Forecasting Natural Disasters to Mitigate their Effects

by

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1. INTRODUCTION

As announced, one of the purposes of this conference is "to examine ways to reduce the institutional vulnerability of Member nations" in respect of natural disasters. In this context, it is envisaged that the Conference will consider possible actions that the Inter-American Development Bank (IADB) had proposed to undertake in Member countries. These actions include:

(i) Defining an effective strategy to reduce long-term and recurrent risk;
(ii) Strengthening capacity to implement the strategy;
(iii) Building national systems for disaster prevention and mitigation; and,
(iv) Enhancing inter-agency coordination.

The formulation and implementation of the proposed actions by the Bank, especially in respect of (iii), require the establishment and operation of internationally coordinated national and regional systems for monitoring and forecasting natural disasters. Such systems represent a cost-effective way to...
reduce vulnerability. In this respect, whilst dealing mainly with
natural disasters of hydrometeorological origin, WMO is also
engaged in promoting:

(a) The development of integrated systems of disaster manage-
ment, which include hydrometeorological aspects of
disaster preparedness, warning, relief and rehabilitation; and
(b) Scientific studies including comprehensive risk assessment.

It is in this spirit that the partnership of WMO with the IADB,
to support the Member countries in Latin America and the
Caribbean is being developed.

Forecasting is an indispensable component of prepared-
ness and response phases of natural disaster reduction. In the i.e.,
predictions and warnings, if reliable and provided with sufficient
advance notice, can obviously play a key role in saving human
life and/or reducing property damage. In the response phase i.e.,
(updated forecasts are equally, if not, more important.

In this presentation, the status of the science and operational
systems for hydrometeorological disaster forecasting will be summa-
rized, particularly as regards the forecasting of the most frequent
and devastating forms of disasters to hit Latin American and
Caribbean countries, namely: tropical storms (including hurricanes),
tornadoes, floods and droughts. In this respect, special emphasis
will be placed on the activities of the national Meteorological and
Hydrological Services (NMHSs), which should constitute a critically
important part of any national disaster prevention and mitigation
system as envisaged by the IADB.

2. HYDROMETEOROLOGICAL DISASTERS: SOME FACTS

Globally, over 70 per cent of natural disasters are related to
weather and climate, but in some countries or regions, the disas-
ters of hydrometeorological origin account for the totality of

8. ROLE AND PLACE OF FORECASTS IN THE PROPOSED
IADB ACTIONS

The actions proposed by the IADB in support of Members relate
to hydrometeorological disaster monitoring, forecasting and early
warning and should involve and be built upon existing coopera-
tion among the NMHSs.

It is therefore imperative that when formulating and imple-
menting its action plan, the IADB take the following into
consideration:

• The definition of an effective strategy to reduce risk would
include the recognition of, and measures to satisfy, the need
for adequate support to existing viable national institutions
such as NMHSs, and the strengthening of regional and
international centres, projects and programmes on scient-
ific and technological aspects of natural disaster reduction;

• The building of technical, scientific and operational
capacity including human resources within the NMHSs
would be the most cost-effective way to realize their poten-
tial to contribute to the implementation of the strategy
related to natural disaster reduction at national, regional
and global levels;

• National and regional systems for natural disaster preven-
tion and mitigation would embrace components based upon
the facilities and capability of the NMHSs. These should be
integrated, as appropriate, with other systems related to
preparedness, public awareness, decision-making, and
relief and rehabilitation;

• National and/or regional coordination between the NMHSs
and the civil defense organizations responsible for disaster
prevention and coordination with the media for dissemi-
nation of forecasts are also important; and

• Inter-agency coordination would take into full account the
existing and planned scientific and technical programmes
and activities of regional and international organizations,
including WMO, especially in the context of the
International Strategy for Disaster Reduction (ISDR).
Other project proposals under consideration include a Flash Flood Threshold Pilot project which would cover certain areas in Central and South America and would assess the ability of modern remote-sensing and computer technology to provide warnings of flash floods in areas with scarce data; a tropical cyclone landfall project and another on urban flooding and environment in Sao Paulo, Brazil are planned under WMO’s World Weather Research Programme.

A Memorandum of Understanding signed a few months ago by the World Bank and WMO will further contribute to developing synergies between relevant programmes of the Bank and those of WMO in areas of common interest, such as natural disaster prevention and mitigation, climate change, and the El Niño event.

In this context, the proposal for the establishment of the El Niño Centre in Guayaquil, Ecuador, should be highlighted as a follow-up to the UN General Assembly Resolution 54/220 on International Cooperation to Reduce the impact of El Niño phenomenon.

Furthermore, partnership with the private sector and commercial activities are also expected to grow in the new millennium due to the increase in benefits that can accrue from meteorological and hydrological information and prediction services. In this regard, WMO will continue to work with Member countries, relevant international organizations and non-state entities in natural disaster mitigation activities in the context of International Strategy for Disaster Reduction (ISDR). It is essential that the future Strategy would include, as a major thrust, scientific and technical activities and ensure the continued involvement of scientific and technical organizations like WMO.

WMO also participated, with other institutions such as the IADB, in the launching of the ProVention Consortium — a global partnership of all stakeholders, including Governments, international organizations, academic institutions, private sector and the media, aimed at reducing the risk of disasters in developing countries, and at making disaster prevention and mitigation an integral part of development efforts.

natural disasters. As can be seen from Figure 1, during the period 1963-1992 tropical cyclones, floods, landslides and droughts account for more than 50 per cent of fatalities, 80 per cent of persons affected by natural disasters, and over 80 per cent of those disasters responsible for significant damage.

