

# In California, Mean Sea Level Doesn't Run Over Your Doorstep!



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# California Department of Parks and 'Wreck'

Combinations of storm waves, high tides, and elevated sea levels cause beach erosion, and coastal flooding and damages



SCOTT LINNETT / Union-Tribune photos

After El Niño: Greg Graham of Leucadia walked near undermined concrete and broken railings at Cardiff State Beach.

## Parks awash in rain damage

Winter 1997-98

Flick, 1986, "A Review of Conditions Associated with High Sea Levels in Southern California," *Science of the Total Environment*, 55, 251-259;

Bromirski, Cayan, and Flick, 2005, "Wave spectral energy variability in the northeast Pacific," *Journal of Geophysical Research*, 110, C03005)

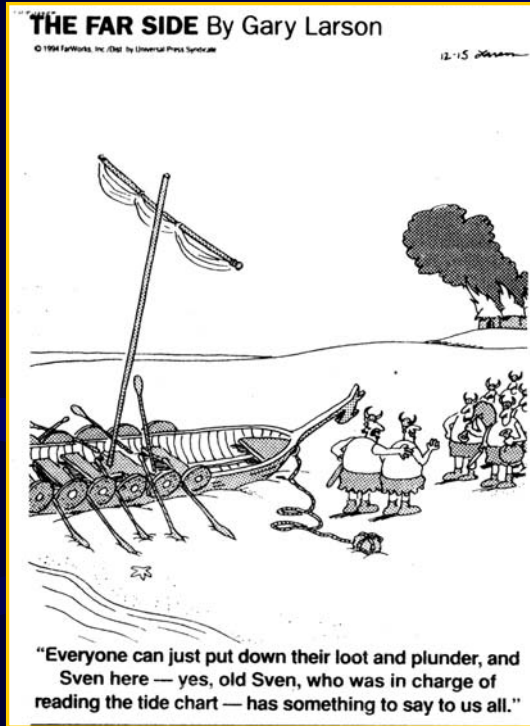
# Coastal Impacts of High Sea Level and Storms

- Beach erosion and sea cliff retreat
- Coastal flooding and debris
- Wave-induced structural damages
- Inundation and sedimentation of coastal wetlands
- Saltwater intrusion into estuaries and freshwater aquifers
- Increased threat to San Francisco Bay/Delta levy system

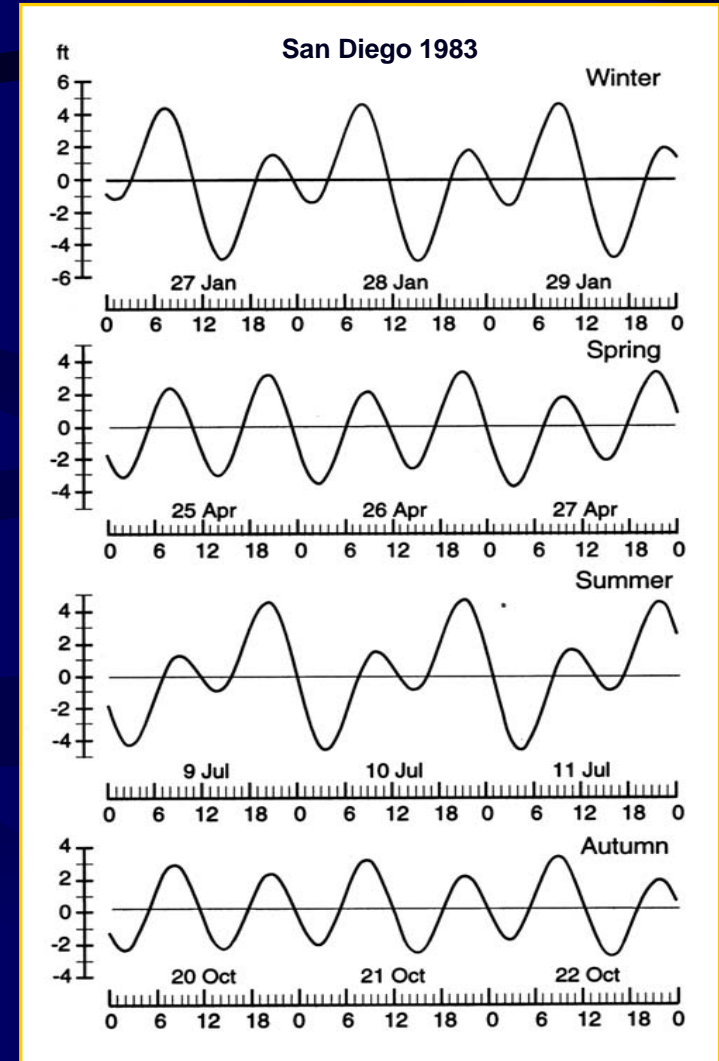
# Extreme Sea Level Processes and Time Scales

