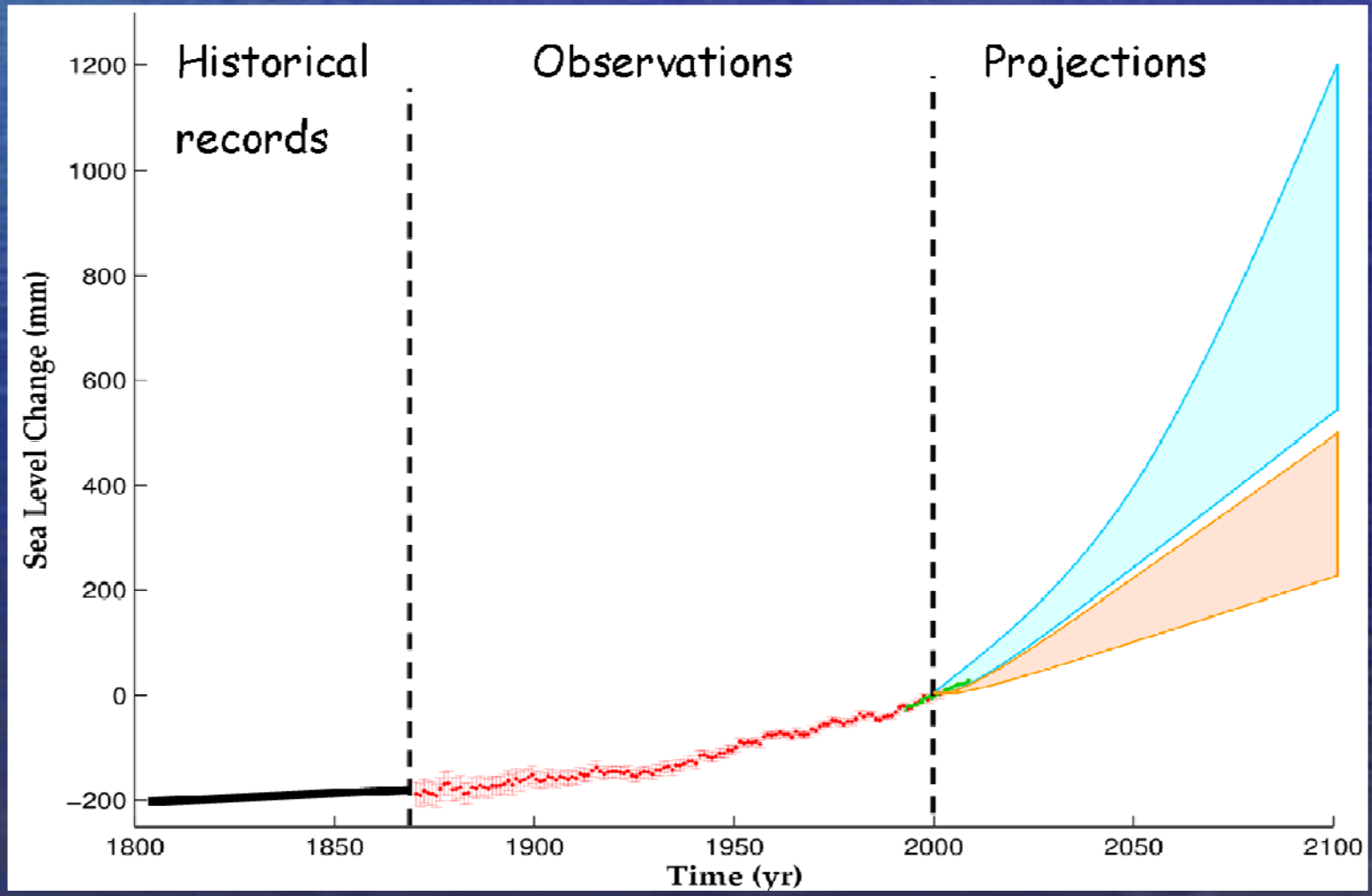
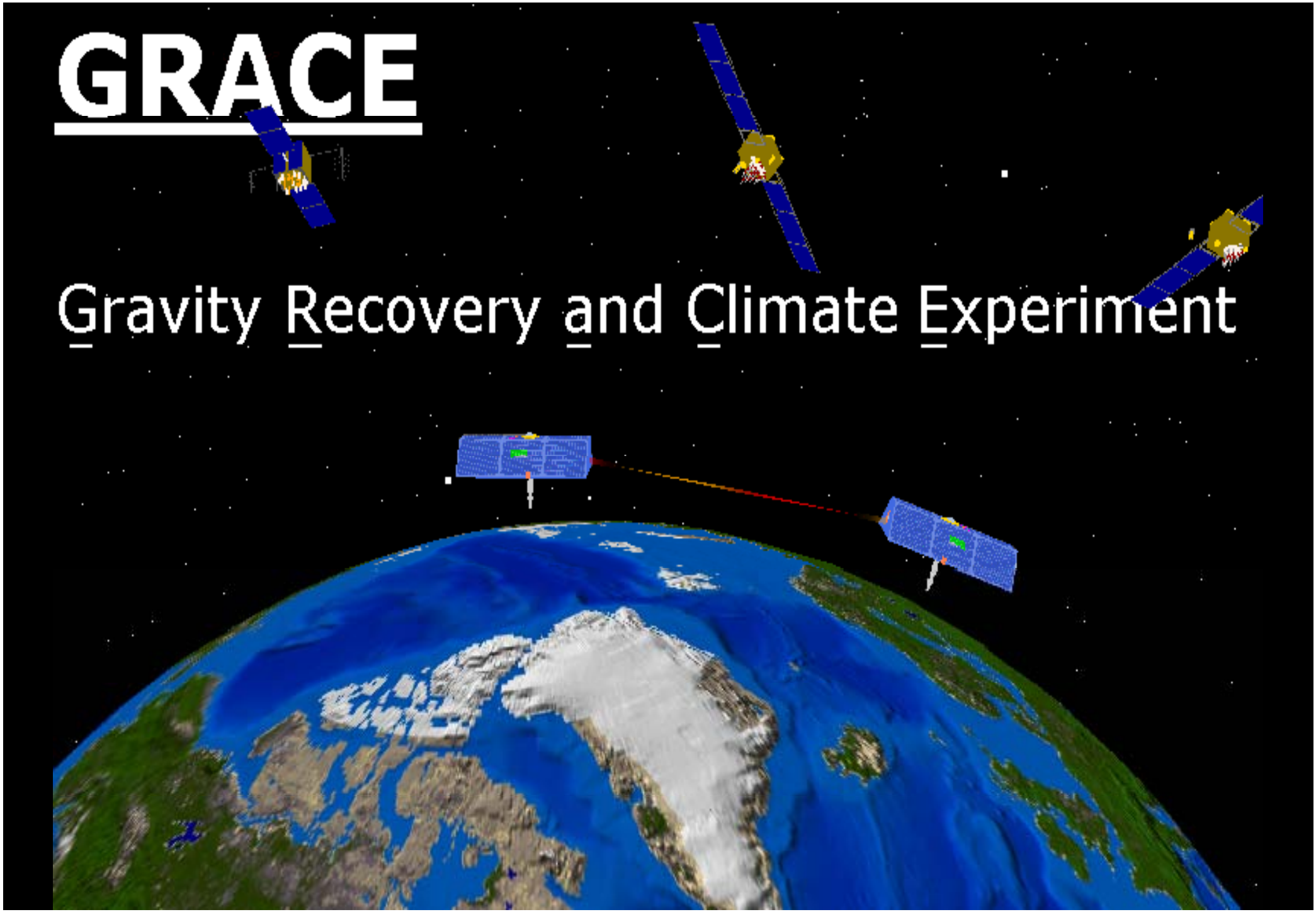
Why has an acceleration of sea level rise not been observed during the altimeter era?

