# 4th Global Conference on Oceans, Coasts, and Islands

## Working Group on Climate, Oceans, and Security

# Policy Brief on Climate, Oceans, and Security

Global Oceans Conference GOC 2008

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## Global Forum on Oceans, Coasts, and Islands--Strategic Oceans Planning to 2016

The Global forum on Oceans, Coasts, and Islands has undertaken a strategic planning effort for the period 2006-2016 to develop policy recommendations for specific next steps needed to advance the global oceans agenda aimed at governments, UN agencies, NGOs, industry, and scientific groups. To this effect, Working Groups have been organized around 12 major topic areas related to the global oceans commitments made at the 2002 World Summit on Sustainable Development and to emerging issues facing the global oceans community.

The Working Groups have been organized and coordinated by the Global Forum Secretariat, under the direction of Dr. Biliana Cicin-Sain, Co-Chair and Head of Secretariat, Global Forum on Oceans, Coasts, and Islands, and involving the following staff from the Gerard J. Mangone Center for Marine Policy, University of Delaware: Miriam Balgos, Kateryna Wowk, Caitlin Snyder, Shelby Hockenberry, and Kathleen McCole.

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**Global Forum on Oceans, Coasts, and Islands**

**Working Group on Climate, Oceans, and Security**

# Policy Brief: Climate, Oceans, and Security

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## Foreword

### *Climate, Oceans, and Security*

The oceans play a significant role in regulating the global climate and moderating weather systems around the world. Changes in climate can have a profound impact on the functioning of ocean, coastal and island ecosystems. In particular, the following impacts can be anticipated:

- Sea level rise, increases in coastal flooding, storm intensity, and potentially changing current patterns;
- Ocean warming, which may result in increased stratification and changed circulation patterns of ocean currents, decrease the amount of sea ice, increase coral bleaching and mortality, and may result in pole-ward migrations of species and increased algal blooms;
- Ocean acidification, which poses adverse effects on calcifying species such as corals, echinoderms, crustaceans, and mollusks as well as certain phytoplankton.

In its 2007 report, the Intergovernmental Panel on Climate Change (IPCC), amid growing global concern, called urgent attention to significant social impacts of climate change as well-- the growing “climate divide” that exists between the developed and the developing world-– that is to say, the brunt of the damage acting as the catalyst for global climate change has been created by the developed world but its impacts will be felt most readily by the developing world. As the chair of the IPCC panel noted “It’s the poorest of the poor in the world, and this includes poor people even in prosperous societies, who are going to be the worst hit … [as] people who are poor are least equipped to be able to adapt to the impacts of climate change and therefore, in some sense, this does become a global responsibility” (IPCC 2007).

Developing nations in Africa (which account for less than three percent of global carbon emissions) and Asia would be most affected and the developed wealthy nations far from the equator least affected. Asia will be particularly vulnerable to the effects of climate change, especially major population centers at low elevations including: Mumbai, India; Shanghai, China; Jakarta, Indonesia; Tokyo, Japan; and Dhaka, Bangladesh. The five most vulnerable countries with large populations are China, India, Bangladesh, Vietnam, and Indonesia. The countries most threatened when looking at largest total land area are Russia, Canada, the United States, China, and Indonesia. The impact of climate change on developing nations, especially SIDS, is significant and the implications of these potential effects range from changes in ocean chemistry and forecasted sea level rise to impacts on ecosystems, human health, and the displacement of coastal peoples. The need to address these issues in the oceans community is a vital first step in combating the potentially devastating effects of climate change with specific attention to the developing world and SIDS.

Ocean and coastal leaders are at the frontline of climate change effects, and are in a unique position to address these effects on the peoples of the world. They can also lend moral voice to the climate negotiations, especially emphasizing the need to address global equity and climate divide issues, and in defining a clear vision and call to action. The climate issues that ocean and coastal leaders around the world will need to face will ineradicably change the nature of coastal and ocean management, introducing increased uncertainty, the need to incorporate climate change planning into all existing management processes, the need to develop and apply new tools related to vulnerability assessment, and the need to make difficult choices in what in many cases will be "no-win" situations involving significant adverse impacts to vulnerable ecosystems and communities.

The Global Forum Working Group on Climate, Oceans, and Security in its Policy Brief recommends that the Global Conference participants focus especially on the following major areas of focus:

1. Identify appropriate policy responses to scientific findings on the effects and differential impacts of climate change on different regions and peoples of the world

2. Address the "climate divide" and encourage international commitments and funding mechanisms to respond to the differential effects of climate change on different regions and peoples

3. Encourage a wide range of adaptation efforts

4. Understand and address global oceans changes, e.g., ocean warming, ocean acidification, changes in current systems, changes in polar regions

5. Properly manage mitigation efforts that use or rely on the oceans
   --alternative energy
   --carbon storage and sequestration
   --restoration and sustainable management of coastal ecosystems

**Discussions on Climate, Oceans, and Security at the Global Conference**

On the basis of the Policy Brief discussion, Conference participants may wish to consider the following:

1. The Global Conference should put climate on the priority agenda of ocean and coastal leaders around the world to address the policy implications of ocean changes and to mobilize international and national responses to these issues;

2. Global Conference participants should discuss the priority topics outlined by the Working Group and confirm (or revise) such priorities;

3. Global Conference participants should mobilize around the issue of the climate divide and work to develop appropriate international and national responses to this central issue;

4. Global Conference participants should focus on the need to develop appropriate regulatory policy frameworks to manage emerging uses of the ocean to mitigate climate change effects, such as carbon sequestration and storage and iron fertilization.

5.  Global Conference participants should focus on mobilizing appropriate frameworks for the use of the oceans for alternative energy purposes.

The Global Forum Secretariat is indebted to Dr. Gunnar Kullenberg, former Executive Director of the Intergovernmental Oceanographic Commission for his leadership of the Oceans, Climate, and Security Working Group, and to Kateryna Wowk, Janot-Reine Mendler de Suarez, and Kathleen McCole for their contributions to the Policy Brief.  The useful concepts and references provided by Margaret Davidson in the adaptation section and by Professor Paul Epstein in the public health section are appreciated very much.

**Biliana Cicin-Sain**
**Global Forum on Oceans,**
**Coasts, and Islands**

# Policy Brief:
# Climate, Oceans, and Security

## I. The Imperative of Factoring in Climate Change Effects in Ocean and Coastal Management

The ocean forms a necessary part of our life support system. It is the fly wheel of the climate system and hydrological cycle. It provides most of the water vapour, the leading greenhouse gas, to the atmosphere and maintains the freshwater balance of the continents. Through photosynthetic production of organic material it keeps the natural or long-term balances of oxygen and carbon dioxide in the atmosphere, together with its natural uptake of carbon dioxide. The interactions and interdependencies between ocean-atmosphere-cryosphere-land and their ecosystems are fundamental elements of related processes. The oceans and coastal areas influence all sectors of our economy, and provide the only source of protein for 1-2 billion people of the poorest parts of the Earth. Many natural hazards have their origin in the ocean: tsunamis, tropical cyclones, storm and tidal surges and flooding, El Niño and monsoon phenomena. Most of these can now to a certain degree be forecasted, based on ocean observations, dynamic modelling and high power computers. Ocean observations provide key information, and are also important for constructing climate scenarios.

Due to ocean dynamics, 'the problems of ocean space are closely interrelated and need be considered as a whole.' The interdependencies are demonstrated through the effects of one ocean use on most other ocean uses: fishing, aquaculture, oil drilling, mineral resources extraction, ports, dredging waste disposal, and many other land-related activities. The human influence and touch now reach all parts of the ocean. The oceans and coasts are basic parts of our human security complex. The ocean community, including the ocean users, has a large responsibility in helping address ocean issues.

The 2007 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provides a helpful starting point to discuss how these issues should be addressed. It unequivocally confirms the assertion which has been gaining traction over the last two decades among thousands of the world's climate and environmental scientists that growing contributions of human-generated emissions as a by-product of industrialization are responsible for forcing the 'greenhouse effect.' Global warming due to this is now triggering a number of still little-understood feedback loops which are further accelerating the amplitude of climate variability and the rate of climate change, placing increasing pressure on the ability of ecosystems and human society to adapt.

Increased variability, by introducing more energy into the cyclical system of ocean/atmosphere interactions (referred to in the vernacular as 'weather conditions'), increased variability is already differentially impacting both the polar regions, which are subject to more extreme warming trends, and the lower latitudes, where coastal communities are subject to sea level rise, compounded by greater frequency, intensity – and unpredictability – in extreme weather events and trends, such as floods, drought, heat waves and storms. The accelerated increase in global temperatures is also impacting species distribution and food-webs underlying globally significant fisheries, while ocean acidification due to increased uptake of $CO_2$ threatens shellfish and coral reefs already under increasing stress from higher ocean temperatures and sea level rise. Degradation of ecosystem complexity reduces both the productivity and the adaptive capacity of living marine resources upon which developing countries significantly depend for subsistence, commercial fishing, and a spectrum of coastal and sectorally-affected livelihoods.

Precise impacts cannot yet be predicted with certainty due to insufficient time series data, modeling, and analysis. However, when the rate of climatic change exceeds the different rates at which interdependent species can adapt to changes in habitat conditions, the integrity of the complex inter-relationships which lend resilience to ecosystems is at a heightened risk. Many scientists have voiced concern with the difficulty of predicting radical or rapid changes in weather and ecosystems that could be triggered by approaching thresholds, or 'tipping points.' A significant weakening of the Gulf Stream may be triggered by a combination of changes in the wind system and freshwater inflow from melting polar ice, which may also force the current to deviate further south. A significant decrease of northward heat transfer from inflow of warm water originating from the Gulf Stream, possibly associated with a weakening of the Stream, may be triggered by an increase of melt water in the north, in combination with a change in the wind system. Such processes could conceivably plunge Northern Europe into a new 'little ice age' with equally dramatic effects upon fisheries and weather patterns throughout the Atlantic system.

At the same time the security of coastal populations is already on a risk trajectory due to sea level rise and increased intensity and frequency of storms, coupled with increasing scarcity of fresh water due to impacts of the greenhouse effect on the hydrological cycle, and combined with coastal population growth trends, threatens developing countries with a growing tide of environmental refugees either permanently – in the case of many small island developing States (SIDS) – or of literally millions more seasonally displaced populations due to 'natural' disasters.

Health impacts of climate change range from spread or reintroduction due to warmer temperatures of diseases such as malaria, dengue and schistosomiasis, to the emergence of outbreaks of rare diseases such as chicungunya. Increased climate stress can be particularly insidious by compounding the impact of exposure to already present disease and infection, such as HIV/AIDS. For example, when women must travel further to get water because of the effects of climate change, they place themselves at greater risk and also reduce their time available for household work, caring for sick family, and farming in the face of other climate-induced risks to food security.

Both the 4$^{th}$ IPCC report and the 2007 UN Human Development Report document the fact that although the developing countries – and in particular SIDS – are least responsible for the greenhouse gasses which are at the root of global warming, these are the nations whose people are most severely affected by the impacts of climate variability and change. The unprecedented present rate of global warming, caused by by-products of a global economic boom, directly impacts the global poor in all countries who are least able to adapt. Failure to take immediate and concerted corrective action to mitigate greenhouse gas emissions constitutes a potent risk to human security for rich and poor alike.

The December 2007 United Nations Climate Change Conference in Bali, hosted by the Government of Indonesia, brought together more than 10,000 participants, including representatives of over 180 countries together with observers from intergovernmental and nongovernmental organizations and the media. The conference culminated in the adoption of the Bali Roadmap, which consists of a number of forward-looking decisions that represent various tracks essential to reaching a secure climate future. The Bali Roadmap charts the course for a new negotiating process designed to tackle climate change, includes decisions on technology transfer and on reducing emissions from deforestation, and launches the Adaptation Fund and the Bali Action Plan.

The Bali Action Plan responds to the findings of the 4th IPCC report that warming of the climate system is unequivocal, and that delay in reducing emissions significantly constrains opportunities to achieve lower stabilization levels and increases the risk of more severe climate change impacts. Recognizing that deep cuts in global emissions are required, a shared vision of cooperative action is called for, including enhanced national and international action on mitigation including long-term commitments of verifiable reductions, sectoral and market-based approaches, and implementation of sustainable forest management policies.

International cooperation is equally called for in stepping up urgent implementation of adaptation actions, including through vulnerability and financing needs assessments and prioritization of actions, capacity-building and response strategies, mainstreaming of adaptation across sectors and spatial planning, and incentives to stimulate climate-resilient development, taking into account the urgent immediate needs of developing countries that are particularly vulnerable, especially the LDCs and SIDS, as well as countries in Africa affected by drought, desertification and floods. Risk management and risk reduction, including risk sharing and risk transfer mechanisms such as insurance are highlighted, as are strategies for disaster reduction and means to address loss and damages associated with climate change. In pursuing economic diversification, and coherence and integration between public and private sectors and civil society to build resilience, enhanced action on adaptation and mitigation technology development and removal of obstacles to transfer, including provision of financial and investment support for adaptation, mitigation and technology cooperation are the building blocks of the Bali Action Plan.

