

Projecting 21st Century Coastal Vulnerability for Southern California Using the Coastal Storm Modeling System (CoSMoS)

Patrick Barnard

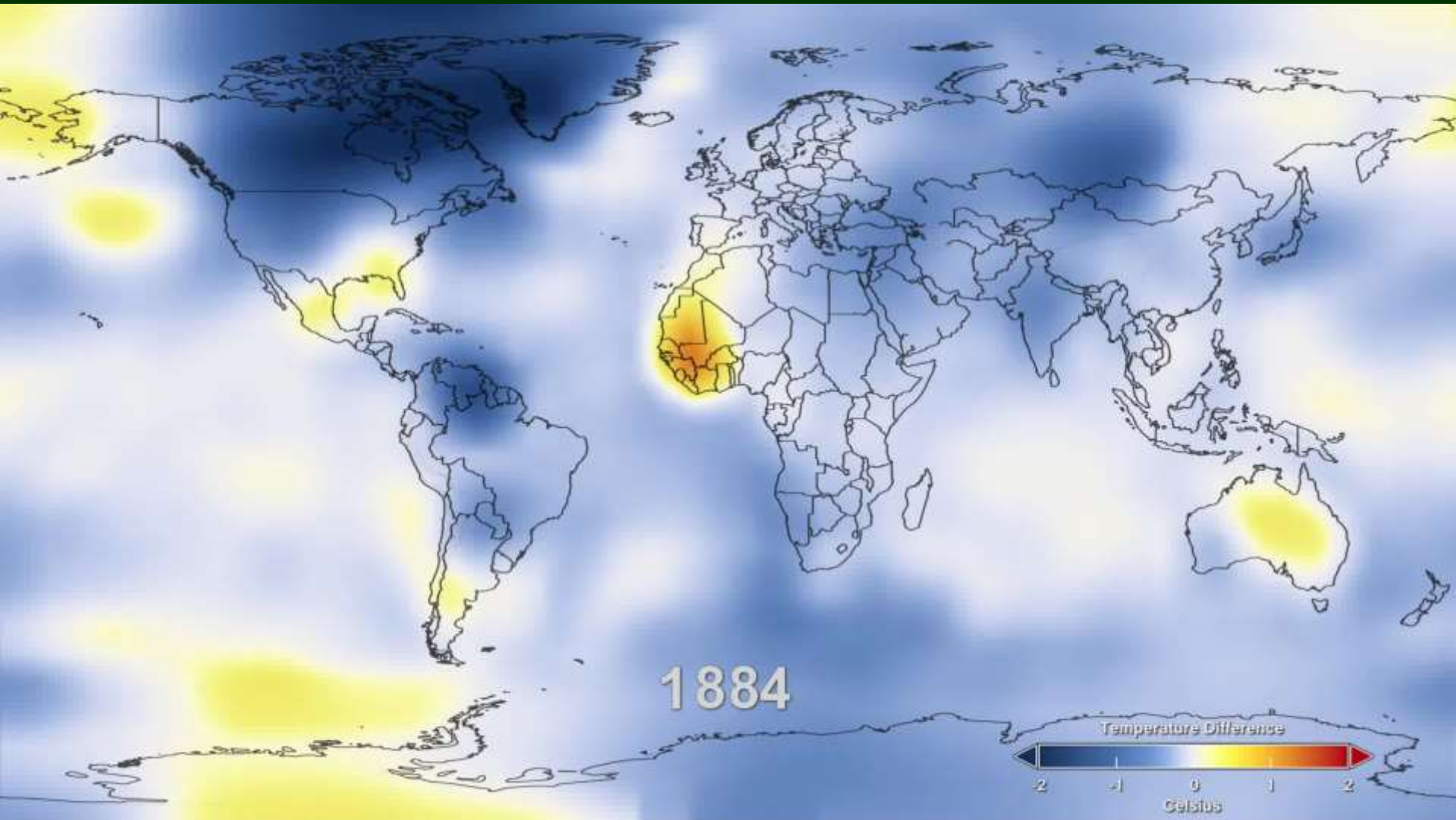
USGS Coastal and Marine Geology Program
Pacific Coastal and Marine Science Center, Santa Cruz, CA

U.S. Department of the Interior
U.S. Geological Survey



CAUTION

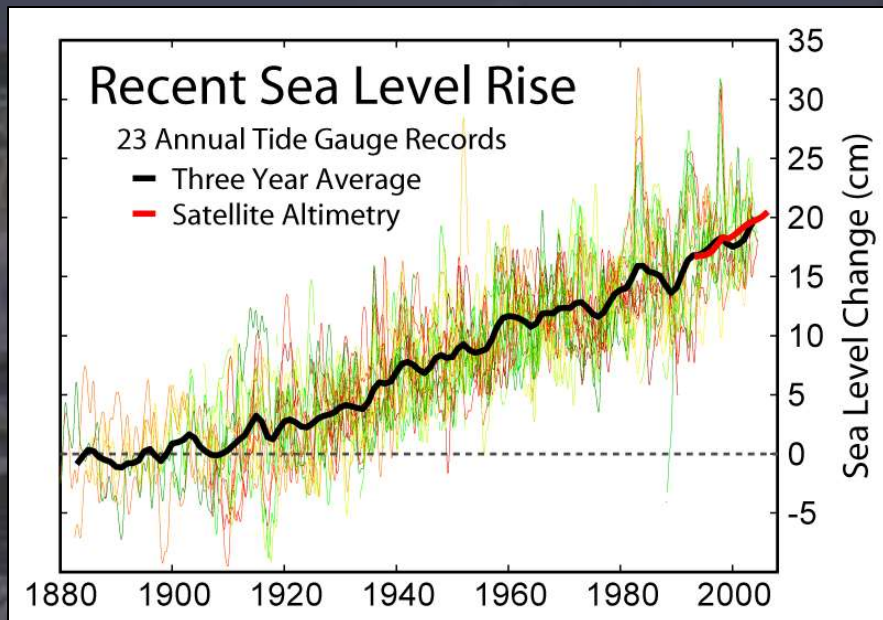
Temperature Change



NASA Goddard Institute for Space Studies

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

Recent Sea Level Rise

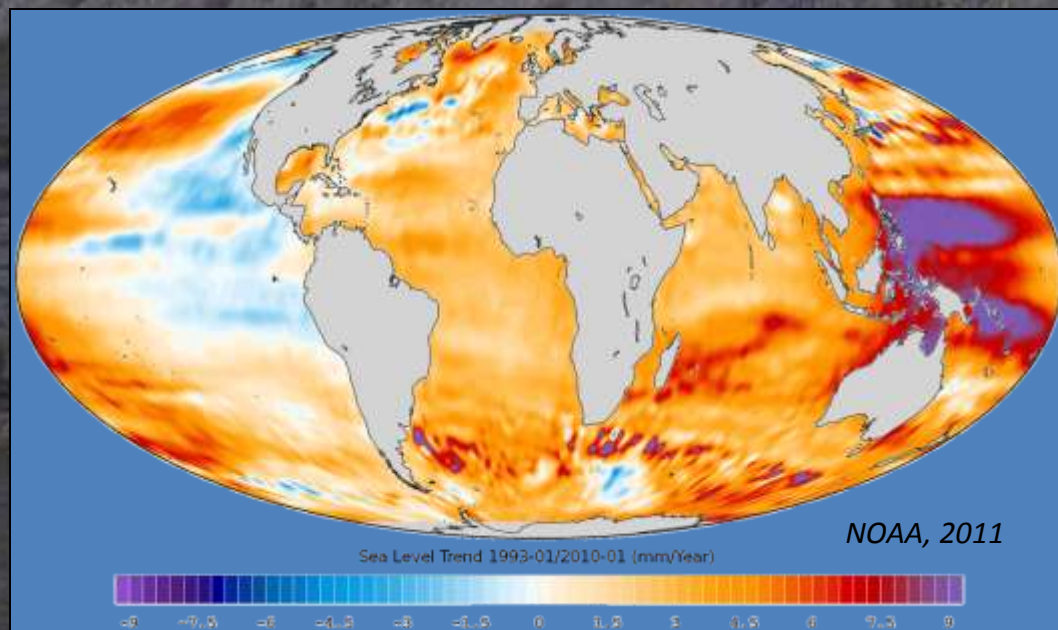


Global SLR is accelerating:

