Changing Climate, Changing Ocean

Observations show that climate warming is already having significant impacts on the ocean. How the ocean and sea ice respond will determine the trajectory of future global climate. Satellite data and observations of the ocean over the last several decades provide clear evidence that surface waters are warming, ice shelves are disintegrating, sea ice and glaciers are retreating in the Arctic and along the Antarctic Peninsula, and fresh water is being redistributed on basin-wide scales in the ocean. Climate change is also inducing changes in river discharges to the ocean, lowering salinities and altering ocean circulation and marine food webs. The ocean plays a critical role in Earth's climate system, helping to regulate the global cycles of heat, freshwater, and carbon, and the rates and regional patterns of land temperature and precipitation. All projections of Earth's climate rely on accurate understanding of the future state of the ocean.

The ocean slows global warming by removing excess carbon dioxide from the atmosphere. But the process increases ocean acidification, which threatens corals and other marine life. The ocean presently removes about a quarter of all the carbon dioxide released by fossil fuel burning and deforestation. Under future climate warming, the ocean's ability to take up excess atmospheric carbon dioxide may slow, further accelerating climate warming. The uptake of anthropogenic carbon dioxide alters ocean chemistry, causing seawater to become more acidic and making it harder for some corals, mollusks and other marine life to build shells and skeletons from carbonate minerals. Ocean acidification could severely damage coral reefs and some marine fisheries and aquaculture.

Polar regions are more sensitive to the effects of climate change than other regions. The reality of recent environmental changes in the Arctic and Antarctica is now widely acknowledged, and the impact of such changes on marine and terrestrial ecosystems and human populations in and beyond polar regions will be profound. Arctic air temperatures are rising about twice as fast as the planetary average, storminess and coastal erosion have increased, sea ice and land-based glaciers are melting much more quickly than models project, and permafrost on surrounding land areas is thawing. Changes in polar regions' distinctive marine ecosystems already have been observed, with ramifications for species such as polar bear, walrus and penguins, and important commercial fisheries. At the same time, a decrease in Arctic summer sea ice increases opportunities for people to use ocean resources such as fisheries, oil and gas reserves, and shipping routes for commerce and tourism. Reliable climate projections for polar regions depend on enhancing our understanding of polar ocean-ice-atmosphere interactions, which has been limited by our ability to make sustained observations, particularly of marine biology and chemistry, in the regions' remote and harsh environments. There is a critical need to instrument polar regions sufficiently to make continual, real-time, autonomous observations across all marine disciplines.

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Rising sea level caused by climate change threatens low-lying coastlines. With ongoing glacial melting and the thermal expansion of warming seawater, projected sea level rises of 0.5 to 1 meter in the next century will have large socio-economic and environmental impacts in coastal areas. Half of Earth's people live near the coast, on less than one-fifth of its land mass. Two-thirds of the world's largest cities are on the coast. Low-lying regions and island nations are threatened with inundation and are more vulnerable to storm surges and flooding. Coastal and climate changes can destroy valuable ecosystems and marine nursery areas and have large impacts on commercial fisheries. Most of the burden to adapt to coastal changes will fall disproportionately on poor and lesser-developed countries.

Climate change will affect essential ocean ecosystems services and biodiversity. Coastal and open ocean ecosystems provide a range of "services" vital to society and to the planet. Ecosystem services range from providing food to cycling water, nutrients and chemicals around the Earth to keep our planetary system functioning. Ocean ecosystems are threatened and in many cases have already been degraded by changes in sea level, coastal erosion, water temperature and chemistry, pollution, and ocean circulation. These changes can alter the growth, reproduction or distribution of marine species in ways that destabilize the structure of ocean communities, disrupt food chains, diminish the production of harvestable living resources, and reduce biodiversity, which plays a fundamental role in maintaining a functioning ocean.

The ocean and ocean technologies can contribute to climate change mitigation strategies. But more research is needed to determine their efficacy and environmental consequences. Ocean geoengineering concepts such as water-column or sub-seabed carbon sequestration and ocean iron fertilization pose risks of undesirable, unintended effects on the marine environment. Atmospheric geoengineering approaches such as stratospheric aerosols and cloud brightening also may have substantial impacts on marine biota, fisheries, ecosystem services, and human communities that depend on the sea. Mitigation strategies that reduce planetary temperatures, but do not reduce atmospheric carbon dioxide concentrations, are likely to further alter ocean chemistry in ways that may significantly damage marine ecosystems. High-resolution observations in the ocean are needed to ground-truth carbon models and verify the efficacy of mitigation strategies. On the other hand, preserving and restoring mangroves, salt marshes, seagrasses and other marine vegetated habitats can help absorb excess carbon dioxide. The ocean is also a potential source for alternative energy solutions including wind, tidal, wave and ocean thermal power, and biofuels from marine algae.

Marine ecosystem management requires science-based information on the ocean and climate. Water, urban environments, fisheries, public health, transportation, energy, and tourism are just a few socio-economic sectors that are affected by climate change impacts on the ocean. A network of global, regional and national institutions should establish a climate services program to synthesize and stream climate information, products, and services and foster dialogue between providers and users.