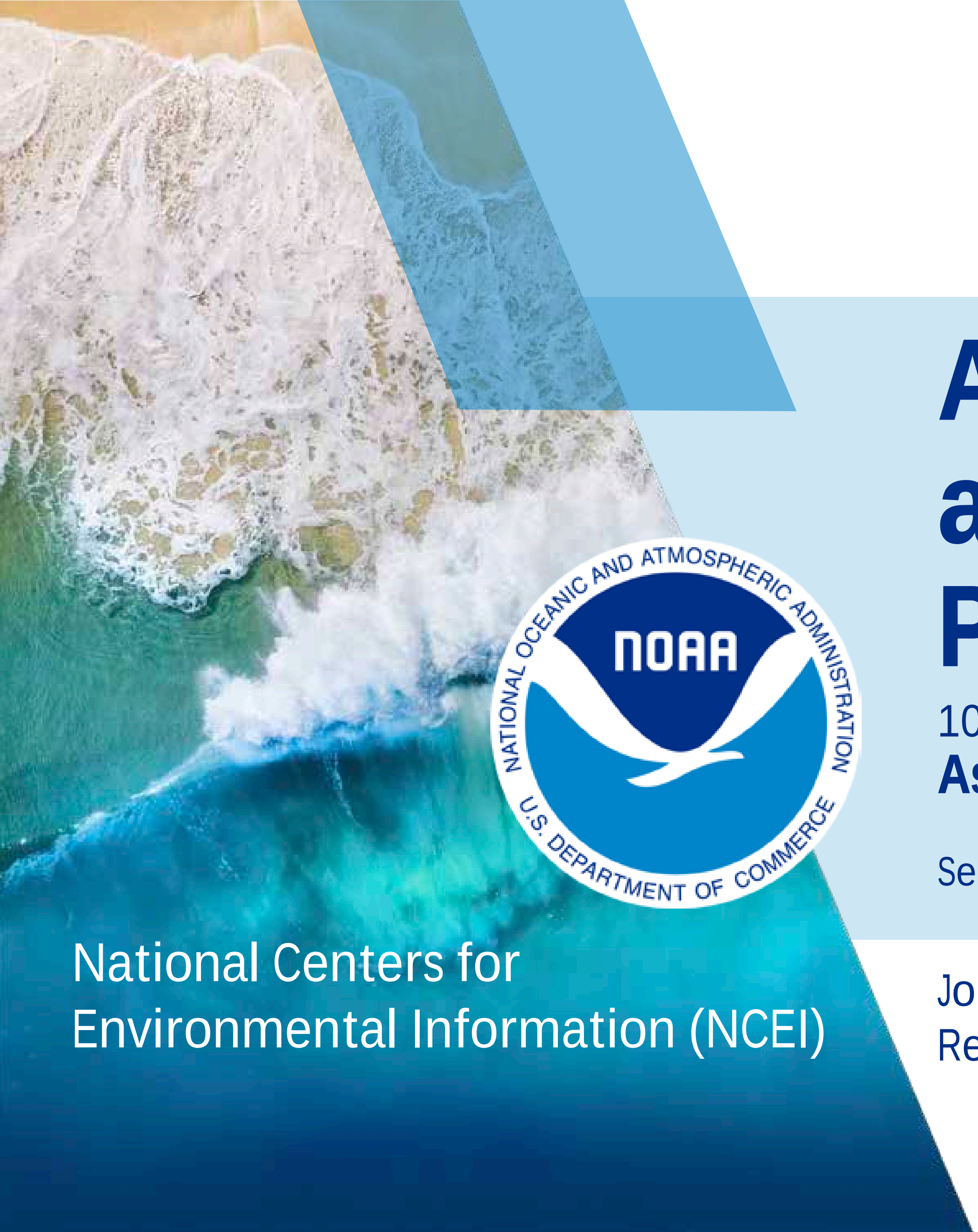

A Changing Climate and its Impacts in the Pacific Islands

108th Annual Conference
Association of Pacific Ports

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National Centers for Environmental Information (NCEI)

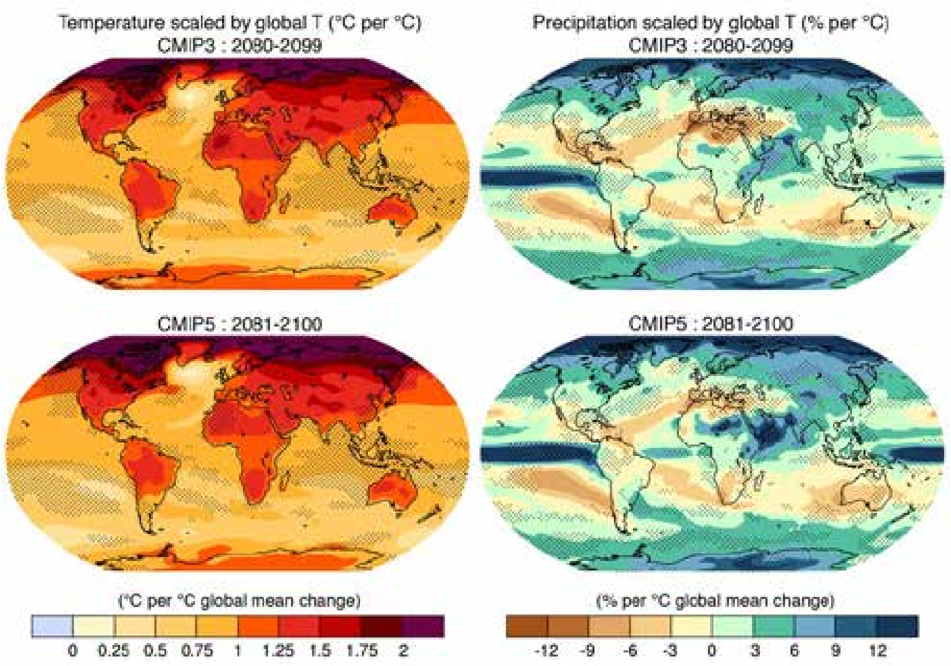
Outline

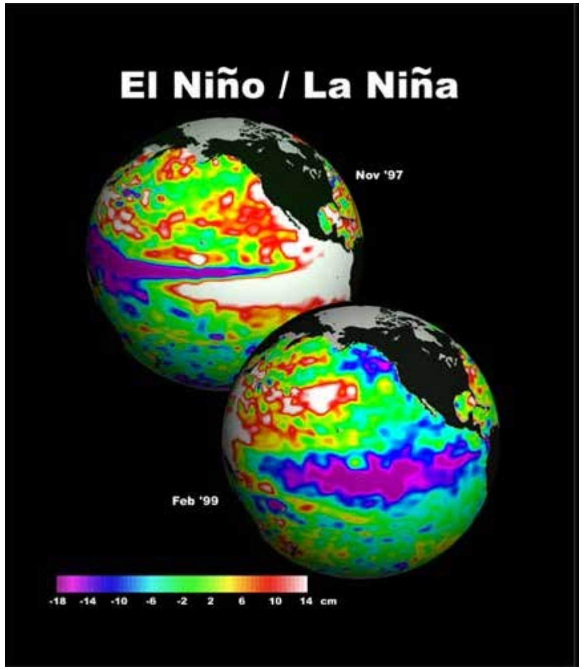
- Climate Change and Variability
- Current and Future Conditions
- Anticipated Impacts
- Vulnerability of Waterfront Structures

Wave-driven runup and flooding of Kwajalein Island, Kwajalein Atoll, Republic of the Marshall Islands, on 9 January 1988 during Typhoon Roy.
Photo credit: Peggy Hood.