The scope of human security risks which are aggravated by anthropogenic climate change underscores the need for the global community to come to grips with what can be characterized as 'the climate divide.' The climate divide essentially reflects the transfer of the risks and externalized costs of the pollution created since the 19th century from the global North to the global South in the form of climate impacts on coastal communities, the economic resource base, and the ocean/atmosphere cycles which underpin the planet's life support system. The achievement of the Millennium Development Goals and the benefits that can be gained through the efforts of countries to cooperate in establishing sustainable economies (based on ecosystem-based management) are directly compromised by the effects of an anthropogenically-accelerated rate of global warming. The additional costs of adaptation in developing countries can be seen as an equity issue, with the industrialized countries sharing responsibility, including the possibility of levies and regulatory controls altering fundamentally the profitability of certain sectors associated with pollution. In this context, there is a need to accurately value ecosystem services and implement necessary measures. The Global Forum on Oceans, Coasts, and Islands provides an opportunity to seriously discuss the development of innovative risk management and distribution mechanisms, including access to insurance or micro-insurance for the vulnerable, and to explore ways to send improved legal, regulatory and pricing signals throughout the global market economy.

The security of the human family, of the global economy, and of world peace depend, crucially, on the degree to which the world community can step up to concerted, coordinated and proactive commitments and action to aggressively mitigate greenhouse gasses, to more equitably redistribute the risks created by anthropogenic climate change, to promote and implement ecosystem-based management of shared natural resource systems at the transboundary scale, to build resilience at the community level while simultaneously empowering self-governance and cooperation across borders and sectors through innovative, integrated and flexible science-based legal and regulatory frameworks, and to create sustainable financing mechanisms and innovative revenue streams to ensure that progress on MDGs, the eradication of poverty, and the path to prosperity for all is not compromised by the impacts of climate.

Ocean and coastal leaders, in particular, are at the frontline of climate change effects, and in coming together as the Global Forum on Oceans, Coasts, and Islands are in a unique position to address these effects on the peoples of the world. They can also lend moral voice to the climate negotiations, especially emphasizing the need to address global equity and climate divide issues, and in defining a clear vision and call to action.

Hence, the major areas that participants in the Global Forum on Oceans, Coasts, and Islands should focus on are:

**1.** Identify appropriate policy responses to scientific findings on the effects and differential impacts of climate change on different regions and peoples of the world

**2.** Address the "climate divide" (i.e., the poorest people on earth will be affected the most by climate changes) and encourage international commitments and funding mechanisms to respond to the differential effects of climate change on different regions and peoples

**3.** Encourage a wide range of adaptation efforts

**4.** Understand and address global oceans changes, e.g., ocean warming, ocean acidification, changes in current systems, changes in polar regions

**5.** Properly manage mitigation efforts that use or rely on the oceans
--alternative energy
--carbon storage and sequestration
--restoration and sustainable management of coastal ecosystems

If our generation of leadership does not take steps to sustain the ability of the global oceans, coasts and islands to support human life in peace and security based on the right to a decent standard of living for all, who will?

## II. Major Areas of Focus

### 1. Identify appropriate policy responses to scientific findings on the effects and differential impacts of climate change on different regions and peoples of the world

-- understand and address global oceans changes, e.g., ocean warming, ocean acidification, changes in current systems, changes in polar regions

Section II.1 includes anticipated climate change impacts and possible policy responses, which illustrates the range of policy issues and potential responses. Tables 1a-c below show some of the observed and forecasted ocean changes, unknowns and potential resulting policy implications. These issues and responses are examined in more detail in relation to regional effects, notably on small island developing States and the underlying issue of public health.

**Tables 1a-c: Ocean, climate change and security**

**Table 1(a): Concern, issue or risk - Weather conditions, variability and security**

| | |
|---|---|
| **Observed, confirmed changes** | Increasing severe droughts, heat waves, storms, flooding, cyclone activity; shifts in climate zones and seasonality; increased sea level, temperature humidity, precipitation in mid-, high-latitudes |
| **Inferred, conjectured** | Indications of increasing frequency of storms, heavy precipitation, flooding, and variability events as El Niño; crop land degradation, agricultural disturbances, decreased food production; deforestation, freshwater decline, soil erosion; increased mortality, increased infectious diseases |
| **Unknown, lack information** | Time scales and extent of changes, quantification at regional, sub-regional level; scale of disruption in food production, agricultural and fisheries yields in transportation and distributions |
| **Impacts, policy implications** | Geopolitical implications as regards food production, migration of people; poverty enhancements, local, regional conflicts, possibly failed States; rural decline, migration to urban centers, increasing unemployment, disruption of livelihoods in vulnerable countries; disruption of services, e.g. for tourism, transport, sanitation |
| **What can the ocean community do** | Provision of education, social advice, awareness in use/produce of forecasting, warning systems; dialogue with users as regards needs, use of forecasting; help in developing, suggesting observations, interpretations, modeling, forecasting, related networks for data/information exchange, identification of gaps; help develop warning systems, protection for coastal zones, development of norms, zonation schemes |

**Table 1(b): Concern, issue or risk - Food security**

| | |
|---|---|
| **Observed, confirmed changes** | Rising prices due to climate change and other factors; use of crops for bio-fuels; impacts on sea and freshwater fisheries through overfishing, pollution, habitat losses, destructive fisheries; ecosystem and biodiversity changes; climate variability (El Niño, other oscillations); shifts in distribution of fish; severe impacts on food security-high risks in view of combined pressures on marine living resources |
| **Inferred, conjectured** | Increasing mortality in poor countries due to hunger related diseases; climate change exacerbating impacts due to temperature changes (air, water); sea level changes, nutrients, primary, secondary production, shifts in timing of production, fish migration, ecosystem changes and migrations |

| | |
|---|---|
| **Unknown, lack information** | Quantification of loss of nutrition, food security, impacts on human health, ability to survive; range of change in fisheries and biodiversity; scales of impacts of acidification, sea level rise, possible changes in upwelling systems and ocean circulation |
| **Impacts, policy implications** | Increasing social unrest; needs for diversification, adjustments, management; economic impacts through prices, availability, lack of nutrition (protein) for most poor populations; disrupting effects on small-scale fisheries and aquaculture; need adapt policy to control fisheries, pressure on habitats as wetlands, estuaries, flood plains, benthic systems; integrated management with land-forestry-water due to interdependencies; promote conservation, use no-take zones, ban fishing, control technology, enforcement of rules, norms; develop aquaculture |
| **What can the ocean community do** | Help identify what and how ocean forecasting can do for management of water resources, seasonal adjustments of agriculture, crops, social conditions; provide information on changes in ocean conditions and what these mean for fisheries, aquaculture; dialogue with fisheries and food production industries on preservation, protection measures; help rural coastal areas implementing ICM by providing information, education, data, forecasting in developing aquaculture |

**Table 1(c): Concern, issue or risk - Coastal areas and habitats, related ecosystems**

| | |
|---|---|
| **Observed, confirmed changes** | Sea level changes, lack of stable coastline, increased erosion, storm and tidal surges, hurricane impacts; inundations; changes in ecosystems due to temperature changes |
| **Inferred, conjectured** | Trends in changes appear confirmed by modeling; changes in wind, current, wave conditions possible and in coastal upwelling; possible changes in nutrient supplies |
| **Unknown, lack information** | Not clear if observed changes are all trends, or variability; quantifications very uncertain |
| **Impacts, policy implications** | Adaptations depend upon coastal development situation: natural systems as beaches, dunes, wetlands, estuaries can adapt naturally to changes in sea level, wind, current, wave patterns; planned retreat also possible when infrastructure development is limited; adaptation in areas with large infrastructure developments need to rely on protection efforts such as dikes, walls, or beach nourishment, restoration, wetland creations |
| **What can the ocean community do** | Train personnel; advice on most appropriate approach; develop forecasting; support institutional developments, identify technological inputs; provide capacity building; advice on specific measures as critical observations, data needs, modeling, use of forecasting, help ensure that a system-oriented approach is used; advocate for integrated management |

### *a) Anticipated Regional Effects of Climate Change*

Climate change will have a variety of impacts on agriculture, human health, biodiversity, coastal areas, and water stress, which will vary by region. A preliminary assessment of expected regional impacts in some areas, based on IPCC reports, has been summarized in Table 2 below. Though not considered by the IPCC, this analysis will be expanded to include open oceans, which is detailed in Section II.4 (Tables 3a-h) of this report. Regions and areas to be considered include: Africa; Australia/New Zealand; Asia; Europe; Latin America; North America; Polar Regions; Small Islands; and Open Oceans.

| TABLE 2: EXPECTED REGIONAL IMPACTS (IPCC 2007) | | | | | |
|---|---|---|---|---|---|
| **Region / Impact** | **Agriculture** | **Water Stress** | **Coastal Areas** | **Human Health** | **Ecosystems and Biodiversity** |
| **Africa** (*one of the most vulnerable continents to climate change)* | decrease in agricultural areas, growing seasons, and yield potential; decrease in yield as much as 50% by 2020; decrease in crop net revenues as much as 90% by 2100 | by 2020: 75 to 250 million people face increased water stress; by 2050: 350 to 600 million face increased water stress | by end of 21st C, sea level rise projected to affect low-lying coastal areas; further degradation of mangroves, coral reefs; cost of adaptation to sea-level rise at least 5- 10%GDP | disease vectors altered by climate change, may increase risk of certain diseases, i.e. malaria | by 2080s, proportion of arid and semi-arid land increase by 5 to 8%; decrease in lake fisheries catch due to rising water temperature |
| **Asia** | in parts of Asia, crop yield decreases between 2.5 to 10% by the 2020s and 5 to 30% in 2050s | 120 million to 1.2 billion people experience increased water stress by 2020s and 185 million to 981 million people by 2050s | predicted significant sea-level rise results in greater risk of flooding and sea-water intrusion; loss of coral reefs estimated at 24% in the next ten years and 30% within thirty years | increase in coastal water temperatures could lead to cases of cholera in South Asia; increase in mortality caused by diarrhoeal disease in East, South, and South-East Asia | within next 20 to 30 years, glacier melt in Himalayas will lead to increased flooding and avalanches and reduced river flows; increased extinction rates |
| **Australia / New Zealand** | increase in drought and fire lead to decline in agriculture and forestry by 2030 in southern and eastern Australia and eastern New Zealand | increase in water security problems by 2030 | continued coastal development and population growth lead to higher risks from sea level rise | increase in number, intensity and duration of heat waves; may cause increased public health risk | significant biodiversity loss by 2020 in several areas, including the Great Barrier Reef and Queensland Wet Tropics |
| **Europe** | initial benefits in Northern Europe, i.e. increased crop yields, but long-term negative impacts, i.e. increased flooding; drought and high temperatures in Southern Europe exacerbated | predicted rise in population facing high water stress will increase from 19% (present) to 35% (2070s); decrease in summer rainfall in Central and Eastern Europe | sea-level rise will cause loss of up to 20% of wetlands; increased risk of flash floods, coastal flooding and coastal erosion; coastal flooding predicted to negatively impact up to 1.6 million people/yr | increase in number, intensity and duration of heat waves; increase in flooding; increase in vector and food-borne disease; all pose increased public health risk | many glaciers and permafrost areas disappear |
| **Latin America** | by 2050s, 50% of agricultural lands will face increased salinization and desertification; decreased productivity of cattle/dairy farms | by 2020s net increase in people facing water stress will be between 7 and 77 million; water availability affected by glacier loss and changes in precipitation | sea-level rise negatively impact Mesoamerican coral reefs; increased risk of flooding in low-lying coastal areas due to sea level rise | concerns include heat stress and water-borne diseases; stagnant air masses in urban areas and health problems related to increases in surface ozone; stratospheric ozone loss, UVB increases in some areas | increases in temperature and decrease in soil water lead to savanna replacing tropical forest in eastern Amazonia by mid-century |
| **Polar Regions** | in the Arctic, climate warming is likely to lead to the opportunity for an expansion of agriculture and forestry where markets and infrastructure exist or are developed | changes in Arctic freshwater systems will affect hydrological extremes, global feedbacks, contaminant pathways; models predict increased flow for major river systems | potential navigable northern sea routes for shipping | negative impacts on indigenous communities, i.e. infrastructure | reduced extent of glaciers and ice sheets; warmer ecosystems vulnerable to species invasions; ocean acidification impact calcified organisms |
| **Small Islands** *(please also see below)* | sea level rise, sea water intrusion, inundation and soil salinization will all negatively impact coastal agriculture | by mid century, water resources in many small islands projected to be reduced | sea-level rise may lead to increased storm surge, erosion and inundation; threats to vital infrastructure; deteriorating coasts coral bleaching/beach erosion | increased incidence of disease, particularly in tropical and sub-tropical islands | warmer temperatures lead to increased risk of invasion by non-native species |

### *b) Climate Change and Small Island Developing States*

While the fourth assessment on small islands confirms and strengthens the findings of the third assessment report, a number of policy and research areas remain unaddressed and require increased attention and further study.