R. S. Nerem, D. P. Chambers, J. Fasullo, M. Merrifield,
G. T. Mitchum, I. Velicogna, and J. Willis

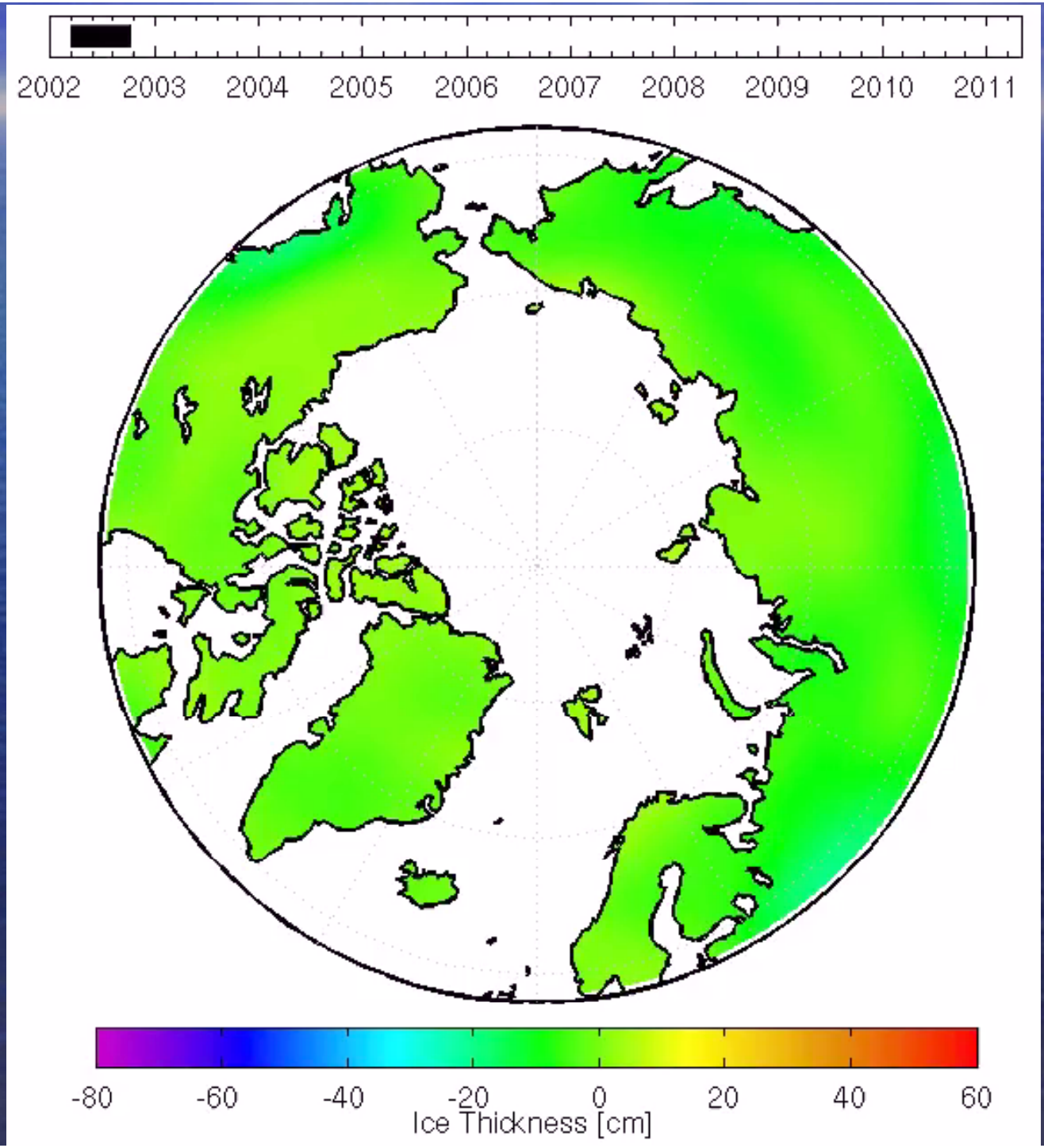


Questions to be Addressed

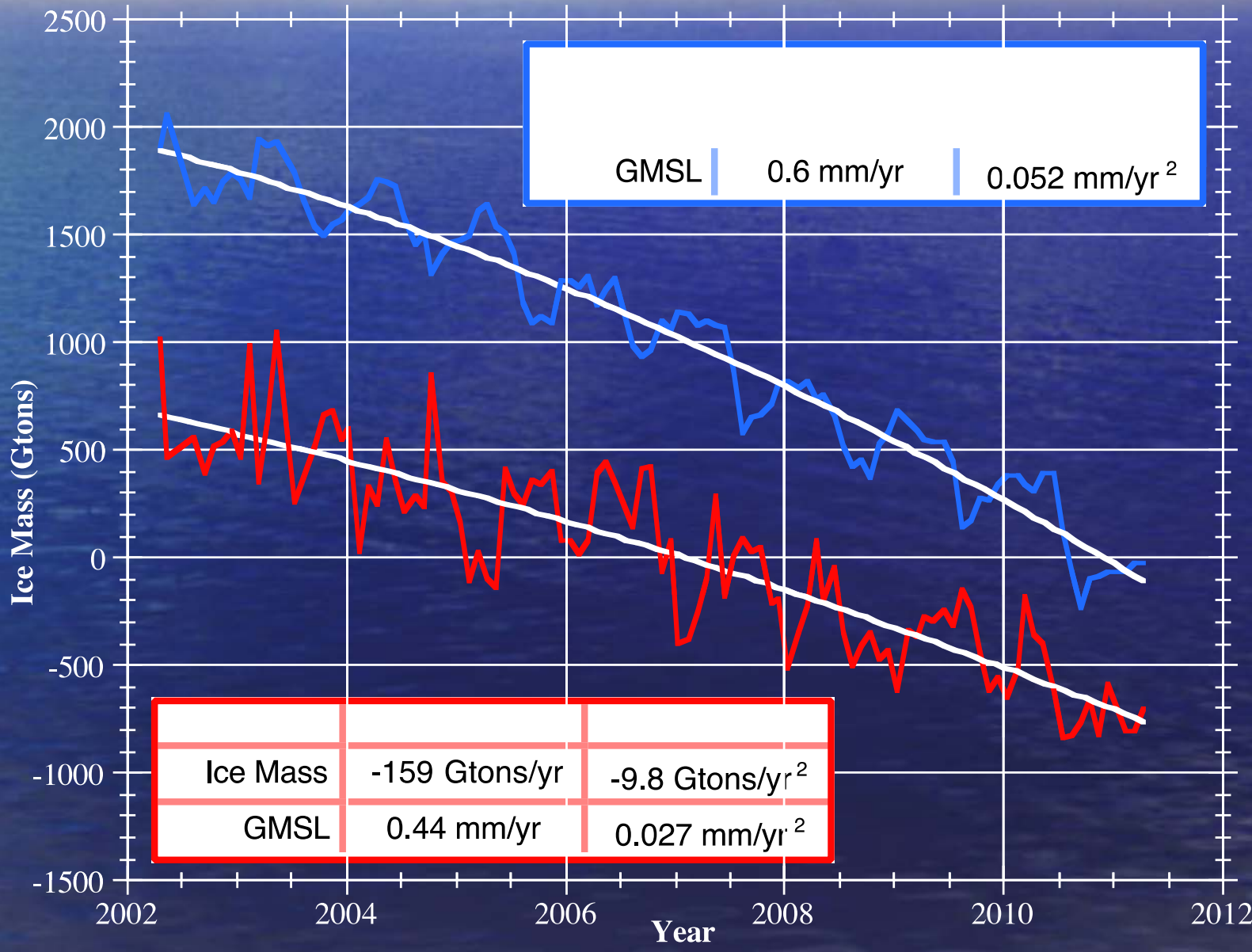
- How large of an acceleration might we expect to see?
- What have we observed during the altimeter era?
- Could there an error in the altimeter data?
- If there has been an acceleration, should we have detected it?
- Could the acceleration of ice melt be masked by a deceleration in other contributions to sea level change?


