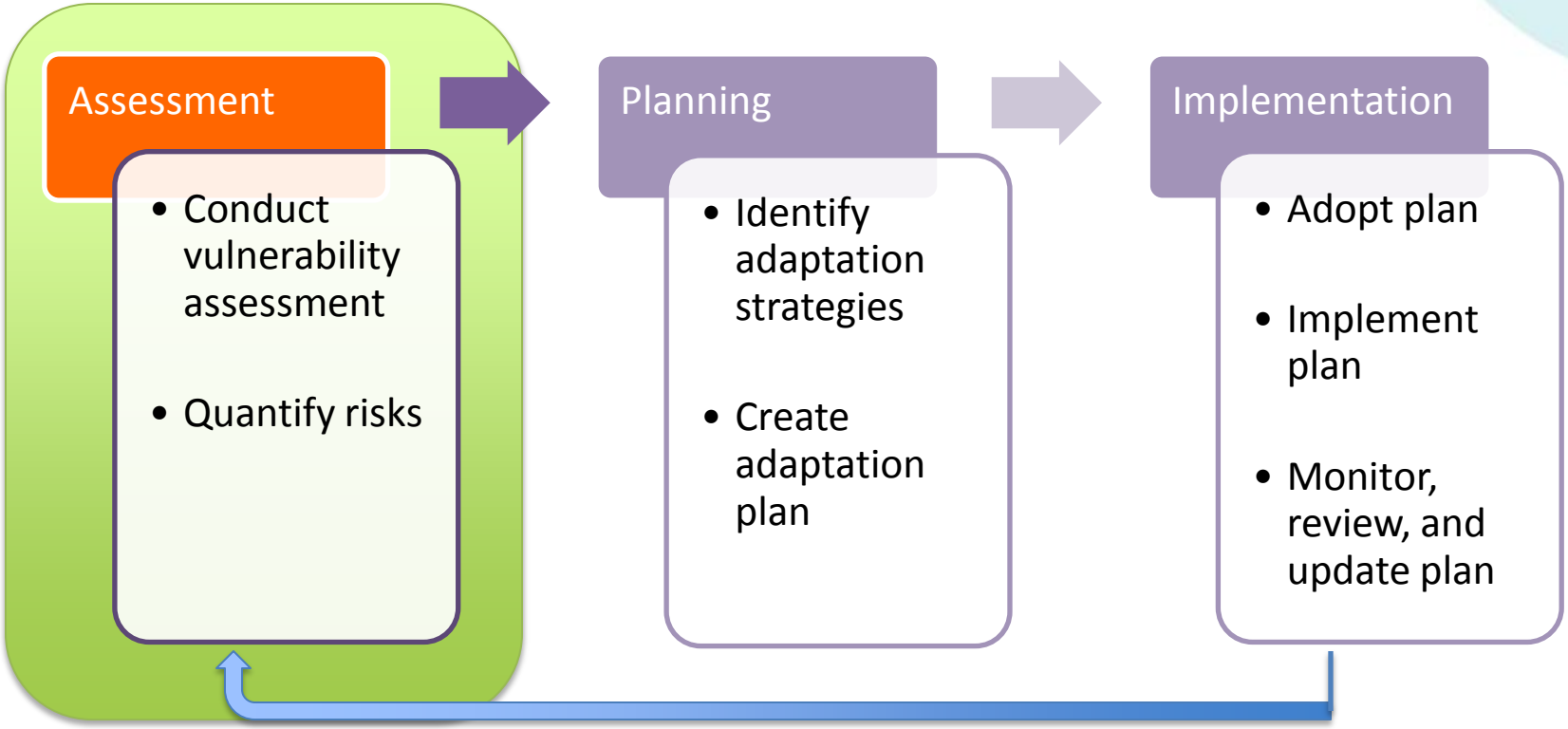
The use of Global Climate Models, the Coastal Storm Modeling System (CoSMoS), and a user tool for managers to assess the future vulnerability of the California coast

Li Erikson[1], Patrick Barnard[1], Amy Foxgrover[1], and Andrea O'Neill[1], Michael Fitzgibbon[2], Grant Ballard[2]

[1]United States Geological Survey, Pacific Coastal and Marine Science Center, Santa Cruz, CA
[2]Point Blue Conservation Science, Bolinas

Motivation & Objectives

Need: Tools for adaptation planning



Modified from
Russell & Griggs, 2012

Motivation & Objectives

Goal:

Provide science-based, decision support tools to help understand, visualize, and anticipate coastal climate change impacts to Bay Area communities and ecosystems.

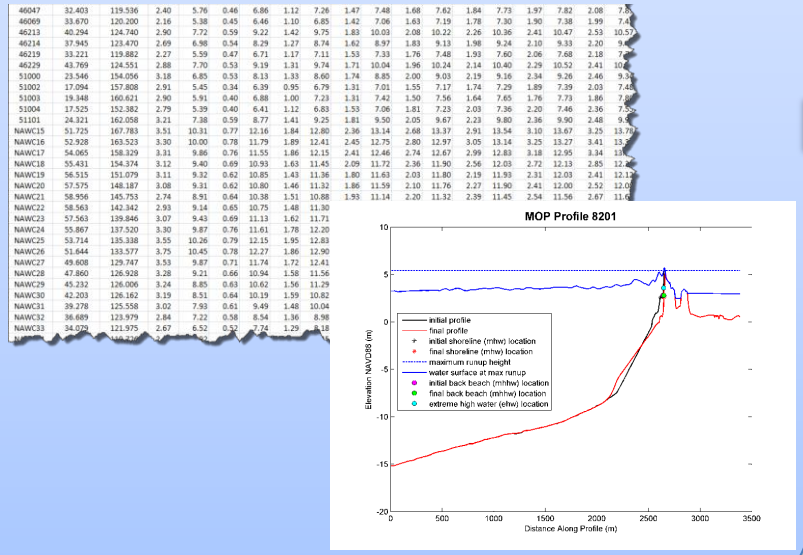
Objective:

