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SCIENTIFIC CHALLENGES AND THE IMPORTANCE OF WEATHER PREDICTION IN NIGERIA

By E. E. Balogun

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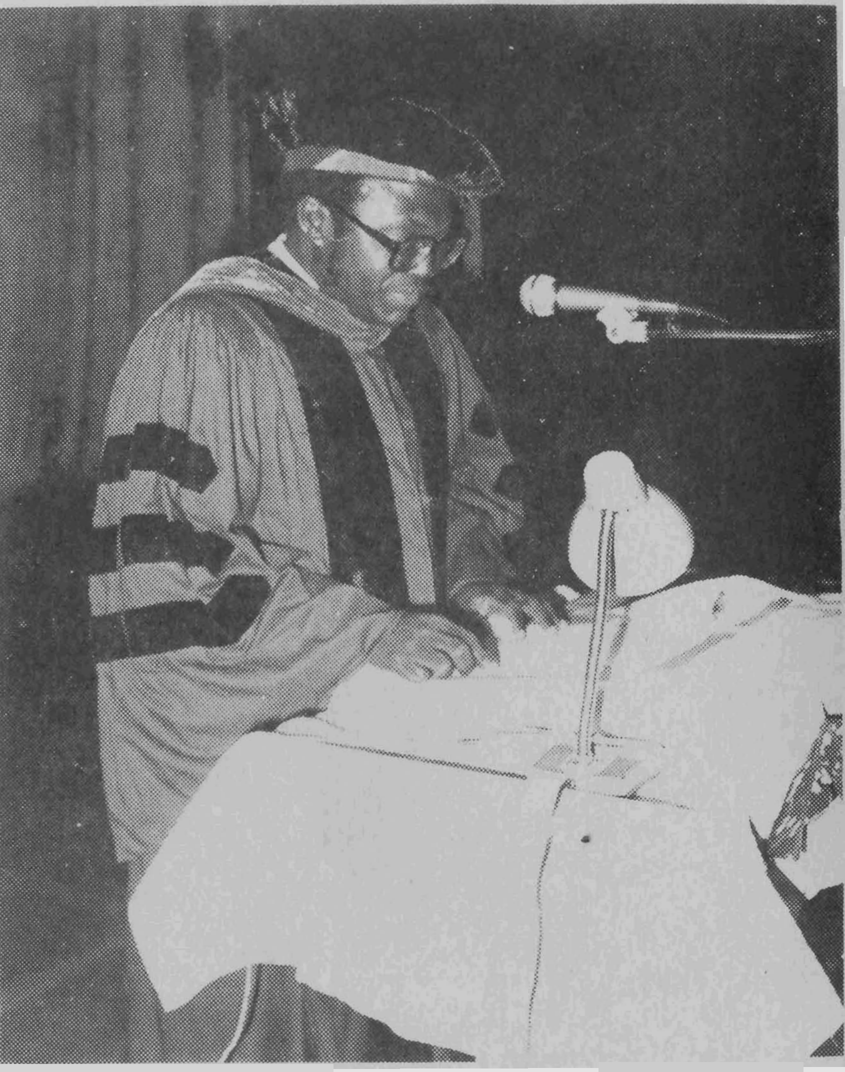

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1. Introduction

A physical scientist involved in a lecture of this type faces two important challenges. The first is how to keep the audience awake and the second is how to express in words ideas that he normally would have expressed by mathematical expressions and equations.

How is the understanding and the prediction of weather and climate essentially a problem in Physics? Physics is the science that deals with matter and energy. Physics studies force, motion, heat, light, sound, electricity, magnetism, radiation and atomic structure. Indeed physics is natural philosophy. Meteorology, the science that deals with the question of weather and climate is a branch of advanced physics. What is then, the physics behind weather phenomena?

As the earth rotates, carrying along with it, its gaseous envelope, it is heated by the sun. First, the sun heats the ground and the ground heats the air above it. The air is made up of Nitrogen, Oxygen, Carbondioxide, Argon, Water vapour and traces of other gases. Water vapour is a gas, and the most important for cloud formation, even though it constitutes a very small percentage of what we call air. Water vapour cannot be seen by the naked eye. When a bubble of air near the ground is heated it rises and expands adiabatically. A good understanding of mass, momentum and energy transfer and boundary layer processes is needed to understand the mechanisms of the rising air. The expansion of air causes cooling and the water vapour inside the bubble condenses. The condensation process involves the principles of physical chemistry, solid state physics, surface physics etc. Once condensation takes place, clouds form. The cloud particles are very tiny and can also not be seen by the naked eye. Sizes of cloud particles are of the order of a few millionths of a meter. Clouds form all the time but it does not rain all the time. For it to rain the cloud particles must grow. They can grow either by diffusion process by which the particles attract more vapour to themselves or by a coalescence process by which bigger particles scoop up smaller particles, as they fall through the clouds. The rain drops may grow up to about 3-4mm in diameter by the time they are ready to fall down as rain. At Ife, diameter sizes up to 6 mm have been measured. The process I have described may only lead to a few showers here and there. Then, how do large thunderstorms form?

For this to happen large air masses must converge over a large area and air must rise vigorously. Air is forced to rise after it must have accumulated in one place. This rising air may be aided by heating or by orography. To understand this process we have to invoke some principles of fluid mechanics. If air rises over a wide area, widespread heavy rain may result. Nature often organizes these weather systems in definite patterns and on different scales. Satellite photographs have provided us with an appreciation of the different cloud organizations which are the manifestations of physical processes on different scales in the atmosphere. With the help of mathematics and physics, physical models of these weather systems have been attempted. These models help us to understand and predict the various weather phenomena.

2. Major Influences on the Weather and Climate of Nigeria

Weather occurrence in Nigeria may be related to events in the Atlantic or Pacific oceans, or to an atmospheric system emanating from the Himalaya mountains in Northern India. The essential ingredients of weather over Tropical Africa are: the Subtropical High Pressure systems of the Northern and Southern Hemispheres; strong jets of wind at a height of about 17 km, called the Tropical Easterly Jet (TEJ), another jet of winds at about 3 km from the ground called the African Easterly Jet (AEJ), the African Easterly Wave Systems that move across the region, the South West Monsoon System; and the interface between the moist south westerly current and the dry winds from the Sahara often referred to as the Inter Tropical Discontinuity (ITD). Other systems that impinge directly and indirectly on the weather and climate of Nigeria are the so called atmospheric teleconnections, like the El-Nino, and the Southern Oscillation (ENSO), the Atlantic ocean influences, the Walker Circulation, and the Hadley cell. Some of these systems are briefly described below.

(a) The South West Monsoon of West Africa

To avoid running into semantic confusion about the terminology "Monsoon" a restrictive definition is adopted in this paper. Here, the word monsoon simply refers to very persistent moisture laden Atlantic Southeast trade wind (which turns southwest wards on

crossing the equator) which flows into West Africa. It is a prominent feature of the lower troposphere in the West African region during the months of May to September.

The south west monsoon forms a wedge under the north easterly trades; the surface of demarcation is usually identified as the Inter Tropical Discontinuity (ITD). The understanding of the structure and the progress of the ITD is basic to the understanding of the rainfall patterns over Tropical Africa north of the equator (Ilesanmi 1971, Adefolalu 1979, Adedokun 1981, 1982). In August, the airflow is not more than 3 - 4 km thick at its deepest points some 12^0 - 15^0 south of the ground position of the ITD. South of these points, the ITD flattens out and loses its identity. The depth and the strength of the moist air is one important factor controlling the convective activity over the region.

