Cambio climático en zonas costeras y zonas bajas
Capítulo 5, AR5

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3 de Abril de 2014

Working Group II : Impacts, Adaptation, and Vulnerability
WMO UNEP
ipcc INTERGOVERNMENTAL PANEL ON climate change

¿Novedades en el AR5?

- Incremento considerable de la literatura científica analizada
- Planteamiento conceptual en términos de riesgo
- Cambio climático, variabilidad, extremos y presiones múltiples
- Detección y atribución
- Comunicación rigurosa del grado de certidumbre
- Estructura general
  - Cambios observados y respuestas
  - Amplio rango de posibles futuros, impactos
  - Potencial para la reducción de riesgos. Mitigación y Adaptación
  - Espacio de problemas y Espacio de soluciones
  - Incluye valores y horizontes temporales diversos

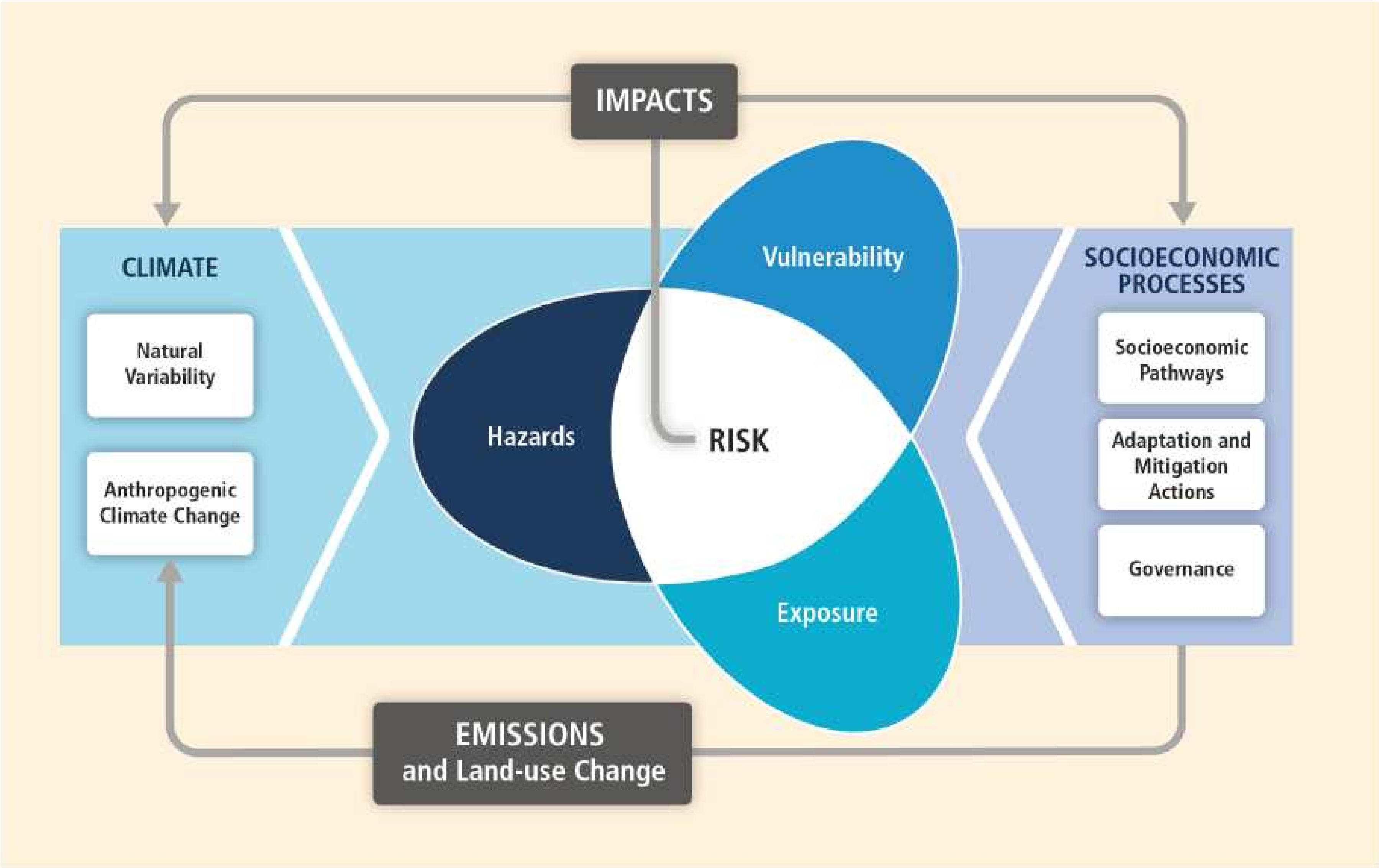
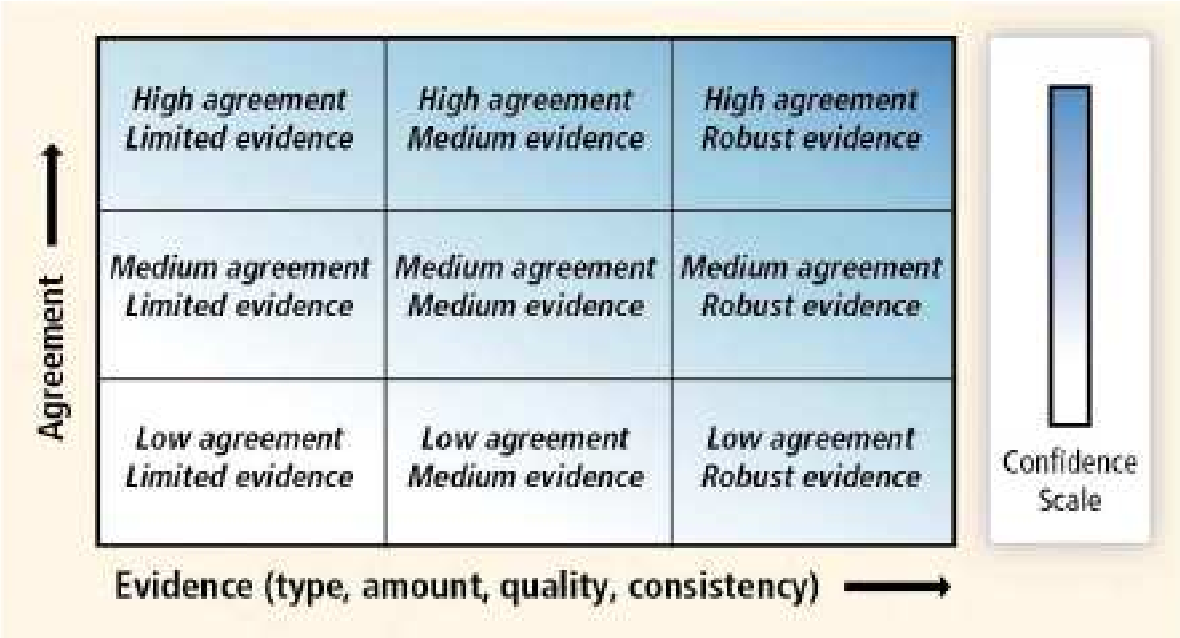

IMPACTS
CLIMATE
Natural Variability
Anthropogenic Climate Change
Vulnerability
Hazards
RISK
Exposure
SOCIOECONOMIC PROCESSES
Socioeconomic Pathways
Adaptation and Mitigation Actions
Governance
EMISSIONS and Land-use Change

Figure SPM.1.

Comunicación del grado de incertidumbre



Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms used more occasionally are *extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability.

