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SUMMARY

Small island states are the countries likely to be most vulnerable to climate variability and long-term climate change, particularly extreme weather and climate events (such as cyclones, floods and droughts) and sea-level rise. Many small island states share characteristics that increase their vulnerability, these include their small sizes, isolation, limited fresh water and other natural resources, fragile economies, often dense populations, poorly developed infrastructures and limited financial and human resources. To understand better the potential health impacts of climate variability and change in small island states and to build capacity to cope with climate change through adaptation planning, a series of workshops and a conference were organized by the World Health Organization (WHO) in partnership with the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP)(WHO 2000; Aron et al. 2003; WHO 2003). This report synthesizes the information presented and identifies key recommendations for improving the health sector's capacity to anticipate and prepare for climate variability and change.

There is ample evidence that many small island states currently are vulnerable to climate variability. Climate change projections increase the level of concern because models suggest that small island states will experience not only warmer temperatures, but also increased climate variability. The consequences of increased climate variability are likely to be related to changes in rainfall, soil moisture budgets, prevailing winds (speed and direction), regional and local sea levels and patterns of wave action. El Niño events are likely to strengthen the short-term and interannual variations. In addition, global mean sea level is projected to increase by 0.09 m to 0.88 m by 2100. To understand better the potential human health consequences of these projected changes, the following questions were addressed.

Key questions

1. Does climate have an impact on health?

A variety of adverse health outcomes are climate sensitive; that is, weather and climate affect their incidence and distribution. Some adverse health outcomes are related directly to weather, such as drowning and injuries in floods or increased morbidity and mortality during heat-waves. Other health outcomes are related indirectly to weather and climate, such as vector-, food- and water-borne diseases, fish poisoning and others. Estimates of the global burden of disease suggest the amount of disease attributed to climate change is larger than the amount attributed to air pollution in many regions.

2. What is the current distribution and burden of climate-sensitive diseases in small island states?

Specific climate-sensitive diseases vary among the small island states. The high priority diseases identified in the workshops include: malaria, dengue, diarrhoeal disease, heat stress, skin diseases, acute respiratory infections and asthma, fish toxins and malnutrition. Although the disease burdens vary, most of these countries experience one or more climate-sensitive diseases. These could be reduced by implementing additional interventions, including the development of early warning systems to alert the population and public health authorities to possible outbreaks.

3. What are the potential future health impacts of climate change in small island states?

There has been only limited modelling of the potential future health impacts of climate change. The results suggest that many climate-sensitive disease burdens can be expected to increase unless public health agencies and authorities begin to implement adaptation policies and measures to increase resilience.

4. What interventions are being used to reduce the current burden of climate-sensitive diseases?

There were many examples of the strategies, policies and measures that small island states have implemented to reduce the current burden of climate-sensitive diseases. Many of these initiatives recognized that the potential health impacts of climate variability and change do not need to be addressed individually; health outcomes with common risk factors, such as malnutrition and diarrhoeal diseases associated with the dry season, may be reduced together by the development of appropriate interventions. Most of these initiatives included the development of an early warning system to enhance opportunities for disease control. Development of early warning systems must be site-specific to take account of local climate/health relationships and local cultural factors.

5. What additional interventions are needed to adapt to current and future health impacts?

Although many small island states have implemented interventions to reduce the current burden of climate-sensitive diseases, clearly there is ample opportunity for improvement. Each workshop generated a long list of potential interventions that are needed both locally and regionally, such as better surveillance systems to facilitate improved detection of, and response to, climate-related risks; more, and more effective, early warning systems; effective health education programmes; strengthened health care infrastructures; disaster preparedness plans; vector monitoring and control; and appropriate sewage and solid-waste management practices.

6. What are the health implications of climate variability and change in other sectors?

Climate change will interact with, and exacerbate, other factors that contribute to the vulnerability of a particular region, such as water, agriculture, fisheries and coral reefs. For example, many small island states rely on a single water supply source such as groundwater, rainwater, surface reservoirs or shallow wells. These sources are climate sensitive and changes in precipitation or rising sea levels may affect fresh water availability, which will present additional challenges to public health.

RECOMMENDATIONS

► *Enhance awareness of climate variability and change's potential impacts on human health. This includes building awareness in small island states across the full range of stakeholders; incorporating a consideration of climate/health interactions in planned and ongoing development programmes as well as in global, regional and local environment and disaster-management planning; and developing advocacy messages for decision-makers and policy audiences.*

► *Enhance development of adaptation strategies, policies and measures to reduce potential impacts. This includes developing, improving and implementing early warning systems and other preventive strategies; monitoring and evaluating the effectiveness of these systems and strategies; developing long-term adaptive strategies for sea-level rise; and assessing the costs and benefits of intervention options.*

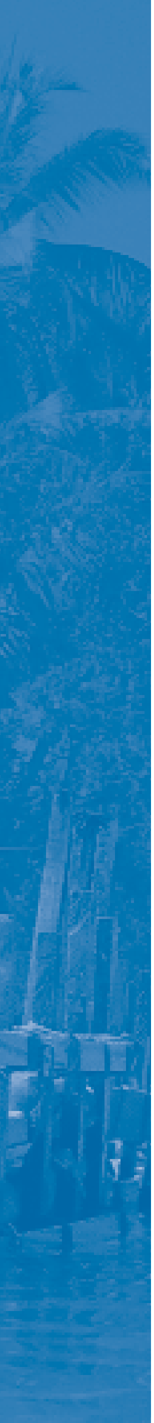
► *Address data needs, including the collection of more valid and comprehensive health, meteorological, environmental and socioeconomic data at the appropriate local, regional and temporal scales. Data management systems require improvement, and appropriate national and regional institutions need to be engaged in handling and analysing the data collected.*

► *Address high priority research questions, including expanding the knowledge of climate-sensitive diseases of importance to small island states through national and regional research; conducting basic entomological research; improving understanding of the complex relationships between the risks posed by climate variability and change and by other factors that influence population health; developing and evaluating indicators of the potential health impacts of climate variability and change; and understanding the links between climate and other sectors, such as agriculture and water supply, and how these could impact on health.*

► *Increase capacity building by developing institutional arrangements for knowledge sharing at national, regional and international levels; improving education and training; encouraging programmes of action and public/private partnerships; and transferring knowledge of adaptation options to countries with similar climate/health concerns.*

► *Develop and improve national and regional climate forecasts. In addition, create partnerships between climate/meteorology and public health/medical specialists to improve awareness of the use and uses of climate forecast information.*

► *Address resource needs by improving international, national and regional facilities and funding for capacity building, interdisciplinary research and regional/national assessments.*



INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) identified small island states as the countries likely to be most vulnerable to climate variability and long-term climate change (IPCC 2001). Former President Leo Falcam of the Federated States of Micronesia noted "for Pacific Island States, climate change and its associated effects are our main security concern" ("Death by warming", Honolulu Advertiser, 12 August 2001).

The world's island states are located mainly in the tropics and subtropics, spanning the Pacific, Indian and Atlantic Oceans, as well as the Caribbean and Mediterranean Seas. Small island states share many features that constrain their ability to adapt to current climate variability and future climate change, including their small or very small physical sizes; remoteness from major land masses; limited natural resources (often with unique animal and plant life); vulnerability to natural disasters and extreme weather and climate events; economies sensitive to external shocks; populations with high growth rates and densities; poorly developed infrastructures; and limited financial and human resources (Nurse et al. 2001).

Small island states also display a great deal of diversity. They may be single islands or groups. The islands differ in geological type, size, elevation, soil composition, drainage characteristics and natural resources. There are barrier, continental, coral, volcanic and mixed type islands. Some of the larger islands have significant elevation; others are low-lying small coral atolls. Natural resources, including water, range from scarce to abundant. Some islands have abundant surface water while others are completely dependent on groundwater; water requirements are just as diverse. Social, cultural and economic settings vary. The islands have achieved different levels of development. Sometimes infrastructures, including health, are poorly developed. Some islands have large commercial or industrial centres; others have extensive agriculture. Human communities range from large densely populated cities to small villages and dispersed populations.

Small island states' diversity in demographic, health, economic, environment and climate indicators is shown in the tables in Annex 1. As shown in Annex 1 Table 1, population ranges from 2000 in Niue to more than 11 million in Cuba; the population living in urban areas ranges from 13% in Papua New Guinea to 100% in Nauru. Particularly in Asia and the Pacific, many small island states have young populations, with a significant fraction below 15 years of age. Most small island states have healthy life expectancies (HALEs) in the 50s and 60s (compared with HALEs of 70 years and more in most developed countries), with approximately 7-8 years of healthy life lost in males and 9-10 in females. As shown by the probability of dying under 5 years old, the young experience most of the lost healthy years. Annual growth rates 1992-2002 ranged from negative in several small island states to more than 3%. Growth rates are not associated with GDP per capita; 3% or higher growth rates were experienced in Comoros with a GDP of $278 and in Bahrain with a GDP of US$12 012.

Annex 1 Table 2 shows the diversity of small island states in environment and climate indicators. As mentioned earlier, most small island states have tropical climates, with a narrow range of minimum and maximum temperatures and expected precipitation patterns. CO_2 emissions range from just a few thousand megatons to more than 35 500 megatons in Singapore. Energy consumption per capita has a similar broad range. Although small island states account for less than 1% of global greenhouse gas emissions, they are likely to be among the nations most seriously affected by climate change.

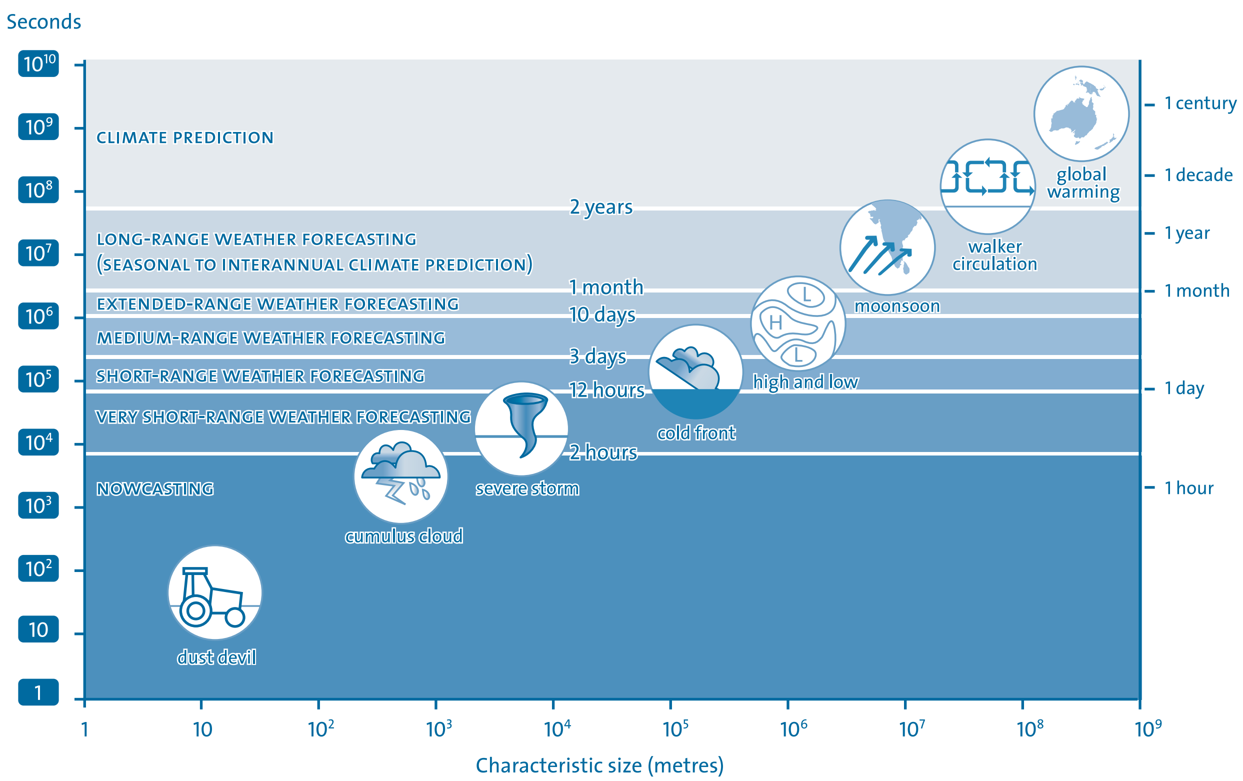
To understand better small island states' vulnerability to current climate variability and to build capacity to cope with climate change through adaptation planning, the World Health Organization, in partnership with the WMO and UNEP, organized a Pacific (Samoa, 25-28 July 2000), Caribbean (Barbados, 23–25 May 2002) and a global workshop (The Maldives, 1–4 December 2003). This report synthesizes the information presented at these workshops (and at a conference on the same topic held in Barbados, 21–22 May 2002) to identify key recommendations for improving the health sector's capacity to anticipate and prepare for climate variability and change.

CLIMATE VARIABILITY AND CHANGE

Often the terms weather and climate are used interchangeably even though they represent different parts of a continuum. Weather is the complex and continuously changing condition of the atmosphere considered on a timescale from minutes to weeks. Climate is typically described by the summary statistics of a set of atmospheric and surface variables, such as temperature, precipitation, soil moisture and sea surface temperature, in a particular region over a particular timescale, usually 30 years. Put more simply - climate is what you expect and weather is what you get.

Climate variability is the variation around the average climate, including seasonal variations as well as large-scale variations in atmospheric and ocean circulation such as the El Niño/Southern Oscillation (ENSO). Climate change operates over decades or longer. Changes in climate occur as a result of internal variability within the climate system and external factors (natural and anthropogenic). Although climate is always changing, over the past 10 000 years it has been both relatively stable and warm. Figure 1 shows the links between weather and climate.

