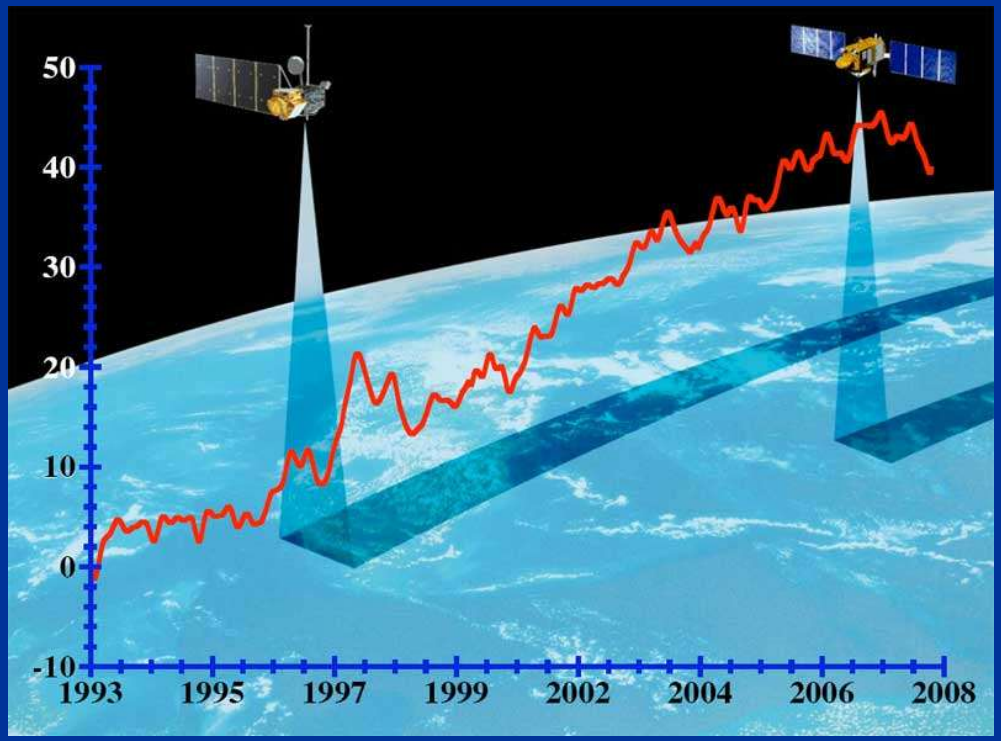
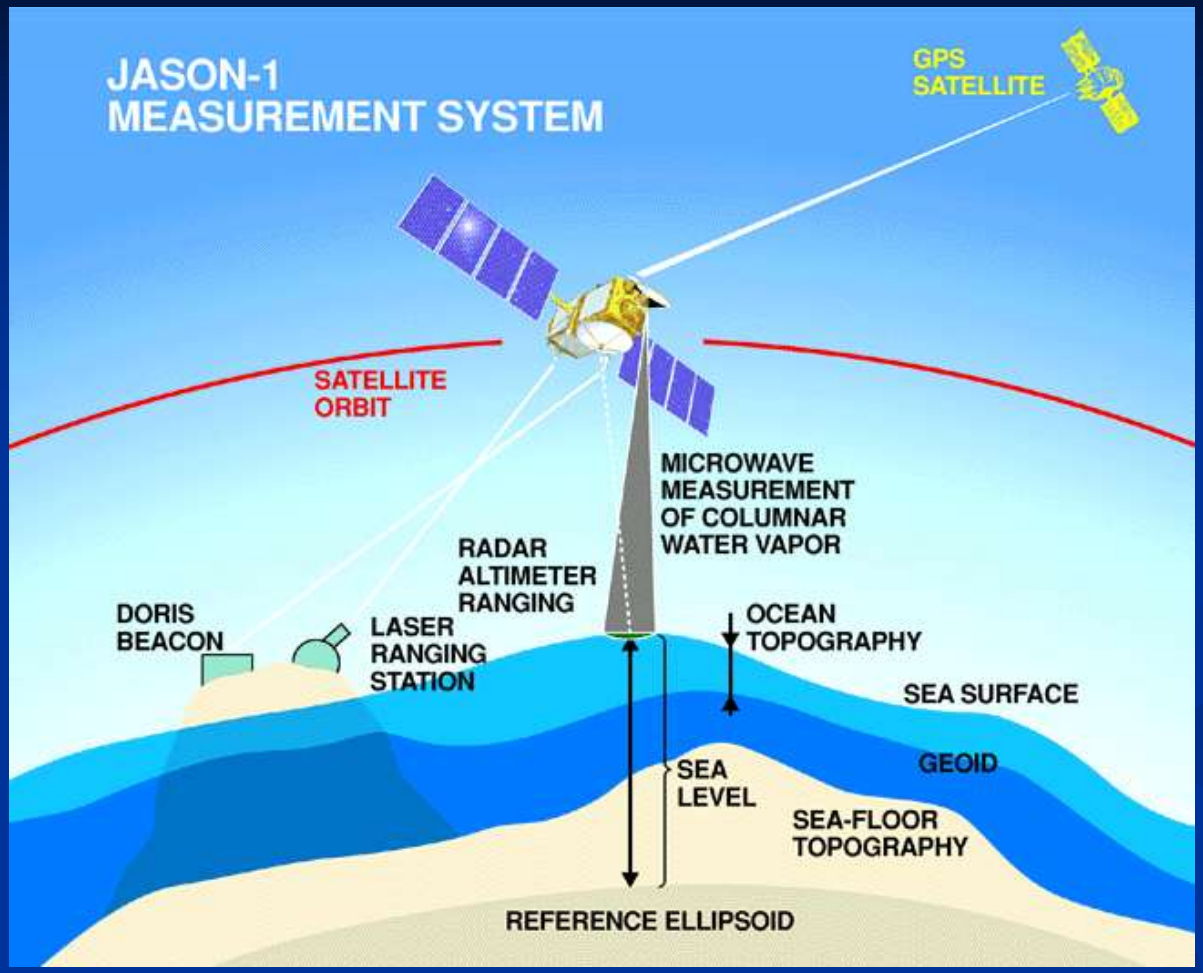
Comparison of Comprehensive Tide Gauge and Satellite Data Sets