Climate Change and Variability

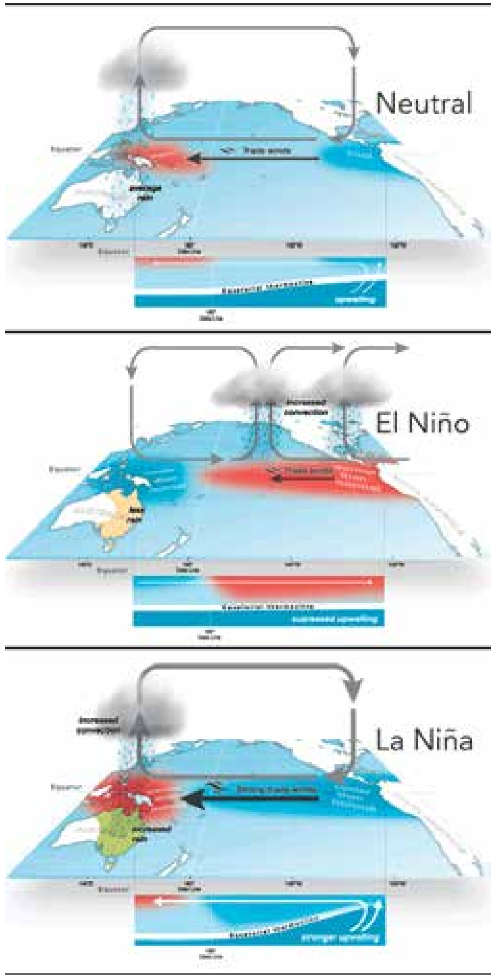
TREND of change is primarily in response to an external forcing (i.e., increasing concentrations of greenhouse gasses in the atmosphere). – YEARS to DECADES



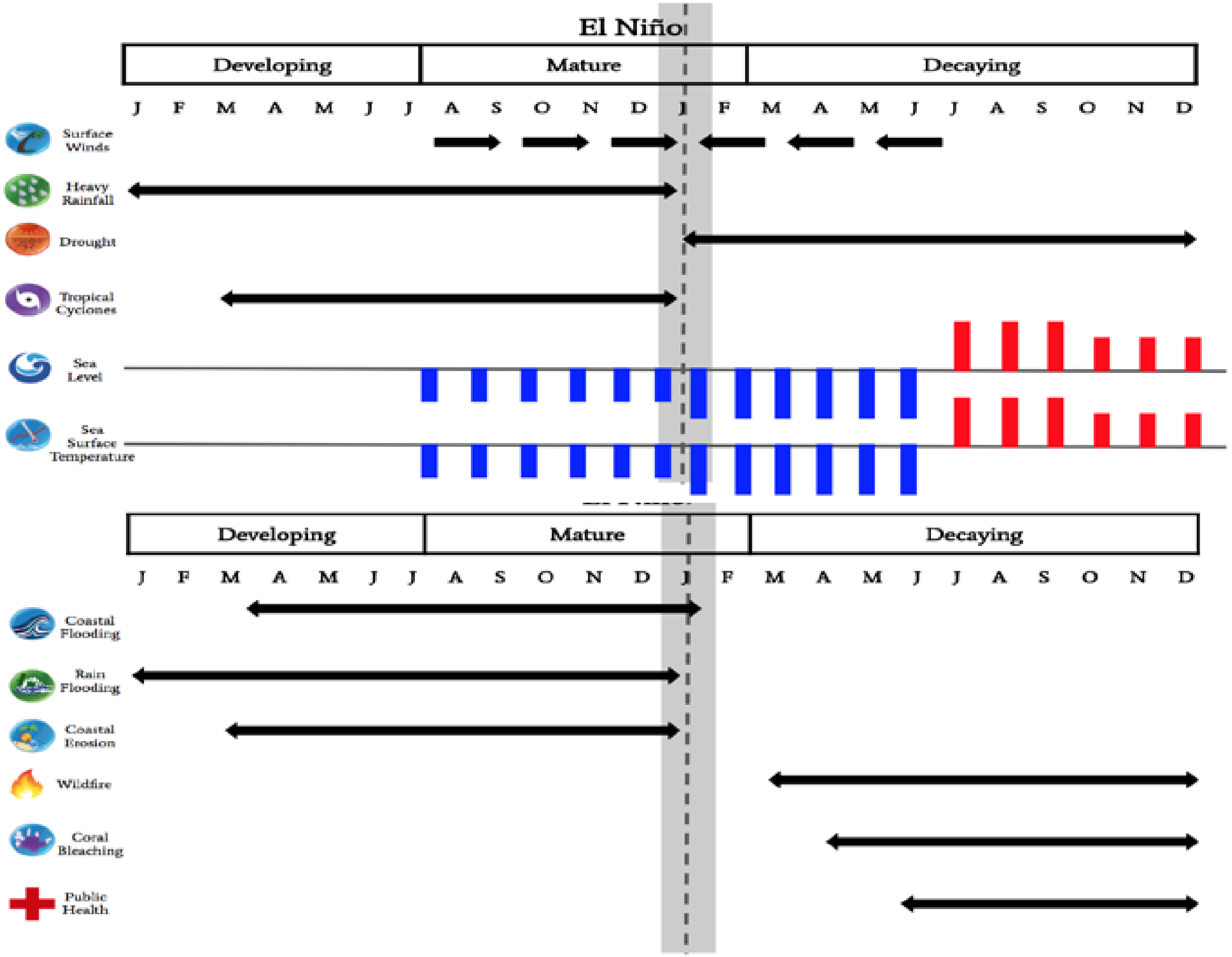


PATTERN of change is primarily due to internal forcing (i.e., natural variability), and is associated with climate indices and teleconnections (e.g. ENSO, MEI, PDO, IPO). – WEEKS to MONTHS

Climate Variability and its Impacts



The primary phases of the ENSO Cycle.



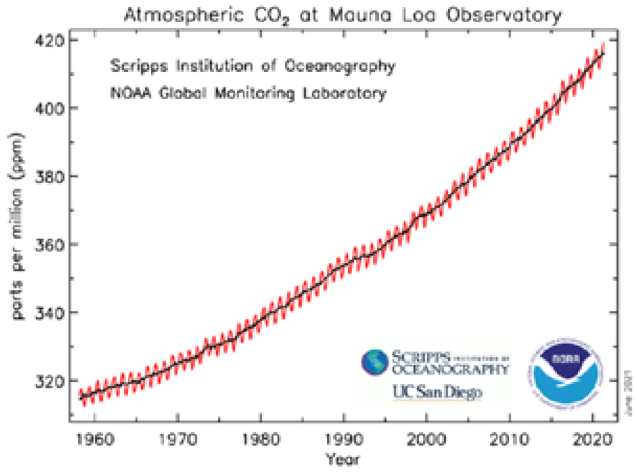
Summary of forcings and impacts during a strong El Niño.

