Coastal extremes in California

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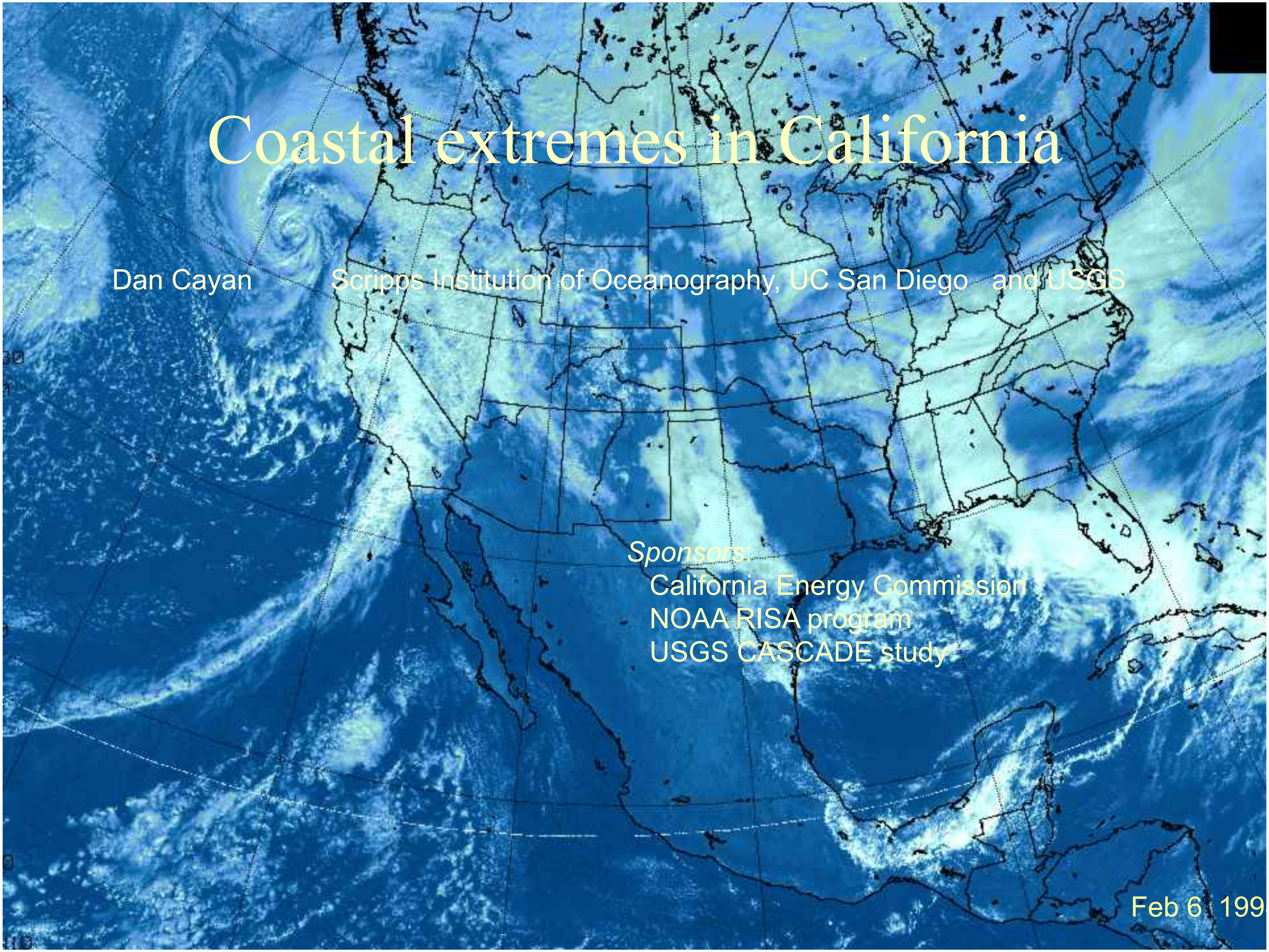
Sponsors:
California Energy Commission
NOAA RISA program
USGS CASCADE study



Short period events matter greatly.

Coincidence of different factors, e.g. high tides, big storms, is key

Storm track might migrate poleward.

Estimates of potential global sea level rise have increased over last few years

Interannual-decadal Pacific basin atmosphere/ocean fluctuations have large impacts.

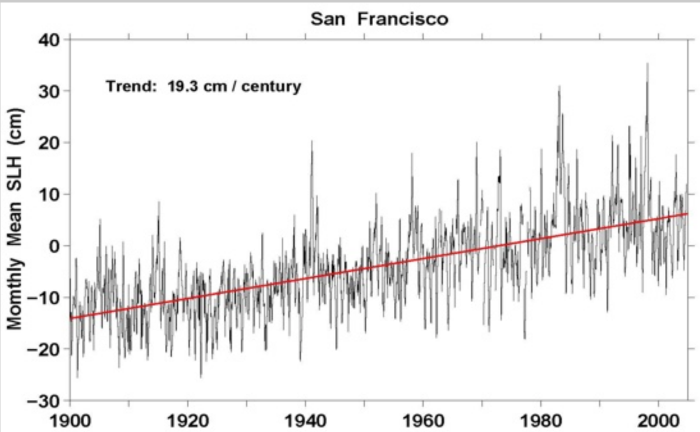
In some settings, fresh water flooding compounds sea level extremes

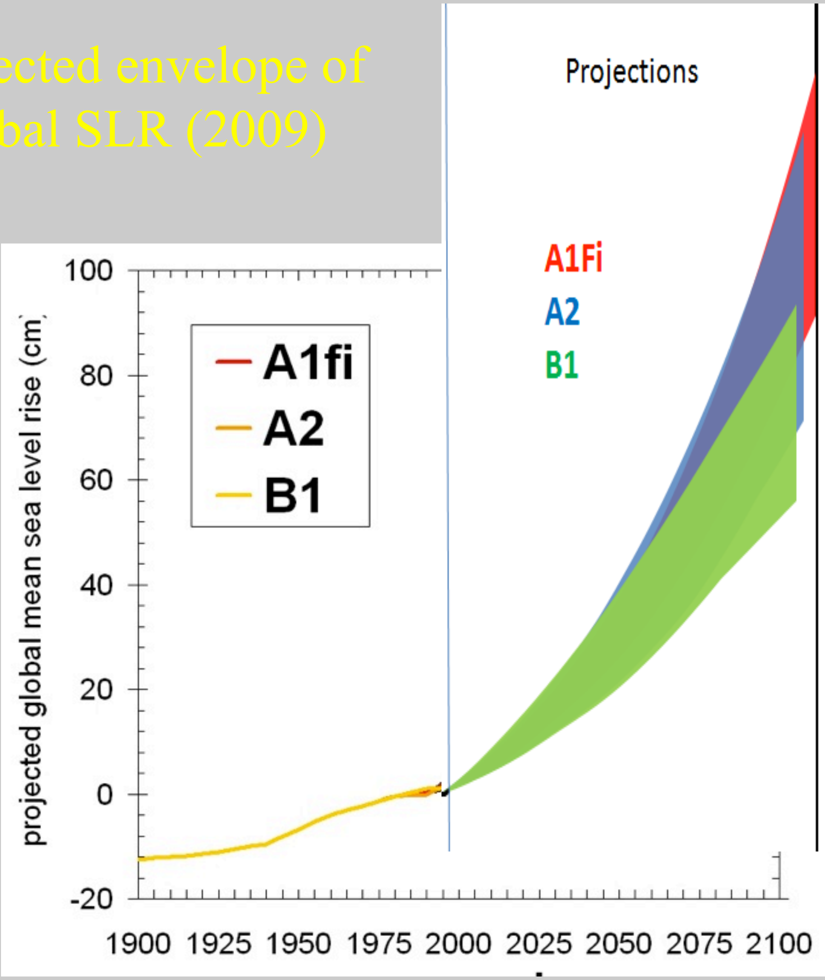
They rarely occur, but tropical storms can make landfall in California

Observed SFO (left) and modeled Global (right). Sea level rise estimates based upon an envelope of output from several GHG emission scenarios

Projected envelope of global SLR (2009)

observed

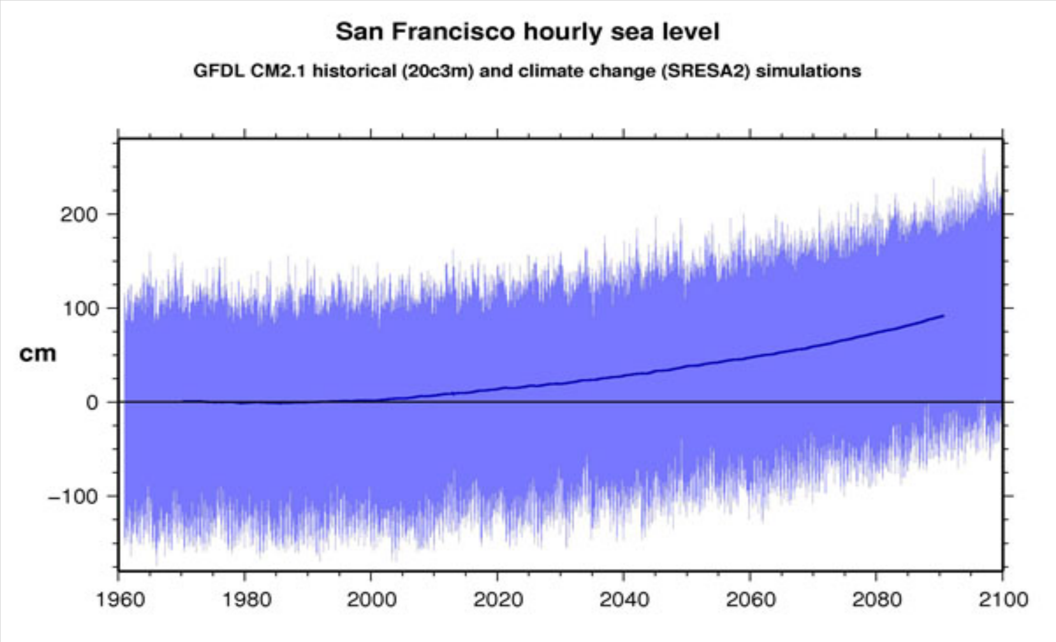




Climate models only provide loose guidance on the amount of sea level rise—full physics models are still under development.