Bob Dean and Jim Houston

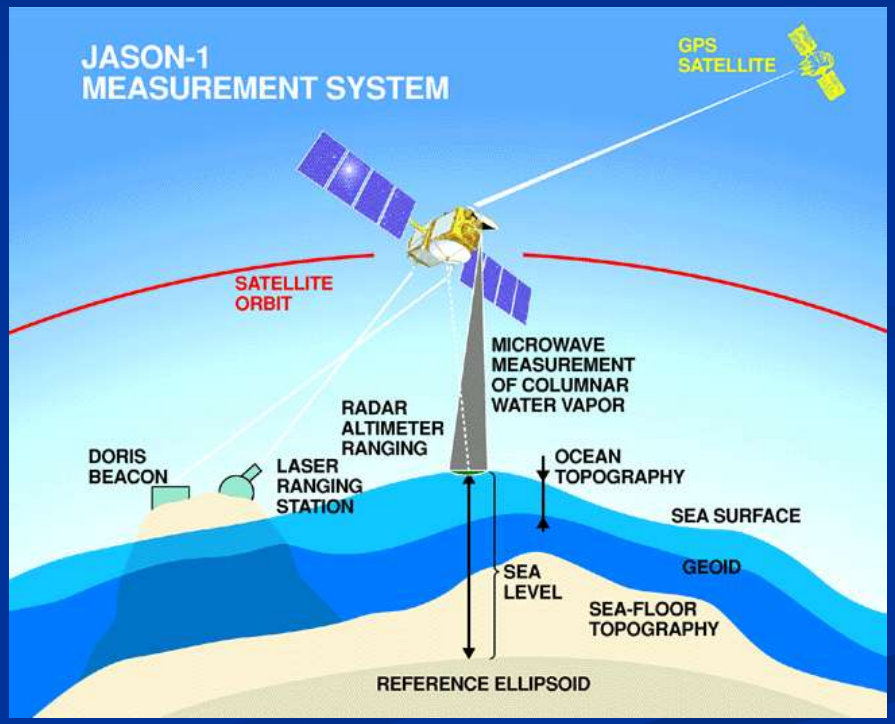
Satellite Altimetry



- Measures sea level from 1,330 km above Earth
- Measurements from - 65 degrees to + 65 degrees of latitude
- Measurements from 1993 through 2011

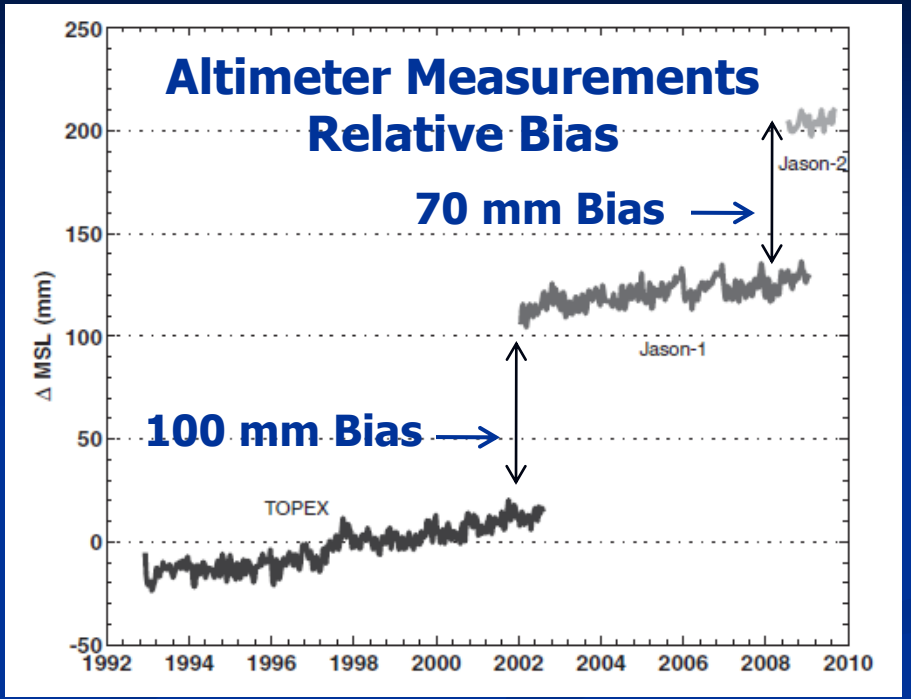
Three Main Questions

- Are satellite altimeter data correct that show a sea level rise of 3.2 mm/yr from 1993 to 2011, which is greater than the 20th Century rise of 1.7 mm/yr?
- If correct, is this increased rise a new trend or part of an oscillation?
- If part of an oscillation, has it occurred in the past?



