

International Underwriting Association Catastrophe  
Modelling 2010

## Climate and Sea Level Change

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### This paper will:

- Review the record of sea level changes which have taken place across the Earth since the end of the last glaciation, about 11700 years ago
- Examine likely changes in global sea levels in the foreseeable future
- Discuss the possible impacts of forecast sea level changes

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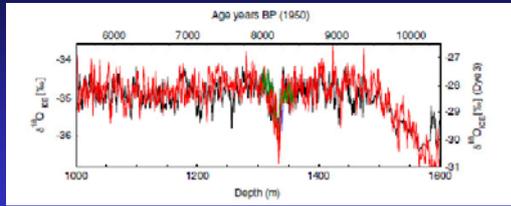
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After Thomas et al., 2002

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Event no.	Name	Original Reference	Possible source	Possible Date, cal. BP	Published Volume, km <sup>3</sup>
1	MWP 1B	Fairbanks, 1989	Lake Agassiz; Baltic Ice Lake; Ross Ice Shelf; Lake Fraser.	10750 – 11,500	Lake Agassiz 9,300; Baltic Ice Lake 5,900. Total at least 15,200, (Nesje et al., 2004)
2	R 1	Nesje et al., 2004	Lake Agassiz; Nedre Glamsjø Lake; Ancylus Lake.	10,000 – 10,500	Lake Agassiz episodes of 7,000, 3,700, 2,100; Nedre Glamsjø Lake 120. Total at least 12,920.
3	MWP 1C	Liu et al., 2004a	Lake Agassiz.	9,200 – 10,000	Lake Agassiz episodes of 1,600, 2,300, 1,600. Total 15,500.
4		Barber et al., 1999	Lake Agassiz.	8,470	Possibly two episodes of 113,100 and 49,900. Total 163,000.
5	MWP 1D	Liu et al., 2004a	Antarctica; Labrador sector of Laurentide Ice Sheet.	7,200 – 7,800	Not known.

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Event	Timing, cal. BP	Details, ages cal. BP	Area occupied
Sunda Shelf and Torres Strait flood	Completed ca. 7,000	Many straits and channels open (see below).	Over 1.8M km <sup>2</sup>
Bering Strait opens	11,000-12,000	Widespread sedimentation across the shelf, including in the Chukchi Sea, largely terminating at ca. 7,000.	Continental Shelf around the Bering Strait, > 0.4M km <sup>2</sup> .
Strait of Dover opens	8,000-8,600	S. North Sea, including "Doggerland" flooded.	~120,000km <sup>2</sup>
Arrival of saline waters into Black Sea	9,300	Most of the surrounding shelf flooded by 7,000.	~400,000km <sup>2</sup>
Öresund Strait opens, Anzylus lake becomes brackish ( <i>Mastogloia</i> Sea)	9,200	<i>Litorina</i> Sea established by ca. 8500; maximum flooding reached ca. 7,000.	~400,000km <sup>2</sup>
Arabian Gulf flooded	Second maximum rate of RSL rise begins ca. 11,000.	Maximum flooding reached ca. 7,000.	~400,000km <sup>2</sup>
Yellow Sea coastline reached	Ca. 7,500		Continental Shelf of Yellow Sea and Bohai Gulf, >0.7M km <sup>2</sup> .