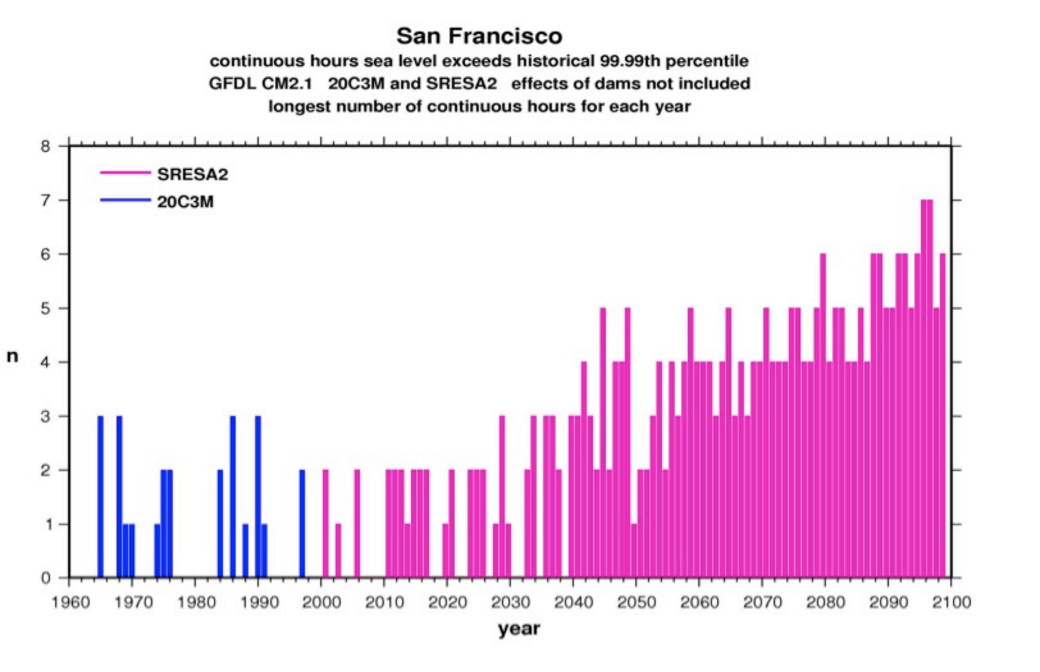
But it is quite likely that rates

Projected sea level San Francisco



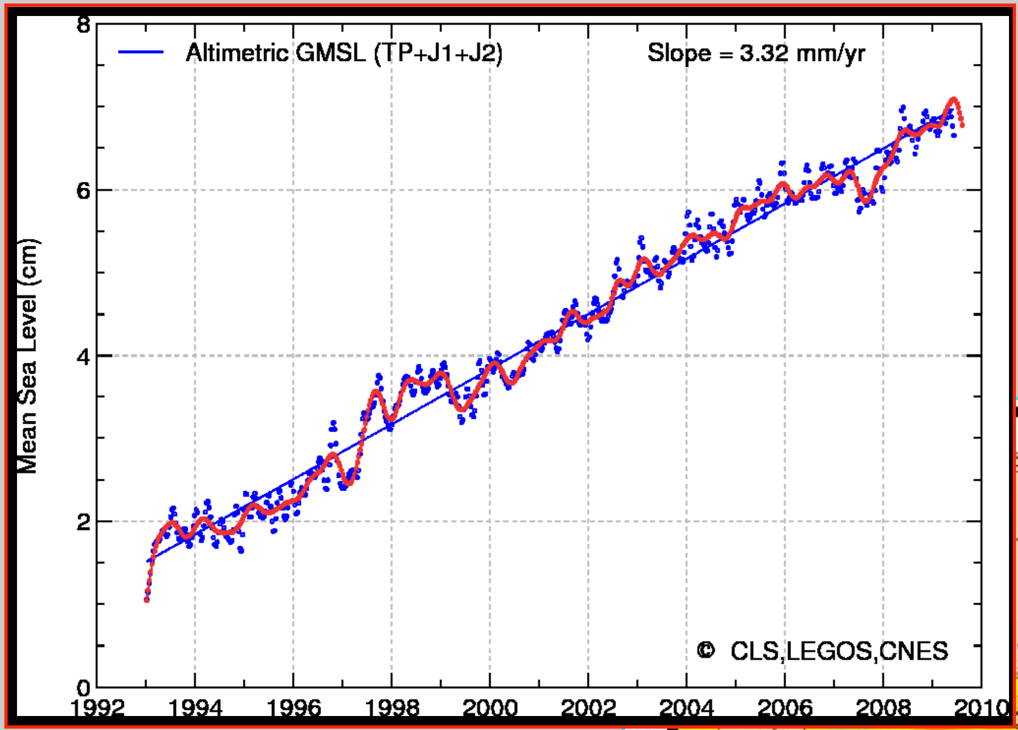
Under projected global warming, sea level rises considerably by 2100.

As estimated from GFDL A2 using Rahmstorf(2007) SLR is approximately 0.9m.

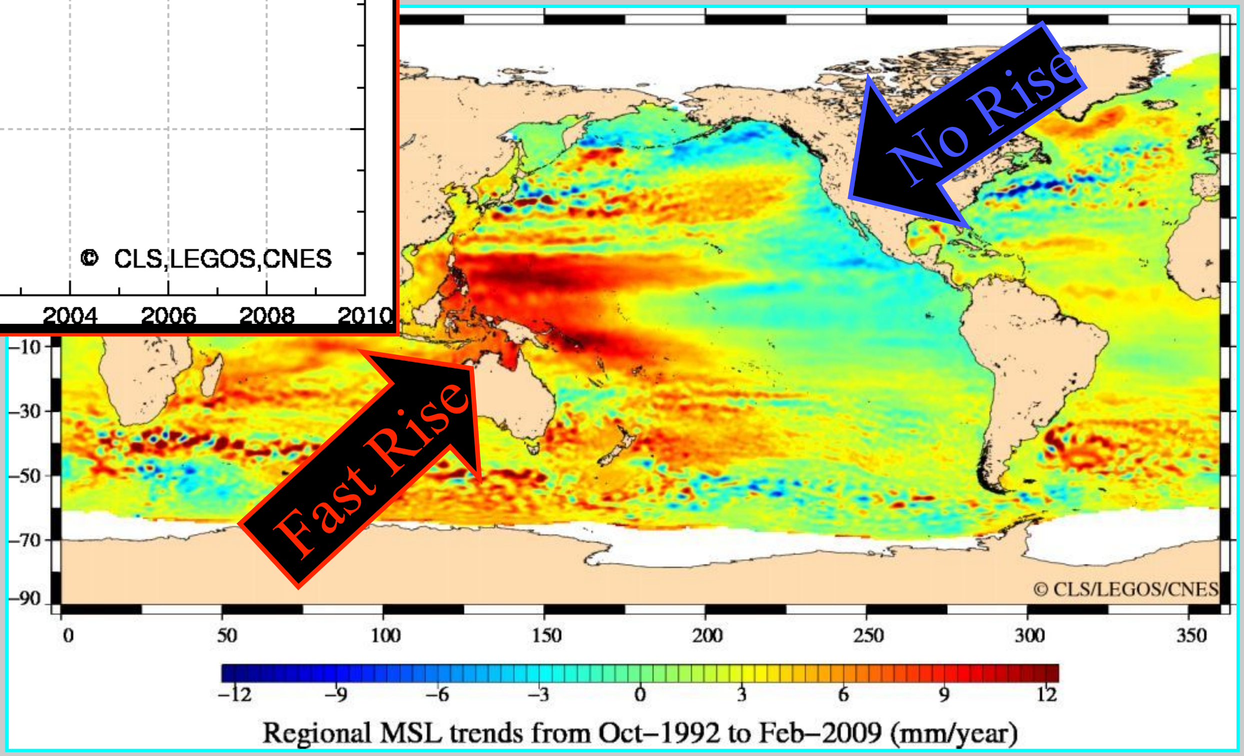


High sea level events, exceeding high threshold *occur increasingly often and persist for longer durations.*