Issues with Satellite Altimeters

- Altimeter measurements have been performed by three different satellites with short overlapping times in orbit
- In addition to relative bias, a GPS study showed Jason-1 had a 150-mm absolute bias, 3 times the rise measured by all 3 altimeters over 19 years

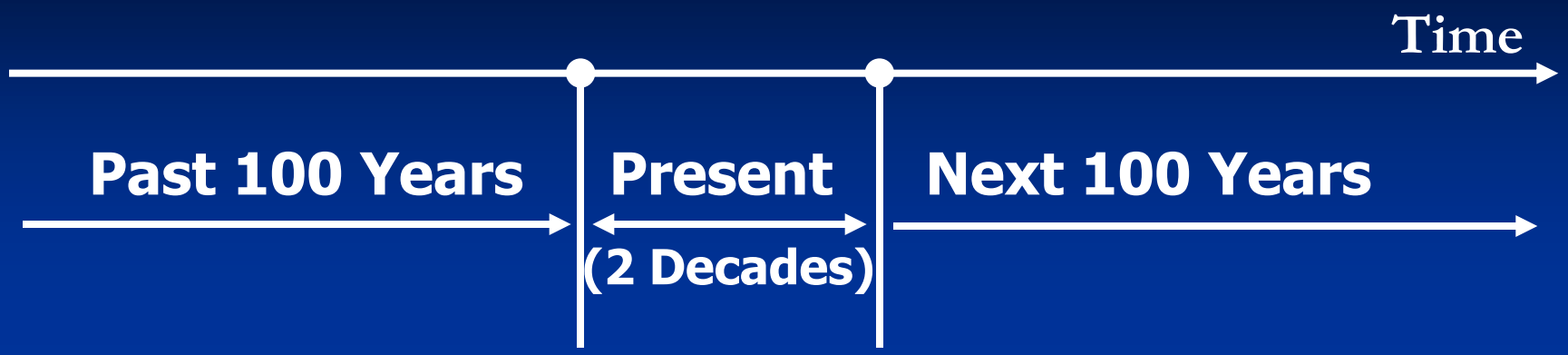


- Domingues et al (2008) in the journal *Nature* called for an "urgent" analysis of the divergence that started in 1999 in the agreement of satellite and tide gauge data
- The disagreement is important because satellite altimeter measurements are calibrated and bias and drift corrected using tide gauge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

Data Sources

- Tide Data from the Permanent Service for Mean Sea Level (PSMSL), United Kingdom
- Altimeter data from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
- GPS data from Étude d'un Système 'Observation du Niveau des Eaux Littorales (SONEL), France

Perspective of Sea Level Determinations



Agreement on a trend of 1.7 mm/yr

Either a very weak acceleration or deceleration

Subject of this presentation

Much greater uncertainties

Significant differences in projections

- **Various studies have determined accelerations of ~ ± 0.01 mm/yr^2 for the past 100 years**
- **A ± 0.01 mm/yr^2 acceleration produces a sea level change over 100 years of only ~ ± 2 inches**

We Use Standard Quadratic Equation

$$y = a_0 + a_1 t + \frac{1}{2} a_2 t^2$$

Sea Level

Constant

Initial Trend (mm/yr)

Time (Years)

Acceleration (mm/yr^2)

Definition of Acceleration

Car moving at a steady 120 miles/hr is not accelerating

Term "trend" is the rate of change of sea level with acceleration the rate of change of trend

Our Approach

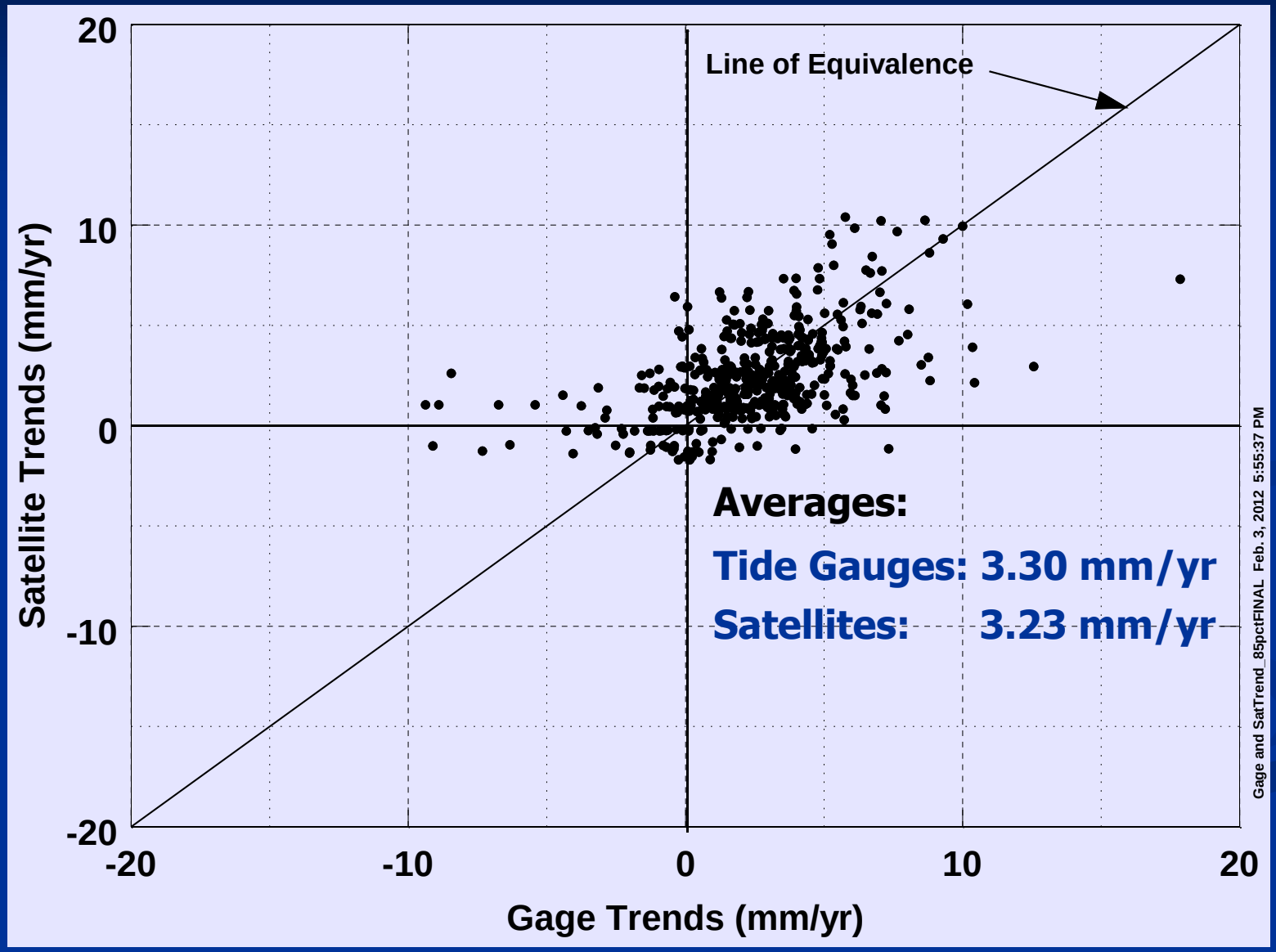
- Analyzed all tide gauge records with >85% measured data over the period 1993 to 2011 (total of 478 gauges)
- Analyzed those of the 478 gauges with nearby GPS gauge measurements (total of 90 gauges)
- Analyzed all satellite data on a 1 by 1 degree grid covering the world (total of 43,160 records)
- Compared trends and accelerations based on the tide gauge and altimeter measured data