According to the Munich Reinsurance Company (IDNDR, 1999), in only one year (1998), over 14 000 deaths in the Americas were caused by 112 storms and 38 floods, and economic losses resulting from these events exceeded US$ 35 billion. The 1998 Atlantic hurricane season, more active than normal, brought 14 tropical storms (the average number is 10), of which 10 became hurricanes (with wind speed more than 119 km per hour), including three major hurricanes (with wind speeds of more than 178 km per hour). They inflicted US$ 7.3 billion in damages and caused 23 fatalities in the United States alone (US Department of Commerce, 1999). Among the most devastating hurricanes of all times were Hurricanes Georges (September 1998) and Mitch (October 1998). Hurricane Mitch alone led to about 9 000 deaths in Nicaragua and Honduras and seriously affected their development plans. In Guatemala, El Salvador and Costa Rica, the impact was less devastating, but nevertheless very significant.

![Figure 1 — Major disasters around the world: 1963-1992](image-url)
The last Atlantic hurricane season, which closed on 30 November 1999 was marked by an above average number of tropical storms (12), five of which became major hurricanes. Among these, hurricanes Floyd (September 1999) and Irene (October 1999) caused widespread and severe flooding.

Large areas of the Americas are prone to extremely heavy rainfall and associated landslides. Table 1 highlights the regional and global impacts of the strong 1997–1998 El Niño event. For example, in December 1997 and January 1998, that is during the 1997-1998 El Niño, the coasts of Ecuador and northern Peru received 350-775 mm of rain, compared to the normal 20-60 mm. Torrential rains were recorded in southern Brazil, south-eastern Paraguay, most of Uruguay, and parts of north-eastern Argentina (UNEP, 1999). Devastating floods and mudslides in the Caracas area in Venezuela caused over 20,000 deaths in December 1999.

In addition the impacts of droughts, including those in central USA, northern Mexico, northeast Brazil and Guyana, as well as large-scale forest fires in Colombia, Brazil, Central America and Mexico should be mentioned.

<table>
<thead>
<tr>
<th>Region</th>
<th>Direct loss (in millions)</th>
<th>Mortality</th>
<th>Morbidity</th>
<th>Affected</th>
<th>Displaced</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>118 m</td>
<td>15 246</td>
<td>107 301</td>
<td>10 400 000</td>
<td>2 217 200</td>
</tr>
<tr>
<td>ASIA</td>
<td>3 220 m</td>
<td>6 018</td>
<td>124 647</td>
<td>33 719 719</td>
<td>318 700</td>
</tr>
<tr>
<td>ASIA PACIFIC</td>
<td>5 331 m</td>
<td>1 317</td>
<td>57 546</td>
<td>66 113 666</td>
<td>90 000</td>
</tr>
<tr>
<td>NORTH AMERICA</td>
<td>6 462 m</td>
<td>542</td>
<td>Incomplete</td>
<td>41 100</td>
<td>400 000</td>
</tr>
<tr>
<td>SOUTH AMERICA</td>
<td>18 068 m</td>
<td>997</td>
<td>243 743</td>
<td>723 033</td>
<td>363 000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33 199 m</td>
<td>24 120</td>
<td>533 237</td>
<td>110 997 518</td>
<td>3 388 900</td>
</tr>
</tbody>
</table>

7. OTHER INTERNATIONAL COLLABORATIVE EFFORTS

In addition to the above, WMO is also involved in several other projects in the region.

The Project entitled "Radar Network Warning System for the Protection and Sustainable Development of the Caribbean Countries" is funded by the European Union. It will provide an advanced weather warning system, and relevant data to weather sensitive sectors in the countries covered by the radars.
Coordination among all national, and as appropriate regional, agencies involved in disaster reduction, in both the planning and operation phases.

Whilst these requirements are generally satisfied in developed countries, forecasting services in developing countries often experience a lack of resources for acquiring adequate facilities and for human resources development. It is therefore of utmost importance that international agencies, including WMO, provide the maximum possible assistance to those countries concerned to enable them to participate in regional and global efforts aimed at mitigating natural disasters and contributing to national sustainable development.

6. IADB AND WMO COOPERATION

In the area of natural disaster reduction, WMO undertook a number of actions, particularly following its Action Plan on the IDNDR, to assist its Members in the Americas to improve their forecasting and warning services. Some of these actions have been undertaken jointly and with the support of the IADB, and include:

(a) The Ibero-American Climate Project Feasibility Study which was funded by the IADB, Spain, USA, Canada and WMO, and carried out between 1997 and 1999. This study provided feasibility projects to 13 countries in Latin America. The implementation of the project will allow NMHSSs of participating countries to provide meteorological and hydrological forecasts to users in order to enable them to prevent and mitigate the impact of natural disasters, as well as make better use of natural resources.

(b) The "Conference on Water Resources Assessment and Management Strategies in Latin America and the Caribbean" which was convened by IADB and WMO in 1996. The main outcome was an action plan which, among its main concerns, included the mitigation of natural disasters. The plan called for the implementation of national and regional studies of hazards of hydrometeorological origin, making it possible to create

Overall, the frequency and impacts of natural disasters are estimated to be increasing. Losses from natural disasters over the decade 1986–1995 were eight times higher than in the 1960s; and unless major efforts are deployed to counteract the impact of such disasters, this tendency will most probably continue. Within these efforts, forecasting of the occurrence, intensity, time and space scales of hydrometeorological disasters should be given priority attention.

