PART III

RISK REDUCTION OF SPECIFIC NATURAL HAZARDS

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1. GLOBAL ENVIRONMENTAL CHANGES

1.1. International conventions and principles

The Rio Conference in 1992 agreed on general principles on sustainable development (Agenda 21). More specific international commitments were gained through the conventions on climate and biodiversity. According to the Convention on Climate Change all governments should ratify, accept or approve the Vienna Convention and Montreal Protocol (1987) on Substances that Deplete the Ozone Layer and its 1990 amendments (London), make available substitutes for CFCs and other ozone-depleting substances, and support the transfer of the technologies to developing countries. Also support to further expansion of the Global Ozone Observing System (through both bilateral and multilateral) funding should be guaranteed. The production and use of chlorofluorocarbons and other ozone-depleting substances should be eliminated. So far by June 1993, from the initial 150 countries that signed under the treaty on climate change only 14 have ratified the Convention (e.g. USA, China, Canada, Australia). For becoming effective the treaty must have altogether 50 signers.

The Convention on Biological Diversity were also approved by most countries in Rio. The main objective of the treaty is the protection and sustainable use of biodiversity. The Convention consists of general commitments both on in situ (conservation areas and gene banks) and ex situ (components of biological diversity outside their natural habitats) protection. At national level each country should formulate an action plan for protection of biodiversity. The treaty also includes regulations for technology transfer and funding of operations. By June 1993, altogether 20 have ratified the Convention (e.g. Canada, Monaco) from the needed 30 to become effective.

As a result of the UNCED-process, negotiations on the International Convention on Desertification are currently taking place. The Convention, focusing especially on Africa, should be finalized in 1994. The protocols of the Convention shall form the basis for national and especially international action to combat desertification. As part of the process existing information on desertification shall be co-piled and organized. Effects of the climate change on desertification shall be analyzed. UNEP has since 70's worked for prevention of desertification through its Action Plan to Combat Desertification.

In Rio, also the non-legally binding authorative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests were agreed. According to these principles:" Forest resources and forest lands should be sustainably managed to meet social, economic, ecological, cultural and spiritual human needs of present and future generations. These needs are for forest products and services, such as wood and wood products, water, food, fodder, medicine, fuel, shelter, employment, recreation, habitats for wildlife, landscape diversity, carbon sinks and reservoirs, and for other forest products. Appropriate measures should be taken to protect forests against harmful effects of pollution, including air-borne pollution, fires, pests and diseases in order to maintain their full multiple value". These principles link the forests to the conservation of biodiversity:"The vital role of all types of forests in maintaining the ecological processes and balance at the local, national, regional, and global levels through their role in protecting fragile ecosystems, watersheds and freshwater resources and as rich storehouses of biodiversity and biological resources and sources of genetic material for biotechnology products, as well as photosynthesis, should be recognized". The principles describe also the economic importance forests have:"the role of planted forests and permanent agricultural crops as sustainable and environmentally sound sources of renewable energy and industrial raw material should be recognized, enhanced and promoted. Their contribution to the maintenance of ecological processes, to offsetting pressure on primary/old-growth forest and to providing regional employment and development with the adequate involvement of local inhabitants should be recognized and enhanced".

1.2. Climatic change

Climate change, induced by the addition of greenhouse gases to the atmosphere, is one of the greatest threats to sustainability at local and at global level. We know today that since the 1860 the global mean surface air temperature has risen about 0.5°C. Noticeable increases occurred between 1910 and 1940, and the 1980s have had the sixth warmest years on record. 1990 was far warmer than the three previous warmest years (1981, 1988, 1989). Climate researchers do agree that the observed increase in mean global surface temperature is caused by the increase in the concentrations of the following gases: carbon dioxide (CO2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons ($CFCl_3$, CF_2Cl_2), and low- stratospheric and tropospheric ozone. Even under the most favourable conditions, the global average temperature increase estimated by the Intergovernmental Panel for Climate Change for the next century is at least 1°C. This is much more faster than the most rapid previous rate of warming in the present geological era. The maximum expected temperature increase in the IPCCs scenarios is 5.5°C.

The impacts can be severe. The overall effect on soil moisture content and thus plant growth and production is of particular importance when considering world and local level food security. Variations in precipitation vary a lot naturally and changes in precipitation are less known. Scientists seem agree on that extreme weather phenomena (e.g. tropical storms, hailstorms, heavy rains, heat waves) will come more frequent because of increases in sea surface temperatures, and that these phenomena will certainly have an undesirable impact on people, productional systems and ecosystems. The third significant impact is the expected rise in the level of world oceans. Already during the last 100 years the sea level has arisen by 15 cm. Estimates for the middle of the next century predict a further sea level rise by 20 to 70 cm. For many low countries, particularly in South Asia, this will constitute an increasing threat with potentially disastrous consequences as already demonstrated by the disastrous storm surge and flood in Bangladesh in 1991.

1.3. Ozone depletion

Since the end of the 1970s, ozone depletions have been recorded over the Antarctic continent. Despite of some annual variations these depletions have been growing. Virtually all ozone between the altitudes of 15 to 22 km has been wiped out. Nowadays, the ozone depletion is affecting the temperate zone as well, approaching 1 % per year during the winter and spring months during the 1980s.

