TWENTY YEARS OF PROGRESS AND ACHIEVEMENT OF THE WMO TROPICAL CYCLONE PROGRAMME (1980-1999)

WMO/TD-No. 1039

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SECRETARIAT OF THE WORLD METEOROLOGICAL ORGANIZATION - GENEVA - SWITZERLAND

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TROPICAL
CYCLONE PROGRAMME

Report No. TCP-43

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OF THE

WMO TROPICAL CYCLONE PROGRAMME (1980-1999)

SECRETARIAT OF THE WORLD METEOROLOGICAL ORGANIZATION - GENEVA - SWITZERLAND

2000

Cover (clockwise from top left): A tropical cyclone viewed by a NOAA (USA) meteorological satellite (courtesy RSMC La Réunion);

Tropical cyclone forecasters participate in a training workshop;

Typhoon forecasts are produced by the Global Spectral Numerical Model run on this super-computer (courtesy JMA, Japan);

Tropical cyclone monitoring radar (courtesy IMD, India).

WMO Secretariat,
WWW-Applications Department
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N O T E

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FOREWORD

In response to a series of United Nations General Assembly resolutions calling for international action to address the problems of the all-too-frequent major disasters caused by tropical cyclones, the WMO Congress expanded and upgraded its Tropical Cyclone Project to become the WMO Tropical Cyclone Programme (TCP) from 1980.

This is an updated version of the fifteenth anniversary report of the TCP (WMO/TD-No. 664). It gives an overview of the remarkable progress and achievement of the TCP over the past two decades. It further takes a look at evaluations of the programme and its humanitarian, social and economic impact.

The credit for this success story belongs to the Members of WMO involved. National Meteorological and Hydrological Services, disaster prevention and preparedness agencies and other national bodies which participated in the work of the TCP, to whom this report will be distributed, can be justly proud of the progress achieved. I would like to thank the other international and regional organisations which supported and contributed to the programme.

Vulnerability to tropical cyclone hazards is increasing, exacerbated by population explosion and ever growing developments in cyclone-prone coastal areas and flood plains. Increased effort in disaster mitigation is required to further lower the fatalities and injuries due to tropical cyclones and to reverse or at least to stem the increase in consequential property damage and other factors that inhibit economic development.

WMO will continue to play its part in providing the international framework, in ensuring coordination and encouraging programme development and activities. It will pursue its endeavours in promoting technical cooperation, transfer of technology and human resources development. Within the WMO Secretariat, in view of its role and the needs for the future, in 1994 I upgraded the TCP office to become the TCP Division of the World Weather Watch Department.

This report concludes with a look at the prospects for the years ahead. It points to the potential of the TCP to increasingly help in the mitigation of tropical cyclone disasters and thus to pave the way for sustainable development and contribute substantially to the call of the United Nation's International Decade for Natural Disaster Reduction (1990-1999) for a safer world, protected from the ravages of natural disasters. In the years ahead its activities will be persued within the framework of the successor programme of the United Nations entitled the International Strategy for Disaster Reduction.

(G.O.P. Obasi)
Secretary-General

TROPICAL CYCLONES AND THEIR EFFECTS

Tropical cyclones are among the most devastating of all natural hazards. Their potential for wrecking havoc caused by their violent winds, torrential rainfall and associated storm surges, floods, tornadoes and mud-slides is aggravated by their severity, size, frequency of occurrence and the vulnerability of the extensive areas they affect. Every year several of them cause sudden-onset disasters of varying harshness, with loss of life, destruction of property and severe disruption of normal activities.

About 80 tropical cyclones form annually over tropical oceans. As they intensify, with warm temperatures and very low atmospheric surface pressure in the centre, or "eye" as it is called, and wind speeds exceeding 118 km/h - and in extreme cases 250 km/h - they are called hurricanes in the western hemisphere and South Pacific, typhoons in the western North Pacific and severe tropical cyclones, tropical cyclones or similar names in other areas.

There have been a number of occurrences when the loss of life in a single tropical cyclone was over 100,000 people and one case where the death toll was about 300,000. The damage caused by the most destructive tropical cyclone was estimated at US$30,000 million. These are extreme events. However, even in the less extreme cases of tropical cyclone disasters, the reported statistics, particularly in some developing countries, often have not reflected the full extent of their adverse impacts. Usually there are inadequate data to show the human suffering caused, for example through loss by the poor of their means of livelihood, the set-back of social and economic development, which in some cases could be measured in years, and environmental degradation such as soil and beach erosion and destruction of flora and fauna.

Schematic diagram of a northern hemisphere tropical cyclone as seen by satellite

THE ORIGINS OF THE WMO TROPICAL CYCLONE PROGRAMME

The responsibility of the World Meteorological Organization (WMO) and its predecessor the International Meteorological Organization has, for more than a century, been to promote measurement of weather and climate parameters and to encourage the application of the science of meteorology for the benefit of people around the globe. To this end, in 1963 the WMO initiated its World Weather Watch (WWW) Programme. Five years later, the United Nations (UN) Economic and Social Commission for Asia and the Pacific (ESCAP), then called Economic Commission for Asia and the Far East, and WMO sponsored the establishment of an intergovernmental Typhoon Committee to promote and coordinate efforts to minimize typhoon damage in the western North Pacific region.

Following the world-wide concern at the series of tropical cyclone disasters in that period, and particularly the loss of some 300,000 lives from a tropical cyclone in Bangladesh in 1970, the United Nations General Assembly adopted resolutions calling for international action to mitigate the harmful effects of these storms, for WMO to mobilize scientists and for its Members to implement the WWW. Thus WMO established a Tropical Cyclone Project from 1972 to include the Typhoon Committee and an intergovernmental Panel on Tropical Cyclones for the Bay of Bengal and the Arabian Sea, which it sponsored in collaboration with ESCAP from 1973. Subsequently two working groups of the WMO Regional Associations for Africa (RA I) and for North America and Central America (RA IV), the RA I Tropical Cyclone Committee for the South-West Indian Ocean and the RA IV Hurricane Committee were set up in 1974 and 1978 respectively as additional regional bodies of the project.

The thirty-second session of the UN General Assembly in 1977 welcomed the report submitted by WMO on its WWW Programme and Tropical Cyclone Project and called on WMO to intensify its efforts, taking into account recent and planned activities on the development and use of satellites for tropical cyclone surveillance. In response, the Eighth WMO Congress in 1979 decided on the upgrading and widening of the scope of the project to become the WMO Tropical Cyclone Programme (TCP) from the beginning of the following year.

Areas of formation, frequent tracks and average annual numbers of tropical cyclones

DEVELOPMENTS, ACTIVITIES AND ACHIEVEMENTS

General

Growth

Since the inception of the programme there has been an increase in the number of TCP regional bodies and in the number of WMO Members participating in their work, as well as development in the scale and intensity of their activities. In addition to the original four regional bodies, a fifth, the RA V Tropical Cyclone Committee for the South Pacific was established in 1985 as a working group of Regional Association V. Subsequently its area of responsibility was extended by the Association to include the South-East Indian Ocean.

Initially, in addition to the ten Members of the Committee, seven non-Members of WMO participated in its work. Subsequently four of these became Members of WMO and of the Committee, with the other three non-Members continuing their active participation in the work of the Committee.

There has been an increase in number of Members of each of the TCP regional bodies and over the period of twenty years the total number has climbed from 46 to 72 plus three participating non-Members.

Programme management

The overall supervision of the TCP was effectively carried out by the WMO Congress and the Executive Council which provided policy decisions, guidance and support for the programme. The TCP regional bodies which are working groups of Regional Associations reported to the relevant Associations, which provided for their continued functioning, their terms of reference and guidance. The two inter-governmental regional bodies also enjoyed the close cooperation and guidance of the Congress, Executive Council and the relevant Regional Associations, that is Regional Association II (Asia) and Regional Association V (South-West Pacific).

Objective, goals and the plan of action

By 1981, a Plan of Action for the TCP had been drawn up, approved by the WMO Executive Council and published, as requested by Congress. It defined the objective, goals, principles, organisation, main action items and implementation arrangements of the Programme. It provided the guidelines for the activities in the initial years and was the basis for the technical plans for the future development of services of the TCP regional bodies and the TCP sections of the WMO Long-term Plans.