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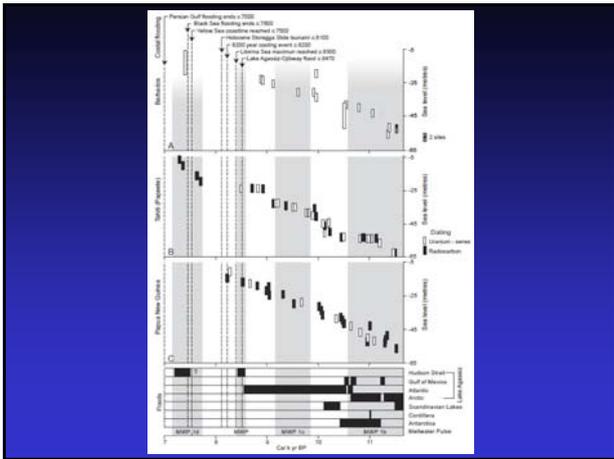
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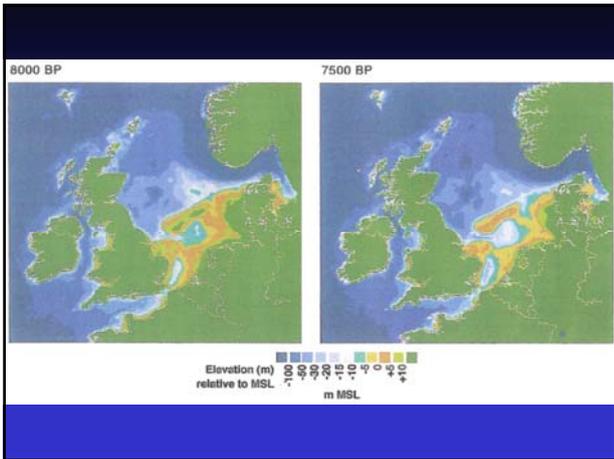
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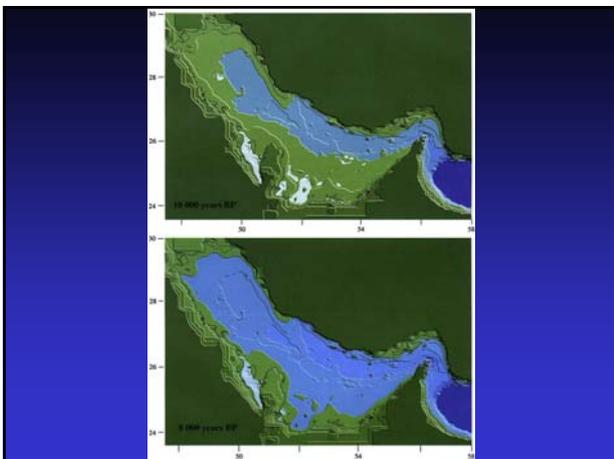
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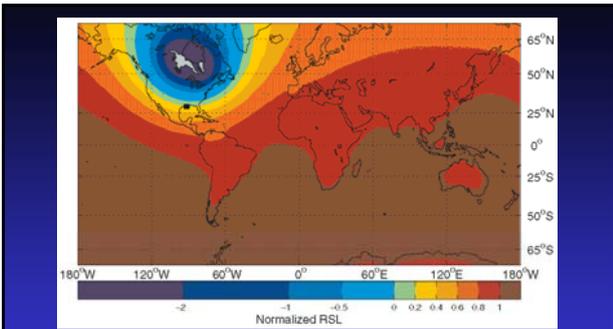
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Numerically predicted sea-level fingerprint due to the catastrophic drainage of Lake Agassiz-Ojibway at 8.4 ka, normalized by the eustatic rise (0.4 m). The blue contours show the zone of predicted sea-level fall; the remaining contours, from green to dark red, are regions of progressively higher sea-level rise. The black square

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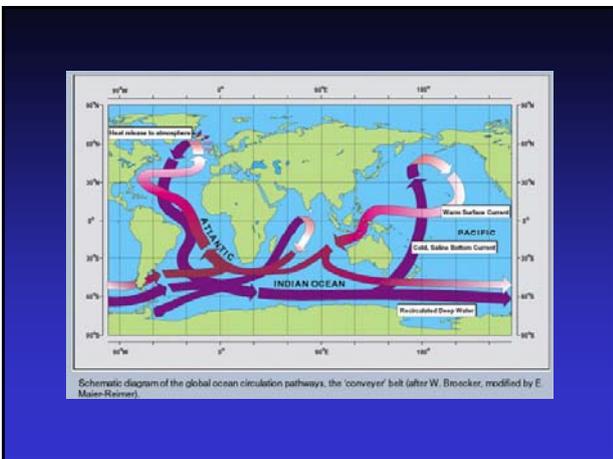
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Schematic diagram of the global ocean circulation pathways, the 'conveyor' belt (after W. Broecker, modified by E. Manabe-Riemer)