Results

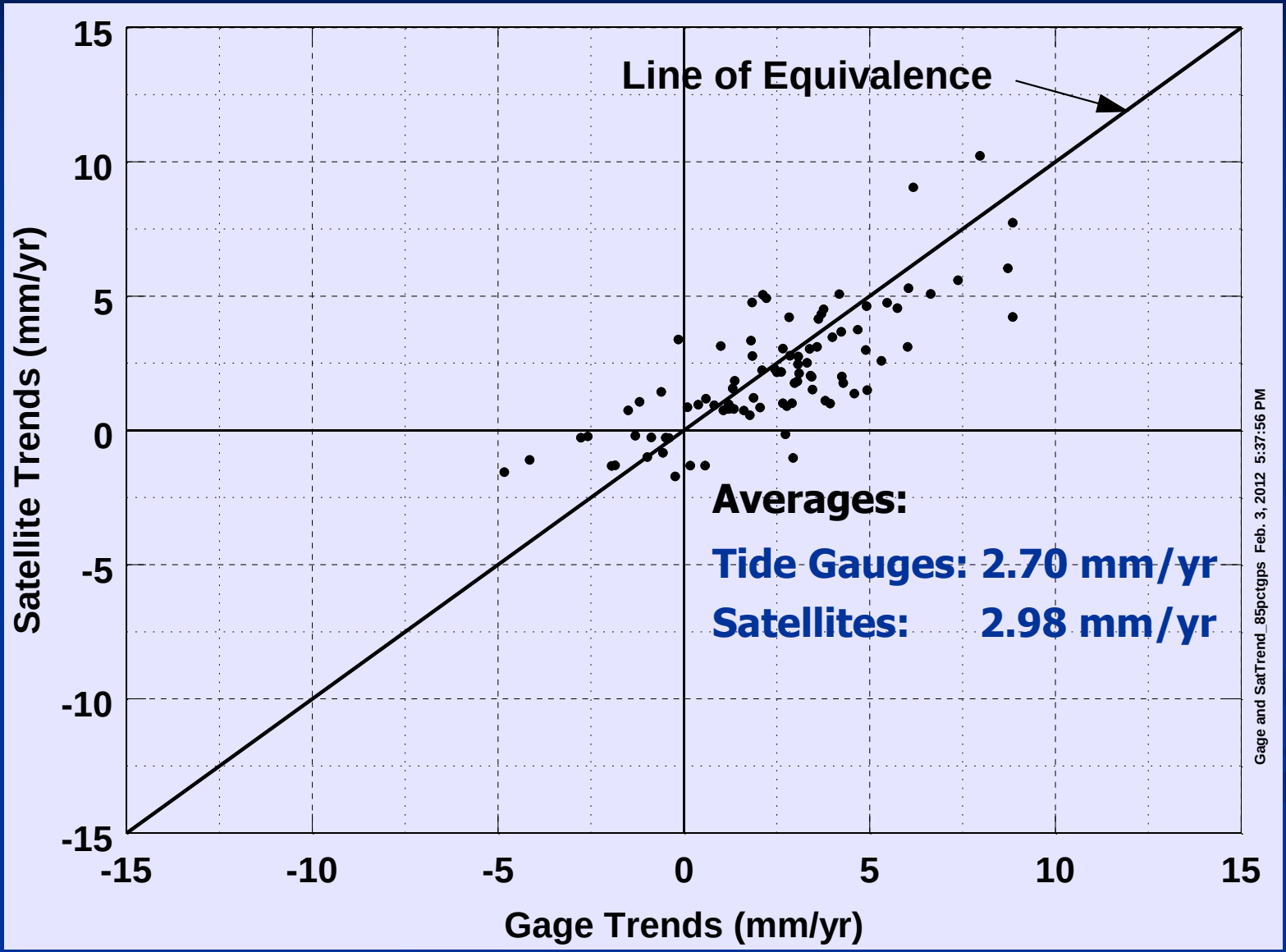
Data Description	No. of Gauges	Trend (mm/year)	Acceleration (mm/year^2)
Records, 85% Complete, adjusted for GPS or Glacial Isostatic Adjustment (GIA)	478	3.3 ± 0.3	- 0.076 ± 0.075
85% Complete, adjusted for GPS	90	2.7 ± 0.5	- 0.025 ± 0.13
Altimeter	43160	3.2 ± 0.5	- 0.042

