

Relative sea level change across the Forth Estuary

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Sea Level Change

Global sea levels:

- Historically - Rose by 17cm between 1900 and 2000 (Church & White, 2006)
- Future - estimated to rise between 18 and 59 cm between 1990 and 2100 (IPCC, AR4 report)

Scotland:

- The land in central parts of Scotland is still rebounding from the last Ice Age, counteracting the global rates of sea level change
- Global projections should be substituted for local land level and sea surface data (Gehrels & Long, 2008)

The Study Background

Sept-2008 – Launch of study

University of Dundee & Forth Ports Ltd

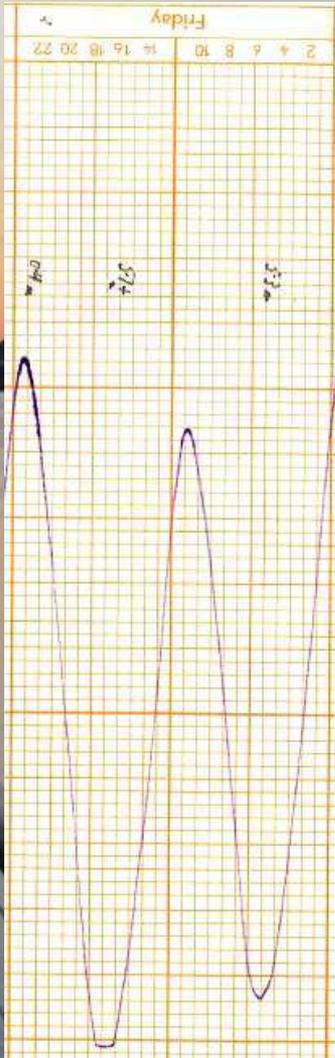


Tide gauge data:

- Local past sea level trends
- Storm surge events
- Future sea level projections



Examples for tide gauge data



Microsoft Excel - 2S030812

Valeport Tidal Monitor

1	Valeport Tidal Monitor								
2	Station Name:	Grangemouth							
3	Date:	12/08/2003							
4	HW	5.54 m @	02:43:00						
5	LW	0.54 m @	09:29:00						
6	HW	5.64 m @	15:05:00						
7	LW	0.92 m @	21:33:00						
8	Gust Period	60							
9									
10	Date	Tide Height	Predicted	Surge	W/Directio	W/Speed	Max Gust	Air Pressu	Air Temp
11	GMT	metres	metres	metres	Deg	knots	knots	mBar	Deg C
12	12/08/2003 11:14	2.506	2.43	0.08	111.2	4.53	5.38	0	0
13	12/08/2003 11:15	2.538	2.46	0.08	108.8	4.7	5.36	0	0
14	12/08/2003 11:16	2.589	2.49	0.08	108.3	5.07	5.71	0	0
15	12/08/2003 11:17	2.599	2.51	0.09	116.5	5.25	6.2	0	0
16	12/08/2003 11:18	2.63	2.54	0.09	116.8	4.49	5.38	0	0
17	12/08/2003 11:19	2.659	2.57	0.09	117.5	4.47	5.13	0	0
18	12/08/2003 11:20	2.69	2.6	0.09	117.8	4.14	5.09	0	0
19	12/08/2003 11:21	2.72	2.63	0.09	118	4.31	5.01	0	0
20	12/08/2003 11:22	2.749	2.66	0.09	116.2	4.47	5.15	0	0
21	12/08/2003 11:23	2.778	2.69	0.09	116.1	4.37	5.56	0	0
22	12/08/2003 11:24	2.806	2.72	0.09	112.6	4.47	5.25	0	0
23	12/08/2003 11:25	2.834	2.75	0.09	114.2	4.08	4.64	0	0

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File Edit View Tools Accounts Window Help

Message TEXT.htm NP1200.SCF NP1100.SCF NP1000.SCF NP900.SCF NP800.SCF NP700.SCF

"Output from HYDRLOG Data Management System V2.53 (C) 1991-98 Hydro-Logic Ltd"

"Report format": "SUMMARY REPORT"

"Creation time": "20/04/2001 at 12:30 hrs"

"Licence name": "SEPA East Region"

"Authority Ref": "015048"

"Station Name": "Newport-on-Tay"

"Location Desc": "Tide Gauge"

"Catchment Ref": "15"

"Report type": "Daily Means"

"Grid Ref": "N0418277"

"Parameter": "Stage"

"Gauge Zero": "-2.900 MACO"

"Units": "metres"

"Period": "01/12/2000 to 31/12/2000"

"Start of Day": "09:00"

