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Synthesis Workshop on Climate Variability, Climate Change and Health in Small-Island States

Bandos Island Resort, Maldives, 1-4 December 2003

Workshop Report

World Health Organization

World Meteorological Organization

United Nations Environment Programme

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Synthesis Workshop on Climate Variability, Climate Change and Health in Small-Island States

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Workshop Summary

A. Workshop objectives

The Synthesis Workshop on Climate Variability, Climate Change and Health in Small-Island States was conducted on Bandos Island Resort, Maldives, from 1 – 4 December 2003.

Specific goals of the Synthesis Workshop included:

- To inform health scientists, practitioners, and officials of the impacts of climate variability, and long-term climate change in the Indian Ocean, Pacific, Caribbean and other regions;
- To address vulnerability assessment and adaptation options for Small Island Countries;
- To address findings and proposed actions as discussed in previous workshops in the Pacific and the Caribbean, with regard to:
    - Integration of health-relevant sectors (e.g., water resources, agriculture and fisheries);
    - Introduction of strategies in coastal zone management as they relate to sewage disposal and other health issues;
    - Fostering joint interdisciplinary research projects among local participants, as well as developed/developing nation scientist partnerships.
- Summarize conclusions and recommendations for common actions and activities for Small Island States and vulnerable islands in general.

The workshop was attended by 40 participants. There were representatives from 13 Small Island Countries (Comoros, Barbados, Cuba, Fiji, Maldives, Mauritius, Palau, Saint Lucia, Sao Tomé-et-Principe, Samoa, Seychelles and Tonga), in addition to participants from Australia, Indonesia, Japan, Sri Lanka, Tanzania, United Kingdom and United States of America; and representatives from the United Nations Environment Programme (UNEP), and the World Meteorological Organization (WMO). WHO provided four temporary advisers and four WHO staff members, serving as the secretariat.

The workshop was opened by the Minister of Health of the Maldives and followed with a keynote presentation by Professor Tony McMichael on climate change and health issues with some reference to the world's small-island states. Presentations were made on the following topics: the Pacific Island workshop on climate variability; the Caribbean workshop on climate variability; weather, climate variability and climate change; challenges of climate prediction and its application in the health sector; climate change and health; sustainable development in small-island developing states; climate forecasts and applications; estimating the burden of disease from climate change; predictions, prevention, and preparedness: application of climate information for public health; analysis of impacts of climate variability on malaria transmission in Sri Lanka and the development of an early-warning system; climate variability and climate change and health in small-island states: the Pacific experience; vulnerability and adaptation: an introduction; vulnerability and adaptation assessment; water and sanitation issues in the Maldives; climate change and health in

Indonesia; modeling the relationship between climate variability and human health: case study from Cuba; weather-related disasters: an approach to managing the potential health impacts of climate variability and change in the Caribbean; and adaptation policy framework.

Mrs Shaheeda Adam Ibrahim, from the Maldives was elected Chair. Dr Ronald Kinght, from Barbados and Mr Navi Litidamu from Fiji were elected Rapporteurs.

This Report is divided into two parts. Part 1 - Workshop Report - includes: the Opening Session; Keynote and other Presentations; Annex A the Workshop Agenda; Annex B the List of Participants; and Annex C the Opening Speeches (Statement of Regional Director SEARO and Opening remarks on behalf of the Interagency Network on Climate and Human Health - WHO, UNEP, WMO). Part 2 - Workshop Background Paper - is entitled "Climate Variability, Climate Change, and Health in Small-Island States".

PART 1 - WORKSHOP REPORT

Opening Session

Opening Address *H.E. Mr. Ahmed Abdullah* (Minister of Health, Maldives)

It is my pleasure to welcome you to the Maldives. We are indeed honored and privileged to be hosting this important workshop on the health impacts of climate change.

I would like to thank the World Health Organization (WHO), the United Nations Environment Programme (UNEP), and the World Meteorological Organization (WMO) for selecting the Maldives as the venue for the workshop. We have always valued our partnership with WHO and other UN agencies and international organizations.

We are also grateful to the family of nations and our partners in development. Their care and support to our country have been tremendous. I would like to extend a special welcome to Professor A. J. McMichael from the Australian National University, Canberra, who is here with us to deliver a keynote address on climate change and human health. I would also like to welcome Dr. C. F. Corvalan from the World Health Organization, Geneva, who will make the opening remarks on behalf of the Interagency Network on Climate and Human Health.

This synthesis workshop on climate change and health bears special significance for all of us. We have all been very concerned about the impacts of environmental degradation and climate change.

In fact, human life and civilization is at great risk from the unthinkable harms and consequences of environmental degradation and climate change. Never before in the modern history of the world has humanity faced such devastating threats from climate change as we are facing now. That is why environment and climate change have dominated the global agenda. This is why the international community is dedicated to working around the clock to find solutions to these threats. And that is why we are here today, working together to discuss some of the urgent health problems that relate to climate change.

The topic under discussion is very broad. But I am glad that the collective wealth of knowledge and experience in our workshop is vast. We are particularly pleased to have among us some eminent health scientists and climatologists from different parts of the world to discuss this serious issue.

I am sure the distinguished delegates will share a great deal of new ideas and problems to develop a holistic approach to reducing the harmful impacts of climate change. We in the Maldives have a special concern and anxiety about environmental degradation and climate change, as we are among the most vulnerable countries to these threats.

For this reason, President Mamoon Abdul Gayoom has taken many initiatives and played a pioneering role in the global efforts to combat environmental degradation. President Gayoom’s leadership has been catalytic in mobilizing international commitment to protect the world from the looming dangers of environmental degradation and climate change.

We are heartened by several positive responses from the international community.

Every country has given national importance to matters of environmental protection. Much effort is also underway at regional levels. We are very hopeful about the formulation of the

Kyoto Protocol and other international conventions, and we keenly await their effective and early implementation.

Climate change and variability are causing unprecedented health problems, putting all humanity at risk. In the recent past, many countries have experienced hot weather, and, in some cases, this has lead to health crises. On the other hand, extremely severe winters and cold waves have also caused great loss and suffering.

In heavily populated cities, air pollution is a very serious problem. Respiratory infections, asthma, and skin ailments and cardiovascular diseases have increased at an alarming rate.

According to new medical findings, some of these diseases are also becoming more virulent and drug resistant. New strains of infections have also been identified. Human beings have become more prone to these diseases and health problems. It is alarming that babies and children are particularly vulnerable.

The depletion of the ozone layer is a major threat. We are receiving reports every day of the far-reaching health risks related to it. Depletion of ozone layer results in higher exposure to ultraviolet rays of the sun, leading to an increase in the incidence of skin cancer.

It could also lead to an increase in the number of people suffering from eye disorders such as cataract. It is also thought to cause suppression of the immune system. According to a recent press release from WHO, children suffer most from ozone depletion.

The report suggests "every year, there are between two and three million new cases of non-malignant melanomas and more than 130,000 new melanoma skin cancer cases worldwide. An estimated 60,000 deaths occur annually from melanoma and other skin cancers."

Global warming and sea level rise is the biggest fear of many low-lying countries like the Maldives. Low-lying countries are at the risk of being submerged as a result of sea level rise. Flooding could cause colossal human losses and devastation. Availability of fresh water will be severely impaired.

The trend, pattern and distribution of insects and infections spreading disease will become fearsome. Supply of food would also be at stake due to the loss of agricultural land. Destroying the habitat of marine life would also have a serious effect on the availability of fish and marine products.

Despite these projections of the extent and direction of some potential health impacts of climate variability and change, there are many layers of uncertainty.

Firstly, methods to project changes in climate over time continue to improve, but climate models are unable to accurately project regional-scale impacts. Second, basic scientific information on the sensitivity of human health to aspects of weather and climate is limited.

In addition, the vulnerability of a population to any health risk varies considerably depending on moderating factors such as population density, level of economic and technological development, local environmental conditions, pre-existing health status, the quality and availability of health care, and public health infrastructure.

Ladies and gentlemen, as I have alluded to before, the Maldives, along with many other small-island nations, is extremely vulnerable to climate change and variability. At present, the rainfall pattern is changing, the dry period is getting longer, ground water is depleting.

Despite our country's achievements in health, economic stability, and technological advance, as well as a solid environmental protection policy, there is still a lot to be done and more international commitment and support needed. We are gratified by the fact that environment has become a vocabulary of everyday life.

Maldivians give great care and protection to the environment through the many measures initiated. Our tourism industry has been lauded as one of the most environment-friendly in the world, thanks to the dedication of the tourism industry, the government, and the community.

The problem of climate is common to all of us. It is one world—one humanity. Even one person is part of the whole human family. Health and life of any one is priceless. Life and good health is a sacred responsibility to be shared by everyone. That is why our task is so gigantic and our responsibility so crucial.

Saving one drop of water, growing one plant, switching off one light can mean a lot. And if that one drop of water and one tree is saved in millions, it can make a world of difference. Let us all try to make that difference. And let us make a real difference.

As today is World AIDS Day, I would like to pledge our full commitment to fight against the deadly disease and help the millions of suffering people around the world.

Keynote Presentation

Climate Change and Human Health: Strategic Issues with Some Reference to the World's Small-Island States *A. J. McMichael* (National Center for Epidemiology and Population Health, Australian National University)

Global climate change is one of a set of inter-related global environmental changes now affecting, for the first time, the biosphere. These changes are manifestations of the great, unprecedented, pressure that humankind is now exerting on the planet. This pressure reflects the combination of rapidly increasing human numbers and intensified economic activity. Recent macroscopic analyses estimate that, collectively, we humans are currently exceeding the long-term human carrying capacity of the planet by approximately 25–30%. That is, we are now operating in "ecological deficit" and in consequence the planet's natural capital is being diminished.

Skepticism about the science of human-induced "climate change" is now receding, as both understanding and empirical evidence increase. We *know* that:

- Greenhouse gas (GHG) concentrations in the atmosphere are increasing
- GHGs affect the climate system (indeed, at natural levels, this phenomenon is what makes the planet inhabitable!)
- World average temperature has risen relatively fast over the past 30 years
- Sea-level rise is gradually accelerating—and is forecast to continue for many centuries, even if we radically curtail greenhouse gas emissions over the next few decades
- Many temperature-sensitive systems/processes (glaciers, sea-ice, bird-nesting, insect migration, flowering, and bud-burst) have changed over the past two decades in ways that, collectively, are reasonably attributable to the documented warmingDespite the accruing evidence of human-induced climate change, one still hears objections that Earth's climate varies naturally (due to various cosmological and geological processes). The important—and surely obvious—point is that this does not preclude a coexistent change in climate due to human actions. That is, "climate change", in this context, refers to an *additional* change induced by human actions superimposed on any ongoing natural variation.

A rise of several degrees C within the coming century, as forecast by the United Nation's Intergovernmental Panel on Climate Change (IPCC), would, by dint of its rapid rate, disrupt some of the foundations of life on Earth. Ecosystems and life in general have evolved within a narrow band of climatic-environmental conditions. While this is clearly a global issue, the national contributions (historically and currently) to GHG emissions, and the vulnerability of national and local populations to adverse impacts, are *very uneven*. This raises major ethical and political issues.

The main categories of adverse health impacts of climate change have been widely discussed elsewhere (see *Climate change and human health: Risks and responses*, published by the World Health Organization (WHO) in 2003). They include the direct effects of climatic extremes—thermal stress, weather disasters—and the various indirect effects mediated by climatic influences on infectious disease transmission (especially vector-borne infectious diseases), local crop yields, fisheries, and, more diffusely, the consequences of social and economic dislocation and of population displacement.

Small-island states face a situation of “double jeopardy.” In addition to the risks posed by the well-known spectrum of direct and indirect health impacts of climate change, small-island states face an additional set of health-related problems due to sea-level rise. These include, in particular:

- Coastal flooding
- Exacerbated storm surges
- Damaged coastal infrastructure (roads, sewerage systems, etc.)
- Salinization of island freshwater
- Impaired crop production
- Damage to coastal ecosystems, coral reefs, and coastal fisheries
- Diverse health risks related to population displacement: (nutrition, infection, mental health, etc.)

Given the increasing importance and urgency of this global environmental change, with its clear-cut risks to population health, national ministries of health should develop a policy and evaluation strategy. This strategy should include carrying out a national assessment of risks to health from climate change (preferably in accordance with the newly released guidelines published by WHO). As an immediate activity, ministries of health should participate in emergency management preparedness (communications, facilities, skills). Well-judged adaptive measures to lessen adverse health impacts need not prove costly if they confer both immediate and long-term benefits and if they are appraised with full-cost accounting methods.

In the larger frame, ministries of health should argue the centrality of population well-being and health as the real “bottom line” in the sustainability debate. On the basis of this argument, the health sector should make links with various other ministries/sectors (such as education, industry, agriculture, fisheries, development planning).

Group discussion

Several factors, apart from climate change, are contributing to an increase of dengue in the African and Indian Ocean region. With increased international travel, different strains of the virus are appearing and different types of mosquito vector are becoming more important.

To prepare for the health effects of climate variability and change, countries will need increased resources for equipment and personnel.

Carbon dioxide and other greenhouse gases linger for a long time in the atmosphere before breaking down. For this reason, levels will be high for many years even if the current level of emissions goes down.

Presentations

1. **Workshop on Climate Variability and Change and their Effects in Pacific Island Countries**
   Navi Litidamu (Fiji School of Medicine)

A Workshop on Climate Variability and Change and their Effects in Pacific Island Countries was held on 25–28 July 2000 in Apia, Samoa. This was the first in a series of three workshops on the effects of climate variability and change in small-island states. The World Health Organization (WHO), the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO), and the United States Environmental Protection Agency (USEPA) and National Oceanic and Atmospheric Administration (NOAA) organized the workshop. Participants represented 11 Pacific Island nations plus resource persons and representatives from international agencies.

The workshop provided an opportunity for health officials to meet their counterparts from national meteorological services and to review and share experiences related to the health impact of climate variability and change in the Pacific. The objectives were to help health officials understand the linkages between climate change and health, to learn about the tools for predicting the nature and extent of climate change and its impacts on health, and to discuss the measures available to mitigate the adverse health effects of climate change. One goal was to broaden the consideration of climate effects on health beyond the context of disaster management.

Participants noted that there is increasing evidence of linkages between climate variability, climate change, and health. Yet specialists in the health sector generally are not familiar with and do not use climate information. High-priority diseases in the Pacific that are affected by climatic conditions include vector–borne diseases, diarrheal diseases, and respiratory infections.

Cultural traditions and other social factors are important in reducing the impact of climate change and variability on health. Pacific island nations need improved policies, appropriate research, and training and technical assistance.

Health specialists need the following information from national meteorological services:

1. User-friendly climate forecasts and applications information at national and regional levels
2. Seasonal temperature and rainfall forecasts and historical graphs and trends for each island and locality3. Accurate and simple information on floods and droughts, tropical cyclones, temperature, and sea-level variability

In 2001, participants from Fiji, the Federated States of Micronesia, and the Cook Islands attended a follow-up workshop in Fiji. The objective was to decide on future studies on climate and health to be conducted in the three countries.

After this workshop, the Fiji Ministry of Health, Fiji Meteorological Service, Fiji School of Medicine, University of Hawaii, and Pacific ENSO (El Niño Southern Oscillation) Applications Center undertook a retrospective analysis of climate and disease data in Fiji to determine if there is a relationship between climate variability and health risks. Data on prevalence of dengue fever, diarrhea, influenza, leptospirosis, and fish poisoning were collected from 14 districts for the period 1965–2000. This information was compared with data on temperature, rainfall, humidity, and the incidence of droughts, floods, and cyclones for the same districts over the same period.

Although the study is not complete, preliminary analysis noted some relationships between climate and health. In general, results were limited by the poor quality of health data in the Ministry of Health records. One outcome is that data recording is now improving.

A national consultation took place in 2003 in Suva, Fiji, to discuss the preliminary findings of the study. This gathering brought together health and meteorological staff from various districts in Fiji to plan how the two ministries can work together more closely in the future. A similar meeting is planned for May 2004 to bring together health and meteorological specialists from the Pacific Island region.

Group discussion

Information from these and other workshops does not always reach important audiences. One solution would be to distribute workshop reports more widely.

There is a broader problem with information dissemination. National meteorological offices often sell climate data, rather than providing information freely for research. If data from meteorological offices are not freely available, then researchers may feel compelled to obtain data from other sources, which has a negative effect on the relationship between the government departments most concerned with climate change and health.

2. Conference and Workshop on Climate Variability and Change and their Health Effects in the Caribbean

Roland Knight (Ministry of Health, Barbados)

A conference on Climate Variability and Change and their Health Effects in the Caribbean: Information for Adaptation Planning in the Health Sector took place on 21–22 May 2002 in St. Philip, Barbados. The conference was followed by a workshop on 23–25 May on the same topic. The Pan American Health Organization (PAHO) and the World Health Organization (WHO) organized this event under the auspices of the Government of Barbados and the Interagency Network on Climate and Human Health formed by WHO, the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP).The conference began with the premise that small-island states are particularly vulnerable to the effects of climate variability and change. Expanding awareness of the possible health effects of climate change and improving strategic planning and the implementation of preparedness programs requires the active partnership of all regional stakeholders. The overall objectives were to:

1. Inform health scientists, practitioners, and officials of the effects of climate variability and long-term climate change in the Caribbean region
2. Integrate sectors such as water resources, agriculture, and fisheries that have implications for human health
3. Introduce strategies in coastal-zone management related to sewage disposal and other health issues
4. Foster interdisciplinary research projects at the national and international level
5. Promote the incorporation of global, regional, and national climate information into planning for national public-health services

Major climate-related health issues in the Caribbean include vector-borne diseases (dengue, malaria) water-borne diseases, heat stress, asthma, disaster response to climate and weather phenomena, and toxins in fish. A number of ecological effects are unique to the region: contamination of seawater linked to river outflows from South America and the annual atmospheric transport of African dust across the Atlantic. Policies and strategies for adaptation to climate variability and change range from the control of specific diseases to general communication strategies for climate and health.

