



Ocean change in Small Island Developing States

Flora Gues¹, Karina von Schuckmann², Mahé Butel², Samantha Hallam³, Alvaro de Pascual⁴,
Axel Alonso Valle⁴, Aurélien Liné², and Lorena Moreira Mendez⁴

¹CELAD, 48 Rte de Lavaur, 31130 Balma, France

²Mercator Ocean international, 2 Avenue de l'Aérodrome de Montaudran, 31400 Toulouse, France

³Maynooth University, Maynooth, Co. Kildare, Ireland

⁴Nologin Oceanic Weather Systems, Paseo de la Castellana 216, 28046 Madrid, Spain

Correspondence: Karina von Schuckmann (karina.von.schuckmann@mercator-ocean.fr)

Published: 30 September 2026

Abstract. Small Island Developing States (SIDS) depend fundamentally on the ocean for their societies, economies and livelihoods, yet they are among the regions most exposed to ocean changes. Here we present an ocean narrative that quantifies the environmental, economic and societal dimensions of this exposure using a suite of integrated ocean indicators. Through their Exclusive Economic Zones (EEZs), SIDS cover approximately 8 % of the global ocean and 15 % of the tropical ocean (30° S–30° N), encompassing globally important biodiversity hotspots, including coral reefs, mangroves and seagrasses. At the same time, 65 % of their EEZ area is experiencing accelerated sea-level rise, widespread ocean warming, and 56 % of EEZs exhibit rapid (above-global-average) increases in tropical cyclone heat potential since 1960, which represents the ocean heat available to fuel cyclone intensification. Nearly one-third of the SIDS EEZ area contains coral reefs classified as vulnerable, endangered or critically endangered, and one quarter of these reefs have experienced severe accumulated marine heat stress. Coastal hazards are further illustrated by cumulative tropical cyclone damages exceeding 50 % of national GDP in approximately 40 % of assessed SIDS, while nearly 20 % of assessed SIDS have experienced storm surges exceeding 3 m. Nature-based coastal protection also emerges as a critical component of climate resilience, with mangrove ecosystems for example providing annual avoided damages exceeding USD 1 million in 18 SIDS. This ocean narrative highlights the dual role of SIDS as custodians of globally important marine ecosystems and sentinels of ocean and climate change, and demonstrates the need to integrate ocean data and science, ecosystem health and resilience and climate risk assessment into ocean governance.

1 Introduction

Small Island Developing States (SIDS) in all ocean basins share both commonalities in their exposure and vulnerability to ocean changes. The SIDS were recognized as a distinct group of developing countries facing specific social, economic, and environmental vulnerabilities at the United Nations Conference on Environment and Development (Earth Summit, June 1992 in Rio de Janeiro, Brazil, <https://www.un.org/en/conferences/small-islands>, last access: 16 June 2026). This group of states comprises 40 UN Member States¹ and

20 non-UN members/Associate Members of Regional Commissions². Despite bearing little historical responsibility for

Republic, Fiji, Grenada, Guinea-Bissau, Guyana, Haiti, Jamaica, Kiribati, Maldives, Marshall Islands, Federated States of Micronesia, Mauritius, Nauru, Niue, Palau, Papua New Guinea, Samoa, São Tomé and Príncipe, Singapore, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Seychelles, Solomon Islands, Suriname, Timor-Leste, Tonga, Trinidad and Tobago, Tuvalu, and Vanuatu. Source: <https://www.undp.org/publications/state-climate-ambition-snapshots-least-developed-countries-ldcs-and-small-island-developing-states-sids> (last access: 17 June 2026).

¹The 40 SIDS that are signatories to the Paris Agreement include: Antigua and Barbuda, Bahamas, Bahrain, Barbados, Belize, Cabo Verde, Comoros, Cook Islands, Cuba, Dominica, Dominican

²Non UN members/associate members of regional commissions (20): American Samoa, Anguilla, Aruba, Bermuda, British Virgin Islands, Cayman Islands, Commonwealth of Northern Marianas, Cook Islands, Curacao, French Polynesia, Guadeloupe, Guam,

Table 1. Products used.

Product ref. No.	Product ID and type	Data access	Documentation
1	Fish Stock Status, Environmental Performance Index	SEDAC (2020)	Kleisner and Pauly (2015), UNDP (2026)
2	Small Island Developing States (SIDS)	UN OHRLLS (2026)	UN (1992), UN DESA (2026)
3	ZEE regions	Flanders Marine Institute (2023)	Claus et al. (2014)
4	Species richness in the Oceans	IUCN (2025a)	IUCN (2026)
5	OMI_CLIMATE_SL_GLOBAL_regional_trends Satellite observations	E.U. Copernicus Marine Service (2025)	QUID: Quet et al. (2025) PUM: Pujol et al. (2025)
6	NOAA Optimum Interpolation Sea Surface Temperature (OISST) Satellite observations & in situ observations	Huang et al. (2020)	Huang et al. (2021)
7	IAP global ocean heat content 1° gridded analysis product (IAPv4) Objective analysis from in-situ observations	Cheng et al. (2024a)	Cheng et al. (2024b)
8	INSITU_GLO_PHY_TS_OA_MY_013_052 Objective analysis from in-situ observations	E.U. Copernicus Marine Service (2026)	QUID: Szekely (2026a) PUM: Szekely (2026b)
9	EN4 quality controlled subsurface ocean temperature Objective analyses from in-situ observations	Good et al. (2013a)	Good et al. (2013b)
10	NCEI ocean heat content from 1955 to present calculated from in situ oceanographic subsurface profile data Objective analysis from in-situ observations	Levitus et al. (2017)	Levitus et al. (2012)
11	IUCN endangered and vulnerable coral reefs Expert-derived species range maps	IUCN (2020)	IUCN (2025b)
12	Dollar value of reef tourism	Spalding et al. (2017)	Spalding et al. (2017)
13	Economic Impact of Emergency Events Compiled multi-source disaster impact database	Guha-Sapir (2020)	CRED (2023b)
14	Gros Domestic Products (GDP) by countries Compiled official national statistics	World Bank (2026)	World Bank (2026)
15	Human Impact of Emergency Events Compiled multi-source disaster impact database	Guha-Sapir (2020)	CRED (2023a)
16	Ocean Cyclone Track Observational best-track record	Gahtan et al. (2024)	Knapp et al. (2010)
17	Global Peack Surge Map Compiled historical observational database	Needham and Keim (2015)	Needham and Keim (2012)
18	Mangrove Coastal Protection Benefit Modeling	The Nature Conservancy (2018)	Menéndez et al. (2018)

global warming, SIDS experience its consequences more acutely than most other nations (Martyr-Koller et al., 2021; Mimura et al., 2007; Vousdoukas et al., 2023). Sea-level rise

Martinique, Montserrat, New Caledonia, Niue, Puerto Rico, Sint Maarten, Turks and Caicos Islands, U.S. Virgin Islands; Source: <https://www.un.org/en/conferences/small-islands>.

poses an existential threat for many low-lying islands, raising unresolved questions about population displacement, resources rights, and sovereignty in case of territorial loss (Bronnen and Chapin, 2013; Green and Wewerinke-Singh, 2025; Marino, 2018; Martyr-Koller et al., 2021; Mimura et al., 2007).

For SIDS, the Exclusive Economic Zone (EEZ) is, on average, 28 times the country's land mass (<https://www.un.org/ohrrls/content/about-small-island-developing-states>, last access: 16 June 2026). An illustrative example of this striking contrast is the Marshall Islands, whose land covers only 183 km², whereas its EEZ represents around 2 million km² (Thorpe, 2005). Thus, for many SIDS, most of the natural resources they have access to come from the ocean. Factors like small population size, remoteness from international markets, high transportation costs, vulnerability to exogenous economic shocks, and fragile land and marine ecosystems, make SIDS particularly vulnerable to biodiversity loss and changes in the ocean, because they lack economic alternatives. Ocean changes already impact SIDS with cascading and compounding risks, and disproportionately higher risks are expected in the course of the 21st century, where vulnerable human communities, especially those in coral reef environments, may exceed adaptation limits well before the end of this century (IPCC, 2019). This emphasizes the need to report on ocean change not only through environmental observations, but also through an understanding of how these changes translate into socioeconomic implications for communities, livelihoods, food security, and sustainable development. Ocean narratives can support this by linking ocean and socioeconomic indicators with scientific evidence, thereby providing a more integrated and societally relevant perspective on ocean change in the areas adjacent to the SIDS.

Here, we provide 3 themes for the ocean narrative with focus on the ocean areas relevant for the SIDS. The first topic puts together information on ocean areas under the jurisdiction, bringing together information on national waters, accelerating sea-level rise, marine species richness, and fisheries. This theme highlights the unique relationship between SIDS and the ocean, emphasizing both the ecological significance of their marine environments and their dependence on ocean resources such as food security, livelihoods, and economic development. The second theme focuses on ocean warming and marine heatwaves in the context of coral reef vulnerability and tourism. Coral reefs provide essential ecosystem services and underpin tourism economies across many SIDS. By linking physical ocean changes with ecosystem impacts and socioeconomic dependence on tourism, this theme explores how increasing thermal stress may affect both marine biodiversity and economic resilience. The third topic examines the role of ocean heat content for fuelling tropical cyclones and discusses the implications for loss and damage in SIDS. It further considers the protective function of mangrove ecosystems, which can reduce coastal exposure to storm surges and flooding. By connecting changes in the ocean climate system with coastal vulnerability and nature-based protection, this narrative highlights the growing importance of adaptation and resilience-building in the face of increasing climate risks.

2 Method

Ocean change is increasingly monitored and reported on through a growing range of physical, biological and chemical ocean indicators, including ocean warming, sea-level rise, deoxygenation, and acidification. At the same time, socioeconomic datasets provide detailed information on, for example, human vulnerability, economic dependence, protection efforts, or governance capacity. However, albeit progress has been achieved for some topics (Gussmann and Hinkel, 2021; Hinkel et al., 2023), these two domains are often analysed separately, making it difficult to understand how changes in the ocean translate into societal impacts and opportunities. The concept of ocean narratives addresses this gap, as they establish scientific linkages between ocean and socioeconomic indicators within a specific thematic context. By combining these datasets and scientific knowledge, the approach helps identify where ocean changes may be having the most impact on human well-being, economic development, and environmental sustainability.

Ocean narratives are a new concept to connect ocean data and indicators to human relevance. The concept has been introduced by an international and multidisciplinary team of scientists (Von Schuckmann et al., 2026), and implemented for the first time in the 8th Copernicus Ocean State Report (von Schuckmann et al., 2025a, b). Ocean narratives create a bridge between ocean science, societal outcomes, and therefore contribute to evidence-based knowledge transfer. They are based on the combination of ocean indicators such as ocean warming, sea level rise, ocean acidification, or sea ice change, together with socioeconomic data relevant to specific themes or regions. Spatial and temporal patterns revealed by indicators can highlight potential relationships and emerging areas of concern, while peer-reviewed scientific literature is used to validate and explain these connections. Therefore, the narrative development follows a strict evidence-based approach: links between ocean change and socioeconomic data are only integrated in the ocean narrative when peer-reviewed literature shows scientifically validated relationships. This ensures that narratives are both scientifically robust and accessible to decision-makers.

The approach offers several benefits. First, ocean narratives translate complex ocean science into societally relevant insights as they provide a transparent framework which connects environmental and socioeconomic data (see Table 1) and information. Second, the approach helps identifying regions, sectors, and communities that may be particularly exposed or resilient to ocean change. Third, ocean narratives can support policy development as they link ocean conditions to tangible societal outcomes. And fourth, they enable communication of ocean knowledge and change through compelling, evidence-based stories, designed to resonate with diverse audiences. In other words, ocean narratives can serve as a bridge between observation and action, helping synthesize large and often disconnected datasets into coherent knowl-

edge that can inform sustainable ocean governance and informed decision-making. By improving the accessibility and relevance of scientific information, ocean narratives can contribute to making data and science more actionable.