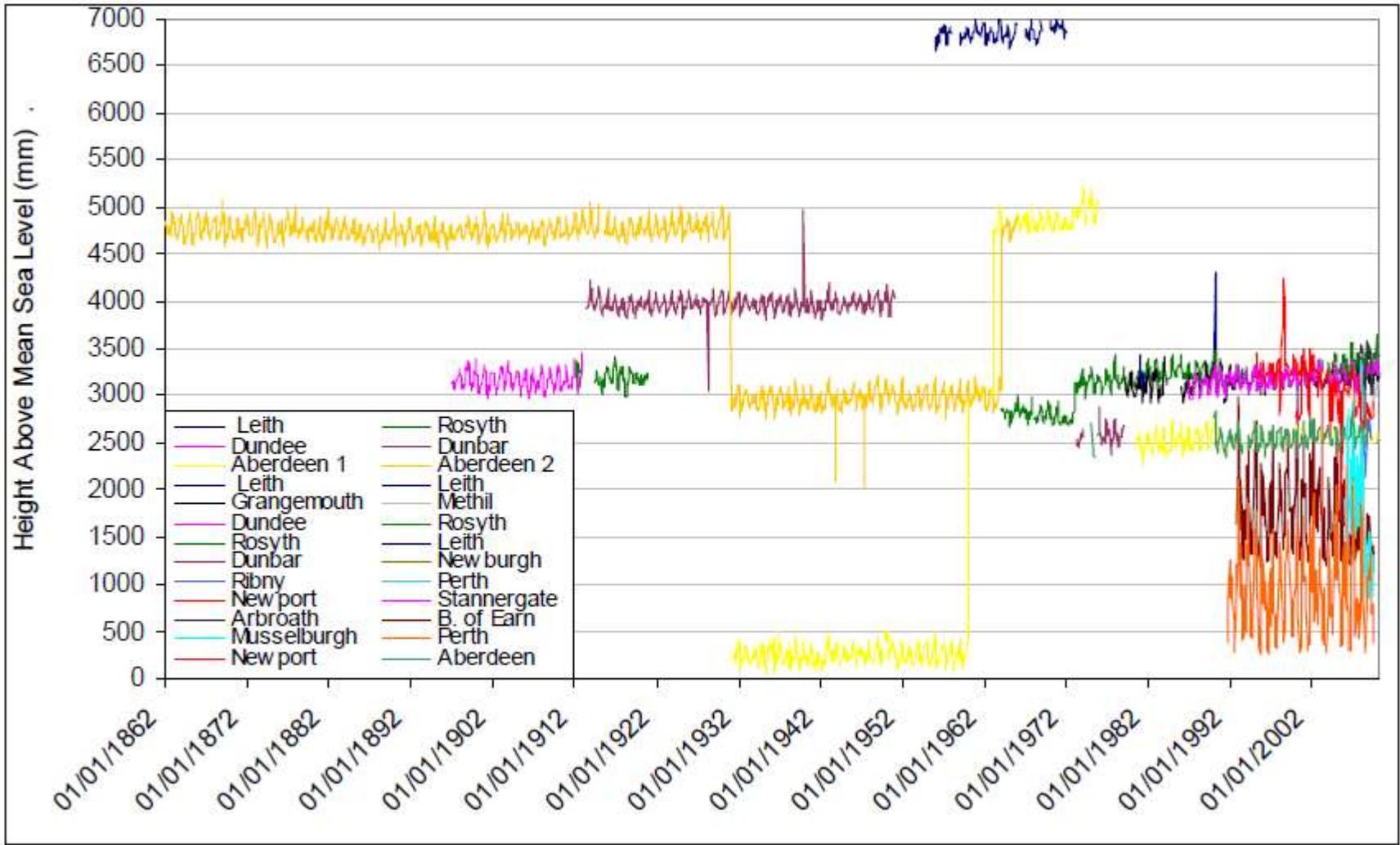
"A reading of -9999 indicates start/end/break in data"

"Data codes": "7 - Start of log 9 - End Of log"

"Year": "Month": "Day": "Hour": "Minute": "Second": "Reading": "Data Code"

