Sea Level Rise Science & Modeling 101

Li Erikson, Patrick Barnard, Andrea O'Neill, Amy Foxgrover, Patrick Limber, Sean Vitousek, etc.

USGS, Coastal and Marine Geology Program

Pacific Coastal and Marine Science Center, Santa Cruz, CA

- Coastal Storm Modeling System -

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

Overview

1. SLR science
   - Trends & impacts
   - Not just SLR….
2. Modeling 101 with CoSMoS
   - Global-regional-local
   - Overview of CoSMoS versions
   - How does the current SoCal CoSMoS differ effort differ from previous versions?
3. Current status and how is this study complementary to other efforts?
   - Grids etc.
   - Storm selection
   - Complementary work

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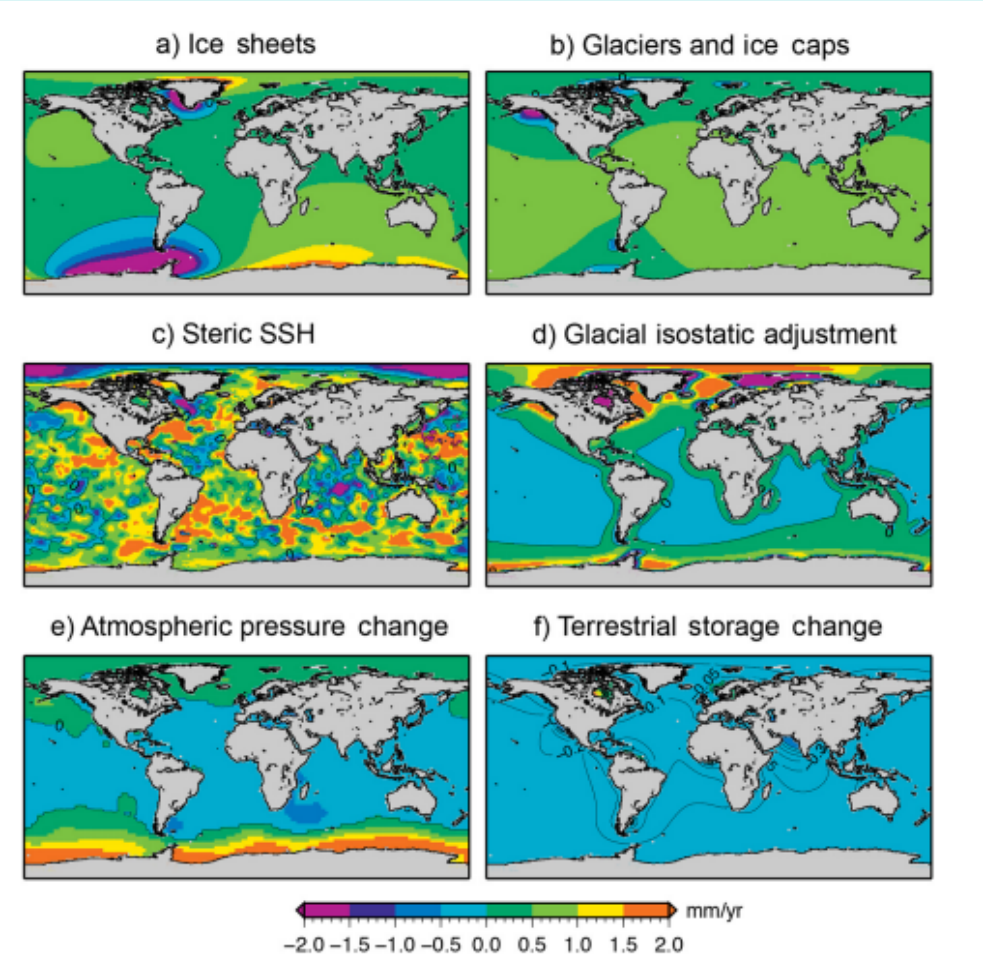
Sea Level Rise 101

What causes sea level change?

70 m of SLR stored in ice sheets of Antarctica, 7 m in Greenland!



Slangen et al. 2014

Part 1. SLR science

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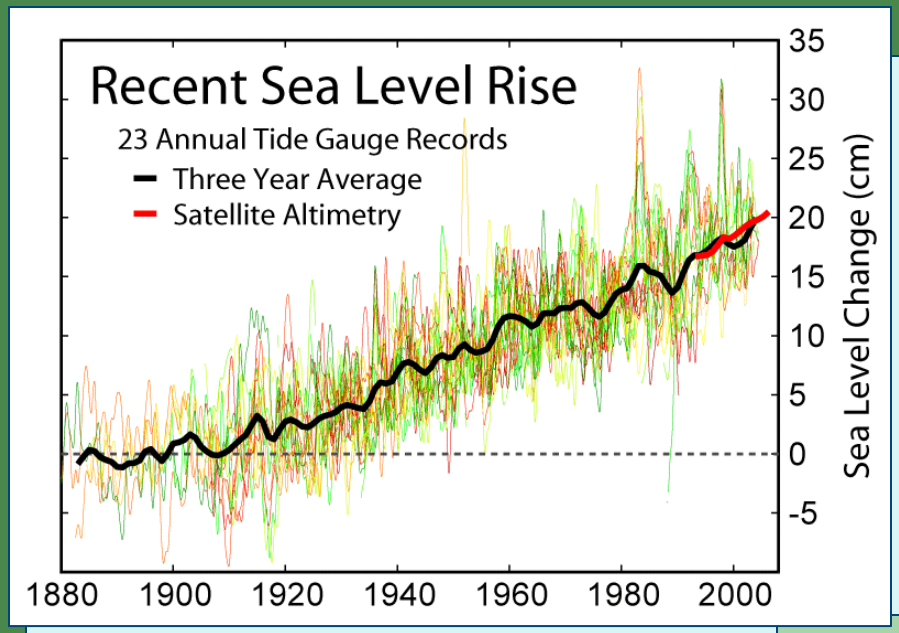
SLR over the past 100+ yrs…