- Tides – hours, days, weeks, months, years, decades
- Storm Surge – hours, days
- Seasonal Cycles – months
- El Niño, PDO – 3-7 years, decades
- Eastern Pacific Dynamical – decades
- Steric & Eustatic – decades, centuries, millennia
- Tectonic – centuries, millennia
- Sedimentation – millions
- Continental Drift – many millions

# Tides Critical to Flooding...



Highest high-tides in the morning during the winter

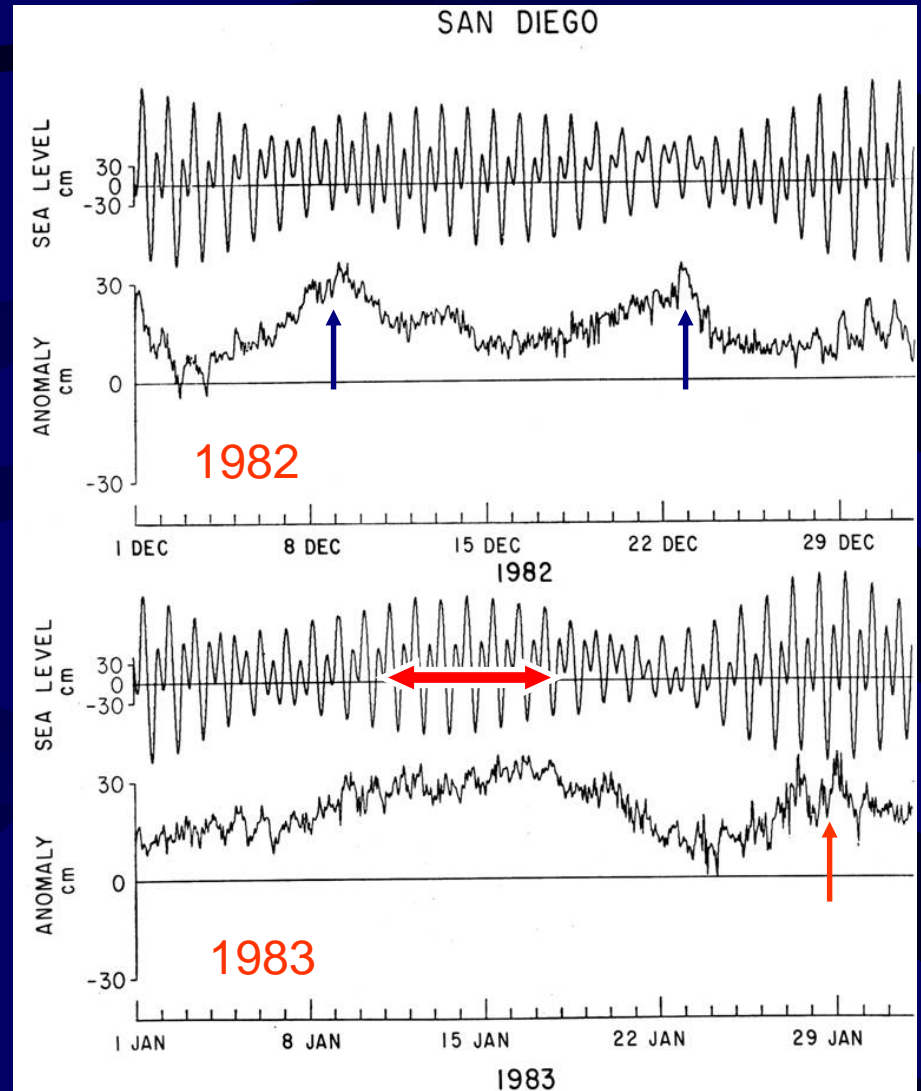


Mixed Tide Regime

# Storm Surge Coincidence with High Tides

Storm surge = 0.5-1 ft

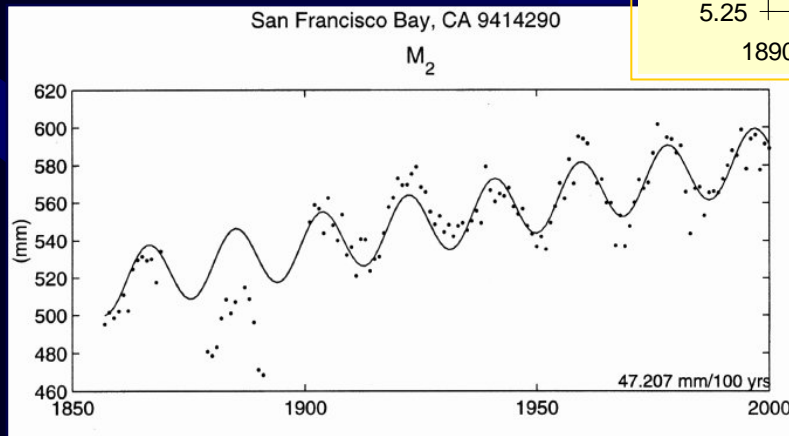
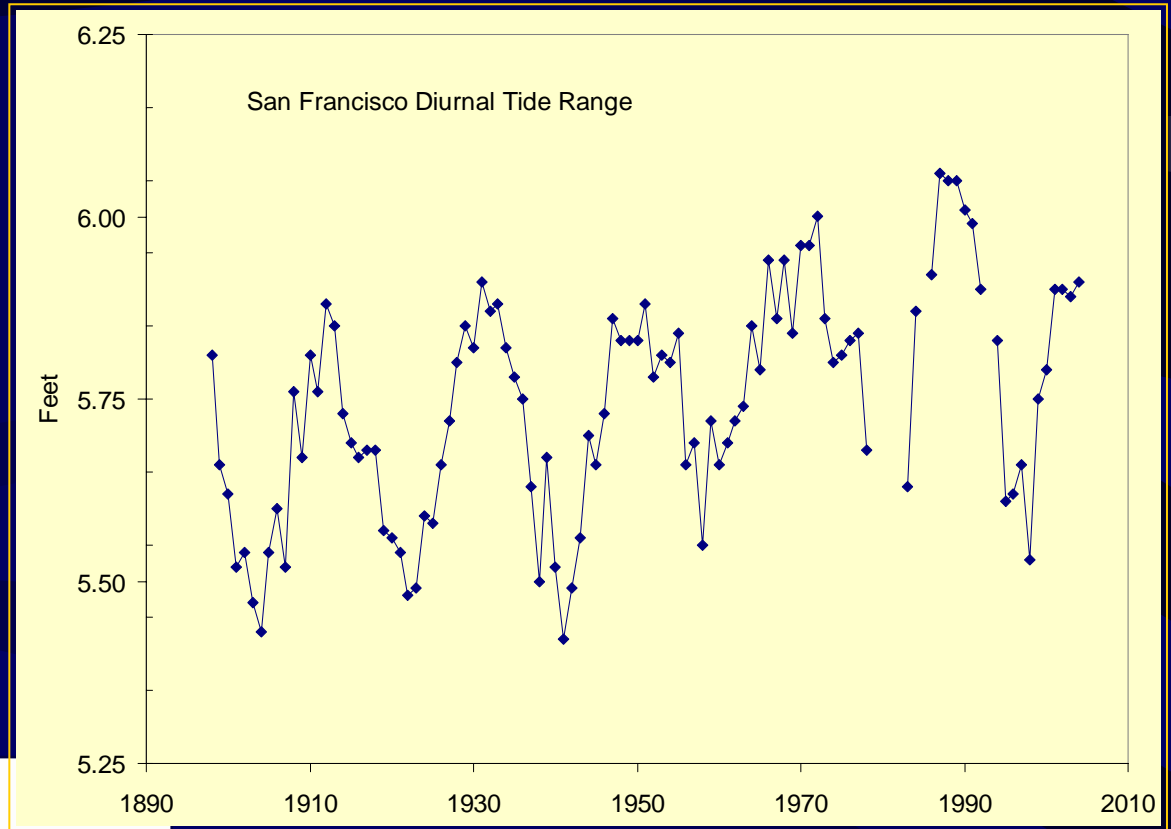
Coincidence with high tide is crucial for flooding



(Flick and Cayan, 1984, "Extreme Sea Levels on the Coast of California,"  