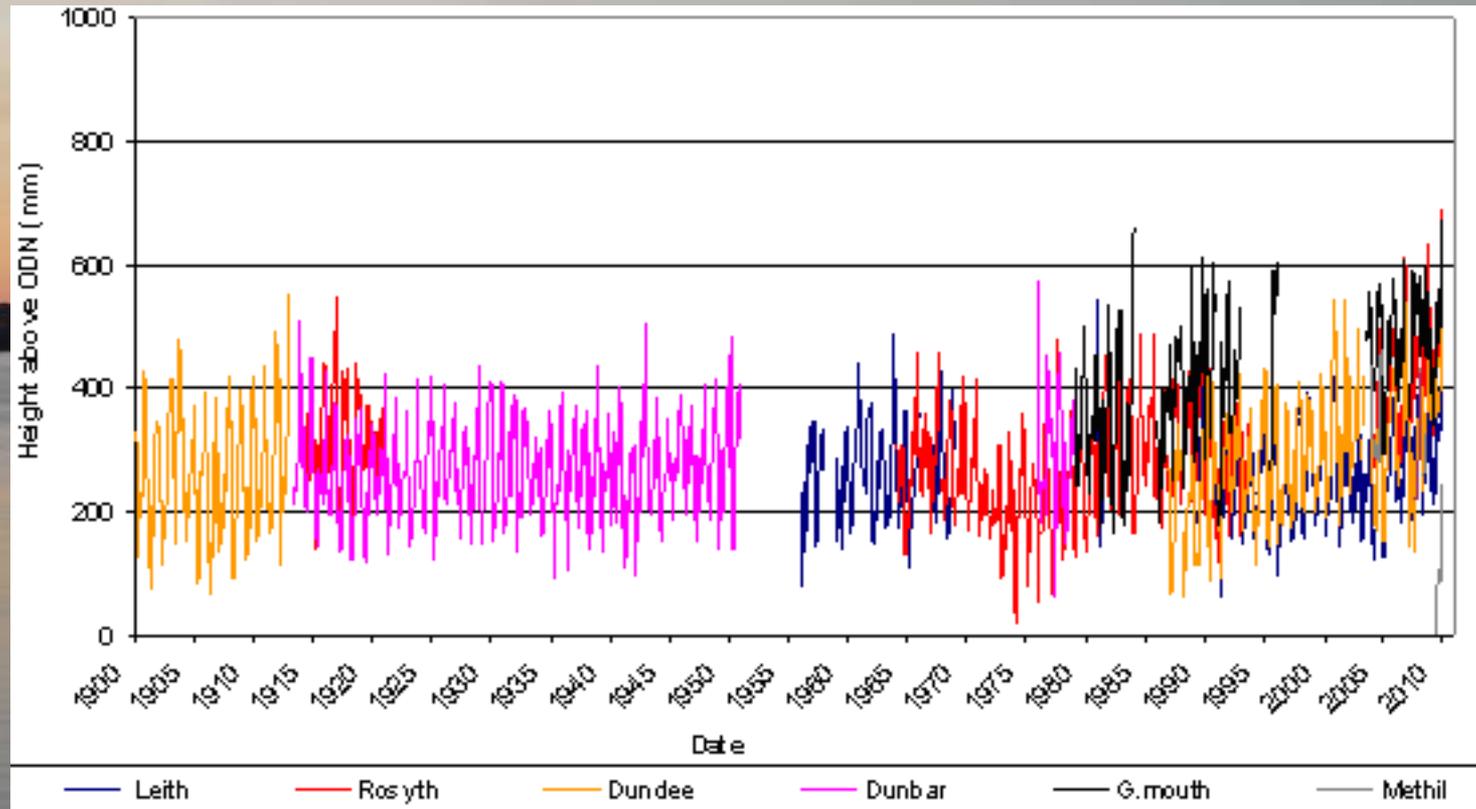
2000,12,01,09,00,00	3,670	4
2000,12,02,09,00,00	3,602	4
2000,12,03,09,00,00	3,489	4
2000,12,04,09,00,00	3,529	4
2000,12,05,09,00,00	3,629	4
2000,12,06,09,00,00	3,510	4
2000,12,07,09,00,00	3,749	4
2000,12,08,09,00,00	3,439	4
2000,12,09,09,00,00	3,503	4
2000,12,10,09,00,00	3,677	4
2000,12,11,09,00,00	3,767	4
2000,12,12,09,00,00	3,826	4
2000,12,13,09,00,00	3,501	4
2000,12,14,09,00,00	3,708	4
2000,12,15,09,00,00	3,465	4
2000,12,16,09,00,00	3,336	4
2000,12,17,09,00,00	3,769	4