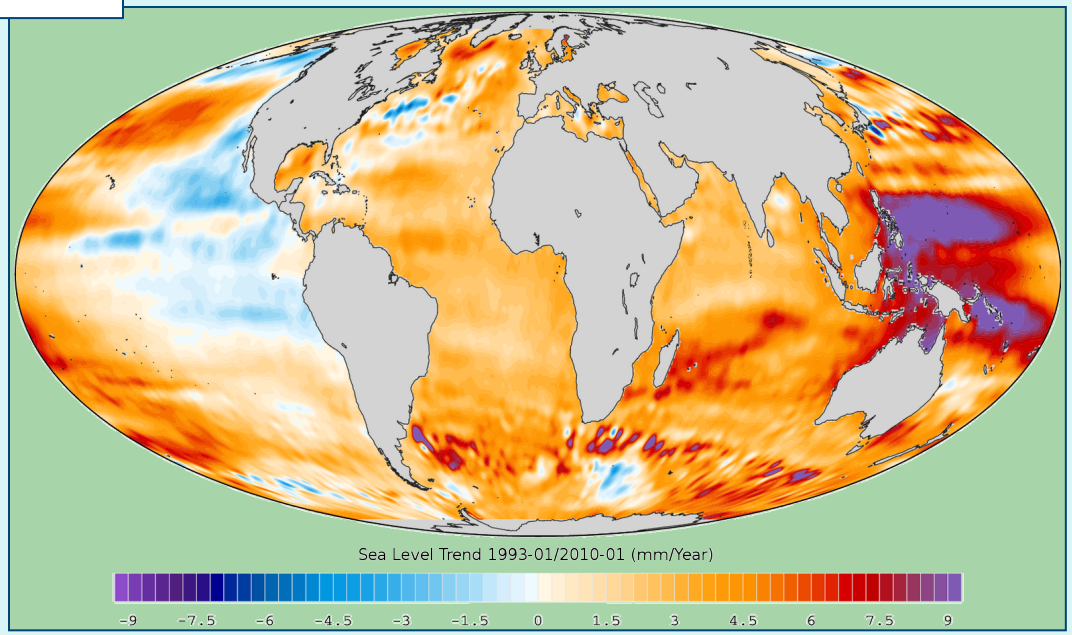


Global SLR is accelerating:

- 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')



Part 1. SLR science

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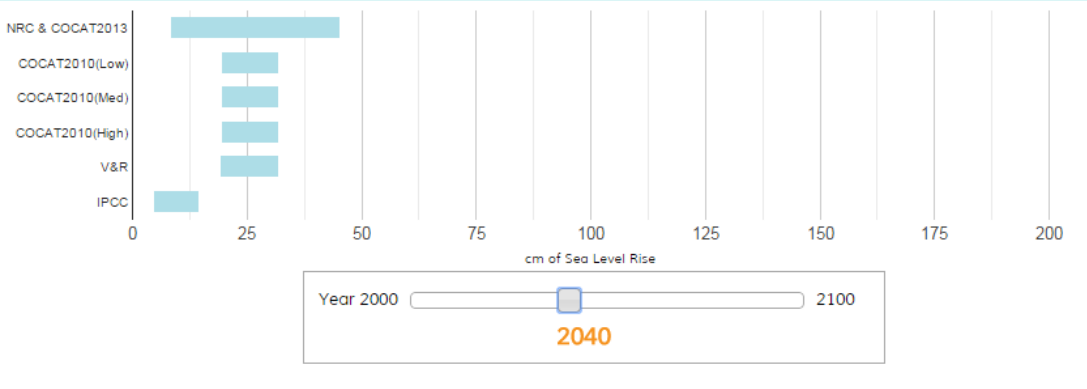
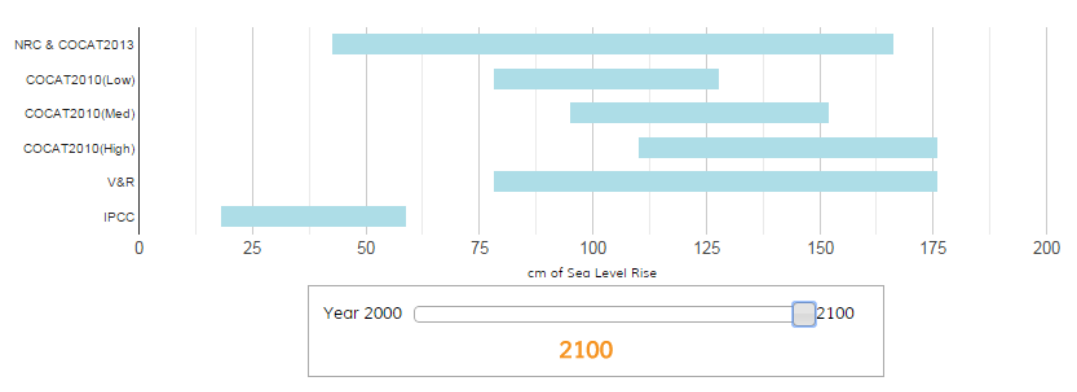
SLR projections for California

- -includes global and regional effects (e.g., wind and circulation patterns, sea level fingerprint, glacial isostatic adjustment, tectonics)





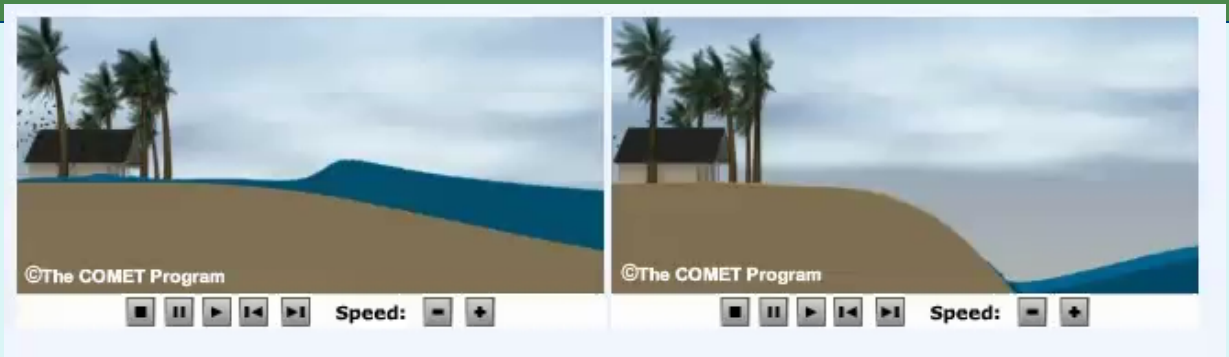
COCA: Coastal and Ocean Working Group of the California Climate Action Team. State of California Sea level rise guidance document.
NRC: National Research Council. Sea level rise for the coasts of California, Oregon, and Washington. 2012

Impacts of SLR

- 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
- In San Diego County: 10,000 people and $2 billion in property at risk (not accounting for river discharge, waves, coastal change, changes in storms, etc.)

photo: Mark Rightmire, Orange County Register

But it's not just SLR…



TWL = SLR + tides + SLA + waves + storm surge + river discharge

Total water level at the shore … aim to account for…

Sea level rise 0 m to 2 m plus an extreme

Astronomic tides (Regular changes in water planetary motions)

Sea level anomalies (Associated with Kelvin waves and thermal expansion (e.g., water levels were raised 0.23m during most of February 1998 (El Nino)).

