The UNESCO Courier

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BUILD YOUR OWN WEATHER STATION

8 pages for children

Unlocking the secrets of tomorrow's weather

Photo © Annette Diaz-Lewis, Mexico City, Mexico

TREASURES OF WORLD ART

MEXICO

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Tlaloc the rain-giver

The most ancient among the fertility gods of the pre-Columbian peoples of Mexico was the rain-god Tlaloc. He was highly revered by the Totonacs, whose civilization is known to have flourished from the 7th to the 14th century on the coast of the Gulf of Mexico in what is now the Mexican state of Veracruz. This recently-discovered Totonac earthenware statuette depicts a warrior bearing the attributes of Tlaloc. The circles round the eyes represent clouds (in the Totonac language "tlaloc" means cloud) and the nose and mouth are in the form of the serpent-jaguar, symbolizing the powers of the earth. These attributes of Tlaloc stood for the life-giving union of agriculture and the burgeoning earth. This statuette is now in the Jalapa Museum, State of Veracruz, Mexico.

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25th anniversary of the Universal Declaration of Human Rights

Photo © APN

UNLOCKING THE SECRETS OF TOMORROW'S WEATHER

The modern meteorologist now has at his or her disposal a vast new battery of instruments for observing and predicting the weather, from radar and rockets to computers and earth-girdling satellites. Certain limited forms of weather modification are already being practised with success, warning systems are taking some of the un-known out of hurricanes, and forecast-ing is reaching new standards of pre-cision. Full mastery of the weather is still a dream, but mankind has begun to forge the key that will unlock the secrets of tomorrow's weather.

The 100th anniversary of the U.N. World Meteorological Organization marks the transformation of the study of the weather into a revolutionary new science on a planetary scale.

UNLOCKING THE SECRETS OF TOMORROW'S WEATHER

A Soviet high-altitude research rocket etches a pattern, recalling the umbrellas on our front cover, against the Arctic night sky. The size of this fiery umbrella, or bow and arrow trajectory, may be judged against the tiny figures of research scientists at bottom left of photo.

Photo © APN, Moscow

by Kaare Langlö

KAARE LANGLO of Norway is Deputy Secretary-General of the World Meteorological Organization. He has devoted his entire scientific career to research in meteorology and was responsible for planning the World Weather Watch to provide the first truly global weather observation and data system. He is a member of the Norwegian Geophysical Society and the author of many studies and papers on meteorology.

THE well-known saying that "weather knows no frontiers" can be said to have a special meaning in 1973 when meteorologists in all countries of the world are celebrating 100 years of organized international collaboration. Most people will probably shrug their shoulders and say: "Yet another centenary; what does it mean to me?"

One of the purposes of this issue is to demonstrate what a knowledge of weather and climate means to every one of us, and to every country in the world—in other words, it deals with some of the global aspects of weather and how the international co-operation is organized after 100 years of experience.

In recent years two apparently unconnected events have had a revolutionary impact on meteorology. One of these is the emergence of high speed electronic computers capable of providing sufficiently rapid numerical solutions to the mathematical equations used to describe atmospheric motions. Major advances in numerical weather prediction have resulted from this capability and will doubtless continue.

The other noteworthy event is the

development of the artificial earth satellite. The launching of the first weather satellite TIROS I in April 1960 surprisingly quickly showed that the latest technological devices could be used profitably by the meteorologist. The potential value of this unique new platform for global observations (see later in this article) was no doubt one of the prime reasons why the United Nations General Assembly twenty months later adopted a decision which in meteorological circles is accorded historic importance and which led to the concept of the World Weather Watch.

What is the World Weather Watch?

The main purpose of the World Weather Watch (WWW) is to establish a system by which all countries can be provided with the weather data and other information they need to carry out their national obligations. All nations participate actively in the system both by receiving and by transmitting weather information. In addition, some countries have specific international functions; thus there are three World Meteorological Centres (Washington, Moscow and Melbourne) and 21 Regional Meteorological Centres at which extensive use is made of high speed electronic computers.

These large meteorological centres carry out numerical forecasts of the future state of the atmosphere, making use of physical laws expressed in mathematical equations (called "models"). In addition to the problem of developing suitable "models", there are three major conditions which must be satisfied:

- We must know the actual state of the entire atmosphere preferably at a chosen hour (i.e. by making represen-

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OF ICE AND MEN

Photo © USIS

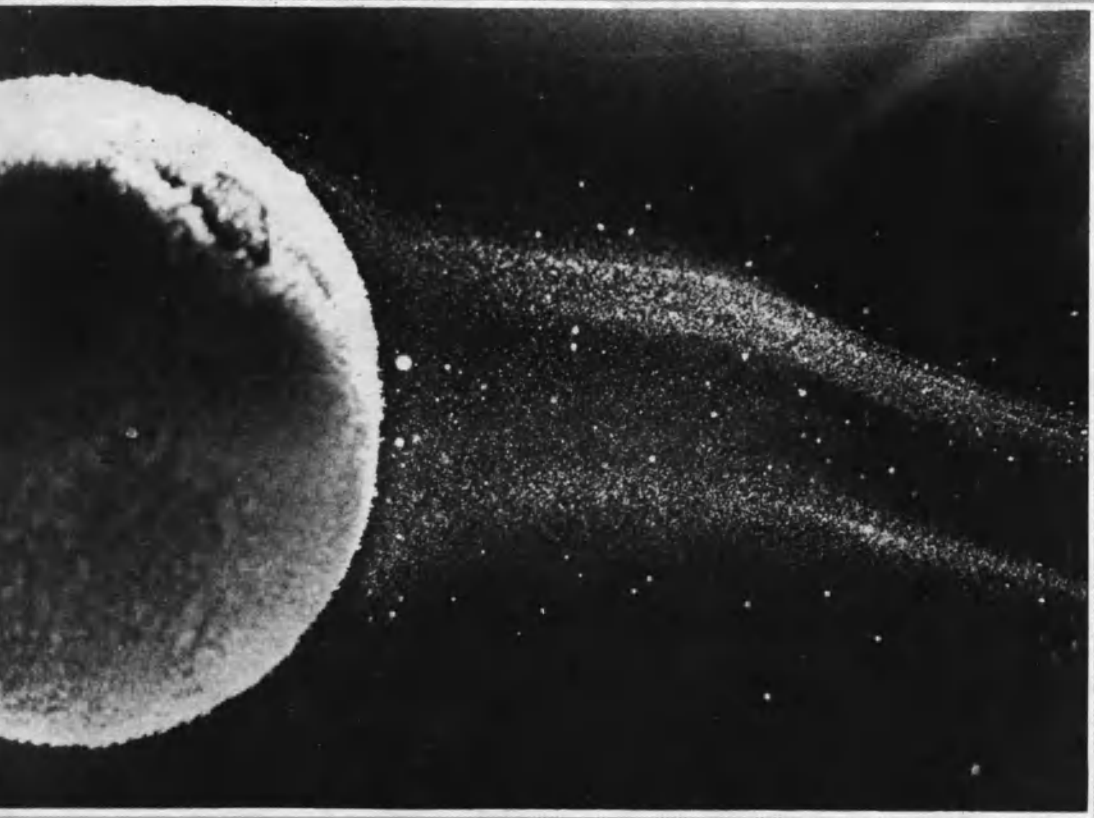

Photo © APN

The ancient Goths of northern Europe believed that storm clouds were evil forces that threatened their gods. Archers were used to repel these "invaders" as this 16th century engraving published in Rome (below) shows. Today their action finds a much more scientific echo in the rockets (right) fired at clouds to eliminate or reduce the destructiveness of hailstones. In recent years the study of the behaviour of hail has become a special branch of research. Scientists have now succeeded in producing artificial hailstones in the laboratory (above).

Photo © Bibliothèque Nationale, Paris. Originally published in "De Gentibus Septentrionalibus", by Olaus Magnus, Rome 1555.

tative observations of temperature, pressure, humidity, wind and so on) and also the conditions at the lower and upper boundaries of the atmosphere;

- We must have the facilities to process this vast quantity of observational data very quickly in order to reduce to a minimum the time delay between the hour of observation and the hour of issuing the forecast;

- We must be able to transmit the original observations rapidly to suitable forecasting centres and to distribute quickly the products of such centres (weather analyses, prognoses, forecasts, warnings, etc.) to their users.

Until the present day the meteorologist has always had to accept a compromise between what is scientifically desirable and what is economically feasible in obtaining data from a world-wide network of meteorological observing stations.

For this reason it has only been practical to sample the state of the atmosphere at fixed hours by taking point observations at a network of stations on the surface of the earth and upper air soundings up to say 30-40 km, by means of balloons carrying instruments transmitting meteorological observations by radio.

The present world network of surface meteorological stations consists roughly of about 9,000 stations on land, to which should be added more than 6,000 ships which send observations when plying the high seas. Soundings are made from about 700 stations on land and from a few stationary weather ships in the North Atlantic and North Pacific Oceans, supplemented by observations from a number of aircraft.

It may seem that these sources would provide a wealth of data and that little more could be required. It is of course true that the density of observations over some of the world's land area is already perfectly adequate; but some three-quarters of the surface of the globe is covered by the oceans and a high proportion of this vast area is far removed from regular shipping routes.

Many land areas in developing countries, particularly where the climatic conditions are harsh, still lack adequate observing networks. The conditions at the boundaries of the atmosphere are also insufficiently known. This means that we do not know the structure of the atmosphere over most of our planet in sufficient detail to understand the physical processes taking place at any given moment. Since current methods of weather forecasting start from a knowledge of actual weather conditions the implications of this ignorance are very serious.

The first condition for satisfactory numerical weather prediction is therefore not fulfilled. This is why one of the first goals of WWW is to plan and develop a truly global observational system. The most promising new techniques to fill the major gaps are meteorological satellites and the so-called constant-level balloons, i.e. relatively large balloons floating with the wind at a constant pressure level in the atmosphere which transmit their observations by radio. Although not a new technique—one of the "secret weapons" during the last world war—the automatic buoy weather station should also be mentioned as a promising supplementary means of obtaining data from ocean areas.

Photo John Dominis © Life

RING OF PROTECTIVE FIRE. Frost can cause incalculable damage to fruit and other crops and is difficult and costly to combat. Above, a huge gas-burner, in the form of a pipe pierced at intervals with holes, encircles an orchard. Burners like these can raise temperature over a limited area to about 25 degrees C.

Meteorological satellites have gone through a remarkable development during the past 13 years. In the beginning they were only able to take television pictures of cloud cover but nevertheless proved immediately to be of great practical value in detecting and tracing the movements of one of the most devastating phenomena in the atmosphere: the tropical cyclone (hurricane, typhoon). In September 1961 hurricane "Carla" was discovered by Tiros 3 in time for 500,000 people to be evacuated from the threatened areas in Texas and Louisiana and only 46 lost their lives.

The introduction of the APT (Automatic Picture Transmission) System was a great success. This system permits any country to receive television pictures direct from the satellite while it is passing overhead by means of relatively simple equipment, and today many hundreds of such stations are in operation all over the world and greatly assist in daily forecasting for the public and aviation.

The same polar orbiting satellites as used for these observations are also able to measure the approximate vertical temperature distribution over cloudless areas. This technique is still in its experimental stages but is sufficiently advanced to create serious

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discussion of the possibility of reducing the number of the very expensive Ocean Weather Ships now stationed in the North Atlantic.

Other types of meteorological satellites are placed in stationary positions over the equator. From a distance of 36,000 km. above the earth these satellites watch the atmosphere permanently and provide invaluable data, particularly from tropical areas.

Constant-level balloons have been tested with promising results in the southern hemisphere. One such balloon circled the Antarctic continent several times, and their average lifetime is 100 days. It is also possible to use satellites to collect observations from a large number of constant-level balloons and automatic buoy stations.

Unsung heroes who risked their lives

It would be a great omission to discuss the observing system without mentioning the human effort involved. Consider the observers, those unsung heroes who provide the basic information on which the whole structure of meteorology depends.

Their task is one of the most inconvenient and modestly paid jobs imaginable. Their duties require them to be present at fixed hours of the day and night, on Sundays and public holidays as well as weekdays. They must follow implicitly the procedures laid down as the result of a hundred years of international collaboration.

If we imagine that it is now time to make the next observation, we can visualize a silent army of some 8,000 to 10,000 people of all nationalities, in all climates from arctic to tropical, making the same observations at the same standard hour. They will read thermometers placed in a special white-painted screen, determine the wind speed and direction over an interval of ten minutes, estimate the cloud cover and cloud type according to an International Cloud Atlas, and so on.

On board several thousand merchant ships, officers are voluntarily making similar observations at the same standard times. These observations must not only be made at standard times but also regardless of weather conditions, however severe they may be. In raging snowstorms or the sweltering tropical heat these brave people do an exacting job for a modest remuneration. No wonder the word "heroes" has been used to characterize them.

Some have given their lives for meteorology. During a severe winter storm at the Norwegian weather station at Jan Mayen, the observer never returned from a night visit to the meteorological screen which was only 20 metres from the hut where he lived. He must have lost his sense of direction and was found the next day frozen to death by the blizzard.

The second condition that must be satisfied if weather forecasting is to be improved is that data-processing technology must provide a rapid means of dealing with a very large amount of global data.

An example will best explain the reason for this condition and consequently the importance of modern high-speed electronic computers to meteorology. As already mentioned, the basic mathematical equations which govern the motions of the atmosphere have been known for many years. It has, however, not yet been possible to solve these equations in their most general form and a number of simplifications and assumptions have had to be made.

In 1922 the English theoretician, Lewis F. Richardson, devised an approximate numerical solution to these equations. The simple desk calculator, which was all that was available at that time, could not handle the job. Richardson himself once worked hard for six weeks to produce an (unsuccessful) forecast for 12 hours; he estimated that 64,000 calculators would be necessary to keep abreast of the changing weather patterns.

The high-speed electronic computer has made calculations of this magnitude feasible and they are now used in many countries to prepare or assist in the preparation of the prognostic weather maps which constitute the basis on which forecasts are made.

The World Weather Watch is based on the most modern techniques of data processing. Each World Meteorological Centre prepares meteorological charts for very large areas and distributes them promptly to other world, regional and national meteorological centres.

It is a basic principle of the World Weather Watch that each national meteorological centre has an obligation to collect and disseminate a selection of weather data for use by the rest of the world. In return, each national meteorological centre receives the global data it needs and has access to those products (charts etc.) of the world and regional centres which are required to meet its national commitments.

What the telegraph hath wrought

There remains the third condition that must be satisfied to improve weather forecasting—efficient telecommunications. A global telecommunication network of higher speed and greater efficiency, is an integral part of the World Weather Watch plan.

Telecommunications are often called the "life-blood" of meteorology. And in this respect two events have had enormous consequences for the development of weather forecasting. The first was, of course, the invention of the electric telegraph and its practical introduction both in North America and in Europe in the 1840s. The second was a disastrous storm which caused heavy losses to the Anglo-French fleet in the Black Sea on November 14, 1854.

Some time after this storm a detailed study was made to see whether it could have been forecast had a weather service based on telegraphed reports then existed. Napoleon III, who commissioned the study, received an affirmative report from Leverrier, and on the same day he gave the famous French astronomer orders to organize a telegraphic weather service. This soon led to the establishment of official meteorological services in a number of countries including England in 1861, France in 1863 and Norway in 1866.

International interest in meteorology

was growing apace and important international conferences were held in Brussels, in 1853, and in Leipzig, in 1872. The first world-wide effort, at governmental level, to standardize and improve international meteorological activities was made a century ago with the holding in Vienna of the first International Meteorological Congress, in 1873. From this Congress was born the International Meteorological Organization which, in 1951, was transformed into the present World Meteorological Organization.

A world-wide telecommunication network for meteorological purposes has been in existence for many years and has been further developed under the auspices of WMO. WWW provides for a main trunk circuit interconnecting the three World Meteorological Centres and appropriate regional centres. This trunk circuit will be of full duplex type and will constitute a closed loop, thus making it possible to transmit simultaneously in opposite directions around the earth.

In 1973 a large part of this circuit is in full operation. WWW also provides for regional telecommunication networks for the collection of observational data from defined parts of the world and for its transmission to centres on the main trunk circuit. These networks are used for the distribution of observation data, analyses and prognoses from world and regional centres to national centres.

Telecommunication satellites are used to provide some of the links in the global telecommunication system such as Dakar-Paris and India-Australia.

Balloons, buoys and satellites for longer-range forecasts

WHAT are the main trends in meteorological research?

It should be clear from the above description of WWW that an enormous effort is being made to build up an efficient world system for exchange of the weather information used both for routine daily weather services and for research.

But our aims—and the wishes of the United Nations General Assembly—go beyond that. We would like to know whether it is possible to forecast the weather longer into the future, for say two weeks, with reasonable accuracy and we would like to know whether it is possible by means of electronic computers to predict future climatic changes and to tell whether such changes are natural or caused by man's activities.

These, in brief, are the purposes of the Global Atmospheric Research Programme (GARP), a joint undertaking between WMO and the International Council of Scientific Unions.

What do we need to do in order to extend the forecasts further into the future? Do we for instance need measurements higher up in the atmosphere and do we need to take into account the changes in ocean temperatures?

The first question is relatively simple. The mass of air above say 30 km. is so negligible that in most cases it can be neglected in the "models" used in the computer. Likewise it is not necessary to take into account the phenomena in the higher atmosphere —the ionosphere—which is very important for the transmission of radio-waves but is of no significance for weather phenomena.

On the other hand, although the temperature changes in the upper levels of the ocean are much slower than in the atmosphere and may be neglected in short-range forecasting, such temperature changes must be taken into account when we attempt to make forecasts for more than a week.

The basic assumption behind GARP is that the day-to-day changes in the weather and also the larger fluctuations, such as the serious drought periods now experienced in Africa, are to a large extent controlled by fluctuations in the so-called "general circulation" of the atmosphere.

In order to improve our understanding of these processes and to produce reliable forecasts for more than three days we need to do two things:

- design the best possible theoretical "models" of the atmosphere and test them in the computer, and,
- arrange "experiments" in the atmosphere to provide the necessary data for the design of such "models" and test how good they are.

GARP therefore includes a number of experiments: A GARP Atlantic Tropical Experiment (GATE) will study specific tropical problems in 1974 (see page 21); a Polar Experiment will study the rôle of the Polar Regions; and the Monsoon Experiment will study the entire monsoon phenomenon from its pre-onset to its full withdrawal.

Finally, a first Global Experiment is planned for 1977 to seek overall answers to the questions raised above. As a by-product it is also hoped that it will assist in determining the most efficient and economical system of global observations. To be successful, a much denser network than at present provided by WWW will be necessary.

The Global Experiment—using the whole atmosphere as its laboratory—calls for five geostationary satellites which it is hoped will be provided by U.S.A. (2), U.S.S.R., Japan and the European Space Research Organization (ESRO). In addition to the usual polar orbiting satellites, the experiment also requires a large number of constant level balloons and automatic buoy stations to obtain better coverage from the tropics and the Southern Hemisphere.

Vast amounts of data from these sources will be fed into powerful computers and it could be that the year of the experiment—1977—will be the year that meteorologists have been waiting for during the past 100 years; perhaps the atmosphere will finally disclose some of its remaining secrets and give the answers to at least some of our questions.

The importance of these global research efforts is well understood both by the man in the street and by governments. It is not necessary to blow the great trumpet of alarm to obtain support for these efforts since it is obviously in the interest of mankind to know more about the behaviour of the atmosphere and the future of our climate.

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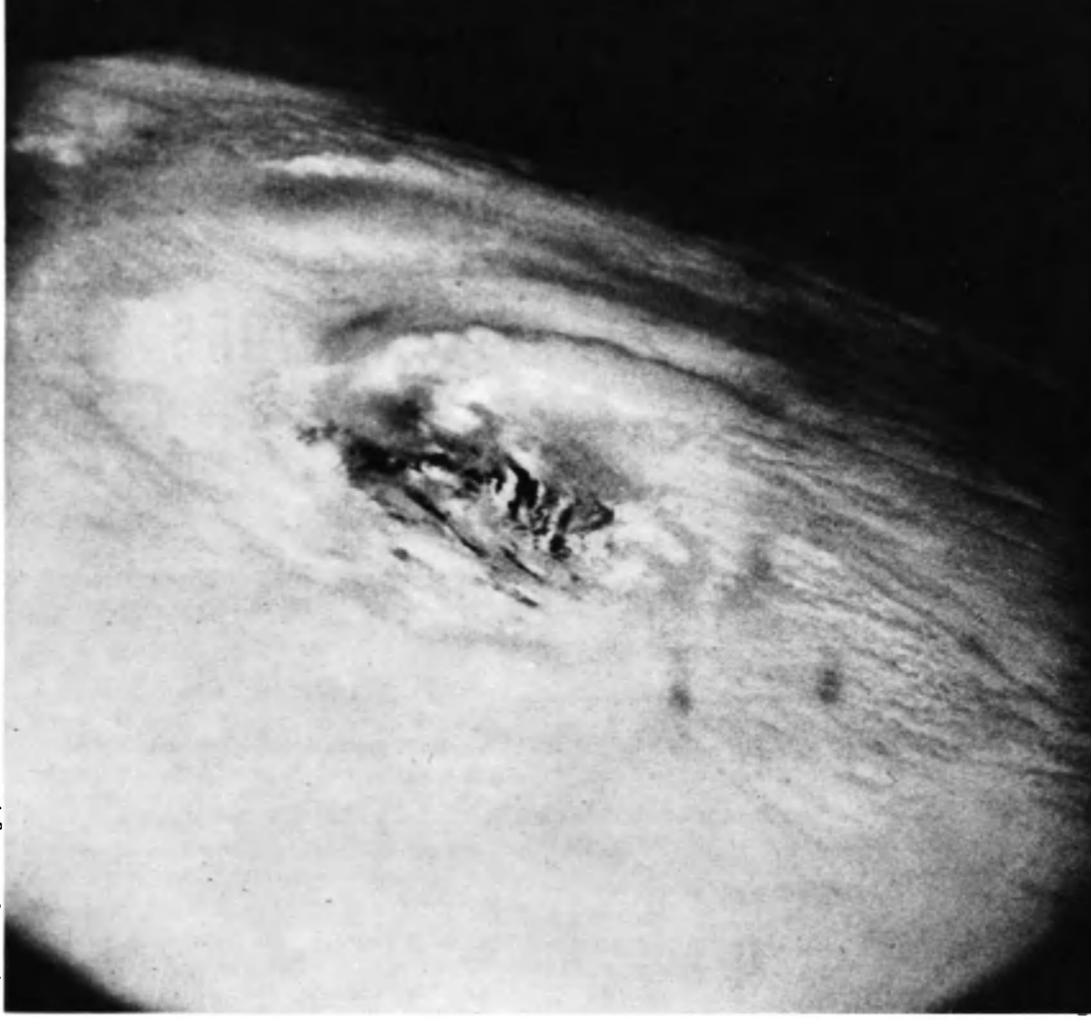
Nature on the rampage

The most violent of all storms, a tornado is a vortex of rapidly spinning air seen as a funnel-shaped cloud that conceals winds of hundreds of kilometres an hour. Tornadoes are born where air currents of different temperature, density and moisture collide and a mass of cold air forces its way beneath warm moisture-laden air. Though rarely more than a few hundred metres wide and averaging speeds of 40 km. an hour, they leave a swathe of devastation wherever their whirling tips touch down. Photos left and below left record the fearful advance of two "twisters" as these storms are called. Tornado in lower photo reaching earthwards from a storm cloud resembles a rampaging elephant's trunk. Right, spacecraft view of Hurricane "Debbie" photographed in September 1961 from 160 kilometres above the Atlantic Ocean. Debbie's "eye"—the comparatively calm centre of a maelstrom of spiralling winds—is clearly visible at centre. Unlike tornadoes which form over the land, tropical cyclones are generally born at sea. They bring shrieking winds and torrents of rain when they sweep over coastal areas. Below, rescuers pull a man to safety in Rio de Janeiro during a tropical storm that hit Brazil in 1965.



A trump card for developing nations

FEW subjects figure more prominently in the daily news than the imperative need to raise the standard of living in developing countries. Despite intensive efforts, it is common knowledge that the gap between the economics of developed and developing countries is still widening.

To combat this trend the full resources of science must be mobilized and this includes as a matter of fundamental importance the application of meteorological knowledge to economic development, whatever the level attained in the country concerned. It is no accident that the countries with the most advanced economies are also those making the most use of meteorological advice.

In any programme of economic development, attention must be given to climate and weather. Over the years it is climate that determines natural vegetation, agricultural yield, the abundance or lack of water supplies and the suitability of different areas for particular human activities. Weather influences the demand for power for industrial and domestic use, the economic operation of dams, the choice of the best period for farming activities, the safety and comfort of transport services, and many other facets of everyday life.

Economists recognize that adequate meteorological information reduces unnecessary expenditure, helps to avoid the waste of natural resources and manpower, and is vital to the planning and implementation of development programmes.

The World Weather Watch will help the developing nations to take part in and grow with the scientific and technological progress that is one of its purposes. It will help to establish the conditions necessary for effective land use and water resource management.

The new global data expected from the WWW will serve to speed up such work. For instance meteorological satellites offer many advantages to developing countries; in particular the APT system mentioned above permits early warning of devastating storms.

In trying to raise the potential of low-income countries, many governments now realize that the investment of funds in meteorological work is an essential preliminary to development projects. For instance, the meteorologist and hydrometeorologist must first acquire weather and water records if they are to avoid the pitfall of building dams at great expense in areas receiving insufficient rainfall.

Surveys and feasibility studies, sometimes sponsored by international aid programmes, today provide economic and technical data on soils, mineral deposits, forests and water resources; on power, transport and communications possibilities, as well as on agricultural and industrial potential.

No country in the world, whatever its size, can operate an effective weather service without information from neighbouring countries, and even, for many purposes, from a whole hemisphere.

The first proposal to set up an international fund to assist in establishing special stations in remote areas or telecommunications facilities goes as far back as 1873 and, it was 90 years before the idea was generally acceptable.

Today, in addition to participating in the United Nations Development Programme, WMO has established its own voluntary assistance programme. Through this programme developing countries may request assistance to establish any facility needed for WWW and any country in a position to assist may offer either equipment or services, or both. Direct financial support is also possible.

In total, during the last 20 years, WMO has carried out 200 expert missions, has granted 1,500 fellowships and has provided equipment and organized training seminars worth about 53 million dollars. In 1972 alone, the total of WMO's aid programmes amounted to more than 10 million dollars.

The very success of technical co-operation in meteorology lies perhaps in the fact that it is a truly reciprocal process in which developing countries are playing a full and indispensable role.

This co-operation also extends to the study of world-wide technical and scientific problems which are handled by eight technical commissions covering all the major branches of meteorology and part of hydrology.

Did you know that...?

WHAT are the trends in the application of meteorology to various human activities?

Most people have the impression that the most important activities of meteorologists, in the sense of economic benefit to the country, are the general forecasts for the public and the daily routine services to civil aviation. This is understandable but far from the truth.

The benefits accruing from meteorological activities, such as special forecasts for aviation, agriculture and industry, are not always easy to calculate; is it possible, for instance, to assess the value of human lives? In spite of such difficulties, comprehensive studies have been made and it has generally been concluded that the savings to the national economy are many times greater than the money spent by a country on meteorology.

What kind of human activities benefit most from meteorological services? They vary from country to country but it will be a surprise to many to see the list below which is valid for a large developed country and gives the activities in the order in which they may benefit from available meteorological services:

1) Fishing, 2) Agriculture, 3) Air transport, 4) Forestry, 5) Construction, 6) Land transport, 7) Water transport, 8) Energy production and distribution, 9) Merchandising, 10) Water supply and control, 11) Communications, 12) Recreation, 13) Manufacturing.

Here are some examples of the practical applications of meteorology.

The effect of bad weather (strong

wind, frost, rain etc.) on industry is obvious when the work takes place in the open, though manufacturing processes and working conditions in indoor industries are also influenced by the weather. It is the meteorologist's job to give advice which will enable these effects to be reduced to a minimum. It is estimated that the annual loss to the United States construction industry due to weather amounts to 3,000 million dollars.

In commerce the demand for certain commodities is greatly affected by weather conditions. The additional load placed on power supplies in cold spells is a good example of the fluctuating demand, and sales of food (ice-cream!) and clothing are also greatly dependent on weather influences. Many of the risks against which people insure themselves or their property are directly or indirectly related to the weather. The rates of insurance are often determined on the basis of climatological statistics. Marine and crop insurance are two obvious examples.

Almost every aspect of agriculture, from the planning of land use to the transportation of crops, calls for expert meteorological advice. Areas previously considered barren can today be made productive thanks to a wider understanding of the significant meteorological factors involved in plant growth.

The social consequences of applied meteorology are seldom as plain as they are in relation to food production. It has often been stated that one half of the world's population does not get sufficient to eat to maintain normal health. This horrifying figure presents a challenge that is all the more desperate because the explosive growth of population of our times tends to absorb every increase in production without providing more food per head.

By the year 2000, we are told, there will be two mouths to feed for every one today. New sources of food must be found and agricultural production must reach unprecedented levels if starvation is not to assume catastrophic proportions.

In many ways our ability to respond to this challenge depends to a considerable degree not only on opening up new land for crops but also on preventing the losses which now result from climate and weather. A much more detailed knowledge of the range of climatic fluctuations in food-producing regions is necessary, as well as a thorough understanding of atmospheric processes if damaging weather conditions are to be predicted far enough ahead.

The implementation of the World Weather Watch should enable meteorologists to play a major part in the food production campaign by enabling them to give better scientific advice to the agriculturalist. A stronger justification than this would be difficult to find.

The safe, efficient and regular operation of air, sea and land transport depends to a considerable extent on the weather along the route. The provision of accurate weather information and forecasts is accordingly of prime importance to these operations. The advent of high-flying jet aircraft and the use of radar and other electronic aids have not made this information redundant but have rather created a demand for more highly specialized advice.

The need to divert to an alternative airport or the effects of clear air turbulence in forcing airliners to reduce altitude also have obvious financial effects, and the coming introduction of supersonic aircraft flying higher and faster will make these problems more critical. It is extremely doubtful whether any radical improvement in accuracy can be expected over many of the world's air routes until more information is available from them. The planned global observational system would furnish this information.

Meteorological information has many other applications to transport, affecting both its safety and the economics of its operation. The effects of even relatively minor delays caused by fog, ice or snow extend beyond the personal inconvenience they cause to passengers, resulting in a loss of working hours which can hamper national economic growth.

The transport of perishable goods by land or sea also depends on specialized weather information. It has been estimated that by 1975 the total world freight costs for ocean cargoes could amount to $15,000 million per year. If better routing along minimum time paths, thus reducing storm losses, fuel consumption and time at sea, could achieve a reduction of only 1 per cent in these costs, the annual savings would be $150 million.

Who will be right in the year 2000?

THROUGHOUT history man has endeavoured to protect himself against unfavourable climatic or weather conditions. To a limited extent he has succeeded. The heating or air-conditioning of buildings, even the wearing of clothes, are attempts to modify the climate in which we must work and play. Out of doors the planting of trees or hedges, frost protection, hail suppression and even irrigation are all examples of the way in which artificial influences have been used to modify the natural climate.

At the same time man has inadvertently created changes in local climate by building large cities and polluting the atmosphere by the burning of fuels. For many years past small-scale experiments have also been carried out in local weather modification such as fog dispersal or cloud seeding to increase rainfall, but the problem of large-scale weather modification has not been solved.

It is believed that much more attention will be given to these questions in the future and in particular it would be of enormous importance if sound advice could be given to governments on the possibilities of future climatic variations and whether such variations are natural or man-made.

The possibility of numerical forecasts for longer periods, say up to two weeks, was discussed under GARP above and it is hoped that in 10 to 20 years time we shall know whether the optimists or pessimists are right.

The potential economic value of long range forecasting is not the same for all activities and is not easy to assess accurately. Aviation is not much interested in such forecasts but if farmers, fuel producers, public utilities, builders and water managers were able to make economies of five per cent only, the probable total saving has been conservatively estimated at $5,000 million per year.

The use of natural resources is another area where great progress is not only possible but will be essential because of the increasing demands on these resources.