The IPCC concluded that sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities which support the livelihood of island communities, with very high confidence.[1] Although the IPCC Working Group I provided sufficient evidence for sea level rise and its links to climate change, sea level rise measurements for small islands are still controversial, leading some researchers to conclude that sea level rise is not occurring. The situation on the ground is, however, different. Many islands have already reported increased coastal erosion and tidal surges. This lack of clarity in available local data has led to policy inaction until disaster strikes, thereby forcing action, often at great cost. Small island leaders have been working to raise attention at the global level to the problem of sea level rise since the 1980s, but so far the islands have had to implement coastal adaptation measures at their own expenditure. Recent efforts by the GEF, the World Bank and other UN agencies have been limited and constrained by a lack of replenishment to the Adaptation Fund, established to finance concrete adaptation projects and programs in developing countries that are Parties to the Kyoto Protocol.

Coastal management efforts have been an area of focus on the global agenda for several decades. The coastal zone management approach can significantly support adaptation to sea level rise, especially through an enhanced stakeholder involvement process. Increased attention and efforts in this area for small islands is imperative to their sea level rise strategies. Integrated coastal zone management must be implemented jointly with adaptation projects to achieve maximum effectiveness and reduce long-term vulnerability.

Regarding freshwater resources, the IPCC found that there is strong evidence that under most climate change scenarios water resources in small islands are likely to be seriously compromised, with very high confidence (see footnote 1). Historically, research on water resources in small islands has been quite intensive, but the uncertainty of climate change and how it will affect the microclimates of small islands is still an area for further research. Many small islands have enhanced their approaches to water conservation, yet future declines in the availability of water would considerably constrain existing measures. Efforts for integrated water management should be further encouraged and lessons shared with other small islands.

Some islands have opted for the installation of seawater desalination plants, but such facilities are potentially high consumers of energy and hence emitters of greenhouse gases. This could be offset, however,

[1] In the IPCC 2007 Report, where uncertainty is assessed more quantitatively using expert judgment of the correctness of underlying data, models or analyses, then the following scale of confidence levels is used to express the assessed chance of a finding being correct: very high confidence at least 9 out of 10; high confidence about 8 out of 10; medium confidence about 5 out of 10; low confidence about 2 out of 10; and very low confidence less than 1 out of 10.

if renewable energy from the sun or ocean (e.g. solar, tidal, OTEC, wave energy, etc.) were used to power desalination. For more information on renewable energy and the ocean please see Section II.5 of this report.

In looking at marine ecosystems and fisheries the IPCC concluded that climate change is likely to heavily impact coral reefs, fisheries and other marine-based resources of small islands, with high confidence (see footnote 1). Sustainable marine ecosystem and fisheries management are critical to island survival. Climate change is expected to have a significant effect on those fragile resources. A primary concern here is that many of the marine resources abutting small islands are already under severe human stress, in particular through overfishing. Coral reefs are also impacted on a daily basis from coastal development and growing tourism pressure. While these economic activities are vital and necessary, conservation of marine ecosystems and proper management of coastal and demersal fisheries remains a priority in small islands. Climate change will place further pressure on these resources.

It is still not clear how climate change will impact the resiliency of coral reefs. Although a number of studies are being undertaken in all parts of the world, it is still unclear how isolated islands recover from extensive and repeated coral bleaching. One researcher has postulated that coral reefs will be extinct by the turn of the century. With such a high dependency on coral reefs, many islands could potentially be abandoned for more productive areas. Demand for many types of fisheries depends upon global market demands, and although some species may attract a premium, such benefits are rarely allocated to the country or community of origin; hence there is always pressure for sustained and even increased resource extraction. Unsustainable practices fuelled by trade to developed nations remains a priority policy challenge to be tackled if islands are to successfully manage their marine fisheries.

Complicating resource management, small island States have large EEZs and hence also large marine ecosystems. Management of such vast areas of the ocean is beyond the abilities of most small islands. As a result, illegal fishing and other forms of unsustainable resource extraction goes on unchecked. Rational approaches to the governance of large ocean areas are still in their infancy, particularly in small islands. Further, the challenges faced by many small island States to submit their claims of an extended continental shelf under the law of sea, despite the deadline, are still evident.

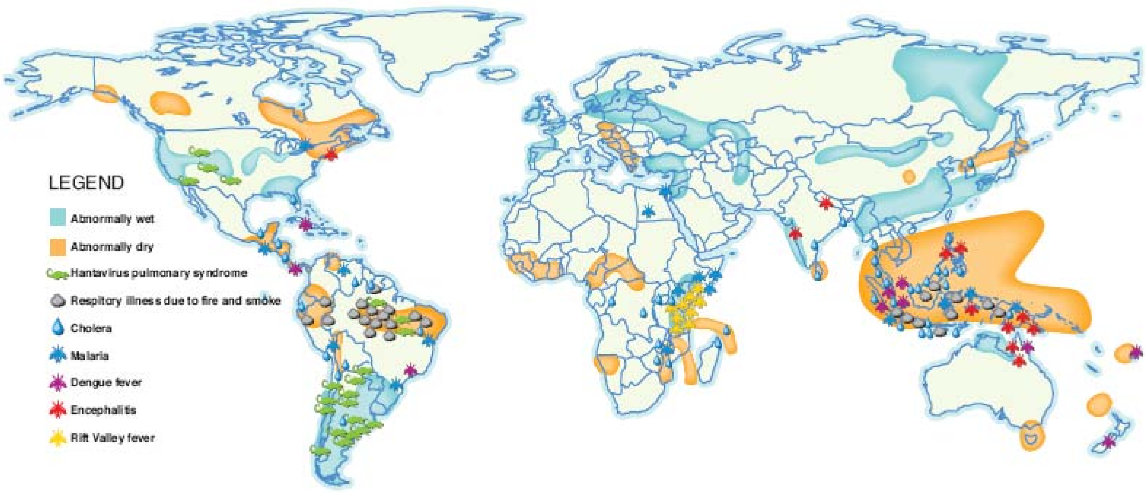
Research is lacking in many areas of marine ecosystem interactions and climate change, though there has been some focus on coral reef recovery in the last few years. However, monitoring is fragmented and lacking which prevents scientists and policy-makers from making informed decisions, and ocean observing systems are absent in many ocean areas under the jurisdiction of small island States. This lack of global coverage leads to serious data gaps, again affecting the abilities of ocean and coastal managers to make informed decisions and meet the challenges posed by a changing climate.

***c) Climate Change and Public Health***

(*this section is based on references provided by Professor Paul Epstein)*

The effects of climate change will have an enormously negative impact on human health worldwide. Increasing temperatures, drought and flooding will cause increases in starvation, disease, and deaths in human populations. In addition, climate change will affect the health of many organisms that humans depend on for survival, such as coral reefs, livestock, crops, and trees, which will increasingly deteriorate the health of humans. One of the most devastating effects of climate change on human health will be the increase in the outbreaks of diseases, such as malaria, dengue fever, encephalitis, rift valley fever, Hantavirus pulmonary syndrome, West Nile virus, Lyme disease, cholera, and respiratory illness caused by increasing episodes of fire.

The map below (Figure 1) shows abnormally wet and dry conditions around the world during the century's largest El Nino event, 1997-1998. Due to these abnormally wet and dry conditions, mosquito and rodent borne diseases surfaced in different areas of the world, which are also represented in the figure. The majority of areas that were most affected are located in developing countries.



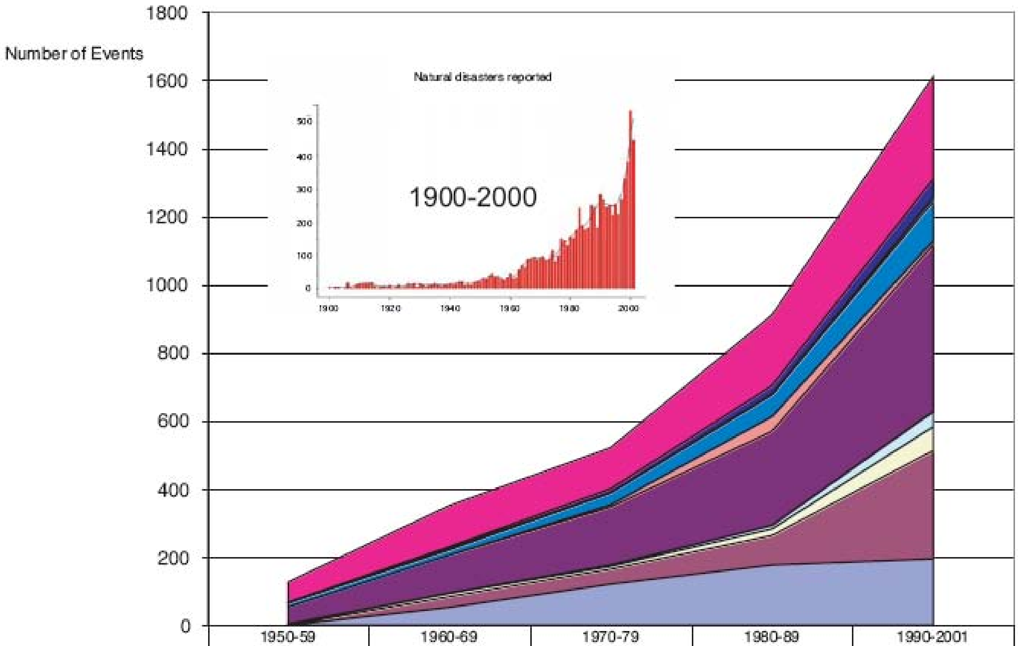

*Outbreaks of infectious diseases carried by mosquitoes, rodents and water often "cluster" following storms and floods. Droughts also lead to water-borne diseases and disease from fires. The events above occurred in 1997-1998, during the century's largest El Niño.*
*Image: Bryan Christie/Scientific American August 2000*

Figure 1: Extreme Weather Events and Disease Outbreaks: 1997-1998 (Harvard Medical School 2005 pg 35)

The increase in outbreaks of mosquito borne diseases in developing countries is one of the most dangerous effects associated with climate change. Malaria is one of the most prevalent and deadly of these diseases, and it is currently plaguing many developing countries, causing between one and three million deaths per year. The most dangerous form of malaria is *Plasmodium falciparum* and is the most abundant form in Africa. Currently there is evidence that suggests that this form of malaria is also becoming increasingly abundant in Venezuela and Sri Lanka. Outbreaks of malaria are caused by flooding and abnormally wet conditions, and can also be linked to drought conditions. For example, flooding in Mozambique in February and March of 2000 caused a malaria epidemic. In Brazil, due to abnormal droughts in the 1980s and 1990s which caused crop failure and famine, people were forced to migrate to other areas of the Amazon where they subsequently contracted malaria and brought it back to their home towns when the drought subsided. With increasing extreme weather events associated with climate change, it can be expected that more droughts and periods of abnormally wet conditions will result in more cases of malaria throughout the world, and more specifically, in developing countries. This conclusion can also be drawn for other mosquito-vectored illnesses, such as dengue fever.

People are also experiencing increases in respiratory illnesses due to the changing climate. For instance, many people suffer from asthma, and in developing countries, asthma can be a very debilitating illness. It has been shown that increases in $CO_2$ causes plants to photosynthesize at a faster rate, producing more pollen. Warming temperatures have also been causing plants to release pollen earlier each year, resulting in longer growing seasons. This phenomenon has negative effects for those who suffer from asthma. In addition, droughts cause increases in dust in Africa and the Caribbean islands, which further agitates respiratory ailments, and which has also increased forest fires in Southeast Asia and the Amazon.

The effects of climate change on the environment also cause a variety of other negative effects on human health. Figure 2 below shows how natural disasters such as wind storms, floods, waves/surge, slide, wild fires, insect infestations, extreme temperatures, and drought all have increased dramatically from 1950 to 2001. All of these natural disasters can have potentially devastating effects for human beings.




| | 1950-59 | 1960-69 | 1970-79 | 1980-89 | 1990-2001 |
|---|---|---|---|---|---|
| Wind storm | 59 | 121 | 121 | 207 | 300 |
| Wild fire | 0 | 4 | 11 | 25 | 54 |
| Wave/surge | 2 | 5 | 2 | 3 | 12 |
| Slide | 11 | 15 | 34 | 63 | 114 |
| Insect infestation | 0 | 1 | 6 | 43 | 13 |
| Flood | 50 | 110 | 170 | 276 | 489 |
| Famine | 0 | 2 | 4 | 11 | 45 |
| Extreme temp | 4 | 10 | 9 | 19 | 70 |
| Epidemic | 0 | 31 | 44 | 86 | 317 |
| Drought | 0 | 52 | 120 | 177 | 195 |

Figure 2: The Frequency of Weather-Related Disasters (Harvard Medical School 2005 pg 23)

Heat waves are very dangerous to human health, and are likely to become more frequent as climate change progresses. For instance, during the summer of 2003, Europe experienced what was considered the hottest summer since at least AD 1500. An event such as this, if it occurred in the United States, "could cause thousands of excess deaths in the inner cities and could precipitate extensive blackouts" (Harvard Medical School 2005 pg 53). Heat waves cause death among the elderly, ill and very young. In addition, increased periods of heat lead to scarce fresh drinking water supplies in some areas, increasing the demand for water and lowering the quality of life of some populations. Increased humidity associated with heat waves also has a negative effect on human health, causing discomfort, respiratory ailments, and further exacerbating the problem of increasing insect populations leading to increasing instances of insect vectored diseases.

