Is the Detection of Accelerated Sea Level Rise Imminent?

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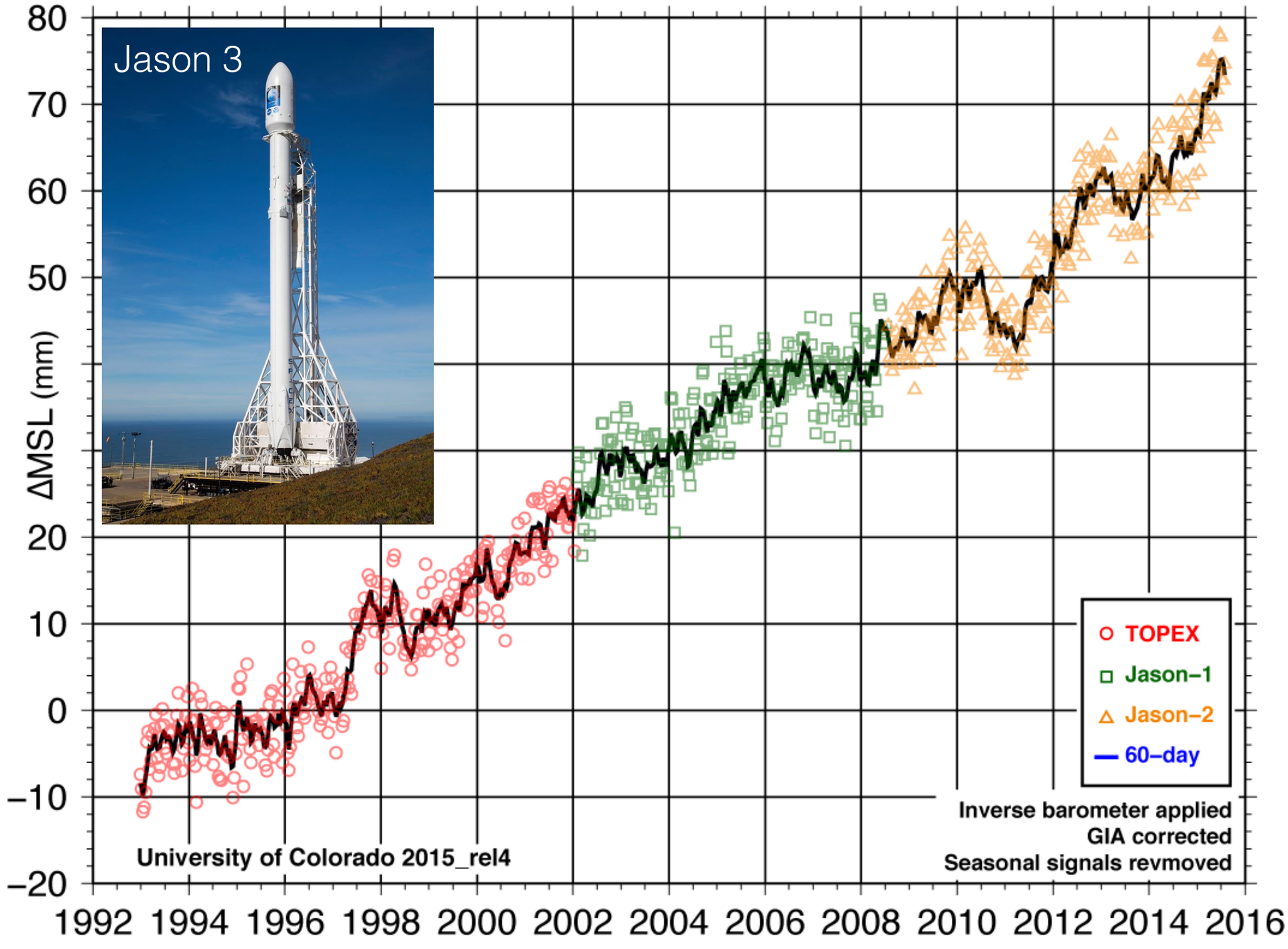
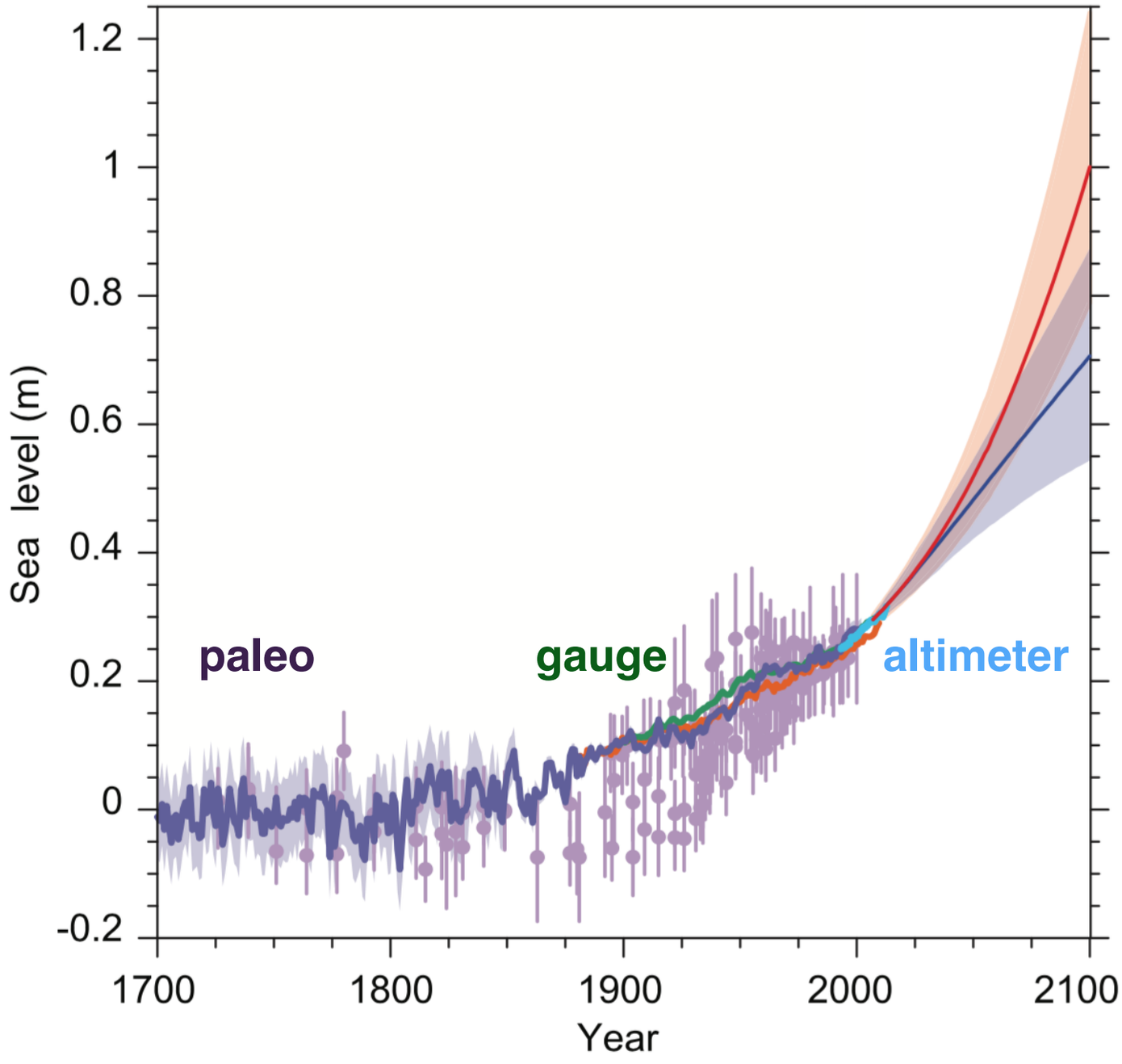
Global Mean Sea Level Anomaly