Wave breaking cause a rise in water level at the shore

A rise in water level due to atmospheric stemming from the Bay and cause a backflow resulting in even higher flood levels

High river discharges may impede the overland flow

Stinson Beach
50 cm SLR

Part 1. SLR science

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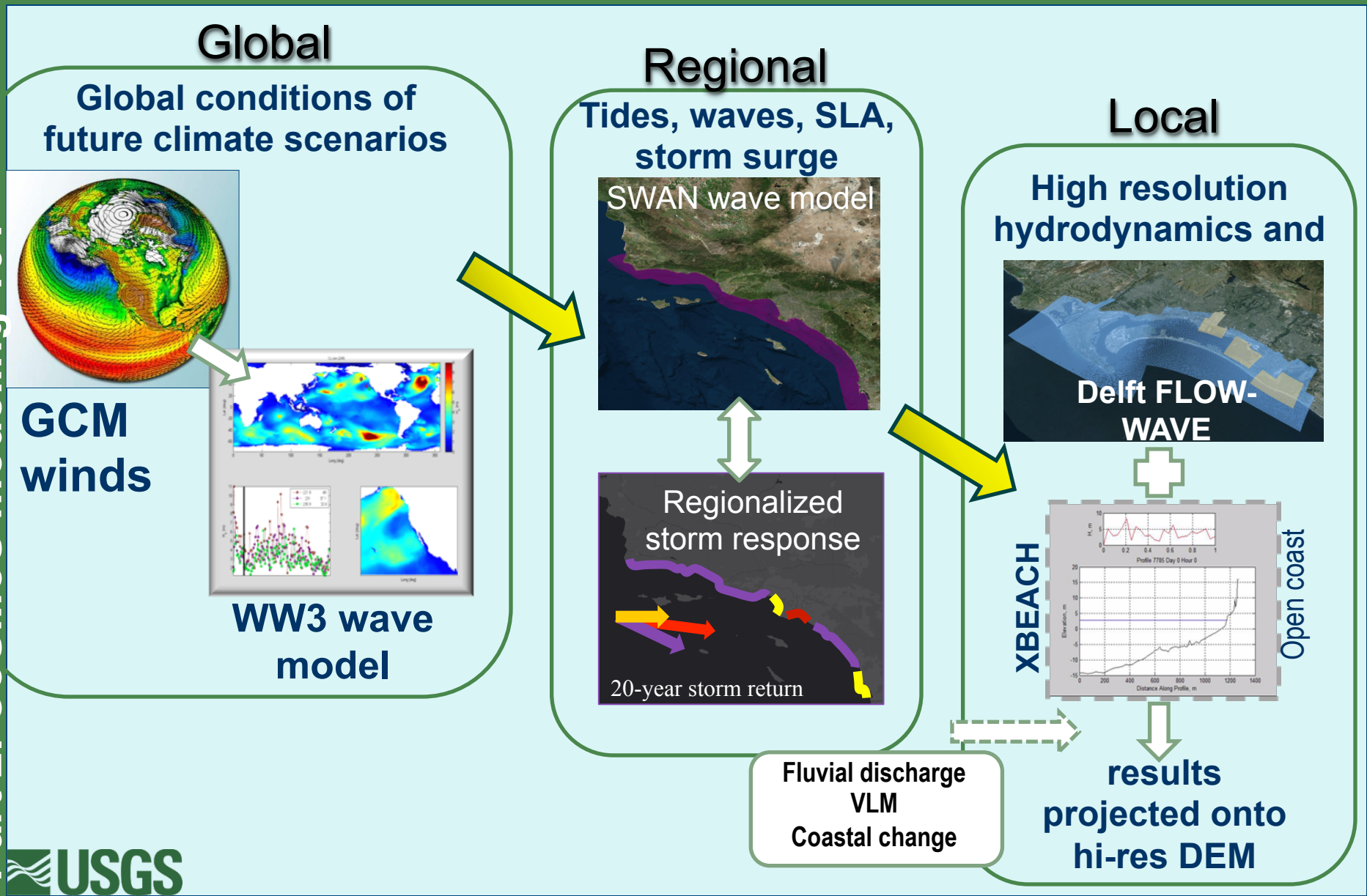
CoSMoS


Global
Global conditions of future climate scenarios
GCM winds
WW3 wave model
Regional
Tides, waves, SLA, storm surge
SWAN wave model
Regionalized storm response
20-year storm return
Fluvial discharge
VLM
Coastal change
Local
High resolution hydrodynamics and
Delft FLOW-WAVE
XBEACH
Open coast
results projected onto hi-res DEM

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CoSMoS versions

CoSMoS ver. 1.0

- So Cal, 470 km coastline (Pt. Conception -> Mexico border)
- 2 SLRs + historical storms
- No overland flow
- Global & regional parts continue to run operationally

CoSMoS ver. 2.0

- NorCen Cal coast, 170 km, (Bodega Head to Half Moon Bay)
- 10 SLRs + 'future' climate change background & storms (1yr, 20yr, 100yr)
- High resolution grids of lagoons and protected areas
- Web-based tool

CoSMoS ver. 2.1

- San Francisco Bay
- Spatial- & time-downscaled climate scenario winds
- Fluvial discharges
- Vertical land motion
- Marsh accretion
- Excluded XBEACH

CoSMoS versions

CoSM

- So Ca
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  Conce
  Mexic
- 2 SLR
  storms
- No ov
- Globa
  parts
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  170 km,
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CoSMoS ver. 3.0

- So Cal, 470 km coastline (Pt. Conception -> Mexico border)
- Long-term coastal evolution of sandy beaches and cliffs
- Improved representation of local extreme events