The narrative presented here is focussed on the ocean area adjacent to the SIDS in the three ocean basins (Atlantic, Pacific and Indian Ocean), as SIDS are directly positioned at the interface between ocean change and human development: their communities and economies are directly dependent on marine and coastal systems. For SIDS, this approach can help answer critical questions: Which islands may be most exposed to sea-level rise? Where could ocean warming have implications for tourism-dependent economies, for example through impacts on coral reefs? How might changes in marine ecosystems affect food security and livelihoods in communities that depend heavily on fisheries? What is the exposure of SIDS to intense tropical storms, fuelled by the power of the ocean? By connecting ocean conditions to development realities, ocean narratives provide a more integrated understanding of risk, vulnerability, and opportunity. They can help policymakers, practitioners, and communities move beyond isolated indicators toward a clearer picture of how ocean change influences sustainable development pathways in Small Island Developing States. All data used for the narrative are documented in Product Table 1, together with information on data access and related references.

3 The Ocean Narrative

3.1 SIDS: Bound by the ocean, united by climate risk

The SIDS are located in the tropical ocean basins of the world ocean between 30° S–30° N (Fig. 1). The SIDS EEZs cover 8 % of the global ocean, and 15 % of the global tropical ocean (30° S–30° N). For the different basins, the SIDS EEZs cover 18 % of the tropical Pacific Ocean, 8 % of the tropical Atlantic Ocean, and 12 % of the tropical Indian Ocean (Fig. 1). SIDS are widely recognized as stewards of the ocean and leading advocates for ocean sustainability and environmental governance (Hassanali et al., 2026; Keo and Yoona, 2022; Martyr-Koller et al., 2021; Vousdoukas et al., 2023). SIDS have become influential voices in global negotiations on marine conservation, fisheries, and ocean sustainability, as they can shape outcomes through coalition-building, scientific expertise, diplomacy, and normative leadership (Haas et al., 2023; Saddington, 2023). Notably, they played an important role in securing the 1.5 °C degree limit within the Paris Agreement and championed an ambitious BBNJ Agreement (Hassanali et al., 2026). SIDS have also been recognised as Large Ocean States because their identities, economies, and governance are defined more by ocean space than by land (Hume et al., 2021), positioning them as key actors in ocean governance. For example, SIDS are emerging as important innovators in ocean governance, developing integrated approaches that link conservation and biodiversity, fisheries,

tourism, and economic development, and hence they play a growing role in shaping sustainable ocean management practices at both national and international scales (Singh et al., 2025). Particularly, SIDS are actively engaged in transformative ocean governance involving key principles such as biodiversity, inclusivity, equity, adaptability, and cross-sectoral coordination, which are key for addressing the interconnected environmental, social, and economic challenges (Lombard et al., 2023). Spalding et al. (2023) argued that strengthening the role of SIDS is essential for more equitable and effective global ocean governance systems as they are well positioned to activate evidence-based and context-specific solutions to ocean-sustainability challenges.

Marine ecosystems hold globally 43 biodiversity hotspots³ which cover 46 600 000 km², representing 9 % of the global ocean area (Costello et al., 2023, their Table CCP1.1; Olson and Dinerstein, 2002), and include coral reef ecosystems, kelp forests, seagrass meadows, polar and upwelling zones. Species in biodiversity hotspots already show changes in response to climate change, and all biodiversity hotspots are impacted, to differing degrees, by human activities (Moon-sammy et al., 2024). SIDS are the stewards of a large share of the world's marine biodiversity, and major ecosystems in their EEZ areas include coral reefs, mangrove forests, seagrass meadows, and coastal wetland systems (Brodie et al., 2020; Costello et al., 2023). The tropical ocean, where most of the SIDS are located, contains the highest marine biodiversity on Earth, where most (83 %) species occurred in shallow depths (0 to 500 m) (Saeedi et al., 2019). For example, the tropical and subtropical areas of the west Pacific host the highest number of marine species worldwide (Asaad et al., 2018; Jablonski et al., 2006). The EEZs of all SIDS cover very high species richness in the world ocean (Fig. 1). For example, SIDS host highly valuable coral reefs and mangrove-seagrass systems, which are among the most species-rich marine ecosystems and support biodiversity, underpin fisheries productivity and provide economic resources (e.g., tourism), and coastal protection (Vasileiadou et al., 2024; Costello et al., 2023; Châles, 2023; Yuan et al., 2024). From this perspective, SIDS are not peripheral actors, they are custodians of a substantial share of the world's ocean biodiversity. Hence, effectively protecting SIDS biodiversity means protecting a large fraction of global marine life.

Transformations in the world's ocean due to climate change will disproportionately affect SIDS. Sea level rise, ocean warming, ocean acidification, and declining warm-water coral reefs will all have adverse impacts on SIDS, who often also have the lowest adaptive capacity (IPCC, 2019). Amongst those, sea-level rise constitutes one of the most

³ Geographic areas that are exceptionally rich in species, ecologically distinct and/or show high endemism (species occurring in that defined geographic area and nowhere else) are broadly recognised as biodiversity hotspots and prioritised for conservation (Costello et al., 2023).

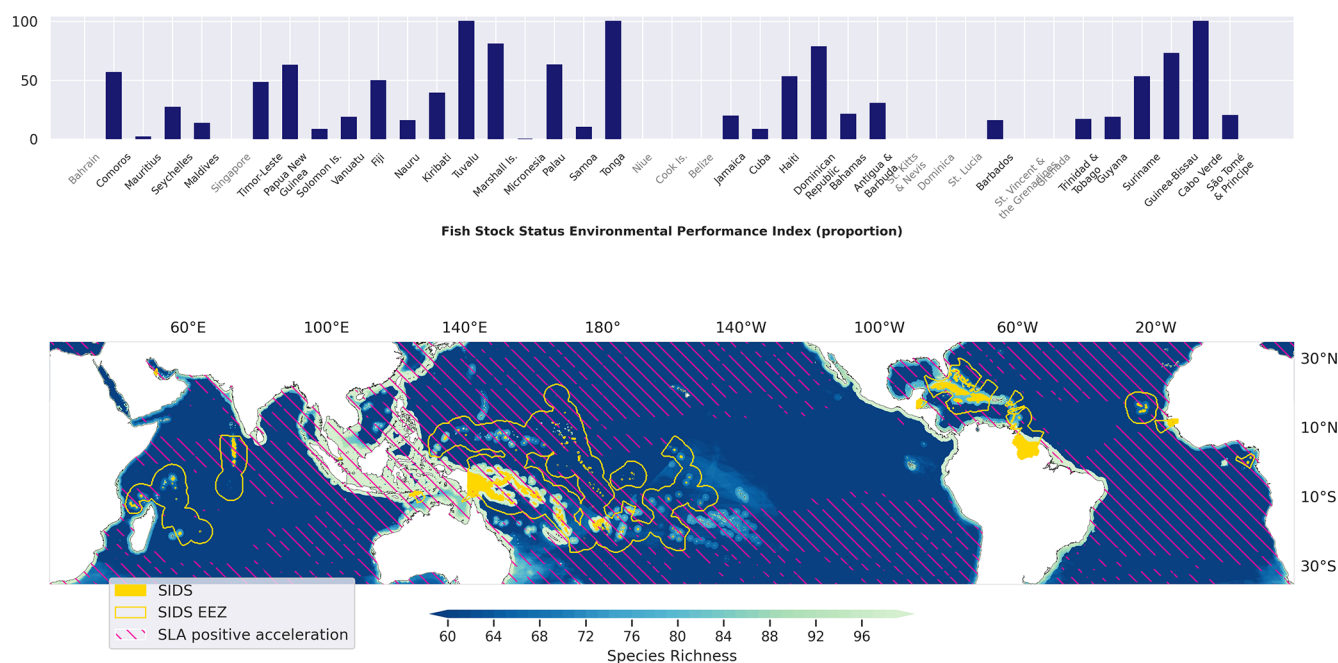


Figure 1. (a) Environmental Performance Index (EPI) scores for Fish Stock Status in 2021 of the 40 UN-member Small Island Developing States (SIDS). These scores assess in percentage format the proportion of a country's total catch that comes from overexploited or collapsed stocks, considering all fish stocks within a country's exclusive economic zone (EEZs). A score of 100 % (0 %) for a particular state indicates that none (all) of its catch comes from overexploited or collapsed stocks. Data is based on product ref. no. 1. (b) Map showing the location of the island countries that make up the SIDS group (solid yellow areas, based on product ref. no. 2) and their corresponding EEZs (yellow contours, based on product ref. no. 3). The richness of species, here provided as the count of the number of species potentially occurring in each grid cell, is represented by the blue-green shaded background (based on product ref. no. 4), whereas the overlaying purple hatched areas mark regions where the rise of sea level has been accelerating in the 1999–2025 period (based on product ref. 5).

significant challenges facing SIDS. Due to the concentration of populations, economic activities, and critical infrastructure within coastal zones, SIDS are disproportionately exposed to the impacts of rising sea levels (Martyr-Koller et al., 2021). Beyond its physical and socioeconomic consequences, sea level rise also raises complex legal and political questions concerning statehood, sovereignty, and the right to self-determination, particularly for low-lying island nations whose territories may become increasingly uninhabitable or submerged (Green and Wewerinke-Singh, 2025; Labh, 2025). Accounting for changes of sea level over the period 1999–2025, 65 % of all SIDS EEZs are directly exposed to sea level acceleration, and 50 % in the Atlantic Ocean, 76 % in the Pacific Ocean, and 33 % in the Indian Ocean (Fig. 1). Adaptation to sea-level rise is therefore a critical component of climate resilience strategies in SIDS.

However, the effectiveness of adaptation measures is constrained by a range of financial, institutional, technical, and geographical barriers (Thomas and Theokritoff, 2024; Robinson et al., 2023). Furthermore, evidence suggests that adaptation limits are likely to be reached in many SIDS under global warming scenarios exceeding 1.5 °C, thereby increasing the risk of irreversible losses and damages (Martyr-Koller et al., 2021). SIDS are hence sentinels for implications of

planetary warming, the processes destabilising their coasts today such as from sea level rise are the same processes that will affect low-lying and densely populated coastal areas worldwide. Also, sea-level rise in SIDS raises fundamental questions about adaptation limits, relocation, and even sovereignty, making them key sites where the future of climate governance is already being negotiated in practice.

SIDS are highly dependent on food from aquatic environments (often also named “blue food”) for food security, employment, and state revenue, with fisheries forming a core pillar of national economies and diets (Bell et al., 2021; Teneva et al., 2023). For example, fishing for tuna plays a vital role in the economic development and food security of most of the 22 Pacific Island countries and territories (FFA, 2023; Bell et al., 2021), and more than 95 % of all tuna caught from their EEZs comes from almost half (10, from which 9 implemented cooperative management) of the Pacific SIDS, where access fees paid by industrial fishing fleets provide an average of 37 % (range = 4 %–84 %) of their government revenue (excluding grants) (Bell et al., 2021). From 2020 to 2022, the annual value of the tuna catch taken in Forum Fisheries Agency waters (17 members; <https://www.ffa.int/>, last access: 17 June 2026) averaged USD 2.6 billion (FFA, 2023). Hence, changes in marine

biodiversity and fish stocks are not just ecological loss, but become a direct precursor for inducing food system stress. SIDS have currently overfished their waters to the extent that their current catch is just under 50 % of the maximum catch potential, which results in direct and indirect food security impacts, including losses in healthy, varied and nutrient-rich food, revenues, incomes and economic impacts in SIDS (Sumaila et al., 2013). For the year 2021, 63 % of 30 SIDS⁴ obtain their catch from overexploited or collapsed fish stocks (index < 50 %), and 37 % of SIDS obtain their catches from healthy fish stocks (Fig. 1) (Sumaila et al., 2013; Teneva et al., 2023). At global scale, EEZs account for the vast majority (> 90 %) of global marine catch, which are making fisheries status within EEZs a direct reflection of how states exercise marine sovereignty and manage natural capital. SIDS are vulnerable to climate change and global food market price volatility (Campling et al., 2024; Teneva et al., 2023; Englander, 2019). As a result, the fish stock status in SIDS is not merely an ecological indicator, but also a measure of how effectively countries can translate sovereign rights over marine resources into food security, economic benefits, and long-term sustainable ocean stewardship.