Expectation of Acceleration : AR5 Chapter 13



↑GHG⇒

↑ΔOHC+

↑Melt(Ts)

∴↑ΔGMSL

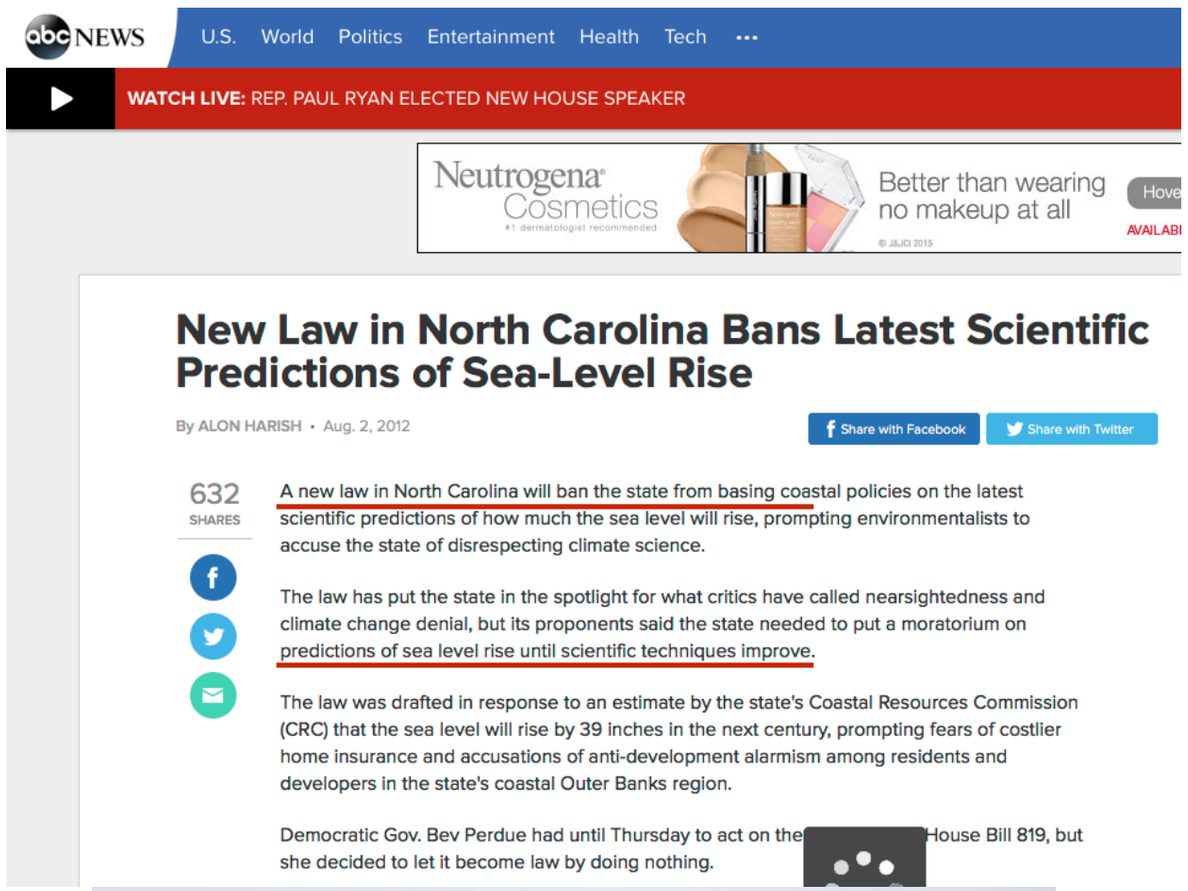
Figure 13.27 | Compilation of paleo sea level data, tide gauge data, altimeter data (from Figure 13.3), and central estimates and *likely* ranges for projections of global mean sea level rise for RCP2.6 (blue) and RCP8.5 (red) scenarios (Section 13.5.1), all relative to pre-industrial values.

Motivation

- Because of the lifespan of infrastructure (30+ yr), projections of sea level rise have major implications for policy today.

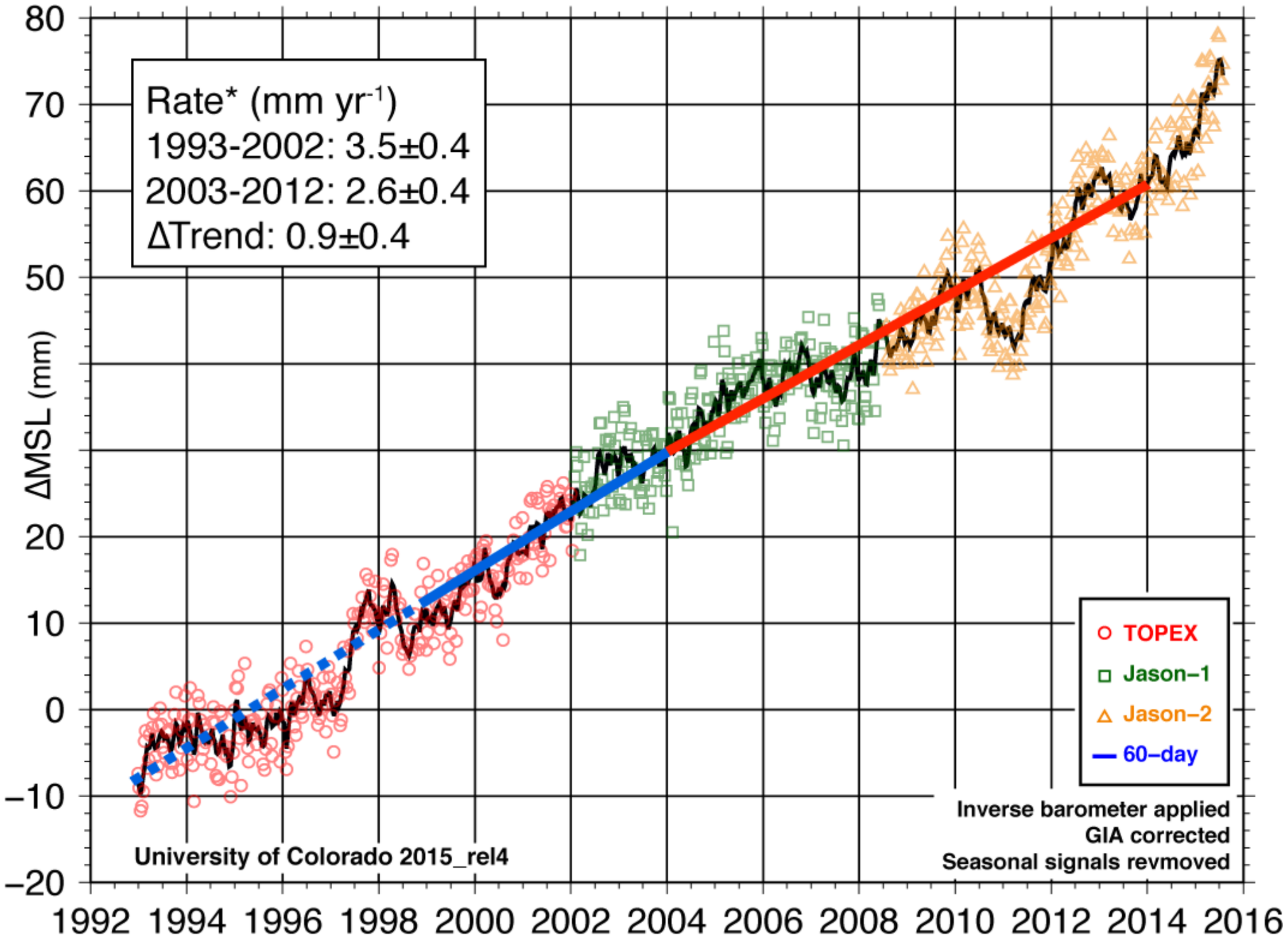
- There is strong resistance in some regions to projections of acceleration (building cost).