Droughts have already been increasing, particularly in parts of Africa (Figure 3 in Section II.2 of this report) and South America. This results in a shortage of drinking and irrigation water, which causes food shortages, and in turn, malnutrition among individuals (IPCC AR4 Synthesis Report). In addition to drought, a rise in sea level will cause many rivers and groundwater sources to become saline, further decreasing the amount of fresh water supplies available. Another issue is the contamination of fresh water by water-borne illnesses. In areas of frequent flooding, such as Mozambique and Bangladesh, much of the freshwater supplies have become contaminated with human waste and bacteria, further decimating the amount of drinking water available and creating sanitation issues. Diseases such as cholera and typhoid are much more abundant following flooding events in developing countries (Center for Disease Control and Prevention 2005).

As discussed in other areas of this report, climate change will have extremely negative impacts on coral reefs, including massive bleaching events and outbreaks of disease. Such events will have an impact on human health. Coral reefs protect many island States by serving as a buffer against storms. A 2005 report by the Harvard Medical School found that "[t]he total value of reef-related shoreline protective services in the Caribbean region has been estimated to be between US $740 million and US $2.2 billion per year. Depending upon the degree of development, this coastal-protection benefit ranges from US $2,000 to US $1,000,000 per kilometer of coastline" (p 77). In addition, because reefs serve as nurseries for many fish species vital to commercial fishing industries, if reef ecosystems continue to perish the livelihoods of many people will be affected.

**2. Address the "climate divide" (i.e., the poorest people on earth will be affected the most by climate changes) and encourage international commitments and funding mechanisms to respond to the differential effects of climate change on different regions and peoples**

*The countries most vulnerable are least able to protect themselves. They also contribute least to the global emissions of greenhouse gases. Without action they will pay a high price for the actions of others.*

--Kofi Annan

In its 2007 report, the IPCC, amid growing global concern, called urgent attention to the growing "climate divide" that exists between the developed and the developing world--that is to say, the brunt of the damage acting as the catalyst for global climate change has been created by the developed world but its impacts will be felt most readily by the developing world. As the chair of the IPCC panel noted "[i]t's the poorest of the poor in the world, and this includes poor people even in prosperous societies, who are going to be the worst hit … [as] people who are poor are least equipped to be able to adapt to the impacts of climate change and therefore, in some sense, this does become a global responsibility" (IPCC 2007).

Changes in the hydrological cycle will have large effects with flooding and other extreme weather events, largely influenced by the ocean, and occurring in some of the most vulnerable areas of the world. It is anticipated that developing nations in Africa (which account for less than three percent of global carbon emissions) and Asia will be most affected and the developed nations far from the equator least affected. The map below (Figure 3) from the 2007/2008 UNDP Human Development Report shows which parts of Africa are predicted to experience an increase in drought conditions due to climate change. Asia will be particularly vulnerable to the effects of climate change, especially major population centers at low elevations including: Mumbai, India; Shanghai, China; Jakarta, Indonesia; Tokyo, Japan; and Dhaka, Bangladesh. The five most vulnerable countries with large populations are China, India, Bangladesh, Vietnam, and Indonesia. The impact of climate change on developing nations, especially small island developing States (SIDS), is significant and the implications of these potential effects range from changes in ocean chemistry and forecasted sea level rise to impacts on ecosystems and human health. The need to address these issues in the oceans community is a vital first step in combating the potentially devastating effects of climate change with specific attention to the developing world and SIDS.

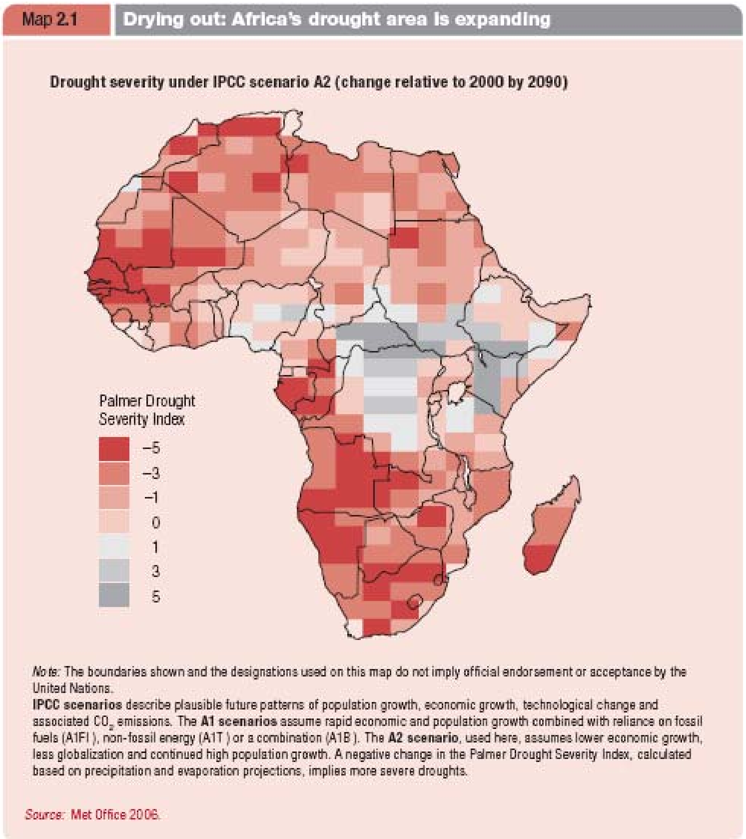
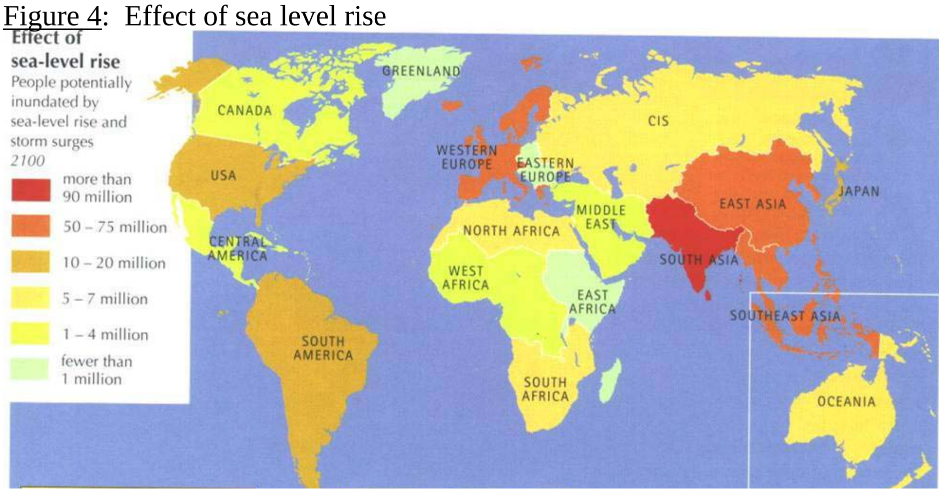



Figure 3: Changing drought conditions in Africa 2000-2090 (UNDP Human Development Report 2007/2008 pg 107)

In certain island States people are already being evacuated due to the threats of increased storm frequency and intensity, and the rising sea. For example, 2000 people living in the Carteret Islands of Papua New Guinea were forced to evacuate their homes and move to an adjacent island following the demise of their homes due to high tides and storms. One hundred people living on the island of Tegua, Vanuatu, were also forced to abandon their homes in 2005 due to rising sea levels. Other islands such as Tuvalu and Kiribati are currently preparing plans for an eventual evacuation.

Figure 4: Effect of sea level rise



Sea level rise is a pressing issue not only for SIDS but for other countries in Asia and Europe. Figure 4 above shows areas of the world that could have areas potentially inundated by sea level rise and storm surges by 2100. Based on this analysis, people living in India, East and Southeast Asia and Western Europe will be most affected by sea level rise by 2100. Within South Asia, more than 90 million people may potentially be affected by sea level rise, and in East and Southeast Asia, as well as Western Europe, between 50 and 75 million people may be affected (Dow et al. pg 63).

In addition, not only are areas in India and South East Asia more susceptible to sea level rise, more of their populations are likely to be affected because a very high concentration of people live in close proximity to the coast. The dark purple areas of the map below (Figure 5) show those regions that had the most people (76-100 percent of the total population) living less than 60 miles from the coast as of 1995. Some of these countries include Vietnam, Australia, Japan, North and South Korea, and Indonesia. On the contrary, developed countries such as the United States and Canada (not shown on this page) only had 1-50 percent of their total population living less than 60 miles from the coast. Adapting to these changing conditions will require strategic planning among developed and developing nations alike.

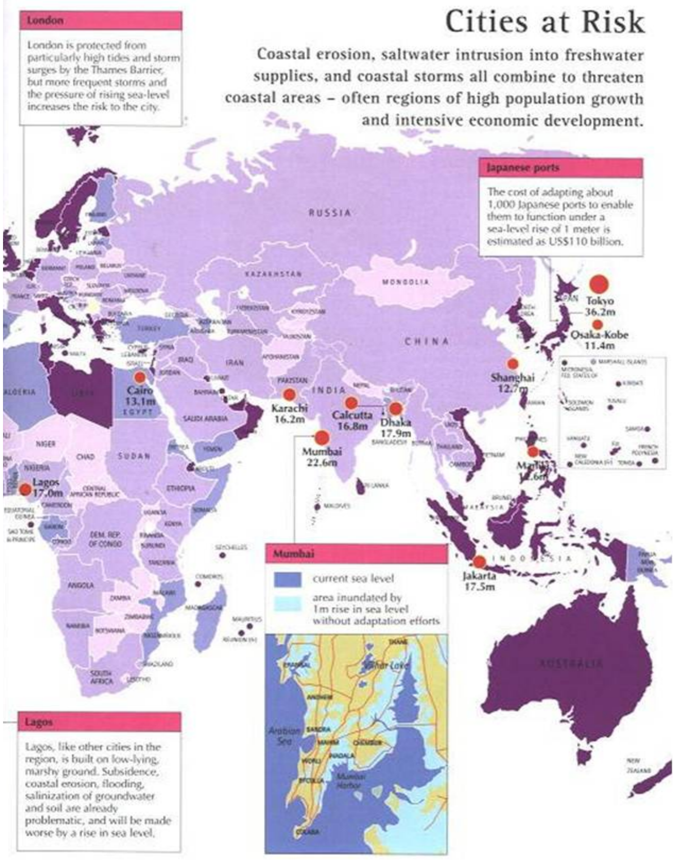



Figure 5: Cities at risk (Dow et al. pg 65)

## Arctic Region

The Arctic region and its populations are particularly vulnerable to the effects of climate change. The indigenous peoples there will be very much influenced, primarily in a negative way and with much of these negative effects driven from the ocean. Mean surface temperatures are projected to increase by another 3°C by 2050, leading to vast reductions in summer sea ice (Figure 6) and an extensive loss of ice-based ecosystems and related species. A global temperature increase of 3–4°C could further result in 330 million people being permanently or temporarily displaced through flooding impacts, particularly those in the Arctic region.

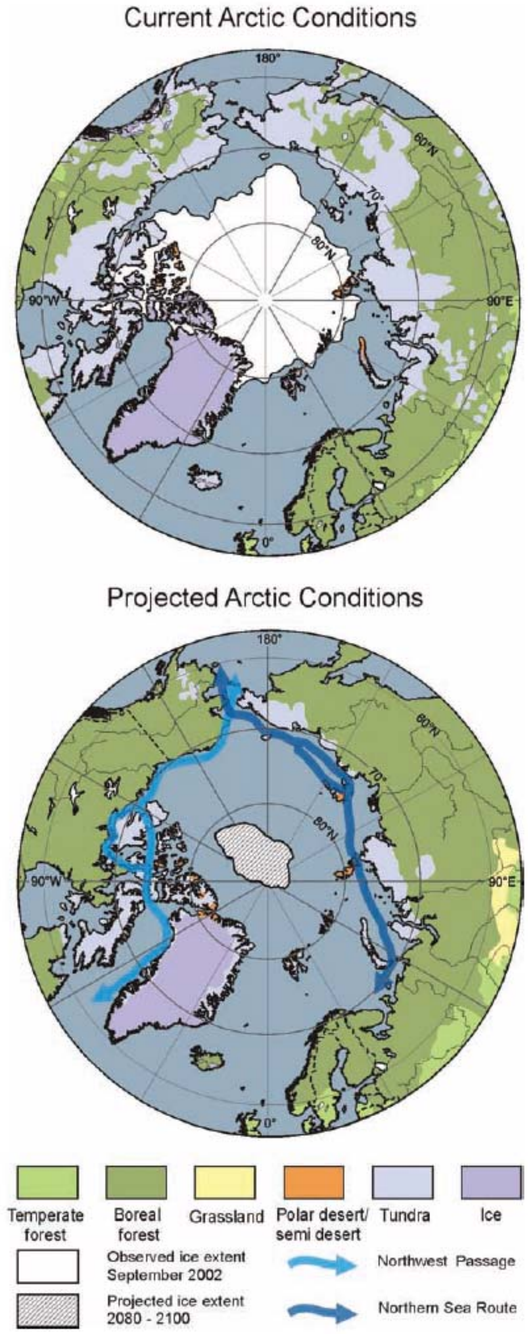



Figure 6: Arctic sea ice (IPCC 2007 pg 659)

Direct impacts, including injury and death, in the region are expected to increase due to exposure to extreme temperatures and weather events. For example, residents in some Arctic regions report respiratory stress associated with extreme warm summer days not previously experienced (IPCC 2007 pg 671). Numerous, more complex, indirect impacts on human-environment interactions in the Arctic are also anticipated.