3. SCIENCE AND TECHNOLOGY OF DISASTER FORECASTING

The impacts of natural disasters related to meteorological and hydrological phenomena can be regional or even global in scope. The spatial and temporal scales of these disasters vary widely from short-lived, violent phenomena of limited extent, including tornadoes, flash floods and severe thunderstorms, through to large systems, such as tropical and extratropical cyclones with life cycles of several days. At the largest scale are widespread droughts, which may affect large areas for months to years. Forecasting of these phenomena therefore requires techniques applicable to very short-term forecasts, for example, for less than one hour for tornadoes, and even nowcasts, to those for seasonal and inter-annual time scales for droughts and major floods which may be associated with the El Niño phenomenon.

The establishment of major weather forecasting centres and the systematic monitoring of the atmosphere and, to a certain extent the oceans, have enabled national Meteorological and Hydrological Services (NMHSSs) to provide information related to the threat of weather- and climate-induced disasters such as hurricanes, floods, droughts, severe storms, forest fires, frosts, heat waves and cold spells (Obasi, 2000). In the United States, for example, improved forecasts of hurricanes with effective dissemination and wider awareness and preparedness have led to significant reductions of loss of life (Figure 2).

The prediction of small or meso-scale meteorological/hydrological events such as tornadoes, severe thunderstorms, squalls and flash floods requires the early detection of precursors. Forecast techniques are based on continuously updated observational information
on storm movement, rainfall intensity, and/or river stage from real-time observations from satellites, radars, stream gauges, automatic weather stations and observers. The greatest difficulty in providing effective warnings of these small-scale events is the usually very short lead-time available to warn the public. The establishment of a comprehensive system for the issuance of forecasts and warnings, which comprises observing and data collection systems, visualization, analysis and modelling tools and adequate telecommunication networks, is therefore absolutely essential.

Forecasts of the behaviour of larger, synoptic scale weather systems such as tropical storms and extratropical cyclones are now made available several days in advance. Prediction of these systems and of the associated phenomena is made using numerical computer models. Weather forecasts of up to eight days in advance can now be provided for the middle latitudes countries. As regards hurricanes, scientific and technological advances (satellites, reconnaissance aircraft, modern computer systems and sophisticated numerical models) make it possible to detect most hurricanes at an early stage of formation, to monitor them throughout their life cycle and to provide forecasts of their tracks and intensity. The accuracy of forecasts and hence the reliability and timeliness of warnings has been steadily improving (Figure 3).

A high level of coordination must therefore exist between the organizations responsible for the detection of, and response to, the phenomenon caused by natural disasters. Of particular importance is the coordination of the issuance of forecasts and warnings. In many countries, the NMHSs have been designated as the authoritative voice for this purpose. WMO fully supports and promotes such arrangements which have proved to be effective. NMHSs must be actively involved in inter-agency disaster planning at national and regional levels to ensure a regular flow of reliable information to the public, political leaders, responsible officials and civil society. Coordination with the media must be given a particularly high priority, as it is a vital element in the dissemination of forecasts and warnings.

To assist NMHSs in improving coordination and interaction at the national level, WMO has developed guidelines on best practices regarding the relationships between NMHSs and the organizations involved in emergency management. The guidelines recommend, amongst others, the organization of seminars for disaster managers and decision makers, the participation of NMHSs in emergency-related bodies and in preparedness and prevention campaigns, joint missions of forecasters and emergency officers, and the publication of educational material on hydrometeorological aspects of natural disaster management.

In the light of the above considerations, the following are essential for forecasting systems to be effective:

- Access through reliable communications to the data from local, national, regional and global observation networks;
- State-of-the-art predictive capability at national level and, as necessary, guidance and information from specialized regional and global centres;
- Effective local and national dissemination systems capable of alerting threatened populations as frequently as may be appropriate;
- Awareness of the population and local and national authorities, regarding the content and meaning of forecasts and warning messages and how they should react to them; and
The NMHSs, in coordination with other national and international organizations concerned, have to be involved in virtually all the activities concerning natural disaster reduction, in particular, risk assessment, detection of disasters causing events, interaction with decision makers and other users, including civil society, as well as participation in public awareness campaigns. This involvement should constitute a framework within which the forecasting and warning capabilities of the NMHSs could be assessed and recommendations made for improvement.

In the area of risk assessment, the NMHSs should provide observational data and statistics required for identifying disaster potential, in particular the intensity and probability of occurrences, and also contribute to planning measures, including early warning, in order to minimize risk.

Detection systems, many of which are managed by NMHSs (for example, the detection and tracking of tropical storms by the National Hurricane Center in Miami), are intimately connected with preparedness systems, providing continuous updating of forecasts and warnings.

An effective and interactive system to communicate with users is a vital component of any forecasting activity. Officials and the public must receive information in a timely manner and be able to interpret it correctly. If the predictive capabilities are to be used to maximum advantage, a clearer understanding by all involved in relevant aspects from prediction to application is needed to enable forecasters and users to work together as a team. An effective forecast system requires that the target population understand the content of the message and knows how to react to it. This implies that well-designed forecast and warning systems must include an ongoing public awareness component on potential risks. This will call for the dissemination of information to be carefully coordinated to ensure timeliness and accuracy. While dissemination systems are generally well-developed and fairly resilient in developed countries, this is not always the case in many developing nations.

Flood forecasting models have only recently been developed and used on a routine basis. Many existing hydrological models must be adjusted in real time as information arrives at the forecasting centre. Progress has been made in the development of methodologies for flood and even flash flood forecasting and nowcasting, especially using new tools such as the Geographic Information System (GIS).