Technical presentations, panel discussions, and poster presentations during the conference:

1. Provided an overview of the basic concepts or climate variability and change
2. Reviewed health status in the Caribbean region with particular reference to climate variability and change
3. Presented frameworks for evaluating the vulnerability of the health system to climate variability and change
4. Presented frameworks for assessing and responding to climate-related health risks
5. Examined linkages between climate and human health
6. Examined public-health policies and strategies for adaptation to climate variability and change

The three-day workshop following the conference reached consensus on 22 recommendations for future work on climate and health in the region. These generally fall into four categories, as follows:

Enhancing awareness of the impact of climate variability and change on health

1. Build awareness throughout the region
2. Expand knowledge of the relationships between climate variability and change and health through national and regional research and engagement of existing interpretive expertise
3. Identify entry points to build awareness and develop adaptation and prevention strategies
4. Promote cross-sectoral communication and consultation (entry points can be event- or stakeholder-based)
5. Establish early-warning systems that incorporate monitoring of seasonal, inter-annual, and long-term climate events

Using data in public-health programs and planning

6. Conduct inventories of existing data, identify current data gaps, and develop strategies to fill these gaps
7. Establish better data-management systems, programs, and practices, including the establishment of data-quality standards and the regional distribution of best practices
8. Identify, engage, and enhance appropriate national and regional institutions for handling and analyzing data, developing tertiary multisectoral products, and facilitating networking
9. Encourage fuller use of available data through regional and national capacity building (human resources, information technology, etc.)
10. Develop and maintain firmer intersectoral linkages

Using data in public-health programs and planning for special situations: El Niño Southern Oscillation (ENSO) and sea level rise

11. Establish verifiable links between ENSO, extreme weather events, climate variability, and health consequences in the Caribbean
12. Identify and map locations, hazards, and communities especially at risk and vulnerable to sea-level rise and associated health risks, taking a holistic, cross-sectoral view
13. Develop long-term adaptive strategies for sea-level rise, based on an understanding of current coping efforts and national development priorities

Strengthening institutions

14. Evaluate current indicators and generate regional standards
15. Work effectively with policymakers to enhance awareness of climate variability and change and to catalyze discussion at national and regional levels
16. Develop institutional arrangements for data integration and dissemination
17. Improve exchange of knowledge by developing effective mechanisms for information sharing
18. Improve national and regional facilities and funding for interdisciplinary research
19. Improve education and training through further workshops, follow-on networking, and structured training at local, national, and regional levels
20. Find and use entry points for climate/health issues

21. Engage existing regional and national institutional mechanisms and processes for climate change adaptation, including national climate committees and the Caribbean Community Climate Change Center
22. Obtain institutional support from international organizations (especially PAHO) in activities related to capacity building, research, and regional/national assessments

Group discussion

A question was raised regarding the increase in asthma cases related to climate change. This appears to be a worldwide trend. One study in Barbados implicates the role of dust from the Sahara, which blows toward Caribbean islands across the Atlantic.

3. Weather, Climate Variability, and Climate Change

Lareef Zubair (International Research Institute for Climate Prediction)

The air around the earth is a very thin envelope, which we call the atmosphere. The density of this envelope of air decreases from about one kilogram per square kilometer at the earth's surface to about one-tenth of a kilogram at an altitude of 20 kilometers. Above altitudes of 20 km, it continues to diminish rapidly with distance from the earth.

The sun influences the atmosphere by radiative heat. Because of the way the earth rotates on its axis and the way it rotates around the sun, there are seasonal and diurnal (night and day) variations in the atmosphere. Diurnality and seasonality are important characteristics of the atmosphere.

Definitions

- Weather is the current or ongoing state of the atmosphere and is generally predictable up to 10 days in advance
- Climate is the long-term average of the weather over many years
- Climate change is the long-term change in the average state of the climate. It can be predicted, but such predictions are speculative
- Seasonal climate variability comprises the departures from the average state of the climate due to shifts in ocean or land conditions. It may be predictable up to one year in advance

Climate change

There is scientific consensus that the climate is changing, both on a global and on a regional scale. There is a risk that climate change can upset ecological systems that have adapted to environmental niches. The causes of climate change include disturbance in energy balances due to anthropogenic (caused by humans) pollution such as burning fossil fuel.

Uncertainty and risk are inevitable in dealing with climate change. Human-induced climate change is also accompanied by equity and moral issues: Who is causing climate change and who pays for the consequences?

Coping with climate variability

The ability to predict climate variations on a seasonal or inter-annual scale presents communities with the opportunity to develop their adaptive capacity. Decision-making is often driven by short-term concerns, and it is thus more feasible to focus on climate variability than on long-term climate change. Developing the capacity and expertise to deal with climate variability also helps prepare communities to deal with the long-term effects of climate change.

Measures to adapt to climate variability are needed immediately. Their efficacy can be tested, and such measures, when well formulated and well presented to the public, are likely to enjoy wide community acceptance. The capacity to undertake climate assessments, predictions, and adaptation measures should be developed regionally. To improve capacity, pilot studies are needed that call on expertise from multiple sectors.

What can we do?

- Improve understanding of climate and its relationship to our societies and environment
- Improve understanding of climate change, its current and potential effects, and the vulnerability of communities to its impact
- Develop strategies to adapt to and mitigate the effects of climate change. Following the precautionary principle, formulation of adaptation and mitigation strategies need not wait for perfect scientific evidence of climate change. In 1998, the Science and Environmental Health Network defined the precautionary principle as follows: “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof.”
- Build capacity and develop resiliency on a regional basis
- Adopt no-regrets policies as a first step. These are policies that will generate net social benefits whether or not there is climate change.

Summing up

While maintaining pressure to develop mitigation strategies, communities need to prepare to adapt to the effects of climate variability and climate change that cannot be avoided or mitigated. To achieve this goal, policymakers and the general public need to develop a good understanding of climate and the effects of climate change.

Information on climate change and climate variability is needed at the local and regional level. 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. Data on projects where climate information was used to develop mitigation and adaptation strategies would provide a particularly important component of the information base.

In improving the collection, analysis, and use of appropriate information, it will be important to support the entry and work of young people in the field of climate-environment-health interactions, particularly in the tropics.

Group discussion

Following the 1997–1998 El Niño event, there was massive coral bleaching in the Indian Ocean. Research findings would be useful on whether and how quickly coral reefs were recovering. There are also reports of excess plankton bloom, but these might be due to poor land use rather than climate change.

Summertime radiation is much stronger in the Southern Hemisphere than in the Northern Hemisphere because during the Southern Hemisphere summer the earth is closer to the sun. No one has established any significant relationship between the 11-year sun-spot cycle and any climate effect on earth. If there is any effect, it is probably not discernible because other factors are more important.

4. Challenges of Climate Prediction and its Application in the Health Sector

Buruhani Nyenzi (World Climate Applications and Climate Information and Prediction Services, World Meteorological Organization)

The world's climate system is essential to human life on earth. The human species has adapted to all but the harshest climates on the planet, and, for the most part, thrives in them. However, climate is not constant at any location. In addition to long-term climate change, natural variability includes occasional extremes of weather and climate, and these can have serious impacts on the health of individuals, communities, nations, and regions.

Improvements in long-range climate forecasting offer important opportunities to help communities anticipate climate-related health risks and plan appropriate adaptation and mitigation actions. Forecast models have been enhanced by rapid advances in communications and computing technologies and by improved understanding of the climatic effects of sea surface temperature (SST) anomalies, the timing and magnitude of the El Niño Southern Oscillation (ENSO), and the extent of sea ice in the polar regions and snow cover at high latitudes. Enhancement of observational networks, especially the development of satellite networks and buoy-platform arrays over the previously data-sparse oceans, has increased data availability and knowledge of the climate system and has helped improve forecast outputs around the world.

National meteorological services typically forecast average surface temperature and total precipitation for a given period. Several also forecast other elements such as the intensity of cyclones, the onset and end of the monsoon season, soil moisture, and extreme weather conditions such as floods, droughts, heat waves, and cold surges. Periods covered by climate forecasts vary from less than one month to longer than one year.

Weather and climate forecasts have proven useful in planning adaptation and mitigation measures in many sectors. In the agriculture sector, long-range forecasting provides early warnings of impending droughts or floods and enables users to select more effective planting times and choose the most appropriate crops for the coming season. In the health sector, early-warning systems help to improve surveillance of diseases affected by climate conditions such as malaria, dengue fever, meningitis, and diarrhea. Early-warning systems also help to mitigate the effects of weather extremes such as heat waves, winter cold, and urban smog events.

Factors that influence both climate and health include human practices such as expanding industrialization and use of fossil fuels and ever-increasing human populations. For many years, the World Meteorological Organization (WMO) and the World Health Organization (WHO) have worked in partnership to identify the relationship between climate and health and to identify health risks associated with climate variability and change.

Group discussion

It would be useful to develop matrices for particular locations that list: climate change and variability factors; health outcomes; environmental, economic, and institutional constraints; and policy needs. This would help identify how key climate-sensitive health issues intersect with other problems.

5. Climate Change and Health

Buruhani Nyenzi (World Climate Applications and Climate Information and Prediction Services, World Meteorological Organization)

Climate and climate extremes affect human health in a number of ways, both direct and indirect. Prolonged droughts affect agricultural output and can decimate livestock populations, leading to malnutrition, dehydration, and sometimes, human starvation. Floods can ruin food stocks, remove fertile topsoil, impair food production for seasons afterwards, and contribute to the severity and extent of water-borne diseases. Climatic factors can cause population displacement and economic disruption, affecting the health of whole sectors of the population.

Even within "normal" conditions, climatic variation can have a substantial impact on human health, for example, affecting the evolution and spread of vector-borne diseases or the quality of the air in urban environments. The combined effects of temperature, humidity, and pollutants lead to respiratory problems. Sudden heat and cold spells have impacts ranging from discomfort to death, and certain sectors of society, especially the very young or old and those already ailing, are particularly vulnerable.

Vector-borne diseases are influenced by temperature, precipitation, humidity, surface water, wind, and biotic factors such as vegetation, host species, predators, competitors, parasites, and human intervention. Temperature, for example, affects the lifecycle of vector species and pathogenic organisms such as bacteria and viruses. Temperature also affects disease transmission. Local climatic changes, due to such factors as the timing or magnitude of an El Niño Southern Oscillation (ENSO) event, can affect the timing and severity of disease outbreaks.

Efforts are underway to collect and distribute the climate, environment, and health data needed to plan mitigation and adaptation actions in the face of climate variability and climate change. Examples of collaboration between the meteorological and health sectors include warning systems set up in a number of cities that work in cooperation with social and emergency services to alert vulnerable communities of impending dangers during heat and cold waves. In Africa, the Malaria Early Warning System relies on climate input to help the health sector prepare for anomalous patterns of disease.

The World Climate Program, and especially the World Climate Applications and Climate Information and Prediction Services, work with the World Health Organization (WHO) and other partners to address climate and health interactions and take steps to ensure that regional activities include building climate/health capacity around the world. Much work needs to be done for climate experts to improve the accuracy of the products generated from prediction models, to downscale and package the information these models produce to serve the needs of users, and to improve communication links between producers and users of this information. Coordination at regional and international levels and between relevant institutions and agencies is important for the successful development and effective application of climate forecasts for the health sector.

Group discussion

Some policymakers confuse climate change with ozone depletion, although these are not the same. Air pollution can mask the full impact of greenhouse gas emissions, so that cleaning up the air may result in increased temperatures. It would be useful to identify which pollutants contribute positively and negatively to global warming.

It is a challenge to convince large, industrialized countries to follow the Kyoto Protocol. Small-island states have been in the forefront as effective advocates on this issue.

6. Sustainable Development in Small-Island Developing States

Mohamed Ali (Environment Research Center, Ministry of Home Affairs and Environment, Maldives)

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” In the Maldives, sustainable development refers, in particular, to safeguarding the reefs that protect the islands and provide the basis for fisheries and tourism. Small-island developing states are defined by their remoteness, their small size, their geographic dispersion, the fragility of their ecosystems, their heavy dependence on imports, and their lack of natural resources and skilled endogenous human resources. As a remote cluster of more than 1,000 small islands, the Maldives suffers from:

- Need to import almost all requirements
- No food or energy security
- High cost of distributing goods and services
- Lack of global competitive advantage
- Nearly all products for consumption or export obtained directly from the environmentThe Maldives is particularly vulnerable to changes in the physical environment including global warming, climate change, ozone depletion, and sea-level rise. The country is also vulnerable to changes in the economic environment including globalization, economic restructuring, and changing trade agreements.

The most important feature of the Maldives’ physical environment is the coral reefs that surround the islands. The reefs play a role in the physical preservation of the islands and in fisheries, tourism, and local traditions and culture. In 2000, tourism provided 33 percent of the Maldives’ gross domestic product (GDP), and the fishing industry provided 6 percent. 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, harbor construction, reclamation, construction of seawalls and jetties, and island-based pollution. Global sources of stress include global warming, 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.

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

In this situation, sustainable development will require a pragmatic approach based on an appreciation of the vulnerability and complexity of small-island environments. It will also require unity and cooperation among all small-island developing states.

Group discussion

The natural growth of coral reefs should be an asset to countries such as the Maldives, but this is negated by coral death due to global warming. The Maldives government has published a study on vulnerability and adaptation to climate change that includes a chapter on health effects. One special problem is the difficulty and expense of providing health services on remote islands.

7. Climate Forecasts and Applications
Steve Palmer (Met Office, UK)

The Met Office, UK, has developed a Unified Model for Numerical Weather Prediction (NWP). There is no inherent distinction between NWP models used for operational weather forecasting, climate studies, or seasonal prediction. The difference is in the initial conditions and the incorporation of observational data. For weather forecasting up to 10 days in advance, observations are used to constrain the model analysis before stepping the forecast forward in a continuous cycle. For climate studies and seasonal forecasts, the model runs from a given analysis, giving realistic climatic parameters but without as much detail.

It is possible to use a number of starting points to give an ensemble forecast. This technique gives an estimate of the "skill" of the forecast based on the variance in the ensemble results.

This and other weather and climate models are based on meteorological observations. These are generally defined by location, time of observation, and quality-control status. Some (especially rainfall and maximum and minimum temperature) are also defined by the period of observation. While this is very simple in database terms, there is also a need for a rich set of metadata, covering such items as the geography and history of the observing station.

The precision and representativeness of meteorological observations must be evaluated. These are all observations of turbulence phenomena, so they will contain sampling noise (apart from errors). Also the geographic scale needs to be considered when using climate data with other information, such as disease incidence. For example, rainfall measurements are typically very precise, but a single rain gauge is only representative of a small area, whereas health data are often gathered for the catchment area of a health center, which is much larger.

Climate data can be used to produce models of user parameters, such as particular diseases. This may be done by "data mining"—using a large set of data to produce empirical relationships. Alternatively, climate data can be used to validate a physical model of a system.

Either an empirical or a physical model may be used for operational services or for long-term impact studies. For an operational service, the daily forecast may be used as input. For example in the case of malaria, an operational five-day forecast allied to the natural cycle of the parasite should give just sufficient time to put preventative measures in place.

The Instat+ statistical package is a good introductory tool for climate modelling. The climatological user's guide is especially helpful. The installation set is included on the resource disk, or it may be downloaded (free) from: the Statistical Services Center, University of Reading, P.O. Box 240, Reading RG6 6FN, U.K; tel: +44 (0) 118 378 8028 or +44 (0) 118 378 6421; fax: +446316107 (0) 118 378 3169; email: instat@reading.ac.uk; website: http://www.reading.ac.uk/ssc.

Note especially that the regional climate-change-impact model (PRECIS) will give daily figures for the weather parameters within the model prediction. While these can be used directly to derive the climatology, they are designed to be used as inputs to models of weather-related events, such as diseases, thus leading to predicted statistics for the parameter being modelled. This is a very powerful technique for providing detailed assessments and also for testing the effect of mitigation activities. Policymakers are likely to understand these models more easily when presented as an animation rather than as static graphs.

Further information on Met Office, UK, products, including those of the Hadley Centre, is available from the Internet at www.metoffice.com. For operational use, see the seasonal forecast section at www.metoffice.com/research/seasonal/monthly_public/forecasts.html. For access to all the forecast products of the UK Met Office and the European Center for Medium-Range Weather Forecasts (ECMWF), see the section on the Data and Products Distribution Service (DPDS). While this is offered as a paid service to private-sector forecasting organizations, access is free for national meteorological and hydrological services of developing countries.

Group discussion

All models need to be calibrated for local conditions. For example, oceans rise by different amounts in different places because the expansion of water is influenced by temperature and salinity.

Improvements in climate forecasting should make it possible to develop early-warning systems for infectious diseases and other health problems. Sceptics are concerned about the cost of mobilizing for health problems that may not occur, given the scarcity of resources. Early-warning systems have been very successful in the UK, however, in predicting outbreaks of winter influenza and injuries following frost and snow.

It is important to determine priority information needs, both for general awareness building and for policy making. Requirements for training, capacity building, and further research also need to be assessed, along with the financial implications.

8. Estimating the Burden of Disease from Climate Change

Carlos F. Corvalán and Diarmid H. Campbell-Lendrum (Occupational and Environmental Health, World Health Organization)

Hippocrates commented on the relationship between climate and health around 400 B.C. in his treatise *On airs, waters, and places:*

> "Whoever wishes to investigate medicine properly, should proceed thus: In the first place to consider the seasons of the year, and what effects each of them produces for they are not at all alike, but differ much from themselves in regard to their changes. Then the winds, the hot and the cold, especially such as are common to all countries, and then such as are peculiar to each locality."

Today, climate change poses a major, and largely unfamiliar, challenge to the health sector. Many diverse health outcomes are sensitive to climate and are therefore likely to be affected in some way by climate change. In order to determine priorities for action, an estimation of the approximate magnitude of the health impacts of climate change is needed. This will indicate which particular impacts are likely to be greatest, in which regions, and how much of the climate-attributable disease burden could be avoided by a reduction of the emissions that cause climate change. Such an estimation will also guide strategies to protect health.

The global burden of disease attributable to climate change has recently been estimated as part of a comprehensive World Health Organization (WHO) project.[1] This project sought to use standardized methods to quantify disease burdens attributable to 26 environmental, occupational, behavioral, and life-style risk factors in 2000 and at selected future times up to 2030.

Disease burdens and summary measures of population health

The disease burden comprises the total amount of disease or premature death within the population. To compare fractions of the disease burden attributable to several different risk factors requires, first, knowledge of the severity/disability and duration of the health deficit, and, second, the use of standard units of health deficit. For this purpose, the widely used Disability-Adjusted Life Year (DALY)[2] 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 into account disease duration, age of onset, and a disability weight reflecting the severity of disease.

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

1 WHO, 2002, *The World Health Report 2002*, Geneva.

2 C. J. L. Murray, 1994, Quantifying the burden of disease—the technical basis for disability-adjusted life years, *Bulletin of the World Health Organization* 72(3): 429–45.

The global assessment

The global assessment uses WHO estimates of the baseline burden of disease caused by a series of climate-sensitive health outcomes (cardiovascular deaths associated with thermal extremes, diarrhea episodes, cases of malaria, malnutrition, and deaths in natural disasters). Existing and new models are 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 socio-economic development. The population distribution of exposure is given by the HADCM2 climate model produced by the UK Hadley Center, which describes future climate under various scenarios of greenhouse gas emissions. Climate change is expressed as the change in climatic conditions relative to those observed in the reference period 1961–1990 (i.e., making the conservative assumption that significant anthropogenic influence occurred only after this period).

Disease burdens are estimated for five geographical regions and for developed countries. The attributable disease burden is estimated for the year 2000[3]. The climate-related relative risks of each health outcome under each climate-change scenario, relative to the situation if climate change does not occur, are estimated for the years 2010, 2020, and 2030.[4] These results are inevitably approximate, partly due to the uncertainty associated with climate projection, but mainly due to the limited understanding of many climate and health relationships. The results do, however, give a first indication of the potential magnitude and distribution of some of the health effects of climate change.

The need for national-level assessments

Although climate change occurs at a global level, the impact is felt locally. It is likely that the impact of climate change will vary according to geographic region, first, because the rate of change in different climate properties will likely vary in different regions of the world, and second, because populations differ in their vulnerability to changes in exposure (due to existing natural conditions and to their capacity to respond to change). Within countries, specific sub-populations may be particularly vulnerable to changing climate exposures, such as those living in flood-prone areas. Therefore there are advantages in carrying out local assessments that:

- Use high-resolution local data on current health states, climate projections, and the relationships between climate and health outcomes
- Take account of climate-sensitive health impacts that are most important locally, rather than globally
- Allow countries to select measures of health status that are most relevant to their own policy-making processes
- Allow the identification of populations that may suffer disproportionately because of their low capacity to adapt to changing conditions, perhaps due to low socio-economic status or poor protection from public health systems

Group discussion

It is important not to overstate the reliability of current models. A better understanding of the links between climate change and health will require more research and capacity building.