Objective

The ultimate objective of the WMO Tropical Cyclone Programme is to establish national and regionally coordinated systems to ensure that the loss of life and damage caused by tropical cyclones are reduced to a minimum.

TCP Plan of Action, 1981

The goals of the TCP are to encourage and assist its Members to:

- provide reliable forecasts of tropical cyclone tracks and intensity, and related forecasts of strong winds, quantitative forecasts or timely assessments of heavy rainfall, quantitative forecasts and simulation of storm surges, along with timely warnings covering all tropical cyclone-prone areas;
- provide forecasts of floods associated with tropical cyclones;
- promote response to warnings and carry out activities at the interface between the warning systems and the users of warnings, including public information, education and awareness;
- provide the required basic meteorological and hydrological data and advice to support hazard assessment and risk evaluation of tropical cyclone disasters;
- establish national disaster preparedness and prevention measures.

The long-term objective and, in broad terms, the goals of the TCP remain valid.

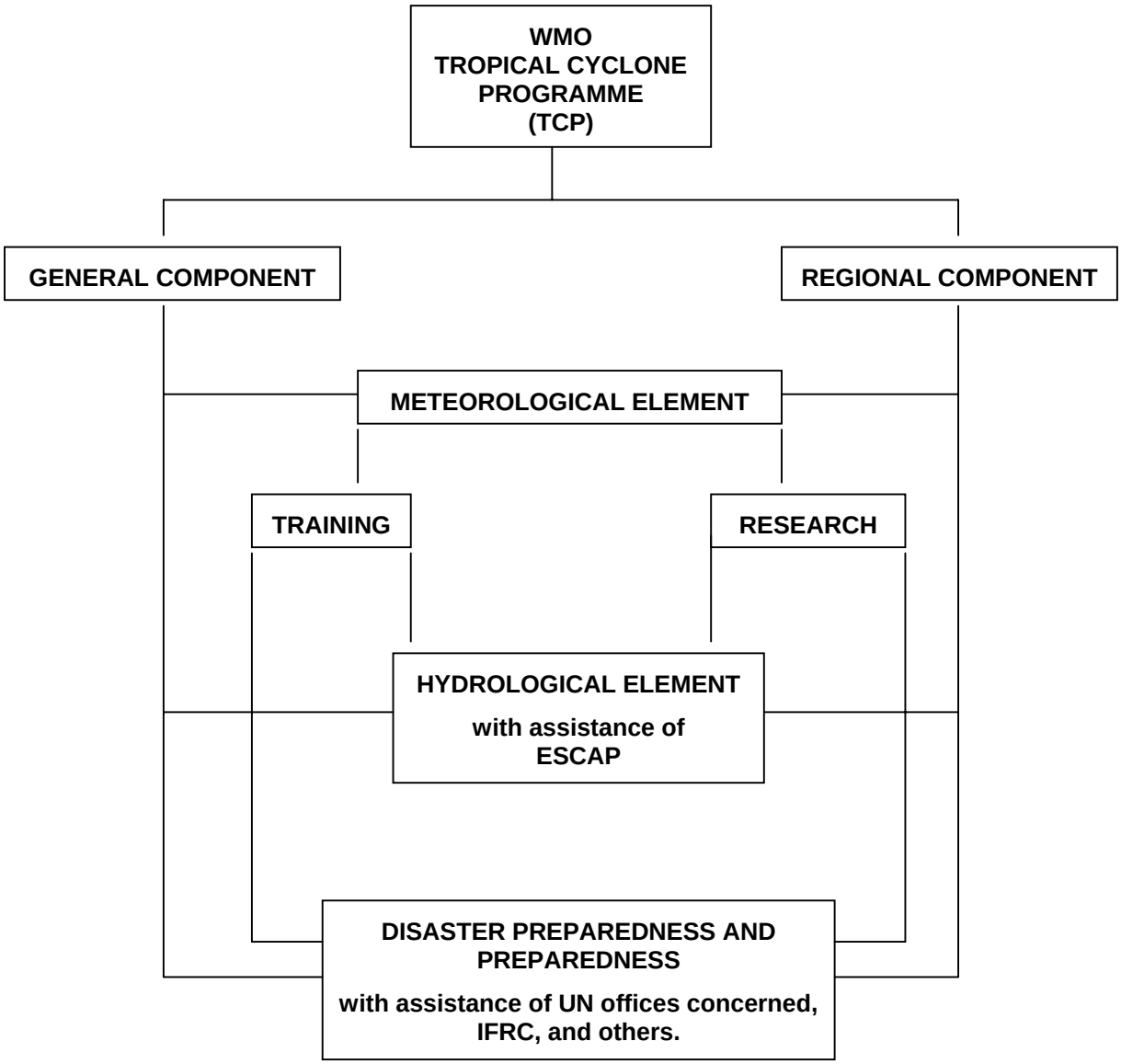
Programme structure and overview of the activities

In the plans, the TCP is described as being composed of a general component and a regional component. The activities pursued under each of these components relate to three main fields:

- ***operational meteorology****,* in which activities have been based on the WMO World Weather Watch (WWW). They are concerned with the provision of the required basic meteorological data, analyses and other processed products together with the application of appropriate techniques to ensure accurate tropical cyclone forecasting and timely warnings. The operational tropical cyclone plans/manual drawn up by TCP regional bodies are important accomplishments in this field;

- ***hydrology*****,** where activities, based on the WMO Hydrology and Water Resources (HWR) Programme, are concerned with the provision of the required basic hydrological data and the application of the appropriate techniques to ensure accurate flood forecasting and timely warnings. Within the programmes of the Typhoon Committee and the Panel on Tropical Cyclones wider accomplishments in this field, related to flood plain management and hydrological research, were achieved with the cooperation of ESCAP;

- ***prevention and preparedness****,* which is concerned with all other structural and non-structural measures required to ensure the maximum safety of human life and the reduction of damage to a minimum. WMO's role of encouraging Members to establish and ensure coordination of measures to protect life and property was performed in close cooperation with the UN offices concerned with natural disaster preparedness, the International Federation of Red Cross and Red Crescent Societies (IFRC - formerly LRCS) and other appropriate bodies having special expertise in these fields.



THE STRUCTURE OF THE TCP

Additionally, ***training*** in each of the three main fields, *research* in meteorology and hydrology and the provision of other meteorological and hydrological information and advice have been carried out under the TCP.

Within WMO, close co-ordination has been maintained between the WWW, HWR and the Technical Cooperation, Education and Training, and Atmospheric Research and Environment Programmes, which have contributed substantially to the work of the TCP. In 1994 the TCP Office in the WMO Secretariat was upgraded to become a Division, while remaining as a part of the WWW Department.

TCP plans and activities, by design, took advantage of and built upon capabilities and developments in other fields where applicable. Examples of such developments are:

- the network of geostationary satellites providing meteorological information and polar-orbiting meteorological satellites, which are of great importance to the TCP;

- advances in the capabilities of the meteorological satellites;

NOAA-II meteorological satellite
(NOAA, USA)

Geostationary and polar-orbiting meteorological satellites

- satellite-based communications;

- technological developments in large computers and PCs (personal computers) capable of handling greater volumes of data at faster speeds and with improved affordability;

- scientific advances in the understanding and modelling (including numerical weather prediction - NWP) of tropical cyclones and their environment;

- technological advances in instruments and equipment such as cyclone monitoring radars.

Special efforts have been made under the TCP to transfer modern technology and apply proven techniques, such as satellite data reception facilities, PC-based workstations and modelling of floods.

An appraisal of the TCP in 1984 showed the success achieved and proposed an acceleration of its progress. A shift in the relative priorities within the programme was proposed, rather than any real change in its goals or structure. Thus from 1985 greater emphasis was placed on improving the capabilities of the national Meteorological and Hydrological Services to provide better forecasts and more effective warnings with substantial improvements at the interface with users. The activities of the TCP were further accelerated and intensified during the 1990s in relation to the **International Decade for Natural Disaster Reduction** (IDNDR) (1990-1999).

The major work of the TCP was in general carried out by Members, through the national Services, research institutions and by working groups or individual experts.

