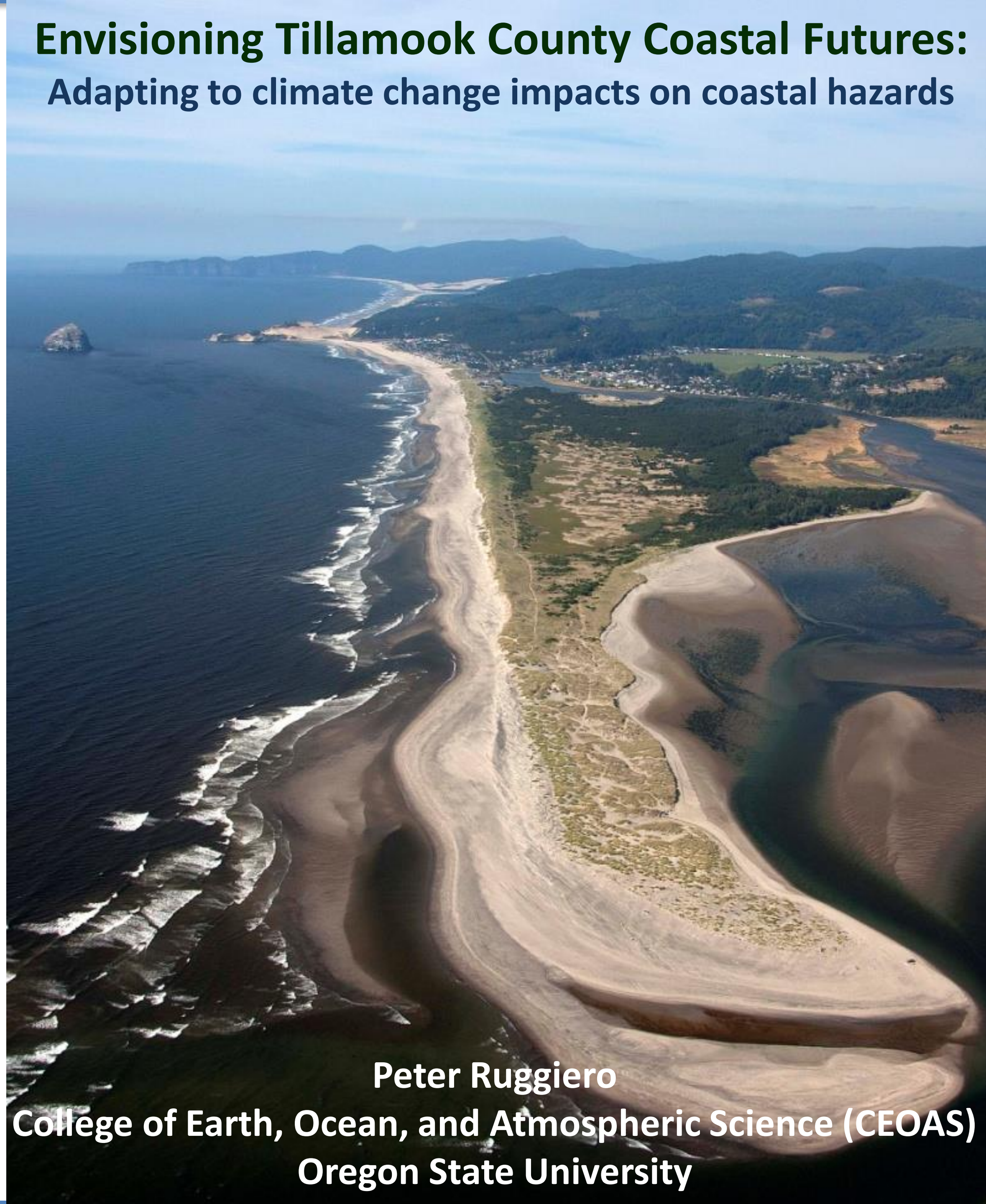
Envisioning Tillamook County Coastal Futures:

Adapting to climate change impacts on coastal hazards



Peter Ruggiero

College of Earth, Ocean, and Atmospheric Science (CEOAS)

Oregon State University

CEOAS

College of Earth, Ocean, and Atmospheric Sciences

OSU

Oregon State UNIVERSITY

Recent Northern Oregon Coastal Problems

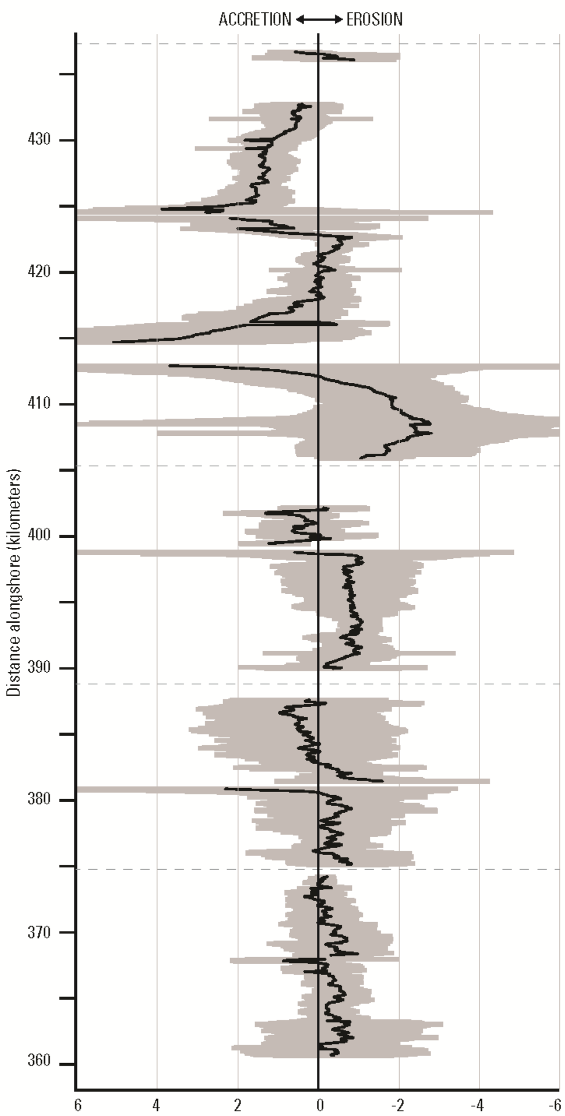
Coastal engineering problems – structure failure

Bluff/dune erosion

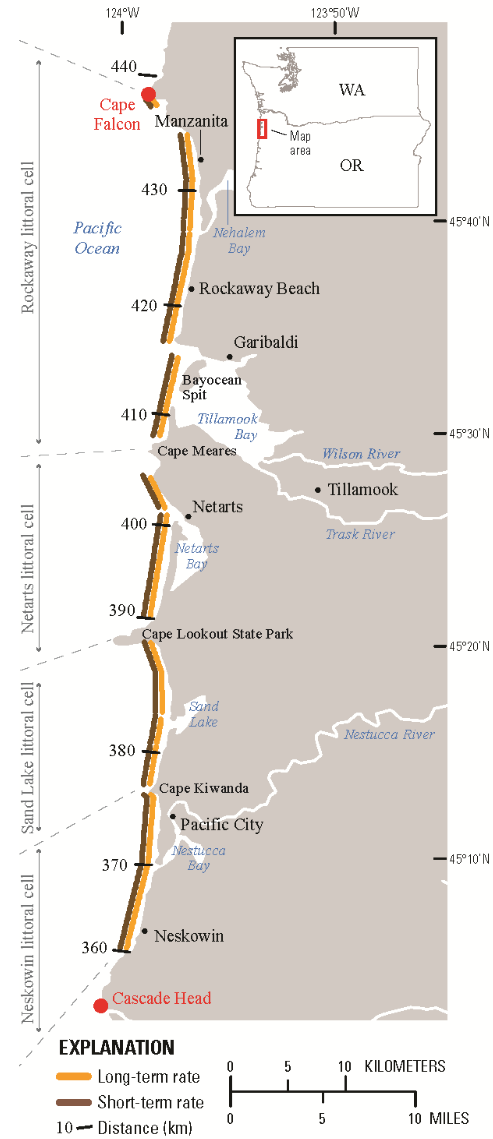
Coastal flooding

Tillamook County Shoreline Change Study

Long-term shoreline change rate



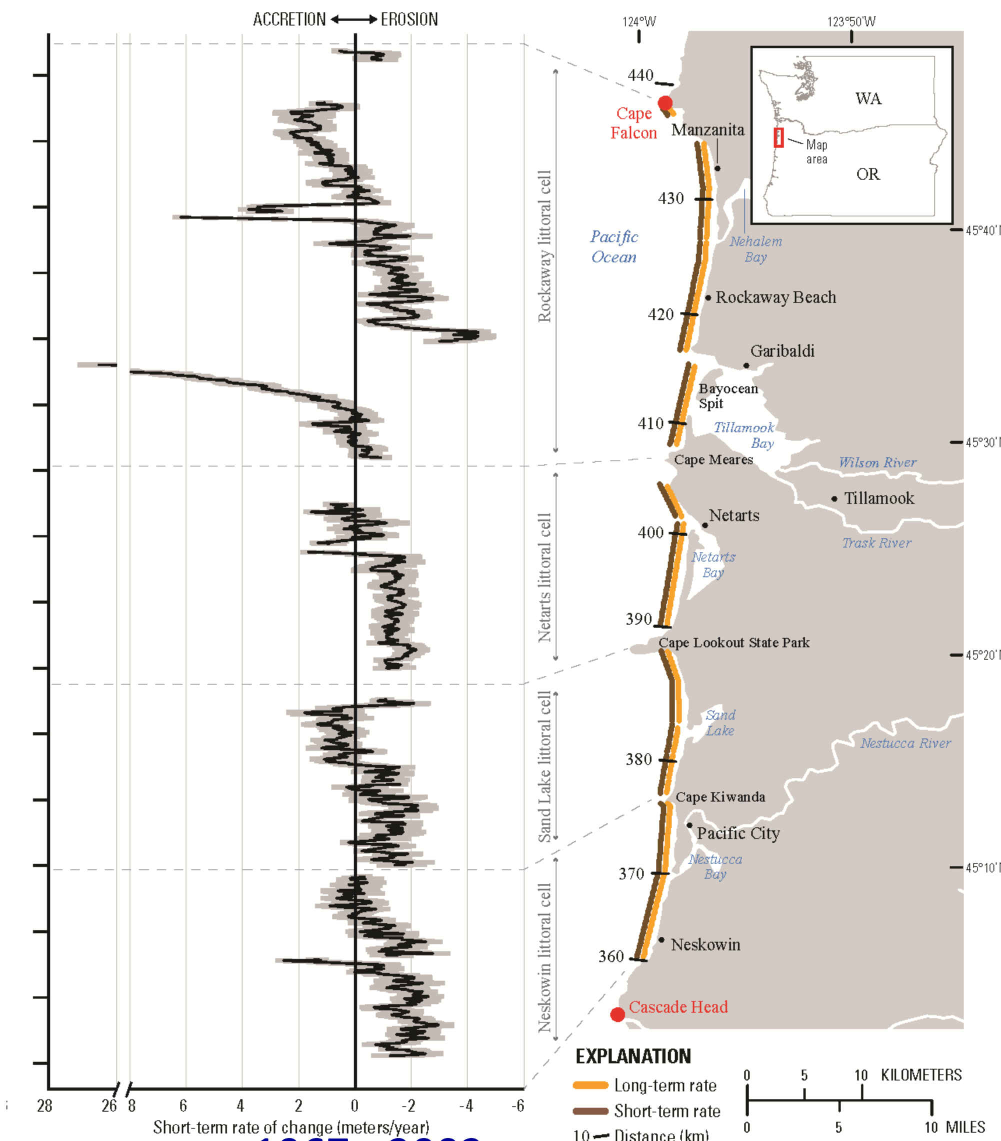
1880s - 2002



Ruggiero et al., 2013

Tillamook County Shoreline Change Study

Short-term shoreline change rate



1967 - 2002

Ruggiero et al., 2013

Tillamook County Shoreline Change Study

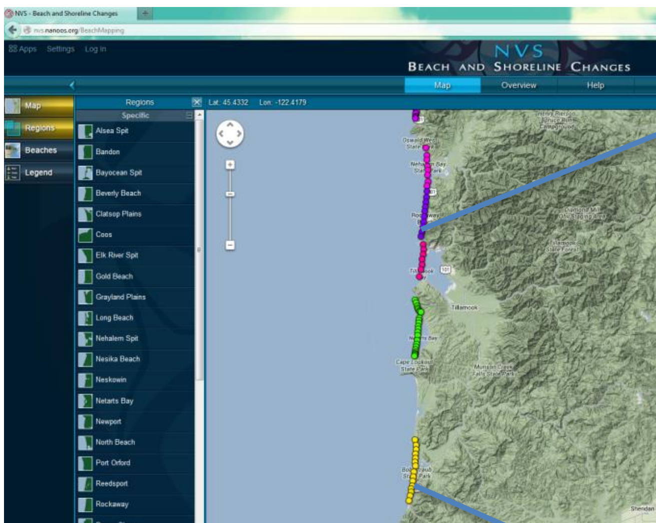
Average decadal-scale (1967—2002) shoreline change rates for the Tillamook County coast.

Littoral Cell	Average of rates (m/yr)	Percent eroding	Percent eroding more than -1 m/yr
Oregon			
Neskowin	-1.1 ± 0.1	86	58
Sand Lake	-0.5 ± 0.1	63	38
Netarts	-1.0 ± 0.1	86	69
Rockaway	0.6 ± 0.1	47	25

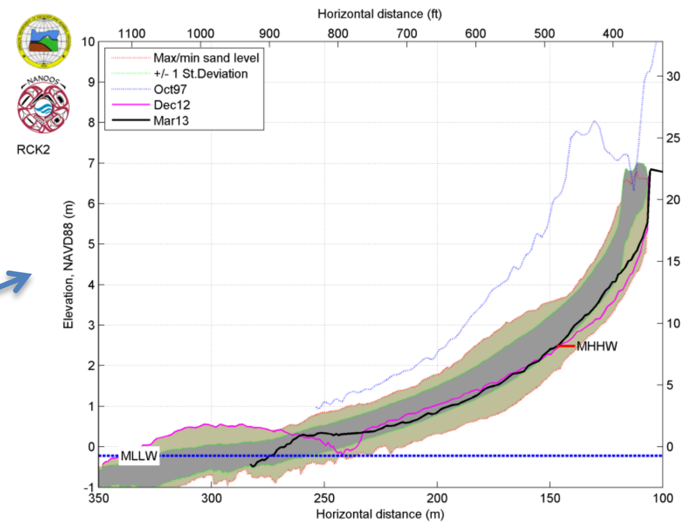
[m/yr, meters per year, numbers in red are indicating that the rate is statistically significant]

Ruggiero et al., 2013

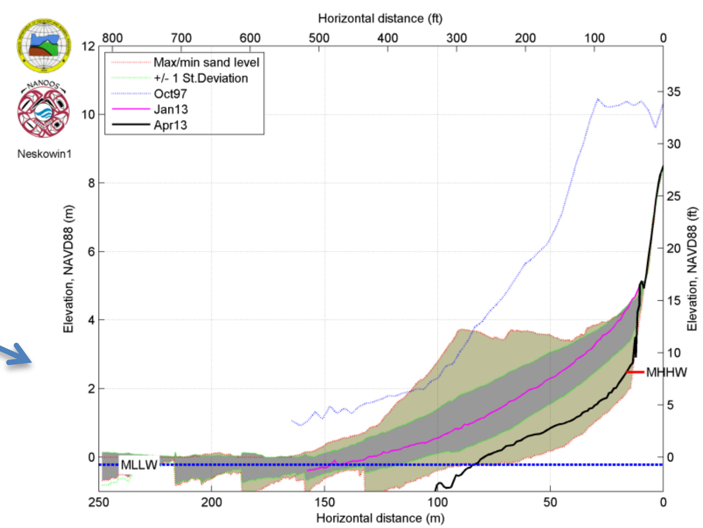
Tillamook County Beach Monitoring (1997-2013)



Rockaway Profile



Neskowin Profile



Courtesy Jonathan Allan, DOGAMI

- **Damage from El Niño-La Niña winters of 1997-1999 re-ignited concerns about erosion and flooding. Subsequent episodes of extreme storminess continue to impact the beach**

- **In September 2009, Neskowin area residents and property owners hosted a public forum with three Commissioners to highlight local concerns and enlist County support**

Neskowin Coastal Hazards Committee

- Committee made up of Neskowin residents, local planning staff, state agency and university representatives, County Commissioner Mark Labhart, Chair
- Met monthly from October 2009 to June 2013
- Held community meetings to survey opinions concerning shoreline protection and land-use issues

Neskowin Coastal Hazards Committee: Mission and Objectives

- **Mission:** Investigate strategies (short and long term) for maintaining the beach and protecting the community, make recommendations, and explore ways to plan for and adapt to the potential future changes

- **Objectives:** 1) Become more knowledgeable, 2) Provide information, 3) Investigate options, 4) Publish Committee findings and advocate, and 5) help garner support and resources necessary to implement agreed upon actions.

Neskowin Coastal Hazards Committee: Partners

- **Residents and elected officials:** "How can we best deal with this today and into the future?
- **OR Dept Geology and Mineral Industries** develops hazard maps:"Where's the hazard zone?"
- **OR State Parks** has jurisdiction for permitting on beach: "Can I get a rip rap permit?"
- **OR Dept Land Conservation and Development** Statewide Planning Goals: "How can Oregon be more resilient in our development?"
- **OSU CEOAS** and **Oregon Sea Grant** apply university research to local problems. "How can research inform our public choices?"

Neskowin Coastal Hazards Committee: Accomplishments

- Research and analysis of possible options & funding
- Riprap Evaluation and Inventory by State Parks
- Tax lot maps w/goal 18 exemptions
- DLCD support for Adaptation Planning
- Community letters, outreach, networking
- Monthly minutes posted to NCA website
- BASECAMP online file sharing site for findings
- Engaged USACE & OSU dune experts for advice
- Using current (OSU) science in hazard assessments

Tillamook County Coastal Futures Project

Research objectives:

1.Build coastal 'Knowledge to Action Networks' consisting of collaborative teams of stakeholders, researchers, and outreach specialists who will co-produce knowledge to inform climate-resilient strategies in select PNW coastal counties.

2.Develop an integrated methodology for projecting the evolving probability of coastal flooding and erosion, through time along the PNW coast, explicitly accounting for climate controls on the various processes relevant to coastal hazards.

3.Develop the information and tools necessary to enable PNW stakeholders to ***envision future scenarios***, assess impacts and associated evolving community and ecosystem vulnerability, and initiate adaptation strategies over the next several decades in the context of SLR and changing storminess...

PIs: Peter Ruggiero (CEOAS), John Bolte (BEE), Pat Corcoran (OSG);
Collaborators: John Stevenson and Denise Lach of CIRC;
GRAs: Alexis Mills (BEE), Katherine Serafin (CEOAS), Eva Lipiec (CEOAS)

Objective 1

Approach

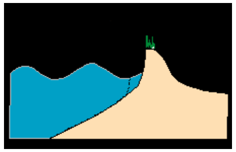
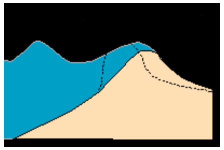
- Collaborative teams co-producing knowledge for climate-resilient strategies.
- Synthesizing and integrating state-of-the-art science into decision support systems.
- Developing frameworks for interactively envisioning future scenarios.

Tillamook County Coastal Futures Project

Objective 2

Projecting the evolving probability of erosion and flooding along the Tillamook County coast

- Created a probabilistic model that captures the variability in extreme Total Water Level events
- Full simulation model gives elevated return level values for TWL when compared to "observational" record
- Model includes **impacts of climate change** and has a variety of uses for coastal management and hazard planning

Chronic or extreme hazards

Katy Serafin and Peter Ruggiero
IH Cantabria Santander, Spain
Ocean Sciences, Honolulu, HI

What is a total water level?