GRACE
Gravity Recovery and Climate Experiment

GRACE-observed mass changes in the Arctic

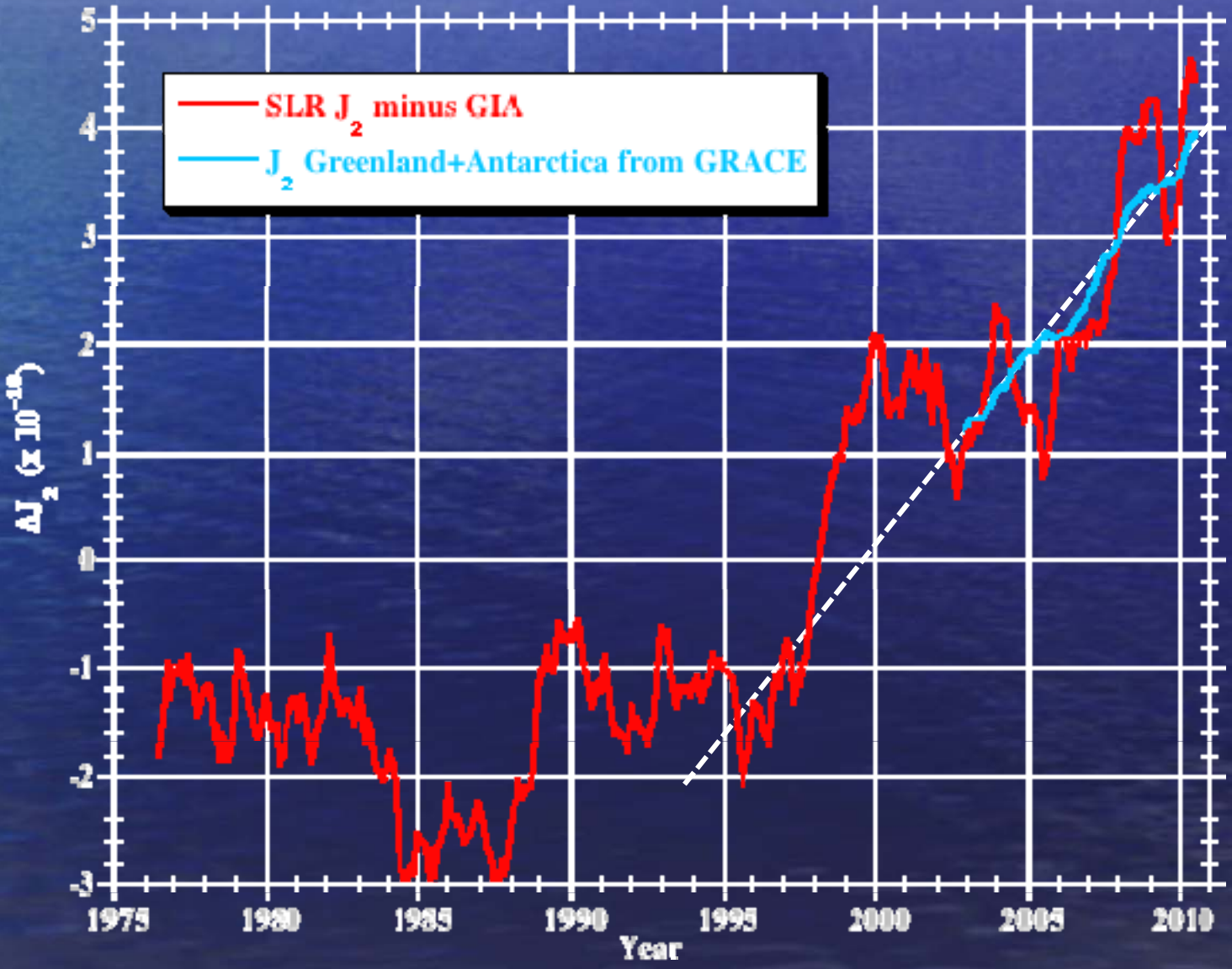


Polar Ice Mass Loss from GRACE



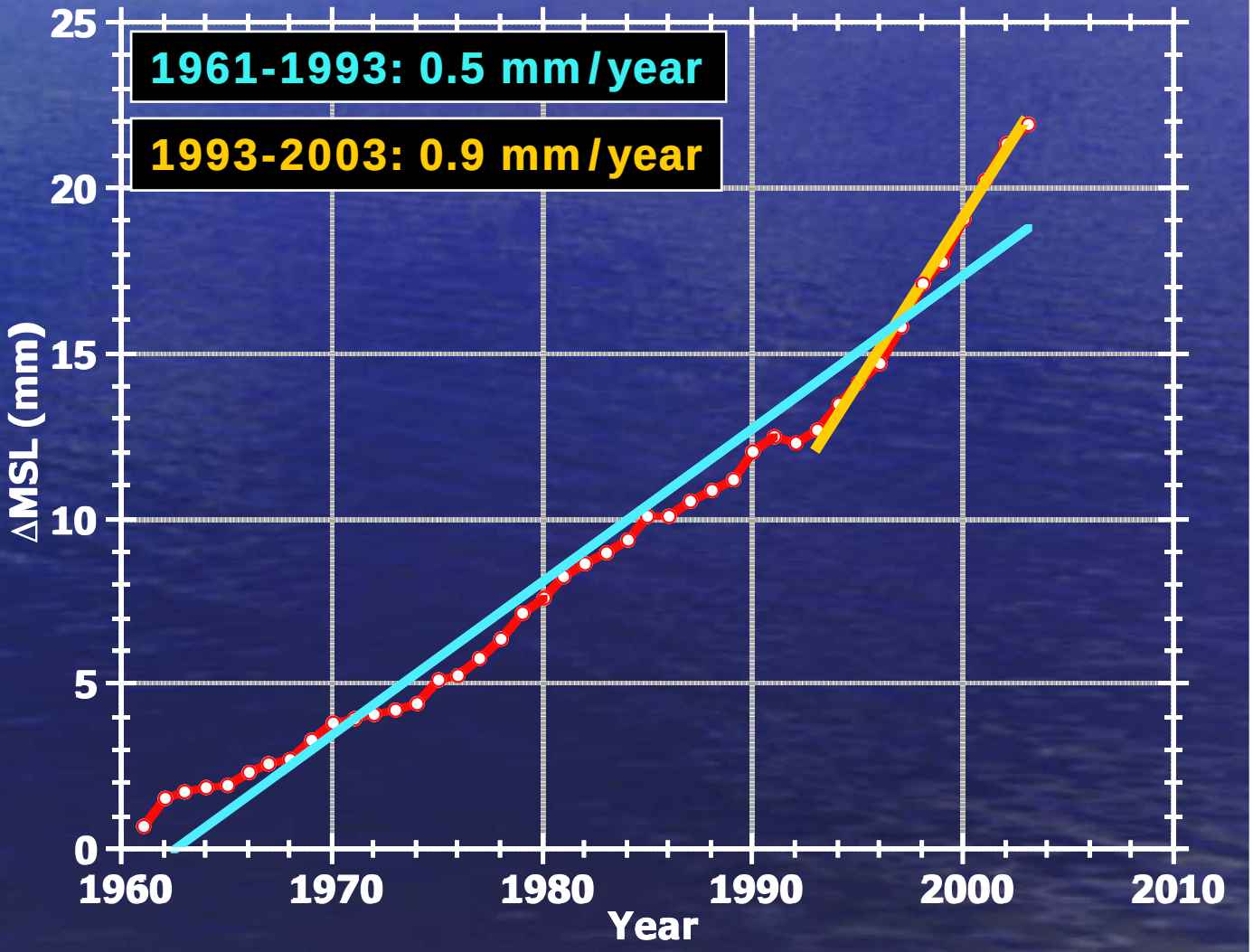
[Velicogna, 2011]

GIA-Corrected J_2 Variations



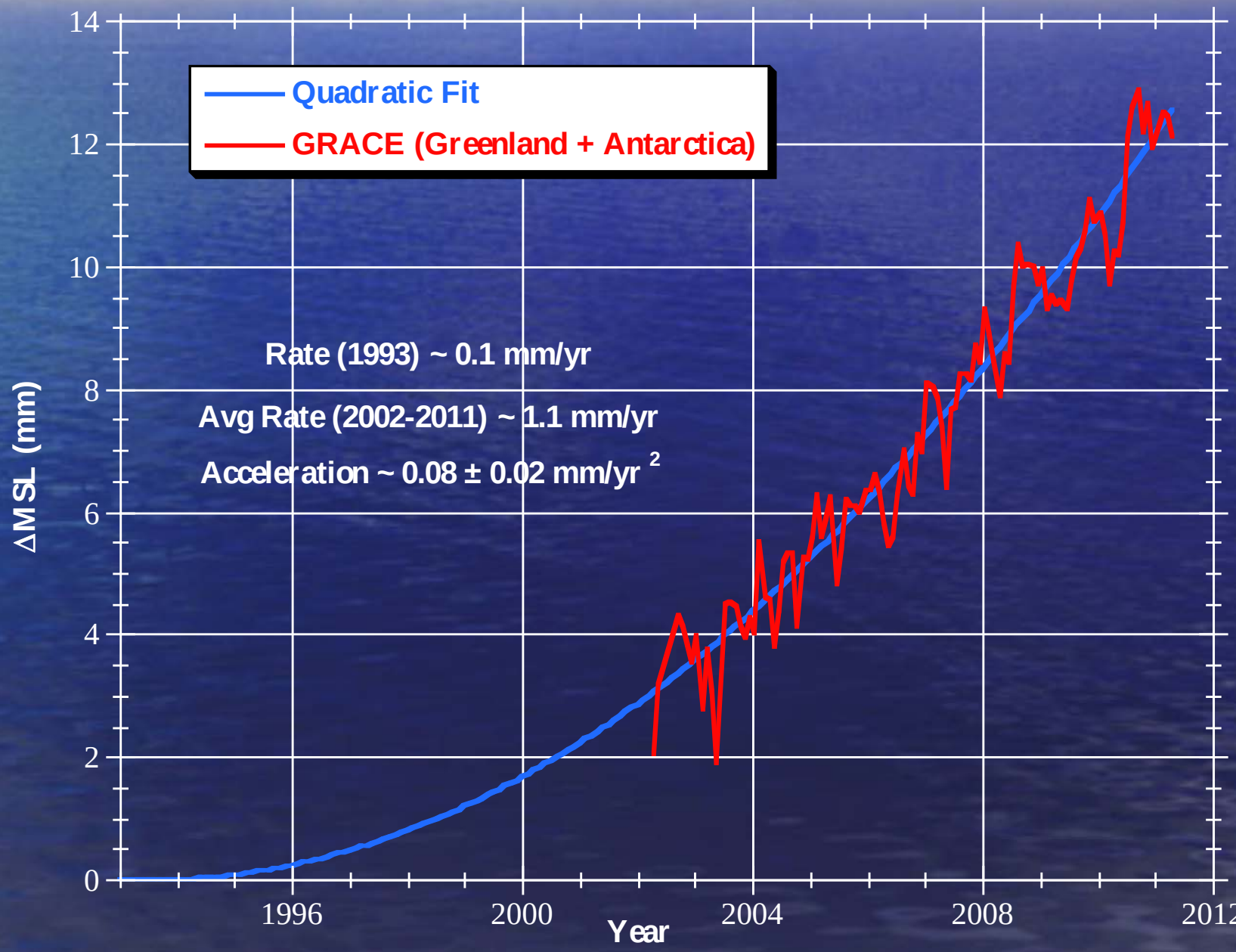
[Nerem and Wahr, 2011]

Mountain Glaciers: Contribution to Sea Level

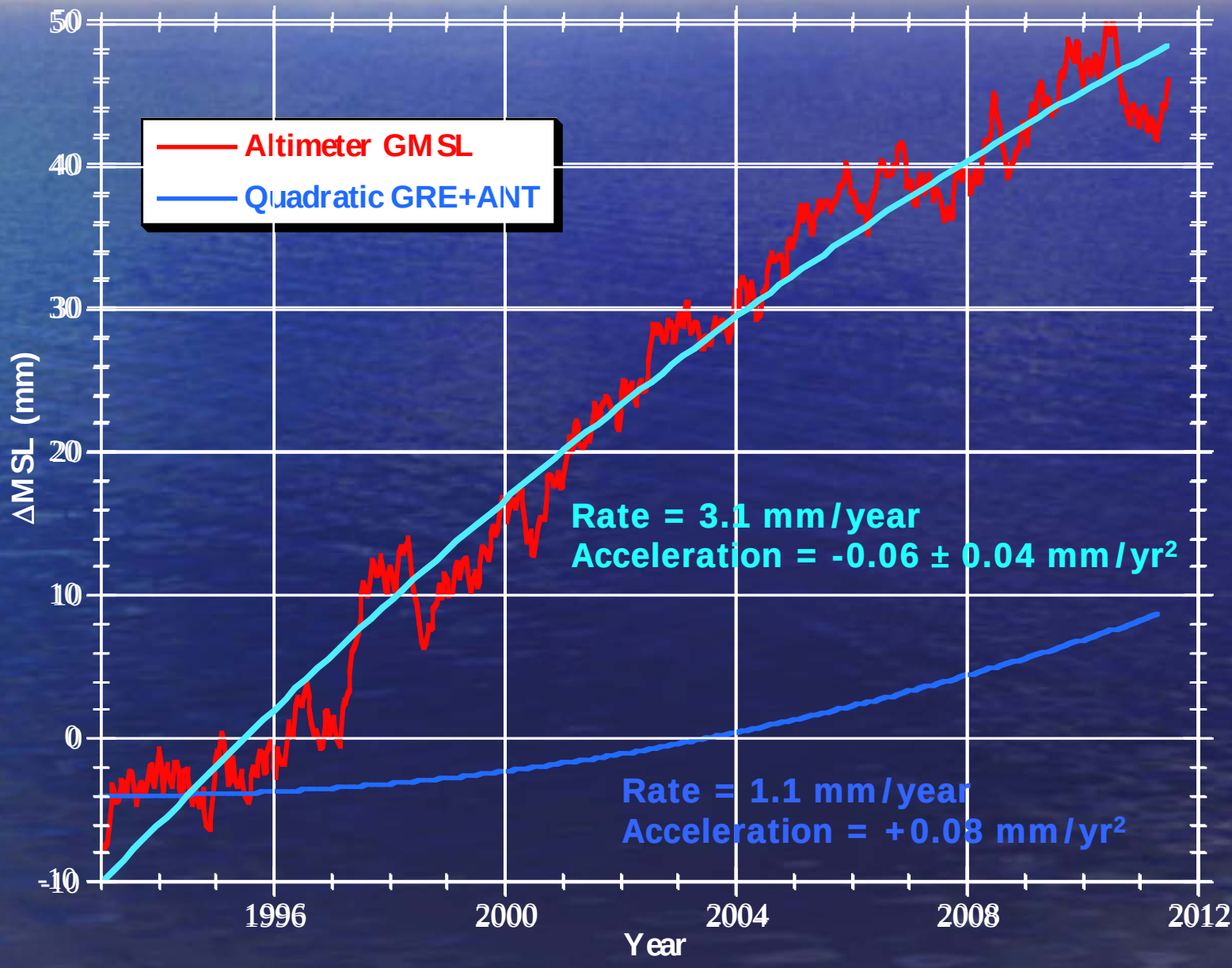


[*Dyurgerov and Meier*, 2005]

