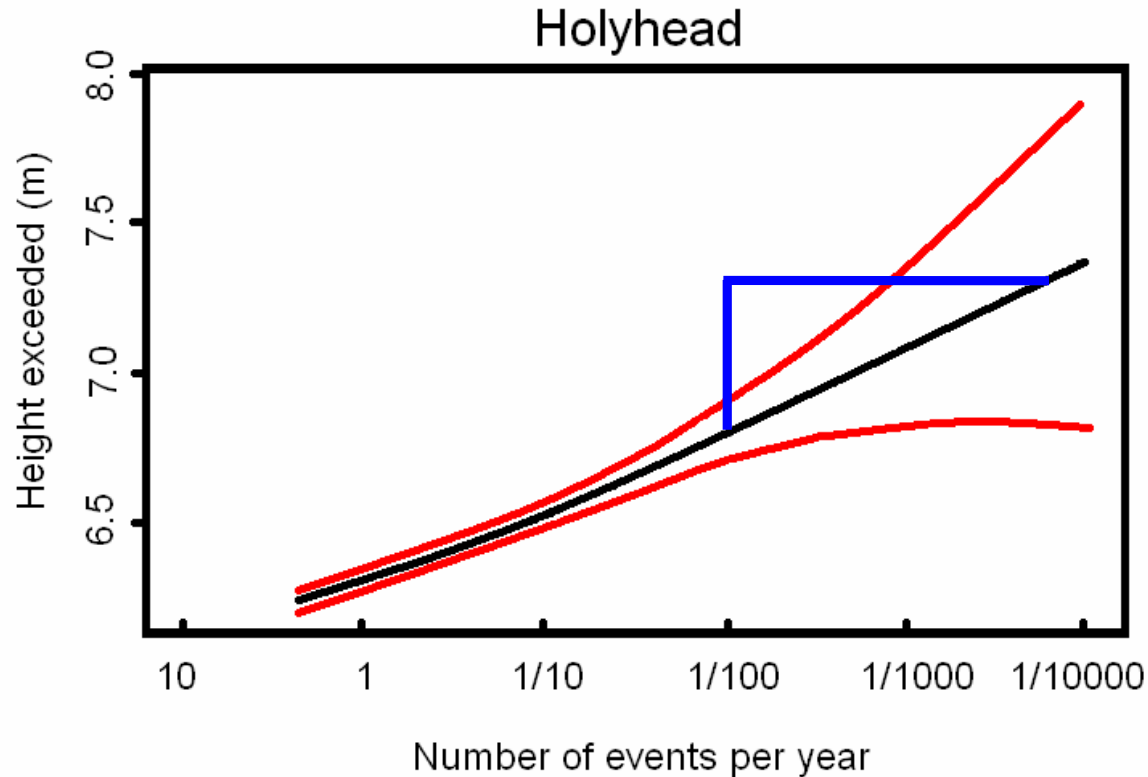


Sea Level Science

Global and local relevance

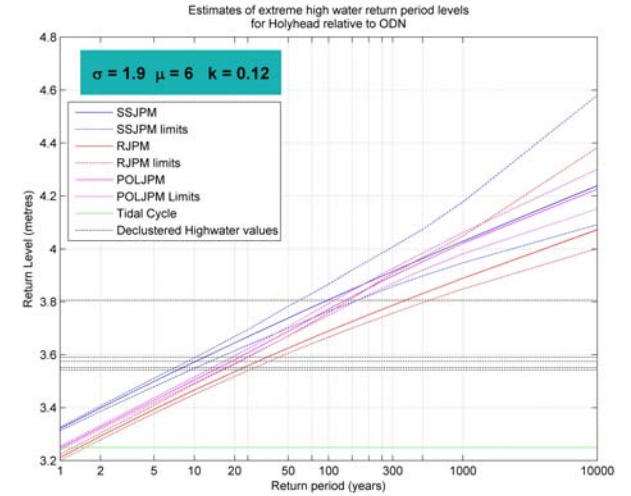
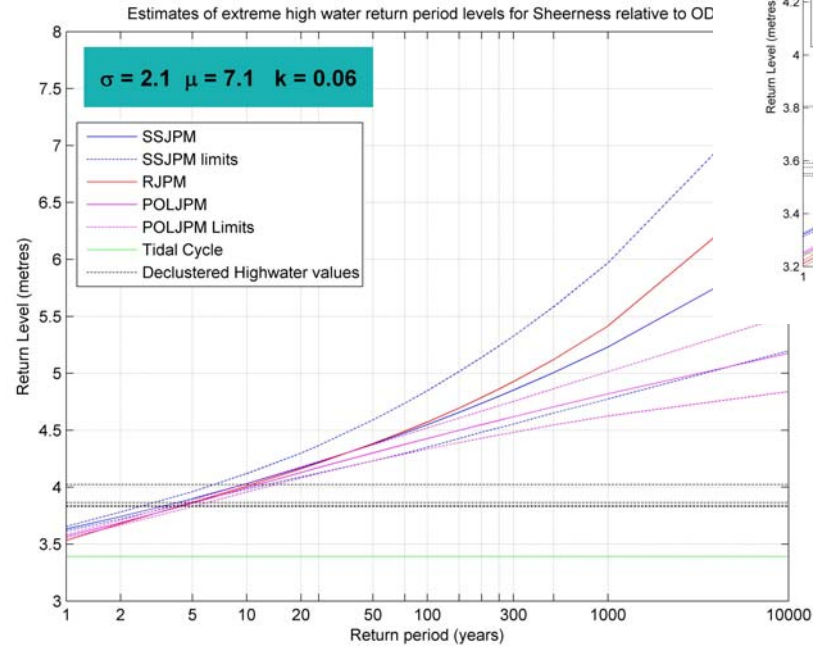
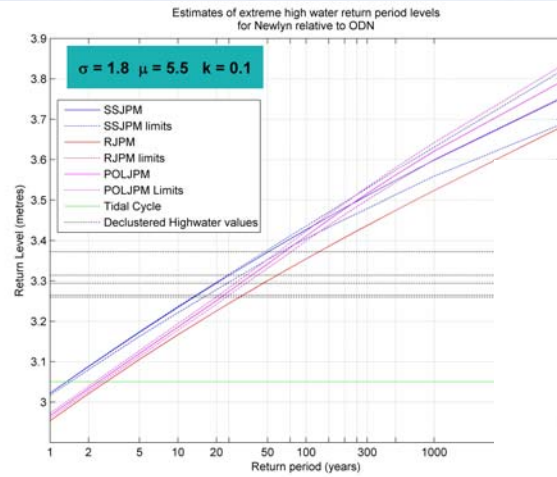
Chris W. Hughes (cwh@pol.ac.uk)
representing the POL Sea Level Group

How much does a small rise matter?



Small increases in mean sea level produce large increases in probability of extremes

