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SKILL ASSESSMENT OF THE EXISTING CAPACITY FOR EXTENDED RANGE WEATHER FORECASTING IN NIGERIA

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ABSTRACT

The need for skillful weather forecasting as a strategy for adapting food production to variable and changing climate is recognized. Frequent assessment of the existing tools provides the needed feedback to encourage the growth of more reliable weather forecasting capacity. A scheme designed for the assessment of the skills demonstrated by published weather forecasts is presented. The existing products of four of the weather forecasting organizations with interests in West Africa are assessed using the observed weather during the period from 1996 to 2000. The weather forecasting organizations concerned are: NOAA (USA), Met Office (United Kingdom), CNRS (France) and CFO (The Nigerian Central Forecasting Office). The forecast skills of the various organizations appear not to have witnessed any significant improvement between 1996 and 2000. Overall the proportion of the forecasts falling into the "low skill" category is not discouraging. However the relatively high percentage of the "moderate skill" and low percentage of the "high skill' categories suggest that there is considerable room for improvement. One may have to give the various organizations more time to perfect the existing tools. However this review has not come too early because it is the type of feedback needed to hasten the emergence of more skillful forecasts. It has been established in this study that better rainfall forecasts could be achieved with a higher resolution SSTA data and the inclusion of more predictors variables especially those of a synoptic nature.

Key Words: Nigeria, Extended Weather Forecasting, Forecast skill.

INTRODUCTION

The capacity for extended weather forecasting in West Africa is modest, but it is growing. The main objective in this paper is to demonstrate the level of skill so far achieved with the tools currently available. This is not just for the benefit of the end users in the agricultural, energy and water supply sectors, but more importantly as a feed back to the forecasting organizations to help in forging more skillful instruments.

Weather forecasts are expected to provide insights into future meteorological conditions for a specified locality or region and over a specified period of time. Depending on the time covered, weather forecasts are classified as short-period, medium range or long-range. Short-period forecasts are for parts or the whole of a 24-hour period with further outlook for another 24 hours. Medium-range forecasts are made for periods covering two to five days ahead. The long-range forecasts are made for periods longer than five days. In the current exercise our interests lie in the long-range category, which we describe as "Extended Weather Forecasts". The ultimate objective is to use the knowledge gained from such forecasts in devising strategies for improved agricultural practices. The immediate question relates to the skill or reliability of the existing capacity to predict climate variability on time scales ranging from weeks (intra-seasonal) to months (inter-seasonal), to years. Ideally, "Extended Weather Forecasts" for the benefit of crop production should be able to anticipate the weather situation for one year ahead. However, the critical period over which knowledge of future weather is needed is the main growing season.

Weather Forecasting Needs

In West Africa, as in the other parts of the tropical world, the weather forecaster is seldom asked what the temperature will be, but everyone is greatly concerned about whether or not it is going to rain. Normally, at elevations below 1000 meters, temperature never falls below levels at which they could be stressful to crop plants. In other words, the growing season lasts thermally, the whole year. Temperature does not constitute a limiting factor on growth, development or maturity of the crop plants. Thus it is moisture rather than temperature that influences the abundance of natural life. Life depends entirely on the amount of rainfall received and so interest in climate or the weather naturally centers on the amount, duration and distribution of rainfall. The crop plants are sensitive to the moisture situation both during their growth, development and especially as they reach maturity. This is reflected in a definite soil and atmospheric moisture range in which field preparations are expected to commence; and also in which such farm operations as sowing, thinning, transplanting, weeding, irrigation, insecticide and fertilizer applications as well as harvesting are scheduled to take place.

APPROACHES TO EXTENDED WEATHER FORECASTING

There are three main approaches to extended weather forecasting. These could be described as statistical, synoptic and dynamic. Statistical models fall into two main groups, including linear regression and linear discriminant models. The candidate predictors in either of the two models almost always now include SSTA (sea surface temperature anomaly) variables observed during the spring preceding the main rainy season. The analyses are carried out on seasonally averaged data for a training period of at least 30 years. The resulting forecast represents a choice of one out of three or five broad weather categories. The linear regression output consists of deterministic ‘best estimate’ forecasts. The predictors have been selected through principal component and stepwise regression analyses. The results give category boundaries as percentages of mean rainfall for the training period. In the case of the Linear Discriminant Model, the probability of the coming seasonal weather falling into any one of the weather categories boundaries are determined by separate linear discriminant equations (Folland, et al, 1986).