CoSMoS versions

CoSMoS ver. 1.0

- So Cal, 470 km coastline (Pt. Conception -> Mexico border)
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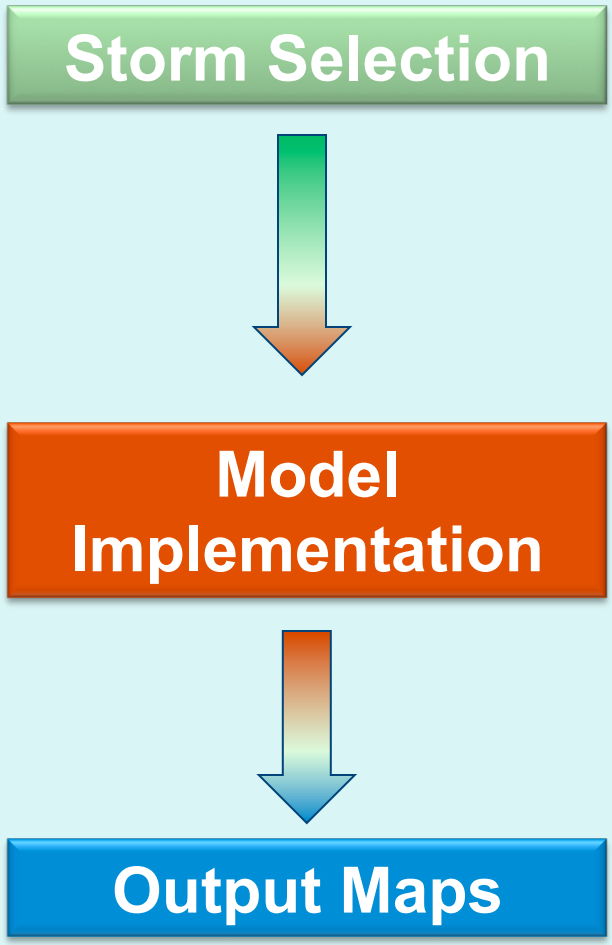
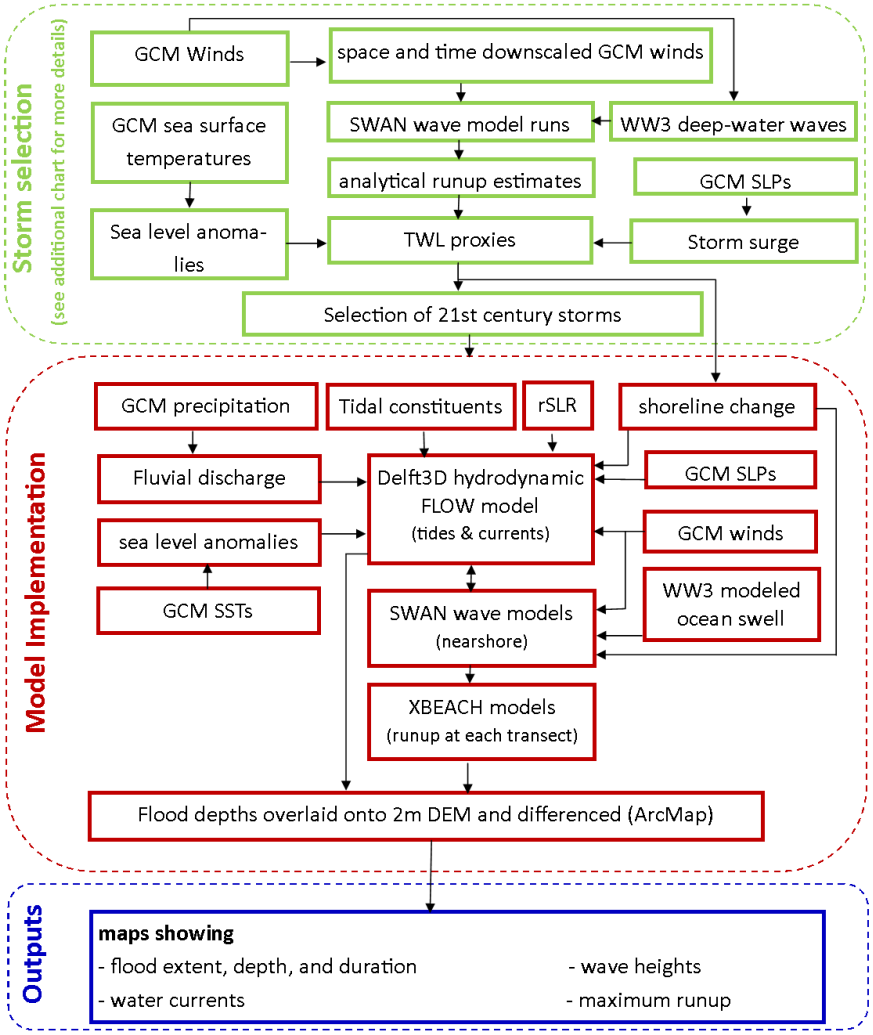
CoSMoS ver. 3.0

- So Cal, 470 km coastline (Pt. Conception -> Mexico border)
- Long-term coastal evolution of sandy beaches and cliffs
- Improved representation of local extreme events
- Fluvial discharges
- Local level downscaled winds
- 10 SLRs + 'future' conditions
- High resolution grids

CoSMoS ver. 3.0 for SoCal





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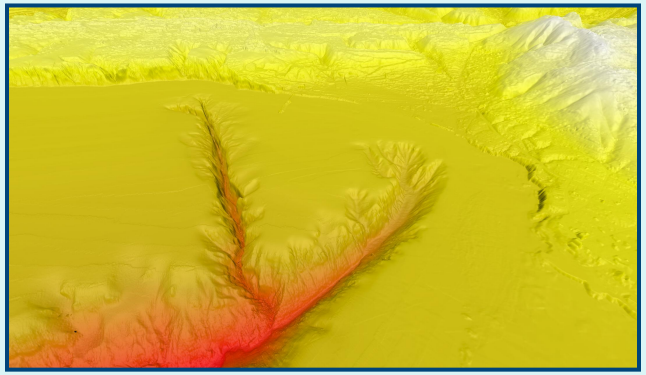
Where are we now?