Climate Change

Carbon dioxide (CO_2) concentration is rising and is expected to continue to rise.

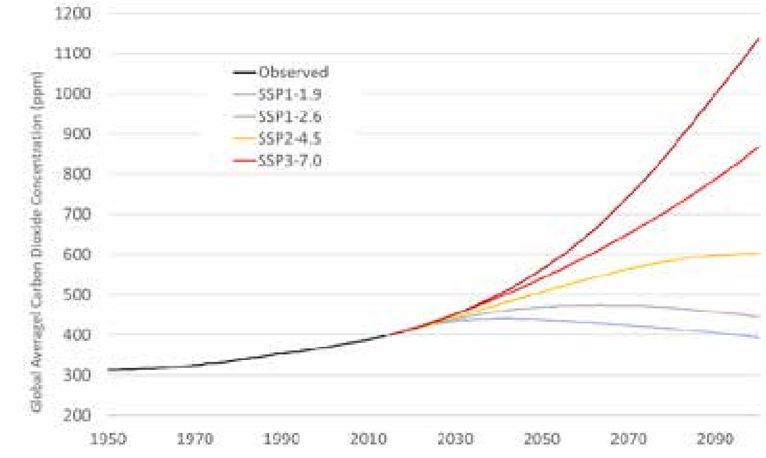
until at least mid-century

- Over the last 62 years the concentration of CO_2 in the atmosphere at Mauna Loa has increased by more than 100 ppm to an annual average value over 416 ppm in 2021.



Monthly Mean Concentration of Atmospheric CO_2 at Mauna Loa since 1959.

- Future concentrations of CO_2 are predominantly dependent on human choices.



Observed and projected global average CO_2 concentration from the SSPs

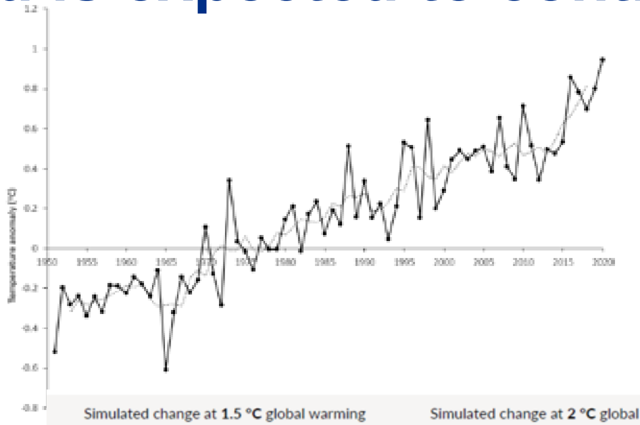
Climate Change

Surface air temperature is rising and is expected to continue to rise.

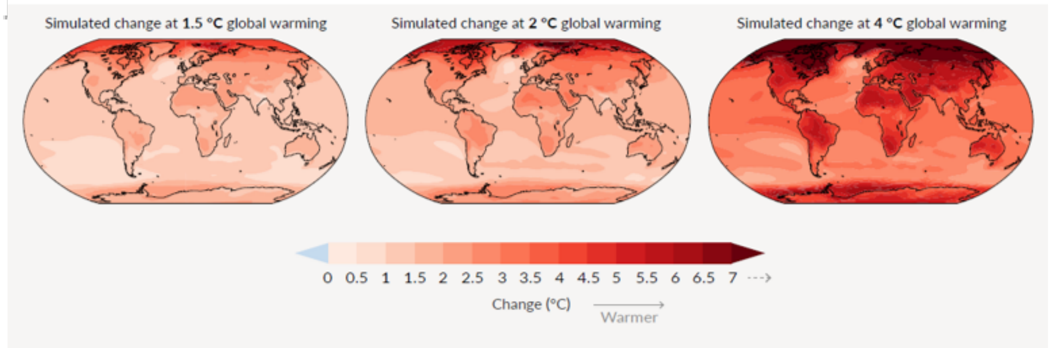
until at least mid-century

- Mean temperature over land has increased by 1.1°C (2°F) since 1951.

- If we plateau at 2 °C global warming, likely warming in most Pacific EEZs is around 1.5 to 1.7 °C (3°F) since 1850-1900 Warming over individual locations over land is likely to be greater.



Regional annual mean temperature anomalies relative to 1961-1990 climatology.



Projected Surface Temperature Change relative to 1850-1900. From the CMIP6 set of global climate models reported in the IPCC Sixth Assessment Report.

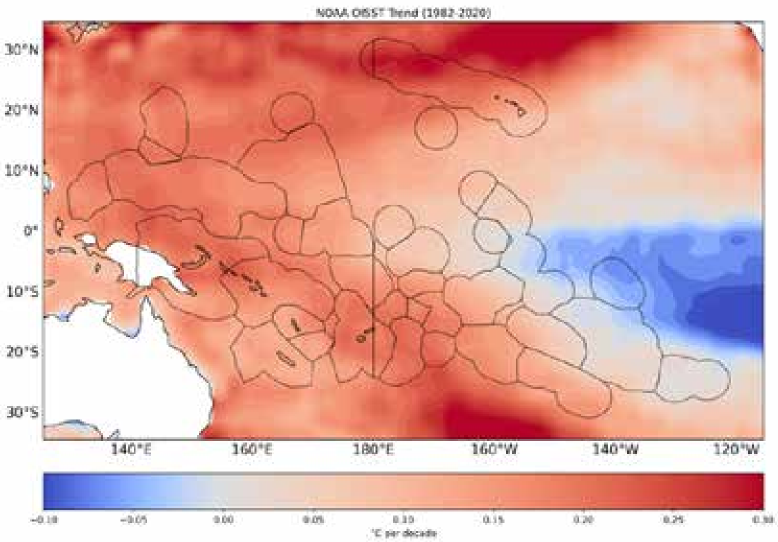
Global warming relative to 1850-1900	Pacific Nations warming relative to 1850-1900	Pacific nations warming relative to 1986-2005
1.5 °C	Around 1.1 °C	Around 0.7 °C
2 °C	Around 1.6 °C	Around 1.0 °C
3 °C	Around 2.4 °C	Around 1.8 °C

Climate Change

Sea-Surface and Subsurface Temperature is rising and is expected to continue to rise.

- Over the past few decades mean SST across most of the Pacific has warmed ~0.90º C (~1.6º.F) since 1982, and the duration of marine heatwaves has increased significantly.

- The lowest intensity "Moderate" heat waves are projected to increase from recent (1995-2014) values of 10-50 days per year (dpy) to >100 dpy by 2050, with >200 dpy nearer the equator.