1) Model vulnerabilities to SLR & storm hazards

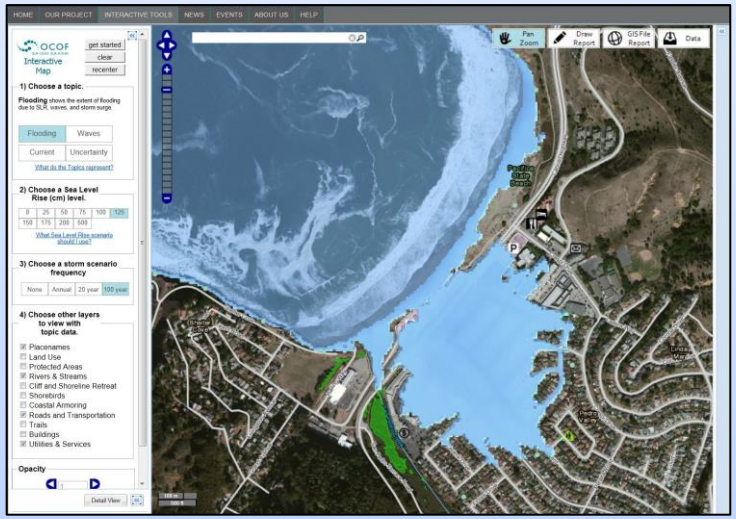
2) Develop a simple online tool

Overview of Methodology

Modeling system



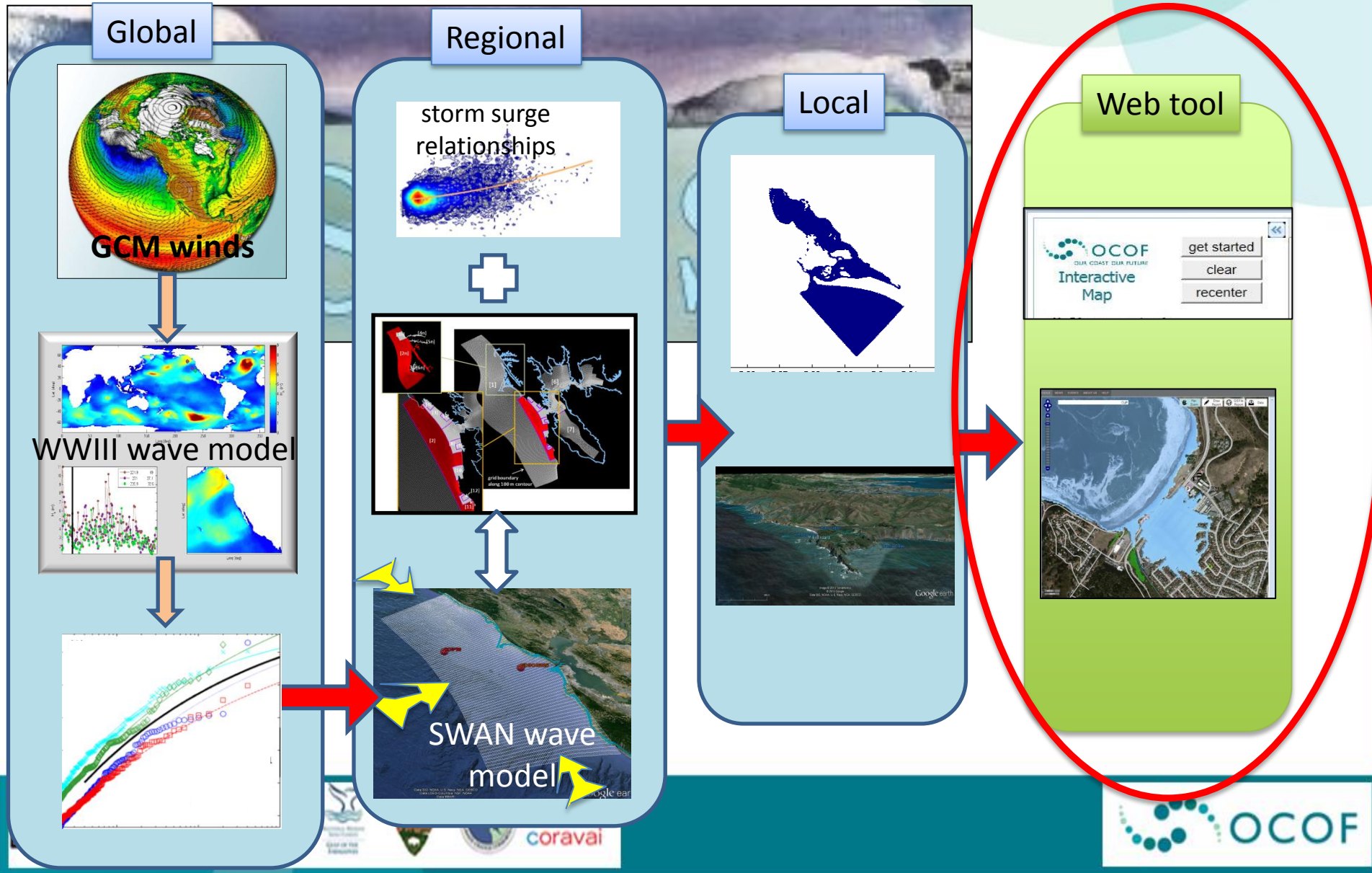
Web tool



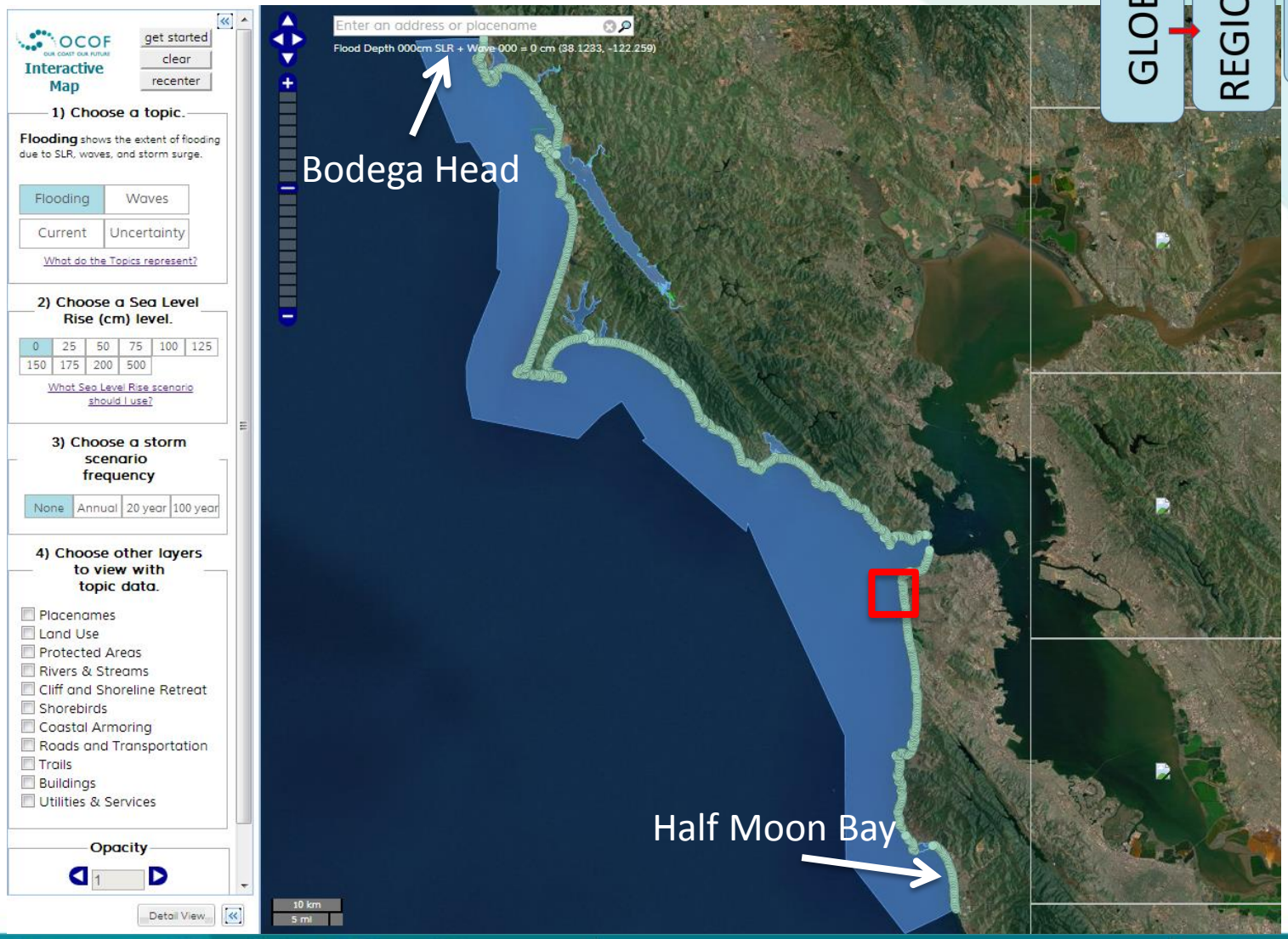
http://data.prbo.org/apps/ocof/
(Our Coast- Our Future)