Zonas Costeras

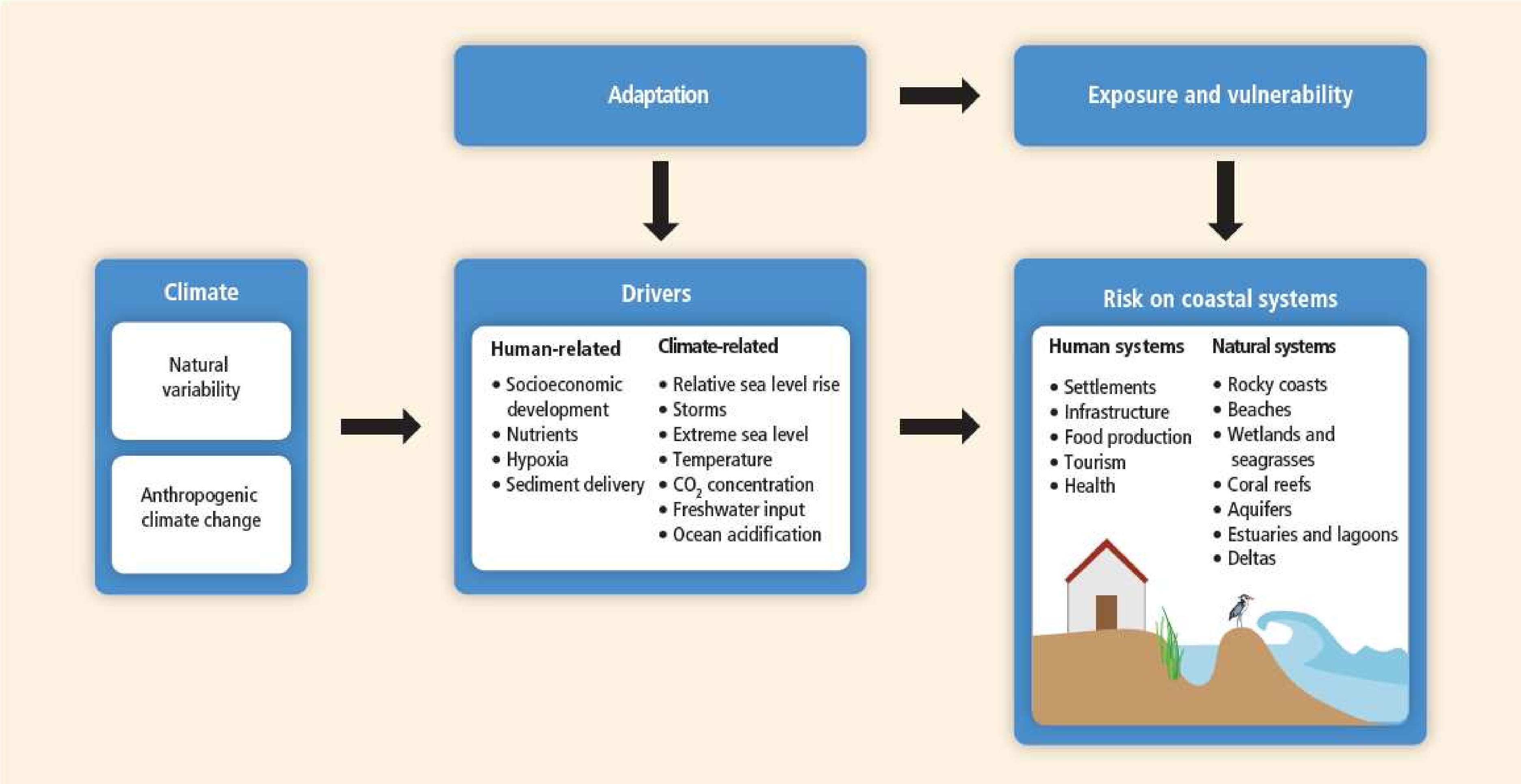


Figure 5-1 | Climate, just as anthropogenic or natural changes, affects both climate- and human-related drivers. Risk on coastal systems is the outcome of integrating drivers and exposure and vulnerability. Adaptation options can be implemented either to modify the drivers or exposure and vulnerability or both.

Climate-related driver	Physical/chemical effects	Trends
Sea level	Submergence, flood damage, erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change).	Global mean sea level *very likely* increase (Section 5.3.2.2; WGI AR5 Sections 3.7.2, 3.7.3).
Storms: tropical cyclones (TCs), extratropical cyclones (ETCs)	Storm surges and storm waves, coastal flooding, erosion; saltwater intrusion; rising water tables/ impeded drainage; wetland loss (and change). Coastal infrastructure damage and flood defense failure.	TCs (Box 5-1, WGI AR5 Section 2.6.3): *low confidence* in trends in frequency and intensity due to limitations in observations and regional variability. ETCs (Section 5.3.3.1; WGI AR5 Section 2.6.4): *likely* poleward movement of circulation features but *low confidence* in intensity changes.
Winds	Wind waves, storm surges, coastal currents, land coastal infrastructure damage.	*Low confidence* in trends in mean and extreme wind speeds (Section 5.3.3.2, SREX, WGI AR5 Section 3.4.5).
Waves	Coastal erosion, overtopping and coastal flooding.	*Likely* positive trends in Hs in high latitudes (Section 5.3.3.2; WGI AR5 Section 3.4.5).
Extreme sea levels	Coastal flooding erosion, saltwater intrusion.	*High confidence* of increase due to global mean sea level rise (Section 5.3.3.3; WGI AR5 Chapter 13).
Sea surface temperature (SST)	Changes to stratification and circulation; reduced incidence of sea ice at higher latitudes; increased coral bleaching and mortality, poleward species migration; increased algal blooms.	*High confidence* that coastal SST increase is higher than global SST increase (Section 5.3.3.4).
Freshwater input	Altered flood risk in coastal lowlands; altered water quality/ salinity; altered fluvial sediment supply; altered circulation and nutrient supply.	*Medium confidence* (*limited evidence*) in a net declining trend in annual volume of freshwater input (Section 5.3.3.6).
Ocean acidity	Increased CO_2 fertilization; decreased seawater pH and carbonate ion concentration (or "ocean acidification").	*High confidence* of overall increase, with high local and regional variability (Section 5.3.3.5).

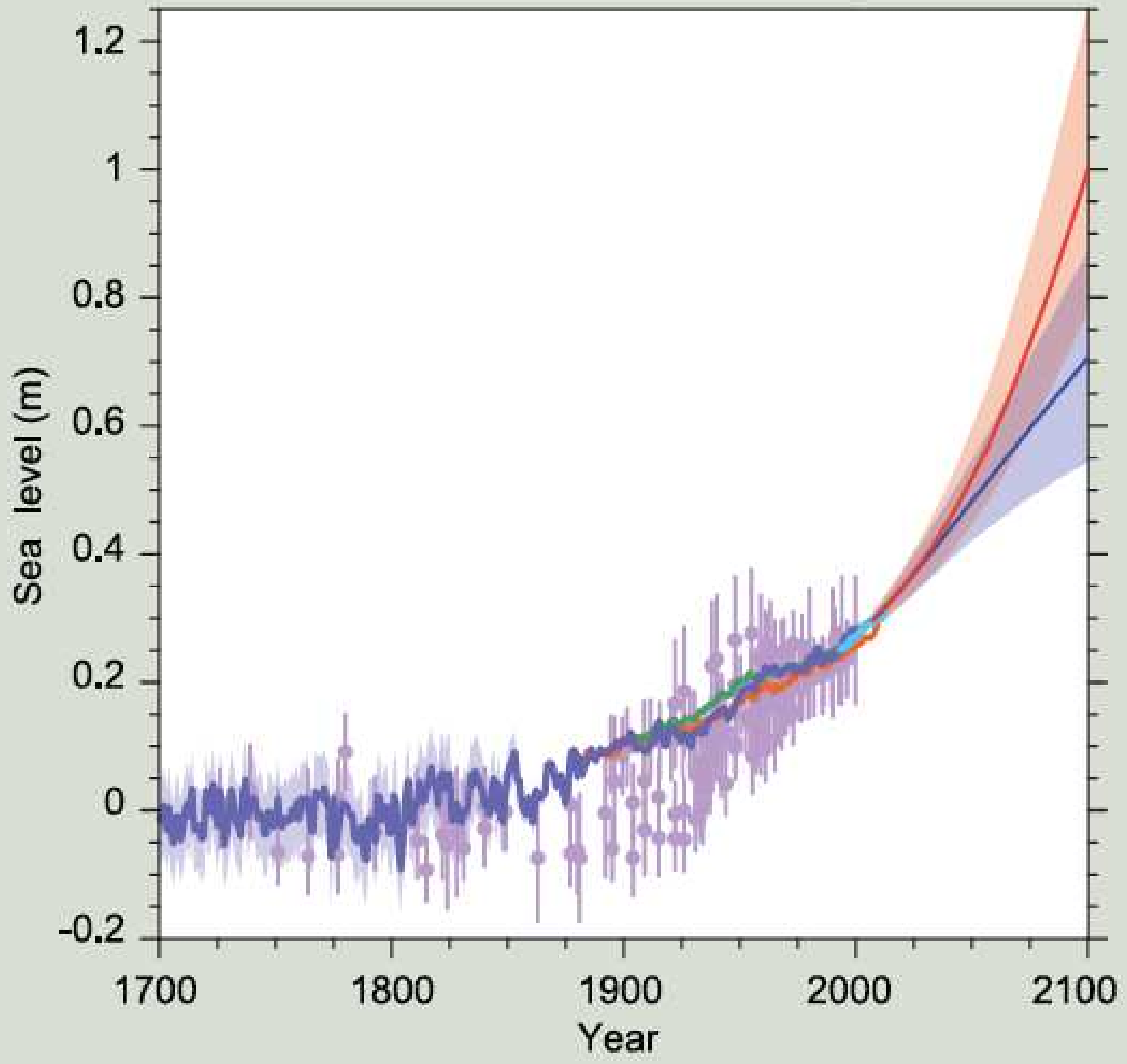
SREX = IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.