FIGURE 1 LINKING WEATHER TO CLIMATE



Source: Nyenzi, Maldives workshop

Many small island states suffer negative health impacts from current climate variability, particularly extreme weather events. The El Niño/Southern Oscillation (ENSO) cycle is one of Earth's dominant modes of climate variability that affects small island states. ENSO is the strongest natural fluctuation of climate on interannual timescales, with global weather consequences (Glantz 2002; Ebi et al. 2003). An El Niño event occurs approximately every two to seven years. Originally the term applied only to a warm ocean current that ran southwards along the coast of Peru about late December. Subsequently an atmospheric component, the Southern Oscillation, was found to be connected with El Niño events. The atmosphere and ocean interact to create the ENSO cycle; there is a complex interplay between the strength of surface winds that blow westward along the equator and subsurface currents and temperatures. The ocean and atmospheric conditions in the tropical Pacific fluctuate somewhat irregularly between El Niño and La Niña events (which consist of cooling in the tropical Pacific) (Philander 1990). The most intense phase of each event usually lasts about one year. Figure 2 shows the links between ENSO and disease.

Although strongest in the tropical Pacific, changes in sea surface temperature during the ENSO cycle also affect temperature and precipitation over much of the subtropics and some mid-latitude areas (Glantz 1996, Glantz 2002). The impacts of El Niño events vary geographically and their severity varies from event to event. For example, during an El Niño year storm tracks in the Pacific shift to the west and tropical cyclones near the Marshall Islands are 2.6 times more likely than in a regular year (Spennemann & Marschner 1995). Similarly, the number of tropical cyclones observed in the north Australasia cyclone season is related to El Niño events and can be forecast by monitoring an ENSO index in the months preceding the cyclone season (Nicholls 1985).

In addition to cyclones, precipitation patterns change with El Niño and La Niña events. Western Pacific islands may be drier during an El Niño event, while eastern Pacific islands may expect more rain than usual (Ropelewski et al. 1987). These changes can have a strong effect on the health of individuals and populations because of associated droughts, floods, heat-waves and other changes that can disrupt food production (Glantz 2002). For example, the strong El Niño of 1997–1998 led to droughts in the Federated States of Micronesia, Fiji, Papua New Guinea, Kiribati and the Marshall Islands. The weather changes experienced during El Niño events may provide clues to the environmental and health impacts that may be expected with long-term climate change. Since the 1970s, El Niño events have been more frequent, persistent and intense than in the previous 100 years.

Scientists have become increasingly able to predict El Niño events nine months or more in advance. This provides an opportunity to develop early warning systems to prepare for adverse health impacts associated with projected changes in temperature and precipitation.

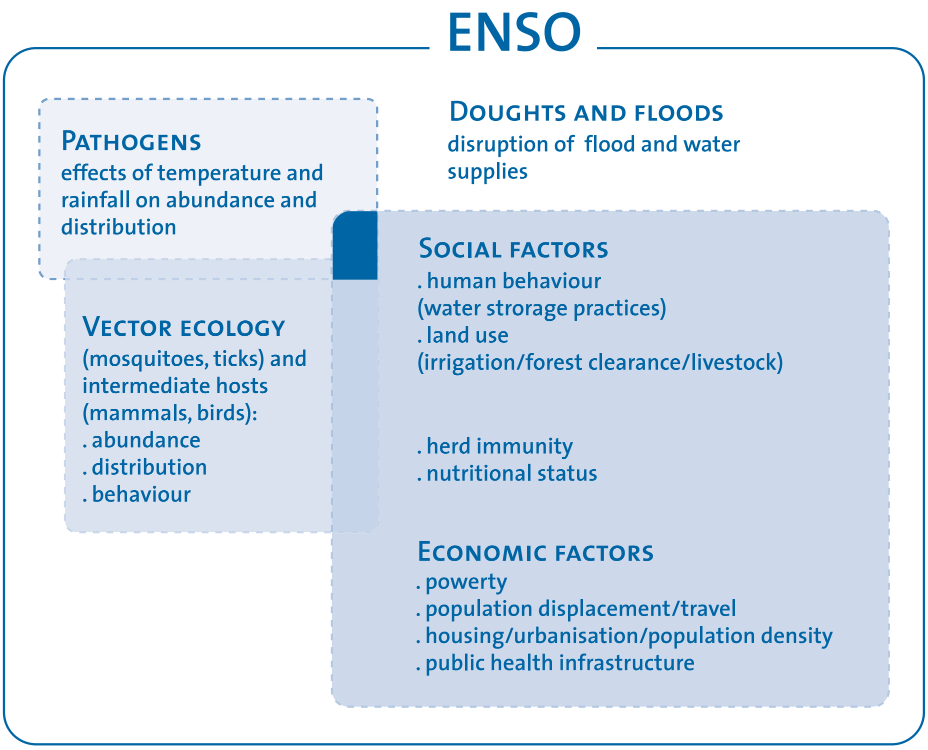
Past climatic trends

The Third Assessment Report of the IPCC summarized climatic changes that occurred over the twentieth century (Nurse et al. 2001). During this time it is likely that precipitation in the northern hemisphere increased by 0.5–1.0% per decade over most of the middle- and high-latitude land areas and decreased by about 0.3% per decade over most of the subtropical land areas (Albritton & Meira-Filho 2001). Precipitation increased 0.2–0.3% per decade over tropical land areas. No consistent changes have been detected in the southern hemisphere.

In small island states' regions, temperatures have been increasing by as much as 0.1 °C per decade and sea level has risen by 2 mm per year. Increases in surface air temperatures have been greater than global rates of warming in areas such as the Pacific Ocean and the Caribbean Sea. For example, based on data from 34 stations in the Pacific from about 160 °E and mostly south of the equator, surface air temperatures increased by 0.3–0.8 °C during the twentieth century (Nurse et al. 2001). Figure 3 shows the percent of days when temperatures exceeded the 90th percentile in the Caribbean over the period 1955-2000.

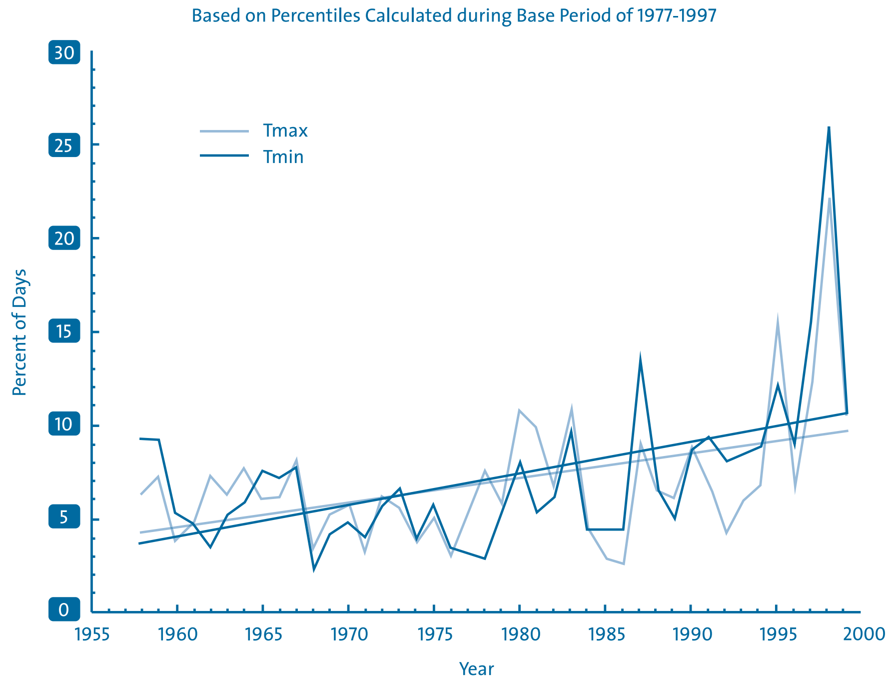
FIGURE 2 **ENSO AND HEALTH IMPACTS**

ENSO events cause physical effects such as droughts and floods (large circle) which may interact with specific ecological and socioeconomic conditions (within dotted lines), and may cause disease outbreaks (dark shaded area).



Source: McMichael et al, 2003

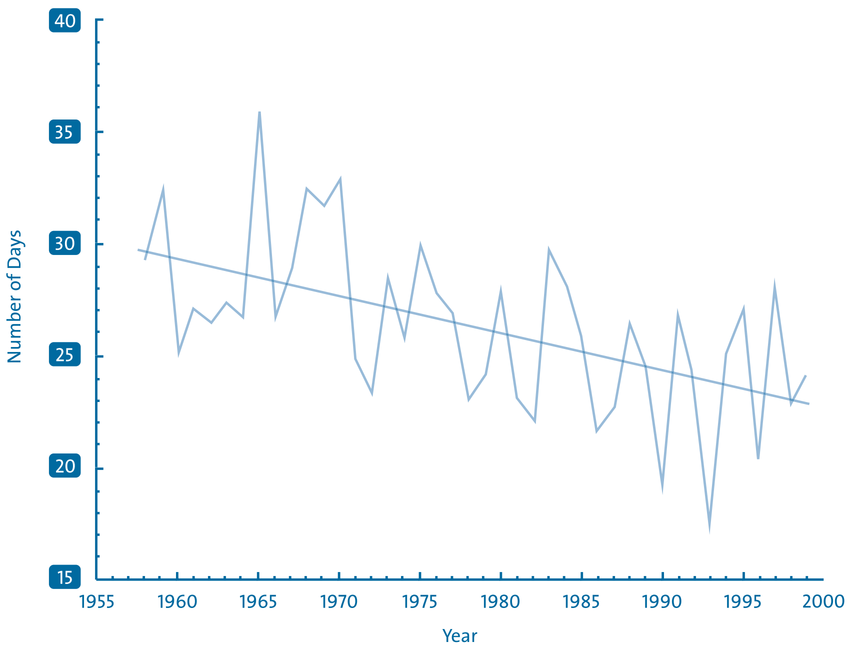
FIGURE 3 PERCENT OF DAYS THAT TEMPERATURE > 90TH PERCENTILE



Source: Taylor, Barbados workshop

The changes in temperature and precipitation observed in the twentieth century are considered to be consistent with patterns related to climate change. In another example from the Caribbean, Figure 4 shows that the maximum number of consecutive dry days decreased over the period 1955–2000.

FIGURE 4 MAXIMUM NUMBER OF CONSECUTIVE DRY DAYS



Source: Taylor, Barbados workshop

Globally, average sea level rose between 0.1 m and 0.2 m. Based on tide gauge data, the rate of global mean sea-level rise was in the range of 1.0 mm to 2.0 mm per year, compared to an average rate of about 0.1 mm to 0.2 mm per year over the last 3000 years (Nichols & Leatherman 1995). For some small islands the limitations of observational records make it difficult to establish clear trends of sea-level change. Some observed changes consistent with global climate change are increased coastal erosion, more saline soils, shifting fishing grounds and more droughts and water shortages.

The best agreement between climate observations and model simulations for global average surface temperatures over the past 140 years was found when both natural factors and anthropogenic forcings were considered (Albritton & Meira-Filho 2001). Further, the IPCC authors concluded that there is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities, and that human influences will continue to change the atmospheric composition throughout the 21st century. Emissions of CO_2 due to fossil fuel burning are virtually certain to be the dominant contributor to the trends in atmospheric CO_2 concentration throughout the 21st century.

Future climate projections

By 2100, atmospheric concentrations of CO_2 are projected to be between 490 ppm and 1260 ppm (75–350% above the concentration of 280 ppm in the year 1750), with the global mean temperature increasing by between 1.4 °C and 5.8 °C (Albritton & Meira-Filho 2001). The projected area-averaged increase in surface air temperature for the 2050s is approximately 2.0 °C for the Atlantic Ocean and Caribbean Sea, 2.0 °C for the Pacific Ocean, 2.1 °C for the Indian Ocean and 2.8 °C for the Mediterranean Sea (Nurse et al. 2001). The projected increase for the 2080s is approximately 3.1 °C, 3.0 °C, 3.2 °C and 4.3 °C, respectively. The increase in surface air temperature is projected to be more or less uniform in both seasons except for the Mediterranean Sea where warming is projected to be greater during the summer. Minimum temperatures are expected to rise more rapidly than maximum temperatures.

Recent trends suggest that surface temperatures in the tropical Pacific are likely to resemble more closely the warmer, El Niño, phase of the ENSO cycle, with the eastern tropical Pacific projected to warm more than the western tropical Pacific. This will shift rainfall eastward.

Precipitation is projected to change only marginally (Nurse et al. 2001). An area-averaged annual mean increase in precipitation of approximately 0.3% for the 2050s and 0.7% for the 2080s is projected for the Pacific Ocean. Greater warming is projected in the tropical Pacific associated with sea surface temperatures increasing more in the eastern than in the western Pacific (Meehl 1997). This could result in long-term changes in precipitation patterns causing drought conditions over Australasia. A marginal decrease in precipitation is projected for the other regions, particularly during the northern hemisphere summer, suggesting reduced water availability (Lal et al. 2002).

