

IS THE RATE OF SEA LEVEL RISE INCREASING?

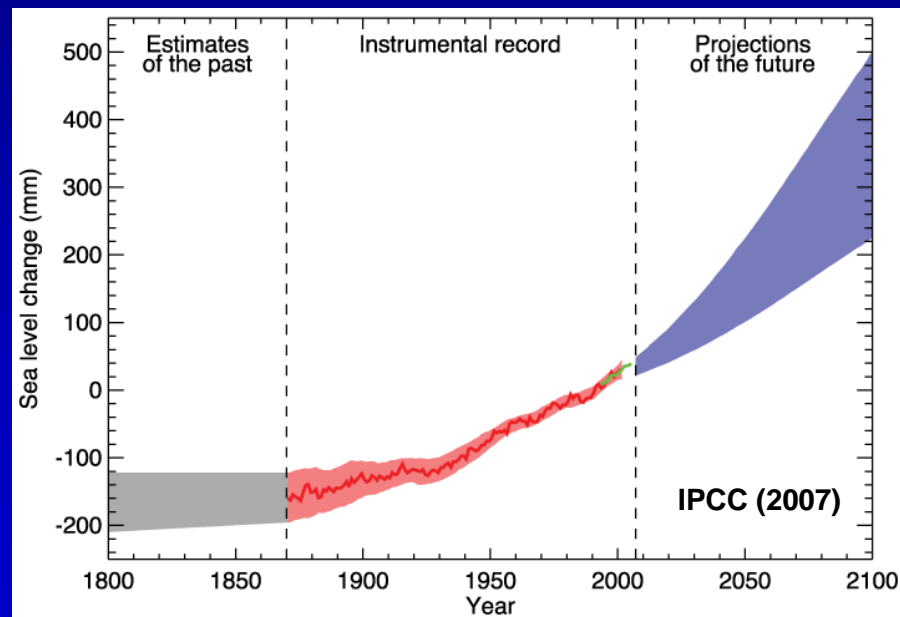
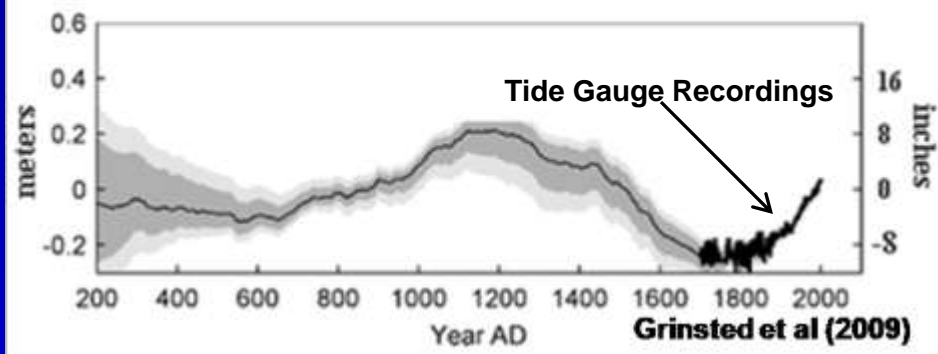
AN ANALYSIS BASED ON U.S. TIDE GAUGES AND COMPARISON TO GLOBAL GAUGE RESULTS

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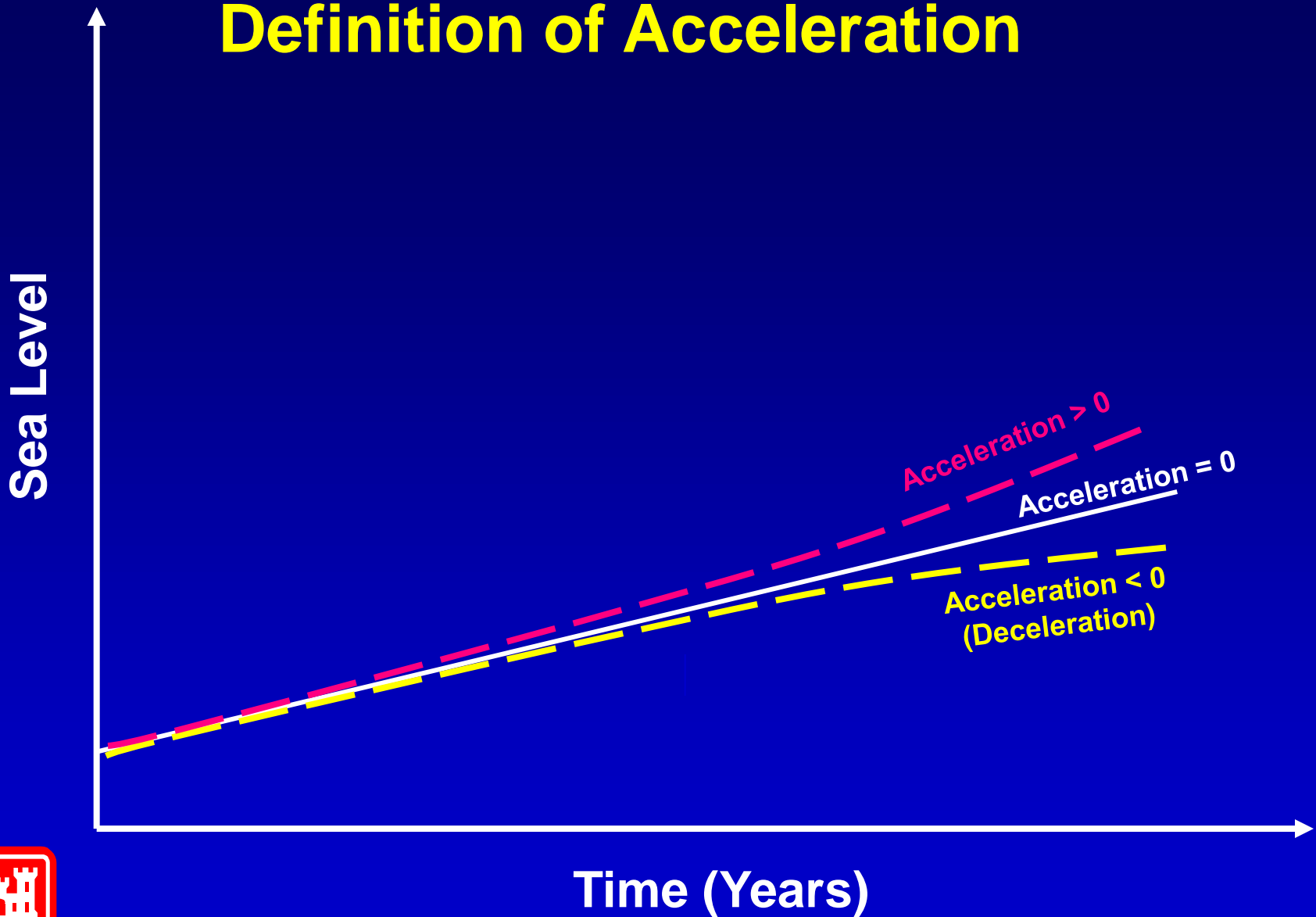
Sea Level Rise since 200 AD