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3 WHO, UNEP, and WMO, 2003, *Climate change and human health: Risks and responses*, Geneva.

4 A. J. McMichael et al., 2003, Climate change, in Global burden of disease, C. J. Murray and A. D. Lopez (eds.), Geneva: WHO.

9. Predictions, Prevention, and Preparedness: Application of Climate Information for Public Health *Aurelia Micko* (Climate Variability and Health Program, National Oceanic and Atmospheric Administration, USA)

The goal of the National Oceanic and Atmospheric Administration's Climate Variability and Health Program is: "To improve public health and well being through the integration of useful climate information into public-health policy and decision-making at the appropriate scale." The objectives of the program are:

1. Understand and define health problems and the appropriate role for climate information.
2. Develop a solid scientific foundation to support public-health policy and decision-making.
3. Build a robust and highly integrated climate and health research and application community.
4. Build capacity within regions to conduct research and apply climate information toward the goals of public health.

Recent activities have included regional climate and health training workshops in Samoa, Niger, and Barbados and work on early-warning systems for malaria in Southern Africa and Colombia, for meningitis in Niger, for dengue in the Asia-Pacific region, and for Rift Valley Fever in Eastern and Southern Africa. Collaborative projects focus on West Nile Virus, cholera, bartonellosis, diarrheal diseases, dengue, asthma, influenza, the dynamics of mosquito populations and mosquito control, energy modeling, and research methods.

An effective early-warning system begins with climate forecasts, environmental observation, epidemiological surveillance, risk analysis, and vulnerability assessment. These feed into predictive models that generate disease-watch and early-warning information. This information provides the basis for a response strategy, which is communicated to decision-makers and the public. Evaluation and feedback are then used to improve the models. This approach can significantly speed up and enhance opportunities for disease control.

Research on Rift Valley Fever, for example, is designed to discover whether outbreaks can be predicted. This is a mosquito-borne disease of humans and domestic livestock in sub-Saharan Africa and the Arabian Peninsula. Research questions include: how is the virus spread: how is it maintained during periods between epidemics; and what is the importance of climatic factors in the disease-transmission cycle. Because a vaccine is available, an early warning could facilitate a quick response that would prevent or diminish a disease outbreak. Early studies suggested a correlation between outbreaks of Rift Valley Fever and vegetation greenness. Research associated with an outbreak in Kenya in 1997–98, however, found a correlation with elevation, human-animal proximity, and rainfall.

Other research projects have found an increase in cholera prevalence with elevated sea-surface temperatures in Peru and Bangladesh. Shellfish poisoning has been related to contaminated runoff and changes in the coastal environment in several localities.

These projects have led to greater program commitment in a number of agencies and expanded international partnerships. Now the challenge is to move from surveillance and response to prediction and prevention. New tools and technologies should make it possible to meet climate-related health threats head-on. The challenge is to build regional capacity for more integrated health early-warning systems and to use climate information as an adaptation tool. The approach should be a mix of research and practical use involving application, intervention, and feedback. This will involve:

- Intellectual framing, problem orientation, and a practical approach
- Development of sustainable information systems
- Assessment as a process, facilitating institutional flexibility, sustainability, the development of human capital, and the formulation of useful solutions

At the community level, it will be important to enhance resilience and to build institutional, human, and scientific capacity for flexible and responsive action. Physical, biological, and social information will facilitate applications that include modeling and prediction, decision analysis, and vulnerability and risk assessment.

10. Analysis of Impacts of Climate Variability on Malaria Transmission in Sri Lanka and the Development of an Early-Warning System

Olivier J. T. Briët (International Water Management Institute)

Malaria is the major public-health problem in Sri Lanka and many other developing countries. It is well established that the disease has climatic determinants, and recent work has shown that climate variability is important in explaining its occurrence. At present, however, there are no practical tools in Asia to predict the occurrence of malaria based on climate forecasts. Such tools would be extremely useful in making efficient use of the limited resources that are typically available in developing countries for malaria control.

The distribution of *Plasmodium vivax* malaria varies markedly across Sri Lanka. The incidence of *Plasmodium falciparum* malaria follows a similar spatial pattern but is generally much lower than the incidence of *P. vivax*. In the northern part of the country, malaria occurs in one seasonal peak at the beginning of the year, while 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 on the Internet at 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. He concluded that in the wet zone of the country, a deficiency of rainfall in the “spring” was favorable for the occurrence of a “summer” epidemic, and a deficiency of rainfall from July to September was favorable for the occurrence of a “winter” epidemic. In the dry zone, excessive rainfall during the “winter” was favorable 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 southwest monsoon tends to fail, confirming Gill's findings for the wet zone of the country. Given this correlation, advances made in predicting El Niño events may be useful for forecasting periods of high malaria risk. One study assessed the possibility of using routinely collected meteorological information to predict outbreaks of malaria at district level.

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 only significant 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 the results of Gill for the dry zone. However, it is possible that the many environmental changes and malaria-control efforts that have occurred in Sri Lanka have affected malaria transmission and local climate conditions enough to weaken and complicate the relationship between rainfall and malaria.

There is concern worldwide that future malaria epidemiology will be influenced by global climate change. Global warming could be important in areas where low temperature is currently a limiting factor for malaria transmission. Most of Sri Lanka already has an optimum temperature for malaria transmission, however, and a slight increase would not have a large impact. Mutuwatte et al. (1996) modeled the impact of climate change on malaria under the scenario of a doubling of carbon dioxide (CO_2), one of the major greenhouse gases. It was concluded that the endemicity of malaria in the dry zone of Sri Lanka is likely to remain unchanged or decrease slightly, provided that other conditions remain the same.

A new project has been initiated on "Analysis of impacts of climate variability on malaria transmission in Sri Lanka and the development of an early-warning system." The project is funded by the Joint Program on Climate Variability and Human Health and supported by the United States National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Environmental Protection Agency (EPA), and Electric Power Research Institute (EPRI).

In this project, personnel attached to the International Water Management Institute, the Anti-Malaria Campaign, the University of Sri Jayawardenapura, the International Research Institute for Climate Prediction, and partners from Columbia University have formulated a program to incorporate climate variability and forecast information into malaria risk maps for the malaria-endemic Uva Province of Sri Lanka. The availability of long, dense, and reliable records on climate, hydrology, entomology, malaria incidence, and malaria control activity, as well as cross-sectional data on socio-economic status, provides a unique opportunity to study the interactions between climate variability and malaria. Based on these rich data, models will be developed to forecast malaria risk using climate forecasts, remote sensing, and spatial analytic techniques. Results from the small-area study will be used to develop a prototype early-warning system for the entire country.

The active involvement of the malaria control agency of Sri Lanka makes it possible to access entomological and epidemiological data and implement the tools that will be developed. The project will assess the use and effectiveness of risk maps in communicating climate-induced malaria risks as well as the economic costs and benefits of malaria incidence and control. The ultimate objective is to develop a practical methodology that can be disseminated in Sri Lanka and in other regions of low to moderate endemicity with similar transmission conditions in South and Southeast Asia.

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11. Climate Variability and Climate Change and Health in Small-Island States: The Pacific Experience *Nancy D. Lewis* (East-West Center, USA)

In the early 1990s, the University of Hawaii, the University of Guam, the U.S. National Weather Service, and the Pacific Basin Development Council established the Pacific ENSO (El Niño Southern Oscillation) Applications Center (PEAC) as a joint endeavor. The objective was to provide ENSO forecast information for the U.S.-affiliated Pacific islands.

Forecasts, especially of strong El Niño events, have become increasingly sophisticated, and PEAC forecasts helped island states cope with the 1997–1998 El Niño. In June 1997, PEAC alerted the governments that a strong El Niño was developing, that changes in rainfall and storm patterns could be expected, that severe droughts could occur as early as December, and that some islands were at unusually high risk of typhoons and hurricanes.

In fact, the region experienced extreme drought during the 1997–98 event, as well as several severe storms. The implications for health were mediated primarily through water availability and the impact on agriculture. Most governments served by PEAC developed drought-response plans and pursued aggressive public-information programs. Water-management agencies developed water-conservation plans.

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

Agriculture was badly affected. In the Commonwealth of the Northern Mariana Islands, citrus and garden crops were damaged. In the Federated States of Micronesia, more than 50 percent of the staple crops of taro and breadfruit were destroyed. The most serious economic loss was kava (*Piper methysticum*), a major cash crop. In Fiji (not a U.S.-affiliated nation), micronutrient deficiencies were found in pregnant women, especially on the western side of Viti Levu where the drought was most extreme.

During the 1997–98 El Niño, Typhoon Paka hit the Marshall Islands and Guam, followed by wildfires on Guam and in the Federated States of Micronesia. Associated events included coral bleaching and changes in the migratory patterns of significant fish stocks.

Research is in progress in the Pacific to ascertain the relationship between ENSO events and specific diseases in order to facilitate the use of forecast information for public-health purposes. Dengue has received the most attention, but researchers are also looking at diarrheal disease, ciguatera, influenza, and leptospirosis.

Before the 1997–1998 event, retrospective analysis indicated that dengue was most common during normal or La Niña years. A region-wide outbreak occurred in 1997 and 1998, however, although the disease had peaked in French Polynesia and New Caledonia before the effects of the ENSO event were experienced. 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 the virus.

It is important to note that in the Pacific, as elsewhere, the impact of an ENSO event is not uniform across the region. Some islands may experience higher rainfall, while others suffer from drought. For this reason, the application of forecast information has to be site specific. Care must also 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 a disease outbreak.

12. Vulnerability and Adaptation: An Introduction

Kristie L. Ebi (Exponent Health Group, USA)

The public-health and climate-change communities share the goal of increasing the ability of countries, communities, and individuals to cope effectively and efficiently with the challenges that are likely to arise because of climate variability and change. Realistically assessing the potential health impacts of climate variability and change requires an understanding of both the vulnerability of a population and its capacity to respond to new conditions.

The Intergovernmental Panel on Climate Change (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. The vulnerability of human health to climate change is a function of:

- Sensitivity, which includes 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
- Exposure to the weather or climate-related hazard, including the character, magnitude, and rate of climate variation
- Adaptation measures 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

Populations, subgroups, and systems that cannot or will not adapt are more vulnerable, as are those that are particularly susceptible to weather and climate change. Understanding a population's capacity to adapt to new climate conditions is crucial to realistically assessing the potential health and other effects of climate change. In general, the vulnerability of a population to a health risk depends on the local environment, the level of material resources, the effectiveness of governance and civil institutions, the quality of the public-health infrastructure, and the access to relevant local information on extreme weather threats. These factors are not uniform across a region or country or across time. They differ based on geographic, demographic, and socioeconomic factors. Effectively targeting of prevention or adaptation strategies requires understanding which demographic or geographical subpopulations may be most at risk and when that risk is likely to increase. Thus, individual, community, and geographic factors determine vulnerability.

Adaptation includes the strategies, policies, and measures undertaken now and in the future to reduce potential adverse health effects. Adaptive capacity describes the general ability of institutions, systems, and individuals to adjust to potential damages, to take advantage of opportunities, and to 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 negative effects of climate variability and change. In other words, coping capacity encompasses the interventions that are feasible to implement today (in a specific population), and 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 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 encompass both spontaneous responses to climate variability and change by affected individuals and 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 closings, and evacuation from lowlands and seashores.

Strategies for adapting to climate change might necessitate a diverse range of modifications to public-health systems. These changes can be thought of in three categories:

- Lessons learned but forgotten or not applied. Lessons learned in one part of the world may be applicable to other public-health systems, or historical lessons may be informative for current and future issues. Knowledge gleaned from experience must be coupled with political and institutional will if change is to be widespread or lasting.
- Win/win or no-regrets strategies. These might include improvements partially motivated by climate that could enhance efficiency or advance sustainable-development goals and thus render public-health systems more capable of confronting challenges.
- Changes that confront new risks posed by climate change. Public-health systems in the future could face novel threats, such as a change in the spatial range of a disease or the introduction of a new disease, which would require deliberate and planned adaptation.

Global climate is already changing and will continue to change for decades, even if far-reaching steps are taken immediately to reduce greenhouse-gas emissions. Given the potentially large health risks, the challenge for the public-health community is to find effective ways to reduce the potential impacts of climate variability and change in the context of other pressing needs. Increased understanding of population health vulnerabilities and targeted actions to reduce those risks will increase resilience to what the future does bring.

For further information:

Kovats, R. S., Ebi, K. L., and Menne, B., eds. 2003. *Methods of assessing human health vulnerability and public health adaptation to climate change.* Geneva: WHO, WMO, UNEP, and Health Canada.

McMichael, A. J., Campbell-Lendrum, D., Corvalan, C. F., Ebi, K. L., Githeko, A., Scheraga, J. D., and Woodward, A., eds. 2003. *Climate change and human health: Risks and responses.* Geneva: WHO, WMO, and UNEP.

13. Vulnerability and Adaptation Assessment

Kristie L. Ebi (Exponent Health Group, USA)

Environmental risk management is the process by which assessments of vulnerability to climate variability and change are integrated with other information to make decisions about the need for, approaches to, and extent of reducing risk. Policymakers decide what interventions to implement, if any, to address current vulnerability, including vulnerability resulting from climate variability and change, even as research continues to provide additional information. Policymakers should consider the concerns and priorities of stakeholders, including the scientific community and the public. One important role of scientists in this regard is to explain the role of uncertainty in the scientific process and contrast it to the role that uncertainty may play in policy development. The steps in a risk-management cycle include: identifying issues; assessing key risk areas; measuring the likelihood of impacts; ranking risks; setting desired results; developing options; selecting a strategy; implementing the strategy; and monitoring, evaluating, and adjusting the strategy as necessary.

Vulnerability and adaptation assessments should aim to evaluate:

- Potential impacts of climate variability and change in a range of areas and populations, especially among vulnerable populations, including, when possible, an assessment of the attributable burden of weather and climate, including extreme events, on climate-sensitive diseases
- Possible threshold effects
- Effects of multiple stresses, including changes in socioeconomic systems
- Uncertainty and its implications for risk management
- Effects of reducing emissions, such as by comparing impacts under scenarios with business-as-usual and emission stabilization
- Coping capacity, especially under different socioeconomic futures and in the context of sustainable development

The available material and human resources will determine at what level vulnerability and adaptation can be assessed. A basic assessment could be conducted using readily available information and data, such as previous assessments, literature reviews by the Intergovernmental Panel on Climate Change (IPCC) and others, and available region-specific health data. Limited analysis may be conducted of regional health data, such as plotting the data against weather variables over time. Consultation with stakeholders would 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.

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 to be useful to stakeholders. An integrated approach is likely to be most informative, as the effects of climate are likely to transcend traditional sector and regional boundaries, with effects in one sector affecting the capacity of another sector or region to respond.

Steps in assessing vulnerability and adaptation include:

1. Determining the scope of the assessment: the geographical region, time period, and health outcomes to be included. The assessment should include the health and security issues of concern today and of potential risk in the future. For some diseases, national boundaries may not provide the most appropriate geographic region to be included. Time periods appropriate to planning should be included

2. Describing 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, including determining the burden of disease that is attributable to weather and climate. All factors affecting the disease outcomes of interest should be evaluated

3. Identifying and describing current strategies, policies, and measures that reduce the burden of climate-sensitive diseases. Describe what is being done now to reduce the burden of disease, and evaluate the effectiveness of those policies and measures. Determine what could be done now to reduce current vulnerability and the main barriers to implementation of those measures. Finally, identify measures that should be implemented to increase the range of possible future interventions

4. Reviewing the health implications of the potential effects 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 on these sectors

5. Estimating future potential health impacts using scenarios of future climate change, population growth, and other factors and describing the uncertainty. Either top-down or bottom-up approaches can be used. This step should include projections of how other relevant factors may change. Uncertainty in all projections must be addressed explicitly, including uncertainty from data, models, and other sources

6. Synthesizing the results and drafting a scientific assessment report. The report should identify changes in risk patterns, links between sectors, vulnerable groups, stakeholder responses, and sources of uncertainty. One approach is to use a panel of experts. The results should be peer-reviewed and published

7. Identifying additional adaptation policies and measures to reduce potential negative health effects, including procedures for post-implementation evaluation

These steps, along with methods applicable for a variety of climate-sensitive diseases, are discussed in detail in *Methods of assessing human health vulnerability and public health adaptation to climate change*, edited by R. S. Kovats, K. L. Ebi, and B. Menne and available from the World Health Organization's European Center for Environment and Health at bme@who.int.

Group discussion

In the past, health specialists did not take weather and climatic factors sufficiently into account, but now more information is available. The links between climate and health need to be considered fully ("mainstreamed") when considering a variety of related issues.

When new activities are introduced, the full range of possible effects should be considered. For example, most current vector-control programs are based on spraying with chemicals, some of which have proven dangerous to human populations. When microcatchments were built in Ethiopia to improve agricultural production, the incidence of malaria increased.

14. Water and Sanitation Issues in the Maldives

Shaheeda Adam Ibrahim (Maldives Water and Sanitation Authority)

The Republic of Maldives is a chain of nearly 1,200 tiny coral islands, of which only 199 are inhabited. The Maldives archipelago contains 26 geographic atolls that together form a chain 820 kilometers in length and 120 kilometers at the widest point. The 26 geographic atolls are grouped into 20 administrative regions. All islands of the Maldives are very low lying, and none exceeds an elevation of 3 meters. More than 80 percent of the land area is less than 1 meter above mean sea level.

The population of the Maldives is about 270,101 (Census 2000). About a quarter of the population live in the capital island of Malé, which has a population of 74,069. The Maldives' population is growing at an annual rate of 1.9 percent (Census 2000).

There are no rivers or streams in any of the islands of the Maldives and only a few wetlands or freshwater lakes. The country's freshwater resources exist as groundwater in basal aquifers, generally unconfined in nature and extending below sea level in the form of a thin fresh water lens. They are vulnerable to saline intrusion owing to freshwater-seawater interaction and the need for careful management to avoid over-exploitation.

Maldivians depend mainly on rainwater for drinking and groundwater for most other domestic needs. Rainwater is tapped from roofs and collected and stored in various types of tanks. All the islands have individual household tanks as well as community tanks. The situation is different in the capital island Malé, however, where the whole population has access to desalinated water distributed through a piped network. As in Malé, many islands are now facing groundwater problems caused by human activities such as over-exploitation and sewage pollution.

The first desalination plant in Malé was installed in 1988 with a capacity of 200 cubic meters per day. In line with increases in population and water consumption, the capacity has been increased steadily and now stands at 5,800 m^3/day. Because it is very expensive, desalinated water is not used for all purposes. Most households use desalinated water for drinking, cooking, bathing, and some other domestic purposes. Groundwater is mainly used for toilet flushing. Many households are still using groundwater for bathing. Those who cannot afford to have house connections can collect limited quantities of water free from tap bays.

