How do we assess the physical and ecological effects of climate change on the San Francisco Bay margin?

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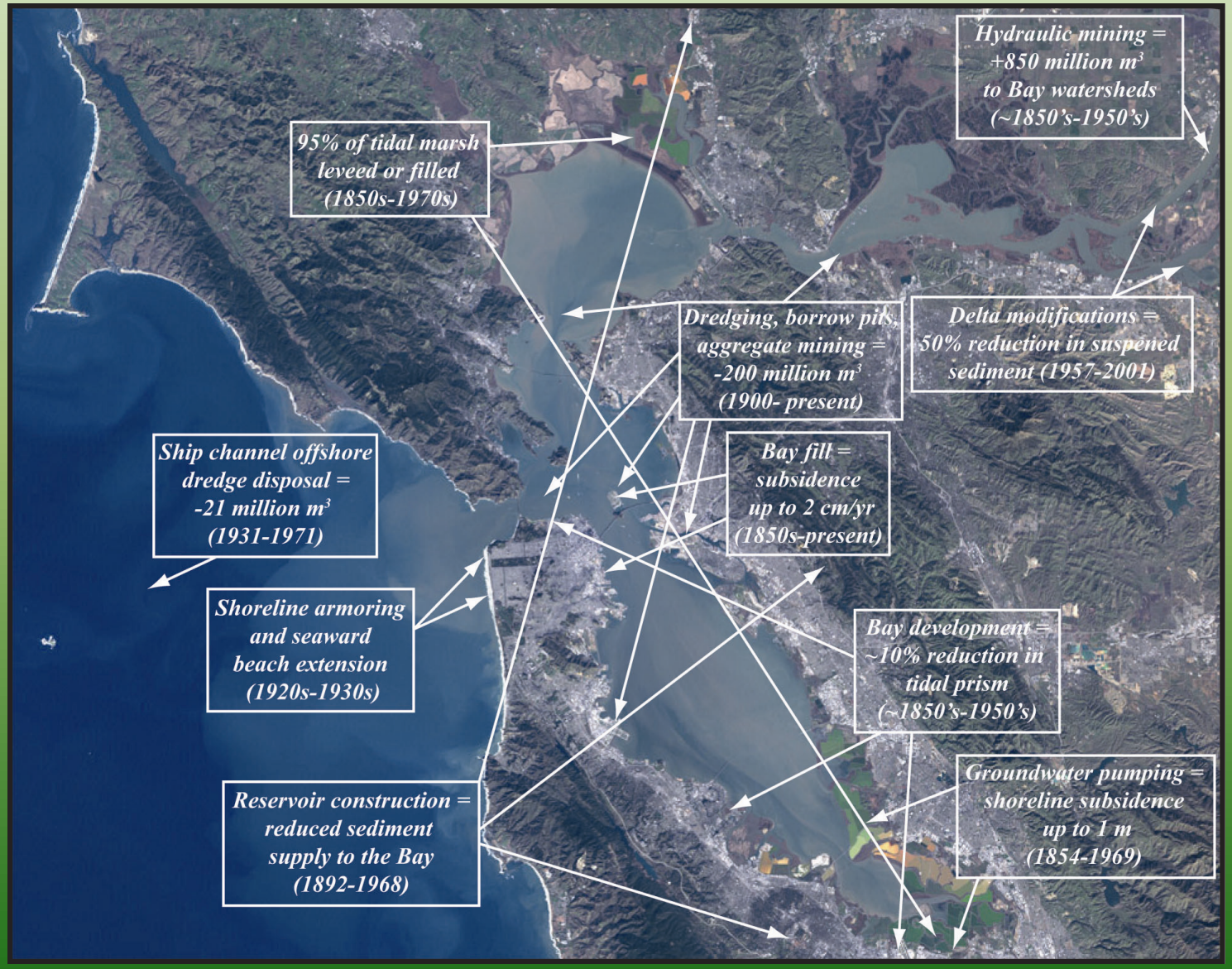
Historical Impacts



Bay Floor Changes

Recent Findings- Sediment Transport

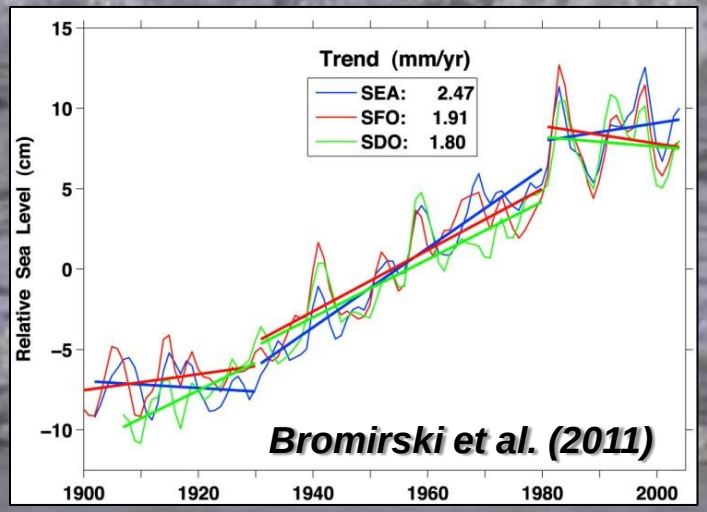
- 36% decrease in suspended sediment concentration between 1991-98 and 1999-2007 (Schoellhamer, *Estuaries and Coasts*, 2011)

- ~3-fold increase in rate of erosion in west-Central Bay between 1947-1979 and 1997-2008 (Barnard and Kvitek, *San Francisco Estuary and Watershed Science*, 2010)

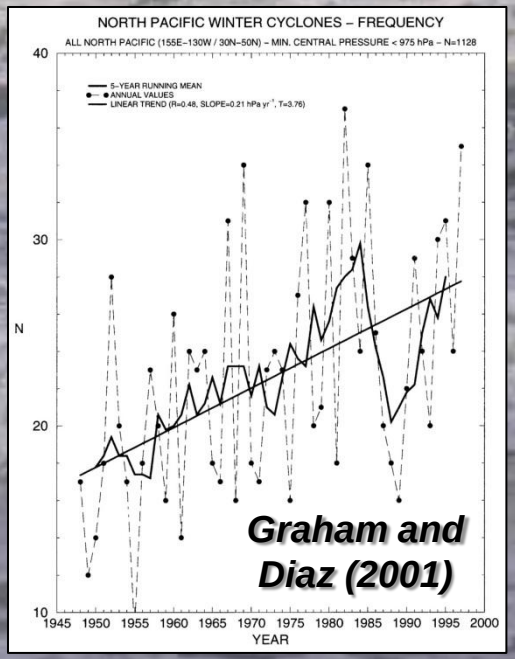
- Along outer coast, shoreline rate of erosion increased by 50% since 1980's (Dallas and Barnard, *Estuarine, Coastal and Shelf Science*, 2011)