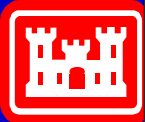
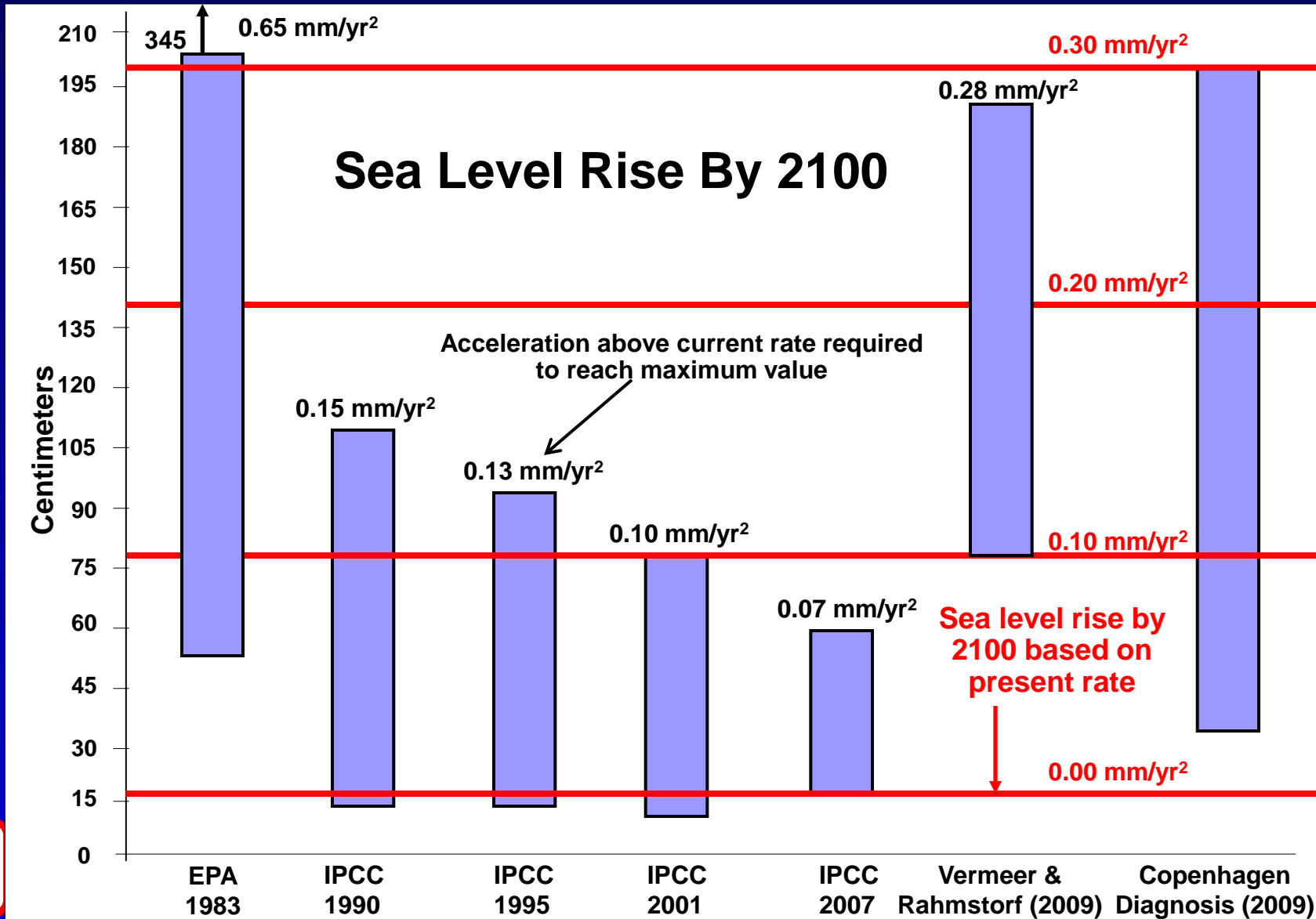
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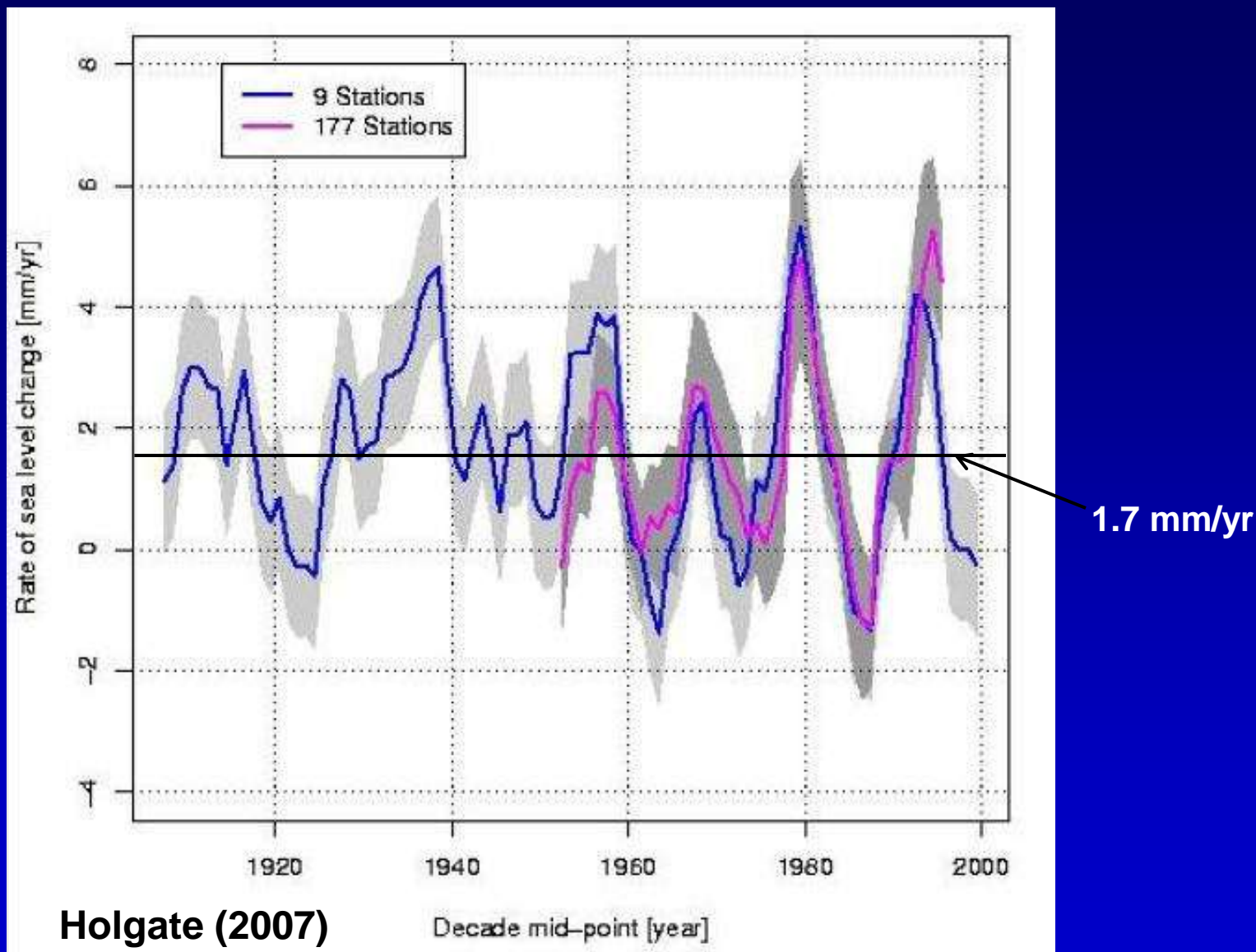
Definition of Acceleration