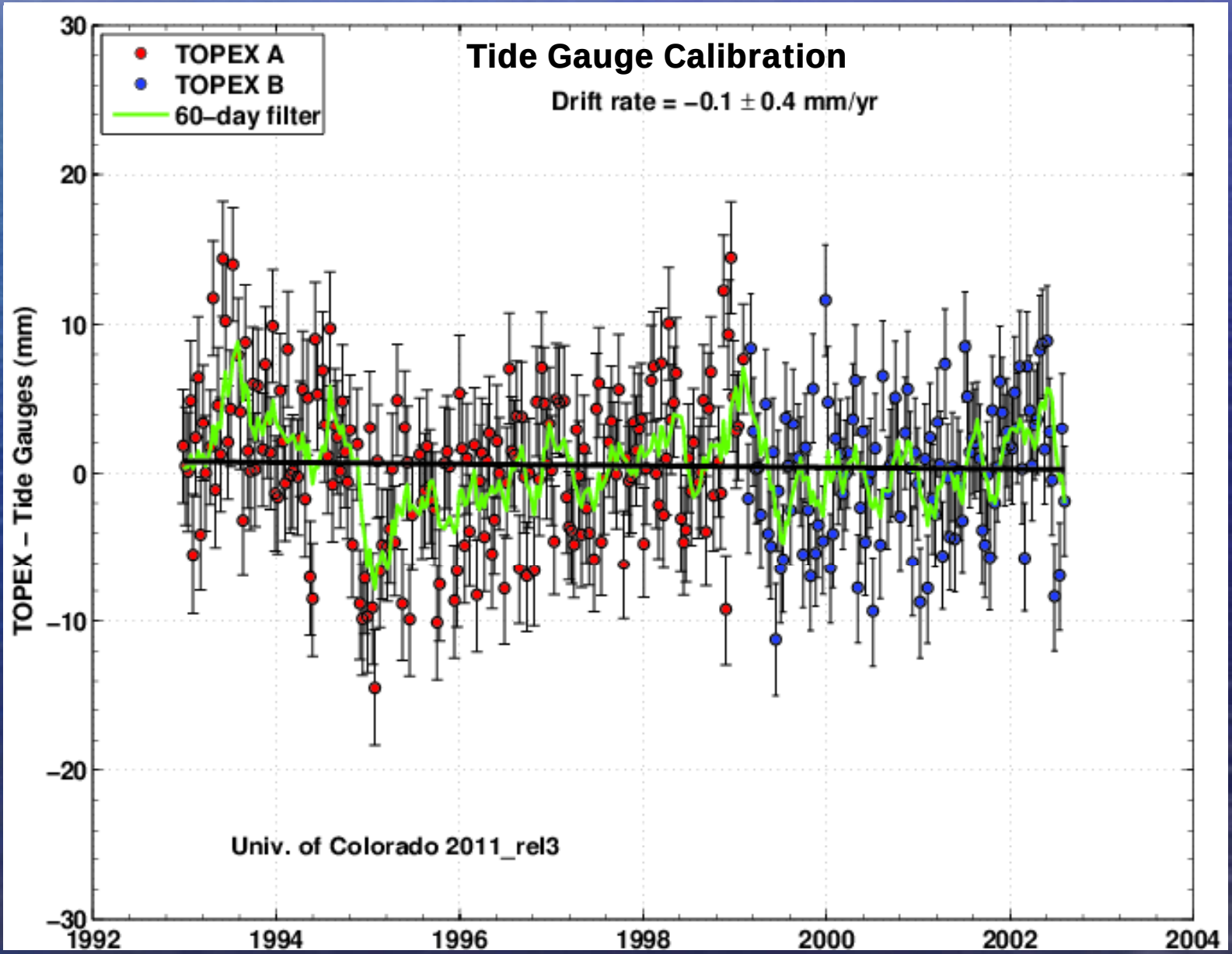
Greenland + Antarctica Sea Level Contributions



Observed GMSL Variations



Could there be errors in the altimeter data?



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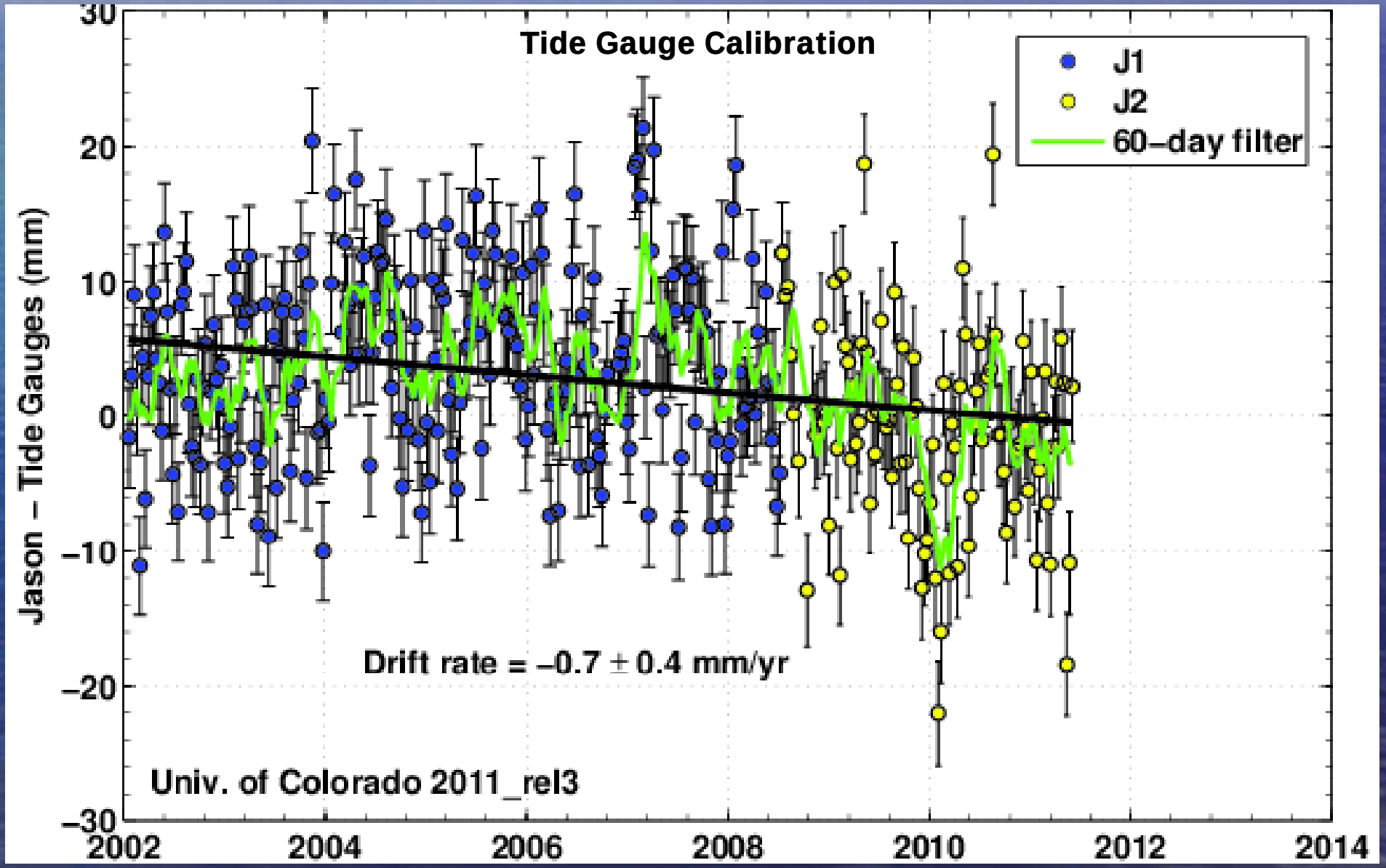
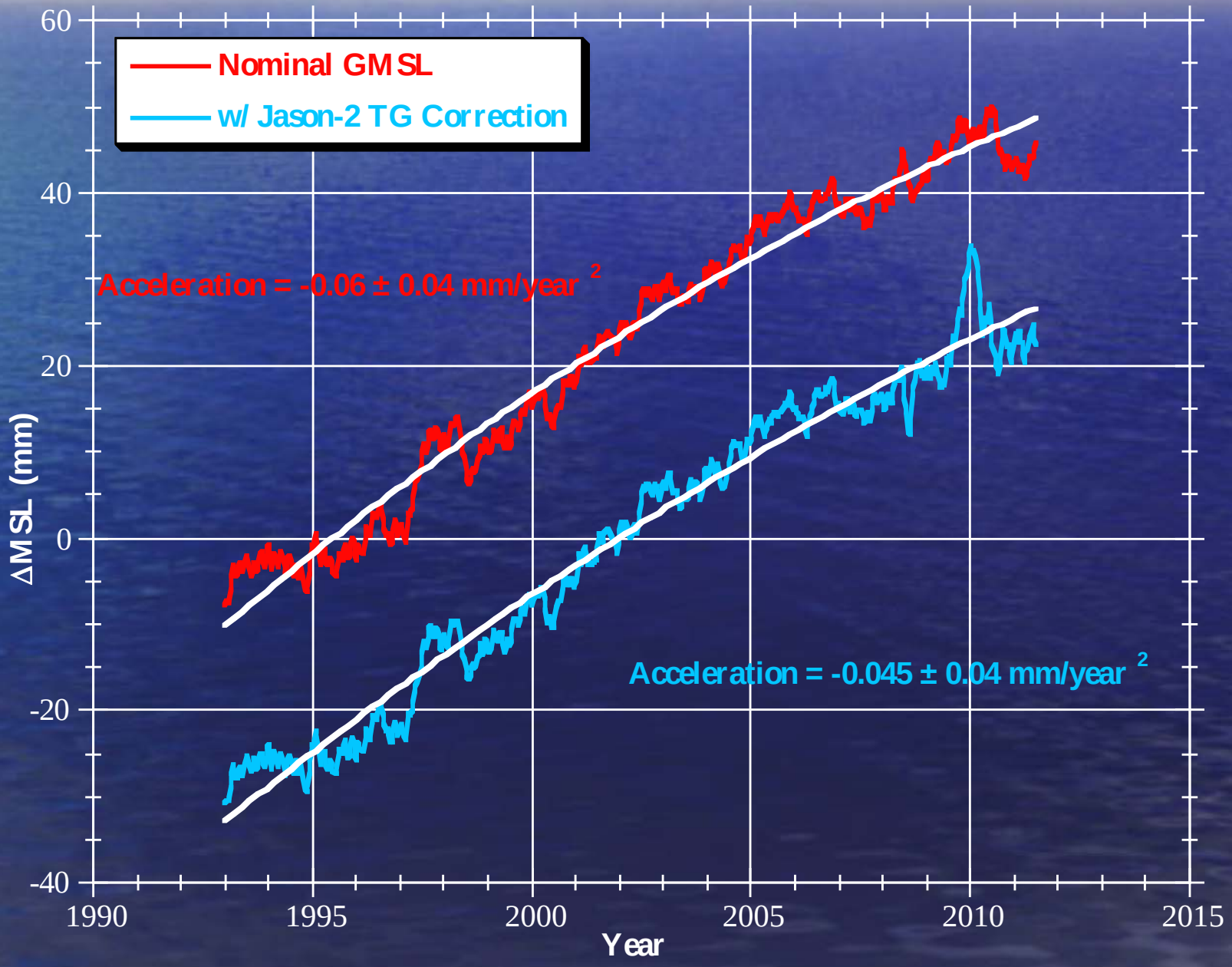
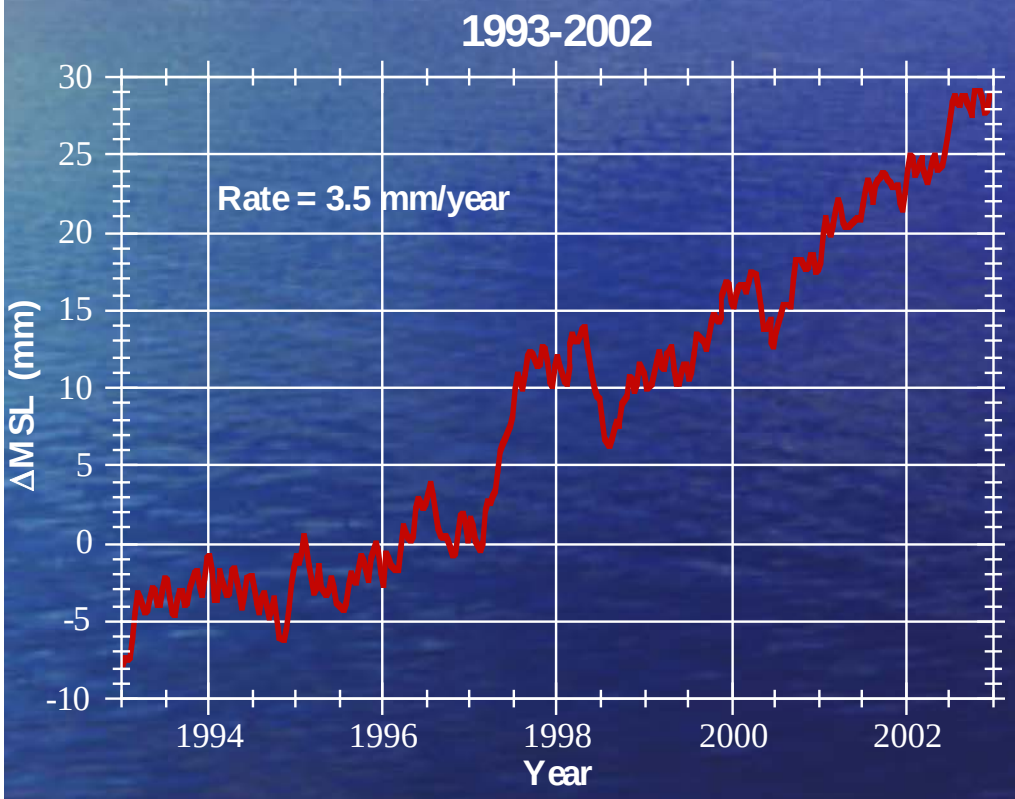
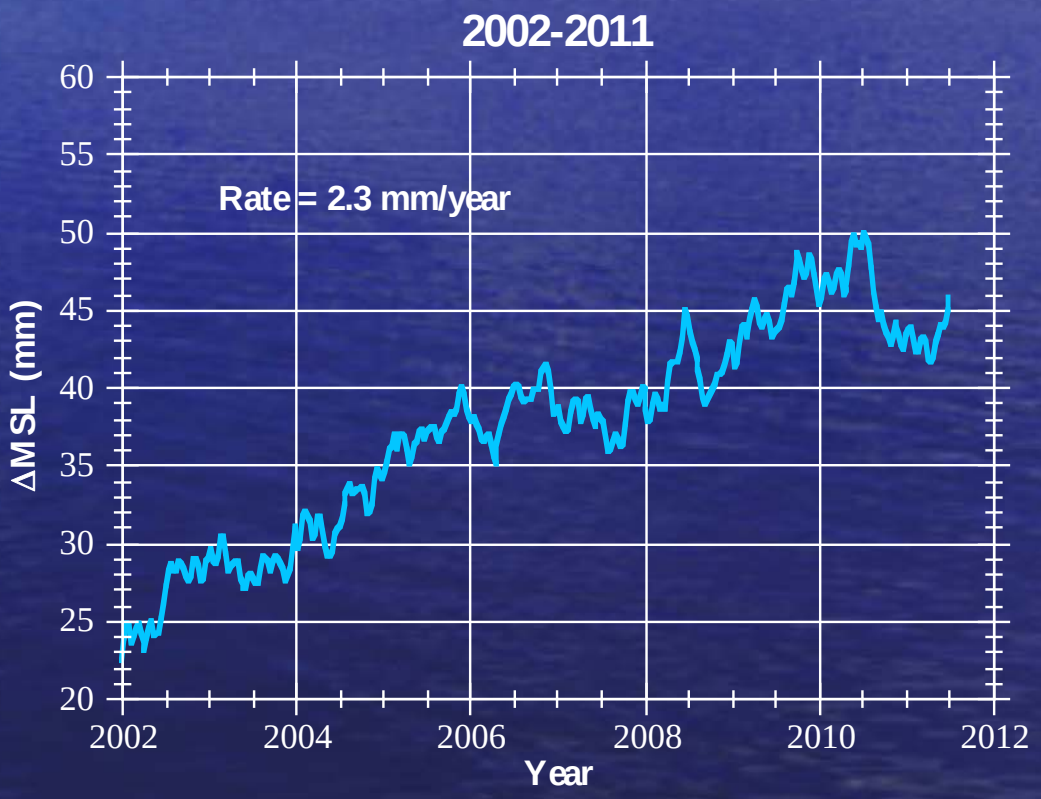