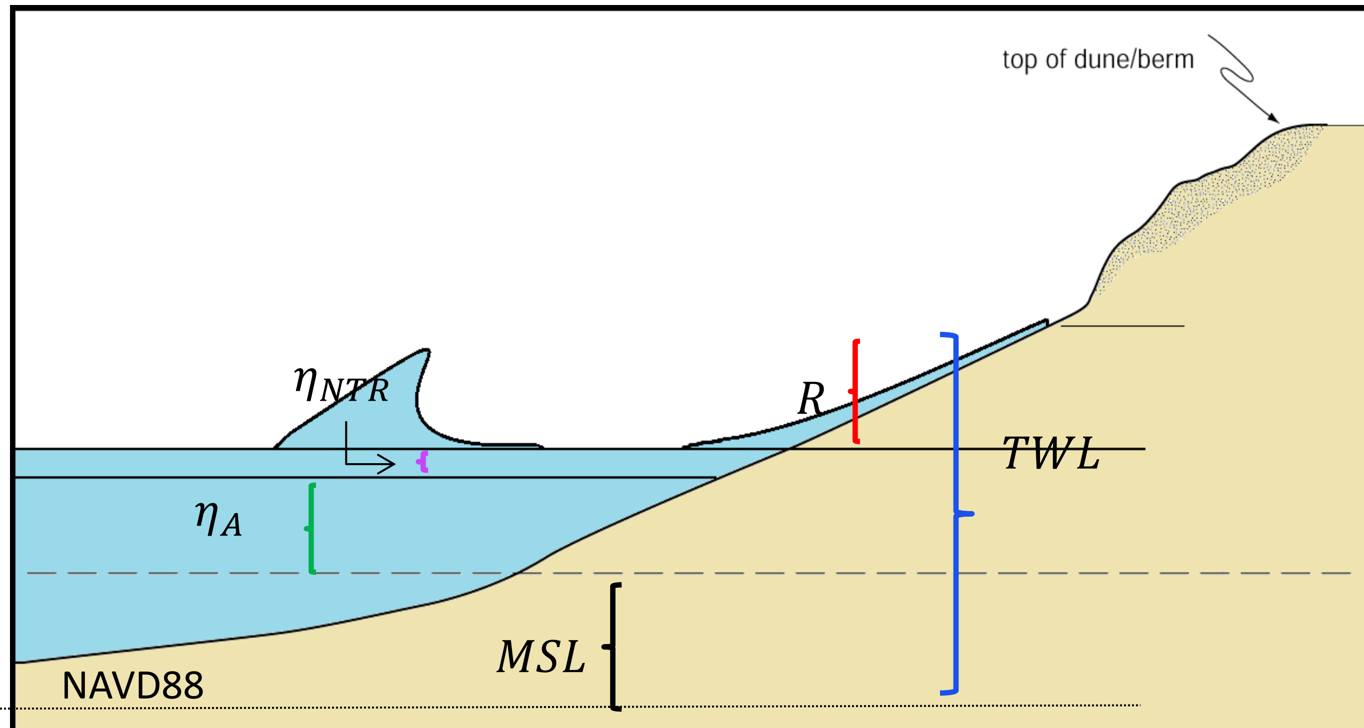
$$TWL = MSL + \eta_A + \eta_{NTR} + R$$

MSL = mean sea level

η_A = astronomical tide

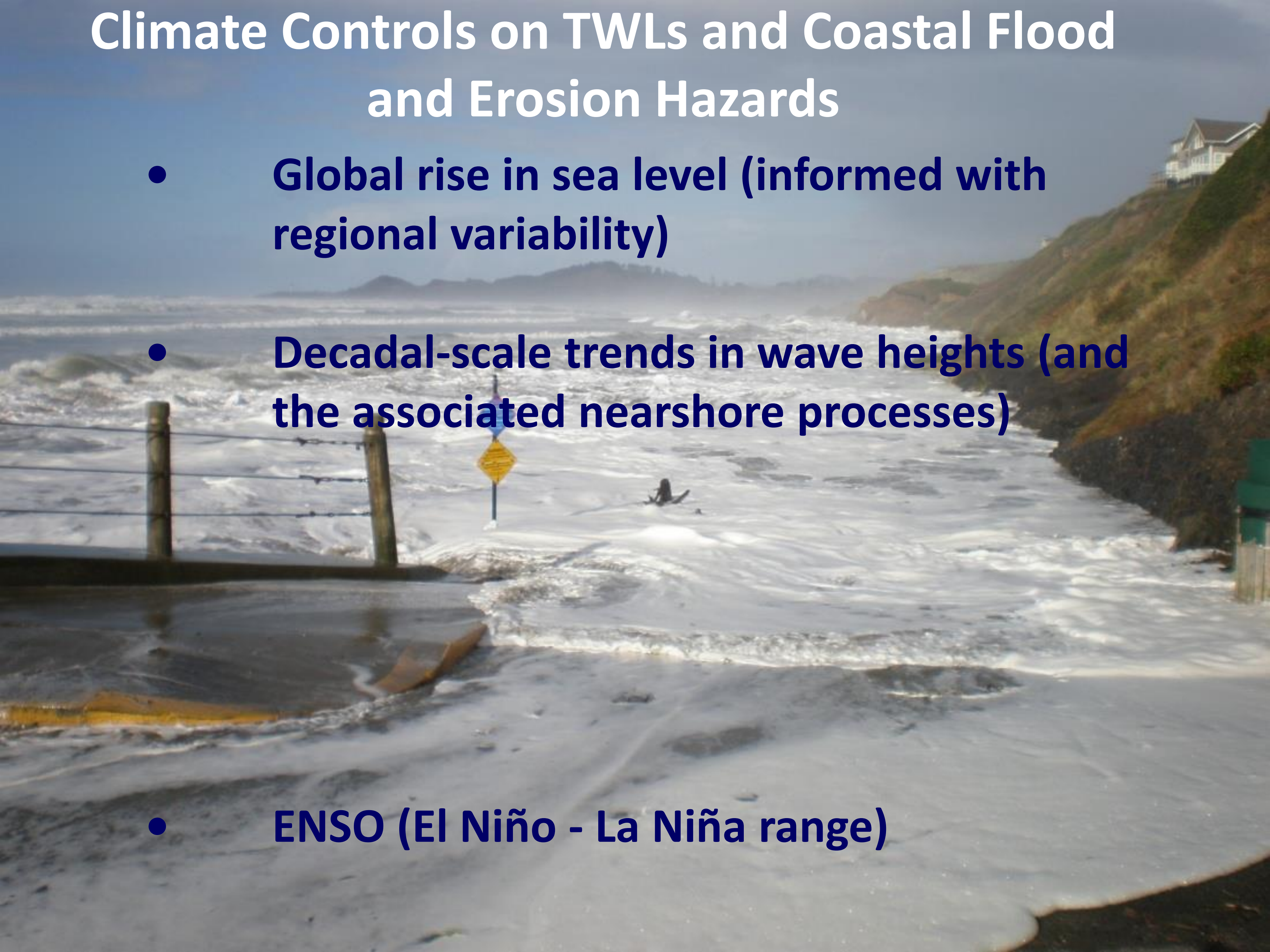
η_{NTR} = non-tidal residual

R = runup, (a function of beach slope, wave height, and wave length)

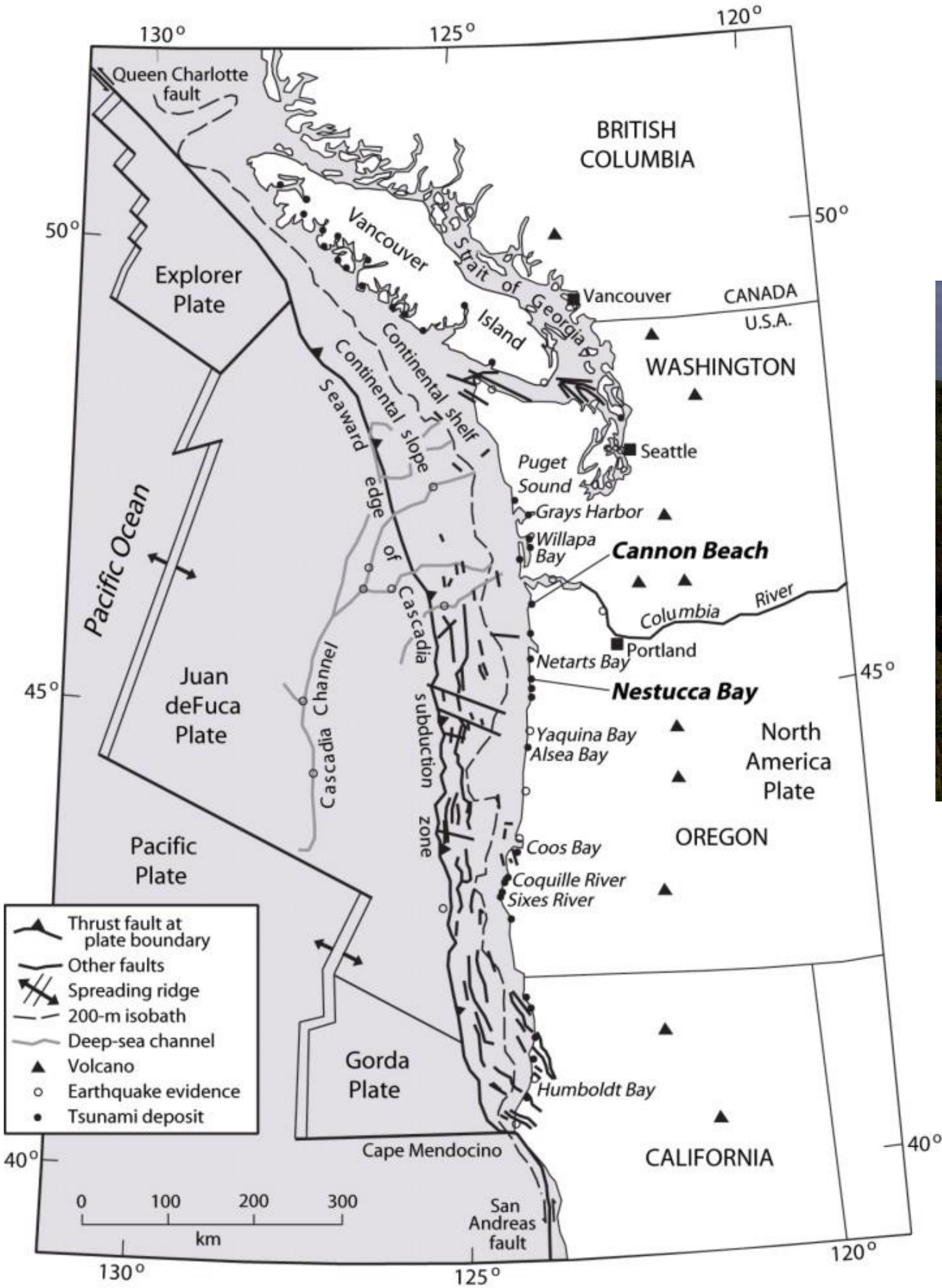


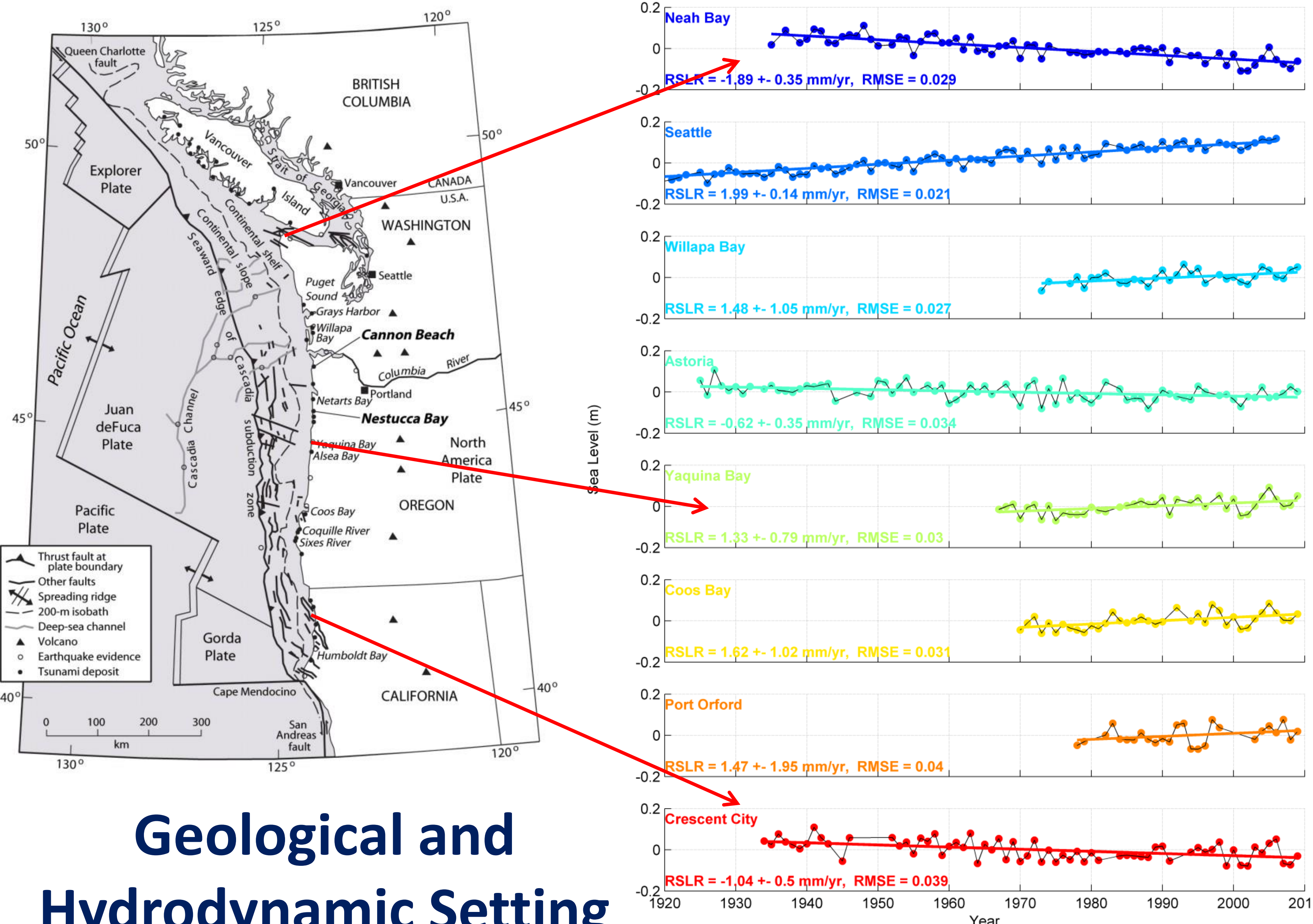
Climate Controls on TWLs and Coastal Flood and Erosion Hazards

- Global rise in sea level (informed with regional variability)
- Decadal-scale trends in wave heights (and the associated nearshore processes)
- ENSO (El Niño - La Niña range)



Regional Tectonics

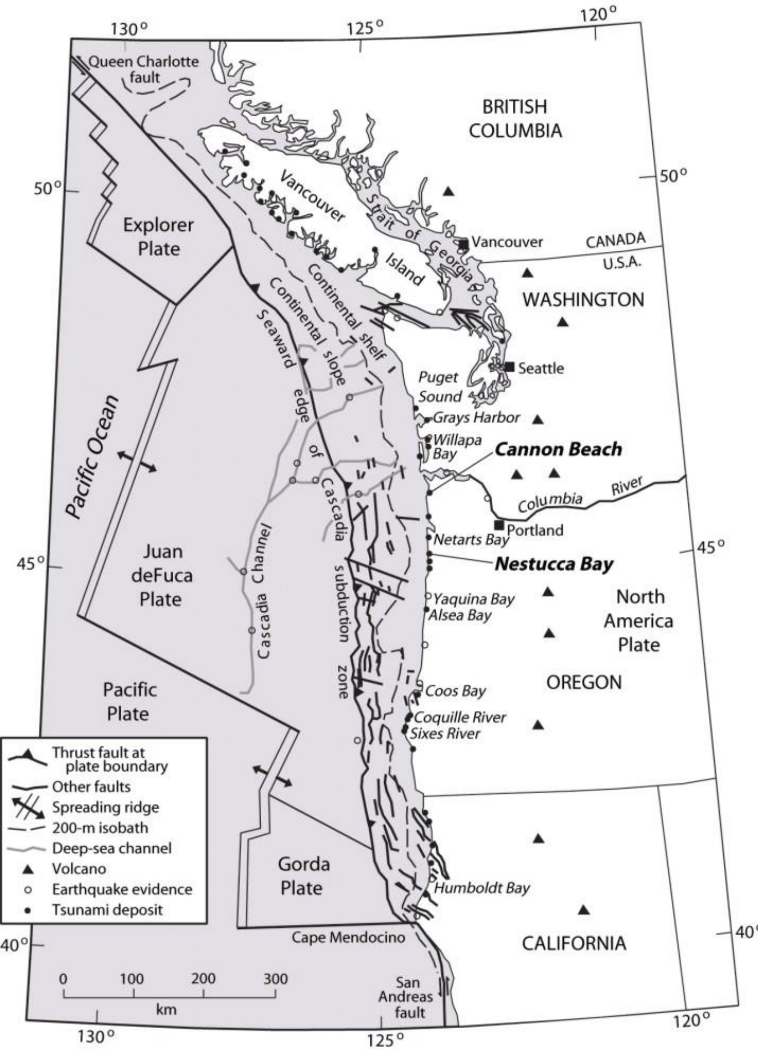




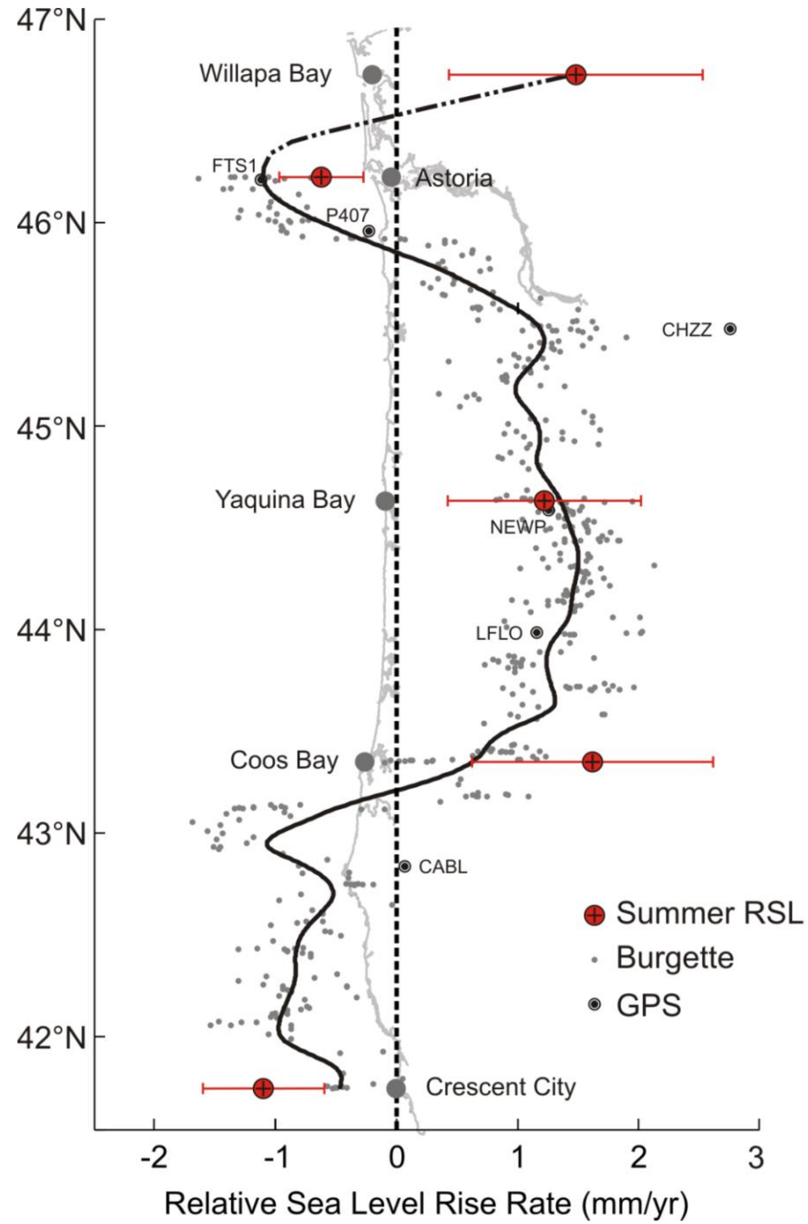
Geological and Hydrodynamic Setting of the PNW