Why is Acceleration Important?



Sea Level Rise is Not Constant in Time



Holgate (2007)

Decade mid-point [year]



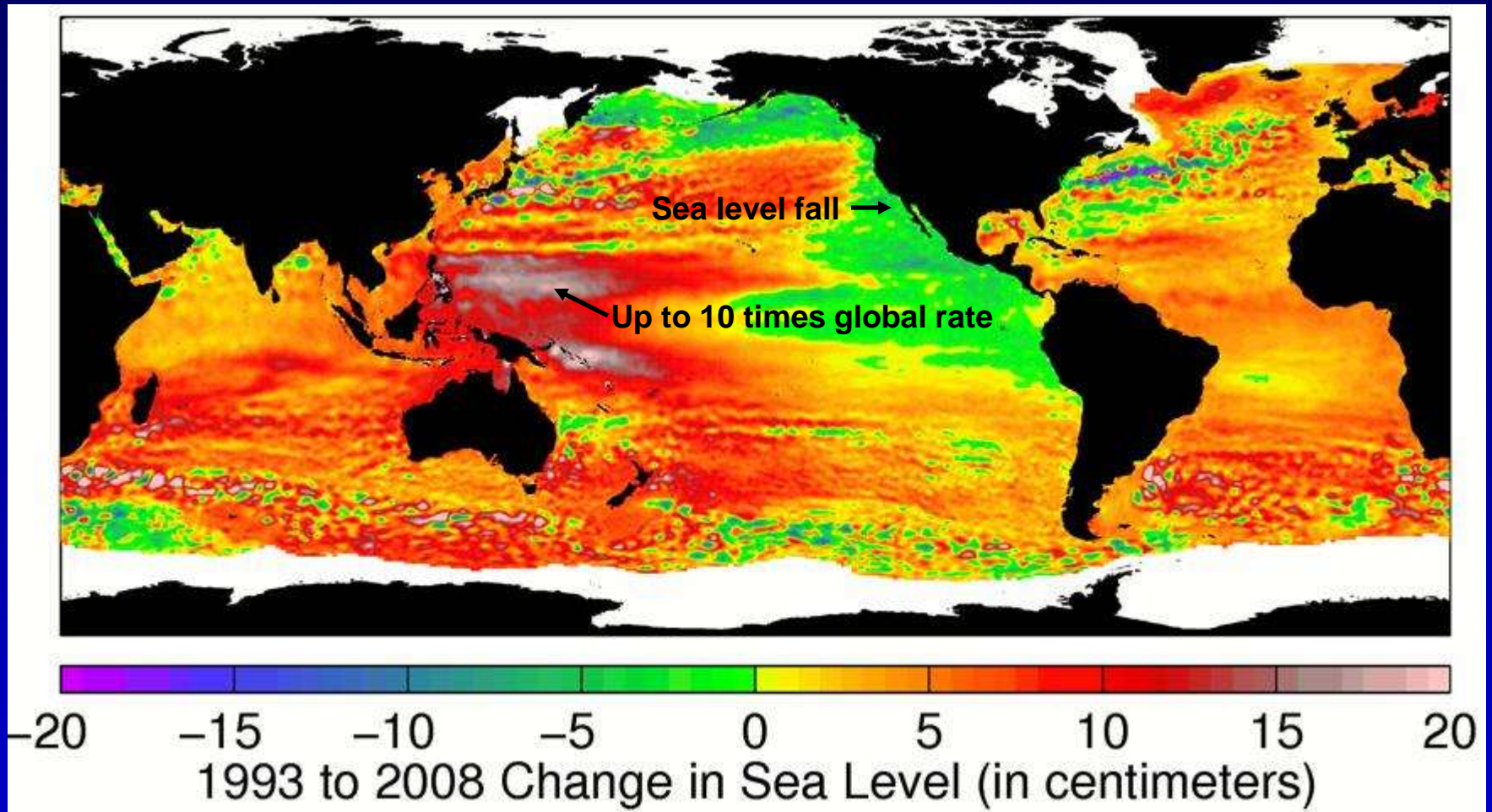
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Sea Level Rise is Not Constant Spatially Like a Bathtub Filling with Water



