

Sea Level Rise Adaptation: Physical science to address issues

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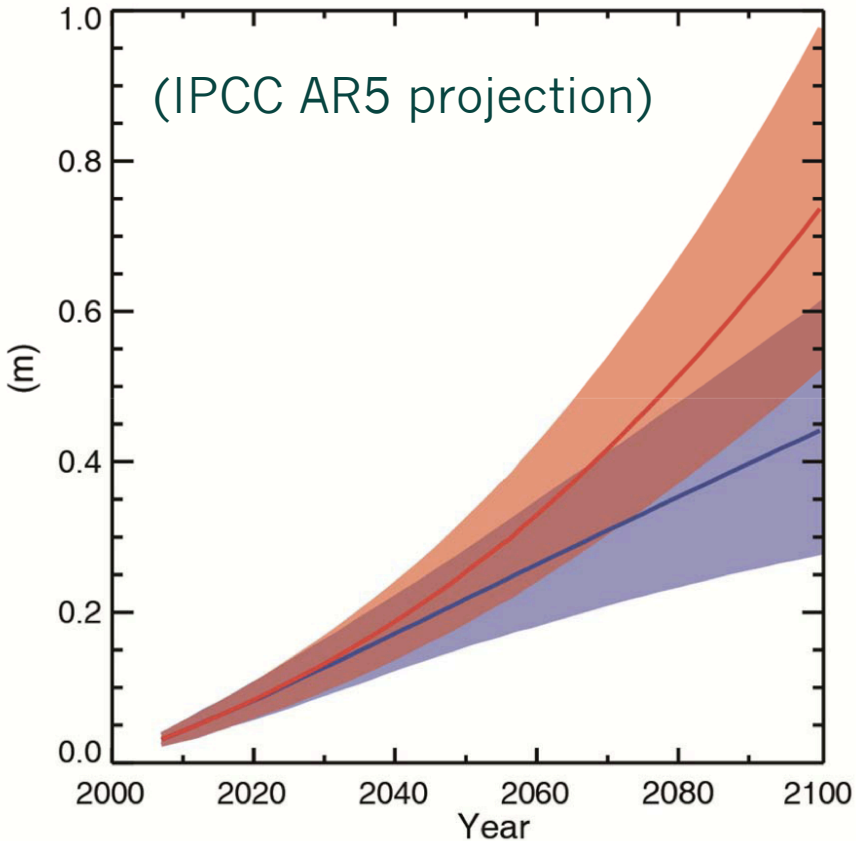
Mark Merrifield (University of Hawaii)



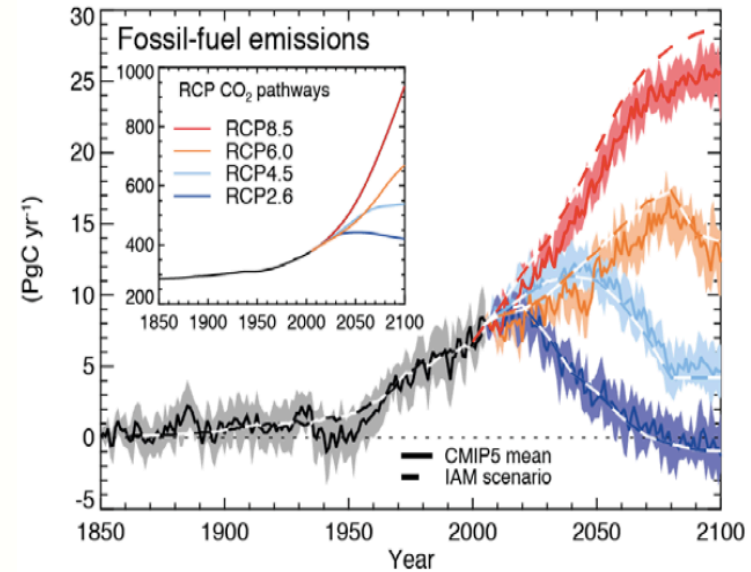
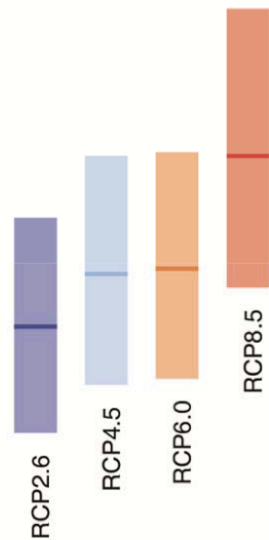
Sea-level will rise with or without CO2 emission reductions

Global mean sea level rise

(IPCC AR5 projection)