Meeting water needs by sustainable and affordable means is of paramount importance to the people of the Maldives. In a number of densely populated islands, it may not be possible to rely totally on natural resources. In these islands, it may be necessary to turn to the expensive alternative of desalination to supplement existing resources.

The Maldives' groundwater resources are especially vulnerable to pollution from human activities. Fortunately, there are relatively few heavy industries outside the capital Malé, and intensive agriculture occurs in only a small number of islands. The major source of groundwater pollution is poor household sanitation.

Outside Malé, the majority of households have septic tanks and soakaways. The tanks are often poorly built or have suffered from hydrogen-sulfide corrosion and are prone to leakage. In addition, tanks are desludged infrequently. As a result, they are often full or nearly full of sludge and have very short retention times. Soakaways are usually deep pits, not shallow trenches. Rather than use the unsaturated soil above the water table to remove at least some of the pollutants from the septic-tank effluent, they effectively create a shortcut for septic-tank effluent to reach the groundwater below.

These factors combine to cause the contamination of groundwater resources by septic-tank effluent. This effluent has relatively high concentrations of suspended solids and nutrients and contains large numbers of pathogens.

The soils of Maldives' islands are formed for the most part from very permeable coral deposits. Although in vegetated areas the upper parts of the soil profile contain organic material, the areas where people live and where poor sanitation systems affect the groundwater have usually been cleared of vegetation. As a result, the soil comprises a fairly uniform sand with very high permeability. In these conditions, groundwater movement can be quite rapid, and pollutants can be transported over large distances.

Each household generally has its own well. Well water is used primarily for bathing, but during the dry season, where rainwater storage is insufficient, well water is sometimes used for cooking and drinking. Under these circumstances, pollution of groundwater by pathogens can have a significant impact on health.

The Government of Maldives has built sewerage systems on some of the most densely populated islands to try to alleviate this problem, and some island communities have built their own sewerage systems. Although these systems have improved the situation, many households still use polluted groundwater.

Maldives' groundwater is not only vulnerable to pollution, but because the lens is quite thin, it is also vulnerable to increases in salinity where over-extraction takes place. Despite low consumption per person in the rural islands, over-extraction occurs by virtue of the high population densities on some islands, and increased salinity can result.

During the dry season, there is no recharge by rainfall, yet groundwater extraction continues at the same rate. As a result, freshwater lenses are gradually depleted, and seawater can often encroach upon the islands' periphery. Studies show that the groundwater at the periphery of many islands is very saline. In some islands the area of saline groundwater extends inland. Inundation of land and associated saltwater intrusion due to the predicted rise in global sea levels will reduce the size of freshwater lenses and thus reduce the availability of freshwater.

Group discussion

At present, the energy source for desalinization in Maldives is diesel fuel, which is imported. There has been some experimental work with desalinization systems that use solar energy. Similar work has been undertaken in Barbados.

Sewage disposal is a growing problem in Maldives. At present untreated wastewater is discharged into the sea. Following an ecological sanitation approach, waste products might be converted for use as a resource.

There have been substantial lifestyle changes in Malé, including greater use of automobiles and changing consumption patterns. Some of these changes might affect the local environment, with negative repercussions for human health. In considering the health effects of climate change, it would be useful to look more broadly at the environmental determinants of health.

15. Climate Change and Health in Indonesia

Umar F. Achmadi (Communicable Disease Control and Environmental Health, Ministry of Health, Indonesia) and *Jan A. Speets* (World Health Organization)

Indonesia consists of five large islands and approximately 17,000 small islands stretching over more than 5,000 kilometers along the Equator. The western islands are volcanic and tend to have high agricultural potential, while the eastern islands tend to be rocky and dry. Out of a total population of 240 million, 60 percent live on the island of Java.

Predicted temperature increases and sea-level rise may increase the risk of air-borne, vector-borne, and water-borne diseases. In the late 1990s, El Niño and La Niña conditions were associated with outbreaks of malaria, dengue, and plague.

Although there is 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.

Because of climate change, these precautions are no longer adequate to prevent outbreaks of disease. In Indonesia, El Niño conditions are associated with prolonged dry weather, while La Niña conditions cause extremely wet periods, resulting in a pattern of long dry seasons alternating with short periods of intense rainfall. The pattern of storms also appears to be changing. In general, weather forecasting has become highly unreliable.

To address this situation, the government identified a number of key persons with lead roles in decision-making, science, and communications to take part in a National Forum on Climate Change and Health Impact in December 2001. The objectives of the Forum were to:

- Facilitate the intersectoral exchange of information on climate change and health
- Create awareness at all levels
- Undertake research
- Support the development of a strategic plan

Commissions have been set up to continue the work of the Forum, focusing on research and development and on advocacy, friendship, and socialization. The Ministry of Health's Communicable Disease Control and Environmental Health Department serves as Secretariat.

The Research and Development Commission:

- Collects research results on climate change and health and disseminates this information to Forum members and the Secretariat
- Designs and develops studies on climate change and health
- Builds networks of research organizations concerned with climate change and health within Indonesia and abroad
- Monitors and evaluates research on climate change and health

The Advocacy, Friendship, and Socialization Commission:

- Communicates findings obtained by the Research and Development Commission to Forum members and other concerned groups in Indonesia and abroad
- Familiarizes groups in Indonesia and abroad with the work of the Forum
- Plans, implements, monitors, and evaluates Forum activities

- Builds friendship networks with various sectors and organizations within Indonesia and abroad

A second seminar and workshop for all stakeholders, held in 2003, began work on a Strategic Plan for Responding to Communicable Disease Outbreaks Related to Climate Change. The focus is on air-borne disease (caused by forest fires), vector-borne disease (dengue, malaria), and food security. The plan includes both long-term and short-term strategies. The long-term focus is on:

- Developing scientific research and technology for monitoring climate change
- Strengthening capacity to forecast climate change and potential health effects
- Improving regulation
- Developing disease surveillance related to climate change
- Periodically informing the public about climate change and health

In the short term, the strategy calls for:

- Strengthening intersectoral collaboration on climate change and health
- Increasing public awareness of climate change and health, particularly related to communicable diseases
- Conducting socialization, partnership, and advocacy activities
- Carrying out research in populous areas
- Developing more efficient use of combustible fossil fuels

In summary, Indonesia is in the early stages of developing an early-warning system related to climate change and health. There is evidence that some disease outbreaks are associated with climatic factors, but no in-depth studies have been conducted on links between climate variability, climate change, and communicable diseases. Greater intersectoral collaboration is needed, including networking and interdisciplinary research. Finally, a regional climate forecasting mechanism is needed that will facilitate the prediction of disease outbreaks.

Group discussion

There has been a lot of work on climate analysis and forecasting in Indonesia, but communication among government departments is often inadequate, and climate data are not widely used. Satellite images are available at high resolution. District-level departments need software to analyze these images and put the knowledge they provide into practice.

Up to now, ongoing activities stemming from the National Forum on Climate Change and Health Impact have not focused specifically on Indonesia's remote small islands, but there are plans to increase attention to these locations and their special problems. The overall planning process has become more decentralized and gives more emphasis to sustainable development.

The activities of the Forum represent a unique approach, not donor-driven but initiated by the Ministry of Health. The Forum meets at least twice a year. The structure is informal and open to a broad range of participants, including a few nongovernmental organizations (NGOs). In a situation where ministries and departments are accustomed to working in isolation, bringing them together is a slow process, which is extremely useful and important but needs to be approached with caution.

16. Modeling the Relationship between Climate Variability and Human Health: Case Study from Cuba *Paulo Lázaro Ortiz Bultó* (Meteorological Institute), *Alina Rivero Valencia* (Meteorological Institute), *Antonio Peréz Rodríguez* (Tropical Medical Institute "Pedro Kourí"), and *Nicolas Leon Vega* (Ministry of Health)

A model-based approach helps explain how climate variability and climate change affect epidemiological patterns. Although many aspects of human systems are difficult to model, this work uses complex indices to simulate the climate and other processes, including ecological and socioeconomic change. The analysis provides an assessment of the economic impact of increased disease incidence due to climate variability.

The model uses three global indices of climate variability: the Multivariate El Niño Southern Oscillation (ENSO) Index, the Quasi-Biennial Oscillation, and the North Atlantic Oscillation. These are all available from the Climate Diagnostic Center in Boulder, Colorado.

The Climate Center of the Cuban Meteorological Institute provides meteorological data for 51 stations across the island. These include monthly minimum and maximum temperature and precipitation, atmospheric pressure, vapor pressure, relative humidity, thermal oscillation, days with precipitation, solar radiation, and insolation. Data are analyzed for 1991–2003, and results are compared with a base period of 1960–1990.

The Ministry of Health provides epidemiological data. These include the incidence of acute respiratory infections, acute diarrheal 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. The first describes inter-month, seasonal, and inter-seasonal variation in climatic factors. The second describes inter-annual and decadal variability in the same climatic factors. The third describes variations in socioeconomic indicators as they affect the risk of an epidemic outbreak, summarized as life quality at the individual level and state of poverty at the community level.

These indices have been 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 that are attributable to climatic factors.

The model can provide decision-makers with a tool to help anticipate the effects of climate variability on disease incidence. The monthly climatic outlook for November 2003 to March 2004, for example, suggests 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 diarrheal 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 of dengue.

For some diseases, changes in variability associated with climate change may be more important that changes in the mean values of climate parameters. Experience to date indicates that climate prediction can be used to prepare for climate variability and extreme events, including an estimation of costs. Experience also demonstrates that interdisciplinary collaboration and the sharing of information, experience, and research methods among sectors are critical for effective policy formulation and the development of support tools for decision-makers.

17. Weather-Related Disasters: An Approach to Managing the Potential Health Impacts of Climate Variability and Change in the Caribbean

Herold Gopaul (Caribbean Environmental Health Institute)

While the Caribbean region is not a major contributor to global warming and climate change, it is particularly vulnerable (economically, environmentally, and socially) to any potential impacts from these phenomena. Most Caribbean countries are small island states, and most lie in the hurricane belt. They are characterized by high levels of biodiversity with very fragile ecosystems, including coral reefs. The smaller countries have a ratio of water to land area exceeding 30:1. Most of the economies are fragile, depending on tourism and/or agriculture as their main source of foreign exchange, and most have a poorly developed public-health infrastructure.

The importance of climate variability and change and the potential impact on health has recently gained recognition in the Caribbean. The issue has been placed on the regional agenda at the highest political level, with the establishment of the Caribbean Community Climate Change Center (CCCCC) in Belize. While recognition has been increasing, it is still not widespread among the general population, however. Most people in the region:

- View climate variability and change as falling within the domain of the scientific and research communities
- Perceive climate variability and change as highly technical and complex and therefore difficult for the lay person to understand
- See climate variability and change as an abstraction rather than a potential reality
- See themselves as separate from, rather than an integral part of, the environment. They view the physical and biological world as something to be conquered or exploited, thus changing the environment without being affected themselves

Until recently, the potential effects of climate variability and change on human health have not figured prominently in regional discussions, nor have the medical or public-health communities been actively involved in the debate. In large part, the lack of emphasis on human health results from two factors. First, the political leaders in the region, by and large, lack the scientific, technical, medical, or public-health knowledge that would help them understand the implications of climate variability and change for human health. For this reason, they tend not to pay much attention to the issue. Second, global environmental issues such as climate variability and change tend not to be an integral part of medical or public-health education in the region, and, as a result, most medical professionals have very little knowledge of the issue. The result is an absence of a health voice in the debate on climate variability and change.

Findings of the Intergovernmental Panel on Climate Change (IPCC) have shown that sustaining human health requires the continued integrity of the Earth's natural systems and that the disturbance, by climate change, of physical systems and ecosystems would pose risks to human health. The IPCC has also concluded that small island states (like those in the Caribbean) are particularly vulnerable to projected climate change. Many direct physical and ecological threats pose risks to human health in these nations.

In the Caribbean, the lack of adequate systems for linking climate variability and change data to information on health compounds the problem. There is very limited research to guide the type of interventions that should be made. Even more critical is the lack of adequate mechanisms for ensuring that research results are packaged in a way that policymakers and planners can use.

In attempting to understand the potential health effects of climate change in the Caribbean, the health effects of weather-related disasters can serve as a starting point. 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 eight hurricanes, of which three were category three or higher. In 2001 there were 15 named storms, including nine hurricanes, of which four were category three or higher. During that year, the region recorded 48 deaths resulting from storm disasters.

In 2002 Tropical Storm Lili was accompanied by 2 to 4 inches of rain in most areas. St. Vincent suffered four deaths and losses of more than US $14.8 million in agriculture. 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 four deaths, relocation of 725 persons, and infrastructure damages worth more than US $1 million.

The effects of climate variability and change on human health can be direct or indirect, immediate or long term. The fact that some important effects are indirect or delayed makes it particularly important to put multisectoral monitoring and surveillance systems in place. The major threats to human health that weather-related disasters pose in the Caribbean are:

- Deaths and direct injuries, including bites from animals
- Insect- and rodent-borne diseases, including dengue, leptospirosis, malaria, and yellow fever
- Water-borne diseases, including schistosomiasis, cryptosporidium, and cholera
- Food-borne diseases, including diarrheal 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 disturbance in food production or distribution
- Anxiety and stress

The region is heavily dependent on rainfall to feed surface water intakes and replenish groundwater reserves. Changes in rainfall patterns are likely to 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 Center (CAREC) and the Water and Sewage Authority (WASA) of Trinidad and Tobago found that 18.6 percent of samples of potable water were positive for cryptosporidium. These samples were taken after heavy rainfall events. In addition to polluting floodwaters, chemicals and other hazardous wastes can and do contaminate groundwater, with long-term health effects.

While there have been some improvements in recent years, the management of liquid and solid waste is largely unsatisfactory. In rural communities, the poor 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 the clogging of waterways with waste.

Large portions of the population in the region 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. In recent years this problem has been clearly evident in the central plains of Trinidad.

The recent increase in the number of reported cases of dengue in the region has focussed attention on vector control. The *Aedes aegypti* mosquito, the vector for dengue, lives in and around human settlements. Poor public-health practices provide ample breeding ground for *A. aegypti*, while rainfall, temperature, and other seasonal weather conditions appear to play a major role in the mosquito's behavior, development, and reproduction. Increases in temperature and rainfall tend to speed up feeding and breeding, while the accumulation of stagnant water provides additional breeding grounds.

Food safety is another priority for public health. Flooding 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. Runoff, contaminated with agrochemical, metals, and untreated or poorly treated waste, contributes to the contamination of coastal waters and reef fish and shellfish.

Normal public-health monitoring and surveillance programs 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 health-care supplies are needed and where. The main areas of focus for monitoring and surveillance systems should be communicable diseases, environmental sanitation, food and nutrition, and disease vectors.

A public-health contingency plan should be put in place to address the health impact of weather-related disasters in the Caribbean. The plan should be comprehensive but not overly detailed to allow for flexibility. It should provide guidance and direction for relevant intervention agencies, serving as a template for what should be done, by whom, and when. Finally, the contingency plan should be well-structured, easy to read, and easy to update.

A rapid public-health needs assessment should be conducted at the initial stages of a weather-related disaster to:

- Determine immediate resource needs of the affected area
- Provide a snapshot of the potential longer-term need for resources
- Determine critical resource requirements to support emergency response activities

The collected information should be uncomplicated but precise.

The effective management of human-health issues associated with weather-related disasters in the Caribbean will provide a good building block for managing the potential human-health effects of climate variability and change.

Group discussion

One problem in creating awareness of the links between climate change and human health is that people tend to see themselves as separate from the environment and to see environmental change as an issue for academics only. Attitudes in the Caribbean are similar to those found in other regions. The issue needs to be demystified and explained in terms of people's everyday experience. In Sri Lanka, traditional farmers understand the relationship between climate and health better than do more modern population groups. In the Caribbean, several organizations are trying to create a sense of environmental ownership or stewardship in the general population.

The conference and workshop on Climate Variability and Change and their Health Effects in the Caribbean, held in Barbados in May 2002, created a better awareness of the effects of climate change on health among ministry officials but not among the general public. One result was that the Caribbean Environmental Health Institute has produced a manual on flood management. If ministries in the region put mechanisms in place for disaster management, these will be useful in coping with the results of climate change.

There have been proposals that some islands in Micronesia will be used as dumping sites for toxic and nuclear waste. This may already be happening. The issue is very controversial in the region.

18. Adaptation Policy Framework

Kristie L. Ebi (Exponent Health Group, USA)

The Adaptation Policy Framework (APF) aims to provide guidance to developing countries that are formulating national policy options for adaptation to climate change. A major focus of the APF is to help countries integrate such adaptation policies into national and sectoral planning. The APF describes the key analytical concepts for developing adaptation strategies, policies, and measures. The framework was initiated by the United Nations Development Program (UNDP) in response to developing countries' needs and builds upon the vulnerability and adaptation assessments conducted within the Initial National Communications of non-Annex 1 Parties. The APF is being elaborated with co-financing from Switzerland and Canada and an in-kind contribution from the Netherlands.

The main objective of the APF is to assist and provide guidance to developing countries in identifying, prioritizing, and shaping potential adaptation options to climate change into a coherent strategy that is consistent with their sustainable-development and other national priorities. The APF provides a flexible approach to developing national strategies for adaptation to climate change that can be modified to meet the specific needs of countries in any region. It is designed to provide "user-friendly" guidance on specific approaches, methods, and tools that best fit unique national circumstances. The APF consists of a User's Guidebook and nine Technical Papers. Each Technical Paper explores a specific aspect of the APF and provides detailed guidance on one or more of the APF components. Each Technical Paper also contains annexes with additional guidance on methods and tools.

The APF was developed to address the United Nations Framework Convention on Climate Change (UNFCCC) Guidelines on the Preparation of National Communications. According to Article 12, paragraph 1(b) and (c) of the Convention, each country shall provide a general description of steps taken or envisaged towards formulating, implementing, publishing, and regularly updating national and, where appropriate, regional programs to facilitate adequate adaptation to climate change.

The APF is structured around four major principles that provide a basis from which actions for adaptation to climate change can be developed:

1. Adaptation to short-term climate variability and extreme events provides a basis for reducing vulnerability to longer-term climate change
2. Adaptation policy and measures should be assessed in a development context
3. Adaptation occurs at different levels in society, including the local level
4. The adaptation strategy and the process by which it is implemented are equally important

The APF is about practice rather than theory. Its starting point is the amount of information that developing countries may already possess on vulnerable systems such as agriculture, water resources, public health, and disaster management. The APF is capable of yielding a variety of outputs, depending on how it is applied. While specific outputs will depend on particular needs and goals, in general a completed APF process leads to a clarification of adaptation strategies, policies, and/or measures that a country could implement, as well as increased adaptive capacity.

The APF consists of five basic components that are linked by two crosscutting components. The five basic components are: Project Scope and Design; Assessing Current Vulnerability; Characterizing Future Climate Risk; Developing an Adaptation Strategy; and Continuing the

Adaptation Process. The crosscutting components are Stakeholder Engagement and Measuring and Enhancing Adaptive Capacity.