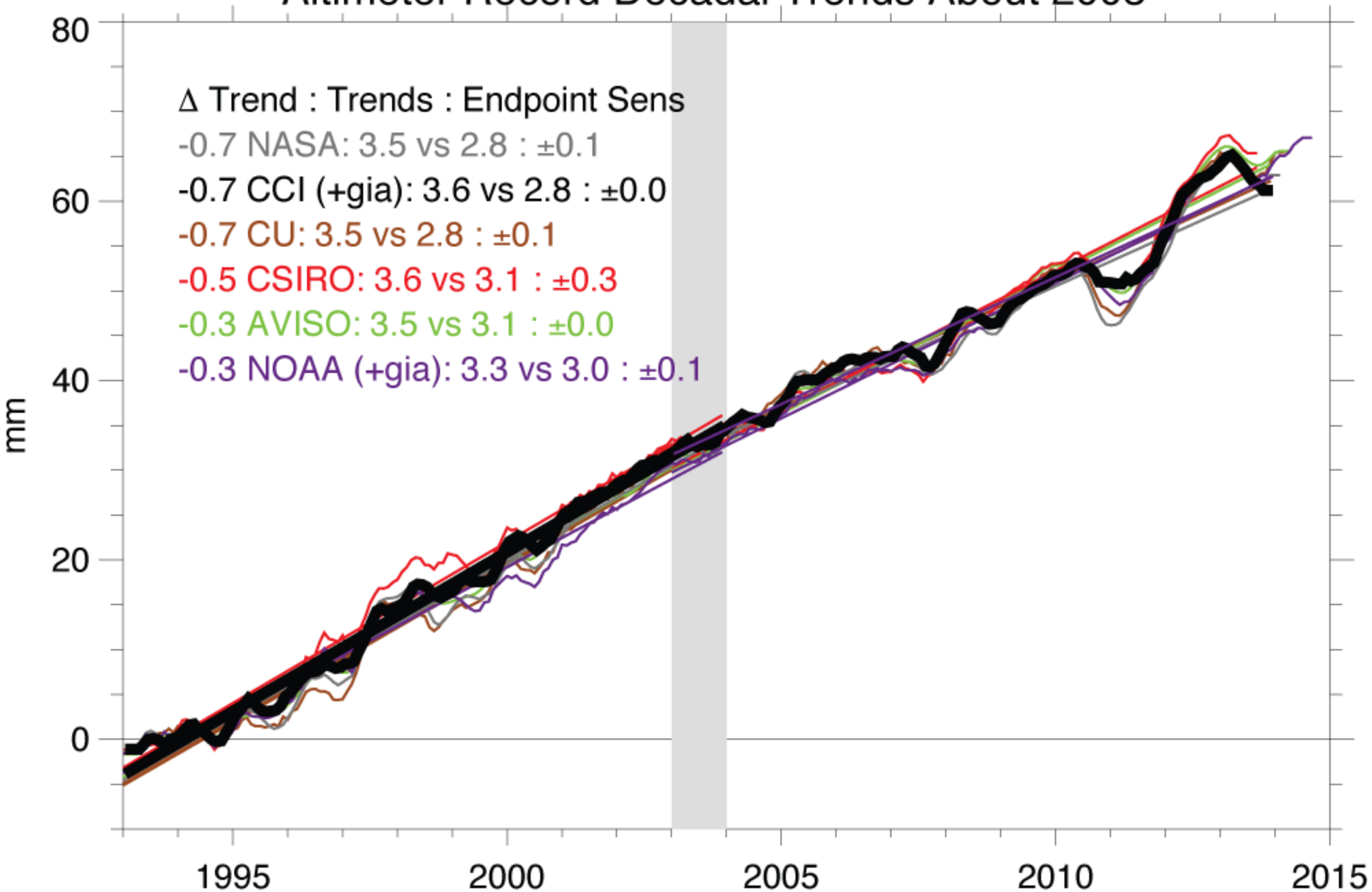
- Unanticipated acceleration also has major costs.



Sandy : $50B, Katrina $128B ($2015)

Yet altimetry reports a deceleration. Why?





1993-2002 mean rate > 2003-2012 mean rate by 7 mm/decade for 3 products
Some dataset dependence and endpoint sensitivity exists yet extending to 2015 yields similar interdecadal change.

Hypotheses for Deceleration

- Increases in terrestrial water storage in the past decade (Cazenave et al. 2014,NCC) ***We have found this result to likely be spurious : arises from the forcing datasets used.***

- Revisions to altimeter bias-drift corrections enabled by GPS. Particularly important from 1993-1998 (Watson et al. 2015, NCC) ***Large uncertainty in magnitude.***

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LETTERS

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The rate of sea-level rise

Anny Cazenave[1]*, Habib-Boubacar Dieng[1], Benoit Meyssignac[1], Karina von Schuckmann[2], Bertrand Decharme[3] and Etienne Berthier[1]

Present-day sea-level rise is a major indicator of climate change[1]. Since the early 1990s, sea level rose at a mean rate of ~3.1 mm yr^{-1} (refs 2,3). However, over the last decade a slowdown of this rate, of about 30%, has been recorded[4–8]. It coincides with a plateau in Earth's mean surface temperature evolution, known as the recent pause in warming[1,9–12]. Here we present an analysis based on sea-level data from the altimetry record of the past ~20 years that separates interannual natural variability in sea level from the longer-term change probably related to anthropogenic global warming. The most prominent signature in the global mean sea level interannual variability is caused by El Niño–Southern Oscillation, through its impact on the global water cycle[13–16]. We find that when correcting for interannual variability, the past decade's slowdown of the global mean sea level disappears, leading to a similar rate of sea-level rise (of 3.3 ± 0.4 mm yr^{-1}) during the first and second decade of the altimetry era. Our results confirm the need for quantifying and further removing from the climate records the short-term natural climate variability if one wants to extract the global warming signal[10]

climate sceptics to refute global warming and its attribution to a steadily rising rate of greenhouse gases in the atmosphere. It has been suggested that this so-called global warming hiatus[11] results from El Niño–Southern Oscillation- (ENSO-) related natural variability of the climate system[10] and is tied to La Niña-related cooling of the equatorial Pacific surface[11,12]. In effect, following the major El Niño of 1997/1998, the past decade has favoured La Niña episodes (that is, ENSO cold phases, reported as sometimes more frequent and more intensive than the warm El Niño events, a sign of ENSO asymmetry[19]). The interannual (that is, detrended) GMSL record of the altimetry era seems to be closely related to ENSO, with positive/negative sea-level anomalies observed during El Niño/La Niña events[2]. Recent studies have shown that the short-term fluctuations in the altimetry-based GMSL are mainly due to variations in global land water storage (mostly in the tropics), with a tendency for land water deficit (and temporary increase of the GMSL) during El Niño events[13,14] and the opposite during La Niña[15,16]. This directly results from rainfall excess over tropical oceans (mostly the Pacific Ocean) and rainfall deficit

