Sea Level Rise for the Southern California Region

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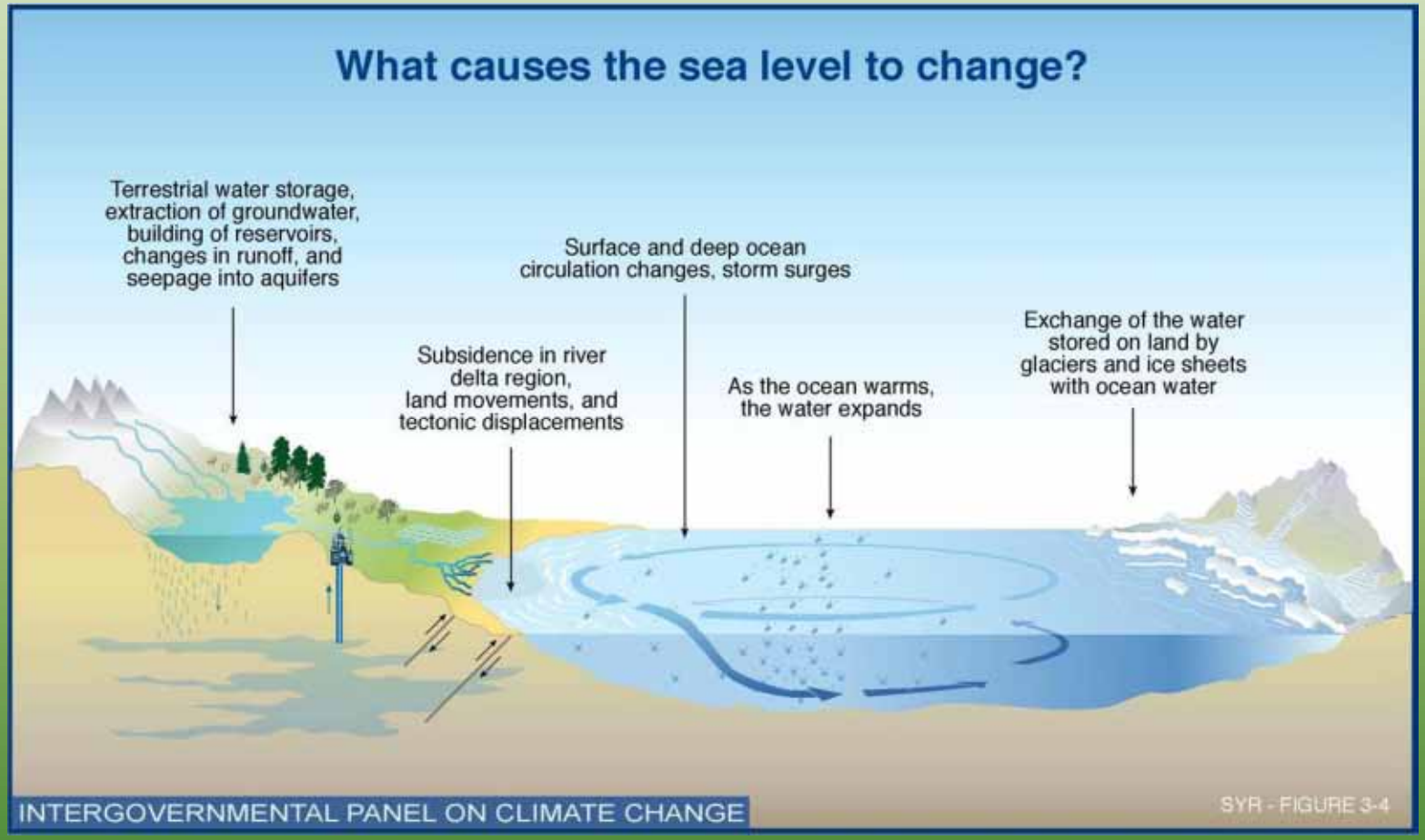
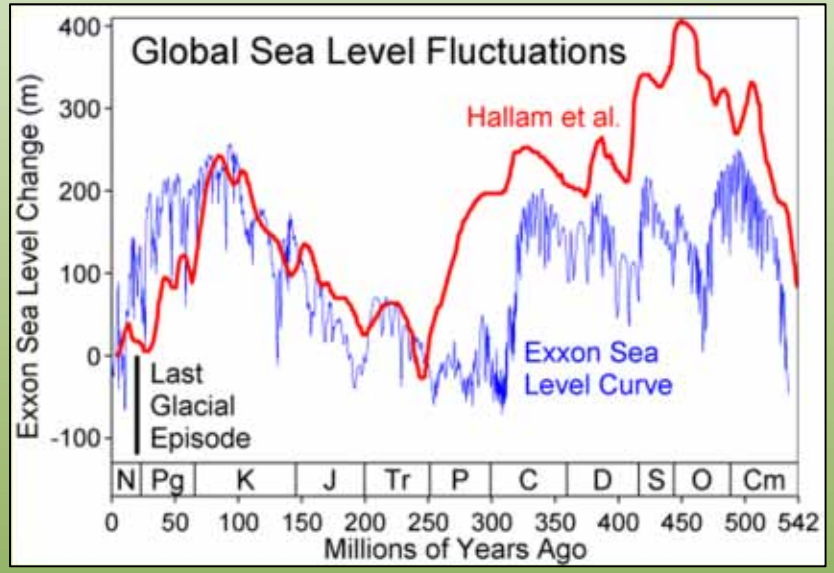
Sea Level Rise 101

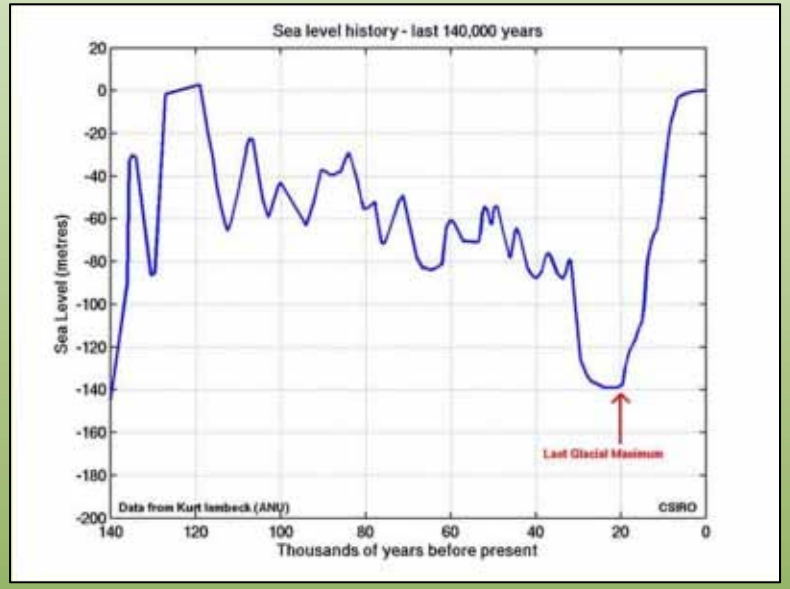


- **Other factors**
  - **Ocean basin configuration (geologic time scales)**
  - **Wind patterns (hourly to decadal)**
  - **Tidal (hourly to decadal)**
  - **Storms (hours to days)**

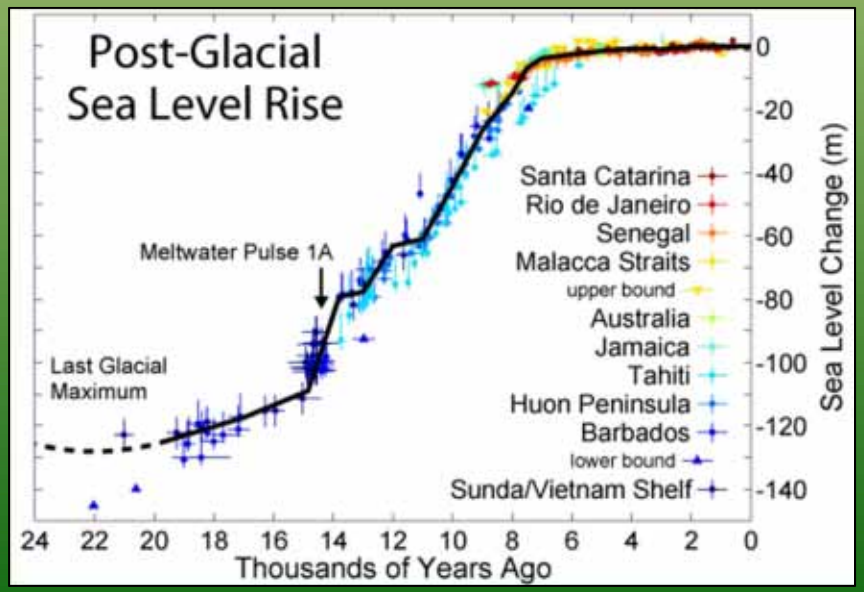
(Geologic) History of Sea Level Rise



Hallam et al. (1983), Ross & Ross (1988)