Resources for implementation

One of the great strengths of the TCP is derived from the extent to which it has been able to engender and benefit from international cooperation and technical cooperation projects. The major resources came from Members themselves. However, substantial support for the attainment of the goals of the programme has come from the participating developed countries, that is Australia, Canada, France, Japan, New Zealand, UK and USA, and through TCDC (Technical Cooperation among Developing Countries) or similar arrangements and also from some developed countries or groups of countries which are not Members of the TCP regional bodies. Some highly noteworthy examples follow:

- Fiji, France, India, Japan and USA are providing the five regional centres which have been designated as Regional/Specialized Meteorological Centres (RSMCs) with activity specialisation in tropical cyclones.

- Radars have been provided by Australia for Fiji, including one for the regional centre and by Japan for Bangladesh and Pakistan.

- Members including Australia, Japan, New Zealand and the USA provided support for the establishment and development of the tropical cyclone RSMC Nadi.

- Japan and then the Republic of Korea provided expert services in hydrology for the Typhoon Committee covering the 20 years.

- The USA was the major donor to the project for upgrading the telecommunication and data processing facilities and it also supports the upper-air observing programmes in the Caribbean and Central America region. Other donors to the telecommunication project included Canada, Finland, France and the United Kingdom.

- A Finnish project supported major improvements in the observing and telecommunication facilities and training of personnel for the Members of the RA I Tropical Cyclone Committee on mainland Africa and there was another similar Finnish project for the Members of the RA IV Hurricane Committee in Central America.

- An Indian Ocean Commission project, with funding support by the European Union, was implemented for improving the tropical cyclone warning systems for the RA I Tropical Cyclone Committee's region. Another similar project was approved towards the end of the 1990s for implementation in the coming years.

Invaluable support was provided, for the developing countries participating in the TCP, by the United Nations Development Programme (UNDP), by the WMO Voluntary Cooperation Programme (VCP), through multilateral and bilateral programmes and arrangements and from other sources. The work of the TCP involved not only WMO but also several governmental and non-governmental organisations, such as ESCAP which co-sponsored and provided support for the work of the two inter-governmental TCP regional bodies. Those UN offices which cooperated in promoting or assisting in activities in disaster prevention and preparedness included the former UN Office of the Disaster Relief Coordinator (UNDRO), the Department of Humanitarian Affairs and the IDNDR Secretariat. Other agencies in this connection included the IFRC, the Asian Disaster Preparedness Center (ADPC), the Caribbean Disaster Emergency Response Agency (CDERA), and the South Pacific Regional Environment Programme.

UNDP Inter-Country projects in support of TCP objectives

Programme support to the Typhoon Committee.

Support to the Panel on Tropical Cyclones in the Bay of Bengal and Arabian Sea.

Tropical cyclone programme for the South Pacific.

Improvement of the hurricane warning system in the English-speaking Caribbean countries.

In the earlier years UNDP provided support for the attainment of the objective of the TCP through Inter-Country projects for the Typhoon committee (1980-1991), the Panel on Tropical Cyclones (1980-1991) and the RA V Tropical Cyclone Committee (1987-1991). These projects provided expert and consultancy services, equipment, fellowship and group training, support to TCDC arrangements and other support. By their design and successful execution, they contributed directly and substantially to the wide range of goals of the TCP. While at the outset they included, as was then needed, a significant element of institutional support, there was, subsequently, a decided move to phase it out in favour of programme support and in conjunction with greater self-reliance by the countries involved. Under the UNDP regional project for improvement of the hurricane warning system in the English-speaking Caribbean countries (1987-1990) the hurricane surveillance radars in Barbados and Jamaica were refurbished and meteorological staff of Members of the RA IV Hurricane Committee were trained.

To illustrate the magnitude of these four projects, the financial contribution of UNDP in the fourth cycle of its Inter-Country Programme (1987-1991) amounted to US$1 million for each of the first three projects and US$750,000 for the last named project. Some UNDP country projects also provided support to developing countries for implementation of activities, within the scope of those projects, towards the goals of the TCP.

There was close cooperation and full coordination between the TCP's RA V Tropical Cyclone Committee and the South Pacific Tropical Cyclone Warning Upgrade Project, which was funded by the European Union, with resulting improved facilities and training of personnel of

participating South Pacific countries and territories towards upgraded capabilities of tropical cyclone warning services.

General component

The general component is concerned with methodology. The activities carried out provided transfer of technology, information and scientific knowledge to Members, towards meeting the objective of the TCP. The general component encompasses the broader training requirements of the programme.

Fourteen projects were completed. Thirteen of them resulted in 25 reports, 17 of which were prepared by experts to provide guidance and scientific information on specific topics. Five of the latter reports were published on TOPEX, one of the completed projects, which is described below under special projects. The progress made on the project on regional aspects of storm surges, which is under implementation, is indicated under the heading RA IV Hurricane Committee. Most of the reports emanating from general component projects and other TCP reports have been published in the TCP series and widely distributed. In some cases new editions of reports have been prepared to incorporate new developments and updated information and other reports have been reprinted to meet heavier demand than foreseen. A new project, under the general component, on the combined effects of storm surges and river floods in low-lying areas is in the planning stage.

Topics on which TCP reports provide guidance include:

- Meteorological and hydrological risk management.
- Meteorological observing systems (radar, automatic weather stations).
- Tropical cyclone structure and motion.
- Satellite techniques for tropical cyclone rainfall estimation.
- Use of satellite data for tropical cyclone forecasting.
- Tropical cyclone forecasting and related numerical weather prediction.
- Tropical cyclone warning systems.
- Tropical cyclone operational arrangements (provided under the regional component, for each of five regions).
- Tropical cyclone research.
- Flood forecasting.
- Human response to warnings.
- Role of meteorologists and hydrologists in disaster preparedness.

Seven training courses on tropical meteorology and tropical cyclone forecasting were organised by the USA's National Oceanic and Atmospheric Administration (NOAA) and US Universities in cooperation with the WMO, and held in Miami, normally on a biennial basis. They provided training for more than 120 professional meteorologists from all tropical cyclone-prone regions. The duration of each course was usually 10 weeks. A number of courses of similar design, but on hydrological forecasting, held initially in Miami and later in Davis, California under the OHP, included training in flood forecasting for hydrologists from tropical cyclone-prone regions.

To meet the requirements by Members from the southern hemisphere, four Southern Hemisphere Training Courses on Tropical Cyclones were held, in co-sponsorship with WMO. Three of these courses were organized by Australia and held in Melbourne since 1994 and one course was organized by France and held in La Réunion in 1999. Taking into account their success, plans have been made to hold similar two-week duration courses annually, in Australia and La Réunion, alternating, during their off-cyclone season.

Training of tropical cyclone forecasters from all tropical cyclone regions at RSMC Miami - Hurricane Center

Southern hemisphere tropical cyclone forecasters training course in Melbourne, Australia

Tropical Cyclone Programme Regional Bodies - Members
(1999)

TYPHOON COMMITTEE	PANEL ON TROPICAL CYCLONES	RA I TROPICAL CYCLONE COMMITTEE	RA IV HURRICANE COMMITTEE	RA V TROPICAL CYCLONE COMMITTEE
CAMBODIA	BANGLADESH	BOTSWANA	ANTIGUA AND BARBUDA	AUSTRALIA
CHINA	INDIA	COMOROS	BAHAMAS	COOK ISLANDS
DEMOCRATIC	MALDIVES	FRANCE	BARBADOS	FIJI
PEOPLE'S	MYANMAR	LESOTHO	BELIZE	FRENCH POLYNESIA
REPUBLIC OF KOREA	OMAN	MADAGASCAR	BRITISH CARIBBEAN	INDONESIA
HONG KONG, CHINA	PAKISTAN	MALAWI	TERRITORIES	MICRONESIA
JAPAN	SRI LANKA	MAURITIUS	CANADA	NEW CALEDONIA
LAO PDR	THAILAND	MOZAMBIQUE	COLOMBIA	NEW ZEALAND
MACAO, CHINA		SOUTH AFRICA	COSTA RICA	NIUE
MALAYSIA		SEYCHELLES	CUBA	PAPUA NEW GUINEA
PHILIPPINES		SWAZILAND	DOMINICA	SAMOA
REPUBLIC OF KOREA		UNITED REPUBLIC OF	DOMINICAN REPUBLIC	SOLOMON ISLANDS
SINGAPORE		TANZANIA	EL SALVADOR	TONGA
THAILAND		ZIMBABWE	FRANCE	UNITED KINGDOM
USA			GUATEMALA	USA
VIET NAM, SOCIALIST			HAITI	VANUATU
REPUBLIC OF			HONDURAS	
			JAMAICA	
			MEXICO	**Invited country:**
			NETHERLANDS ANTILLES	FRANCE
			AND ARUBA	
			NICARAGUA	**Non-Members of WMO**
			PANAMA	**participating in the work of**
			ST. LUCIA	**the Committee:**
			TRINIDAD AND TOBAGO	
			USA	KIRIBATI
			VENEZUELA	TOKELAU
				TUVALU

Regional component

The regional component comprises the planning and implementation of the programmes of the TCP regional bodies.