Sea Level Rise Is Spatially Very Non-Uniform



Satellite altimeter measurements over 15 years

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Common Assumption: Sea Level Rise is Accelerating

- *“Satellite and tide-gauge measurements show that the rate of sea level rise has accelerated”*
 - Copenhagen Diagnosis (2009)
- *“... there is strong scientific consensus that climate change is accelerating sea-level rise ...”*
 - U.S. Climate Change Science Program (2009)
- *“The rate of sea level rise is accelerating”*
 - Sea Grant (2008)
- *“So it is now apparent that SLR has accelerated over the twentieth century”*
 - Pew Center on Global Climate Change (2009)
- *“There is increasing evidence of continued and accelerating sea-level rises around the world”*
 - Royal Society (2009)

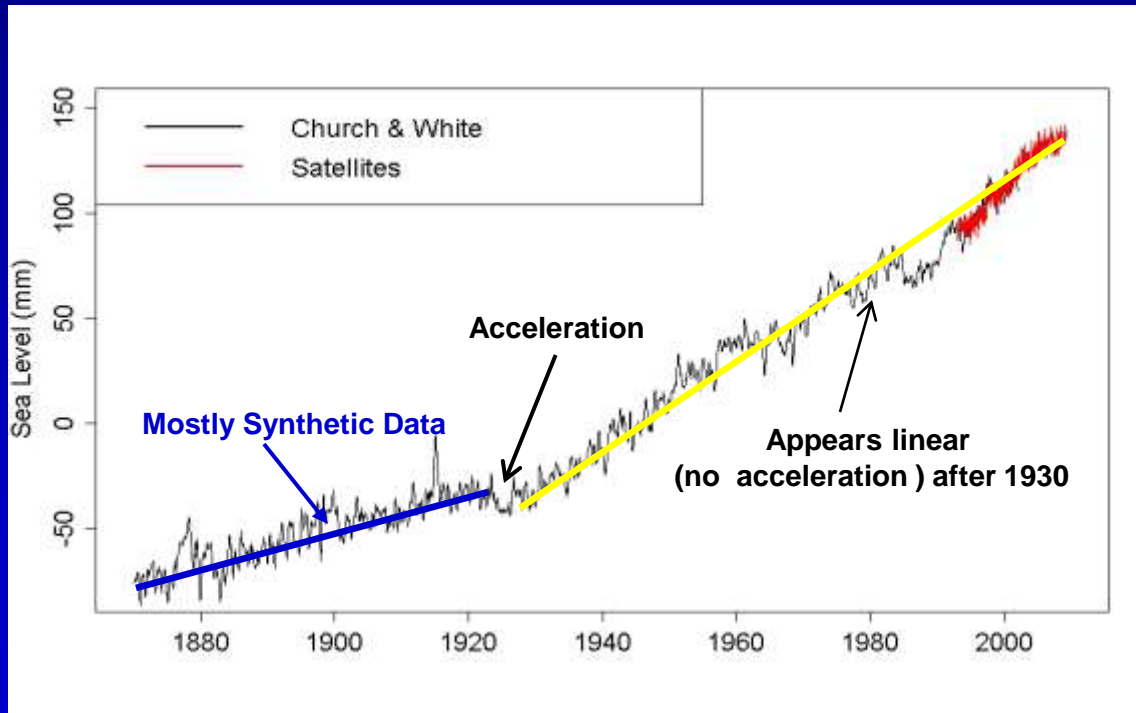


Not According to the Peer Reviewed Literature

- Douglas (1992), Journal of Geophysical Research (JGR), analyzed world-wide gauges and found a deceleration from 1905-1985
- Holgate (2007), Geophysical Research Letters, found a deceleration from 1904-2003
- Jevrejeva et al (2006), JGR, found a deceleration for 20th Century
- Church et al (2004), Journal of Climate, found no increase in the rate of sea level rise from 1950-2000
- Woodworth et al (2009), International Journal of Climatology, note *“... little evidence has been found in individual gauge records for an ongoing positive acceleration of the sort suggested for the 20th Century by climate models”*
- Woodworth (2006), Philosophical Transactions of the Royal Society, said *“... No definitive long-term acceleration of sea level has been identified using 20th Century data alone”*



- Church and White (2006) determined an acceleration of 0.013 ± 0.006 mm/yr², 1870-2001, and 0.008 ± 0.008 mm/yr², 1900-2001
- First 50 years of data are mostly “synthetic” rather than measured
- Acceleration since about 1930 is not apparent, although 80% of the atmospheric carbon dioxide loading by man has occurred since 1930
- An acceleration of 0.008 mm/yr² would raise sea level above current trend by only 3.2 cm = 1.3 inches by 2100