Vertical land motions alter impacts of SLR

Komar, Allan, and Ruggiero, 2011

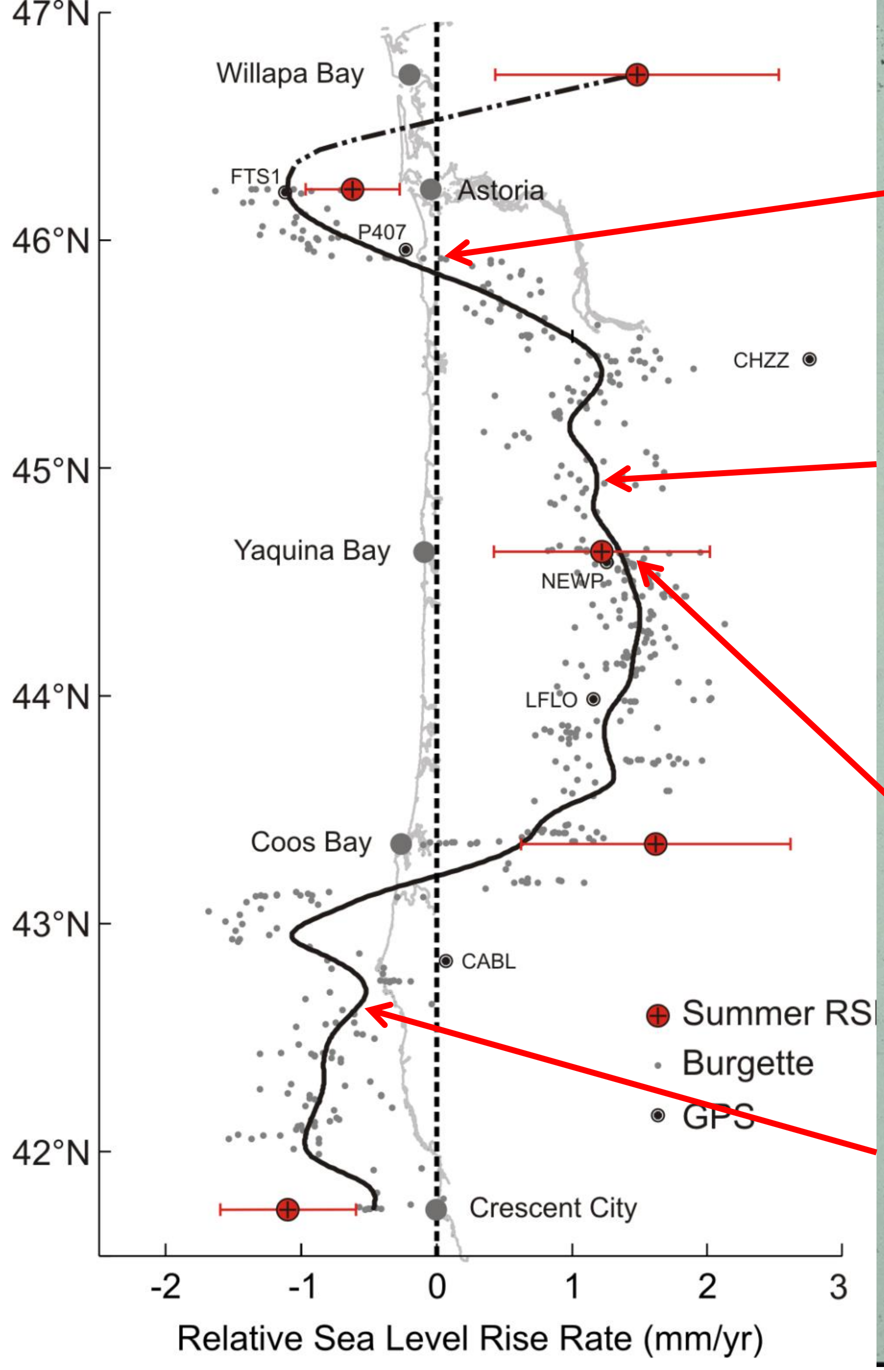


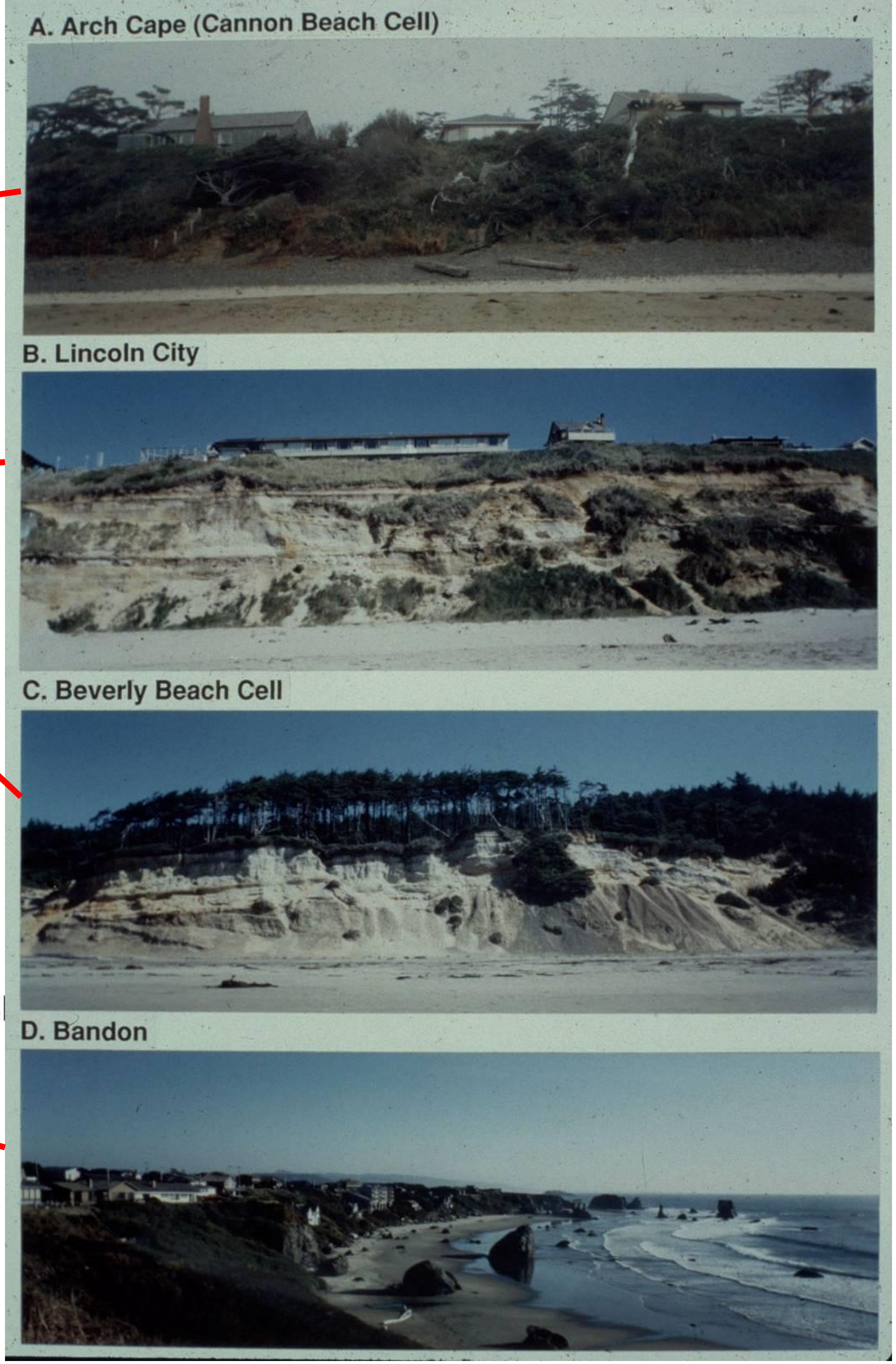
Geological and Hydrodynamic Setting of the PNW



Varying rates of uplift are reflected in RSLR

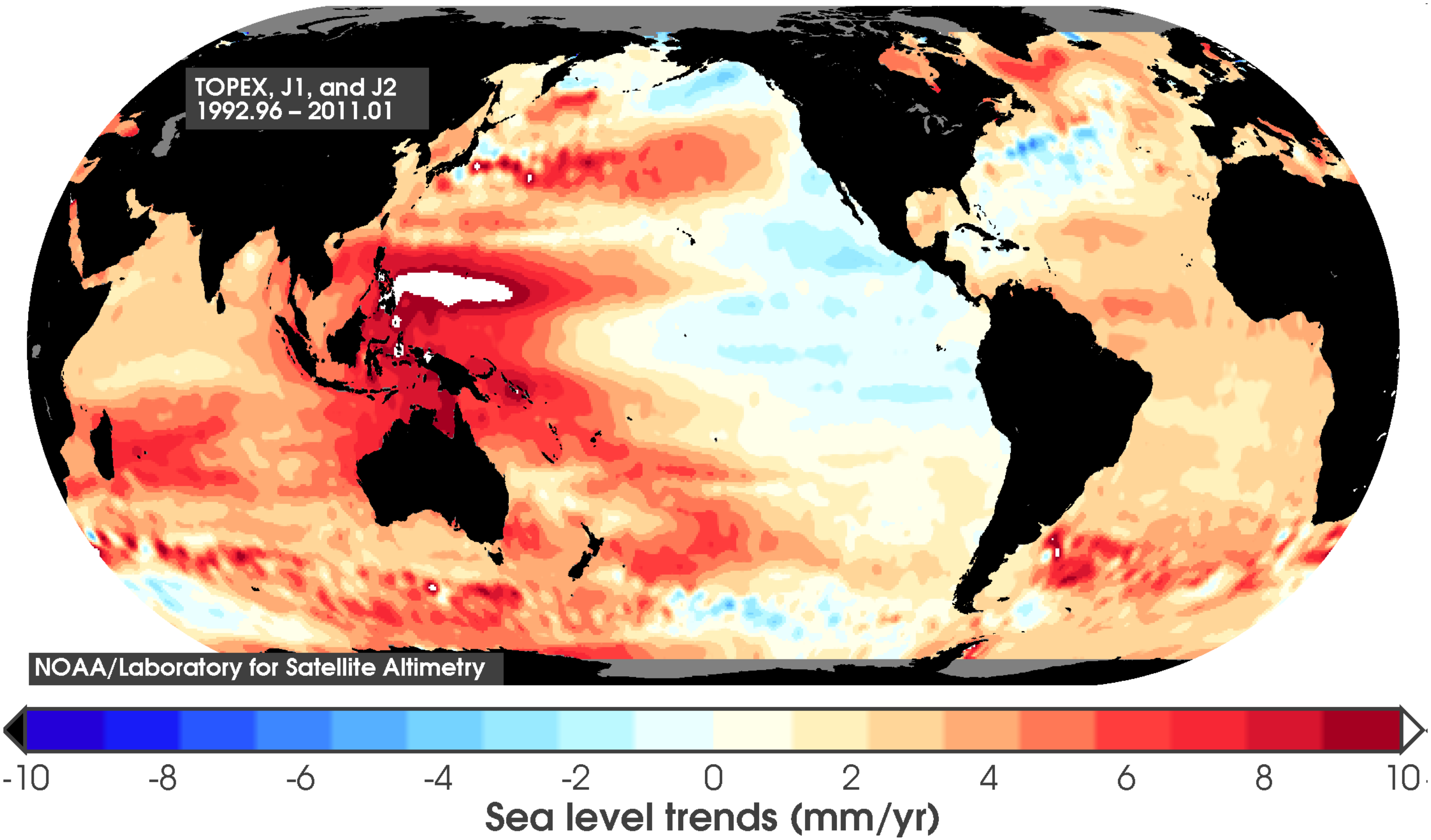
Komar, Allan, and Ruggiero, 2011. after Burgette et al. 2009





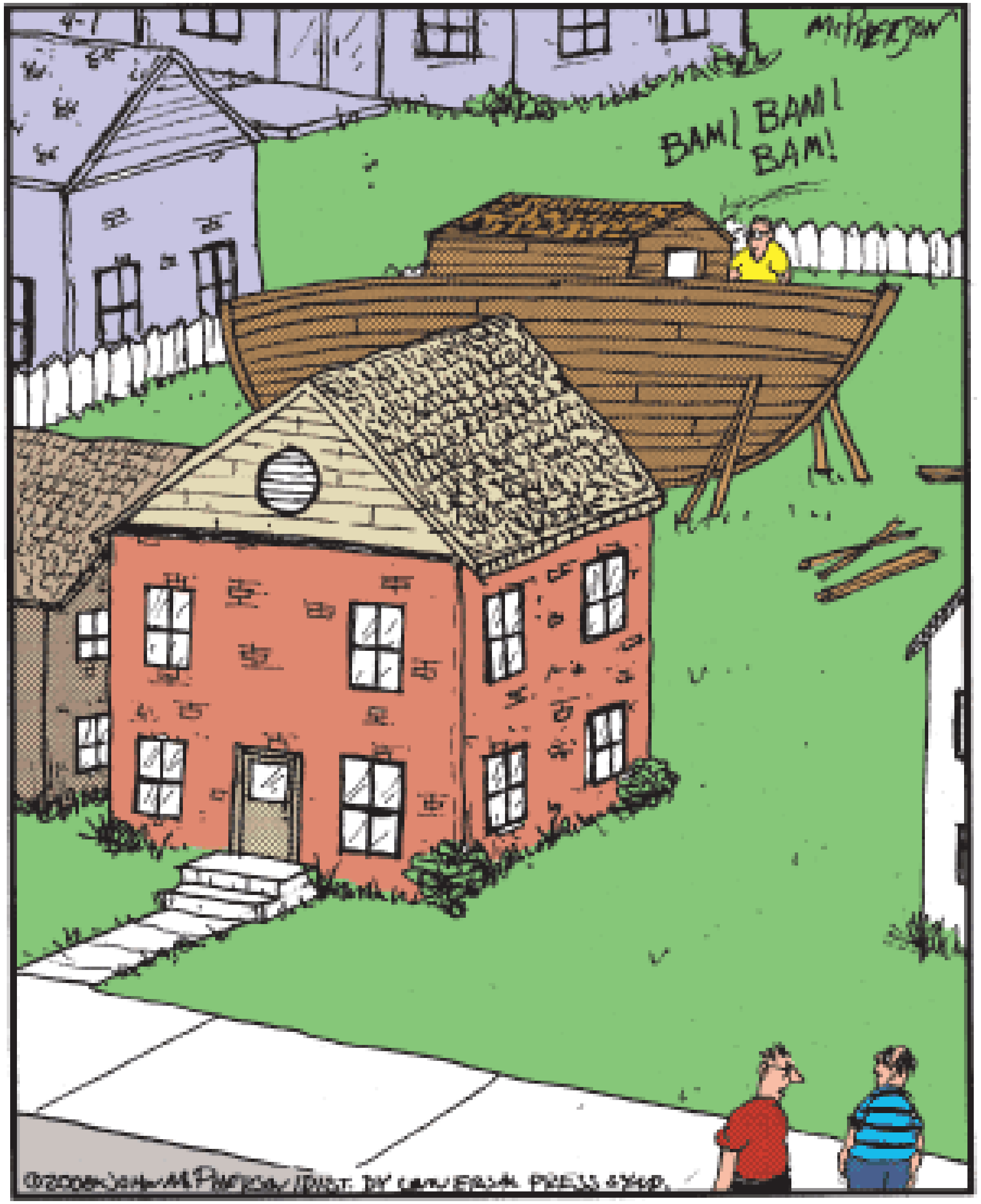
Komar, Allan, and Ruggiero, 2011

Sea-level Rise: Regional variability



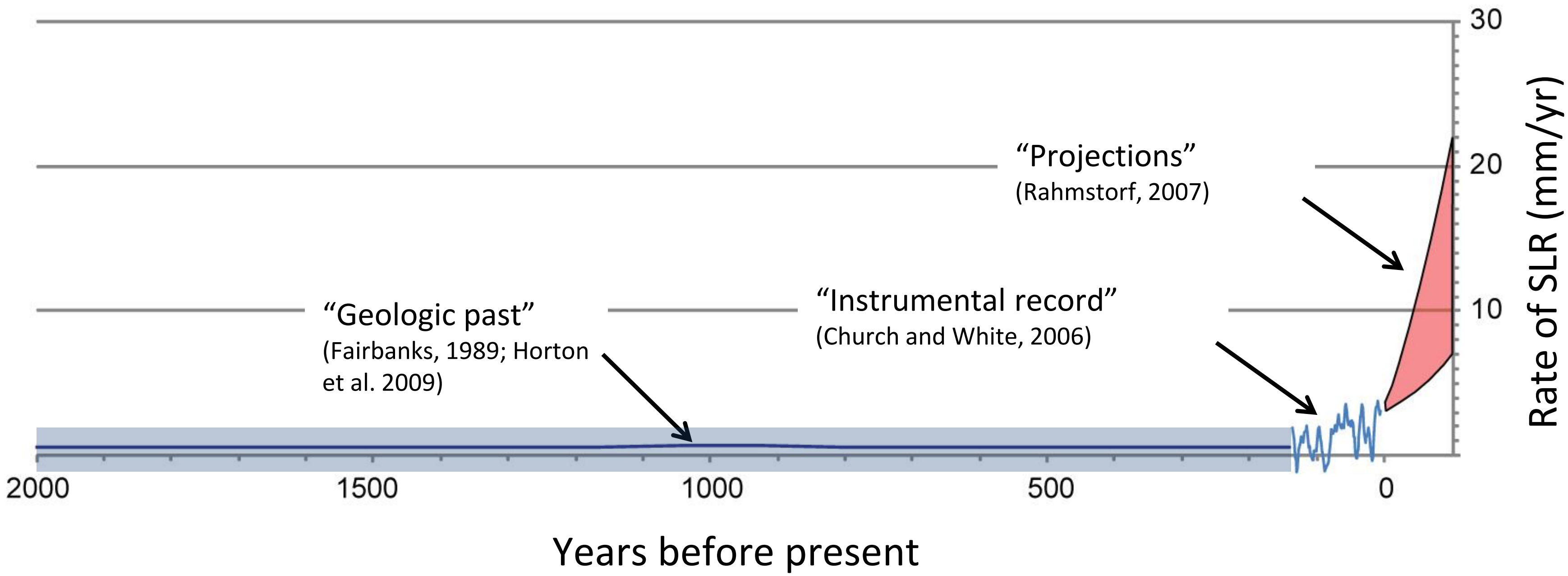
NOAA Laboratory for Satellite Altimetry/ Sea-level rise

Since the PDO regime shift in the late 1970s, the predominant wind stress patterns along in the North Pacific have served to attenuate the rising trend in sea levels seen globally, for the most part suppressing regional ocean levels. (Bromirski et al., 2011)



"I'd chalk it up to just another crazy backyard hobby, except that he's the world's leading authority on global warming."

Past, present, and potential future rates of sea-level rise



- Wide range of SLR_{2100} estimates
  - **0.18-0.59 m (IPCC, 2007)**
  - Up to 2.0 m (Pfeffer et al., 2008)
  - 0.5-1.4 m (Rahmstorf, 2007; 2010)
  - 0.2-2.0 m (National Climate Assessment, 2012)
  - .2-1.4 m (NRC Committee on SLR, 2012)
  - **.26-.97 m (IPCC, 2013)**

Uncertainty is increasing!