*Proceedings, 19th International Conference on Coastal Engineering*, 886-898)

# Tide Range is Increasing

High tides keep getting higher by 0.25 ft/century  
(1/3 again as large as SLR)



4.4 and 18.6 yr cycles in peak tides

(Flick, Murray and Ewing, 2003, "Trends in United States Tidal Datum Statistics and Tide Range," *Jour. Waterway, Port, Coastal and Ocean Eng.*, 129(4), 155-164)

# Seasonal Cycle – Normal v. El Niño

Seasonal Cycle = 0.5 ft

El Niño = 1 ft with +0.5 ft mean

(Flick, 1998, "Comparison of California Tides, Storm Surges, and Sea Level During the El Niño Winters of 1982-83 and 1997-98," *Shore & Beach*, 66(3), 7-11)

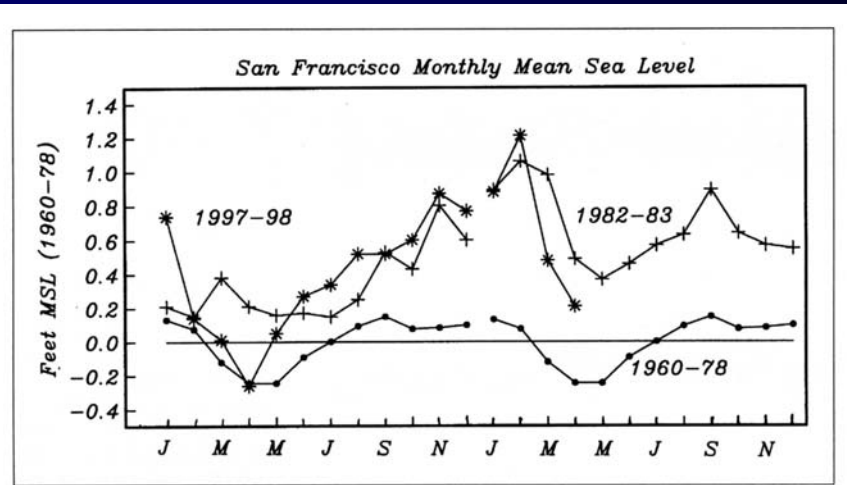


Figure 5. Monthly mean sea levels at San Francisco, winters of 1982-83 and 1997-98 compared with the mean values over the 1960-78 tidal datum epoch.

