GLOBAL
ENVIRONMENT
FACILITY

Global

Monitoring of Greenhouse Gases Including Ozone

Project Document

This Project Document has been edited to facilitate public dissemination.
The original is on file in the GEF Office at UNDP Headquarters in New York.

ABBREVIATIONS

BAPMoN	Background Air Pollution Monitoring Network
CAS	Commission for Atmospheric Sciences
CFC	Chlorofluorocarbon
CO_2	Carbon dioxide
EMEP	European Monitoring and Evaluation Programme
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEMS	Global Environment Monitoring System
GO_3OS	Global Ozone Observing System
GWP	Global Warming Potential
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere-Biosphere Programme
IPCC	Intergovernmental Panel on Climate Change
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

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UNITED NATIONS DEVELOPMENT PROGRAMME

GLOBAL ENVIRONMENT FACILITY

Project of the Governments of Algeria, Argentina, Brazil, China, Indonesia, Kenya and Malaysia

Title:	Global Monitoring of Greenhouse Gases Including Ozone
Number:	GLO/91/G32/B/1G/16
Duration:	Three years
UNDP Sector:	Science and Technology
Subsector:	Meteorology
Government Sector:	Science and Technology
Government Implementing Agency:	National Meteorological Services
Executing Agency:	World Meteorological Organization (WMO)
Estimated Starting Date:	January 1992
Government Inputs:	US$ 1.2 million (in kind)
GEF/UNDP:	US$ 4.8 million

Brief Description:

This project aims to fulfil the critical need for global baseline data related to emissions of greenhouse gases which cause global warming. Global stations will be established in carefully selected locations to carry out a wide range of measurements of background concentration levels of selected atmospheric constituents, thereby filling major gaps in the global data network. This global network is currently part of WMO's Global Atmosphere Watch (GAW). A fully functional database of atmospheric observations is essential to provide a sound scientific basis for political, economic, and public safety decisions regarding the impacts of greenhouse gases on global warming.

This project is a response to the general appeal made by the Intergovernmental Panel on Climate Change (IPCC) and the Ministerial Declaration of the Second World Climate Conference in favour of developing countries. Funds from the Global Environment Facility will complement ongoing efforts under GAW to benefit the participating developing countries—Algeria, Argentina, Brazil, China, Indonesia, Kenya, and Malaysia.

A. CONTEXT

1. Description of subsector

WMO Global Atmosphere Watch (GAW)

Establishment, objectives, composition, and implementation principle

In 1989, the Executive Council (EC) of the WMO integrated existing WMO activities related to the monitoring and assessment of the chemical composition and associated physical characteristics of the atmosphere, with the meteorological aspects of the long-range transport and deposition of air pollutants, to form GAW. The day-to-day management of GAW operations is the responsibility of the Environment Division of WMO's Research and Development Programme (RDP, later renamed the Atmospheric Research and Environment Programme).

GAW has two major objectives. The first is to measure, on an ongoing basis, the background concentration levels of selected atmospheric constituents and related physical characteristics of the atmosphere, representative of all parts of the globe. The second is to encourage and support scientific studies that utilize GAW measurements. Both the data from the measurements, and the results of the research, are expected to establish a scientific basis for guidance on environmental issues to governments, international organizations, and entities such as the Global Environment Facility. GAW activities would:

- Help to detect and explain changes in the chemical composition and related physical characteristics of the atmosphere

- Contribute to an understanding of: the relationship between such changes and changes in global and regional climate; the long-range transport and deposition of potentially harmful air-borne substances; and the natural cycling of chemical elements in the global atmosphere/ocean/cryosphere/biosphere system and the impact of human activities thereon

- Help to forecast future states of the environment.

GAW is based mainly on two WMO networks of global and regional stations, namely the Global Ozone Observing System (GO_3OS) and the Background Air Pollution Monitoring Network (BAPMoN), established in the mid-1950s and 1960s respectively. GAW is the main contributor of atmospheric data to the Global Environment Monitoring System (GEMS) of the United Nations Environment Programme (UNEP). It will also be an essential component of the currently planned Global Climate Observing System (GCOS). GAW activities are usually implemented in the territories of participating member countries, and are the responsibility of the countries themselves. As far as possible, the countries' own resources are also used. However, in the case of developing countries, partial support is sometimes considered by or through WMO for joint bilateral/multilateral projects with other member countries, or with other organizations, programmes, or institutions such as UNEP or UNDP. These arrangements are a part of the ten-year plans that are approved by the WMO Congress, and revised every four years.

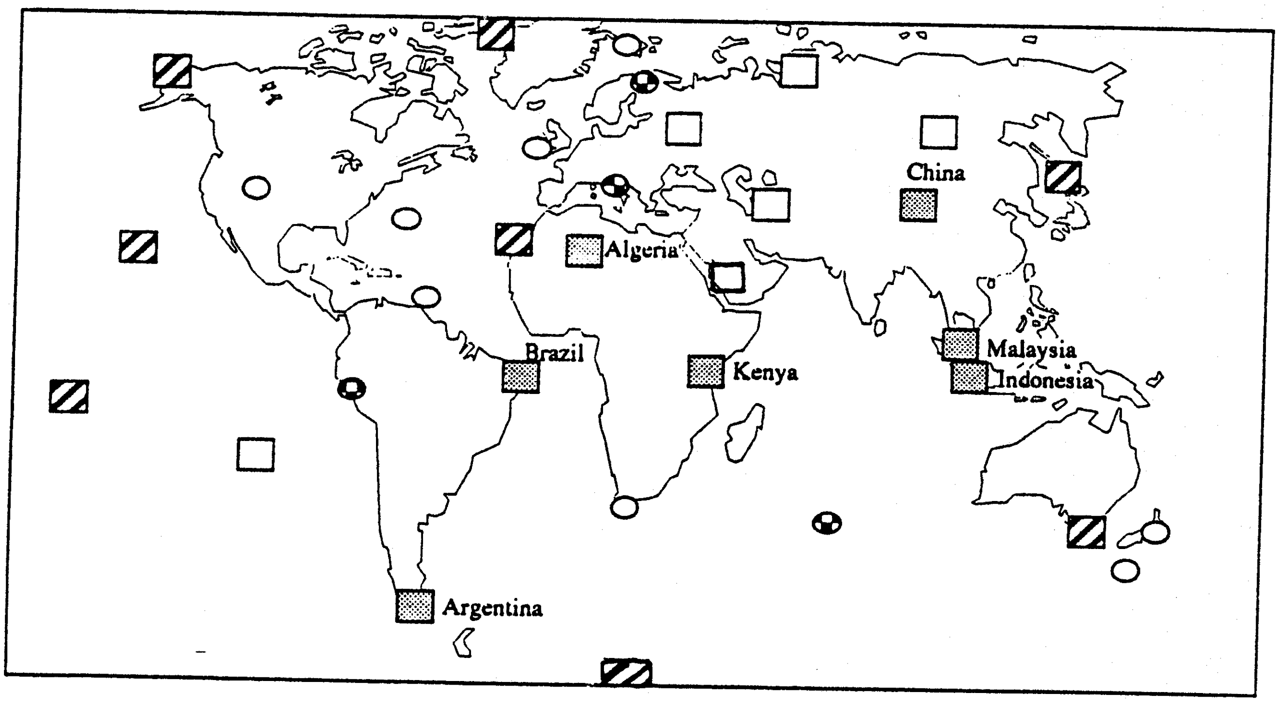
Suitable locations for GAW global stations

In November 1989, WMO and UNEP held consultations with several experts in Bermuda to consider suitable locations and observational practices for GAW global stations. It was agreed that about thirty to thirty-five GAW global stations should be established and kept in continuous operation, in order to achieve the minimum desirable density of one station per representative climatic zone/major biome. These stations would have to be established at fairly remote locations not affected by direct sources of pollution.

The locations recommended by the Bermuda consultation, together with their implementation status, are shown in figure 1.

Figure 1

Location of GAW global stations



Existing global stations carrying out a full measurement programme.

Existing stations for which upgrading to global station status is being considered by the WMO Member Countries concerned.

Existing stations to be upgraded to global station status. Funds are being sought by WMO from other sources on behalf of the Member Countries concerned.

Proposed locations for new global stations to be funded under this project.

Proposed locations for new global stations, but not to be funded under this project

Measurement requirements at global stations

The Bermuda consultation led to an agreement that the measurements undertaken by GAW global stations must conform to certain specifications and standards. These requirements are summarized below.

The monitoring of atmospheric composition and related physical characteristics of the atmosphere at GAW global stations is a research-oriented activity. It is intended to satisfy the observational needs of scientists and policy-makers with respect to: (i) the actual changes in chemical composition and physical characteristics of the atmosphere, and their role in future climate; (ii) an understanding of the natural cycling of elements in the global biogeosphere, and hence the capacity for humans to interfere with these cycles; and (iii) the study of the interaction of atmospheric transport and the redistribution of atmospheric constituents throughout the global atmosphere.

Results from one location should be strictly comparable with those from any other location. For this reason, the selection of the location for the station is as important as the quality of the measurement itself. Present criteria for the establishment of GAW global stations as formulated by the Commission for Atmospheric Sciences (CAS)[1] in 1990 are:

- *GAW global stations.* These stations should have extensive research and monitoring programmes. They should carry out a complete range of measurements relevant to atmospheric ozone changes and climate, and other environmental issues of global scale and importance. They should serve as reference stations for regional networks and have facilities for visiting investigators to conduct complementary short-term research and development studies. They should provide data on global environmental issues and include the major climatic and ecological regions.