The cause for the phenomena has been clearly identified from atmospheric observations. Ozone depletion involves catalytic destruction of ozone by chlorine (Cl) atoms and chlorine monoxide (ClO) radicals, the photochemical breakdown products of the industrial chloroflurocarbon gases in the stratosphere. An unexpected sequence of events, involving several feedbacks, is responsible for the particularly damaging activity of the chlorine gases during these conditions:

* cold winter and early springtime temperatures which promote the removal of oxides of nitrogen from the gas phase by freezing them into solid nitric acid trihydrate (HNO_3, $3H_20$), so called "NAT" particles. The presence of gaseous nitrogen oxides tend to trap inorganic chlorine as hydrochloric acid and chlorine nitrate, which do not react with ozone. Their absence from the gas phase favours the conversion of the latter compounds into chemically reactive Cl and ClO.

* the production of molecular chlorine (Cl_2) by the reaction of hydrochloric acid (HCl) and chlorine nitrate ($ClONO_2$) on the surface of the trihydrate particles.

* the dissociation of Cl_2 by solar ultraviolet radiation, producing Cl atoms

* the establishment of an ozone destruction cycle, involving a reaction of ClO with itself, which is particularly effective in the lower stratosphere. The efficiency of this process is proportional to the square of the stratospheric chlorine content, and thus growing by about 7 % per year.

The interaction between reactive chlorine and nitrogen is remarkable - especially the protective role of the oxides of nitrogen against ozone destruction by the chlorine species. It is especially significant in view of the fact that the oxides of nitrogen themselves, under natural conditions, are largely responsible for controlling ozone concentrations above about 25 km!

For five to ten years after the industrial production of chlorofluorocarbons is curtailed (by the end of this century as agreed in the international treaty on climate change in Rio in 1992), the chlorine content of the atmosphere will continue to increase due to their slow diffusion into to the stratosphere, hence aggravating the ozone loss. Further damage to the ozone layer by chlorine gases, possibly in combination with bromine gases, must therefore be expected until the year 2010. A return of the stratosphere will start, but because of the slow breakdown of the chlorofluorocarbon gases the healing process will last a hundred years. Additional problems may be caused by the continuing increase by about 25 percent per year of the reservoir of atmospheric N_2O, the precursor of the NOx catalysts. For the future, the emissions of NO and H_2O by hypersonic aircraft, which are in their planning stages in the US, Europe and Japan, may also become of great concern, because they may lead to further ozone depletions, through reactions with NO and NO_2 as catalysts in the middle and upper stratosphere. In addition following reaction of $ClONO_2$ and H_2O may also promote "ozone hole" reactions in the cold winter and springtime due to increasing likelihood of formation of NAT particles.

1.4. Biodiversity

Biological diversity is the total variety of genetic strains, species and ecosystems. It is continually changing as evolution gives rise to new species, while new ecological conditions cause others to disappear. There exist no accurate data on the decline in biodiversity but according to estimates of UNEP some 25 percent of the world's species could become extinct, or reduced to remnants, by the middle of the next century, if present trends of destruction continue. Biological resources constitute also a capital asset if they are maintained and sustainably managed.

2. DROUGHT AND DESERTIFICATION

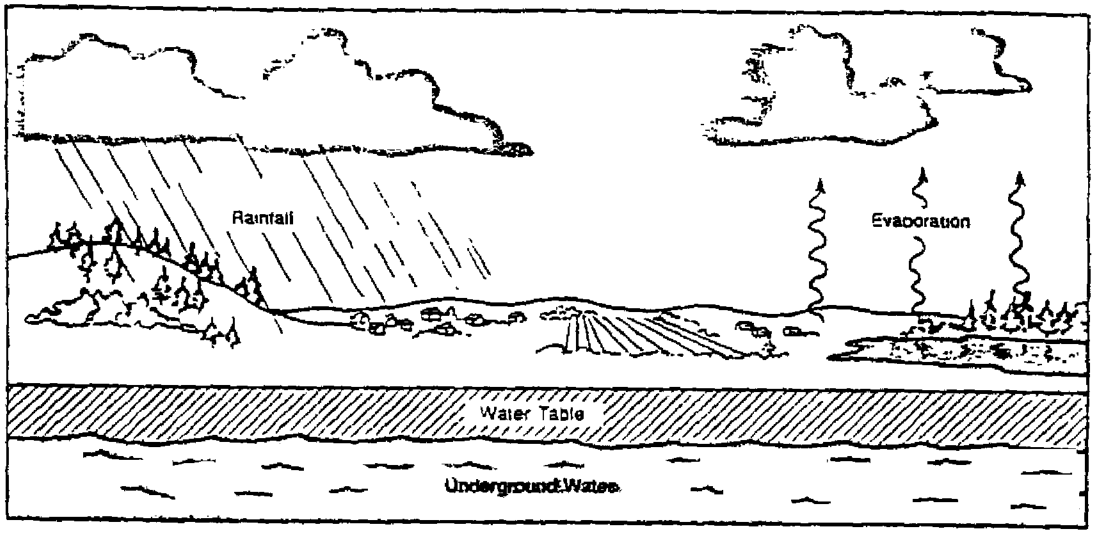
Description of phenomenon

Drought and desertification are hazards that can be particularly severe in arid and semi-arid regions. **Drought** is a common feature for all climatic regions. The semi-arid and sub-humid areas where drought is a recurrent phenomenon are located at the edges of large sub-tropical high pressure cells where precipitation is in normal years adequate for agriculture, river flow and water supplies. Drought can be described as an extended period of dryness that is usually any period of moisture deficiency that is below normal for a specific site. There are several definitions which vary by discipline - meteorological drought, agricultural drought, hydrological drought, socio-economic drought - and by climatic zone.