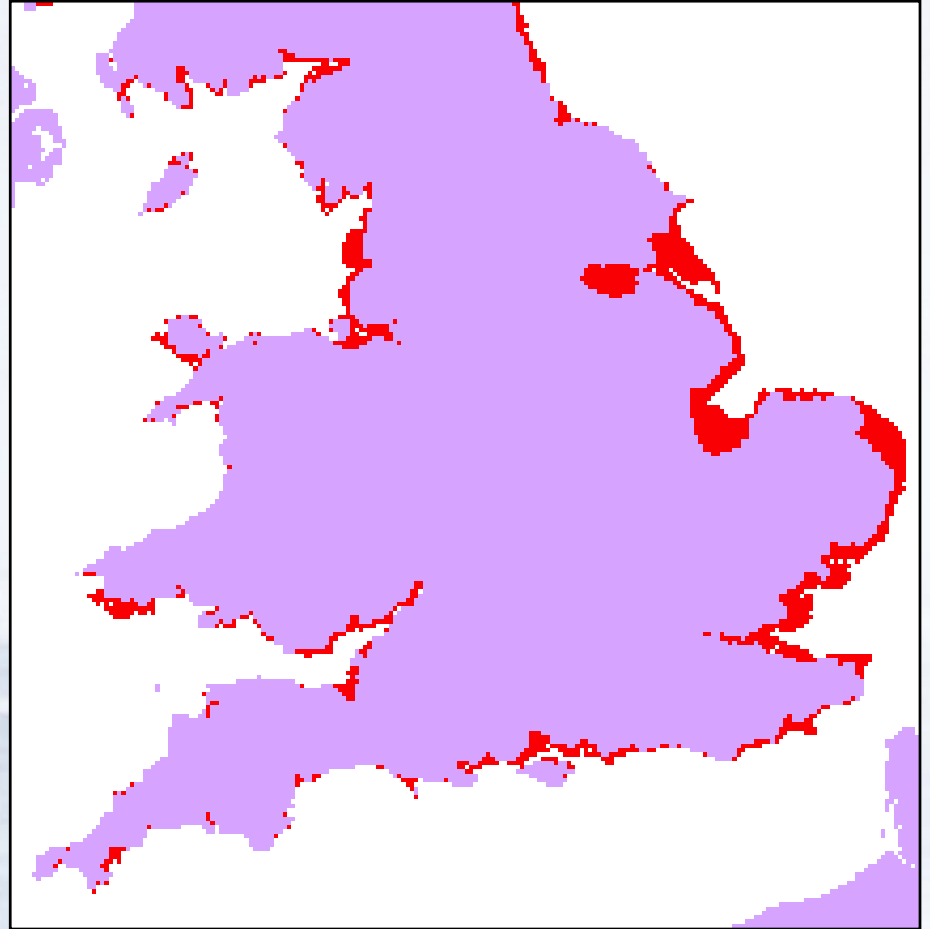
Coastal areas at risk



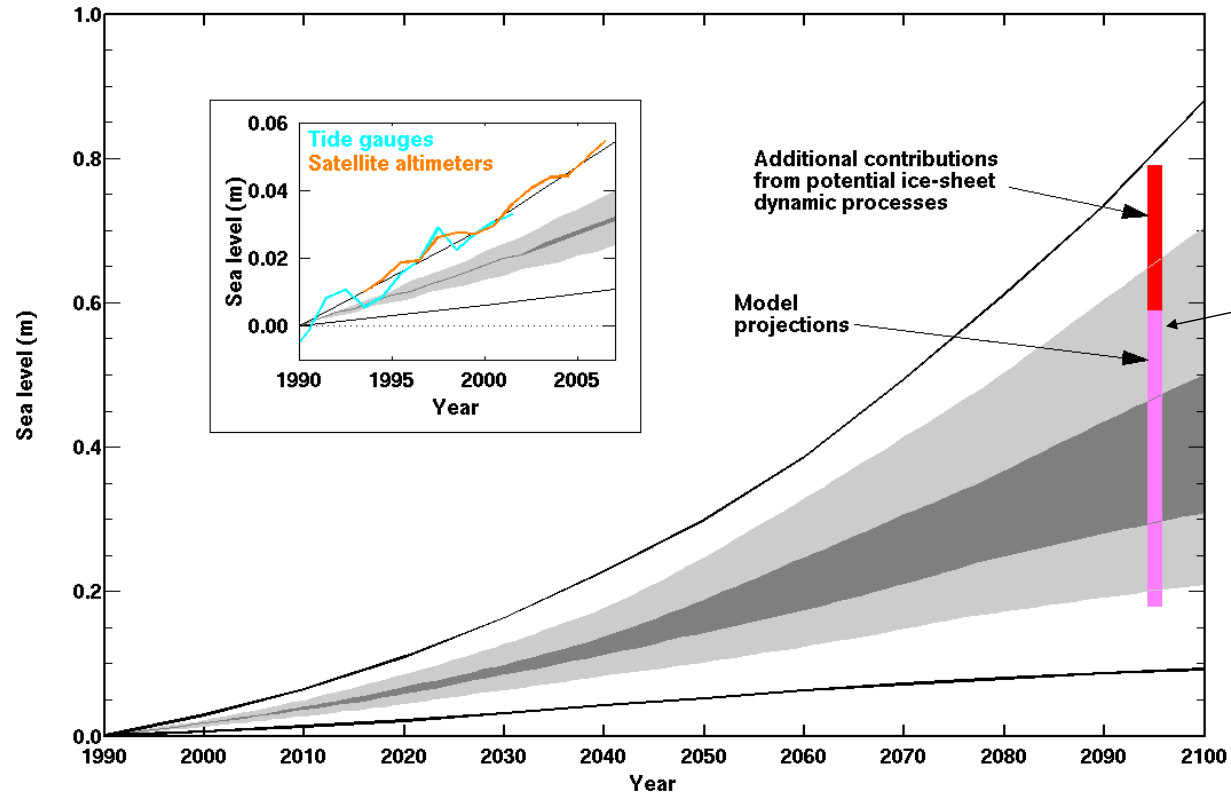
Different regions have different curves, but roughly...

Coastal areas at risk

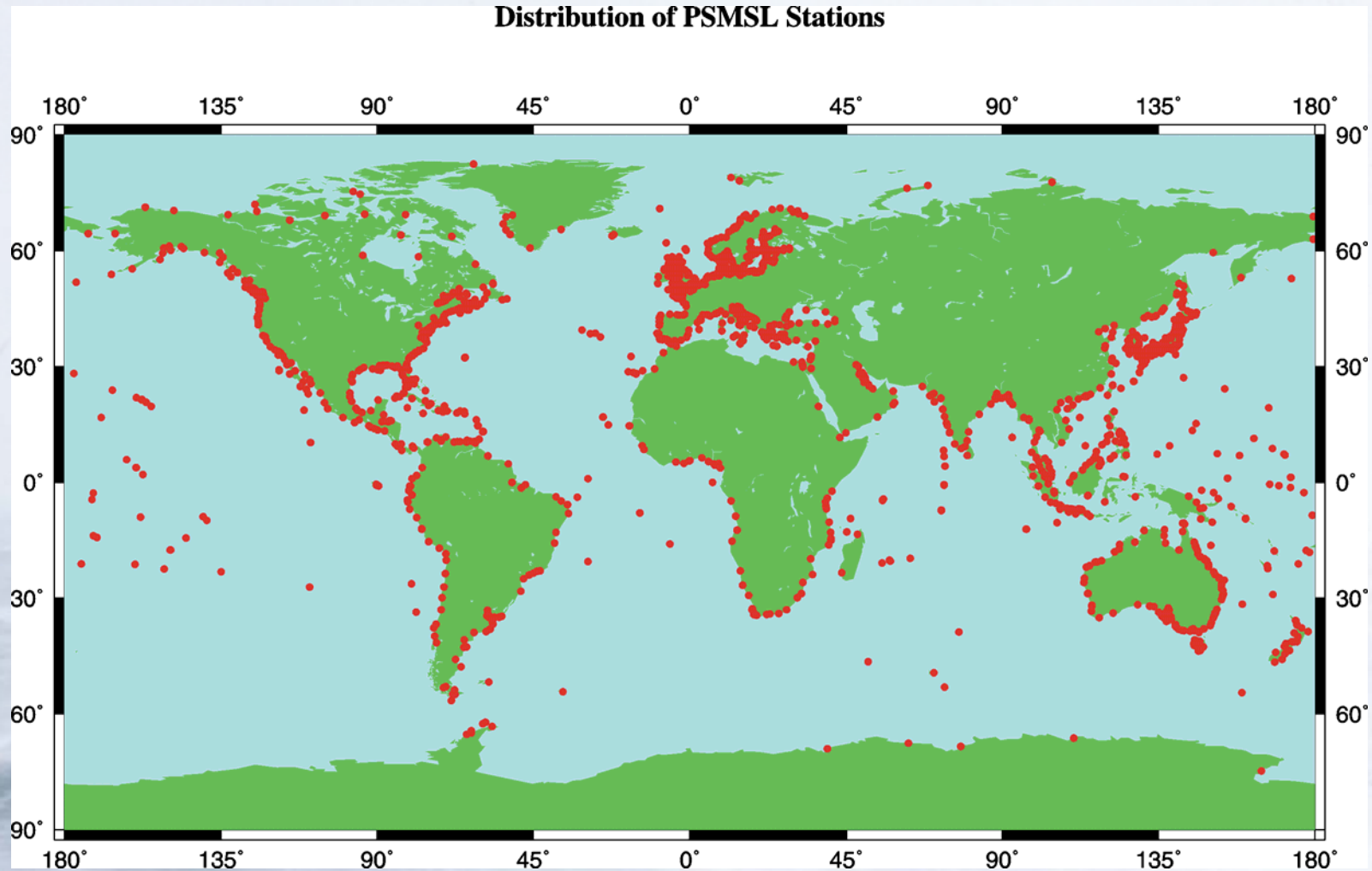
- If mean sea level was constant, red regions have a 1 in 1000 chance of flooding each year, **without appropriate coastal defences**
- By 2100: If mean sea level is 35 cm higher, this becomes about 1 in 100