Recent Findings- Oceanographic Processes

- **Global SLR is accelerating: 1993-present (satellite altimetry) = 3 mm/yr**
  - West Coast sea level rise has been suppressed since 1980! BUT wind pattern changes may signal return to global or higher rates of SLR



- **Storms and waves are getting bigger and more frequent**



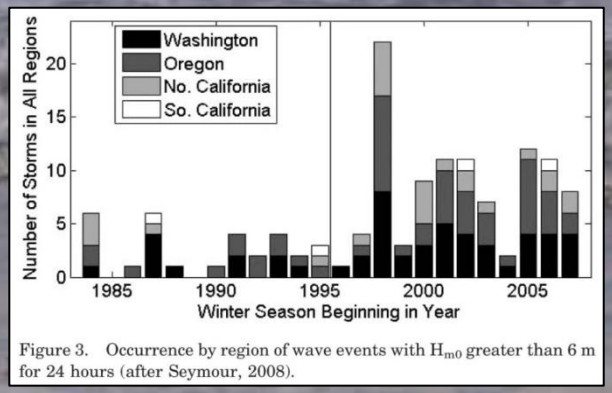
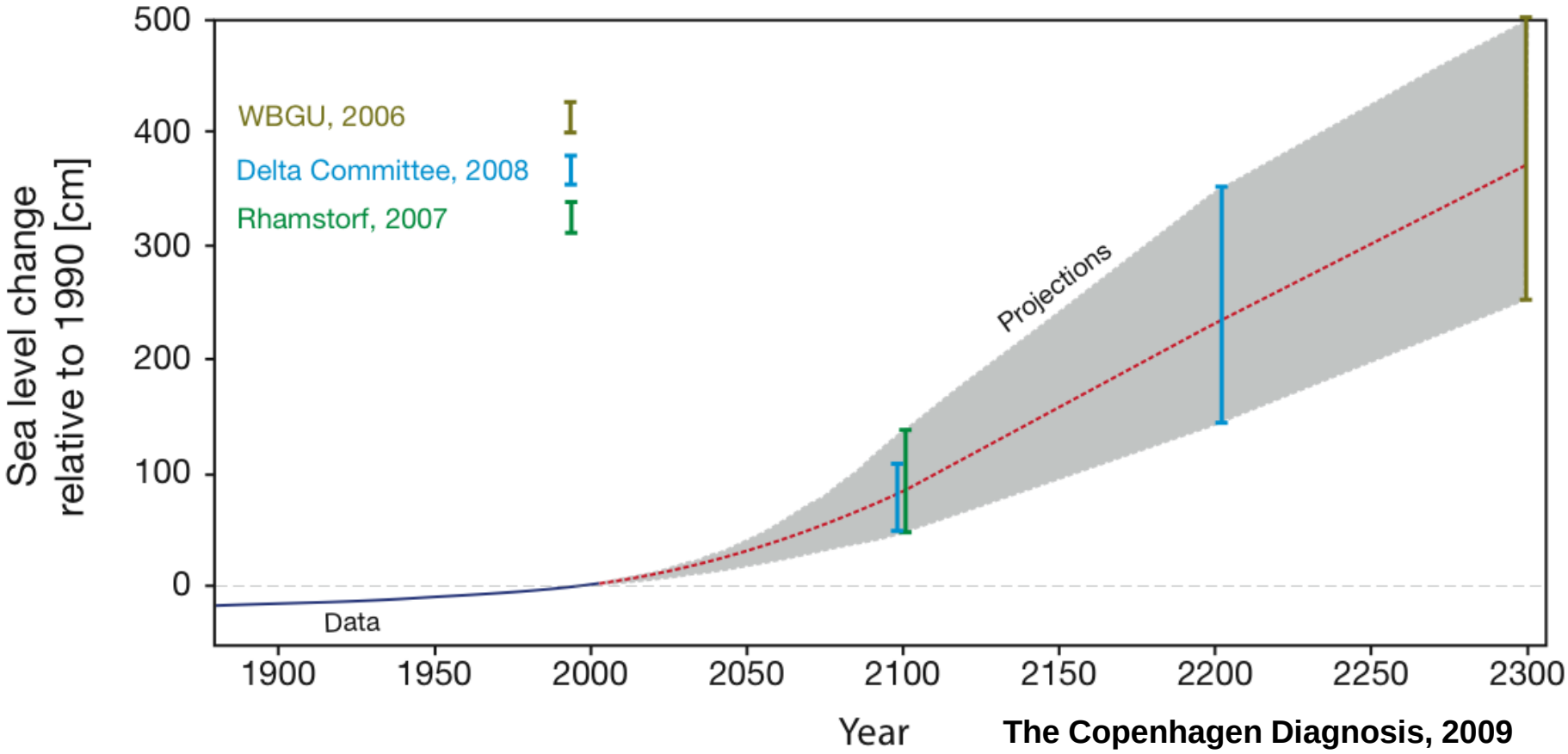


Figure 3. Occurrence by region of wave events with H_{m0} greater than 6 m for 24 hours (after Seymour, 2008).