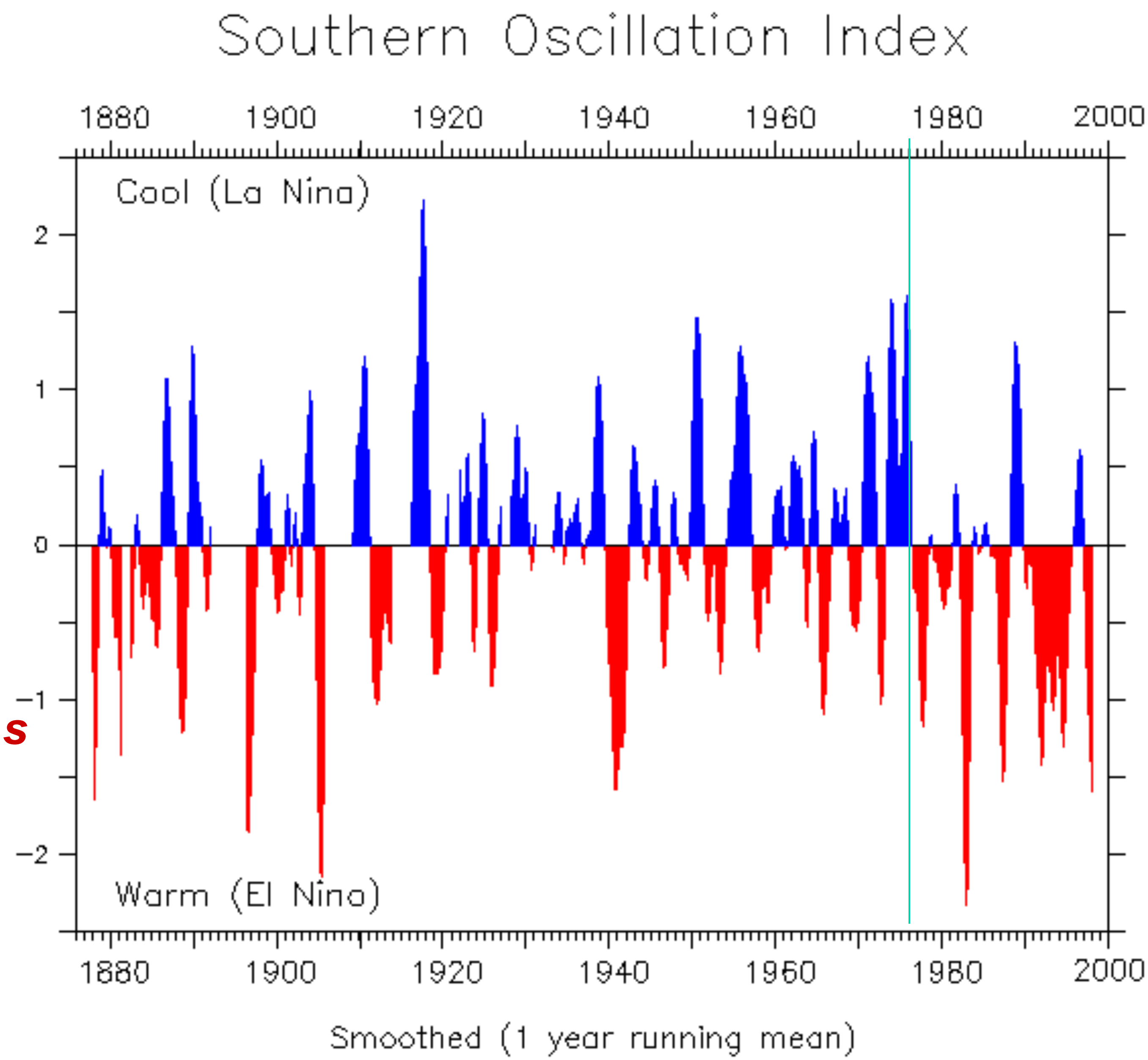
The Satellite Data 1992-2009



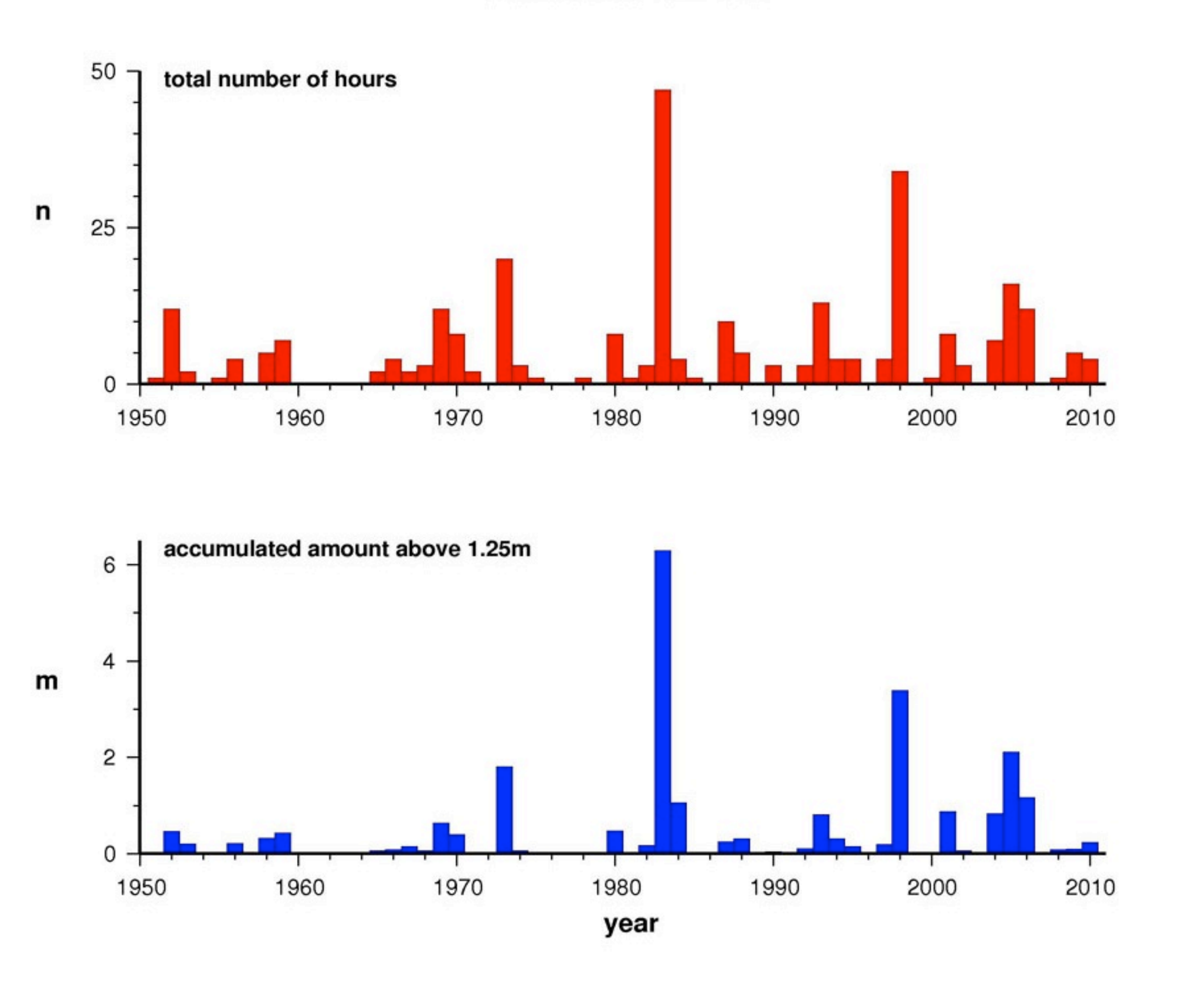
Global MSL not evenly distributed



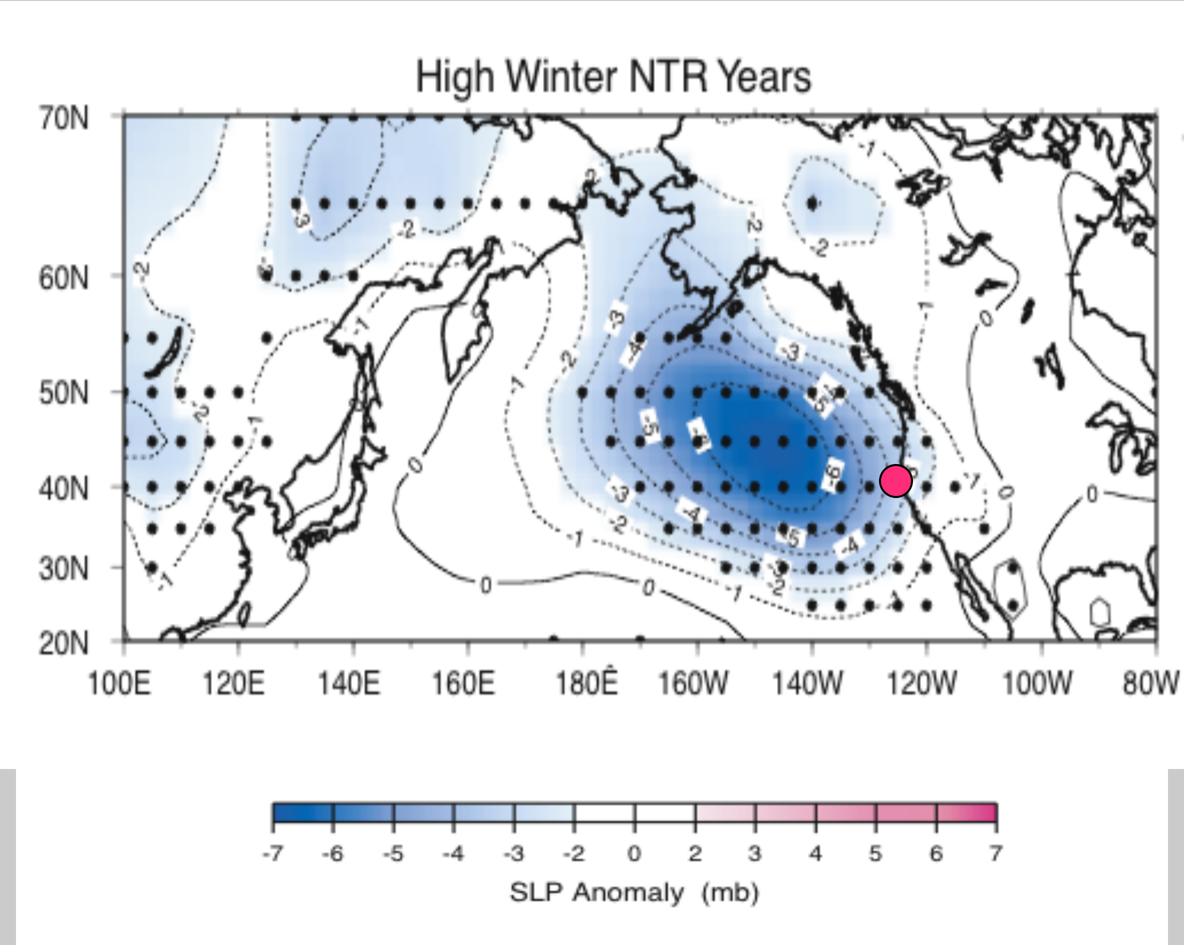
Note spell Of frequent El Ninos After mid-1970's