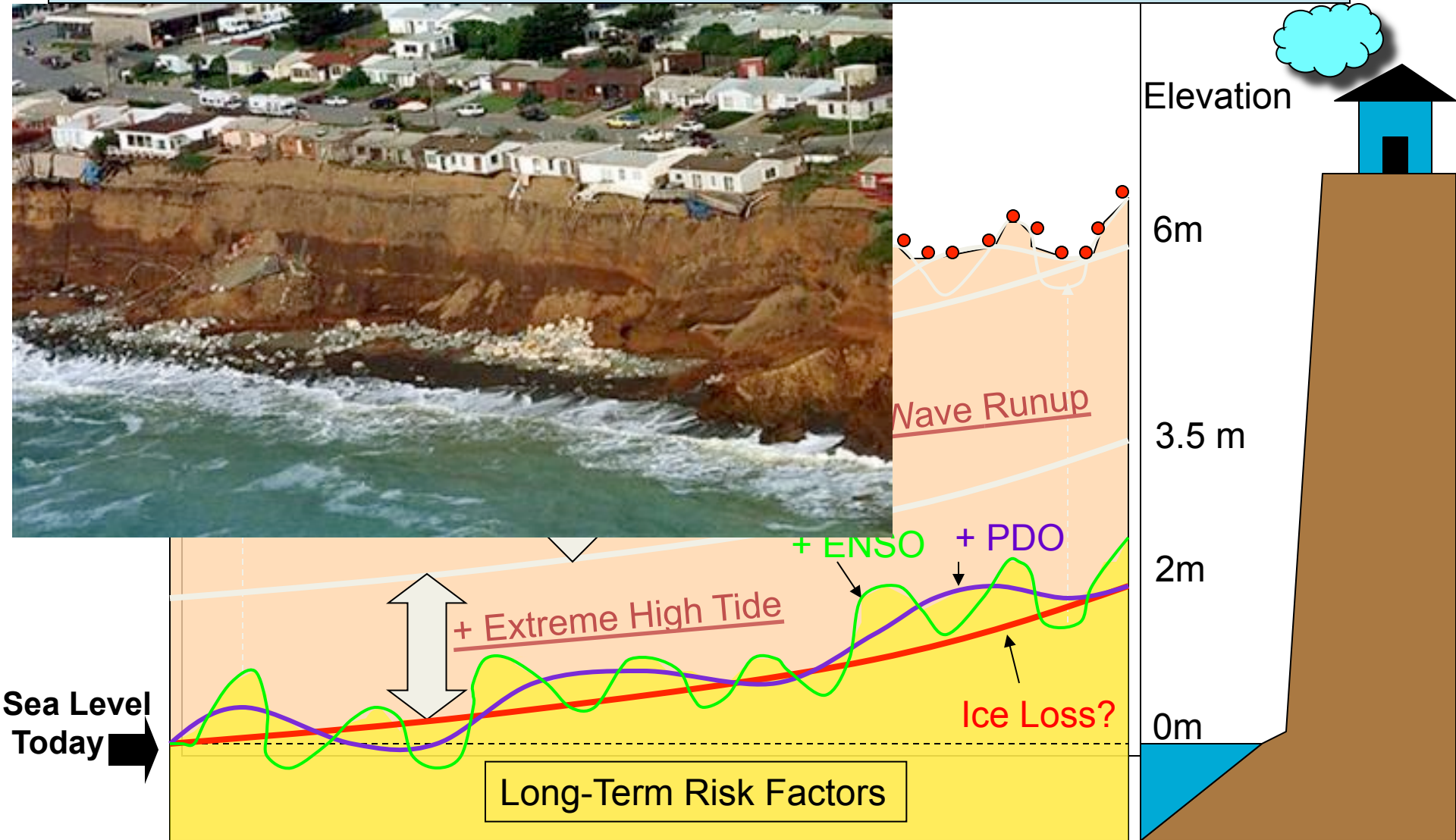


Mean over 2081–2100



Adaptation is not an option

Combined Effect of Sea Level Rise, Ocean Warming Events, Tides and Waves



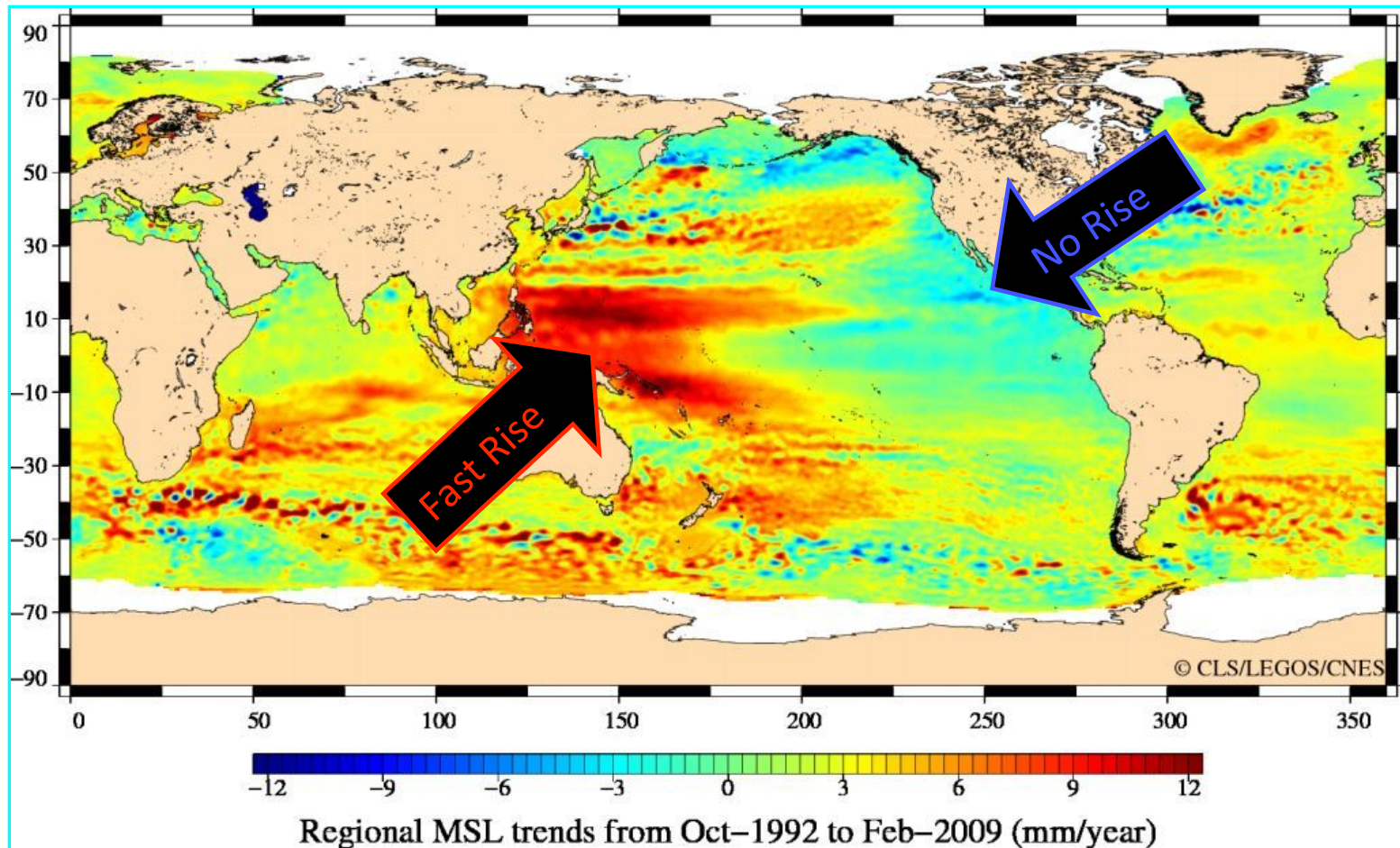
California Today



California in 2100+

Pacific Sea Level Rise is Complex—

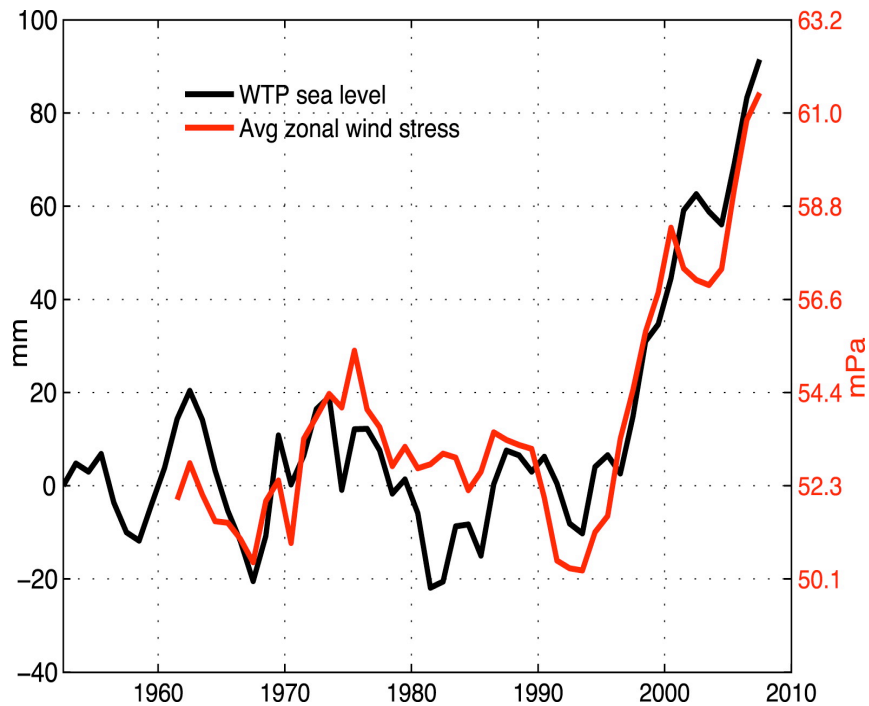
to understand and predict SLR requires global & basin scale observations and models
recent Sea Level Rise has varied greatly over the Pacific basin



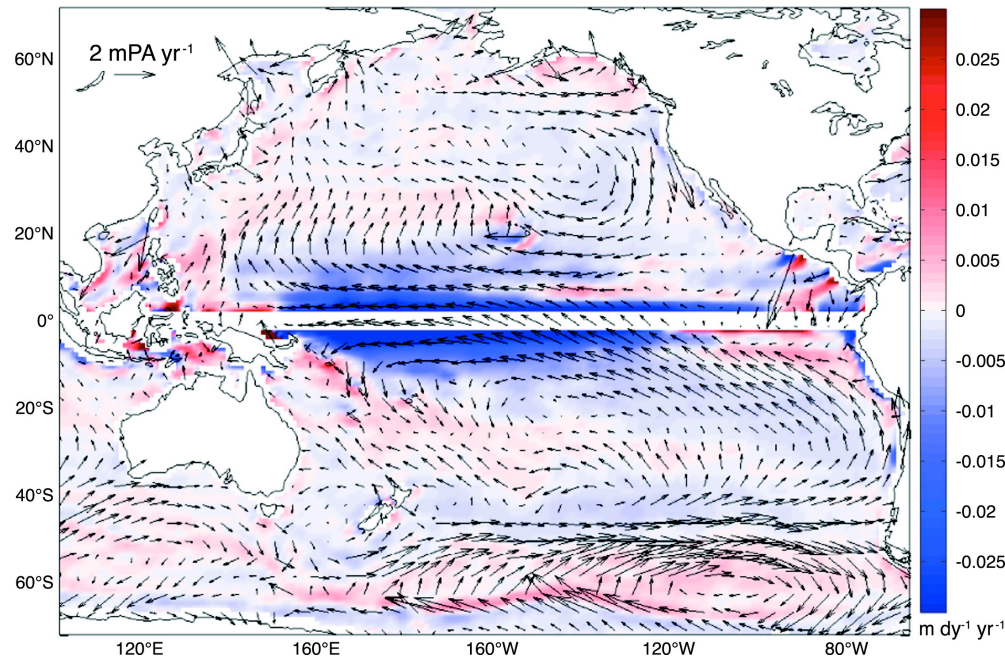
Recent sea level rise & variability related to multi-year fluctuations in Pacific basin wind stress

(Merrifield, 2011; Bromirski et al., 2011; Merrifield et al., 2012)