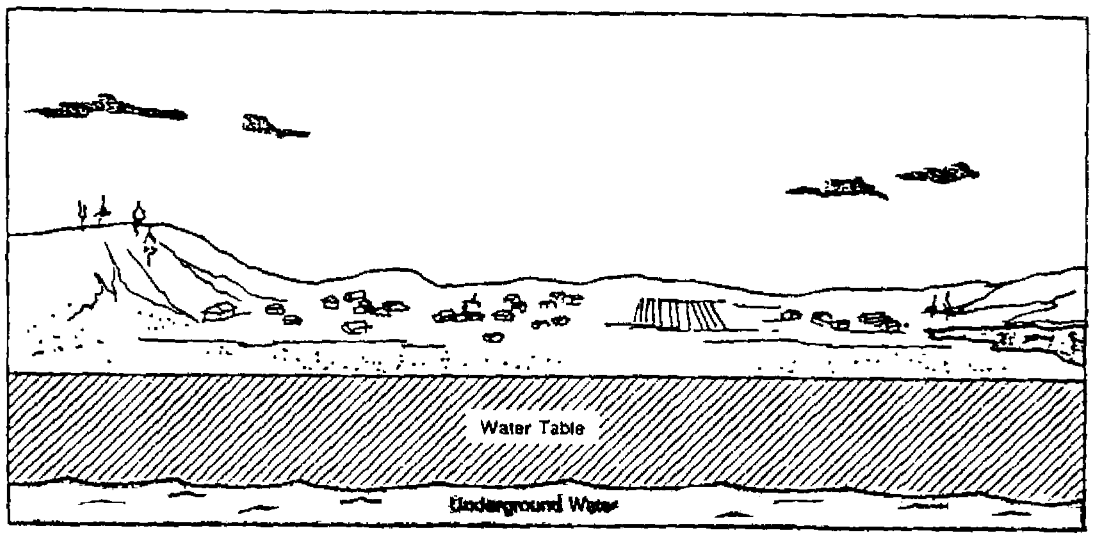
While there are normal drier periods because of natural climatic fluctuations, there are also abnormal dry periods that are caused either by a climatic change or, to a large extent, by human interference. These abnormal weather periods result frequently in malnutrition, famine, diseases, depletion of animal stocks, water resources, vegetative cover, and they result in increase of food prices and aggravate poverty, because local people and authorities have not been able to prepare themselves sufficiently to a creeping but sudden change of climate.

Desertification can be described as a process of resource degradation through such natural phenomena like waterlogging, salinization, increased soil temperature and aridity, increased dune formation, decreased soil organic matter, and increased albedo. As there exist a variety of deserts, not necessarily all the mentioned factors need to occur at the same time on a same site. However, all these factors - jointly or alone - might result in a decrease of total biomass production and in an increase of noxious or unwanted flora and fauna which are typical desert features. Principally, desertification is caused by long-term climatic changes (e.g. high rates of evapotranspiration, scarce and erratic rainfall, and recurring drought), physical characteristics of the site (extremely permeable or impermeable soils and high water tables), and man-made land degradation. The term desertification usually refers to irreversible land degradation.

THE DROUGHT CYCLE



NORMAL HYDROLOGICAL BALANCE. Water supply is adequate to meet demand. The community grows and land use intensifies.



DROUGHT. Meteorological changes reduce rainfall, while urbanization overgrazing, deforestation, and farming reduce water retention of the soil. The normal hydrological balance is broken. The topsoil erodes and the water table is lowered making recovery difficult. Food production and drinking water are reduced and people migrate out of the area.

Source: Cuny, Frederick; Disasters and Development, 1983

Hazard prediction

The impacts of a drought are relatively difficult to predict, although continuous studies have been made in drought-prone areas since meteorological observations started. The prediction becomes complex for two major reasons. Firstly, the climatic fluctuation caused by the interrelated land-ocean-atmosphere system which can vary. Secondly, the existing land use and land management practices, particularly agriculture, cattle grazing and deforestation, can change a lot the micro-climate. Hence, such factors as surface albedo, surface roughness and moisture convergence may be radically changed. Such changes can have severe feedback effects on moisture recycling mechanisms. Thus, as a result a reduction in soil moisture can lead to reduced evaporation and finally to reduced available atmospheric moisture and water vapour for cloud formation, and to the presence of a deep layer of dust in the lower troposphere. This in turn reduces incoming solar radiation and convective activity.

The Sahelian episodes of drought have been studied rather systematically, and as a result, there exist some basis for prediction of coming periods of drought. In the Sahel, a correlation has been discerned between sea-surface temperatures south of the Equator and monsoonal rainfall in the Sahel (high summer temperatures in these waters apparently being related to Sahelian drought). It seems also that the two recent episodes of slow oceanic and accompanying atmospheric circulation (i.e. El Niño events) are in some way connected with the Sahelian droughts. Conversely, episodes of rapid oceanic circulation in the Atlantic Ocean were found to be related to increased rainfall in western Africa. There is also some evidence that several long-lasting periods of decreased salt concentrations in the upper layers of the North Atlantic Ocean have during the last 14 thousand years coincided with periods of drought in the Sahel. It has been suggested that deforestation in the Congo River basin in recent decades has contributed to the droughts occurred in the Sahel.