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

Regional factors:

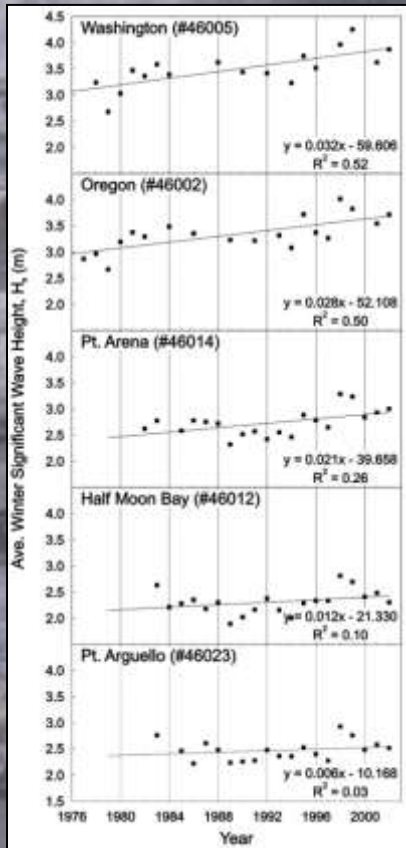
- The global sea level rise signal is NOT spatially uniform due to variations in:
 - prevailing wind and ocean circulation patterns
 - ocean temperature and salinity ('steric effect')
 - gravitational forces ('glacial fingerprinting')



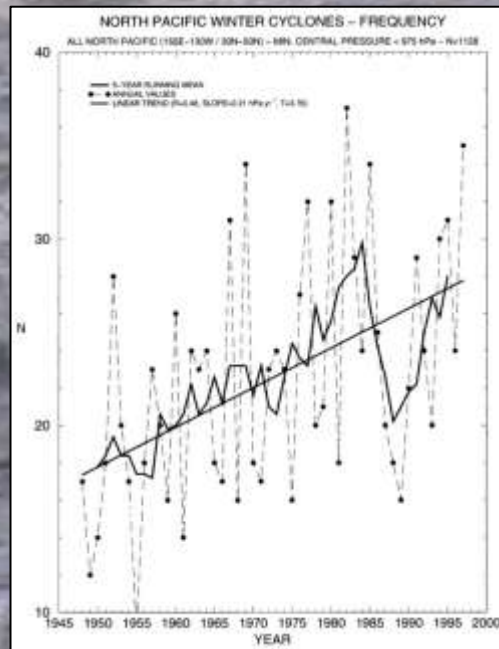
Recent Findings- Storms

- Storms and average winter and extreme waves are getting larger and more frequent for much of U.S. West Coast

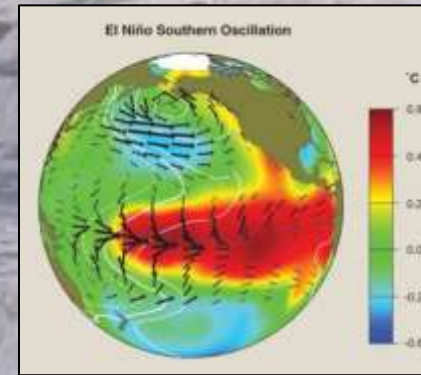
- No evidence for changes in the strength or frequency of El Niños over last ~150 years (Ray and Giese, 2012) but perhaps a shift in styles



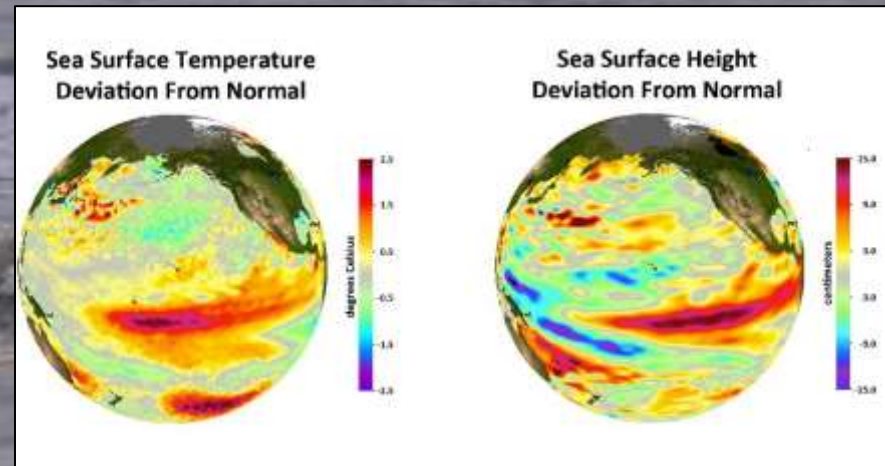
Allan and Komar (2006)



Graham and Diaz (2001)



McPhaden et al. (2006)



Lee and McPhaden (2010)

Projections for Southern California

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)

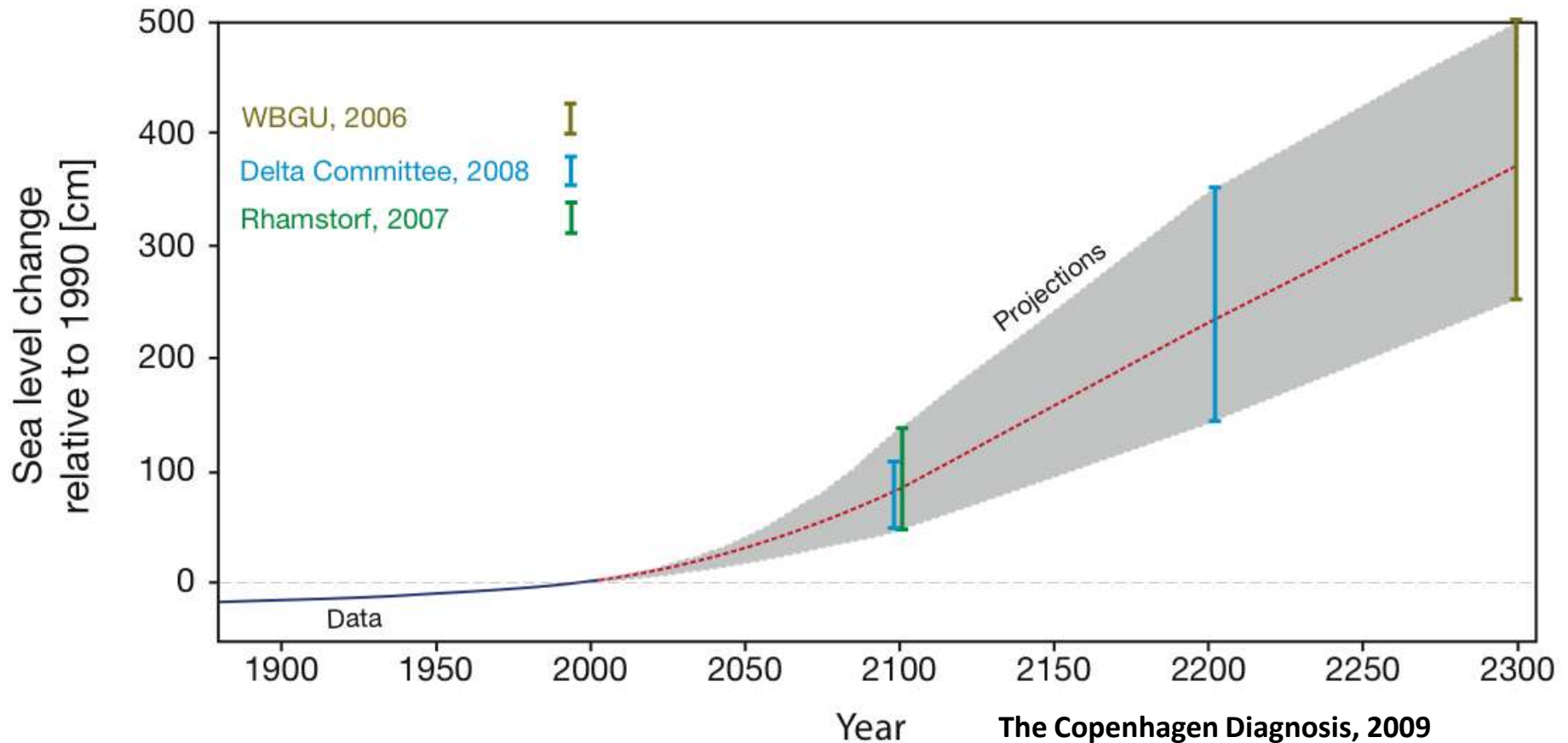


Storms for Southern California (Bromirski et al., 2012; USGS)

- No significant changes in wave height
- Extreme events approach from ~10-15 degrees further south



Sea Level Rise Beyond 2100



- 1.8 to 5.5 m of SLR by 2500 using latest IPCC Models (2013)
- Sea level will rise for several centuries after stabilization

What is the problem?