TCP regional bodies

Each of the two inter-governmental bodies has a secretariat, or technical support unit to serve as its executive arm. These bodies and the RA IV Hurricane Committee have, generally, held sessions within their respective regions annually, while sessions of the other two bodies were convened biennially. In each of the five cases the Committee or Panel has a defined area of responsibility and formulated a regional cooperation programme. Within this context, each regional body drew up a tropical cyclone operational plan or manual and a technical plan and its implementation programme. They also conducted special projects and activities, as well as regularly monitoring and reviewing the plans and the progress made towards meeting the objective of the TCP. Activities and achievements common to regional bodies are outlined below, followed by some additional information unique to each of the bodies and then by summary reports on special projects and activities.

Operational plans/manual

A major development in the field of meteorology, providing a quantum jump towards the goals of the programme arose from the designation by the WMO Executive Council of five tropical cyclone RSMCs under the WWW and the formulation and publication of an operational plan or manual

for each of the five TCP regional bodies. Each operational plan or manual records the agreements reached on the sharing of responsibilities for the warning services, and their infrastructures, throughout its region. The plans were designed to provide the most effective tropical cyclone warning systems, making the best use of the currently available facilities, ensuring full co-ordination and taking advantage of the high level of co-operation which has been generated. Thus the plans describe the agreed comprehensive arrangements for the ongoing provision of meteorological observations, telecommunications facilities, exchange of data and products and forecasting and warning services.

As a core feature of the operational plans, each region has a centre which is carrying out special regional and international functions as agreed upon. These functions are, principally, the detection, monitoring and track and intensity forecasting for all tropical cyclones in its region, the provision of real-time guidance and advisory information for national Meteorological Services in the region, information for the international community, the training of personnel, and research. The five centres, located in Miami, Nadi, New Delhi, La Réunion and Tokyo have been designated as Regional/ Specialized Meteorological Centres (RSMCs) with activity specialisation in tropical cyclones, within the framework of the WWW. The operational plans and manual have demonstrated in a practical way the benefit of the high level of regional cooperation achieved. They not only record the agreed upon arrangements, but also serve as a readily accessible source of information which is particularly useful to the operational services during times of tropical cyclone threat when staff are working under conditions of stress.

Regional bodies of the TCP, their secretariats and associated RSMCs

ESCAP/WMO Typhoon Committee [1)]

- Typhoon Committee Secretariat (TCS)
- RSMC Tokyo-Typhoon Center

WMO/ESCAP Panel on Tropical Cyclones for the Bay of Bengal and the Arabian Sea [1)]

- Technical Support Unit (TSU)
- RSMC - tropical cyclones New Delhi

RA I Tropical Cyclone Committee for the South-West Indian Ocean [2)]

- RSMC La Réunion-Tropical Cyclone Centre

RA IV Hurricane Committee [2)]

- RSMC Miami - Hurricane Center

RA V Tropical Cyclone Committee for the South Pacific and South-East Indian Ocean [2)]

- RSMC Nadi - Tropical Cyclone Centre

1) Intergovernmental body
2) Working group of WMO Regional Association (RA)

As agreed upon, in principle the responsibility for the provision of tropical cyclone warnings for territorial areas and coastal waters is a national responsibility. In the few cases where the national Service is not able to provide the warnings, this is being provided by the relevant RSMC or a neighbouring national Meteorological Service under bilateral arrangements and recorded in the Operational Plan. As shown in the operational plans, warnings are now being provided for all areas of the five regions, including the high seas and upper atmosphere as required by marine and aviation interests. Global coverage has been achieved.

Technical plans and implementation programmes

Each TCP regional body has drawn up a technical plan, covering all its fields of activity, for the future development of services. The plans and implementation programmes identify the tasks to be accomplished, the schedule for activities, those responsible for action and indicates the resources to be tapped. While coordination was a facet in the preparation of the plans, with few exceptions the requirements for action were addressed to Members. These plans have been coordinated with the WMO Long-term Plan.

(INSERT DIAGRAM)

Meteorology. In the meteorology section of the technical plans, the tasks relate mainly to the implementation of the regional and national observing, telecommunication and data processing systems of the WWW, which have been areas of major attention under the TCP. Substantial progress has been made in all these areas through implementation of requirements in the technical plan or the preparation of projects which have been approved and are under implementation. There are two major projects for implementation in the future: for the South-West Indian Ocean area and for the Bay of Bengal and the Arabian Sea.

While in 1980 there were few developing countries which were able to receive information directly from the meteorological satellites, twenty years later there are stations in very nearly all Members of the TCP regional bodies with the facilities enabling them to do so. Furthermore, in line with developments in satellite transmission systems, several of these stations were upgraded during the period and are receiving high resolution imagery, stretched-VISSR (visible and infra-red spin scan radiometer) information and grid point values.

Programmes for more frequent observations from conventional observing networks during cyclone threats, have been implemented. Steps have been taken to improve the collection of reports from ships and aircraft. Storm monitoring radars, upper-air observing stations, automatic weather stations, tide gauges and other observing equipment and facilities have been established or upgraded. Some of the newly installed radars are doppler radars with the capability of providing not only information on the horizontal and vertical cloud structures but also measurements of wind velocities in the cyclone and its environment. These are indeed major achievements and further progress is being made.

One of the great concerns over the years has been on the effectiveness of the exchange of data and products, which has been a growing requirement. Telecommunication links are the arteries and veins of the system. This was an area of particular weakness at the beginning of the period. While progress has been at times slow, there have been major strides forward through the implementation of projects for the establishment and upgrading of facilities. Links have been established as required in some areas, and in several cases where the links were slow and unreliable, the deficiencies were overcome or greatly reduced by upspeeding and changing from terrestrial to satellite based circuits. Some telecommunication centres have been automated. A major project for upgrading the telecommunication system in the Caribbean and Central America region was implemented in recent years with outstanding results.

Cyclone monitoring radar in the Republic of Korea

Computation of upper-air observation (Government of Trinidad and Tobago)

Experience has shown that in addition to the establishment and upgrading of facilities, operation and maintenance of existing systems are also highly important. These subjects were given serious attention, with substantial but not full success. For example, support to some Members was provided, on request, for training of maintenance technicians, establishing maintenance workshops, obtaining spare parts and consumables. However there were instances when upper-air and radar observations were not made and information was not exchanged due to problems related to these subjects.

The USA provided throughout the period, and continues to provide the aircraft reconnaissance programme in the Atlantic Ocean, Caribbean Sea and Gulf of Mexico which has been adjudged to be of crucial importance to those regions. The USA also operated, for the period up to 1987, a similar programme in the western North Pacific, which contributed substantially to the detection, monitoring and forecasting of tropical cyclones in that region.

Remarkable progress has been made by each of the RSMCs in improvement of their facilities, procedures and scientific activities. Areas of major advances were computer and other data processing systems, analysis and forecasting techniques, the range and usefulness to other Meteorological Services and the international community of their products such as the bulletins and advisory messages they provide. Special mention may be made of improvements in medium and longer range tropical cyclone track forecasts by numerical weather prediction issued by RSMCs. There have also been significant developments in other activities by tropical cyclone RSMCs helpful to their region, such as evaluation of tropical cyclone forecasts, monitoring of data exchange, collection of historical records, publication of annual reports or technical summaries, training of personnel from other countries, and tropical cyclone research.