Sea Level Rise Beyond 2100



The Copenhagen Diagnosis, 2009

- **1.8 to 5.5 m of SLR by 2500 using latest IPCC Models (2013): Representative Concentration Pathways (RCP) radiative forcing scenarios**
- **Sea level will rise for several centuries after stabilization (Jevrejeva et al., *Global and Planetary Change,* 2011)**

Future Projections

- Higher sea levels

- Reduced fluvial discharge, increased Bay salinity, decline in suspended sediment concentration, and a marked increase in the frequency of extreme water levels (Cloern et al., 2011)

- Wetlands will require a total sediment input (i.e., organic matter and inorganic sediment) of up to 10.1 Mm^3/yr (~2.6 cm/yr) by 2100 (Knowles, 2010)- only ~0.4 Mm^3/yr are actually being deposited (Schoellhamer et al., 2005)

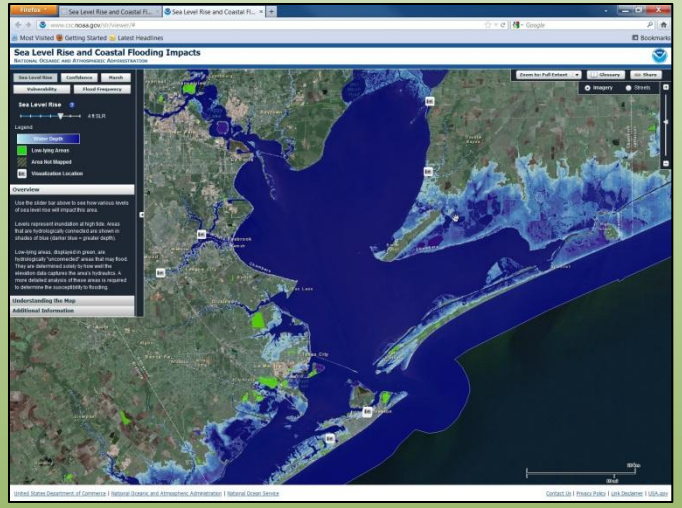
- Enhanced vulnerability overall

Coastal Impact of Projected Climate Trends

- Accelerated beach and wetland erosion rates
- Greater incidence of bluff failures
- Landward translation and more frequent coastal flooding
- Loss of accommodation space
- Ecosystem stress, particularly more sensitive species

Bay-wide Vulnerability Efforts

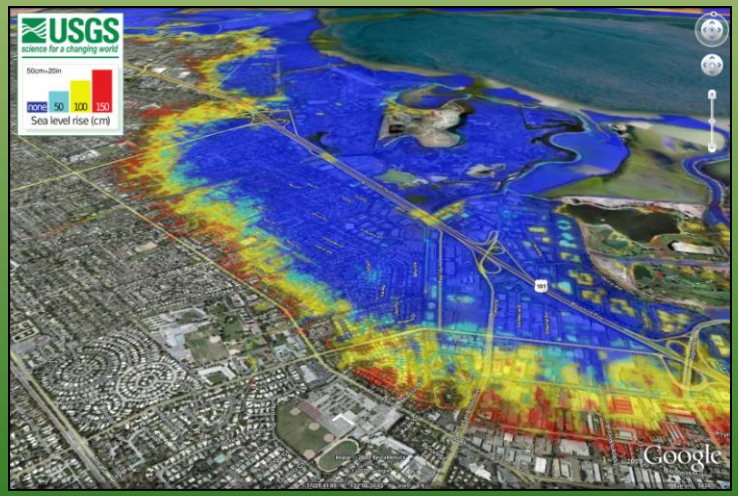
- NOAA SLR Viewer (1st Order- 'screening tool')
  - Coming Summer 2012
  - Bath-tub model, hydrological connectivity
  - Tides only (MHHW)
  - Excellent elevation data, datum control
  - Wetland migration model, socioeconomic impacts



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

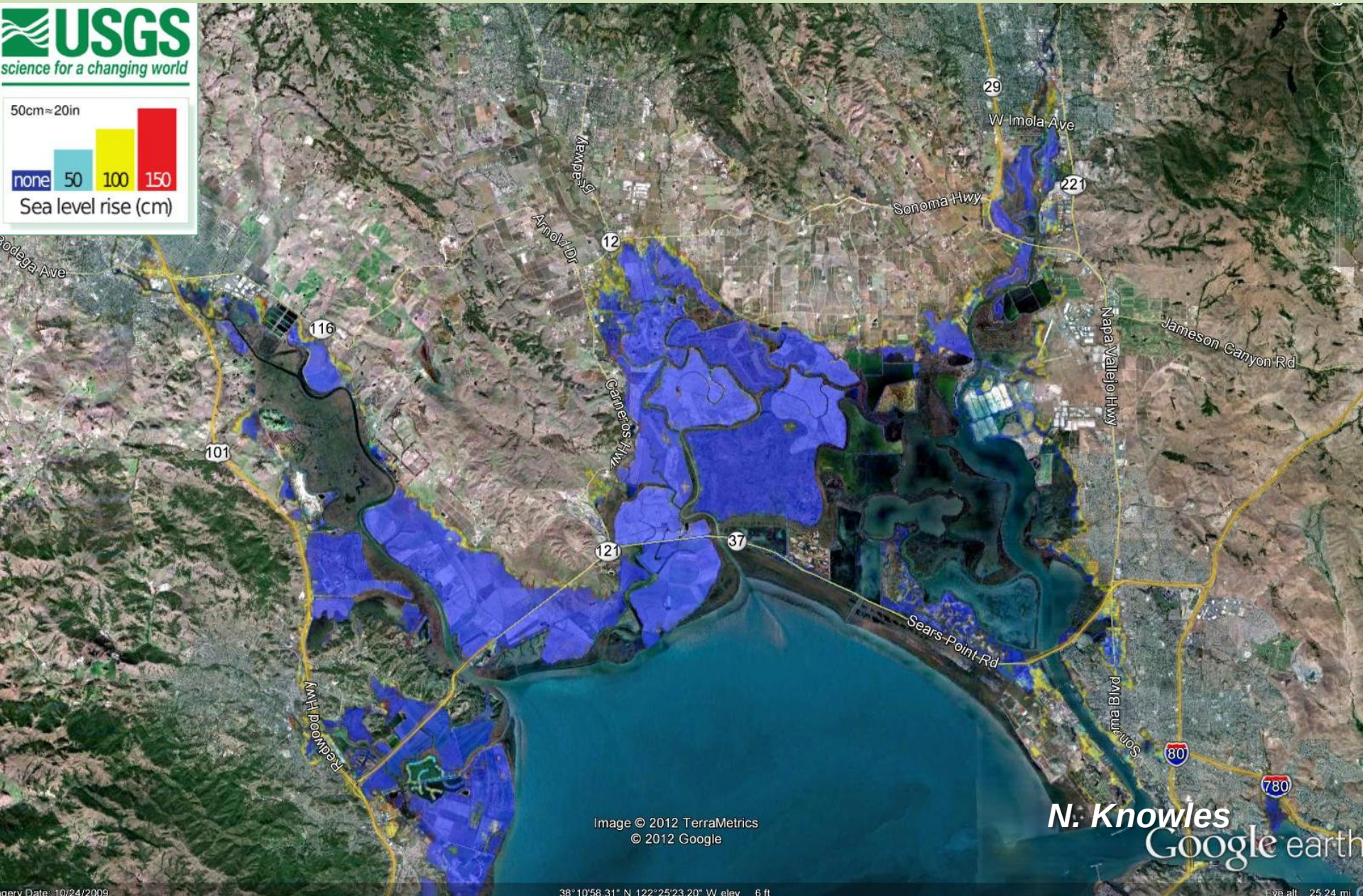
- Knowles (2nd Order)
  - Completed 2010
  - GCM-forced water levels at Golden Gate
  - Hydrodynamic modeling
  - 100-year flood events
  - Flooding extent based on bath-tub model
  - No wind, waves
  - Levees ignored

