

# Past, present and projected changes to the San Francisco Bay Coastal System

Patrick L. Barnard<sup>1</sup>, Li H. Erikson<sup>1</sup>, Jeff E. Hansen<sup>1,2,3</sup>,  
Amy Foxgrover<sup>1</sup>, Edwin Elias<sup>4</sup> and Kate Dallas<sup>1,2</sup>

<sup>1</sup>USGS, Pacific Coastal and Marine Science Center, Santa Cruz, CA, USA, pbarnard@usgs.gov

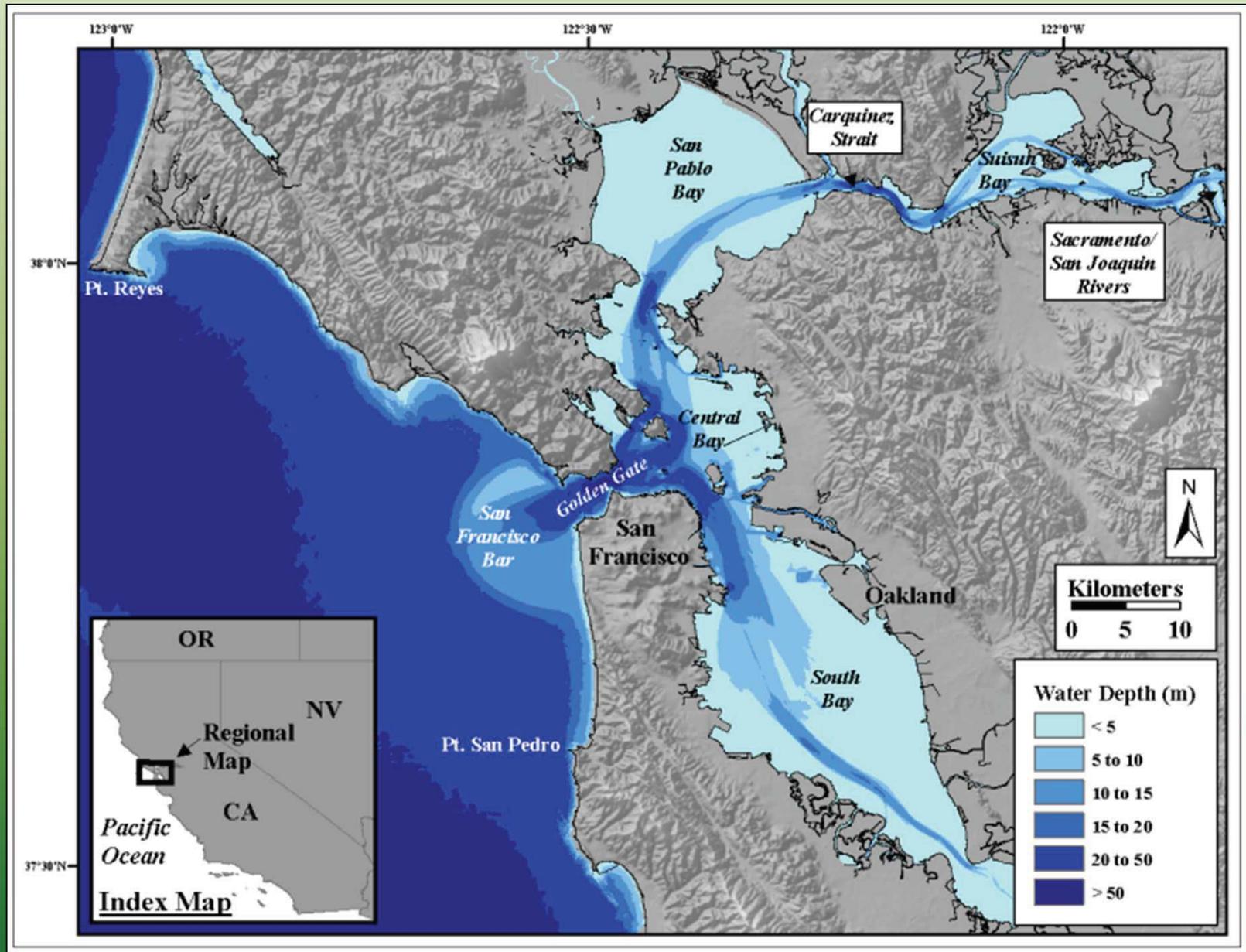
<sup>2</sup>UC Santa Cruz, Department of Earth and Planetary Sciences, Santa Cruz, CA, USA

<sup>3</sup>Woods Hole Oceanographic Institution, Woods Hole, MA, USA

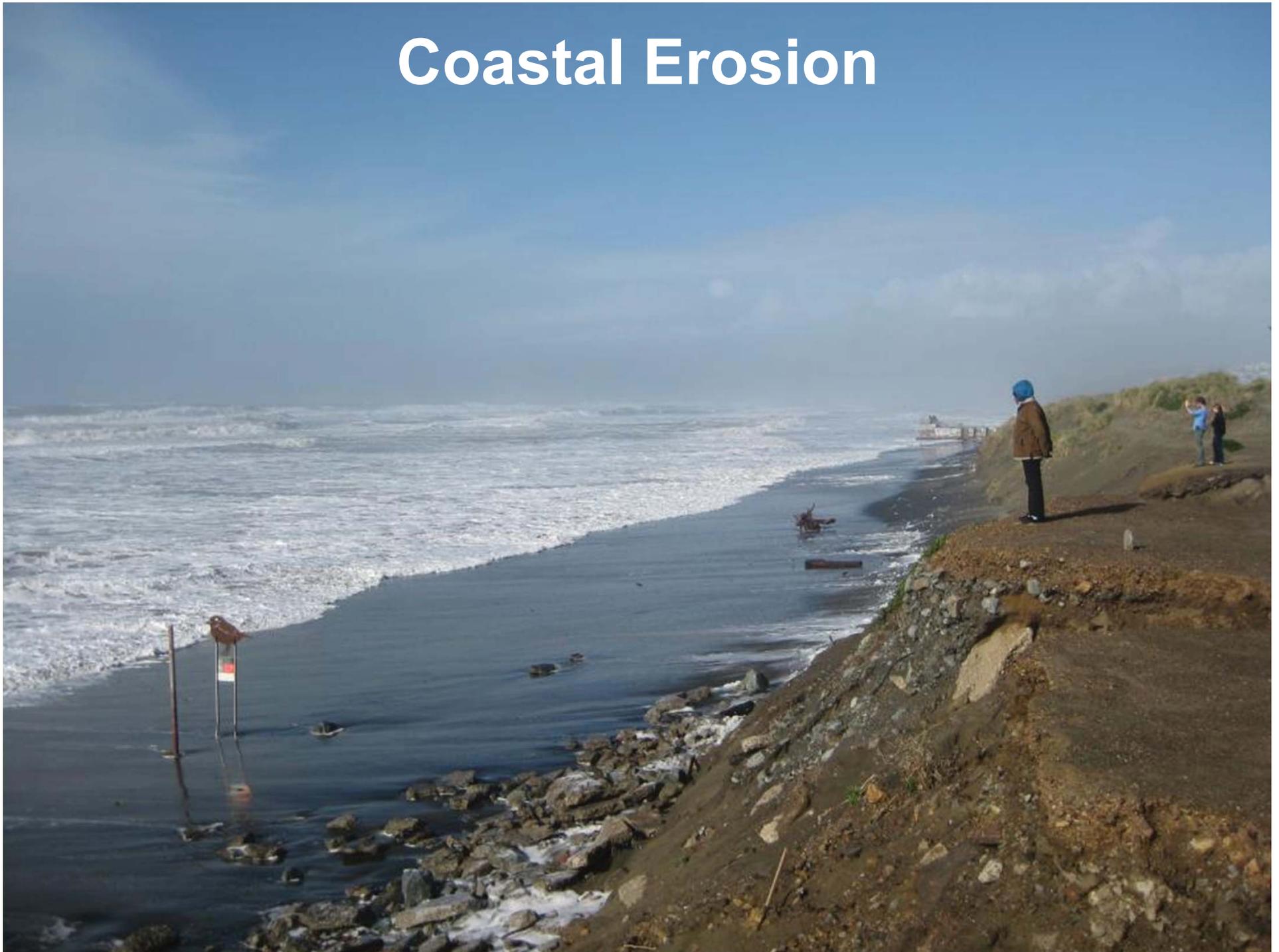
<sup>4</sup>Deltares, Delft, The Netherlands