(b) The Inter-Tropical Discontinuity (ITD)

The W.M.O. (The World Meteorological Organization) commission on synoptic meteorology has defined the Inter-Tropical Discontinuity as "a discontinuity separating very hot and dry continental air from the cooler moist air from the equatorial region." There is a growing tendency among meteorologists working in the West African region to refer to the intersection of the surface of demarcation between the moist southwesterly flow and the dry northeasterly flow and the ground as the ITD. Above the ground the surface of demarcation is often referred to as the monsoon trough. The surface position of the ITD reaches its most northernly position (Lat 22^0 - 25^0N) around August 15th while the most equatorward shift (Lat 4^0 - 6^0N) takes place towards the end of January over most of the region. The northward movement of the surface position of the ITD is relatively slower (1.9^0 per month) than that of the southward movement (4.9^0 per month). The slope of the ITD is about 1/500 in August and about 1/300 in January, on the average. The slope is somewhat steeper near the top of the ITD surface than near the ground. The seasonal variations of the surface ITD has been documented by Clarkson (1959) Adejokun (1966) Ilesanmi (1971) and Dhonneur (1974) and others. These investigations treated the surface ITD as a climatological feature of the West African region. In some of those publications, attempts were made to associate the surface positions of the ITD with the amount of rainfalls at particular stations. Such studies neither considered the ITD as a phenomenon extending beyond the surface; nor did they consider in detail the phenomenon in relation to other atmospheric features of the region. Apart from the south westerly flow in the lower layers of the atmosphere over West Africa; there are other large scale flow at the middle and upper levels of the atmosphere over West Africa whose roles in the weather processes over the region are yet to be properly ascertained. Two large scale flows which characterize the middle and upper level as mentioned earlier, are the African Easterly Jet, and the Tropical Easterly Jet.

(c) The African Easterly Jet (AEJ)

Near the 600 - 700 hPa level over the West African region relatively high winds (10 - 15 meters per second) are sometimes found. These winds disappear over the Atlantic. Some scientists (e.g. Burpee 1972) have attributed the origin of these winds to the temperature fields over the Sahara. The African Easterly Jet is suspected to play an important role in the formation of the Easterly waves; (Burpee 1972, 1974), Rennick (1975), Reed, Norquist and Recker (1977); and in the generation of line squalls (Pyne and McGarry, (1977). The Easterly waves and the line squalls modulate the rainfall patterns over the region.

The strength and position of the airstream are variable in both time and space. The nature of the interaction between the AEJ and the moist south west monsoon is not known adequately. The system is believed to be an important link in the energy cycle of the West African monsoon

(d) The Tropical Easterly Jet (TEJ)

The Tropical Easterly jet (TEJ) is an upper tropospheric easterly maximum wind system originating over the South East Asia and believed to extend across the West African region into the East Atlantic. It is believed to be formed to the south of the quasi-stationary anticyclones over the Tibetian Plateau. Easterly momentum is transferred southwards on the eastern slopes of the anticyclone providing the jet with a source of momentum. The main features of the system over the West African region are poorly

understood because of paucity of data. There is need for research to relate the intensity of convective activity associated with the occurrence and disappearance of these winds. The core of these jets may be found as far south as the equator and as far north as Latitude 20^0N.

(e) Atmospheric Teleconnections and Ocean Influences on Tropical African Environment

Anomalous atmospheric heating over the sea surfaces (due to sea surface Temperature – SST – anomalies) as in severe El- Nino events can cause atmospheric disturbances which propagate around the globe perturbing remote regional climates. These long range events are called Teleconnections. Such teleconnections are suspected to have modulating influences on the rainfall pattern over Tropical Africa. Some of these are described below:

(i) *El-Nino, and the Southern Oscillation (ENSO)*

El-Nino originally described the oceanic perturbation which caused an increase in temperature of the coast of Peru and Ecuador during the winter months. At irregular intervals, about 2 - 10 years, a very severe El-Nino occurred. Normally in those areas, nutrient rich cold water (which supports a most productive fishing ground in the world) is upwelled from the depths. However during El Nino, the warm surface water is nutrient poor and in severe cases, there is mass mortality of fish. El-Nino is a natural climate perturbation. An associated phenomenon called the Southern Oscillation is a global scale variation of surface pressure with centres of action around Indonesia, North Australia and Southeast Pacific Ocean. The joint action of El-Nino and the Southern Oscillation is often referred to as ENSO. Contemporary studies of world climate indicate that the ENSO phenomenon is a year to year climate variability whose influence could be felt as far away as tropical Africa. Major ENSO episodes such as that which occurred during 1982/83 led to massive displacement of rainfall regions of the tropics bringing drought to vast areas and torrential rains to otherwise arid regions. However, linkages between deficient rainfall in Africa and the Pacific El-Nino are complex and further studies are needed to unravel the complexities.

(ii) *Influences of the Atlantic Ocean*

It is expected that the climate of Africa will be influenced by the oceans surrounding it. The climate of Africa is influenced by the Atlantic and the Indian Oceans. However the influence of the atlantic Ocean is more prominent over the region of interest for the present discussions. Upwelling phenomenon similar to that observed over the Pacific coast of Peru is also observed along the Guinea Coast of West Africa. The basic physics governing the coupled atmosphere ocean systems are the same in both the Pacific and Atlantic ocean. However a significant difference between the Atlantic and the Pacific Oceans is that the Atlantic is a meridional ocean and its tropical part is one of the meridional heat exchange regions of the World's oceans and thus has an important influence on the Earth's global climate on long time scales. The thermal capacity of the upper ocean is about 10^3 larger than that of the atmosphere and the transport of heat by the ocean currents, although much slower than winds, is comparable to the transport by the atmosphere. Heat flow northwards across Lat 24^0N in the Atlantic is estimated to be about 10^{15} Watts. The release of the oceanic heat to the Atmosphere in the North East Atlantic Area sometimes renders Europe pleasantly habitable in comparison with other regions of the same latitude. El-Nino type events also occur (Guinea Coast and parts of the Southern Atlantic) over the Atlantic Ocean. Although this phenomenon is weaker compared to what obtains over the Pacific, there are observed links betwee: the Atlantic El- Nino and variations of rainfall in the northern and north-eastern parts of Brazil and the Sahel. It has been found also that anomalously warm South Atlantic sea surface temperature (SST) favour above average rainfall in the Western Sector (north East Brazil) and below average rainfall in the Sahel region and vice- versa. Moura and Shukla, (1981) found that March - May rainfall departures from normal were positively correlated (0.7) with SST anomalies in the tropical South Atlantic and negatively correlated (0.5) with SST anomalies in the tropical North Atlantic. The extreme drought in the Sahel region of African in 1984 and the abnormally wet conditions in North-Eastern Brazil are attributed to the warm SST anomalies during the Atlantic El Nino of 1984. Nobre (1986) hypothesized that a link could exist between the fluctuations in Brazilian rainfall and Atlantic SST via a

teleconnection between the tropical and extra tropical atmospheric circulations.

(iii) *The Walker Circulation*

The Walker Circulation (Bjerkness 1969, Krishnamurti 1971), is an east-west circulation of the equatorial regions which represent the atmospheric realizations of the theoretical equatorial waves (atmospheric Kelvin Waves and Mixed Rossby – gravity wave). The rising and descending portions of these circulations are of varying strengths and are supposed to be detectable as one proceeds along the equator, round the earth. The dry Savana type vegetation along the Guinea Coast (coastal regions of Ghana and Togo) have been attributed to the influence of a descending branch of the Walker circulation system.