- *GAW regional stations.* These stations should be similar to the existing BAPMoN and GO_3OS stations, but have a more flexible measurement programme. Their goals should be to address regional environmental problems, to help resolve regional aspects of global environmental issues, and to permit participation in GAW by all WMO member countries. The frequency and spacing of observations should be adjusted to the physical and temporal scales of the atmospheric chemical composition.

Each station must establish its conditions for recording background levels in the atmosphere. The frequency distribution of the daily values of the various variables and their suitable combination with meteorological parameters will help to define those periods of time and associated ranges of meteorological data for which background conditions prevail. Sequences of data that do not meet the criteria fully should be excluded from determinations of background levels.

The final selection of sites should be based on the presence of certain significant constituents of the atmosphere in the vicinity of the site. The choice of suitable constituents to be included will

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[1] CAS is one of eight Technical Commissions of the WMO. It includes researchers and research managers from all member countries.

depend on the type of location considered. For example, for sites in an oceanic environment, measurements of the concentration of Aitken nuclei may be suitable. Other variables that could be included are the light scattering coefficient and the chemical composition of precipitation and aerosols. For sites at high altitudes, carbon dioxide could be included. Sites must also satisfy certain other criteria. A station built on a chosen site must provide background information for at least 40 to 60 percent of the time; this situation must continue long enough to warrant the installation of the station. The geographical location of the station should also contribute to the global distribution of sites. If all these requirements are met, a request may be submitted to WMO for inclusion of the station into the WMO baseline network of GAW global stations. A continuing programme for testing the validity of the records for each site is necessary.

It was decided at the Bermuda consultation that it would be unrealistic to propose a rigid set of parameters to be measured at every global station. Several reasons were cited for this. Monitoring, like research, cannot have pre-programmed results. The results obtained will inevitably reflect a wide range of scientific objectives, initiatives, and perceptions. These results are also likely to be affected by economic considerations, available infrastructure, and individual ability. The different observatories will therefore only be given a common set of recommendations to serve as a guide for observational requirements aimed at current scientific objectives. Observational needs are likely to evolve steadily with the development of the science of atmospheric physics and chemistry.

However, certain essential observational requirements must be regarded as priority measurements at all global stations. These would include measurements of:

- Greenhouse gases (carbon dioxide, methane, nitrous oxide, tropospheric ozone, and the long-lived chlorofluorocarbons (CFCs) and their substitutes). These should be measured continuously at global stations, although flask sampling may also be suitable in certain locations. Vertical profile measurements should be made at least once every season. Isotopic composition analyses of selected gases (such as carbon dioxide and methane) should also be made. CFC monitoring would only be required at half the stations because of the difficulties of such measurement.

- Ozone. The measurements required would be surface, total column, and vertical profile. These measurements should draw upon a variety of techniques and instruments: spectrophotometres, ozone sondes, lasers, microwave techniques, and satellites. Surface ozone should be monitored continuously. Total ozone daily values, and vertical profiles in general, could be measured twice a week. Umkehr measurements on any clear day could be used in addition to, or instead of, these bi-weekly soundings.

- Radiation and optical properties—solar radiation, including UV-B radiation (280-320 nm) reaching the surface, turbidity, visibility, total aerosol load, vertical profile of aerosols, total water vapour, and vertical profile of water vapour.

- Chemical composition of precipitation.

- Reactive gas species such as sulfur dioxide and reduced sulfur species; nitrogen oxides (NO_x) and reduced nitrogen species; carbon monoxide; and light hydrocarbons.

- Particle (including mineral aerosol) concentration and chemical composition characteristics (at least two size fractions); cloud condensation nuclei and ice nuclei.

- Selected heavy chlorinated hydrocarbons.

- Selected trace metals such as Pb, Fe, and Cd, particularly at marine sites.

- Radionuclides such as Kr-85, Rn-222, H-3, Be-7, and Pb-210. These are useful as tracers of transport and flux measurements, for example, Rn-222 for continental air masses, and Be-7 for stratosphere-troposphere exchange.

- Routine measurements of meteorological parameters, including water vapour above 500 hPa and air mass trajectories for the stations.

- Time-integrated air-constituent samples (such as those on filters) for archiving.

Suggestions were also made at the consultation about additional uses of the stations. Since the field of remote sensing of atmospheric properties and composition by satellite is developing rapidly, programmes at global stations should be linked with satellite programmes. Stations should be equipped to provide factual ground data and reference measurements for satellites. Global atmospheric monitoring sites should also be located in conjunction with ecosystem study stations, provided criteria for the siting and operation of both are satisfied. Combining sites in this way would result in savings, and also integrate the study of atmosphere-biosphere interactions. Finally, global stations should be equipped to collect and analyse rainwater samples (on as real-time a basis as possible) in the eventuality of a nuclear accident. The above linkages highlight the multiple potential of global observatories and the role they can play in programmes such as the Cooperative Programme for the Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP), the International Geosphere-Biosphere Programme (IGBP), and space programmes.

A brief explanation for the choice of many core component measurements to be carried out at global stations (such as carbon monoxide, precipitation chemistry, solar radiation, chemical properties of suspended particles, and station climatology) has been prepared.

Chemical laboratories

Air and water samples collected at GAW stations (on air filters or in flasks, and in precipitation) should be chemically analysed at laboratories in each participating country. All countries must therefore explore the possibilities for samples from prospective stations to be analyzed at a well-equipped chemical laboratory, preferably within the country. This must be done before measurements can begin, especially at GAW stations.

WMO world centres for GAW data

GAW stations and participating laboratories must report their data in an agreed format on forms and/or magnetic tapes/diskettes. These must be submitted to particular WMO World Data Centres within two months after the completion of observations. There are four such centres established and operated under the guidance of WMO in the relevant WMO member countries. All submitted data is stored at the centres and available to any private or governmental institutes, or individual scientists. These four centres are located in Canada, the United States, Tokyo, and the Russian Federation.

- *Ozone.* WMO World Ozone Data Centre (WO_3DC), Ontario. The WO_3DC processes all received ozone data (surface, total column, and vertical distribution). It publishes several documents containing ozone data and listings of ozone stations.

- *Turbidity, precipitation chemistry, and aerosol data.* National Climatic Data Center (NCDC), and the WMO Collaborating Centre on Background Air Pollution Data, Asheville, North Carolina. NCDC processes and prepares turbidity data for publication. It also forwards data on precipitation chemistry and suspended particles to archives at the WMO Collaborating Centre.

- *Greenhouse gases and other atmospheric gases.* WMO World Data Centre for Greenhouse Gases (WDCGG), Tokyo.

- *Radiation data.* WMO World Radiation Centre (WRC), St. Petersburg. WRC compiles, archives, and publishes monthly radiometric data.

Certain GAW handbooks and other material provide guidelines on the use of instruments, sampling frequencies, the rationale for measuring each major variable, methods and procedures for measurements, chemical analyses, reporting, archiving, and so on. Additional guidance materials are being prepared to meet emerging GAW requirements.

Scientific and institutional guidance for the continual development and implementation of GAW, and for its coordination with other relevant programmes inside and outside WMO, are provided by the WMO Executive Council Panel of Experts/Commission for Atmospheric Sciences Working Group on Environmental Pollution and Atmospheric Chemistry. The terms of reference for this body include: acting as the focal point for GAW; the further design of the global stations component as a top priority; and providing new impetus to the education and training of environmental specialists. Representatives of other international organizations, in particular UNEP, and of programmes such as IGBP and EMEP, participate in sessions of the Panel/Working Group which are held every two years.

The WMO Secretariat is responsible for overseeing GAW operations, with guidance from CAS and the EC Panel/CAS Working Group. The secretariat assists in: the implementation of activities; the monitoring of overall GAW performance; the adherence to standards by the stations, chemical laboratories, and data centres; the publication of GAW data; the preparation of summaries

and scientific assessments utilizing the available data; and obtaining financial support for member countries for relevant activities.

Cooperation with similar programmes outside WMO

GAW interacts and collaborates with many similar programmes outside WMO. It is the main contributor to UNEP's Global Environment Monitoring System (GEMS). It also collaborates with programmes such as the European Monitoring and Evaluation Programme (EMEP), and the International Global Atmospheric Chemistry (IGAC) Programme of the International Geosphere-Biosphere Programme. GAW will also be one of the three main components of the planned Global Climate Observing System (GCOS).

Present status of GAW stations

Tables 1 and 2, and figure 2 show the current status of the GAW station network in terms of the number of stations, their geographical distribution, and their measurement programmes. Greenhouse gases and surface radiation are measured at very few existing GAW stations. Table 2 also shows that the distribution of GAW stations is very uneven, with the largest gaps found in tropical/equatorial parts of Africa, Asia, South America, and the Southwest Pacific.

Table 1

Total number of GAW stations and number of participating countries currently carrying out measurements, by parameter

Variables	Number of countries	Number of stations*
Precipitation chemistry	55	168
Ozone	38	141
Turbidity	43	101
Aerosols	35	80
Carbon dioxide	17	40
Sulfur dioxide	15	31
Oxydes of nitrogen	9	22
Radioactivity	8	8
Solar radiation	6	6
Nitrous oxide	6	6
Methane	6	6
Chlorofluorocarbons (CFCs)	5	5
CFCs substitutes and products	0	0
Heavy metals (in aerosols)	2	4
Ammonia	2	2
Nitric acid	2	2
Carbon monoxide	2	2
Other (excluding meteorology)	5	5
Total	78	337

* For further detail, see Table 2.