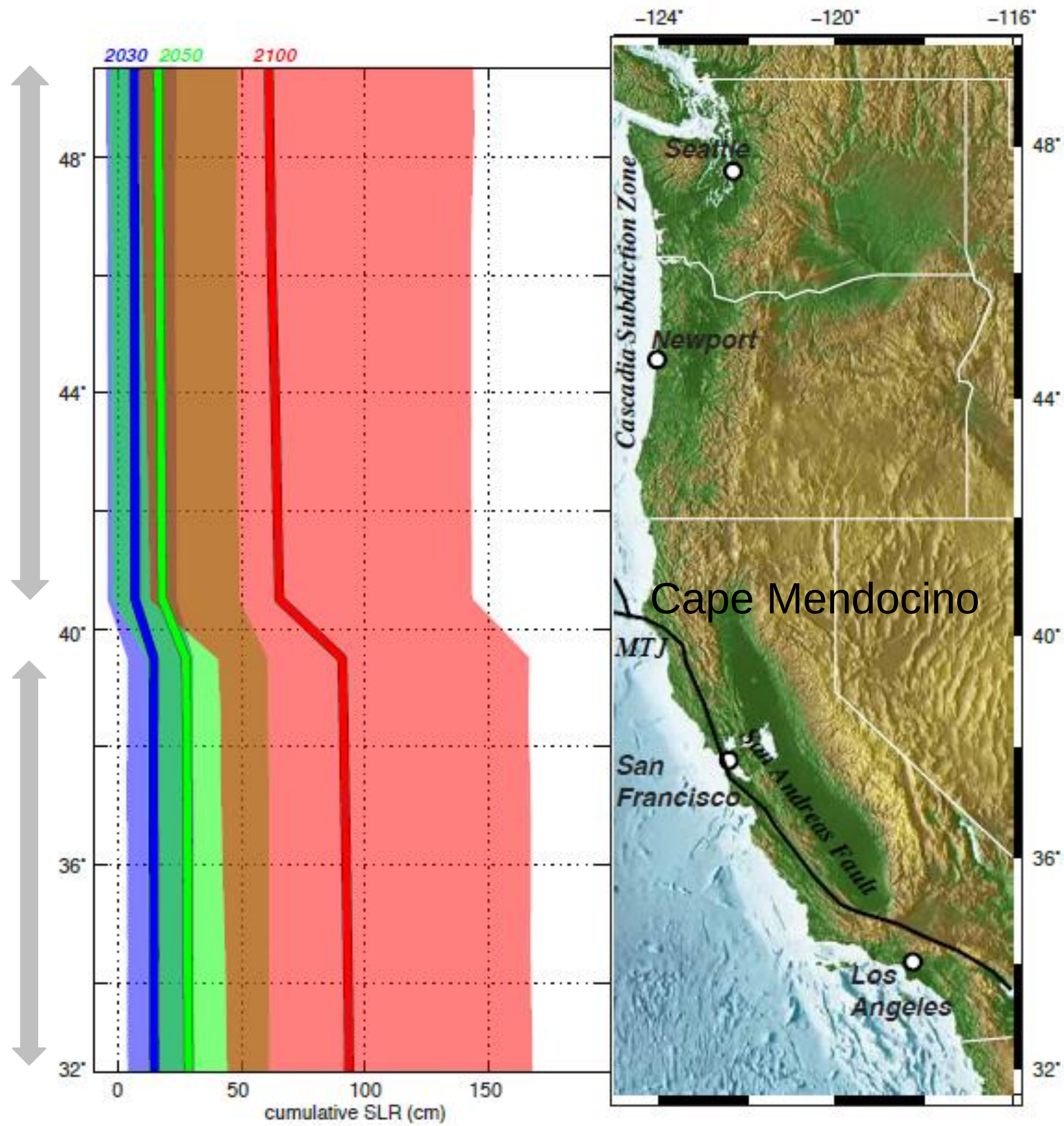
From Thieler et al., 2009

Committee's West Coast Projections

Land uplift + fingerprinting

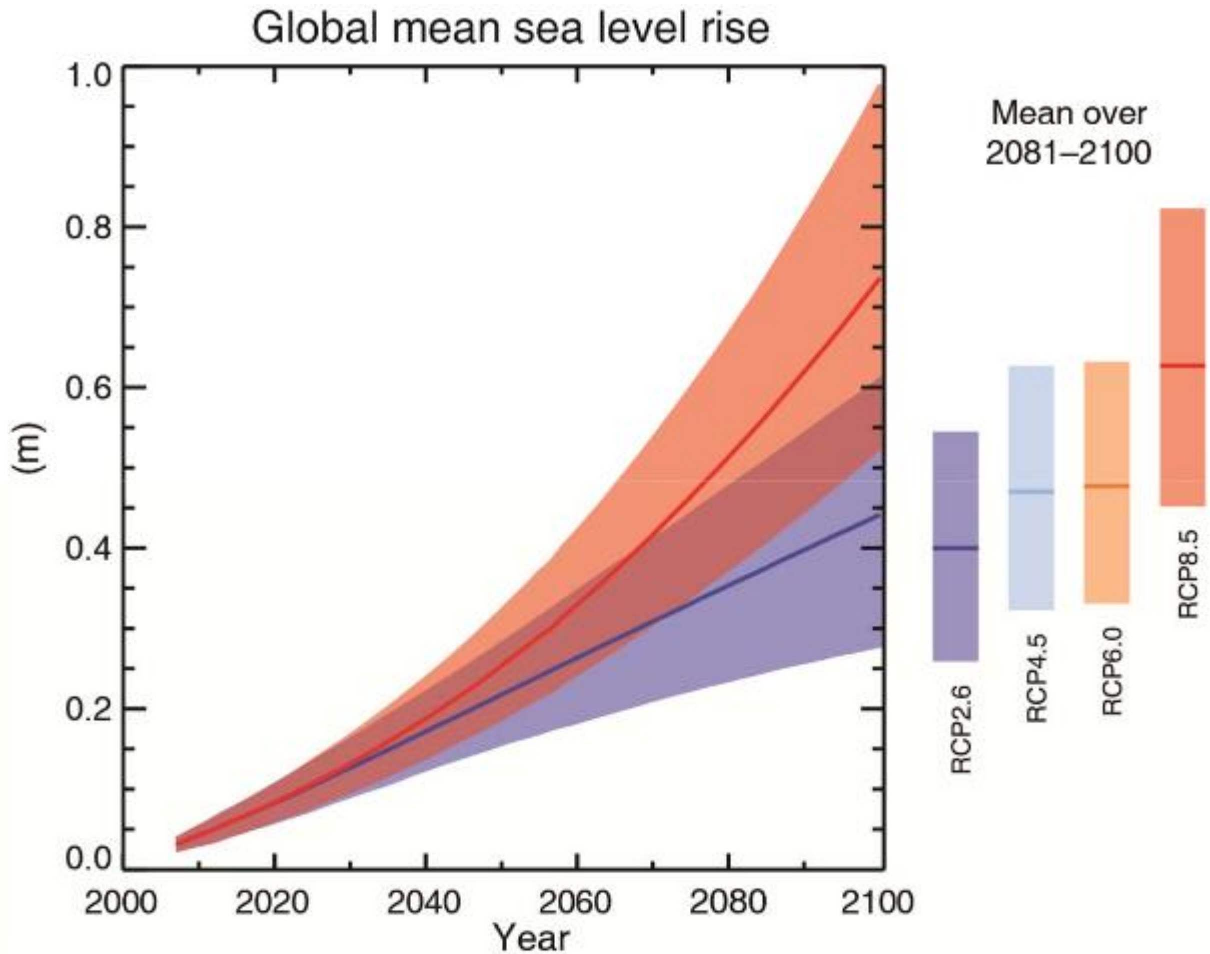
Land subsidence

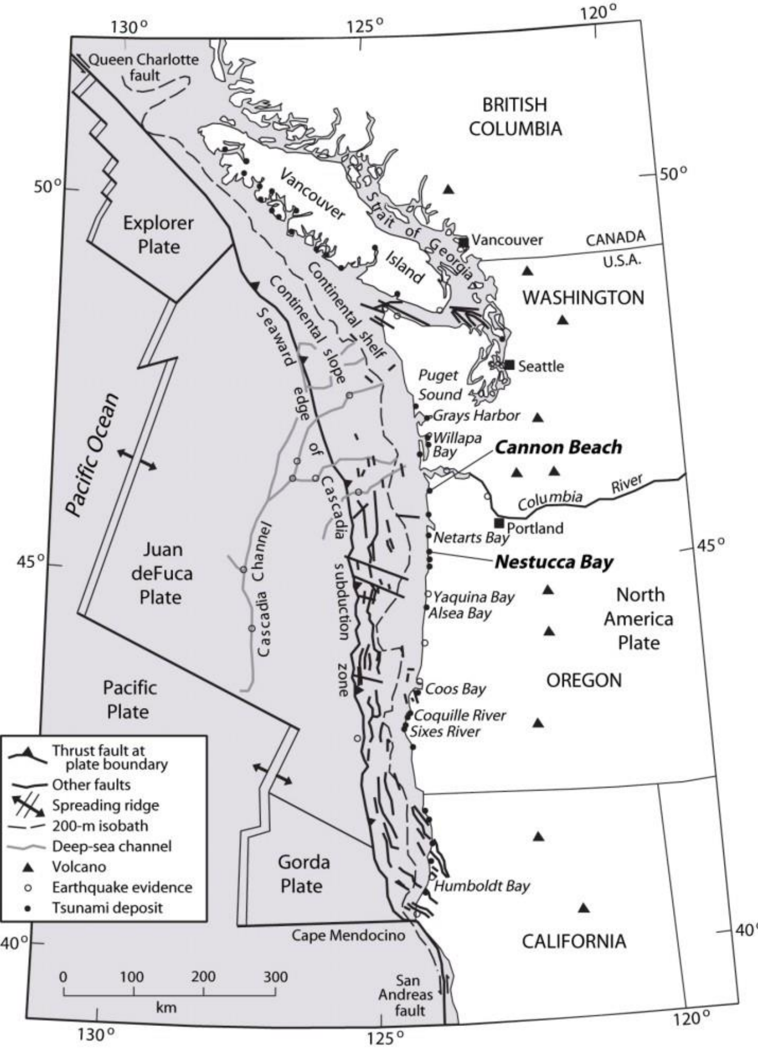
Blue: 2030
Green: 2050
Red: 2100



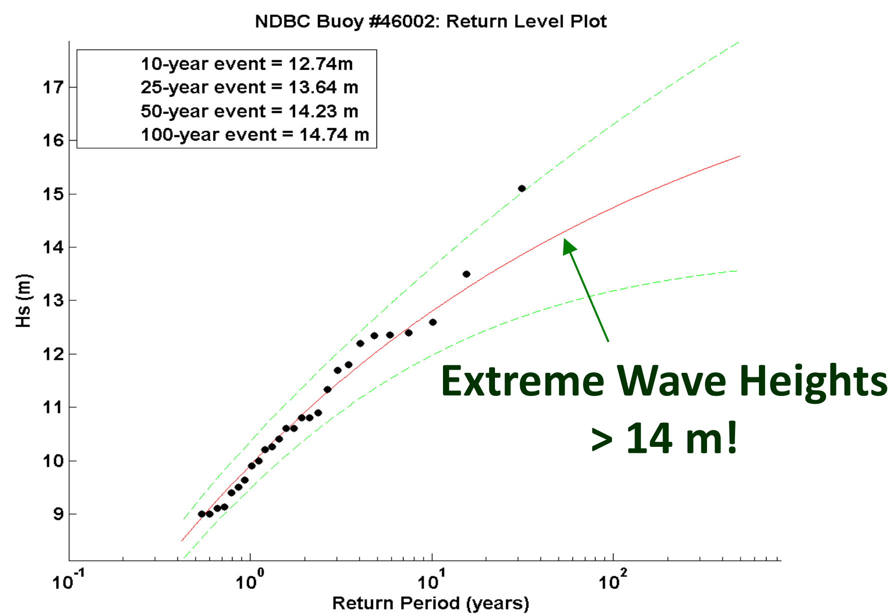
NRC, 2012

IPCC AR5 Global Mean Sea Level Rise Projections



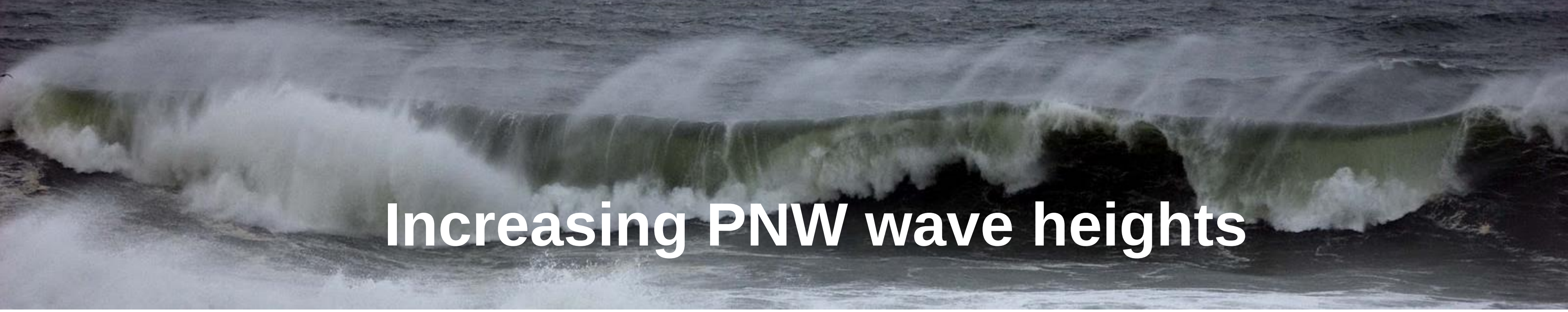


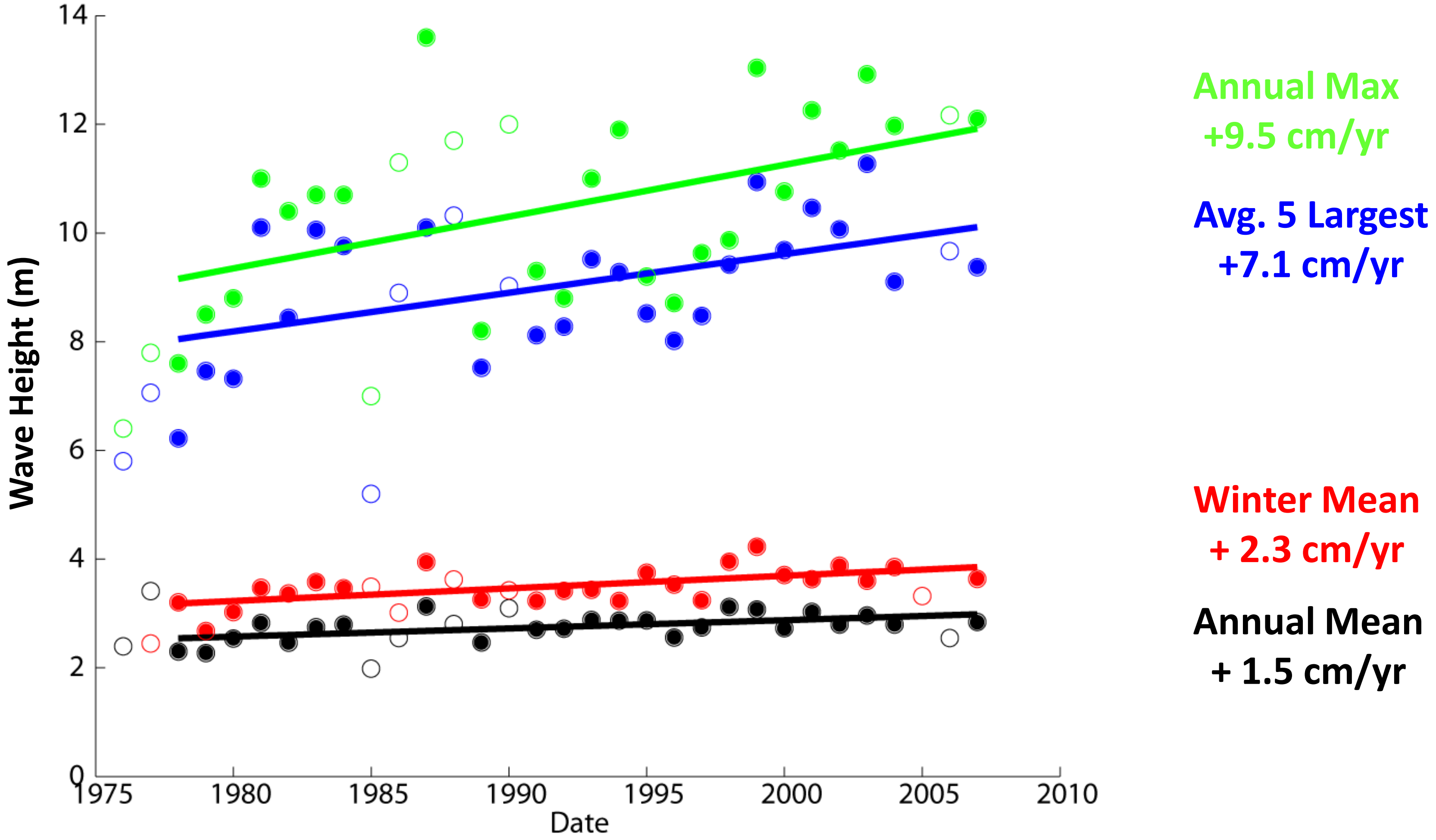
Geological and Hydrodynamic Setting of the PNW



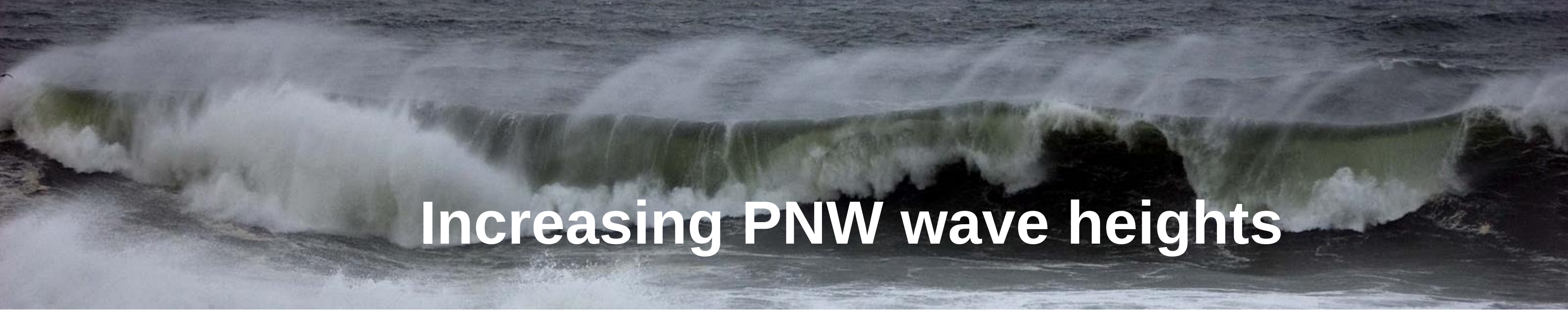
One of the most intense wave climates in the world

Increasing PNW wave heights

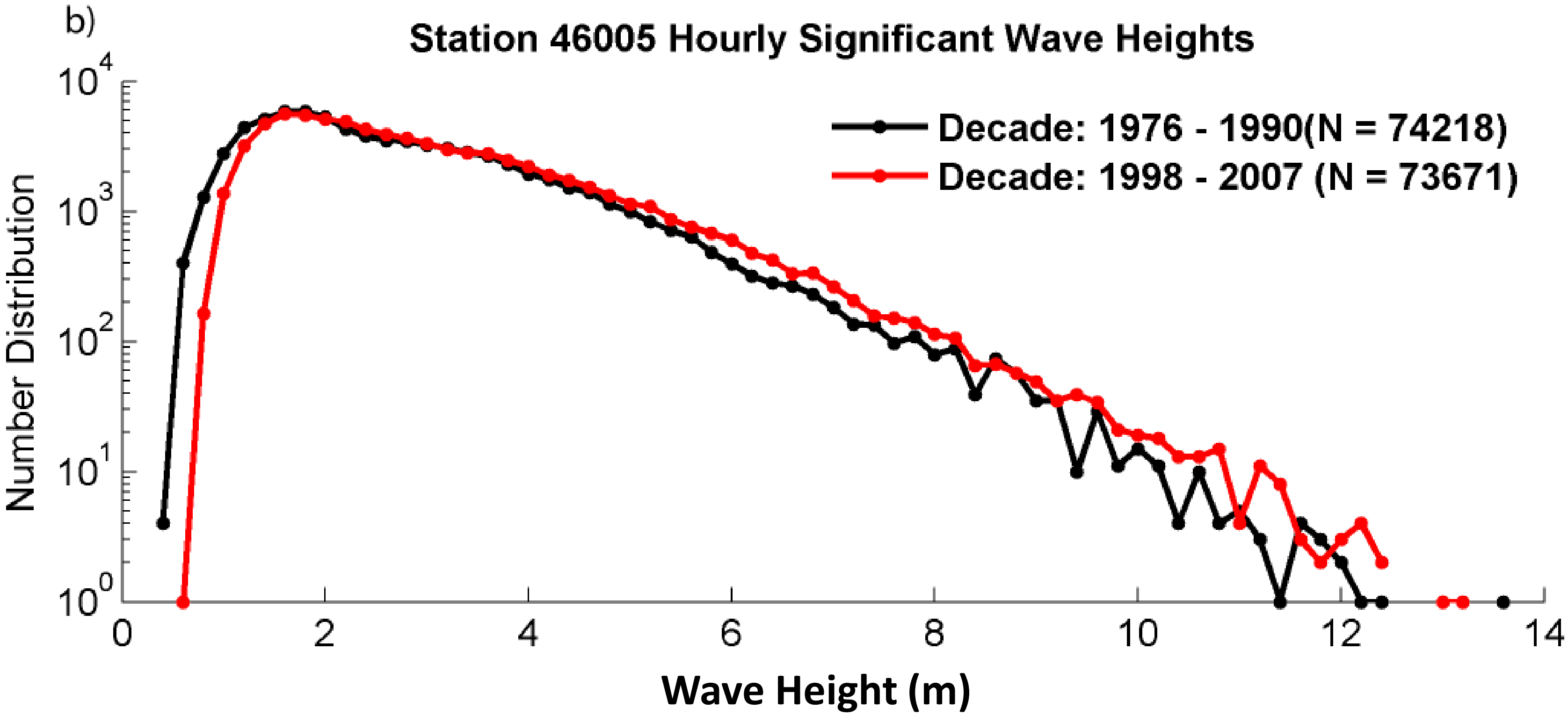




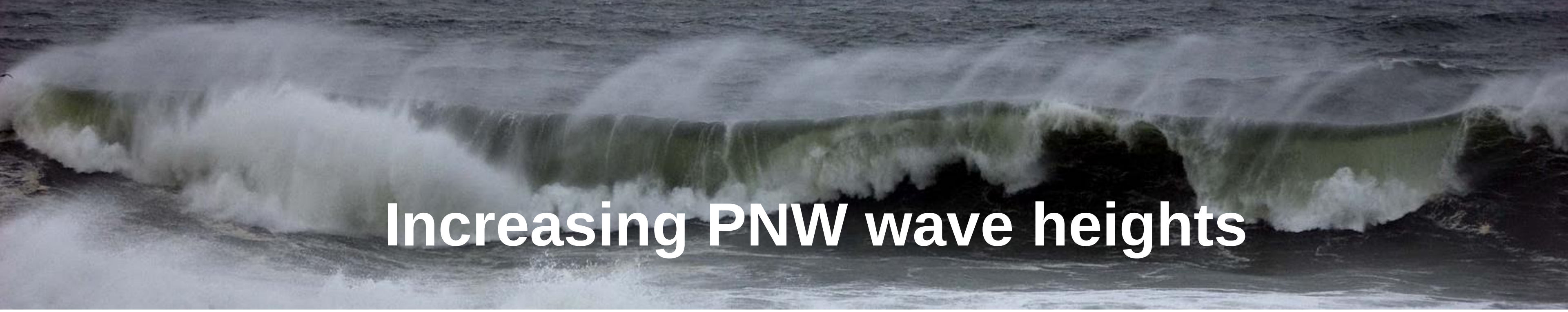
Ruggiero et al., 2010; after Allan and Komar, 2000; 2006