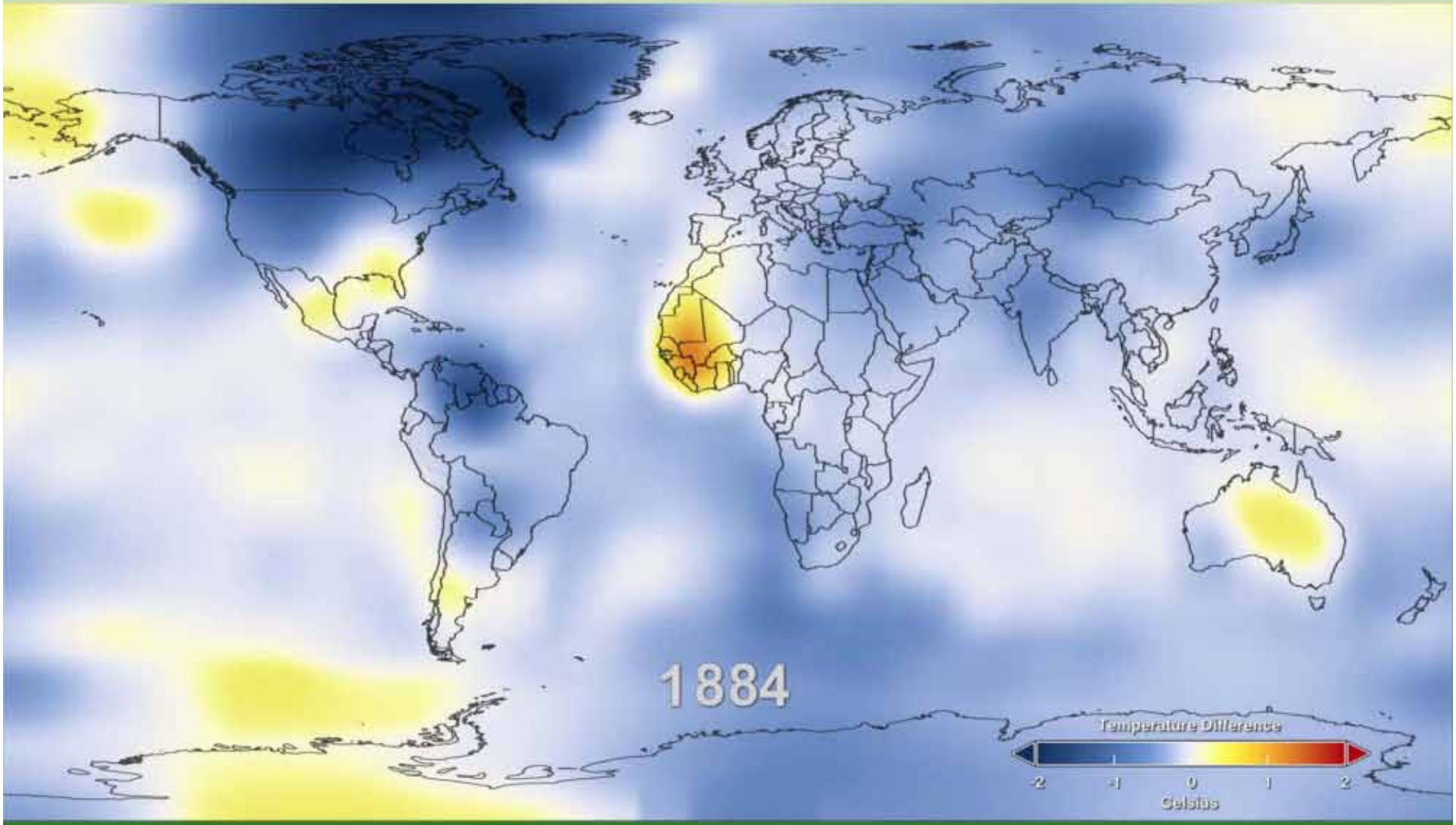


http://www.azimuthproject.org/



Fleming et al. (1998), Fleming (2000), Milne et al. (2005)

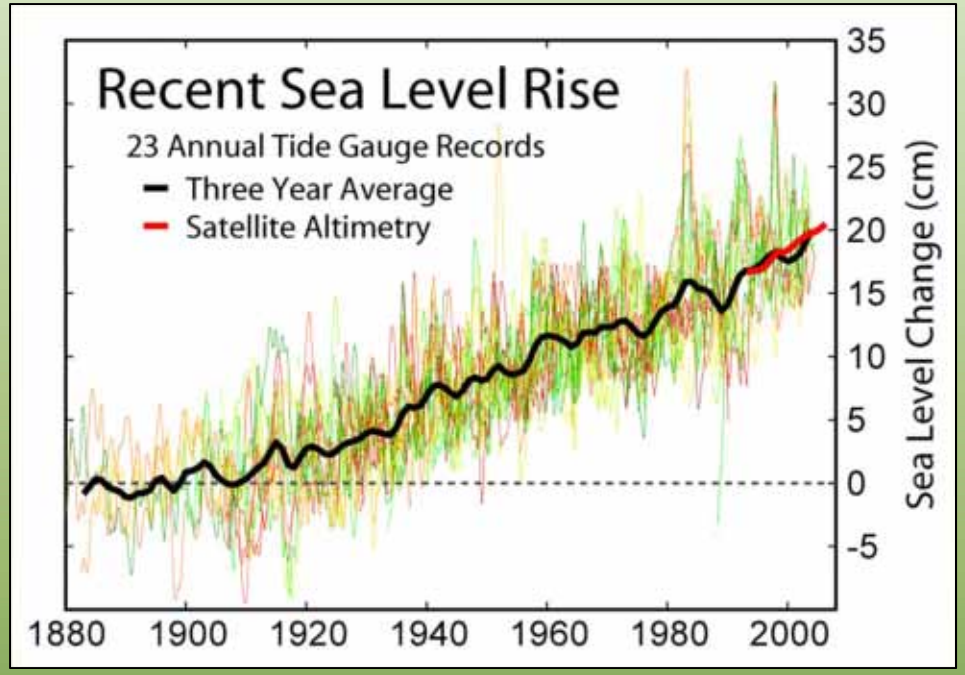
Temperature Change



NASA Goddard Institute for Space Studies

http://www.nasa.gov/multimedia/videogallery/index.html?media_id=129395671

Recent Sea Level Rise

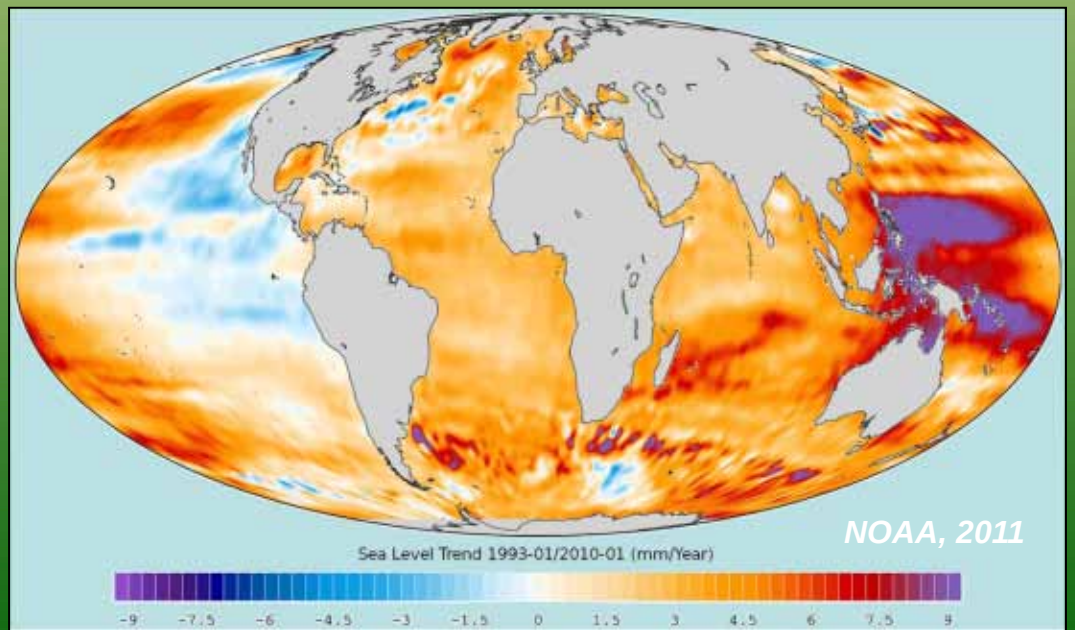


Global SLR is accelerating:

- **20th century = 2 mm/yr (e.g., Church et al., 2004)**
- **1993-present = 3 mm/yr (e.g., Merrifield and Merrifield, 2009)**

Regional factors:

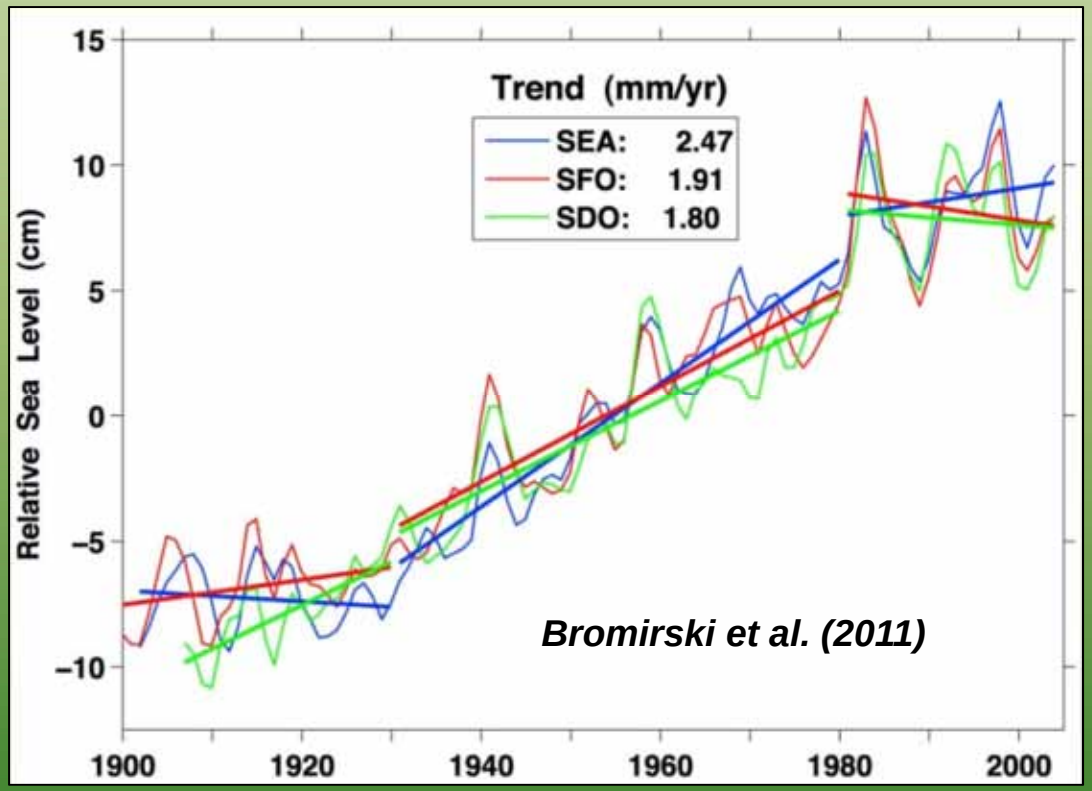
- **Ocean circulation patterns**
- **Wind patterns**
- **Glacial fingerprinting**



NOAA, 2011

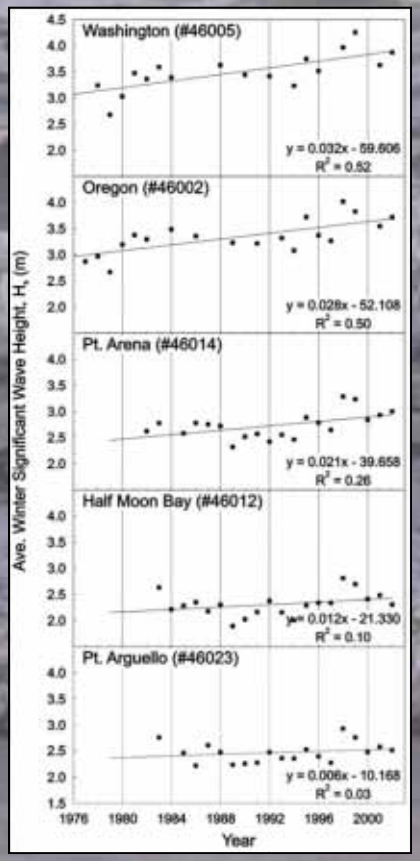
West Coast SLR

West Coast sea level rise has been suppressed for the last thirty years! BUT wind pattern changes may signal return to global or higher rates of SLR.