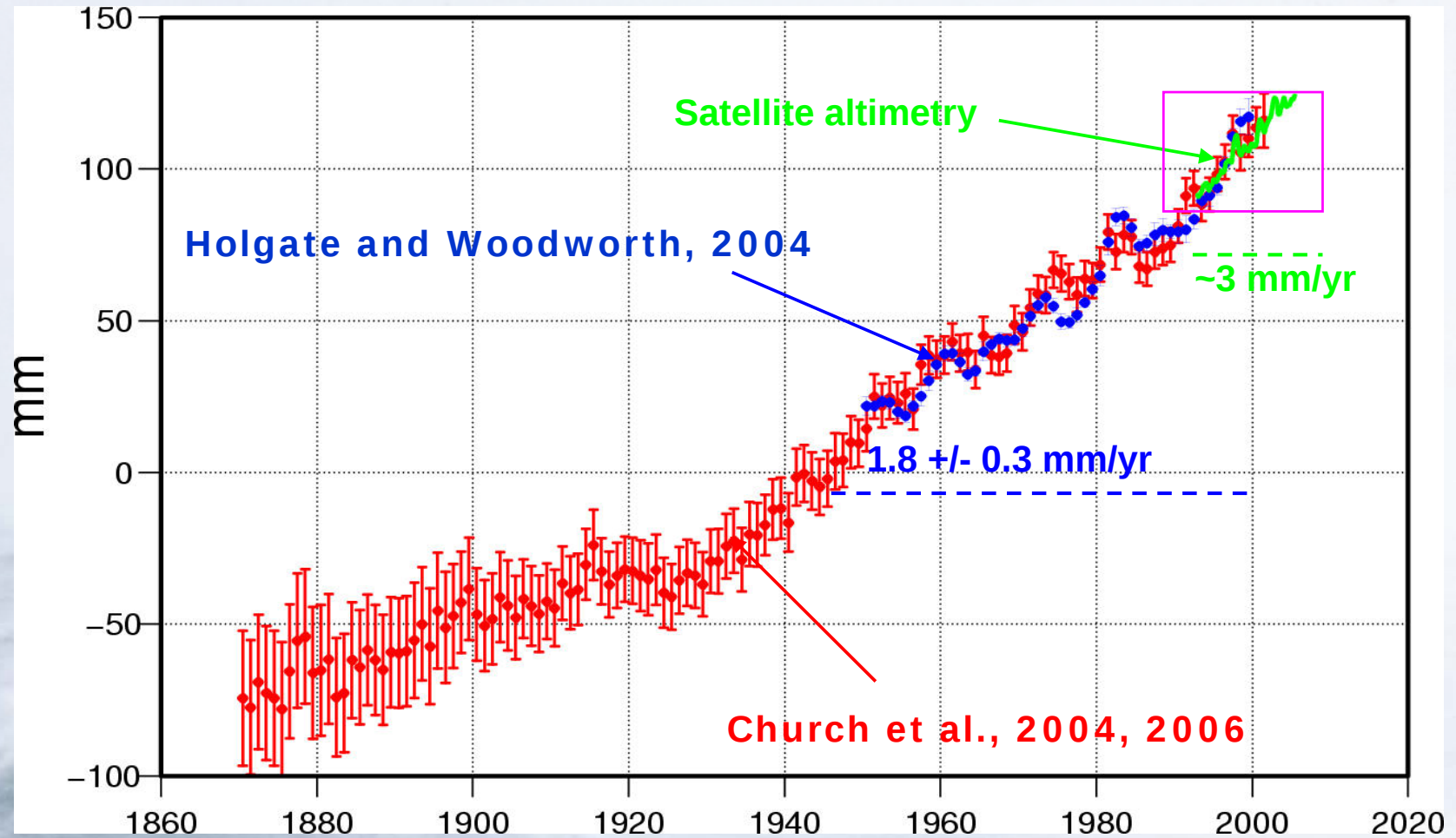
IPCC Projections



The Permanent Service for Mean Sea Level



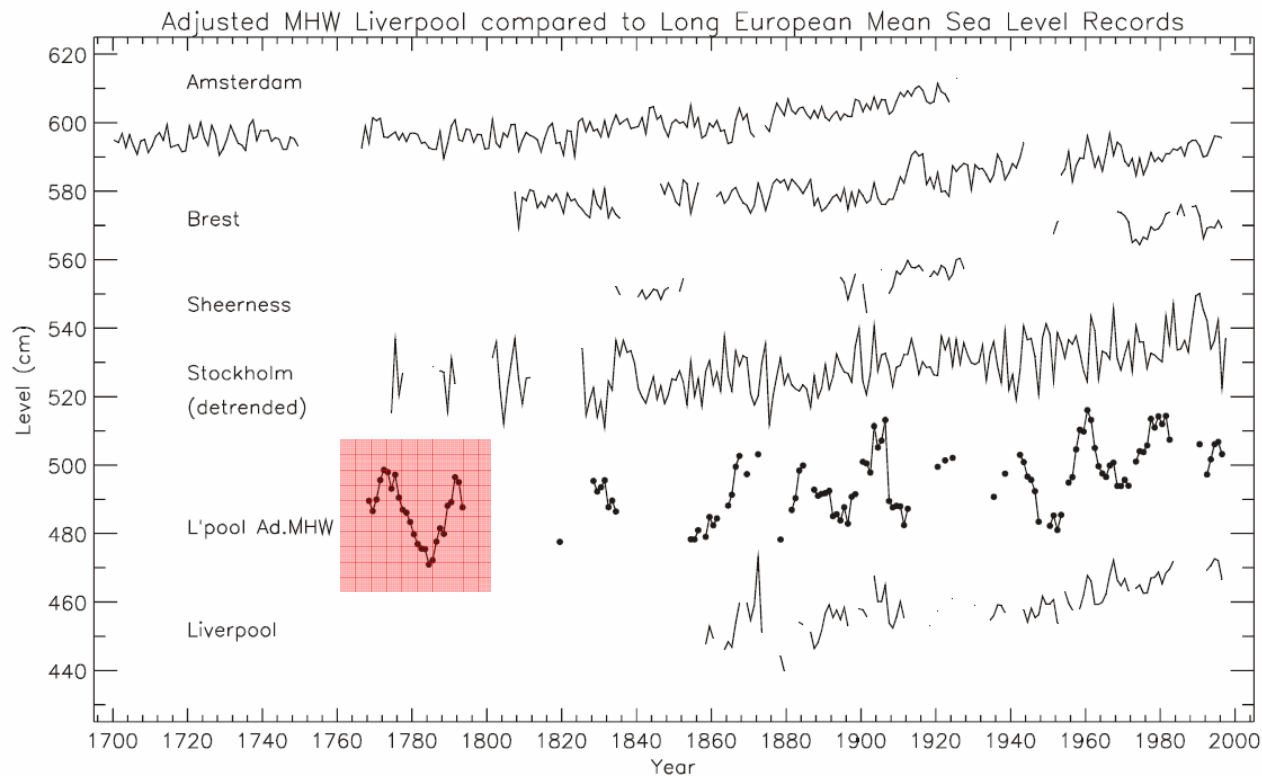
Measurements



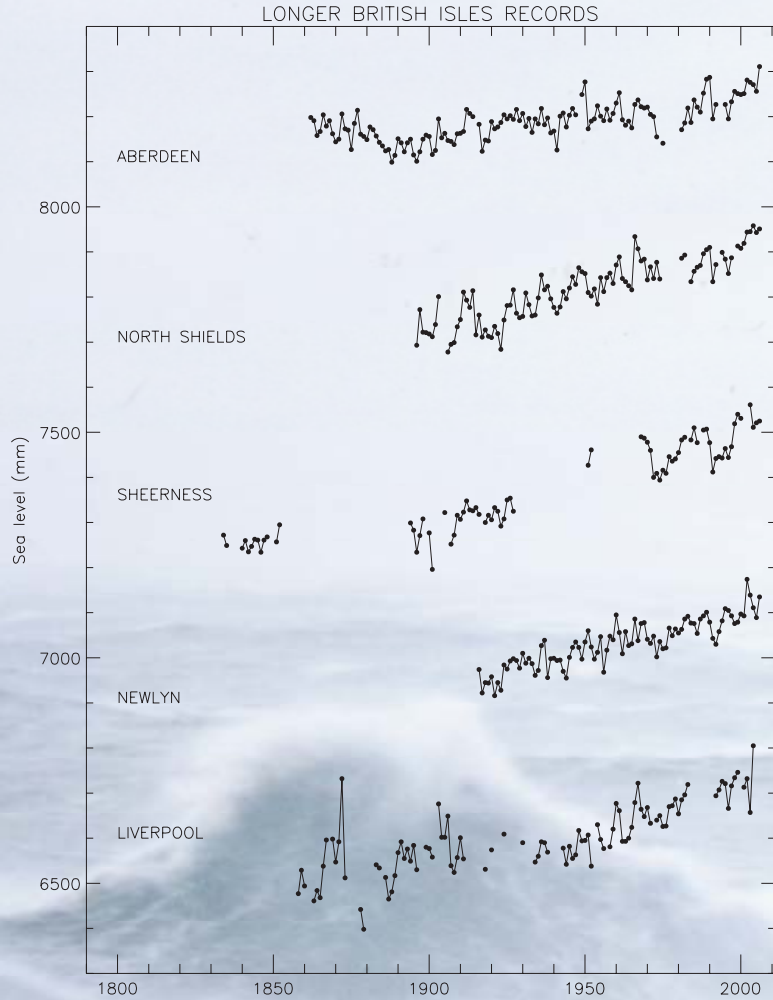
William Hutchinson



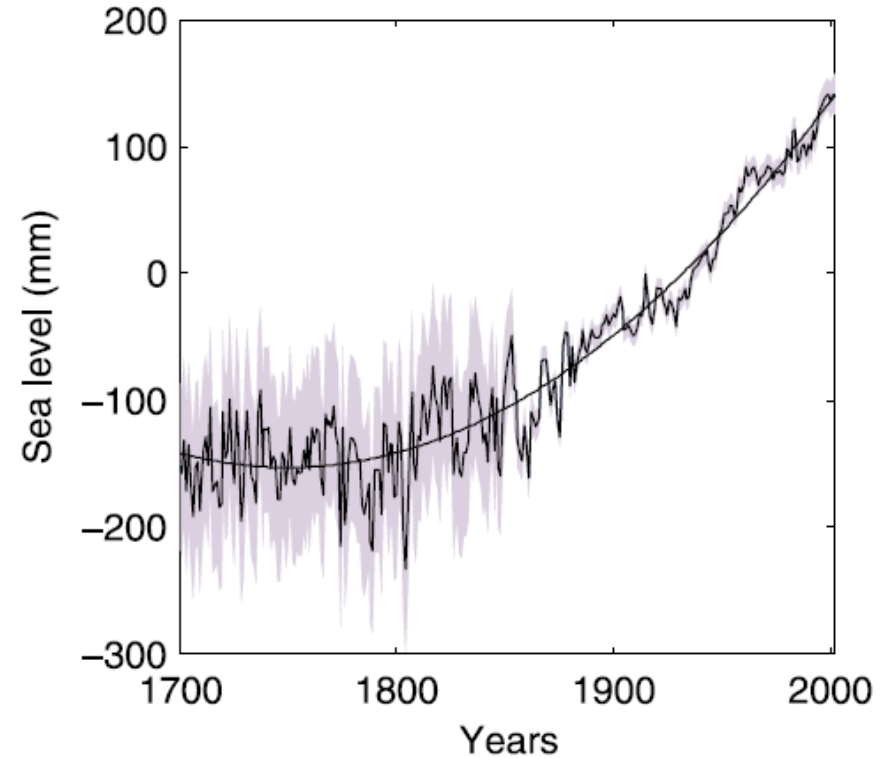
1771.	Moon's Age, Apogee, &c.	MORNING,				EVENING,				NOON,	
		Time of High Water.	Height of the Tides.	Tides differ in Minutes.	Wind and its Velocity.	Time of High Water.	Height of the Tides.	Tides differ in Minutes.	Wind and its Velocity.	Barometer.	Thermomet.
February		H. m. F. I.				H. m. F. I.					
Friday, 1	16	11 55	22.0	20	40. 30	40 high water			W. 30	29.80	50
Saturday, 2	17	0 25	21.7	30	40. 30	0.40	21.10	15	W. 30 to 10	29.95	48
Sunday, 3	18	1 10	21.2	30	40. 30	1.30	20.2	20	W. 30 to 10	30.25	51
Monday, 4	19	2 00	20.9	30	40. 30	2.20	19.10	25	S.E. 5	30.30	51
Tuesday, 5	20	2 50	20.6	30	40. 30	3.10	18.0	30	S.E. 7	30.30	50
Wednesday, 6	21	3 40	20.3	30	40. 30	4.00	16.50	35	S.E. 10	30.30	50
Thursday, 7	22	4 30	20.0	30	40. 30	4.50	15.40	40	S.E. 10	30.30	47
Friday, 8	23	5 20	19.7	30	40. 30	5.40	14.30	45	E. 20	30.30	42
Saturday, 9	24	6 10	19.4	30	40. 30	6.30	13.20	50	N.E. 15	30.44	41
Sunday, 10	25	7 00	19.1	30	40. 30	7.20	12.10	55	E.N.E. 10	30.20	43
Monday, 11	26	7 50	18.8	30	40. 30	8.10	11.00	60	N.E. 7	29.80	42
Tuesday, 12	27	8 40	18.5	30	40. 30	9.00	10.00	65	N.E. 7	29.70	42
Wednesday, 13	28	9 30	18.2	30	40. 30	9.50	9.00	70	S.E. 15	29.85	40
Thursday, 14	29	10 20	17.9	30	40. 30	10.40	8.00	75	S.E. 10	29.70	40
Friday, 15	30	11 10	17.6	30	40. 30	11.30	7.00	80	S.E. 20	29.85	43
Saturday, 16	1	12 00	17.3	30	40. 30	12.20	6.00	85	S.E. 10	29.83	43
Sunday, 17	2	12 50	17.0	30	40. 30	1.10	5.00	90	S.E. 10	30.20	49
Monday, 18	3	1 40	16.7	30	40. 30	2.00	4.00	95	S.E. 5	30.50	50
Tuesday, 19	4	2 30	16.4	30	40. 30	2.50	3.00	100	S.E. 20	30.3	55
Wednesday, 20	5	3 20	16.1	30	40. 30	3.40	2.00	105	S.E. 10	30.10	48
Thursday, 21	6	4 10	15.8	30	40. 30	4.30	1.00	110	Northly Light	30.0	52
Friday, 22	7	5 00	15.5	30	40. 30	5.20	0.00	115	Northly Light	29.97	51
Saturday, 23	8	5 50	15.2	30	40. 30	6.10	0.00	120	S.E. 5	29.80	52
Sunday, 24	9	6 40	14.9	30	40. 30	7.00	0.00	125	S.E. 15	29.82	56
Monday, 25	10	7 30	14.6	30	40. 30	7.50	0.00	130	S.E. 20 to 6	29.35	56
Tuesday, 26	11	8 20	14.3	30	40. 30	8.40	0.00	135	S.W. to S.E. 5	29.90	56
Wednesday, 27	12	9 10	14.0	30	40. 30	9.30	0.00	140	S.E. 5	29.90	55
Thursday, 28	13	10 00	13.7	30	40. 30	10.20	0.00	145			
Friday, 29	14	10 50	13.4	30	40. 30	11.10	0.00	150			
Saturday, 30	15	11 40	13.1	30	40. 30	12.00	0.00	155			