Increasingly uncharacteristic environmental conditions are being reported throughout the region, and evidence suggests that climate-related injuries are exasperated as a result of these changing conditions, such as thinning and earlier break-up of sea ice.

Indigenous peoples in the Arctic are poised to be among the first and worst impacted by the effects of climate change. As the 2007/2008 UNDP Human Development Report includes, a leader of the Inuit community commented "[t]he Arctic is the world's climate change barometer. Inuit are the mercury in that barometer" (UNDP 2007 pg 103).

## 3. Encourage a wide range of adaptation efforts

*(This section is based on information provided by Margaret Davidson)*

Enhancing options for adapting to climate change is a multifaceted process. First, as has long been discussed, many of the physical and ecological mitigation strategies that we would wish to undertake in order to 'contain' the rapidly escalating costs of coastal disasters are also the same practices that we need to promote to ensure coastal community resilience in the face of climate change. For instance, siting, engineering and construction practices with regard to physical structures (elevation of buildings, enhanced construction standards) are designed societally and economically. There are infrastructure siting and design projects that are being conceptualized today that by the time that they are actually built, it will be apparent that they are unfortunately sited or inadequate in their design capacity. We need to begin now to rescope physical infrastructure requirements for coastal margins and take an approach that is economically strategic given limited funds worldwide for physical infrastructure. Secondly, the need to recognize, enhance or preserve coastal ecosystem functions such as flood mitigation or water filtration is even greater in an era of rapid acceleration of sea levels and increasing extremes of drought and floods. Communities through proper change analysis can begin to understand a much more strategic approach toward 'green infrastructure', e.g. the acquisition, restoration and even creation of ecologically essential habitats so as to ensure the availability of services such as wildlife corridors and flood protection in a few decades from now.

A comprehensive approach towards 'coastal change detection' will allow us to more effectively identify climate threats to human and associated ecological communities. A climate vulnerability assessment will enable government at all levels to be more strategic about their physical and green infrastructure siting and investments. The following provides further description of some of these concepts. For information on specific ocean-related/ocean-driven changes, as well as mitigation efforts, as related to climate change please see Sections II.4 and II.5, respectively, of this report.

### *a) Mainstreaming Climate Adaptation through Emphasis on Climate Variability and Extremes*

<u>Climate adaptation</u>

Climate adaptation refers to the policies and actions designed and implemented to reduce the negative impacts of climate change. Key issues associated with adaptation include:

- Adaptation can have many different dimensions and is most effective when approached as an ongoing and flexible process.
- Adaptation vs. Mitigation - Climate adaptation is different from climate mitigation, which focuses on lessening human impacts through reduction of greenhouse gas emissions.
- Mainstreaming - Mainstreaming involves integrating climate adaptation strategies into existing decision processes such as planning, economic development, and environmental protection activities.
- Climate Change vs. Climate Variability and Extremes - For

most stakeholders and decisionmakers, impacts associated with gradual increases in average temperatures over the next 50 years are too distant to result in immediate adaptation actions. Decisionmakers are, however, interested in the potential near-term impacts of climate variations and extremes. There is a need to more clearly demonstrate relevant connections between long-term climate change (e.g. long-term temperature increases) and shorter-term variability and extremes (e.g. flood frequency, drought magnitude and probability, rainfall intensity storm locations and frequency).

<u>Climate Change and Variability Overview</u>

The summary below highlights ongoing trends in global climate change and anticipated regional-scale impacts. Successfully engaging decisionmakers and mainstreaming adaptation will depend heavily on the ability to translate long-term global climate change trends into regional and local risks related to climate variability and extreme events. The information below comes from "Climate Change Impacts on the United States - The Potential Consequences of Climate Variability and Change" by the National Assessment Synthesis Team, US Global Change Research Program, published in 2000.

Current global climate change trends include:

- Global average surface temperature has increased by over 1°F during the 20th century. About half this rise has occurred since the late 1970s.
- Seventeen of the eighteen warmest years in the 20th century occurred since 1980.
- Higher latitudes have warmed more than equatorial regions, and nighttime temperatures have risen more than daytime temperatures.
- As the Earth warms, more water evaporates from oceans and lakes, which will eventually fall as rain or snow. During the 20th century, annual precipitation has increased about 10 percent in the mid- and high-latitudes.
- Warming is also causing permafrost to thaw, and is melting sea ice, snow cover, and mountain glaciers. Global sea level rose 4 to 8 inches (10-20 cm) during the 20th century because ocean water expands as it warms, and because melting glaciers are adding water to the oceans.
- The relevant question is not whether the increase in greenhouse gases is contributing to warming, but rather, what will be the amount and rate of future warming and associated climate changes, and what impacts will those changes have on human and natural systems.

Projected climate variability and extreme event impacts at the regional scale include:

- Increases in flooding associated with stronger rainfall events, increased saturation and overall increased precipitation amounts.
- Increases in flash flooding associated with more sudden

snow melts and unseasonal rainfall.

- More catastrophic impacts from more frequent and intense hurricanes.
- More damaging storm surges associated with sea level rise.
- More damaging overall storm impacts associated with loss of natural buffers to sea level rise.
- Permanent loss of coastal infrastructure to inundation from sea level rise.
- Coastal erosion associated with sea level rise.
- Reduction in freshwater sources due to increased evaporation from warming temperatures or drought conditions in certain areas.
- Increasing fluctuations in weather and climate extremes such as increased flooding in one year and severe drought the next.
- Reduced availability of water resources in dryer areas, exacerbating current competition for water among various sectors.
- Increases in landslides from more intense and frequent rainfall.
- Permafrost thawing from warming temperatures causing increased erosion, landslides, and sinking of ground surfaces.
- Retreating and thinning of sea ice increasing inundation, storm surges and significant coastal erosion.

Risk-Based Climate Adaptation

Risk is the combination of likelihood and consequences. Risks are assessed for both current and future conditions, with the option of examining either specific events or an aggregation of events over time. Key characteristics of risk-based approaches to climate adaptation include:

- Assessment of likelihood of climate events based on historic trends and predictions of climate variability and extremes.
- Assessment of the potential consequences of climate events to physical, social and natural systems.
- Assessment of baseline conditions and methods to facilitate adaptive approaches to implementation.
- Evaluation of climate adaptation options in terms of their costs and benefits in reducing unacceptable risks.
- Development of policies and action plans to reduce risks to acceptable levels.
- Identification of effective mechanisms for mainstream adaptation programs into regional and local decision processes.
- Flexibility to accommodate changes to risks over time.
- Mainstreaming through connections to ongoing hazard risk assessment and management processes.

Resiliency-Based Approaches to Climate Adaptation

Vulnerability is defined as susceptibility to damages from climate extremes or variability. It is often referred to as the sensitivity of a system to anticipated impacts. Resilience goes a step further than vulnerability, identifying the extent to which communities have the adaptive capacity to absorb and rebound from anticipated impacts. Characteristics of resiliency-focused approaches to climate adaptation include:

- Identification of indicators of resilience capacities of physical, social, economic and environmental systems and their interdependencies with each other.
- Development of locally-specific thresholds associated with resilience indicators.
- Identification and implementation of processes to assess and track community capability to withstand the consequences of climate variability and extremes.
- Community-based resilience assessment processes to facilitate necessary coordination and cooperation among different sectors (public, private, non-profit) and across numerous disciplines such as land use planning, economic development, natural resource management, social agencies, education and emergency management.
- Mainstreaming climate adaptation strategies into resilience-focused policies, actions and initiatives.

Future Directions

There are a number of things that can be done or explored in the near future to strengthen the linkages between climate, hazards, community resilience and climate adaptation. Some of these include:

- *Improve Climate Change Impact Science* – through improved observations, modeling and forecasting, continue efforts to better understand and predict on a regional scale, the effects of climate change and variability. Increase the understanding of socioeconomic relevance of adaptation in addition to focusing on the natural science components.

- *Improve Local Relevancy of Climate Information* – provide credible climate information in contexts that are useful and usable to local decisionmakers. It is critical to provide clear and understandable information upon which to base local adaptation decisions. Whenever possible, link climate change predictions to past and current experiences with extremes and variability to more effectively demonstrate meaningful context for non-scientists. Given the nature of uncertainty associated with current climate models, it is also imperative that we improve our ability to effectively communicate uncertainty to non-technical audiences.

- *Develop Improved Risk-Based Tools* – provide risk assessment tools (useful at regional and local scales) to identify current and projected exposure to existing and predicted climate extremes and variability. Linking climate change variables to more local and immediate risks associated with extreme events will generate higher interest and use than tools focused exclusively on long-term climate risks. Focusing on the development of risk-based tools to be used in screening for climate considerations as part of existing planning and implementation processes will likely be more effective in mainstreaming climate adaptation than the development of new stand alone plans.

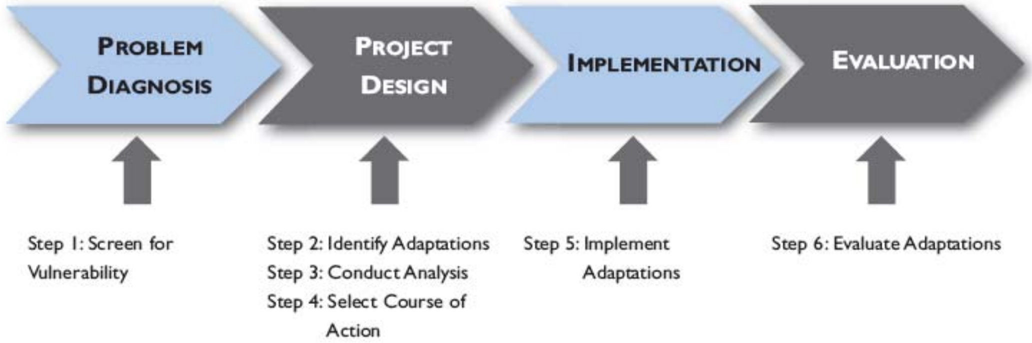
- *Develop Resilience Assessment Processes and Tools* – provide tools and information resources for use in assessing resilience at the community scale. Link specifically to risks associated with current and future climate extremes and variability. Identify the most appropriate indicators of resilience across physical, social, economic and environmental systems of communities. Develop community-based processes and methods for pursuing collaborative approaches to resilience assessment and implementation of adaptation strategies.
- *Provide for Outreach, Training and Technical Support* – Build off of existing networks dedicated to reducing hazard impacts such as coastal managers, floodplain managers, land use planners, conservation planners, natural resource managers, and emergency managers. Those currently involved in hazards management are most likely to be the "early adopters" in incorporating climate change considerations into decision processes. The experiences of early audiences will provide case studies and best practices upon which to expand and improve future activities.

***b) USAID and the Adaptation Guidance Manual***

In the summer of 2007 the U.S. Agency for International Development (USAID) published a manual intended to assist with the integration of climate information into development and adaptation efforts, *Adapting to Climate Variability and Change: a Guidance Manual for Development Planning to assist with the integration of climate information into development efforts*. This is the first of many tools USAID is developing to assist planners and stakeholders in adapting to a changing climate.