Western Tropical Pacific Sea Level & Zonal Wind Stress



Trend in wind stress (arrows) & curl (colors)



inhabited coral atolls and low-lying islands are vulnerable to rising sea levels



OBSERVATION NETWORK GAPS: REMOTE WEATHER, WAVE, & SLR STATIONS



SUPPORT

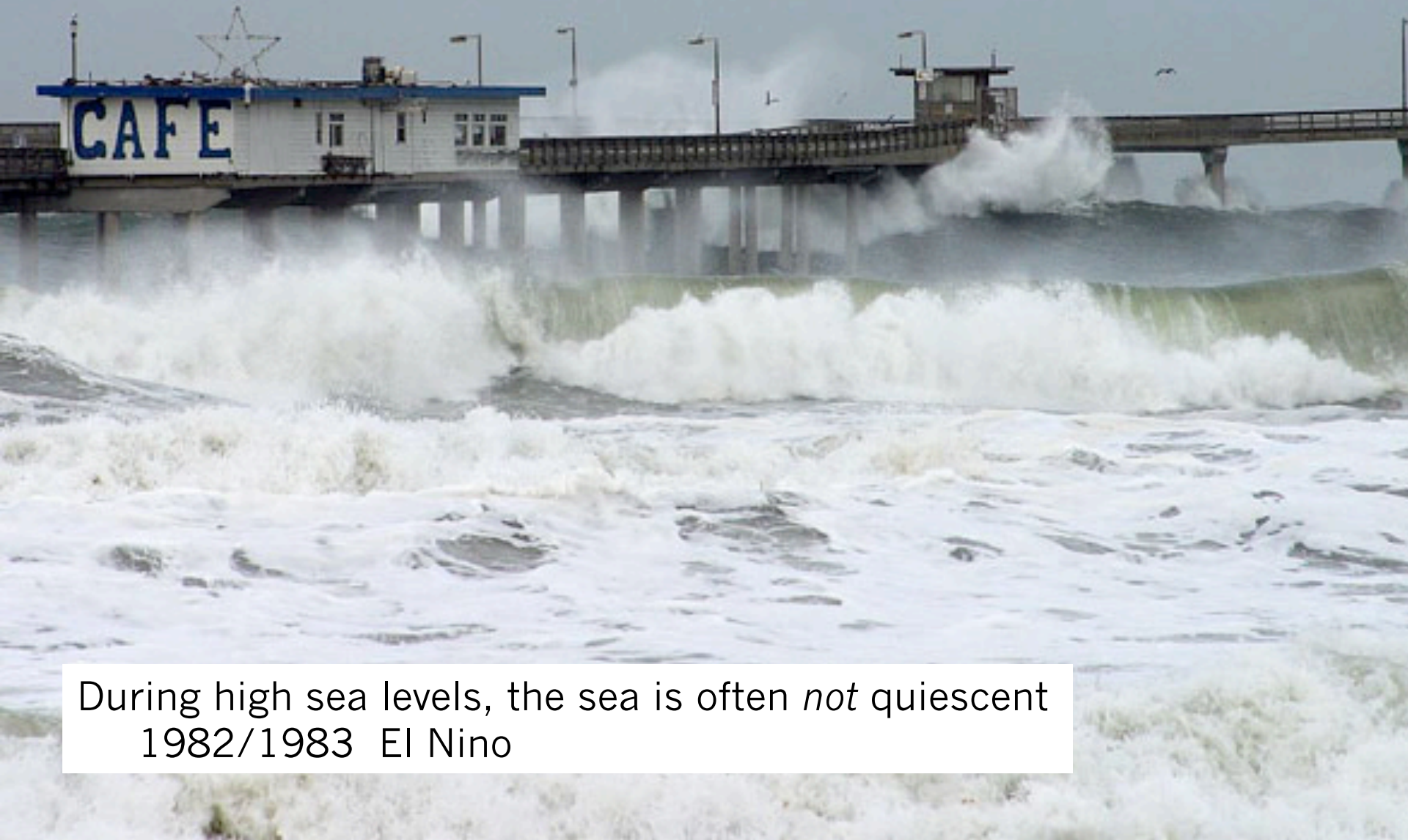
Station 044
2012-11-14 19:26:17 UTC
Sample Age: 00:54

Obs.	Value	Units
Avg. WDir	47	deg
Avg. WSpd	15	Knots
Min Wind	12	Knots

Current Location [Palau](#)
Satellite

METAR XM44 141926Z AUTO 05015G20KT 9999 -RA 28/24 A2977 RMK A02 SLP084 P0000 T02830244 PA159 DA2132

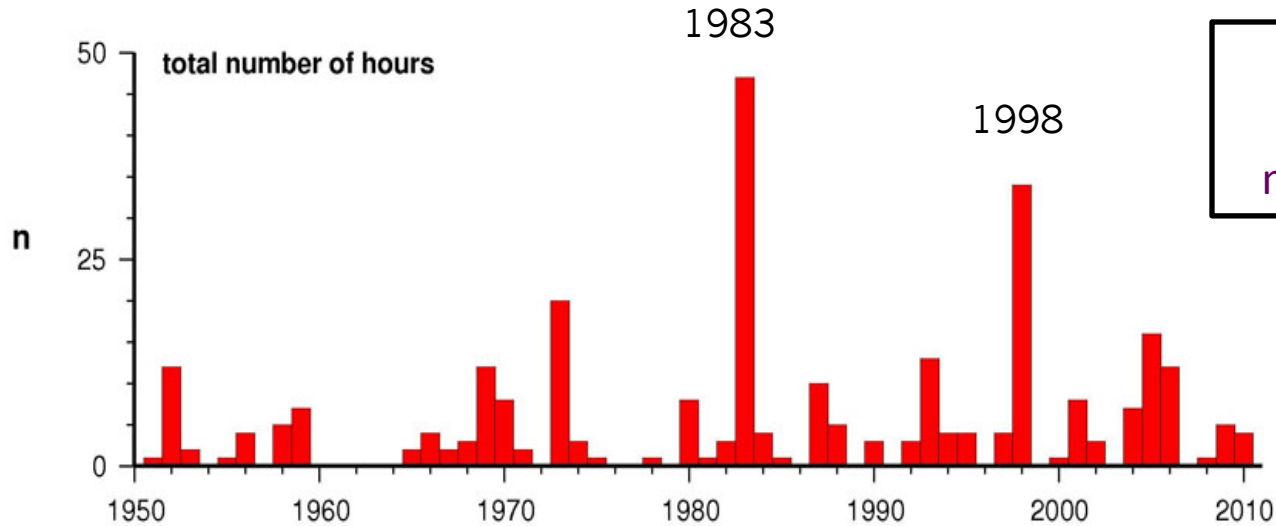
Sea Level Rise Issues



During high sea levels, the sea is often *not* quiescent
1982/1983 El Nino

Extreme sea levels have occurred intermittently in response to unusual climate patterns.

San Francisco observed at or above 99.99% historical hourly threshold 1.41m above mean



from hourly sea level record at Ft Point, mouth of San Francisco Bay

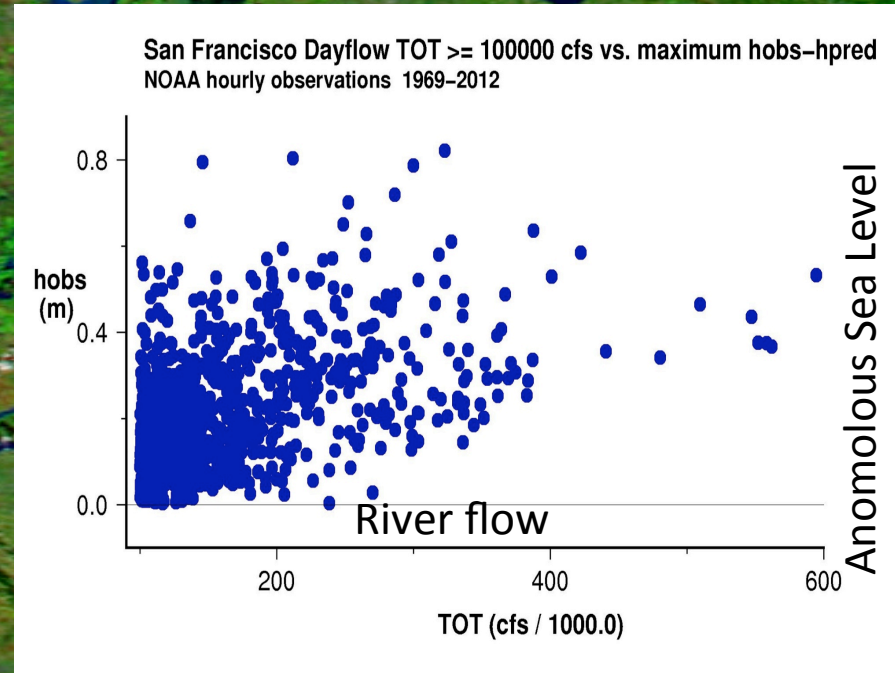
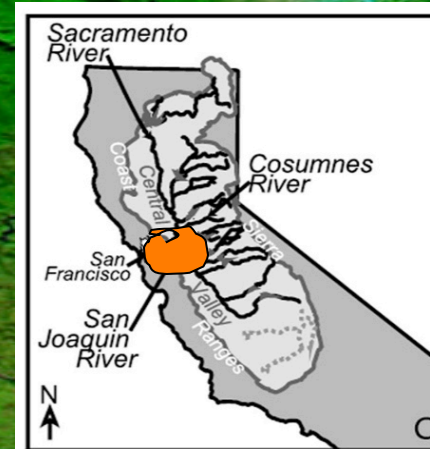
Flick et al., 1998
Cayan et al., 2009