Drought prediction requires, among others, monitoring the patterns of monthly and seasonal rainfall, reservoir and ground water levels, soil moisture and snow cover. Progress in developing predictive skill for large geographical regions on seasonal time scales makes it possible to provide increasingly useful forecasts of the onset, severity and duration of drought.

Figure 3 — Forecast Accuracy. The lines give the error in the track forecast of Atlantic hurricanes for various forecast periods over the years from 1965 to 1998.
Further progress in the provision of useful natural disaster forecasting services is based on three main pillars:

- Maintenance and enhancement of observational network and data collection systems;
- Further technological advances in data processing and dissemination; and
- Continuing development of methodologies, including advanced weather and climate models.

Bearing this in mind, WMO promotes and implements a number of major international programmes and projects to coordinate and stimulate national, regional and international actions in these domains.

3.1 Observation and Data Collection Networks

Observational data requirements for natural disaster forecasting are provided by meteorological and hydrological observing systems, primarily in the context of WMO’s World Weather Watch (WWW) (Figure 4) and its Hydrology and Water Resources Programmes (HWRP). The establishment of the operational World Weather Watch in 1963 was instrumental in the development of the present worldwide network of about 10 000 surface stations, 700 ocean buoys, 7 300 ships and 1 000 upper air stations, complemented by some 75 000 observations daily from commercial aircrafts, and a constellation of nine geostationary and polar-orbiting meteorological satellites.

The hydrological data collected by NMHSs, for use in flood and drought forecasting, is complemented by the World Hydrological Cycle Observing System (WHYCOS) (Figure 5) whose regional components including the CARIB-HYCOS is being developed by WMO in cooperation with countries of the Caribbean Basin. CARIB-HYCOS will enhance the ability of these countries to assess their freshwater resources, and provide valuable data useful for mitigating flood-related disasters and for better understanding of the impacts of El Niño on the hydrological regime of the region.

4.3 The Case of Colombia: El Niño and Malaria Epidemic

Too much or too little rainfall, which are common in some regions during the warm and cold El Niño phases, have been associated with various vector borne and food-related diseases. Similar observations have also been made in other parts of the region and many parts of the tropics. Figure 12 shows the linkages between El Niño and malaria cases in Colombia.

5. DISASTER MITIGATION AND MANAGEMENT POLICIES

The provision of timely warnings and forecasts to the public in safety of life and protection of property is one of the primary roles of all national Meteorological and Hydrological Services (NMHSs). The achievement of optimal results from the forecasts for preparedness and response to natural disasters therefore requires effective coordination and cooperation between NMHSs, the responsible agencies and institutions, the media, political leaders and civil society at local, national and international levels. Timely and effective forecasts and warnings of natural disasters coupled with local capability to take mitigating actions are fundamental for effective disaster reduction.
Figure 4 — World Weather Watch

Figure 10. Agricultural areas sown in northern coastal region in Peru.
(Source: NOAA)

Figure 11. Applications of experimental climate forecasts in north-east Brazil.
(Source: NOAA)
3.2 Data Processing and Dissemination of Warnings

The data processing and dissemination of forecasting services form part of the WWW network which includes meteorological centres at the global, regional and national levels. Some of the regional centres specialize in the monitoring and prediction of natural disasters such as tropical cyclones.

The infrastructure that supports the preparation and dissemination of forecasts to the end-users including the public, national and local authorities, civil society and the ... WMO principle and policy of free and unrestricted exchange of meteorological and hydrological data and products.

3.3 Development of Methodologies for Improved Forecasting

As regards the development of methodologies for improved forecasting, WMO provides a global framework for collaboration in research in the fields of meteorology, hydrology and other geosciences. In particular, WMO’s World Weather Research

conditions or anomalies, and also at taking advantage of any positive impacts (Obasi, 1999). For a number of years, El Niño predictions have been used by several countries in the region and elsewhere to provide early warnings and in disaster preparedness. The following cases are just a few examples:

4.1 The Case of Peru

Figure 10 indicates how El Niño information has been used for sustainable agricultural production in Peru through the alternation of crops during dry years; for example, the alteration between rice and cotton.

4.2 The Case of Brazil

Figure 11 highlights two El Niño cases of 1987 and 1992 where the rainfall deficits were almost the same. Enhanced agricultural production is obtained when El Niño information was used in making specific agriculture-related decisions in 1992 compared to 1987.
(i) Acknowledged ability to predict weather phenomena on a routine basis including extreme events (hurricanes, extratropical storms, tornadoes, etc.) several days in advance;

(ii) The ability to simulate large-scale features of the components of the climate system. For example, Figure 8 shows the observed and model-predicted geographic distribution of December to February surface temperature and June to August precipitation, simulated by comprehensive coupled atmosphere-ocean models;

(iii) The use of these coupled models in the successful prediction of El Niño (1997-1998) and La Niña (1998–) phenomena, and their possible impacts, several months ahead of their occurrences; and

(iv) The ability to predict global temperature variations between the time of eruption of Mt. Pinatubo (June 1991) and the end of 1994. The result agreed closely with the observations (see Figure 9).