3.2 Ocean Warming and Coral Reef Impacts in SIDS

Ocean warming is driven by global warming and has reached record values globally in 2025 (WMO, 2026). For coral reefs, ocean warming disrupts the coral-algae symbiosis, leading to coral bleaching and metabolic stress, which in turn reduce growth and reproduction, increase disease susceptibility, and decrease calcification and reef-building capacity (IPCC, 2023; Pfab et al., 2024; Hughes et al., 2020, 2017). But ocean warming can induce also other implications such as sea level rise, ocean circulation change, increased frequency and intensity of marine heatwaves, reducing carbon uptake capacity, fuel tropical storms, changes in marine ecosystem structure and species distributions, and impacts on fisheries and coastal communities (Cheng et al., 2022). Ocean warming is widespread in the tropical ocean (Pan et al., 2026), and approximately 7 % of all SIDS EEZs are exposed to rapid ocean warming as estimated over the period 1960–2025 (Fig. 2).

Globally, coral reef ecosystems are among the most biologically diverse and economically important marine habitats (Bohorquez et al., 2025). They support an estimated 25 % of all marine species and provide hundreds of billions of dollars annually in goods and services, including coastal protection, fisheries, tourism, and medicine, among other benefits (Beck et al., 2018; Costanza et al., 1997; Spalding et al., 2017; Teh et al., 2013). Beyond their economic value, coral reefs also hold subsistence, cultural and spiritual significance

for many islands communities (Cramer et al., 2022; Robles-Zavala and Chang Reynoso, 2018). Climate change, together with pollution and overexploitation, now represents an existential threat to coral reefs (Bhuyan et al., 2026; Bohorquez et al., 2025; Pearce-Kelly et al., 2025), and repeated thermal stress drives widespread bleaching, mortality, and long-term loss of ecosystem function (IPCC, 2019; Hughes et al., 2020). Reefs are currently undergoing rapid global-scale ecological reorganisation, threatening their role as key marine biodiversity reservoirs (Tebbett et al., 2023). Approximately 28 % of the EEZ area of SIDS contains coral reefs classified as vulnerable, endangered or critically endangered, and which amounts to 27 % in the Pacific, 41 % in the Atlantic, and 22 % in the Indian ocean SIDS EEZ areas (Fig. 2).

Between January 2023 and September 2025, 84.4 % of the world's coral reefs have experienced bleaching-level heat stress, exceeding the previous mass bleaching of 68.2 % during 2014–2017 (Lévy et al., 2026). Approximately 25 % of vulnerable, endangered or critically endangered coral reefs⁵ in SIDS' EEZs have been exposed to accumulated heat stress conditions (Degree Heating Week (DHW) > 16 °C weeks) for at least one month during the period 1982–2025 (Fig. 2). Although sustained heat stress of this kind remained episodic it affected already about 1/3 of already vulnerable reef systems and the repeated occurrence over four decades signals a growing and cumulative threat to coral reef systems at SIDS EEZ level. Given the diverse and essential contributions provided by tropical reefs to people, degradation at such a scale implies severe consequences for human livelihood and welfare, primarily in developing countries (Pereira et al., 2022; Seguin et al., 2022). Also, coral reef loss is a risk multiplier for SIDS vulnerability, as this amplifies coastal flooding risk, food insecurity, and economic instability (IPCC, 2019). Consequently, SIDS are explicitly highlighted as a priority region in coral reef policy work as they build the natural infrastructure for low-lying island states (<https://www.unep.org/topics/ocean-seas-and-coasts/ecosystem-based-approaches/small-grants-programme>, last access: 21 September 2026).

Coral reef tourism is a critical ecosystem service, and very high-value reefs in monetary and visitor terms are found in most coral reef jurisdictions, which provides an important incentive for sustainable reef management (Spalding et al., 2017). For 30 % of the world's reefs that are of value in the tourism sector, a total value of nearly USD 36 billion per year has been estimated related to on-reef (e.g., indirect benefits such as the provision of sandy beaches, sheltered water, food and attractive views) and reef adjacent value (in-water activities such as diving and snorkelling) (Spalding et

⁴No data available for Singapore, Niue, Cook Islands, Belize, Saint Kitts and Nevis, Dominica, Saint Lucia, Saint Vincent and the Grenadines, Grenada.

⁵In the IUCN Red List framework, Vulnerable, Endangered and Critically Endangered represent increasing levels of extinction risk, from high to very high and extremely high risk of extinction in the wild, respectively. Source: <https://www.iucnredlist.org/> (last access: 17 July 2026).

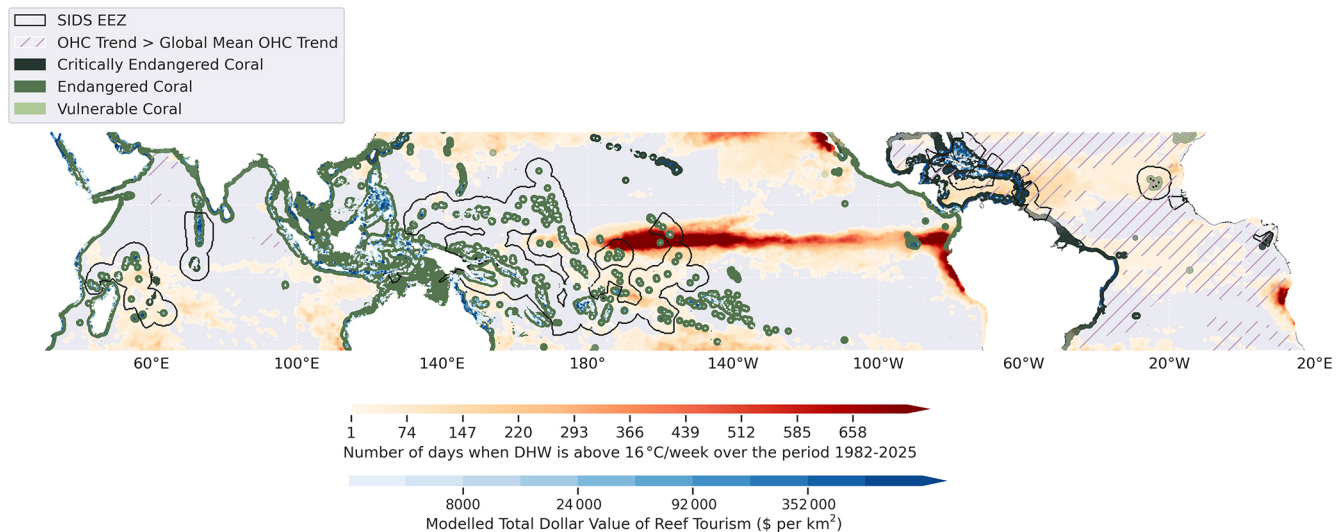


Figure 2. Map displaying combined data about Small Island Developing States' exclusive economic zones (SIDS EEZ, black contours, based on product ref. no. 3), ocean warming trends and coral reefs in order to estimate the potential ecological and socioeconomic impacts on SIDS of coral reefs' bleaching due to extreme temperatures. The yellow-red shading indicates the number of days at each location over the period 1982–2025 in which the Degree Heating Week (DHW) value was over 16°C weeks (based on product ref. no. 6); beyond this threshold, corals are at risk of severe bleaching and multi-species mortality (> 50 % of corals) (Eakin et al., 2026). The DHW index measures the accumulated heat stress of corals due to positive anomalies in sea surface temperature sustained over periods of several weeks or months (Whitaker and DeCarlo, 2024). Overlaying purple hatched areas highlight regions where at least 95 % of the local Ocean Heat Content (OHC) trend range surpass the global mean OHC trend over period 1960–2025 (trend ranges and averages are computed from an ensemble of product refs. no. 7, 8, 9 and 10). Green shaded areas mark the location of critically endangered, endangered or vulnerable coral reefs (based on product ref. no. 11). The blue dots indicate the estimated monetary values of coral reefs to the local tourism sector, expressed in US dollar revenue per square kilometer and per year. For clarity, the value distribution (based on product ref. no. 12) has been split in deciles, which are differentiated on the map by means of a color gradient; for a full description of the modeling process followed to obtain these estimates, see Spalding et al. (2017).

al., 2017). Globally, SIDS are the most economically dependent states on coral reefs for tourism and fisheries (Bartelet et al., 2024; Teelucksingh et al., 2013). Coral reefs also represent favourable locations for luxury resorts, which play a significant role in the economic development of SIDS (de-Miguel-Molina et al., 2014).

In terms of tourism, coral reefs can account for over 20 % of GDP in some SIDS (OECD, 2020). For the Maldives, Palau, the Turks and Caicos Islands, and the British Virgin Islands in particular, they underpin more than one third of total tourism value (Spalding et al., 2017). In many cases, tourism represents one of the few income sources given the limited availability of alternative livelihoods (Chaijaroen, 2023). Coral reefs also provide coastal protection of tourism infrastructure as they act as natural breakwaters, reducing wave energy and protecting beaches, hotels, resorts, and other coastal infrastructure from erosion and storm damage, which is particularly important for low-lying island nations vulnerable to sea-level rise and extreme weather (Vousdoukas et al., 2023; Ferrario et al., 2014).

3.3 Tropical storms, damages and coastal protection

SIDS are faced with a multitude of disasters, including high vulnerability to cyclones, floods, droughts, earthquakes, tsunamis, and sea-level rise. The disaster mortality rate across SIDS is more than double the global average (IPCC, 2023) associated with high hazard frequency, high concentrations of population in low elevation coastal zones, geographical isolation and lack of economic scale. At the same time, and as of 2023, only 38 % of SIDS reported having multi-hazard early warning systems in place (UNDRR, 2025). According to the Emergency Events Database (EM-DAT), a total of 393 natural hazard-related disasters had been recorded in 2024, which caused 16 753 fatalities, and affected 167.2 million people (CRED, 2025). Regarding tropical cyclones, Hurricane Beryl in 2024, the earliest Category 5 hurricane on record, caused over USD 1 billion in damages across Grenada and Jamaica (Bevan et al., 2025). In the South-West Indian Ocean, Cyclone Belal and Cyclone Hidaya severely affected island nations, such as Réunion, Mauritius and Madagascar, resulting in fatalities, large-scale displacement, and substantial infrastructure damage (CRED, 2025). In 2025, 358 natural hazard-related disasters have been recorded by EM-DAT, which resulted in 16 607 fatal-

ities, affected 110.2 million people, and caused USD 170 billion in economic losses (Delforge et al., 2026). During this year, Hurricane Melissa, for example, affected approximately 7.6 million people across Jamaica, Haiti, Cuba, and the Dominican Republic. Jamaica alone, where Hurricane Melissa made landfall as a category 5 hurricane, experienced an estimated USD 10 billion in losses, one of the highest recorded in 2025 (Delforge et al., 2026). Based on available records, cumulative tropical cyclone damage exceeded 50 % of national GDP in approximately 40 % of SIDS with available data, although data availability and record length vary among countries (1903–2026) (Fig. 3).

Key drivers of tropical cyclone intensification include ocean temperature, vertical wind shear and dry air entrainment, with the intensification potential dictated by complex causal chains (Emanuel et al., 2004). These constraints can influence the way the critical thermodynamic interface for ocean–storm interaction evolves, and thus modifies storm intensity (Dzwonkowski et al., 2020). Tropical cyclones intensify by extracting energy from the warm ocean surface with the upper ocean thermal structure critical for their development, and ocean temperature over 26 °C generally regarded a necessary condition (e.g. Gray, 1968). Warm ocean temperatures increase the potential intensity of a tropical cyclone and lead to its intensification (e.g., Dzwonkowski et al., 2020; Jaimes et al., 2015, 2016; Hallam et al., 2019). Tropical Cyclone Heat Potential (TCHP) quantifies the integrated heat content of the upper ocean above the 26 °C isotherm and is widely used as an indicator of the oceanic energy available to support tropical cyclone intensification, as it refers to the subsurface thermal structure as a measure of the potential for cyclone intensification (Momin et al., 2021; Sasaki and Motoi, 2022). Rising ocean temperatures are leading to increases in tropical cyclone intensity (Hallam et al., 2021) and marine heatwaves have shown to increase tropical cyclone intensity, and precipitation richer cyclone conditions (Choi et al., 2024). IPCC (2021) has assessed that the global proportion of Category 3–5 tropical cyclones (TC) has increased over the past four decades, and some studies have linked this increase to an increase in THCP (Liu and Chan, 2022; Song et al., 2021; Wada and Chan, 2021), together with other potential drivers (Wada and Yanase, 2024). Over the period 1960 to 2025, approximately 56 % of the SIDS EEZ areas have experienced above global average increases in tropical cyclone heat potential (Fig. 3), indicating increase in upper-ocean heat availability for tropical cyclone intensification. For the EEZ SIDS areas in the Pacific Ocean, 73 % are exposed to rapid increase in tropical cyclone heat potential, and 32 % in the Atlantic, while EEZs of SIDS in the Indian Ocean are less exposed to this change (1 %) (Fig. 3). There is an increasing number of Category 4 tropical cyclones observed in recent years (Fig. 3), together with high cumulative damages relative to national GDP. Based on available country records, 10 SIDS (Jamaica, St Kitts and Nevis, Grenada, Dominica, Belize, Samoa, Bahamas, Antigua and Barbuda,

Vanuatu, and Tonga) have experienced cumulative damages exceeding 50 % of Gross Domestic Product (GDP), although the length of the historical record varies among countries.