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LETTERS

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Unabated global mean sea-level rise over the satellite altimeter era

Christopher S. Watson[1]*, Neil J. White[2], John A. Church[2], Matt A. King[1,3], Reed J. Burgette[4] and Benoit Legresy[2]

The rate of global mean sea-level (GMSL) rise has been suggested to be lower for the past decade compared with the preceding decade as a result of natural variability[1], with an average rate of rise since 1993 of +3.2 ± 0.4 mm yr^{-1} (refs 2,3). However, satellite-based GMSL estimates do not include an allowance for potential instrumental drifts (bias drift[4,5]). Here, we report improved bias drift estimates for individual altimeter missions from a refined estimation approach that incorporates new Global Positioning System (GPS) estimates of vertical land movement (VLM). In contrast to previous results (for example, refs 6,7), we identify significant non-zero systematic drifts that are satellite-specific, most notably affecting the first 6 years of the GMSL record. Applying the bias drift corrections has two implications. First, the GMSL rate (1993 to mid-2014)

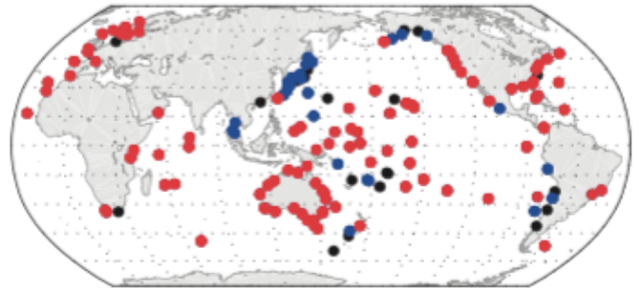


Figure 1 | Map of the initial 122 TGs used in this analysis. Additional quality control procedures (for example, obvious nonlinear VLM) eliminate

The 1991 Eruption of Mt Pinatubo

- **June 15, 1991**

- 2nd largest eruption of the 20th Century

- ~25 Tg of stratospheric aerosol loading

- Global cooling of ~0.5 C, substantial ozone depletion, weakening water cycle

What role did Pinatubo play in sea level rise of the 1990's?

The NCAR Large Ensemble

- **Motivation**: separating forced-response from internal variability. As variance of internal variability scales as $1/\sqrt{(N-1)}$, in the ensemble mean it is << forced response.

- **40 members:** using the CESM-CAM1 from 1920-2100: *no ice sheet contributions*

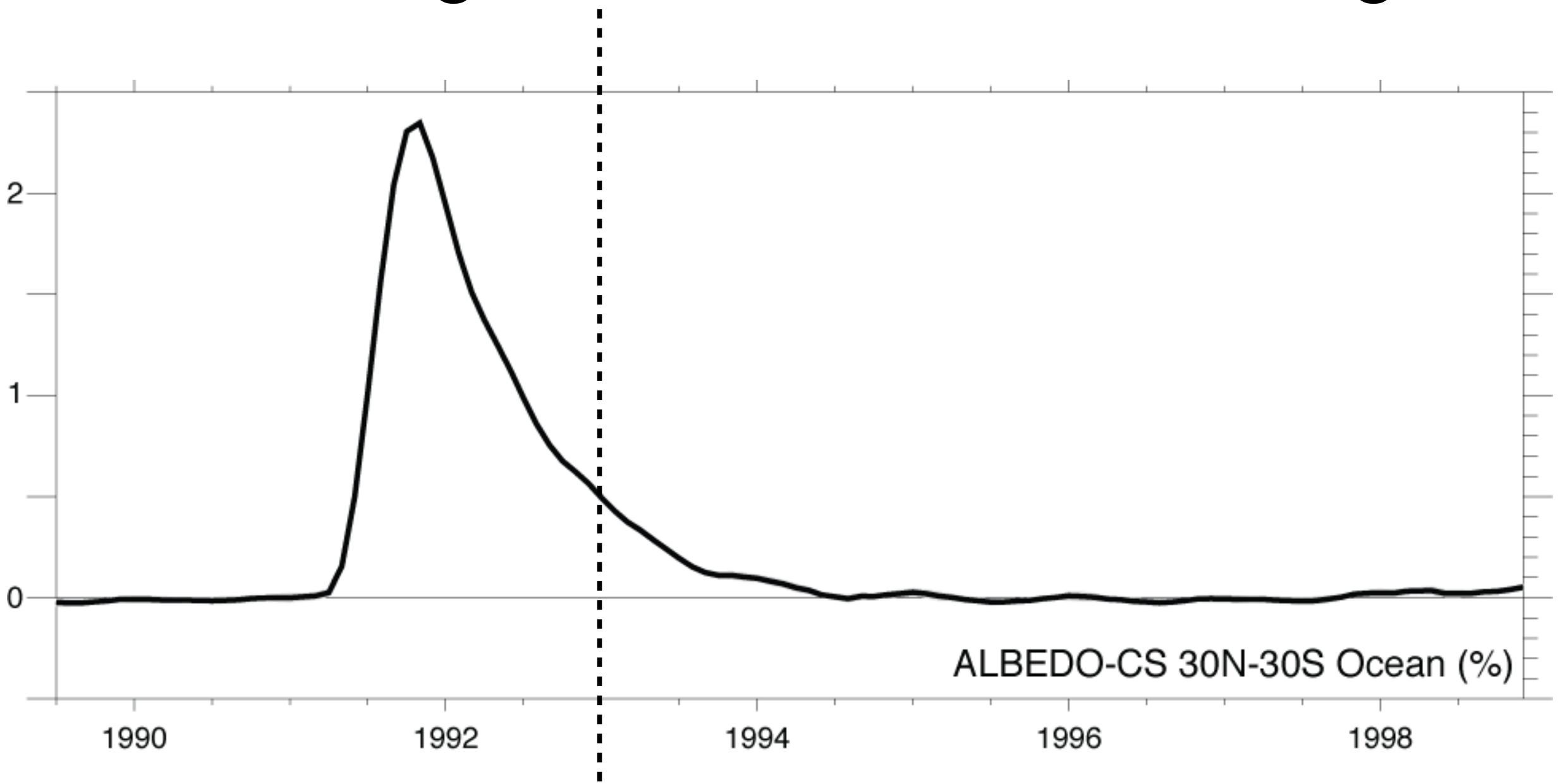
- **Fixed volume ocean** - Church conversion between OHC and GMSL (3e22 J=5 mm)

- **TWS** = ∫SOILLIQ+SOILICE+WA +H2OSNO+H2OCAN+VOLR

- ***Also using 4 "all-but-one(volc)" members of CESM1-CAM5 (run@ NERSC) to isolate volcanic effects***.