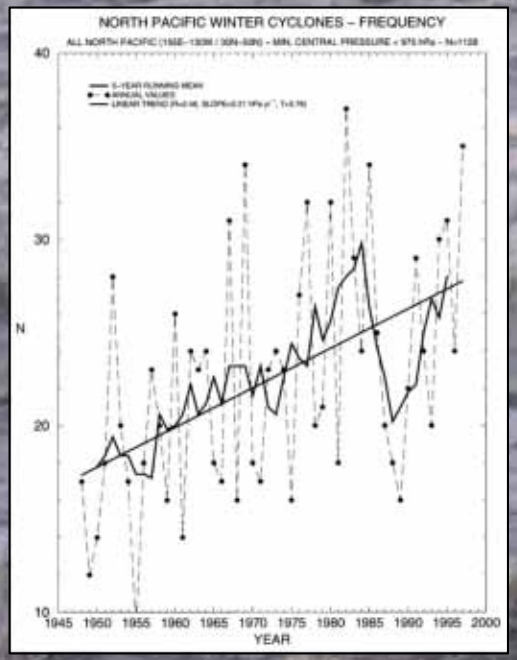


Recent Findings- Storms

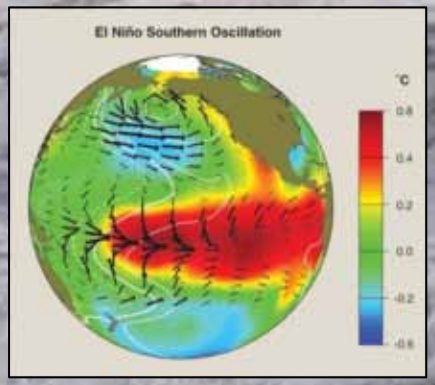
- Storms and average winter and extreme waves are getting larger and more frequent for much of U.S. West Coast
- No evidence for changes in the strength or frequency of El Niños over last ~150 years (Ray and Giese, 2012) but perhaps a shift in styles



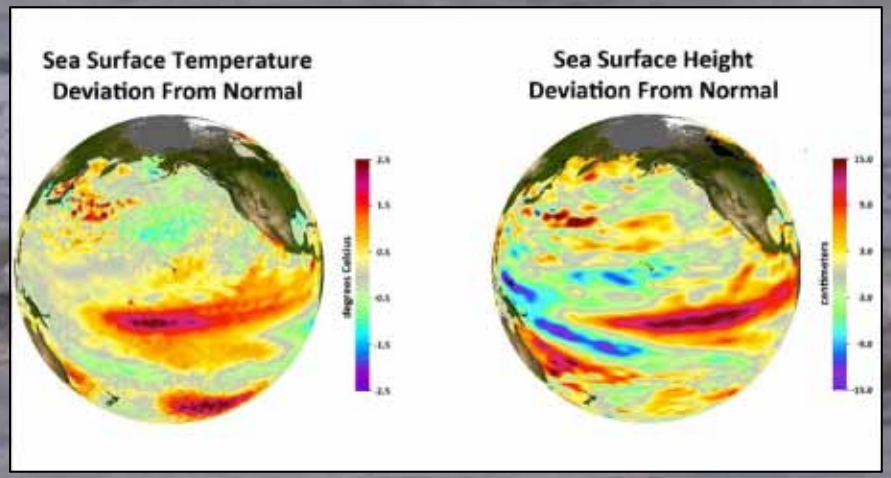
Allan and Komar (2006)



Graham and Diaz (2001)

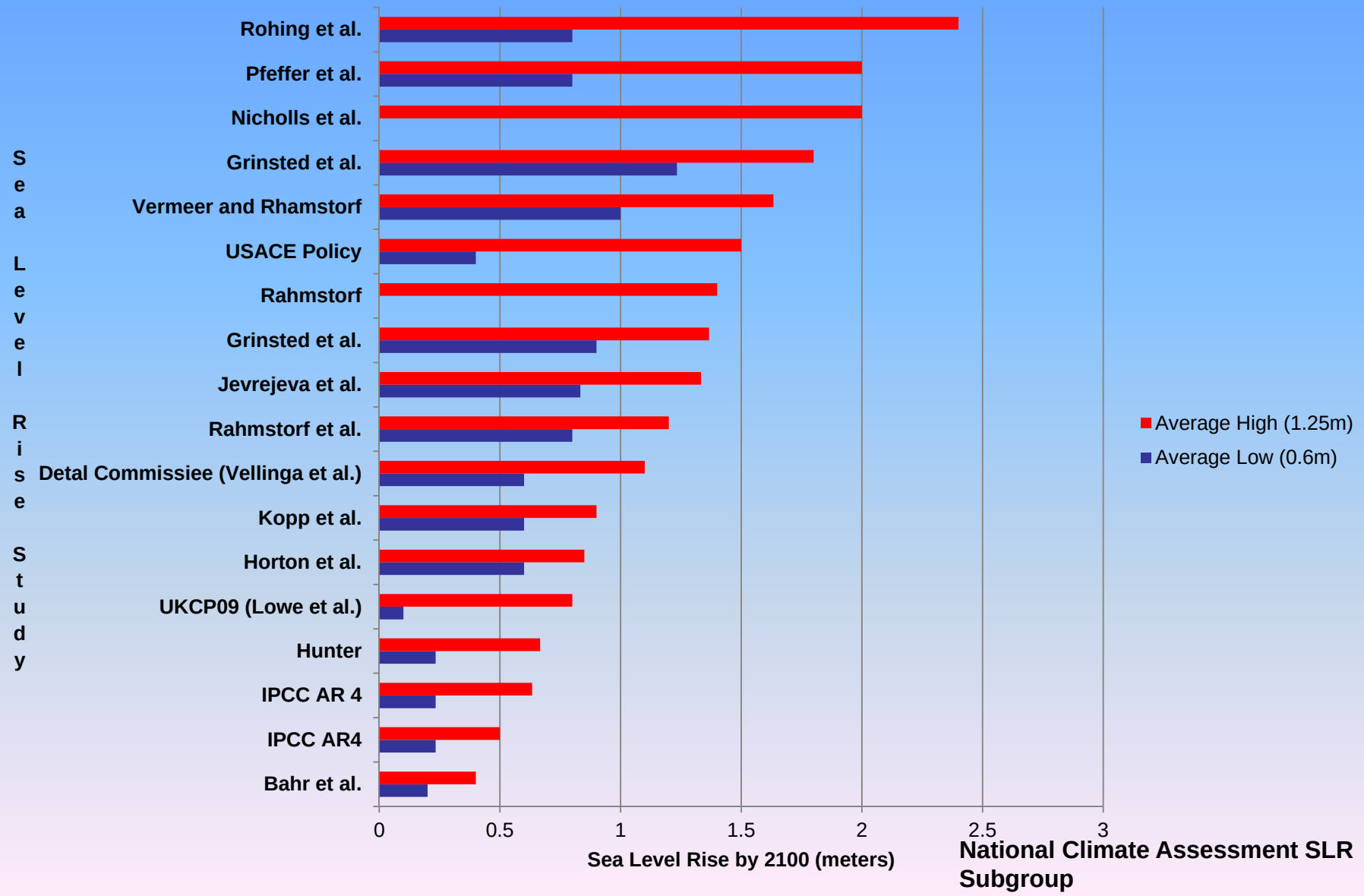


McPhaden et al. (2006)



Lee and McPhaden (2010)

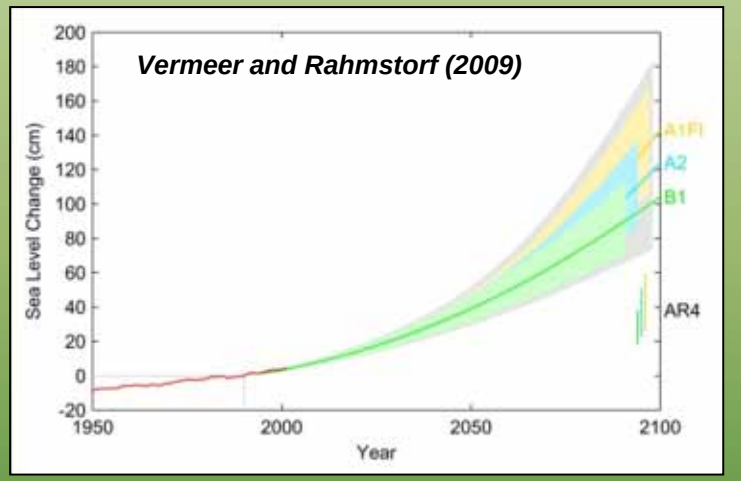
Sea Level Rise Projections
(based on various climate scenarios)