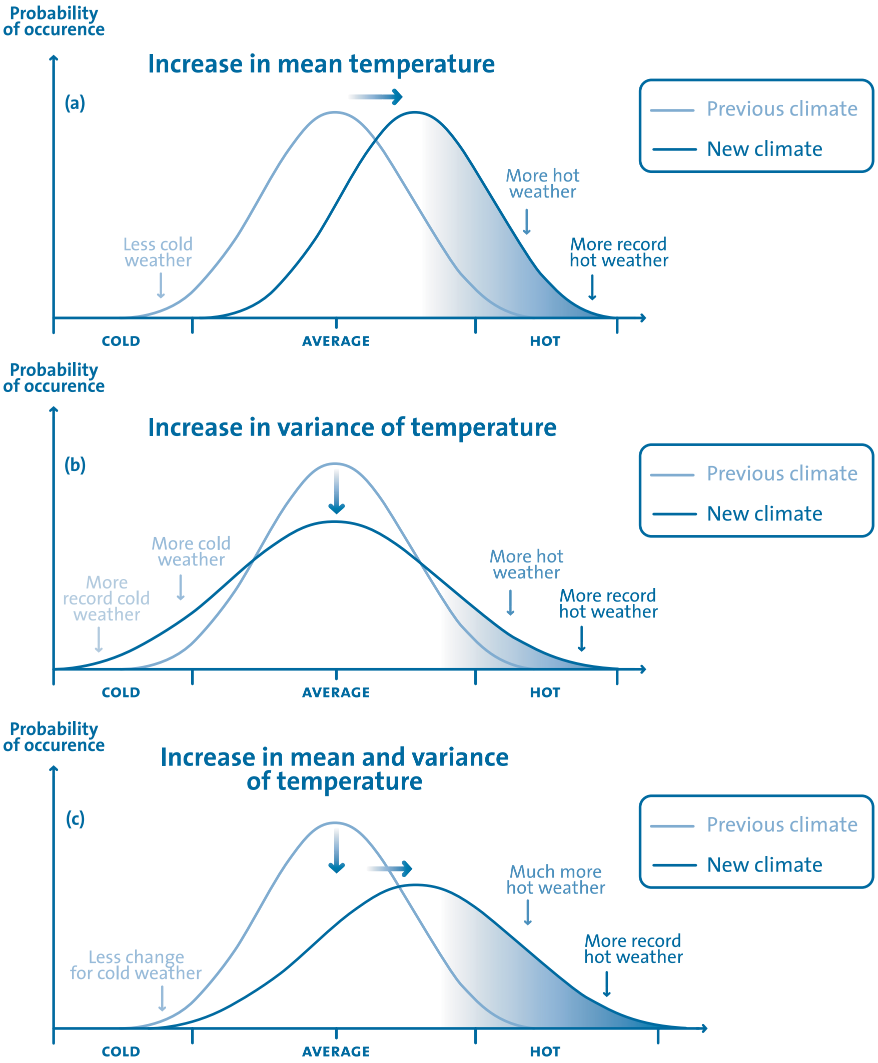
Models suggest that small island states will experience greater climate variability, such as more extreme high temperature and precipitation events (Nurse et al. 2001). As shown in Figure 5, changes in climate variance could result in a large increase in extreme events.

For small island states the consequences of increased climate variability are likely to be related to changes in rainfall, soil moisture budgets, prevailing winds (speed and direction), regional and local sea levels and patterns of wave action. El Niño events are likely to strengthen the short-term and interannual variations. Any changes in ENSO patterns affect precipitation and sea level, with consequences for both Caribbean and Pacific islands. Although there is no consensus regarding the projected formation and behaviour of tropical cyclones in a warmer world, there are indications that their intensity may increase (Royer et al. 1998; Spennemann & Marschner 1995).

Between 1990 and 2100 global mean sea level is projected to rise by 0.09 m to 0.88 m (Albritton & Meira-Filho 2001). This will be due primarily to thermal expansion of the oceans and loss of mass from glaciers and ice caps. Sea levels are projected to continue rising for hundreds of years after stabilization of greenhouse gas concentrations due to the long timescales on which the deep ocean adjusts to climate change.

Regional models need to be developed that are appropriate for, and specific to, particular small island states. For example, sea-level rise will differ between regions because the expansion of water is influenced by temperature and salinity. A rise in sea level could result in saline contamination of estuaries and aquifers, direct inundation of low-lying areas, shore erosion, destruction of coral reefs and fisheries and exacerbation of coastal flooding and storm damage. Table 1 shows trends in climate change for the Caribbean region as estimated by the HadCM3 model under the B2a Standardized Reference Emission Scenario (SRES) (Annex 3 describes these scenarios).

FIGURE 5 CLIMATE CHANGE MAY ENTAIL CHANGES IN CLIMATE VARIANCE



Source: Folland CK, Karl TR, Christy JR, Clarke RA, Gruza GN, Jouzel J, et al. Observed climate variability change. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, Van der Linden PJ, Dai X, et al., editors. Contribution of Working Group 1 to the Third Assessment Report of the Inter-Governmental Panel on Climate Change. New York: Cambridge University Press; 2001. p. 99-187

TABLE 1 TRENDS IN CLIMATE CHANGE IN THE CARIBBEAN REGION AS ESTIMATED BY HADCM3 UNDER THE B2A SRES

	TAVG (C)			SATURATION DEFICIT (mB)			RAINFALL (cm)		
LOCATION	2014	2099	DELTA	2014	2099	DELTA	2014	2099	DELTA
TOBAGO	27.5	28.8	1.3	7.3	7.2	-0.1	119.6	67.6	57%
BRITISH VIRGIN ISLAND	27.4	28.7	1.3	7.4	7.7	0.3	75.4	43.7	58%
NORTH BAHAMAS	27.5	28.8	1.3	7.3	8.5	1.2	147.7	86.3	58%
CAYMAN ISLANDS	28.1	30.1	2.0	9.0	9.7	0.7	139.4	99.3	71%
BARBADOS	27.5	28.7	1.2	7.3	7.3	0.0	91.5	55.5	61%
AVERAGES			1.4			0.4			61%

Source: Presented by Focks, Barbados workshop

Definitions of vulnerability and adaptation

Realistic assessment of the potential health impact of climate variability and change requires understanding of a population's vulnerability and its capacity to respond to new conditions. The terms vulnerability and adaptation are used by the climate change community and are analogous to the concept of prevention used in public health (Yohe & Ebi, 2005). The relationships between vulnerability, adaptive capacity and potential impacts are discussed below and shown in Figure 6.

The IPCC defines vulnerability as the degree to which individuals and systems are susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes (Smit & Pilifosova 2001). Human health's vulnerability to climate change is a function of the following.

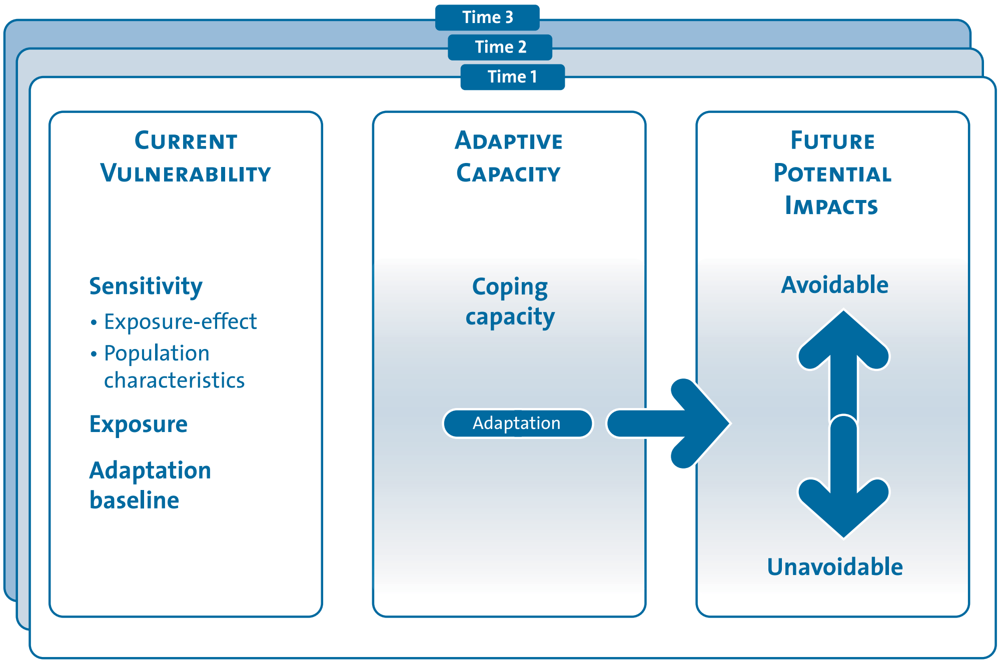
- Sensitivity, including the extent to which health, or the natural or social systems on which health outcomes depend, are sensitive to changes in weather and climate (the exposure–response relationship) and the characteristics of the population, such as the level of development and its demographic structure.
- The exposure to the weather or climate-related hazard, including the character, magnitude and rate of climate variation.
- The adaptation measures and actions in place to reduce the burden of a specific adverse health outcome (the adaptation baseline), the effectiveness of which determines in part the exposure–response relationship (Kovats et al. 2003).

Populations, subgroups and systems that cannot, or will not, adapt are more vulnerable, as are those that are more susceptible to weather and climate variability. In general, a population's vulnerability to a health risk depends on the local environment, level of material resources, effectiveness of governance and civil institutions, quality of the public health infrastructure and access to relevant local information on extreme weather threats (Woodward et al. 1998). Effective targeting of prevention or adaptation strategies requires an understanding of which demographic or geographical subpopulations may be most at risk and when that risk is likely to increase. Thus, individual, community, regional and geographical factors determine vulnerability.

Adaptation includes the strategies, policies and measures undertaken now, and in the future, to reduce potential adverse health effects (Kovats et al. 2003). Adaptive capacity describes the general ability of institutions, systems and individuals to adjust to potential damage, take advantage of opportunities and cope with the consequences. The primary goal of building adaptive capacity is to reduce future vulnerability to climate variability and change. Coping capacity describes what could be implemented now to minimize the negative effects of climate variability and change. In other words, coping capacity encompasses the interventions that are feasible to implement immediately (in a specific population), adaptive capacity encompasses the strategies, policies and measures that have the potential to expand future coping capacity. Increasing the adaptive capacity of a population shares similar goals with sustainable development – increasing the ability of countries, communities and individuals to cope effectively and efficiently with the changes and challenges of climate change.

Specific adaptation interventions arise from the coping capacity of a community, country or region. These interventions, similar to all interventions in public health, are designed to maximize the number of avoidable adverse health effects. Adaptation can be anticipatory (actions taken in advance of climate change effects) or responsive and can include affected individuals' spontaneous responses to climate variability and change as well as planned responses by governments or other institutions. Examples of adaptation interventions include watershed protection policies and effective public warning systems for floods and storm surges, such as advice on water use, beach closures and evacuation from lowlands and seashores.

FIGURE 6 FRAMEWORK FOR VULNERABILITY AND ADAPTATION



Source: Ebi et al., 2005

It is important to identify where populations are unable to cope with current climate variability and extremes such as floods, droughts and heat-waves. This shows where additional interventions are needed now. Improving the capacity to cope with current climate variability will improve the capacity to cope with long-term climate change.

An adaptation assessment describes specific strategies, policies and measures that can be implemented to reduce current and future vulnerability as well as the resources needed (financial, technological and human capital) to implement them. The information generated from an adaptation assessment can be combined with a cost–benefit or other economic analysis to inform priority setting by policy-makers.

Steps in assessing vulnerability and adaptation

The following steps are used to assess vulnerability and adaptation (Kovats et al. 2003).

1. Determine the scope of the assessment: the geographical region, time period and health outcomes to be included.
2. Describe the current distribution and burden of climate-sensitive diseases. Describe the associations between disease outcomes and climate variability and change. If data and resources are available, quantify the relationships using epidemiological methods.
3. Identify and describe current strategies, policies and measures that reduce the burden of climate-sensitive diseases.
4. Review the health implications of the potential impact of climate variability and change on other sectors such as agriculture and food supply, water resources, disasters and coastal and river flooding. Review the feedback from changes in population health status in these sectors.
5. Estimate the potential health impact using scenarios of future climate change, population growth and other factors and describe the uncertainty.
6. Synthesize the results and draft a scientific assessment report.
7. Identify additional adaptation policies and measures to reduce potential negative health effects, including procedures for evaluation after implementation.

The available material and human resources will determine the level at which vulnerability and adaptation may be assessed. A basic assessment can be undertaken using readily available information and data, such as previous assessments, literature reviews and available region-specific health data. Limited analysis of regional health data, such as plotting the data against weather variables over time, may be conducted. Consultation with stakeholders will be fairly limited. The result may produce trends in disease rates, and the effects may be minimally quantified, if at all.

A more comprehensive assessment could include a literature search focused on the goals of the assessment, some quantitative assessment using available data (such as the incidence or prevalence of weather-sensitive diseases), more involvement by stakeholders, some quantification of effects and a formal peer review of results. An even more comprehensive assessment could include a detailed literature review, collecting new data and/or generating new models to estimate impacts, extensive analysis of quantification and sensitivity, extensive stakeholder involvement throughout the assessment process, formal uncertainty analysis and formal peer review.

No matter how comprehensive the assessment, other small island states can identify valuable information about how they have dealt with similar issues. This can be used to identify and prioritize possible adaptation options. For example, the same force hurricane does not have the same impact on each country because of differences in vulnerability, degrees of preparedness, effectiveness of early warning systems, etc.

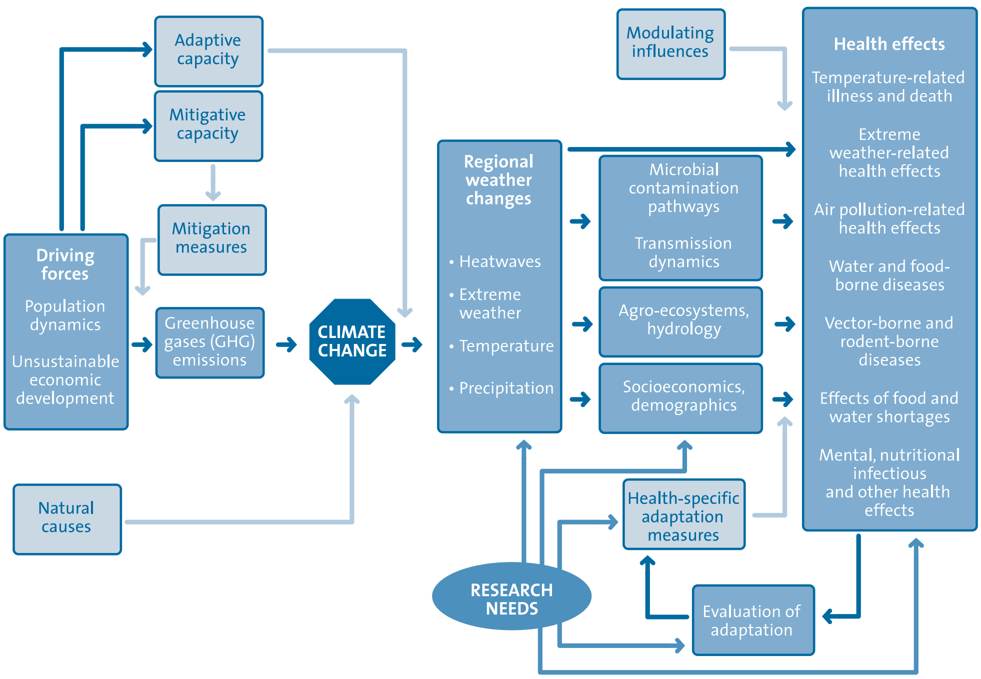
Assessments of the potential health effects of climate variability and change have used a variety of methods. Both qualitative and quantitative approaches may be appropriate depending on the level and type of information available. The outcome of an assessment need not be quantitative in order to be useful to stakeholders. An integrated approach is likely to be most informative because the effects of climate are likely to transcend traditional sector and regional boundaries, with effects in one sector affecting another sector or region's capacity to respond.