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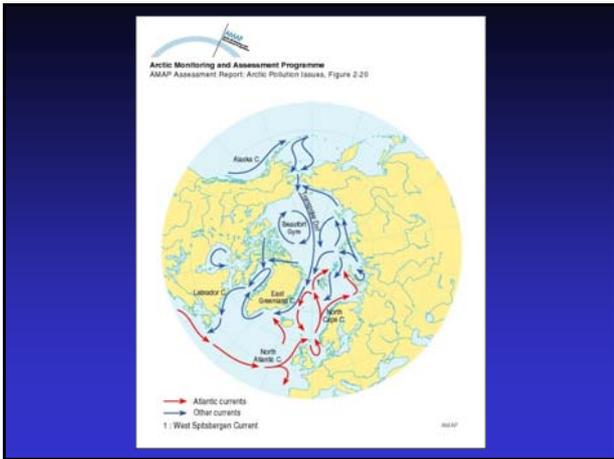
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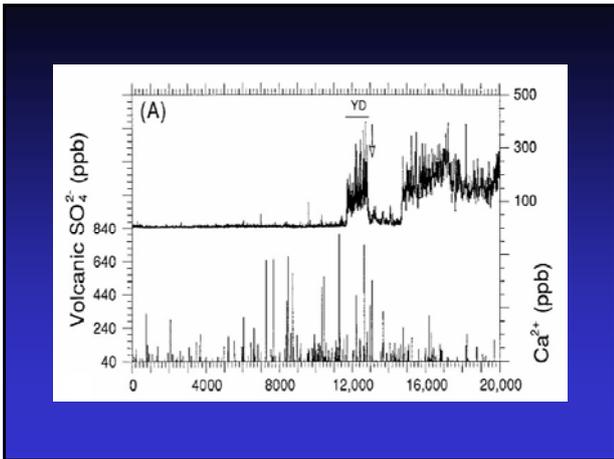
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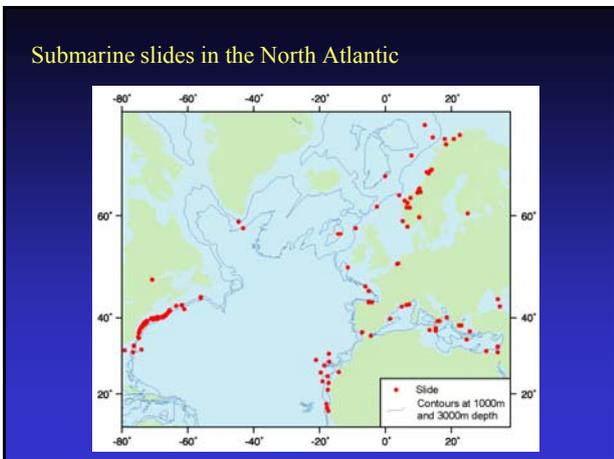
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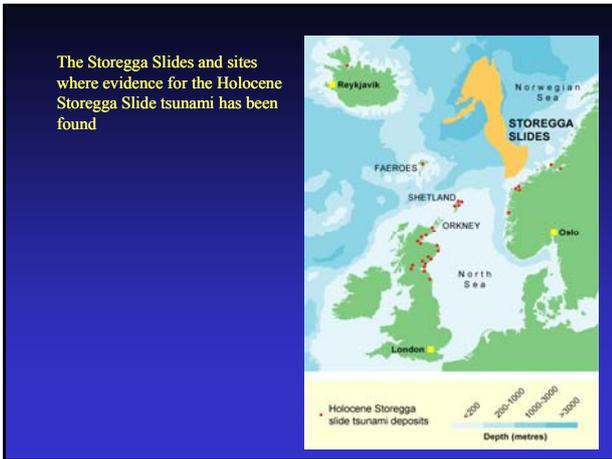
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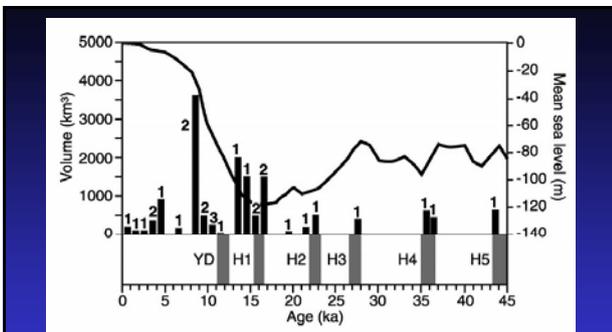
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Total volume of mass transport or slide deposits (black bars) and number of failures (small numbers next to bars) compared with mean relative sea level (curve) for past 45 k.y. (McGuire et al., 1997). Heinrich events (H1–H5) and Younger Dryas (YD) are shown for comparison.