Some trials are on-going in selected WMO member countries, using interrelationships between atmospheric processes and seasurface temperature anomalies (e.g. El Nino-Southern oscillation phenomena). WMO has several programmes that indirectly or directly aim at drought (/desertification) preparedness: Tropical Meteorology Research Programme, the Tropical Cyclone Programme, the World Climate Programme, the World Climate Research Programme and research programmes on weather forecasting. WMO Agrometeorology Programme studies the interrelationships between crop and animal production and the climate. Effective drought (/desertification) prediction means in fact a functional network, data collection and processing, and efficient information exchange between meteorological, hydrological stations and agricultural institutions. For instance, monitoring of food prices gives relevant information about the trends in food security.

In the Eastern and Southern Africa in 1989, as a result of a joint effort of UNDP and WMO a network of Drought Monitoring Centres (DMCs) was established. These centres operate as sub-regional climate diagnostic centres and offer information relating to drought and weather patterns to all interested users within or outside the Eastern and Southern African region. The main centre is in Nairobi at the Kenya Meteorological Department on Ngong Road.The sub-centre is located in Harare at the Zimbabwe Meteorological Department. The objectives, operations and services of both centres are complementary. Currently the centres publish and deliver a monthly drought monitoring bulletin, ten day advisory and dekatal, monthly and three monthly actual meteorological data for the region. USAID has similar kind of programme in the Sahel region.

Issues related to environmental protection, and in particular those related to regional climate change and its impact on agriculture, will receive attention through strategic programmes on food and desertification in the region. For instance, these two centres warned well ahead of the anomalous weather pattern that resulted in the latest drought in Eastern and Southern Africa.

A more political body that works with drought prevention is the Inter-Governmental Authority on Drought and Development (IGADD) including six East African countries (Djibouti, Ethiopia, Kenya, Somalia, Sudan, Uganda). This is one of the main bodies and organizations that the DMCs collaborate with in matters of drought monitoring. IGADD has special programmes on food security, environmental protection and desertification control.

Wind is a factor that can drastically intensify desertification process. In dry areas, for instance, wind leaves coarser material behind and continues transporting the finer soil particles. Although dunes can also exist in non-desertification environments like coastlines or close to loosely cemented sandstones, their movements towards the desert borders is a clear indication of existence of an accelerating desertification. Wind increases water evaporation rates from land and plant surfaces. This increase can be strengthened further by higher temperatures and decreased relative humidity.

Soil quality is perhaps the most important factor in erosion control. Erosion by water and wind occurs on any sloping land regardless of its use. Soil organic matter increases the infiltration capacity and thus, soil moisture even when the precipitation itself remains scarce. Organic matter decreases soil erosivity. It means also more aeration for root systems and more nutrients for plant growth. Soil texture affects other soil characteristics particularly soil moisture and soil fertility. Sandy soils that are irrigated need more water than fine-textured soils but an overdose of water may lead to leaching of nutrients and colloids important and otherwise available for plant growth. Fine-textured soils can hold more water than coarse-textured ones, and in general: 1) they hold water in the upper soil layers where drying is greater, 2) there is greater water loss due to lower rates of infiltration and higher rates of surface flow or run-off, 3) they inhibit growth of root systems (shallow roots) and seedlings, which increases the drought-sensitiveness of the plant; and 5) they are less susceptible to gully and sheet erosion.

Evaluation of a desertification hazard can and should be done in all planning phases of a project and during its implementation. Planning should include components or sub-projects to reduce hazard risk and ways to monitor the effects that the project might have on desertification process. Assessments as to whether the project area/site will probably suffer from desertification can be started on locally/regionally available maps (e.g. UNEP) showing critical regions. The project area/site should be zoned according to as many of the major factors (precipitation, historical occurrence of drought, potential evapotranspiration, wind, soil texture, land form, land use, land management) active in the desertification process as possible.

Mitigation

The most effective way to reverse or mitigate desertification process is land use planning and land use control. Land use plans should have an effective mandate to protect the most fragile sites (e.g. erosive soils, salinization-prone soils, drainage patterns/watersheds, etc.) from intensive land use and economic activities (e.g. grazing, mechanical farming, large-scale irrigation, large-scale construction activities).

The existing land management practices can be mitigative or destructive. Land management should be understood both as a physical measure of balancing soil structure or status of nutrients, and as a social, economic and cultural measure. As population growth seems to continue without drastical decrease, in many parts of the drought-prone (/desertification-prone) region the consequent increase in herd sizes competes of same critical factors that accelerate desertification: vegetation cover and water. Thus, changes in grazing practices and a reduction in herd sizes are essential methods in disaster prevention. In conclusion, more integrated measures and political will to invest on dry regions are needed to combat drought and desertification. Programmes for rural, community and urban development including awareness building through training and extension, fulfillment of basic needs, access to credit for small-scale agricultural production and income-generation activities, improved but sustainable practices of economic activities are needed steps to be taken in long-term prevention. In many places, (traditional) agriculture has no longer the capacity to employ the growing population.