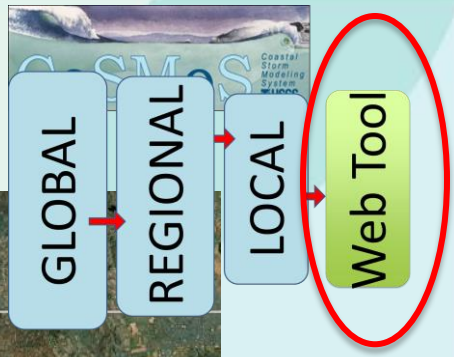
Overview of Methodology

Overview of Methodology

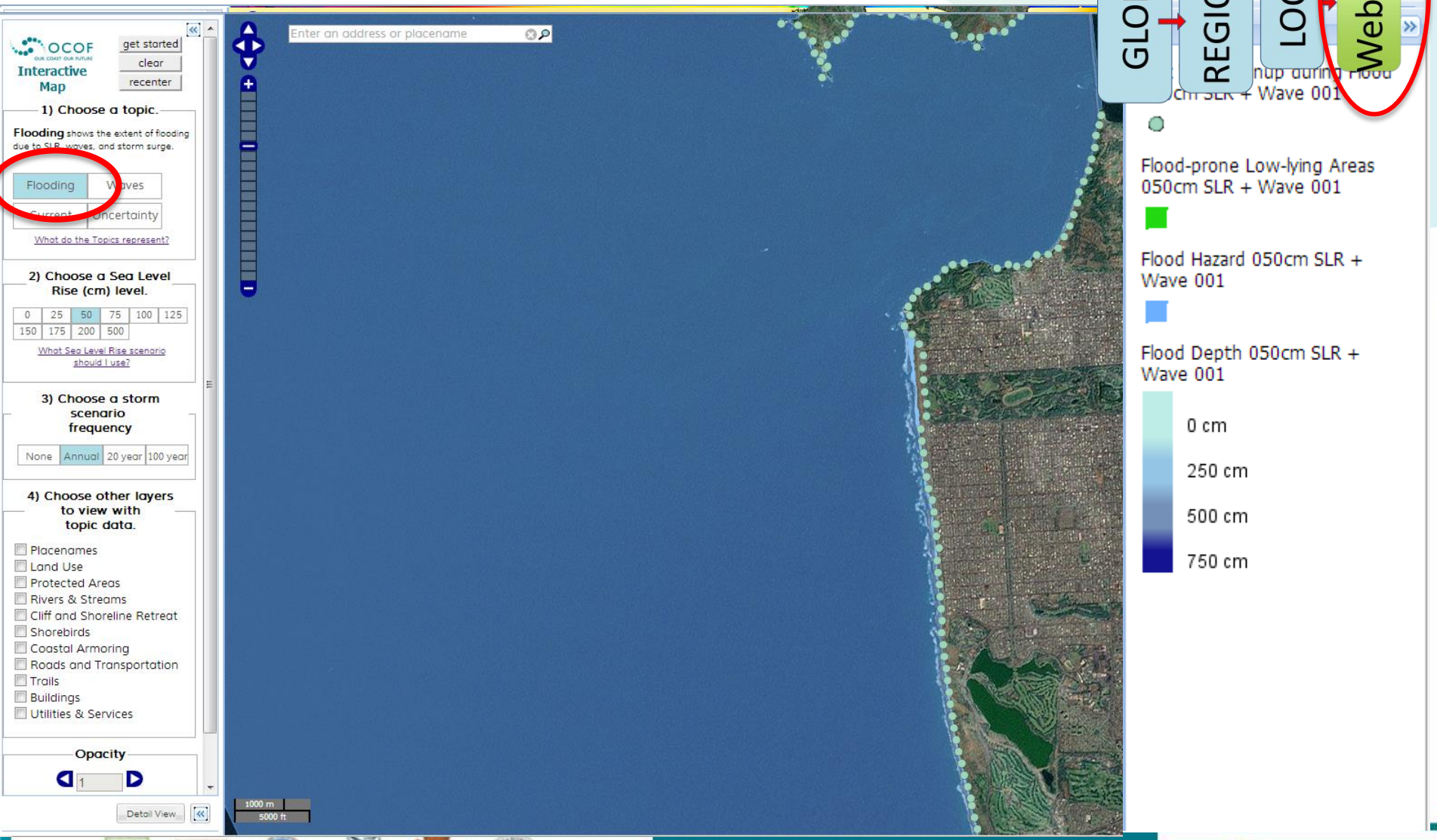


Results

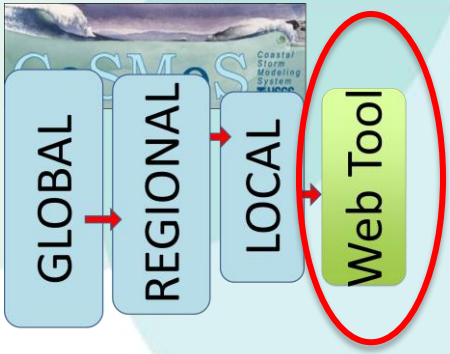

OCOF
Interactive Map
get started
clear
recenter
1) Choose a topic.
Flooding shows the extent of flooding due to SLR, waves, and storm surge.
Flooding
Waves
Current
Uncertainty
What do the Topics represent?
2) Choose a Sea Level Rise (cm) level.
0 25 50 75 100 125 150 175 200 500
What Sea Level Rise scenario should I use?
3) Choose a storm scenario frequency
None Annual 20 year 100 year
4) Choose other layers to view with topic data.
Placenames
Land Use
Protected Areas
Rivers & Streams
Cliff and Shoreline Retreat
Shorebirds
Coastal Armoring
Roads and Transportation
Trails
Buildings
Utilities & Services
Opacity
1
Detail View
Enter an address or placename
Flood Depth 000cm SLR + Wave 000 = 0 cm (38.1233, -122.259)
Bodega Head
Half Moon Bay
10 km
5 mi


GLOBAL
REGIONAL
LOCAL
Web Tool

Results


GLOBAL
REGIONAL
LOCAL
Web Tool
OCOF
Interactive Map
get started
clear
recenter
1) Choose a topic.
Flooding shows the extent of flooding due to SLR, waves, and storm surge.
Flooding
Waves
Current
Uncertainty
What do the Topics represent?
2) Choose a Sea Level Rise (cm) level.
0 25 50 75 100 125
150 175 200 500
What Sea Level Rise scenario should I use?
3) Choose a storm scenario frequency
None Annual 20 year 100 year
4) Choose other layers to view with topic data.
Placenames
Land Use
Protected Areas
Rivers & Streams
Cliff and Shoreline Retreat
Shorebirds
Coastal Armoring
Roads and Transportation
Trails
Buildings
Utilities & Services
Opacity
1
Detail View
Enter an address or placename
1000 m
5000 ft
Flood-prone Low-lying Areas 050cm SLR + Wave 001
Flood Hazard 050cm SLR + Wave 001
Flood Depth 050cm SLR + Wave 001
0 cm
250 cm
500 cm
750 cm

Results

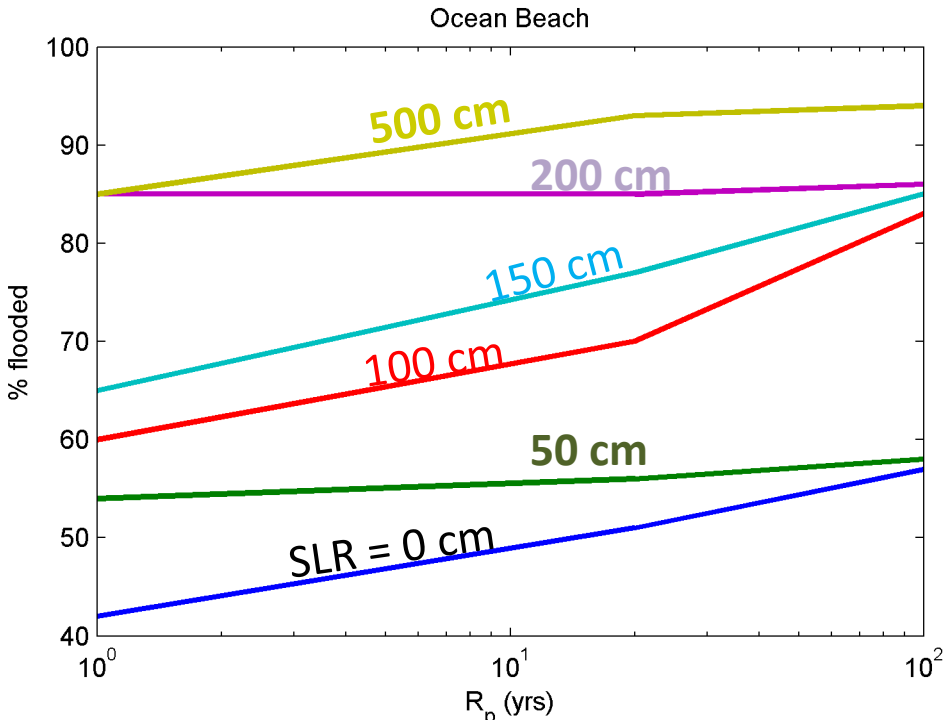


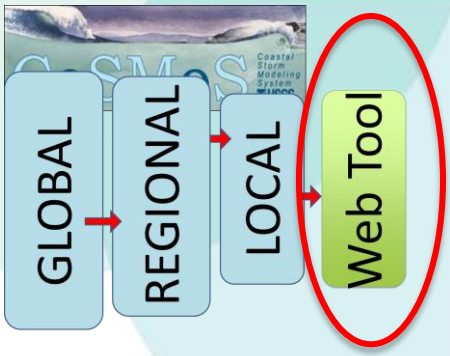
Projected Percent Area Flooded

Values indicate the percentage of the selected area flooded for the Storm and Sea Level Rise Scenario combination.