Table 2

Number of GAW stations in operation as on 31 December, 1990, by parameter measured and WMO region

Parameter	I	II	III	WMO REGION[3] IV	V	VI	Antarctica	All Regions
Precipitation Chemistry	14	17	7	41	14	74	1	168
Particles (aerosols, dust, ions, SPM,TSP)	8	5	2	11	20	33	1	80
Sulfur dioxide (SO_2)	1	-	-	-	2	28	-	31
Turbidity	15	17	5	26	7	30	1	101
Oxides of nitrogen (NO, NO_2, NO_x)	-	-	-	-	1	20	1	22
Carbon monoxide (CO)	-	-	-	-	2	-	-	2
Carbon dioxide								
NDIR (continuous analysis)	2	1	1	1	4	7	1	18
Flask sampling	3	-	-	13	4	5	2	27
Ozone (O_3)	9	43	5	17	11	49	7	141
Surface	1	5	-	1	4	11	1	23
Total column	8	41	5	17	10	38	6	125
Vertical distr.: Umkehr	3	14	2	6	7	6	3	33
Ozonesonde	-	7	1	8	-	11	2	29
Chlorofluorocarbons (CFC)	-	1	-	1	2	-	1	5
CFC substitutes	-	-	-	-	-	-	-	-
Radioactivity	1	-	1	-	3	2	2	8
Heavy metals	-	-	-	-	-	4	-	4
Ammonia ($NH_3(g)$)	-	-	-	-	-	2	-	2
Nitric acid /$HNO_3(g)$)	-	-	-	-	-	2	-	2
Nitrous oxide (N_2O)	-	1	-	1	3	-	1	6
Methane (CH_4)	-	-	-	1	3	1	1	6
Solar radiation	-	1	2	1	3	-	1	8
Other (excl. meteorology)	-	-	-	1	3	-	1	5
Total NUMBER OF DISTINCT STATIONS[1], all parameters	27	56	13	80	37	116	8	337
Total NUMBER OF COUNTRIES all parameters	20	10	7	6	8	26	6	78[2]

Notes:

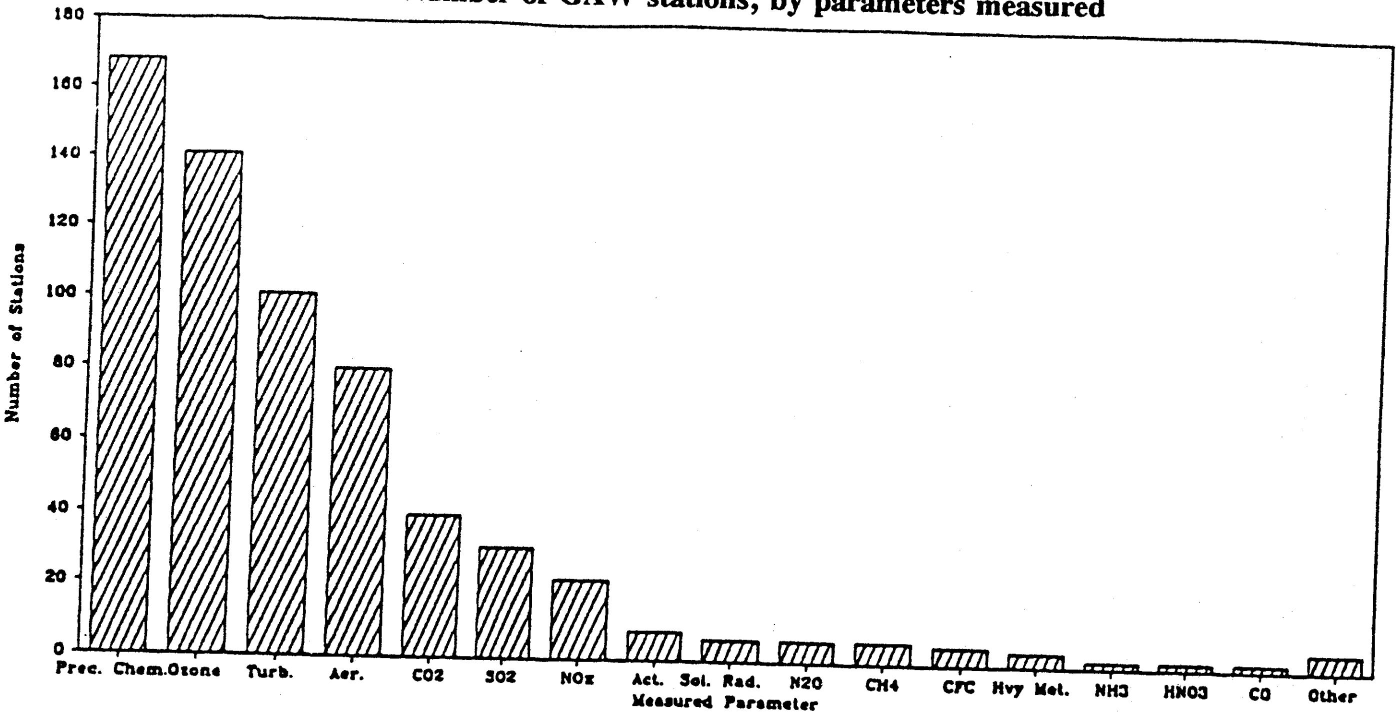
(1) Not the sum of the stations measuring the various parameters, as several parameters may be measured at a given station.

(2) Not the sum of the countries in the various Regions, since some countries are Members of more than one Region.

(3) WMO Regions I - Africa, II - Asia, III - South America, IV - North and Central America, V Pacific South West, VI - Europe

Figure 2

Number of GAW stations, by parameters measured



Of the global stations depicted in figure 1, only eight already exist. All these are located in, or operated with funds from, developed countries. Five of the existing regional stations may be upgraded to global stations. Some of these are in developing countries and would need support from developed countries. Though a similar upgrading has been recommended for seven other existing regional stations, no arrangements have yet been made for funding. It has been proposed that twelve new global stations be established, including the seven for which funds are being provided under this project. These seven locations are Natal (Brazil), Xining (China), Tierra del Fuego (Argentina), Tamanrasset (Algeria), Mount Kenya (Kenya), Bukittinggi (Indonesia), and Taman Negara (Malaysia). These sites have been chosen on the basis of detailed surveys and the willingness of governments to commit themselves to a long-term programme.

2. Host country strategy

Six of the countries involved in this project (Algeria, Argentina, Brazil, China, Indonesia, and Malaysia) have been operating GAW regional stations and reporting data to the appropriate centres for many years, with guidance from WMO and UNEP. The seventh country, Kenya, had earlier been the subject of a two-year study by these two organizations, and been highly recommended as an excellent choice for the construction of a station. However, such a station was never established due to a lack of funds. The governments of these seven countries are willing to make efforts, with outside financial support, to establish global stations within their countries. They recognize that no single country alone can collect or process all the atmospheric data required, and that collaboration is needed between countries in equatorial, mid-latitude, and polar latitude regions. The WMO Executive Council is particularly keen to foster "twinning" arrangements whereby an experienced laboratory from an industrialized country can assist another with less developed capabilities.

In participating in this project, host countries will build upon the experience of their meteorological services that have already been operating and maintaining stations, including GAW regional stations. These stations will be upgraded to global stations through an expansion of training and collaboration with relevant interested groups in national agencies and universities.

3. Prior and ongoing assistance

No assistance has been provided to the countries involved in this project for the establishment of global stations. In the past, however, partial assistance has been provided by UNEP and WMO for a few instruments at BAPMoN and GO_3OS regional stations. These countries have also benefitted from the annual WMO training course on GAW measurements in Budapest, Hungary. WMO has established a special Trust Fund for Climate and Atmospheric Environment Activities from which funds for global stations may become available in the future.

4. Institutional framework for subsector

This project will be part of the ongoing Global Atmosphere Watch that covers background air pollution and ozone monitoring activities. It will be coordinated with, and complementary to, any other related regional or national projects, and will contribute to UNEP's Global Environment Monitoring System (GEMS) and the Global Climate Observing System (GCOS) proposed by the Second World Climate Conference. WMO, as the executing agency, will implement the project in partnership with the host countries, and in consultation with external experts as required.

B. PROJECT JUSTIFICATION

1. Problem to be addressed and the present situation

The threat of global climate change due to increasing concentrations of greenhouse gases has moved to the forefront of the political agenda. The issue, its likely consequences, the actions required, and the monitoring capability of developing countries, have been the focus of much recent debate. The Intergovernmental Panel on Climate Change (IPCC), established by WMO and UNEP in November 1988, provides the following assessment of the problem.

What is the issue?

There is concern that human activities may inadvertently be causing global warming through the enhanced greenhouse effect, by past and continuing emissions of carbon dioxide and other trace gases which raise the temperature of the Earth's surface. The consequences of such change could be significant for human society.

What factors determine climate?

The climate of the Earth has the potential to be changed on all timescales by the way in which short-wave radiation from the sun is scattered and absorbed, and long-wave, invisible, infrared radiation from the Earth's surface is absorbed and emitted by the Earth-Atmosphere system.

The driving energy for weather and climate comes from the Sun. The Earth intercepts solar radiation (including that in the short-wave and visible part of the spectrum). About a third of the energy intercepted is reflected, while the rest is absorbed by the different components of the climate system (atmosphere, ocean, ice, land, and biota). If the climate system is in equilibrium, the energy absorbed from solar radiation is balanced exactly by the radiation emitted to space by Earth and the atmosphere. Any factor that can perturb this balance, and thus potentially alter the climate, is called a radiative forcing agent.