3. TROPICAL STORMS

Description of phenomenon

There are two definitions for tropical storms:

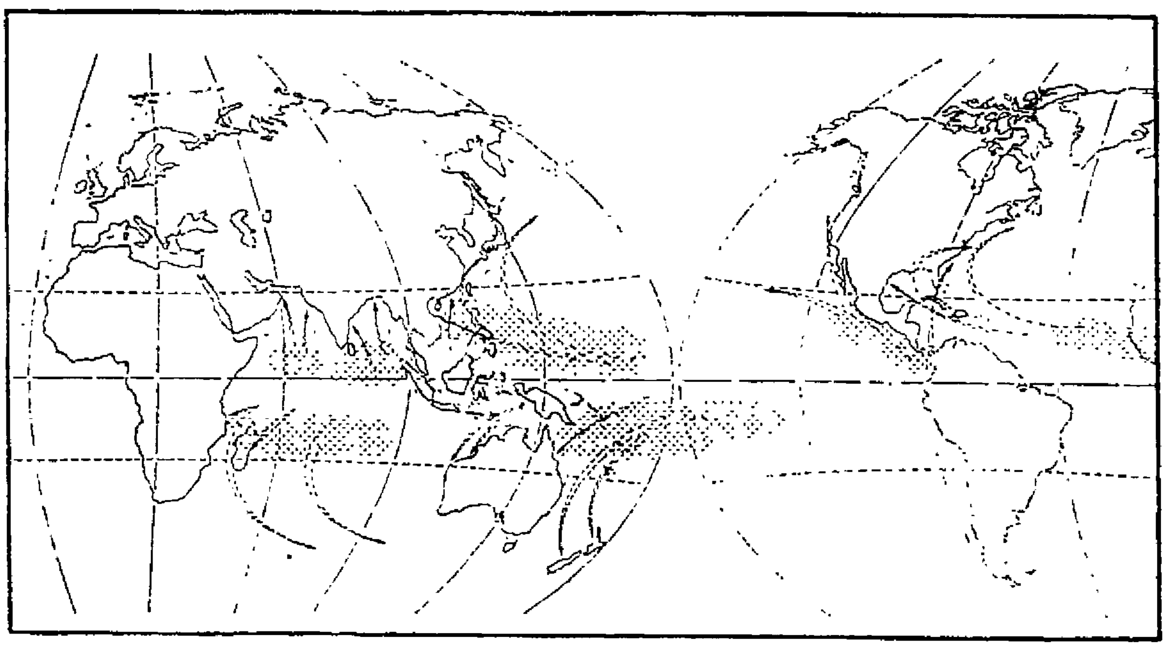
- Cyclones (generic term) - A non-frontal cyclone of synoptic scale (i.e. diameter of the order of some hundreds of kilometers) originating over tropical waters, with organized convection and in which the maximum average wind speed is from 17 m/s to 31 m/s

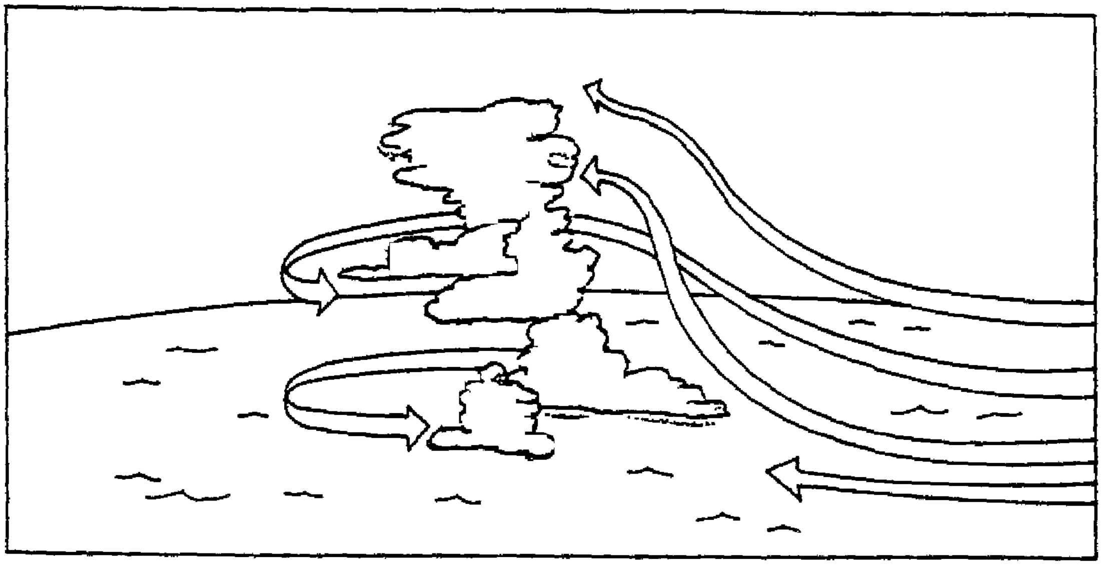
- Tropical cyclones (term used regionally) - A warm core tropical vortex in which the maximum average wind speed is 32 m/s or more.

In the following the latter phenomenon is considered a tropical storm.

Tropical storms are severe cyclonic disturbances of the atmosphere that form in low latitudes: between 5° and 30° in both northern and southern hemispheres. They can exist as fully fledged storms far to the north or south from 30°. The storms develop over the warm waters of the tropical oceans where the water temperature is 27° or higher and where atmospheric pressure is relatively low. The main areas where they originate as well as the main tracks they normally follow are shown in Figure 5.