Defining Project Scope involves ensuring that the project is well designed and integrated into the national policy-planning and development process. Assessing Current Vulnerability involves an assessment of the present situation. It addresses the questions: Where does a society stand today with respect to vulnerability to climate risks? What factors determine its current vulnerability? How successful are its efforts to adapt to current climate risks? Characterizing Future Climate Risks involves the development of scenarios of future climate vulnerability and socioeconomic and environmental trends as a basis for considering future climate-related risks. Developing an Adaptation Strategy involves the development of a set of adaptation policy options and measures in response to current vulnerability and future climate-related risks. Continuing the Adaptation Process involves the process of implementing, monitoring, evaluating, and sustaining the initiatives begun by the adaptation project.

Engaging Stakeholders is a crosscutting component that involves an active and sustained dialogue among affected individuals and groups and is crucial to the successful implementation of the APF. Enhancing Adaptive Capacity involves the integration of activities to better cope with climate change and variability into national capacity-strengthening efforts.

The APF is flexible enough to allow countries to use only one or two components, or even to follow components only in part. Decisions about how to use the APF will depend on a country's prior work, needs, goals, and resources.

The Global Environment Facility (GEF) project on Capacity Building for Stage II Adaptation to Climate Change in Central America, Mexico, and Cuba is currently testing the APF. For more information, contact Dr. Bo Lim (bo.lim@undp.org).

Group discussion

The flexibility built into the APF process allows countries with different needs and resources to conduct at least a preliminary assessment of vulnerability to climate-related health risks. This same flexibility, however, may make it difficult to compare the assessments of different countries.

Workshop Recommendations

Small-island states are among the most vulnerable places in the world to climate variability and climate change. Their small size, isolation, fragile ecological systems, and vulnerability to sea level rise and extreme climate events put them at particularly high risk. Former President Leo Falcam of the Federated States of Micronesia noted that "for Pacific Island States, climate change and its associated effects are our main security concern" ("Death by warming," *Honolulu Advertiser,* 12 August 2001).

1. Established evidence

- Climate variability and climate change are among the most important local, regional, and global environmental challenges that affect human health.
- Small-island states are particularly vulnerable to the health effects of climate variability and climate change.
- Key health outcomes of concern for small-island states include vector-borne diseases, diarrhoeal and other water-borne diseases, acute respiratory infections**,** undernutrition, and adverse health outcomes due to (or associated with) extreme weather events.
    a. The observation of adverse health effects provides a clear signal that climate change—often evidenced as increased climate variability—is contributing to the destabilization of the conditions for life on Earth.
- Because overall sustainability includes the security, health, and well-being of human populations, minimizing climate change is a prerequisite to the achievement of sustainable development.
- While adaptive measures for the consequences of climate variability and change need urgent and immediate attention, long-term mitigation measures to reduce greenhouse gas emissions are vital to the survival and sustainable development of small-island states.

2. Awareness, education and policy advocacy

- Build awareness of climate/health links in local communities and among the media.
- Educate young people and medical/health professionals about climate/health links through school and university curricula.
- Frame 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.
- Ensure that recommendations from this workshop receive full consideration in ongoing policy processes at the national, regional, and global level, including key international conventions.
- Monitor and evaluate the effectiveness of public-awareness activities. Encourage governments to recognize the significance of health effects related to climate variability and change, especially the relationship to sustainability.

- Advocate for integrated policy development across sectors to take account of the effects of climate variability and change on health.Improve early-warning systems to predict climate variability and change and the likely implications for health.
- Enhance collaboration, communication, and information flow among all stakeholders.
- Encourage programs of action and partnerships between public and private sectors including business and nongovernmental organizations.Incorporate a consideration of climate/health interactions in planned and ongoing development programs, and include health aspects in global, regional, and local environmental and disaster-management planning.

3. Need for (more) evidence-based data

- Collect more valid and comprehensive health, meteorological, environmental, and socio-economic data at appropriate local, regional, and temporal scales for research, program planning, and advocacy.
- Improve health surveillance systems to allow assessment of the impact of climate variability and change on health.
- Establish or improve data standards and quality criteria to facilitate the better integration of data sets across sectors.
- Improve sharing and timely access to relevant data sets.
- Expand research on the links between climate variability and change and specific diseases of importance in small-island states.Improve understanding of the complex relationship between the risks posed by climate variability, climate change, and other factors that influence population healthEvaluate the effectiveness of early-warning systems and other response strategies for climate-sensitive health impacts.
- Assess costs and benefits of intervention options.
- Promote the creation of national and regional interdisciplinary working groups to study the impact the climate variability and change on health.

4. Capacity Building: Training and Technical Assistance

- Develop mechanisms for knowledge sharing at national, regional, and international levels, including:
    - Identifying regional centers of excellence and promote partnerships with local institutions.
    - Establishing programs with WHO, WMO, and UNEP in collaboration with other relevant agencies to provide country assistance in conducting vulnerability and adaptation assessments.
    - Transferring knowledge of adaptation options to nations with similar climate/health concerns.
- Create partnerships between climate/meteorology and health/medical specialists that include:
    - Sensitising climate and meteorology specialists to the health effects of climate variability and climate change.

- Improving the awareness of health and medical specialists on global environmental issues and the use of climate-forecast information.

5. Resource Mobilization

- Ensure that adequate funding is made available for priority research on climate and health from both the public and private sectors.Mobilize funding through all available mechanisms. These include the Program of Action for the Sustainable Development of Small Island Developing States (Barbados Program of Action or BPoA), and the U.N. Framework Convention on Climate Change, the Global Environmental Facility (GEF), the U.N. Convention on Biological Diversity, and the U.N. Convention to Combat Desertification.
- Balance the optimal use of national and regional human resources with sound, appropriate technical assistance.

6. Next Steps: suggestions from participants to workshop organizing agencies and country officials

- Find success stories to be highlighted.
- Develop a database of experts from small-island states and elsewhere who could facilitate climate and health assessments, projects, and research.
- Organize hands-on workshops to help participants analyze national health and climate time-series data and assess climate-health linkages.
- Within countries, establish inter-agency groups at ministerial level to help promote and sponsor research and coordinate activities on the links between climate and health.
- Establish regional data centers that would gather and disseminate information related to climate and health.
- Through pilot projects, support research on the relationship between climate and health in small-island states.
- Place climate and health on the agendas of national, regional, and international gatherings, such as the World Health Assembly, meetings of the Pan American Health Organization (PAHO), and the International Meeting on Sustainable Development of Small Island Developing States (Barbados+10).
- Ensure formal input into the 4th Assessment Report of the Intergovernmental Panel on Climate Change. (Note that in order for that to happen, a peer-reviewed document will have to be published by early 2006.)
- Send letters to all regional WHO, WMO, and UNEP offices giving recommendations from this meeting.

ANNEX A: Workshop Agenda

Monday, December 1

8:55 am	Recitation from Holy Quran – *Ibrahim Zahid*
	Welcome Address – *Abdul Azeez Yoosuf*
	Director General of Health Services, Maldives
	Statement of Regional Director SEARO
	Jorge M. Luna
	WHO Representative to the Maldives
	Opening remarks on behalf of the Interagency Network on Climate and Human Health (WHO, UNEP, WMO)
	Carlos F. Corvalan
	WHO, Geneva
	Opening Remarks by the Minister of Health, Maldives
	Honorable Ahmed Abdullah
	Keynote address "Climate Change and Human Health"
	Anthony J. McMichael,
10:00	Coffee
10:10	Sponsoring Organizations Welcome
	Alex von Hildebrand (WHO)
	Buruhani Nyenzi (WMO)
	Hiremagalur Gopalan (UNEP)
10:20	Overview and Charge to the Meeting – *Nancy Lewis, Carlos Corvalan*
10:30	Coffee
10:45	Self Introductions and Selection of Meeting Officers
11:10	Keynote presentation by *A. McMichael*, "Climate Change, Climate Variability and Health"
12:00 pm	Lunch
1:30	Overview of the Samoa and Barbados workshops *Navi Litidamu* and *Roland Knight*
2:15	"Climate and Weather 101": Climate change, climate variability, ENSO/decadal variations – *Lareef Zubair*
3:00	Coffee
3:20	Challenges of Climate Prediction and Its Application in the Health Sector - *Buruhani Nyenzi*
3:50	Brainstorming (in breakout groups)– what are the major health problems in the Indian Ocean region that maybe climate sensitive?
4:45	Report back and Discussion of meeting recommendations – *Alex von Hildebrand*
5:30	Close

Tuesday, December 2

8:30 am	Climate and Climate Variability in the Indian Ocean Region – *Satyabhama Cahoolessur*
9:00	Sustainable Development in Small Islands – *Mohamed Ali*
9:30	Coffee
9:50	Breakout Groups: Exploring the relationships between climate sensitive diseases and weather and climate.
10:45	Report Back from Breakout Groups
11:15	Forecasting and Applications – *Steve Palmer*
12:00 pm	Lunch
1:30	Environmental Burden of Disease – *Carlos Corvalan*
2:00	Application of Forecast Information – *Aurelia Micko*
2:30	Forecast Applications in the Pacific – *Nancy Lewis*
3:00	Coffee
3:20	Vulnerability and Adaptation – an Introduction – *Kristie Ebi*
3:50	Risk and Vulnerability Assessment – *Kristie Ebi*
4:20	Adaptation Policy Framework
4:50	Review and Recommendations
5:30	Close

Wednesday, December 3

8:30 am	Steps in Risk and Vulnerability Assessment – *Kristie Ebi*
9:15	Breakout by Health Outcome
10:30	Coffee
11:00	Plenary – Report of Breakout Groups
12:00 pm	Lunch
1:30	From Problem to Policy
2:00	Breakout Groups: Policy Table
3:15	Coffee
3:45	Report of Policy Table Breakout Groups
4:00	Weather Related Disasters – Caribbean Perspectives on impacts on health from climate variability and climate change – *H. Gopaul*
4:30	Recommendations Working Groups
5:30	Close

Thursday, December 4

8:30 am	Introduction and Breakout Groups: Intersectoral collaboration
10:30	Coffee
11:00	Plenary Discussion of Intersectoral collaboration
12:00 pm	Lunch
1:30	Dialogue: What national, regional, international institutional arrangements exist that could facilitate the use of climate information for health - -Capacity Building strategies and partnerships
3:00	Coffee
3:20	Research Needs
4:30	Recommendations/Best Practices (Plenary)
5:30	Close

ANNEX B: List of Participants

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ANNEX C: Opening Speeches

Synthesis Workshop on Climate Variability, Climate Change and Health in Small Island States

Message from Dr Uton Muchtar Rafei, Regional Director

South-East Asia Regional Office, New Delhi

(To be delivered by Dr Jorge Luna, WHO Representative to the Maldives)

Distinguished delegates, guest speakers, colleagues, ladies and gentlemen, I am very happy to welcome you all and to convey the greetings of the Regional Director, Dr Uton Muchtar Rafei. Dr Uton would have liked to attend this important consultation but is unable to do so because of urgent commitments. I have great pleasure in delivering his message.

QUOTE:

The health of any human population reflects, in a basic sense, the conditions of the social and natural environment. We know that the state of the environment affects human health and have largely identified what elements of the environment are supportive to good health. But, increasingly, the life support functions of the global environment are being stretched to the limit, and in some cases, are actually being exceeded. As a result, new threats to human health – and quite possibly the re-emergence of old threats – can be anticipated.

For these reasons, WHO advocates the protection of the environment and health. WHO’s work in the field of environmental health is to be understood as a constantly active and vigilant process that needs to be integrated into economic development analysis and decision-making.

Currently, one of the most worrying environmental concerns is the potential adverse and large-scale impact that human activities can have on the climate of the planet. Indeed, the scientific community has learnt much about climate change in recent years. In 2001, the Intergovernmental Panel on Climate Change published its Third Assessment Report, with better predictions and increasing acceptance and agreement on the fact that global warming can seriously disrupt the natural balance of the world's climate. Atmospheric levels of heat trapping “greenhouse gases” such as CO2 are now higher than at any time in the past.

We know, for example, that the average temperature in many regions has been registering on increase in recent decades. In fact, 1998 was the warmest year and the 1990s the warmest decade on record. Many parts of the world have experienced more rainfall, while in others, the frequency and intensity of droughts have also been observed to increase. The frequency and intensity of El Niño has been amplified manifold. If this is the result of the 0.6 degrees centigrade rise in temperature in the last century, there is reason to be concerned about the 1.4 to 5.8 degrees centigrade rise expected in the course of the current century.

The burden of disease assessment was published in the WHO's World Health Report 2002. According to the report, over 150000 people are estimated to have died in 2000 as a direct or indirect result of climate change. Climate change may impact health on many fronts:

- Fresh water supply and food production may be compromised by a changing climate.
- Climate-associated natural disasters could become more frequent and/or severe.
- The geographical distribution of certain vectors may change, spreading diseases in previously unexposed populations.
- Heat-waves and increased urbanization will continue to take their toll, indeed increasing their impact on vulnerable populations such as the elderly and children. In the past months, the European summer turned into a heat ordeal. Up to 20000 people died of the effects of extreme heat. Prior to this, a heat wave struck India, officially causing more than 1300 deaths.

We are also fully aware of the uncertainties behind current trends and predictions. For example, recent studies have questioned the notion that climate change is linked to the worsening of malaria in East Africa - suggesting instead that this is the result of other factors such as drug resistance, vector control and population movement. However, others believe it is too early to disregard completely the additional contribution of climate change, now or in the future.

We need to address the problem despite uncertainties, identify vulnerabilities and find appropriate mechanisms to protect human health. As our former DG Dr Brundtland said in this respect: "Having unintentionally initiated a global experiment, we cannot wait decades for sufficient empirical evidence to act. That would be too great a gamble with our children's future". Unless effective climate protection policies are introduced, atmospheric levels of greenhouse gases could increase dramatically in the near future and put us on a pathway that would lead to a point of no return.

Let me briefly address the tasks for the next four days. The goal of this meeting and your task is to increase knowledge on climate-sensitive health problems in your respective countries and geographical regions, to provide guidance for action to policy officials from ministries of health. To reach this aim, the following set of proposed objectives need to be achieved:

First, to inform scientists, practitioners and officials as well as key individuals in other climate-sensitive sectors, of the dimensions and potential impacts of climate variability and long-term climate change in the Indian Ocean region; and also in the Pacific and Caribbean. You will be the first to see the book Climate Change and Human Health – Risks and Responses, prepared by WHO in collaboration with World Meteorological

Organization and United Nations Environment Programme, and to be officially launched at the United Nations Framework Convention on Climate Change, Conference of the Parties COP9 in Milan, next week.

Second, to explore the relationships between climate variability and climate change and human health in small island states. As we all know, these issues have not always been addressed by ministries of health, but rather by other sectors. It is now time for the health sector to play a more important role. The Indian Ocean region is well represented by participants from India, Nepal, Indonesia, Sri Lanka and of course the host country, Maldives.

The third objective of this workshop is to address vulnerability assessment and adaptation options for small island states, stressing the need for multisectoral approaches and issues of scale. You will learn about this activity and your input will be very valuable to better understand countries' needs in this respect. The added value of these proposed assessments in combating current environmental health problems, as well as the value of learning from each others' efforts in developing adaptation mechanisms cannot be overlooked. The inputs of this workshop will be of high significance for the UNFCC, as the guidelines on assessing vulnerability and adaptation will also be discussed at COP9, in Milan, next week.

Fourthly, building on the workshops in the Pacific and the Caribbean as well as developments in the field of climate and health research and assessment, you will further address issues on how to integrate other health-relevant sectors, and define strategies for coastal zone management that are relevant to public health. A joint task will be to identify potential joint interdisciplinary research projects and options for capacity-building to improve health and climate information systems as well as to assess vulnerability and adaptation to climate variability and change.

It would be most useful to identify "centres of excellence" in each Region, and mechanisms to enhance our current links with other international agencies working in this area. To ensure that our work remains focused, we should primarily concentrate our efforts where they are needed most.

The final results of this four-day workshop will be reflected in your recommendations for common action. It is my wish that these are formulated in such ways that our Member Countries can implement them swiftly, as much in the fields of prevention and preparedness as in the fields of remediation and response. The task is to identify key “non-regret” options, where our investment is valid for today’s problems as well as for problems likely to be made worse by climate change in future.

These are not easy tasks and time is short. I wish all participants a fruitful workshop.

UNQUOTE:

I will, of course, apprise the Regional Director on the outcome of this consultation. Before concluding, I would like to wish you fruitful discussions and a pleasant stay in Male.

Thank you.

Opening remarks on behalf of the

Interagency Network on Climate and Human Health

Dr Carlos Corvalan

World Health Organization

The Hon. Ahmed Abdullah *Minister of Health*

Dr Abdul Azeez Yoosuf, *Director General of Health Services*

Dr Jorge Luna *WHO Representative to the Maldives*

Ladies and Gentlemen, Colleagues and Friends,

On behalf of the Interagency Network on Climate and Human Health I wish to welcome you to this "Synthesis Workshop on the Health Impacts of Climate Variability and Climate Change in Small Island States".

The Interagency Network is a formal recognition of the partnership between WHO, UNEP and WMO in addressing climate and health issues in the past decade. The three agencies have worked together in public awareness and information projects for many years. In the last five years, our agencies agreed in expanding our work to focus on three areas: Capacity building activities, Information exchange and Research promotion. Our activities benefit from the strengths of the three agencies, by using climatic and environmental information to protect human health at all levels - from local to national to global. This workshop will address all three focus areas, expanding upon the lessons learned through a similar workshops held by the Interagency Network in Samoa, for Pacific Island Countries, in 2000, and an international conference and workshop held in Barbados for Caribbean countries in 2002. For this Synthesis Workshop we have expanded out efforts in order to bring representatives from Small Island Countries in the Indian Ocean, the Pacific, Atlantic and the Caribbean, in order to discuss common problems and exchange experiences.

In recent years the scientific community has learnt much about climate change and its expected impacts on many sectors. The most authoritative report was released in 2001 by the Intergovernmental Panel on Climate Change - its Third Assessment Report. The two other agencies of the our Interagency Network on Climate and Human Health – WMO and UNEP – are the sponsors of the Intergovernmental Panel on Climate Change.

Our collaborative effort has also produced the most recent global report on Climate Change and Human Health, which addresses specifically the risks to human health and the responses which individual and societies may need to give in order to protect human heath.

You are all receiving today and advance copy of this book, which will be officially launched on the 11th December, during the meetings of the Conference of the Parties to the United Nations Framework Convention on Climate Change, which is taking place in Milan, Italy. We are very glad to have with us the senior editor of the book, Professor McMichael from the Australian National University, a leading scientist in the field of global environmental change and health.

Climate variability has always impacted on human health. Hurricanes, floods, heat-waves, all these weather phenomena when manifested in extreme are associated with death, disease, and with overall suppression of well-being.

Today there is general acceptance in the scientific community that climate change is a reality. The facts are undeniable:

There are observed average temperatures increases in recent decades.

Record temperatures in recent years

Changes in the patters of rainfall

And a more frequent and persistent El Niño phenomenon

In addition to these measured and observed facts, there is general agreement among scientists of predictions about climate change:

Global temperature will continue to increase - the current projections are between 1.4 and 5.8 degrees Celsius by the end of the century

The frequency of weather extremes is also likely to change: this would lead to an increased risk to floods and droughts in certain areas.

The global mean sea level is projected to increase between 9 and 88 cm by 2100 - and some scientists believe this to be an underestimate.

