Coastal hazards in a changing world: projecting and communicating future coastal flood risk at the local-scale using the Coastal Storm Modeling System (CoSMoS)

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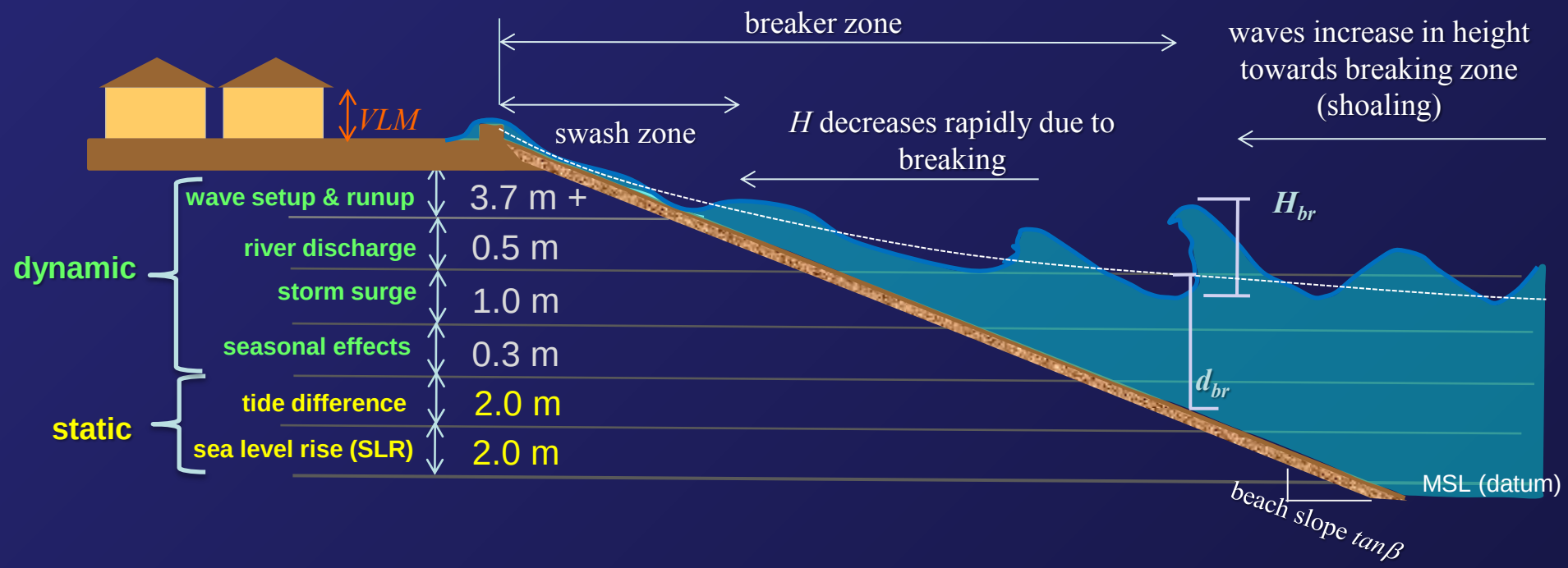
What is CoSMoS?

- Explicit numerical modeling system for assessing coastal hazards due to climate change
  - high-resolution, dynamic modeling of waves, currents, storm surge, flooding, and beach change
- Considers the future evolution of storm patterns based on Global Climate Models
- Scenario-based coastal hazard projections for the full range of sea-level rise (SLR; 0-2, 5 m) and storm possibilities (up to 100 yr storm)
- Emphasis on directly supporting federal and state-supported climate change guidance and vulnerability
- Designed for community-scale planning

Ventura Pier, December 2015
(Ricky Staub)

Processes included in CoSMoS

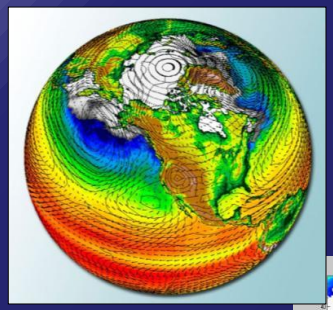
flood level is the combination of
SLR + tides + seasonal effects + storm surge + wave setup + wave runup + fluvial discharge backflow



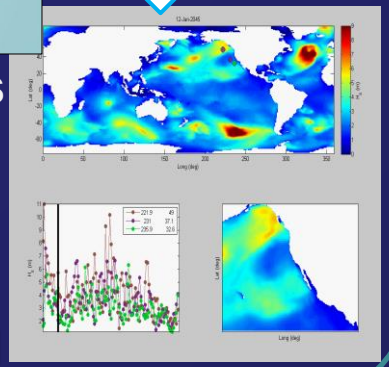
Conceptual Modeling Framework

Global

Global climate models (GCMs)