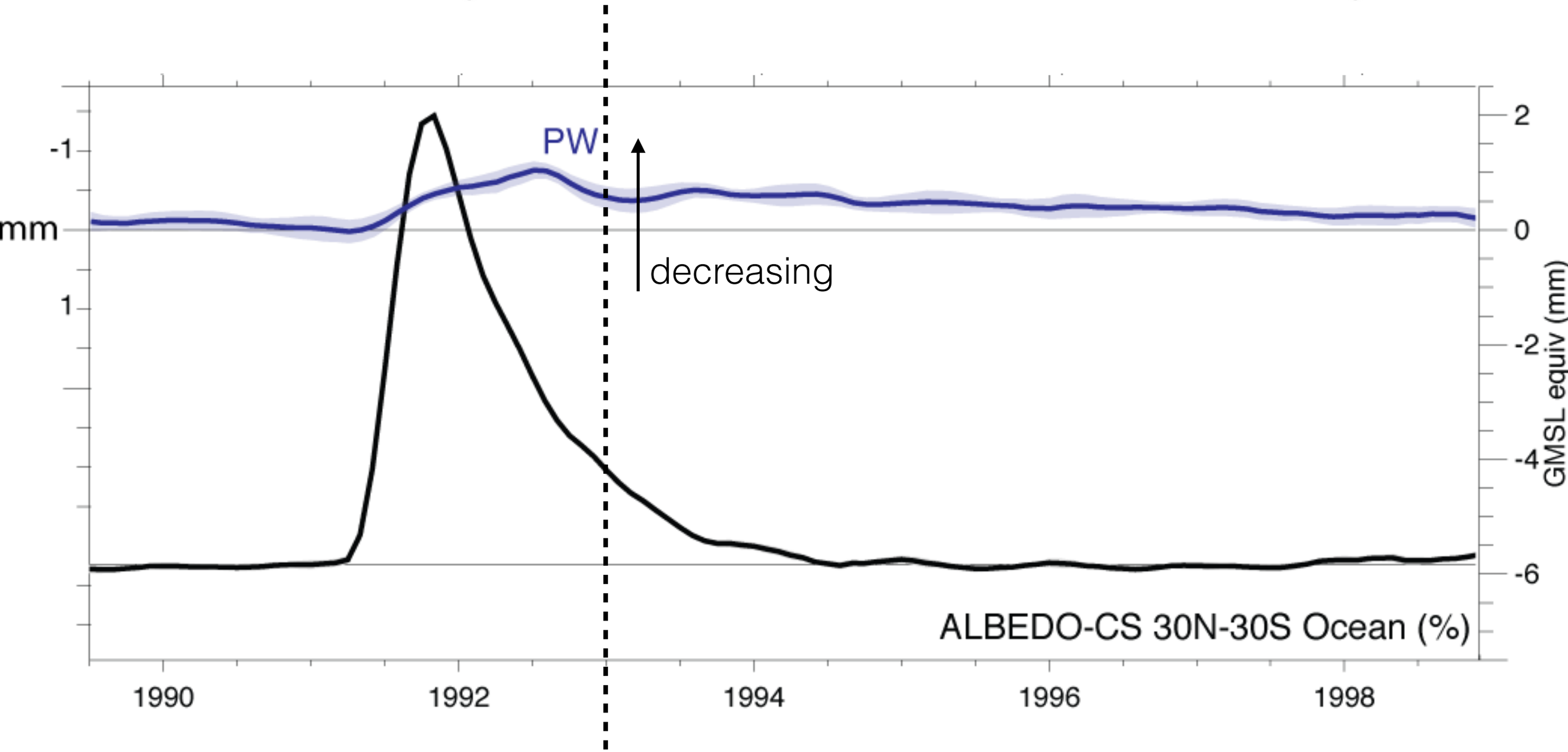
Yellowstone, Wyoming Supercomputing Center

The 1991 Eruption of Mt Pinatubo in the Large Ensemble: GMSL Budget



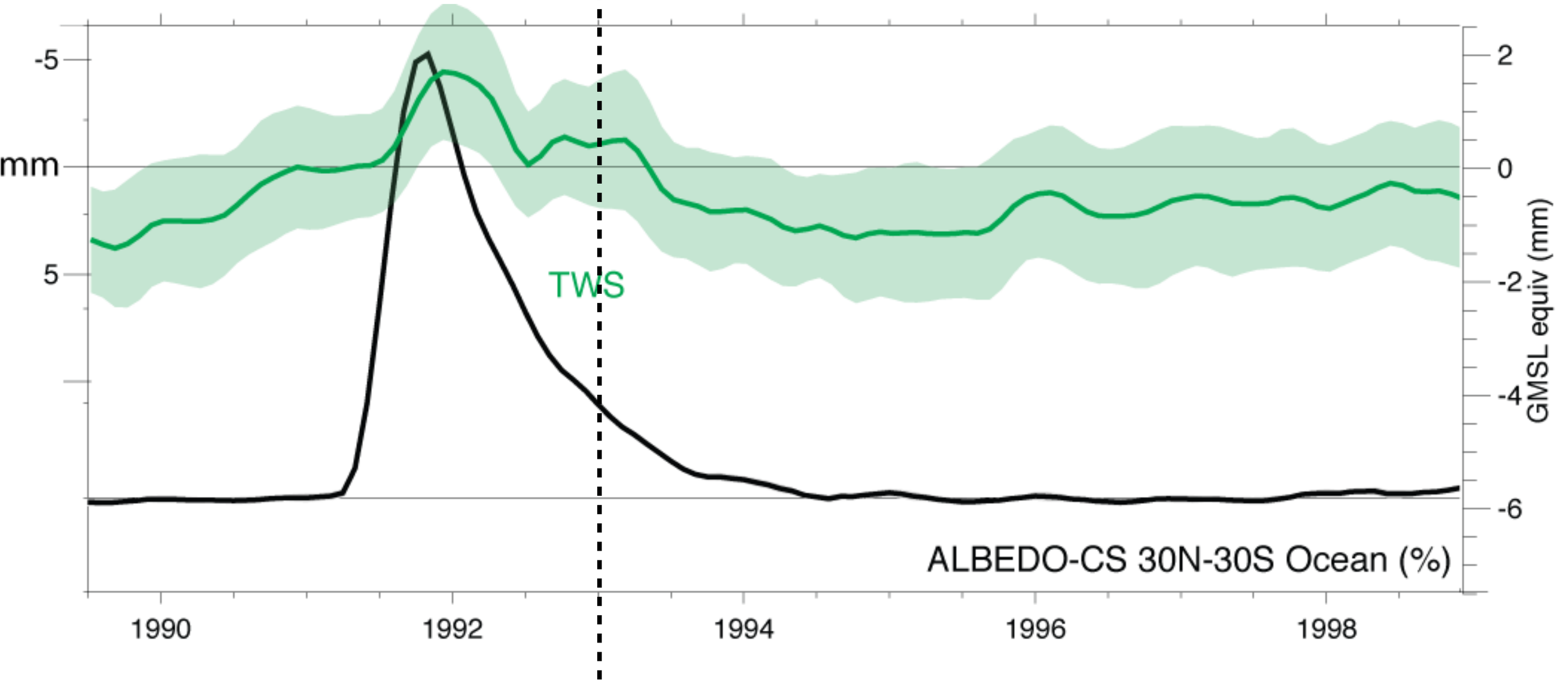
- Ensemble-mean clear sky albedo anomaly is a useful diagnostic for the eruption