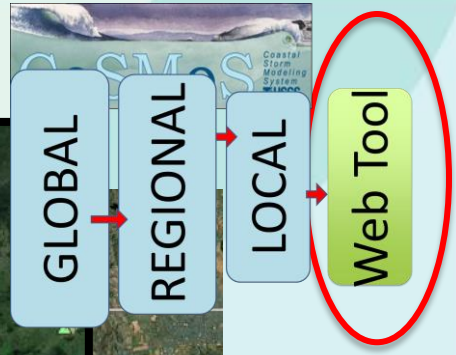
Storm Scenario	100 yr Storm	57%	58%	83%	85%	86%	94%
	20 yr Storm	51%	56%	70%	77%	85%	93%
	Annual Storm	42%	54%	60%	65%	85%	85%
	No Storm	12%	23%	45%	55%	61%	88%
		none	50 cm	100 cm	150 cm	200 cm	500 cm
	Sea Level Rise Scenario						

under 25% flooded | 25-50% flooded | 50-75% flooded | over 75% flooded

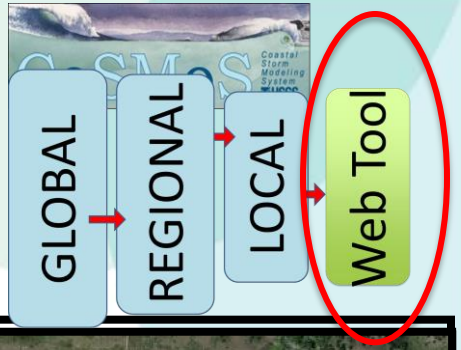

Ocean Beach
500 cm
200 cm
150 cm
100 cm
50 cm
SLR = 0 cm
% flooded
100
90
80
70
60
50
40
10^0
10^1
10^2
R_p (yrs)