90-100%

66-100%

66-100%

Los sistemas costeros son especialmente sensibles a tres factores de cambio vinculados al cambio climático : nivel del mar, temperatura del océano y acidez del océano *(nivel de confianza muy alto*)



TFE.2, Figure 2 | Compilation of paleo sealevel data (purple), tide gauge data (blue, red and green), altimeter data (light blue) and central estimates and *likely* ranges for projections of global mean sea level rise from the combination of CMIP5 and process-based models for RCP2.6 (blue) and RCP8.5 (red) scenarios, all relative to pre-industrial values. {Figures 13.3, 13.11, 13.27}

Table 5-3 | Main impacts of relative sea level rise. Source: Adapted from Nicholls et al. (2010).

Biophysical impacts of relative sea level rise	Other climate-related drivers	Other human drivers
Dryland loss due to erosion	Sediment supply, wave and storm climate	Activities altering sediment supply (e.g., sand mining)
Dryland loss due to submergence	Wave and storm climate, morphological change, sediment supply	Sediment supply, flood management, morphological change, land claim
Wetland loss and change	Sediment supply, CO_2 fertilization	Sediment supply, migration space, direct destruction
Increased flood damage through extreme sea level events (storm surges, tropical cyclones, etc.)	Wave and storm climate, morphological change, sediment supply	Sediment supply, flood management, morphological change, land claim
Saltwater intrusion into surface waters (backwater effect)	Runoff	Catchment management and land use (e.g., sand mining and dretching)
Saltwater intrusion into groundwaters leading to rising water tables and impeded drainage	Precipitation	Land use, aquifer use

A pesar de la falta de atribución detectada en los cambios en la costa estamos expuestos, en el largo plazo, a experimentar los impactos del aumento del nivel del mar debido a que su respuesta al aumento de la temperatura es dilatada en el tiempo (*gran acuerdo*).

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Por contra, el blanqueo de los corales y el desplazamiento espacial de algunas especies se puede atribuir directamente a los cambios en la temperatura del océano y a la acidificación.

Para muchos otros impactos observados (p.e. erosión, inundaciones), es difícil separar la señal del cambio climático de los factores de cambio debidos al hombre (p.e. cambio en los usos del suelo, desarrollo de la costa, contaminación) (*gran acuerdo, evidencia robusta*)

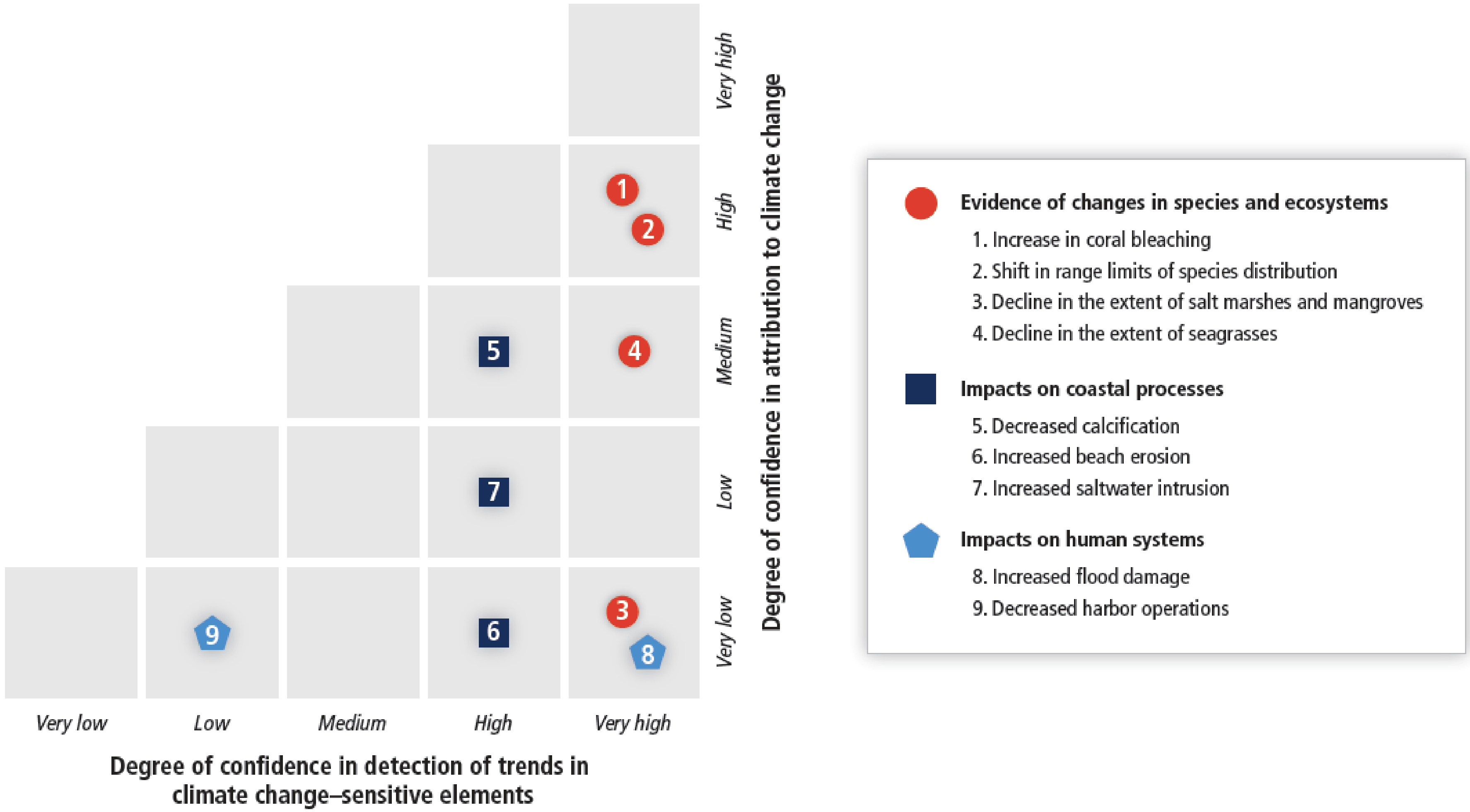


Figure 5-5 | Summary of detection and attribution in coastal areas.

Table 5-2 | Projections of global mean sea level rise in meters relative to 1986–2005 are based on ocean thermal expansion calculated from climate models, the contributions from glaciers, Greenland and Antarctica from surface mass balance calculations using climate model temperature projections, the range of the contribution from Greenland and Antarctica due to dynamical processes, and the terrestrial contribution to sea levels, estimated from available studies. For sea levels up to and including 2100, the central values and the 5–95% range are given whereas for projections from 2200 onwards, the range represents the model spread due to the small number of model projections available and the high scenario includes projections based on RCP6.0 and RCP8.5. Source: WGI AR5 Summary for Policymakers and Sections 12.4.1, 13.5.1, and 13.5.4.

Emission scenario	Representative Concentration Pathway (RCP)	2100 CO_2 concentration (ppm)	Temperature increase (°C)	Mean sea level rise (m)					
			2081–2100	2046–2065	2100	Scenario	2200	2300	2500
Low	2.6	421	1.0 [0.3–1.7]	0.24 [0.17–0.32]	0.44 [0.28–0.61]	Low	0.35–0.72	0.41–0.85	0.50–1.02
Medium low	4.5	538	1.8 [1.1–2.6]	0.26 [0.19–0.33]	0.53 [0.36–0.71]	Medium	0.26–1.09	0.27–1.51	0.18–2.32
Medium high	6.0	670	2.2 [1.4–3.1]	0.25 [0.18–0.32]	0.55 [0.38–0.73]	High	0.58–2.03	0.92–3.59	1.51–6.63
High	8.5	936	3.7 [2.6–4.8]	0.29 [0.22–0.38]	0.74 [0.52–0.98]				

Los sistemas costeros experimentarán un aumento en los impactos adversos debidos a la sumergencia, inundación ante eventos extremos, y erosión por aumento del nivel del mar relativo (*muy alta confianza*)

Playas, dunas y acantilados actualmente en erosión, seguirán erosionándose con el incremento del nivel del mar (*confianza alta*).

La gran variabilidad espacial en el aumento de nivel del mar, conjuntamente con factores locales dará lugar a que el nivel del mar relativo local (RSLR) pueda diferir considerablemente de las proyecciones del nivel medio del mar global (GMSLR) (*confianza muy alta*)

Los impactos debidos a grandes borrascas y su marea meteorológica asociada serán peores debido al aumento del nivel de medio del mar global, a pesar de que las incertidumbres asociadas a los cambios a escala regional en los ciclones tropicales y de latitudes medias hace que las proyecciones de los cambios de la marea meteorológica tengan baja confianza.