Potential health impacts of climate variability and change

Three well-recognized physical consequences of climate change are increasing global average temperature, sea-level rise and extremes in the hydrological cycle. Each can have negative impacts on health. The main categories of the adverse health impacts of climate change have been discussed widely elsewhere (McMichael et al. 2003). They include the direct effects of climatic extremes (thermal stress, weather disasters) and the various indirect effects mediated by climatic influences on vector-, water- and food-borne disease transmission; food and water security; and, more diffusely, the consequences of social and economic dislocation and population displacement. The 1997–1998 El Niño event led to widespread coral bleaching in many regions (Epstein 1999). Figure 7 illustrates some of these potential impacts of climate variability and change.

Potential health impacts of climate variability and change for small island states also include increases in the prevalence of marine biotoxins and damage to coral reefs. Climate-sensitive marine biotoxins, such as scromboid fish poisoning, paralytic shellfish poisoning, diarrhoetic shellfish poisoning, and ciguatera can pose a serious threat, affecting fish, other marine life and human health. Ciguatera is the human poisoning caused by the consumption of certain species of tropical and subtropical marine fish that have accumulated toxins in their diet. Between 1955 and 1983, 96% of the cases of fish toxins affecting humans in Fiji were attributed to ciguatera (Aalbersberg & Saini 2002). Coral reefs are important to the environmental and economic health of many small island states. They not only provide natural breakwaters and a habitat and food source for reef fish and other marine animals, but also contribute to an island's attractiveness as a tourist destination. Many coral reefs are growing in waters where temperatures are at, or near, their thermal tolerance.

FIGURE 7 POTENTIAL HEALTH IMPACTS OF CLIMATE VARIABILITY AND CHANGE



Source: McMichael et al., 2003

A major concern for many small island states is that climate change could alter the frequency and severity of extreme weather and climate events such as cyclones, floods and droughts. Currently many small island states are vulnerable to these events. Droughts and floods adversely affect health directly through injuries and fatalities and indirectly through deterioration of water quality and quantity. More intense storms could lead to coastal inundation. This poses substantial risks for the most vulnerable populations - those who live in substandard housing with already limited food and water sources.

In addition to direct and indirect health impacts of climate variability and change, small island states also face health-related problems due to sea-level rise (McMichael, Maldives workshop). These include, in particular:

- coastal flooding
- exacerbated storm surges
- damaged coastal infrastructure (roads, sewerage systems, etc.)
- salination of island fresh water
- impaired crop production
- damage to coastal ecosystems, coral reefs and coastal fisheries
- population displacement: diverse health risks (nutrition, infection, mental health, etc.).

Estimating the burden of disease from climate change

The global burden of disease attributable to climate change was recently estimated as part of a comprehensive WHO project (WHO 2002; Campbell-Lendrum et al. 2003). This project used standardized methods to quantify disease burdens attributable to 26 environmental, occupational, behavioural and lifestyle risk factors in 2000 and at selected times up to 2030. The disease burden comprises the total amount of disease or premature death within the population. Comparison of the fractions of the disease burden attributable to several different risk factors requires (1) knowledge of the severity/disability and duration of the health deficit; and (2) the use of standard units of health deficit. For this purpose, the project used the disability-adjusted life year (DALY) (Murray 1994), which is the sum of:

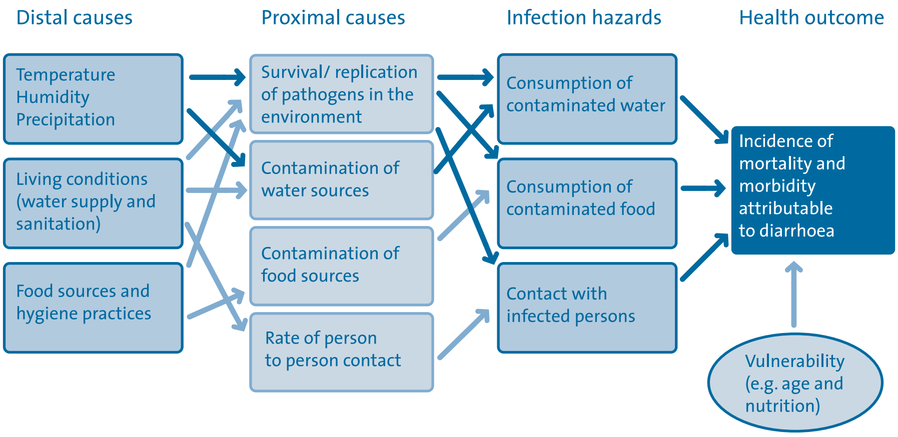
- years of life lost due to premature death (YLL)
- years of life lived with disability (YLD).

YLL takes into account the age at death. YLD takes account of disease duration, age of onset and a disability weight reflecting the severity of disease.

Comparison of the attributable burdens for specific risk factors required knowledge of the (1) baseline burden of disease, excluding the particular risk factor; (2) estimated increase in risk of disease/death per unit increase in risk factor exposure (the relative risk); (3) current or estimated future population distribution of exposure. The avoidable burden was estimated by comparing projected burdens under alternative exposure scenarios.

FIGURE 8 DOES CLIMATE HAVE AN IMPACT ON HEALTH?

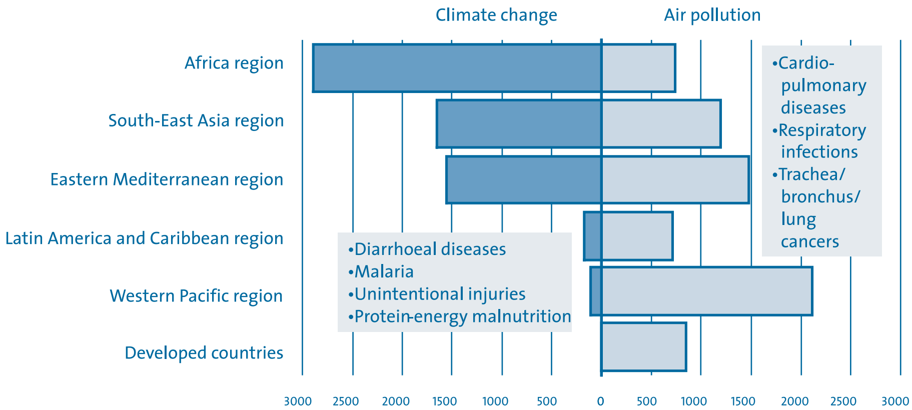
Example: Diarrhoeal diseases



Source: Corvalan, Maldives workshop

FIGURE 9 DOES CLIMATE HAVE A LARGE IMPACT ON HEALTH?

Burden of disease by region: Climate change and urban air pollution
Disability Adjusted Life Year per million. World Health Report 2002



Source: Corvalan, Maldives workshop

The global assessment used WHO estimates of the baseline burden of disease caused by selected climate-sensitive health outcomes (cardiovascular deaths associated with thermal extremes, diarrhoea episodes, cases of malaria, malnutrition and deaths in natural disasters). For example, Figure 8 shows how climate change could affect diarrhoeal diseases.

Existing and new models were used to quantify the effect of climate variations on each of these outcomes (the relative risk), taking into account adaptation to changing conditions and potentially protective effects of socioeconomic development. The HadCM2 climate model produced by the United Kingdom's Hadley Centre gave the population distribution of exposure. This model describes future climate under various scenarios of greenhouse gas emissions. Climate change was expressed as the change in climatic conditions relative to those observed in the reference period 1961–1990.

Disease burdens were estimated for five geographical regions and for developed countries (Figure 9). The attributable disease burden was estimated for 2000 (Campbell-Lendrum et al. 2003). The climate-related relative risks of each health outcome under each climate-change scenario, relative to the situation if climate change does not occur, were estimated for 2010, 2020 and 2030 (McMichael et al. 2004). Inevitably these results are approximate, due partly to the uncertainty associated with climate projections but mainly to the limited understanding of many climate and health relationships. However, the results do give a first indication of the potential magnitude and distribution of some of the health effects of climate change.

Further development of burden of disease methods will allow its application to small island states.

What is the current distribution and burden of climate-sensitive diseases in small island states?

Specific climate-sensitive diseases vary between the small island states. The high priority diseases identified in the workshops include: malaria, dengue, diarrhoeal disease/typhoid, heat stress, skin diseases, acute respiratory infections and asthma, toxins in fish and malnutrition. The possibility of dust-associated diseases associated with the annual atmospheric transport of African dust across the Atlantic, is unique to the Caribbean islands. In addition to weather and climate factors, social aspects such as culture and traditions are important in disease prevalence.

Extreme weather and climate events

Many small island states are particularly vulnerable to tropical cyclones, storm surges, flooding and drought. These events can have both short- and long-term effects on human health. The main health effects include drowning, injuries, increased disease transmission, reduced agricultural productivity and an increased incidence of common mental disorders. Because these potential impacts are complex and far-reaching, the true health burden is appreciated rarely.

A well-studied example is the 1997–1998 El Niño's impact on Pacific nations. In June 1997, the Pacific ENSO Applications Center (PEAC) alerted governments that a strong El Niño was developing, changes in rainfall and storm patterns could be expected, severe droughts could occur as early as December and some islands were at unusually high risk of typhoons and hurricanes (Hamnett et al. 1999). In fact, the region did experience extreme drought, as well as several severe storms. The health impacts were mediated primarily through water availability and the effects on agriculture. Most governments served by PEAC developed drought-response plans and pursued aggressive public-information programmes. Water-management agencies developed conservation plans.

Water rationing was necessary, despite corrective actions such as repairing water-distribution systems. On Majuro, the capital of the Marshall Islands, water was available for only 7 hours over 14 days. In Palau and on Pohnpei in the Federated States of Micronesia, water was available for only two hours a day at the height of the drought. Despite the water shortage in Pohnpei, fewer children were admitted to hospital with severe diarrhoeal disease than under normal conditions, thanks to frequent public-health messages about water safety.

Agriculture was badly affected. Citrus and garden crops were damaged in the Commonwealth of the Northern Mariana Islands. More than 50% of the staple crops of taro and breadfruit were destroyed in the Federated States of Micronesia. The most serious economic loss was kava (Piper methysticum), a major cash crop. Micronutrient deficiencies were found in pregnant women in Fiji, especially on the western side of Viti Levu where the drought was most extreme.

In addition, during the 1997–1998 El Niño, Typhoon Paka hit the Marshall Islands and Guam, followed by wildfires on Guam and in the Federated States of Micronesia. Massive forest fires caused by El Niño-driven droughts raged across the Indonesian island of Sumatra. Air quality was affected in regions beyond the immediate burn areas. People in Yap and Palau thought their air quality was being affected by the Indonesian fires, as well as more local wildfires. More cases of respiratory illnesses and allergy symptoms than normal were reported.

The Caribbean also experiences adverse health impacts from natural hazards (Sempris, Barbados workshop). The common weather-related disasters in the region are hurricanes, tropical storms, flooding, droughts and, in Trinidad, localized tornadoes. In 2000, there were 66 named storm days and 14 named storms, including 8 hurricanes of which 3 were category 3 or higher (there are 5 categories of hurricanes based on wind speed; categories 3 or higher carry higher risks of damage). In 2001, there were 15 named storms, including 9 hurricanes of which 4 were category 3 or higher. There were 48 storm-related deaths in the region that year. In 2002, Tropical Storm Lili was accompanied by 5 to 10 cms of rain in most areas. St. Vincent suffered 4 deaths and agricultural losses of more than US$ 14.8 million. In Barbados, 400 housing units were damaged and the poultry industry lost more than US$ 100 000. The banana industry in St. Lucia lost more than US$ 7.52 million. In May and September 2002, Jamaica experienced major flooding, resulting in 4 deaths, the displacement of 725 persons and infrastructure damage costing more than US$ 1 million.

Extreme weather disasters in the Caribbean produce major threats to human health including:

- deaths and direct injuries including bites from animals;
- insect- and rodent-borne diseases including dengue, leptospirosis, malaria and yellow fever;
- waterborne diseases including schistosomiasis, cryptosporidium and cholera;
- food-borne diseases including diarrhoeal diseases, food poisoning, salmonellosis and typhoid;
- respiratory diseases including asthma, bronchitis and respiratory allergies and infections;
- heat-related illness including sunstroke, sunburn, heat stress, heat exhaustion and dehydration;
- malnutrition resulting from disturbances in food production or distribution; and
- anxiety and stress.