Figure 5. Main areas of origin and main tracks of tropical cyclones

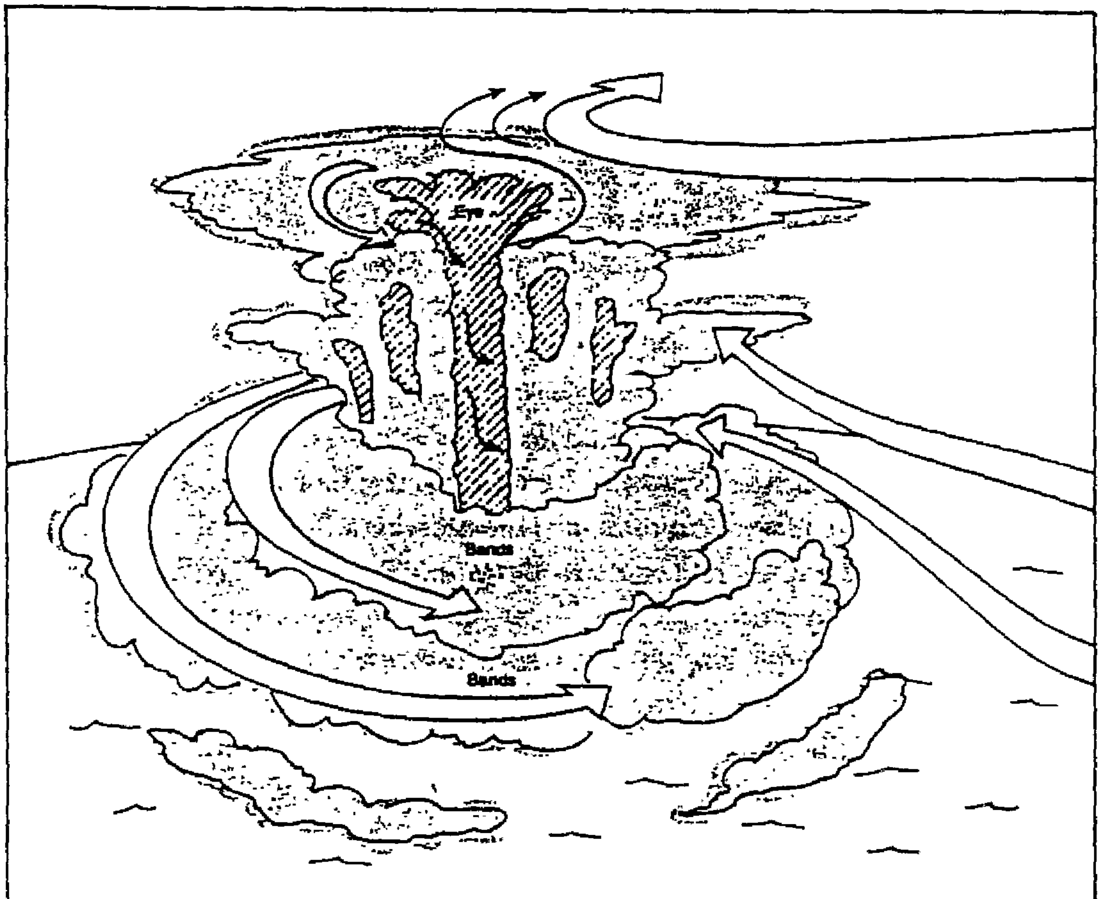




HOW A HURRICANE FORMS

An atmospheric disturbance forces warm moist air of the prevailing Easterlies to rise. As the air cools, water vapor condenses and falls as rain; heat energy is released, and winds intensify.

The storm grows as air spirals inward, rises, and is exhausted from the top by high level winds. Surface air converges at an increasing rate toward the low pressure at the storm center. High winds, heavy rain, and storm surges occur as the storm becomes a mature hurricane.



Source: Cuny, Frederick; Disasters and Development, 1983

These storms are cyclonic spirals, the wind forming a vortex which, as a result of the earth's rotation, turns clockwise in the southern and counter-clockwise in the northern hemisphere. The vortex of air spirals inwards towards the centre where the pressure is at a minimum. This area, known as the eye of the storm, contains only light winds or may be even calm.

Around the eye explosive cloud growth takes place as warm, moist tropical air escapes upwards to heights of 12 000 meters or more. This is the region of maximum winds which may exceed 60 m/s. If the winds in such a cyclonic spiral exceed 32 m/s the storm is called a hurricane in the western Atlantic, a typhoon in the western Pacific, a willy-willy in Australia, and a tropical cyclone or cyclone in the Indian Ocean.

From the mass of clouds around the eye, rainfall can be exceedingly heavy, amounting to 150-250 mm during the passage of a fully developed cyclone over coastal regions, and as much as 1000 mm is possible.

One further characteristic of a cyclonic storm is its association with a strong reduction in atmospheric pressure. This reduction is normally from 60 to 100 hPa and together with the wind, drawing sea-water inland, waves and tide may bring a rise in water level up to 14 meters. The wind, rain and water effects of the cyclonic storm may be felt as much as 500 km from the eye, diminishing progressively from the centre.

There are also smaller meteorological phenomena such as tornadoes, thunderstorms, typhoons which can locally have severe impacts.

Hazard prediction

The responsibility of forecasting and early warning falls upon the national meteorological and hydrological services, which must predict the time and area of impact and the expected dangers in terms of high winds and flooding. The system has been developed over many years, making use not only of more conventional sources of data collection, but also of the advance technology now available. In general, this system is based upon the global and regional requirements for the World Weather Watch and Operational Hydrology Programmes of the World Meteorological Organization (WMO). Other national activities may also be set up to assist in the more accurate prediction and warning of tropical cyclones - considerable input in itself. The aim is usually to provide twelve daylight hours' warning to the population and it may be said without fear of contradiction that this system works with a high degree of efficiency in most tropical cyclone areas.