Highest California sea levels mainly occur in stormy years, particularly large El Ninos (1983 and 1998)

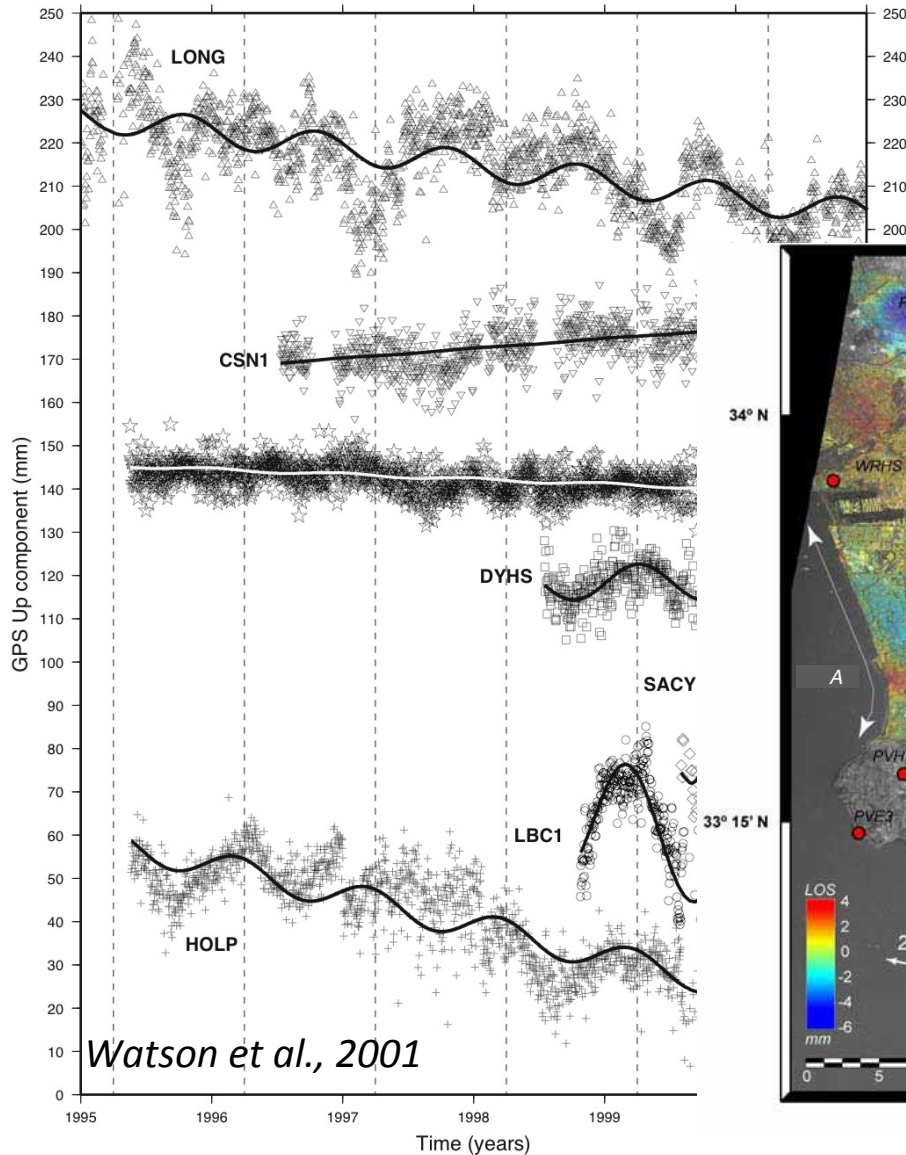
San Francisco Bay/Delta

The key fixture of California's water supply is affected by land subsidence, and threatened by heightened sea levels and heavier mountain runoff.

(Cayan *et al.*, 2008)



Vertical Land Motions (VLM) may occur within short distances and over seasonal and longer time-scales: LA County



Note regional variability in 1992-2000 VLM trend (Brooks et al. 2007)