The basic assumption in synoptic weather forecasting is that each composite weather situation develops after certain predisposing conditions have been met. Such conditions could relate to the earth’s surface or to any of the identifiable layers in the atmosphere. What later becomes a weather system is initiated at specific locations over specific time spans. Then it takes time to develop and mature before “breaking out” as a recognizable weather type that could be experienced and observed. The same weather system, while moving across land and ocean surfaces in characteristic pathways, is often experienced at different locations in succession. Along its path, the weather system could be modified as it persists for shorter or longer spans of time at the various locations it affects. In the final phase of its life cycle, the weather system and its characteristic weather disintegrate and fade, to be replaced by other systems and the next generation of weather types. Thus each weather system is characterized by a set of time and space antecedents that herald its eventual “break out” or arrival. Such antecedents represent the scientific basis for forecasting and anticipating particular weather events. The synoptic approach is the main tool for short period forecasting. However, there are synoptic systems in West Africa, which persist for periods long enough, and follow predictable paths, that they could be used for extended weather forecasting. Such systems are indicated by the presence of the Inter-tropical Convergence Zone or either of the two air masses converging on the zone. For each season, the onset or cessation of the rainy period could be predicted by monitoring the movements of these weather indicators.

Dynamic models are in essence mathematical representations of the earth-atmosphere-ocean system. They, individually consist of a set of simultaneous equations written in the language of differential calculus. The equations are statements that are consistent with the laws of classical physics, (specifically, those of fluid dynamics} which apply to a continuous moving fluid around a spherical object. Among such laws are those pertaining to thermodynamics, motion and gases. The fundamental variables that appear in the equations are referenced at grid points describing the atmosphere in its vertical and horizontal dimensions. Each grid point is a member of a network representing a layer in the atmosphere. As many as 19 such layers extending from the earth’s surface to the middle stratosphere constitute the HADAM 3 Version of the UK Met Office’s atmospheric general circulation model. Apart from truly representing changing temperatures, air densities and moisture at various points in the atmosphere, a GCM could produce clouds and calculate yields of precipitation (Harrison et al., 1997).

GCM models can incorporate external input either from space or from the earth’s surface. For example, variations in solar heating with latitude, season and time of day, as well as rotation of the earth, the effect of friction of the earth’s surface and other major effects of mountains are reflected in changes in model variables. The land surface and the atmosphere exchange moisture, which, in turn, translate into heat exchange. At each model grid node, feedback between soil and the atmosphere takes place and is reflected in the model as precipitation, evaporation, sublimation and runoff changes. Similar exchanges of heat and moisture are observed between ocean surfaces and the atmosphere. Each GCM primarily models the earth planet and could be used to forecast the weather or future climate of any part of the earth's surface. However, there is always the need to fine-tune each model before application to specific regions. After such fine-tuning, empirical methods could be devised to downscale to the level that is appropriate for the specific objective.

FORECASTING ORGANIZATIONS

The forecasts assessed have been prepared by various meteorological organizations including: MO (Met Office - UNITED KINGDOM), C.N.R.S (Centre de Recherchede climatologie, 21000 Dijon – FRANCE), NOAA (USA National Oceanic and Atmospheric Administration) and CFO (Central Forecasting Office – NIGERIA). The forecasts of the International Organizations have been obtained from articles published in Experimental Long-Lead Forecasts Bulletin. The forecasts of the Nigerian Central Forecasting Office were obtained directly from their offices in Lagos, Nigeria.

Met Office Forecasts

The Met Office has been engaged in experimental forecasts of seasonal rainfall in the Sahel (region 1) since 1986. Since 1992, the organization has extended the coverage of its forecasts to a slightly re-defined Sahel (region 2, 15^0 W to 37.5^0 E and 12.5^0 N to 17.5^0 N). The new areas covered also include an area south of the Sahel (region 3, 7.5^0W to 33.75^0E, 10^0N to 12.5^0N) and another area extending to the coast of the Gulf of Guinea (region 4, approximately 7.5^0W to 7.5^0E, 5^0N to 10^0N). The forecasts are based on ocean and atmospheric information available in early May (Colman et al., 1996, 1997, 1998 and Graham et al, 2000).