GCM winds

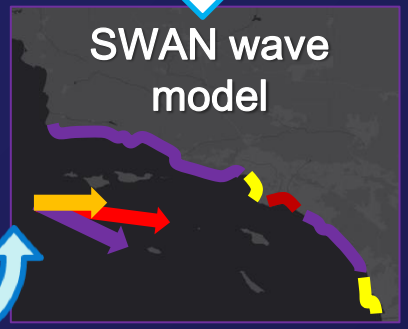


WW3 wave model

Select storm events

Regional

Tides, water levels, and regional forcing

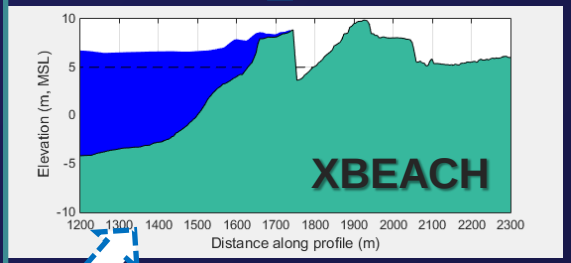


Downscaled winds and SLPs for storm events

Boundary conditions

Local

High resolution hydrodynamics, waves, & fluvial discharge

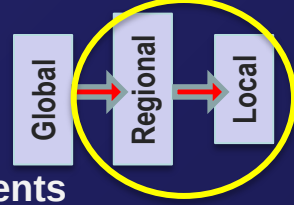


Long-term cliff recession and shoreline change

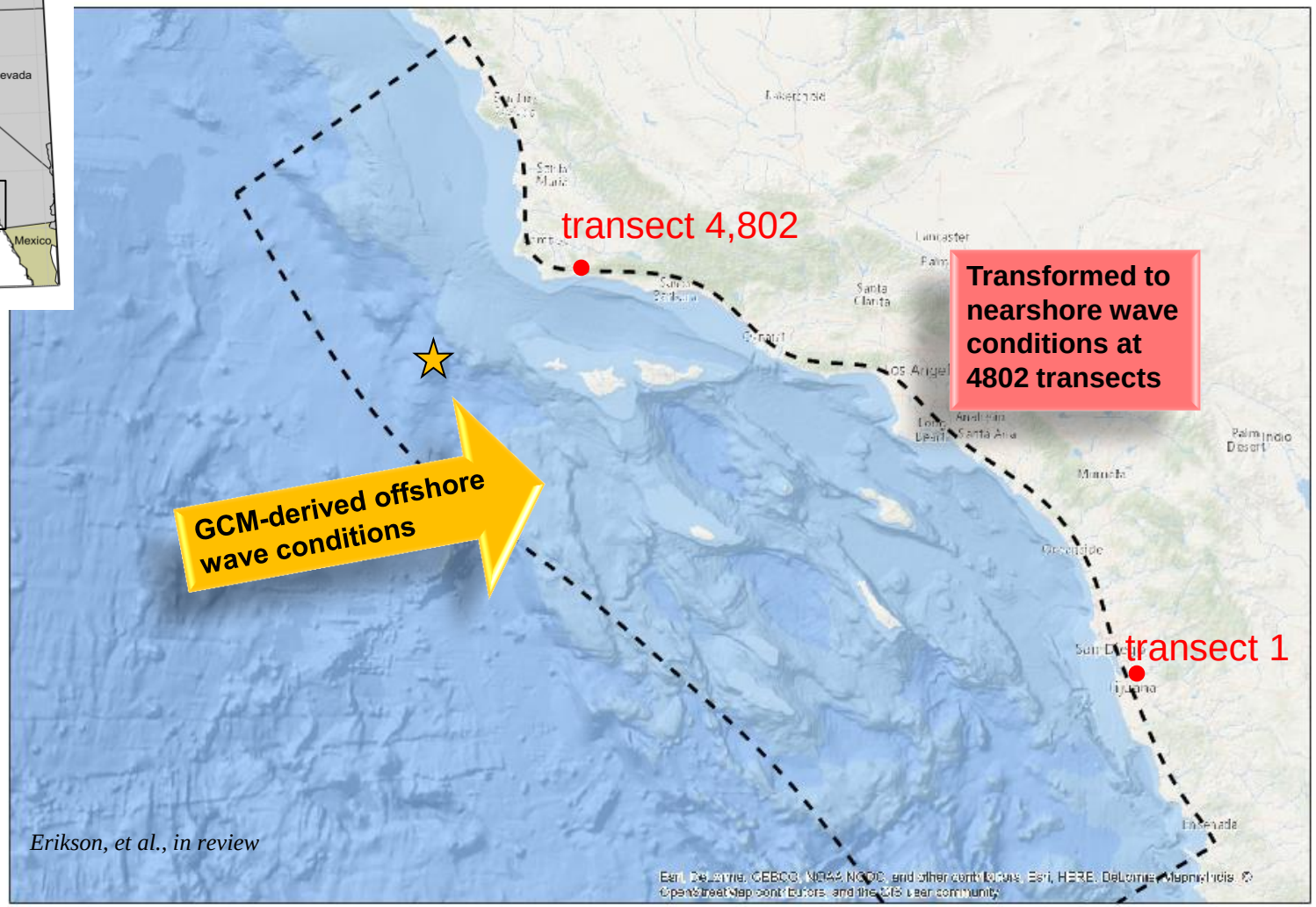
results projected onto hi-res DEM

CoSMoS Coastal Storm Modeling System USGS

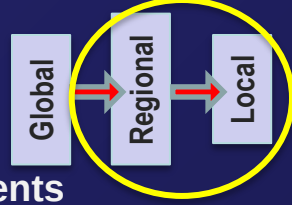
Storm Selection



- 21st century wave time series generated for all non-tidal water level components
  - Output every 100 m at 10 m contour
- determine local return periods



Storm Selection



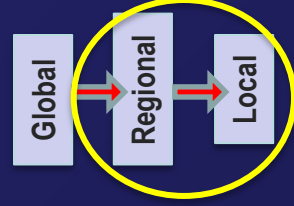
- 21st century wave time series generated for all non-tidal water level components
  - Output every 100 m at 10 m contour
- determine local return periods

Los Angeles

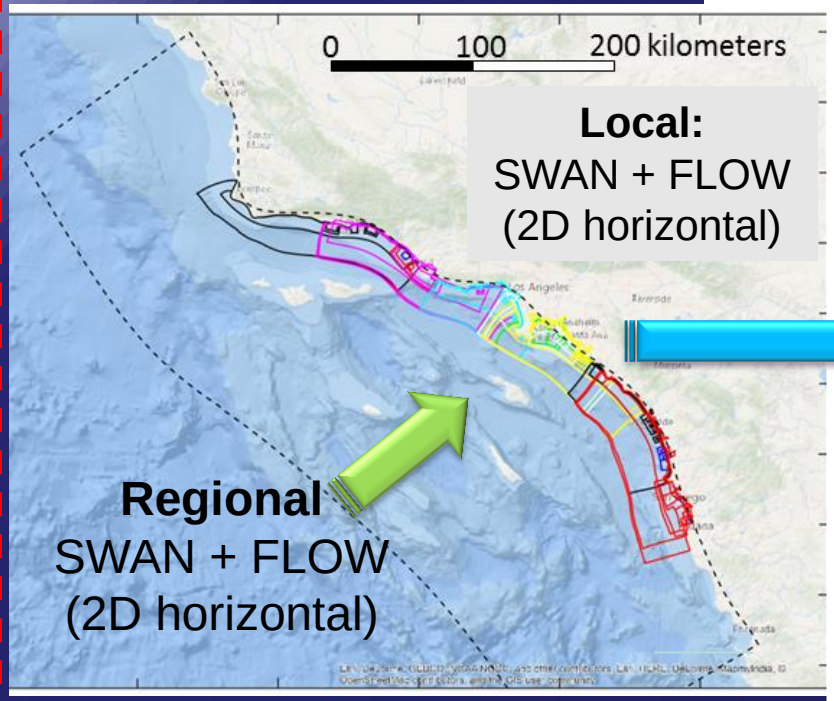
	20-yr RP	100-yr RP
Storm A	39%	95%
Storm B	30%	3%
Storm C	22%	2%
Storm D	9%	0%