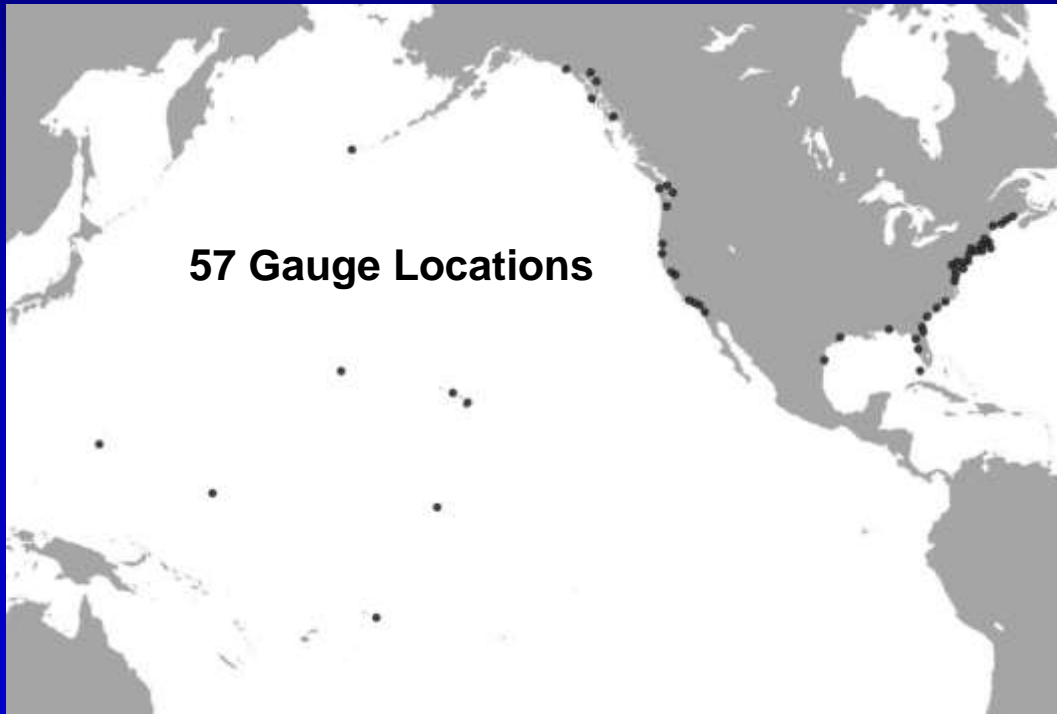


Data set used by Intergovernmental Panel on Climate Change (2007) and several researchers



Our Sea Level Rise Analysis

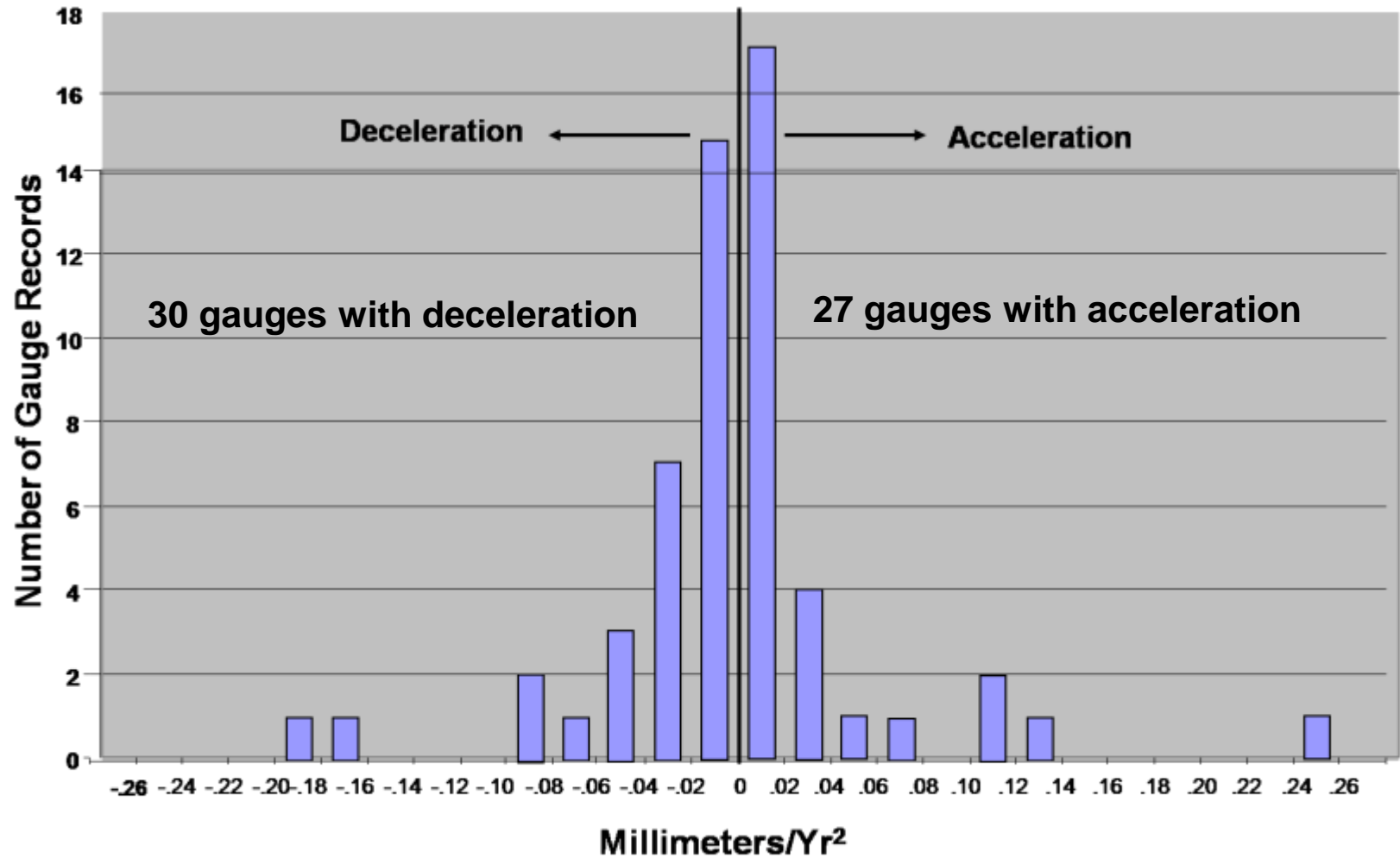
- Considered 57 U.S gauge records with a minimum of 60 years of data (record lengths 60-154 years)
- For each of the 57 records and also the period 1930-2010, we determined the linear slope and quadratic acceleration using the quadratic equation $y(t) = a_0 + a_1t + a_2t^2$



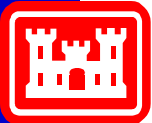
Data from Permanent
Service for Mean Sea
Level



