NATURAL DISASTER MANAGEMENT

A presentation to commemorate the
International Decade for Natural Disaster Reduction (IDNDR)
1990–2000

Edited by Jon Ingleton

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STATEMENT BY THE SECRETARY-GENERAL

Almost daily, we are reminded of the threat of natural disasters. We cannot stop the forces of nature, but we can and must prevent them from causing major social and economic disasters.

Natural disasters profoundly affect our efforts to achieve sustainable development. By their powerful impact on the supply of primary commodities, they disrupt market stability, leading to steep declines in national revenue. In many developing countries, five per cent of gross national product may be lost to natural disasters each year.

We can no longer afford, financially or socially, to rely only on the expectations of emergency relief when disaster strikes. Much greater attention must be paid to preventive strategies aimed at saving lives and protecting resources and assets before they are lost. The programme for the International Decade on Natural Disaster Reduction, adopted by the United Nations General assembly in 1989, has taken up this battle, combining resources, advanced scientific and technological development, information dissemination, human resource management and risk assessment in an integrated package. Agencies of the United Nations system such as the World Meteorological Organization, UNESCO and the World Bank have been particularly active in contributing their technical expertise.

As the International Decade for Natural Disaster Reduction comes to a close, it is essential that the aims of this initiative are continued. As more and more countries incorporate disaster prevention policies into national development plans, they are trying to enlist the help of educators, non-governmental organisations, civil society institutions and private sector enterprises. Indeed, prevention begins with information. This publication will make an important contribution by encouraging the widest possible partnership, communication and exchange of information among all groups of society and all nations to ensure a sustained commitment to a safer world, a world more resilient to the impact of natural hazards and disasters.

Kofi Annan
Secretary-General of the United Nations

Photo: E. Schneider, *United Nations*

ERRATUM

On page [34] the last three lines of the last paragraph should read as follows:

“watts/square meter. The significance of this value is revealed when the Earth’s surface area, 5,100,000,000,000,000 square metres (5.1 ×10^{14} m^{2}), is taken into account”

Tropical cyclone

Ricardo Alvarez, Florida International University, USA

Debris is widely scattered after a cyclone in Bangladesh

Photo: Associated Press

NINE-HUNDRED YEARS ago the poet Jelaluddin Rumi wrote about our vulnerability to (damaging) winds. An extinct aboriginal people of the Caribbean, the Taino, called the deity of terrible winds hurakán. The derived Spanish word huracán translates into English as hurricane. The Chinese word taa-fung, meaning great wind, refers to storms occurring in the China sea and traces its roots to typhoon the Greek word for whirlwind, which in English defines a rotating windstorm or a destructive force. This bit of anecdotal history and etymology illustrates the importance given by humankind to the destructive force of wind and attempts to describe the characteristics of certain windstorms.

This article addresses specific windstorms known as tropical cyclones, their inherent potential for damage and society's efforts for damage reduction through mitigation, preparedness and education.

Cyclone from the Greek kykouma wheel, coil, from kycloun to go around, from kyklos circle. A clear etymological reference to closed circulation and the rotation of wind. Tropical cyclones are large-scale weather systems developing over tropical or subtropical waters, where organised surface wind circulation is present. Depending on central sustained wind speed these may be classified as depressions, storms or hurricanes.

Behold the atmosphere

To understand the nature and characteristics of tropical cyclones it is important to look at the Sun, the engine that starts it all, a 4.5 billion-year old second-generation star made mostly of hydrogen and helium and minute fractions of oxygen, carbon, nitrogen and many other elements. Considered ordinary by many astronomers, the sun nevertheless, by a process of internal nuclear reaction and radiation though space, is by far the main source of energy and light for the Earth.

The magnitude of energy reaching the Earth from the Sun, known as solar constant or total irradiance, equates to 1,367 watts/square metre. The significance of this value is revealed when the area Earth's surface, 5,100,000,000,000,000 square metres (5,1 x 1014 m^2), is taken into account.

Jon Ingleton (Editor)
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The primary receptor of such immense amount of solar energy is that gossamer thin and seemingly insubstantial envelope surrounding the Earth: the atmosphere.

With a total mass less than one millionth that of the Earth, this layer of gases held by gravity around our planet is where we live and breathe. The atmosphere is the venue for complex and interactive chemical and physical processes that are essential for the support of life as we know it. The atmosphere is in constant motion, and it is where our climate and weather events take place.