GLOBAL
REGIONAL
LOCAL
Web Tool

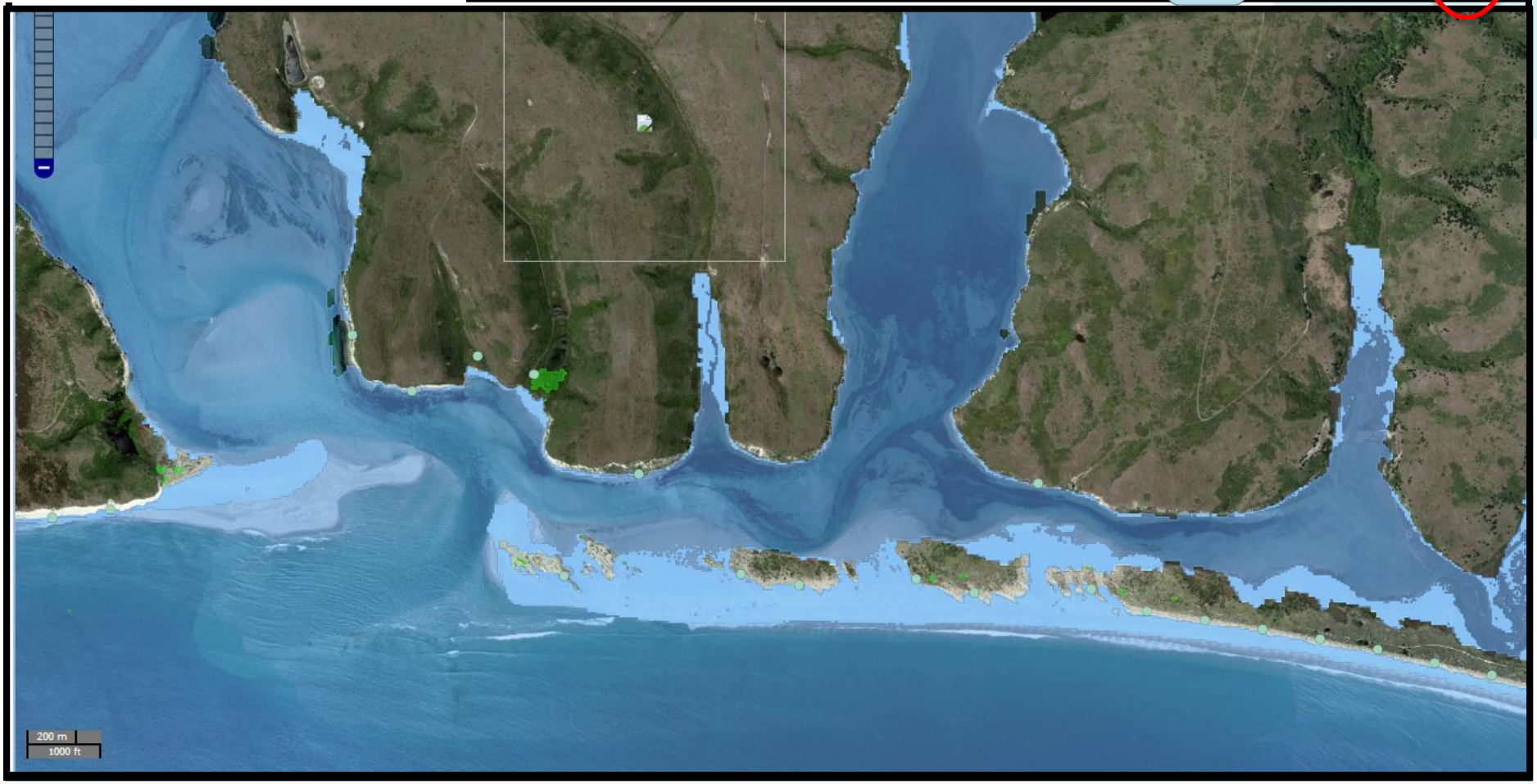
Results



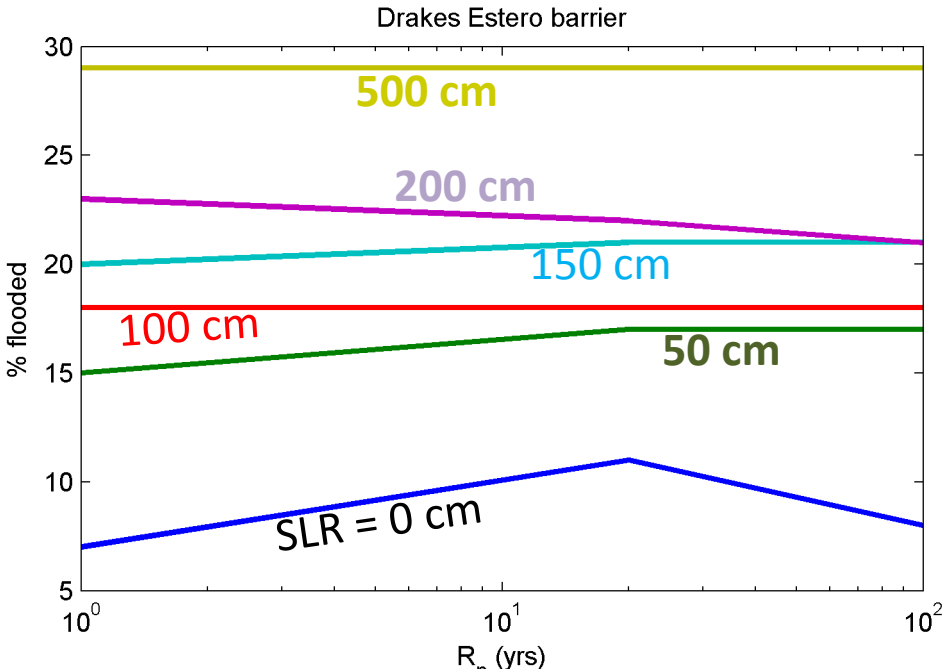
Results

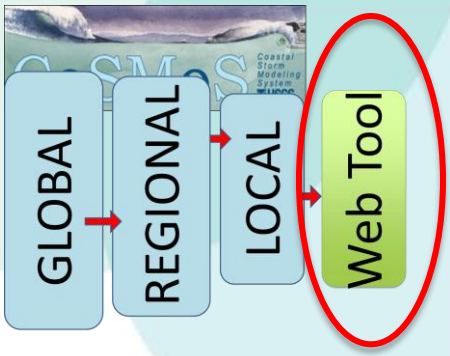


SLR = 50cm; Storm: 100yr



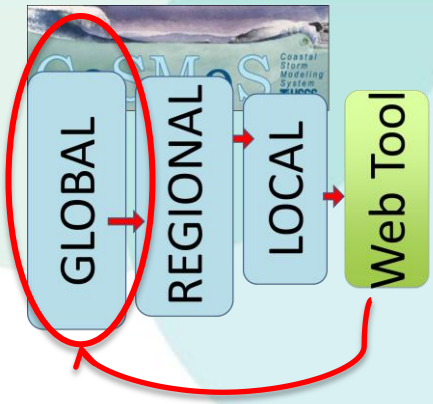
Results

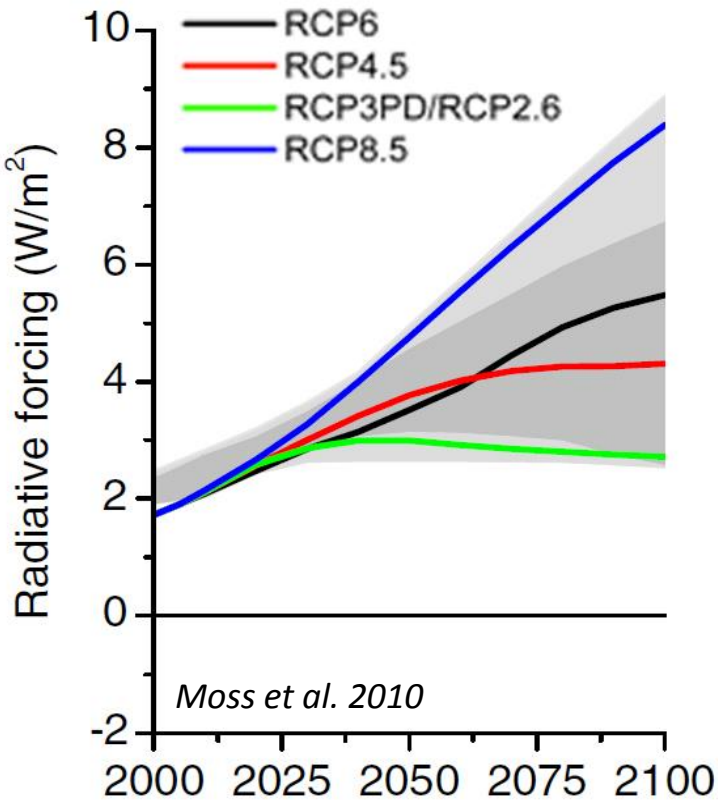

Drakes Estero barrier
500 cm
200 cm
150 cm
100 cm
50 cm
SLR = 0 cm
% flooded
30
25
20
15
10
5
10^0
10^1
10^2
R_r (yrs)


GLOBAL
REGIONAL
LOCAL
Web Tool

Methods

IPCC-AR5 Climate Change Scenarios





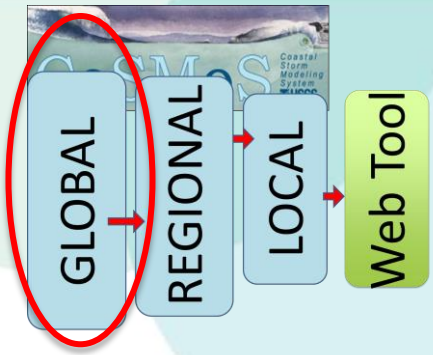
- Emission trajectories
- Labeled according to how much radiative forcing (W/m^2) would be produced by 2100
- Parallel development of climate models and socio-economic scenarios
- Contributions for IPCC AR5

RCP4.5 ~ SRES B1
(AR5) (AR3)

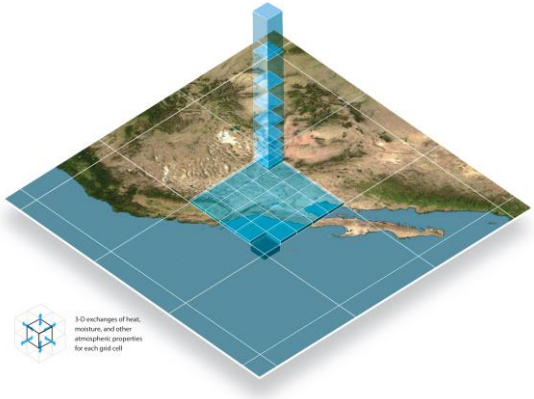
RCP8.5 ~ SRES A2
(AR5) (AR3)

Methods

IPCC-AR5 Climate Change Scenarios

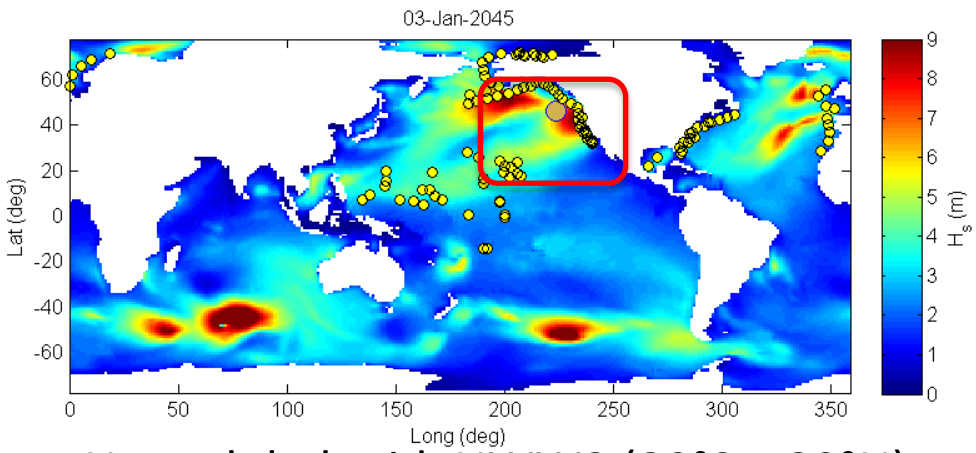


Modeling Center	model	GCM model resolution
Beijing Climate Center, Meteorological Administration, China (BCC)	BCC-CSM1.1	2.8^{o} x 2.8^{o}
Institute for Numerical Mathematics, Russia (INM)	INM-CM4	2° x 1.5^{o}
Model for Interdisciplinary Research on Climate - AOEI, NIES, JAMSTEC, Japan (MIROC)	MIROC5	1.4^{o} x 1.4^{o}
NOAA Geophysical Fluid Dynamics Laboratory	GFDL-CM3	2.5^{o} x 1.5^{o}