Measurements



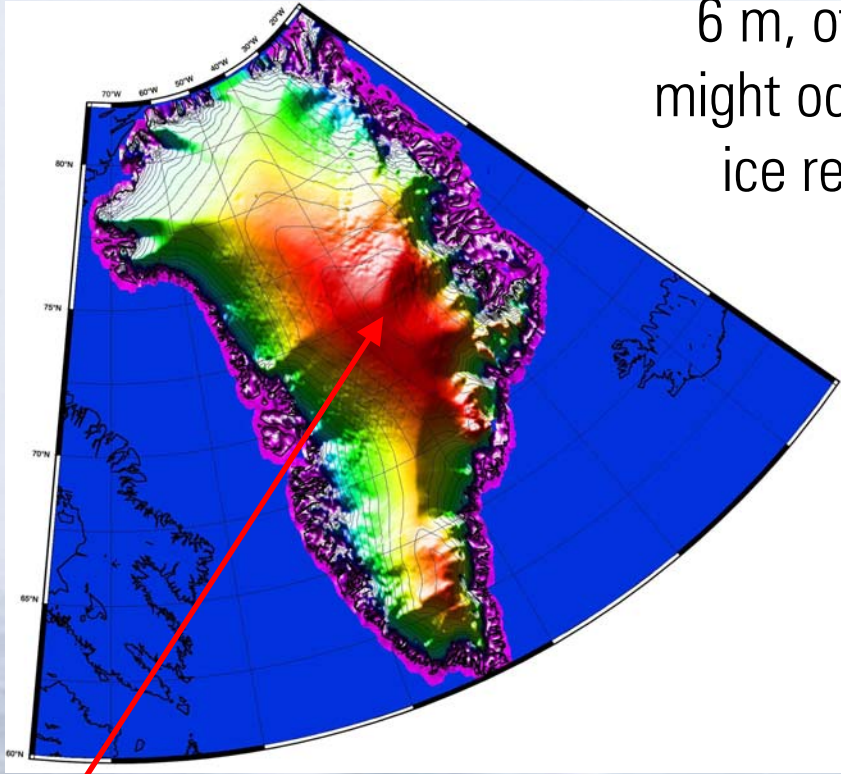
Global average from tide gauges



Causes of sea level change 1: Vertical land movement

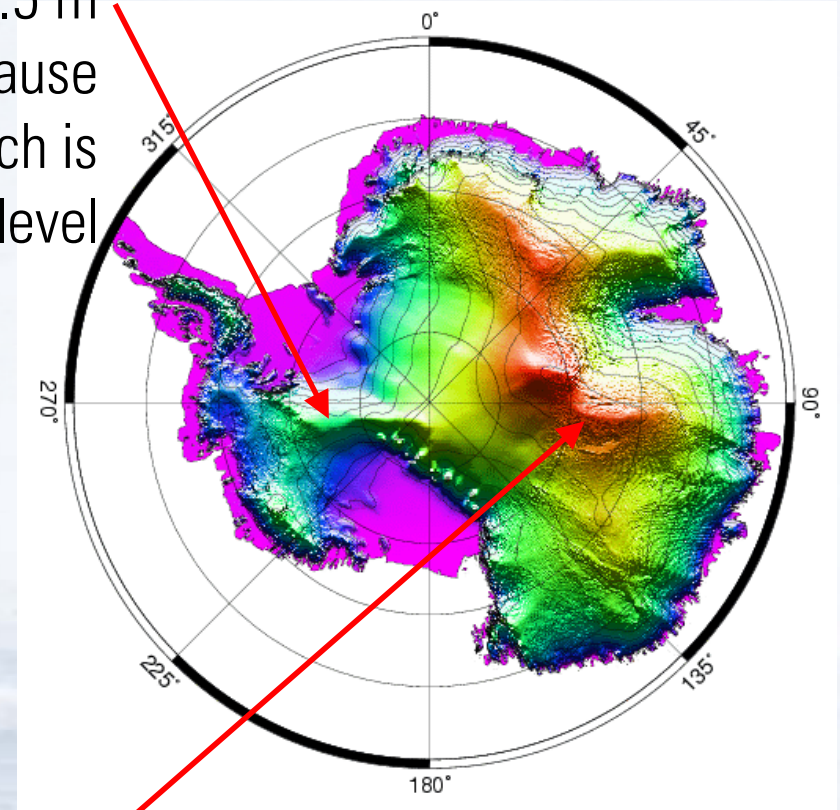


Causes of sea level change 2: Melting land ice



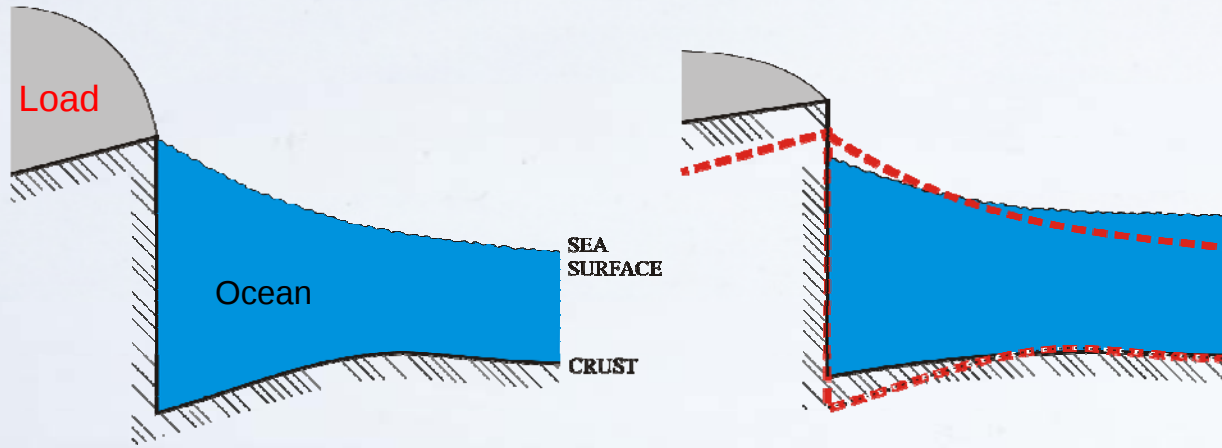
6 m, of which about 3.5 m might occur quickly because ice rests on land which is below sea level

6 m. Expected to melt completely (slowly) if global temperature rises by $\sim 3^{\circ}\text{C}$