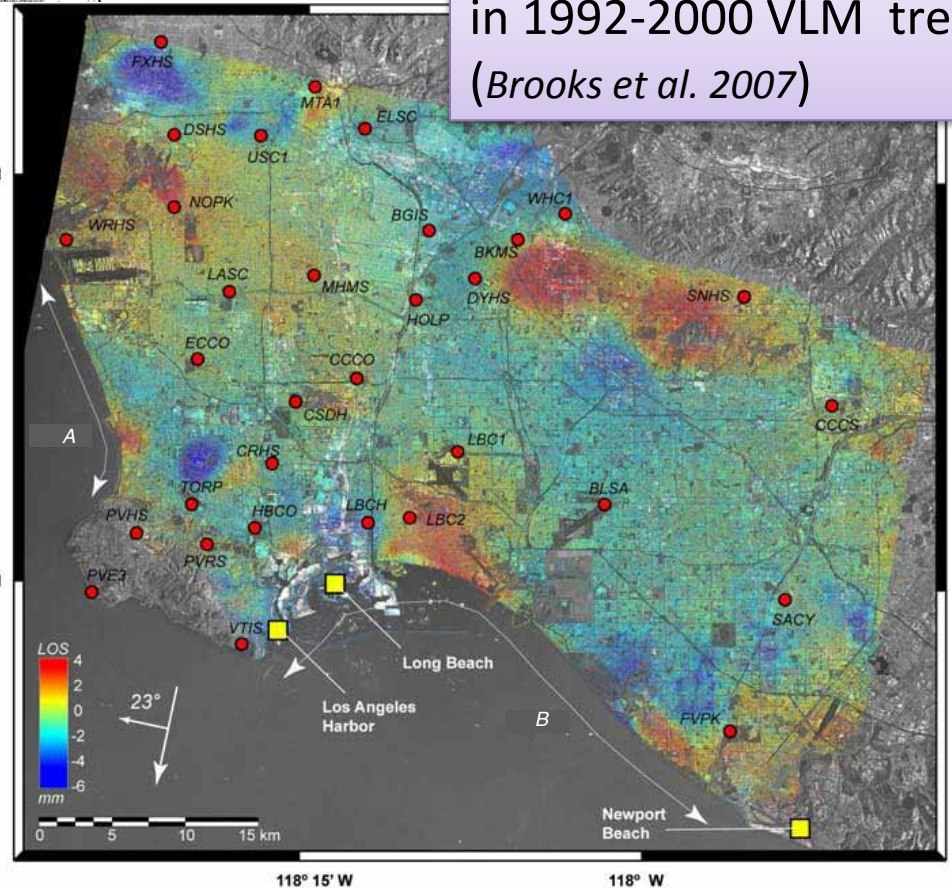


Figure 4

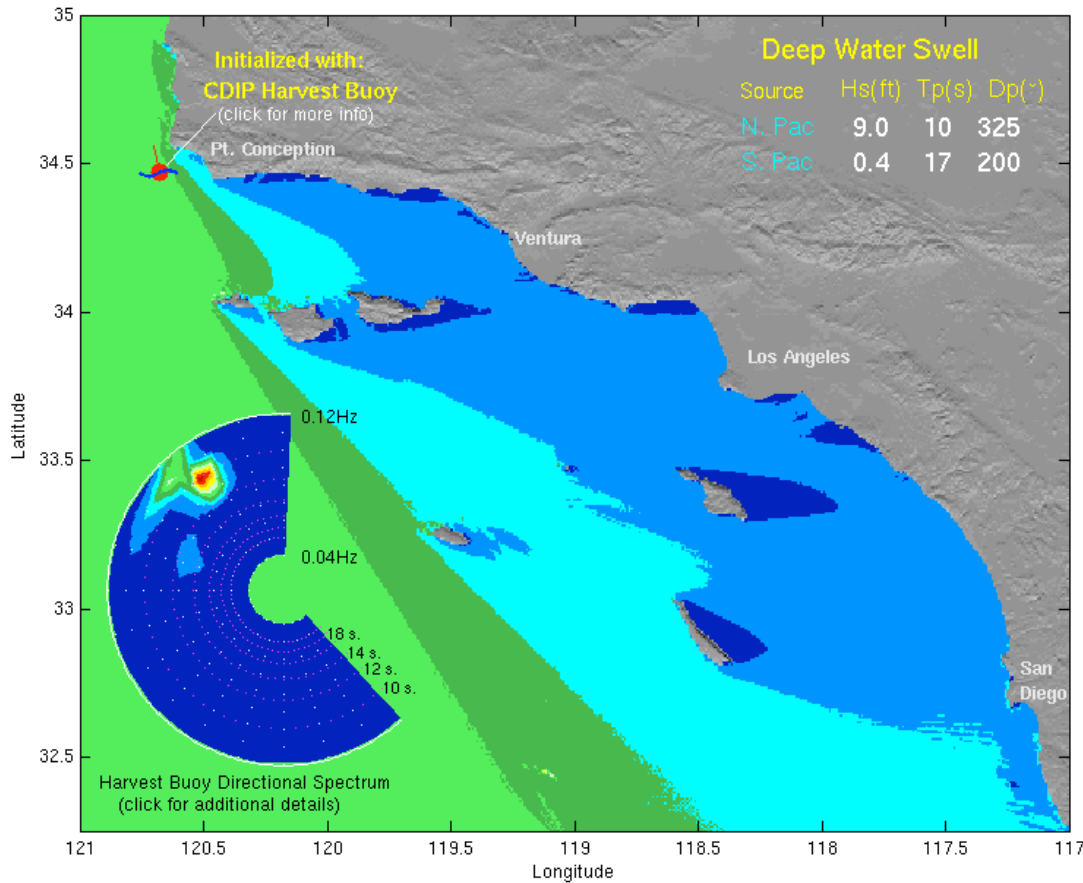
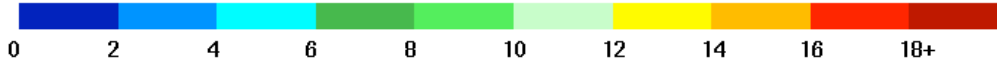


The Coastal Data Information Program
Integrative Oceanography Division



Analysis Time – 7 MAY 2014 : 0802 PST

Swell Height (ft) – Southern California Bight



Additional Information @ <http://cdip.ucsd.edu/>



California Department of Boating and Waterways

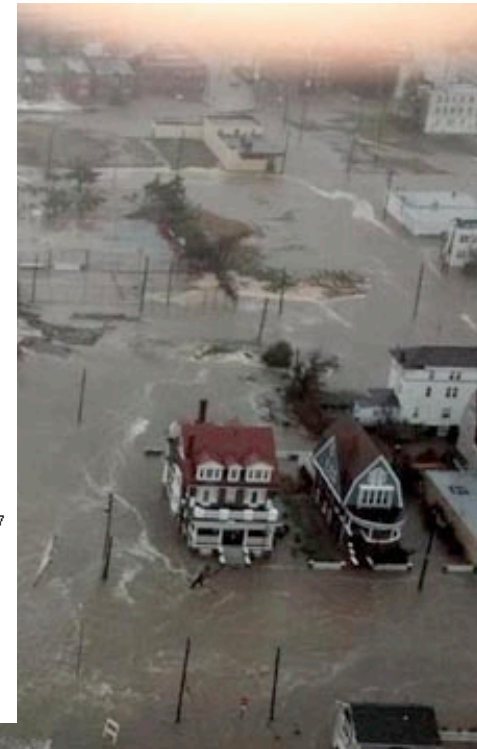


U.S. Army Corps of Engineers
Field Wave Gaging Program

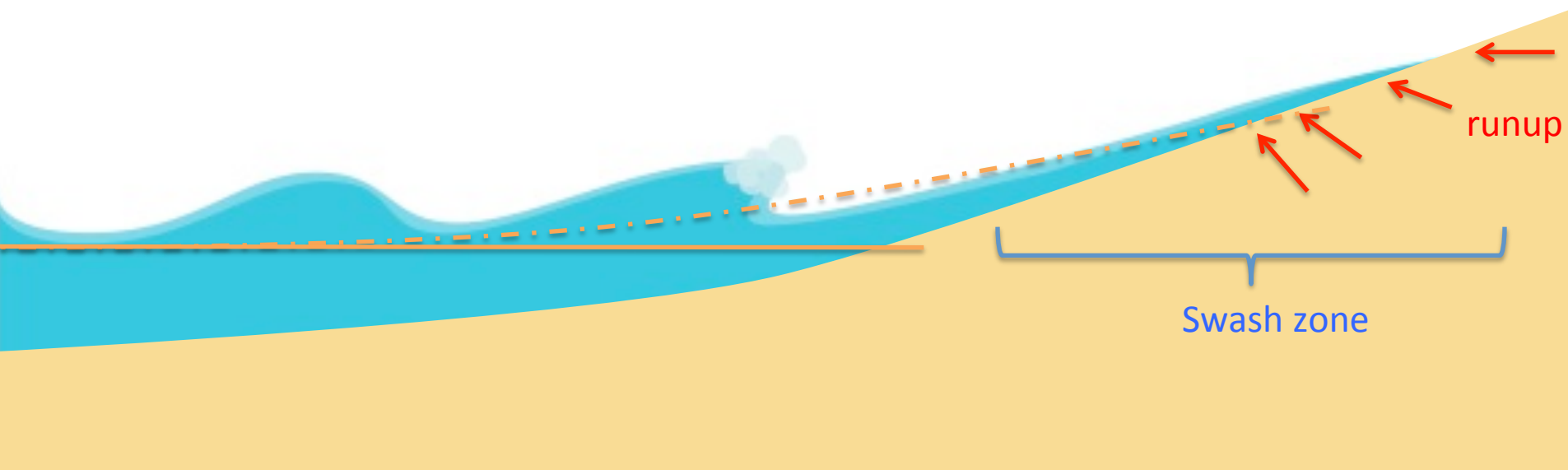


Office of Naval Research
Advanced Wave Prediction Program

WAVES



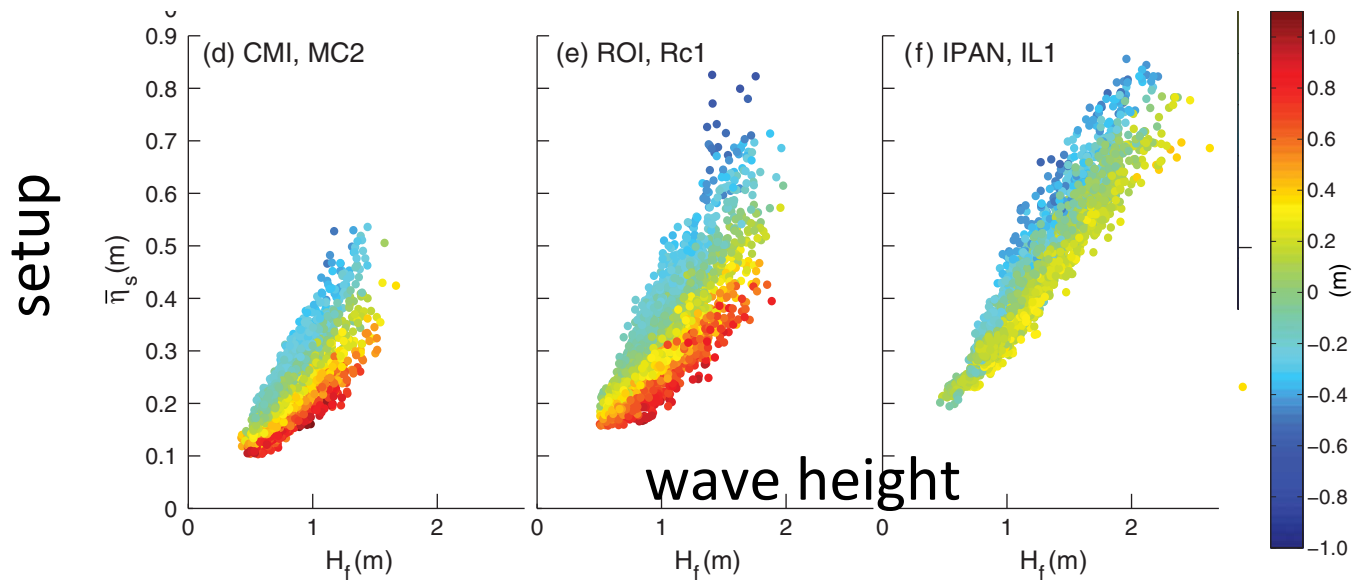
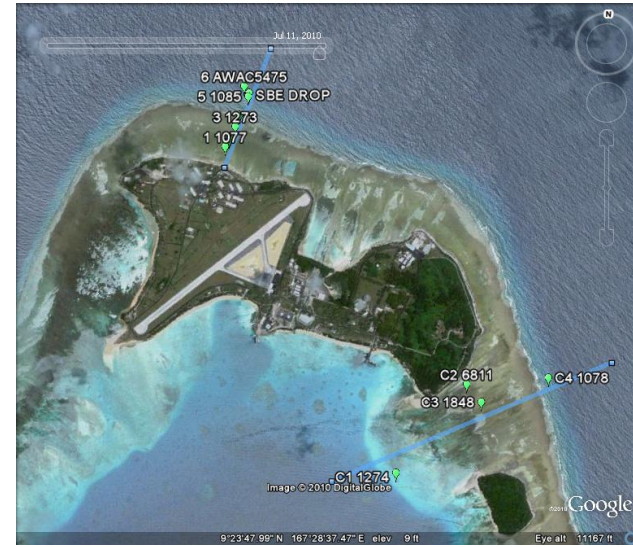
Q: How big is **setup** & **runup** on beaches & atolls especially in extreme conditions, and why?