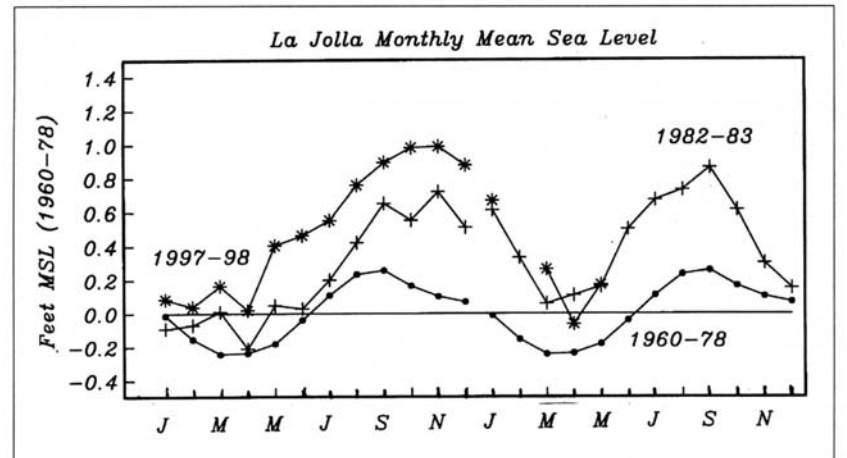


Figure 6. Monthly mean sea levels at La Jolla during winters of 1982-83 and 1997-98 compared with the mean values over the 1960-78 tidal datum epoch.

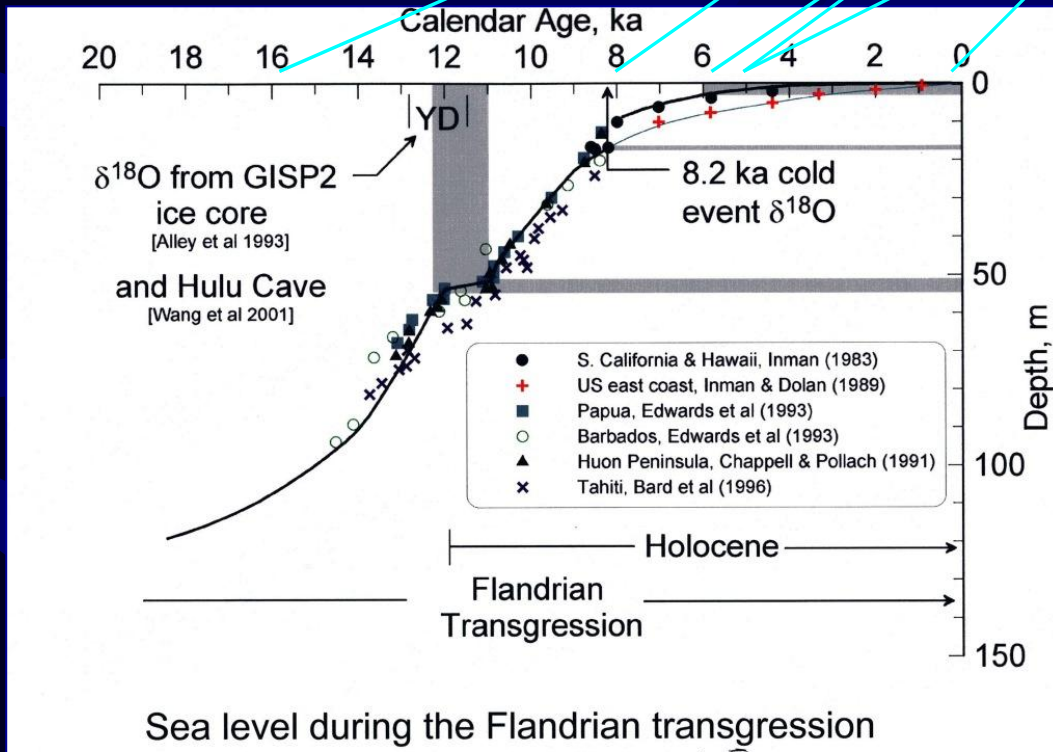
# Past Rates of Sea Level Rise

(have been much faster than the current)