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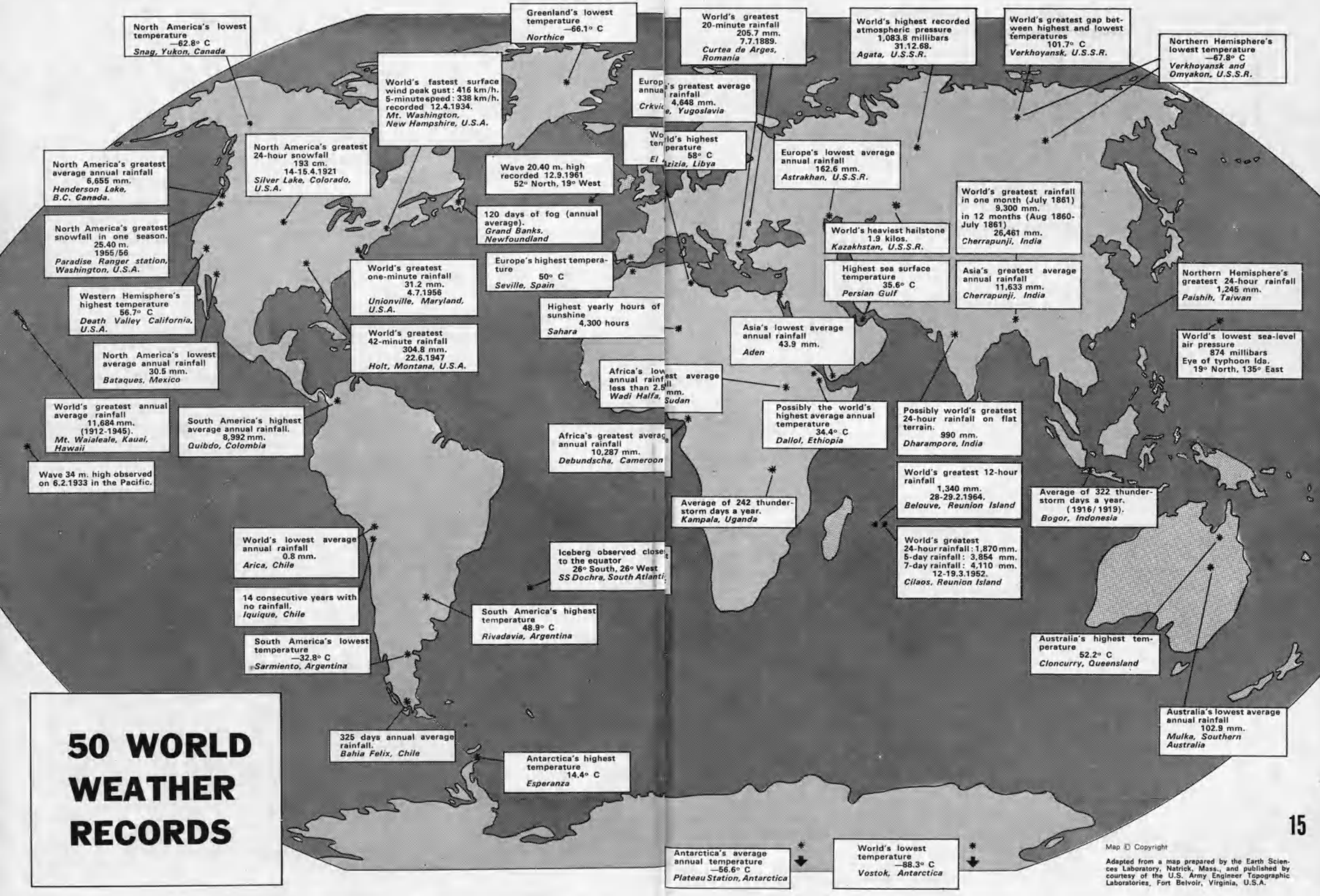
50 WORLD WEATHER RECORDS



Adapted from a map prepared by the Earth Sciences Laboratory, Natrick, Mass., and published by courtesy of the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia, U.S.A.

TOMORROW'S WEATHER *(Continued from page 13)*

For the purpose of studying these problems the WMO has established a world-wide network of "background" pollution stations which are placed far away from industrial areas and which are monitoring certain pollutants and gases in the atmosphere. In the future the measurements from these stations will play a major rôle when studying changes in climate.

FINALLY, one of the fundamental problems for the future is the clear trend towards a greater automation of all meteorological work and the increasing dependence on meteorological satellites to obtain global observations. The automation of observations, plotting of charts, calculation of future weather charts, etc., is a gradual process which changes the work of many people but creates no basic problems.

On the other hand, the greater use of satellite observations could mean that important global observing facilities will be dependent on the national plans of a few powerful countries or group of countries. While there is no reason to believe that this powerful position of a few countries will be misused in the future, it is most likely that future satellite systems will be based on a broader participation by all benefiting countries through WMO, the responsible international organization.

There is no doubt that the World Weather Watch and GARP will have a great impact on future developments in meteorology. For several generations the countries of the world have endeavoured to develop the science of meteorology without having adequate tools to do the job. We still do not have all the tools necessary but at least a great effort is now being made to state in detail what is required in terms of observations, equipment and personnel.

It would be premature to try to define the full consequences of WWW and GARP, but a great deal will obviously depend upon technological developments now in hand and those to come in the next few years. If they prove capable of meeting the complex demands placed upon them, and if the spirit of international collaboration continues to prosper and grow, the realization of these great scientific projects could be within our grasp.

At least it is certain that the age-old desire of mankind to harness the forces of nature will continue to be a driving force and the World Weather Watch and the Global Atmospheric Research Programme are natural steps in this direction. We may therefore be optimistic about the outcome which will, inevitably, bring changes affecting the way of life of each one of us. ■

Kaare Langlö

A global search for new energy sources and an all-out attack on air and water pollution

WATER is life. Not only is it vital to man's physical being but practically nothing that he undertakes can be carried out without its use in one form or another. Weather records are a prerequisite to an assessment of water resources and to the national planning of water use.

As a low-cost source of power it can constitute a sound basis for agricultural and industrial growth. At both the planning and operational stages, the forecasting of weather and floods is important if efficient and profitable use is to be made of the available resources. As an example, a one per cent improvement in the spring flood forecasting on the Peace River in Canada will permit an annual saving of one million dollars in the operation of the huge power dam at Portage Mountain.

The subsequent development of river basins will aid irrigation and drainage, flood control, soil conservation, navigation and fisheries as well as the production of hydro-electric power.

The international programmes in hydrology developed jointly between Unesco and WMO will ensure that full attention will be give to these problems in the future years.

The idea of using wind and solar energy as power sources is by no means new but is receiving increasing attention partly because these resources are non-pollutant. An essential prerequisite to future development would be a detailed meteorological survey of the distribution in both time and space of wind and solar energy in selected areas and taking into account the possibilities of using other forms of energy.

It will be necessary in the future to pay more attention to the pollution of the atmosphere.

The industrialization of the highly developed countries of the world has brought with it new problems for the meteorologist. It is a well-known fact that the burning of fossil fuels has created changes in the local climate of some areas and it is only in recent years that active steps have been taken to control the further pollution of the atmosphere.

The level of pollution in some places has reached a point at which it has serious social and economic consequences. The effect on the health of the population of breathing impure air is generally slow but nevertheless lethal when meteorological conditions inhibit the transport and dispersal of the polluting agents. In the great London smog of early December 1952 more than 4,000 people died, mainly from bronchial or chest complaints aggravated by the toxic air.

This example is, happily, one of rare occurrence, and active measures are being taken in many countries to avoid similar disasters; we should not, however, overlook the fact that the annual toll of illness resulting from pollution costs a great deal in terms of man-hours. The long-term effects of lower concentrations also constitute a serious risk to the health of the public.

A good deal more research into the relationship between health and pollution will be necessary before these effects are fully understood. Meanwhile, more rigorous legislation to control the release of pollutants will help to reduce the dangers, as will the planning of towns to ensure that there is adequate air movement to remove pollution and disperse contaminants.

Another vital problem for the future is that the burning of fossil fuel is believed to steadily increase the amount of the natural gas carbon dioxide in the atmosphere and that industrial activities are changing the amount of solid particles present in the atmosphere. The possible impact of these human activities on the future climate is now receiving considerable attention.

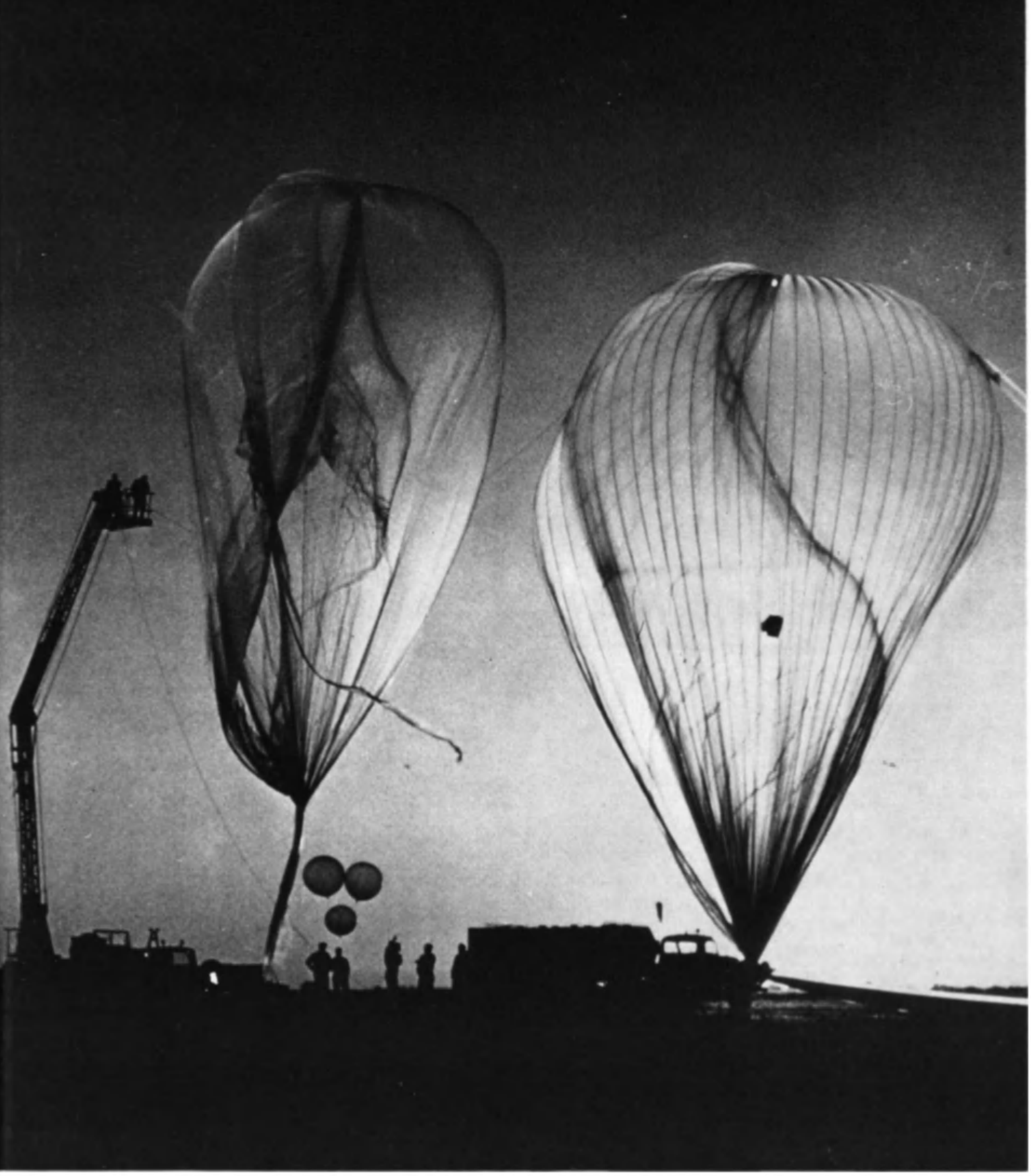


Photo © USIS

Weather research sounding-balloons, here being filled with helium, a lighter-than-air, non-inflammable gas, are able to drift for hours at heights between 25 and 40 kilometres, where there is no risk of them encountering either high altitude jets or earth-circling satellites. These explorers of the stratosphere carry measuring instruments to record air pressure and temperature, wind speed and direction and other weather information. Their mission accomplished, the instruments parachute back to earth.

IS THE EARTH'S CLIMATE CHANGING ?

For the past 30 years the temperature of our planet has been steadily dropping

by Hubert H. Lamb

HUBERT H. LAMB *of Great Britain is an international authority on the long term processes of climatic change. He is director of the Climatic Research Unit at the University of East Anglia (U.K.) and for many years has been actively engaged in international research on climate, in particular polar meteorology and the study of climatic fluctuations. Among his many writings are "The Changing Climate" (1966) and, most recently, "Climate: Present, Past and Future", a major study of which Volume I, "Fundamentals and the Climate Now" appeared last year (Methuen, London; Barnes and Noble, New York).*

AT the beginning of this century, and right up to the Second World War, the accepted view in climatology was that, though there had been significant changes of climate in the geological past—ice ages and interglacial periods somewhat warmer than now (not to mention the many millions of years of the Earth's history in warm geological eras with little or no ice even at the poles)—climate was now essentially constant and had been so for at least the last two thousand years.

Descriptions of the climates of Britain, Germany and southern Russia by Roman and Greek writers in classical times were so similar to the impressions of visitors from the Mediterranean countries in modern times that they seemed to prove the point: evidently nobody stopped to think that the coun-

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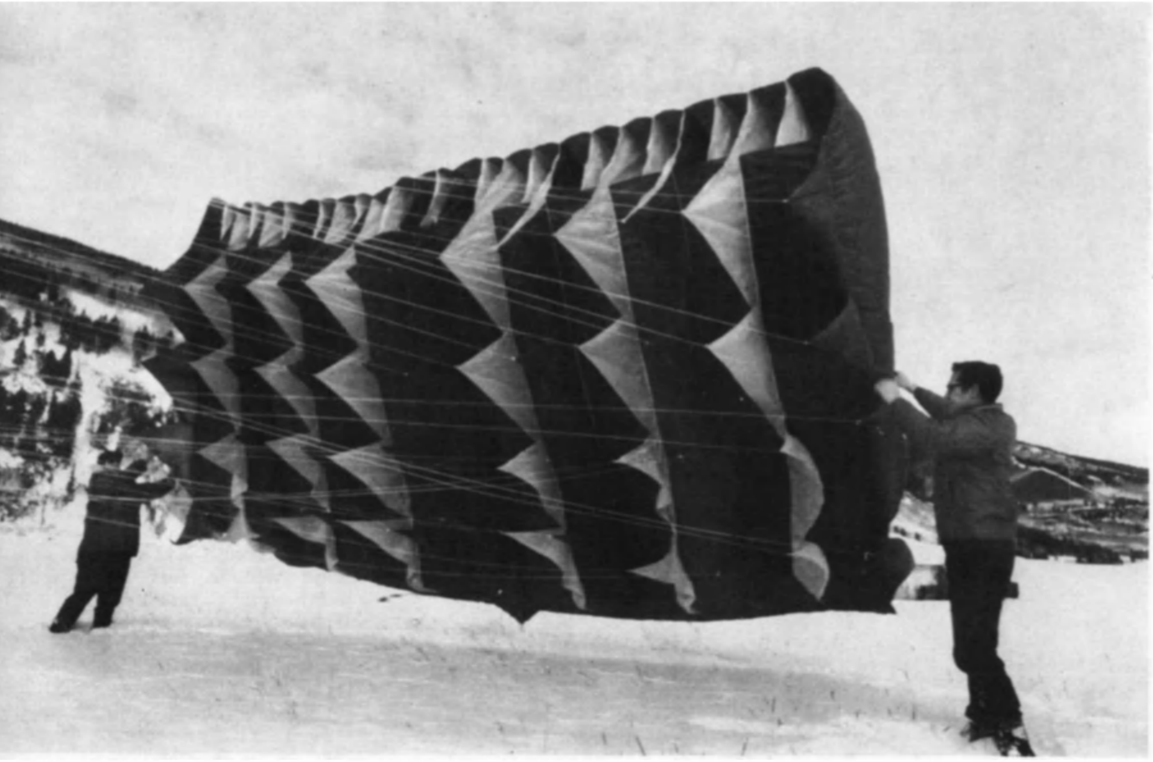

Photo © USIS

Man's major impact on the earth's climate (through atmospheric pollution, agriculture, deforestation, etc.) is largely accidental, but deliberate attempts at local weather modification date back to the early rain-making experiments of the 1890s. Today serious scientific attempts at artificially inducing rain and snow by cloud seeding are achieving a certain limited success. Silver iodide crystals, salt particles, ammonium sulfate or other substances are released into a cloud. Under favourable conditions the tiny water droplets in the cloud collect round each "seed" and fall to earth as rain or snow. Right, artist's impression of an aircraft seeding a cloud and then, at a lower altitude, gathering samples of the resulting precipitation. Left, in the Rocky Mountain region of Colorado a 6m.×3.7m. kite is released, loaded with instruments, to monitor the effects of cloud seeding to provoke the snowfalls whose melt feeds the Colorado river, life stream of the arid regions of the south-western United States.

IS OUR CLIMATE CHANGING ? *(Continued)*

tries at both ends of the journey might have been either colder or warmer than now.

Granted the variations of weather from one year to another produced alternate times of ease and difficulty and occasional disasters, but these were taken to be just random variations about the mean or, at most, the product of cycles of no more than a few years or decades duration (and somewhat capricious amplitude).

Hence, any table of climatic statistics comprising the weather observations of 30 years or more was thought to be an adequate basis for future planning (and even for the calculation, by refined statistical methods, of such rare hazards as the extreme flood or gust of wind, or the severest frost, to be expected once in 100, 200 or 500 years).

This view and these methods got into the standard textbooks, and were taught in schools and universities to the generation now holding the positions of responsibility in government and industry in most countries. The methods were, of course, sound enough, provided the series of observation data were really adequate to the purpose in mind; but this has come to be seriously questioned. In many areas the methods are still in use, pending a better understanding of climatic trends and changes.

The need for a reassessment has become clear for a number of reasons.

Computations in the United States from surface air temperature observations all over the world show that from the 1880s to some time after 1940 the Earth's climate was becoming generally warmer. The global warming over those years amounted to about half a degree Centigrade, but in the Arctic it was much stronger and amounted to several degrees between 1920 and 1940.

The ice on the Arctic seas decreased in extent by about 10 per cent and decreased in general thickness by about one third. Glaciers in all parts of the world were receding, opening up new pastures and land for cultivation, while the melt-water swelled the flow of the mountain rivers in spring and summer.

The greater warmth increased the length of the growing season by two to three weeks in England. The wild flora and forests, the cultivation of various crops, and the ranges of seasonal migration of birds and fish, all spread to new regions under the increasingly genial conditions.

Mankind takes naturally to easier conditions. Old habits of wearing heavy clothing and laying in food stocks for the winter in northern lands were more and more given up, and often unkindly attributed to the outmoded mental attitudes of the nineteenth century, while the climatic improvement affecting most of the developed countries in temperate (and higher northern) latitudes passed unnoticed for some time.

Once the climatic trend *was* noticed, speculation began about the causes and possible future consequences. Some of the first scientific work on the subject, published in the 1950s, attributed the warming to Man's output of carbon dioxide from the burning of fossil fuels (coal, oil, etc.), which increased the quantity of this gas in the atmosphere by almost 10 per cent in the first half of this century.

Carbon dioxide is a minor constituent of the atmosphere, only about three parts in ten thousand by volume; but its effects on the heating of the Earth are important. It is much less transparent to the outgoing long-wave radiation from the Earth (which it therefore traps and re-radiates, partly back towards the Earth) than it is to the incoming radiation from the sun (which it allows to pass almost without loss).

The effect is therefore something like that of a blanket or a glass-house, holding in heat which the Earth has received. It was calculated that a doubling of the amount of carbon dioxide in the atmosphere should increase the overall temperature of the Earth by 3 to 4°C.

It soon became clear, however, that carbon dioxide was not the whole story. Despite increasing production of this gas, with more and more industrialization and the ever-increasing burning of oil and other fuels, the temperature trend reversed.

For the past 25 to 30 years the Earth has been getting progressively cooler again. Around 1960 the cooling was particularly sharp. And there is by

now widespread evidence of a corresponding reverse in the ranges of birds and fish and the success of crops and forest trees near the poleward and altitudinal limits.

Moreover, the longest temperature records available in various northern countries from the early eighteenth century (in England from the late seventeenth century) showed that the previous warming had a very long history, traceable from the beginning of the record through various shorter-term ups and downs.

This meant that the warming began before the industrial revolution and could not be altogether attributable to the effects of human activity.

Thus, quite recent climatic trends have forced us to recognize that climatic changes and fluctuations are forever going on, even in our own times, and that we have to reckon with changes brought about both by natural causes and the actions of Man. The decline of prevailing temperatures since about 1945 appears to be the longest-continued downward trend since temperature records began.

In face of this and the many new types of pollution put into the atmosphere by industrial processes, bomb tests, high-flying aircraft, rockets and so on, the question of what we should expect the climate to do next is often asked but is not easily answered, and the improvement of knowledge and understanding has become an urgent task.

Investigation readily shows that the general wind circulation over the globe undergoes continual variations of vigour and to a certain extent of its basic pattern. The variations range from great predominance of the "zonal" westerly and easterly currents to considerable prominence of "meridional" (southerly and northerly) flows which are accompanied by stationary "blocking anticyclones" at certain longitudes straddling the middle latitudes zone that is normally the zone of prevailing westerlies.

THESE changes are the "mechanism" by which climatic changes are brought about, whatever the ultimate causes may be. And the effects are by no means confined to temperature and the extent of snow and ice.

Among the successive 10-year averages of yearly precipitation in many parts of the world, let us examine some figures from about 1840 for Barnaul (53° N 84° E) in the heart of Asia.

The decades of global warming in the early part of this century were a time of abnormally maintained vigour of the zonal wind circulation, and they seem to have been marked by exceptional transport of moisture-bearing winds from the Atlantic all across Europe and onwards as far as this area of central Asia.

In previous decades in the nineteenth century and again after 1950, the precipitation at Barnaul was less by a substantial percentage. As the average annual downput of rain and snow beween 1900 and 1940, equivalent to a rainfall of 482 mm. per year, was just sufficient for agriculture with careful management and some artificial irrigation, the provision of enough water in that region, as in other parts of the world, in the long term raises anxious problems.

With the rising population of Soviet Central Asia, and increasing industrial need for water as well, the authorities have been obliged to consider diverting water from the great rivers of Siberia which flow north to the Arctic Ocean.

This proposal is one, however, which demands a more exact understanding of the large-scale processes of climate than is so far within our reach. If it is undertaken, it will have to be attempted in very limited stages and with a careful watch on possible side-effects on the grandest scale.

This is because it is the water of the Siberian rivers which largely provides the ice-bearing layer of low salinity on the surface of the Arctic Ocean : if that ocean were converted into a normal salt-water ocean with an open surface free of ice, most of the Arctic would be on average 10 to 20°C warmer than it now is (and over 30°C warmer in the winter time). This change could alter the whole pattern of the wind circulation, and hence the distribution of rainfall, over the northern hemisphere.

A recent experiment (by R.L. Newson, in 1973) with a mathematical "model" of the atmospheric circulation suggests that the winters would become colder over the northern hemisphere landmasses in middle latitudes. And other studies (by a Soviet scientist, O.A. Drozdov, in 1966) have suggested, apparently in agreement with this, that the rain and snow-bearing cyclonic disturbances would be largely diverted into the Arctic, leaving many continental regions drier than before.

This problem of the water needed in the arid lands in central Asia is one point (and there may be others) at which our understanding of climate becomes involved with the human population explosion and presents mankind with a dilemma which may be very hard to solve.

The great internationally organized observation network set up by the World Meteorological Organization in the World Weather Watch (WWW, see article page 4) involving the use of satellites and many fixed observation points in all the world's oceans as well as in Antarctica, greatly improves our ability to monitor the symp-

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toms of climatic change as they occur and wherever they are most clearly seen.

And the Global Atmospheric Research Project (GARP, see article page 21) scheduled by WMO for the mid-1970's should improve our understanding of the large-scale atmospheric circulation and its interactions over the whole globe.

But there is a great need also to establish the facts of the past record of climate in as much detail as possible, to give climatology the longest possible observation base for investigating the natural climatic fluctuations and their causes. Moreover, the causes are known to go beyond meteorology as ordinarily understood. To identify them, and indeed to reconstruct the facts of the climatic record in past centuries and millennia, will entail an exciting collaboration between many branches of science and learning.

The measurements of the strength of the incoming solar radiation available from 1883 to recent years show very clearly the effects of great volcanic eruptions which put up persistent veils of dust into the high atmosphere in 1883, 1888, 1902, 1912 and 1963.

From comparison of the temperatures and wind circulation patterns prevailing in the years immediately following these and other great volcanic explosions in the eighteenth and nineteenth centuries, the effects upon climate, though temporary, are seen to be real and in some cases drastic.

BUT there has been a gradual decline in strength of the solar beam since 1945 which may have to be attributed to the sun itself. There is probably no need for undue alarm about this, because similar changes affecting climate and of the global wind pattern appear to have occurred many times before and what we are witnessing may be a recurring fluctuation of the solar output, apparently tending to repeat itself at about 200 or 400-year intervals. The effects are, however, likely to be world-wide and to pose awkward problems wherever we are exploiting climatic resources (such as water or summer warmth) to the limit.

Records exist of the number of days each year from 1861 to 1970 when the general zonal current of the westerly winds of middle latitudes has swept across the British Isles. Particularly noticeable are the high frequencies sustained between about 1902 and 1938, at the height of the global warming, and the marked decline in recent years to previously unrecorded low levels in 1968 and 1969 (and again in 1971).

Other records present the 600 year-long history of the frequency of the south-westerly surface wind in eastern England (based upon various data, including an early weather diary about 1340, and strictly daily observations in London from 1669).

They broadly parallel the record of westerly winds in the last hundred years and seem to indicate a marked decline of the westerlies, as in recent years, recurring at about 200-year intervals.

Apart from their possible ultimate origin in a long-term fluctuation of the solar energy available, linkages have been demonstrated between the changed patterns of the atmospheric circulation and corresponding persistent anomalies in the circulation of the oceans.

Because large volumes of warmer or colder than normal sea water cannot be reduced to normal at all quickly, these have persistent effects on the wind circulation which are useful in forecasting.

Among the effects of the changes of climate and the wind circulation in recent years which have given cause for concern are :

- a renewed increase (especially since 1961) of the Arctic sea ice, which has created difficulties on the northern sea routes in Soviet and Canadian Arctic waters and has produced some bad seasons on the coasts of Iceland and Greenland.
- a substantial rise, also since 1961, in the levels of the great lakes in eastern equatorial Africa and, more recently, of the Great Lakes of North America;
- some 200-year extremes of temperature in individual cold winters in various parts of the northern hemisphere (and probably also in the warmth of summer in 1972 in northern European U.S.S.R. and Finland).

The most serious effects, however, have probably been the long-continued droughts and deficient rainfalls in various parts of the world associated with shifts of the world's anticyclone belts.

Observations have shown changes of prevailing atmospheric pressure over the northern hemisphere in the 1950's and 1960's compared with the averages of the first forty years of the century. Pressure became higher, and the situations therefore frequently anticyclonic and drier, over most of the Arctic, particularly the Arctic fringe the change amounting to + 3 millibars over part of Greenland.

A belt of lower pressure than before in middle latitudes, particularly near 40°N (where the change was minus 2 millibars in some areas), marks a shift of the main cyclonic disturbances and rainfall towards lower latitudes than before. (There was also some increase of cyclonic disturbances in the inner Arctic, near the pole.)

THE subtropical anticyclones associated with the desert belt were correspondingly displaced somewhat towards the equator, and the equatorial rainbelt seems to have been restricted in the range of its seasonal migrations. In consequence, rainfall increased in Africa close to the equator, causing the lakes to rise, while drought began to afflict places nearer the fringe of the desert belt, no longer reliably visited in summer by "equatorial" rains.

Rainfall at eight places in northern India, the Sudan and at 16 to 20°N in west Africa averaged 45 per cent less in the years 1968-72 than in the 1950's. In all these areas people have been driven from their homes by the continued failure of the rains, and in the Cape Verde Islands at the same latitude in the Atlantic an emergency was declared in 1972 because of the last five years of drought.

There are indications that corresponding shifts have taken place in the anticyclone and cyclone belts of the southern hemisphere and that the droughts affecting Zambia, Rhodesia and parts of the Transvaal in recent years are essentially part of the same phenomenon.

Since 1970 the area of increased cyclonic disturbance in the inner Arctic has grown in size, and the belt of increased pressure and more anticyclonic influence has expanded to embrace most of the zone between 45 and 70°N, where droughts may also be serious to the many densely populated countries.

At the same time, the shifting positions from month to month, and from one year to the next, occupied by the main anticyclone centres in this belt have introduced an abnormal variability of temperature and precipitation. A similar development may explain the sequence of droughts and floods in different parts of Australia in 1972-3.

All these events have raised an anxious demand for ultra-long-range forecasting of climate, which calls for intensified effort towards understanding of the atmosphere (and its interactions with the ocean) and for further reconstruction of the facts of the past climatic record. ■

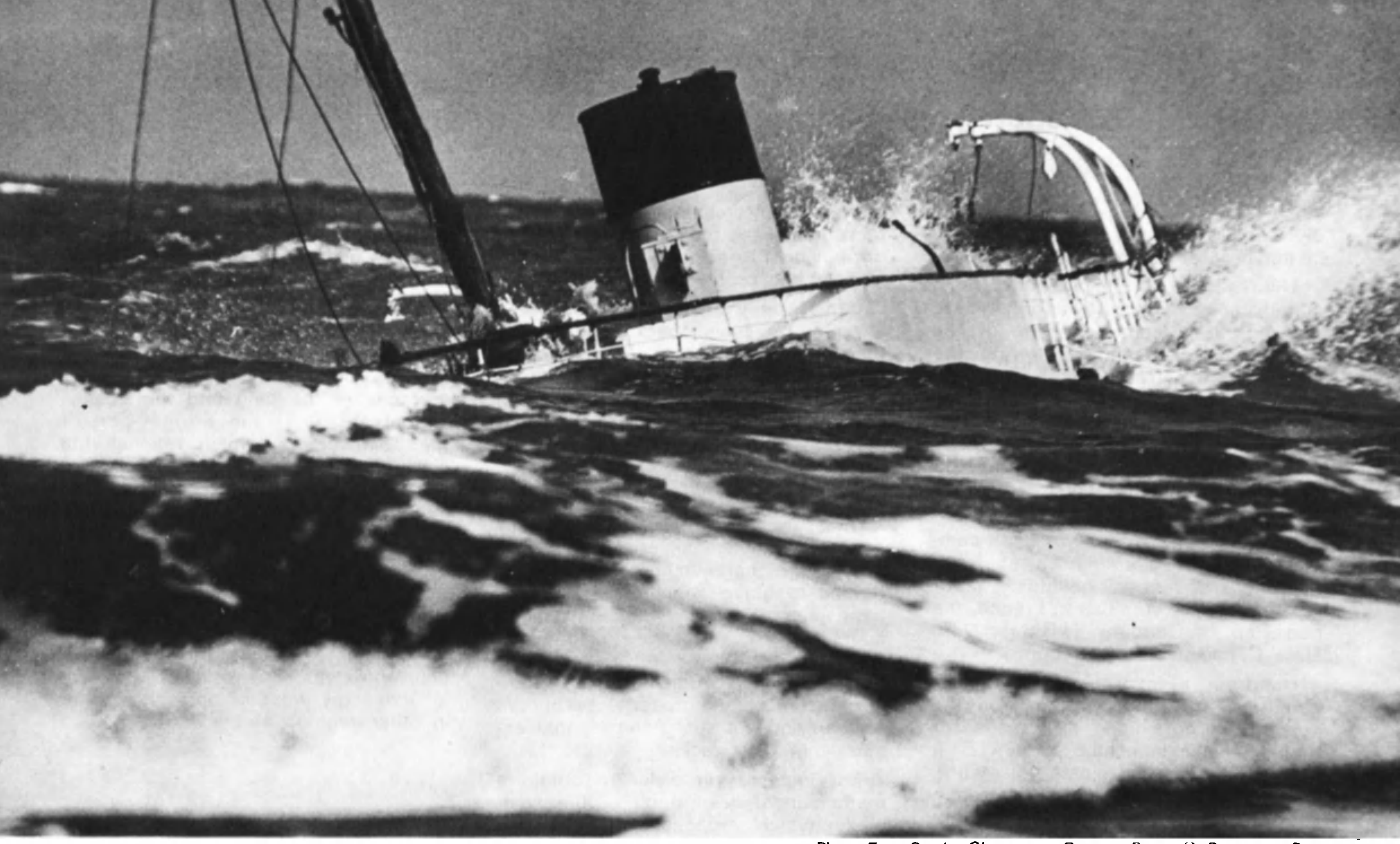

Photo Tom Smith, Observer - Camera Press © Parimage, Paris

Disasters such as this shipwreck, in which 13 men lost their lives when their ship ran aground in a sudden gale, may perhaps be a thing of the past when the results of GATE, the vast international hydrometeorological research project in the tropical Atlantic, beginning in June 1974, are known. The project will provide a wealth of new information on the movement of atmospheric disturbances over both land and sea and will enable new methods of forecasting and influencing them to be developed.