55 m, but slow and uncertain change

Load Changes

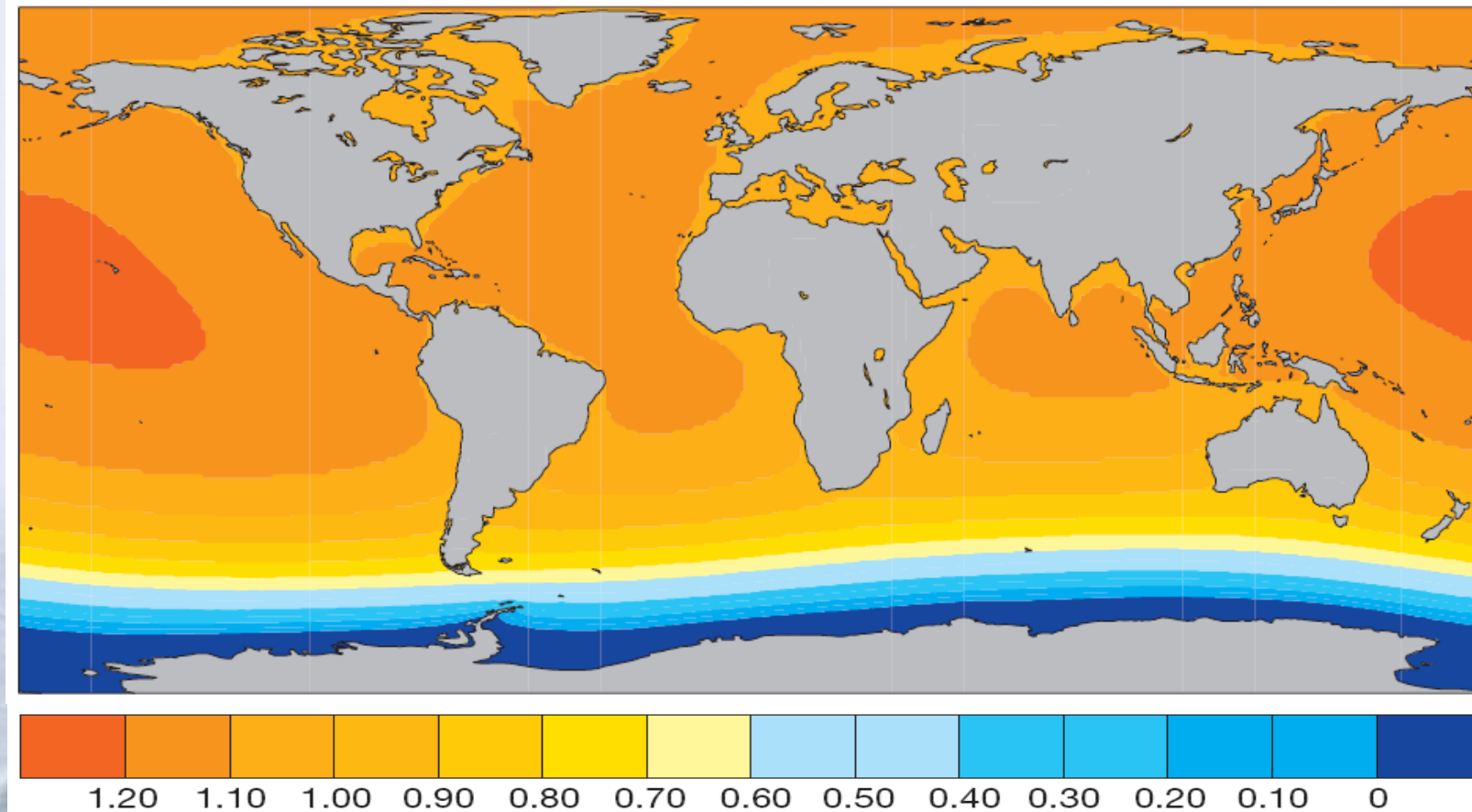


Ice sheet melts
-- or --
River basin loses water

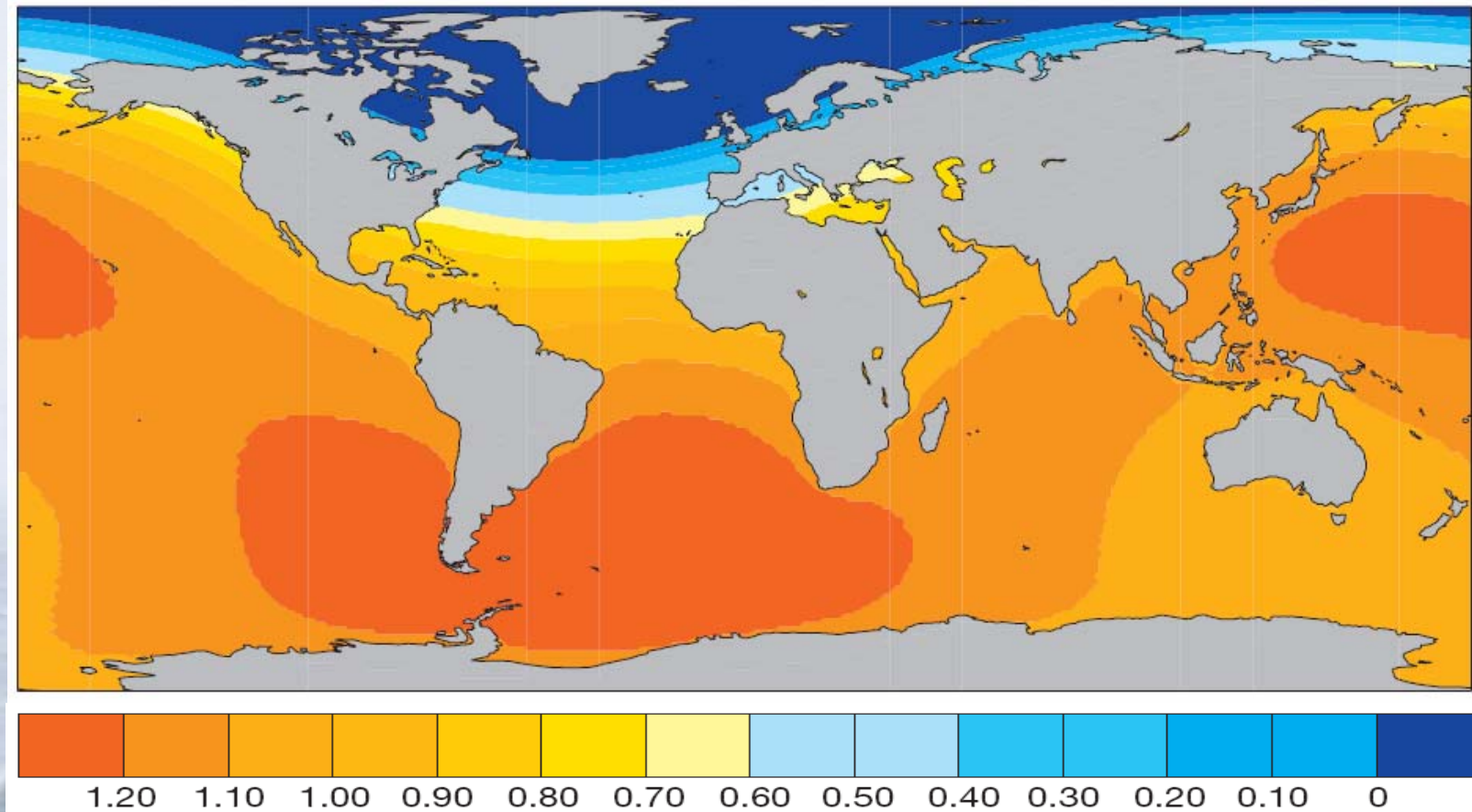


- More water in ocean
- Crust and sea surface adjust to the changing mass load

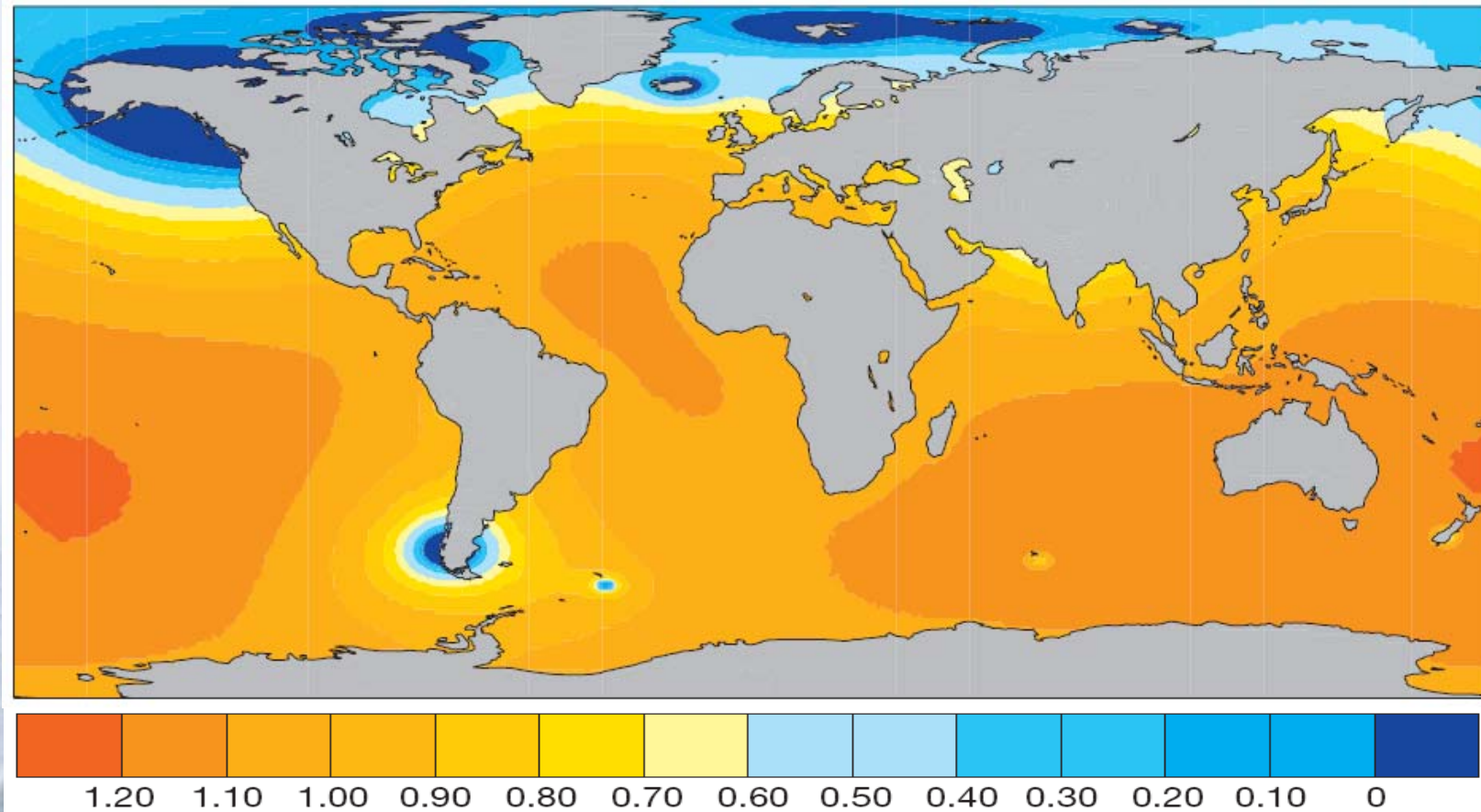
Pattern of sea level rise due to Antarctic melt