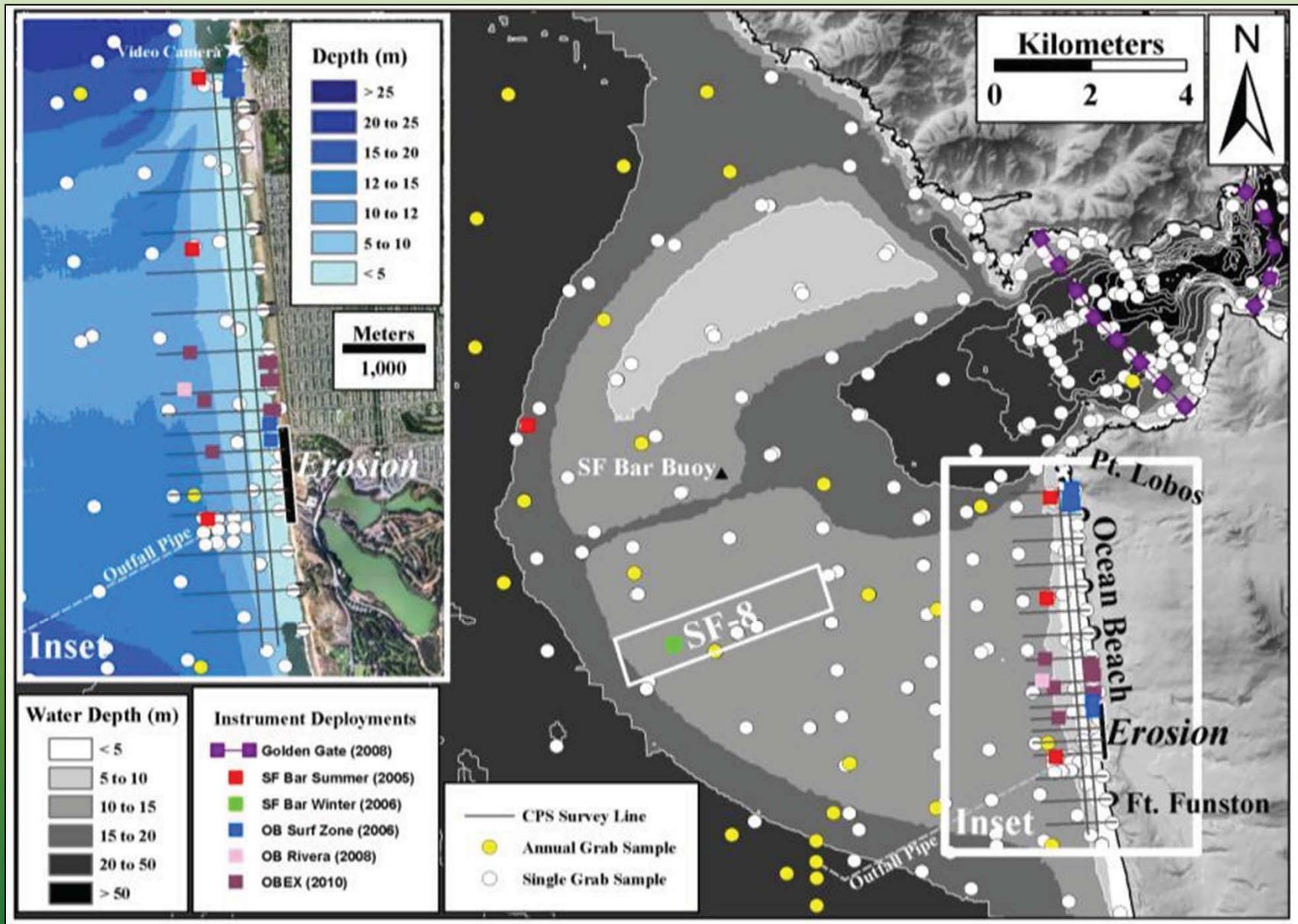
# Study Area



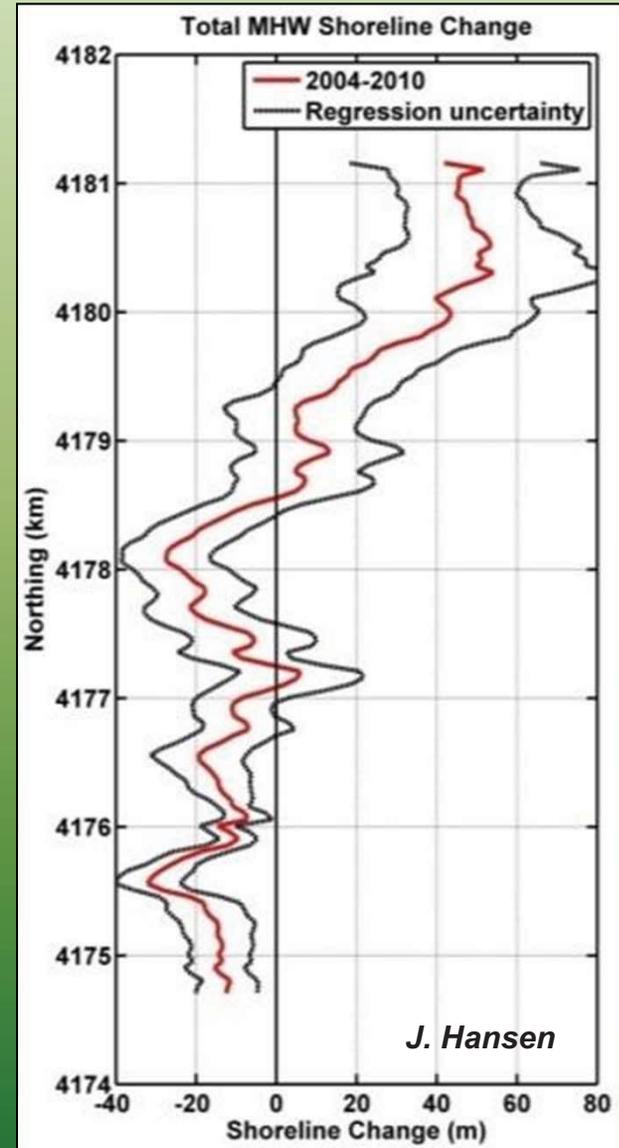
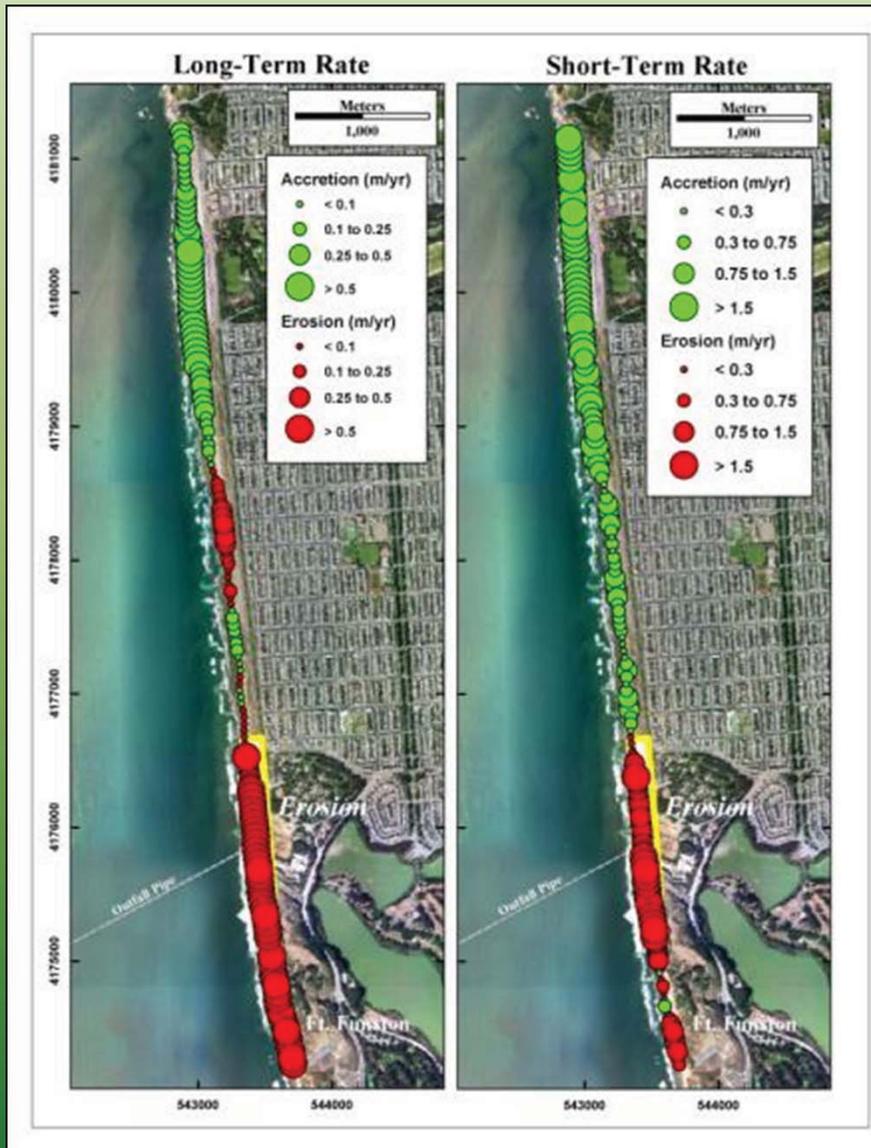
# Coastal Erosion