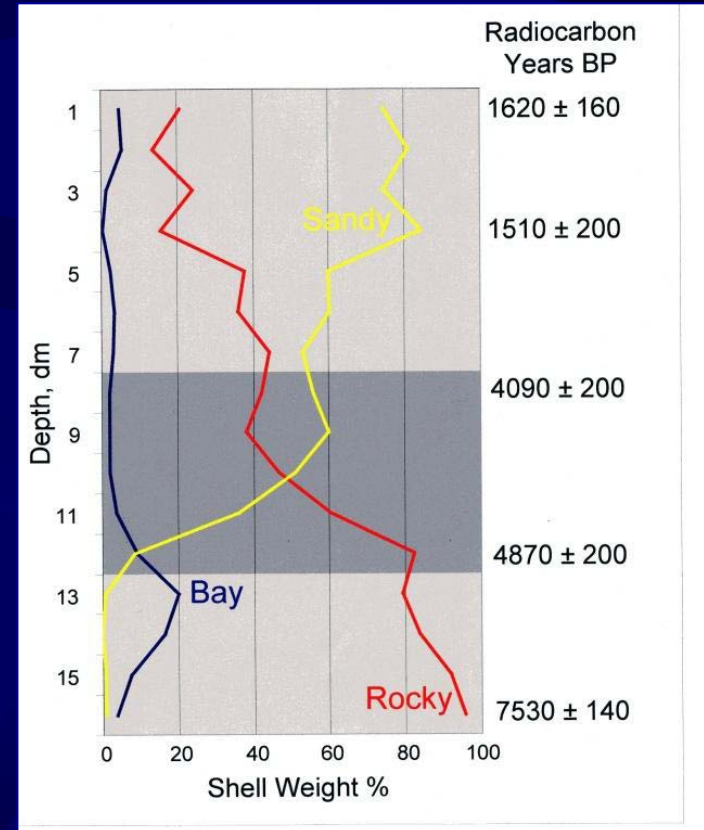
16 ky-8 ky ..... 125 cm/cy

6 ky-5 ky ..... 20 cm/cy

5 ky-1800 ..... 1-2 cm/cy

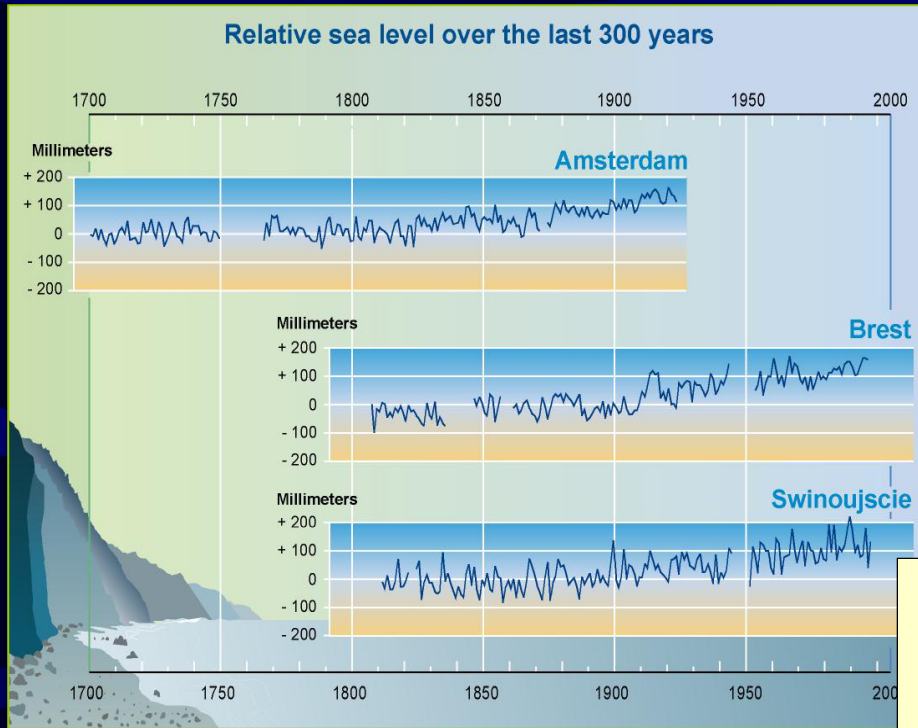


Beaches since 5 ky ago!



(Inman, Masters, 2005)

# Global Mean Sea Level has been Rising for Awhile...



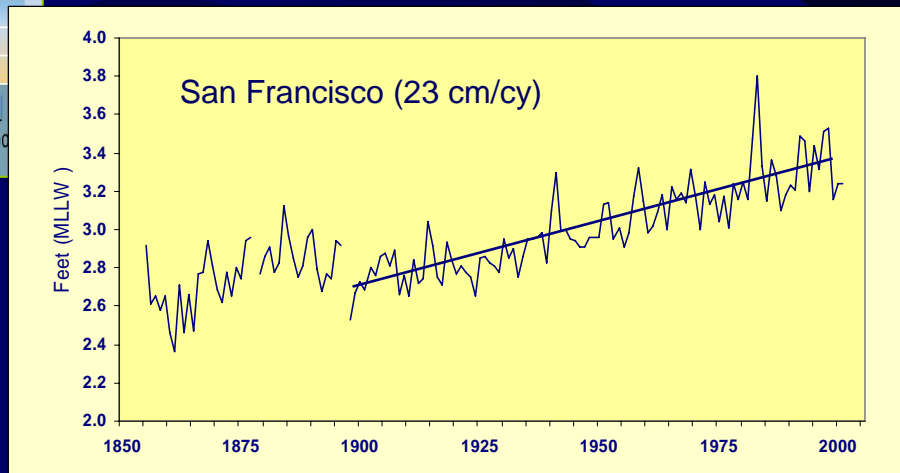
(IPCC 2001)