(iv) *The Hadley Cell*

In order to explain the trade winds of the tropical regions, George Hadley in 1735 proposed a direct thermally driven and zonally symmetric circulation system. The system consists of the equatorward movement of the trade winds between about latitude 30^0 and the equator in each hemisphere with rising wind components near the equator, poleward flow aloft and finally descending components at about latitude 30° again. The major arid regions of the World i.e. North and South Africa, Arabia, Southern parts of Asia, Central and Western Australia and parts of southern USA and Mexico lie in the sub-tropics and subject to the large scale sub-sidence long recognized as the descending branches of the Hadley cell. The maintenance of the Hadley cell is now essentially understood as being thermally controlled by radiational cooling in the sub-tropics and latent heat release in the tropics; it is dynamically controlled by the need for the zonal mean angular momentum balance to be satisfied in the presence of a surface frictional source and polewards eddy transport mainly in the upper troposphere. The desert regions of West Africa are among climatological subsidence zones and therefore regions of radiative cooling.

3. Weather Forecasting

In this section, I will discuss as simply as I can, the contemporary scientific approaches to weather forecasting.

First, let us consider operational weather forecasting using weather maps and also the process of preparing weather maps. There are several hundreds of weather stations over the globe. The mode of operations of these stations are governed by regulations and conventions agreed upon by the different nations of the world. The World Meteorological Organization is a regulating body for such operations. These stations make observations every hour on the hour. We have about forty of such stations in Nigeria. All these stations whether they be in Moscow or in Yola, use the Greenwich Mean Time as their time reference. These stations also send their messages in coded forms, so that the various stations can understand one another. Weather parameters like temperature, wind direction and speed, atmospheric pressure, cloud amount and type, humidity, rainfall, radiation etc. are made and are sent to central collection centres. Those collected over Nigeria are sent to Lagos or Kano. From Kano these observations go on the international telecommunication system and the data is made available to other parts of the world. At Lagos and Kano the observations relevant to the African Region are integrated into surface weather maps. Meteorologists with degrees in Mathematics and Physics analyse these maps and produce weather forecast. As an aid to this process the forecaster may also have at his disposal observations of the upper parts of the atmosphere. These upper air observations are made once or twice a day at designated stations around the globe. We have about four of such stations in Nigeria but observations from them are very irregular. There are also pilot balloon stations which provide information on upper level winds. There are about half a dozen of those in Nigeria. These upper air observations permit the display of temperatures and winds at various levels of the atmosphere. With these upper air maps, meteorologists make forecasts for air line routes and provide other useful information for the aircrew.

A series of prognostic charts can be developed by the procedure described above. The construction of such charts depends very much on the experience of the meteorologists. The sequence of charts has to be examined with care in order to estimate how the various weather systems are moving. From today's charts, charts for tomorrow are often constructed and forecasts for the following day

can be built up. This procedure can produce reliable weather forecast for one or two days ahead. This is known as short range weather forecasts.

The process of analysing weather charts described above is subjective and much depends on the experience and skill of the forecasters. In many advanced countries, a completely objective method of preparing weather charts, called numerical weather forecasting is in common use. The laws of mathematics and physics are directly applied in the production of such prognostic charts.

Much of meteorological science involves what is known to physicists, mathematicians and engineers as boundary value or boundary condition problems. The numerical weather forecasting approach involves the solution of a set of differential equations consisting of about six equations. Three of these are called momentum equations or simply equations of motion. One is the equation of continuity which is the mathematical formulation of the principle of conservation of matter. The remaining two equations describe respectively the thermodynamics and the moisture content in the atmosphere. These equations are difficult to solve by analytical methods. Several assumptions are usually required to make the equations tractable. Numerical Prediction is routine in advanced countries; but because the assumption often made are not applicable to the tropics, progress in numerical weather prediction in the tropics has been very slow. Even though Nigerian scientists know the principles behind the use of these method, they have not been able to find the most suitable assumptions. Some experimental results have been obtained for the tropics but the use of these procedures in Nigeria is still many years away. (see Adejokun, 1981).

Numerical Weather Prediction require super computers. We don't have these in Nigeria. The motion and state of the atmosphere are determined by the equations mentioned earlier if the initial and boundary conditions are known. If the equations could be completely solved at a given time we should know the subsequent states of the atmosphere for an unlimited period ahead unless external influences intervene. This approach can produce reliable forecasts for about a week ahead. This is medium range weather forecasting. This approach too is not foolproof. Britain experienced the worst weather phenomenon in October 1987 although that country had these super computers at her disposal. Scientific approaches to weather forecasting in Nigeria are not as good as they should be, for several reasons.

First, because of inadequate facilities, all the forty-two specialized stations do not make regular observations. the forecasters at Ikeja and Kano often have inadequate information to base their analysis on.

Secondly, because of poor communication systems in Nigeria useful weather information from other parts of the world even from the different parts of the country arrive too late to be useful in making forecasts.

Thirdly, our understanding of the physics of the tropical atmosphere is still very limited and we do not have the proper mathematical and physical framework for understanding all the processes taking place in the tropical atmosphere. The lack of explicative and quantitative base of knowledge for comprehending the atmospheric processes over the Tropics, and especially over Tropical Africa, had been the bane of research effort to understand climate and weather variations over those areas. In the last twenty-five years however, some progress had been made to collect, analyse and interpret data obtained over the tropical regions through cooperative effort among nations. The data collected during GARP (Global Atmospheric Research Project) experiments and in particular during GATE (GARP Atlantic Tropical Experiments; 1974) WAMEX (West African Monsoon Experiment, 1979), FOCAL (French Programme for the study of the Equatorial Atlantic Ocean) SEQUAL (US programme for the study of seasonal variations of the equatorial Atlantic) TOGA (Tropical Ocean and Global Atmospheric programme; 1985) etc. have thrown some light on Tropical atmospheric processes and in particular on weather and climate patterns over the West African region. The understanding of the new data acquired during the execution of these experiments have however not reached the level where definite linkages between atmospheric processes; drought situations and desertification mechanisms can be firmly established. Some progress has however been made. It is important to make further comments on WAMEX.

The WAMEX is of major interests to us in West Africa. Unlike GATE which was mounted over the Tropical Ocean of the coast of

Dakar, WAMEX took place over continental West Africa. The major scientific objective of WAMEX included observing, describing, understanding and predicting the monsoon circulation in West and Central Africa.

The objectives also included the definition of the planetary, synoptic and to a lesser extent the subsynoptic scale aspects of the West African Monsoon Circulation.

The experiment did not achieve all its aims because of operational problems and poor participation in the Programme by some West African countries. The experiment did provide more data for the period (May - September, 1979) than we normally would have had. Some of the data collected have already been analysed at Ife. One of my post graduate students at the Department of Physics has almost completed a Ph.D. thesis on some of the dynamical and thermodynamical aspects of the West African weather, as revealed by the WAMEX data.

The fourth reason why the quality of weather forecasts in Nigeria has not reached the desirable level is the inadequate support of the Nigerian Meteorological services by the government, coupled with the fact that the general public is really not weather conscious. As long as rain does not disturb our parties or some of our other outdoor programmes, we feel very unconcerned. We do not appreciate the link between our económic survival and our understanding of the weather, and indeed the understanding of our environment in general. In colonial Nigeria, the colonial government ensured the participation of the measurement of weather parameters over different parts of the country by schools, government institutions, trading companies, and other voluntary agencies by providing basic items like rain gauges, thermometers, wind vanes and so on. These observations were in addition to those made regularly at the special synoptic stations mentioned earlier. These pieces of information were published by the Government printing press and copies could be purchased. The colonial government used the information as imput to the forecast of the production of cocoa, palm kernel, groundnuts, soya beans and other agricultural products. These days, only about 10% of these voluntary agencies bother to make such observations. A good percentage of the synoptic stations no longer make twenty four hour observations. It is unbelievable that

Nigeria had less information about its weather and climate thirty years after political independence, than it had in pre-independence days.