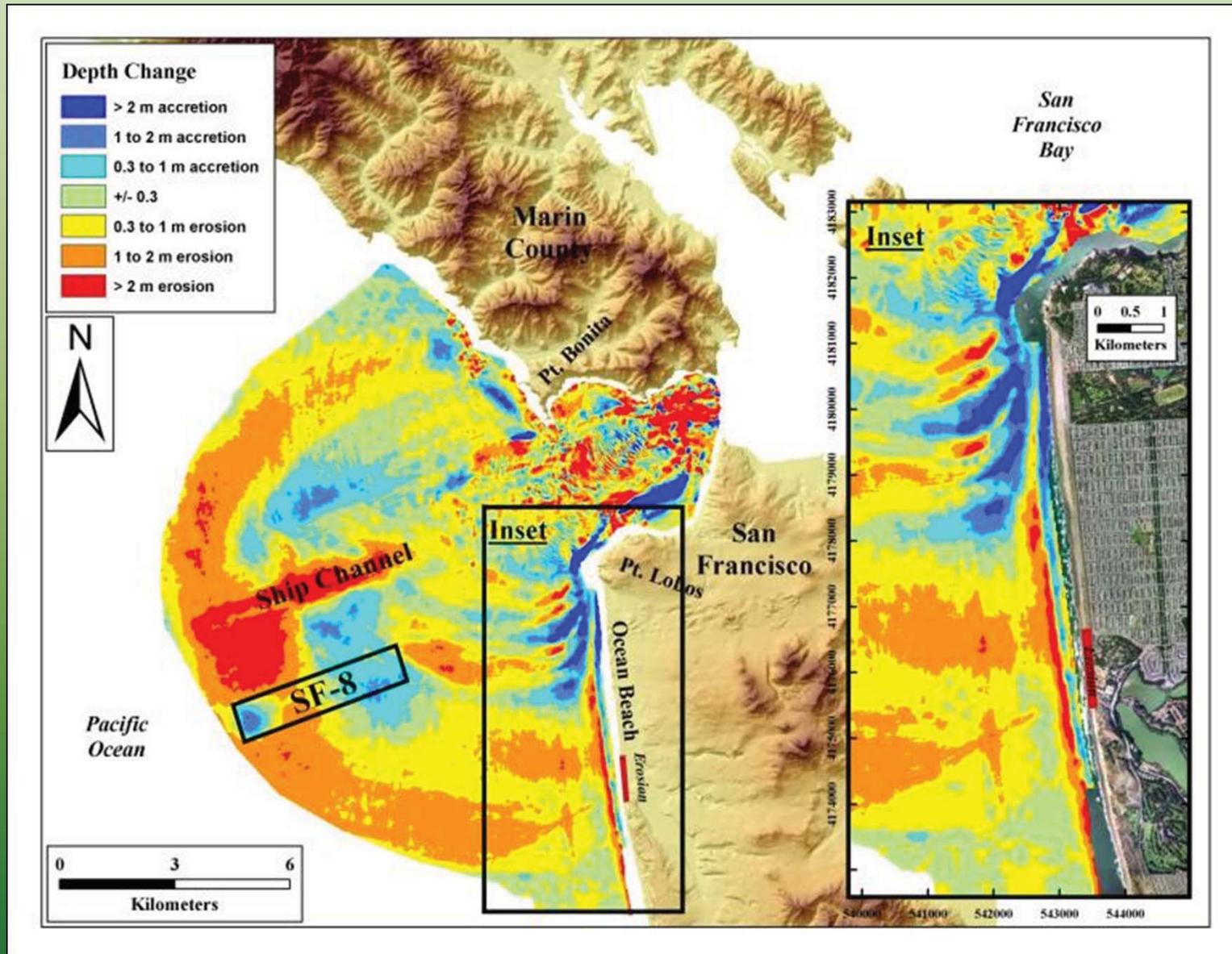
# Data Collection



# Shoreline changes

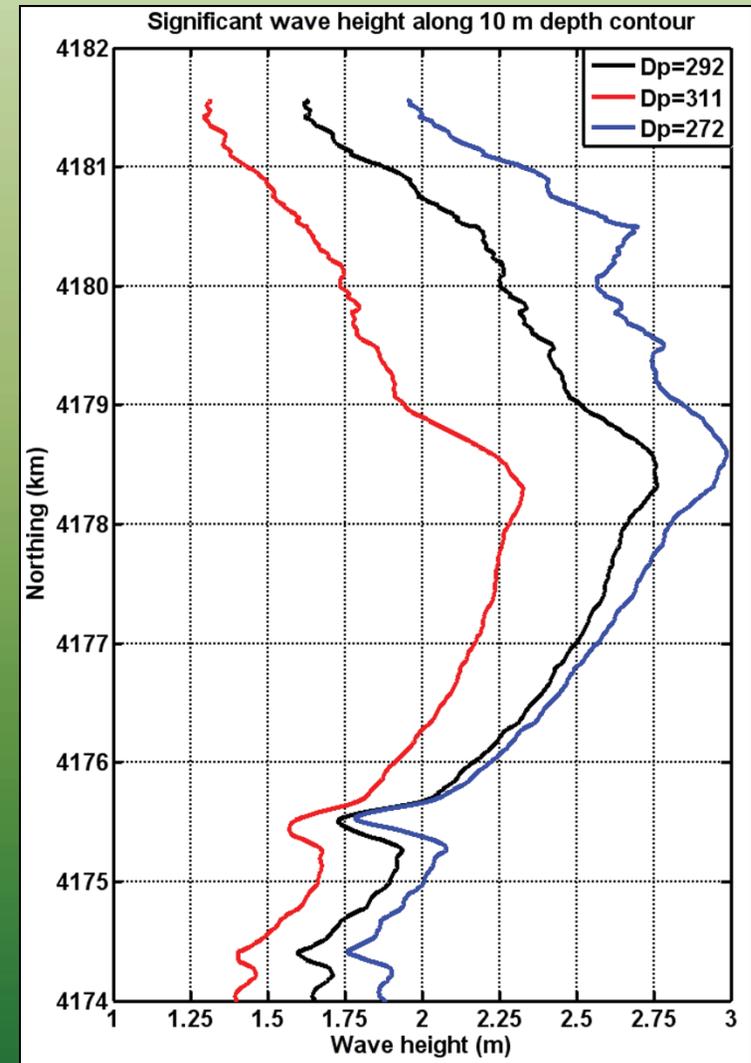
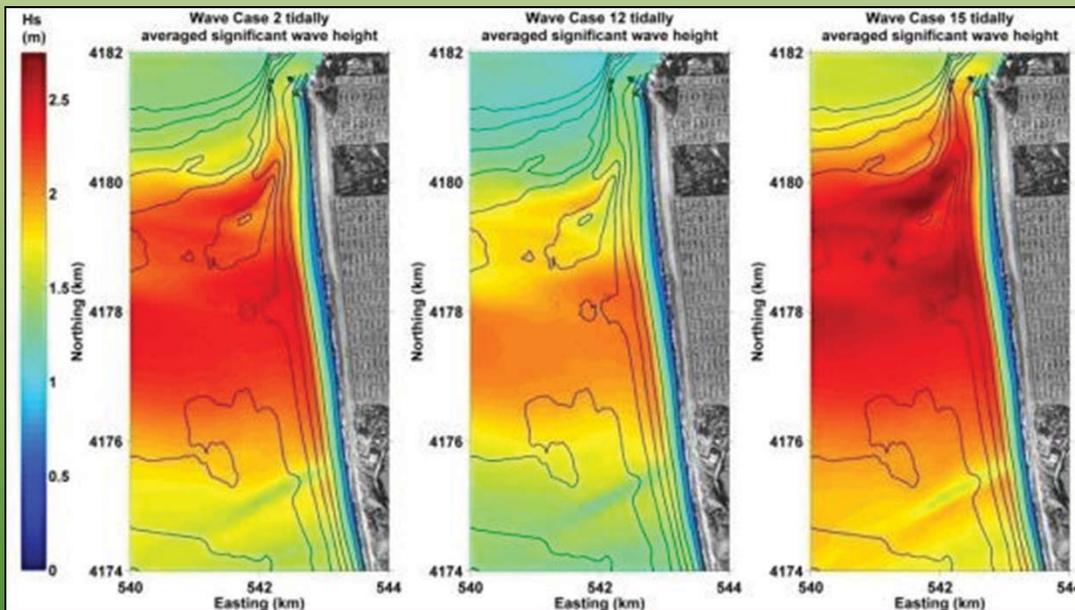


# Bathymetric Change (1956-2005)



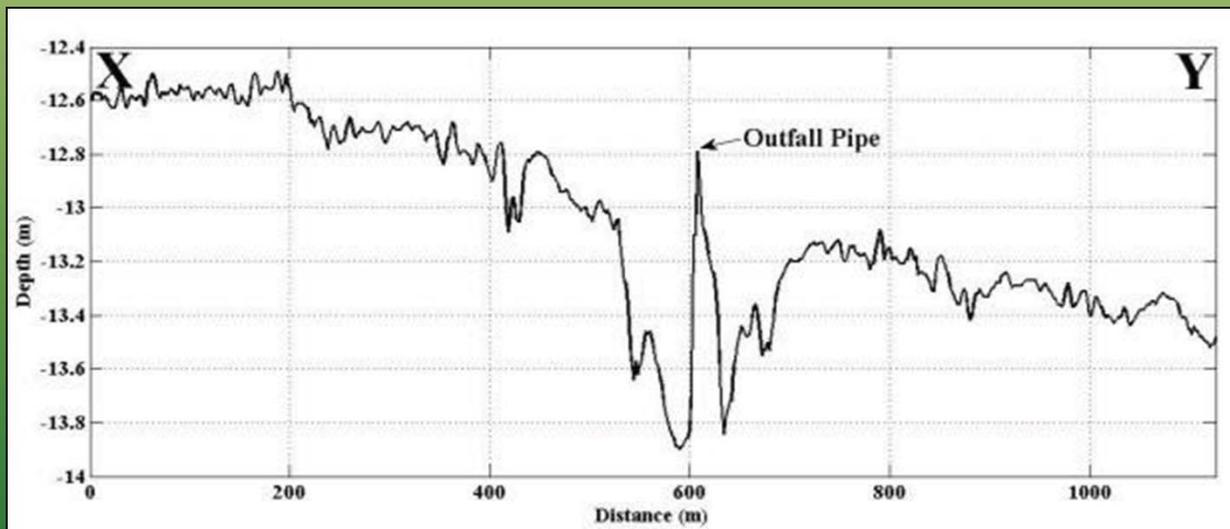
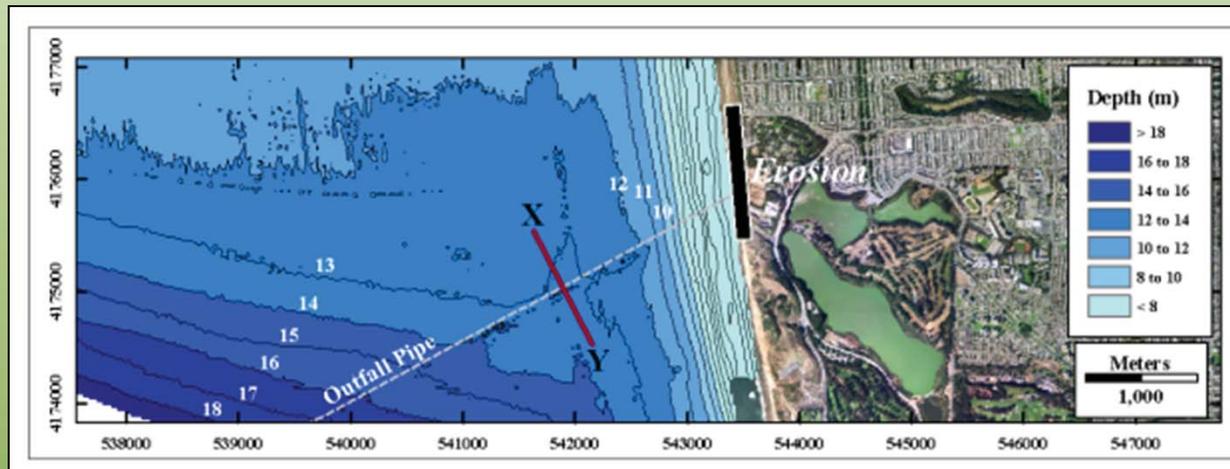
# Wave focal patterns

- Degree of focusing mostly dependent on wave direction.
- Cases 2, 12, and 15 all have same  $H_s \sim 2.5$  m and  $T_p \sim 14$  s, but different directions,  $292^\circ$ ,  $311^\circ$ , and  $272^\circ$  respectively.
- Noticeable discontinuity in southerly decreasing wave height gradient.

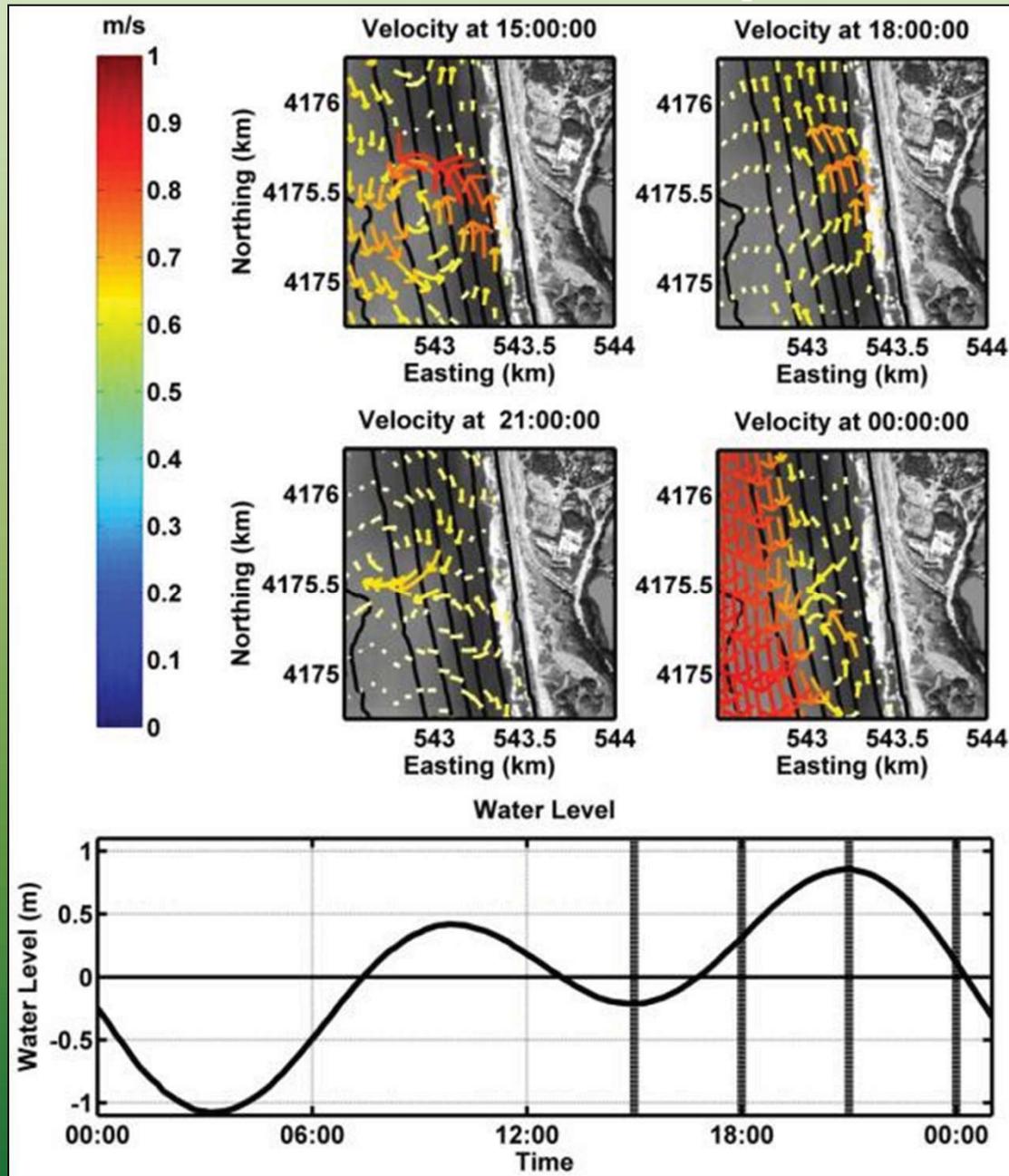


# Exposed waste water outfall pipe

- Acts as wave guide and leads to strong local variability in wave height, pressure gradient, and radiation stresses.