OPERATION 'GATE'

35 countries assemble a scientific armada to study atmospheric phenomena in the tropical Atlantic

by Yuri V. Tarbeev

A one-hundred day international scientific experiment to investigate the atmosphere and ocean in the tropical zone of the Atlantic, and of Africa and Central America is due to begin on June 15, 1974. Known as GATE (1) (GARP Atlantic Tropical Experiment), the operation will be unprecedented in its scale and scientific significance.

For the first time in history, 35 countries of Africa, Europe and America are to join forces in a vast programme of atmospheric and oceanographical research concentrated over a relatively small area of the earth's surface.

More than one hundred meteorological stations, located in the tropical areas of Africa, on islands in the Atlantic and in Latin America, over 25 research vessels, dozens of ocean buoys, 11 aircraft equipped as flying laboratories and several orbiting and geostationary earth satellites will be operating according to a synchronized

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(1) GATE is being carried out under the Global Atmospheric Research Programme (GARP), the far-reaching international research project jointly planned by the World Meteorological Organization and the International Council of Scientific Unions. (See page 9.)

YURI V. TARBEEV is Deputy Director of the International Scientific and Management Group (ISMG) of the GARP Atlantic Tropical Experiment (GATE) described in this article. He is a member of the WMO Commission for Marine Meteorology and of the International Co-ordinating Group for the Pacific Tsunami Warning System. Dr. Tarbeev has headed a number of oceanographic research expeditions.

5,000 deaths each year from tropical hurricanes

single scientific programme and plan. Over 3,500 persons will be engaged in the programme of observations.

The results will be immediately transmitted back to Dakar (Senegal), where an operations control centre for the experiment is to be set up, to the World Data Centres in Washington and Moscow, and to Bracknell (U.K.), Paris and Munich (German Fed. Rep.) as well as to other cities. At these centres, the data obtained during the experiment will be processed by computer.

When the experiment has been completed, the results will be analysed by dozens of research institutes, laboratories and universities in France, the Fed. Rep. of Germany, U.S.S.R., U.S., U.K., Canada and other countries.

Hundreds of experts from different countries are today working on the scientific programmes and plans for the full-scale launching of GATE in June 1974. To co-ordinate this work, the World Meteorological Organization and the International Council of Scientific Unions have set up an International Scientific and Management Group.

Between June and August 1972, in preparation for GATE, the Soviet Union carried out a one-nation "rehearsal" of the experiment, with the participation of six research vessels and an aircraft. This expedition discovered a number of previously unknown features of the atmospheric processes in the tropical Atlantic and also produced important data which will be used in planning the global experiment.

AN international rehearsal of the tropical experiment is being held (August 1 to 10, 1973), in the Western Atlantic.

Two Soviet research vessels, "Akademik Korolev" and "Ernest Krenkel", the U.S. vessel "Researcher" and the Mexican ship, "Cadete Virgilio Uribe" will rendezvous at a point 20° northern latitude and 60° western longitude to carry out joint research. Their mission is to make an "intercomparison test" of various instruments and observation systems to be used for measurement in the stratosphere, atmosphere and ocean, to work out uniform observation methods and to get the necessary experience in the organization of joint oceanographic work by vessels from different countries.

In the first fortnight of August 1973, whilst work continues at sea, the network of land-based stations and telecommunication links in Africa and Latin America are being checked out. The purpose of these two international rehearsals in 1973 is not simply to compare instruments and to work out joint operations for the vessels involved, but also to solve a certain number of scientific problems.

It may be wondered why so much attention is being paid to the very early stages of preparation for GATE. There are several reasons.

Firstly, there are likely to be many more experiments of this kind which help to solve practical scientific problems but which are expensive and difficult to organize.

Until recently, meteorological research in the oceans was mainly descriptive in character or else was intended to solve specific problems of atmospheric physics. Scientists, of course, were well aware of the importance of the need for an integrated approach to the problem, but the requisite technical and material resources for carrying out such international experiments were lacking.

For instance, in order to obtain a mathematical description of the complex physical processes in the atmosphere which govern the weather, with all their interrelationships, a large number of simultaneous observations have to be carried out, employing satellites, aircraft and large numbers of research vessels.

It is not a practical possibility for any country, even the most economically advanced, to carry out such research single-handed. The joint efforts of many countries are needed, and there must be a common interest in the results of the experiment and mutual agreement to carry out the observations simultaneously on the territory of all the countries concerned and at sea. Without powerful computers it would be impossible to deal with the flood of information produced by such experiments.

Today, the practical conditions for the success of the operation have been fulfilled.

Secondly, and this is perhaps the most important factor, GATE has attracted considerable attention because of the need to find more reliable methods for weather prediction, long-range forecasts in particular.

The present rapid growth of industry and agriculture gives increasing economic importance to long-term forecasts, since early warning of such natural disasters as droughts or severe winter conditions, combined with modern facilities for operational planning, can considerably reduce the losses which they cause and their other harmful consequences.

But if industry and farming are to be planned on the basis of such forecasts, the predictions have to be reliable. Reliable forecasting methods can be established using numerical models of atmospheric circulation which describe all the major factors in the state of the atmosphere and its relationship with the underlying surface of the land and the oceans.

Such mathematical models as these cannot be drawn up without a detailed study of the processes occurring in the tropics. This is because the surfaces of the land and the oceans in that area store up a great part of the solar energy which reaches the earth. The processes taking place in the tropics thus have a considerable influence on atmospheric circulation as a whole.

The research which is to be carried out during GATE will provide vital experimental material for a far-ranging assessment of the processes occurring in this area and will help to explain how and to what extent they influence the weather and the climate in other regions of the world.

FINALLY, some processes such as convection (the upward movement of warm, moist air), evaporation from the surface of the oceans, the formation of cloud systems, etc., which are of fundamental importance for the atmosphere as a whole, are particularly marked in the tropical zone. By investigating them there it will be possible to discover the physical mechanism which governs them more quickly and more easily.

Until this physical mechanism is properly understood, it will be impossible to deal with such practical problems as artificial rain-making or the use of artificial means to reduce the destructive force of tropical hurricanes. A practical example can illustrate the capital importance of solving these problems.

Tropical hurricanes and the flooding which accompanies them cause more casualties and more damage than any other natural disaster (for a general article on typhoons and hurricanes see page 52). It has been reckoned that in the hundred years between 1870 and 1970, they caused on average 1,500 million dollars worth of damage and more than 5,000 deaths per year.

Out of the world total, the countries of Asia and the Far East suffered losses to the tune of 950 million dollars a year, the countries of the Caribbean and the United States about 400 million dollars and the countries on the south-western shores of the Indian Ocean about 46 million dollars. The heaviest losses were suffered by the economically developed countries—the United States and Japan—whose losses totalled about 1,000 million dollars a year— more than 66 per cent of the total.

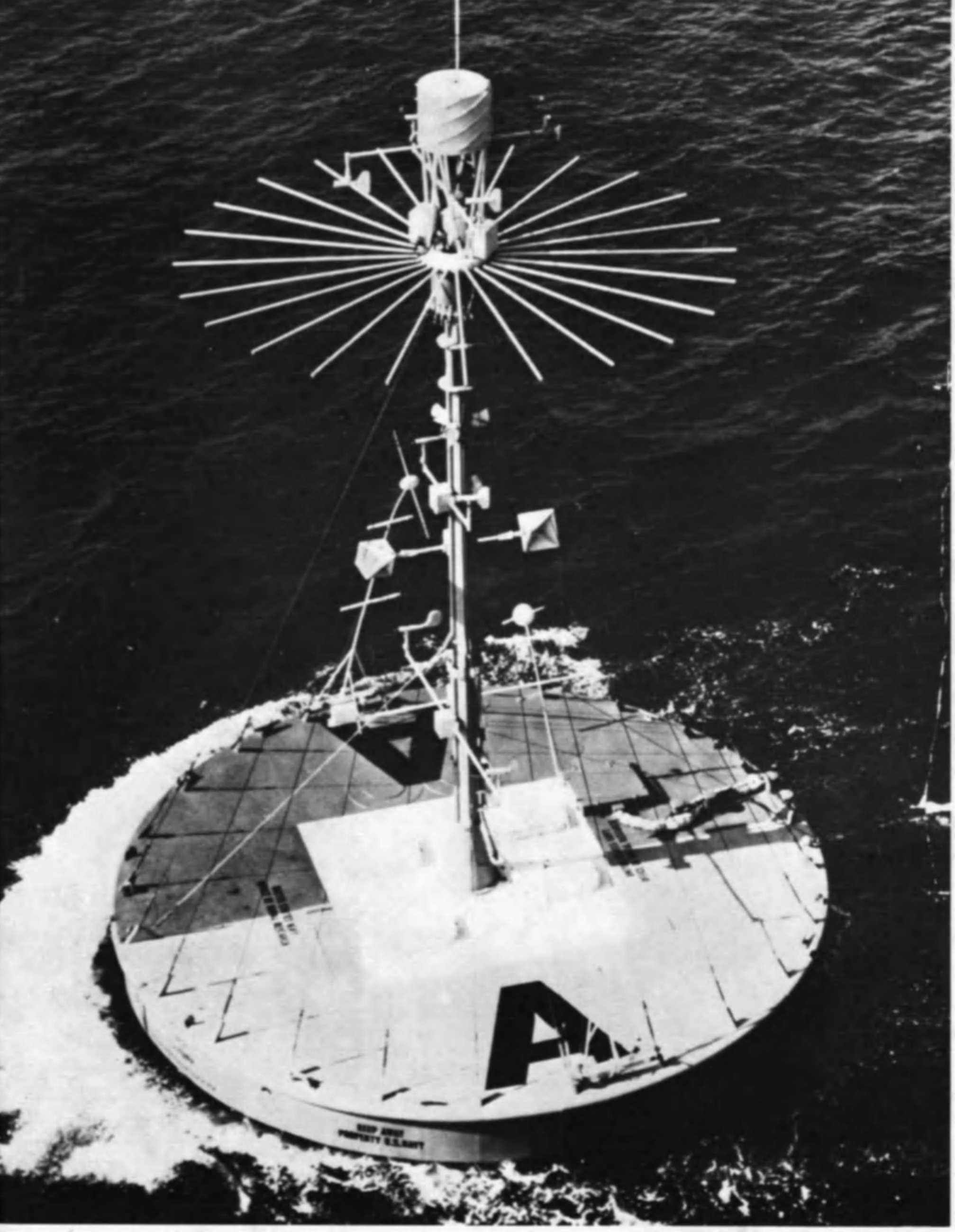

Photo © General Dynamics • Convair Division, St Louis, Missouri

Automatic ocean weather buoys are important links in the World Weather Watch meteorological network. Dozens of these giant buoys are to be used in the forthcoming tropical Atlantic research project.

According to the secretariat for the international Typhoon Committee, set up under the auspices of the U.N. Economic Commission for Asia and the Far East and WMO, 22 countries in Asia and the Far East during the period 1961-1970 suffered damage averaging 930 million dollars a year from hurricanes and typhoons. This figure is equivalent to the total amount paid out annually to these countries by the International Bank for Reconstruction and Development.

The losses caused by tropical hurricanes are a heavy burden on the economies of many countries, particularly the developing countries. Although considerable progress has been made in forecasting and in providing early warnings of the approach of hurricanes, the losses suffered by many countries at present total five per cent, or even more of the national income.

In this connexion, it is interesting to look at a breakdown of these losses by years for countries with different levels of economic development. Losses due to hurricanes in the United States during the period 1915-1924 amounted on average to only 63 million dollars. Thus in the last fifty years the scale of these losses has increased by 473 per cent, a yearly average increase of 9.5 per cent—which is about twice as high as the rate of growth of national income. In the 25 years beginning in 1945, the cost of damage caused by typhoons in Japan increased from about 273 million to 600 million dollars—a rate of growth of about 6 per cent per annum.

In the Caribbean countries, the cost of hurricane damage increased in the course of ten years from 33,200,000 to 92,900,000 dollars, i.e. an increase of 18 per cent per annum, which is nearly three times the rate of growth of the national income. Similar trends are noted in the Philippines, Taiwan and other places.

The increasing cost of such damage is due to intensive economic development in the areas affected by hurricanes and typhoons, the main factor being the rising cost of construction and the growing number of technical installations being built, and these are reasons which will continue to hold good in the future.

This means that unless radical solutions to the problems of tropical hurricanes are found, the time will come when the cost of damage will draw level with the figure for the growth of the national income—in other words cancelling out any progress.

To prevent such a situation from arising, we must seek new ways of dealing with the problem. In other words, we must develop scientific techniques for preventing hurricanes.

Such methods will undoubtedly be found, along with methods for making clouds shed their rain and techniques for influencing other meteorological phenomena, since many atmospheric processes are of a similar physical nature.

The GARP Atlantic Tropical Experiment is certain to produce numerous observations which will throw much light on the physical nature of atmospheric processes, in large and small scale terms. This will mark a decisive step in the development of effective means of influencing such processes.

Since hitherto only a few ships have usually taken part in ocean expeditions to investigate the atmosphere and the hydrosphere, the results obtained have given only a very approximate idea of atmospheric and oceanic processes. The forthcoming tropical experiment, however, will simultaneously cover the whole tropical zone of the oceans and the surrounding land areas of Africa and Central America.

It will thus be possible to follow the development of atmospheric processes and the movement of atmospheric disturbances over land and sea alike, and hence to determine on a large scale the influence of the ocean on these processes.

At the same time, 15 ships, a large number of data buoys, more than ten aircraft and several tethered balloons will be concentrated in a smaller area of more intensive observations in an area covering about 800 by 800 km. to the south of the Cape Verde Islands. They will keep constant watch on the atmosphere in this area when the most interesting phenomena are occurring.

All this should provide material of unique value for the solution of present and future problems of hydrometeorology, and should pave the way for many scientific discoveries. ■

Artificial satellites and high-speed computers, coupled with the more recent development of relatively inexpensive ground receiving equipment known as Automatic Picture Transmission (APT), have revolutionized international meteorology. Direct reception of weather information in the form of photographs covering an area of a radius of 1,600 km. around the receiving station is now within reach of every country in the world. Right, antenna of the European Space Research Organization (ESRO) satellite tracking station at Redu, Belgium.

Photo © Erich Hartmann - Magnum, Paris

MAKING THE WEATHER PAY OFF

An international report reveals the important changes meteorology is bringing to economic and social development

by Dan Behrman

UNLIKE someone in another profession, the meteorologist cannot bury his mistakes. They are there for all to see and suffer: the rain that drenches picnickers on a "fair and warmer" Sunday; the forecast of chill that leaves vacation resort operators fuming under a hot sun with their rooms empty. When such things happen, the weatherman gets the blame and his reputation suffers.

A great deal to change this image is to be found in a new technical publication issued by the World Meteorological Organization on the applications of meteorology to economic and social development. It is a report by the panel that WMO's Executive Committee set up to look at the subject.

There are two ways that meteorology can change the odds in the great economic game that man plays with nature. It can predict what nature will do, the equivalent of giving the

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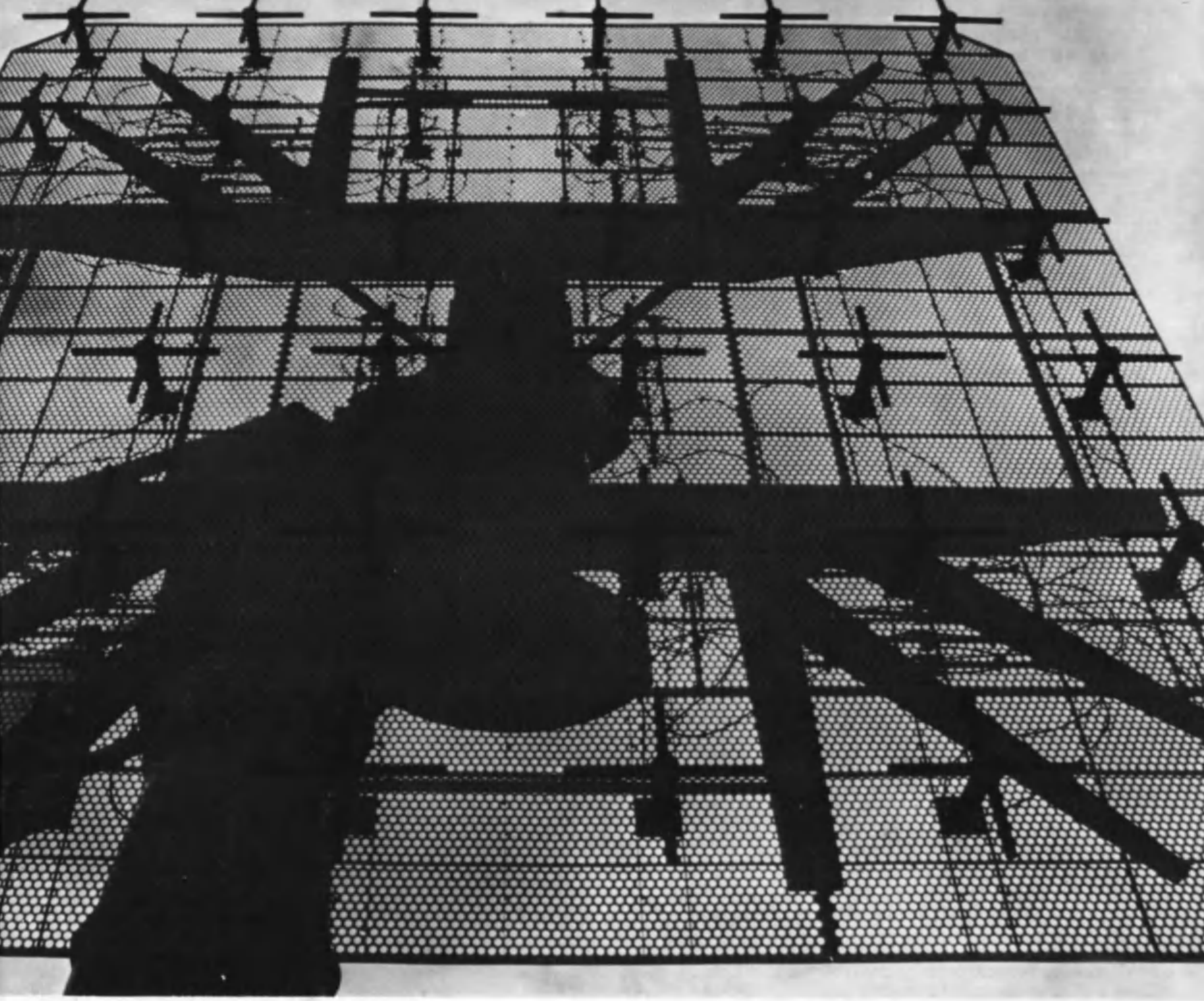

punter inside information on a horse race. Or it can try to manipulate nature so that, in effect, our bettor has a sure thing. The WMO gives us an idea of how far we have come towards foretelling and changing the weather—two of man's oldest dreams.

James McQuigg, an American research meteorologist and professor of atmospheric science, produces a host of examples to show how accurate weather forecasts can pay off. Paradoxically, the more developed an economy, the more weather-dependent it may be. The effects of nature's whims are extremely expensive when large capital investments are involved.

A good case is the routing of ships across the North Atlantic. The cost of producing a recommended route is about that of running a medium-sized tanker for half an hour. Since the forecast may save from four to twelve hours on a voyage, the shipowner gets his money back eight to twenty-four times over.

Ships eat up money in harbour. If dockers are called out to unload deck Cargo from a freighter in New York harbour and rain starts to fall, they cannot work safely. But they must be paid a minimum which can amount to $3,000 or $4,000 for one day. On the other hand, it costs $5,000 a day to keep a ship in dock with no one unloading it. In New York harbour, a good weatherman earns his pay.

He does on the Missouri River, too, between Kansas City and St. Louis. A river forecast centre in Kansas City can predict river levels from one to three days in advance. This is precious information to skippers of towboats hauling barges on the Missouri. They cannot use memory and instinct to get over snags and sandbars the way Mark Twain and his fellow pilots did a century ago.

When the Missouri is low, every extra inch of draught means more cargo and a gain of $125 per barge on the 400-kilometre run from Kansas City to St. Louis. If the forecaster can safely predict a rise of two feet above minimum flow, then a towboat can take half again as many barges.

As one might expect, farmers are good customers for weather information. The more they modernize, the more they need it. McQuigg tells us the implications of the Green Revolution and the new varieties of crops it has introduced

"Old locally-developed maize varieties in Kenya apparently had a broader spectrum of genetic characteristics, resulting in less uniform sowing-maturity requirements (and lower yields). The climatological information that proved to be directly applicable was identification of two maximum rainfall periods during the growing season, with the recommendation that two plantings be made, each using a strain

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A breakthrough in airport fog dispersal: underground jet engines

of maize with a short growing period.

"In some areas, this resulted in a nine-fold increase in yield."

On the Mississippi Delta in the United States where cotton is king, a different need arose. In the old days when cotton was planted by hand, it had to be replanted if a cold snap struck. Then came mechanization and higher costs that made replanting more expensive.

Meteorologists found that a cotton grower could cut his risks if he knew the actual soil temperature at planting depth and then used the five-day temperature forecast for his region. McQuigg estimates that farmers in southeast Missouri saved about $500,000 a year using information that cost $25,000 to produce.

NEW techniques mean new problems, particularly when animals are kept indoors. The climatologist is now called upon to assess the pros and cons of air-conditioning dairy cattle to see if higher yields are worth the added cost (the answer, according to McQuigg, varies from one place to another).

Animals raised indoors are not as tough as those that roam pastures or woodland. So the meteorologist is needed to make sure that weather conditions will be right when pigs or cattle are shipped to market or to warn farmers of the onset of a humid heat wave that can hurt their indoor herds.

Wherever McQuigg pries with his inquiring mind, he overturns some interesting stones. He tells us that the construction industry would like to be able to work all the year round in cold latitudes, thereby getting a better return on its capital (interest has to be paid all the year round). Meteorology must be able to say when the temperature will go down to freezing so that the right precautions are taken when concrete is poured.

In hot weather, precise short-range forecasts are the answer to the electric power industry's prayer in a country such as the United States where human beings, unlike cattle, want to be air-conditioned no matter what the price.

McQuigg cites a case: "One midwest U.S. electric power company serves an area with the demand for power most sensitive to weather in the summertime. The cost of providing electric power, using a combination of hydroelectric, steam and gas turbine generators owned by the company and electric power bought from other companies, on a very warm humid summer day is three to five times higher than on a cool dry summer day. Short-term weather forecasts are very useful to the manager of this kind of system."

The electric power industry also needs long-term forecasts five to ten years ahead so that it can plan how to meet future energy needs without saddling itself with expensive excess capacity.

Meteorologists are in demand on the marketplace. The clothing industry may produce large numbers of bathing suits only to hear customers clamouring for raincoats. In New York City, it has been found that a warm September will drive sales of women's winter coats down to only 14 per cent of the seasonal average. If September is cool, sales will run to twice the average.

When it comes to vacation and leisure pastimes, meteorologists have gone far beyond the stage of trying to learn whether it will be a good day for the beach. McQuigg tells how a climatologist in the state of Michigan was asked by two groups of businessmen if certain sites would have enough snow to warrant setting them aside as recreation areas for snowmobile enthusiasts.

Records showed that one site only had from ten to twenty suitable days per winter season so peace and quiet prevailed there. But the probabilities looked better for the other site and it is now being developed.

PEOPLE in the United States can now go south for the skiing thanks to the collaboration of meteorologists, businessmen and engineers on the mountains of North Carolina. At first, Albert V. Hardy, the state climatologist, said that nature could not supply enough snow for skiing and what there was did not last long enough.

Then engineers found that man-made snow could be used and, said Hardy, the outlook brightened. "Many of the northern facing slopes have a winter climate able to support a base snows tends to help nature by cooling of snow for extended periods. In fact, the process tends to be self-perpetuating since a continuous supply of the air around the area." Air-conditioned cattle and snow-cooled air...

Chilling a mountain is weather modification, albeit on a very small scale. The WMO has looked closely at the possibility of changing the weather over large areas and the benefits that might be expected. L.L. Means sums up progress in his report on economic and social aspects of weather modification.

The benefits are huge when one looks at the havoc that the weather can wreak. Means states that in the United States alone, hurricane damage averages about $500 million a year, hail damage amounts to more than $300 million and the bill for forest fires started by lightning is another $100 million.

FOG delays cost domestic airlines more than $75 million a year and no one knows how much they affect ground and water transportation. Costs that can be directly identified with hurricanes, hail, lightning and fog run to around $1,000 million a year in the United States alone.

The brightest prospects seem to lie in airport fog dispersal. In the past, a number of techniques have been used. In particular, freezing fog has been seeded with silver iodide or dry ice pellets so that it precipitates out as ice crystals. Warm fog is tougher. Helicopters can blow it away with a warm downwash from their rotors but that only clears enough space to land a helicopter. Heating the air with open flames along a runway is costly and dangerous to planes veering to one side.

No method really worked until the French got the idea of putting jet engines underground at Orly Airport outside Paris and using them to heat the air. Means says this could be "a significant breakthrough from both the technical and economic viewpoints".

It comes at the right time. The

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Photo © CIRIC, Geneva

INDIA: A LEADING ROLE IN WORLD WEATHER RESEARCH

The Indian Meteorological Department, set up in 1875, is one of the world's longest-established meteorological services. During the last twenty years it has expanded dramatically. 1954 saw the first storm detection radar installed at Calcutta airport; in 1956 the Directorate of Radio-Meteorology was established in New Delhi; and in 1962 the Northern Hemisphere Exchange and Analysis Centre was set up, also in New Delhi.

This expansion was given added impetus with the launching in 1963 of the International Indian Ocean Expedition by Unesco, the Scientific Committee for Ocean Research (SCOR), and the World Meteorological Organization (WMO). An International Meteorological Centre was established in Bombay to collect and process data acquired during th Expedition. At the conclusion of the Expedition, in 1966, the Centre was transferred to the city of Poona, south-east of Bombay, to become the Indian Ocean and Southern Hemisphere Analysis Centre.

Meanwhile, 1963 also saw the establishment at Poona of a new Institute of Tropical Meteorology. Now an autonomous body, the Institute is undertaking important research on tropical and sub-tropical meteorology including the study of monsoons, forecasts and warnings of floods and tropical cyclones, medium-range forecasting for agriculture, etc.

While the development of meteorological services is of vital national importance to India, the Indian Government is making a very broad contribution to international meteorology. With the establishment in 1971 at New Delhi of a Regional Meteorological Centre and a Regional Telecommunications Hub of the World Weather Watch, the Indian Meteorological Department is now one of the vital links in the world's meteorological observation system.

Photo © Paul Almasy, Paris

INTER-CONTINENTAL DUST CLOUD

Scourge of the world's deserts and adjoining regions, sand and dust storms can attain peaks of tremendous violence. Above, a mountain-high "wave" of sand raised by the wind streaks across the Sahara, blotting out the sky and enveloping everything in its path. Storms such as these cover enormous distances. In June and July 1969, the American satellite ATS III tracked and photographed the extraordinary journey of a dust cloud across thousands of kilometres from the Sahara across the Atlantic to Barbados in the Caribbean. Series of photos on left are the actual images transmitted by satellite; right, the same pictures showing the African continent and Caribbean area and the moving dust cloud. Not all the effects of dust clouds on weather are known and satellite photographs are expected to throw new light on these problems.

MAKING THE WEATHER PAY OFF *(Continued)*

wide-bodied airbuses now being introduced carry so many passengers that, according to one estimate, delays and cancellations may cost twice as much as in the past. Tests in the U.S. in the winter of 1969-70 showed that it cost $118,300 to clear fog at nine cities while benefits amounted to $339,970. With bigger planes and better techniques it is expected that this ratio will be considerably improved.

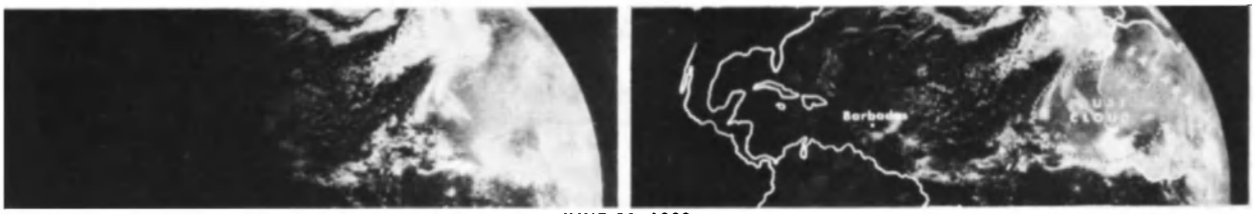
Operations on a much bigger scale are being carried out to stop hail. The world leader here appears to be the Soviet Union. According to Means, at least four Soviet programmes are now serving nearly 2,500,000 hectares of farm land. He writes: "Ice-nuclei (usually lead iodide) are usually delivered directly into the clouds at appropriate altitudes through the use of artillery or rockets. Soviet scientists have reported success in all of these projects with reduction in hail damage ranging from 50 to 90 per cent."

In Kenya, hail losses were reported cut by 58 per cent over an area of 800 square miles where 40,000 acres of tea are grown. The verdict, however, is far from unanimous. Swiss experiments "showed no significant difference in duration, areal extent or intensity of hail when it occurred on seeded and unseeded days."

The Swiss report said hail actually fell more often on seeded days which also saw a 21 per cent increase in average rainfall. In the United States, hail-raisers found they were taken to court because *less* rain fell after their cloud-seeding.

Clouds are also seeded in attempts to stop lightning from starting forest fires. The U.S. Forest Service says that its Skyfire experiment has reduced lightning-lighted fires by up to 90 per cent in the seeded areas. Some scientists query this figure and the method is now being given a more extensive test.

It would cost $50,000 to send aircraft up to seed a front of convection cells likely to produce lightning as it advanced across the Pacific Northwest in the U.S., but it cost $11 million



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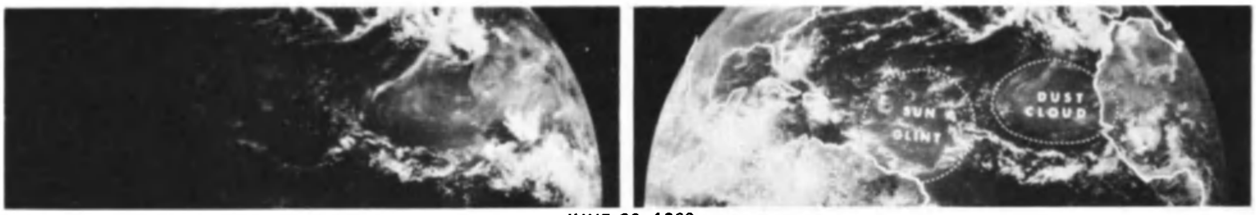

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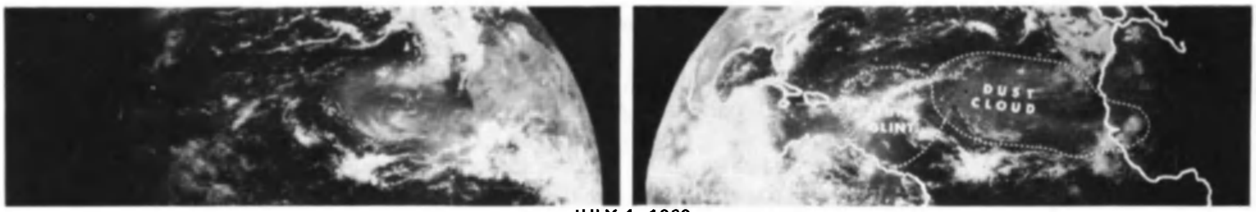

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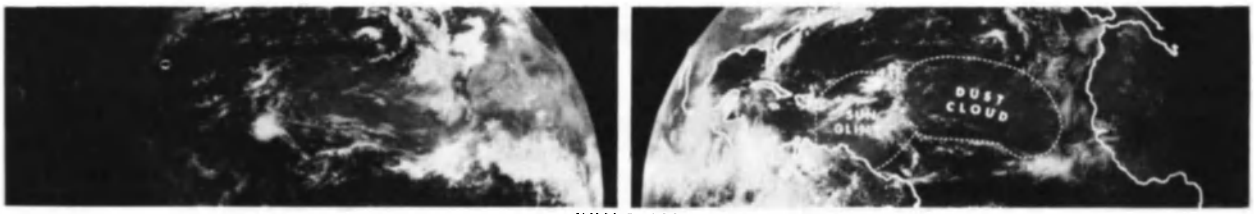

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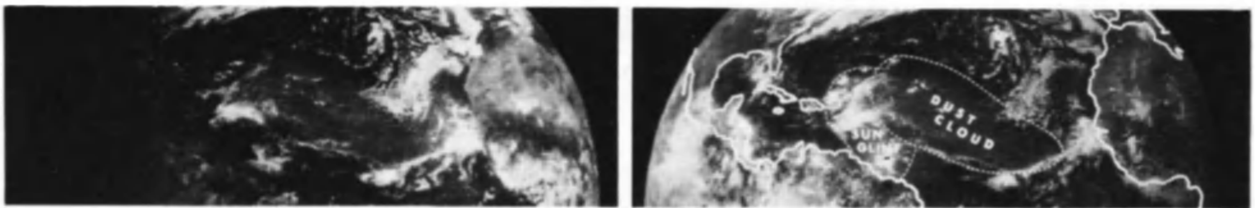

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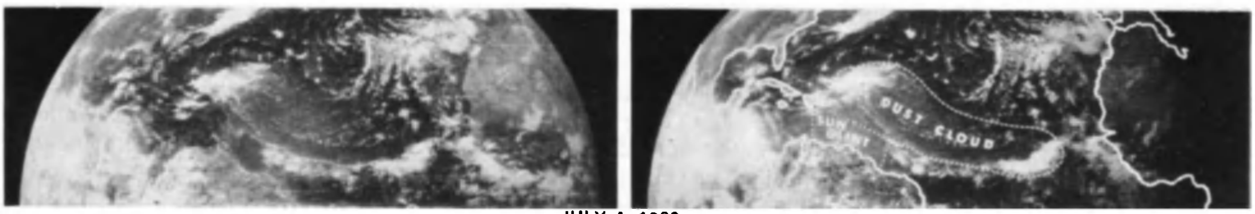

JULY 4, 1969

Photo © USIS

to fight 124 lightning fires that struck one forest in that area during eleven days in 1971.