Tanto el nivel del mar relativo como los impactos están afectados por un conjunto de procesos no relacionados con el clima (p.e. subsidencia, ajuste glacial isostático, transporte de sedimentos, desarrollo de la costa (*muy alta confianza)*

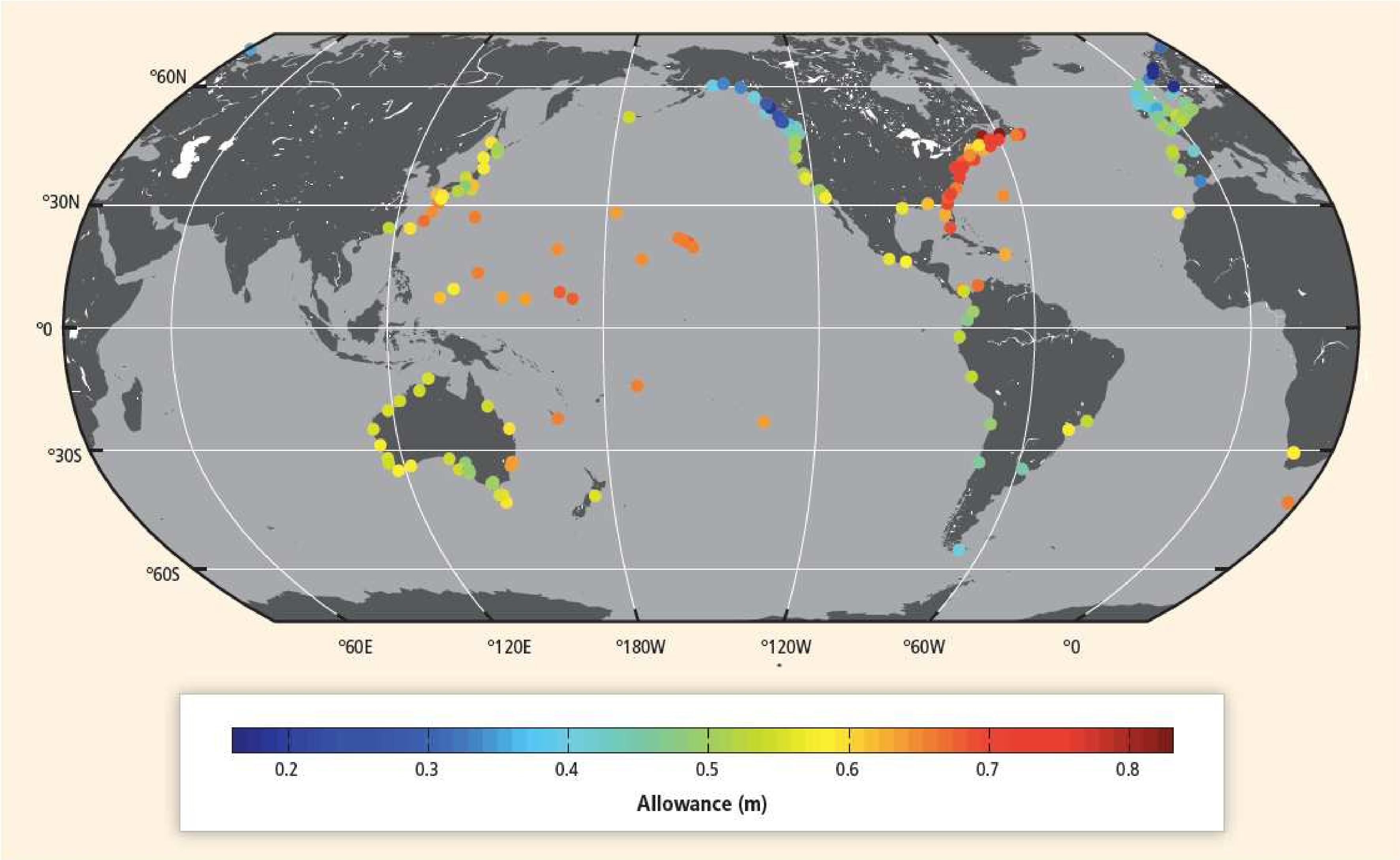


Figure 5-2 | The estimated increase in height (m) that flood protection structures would need to be raised in the 2081–2100 period to preserve the same frequency of exceedences that was experienced for the 1986–2005 period, shown for 182 tide gauge locations and assuming regionally varying relative sea level rise projections under an Representative Concentration Pathway 4.5 (RCP4.5) scenario (adapted from Hunter et al., 2013).

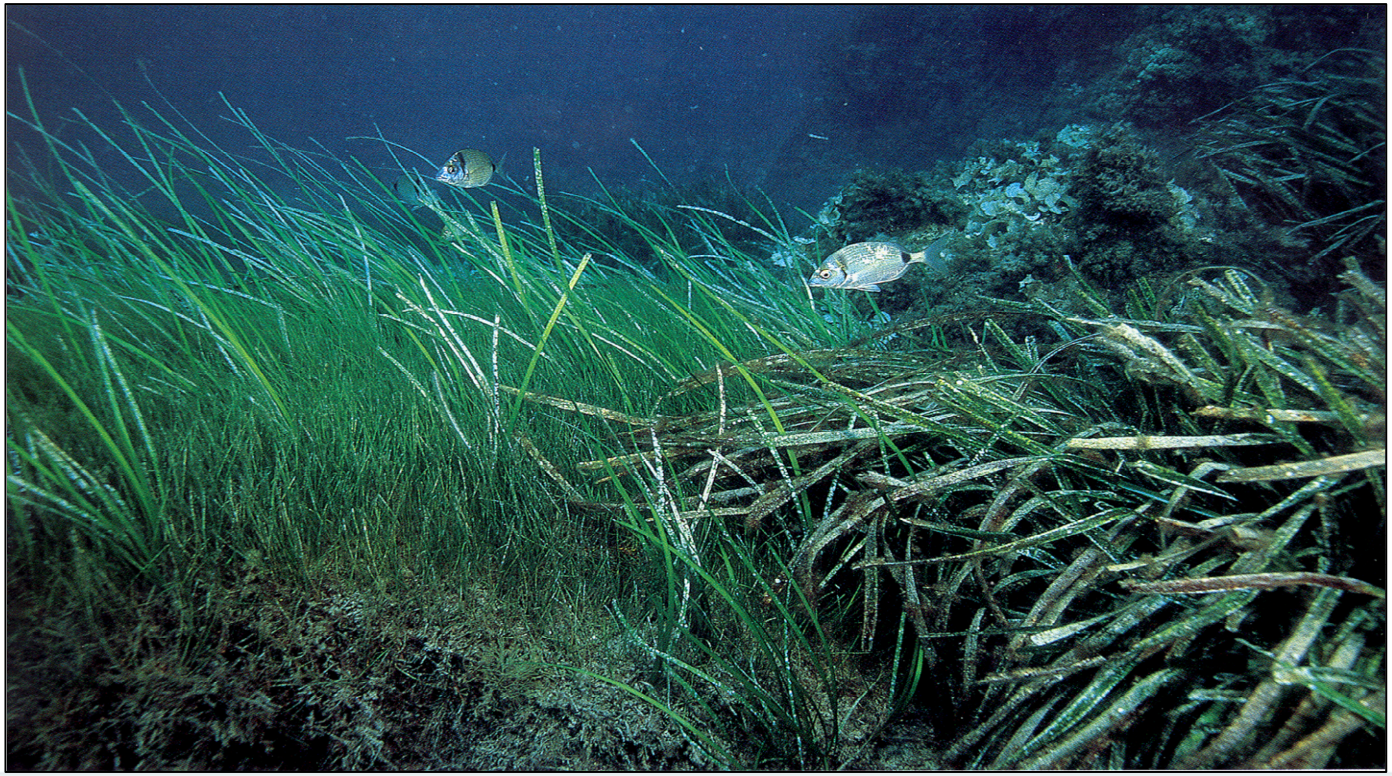
La acidificación y calentamiento de las aguas costeras continuará dando lugar a consecuencias negativas para los ecosistemas costeros (*alta confianza*).

El incremento en la acidez será mayor en zonas donde la eutrofización o los afloramientos sean importantes. Tendrá impactos negativos en muchos organismos calcáreos (*confianza alta*).

El calentamiento y la acidificación darán lugar al blanqueo y mortalidad de los corales, reduciendo su capacidad de generación (*alta confianza),* haciendo de los corales el ecosistema marino más vulnerable y con menor capacidad de adaptación.

Figure CR-1: A and B: the same coral community before and after a bleaching event in February 2002 at 5 m depth, Halfway Island, Great Barrier Reef. Coral cover at the time of bleaching was 95% bleached almost all of it severely bleached, resulting in mortality of 20.9% (Elvidge *et al*., 2004). Mortality was comparatively low due in part because these coral communities were able to shuffle their symbiont to more thermo-tolerant types (Berkelmans and van Oppen, 2006; Jones *et al*., 2008). C and D: three CO_2 seeps in Milne Bay Province, Papua New Guinea show

La vegetación de aguas templadas y los ecosistemas de laminarias se verán reducidos por el incremento en las olas de calor y los extremos de la temperatura del océano, así como por el impacto de especies invasivas subtropicales. (*alta confianza*).