(Church and White, 2006, 20<sup>th</sup> Century Acceleration in Global Mean Sea Level, Geophysical Research Letters, 33, LO1602)

Pre-1830 ..... < 4 cm/cy

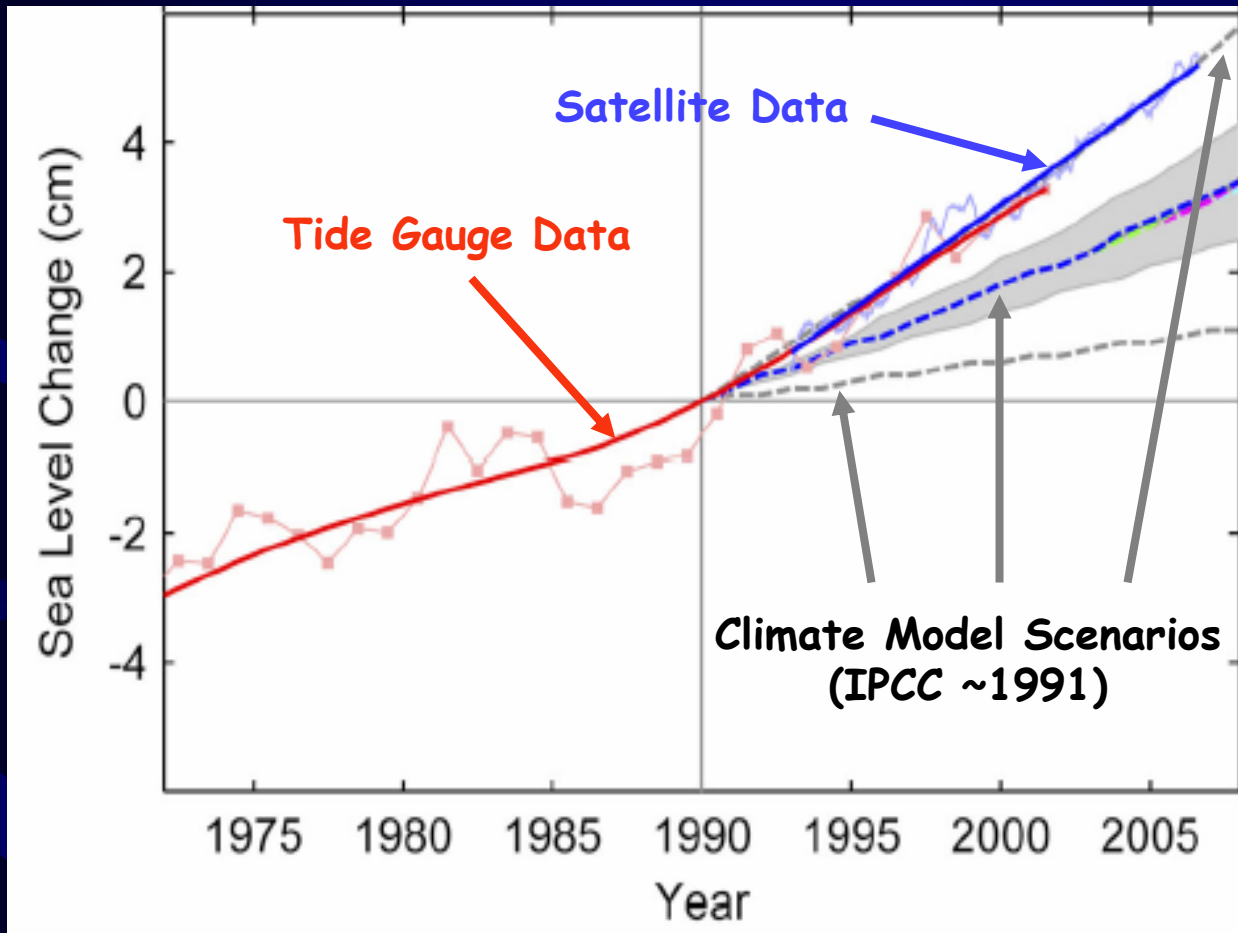
1900-2000 ..... 15-20 cm/cy  
0.75 ft / 100 yr