Even bigger money is involved when the WMO report turns to the modification of hurricanes and typhoons. This work is being carried on in the United States under another impressive name, Project Stormfury. It aims to seed hurricanes and thereby reduce the intensity of their maximum winds.

The WMO report states: "In Hurricane Debbie (August 1969) data collected by aircraft showed that on successive runs extending over a period of about three hours before the first seeding until five or six hours after the fifth seeding, the winds at 12,000 feet decreased about thirty per cent on August 18.

"The storm re-intensified on August 19, starting about eight hours after the last seeding on the 18th. On August 20, Debbie was again seeded five times. The maximum winds decreased about fifteen per cent... It is not known whether the decreases in intensity... were caused by seeding or by natural forces.

"More experiments are needed to confirm the encouraging results of seeding Debbie. Proposals have been made to move the project to the Pacific where opportunities to seed typhoons would occur more often."

As noted earlier, hurricane damage in the United States runs to $500 million a year, and an incalculable toll in human lives is taken by the typhoons that strike in the Bay of Bengal. Means notes: "The costs of Stormfury experiments and research by contrast are relatively low. If spending continues during the next ten years at the current annual rate, and if at the end of ten years it is possible to modify one hurricane such as Camille (1969) sufficiently to reduce the damage by ten per cent, that reduction will amount to more than ten times the costs over the ten-year period."

He does remark, though, that hurricane modification raises some economic and legal problems which are easy to imagine. Anyone who could

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Rain-making stories with a happy ending
Rain-making stories with an unhappy ending

prove that cloud seeders brought a hurricane down upon his head could collect astronomical damages.

While the United States is alone in hurricane modification research and the Soviet Union suppresses hail on a much greater scale than anyone else, a number of countries have made an attempt at "precipitation enhancement"—a piece of jargon that the meteorologist uses because it sounds so much more respectable than "rain-making".

One cannot blame him for trying to get away from the old picture of the medicine man beating a drum or the quack scientist firing a popgun at the sky. In the past, meteorologists have always displayed great caution when the issue of "rain-making" arose. Now, according to the highly respectable WMO, they are less suspicious.

MEANS describes a few examples. One from Florida in the United States is illustrative. "The approach used 'dynamic seeding' which involves massive doses of silver iodide introduced into the top of cumulus clouds by dropping pyrotechnic flares from aircraft. Dynamic seeding is directed toward producing large growth of the cloud by releasing the latent heat of freezing available in the supercooled water content.

"Clouds seeded by such a method are said to rain more because of increased cloud size and lifetime... Dynamic seeding, if successful, is described as causing one or more cumulus congestus clouds to grow into towering cumulonimbi which may merge into a huge cumulonimbus complex.

"It was noted that merged clouds produced ten times more precipitation than isolated clouds on the same day... If optional rain enhancement is desired, dynamic seeding should be used deliberately to produce mergers.

"The main result reported of the experiments and statistical analyses is that the effect of dynamic seeding on rainfall is large, positive and significant... The seeded clouds were reported to have produced more than three times as much rain as the control clouds."

In the Soviet Union, WMO states, scientists have found that precipitation could be increased from 13 to 18 per cent over the Ukraine in winter. Results from two areas in Australia showed increases in rainfall up to 300 kilometres downwind from the area where the clouds were seeded.

The Australians have long adopted a "show-me" attitude towards rain enhancement. But now Means quotes the results of a major experiment in Tasmania: "In the determination of the effects of cloud-seeding on the rainfall over a hydroelectric catchment area, it was concluded that rain was increased by 10 per cent or 20 per cent. It has been estimated that a one per cent increase in this area could be worth about $100,000 per year."

One rain-making story with a happy ending comes from the Philippines. "The project was started in April 1970 after months of drought. In central Luzon, the sugar-cane and other crops were dying. By the time the project was completed in June, the islands were reported as verdant. The Philippine Sugar Institute assembled information and estimated the impact on the economy. The value of net gain in production was estimated at $43 million. The cost of the project was roughly $500,000."

Writing for WMO, Means concludes cautiously: "There appears to be a general consensus that cloud-seeding can affect precipitation, but the effect can be positive or in some cases negative, depending upon meteorological conditions, background contamination and possibly other factors. Some progress is being made in selecting meteorological conditions for positive results. Cloud-seeding for the enhancement of precipitation has not yet reached the engineering phase as has dissipation of cold fog."

Nor is it a cheap solution for economic growth. WMO, in fact, issues a warning by Prof. E.A. Bernard: "It is time to react against the tendency, far too common in the developing countries, to conduct experiments or operations with artificial rainfall in an attempt to mitigate the deficiencies of the rainfall regime. These tempting but costly practices should be left to the advanced countries.

"So long as the latter have not succeeded in providing a tested scientific and technological basis for such operations, it will pay better to invest the budgetary resources involved in taking better advantage of the water available on the basis of agrometeorological and hydrometeorological studies."

There is another factor that slows such studies, in Prof. Bernard's opinion. Virtually every country has airline services and there is no question of cutting corners on the quality of meteorological facilities for air travel. The result, he says, is that the best of limited facilities must be made available for aeronautical meteorology.

"As a result", he writes, "public authorities have been led to consider meteorology as an operational technique for civil aviation. This regrettable state of affairs prevails in many countries of the Third World. It inhibits the setting up of true meteorological services intended primarily to serve national priorities in development."

THE moral of this story is that no meteorologist can make manna fall from the heavens. The kind of benefits that James McQuigg describes are the returns from heavy investment in adequate meteorological services and in training scientists to man them.

Prof. Bernard cites some eloquent figures that WMO has gathered. Of its 133 member nations, 105 are developing countries. They spent $109 million in meteorology in 1968 as against $854 million spent by twenty-eight industrially developed countries. On a per capita basis, this worked out to $1.38 per North American and .02 cents per Asian, a ratio of 70 to 1.

Until this ratio changes, it is likely that in meteorology, as so many other realms, the rich countries will get richer and the poor countries will become... what they have been all along. ■

AN ABC OF METEOROLOGY

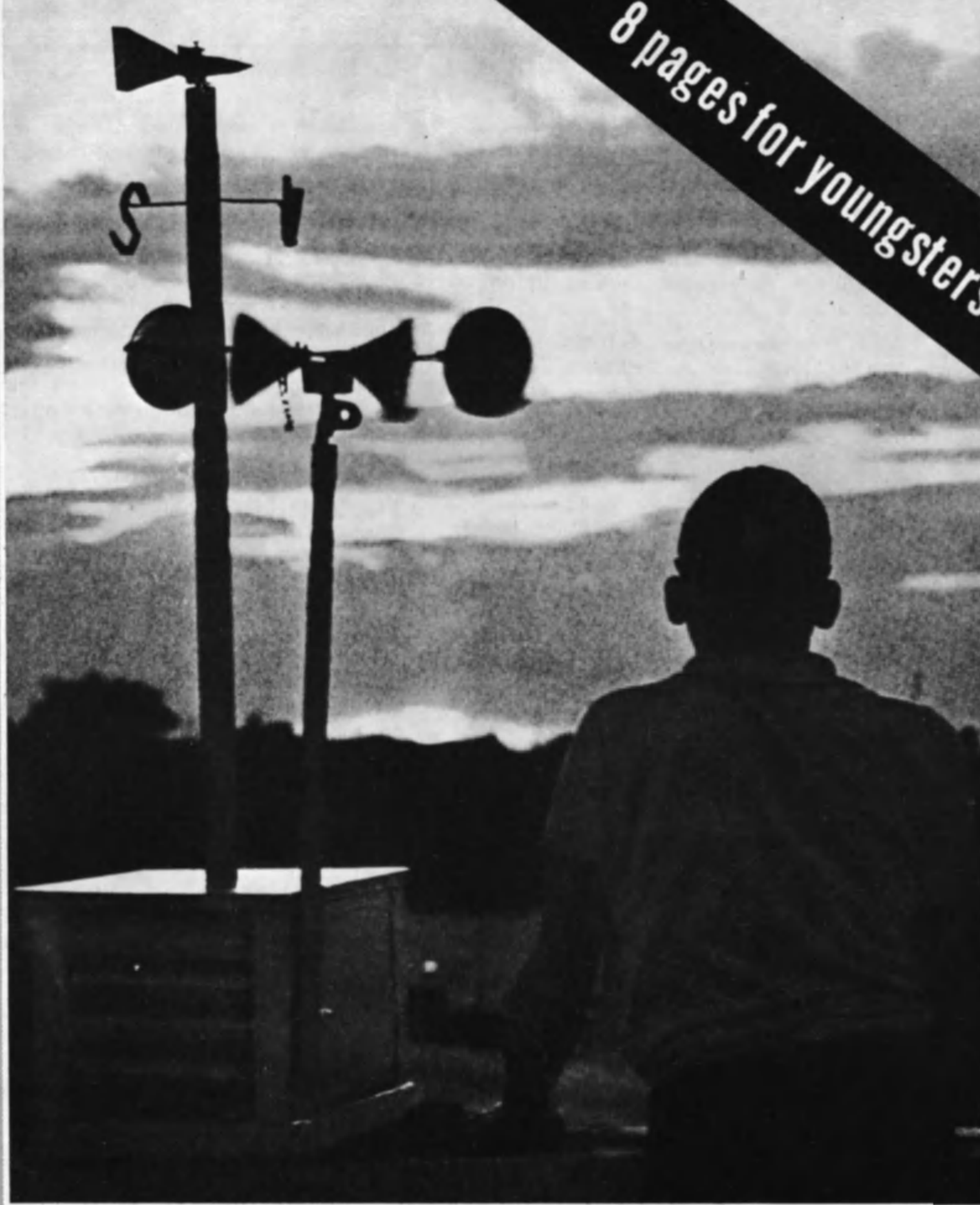

Photo Ted Russel - Life

WHEN you hear the radio announce that it will be sunny or that it is going to rain, have you ever wondered how these forecasts are made? Do forecasters simply observe the sky as our ancestors used to do?

It's quite true that a careful observer can predict what the weather will be like a few hours in advance. But longer-range forecasts call for observations of the atmosphere by weather stations on sea and land covering a very wide area (Europe and the Atlantic Ocean as far as the American coast, for example).

Above all, weather forecasters need to study the laws that govern the behaviour of the atmosphere. Using this information they can draw up meteorological maps and predict what the weather will be like tomorrow or during the next few days.

THE EARTH'S ATMOSPHERE The earth is enveloped in a layer of gases extending about 1,000 kilometres above its surface. This layer is very thin when compared with the earth's radius (about 6,000 kilometres). The upper limit of the atmosphere is not clearly defined; it is the zone in which molecules of air can reach high enough speeds to be able to escape from the gravitational pull of the earth, and is called the exosphere.

The air composing the atmosphere is a mixture of gases—mainly nitrogen and oxygen—in fairly constant proportions. Water in the form of vapour is mixed with these gases in widely varying amounts. Together they make up the air which we breathe and which makes life on earth possible.

The four main features of the atmosphere are:

Temperature: measured with a thermometer;

Pressure: measured by a barometer; atmospheric pressure is the force acting on the surface of any object; a thin-sided box in which a vacuum has been produced would be crushed by this pressure;

Humidity: measured by means of a hygrometer or psychrometer; it is the proportion of water vapour mixed with the air;

Wind: measured by means of an anemometer; it is the speed of moving air at a given point.

All these features vary according to height and geographical location.

Variations due to altitude: pressure falls the higher one rises in the atmosphere. At 5,000 metres it is only half the pressure at the earth's surface, and

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at 12,000 metres only a tenth. Pressure cannot be directly measured in the exosphere.

Temperature varies in a more complex fashion. The atmosphere is divided into layers in which the temperature either rises or falls as altitude increases.

In the lower layers of the atmosphere, temperature decreases on average six degrees centigrade per 1,000 metres of altitude, up to the level known as the tropopause above which it stops decreasing.

The tropopause is at an altitude of about 6,000 metres at the poles and about 15,000 metres at the equator.

The temperatures are about —50 degrees centigrade and —85 degrees centigrade respectively.

Below the tropopause is the atmospheric layer called the troposphere. It contains four-fifths of the mass of the atmosphere and almost all its water vapour. Within the troposphere vigorous mixing of air and other interactions take place. This layer has been called the world's "weathersphere".

At altitudes of over about 100 kilometres changes take place in the physical properties of atmospheric gases and particularly in their electrical charges, due to bombardment of rays coming from the sun. They become what is known as "ionized", thus giving the name "ionosphere" to this layer of the atmosphere.

Variations due to geographical position: pressure and temperature, at a given altitude, vary according to geographical location, but such horizontal variations are far less marked than the vertical ones.

To find out about these variations, and to collect other vital information for meteorologists, a network of stations is needed to make observations simultaneously and using the same methods for accurate comparison.

The results of these observations are then rapidly exchanged, and this can only be done through close international collaboration.

WATER IN THE ATMOSPHERE Water is found in nature in three forms: liquid (water), solid (ice), gas (water vapour).

Water exists as very fine droplets which are so small that they fall only very slowly—like the mist from a vaporizer—forming clouds. Larger drops fall more rapidly as rain.

Ice exists as fine crystals in the higher clouds (cirrus), groups of crystals in snowflakes, or pellets of ice in hail.

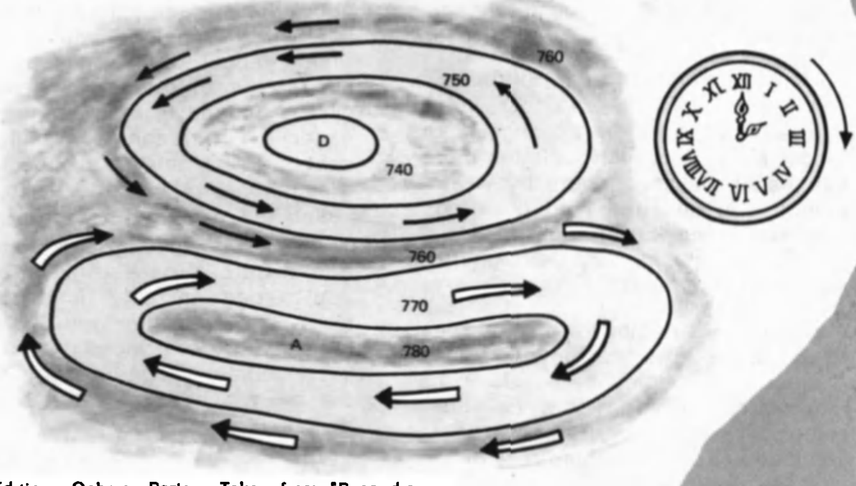
Water vapour is a colourless gas mixed with air. The amount of water vapour in the air varies up to the so-called saturation limit which depends on the temperature. The higher the temperature the more water vapour there can be in the same volume of air.

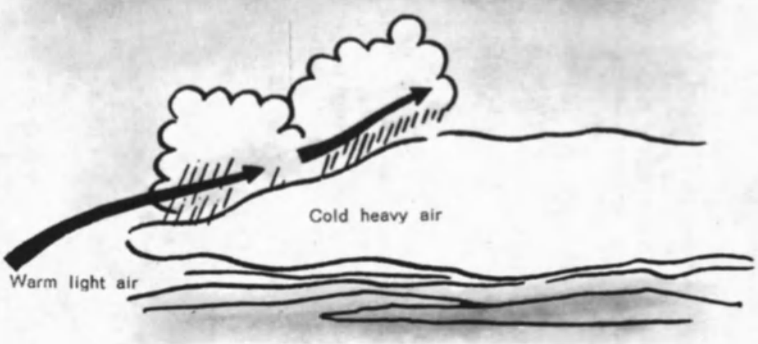
If air saturated with water vapour cools, this creates an excess of water vapour which becomes liquid, condensing on a surface or forming droplets. In winter, in a warm, humid kitchen, the windows, which are colder than the air in the room, become covered with mist.

Birth and death of a cloud

Mapping atmospheric pressure

When you look at a weather map, you will see a number of concentric circles. They indicate the presence of low pressure areas (depressions) or high pressure areas (anticyclones) which are a vital factor in weather forecasting. The circles are formed by drawing lines, called isobars, joining points of equal pressure, just as on a geographical map contour lines join points of equal height. The pressure becomes progressively lower towards the centre of a depression and higher towards the centre of an anticyclone (see drawings right). In the northern hemisphere winds move in a clockwise direction round anticyclones and anti-clockwise round depressions. In the southern hemisphere these directions are reversed.





Clouds can form in many different ways. Moisture in the form of water vapour is constantly being drawn up from the earth and the oceans by evaporation to mix with the other gases of the air. Carried by the wind, the vapour-laden air is forced to rise when it meets an obstacle, such as a mountain (above left) or a mass of cold air (above). As it rises the air cools and the water vapour condenses into tiny particles of water which we see as clouds. Higher clouds (from 5 to 10 km. above the earth) are formed of minute ice crystals and these are one of the most important causes of rain. In fact, at one time it was thought that all rain, with the exception of some tropical rain, was caused when these ice crystals, in dropping through a cloud, collided with droplets below becoming bigger and bigger until they fell to earth as raindrops, or as snow if it was very cold (right). Nowadays many scientists believe that rain can form without ice crystals, even in non-tropical regions, when droplets collide forming larger and larger drops which finally fall as rain.

In the troposphere, in addition to the horizontal air movements which we note as wind, important vertical movements occur which are more difficult to detect. These movements may be very extensive and cause a general upward movement of a mass of air over a whole region, or they may be very localized, forming upward air currents—the "lift" used by certain birds and by glider pilots.

Since pressure decreases with altitude, the air that rises becomes decompressed and as a result its temperature falls. The same effect can be seen in reverse with a bicycle pump which heats up more and more as the air is compressed.

If air is very humid, the water vapour condenses into fine droplets and a cloud forms. Under certain conditions, the small droplets may come together to form large drops which fall as rain.

THE CIRCULATION OF THE ATMOSPHERE

Atmospheric pressure is not uniform at a given level, such as the surface of the earth. If we look at pressure readings taken at the observation posts of a chain of weather stations we see that the weather has its own "topography".

If we join the points of equal pressure on a weather map by curves known as isobars, we find that the outlines resemble the height contours on an ordinary relief map. Zones of high pressure or anticyclones stand out like hills, and areas of low pressure or cyclones (depressions) correspond to hollows or valleys. An isobar map is thus a valuable aid for finding out about the great movements of the atmosphere, since isobars show the pressure patterns which control the way air flows.

Air does not flow directly from high pressure to low pressure zones. Air movement is influenced by the rotation of the earth and the wind blows in a direction parallel to the isobars. In the northern hemisphere it turns in a clockwise direction round the anticyclones and in the opposite direction around cyclones (or depressions). In the southern hemisphere, the direction of movement is reversed. This movement can be observed by studying wind observations reported by each weather station.

Points of equal temperature are linked by curves known as isotherms which give us a general picture of the temperature at a given level (ground-level, for instance). Horizontal variations in temperature are seen generally to be minor except along certain lines where they can be quite abrupt.

The atmosphere thus contains narrow zones in which sharp contrasts in temperature occur. The lines representing these zones are called "fronts". A front is described as "warm" if warm air tends to displace cold air, and "cold" if cold air replaces warmer air. Various changes in the weather are associated with these fronts, particularly the formation of clouds and quite often showers of rain or snow.

A WEATHER OBSERVATION STATION

A meteorological observation station is the basic unit of a weather service network. Each station is set up to conform to identical standards: on an unshaded site, preferably a grassy one so as to eliminate reflected solar radiation.

It consists basically of a meteorological shelter which shields the various instruments inside from the direct rays of the sun and from wind and rain. It is like a large crate, well-ventilated and with its open side facing north. Thus conditions inside are everywhere the same.

What instruments are kept inside the shelter?

Thermometers. An ordinary thermometer; a minimum thermometer which indicates the lowest temperature reached; a maximum thermometer showing the highest temperature; and sometimes a thermograph, a special thermometer which makes a continuous record of temperatures.

A hygrometer. This instrument indicates the amount of moisture in the

CONTINUED PAGE 38

10 MAJOR CLOUD TYPES

Clouds are valuable aids in forecasting the weather because they show what changes are taking place in the atmosphere. In themselves individual clouds do not tell us too much. The weatherman has to know how they have been developing, changing or breaking up over a period of time and the patterns they form. Generally speaking, chances for rain are greater if isolated high clouds thicken, increase in number and the cloud base becomes lower. Sunny weather may be on the way if fog clears before noon and if cloud bases become higher. Here we show the ten main cloud families classified internationally into three groups according to height: low, middle and high.

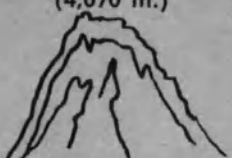
18,000 m

Everest (8,882 m.)

7,000 m

Aconcagua (6,959 m.)

Mt. Cameroon (4,070 m.)



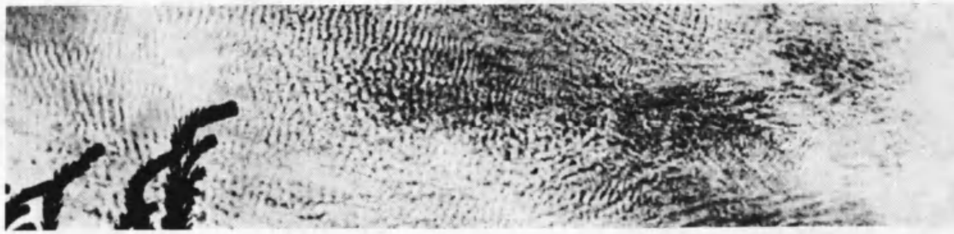
HIGH CLOUDS

CIRRUS

Wispy, whitish and transparent clouds formed of delicate filaments, white patches or narrow bands. (Sometimes called "mares' tails"). Wisps may lie parallel to each other or appear entangled. Cirrus clouds, consisting of tiny ice crystals, have a transparent look.

If the sky becomes overcast with cirrus clouds, bad weather often follows.

CIRRO-CUMULUS



Look like many small tufts of cotton, forming a "fleecy" sky. Usually arranged in very small ripples, layers, patches or globular forms, merged or separate, and more or less regularly arranged.

Often associated with cirrus clouds (preceding the arrival of bad weather). They also often appear before storms.

CIRRO-STRATUS

Veil-like sheets of cloud, sometimes giving the sky a whitish or milky look. Not thick enough to block out the sun. A good way to recognize a cirrostratus cloud is by the accompanying halo around the sun or moon.

Like cirrus clouds, which they generally follow, cirrostratus clouds often indicate the approach of bad weather.

IDDLE CLOUDS

ALTO-CUMULUS

A "dappled" sky. White or grey cloud in form of sheets or layers. May appear in small, isolated, globular patches, parallel bands or flattened, slightly rolled masses. Sun sometimes visible through upper layers.

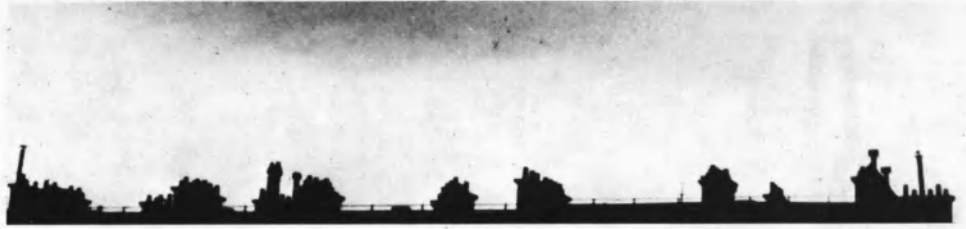
A dappled sky is usually followed by rather poor weather.

ALTO-STRATUS

Forms a smooth white or grey sheet across the sky, but has parts thin enough to reveal the sun at least dimly, and seen as though shining through ground glass.

These clouds are a warning sign of light rain.

NIMBO-STRATUS



Thick, dark, grey masses of clouds, often threatening in appearance.
Low, ragged clouds often occur below the main layer.

Typical rain or snow clouds.

2,000 m
Mt. Washington
(1,917 m.)

LOW CLOUDS

STRATO-CUMULUS

A grey, whitish sheet of cloud. Nearly always has dark parts composed of checkerboard patterns, rounded masses, etc. "Cumulus" (from *cumulo,* meaning "pile" or "heap") indicates piled-up clouds.

It rarely brings rain except when, as sometimes happens, it develops into nimbostratus.

STRATUS

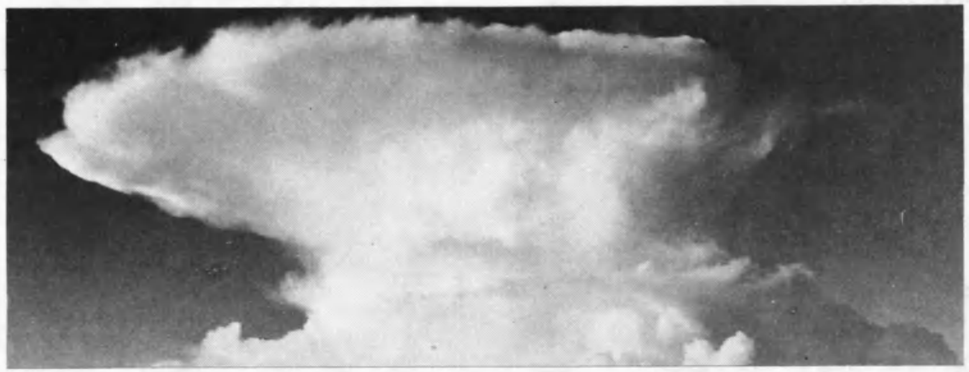
A generally grey cloud layer, very much like a light fog lifted a hundred metres or so off the ground. Stratus (from *strato,* meaning "sheet-like") spreads over a wide area, sometimes appearing in ragged patches.

In winter, often persists all day; in summer, disperses and is followed by fine weather.

VERTICALLY-DEVELOPING CLOUDS

Can rise to great heights while their bases remain near ground

CUMULO-NIMBUS



Heavy, dense cloud that develops vertically to great heights in the shape of a mountain or huge tower. Its peak usually flattens out and spreads into the shape of an anvil or vast plume.

The cloud of rain shower or storm; often called a "thunderhead".

CUMULUS

Detached low cloud, generally dense and with sharp outlines, it develops upwards in the form of rising domes or towers of which the bulging upper part often resembles a cauliflower.

When humidity is low and there are only slight upward air currents, cumulus clouds are an indication of fine weather. Otherwise, they build up considerably during the day and may lead to storms.

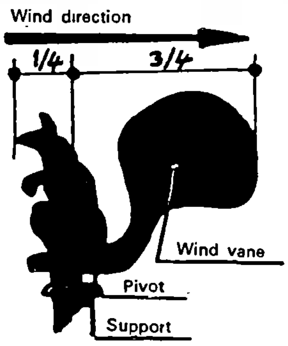
Eiffel Tower
(320 m.)

Photos WMO, Unesco, and French National Weather Bureau, Paris

BUILD YOUR OWN

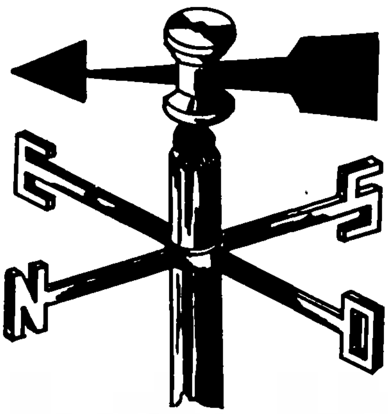
How would you like to build and run your own weather station? It's not as difficult as you might think. You may have to buy or borrow a few items of equipment but you can quite easily make some of the instruments you'll need from odds and ends. Another idea would be to make this a class project in your school with the help of your teacher.

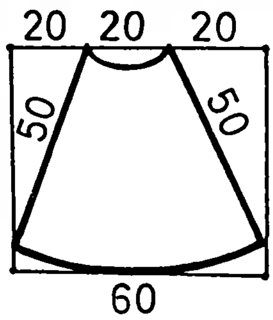
Some of the instruments must be housed in a well-ventilated shelter or " weather box ". Others, including a barometer, should be grouped in the open air. Instrument stands and weather box should be painted white to prevent the sun's radiation from affecting the readings. You can even give your " met station "

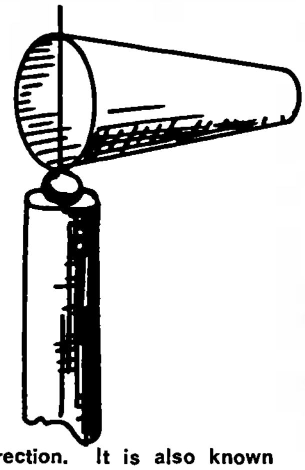


WIND VANE

This instrument tells you which way the wind is blowing. It is placed at the top of a pole. The vane can be made of wood or metal in any shape or form, ranging from the simple arrow on a cotton reel to the perky squirrel shown here. But in every case the tail or fin must be larger in surface than the head or arrow point so that the wind can swing it around. A large nail can be used as the axis. A bead makes a good pivot to allow the vane to turn freely. Complete the wind vane by placing below it indicators showing the four points of the compass.







WIND CONE

This instrument also shows wind direction. It is also known as a wind sock or wind sleeve. From a piece of lightweight, white cloth cut out the shape shown in the diagram above at left (figures show suggested size in centimetres). Then sew the two straight edges (marked "50") together to form the cone. Take a piece of strong wire and bend it into a circle to fit the big end of the cone. Slip two small curtain rings on to the wire and then fix them at opposite sides of the ring. Sew the cone to the wire circle. Slip a thin metal rod through the two curtain rings and attach the rod to the end of a pole fixed in the ground. As with the wind vane, a small bead slipped onto the rod allows the cone to rotate easily. If desired, the wind cone and the wind vane can be fitted to the same pole.

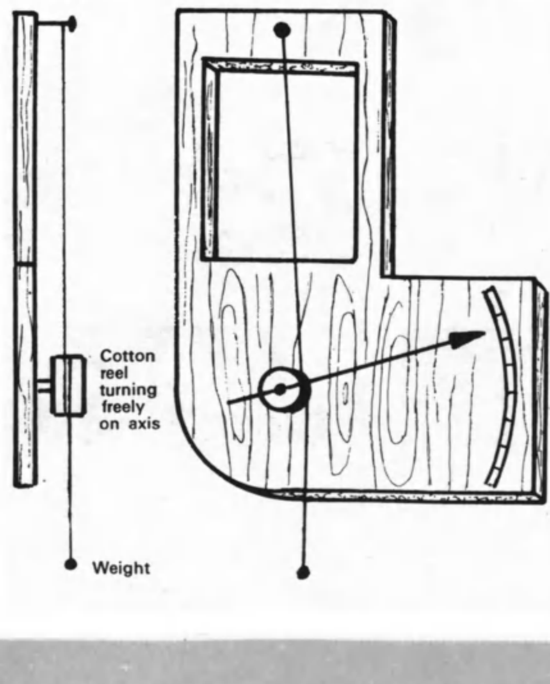
HYGROMETER

Used to measure the humidity of the atmosphere, a hygrometer is quite simple to make. Take an "L-shaped" piece of wood and cut a small window in it. Below the window fix a small cotton-reel in such a way that it can rotate freely. Attach a pointer to the cotton-reel and mark out a scale opposite the pointer.