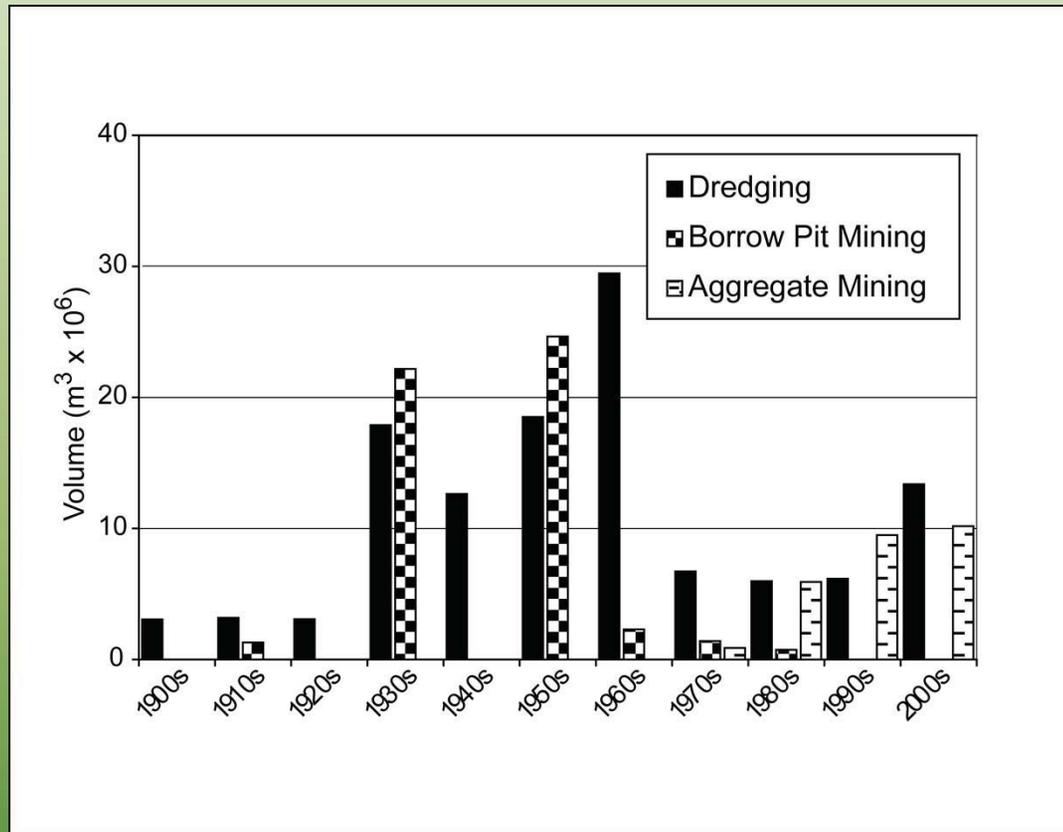
# Flow in erosion hot-spot area



# Assessing Regional Impacts

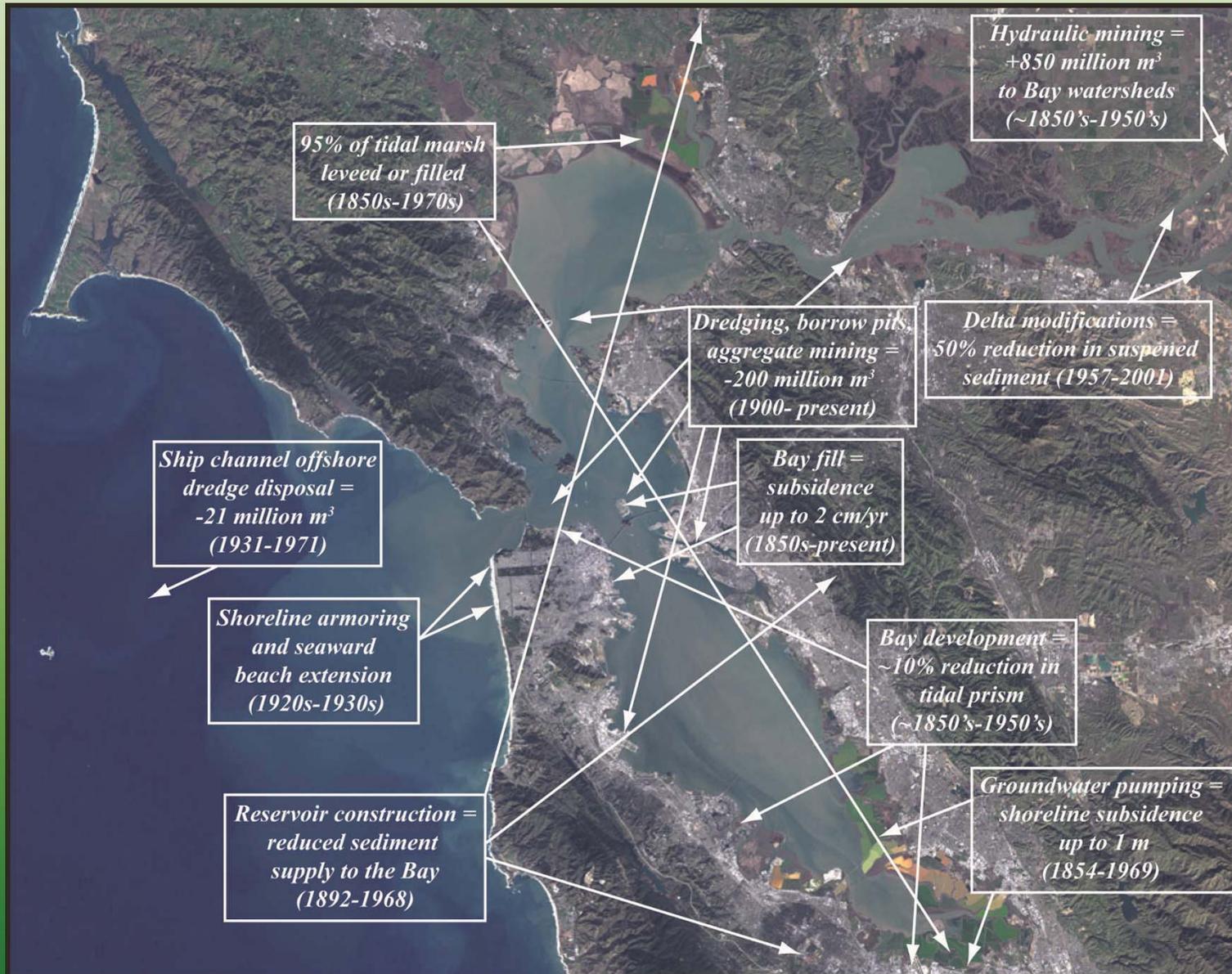
- Tally up sediment removed from system
- Identify sediment transport pathways, patterns and sources
  - Historical shoreline and bathymetric change analysis
  - Bedform morphology
  - Numerical modeling
  - Physical process studies
  - Sediment provenance

# Sediment Removal

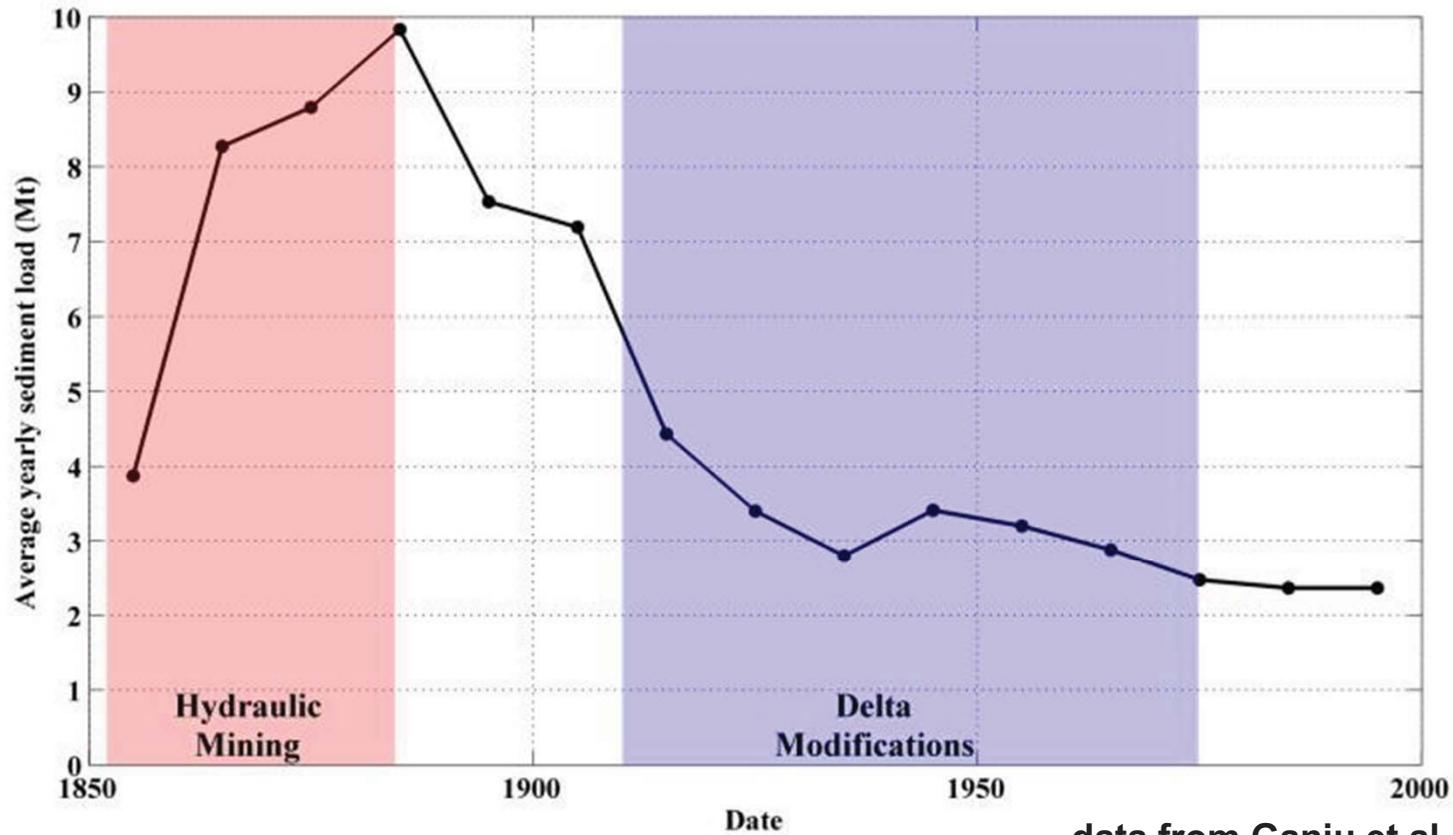


- 200 million m<sup>3</sup> of sediment removed from system
  - 113 million<sup>3</sup> from Central Bay
  - 75 million<sup>3</sup> identified as sand (50 million<sup>3</sup> from Central Bay)
- Records incomplete
  - Missing many borrow pit mining records
  - No aggregate mining records pre-1974 (began in 1930's)