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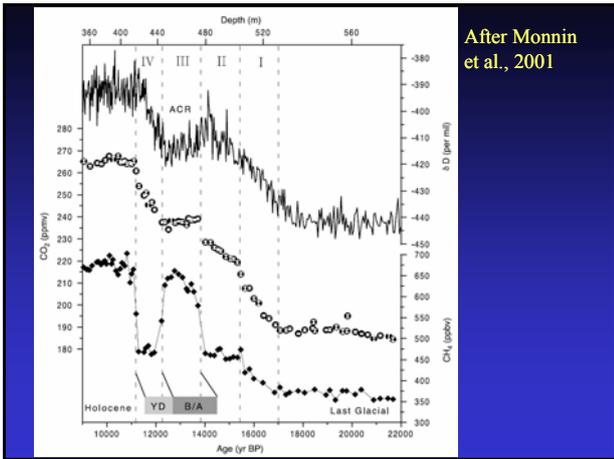
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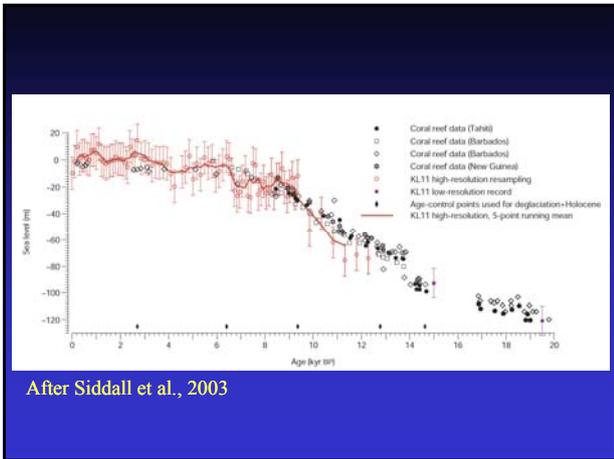
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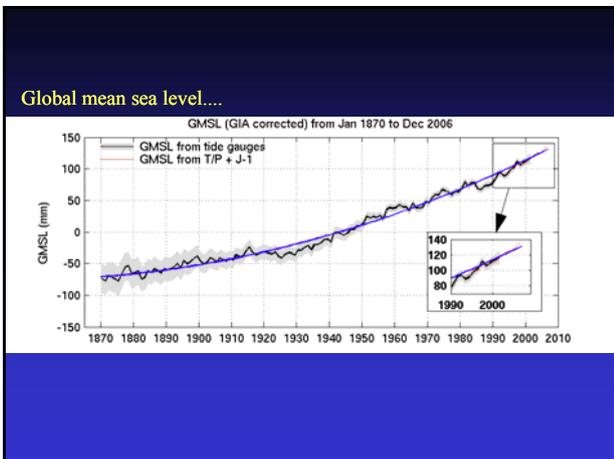
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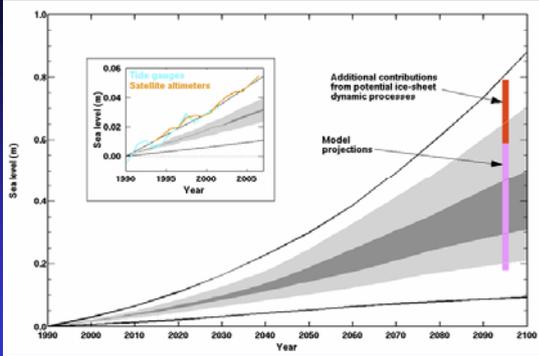
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Projected sea level rise for the 21<sup>st</sup> century




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Source of sea surface rise

Rate of sea surface rise  
(mm/yr - 1)  
1993 - 2003

Thermal expansion of ocean water	1.6±0.5
Melting of glaciers and ice caps	0.77±0.22
Greenland ice sheet	0.21±0.07
Antarctic ice sheet	0.21±0.35
Sum of individual contributions to sea surface rise	2.8±0.7
Actual observed sea surface rise	3.1±0.7

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After Rignot et al., 2008

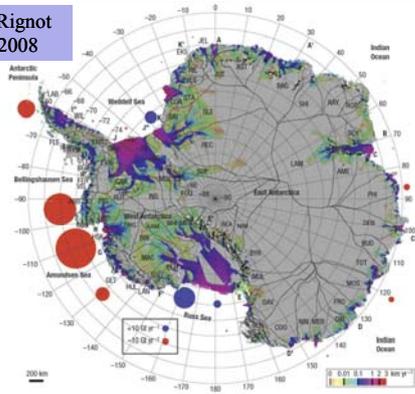


Figure 1 Ice velocity of Antarctica colour coded on a logarithmic scale and overlaid on a MODIS mosaic<sup>1</sup>. Circles denote mass loss (red) or gain (blue) of large basins in gigatonnes per year. Orange basins are black lines extending from the grounding line flow gates. Letters A-F indicate large basins<sup>2</sup>. Ice velocities for Signe Coast ice streams and Ronne Ice Shelf are from refs 22,23. See Supplementary Information for acronyms and the Methods section for velocity precision.