Aberdeen, Forth and Tay Estuaries tide gauge data



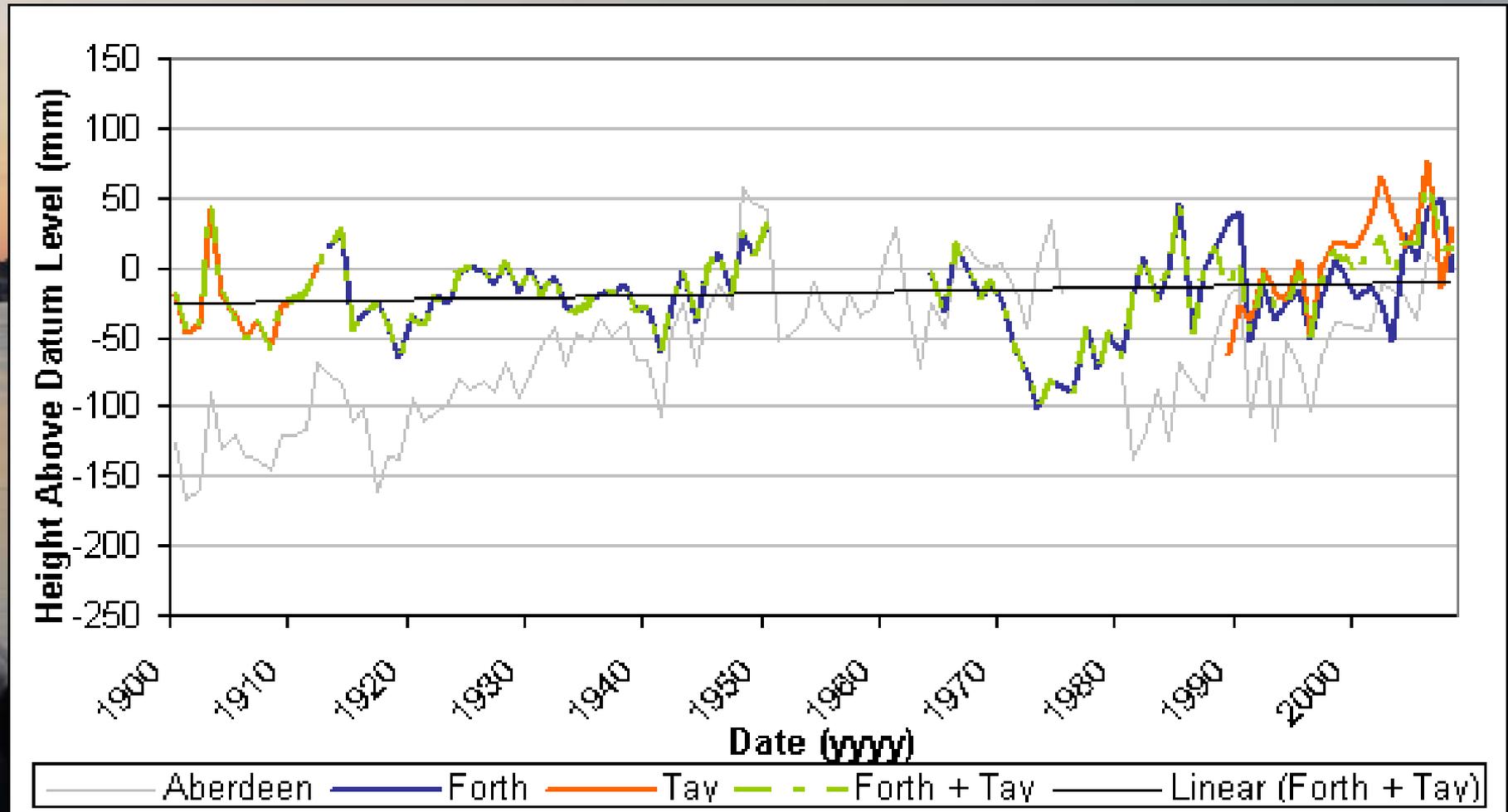
Above: Pre-corrected tide gauge data from Aberdeen, Tay Estuary, Forth Estuary and a combined dataset covering both the Tay and Forth Estuaries.

Forth and Tay Estuaries tide gauge data



Above: Post-corrected tide gauge data from Aberdeen, Tay Estuary, Forth Estuary and a combined dataset covering both the Tay and Forth Estuaries.

Aberdeen, Forth and Tay Estuaries tide gauge data



Above: Relative sea level changes in the Aberdeen, Tay Estuary, Forth Estuary and a combined dataset covering both the Tay and Forth Estuaries.

Land rebound

Shennan et al. (2012) Relative land-level change GIA model



Above: The Shennan et al. (2012) map of GIA (relative land-level change) across the UK and Ireland.

Long-term trends

The sea level results

	Rosyth	Leith	Grangemouth	Dunbar	Global
Date range	1912-2011	1949-2011	1987-2011	1913-1979	1900-2000
Trends:					
1900-2008	0.6 mm/yr	0.3 mm/yr	5.1 mm/yr	0.3 mm/yr	1.8 mm/yr

Data also collected from Methil and Burntisland (2003-2011) and Musselburgh (2006-2008)