Extreme sea level occurrences
San Francisco

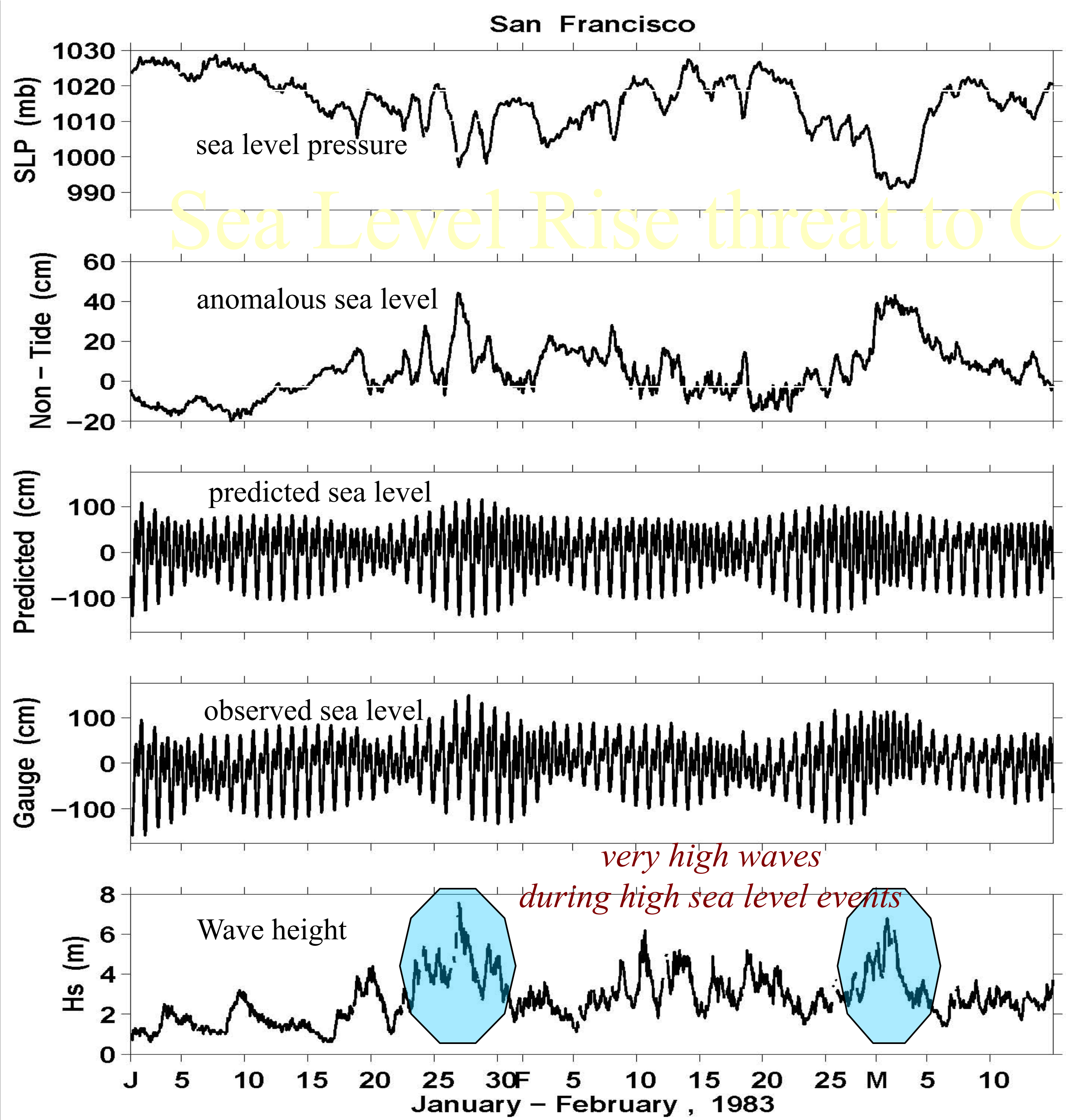


highest hourly sea levels have mainly occurred in just a few years strong cyclonic atmospheric circulation patterns during highest San Francisco sea level winters (non-tide residuals)



Intensified, southerly displaced Aleutian Low during the 10 highest non-tide winter sea level extremes since 1900

Bromirski, Flick Cayan 2003 *J. Climate* during high sea levels, the sea is often *not* quiescent



Sea Level Rise threat to California

Winter 1983

sea level anomalies

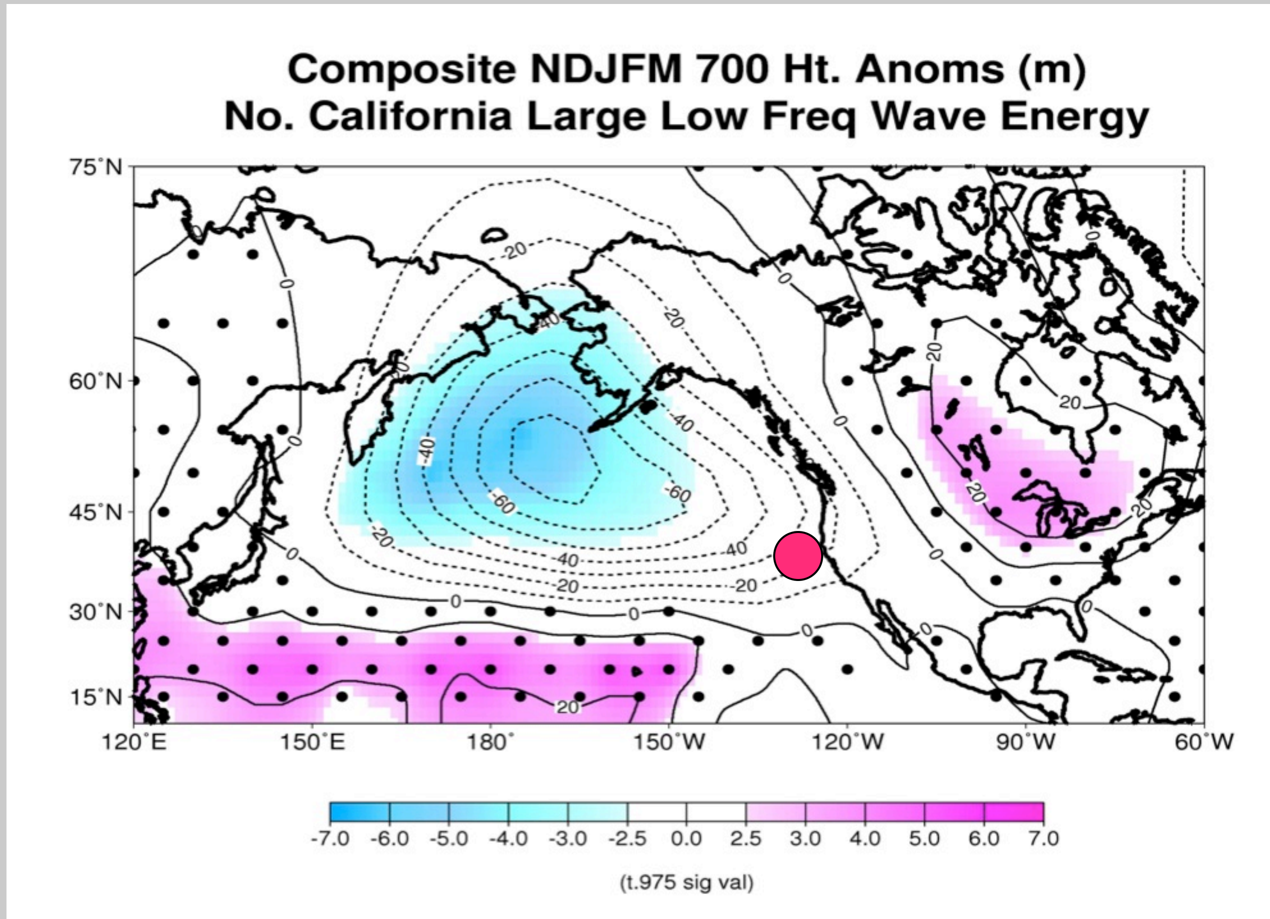
sea level, observed

significant wave heig

Flick and Cayan 1980’s

Highest California coastal wind waves occur in winter months with extensive North Pacific Low pressure Patterns.

Long period waves require extensive basin wide low pressure and westerly winds

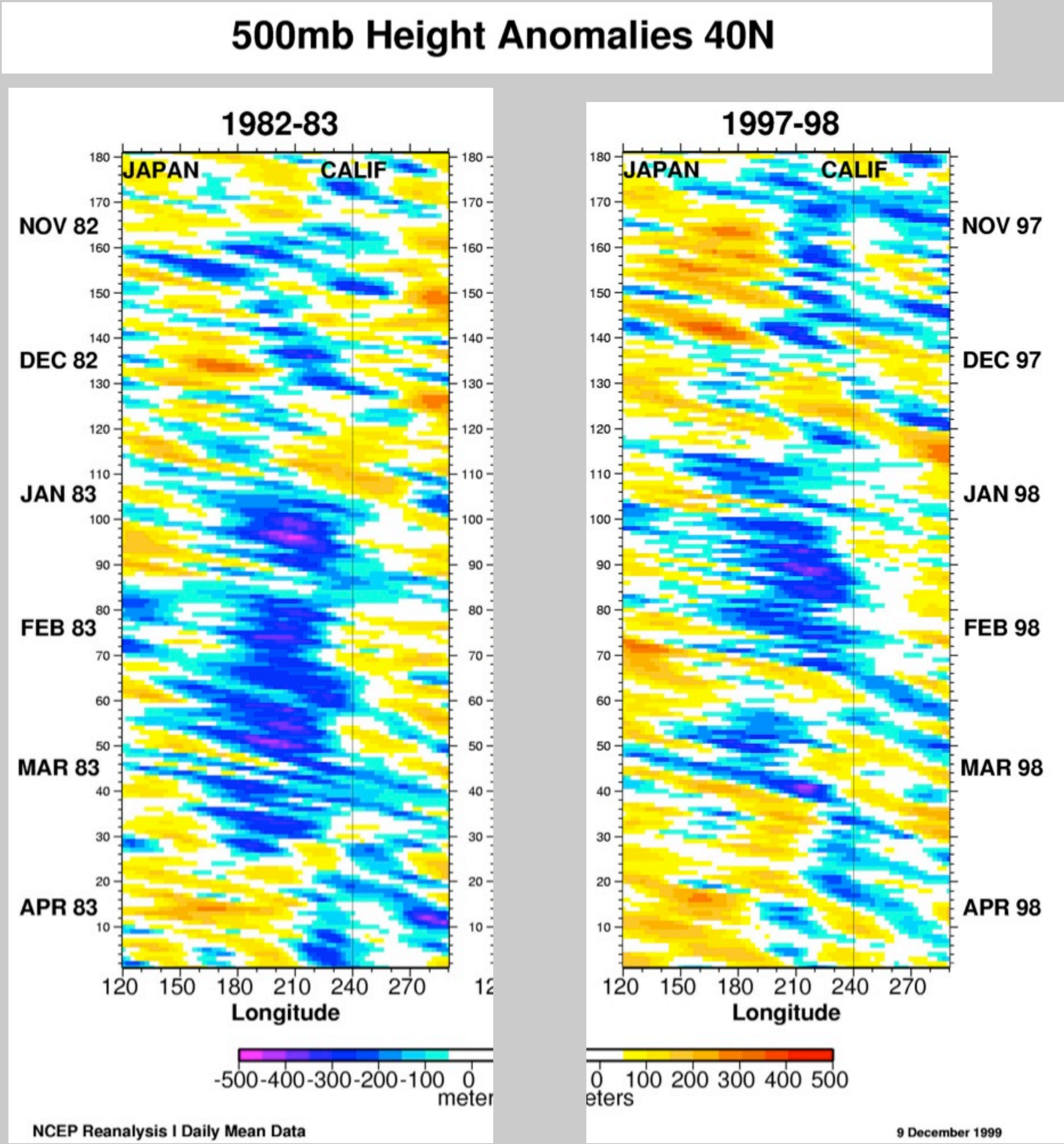


Bromirski, Cayan, Flick 2005 *JGR*

Hovemoller diagram, two large El Nino's-- North Pacific Basin fills w winter cyclones