One important function of the atmosphere is in distributing energy and in attempting to balance temperature, pressure and moisture around the planet. The atmosphere moves air to carry heat away from the tropics, a band of earth reaching to 23°27' north and south of the equator, toward the polar regions where it is cooler. It is beyond the scope of this text to describe in detail how this redistribution of heat takes place. However it is important to note that it involves a divergent component resulting in the movement of air away from the tropics, and a rotational wind component resulting from the vorticity generated by the Earth's rotation. This mechanism involves the large-scale motion known as tropical circulation and the interaction of the atmosphere with the oceans and land masses.

One area of concern is the interaction of atmospheric processes with human activity. Although uncertainty remains, there is an accumulation of scientific empirical data suggesting that human activity may be contributing to changes in atmospheric balance. This may affect climate and extreme weather events, if it is not doing so already. In consequence, humankind must be observant of its role in altering important natural processes and the need for corrective and timely actions.

Tropical cyclones are needed

Tropical cyclones are needed as an effective method, or safety-valve, for dissipating heat accumulated in the ocean and in the tropical regions of the atmosphere. This need is evidenced by the fact that most hurricanes take place during summer and autumn, when the tropics reach their highest temperatures. It is then that the coupled atmosphere-ocean heat transfer engine must be most effective in diverting heat toward the polar regions. In some countries there is a consequential need for tropical cyclones which result from the rains associated with these systems, that are critical for the irrigation of crops and the production of foodstuffs to feed many millions of people.

Cyclogenesis

Cyclogenesis refers to the formation of cyclones. To the combination of conditions needed for cyclone formation, the area where such conditions may be present, and to triggering events as well.

Although the main conditions and favourable areas for tropical cyclogenesis and triggering events have been identified, the genesis of tropical cyclones is still poorly understood. In general, tropical cyclogenesis requires:

- An area of warm sea surface water with a thermocline of 26°C or higher
- Coinciding low atmospheric pressure
- A disturbed atmosphere with large cloud mass, embedded rain bands and thunderstorms
- Absence of or minimal upper wind shear
- Steering winds, generally from the east
- A relative humidity of 80 per cent in the tropical atmosphere.

These conditions are generally present in tropical waters during summer and early fall, giving rise to an accelerated transfer of heat from the sea surface to the tropical atmosphere creating the energy source for tropical cyclones.

Despite these ubiquitous conditions tropical cyclones do not form spontaneously, outside triggers are needed. In the Atlantic tropical cyclones are most often triggered by atmospheric waves moving westward over sub-Saharan Africa.

Other phenomena, often extra-regional, have significant influence on cyclogenesis. For example, tropical cyclone formation in the North Atlantic is related to periodic El Niño events in the Pacific and related to drought in the Sahel region of Africa. Empirical data clearly shows these connections, but they are not yet fully understood.

Even under ideal conditions tropical cyclones are relatively rare, with an average of 80 such systems forming all over the globe in six areas known as tropical cyclone basins that include:

A large portion of the North Atlantic (including the Caribbean and Gulf of Mexico), The Western North Pacific,The Eastern North Pacific, The Northern Indian Ocean, The Southern Indian Ocean, and The Southwest Pacific/Australia region.

Vulnerability

Vulnerability results from the interaction of human activity with hazards. With few exceptions, most coastal and island regions of the world are vulnerable to tropical cyclones.

Vulnerability to tropical cyclones can be absolute or relative. Absolute vulnerability is a function of location. For example: islands in the western Caribbean are vulnerable to hurricanes by virtue of being located in the path of such weather events.

Relative vulnerability involves exposure to consequential hazards resulting from the interaction of local factors, such as topographic relief, and components of tropical cyclones such as high winds or storm surge. Such consequential hazards include flash floods, mud-slides and beach erosion.

With regards to adverse impacts from tropical cyclone on a given location, vulnerability must be viewed, analysed and understood, from a range of perspectives including: a) physical, b) ecological, c) structural, d) social (human), e) economic, and f) political aspects.

Components

Assessing vulnerability to tropical cyclones, requires knowledge of conditions for, and area of, cyclogenesis, specific local factors, the physical characteristics on such events, and a knowledge and understanding of the family of components that constitute a tropical cyclone.