- Climate change, including sea level rise, changing wave climates, and storms will place additional stresses on coastal systems worldwide
- Coastal flooding from SLR alone could displace ~200 million people by 2100
- Nationally, \$1.4 trillion of coastal property could be at risk at high tide by the end of the century
- Hurricane Sandy caused \$50 billion in damage
- 1982-83 El Niño storms caused more than \$200 million in damage to California
- 500,000 people, one million jobs, and \$100 billion in property are threatened by climate change along the California coast over the next century
- In San Diego County: 10,000 people and \$2 billion in property at risk (not inclu. river discharge, waves, coastal change, changes in storms, etc.)



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
- Saltwater intrusion into coastal aquifers



Southern California Vulnerability



Critical Infrastructure



Coastal Vulnerability Considerations

- **Global factors:**

- Eustatic sea level

- **Regional factors:**

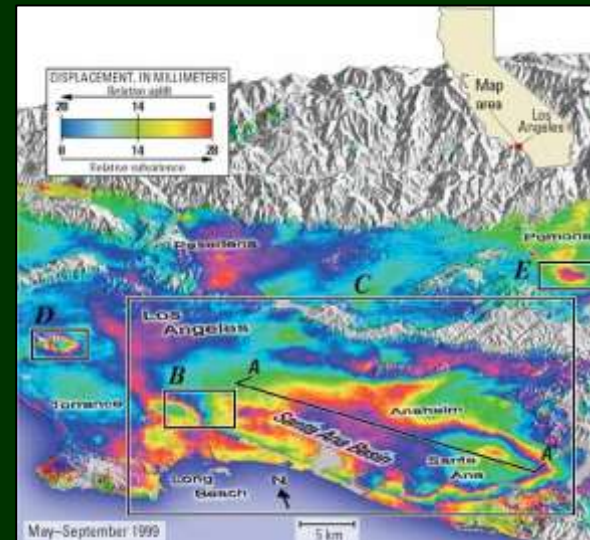
- Ocean circulation patterns
- Glacial fingerprinting
- Tectonics (large-scale)
- Isostasy

- **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



Coastal Vulnerability Approaches

- **STATIC**: NOAA SLR Viewer

- Passive model, hydrological connectivity
- Tides only (MHHW)
- Excellent elevation data, datum control
- Wetland migration model, socioeconomic impacts
- ‘1st order screening tool’



<http://www.coast.noaa.gov/slr/>

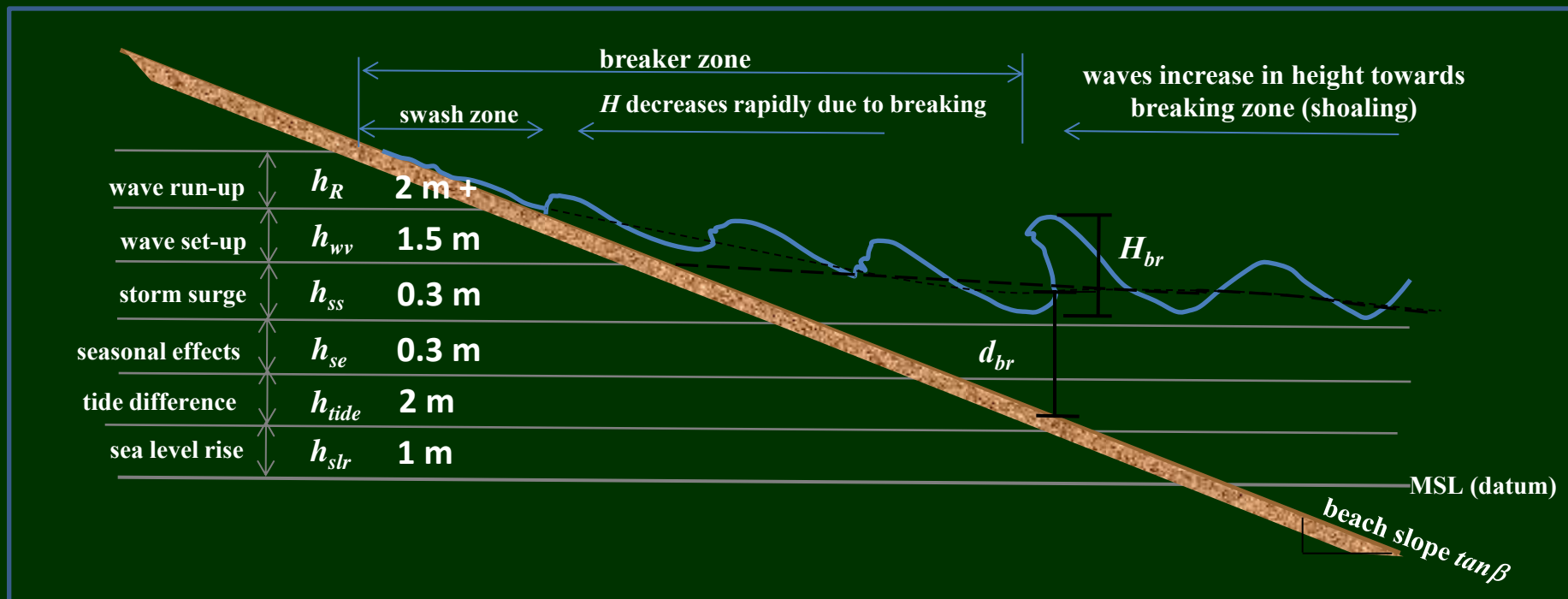
- **DYNAMIC**: CoSMoS

- 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



Our Coast Our Future: www.prbo.org/ocof

Components of Total Water Level Predictions



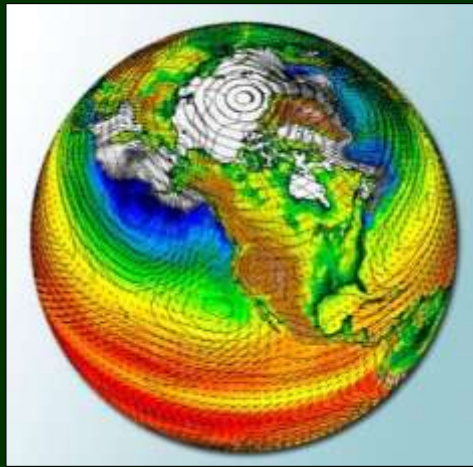
Stinson Beach
50 cm SLR



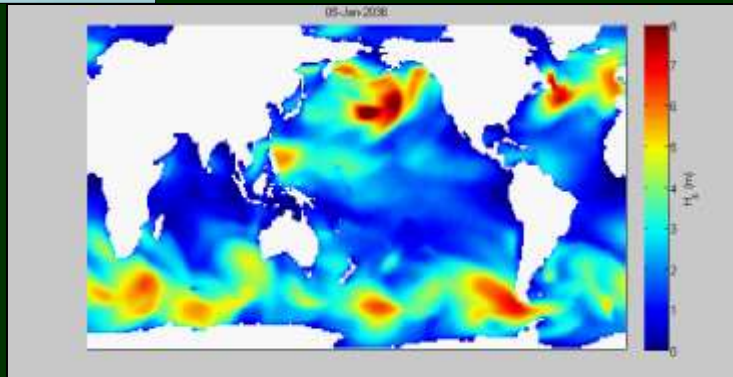
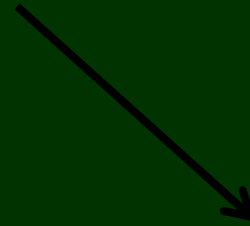
What makes CoSMoS unique?