- Our Coast-Our Future (3rd Order)
  - Completion in 2014
  - 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, including levees

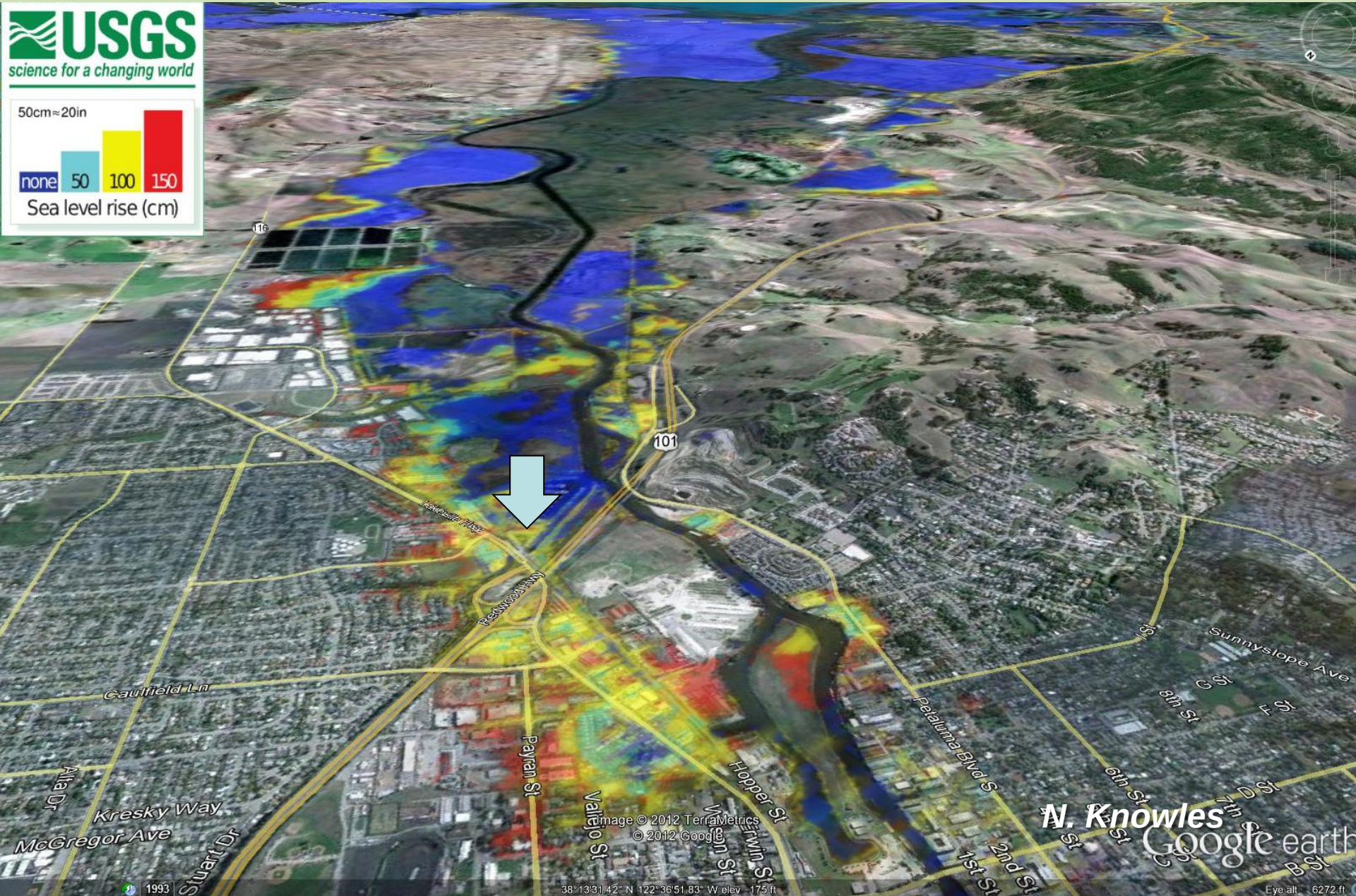


http://cascade.wr.usgs.gov/data/Task2b-SFBay/inundmap_data/googleearth/SFBay_SLR_100yr_nowetlands.kmz