# Historical Impacts



# Sediment Supply Changes

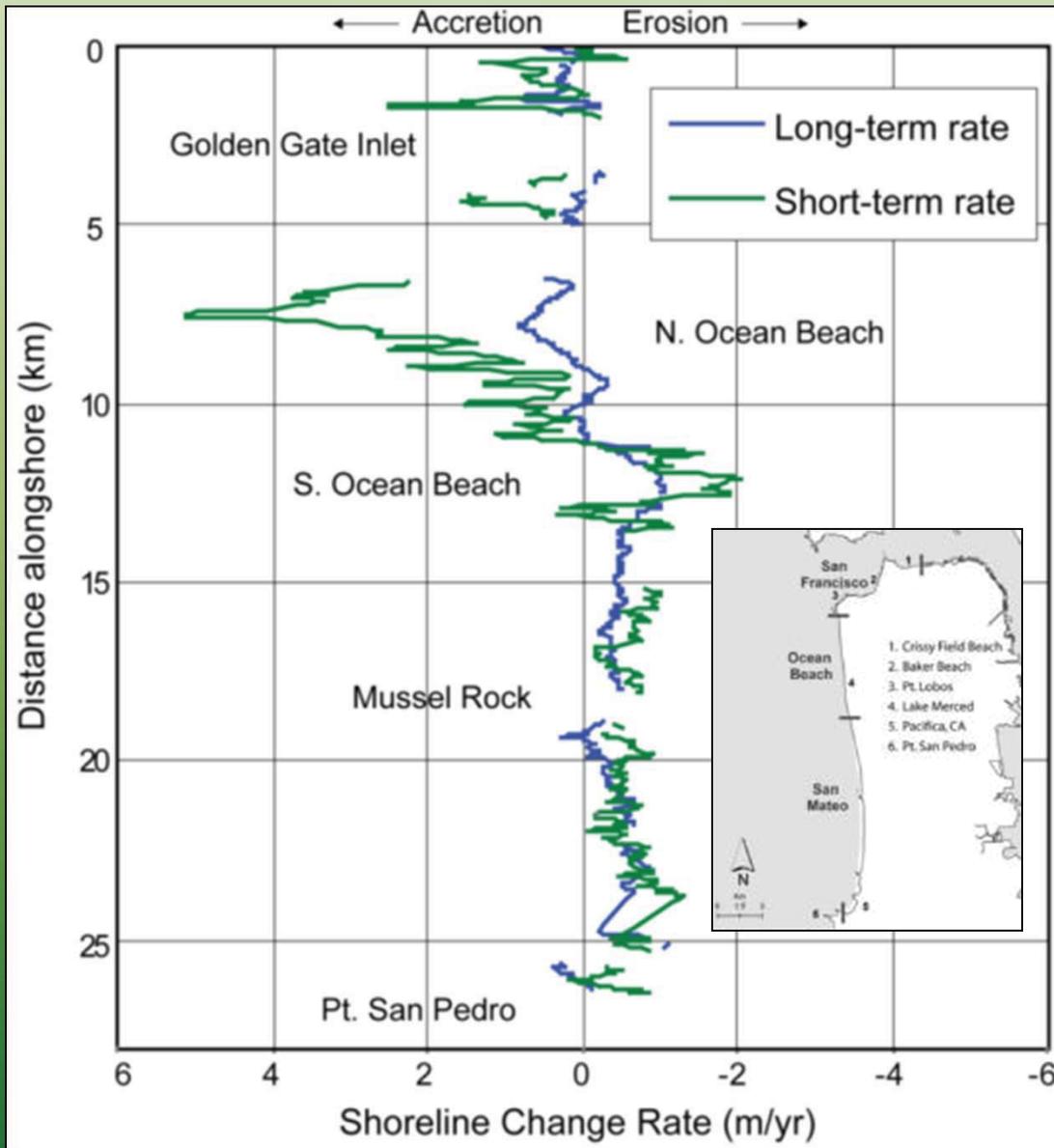


\*Using both a low and high-end emissions scenario through 2100, Cloern et al. (2011) project reduced fluvial discharge from the Delta and a decline in suspended sediment concentration

# Historical Changes

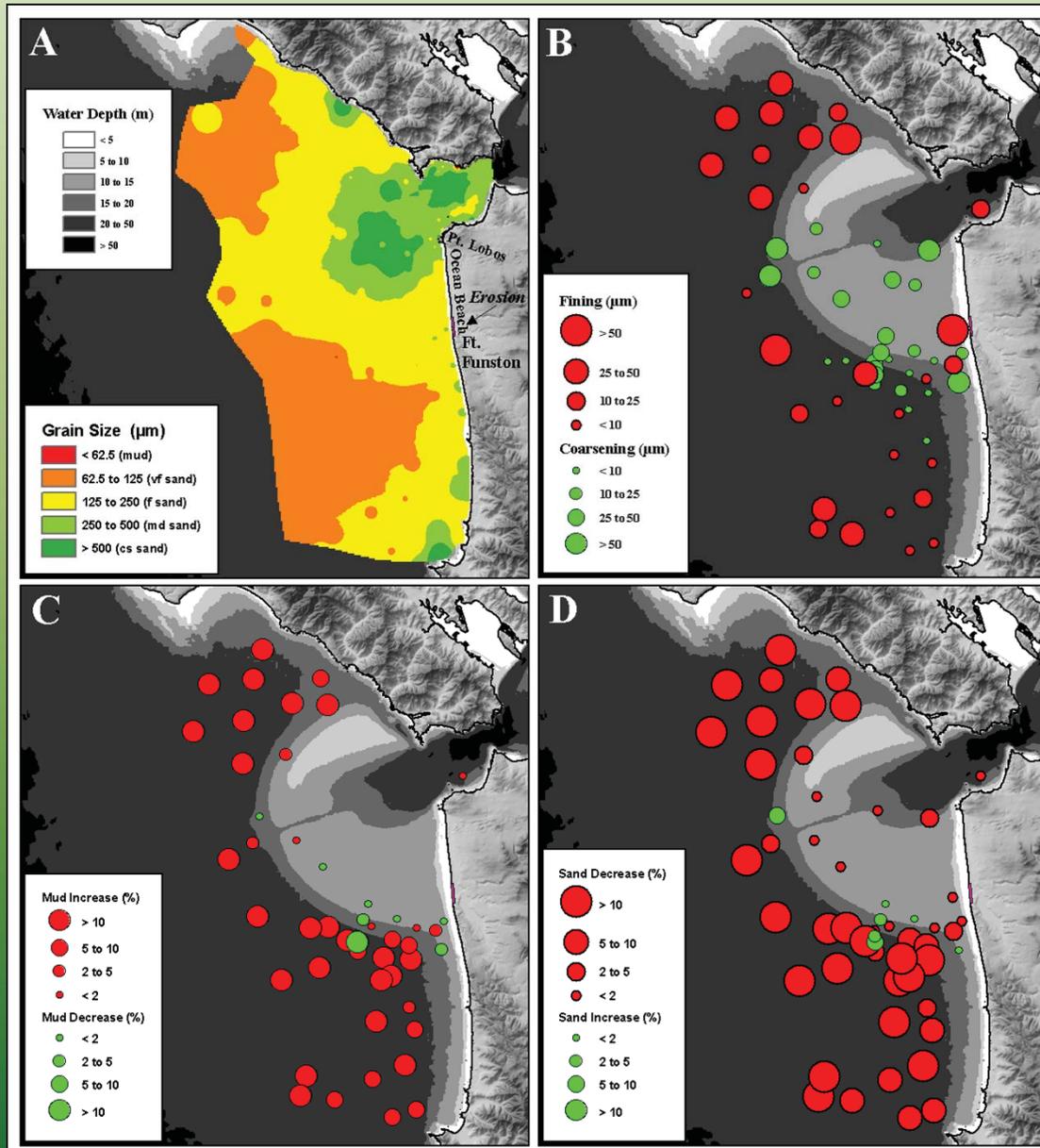


# Regional Shoreline Changes



- In SF Region, rate of accretion increased 4-fold from long (~ last 100 years) to short term (~ last 20 years)
- Shift to erosion where SF Bar attaches at Ocean Beach
- San Mateo region strongly erosional in long-term (93%) and short-term (98%)
- In SM region rate of erosion increased by 50% from long to short term

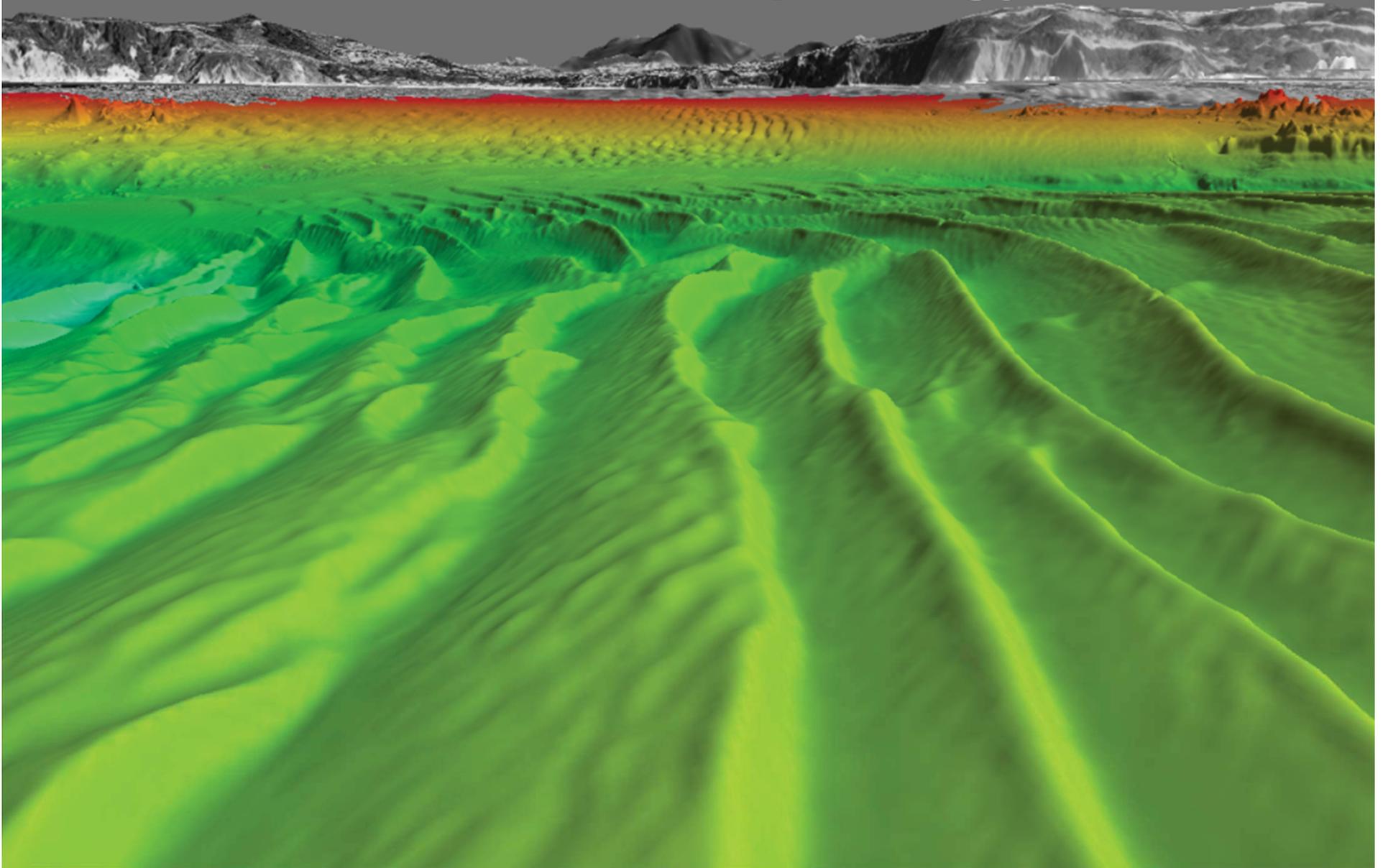
# Grain Size Changes (1997-2008)