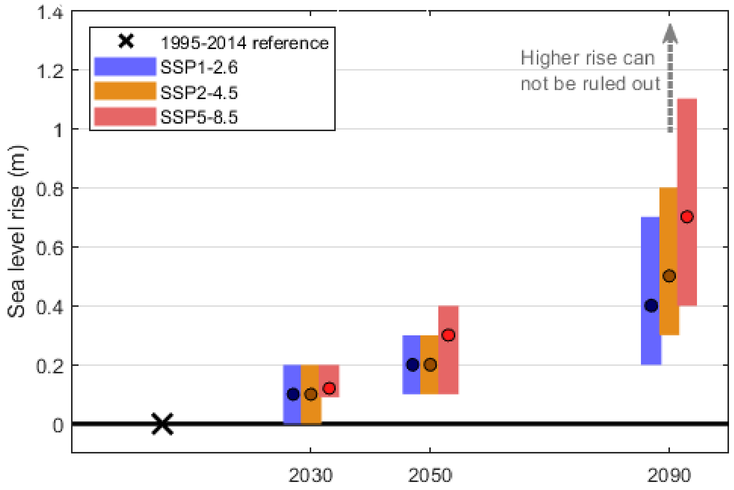
Sea Surface Temperature Trends. (ºC per decade) over the period 1982-2020.

Projected increase in the mean number of marine heatwave days per year by 2050.

Climate Change

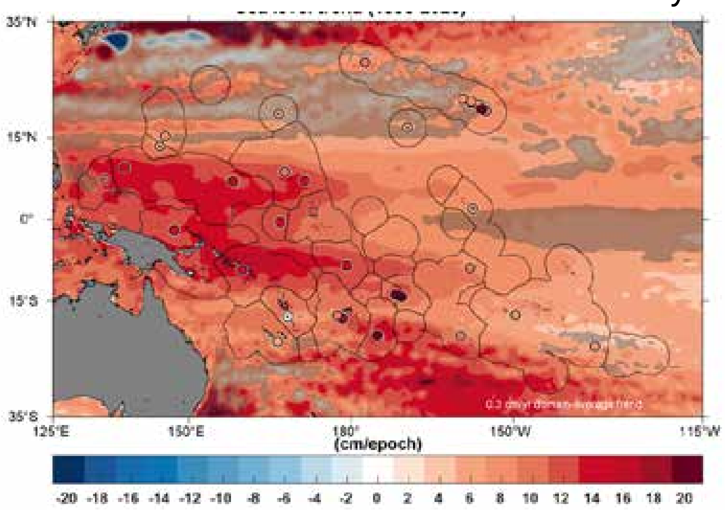
Sea Level is rising and is expected to continue to rise.

- Since 1993, mean sea level has risen ~10–15 cm in much of the western tropical Pacific and ~ 5–10 cm in much of the central tropical Pacific, resulting in increases in the frequency of minor flooding.
- The global average sea level is projected to continue to rise this century under any emissions pathway; under lower pathways (0.28 to 0.55 m (0.9 to 1.8 feet) by 2090 and under higher pathways (0.63 to 1.01 m (2.0 to 3.3 feet).



Range of *likely* sea level rise averaged over the Pacific Small Islands region.

Into the next century

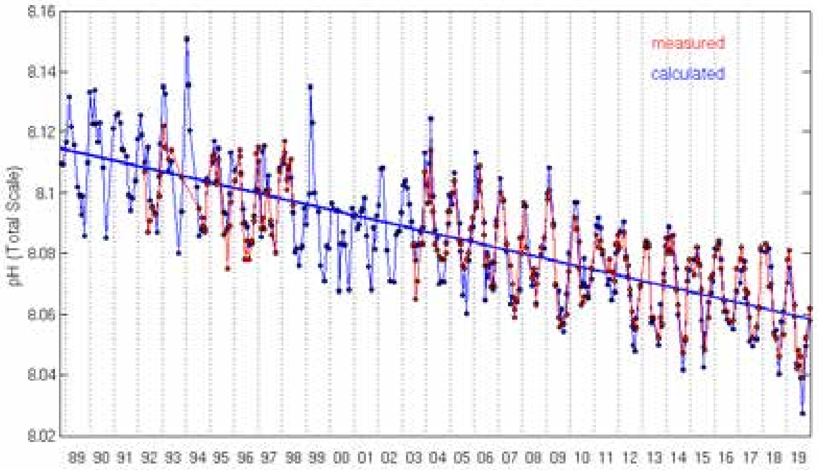


Regional Sea Level Trends from Satellite Altimetry and Tide Gauges since 1993.

Climate Change

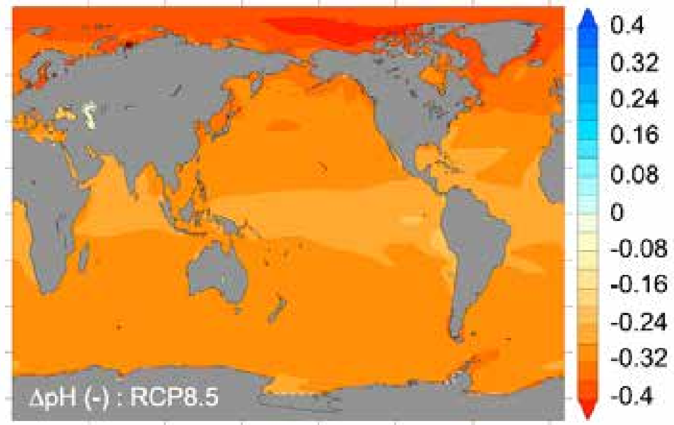
Ocean conditions are changing.

- Oceanic pH measurements at Station ALOHA since 1988 show that the ocean became 12% more acidic over this time (0.05 pH units), and significant declines in phytoplankton concentration and size occurred across major portions of the Pacific Islands region.



Measured and calculated trends in surface (0–10 meter) pH at Station ALOHA.

- Oceanic pH is projected to decrease by 0.3 pH in much of the Pacific under a high emissions pathway along with widespread decreases in oxygen concentration except for along the equator.

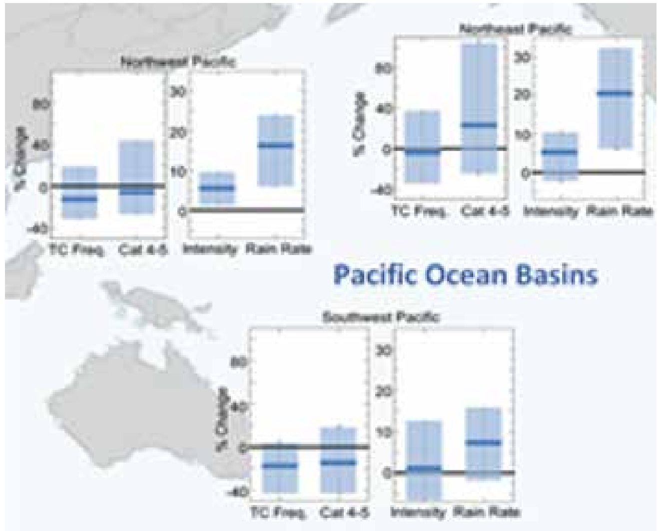


Projected multimodel mean change in surface ocean pH under a high emissions scenario.