The region is heavily dependent on rainfall to feed surface water intakes and replenish groundwater reserves. Changes in rainfall patterns can have a great impact on water resources. The drought in 2001, for example, had a negative impact on the water resources of all Caribbean nations. At the other extreme, heavy rainfall, severe storms and hurricanes can lead to contaminated water supplies as a result of flooding and heavy runoff carrying agrochemicals, silt and human and animal waste. A recent study by the Caribbean Epidemiology Centre (CAREC) and the Water and Sewerage Authority (WASA) of Trinidad and Tobago found that 18.6% of samples of potable water taken after heavy rainfall events were positive for cryptosporidium. In addition to polluting floodwaters, chemicals and other hazardous wastes can and do contaminate groundwater, with long-term health effects.

Flooding also poses health risks to those consuming food produced in low-lying agricultural areas. This seems to be a perennial problem in some of the agricultural areas of Trinidad. Agrochemicals, metals and untreated or poorly treated waste contaminate runoff that contributes to the contamination of coastal waters, reef fish and shellfish.

While there have been some improvements in recent years, the management of liquid and solid waste in the Caribbean remains largely unsatisfactory. In rural communities, the practice of dumping waste in rivers, streams and ravines is widespread. One of the reasons advanced for the massive flooding in Castries, St. Lucia, after Tropical Storm Debbie in 1994 was waterways clogged with waste.

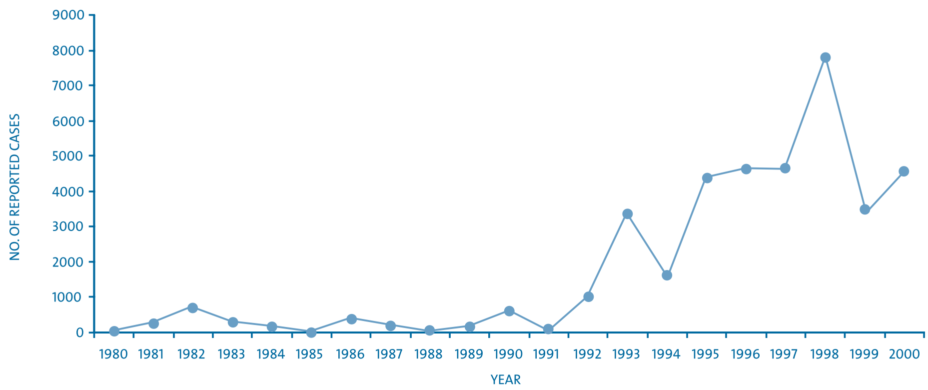
Large portions of the Caribbean population are not serviced by sewage-collection systems but rather depend on individual systems such as septic tanks, soakaways and pit latrines. In times of high rainfall and flooding, storm-water runoff and floodwaters may become contaminated with faecal waste from these systems and can pose serious health risks. This problem was clearly evident in recent years in the central plains of Trinidad.

In Indonesia, El Niño conditions are associated with prolonged dry weather. La Niña conditions cause extremely wet periods resulting in a pattern of long dry seasons alternating with short periods of intense rainfall. In the late 1990s, El Niño and La Niña conditions were associated with outbreaks of malaria, dengue and plague (Achmadi & Speets, Barbados workshop).

Vector-borne and waterborne diseases

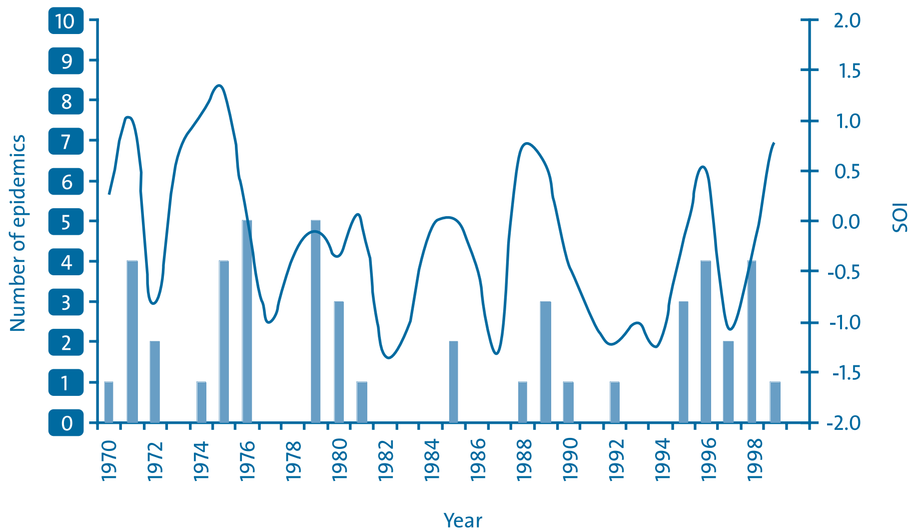
Many vector-borne diseases are sensitive to ambient temperature and precipitation. Even small changes in temperature and precipitation, vegetation, host populations or water availability, may increase or decrease the distribution and abundance of vectors, especially at the margins of their distribution. Many small island states lie in tropical or subtropical zones with weather conducive to the transmission of diseases such as malaria, dengue, filariasis and schistosomiasis. The rates of many of these diseases are increasing in small island states for a number of reasons including poor public health practices, inadequate infrastructures, poor waste management practices, increasing global travel and changing climatic conditions. For example, Figure 10 shows the reported cases of dengue fever by year in all CAREC member countries for the period 1980 to 2000.

FIGURE 10 REPORTED CASES DENGUE FEVER BY YEAR ALL CAREC MEMBER COUNTRIES 1980 – 2000



Source: Hospedales, Barbados workshop

FIGURE 11 DENGUE EPIDEMICS IN SOUTH PACIFIC 1970 – 1999



The line indicates the Southern Oscillation Index (higher SOI is associated with La Niña, lower SOI with El Niño events), the bars indicate dengue epidemics.

Source: Hales, Samoa workshop

Dengue fever

Dengue fever is carried by the domesticated mosquito *Aedes aegypti*. This thrives in urban environments and breeds in artificial containers that hold water. Four dengue viruses cause disease in humans and the incidence is seasonal. Temperature affects the rate at which the virus develops inside the mosquito. Increases in incidence are often associated with warmer, more humid weather (Foo et al. 1985). During El Niño events when temperatures increase, the virus replicates much faster and mosquitoes become infectious more quickly and bite more frequently, thus increasing transmission rates. An epidemic will occur if enough A. aegypti mosquitoes spread the virus effectively and if there are sufficient people who have not had that type of dengue virus before. For example, an outbreak of dengue fever in Fiji coincided with the 1997–1998 El Niño: in a population of approximately 856 000, 24 000 people were affected and 13 died (World Bank 2000). The epidemic cost US$ 3–6 million.

Hales et al. (1999) investigated the relationship between the incidence of dengue fever and El Niño in 14 island nations in the South Pacific. Their research showed that dengue epidemics tended to be initiated during La Niña years, except in 1972 and 1997 when they were initiated during El Niño years. In general, the islands that were wetter and warmer during La Niña events had a greater number of dengue epidemics with some evidence of island-to-island spread. Preliminary evidence suggests that one to two dry months followed by heavy rainfall, possibly during a hurricane or cyclone, increases the likelihood of a dengue outbreak. There are many confounding variables, however, including the immune status of the population and the introduction of various strains of the virus (Figure 11).

In Trinidad and Tobago, an association was found between rainfall and an upsurge in dengue fever (Rawlins, Barbados Workshop). The strongest effect was observed for 1998, an El Niño + 1 year. It was suggested that improper water storage during El Niño years promoted breeding of the vector. High rainfall periods subsequent to an El Niño naturally provide conditions for the larval development of the mosquito vector. Temperature also was a factor because of its influence on the mosquito breeding cycle.

Malaria

Malaria is a growing problem in the Caribbean and in other regions. For example, Figure 12 shows the number of cases of malaria in all CAREC member countries between 1980 and 2000.

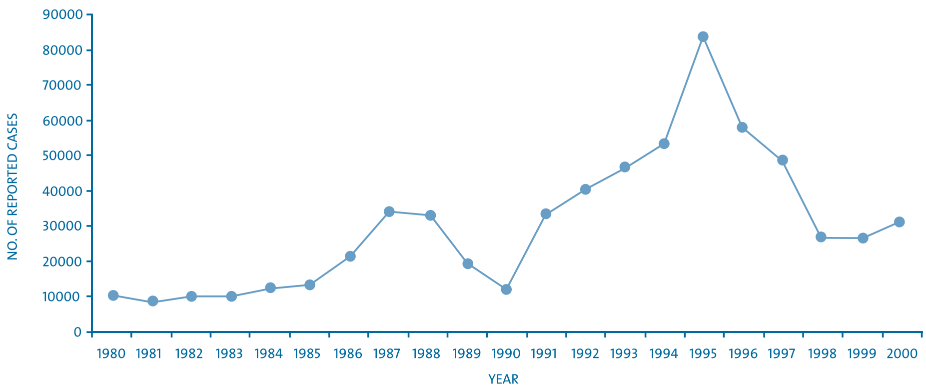
In Nuqui, Colombia a strong association was observed between malaria cases and temperature (Figure 13) but malaria transmission was not associated with either precipitation or humidity. Increases in malaria cases during El Niño events were not associated with vector density or parity of the vector population. An inverse association was found between temperature and larval density, and an association observed between mosquito density and rainfall.

Malaria is the major public-health problem in Sri Lanka. The distribution of *Plasmodium vivax* malaria varies markedly across the country (Briet, Maldives workshop). The incidence of *Plasmodium falciparum* malaria follows a similar spatial pattern but generally has much lower incidence. In the north of the country, malaria occurs in one seasonal peak at the beginning of the year; in the south a second peak around June is more pronounced. The current status of malaria and recent trends are described in detail in "Sri Lanka Malaria Maps" (available at http://www.malariajournal.com/content/2/1/22).

Gill (1936) described the epidemic nature of malaria in Sri Lanka based on data from 1906 to 1934. He found that epidemics in the island occurred at five-year intervals. Gill also analysed the relationship between rainfall patterns and the occurrence of malaria epidemics. For the wet zone of the country, he concluded that a deficiency of rainfall in the spring was favourable for the occurrence of a summer epidemic; a deficiency of rainfall from July to September was favourable for a winter epidemic. In the dry zone, excessive rainfall during the winter was favourable to the occurrence of a winter epidemic. He also suggested that malaria epidemics were closely related to an abrupt rise in atmospheric humidity during the pre-epidemic period. Bouma and van der Kaay (1996) correlated malaria epidemics with the El Niño weather pattern between 1867 and 1943. Epidemics were significantly more prevalent during El Niño years, when the south-west monsoon tends to fail, confirming Gill's findings for the wet zone of the country.

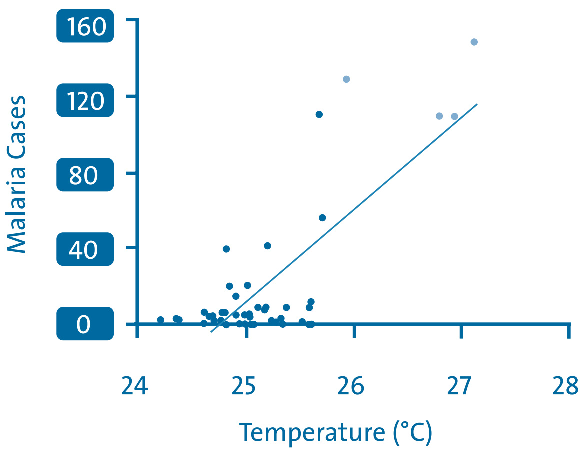
Van der Hoek et al. (1997) correlated monthly rainfall and monthly malaria incidence in Kekirawa, in the northern dry zone of the country, for the period 1979 to 1995. The correlation was weak and significant only when a two-month time lag was observed. The study concluded that the relationship between higher than average seasonal rainfall and higher than average seasonal malaria incidence was not very strong. Despite its statistical significance, the practical relevance of the correlation for planning malaria control seemed limited. This finding is in contrast with Gill's results for the dry zone. However, it is possible that the many environmental changes and malaria-control efforts in Sri Lanka may have affected malaria transmission and local climate conditions enough to weaken and complicate the relationship between rainfall and malaria.

FIGURE 12 REPORTED CASES OF MALARIA (INDIGENOUS) BY YEAR ALL CAREC MEMBER COUNTRIES 1980 – 2000



Source: Hospedales, Barbados workshop

FIGURE 13 RELATIONSHIP BETWEEN CASES OF MALARIA AND TEMPERATURE IN NUGUI, COLOMBIA



Source: Rua, Barbados workshop

Cholera

Cholera is not endemic in the south Pacific, but there is evidence that rising sea surface temperatures may increase the risk of cholera spreading beyond endemic regions (WHO 1999). Indonesia, Malaysia and the Philippines experienced significant outbreaks of cholera during the 1997–1998 El Niño (Epstein 1999). Waterborne diseases such as typhoid, shigella and hepatitis A and E can become more of a problem with flooding and sewage contamination of surface water (WHO 1999). Drought conditions can lead to increased concentrations of pathogens in surface water and increased morbidity and mortality from a combination of diarrhoea and dehydration (Epstein 1999).

Ciguatera

Ciguatera is positively associated with El Niño events in the eastern Pacific islands that experience warmer sea surface temperatures during El Niño events (Hales, Samoa workshop). Small negative correlations were found between the annual incidence of fish poisoning and El Niño events in the western Pacific islands that experience no warming during El Niño events.

Table 2 shows Pearson correlations using January to December annual averages of the SOI, sea surface temperature (SST) and ciguatera fish poisoning reports. Average fish poisoning reporting rates were calculated based on 1994 populations.

What are the potential health impacts of climate change in small island states?

Many small island states currently experience a high burden of disease from climate-sensitive diseases. This suggests that future vulnerability is likely to increase unless public health agencies and authorities take seriously the threat of climate change and begin implementing adaptation policies and measures to increase resilience. There have been few studies of the potential health impacts of climate change under different climate change scenarios. In one study, the Pacific Regional Environment Programme (SPREP) estimated that Fiji's costs for ignoring the potential impacts of climate change would be US$ 5–19 million by 2050. This covered loss of public safety, increased vector- and water-borne diseases and increased malnutrition from food shortages during extreme events, but did not include direct damage from cyclones.