To conclude this section on weather forecasting I must add that there are other approaches to the prediction of weather elements. There is the statistical approach; and what I call the traditional approach. Weather and climate elements can be subjected to time-series analysis and, probability theory can be employed to estimate trends in the climate of a region. Such an exercise had just been concluded by a member of staff of this University and some of the results have thrown some light on Rainfall trends in Nigeria. Sophisticated Statistical techniques like Markov chains have also been used to model sequence of days on which particular weather events occur. Time will not permit us to go into the details of such techniques.

To forecast the weather, we can also consult a Babalawo. I have found to my amazement that the Ifa includes so much information about the weather over the Guinea Coast of West Africa that if these pieces of information had been written down several centuries ago, they would have contributed immensely to the classical scientific knowledge on the atmosphere over Tropical West Africa. Ifa is not as satanic as we may think. It is a body of knowledge, which have been accumulated over centuries.

4. Weather and Climate Events in Nigeria and the Challenges they Pose

At the outset, it is important to distinguish between weather and climate. Weather is localized in time and space; climate is the summation of weather on local, regional, and global scales over periods of years to centuries. The weather is what is happening right now. The temperature, pressure, humidity, wind direction and speed, cloudiness, visibility, state of the earth surface, the amount of radiation reaching the ground or given off by the ground and a few other parameters can be used to specify what the weather is at a particular location, and at a given time. Weather however may appear local but its causes may be global. On the other hand, climate is the synthesis of weather, the long term manifestation of weather however they may be expressed. More rigorously, the climate of a

specified area is represented by the statistical collective of its weather condition during a specified interval of time usually about thirty years.

Let us now consider specific weather events.

(a) Local showers

The scale of this phenomenon is usually of the order of a few kilometers. We may have showers over the residential areas of the campus of this University and the showers may not be observed at the academic areas. These events happen on the scale that cannot be captured by the kind of observational network we have in Nigeria. We have an idea of the mechanisms responsible for this phenomenon but we do not as yet have a good understanding of how they may be properly predicted. Local showers may spread over a large area. We are not as yet able to forecast the specific areas over which they may fall. We need to understand this system because of its adverse effects on the propagation of Electromagnetic Waves and our telecommunication systems. Road users whose vehicles run into local showers are also in danger of freak accidents.

(b) Local Thunder Storms and Rain Showers

This phenomenon may cover areas of the order of tens of kilometers. The phenomenon is accompanied by heavy showers, thunder and lightning. This is an important feature of hilly areas. The phenomenon usually has a short duration in spite of its fury. It is common at the beginning of rains. A locality surrounded by hills may experience heavy thunder activity around it but it may not rain or shower at the locality. This situation often obtains around Ife, and Ife people are usually blamed if it rains around Ife and does not rain within Ife town. Local 'rain-makers' or good farmers, especially experienced ones, are usually able to forecast this kind of weather. Because they have a better understanding of this phenomenon than the ordinary person, they can claim to stop or start this type of rain. Scientists have been able to model this type of events fairly successfully and the course of the events can be properly predicted. We can, with careful study, provide information about the characteristics of such phenomena at areas around Efon Alaye in Ondo State; Kutigi in Niger State; and Afikpo in Imo State. With proper meteorological information, these areas can be made to produce rice, and yams to feed the entire nation.

Further research into the two weather events described above is necessary, but inadequate observations, and funding seriously limit such effort.

(e) The West Africa Squall Line System

This system is the most studied by the Nigerian scientists because it occurs on a larger scale and some of its characteristics can be captured by the existing meteorological network over Nigeria. (See Omotosho (1985, 1987); Nnodu (1983); Obasi (1974); Okulaja (1979); Balogun (1979)).

The Squall line is a line of disturbed weather about 300-1000 km long lying roughly north-south which move in general from East to West over the West African Region with a speed of about fifteen to twenty meters per second; and which is accompanied by heavy banks of convective clouds, strong gusts of wind, precipitation, thunder and lightning. Operational weather forecasters and observers working in Nigeria are usually not left in doubt when they observe a squall line system. With good weather maps and with the help of Radar Systems and satellite data, these systems can be tracked for several days and their course can be properly predicted.

This system is the largest rain producing system over West Africa. It provides over 80% of the rainfall measured over the Sahelian regions of Nigeria. In the southern part of the country these storms produce floods and promote rapid soil erosions if the precipitation from these systems is not properly channelled. Strong winds accompanying these systems destroy schools, hospitals and other public buildings and installations. NEPA lines are destroyed and Airlines are grounded as a result of the fury of these systems. Estimates from Nigerian Newspapers indicate that the country has suffered over 100 million naira loss of property in the last three months as a result of these systems. What can we do about these systems? It is true we may not be able to do anything about them, but we should know what the systems are doing; and we could devise means of mitigating their adverse impacts on our economic and social activities. We need to know parameters of these storms which are inimical to public buildings and structures. We can then ensure

that our public buildings conform to proper specifications that have taken these parameters into consideration. Rain rates and Rain duration and sizes of drops of these systems need to be studied carefully so that they can serve as inputs to the design of our drainage systems and in fact to the design of our telecommunication systems. Although it is in connection with the design of communication systems that these parameters are measured by scientists at the Department of Electronics and Electrical Engineering and the Department of Physics of this university, it has been discovered that the data could also be used as background knowledge to the control of erosion process in the country. Such measurements are done routinely at the University here.

There are other positive aspects of the squall lines. A study of their characteristics is of utmost importance to water resources management in the country. Knowledge about the behaviour of these storms can be useful for the construction and maintenance of dams. 'Harvesting' rain from these weather systems is now a major preoccupation of scientists working in the Sahelian region. See Dugdale, *et. al.* (1986); and Milford, (1986). Predicting the frequency of these systems; the amount of rain expected from then and how much of the rain is retained in the soils, are important challenges confronting a weather scientist in Nigeria. In the last few years I have been engaged in the research of how to estimate the amount of rains from the cloud patterns of these systems as depicted on satellite infrared imageries. (See Balogun, 1984).

One interesting aspect of these systems is that the traditional 'Rain makers' can predict these systems about a few hours of their arrival at a particular location. His reputation is enhanced immensely if its arrival coincides with any outdoor activity on which his opinions have been sought. He can threaten to disrupt such activities especially if the participants are his perceived enemies, or offer to parry off these systems if such activities involve him and if he is aware that the system will bypass his location.

(d) Thunder and Lightning

These are common features of the last two weather events discussed. Local thunderstorms and linesqualls are made up of thunderstorm cells. Each cell is a huge battery that is continually being charged by the action of the upward current on drops and ice particles in the cloud and discharged by the lightning strokes. A lightning flash or stroke is an enormous spark and a thunder cell is an electrostatic generator that works by producing positive and negative electrical charges (see Sutton, 1974). The positive charge is mainly in the upper portion of the cloud and the negative charge in the lower regions. The lightning stroke occurs when the potential difference between the regions or between one of the regions and the earth, reaches a value sufficiently large to cause a break-down. The potential difference immediately before a stroke takes place, is estimated between 100 million and one billion volts. The current in a typical stroke is about 30,000 to a quarter of a million amperes. The time taken for the stroke to be completed is between a hundredth and a hundredth-thousandth of a second. The quantity of electricity used in a stroke is between 20 - 30 coulomb. A typical storm producing a stroke every 20 seconds dissipates electrical energy at the rate of about one million kilowatt. A small storm of about 1 km radius is equivalent in energy to about ten atomic bombs of Hiroshima vintage.