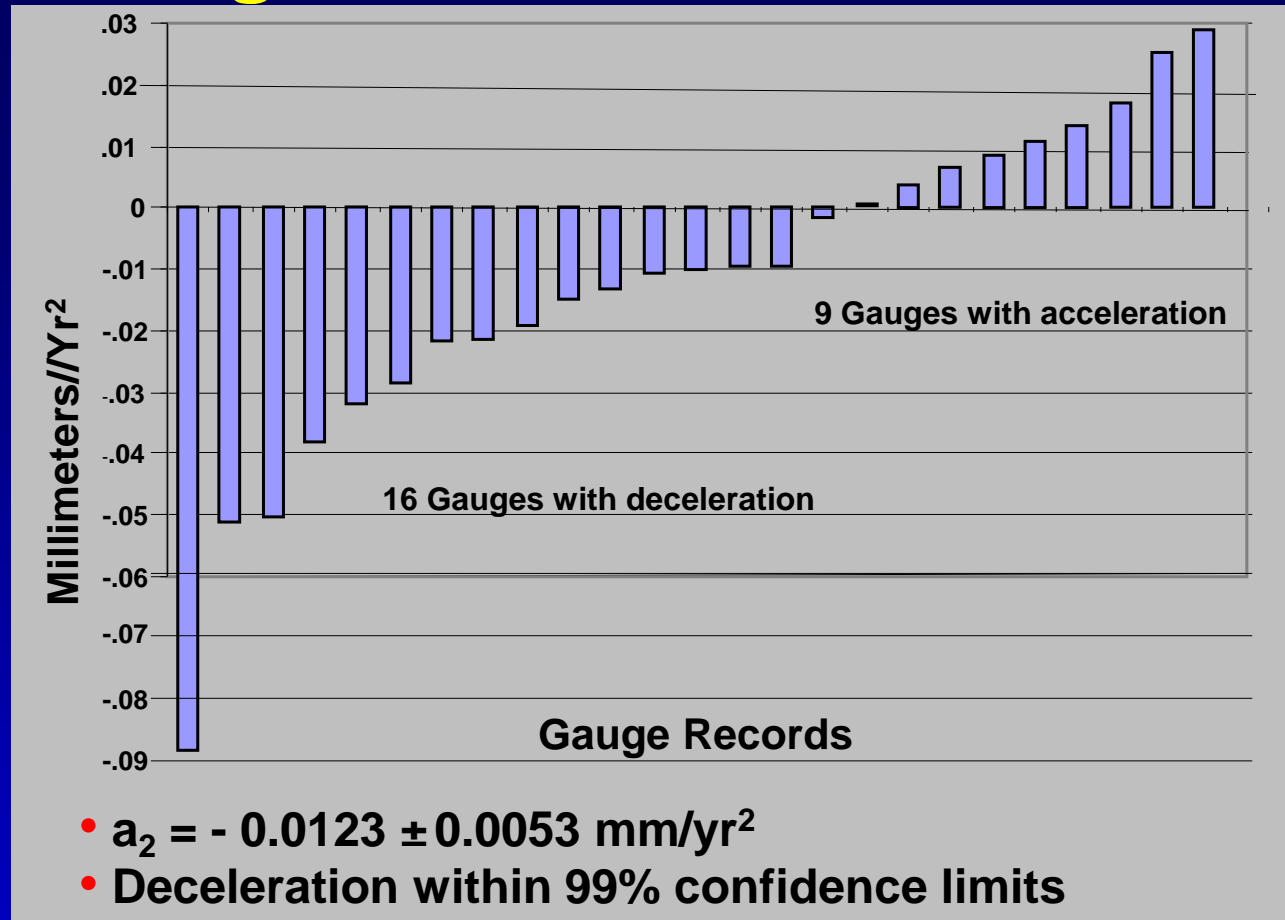
57 Gauge Accelerations/Decelerations



- $a_2 = -0.0014 \pm 0.0082 \text{ mm/yr}^2$ – a small deceleration
- Opposite sign & 2 orders of magnitude less than required to reach 1 meter by 2100



25 Gauges with Records 1930-2010



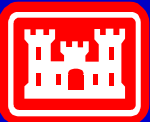
“... previous analyses suggest a general deceleration in sea level rise during the 20th century (Woodworth, 1990; Douglas, 1992; Jevrejeva et al., 2006)”

- Holgate (2007)