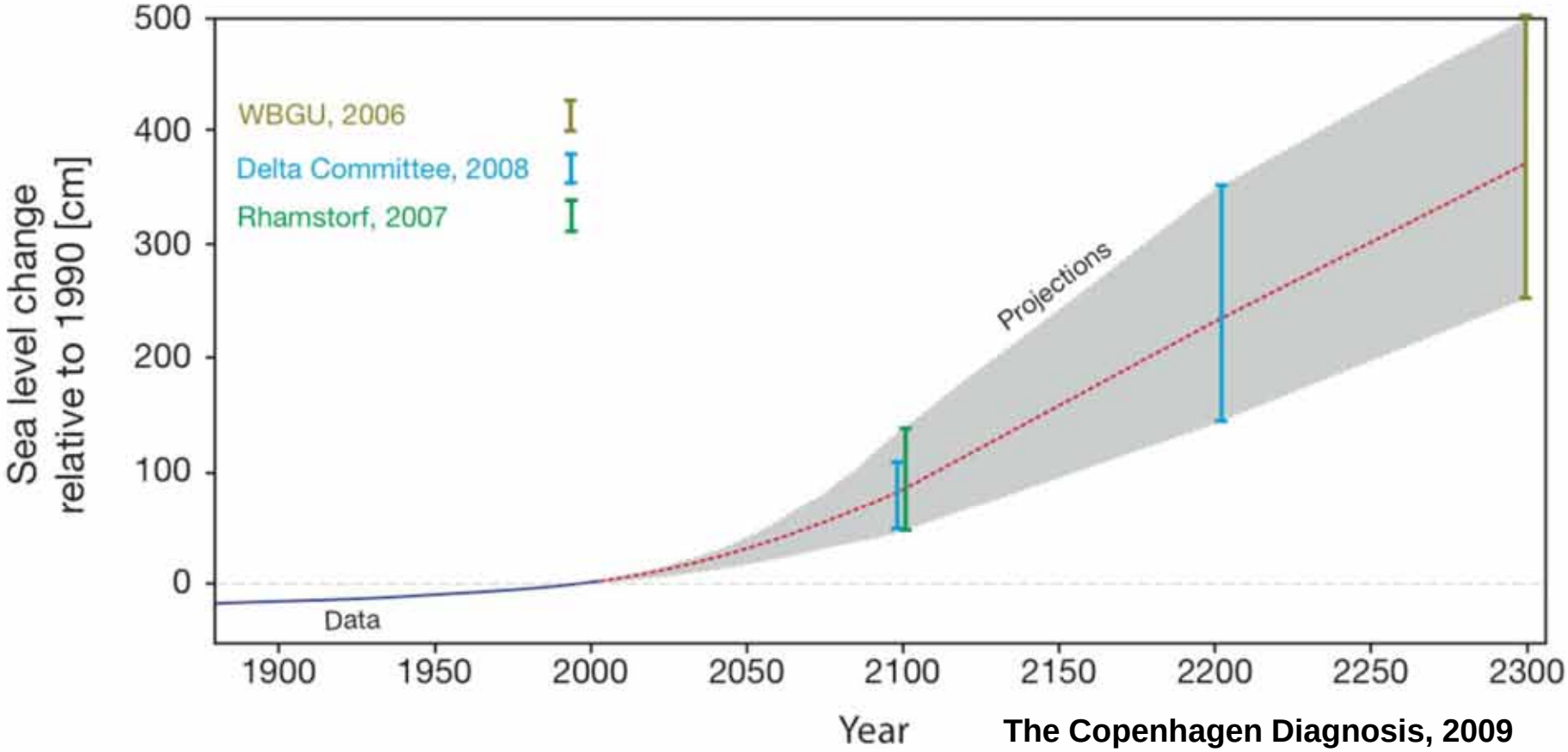
National Climate Assessment SLR Subgroup

Global Sea Level Projections (by 2100)

- **0.18 to 0.59 m** Intergovernmental Panel on Climate Change (*IPCC*, 2007)
  - does not include ice sheet contributions from Greenland (7 m stored) and Antarctica (60 m + stored)
- **0.5 to 1.9 m** Rahmstorf (*Science*, 2007)/ Vermeer and Rahmstorf (*PNAS*, 2009)
  - relates sea level rise to mean surface temperature
- **0.8 to 2 m** Pfeffer et al. (*Science*, 2008)
  - constrained by observations of ice sheet dynamics
- **5 m** Hansen (*Environ. Res. Lett.*, 2007)
  - non-linearity, amplifying polar feedbacks- 'albedo flip'
  - sea level was 75 m higher at ~50 Ma
  - at 5 Ma, sea level was ~25 m higher , but only 2-3°C warmer (A2 emissions scenario is 4.5 ^{o}C warmer)



Sea Level Rise Beyond 2100



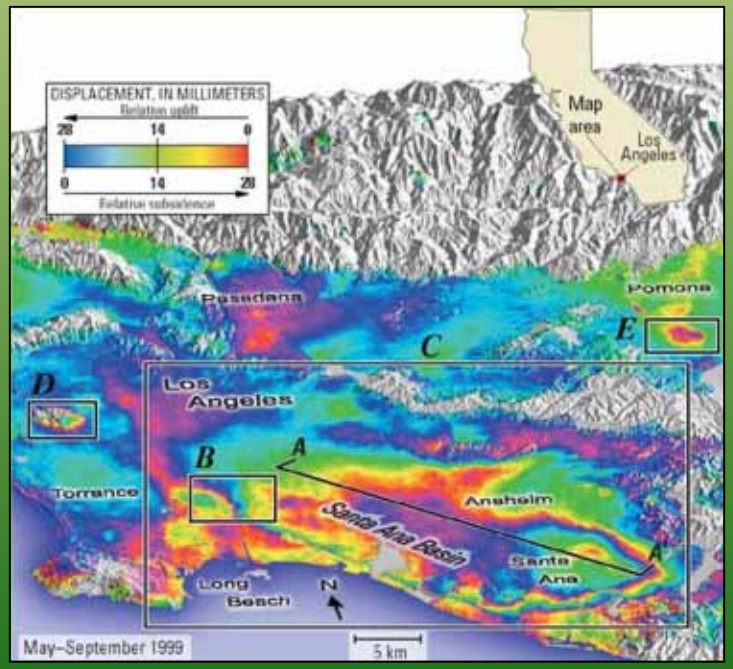
The Copenhagen Diagnosis, 2009

- **1.8 to 5.5 m of SLR by 2500 using latest IPCC Models (2013)**
- **Sea level will rise for several centuries after stabilization (Jevrejeva et al., 2011)**

Coastal Vulnerability Considerations

- Global factors:
  - Eustatic sea level
- Regional factors:
  - Ocean circulation patterns
  - Storminess
  - Tectonics (large-scale)
- Local factors:
  - Subsidence
  - Local tectonic deformation
  - Fluvial discharge AND sediment supply changes
  - Development and restoration
- Seasonal and storm impacts:
  - Steric effects
  - Waves and storm surge
  - River discharge

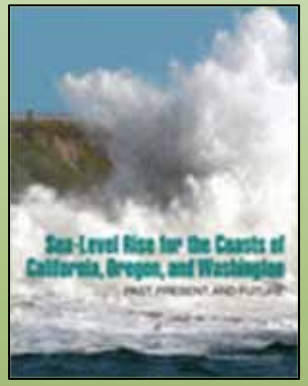
Shore and Beach (1989)



Bowden et al. (2001)

Projections for Southern California

http://www.nap.edu/catalog.php?record_id=13389



SLR for Los Angeles (NRC, 2012)

-28 cm of sea level rise by 2050 (range 13-61 cm)
-93 cm of sea level rise by 2100 (range 44-167 cm)
-includes global and regional effects (e.g., wind and circulation patterns, sea level fingerprint, glacial isostatic adjustment, tectonics)

Storms for Southern California (Bromirski et al., 2012; USGS)

-No significant changes in wave climate
-Extreme events approach from ~5-10 degrees further south

Coastal Impact of Projected Climate Trends

- Accelerated beach erosion rates
- Greater incidence of cliff failures
- Landward translation of coastal flooding and inundation
- More dangerous navigation conditions
- Beach/shore safety more often compromised

L.A. City Lifeguards

L.A. City Lifeguards

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What is the problem?

- 480,000 people and $100 billion in property are at risk of flooding along the California coast over the next century (*Pacific Institute Report*)

- California beaches support 883,000 jobs and contribute $73 billion to the national economy (*King, 1999*)

- 1982-83 El Niño storms caused more than $200 million in damage to California

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Southern California Vulnerability

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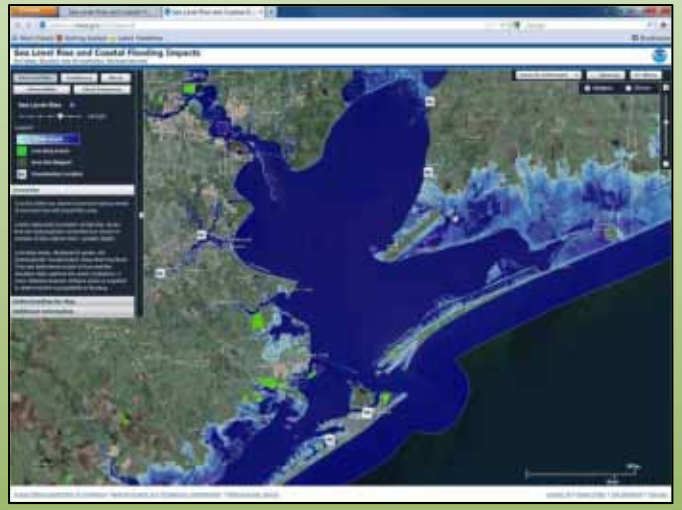
Critical Infrastructure

Coastal Vulnerability Efforts

- NOAA SLR Viewer (static)
  - Passive model, hydrological connectivity
  - Tides only (MHHW)
  - Excellent elevation data, datum control
  - Wetland migration model, socioeconomic impacts
  - '1st order screening tool'



http://www.csc.noaa.gov/digitalcoast/tools/slrviewer

- CoSMoS (dynamic)
  - GCM ensemble forcing
  - Includes wind, waves, sediment transport, fluvial discharge, and vertical land movement rates
  - Range of SLR and storm scenarios
  - Flooding extent explicitly modeled, hydrological connectivity