It is estimated that about 16 million thunderstorms occur every year. About 2000 thunderstorms events occur every hour around the globe. Two challenges face scientists concerning thunder and lightning. The first is the understanding of charge separation within the clouds. There are many theories put forward by many scientists but most of the questions about this phenomenon have not been answered. A prominent Nigerian Scientist, Prof. A. I. I. Ette, of international repute and his former student Dr. Oladiran (both of them are at the University of Ibadan) should be consulted on such matters. One other challenge is how to tap the tremendous energy for use. If the energy from a single thunder cell can be tapped, it will be enough to serve the oranmiyan local government area for one year without one second interruption. About 12 years ago this University set up a research committee to look into the possibility of tapping energy from lightning, with our current Vice-Chancellor as the chairman. Other members of that committee were Prof. V. A. William of this University, Prof. I. E. Owolabi, the current Deputy Vice- Chancellor of the University of Ilorin and myself. We have run out of funds but we are in a better position to understand the

problems. Because the lightning event takes place on the order of microseconds it is difficult to devise a system to capture the energy. The materials needed to collect such energy must be able to withstand a lot of heat without melting. the lightning stroke can heat up the air to about 20,000 degrees centigrade in a few ten-millionths of a second. If we can capture the energy, how do we store it? These problems continue to agitate our minds. How do we direct the lightning to where we can collect the energy? That was the task given to our Vice-Chancellor. He was to go through Ifa corpus to find out how that could be done. After all, our people claim that they could send thunderbolts to kill their enemies and use the phenomenon to identify thieves and miscreants. He had collected many useful pieces of material on the subject but these have not been fully analysed. We hope that money will be available to complete the analysis in due course. Some results from our findings have however been published.

(e) The Monsoon Rains

This is the terminology often ascribed to rains that go on for days during the rainy season. These rains are, most of the time, not accompanied by thunder and lightning. However during the rainy season, it does not rain everyday, and it does not rain with the same intensity all the time. Forecasting rain and no rain during this season is one of the greatest challenges meteorologists in this country face all the time. A numerical prediction of systems of this type has been attempted by some Nigerian scientists and others are making an effort in that direction. See Adejokun and Krishnamurti (1983). 'Rain makers' don't make attempts to forecast such rains for fear of serious damage to their reputation.

This type of rains are also flood producing and can intensify erosion and land slide processes. I have mentioned in passing, the types of weather measurements, necessary to plan against such disasters.

(f) The Harmattan Haze

Perhaps the best description of this phenomenon was the experience in Nigeria and most of West Africa from November 1988 to February, 1989. It is estimated that about two billion tons of sand was deposited on West Africa and the adjacent oceans during the period. This phenomenon, like the West African squall line has been studied by many Nigerian Scientists, (see Kalu, 1983). We know the origins of the dust that get to us in Nigeria to be Chad and the Sudan. We have a fair idea about the deposition pattern, size distribution, and the composition of the dust. The challenges the Nigerian scientists face are the proper understanding of the transportation of the dust from the source regions to the West African countries and the prediction of changes in the visibility accompanying the Harmattan Haze. Airline operators over west Africa lose millions of dollars every year. These losses can be reduced by about 60% if the present approaches to the prediction of the dust is encouraged and perfected. The parameters involved in the prediction of dust movements and intensity over West Africa are the pressure gradients over the Sahara, the stability of the atmosphere near the ground and the characteristics of the general flow field near the ground over the region.

(g) **Fog**

Fog is another weather element that needs to be accurately predicted because of its effect on the aviation and the shipping industries. It is also a real danger to motoring. Because of inadequate data, it has not been possible to predict this phenomenon accurately for many locations in the country. Fog is essentially cloud on the ground. The physical principles for the formation and clearance of fog are known. If facilities are available to predict the formation and clearance of fog on runways and quays, the loses due to this phenomenon can be reduced by about 50%.

(h) **Non-Visible Weather Events**

A combination of high humidity, high temperature and calm condition can be unbearable, to human beings, livestock and electronic equipment. The prediction of situations of this type is useful for human and animal comfort. Infectious and debilitating diseases among human, animals and plants thrive under such conditions. A critical balance between temperature and humidity must exist to enhance livestock productivity. An 'unseen' but adverse weather situation can lead to the extinction of thousands of chickens within a few hours.

Apart from the menace of dust; high humidity and high

temperature ruin many electronic equipment. Setting up specifications for the kind of electronic instruments that can survive in our environment is a challenge to Nigerian Scientists.

5. Monitoring and Prediction of Weather-Related Natural Disasters

(a) **Droughts and Desertification**

There is a very delicate and complex interaction between weather and climate variation and desertification process. It is often difficult to assert that one is a direct cause of the other. What has been established is that recurring droughts are one of the major inherent causes of increasing desertification in arid and semi-arid regions where the ecological balance is precarious and where very little perturbation is required to precipitate desertification. The severe drought in the Sudano-Sahelian regions of Africa — of which the far Northern regions of this country is a part — between 1968 and 1973 was an example of such environmental perturbation in a situation where the environment had been subjected to man-made stresses from overgrazing and bad land management. Uneasing drought is not the only culprit. the ultimate result of persistent erosion of the land from over-abundant rainfall may well be desertification. Any process that removes vegetation can lead to desertification. That too much rain could lead to desertification, may seem contradictory; but it is within human experience that severe erosion can denude and degrade the land. The definition of desertification accepted at the United Nations Conference on Desertification is as follows:

> Desertification is the diminution or destruction of the biological potential of the land and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystem, which has diminished or destroyed the biological potential, i.e. plant and animal production, or multiple use purposes at a time when increased productivity is needed to support growing populations in quest of development.

The definition does not make any direct reference to weather and climate. Therefore conditions of weather and climate that contribute to the diminution or destruction of the biological potential of the land can be considered only as factors that aggravate the desertification process.

Although the semi-arid zones of West Africa have experienced sequences of dry years repeatedly in this century (Grove 1972, 1973; Hastenrath, 1976; Nicholson 1980, 1985), the Sahalian drought of the late nineteen sixties and the early nineteen seventies and the more continental scale drought in Africa between 1982 and 1984 have pressed on the attention of the world's scientific community, the need to identify and collect the necessary meteorological information required for the understanding, monitoring, assessing and the mapping of the desertification process accompanying persistent droughts. I have earlier identified some of the atmospheric circulation features that have modulating effects on the weather over the West African region. What are the causes of droughts? The recent episode of droughts over the Tropical African Region affecting in varying degrees the sub-saharan zone of Africa from the Atlantic Ocean to the Red sea, (Motha *et. al.*, 1980, Glantz 1977 and others) provoked several hypotheses about the causes of droughts over the region. Some of the hypotheses are briefly discussed below:

(i) *Equatorward Displacement of the Sub-tropical High Pressure Belts*

It was discovered by some scientists (Byson, 1973, Winstanley 1973a, b, Angell and Korshover 1974) that the 1945-1970 cooling of the Northern Hemisphere extra-tropical cap caused an equatorward displacement of the subtropical high pressure belt which in turn reduced the penetration into West Africa of the Tropical circulation systems controlling Sahel rainfall. Bryson (1973) also discussed the implications of a "Z criterion" which specified the latitude of sub-tropical anticyclones in terms of meridional temperature gradient and lapse rate. By further inference, the latitude of the sub-tropical anticylones was related to that of the Inter Tropical Discontinuity. Bryson (*op. cit.*) also suggested that man made increase of CO_2 and air pollution in the atmosphere of the Northern Hemisphere extratropical cap might be responsible for the Sahel drought via a southward displacement of the sub-tropical high

pressure belt. However, southward displacements of components of the general circulation systems have not been supported by other studies (Bunting *et. al.*, 1976; Beer *et al.*, 1977; Greenuy 1977; Nicholson 1980 a, b).