The 1991 Eruption of Mt Pinatubo in the Large Ensemble: GMSL Budget



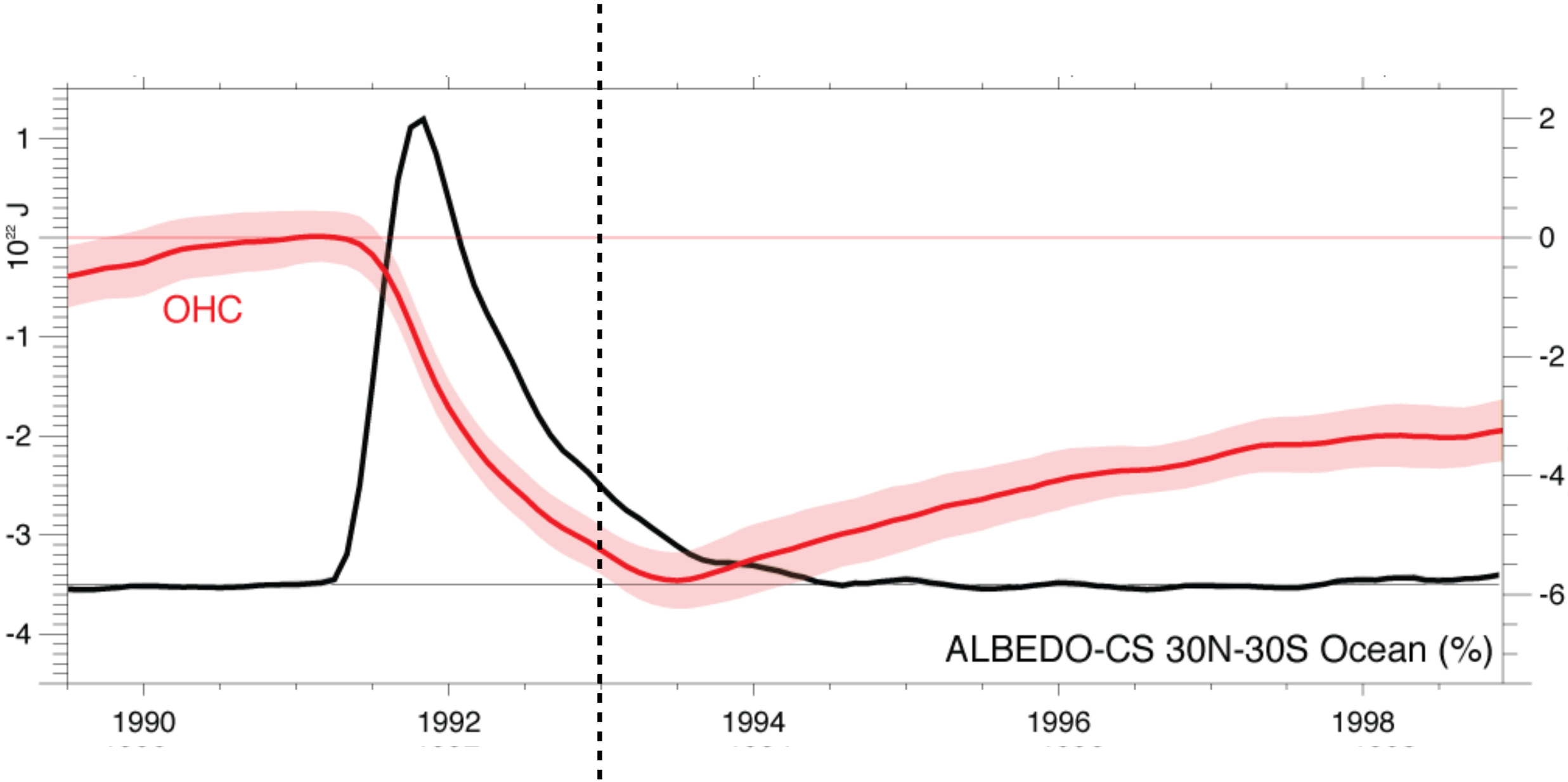
- Atmospheric PW DECREASES, contributing to an INCREASE in GMSL

The 1991 Eruption of Mt Pinatubo in the Large Ensemble: GMSL Budget



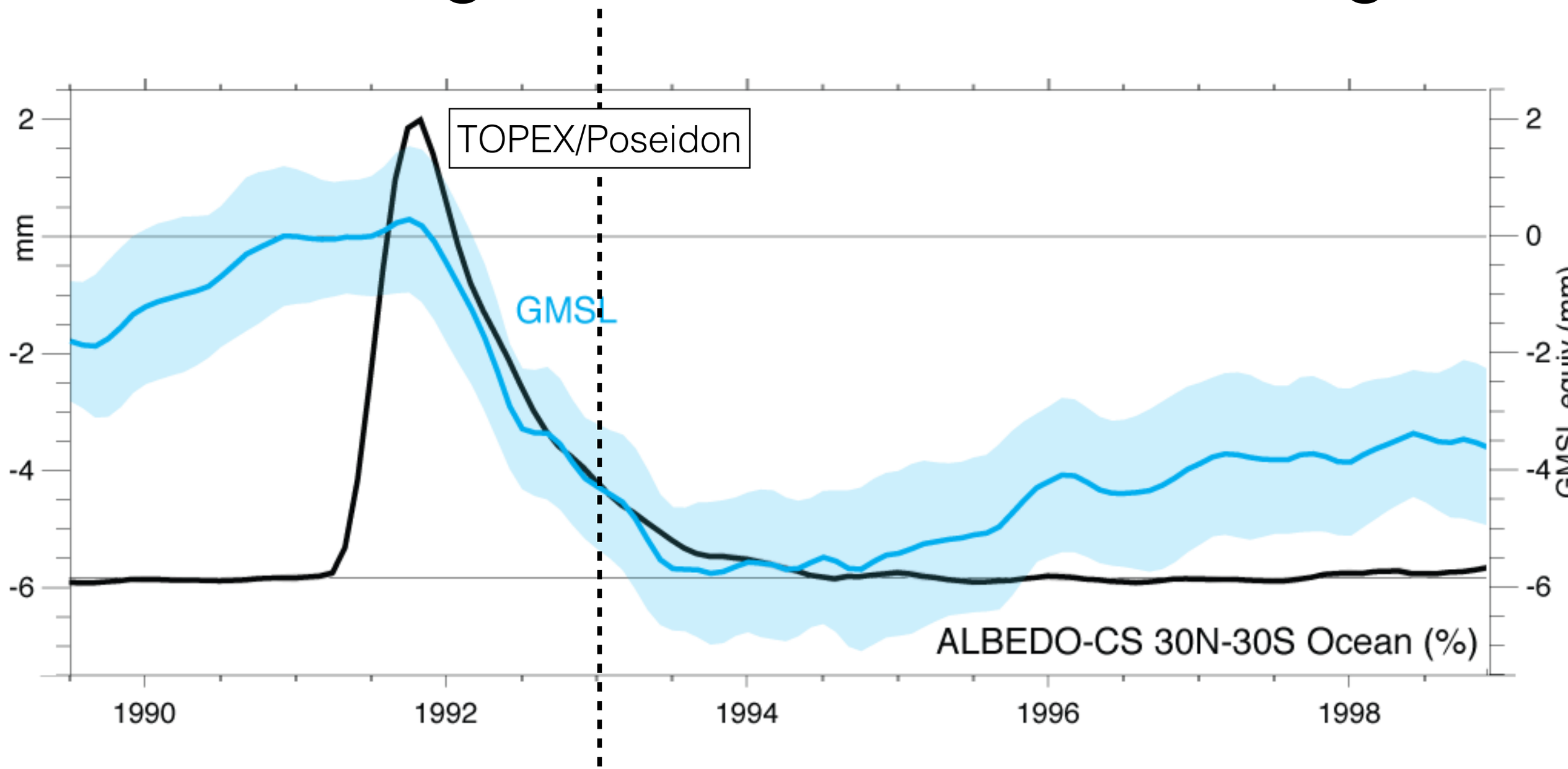
- Terrestrial water also DECREASES, contributing to an INCREASE in GMSL