Note: The "±" represents 95% confidence limits

Comparison of Trends From 478 "Paired" Gauges and Satellites (< 1 Degree Separation)



Comparison of Trends from 90 Tide Gauges Corrected for GPS and Satellites

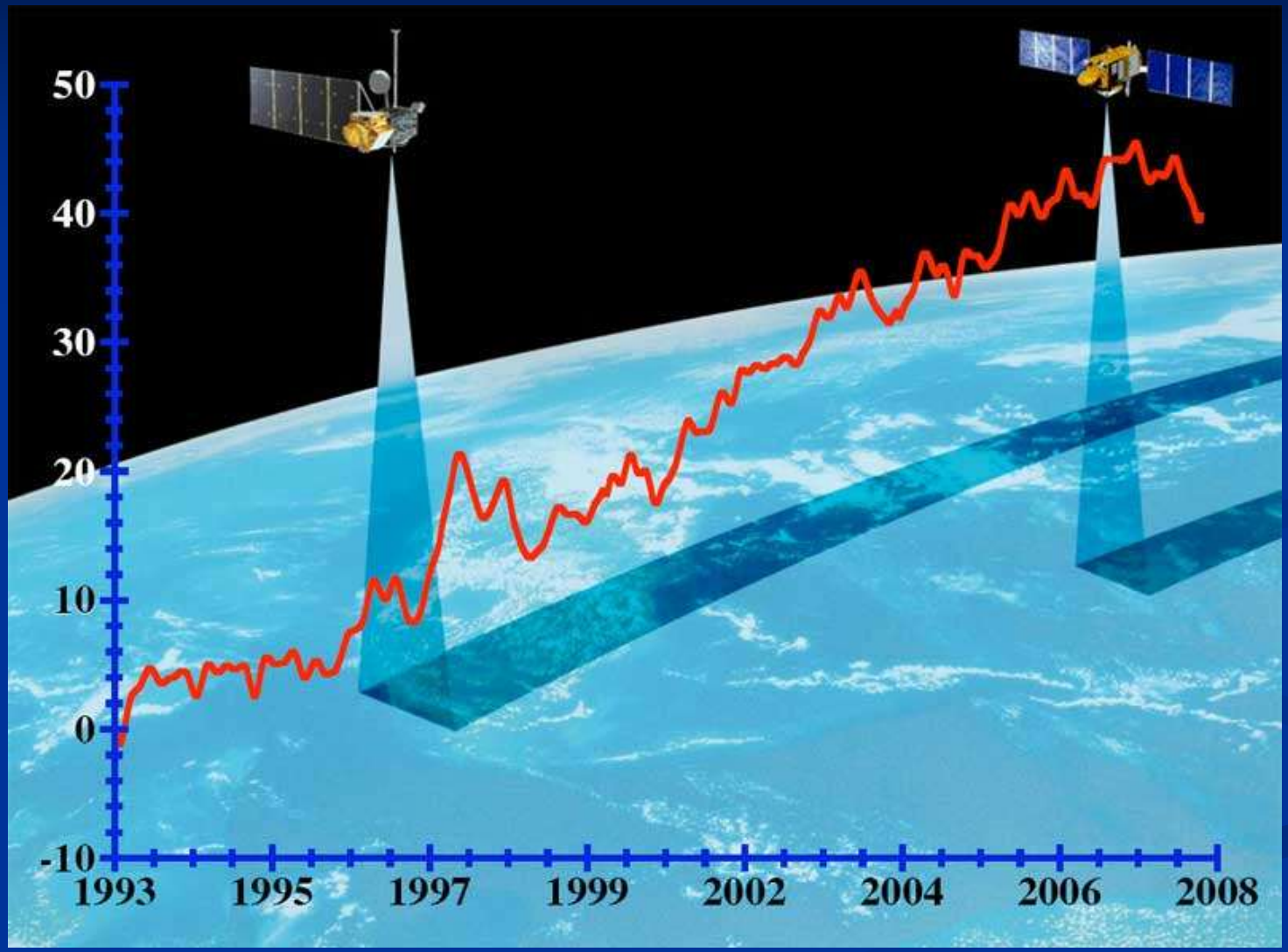


Adjustment of Tide Gauge Data for Spatial Bias Using Satellite Data

$$V_{Tide\ Gauge\ Adjusted} = \frac{V_{Satellite,\ All\ WaterAreas}}{V_{Satellite,\ Same\ Areas\ as\ Gauges}} V_{Tide\ Gauge\ Unadjusted}$$