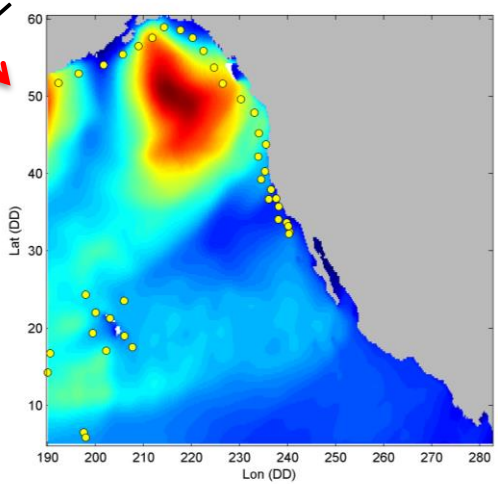
- 3 hourly winds converted to 10 m height
- Historical runs 1996-2006
- Projections
  - 2026-2045 & 2081-2100
  - RCP4.5 & RCP8.5

Methods – wave model



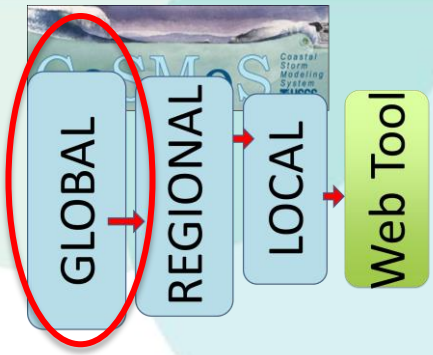
Near global grid, NWW3 (80°S – 80°N)
1° x 1.25° spatial resolution

nested

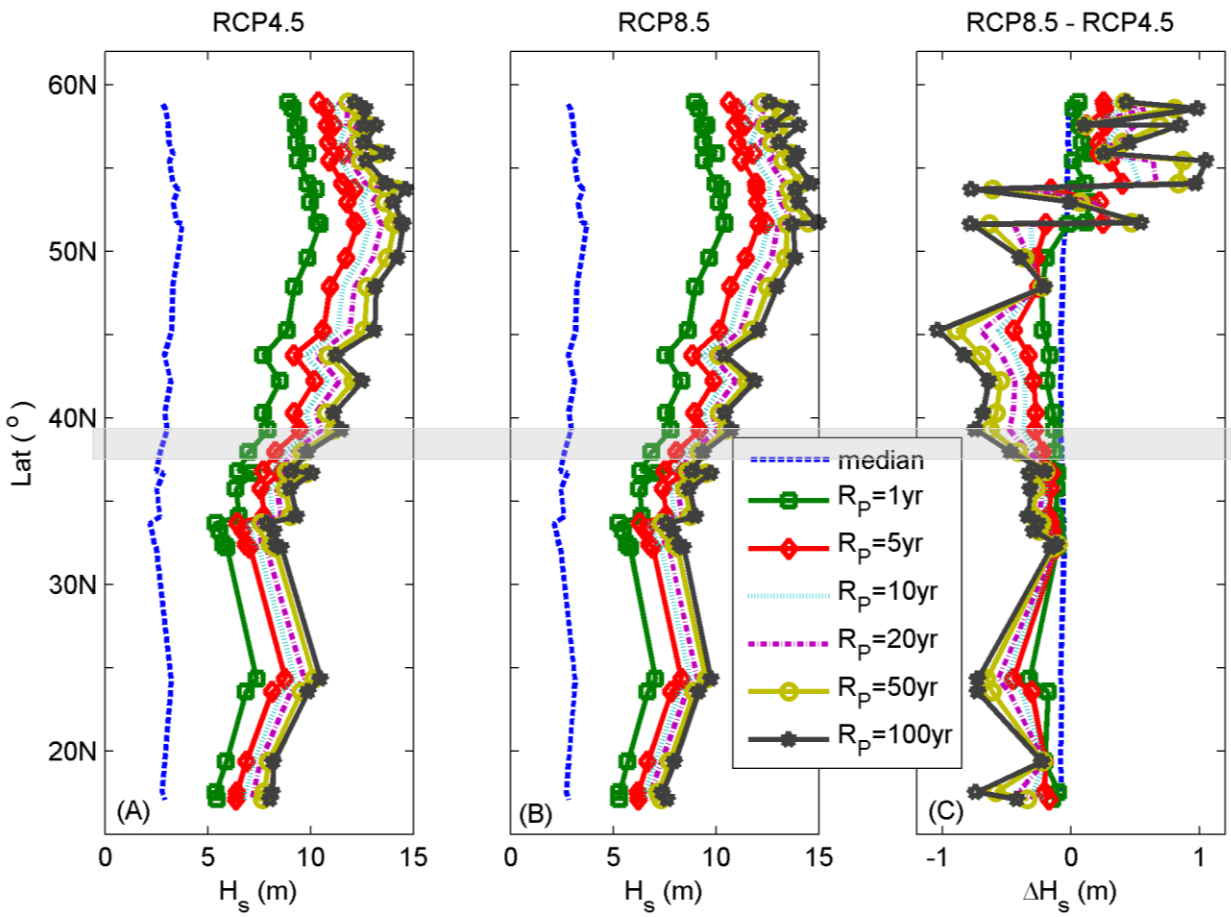


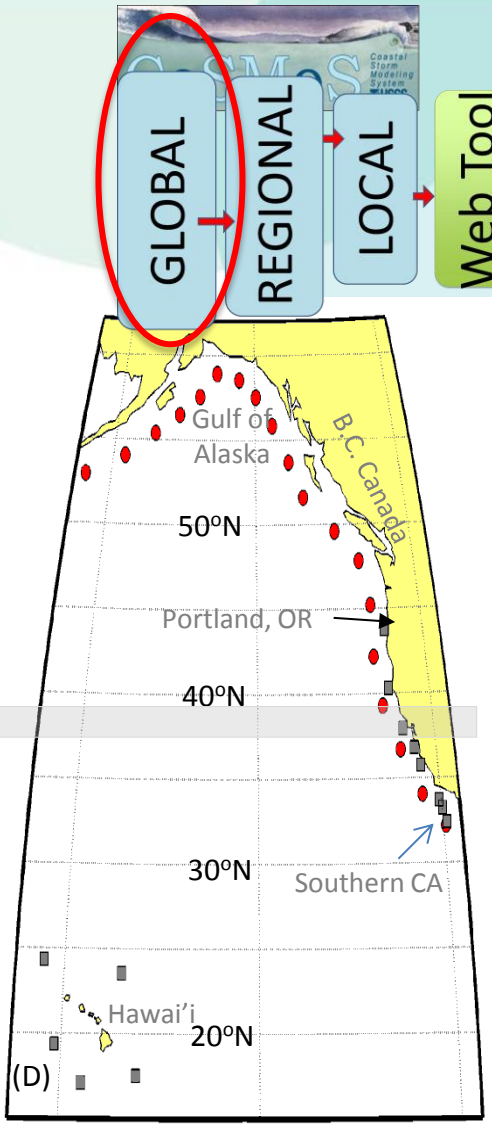
Eastern North Pacific grid (ENP)
180°W to 130°W
0.25° spatial resolution (~27 km at latitude 37°N).