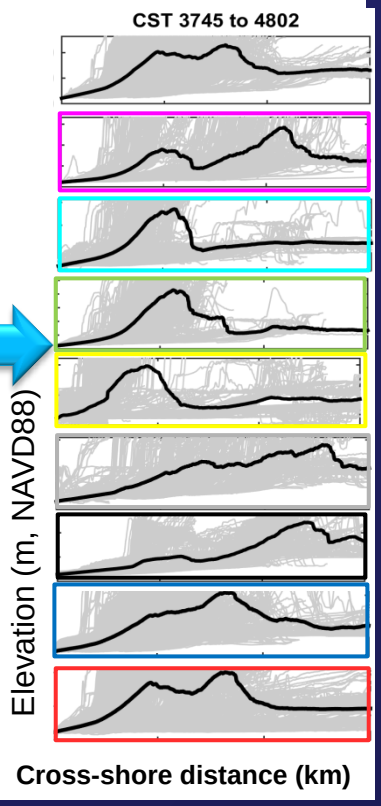
1. Transect TWL_{proxy} = Runup + Surge + SLA
2. From RP curves at each transect define coastal segments of similar storm response
3. Select storm events for 1 yr, 20 yr, and 100yr RP for each segment

Model setup

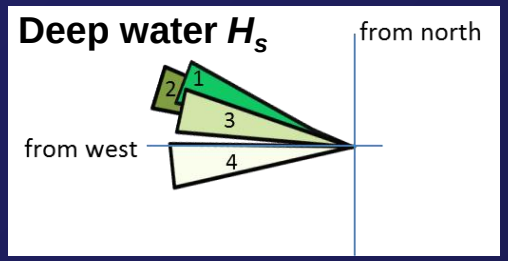


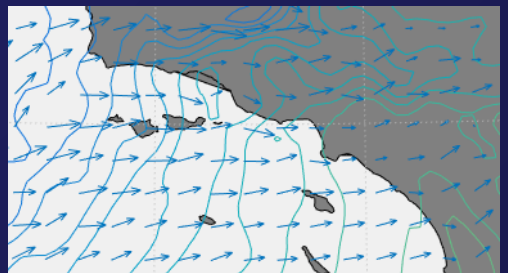
Local: XBeach (transect)



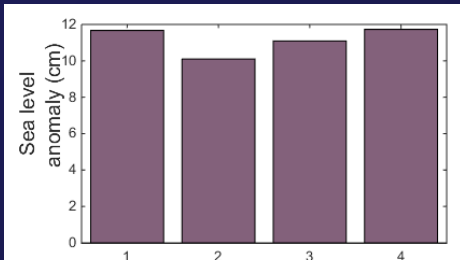


Selected storm event:





Time- and space-varying wind and sea-level pressure



sea-level anomalies (e.g. ENSO, PDO, etc.)