La población y bienes expuestos a riesgos en la costa, así como las presiones ejercidas por el hombre sobre los ecosistemas costeros, se incrementarán de forma significativa en las próximas décadas debido al aumento de población, el desarrollo económico y la urbanización (*confianza alta*).

La exposición de la población y de los bienes expuestos a riesgos costeros ha crecido rápidamente y se espera que esta tendencia continúe. El hombre ha sido el principal factor de cambio en los acuíferos costeros, lagunas, estuarios, deltas y humedales (*confianza muy alta*). Se espera que la presión del hombre se vea incrementada sobre los ecosistemas costeros debido a una aportación excesiva de nutrientes, cambios en la escorrentía o una reducción de la aportación de sedimentos a la costa (*confianza alta*)

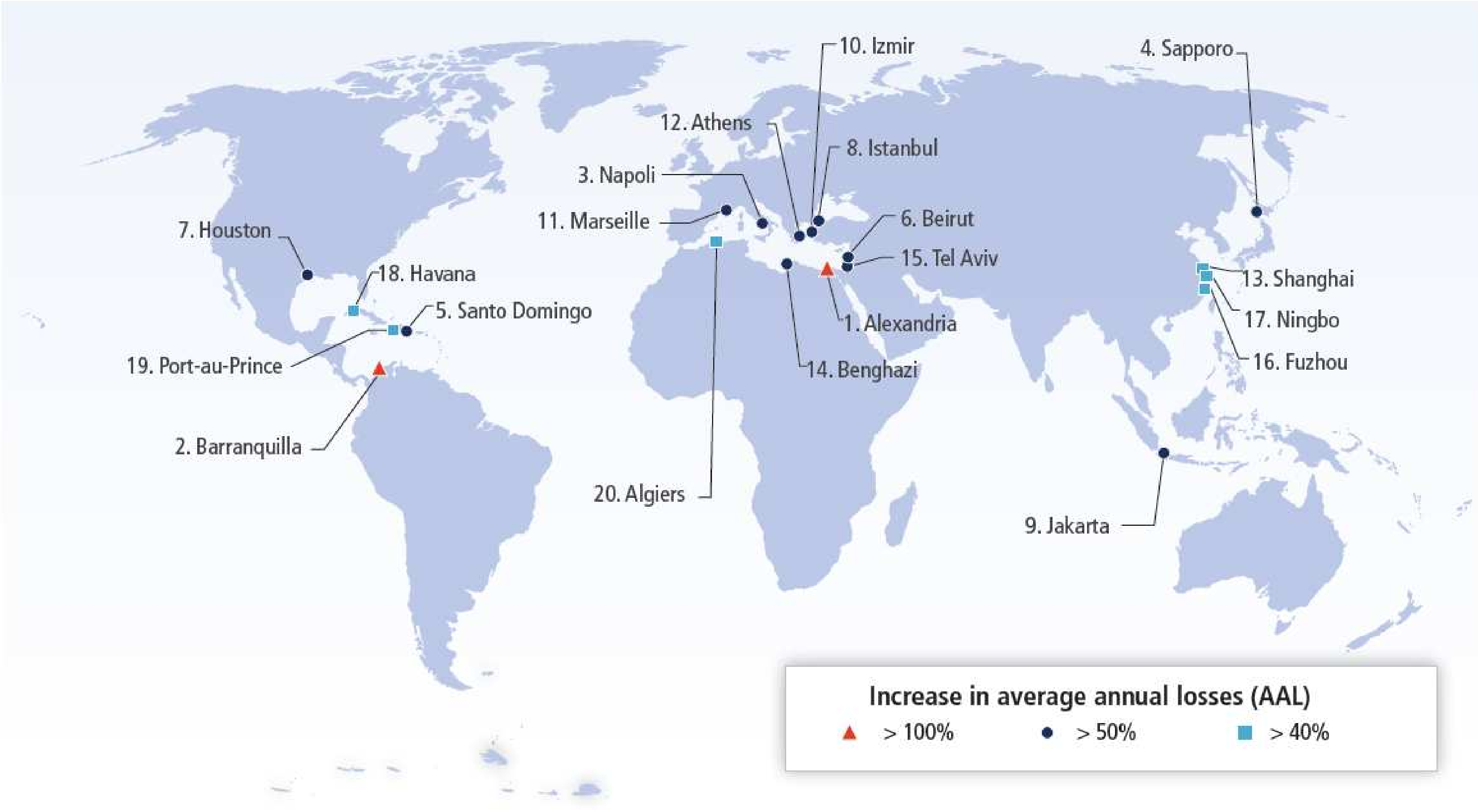


Figure 5-4 | The 20 cities where average annual losses (AALs) increase most (in relative terms in 2050 compared with 2005) in the case of optimistic sea level rise, if adaptation maintains only current defense standards or flood probability (PD) (Hallegatte et al., 2013).

En el siglo 21, los beneficios de protegerse frente al incremento de las inundaciones costeras y la pérdida de territorio debido a la sumergencia y la erosión son, a escala global, mayores que los costes sociales y económicos de la adaptación (*acuerdo alto, evidencia limitada*).

Sin adaptación cientos de millones de personas son susceptibles de verse afectados por inundaciones costeras o desplazados por pérdida de territorio en 2100; la mayor parte de la población afectada se encuentra en el este, sudeste y sur de Asia (confianza alta).

Al mismo tiempo, para cualquier escenario socioeconómico o de aumento de nivel del mar analizado, incluyendo un aumento de nivel del mar global superior a 1 m, la protección frente a la inundación y erosión se considerada económicamente racional para la mayor parte de las líneas de costa más desarrolladas en muchos de los países del mundo. (*acuerdo alto, evidencia baja)*

Los costes económicos de la adaptación en el siglo 21 varían fuertemente entre regiones y países (*confianza alta)*.

Algunos países en cotas bajas con respecto al nivel del mar (p.e. Bangladesh y Vietnam) e islas estado se espera que tengan que asumir muy altos impactos con costes anuales de daños y adaptación de varios puntos de su PIB. Los países en desarrollo y las islas estado en los trópicos, altamente dependiente del turismo, se verán directamente impactados no solo por el aumento del nivel del mar proyectado y los eventos extremos asociados, sino también por el blanqueo del coral y la acidificación, lo que supondrá un descenso en el interés turístico. **(***confianza alta*).

El análisis e implementación de la adaptación en zonas costeras en la búsqueda de una costa más resiliente y sostenible ha progresado más significativamente en países desarrollados que en países en desarrollo (*confianza alta*).

Aunque existe un gran número de opciones de adaptación, las respuestas más proactivas pueden concretarse con base en aspectos tecnológicos y el apoyo de políticas, de instrumentos financieros e institucionales. Entre las adaptaciones observadas con éxito se encuentran (p.e. Estuario del Támesis, Laguna de Venecia, Obras del Delta, Holanda) y prácticas específicas implmentadas, tanto en países desarrollados (p.e Holanda, Australia) como en desarrollo (p.e. Bangladesh)

Muchos otros países y comunidades han introducido medidas de adaptación costera basadas en gestión integrada de zonas costeras, comunidades locales, ecosistemas, reducción de desastres. Dichas mediadas han sido integradas en las estrategias relevantes y planes de gestión (*gran confianza*)