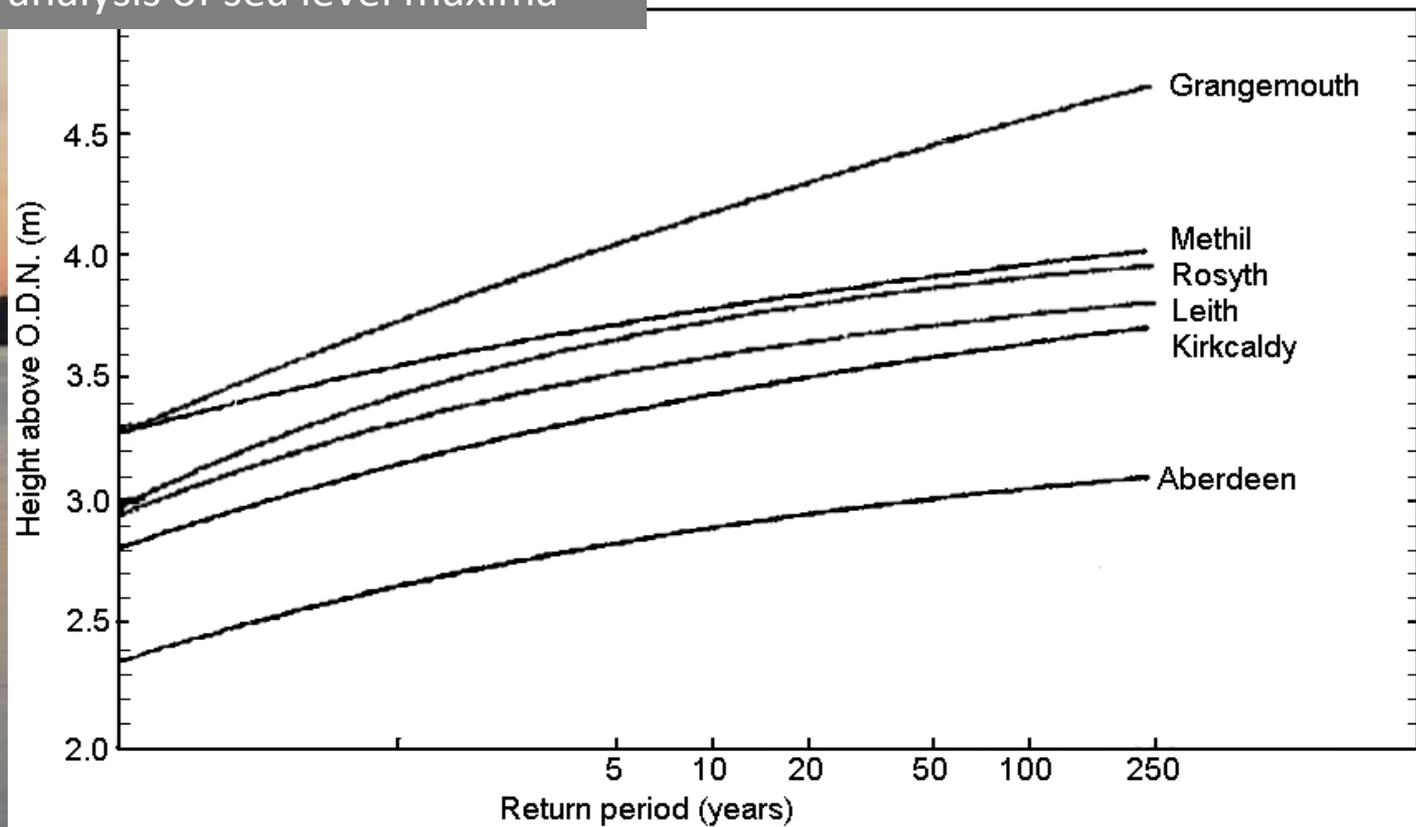
Storm surge analysis

Storm surges in sea level data:

- Analysing individual surge events
- Graff (1981) analysis of sea level maxima
- 'Residual' surge data from tide gauges

Sea level maxima analysis (highest historical sea levels)

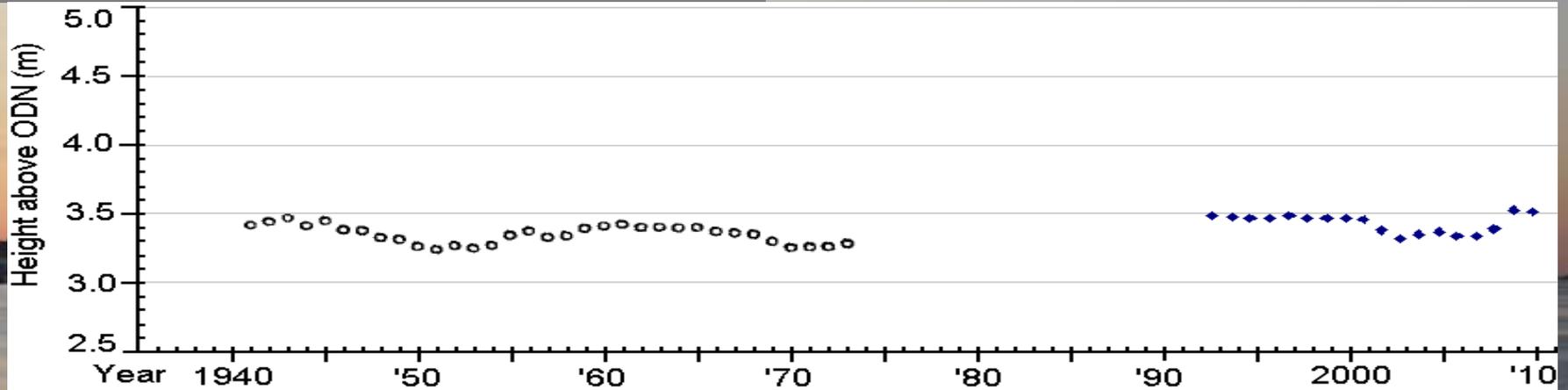
Graff (1981) analysis of sea level maxima