The statistical forecasting methods used are the multiple linear regression and discriminant analysis. Predictors include indices of March and April sea surface temperature anomaly patterns which are represented by eigenvectors. The same predictors are used by both forecasting methods. They were selected using statistical forecast hindcasts and Global Circulation Model simulation experiments. The predictors for regions 1, 2 and 3 include a global SSTA pattern showing opposing signs north and south of the equator, a global pattern with strong weights in the tropical South Atlantic, and a global pattern showing ENSO related variability and regional patterns for South Atlantic. The one predictor used for the Guinea Coastal region (region 4) is a South Atlantic pattern with strong weights in the Gulf of Guinea (Colman et al, 2000).

Both the Stepwise Linear Regression and the Linear Discriminant techniques are based on Folland et al (1991). The analyses were carried out on seasonally averaged 10^0 x 10^0 square SSTA data and the mean seasonal rainfall for a training period of at least 30 years. The results, given for the four regions defined by longitude and latitude mainly, give boundaries for five rainfall predictand categories as percentages of mean rainfall for the training period. In the case of the Linear Discriminant Model, the predictands also consist of five categories. Using archival data, the category boundaries are defined so that each category, known at quint, is equiprobable in the training period (Folland, et al, 1986). The forecasts are given, relative to the mean of the training period as very dry, dry, average, wet and very wet. Attempts are now being made to forecast seasonal weather using multiple model configurations (Graham et al, 2000). It is expected that a higher skill level would be attained with a combination of dynamic models than with single model forecasts.

CNRS - France
Two complementary statistical tools are applied by The Centre de Recherche de Climatologie of France in forecasting rainfall in West Africa (Philippon and Fontaine, 2000). The tools, consisting of the Multiple Linear Regression Analysis (MLR) and the Linear Discriminant Analysis (LDA)- have been adapted from Folland et al (1991). However, the predictor composition is quite different. Also different is the procedure for their computation and selection. In order to make the forecasts available before the beginning of the growing season, only information available by the end of April is employed. The predictands (June to September cumulated rainfall) refer to the entire West African sub continent (17.5^{0}N - 5^{0}N; 17.5^{0}W - 17.5^{0}E) and utilizes 2.5^0 latitude and 3.75^{0}longitude grid box rainfall database. The predictands also consist, on the one hand, of a regional Sahel index computed over the zone extending from 10^{0}N to 17.5^{0}N and from 15^{0}W to 15^{0}E. On the other hand, they consist of 41 local indexes covering the whole of West Africa. Thus each block in the 2.5 x 3.75 grid has its own forecast results. The data utilized include a set of 27 potential and tropical (30^{0}N - 30^{0}S) SST indexes analyzed on a 5 x 5 degrees grid. There is also another set of data of 50 potential regional (25^{0}W - 15^{0}E; 25^{0}N - 5^{0}S) atmospheric indexes describing near surface humidity, moist static energy and geo potential values.

The stepwise procedure helped to reduce the number of predictors to four including:

1. HUM designating the specific humidity content at 17.5^{0}N over longitude 5^0 E to 15^0 E
2. MSE 1, which is the Moist Static Energy gradient along the 10^{0}W between the Guinea shore and the Saharan margins
3. MSE 2 is represents the Moist Static Energy gradient along the 10^{0}W meridian between the Sudan and the Saharan margins of the Sahel band.
4. ATL which documents surface temperature gradient over the tropical Atlantic South East basin. This is to give credit to a recurring observation that April-June SSTAs in the South tropical Atlantic are associated with July-September West African rainfall.

NOAA. USA
An African Desk has been established at the Climate Prediction Center, National Oceanic and Atmospheric Administration, Springs, Maryland, USA. The ‘Desk’ has been experimenting with African seasonal forecasting in collaboration with the CPC (Climate Prediction Centre). Efforts have so far been limited to statistical methods. In 1996, 1997 and 1999 Canonical Correlation Analysis (CCA) was employed to produce experimental forecasts for rainfall anomalies for July August and September in the Sahel (Thiaw and Barnston, 1996, 1997 and 1999). Sahel in these forecasts was defined as lying within 10^{0}N - 25^{0}N and 20^{0}W - 45^{0}E.