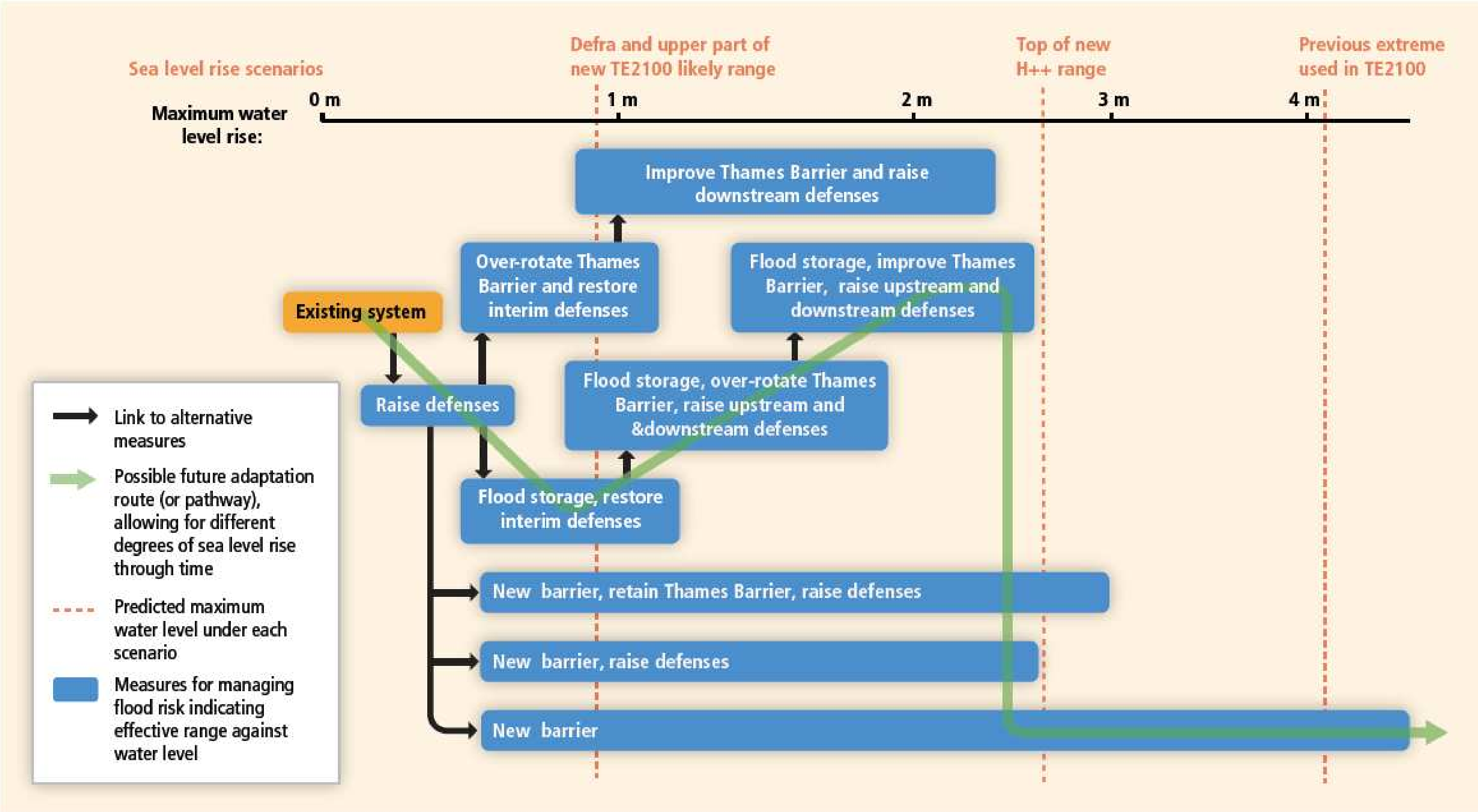
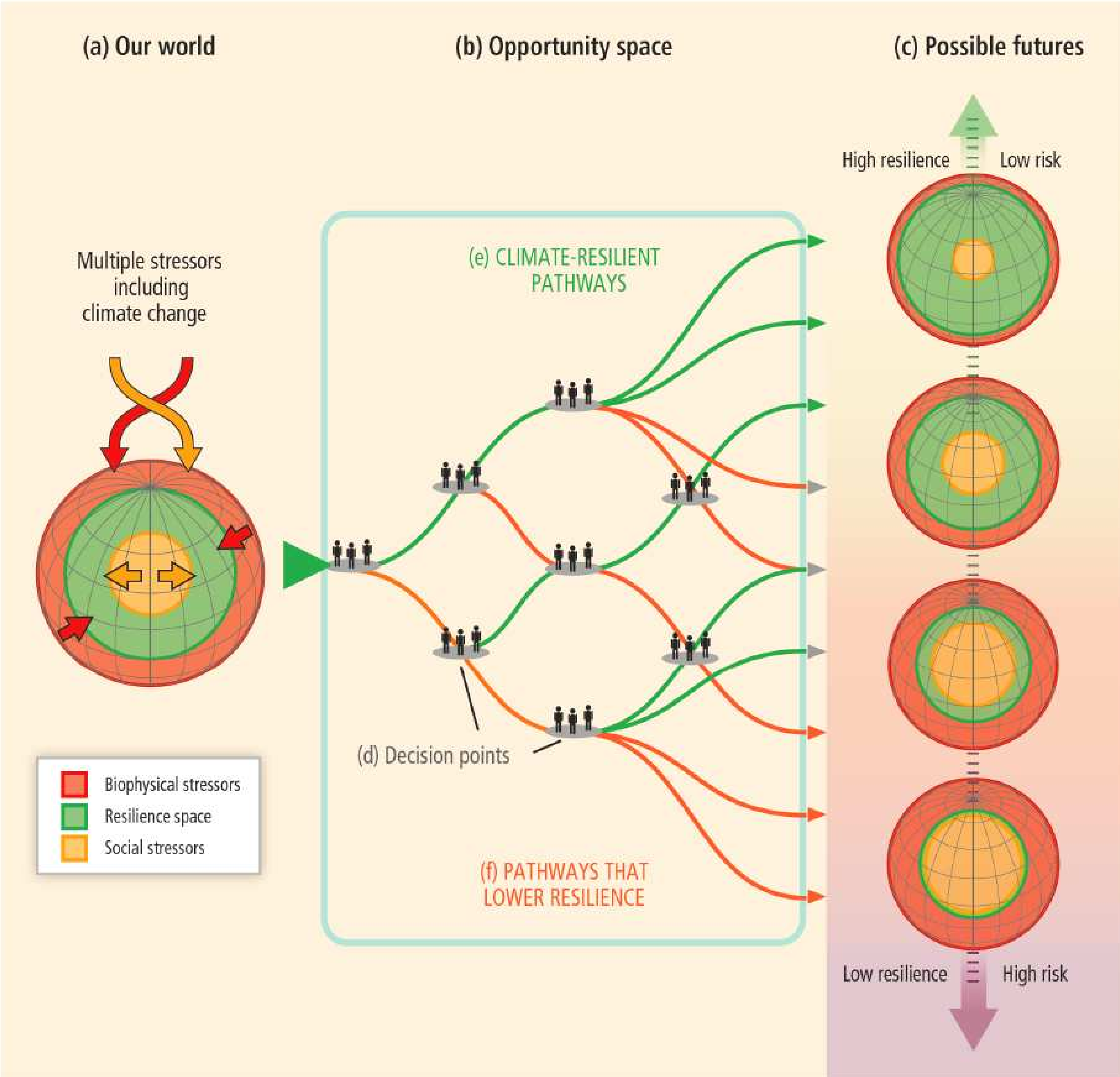


Figure 5-6 | Adaptation measures and pathways considered in the TE2100 project. The boxes show the measures and the range of sea level rise over which the measures are effective. The black arrows link to alternative measures that may be applied once a measure is no longer effective. The red lines show the various 21st century sea level rise scenarios used in the analysis including a conservative estimate of about 0.9 m by the UK Department for Environment Food and Rural Affairs (Defra), a high-level scenario of 2.6 m (H+) and an extreme scenario of over 4 meters (H++). The fat green line shows a possible future adaptation route (or pathway), allowing for different degrees of sea level rise through time (adapted from Lowe et al., 2009).



(a) Our world
(b) Opportunity space
(c) Possible futures
High resilience
Low risk
Multiple stressors including climate change
(e) CLIMATE-RESILIENT PATHWAYS
(d) Decision points
Biophysical stressors
Resilience space
Social stressors
(f) PATHWAYS THAT LOWER RESILIENCE
Low resilience
High risk

Figure SPM.9.