The operation of the hygrometer is based on the fact that hair strands lengthen when humidity rises and shorten when the air is drier.

Attach a human hair, free from grease, to a point above the window, pass it two or three times round the cotton-reel and suspend a small weight at the end of the hair to maintain tension.

Placing a container of boiling water under the apparatus will cause the hair strand to lengthen and will send the arrow to the point of 100 per cent relative humidity. Mark this point on the scale and calibrate the rest of the scale if possible by comparison with another hygrometer that has already been calibrated.

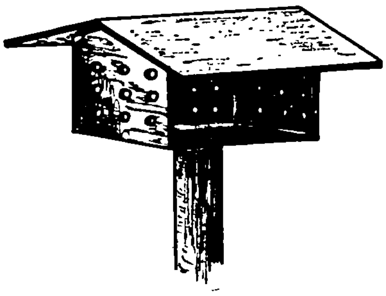


WEATHER STATION

a really professional look by putting a decorative fence around it. After you've built your weather station you can start noting and recording the instrument readings. But you must do this as regularly as clockwork — if the records are to be meaningful.

Then you can try your hand at forecasting the weather in your locality. Compare your own predictions with the radio and TV forecasts. If they don't tally, try to work out the reasons. Building and operating a do-it-yourself weather station can be an exciting and fascinating hobby that will be richly rewarding for many years to come.

WEATHER BOX



Two wooden boxes are all you need—one small enough to fit inside the other with a space in between. Remove one side of each box (the one that will face North) and pierce airholes through the other sides. Make sure that the holes of the outside box do NOT line up with the holes of the inner box, so that the sun's rays can never penetrate the inner box.

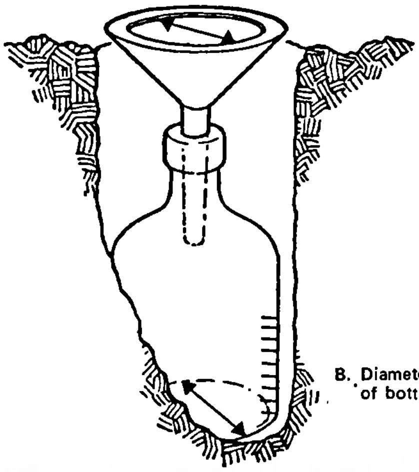
Thermometers and other instruments must be carefully protected from the sun, the rain and the snow, in order to obtain true readings, unaffected by the sun's rays or radiation reflected from the ground or nearby buildings.

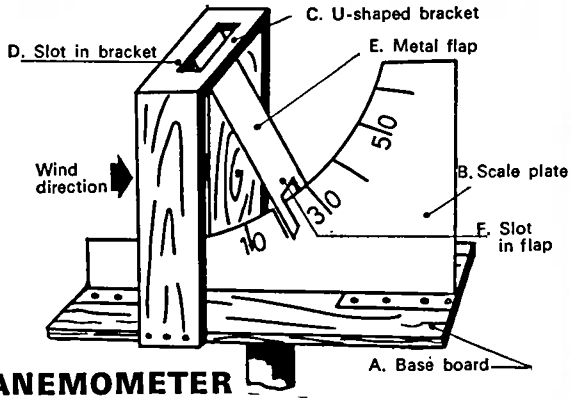
Cap the box with a double-sloping roof that gives good protection on the open North side.

Fix the box in an open place on a post or picket 1½ metres from the ground (this is the internationally agreed standard height). Hang the instruments on hooks to keep them from touching the sides of the box.

RAIN GAUGE

A simple rain gauge to measure the amount of rainfall is very easy to make. All you need is a straight-sided bottle and a funnel. The funnel should have either a very sharp vertical edge or a horizontal lip to prevent the raindrops bouncing out again. The diameter of the mouth of the funnel (A) must be the same as the diameter of the bottle (B). If you cannot find a bottle and a funnel of exactly the same diameter, take a larger funnel and cut away the top until it is the same diameter as the bottle. With a ruler mark a scale in millimetres up the side of the bottle. Place the funnel in the bottle and put them both in a hole dug in the earth so that the mouth of the funnel is just a few centimetres above ground level. After a period of rain, take the bottle out of the earth and check the water level against the scale. If you get a reading of, for example, 3 mm., then this is the rainfall for your area.





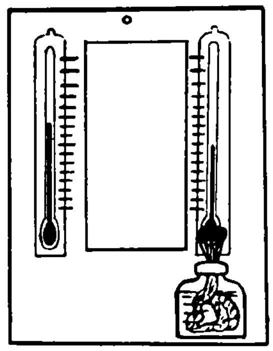
ANEMOMETER

This instrument is used to measure the force of the wind. Take a piece of wood (about 30 cm. × 30 cm.) to form the base board A and fix it to the top of a post. Take a rectangular piece of metal, cut it out in the curved shape shown at B in the diagram. Mark it to form a scale and attach at right angles to the centre of the base. With three pieces of wood make an inverted "U-shaped" bracket C bridging the scale, having first cut a slot D in the cross-piece of the bracket. Cut a rectangular flap E from a piece of light metal (an empty food tin would do) with a "U-shaped" portion cut out of one end F. Fix a nail across the slot at the top of the bracket and curve the end of the metal flap around the nail so that it can swing freely. The other end of the flap F will straddle the scale. Turn the apparatus in the direction of the wind and the flap will be tilted at an angle varying with the force of the wind.

One way to calibrate the anemometer is to hold it out of the window of a moving car (your school bus driver may help you with this) and note the angle of tilt of the flap at 10, 20, 30, 40, etc. kilometres per hour.

Another way to calculate wind velocity is by using the Beaufort scale (see page 38).

PSYCHROMETER



This is another instrument used for measuring the humidity of the atmosphere (see hygrometer). Fix two identical thermometers side by side on a board. One of them (here shown at left) will record the temperature in the normal way.

Below the thermometer at right attach a wide-mouthed jar filled with water. Make a wick out of a piece of cloth about 20 centimetres high. Wind the wick round the base of this thermometer and leave the other end soaking in the water.

If the atmosphere is very humid the two thermometers will show the same temperature. If the atmosphere is very dry there will be a marked difference between the two temperature readings. In this way you will have a relative idea of how humid the air is. Scientists use special tables (called psychrometric tables) to obtain very precise humidity readings.

 (Continued from page 33)

atmosphere by the use of catgut or strands of hair which expand when the air is moist and contract when it is dry.

A psychrometer, also used to measure humidity.

An evaporimeter. This instrument is used to measure evaporation.

Other instruments are placed just outside the shelter:

A wind vane (the modern version of the weather-cock often seen on church steeples) which indicates the direction of the wind.

An anemometer (four small cone-shaped cups at the end of rods that rotate on a vertical spindle) to measure wind speed.

These instruments are electrically linked to the observation hut where the measurements are shown on dials.

A heliograph, which records on sun-sensitive paper the amount of sunshine during the day.

The station is also equipped with a mercury barometer to measure atmospheric pressure and a recording barometer that gives a continuous graph of pressures.

To measure wind speeds at high altitudes, meteorologists release hydrogen-filled "sounding balloons" whose rate of climb is known. By tracking their flight the speed and direction of winds can be determined as well as the altitude of the base of a cloud layer at the moment the balloon penetrates it.

A basket can be attached to larger balloons containing a radiosonde that transmits back to earth details of air pressure, temperature and humidity.

CODED WEATHER INFORMATION

All these observations are sent in, assembled and retransmitted. Information comes in from every corner of the globe, from stations perched on the peaks of exposed mountains, from meteorological outposts deep in the Arctic, from weather-ships, aircraft, etc. They are sent to forecasting centres in a condensed international code consisting of five figure groups. Each group and each figure represents a different element of the weather.

SYNOPTIC WEATHER MAPS

Observations made at scheduled times are transcribed by figures and symbols on an outline map to produce what is called a "synoptic map".

The synoptic map gives, in schematic form, a broad picture of the state of the atmosphere at a particular time, over a certain area of the globe.

If we compare a series of maps drawn up at fixed intervals (at 6, 12 or 18 hour periods), we see that the "weather picture" on the maps changes very considerably during these periods. Depressions and anticyclones move at greater or lesser speeds, either growing larger or tending to disappear. Anticyclones may remain stationary or may move, though generally rather slowly. Although depressions are sometimes stationary, they usually tend to be more mobile. Fronts move in the direction of the air currents in which they occur.

Generally speaking, these different weather "ingredients" are carried along in a larger current, at varying speeds, from west to east. To complement the surface maps, upper-air charts are drawn up at different levels using data supplied by sounding stations. These charts contain only part of the data used for surface maps (pressure for charts at constant level or altitude for charts at constant pressure, temperature, humidity and wind).

FORECASTING

Using a series of maps it is possible to estimate the movements and developments of various weather elements and thus to draw up a forecast map showing atmospheric conditions for some time ahead, usually during the next 24 or 48 hours.

But to determine how the situation will develop the meteorologist must also apply a number of rules and physical laws in his calculations. Nowadays meteorologists use electronic computers to help them in making forecast maps.

The meteorologist uses these forecast maps to draw up his weather predictions for a particular area, while taking local conditions into account. ■

The texts and diagrams in this children's section are based on material drawn from: 1. a "meteorology kit", prepared and published by the Centre de Documentation Pédagogique, Geneva, Switzerland, under the direction of J.J. Dessoulavy; 2. the "Unesco Source Book for Science Teaching"; 3. "A Manual for Improvised Science Equipment", by T.E. Calvero and E.S. Sabado, under the direction of Pedro Orata, Quezon City Philippines.

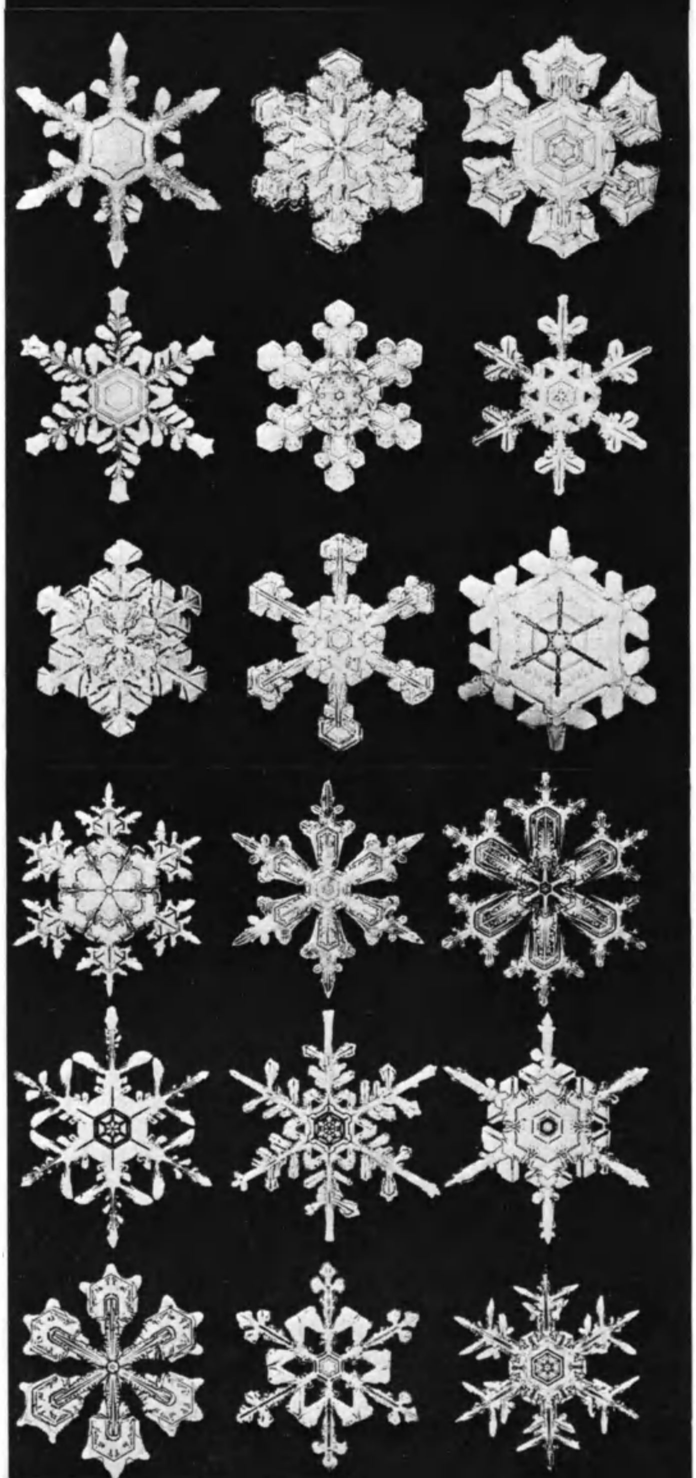
The Beaufort wind scale

To indicate the velocity of the wind meteorologists use a series of numbers known as the Beaufort scale. The scale was devised in 1806 by a British admiral, Sir Francis Beaufort who defined the numbers in terms of the effect of various winds on sailing vessels from a calm, force 0, to a hurricane, force 12, "that which no canvas could withstand." The scale was adopted in 1874 by the International Meteorological Committee for international use in telegraphy. Today the Beaufort scale is defined in terms of wind speeds measured in some countries at 10 metres above the ground and in others at 6 metres.

Force	Name	Effect on Land	Wind speed km./h.
0	Calm	Calm; smoke rises vertically.	0-1
1	Light Air	Weather vanes inactive; smoke drifts with air.	1-5
2	Light Breeze	Weather vanes active; wind felt on face; leaves rustle.	6-11
3	Gentle Breeze	Leaves and small twigs move; light flags extend.	12-19
4	Moderate Breeze	Small branches sway; dust and loose paper blow about.	20-28
5	Fresh Breeze	Small trees sway; waves break on inland waters.	29-38
6	Strong Breeze	Large branches sway; umbrellas difficult to use.	39-49
7	Moderate Gale	Whole trees sway; difficult to walk against wind.	50-61
8	Fresh Gale	Twigs broken off trees; walking against wind very difficult.	62-74
9	Strong Gale	Slight damage to buildings; shingles blown off roof.	75-88
10	Whole Gale	Trees uprooted; considerable damage to buildings.	89-102
11	Storm	Widespread damage; very rare occurrence.	103-117
12	Hurricane	Violent destruction.	118 and above.

Like human fingerprints, no two snow crystals are ever exactly alike. Although often similar in general outline and structure, snow crystals come in a bewildering variety of size, shape and pattern. They often take the form of triangles, hexagons or six-pointed stars. When the air is very moist they may clump together to form snowflakes. One snowflake may consist of as many as 50 interlocking crystals. Enthralled by their beauty, an American farmer-meteorologist, Wilson A. Bentley, spent hours each winter photographing snow crystals near his home in Vermont. Nearly half the 5,000 photomicrographs he prepared appeared in the book "Snow Crystals", first published in 1931 by McGraw-Hill Books, New York; we reproduce 18 of these illustrations below.

Photo W.A. Bentley © taken from "Snow Crystals", by W.A. Bentley and W.J. Humphreys, Dover Publications Inc., New York.



A SHORT GUIDE TO WEATHER-SPEAK

by François Le Lionnais and Roger Clausse

FRANÇOIS LE LIONNAIS. — Meteorologists use lots of technical words that are unknown to the man-in-the-street. As a meteorologist, would you like to give a few examples?

ROGER CLAUSSE — Well, to take a few at random, I could mention anticyclone, isobar, cyclogenesis, frontolysis, hydrometeor or isohypse. Then there are everyday words with a special meaning, such as "waves"—as in "polar frontal waves"—or the word "family" in the expression "family of disturbances", which means alternate zones of rain clouds, showers and brief intervals of fine weather. Another familiar word with a special meaning is "front", in the sense of a surface where masses of warm and cold air come into "conflict"—the same idea as front in the military sense.

F. L. L. — The words you just mentioned—front, conflict, masses of air—aren't they connected with what we usually call bad weather? What causes bad weather?

R. C. — Bad weather is caused by differences of atmospheric pressure in different parts of the world. Generally speaking, bad weather is linked with zones of low pressure, while zones of high pressure keep the bad weather out.

F. L. L. — Perhaps you would explain what exactly atmospheric pressure means?

R. C. — Anyone who has looked at a barometer knows that atmospheric pressure, which corresponds to the weight of air pressing down on a given surface area, can vary

CONTINUED NEXT PAGE

Photo © Laurence Brun, Paris

January in Kabul market-place, Afghanistan.

TALKING ABOUT THE WEATHER *(Continued)*

from one reading to the next. Atmospheric pressure varies from one part of the world to another, but at any given moment pressure will be constant along imaginary lines which one can draw on the map.

For example, in Brazil pressure might be the same in Bahia, Carinhanah, Brasilia and Araguari. The line joining these points is what we call an isobar, which simply means a line of equal pressure. A different isobar with a different value might, for instance, pass through other Brazilian cities such as Ilheus, Belo, Horizonte and Rio de Janeiro.

These isobars thus correspond to varying values of atmospheric pressure at a given moment over a region which can vary considerably in extent. Taken all together they make up what is called the field of pressure. They are given in millibars, a unit signifying the amount of pressure which will support, roughly, three-quarters of a millimetre of mercury in a barometer tube. So what is known as standard pressure (1013.3 millibars) will support a column of mercury 760 mm. high or, to give you a better idea, it represents 1,033 grammes of air pressing down on every square centimetre.

These isobars form curvy shapes. One might imagine one of them, say isobar 1,000, passing in the U.S.S.R. through Odessa, Berdichev, Gómel, Voronezh, Mizlerovo and back to Odessa, thus describing a rather irregular circle. Inside this line, there may be other "contour lines", getting smaller and representing lower and lower pressures —975 - 970 - 965 millibars, etc. This is what we call a depression, in which the nearer the isobars are to the centre the lower the pressures they represent.

In other zones the pressure increases towards the centre, and these are called anticyclones.

Broadly speaking:

a depression is a zone of low pressure and an anticyclone is a zone of high pressure.

If we keep this idea in mind, it will help us to identify zones of fine weather and bad weather.

F. L. L. — From this idea of anticyclones and depressions, can we tell what the weather is going to be like?

R. C. — Certainly. The deeper a depression—that is, the lower the pressure at the centre, the smaller its diameter, and the more rapidly it moves—the more marked will be the meteorological processes which go with it. In other words a small depression with a very low pressure at the centre is likely to be accompanied by a storm. Once we understand this code, we can at once decipher any graphic representation of the weather situation such as maps shown in television weather forecasts.

Because of the effect of the Earth's rotation, winds move in a clockwise direction around anticyclones and in the opposite direction around depressions in the northern hemisphere, and these directions are reversed in the southern hemisphere.

The position of these elements on the map thus gives an immediate idea of the general movement of winds in a particular area. To the east of a large-scale anticyclone, in the northern hemisphere, for instance, the wind will be coming from the north and will therefore be cold, while to the west it will be a warm south wind. It is easy to get a mental picture of all the possible combinations and all the winds which would result from them and thus to have some idea of the likely temperature.

F. L. L. — You mentioned storms just now. Could you say a few words about the storms we call cyclones?

R. C. — Yes, because there may be some confusion about the word cyclone. The basic idea behind the word cyclone is that of a circular, turning movement. We now know that this is what happens in the case of depressions around which the wind and in some cases rain move in a circle.

A depression is thus a cyclone in this sense, and meteorologists use either word to mean the same thing. But most persons use the term cyclone when they mean tropical cyclones, which originate in the warmer regions of the world over the oceans. These disturbances are relatively small—a few hundred miles across—and the pressure at their centre is very low—900 millibars, the equivalent of 675 mm. of mercury. They are accompanied by very violent winds sometimes reaching more than

200 km./h. They have the typical circling movement corresponding to the word cyclone.

F. L. L. — Do cyclones move about from place to place very rapidly?

R. C. — No, fortunately they move relatively slowly, at about 20 to 50 km./h., which means that it is possible to detect them and to forecast their arrival either by means of radar or by pictures sent back by satellites, from which they are easily visible in the form of a ring of clouds.

F. L. L. — By a ring of clouds, do you mean that the sky is clear in the middle?

R. C. — Yes, this is called the eye of the cyclone, where the sky is usually clear. Satellite photographs have shown that even the cyclones in the temperate part of the world —depressions accompanied by clouds and rain—often have a small eye in the middle, which goes to prove that they are formed in the same way as tropical cyclones.

F. L. L. — Just how and why do tropical cyclones begin?

R. C. — Cyclones originate for the most part over the oceans in the tropics, where the temperature of the sea and of the layer of air in contact with it is very high in relation to the upper levels of the air. This causes violent upward movements, drawing masses of very humid air up from sea level. These conditions often occur during the hot season in both hemispheres.

F. L. L. — How long does a cyclone last?

R. C. — Usually about a week. After that the depression either fills or spreads out, in either case becoming less intense. We might in passing mention two other names connected with cyclones: typhoon, which is simply another name for the cyclones occurring in the China Sea, and hurricane, which is another synonym of tropical cyclones, used in the English-speaking parts of the world.

F. L. L. — What word from the language of the meteorologist shall we look at now?

R. C. — Well, as a change from the more violent aspects of the weather, let's talk about trade winds. Most people have heard about them and associate them with the sea.

F. L. L. — That's right, because in the days of sailing ships, merchant ships depended greatly on trade winds. And as a matter of fact they helped the ships of Christopher Columbus to sail from Europe to America.

R. C. — Some people say that Columbus discovered these winds. Incidentally the French word for the trade winds—"alizés"—is believed to come from an old French word meaning "regular". The trade winds do in fact blow fairly regularly in the intertropical zone, from the north-east in the northern hemisphere and from the south-east in the southern. They are caused by the same sort of phenomenon as we have just been describing, that of air currents circulating around the anticyclones which persist over the tropical regions of the oceans while low pressures prevail over the equator. They are not very strong—from about 15 to 30 km./h.—and are usually accompanied by fine weather.

F. L. L. — What happens between these two belts of winds, at the equator itself?

R. C. — This is where the equatorial calms occur, the "doldrums" which sailors in bygone days used to dread. English sailors also called these regions the "horse latitudes", apparently because when ships were becalmed for days or even weeks on end, they had to throw their horses overboard when their supplies of water and hay ran out.

F. L. L. — While we are on the subject of wind, perhaps you could tell us about the various terms used by meteorologists and sailors for strong winds.

R. C. — First of all there are the gusts of wind which occur during a thunderstorm, and which, if they recur frequently, are characteristic of an unstable, turbulent state of the atmosphere. Wind speeds in such gusts can vary widely and rapidly and can reach over 20 m. per second in a few seconds, which is dangerous for anything which is susceptible to the wind, such as tents, cranes or sailing boats.

Gales, for which warnings to shipping are sometimes broadcast, are winds with an average force of more than 34 knots (62 km./h), which is equivalent to force 8 on the Beaufort scale, so called after the English admiral who invented it (see page 38). Gale force winds can whip up waves over 5 m. high, which are very dangerous for sailing craft. After the gale comes the "strong gale", a wind which blows at between 75 and 88 km./h.

F. L. L. — While on the subject of winds and the sea, could you tell us about breezes, which are more popular with sailors than storms?

R. C. — Breezes are local winds, usually not very strong and changing direction depending on the time of day. When the sun is shining over the coast, both the shore and the sea are heated by the sun but the land gets hotter than the sea. Upward currents are formed over the land, drawing in the cooler sea air. An on-shore (towards the land) breeze is thus created—this happens about three hours after sunrise and goes on until the sun sets. Sandy or rocky coasts absorb more heat than wooded coasts, so that the breezes will be more noticeable.

At night the land cools more quickly than the sea, with the result that the movement of air is reversed and we have an off-shore (towards the sea) breeze. This partly explains why the climate is mild at the seaside because it is warmed at night by the breezes coming from the land and cooled in the daytime by the sea breezes.

F. L. L. — Does this also happen in other places?

R. C. — Yes, in mountain regions where the cold air comes down from the mountains at night, bringing lower temperatures with it, while in the daytime the warmer air rises from the valleys towards the mountain peaks, sometimes causing the sudden thunderstorms which are a menace to mountaineers. Incidentally, the alternate heating and cooling of land and sea which produce land and sea breezes are reproduced on a larger scale in the case of monsoons.

F. L. L. — I always thought monsoons were seasonal winds.

R. C. — You're right. They are seasonal. In summer, the continents heat up more quickly than the oceans. Rising warm currents over the land create low pressure areas and cooler air over the oceans flows towards the continents. These air currents laden with moisture from the oceans bring with them clouds and torrential rains. Passing over the steadily rising land to the mountains of Tibet, for instance, the rising air begins to condense and precipitate its water vapour. In the winter the process is reversed and dry air pours seawards from the colder continental mass. "Monsoon" comes from the Arabic word for "season", and was first applied to winds of the Arabian Sea that blow six months from the south-west and six months from the north-east.

F. L. L. — So monsoons occur in other places than India.

R. C. — Yes, monsoons are particularly intense in south-east Asia, but they also exist, to varying degrees, in the western part of the Pacific Ocean, northern Australia, parts of Africa and even along the edge of the Gulf of Mexico.

F. L. L. — Now, what about a word which interests all of us—sunshine.

R. C. — Meteorologists use the word insolation, rather than sunshine, in other words, the amount of direct solar radiation received. They also speak of "insolation duration", meaning the number of hours and minutes in a day, month or year when the sun is visible from a given point.

Paris in July, for instance, gets on average 238 hours of sunshine, Nice 363, Kazan 300, New Delhi about 200 (since it is the monsoon season in India), Perth 250, Rio and Addis Ababa 200 each, and of course there is none at all in the Antarctic, where it is the middle of the long winter night.

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F. L. L. — When the sun is more or less covered by hazy cloud, one sometimes sees rings round it. Such optical phenomena, which usually occur near the sun or the moon, are known as haloes and coronas, but people tend to confuse them. Would you tell us about them?

R. C. — Yes, we call them "photometeors", in other words, optical phenomena of the atmosphere as against "hydrometeors", which are composed of solid or liquid water particles such as rain, snow or fog. The commonest of the photometeors are the halo, the corona and of course the rainbow, which we all know.

The halo forms a circle of bright light around the sun or moon. If you hold out your hand at arm's length with the palm covering the sun, the circle should appear at the end of your fingers. Sometimes there is another circle around the first and sometimes there are even bright spots on either side of the sun or moon—so-called "pillars" or luminous tangent arcs.

These effects are caused by the refraction of the light passing through the ice crystals of which high clouds are formed, when such clouds form a continuous "cloud veil"—often a sign of bad weather.

F. L. L. — So the popular belief that a wide ring around the sun means rain really has some basis.

R. C. — Yes, and the belief that a smaller circle means that rain is not in the offing is also correct. This smaller ring, which is much less clear, is a corona. The corona has more colours than the halo, and is closer to the sun or moon.

It is caused by the diffraction of light through the fine water droplets—not ice crystals this time—of the thin clouds covering the sun. The corona thus usually appears when there is what is called a "mackerel sky". It may be a sign of poor weather, with light rain, but this is not an absolute certainty.

These ideas about the approach of bad weather, bring us to the term "atmospheric disturbance". A disturbance is a kind of atmospheric "ailment", which corresponds to the arrival of a depression and begins with a period of "incubation". The wind changes to south or south-west (to take a typical example in the temperate zones of the northern hemisphere).

Pressure falls, thin clouds appear and begin to accumulate until they have formed a fine, continuous veil of cirrostratus cloud which completely covers the sky—the sort of cloud veil we were talking about a moment ago. The barometer is now at its lowest point, the wind has veered to the west, and now a hole appears in the cloud cover.

There may now be a clear interval, but before the fine weather returns, there will be more showers, with fine periods becoming more and more frequent. The wind which is now blowing more strongly, sometimes in gusts, has veered further to the north-west, the barometer rises again and finally the sky clears.

F. L. L. — What about the question of fog and visibility.

R. C. — Fog is another phenomenon which we come across at the seaside. Sailors sometimes call anything that hampers visibility a sea mist, but the meteorologist uses the terms more precisely. He uses the word fog in cases where visibility is less than one kilometre and mist when visibility is between one and two kilometres.

F. L. L. — Is there an accurate way of measuring visibility?

R. C. — Yes, there are instruments called visibility meters, which use a light source at a set distance linked to a photoelectric cell which makes it possible to measure the degree of opacity of the air through which the light passes. The major airports have a very sophisticated system of this sort on their runways. Instruments in the control tower enable the air traffic controllers to see at what distance the landing lights on the runways will be visible to pilots.

F. L. L. — Talking about fog, which consists of minute water droplets suspended in the air, brings us to the question of pollution, one of the major problems of our time.

R. C. — To see how the various pollutants which are pumped into the air collect in the lower levels, we need to go higher into the atmosphere.

We know that in the lower part of the atmosphere, which is called the troposphere, temperature falls as we go up, at the rate of about 0.6° C. for every 100 metres or so, which means that at an altitude of 10 km., the temperature will be minus 60° C. So we can understand why aircraft are properly insulated!

But in the layers of air nearest to the ground, there are many exceptions to this general rule. When thick fog covers Paris, a thermometer at the bottom of the Eiffel Tower may show 10° C, while another thermometer at the top of the tower may register 15°. This often happens in winter. When the night sky is clear and there is not much wind, the ground loses much of its heat by radiation. The air nearest to it also cools, becoming heavier and remaining close to the earth's surface, whereas the air above it, being a poor conductor, keeps more or less the same temperature. It becomes warmer than the air near to the ground, or at least warmer than it would be if temperature fell off with altitude in the normal way.

Thus we have what is called an inversion of temperature. When it occurs, the air is very stable, since the upper layer forms a sort of lid which prevents smoke, dust and exhaust fumes from escaping. They thus stagnate at ground level for days on end, making the pollution worse and worse.

F. L. L. — If inversions of temperature can be forecast, do special precautions need to be taken?

R. C. — Yes, in heavily industrialized areas measures may be taken to cut back production in industries which cause pollution or where possible to use products which cause less pollution. Inversions of temperature can be detected by means of radiosondes (balloons carrying instruments aloft whose recordings are transmitted by radio to ground stations). These devices enable us to find out the temperature of the air at various levels up to a height of more than 20 km.

F. L. L. — What happens above the inversion layer?

R. C. — The temperature again falls off with the altitude, unless there happens to be a second inversion layer. This may be caused by the arrival of warm air from a higher level, which might be the sign of an atmospheric disturbance on the way. Higher still, about 10 km. up in the temperate regions, about 7 km. at the poles and about 17 km. at the equator, comes the stratosphere where the temperature stops falling and starts rising.

F. L. L. — What is the temperature at that level?

R. C. — At the poles it is about -50° C., in the temperate regions about -56° C., and at the equator -85° C. This means that an aircraft flying from the North or South Pole towards the equator at an altitude of 15 to 17 km. would have to turn up its heating system, since the outside temperature would fall from -50° C. to -85° C. in the course of the journey, in spite of the fact that at ground level the temperature is getting higher all the time.

F. L. L. — Why not go even higher and take a look at the upper atmosphere which spacemen now traverse on their missions? You mentioned the troposphere, in which the temperature falls as one rises, but you said that above that, in the stratosphere, the temperature is at first stationary and then begins to increase.

R. S. — That's right, the temperature within this layer of the atmosphere, which extends from about 10 km. up to about 50 km., rises from -56° C. to 0. This is due among other things to the presence of ozone, which is concentrated about 35 km. up. Contrary to what used to be thought, violent winds blow through the stratosphere, sometimes reaching well over 350 km./h.

Above the stratosphere, in the layer known as the mesosphere, extending up for about a further 30 km., the temperature falls off again rapidly, reaching 90° below zero C. at its upper limit, a height of about 80 km.

Patterns in the sky

A sodium vapour cloud writes a strange message hundreds of miles up in the sky during a rocket experiment designed to measure high-altitude winds and temperatures. Here, French scientists study the vapour experiment, launched from NASA's Wallops Island Station in Virginia.