We also know that climate change impacts will not be evenly distributed around the world. Some regions are expected to fare worse than others. Small Island States, for example, face a growing problem and they that global climate change is not a problem in the far horizon.

It is not hard to see how health impacts could become overwhelming for the health sector in the Small Island Countries. For example,

Storms, floods and sea level rise can affect fresh water supplies. Sewage systems may be damaged increasing the risk and spread of infectious diseases.

Climate change could impact on food production, adding to current pressures in many countries.

> Climate change could alter the distribution of some disease vectors, potentially increasing the spread of vector-borne diseases where currently absent.

This is a new challenge for the health sector, for which we will need increasing intersectoral collaboration, both in the assessment of vulnerabilities and in the introduction of cost effective interventions. We have much work to do this week, by learning from each other and planning responses to ensure that any impacts of climate variability and change on human health are minimized.

Let me finish by saying that this conference would not have been possible without the strong commitment of our three agencies and our Regional and Country offices.

We are also grateful for the contributions and participation in the organization of the conference and the workshop, of several partner agencies, including:

The U.S. Environmental Protection Agency (EPA) who helped make this event possiblee, the support of the United Kingdom Meteorological Office and the U.S. National Oceanic and Atmospheric Administration (NOAA).

On behalf of the World Health Organization and the Interagency Network on Climate and Human Health I wish you great success with the workshop,

Thank you.

Part 2 - Workshop Background Paper

Climate Variability, Climate Change, and Health in Small-Island States

Paper prepared for Synthesis Workshop on Climate Variability and Climate Change in Small Island States

Bandos, Maldives, 1–4 December 2003

Nancy Lewis, Ph.D.

East-West Center

Honolulu, HI, USA

Introduction

There is increasing recognition that climate variability and climate change can have important effects on human health, many of which are adverse. Assessing the vulnerability of populations to climate variability and climate change is becoming a priority for both national governments and international agencies. The goal is to formulate adaptive strategies, policies, and measures that will reduce the potential for adverse health and other effects on human populations. A priority is to develop an integrated approach across sectors.

The focus of this discussion is on assessing the potential health impact of climate variability and climate change on a particularly vulnerable population group—the people of small-island states. Indeed, small-island states are among the most vulnerable places in the world to climate variability and climate change. Their small size, isolation, fragile ecological systems, and vulnerability to sea-level rise and extreme climate events put them at risk (see Box 1). Former President Leo Falcam of the Federated States of Micronesia noted that "for Pacific Island States, climate change and its associated effects are our main security concern" ("Death by warming," *Honolulu Advertiser,* 12 August 2001).

Several international bodies support research and program implementation on health and other effects of climate variability and climate change. Adopted in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) provides an integrating framework for international programs on climate change, including data collection and application, climate system research, and studies of socio-economic, health, and ecosystem effects of climate variability. In 1998, an Inter-Agency Network on Climate and Human Health was established with a secretariat at the World Health Organization (WHO). The network focuses on three areas: capacity building, information exchange, and research promotion. WHO has developed methods and tools for assessing the potential effects of environmental change on health, designed to fit into international efforts.

Box 1. Small-island Developing States (SIDS)

The world's island states vary in many respects but are typically characterized by small or very small land areas, remoteness from major land masses, predominately tropical maritime climatic regimes, limited but often unique animal and plant life, small human populations, and—in some cases—great cultural diversity. The islands are differentially endowed with natural resources, and they have achieved different levels of "development" or "modernization." Infrastructure, including health infrastructure, is sometimes poorly developed.

Many Small-island Developing States have joined the Alliance of Small-island States (AOSIS), a coalition of 43 small-island and low-lying coastal nations and observers that share similar development challenges and concerns about the environment. A particular concern is vulnerability to the negative effects of global climate change.

Thirty-seven small-island states are members of the United Nations, and AOSIS serves as an ad hoc lobbying and negotiating voice within the U.N. system. The small-island states comprise 20% of the U.N.'s member countries but only about 5% of the total global population.

Members of AOSIS in the Caribbean and Latin America are: Antigua and Barbuda, Bahamas, Barbados, Belize, Cuba, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, and Trinidad and Tobago. Members in the Pacific and Asia are: Cook Islands, Fiji, Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Singapore, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Members in the Indian Ocean are: Comoros, Maldives, Mauritius, and Seychelles. Members in the Atlantic Ocean are: Cape Verde, Guinea-Bissau, and Sao Tome and Principe. Members in the Mediterranean are: Cyprus and Malta.

Feeding into the international policy process through the UNFCCC, a number of countries have conducted national assessments of the potential impacts of climate change. Objectives are: to understand current vulnerabilities; to evaluate a country's capacity to adapt through modifications of its health infrastructure or other strategies, policies, or measures; and to determine knowledge gaps that need to be filled (WHO 2003).

Climate variability and climate change

In a discussion of climate variability and climate change, it is useful to distinguish the terms "climate" and "weather." Weather is the day-to-day state of the atmosphere. Climate, on the other hand, refers to the average state of the atmosphere over a specified period of time, usually a month or longer. Both are characterized by meteorological conditions such as temperature, humidity, rainfall and other precipitation, and wind.

Temperature varies along general gradients determined by latitude and altitude and follows complex regional and local patterns (NRC 2001). In most places, changes in temperature over a 24-hour period are in the range of 5–15º C. In the tropics and subtropics where most small-island states are located, seasonal variations in temperature are usually smaller than the normal changes over 24 hours. There are also relatively small variations in seasonal temperatures between years. Annual amounts of rainfall and other precipitation vary much more widely (NRC 2001).

The term “climate change” generally refers to long-term change in the mean state of one or more climatic conditions (such as temperature and/or rainfall) over decades, centuries, or even millennia. The term “climate variability” refers to shifts in patterns of the natural climate system that are relatively short term—over years or decades—but that go beyond individual weather events (WHO, Health Canada, and UNEP 2003).

Scientists are beginning to understand the “modes” of climate variability between years. Best understood is the El Niño Southern Oscillation (ENSO) cycle. ENSO is a result of a complex interplay between anomalies and surface winds blowing along the equator and ocean currents and temperatures (NRC 2001). This interplay results in warm (El Niño) and the cold (La Niña) phases.

Although strongest in the tropical Pacific, ENSO effects are experienced across the globe, causing variations in rainfall and temperature over much of the tropics, subtropics, and some mid-latitude areas (IPCC 2001a). ENSO warm events (El Niño) have been more frequent, persistent, and intense since the mid-1970s than in the previous 100 years.

In addition to climate variability between years, long-term climate change is of increasing concern. The Third Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) concluded that the global average temperature increased by about 0.6ºC plus or minus 0.2ºC during the 20th century (IPCC 2001a). Most of this warming occurred during two time periods, 1910–1945 and 1976–2000. It is very likely (90–99% probability[1]) that the 1990s were the warmest decade on record and that 1998 was the warmest year since 1861 (IPPC 2001a). This general increase in temperature has been accompanied by a reduction in the frequency of extreme low temperatures since 1950 and a small increase in the frequency of extreme high temperatures. It is important to note that warming is not uniform, however.

The average global sea level rose between 0.1 and 0.2 meters during the 20th century. Global ocean heat content has increased since the late 1950s, the period for which data are available. Parts of the Southern Hemisphere oceans and Antarctica have not warmed, however.

During the 20th century, it is likely that rainfall and other precipitation increased by 0.5–1.0% per decade over most of the middle- and high-latitude land areas of the Northern Hemisphere and decreased by about 0.3% per decade over most of the Northern Hemisphere’s sub-tropical land areas (10ºN–30ºN). Over the same century, precipitation appears to have increased by 0.2–0.3% per decade over tropical land areas (10ºS–10ºN). No consistent changes in precipitation have been detected in the Southern Hemisphere, and there are insufficient data to establish trends in precipitation over the oceans (IPCC 2001a).

There were small increases during the 20th century in global land areas experiencing severe drought and severe wetness. In parts of Africa and Asia, there seems to have been an increase in the frequency and intensity of droughts in recent decades. There have been no significant trends in the frequency or intensity of storms, however, either in the tropics or in the temperate regions.

The impact of human activities

> While there are skeptics both within and outside the scientific community, the preponderance of evidence suggests that in recent decades human activity has altered the global climate system. The emission of carbon dioxide (CO_2) and other greenhouse gases appears to be contributing to global warming, creating new and far-reaching challenges to human—and ecosystem—health.

The atmospheric concentration of CO_2 has increased by 31% since 1750. Over the past 20 years, about three-fourths of CO_2 emissions from human activity have been linked to the burning of fossil fuels. The remaining emissions are predominately due to land-use change, especially deforestation. The land and ocean together take up about half of these CO_2 emissions—the rest remain in the atmosphere. There have also been significant increases in methane (CH_4) and nitrous oxide (N_2O) in the atmosphere. The atmospheric concentration of some other greenhouse gases is increasing more slowly or decreasing as a result of emission controls in response to international agreements.

The third IPCC assessment report found new and stronger evidence that most of the warming over the past 50 years can be attributed to human activities, likely due to increases in greenhouse-gas emissions. The report also concludes that warming in the 20th century has contributed significantly to sea-level rise, due both to the expansion of water at higher temperatures and to the melting of alpine glacier ice (IPCC 2001a). Small-island states account for less than 1% of global greenhouse-gas emissions, but they are likely to be among the nations most seriously affected by global warming.

Predictions for the future

To help predict the impact of human activity on future climate change, the IPCC used projections to develop six groups of emissions scenarios based on different assumptions about economic development, population growth, and globalization (Box 2). Average surface temperatures are projected to increase by 1.4ºC–5.8ºC between 1990 and 2100. It is very likely that nearly all land areas will warm more rapidly than the global average, especially North America and Central Asia. Warming is projected to be less than the global average in South and Southeast Asia in the summer and in southern South America in the winter.

Recent trends also suggest that surface temperatures in the tropical Pacific will resemble more closely the warmer, El Niño, phase of the ENSO cycle. The eastern tropical Pacific is projected to warm more than the western tropical Pacific, and this will shift rainfall eastward. Although there is no consensus, some studies have suggested that tropical cyclones will increase in intensity by 10–20% with increasing CO^2 in the atmosphere (Holland 1997; Tonkin et al. 1997).

Current projections show little change or a small increase in El Niño events in the next 100 years. Global warming, however, is likely to lead to greater extremes of drying and an increase in the risk of both droughts and floods associated with El Niño events. It is also likely that the warming associated with increased greenhouse gases will cause greater variability in the Asian summer monsoon.

Box 2. Forecasting climate variability and climate change

Seasonal climate variability is the result of complex interactions between the atmosphere and the surface of the Earth, primarily the world's oceans. Numerical computer modeling of seasonal climate couples the mean state of the atmosphere with the mean state of Earth's surface (NRC 2001). Scientists run models with different initial conditions to produce a set of forecasts called an "ensemble." All these predictions are probabilistic.

To increase accuracy, seasonal predictions often incorporate empirical and statistical tools. Current understanding of the interactions that result in climate variability is probably best for the equatorial Pacific Ocean where scientists have focused attention on the ENSO cycle. Research is in progress on patterns of ocean/atmosphere interactions over 10-year periods (Pacific Decadal Oscillation), on interactions among climate processes within the Atlantic, Pacific, and Indian Oceans, on interactions between ENSO and monsoon processes, and on the "teleconnections" within Earth's coupled ocean/atmosphere system.

For the shorter term (six to nine months), scientists are increasingly able to predict ENSO and other events, especially strong El Niño events, which makes it possible to prepare for such phenomena and to reduce their negative effects. Researchers have also begun to explore shorter, within-season rainfall patterns in the tropical Indian and Pacific Oceans and have found evidence that these patterns interact with ENSO (NRC 2001). Advances in ENSO forecasting have made scientists optimistic about predicting other weather and climate events and have increased interest in studying historic weather patterns (NRC 2001). This has implications for the utility of climate forecasting for health and other sectors.

The inter-annual and decadal variations in climate are set against changes measured on timescales of centuries or millennia—the glacial-interglacial transitions that result in large extensions and retreats of the polar ice caps (NRC 2001). Projections of climate change on this scale may be based on general-circulation models (GCMs) that represent large-scale circulations and interactions of the atmosphere, ocean, and land surface in three-dimensional space. Scientists continue to improve these GCMs and couple them with more detailed models on smaller spatial scales to better understand the Earth/atmosphere system and climate.

Climate-change projections are limited because it is uncertain how and to what extent human activities contribute to climate change. Understanding of the local consequences of climate change in particular places is also limited. For example, limitations on the resolution of GCMs restrict their utility for small islands. Because of the inherent uncertainties, it is common to develop a set of plausible future scenarios for the middle and long term rather than making specific predictions.

In the Northern Hemisphere, snow cover and sea ice are projected to continue shrinking, and glaciers and ice caps are projected to continue their widespread retreat. The Greenland ice sheet is likely to lose mass, but the Antarctic ice sheet is likely to gain mass because of greater precipitation over Antarctica.

Global mean sea level is projected to rise by as much as 0.05 meters a year over the next 100 years, although this will not be uniform across the globe. This predicted rise in sea level is somewhat lower than earlier projections, but it is two to four times greater than the rise measured over the previous 100 years (IPCC 2001b).

Climate variability and climate change on small islands

Global assessments of the potential impact of climate variability and climate change "…have consistently identified small-island states as one of the most high-risk areas…" (IPCC 2001b). Small-island states by their nature are particularly vulnerable to sea-level rise, tropical cyclones, flooding, and beach erosion. Much of the land on atolls and other low-lying islands is only a few meters above mean sea level. Even on volcanic islands with some higher-altitude areas, the coastal zones are vulnerable, and these zones typically contain the highest population densities, most concentrated settlements, and most developed infrastructure.

Many small-island states share characteristics that increase their vulnerability to climatic conditions and limit their ability to mitigate or adapt to climate change. These include: small size; isolation; limited freshwater and other natural resources; fragile economies; high susceptibility to natural hazards such as storms, cyclones, droughts, tsunamis, and volcanic eruptions; generally dense populations; frequently poorly developed infrastructure including health-care infrastructure; and limited financial and human resources (IPCC 2001b).

The most immediate consequences of climate change for small islands are changes in sea level, in rainfall patterns, in prevailing winds, and in patterns of wave action (IPCC 2001b.) Hay et. al. (2003) underscore the importance of extreme events and climate variability in these locations. A review of the research on past climate change suggests that in the tropical ocean regions—where most small-island states are located—sea levels have risen by as much as 0.02 meters per year, and temperatures have increased by as much as much as 0.1° C per decade. Observational data suggest that increases in surface air temperature have been greater in the Pacific and the Caribbean than for the Earth as a whole.

These trends are likely to continue in the future. Coupled atmosphere-ocean general circulation models (AOGCMs) suggest that surface air temperature will continue to increase in the Pacific and that rainfall will increase over current levels in the region by 0.3% by the 2050s and 0.7% by the 2080s. The models also project a marginal decrease in diurnal temperature range (variation over a 24-hour period) in tropical ocean regions. Temperatures will be higher in the summer, and both droughts and floods will be more frequent. Other research predicts an increase in rainfall intensity of 20–30% over tropical oceans.

Warming associated with greenhouse-gas emissions will likely cause greater variability in rainfall associated with the Asian summer monsoon. As a result of global warming, sea levels will rise by as much as 0.05 meters a year over the next 100 years, with some variation in different parts of the world.

ENSO in the Pacific

> Normally, trade winds blow westward over the tropical Pacific, piling up warm surface water in the western part of the ocean. As a result, the sea surface is about 0.5 meter higher in Indonesia than along the coast of South America. Sea-surface temperatures are about 8ºC cooler off South America than in the western Pacific, due to the upwelling of cold, nutrient-rich water from deeper levels of the ocean. Rainfall is greater in the western Pacific due to rising air over warm water, while the eastern Pacific is relatively dry.

During El Niño (warm) conditions, the trade winds decrease in the central and western Pacific. This lowers the “thermocline” (transition layer between warm, well-mixed surface water and colder, deeper water) in the eastern Pacific and raises it in the west, as experienced in Australia and Indonesia during the 1997–98 El Niño. During La Niña (cold) conditions, the pattern tends to be reversed, especially in the tropics. This shifting back and forth is referred to as ENSO—the El Niño Southern Oscillation.

ENSO is measured by deviations in sea-surface temperature and by the Southern Oscillation Index (SOI), the difference in barometric pressure between Tahiti, French Polynesia, and Darwin, Australia. During an El Niño phase, the SOI goes down as surface pressures rise in the west and drop in the east. Such conditions usually last one to two years and occur every two to seven years. These changes in the Pacific result in large changes in global atmospheric circulation that also affect the Caribbean and the Indian and Atlantic Oceans. The source areas and paths of tropical storms in the Pacific shift during ENSO phases, with storms under El Niño conditions forming far to the east of their normal spawning grounds.

A number of organizations are monitoring climate change and climate variability across the Pacific (Box 3). Research has shown that the impact of an El Niño or a La Niña is not uniform across the region. In a strong El Niño, warm water spreads from the western Pacific Ocean towards the east in the shape of an elongated, extended tongue. In general, a strong El Niño results in wet weather along the coasts of North and South America and droughts in Australia and Southeast Asia. Some oceanic islands experience wetter conditions and some drier, and, as noted, the source areas and paths of tropical cyclones shift. ENSO phenomena vary in strength and thus in their spatial extension. As a result, forecast information is specific to particular locations.

The 1997–98 El Niño provided strong evidence that climate variability in the Pacific can cause extreme climate or climate-associated events such as cyclones, floods, droughts, and wildfires. As noted, current models predict that the prevailing climatic state in the Pacific will resemble an El Niño pattern, with variability continuing on a seasonal and decadal scale. In the near term, the impact of climate variability will be more apparent that the effects of global warming.

The Indian Ocean

The southern Asian monsoon is one of the most important and influential phenomena of the Earth's climate system. A dry monsoon can cause disastrous droughts, while flooding related to extreme monsoon rains can provoke deadly natural catastrophes.

Box 3. Organizations monitoring climate change and climate variability in the Pacific

The Pacific ENSO Applications Center (PEAC) was established in 1994 as a pilot project to provide ENSO forecasts and information to the U.S.-affiliated Pacific Islands. The University of Hawaii, University of Guam, U.S. National Oceanic and Atmospheric Administration (NOAA), and Pacific Basin Development Council set up PEAC as a partnership venture to serve American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, the Marshall Islands, the Federated States of Micronesia, Palau, and the State of Hawaii. Beginning in 2001, the U.S. National Weather Service assumed operational responsibility for PEAC.

In the summer of 1999, a number of scientific and regional organizations began working toward creation of a Pacific Islands Climate Information System (PICIS). The goal is to combine the unique assets and special expertise of a number of national, regional, and international institutions and programs to develop and strengthen an information system that will support practical decision-making in the context of climate variability and climate change. Initial participating organizations include the South Pacific Regional Environment Program (SPREP), the East-West Center, the University of Hawaii, the University of the South Pacific, the University of Waikato's International Global Change Institute (IGCI), the Schools of the South Pacific Rainfall Climate Experiment (SPaRCE), the South Pacific Applied Geosciences Commission (SOPAC), the World Meteorological Organization (WMO), the International Research Institute for Climate Prediction (IRI), NOAA, the U.S. Department of Energy (DOE), and the national meteorological services of the U.S., Australia, and Fiji.