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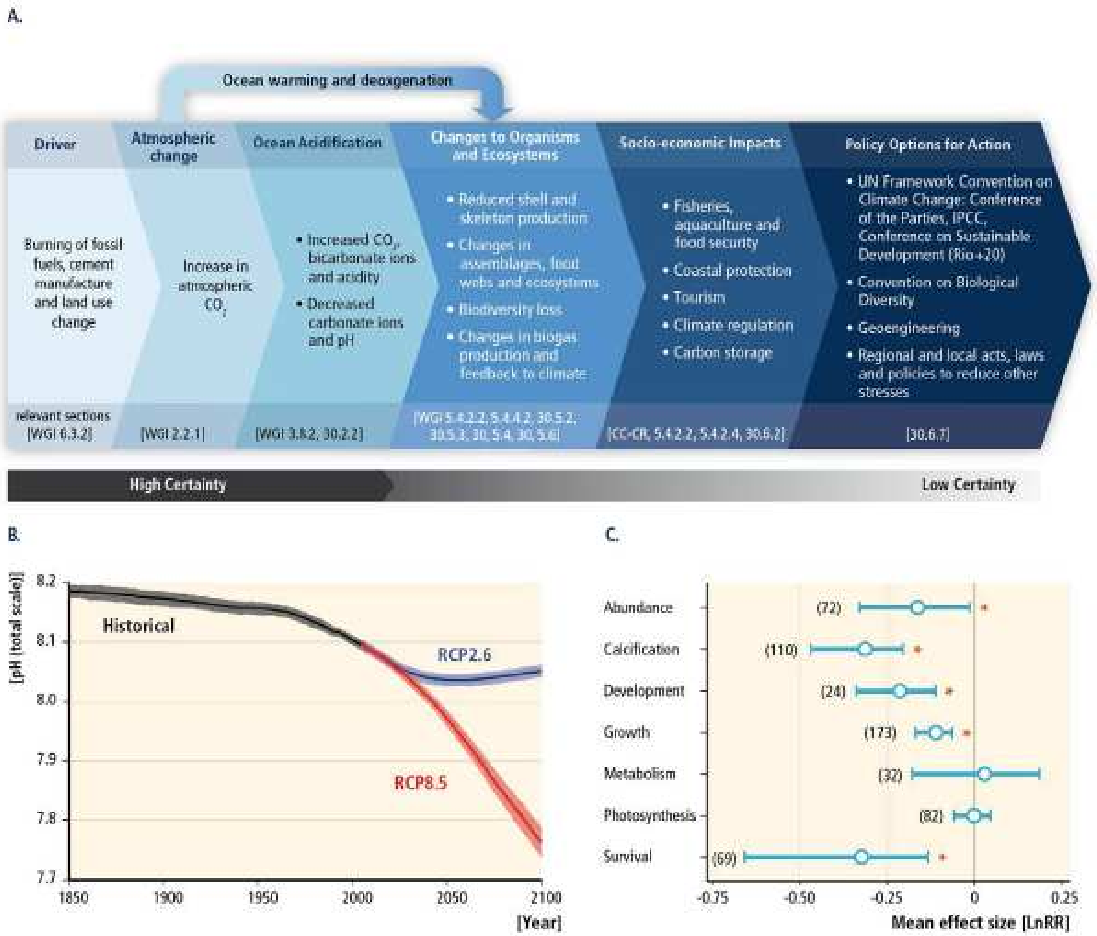


Figure OA-1: A: Overview of the chemical, biological, socio-economic impacts of ocean acidification and of policy options (adapted from Turley and Gattuso, 2012). B: Multi-model simulated time series of global mean ocean surface pH (on the total scale) from CMIP5 climate model simulations from 1850 to 2100. Projections are shown for emission scenarios RCP2.6 (blue) and RCP8.5 (red) for the multi-model mean (solid lines) and range across the distribution of individual model simulations (shading). Black (grey shading) is the modelled historical evolution using historical reconstructed forcings. The models that are included are those from CMIP5 that simulate the global carbon cycle while being driven by prescribed atmospheric CO_2 concentrations. The number of CMIP5 models to calculate the multi-model mean is indicated for each time period/scenario (WGI AR5 Figure 6.28). C: Effect of near future acidification (seawater pH reduction of 0.5 unit or less) on major response variables estimated using weighted random effects meta-analyses, with the exception of survival which is not weighted (Kroeker et al., 2013). The log-transformed response ratio (LnRR) is the ratio of the mean effect in the acidification treatment to the mean effect in a control group. It indicates which process is most uniformly affected by ocean acidification but large variability exists between species. Significance is determined when the 95% bootstrapped confidence interval does not cross zero. The number of experiments used in the analyses is shown in parentheses. * denotes a statistically significant effect.

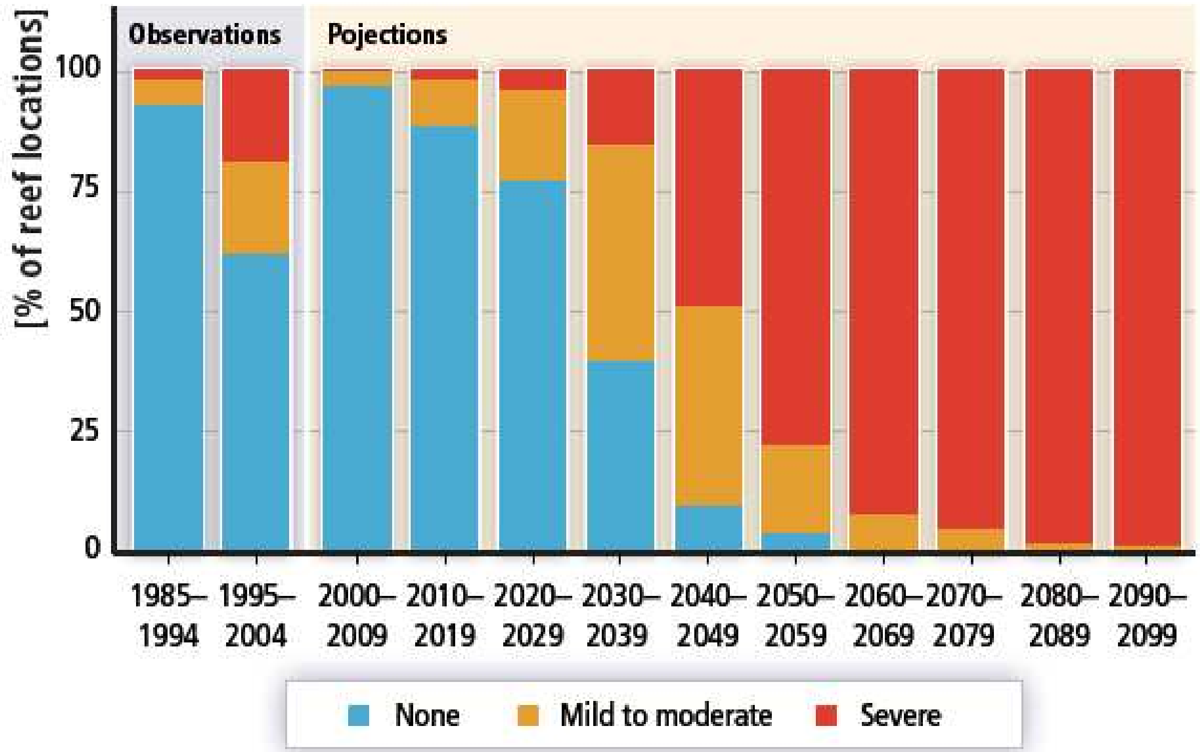
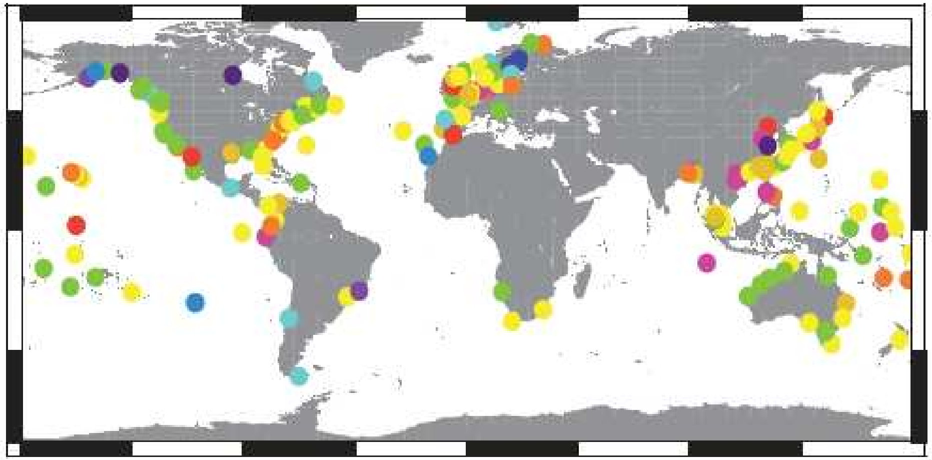


Figure 5-3 | Percent of reef locations (1° × 1° grid cells which have at least one reef) that experience no bleaching, at least one mild bleaching event, or at least one severe bleaching event for each decade. Observed bleaching events are summarized from the ReefBase data set (Kleypas et al., 2008). In the observations, some of the "no bleaching" cells may have experienced bleaching but it was either not observed or not reported. Modeled bleaching events are averages of data from four ensemble runs of the Community Climate System Model version 3 using the Special Report on Emissions Scenarios (SRES) A1B CO_2 scenario and the standard degree heating month formula (Teneva et al., 2011). The labels of values ≤1% are not shown.