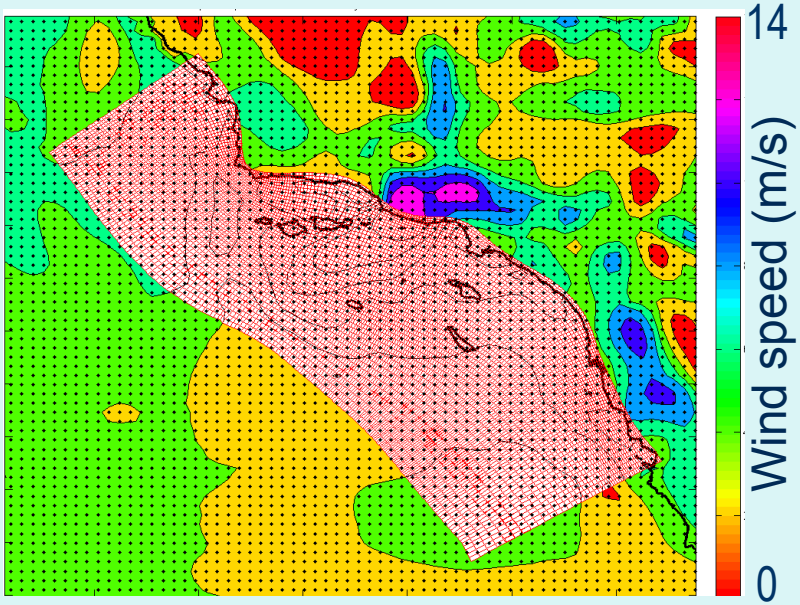
Digital Elevation Model (DEM)

- Compilation of the latest available data from multiple sources
- …nearly complete



Downscaling of winds to 10km resolution over CA (CaRD10, SCRIPPS)

- Reanalysis (1975 – 2010) complete, QA/QC…
- Projections under climate change scenarios..PhaseII



Part 3. Current status

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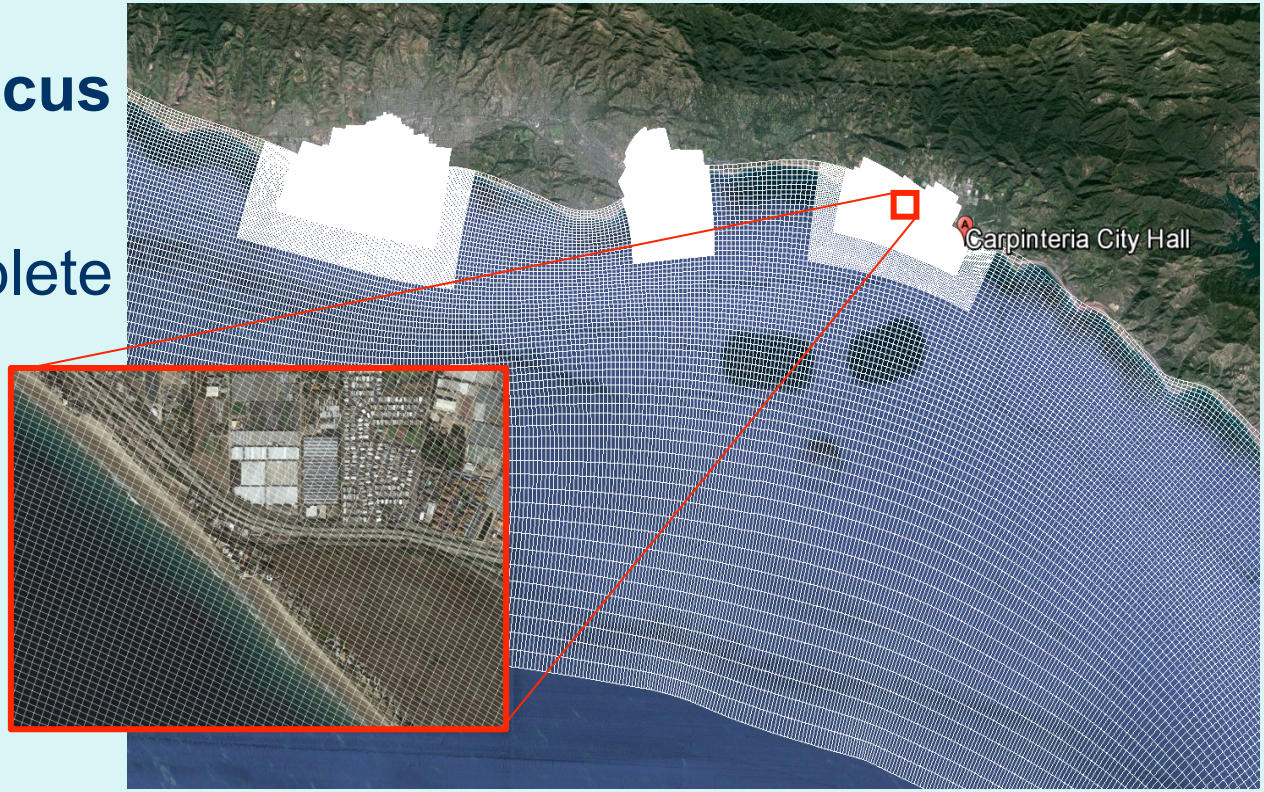
Where are we now?

Regional & focus area grids

- nearly complete



Validations

- Jan 2010 storm

  running for North County San Diego

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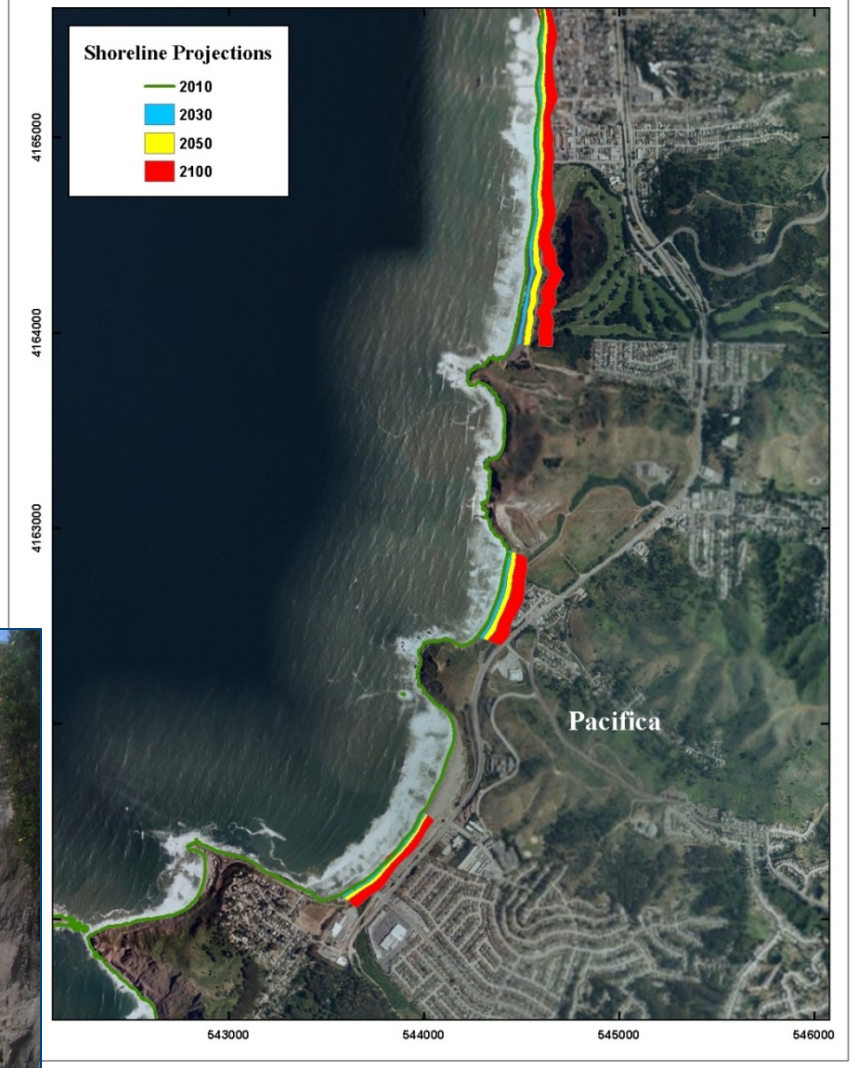
Where are we now?