4. SUCCESS IN REGIONAL USE OF EL NIÑO FORECAST

Climate information and prediction services are frequently aimed at alleviating or mitigating negative impacts of extreme climate

For seasonal forecasting, the WMO Climate Information and Prediction Services (CLIPS) project provides the necessary framework. The ability to forecast on time scales of a season or more depends on the fact that sea surface temperature (SST) anomalies may be associated with persistent atmospheric circulation patterns at locations which may be distant from their source. The best known of these anomalies is the El Niño, marked by a warming of the ocean surface in the eastern parts of the tropical Pacific. A particularly strong El Niño event occurred in 1997 and 1998. El Niño events in the Americas are marked by the following events, although it needs to be stressed that they do not occur during every El Niño event: excessively heavy rainfall along the west coast of South America and California; heavy rainfall in southern Brazil and northern Argentina; drought in

Figure 6 — Tropical Cyclone Centres and some statistics regarding tropical cyclones/typhoons/hurricanes

Figure 8 — The geographic distribution of December to February observed surface temperature (a); June to August observed precipitation (c); compared respectively to (b) and (d) which were simulated by comprehensive coupled models of the type used for climate prediction.

(Source: IPCC, 1995a)
northeast Brazil; and changes of the tracks and frequency of Atlantic hurricanes and tropical cyclones in the Pacific.

Skills of extended-range forecasts for tropical Pacific Ocean SSTs have improved markedly. Numerical and statistical models were in general agreement on the behaviour of El Niño/La Niña. In Figure 7 an example of the forecast, a year ahead, of sea surface temperatures anomalies in the tropical areas of the Indian Ocean and the Pacific is given. Such forecasts are produced operationally by a few centres. At present, the most accurate forecasts are, in general, those for the tropical Pacific.

Current seasonal prediction models range from simple statistical approaches, through intermediate models, which combine the statistical and numerical approaches, to complex numerical coupled models, which use basic physical laws to predict the future state of both the atmosphere and the oceans. Much of the success in the development of models to predict these climate anomalies is based on the results of the Tropical Ocean and Global Atmosphere (TOGA) programme (1985-1994) and the Climate Variability and Predictability Study (CLIVAR) of the World Climate Research Programme (WCRP) co-sponsored by WMO.

TOGA provided fundamental insight into the mechanisms of the El Niño event and also facilitated the development of an observing network of moored buoys across the tropical Pacific Ocean, which provide invaluable real-time data for input to the prediction models. CLIVAR includes the development of seasonal to interannual prediction models under its GOALS (Global Ocean Atmosphere Land System) sub-programme.

3.4 THE BASIS OF CONFIDENCE IN PREDICTION MODELS

Weather and climate models incorporate mathematical descriptions of the atmosphere, ocean, land, biosphere and cryosphere in various degrees of complexity. Several factors provide confidence in these models including:
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The hydrological data collected by NMHSs, for use in flood and drought forecasting, is complemented by the World Hydrological Cycle Observing System (WHYCOS) (Figure 5) whose regional components including the CARIB-HYCOS is being developed by WMO in cooperation with countries of the Caribbean Basin. CARIB-HYCOS will enhance the ability of these countries to assess their freshwater resources, and provide valuable data useful for mitigating flood-related disasters and for better understanding of the impacts of El Niño on the hydrological regime of the region.

### 4.3 The Case of Colombia: El Niño and Malaria Epidemic

Too much or too little rainfall, which are common in some regions during the warm and cold El Niño phases, have been associated with various vector borne and food-related diseases. Similar observations have also been made in other parts of the region and many parts of the tropics. Figure 12 shows the linkages between El Niño and malaria cases in Colombia.

### 5. DISASTER MITIGATION AND MANAGEMENT POLICIES

The provision of timely warnings and forecasts to the public in safety of life and protection of property is one of the primary roles of all national Meteorological and Hydrological Services (NMHSs). The achievement of optimal results from the forecasts for preparedness and response to natural disasters therefore requires effective coordination and cooperation between NMHSs, the responsible agencies and institutions, the media, political leaders and civil society at local, national and international levels. Timely and effective forecasts and warnings of natural disasters coupled with local capability to take mitigating actions are fundamental for effective disaster reduction.
The NMHSs, in coordination with other national and international organizations concerned, have to be involved in virtually all the activities concerning natural disaster reduction, in particular, risk assessment, detection of disasters causing events, interaction with decision makers and other users, including civil society, as well as participation in public awareness campaigns. This involvement should constitute a framework within which the forecasting and warning capabilities of the NMHSs could be assessed and recommendations made for improvement.

In the area of risk assessment, the NMHSs should provide observational data and statistics required for identifying disaster potential, in particular the intensity and probability of occurrences, and also contribute to planning measures, including early warning, in order to minimize risk.

Detection systems, many of which are managed by NMHSs (for example, the detection and tracking of tropical storms by the National Hurricane Center in Miami), are intimately connected with preparedness systems, providing continuous updating of forecasts and warnings.

An effective and interactive system to communicate with users is a vital component of any forecasting activity. Officials and the public must receive information in a timely manner and be able to interpret it correctly. If the predictive capabilities are to be used to maximum advantage, a clearer understanding by all involved in relevant aspects from prediction to application is needed to enable forecasters and users to work together as a team. An effective forecast system requires that the target population understand the content of the message and knows how to react to it. This implies that well-designed forecast and warning systems must include an ongoing public awareness component on potential risks. This will call for the dissemination of information to be carefully coordinated to ensure timeliness and accuracy. While dissemination systems are generally well developed and fairly resilient in developed countries, this is not always the case in many developing nations.

Flood forecasting models have only recently been developed and used on a routine basis. Many existing hydrological models must be adjusted in real time as information arrives at the forecasting centre. Progress has been made in the development of methodologies for flood and even flash flood forecasting and nowcasting, especially using new tools such as the Geographic Information System (GIS).