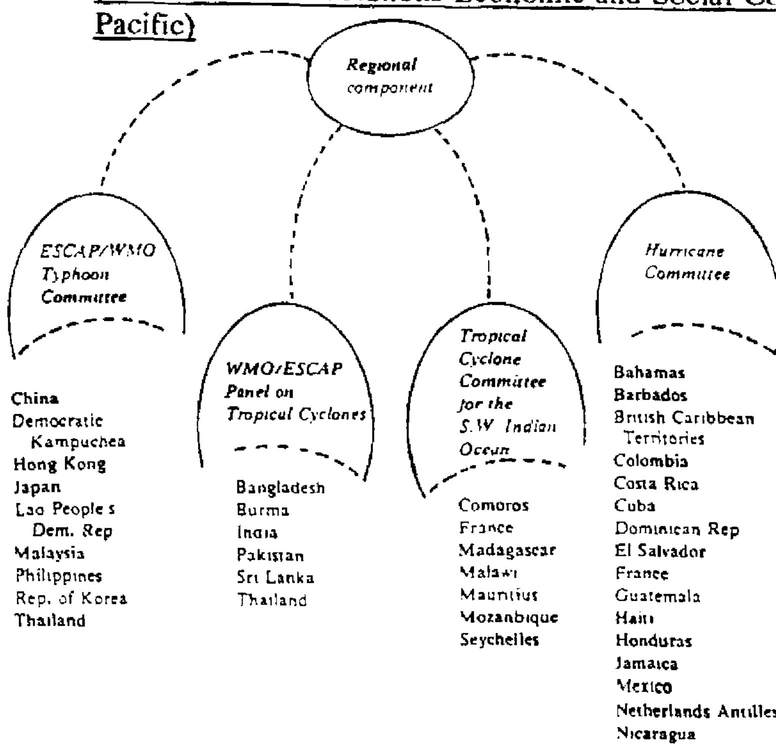
The earth-orbiting satellites and, particularly, geostationary satellites, have largely relieved the meteorologist from the difficult problem of detecting the formation of a cyclone over distant ocean waters, from which he has little other information. However, cyclone tracks are notoriously erratic and in a twentyfour-hour forecast, an error of only 10 degrees in predicted track results in the cyclone striking the coast more than 185 km from the expected spot. Surveillance by satellite and finally by storm-warning radar when the cyclone is within 300-400 km can ensure that its path into the coast is monitored. This in turn enables the forecast to be constantly up-dated and refined in the hours leading up to landfall. One of the major purposes of the WMO Tropical Cyclone Programme (TPC) is to improve the ability of member states, individually and collectively, to meet the challenge posed by tropical cyclone.

Almost all the countries located on tropical cyclone-prone areas are equipped with efficient satellite data receiving stations, but the weather radar network is not dense enough. The predictability of the location where the storm will hit the coast is in the last hours based on the use of the weather radar. The missing piece of equipment will reduce the accuracy of the forecast, but anyway the existing satellite data will supply enough information for ensuring correct action.

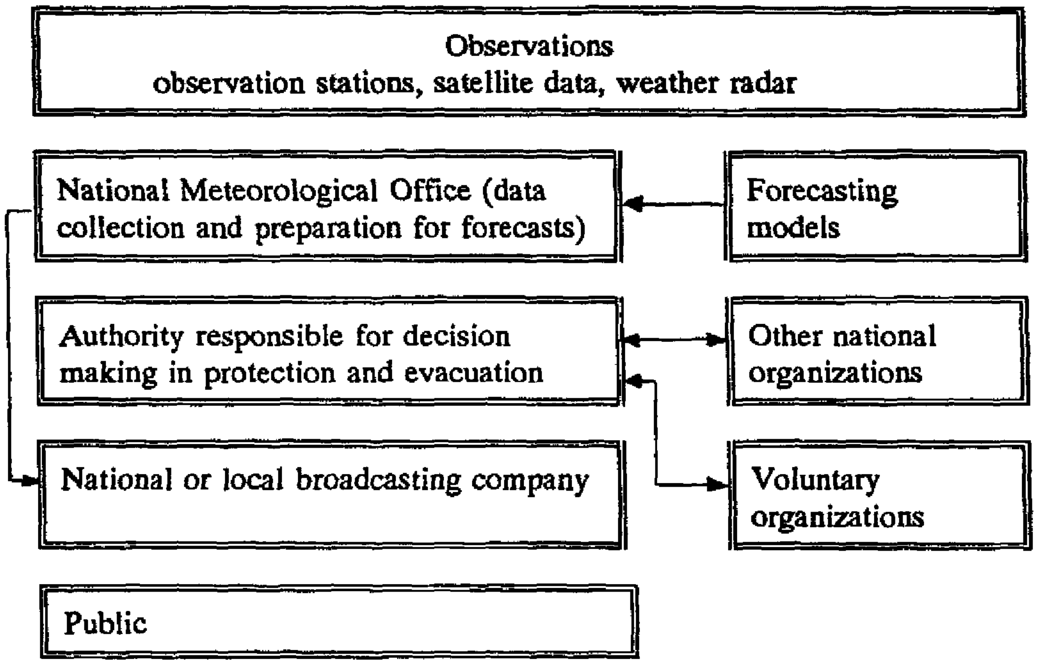
The Tropical Cyclone Programme was founded by WMO in order to establish national and regionally co-ordinated systems to minimize the loss of life and damage caused by tropical cyclones. The activities of the programme are divided into two categories, general and regional. Under the regional component, the principal advances have been made by grouping together countries in specific tropical cyclone areas to carry out cooperative programmes designed to improve the warning system as a whole. These programmes cover meteorology, operational hydrology, disaster prevention and preparedness, training and research.