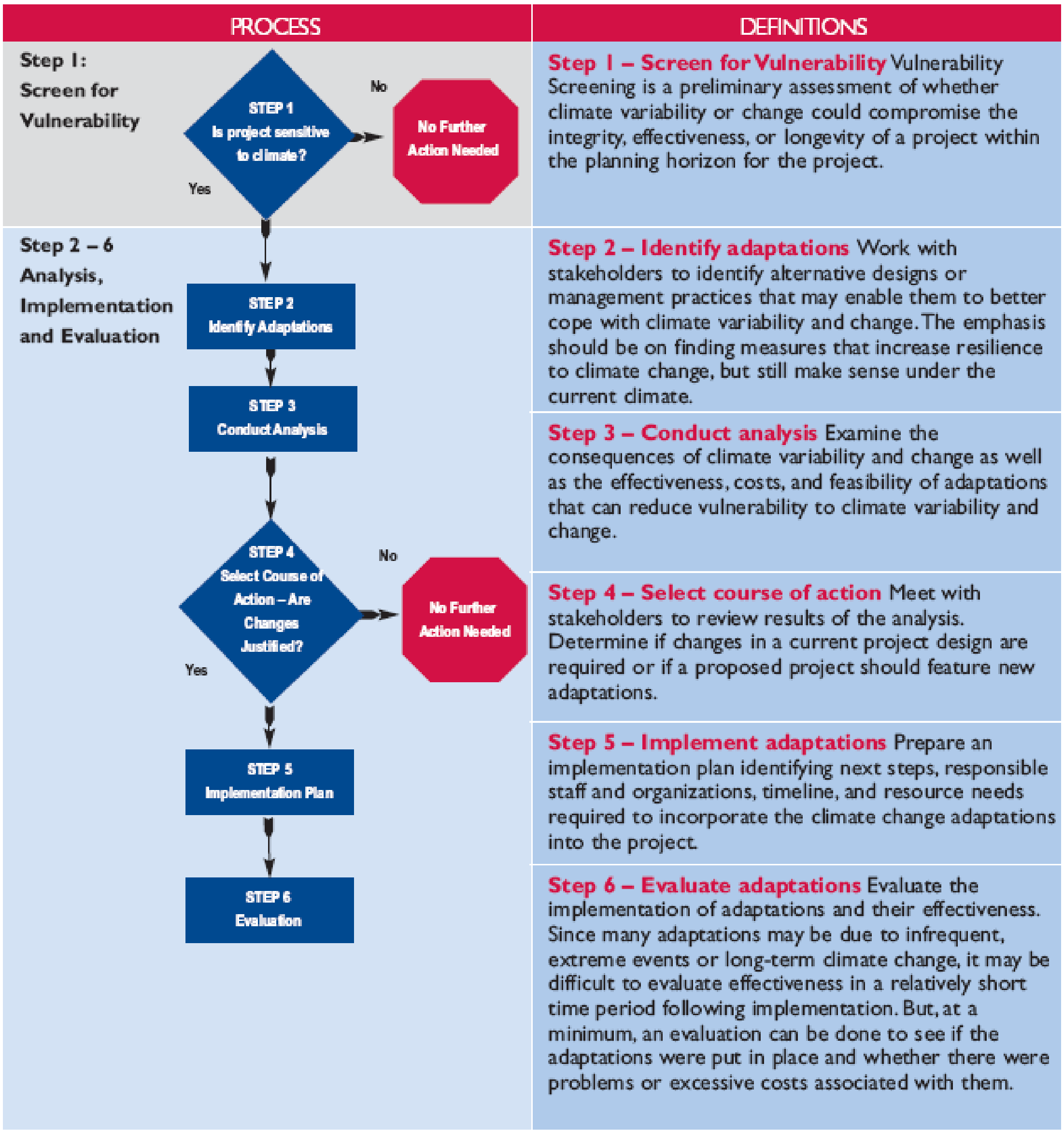
The Global Climate Change Team of USAID has been working to address the causes and effects of climate change since 1991. The organization has developed a design process referred to as a "project cycle" that includes four basic steps of problem diagnosis, project design, implementation and evaluation. This basic process is then further developed into a flexible six-step approach for assessing vulnerability and identifying and implementing climate change adaptations, termed the V&A approach (Figure 5).

Figure 5:  The Project Cycle and the V&A Approach (USAID 2007)




As noted above, the V&A approach is flexible and intended to be tailored and applied to various projects at any stage. The approach observes the needs of a specific project and uses only those steps that a certain project requires. Following is a brief description of the six-step approach, which is also summarized in Figure 8.

Figure 8:  Steps to Incorporate Climate Change into Project Planning (USAID 2007)



Step 1: Screen for Vulnerability – Screening for a prospective project's vulnerability involves a determination of whether the project might be affected by climate variability or climate change. This also involves determination of whether or not a project is within the organization's manageable interests, capacity, or resource constraints. Furthermore, analysts must be cognizant that not only are some projects particularly sensitive (e.g. water resources, coastal development, and natural resource management), but also that projects will likely need to rely on readily available information and expert opinions. According to USAID "[t]he most difficult part of adapting to climate change will be gathering data about climate change for a specific location and interpreting that data to understand possible impacts on your project".

Step 2: Identify Adaptation Options – Step 2 involves the compilation of an initial list of adaptation strategies and the application of a mutually agreed upon process by the organization, its implementing partners, and stakeholders. The initial list is then prioritized. A high degree of participation, including local and national decisionmakers and stakeholders, should be pursued.

Step 3: Conduct Analysis – This step is conducted to evaluate each of the adaptation options for effectiveness at building resilience to the effects of climate change. Imperative in this step is consideration of the project's timeframe, budget, and analytical requirements for implementation. A variety of criteria can be used in this analysis, listed in the report.

Step 4: Select Course of Action – In selecting an adaptation option it is important to engender a sense of local ownership of both process and decision among the organization, its implementing partners, decisionmakers, and stakeholders. Further, the decision must take into account a nation's economic, environmental and social goals, not in terms of the success of the project.

Step 5: Implement Adaptations – Implementation typically includes the following: better definition of the specific tasks, schedule, and roles of the implementing partners, decisionmakers, and stakeholders; and resource requirements.

Step 6: Evaluate the Adaptations – This step is taken to determine whether the project delivers the intended benefits and/or causes unanticipated adverse outcomes.

Evaluation should also be conducted of the process itself to determine how well the steps worked, the role stakeholders played, the usefulness of the analysis, etc. For further information on this process please visit the USAID 2007 report at: http://www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamanual.pdf

### *c) ICZM, IWRM and the LME approach*

In addition to the above adaptation methods, we must remain cognizant of those tools which have been effectively utilized by the global oceans community to adapt to changing environmental conditions. Integrated coastal zone management (ICZM), integrated water resources management (IWRM) and the Large Marine Ecosystem (LME) approach are arguably the best management tools the global community has for adaptation to climate change and ensuring environmental security.

Further, their successful application has been demonstrated and documented. These approaches are embraced at varying levels of policy by a growing number of countries as a means to balance multiple users, build the integration across sectors and increase benefits from coastal and marine resources while sustainably managing the ecosystem to ensure its continued production of goods and services.

These methods require adaptive, ecosystem-based management which allows mangers to: focus on the structures, processes, resilience, functions and interactions among ecosystems; respond to the complex, shifting interactions; and, alter management schemes in light of new information and enhanced understanding of ecosystem processes. In applying ICZM, IWRM or the LME approach managers should be aware that the specific stages of the processes will vary according to the area being managed and the actors involved. Coastal and ocean managers should further keep in mind that the transition to these approaches to oceans must be incremental and collaborative.

Climate variability is introducing new threats to human and environmental security, creating a need for policymakers, governments and stakeholders alike to invest in building capacity in ecosystem-based adaptive management approaches at all levels, and deploy these methods to manage, reduce and adapt to vulnerability and risk. ICZM, IWRM and the LME approach facilitate this process by providing methods which bridge science and policy based on the precautionary principle, embrace the use of environmental valuation, flows, and payments for ecosystem services, and expand access to risk management, reduction, and transfer through insurance and innovative financial instruments and funding mechanisms.

***d) UNDP adaptation learning mechanism (country-level data)***

The Adaptation Learning Mechanism is a GEF project capturing and disseminating adaptation experiences and good practices via an open knowledge platform, with co-financing from the Swiss Agency for Development and Cooperation and the Institut de l'Énergie et de l'Environnement de la Francophonie. UNDP is implementing the project in partnership with World Bank and the United Nations Environment Programme (UNEP). Launched in December 2007, the ALM Web site provides access to adaptation resources, including project case studies, best practices and other tools, such as the UNDP-developed database of adaptation profiles of individual countries. Initially developed by UNDP, the country adaptation profiles contain climate-change adaptation information for over 140 developing countries. This regularly updated online database includes information ranging from key vulnerabilities to historical scientific data on climate risks, climate change and impacts projections, and links to related online resources and project Web sites. Country profiles also allow user submissions of related documents and links.
http://www.adaptationlearning.net/

***e) Nairobi Work Programme on Impacts, Vulnerability & Adaptation to Climate Change***

Unlike mitigation of greenhouse gases, adaptation to the impacts of climate change is a cross-cutting theme under the UNFCCC, which in 2006 mandated the five-year Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP) to assist countries, in particular developing countries, least developed countries and SIDS, to improve their understanding and assessment of impacts, vulnerability and adaptation, and in making informed decisions on practical adaptation actions and measures to respond to climate change on a sound, scientific, technical and socioeconomic basis, taking into account current and future climate change and variability, through nine areas of work: methods and tools; data and observations; climate modeling, scenarios and downscaling; climate-related risks and extreme events; socioeconomic information; adaptation planning and practices; research; technologies for adaptation; and economic diversification.

The expected outcomes of the NWP are enhanced *capacity* at the international, regional, national, sectoral and local levels to further identify and understand impacts, vulnerability, and adaptation responses, and to select and implement practical, effective and high-priority adaptation actions; improved *information* and advice to the UNFCCC on the scientific, technical and socioeconomic aspects of impacts, vulnerability and adaptation; enhanced development, dissemination and *use of knowledge* from practical adaptation activities; enhanced *cooperation among all actors*, aimed at enhancing their ability to manage climate change risks; and enhanced *integration of adaptation to climate change with sustainable development* efforts. Climate, oceans and security policies can effectively be aligned with and build on Nairobi Work Program objectives.

***f) Gender and Climate Change***

From a gender perspective, a significant breakthrough was achieved at COP13 in Bali: For the first time in UNFCCC history, a worldwide network of women, organizations and institutions, gendercc –women for climate justice (http://www.gendercc.net/), was established. The group published several position papers articulating the women's and gender perspectives on the most pressing issues under negotiation, and for the first time a range of activities on women's and gender issues was organized in conjunction with the COP.  Women for Climate Justice call upon governments, international agencies and all stakeholders to confront in particular the causes of vulnerability to climate change, and to ensure gender equity in all phases and aspects of funding: when designing, implementing, and evaluating proposals, and in reporting on programs.

Adaptation must be defined as an integrated concept, which is targeting the causes of vulnerability in social groups and in particular of women. Whereas new funding mechanisms are needed to cover the costs of adaptation for those countries contributing proportionally little to climate change and lack the resources to cope with its impacts, the same applies within nations, where women and the poor suffer the impacts of climate change disproportionately, *inter alia* due to lack of information, capacity, financial constraints.

Women and gender experts should be involved in the development of funding criteria and programs as well as in decisions about funding. Gender analysis should be mandatory and attention should be paid to meeting both quantitative and qualitative targets for the participation of women, with primary consideration to impacts of programs on the social situation of women and men in all aspects of their lives, communities and livelihoods. Women are rarely involved in technology needs assessment or transfer schemes; strategies need to be developed for technology exchange processes to help rural and indigenous women increase household productivity and alleviate work loads while adapting to climate change. Adaptation and mitigation technologies need to be embedded in broader capacity building and properly adapted to women's needs.

Gender responsible criteria for programs/projects should include social and economic justice, women's human rights, environmental sustainability, and contributing to the reduction of poverty and social inequalities, while encompassing a gender perspective. Gender sensitive indicators for measuring progress in the review of funds, programs and mechanisms should be based on these criteria.

Women and men do not have equal access to property, money, funds and markets, hence benefits from funding and financing mechanisms are also unequal. Gender analysis should include examination of the effects of market-based approaches on women, indigenous and poor communities, in order to ensure that factors critical to sustainable development, such as social justice, gender equality and poverty reduction, are not overlooked. Women for Climate and Justice have proposed that the UNFCCC allocate 20 percent of all donor funds to be earmarked for activities and projects explicitly addressing women and designed by women / gender experts.

## 4. Understand and Address Global Ocean Changes (ocean warming, ocean acidification etc.)

Global oceans changes are occurring at rates and in ways unprecedented. For example, recent analyses by the National Oceanic and Atmospheric Administration (NOAA) provide evidence of high rates of warming in all but three (94 percent) of the world's 64 Large Marine Ecosystems (LMEs), which significantly exceeds reports of the IPCC. This has serious implications for addressing the science needed to understand and confirm the preliminary climate change indicators of LME warming in relation to fisheries, chlorophyll, primary productivity and hydrography, and further implications for enacting policy to address these extreme changes. (See findings of the Working Group on Large Marine Ecosystems).

Global warming's impact on the world's fisheries provides another example. A variety of future climate change projections have been proposed in relation to climate change and fisheries, ranging from the mildly beneficial to the truly catastrophic. At the most benign end of the spectrum, a few scientists have suggested that a general global warming of ocean waters will increase global ocean productivity. However, even these still concede that this will be accompanied by significant changes in species distributions and ecosystem biodiversities. Some have also suggested that the general warming trend will especially increase the productivity of new species in high-latitude regions. Most mainstream scientists, however, have offered projections describing more disruptive changes in marine-species distribution and ecosystem biodiversity. Some also add that there will be outright extinctions at the margins or edges of various species' current distributional ranges, and in any event most think that the impact of ocean warming on various marine species will be most pronounced at the northern and southern margins of their customary ranges. Moreover, because these margins or transitional regions are usually characterized by greater degrees of biodiversity, changes in these margins will impact biodiversity to a greater degree than will be seen in ocean regions that are well away from them. There is a need to understand and address changes in the global ocean environment to ensure its sustainable production and use into the future. (See paper on fisheries and climate change, part of the Fisheries and Aquaculture Policy Brief).