Canonical Correlation Analysis consists of a regression procedure that forecasts a multivariate predictand field from a multivariate predictor field. Originally, Barnston designed the CCA tool for extended weather forecasting in the USA (Thiaw and Barnston, 1999). In its basic pattern, four consecutive 3-month predictor periods are followed by a lead-time, and then a single 3-month predictand, or target period. So far, the experiments confirm that the global SSTA field is the best predictor. This is also the view shared by the European and African forecasting teams. Additional fields could enhance forecast skill. However, the data do not extend far enough into the past (minimum of 25 years for an adequate training period). The candidate additional fields include upper air geo-potential heat, tropical low level wind and outgoing long wave radiation. For 1999 Sahel rainfall forecasts, the predictor data are the global SSTA field over the four 3-month periods of June-July-August, 1998; September-October-November, 1998; December-January-February 1998-99; March-April-May, 1999. Based on data from 1955 to 1996, the CCA is employed to model linearly, the relationship between the previous year's SST anomaly and the target year's July-August-September rainfall anomaly. Using the model developed', the 1999 July- August- September rainfall anomaly is projected from the previous years quarterly SST anomalies.

The predictor SSTA data are derived from a combination of COADS data (Slutz et al, 1985) and OI (Optimal Interpretation) data (Smith et al, 1996). The predictands Sahel rainfall data come from the gridded global rainfall data set developed by Hulme (1994) at 2.5^0 x 3.75^0 resolution resulting in 72 points in the Sahel. Some of these points in Northern Nigeria lie to the south of the Sahel as it is generally known, that is in ecological zones traditionally known as Sudan and Northern Guinea.

CFO (Nigerian Central Forecasting Office)

The forecasts issued from the Nigerian Central Forecasting Office ahead of each cropping season are primarily based on statistical forecasts by regional organizations, an example of which is the PRESAO (West African Forum on Climate Variability and Prediction and its Applications in Early Warning Systems for Food Security). The regional forecasts are presented first in terms of broad zones including the Far North, the Middle Belt and the Southern Forest Zone. They are downscaled, supplemented with local synoptic observations and published as forecasts for the main weather observing stations spread across the country.

The first PRESAO extended range weather forecasts were published in 1998 on the web site of ACMAD (African center for Meteorological Applications and Development; http://www.acnad.ne). The PRESAO forecast map, like the other ACMAD weather forecast products, is meant to be downscaled by national meteorological services to better serve the need of users. The target area of the PRESAO forecasts extends from north of latitude 10^0 N to the coast of the Gulf of Guinea, and lies between longitudes 7.5^o W and 7.5^oE. This is a region, whose July - September rainfall total has a strong correlation (approximately r=0.7) with Equatorial Atlantic sea surface temperature; (Ward, et al, 1990; Janicot, 1992; Rowell et al, 1995). This association is quite robust, having remained steady through complete historical record going back to the first decade of the 20^{th} century. Compared with the Sahel, the July-September rainfall in this region has not shown large multi-decadal fluctuations While making its own local forecasts, CFO makes use of SSTA data of 2^o x 2^o resolution (Tourre, 2000), compared with SSTA data on a resolution of 5^o x 5^o employed by CNRS (Philippon and Fontaine, 2000) and the 10^o x 10^o grid SSTA data used by the Met Office (Colman et. al, 2000). CFO makes additional use of the current trend of weather, pressure systems and the position of the inter- tropical discontinuity (ITD).

Like most of the other forecasting tools designed for West Africa, the predictand period is July to September. However, in the coastal region, the growing season begins in April and extends to October. As a matter of fact, by the first week of July, early maize crop and early ripening yam have been harvested. With this in mind, PRESAO forecasters make additional forecasts that could be viewed as forecasts for such "rainy seasons characteristics that are relevant to agriculture including such features as dry spells".