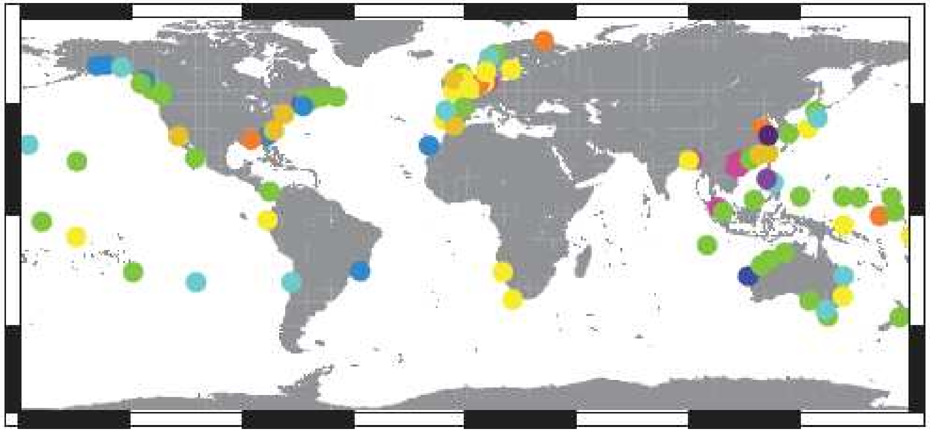
Table 5-4 | Community-based adaptation measures.

Impact	Type of option	Measures	Brief description	References
Increased salinity	New and diversified livelihoods	Saline-tolerant crop cultivation	Farmer production of saline-tolerant multi-vegetable varieties and non-rice crops	Ahmed (2010); Rabbani et al. (2013)
	New and diversified livelihoods	Keora nursery	Mangrove fruit production to develop local female entrepreneurship	Ahmed (2010)
	New and diversified livelihoods	Crab fattening	Collection, rearing, and feeding of crabs for 15 days to increase local market value	Pouliotte et al. (2009)
	Structural	Homestead protection	Houses constructed on raised foundations to mitigate salinity ingress	Ayers and Forsyth (2009)
Flooding/ inundation	Socio-technical	Disaster management committees	Multi-community stakeholder committees established to discuss disaster preparedness and response on a monthly basis	Ahammad (2011)
	Socio-technical	Early flood warning systems	Established systems converted into a language and format understood by local communities; warning dissemination through community radio services	Ahmed (2005); Saroar and Routray (2010)
	New and diversified livelihoods	Aquaculture: cage and integrated approaches	Small-scale fish culture in cages on submerged agriculture land; aquaculture integrated with other livelihood practices	Pomeroy et al. (2006); Pouliotte et al. (2009); Khan et al. (2012)
	New and diversified livelihoods	Embankment cropping	Growing different vegetable varieties around heightened shrimp enclosures/coastal polders for productive use of fallow land	Ahmed (2010)
	New and diversified livelihoods	Hydroponics	Cultivating vegetables and other crops on floating gardens	Ayers and Forsyth (2009); Ahmed (2010); Dev (2013)
Cyclones/storm surges	Structural/hard	Homestead reinforcement	Low-cost retrofitting to strengthen existing household structures, especially roofs; strict implementation of building codes	Sales (2009); Ahmed (2010)
	Structural/soft	Homestead ecosystem protection	Plantation of specific fruit trees around homestead area	Haq et al. (2012)
	Structural/hard	Underground bunker construction	Underground bunker established, providing protected storage space for valuable community assets	Raihan et al. (2010)
Sea level rise	Institutional	Risk insurance mechanisms	Farmers educated on comprehensive risk insurance, focusing on sea level rise and coastal agriculture	Khan et al. (2012)
Multi-coastal impacts	Institutional	Integrating climate change into education	Formal and informal teacher training and curriculum development on climate change, vulnerability, and risk management	Ahmed (2010)
	Institutional	Integrated coastal zone management (ICZM) plan	ICZM plan development at local institutional level, including land and sea use zoning for ecosystem conservation	Sales (2009)
	Structural/soft	Restoration, regeneration and management of coastal habitats	Community-led reforestation and afforestation of mangrove plantations, including integration of aquaculture and farming to increase household income levels	Rawlani and Sovacool, (2011); Sovacool et al. (2012)
	Institutional	Community participation in local government decision-making	Active female participation in local government planning and budgeting processes to facilitate delivery of priority coastal adaptation needs	Faulkner and Ali (2012)
	Institutional/ socio-technical	Improved research and knowledge management	Establishment of research centers; community-based monitoring of changes in coastal areas	Sales (2009); Rawlani and Sovacool (2011)

(a)



(b)



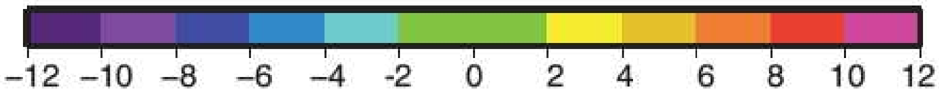


Figure 3.15 | Estimated trends (cm per decade) in the height of a 50-year event in extreme sea level from (a) total elevation and (b) total elevation after removal of annual medians. Only trends significant at the 95% confidence level are shown. (Data are from Menéndez and Woodworth, 2010.)

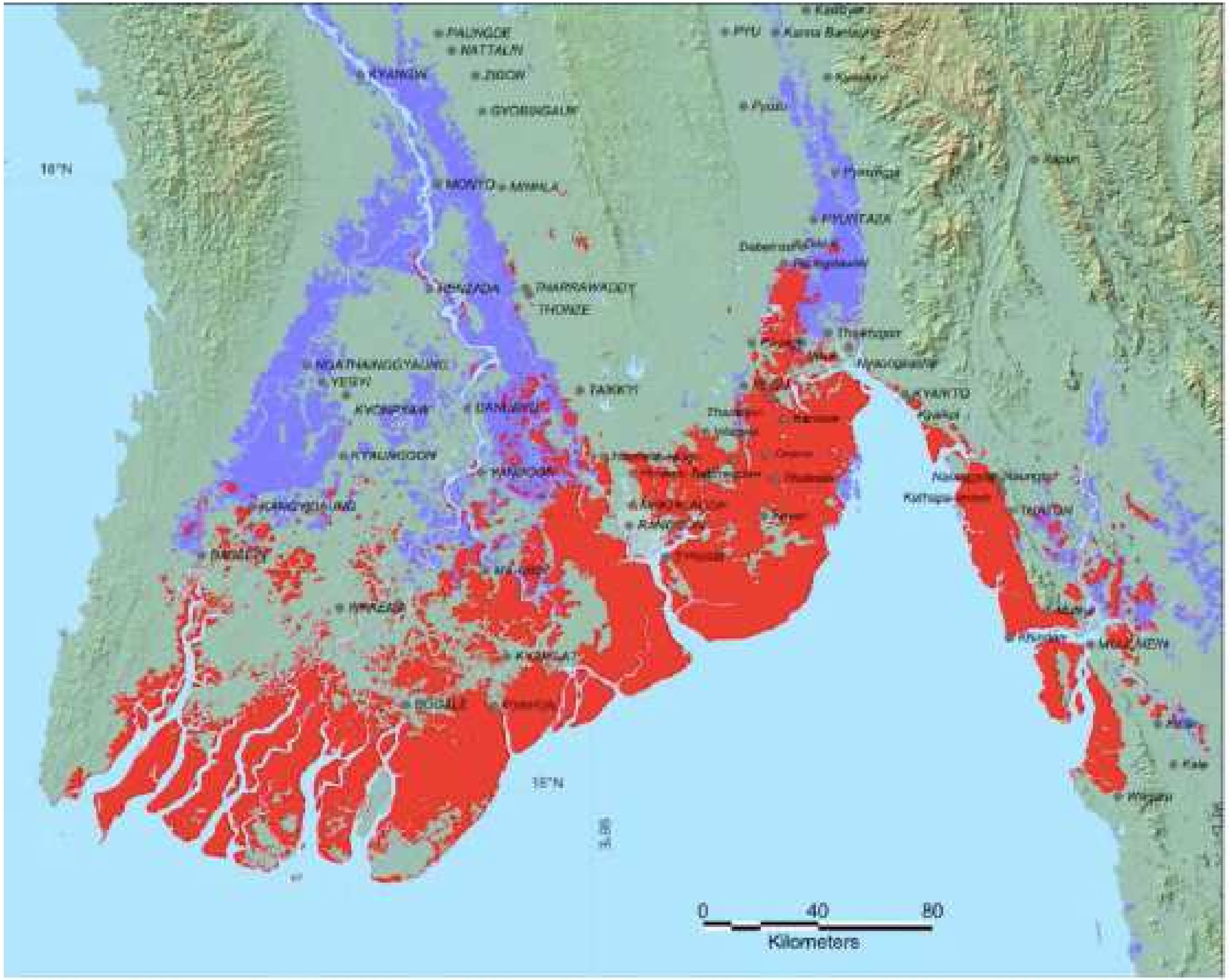


Figure TC-1: The intersection of inland and storm surge flooding. Red shows May 5, 2008 MODIS mapping of the tropical cyclone Nargis storm surge along the Irrawaddy Delta and to the east, Myanmar. The blue areas to the north were flooded by the river in prior years. Source: Brakenridge et al., 2013.