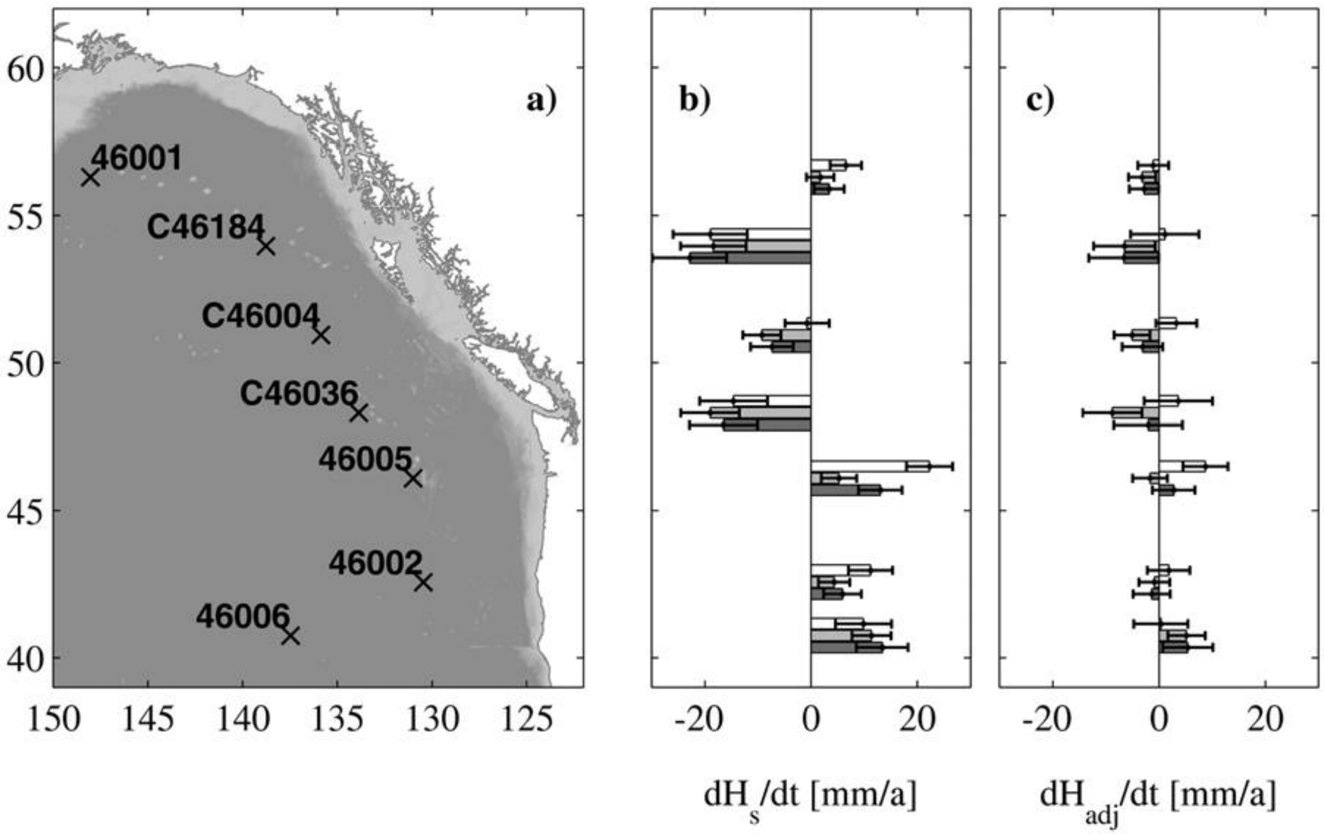
Increasing PNW wave heights



If trends continue they have the potential to increase coastal hazards - but changes have not been attributed to climate change, and…



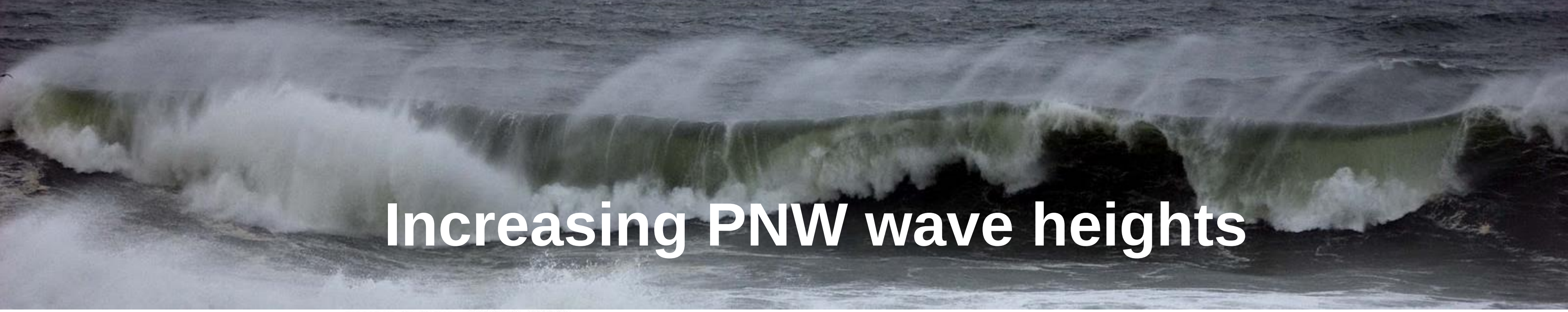
Increasing PNW wave heights

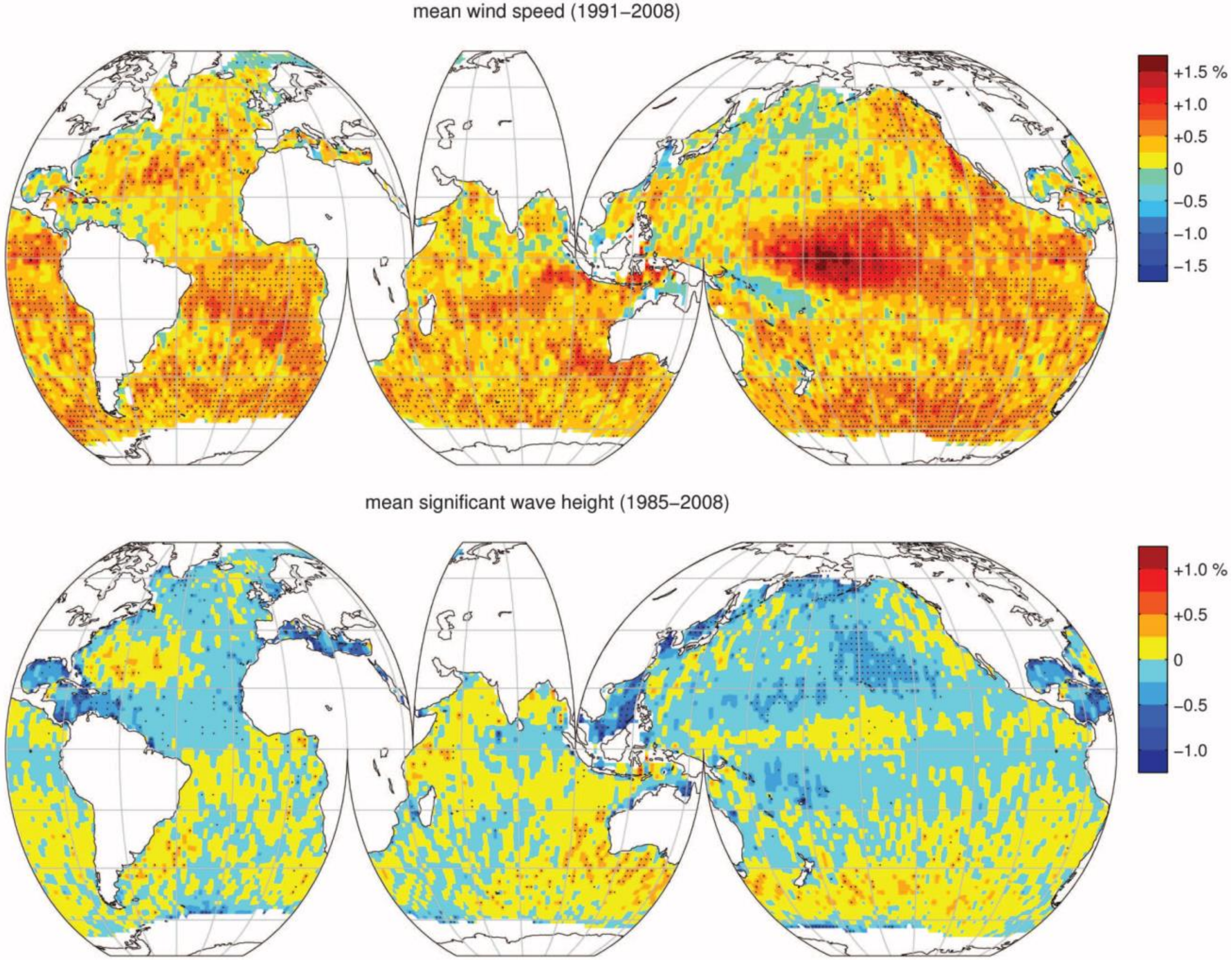


Modifications of buoy hardware and analysis procedures call into question magnitudes of trend analyses due to step changes, however…

Gemmrich et al., 2011, GRL

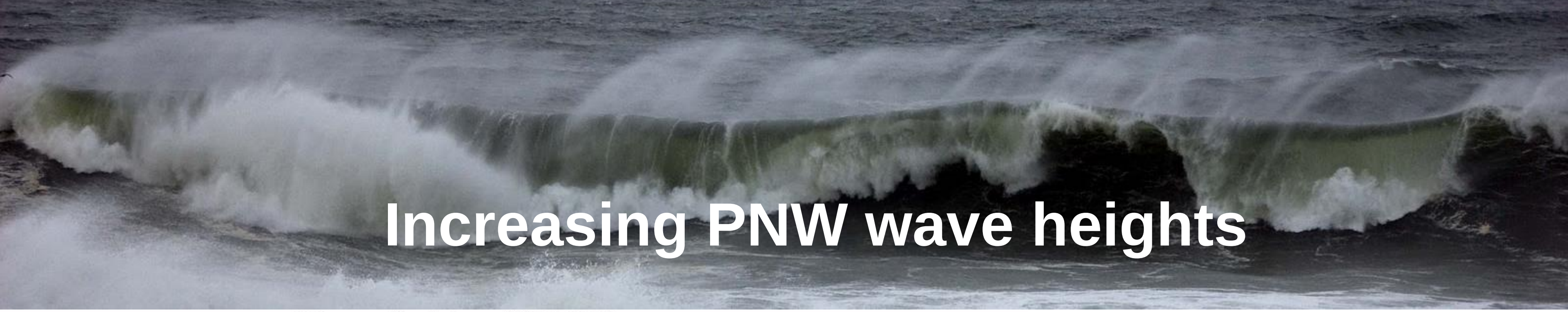
Increasing PNW wave heights



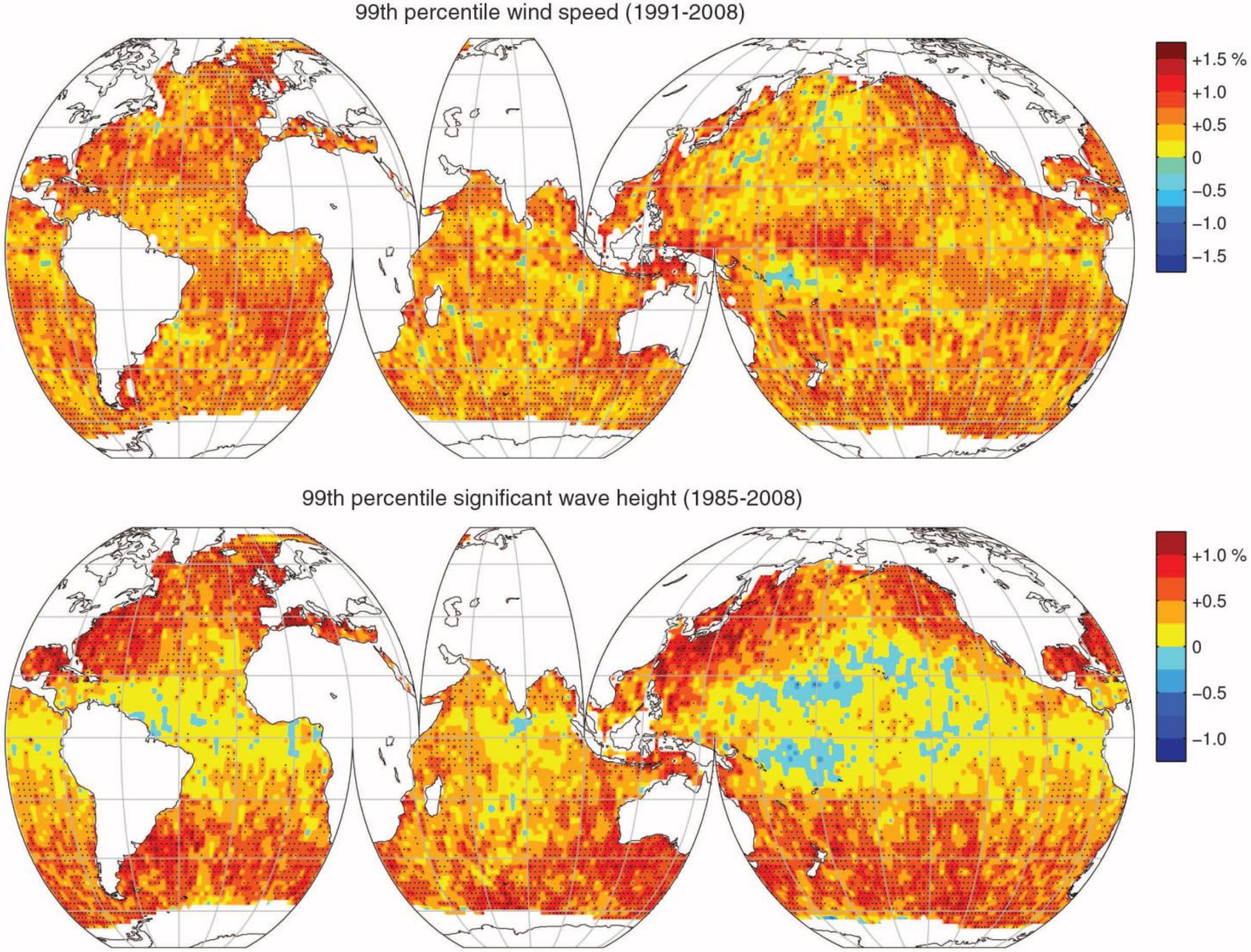


Altimetry measurements (1985-2008) indicate increases in mean global winds.

Young et al., 2011, Science



Increasing PNW wave heights



Altimetry measurements (1985-2008) indicate increases in both extreme winds and wave heights.

Young et al., 2011, Science

Impact of Increasing Storminess on ‘Design’ Conditions: Non-Stationary Extreme Value Analysis

‘Stationarity is Dead’

- Milly et al., 2008, Science

** Today’s100-yr return level wave height (1% chance of occurring) has between a 30 - 60% chance of occurring in 2032!!

Ruggiero et al. 2010

Coastal Impacts, Adaptation and Vulnerabilities

A Technical Input to the 2013 National Climate Assessment

USGS
science for a changing world

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

'Stationarity is Dead'

Milly et al., 2008, Science

Variability in the location and time-of-year of storm genesis can influence landfalling storm characteristics, and even small changes can lead to large changes in landfalling location and impact. While there is only <u>low confidence</u> in the sign of projected changes in storm-related hazards along the coast (which depend on a combination of factors, such as frequency, track, intensity, and storm size), any sea-level rise is virtually certain to exacerbate storm-related hazards. <u>(High Confidence)</u>

There is low confidence in wave height projections because of the small number of studies, the lack of consistency of the wind projections between models, and limitations in the models' ability to simulate extreme winds.

NCA, 2012.

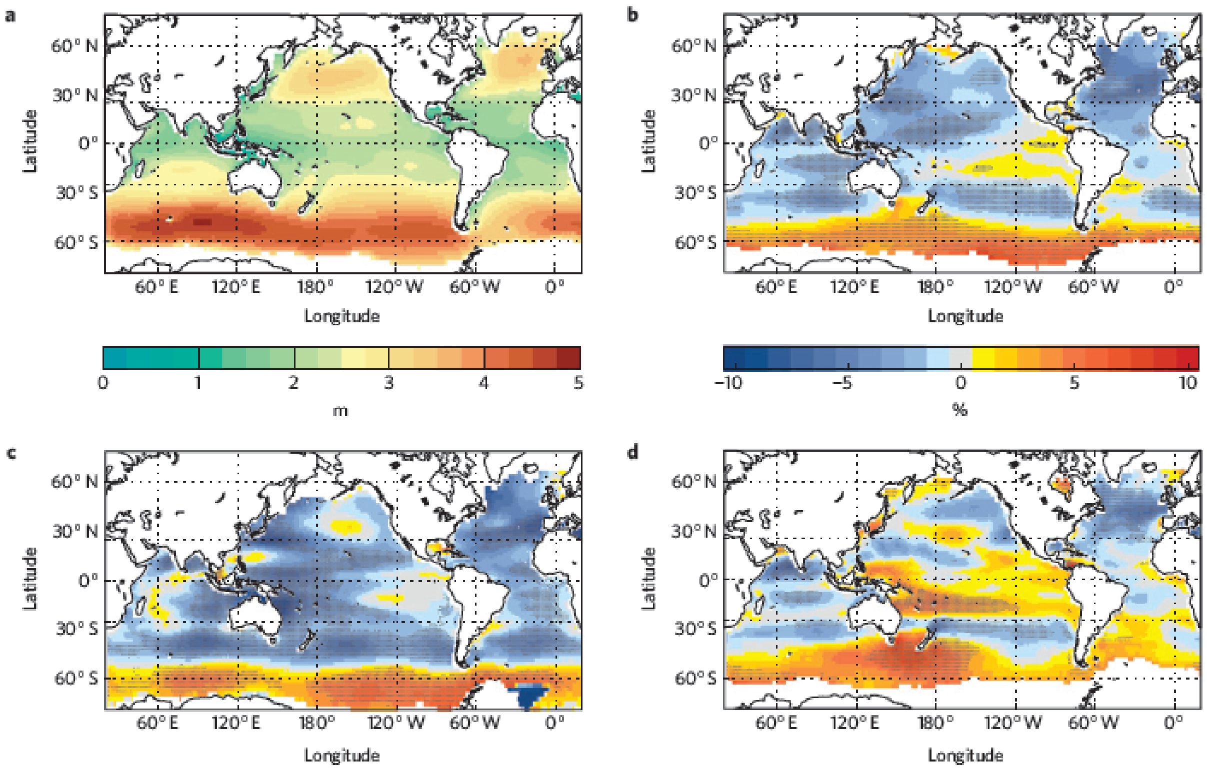


Figure 2 | Projected future changes in multi-model averaged significant wave height. **a**, Averaged multi-model annual significant wave height (H_S, m) for the time-slice representing present climate (~1979–2009). **b–d**, Averaged multi-model projected changes in annual (**b**), JFM (**c**) and JAS (**d**) mean H_S for the future time-slice (~2070–2100) relative to the present climate time-slice (~1979–2009) (% change). Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models are included in the Supplementary Information.

Table 1 | Percentage area of global ocean where projected increase/decrease is robust within the multi-model ensemble.

	Annual		JFM		JAS	
	Percentage area of robust projected increase	Percentage area of robust projected decrease	Percentage area of robust projected increase	Percentage area of robust projected decrease	Percentage area of robust projected increase	Percentage area of robust projected decrease
H_S	7.1	25.8	4.9	38.5	8.8	8.4
T_M	30.2	19.0	8.7	44.6	33.6	10.7
θ_M	18.4	19.7	8.95	21.4	17.1	12.7

See Methods for definition used for robustness. Increase (decrease) in direction (θ_M) corresponds to clockwise (anti-clockwise) rotation.

Hemer et al., 2013

Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century

Kerry A. Emanuel – PNAS, 2013

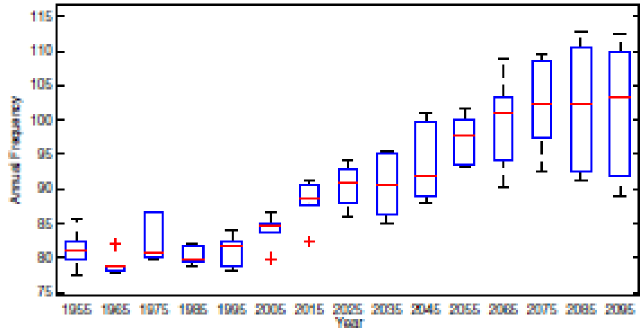


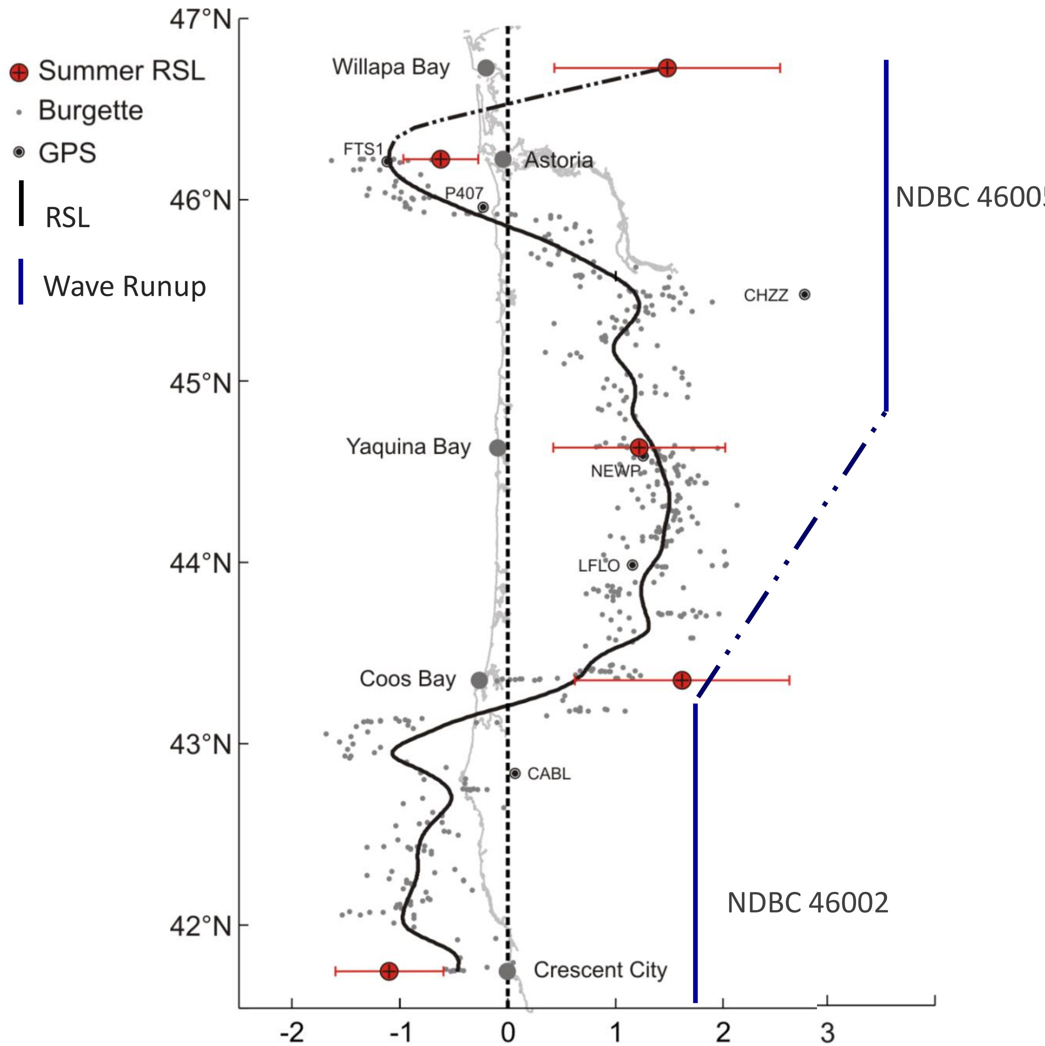
Fig. 1. Global annual frequency of tropical cyclones averaged in 10-y blocks for the period 1950–2100, using historical simulations for the period 1950–2005 and the RCP8.5 scenario for the period 2006–2100. In each box, the red line represents the median among the six models, and the bottom and tops of the boxes represent the 25th and 75th percentiles, respectively. The whiskers extend to the most extreme points not considered outliers, which are represented by the red + signs. Points are considered outliers if they lie more than 1.5 times the box height above or below the box.