There are several natural factors that can change the balance between the energy absorbed by the Earth and that emitted by it in the form of long-wave infrared radiation, thus causing the radiative forcing effect. The most obvious of these is a change in the output of energy from the Sun. There is direct evidence of such variability over the eleven-year solar cycle; longer period changes may also occur. Slow variations in the Earth's orbit affect the seasonal and latitudinal distribution of solar radiation; it is possible that these were responsible for initiating the ice ages.

One of the most important factors causing radiative forcing is the greenhouse effect. Short-wave solar radiation can pass through the clear atmosphere relatively unimpeded. But long-wave terrestrial radiation emitted by the warm surface of the Earth is partially absorbed and then re-emitted by a number of trace gases in the cooler atmosphere above. Since, on average, the outgoing long-wave radiation must balance the incoming solar radiation, both the atmosphere and the surface will be warmer than they would be without greenhouse gases.

The main natural greenhouse gases are not the major constituents, nitrogen and oxygen, but water vapour (the biggest contributor), carbon dioxide, methane, nitrous oxide, and ozone in the troposphere (the lowest 10 to 15 kilometres of the atmosphere) and stratosphere. The analysis of air trapped in the Antarctic ice core shows that methane and carbon dioxide concentrations were closely correlated with local temperature over the last 160,000 years.

Aerosols (small particles) in the atmosphere can also affect climate because they can reflect and absorb radiation. The most important natural perturbations result from the explosive volcanic eruptions that affect concentrations of aerosols in the lower stratosphere. Lastly, the climate has its own natural variability on all timescales and can change without any known external influence.

The greenhouse effect is a real and well-understood effect, based on established scientific principles. It is known that the greenhouse effect works in practice, for the following reasons:

- The mean temperature of the Earth's surface is already warmer by about 33°C (assuming the same reflectivity of the Earth) than it would be if natural greenhouse gases were not present. Satellite observations of the radiation emitted from the Earth's surface and through the atmosphere demonstrate the effect of the greenhouse gases.

- It is known that the composition of the atmospheres of Venus, Earth, and Mars are very different—their surface temperatures are in general agreement with the greenhouse theory.

- Measurements from ice cores going back 160,000 years show that the Earth's temperature closely paralleled the amount of carbon dioxide and methane in the atmosphere. Although the details of cause and effect are not known, calculations indicate that changes in these greenhouse gases were part, but not all, of the reason for the large (5 to 7°C) global temperature swings between ice ages and interglacial periods.

Naturally occurring greenhouse gases keep the Earth warm enough to be habitable. By increasing their concentrations, and by adding new greenhouse gases like CFCs, humankind is capable of raising the global average annual mean surface air temperature (or "global temperature"), although we are uncertain about the rate at which this could occur. Strictly, this is an enhanced greenhouse effect—above that occurring due to natural greenhouse gas concentrations; the word "enhanced" is usually omitted, but it should not be forgotten. Other changes in climate could be expected to result, for example, changes in precipitation, and a global warming which could cause sea levels to rise.

Other human activities also have the potential to affect climate. A change in the albedo (reflectivity) of the land, brought about by desertification or deforestation, affects the amount of solar energy absorbed at the Earth's surface. Human-made aerosols, from sulphur emitted largely in fossil-fuel combustion, can modify clouds, and this may act to lower temperatures. Changes in ozone in the stratosphere due to CFCs may also influence climate.

What are the greenhouse gases and why are they increasing?

It is certain that the concentrations of greenhouse gases in the atmosphere have changed naturally with ice-age timescales, and have been increasing since pre-industrial times due to human activities. Table 3 summarizes the present and pre-industrial abundances, the current rate of change, and the current atmospheric lifetimes of greenhouse gases influenced by human activities. Carbon dioxide, methane, and nitrous oxide all have significant natural and human sources, while CFCs are only produced industrially.

Table 3

Summary of key greenhouse gases affected by human activities

	Carbon Dioxide	Methane	CFC-11	CFC-12	Nitrous Oxide
Atmospheric concentration	ppmv	ppmv	pptv	pptv	ppbv
Pre-industrial (1750-1800)	280	0.8	0	0	288
Present day (1990)	353	1.72	280	484	310
Current rate of change per year	1.8 (0.5%)	0.015 (0.9%)	9.5 (4%)	17 (4%)	0.8 (0.25%)
Atmospheric lifetime (years)	(50-200)†	10	65	130	150

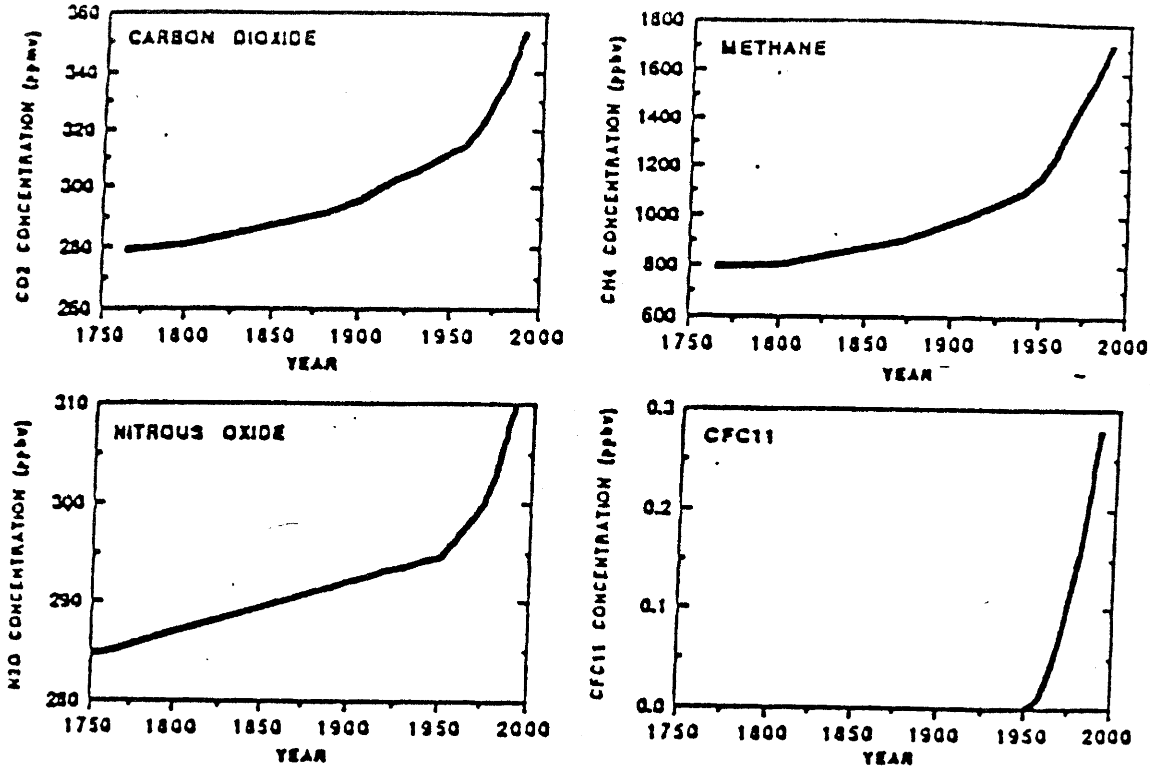
ppmv = parts per million by volume;
ppbv = parts per billion (thousand million) by volume;
pptv = parts per trillion (million million) by volume.
† The way in which CO_2 is absorbed by the oceans and biosphere is not simple and a single value cannot be given;

Table 3 does not include two important greenhouse gases: water vapour and ozone. Water vapour has the largest greenhouse effect but its concentration in the troposphere is determined internally within the climate system, and, on a global scale, is not affected by human sources and sinks. Water vapour would increase in response to global warming and further enhance it; this process is included in climate models. The concentration of ozone is changing both in the stratosphere and the troposphere due to human activities, and continuous observations are necessary in order to quantify the changes and propose further measures to revaluate the situation.

For thousands of years prior to the industrial revolution, abundances of the greenhouse gases were relatively constant. However, as the world's population increased, as the world became more industrialized, and as agriculture developed, the abundances of these gases increased markedly. Figure 3 illustrates this for carbon dioxide, methane, nitrous oxide and CFC-11. WMO stations have been practically the only source of the data used to determine these trends.

Figure 3

Concentrations of carbon dioxide, methane, nitrous oxide, and CFC-11 since 1750



Since the industrial revolution, deforestation and the combustion of fossil fuels have led to an increase of 26 percent in carbon dioxide concentration in the atmosphere. Although the magnitude of the present day fossil-fuel source is known, the input from deforestation cannot be estimated accurately. In addition, although about half of the emitted carbon dioxide stays in the atmosphere, it is not known how much of the remainder is absorbed by the oceans, and how much by terrestrial biota. Emissions of CFCs, used as aerosol propellants, solvents, refrigerants, and foam-blowing agents, are also well known; they were not present in the atmosphere before their invention in the 1930s.

The sources of methane and nitrous oxide are less well known. Methane concentrations have more than doubled because of rice production, cattle rearing, biomass burning, coal mining, and ventilation of natural gas; fossil-fuel combustion may also have contributed through chemical reactions in the atmosphere which reduce the rate of removal of methane. Nitrous oxide has increased by about 8 percent since pre-industrial times, presumably due to human activities; it is difficult to pinpoint the sources, but it is likely that agriculture plays a part.

The effect of ozone on climate is strongest in the upper troposphere and lower stratosphere. Model calculations indicate that ozone in the upper troposphere should have increased due to human-made emissions of nitrogen oxides, hydrocarbons, and carbon monoxide. While ozone at ground level has increased in the northern hemisphere in response to these emissions, observations are insufficient to confirm the expected increase in the upper troposphere. The lack of adequate observations prevents an accurate quantification of the climatic effect of changes in tropospheric ozone.