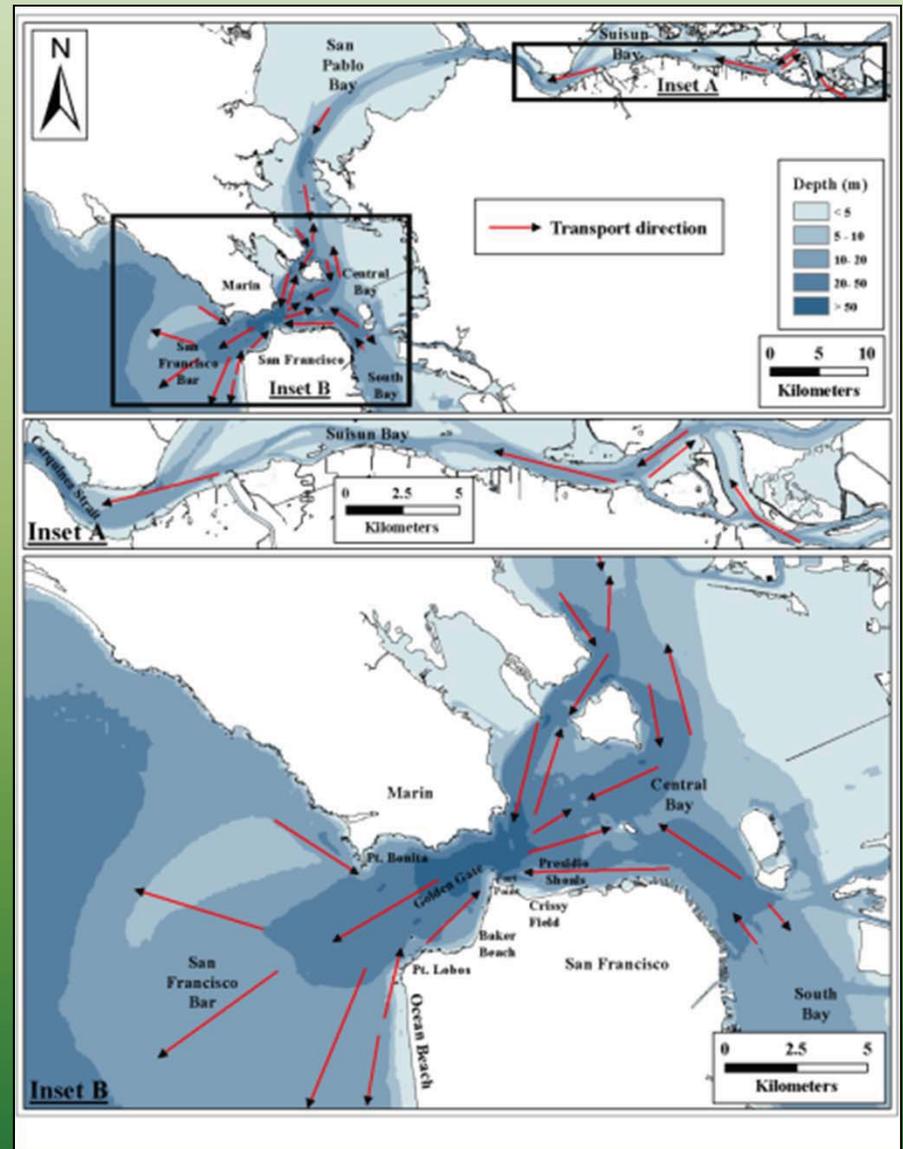
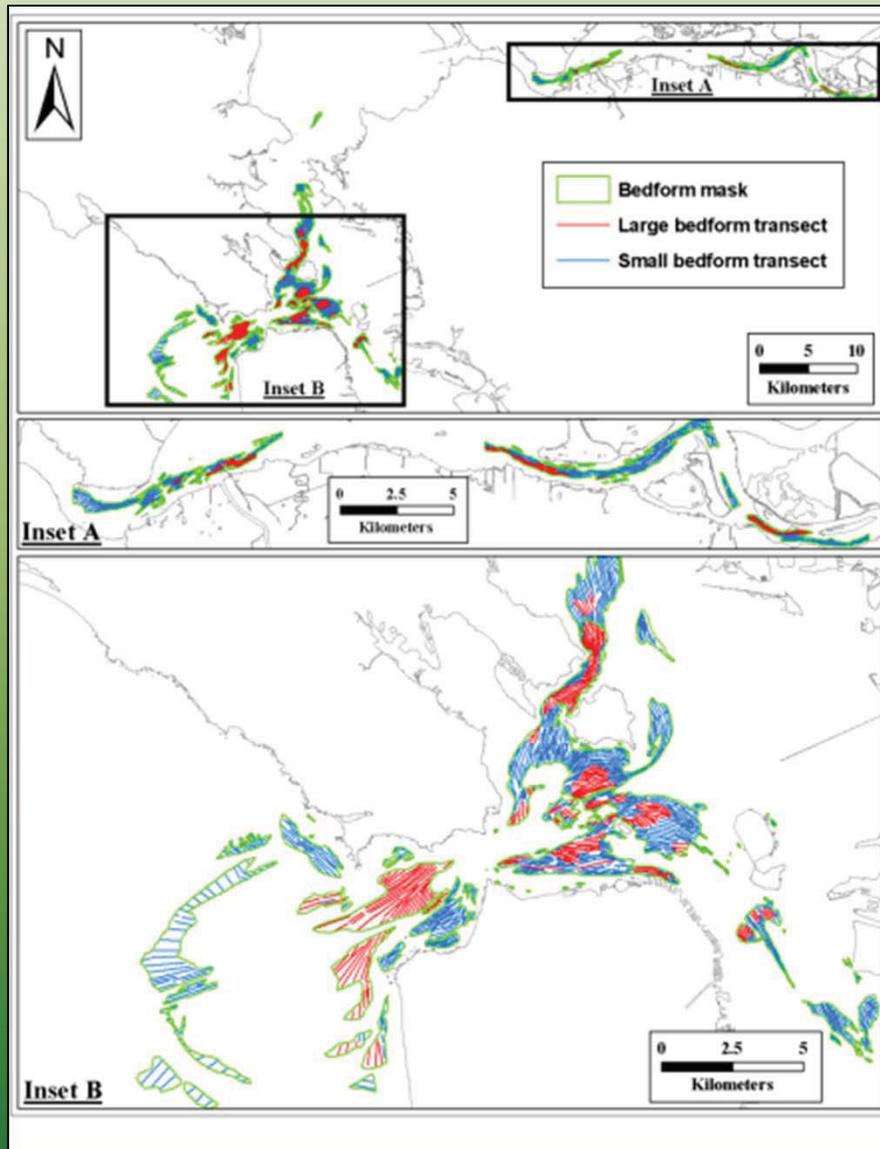
•36% decrease in suspended sediment concentration between 1991-98 and 1999-2007 (Schoellhamer, *Estuaries and Coasts*, 2011)