### *a) Background*

While climate change science has made considerable progress, large uncertainties still continue to exist in regards to our understanding of the impacts of climate on change on oceans, their biota and ecology. Much of the current scientific research has focused on climate change impacts in coastal regions, particularly in regards to coral bleaching and sea level rise. Less is known about potential impacts to open oceans and deep seas <u>Tables 3 a-h</u> below summarize some of the anticipated effects of climate change on the marine environment.

Climate change may bring about large changes in ocean temperature and circulation. In 2006, the German Advisory Council on Global Change (WBGU) released a *Special Report, "The Future Oceans – Warming up, Rising High, Turning Sour"* which shows that climate change is having severe impacts on the state of the oceans. Three critical processes, ocean warming, ocean acidification and sea-level rise, are a direct outcome of the atmospheric enrichment of pollution with greenhouse gases, especially carbon dioxide. The report emphasizes the need for a rapid response - because of the major time lags, human action now will determine the state of the oceans for many centuries to come.

According to the fourth IPCC report, observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 meters and that the ocean has been taking up over 80 percent of the heat being added to the climate system. Most coupled ocean-atmosphere models suggest a weakening of the convective overturning of the ocean in the North Atlantic and around Antarctica, which would affect ocean circulation and could have significant regional impacts on climate. Conditions setting up such changes may be initiated in the 21$^{st}$ century, but the effects may not become evident until centuries later.

Oceanographic changes caused by climate change may affect marine organisms in a variety of ways including their abundance, distribution and breeding and migration cycles. These changes may cause community-level shifts that will affect the functioning of the oceanic ecosystem. In addition, international studies indicate that the productivity of marine systems will be affected by climate change. These changes may also influence the ability of ocean ecosystems to produce food for human consumption.

*b) Climate change and the pelagic environment*

Climate change may have a potentially large impact on pelagic systems in the high seas. Dynamics of pelagic systems depend largely on sea water temperature and current flow patterns, which affect the magnitude and temporal and spatial distribution of primary productivity. These factors, in turn, affect the distribution of zooplankton, pelagic fishes and other pelagic megafauna. However, the extent to which climate change may threaten species in the pelagic systems requires further research. For example, there is as yet insufficient knowledge about impacts of climate change on regional ocean currents and about physical-biological linkages to enable confident predictions of changes in fisheries productivity.

***c) Ocean acidification***

According to the fourth IPCC report, the uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric $CO_2$ concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21$^{st}$ century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms and their dependent species.

Consequently, ocean acidification presents a potentially serious future threat to cold water coral reefs and plankton with calcareous shells (such as foraminifera). Increasing acidification de-saturates aragonite in water, making conditions unfavorable for corals to build their carbonate skeletons. Current research predicts that tropical coral calcification would be reduced by up to 54 percent if atmospheric carbon dioxide doubled. Because of the lowered carbonate saturation state at higher latitudes and in deeper waters, cold water corals may be even more vulnerable to acidification than their tropical counterparts. Also, the depth at which aragonite dissolves could become shallower by several hundred meters, thereby raising the prospect that areas once suitable for coldwater coral growth will become inhospitable in the future. It is predicted that 70 percent of the 410 known locations with deep-sea corals may be in aragonite-undersaturated waters by 2099.

**Table 3(a): Warming, heat content**

| | |
|---|---|
| *Observed changes, or variations* | Since 1961 significant increase measured in ocean heat content warming in top 700/750m; in N.A. to 1000 m, under Gulf Stream-N.A. current at 40°N, there warming is possibly deeper but so far has not penetrated bottom waters; increased surface warming in Arctic; ice cover in Arctic decreasing |
| *Inferred or conjectured* | Accounts for over 90% of possible increase of Earth's heat content; ocean heat content variability is a critical variable for detecting effects of GHG increases or resolving heat balance; slower ocean circulation, increased density layering |
| *Modeling results* | Increase in ocean heat content from 1993-2003 from 2 models are much larger than observed; rising SST leads to increasing El Niño frequency; decreasing ice cover, increasing sea level, but some rates at lower end are lower than observed rates |
| *Effects, impacts, confirmed or possible* | Possible increased uptake of $CO_2$ through photosynthesis, but warming results in more release; sea level rise through thermal expansion, melting of ice; increased humidity, spreading of diseases; decreased ocean ventilation; changes in biodiversity, biological systems, migration of species, harmful algae; possible changes in deep-bottom water formation, thermohaline circulation; intensification of weather, hydrological cycle, droughts, precipitation, runoff |
| *Possible policy implications* | Need quantifications, economic coupling; human security complexes with changes in food, health, hazards due to weather, flooding, climate variability |

**Table 3(b): Salinity, fresh water content, hydrological cycle**

| | |
|---|---|
| *Observed changes, or variations* | Subpolar surface and intermediate waters freshened in Atlantic, Pacific; intermediate waters around 1000m freshened in southern hemisphere in Atlantic, Pacific; in northern hemisphere freshening in Pacific with decrease in oxygen content; in N.A. layer around 1000m saltier due to Mediterranean Outflow |
| *Inferred or conjectured* | Estimates of changes in freshwater suggest freshening of ocean; pattern in salinity changes compatible with changes in hydrological cycle, precipitation, larger water transports in atmosphere from low to high latitudes; agrees with increase in hydrological cycle over ocean |
| *Modeling results* | -- |
| *Effects, impacts, confirmed or possible* | Could result in changing ocean circulation, advection and overturning; changes in heat, salt distribution linked to changes in ocean circulation, changes in hydrological cycle and freshwater exchanges between ocean basins; possible changes in ocean biological production, biodiversity, species distributions |
| *Possible policy implications* | Freshwater balances and availability; changes in river flows, precipitation, flooding and desertification/drought conditions; spreading of diseases; changes in agricultural and food stock productions; a comprehensive security approach called for concerning water, food and health |

**Table 3(c): Ocean circulation**

| | |
|---|---|
| *Observed changes, or variations* | Strong variation in N.A. circulation over last decades; N.A. oscillation variability and increase since early 1960's; sedimentary records show changes in N.A. circulation during glacial climate, cut off of warm water flow to northern seas, fronts displaced south, Gulf Stream diverted |
| *Inferred or conjectured* | Not known if these are trends; formation of deep water reduced; warming expected to give slower ocean circulation, increased density stratification, slowing down vertical transport of carbon-positive feed back |
| *Modeling results* | Some suggest slowing of thermohaline circulation and deep water formation in N.A.; model projections show large range in possible changes, high uncertainty |
| *Effects, impacts, confirmed or possible* | Ocean ventilation reduced; decrease in heat transfer to north; possible effects on coastal and shelf seas giving increased export of nutrients and carbon to deep sea, or increased inflow to shallow seas; possible effects on biological community structures; influences on pelagic ecosystems, zooplankton, fish, others; effects on particular biodiversity areas such as coral reefs, seamounts, vents, combined with other factors as acidification, warming, species changes, inflows of new species |
| *Possible policy implications* | Need quantify and look at synergistic effects and feedbacks potentially amplifying other effects |

**Table 3(d): Oceanic uptake of CO2; other GHG's; acidification; generation of aerosols**

| | |
|---|---|
| *Observed changes, or variations* | Oceanic uptake of emitted $CO_2$ in 1750-1990 42%, 1980-2005, 37%; flux of carbon out 90Gt, in 92Gt in mean annually; oceanic uptake over decade 2.2 Gt/year; increase of inorganic C in ocean 120Gt since 1750, about 1000Gt stored in ocean surface layer; 50% of uptake in top 400m; deepest penetration about 1000m in N.A. and sub-Antarctic; tropical ocean is out-gassing $CO_2$; high growth-rates coupled to El Niño events then leads to low uptake; extra-tropical northern hemisphere net sink; Southern Ocean large sink; carbonate buffer system transforms C from $CO_2$ into dissolved C; methane is released from sea floor, observations suggest most is absorbed in sea water; ocean ecosystems affect the chemical composition of the atmosphere: oxygen, $NO_2$, dimethyl sulfide, sulphate aerosols |
| *Inferred or conjectured* | Likely a decrease in $CO_2$ uptake due warming and acidification, positive feedbacks; saturation can occur, which has been indicated for Southern Ocean; carbonate saturation depth shallows; small percentage of methane released from sea floor can reach atmosphere; coral reef calcification reduced by 50% for doubling of $CO_2$ level in atmosphere, cold water coral reefs potentially even more affected, as well as sponge reefs |
| *Modeling results* | Model results suggest overall effect of combined carbon-climate systems interactions gives positive feedback, giving higher $CO_2$ levels than without the interactions; up to 70% of known 410 locations of deep sea corals may be in calcite (aragonite) undersaturated waters by 2099 |
| *Effects, impacts, confirmed or possible* | Acidification, decrease in carbonate concentration, availability of carbonate, bicarbonate ions with impacts on ecosystems, calcifying organisms, corals; saturation depth shallows, serious for high latitude ecosystems; shifts in ecosystem structure, changes in biodiversity and marine food web; increase in $CO_2$ in atmosphere increase partial pressure of $CO_2$, resulting in increasing acidity, and decreasing ocean buffer capacity; a decrease in uptake capacity for $CO_2$ is certain and serious; dissolution of carbonate from ocean floor will increase, impact not known; sulphate aerosols counteract warming by GHG, but their residence time much less than $CO_2$; feedbacks very difficult to quantify involving physical and biochemical processes; acidification is a very serious threat to calcite forming |

| | |
|---|---|
| | species such as coral reefs, which are also particularly threatened due to other changes such as warming, sea level rise and shallowing of saturation depth, for cold water reefs in particular |
| *Possible policy implications* | Effects confirm GHG emission is a global problem which should act as a unifying not a dividing force; ocean can provide for various contributions to remedies and adaptations including alternative renewable energy sources as wind, waves, tidal, ocean thermal energy conversion; sequestration of $CO_2$, theory and experiments suggesting it can be done, but implications must be studied; role of sea floor in climate system needs be considered, for biodiversity, genetic resources, and acidification; this includes abyssal plains, hydro-thermal vents, cold seeps, biodiversity hot-spots, life below the sea bed |

### Table 3(e): Biological production, ecosystems, biodiversity, nutrients

| | |
|---|---|
| *Observed changes, or variations* | Nutrient inputs increased due to increased fertilizer use and waste water releases; confirmed by enhanced areas of eutrophication; atmospheric inputs reach open ocean; nitrogen cycle accelerated (fertilizer, agriculture, fossil fuel uses); increase in plankton blooms suggested in high north latitudes; shifts in plankton biomass observed in N.A., N.P., S. Indian Ocean; changes in nutrient levels found in all deep waters, no clear pattern; decrease in oxygen content in intermediate waters |
| *Inferred or conjectured* | Warmer water could lead to higher photosynthetic uptake of $CO_2$, but increased stratification, decreased ventilation giving lower nutrient inputs from below can counter this; warmer climate may decrease inputs of micronutrients as zinc, iron to open ocean through decreased dust deposition, a positive feedback through decrease of $CO_2$ uptake; inferred decrease by 6% of primary production since 1980's to late 1990's; large scale changes in ocean conditions clear, including in biodiversity |
| *Modeling results* | Changes in ocean productivity are key to reconstruction of conditions in other climate periods, including on winds, currents, by means of isotope paleontology; not clear if observed large scale changes in open ocean conditions are caused by natural variability or represent trends of change due to anthropogenic influences |
| *Effects, impacts, confirmed or possible* | Increased photosynthetic production would increase uptake of $CO_2$, decreased would decrease it; possible changes in plankton species and biodiversity, with influences on food web and higher production, fish migration and distribution, also influenced by changing physical conditions; decrease of nutrient inputs through decreased interior upwelling and ventilation of intermediate waters decrease primary production, decrease $CO_2$ uptake and release of oxygen; increased temperature leads to increased rates of oxygen consumption, faster re-mineralization; changes in biodiversity can influence food web, and impact pelagic biological systems; displacement, extinction of species, possibly genetic resources, which could be needed for biological adaptation/production |
| *Possible policy implications* | Research on effects of acidification and biodiversity; continue/enhance observations over long term to clarify trends; role of ocean floor in climate and biological system; management of fisheries, top ocean predators, productive fish; ensure fast release of new results, adaptive management; creation/use of protected areas; need for much education on climate change implications; loss of biodiversity and genetic resources also show this is a global problem which should act as a unifying force needing a global shared policy with a comprehensive security approach |