In the lower stratosphere at high southern latitudes, ozone has decreased considerably due to the effect of CFCs. Indications also exist of a global-scale decrease which, while not completely understood, may also be due to CFCs. These observed decreases should act to cool the Earth's surface, thus providing a small offset to the predicted warming produced by the other greenhouse gases. Further reductions in lower stratospheric ozone are possible during the next few decades as the atmospheric abundances of CFCs continue to increase.

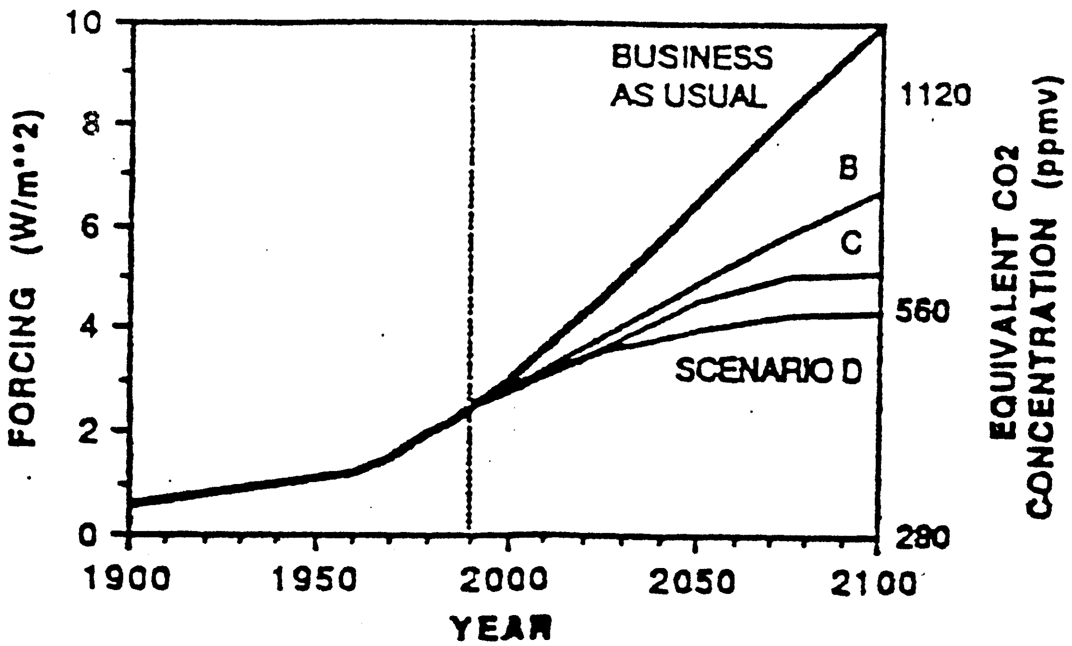
Which greenhouse gases are the most important?

It is certain that increased greenhouse gas concentrations increase radiative forcing. This forcing can be calculated with much more confidence than the climate change that results, because it avoids the need to evaluate a number of poorly understood atmospheric responses. It provides a base for the calculation of the relative effect on climate of an increase in concentration of each gas in the present day atmosphere, both in absolute terms and relative to carbon dioxide. These relative effects span a wide range; methane is about 21 times more effective, molecule for molecule, than carbon dioxide, and CFC-11 about 12,000 times more effective. On a kilogram-per-kilogram basis, the equivalent values are 58 for methane and about 4,000 for CFC-11, both relative to carbon dioxide. Values for other greenhouse gases are to be found in the full report of the IPCC.

The total radiative forcing at any time is the sum of the forcing effect of the individual greenhouse gases. Figure 4 shows how this quantity has changed in the past (based on observations of greenhouse gases) and how it might change in the future (based on the four IPCC emission scenarios). For simplicity, total forcing can be expressed in terms of the amount of carbon dioxide which would give that forcing; this is termed the equivalent carbon dioxide concentration. Greenhouse gases have increased since pre-industrial times (the mid-18th century) by an amount that is radiatively equivalent to about a 50 percent increase in carbon dioxide, although carbon dioxide itself has risen by only 26 percent; other gases have made up the rest.

Figure 4

Increase in radiative forcing since the mid-18th century, predicted to result from four IPCC emission scenarios, also expressed as equivalent carbon dioxide concentrations



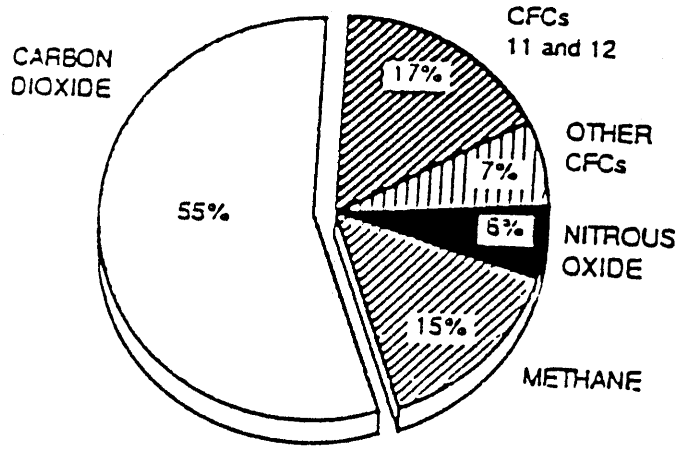
The four IPCC scenarios

Scenario	*Assumptions*
Business-as-usual	Few or no steps are taken to limit greenhouse emissions. Energy use and the clearing of tropical forests continue and fossil fuels, especially coal, remain the world's primary energy source. The Montreal Protocol comes into effect, but without being strengthened and without achieving 100 percent compliance.
Low emissions	The energy supply mix of fossil fuels shifts towards natural gas and large efficiency increases are achieved. Deforestation is reversed and CFCs are reduced by 50 percent from 1986 levels.
Control policies	A shift towards renewable energies and safe nuclear energy takes place in the latter part of the next century. CFC gases are phased out and agricultural emissions (methane and nitrous oxide) are limited.
Accelerated policies	A rapid shift to renewable energies and safe nuclear energy takes place early in the next century, accompanied by stringent emissions controls in industrial countries and moderate growth of emissions in developing countries. Carbon dioxide emissions are reduced to 50 percent of 1985 levels.

The contributions of the various gases to the total increase in climate forcing during the 1980s is shown in figure 5 as a pie diagram; carbon dioxide is responsible for about half the increase during the ten-year period from 1980 to 1990. The contribution of ozone may also be significant but cannot yet be quantified.

Figure 5

Contribution of each man-made greenhouse gas to change in radiative forcing from 1980-1990



To evaluate possible policy options, it is useful to know the relative radiative effect (and therefore the potential climate effect) of equal emissions of each of the greenhouse gases. The concept of relative Global Warming Potential (GWP) has been developed to take into account the differing times that gases remain in the atmosphere.

An index defines the time-integrated warming effect due to an instantaneous release of unit mass (1 kilogram) of a given greenhouse gas in today's atmosphere, relative to that of carbon dioxide. The relative importance will change in the future as atmospheric composition changes because, although radiative forcing increases in direct proportion to the concentration of CFCs, changes in the other greenhouse gases (particularly carbon dioxide) have an effect on forcing which is much less than proportional.

The GWPs in table 4 are shown for three time horizons, reflecting the need to consider the cumulative effects on climate over various timescales. The longer time horizon is appropriate for the cumulative effects, while the shorter timescale will indicate the response to emission changes in the short term. There are a number of practical difficulties in devising and calculating the value of the GWPs, and the values given here should be considered as preliminary. In addition to these direct effects, there are indirect effects of human-made emissions arising from chemical reactions between the various constituents. The indirect effects on stratospheric water vapour, carbon dioxide, and tropospheric ozone have been included in these estimates.

Table 4

Global warming potential of some greenhouse gases for three time horizons

GLOBAL WARMING POTENTIALS

The warming effect of an emission of 1kg of each gas relative to that of CO_2

These figures are best estimates calculated on the basis of the present day atmospheric composition

	Time Horizon 20 yr	100 yr	500 yr
Carbon dioxide	1	1	1
Methane (including indirect)	63	21	9
Nitrous oxide	270	290	190
CFC-11	4500	3500	1500
CFC-12	7100	7300	4500
HCFC-22	4100	1500	510

Table 4 indicates the effects of certain gases on climate change over time. For example, the effects of methane will be greater in the first few decades after release, whereas emission of the longer-lived nitrous oxide will affect climate for a much longer time. The lifetimes of the proposed CFC replacements range from 1 to 40 years; the longer-lived replacements are still potentially effective as agents of climate change. One example of this, hydro-chlorofluorocarbon-22 (with a 15-year lifetime), has a similar effect (when released in the same amount) as CFC-11 on a 20-year timescale; but less over a 500-year timescale.

Table 4 shows carbon dioxide to be the least effective greenhouse gas per kilogram emitted, but its contribution to global warming, which depends on the product of the GWP and the amount emitted, is largest. In the example in table 5, the effects over 100 years of emissions of greenhouse gases in 1990 are shown relative to there being no carbon dioxide. This is illustrative; to compare the effect of different emission projections we have to sum the effect of emissions expected in future years.

Table 5

Relative cumulative effects of man-made emissions, 1990

	GWP (100yr horizon)	1990 emissions (Tg)	Relative contribution over 100yr
Carbon dioxide	1	26000†	61%
Methane*	21	300	15%
Nitrous oxide	290	6	4%
CFCs	Various	0.9	11%
HCFC-22	1500	0.1	0.5%
Others*	Various		8.5%

*These values include the indirect effect of these emissions on other greenhouse gases via chemical reactions in the atmosphere. Such estimates are highly model dependent and should be considered preliminary and subject to change. The estimated effect of ozone is included under "others". The gases included under "others" are given in the full report.