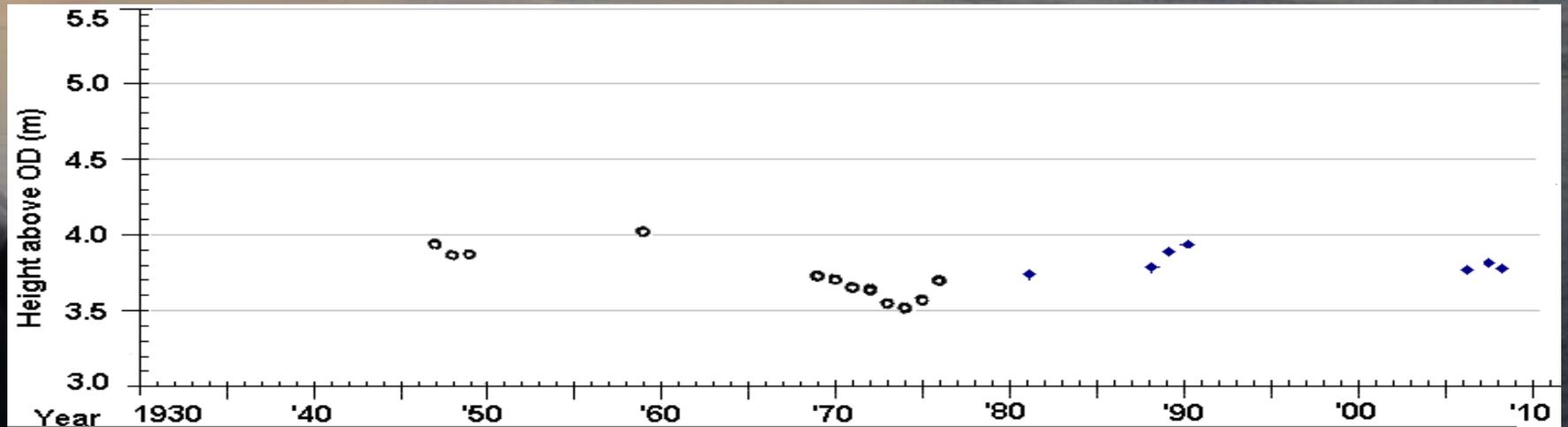
'Frequency distribution curves for north east coast regions between Firth of Forth and Lerwick' (Graff, 1981:406). Graff (1981) created these frequency curves using the Jenkinson (1955) General Extreme Value (GEV) distribution method for maxima and minima.

Sea level maxima analysis (highest historical sea levels)

Graff (1981) analysis of sea level maxima



Maxima height at Leith from Graff (1981) (circles) and Powell (2012) (diamonds).