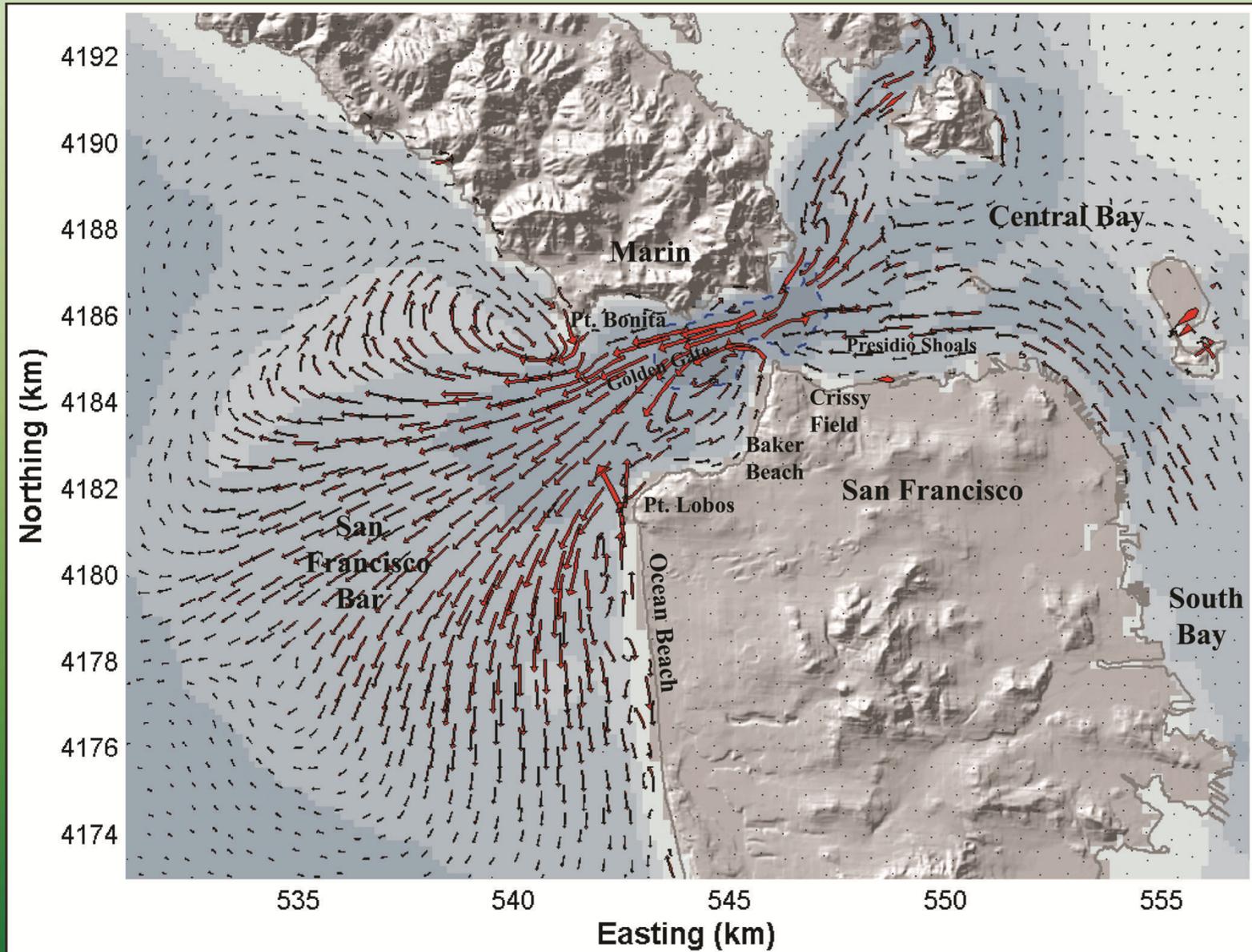
# Bedform Morphology



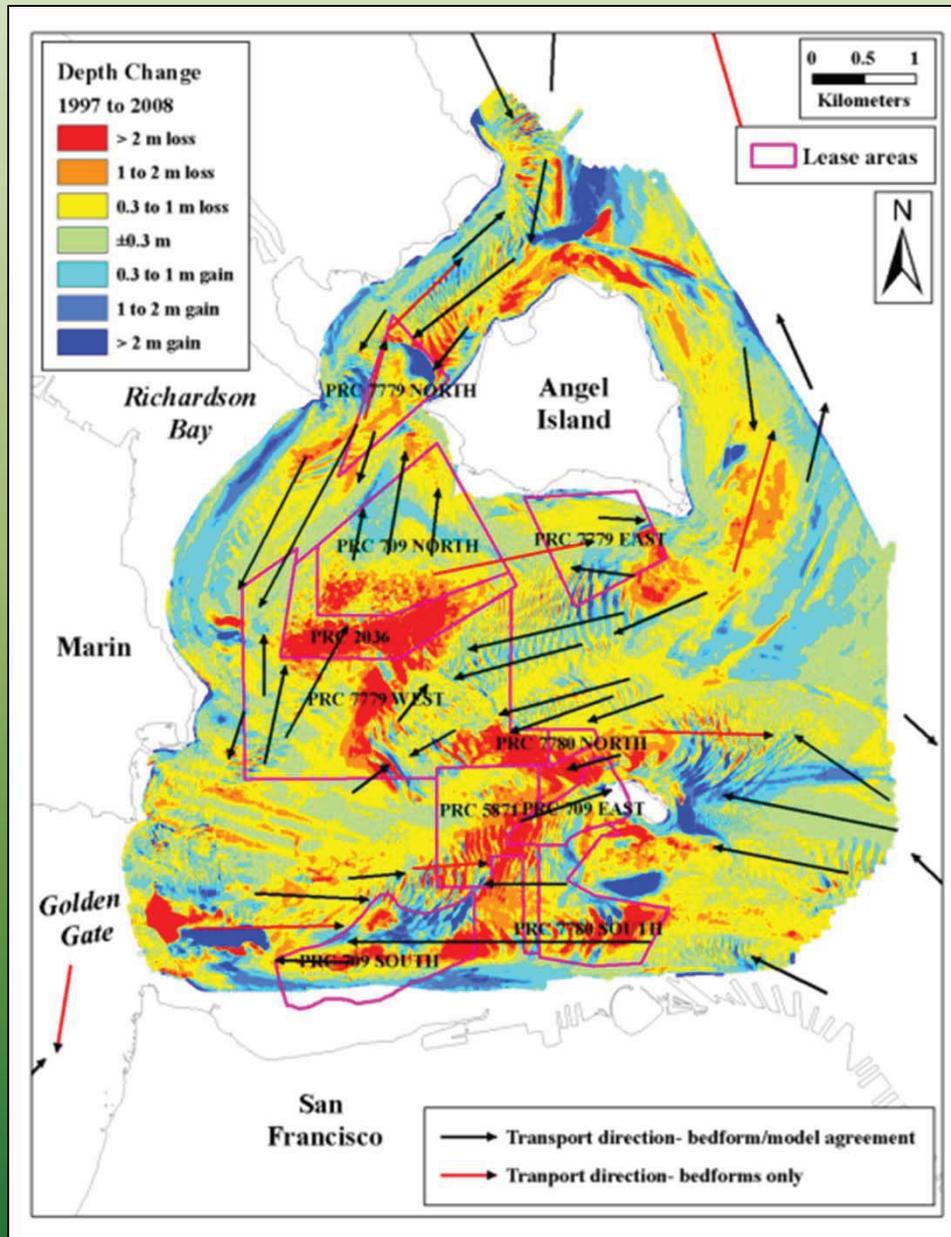
# Bedform Morphology



# Numerical Modeling- Annual Transport

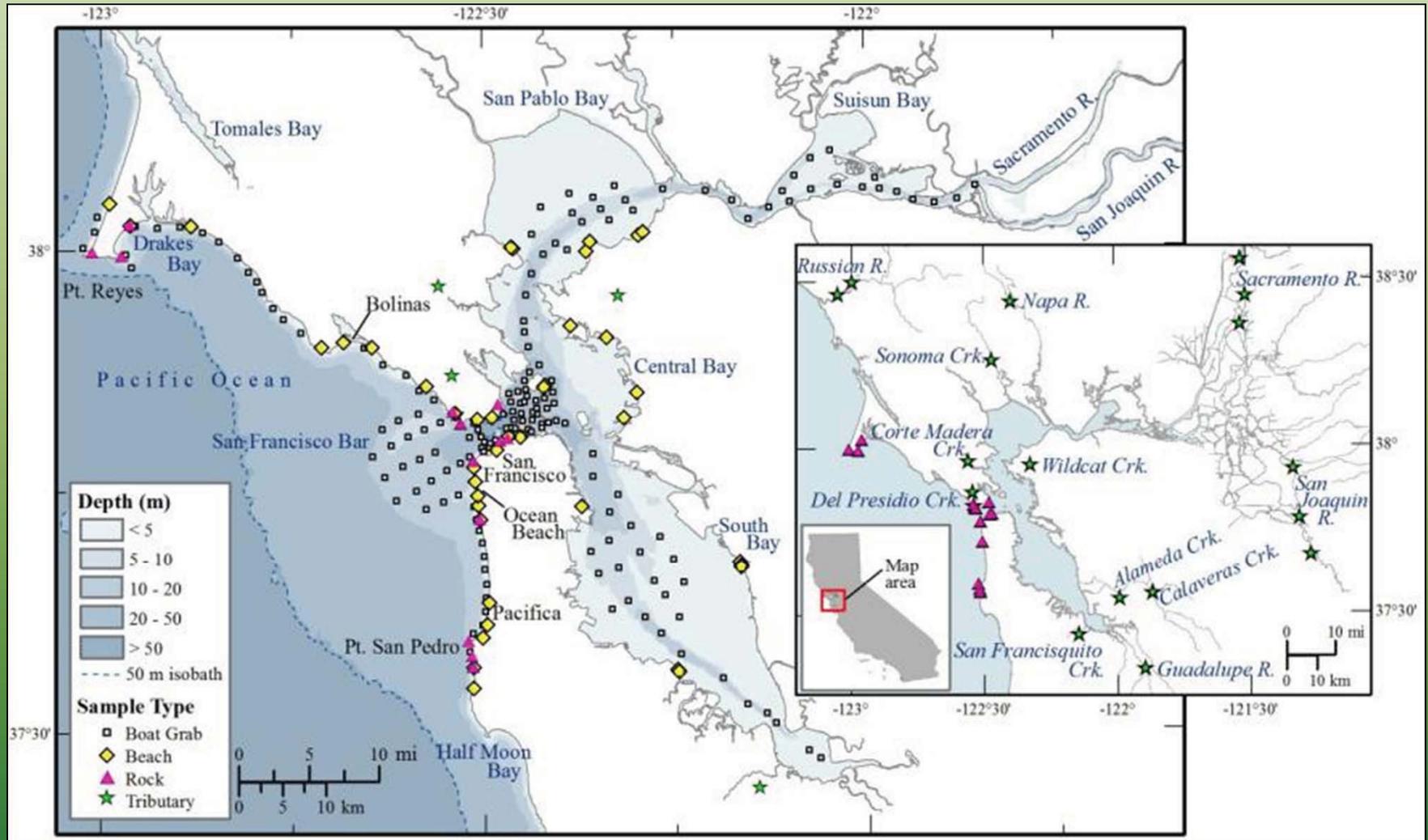


# 1997-2008 Bathymetric Change

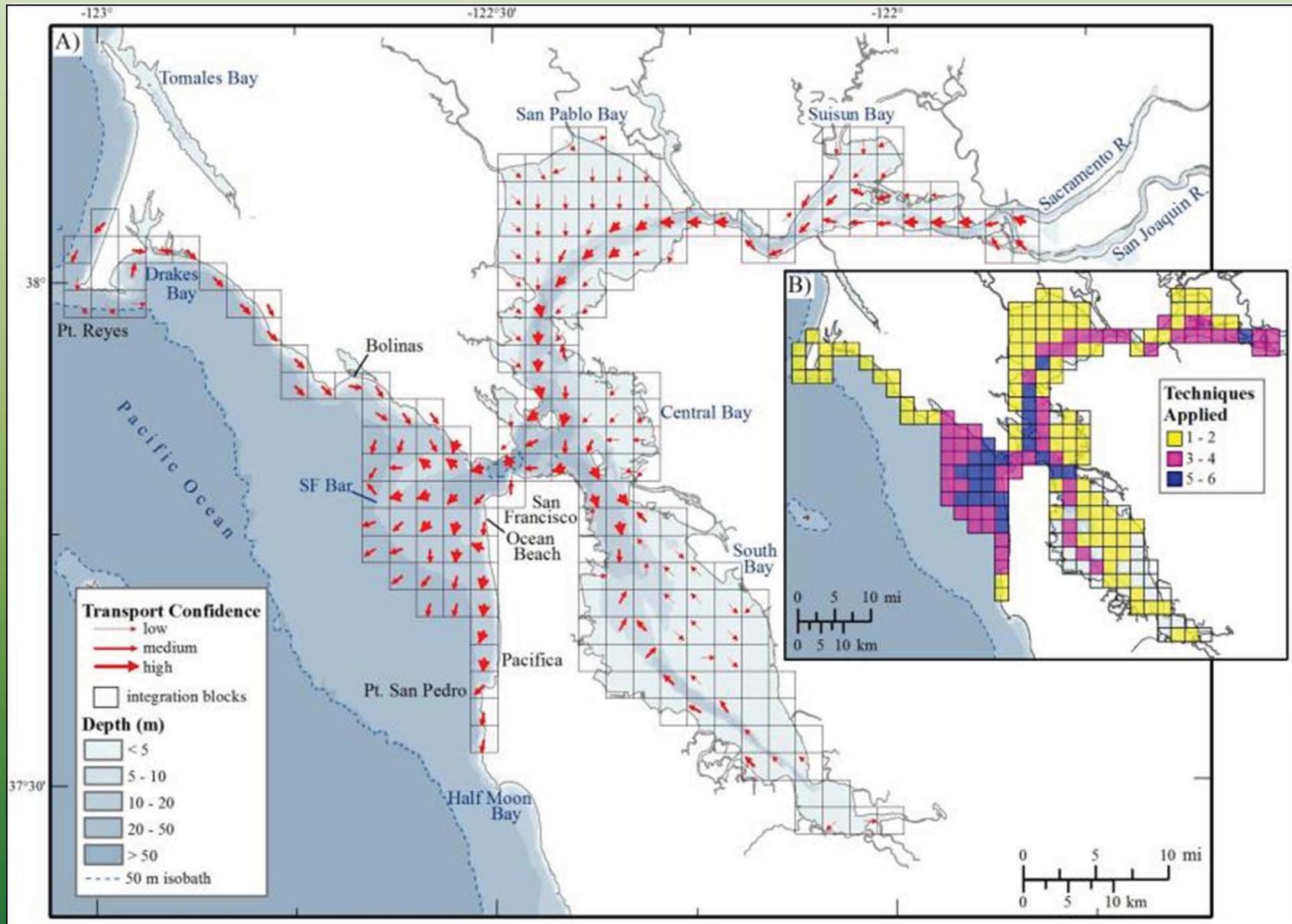


- ~3-fold increase in rate of erosion (-3.2 cm/yr) from 1947-1979 change analysis (Fregoso et al., 2008)
- Lease sites lost sediment at a rate 5 times higher than rest of study area
- 10.8 million m<sup>3</sup> of sediment was removed by aggregate mining from 1997-2008 (total loss of 14.1 million m<sup>3</sup>)