Omotosho et al (2000) have developed for Nigeria a new set of empirical long-range scheme for the prediction of onset, cessation, monthly and seasonal amounts of rainfall using only surface synoptic data. This has become the main tool at present being employed by the CFO for adding details to the regional forecasts obtained from PRESAO. The new scheme has four important advantages over all other methods. First, the surface data required for the forecasts are readily available at many stations in each country. Second, the annual variations in the dates of onset, the dates of cessation, the monthly, seasonal and annual amounts of rainfall are linked to the variability of equivalent potential temperature. Third, the new schemes are capable of predicting the cessation and the annual amount of rainfall prior to the onset of the rains, thus allowing advance effective planning of agricultural and water resource activities. There is no doubt that the prediction of rainfall for the first two months of the rainy season will greatly assist irrigation planning. Fourth, the forecast can be made at resolutions of single climatic stations, that is, for localities not more than 0.5^{o} latitude by 0.5^{o} longitude. The most important problem addressed by the schemes is related to the variable dates of onset of the rainy season, not only at one station, but also from one station to another. Such variations could be up to 70 days from one year to another at a single station, and from one station to the next during the same year. Another problem concerns the monthly and annual distribution of the rainfall at each station or over a small area. The third problem is the cessation of the rainy season together with the concomitant length of the growing season.

ASSESSMENT OF THE SKILLS

The stations selected to test the forecasting skills of the various tools include Benin City, Lagos, Ibadan, Ilorin, Enugu, Minna, Jos, Kaduna, Lokoja, Maiduguri and Kano (Fig 1). They have been selected to represent the various climatic and ecological zones between the Gulf of Guinea in the South and Sahara Desert in the North. The forecasts for the five years from 1996 to 2000 are the targets of the skill assessment presented in this exercise. Most of the forecasting organizations give their forecasts for July, August September rainfall. However, the Nigerian CFO gives its own forecasts for June, July, August and September. Table 1 shows which types of forecasts were available in each year; it lists whether or not a forecast was made. It also shows whether the forecasts were in terms of quint or tercile categories and whether they were based on statistical, dynamic or synoptic approaches

Skillful forecasts are those that are subsequently confirmed by observations. High skills are demonstrated when forecasts are very close to observations while low skills are recorded when the two are substantially different. One practical problem in assessing the skills is the fact that observations and forecasts are not presented in the same units of measurement. Observations are usually presented on an interval scale with the amounts of rainfall given in millimeters. On the other hand forecasts are stated using ordinal categories. The most common are quint categories varying from very wet, to wet, average, dry, and very wet. Determination of what is very wet, wet, etc in this exercise was based on the records from 1951 to 1990. Sometimes, tercile categories are used, by simply forecasting near normal, above normal or below normal. The data covering the period from 1951 to 1980 were used to define the limits of quint categories forecasted by Met Office for the 1996, 1997 and 1998 seasons. The data covering the period from 1961 to 1990 were used to define the limits of quint and tercile categories forecasted by Met Office for 2000 and by the other organizations for all the years from 1996 to 2000.

To define quint categories, rainfall values for each year, whether annual, seasonal or monthly, were arranged in descending order of magnitude and divided into five groups. The resulting highest quint consists of the values for the six wettest years and the lowest those of six driest years. The years with rainfall values falling within the range in the highest quint were classified as very wet while years with values falling within the range or rainfall in the lowest quint were classified as very dry. Other years were similarly classified as wet, average or dry.

Determination of what is above normal, near normal or below normal was also conducted in the same way. Rainfall values for each year, whether annual, seasonal or monthly were arranged in descending order of magnitude and divided into three groups. The resulting highest tercile (above normal) consists of the ten wettest years and the lowest (below normal) those of the ten driest years. The ten middle years defined the near normal range. The quint and the tercile limits provided the framework for converting both observations and forecasts to the same units of measurement.

Some forecasts are given in the form of percentage departures from the mean. In such cases, the percentage departure of the rainfall of each year from the mean was computed for each of the 30 years. This was used to determine which percentages place forecasts and observations into the various quints. Using the case of Ibadan, south western Nigeria as an example, ‘average’ or ‘normal’ falls between 87 and 107 percent, ‘wet’ falls between108 and 119 percent, ‘dry’ falls between 70 and 86 percent, ‘very wet’ is above 119 percent, while ‘very dry’ is less than 70 percent.

In assessing the skills of forecasts, the same criteria were used to classify observations as were used for forecasts. Where observations and forecasts fell within the same category, skill was assessed as high. Where there was a one-category difference, as for example observation was very wet and forecast was average skill was assessed as moderate. In situations of more than one category disparity between observation and forecasts, the skill was assessed as low. Tables 2a and 2b provide the framework for the assessment of the skills of the forecasts.