The 1991 Eruption of Mt Pinatubo in the Large Ensemble: GMSL Budget



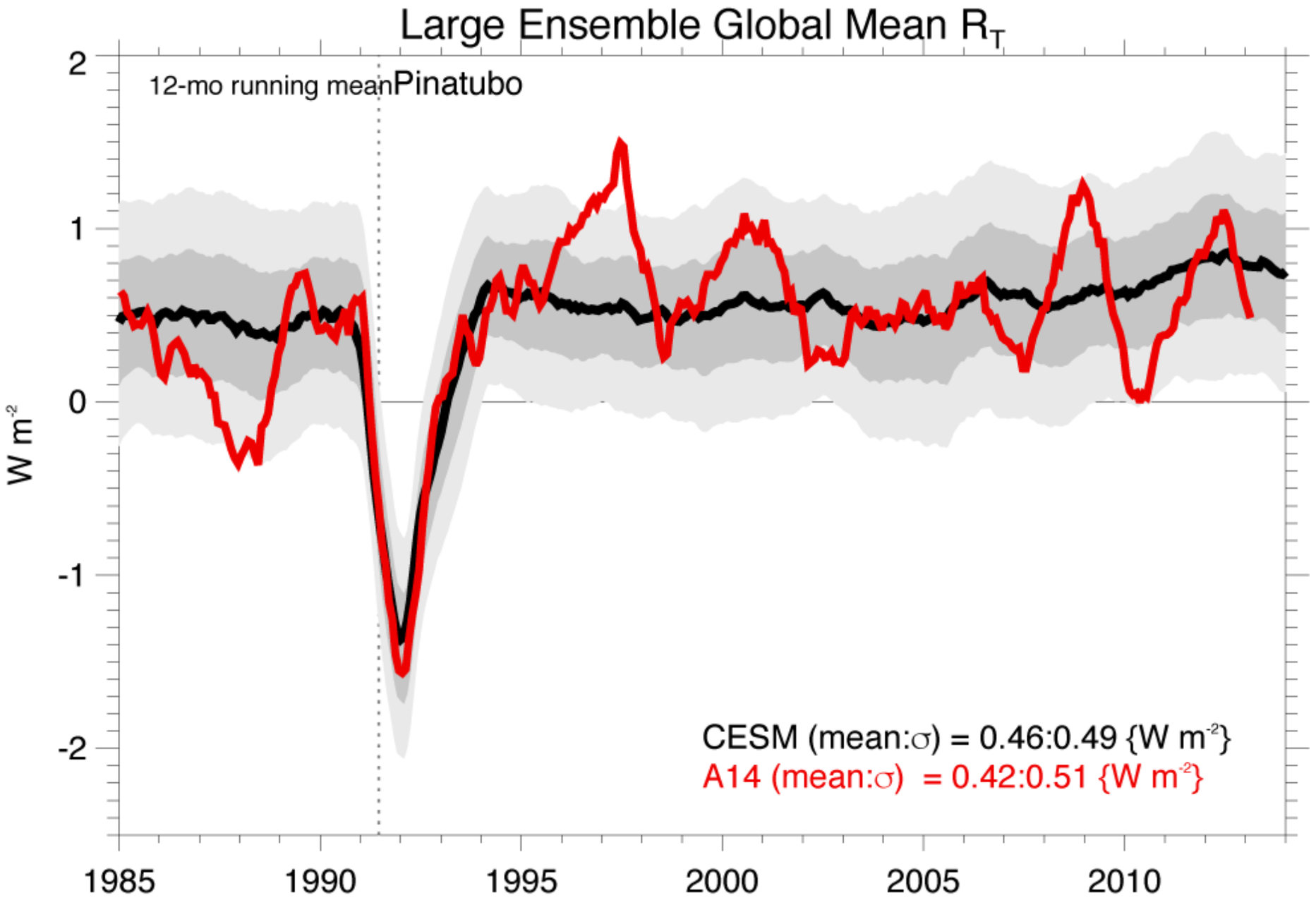
- Ocean heat content drops substantially due to the radiative forcing of the eruption

