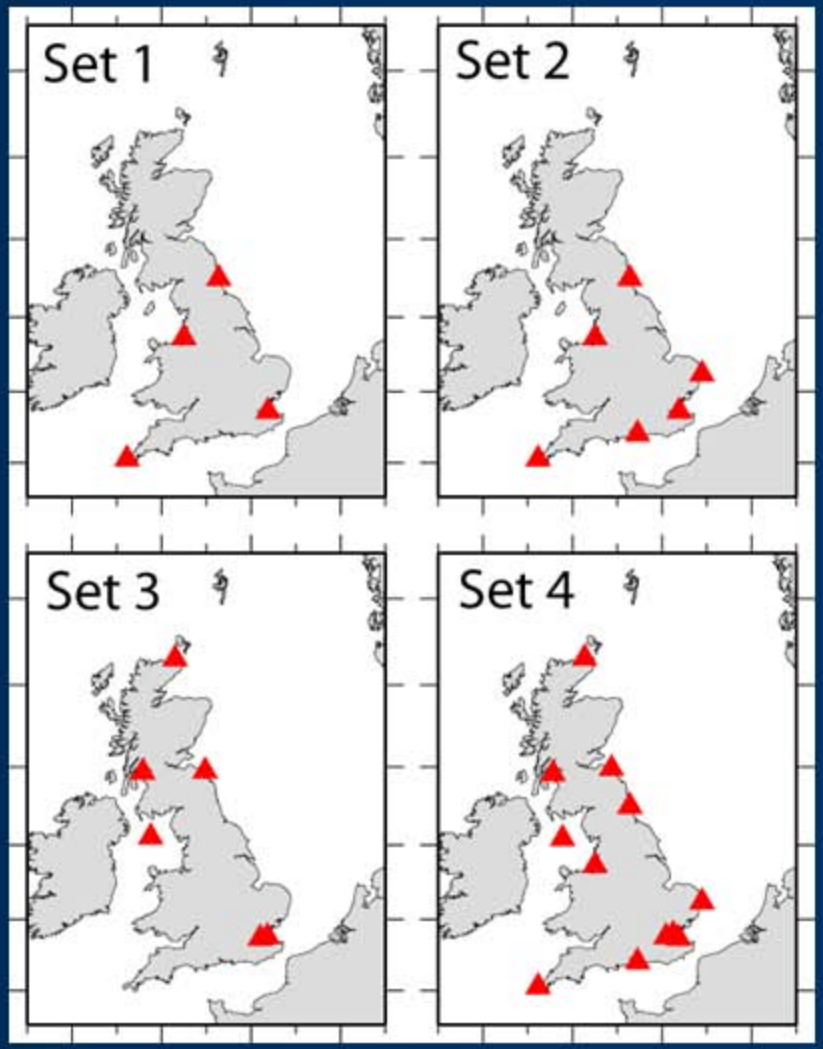




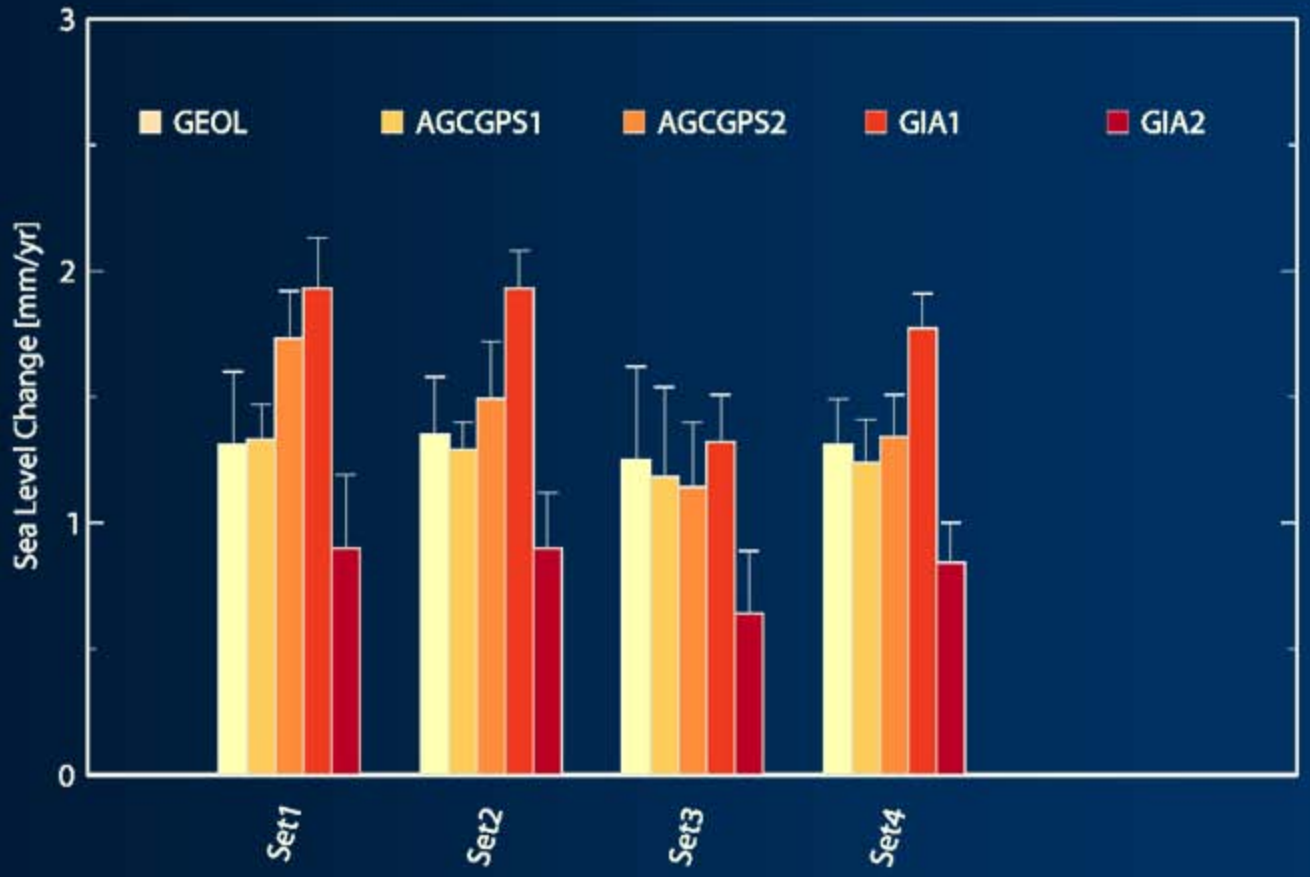


TG Selections for Tests

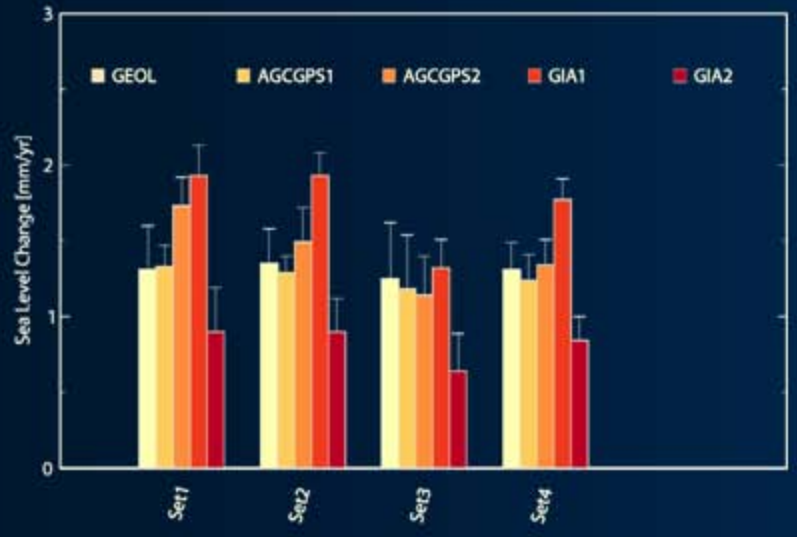
- We investigate several subsets and the complete selection of TG and estimate an average change in sea level around the UK for these
- The selection is mainly restricted by the number of CGPS stations close to or at the TG
  - Not all TG in the PSMSL RLR data base can be used for which geological evidence was used in previous studies
- We can separate four sets:
  - Set1: TG with long records and adjacent CGPS@TG station
  - Set2: TG with adjacent CGPS@TG station
  - Set3: TG with no CGPS@TG station, but with nearby non-TG CGPS station
  - Set4: TG with adjacent CGPS@TG and TG with nearby non-TG CGPS stations (combination of the above)
- A special case for the geodetic evidence from AG and CGPS only:
  - TG with long records and adjacent CGPS@TG station but using the AG-aligned CGPS estimate of vertical station velocity from a nearby CGPS station