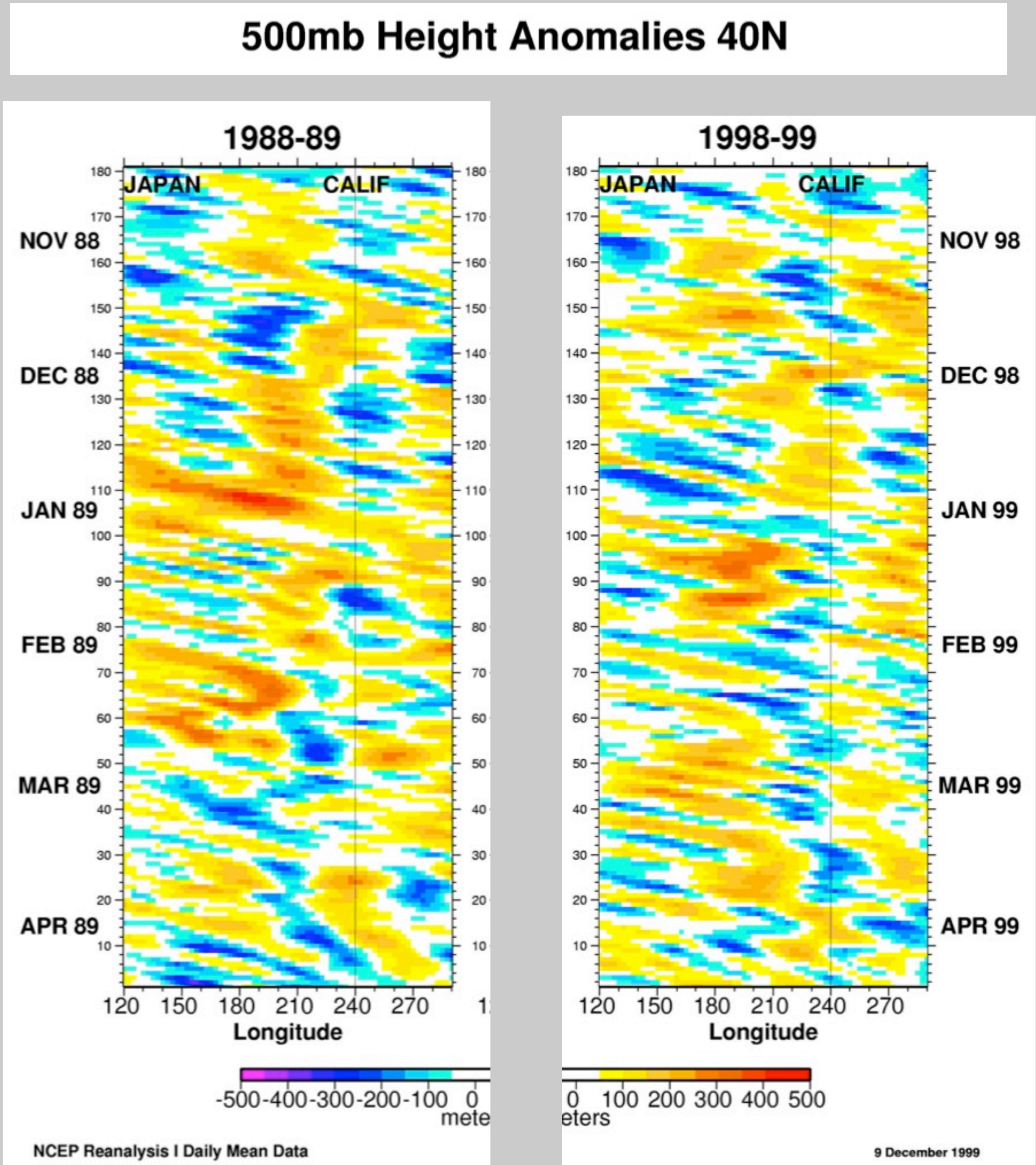
both years had persistent storminess and a long, extended storm season

cyclones tracked from Asia to West Coast in 5-6days; storm track was zonal and extended far south.



Two La Nina years

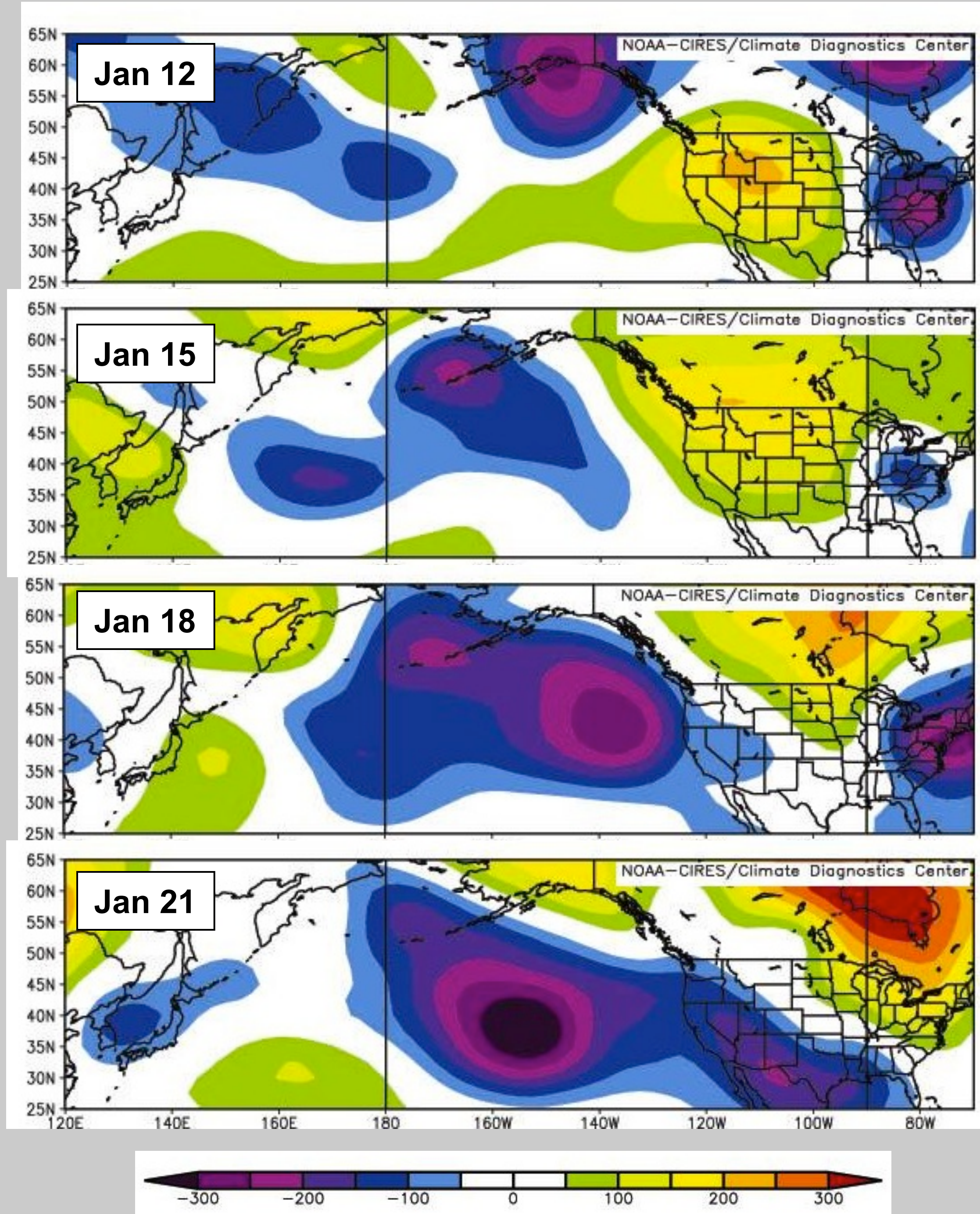
In contrast to the El Nino cases, the North Pacific Basin was much less active. Propagation speed of cyclones and anticyclones is still approx 5-6 days to traverse the basin at 40N