Multiple storm events are simulated explicitly with regional and local models

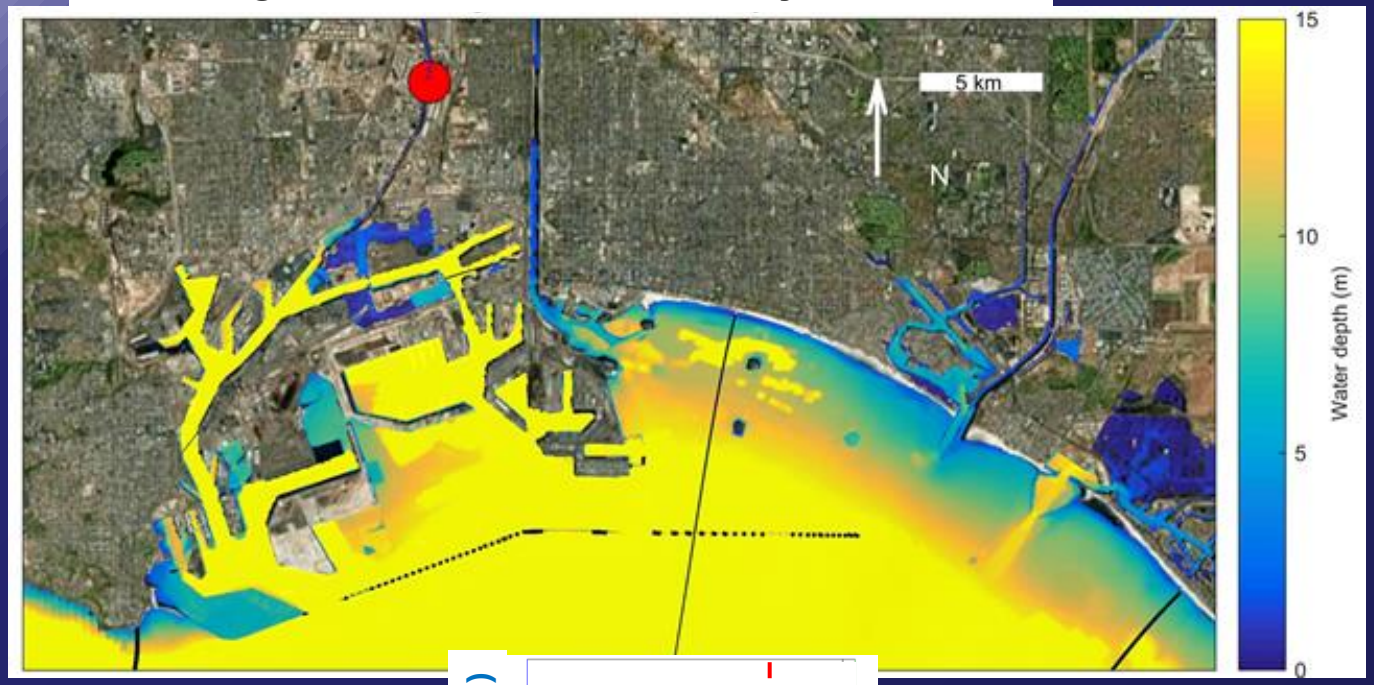
Return Period

Storm A

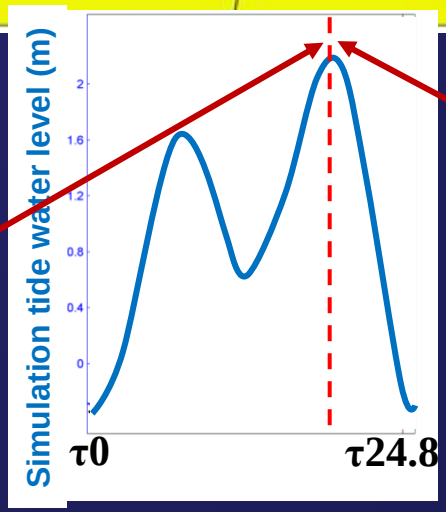
Storm B

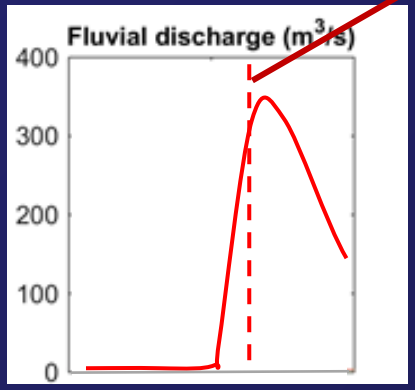
Storm C

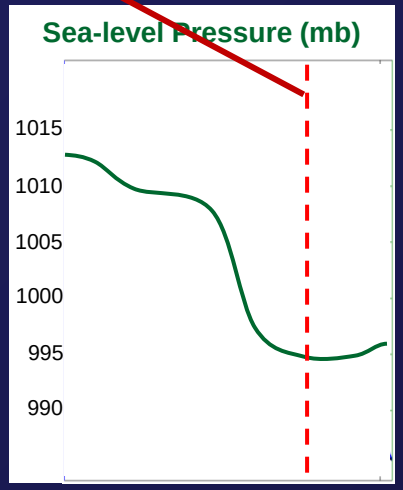
Los Angeles 50 cm SLR + 100 year storm



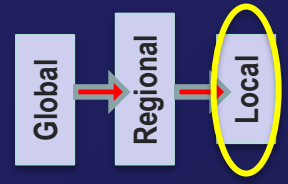
Global → Regional → Local





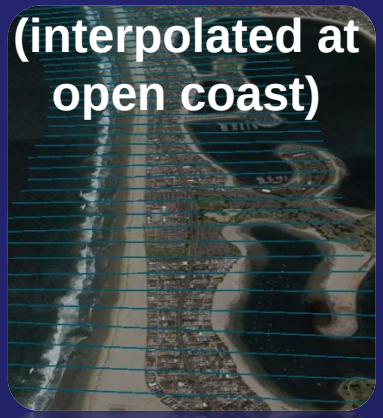


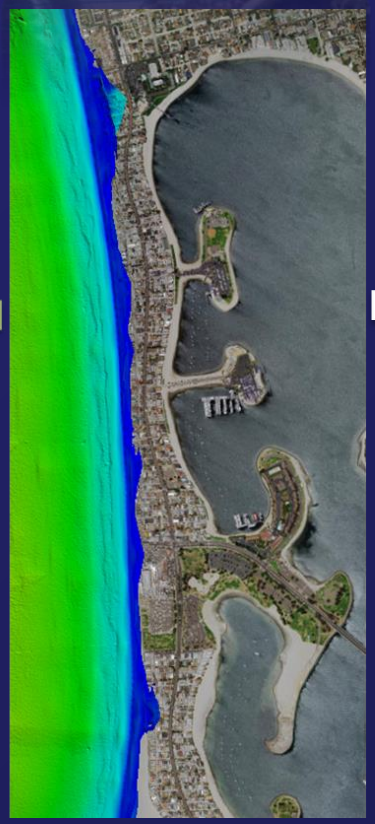
Flood projection



High-res. Delft3D (harbors, estuaries, lagoons …)

XBeach transects (interpolated at open coast)