† 26 000 Tg (teragrams) of carbon dioxide = 7 000 Tg (=7 Gt) of carbon

There are other technical criteria which may help policy-makers to decide, in the event of emissions reductions being deemed necessary, on the gases to be reduced. Does the gas contribute substantively to current and future climate forcing? Does it have a long lifetime, so that earlier reductions in emissions would be more effective than those made later? And are its sources and sinks known well enough to decide on the ones to be controlled in practice? Table 6 below illustrates these factors.

Table 6

Characteristics of greenhouse gases

GAS	MAJOR CONTRIBUTOR?	LONG LIFETIME?	SOURCES KNOWN?
Carbon dioxide	yes	yes	yes
Methane	yes	no	semi-quantitatively
Nitrous oxide	not at present	yes	qualitatively
CFCs	yes	yes	yes
HCFCs, etc	not at present	mainly no	yes
Ozone	possibly	no	qualitatively

What other factors could influence future climate?

Variations in the output of solar energy may also affect climate. On a 10-year timescale, solar variability and changes in greenhouse gas concentration could lead to changes of a similar magnitude. However, the variation in solar intensity changes sign, so that over longer timescales the increases in greenhouse gas are likely to be more important. Aerosols produced as a result of volcanic eruptions can lead to a cooling which may oppose the greenhouse warming for a few years following an eruption. Again, over longer periods the greenhouse warming is likely to dominate.

Human activity is leading to an increase in aerosols in the lower atmosphere, mainly from sulphur emissions. These have two effects, both of which are difficult to quantify but which may be significant, especially at the regional level. The first is the direct effect of the aerosols on the radiation that is scattered and absorbed by the atmosphere. The second is an indirect effect whereby the aerosols affect the microphysics of clouds, leading to an increased cloud reflectivity. Both of these effects might lead to a significant regional cooling; a decrease in emissions of sulphur might be expected to increase global temperature.

Because of couplings over time between different components of the climate system, for example, between ocean and atmosphere, the Earth's climate could still vary without being perturbed by any external influences. This natural variability could add to, or subtract from, any human-made warming; on a century timescale, this would be less than changes expected from greenhouse gas increases.

What are the major uncertainties? What should be done to reduce them?

Although it may be said that some climate change is unavoidable, much uncertainty exists in the prediction of global climate properties such as temperature and rainfall. Even greater uncertainty exists in predictions of regional climate change, and the subsequent consequences for sea level and ecosystems. The key areas of scientific uncertainty are:

- Clouds: primarily cloud formation, dissipation, and radiative properties, which influence the response of the atmosphere to greenhouse forcing

- Oceans: the exchange of energy between the ocean and the atmosphere, between the upper layers of the ocean and the deep ocean, and transport within the ocean, all of which control the rate of global climate change and the patterns of regional change

- Greenhouse gases: quantification of the uptake and release of greenhouses gases, their chemical reactions in the atmosphere, and how these may be influenced by climate change

- Polar ice sheets: important for predictions of sea-level rise. Studies of land surface hydrology, and of the impact of ecosystems, are also important.

To reduce the current scientific uncertainties in each of these areas will require internationally coordinated research, the goal of which is to improve our capability to observe, model, and understand the global climate system. Such a programme of research will reduce the scientific

uncertainties and assist in the formulation of sound national and international response strategies. *Systematic long-term observations of the system are of vital importance for understanding the natural variability of the Earth's climate system, detecting whether man's activities are changing it, parametrizing key processes for models, and verifying model simulations. Increased accuracy and coverage in many observations are required. Associated with expanded observations is the need to develop appropriate comprehensive global databases for the rapid and efficient dissemination and utilization of data.*

The main observational requirements according to the IPCC assessment report are:

- The maintenance and improvement of observations (including those from satellites) provided under relevant WMO programmes, especially GAW

- The maintenance and enhancement of a programme of monitoring, both from satellite-based and surface-based instruments, of key climate elements for which accurate observations on a continuous basis are required, such as the distribution of important atmospheric constituents; clouds; the Earth's radiation budget; precipitation; winds; sea surface temperatures; and extent, type, and productivity of terrestrial ecosystems

- The establishment of a global ocean observing system to measure changes in such variables as ocean surface topography, circulation, transport of heat and chemicals, and extent and thickness of sea ice

- The development of major new systems to obtain data on the oceans, atmosphere, and terrestrial ecosystems using both satellite- and surface-based instruments, on automated instrumented vehicles in the ocean, on floating and deep sea buoys, and on aircraft and balloons.

This GEF project will contribute towards fulfilling the observational requirements listed in the IPCC report. As the proposed new stations will be located in developing countries and operated by staff trained under the project, it will also help give effect to IPCC recommendations concerning the need to develop informed manpower in developing countries, thereby assisting them to contribute to the management of climate change.

Indeed, the IPCC is of the view that, *inter alia*, the acquisition, analysis, and interpretation of climate-related data could enable developing countries to formulate more effective national policies. Such actions are also necessary at the regional level to undertake and refine impact studies. The current unevenness in the acquisition and use of such data which is evident between the hemispheres needs to be eliminated. The IPCC further recommended that developing countries take immediate action to identify their specific needs and to determine the financial implications of such action. This project is a response to the IPCC's appeal to the international community for the mobilisation of appropriate funding in order to mount a sustained programme and create regional centres to organize information networks on climate change.

In many developing countries, the meteorological/hydrological services are the main and often the only institutions collecting and recording data of relevance to climate. If associated weather

patterns are modified, as some predict they will be as a result of climate change, then the capabilities of such services would need to be reinforced to enhance their contributions to sustainable development. This project will also contribute to this reinforcement.

Finally, the project will address some of the concerns expressed in the Final Conference Statement of the Scientific/Technical Sessions and the Ministerial Declaration of the Second World Climate Conference regarding needs and priorities for enhanced observational systems.

2. Expected end-of-project situation

Some or all of the seven proposed sites for new global stations will operate with complete instrumentation and equipment, and carry out some or part of the measurements recommended by IPCC. The parameters to be measured at each location (based on preparatory assistance missions) are given in country reports. Samples will have to be analyzed in chemical laboratories in the participating countries, except for flask samples which will sometimes be analyzed outside the countries. The resulting data will, after quality control, be sent on regular time schedules to the appropriate GAW World Data Centres, where they will be subject to further quality control and processed for publication and central storage. Upon request, this data will be available to any qualified scientist or organization for further analysis and research.

Each station will be manned by professionals trained in atmospheric chemistry and physics. All technical staff will have been trained in the operation, calibration, and maintenance of equipment; and in the chemical analysis of precipitation and aerosol samples. The exact number of professional and technical staff requirements for each station have been estimated carefully. Each station will be part of the overall facility currently being contemplated to provide routine near-real-time communication of GAW data to the WMO Secretariat. This data will be the basis for early warnings of any changes in the chemical composition and related physical characteristics of the atmosphere.

3. Target beneficiaries

The initial beneficiaries will be scientists, researchers, and experts who use the data in their experimental and theoretical studies. Their research will eventually result in: baselines for global trends and the evaluation of regional sources and sinks of greenhouse gases, and the refinement of numerical models. This will help to reduce uncertainties about the role of greenhouse gases and aerosol particles in climate change. Ultimately, planners and policy- and decision-makers, both inside and outside the countries involved, will be able to make better informed choices between options aimed at regulating emissions of greenhouse gases and aerosols. The proposed measurements will also benefit the agencies responsible for monitoring compliance with relevant international conventions and protocols. International organizations such as UNDP, UNEP, and the World Bank that work on strategies, programmes, and projects to control global warming and ozone depletion, will also be beneficiaries of this project.

4. Project strategy and institutional arrangements

The location of sites, the availability of trained scientific and operational personnel, the provision of appropriate facilities, and long-term government support are all critical to the success

of this project. Another key element is the measurement strategy for the project. Should a full set of measurements be required at *some* of the seven sites, or only selected parameters at *all* the sites?

This question arises because the ideal measurement strategy for a particular gas is dependent upon its atmospheric lifetime. Long-lived gases such as the CFCs, nitrous oxide, and carbon dioxide need to be measured at a limited number of geographic locations in order to quantify their global abundances and trends. But relatively short-lived gases (such as ozone) or gases with mainly regional sources (such as methane) need to be measured at many more sites. The identification of source and sink regions for any particular gas needs a fairly dense network of measurement sites. It should be noted that while the global trends for carbon dioxide are well established, there is significant controversy as to whether it is the oceans or the terrestrial biosphere in the northern hemisphere that provides the dominant sink for anthropogenic carbon dioxide. Short-lived gases such as ozone require a measurement system that combines ground-based measurements (which provide high-precision details) with satellite observations to create a global perspective.

In light of the above considerations, and given that many previous monitoring programmes have failed because of poor site selection and inadequate equipment and training of personnel, the project will be implemented in two phases—the Preparatory Assistance Phase and the Full Implementation Phase.

The Preparatory Assistance Phase included the visit of experts to many countries to identify the location of sites. Each site was evaluated according to several criteria, including whether certain essential facilities (such as building, all-weather access road, power and water supply, and communications facilities) and appropriate personnel would be available, and whether the government would sign and be able to comply with the host government agreement. Recommendations were then made regarding the exact number of stations to be established, the location of these stations, the variables to be measured at each station, the number of persons to be trained, the equipment likely to be required, and the proposed UNDP financial contribution for each station. Following these recommendations, the host government agreements will be signed before implementation of the project in each participating country.