With regard to their physical characteristics tropical cyclones come in an ample range of sizes often affected by the specific basin where they originate. While there are no average hurricanes, the following are typical of most tropical cyclones:

- Basically circular in shape with a diameter ranging from 180 to 1000 kilometres
- A central 'eye' around which rotation takes place counter-clockwise in the Northern Hemisphere, and clockwise in the Southern Hemisphere. The diameter of the eye ranges from 15 to 50 kilometres. The 'eye' is usually cloud free or partially overcast and it is the point of lowest surface barometric pressure
- The eyewall surrounds the 'eye' and consists of tall cumulonimbus clouds that descend almost to the ocean surface
- One or more rain bands embedded in cumulonimbus cloud formations, spiralling cyclonically about the central eyewall
- Minimum sustained rotational wind speed of 32 metres per second for hurricanes, ranging up to 90 metres per second for the strongest hurricanes

- Low central surface barometric pressure that may drop to 870 millibars (normal sea level pressure is 1013 millibars) in the 'eye of the storm' region
- Forward system motion at velocities ranging from near zero to eight metres per second, or higher as a tropical cyclone moves farther from the equator.

Embedded within these typical physical characteristics are components that are important causes of potential damages:

- Intense winds with all their characteristics of higher gusts, turbulence, shear etc
- Changes in pressure resulting from the movement of air against, over, or around, obstacles, such as buildings
- Storm surge
- Precipitation, mainly in the form of rain but also as hail
- Severe lightning
- Tornadoes and water spouts.

The potential for damage

Tropical cyclones must be viewed as hazards or potential sources of damage. Damage results from the action of single or combined components of a tropical cyclone on built or natural structures.

However, a considerable amount of damage from hurricane impact is also due to human factors or decisions. For example, strong hurricane winds can generate flying debris that can break unprotected windows, allowing wind and rain inside buildings to cause injury and major property damage. The emphasis here is placed on the lack of window protection as this implies a human decision.

Tropical cyclones, hurricanes in particular, are very complex systems in which a large number of components and factors interact, often in rapidly and continuously changing ways to cause damage upon landfall.

Although no scientific method or engineering formula can precisely predict the amount of damage caused by a hurricane there are scales, mostly based on descriptive, generic and subjective elements, that provide qualitative estimates of damage from hurricanes. The best known — The Saffir/Simpson Hurricane Damage Potential Scale — is shown in Table 1.

Even a widely adopted scale, such as the Saffir/Simpson, needs to be complemented by comprehensive vulnerability assessment and hazard identification efforts, taking into account the specific factors involved in the region or community under analysis.

For example: storm surge is a function of several factors including near-shore bathimetry/slope, coastal topography, barometric pressure, astronomical tides, maximum sustained wind speed, velocity of forward motion, characteristics of the basin under impact, and the angle of approach of the hurricane with respect to the shoreline. While the Saffir/Simpson scale provides a range of values for storm surge for each category of hurricane, an accurate estimation of surge at a specific location requires analysis of the factors listed above.

The same argument applies to the estimation of damage potential from a hurricane. The Saffir/Simpson scale provides a qualitative and subjective measure of damage potential for each category of storm, but the analysis of numerous specific factors is needed for more accurate damage projections.

Experience shows even a low category storm (Hurricane Mitch, 1998) may cause extreme damage when certain factors, such as slow forward motion, interaction with mountainous terrain and large amounts of rain combine with human factors, such as deforestation, to devastate entire regions in two countries.

There is an obvious need for complementary tools to help provide more accurate estimations of damage potential from hurricanes, especially with respect to human or social vulnerability. These may include new hurricane-impact simulation and visualisation models, and advanced data acquisition technologies to assist with hazard assessment and risk identification.

Damage reduction through mitigation

In its simplest definition hazard mitigation is damage reduction. A regulatory definition in the United States reads 'Hazard mitigation means any cost effective measure which will reduce the potential for damage to a facility from a disaster event'.

Hazard mitigation measures must also be practical, structurally and technically effective, addressing specific causes of damage identified through analysis of vulnerability.

Mitigation through education

Effective hazard mitigation requires constant application by everyone, from policy-makers and professionals to the general public. It also requires the creation of a true culture of mitigation in vulnerable communities.

These requirements can only be met through an educational effort that will provide the knowledge and tools so that all concerned practice hazard mitigation on a regular basis. Education of everyone involved, from children to adults, professionals in many fields to elected officials, from bureaucrats to the citizen-at-large, becomes an essential component of mitigation.

Table 1: The Saffir/Simpson Hurricane Damage Potential Scale

Scale Number (category)	Central Pressure (inches)	Winds (mph)	Surge (feet)	Damage	Examples (in Florida)
1	≥ 28.94	74–95	4–5	Minimal	Hurricane Agnes '72
2	28.50–28.91	96–110	6–8	Moderate	Hurricane Cleo '64
3	27.91–28.47	111–130	9–12	Extensive	Hurricane Eloise '75
4	27.17–27.88	131–155	15–18	Extreme	Hurricane Andrew '92
5	<27.17	>155	>18	Catástrophic	Hurricane Florida Keys '35