As discussed above, increasing tropical cyclone heat potential can intensify tropical cyclones, which in turn enhances storm surge potential through stronger winds and lower atmospheric pressure (Balaguru et al., 2024; Guo and Tan, 2026). For SIDS, storm surge represents one of the most destructive impacts of tropical cyclones, as intensified storms can generate extreme coastal water levels that rapidly inundate densely populated low-lying coastal zones (IPCC, 2023; Irish et al., 2011; Vousdoukas et al., 2023). In addition, rising ocean heat content not only increases tropical cyclone intensity but also contributes to higher baseline sea levels through thermal expansion, amplifying storm surge impacts when cyclones make landfall (Vousdoukas et al., 2023). In SIDS, storm surge impacts are increasingly compounded by heavy rainfall and rising mean sea level, leading to more frequent and severe coastal flooding events during tropical cyclones (Grimley et al., 2024; IPCC, 2023). Nearly 20 % of assessed SIDS (7 out of 40) have experienced tropical cyclone-induced storm surges exceeding 3 m based on historical records spanning 1961–2012 (Fig. 3).

Mangroves provide a critical form of natural coastal protection as they reduce waves and storm surges, and serve as a first line of defence against flooding and erosion (Gedan et al., 2011; Sandi et al., 2018; Thampanya et al., 2006; Krauss et al., 2014). Globally, mangroves provide flood protection benefits exceeding USD 65 billion per year, and if mangroves were lost, 15 million more people would be flooded annually across the world (Menéndez et al., 2020). This demonstrates that the essential value of mangroves as natural coastal defences at global, national, and local scales and can provide incentives for mangrove conservation and restoration in development, climate adaptation, disaster risk reduction, and insurance (Menéndez et al., 2020). Yet, mangroves have experienced significant losses over the last decades with a global loss of 11.8 % since 1970 (Lévy et al., 2026; RAMSAR et al., 2025). The mangrove coastal protection annual expected benefit exceeds USD 1 million in 18 SIDS.

4 Conclusion

Here, we provide an ocean narrative across three themes relevant for SIDS. The first topic highlights the unique relationship between SIDS and the ocean, emphasizing both the ecological significance of their marine environments and their dependence on ocean resources for food security, livelihoods, and economic development. The second theme is linking physical ocean changes with ecosystem impacts and socio-economic dependence on tourism. The third topic is connecting changes in the ocean climate system with coastal vulnerability and nature-based protection, highlighting the growing importance of adaptation and resilience-building in the face

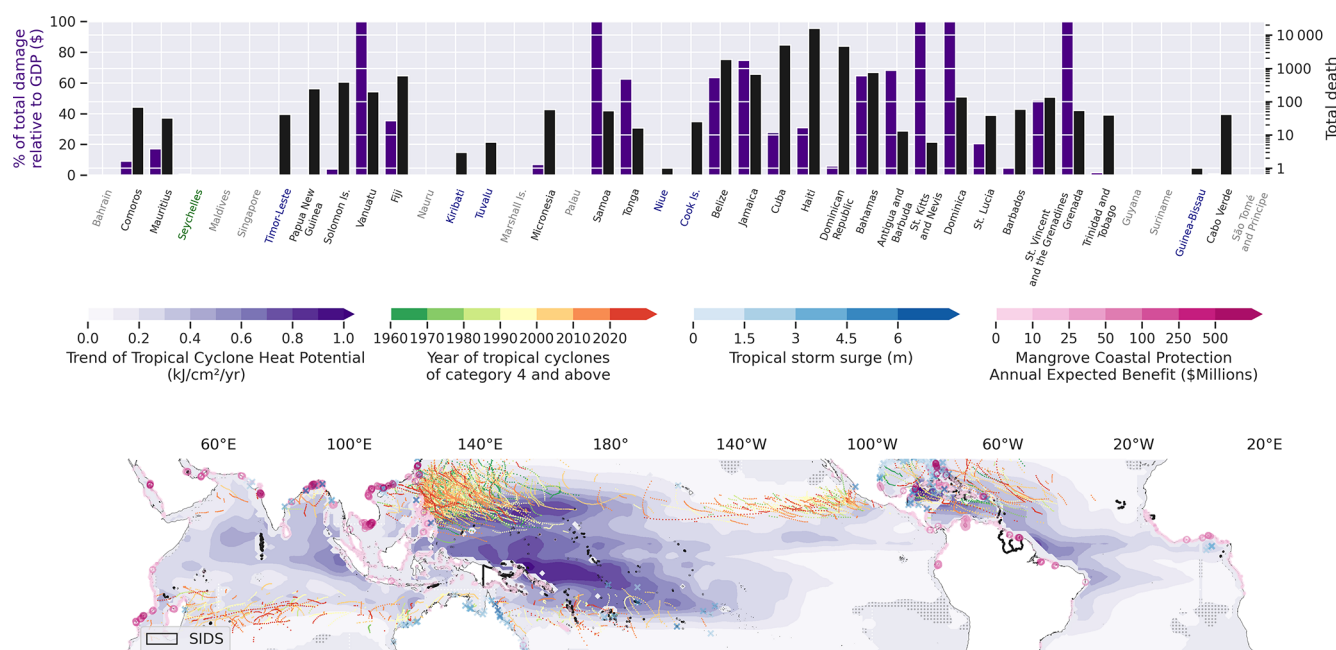


Figure 3. Tropical storms, damages and coastal protection. **(a)** Bar plot summarizing the economic impact and the toll in human lives of cyclones in Small Island Developing States (SIDS). Purple bars represent the percentage of total economic damage (in US dollars) relative to the national Gross Domestic Product (GDP) (based on product refs. no. 13 and 14), whereas black bars indicate the total number of deaths caused by cyclones in each state (product ref. no. 15). Both metrics have been calculated considering all data available since records began. **(b)** Map showing the location of SIDS (black areas, product ref. no. 2) together with different data on tropical storms and coastal protection: local trends in Tropical Cyclone Heat Potential (TCHP) computed over period 1960–2025 (purple shading; based on an average of product refs. no. 7, 8, 9 and 10), with areas dotted in grey indicating a confidence level inferior to 95 % for the trend value (based on product refs. no. 7, 8, 9 and 10); tracks for ocean cyclones of category 4 and above (wind ≥ 113 kn) coloured according to their year of occurrence (green-yellow-red dotted lines, based on product ref. no. 16; Saffir-Simpson Hurricane Scale information based on the wind speed provided by the US agency); global peak storm surges registered in situ (blue crosses, based on product ref. no. 17), and annual expected economic benefit from the coastal protection provided by mangroves at marked locations (pink dots, based on product ref. no. 18).

of increasing climate risks. The outcomes can be synthesized as:

- The SIDS EEZs cover 8 % of the global ocean, and 15 % of the global tropical ocean (30° S–30° N), and SIDS are actors in transformative ocean governance. SIDS govern vast marine territories through their EEZs, which place them at the centre of ocean governance debates, where they actively shape and advance discussions on marine conservation, fisheries management, the blue economy, and climate–ocean policy.
- SIDS are custodians of a substantial share of the ocean biodiversity as the EEZs of all SIDS cover very high species richness in the world ocean. SIDS steward a large share of global marine biodiversity through their EEZs, which overlap major tropical biodiversity hotspots including coral reefs, mangroves, seagrass, and coastal wetlands, meaning that protecting SIDS biodiversity is critical to safeguarding a large fraction of the world’s ocean life. SIDS provide important insights into the challenges of balancing marine conservation, food security, and economic development under increasing pressures from climate change, globalization, and competing claims on ocean resources.
- SIDS are sentinels for climate change, with 65 % of the EEZ areas of all SIDS directly exposed to sea level acceleration. SIDS are some of the most vulnerable regions to climate change due to high concentration of populations, critical infrastructure within coastal zones, compounded by economic, technological, social, and ecological barriers to adaptation.
- Ocean warming is widespread in the tropical ocean, with approximately 7 % of EEZs of all SIDS exposed to rapid ocean warming over the period 1960–2025. Ocean warming increases the frequency and intensity of marine heatwaves, which adversely impacts coral reef ecosystems. Ocean warming also has many other implications such as sea level rise, ocean circulation change, reduced carbon uptake capacity, increased frequency and strength of tropical storms, changes in marine ecosystem structure and species distributions, and impacts on fisheries and coastal communities.

- Nearly one-third (28 %) of the EEZ area of SIDS contains coral reefs classified as vulnerable, endangered or critically endangered. Coral reef ecosystems are among the most biologically diverse and economically important marine habitats holding unique economic, social and cultural value for SIDS, but climate change, together with pollution and overexploitation, now represents an existential threat to coral reefs.
- Approximately 25 % of vulnerable, endangered or critically endangered coral reefs in SIDS' EEZs have been exposed to accumulated heat stress conditions (DHW > 16 °C weeks) for at least one month during the period 1982–2025. This indicates that while extreme heat stress was episodic in time, it repeatedly impacted a large fraction of coral reef systems already vulnerable at SIDS's EEZ level.
- Based on available records, cumulative tropical cyclone damage exceeded 50 % of national GDP in approximately 40 % of SIDS with available data, although data availability and record length vary among countries (1903–2026). SIDS are faced to a multitude of disasters such as tropical cyclones, but only 38 % of SIDS reported having multi-hazard early warning systems in place.
- Over the period 1960 to 2025, around 56 % of the SIDS EEZ areas have experienced rapid (above global average) increases in tropical cyclone heat potential, indicating increase in upper-ocean heat availability for tropical cyclone intensification.
- Nearly 20 % of assessed SIDS (7 out of 40) have experienced tropical cyclone-induced storm surges exceeding 3 m based on historical records spanning 1961–2012. Storm surge represents one of the most destructive impacts of tropical cyclones, as intensified storms can generate extreme coastal water levels that rapidly inundate densely populated low-lying coastal zones.
- The mangrove coastal protection annual expected benefit exceeds USD 1 million in 18 SIDS. The value of mangroves as natural coastal defences at global, national and local scales is essential and can provide incentives for mangrove conservation and restoration in development, climate adaptation, disaster risk reduction and insurance.

Code availability. All codes are available upon request.

Data availability. All data used are available, and their sources are listed in Table 1.

Author contributions. FG: writing (original draft), conceptualization, methodology and formal analysis. KvS: conceptualization, designing, methodology, writing (original draft), investigation, supervision, and formal analysis. All authors: writing (review and editing).

Competing interests. At least one of the (co-)authors serves as topic editor for the report to which this paper belongs. The peer-review process was guided by an independent editor, and the authors also have no other competing interests to declare.

Disclaimer. The Copernicus Marine Service offering is regularly updated to ensure it remains at the forefront of user requirements. In this process, some products may undergo replacement or renaming, leading to the removal of certain product IDs from the catalogue. If readers have any questions or require assistance regarding these modifications, please feel free to reach out to the Copernicus Marine Service user support team for further guidance. They will be able to provide the necessary information to address concerns and find suitable alternatives.

Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims made in the text, published maps, institutional affiliations, or any other geographical representation in this paper. The authors bear the ultimate responsibility for providing appropriate place names. Views expressed in the text are those of the authors and do not necessarily reflect the views of the publisher.

Financial support. This research was carried out as part of the Copernicus Marine Service implemented by MOI under a contributing agreement with the European Commission, and “Ocean observations and indicators for climate and assessments” (ObsSea4Clim) is funded by the European Union Horizon Europe Funding Programme for Research and Innovation under grant no. 101136548.

Review statement. This paper was edited by Marilaure Grégoire.

References

- Asaad, I., Lundquist, C. J., Erdmann, M. V., and Costello, M. J.: Delineating priority areas for marine biodiversity conservation in the Coral Triangle, *Biol. Conserv.*, 222, 198–211, <https://doi.org/10.1016/j.biocon.2018.03.037>, 2018.
- Balaguru, K., Chang, C., Leung, L. R., Foltz, G. R., Hagos, S. M., Wehner, M. F., Kossin, J. P., Ting, M., and Xu, W.: A Global Increase in Nearshore Tropical Cyclone Intensification, *Earth's Future*, 12, e2023EF004230, <https://doi.org/10.1029/2023EF004230>, 2024.
- Bartelet, H. A., Barnes, M. L., and Cumming, G. S.: Estimating and comparing the direct economic contributions of reef fisheries and tourism in the Asia-Pacific, *Mar. Policy*, 159, 105939, <https://doi.org/10.1016/j.marpol.2023.105939>, 2024.

- Beck, M. W., Losada, I. J., Menéndez, P., Reguero, B. G., Díaz-Simal, P., and Fernández, F.: The global flood protection savings provided by coral reefs, *Nat. Commun.*, 9, 2186, <https://doi.org/10.1038/s41467-018-04568-z>, 2018.
- Bell, J. D., Senina, I., Adams, T., Aumont, O., Calmettes, B., Clark, S., Dessert, M., Gehlen, M., Gorgues, T., Hampton, J., Hanich, Q., Harden-Davies, H., Hare, S. R., Holmes, G., Lehoudey, P., Lengaigne, M., Mansfield, W., Menkes, C., Nicol, S., Ota, Y., Pasisi, C., Pilling, G., Reid, C., Ronneberg, E., Gupta, A. S., Seto, K. L., Smith, N., Taei, S., Tsamenyi, M., and Williams, P.: Pathways to sustaining tuna-dependent Pacific Island economies during climate change, *Nat. Sustain.*, 4, 900–910, <https://doi.org/10.1038/s41893-021-00745-z>, 2021.
- Bevan, J. L., Fritz, C., and Alaka, L.: Hurricane Beryl 28th June–9th July 2024, National Hurricane Center Tropical Cyclone Report (AL022024), https://www.nhc.noaa.gov/data/tcr/AL022024_Beryl.pdf (last access: 21 September 2026), 2025.
- Bhuyan, Md. S., Jenzri, M., Islam, M. T., Adikari, D., and Hoque, M. M.: Climate change impacts on coral reefs and emerging resilience pathways: A systematic review, *Ocean Coast. Manage.*, 276, 108134, <https://doi.org/10.1016/j.ocecoaman.2026.108134>, 2026.
- Bohorquez, J., Fine, M., Grieco, D. I., Gill, D. A., Al-Sawalmih, A., Padilla-Gamiño, J., Bolden, I. W., Hein, M., Backstrom, C., McField, M., Martinez, R., Midberry, B., Al-Guthmy, F., Pikitch, E., Benejam, N., Azulay, C., Ronen, B., Levy, O., McElroy, A., and Kleinhaus, K.: Coral reefs span borders, so must solutions: transboundary conservation in complex political environments, *npj Ocean. Sustain.*, 4, 64, <https://doi.org/10.1038/s44183-025-00166-x>, 2025.
- Brodie, G., Holland, E., N'Yeurt, A. D. R., Soapi, K., and Hills, J.: Seagrasses and seagrass habitats in Pacific small island developing states: Potential loss of benefits via human disturbance and climate change, *Mar. Pollut. Bull.*, 160, 111573, <https://doi.org/10.1016/j.marpolbul.2020.111573>, 2020.
- Bronen, R. and Chapin, F. S.: Adaptive governance and institutional strategies for climate-induced community relocations in Alaska, *P. Natl. Acad. Sci. USA*, 110, 9320–9325, <https://doi.org/10.1073/pnas.1210508110>, 2013.
- Campling, L., Havice, E., Virdin, J., Carmine, G., Andriamahafazafy, M., Barbesgaard, M., Chakravarty, S., Gorez, B., Hetherington, D., Kim, H., Mfodwo, K., and Standing, A.: A geopolitical-economy of distant water fisheries access arrangements, *npj Ocean. Sustain.*, 3, 26, <https://doi.org/10.1038/s44183-024-00060-y>, 2024.
- Chaijaroen, P.: Coral Reef Deterioration and Livelihoods of Coastal Communities: An Economics Perspective, in: *Corals – Habitat Formers in the Anthropocene*, edited by: Chimienti, G., IntechOpen, <https://doi.org/10.5772/intechopen.105355>, 2023.
- Châles, F.: A systematic review of coral reef, mangrove, and seagrass ecosystem services in Pacific Small Island Developing States, *Mondes Dév.*, 203, 125–149, <https://doi.org/10.3917/e.med.203.0125>, 2023.
- Cheng, L., Von Schuckmann, K., Abraham, J. P., Trenberth, K. E., Mann, M. E., Zanna, L., England, M. H., Zika, J. D., Fasullo, J. T., Yu, Y., Pan, Y., Zhu, J., Newsom, E. R., Bronselaer, B., and Lin, X.: Past and future ocean warming, *Nat. Rev. Earth Environ.*, 3, 776–794, <https://doi.org/10.1038/s43017-022-00345-1>, 2022.
- Cheng, L., Tan, Z., Pan, Y., Zheng, H., Zhu, Y., Wei, W., Du, J., Li, G., Ye, H., and Gouretski, V.: IAP global ocean heat content 1° gridded analysis product (IAPv4), Marine Science Data Center of the Chinese Academy of Sciences [data set], <https://doi.org/10.12157/IOCAS.20240117.001>, 2024a.
- Cheng, L., Pan, Y., Tan, Z., Zheng, H., Zhu, Y., Wei, W., Du, J., Yuan, H., Li, G., Ye, H., Gouretski, V., Li, Y., Trenberth, K. E., Abraham, J., Jin, Y., Reseghetti, F., Lin, X., Zhang, B., Chen, G., Mann, M. E., and Zhu, J.: IAPv4 ocean temperature and ocean heat content gridded dataset, *Earth Syst. Sci. Data*, 16, 3517–3546, <https://doi.org/10.5194/essd-16-3517-2024>, 2024b.
- Choi, H.-Y., Park, M.-S., Kim, H.-S., and Lee, S.: Marine heat-wave events strengthen the intensity of tropical cyclones, *Commun. Earth Environ.*, 5, 69, <https://doi.org/10.1038/s43247-024-01239-4>, 2024.
- Claus, S., De Hauwere, N., Vanhoorne, B., Deckers, P., Souza Dias, F., Hernandez, F., and Mees, J.: Marine Regions: Towards a Global Standard for Georeferenced Marine Names and Boundaries, *Mar. Geod.*, 37, 99–125, <https://doi.org/10.1080/01490419.2014.902881>, 2014.
- Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hanon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., and Van Den Belt, M.: The value of the world's ecosystem services and natural capital, *Nature*, 387, 253–260, <https://doi.org/10.1038/387253a0>, 1997.
- Costello, M. J., Vale, M. M., Kiessling, W., Maharaj, S., Price, J., and Talukdar, G. H.: Cross-Chapter Paper 1: Biodiversity Hotspots, in: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1st edn., Cambridge University Press, Cambridge, UK and New York, NY, USA, <https://doi.org/10.1017/9781009325844>, 2023.
- Cramer, K. L., Bernard, M. L., Bernat, I., Gutierrez, L., Murphy, E. L., Sangolquí, P., Surrey, K. C., and Gerber, L. R.: The Present and Future Status of Ecosystem Services for Coral Reefs, in: *Imperiled: The Encyclopedia of Conservation*, Elsevier, 46–54, <https://doi.org/10.1016/B978-0-12-821139-7.00177-X>, 2022.
- CRED: Human Impact Variables, EM-DAT, CRED (Centre for Research on the Epidemiology of Disasters), <https://doc.emdat.be/docs/data-structure-and-content/impact-variables/human/> (last access: 1 July 2026), 2023a.
- CRED: Economic Impact Variables, EM-DAT, CRED (Centre for Research on the Epidemiology of Disasters), <https://doc.emdat.be/docs/data-structure-and-content/impact-variables/economic/> (last access: 1 July 2026), 2023b.
- CRED: 2024 Disasters in Numbers. Brussels, Centre for Research on the Epidemiology of Disasters (CRED), Belgium, https://files.emdat.be/reports/2024_EMDAT_report.pdf (last access: 21 September 2026), 2025.
- Delforge, D., Below, R., Wathélet, V., Tonnelier, M., Alonso, A., and Speybroeck, N.: 2025 Disasters in Numbers, Centre for Research on the Epidemiology of Disasters (CRED), Belgium, https://files.emdat.be/reports/2025_EMDAT_report.pdf (last access: 21 September 2026), 2026.
- de-Miguel-Molina, B., de-Miguel-Molina, M., and Rumiche-Sosa, M. E.: Luxury sustainable tourism in Small Island Developing States surrounded by coral reefs, *Ocean Coast. Manage.*, 98, 86–94, <https://doi.org/10.1016/j.ocecoaman.2014.06.017>, 2014.