Estimated Average Changes in Sea Level around the UK for different VLM Data Sets and TG Selections



Estimated Average Changes in Sea Level (2)



- Estimates based on geological and geodetic evidence agree well

	GEOL	AGCGPS1	AGCGPS2	GIA1	GIA2	Mean	S.D.
Set1	1.31 ± 0.29	1.33 ± 0.14	1.73 ± 0.19	1.93 ± 0.20	0.90 ± 0.29	1.44	0.40
Set2	1.35 ± 0.23	1.29 ± 0.11	1.49 ± 0.23	1.93 ± 0.15	0.90 ± 0.22	1.39	0.37
Set3	1.25 ± 0.37	1.18 ± 0.36	1.14 ± 0.26	1.32 ± 0.19	0.64 ± 0.25	1.11	0.27
Set4	1.31 ± 0.18	1.24 ± 0.17	1.34 ± 0.17	1.77 ± 0.14	0.84 ± 0.16	1.30	0.33
Mean	1.31	1.26	1.43	1.74	0.82		
S.D.	0.04	0.06	0.25	0.29	0.12		

Effect of Using "nearby" Geodetic Evidence for Correcting TG records for VLM

- AG-aligned CGPS estimates of VLM for CGPS@TG stations in North Shields, Sheerness, Newlyn and Liverpool are replaced by the estimates for CGPS stations in Newcastle, Barking, Camborne and Daresbury

Average Change in Sea Level [mm/yr]	AGCGPS1	AGCGPS2
CGPS@TG	1.33 ± 0.14	1.73 ± 0.19
CGPS	1.16 ± 0.14	1.34 ± 0.35

CGPS@TG Station	Replacement CGPS Station	AGCGPS1 dV [mm/yr]	AGCGPS2 dV [mm/yr]	Distance [km]
North Shields	Newcastle	-0.72	-0.63	12
Sheerness	Barking	0.65	0.43	45
Newlyn	Camborne	0.07	0.90	20
Liverpool*	Daresbury	0.10	0.60	28

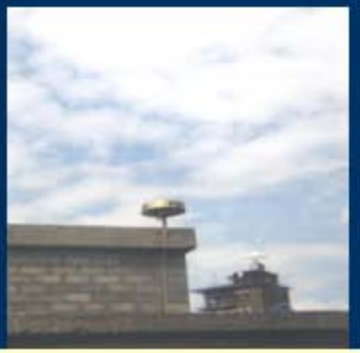
Conclusions

- We have presented
  - Recent MSL trend estimates for UK tide gauges in the PSMSL RLR data base
  - Updated and recent estimates for VLM from geological and geodetic evidence
  - Predictions of VLM from a global and a “revised” (for the British Isles) GIA model
- We show that the estimate for an average change in sea level around the UK seems to be
  - Unaffected by the TG selection when using VLM estimates from geological evidence
  - Largely unaffected by the TG selection when using VLM estimates from geodetic evidence
  - Affected by the TG selection when using VLM predictions from a global GIA model
  - Less affected by the TG selection when using VLM predictions from a revised GIA model specific for the British Isles
- We show that the estimate for an average change in sea level around the UK seems to be dependent on the VLM data set used to correct the TG records :
  - 1.26 to 1.43 mm/yr (VLM estimates from geological and geodetic evidence)
  - 1.7 ± 0.3 mm/yr (VLM predictions from the global GIA model)
  - 0.8 ± 0.1 mm/yr (VLM predictions from the revised GIA model specific to the British Isles)
- Our results for testing the effect of using VLM estimates from CGPS station within 45km of a tide gauge are inconclusive, but suggest an effect of <0.5mm/yr on the estimated average change in sea level around the UK
  - This is inline with the findings of Snay et al. (2007)

Thank you !







Tomorrow: EGU2008-A-07948; Poster Area: Halls X/Y
Teferle, F. N.; Bingley, R. M.; Williams, S. D.
Geodetic Monitoring of UK Tide Gauges in the Permanent Service for Mean Sea Level Revised Local Reference Data Base


Dover


Portsmouth


Newlyn


Liverpool


Stornoway

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