Shoreline change

- Projection of historical rates
- probabilistic approaches
- processed based methods



Part 3. Current status

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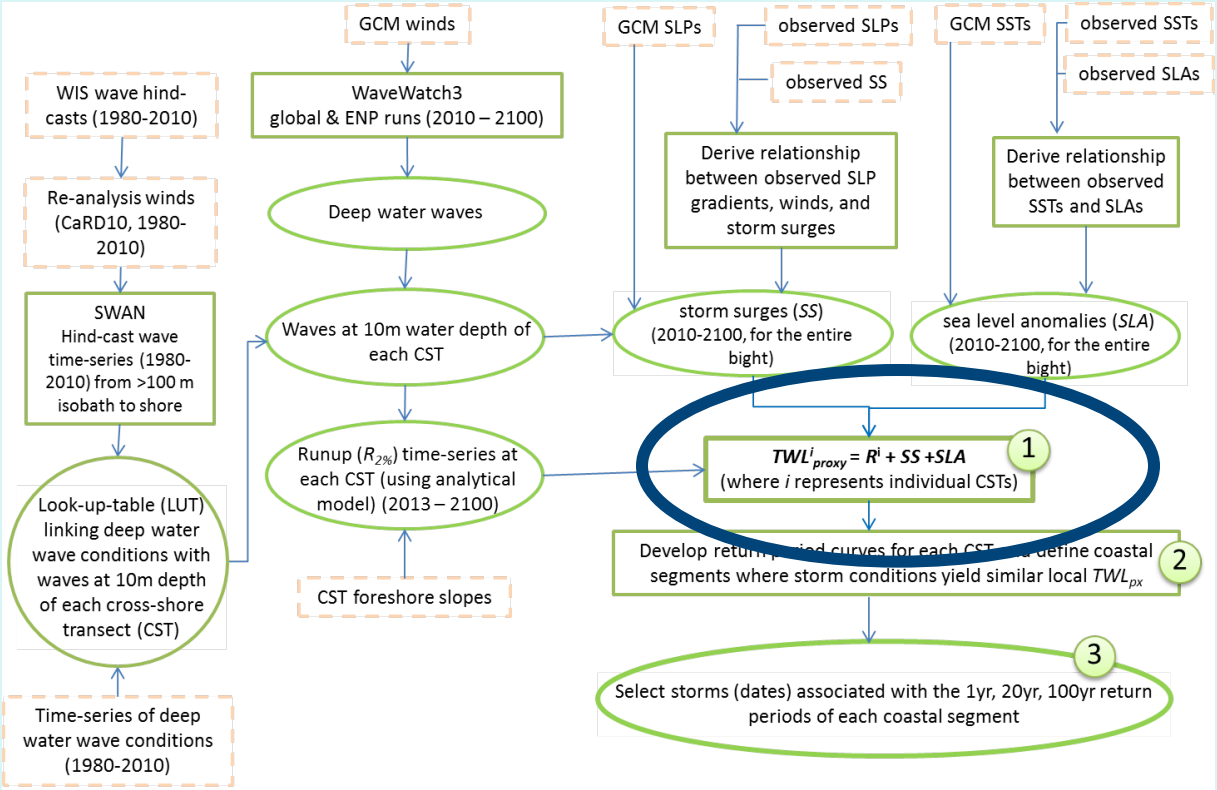
Where are we now?

Local storm identification

- Simulated full 30 year hindcast (1980-2010) of waves
- Projected time-series (2010-2100) of waves
- Projected time series of TWLs for storm selection