- **Explicit, deterministic modeling of all the relevant physics of a coastal storm using the most sophisticated global climate and ocean modeling tools**
- **Waves are modeled at the global scale forced from the most sophisticated Global Climate Models (GCMs) developed for IPCC 2013, and then dynamically downscaled, along with regional additions of wind, atmospheric pressure, tides and sea level rise, to produce hazards projections at the parcel scale**
- **Scenarios feature the full spectrum of SLR rise (0-2 m, 5 m) and coastal storms (daily-100 year return) to meet every possible planning horizon**
- **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**

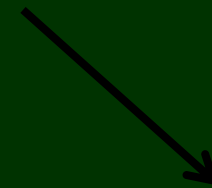
Identifying Future Risk with CoSMoS



1. Global forcing using the latest climate models



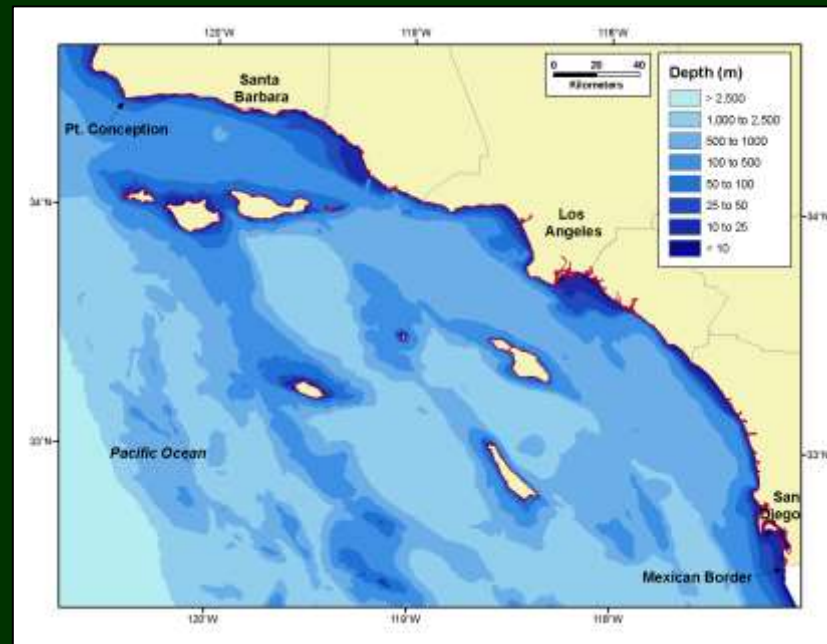
2. Drives global and regional wind/wave models



3. Scaled down to local hazards projections

CoSMoS Version 1.0- SoCal

- Outer coast focus- protected bays not modeled
- Flooding based on maximum wave run-up
- Limited set of scenarios
 - ArKStorm
 - January 2010 hindcast
 - January 2010 hindcast + 50 and 100 yr SLR per Rahmstorf (2007)