Tide Gauge Corrected Jason-2 GMSL

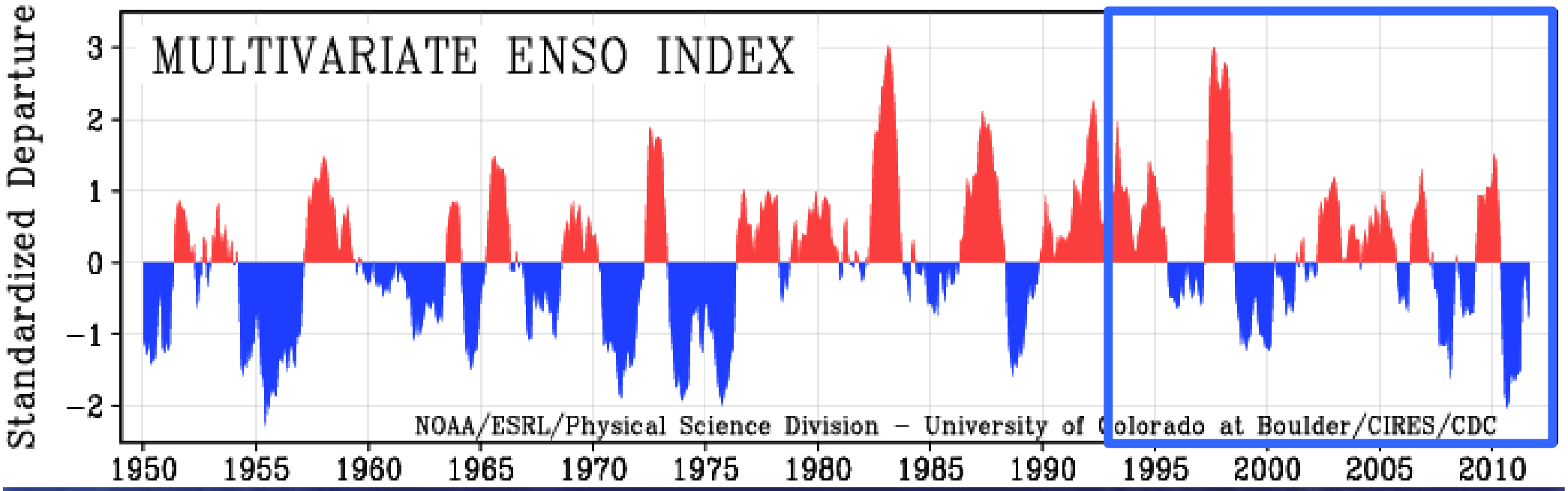


The Two Decades of the Altimeter Era



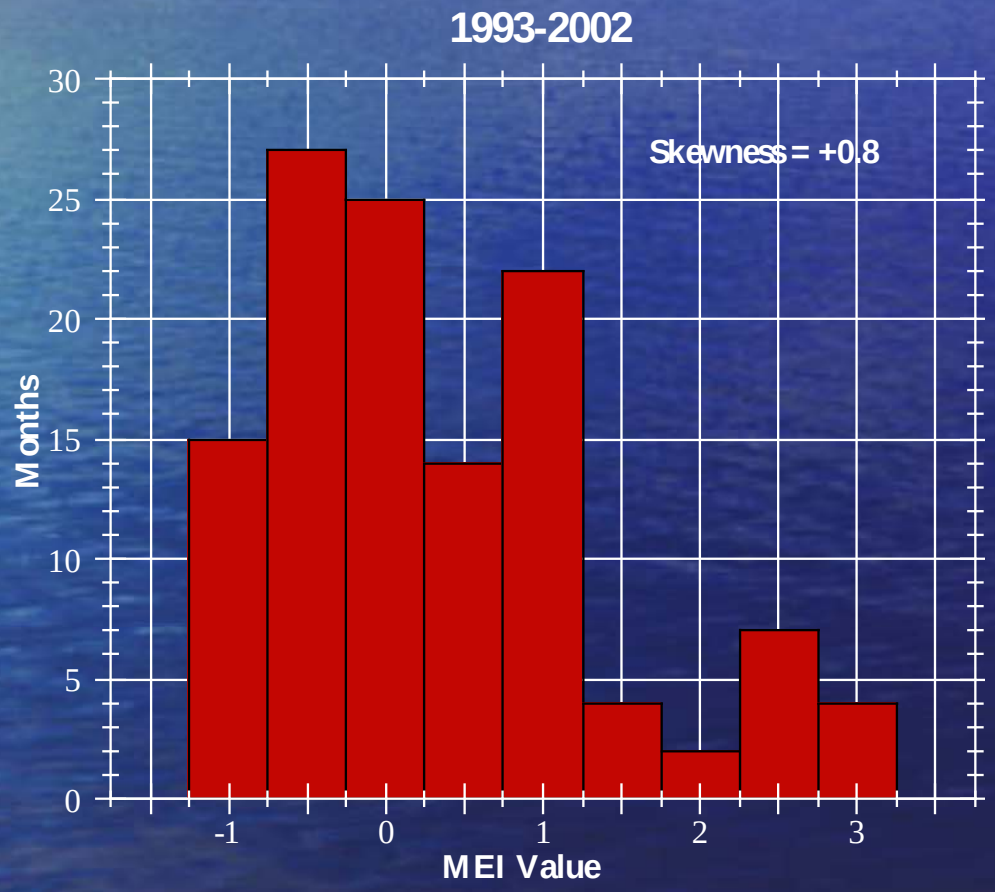


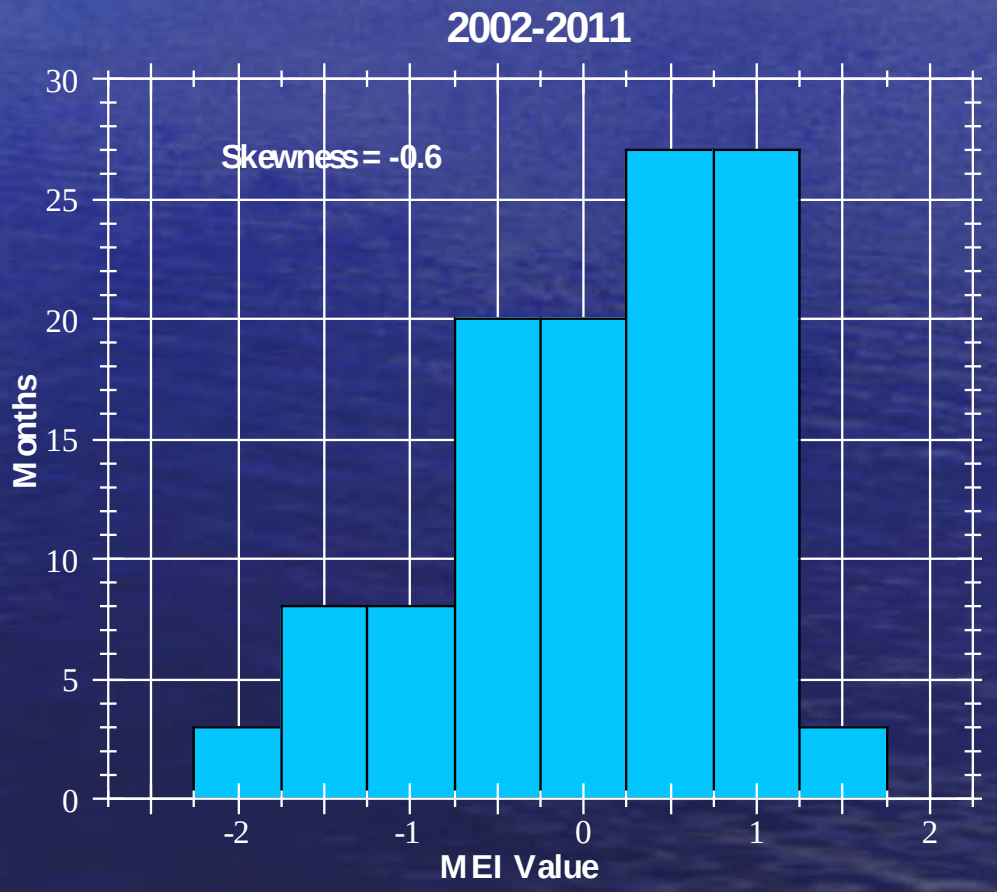
Multivariate ENSO Index (MEI)



[Wolter and Timlin, 1993; 1998]

Histogram of MEI during the Altimeter Era

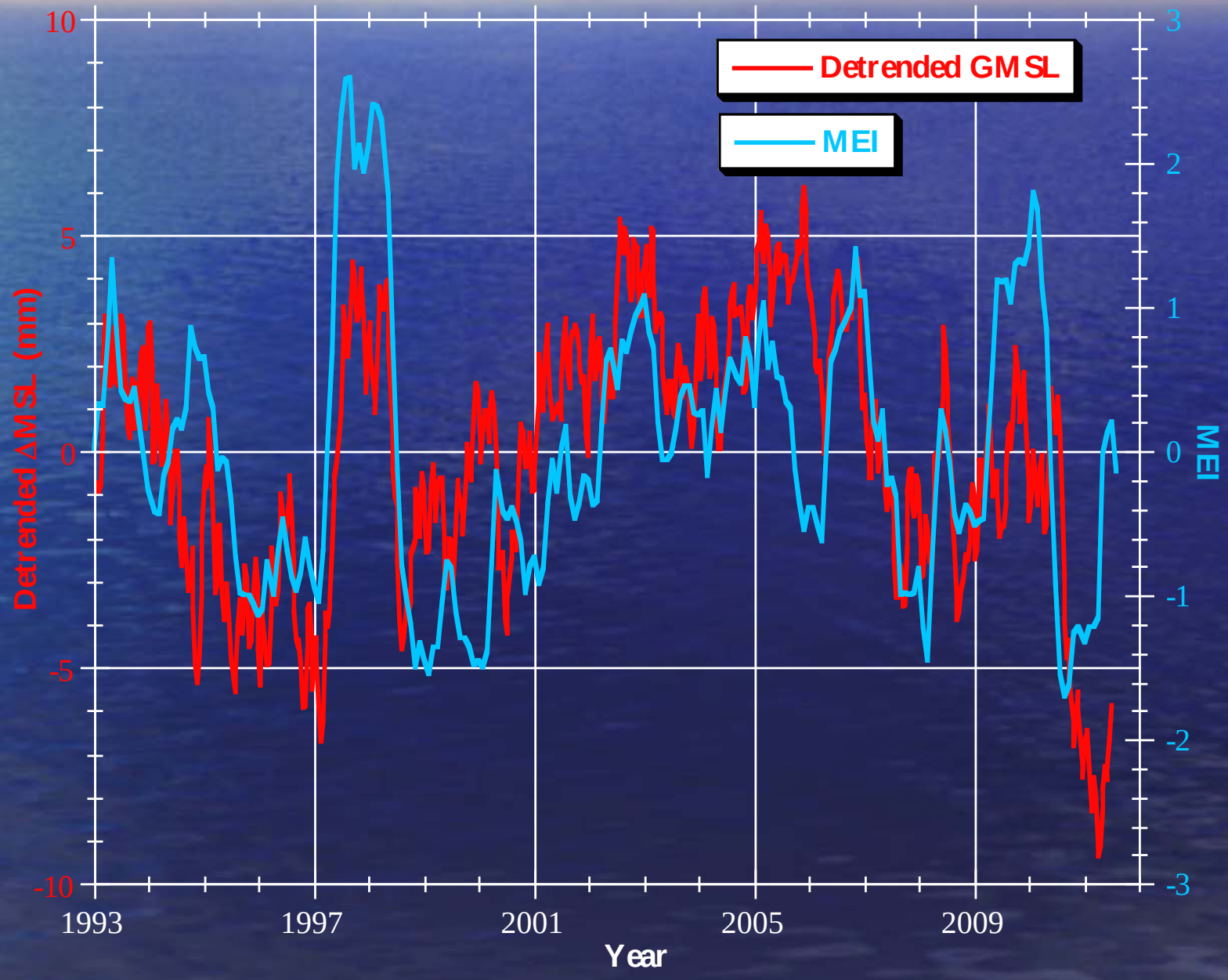




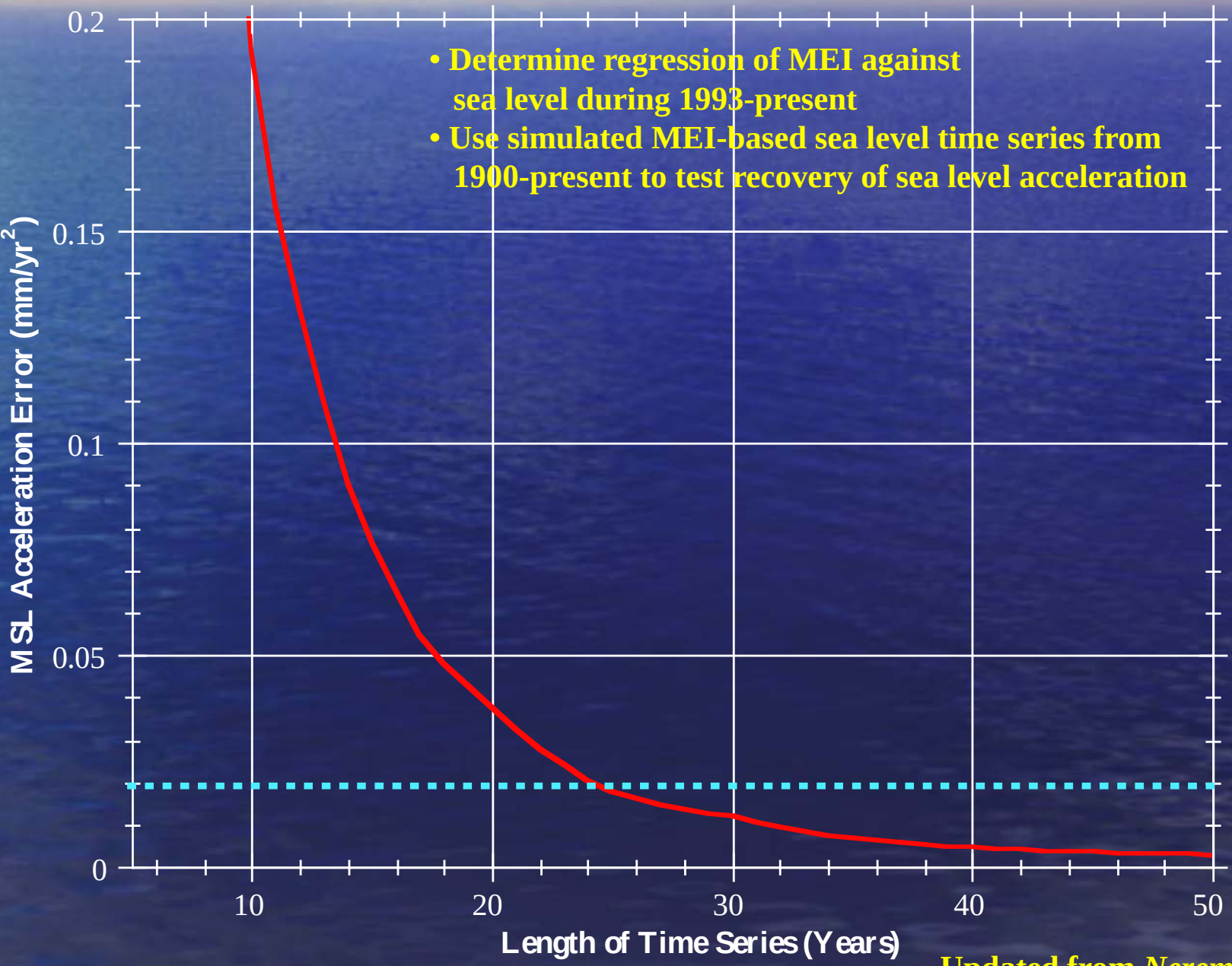
Historical Ranking of MEI (1950-present)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1992	60	60	60	60	60	59	54	42	42	44	42	44
1993	48	54	55	58	58	58	56	54	54	54	47	43
1994	40	36	39	45	45	46	50	48	53	57	56	54
1995	55	53	52	44	44	41	34	25	23	19	19	21
1996	17	21	23	19	24	31	22	20	21	20	29	25
1997	24	19	25	48	57	62	62	62	62	61	61	60
1998	61	61	61	61	61	55	36	18	14	14	11	13
1999	8	9	13	9	12	17	16	12	12	13	14	8
2000	6	8	10	18	34	23	23	29	27	22	16	20
2001	23	17	20	26	35	28	35	40	28	25	26	32
2002	34	30	27	41	53	50	44	52	51	49	51	52
2003	54	52	50	39	29	32	33	36	41	42	40	36
2004	39	39	28	34	42	35	41	46	43	40	46	45
2005	37	48	56	51	51	43	43	38	36	26	22	19
2006	26	24	21	16	28	45	46	49	50	47	57	49
2007	51	44	34	28	36	18	20	17	10	10	10	9
2008	12	5	3	13	17	34	30	22	15	15	18	16
2009	15	16	18	25	39	52	52	53	46	53	52	51
2010	53	59	58	55	47	16	7	2	1	2	3	4
2011	2	2	4	4	19	22	28	16	13			