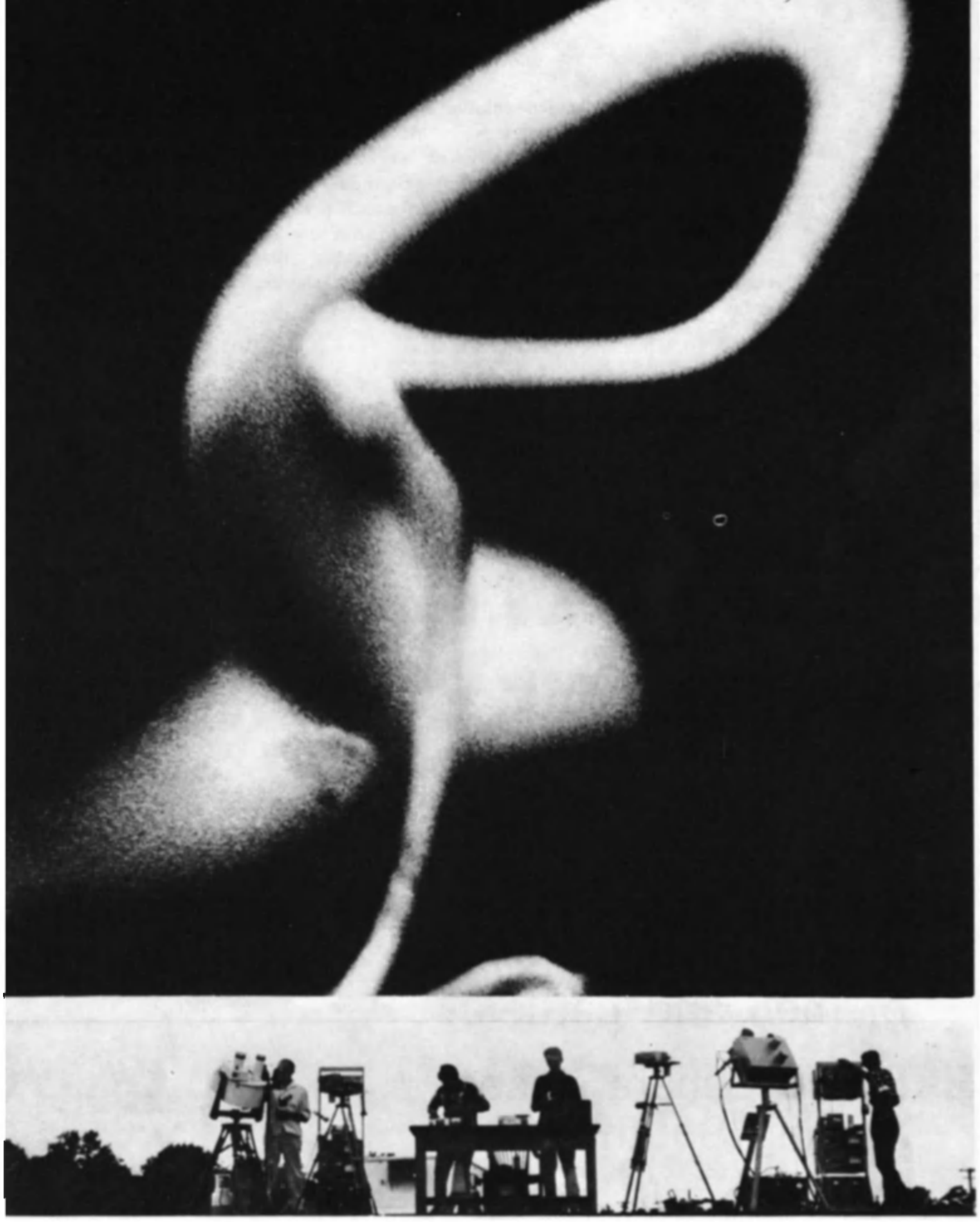

Photo © USIS

Beyond that again, in the thermosphere which extends to the outer limits of our atmosphere, 1,000 or so km. up, the temperature again rises, though it varies considerably. Beyond the level of 200 km., the speed of the highly rarefied molecules of gas corresponds to temperatures of several hundreds of degrees but because the air is so rarefied, its real temperature—in normal physical terms—is extremely low.

F. L. L. — One word in the meteorologist's vocabulary which everybody knows and understands is "forecasting". But some people feel that weather forecasters tend to be overconfident in their predictions; that their forecasts are still a far from sure guide to tomorrow's weather, unlike forecasts of the tides or the positions of the stars.

R. C. — It's true that weather forecasts sometimes tell us: "Cloud will develop tomorrow morning in the eastern part of the country" in much the same way as an astronomer might announce: "The annular eclipse of the sun will begin at 1 hr. 30.3 minutes Universal Time at 66°20 minutes East and 20° North"—and as far in advance as you like.

Yet there is clearly quite a different degree of accuracy in these two forecasts: one tends to be rather vague while the other has a mathematical precision. But I'm sure it would be rather boring if forecasters were to tell us: "All we can say about the weather tomorrow is that cloud may develop in the morning west of a line drawn very roughly from..., etc."

What is certain is that even with the most powerful computers, meteorologists can only give the most likely interpretation, based on the information they have and using approximate equations which enable them to simulate the state of the atmosphere and the changes taking place in it. I agree it would be better if they could indicate the degree of probability of the prediction they have come up with, but there are still problems to be solved in this area.

F. L. L. — Before we end our visit to the world of meteorology, would you please explain the mysterious terms which you mentioned at the beginning—cyclogenesis, frontolysis and isohypse.

R. C. — These terms are hardly ever used in weather forecasts for the general public, but I can give you a brief definition: cyclogenesis, as its name suggests, is the process by which a cyclonic circulation is formed; frontolysis is the process which causes a weather front to weaken or disappear, in other words, the effects produced by the encounter of masses of air originating from different sources; and an isohypse is a surface, generally an isobaric surface, within which pressure is constant. So as you see, the meanings of even these unfamiliar words are really quite simple. ■

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ROGER CLAUSSE *is a leading official of the French Meteorological Office and for many years headed its Information and Public Relations Service. A member of the Council of the French Science Writers' Association, he has written on meteorology for the press, radio and television and is the author of many popular science books on meteorology, including one for children entitled "Papa dis-moi... Fera-t-il beau demain?" (Daddy, will it be sunny tomorrow?) published by Editions Ophrys, Paris, 1971.*

This scene of death and desolation in Mauritania is being repeated over thousands of kilometres in Africa south of the Sahara. Drought and famine have stricken at least a dozen countries, among the worst affected being Senegal, Mauritania, Upper Volta, Mali, Niger and Chad. Cattle are the livelihood of some 70 per cent of the population of this area and the U.N. Food and Agriculture Organization has estimated that the virtual extinction of many of the herds vital to villagers and nomad herdsmen is now a serious possibility.

Photo Marie-Laure de Decker © Gamma, Paris

DROUGHT OVER AFRICA

1 - tragedy strikes millions of men and cattle

2 - is the Sahara desert moving South?

by Jean Dresch

FAMINE threatens millions of villagers and herdsmen with their decimated flocks, today forced into an unprecedented migration in search of food and water, in all the West African countries to the south of the Sahara, from Mauritania to the Sudan.

Its cause is drought, a prolonged decline in rainfall that has been recorded as far as central Asia, throughout the periphery of the arid zone, extending from the tropical desert of the Sahara to the continental deserts of temperate Eurasia.

Drought, admittedly, is the normal condition in these countries, and the living world has adapted to it. In Africa these regions bear the Arabic name of Sahel, which means the border, whether of the desert or of the sea; for they are not really part of the desert proper.

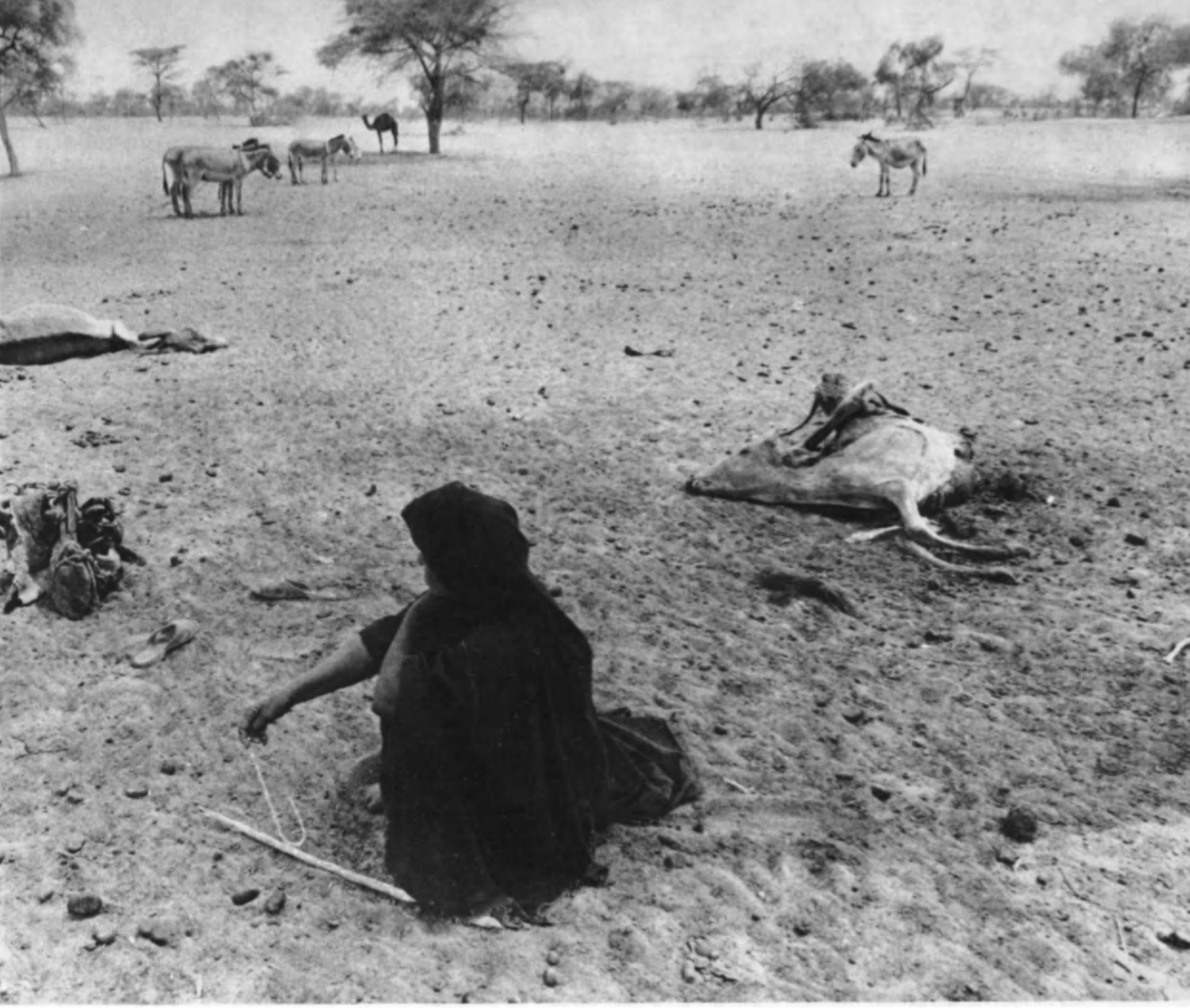
The soil is less purely mineral than the present-day soil of the Sahara and bears a generally open, scattered vegetation in the form of "steppes" of trees, bushes and annuals—Gramina-ceae or of other families.

The vegetation grows denser and lusher in the lower latitudes and becomes savanna, a closed formation which feeds herbivores, and hence carnivores, in increasing numbers but exposes them to burning in brush fires.

In these regions man is no longer obliged, as he is in the desert, to lead either a nomadic life linked to the dromedary or the secluded life of the watered oases. He can raise cattle and small livestock. He can till the soil without irrigation.

For all that, these are the frontiers of the desert. Man and the other living creatures follow the rhythm of two main seasons, one—the longer—almost completely dry, the other both humid and hot.

JEAN DRESCH *is professor of geography at the University of Paris and at France's Ecole Normale Supérieure. He is a leading authority on the world's arid zones, notably those of North Africa and Africa south of the Sahara, and has written extensively on this subject.*



The Sahel feels the effect of cells of tropical high pressure, which separate the low-pressure areas of the equatorial latitudes from those often characteristic of medium latitudes. These high-pressure cells set very regular, dry winds blowing towards the low latitudes: these are the continental trade winds, called in West Africa the Harmattan.

The rains follow the apparent motion of the sun to the Tropic of Cancer during the northern summer. Thus masses of moist air advance coming from the Atlantic Ocean or the Congo Basin with southerly winds, which are diverted north-eastwards as they cross into the northern hemisphere.

These air masses and winds, known as monsoons, encounter the tropical dry air and the trade winds (intertropical convergence), plunge beneath them and lift them. That is the time when the rains fall; they are plentiful and long-lasting in the south when the moist air mass is thick. Further north they are less and less so. Disturbances still occur but the hot-air tornadoes of the late afternoon are increasingly often dry as the moist air mass thins out and loses more of its moisture.

Under these conditions the precipitation decreases together with the duration of the wet season from 600 to 800 mm., where the wet season lasts five to six months, down to 250 mm., where the season is only three months long.

The shorter the rainy season, the more irregular it is in space, in time over the year, and from one year to another. The rains may start earlier or later, and may last a longer or a shorter time.

Furthermore, temperatures also rise with the apparent motion of the sun, so that mean maximum temperatures exceed 35 and 40 degrees C. in April and May, except near the sea. The coming of the rains brings them down a little, but they are still high enough to cause three times more evapotranspiration (loss of water by evaporation from the soil and by transpiration from plants) during the day than during the night.

To be of practical value, therefore, the rainfall must not only be generally abundant, but also intense—yet not too intense, about 20 to 25 mm. during one or two days at the beginning of the rainy season.

The rains are not always spread to the best advantage over the course of a year, and each year is different from the next. Sometimes a series of good years occurs, only to be followed by a bad year or a series of bad years.

A sequence of dry years is remembered in 1910-1914, when they caused a real famine. 1941 and 1942 were

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Horns of thousands of cattle killed by thirst in Senegal lie whitening under the African sun (below), while survivors (left) rummage in anything they can find. Since 1968 a vast belt of countries south of the Sahara has been hit by unremitting drought. Last year and this year famine and death have reached crisis proportions. Some rainfall in Mauritania and elsewhere in the summer of 1973 has brought slight relief. Right, in a Chad village, two children gulp down a rare drink of water. Below right, a woman of Upper Volta shares her water ration with her donkey.

Photo Brûle © Gamma, Paris

no better; and dry years have been succeeding one another since 1968, whereas the decade 1951-1960 was wetter. But there is no cyclical rhythm from which to predict disasters.

This year-to-year irregularity in rainfall is also characteristic of the Sahel on a larger time-scale. More and more is being learned about the detailed development of climatic conditions over the Quaternary era. It appears that sweeping changes occurred, from fairly wet periods to extremely dry periods in which the Saharan winds pushed the dunes 200 to 300 km. further south than the living dunes of today.

On the other hand several wet phases have been detected, the most recent being put at 6,000 to 2,300 years ago. The entire Sahara was better watered during that time. There were extensive lakes, and it is probable that black populations practised agriculture in the Sahel.

Cattle-rearing went on till much later. it was replaced by horse and then camel-rearing. Even in the Middle Ages, however, the aridity was not so severe. Many farming villages survived in the Mauritanian Adrar for example. The rate of precipitation must have been 400 to 450 mm, the strict minimum for rain-watered tillage and double the present rate.

It is thought likely that the subsequent drying-out process has speeded up since the end of the last century. It is said that rainfall is diminishing, wells are running dry, rivers are flooding less often and in less volume, dunes are being revitalized, vegetation is deteriorating and game animals are scarcer.

Does this mean that the climate itself is becoming drier? Fluctuations are a matter of historical record; they are as yet unexplained, but they are not always in the same direction.

Over the decade 1950-1960 there was enough rain to speed up the northward movement of the cattle-herders, the Peul, and of the millet-growers. The herdsmen come looking for grazing, and contend for it with the Saharans who have to leave the desert in the dry season.

The millet-growers colonize the Sahel, like a pioneer fringe, in search of new lands, whether they are black peasants or former Saharans, often the servants of nomadic tribes in process of settling.

The natural conditions in the Sahel, then, are known, and man, with his age-old techniques, has managed to adapt his economy and his migratory movements to them.

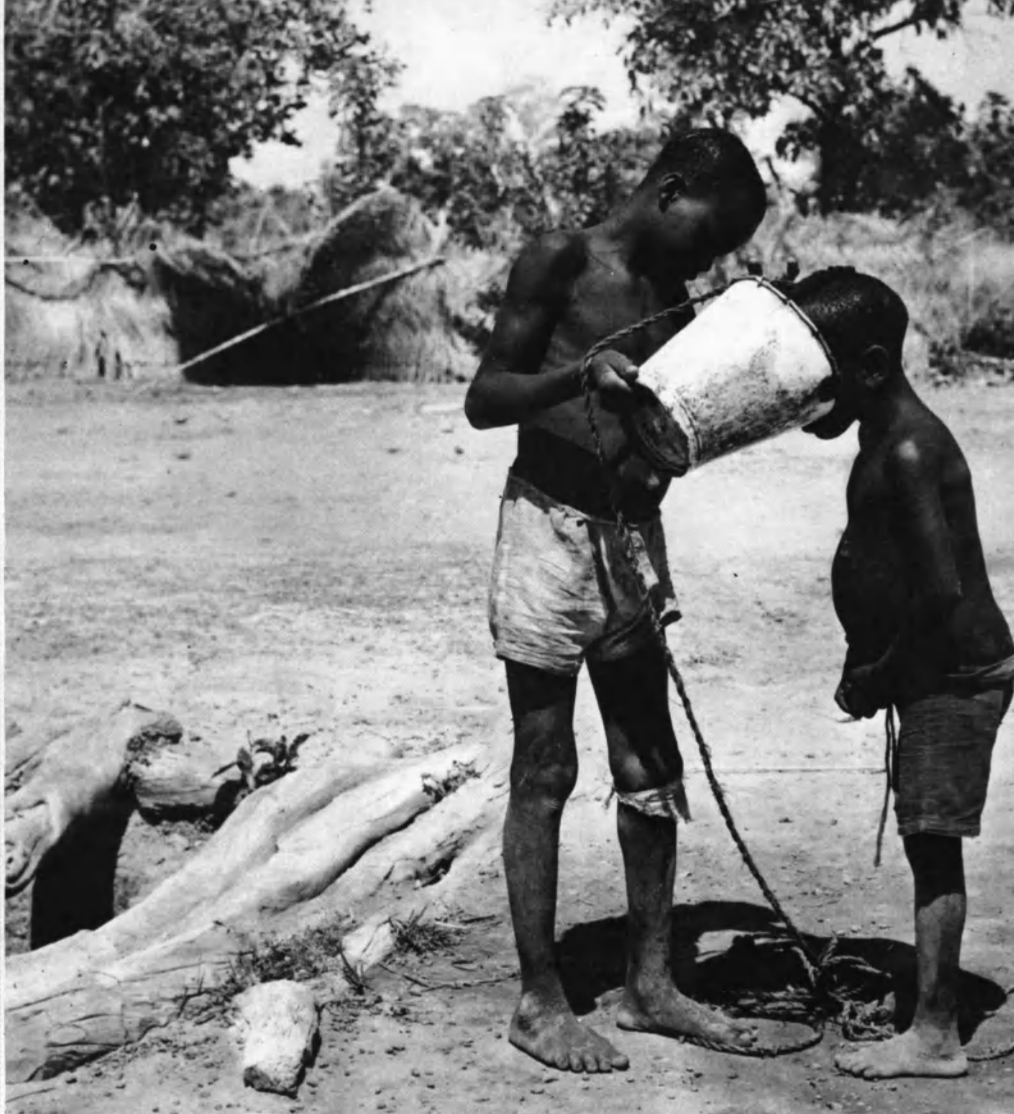
Today it should be possible to put better scientific knowledge of the Sahel and modern techniques to use, not only in relieving the victims of drought but in bringing drought itself under control. However, it must be recognized that the Sahels are very marginal regions for the international economy.

Development activities have been focused on regions further south, which were better watered and which could grow crops at a profit for foreign markets. As a rule these are non-food crops such as groundnut and cotton; it is known that they have not enriched the countries where they are grown, much less the peasants who grow them. They have helped to degrade the vegetation and hence to worsen the threat of drought.

Population growth has forced the Sahelian peoples to increase their herds and to bring more land under cultivation. In dry-year periods, overgrazing and renewed ground-clearing activity are carried to danger point. But people must live.

HORNS OF UNPLENTY

Photo Marie-Laure de Decker © Gamma, Paris



Photos © CIRIC, Geneva

However, there has never been enough investment in these marginal regions. Wells have been dug, but not enough of them, and they require upkeep. Grazing land can be developed, controlled and improved; but little of this has been tried. Better use can be made of water resources, aquifers and, even more, rivers; but their development often stops short at the planning stage.

In this ebbing century, forecasting is feasible. Through scientific studies of natural and human conditions, solutions can be found. But that entails applying the will and the necessary means, before disaster strikes. ■

This article first appeared in the May 1973 issue of "Development Forum", a new monthly newspaper published by the United Nations Centre for Economic and Social Information (C.E.S.I.). "Development Forum" deals with the action of the United Nations in the economic and social fields, and notably with the major problems of the developing countries, wasteful spending on arms, the inequitable distribution of resources, the population explosion and the deterioration of the environment. For a complimentary subscription, write to: C.E.S.I., P3/16, Room C 525, Palais des Nations, 1211, Geneva, Switzerland.

Like some horrific, mythical monster rising from the sea, this infra-red photograph shows atmospheric pertubations over a huge area of the Atlantic. The photo was taken from a height of 800 kilometres by the weather satellite Nimbus II. Study of the general circulation of the atmosphere under the Global Atmospheric Research Programme of the World Meteorological Organization promises to result in much more reliable long-range weather forecasting.

Photo © Météorologie Nationale, Paris

LONG-RANGE FORECASTING OF DROUGHT AND FLOODS

Is there any chance that present forecasts can be extended beyond a month?

by Jerome Namias

JEROME NAMIAS, *Research Meteorologist at Scripps Institution of Oceanography, La Jolla, California, is one of America's leading weather scientists. He has received many awards for his research in meteorology, and he is widely known for the system he developed of up-to-one-month weather forecasting.*

IN this era of rapid communication everyone is quickly informed about meteorological disasters such as floods, droughts, tropical cyclones and tornadoes. Some disasters, such as cyclones and tornadoes, are predictable over a time span of a day or so, so that precautions can save life and property.

Other natural phenomena are more insidious. Drought, for example, develops over months, seasons, and sometimes years and causes even greater human suffering through famine and economic dislocations. Are these insidious long-term disasters predictable? If not, what is the hope that they ever will be?

We are all aware of the ravages of natural events of the recent past—the devastating Russian drought of 1972; current drought in sub-Saharan countries, especially Mali, Mauritania and the Upper Volta, which seems to have persisted and become aggravated in the last few years; the occasional seasonal droughts in parts of India and Australia and the "Seca" or drought which occurs in some years in northeast Brazil.

On the wet side, we have the eastern U.S.A. floods in June, 1972, associated, in part, with hurricane Agnes—the most costly storm in U.S. history, and we remember the 1966 tragic flood of Florence. These are

but a sample of spectacular events from the climatological record.

From time immemorial there have been occasions when nature "goes on a rampage" and makes it appear that the climate is changing. Why does nature do this? Unfortunately man does not yet fully understand the causes of these events, and therefore he is unable to predict them reliably.

Yet meteorologists and climatologists have made great strides in studying them over the past few decades. The World Weather Watch (WWW) programme of the World Meteorological Organization (WMO) and complementary (WMO - International Council of Scientific Unions) Global Atmospheric Research Programme (GARP) promises to bring much greater understanding and perhaps reliable long-range weather prediction (see articles pages 4 and 21).

At present scientifically-based long-range predictions are limited to a month or, at most, to a season in advance. These are general in nature and mainly attempt to predict whether precipitation over broad areas will be above, below or near the long period average (normal) and whether these areas will have subnormal, normal or above normal temperatures.

The methods used are, for the most part, not precise enough to indicate the beginning or ending of great droughts, which span more than one season and may last for years. Neither are the methods precise enough to forecast the record-breaking persistent rains which lead to floods.

Let us examine some of the known factors associated with drought, for this may give some idea of the complexity of long-term atmospheric behaviour. The immediate cause of drought is sinking motions of air masses. These descending air motions, of the order of a few hundred metres a day, result in compressional warming of the air since it is subjected to increasing pressure in descent. This is analogous to the heating of a bicycle pump in use.

While the absolute quantity of water vapour in an air parcel remains unchanged in descent, the *relative humidity* decreases because the capacity for holding moisture has been increased in the warmed air. In this manner cloud formation is inhibited—or if clouds are formed, they are soon dissipated.

The areas over which such sinking air motion (called subsidence) prevails may involve 5,000,000 square kilometres or an area as great as western Europe. With ascent of air, cooling leads to increase in relative humidity, cloud and eventually precipitation.

The atmospheric circulations which lead to this subsidence or ascent (the "centres of action"), are linked to horizontal wave patterns in the west to east flow that prevails in temperate latitudes. These wave patterns are clearest at levels between 3 and 15 km. above the earth.

Thus the westerly winds aloft are usually contorted in the form of poleward or equatorward bulges (ridges or troughs, respectively)—great meanders resembling the sine waves of trigonometry. There may be five or six such waves in a hemisphere at one time. The sinking motion takes place mainly in the ridges and the air ascends in the troughs.

These planetary features can be observed, of course, on any one day's weather map, but they also appear even when maps are averaged over a month, a season, and even a year or period of years. The reason is that a series of persistently recurrent atmospheric systems, often of an abnormal type, can dominate a specific area. If these systems are ridges, then the stage is set for persistent subsidence of air masses, dryness and drought; if troughs persist, the stage is set for ascent of air, cloud and rain.

The placement of these statistically averaged troughs and ridges is not chaotic; they are frequently arranged

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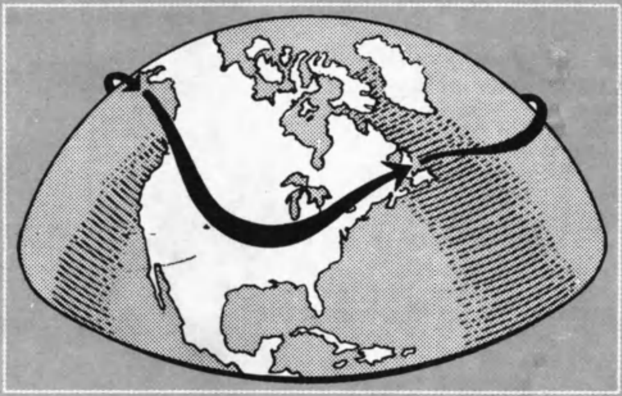


THE JET

Mystery air currents of the upper atmosphere

Photo © Vincent Schaefer, New York

In the upper reaches of the troposphere, several miles above sea level, narrow currents of fast-moving air flow in irregular, meandering paths in an easterly direction around the globe. The presence of these currents was suspected early in this century, but it was the advent of high-flying aircraft in the 1940s that confirmed the existence of "jet streams" as these currents are called. The strongest of these streams occur in the middle latitudes. Over the southern hemisphere they almost always blow from due west. In the northern hemisphere the disturbing influence of the continents causes some deviation and at times they blow from west south-west over the Atlantic and Pacific oceans and from the west north-west over the continents of North America, Europe and Asia. Above, diagram of a jet stream encircling the northern hemisphere. A jet stream generally reaches its maximum speed at heights of

LONG-RANGE FORECASTING ***(Continued)***

in patterns suggestive of a vast teleconnective mechanism. In other words, the position of one prevailing ridge in the westerlies usually implies troughs on either side and frequently other ridges beyond these troughs.

This interrelationship is reasonably well understood by meteorologists—both through theory and through empiricism. But what factors cause one or more of the ridges or troughs? A solution to this question would be a major advance.

The present quest for reliable long-range forecasting seems to narrow down to two major possibilities, both external to the atmosphere:

- The abnormal waves in the westerlies are in some unknown way generated and maintained by extraterrestrial events such as variations in solar activity;
- They are generated and maintained by variations in the character of the underlying earth's surface.

The latter possibility refers to changes in the amount of snow and ice, mainly on the continents, and also to the variable temperatures of the surface layers of the oceans. Both of these surface features change much more slowly than the restless overlying atmosphere and thereby might provide a "memory" so that persistently anomalous wind and weather patterns are periodically restored.

Today's meteorologists are more apt to espouse the second rather than the first (extraterrestrial) hypothesis. Many feel that we must first study, as completely as possible, the terrestrial air-sea-land system before introducing abnormal solar influences.

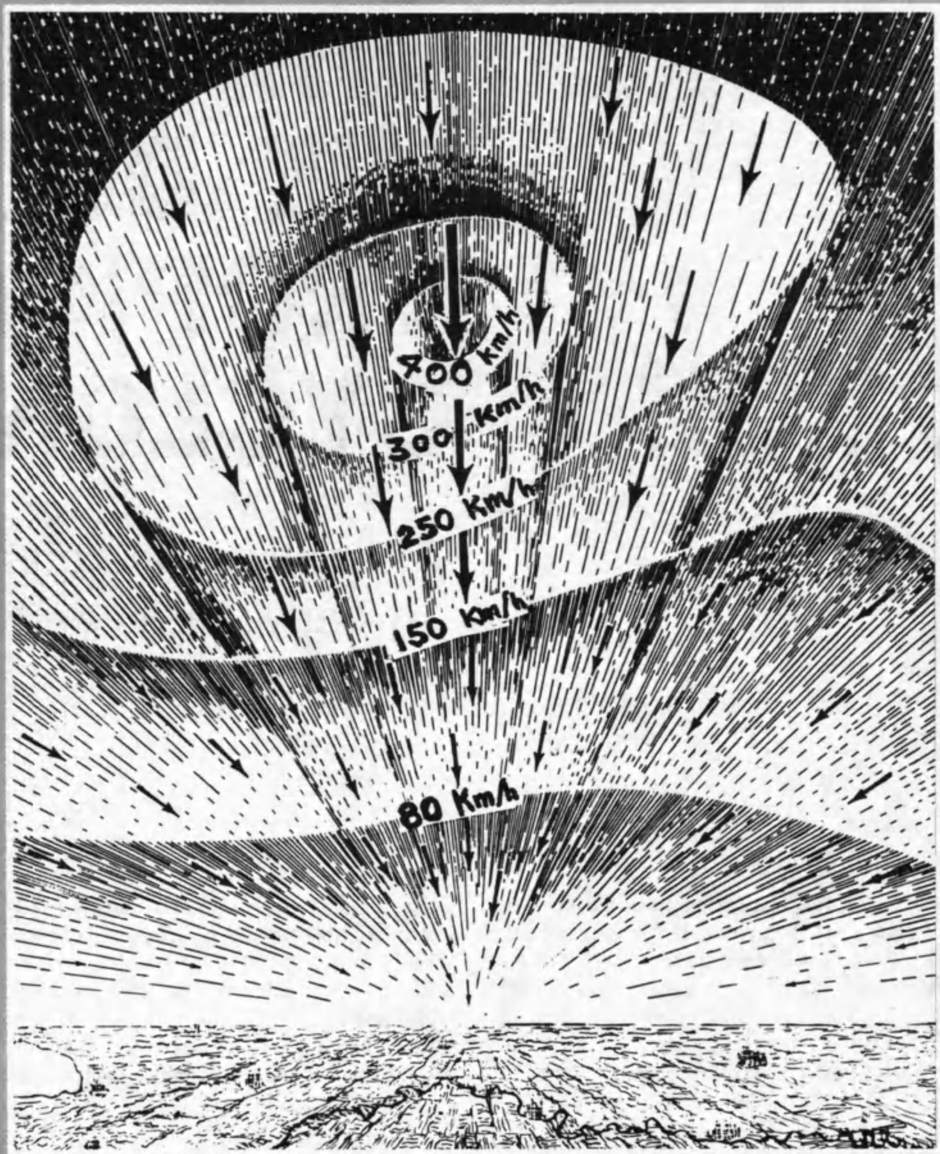
Of course, there exists another possibility, which hopefully is not a probability—namely that the planetary atmospheric wind systems are at the whim of very small and immeasurable forces so that chance alone determines what form the atmosphere will assume in the next month or next season. Fortunately, meteorologists have reason to believe that nature is not playing dice with them.

In addition to the waves in the upper westerlies, there are variations in the latitudinal positions of these air streams. Thus in some winters the central core of the westerlies may be 10° to 15° of latitude farther south than in others, so that storms prevail in the sub-tropics while higher latitudes remain relatively storm free.