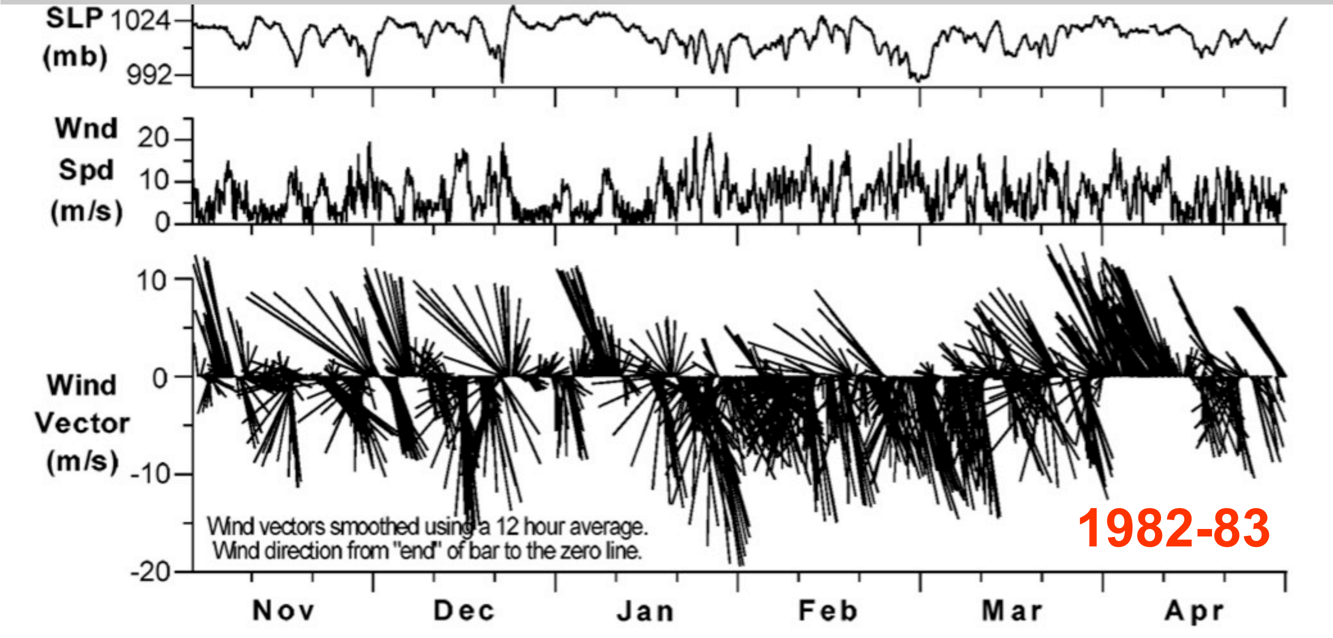


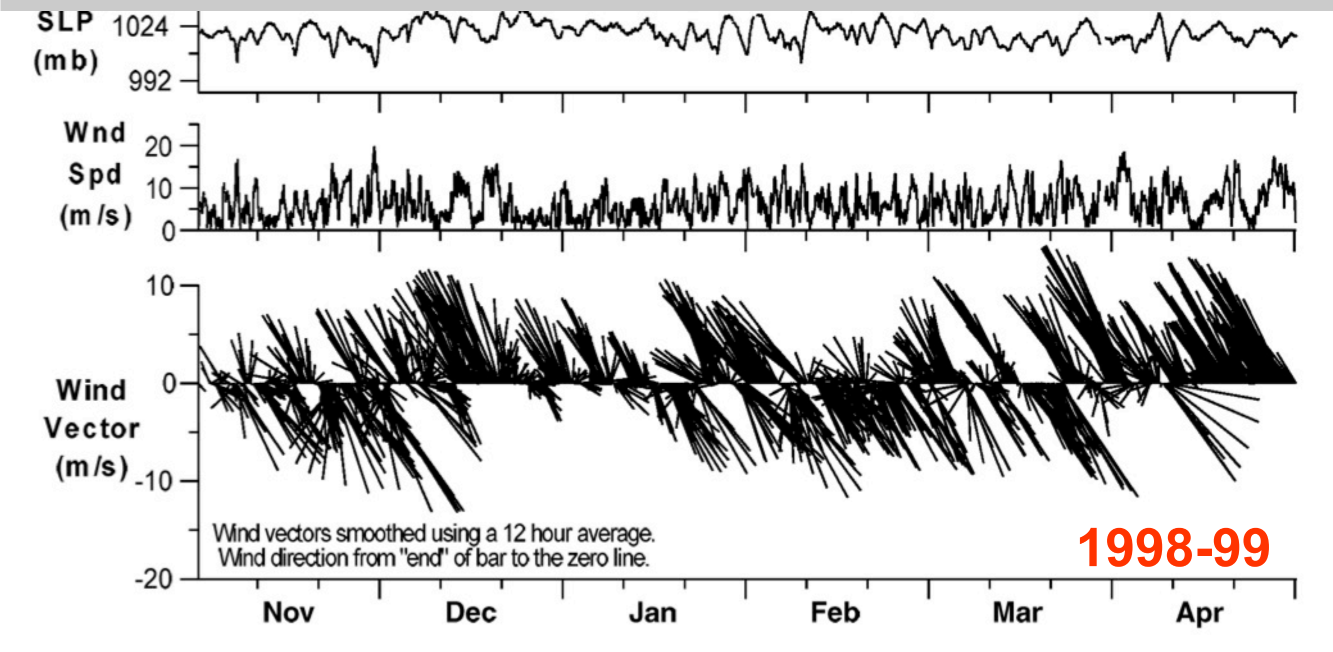
January 12-21 1983

500mb Geopotential Height Anomalies

Commencement of a remarkable North Pacific Winter storm season





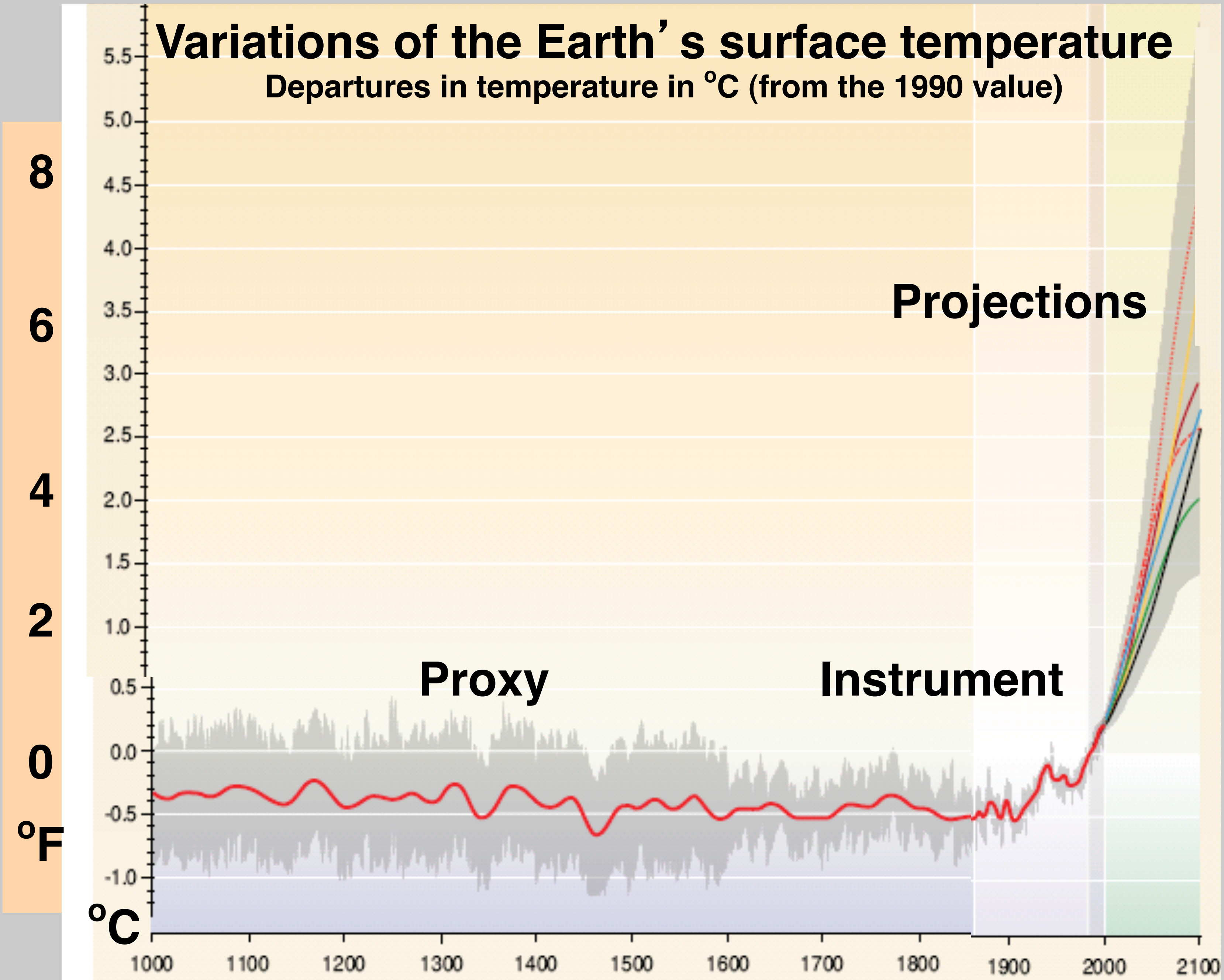


NOAA Buoy 46014

(~39N 123W)