**Table 3(f): Sea level**

| | |
|---|---|
| *Observed changes, or variations* | Global mean sea level rose 1.8mm per year for decades prior to 1990; increased to 3.1mm in 1990's, decade 1993-2003 thermal expansion in top 750m generated 1.6mm per year; loss of ice sheets 2.8mm; rise is not uniform: largest in western Pacific and eastern Indian Ocean; dropping sea level in eastern Pacific and western Indian; large regional variability due to S, T, freshwater |
| *Inferred or conjectured* | Thermal expansion accounted for 0.4mm; thermal expansion 1.5mm; climate change main factors of sea level change and associated budget; rise appears largest along coasts; climate variability has large effects; El Niño effect 10mm 97-98, and at Pacific islands 20cm or larger; some uncertain factors not included in projections; ice-melting in particular uncertain; unabated warming could give a 7-7.5 feet rise |
| *Modeling results* | Actual sea level rises seem to follow uppermost limit of model forecasts, or be even larger; model projections suggest rates of 4mm per year |
| *Effects, impacts, confirmed or possible* | Increased coastal erosion, inundations, flooding combined with more frequent and stronger possibly more persistent storm events, and with tidal motion; shifts in wetlands, possibly migrations of such, coral reefs, mangroves, tidal flats; loss of coastal protections from such ecosystems; long-term changes relatively certain, coasts in retreat, no coastal stability, enhanced erosion |
| *Possible policy implications* | Security concern for humans, infrastructure, zonation schemes; diseases, insurance and coastal protections; risk and vulnerability evaluations, assessments of construction norms, enforcement of norms, codes, zonations; ensure coastal observations, data banks, development of forecasting tools and their proper use; adaptive management; sea level rise also shows climate change as a global problem calling for a common response policy, acting together within a comprehensive security philosophy, considering interdependencies and synergistic effects |

**Table 3(g): Weather and variability**

| | |
|---|---|
| *Observed changes, or variations* | Confirmed changes, increases in extreme storm events, strengths and frequency in mid-latitudes; changes in precipitation and drought conditions increases; record breaking weather events globally in 2007 |
| *Inferred or conjectured* | Changes in tropical cyclone distributions, frequency, strengths; stronger effects of El Niño, other oscillations like Indian Ocean Dipole, North Atlantic Oscillation |
| *Modeling results* | Increasing trend in extreme weather events over the past years confirmed (IPCC); climate variability can be modeled and reasonably forecasted |
| *Effects, impacts, confirmed or possible* | Increasing intensity and frequency of coastal disasters; inland flooding due to precipitation, river overflows, generating loss of infrastructure; heat waves, humidity with impacts on human health; spreading of diseases, migration of species, invasive species can be harmful to agriculture, health; loss of food production, agricultural losses; seasonal patterns/regularity changing with earlier heating, displaced rainy season, changed timing of primary production; consequences for human health due to changes in ocean ecosystem structures, bacteria-virus; disease now spreading faster |
| *Possible policy implications* | Security needs more attention; well-managed environment helpful; awareness, combined with adaptation, protection and mitigation; ensure observation, data exchange, use of forecasts, education, strengthen model-based seasonal forecasting with international coordination, cooperation between centers; risk evaluations critical, combine with modeling forecasting tools; changing weather and seasonal conditions also bring out the globality and unifying aspects of the overall problem |

**Table 3(h): Arctic Basin**

| | |
|---|---|
| *Observed changes, or variations* | Warming; decreasing ice coverage, record low ice cover in 2007; permafrost decreasing; retreating glaciers and Greenland ice cover; biological degradation threats to top level parts of system, bears, walrus; sea level rise shrinking habitats for wildlife and coastal life |
| *Inferred or conjectured* | Ice cover decrease appears to occur much faster than forecasted; accelerated loss in Greenland; potentially serious consequences for ocean conditions, effects on the circulation, overturning, ventilation, and changing circulation in Arctic basin |
| *Modeling results* | Models predict loss of ice cover 2.5% per decade; observed loss larger by about factor of 3; open water season will increase in length by a factor of 2-3 over few coming years |
| *Effects, impacts, confirmed or possible* | Increased pressure on whole environment, increased exploration pressure and competition, including hydrocarbons, minerals mining, fisheries, shipping; threats to biodiversity; positive feedbacks through methane releases, decreased reflection; accelerated coastal erosion, coastal instability; enhanced extreme weather exposure; enhanced agricultural possibilities in Greenland; impacts will reach beyond Arctic through possible changes in ocean circulation, leaking out of other substances, permafrost melting releasing methane and oxidizable carbon |
| *Possible policy implications* | Increased political tension requires more intergovernmental dialogue; regional, possibly global regime formation, with comprehensive security needs; change threatens all aspects of northern life, and opens up to broader and more frequent accessibility |

**5. Properly manage mitigation efforts that use or rely on the oceans**

--alternative energy
--carbon storage and sequestration
--restoration and sustainable management of coastal ecosystems

Increasingly, the oceans are being looked to not only as alternative renewable suppliers of energy, but as storage sites for carbon dioxide and other greenhouse gases as well. Yet in many instances the technology is lacking, has extremely high implementation or operational costs, or has unknown consequences. This section will briefly address emerging initiatives in this field and potential problems that may arise as we look to the oceans to mitigate the effects of a changing climate.

***a) Alternative energy and the oceans***

Another important resource originating from the ocean, also as food in the form of energy for humans, is renewable energy from the tides, the wind, the waves and currents, and the temperature (heat content) differences between the surface layer and the deeper waters in tropical-subtropical zones. The alternative energy sources are only very gradually becoming commercially attractive. Despite this, considerable research and technological development as regards these sources of energy has been going on over the last several decades. Most oil is subsidized. Perhaps the subsidies could instead be used for research on alternative energy sources, so as to help decrease our overall dependence on the fossil energy sources.

The wind, of course, was the major source of energy for shipping during the period of sailing ships. Today sailing with the wind is mainly a sport and a recreation, although taking many different forms. There have been attempts to introduce sailing ships as commercial transport alternatives, using computer technology to manage the sails. However, this has not established itself. Wind energy is, however, being tapped for electricity generation in some countries where the topography of the land is suitable, for instance in many European countries. Many of these countries also use the coastal winds and plan for sea-based windmills to generate electricity. Large-scale offshore windfarms have already been implemented and are in operation in Denmark and Ireland.

The energy of the tides has been tapped for some time in areas of large tides with related strong tidal currents. These are predictable, regular, and sustained and thus very suitable as renewable energy sources. Along the European coasts tidal mills have supplied mechanical power for hundreds of years, using the rise and fall of the tide, or the tidal current. Through immigration from Europe this technology has also been introduced in America.

In our time technology permits the construction of large barrages in areas of high tidal range. An example is the Rance barrage in Brittany, France, built in 1966 (see Summerhayes 1996). This generates half a million kilowatts of power per tidal cycle. The cost was 100 million USD. The operating costs, however, are lower than any other power station in France, the fuel is free and there are no waste products. Areas with a tidal range exceeding 10m, which appears to be the requirement, exist in many countries, e.g. UK, Russia, Canada, China, and tidal barrages have also been constructed in these countries. The technology is clearly available. Summerhayes (1996) presents the case of the Severn Estuary barrage project, which has been proposed. If implemented, the 16 km long barrage would include 216 turbo-generators of 9 m in diameter, each giving 8640 MW. The annual output would amount to 17 TW hours of electricity, equivalent to burning of 8 million tons of oil, and corresponding to 7 percent of the electrical use of England and Wales. The environmental impacts must, of course, be assessed in detail, but early evaluations suggest they would not be prohibitive. They should also be evaluated in the context of the impacts of burning oil.

The force of the ocean surface wind-generated waves is well known by all sailors and can also be observed at the coast where this energy can cause considerable disruptions. Clearly the energy could be used more constructively if properly tamed so as to generate electricity. The power potential of an average wave per kilometer of beach is estimated at about 40 MW. In regions where such waves reasonably regularly occur they could constitute a very substantial energy source with no other environmental impacts than that of the required constructions. These, of course, as in the case of the windmills, can be substantial enough mainly with respect to amenities and aesthetics. The wave energy can be transformed by means of floating or fixed constructions. The latter uses the oscillating water column generated by the wave to push air through a turbine. This concept has been proven by a pilot plant in the UK and is commercially utilized. The floating devices convert the wave energy by being lifted up and down through coupling to a hydraulic system. Techniques for extracting wave energy are also being developed and used in India.

Some of the ocean currents such as the Gulf Stream off Florida, U.S. and the Kuroshio off the east coast of Japan flow as enormous rivers carrying many millions of $m^3$ of water per second at speeds up to some meters per second. This energy source could potentially be utilized. However, the transformation is so far not commercially viable.

The conversion of the thermal energy stored in parts of the ocean into electricity is a more viable option. The principle of ocean thermal-energy conversion, commonly referred to as OTEC, uses the difference in temperature between the surface waters and the subsurface waters, about 20-25 °C over a depth range of 500-1000 m in the tropical zones of the ocean. A first modern-type but very small closed-cycle OTEC plant was constructed in Hawaii in 1979. Of the electrical output of 50 KW, about 80 percent was used to pump up cold water for the system. There is much potential in the OTEC principle for oceanic islands in the tropics lacking other energy sources. Considerable research is therefore going on. The environmental impacts are mainly related to lowering of the surface water temperature and increasing the nutrients in the euphoric zone, thus possibly enhancing the biological productivity. One possibility of making the system commercially attractive is actually to utilize the cold subsurface waters, which are rich in nutrients to support mariculture installations in association with the OTEC plant. The cold water could also be utilized for air-conditioning or to cool the soil or to obtain clean freshwater through desalination. It is this combination of OTEC, mariculture and to achieve a number of other by-products which is currently being researched in order to make the integrated system commercially attractive. We see how an integrated approach is being adopted, involving science, technology and users in partnerships.

***b) Oceanic carbon sequestration and storage***

Carbon dioxide capture and storage (CCS) has been identified as a potential method to reduce anthropogenic $CO_2$ emissions to the atmosphere. Carbon dioxide capture and storage could help to lower atmospheric concentrations by gathering carbon dioxide at industrial point sources, compressing it, and injecting it into geological formations and the ocean. Arguably the most controversial component of carbon dioxide capture and storage, the oceans have been looked to as a reservoir due to their enormous capacity. The large amount of carbon in the ocean, approximately 38,000 Gt stored in the deep layers of the ocean and 1000 Gt stored in the surface layers of the ocean, is 50 times the amount of carbon stored in the atmosphere (~750 Gt) and 20 times the amount in plants and soils (~2,200 Gt). In addition, there are no practical limits to the ocean's capacity for carbon dioxide, which may account for the ocean's appeal as a reservoir. From a ship or a fixed pipeline, carbon dioxide could be injected into the ocean at any depth. At depths in excess of 3000 meters, carbon dioxide is denser than seawater and would sink as plumes or form lakes in closed basins.

The controversy surrounding the ocean storage option stems from two significant drawbacks: 1) even slight increases in acidity associated with a carbonated ocean can have disastrous impacts on the marine ecosystem, and 2) on millennial timescales, a carbonated ocean would ensure high $CO_2$ concentrations in the atmosphere. To date, large-scale injection of carbon dioxide into the ocean has not been done, and there have been few studies that address the effects of such an introduction on the marine ecosystem or studies regarding rates the diffusion of a large amount of carbon dioxide into the surrounding water masses and ultimately to the atmosphere. Though the UNFCCC encourages using the ocean as a $CO_2$ reservoir, application of UNCLOS is ambiguous, as marine carbon dioxide falls under the definition of a pollutant. OSPAR, the London Convention, and the London Protocol also apply internationally to ocean storage of carbon dioxide.

The environmental consequences of this activity are unknown, and the carbon dioxide dumped in the oceans will eventually percolate to the surface and back into the atmosphere. Before CCS can be implemented on a large scale as an anthropogenic supplement to the Earth's natural methods of removing carbon dioxide from the atmosphere, policy makers must be confident that the new strategies are both effective in actually reducing carbon dioxide emissions over the long-term and facilitate safe, practical, and sustainable solutions to our growing energy needs.

***c) Iron Fertilization***

It is thought that fertilization with iron or nitrogen of large areas of the global oceans may potentially sequester carbon and increase the production of living marine resources. This speculation has led to an increased focus on this possibility by researchers and the commercial sector. However, this method of sequestering carbon, thereby mitigating some effects of a changing climate, while potentially conceptually attractive, may also have disastrous consequences. In March 2008 the Scientific Committee on Oceanic Research (SCOR) of the International Council for Science and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) of the United Nations released a joint statement to this effect. The groups noted that while such a potential for ocean fertilization does exist, these large-scale proposals fail to address a major underlying problem – we simply do not know how the marine ecosystem will respond. While our understanding of the ocean environment is improving, there are still too many unknowns to be able to undertake such operations. Thus, SCOR and GESAMP provide that "any deliberate large-scale addition of nutrients to the ocean must be conducted in such a way that the outcomes of these experiments are statistically quantified and independently verified…" Furthermore, the groups call for any such experiment to be transparent and for the results be made publicly available. Finally, SCOR and GESAMP recommend that carbon credits for ocean fertilization should not be allowed "unless and until reliable methods have been developed to estimate and verify the amount of carbon actually sequestered, and side effects have been properly understood and taken into account."

**Key sources**

The sources are on the Global Forum website and may be downloaded by participants.

Observations, some current conditions and evaluations on climate change and marine areas beyond national jurisdiction, Dr. Gunnar Kullenberg, former Executive Secretary, Intergovernmental Oceanographic Commission

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