Climate change's potential effects on dengue in the Caribbean were projected using the CIMSiM/DENSiM models and HadCM3 climate projections (Focks et al. Barbados workshop). Results suggested that the temperature-enhanced aspects of the system would be roughly balanced by attenuation due to reduced numbers of larval breeding sites. The conclusion was that climate change is unlikely to influence dengue either positively or negatively in the locations examined. The incidence of dengue in the Caribbean in coming decades principally will reflect the success of vector control programmes and infrastructure changes.

The potential health costs of climate variability and change in Cuba were estimated to be approximately USD 121 million, assuming no adaptation measures are implemented. The costs are summarized in Table 3.

TABLE 2 CORRELATION COEFFICIENTS BETWEEN LOCAL SST AND SOI, FISH POISONING RATES AND LOCAL SST

	LOCAL SST VS SOI	FISH POISONING VS LOCAL SST
TUVALU	-0.76	0.65***
RAROTONGA	-0.51	0.61**
KIRIBATI	-0.93	0.54*
WEST SAMOA	-0.53	0.49*

* Indicate statistical significance

Source: Hales, Samoa workshop

TABLE 3 ESTIMATED HEALTH COSTS (MILLIONS US$) ASSOCIATED WITH CLIMATE VARIABILITY AND CHANGE IN CUBA

PRICES IN US$

DISEASES	INCREASED CASES	COST	HOSPITAL ADMISSIONS	COST TOTAL	COST
ARI	329 976	43.2	98 993	33.8	77.0
ADD	136 423	18.1	40 927	8.0	26.1
VH	10 860	1.4	3 258	1.9	3.3
V	19 200	2.5	-	-	2.5
MD	3 196	-	3 196	2.6	2.6
MD*	11 523	-	11 523	9.2	9.2

ARI = acute respiratory infections;
ADD = acute diarhoeal disease;
VH = viral hepatitis;
V = varicella;
MD = meningococcal disease;
MD* = meningococcal disease with epidemic

Source: Ortiz-Bulto, Maldives workshop.

What interventions are being used to reduce the current burden of climate-sensitive diseases?

Small island states have designed and implemented a variety of strategies, policies and measures to reduce the current burden of climate-sensitive diseases. The following are some of the examples discussed in the workshops. Many of these initiatives recognize that the potential health impacts of climate variability and change do not need to be addressed individually; health outcomes with common risk factors, such as malnutrition and diarrhoeal diseases associated with the dry season, may be reduced together by the development of appropriate interventions.

Most of these initiatives include the development of some form of early warning system to enhance opportunities for disease control. Coupled with effective interventions these can reduce the impacts of weather and climate extremes and of climate-sensitive diseases. The development of early warning systems must be site-specific. For example, some islands affected by El Niño events may experience higher rainfall, others suffer from drought. Also, care must be taken to explain to users that researchers are not predicting an outbreak of a specific disease but rather the conditions that may be conducive for one.

Normal public-health monitoring and surveillance programmes are likely to be disrupted during weather-related disasters. However, the information that is generated through these systems is critical for planning and conducting public-health interventions. In the absence of normal monitoring and surveillance systems, quick and simple monitoring mechanisms must be put in place to provide an early warning of changes in health status and to determine what and where health-care supplies are needed. Both during normal operations and during an emergency, the main areas of focus for monitoring and surveillance systems should be communicable diseases, water and sanitation, food and nutrition and disease vectors.

Early-warning systems typically are based on models developed using weather/climate forecasts, environmental observations and epidemiological data. The models are designed to provide warnings when increased risks could be expected. When increased risks are projected, interventions are undertaken to reduce the possible burden of disease. Evaluation and feedback are used to improve the models. Workshop participants agreed that any small island states need to build the capacity to develop integrated climate and health early warning systems. In addition, it will be important to build institutional, human and scientific capacity for flexible and responsive action.

The text box summarizes hurricane emergency preparedness in Cuba and the United States of America, showing the effectiveness of the Cuban community-based disaster management programme.

Box 1.

Hurricane Emergency Preparedness in Cuba and the United States

Both Cuba and Florida are frequently at risk of hurricanes making landfall, and both governments have set as priorities saving lives when hurricanes threaten. However, Cuba's disaster preparedness strategy has been more effective. Between 1996 and 2002, six major hurricanes hit Cuba and 16 people died. This low mortality rate is remarkable when placed in the context of Cuba's economic crisis, constraints on transportation and other resources, and the almost annual occurrence of a hurricane during the period. By comparison, when Hurricane Isabel hit the mid-Atlantic United States in September 2003, 28 deaths were attributed directly or indirectly to the hurricane. During 11-15 August 2004, Hurricane Charley hit Jamaica, Cuba, and the United States. Four people died in Cuba compared with 31 in Florida. When Hurricane Charley hit Cuba with 105 mph winds, the power grid had already been shut off to avoid accidents, 159 000 animals had been moved to higher ground, and 235 000 people were evacuated.

In Cuba, community-based disaster management is an integral component of a comprehensive national risk reduction program that also includes disaster legislation, public education on disasters, meteorological research, early warning systems, an effective communication system for emergencies, a comprehensive emergency plan, and Civil Defense. The Civil Defense structure depends on community mobilization at the grassroots level under the leadership of local authorities, and widespread participation of the population in disaster preparedness and response measures. The media updates the population on the status of the storm, authorities at the national, provincial, municipal, and local levels implement emergency plans, and communities implement lifeline structures including extensive early evacuation.

In the United States, 18 of the deaths reported from Hurricane Isabel were caused by: (1) people seeking shelter in structures (trailers) that were damaged or destroyed in the hurricane; (2) drowning, many in cars; and (3) traffic accidents amid traffic chaos caused by late evacuation. These deaths were preventable. However, municipalities are not mandated to evacuate when called to do so by national authorities. In addition, once a decision to evacuate is made, there is no enforcement capacity at the municipal level.

Martha Thompson with Izaskun Gaviria, 2004. Cuba weathering the storm: lessons in risk reduction from Cuba. Oxfam America Report. (www.oxfamamerica.org/cuba, accessed 1 November 2004).

Extreme weather and climate events

In June 1997, PEAC alerted the governments of Pacific countries that a strong El Niño was developing, allowing countries time to develop and implement emergency plans to mitigate the impacts (Hamnett et al. 1999). Extensive public education and awareness campaigns were launched to reduce the risk of waterborne diarrhoeal diseases and vector-borne diseases, such as dengue fever. During the severe drought following the 1997–1998 El Niño event, PEAC's early warning allowed islands to repair leaky water distribution systems and water catchment systems, educate the public about water conservation plans, install new household catchment tanks in some areas and procure reverse osmosis. Despite the advanced warning, the nations affected sustained substantial losses through damaged lands and ecosystems, damaged crops and increased costs for importing water and food. The lessons learned from this experience include the following.

- Annual, seasonal and interannual climate forecasting is possible and useful.
- Health and other sector professionals can use climate forecasts and information now.
- There are research and practical challenges to linking health and climate data.
- Spatial and temporal resolution may be the biggest challenge.

Pacific Regional Environment Programme (SPREP)

SPREP is spearheading regional initiatives to address the health impacts of climate change in the Pacific by supporting international negotiations, adaptation in the Pacific, strengthened participation in global observation networks and the formation of a regional climate centre.

Drought in Fiji

A national strategy for drought disaster planning was developed in Fiji during the 1997–1998 El Niño (Atu Kalowmaira, Samoa workshop). First, the drought had to be defined and perceived as a threat. A vulnerability assessment was conducted in order to anticipate problems and concentrate resources where they were needed most. However, there was a lack of information about the past impacts of droughts which may be difficult to recognize because of their slow onset and a tendency for impacts to linger into subsequent years. Threshold criteria and indicators needed to be developed. For example, the drought had an economic impact resulting from a drop of sugar-cane harvest.

Dengue

Focks has developed a dengue simulation model to reduce the risk of an epidemic (Samoa workshop). The model uses actual data from household surveys of the numbers of mosquito pupae, current or anticipated temperatures and seroprevalence rate (to determine how many people are susceptible to a particular type of dengue) to compute a threshold number. Below this threshold the risk of dengue epidemics is low, above it the risk increases. The threshold number decreases as temperature increases, so a climate forecast can be very helpful to alert public health officials to an increased risk of a dengue epidemic when higher temperatures are expected.

Information from the household survey is used to target specific containers to empty or scrub so that the number of pupae per person can be reduced to below the threshold number and avert an epidemic. Certain types of containers regularly have been found to harbour a greater number of pupae in a particular area. In some areas less than 1% of the containers have been found to produce more than 95% of the adult mosquitoes. This targeting of especially productive breeding containers has been found to be more cost effective than insecticides or more traditional source reduction. Control based on eliminating these high-production containers can be initiated in response to an epidemic or a climate forecast of higher temperatures.

Indonesia

Although Indonesia has no national early warning system for disease outbreaks, the Ministry of Health advises all governors to prepare for possible outbreaks of dengue before the rainy season. Every local government carries out regular health-education campaigns urging people to clean up breeding sites for mosquitoes, and hospitals collect data on the incidence of dengue. Climate change means that these precautions are no longer adequate to prevent outbreaks of disease.

Cuba

A model has been developed of the relationship between climate variability and human health in Cuba (Ortiz, Maldives workshop). This work uses complex indices to simulate climate and other processes, including ecological and socioeconomic change. The model uses three global indices of climate variability: the Multivariate ENSO Index (MEI), the Quasi-Biennial Oscillation (QBO) and the North Atlantic Oscillation (NAO). The Climate Center of the Cuban Institute of Meteorology provided meteorological data for 51 stations across the island, including monthly minimum and maximum temperature and precipitation, atmospheric pressure, vapour pressure, relative humidity, days with precipitation, thermal oscillation and solar radiation. Data for 1991–2003 were analysed and results compared with a base period 1960–1990.

The Ministry of Health provided epidemiological data, including the incidence of acute respiratory infections, acute diarrhoeal disease, viral hepatitis, varicella (chicken pox), meningococcal disease, streptococcal pneumonia, viral meningitis, malaria and dengue. Ecological data include the larval density and biting density per hour of mosquito vectors, as well as the number of houses where larval activity was observed. Socioeconomic data include the percentage of houses without potable water, the percentage of houses with dirt floors, the adult (age 16 and above) illiteracy rate, monthly birth rates and a monthly index based on the number of houses where a focus of Aedes aegypti mosquitoes was observed.

The model provides three indices: inter-monthly seasonal and inter-seasonal variation in climatic factors; interannual and decadal variability in the same climatic factors; and variations in socioeconomic indicators as they affect the risk of an epidemic outbreak, summarized as quality of life at individual level and state of poverty at community level. These indices were used to characterize climatic variation by region, to build maps of climatic risk across the country and to determine periods of high risk for various diseases. In addition to expected disease incidence, the model provides estimates of the economic costs of disease outbreaks attributable to climatic factors.

The model can provide decision-makers with a tool to help anticipate climate variability's effects on disease incidence. The monthly climatic outlook for November 2003 to March 2004, for example, suggested lower than normal risk of bronchial asthma; more frequent epidemic outbreaks and a change in the seasonal distribution of acute respiratory disease; displaced epidemic outbreaks and increasing risk of acute diarrhoeal disease; more frequent epidemics of viral hepatitis; displaced outbreaks of chicken pox; higher risk of meningococcal diseases; and large populations of *Aedes aegypti*, the vector for dengue.

What additional interventions are needed to adapt to current and future health impacts?

As the workshops highlighted, policies and measures are needed immediately to reduce the burden of climate-sensitive diseases. For example, in his presentation at the Maldives workshop Gopaul identified the following requirements.

- Capacity to detect, recognize, monitor and assess/study the threats to human health.
- Capacity to respond appropriately to these threats and their underlying causes.
- Health and illness monitoring systems, such as the Caribbean Surveillance System (CARISURV), to allow improved detection and response to threats.
- Strengthening of the national and regional capacity to monitor and respond in a sustainable manner, including the integration of health and environment surveillance systems.

The capacity to undertake vulnerability assessments and develop adaptation policies and measures requires information on the impacts of climate variability and change at local and regional levels. This information must include a comprehensive perspective from multiple sectors, such as health and agriculture. Understanding the vulnerability of the environment and of human society is as critical as understanding climate. Often decision-making is driven by short-term concerns and policy-makers primary focus is likely to be climate variability rather than long-term climate change. The development of regional mechanisms would facilitate the exchange of information between National Ministries of Health, other relevant agencies and stakeholders.

Interventions for reducing the health impacts of climate variability include effective health education programmes, improvement of health care infrastructures, disaster preparedness plans, vector monitoring and control and appropriate sewage and solid-waste management practices. The ability to predict climate variations on a seasonal or interannual scale presents communities with the opportunity to develop the capacity and expertise to deal with climate variability. This will also help them to prepare for the effects of climate change.

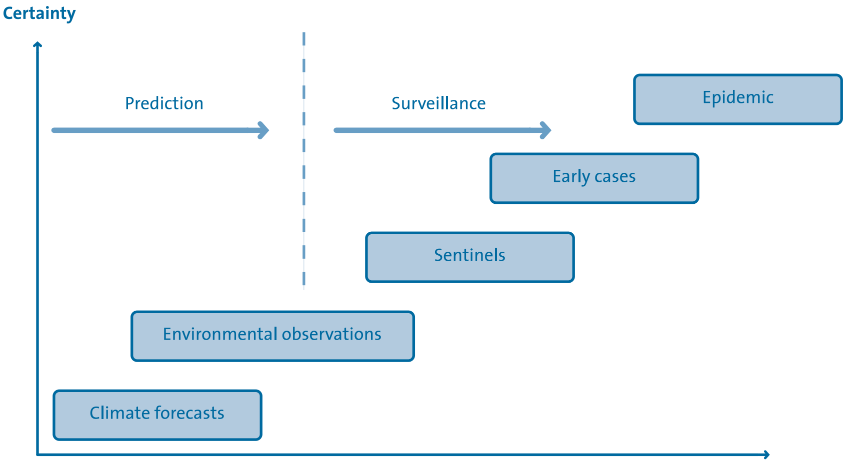
As discussed earlier, an important intervention that is gaining interest is the development of early warning systems based on climate forecasts and environmental observations. Figure 14 illustrates the degree of certainty associated with data from prediction and surveillance activities. Climate forecasts and ongoing environmental observations can be combined with knowledge of disease etiology to create disease early warning systems. Effective early warning systems can be used to inform surveillance systems to help reduce the impact of an epidemic. Components not illustrated in this figure include the development of appropriate response strategies, design of strategies for public dissemination of early warning information and the development of mechanisms for evaluating the effectiveness of early warning systems.