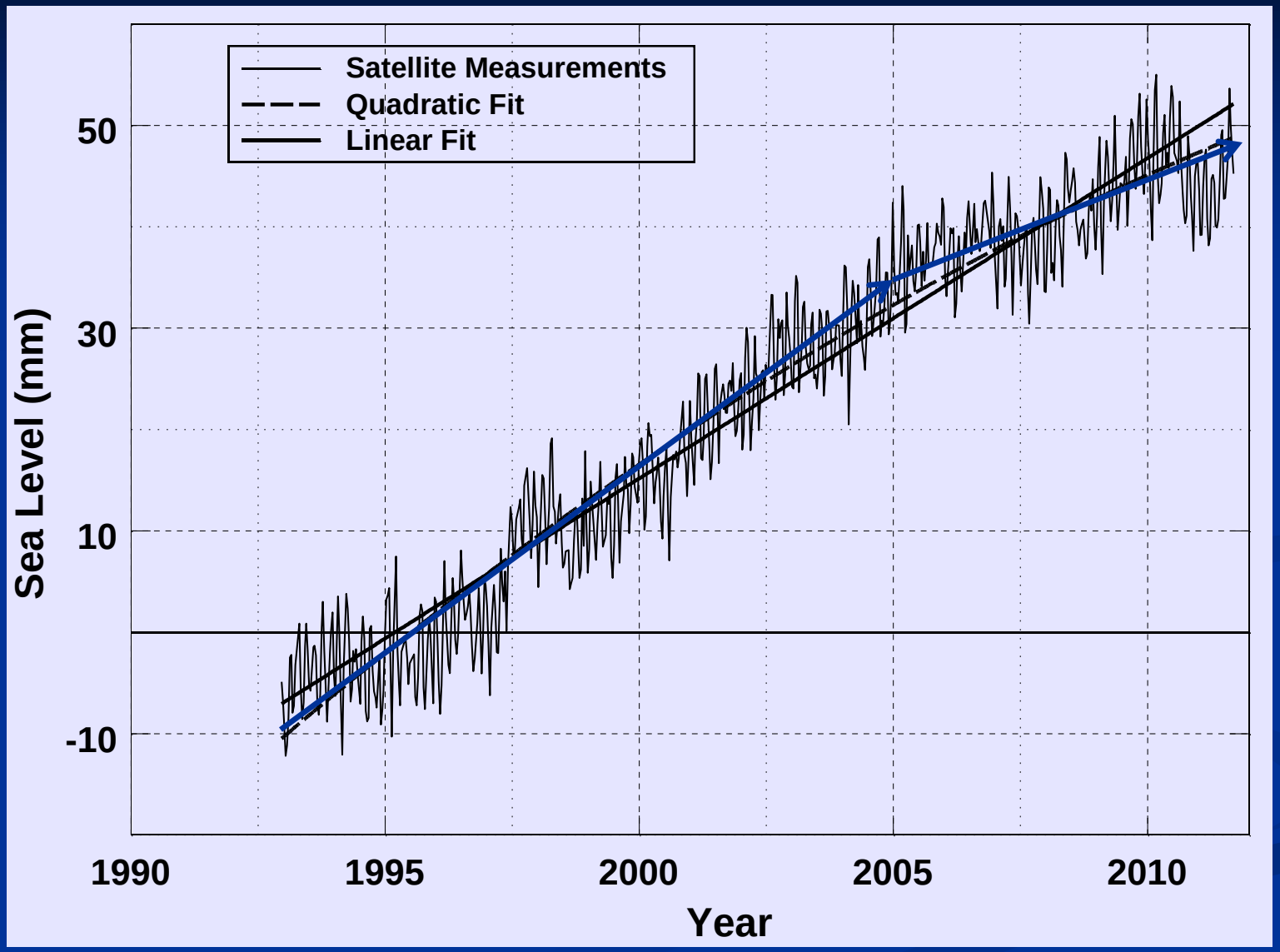
Data Set	Trend (mm/year)	Acceleration (mm/yr^2)
Full 85% (478 Gauges)	3.16 (vs 3.30 Unadjusted)	- 0.041 (vs - 0.076 Unadjusted)
GPS 85% (90 Gauges)	2.80 (vs 2.70 Unadjusted)	- 0.013 (vs – 0.025 Unadjusted)
Altimeter	3.2 ± 0.5	- 0.042

Are Satellite Measurements 1993-2011 Leading Edge of Acceleration?



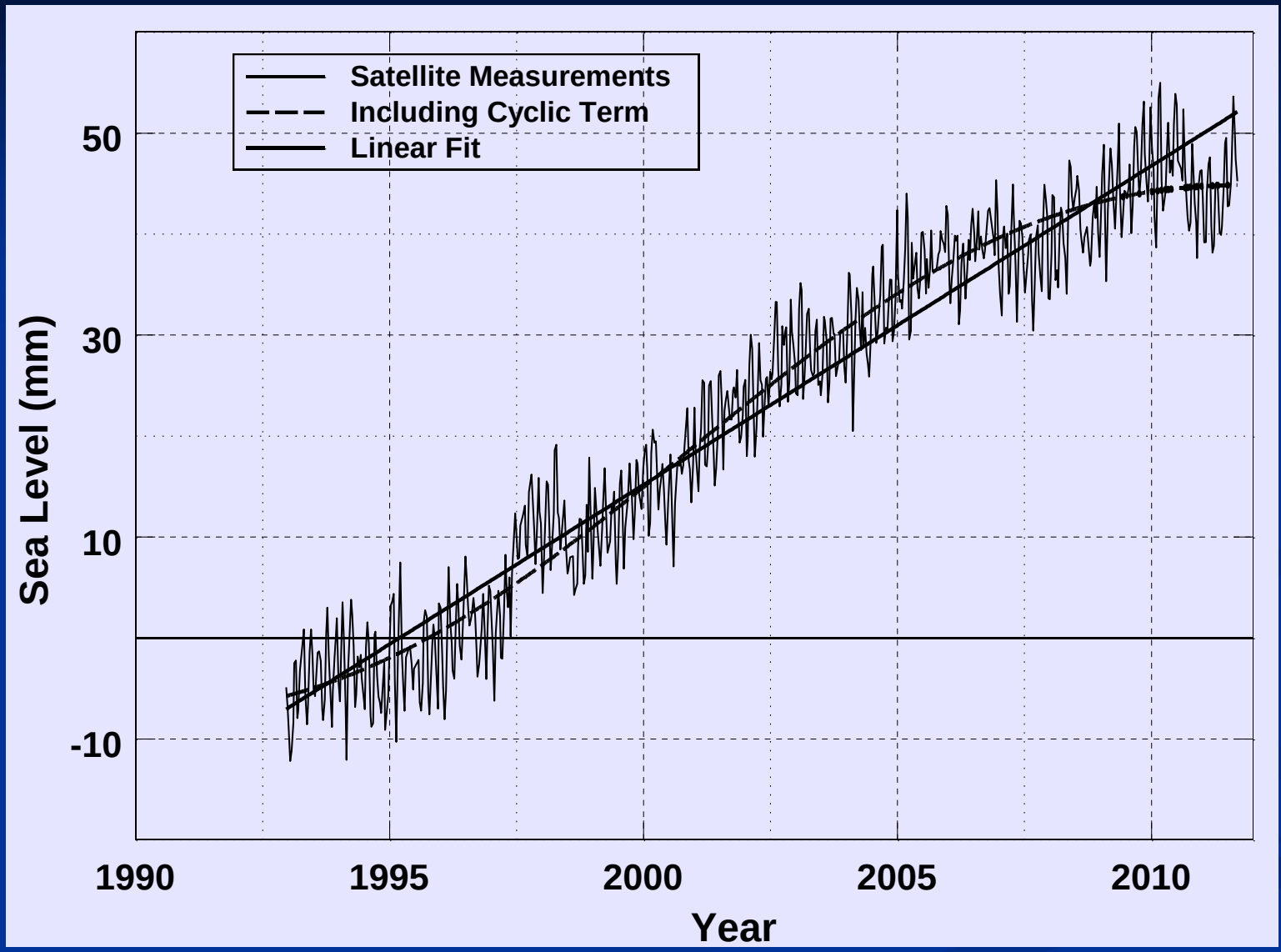
3.2 mm/yr trend is greater than 20th Century trend of 1.7 mm/yr