Set up: Super elevation of mean water level

Run-up: The time-varying excursion of water up the beach, measured in the vertical.

Water level effects on wave driven setup for low lying atolls



Need: better understanding of waves on reefs

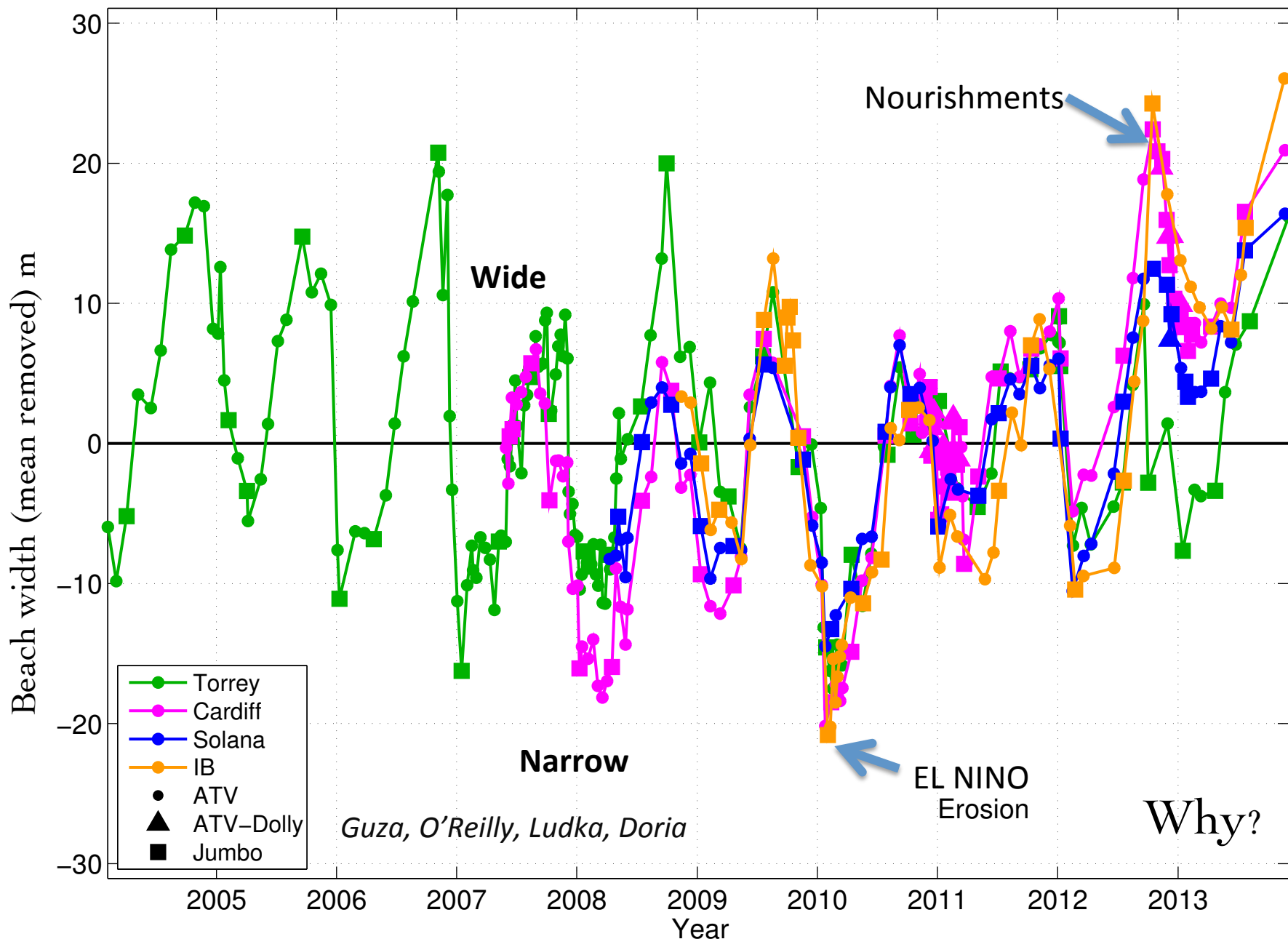
Becker et al., 2014

Runup drives coastal flooding



- Runup models not well tested
- Runup models not linked to coastal flooding models

Beaches “Breathe” Seasonally Due to Waves



California coastal cliff evolution:

Young et al., 2011-2014

how rapid/large are cliff retreat events?

how is cliff erosion rate related to waves?



Long-term Beach Erosion Has Political & Economic Ramifications: Broad Beach Malibu

1972



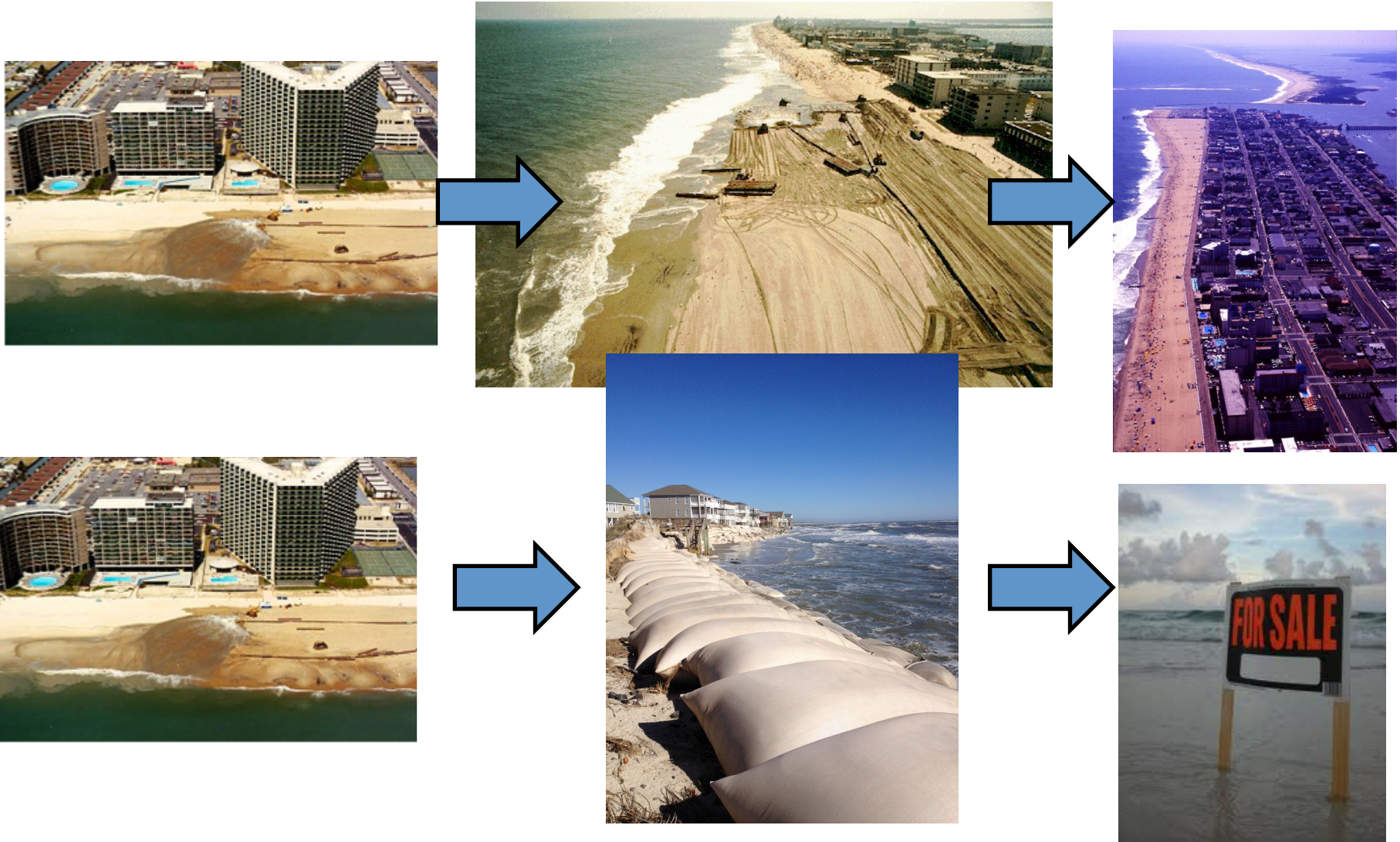
2013



"From Coast to Toast", Vanity Fair, August 2013

Morpho-economic bubble tipping point?