WavewatchIII version 3.14 (Tolman 1999)

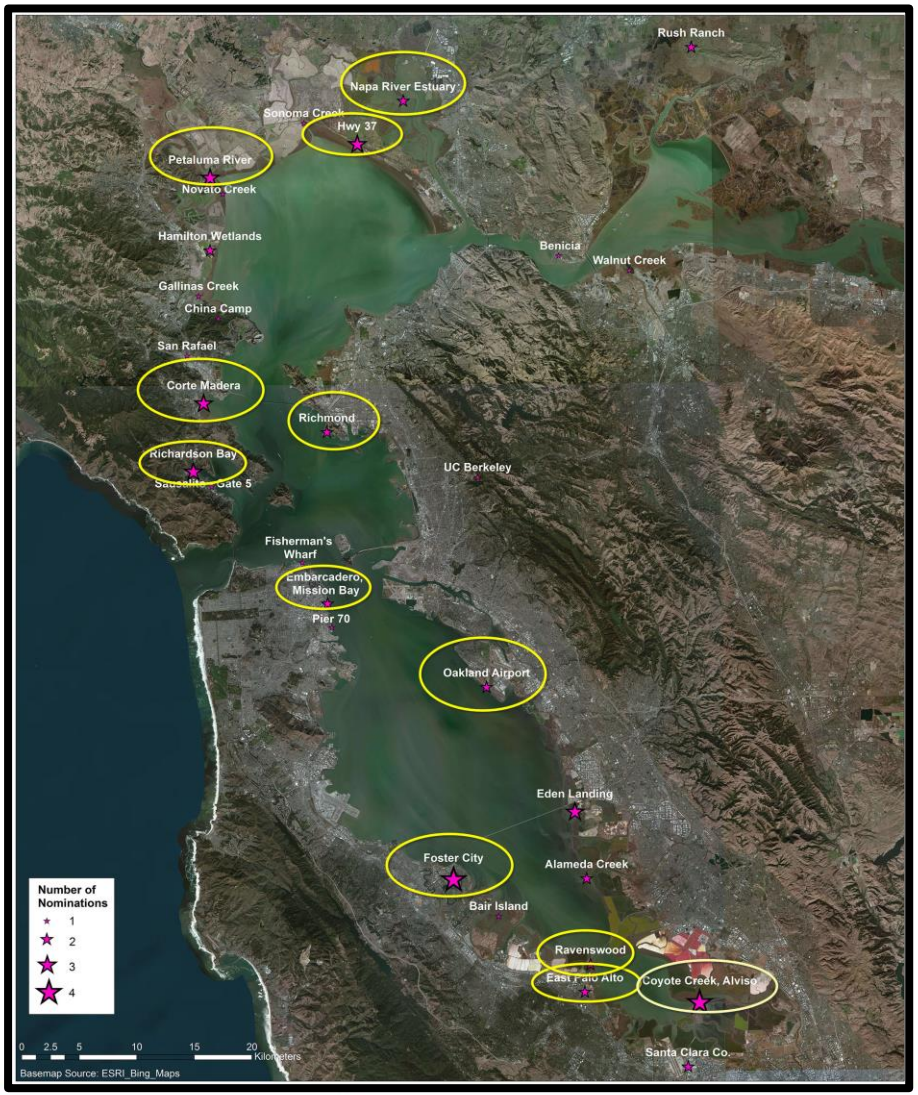


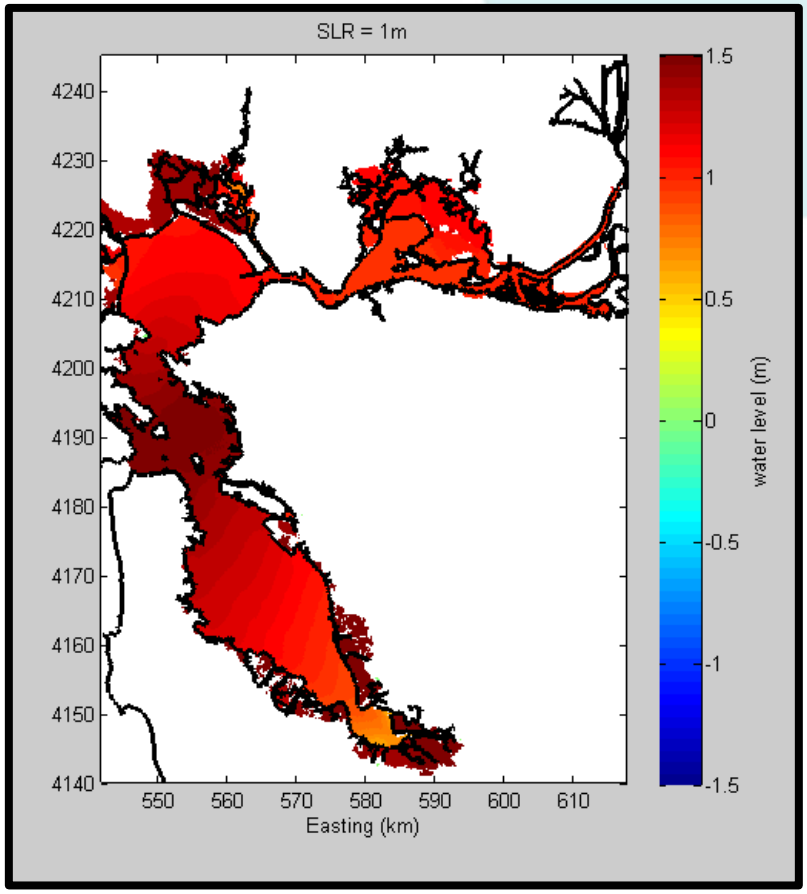
Results – wave model





Current and near future work



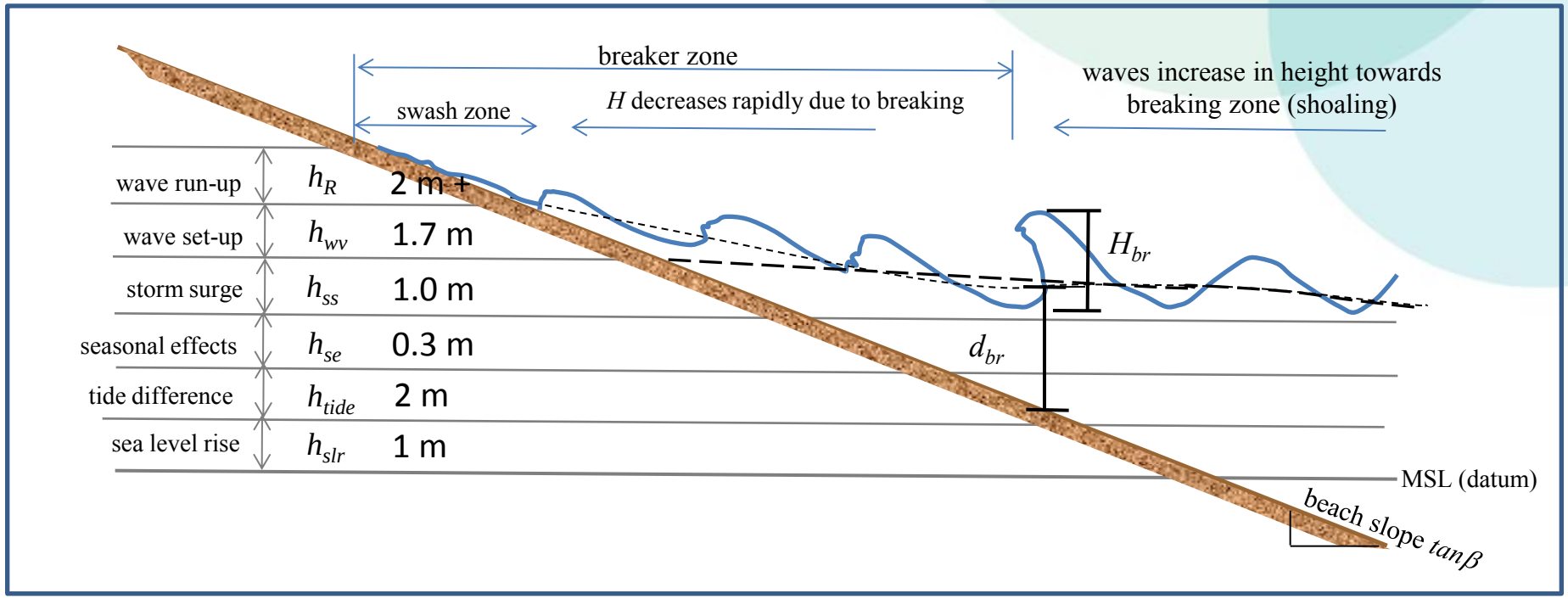


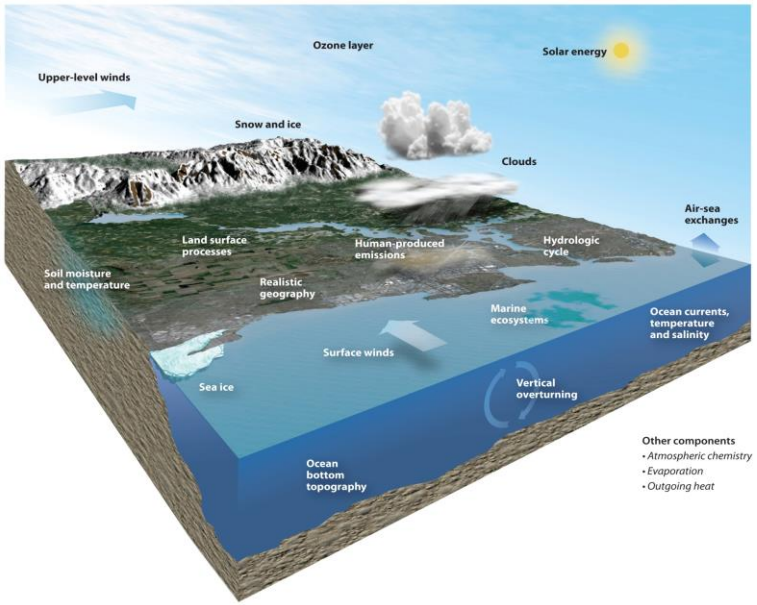
Results and conclusions

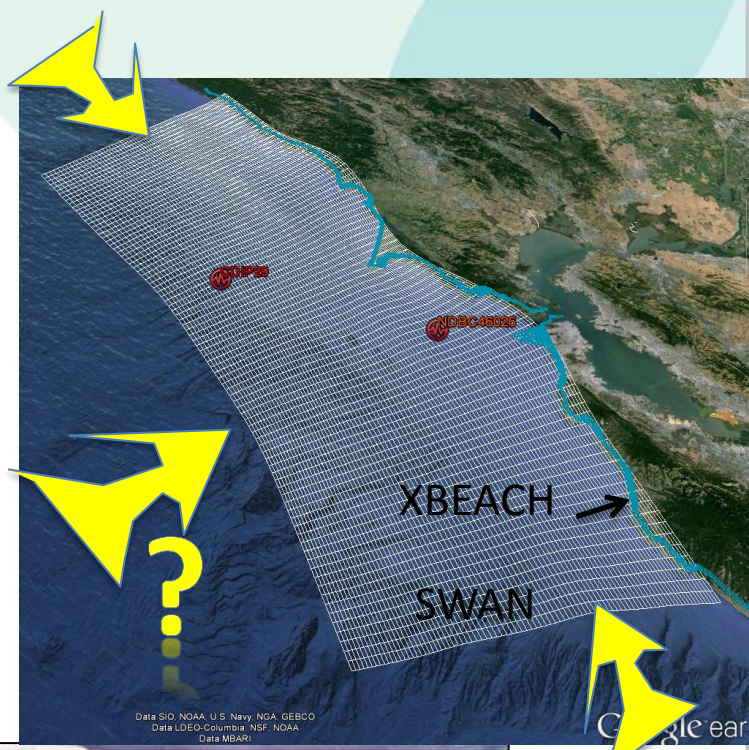
- Developed and easily accessible and simple to use online tool to model vulnerabilities to SLR & storm hazards
- Including the dynamic components can increase flood extents by >20% on west (and northwest) facing shores
- Flood extents on south facing shores are less affected by wave-induced changes in water level
- Comparison of storm conditions under the CMIP5 high (RCP8.5) and medium (RCP4.5) radiative climate scenarios show more severe storms with the medium (RCP4.5) scenario

Thank you!

Components of Total Water Level Predictions



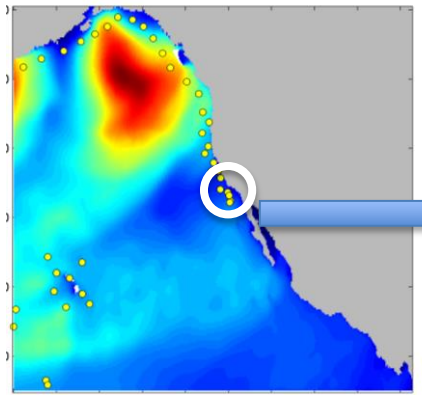

Ozone layer
Solar energy
Upper-level winds
Snow and ice
Clouds
Air-sea exchanges
Land surface processes