Substantial advances were made by national meteorological centres towards meeting their responsibilities for providing warnings of tropical cyclones and storm surges, through improved facilities and data handling and processing, application of research results and modern techniques and the interpretation and use of guidance material from the RSMCs and global centres which is increasingly available and applicable. Special projects and activities of the regional bodies also provided major inputs to advancements in the tropical cyclone forecasting and warning services.

Stations with meteorological satellite data reception facilities, in developing countries which are Members of TCP regional bodies

A forecaster reviewing rainfall distribution on an operational workstation
(Courtesy Korean Meteorological Administration)

Hydrology. Earthquakes and tropical cyclones kill more people than any other type of geophysical disaster but in the 1988-1997 period floods caused about a third of all natural catastrophes, a third of the overall economic loss and more deaths than any other geophysical disaster type, according to Munich Reinsurance.

Floods produced by tropical cyclones not only damage property but frequently also take a toll of life in many countries. Almost 400,000 people have been killed by disasters of hydrometeorological origin over the last 10 years. Growing development and settlement have continued unabated in many flood-prone areas, especially in informal settlements on the peripheries of cities in developing countries. These aggravate the problems of flooding, erosion and pollution. Efforts to mitigate the effects of flooding, in some cases produced by the combined effects of rivers and storm surge, have thus become increasingly important. The identification of areas which are likely to be flooded is essential for the effective management of the flood plains concerned and over the years this has been increasingly recognised by those responsible for land management. Within the Asian region, valuable work has been undertaken in this regard under the TCP, resulting in the publication and application of a set of guidelines on flood plain management. If, as is so often the case, it is not possible to restrict the development of flood plains, those who live and work there are at risk of losing their lives and property through flooding. Such losses can be greatly reduced if those concerned can be given advance warning of the magnitude and timing of the anticipated flood. In this regard, flood forecasting has been recognized as one of the most cost-effective non-structural means of reducing the loss of life and damage.

The forecasting of high flows also constitutes an important input to the efficient operation of any water-resource system, be it for hydropower generation, irrigation, water supply, wastewater dilution or water supply for transport on rivers. Forecasting of streamflow, in particular floods, is therefore important for socio-economic development in general and is of value on both large and small river systems.

Flash floods on small rivers are one of the major causes of destructive floods in urban areas, which necessarily continue to encroach on neighbouring river basins. Any improvements in quantitative precipitation forecasting will significantly increase the effectiveness and range of application of flood forecasting. All activities in relation to flood forecasting can be seen as contributions to natural disaster management.

Within the Hydrology and Water Resources Programme (HWRP), the Programme on Forecasting and Applications in Hydrology has as its central objective the promotion of application of forecasting techniques and hydrological modelling for the mitigation of water-related disasters of both natural and anthropogenic origin. This programme provides support for hydrological and water-related aspects of disaster mitigation through hazard assessment and forecasting. It includes the investigation of various methods used to model the processes involved in the hydrological cycle and the choice of the most appropriate method for deriving accurate forecasts and zoning of hazard-prone areas. Action is being taken on quantitative precipitation forecasting and guidance material is being developed on improved integrated flood-forecasting systems. Attention is given to coordination between relevant agencies at times of major floods and other natural disasters as part of integrated water-resources management.

Work in the field of quantitative precipitation forecasting associated with tropical cyclones is a major contribution to improving the effectiveness of flood forecasting systems. Close cooperation between meteorologists and hydrologists will be the key of success. New products that might be deliverable by the meteorological community would be of enormous importance, and the hydrological community, which is responsible for flood management, has to define precisely the information it needs in consultation with meteorologists. Enhanced cooperation between meteorology and hydrology is thus being promoted both by the TCP and the HWRP.

The spirit of mutual support exemplified in the TCP has led to a series of projects designed to coordinate the monitoring of flood forecasting systems. One major effort in this regard was made during TOPEX and, subsequently, MOFFS (see special projects and activities) was instituted as a practical way for monitoring and managing the systems so as to ensure that they are as effective as possible in their mission of issuing the forecasts and warnings that are required to save people from drowning and protect property from the ravages of flooding.

Flood in Mozambique

Flood warning system
(River Bureau, MOC, Japan)

Some tropical cyclone preparedness actions

- Before a tropical cyclone threatens, check your level of preparedness, such as availability of a battery powered torch and radio, non-perishable food and items you will need when a tropical cyclone strikes your area.
- Throughout a tropical cyclone threat and during the storm follow all official releases and warnings on radio and television, recorded telephone messages and on Internet. Keep calm and follow all local official advice and instructions. Start early to take precautionary actions such as saving several days water supply, putting fuel in your car, etc.
- When warnings have been issued for your area, moor boats securely or move to designated safe harbour, secure or place loose objects indoors, protect windows, leave low-lying areas subject to inundation by storm surges and floods and also mobile homes and lightly constructed shelters for safer areas. Follow official advices and instructions on evacuation. Stay indoors during the storm.

Disaster prevention and preparedness. The TCP regional bodies took steps to promote the concept that a carefully planned and executed programme of disaster preparedness based on risk assessment is essential for protection of life and property against tropical cyclones. Agencies with expertise in disaster prevention and preparedness such as the former UNDRO, DHA, IDNDR Secretariat, and IFRC cooperated with WMO in providing the main support to the planning and implementation of activities in these areas. Consultancy missions, expert services, training and guidance material were provided at the regional level to support the national activities. The national Meteorological and Hydrological Services were involved in various aspects such as hazard assessment, warning dissemination and public information and education programmes to promote better response to warnings. As examples, India established a national warning dissemination system based on its satellite, INSAT and IFRC supported building of shelters and door-to-door level dissemination of warnings in Bangladesh. Many of the activities of the regional bodies were focused on public awareness, through the media, publications and displays. Sessions of the bodies and regional group training were often used as opportunities to generate public awareness of the dangers of tropical cyclones.

Training. A large part of the effort under the TCP was devoted to training of personnel. At the international level, this took place through group training (courses, workshops, seminars), fellowships, training by experts provided under projects, exchange programmes of forecasters and attachments of personnel to advanced centres. Several training events were organized by TCP, tropical cyclone RSMCs and under TCDC arrangements, which proved to be valuable and a cost-effective mechanism for this purpose. This was complimentary to considerable training at the WMO Regional Meteorological Training Centres and at the national level, both on a formal basis such as courses at national training centres and institutions and informally such as on-the-job training. Steps were taken to promote or support training by other agencies, such as the provision of training material by TCP for the series of seminars on disaster preparedness organised by ADPC.

In the field of meteorology, training at the regional level of tropical cyclone and storm surge forecasters and of maintenance technicians was given priority to meet the expressed needs of Members. Several regional training events on flood forecasting and disaster preparedness were also organised.

Research. Activities in this field were carried out for the application of research results in meteorology through special projects. Other activities relating to research in meteorology and in hydrology were organised by the separate regional bodies and at the national level. At the regional level some studies were conducted by small groups of experts.

An example of the links for dissemination of tropical cyclone warnings

Typhoon Committee

The Typhoon Committee, the oldest of the TCP regional bodies, has been highly innovative. It carried out special projects and activities, notably TOPEX and SPECTRUM and recently it initiated consideration of the impact of the Southern Oscillation El Niño/La Niña, as related to typhoons in its region. It published the Typhoon Committee Annual Review (TCAR) each year since the report for 1985. The editors for the TCAR were designated by the Member countries with the Chief Editor being designated for several years by Hong Kong, China. The Typhoon Committee Secretariat, which has been hosted in Manila by the Philippine Government published an annual newsletter and, in more recent years, the TCAR. The Committee encouraged and monitored progress in research through its three research coordinators, in meteorology, hydrology and disaster prevention preparedness. At the Committee's request, the WMO established the Typhoon Committee Trust Fund in 1987, to which its Members have been making voluntary cash contributions. The Trust Fund has been serving its purposes to provide institutional support and making possible a number of activities of the Committee such as regional training events and symposia. Equipment maintenance workshops were established and six group training seminars or workshops in typhoon research, radar and message switching were organized under the regional programme.