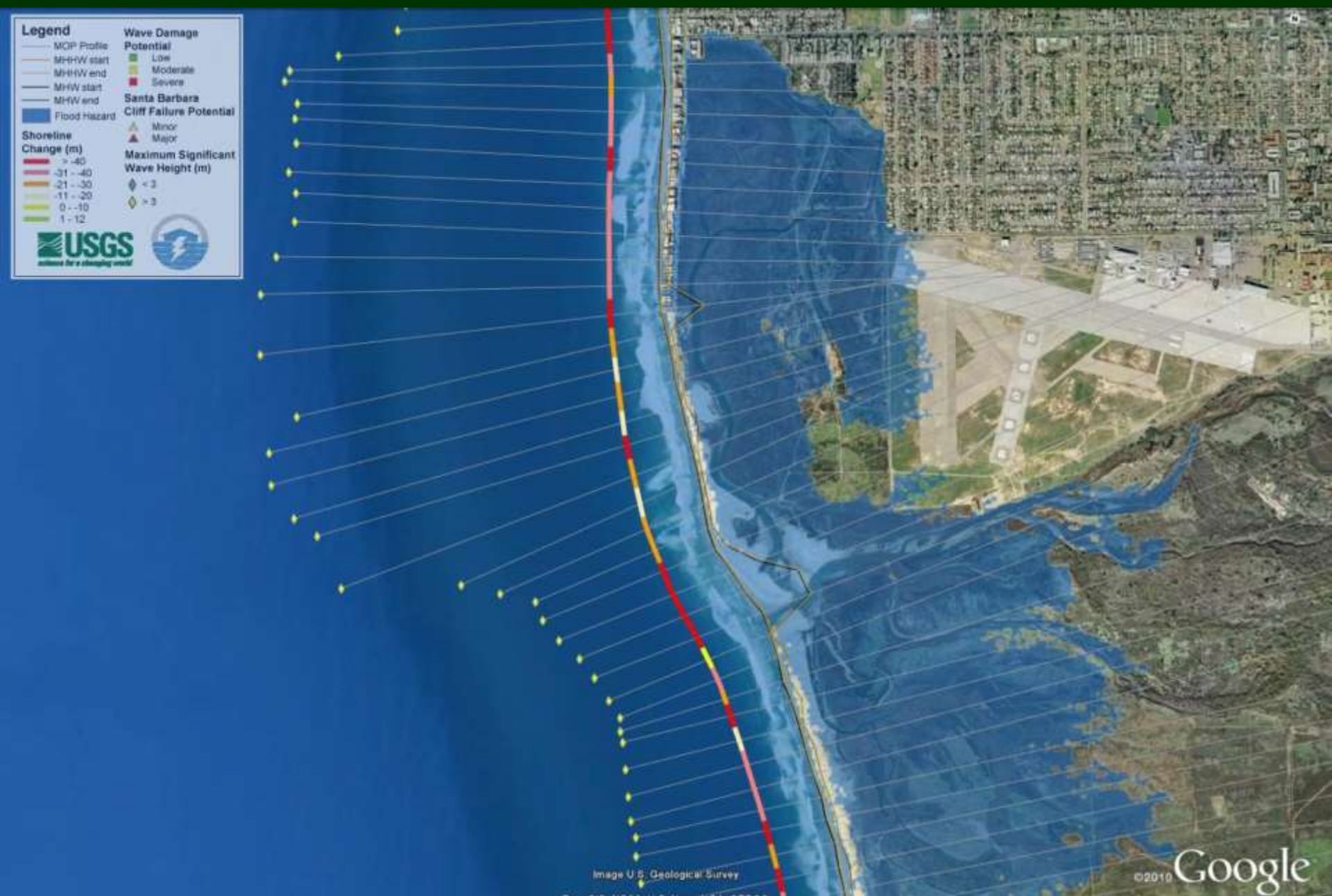
Del Mar



Mission Bay



Imperial Beach



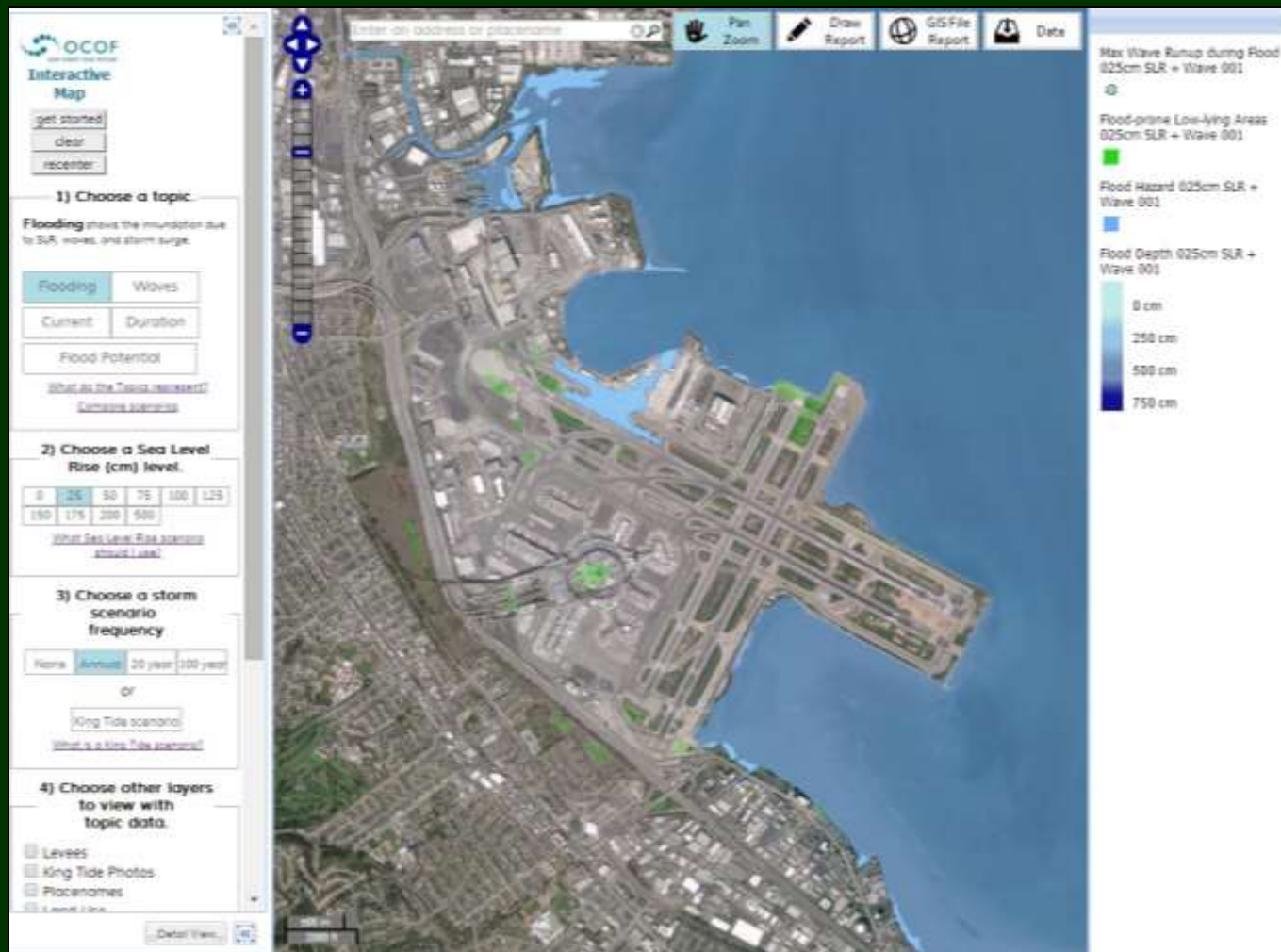
CoSMoS 2.1- SF Bay

- In-bay generated waves and outer coast swell penetration
- River discharge, incl. 21st century delta discharge projections
- Hydrological connectivity
- Levees (100s of kms)
- Vertical land motion, incl. projections of tidal marsh accretion and land uplift/subsidence

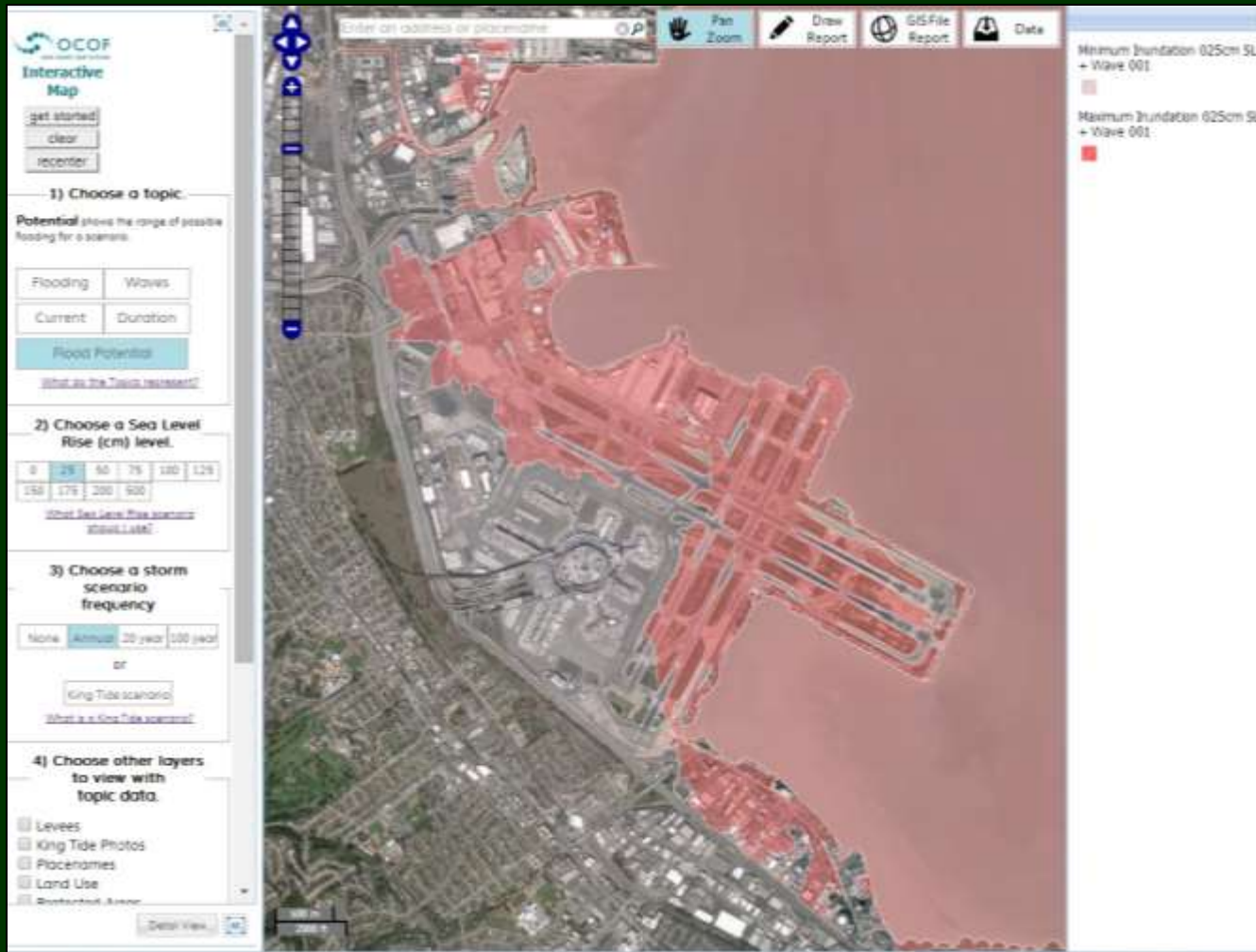


Study Area

CoSMoS 2.1- SF Bay



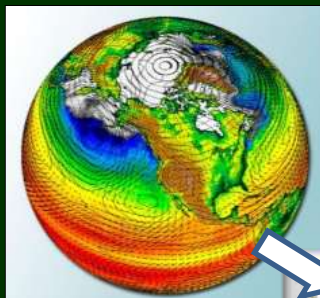
Uncertainty



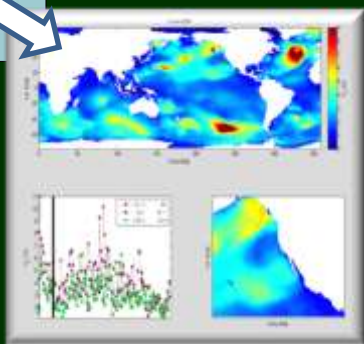
CoSMoS 3.0 Southern California

Global

Global conditions of future climate scenarios



GCM winds



WW3 wave model

Regional

Tides, water levels, and regional forcing

SWAN wave model



Regionalized storm response



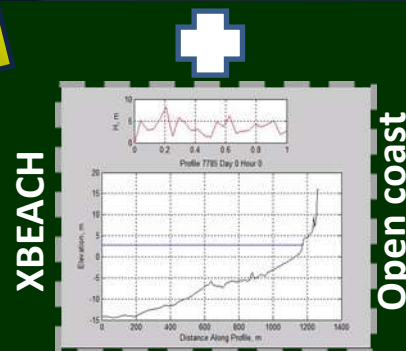
20-year storm return

Local

High resolution hydrodynamics and waves



Delft FLOW-WAVE



Fluvial discharge
VLM
Coastal change

results projected
onto hi-res DEM

USC Sea Grant – The Urban Ocean Program



- Funds research
- Community outreach & education
- Technical assistance to local/regional government