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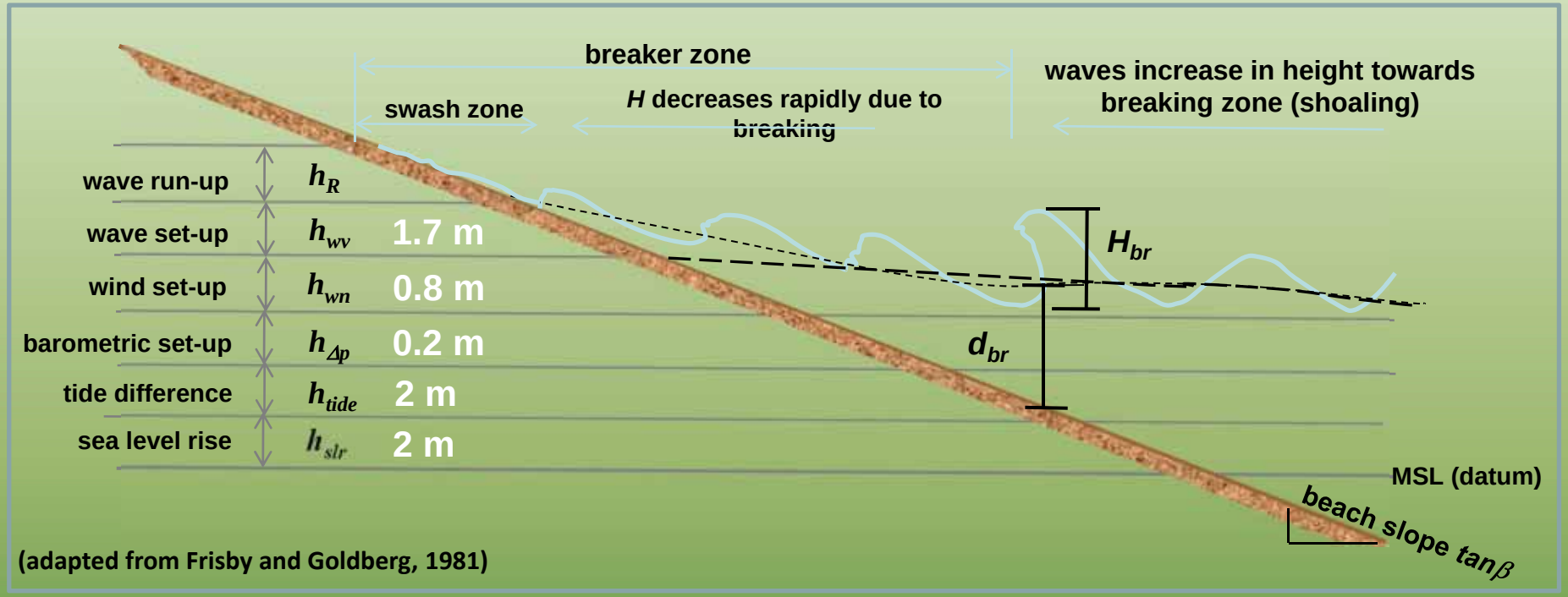
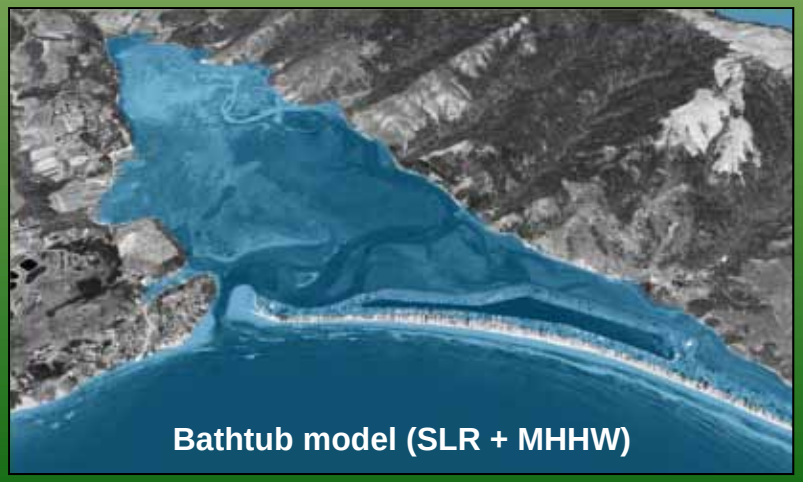
Components of Total Water Level Predictions



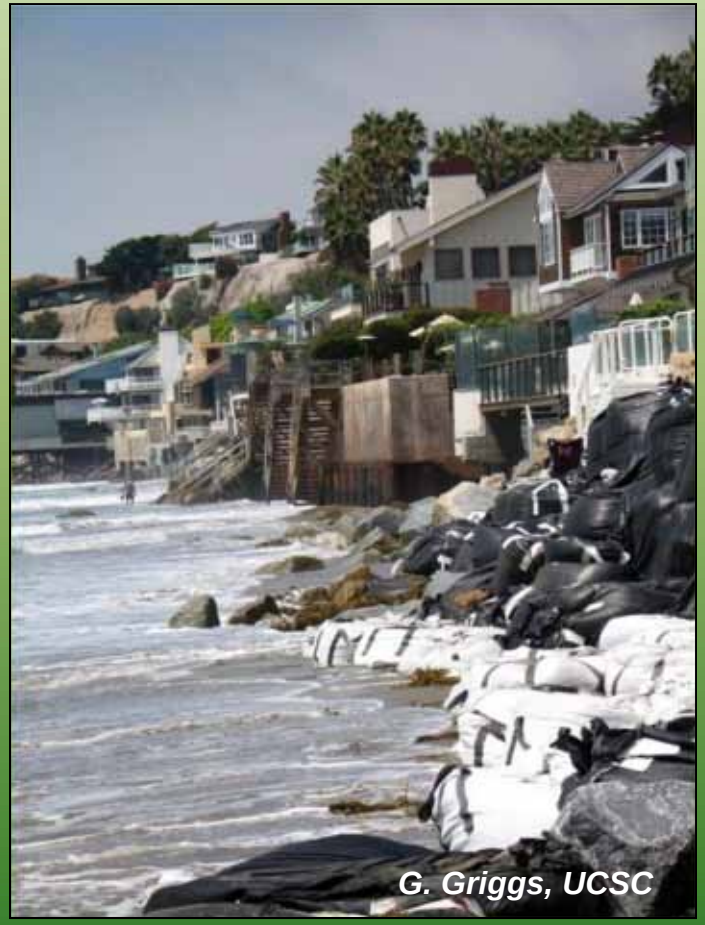
(adapted from Frisby and Goldberg, 1981)

Bolinas Lagoon



CoSMoS: A Tool for Coastal Resilience

- Physics-based numerical modeling system for assessing coastal hazards on West Coast
- Predicts coastal hazards for the full range of sea level rise and storm possibilities using the most sophisticated global climate and ocean modeling tools
- Developing coastal vulnerability tools with guidance from federal (e.g., NOAA, NPS), state (e.g., California State Parks), and city governments (City of San Diego, L.A., and San Francisco) to meet their planning and adaptation needs



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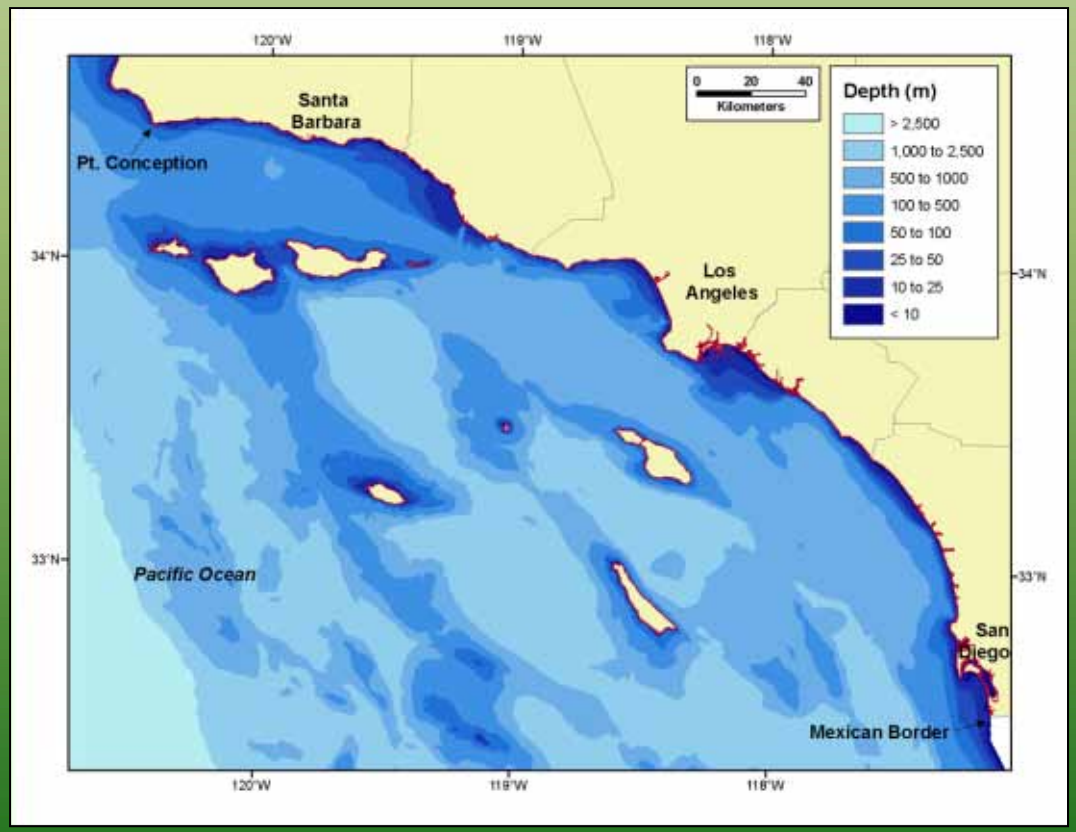
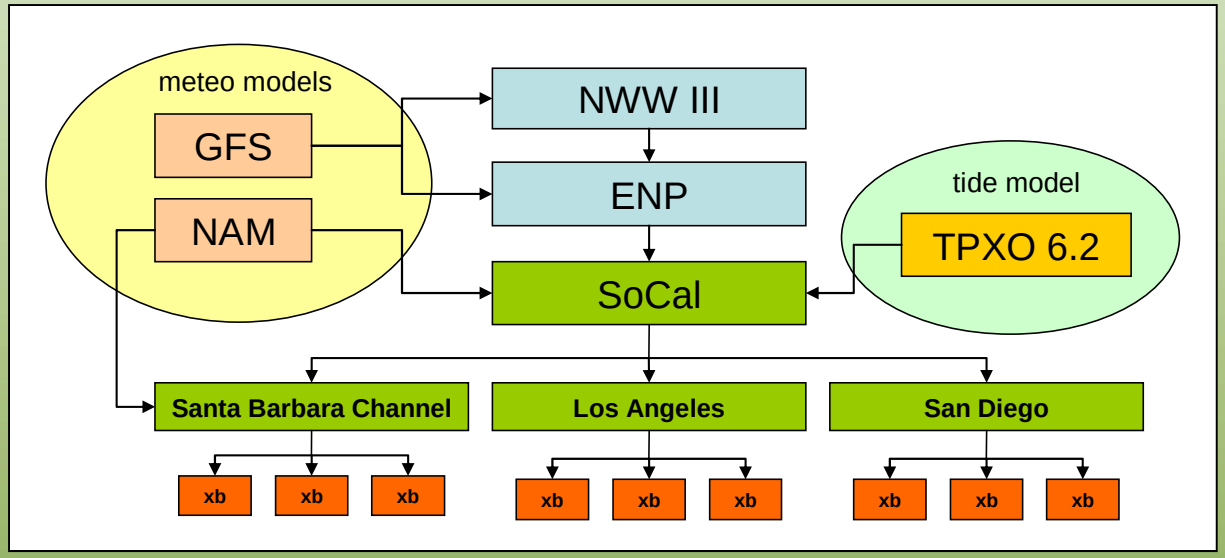
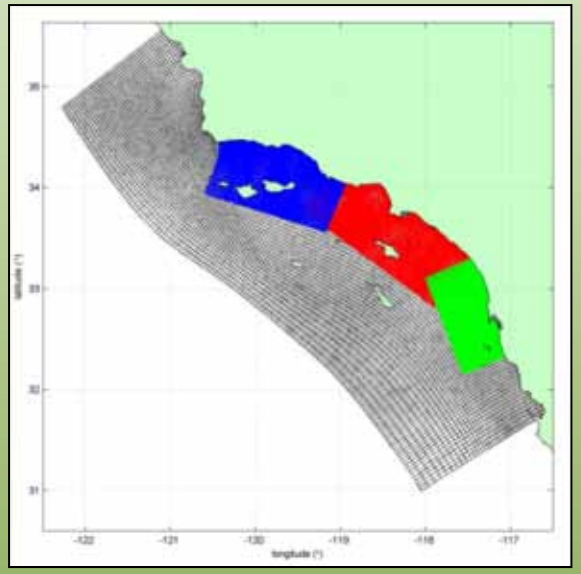
CoSMoS Version 1.0- SoCal