Linear and Quadratic Fits to Altimeter Data



Trends: In 1993, 4.3 mm/yr. In 2011, 2.10 mm/yr and decreasing

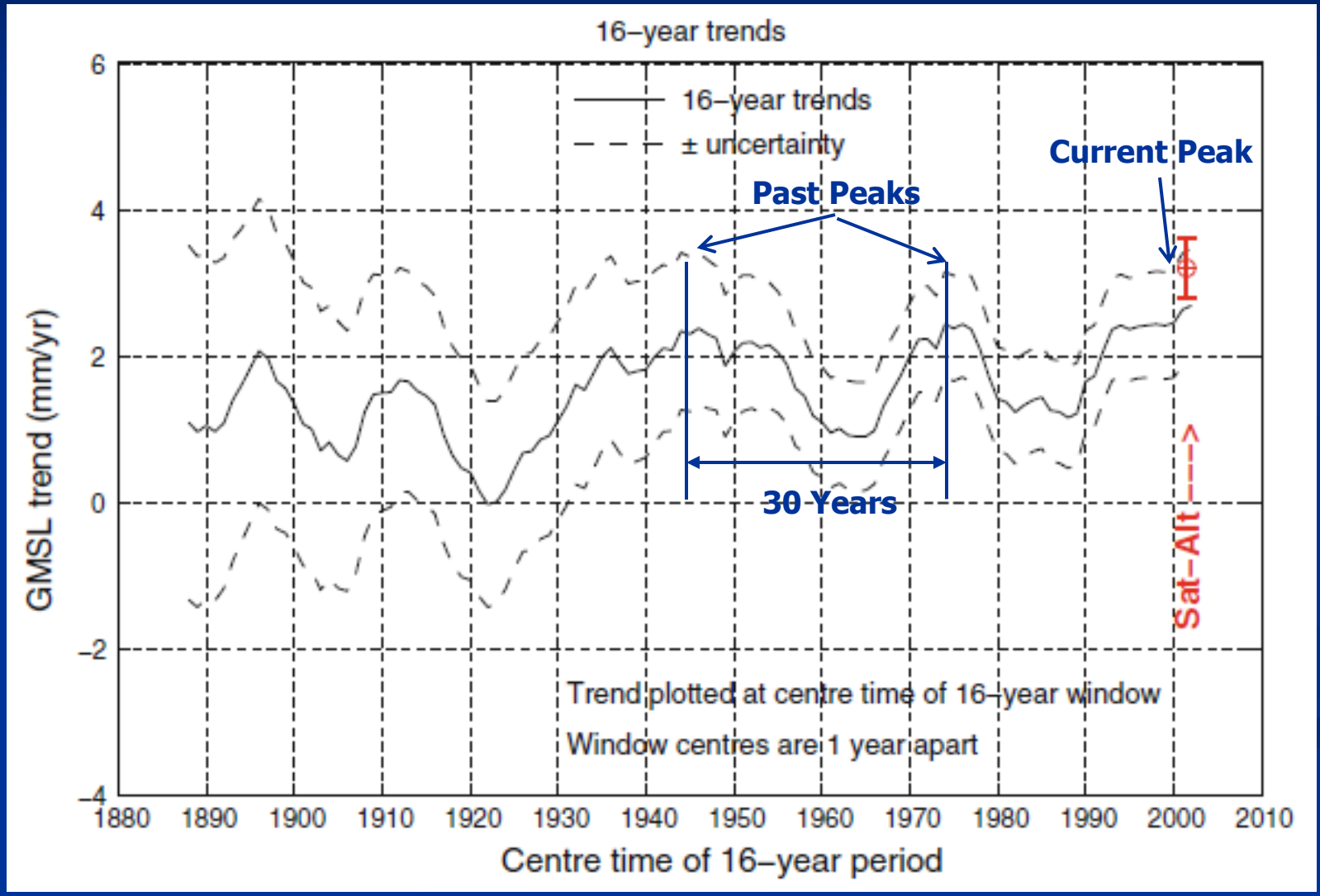
Linear and Sinusoidal Fits Altimeter Data