Examples of interventions discussed in the workshops include the following.

Extreme weather and climate events

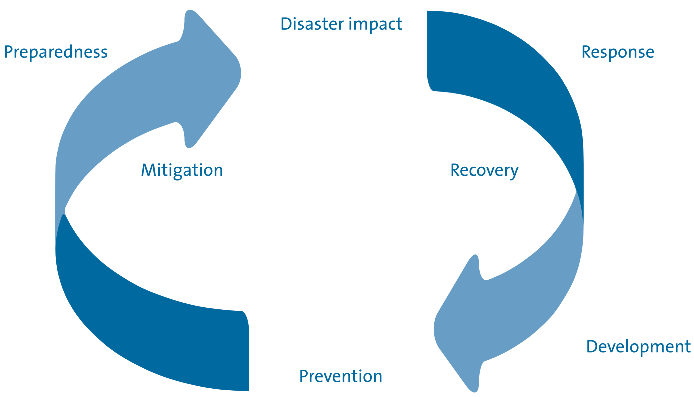
Weather-related disasters' impacts on human health can be direct, indirect, multiple, simultaneous and significant. This poses major challenges to governments, policy-makers, decision-makers and resource managers. Hazard or risk mapping can be useful for the development of a disaster management plan. This could include areas of important food sources, water sources, areas prone to inundation, coastal areas at risk of degradation, population centres and other areas determined to be important or at risk. Figure 15 shows the disaster management cycle for extreme weather events - from impact, through response, recovery and development to prevention, mitigation and preparedness.

FIGURE 14 TASKS IN PREDICTION AND SURVEILLANCE



Source: Pulwarty, Barbados workshop

FIGURE 15 DISASTER MANAGEMENT CYCLE FOR EXTREME WEATHER EVENTS



Source: Pulwarty, Barbados workshop

As an example, Pulwarty described the following tasks in developing a disaster management plan in the Caribbean.

- Document the seasonal calendar of planning activities and associated decision-making in different sub-systems.
- Undertake planning, information gathering, forecasting, implementation and evaluation to identify appropriate entry points for information.
- Clearly document single historical events of significance and evaluate the contexts in which decision-making occurred.
- Include lessons learned and incorporated, particular ENSO years, non-ENSO related outbreaks and analogues.
- Evaluate decisions within the contexts of longer-term climate variations (beyond ENSO, such as responses during 3-10 year period of drought, etc.).
- Clarify fundamental features and knowledge gaps in the relationship between climate and respective disease.
- Treat the development, communication and use of climate and other research-based information as a process where symmetrical learning takes place between providers of information, practitioners and the public.

To manage the potential health impacts of extreme weather and climate events in the Caribbean, Caricom EHI recommends establishing monitoring and surveillance systems, creating an enabling environment, strengthening the public health infrastructure and promoting research, awareness and education. Adaptation options for Cuba include continuing the programmes of environmental education, improving water systems, strengthening surveillance systems, designing infrastructure to reduce impacts, strengthening vaccination programmes and understanding of the associations between climate variability and health.

Water

Water may be an island's most precious resource. Climate change may cause more frequent episodes of water supply extremes and a number of measures will be necessary to protect water resources. Timely, site-specific, reliable forecasts of impending droughts and floods that are rapidly disseminated to water resource managers and disaster planners are needed. Better management of the demand for water, water storage and water loss prevention will help conserve supplies during times of drought. More vigilant monitoring of water quality will be required.

Sea-level rise

Strategies for adaptation to sea-level rise fall into three main categories: retreat, accommodate and protect. Retreat indicates the planned abandonment of land to reduce risk and minimize the loss of associated infrastructure (Nicholls & Leatherman 1996). In the Pacific islands, this could mean abandoning some low-level islands or, if available on the same island, abandoning low-level areas and moving to higher ground. Accommodation suggests changing land use as water levels rise, such as raising buildings or changing to more salt-tolerant crops. Protection often uses constructed barriers to keep the sea away from coastlines (Nicholls & Leatherman 1996). Approaches can use hard structures such as sea walls and breakwaters, or softer options such as the use of vegetation to stabilize beaches (Watson et al. 1996). Adding sand and stone to existing beaches or raising the height of some coastal villages may be useful in some places (Nicholls & Leatherman 1996). Precautionary approaches include the enforcement of enlarged building setbacks, land-use regulations and building codes (Watson et al. 1996).

FIGURE 16 Climate influence (warm wet season)

climate and water supplies

CLIMATE INFLUENCE

- Tropical oceanic climate with distinct seasons
- Two seasons

Warm wet season

- Around November to April.
- Season infested with tropical cyclones - abundance of water.
- Threats of water damage - floods are common.
- Up to 80% of annual total rainfall.
- Up to 25% of annual total rainfall can fall in one storm (over several days).

Excessive water creates other problems.

- taxes water treatment facilities - excessives contamination - health risk, threat to food security, landslides, environmental damage.

Source: Raj, Samoa workshop.

FIGURE 17 Climate influence (cool dry season)

climate and water supplies

CLIMATE INFLUENCE

Cool dry season

- Around May to October.
- In rain deficient period usually leeaward side of islands more deficient.
- 20% to 30% of annual rainfall over 6 months.
- Higher water demand for cultivation season, high tourist arrivals, agricultural product processing.
- Over exploitation of groundwater.

Water deficiency creates other problems.

- Depleting storage - problems with supply systems (airlocks).
- Contamination risk increases: health risk, food production declines, forest fires and environmetal damage
- Salinity problems with coastal groundwater sources and contamination from wastes.

Source: Raj, Samoa workshop.

Agriculture

Adaptations to reduce crop failures and the resulting food shortages in the medium- to long-term include crop breeding to select species better equipped to handle the lower-water, higher temperature conditions; growing different crops or species that survive better under adverse conditions; and improved soil-building techniques (Watson et al. 1996).

What are the health implications of climate variability and change in other sectors?

Climate change will interact with and exacerbate other factors that contribute to the vulnerability of a particular region. These interactions were highlighted in the following examples from the workshops.

Water

Many small island states rely on a single source for their water supply, such as groundwater, rainwater, surface reservoirs or shallow wells that draw from freshwater lenses just beneath the surface (Meehl 1996a). These sources are climate sensitive and changes in precipitation or rising sea levels will present challenges to public health. For example, the freshwater supplies of almost all Pacific islands are threatened during times of drought. Rising sea levels can result in salinity intrusion into the freshwater lens (Meehl et al. 1996b). Climate's influence on water supplies in Pacific islands, which generally experience two distinct seasons, is summarized in figures 16 & 17. It may not be possible completely to protect water sources from adverse effects of climate variability and change, but the management of water resources can be improved.

Agriculture

Farming of subsistence food crops and crops for export may be adversely affected by: changes in precipitation; rising temperatures causing heat stress to plants; salinization resulting from sea-level rise; and extreme weather and climate events, such as cyclones, floods or droughts. For example, El Niño changes in 1991 and 1994 caused widespread rice crop failures in Indonesia (Buan et al. 1996). Approximately 50% of the rice and corn crop losses in the Philippines were due to climate variability, primarily cyclones and floods but also droughts. Almost all of the islands in the Pacific sustained crop damage and loss of both food and cash crops during the drought following the 1997–1998 El Niño, including (Hamnett et al. 1999):

- Pohnpei: over half of the banana trees died or were seriously stressed
- Yap: taro losses were estimated at 50-65%
- the Marshall Islands: supplies of relief food were required from January 1998 after Typhoon Paka's impact; other islands didn't require relief food until May, during the drought.

Fisheries

Already habitat loss and over-exploitation have stressed fisheries in many locations. In addition, breeding grounds for many fish and shellfish are located in shallow waters near coasts where mangrove forests, coral reefs, seagrass beds and salt ponds are likely to be affected by climate change (Watson et al. 1996).

Coral reefs

Coral reefs are an integral part of many island ecosystems. They are likely to experience adverse effects from a range of climate change related events such as increases in seawater temperature, sea-level rise, changes in storm patterns and coastal currents, changes in rainfall patterns and additional pressures from nearby cities and settlements (Watson et al. 1996). Coral reefs can recover from brief episodes of warmer water but prolonged periods (greater than 6 months) of increases in seawater temperature results in irreversible bleaching (Brown & Suharsono 1990). For example, during the 1982–1983 El Niño, sea surface temperatures in the Caribbean exceeded 29 °C and led to extensive coral bleaching throughout the Caribbean. The coral reef surrounding Jamaica experienced several stresses that resulted in its total collapse. These stresses included previous over-harvesting of reef fish that clean the reef of unwanted algae and detritus; widespread coral bleaching; the proliferation of algal populations associated with waste runoff from the island; and the simultaneous disease and die-off of the sea urchins that normally clean the bottom of the reef and remove macroalgae (Lessios 1984). The entire island ecosystem was affected, the reefs and fish populations still have not recovered, resulting in extended losses in food, tourism and the economy (Epstein 1998).

The most important feature of the Maldives' physical environment is the coral reefs that surround the islands (Ali, Maldives Workshop). These reefs play a role in the physical preservation of the islands and in fisheries, tourism, local traditions and culture. In 2000, tourism provided 33% of the Maldives' gross domestic product (GDP); the fishing industry provided 6%. The reefs are the main attraction for tourism and provide fish for consumption and export as well as bait for the tuna fishery. Stress on the reefs originates from dredging, coral and sand mining, harbour construction, construction of sea walls and jetties, reclamation and island-based pollution. Global sources of stress include climate change, El Niño conditions, ozone depletion and sea-level rise. Stress on the reefs threatens fresh water and other natural resources and island communities become more vulnerable to natural disasters.

Others

Over-exploitation of resources, decreasing freshwater supplies, urbanization, pollution, rapid population growth, changes in social structure and the effects of economic globalization all decrease the coping and adaptive capacity of populations in small island states (Klein & Nicholls 1999). In addition, dependency leads to a sense of fatalism and enhanced vulnerability (Woodward et al. 1998). For example, many small island states must rely on larger nations to provide and interpret weather data. Therefore, one step in reducing vulnerability to climate variability and change would be for small island states to acquire the skills and technology needed to make effective use of, and share, data collected in and pertinent to their region.

Like other small island developing states, the Maldives is losing market preferences, export benefits, preferential borrowing rights and access to special funds (Ali, Maldives Workshop). Economic threats include trade blocks, regional associations, phytosanitary restrictions and ecolabelling requirements that limit commerce in the few products potentially available for export. The result is a situation of compounding vulnerabilities: environmental vulnerability hastens economic vulnerability and both contribute to increased social vulnerability.

Recommendations

The workshops identified a variety of recommendations that can be grouped into: enhance awareness of the potential impacts of climate variability and change; enhance the development of adaptation strategies, policies and measures to reduce potential impacts; data needs; high priority research questions; capacity building (including institutional needs); climate forecasts; and resource needs.

Enhance awareness of the potential impacts on human health of climate variability and change

- Build awareness of the potential impacts of climate variability and change in small island states across the full range of stakeholders, including local communities and the media.
  - Educate young people and medical/health professionals about climate/health links through school and university curricula.
  - Work with policy-makers to enhance awareness of climate variability and change and to catalyse discussions at national and regional levels.
- Incorporate a consideration of climate/health interactions in planned and ongoing development programmes. Include health aspects in global, regional and local environmental and disaster-management planning.
  - Advocate for integrated policy development across sectors to take account of the effects on health of climate variability and change.
- Develop advocacy messages in brief, non-technical language for decision-makers and policy audiences.
  - Ensure that advocacy messages reach key decision-makers and policy audiences through appropriate channels and formats.

Enhance development of adaptation strategies, policies and measures to reduce potential impacts

- Develop, improve, implement and monitor early-warning systems.
- Monitor and evaluate the effectiveness of other public health interventions implemented to address the health impacts of climate variability and change, including integrated pest management.
- Develop long-term adaptive strategies for sea-level rise, based on an understanding of current coping efforts and national development priorities.
- Assess the costs and benefits of intervention options.

Data needs

- Collect more valid and comprehensive health, meteorological, environmental and socioeconomic data at appropriate local, regional and temporal scales for research, programme planning and advocacy.
  - Conduct inventories of existing data, identify current data gaps and develop strategies to fill them.
  - Improve health surveillance systems to allow assessment of the impacts on health of climate variability and change.
- Establish better data-management systems, programmes and practices, including the

establishment of data-quality standards and best practices.

- Identify, engage and enhance appropriate national and regional institutions for handling and analysing data.
- Encourage fuller use of available data through regional and national capacity building (human resources, information technology, etc.).
  - Improve sharing and timely access to relevant data sets.

High priority research questions

- Expand knowledge of climate-sensitive diseases of importance in small island states through national and regional research.
  - Research is needed particularly for diseases about which information is limited, such as skin, respiratory and waterborne diseases.
  - Identify and map locations, hazards and communities especially vulnerable to climate variability and change, including sea-level rise, taking a holistic, cross-sectoral view.
  - Establish verifiable links between ENSO, extreme weather events, climate variability and health consequences in small island states.
- Conduct basic entomological research, including the distribution of vector species, their habitats, biting habits and responses to climate variability.
- Improve understanding of the complex relationship between the risks posed by climate variability and change, and by other factors that influence population health.
  - Expand knowledge of the social, cultural and economic factors that modify vulnerability.
- Develop and evaluate indicators of the potential health impacts of climate variability and change at the national and regional level.
  - Incorporate environmental, social and human dimensions.
- Understand the links between climate and other sectors, such as agriculture and water supply, and how these could impact on health.