North Bay Vulnerability



Petaluma Vulnerability

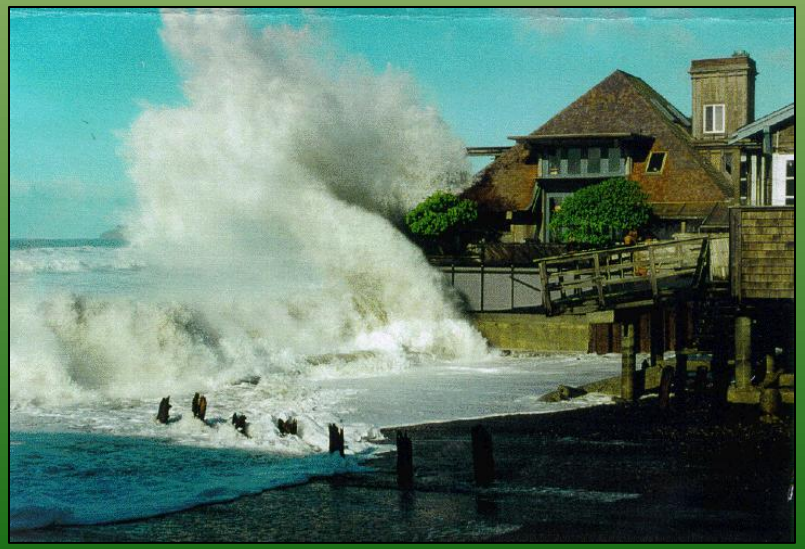


Modeling System Essentials

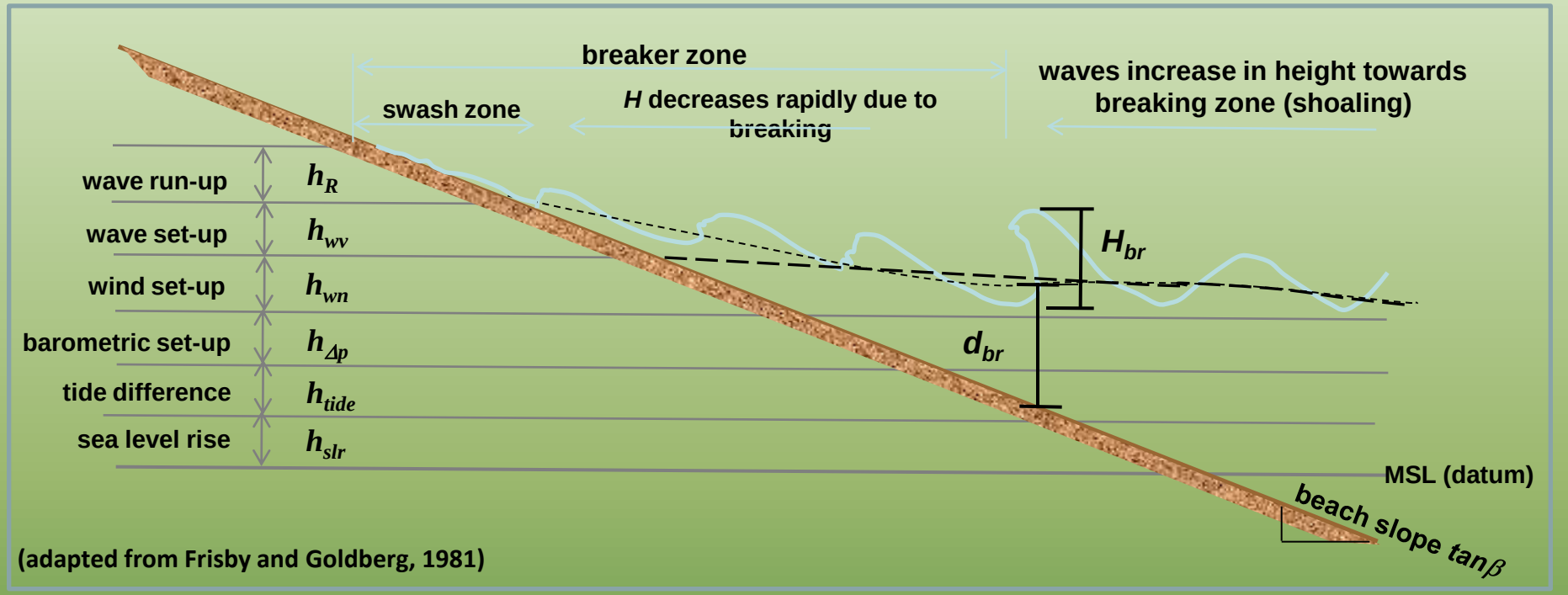
- Accurate, high resolution Digital Elevation Model (DEM)
- Physics included
  - Long waves important (infragravity)
  - Wave set-up and run-up
  - Surge (wind/pressure fields)
- Realistic forcing conditions/scenarios
  - Appropriate SLR scenarios
  - Atmospheric forcing from Global Climate Models
- Relevant products

CoSMoS Highlights

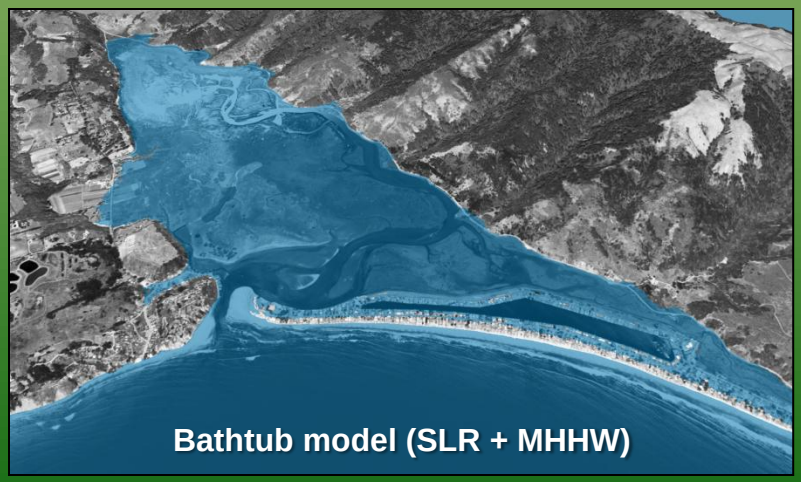
- 1st physics-based numerical modeling system for assessing coastal hazards on West Coast
- Predicts coastal inundation/flooding, wave heights, beach erosion, and cliff failures
- Uses Pacific Ocean-scale atmospheric forcing to make predictions every 100 m alongshore
- Flood hazards based on a 2 m resolution digital elevation model
- Uses Global Climate Models as forcing to simulate both typical and extreme events