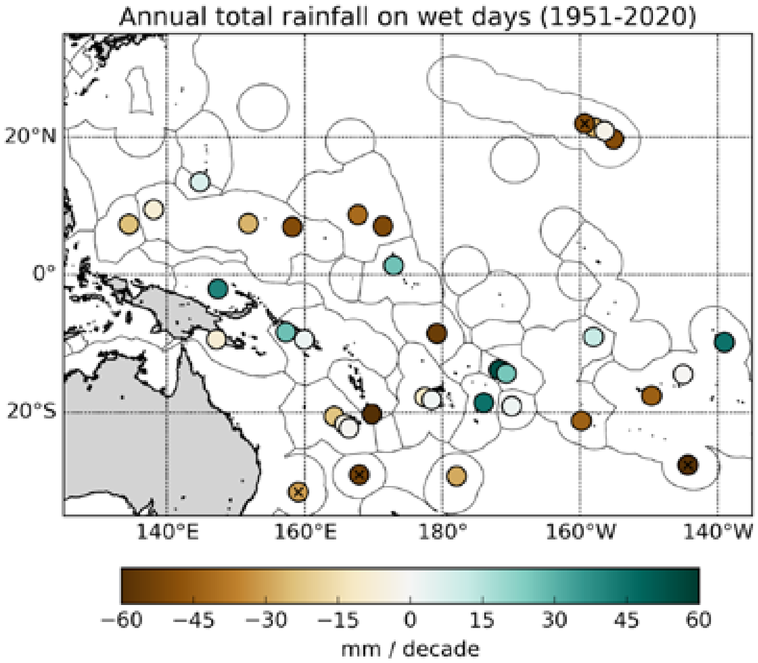
Climate Change

Extremes are changing.

- Over the last 70 years change in rainfall at Pacific Islands observation sites is mixed. At some locations drying trends are observed; at others annual heavy rainfall has increased.
- No robust trends in the frequency or magnitude of Tropical Cyclones (TCs) since the 1980s are evident..
- With warmer sea and air temperatures mean a greater proportion of TCs in the intense categories (Cat 3-5) is expected (i.e., increased peak wind intensity and higher rain rates).



TC activity projection for 2°C global warming.



Trends in annual total rainfall on wet days over 1951-2020.

Climate Change Impacts

Decreasing Freshwater Availability

Freshwater supplies are already constrained and will become more limited on many islands.

Increasing Flood Damage

Rising sea levels, coupled with high water levels caused by storms, will incrementally impact coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism.

Declining Marine and Terrestrial Ecosystems

Warmer oceans will increase coral bleaching and change the location of ocean fisheries. Warming and acidification, combined with existing stresses, will adversely impact coastal fisheries. Increasing temperatures, and in some areas reduced rainfall, will stress terrestrial plants and animals.
All will increase the risk of extinctions.

Takeaways

Mounting Threats to Lives and Livelihoods

Impacts to food and water security, infrastructure, health, and safety are expected to lead to increased social strife and human migration, making it increasingly difficult to sustain the region’s economies and cultures.

Natural Variability means there is a Range of Possibilities in any given year.

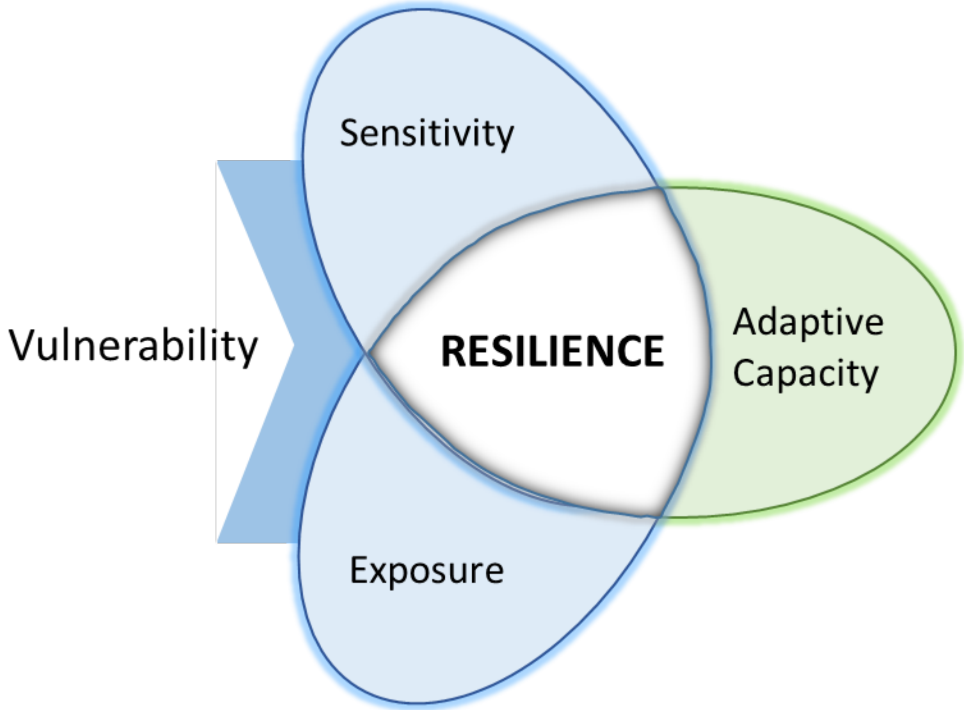
Natural climate drivers operating at annual to decadal time scales may act to dampen or amplify the long-term multi-decadal projected trend due to climate change.

Pause

Vulnerability of Waterfront Structures

The Challenge

Get harbor/port managers and planners **information that will enable them to identify and prioritize actions** necessary to maintain a desired level of operational capabilities in light of a rapidly changing climate.



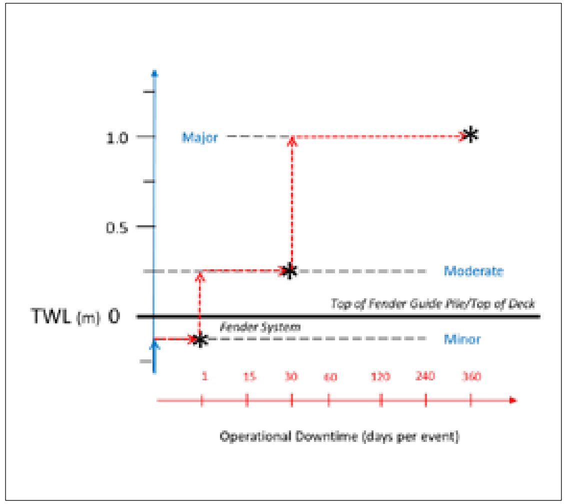
What eventful impacts will happen first, and when?