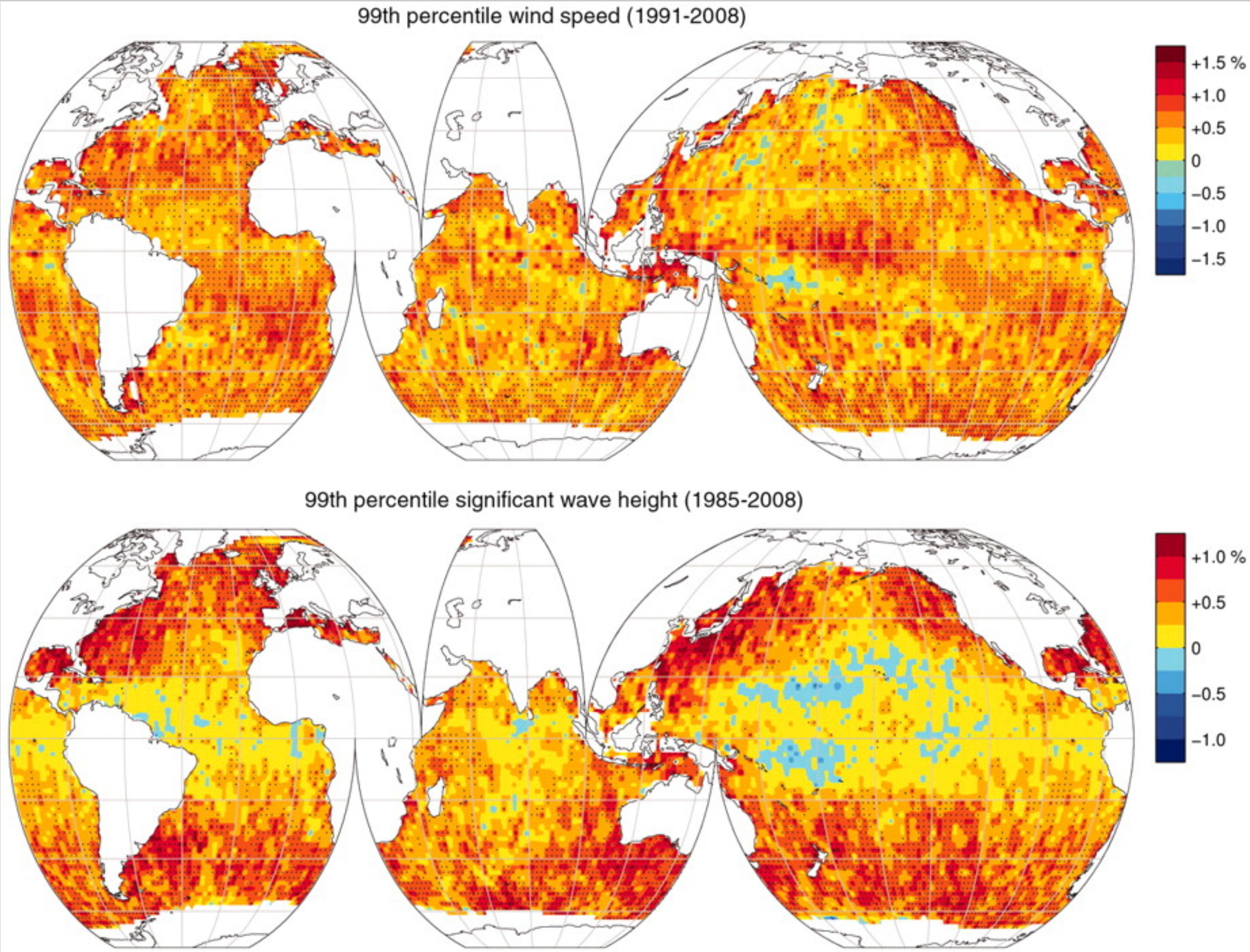
1982-1983
lower LOWs
higher winds
more westerlies
more southerlies
than
1998-1999

strong southerly winds
+ low barometric pressure
favor high sea levels



Variations of the Earth's surface temperature
Departures in temperature in °C (from the 1990 value)
Projections
Proxy
Instrument
8
6
4
2
0
°F
°C
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100

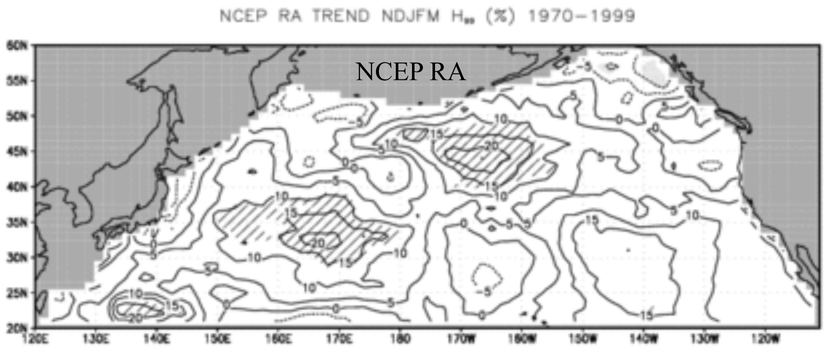
Fig. 3 Color contour plots of the 99th-percentile trend (percent per year).

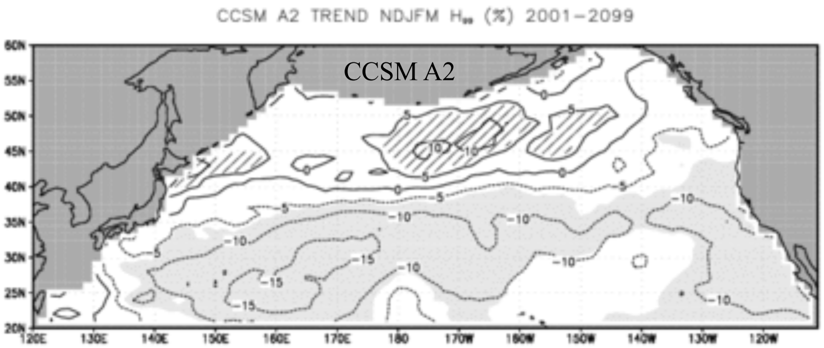


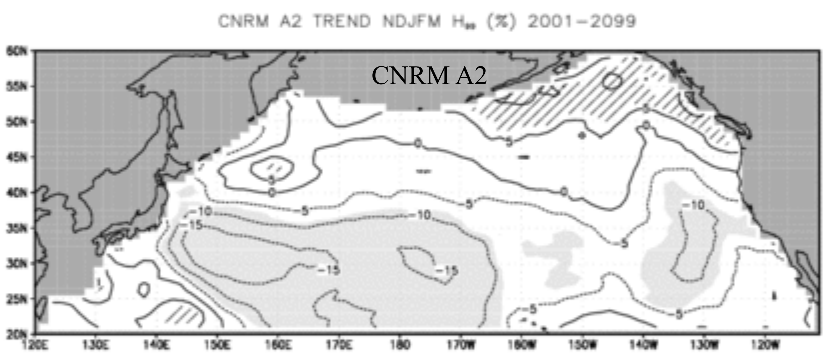
I R Young et al. Science 2011;332:451-455

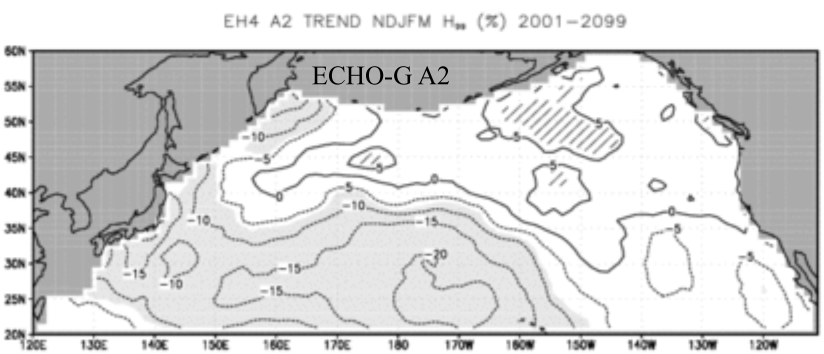
Published by AAAS

TRENDS H_{99} (% CLIMATOLOGY) WINTER (NOV-MARCH)
Note: H_{99} = 99^{th} ptile H_S; NCEP RA FOR 1970-1999; A2 SIMULATIONS 2000-01 to 2098-99
Shading (negative) and hatching (positive) significant trends @ 99% (t-test)