The outstanding work of the Typhoon Committee was specifically recognised when the Committee had the distinction of receiving the prestigious Sasakawa-UNDRO Disaster Prevention Award in 1988. This enabled the Typhoon Committee Secretariat to establish a Typhoon Committe Foundation Incorporated, at the Committee's request. Income derived from the foundation has been used for annual awards to persons or organisations in its region for distinguished services in disaster prevention and preparedness activities, thus perpetuating promotion of disaster preparedness and generating greater public awareness.

Panel on Tropical Cyclones

As decided by the Panel, the location of its Technical Support Unit is being rotated among its Members. It has been hosted by the Government of India, Sri Lanka and Bangladesh, respectively in New Delhi (up to 1981), Colombo (1981-1985), Dhaka (1985-1996) and the current location, Bangkok (1996-1999), with a move to Islamabad set for 2000. The Panel has given special attention to storm surge and regional computer network (RCN) projects and to public awareness programmes to meet the circumstances in its region.

After the storm surge associated with a tropical cyclone in Bangladesh
(Courtesy of the UK Overseas Development Administration)

The Bay of Bengal area is extremely vulnerable to the very high storm surges and storm tides caused by tropical cyclones in that region. As an activity coordinated by the International Oceanographic Commission (IOC), the TCP and the UNESCO/International Hydrological Programme, the Panel formulated a detailed and comprehensive storm surge project and action plan for implementation in the years ahead. Under the TCP, a consultancy and advisory mission to Members was carried out in 1987. Follow-up action focused on training of personnel and also on the RCN, installation of special equipment, mainly high gust anemometers and storm surge gauges and on storm surge modelling and forecasting. Four workshops on storm surges and one on the use of satellite data were organized under the regional programme and several people were trained under TCDC arrangements. The Technical Support Unit published newsletters periodically and the national Meteorological and Hydrological Services carried out wide-ranging activities to establish and maintain closer collaboration with users of their services and to promote greater response to warnings.

The application programme of the Indian geostationary satellite INSAT includes substantial support for RSMC - tropical cyclones New Delhi's role, under the Panel's programme, of detection, monitoring and also forecasting of tropical cyclones.

RA I Tropical Cyclone Committee

From the outset, several training events were organised at the regional level under the Committee's programme. In response to the recommendation of a joint UNDRO/WMD/LRCS advisory mission In 1980-1981, a regional training seminar in disaster preparedness was held in the region in 1984. Two roving seminars, which took place in five Member countries, two workshops and an exchange programme under TCDC arrangements, provided training for tropical cyclone forecasters. More recently the rate of progress in implementation of the technical plan accelerated sharply with the support of a FINNIDA (Finnish aid) project for mainland African countries and a major project of the Indian Ocean Commission, with funding support by the European Union, for South-West Indian Ocean countries. The latter project was implemented with the guidance of a committee established for the purpose by the RA I Tropical Cyclone Committee. Near the end of the reported period a successor project to the Indian Ocean Commission project was formulated for implementation in the years ahead.

Training of tropical cyclone forecasters from Region I on the use of the MTCW software under the Regional Computer Network

RA IV Hurricane Committee

The RA IV Hurricane Committee, which pioneered the regional operational plans of the TCP, regularly reviewed the performance of its own operational plan, which functioned in an outstanding way during the severe tests on it by major hurricanes in the region. The operational plan included a US aircraft reconnaissance programme throughout the period, the only region in which this was so. Under a project on the regional aspects of storm surge, training was carried out and a storm surge atlas has been prepared for the Bahamas and existing storm surge models were evaluated by the USA to determine the most appropriate one for the region. Over 200 forecasters were trained on nine workshops conducted at the RSMC Miami under the regional programme. A workshop was organised in cooperation with the former Pan-Caribbean Disaster Preparedness and Prevention Project to train disaster preparedness personnel and another, on the application of the Management Overview of Flood Forecasting Systems (MOFFS), for hydrologists, also under the Committees programme. A major project was implemented to replace the terrestrial point-to-point telecommunication links in the Caribbean and Central America with two-way multipoint telecommunication services via satellite, together with computer workstations for improved exchange, processing and display of meteorological

data and information. Another project, for Central America, to support those activities and upgrade other aspects of the meteorological service was also accomplished.

Hurricane reconnaissance aircraft
(NOAA, USA)

RA V Tropical Cyclone Committee

The RA V Committee is the youngest of the TCP regional bodies but much has been done since its establishment in 1985. Non-Members of WMO, which are within the region and are affected by tropical cyclones, participate in the work of the Committee. RSMC Nadi provides not only advisories for its region of responsibility but also tropical cyclone warnings for several of the participating countries and territories.

RA V Tropical Cyclone Committee session in Nadi, Fiji, in October 1994

In addition to formulation of the operational and technical plans, commendable progress was made towards rapid implementation of the latter. During the first part of the period, seven workshops organised under the Committee's programme, four for tropical cyclone forecasters and three on tropical cyclone warnings and disaster preparedness, for disaster preparedness and senior meteorological personnel, were held in a cost-effective way in conjunction with sessions of the Committee. The rate of progress was maintained in the following years with training of personnel and improvement of telecommunications and other facilities for upgrading the tropical cyclone forecast and warning services through coordination with the South Pacific Tropical Cyclone Warning Upgrade Project and other technical cooperation projects.

Special projects and activities

TOPEX

In the early 1980s the Typhoon Committee carried out TOPEX - a **T**yphoon **Op**erational **Ex**periment - to test the typhoon warning system under real typhoon conditions. The experiment consisted of three components: on meteorology, hydrology, and warning dissemination and information exchange.

Under the meteorology component there was a three week duration pre-experiment in 1981 as a systems test in advance of the two 10-week duration operational experiments in the following two years. An experiment centre set up in Tokyo by the Japan Meteorological Agency was staffed by scientists from the participating Members. It worked in conjunction with national experiment sub-centres to monitor and forecast tropical cyclones under operational conditions using data from an intensified observing network and common procedures. The experiment was followed by a research period.

The other two components focused more on national activities. The effectiveness of existing flood forecasting and warning systems and the hydrological effects of typhoons were monitored and evaluated and the results from forecasting models were compared in real time. Attention was given to the dissemination of typhoon and flood warnings and the exchange of operational information. Additionally efforts were made to plan programmes on public awareness of the dangers of typhoons to enhance community preparedness and human response to warnings.

Much was gained from the experience of an international typhoon monitoring and forecasting centre in the region and of the value of enhancement of observational data. TOPEX produced a useful data set. The forecasting centre in Tokyo subsequently became the RSMC Tokyo-Typhoon Center and Committee Members continued after TOPEX some programmes of enhanced observations.

MOFFS

Given that the greatest loss of life from tropical cyclones is caused by flooding, the hydrological component of the TCP has always concentrated on the establishment and operation of flood forecasting systems and the monitoring of their performance under flood conditions. During TOPEX, participating countries were invited to implement a comprehensive monitoring exercise, the results of which were published in the TCP series in 1985. Though successful over those few years, it was clear that the national agencies concerned could not maintain these activities in the long term and a quite new and much simplified methodology was therefore developed. This is referred to as Management Overview of Flood Forecasting Systems (MOFFS).

MOFFS is a points scoring system, developed by WMO, which is extremely flexible in form and very simple in application. It provides a measure of the effectiveness of performance of the forecasting system with respect to each forecast location and each major flood event, and summarises the results on a single sheet of paper. Irrespective of the size or level of complexity of the system, it quickly highlights problem areas for appropriate remedial action. MOFFS has been adopted for use by all TCP regional bodies, and is being recommended for use world-wide. While primarily intended for national use and review, many countries are providing information on the results for wider regional information and analysis.