10 Million by the Sea...

- Climate Change Science & Planning
- Coastal Ecosystem Science
- Coastal Management
- Maritime Affairs

Southern California Coastal Impacts Project




- Stakeholder Engagement and Capacity Building
 - SoCal Sub-Regions – Santa Barbara, Ventura, L.A., O.C. & San Diego
 - Initial Process Workshops
 - Webinar series (2015 until model results are available)
 - Technical Outreach Workshop (Summer 2016)



Southern California Coastal Impacts Project


- San Diego Workshop – held on Oct. 30, 2014
 - Presentations & info available here:
<http://dornsife.usc.edu/uscseagrantsandiego-workshop/>
- Upcoming Webinar – Beach Dynamics & Processes
 - March 17, 2015 - 11am – 12pm
 - Presenters Dr. Ron Flick (SIO) and Dr. Karen Martin (Pepperdine)
 - Register: <http://adaptlawebinar-beaches.eventbrite.com/>



Sea Level Rise & Coastal Impacts
Professional Development Webinar Series

Webinar 2: Why Beaches Matter - Beach Dynamics & Ecology
March 17, 2015 | 11:00 am - 12:00 pm
Register: <http://adaptlawebinar-beaches.eventbrite.com>

As Southern Californians, we highly value the beaches that provide us with our "endless summer" culture. Beach-related tourism is a major economic driver for our coastal counties, with an estimated \$16.5 billion in tourism expenditures in 2012 for L.A. County alone. Beaches also provide a critical first line of defense against sea level rise and coastal storms. Maintaining our beaches maintains our way of life.




Webinar focus:


- Discuss the physical forcings that shape our coastline.
- Learn about the ecology of our beaches and how our actions impact the other organisms who live along the coast.
- Discuss strategies to help maintain our beaches.

Featured Speakers:

- Dr. Reinhard ("Ron") Flick, Scripps Institution of Oceanography
- Dr. Karen Martin, Pepperdine University



USC Sea Grant Website: dornsife.usc.edu/uscseagrants/adapta-webinars



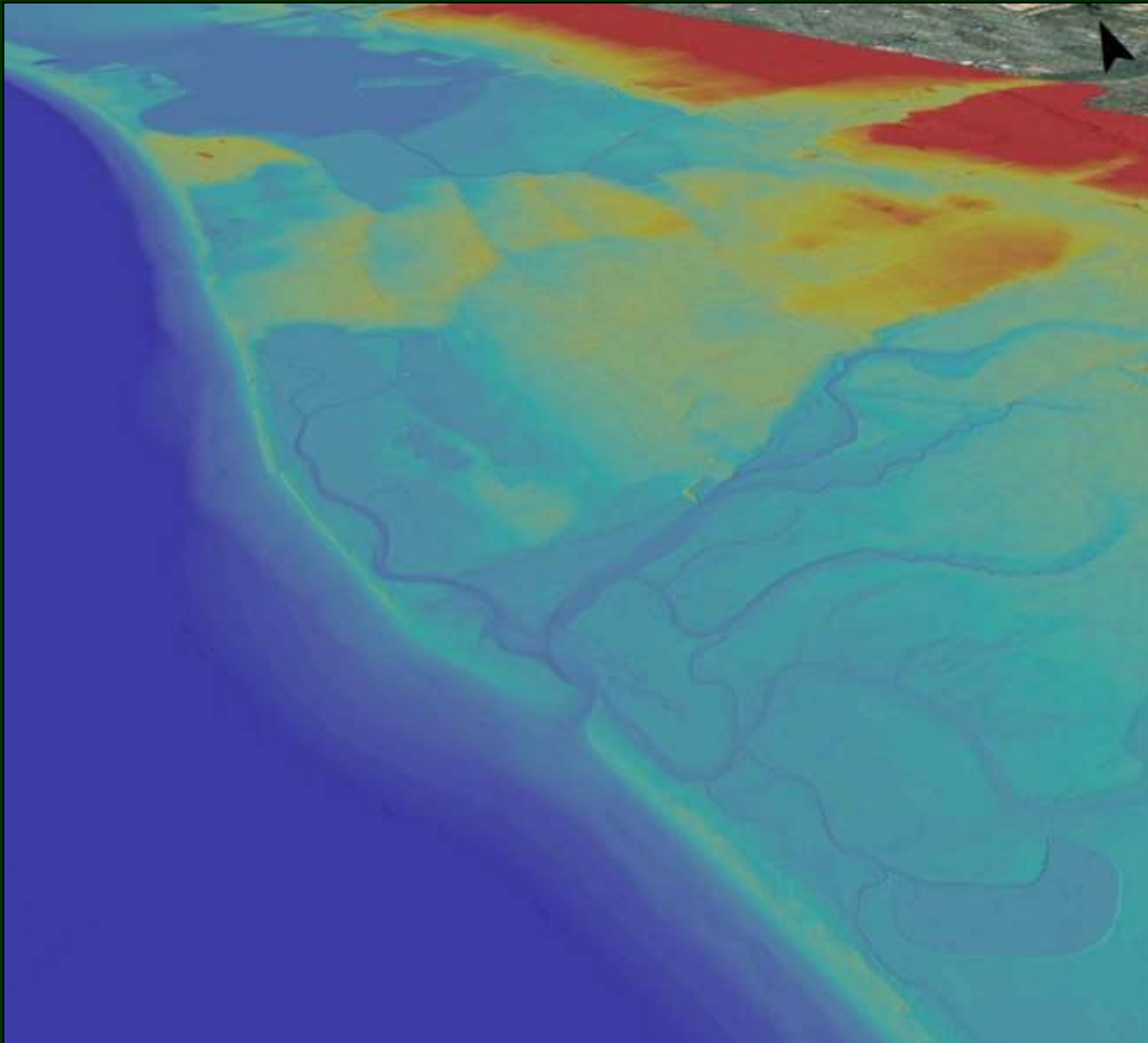
Southern California Coastal Impacts Project

- City of Imperial Beach SLR Adaptation Planning Study
 - Revell Coastal – lead consultant; USC SG and Tijuana River NERR providing support
 - Utilizing “adaptive management” approach

- For more information on SCCIP
 - Juliette Finzi Hart
jahart@usc.edu
424.241.2457



Digital Elevation Model (DEM)