During the Full Implementation Phase, the WMO, in close cooperation and full coordination with the national meteorological services of the host countries, will implement the new global stations in locations that offer sustainability and satisfy the scientific requirements of GAW and other programmes which deal with scientific issues of global change. In each country, a senior level National Project Coordinator, with a strong background in atmospheric composition monitoring, will be appointed to serve as a counterpart to the experts who will be visiting and/or residing at the sites for periods of varying durations. Assistance, as required, will be provided by WMO staff, WMO consultants, and suppliers of equipment. Even after termination of the project, WMO will continue to provide support to the stations from its Voluntary Cooperation Programme, Special Trust Fund for Climate and Atmospheric Environment Activities, and Education and Training Programme.

5. Reasons for assistance from GEF/UNDP and WMO

In the current economic situation, it is not possible for the host countries to obtain, without outside financial support, the hard currency funds needed to: purchase the complex instrumentation

systems for this project; arrange for their installation and operation; or ensure the requisite training needs for the project, including the overseas post-graduate training in atmospheric chemistry and physics.

The assistance to be provided under this project will respond to the general appeal for financial support made at the Ministerial Declaration of the Second World Climate Conference in favour of developing countries. It will also complement the efforts that host countries will undertake in line with the proposed agreement.

6. Special considerations

The last decade has revealed disturbing evidence that human activities are rapidly changing the chemical composition of the atmosphere, one of the life support systems of the Earth. We now witness the depletion of the stratospheric (upper atmosphere) ozone layer, an increase in tropospheric (lower atmosphere) ozone, a rise in carbon dioxide and methane concentrations, and higher levels of acidity in rain.

Substances introduced into the atmosphere by man may be causing a change in the climate of the planet. Some of these substances are pollutants that affect the health of human beings and animals, and damage vegetation, soil, water, and other resources. The need to strengthen the monitoring of these substances, and related research activity, has been stressed repeatedly in international forums.

WMO and its 160 members have been monitoring the composition of the atmosphere for decades through national meteorological and hydrological services. This has been accomplished mainly through the WMO Global Ozone Observing System (GO_3OS), which was established in the 1950s, and through the Background Air Pollution Monitoring Network (BAPMoN) of the mid-1960s.

Today more than 140 ground-based ozone stations, supplemented by satellites, constitute the backbone of the Global Ozone Observing System. Some 40 WMO members operate these stations with the involvement of hundreds of scientists. The ratification and implementation of the Vienna Convention for the Protection of the Ozone Layer in 1986, the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987, and its amendment in June 1990, owe much to scientists all over the world who have been working on this problem for decades.

BAPMoN is a worldwide network of nearly 200 stations, where scientists and technicians make chemical analyses of rain, snow, and the air itself. The main greenhouse gases which contribute to global warming are monitored as part of this programme. These measurements provide evidence of the changes in the global atmosphere resulting from human activities.

In 1989, GO_3OS and BAPMoN were integrated to form part of WMO's Global Atmosphere Watch (GAW). The Global Atmosphere Watch is essential to the improvement of our understanding of atmospheric composition and behaviour, and of the atmosphere's interactions with the oceans and the biosphere. It is designed to contribute to the prediction of future states of the atmosphere and related Earth systems. It is also intended to serve as a framework for activities which aim to plan, design, coordinate, and scientifically evaluate the monitoring of atmospheric composition. Decisions

affecting the environment in the 21st century will be highly dependent on the series of observations carried out within the framework of this programme.

To assist in taking such decisions and in response to increasing global concern about climate change issues, WMO and UNEP established the Intergovernmental Panel on Climate Change in 1988. Its task was to prepare assessments on the science and impacts of climate change, and examine response strategies to adapt to climate change or limit its adverse consequences. Numerous organizations, institutions, and more than 1000 scientists and experts from developed and developing countries all over the world have been involved in this work.

The conclusions of the panel were published in *Climate Change: The IPCC Scientific Assessment*[2] in August 1990. This document provides governments with the information they need to consider negotiations on a Framework Convention on Climate Change, and presents a blueprint for global action required in the near future. The report was an important input for the Second World Climate Conference, especially for the ministerial meeting and its Ministerial Declaration which called for action on various aspects of climate. The conference marked another step towards worldwide cooperation in matters related to climate change.

Countries have since begun negotiations on an international climate convention, starting with the establishment of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change. The active participation of all countries is essential to the success of these negotiations. Developing country participation is being supported through a special Voluntary Fund. It is imperative that these nations be assisted in strengthening their capabilities to contribute more fully to the mitigation of climate change.

As we move towards the next century, national meteorological and hydrological services, under the auspices of WMO, will be called upon to improve activities related to atmospheric composition and climate change. They will also need to accelerate such research to provide more accurate information needed by governments anxious to protect the global environment for future generations.

7. Coordination arrangements

This project has been developed under scientific guidance from highly reputed panels of experts. It has also drawn on several United Nations conferences, and meetings of non-governmental organizations active in the field. WMO will continue to coordinate the scientific and technical inputs of these organizations during the implementation of the project and after its completion. WMO will also ensure the coordination of project activities with national development strategies in the host countries.

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[2] Houghton, J.T., G.J. Jenkins and J.J. Ephraums, eds., *Climate Change: The IPCC Scientific Assessment*, Intergovernmental Panel on Climate Change, Report by Working Group 1 (Cambridge, U.K.: Press Syndicate of the University of Cambridge, 1990).

8. Counterpart support capacity

Preliminary discussions were held between the permanent representatives of the host countries and WMO during the Eleventh World Meteorological Congress (May 1991). The Secretary-General of WMO communicated the requirements for this project to the countries in July 1991. Indications are that the organizational support, facilities, staffing, and other resources required for project implementation will be made available. During the Preparatory Assistance Phase, efforts were made to ascertain that host country governments fully understood, and agreed to, their responsibilities, functions, and commitments both during and after the project.

C. DEVELOPMENT OBJECTIVE

To establish seven new global stations (at carefully chosen geographical sites) for the purpose of gathering accurate, high-precision data that indicates the representation of certain gases in the atmosphere, including greenhouse gases, trace gases, and aerosols. The data will also cover precipitation chemistry, solar radiation, and related meteorological parameters to arrive at a better understanding of atmospheric changes, including climate change, which have consequences for life on Earth.

D. IMMEDIATE OBJECTIVES, OUTPUTS AND ACTIVITIES

Preparatory Assistance Phase

IMMEDIATE OBJECTIVE 1

To select sites, advise on specific measurement programmes, make the necessary local plans and preparations, communicate the long-term obligations for global observatories, and discuss in detail the host government agreements with each participating country.

Output 1.1

Completion and approval of the final Project Document, including host country agreements. This implies the finalization of station sites, measurement programmes, training requirements, financial contribution proposals, and implementation plans.

Activities for Output 1.1

1.1.1 Recruit consultants for missions to six countries for a total duration of 3 man-months.

Responsible parties: WMO and all seven countries.
Target date: August 1991.

1.1.2 Make advance arrangements for visits to the countries by informing local authorities, scheduling meetings, arranging visas, and so on.

Responsible parties: WMO and all seven countries.
Target date: September 1991.

1.1.3 Undertake missions that include discussions with host government authorities; prepare reports summarizing mission results.

Responsible parties: WMO and consultants.
Target date: November 1991.

1.1.4 Finalize measurement strategy; select stations.

Responsible parties: WMO meeting of experts.
Target date: November 1991.

1.1.5 Encourage host governments to finalize and ultimately sign agreements with WMO.

Responsible parties: WMO and participating countries.
Target date: April 1992.

1.1.6 Approve the final Project Document.

Responsible parties: UNDP, WMO, and participating countries.
Target date: April 1992.

Full Implementation Phase

IMMEDIATE OBJECTIVE 2

To provide training for each station's scientific personnel in: atmospheric chemistry and physics; the calibration and operation of instruments; the techniques of sample analysis; and data reduction, reporting, and utilization. To arrange training for the station's technical and operational personnel in the operation and maintenance of instruments, and the handling of samples. To enable scientific and technical staff at the stations to meet in order to share their experience, and to receive advice on various aspects of the programme.

Output 2.1

Staff trained to handle instruments and equipment, conduct measurements, and report data.

Activities for Output 2.1

2.1.1 Select and hire candidates for training in atmospheric chemistry and physics.

Responsible parties: WMO and participating countries.
Target date: S[3] + 2 months.

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[3] Date at the beginning of project implementation.

2.1.2 Conduct training in atmospheric chemistry and physics.

Responsible party: WMO.
Target date: S + 12 months.

2.1.3 Select and hire candidates for training as operational personnel.

Responsible parties: WMO and participating countries.
Target date: S + 8 months.

2.1.4 Conduct on-the-job training of operational personnel after delivery of instruments.

Responsible parties: WMO and consultants.
Target date: S + 13 months.

2.1.5 Organize a workshop on station operations for all recipient countries.

Responsible parties: WMO and participating countries.
Target date: S + 15 months.

2.1.6 Organize seven small consultations, one for each recipient country and its twinning partner/s, to plan and design collaboration in scientific analysis.

Responsible parties: WMO and participating countries.
Target date: S + 18 months.

IMMEDIATE OBJECTIVE 3

To provide instruments and equipment for the seven global stations.

Output 3.1

Specification, selection, purchase, delivery, installation, and operation of instruments and other equipment, along with consumables and spares to last two years.

Activities for Output 3.1

3.1.1 Obtain and evaluate quotes from instrument manufacturers.

Responsible parties: WMO and participating countries.
Target date: S + 6 months.