The regional cyclone bodies cover nearly all the world's tropical cyclone areas (see figure 6). Though much remains to be done, the years of operation of these bodies have seen immense improvements in observation and telecommunication systems, most notably in the radar and satellite facilities, which are of such vital importance for forecasting and warning.

Figure 6. Regional cyclone bodies of the WMO Tropical Cyclone Programme (ESCAP = United Nations Economic and Social Council for Asia and the Pacific)



Although the warning systems may differ to some degree from the country to country the information flow is generally speaking the same everywhere and can be described as follows:



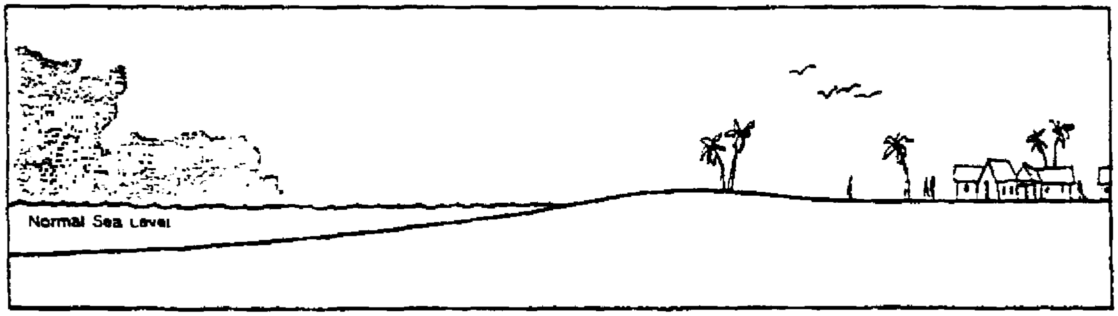
The scheme shows that the National Meteorological Office (NMO) is responsible for data collection, preparation of forecasts and giving early warning. Later, when the decisions are made concerning protection and evacuation, the cooperation between the NMO and the Authority concerned is essential.

Mitigation

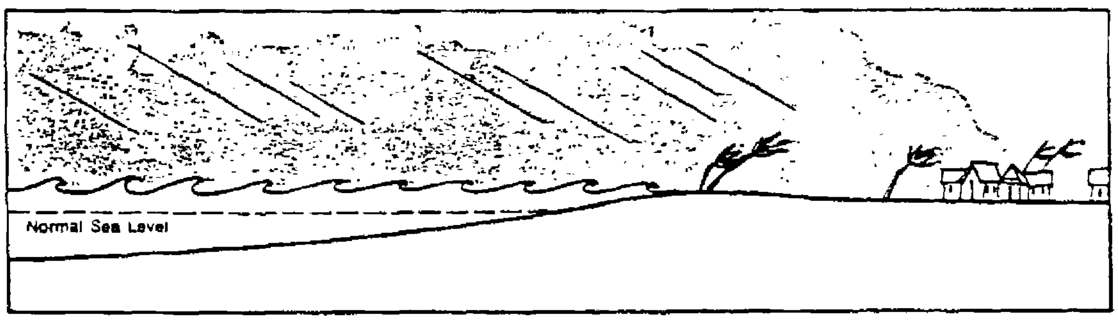
When planning activities in the cyclone-prone areas, some preliminary measures are compulsory. The most important is collecting meteorological statistics from which some of the considered values can be found. Those statistics are available from the nearest NMO, WMO in Geneva or from the NMO in the country concerned.

The first and most important of the parameters is the probability of existence of tropical cyclones in the region. From the probability it is possible to assess the risks for different activities and to make decisions, such as cancelling some measures during the cyclone season. The second are the values of maximum wind speed and its distribution. This gives an idea of the strength of constructions and for forest planting, for example.
The third are the values of the amount and intensity of rain. These figures can assist drainage planning and the assessment of the survival of cultivation as well as flood prediction.

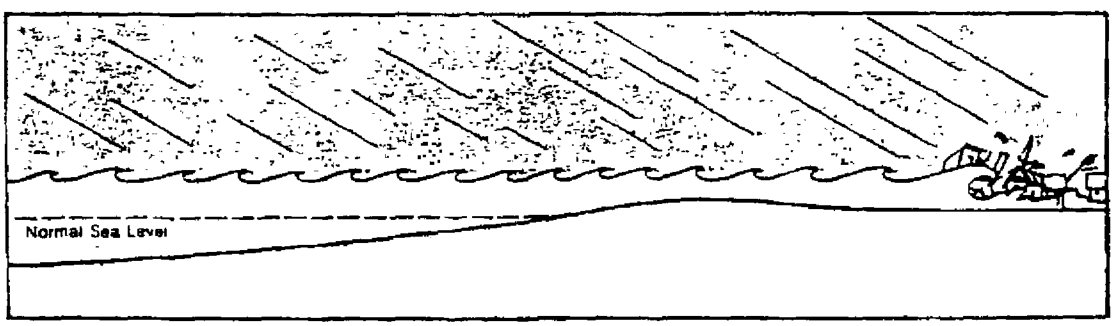
STORM SURGE



As a tropical storm forms, winds increase and atmospheric pressure drops.



Decreased atmospheric pressure causes the sea level to rise.



As the storm approaches land, winds pile up water to raise the sea level even higher, and the sea sweeps inland.

Source: Cuny, Frederick; Disasters and Development, 1983