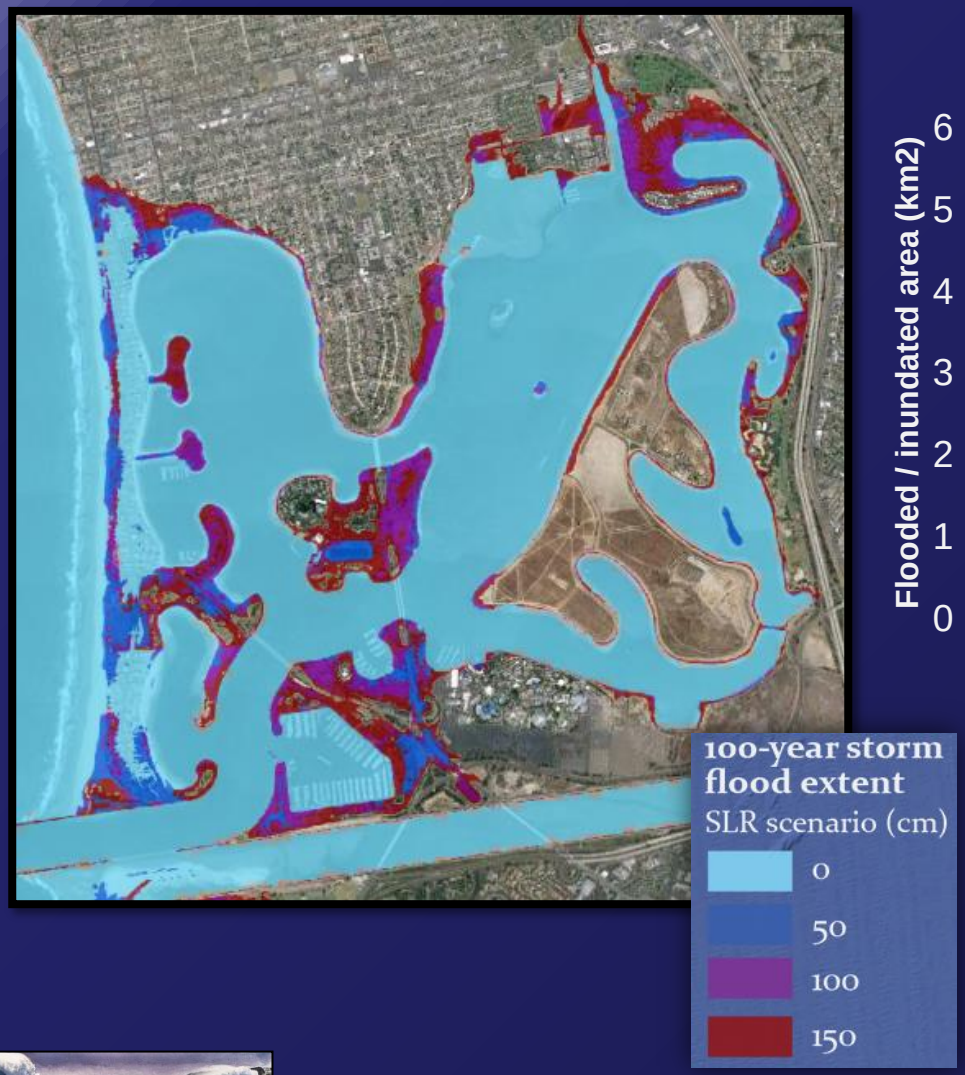


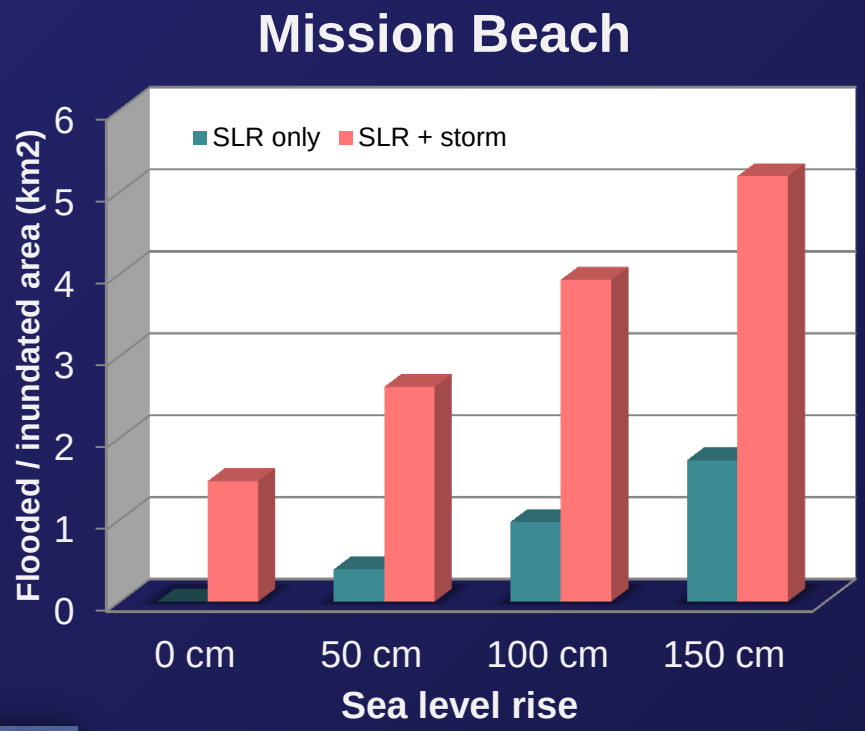


Digital Elevation Model

Storm flood map

Impact of dynamic processes

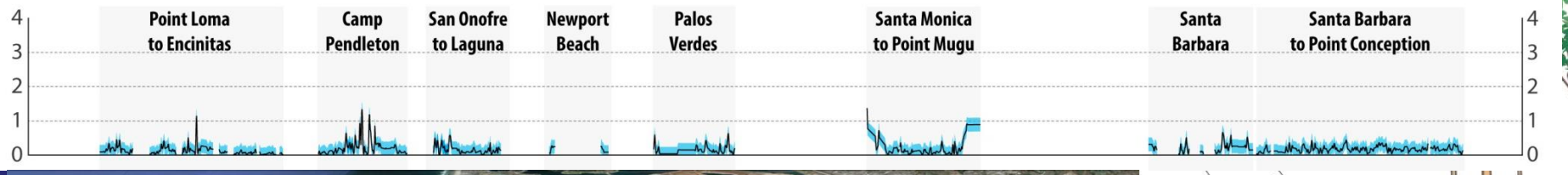


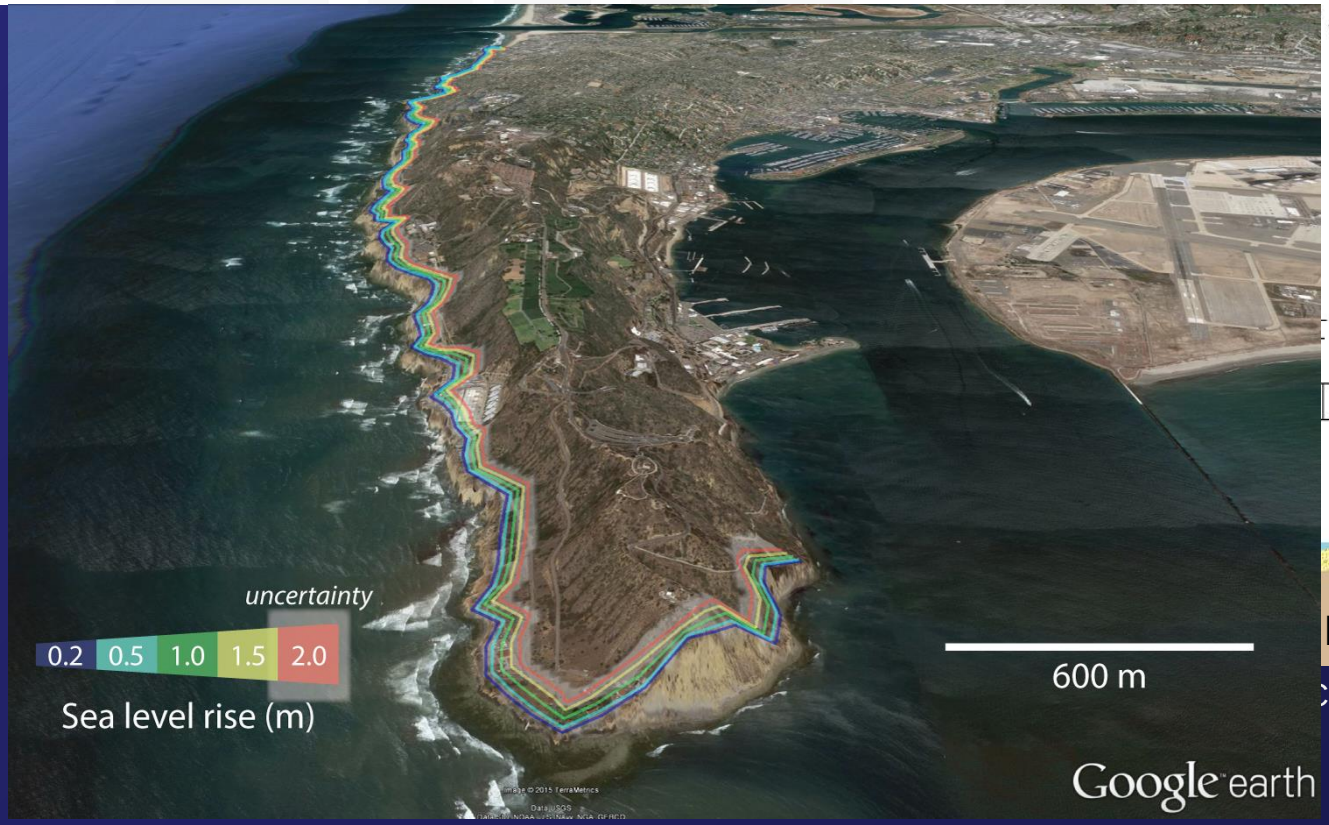


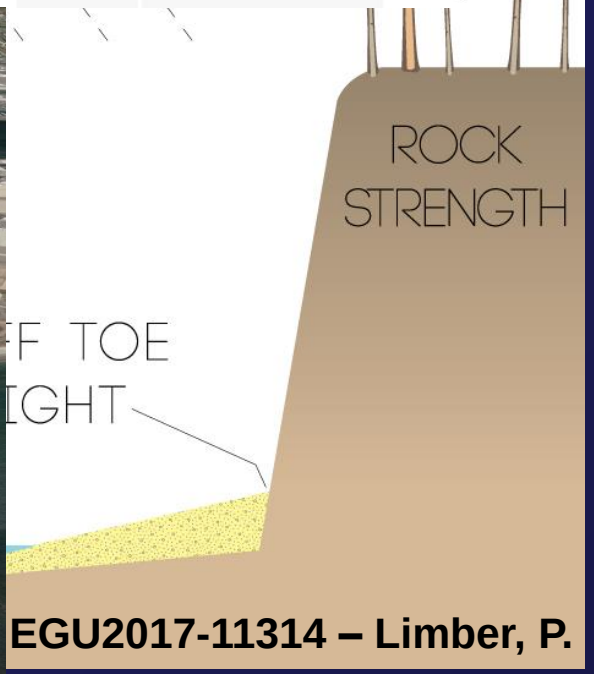
Multi-decadal cliff retreat

Global → Regional → Local

Long-term retreat rate (m/yr) for 25 cm SLR







EGU2017-11314 – Limber, P.