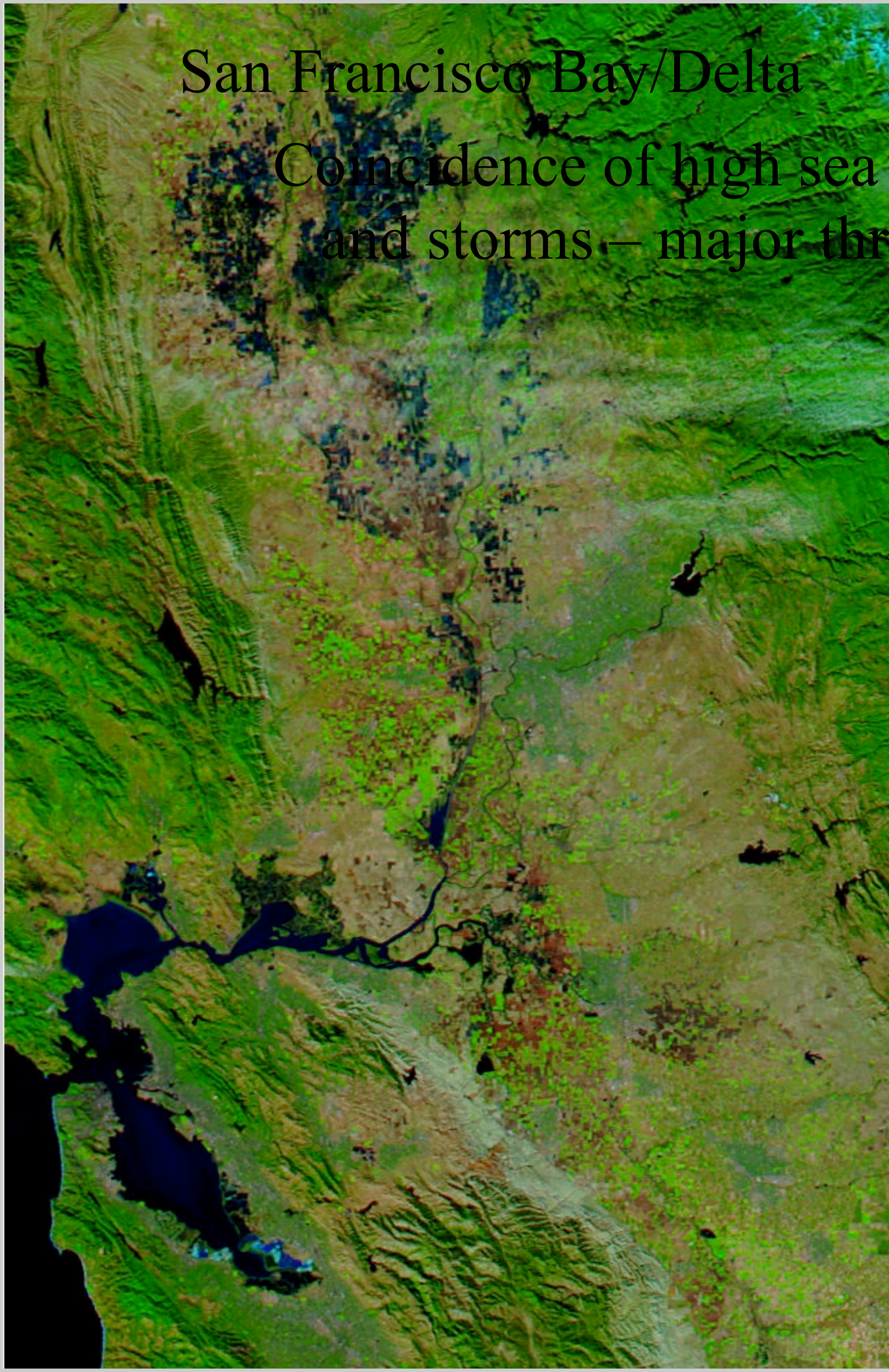
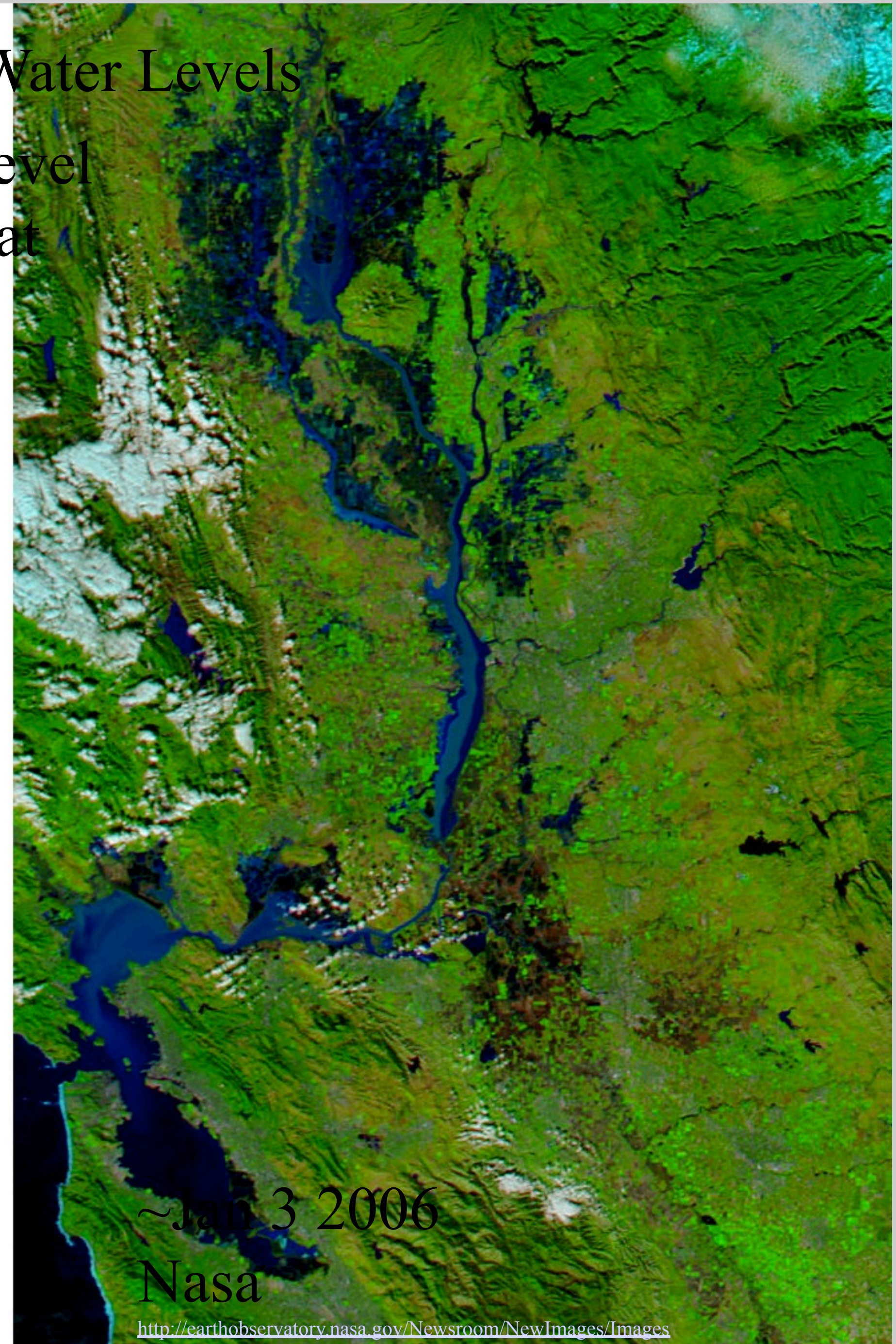


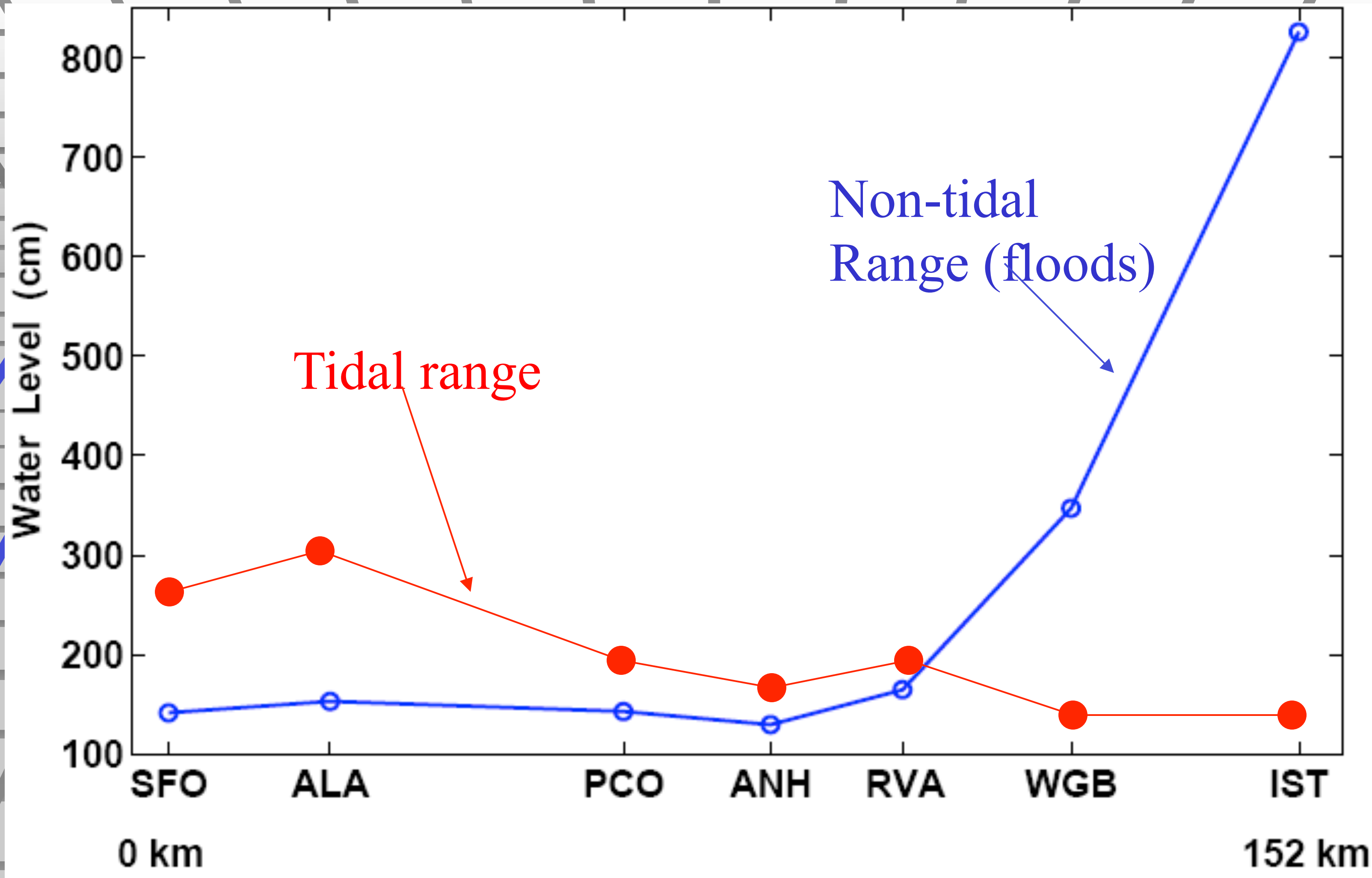






Nick Graham



San Francisco Bay/Delta Water Levels
Coincidence of high sea level
and storms – major threat
~Jan 3 2006
Nasa
http://earthobservatory.nasa.gov/Newsroom/NewImages/Images
/ncalifflood_amo_2006004_lrg.jpg



Extreme water levels from San Francisco to Sacramento

Extreme elevations are the 99.99th percentile levels for 1993-2002, relative to the mean low river flow, from all data within that span (may be different numbers of observations due to different recording gaps). Mean low river flow reference levels were estimated as the mean of the all of the data from the low river flow period during 1991 and 1992.

SUMMARY

Sea level along the California coast has risen about 7” over the last 100yrs, nearly same as global rate.

Global warming causes sea level rise (SLR) through two processes:
a) thermal expansion of the ocean, *b)* melting land ice adding water to global ocean.
The land ice contribution is not accurately modeled but will likely dominate over next several decades.

Recent studies have predicted much higher sea level rise for the 21^{st} Century than the IPCC, exceeding 3 feet if greenhouse gas emissions continue to escalate

SLR causes inundation, but *does not*, by itself, cause beach erosion and flooding. Run-up of big waves during high tides causes erosion and flooding. SLR worsens effects of waves as time goes by.

Big storms, high tides and El Niño conditions will likely continue be the most potent combination leading to coastal damage and erosion during the next few decades.

The key to understanding the coastal effects of future SLR is to measure the wave-driven beach and cliff erosion and flooding _today_ so we can construct data-based models of shoreline retreat. What is needed is repeated LiDAR beach and cliff retreat monitoring, along with wave data (CDIP) to connect the measured changes with the waves.

Storm runoff will exacerbate high sea levels in estuaries—in particular the San Francisco Bay/Delta