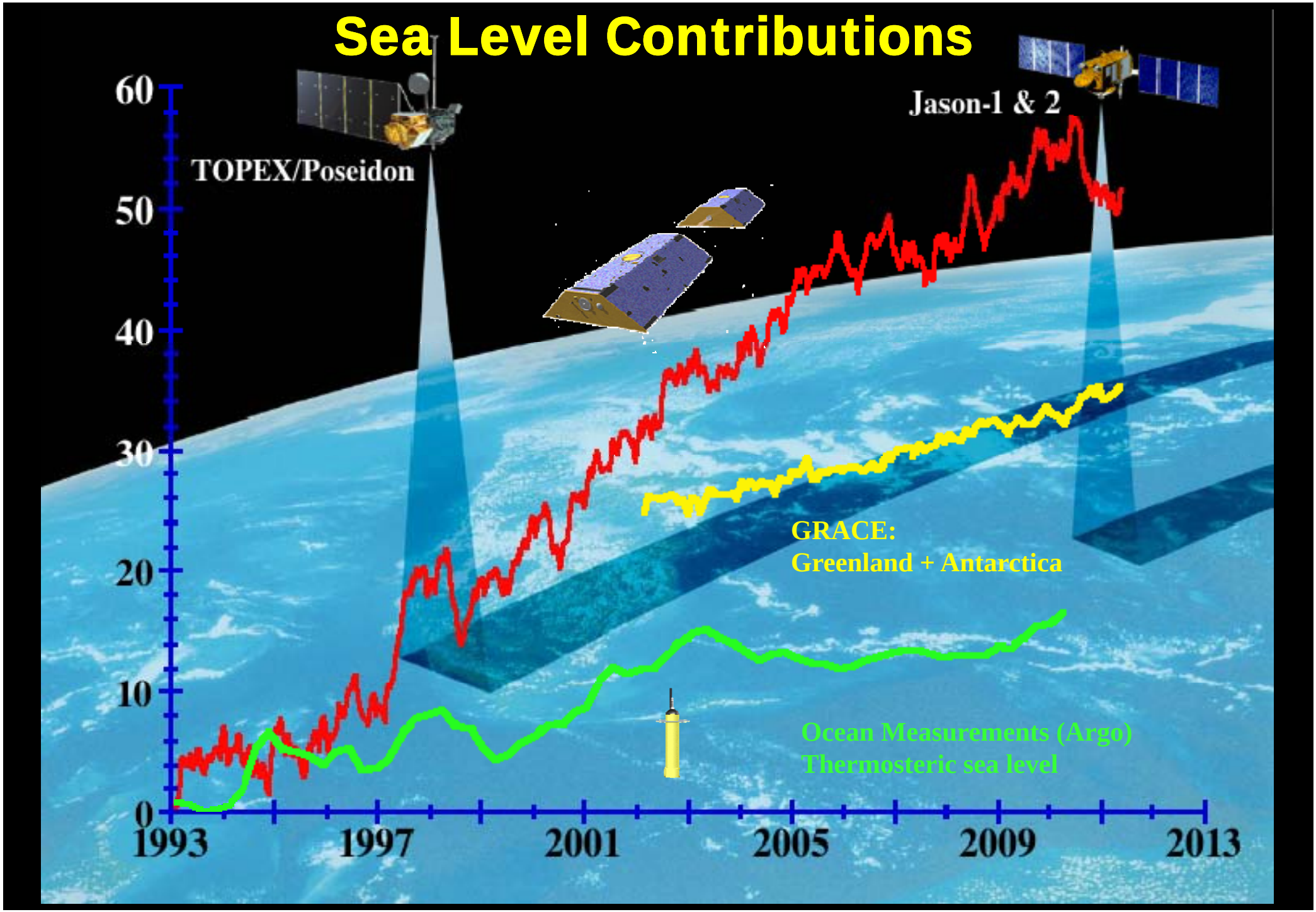
Detrended GMSL versus MEI



Simulated GMSL Acceleration Recovery

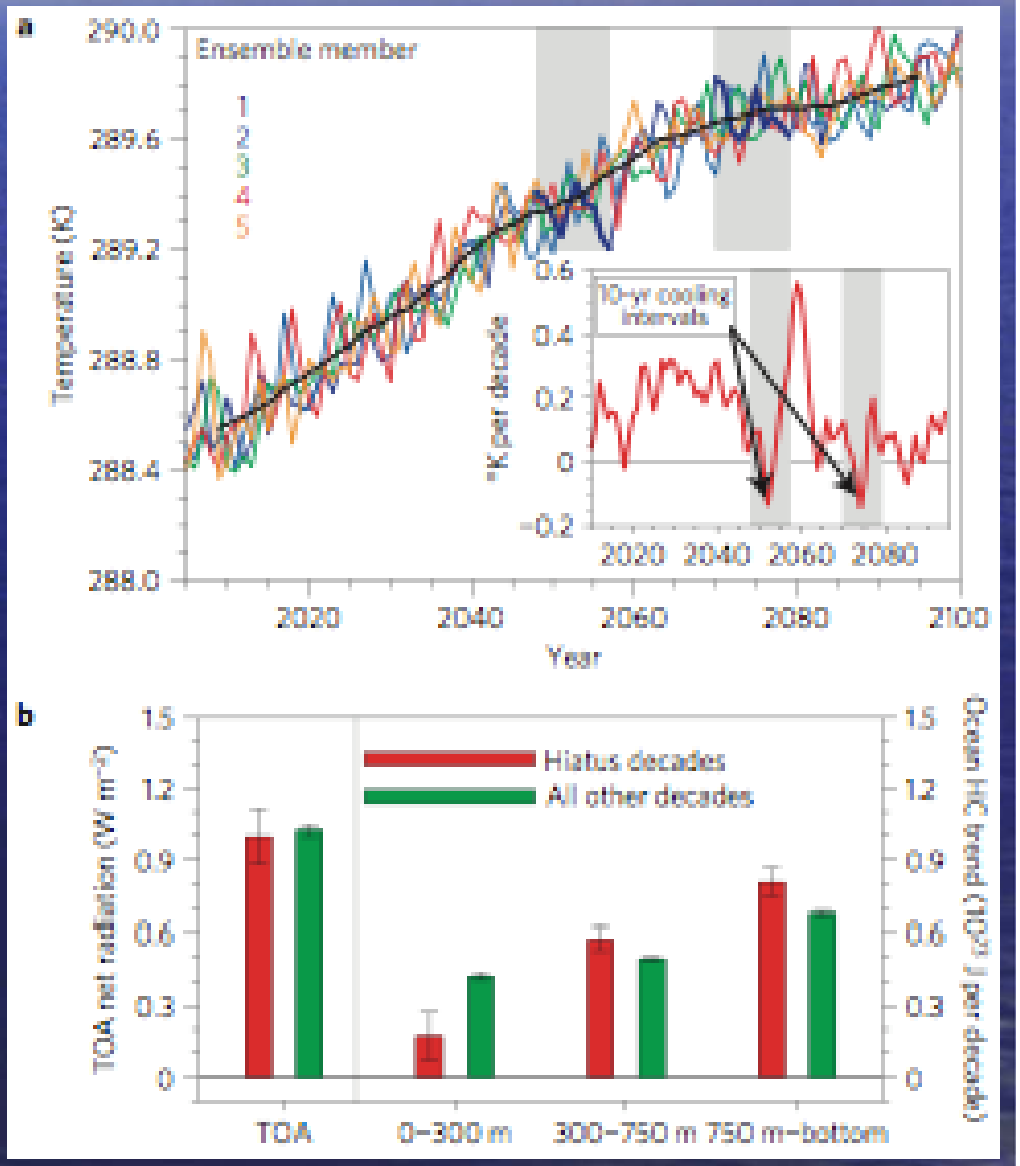


Updated from *Nerem et al.* [1999]


Sea Level Contributions
TOPEX/Poseidon
Jason-1 & 2
GRACE:
Greenland + Antarctica
Ocean Measurements (Argo)
Thermosteric sea level
60
50
40
30
20
10
0
1993
1997
2001
2005
2009
2013