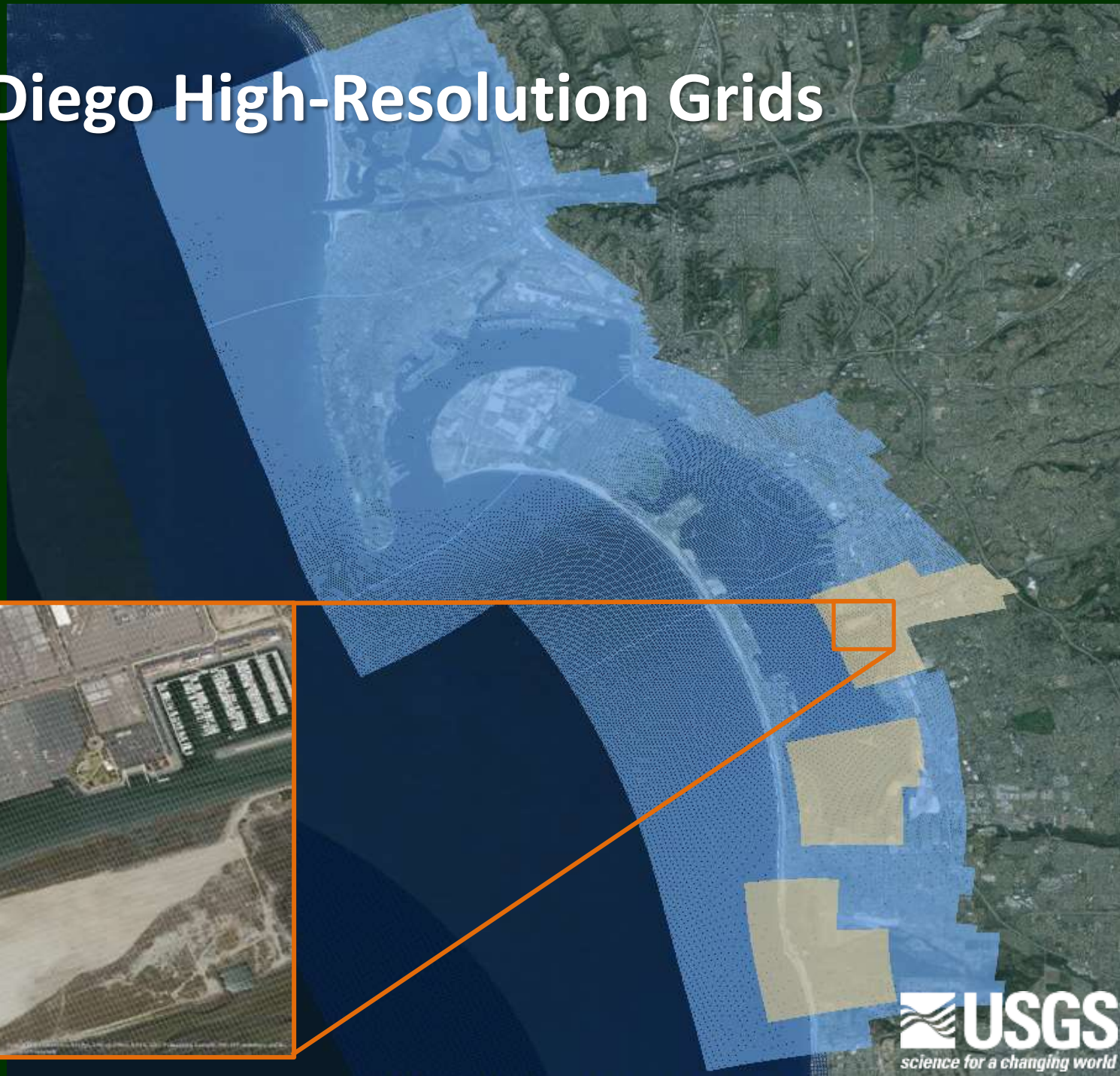


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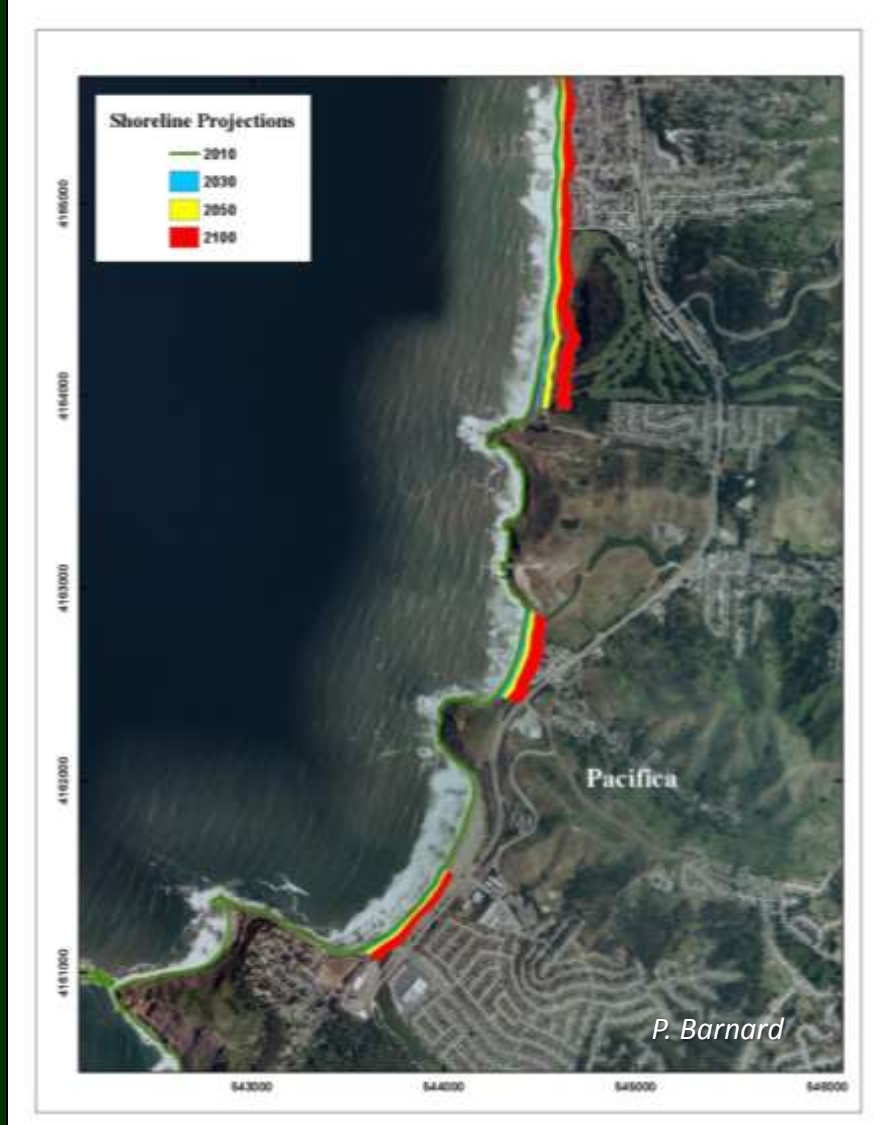
Scripps