Beginning in 1997, the Global Environmental Facility (GEF) and the United Nations Development Program (UNDP) supported a four-year Pacific Islands Climate Change Assistance Program (PICCAP) for 10 island nations. This program was designed to strengthen the capacity of participating countries to prepare their national communications to UNFCCC. Coordinated and executed by the South Pacific Regional Environment Program (SPREP), the program provided training, institutional strengthening, and planning assistance.

Typically, the monsoon starts over Southeast Asia in March and April and moves to south China. By mid-May, strong, low-level winds increase, and warm surface temperatures in the South Indian Ocean and the Arabian Sea feed moisture into the atmosphere. By June, heavy rain falls in East Asia and on the southern tip of the Indian subcontinent. Winds intensify and move northward throughout June, carrying heavy rainfall across South Asia.

Research has provided some evidence that the Indian Ocean monsoon was closely linked to ENSO between 1960 and 1988 but not since then (Webster et al 1999). Other research suggests that the Pacific and Indian Oceans have a competing influence over the South Asia/African region through the Walker circulation.[2] There is a high correlation between sea-surface temperature variability in the Indian and Pacific Oceans, with the Pacific leading by about three months, which may make it possible in the future to predict longer-term climate phenomena (Goddard and Graham 1999). Scientists are using information on ENSO and sea-surface temperatures in the Indian Ocean to help forecast the intensity of the monsoon rains.

An inter-annual cycle, apart from ENSO, also affects climate in the Indian Ocean and along the east coast of Africa. Referred to as the Dipole Mode (DM), the cycle is characterized by dipole anomalies in sea-surface temperatures. During the positive phase, sea-surface temperatures are cooler in the southeastern tropical Indian Ocean and warmer to the west. The pattern is reversed in the negative phase. Temperature differences are accompanied by strong easterly wind anomalies along the equator. The Dipole Mode Index (DMI) is defined as the difference in sea-surface temperature between the tropical western Indian Ocean (50–70ºE, 10ºS–10ºN) and the tropical southeastern Indian Ocean (90–110ºE, 10ºS–0º) (Saji et al. 1999).

Dipole Mode events are strongly linked to the seasonal cycle. The anomalies appear in June and peak in November. When they occur, rainfall is deficient in Indonesia and heavy in the western equatorial Indian Ocean and in East Africa. The rains in East Africa can be torrential, with associated implications for human health. In 1997, this resulted in increases in Rift Valley Fever, cholera, and malaria in the region.

The islands of the southwestern Indian Ocean are subject to tropical storms or cyclones between November and May. Cyclone early-warning systems, such as the Regional Tropical Cyclone Warning System in the southwestern part of the Indian Ocean, are well developed.

The Caribbean

The Caribbean has a maritime tropical climate with wide variation in rainfall. Haiti and Antigua and Barbuda receive less than 200 centimeters of rainfall annually, while Dominica receives 770 centimeters. Most of the Caribbean islands are also in the seasonal hurricane belt. Rainfall in the region peaks at the start of the hurricane season in May and at the end of the season in October and November. There is a dry period from December to March/April.

A number of organizations are monitoring climate change and climate variability in the Caribbean (Box 4). Research on inter-annual climate variability has shown that both ENSO and events in the tropical Atlantic affect conditions in the region. Links have been identified between rainfall and sea-surface temperature. During the dry season from November to April and to a lesser extent during the latter half of the wet season in September and October, ENSO appears to be the major cause of variability. In the northern part of the Caribbean, this results in increased rainfall, while in the southern part rainfall diminishes. In the north, variability in rainfall during the early wet season, from May to June, is influenced by the Tropical North Atlantic Ocean**,** although the ocean is itself linked to ENSO variability four to six months earlier (Stephenson and Chen 2002).

Box 4. Organizations monitoring climate change and climate variability in the Caribbean and a Caribbean/Pacific action program

The Caribbean Institute of Meteorology and Hydrology (CIMH) collects rainfall data from 16 Caribbean countries. The establishment of the Caribbean Planning for Adaptation to Climate Change Project (CPACC) in 1996 has improved data collection related to climate change in the region, especially with respect to sea-level rise. The Caribbean Epidemiology Center (CAREC) is conducting a three-year project to determine the relationships between climate variability, climate change, and dengue fever. The Caribbean also has a project on Mainstreaming Adaptation to Climate Change (MACC), funded by the Global Environmental Facility, and a project on Adaptation to Climate Change in the Caribbean (ACCC), funded by the Canadian International Development Agency (CIDA). Launched in February 2002, the Caribbean Community Climate Change Center (CCCCC) executes these projects and serves as a regional institution to articulate and support a program of action on climate change.

There is active collaboration between the small-island states of the Pacific and the Caribbean. Together, they have formulated a program of action that will be undertaken in collaboration with WMO, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and regional partners to develop and enhance capacity in research, outreach, education and training, and policy and institutional development.

The program of action includes the following elements:

Research

- Strengthen the application of climate information and the links between meteorological and hydrological services
- Strengthening institutional capacity for data generation
- Develop rainfall- and drought-prediction schemes based on existing models
- Build regional capacity to use climate information and prediction to secure water supplies

- Implement a climate-analysis program to assess extreme weather events
- Develop minimum standards for risk assessments
- Strengthen national capacity (equipment, training, etc.) using the model outlined in the Pacific Hydrological Cycle Observation System (HYCOS) proposal and recommendations regarding water quality
- Conduct applied research to address knowledge gaps in line with recommendations and priorities
- Develop and/or implement minimum standards for assessing and monitoring island water resources
- Implement appropriate water-quality testing capability and associated training at local, national, and regional levels
- Strengthen and enhance communication and information exchange between national agencies involved in meteorological, hydrological, and water-quality data-collection programs (including water-supply agencies and health departments)
- Utilize the research capabilities at the University of the West Indies, the Caribbean Institute for Meteorology and Hydrology, national universities in Guyana, Suriname, and Cuba, and other regional science institutions

Public education, awareness, and outreach

- Provide high-level briefings on the value of hazard-assessment and risk-management tools
- Support community participation in appropriate water-quality testing programs to promote environmental education and community awareness, using existing and proposed programs as models
- Recognize the value of informal community groups
- Include the media as a specific institution

Education and training

- Enhance education and career-development opportunities in the water sector
- Implement hydrological training for technicians

Policy and institutional development

- Build an environment to facilitate the emergence of an integrated water resources management framework
- Incorporate the community in policy development at the ground level
- Develop a generic model for integrated community-based planning
- Build capacity in the use of a risk-management approach to integrated resource management in areas such as geographic information systems (GIS) and hazard mapping
- Develop appropriate policy/legislative instruments
- Enforce zoning of risk areas
- Enforce building regulations
- Offer incentives for risk-mitigation measures
- Harmonize legislation, regulations, and policy

Source: CEHI and OAS 2002.

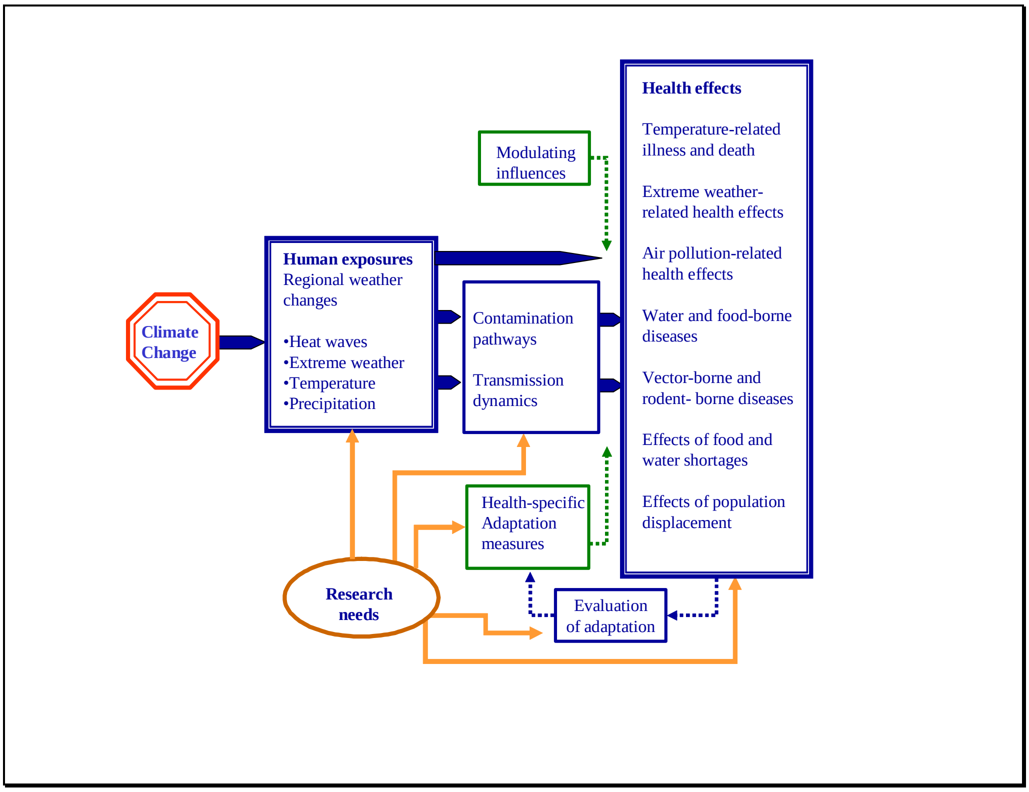
Health effects of climate variability and climate change

> In recent years, a better understanding of the Earth's climate system has facilitated research on the links between climate change, climate variability, and human health (Epstein 1994; McMichael et al. 1996; NRC 2001; McMichael et al. 2003b; WHO 2003). Climate and health scientists are elucidating the links between seasonal and inter-annual changes in rainfall and temperature and the incidence of specific health conditions and diseases (Glanz 1966; Bouma and van der Kay 1996; Hales et al. 1999a; 1999b; WHO 1999).

Climate can affect health directly, most often through extreme events such as cyclones, droughts, floods, storm surges, landslides, or heat waves. Globally, there has been a general upward trend in people adversely affected by weather disasters, with peak impacts during El Niño events (IPCC 2001b).

Climate also affects health indirectly through biological, ecological, epidemiological, and socioeconomic processes (Chan et al. 1999). Environmental disturbance associated with climatic factors can affect disease vectors, infective parasites, water- and food-borne pathogens, agricultural productivity, water availability, air pollution, and living conditions. This is true for longer-term climate change associated with global warming as well as for seasonal and inter-annual climate variability such as that associated with ENSO. Figure 1 illustrates some of the relationships.

Figure 1 Climate change and health: Pathways of influence



Source: Patz et al. 2000.

Note: Modulating influences include nonclimatic factors that affect climate-related health outcomes, such as population growth and demographic change, standards of living, access to healthcare, improvements in healthcare, and public-health infrastructure. Adaptation includes actions to reduce risks of adverse health outcomes, such as vaccination programs, disease surveillance, monitoring, use of protective technologies, use of climate forecasts and development of weather-warning systems, emergency-management and disaster-preparedness programs, and public education.

Entire populations of small-island states are vulnerable to the adverse health effects of climate variability and climate change. Many of these islands must also deal with fragile economies, low levels of economic development, and challenges in the provision of infrastructure and social services. In some cases, public-health infrastructure has actually deteriorated in recent years. This discussion will focus on seven climate-related health threats that are particularly important for small-island states:

- Vector-borne diseases
- Water- and food-borne diseases
- Marine biotoxins
- Food and water security
- Extreme events and weather disasters
- Sea-level rise and degradation of coastal zones

- Damage to coral reefs

In addition to these health threats, stratospheric ozone pollution may lead to increases in skin cancer and eye damage. Ultraviolet radiation also causes local and whole-body immunosupression, although the effects in humans are not well understood (McMichael et. al. 2003). Thermal stress and outdoor air pollution are not major problems in most small-island locations, although climate change may affect the abundance of airborne allergens, and urban air pollution may pose a problem on some larger islands (Beggs and Curson 1995).

Vector-borne diseases

> Scientists exploring the potential impact of climate change on human health have examined the effect of climate variation on a number of vector-borne diseases. These include malaria, filariasis, dengue, West Nile Fever, leishmaniasis, Chagas's disease, Rift Valley Fever, Lyme Disease, tick-borne encephalitis, trypanosomiasis, and onchocerciasis.

Vector organisms that do not regulate their internal temperatures are particularly sensitive to changes in ambient temperatures and humidity. Changes in vegetation, host populations, or water availability may increase or decrease the distribution of vectors, especially on the margins of their natural distribution. Higher temperatures can also shorten the incubation period of the disease agent.

If the transmission season is lengthened, transmission rates may increase exponentially. There may also be a geographical change in disease transmission—both in terms of latitude and altitude. If disease vectors move to a new area, disease transmission may increase disproportionately because the local human population may lack acquired immunity (WHO 2003).

Most small-island states lie in topical or subtropical zones conducive to the transmission of diseases such as malaria, dengue, filariasis, schistosomiasis, and leptospirosis. For malaria and dengue, models predict that the largest change in transmission potential will be in areas where the vector mosquitoes already occur but where development of the disease agent is limited by temperature during part of the year.

There is evidence from the Pacific to link dengue with both cold and warm ENSO events, possibly related to temperature and rainfall (Hales et al. 1997; 1999a; Lewis et al. 1998). In Fiji, with a population of 856,346 (July 2002 estimate), the outbreak of dengue that coincided with the 1997–98 El Niño affected 24,000 people, killed 13, and cost US$3–$6 million (World Bank 2000).

Considerable effort has been expended to develop predictive models for specific diseases. Some of these are "biological," exploring the aggregated effect of climate on individual components of the disease transmission cycle. Others are "statistical," noting direct correlations between geographic or temporal variations in climate and disease incidence or distribution.

Both approaches have weaknesses. Biological models are based on laboratory data and are assumed to apply under real-world conditions. Statistical models that define the distributional limits of a disease do not address the specific mechanism of its transmission or the climate sensitivity of the disease agent or its vector.

Adding complexity, the factors influencing the incidence and geographical distribution of vector-borne diseases include population movement and other social and demographic variables. Since dengue was reintroduced in the Pacific Islands in the 1970s, for example, several multi-country outbreaks have been linked to regional sporting and cultural events.

In 2001, the IPCC concluded that because predictive models do not include social, economic, or demographic factors or public-health interventions, projected temperature increases cannot be predicted to affect disease transmission significantly (IPPC 2001c).

Although there is evidence linking El Niño events to increased outbreaks of malaria in the African highlands, for instance, the panel determined that there are insufficient data to assess the role of global warming in the resurgence of highland malaria in Africa (IPCC 2001a).

Geographic information systems (GIS) provide an important tool for linking geographic, epidemiological, and climate information, and recent developments in GIS are facilitating the construction of better predictive models. GIS can incorporate remotely sensed satellite data, assessing factors such as vegetation change that may be associated with vector distribution and transmission potential for endemic disease.

In Africa, the MARA/ARMA (Mapping Malaria Risk in Africa) collaboration has used GIS with a robust database to support studies of climate change and disease vulnerability down to the district level. The MARA/ARMA team has developed a model to describe the climatic limitations on the distribution of the *Anopheles* mosquito vectors and the *Plasmodium* parasites that cause malaria. In the Pacific region, a generic climate-change model, PacClim, is being adapted for individual island countries. Developed at the International Global Change Institute (IGCI) in New Zealand, the model is not health specific but does include components on malaria, dengue, and ciguatera.

Most modeling efforts for dengue have focused on the capacity of the *Aedes* mosquitoes to transmit the virus. In some areas, disease levels peak in months with high rainfall and humidity. Research has also shown that temperature affects the development of mosquito larvae, the survival and size of adults, the reproductive cycle, and the maturation of the virus in the mosquito (Focks et al. 1995). At higher temperatures, the mosquito matures more rapidly, and this results in smaller adults that have to feed more often, increasing transmission potential. Field studies have supported the results of modeling, showing that climate affects the seasonal abundance and distribution of the *Aedes* mosquito. While there were outbreaks during the 1997–98 El Niño event in the Pacific and Latin America, global warming per se (as opposed to climate variability) is not projected to have a major impact on the distribution of dengue according to the Synthesis Report of the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC 2001a). Rather, human activities and the prevalence of acquired immunity are considered important factors influencing disease distribution. A recent research paper, however, reports on the development of an empirical model that argues that 5 to 6 billion people (50-60% of the projected population) would be at risk of dengue transmission by 2085 due to both population growth and climate change. Without climate change the estimated population at risk would be three to five billion (Hales et. al. 2002).

Public-health efforts, especially vector-control measures, are the key to limiting malaria, dengue, and other vector-borne disease. Pesticide and parasite resistance are key concerns in many areas. The incidence of some vector-borne diseases can also be reduced by integrated environmental management. Early consultations between health and agricultural planners can greatly reduce the burden of diseases such as malaria and schistosomiasis in large-scale irrigation projects. One example of this type of integrated planning is the Environmental Risk Management Authority (ERMA), recently established in New Zealand as a collaboration between health, forestry, environment, and conservation agencies with links to other sectors.

Water- and food-borne disease

> The relationship between climate change, climate variability, and water- and food-borne disease is highly complex. Both droughts and floods can result in contaminated water supplies, poor hygiene, and increased risk of illness. Temperature and humidity also have a direct influence on the replication of bacterial and protozoan pathogens and on the survival of enteroviruses in the environment (WHO 2003). Because of limited fresh-water availability and poor sanitation infrastructure, many islands are prone to outbreaks of water-borne disease.

Diarrheal disease can by transmitted by food, water, insects, or human-to-human contact and is very sensitive to local sanitation. When water is in short supply, bathing and hand-washing may be curtailed, and water that is not normally considered potable may be used for drinking. This can lead to an increase in diarrheal disease due to fecal contamination and other conditions associated with poor hygiene. When water supplies are limited, the effectiveness of local sewage systems may also be compromised.

High temperatures may accelerate the multiplication of pathogens that cause food to spoil, resulting in gastrointestinal infections. Warm and humid conditions may also promote skin infections. Several studies have used time-series methods to explore the relationship between diarrhea incidence and ambient temperature (Checkley et al. 2000; Singh et al. 2001).

Singh et. al. (2001) found a positive association between annual average temperature and the incidence of diarrhea in adults in 18 Pacific-Island nations. Using a crude measure, they also found a negative association between water availability and diarrhea. In a second study in Fiji, they found positive associations between diarrhea and temperature and between diarrhea and extremes in rainfall.

Heavy rainfall and runoff increase pathogen populations in coastal waters, and these can be concentrated in shellfish or can cause disease in humans through direct exposure. Higher temperatures may increase the proliferation of microorganisms in coastal waters, and some of these, such as *Vibiro* species, can cause diarrhea (Lipp and Rose 1997).

Borroto and Haddock (1998) found a significant correlation between monthly rainfall and monthly incidence of cholera in Guam. In South Asia, it appears that copepod zooplankton provide a marine reservoir for the cholera pathogen (Colwell 1996), and seasonality of cholera outbreaks may be related to plankton blooms associated with elevated sea-surface temperatures (IPCC 2001a).