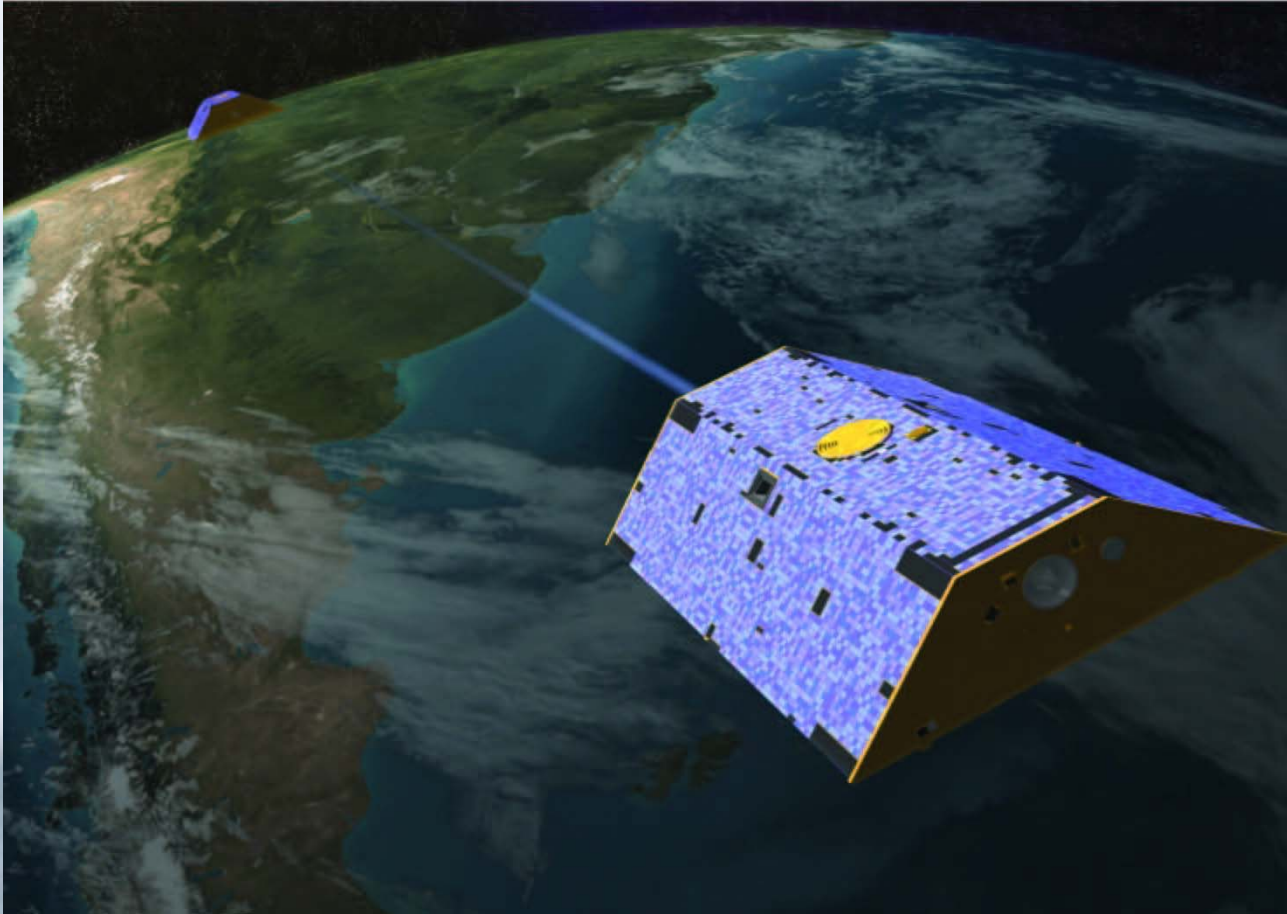
Pattern of sea level rise due to Greenland melt



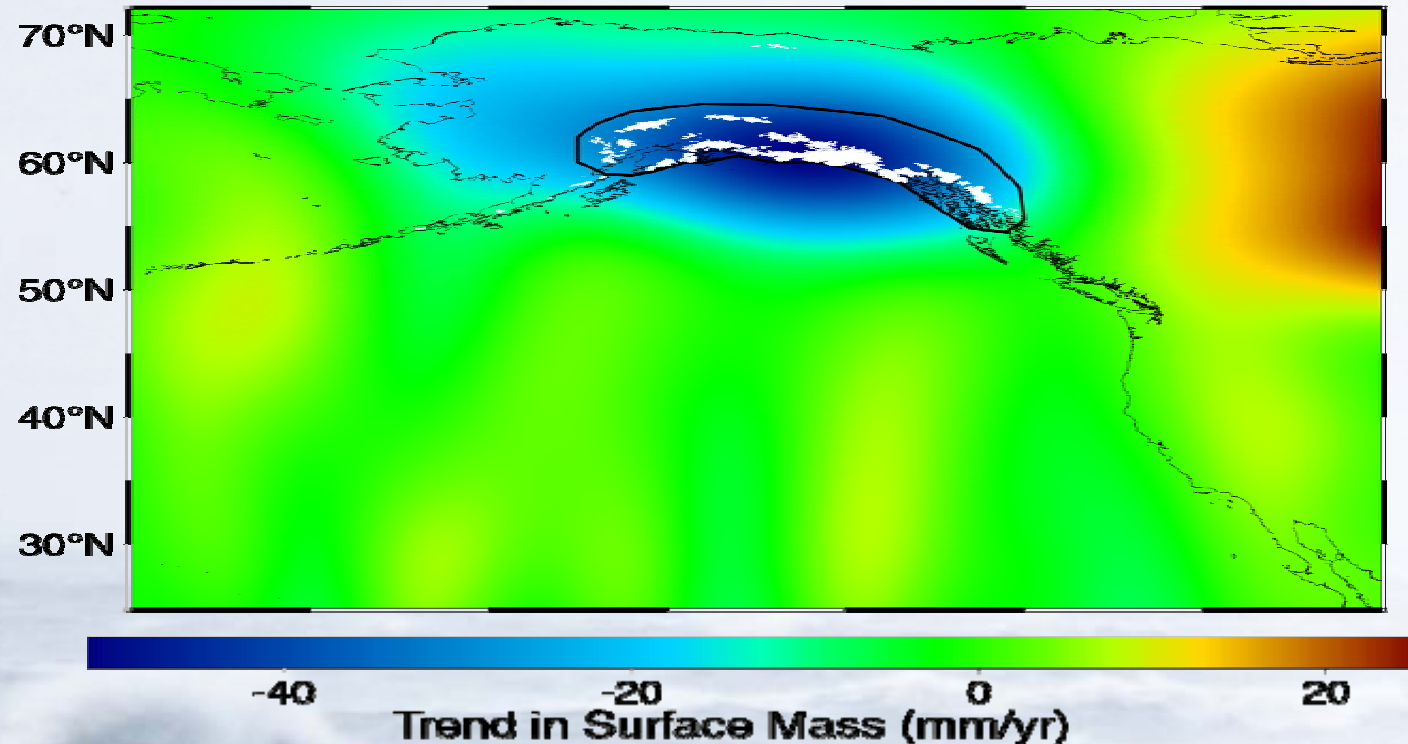
Pattern of sea level rise due to Glacier melt