Human-produced emissions
Hydrologic cycle
Soil moisture and temperature
Realistic geography
Marine ecosystems
Ocean currents, temperature and salinity
Surface winds
Sea ice
Vertical overturning
Ocean bottom topography
Other components
• Atmospheric chemistry
• Evaporation
• Outgoing heat

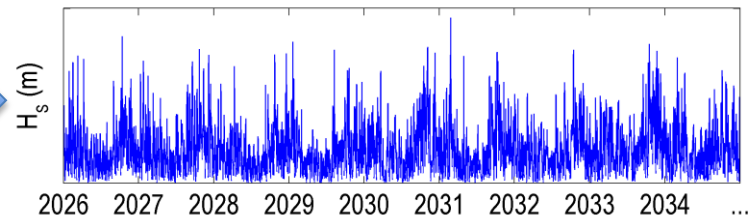

XBEACH
SWAN
?
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA
Data MBARI

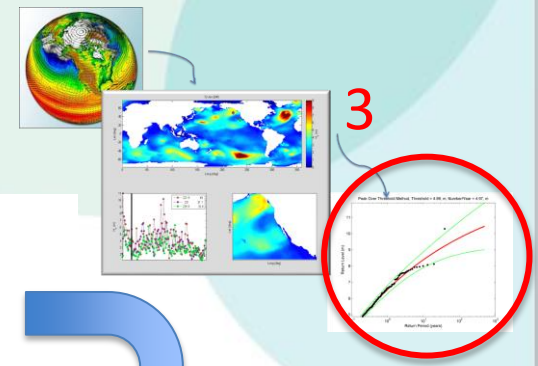
CoSMoS
Coastal Storm Modeling System
USGS

http://data.prbo.org/apps/ocof/ (Our Coast- Our Future)

Methods – extreme value analysis





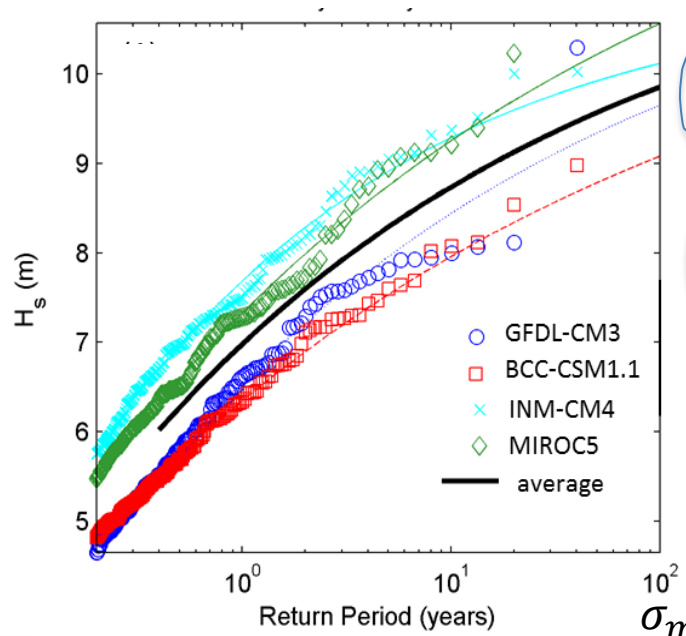


Select top 200 events at each station from each GCM run

GPD

$$F(x) = \begin{cases} [1 + \kappa\sigma^{-1}(x-u)]^{1/\kappa}; k \neq 0 \\ \exp(-(x-u)/\sigma);\ \kappa = 0 \end{cases}$$

σ: scale parameter
κ: shape parameter
obtained by MLMs



Mean of all 4 RP curves with uncertainty estimated with

$$\sigma_m = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{\bar{x}})}{N-1}}\, N^{-0.5}$$