Drought prediction requires, among others, monitoring the patterns of monthly and seasonal rainfall, reservoir and ground water levels, soil moisture and snow cover. Progress in developing predictive skill for large geographical regions on seasonal time scales makes it possible to provide increasingly useful forecasts of the onset, severity and duration of drought.
on storm movement, rainfall intensity, and/or river stage from real-time observations from satellites, radars, stream gauges, automatic weather stations and observers. The greatest difficulty in providing effective warnings of these small-scale events is the usually very short lead-time available to warn the public. The establishment of a comprehensive system for the issuance of forecasts and warnings, which comprises observing and data collection systems, visualization, analysis and modelling tools and adequate telecommunication networks, is therefore absolutely essential.

Forecasts of the behaviour of larger, synoptic scale weather systems such as tropical storms and extratropical cyclones are now made available several days in advance. Prediction of these systems and of the associated phenomena is made using numerical computer models. Weather forecasts of up to eight days in advance can now be provided for the middle latitudes countries. As regards hurricanes, scientific and technological advances (satellites, reconnaissance aircraft, modern computer systems and sophisticated numerical models) make it possible to detect most hurricanes at an early stage of formation, to monitor them throughout their life cycle and to provide forecasts of their tracks and intensity. The accuracy of forecasts and hence the reliability and timeliness of warnings has been steadily improving (Figure 3).

Figure 2 — Trends of Coastal Population versus Hurricane Deaths and Damage (1900-1996)

A high level of coordination must therefore exist between the organizations responsible for the detection of, and response to, the phenomenon caused by natural disasters. Of particular importance is the coordination of the issuance of forecasts and warnings. In many countries, the NMHSs have been designated as the authoritative voice for this purpose. WMO fully supports and promotes such arrangements which have proved to be effective. NMHSs must be actively involved in inter-agency disaster planning at national and regional levels to ensure a regular flow of reliable information to the public, political leaders, responsible officials and civil society. Coordination with the media must be given a particularly high priority, as it is a vital element in the dissemination of forecasts and warnings.

To assist NMHSs in improving coordination and interaction at the national level, WMO has developed guidelines on best practices regarding the relationships between NMHSs and the organizations involved in emergency management. The guidelines recommend, amongst others, the organization of seminars for disaster managers and decision makers, the participation of NMHSs in emergency-related bodies and in preparedness and prevention campaigns, joint missions of forecasters and emergency officers, and the publication of educational material on hydrometeorological aspects of natural disaster management.

In the light of the above considerations, the following are essential for forecasting systems to be effective:

• Access through reliable communications to the data from local, national, regional and global observation networks;
• State-of-the-art predictive capability at national level and, as necessary, guidance and information from specialized regional and global centres;
• Effective local and national dissemination systems capable of alerting threatened populations as frequently as may be appropriate;
• Awareness of the population and local and national authorities, regarding the content and meaning of forecasts and warning messages and how they should react to them; and
• Coordination among all national, and as appropriate regional, agencies involved in disaster reduction, in both the planning and operation phases.

Whilst these requirements are generally satisfied in developed countries, forecasting services in developing countries often experience a lack of resources for acquiring adequate facilities and for human resources development. It is therefore of utmost importance that international agencies, including WMO, provide the maximum possible assistance to those countries concerned to enable them to participate in regional and global efforts aimed at mitigating natural disasters and contributing to national sustainable development.

6. IADB AND WMO COOPERATION

In the area of natural disaster reduction, WMO undertook a number of actions, particularly following its Action Plan on the IDNDR, to assist its Members in the Americas to improve their forecasting and warning services. Some of these actions have been undertaken jointly and with the support of the IADB, and include:

(a) The Ibero-American Climate Project Feasibility Study which was funded by the IADB, Spain, USA, Canada and WMO, and carried out between 1997 and 1999. This study provided feasibility projects to 13 countries in Latin America. The implementation of the project will allow NMHSs of participating countries to provide meteorological and hydrological forecasts to users in order to enable them to prevent and mitigate the impact of natural disasters, as well as make better use of natural resources.

(b) The "Conference on Water Resources Assessment and Management Strategies in Latin America and the Caribbean" which was convened by IADB and WMO in 1996. The main outcome was an action plan which, among its main concerns, included the mitigation of natural disasters. The plan called for the implementation of national and regional studies of hazards of hydrometeorological origin, making it possible to create

Overall, the frequency and impacts of natural disasters are estimated to be increasing. Losses from natural disasters over the decade 1986–1995 were eight times higher than in the 1960s; and unless major efforts are deployed to counteract the impact of such disasters, this tendency will most probably continue. Within these efforts, forecasting of the occurrence, intensity, time and space scales of hydrometeorological disasters should be given priority attention.

3. SCIENCE AND TECHNOLOGY OF DISASTER FORECASTING

The impacts of natural disasters related to meteorological and hydrological phenomena can be regional or even global in scope. The spatial and temporal scales of these disasters vary widely from short-lived, violent phenomena of limited extent, including tornadoes, flash floods and severe thunderstorms, through to large systems, such as tropical and extratropical cyclones with life cycles of several days. At the largest scale are widespread droughts, which may affect large areas for months to years. Forecasting of these phenomena therefore requires techniques applicable to very short-term forecasts, for example, for less than one hour for tornadoes, and even nowcasts, to those for seasonal and inter-annual time scales for droughts and major floods which may be associated with the El Niño phenomenon.