GRACE – launched March 2002



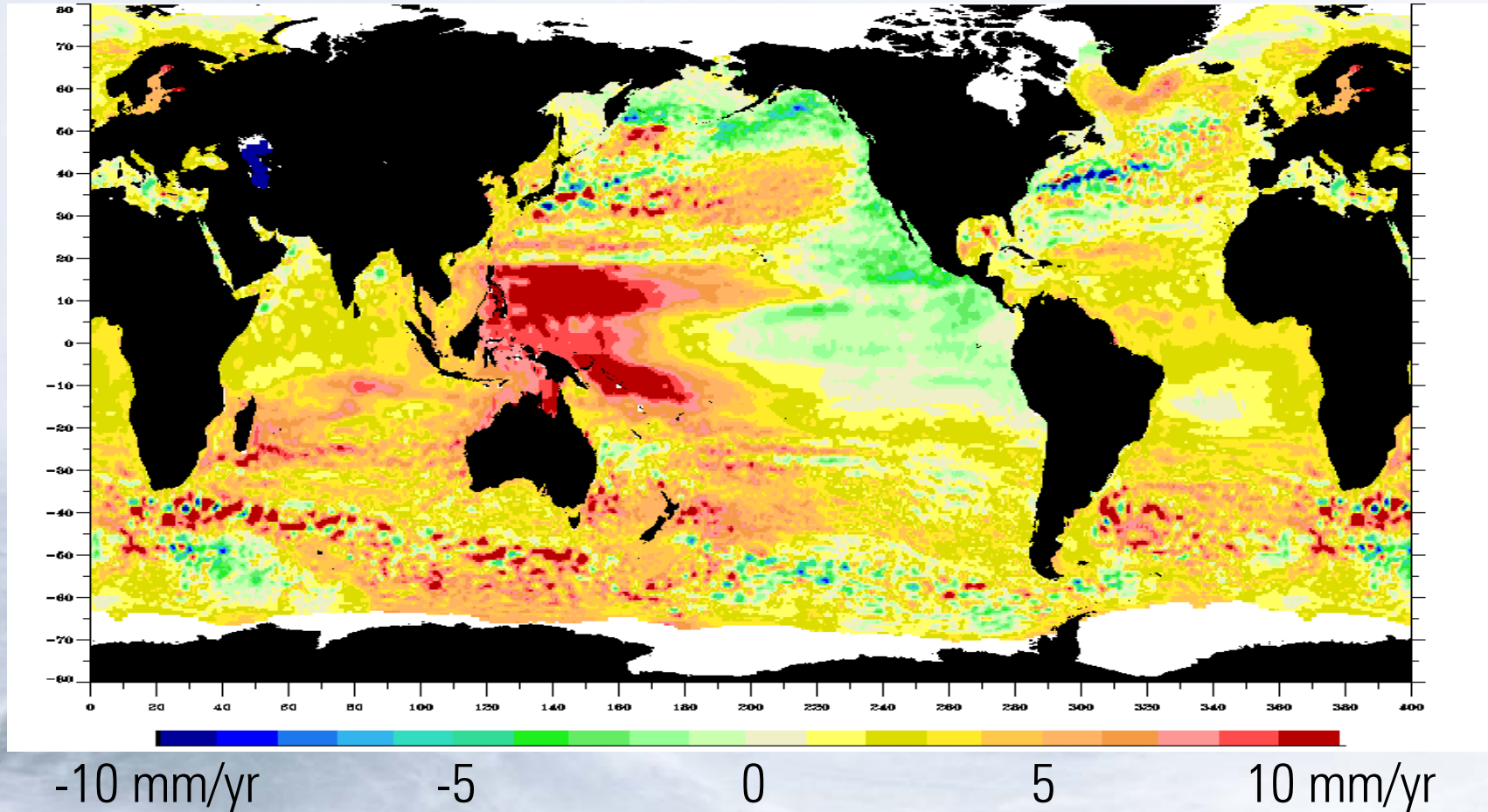
GRACE – melting Alaskan glaciers



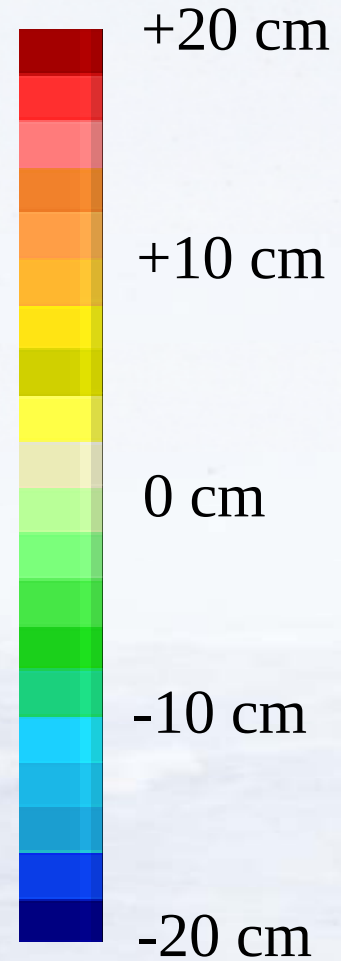
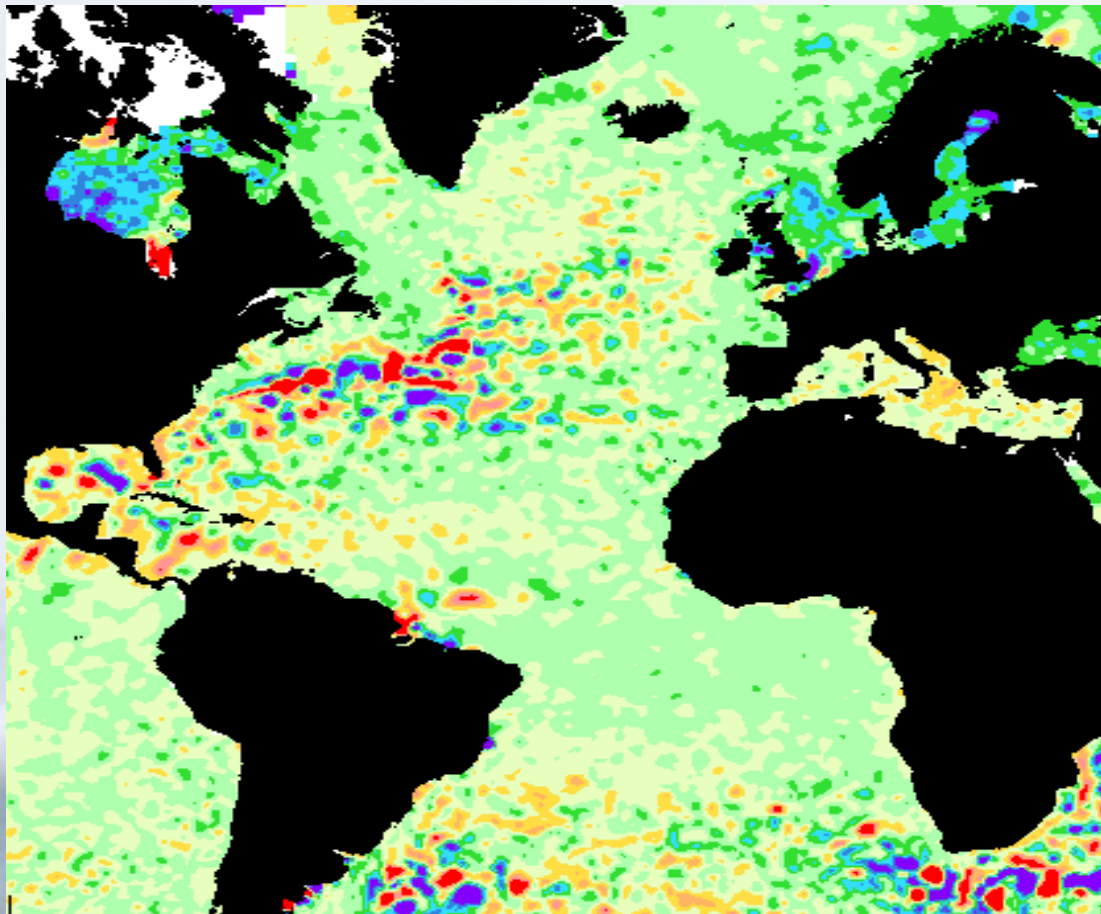
Rate of mass loss from Alaskan glaciers calculated from satellite gravity measurements