3.1.2 Purchase and deliver instruments and other equipment.

Responsible parties: WMO, UNDP, and suppliers.
Target date: S + 11 months.

3.1.3 Check, install, calibrate, and test instruments.

Responsible parties: WMO with experts and participating countries.
Target date: S + 14 months.

IMMEDIATE OBJECTIVE 4

To ensure the operation and periodic calibration of instruments; the handling, storage, and analysis of samples; and the reporting and archiving of data. To ensure that continuous measurements are taken in accordance with established programmes and procedures, and post-project arrangements are put into place.

Output 4.1

Monitoring stations equipped with well-trained staff and operating in accordance with established measurement programmes and procedures.

Activities for Output 4.1

4.1.1 Organize long- and short-term expert consultations in various aspects of countries' instrumentation and measurement.

Responsible parties: WMO, consultants, and participating countries.
Target date: S + 24 months.

4.1.2 Establish collaboration with analytical laboratories within and outside the countries for the analysis of samples.

Responsible parties: WMO and participating countries.
Target date: S + 12 months.

4.1.3 Organize a workshop to evaluate project implementation, and to make recommendations on post-project arrangements.

Responsible parties: WMO, UNDP, and participating countries.
Target date: S + 30 months.

A preliminary workplan has already been prepared. A detailed workplan, by country, will be prepared by WMO at the start of implementation, in consultation with the National Project Coordinators and, as appropriate, the consultants and the instrument suppliers.

E. INPUTS

1. Global Environment Facility/UNDP

For the purpose of this Project Document, it is clearly understood that the needs for full-fledged GAW global stations in the seven countries exceed the funds available. It has therefore been assumed that out of UNDP's total funding of US$ 4.8 million, a sum of US$ 4,248,000 will be available to WMO as the executing agency to cover all or part of the items listed below, with 13 percent of this latter amount (US$ 552,000) going towards reimbursing WMO for implementation support costs.

Assignment of international staff

- Consultants to advise on site selection, measurement programme, number of nationals to be trained, local requirements, preparations, and planning, during the Preparatory Assistance Phase (3 man-months)

- Consultants for instruments and equipment (installation, calibration, operation, maintenance) and on-the-job training during the Full Implementation Phase (about 87.5 man-months).

Equipment

Instruments and equipment for the seven new global stations.

Training

Training of nationals from the recipient countries, as detailed in the training component and the country reports.

2. World Meteorological Organization

Since the stations to be established under this project will be an integral part of the GAW network of stations, WMO will play an active role in project implementation. Through its Secretariat and data centres, WMO will provide advice, staff training, guidance, and technical assistance concerning, as applicable, the siting of stations, the instruments and equipment to be supplied, and the operational standards and procedures to be followed with regard to data acquisition, data quality control, analysis, archiving, reporting, and utilization. In accordance with normal GAW practice, all this will be done, as applicable, prior to, during, and after the project. At its one-month special course held every year in Budapest, Hungary, to train observers carrying out measurements at GAW stations, WMO will give priority to nationals of the selected countries. Under the WMO fellowship programme, priority will again be given to funding one fellowship per country to enable well qualified WMO meteorologists, who will be involved in the scientific aspects of the stations, to take university-level courses in atmospheric chemistry and physics at suitable institutions.

3. Government inputs

Host country governments will be responsible for providing: staffing (including qualified candidates for training), premises, utilities, secretarial services, operating costs, and maintenance costs after the end of the various warranty periods. They will also arrange local travel for consultants and counterparts. These inputs are likely to amount to US$ 1.2 million (in kind) for all the seven participating countries together. The exact amount estimated for each country will be determined and attached to the final agreement.

F. RISKS

Risks that could delay or prevent the achievement of project outputs and objectives are listed below.

<u>At the outset of the project</u>

1. The required experts could be unavailable, unwilling to be available for the necessary length of time, or difficult to attract.
   Estimated probability: Low.
   Possible corrective measure: The WMO Secretariat will do its utmost to hire suitable consultants as needed.

2. The complexity of the national and administrative regulations could lead to in-country problems and delays.
   Estimated probability: Medium.
   Possible corrective measure: The WMO Secretariat and UNDP country offices will monitor and expedite proceedings.

<u>During the project</u>

1. Staff trained under the project could be unemployed or underemployed at stations.
   Estimated probability: Medium.
   Possible corrective measure: Governments guarantee against this risk under the host government agreement, paragraph (b).

2. Infrastructure and facilities for the station may not be available on time.
   Estimated probability: Medium.
   Possible corrective measure: Governments guarantee against this risk under the host government agreement, paragraph (c). In addition, it is agreed that funds may be shifted, as needed, from the delinquent countries, if any, to the countries where implementation is on schedule.

3. Data produced under this project may not be utilized within the country.
   Estimated probability: Medium.
   Possible corrective measure: Governments guarantee against this risk under the host government agreement, paragraph (i).

After the project

1. Station operations and/or data reporting could be discontinued because trained staff, consumables, spare parts, and/or premises are no longer available.
Estimated probability: Medium.
Possible corrective measure: Governments guarantee against this risk under the host government agreement, paragraph (g).

G. PRIOR OBLIGATIONS AND PREREQUISITES

Each host government will enter into an agreement with WMO wherein it will give assurance that the government inputs described above will receive budgetary and other necessary approvals, and will be available for timely implementation of the project, and for the continuity of measurements and data reporting after project termination. The agreements will be finalized after the Project Document has been approved in principle. Implementation of the project will not begin in any country until the host government agreement for that country has been signed.

For each host country, the Project Document will be signed by UNDP, and UNDP inputs to the project will be provided subject to UNDP being satisfied that the government's obligations under the agreement have been fulfilled, or are likely to be fulfilled. If, during implementation, it appears to UNDP that one or more of the government's obligations is or are not or may not be fulfilled, UNDP may, at its discretion, either suspend or terminate its assistance to this project in that country.

H. PROJECT REVIEWS, REPORTING AND EVALUATION

The project will be subject to tripartite review by representatives of the governments, WMO, and UNDP, at least once every twelve months. The first meeting for such review will be held in the last quarter of 1992 and will, *inter alia* and as applicable, reconsider the allocation of funds for those participating countries which may not, by then, have signed the agreements or started implementation, with a view to satisfying the needs, if any, identified in the other countries where implementation may have begun. The WMO Secretariat, making use, as necessary, of reports from National Project Coordinators and consultants, will prepare and submit to each tripartite review meeting a Project Performance Evaluation Report (PPER). An independent evaluation of project implementation will be made at the end of the third year.

Project terminal reports, also prepared by the WMO Secretariat, using as necessary, reports from National Project Coordinators and project consultants, will be considered at the terminal tripartite review meeting. The reports from National Project Coordinators and project consultants shall be prepared in draft at least four months prior to the terminal tripartite review meeting.

I. LEGAL CONTEXT

This Project Document shall be the instrument envisaged in the Supplemental Provisions to the Project Document, attached thereto. The host country implementing agencies shall, for the

purpose of the Supplemental Provisions to the Project Document, refer to the government cooperating agencies described in the Supplemental Provisions.

The following types of revisions may be made to the final Project Document with the signature of the UNDP Resident Representative only, provided he or she is assured in writing that the other signatories of the Project Document have no objections to the proposed changes:

- Revisions in, or additions to, any of the annexes of the final Project Document
- Revisions which do not involve significant changes in the immediate objectives, outputs, or activities of the project, but are caused by the rearrangement of inputs already agreed to or by cost increases due to inflation
- Mandatory annual revisions which rephase the delivery of agreed project inputs or result from increased expert or other costs due to inflation, or take into account agency expenditure flexibility.

J. BUDGETS

A budget showing the GEF/UNDP contribution to the project is attached.

PROJECT BUDGET COVERING GEF/UNDP CONTRIBUTION
(in US$)

Project Title: Global Monitoring of Greenhouse Gases Including Ozone
Project Number: GLO/91/G32/B/1G/16

		TOTAL m/m	TOTAL $	Prior year 1991 m/m	Prior year 1991 $	1992* m/m	1992* $	1993* m/m	1993* $	1994* m/m	1994* $
10.	PROJECT PERSONNEL										
11.	International experts										
11.50	Consultants	87.5	700,000	--	--	25.2	202,000	48.1	385,000	14.2	113,000
11.97	short-term consultants	2	35,000	2	35,000	--	--	--	--	--	--.
11.99	Subtotal: experts/ consultants	89.5	735,000	2	35,000	25.2	202,000	48.1	385,000	14.2	113,000
16.	Mission travel		40,000		--		8,000		16,000		16,000
19.	Personnel component total:		775,000		35,000		210,000		401,000		129,000
30.	TRAINING										
31.	Fellowship		435,000		--		127,000		239,000		69,000
32.	Group training		145,000		--		27,000		72,000		46,000
39.	Component total:		580,000				154,000		311,000		115,000
40.	EQUIPMENT										
41.	Expendable equipment		113,000		--		30,000		63,000		20,000
42.	Non-expendable equipment (including installation)		2,760,000		--		775,000		1,540,000		445,000
49.	Component total:		2,873,000		--		805,000		1,603,000		465,000
50.	MISCELLANEOUS		20,000		--		6,000		7,000		7,000
59.	Component total:		20,000				6,000		7,000		7,000
93.	SUPPORT COSTS (to WMO):		552,000		--		112,000		276,000		164,000
99.	UNDP TOTAL CONTRIBUTION:		4,800,000		35,000		1,287,000		2,598,000		880,000

* Figures for 1992, 1993 and 1994 are indicative and subject to amendment when the host country agreements are signed.