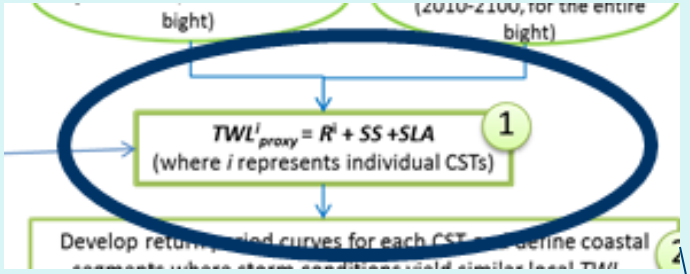


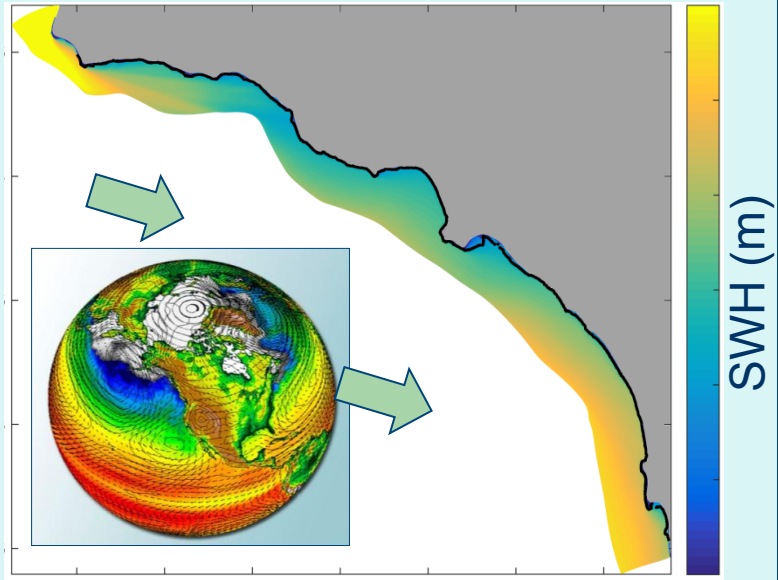
Part 3. Current status

USGS

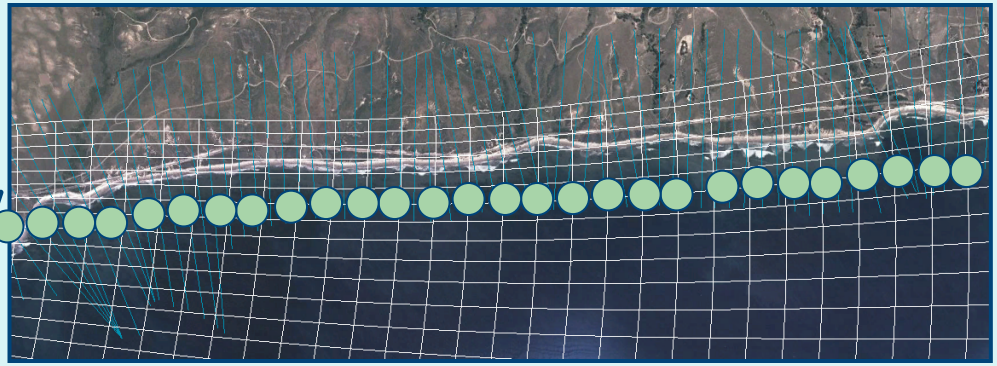
Where are we now?

Local storm identification





- at each of 4,800+ nearshore points
- for yrs 2010-2100



Part 3. Current status

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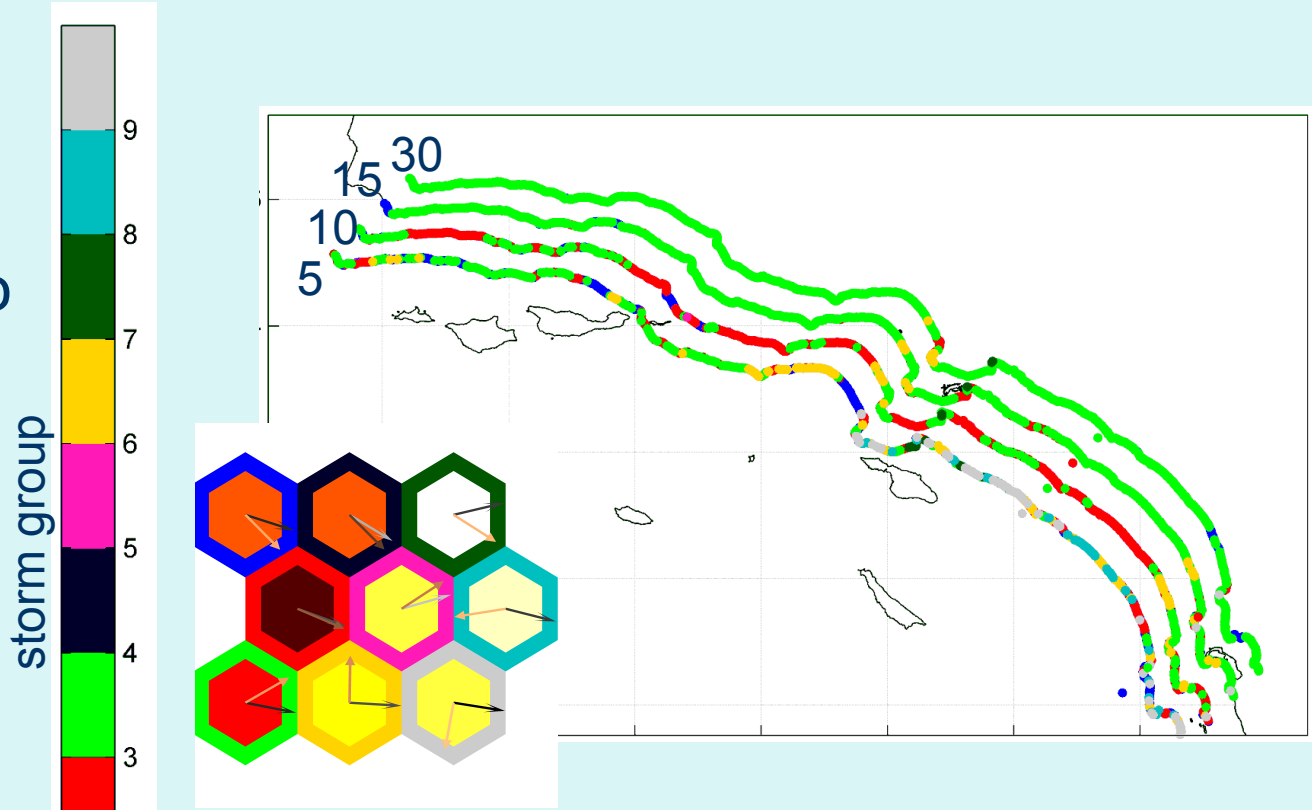
Where are we now?