Coastal Sediments 2015 Conference

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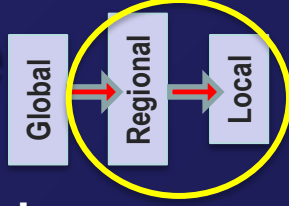
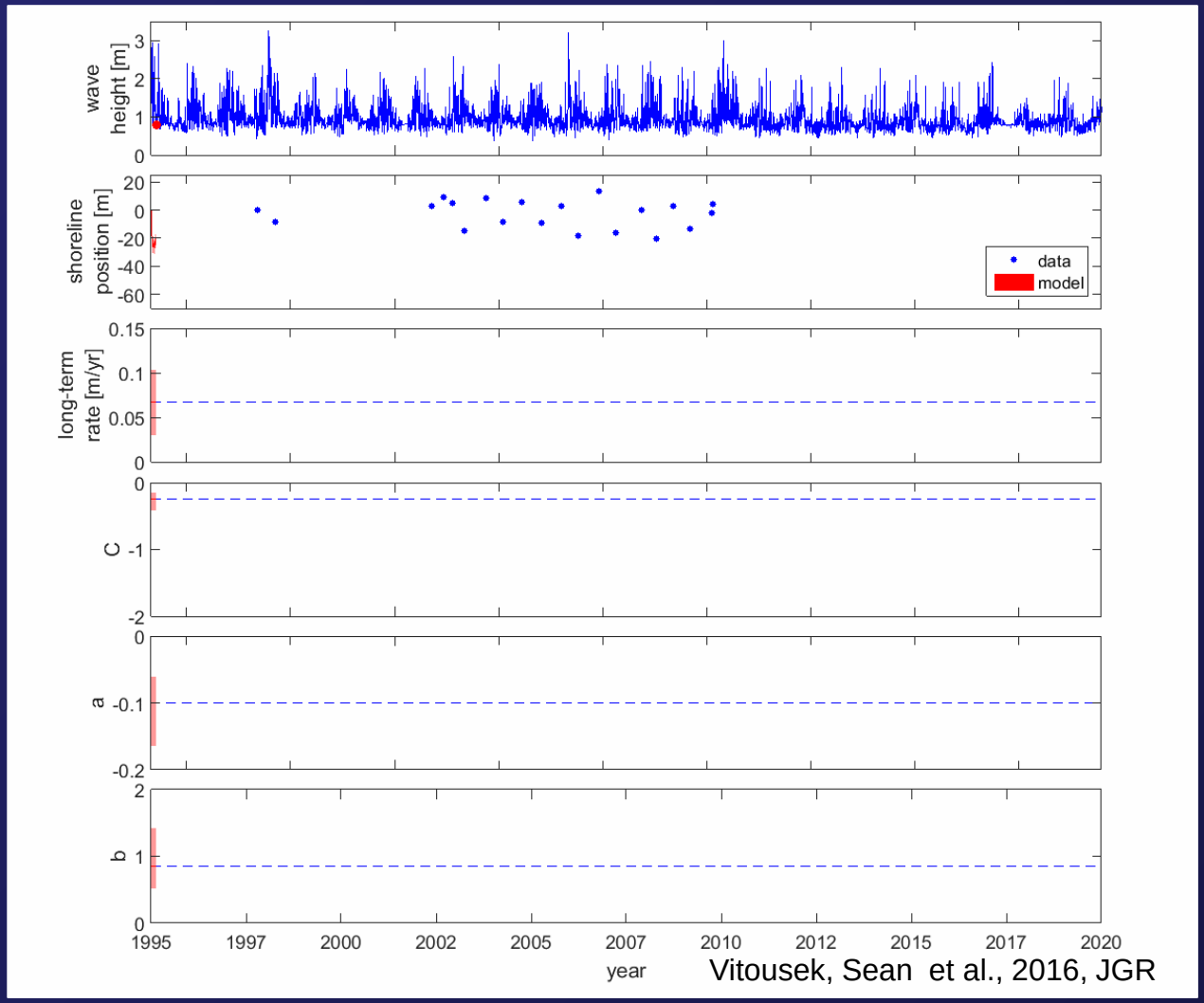
Long-term sandy shoreline change

Coastal One-line Assimilated Simulation Tool



A (hybrid) numerical transect model solving conservation of sediment by waves and SLR

- **Uses data assimilation to auto-tune model parameters at each transect**

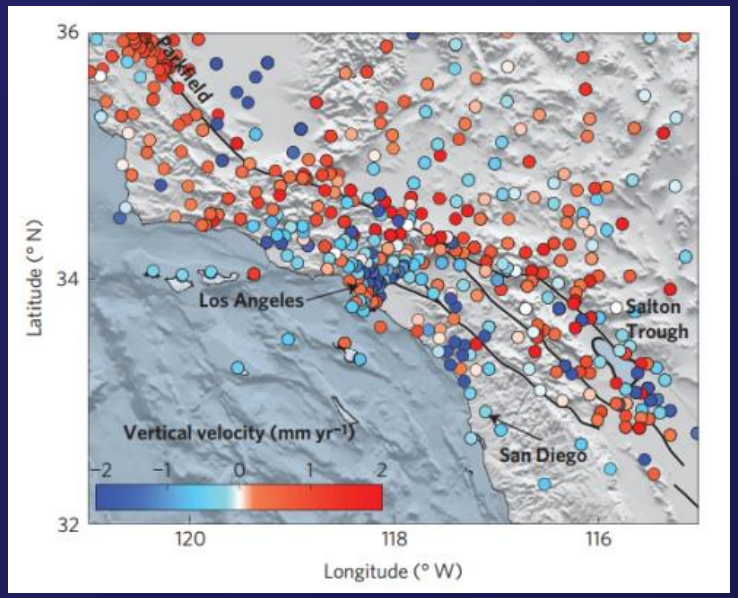


Vitousek, Sean et al., 2016, JGR

Flood potential – mapped uncertainty

Global → Regional → Local

raising and lowering flood elevation data by ε



$$\varepsilon = \pm 0.50\ m \quad \pm 0.18\ m + \ (0.4\ mm/yr | -0.6\ mm/yr)$$

Model uncertainty
(*rms* = 0.12 m at tide stations, increased as projected area >> tide stations)