Capacity building (including institutional needs)

- Develop institutional arrangements for knowledge-sharing at national, regional and international levels.
  - Identify regional centres of excellence and promote national and regional interdisciplinary working groups to study the impacts on health of climate variability and change.
  - Develop effective mechanisms for information sharing.
- Improve education and training through workshops, follow-on networking and structured training at local, national and regional levels.
- Encourage programmes of action and partnerships between public and private sectors including business and nongovernmental organizations.
- Transfer knowledge of adaptation options to countries with similar climate/health concerns.

Climate forecasts

- Develop and improve national and regional forecasting capacities.
- Create partnerships between climate/meteorology and public health/medical specialists to improve awareness of the use and uses of climate forecast information.
  - Provide user-friendly forecasts and applications information at national and regional levels.
- Facilitate communication between the public health/medical communities and national meteorological and hydrological services, other relevant agencies and organizations.

Resource needs

- Improve international, national and regional facilities and funding for capacity building, interdisciplinary research and regional/national assessments.
  - Establish programmes with WHO, WMO and UNEP in collaboration with other relevant agencies to provide country assistance in conducting vulnerability and adaptation assessments.
  - Ensure that adequate funding is made available, from both the public and private sectors, for priority research on climate and health.
- Mobilize funding through all available mechanisms, including the Programme of Action for the Sustainable Development of Small Island Developing States (Barbados Programme of Action), the UN Framework Convention on Climate Change (UNFCCC), the Global Environmental Facility (GEF), the UN Convention on Biological Diversity and the UN Convention to Combat Desertification.

CONCLUSIONS

Small island states are likely to be the countries most vulnerable to climate variability and long-term climate change, particularly extreme weather and climate events (such as cyclones, floods and droughts) and sea-level rise. As stated in the Madang Commitment Towards Healthy Islands, small island states also are places where children are nurtured in body and mind, environments invite learning and leisure, people work and age with dignity, the ecological balance is a source of pride and the ocean is protected (WHO 2001). Increasing understanding of the potential health impacts of climate variability and change in small island states and building capacity to cope with climate change through adaptation planning will help to ensure that these states will be prepared to deal with what the future does bring.

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Glossary

Adaptation is the strategies, policies and measures undertaken now and in the future to reduce potential adverse health impacts.

Adaptive capacity describes the general ability of institutions, systems and individuals to adjust to potential damages, take advantage of opportunities or cope with the consequences of climate change in the future.

Attributable burden is the reduction in current disease burden that would have been observed if past levels of exposure to a risk factor had been reduced to zero. The attributable burden is the attributable risk multiplied by the disease burden.

Attributable risk is the proportion of disease burden in an exposed population that can be attributed to a specific risk factor.

Climate is the average state of the atmosphere and the underlying land or water in a specific region over a specific timescale.

Climate change is defined as a statistically significant variation in either the mean state of the climate or its variability, persisting for an extended period (typically decades or longer).

Climate-sensitive disease is a disease that is sensitive to weather or climate factors, with the current spatial distribution and seasonal transmission being affected.

Comparative risk assessment is defined by WHO as the systematic evaluation of the changes in population health that result from modifying the population's exposure to a risk factor or a group of risk factors.

Coping capacity describes the ability to implement new strategies, policies and measures to minimize potential damage from climate variability and change.

Environmental burden of disease is the burden of disease caused by environmental factors estimated using methods described by WHO.

Vulnerability is defined as the degree to which individuals and systems are susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes.

Weather describes the day-to-day changes in atmospheric conditions in a specific place at a specific time. More simply, climate is what you expect and weather is what you get.

ANNEX 1 **TABLE 1** **DEMOGRAPHIC, HEALTH AND ECONOMIC INDICATORS IN SMALL ISLAND STATES**

Small island state	Population: Thousands	Population: 0-14 years (%)	Population: % urban	Population: HALE* (At birth)	Expectation of lost healthy years at birth (years): Males	Expectation of lost healthy years at birth (years): Females	Probability of dying per 1000 (under age 5): Males	Probability of dying per 1000 (under age 5): Females	Annual growth rate (%) 1992-2002	GDP (per capita US$)
Africa										
CAPE VERDE	454	39.0	62	60.8	7.9	10.0	42	30	2.2	1259
COMOROS	747	43.0	33	54.6	7.8	9.6	80	72	3.0	278
MAURITIUS	1 210	25.6	43	62.4	8.1	10.9	20	14	1.1	3779
SAO TOME AND PRINCIPE	157	47.0	47	54.4	7.5	9.0	80	82	2.6	312
SEYCHELLES	80	39.0	64	61.2	9.6	12.3	15	10	1.0	7850
Asia and the Pacific										
BAHRAIN	709	27.0	92	64.3	7.9	10.1	13	10	3.0	12012
COOK ISLANDS	18	+	59	61.6	8.6	11.5	21	19	-0.2	4388
FIJI	831	33.0	49	58.8	7.7	9.7	30	27	1.2	2046
KIRIBATI	87	+	39	54.0	9.5	11.0	80	69	1.5	468
MALDIVES	309	37.8	27	57.8	7.5	9.0	38	43	3.0	1806
MARSHALL ISLANDS	52	49.0	72	54.8	7.2	8.9	46	36	1.3	1938
MICRONESIA, FEDERATED STATES OF	108	44.0	28	57.7	7.9	9.6	63	51	0.7	2215
NAURU	13	+	100	55.1	6.9	9.0	18	12	2.5	2500
NIUE	2	+	+	60.4	8.6	11.3	38	24	-1.2	+
PALAU	20	+	72	59.6	7.7	10.4	24	22	2.3	6179
PAPUA NEW GUINEA	5 586	40.0	13	51.9	7.0	9.1	98	92	2.6	545
SAMOA	176	41.0	22	59.7	7.6	9.4	27	21	0.8	1402
SINGAPORE	4 183	21.2	100	70.1	8.6	10.4	4	3	2.8	20544
SOLOMON ISLANDS	463	45.0	20	56.2	8.3	10.3	86	75	3.2	760
TONGA	103	39.0	38	61.8	8.2	9.6	23	15	0.3	1284
TUVALU	10	41.0	52	53.0	7.0	8.3	72	56	1.4	1342
VANUATU	207	42.0	20	58.9	8.0	9.8	40	40	2.7	1085
Europe										
CYPRUS	796	22.0	57	67.6	8.8	10.6	7	7	1.2	11504
MALTA	393	19.0	91	71.0	6.2	8.0	7	6	0.7	9245
Latin America & the Caribbean										
ANTIGUA AND BARBUDA	73	28.0	37	61.9	8.9	10.3	22	18	1.2	10204
BAHAMAS	310	29.0	89	63.3	8.1	9.5	13	11	1.5	14856
BARBADOS	269	20.0	50	65.6	7.6	9.8	17	15	0.4	9255
CUBA	11 271	20.0	75	68.3	7.9	9.8	8	7	0.4	2545
DOMINICA	78	33.0	71	63.7	9.1	10.2	13	14	0.7	3367
DOMINICAN REPUBLIC	8 616	32.0	65	59.6	7.7	9.6	37	30	1.7	2500
GRENADA	80	+	38	59.2	7.5	8.9	25	21	-0.5	4682
HAITI	8 218	39.0	36	43.8	5.6	6.9	138	128	1.4	431
JAMAICA	2 627	31.0	56	65.1	6.9	8.6	16	14	0.9	2990
SAINT KITTS AND NEVIS	42	30.6	34	61.5	8.7	9.1	20	24	0.0	6396
SAINT LUCIA	148	32.0	38	62.7	8.6	10.2	14	15	0.9	4994
SAINT VINCENT AND THE GRENADINES	119	37.0	55	61.0	7.9	9.8	25	20	0.6	1940
TRINIDAD AND TOBAGO	1 298	23.0	74	62.0	7.3	8.6	24	18	0.5	6817

+ Data missing; Sources: World health report 2002; World statistics pocketbook: small island developing states 2003.
* HALE= Healthy life expectancy

ANNEX 1 TABLE 2 ENVIRONMENT AND CLIMATE INDICATORS IN SMALL ISLAND STATESATES

Small island state	CO^2 emission (000s Mt)	Energy consumption per capita (kg oil equivalent)	Annual minimum temperature	Annual maximum temperature	Annual precipitation (mm)
Africa					
CAPE VERDE	121	108	23.5*	29.3	70
COMOROS	66	38	21.2	29.5	2700
MAURITIUS	1704	680	20.2	26.9	1793
SAO TOME AND PRINCIPE	77	226	23.3**	28.6**	1040**+
SEYCHELLES	198	893	23.9	31.0	2172
Asia and the Pacific					
BAHRAIN	14847	12889	14.1	38.0	72
COOK ISLANDS	22	578	20.7**	26.7**	2103**
FIJI	755	323	20.4	31.0	3040
KIRIBATI	22	100	27.6	28.1	100
MALDIVES	304	557	25.1	31.5	1951
MARSHALL ISLANDS	+	+	26.7	27.7	2407
MICRONESIA, FEDERATED STATES OF	141	+	23.4**	31.2**	469**
NAURU	139	3666	25.0**	29.9**	2236
NIUE	+	+	+	+	+
PALAU	234	4404	24.2**	31.0**	3746
PAPUA NEW GUINEA	2451	188	25.4	27.7	1150
SAMOA	132	287	24.4**	29.9**	2928
SINGAPORE	35634	3873	24.9	31.6	2191
SOLOMON ISLANDS	161	128	22.3	30.7	3290
TONGA	121	406	20.2**	26.8**	1610**
TUVALU	5	+	+	+	+
VANUATU	62	138	21.5	28.2	2222
Europe					
CYPRUS	5456	2365	7.3	32.3	320
MALTA	1759	2841	9.2	30.7	553
Latin America & the Caribbean					
ANTIGUA AND BARBUDA	337	1799	23.9	29.6	1052
BAHAMAS	1740	1994	16.7	31.8	1360
BARBADOS	898	1438	25.1	27.1	1273
CUBA	25113	581	18.6	31.6	1189
DOMINICA	81	419	21.6	30.5	654
DOMINICAN REPUBLIC	13224	847	19.6	31.5	1448
GRENADA	183	707	25.1**	29.3**	1359**
HAITI	1389	63	+	+	+
JAMAICA	10728	1301	22.9	31.4	813
SAINT KITTS AND NEVIS	103	807	25.1**	29.3**	+
SAINT LUCIA	198	741	25.9**	29.1**	+
SAINT VINCENT AND THE GRENADINES	161	505	+	+	+
TRINIDAD AND TOBAGO	21966	8084	23.2	31.8	1714

Sources: World Health Report 2002; World statistics pocketbook: small island developing states 2003
*Average mean temperature
** Source: Weather.com
+ Data missing

ANNEX 2.
Climate variability, climate change and human health workshops: participating countries

Small Island Countries

Antigua and Barbuda, Bahamas, Barbados, Comoros, Cook Islands, Cuba, Dominica, Dominican Republic, Fiji, Grenada, Haiti, Jamaica, Kiribati, Maldives, Mauritius, Federated States of Micronesia, Niue, Palau, Papua New Guinea, Saint Kitts and Nevis, Saint Lucia, Samoa, Sao Tome and Principe, Seychelles, Tonga, Trinidad and Tobago, Tuvalu, Vanuatu.

Other Countries:

Australia, Belize, Colombia, Indonesia, Kenya, Mexico, New Zealand, Panama, Philippines, Sri Lanka, Suriname, Tanzania, United Kingdom of Great Britain and Northern Ireland, United States of America (Puerto Rico, Hawaii).

ANNEX 3.[1,2]

The projection of future climate change first requires projection of future emissions of greenhouse gases and aerosols, for example, the future fossil fuel and land-use sources of CO_2 and other gases and aerosols. The increase in the amount of atmospheric CO_2, caused by the carbon from future use of fossil fuels, will depend on the fractions taken up by land and the oceans.

Future climate change also depends on climate sensitivity. For the Third Assessment Report, the IPCC developed a series of scenarios that include a broad range of assumptions about future economic and technological development to encompass uncertainty about the structure of society in 2100. Collectively these scenarios are called the SRES - the Special Report on Emission Scenarios. An earlier baseline, or business as usual, scenario (or IS92a) assumed rapid growth rates such that annual greenhouse gas emissions continue to accelerate. This scenario was developed for the Second Assessment Report. The SRES scenarios produce a range of emission projections that are both larger and smaller in 2100 than the IS92a scenario.

The SRES scenarios are grouped into four narrative storylines. These can be categorized basically in a 2x2 table, with the axes global versus regional focus, a world focused more on consumerism versus one focused more on conservation. The basic storylines are A1 (world markets), B1 (global sustainability), A2 (provincial enterprise) and B2 (local stewardship). Each storyline contains underlying assumptions about population growth, economic development, lifestyle choices, technological change and energy alternatives. Each leads to different patterns and concentrations of emissions of greenhouse gases. In some storylines, the large growth in emissions could lead to degradation of the global environment in ways beyond climate change. No attempt was made to assign probabilities to the SRES scenarios; they are designed to illustrate a wide range of possible emissions outcomes.

[1] Ebi KL, Mearns LO, Nyenzi B. 2003. Weather and climate: changing human exposures. In: Climate Change and Human Health: Risks and Responses. Eds: McMichael AJ, Campbell-Lendrum D, Corvalan CF, Ebi KL, Githeko A, Scheraga JD, Woodward A. WHO/WMO/UNEP.

[2] Nakicenovic N et al. 2000. IPCC Special Report on Emission Scenarios. Cambridge University Press.