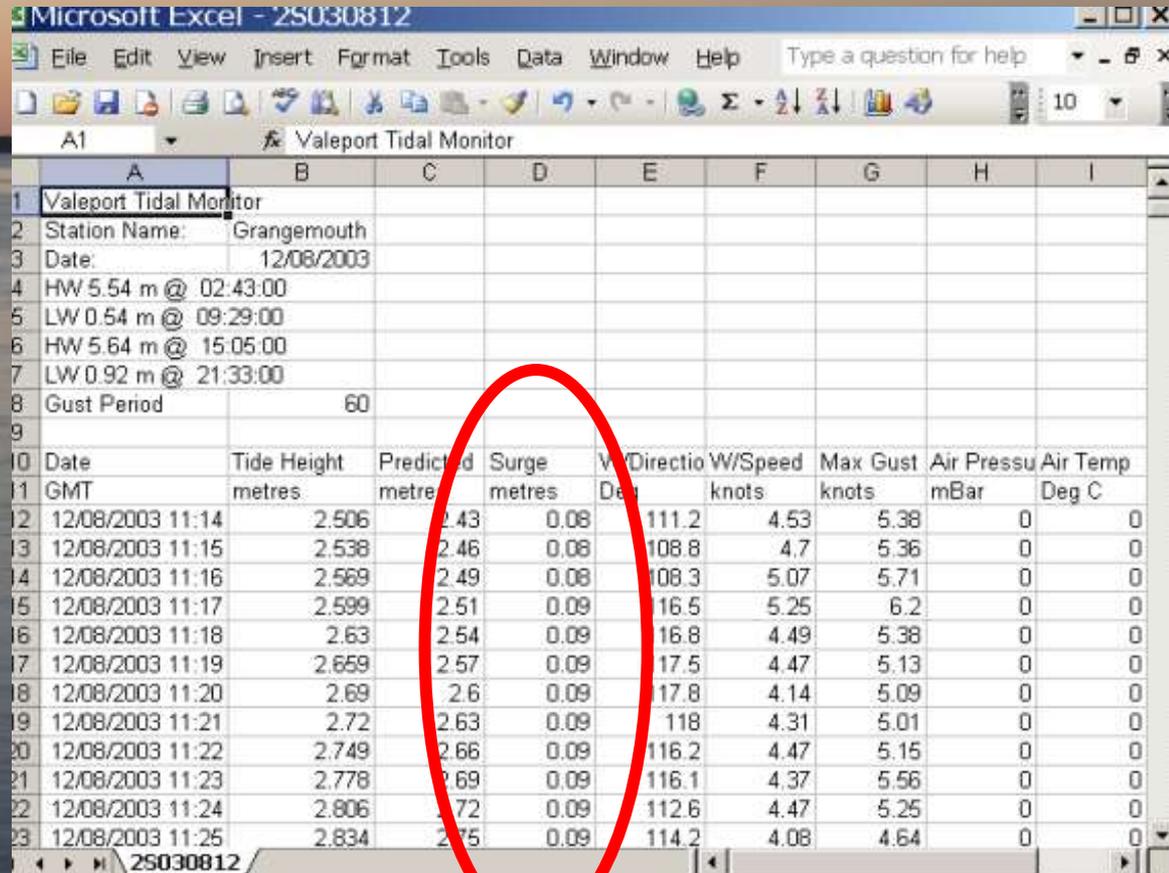


Maxima height at Grangemouth from Graff (1981) (circles) and Powell (2012) (diamonds).

Residual surge events (sea level heights above predicted levels)

Recent digital tide gauge data has calculated the minute-by-minute difference between projected sea heights and actual sea heights. This is known as 'residual'.

A surge can occur at any point of a tide, but can cause flooding at high tide.



Date	Tide Height	Predicted	Surge	Wind Directio	W/Speed	Max Gust	Air Pressu	Air Temp
GMT	metres	metres	metres	Dir	knots	knots	mBar	Deg C
12/08/2003 11:14	2.506	2.43	0.08	111.2	4.53	5.38	0	0
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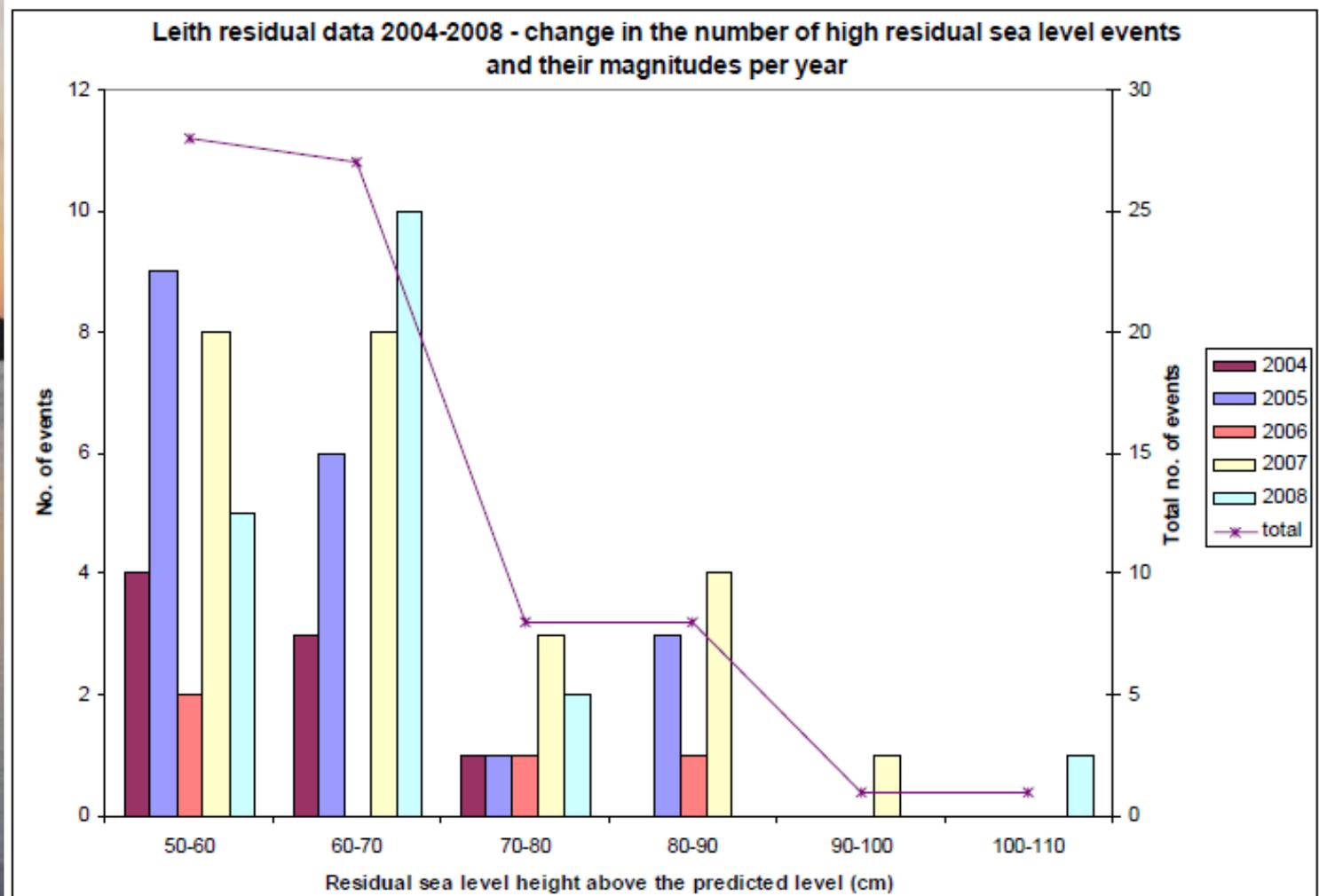
Highest Residual Heights across the Forth