1993-2006 ..... 35 cm/cy



...what's new is acceleration since about 1830, and future scenario projections

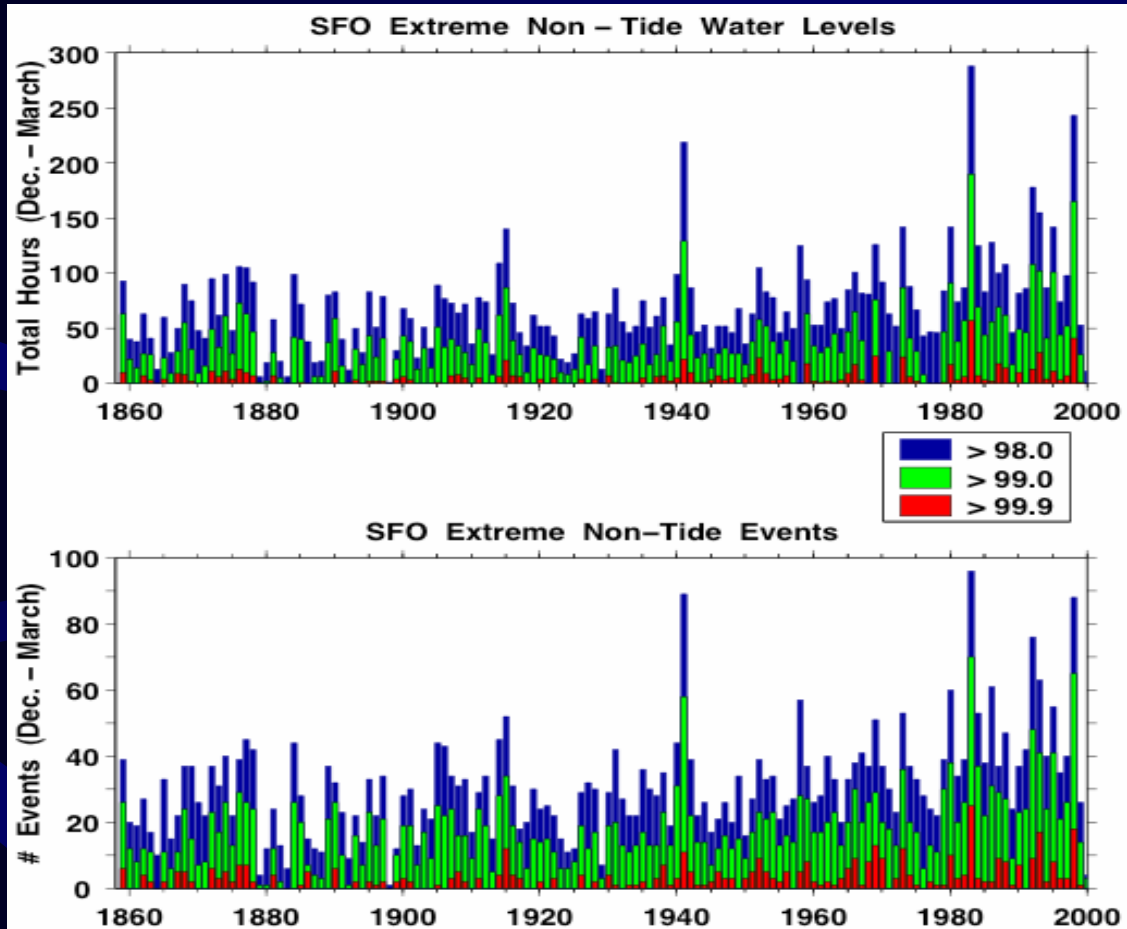
# Sea Level Observations v. "Predictions"



6 cm MSLR  
since 1990  
or  
35 cm/cy

(Modified from H.A. Fricker)

# Long-Term Increase in Extreme Sea Levels

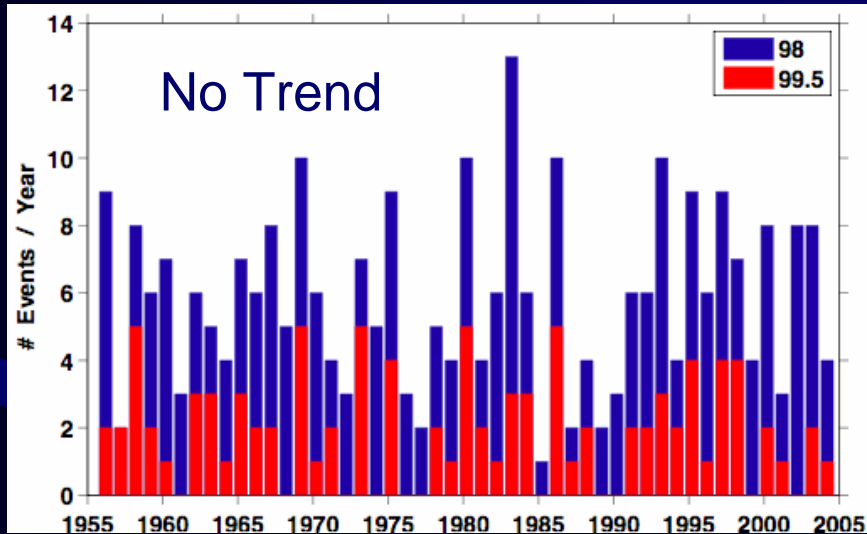


Underlying MSL trend causes increasing duration and frequency of extreme water level events

(Bromirski, Flick, and Cayan, 2003, "Storminess variability along the California coast 1858-2000," *Journal of Climate* 16(6))