Table 3a and 3b give the observed July, August and September rainfall (mm) of the various stations between 1996 and 2000. While Table 3a expresses and defines the rainfall amount in terms of the quint categories (i.e. very wet, wet, average, dry or very dry), Table 3b depicts the corresponding tercile categories (i.e. above normal, near normal and below normal). Table 3c also gives the observed rainfall amount (mm) and defines it in terms of tercile categories (as in

Table 3b) but for the months of June, July, August and September. These three tables were employed to assess for each year, the forecasts of the various forecasting organizations.

RESULTS

For the year, 1996, the available forecasts for the assessment were only those of Met Office (Fig 2a) and NOAA (Fig 2b). However, out of the eleven stations under study, data for forecast assessments were available for only five. With regards to Met Office, the skill was low for Kano and Kaduna, moderate in Ilorin and Ibadan but high in Ikeja. With regards to NOAA, the forecast was for the northern region only and only two of the stations under study had the required observed data for the assessment. The forecast skill was high in Kano but moderate in Kaduna.

For the year 1997, the forecasting organizations whose forecasts were available include: NOAA, CFO and Met Office. Met office released in 1997, a statistical forecast (MOS) and a dynamic forecast (MOD). With regards to MOS and MOD, only seven stations had complete data for the assessment. The assessment of the forecast skill of MOS for the year showed that the skill was low in Kano, moderate in Kaduna, Jos Ilorin and Ikeja, but high in Lokoja and Ibadan (Fig 3a). That of MOD for 1997 showed that, except for Ibadan, where the skill was assessed as moderate, the forecast skill was the same as for MOS in all stations (Fig 3b). With regards to NOAA, only three stations had complete data for the assessment. The skill was assessed as low in Kano, moderate in Kaduna but high in Jos (Fig 3c). Five stations had complete data for assessment of the CFO's forecasts for the year 1997. The skill was assessed as low in Kano, moderate in Bauchi, Ibadan and Ikeja, but high in Maiduguri (Fig 3d).

Met Office was the only forecasting organization whose forecasts were available for the assessment of forecast skill for the year 1998. Nine stations had complete data for the assessment. The skill was assessed as moderate in Ilorin, Ibadan, and Benin, but low in Kano, Bauchi, Jos, Minna, Enugu and Ikeja (Fig 4).

NOAA and CFO were the only forecasting organizations whose forecasts were available for the assessment of forecasts skills for the year 1999. With regards to NOAA, only four stations had complete data for the assessment. The skill was assessed as high in Kano, Kaduna, and Minna, but low in Maiduguri (Fig 5a). Only three stations had complete data for the assessment of forecast skill of CFO for the year. The skill was assessed as high in Maiduguri, but moderate in Kano and Kaduna (Fig 5b).

There were three forecasting organizations whose forecasts were available for the assessment of forecast skills for the year 2000. These organizations include: Met Office, CNRS and CFO. For both Met Office and CNRS, eleven stations had complete data for the assessment of the skill for the year. With regards to Met Office, the skill was assessed as high in Kaduna, Ibadan, Enugu and Ikeja, moderate in Minna Ilorin and Benin but low in Maiduguri, Kano, Jos and Lokoja (Fig 6a). The assessment of CNRS skill for the year indicated high skill for Ilorin and Benin, moderate in Kaduna, Jos, Lokoja, Ibadan, Enugu and Ikeja, but low in Maiduguri, Kano and Minna (Fig 6b). Only two stations had complete data for the skill assessment of CFO's forecasts for the year. The two stations were Maiduguri and Kano, and the skill was assessed moderate in both cases (Fig 6c).

Skill level for each year

The annual forecasting skill performance is summarized in Table 4. The assessment was carried out for five consecutive years, 1996 to 2000. Based on the proportion in the low skill category, forecast skill appears to be best in 1999 (14%), followed by the year 1997 (18%), 2000 (26%), 1996 (29%) and lastly, 1998 (67%). However, when the proportion of the "skill high" category is considered, the best year is again 1999 (57%). This is followed by 1996 (29%), 2,000 (25%), 1997 (23%) and 1998 (0%). Thus, whichever way one looks at it, the best forecast results were for 1999 and the worst forecasts were for 1998. The low level of forecast skill for 1998 is thrown into greater relief if one considers the proportion falling under high plus moderate skill. While high plus moderate skill forecasts constituted more than 70 percent in the other years, they were responsible for only 33 percent in 1998. One probable reason for the low skill level recorded for 1998 is the fact that only one organization presented any forecasts. This could be interpreted to mean that the more forecasts there were, the higher the skill level of the entire forecasting capacity.