Highest recorded residual sea surface heights (recorded during any point in the tidal cycle)

Date	Leith	Date	Grangemouth
01/03/2008	1.09	03/04/2006	2.06
08/11/2007	0.92	21/09/2005	1.99
20/01/2005	0.89	30/09/2003	1.76
08/11/2005	0.88	24/08/2005	1.70
12/01/2005	0.87	23/08/2005	1.67
Ave.:	0.93		1.84

Dundee, Leith and Grangemouth highest five residual tidal heights, 2003-2008 (Dundee and Grangemouth) / 2004-2008 (Leith) measured in metres above the predicted height.

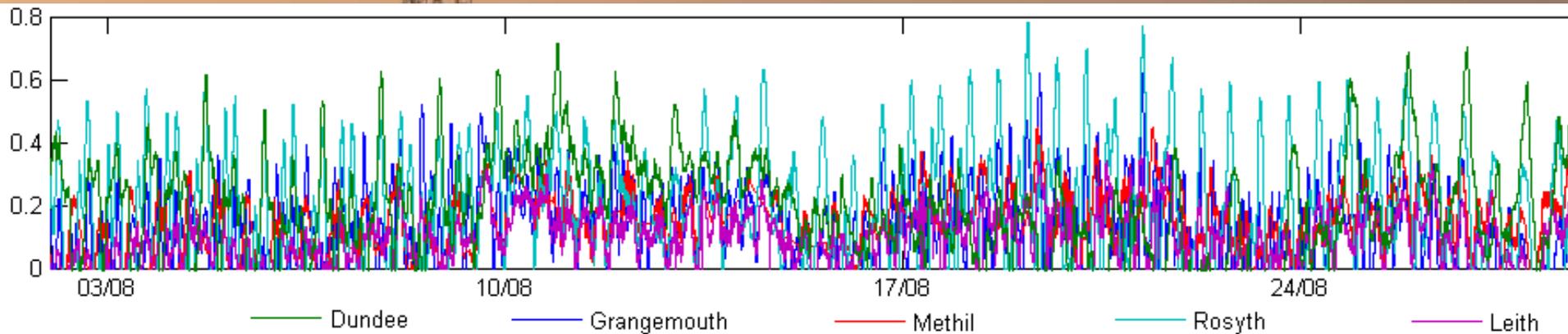
Residual surge events (sea level heights above predicted levels)



Leith residual data, 2004 to 2008. Variation in the number of high residual sea level events per year over 50 cm above the predicted tidal height.

Residual surge events (sea level heights above predicted levels)

Unlike Maxima data, Residual calculations rely on the accuracy of a tide prediction model...



Residual data from five tide gauges during a surge event in August 2004. Daily high tide predictions are underestimated at Rosyth and Dundee by 40-70cm during this period.

Maxima data are the preferred method, if predictions underestimate sea levels.

Conclusion

Historically, relative sea levels in the Forth & Tay Estuaries have risen on average by 3.6 cm since 1900.

Land rebound in the Forth Estuary has counteracted global sea level rise by between 0.9 and 1.2 mm per year.

In addition to sea level rise, surge events should also be accounted for when planning long-term coastal management adaptations.

... The study went on to project relative sea level change until 2100 and how this would relate to local quayside heights.

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