(ii) *Biogephysical Fedback*

Another hypothesis for the recent sub-saharan drought episode attributed it to vegetation depletion in the sub-Saharan zone. Some scientists (Charney, 1975; Berkofsky 1976; Otterman 1977; Ogunmoyela and others) attributed the drought situation to increased albedo over the zone; caused by man's activity. In a simple form, the biogeophysical feed back mechanism operates as follows: As a result of overgrazing and the poor land management practices, the semi-desert regions are further deprived of the little vegetation they have. The reduced vegetation leads to increased albedo. The high albedo means that more of the solar radiation that impinges on the earth surfaces is reflected back to space. This leads to a net radiative loss over the region relative to its surroundings. The atmosphere near the ground cools and sinks. Sinking motion in the atmosphere prevents growth of clouds and hence there is reduction in rainfall; and vegetation is further reduced. Drought situation is thereby accentuated. There have been some reservations about albedo feed back mechanisms. Gutman *et. al.* (1984) have, more recently, concluded that the importance of the albedo feedback mechanism may have been overstated in previous studies. Norton *et. al.* (1977) reported an increase of satellite derived surface albedo in sub-Saharan West Africa from 1967-1973 but they found no relation between albedo and subsequent rainfall. It seems therefore that albedo feed back alone may not explain the severity and the extent of the Sahelian drought.

(iii) *Temperature of the Oceans*

For a long time, scientists have suspected that the three most important controls of weather and climate are: the Earth's surface, the distribution of Land and Sea, and the temperature of the sea. The precise manner in which these controls are applied are not well known. During and soon after the 1982/1983 El Nino, the first signs of linkage between deficient rainfall in Africa and the Pacific El Nino began to appear in the literature. The continental scale drought in Africa in 1982 - 1984 has been linked with the El-Nino. The linkages and relationships are however considered to be very complex and more detailed analysis are still needed to establish the true nature of the relationships. Rainfall in most parts of Africa improved in 1985 but was still below normal. Preliminary information on rainfall in West Africa for 1986 indicates a rainy season still below normal but better than 1985. The continuing below normal rainfall in Western Africa is thought to be partly associated with the warm sea-surface temperatures in the equatorial and tropical South Atlantic. The positive SST anomalies in the tropical South Atlantic which occurred in December/January/February 1984/85, and continued throughout 1985, are said to contribute to weakened low-level thermal gradients over Western Africa which could result in fewer squall lines, the major rain producing system of the region. The establishment of the links between SST and drought or rainfall events over the Tropical West African region is an active area of research and research findings are expected in the literature (in the next few years) which hopefully will clarify the linkages.

(iv) Moisture Flux Convergence

Some investigators (Newell and Kidson, 1984)have suggested that a contributory reason for drier years in the Sahel may be a weaker moisture — flux convergence into the West African sector of the Sahel. Although they have arrived at such conclusions from limited analysis of atmospheric conditions accompanying dry and wet Sahel summers, yet their findings confirm the experience of scientists working in the region. They found that the lower tropospheric south westerly winds were shallower and weaker in dry years. They also found evidence of reduced upper tropospheric easterly flow over the Sahel in the dry years.

(b) **Land Slides and Erosion**

Erosion is the movement of soil or rock from one point to another by the action of the sea, running water, precipitation or wind. Erosion is distinct from weathering; the latter does not necessarily imply transport of materials. We have sheet erosion which is a

gradual process of wasteful transportation of valuable top soil by either water or wind. Gully erosion is an advanced stage of sheet erosion. Where human agency has increased erosion beyond the normal geologic rate, it is termed accelerated erosion. Erosion is a problem in Nigeria. The problem is more acute in the southern parts of the country than in the north.

I have received the news of the huge amount of money released by the government to check ecological disasters in this country with mixed feelings. On the one hand, I am happy that the government has become aware of the problems and is prepared to do something about them. On the other hand I am convinced that about 60% of the funds will be wasted because we do not have the necessary information on erosion and desertification process in the country to utilize the money wisely. To check erosions, we need good information about flood producing storms, their tracks, their duration and their intensities. We also need information on the strength of wind near the ground, and on the characteristics of the soil. As far as I know we do not have adequate information on these parameters for many parts of the country. In trying to combat erosion process for example, a lot of money will go to contractors who will proceed to build concrete gutters, water channels, dykes, weirs, and earth embarkment that will be washed away or buried by land slides within a few months of their erection. This is so because the contractors don't have the necessary meteorological, geological, and satellite-derived information to guide the erection of such structures. I am not a prophet of doom, I raised similar questions about the much- talked-about Aerostat Balloon Project thirteen years ago. I was proved right. The project failed partly because we did not get the necessary information about the atmosphere before we embarked upon that 160 million naira project (when the Naira had value).

6. How the Challenges are being met by Nigerian Scientists

There were five members in the atmospheric physics research group in the Department of Physics, of the Obafemi Awolowo University at Ile-Ife about five years ago. Dr. Isherwood returned to his native England; and Prof. Kolawole transferred his services very recently to FUTA, Akure. These two members of the group addressed the problems of the upper atmosphere. Prof. Kolawole later changed his focus to the optical properties of the lower atmosphere and the interaction between the atmosphere and electromagnetic waves. The results of his investigations were useful for communication engineering in Nigeria. Dr. Isherwood's attention was focussed on some properties of the upper atmosphere in a tropical setting. The characteristics of the phenomenon of airglow was his speciality.

Dr. Adedokun, another member of this group, has specialized in the thermodynamics of the lower atmosphere in West Africa. The important contribution he made was the discovery of the fact that we could predict with a fair degree of certainty the pattern of rainfall in Nigeria two months before the beginning of the rain season. His techniques require fine-tuning. The United States Governments has funded one of its scientists to look further into Dr. Adedokun's techniques and other similar techniques. It is curious to note that the American Government would be interested in what we are doing here concerning our weather. We don't seem to appreciate the utility of such scientific information. Dr. Adedokun also works with the other members of the group to study the problems of turbulence in the lower atmosphere; the Harmattan dust and its effect on the amount of Solar radiation received at Ile-Ife using radiometers we have borrowed from the University of Upsalla, Sweden. Dr. Adedokun is a product of this University and of the Imperial College, University of Ibadan.

Another member of this group is Mr. Jegede whose specialty is the Dynamics of the tropical atmosphere. He is an up-and-coming atmospheric and space physicist. He was originally trained as a nuclear physicist by one senior member of the Department. The experience of Chernobyl, in Russia and our energy programmes at the University, require that we have in our group somebody with Mr. Jegede's background. Another member of this group is myself. My introduction to the Science of the Weather dates back to 1957. I joined the Nigerian Meteorological Department the very day I concluded my school certificate examinations. It is not as easy to get jobs these days. I was trained as a weather observer at Ikeja. The qualification required was a good background in mathematics and physics. I also joined Mr. Pretty in the measurement of Weather parameters when I was preparing for the advanced level in science at the Old Nigerian College of Arts, Science and Technology at Ibadan.