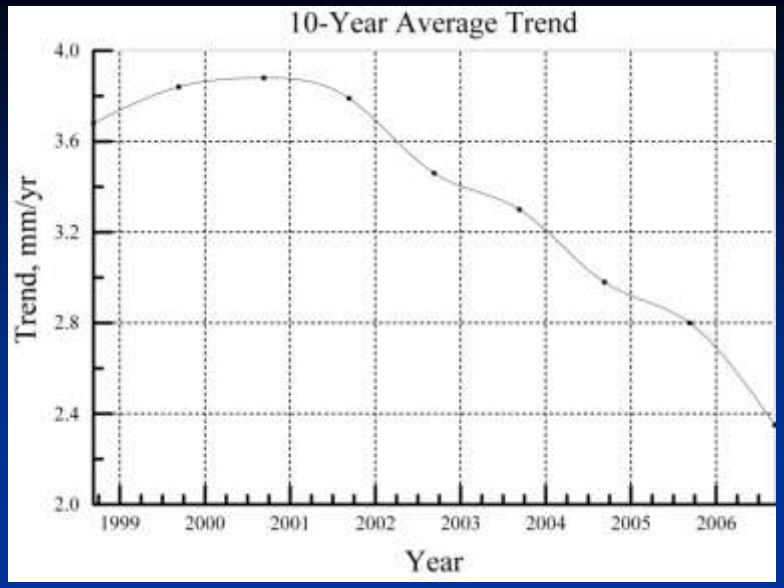


Trends: In 1993, 2.1 mm/yr, increases to 4.1 mm/yr in 2000 and decreases to 0.05 mm/yr in 2011. Period 29 years

Past Oscillations (Church and White, 2011)

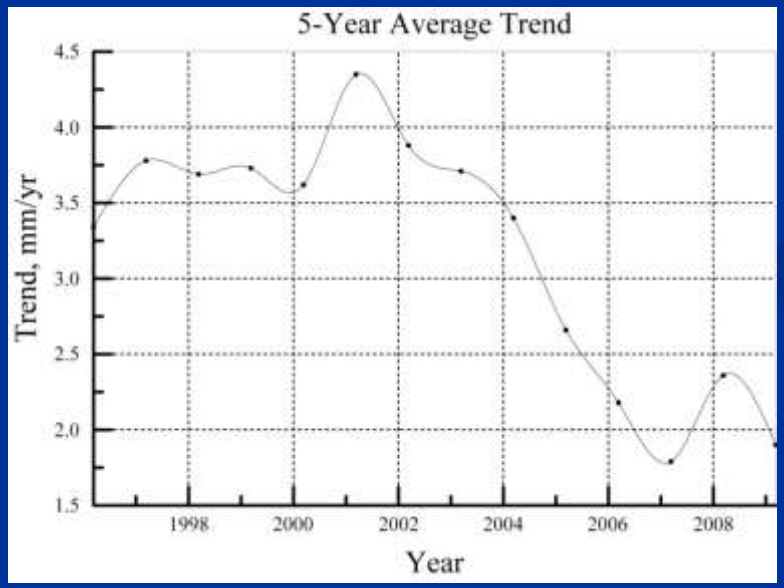
There have been periodic peaks in trend throughout the 20th Century equal to the current peak





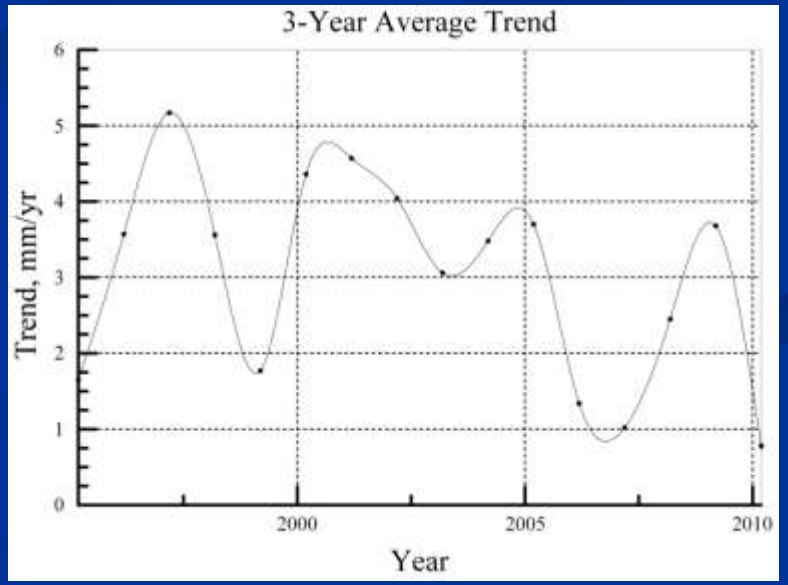
16-year trend from Church and White (2011) is ~ 3.2 mm/yr

10-year trend now ~ 2.4 mm/yr



5-year trend now ~ 1.9 mm/yr

3-year trend now <1.0 mm/yr



Summary

1. Satellite altimeter measurements are consistent with measurements by a large number of tide gauges
2. It is too soon to determine whether the increased trend measured from 1993 to 2011 is the leading edge of a permanent change in trend or an oscillation
3. There are indications that the trend change is an oscillation similar to several oscillations that occurred in the 20th Century
4. Additional years of satellite data are required to answer the oscillation question definitively

Thank You!