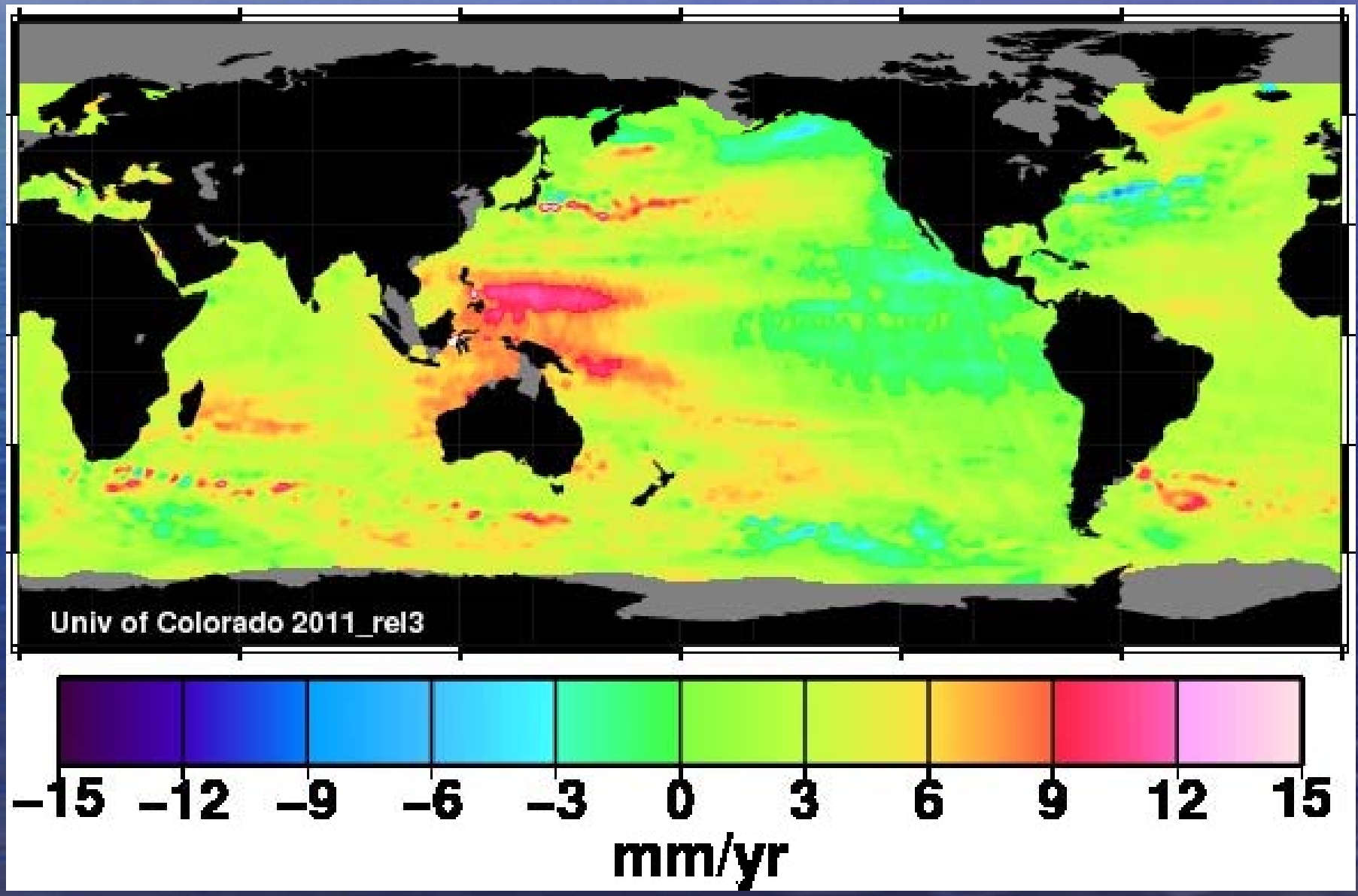
Hiatus Periods of Upper Ocean Heat Uptake?

- Ensemble model runs show evidence of “hiatus decades” where the ocean above 300 m takes up significantly less heat than the ocean below 300 m.
- Relatively common climate phenomenon likely linked to La Nina conditions.

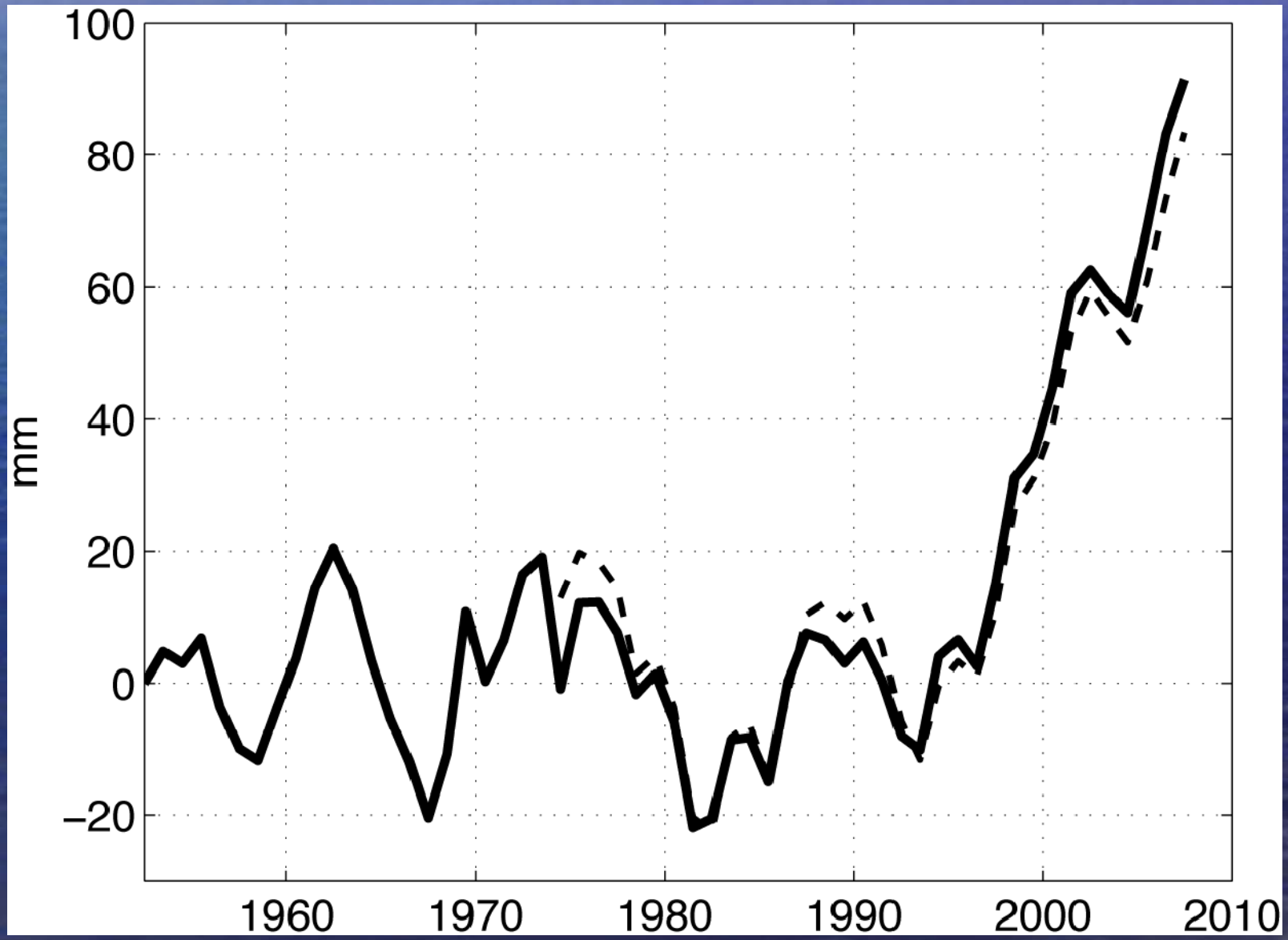


Meehl et al., 2011, *Nature Climate Change*, Model-based evidence of deep-ocean heat uptake during surface-temperature hiatus periods

Spatial Variations in Sea Level Rise 1993-2011



Western Pacific Sea Level Change

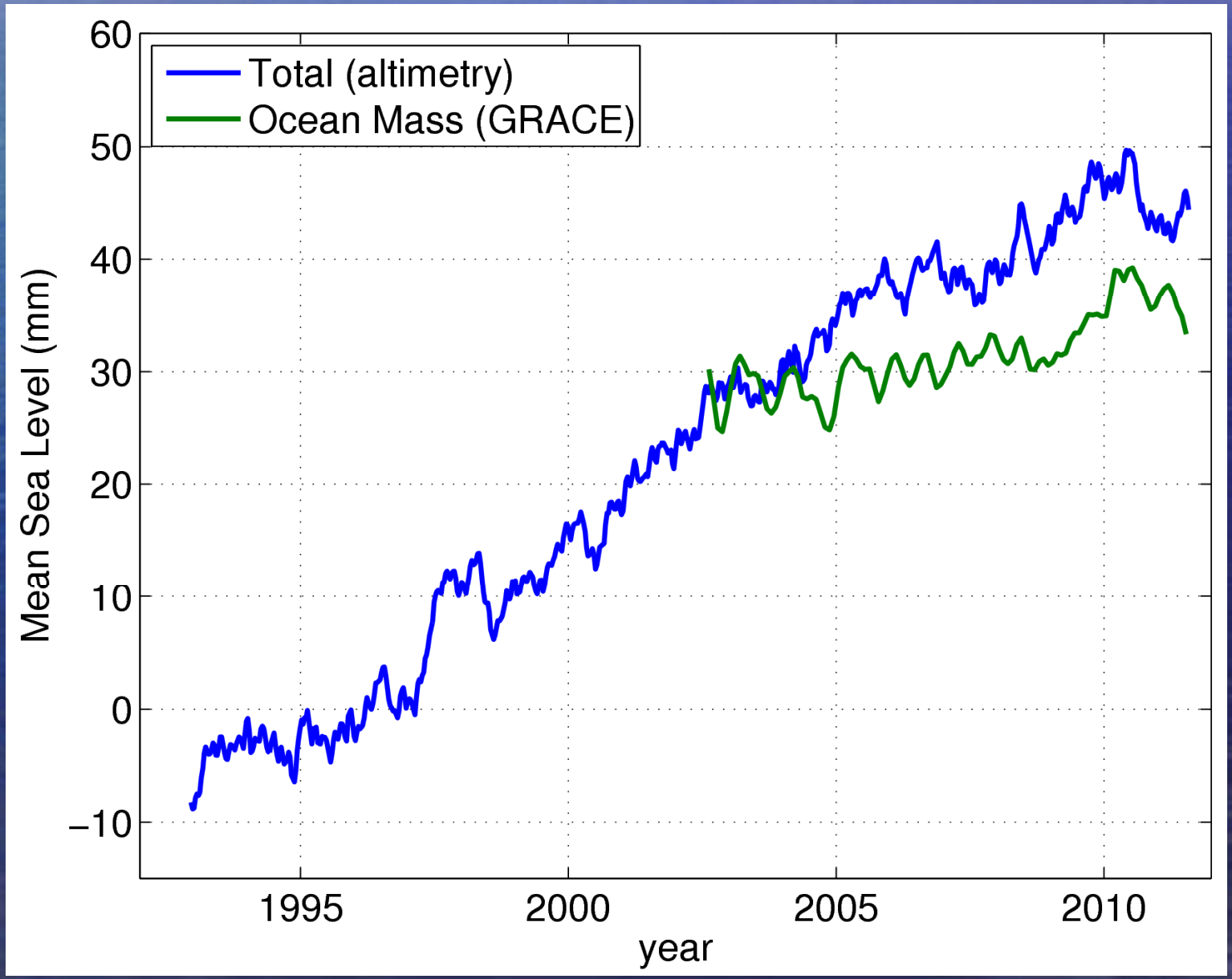


Merrifield (2010)

Summary

- The cryosphere has clearly seen an acceleration of mass loss during the altimeter era of (0.05 – 0.1 mm/year^2 ???).
- ENSO-related variability contributes an error to determining the acceleration of ~0.04 mm/year^2
- It is likely that a slowdown in thermosteric sea level rise over the last decade has masked some of the acceleration from the cryosphere.
- There is still the possibility of errors in the altimeter data, especially Jason-2. Calibrating the altimeter systems to detect such small accelerations is very difficult.

Total Sea Level and Ocean Mass



Observed Acceleration