Application of meteorological research results

Four WMO International Workshops on Tropical Cyclones (IWTC) were held at about four-yearly intervals from 1985. The third and fourth, in 1993 and 1998, were co-sponsored by the International Council of Scientific Unions. Each workshop served as a forum for the interaction between tropical cyclone researchers and forecasters and was aimed at encouraging the application of research results to operational usages. As a follow up to IWTC-I, participants contributed to a text book entitled "Global view of tropical cyclones" which was based largely on material prepared for the first workshop in the series. In conjunction with the second workshop a project was established, under the general component of the TCP, to produce a guide on tropical cyclone forecasting for forecasters in all tropical cyclone regions. This TCP project was successfully carried out, resulting in the publication and wide distribution of a "Global guide to tropical cyclone forecasting". A book entitled "Global perspectives on tropical cyclones", which is a revision of and will replace the "Global view", was prepared in draft form for submission to IWTC-III, where it was finalized and subsequently following final editing it was published in the TCP series. The practice of IWTCs revising and updating, alternatingly, the forecasting guide and the global perspectives is continuing. Additionally, IWTC-IV also considered the impact of climate change on tropical cyclones.

Regional computer network

All TCP regional bodies established regional computer network (RCN) projects to computerise operational data handling, processing and display for tropical cyclone and storm surge forecasting and warning. In the smaller and less advanced Meteorological Services the project hardware would generally be limited to PC workstations or micro-computers, possibly connected to the regional and national telecommunication networks.

In the Typhoon Committee's area, the project is being implemented nationally, while for the RA IV Hurricane Committee the initial goals were achieved in connection with the establishment of the new satellite-based telecommunication services with micro-computer terminals. The TCP cooperated with SHARE, another WMO project which developed meteorological application software and decided on hardware and other requirements for a turn-key micro-computer based system. Hence, as a first phase for the RCN project in the Panel area, micro-computers, SHARE software and associated telecommunications and interface software were installed in Bangladesh, Pakistan and Sri Lanka. Training for staff was provided by the SHARE project and TCP. As the next step the AFDOS system (analysing, forecasting and date processing operational system) with software provided by China through VCP, and PCs by WMO/UNDP was installed by TCP in Maldives and then in Myanmar. Subsequently ATCW (the Australian Tropic. Cyclone Workstation) software was installed under the RCN in operational computers in Bangladesh, Myanmar and Thailand and training was provided on its use. ATCW was also installed in countries in the RA V Committee's region as phase one of its RCN project. Training on ATCW and a version prepared by Madagascar called MTCW was provided for forecasters in the South-West Indian Ocean region.

IDNDR

The UN designated the 1990s as the International Decade for Natural Disaster Reduction (IDNDR) to reduce, through concerted international actions, especially in developing countries, loss of life, property damage and social and economic disruptions caused by natural hazards. The decade related specifically to calamities caused by tropical cyclones, floods, landslides and other natural hazards. The objectives of the TCP were thus fully within the scope and purpose of the IDNDR.

From the outset WMO, mainly through its HWRP and TCP, gave active support to the planning and implementation of the IDNDR. The WMO Executive Council called upon Members to become actively involved at the national level and for more accurate forecasts and reliable warnings with increased lead time by the national Meteorological and Hydrological Services, to respond to the challenge of reducing the impact of meteorological and hydrological hazards. The Services were urged to play a catalizing role in the coordination of disaster preparedness nationally. In 1991 Congress adopted a WMO Plan of Action for the IDNDR and, as required in the plan, TCP activities were intensified and accelerated in support of the Decade. The plan also included three special projects which were classified as IDNDR demonstration projects, a TCP project and two other projects: STEND (System for technology exchange for natural disasters) and Comprehensive Risk Assessment. The TCP project "Tropical cyclone warning system for the South-West Indian Ocean region" achieved its objective of upgrading substantially the tropical cyclone warning system for that region. It formed part of the Regional Cooperation Programme of the RA I Tropical Cyclone Committee and its Technical Plan and included its RCN project and support from RSMC La

Réunion-Tropical Cyclone Centre. The project was successfully implemented, in effect through the Indian Ocean Commission meteorological project in that region, with funding support from the European Union.

The UN World Conference on Natural Disaster Reduction was convened in 1994 as a mid-Decade review of the IDNDR and to formulate the direction for the rest of the Decade. TCP was involved in WMO's role in contributing to preparations for the Conference and organising, in cooperation with UNESCO, its Technical Committee on Warning Systems. Furthermore, two reports, on risk management and on disaster preparedness, were prepared under the TCP's general component specially for distribution at the Conference and subsequently to a wider readership. The IDNDR came to an end with a call for attention to natural disaster mitigation and the establishment of a successor UN programme centered on an International Strategy for Disaster Reduction.

WMO poster at UN World Conference on Natural Disaster Reduction

Scientific exchanging results of post-SPECTRUM research

SPECTRUM

In August and September 1990 the most comprehensive meteorological observation programme ever mounted to study typhoons took place in the western North Pacific. Under the auspices of the Typhoon Committee the field experiment phase of SPECTRUM, a Special Experiment

Concerning Typhoon Recurvature and Unusual Movement was carried out by Typhoon Committee Members. During the same period the USA and the Russian Federation (the former USSR) carried out separate but complementary programmes. There was close coordination between the three experiments, which marked the commencement of the IDNDR. RSMC Tokyo-Typhoon Center served as the SPECTRUM centre. It identified seven target tropical cyclones and gave the signals to activate the intensive observation periods in accordance with predetermined criteria. Constant operational contact was maintained between the SPECTRUM centre and the Members' operational centres which oversaw SPECTRUM activities within their own territories.

Following the field experiment, data sets were prepared with the cooperation of the USA experiment group. In ensuing years Typhoon Committee Members and scientists in the USA and other countries used the enhanced meteorological observation data in studies on the unusual movement and recurvature of tropical cyclones in the north Pacific, aimed at improving operational typhoon forecasting. This was facilitated by the exchange of research results and views at international technical conferences and the publication in the TCP series of research papers. The conferences organised under the Typhoon Committee's programme defined seven topics for research, including asymmetry, environmental steering and numerical simulation. SPECTRUM proved to be a wonderful example of international cooperation and coordination.

SPECTRUM, USA and USSR field experiments: observations from upper-air sounding stations and wind-profilers (dots and arrows), weather ships and buoys (triangles and flags). The track of target Typhoon Yancy (9012) is shown

Coordination between TCP regional bodies

Over the years all regular sessions of TCP regional bodies have reviewed comprehensive reports on the overall TCP to exchange experiences and to promote strengthening of coordination. As a new initiative the first joint session of TCP regional bodies took place in 1992. This meeting of both the Panel on Tropical Cyclones and the Typhoon Committee was convened in response to a proposal by RA II (Asia). It led to further strengthening the coordination of activities between the adjacent regional bodies in a cost-effective way and facilitated exchange of experiences and consideration of items of mutual concern. Special attention was given to mutually beneficial training and to the exchange of information between the TCS and TSU. Later in the year, the first in a new series of technical coordination meetings, involving all the tropical cyclone RSMCs, resulted in significant further strengthening in the coordination of the work of the regional bodies as well as the valuable exchange of information on the scientific and operational activities of the centres. Progress was made on global data archival, classification and terminology for tropical cyclones. Another joint session of the two intergovernmental TCP regional bodies was held in 1997 and the second and third meetings of the tropical cyclone RSMCs took place in 1996 and 1999 with repeated success.

Workshop on storm surges for Members of the Panel and the Typhoon Committee

Joint session of the Panel on Tropical Cyclones and the Typhoon Committee in 1997

PROGRAMME EVALUATION AND IMPACT

In-depth evaluations of segments of the TCP and overall reviews of the programme have been carried out frequently, generally with results supportive of the consistent progress made. Members have from time to time expressed complete satisfaction with the programme. There were regular appraisals of the related UNDP inter-country projects at tripartite review meetings, held mostly in conjunction witt sessions of the inter-governmental TCP regional bodies, as a cost-effective arrangement. The TOPEX evaluation meeting felt that TOPEX had enabled Typhoon Committee Members to greatly improve their forecasting ability and measures related to disaster preparedness. The evaluation meeting for SPECTRUM concluded that from the planning stage, through the execution phase, those concerned fulfilled their respective roles with a high degree of skill and professionalism to make the field phase such a well-accomplished undertaking and a model of international cooperation and coordination. It was subsequently agreed that the production of the excellent data set and the follow-up, planning and arrangements led smoothly to a productive research phase. Evaluations of individual training events were useful in improving and stimulating subsequent training within the regional programmes.