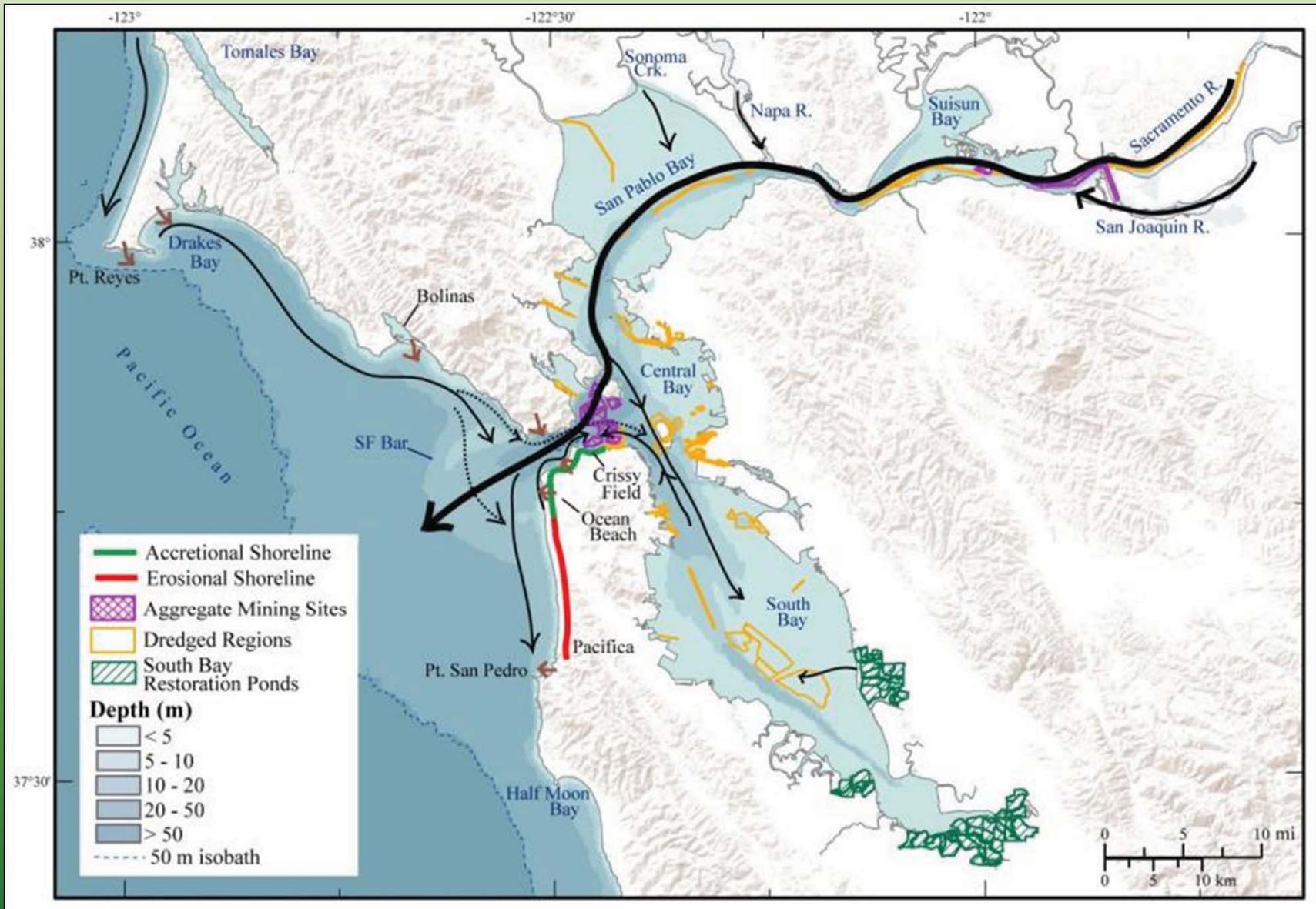
# Provenance Sampling



# Technique Integration

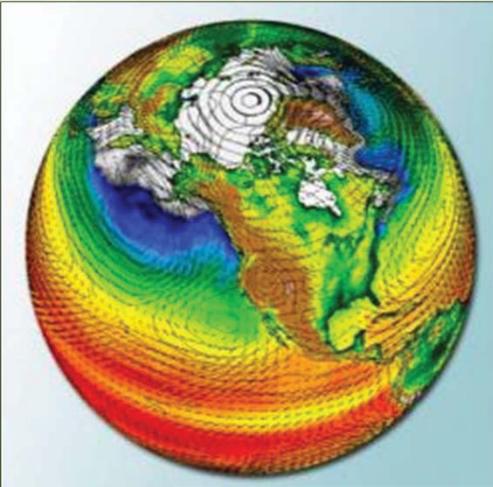


# Sources and Sinks

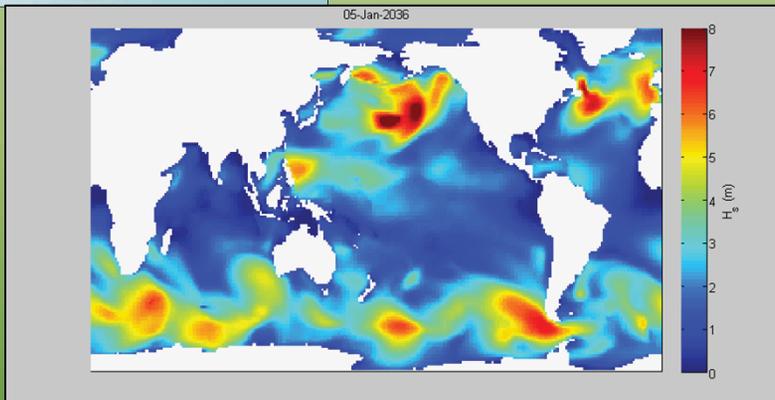


# Identifying Future Risk with CoSMoS

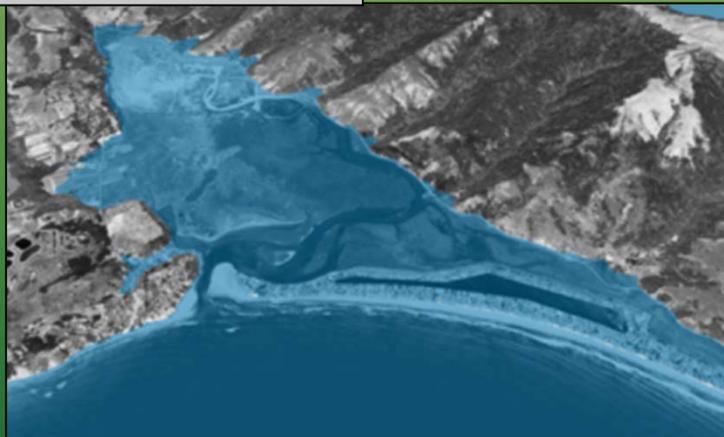
1. Global forcing using the latest climate models



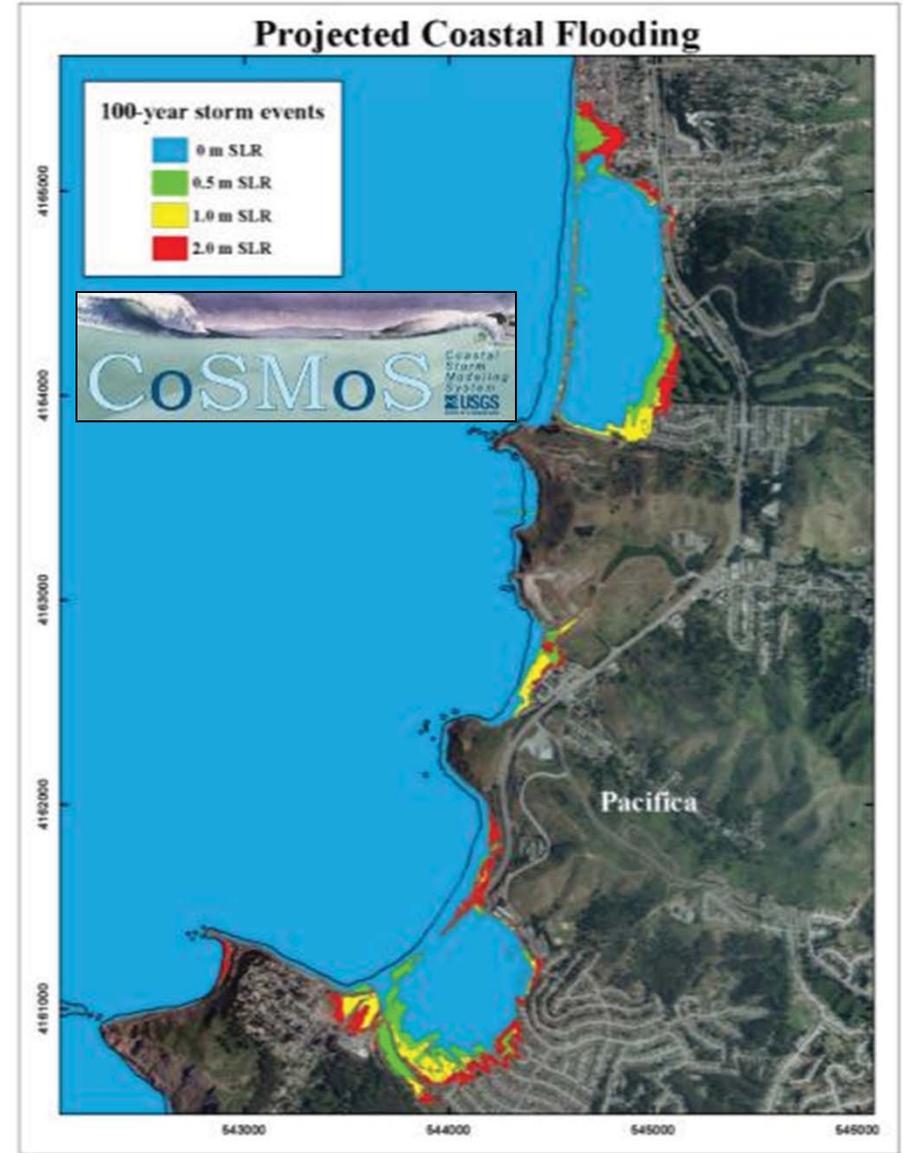
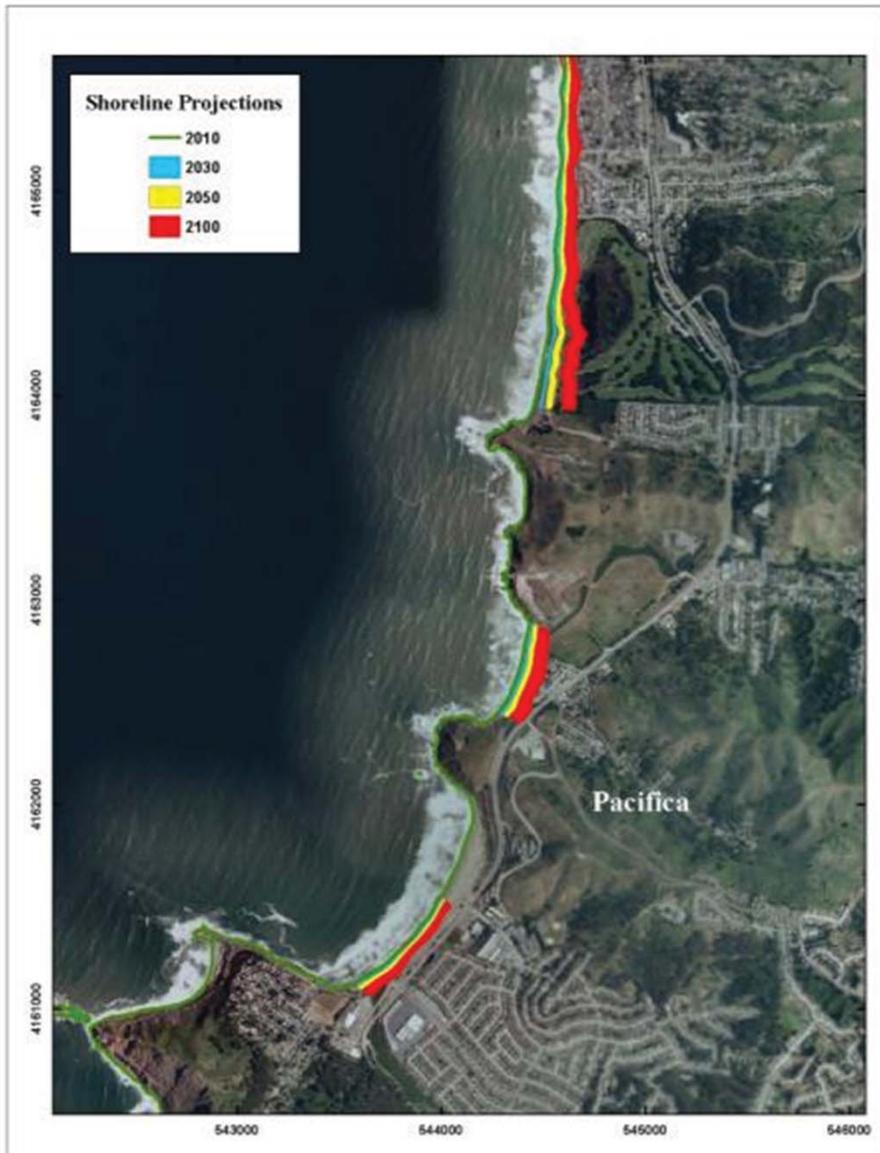
2. Drives global and regional wave models



3. Scaled down to local hazards projections



# Future Vulnerability



# Conclusions

- Pervasive loss of sediment from the San Francisco Bay Coastal System over the last 50 years, driven by anthropogenic impacts
- Reduction in sediment supply from the Delta via the Bay to the outer coast drives shrinking of the ebb tidal delta and regional coastal erosion
- Ebb tidal delta contraction modifies wave focusing patterns and nearshore hydrodynamics at Ocean Beach, leading to significant shoreline erosion in the south, further accentuated by an exposed outfall pipe
- Projected sediment supply reduction in the future will exacerbate SLR impacts



Project Website: [http://walrus.wr.usgs.gov/coastal\\_processes/](http://walrus.wr.usgs.gov/coastal_processes/)