San Diego High-Resolution Grids



Future Shoreline Change

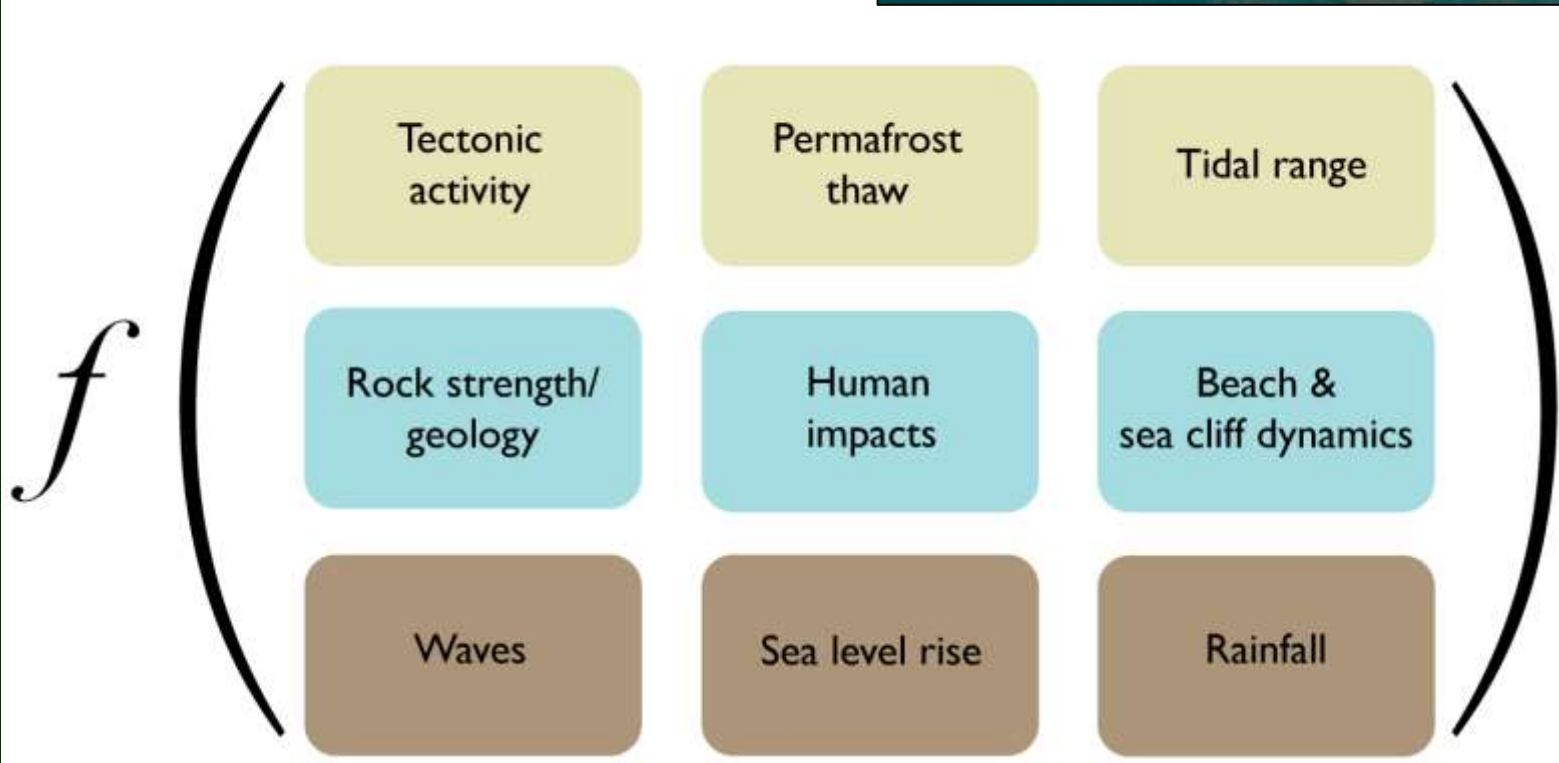


- Rising sea level will drive shorelines further inland, increasing physical and economic impacts
- Reduced sediment supply from dams, dredging, shoreline armoring, etc., likely to further exacerbate the problem
- For CoSMoS 3.0: focus on both sandy beach and cliff changes, and integrating those projections into the future flood scenarios

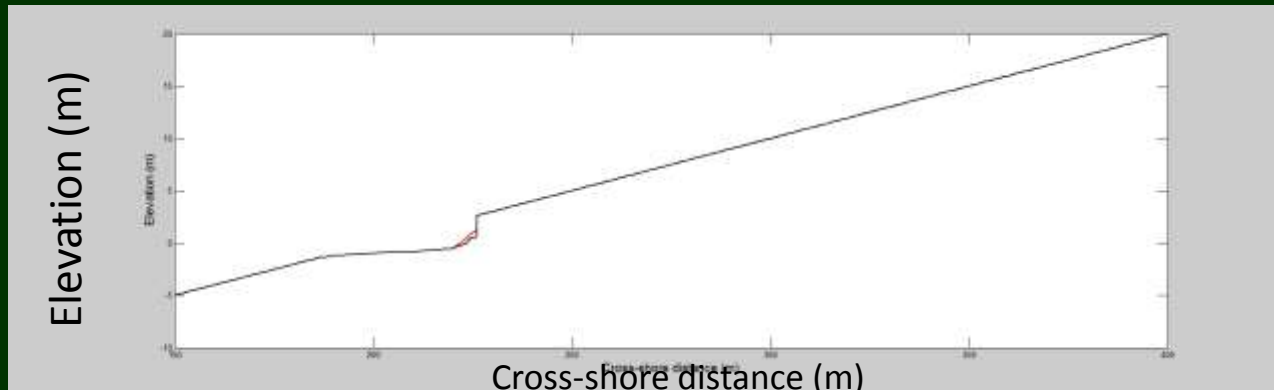
Controls on Cliff Behavior



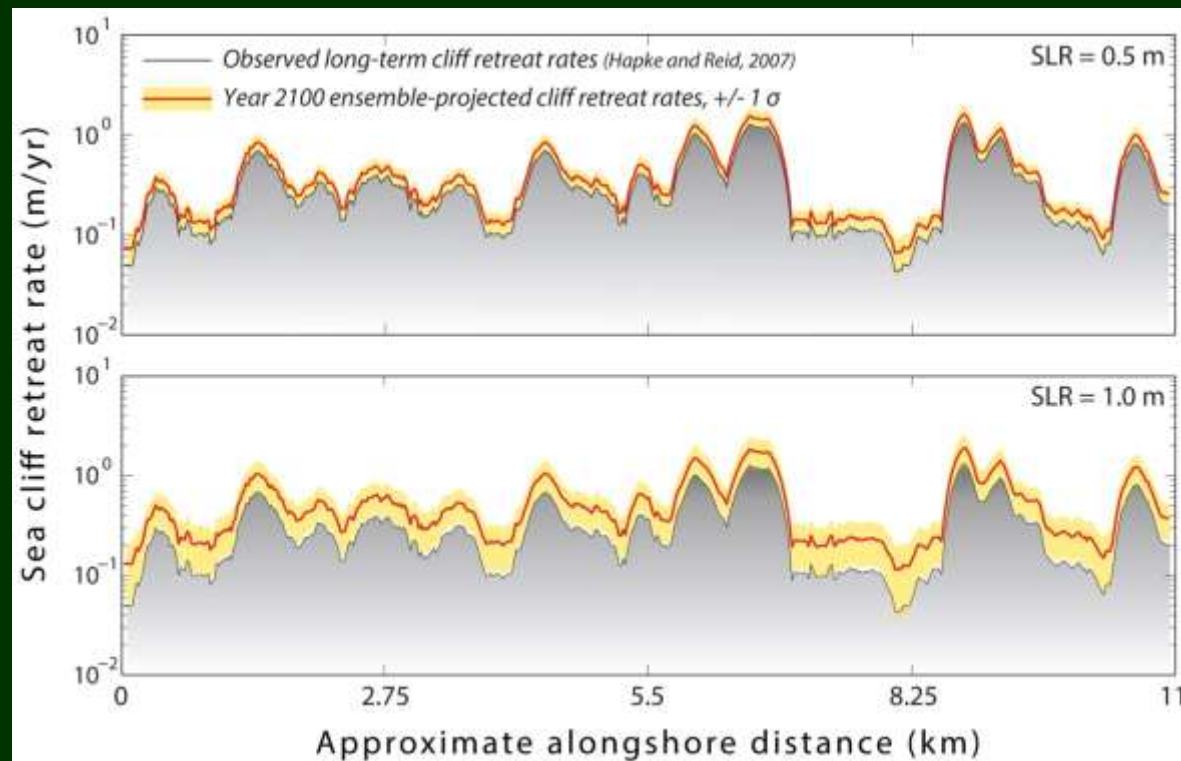
Sea cliff retreat =



San Onofre/Camp Pendleton Cliff Retreat



- + wave & rainfall time series
- + sea level rise
- + talus deposition & erosion
- + landslide threshold



Highlights of New SoCal Work

- Multi-agency collaboration featuring top coastal and climate scientists from Scripps, Oregon State University, private sector, and USGS
- Long-term coastal evolution modeled, including sandy beaches and cliffs
- Downscaled winds from GCMs to get locally-generated seas and surge
- Discharge from rivers for event response and long-term sediment supply
- Preliminary scenarios delivered in fall 2015, final in summer 2016

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

USGS CoSMoS website: http://walrus.wr.usgs.gov/coastal_processes/cosmos/index.html

Our Coast- Our Future tool: www.prbo.org/ocof