The 1991 Eruption of Mt Pinatubo in the Large Ensemble: GMSL Budget



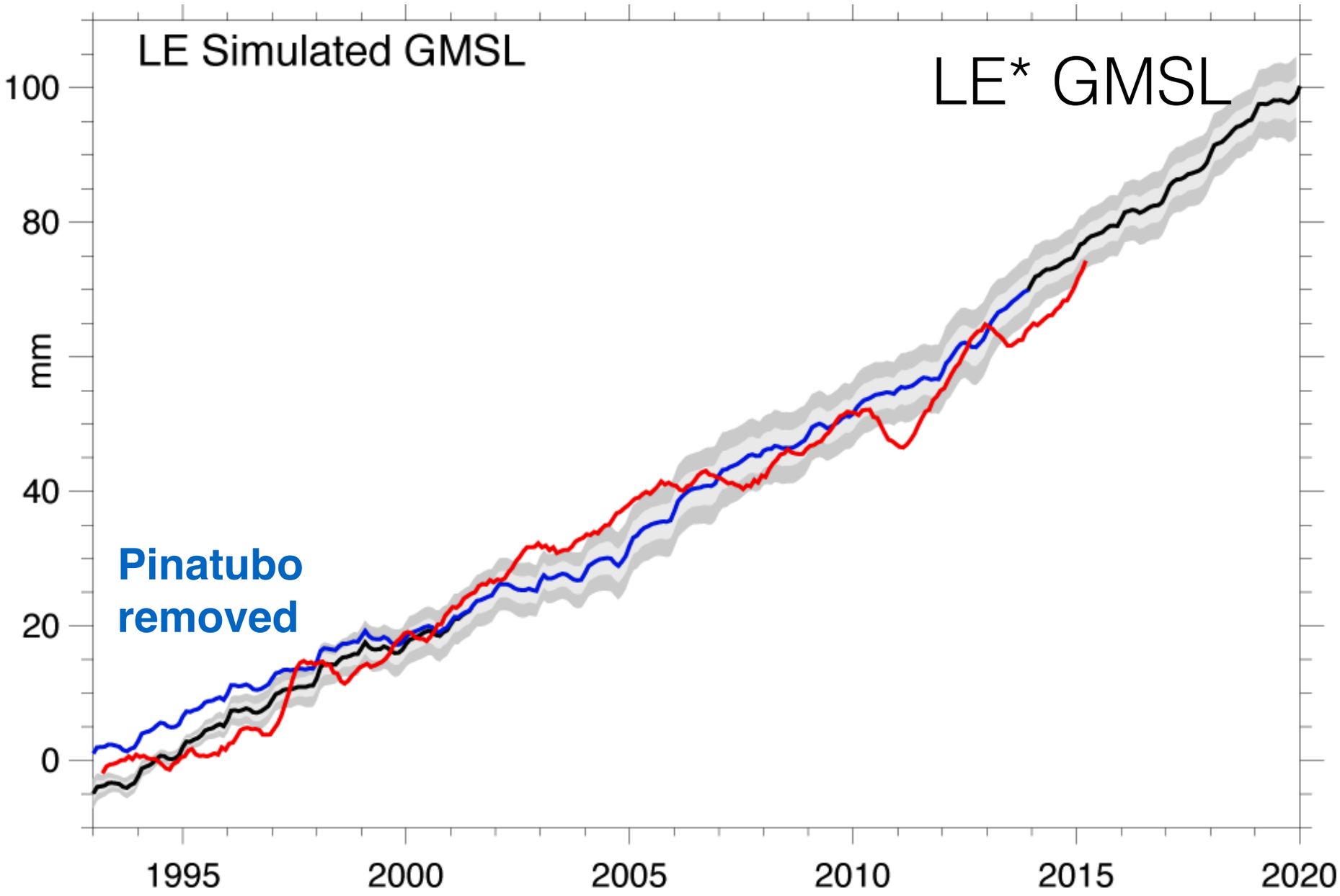
- The ensemble mean GMSL deficit reaches a minimum in 1993 of 5-7 mm

Validation of CESM with CERES



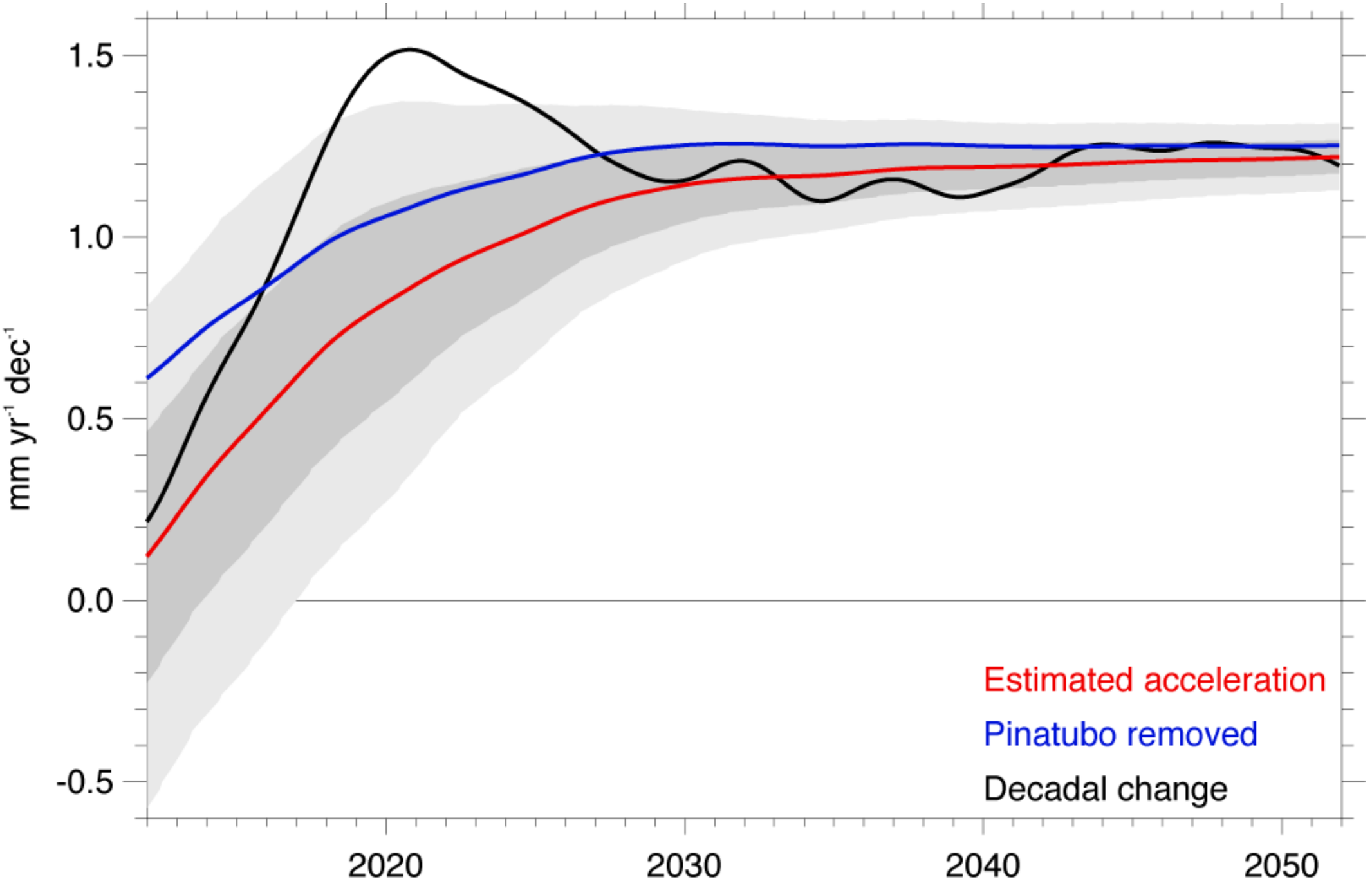
- LE Net TOA flux anomaly matches CERES' blended ERBS-CERES data

Removing Pinatubo's GMSL Influence



*Using AR5 simulated ice sheet contributions (lower bound, Ch 13)

Detecting and Projecting Acceleration



*Using AR5 simulated ice sheet contributions (lower bound, Ch 13)

Conclusions

- **Altimetry products robustly report GMSL deceleration** (1993-2002 vs 2003–2012).

- **The 1991 eruption of Mt. Pinatubo significantly lowered OHC and GMSL** - reaching a minimum in 1993, the start of the altimeter era, recovered gradually through the 1990s

- **An anomalous GMSL↑ of 5-7 mm in the decade following 1993 is estimated by the LE** - dominant driver of observed deceleration.

- Removing this signal from altimetry substantially reduces observed decadal variability and suggests that **acceleration should be evident within the next decade** (during Jason3), barring another major volcanic eruption.

Jason-3 launch vehicle's failed landing

a reminder that the best laid plans (and predictions) sometimes go awry…

https://youtu.be/c5qEJncn8Ms?t=29