Vertical accuracy of DEM
(*rms* = 0.18 m in open terrain) (Dewberry 2012)

Vertical land motion
Spatially variable based on GPS data and statistical and physical tectonic models (Howell et al., 2016)

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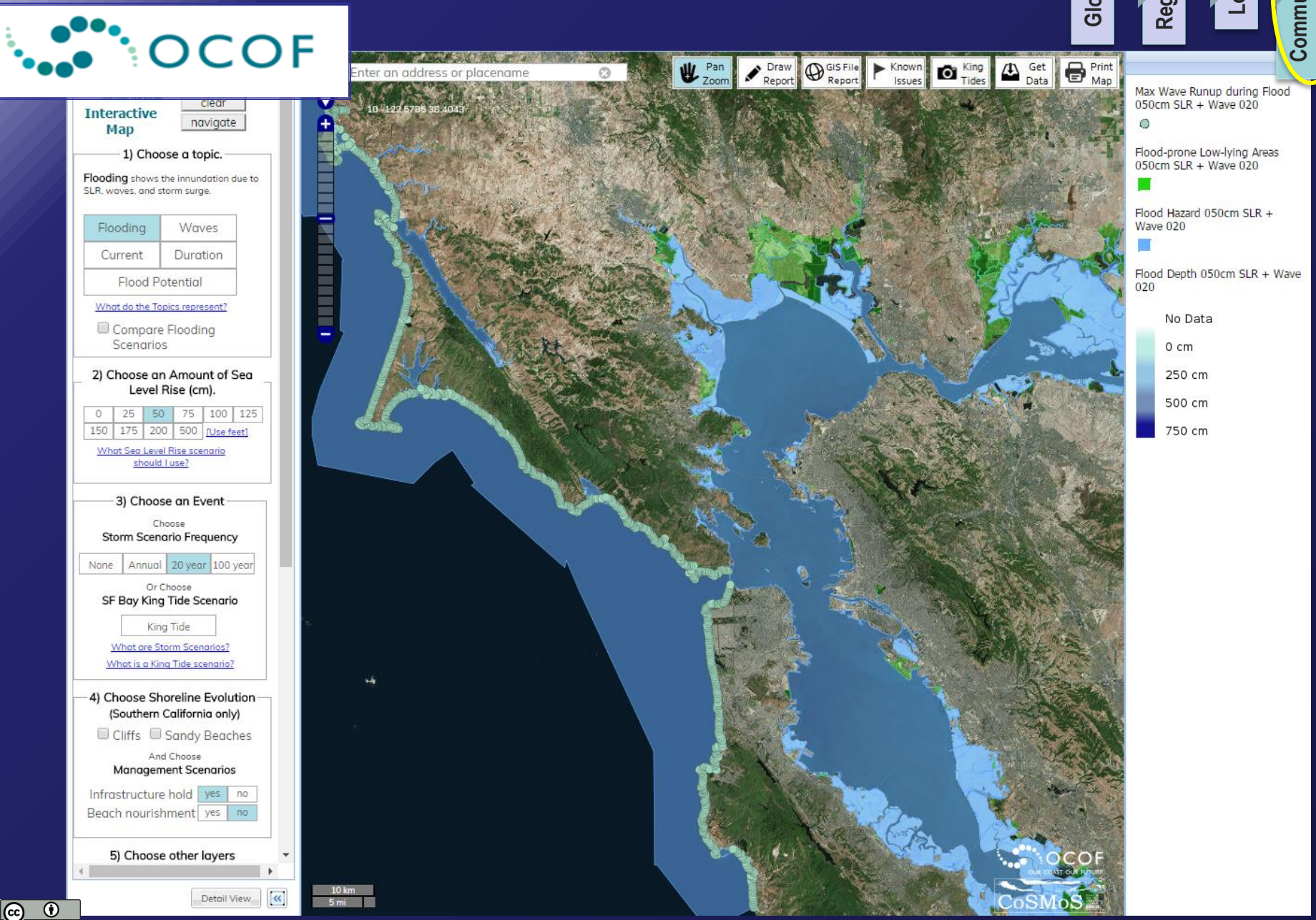
CoSMoS web tool

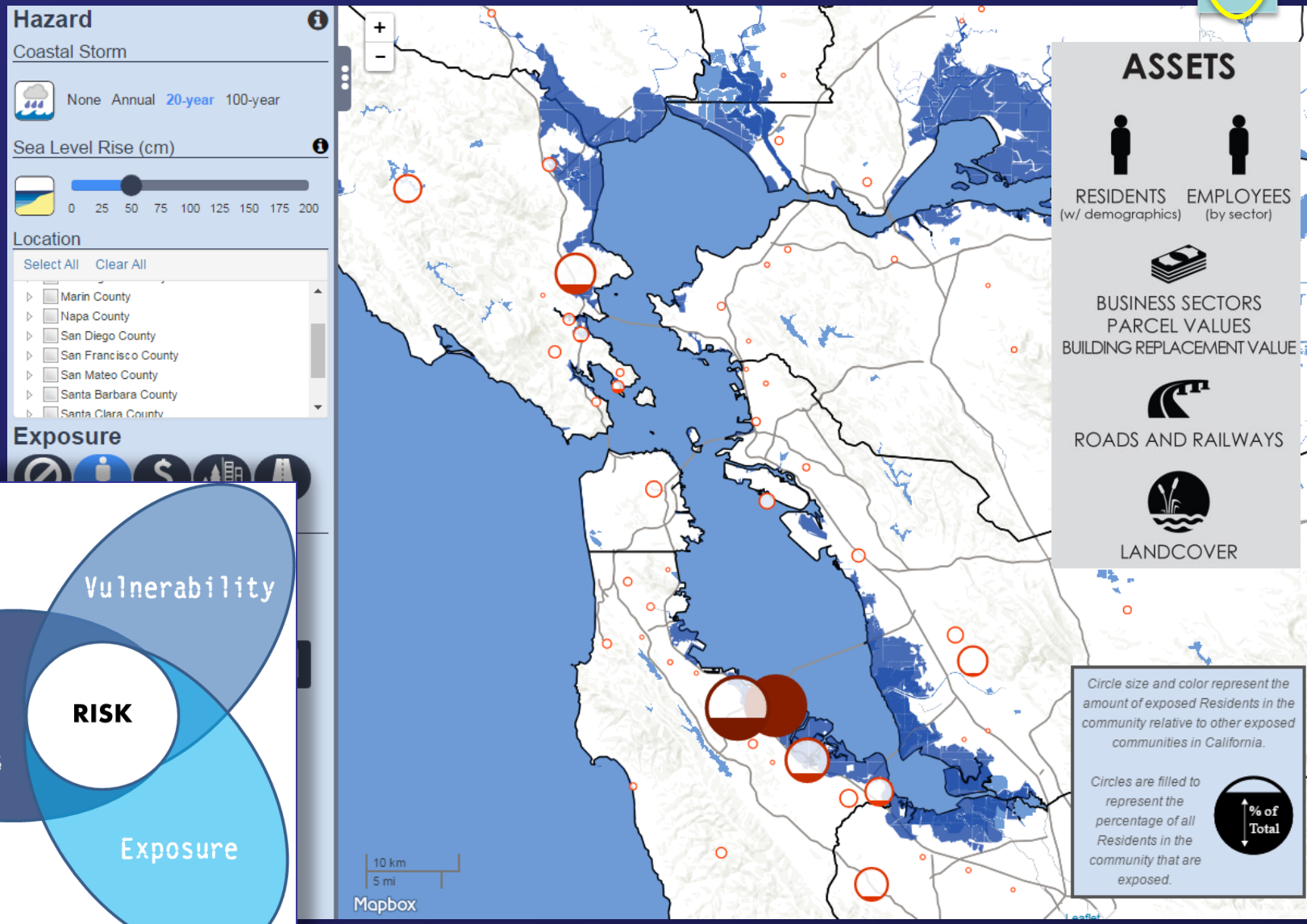
Global → Regional → Local → Communicating hazards