Such variations appear to be associated with big weather variations in the tropics and even with hemispheric

STREAM

9,000 to 12,000 metres. It usually blows at about 190 km/h., but may attain speeds of up to 500 km/h. Several distinct currents of wind flow at differing speeds along the axis of a jet stream with the higher speeds occurring at the core of the stream (see diagram right). The difference in wind speeds along the axis of a jet stream may be as much as 160 km/h. or more. Occasionally a jet stream divides into two main belts of very strong winds a considerable distance apart. Jet streams are of very great importance to aviation. Modern aircraft often make use of these powerful air currents. By "hitching-a lift" in a jet stream an airliner can cut a long-distance flight time by nearly half with a great saving in fuel. In weather forecasting jet streams are important because certain types of storm occur most often just beneath them. Left, high-flying cirrus clouds being swept along in a jet stream.



Drawings © U.S. Dept. of Commerce Weather Bureau, Washington, D.C., taken from "The Jet Stream" Aviation Series nº 3

inter-actions between northern and southern hemispheres. One of the ideas to emerge during the past few years is that the tropical atmosphere is forced into abnormal behaviour by variations in the underlying ocean temperatures along the equator, and that these variations, by complex transports, mould the patterns of the westerlies in mid-latitudes.

There is also some evidence to indicate that the tropical systems, including the ocean temperatures along the equator, are frequently forced by events in the middle and sub-tropical latitudes. Most probably there are interactions and "feedbacks" both ways.

Thus the question of which comes first, like the "chicken or the egg", may not get a satisfactory answer. But this need not stop progress in long-range forecasting—a subject replete with complexly coupled systems of many kinds.

To return to some of the anomalous weather events cited at the beginning of the article, we find some evidence for the following connexions: The Russian drought of 1972 was associated with a persistent and strong ridge aloft in both summer and the antecedent winter—a ridge which may have been initially engendered by a strong trough affecting the British Isles, a strong ridge in mid-Atlantic, and by anomalous sea surface temperature patterns over the North Atlantic (cold in the north, warm in the south).

The sub-Saharan drought seems to have been associated with a failure of the intertropical convergence zone (the tropical mechanism for lifting large quantities of air) to move northward in the rainy seasons—this failure may have been due to wind systems in temperate latitudes or elsewhere.

The Eastern U.S.A. floods associated with hurricane Agnes, and perhaps the wet soil left from preceding storms, appears to have occurred in a vulnerable trough area separating two ridges—the strongest of which lay in mid-Atlantic.

This ridge was probably related to the one immediately responsible for the Russian summer drought.

The above conclusions are by no means borne out by physical calculations, but a world-wide effort by GARP and WWW may result in development of mathematical-physical models using billions of observations and high-speed computers to unravel the secrets of what is probably the world's second most difficult problem. ■

WHAT CAN WE DO ABOUT TROPICAL CYCLONES?

by Peter Rogers

The answer is 'quite a lot'. An early-warning system now exists, but...

NOT without justification the tropical cyclone has been described as the greatest storm on earth. Spawned over the warm waters of the tropical oceans, cyclones have, throughout the ages, taken a terrible toll of human lives and created misery and damage of unknown extent. In the long catalogue of meteorological disasters from which mankind suffers they have been responsible for 80 per cent of all the lives lost.

What is a tropical cyclone? It may be broadly described as a large vortex of air spiralling inward towards the centre where the pressure is at a minimum. This area, known as the eye of the storm, contains only light winds or may even be calm.

Around the eye explosive cloud growth takes place as warm, moist tropical air escapes upwards reaching perhaps, above 12.000 metres. This is the region of maximum winds which in a mature storm may exceed 270 km. per hour.

The effects of the cyclone may be felt over as much as 500 km. from the eye, diminishing progressively in violence away from the centre.

The meteorologist classifies them according to their intensity, calling them tropical depressions with winds up to 60 km. per hour, tropical storms with winds up to 115 km. per hour and hurricanes at higher sustained wind speeds. Considerable areas are affected by violent winds and protracted heavy rains, causing extensive flooding and damage.

For the layman there is often confusion between tropical cyolones, hurricanes and typhoons. In fact all are the same phenomenon; in the Caribbean they are known as hurricanes and in the north-west Pacific they are termed typhoons. Tropical cyclones also occur in the south-west Indian Ocean, in the Bay of Bengal and the Arabian Sea, and in parts of the South Pacific, as well as around the northern coasts of Australia.

History records many examples of severe tropical cyclones causing enormous loss of life and destruction. We need not look back far because what may have been the worst cyclone ever struck what is now Bangladesh on the night of 12-13 November 1970.

The accompanying storm surge, caused by low barometric pressure and hurricane force winds, was funnelled into the head of the Bay of Bengal by the converging coastline and shallow waters. Its landfall almost coincided with flood tide. The height of the surge varied from 3 to 9 m. and when it had swept over the offshore islands and low-lying coastal belt 300,000 people lay dead.

Catastrophes of this magnitude invariably arouse man's indignation. He feels strongly that nature must be tamed and not permitted to wreak its havoc unchecked. Man has always resisted the intemperate moods of nature, too often vainly. Can we do anything about tropical cyclones? The answer to this question is an emphatic "Yes".

Even though we may be far from discovering how to tame their fury, sensible precautions together with an effective warning system save many lives and limit damage. In fact it has been estimated that at least 80 per cent of the lives lost can be saved.

While the cost of damage shows a steady upward trend in almost all countries, much can still be done to keep it to a minimum. For example, a building code that increases the cost of construction by only 6 per cent can reduce damage by 60 per cent for sustained winds up to 240 km. per hour. It is not considered economically feasible to build to protect property against winds over 270 km. per hour.

To achieve this calls for a sophisticated warning system and the closest co-operation between all those with responsibilities for community preparedness and disaster prevention, as well as relief and rehabilitation. The first step is, naturally, the detection, tracking and forecasting of where the cyclone will strike, and of its expected

CONTINUED PAGE 56

PETER ROGERS *is a specialist on tropical cyclones at the World Meteorological Organization. He has been closely associated with the World Weather Watch and with WMO projects to reduce damage and loss of life caused by cyclones, in particular the programme of the typhoon committee of south-east Asian countries set up in 1968.*

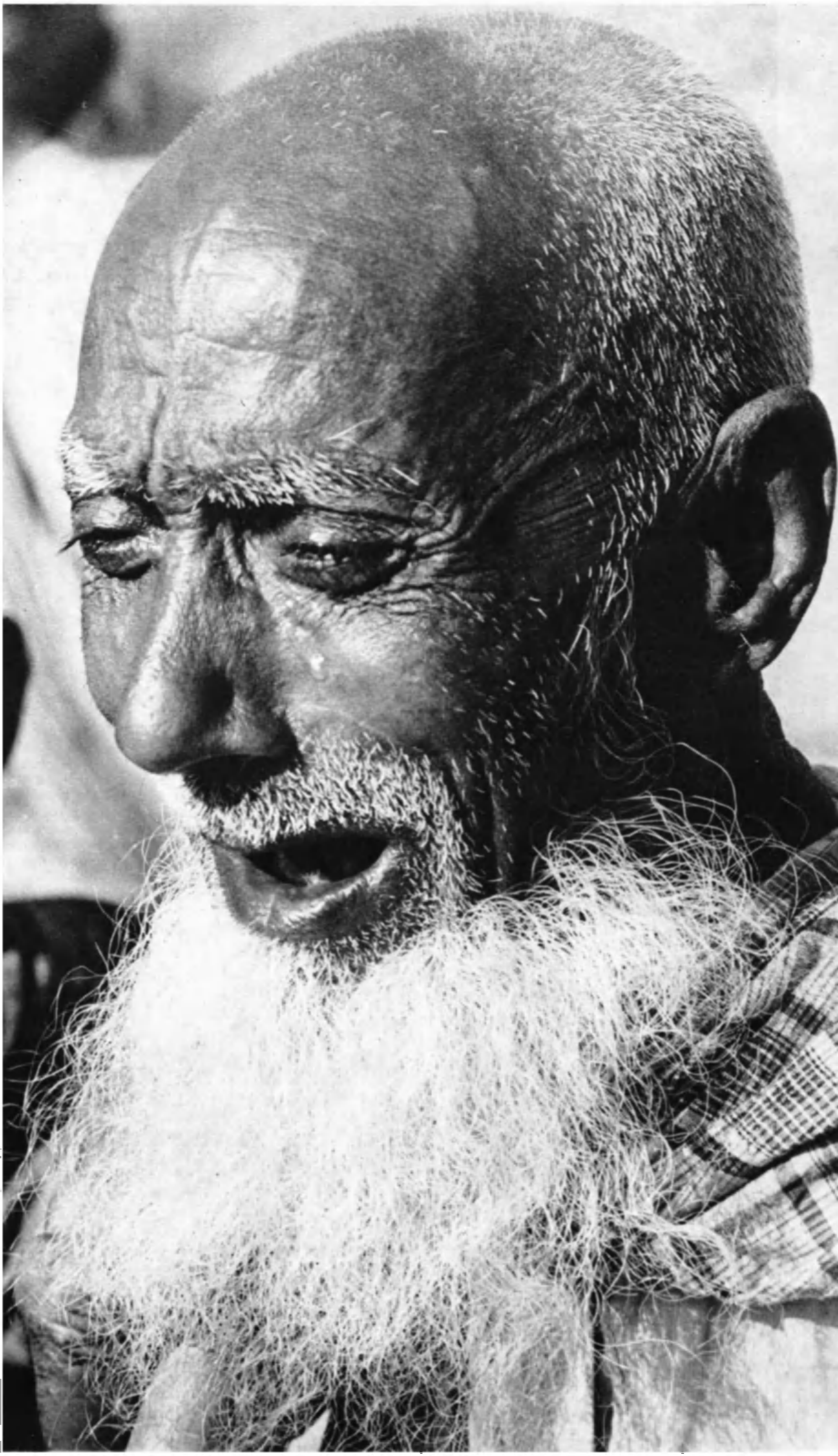


Photo Henri Bureau © Gamma, Paris

BANGLADESH

most devastating cyclone of this century

The tropical cyclone which ravaged Bangladesh in November 1970 was one of the most devastating of this century. Here an elderly man from Bangladesh weeps for the loss of family and friends swept away in the disaster.

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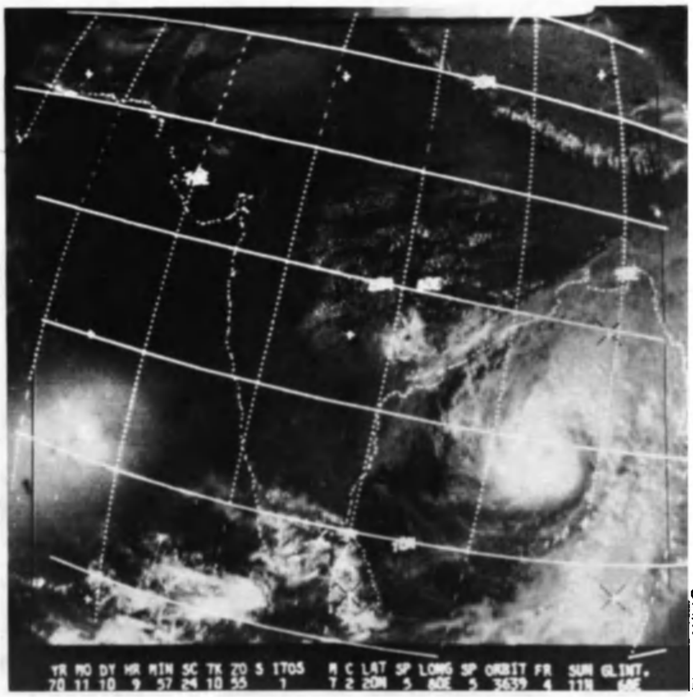

Photo WMO

BANGLADESH *(Continued from page 53)*

Life-saving ' Killas '

Nearly half a million people lost their lives in the cyclone that struck Bangladesh on the night of November 12/13, 1970. Many of these lives could have been saved if communications had been better and if the chain of artificial mounds known as "killas" (opposite bottom) where men and cattle can take refuge in time of flood, now being constructed with the help of the Red Cross, had been in existence. Evidence of the formation of a cyclone over the Bay of Bengal, moving rapidly north north-east, was provided by photos such as the one above received from satellite ITOS 1 at 0957 hours on November 10, 1970. By then it was apparently too late to alert the inhabitants of the scattered villages of the low-lying, coastal regions of Bengal in time for them to flee the huge tidal wave bearing down on them in the path of the cyclone. With nowhere to run to (above) most of the victims died of drowning. Material damage (below) was immense, leaving the survivors deprived of their livelihood and entirely dependent for many months on supplies flown in in a vast international rescue operation (opposite top).

Photo Marilyn Silverstone © Magnum, Paris

Photos Ch. Simonpietri © Gamma, Paris

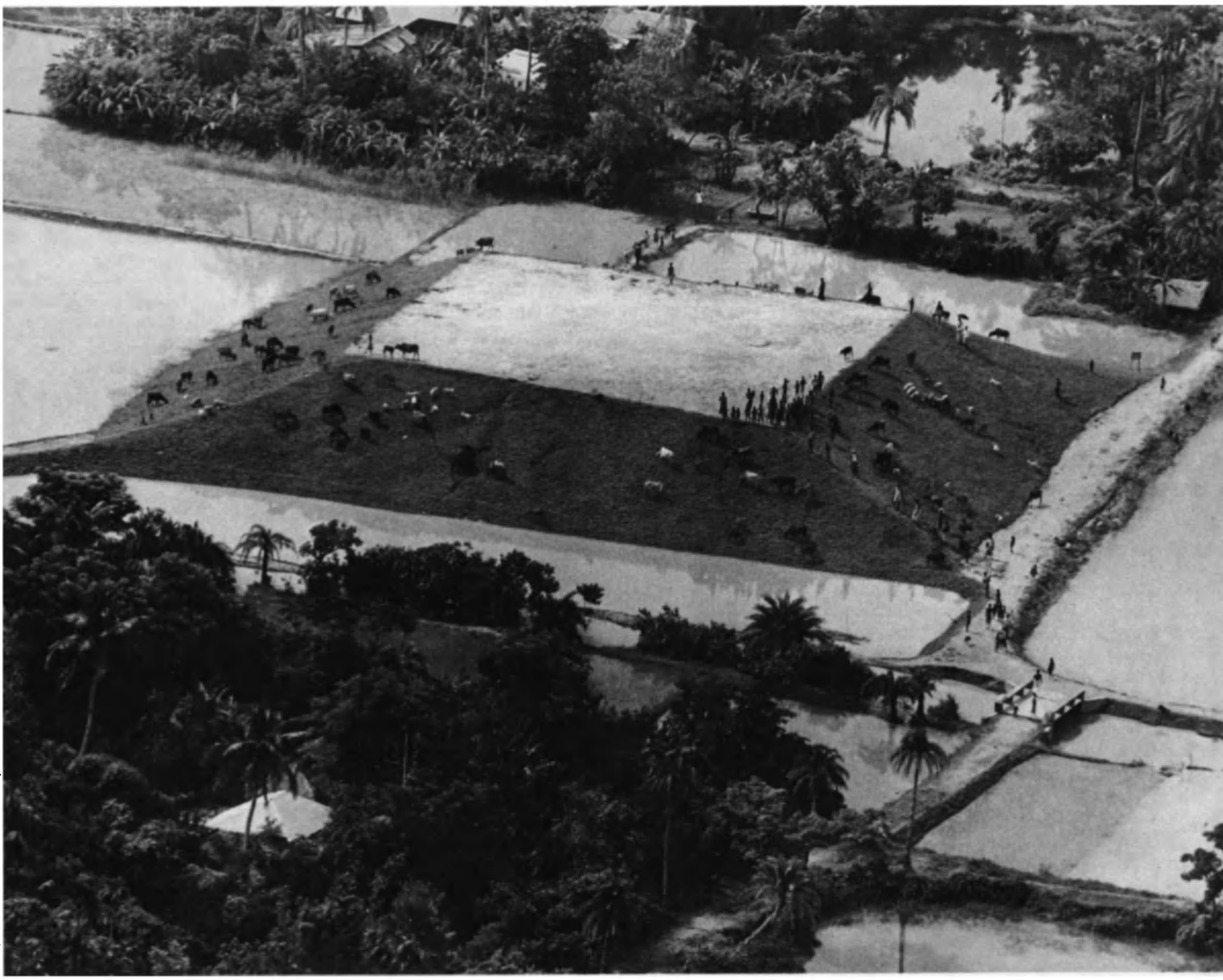

Photo Jean Mohr-Red Cross, Geneva

... much remains to be done to save lives and reduce damage from typhoons

effects in terms of wind strength, rainfall and flooding.

Earth-orbiting satellites, and more especially geostationary satellites, have largely relieved the meteorologist of the difficult problem of detecting the formation of a cyclone over distant ocean waters from which he has little other information. Precise positioning of the cyclone centre sometimes remains difficult but steadily advancing technology should resolve this problem.

Cyclone tracks are notoriously erratic. In a 24-hour forecast, an error of only 10° in predicting the track results in the cyclone striking the coast more than 185 km. from the expected spot. Surveillance by satellite, by specially-equipped reconnaissance aircraft and finally by 10 cm. storm warning radar when the cyclone is within 300-400 km. can ensure that its path into the coast is closely monitored. Thus, a meteorological system making full use of modern technological aids is a prerequisite for the accurate forecasting of cyclone movement and development and the issue of accurate warnings.

BUT the best forecast is useless if nothing is done to act upon it. There must be carefully prepared and detailed national plans so that all those responsible for the safety of human lives and property know exactly what to do when a warning is received. Above all, it is vital that the warnings reach everyone threatened by the cyclone in good time; people must also know how to protect themselves and their property and fully understand what the risks are.

A vigorous campaign of public education is the only means of achieving this and must be repeated before each tropical cyclone season if the lessons learned are not to be forgotten. There must be the closest co-operation between the technical agencies and those in the social welfare field if the total system is to work efficiently.

The population cannot be successfully protected from the onslaught of a tropical cyclone if responsibilities for different parts of the system are broken down into separate, uncoordinated parts.

Ultimately, the success or failure of the warning system depends upon its weakest link—man himself. An accurate forecast, a well-designed disaster prevention system, and all the aids that technology provides count for little if the human response is not geared to the realities of the occasion.

Every cyclone brings forth a crop of stories demonstrating the endless diversity of human reaction to the disaster threat. Age, health, education, family situation, previous disaster experience and many other factors play a role, but a role so complex that no clear-cut pattern of behaviour emerges for general application to future disaster situations. The aerospace engineer in Texas can be as obstinate as the Bengali farmer in refusing to leave his home when advised to do so.

Few authorities have the power to compel evacuation of danger areas. And yet the pressures of increasing population force people into low-lying agricultural or coastal areas prone to storm-surges. The potential for loss of human lives is growing in many cyclone areas and can only be reversed by the remorseless application of strict development controls. Very little has so far been done in this respect and even the planning of satisfactory escape routes for evacuation is frequently neglected.

In some regions such as Bangladesh, evacuation from low-lying islands may not be feasible. There, under a project sponsored by the League of Red Cross Societies, "killas" —earthen mounds about 7 m. high—have been constructed to provide refuge for the local population. Such relatively simple measures can drastically reduce the loss of life from tropical cyclones, 90 per cent of which is caused by drowning.

In spite of their violence, hurricane-force winds account for relatively few deaths. Flying objects propelled at great speeds constitute the prime menace but are easily avoided by taking cover within a sound structure until the danger is past.

The eye of the storm, with its light winds, must not be taken as an indication that danger is over. After a short pause, the wind will blow with renewed violence from the opposite quarter. Here, the need for careful education of the public is again evident.

How are these measures being carried out in the 40-odd nations of the world afflicted by tropical cyclones? Obviously the problems have been the same for many centuries but it is only in recent times that man has realized how much he can do to reduce casualties and prevent the serious inroads of cyclone damage into the national economy.

In most countries a warning system has grown up to face this age-old menace but in many lands it is insufficiently well-developed to be completely effective. The World Meteorological Organization began to take a special interest in helping these countries in 1966, in close co-operation with the U.N. Economic Commission for Asia and the Far East (ECAFE).

THE urgent need to reduce the economic impact of typhoons amongst the developing countries of south-east Asia led to the setting up of the Intergovernmental Typhoon Committee in 1968. Seven countries and territories (1) formed this Committee with the avowed purpose of conducting a joint programme to accelerate action to reduce the loss of life and damage caused by typhoons.

The programme encompasses meteorological and hydrological facilities in the member countries to improve the forecasting and warnings of typhoons, training and research, and community preparedness and disaster prevention to ensure that the public are ready to meet the risks brought each year by typhoons.

Five years have elapsed since this programme began, bringing substantial improvements to the Typhoon Committee countries. New technological aids, such as satellite read-out equipment (APT), radar, telemetering rain and stream-gauging equipment, help in the fight to improve the prediction of typhoons and life-claiming floods. Speedier telecommunications permit the flow of vital data to all interested countries, and the training of national staff in the latest techniques fosters increased awareness of the ways in which science can help to defeat the typhoon bogy.

In March this year, with the help of the League of Red Cross Societies, WMO and ECAFE sent a three-man team to Hong Kong, Korea and Thailand. Its object was to promote closer co-operation between the various national agencies active in pre-disaster

(1) Hong-Kong, Japan, Khmer Rep., Rep. of Korea, Laos, Philippines, Thailand.

planning and to prepare a programme of further action. This enterprise was the first of its kind and should do much to stimulate a more co-ordinated approach to disaster prevention.

These pioneering activities of the Typhoon Committee soon evoked growing attention in other tropical areas. One direct consequence has been the setting up of two other regional groups with closely similar objectives—one for the Bay of Bengal and the Arabian Sea, and the other for the south-west Indian Ocean. Although they are only now beginning their task, there are good grounds for hoping that the regional approach applied in the typhoon area will be equally efficacious in these other areas.

The tragic Bay of Bengal cyclone of 1970 became the starting point for a further focussing of WMO's efforts on the cyclone problem. When soon afterwards a series of typhoons ravaged the Philippines causing further heavy loss of life and massive damage, the Typhoon Committee appealed to the United Nations General Assembly for international action. The General Assembly reacted promptly to this appeal, calling upon WMO to mobilize scientists and resources to discover ways of mitigating the harmful effects of these storms and of removing or minimizing their destructive potential.

WMO responded by setting up its Tropical Cyclone Project. It then assembled a group of international experts in tropical cyclones to review the state of forecasting, warning and other needs for damage reduction, and to define the objectives of the Project. It next drew up a plan of action for this long-term project. The plan covers the detection and forecasting of tropical cyclones, storm-surge and flood forecasting, warning systems, risk evaluation and disaster prevention and community preparedness, as well as disaster relief, training and research, and the development of instruments and equipment.

If the best methods and techniques available in the world are to be used by all countries in their struggle to reduce the impact of tropical cyclones, a great many studies and much development work must be carried out. It is an ambitious scheme in which the topmost scientific talent in this field must be given the resources to do a job of profound humanitarian importance.

Research into tropical cyclones has been carried out in many countries over a long period of years. Much progress has been made but there is a pressing need to harness the talents of scientists in different lands for an all-out attack on outstanding problems.

Only by the co-ordinated efforts of many workers can these problems be finally solved. One of the objectives of the WMO Tropical Cyclone Project is to foster this international effort and to see that it is mainly directed to saving human lives and improving the quality of life by damage reduction.

It would be idle to deny that no instant breakthrough can be expected. The horrors caused by tropical cyclones have plagued mankind for centuries and it would be unrealistic to think that they can be effaced overnight. We must plan for a long-term programme, measured perhaps in decades.

Whilst this essential work is going on, it may confidently be expected that steady progress in applying modern technology to improving warning systems through the various regional programmes sponsored by WMO will continue and will effectively benefit many countries. ■

Photo © Paul Almasy, Paris

Japan, the Philippines and other parts of East Asia are periodically swept by typhoons and other natural disasters that take a heavy toll of life and property. Effective warning systems are being set up in different areas to meet the danger. Here, a storm signal is posted in a street in Zamboanga on the island of Mindanao (Philippines). In this warning system one siren blast means 50 to 90 km/h winds; two blasts signifies 90 to 120 km/h winds.

WEATHER LORE DOWN THE AGES

A meteorologist discusses facts and fancies of traditional weather-wise sayings

by Roger Clausse

THE time may come when tomorrow's weather will be announced with sure-fire certainly because by then Man will make his own weather, causing clouds and rain to appear and disappear as he pleases.

Strangely enough this is how the peoples of ancient times approached the problems of meteorology, although it was then believed that weather was controlled by the gods who had only to be invoked in order to change the course of a storm or end a drought.

Such practices existed in all bygone civilizations, from the shamans of the Arctic who were reputed to control the cold and the ancient peoples of Black Africa with their tom-toms for calling down the rain, to the rain-making sacrifices shown in 3,000-year old pictures discovered at Sumer in Asia.

Similar methods and beliefs also existed in ancient China and Japan, among the North American Indians and the Aryans in India, the Greeks and Romans, in short in all the countries now represented in organizations and authorities concerned with world meteorology.

But in terms of ideas and research on the study of the weather, a world of difference exists between these ancient and outmoded practices and the still tentative attempts being made in our own time to influence the weather.

Men learned first to observe phenomena in order to understand them. Then, noting coincidences or instances when the same phenomena were repeated, they learned to distinguish the laws, or rather regularities, linking these phenomena together.

The first things that men observed were naturally those around them, and hence their observations and their deductions were based on the behaviour of plants and animals.

The weight which these deductions carried and the wide credence which they gained depended on the relationship between the village headmen or elders who made them and their audiences. The authority of the elders (in days when they were listened to and respected) gave their sayings the character of infallible pronouncements. It is thus no wonder that, transmitted from generation to generation with varying degrees of distortion, these old saws of weather wisdom have survived for centuries.

At all events, we can take a look at some of the ancient sayings, that certain persons still accept without question, and try to distinguish between what is clearly true or false in them, though we cannot hope to explain certain "mysteries" of the animal world.

Old almanacs going back nearly five hundred years and manuscripts much older still give impressive lists of various symptoms of animal behaviour presaging rain or the return of fine weather.

It is quite true that animals, being closer to nature than man and, unlike man, not taking medicaments of all kinds, have preserved a number of primitive responses to natural phenomena and to the various ways in which they impinge on the living world.

Just as some species possess instincts, probably based on sensorial perceptions unknown to us, which enable them to find their way back over great distances to their seasonal haunts or to detect the approach of an enemy from far away, it is quite likely that some animals are sensitive to variations in atmospheric conditions heralding changes in the weather. As we shall see, men can also forecast these changes by looking out for certain clues.

Let us take a few examples of behaviour in animals and even in plants which are supposedly significant in relation to the weather. Right away, and at the risk of seeming ignorant, we have to admit we are not sure what to make of the various sayings, often contradictory—or perhaps too subtle—about the abilities of frogs and toads to forecast fine weather or rain.

ACCORDING to one old French saying:

"If toads call today, the sun's on the way".

But another saying goes:

"When toads loudly call, rain's sure to fall."

Are the sayings really contradictory, or does it take a keen musical ear to distinguish between one kind of call and another? In any case, a tame frog kept in a bowl in a warm house is hardly in contact with nature, and must have lost any instinctive reactions to the weather it may ever have had.

ROGER CLAUSSE *(see biographical note on page 43).*

"No one recognizes the value of water until it is lacking," says a Spanish proverb. Right, a young Mexican boy drinking from a stream.

Photo © Dominique Darbois, Paris

Before a shower of rain, certain kinds of voles and field mice are supposed to run about outside their burrows, moles are supposed to scurry in and out of their holes in agitation, wolves howl, goats and rams butt each other, donkeys bray and waggle their ears, and pigs grunt and become restless —in other words, they all "feel the bad weather coming on".

This agitated behaviour would be understandable if the particular sensations they felt really did herald storms or rain, which are indeed no fun for creatures dwelling in the open or in burrows which can be flooded by sudden downpours. But for this to be the case, the animal "forecasters" would have to be surrounded by a mass of air possessing certain characteristics announcing the change in the weather.

We now know, of course, that the weather for the next twenty-four hours, at any given place, is in process of formation at distances of hundreds of kilometres around that place, and that atmospheric changes occur only shortly before the arrival of rain, usually starting in the upper atmosphere.

Some factors may perhaps vary in the preceding twenty-four hours, atmospheric pressure for instance (though it seems fairly unlikely that animals are sensitive to this) or gradual changes in wind direction, sometimes also the moisture content of the air or atmospheric electricity.

Since the atmospheric changes preceding the approach of rain are so complex and give so little clue as to what the weather is going to be, and especially as any of these changes can occur without rain or storm following, one can be pretty sure that the ways in which animals behave are probably due to a variety of causes; if their behaviour sometimes precedes a change in the weather, this is a mere coincidence.

It is commonly believed that when a cat rubs its paw behind its ear, it means there will be rain. The cat itself doesn't "mean" anything by its gesture: it rubs its ear because atmospheric electricity has changed, the humidity has decreased, or simply because it has an itch. But it is true that felines are particularly sensitive to changes in the magnetic field of the atmosphere and become restless when thunderstorms or snow are in the air.

Birds have always been regarded as weather prophets. This reputation may be due in no small measure to the great bird migrations. Although the why and how of these great movements are still not fully explained, experts have pointed out that some species, such as swifts and storks, set off practically on the same date every year, and that the occasional slight differences of a few days either way are connected mainly with local variations in atmospheric conditions and in particular with the availability of food—small insects or seeds—but not with ap-

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proaching changes in meteorological conditions.

Swallows often die on the way south in sudden cold snaps, such as the snowstorm in Burgundy (France) in October 1939 in which thousands of these birds perished. Sea-gulls fleeing inland may indeed be harbingers of the storm—provided the storm is going the same way as they are; but it sometimes happens that after sea-gulls have prudently taken refuge from an Atlantic gale on the banks of the Seine, the sky in Paris remains clear while the storm veers away towards Amsterdam.

Other instances of bird behaviour which have been noted seem to be connected with more immediate meteorological factors. Swallows flying low are supposed to foretell rain, and flying high, fair weather.

The explanation may be that convection currents from the overheated ground in fine weather carry up the midges which provide the swallows' food, whilst the general downward movement of air masses preceding rain keeps them close to the ground and thus compels the birds to fly low.

On the other hand, the upward movements of air and convection currents that cause the swallows to fly high can, if they are strong enough, be followed by rain or thunderstorms—so meteorology poses problems, even for the birds.

In India, certain lizards are even reputed to go into reverse when rain and floods are in the offing, climbing trees tail first. Throughout India, incidentally, when popular sayings speak of fine weather, rain is meant, drought being reckoned as "bad weather".

POPULAR wisdom attributes to creatures lower down the animal scale a similar sensitivity to the approach of bad weather: crayfish are supposed to leave their hiding places and come out of their streams, dragon-flies skim the surface of the water, snails venture forth (especially after the rain!) spiders spin their webs, fish refuse to bite and stay near the surface ready to snap at the insects which now fly low above it.

Is this behaviour due to changes in atmospheric pressure or temperature, which by acting on the oxygen content of the water, make the fish rise as the pressure falls, perhaps because rain is on the way?

True or not, this belief is firmly held by anglers for whom it provides an additional excuse when they come home empty-handed, so let us not be so rash as to challenge it.

Plants as well as animals respond to the weather and its changes, hence their reputation as weather forecasters. Their life-cycle is so closely bound up with atmospheric conditions that they can be taken as ready-made devices for totalizing the climatic variables.

The cycle of germination and vegetation—buds, leaves, flowers, fruit—is controlled by rain, sun and temperature; by taking the dates on which different species flower, it is even possible to draw up charts showing the climatic conditions in different areas in the preceding months.

But here we are dealing with direct climatic effects, not the forecasting of weather. At most, they make it possible to reckon the probable date of the harvest from the state of advancement of the crop, always provided that weather conditions are normal in the intervening months.

Thus, for instance, the fact that an onion has many thick skins does not, as some people claim, mean that it will be a hard winter, but indicates merely that certain conditions of heat and dryness obtained while it was growing, and statistically speaking, next winter's weather bears no relation to the weather in the preceding seasons.

Plants are sensitive to immediate local conditions of humidity, heat or sunlight, and there is nothing mysterious about the fact that the pimpernel, the convolvulus or the daisy close when the air becomes humid, although this does not necessarily mean it is going to rain.

The leaves of the artichoke, like the scales of the pine cone, open in dry weather and close in damp, but all that this tells us is how humid the air is, just as does the little man with the umbrella who pops out of the weather house when the hair to which he is attached expands with the dampness of the air.