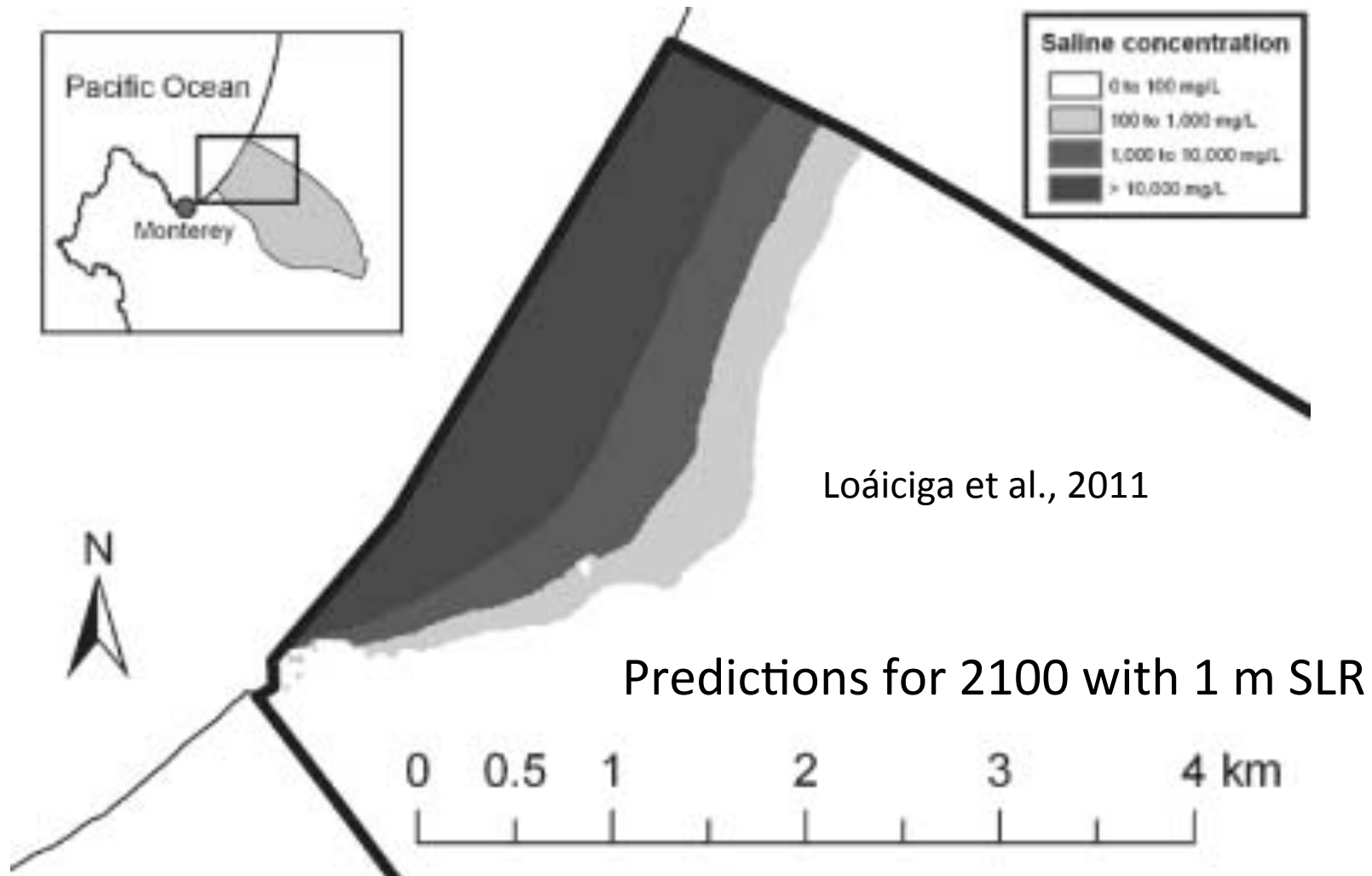
McNamara and Keeler, Nature Climate Change, 2013



Key Factors: Sea level rise, Nourishment costs, belief in sea level rise

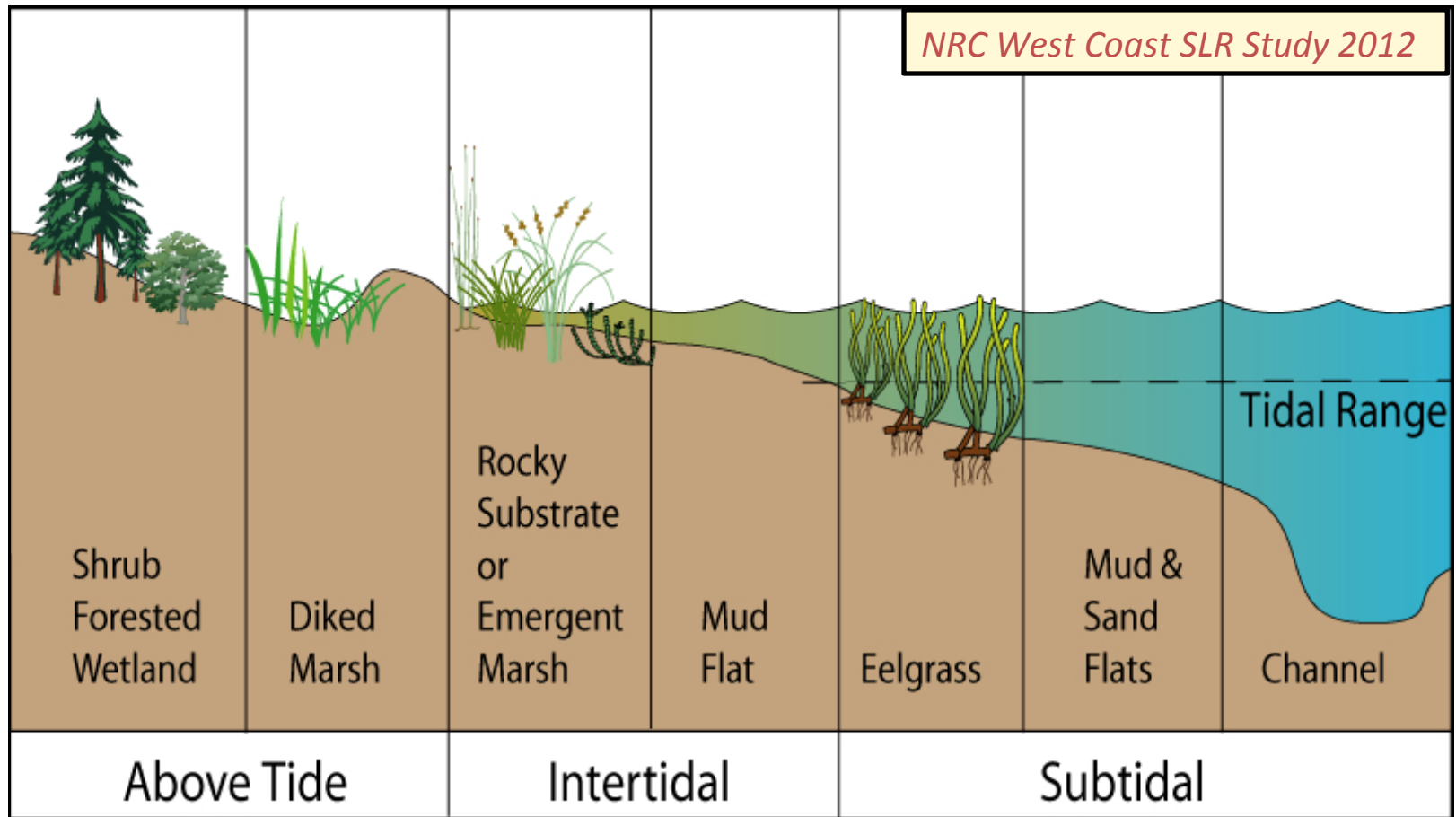
Sea Water Intrusion into Groundwater by Sea-Level Rise:

(Loáiciga et al., 2011; Rotzoll & Fletcher 2012)