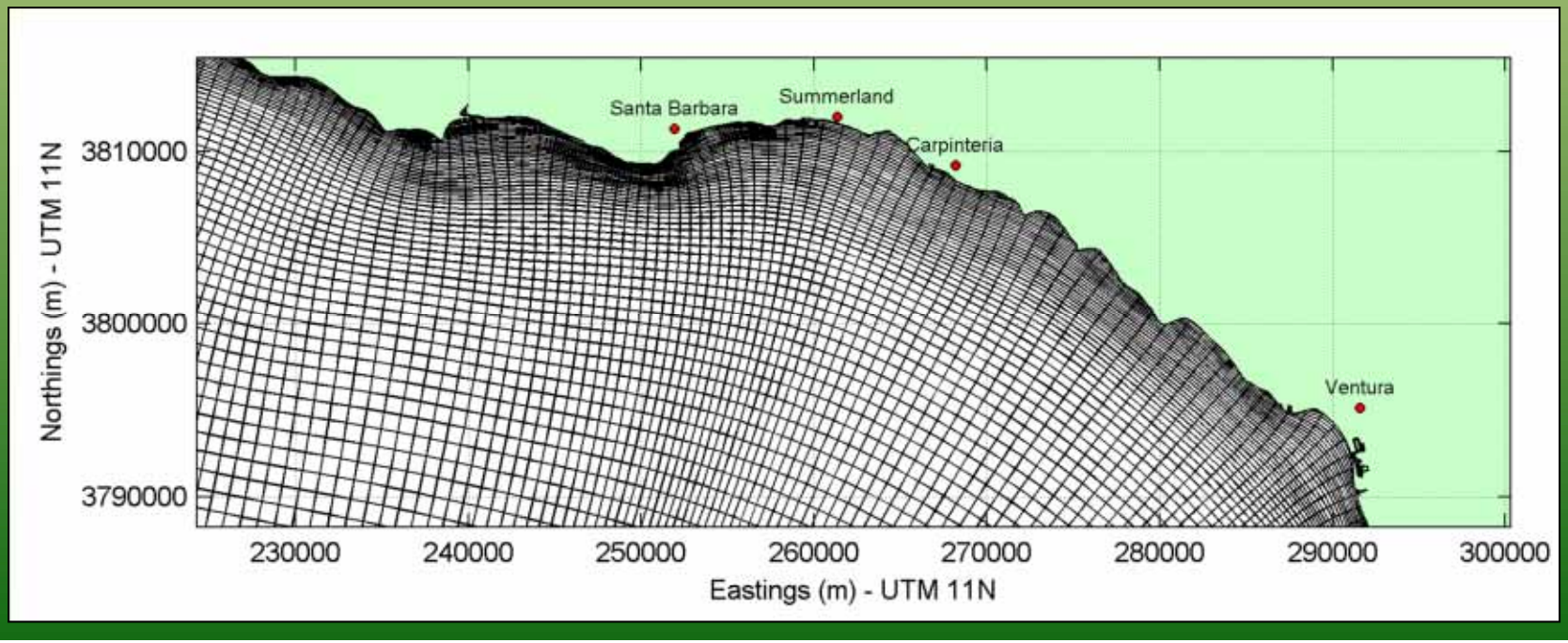
- **Limited set of scenarios**
  - **January 2010 hindcast**
  - **January 2010 hindcast + 50 and 100 yr SLR per Rahmstorf (2007)**