Thereafter, I was trained as a Weather Forecaster at the British Meteorological Office, Air Ministry, Middlesex, England. That was followed by a degree in Science (Mathematics and Physics) at the University of Toronto, in Canada. My postgraduate training was in the use of satellite derived data in the interpretation of weather events. That training took place at the University of Chicago, U.S.A. Because we were pioneering students in that field at that time the training covered the behaviour of man made satellites in orbit and in the use of all kinds of data obtainable from satellite orbits. After my successful training at Chicago, I joined the services of this University in 1972, through the invitation, encouragement and support of late Professor H. A. Oluwasanmi. My contributions to the understanding of the tropical weather and tropical weather systems can be summarized as follows:

(i) In my contributions to satellite meteorology, I have suggested techniques by which tropical cyclones and other tropical weather systems could be studied using radiation and cloud data obtained by satellites over these systems. Using such data along with data obtained conventionally, I have explained some of the mechanisms governing the development of these weather systems and which could facilitate their prediction. Currently I am studying how rainfall amounts could be estimated from satellite data collected over these weather systems. The tracks of these systems over Nigeria are also being identified and results of such activities should be useful to water resources development and agriculture. The detection and tracking of clouds and water vapour in the atmosphere using satellite data are some of my major contributions to satellite meteorology. My works on satellite meteorology have been sponsored by the United States Government through some of its agencies such as the National Aeronautic and Space Administration, (NASA) National Science Foundation, (NSF) and the United States Weather Bureau. I did some work on the retrieval of satellite data while I was a Fullbright scholar in the United States of America. Most of the results however are relevant and useful to the understanding of the weather and climate of Nigeria. (See Balogun, 1972, 1975, 1977(a, b), 1982, 1986).

(ii) I have collected conventional meteorological data from the Nigerian meteorological stations with a view to creating a data bank at Ife. My group has also made effort to set up an observatory on

Tonkere Road near the campus and on one of the hills around the campus. The activity on Tonkere Road near this campus foundered on lack of funds. We now make observations from the top of Physics Building. On the Physics building we have installed an accoustic sounder system. The installation of the system was a cooperative effort between three Swedish institutions and this university. Other meteorological instruments with which we monitor the lower atmosphere have also been installed on the building. We have also set up instruments on the BCOS tower at Ibadan from which we collected useful information. The setting up of these gargets and the collection of data are group effort. The success of the effort should be shared by colleagues in my department and at the Department of the Electronics and Electrical Engineering of this University. (See Babatunde and Balogun (1983), Balogun and Babatunde (1983), Balogun and Adedokun (1986), Jegede and Balogun (1989), Fasheun and Balogun (1988), Adejunwon, Balogun and Adejunwon (1989) etc.).

(iii) Contributions to the training of meteorologists has been a joint effort. Some of the meteorologist working at the Nigerian meteorological office were trained at Ife by all the teachers in the Department of Physics. These former students are helping to meet the challenges of understanding and forecasting the weather in Nigeria.

It is fair to mention at this point some aspects of the research effort of other members of the Physics Department that are germane to the present theme of my lecture. We have the solid state group in the Department who are involved in the development of materials and techniques to harness solar energy. We have the Nuclear science group, which along with its main research activities, is also involved in the monitoring of radiation from natural and man made sources. The Geophysics group specializes in the physics of the solid earth. The theoretical physics group in the Department provide some of the theoretical framework for understanding some measurements we made in the atmosphere. Members of the Centre for Energy Research and Development (the Centre was an offshoot of the Department of Physics) played significant role in the monitoring and the clearing of the notorious Koko waste dump. The European Economic Community (EEC) has also promised to sponsor projects

on Environmental Monitoring in the Department of Physics.

There are other weather related research activities at the University worth mentioning. Prof. G. O. Ajayi and his group at the Department of Electronics and Electrical Engineering have been involved in the study of microwave propagation in the atmosphere for some time. This project investigates effects of the weather elements on propagation of radio waves. Some of the findings of his group have enriched our knowledge on the intensity of various types of precipitation, size of precipitation drops and the duration of precipitation. Mention must also be made on the earlier work done in that Department by Prof. William and Prof. Owolabi on atmospheric refractivity. Results from such activities have made some impact on communication Engineering in this country. The Institute of Ecology of the Faculty of Science is also taking a leading role in providing answers to the weather-related ecological problems in Nigeria. Some members of the Faculty of Agriculture, Technology, Environmental Design and Management, Social Sciences, are also presently engaged in research programmes which have the monitoring of some aspects of weather, and climate as major components. A recent Ph.D thesis written by Dr. Adejuwon (not Prof. Adejuwon) in the Department of Geography of this University focussed attention on the trends of rainfall in the country.

There are other Nigerians who are actively engaged in the study of the Tropical Atmosphere and in weather related research activities. among these are the University of Ibadan group, (Awe, Ette, Giwa, Oladiran, Adedoyin, Oguntoyinbo, Ayoade) the University of Lagos group (Ojo, Oluwafemi, Olatunji Oyebande and their groups). The Federal Universities of Technology, Akure (Omotosho, Fasheun and their group), Minna (Adefolalu); Owerri (Ananaba) and the University of Ilorin (Oyinloye, Aro, Bamigboye and their groups). There is a strong group of agricultural climatologists at the Ahmadu Bello University. (Abdul Mumuni, Owonubi, Yayock, and their groups). We also have some researchers at the Anambra State University Enugu, (Kalu and Adibe). There are also active researchers at the Nigerian Meteorological Department of the Ministry of Aviation, led by Dr. Adejokun and Alhaji Rufai.

7. Applications of the Science of Meteorology

The practical applications of the science of meteorology are indicated in the following disciplines; marine meteorology, agricultural meteorology, aeronautical meteorology, industrial meteorology, radio meteorology, hydro meteorology, biometeorology etc. Each of the discipline is primarily concerned with the application of the science of meteorology to specific problems of marine environments, agriçulture, aviation and aeronautics, industry, radio communications water resources management, animal and plant health and so on. Each of these disciplines can be subject of an inaugural lecture. I only have time to outline briefly the application of meteorology to agriculture, water resources and aviation.

(a) Agriculture

The yield of crops is often determined, in the absence of diseases and pests, by both soil and climatic factors. The soil factors can be mitigated through appropriate fertilization and soil management techniques. The major climatic factors are temperature, evaporation, evapotranspiration, rainfall and solar radiation. Information on the first four factors are available in Nigeria. Through the use of statistics, mathematics and physics, Nigerian scientists have collated information on the onset and end of the rains, length of rainy season, water needs of some common Nigerian crops at various stages of their growth, trends in annual and peak rainfall; periodicities and patterns of rainfall, coherent rainfall regions, expected rainfall and their parameters that are essential to the planning of agricultural operations in this country. The use of such information has resulted in good irrigation rescheduling and mulching system to combat inadequate rainfall and temperature extremes on experimental farms. However, our information dissemination systems – the news media and the agricultural extension facilities have not done much to make information on climatic factors available to the big time and peasant farmers.

Not much information has been collected on solar radiation in Nigeria. Some climatological work on radiation has been done at Ibadan. The direct effect of solar radiation on crops in Nigeria has not been well researched. The ability of crops to intercept and utilize solar radiation is the most important climatic factor provided other

factors are not limiting. The descrepancy between the actual and potential yield of crops can be attributed to factors which prevent the expression of the genetic potentials of plants. Radiation is such a factor. One of my students should complete, in the next few months his Ph.D. thesis on the optical properties (the absorption, reflection and transmission of solar energy) of the plant, *Grain Amaranthus*. He has looked at the micro-physics of the crops environment and also at the sources and sinks of heat and water vapour within the canopy of the plant and the definition of the environmental stress of the plant. Such close studies of our economic and cash crops in Nigeria will point the way to proper application of fertilizers and pest killers to crops. A few other research centres (e.g. IITA, SAMARU, UMUDIKE) are planning or have mounted similar experiments to ours and results of such activities should have direct impact on agricultural practice in Nigeria.

(b) Water Resources

A few years back I gave the following questions to my students in a test: "The mean annual rainfall for the entire earth is 1,000mm. How long does an average water vapour molecule remain in the air between the time it evaporates from the surface of the earth and the time it precipitates again?" One student wrote as an answer. 'Sir, we are no wizards; how do we know how long a water molecule can stay in the air?" Nigerian hydrologists and water resources managers are faced with such questions any time they consider the hydrological cycle. Hydrology studies the effects of precipitation upon the occurrence and character of water in streams, lakes and on or below the land surface. Applied hydrology utilizes meteorological research findings as I have earlier enumerated to predict rates and amounts of runoff (river forecasting), to estimate required spillway and reservoir capacities; to study soil-water-plant relationships in agriculture, and to estimate available water supply and other application necessary to the management of water resources. Even now we do not have adequate meteorological information for optimum development of our river basins, and water sheds. Our knowledge of the drainage areas or catchment areas in this country is still limited.