A critical appraisal of the programme carried out in 1984, mainly through consultations with Members and with TCP regional bodies, showed that the TCP was a significantly successful programme. The TCP regional bodies and Regional Associations regularly evaluated the activities in their respective regions, and the Executive Council and Congress reviewed the overall programme with favourable conclusions. For example, Regional Association IV acknowledged the high level of activity of its Hurricane Committee and the highly successful work it accomplished.

In regard to the Tropical Cyclone Programme, Congress gave recognition to the important roles of:

- meteorological satellites in the operational warning systems, particularly in the detection and monitoring of tropical cylcones;
- regional cooperation and coordination, and
- the RSMCs with activity specialization in tropical cyclones.

It noted that Members were pleased with advances made in the improvement of:

- the operational tropical cyclone and flood forecasting and warning systems;
- the provision of products to meet user requirements;
- the enhancement of response to warnings, and
- training of personnel under the programme.

Congress concluded with great satisfaction that considerable progress had been made in the implementation and further planning of the TCP.

Eleventh Congress 1991

The importance of warnings and response to warning: years ago twenty-five people decided to have a "hurricane party" in this apartment building …..

….. the next day, after the storm surge, twenty-three of them were dead
(NOAA, USA)

Special mention must be made of the progress devolving from the formulation of the operational plans which, taken together, represent the establishment of a global tropical cyclone and cover land, sea and air, of all regions where there is a significant threat of tropical cyclone disasters. Advantage is taken of meteorological satellites and all tropical cyclones are now detected from the early stages of formation and monitored throughout their lifetime. The plans go a far way towards ensuring the best possible forecasting and warning services within the limits of scientific knowledge and technological developments and of the available resources, taking the maximum advantage of the high level of cooperation and coordination attained. They are regularly updated to incorporate new facilities, advances and developments.

In the advanced Meteorological Services with state-of-the-science tropical cyclone forecasting services, the average accuracy of track forecasts and hence the reliability and timeliness of warnings has been steadily improving, with some indications of a slightly faster rate during recent years, than in earlier periods. Advances in NWP, particularly for the forecasts with longer lead times, have made a substantial contribution to these gains.

On the basis of the results of tests on the effectiveness of the operational plans, it may be inferred that the rate of improvement of warning services In more recent years has been more marked in lesser developed and small Services which have benefited most from the new arrangements including those, in particular, with regard to tropical cyclone RSMCs. A degree of overwarning is and will continue to be necessary in all cases. Usually overwarning leads to unnecessary actions and expenditures, that is they may be costly, and it often detracts from confidence in and response to future warnings. However, this will diminish as the accuracy of forecasts improve.

The improved monitoring and warnings of tropical cyclones have had a highly beneficial impact on the aviation and marine communities, for all types of aircraft, vessels on the high seas and small craft which are very vulnerable to such severe weather.

There has been an increase not only in the number but also in the effectiveness of flood forecasting systems and hence real progress in the provision of flood warning services. Progress has also been made in risk evaluation, response to warnings and in the field of disaster preparedness and prevention. However, as activities in these fields are generally carried out at the national or community levels, there is less information available and likelihood of greater variability from place to place in the progress made.

The overall progress and achievements have resulted in significant advances towards attainment of the objective of the TCP.

Improvements to tropical cyclone disaster mitigation arrangements, including the warning systems, have reduced the loss of life and destruction of property caused by cyclones and associated floods and storm surges. This has been countered by increasing vulnerability, due mainly to sharp increases in population and property at risk in areas subject to these hazards.

Global data, national statistics and individual case studies have clearly indicated overall decreasing trends in loss of life, despite the rising populations. Certainly improved warnings, evacuation and disaster prevention measures have been major contributors. Some examples may be given.

Annual average RSMC Miami official forecast errors
for 24 h, 48 h, and 72 h adjusted for forecast difficulty

Hurricane Andrew, which hit southern Florida and parts of Louisiana in the USA in August 1992, caused property damage estimated at a staggering US $25-30 billion but only 23 lives were lost, the latter remarkably low attributable to a large extent to excellent warnings, disaster preparedness and other hurricane disaster mitigation measures.

In China effective warnings during 1998 contributed to reducing loss of life to only six in two major typhoons which affected over one million people in one case and over three quarters of a million in the other. The total damage was estimated at US $200 million.

The decrease in the death tolls in Jamaica, from 152 to 45 people caused by similar hurricanes in 1951 and 1988, respectively, was attributed in large part to better hurricane warnings, a community flood-warning system in one of the most vulnerable areas, which proved effective and disaster preparedness activities in the 1980s.

Two severe tropical cyclones, both making landfall at the time of high astronomical tide on the Bangladesh coast, in 1970 and 1991 took about 300,000 and 134,00 lives respectively. A detailed local case study concluded that the decrease in loss of life was due mainly to:

(i) a tremendous improvement in the cyclone warning system;

(ii) markedly improved cyclone preparedness, including the mobilisation of over 20,000 Bangladesh Red Crescent Society volunteers to assist in warning dissemination an evacuation;

(iii) erection of embankments along the coast, partially successful, and

(iv) continuation of the construction of a large number of cyclone shelters.

On the other hand, the economic losses have been growing ever larger with the years. Th alarming increase in damage as the years go by is not unique to tropical cyclone disasters. On the contrary, the available data indicates that there is an even faster rate of increase in damage due to all great natural disasters combined. According to a Munich Re study published by DHA, the trend of economic losses due to the great natural disasters of 1960 to 1993, showed an increase of about 50% from 1960 to 1970,100% from 1970 to 1980,150% from 1980 to 1990, with continuing increases at an escalating rate in subsequent years.

The conclusions that may be reached are that the death tolls due to tropical cyclones world-wide have decreased remarkably and can be further diminished by strengthened disaster mitigation particularly in the developing countries where most of the deaths occur, and that acceleration of disaster mitigation is required to stem or at least slow the continuing escalation of tropical cycle damage statistics, particularly in areas which are developing rapidly.

1900-1996 trends of coastal population versus hurricane deaths and damage in the USA

A LOOK TO THE FUTURE

Clearly there is a great deal yet to be done and that can be achieved. The TCP will continue to take advantage of scientific and technical developments to strengthen the warnings and mitigation systems for tropical cyclone disasters. Further advances in meteorological satellites, such as the launch of meteorological satellites, by the Russian Federation in 1994 of GOMS, parked over the Indian Ocean, and by China in 1997 of the FY series, the continuing developments in computers and electronics, in scientific knowledge and mathematical modelling of tropical cyclones as well as in international cooperation and other factors will provide an impetus for continued improvements in tropical cyclone forecasts in various timescales. This will lead to tropical cyclone, flood and storm surge warnings with longer lead times and enhanced reliability. Combined with more effective risk evaluation, awareness programmes, and other disaster prevention and preparedness measures, such actions will ultimately result in the attainment of the objective of reducing loss of life and damage caused by tropical cyclones to a minimum. In addition to its humanitarian goals, the TCP will help to pave the way for sustainable development.

YOKOHAMA STRATEGY FOR
A SAFER WORLD

adopted at the

World Conference on Natural Disaster Reduction (1994)

The **Plan of Action** included:

- At the regional and sub-regional levels, establishment and/or strengthening early warning mechanisms for disaster reduction and improving related communications.
- Through international cooperation, establishment or implementation, as a priority, of national, regional and international warning systems and more effective dissemination of warnings.
- Incorporation of cost-effective techniques in (disaster) reduction programmes, including forecasting and warning systems.
- Developing and implementing risk assessment and public awareness programmes.

The UN World Conference on Natural disaster Reduction in 1994 appealed to the world for decisive action to reduce natural disasters towards the goal of the IDNDR for a safer world in the future, protected from the ravages of natural disasters. In this connection it urged the development of a global culture of prevention, as an essential component of the strategy to be followed and formulated a plan of action. Undoubtedly the TCP has the potential to contribute greatly to the proposed actions and hence to this goal. The TCP's future activities will thus be in concurrence with the International Strategy for Disaster Reduction, the UN's successor programme to the IDNDR.

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TROPICAL CYCLONE PROGRAMME REPORTS

(including TOPEX report sub-series)

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