Components of Total Water Level Predictions

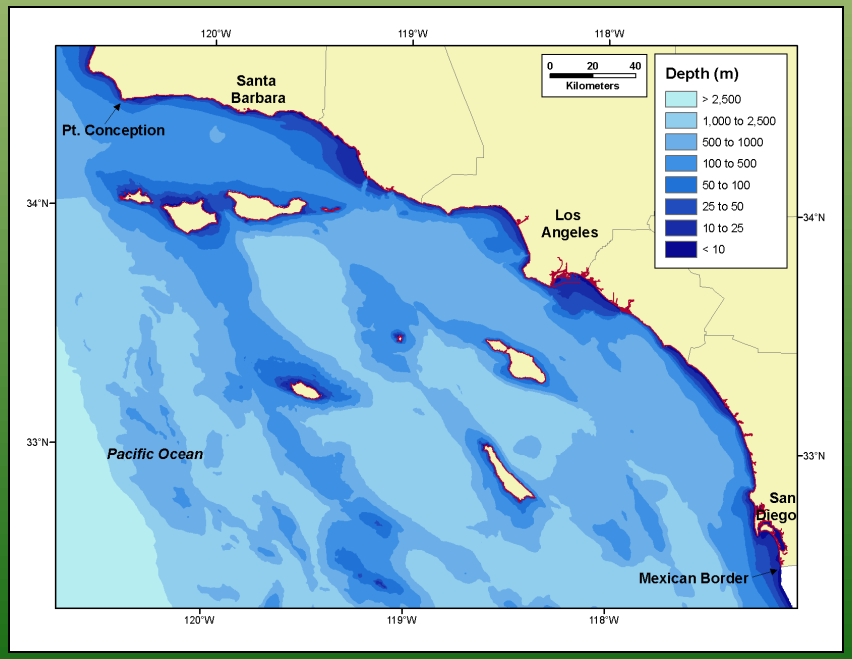


Bolinas Lagoon

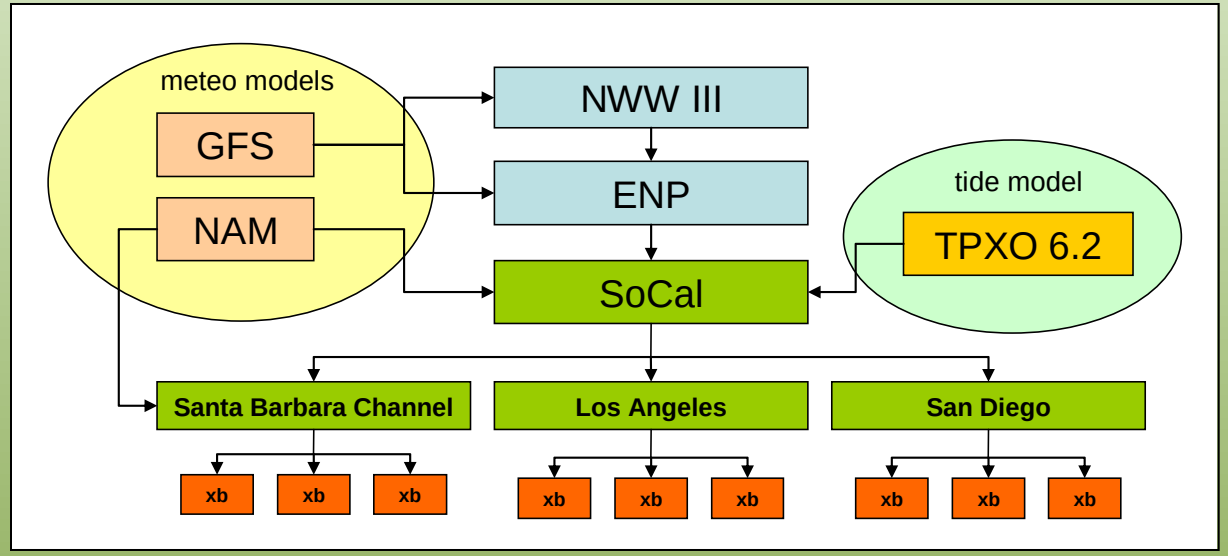


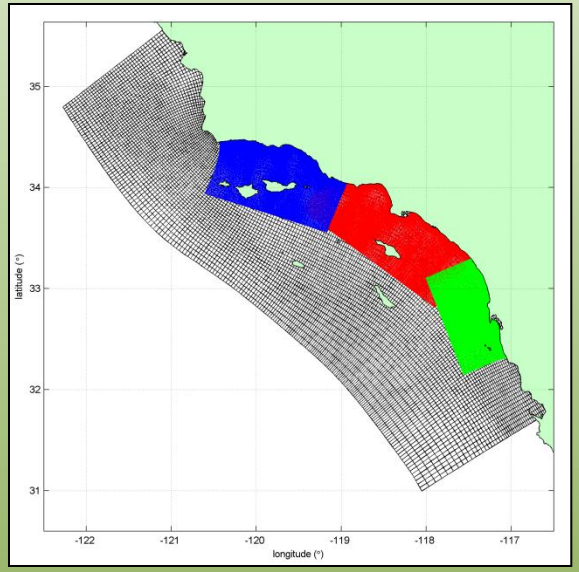
CoSMoS Version 1.0- SoCal

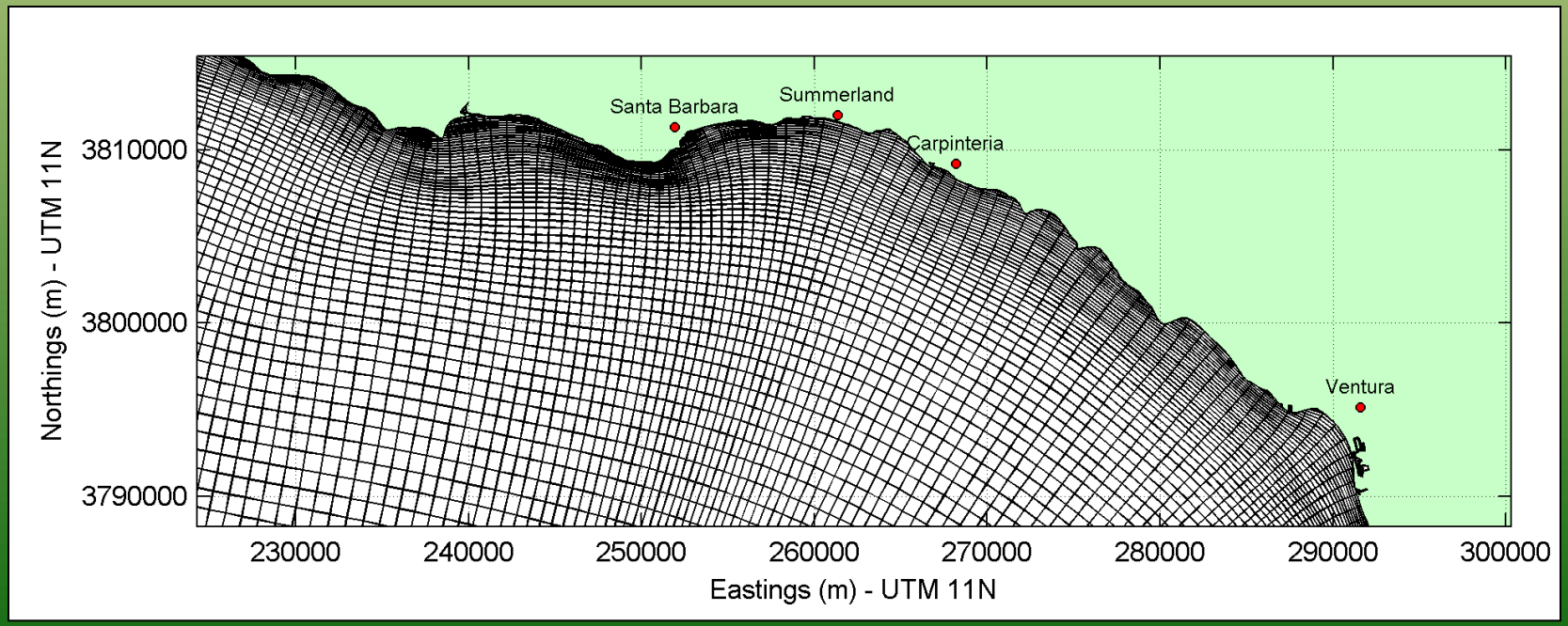
- Outer coast focus- protected bays not modeled
- Flooding based on maximum wave run-up
- Limited set of scenarios
  - ArKStorm
  - January 2010 hindcast
  - January 2010 hindcast + 50 and 100 yr SLR per Rahmstorf (2007)