The establishment of major weather forecasting centres and the systematic monitoring of the atmosphere and, to a certain extent the oceans, have enabled national Meteorological and Hydrological Services (NMHSs) to provide information related to the threat of weather- and climate-induced disasters such as hurricanes, floods, droughts, severe storms, forest fires, frosts, heat waves and cold spells (Obasi, 2000). In the United States, for example, improved forecasts of hurricanes with effective dissemination and wider awareness and preparedness have led to significant reductions of loss of life (Figure 2).

The prediction of small or meso-scale meteorological/hydrological events such as tornadoes, severe thunderstorms, squalls and flash floods requires the early detection of precursors. Forecast techniques are based on continuously updated observational information
The last Atlantic hurricane season, which closed on 30 November 1999 was marked by an above average number of tropical storms (12), five of which became major hurricanes. Among these, hurricanes Floyd (September 1999) and Irene (October 1999) caused widespread and severe flooding.

Large areas of the Americas are prone to extremely heavy rainfall and associated landslides. Table 1 highlights the regional and global impacts of the strong 1997–1998 El Niño event. For example, in December 1997 and January 1998, that is during the 1997–1998 El Niño, the coasts of Ecuador and northern Peru received 350-775 mm of rain, compared to the normal 20-60 mm. Torrential rains were recorded in southern Brazil, southeastern Paraguay, most of Uruguay, and parts of north-eastern Argentina (UNEP, 1999). Devastating floods and mudslides in the Caracas area in Venezuela caused over 20 000 deaths in December 1999.

In addition the impacts of droughts, including those in central USA, northern Mexico, northeast Brazil and Guyana, as well as large-scale forest fires in Colombia, Brazil, Central America and Mexico should be mentioned.

Table 1

<table>
<thead>
<tr>
<th>Region</th>
<th>Direct loss (in millions)</th>
<th>Mortality</th>
<th>Morbidity</th>
<th>Affected</th>
<th>Displaced</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>118 m</td>
<td>15 246</td>
<td>107 301</td>
<td>10 400 000</td>
<td>2 217 200</td>
</tr>
<tr>
<td>ASIA</td>
<td>3 220 m</td>
<td>6 018</td>
<td>124 647</td>
<td>33 719 719</td>
<td>318 700</td>
</tr>
<tr>
<td>ASIA PACIFIC</td>
<td>5 331 m</td>
<td>1 317</td>
<td>57 546</td>
<td>66 113 666</td>
<td>90 000</td>
</tr>
<tr>
<td>NORTH AMERICA</td>
<td>6 462 m</td>
<td>542</td>
<td>Incomplete</td>
<td>41 100</td>
<td>400 000</td>
</tr>
<tr>
<td>SOUTH AMERICA</td>
<td>18 068 m</td>
<td>997</td>
<td>243 743</td>
<td>723 033</td>
<td>363 000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33 199 m</td>
<td>24 120</td>
<td>533 237</td>
<td>110 997 518</td>
<td>3 388 900</td>
</tr>
</tbody>
</table>

early warning systems and disseminate information on disasters;

(c) The Study on the Prediction and Amelioration of Socio-economic Impacts of El Niño Southern Oscillation (ENSO) in Latin America and the Caribbean (LAC) which was initiated by WMO and IADB in September 1999. The Study will respond to the request expressed by the LAC countries through the Guayaquil Declaration (November 1998) and to the long-term objectives of the UN Resolution 52/200 on "International Cooperation to Reduce the Impact of the El Niño Phenomenon"; in the context of the ENSO Study, the development of early warning systems, including forecast components, will be analysed in selected countries and sub-regions from the technical, economical, social, environmental, legal and institutional points of view. The Study therefore includes evaluation of the existing institutional and technical forecasting capabilities in Latin American and Caribbean countries, as well as the formulation of project proposals and the analysis of the economic value of improved early warning systems; and

(d) The project “Support to Natural Disaster Prevention and Water Resources Management” based on the modernization of the NMHSs affected by Hurricane Mitch, which was prepared by WMO in collaboration with the NMHSs of the four affected countries, namely, Honduras, Nicaragua, Guatemala and El Salvador. Similar proposals are being formulated for the other Central American countries.

7. OTHER INTERNATIONAL COLLABORATIVE EFFORTS

In addition to the above, WMO is also involved in several other projects in the region.

The Project entitled “Radar Network Warning System for the Protection and Sustainable Development of the Caribbean Countries” is funded by the European Union. It will provide an advanced weather warning system, and relevant data to weather sensitive sectors in the countries covered by the radars.
Other project proposals under consideration include a Flash Flood Threshold Pilot project which would cover certain areas in Central and South America and would assess the ability of modern remote-sensing and computer technology to provide warnings of flash floods in areas with scarce data; a tropical cyclone landfall project and another on urban flooding and environment in Sao Paulo, Brazil are planned under WMO’s World Weather Research Programme.

A Memorandum of Understanding signed a few months ago by the World Bank and WMO will further contribute to developing synergies between relevant programmes of the Bank and those of WMO in areas of common interest, such as natural disaster prevention and mitigation, climate change, and the El Niño event.

In this context, the proposal for the establishment of the El Niño Centre in Guayaquil, Ecuador, should be highlighted as a follow-up to the UN General Assembly Resolution 54/220 on International Cooperation to Reduce the impact of El Niño phenomenon.

Furthermore, partnership with the private sector and commercial activities are also expected to grow in the new millennium due to the increase in benefits that can accrue from meteorological and hydrological information and prediction services. In this regard, WMO will continue to work with Member countries, relevant international organizations and non-state entities in natural disaster mitigation activities in the context of International Strategy for Disaster Reduction (ISDR). It is essential that the future Strategy would include, as a major thrust, scientific and technical activities and ensure the continued involvement of scientific and technical organizations like WMO.