Table 2. Comparison between CMIP3 and CMIP5 changes in downscaled tropical cyclone frequency and power dissipation

Institute ID	CMIP3 model	CMIP5 model	CMIP3 change in global frequency, %	CMIP5 change in global frequency, %	CMIP3 change in global power dissipation, %	CMIP5 change in global power dissipation, %
NCAR	CCSM3	CCSM4	−3	+11	+5	+8
GFDL	CM2.0	CM3	−13	+41	+2	+72
MOHC		HADGEM2-ES		+22		+31
MPI	ECHAM5	MPI-ESM-MR	−11	+29	+4	+57
MIROC	MIROC3.2	MIROC5	−12	+38	+8	+80
MRI	MRI-CGCM2.3.2a	MRI-CGCM3	+2	+13	+22	+26

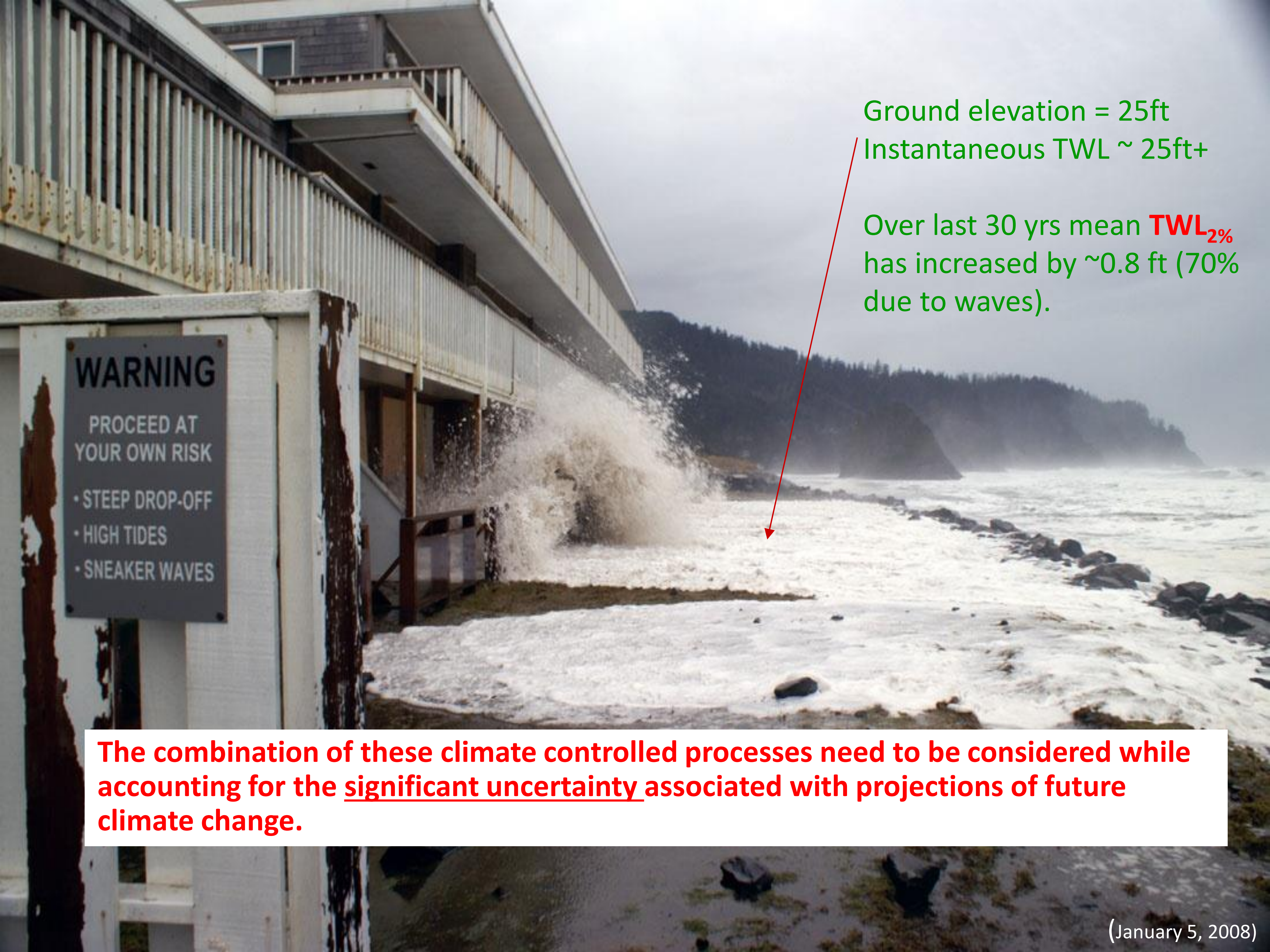
For CMIP3 models, the listed numbers are percentage changes from the 20-y period 1981–2000 to the 20-y period 2181–2200 under emissions scenario A1b. For the CMIP5 models, the listed numbers represent percentage changes from 1981–2000 to 2081–2100 under radiative forcing scenario RCP8.5.

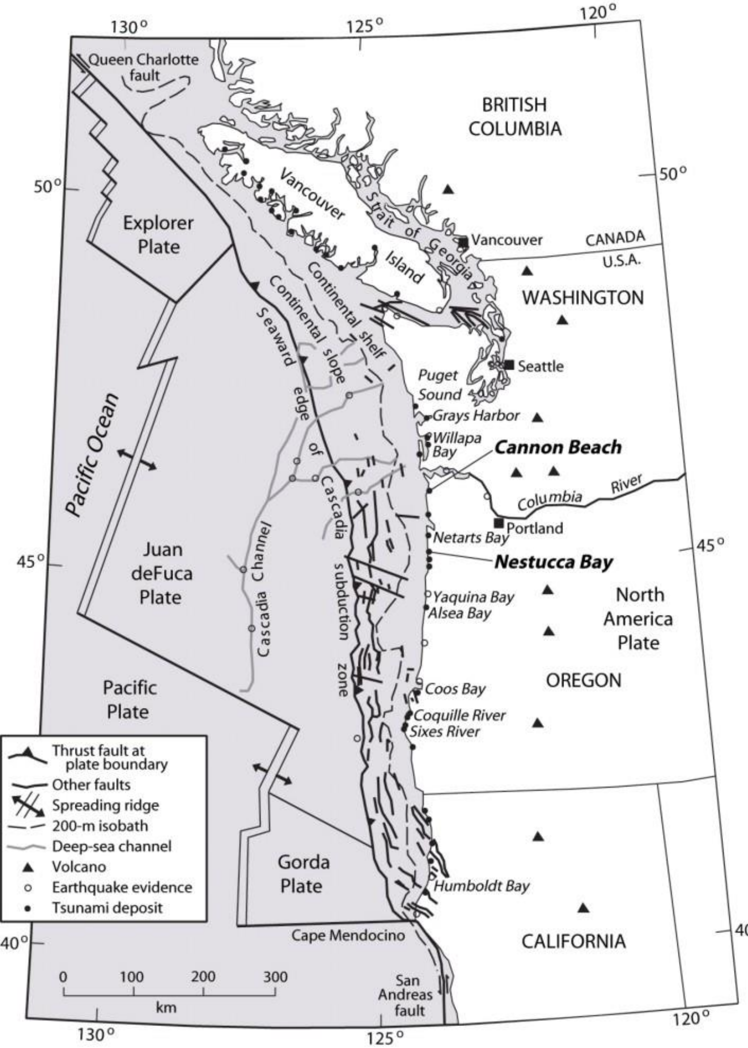
Tillamook County Coastal Futures Project



Over the last 30 years increasing wave heights have been more important than relative sea level rise over much of the PNW coast!

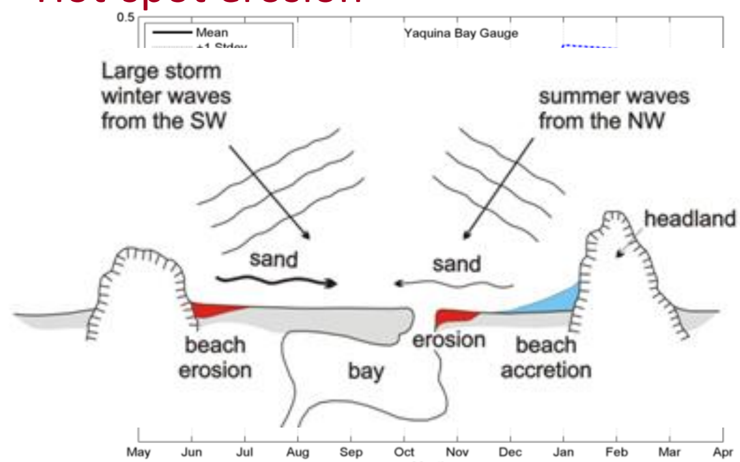
Ruggiero, 2013


WARNING
PROCEED AT YOUR OWN RISK
• STEEP DROP-OFF
• HIGH TIDES
• SNEAKER WAVES
Ground elevation = 25ft
Instantaneous TWL ~ 25ft+
Over last 30 yrs mean **$TWL_{2\%}$** has increased by ~0.8 ft (70% due to waves).
The combination of these climate controlled processes need to be considered while accounting for the significant uncertainty associated with projections of future climate change.
(January 5, 2008)



Geological and Hydrodynamic Setting of the PNW

- **High water levels (10s of cms)**
- **Larger than typical wave heights**
- **Anomalous wave approach angles**
- Enhanced longshore and cross-shore sediment transport
- Hot-spot erosion



During **El Niños** the PNW effectively experiences decades worth of SLR for months

Future frequency and magnitude of El Niños?

More, less, no change from present-day??

nature climate change

LETTERS

PUBLISHED ONLINE: 19 JANUARY 2014 | DOI: 10.1038/NCLIMATE2100

Increasing frequency of extreme El Niño events due to greenhouse warming

Wenju Cai[1,2]*, Simon Borlace[1], Matthieu Lengaigne[3], Peter van Rensch[1], Mat Collins[4], Gabriel Vecchi[5], Axel Timmermann[6], Agus Santoso[7], Michael J. McPhaden[8], Lixin Wu[2], Matthew H. England[7], Guojian Wang[1,2], Eric Guilyardi[3,9] and Fei-Fei Jin[10]

Major ENSO events may double in frequency!

Objective 3

Envision

- Scenario modeling and analysis tool for capturing and integrating multiple drivers of landscape change
- Policy-centric: Directly captures policy alternatives related to land management
- Spatially explicit, integrating multiple landscape features influencing landscape change
- Can report multiple landscape performance metrics; visualization of results

Tillamook County Coastal Futures Project

NOAA

CIRC
Climate Impacts Research Consortium

Data Sources

Landscape Data
- Land Use/Land Cover
- Zoning, Population, Structures
- Topography, **Climate**
- Many more…

Policy Sets
Stakeholder Engagement

Landscape Change Models

Population Growth

Development

Total Water Level

ENVISION

Evaluative Models/Metrics

Flooding
Structures, Infrastructure Impacted,
Economic Value of Structures Impacted

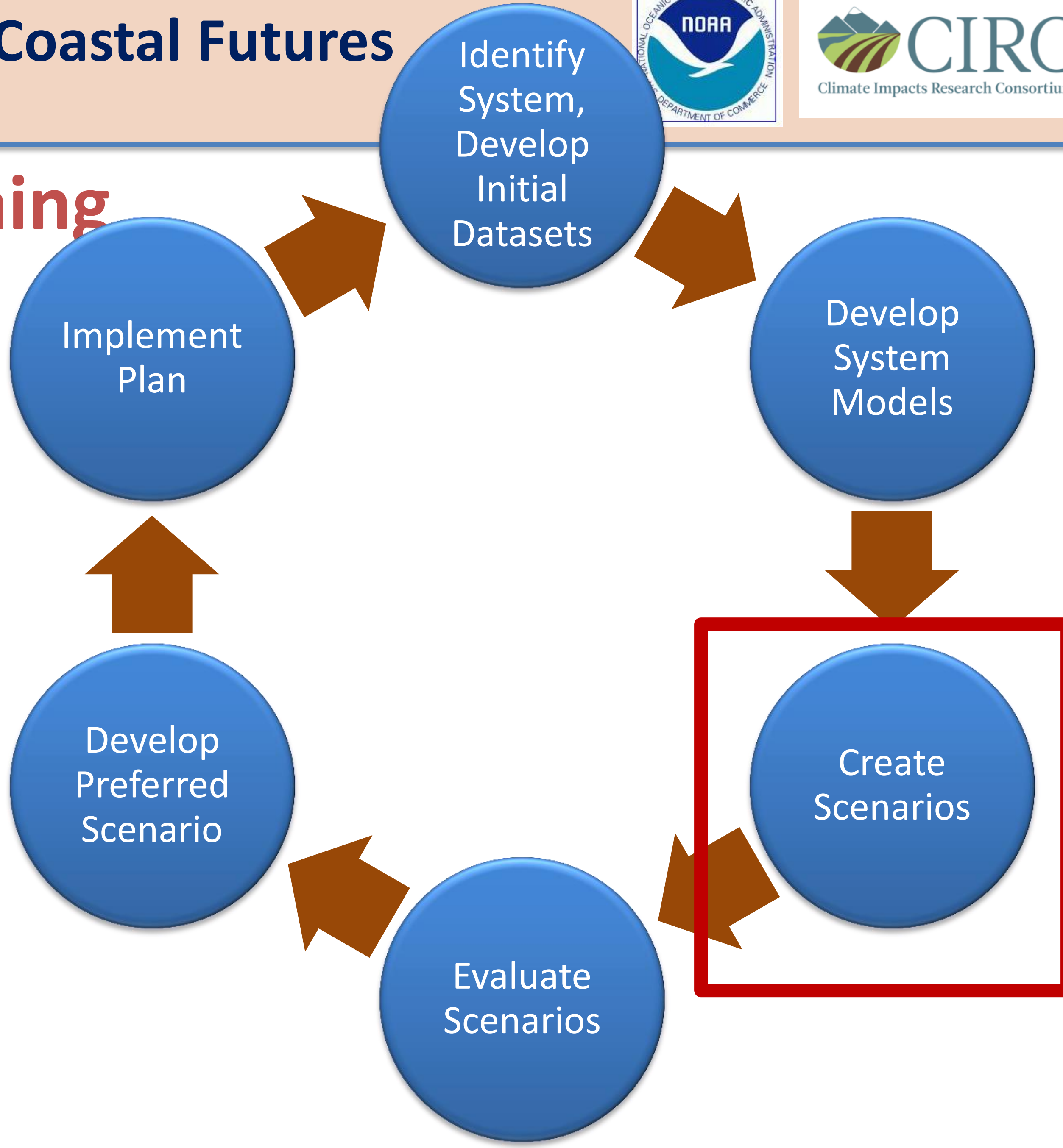
Erosion
Structures, Infrastructure Impacted,
Economic Value of Structures Impacted

Residential Land Supply

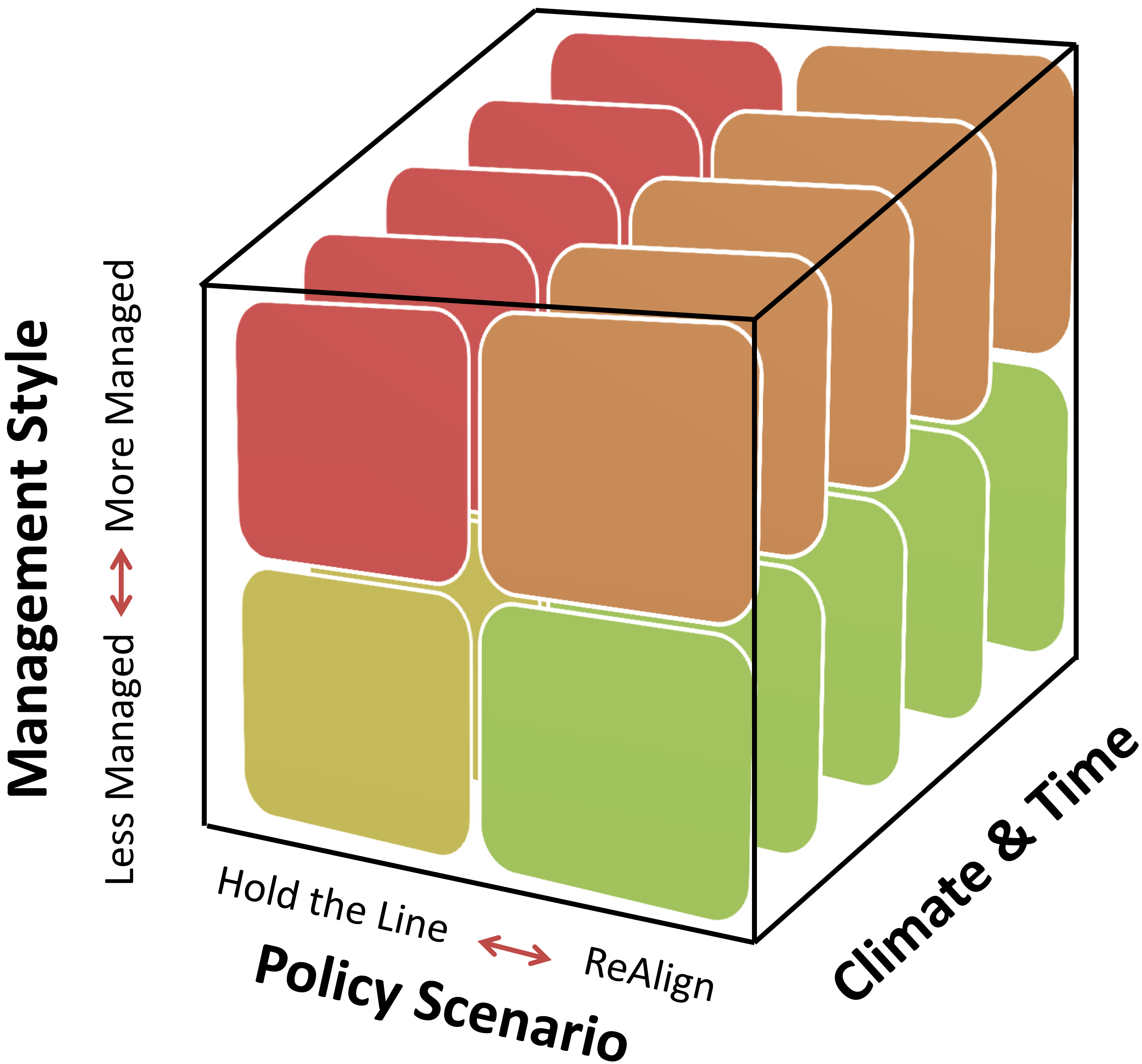
Economic Costs/Returns
Economic Development