Socioeconomic impacts

USGS science for a changing world — Hazard Exposure Reporting and Analytics (HERA)

Global → Regional → Local → Communicating hazards



Thank you

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

Andy O'Neill: *aoneill@usgs.gov*

USGS CoSMoS website and links to technical reports/publications:

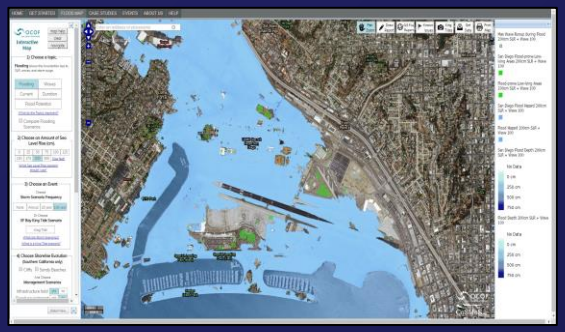
http://walrus.wr.usgs.gov/coastal_processes/cosmos/

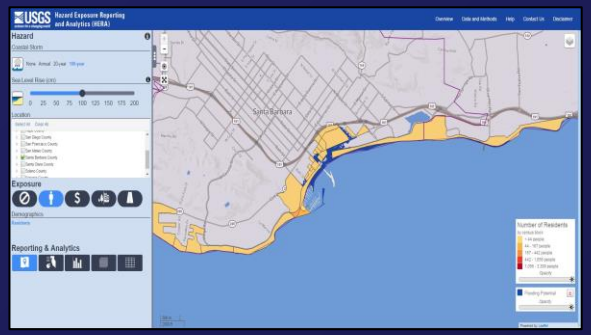
Our Coast - Our Future tool:

www.ourcoastourfuture.org

HERA Tool:

www.usgs.gov/apps/hera





Supporting References

Barnard, P.L., van Ormondt, M., Erikson, L.H., Eshleman, J., Hapke, C., Ruggiero, P., Adams, P.N. and Foxgrover, A.C., 2014. Development of the Coastal Storm Modeling System (CoSMoS) for predicting the impact of storms on high-energy, active-margin coasts. *Natural Hazards*, Volume 74 (2), p. 1095-1125, http://dx.doi.org/10.1007/s11069-014-1236-y

Erikson, L.H., Hegermiller, C.A., Barnard, P.L., Ruggiero, P. and van Ormondt, M., 2015. Projected wave conditions in the Eastern North Pacific under the influence of two CMIP5 climate scenarios. *Ocean Modeling*, Volume 96, p. 171-185, http://dx.doi.org/10.1016/j.ocemod.2015.07.004

Limber, P., Barnard, P.L. and Hapke, C., 2015. Towards projecting the retreat of California's coastal cliffs during the 21st Century. In: P. Wang, J.D. Rosati and J. Cheng (Eds.), *Coastal Sediments 2015 Conference Proceedings*, World Scientific, 14 pp., http://dx.doi.org/10.1142/9789814689977_0245

Vitousek, S. and Barnard, P.L., 2015. A non-linear, implicit one-line model to predict long-term shoreline change. In: P. Wang, J.D. Rosati and J. Cheng (Eds.), *Coastal Sediments 2015 Conference Proceedings*, World Scientific, 14 pp., http://dx.doi.org/10.1142/9789814689977_0215

Hegermiller, C.A., Antolinez, J.A.A., Rueda, A.C., Camus. P., Perez, J., Erikson, L.H., Barnard, P.L. and Mendez, F.J., 2016. A multimodal wave spectrum-based approach for statistical downscaling of local wave climate. *Journal of Physical Oceanography*, http://dx.doi.org/10.1175/JPO-D-16-0191.1

Hoover, D.J., Odigie, K.O., Swarzenski, P.W. and Barnard, P.L., 2016. Sea level rise and coastal groundwater inundation and shoaling at select sites in California. *Journal of Hydrology: Regional Studies*, 16 pp., http://dx.doi.org/10.1016/j.ejrh.2015.12.055

Danielson, J.J., Poppenga, S.K., Brock, J.C., Evans, G.A., Tyler, D.J., Gesch, D.B., Thatcher, C.A., and Barras, J.A., 2016, Topobathymetric elevation model development using a new methodology—Coastal National Elevation Database: Journal of Coastal Research, SI no. 76, p. 75–89, at http://dx.doi.org/10.2112/SI76-008

Palaseanu-Lovejoy, M., Danielson, J., Thatcher, C., Foxgrover, A., Barnard, P.L., Brock, J. and Young, A., 2016. Automatic delineation of seacliff limits using Lidar-derived high-resolution DEMs in Southern California. *Journal of Coastal Research*, Special Issue Volume 76, p. 162-173, http://dx.doi.org/10.2112/SI76-014

Thatcher, C.A., Brock, J.C., Danielson, J.J., Poppenga, S.K., Gesch, D.B., Palaseanu-Lovejoy, M.E., Barras, J.A., Evans, G.A., and Gibbs, A.E., 2016, Creating a Coastal National Elevation Database (CoNED) for science and conservation applications: Journal of Coastal Research, SI no. 76, p. 64–74, at http://dx.doi.org/10.2112/SI76-007

Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., in press. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface,* http://dx.doi.org/10.1002/2016JF004065