WMO also participated, with other institutions such as the IADB, in the launching of the ProVention Consortium — a global partnership of all stakeholders, including Governments, international organizations, academic institutions, private sector and the media, aimed at reducing the risk of disasters in developing countries, and at making disaster prevention and mitigation an integral part of development efforts.

natural disasters. As can be seen from Figure 1, during the period 1963-1992 tropical cyclones, floods, landslides and droughts account for more than 50 per cent of fatalities, 80 per cent of persons affected by natural disasters, and over 80 per cent of those disasters responsible for significant damage.

According to the Munich Reinsurance Company (IDNDR, 1999), in only one year (1998), over 14 000 deaths in the Americas were caused by 112 storms and 38 floods, and economic losses resulting from these events exceeded US$ 35 billion. The 1998 Atlantic hurricane season, more active than normal, brought 14 tropical storms (the average number is 10), of which 10 became hurricanes (with wind speed more than 119 km per hour), including three major hurricanes (with wind speeds of more than 178 km per hour). They inflicted US$ 7.3 billion in damages and caused 23 fatalities in the United States alone (US Department of Commerce, 1999). Among the most devastating hurricanes of all times were Hurricanes Georges (September 1998) and Mitch (October 1998). Hurricane Mitch alone led to about 9 000 deaths in Nicaragua and Honduras and seriously affected their development plans. In Guatemala, El Salvador and Costa Rica, the impact was less devastating, but nevertheless very significant.
reduce vulnerability. In this respect, whilst dealing mainly with natural disasters of hydrometeorological origin, WMO is also engaged in promoting:

(a) The development of integrated systems of disaster management, which include hydrometeorological aspects of disaster preparedness, warning, relief and rehabilitation; and

(b) Scientific studies including comprehensive risk assessment.

It is in this spirit that the partnership of WMO with the IADB, to support the Member countries in Latin America and the Caribbean is being developed.

Forecasting is an indispensable component of preparedness and response phases of natural disaster reduction. In the i.e., preparedness phase (pre-disaster activities intended to increase the effectiveness of emergency response during a disaster) forecasts and warnings, if reliable and provided with sufficient advance notice, can obviously play a key role in saving human life and/or reducing property damage. In the response phase i.e., (activities undertaken immediately prior to and during the impact or the acute phase of an event) updated forecasts are equally, if not, more important.

In this presentation, the status of the science and operational systems for hydrometeorological disaster forecasting will be summarized, particularly as regards the forecasting of the most frequent and devastating forms of disasters to hit Latin American and Caribbean countries, namely: tropical storms (including hurricanes), tornadoes, floods and droughts. In this respect, special emphasis will be placed on the activities of the national Meteorological and Hydrological Services (NMHSs), which should constitute a critically important part of any national disaster prevention and mitigation system as envisaged by the IADB.

2. HYDROMETEOROLOGICAL DISASTERS: SOME FACTS

Globally, over 70 per cent of natural disasters are related to weather and climate, but in some countries or regions, the disasters of hydrometeorological origin account for the totality of

8. ROLE AND PLACE OF FORECASTS IN THE PROPOSED IADB ACTIONS

The actions proposed by the IADB in support of Members relate to hydrometeorological disaster monitoring, forecasting and early warning and should involve and be built upon existing cooperation among the NMHSs.

It is therefore imperative that when formulating and implementing its action plan, the IADB take the following into consideration:

• The definition of an effective strategy to reduce risk would include the recognition of, and measures to satisfy, the need for adequate support to existing viable national institutions such as NMHSs, and the strengthening of regional and international centres, projects and programmes on scientific and technological aspects of natural disaster reduction;

• The building of technical, scientific and operational capacity including human resources within the NMHSs would be the most cost-effective way to realize their potential to contribute to the implementation of the strategy related to natural disaster reduction at national, regional and global levels;

• National and regional systems for natural disaster prevention and mitigation would embrace components based upon the facilities and capability of the NMHSs. These should be integrated, as appropriate, with other systems related to preparedness, public awareness, decision-making, and relief and rehabilitation;

• National and/or regional coordination between the NMHSs and the civil defense organizations responsible for disaster prevention and coordination with the media for dissemination of forecasts are also important; and

• Inter-agency coordination would take into full account the existing and planned scientific and technical programmes and activities of regional and international organizations, including WMO, especially in the context of the International Strategy for Disaster Reduction (ISDR).
1. INTRODUCTION

As announced, one of the purposes of this conference is "to examine ways to reduce the institutional vulnerability of Member nations" in respect of natural disasters. In this context, it is envisaged that the Conference will consider possible actions that the Inter-American Development Bank (IADB) had proposed to undertake in Member countries. These actions include:

(i) Defining an effective strategy to reduce long-term and recurrent risk;
(ii) Strengthening capacity to implement the strategy;
(iii) Building national systems for disaster prevention and mitigation; and,
(iv) Enhancing inter-agency coordination.

The formulation and implementation of the proposed actions by the Bank, especially in respect of (iii), require the establishment and operation of internationally coordinated national and regional systems for monitoring and forecasting natural disasters. Such systems represent a cost-effective way to
Role of Meteorology in Renewable Energy Resources

by

Professor Godwin O. P. Obasi
Secretary-General
World Meteorological Organization

Lecture at the Sharjah Solar Energy Conference — 7th Arab Conference on Solar Energy and Regional World Renewable Energy Congress (Sharjah, United Arab Emirates, 19 February 2001)