- Dzwonkowski, B., Coogan, J., Fournier, S., Lockridge, G., Park, K., and Lee, T.: Compounding impact of severe weather events fuels marine heatwave in the coastal ocean, *Nat. Commun.*, 11, 4623, <https://doi.org/10.1038/s41467-020-18339-2>, 2020.
- Eakin, C. M., Heron, S. F., Connolly, S. R., Devotta, D. A., Liu, G., Geiger, E. F., De La Cour, J. L., Gomez, A. M., Skirving, W. J., Baird, A. H., Cantin, N. E., Couch, C. S., Donner, S. D., Gilmour, J., Gonzalez-Rivero, M., Gudka, M., Harrison, H. B., Hodgson, G., Hoegh-Guldberg, O., Hoey, A. S., Hoogenboom, M. O., Hughes, T. P., Johnson, M. E., Kerry, J. T., Kimura, T., Mihaly, J., Muñoz-Castillo, A. I., Obura, D. O., Pratchett, M. S., Rivera-Sosa, A., Ross, C. L., Stein, J., Thompson, A., Torda, G., Viehman, T. S., Walter, C. S., Wilson, S., Marsh, B. L., Spady, B. L., Dyer, N., Adam, T. C., Alcolado, P., Alidoostsalimi, M., Alidoostsalimi, P., Alvarez-Filip, L., Álvarez-Noriega, M., Arias-González, J. E., Bahr, K. D., Barnes, P., Barraza Sandoval, J. E., Baum, J. K., Bauman, A. G., Beger, M., Berry, K., Bessell-Browne, P., Bigot, L., Bonito, V., Brodnicke, O. B., Burdick, D., Burkepile, D. E., Burt, A. J., Burt, J. A., Butler, I. R., Caldwell, J. M., Chancerelle, Y., Chen, C. A., Cherh, K.-L., Childress, M. J., Coker, D. J., Costa, B., Coward, G., Crabbe, M. J. C., Dallison, T., Dalton, S., DeCarlo, T. M., Drury, C., Drysdale, I., Edwards, C. B., Eggertsen, L., Elma, E., Ennis, R. S., Evans, R. D., Eyal, G., Fenner, D., Figueroa-Zavala, B., Fisch, J., Fox, M. D., Gadoutsis, E., Gilbert, A., Halford, A. R., Heintz, T., Hewlett, J., Hobbs, J.-P. A., Hoot, W. C., Houk, P., Johnston, L., Johnston, M. A., Kayanne, H., Kennedy, E. V., Kikuchi, R. K. P. D., Kloiber, U., Koike, H., Kramer, K. L., Kuo, C.-Y., Lang, J., Lawrence, A., Leadbeater, A., Leão, Z. M. A. N., Lee, J. N., Lewis, C., Lirman, D., Longo, G. O., MacDonald, C., Mallela, J., Mangubhai, S., Da Silva, I. M., Mason-Parker, C., McDonough, V., McField, M., Mello, T., Mitermiqué-Agathe, C., Madi, M., Moldzio, S., Monroe, A. A., Montefalcone, M., Moses, K. S., Mostafavi, P. G., Moura, R. L. D., Munasinghe, C. S., Mwaura, J., Nakamura, T., Nicet, J.-B., Nuttall, M. F., Oliveira, M. D. M., Oxenford, H. A., Pandolfi, J. M., Patankar, V., Perez, D., Perera, N., Prabuning, D., Precht, W., Raj, K. D., Reimer, J. D., Richardson, L. E., Rotjan, R., Ryan, N., Salm, R., Sandin, S. A., Schopmeyer, S., Shedrawi, G., Shokri, M. R., Smith, J. E., Smith, K., Smith, S. R., Smith, T. B., Sommer, B., Soto, M., Suckoo, R., Sykes, H., Tagarino, K. A., Teoh, M., Thai, M. Q., Toh, T. C., Tredinnick, A., Tso, A., Tyley, H., Ussi, A. M., Vargas-Angel, B., Vaterlaus, C., Vermeij, M. J. A., Vo, S. T., Voolstra, C. R., Wee, H. B., Weiler, B. A., Williams, D. E., Yahya, S. A. S., Yeemin, T., Ziegler, M., and Manzello, D. P.: Severe and widespread coral reef damage during the 2014–2017 Global Coral Bleaching Event, *Nat. Commun.*, 17, 1318, <https://doi.org/10.1038/s41467-025-67506-w>, 2026.
- Emanuel, K., DesAutels, C., Holloway, C., and Korty, R.: Environmental Control of Tropical Cyclone Intensity, *J. Atmos. Sci.*, 61, 843–858, [https://doi.org/10.1175/1520-0469\(2004\)061<0843:ECOTCI>2.0.CO;2](https://doi.org/10.1175/1520-0469(2004)061<0843:ECOTCI>2.0.CO;2), 2004.
- Englander, G.: Property rights and the protection of global marine resources, *Nat. Sustain.*, 2, 981–987, <https://doi.org/10.1038/s41893-019-0389-9>, 2019.
- E.U. Copernicus Marine Service: Global Ocean Mean Sea Level trend map from Observations Reprocessing, Marine Data Store (MDS) [data set], <https://doi.org/10.48670/moi-00238>, 2025.
- E.U. Copernicus Marine Service: Global Ocean in situ – Delayed Mode temperature and salinity CORA – objective analysis, Marine Data Store (MDS) [data set], <https://doi.org/10.48670/mds-00383>, 2026.
- Ferrario, F., Beck, M. W., Storlazzi, C. D., Micheli, F., Shepard, C. C., and Airoidi, L.: The effectiveness of coral reefs for coastal hazard risk reduction and adaptation, *Nat. Commun.*, 5, 3794, <https://doi.org/10.1038/ncomms4794>, 2014.
- FFA: FFA 2023 Tuna Economic Indicators Brochure, Pacific Islands Forum Fisheries Agency, HONIARA, Solomon Islands, <https://www.ffa.int/publications-and-statistics/statistics/> (last access: 21 September 2026), 2023.
- Flanders Marine Institute: Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 12, Flanders Marine Institute [data set], <https://doi.org/10.14284/632>, 2023.
- Gahtan, J., Knapp, K. R., Schreck, C. J. III, Diamond, H. J., Kossin, J. P., and Kruk, M. C.: International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4.01, NOAA National Centers for Environmental Information [data set], <https://doi.org/10.25921/82ty-9e16>, 2024.
- Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., and Silliman, B. R.: The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm, *Climatic Change*, 106, 7–29, <https://doi.org/10.1007/s10584-010-0003-7>, 2011.
- Good, S. A., Martin, M. J., and Rayner, N. A.: EN4 quality controlled subsurface ocean temperature and salinity profiles and objective analyses, Met Office Hadley Centre [data set], <https://www.metoffice.gov.uk/hadobs/en4/index.html> (last access: 1 July 2026), 2013a.
- Good, S. A., Martin, M. J., and Rayner, N. A.: EN4: Quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates, *J. Geophys. Res.-Oceans*, 118, 6704–6716, <https://doi.org/10.1002/2013JC009067>, 2013b.
- Gray, W. M.: Global View Of The Origin Of Tropical Disturbances And Storms, *Mon. Wea. Rev.*, 96, 669–700, [https://doi.org/10.1175/1520-0493\(1968\)096<0669:GVOTOO>2.0.CO;2](https://doi.org/10.1175/1520-0493(1968)096<0669:GVOTOO>2.0.CO;2), 1968.
- Green, A. and Wewerinke-Singh, M.: State Continuity, Self-Determination and Sea-Level Rise, *Int. Comp. Law Q.*, 74, 555–585, <https://doi.org/10.1017/S0020589325100961>, 2025.
- Grimley, L. E., Hollinger Beatty, K. E., Sebastian, A., Bunya, S., and Lackmann, G. M.: Climate change exacerbates compound flooding from recent tropical cyclones, *npj Nat. Hazards*, 1, 45, <https://doi.org/10.1038/s44304-024-00046-3>, 2024.
- Guha-Sapir, D.: EM-DAT, the Emergency Events Database, Centre for Research on the Epidemiology of Disasters (CRED), Université catholique de Louvain, <https://www.emdat.be> (last access: 1 July 2026), 2020.
- Guo, Y.-P. and Tan, Z.-M.: Enhanced global storm surges by tropical cyclone poleward migration, *P. Natl. Acad. Sci. USA*, 123, e2535524123, <https://doi.org/10.1073/pnas.2535524123>, 2026.
- Gusmann, G. and Hinkel, J.: A framework for assessing the potential effectiveness of adaptation policies: Coastal risks and sea-level rise in the Maldives, *Environ. Sci. Policy*, 115, 35–42, <https://doi.org/10.1016/j.envsci.2020.09.028>, 2021.
- Haas, B., Jaeckel, A., Pouponneau, A., Sacedon, R., Singh, G. G., and Cisneros-Montemayor, A. M.: The use of influential

- power in ocean governance, *Front. Mar. Sci.*, 10, 1045887, <https://doi.org/10.3389/fmars.2023.1045887>, 2023.
- Hallam, S., Marsh, R., Josey, S. A., Hyder, P., Moat, B., and Hirschi, J. J.-M.: Ocean precursors to the extreme Atlantic 2017 hurricane season, *Nat. Commun.*, 10, 896, <https://doi.org/10.1038/s41467-019-08496-4>, 2019.
- Hallam, S., Guishard, M., Josey, S. A., Hyder, P., and Hirschi, J.: Increasing tropical cyclone intensity and potential intensity in the subtropical Atlantic around Bermuda from an ocean heat content perspective 1955–2019, *Environ. Res. Lett.*, 16, 034052, <https://doi.org/10.1088/1748-9326/abe493>, 2021.
- Hassanali, K., Catzim, N., Derrig, R., Harden-Davies, H., Nelson, V. G., and Pouponneau, A.: Big schools of small fish in a big pond – the influence of small-island developing states in the BBNJ process, *Front. Mar. Sci.*, 13, 1762739, <https://doi.org/10.3389/fmars.2026.1762739>, 2026.
- Hinkel, J., Garcin, M., Gussmann, G., Amores, A., Barbier, C., Bisaro, A., Le Cozannet, G., Duvat, V., Imad, M., Khaleel, Z., Marcos, M., Pedreros, R., Shareef, A., and Waheed, A.: Co-creating a coastal climate service to prioritise investments in erosion prevention and sea-level rise adaptation in the Maldives, *Climate Services*, 31, 100401, <https://doi.org/10.1016/j.cliser.2023.100401>, 2023.
- Huang, B., Liu, C., Banzon, V. F., Freeman, E., Graham, G., Hankins, W., Smith, T. M., and Zhang, H.-M.: NOAA 0.25-degree Daily Optimum Interpolation Sea Surface Temperature (OISST), Version 2.1, NOAA National Centers for Environmental Information [data set], <https://doi.org/10.25921/RE9P-PT57>, 2020.
- Huang, B., Liu, C., Banzon, V., Freeman, E., Graham, G., Hankins, B., Smith, T., and Zhang, H.-M.: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1, *J. Climate*, 34, 2923–2939, <https://doi.org/10.1175/JCLI-D-20-0166.1>, 2021.
- Hughes, D. J., Alderdice, R., Cooney, C., Kühl, M., Pernice, M., Voolstra, C. R., and Suggett, D. J.: Coral reef survival under accelerating ocean deoxygenation, *Nat. Clim. Chang.*, 10, 296–307, <https://doi.org/10.1038/s41558-020-0737-9>, 2020.
- Hughes, T. P., Kerry, J. T., Álvarez-Noriega, M., Álvarez-Romero, J. G., Anderson, K. D., Baird, A. H., Babcock, R. C., Beger, M., Bellwood, D. R., Berkelmans, R., Bridge, T. C., Butler, I. R., Byrne, M., Cantin, N. E., Comeau, S., Connolly, S. R., Cumming, G. S., Dalton, S. J., Diaz-Pulido, G., Eakin, C. M., Figueira, W. F., Gilmour, J. P., Harrison, H. B., Heron, S. F., Hoey, A. S., Hobbs, J.-P. A., Hoogenboom, M. O., Kennedy, E. V., Kuo, C., Lough, J. M., Lowe, R. J., Liu, G., McCulloch, M. T., Malcolm, H. A., McWilliam, M. J., Pandolfi, J. M., Pears, R. J., Pratchett, M. S., Schoepf, V., Simpson, T., Skirving, W. J., Sommer, B., Torda, G., Wachenfeld, D. R., Willis, B. L., and Wilson, S. K.: Global warming and recurrent mass bleaching of corals, *Nature*, 543, 373–377, <https://doi.org/10.1038/nature21707>, 2017.
- Hume, A., Leape, J., Oleson, K. L. L., Polk, E., Chand, K., and Dunbar, R.: Towards an ocean-based large ocean states country classification, *Mar. Policy*, 134, 104766, <https://doi.org/10.1016/j.marpol.2021.104766>, 2021.
- IPCC: The Ocean and Cryosphere in a Changing Climate: Special Report of the Intergovernmental Panel on Climate Change, 1st edn., Cambridge University Press, <https://doi.org/10.1017/9781009157964>, 2019.
- IPCC: Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st edn., Cambridge University Press, <https://doi.org/10.1017/9781009157896>, 2021.
- IPCC: Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st edn., Cambridge University Press, <https://doi.org/10.1017/9781009325844>, 2023.
- Irish, J. L., Resio, D. T., and Divoky, D.: Statistical properties of hurricane surge along a coast, *J. Geophys. Res.*, 116, C10007, <https://doi.org/10.1029/2010JC006626>, 2011.
- IUCN: Reef-forming Corals (spatial data), The IUCN Red List of Threatened Species, IUCN [data set], <https://www.iucnredlist.org/resources/spatial-data-download> (last access: 1 July 2026), 2020.
- IUCN: Species Richness and Rarity-Weighted Richness spatial data, International Union for Conservation of Nature [data set], <https://www.iucnredlist.org/resources/other-spatial-downloads> (last access: 1 July 2026), 2025a.
- IUCN: Red List Technical Working Group: Mapping Standards and Data Quality for IUCN Red List Spatial Data. Version 1.21, IUCN, https://nc.iucnredlist.org/redlist/content/attachment_files/Mapping_Standards_Version_1.21_Nov2025.pdf (last access: 1 July 2026), 2025b.
- IUCN: The IUCN Red List of Threatened Species, Version 2025-2, <https://www.iucnredlist.org> (last access: 1 July 2026), 2026.
- Jablonski, D., Roy, K., and Valentine, J. W.: Out of the Tropics: Evolutionary Dynamics of the Latitudinal Diversity Gradient, *Science*, 314, 102–106, <https://doi.org/10.1126/science.1130880>, 2006.
- Jaimes, B., Shay, L. K., and Uhlhorn, E. W.: Enthalpy and Momentum Fluxes during Hurricane Earl Relative to Underlying Ocean Features, *Mon. Weather Rev.*, 143, 111–131, <https://doi.org/10.1175/MWR-D-13-00277.1>, 2015.
- Jaimes, B., Shay, L. K., and Brewster, J. K.: Observed air-sea interactions in tropical cyclone Isaac over Loop Current mesoscale eddy features, *Dynam. Atmos. Oceans*, 76, 306–324, <https://doi.org/10.1016/j.dynatmoce.2016.03.001>, 2016.
- Keo, K. and Yoona, J.: The State of Climate Ambition, UNDP, New York, <https://www.undp.org/publications/state-climate-ambition-snapshots-least-developed-countries-ldcs-and-small-island-developing-states-sids> (last access: 17 June 2026), 2022.
- Kleisner, K. and Pauly, D.: Stock-Status Plots (SSPs), Sea Around Us, <https://www.seaaroundus.org/doc/Methods/StockStatusMethod/Method-SSP-new-June-08-2015.pdf> (last access: 21 September 2026), 2015.
- Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., and Neumann, C. J.: The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying Tropical Cyclone Data, *B. Am. Meteorol. Soc.*, 91, 363–376, <https://doi.org/10.1175/2009BAMS2755.1>, 2010.
- Krauss, K. W., McKee, K. L., Lovelock, C. E., Cahoon, D. R., Saintilan, N., Reef, R., and Chen, L.: How mangrove forests adjust to rising sea level, *New Phytol.*, 202, 19–34, <https://doi.org/10.1111/nph.12605>, 2014.