The most important adaptive measure to limit the impact of water-borne disease associated with climate change is to assure access to sanitation and to clean drinking water. During the 1997–98 El Niño event in the Pacific, water supplies were extremely limited in some locations. The island states served by the Pacific ENSO Applications Center developed drought-response plans. In Phonpei, Federated States of Micronesia, an effective public-health campaign that focused on water safety resulted in fewer children being admitted to hospital with diarrheal disease than during normal years. To address the health risks associated with inadequate or contaminated water supplies, health planners need to work closely with officials in public works and disaster management.

Marine biotoxins

> Marine biotoxins can pose a serious threat in island locations, affecting fish, other marine life, and human health. Some marine biotoxins are associated with algae blooms, which may, in turn, be influenced by solar energy, salinity, currents, winds, sea-surface temperature, and runoff. Marine biotoxins that may be climate sensitive include scrombroid fish poisoning, paralytic shellfish poisoning, diarrhetic shellfish poisoning, ciguatera, and the clupeotoxins. From an epidemiological perspective, these health conditions are often difficult to investigate because they are lumped into a single category of fish (or food) poisoning.

Ciguatera is an important but poorly understood problem in tropical waters. First identified in the Caribbean in the 1500s, 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. Although the case fatality rate is lower than for some other marine biotoxins, ciguatera is more prevalent. Between 1955 and 1983 in Fiji, 96% of the cases of fish toxins affecting humans were attributed to ciguatera (Aalbersberg and Saini 2002).

The main causative agent is an epiphytic dinoflagellate, *Gambierdiscus toxicus*, growing on algae and coral rubble. *Gambierdiscus toxicus* produces a neuromuscular toxin with a suite of symptoms that include abdominal pain, nausea, diarrhea, vomiting, weakness, muscle and joint pain, and numbness and tingling of the mouth and extremities. Unique to ciguatera is a paradoxical sensory reversal where cold things seem hot to the touch and vice versa. In the Pacific and other tropical oceans, human consumption of the larger carnivorous fish is typically responsible for ciguatera poisoning.

Researchers have found an association between ciguatera and sea-surface temperatures in topical waters, although the relationship is complicated (Hales et al. 1999b). Islanders have long associated ciguatera with disruptions of the reef environment, for example, when a vessel is wrecked on a reef. In the laboratory, *Gambierdiscus* has been shown to be sensitive to both salinity and temperature. In Fiji, reports of ciguatera (possibly confused in some cases with other marine toxins) jumped from 800–850 cases in the mid 1990s to 1,175 cases in 1998, 2,827 in 1999 and 1,932 in 2000 (Aalbersberg and Sauni 2002). Taking into account a lag phenomenon associated with the build-up of the toxin in the food chain, research should be directed at the relationship between ciguatera and the 1997–98 El Niño event.

Food and water security

> Drought, floods, and other extreme weather events may have serious negative effects on both food and water supplies. When weather-related problems affect local food production, malnutrition may act together with infectious disease to lower the overall health of island populations. Most vulnerable are the very young, the old, and pregnant women.

In addition to effects on agriculture, changes in sea-surface temperature and storm and cyclone patterns may affect both the diversity and abundance of marine species that provide food for human consumption and a commodity for export. The ENSO phenomenon is known to affect the distribution of fish in the Pacific Ocean, with pelagic species moving from the western to the eastern Pacific during El Niño conditions.

During the drought associated with the 1997–98 El Niño event in Fiji, increased rates of anemia were observed among pregnant women, and micronutrient deficiencies were observed in pregnant women and children, especially on the western side of Viti Levu where drought conditions were most severe (OCHA 1998). The 1997–98 El Niño was accompanied by frosts in the New Guinea highlands as well as drought. In the aftermath, one-third of the rural population of Papua New Guinea lacked adequate food.

In many small-island states, the supply of freshwater limits economic development as well as affecting health. A number of islands rely on a single source of water: groundwater in Barbados, Antigua, the Bahamas, and Kiribati; rainwater in Tuvalu, the northern atolls of the Cook Islands, and the Maldives; surface reservoirs and imports in Singapore; rivers and other surface flows in the Seychelles and Dominica (IPCC 2001).

Atolls and other low islands depend on surface catchments and limited supplies of groundwater that may become contaminated or depleted. Underground water sources are permeated by seawater beneath a narrow upper layer (or “lens”) of freshwater. If rainfall is low or if too much freshwater is removed, the seawater mixes with the top layer, and the entire freshwater supply may be lost. Salinization of the freshwater lens is already occurring on some islands due to overpumping of aquifers, for example in the Bahamas and Barbados.

Low rainfall coupled with sea-level rise reduces both surface catchments and the freshwater component of groundwater supplies. Apart from long-term climatic trends, ENSO events are known to influence rainfall patterns in many parts of the world, including the tropics. In the Caribbean, drought is more frequent during El Niño events, while in the Pacific some islands receive more rain and some less, depending on their location.

Today, many small islands have substandard water and sanitation systems. In such cases, adopting a “no-regrets” strategy—investing in improved water storage and distribution systems whether or not a drought is expected—will promote sustainability. Integrated approaches include more efficient rainwater harvesting, prompt detection and repair of leaks, installation of water-saving devices, and aggressive recycling (IPCC 2001b). Desalination may be an option where there are no alternatives and financial resources are adequate.

Extreme events and weather disasters

> Small-island states are particularly vulnerable to extreme weather events. These events have both short- and long-term effects on human health. Extreme events themselves are associated with injuries and deaths. They also lead to changes in the ecology of disease vectors, supplies of freshwater, agricultural productivity, and the viability of physical and social infrastructure.

Globally, the impact of climate variability and climate change on human health will, to a great degree, be directly related to changes in the magnitude and frequency of extreme events. Insofar as climate change may be exacerbating the ENSO phenomenon, this may already be occurring. A good example is the El Niño of 1997–98, which had effects across the globe, particularly in the island states of the Pacific and archipelagic nations of Southeast Asia.

Cyclones (hurricanes, typhoons) pose a significant threat to populations living in coastal and low-lying areas. While the most striking effects of cyclones in recent history have been in Bangladesh, island locations are at significant risk. In 1998, Hurricane Mitch struck Central American and the Caribbean, providing a clear example of the devastation that a tropical storm can cause in coastal areas.

Cyclones are associated with both riverine and coastal flooding. In the immediate term, flooding may cause deaths due to physical trauma or drowning. The incidence of water-borne disease may also increase due to contaminated water supplies, and overcrowding in shelters may increase respiratory and other disease.

Cyclones and the physical damage they cause may also lead to wildfires. During the 1997–98 El Niño, Typhoon Paka was followed by a drought in Guam. The debris left in the wake of the storm contributed to wildfires that burned 13,000 acres of grassland—more than 10% of the island’s land area. While there is no quantitative evidence of health effects, there were complaints of eye irritation and upper respiratory infection associated with the smoke from these wildfires.

Extreme weather events are bound to occur. The improved ability to forecast climate variability, for example related to ENSO in the Pacific, should provide planners and emergency managers with enough lead-time to help minimize their impact.

Sea-level rise and degradation of coastal zones

> Projected sea-level rise is going to affect many small-island states, although the impact will vary among islands and across regions (IPCC 2001b). Sea-level rise will result in the loss of coastal land areas, where much of the infrastructure of small islands is concentrated, and it will affect coastal biodiversity and supplies of freshwater. The impact will be particularly severe on atolls and low limestone islands. Storm surges will exacerbate the effect. In extreme cases on islands with no higher land, sea-level rise may force populations to abandon their homes.

Many islands are already experiencing coastal erosion due to human activities, such as sand and coral mining and the degradation of offshore reefs. Nunn and Miura (1977) report that the coasts of some islands have retreated by more than 30 meters in the past 70 years due to human-induced causes, such as loss of coastal mangrove forests or elevated sea levels.

On many islands, coastal sea-grass beds and mangrove forests are under stress from human activities. Mangrove forests provide important protection against storms, high tides, and cyclones. Apart from stabilizing coastlines, they provide a source of wood, if properly harvested, and an environment for fish and other important marine organisms.

IPCC's Third Assessment Report discusses three strategies for adapting to sea-level rise—retreat, accommodation, and protection. There are limitations to all three strategies, especially in small-island environments where material for raising the height of settlements or nourishing beaches may not be available. Emphasis should be on a precautionary approach, including the enforcement of land-use regulations, building codes, and insurance (IPCC 2001a). Traditional strategies, such as building on stilts, should also be considered. Such precautions are a critical aspect of Integrated Coastal Zone Management (ICZM), as endorsed by the Federated States of Micronesia, Samoa, Fiji, the Marshall Islands, Sri Lanka, and Mauritius (Huang 1977 cited in IPCC 2001b).

With respect to land area, not all the results of climate change on islands will be negative. Roy and Connell (1991) present an interesting review of the effects of climate change on atoll islands using historic evidence from Kiribati, the Maldives, the Marshall Islands, Tokelau, and Tuvalu. They point out that for atolls, the effects of climate change must be viewed as a process of "dynamic equilibrium." For example, cyclones can erode coral from reef fronts and form large storm ridges on windward reef flats that subsequently become welded to existing islands. Both sea-level rise and increased storminess can affect this equilibrium.

Damage to coral reefs

Most tropical islands have associated coral reefs that provide natural breakwaters and a habitat and food source for reef fish and other marine animals. Coral reefs are also a source of beach sand and building material, and they contribute to an island state's attractiveness as a tourist destination.

Coral reefs across the globe are facing multiple threats, some related to climate. Many corals are growing at or near their upper limit in terms of water temperature (Goreau 1992 cited in IPCC 2001a), and ocean temperatures of about 1ºC above the normal summer maximum have been associated with major coral bleaching,[3] possibly leading to coral death. Changing conditions during the 1997–98 El Niño, for example, had adverse effects on 80% of the corals in the Seychelles.

Projections from the IPCC suggest that the thermal tolerance of reef-building corals will be exceeded in many places over the next few decades as ocean temperatures rise (IPCC 2001a). Hoegh-Guldberg (1999 cited in IPCC 2001a) suggests that the incidence of coral bleaching will increase rapidly, with the rate of increase highest in the Caribbean and slowest in the Central Pacific. Coles and Brown (in press) argue, however, that corals and their symbionts may be capable of greater acclimatization than is currently recognized.

There is some evidence to suggest that increased CO_2 concentrations impede the ability of reef fauna to make limestone skeletons, but the process is not well understood. The effect of sea-level rise on coral reefs is projected to be negligible, however (IPCC 2001a). Given appropriate conditions, reef growth should be able to keep up with sea-level rise unless stressed by human activities or in areas at the margins of reef-building activity.

Assessing vulnerability and adaptation to climate variability and climate change

Assessing the health and other effects of climate variability and climate change is critical for effective planning in small-island states. Because climate change—including extreme climate events—affects not only human health, but also agriculture, water supply, tourism, the coastal zone, and other aspects of island life, policymakers need to address climate variability and change within an integrated framework that includes assessing vulnerability, mitigating potential disasters, and building resilient communities. The concepts of vulnerability and adaptation as used by the climate-change community are analogous to concepts used in public health (Box 5).

Box 5. Definitions of terms used in vulnerability and adaptation assessment

- **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 extreme events (WHO 2003).

- **Adaptation** is adjustment by natural and human systems in response to actual or expected climate stimuli or their effects. Adaptation includes current and future strategies, policies, and measures undertaken to exploit opportunities or moderate harm (WHO 2003).
- **Adaptive capacity** is the general ability of institutions, systems, and individuals to adjust to or moderate potential damages, take advantage of opportunities, and cope with consequences. It encompasses current coping capacity plus the potential to expand coping capacity in the future. Increasing a community's capacity to cope with current climate variables is believed to improve the community's capacity to cope with long-term climate change.

Assessments can be carried out at different levels. Both human and material resources are often limited in small-island states, and the sophistication of the assessment needs to match the resources that are available. A basic health-impact assessment, for example, would use readily available information and data—previous assessments, if available, literature reviews, and region-specific health data.

Collaborations between scientists and policymakers during the 1997–98 El Niño event demonstrated that even small steps can significantly lessen some of the negative effects of climate-related crises. Forecasts of drought conditions by the Pacific ENSO Applications Center (PEAC) were followed by effective measures to stabilize water supplies and to reduce the effects of water scarcity in many nations of the region (Box 6).

Box 6. Application of forecast information: The 1997–98 El Niño in the Pacific

In June 1997, the Pacific ENSO Applications Center (PEAC) alerted governments in the U.S.-affiliated Pacific Islands that a strong El Niño was developing and that changes in rainfall and tropical storm patterns might be expected during the next 12 months. Three months later, PEAC issued its first definitive rainfall forecast, saying that severe droughts were likely to begin in December and that certain islands were at an unusually high risk of typhoons and hurricanes. Most of the Pacific-Island governments served by PEAC developed drought-response plans, drought or El Niño task forces, and aggressive public-information programs about what to expect from El Niño and what measures could lessen damaging consequences.

Water-management agencies developed and implemented water-conservation plans. In the Republic of Palau, the public works department completed repairs on about 80% of the water-distribution system before the drought set in. Throughout the Federated States of Micronesia (FSM), people repaired water-catchment systems, and the government delivered water to outer islands in Chuuk and Yap. In November, the FSM Congress appropriated $5 million to address the potential effects of drought, and U.S. military assistance was requested to secure replacement parts for well equipment.

Even with these precautionary measures, the 1997–98 El Niño produced such extensive drought conditions that widespread water rationing became necessary. In spring 1998, the water utility on Majuro, the capital of the Republic of the Marshall Islands (RMI), supplied water for only seven hours every 14 days until pumps were repaired. In Palau and Pohnpei, municipal water was available for only two hours each day at the height of the drought. Water supplied to one area in Palau was reduced from 111 million to 9 million gallons per month.

Agriculture was especially hard hit. In the Commonwealth of the Northern Mariana Islands (CNMI), citrus and garden crops were most affected, and Pohnpei sustained serious losses of food and cash crops. More than 50% of staple crops of taro and breadfruit were destroyed in FSM, and vast numbers of banana trees suffered. Kava was probably the most serious economic loss because it had recently become a major cash crop. On Yap, taro losses were estimated at 50–60%, and betel nut prices increased more than 500%.

Other climate-related consequences felt throughout the islands included:

- Changes in the migratory patterns of economically significant fish stocks
- Stresses on coral reefs associated with increased temperatures
- Increased sedimentation from erosion in areas scorched by wildfires
- Losses of freshwater shrimp, eels, and fish as waterways dried up
- Reduced air quality in areas affected by local wildfires and haze from wildfires in Indonesia

Still, the consequences could have been much worse. Advance warning made possible by emerging forecasting capabilities and a focused program of education helped mitigate the negative impacts of these climate effects—providing a good example of how people can benefit from climate assessment and adaptation.

Comprehensive, multisectoral assessments have been undertaken in several developed countries, and some assessments, including health-impact assessments, have been conducted as part of capacity-building initiatives in developing countries. Often, the focus has been on vector-borne diseases, such as malaria and dengue.

Health Canada has prepared an initial framework for national assessments with three distinct phases:

- **Scoping:** To identify the climate-change problem (concerns of vulnerable groups) and its context, describe the current situation (health burdens and risks), and identify key partners and issues for assessment
- **Assessment:** To estimate future effects and adaptive capacity and evaluate adaptation plans, policies, and programs
- **Risk management:** To take actions to minimize negative effects on health, including follow-up assessments (WHO 2003)

WHO, in cooperation with Health Canada, UNEP and WMO published a report on *Methods for assessing vulnerability and adaptation: Climate change and human health* (WHO, Health Canada, UNEP and WMO 2003), which has clear guidelines for health-impact assessment. The authors list seven steps in the vulnerability and adaptation assessment process:

1. Determine the scope of the assessment: geographic region, time period, and health outcomes to be included
2. Describe the associations between disease outcomes and climate variability. If data and resources are available, quantify the relationships using epidemiological methods. Describe current distribution and burden of climate-sensitive diseases
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 effects of climate change on other sectors, such as agriculture/food supply, water resources, disasters, and coastal and river flooding
5. Estimate future health effects using scenarios of future climate change, population growth, and other factors and describe the uncertainty
6. Synthesize results and draft scientific assessment
7. Identify additional adaptation policies and measures, including procedures for post-implementation evaluation

It is important to note that not all steps may be possible or desirable, depending on the objectives of the assessment and the resources available.

An integrated approach to vulnerability assessment should include the value of non-market goods and services—such as subsistence assets, community structure, and traditional skills and knowledge—which may be at risk from climate change. The traditional methods that island people have developed for coping with climate variability are an important component of the global knowledge base. Any assessment must take into account all the other factors that affect environmental systems and human health, including public-health interventions such as vector-control programs that may be introduced or may already be in place.

Conclusion

> The uncertainty associated with climate change encourages skeptics to argue that policymakers cannot take action in anticipation of future trends or events. Small-island states do not have the luxury of non-action, however. They are currently coping with climate variability, and some are already coping with the effects of global warming.

Scenarios can be developed that are simplified, but plausible, descriptions of what might happen in the future, based on a coherent and internally consistent set of assumptions about driving forces and relationships. Climate forecasts can be used to prepare for climate variability and extreme events, and they can help policymakers build resilient communities and attain the goal of sustainable development.

Past and current experience with climate variability—such as ENSO, the Pacific Decadal Oscillation, and the North Atlantic Oscillation—provides some guidance for planning in anticipation of long term-climate change. Island people, in the Pacific and elsewhere, are already coping with and adapting to the extreme events associated with ENSO—cyclones, droughts, and floods. Valuable lessons can be learned from their experience.

In the Pacific, strong El Niño events can be predicted with considerable accuracy approximately six months in advance. Climate forecasts for other regions, including the Indian Ocean and the Caribbean, are also becoming increasingly sophisticated. As scientists learn more about the relationships between predictable climatic events and specific diseases—such as malaria, dengue, and ciguatera—policymakers will be able to use forecast information to plan and implement appropriate interventions in public health, water supply, sanitation, agriculture, disaster management, and other sectors.

Learning how to incorporate climate-forecast information (as part of decision information systems) into local planning is a challenge, but one well worth addressing. Forecast information, coupled with a "no-regrets" orientation to planning that includes general improvement in public-health infrastructure, will help protect the health of island peoples and further the goal of sustainable development in small-island states.

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[1] The IPCC (IPCC 2001c) uses the following convention to assess levels of confidence: “virtually certain” (greater than 99% chance that the result is true), “very likely” (90–99% chance); “likely” (66–90% chance); “medium likelihood” (33–66% chance); “unlikely” (10–33% chance); “very unlikely (1–10%); “exceptionally unlikely” (less than 1% chance).

[2] The Walker Circulation is a large-scale atmospheric circulation over the equatorial Pacific Ocean. Low-level winds blow from east to west across the central Pacific, rise over the warm water of the western Pacific, return from west to east in the upper troposphere, and sink over the cold water of the eastern Pacific. Similar east-west circulations have been identified along other parts of the Equator, including over the Indian Ocean. Today, the term “Walker Circulation” generally refers to all of these phenomena.

[3] Coral bleaching is the whitening of coral colonies due to the loss of symbiotic zooxanthellae from the tissues of polyps. This loss exposes the white calcium-carbonate skeletons of the coral colony and can lead to death. Adverse changes in a coral's environment can cause an increase in the number of zooxanthellae lost. Such adverse changes include disease, excess shade, increased levels of ultraviolet radiation, sedimentation, pollution, salinity changes, and a rise in temperature.