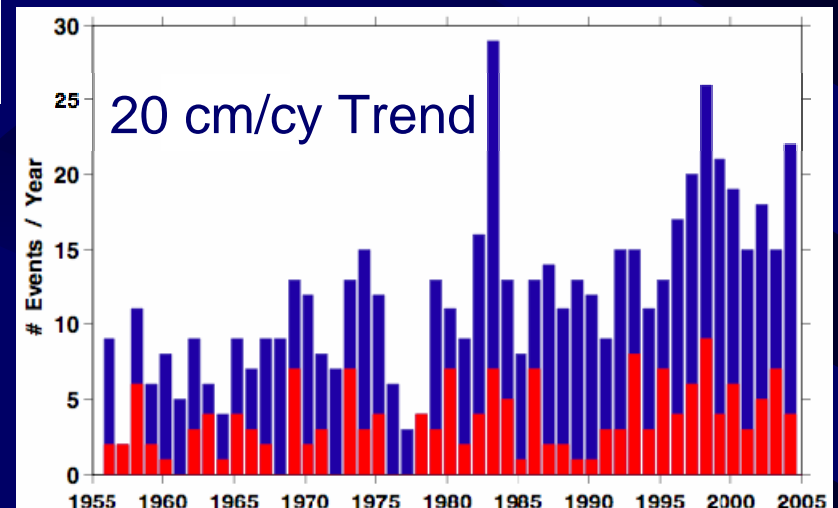
Based on the entire SFO tide gauge record, 1858-2000

# Impact of SLR on Extreme Storm Surge Frequency

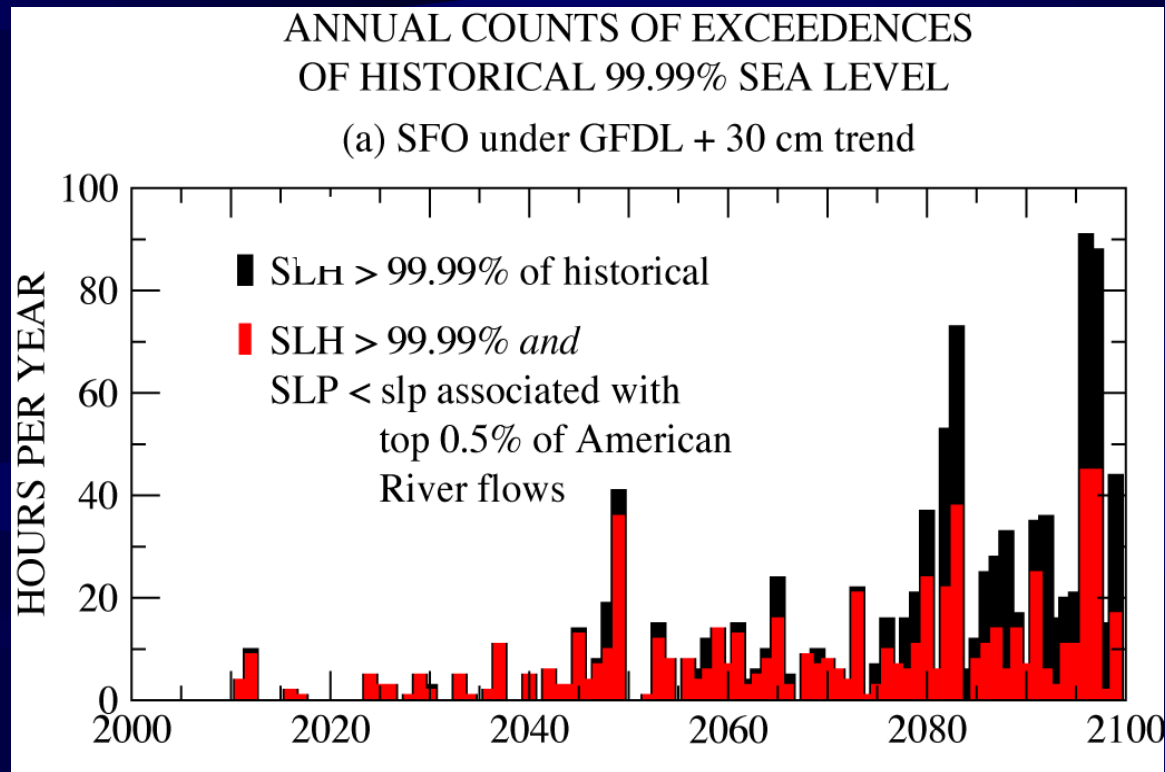


Corresponding to  
20 and 30 cm thresholds

About double the number of  
extreme events since 1990!



# Projected Incidence of Extremes



High river flows commonly occur during extreme storm surge, increasing risk to the San Francisco Bay/Delta levy system

# What We'll Be Up To...

- Verify cause of tide range increase
- Produce projected wave climate scenarios
- Produce joint probabilities of tide, surge, and waves
- Assess flooding risk with run-up analyses

I have a boat...



Do you?