Salt water intrusion threatens ecosystems, water supplies and agriculture

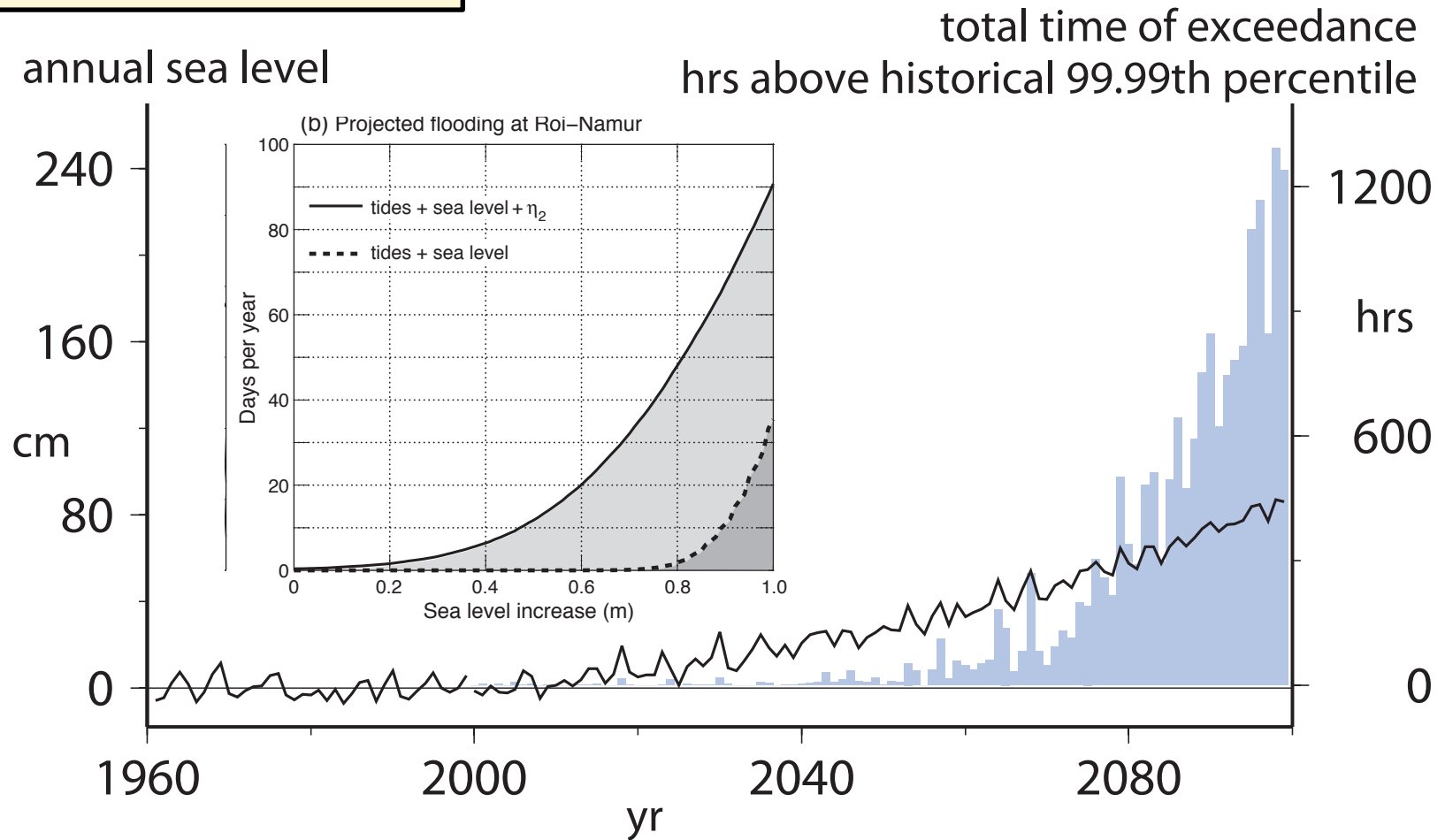
Coastal Ecosystems are vulnerable to SLR and in some cases buffer SLR impacts



- *SLR must be considered in restoration programs (e.g., SF bay-delta).*
- *Consider the ecosystem in adaptation strategies (e.g., planting mangroves in Kiribati).*

As mean sea level rises, projections indicate an increased likelihood of exceeding historical extreme levels

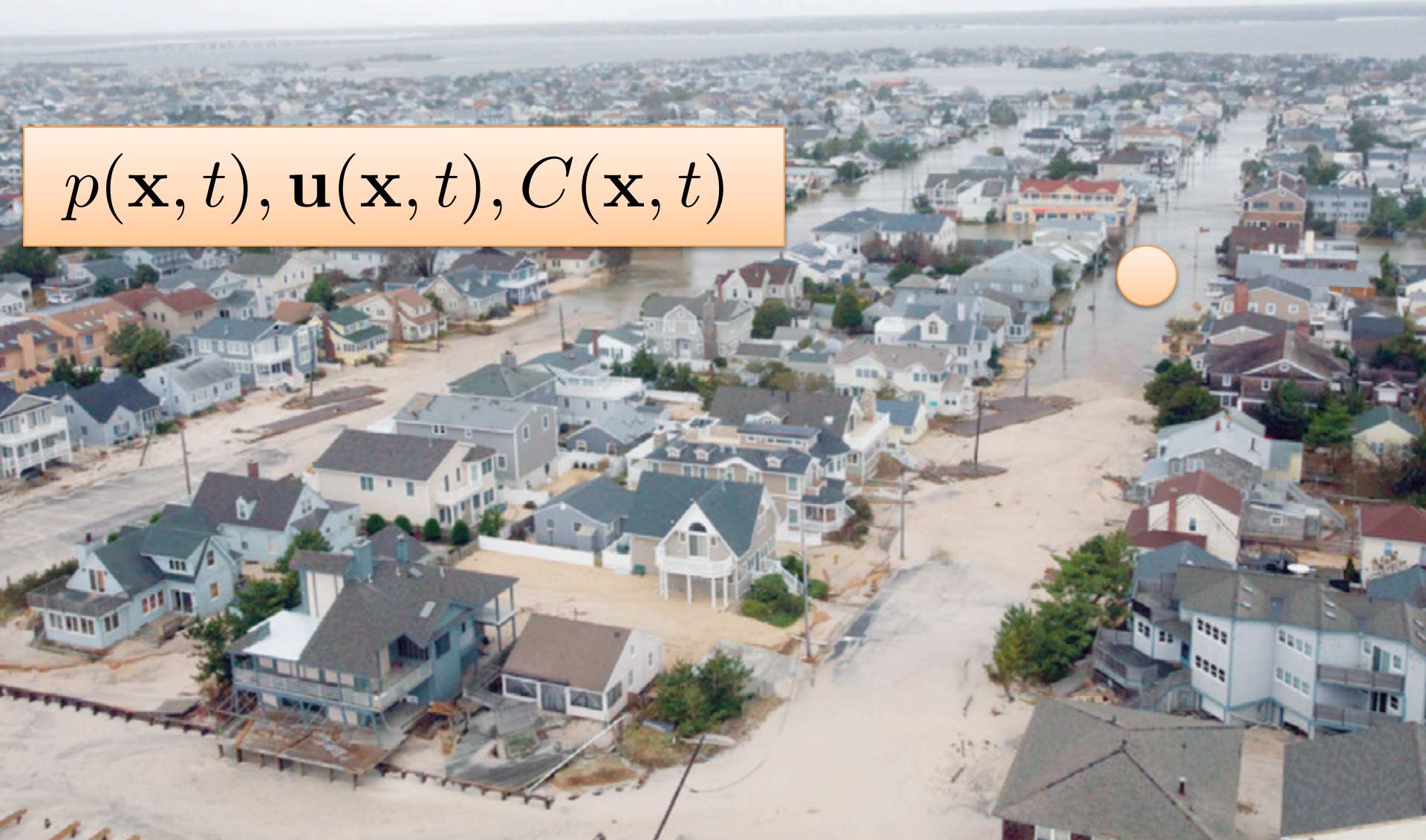
NRC West Coast SLR Study 2012



Potential global political instability issues: Mekong Delta & Bangladesh

Episodic becomes more common

$p(\mathbf{x}, t), \mathbf{u}(\mathbf{x}, t), C(\mathbf{x}, t)$



Sea Level Rise Adaptation Science Issues

- Pacific Basin SLR rates and spatial patterns have considerable uncertainty, requiring adaptive science-based management.
- Sea-level rise will magnify the adverse impact of storm surges and high waves on the coast. Role of episodic extreme events in future impacts.
- Regional and local variation in vertical land motion
- Cross-disciplinary impacts (*flooding, erosion, groundwater, ecosystems, society*)

Actions

- Sustained coastal (*e.g., beaches, waves, flooding, groundwater, ecosystems, society*) observations particularly, of extreme events, using new technologies to understand multi-disciplinary impacts and linkages
- Suites of improved models at nested scales to provide better predictions of SLR and its impacts (*flooding, erosion, groundwater, ecosystems, society*)