(c) Aviation

When organized meteorological activities started in Nigeria in 1937, the major objective of the organization was to provide information for aviation. Because of the need for weather information to support British war effort during the Second World War, meteorological facilities in Nigeria were expanded. Weather forecast offices were established at Ikeja and Kano and several observing stations were also established. Over the years, Nigerian weather forecasters have performed very well within the limits of the facilities available to them. They have provided route and station landing forecasts for both local and foreign airlines. They have given appropriate warning of potential weather hazards to aircrew both civil and military for four decades. What bothers one is the lackadaisical attitude of some Nigerian pilots both military and civilian to weather forecasts provided by the Nigerian Meteorological Services.

Unlike their foreign counterparts, some (there are definitely some exceptions) Nigerian pilots do not bother to visit the weather forecast office before they take off. They don't even bother to send for the weather forecasts. They are required to do these by international regulations and conventions. If a Kano bound aircraft from Lagos has to return to Lagos without landing in Kano because of bad weather, the airline loses thousands of naira and perhaps ruins the business of some of the passengers on board. Foreign air pilots never miss the opportunity to visit forecast office or collect information whatever the worth of such information. Why can't our pilots develop the same attitude?

8. Concluding Remarks

In this lecture, I have briefly summarized the various problems associated with the understanding of weather and climate in the tropical regions and in Nigeria in particular. The following comments and suggestions will be useful if we are to have an understanding of the course of weather events in this part of the world.

(a) Nigeria must pay attention to the observation of weather elements. More people must be involved in the observation and monitoring of weather and climate as was done during the colonial era. The Department of Food, Roads and Rural Infrastructure

should assist in the establishment of climatological stations in the rural areas. The establishment of such facilities should be one of the cardinal programmes of that organization.

(b) The existing standard meteorological stations should be rehabilitated and the number increased from forty to sixty. The probing of the upper atmosphere should be carried out more frequently; at least twice a day. The present existing facilities should be improved upon and the number of such facilities increased. Attention should now be paid to the monitoring of ozone and carbondioxide in the atmosphere. The country has signed an international accord on ozone but routine monitoring of this important gas is not done anywhere in this country.

(c) The Director of the Nigerian meteorological services himself has alerted the country about the problem of acid rain. Dr. Adeniyi of the Department of Zoology in this University had carried out some routine measurements of the acidity of rain water and had concluded that rain water at Ife and environs is gradually becoming more acidic. The pH of the rain water was found to be around 5.0 and dropping. The scientist is interested in the animal life in our inland water systems. The assessment of the quality of our inland water system requires, among other things, the measurement of the properties of the rain water falling into them. Since Ile-Ife is at present not an industrialized area, the observation can only mean that acid forming constituents of the air, both natural and man made, have been introduced into the air somewhere else, and carried to Ife and environs by the atmospheric circulation system. It is therefore suggested that the monitoring of our environment should rank very high in the minds of our government officials and politicians. The installation of oil refineries, cement factories, petrochemical, and iron and steel factories do not only revitilize our economy but also add dangerous pollutants to the atmosphere. These pollutants are sooner or later washed down by the rain to pollute our rivers and lakes. The Nigerian laws governing effluents from our factories are not adequate. Our lawyers should look into this.

(d) The data available to the country on natural disasters is grossly inadequate.. In order to predict and monitor the course of these disasters, it is important to set up Natural Disaster Alert Centres which will work hand in hand with the Nigerian Meteorological

Services to provide the necessary warning to the general population on imminent dangers from weather elements.

(e) I wish to reiterate the call I made on March 23, 1988 on the occasion of the observance of the World Meteorological day for the creation of weather desks at our radio and television stations. Every State capital has a standard weather station. It should therefore not be difficult for the radio and television stations to provide information on the weather situation at their localities every hour on the hour. The stations can work out the mode of operation of such a service to the community with the Nigerian Meteorological services. The present weather forecasts given on the Nigerian Television Authority and the Federal Radio Corporation in Nigeria are too terse to be useful to the general public.

(f) Monitoring Weather and Climate should be an essential component of the proposed remote sensing programme of the government.

(g) The Nigerian Meteorological services should make deliberate effort to improve its services to include forecast for marine, agricultural and water management activities. The Department should extend its services to cover retail and wholesale trade. Although Nigerian Meteorologists had anticipated the last Harmattan season, Nigerian Businessmen had not capitalized on the information to provide adequate warm clothing to the Northern States. The hospitals in those states were also not prepared for the increase in chest and lung ailments brought about by the inclement harmattan season.

(h) I have been asked many times if it is really true that some people can control rain through supernatural means. My opinion on that is as follows:

Every traditional society whether in Europe, China or Australia had within its ranks some people who were dedicated to the study of nature. In traditional societies in Nigeria members of some families were known to dedicate their lives to the study of the weather. Whatever they knew, they kept within the family. Sometimes such knowledge were incorporated into some divination system like the Ifa. These people were more knowledgeable than the ordinary villagers about the weather. They know the sequence of some weather events and can predict fairly well some weather phenomena. They offer their

services to stop rain when they know that the rain will not fall at a particular location anyway. They threaten rain when they are sure rain would fall. If they fail they can easily attribute failure to the influence of some witches.

I must add however that I have had experience of situations when some members of churches and mosques pray for rain and rain fell. Such events could happen when rain had not fallen when it was the right season for it to fall. I however believe that the laws of nature cannot be contravened. It will require a very unusual circumstance for God or any supernatural power to permit rain to fall during the Harmattan season.

All Nigerian citizens who claim to have the ability to make rain or to prevent rain from falling should come forward to make their knowledge available to the country to solve the drought and erosion problems.

Modern scientists use dry ice and silver iodide to seed clouds and induce rain. The results of such procedures have not been cost effective. Imput to such procedure by our rain makers will be a tremendous contribution to science. In addition to making contributions in such areas, these rainmakers could contribute in the area of long range forecasting. Forecasts, using numerical procedures are not reliable for periods longer than two weeks. In fact, scientists have to rely more on climatology and statistics for long range forecasting. Our rain-makers can help in the area of long range forecasting if indeed they are sure of their approach to forecasting the weather.

While I agree that some traditional rainmakers had some knowledge about the weather and could make some predictions, I believe such knowledge was based more on experience and observations than on some secret power. Most of this traditional knowledge had been lost, because they were not written down.

Unless our rainmakers can assist the country to solve the drought problem, they will not be taken seriously.

9. Acknowledgements

In bringing this lecture to an end, I wish to express my appreciation to my wife and my children for the support they have given me in my academic pursuit. I am appreciative of the moral

support given me by the other members of my family, relations, former classmates and friends. I wish to thank my colleagues in the Department of Physics, in the Faculty of Science and in the University at large, for giving me the necessary support to enable me to earn my daily bread and to make some little contributions to science. I am also grateful to the members of the Department of Meteorology, Federal Ministry of Aviation for the support they have given me as professional colleagues. I thank members of the Nigerian Meteorological Society and the Nigerian Remote Sensing Society who have come to give some moral support for this lecture. Finally, I thank the Almighty God for all he has done for me. Glory be to His name.

This lecture is dedicated to all Nigerian Academics who still struggle on in pursuit of excellence in an atmosphere of anti-intellectualism. The temptation to become an academic apostate is great.

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