Tillamook County Coastal Futures

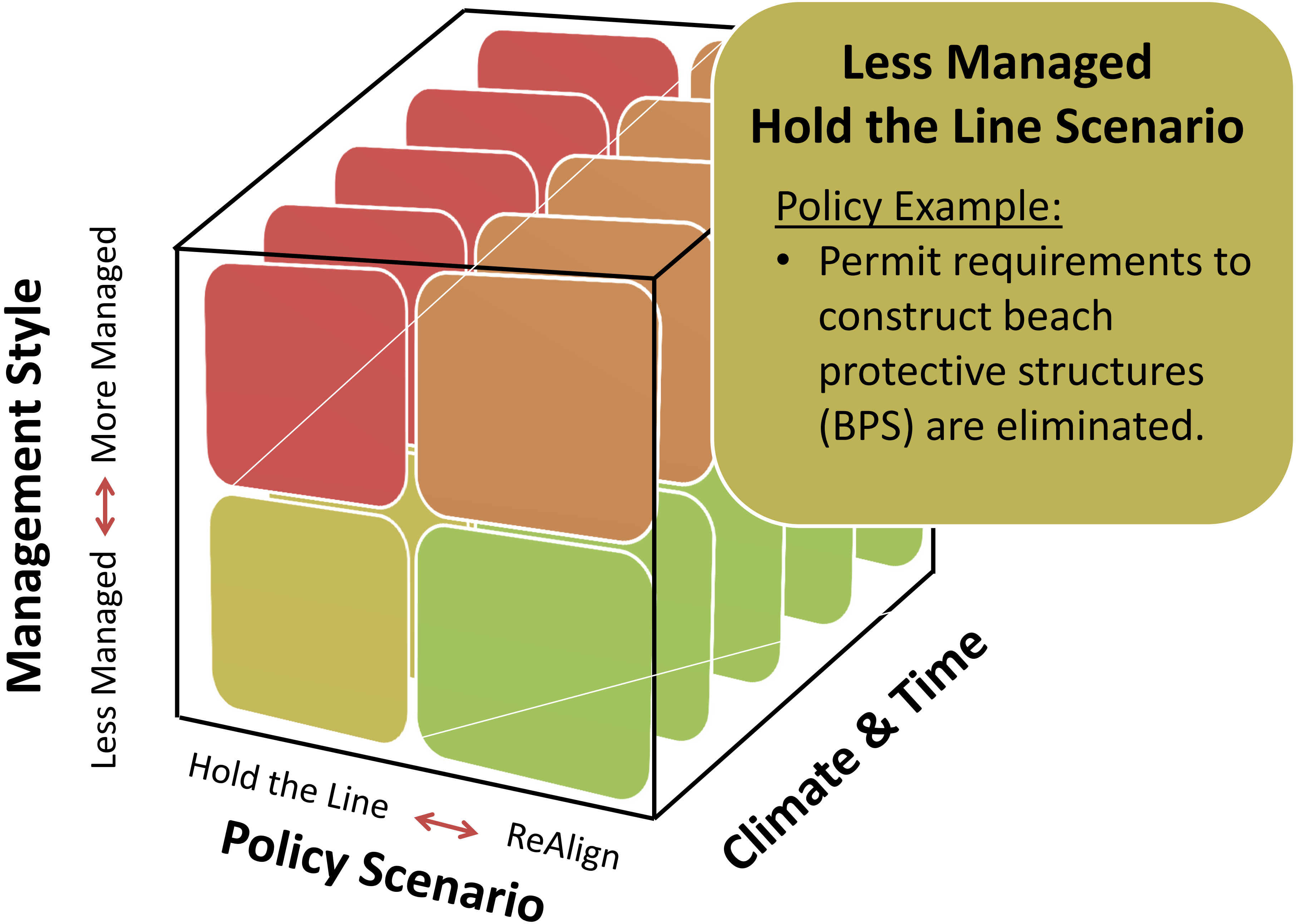
Scenario Planning Process



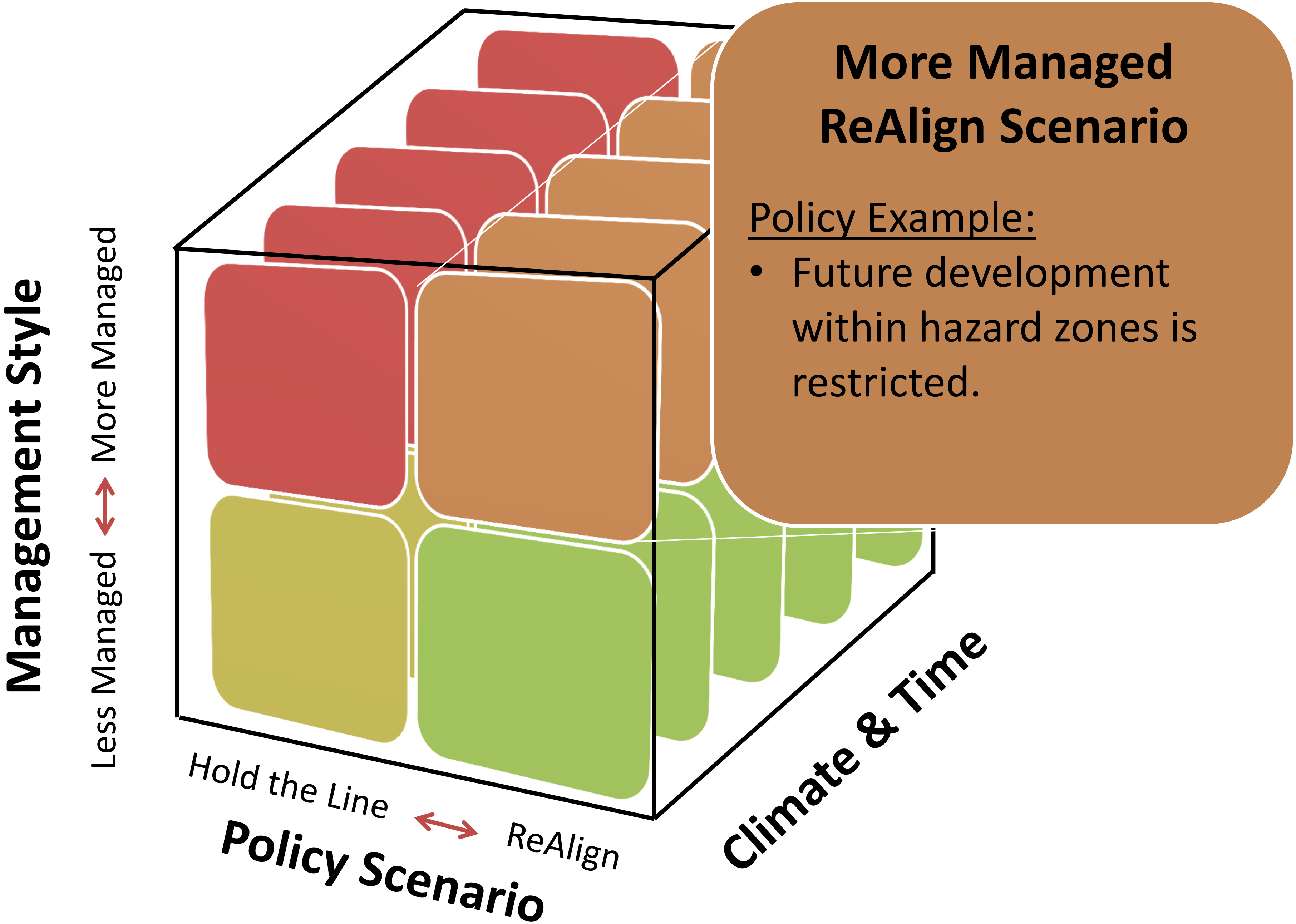
October 2013 Workshop



Management Style
Less Managed
More Managed
Hold the Line
ReAlign
Policy Scenario
Climate & Time

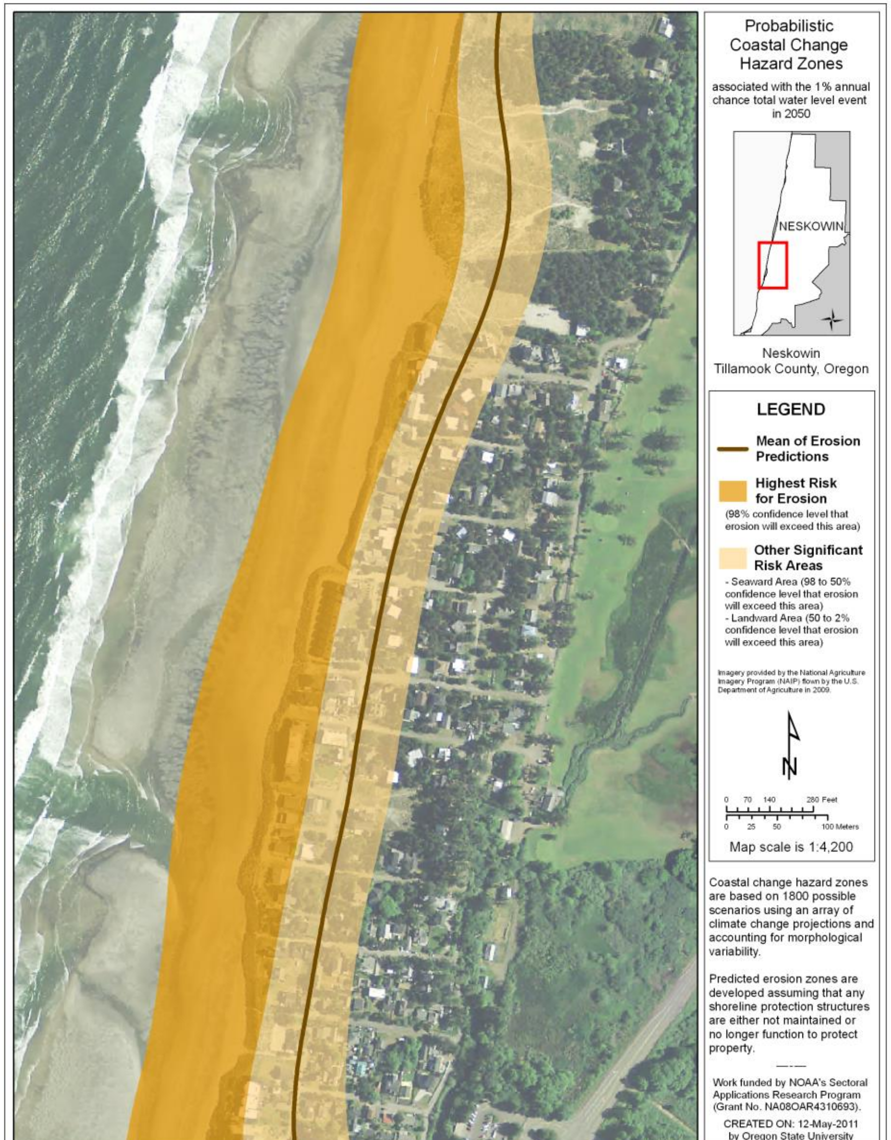


Less Managed
Hold the Line Scenario
Policy Example:
• Permit requirements to construct beach protective structures (BPS) are eliminated.
Management Style
Less Managed ↔ More Managed
Hold the Line ↔ ReAlign
Policy Scenario
Climate & Time


More Managed
ReAlign Scenario
Policy Example:
• Future development within hazard zones is restricted.
Management Style
Less Managed
More Managed
Hold the Line
ReAlign
Policy Scenario
Climate & Time

Tillamook County Coastal Futures Project

Probabilistic Coastal Change Hazard Zones



Ruggiero et al., 2011, Baron, 2011

Climate Change Scenario Matrix

Sea level rise

High → *Low*

Wave climate: *High* → *Low*; El Niño: *High* → *Med*

H H H	M H H	L H H
H M H	M M H	L M H
H L H	M L H	L L H

H H M	M H M	L H M
H M M	M M M	L M M
H L M	M L M	L L M

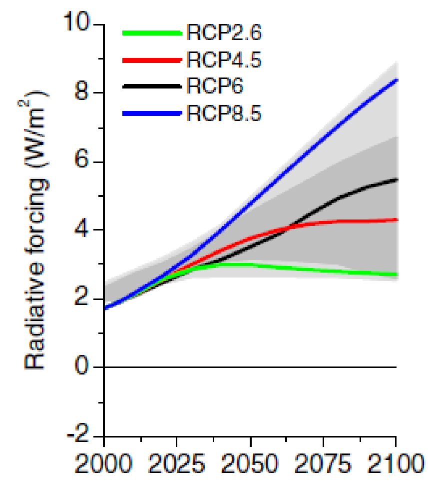
Baron, Ruggiero et al. in review

Tillamook County Coastal Futures

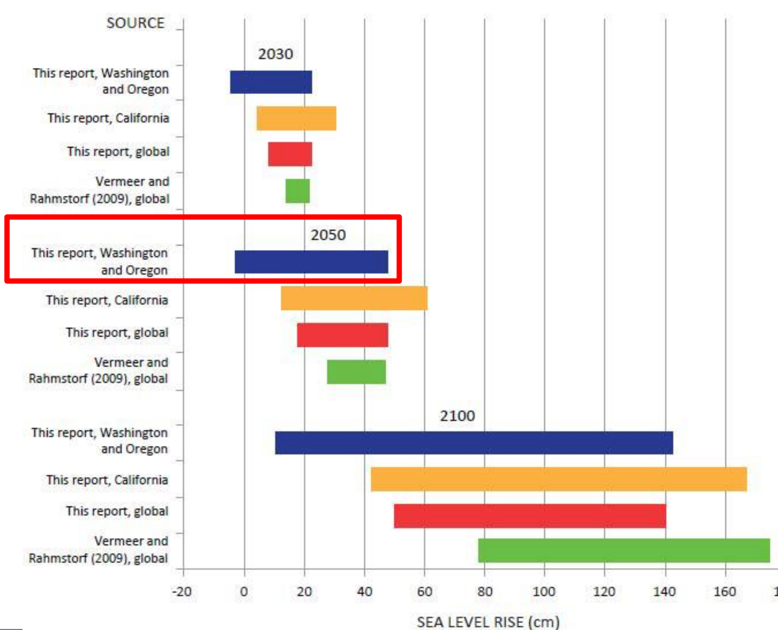
Example Envision Run: Climate Change Scenario

Mid-Century Projection (2010-2045)

- *Waves*
  - Dynamically downscaled from Global Climate Models (GCMs) using a **mid-level emissions scenario** (RCP 4.5)
- *Sea Level*
  - **High sea level rise scenario,** 45 cm increase from 2000-2050

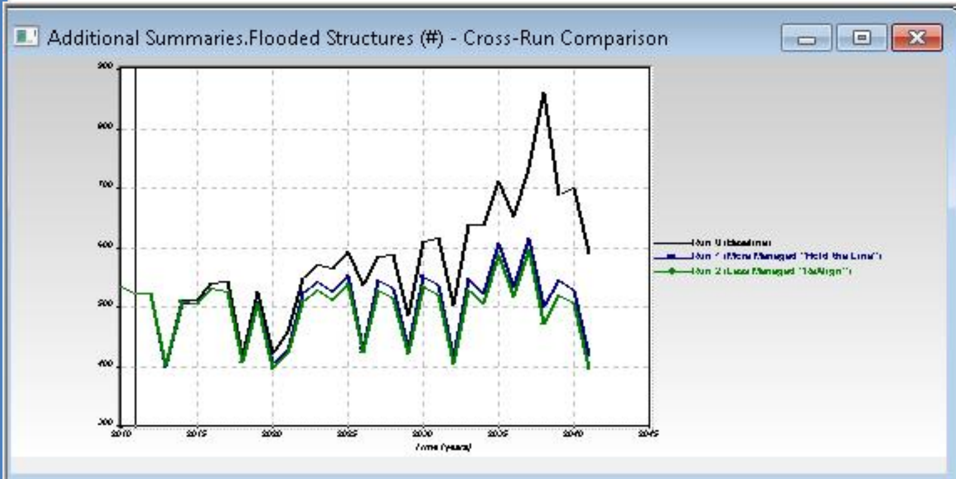


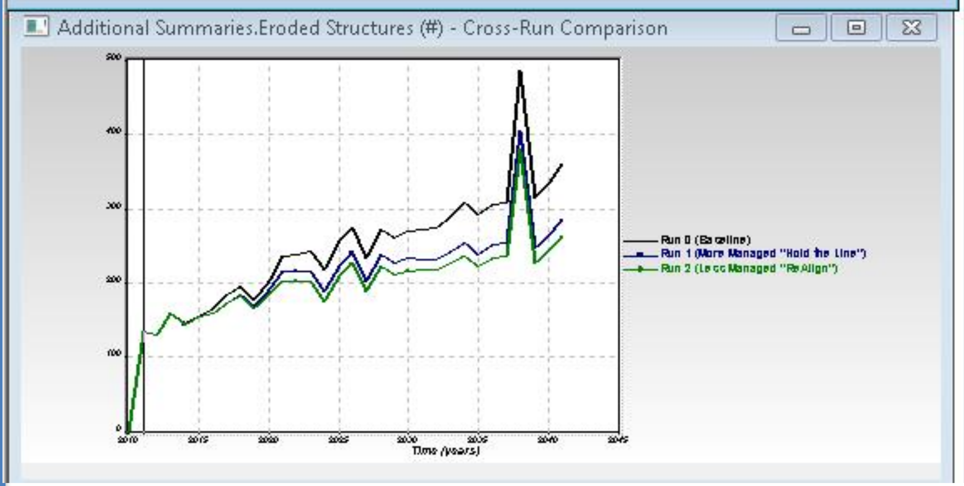
Van Vuren et al., 2011

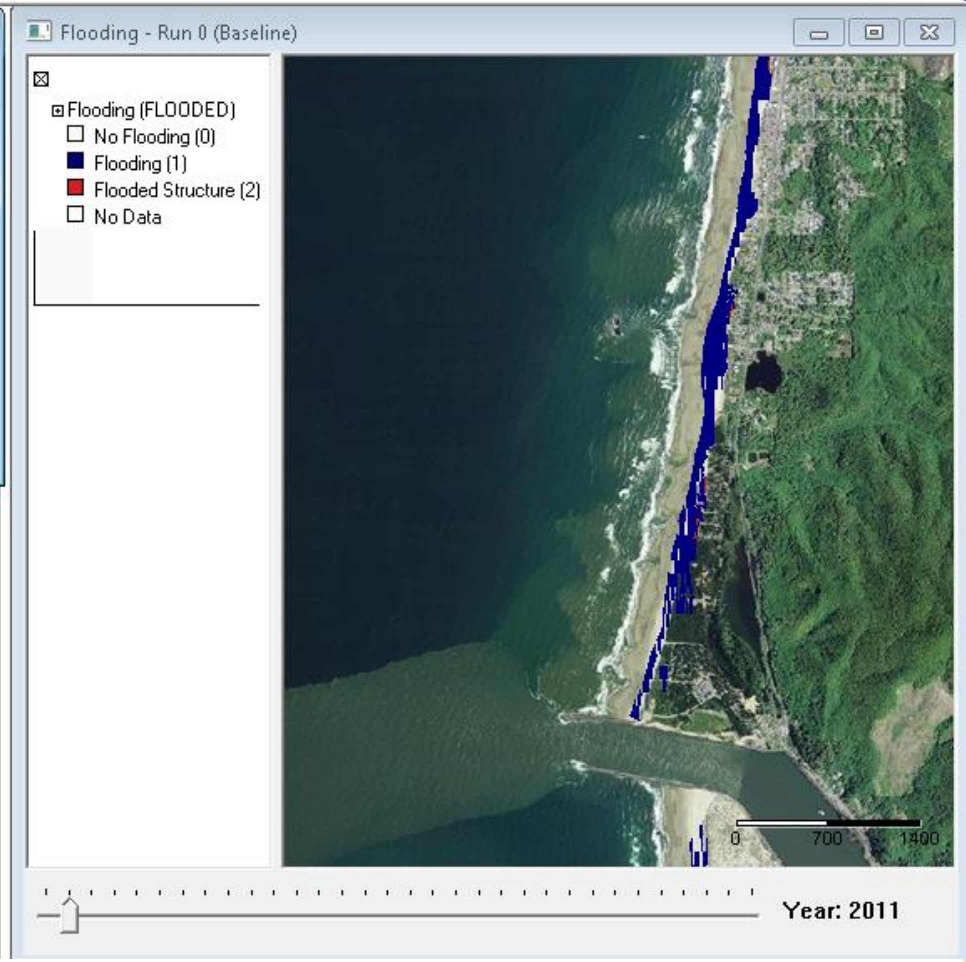


NRC, 2012

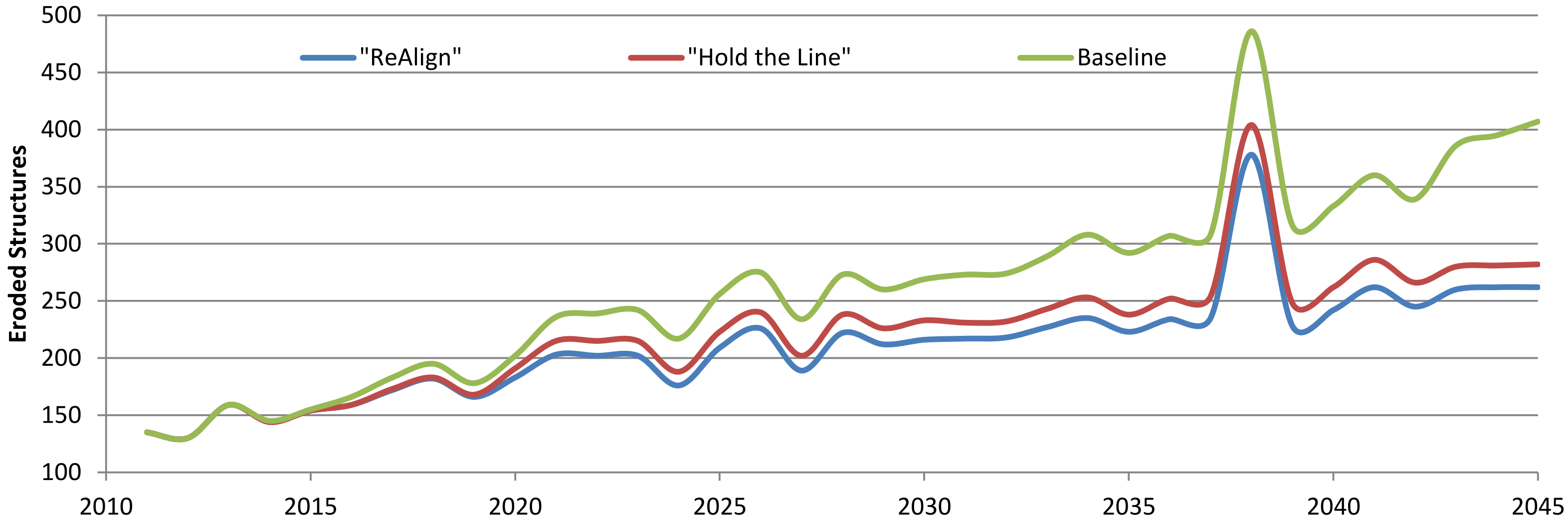
Tillamook County Coastal Futures: Flooding and Erosion