Local storm identification

- k-means clustering to find common storm cell regions
- Next…run these storms with CoSMoS



5 to 30 yr return period storms

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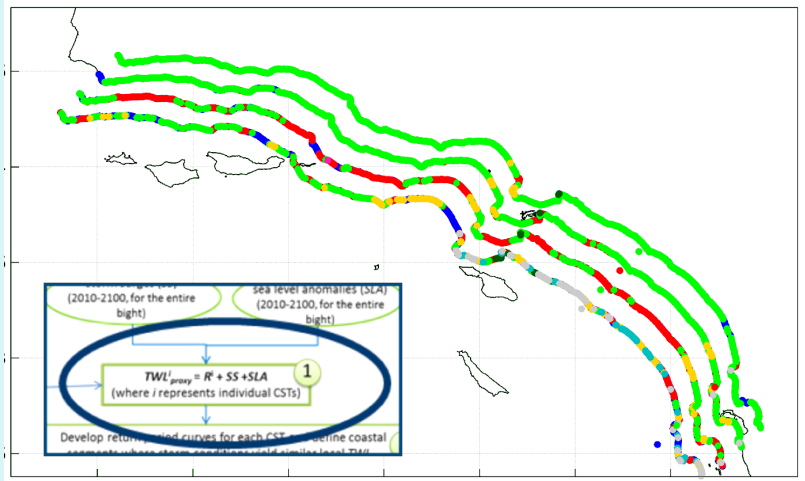
Complementary work & collaborations

- Employing same model forcings
- Same events
- Comparing & contrasting coastal response, shoreline change
- Effects and locales of hard structures, variations in DEMs/ profiles



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Summary

Some major findings thus far…

- Slight decrease in SWHs
- increases in wave period
- extreme events projected to approach from a more southerly direction
- Varying local response to coastal storms; the number of storm cells reduce with more extreme events

CoSMoS model will asses flood extents of these changes employing physics-based numerical models. Results will be compared to TWL proxies and other approaches.

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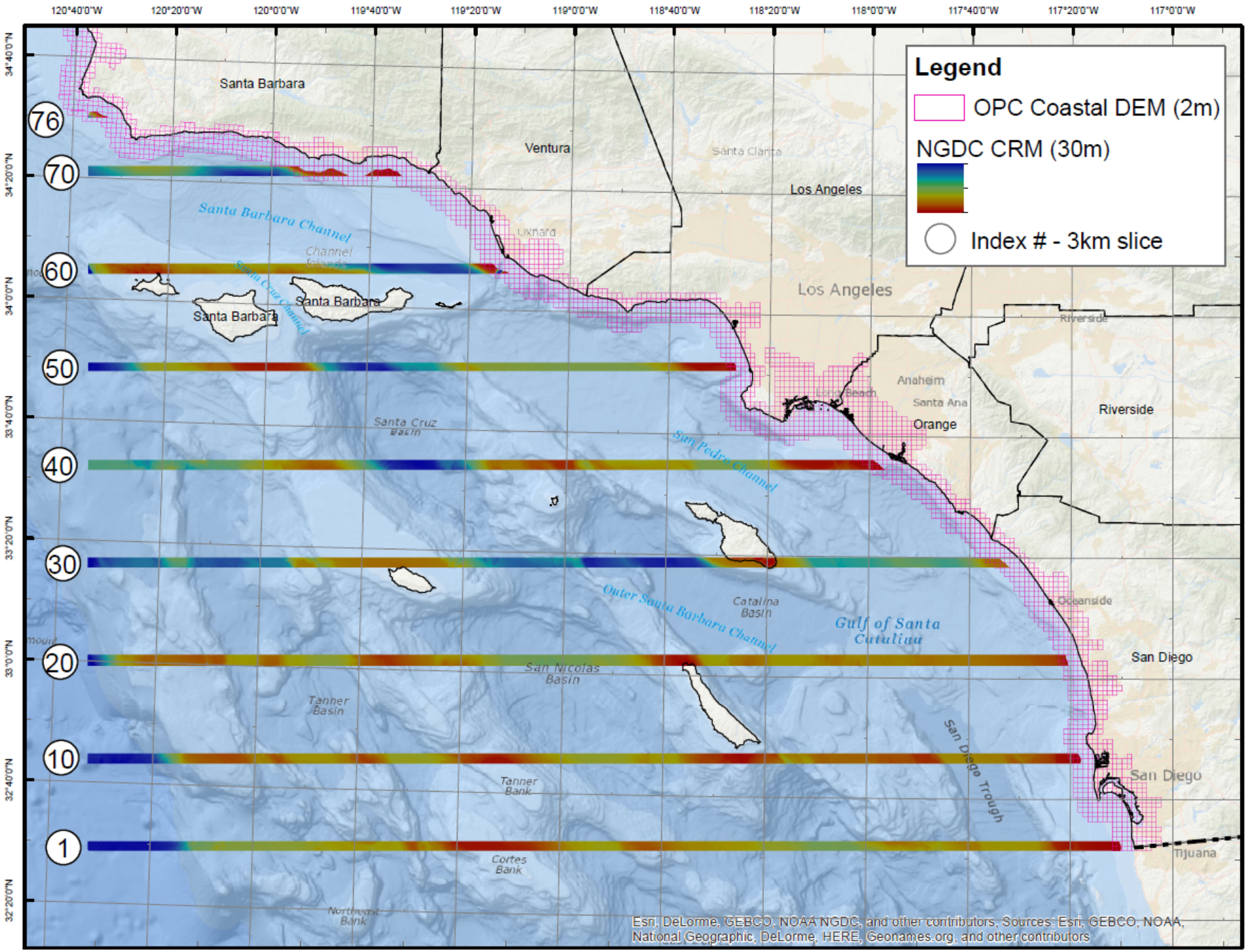
Thank you


Legend
OPC Coastal DEM (2m)
NGDC CRM (30m)
Index # - 3km slice
120°40'0"W
120°20'0"W
120°0'0"W
119°40'0"W
119°20'0"W
119°0'0"W
118°40'0"W
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76
70
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40
30
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10
1
Santa Barbara
Ventura
Santa Clarita
Los Angeles
Oxnard
Santa Barbara Channel
Channel Islands
Santa Cruz Channel
Santa Barbara
Santa Barbara
Los Angeles
Riverside
Anaheim
Long Beach
Santa Ana
Orange
Riverside
Santa Cruz Basin
San Pedro Channel
Oceanside
Catalina Basin
Outer Santa Barbara Channel
Gulf of Santa Catalina
San Diego
San Nicolas Basin
Tanner Basin
San Diego Trough
San Diego
Tanner Bank
Tijuana
Cortes Bank
Northeast Bank
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

Controls on Cliff Behavio

Sea cliff retreat =

$$f\left(\begin{array}{ccc} \text{Tectonic activity} & \text{Permafrost thaw} & \text{Tidal range} \\ \text{Rock strength/ geology} & \text{Human impacts} & \text{Beach \& sea cliff dynamics} \\ \text{Waves} & \text{Sea level rise} & \text{Rainfall} \end{array}\right)$$

What makes CoSMoS unique?

- Explicit, deterministic modeling of all the relevant physics of a coastal storm with regional consistency
- Wave climate developed from the most sophisticated Global Climate Models (GCMs) developed for IPCC 2013
- Waves are modeled at the global scale, 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

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

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CoSMoS USGS science for a changing world