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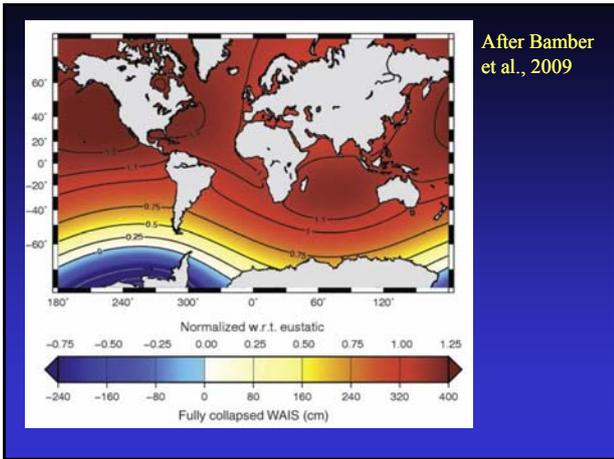
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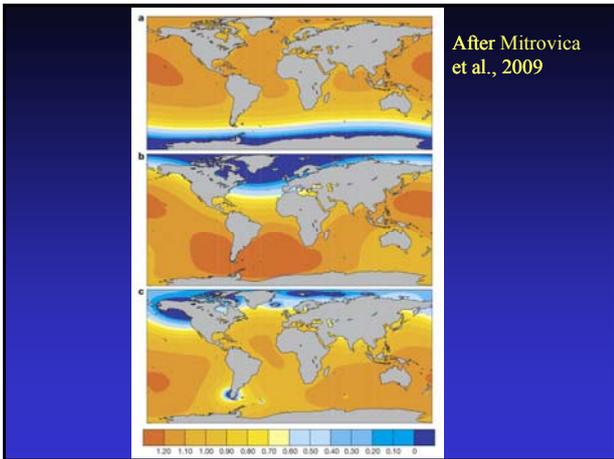
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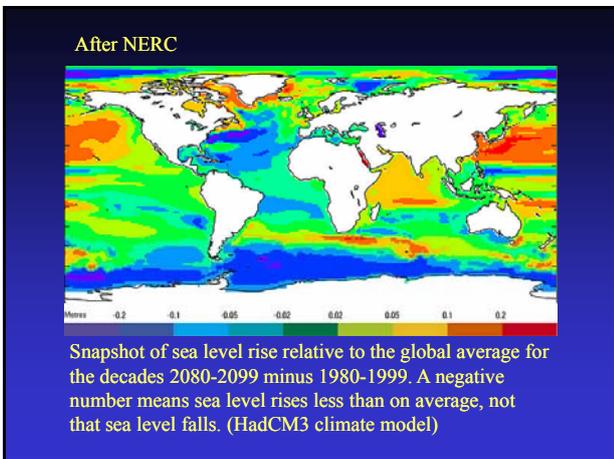
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# Conclusion

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1. Mean global sea levels are probably rising at a faster rate now than at any time in the last 7000 years. However there are uncertainties about the actual rate and there are strong regional variations.
2. At the coastline, the observed sea level will depend upon land movement, and in areas still recovering from the load imposed by former ice sheets, sea levels are receding. However, these areas are shrinking and along their margins increasing areas are experiencing sea level rise.

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3. Overall, therefore, the volume of the oceans is increasing and at a rate which may become comparable to that achieved at the end of the last glaciation. This may have important effects on coastlines, tidewater glaciers, ocean currents, submarine sliding and volcanic activity.

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4. Climate and sea levels are inextricably linked. Climate change affects sea level and the changing sea level transmits the effect of climate change throughout the coastal regions of the Earth.

5. The recent Royal Society report emphasises that climate change is occurring and that it is to a large extent anthropogenically caused. The document probably understates the imperatives of climate change and underplays the developing problems of ice sheet decay, but supports the IPCC view on sea level rise. It is maintained in this paper that sea level rise is a major consequence of climate warming and its effects may be more serious and felt more widely than is sometimes thought.

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