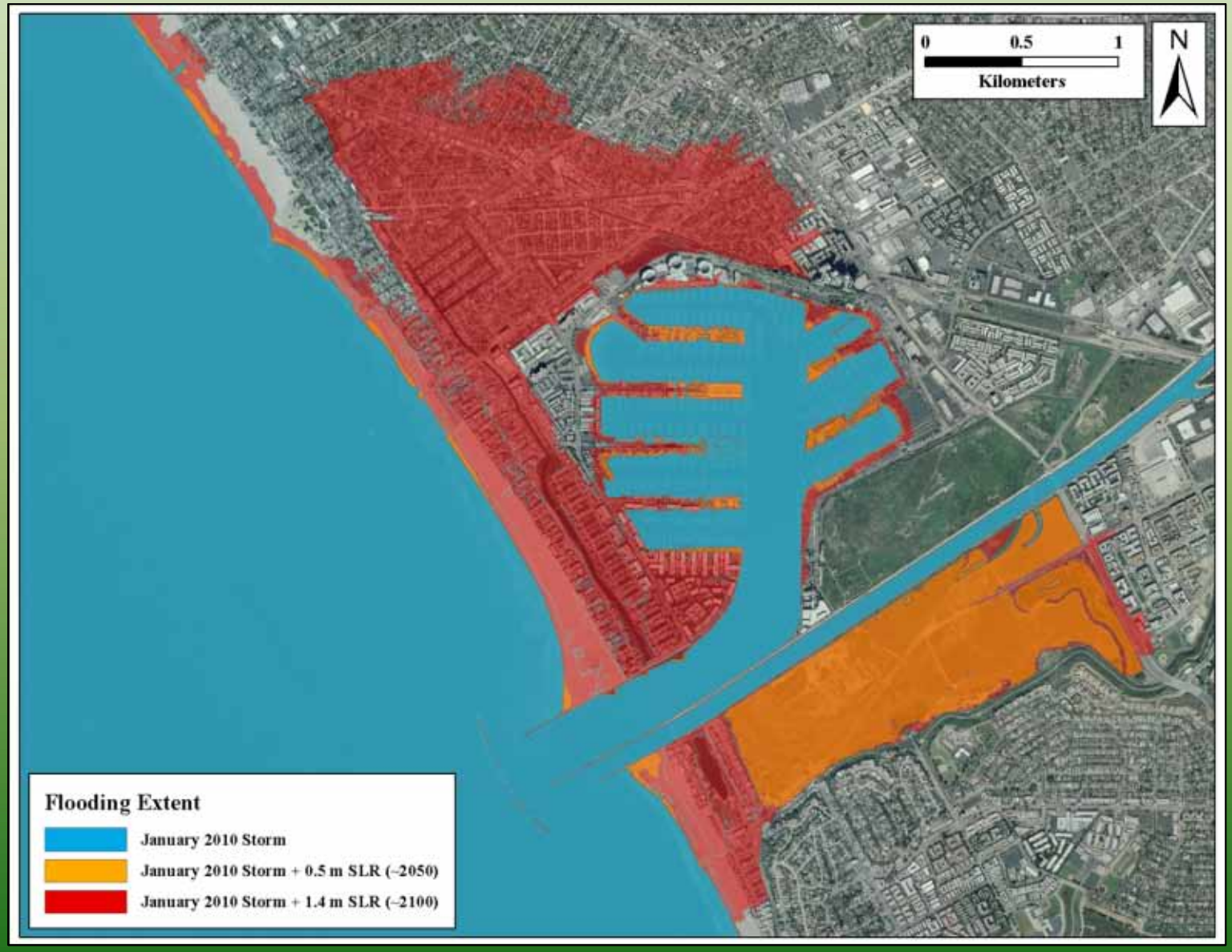
Dynamic Model Grids



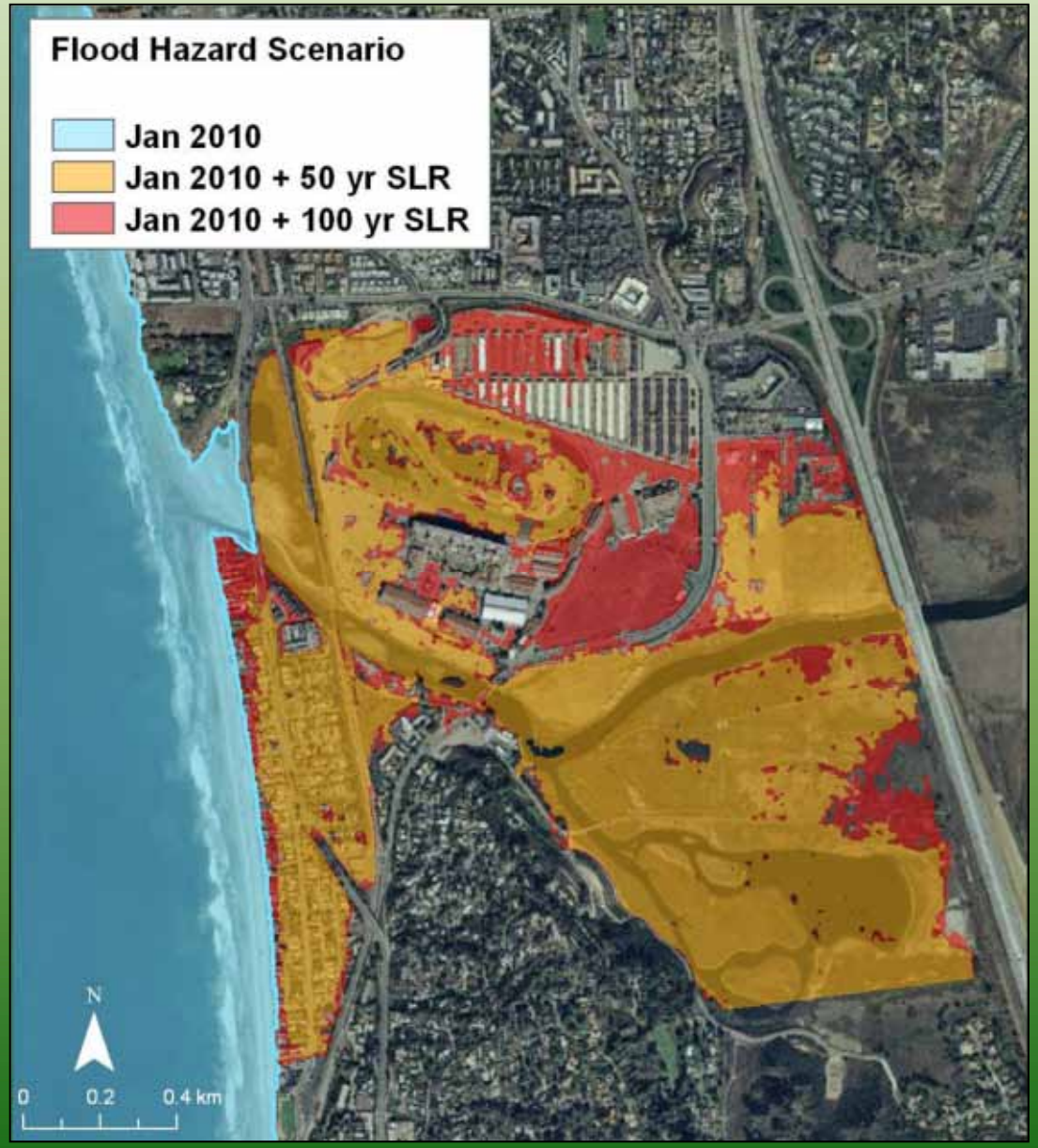




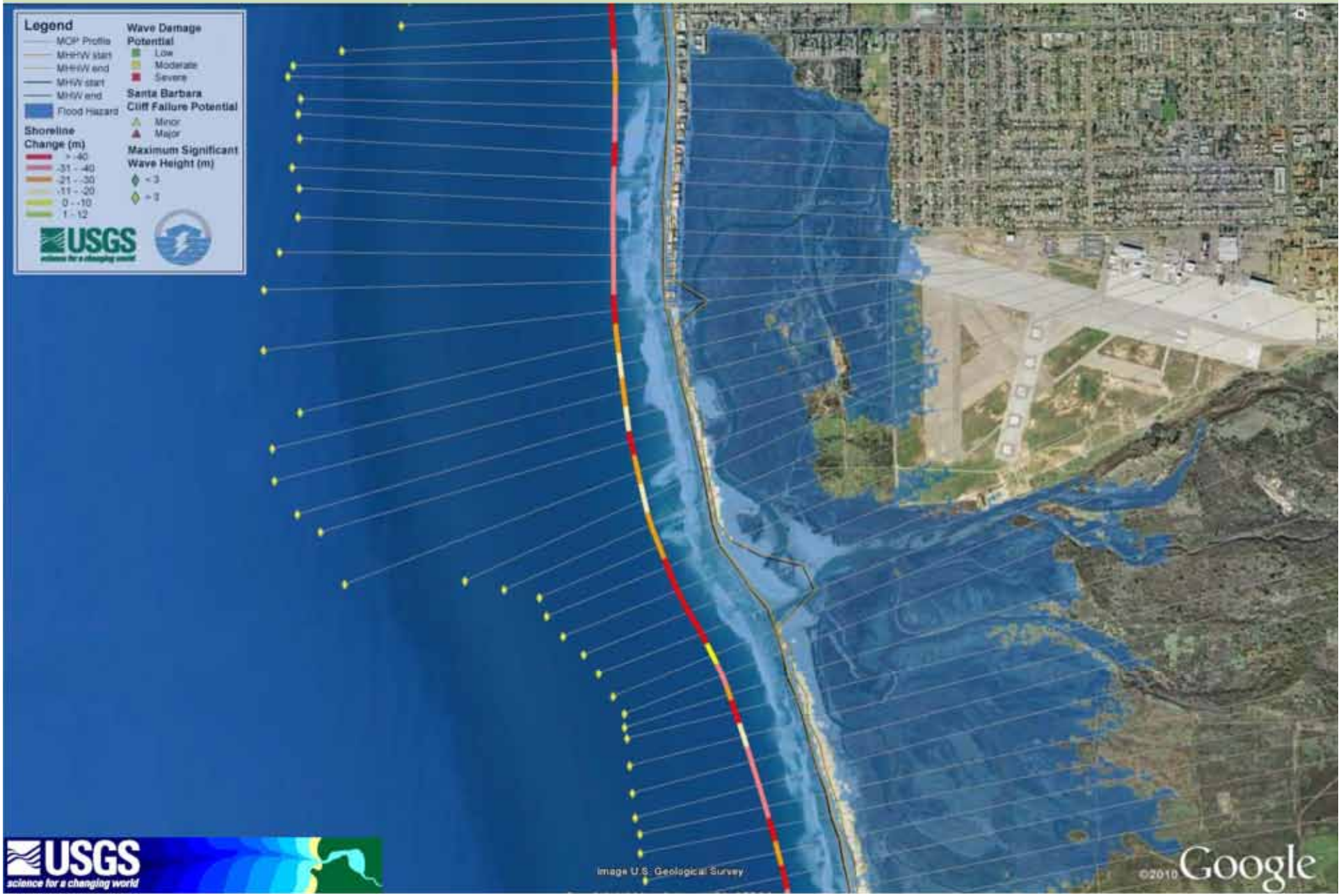
Marina Del Rey/Venice



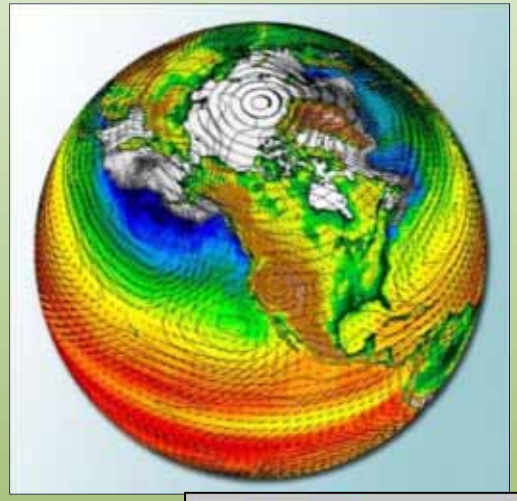
Del Mar


Flood Hazard Scenario
Jan 2010
Jan 2010 + 50 yr SLR
Jan 2010 + 100 yr SLR
N
0
0.2
0.4 km