Causes of sea level change 3: Ocean dynamics

Trend between Jan 1993 and Feb 2009



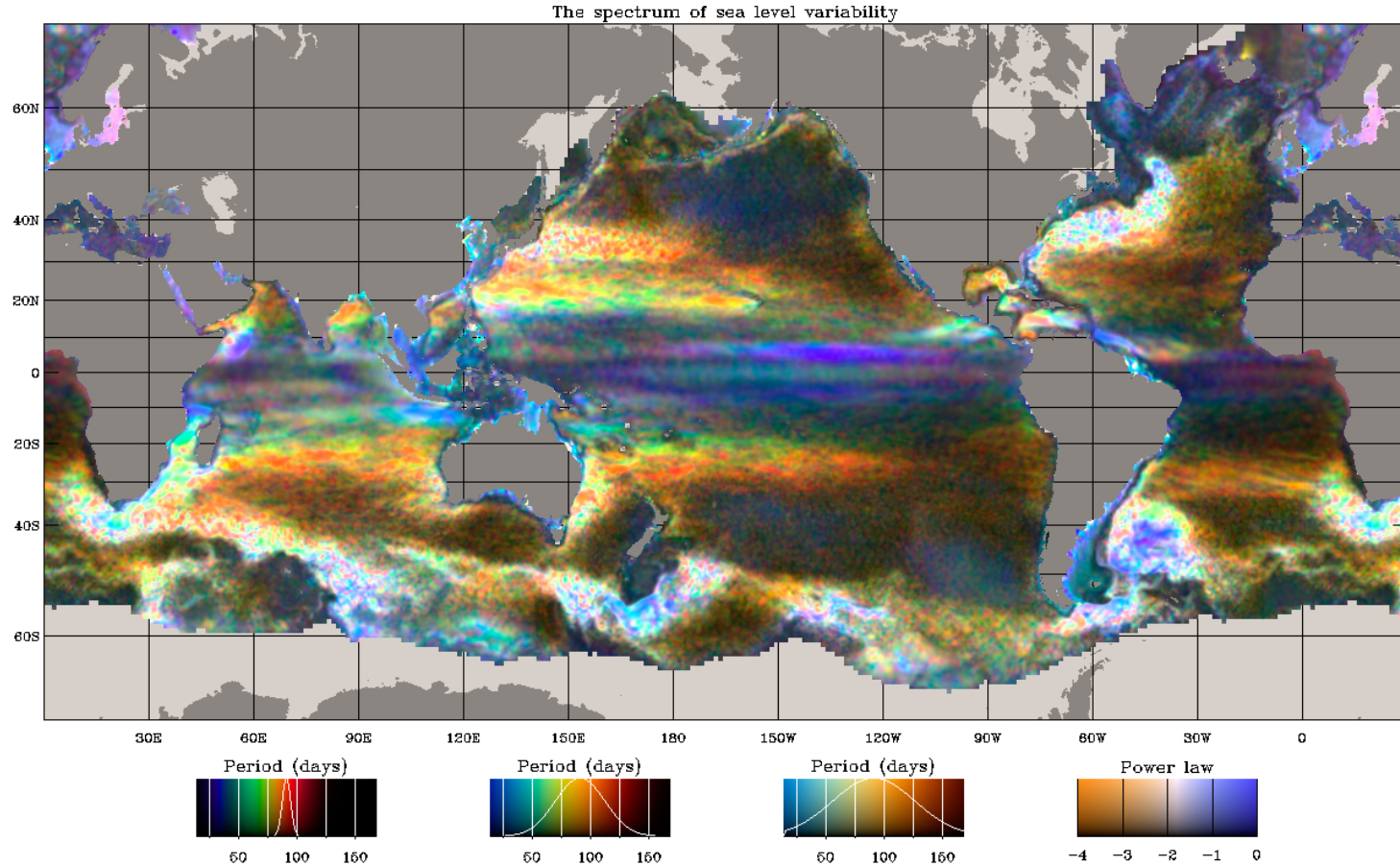
Sea level from ocean dynamics



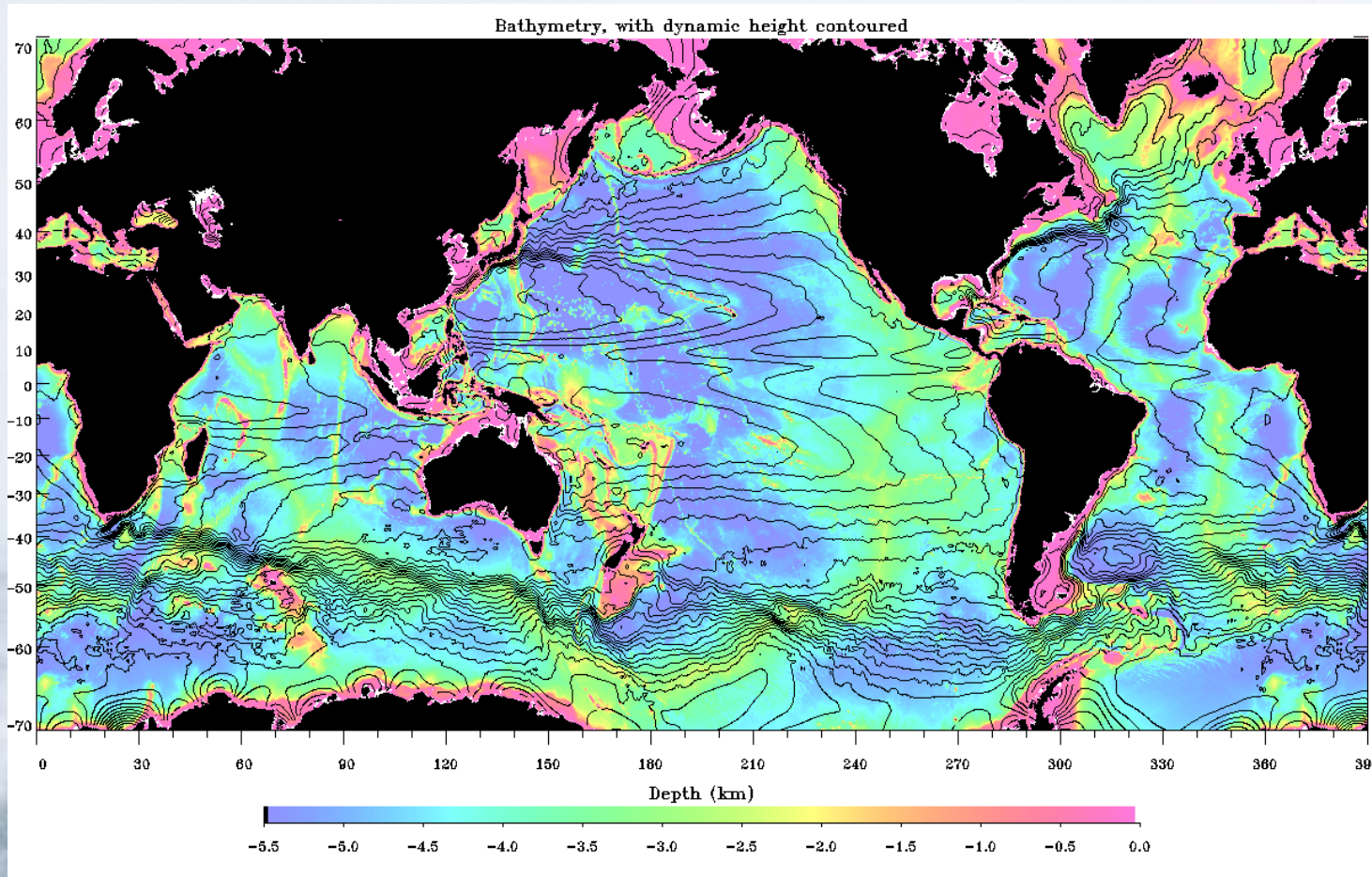
1992

2002

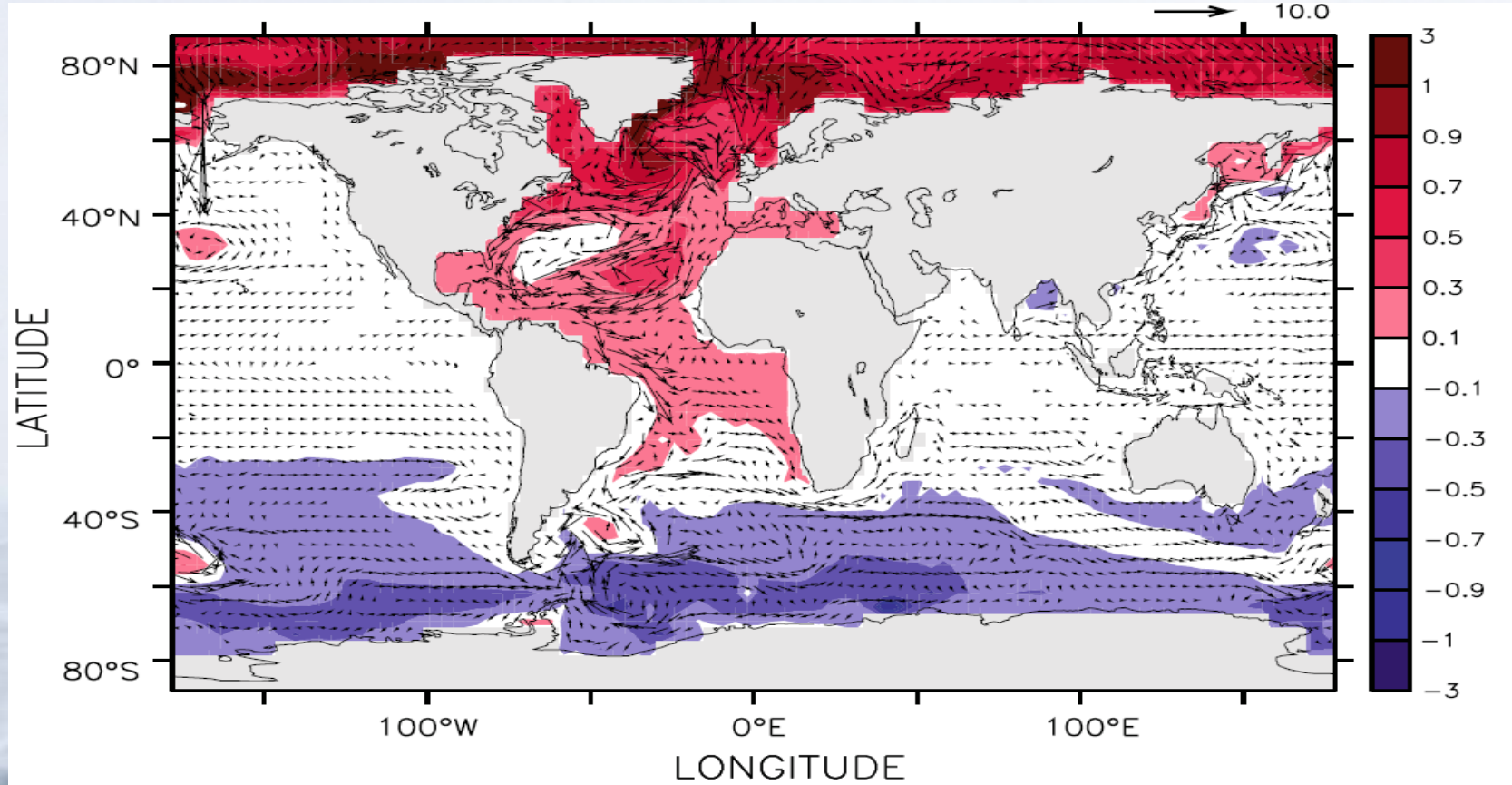
Different frequencies of sea level variability



Sea level from ocean dynamics

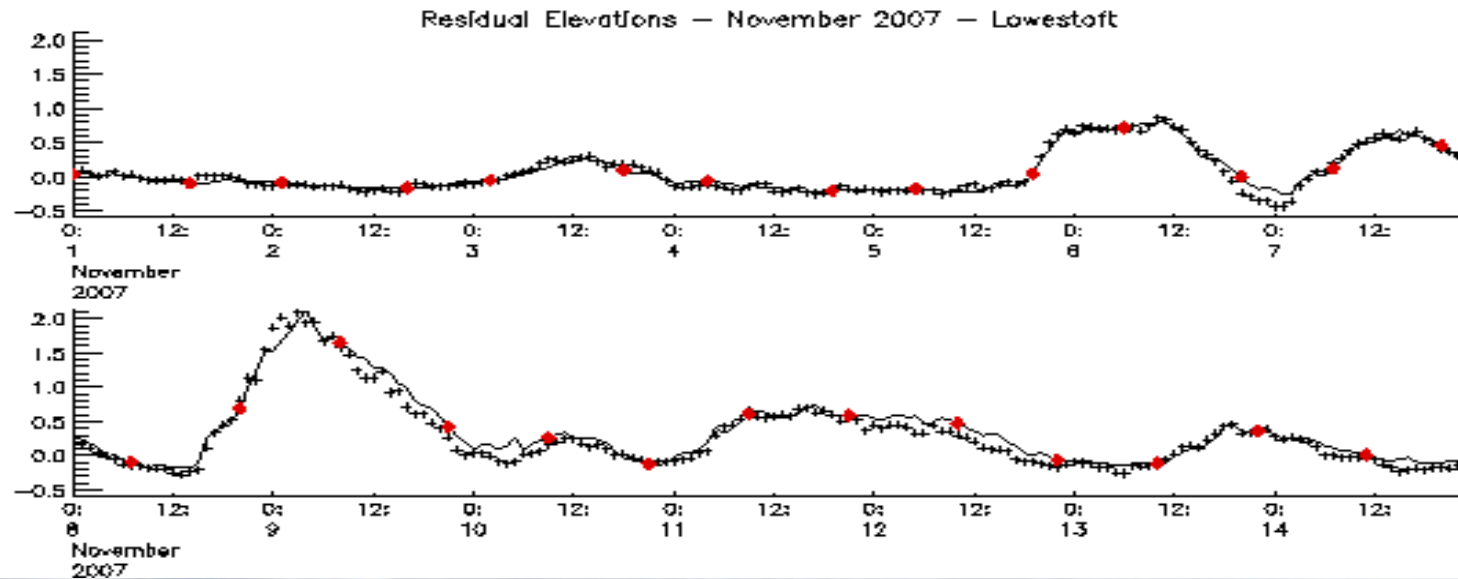


Effect of a shift in large-scale ocean circulation



Leverman 2005: Dynamical sea level change (metres) following THC collapse.

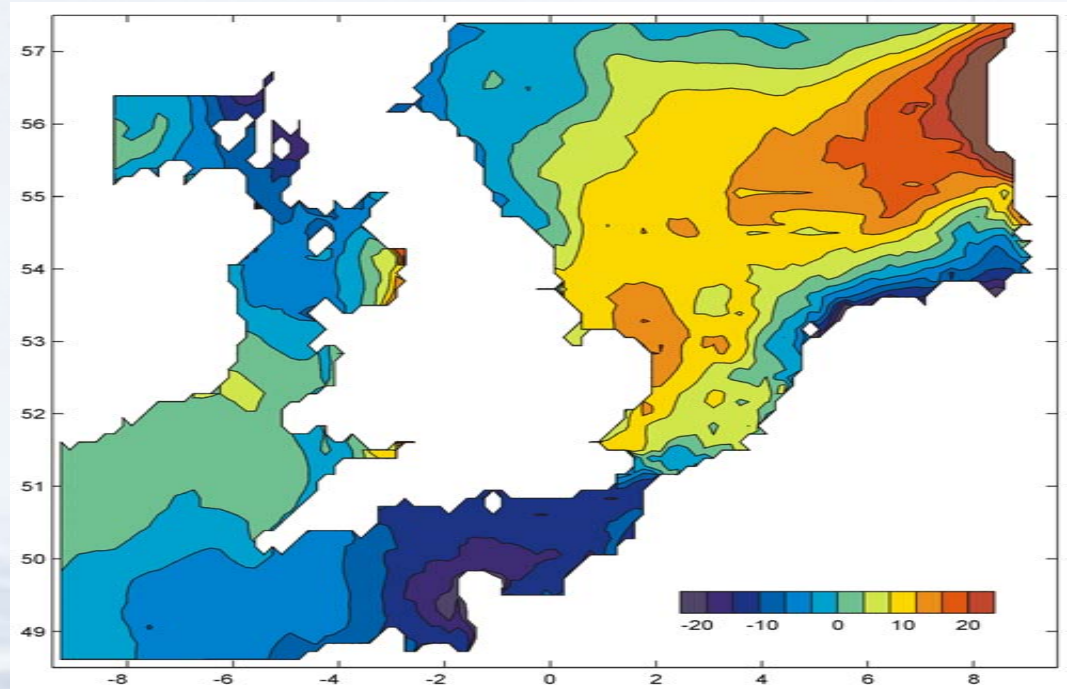
Surges – effect of the local wind and pressure



Extreme storm surge

One example of a prediction of how the 50-year surge (local weather-driven sea level) will change by 2100.

Using weather from different climate models produces different patterns, but similar amplitudes.



Conclusions

- Sea level is rising, and will continue to do so, probably at an increasing rate.
- Mean sea level around the UK will increase by between about 20cm and 1.5 metres by 2100, depending on ocean currents and ice melt.
- Patterns of storminess may also change, though this is very uncertain.
- This will mean that coastal flooding events will increase in frequency by a factor of about 10, perhaps much more.

Thank you for your attention

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