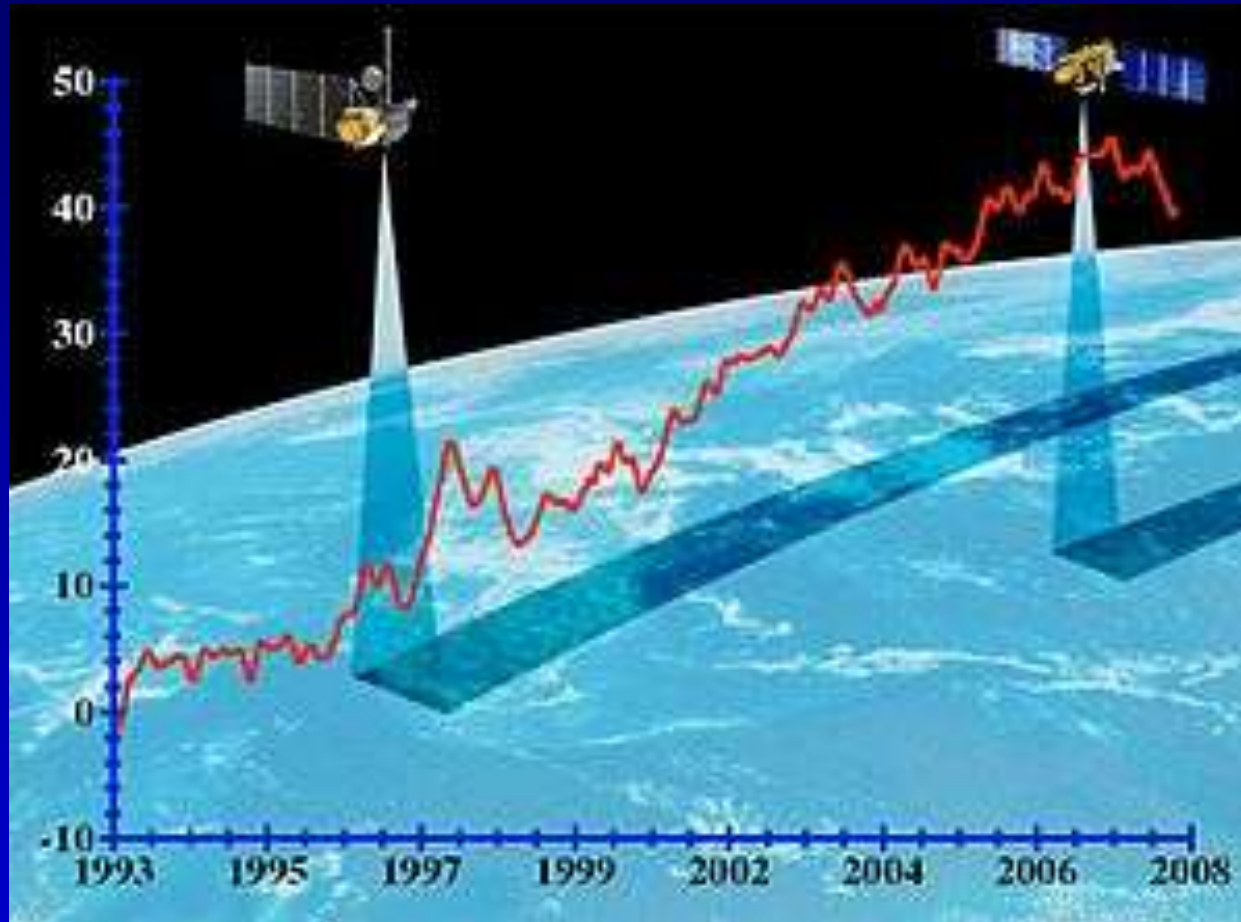


World-Wide Gauge Records

- Douglas (1992) analyzed world-wide gauges for 1905-1985 and found a deceleration of $- 0.011 \pm .012 \text{ mm/yr}^2$
- We added 25 years to his analysis, including the years of altimeter measurements, and obtained a deceleration of $- 0.012 \pm 0.012 \text{ mm/yr}^2$ for 1905-2010 and $- 0.015 \pm 0.011 \text{ mm/yr}^2$ for 1930-2010. Similar to our results.
- We analyzed the latest Church and White data from 1930-2007 and obtained a deceleration of $- 0.013 \text{ mm/yr}^2$
- World-wide gauge records agree with our analysis, displaying an even somewhat greater deceleration
- Addition of altimeter years makes little difference



Are Satellite Altimeter Measurements 1993-2010 The Leading Edge of An Acceleration?

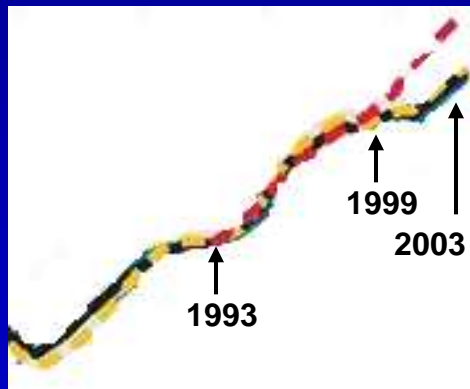


3.0 mm/yr trend is greater than 20th Century trend of 1.7 mm/yr



Satellite Altimeter & Gauge Recordings Diverge

- Domingues et al (2008) called for an “urgent” analysis of the divergence that started in 1999 in the agreement of satellite and tide gauge data
- The disagreement is important because satellite altimeter measurements are calibrated and drift corrected using tide gauge measurements