- Labh, N.: Reconsidering Sovereignty Amid the Climate Crisis, Carnegie Endowment for International Peace Publications, <https://assets.carnegieendowment.org/static/files/Labh-Climate%20Sovereignty.pdf> (last access: 16 June 2026), 2025.
- Levitus, S., Antonov, J. I., Boyer, T. P., Baranova, O. K., Garcia, H. E., Locarnini, R. A., Mishonov, A. V., Reagan, J. R., Seidov, D., Yarosh, E. S., and Zweng, M. M.: World ocean heat content and thermosteric sea level change (0–2000 m), 1955–2010, *Geophys. Res. Lett.*, 39, 2012GL051106, <https://doi.org/10.1029/2012GL051106>, 2012.
- Levitus, S., Antonov, J., Boyer, T., Baranova, O. K., Garcia, H. E., Locarnini, R. A., Mishonov, A. V., Reagan, J. R., Seidov, D., Yarosh, E., and Zweng, M. M.: NCEI ocean heat content, temperature anomalies, salinity anomalies, thermosteric sea level anomalies, halosteric sea level anomalies, and total steric sea level anomalies from 1955 to present calculated from in situ oceanographic subsurface profile data (NCEI Accession 0164586), Version 1.1, NOAA National Centers for Environmental Information [data set], <https://doi.org/10.7289/V53F4MVP>, 2017.
- Lévy, M., von Schuckmann, K., Butel, M., Cheung, W. W. L., Claudet, J., Frölicher, T. L., Guillotreau, P., Haugan, P., Adams, J., Amon, D., Bambridge, T., Barzuna, C., Blanke, B., Cheng, L., Chiba, S., Cortés, J., Friedlingstein, P., Gattuso, J.-P., Gellach, S., Gephart, J., Greaves, D., Hasson, A., Jolly, C., Li, D., Shin, Y.-J., Slangen, A., Takoko, M., Thébaud, O., Vincent, A., and Vincent, P.: The 2026 Starfish Barometer, in: 10th edition of the Copernicus Ocean State Report (OSR10), edited by: Grégoire, M., Brasseur, P., Garric, G., Karstensen, J., Lionello, P., Marcos, M., Poulain, P.-M., and Staneva, J., Copernicus Publications, State Planet, 7-osr10, 1, <https://doi.org/10.5194/sp-7-osr10-1-2026>, 2026.
- Liu, K. S. and Chan, J. C. L.: Growing Threat of Rapidly-Intensifying Tropical Cyclones in East Asia, *Adv. Atmos. Sci.*, 39, 222–234, <https://doi.org/10.1007/s00376-021-1126-7>, 2022.
- Lombard, A. T., Clifford-Holmes, J., Goodall, V., Snow, B., Truter, H., Vrancken, P., Jones, P. J. S., Cochrane, K., Flannery, W., Hicks, C., Gipperth, L., Allison, E. H., Diz, D., Peters, K., Erinosho, B., Levin, P., Holthus, P., Szepeggyi, M. N., Awad, A., Golo, H., and Morgera, E.: Principles for transformative ocean governance, *Nat. Sustain.*, 6, 1587–1599, <https://doi.org/10.1038/s41893-023-01210-9>, 2023.
- Marino, E.: Adaptation privilege and Voluntary Buyouts: Perspectives on ethnocentrism in sea level rise relocation and retreat policies in the US, *Global Environ. Chang.*, 49, 10–13, <https://doi.org/10.1016/j.gloenvcha.2018.01.002>, 2018.
- Martyr-Koller, R., Thomas, A., Schleussner, C.-F., Nauels, A., and Lissner, T.: Loss and damage implications of sea-level rise on Small Island Developing States, *Curr. Opin. Env. Sust.*, 50, 245–259, <https://doi.org/10.1016/j.cosust.2021.05.001>, 2021.
- Menéndez, P., Losada, I. J., Beck, M. W., Torres-Ortega, S., Espejo, A., Narayan, S., Díaz-Simal, P., and Lange, G.-M.: Valuing the protection services of mangroves at national scale: The Philippines, *Ecosyst. Serv.*, 34, 24–36, <https://doi.org/10.1016/j.ecoser.2018.09.005>, 2018.
- Menéndez, P., Losada, I. J., Torres-Ortega, S., Narayan, S., and Beck, M. W.: The Global Flood Protection Benefits of Mangroves, *Sci. Rep.*, 10, 4404, <https://doi.org/10.1038/s41598-020-61136-6>, 2020.
- Mimura, N., Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L., Lefale, P., Payet, R., and Sem, G.: Small islands, in: *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E., Cambridge University Press, Cambridge, UK and New York, NY, USA, 687–716, https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap29_FINAL.pdf (last access: 28 September 2026), 2007.
- Momin, I. M., Karmakar, A., Gupta, A., and Mitra, A. K.: Tropical Cyclone Heat Potential (TCHP) from the NCMRWF NEMO based global ocean analysis and forecast system, MAUSAM, 72, 207–214, <https://doi.org/10.54302/mausam.v72i1.136>, 2021.
- Moonsammy, S., Boman, M., Ramdhanie, V., and Renn-Moonsammy, D.-M.: State-of-the art valuation of wetland ecosystem services in Small Island Developing States: A systematic review with an emphasis on future research needs, *Ecosyst. Serv.*, 68, 101625, <https://doi.org/10.1016/j.ecoser.2024.101625>, 2024.
- Needham, H. F. and Keim, B. D.: A storm surge database for the US Gulf Coast, *Int. J. Climatol.*, 32, 2108–2123, <https://doi.org/10.1002/joc.2425>, 2012.
- Needham, H. F. and Keim, B. D.: Global Peak Storm Surge Map, SURGEDAT – The World's Storm Surge Information Center, Louisiana State University [data set], <https://surge.climate.lsu.edu/data.html> (last access: 1 July 2026), 2015.
- OECD: Sustainable Ocean for All: Harnessing the Benefits for Developing Countries, OECD Publishing, <https://doi.org/10.1787/bede6513-en>, 2020.
- Olson, D. M. and Dinerstein, E.: The Global 200: Priority Ecoregions for Global Conservation, *Ann. MO Bot. Gard.*, 89, 199, <https://doi.org/10.2307/3298564>, 2002.
- Pan, Y., Cheng, L., Abraham, J., Trenberth, K. E., Reagan, J., Du, J., Wang, Z., Storto, A., Von Schuckmann, K., Zhu, Y., Mann, M. E., Zhu, J., Wang, F., Yu, F., Locarnini, R., Fasullo, J., Huang, B., Graham, G., Yin, X., Gouretski, V., Zheng, F., Li, Y., Zhang, B., Wan, L., Chen, X., Wang, D., Feng, L., Song, X., Liu, Y., Reseghetti, F., Simoncelli, S., Chen, G., Zhang, R., Mishonov, A., Wei, W., Tan, Z., Li, G., Cao, L., Chen, L., Yuan, H., Lyu, K., Sulaiman, A., Mayer, M., Wang, H., Ma, Z., Bao, S., Yan, H., Liu, Z., Yang, C., Liu, X., Hausfather, Z., Gues, F., Song, X., Zhang, M., and Chen, L.: Ocean Heat Content Sets Another Record in 2025, *Adv. Atmos. Sci.*, <https://doi.org/10.1007/s00376-026-5876-0>, 2026.
- Pearce-Kelly, P., Altieri, A. H., Bruno, J. F., Cornwall, C. E., McField, M., Muñoz-Castillo, A. I., Rocha, J., Setter, R. O., Shepard, C., Roman-Cuesta, R. M., and Yesson, C.: Considerations for determining warm-water coral reef tipping points, *Earth Syst. Dynam.*, 16, 275–292, <https://doi.org/10.5194/esd-16-275-2025>, 2025.
- Pereira, P. H. C., Araujo, J. C., Lima, G. V., Côrtes, L. G. F., Gomes, E., and Magris, R. A.: Effectiveness of management zones for recovering parrotfish species within the largest coastal marine protected area in Brazil, *Sci. Rep.*, 12, 12232, <https://doi.org/10.1038/s41598-022-15990-1>, 2022.