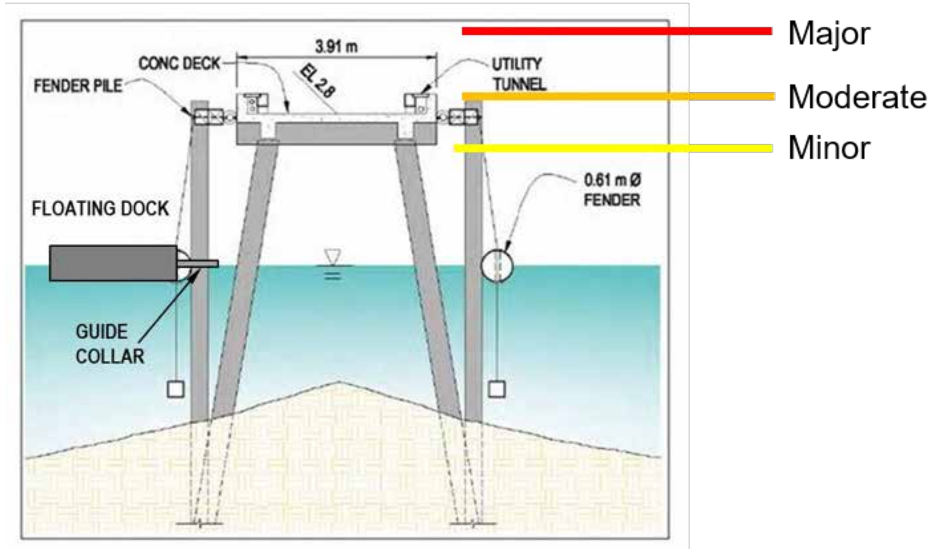
Sensitivity Assessment

Failure Modes

Fragility Relationships

Disruption/Damage States





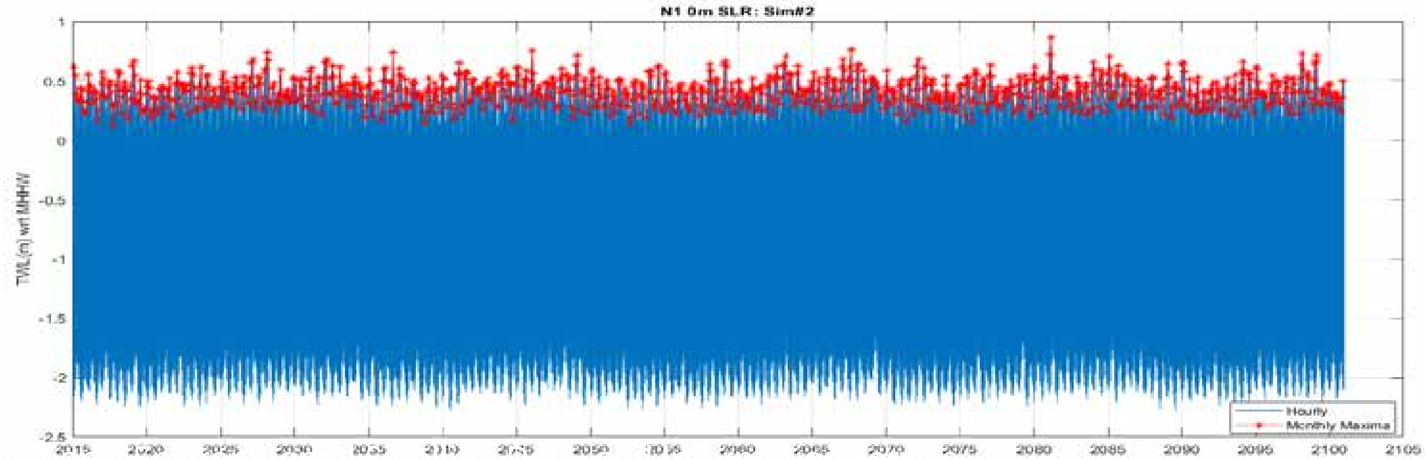
Section Through Small Boat Pier.

Disruption/Damage State	Baseline	Minor	Moderate	Major
Disruption *Utilities BELOW Deck*	Fully Functional	**1 day** loss of use.	**30 day** loss of use.	**360 day** loss of use.
Damage *Direct Costs* *Utilities BELOW Deck*	No Damage	No Damage	**Moderate Damage** - 100% RPV of brackets attaching floating deck to guide pile system and brow, or **5 % of full dock RPV**. Minor utility damage. Can be	**Major Damage** - 100% RPV of floating deck, guide piles and brow, or **30% of full dock RPV**. Major utility damage. Must be replaced.
Indirect Costs		*minor cleanup*	*major cleanup*	*major cleanup including top of deck*