Dynamic Model Grids

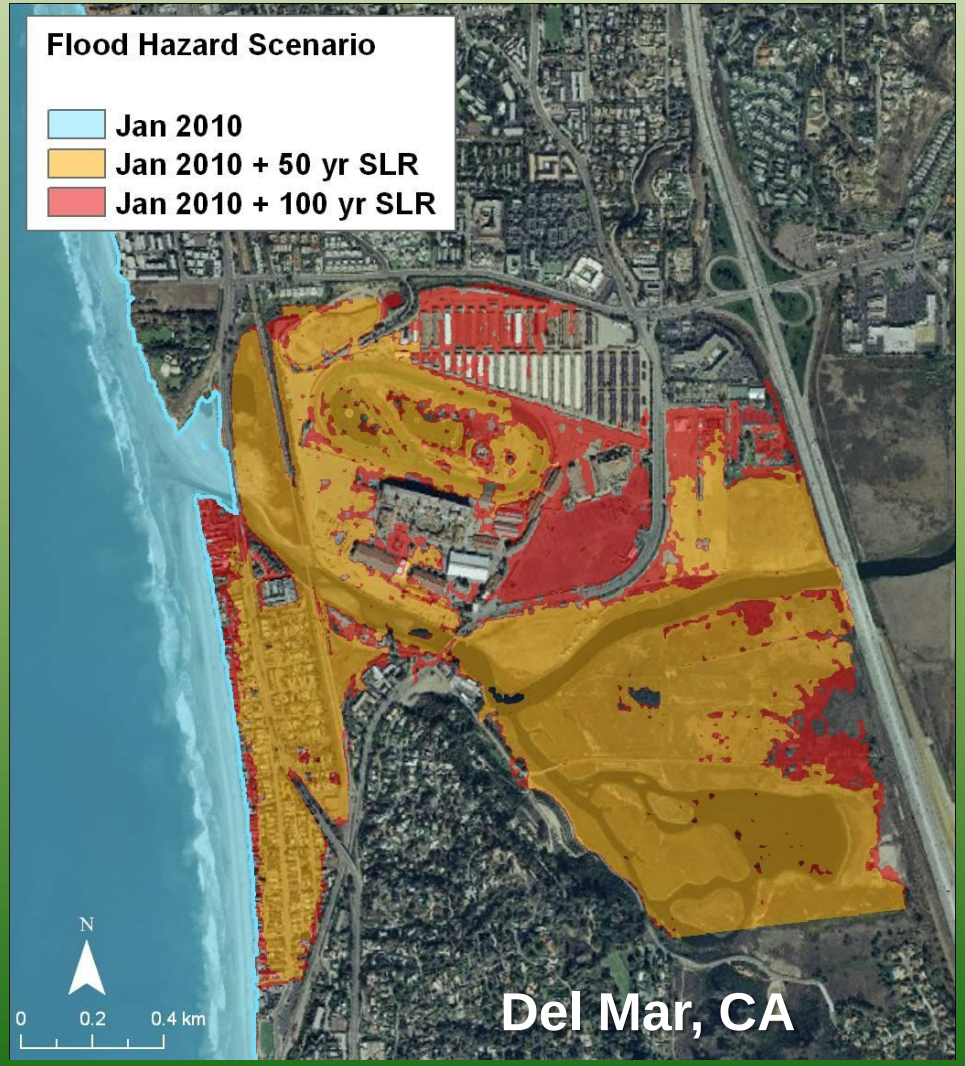




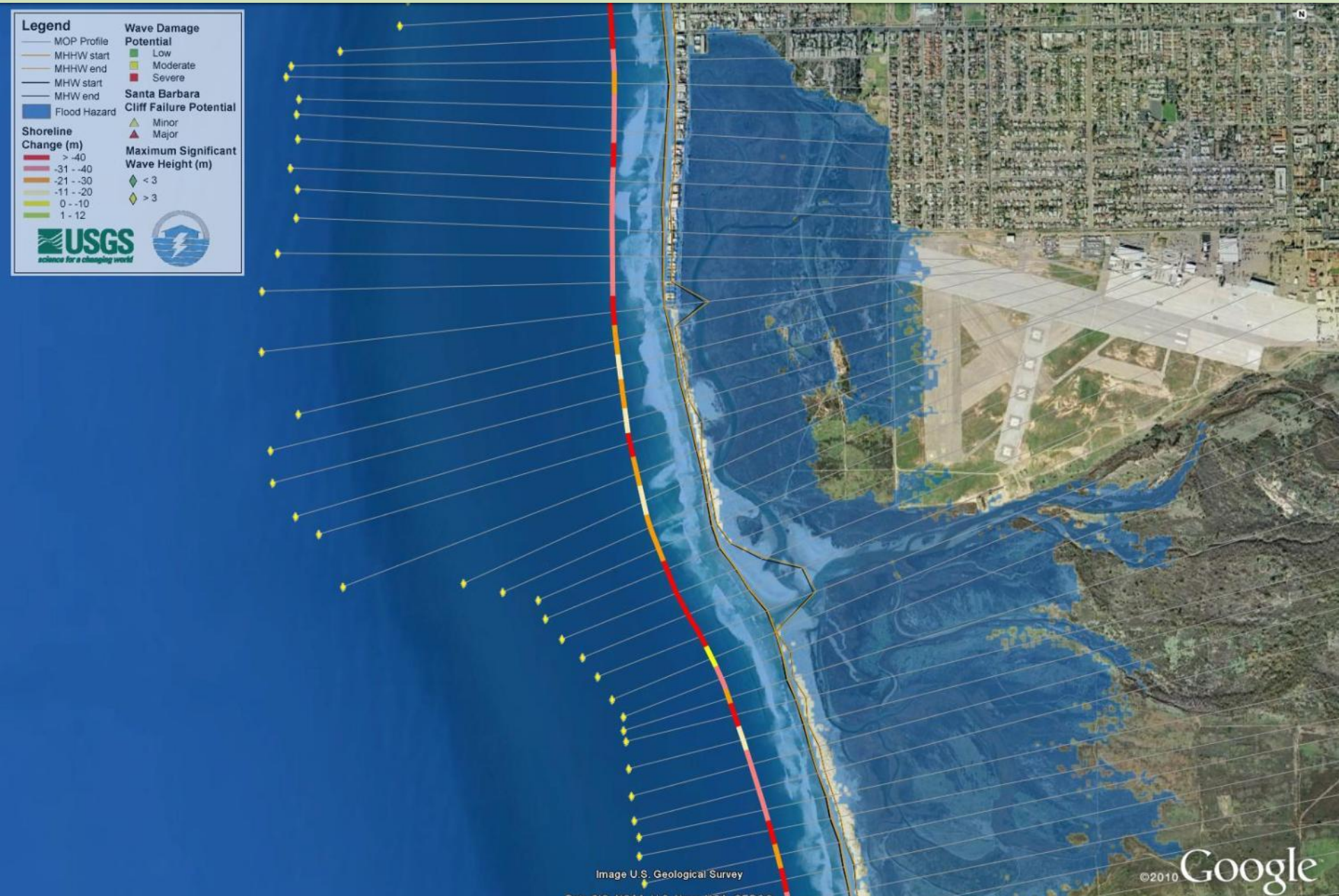


Products

Examples from Southern California



Products


Legend
MOP Profile
MHHW start
MHHW end
MHW start
MHW end
Flood Hazard
Shoreline Change (m)
> -40
-31 - -40
-21 - -30
-11 - -20
0 - -10
1 - 12
Wave Damage Potential
Low
Moderate
Severe
Santa Barbara Cliff Failure Potential
Minor
Major
Maximum Significant Wave Height (m)
< 3
> 3
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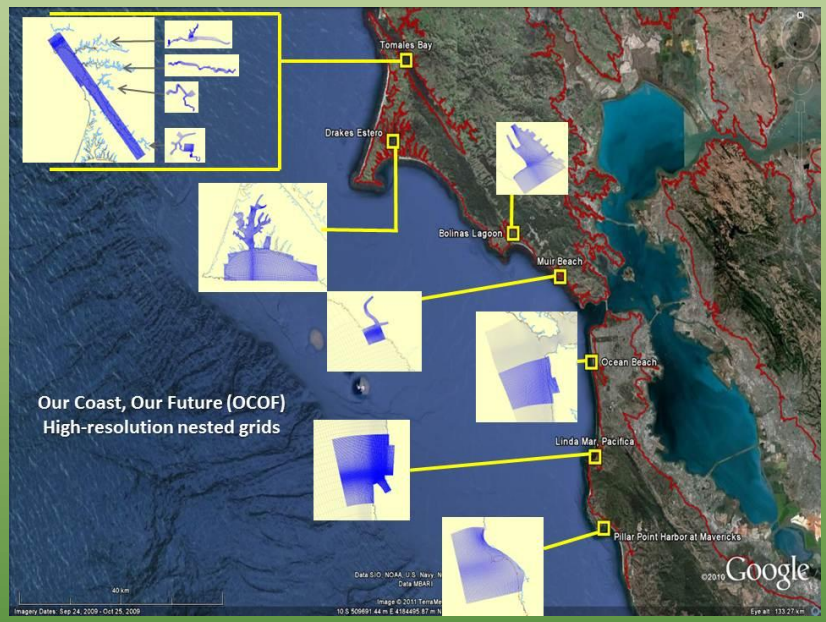
CoSMoS Version 2.0- NorCal

- Collaboration with NOAA, PRBO Conservation Science and NPS- Our Coast-Our Future (OCOF)
- Focus on climate change impacts to SF Bay and outer coast
- Sophisticated product tool with emphasis on ecological impacts
- Storm scenarios developed using latest IPCC (2013) radiative forcing scenarios and GCMs
- Flood flows and Bay hydrodynamics modeled, incl. depth of flow and uncertainty
- Fluvial discharge (2013)
- Wind forcing downscaled (2013)
- Relative land movement estimated (2013)



OCOF Summary

- SLR = 0 to 2 m in 25 cm increments, and 5 m extreme scenario
- Tide = MHHW for non-storm testing, otherwise joint probability
- Waves and storm conditions = average, annual extreme event, etc., and 100-year return interval extreme event
- Ecosystem and infrastructure vulnerability using available GIS data
- Scenarios completed by summer 2012
- Tool available winter 2012

CoSMoS - The Path Forward

- Currently used to assess coastal vulnerability to climate change for Our Coast-Our Future (OCOF)
- Expansion into SF Bay begins in a few months
- Easily adaptable as more sophisticated climate change models/predictions emerge
- Available as a real-time warning system for emergency managers, lifeline operators, and resource managers

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

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

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

http://data.prbo.org/apps/ocof/