Satellite Altimeter
Red line

Domingues et al (2008)
Yellow dashed line

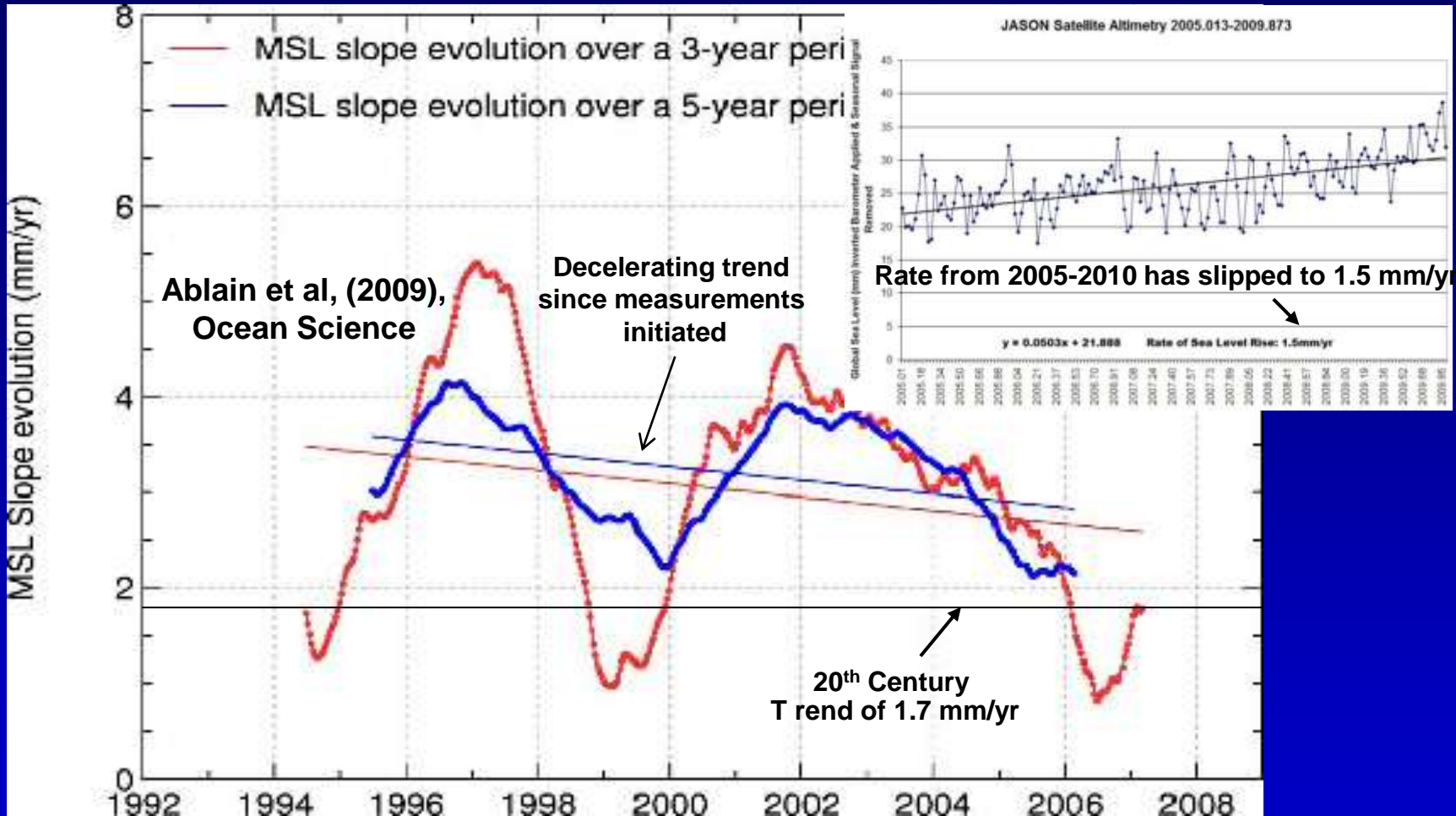
Jevrejeva et al (2006)
Black line

Holgate (2007)
Not shown

**Divergence observed in at least
3 separate world-wide tide gauge
data sets**

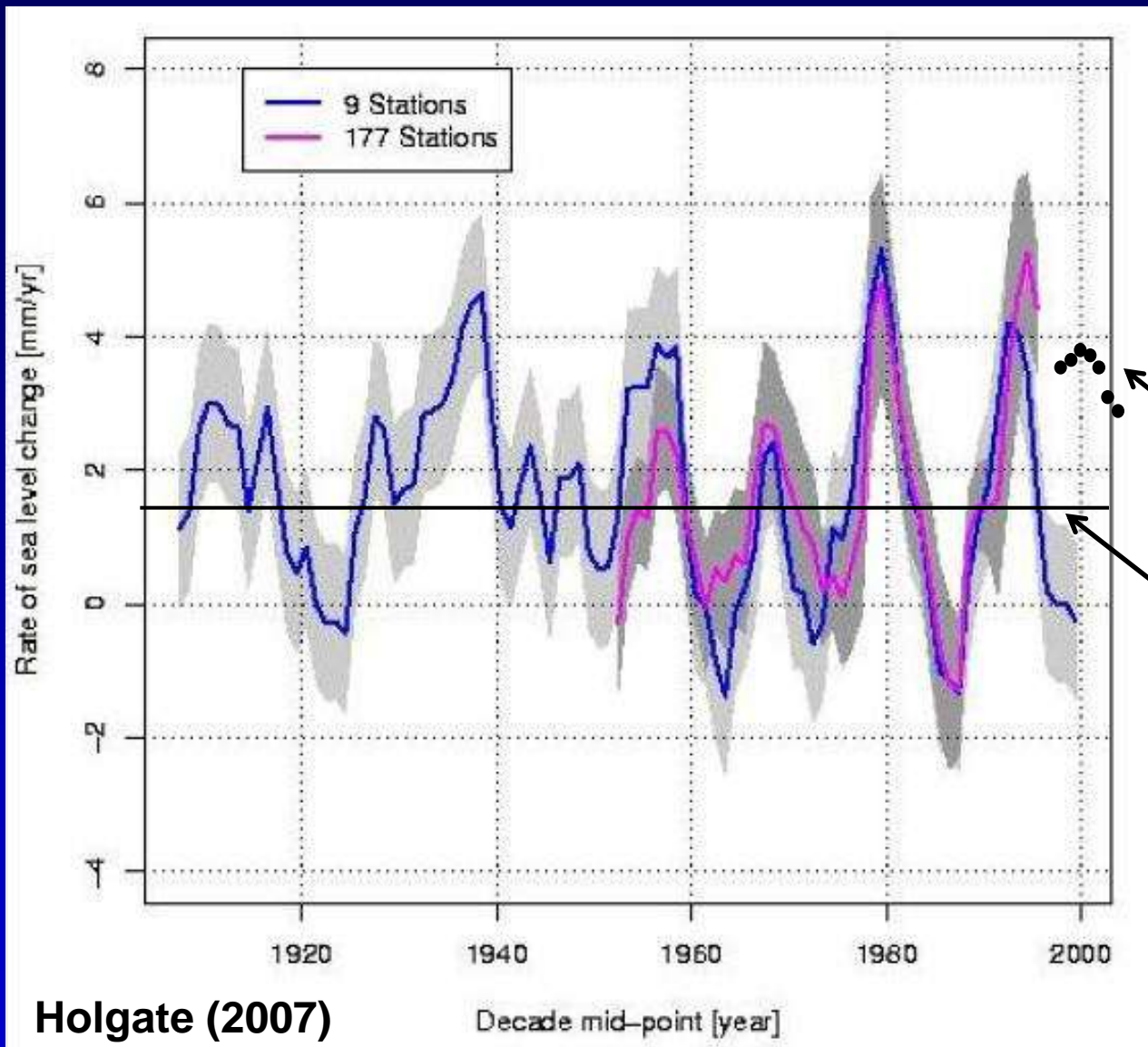


Sea Level Rise Rate Measured by Satellite Altimeters has been Decelerating



Altimeter data from Nov 1992 to April 2010 show a deceleration of $- 0.06 \text{ mm/yr}^2$

Sea Level Oscillations



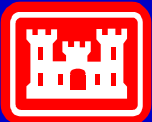
Holgate (2007)

Decade mid-point [year]



Concluding Remarks

- No study has changed the conclusion by Douglas (1992) that :
“There is no evidence for an apparent acceleration in the past 100+ years that is significant either statistically, or in comparison to values associated with global warming”
- Studies are needed such as that by the legendary oceanographer Walter Munk (2002), Proceedings of the National Academy of Sciences and entitled “Twentieth Century Sea Level: An Enigma”
- Munk concluded that based on everything he could muster to shed light on sea level rise, he could not explain why the current rate of sea level rise of 1.7 mm/yr *“... started too early, has too linear a trend, and is too large.”*



Recommendations

It is difficult to project the future when we do not understand the past or present

We need to determine why sea level rise has not accelerated in the 20th Century despite warming of about 1.35° F