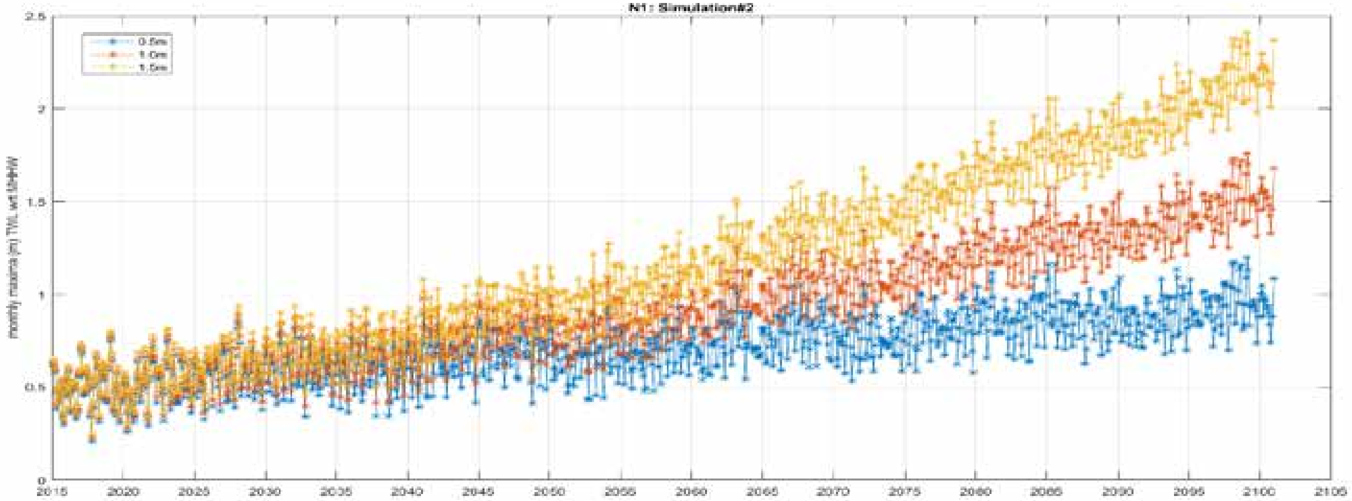
Exposure Assessment

Frame Processes and Methods

Characterize Current and Future Conditions



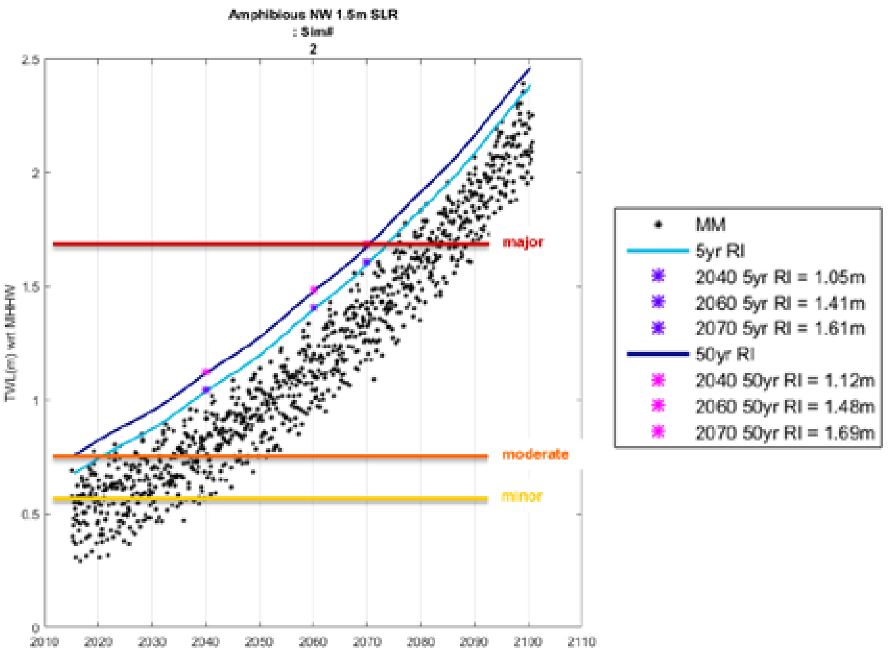
Hourly (blue) and Monthly (red) Maximum Total Water Level Time-Series.



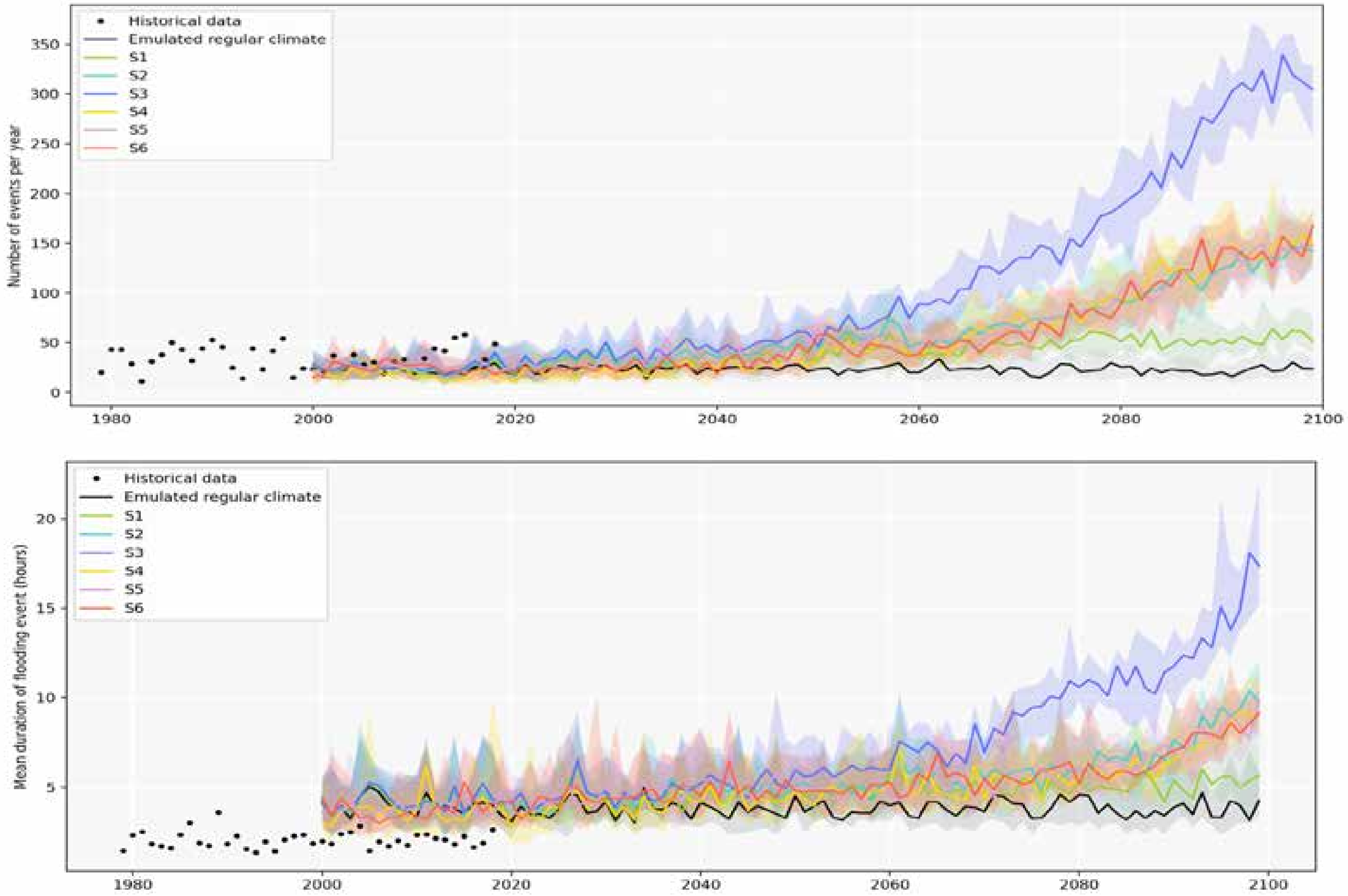
Monthly Maximum Total Water Level Time-Series with SLR.

Vulnerability Assessment

Identify Scope and Timing of Impacts



Projected TWL Elevation Return under 1.5m by 2100 SLR Scenario.

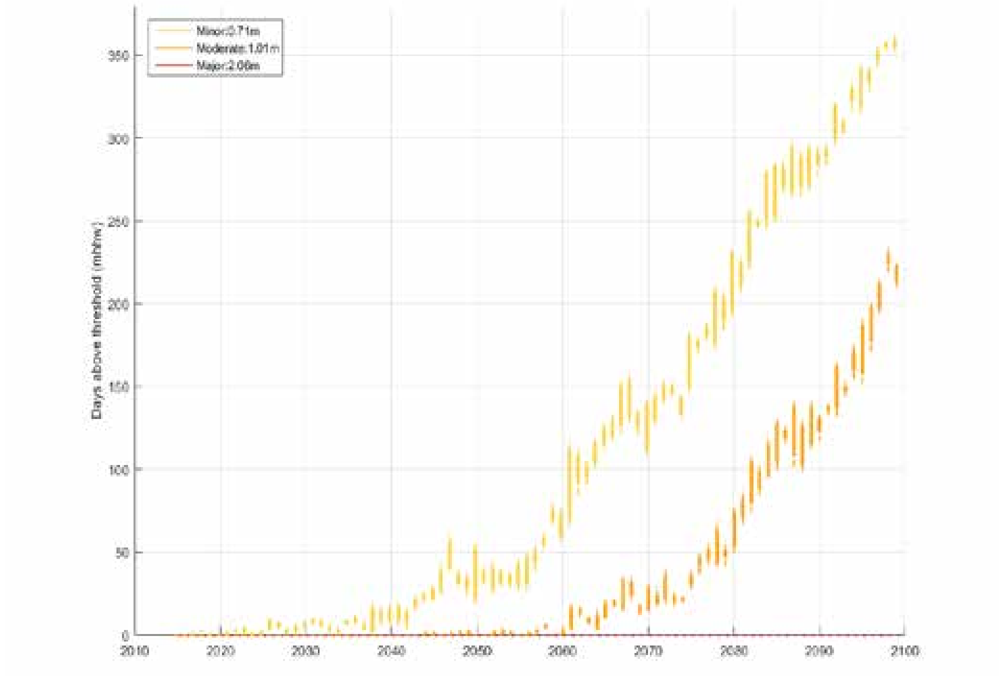


Number of flooded events per year and mean duration of events through the 21st century for different climate change scenarios analyzed.