- Pfab, F., Detmer, A. R., Moeller, H. V., Nisbet, R. M., Putnam, H. M., and Cunnig, R.: Heat stress and bleaching in corals: a bioenergetic model, *Coral Reefs*, 43, 1627–1645, <https://doi.org/10.1007/s00338-024-02561-1>, 2024.
- Pujol, M. I., Quet, V., and Legeais, J. F.: EU Copernicus Marine Service Product User Manual for the OMI_CLIMATE_SL_GLOBAL_regional_trends, issue 6.0, Mercator Ocean International, <https://documentation.marine.copernicus.eu/PUM/CMEMS-SL-PUM-CLIMATE.pdf> (last access: 1 July 2026), 2025.
- Quet, V., Taburet, G., and Pujol, M. I.: EU Copernicus Marine Service Quality Information Document for OMI_CLIMATE_SL_GLOBAL_regional_trends, issue 7.0, Mercator Ocean International, EU Copernicus Marine Service, <https://documentation.marine.copernicus.eu/QUID/CMEMS-SL-QUID-CLIMATE.pdf> (last access: 1 July 2026), 2025.
- RAMSAR, Robertson, H., Fennessy, S., Hilton, G., Job, N., Kumar, R., Simpson, M., Aggestam, F., Aldred, M., Chacón, A., Costanza, R., Davidson, N., Field, C., Finlayson, C. M., Gandra, F., Gillis, L. G., Hernández-Blanco, M., Moritsch, M., Thornton, S., Wood, K., and Van'T Hoff, V.: Global Wetland Outlook 2025: Valuing, conserving, restoring and financing wetlands, Convention on Wetlands, <https://doi.org/10.69556/GWO-2025-eng>, 2025.
- Robinson, S., Carlson, D., Bouton, E., Dolan, M., Meakem, A., Messer, A., and Roberts, J. T.: The dynamics of institutional arrangements for climate change adaptation in small island developing states in the Atlantic and Indian Oceans, *Sustain. Sci.*, 18, 251–264, <https://doi.org/10.1007/s11625-022-01186-z>, 2023.
- Robles-Zavala, E. and Chang Reynoso, A. G.: The recreational value of coral reefs in the Mexican Pacific, *Ocean Coast. Manage.*, 157, 1–8, <https://doi.org/10.1016/j.ocecoaman.2018.02.010>, 2018.
- Saddington, L.: Geopolitical imaginaries in climate and ocean governance: Seychelles and the Blue Economy, *Geoforum*, 139, 103682, <https://doi.org/10.1016/j.geoforum.2023.103682>, 2023.
- Saeedi, H., Costello, M. J., Warren, D., and Brandt, A.: Latitudinal and bathymetrical species richness patterns in the NW Pacific and adjacent Arctic Ocean, *Sci. Rep.*, 9, 9303, <https://doi.org/10.1038/s41598-019-45813-9>, 2019.
- Sandi, S. G., Rodríguez, J. F., Saintilan, N., Riccardi, G., and Saco, P. M.: Rising tides, rising gates: The complex geomorphic response of coastal wetlands to sea-level rise and human interventions, *Adv. Water Resour.*, 114, 135–148, <https://doi.org/10.1016/j.advwatres.2018.02.006>, 2018.
- Sasaki, H. and Motoi, T.: Accelerated Increase in Tropical Cyclone Heat Potential in the Typhoon Rapidly Intensifying Zone during 1955–2020, *SOLA*, 18, 65–70, <https://doi.org/10.2151/sola.2022-011>, 2022.
- SEDAC: 2020 Environmental Performance Index, NASA Socioeconomic Data and Applications Center (SEDAC), Yale Center for Environmental Law & Policy (YCELP) [data set], <https://doi.org/10.7927/F54C-0R44>, 2020.
- Seguin, R., Mouillot, D., Cinner, J. E., Stuart Smith, R. D., Maire, E., Graham, N. A. J., McLean, M., Vigliola, L., and Loiseau, N.: Towards process-oriented management of tropical reefs in the anthropocene, *Nat. Sustain.*, 6, 148–157, <https://doi.org/10.1038/s41893-022-00981-x>, 2022.
- Singh, P., Linnér, B.-O., and Singh, A. A.: Marine spatial planning and ocean governance in Small Island Developing States, *Reg. Environ. Change*, 25, 91, <https://doi.org/10.1007/s10113-025-02412-x>, 2025.
- Song, J., Klotzbach, P. J., and Duan, Y.: Increasing lifetime maximum intensity of rapidly intensifying tropical cyclones over the western North Pacific, *Environ. Res. Lett.*, 16, 034002, <https://doi.org/10.1088/1748-9326/abdbf1>, 2021.
- Spalding, A. K., Grorud-Colvert, K., Allison, E. H., Amon, D. J., Collin, R., De Vos, A., Friedlander, A. M., Johnson, S. M., Mayorga, J., Paris, C. B., Scott, C., Suman, D. O., Cisneros-Montemayor, A. M., Estradivari, Giron-Nava, A., Gurney, G. G., Harris, J. M., Hicks, C., Mangubhai, S., Micheli, F., Naggea, J., Obura, D., Palacios-Abrantes, J., Poupouneau, A., and Thurber, R. V.: Engaging the tropical majority to make ocean governance and science more equitable and effective, *npj Ocean. Sustain.*, 2, 8, <https://doi.org/10.1038/s44183-023-00015-9>, 2023.
- Spalding, M., Burke, L., Wood, S. A., Ashpole, J., Hutchison, J., and Zu Ermgassen, P.: Mapping the global value and distribution of coral reef tourism, *Mar. Policy*, 82, 104–113, <https://doi.org/10.1016/j.marpol.2017.05.014>, 2017.
- Sumaila, U. R., Dyck, A., and Cheung, W. W. L.: Fisheries subsidies and potential catch loss in SIDS Exclusive Economic Zones: food security implications, *Envir. Dev. Econ.*, 18, 427–439, <https://doi.org/10.1017/S1355770X13000156>, 2013.
- Szekely, T.: EU Copernicus Marine Service Quality Information Document for In Situ TAC Objective Analysis product INSITU_GLO_PHY_TS_OA_MY_013_052, issue 1.15, Mercator Ocean International, <https://documentation.marine.copernicus.eu/QUID/CMEMS-INS-QUID-013-052.pdf> (last access: 1 July 2026), 2026a.
- Szekely, T.: EU Copernicus Marine Service Product User Manual for the In Situ TAC objective analysis Products INSITU_GLO_PHY_TS_OA_MY_013_052 and INSITU_GLO_PHY_TS_OA_NRT_013_002, issue 1.13, Mercator Ocean International, <https://documentation.marine.copernicus.eu/PUM/CMEMS-INS-PUM-013-002-052.pdf> (last access: 1 July 2026), 2026b.
- Tebbett, S. B., Connolly, S. R., and Bellwood, D. R.: Benthic composition changes on coral reefs at global scales, *Nat. Ecol. Evol.*, 7, 71–81, <https://doi.org/10.1038/s41559-022-01937-2>, 2023.
- Teelucksingh, S., Nunes, P. A. L. D., and Perrings, C.: Biodiversity-based development in Small Island Developing States, *Envir. Dev. Econ.*, 18, 381–391, <https://doi.org/10.1017/S1355770X13000260>, 2013.
- Teh, L. S. L., Teh, L. C. L., and Sumaila, U. R.: A Global Estimate of the Number of Coral Reef Fishers, *PLoS ONE*, 8, e65397, <https://doi.org/10.1371/journal.pone.0065397>, 2013.
- Teneva, L., Free, C. M., Hume, A., Agostini, V. N., Klein, C. J., Watson, R. A., and Gaines, S. D.: Small island nations can achieve food security benefits through climate-adaptive blue food governance by 2050, *Mar. Policy*, 151, 105577, <https://doi.org/10.1016/j.marpol.2023.105577>, 2023.
- Thampanya, U., Vermaat, J. E., Sinsakul, S., and Panapitukkul, N.: Coastal erosion and mangrove progradation of Southern Thailand, *Estuarine, Coastal and Shelf Science*, 68, 75–85, <https://doi.org/10.1016/j.ecss.2006.01.011>, 2006.
- The Nature Conservancy: Mapping Ocean Wealth – Mangrove Coastal Protection Benefit, The Nature Conservancy [data set],

- <https://maps.oceanwealth.org/#/data> (last access: 1 July 2026), 2018.
- Thomas, A. and Theokritoff, E.: Adaptation constraints, limits and enabling conditions in small island developing states, *Curr. Opin. Env. Sust.*, 71, 101488, <https://doi.org/10.1016/j.cosust.2024.101488>, 2024.
- Thorpe, A.: Mainstreaming Fisheries into National Development Plans and Poverty Reduction Strategies: Current Situation and Opportunities, FAO Fisheries Circular No. 997, FAO, Rome, <https://openknowledge.fao.org/items/f54a6f47-c723-4f26-b353-274ca8242f42> (last access: 28 September 2026), 2005.
- UN: Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3–14 June 1992, Agenda 21, Chap. 17, Section G, A/CONF.151/26/Rev.1 (Vol. I), United Nations, New York, <https://sdgs.un.org/sites/default/files/publications/Agenda21.pdf> (last access: 1 July 2026), 1992.
- UN DESA: Small Island Developing States, UN DESA, <https://sdgs.un.org/topics/small-island-developing-states> (last access: 1 July 2026), 2026.
- UNDP: Fish Stock Status, Environmental Performance Index, SIDS Data Platform Development Indicators, United Nations Development Programme (UNDP), <https://sids.data.undp.org/development-indicators/key-epi-FSS/recentValue/bars> (last access: 21 September 2026), 2026.
- UNDRR: Global Assessment Report on Disaster Risk Reduction. Resilience Pays: Investing and Financing for Our Future, UNDRR, <https://www.undrr.org/gar/gar2025#download> (last access: 24 June 2026), 2025.
- UN OHRLLS: List of SIDS, Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, UN OHRLLS [data set], <https://www.un.org/ohrlls/content/list-sids> (last access: 1 July 2026), 2026.
- Vasileiadou, K., Chatzinikolaou, E., Klayn, S., Pavloudi, C., and Reizopoulou, S.: Editorial: Marine biodiversity hotspots – challenges and resilience, *Front. Mar. Sci.*, 11, 1338242, <https://doi.org/10.3389/fmars.2024.1338242>, 2024.
- von Schuckmann, K., Gues, F., Moreira, L., Liné, A., and de Pascual Collar, Á.: Global ocean change in the era of the triple planetary crisis, in: 9th edition of the Copernicus Ocean State Report (OSR9), edited by: von Schuckmann, K., Moreira, L., de Pascual Collar, Á., Grégoire, M., Brasseur, P., Garric, G., Karstensen, J., Lionello, P., Marcos, M., Poulain, P.-M., and Staneva, J., Copernicus Publications, State Planet, 6-osr9, 2, <https://doi.org/10.5194/sp-6-osr9-2-2025>, 2025a.
- von Schuckmann, K., Gues, F., Moreira, L., Liné, A., and de Pascual Collar, Á.: Ocean change in the northeastern Atlantic and adjacent seas: a multi-dimensional challenge for the environment, society, and economy, in: 9th edition of the Copernicus Ocean State Report (OSR9), edited by: von Schuckmann, K., Moreira, L., de Pascual Collar, Á., Grégoire, M., Brasseur, P., Garric, G., Karstensen, J., Lionello, P., Marcos, M., Poulain, P.-M., and Staneva, J., Copernicus Publications, State Planet, 6-osr9, 3, <https://doi.org/10.5194/sp-6-osr9-3-2025>, 2025b.
- Von Schuckmann, K., Godoy-Faundez, A., Garçon, V., Muller-Karger, F. E., Evans, K., Appeltans, W., Bax, N., Benedetti Cecchi, L., Bernard, A., Bernard, K., Byrnes, J., Canonico, G., Chapuis, L., Clark, M. R., Darnaude, A. M., Davies, C., Englyst, P., Fransson, A., Hallam, S., Heslop, E., Holland, E., Hood, M., Kern, S., Liné, A., Lara-Lopez, A., Loose, N., Martín Míguez, B., McMahon, C. R., Nordlund, L. M., Post, J., Speich, S., Sutton, A., Tanhua, T., Telszewski, M., Poursanidis, D., and Yu, W.: Global ocean indicators: Marking pathways at the science-policy nexus, *Mar. Policy*, 184, 106922, <https://doi.org/10.1016/j.marpol.2025.106922>, 2026.
- Vousdoukas, M. I., Athanasiou, P., Giardino, A., Mentaschi, L., Stocchino, A., Kopp, R. E., Menéndez, P., Beck, M. W., Ranasinghe, R., and Feyen, L.: Small Island Developing States under threat by rising seas even in a 1.5 °C warming world, *Nat. Sustain.*, 6, 1552–1564, <https://doi.org/10.1038/s41893-023-01230-5>, 2023.
- Wada, A. and Chan, J. C. L.: Increasing TCHP in the Western North Pacific and Its Influence on the Intensity of FAXAI and HAGIBIS in 2019, *SOLA*, 17A, 29–32, <https://doi.org/10.2151/sola.17A-005>, 2021.
- Wada, A. and Yanase, W.: Is the Increasing Trend in the Environmental Upper-Ocean Heat Content in the Northwest Pacific Strengthening Tropical Cyclone Intensity?, in: *Advances in Hurricane Risk in a Changing Climate*, vol. 3, edited by: Collins, J., Done, J., Zhu, Y.-J., and Wilson, P., Springer Nature Switzerland, Cham, 97–124, https://doi.org/10.1007/978-3-031-63186-3_5, 2024.
- Whitaker, H. and DeCarlo, T.: Re(de)fining degree-heating week: coral bleaching variability necessitates regional and temporal optimization of global forecast model stress metrics, *Coral Reefs*, 43, 969–984, <https://doi.org/10.1007/s00338-024-02512-w>, 2024.
- WMO: WMO State of the Climate in 2025, WMO, <https://wmo.int/publication-series/state-of-global-climate/state-of-global-climate-2025> (last access: 21 September 2026), 2026.
- World Bank: GDP (current US\$), World Development Indicators, World Bank [data set], <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?view=map> (last access: 1 July 2026), 2026.
- Yuan, M.-H., Lin, K.-T., Pan, S.-Y., and Yang, C.-K.: Exploring coral reef benefits: A systematic SEEA-driven review, *Sci. Total Environ.*, 950, 175237, <https://doi.org/10.1016/j.scitotenv.2024.175237>, 2024.