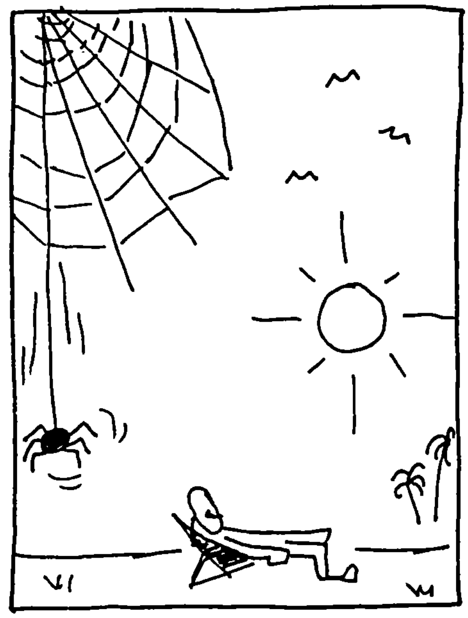
In any case, even if all our doubts were to be removed and our scepticism shown to be misplaced, even if it were to be conclusively proved that in a reasonable percentage of cases these signs were reliable, what could we learn from close observation of the convolvulus, the toad or the grooming habits of cats? It would not in fact amount to very much.

At a more scientific level of observation, we know for certain that a halo, the bright ring sometimes seen round the sun or moon, indicates to the meteorologist the presence of warm air at high altitudes, often the prelude to rain.

Whereas human beings have few instincts to alert them to weather changes—except for the aches and pains which may start in wet or cold weather—what they do have are means for observing and measuring the atmospheric factors to which animals and plants may unconsciously react.

Every day, thousands of meteorologists, at stations equipped with radar, barometers, hydrometers, thermometers, radiosonde balloons and even receivers for picking up pictures sent back by satellites of the clouds surrounding the earth, measure with great accuracy the same water vapour or electricity in the air which disturbs cats, the same variations in atmospheric pressure which bring fish to the surface, the strength of the rising or falling currents which makes swallows fly high or low, and many other parameters.

Drawing © Mas, Paris.
Specially drawn for the "Unesco Courier" (see also pages 62 and 64)



"When spiders weave their webs by noon, fine weather is coming soon." (Japan)

It must be admitted that the results of these measurements, taken at some 10,000 different points around the world, are much more reliable and more readily usable than the purely subjective reactions of animals. The measurements can be transferred to maps covering vast areas—a quarter, a half or even the whole of a hemisphere—to give an overall picture of world weather.

These maps help meteorologists to analyse the state of the atmosphere at any given moment, to discover

CONTINUED PAGE 64

"Wild duck arriving fat and prime, long and cold will be springtime" (U.S.S.R.).

Woodcut taken from "De Gentibus Septentrionalibus", by the Swedish writer Olaus Magnus, Rome, 1555 (see also engraving page 6)

Every proverb has a silver lining

BIRDS AND INSECTS

— When in spring storks northwards wing, two days later rain will spatter *(Arab countries, Germany, Italy)*

— If ducks shake and flutter their wings when they rise, rain can be expected *(Iran, U.K.)*

— A fowl spreading its wings is a presage of heavy rain *(India)*

— The lark soaring high heralds a blue sky *(Japan, U.K.)*

— Wild geese moving south: cold weather ahead; moving north: winter is nearly over *(U.S.A.)*

— When the cuckoo calls throughout the day, a cold year is on the way *(U.S.A.)*

— Hen on one leg, head under wing, wet weather will surely bring *(Iran)*

— When the curlew cries, expect wet skies *(Ireland)*

— When crows take a bath, rain is in our path *(Spanish-speaking countries)*

— When the cocks crow and then drink, rain and thunder are on the brink *(Spanish-speaking countries)*

— Swallows fly high: clear blue sky; swallows fly low: rain we shall know *(China, France, Japan, Korea, Switzerland, Turkey, U.S.S.R., etc.)*

— Shrill calling cranes flying high and slow, a pleasant autumn we shall know *(U.S.S.R.)*

"Thunder before the beginning of spring 49 days of bad weather will bring" (China).

Inscription on a stele of the Han period (206 BC to 220 AD)

— Sea-gull, sea-gull sit on the sand, It's never good weather while you're on land *(U.K.)*

— When the barnyard goose walks south to north, rain will surely soon break forth *(Iran)*

— Ants that move their eggs and climb, rain is coming anytime *(India, Japan)*

— When gnats swarm in January, the peasant will have an empty granary *(Netherlands)*

— Mosquitoes in late fall, a mild winter for all *(U.S.S.R.)*

— Ant-hills on dry river beds mark a full year of drought *(Brazil)*

— Spiders and mosquitoes in the month of May announce a dry June is on the way *(India)*

— Spiders webs at dawn, expect a fine morn *(Japan, Uruguay)*

— If bees stay in the hive, rain will soon thrive *(Germany)*

— When spiders drop quickly down their webs, it is a sign of rain *(Spanish-speaking countries)*

— When bees close their hives, a cold winter arrives; if they don't shut the door, a mild winter in store *(U.S.S.R.)*

— Swarms of mosquitoes, a sign of rain *(China)*

MAMMALS, FISH, REPTILES, ETC.

— Fish leap before a storm *(France, Germany)*

— When pike lie on the bed of a stream quietly, expect rain or wind *(U.S.A.)*

— When grass-snakes hiss, the weather will be rainy *(France, Spanish-speaking countries)*

— When a frog croaks in the meadow, it will rain three hours later *(India)*

— When frogs spawn in the middle of the water, it is a sign of drought; and when at the edge, it foretells a wet summer *(U.K.)*

— When frogs croak much, it is a sign of rain *(Iran, Japan, Korea, Philippines, Iran)*

— When the leech comes out of the water to hide under grass or stones, a storm is at hand *(Germany)*

— When fish gather in the middle of a lake, soon the earth will tremble and quake *(Japan)*

— When the fisherman takes a very mixed catch, an earthquake or a tsunami is heading down the hatch *(Japan)*

— When asses their ears do toss and sway, rain before the end of day *(France and Spanish-speaking countries)*

— When goats begin to sneeze and snort, soon comes weather of another sort *(Spanish-speaking countries)*

— When horses rub their backs on the ground, rain is sure to come around *(Norway, Switzerland)*

— When cows lick the walls, fine weather befalls *(Norway)*

— As a dry cow bellows most, so a rainless cloud thunders most *(India)*

CONTINUED NEXT PAGE

EVERY PROVERB HAS A SILVER LINING *(Continued)*

— When cats scratch the table legs, a change is coming *(U.K.)*
— When cats wash themselves, rain will come *(Belgium, Netherlands)*
— When cats stand and lick their paws, it will soon be sunny out of doors *(Iran)*
— If a cat looks out of the window it is looking for rain *(U.S.A.)*
— When an elephant calves in the forest, it means rain and sun *(Cameroon)*
— When squirrels lay in a large store of nuts, expect a cold winter *(Finland, Greece, Norway, Sweden, U.S.A., etc.)*
— "The mouse dug a hole in the river bank before the flood" (meaning seek shelter before disaster strikes) *(Angola)*
— When sheep constantly shake their ears, rain is coming *(Iran)*
— When donkeys walk crabwise, rain is on the way *(Brazil)*
— Sheep butt and stamp before a storm *(France, Iran)*
— When the hare's coat is thick the winter will be hard *(Germany)*
— When the jackal howls near the village, the wise man prepares for rain *(Iran)*

THE DAYS AND SEASONS

— If it rains at Pubba (Aug 30 - Sept 11), it will rain incessantly; slight wind at Hasta (Sept 22 - Oct 8), no rain until Chitta (Oct 9 - Oct 22); if it does not rain at Chitta, even the ants will find the drought a torment *(India)*
— A heavy November snow will last till April *(U.S.A., France)*
— Snowy winter, rainy summer; icy winter, hot summer *(U.S.S.R.)*
— An icy May fills the granaries *(U.S.S.R.)*
— The dews of April and May make August and September gay *(France)*
— A leaky May and a dry June brings in the harvest very soon *(U.K.)*
— March winds and April showers bring forth May flowers *(U.K. and Spanish-speaking countries)*
— Spring without rain, abundant grain; a dry fall, no grain at all *(China)*
— White Christmas, green Easter; green Christmas, white Easter *(Belgium)*
— When the leaves of wheat are narrow and short there will be much snow *(Japan)*
— The evening red and the morning grey are the tokens of a bonnie day *(France, Italy, U.K.)*
— A yellow glare as the sun doth set foretells a night both windy and wet *(U.K.)*
— A good day can be told from its dawn *(Syria)*
— A red sky in the morning means rain in the evening; a red sky in the evening means fine weather *(China, Finland)*
— Long icicles foretell a long spring *(U.S.S.R.)*

"When a black cow scratches her flanks she foretells bad weather." (Norway.)

Drawing © Mas, Paris

Photo © Paul Almasy, Paris

— Mushrooms galore, much snow in store; no mushrooms at all, no snow will fall *(Germany, U.S.S.R.)*
— If your spittle floats on the surface of a pond, it will be fine; if it sinks, rain will come *(Japan)*
— When chilblains hurt, it will be windy *(Japan)*
— Snow is the peasant's wealth *(Norway, U.S.S.R.)*
— Frost year, wheat year *(France, Italy, U.S.S.R.)*
— A year of snow a year of plenty *(France, Byelorussia, Germany, Italy, Ukraine, Spanish-speaking countries)*
— If the mountains seem near, rain you must fear *(Austria, France, Japan, Switzerland, etc.)*
— Morning rain does not delay the pilgrim *(France)*

SKY

— When the sun is at home (encircled with a halo), it will soon rain *(Zuñi Indians of New Mexico, U.S.A.)*
— Large halo round the moon: heavy rain very soon; small halo means, they say: it will not rain for many a day *(India)*
— If the Pleiades stars rise fine they set rainy, and if they rise wet they set fine *(Kenya, Tanzania)*
— Sky clear just overhead, bad weather lies ahead *(China)*
— A rainbow at night is a sailor's delight, a rainbow in the morning is a sailor's warning *(U.S.A.)*
— When no clouds mask the Milky Way, it will be fine for a week and a day *(Japan)*
— When the sun sets with a bright red blush upon the clouds, the morrow will bring a fierce heat; when it sets amid darkening clouds, the next day will surely be rainy *(China)*
— A rainbow in the eastern sky, the morrow will be fine and dry; a rainbow in the west that gleams, rain tomorrow falls in streams *(China)*
— If the first thunder is from the east, the winter is over *(Zuñi Indians, New Mexico, U.S.A.)*
— Autumn thunder means a mild winter *(Norway)*
— Fog leaves the weather as it found it *(France, Italy)*
— Mountains covered in mist mean fine weather *(Japan)*
— Thunder before the beginning of spring 49 days of bad weather will bring *(China)*
— A summer fog is for fair weather *(U.S.A.)*
— Lightning under the north star will bring rain in three days *(U.K.)*
— Cloudy mornings turn to clear evenings *(U.K.)*
— Three foggy or misty mornings indicate rain *(U.S.A.)*

Throughout the ages the Egyptian has recognized the role of the life-giving water of the Nile. Right, on this 19th dynasty (2300 BC) mural from Deir el-Medina a gardener hoists water to a terrace garden with a Shadoof, a pole and bucket with a counterbalance still in use (left) in the Nile valley today.

Photo © Editions Rencontre, Lausanne

THE SEASONS OF THE NILE

A weather and farming calendar from the time of the Pharaohs

by Abdel Moneim El Sawi

Nearly 2,500 years ago, the Greek historian Herodotus described Egypt as "the gift of the Nile", and ancient proverbs confirm how closely life in Egypt has, since ancient times, been bound up with the Nile, with agriculture and with the weather.

Throughout history, the Egyptian has expressed his feelings about the weather in sayings and proverbs that are still in current use today. Egyptian proverbs are often related to the months of the year and the weather appropriate to them and its effect on the state of irrigation and agriculture.

ABDEL MONEIM EL SAWI *is editor of the Arabic edition of the "Unesco Courier", published in Cairo, and is chairman of the Unesco National Publications Centre in Egypt. A former Under-Secretary of the Ministry of Culture of the Arab Republic of Egypt, he is well known in the Arab world for his novels, essays and radio and television programmes*

For the ancient Egyptians the year was divided into three seasons directly related to the flooding of the Nile, the stages of agriculture and the type of crops and the weather. These seasons were:

- The season of planting.
- The season of inundation.
- The season of harvest.

The flooding of the Nile was of paramount importance in the beliefs of the ancient Egyptians. To them the floodwaters of the Nile were a sea of tears shed by Isis in mourning for her husband Osiris.

Considered as a token of well-being and prosperity, the floods were celebrated at the festival of Wafaa el-Nile (the faithful Nile) during the second half of August (Misra to the ancient Egyptians).

A painting from the time of Rameses II (about 1290 B.C.) depicts a ceremony of the "Wafaa el-Nile" festival at which the "Calf of Ibis", three geese and valuable presents were thrown into the Nile. Popular belief had it that a bride was also thrown into the waters of the river as part of this ceremony, but this was no more than superstitious rumour.

The year in Pharaonic Egypt, and later in the Coptic calendar, was astral and was connected with the star Sirius. The ancient Egyptian year was considered to begin on the first of "Toot" (11th of September).

According to the Pharaonic almanac the months of the year and the prevailing weather were as follows:

Toot (11 September - 10 October): attributed to T-hoot, god of wisdom and science and father of astronomy and geometry, it coincides with the appearance of Sirius at dawn. The Ist of Toot was also called the feast of Nayrooz (the Persian New Year), a feast celebrated by Egyptians up to the time of Sultan Barkook (end 14th

CONTINUED NEXT PAGE

century). Toot is considered the start of the inundation period and one proverb says "Irrigate in Toot or you will be too late." It is thought to be a bad time for the rearing of chickens and the hatching of eggs. "Chicks of Toot", runs one saying, "eat and die."

Baba (11 October - 9 November): attributed to the god of agriculture (Bee-net-ret). The floodlands dry out after the inundation and winter crops are harvested. During this month there is the tempest of the big flood, which lasts six days.

There is some wind and the first signs of winter are seen. "Baba has entered and has closed the roads", says one proverb, meaning that Baba is the time to close doors to keep out the cold. "The bride of Baba is blackened with smut", goes another saying, expressing the view that this month of change is an unsuitable one in which to get married.

Hatoor (10 November - 9 December): attributed to the gods of love, beauty and heaven. The land becomes verdant, the cold becomes more intense and the Nile waters become clear again after the floods. Hatoor is connected with rain and the growing of wheat: "Hatoor is the father of scattered gold", and, "If you fail to plant in Hatoor, wait till the coming year." To fishermen and sailors this is the beginning of the stormy season.

Kiyahk (10 December - 8 January): attributed to the god of welfare (Kahaka). The days shorten and the nights lengthen: "In Kiyahk your morning takes the place of your evening." . . . "You rise from your bed only to look for your supper." It is a month of frost and intenser cold and tempests.

Tooba (9 January - 7 February): attributed to the god Tobias the Supreme, the god of rains. The end of Tooba is marked by days of biting cold. "Tooba makes the old woman crippled", says one proverb, stressing the discomfort caused to the elderly by the cold.

Amsheer (8 February - 9 March): attributed to the god of tempests. Hot winds cause buds to break into blossom, but there are many tempests: "Amsheer tells the small plants to catch up with the big plants." "Amsheer is the father of many tempests." A changeable month, Amsheer has days of biting cold and this has given rise to one of the most common proverbs: "The name is that of Tooba, but the act is that of Amsheer."

Baramhat (10 March - 8 April): Beans ripen, the mulberry trees are green, silk worm eggs hatch out and ears of corn appear. It is the beginning of spring: "In Baramhat go to the fields and get what you want." It is marked by the last and most violent tempest of the year, the two-day "howling tempest": "There is no tempest like the howling tempest."

Barmouda (9 April - 8 May): attributed to the sacred snake, Remoota, the goddess of harvest. In this month wheat and flax are harvested, honey is gathered and bees multiply. As this is the harvest season one saying goes: "In Barmouda strike the shafts", which means strike the stems of flax to extract its fibres and thresh the corn.

Bashans (9 May - 7 June): attributed to the god of light. Days become much longer than the nights, the temperature rises and there is virtually no rain. This was the dry season when the Nile was at its lowest and the land was bare and cracked after the harvest. In the past it was said: "Bashans sweeps the ground completely." The picture has now changed, however, with various irrigation schemes and the construction of the Aswan High Dam.

Ba-oona (8 June - 7 July): attributed to the god Khenti, god of minerals. Ba-oona means stone and during this month Egyptians used to leave their fields and turn to mining and the building of houses and temples. The 11th of Ba-oona (17 June) is called "The Night of the Drop", because it was believed that a divine teardrop fell from heaven to cause the coming of the floods.

Abeeb (8 July - 6 August): its name is derived from that of the god of happiness, Habi, to mark the coming of the floods. The floodlands are opened to receive the floodwater and the grapes become sweeter as they drink up the Nile water and fruits generally ripen: "Abeeb, the cook of grapes and raisins."

Misra (7 August - 5 September): attributed to Misra the Sun, or the child of the sun. The temperature drops as a prelude to winter. It is the season of floods and water. Summer fruits become ripe, dates, figs and grapes become abundant: "Misra is the month in which each difficult canal runs." ■

WEATHER LORE DOWN THE AGES

Continued from page 60

where storms are raging, how the currents which carry them along move, which regions are likely to suffer cyclones and which are likely to have flat calm and mists.

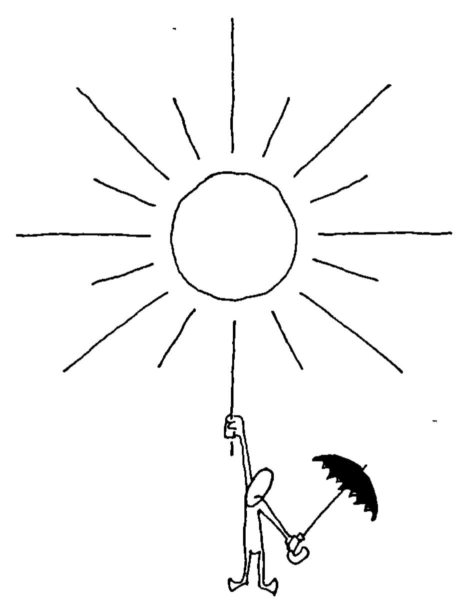
Taking into account this up-to-date information on what is happening between ground level and an altitude of 25 to 40 km., together with the physical laws and rules governing the atmosphere, they can foresee the air currents for the next day and following days, pinpoint the cloud masses and the rain, in short, forecast the weather.

For some time now, they have been able to do even better. The number of instrument readings going to make up the overall weather picture is so great, and the equations needed to calculate their significance are so complicated that it would take all the meteorologists in the world several months to work out the data required for one twenty four-hour forecast. Big modern computers, however, once they have been programmed to understand the laws of the atmosphere, can process all the information in an hour.

Bemusing, certainly, for those who base their weather forecasts on hints gleaned from plants or animals.

Though, during the process of civilization, man may have lost some of his natural "instruments", he has replaced them with scientific methods that tell him far more accurately whether or not it will be fine tomorrow. ■

Roger Clausse



Drawing © Mas, Paris

BOOKSHELF

■ **Memories II**

By Sir Julian Huxley
In this second volume of his "Memories", the famous British biologist takes up the story with his appointment as first Director-General of Unesco. George Allen and Unwin Ltd., London, 1973 (£4.95).

■ **A Natural History of Giraffes**

Pictures by Ugo Mochi, text by Dorcas MacClintock. Charles Scribner's Sons, New York, 1973 ($5.95).

■ **Society in Conflict**

By G. Hardy. Reform Publishing Co., Melbourne, Australia, 1973

■ **Man and the Social Sciences**

Edited by William Robson. George Allen and Unwin Ltd., London, 1972 (hardback £5; paperback £1).

■ **Revolution in China**

By R.J. Saywell. Ginn and Co., Ltd, London, 1972.

■ **The Unclean Planet**

By R.E. Baker and J.A. Bushel, Ginn and Co., Ltd., London, 1972 (£1.25).

■ **Environmental Quality and Water Development**

Edited by Charles R. Goldman, James McEvoy III and Peter J. Richardson. W.H. Freeman and Co., San Francisco, U.S.A. and Reading, U.K., 1973 (£8.40).

■ **The United Nations and the Population Question**

By Richard Symonds and Michael Carder. A Population Council Book. McGraw-Hill Book Company, New York, 1973 ($8.95).

■ **Leisure and the Third Age**

Proceedings of the Third International Course of Social Gerontology, held at Dubrovnik in May 1972. International Center of Social Gerontology, Paris, 1972, ($7).

■ **The Roots of Civilization**

By Alexander Marshack. McGraw-Hill Book Company, New York, 1972 ($17.50).

■ **Cooking Our Way**

Book I. A course in Caribbean cookery and nutrition. By Yvonne Collymore, illustrations by George Glaze. Caribbean Universities Press, Barbados, Ginn and Co. Ltd., London, 1972 (75p).

■ **Kenya's National Report to the United Nations on the Human Environment**

National Committee on the Human Environment, Nairobi, Kenya, 1972 ($2.80).

UNESCO NEWSROOM

Brazil's 'army of knowledge'

2,500,000 young Brazilians will do their national service next year by joining in a nation-wide adult literacy drive as students or teachers. Illiterate draftees will go as students to the literacy centre nearest to their unit and those not required for the forces will attend classes part time during the regular 11-month period of military service.

Everything under the sun

A Unesco-sponsored congress on "Sun in the Service of Mankind", the largest of its kind ever held, recently brought 600 scientists to Unesco's Paris H.Q. Embracing three major themes—Sun and Life, Sun and Energy and Sun and Habitat—studies and discussions ranged over almost "everything under the sun", from solar power plants and home cookers to the effects of sunlight on plants and animals.

No place like home —for accidents

Accidents are one of the three leading causes of death in many countries, with accidents in the home accounting for a large proportion of fatalities, says a World Health Organization report. In the U.S.A., during a single year, 20 million people were injured in domestic accidents—five times more than the number injured on the roads. The most common causes of home accidents are falls and burns.

India's women book-lovers

In India more women than men read books says a survey by the Indian National Book Trust. The survey also reveals that 60 per cent of readers buy books and the rest borrow from libraries or friends. India is one of the world's major book-producing countries (its national bibliography lists an average of 11,200 titles annually) but its total production still represents only 23 titles per million of its population, as compared with 418 per million people in Europe.

International response to Borobudur appeal

Australia has contributed over $283,000 and India has pledged $66,000 worth of goods and services for the preservation of the ancient Buddhist sanctuary of Borobudur in Indonesia. Other countries which have responded to Unesco's appeal for help in restoring Borobudur include Belgium, Cyprus, France, Fed. Rep. of Germany, Iran, Japan and the Netherlands.

New look at history and geography

Several countries have recently taken a fresh look at their history textbooks with the aim of removing stereotyped images and age-old prejudices concerning their neighbours. Co-operation between Unesco National Commissions in Austria and Italy has led to the publication of a history book with a new approach, "Austria and Italy", (1) which tells the story of relations between the two countries with candour and objectivity. Textbooks incorporating a new view of German and Polish history from which prejudiced accounts have been eliminated are about to appear, following meetings organized by the Fed. Rep. of Germany and Polish National Commissions for Unesco. Educators from the German Fed. Rep. and from Romania have proposed changes for improving how each country is presented in the other's geography books.

(1) "Austria and Italy", by Silvio Furlani and Adam Wandruszka, published in German by Jugend und Verlagsgesellschaft, Vienna and Munich, and in Italian by Casa Editrice L. Cappelli, Bologna.

African H.Q. for U.N. environment programme

Nairobi, Kenya, has been selected as headquarters for the new U.N. Environment Programme which was launched following last year's U.N. Stockholm Conference on the Human Environment. The programme, endorsed by the U.N. General Assembly last December, includes an "Earthwatch" pollution monitoring system, an international computerized service for environmental information and a "gene-bank" for conserving threatened plant species. A 58-nation governing council will oversee U.N. work on protection of the environment.

Cuban stamps aid Venice

Cuba's Ministry of Communications has issued a special series of three stamps as a contribution to the Unesco-sponsored international campaign to save Venice. Bearing the inscription, "Pro Venecia Unesco", the stamps portray two famous landmarks in Venice, the Bridge of Sighs and the Cathedral of St. Mark (shown below) and the winged lion emblem of the former Venetian Republic.

Flashes...

■ *Over half the world's population live in Asia (2,104 million persons representing 56.7 per cent of the world total) according to the latest U.N. Demographic Yearbook.*

■ *Norway is helping Unesco to train radio and TV technicians and programme specialists in Upper Volta.*

■ *The U.S.S.R. is to build a city protected by a transparent dome covering several sq. km. in the oil-and-gas-producing region of western Siberia.*

■ *The Fed. Rep. of Germany and Belgium have set up a 568,000-acre nature preserve along their common frontier in the northern Eifel region.*

■ *The International Law Association celebrates its centenary on August 30 with ceremonies in Brussels, in co-operation with the Institute of International Law which will mark its centenary in Rome a few days later.*

Letters to the Editor

SHREWD INSIGHT

Sir,

Bravo for Marcel Hicter's shrewd and penetrating article "Drugs and Society", in your May 1973 issue. For the first time I find the problem of drugs examined in its proper context: present-day society in which youth is not always guilty and adults are not always innocent.

Serge Guerot
Villebon-sur-Yvette, France

SCIENCE AND MYTH

Sir,

Your issue on "Science and Myth" (February 1973) is a timely step towards the debunking of beliefs which tend to make some people accept myths that are contrary to the laws of science.

This is true of all myths. They are simply legends concocted with a basis of historical or scientific fact and presented to the public as factual or religious truths.

The more science broadens our horizons, the better we become aware of the false reasoning on which religions are based, even though they all have a foundation of morality and of social laws and custom.

Congratulations too for your issue "The Emergence of Man" (August-September 1972). Its examination of the question of the origins of man on the basis of scientific fact was a first step towards the demystification of this subject.

M. Capdeville
Toulouse, France

CARTHAGE, LIVING SYMBOL OF THE PAST

Sir,

I am 18 years of age and a college student. Just recently I read about the project to save the ruins of Carthage. (See also "Carthage must not be destroyed", "Unesco Courier", December 1970.) I don't know if my letter will help much, but it is my way of showing you that I am concerned too.

I have never been to Carthage, but I have been to Rome and to Ostia Antica, in Italy, and they impressed me more than anything else I have ever seen. The sheer power and beauty of those ruins have impressed me ever since, and I often think of them. To destroy any such ruins is a crime against humanity. These ruins are not just ruins; they have inspired artists, writers, and poets, of all ages, and for some people like me they bring to life that great period of our past like nothing else can. I have stood in the ruins of the Colosseum for 1½ hours, just imagining how it was then. I would hate to see the ruins of another great city, such as Carthage, destroyed. It would be different if these ruins no longer gave anyone inspiration, a sense of beauty or the past, or any answers. The fact is, we still gather inspiration and the sense of beauty and past, we are still finding answers to our past history and we are still learning from these. To me, the beauty, impressiveness, and uniqueness of the ruins are reasons enough for not destroying them. Too many people don't stop to think in the rush of progress, that all of the things we get from these ruins of our past, once destroyed, can never ever again be replaced. It would be one of the great idiocies of our time if they were covered over in the concrete of "progress".

I hope that your efforts to save them will be rewarded, and for all of us who are behind you please don't stop trying. As Macaulay wrote: "People who take no pride in the noble achievements of remote ancestors will never achieve anything worthy to be remembered with pride by remote descendants."

Marian E. Seiders
Anaheim
California, U.S.A.

OUR WINDMILLS WERE TILTED

Sir,

I was delighted to see that your interesting issue "Music of the Centuries" (June 1973) marked the centenary of Fedor Chaliapin. But I was surprised to read in the caption accompanying the photo of the great bass (page 14) that it showed him in the title role of Richard Strauss' "Don Quixote". The "Don Quixote" composed by Richard Strauss in 1898 was a work for 'cello and orchestra and therefore could not have been sung by Chaliapin.

Works based on Cervantes' famous character have been written by a score of composers including Purcell, Conti, Salieri, Von Dittersdorf, Massenet and Pierné.

Jules Massenet's "Don Quixote", first performed at the Monaco Opera House in 1910, provided Chaliapin with one of his most striking roles. Later, in 1934, Chaliapin appeared as Don Quixote in a film directed by G. W. Pabst, though this was not an adaptation of Massenet's work. Commissioned to write the score, Ravel eventually withdrew, but not before he had written his admirable "Three songs of Don Quixote to Dulcinea". The film score was ultimately written by Jacques Ibert and it is more than likely that your photo is a still from this film.

Hubert Gassart
Neuilly, France

A MATTER OF RELATIVITY

Sir,

Why all this controversy about whether the sun goes round the earth or vice versa (Letters to the Editor, June 1973) following Jean-Claude Pecker's article "Copernicus as told to children" (April 1973) issue.

Did you not know that *I* am the centre of the Universe (my Universe)?

As I sit here, I feel that *I* am still, and everything else moves round me—or towards *me*—or away from *me*.

But I know that *you* are the centre of your universe and so long as I recognize this and *you* recognize that I, also, am the Centre, we shall not quarrel or come to any harm from each other.

Everything will be O.K. for *both* of us. It is all a matter of relativity!

Iris Sharratt
Headmistress
Secondary Modern School for Girls,
Dereham Norfolk, U.K.

RASH ASSERTIONS ?

Sir,

I would like to comment on the article "Copernicus as told to children" by Jean-Claude Pecker, in your fascinating issue on Copernicus (April 1973).

There are those who still share not only Copernicus' love of science but also his religious faith. I'm sure Copernicus would have been unhappy to read in Prof. Pecker's article that "One day... we'll have to admit that the old (Biblical) legends were lovely stories and perhaps nothing more". The Bible stories of the Creation are not "legends", but myths—writings full of imagery (with no pretensions to being scientific) and expressing a religious truth.

And isn't it rather rash to assert that "Man is a highly developed animal, but in the universe there must certainly be others even more highly developed"? I question this statement not on religious grounds but on the basis of existing scientific data. Shouldn't we be more circumspect about the possibility that other planets, identical or similar to the earth and inhabited, exist in other galaxies?

Father Jules Dubois
Boboto College
Kinshasa, Zaïre

TOO MANY ACCIDENTS

Sir,

In recent years the "Unesco Courier" has dealt at length with two burning issues of world health—cardiovascular disease (April 1972) and cancer (May 1970).

World Health Organization surveys show that accidents are another crucial issue which needs to be spotlighted. Accidents have become a modern scourge and their prevention is now a leading social problem. Though accident figures in the U.S.S.R. are lower than in many other countries, the problem is no less pressing here.

All countries are undoubtedly focussing their attention on this question. It would be interesting to read about their various approaches, achievements and plans, and to have the opinions of experts who study the causes of accidents. The prevention and elimination of accidents equally concerns research establishments, design offices, sociological laboratories, factories, transport organizations and medical institutes. It would also be stimulating to hear what philosophers have to say on this subject.

Victor Degtyarev
Moscow, U.S.S.R.

The Unesco Courier devoted an entire issue (April 1961 "Accidents Need Not Happen") to the subject of accidents and their prevention. See also "Unesco Newsroom" in our current issue — Editor.

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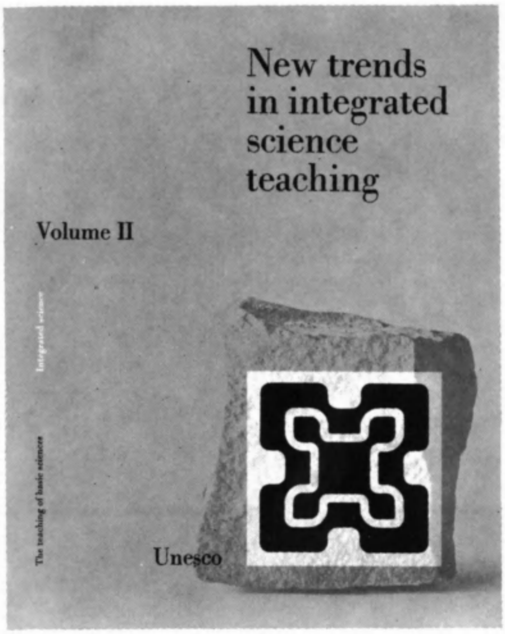

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Drought over Africa

This young African, eagerly slaking his thirst with a trickle of water from a gourd, is one of millions today suffering the catastrophic effects of a drought that stretches across the African continent from Mauritania on the west coast to the Sudan in the east. During the past seven years, declining rainfall in this immense area of Africa south of the Sahara has destroyed crops, decimated herds and forced untold numbers of persons into an unprecedented migration in search of food and water (see article page 44).