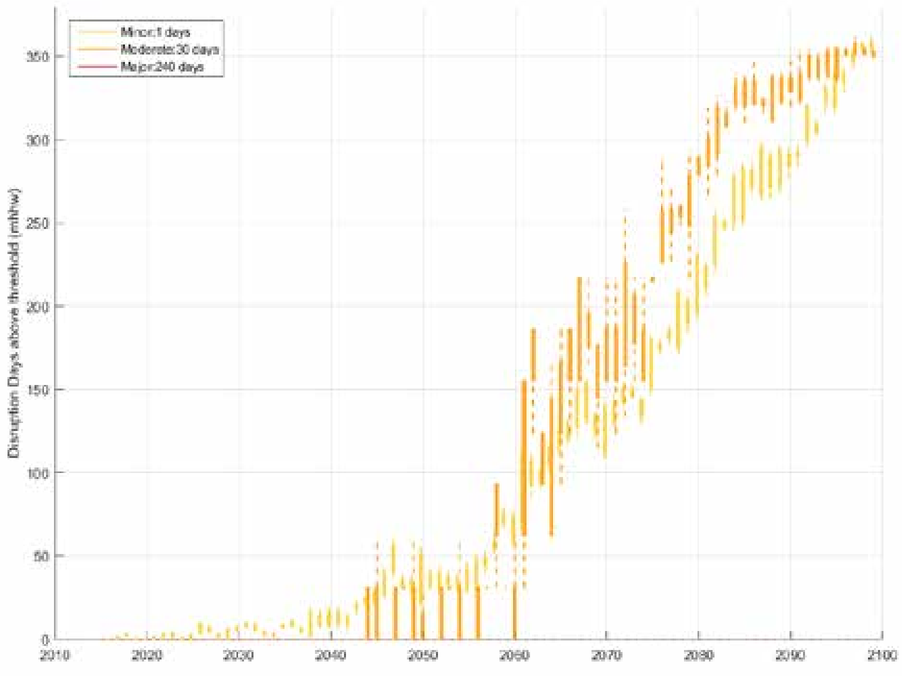
Vulnerability Assessment

Individual Element Assessment

Operational Downtime



Event days per year above minor (yellow) , moderate (orange), and major (red) elevation thresholds over the period 2015 to 2100 for Pier for1.0m GMSLR by 2100.

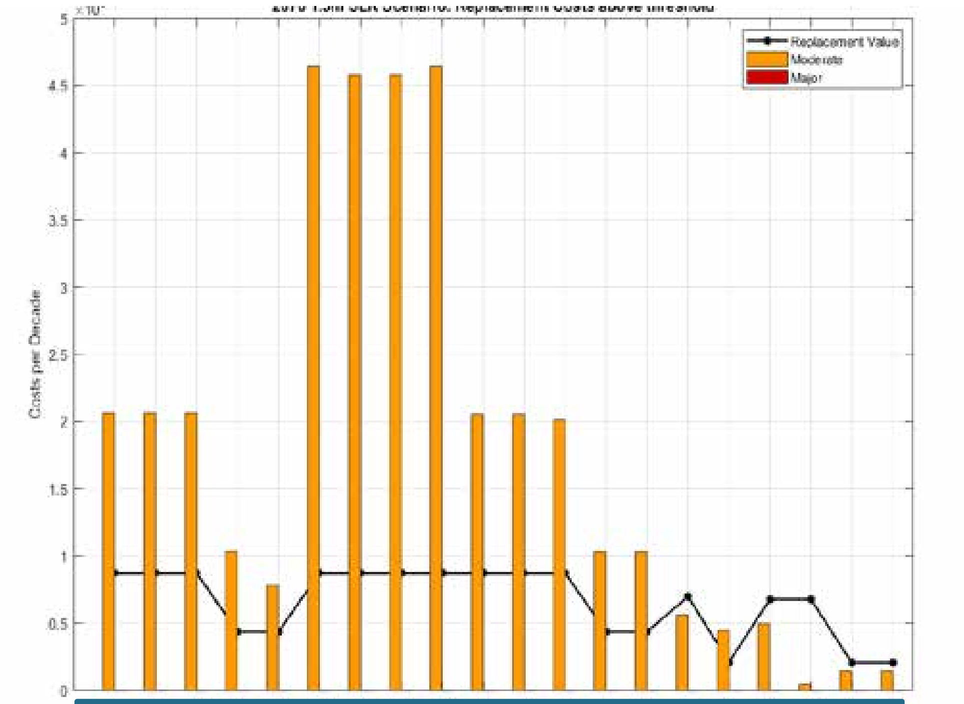


Disruption days per year above minor (yellow) , moderate (orange), and major (red) elevation thresholds over the period 2015 to 2100 for Pier for1.0m GMSLR by 2100.

Vulnerability Assessment

All Elements Assessment

Capital Expenditures



Average yearly replacement costs associated with exceedance of moderate and major thresholds for 1.5m GMSLR by 2100 in 2070.

Operational Downtime

	2020	2030	2040	2050	2060	2070	2080	2090
Docks	7	16	43	69	145	196	306	348
Docks	7	16	43	69	145	196	306	348
Docks	2	6	23	40	127	208	313	345
Docks	2	6	23	40	127	208	313	345
Docks	3	8	27	46	116	166	273	329
Docks	0	0	0	0	1	4	29	78
Docks	0	0	2	5	29	61	183	282
Docks	0	0	0	0	1	3	25	70
Docks	0	0	0	0	1	3	25	70
Docks	3	7	25	43	133	214	316	346
Docks	3	7	25	43	133	214	316	346
Docks	3	8	27	46	138	225	320	347
Docks	0	0	2	5	29	60	141	215
Docks	2	6	23	40	127	208	313	345
Docks	0	0	6	12	53	94	181	271
Docks	0	1	7	15	60	103	191	282
Docks	0	1	7	15	60	103	191	282
Docks	0	0	6	12	53	94	181	271
Docks	0	0	0	0	0	1	9	37
Docks	0	0	0	0	1	4	27	74
Ramps	0	0	0	0	0	0	0	3
Ramps	0	0	0	0	0	0	0	0
Ramps	0	0	0	0	1	6	61	161

Heat maps of disruption days above minor, moderate or major thresholds and associated operational impacts to waterfront structures for 1.0m GMSLR by 2100

Takeaways

For information about vulnerability to be actionable, reduce and reasonably bound uncertainty.

- clearly define the purpose and consider the complete system of interest;
- seek a high level of granularity with respect to sensitivity and exposure; and
- frame results within a scenario construct.

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