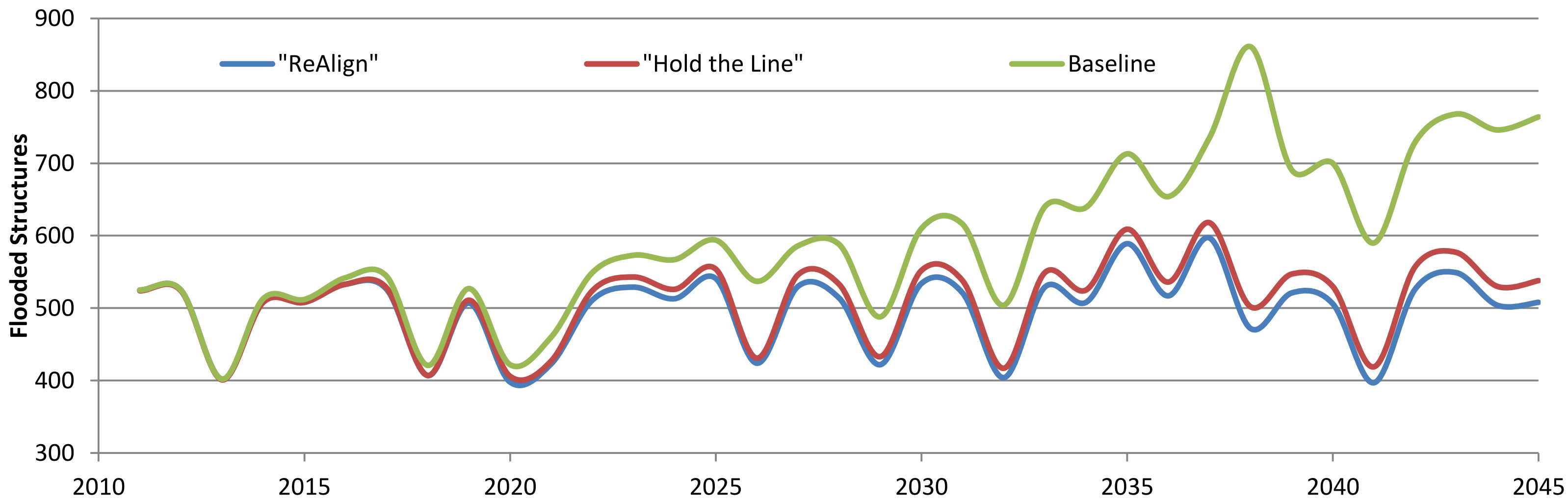




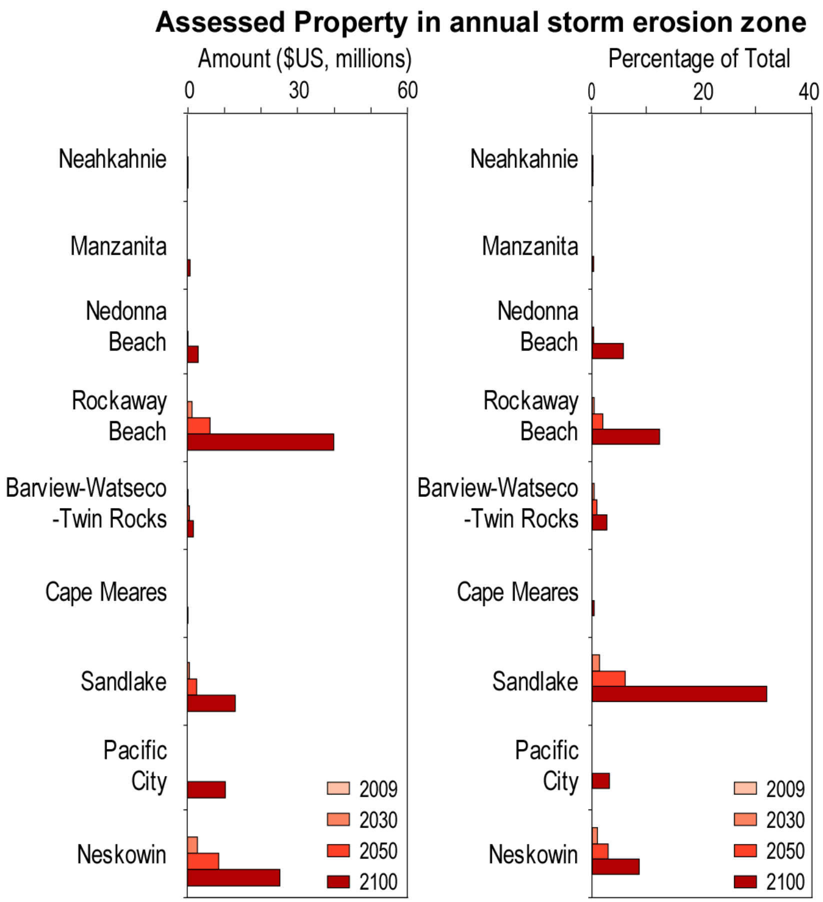


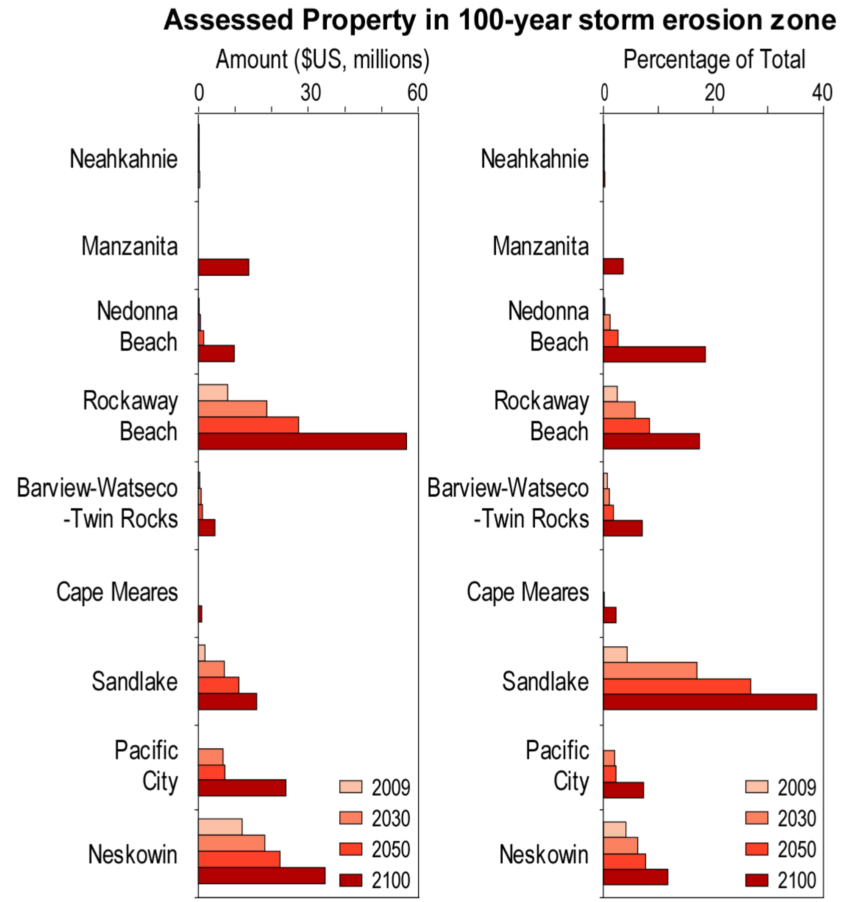
Tillamook County Coastal Futures: Flooding and Erosion



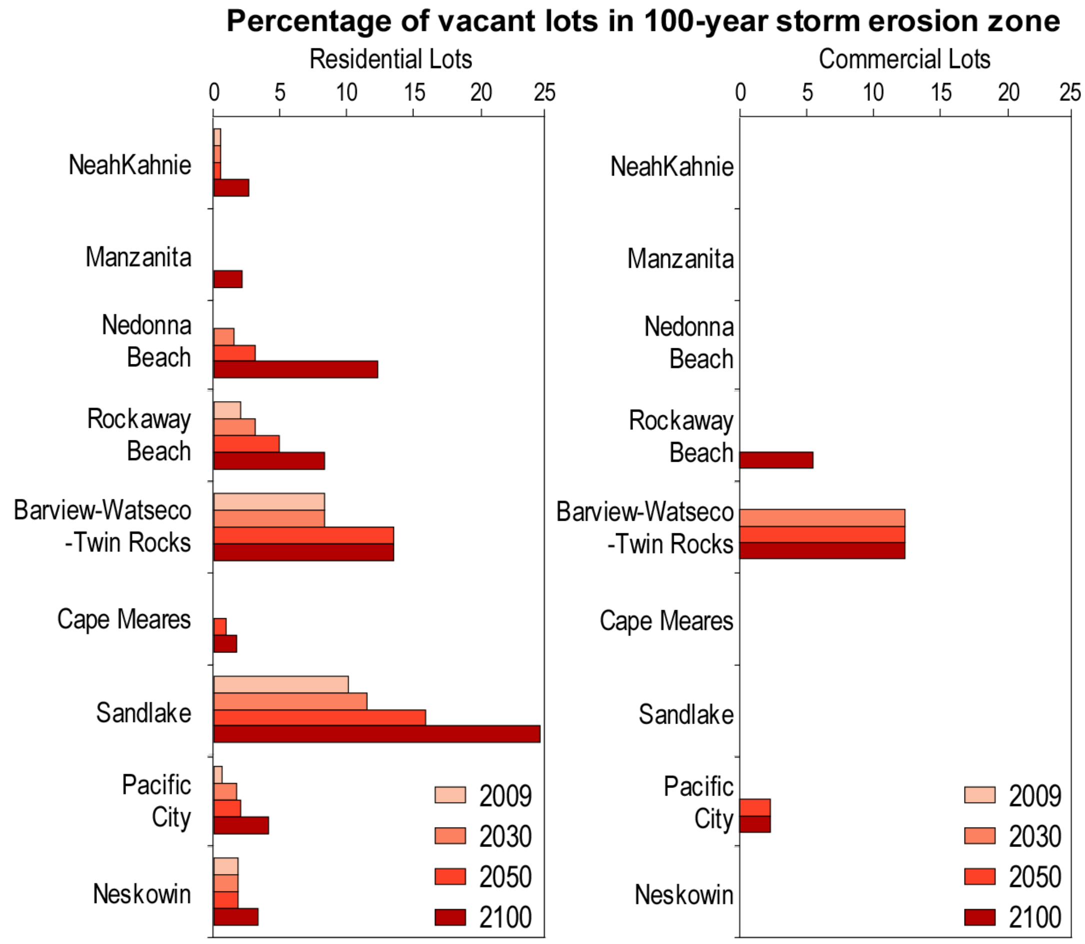


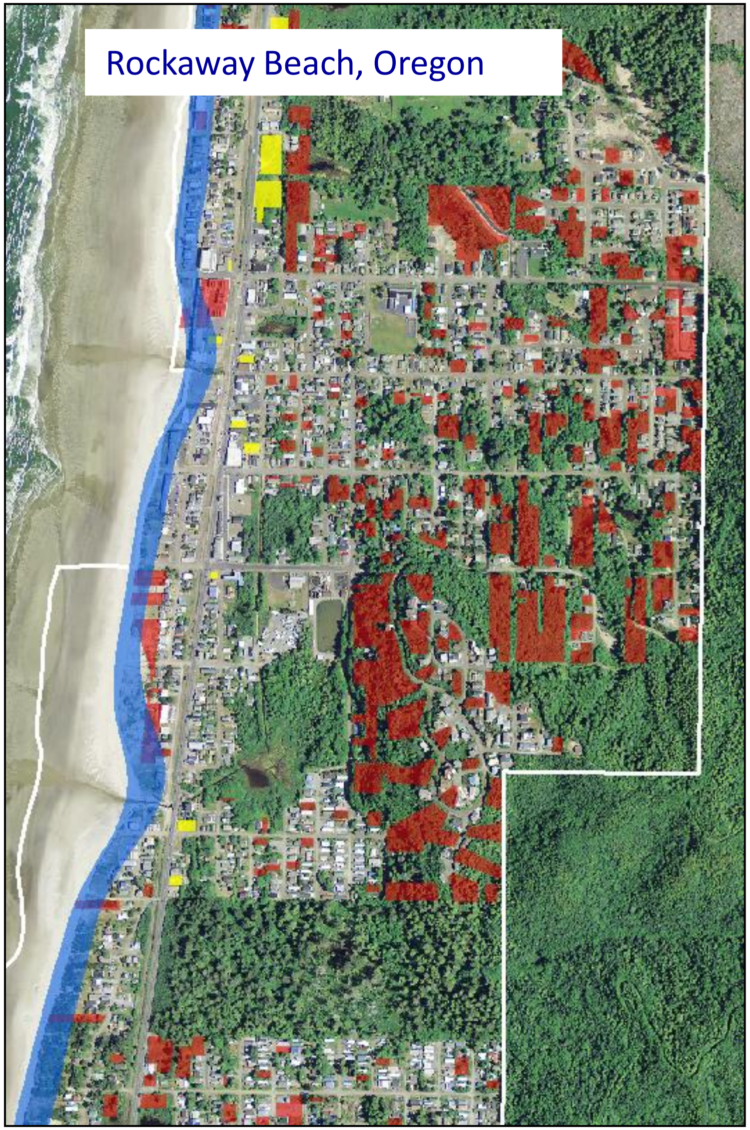
Assessed Property Value in Hazard Zones





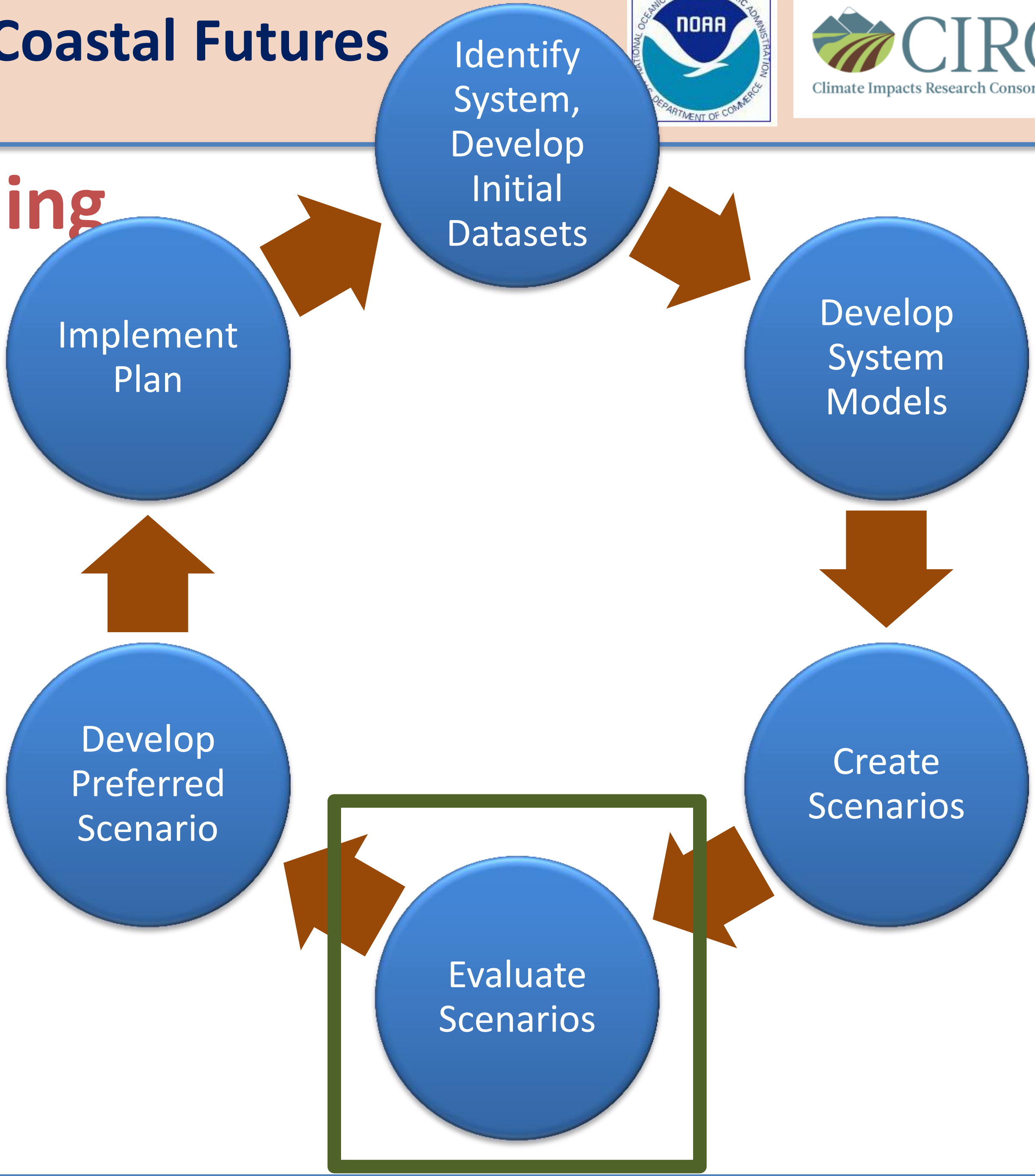
Can Future Development Avoid the Hazard Zones?





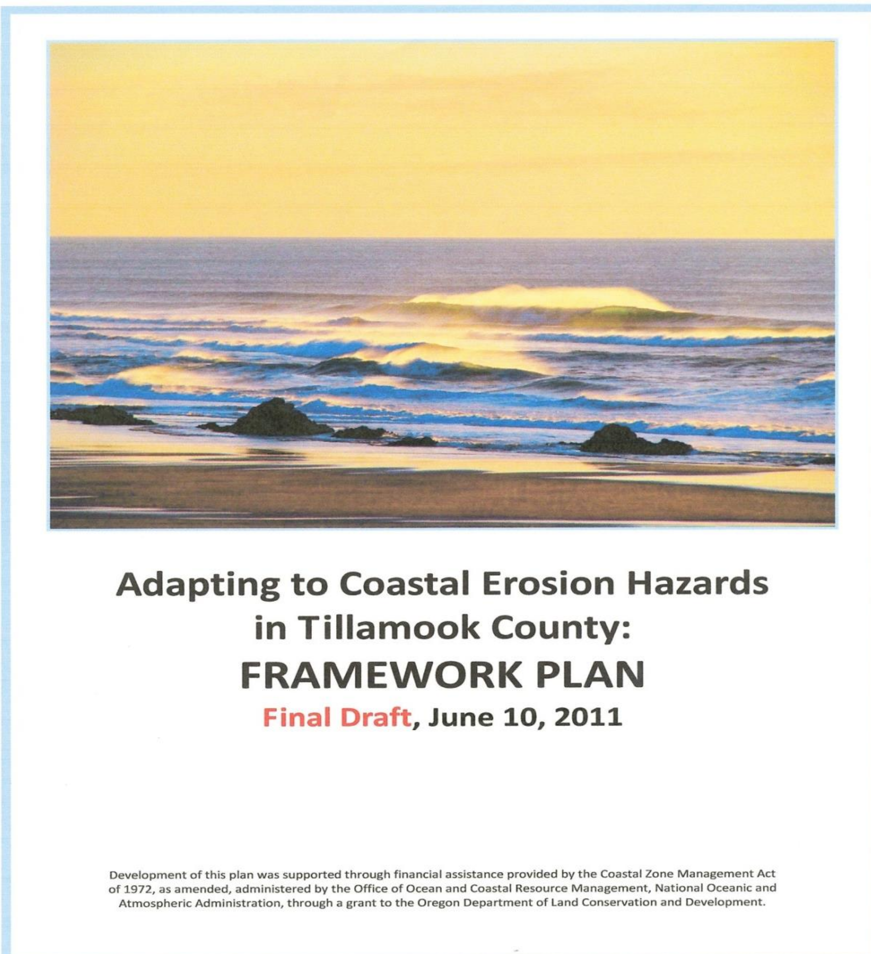
Tillamook County Coastal Futures

Scenario Planning Process



April 2014 Workshop

Neskowin Coastal Hazards Committee: Accomplishments



Adapting to Coastal Erosion Hazards in Tillamook County:

FRAMEWORK PLAN

Final Draft, June 10, 2011

Development of this plan was supported through financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, through a grant to the Oregon Department of Land Conservation and Development.

- The Neskowin Community Planning Advisory Committee (CPAC) with the assistance of Oregon Department of Land Conservation and Development planners, proposed specific land use ordinances and revisions to the Tillamook County Comprehensive Plan and the Neskowin Community Plan

- The plan is pending before the Tillamook County Planning Commission

- Specific to Neskowin but part of larger county and statewide planning effort

Thanks very much!