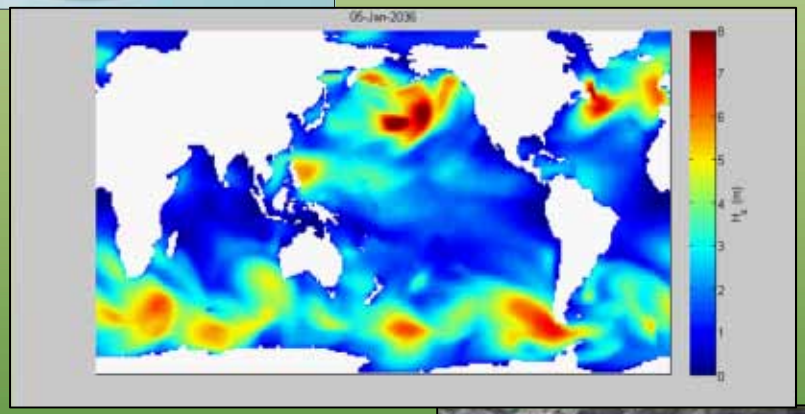
Imperial Beach



Identifying Future Risk with CoSMoS 2.0



1. Global forcing using the latest climate models



2. Drives global and regional wave models

3. Scaled down to local hazards projections

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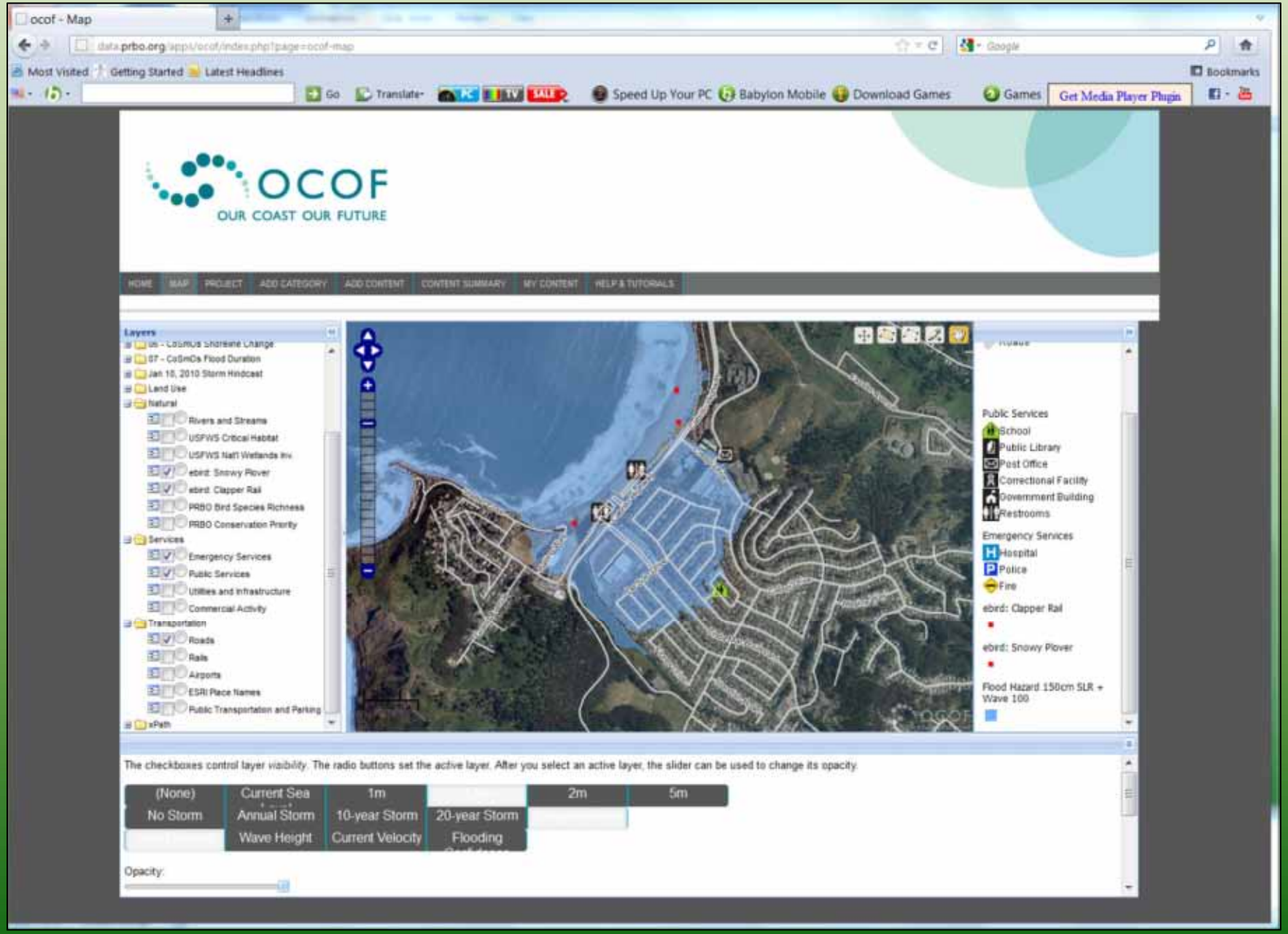
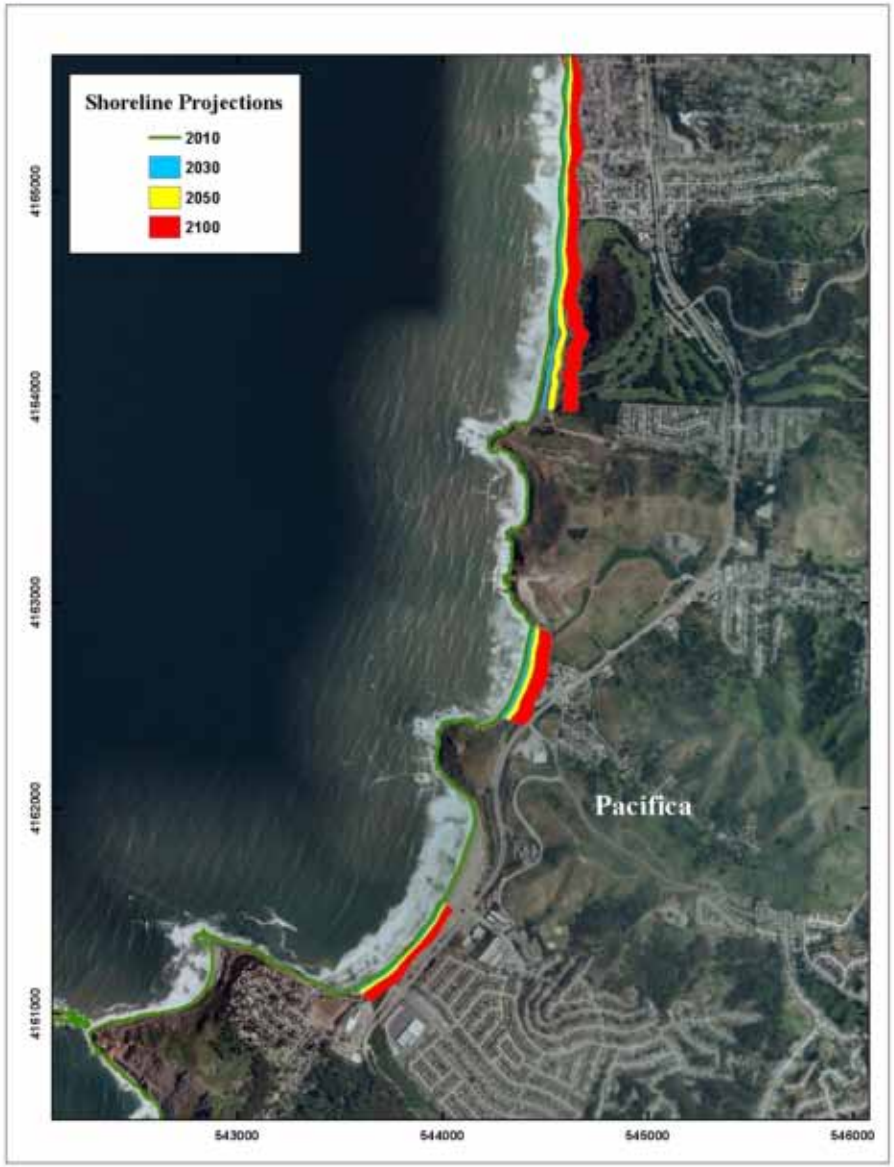
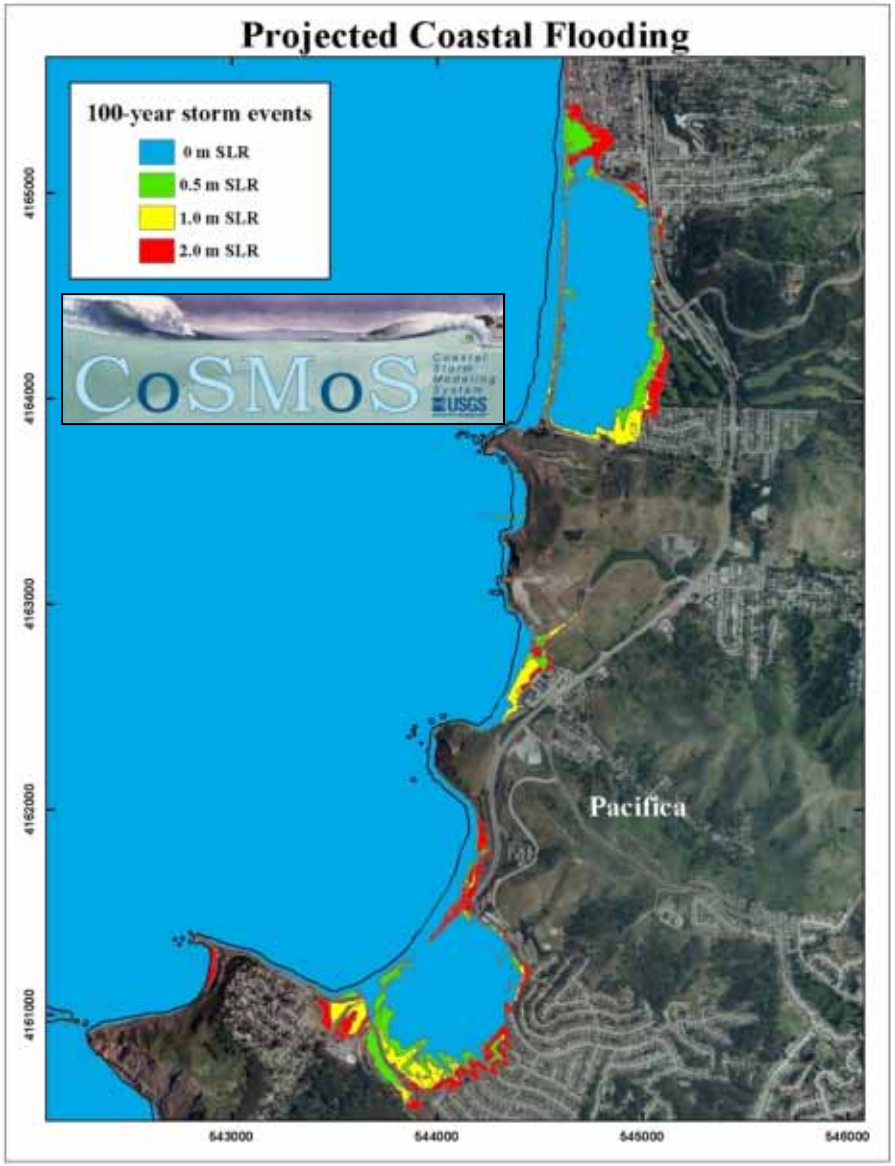
Online Tool


ocof - Map
OCOF
OUR COAST OUR FUTURE
HOME
MAP
PROJECT
ADD CATEGORY
ADD CONTENT
CONTENT SUMMARY
MY CONTENT
HELP & TUTORIALS
Layers
Land Use
Natural
Rivers and Streams
USFWS Critical Habitat
ebird: Snowy Plover
ebird: Clapper Rail
PRBO Bird Species Richness
PRBO Conservation Priority
Services
Emergency Services
Public Services
Utilities and Infrastructure
Commercial Activity
Transportation
Roads
Rails
Airports
ESRI Place Names
Public Transportation and Parking
Public Services
School
Public Library
Post Office
Correctional Facility
Government Building
Restrooms
Emergency Services
Hospital
Police
Fire
ebird: Clapper Rail
ebird: Snowy Plover
Flood Hazard 150cm SLR + Wave 100
The checkboxes control layer visibility. The radio buttons set the active layer. After you select an active layer, the slider can be used to change its opacity.
(None)
No Storm
Current Sea
Annual Storm
Wave Height
1m
10-year Storm
Current Velocity
20-year Storm
Flooding
2m
5m
Opacity:

Future Vulnerability





CoSMoS - The Path Forward

- Pilot project for Southern California (Pt. Conception to Mexico) completed- kmz files are available showing flooding extent
- Supporting the AdaptLA climate change assessment
- North-central coast will be completed and tool available this year
- New Southern California project proposed for 2013-2015
- Available as a real-time warning system for emergency managers, lifeline operators, and resource managers
- Internal project at USGS drives ongoing research and development of this modeling system

For more information, contact Patrick Barnard: pbarnard@usgs.gov

http://walrus.wr.usgs.gov/coastal_processes/socalhazards

http://cosmos.deltares.nl/SoCalCoastalHazards/index.html

USGS science for a changing world

CoSMoS USGS science for a changing world