Skill level achieved by each forecasting organization

In this study, the data available for the forecast skill assessment between 1996 and 2000 were from four forecasting centres only. These centres include: Met Office, NOAA, CNRS and CFO. Using the percentage of the low skill category, CFO came first with only 10% of its skill rated low, followed by NOAA (22%), CNRS (27%) and lastly, Met Office (35%), (Table 5). However, using the percentage of the skill rated high NOAA (56%) becomes first, followed by Met Office (21%), CFO (20%) and lastly CNRS (18%). The remaining forecasts fall under moderate category forecasting skill. Thus based on the percentage falling into high plus moderate skill categories, CFO (90%) ranks first followed by NOAA (70%). In general, all the forecasting organizations appear to be fairly reliable as there was no centre, whose high plus moderate category skill did not constitute more than 50%. Also, the overall performance of all the stations in all the years studied showed that 25% of the skill belonged to high category, 46% to moderate category with only 29% to low skill category. This suggests that the existing forecasting tools of the various forecasting organizations are still fairly reliable.

Regional Disparities in the level of skill achieved

Using the percentage falling into the "low skill" category, forecasting tools did not performed satisfactorily in three stations, namely: Kano (66%), Maiduguri (50%) and Minna (50%). All these stations are located in th Middle Belt and the Far North. The skill was fair in five locations, namely: Ikeja, (14%), Kaduna (20%), Lokoja (25%), Jos (33%) and Enugu (34%). The skill level was relatively high in three locations, namely: Ilorin, Ibadan and Benin where 0% of the assessments fell into the low category. A careful observation of these results shows that, forecasting skill was generally higher in the south and declined with progress towards the interior of the continent. The various results are summarized in Table 6.

DISCUSSION

The results of the analysis do not indicate a trend towards a higher level of skill from 1996 to 2000. This suggests that the predictor factors are yet to be fully understood by the forecasting organizations and underlines the need for research to develop improved forecasting tools.

The results ranked NOAA and CFO ahead of CNRS and Met Office in weather forecasting skill. A careful look at the background of the methods of data collection and analysis appear to explain this. Virtually, all these forecasting organizations made use of the sea surface temperature anomalies as a predictor among others. However, a noticeable difference in the nature of the sea surface temperature data used by various organizations is in respect of the spatial resolution. While CFO and NOAA made use of SSTA data of 2^o x 2^o resolution (Tourre, 2000), CNRS employed 5^o x 5^o grid SSTA data (Philippon and Fontaine, 2000) and Met Office employed seasonally averaged 10^o x 10^o square SSTA data (Colman et. al, 2000). It thus appears that the finer the SSTA resolution, the better the forecasting skill. It is evident in the results obtained in this study that the forecasting skill varies directly as the spatial resolution of the grid used for the collection of SSTA data.

The number of predictor variables used in the forecast models also seems to have played a role in determining the level of skill. While Met Office whose tools seem to be less skillful than the others made use of SSTA data alone in the construction of their prediction models, other forecasting centres made use of additional rainfall-formation-related factors. For instance CFO which came first, on the basis of having the least 'low skill' score, made additional use of synoptic data including current weather, pressure systems, equivalent potential temperature and the position of the inter tropical discontinuity (ITD). NOAA that came first, on the basis of the highest 'high skill' score made additional use of upper air geopotential heat, tropical low level wind and outgoing long-wave radiation (Thiaw and Barnston, 1999). CNRS, which came third employed additional factors such as geopotential indexes describing near surface humidity, and moist static energy values (Philippon and Fontaine, 2000). Note that ITD is one major factor not used by CNRS in the construction of their prediction model. This study thus shows that the more predictor variables employed in the construction of a forecast model the better the skill of forecast attained.

The study clearly demonstrates regional disparities in the skills of the forecasting tools. The prediction skill is generally higher for southern coastal locations than for the northern continental locations. It is well known that the Atlantic Ocean is the major if not the only source of moisture into the West African Sub Continent. The moisture is brought to the land areas by the south-westerly winds moving in after the northward migrating ITD (Inter Tropical Discontinuity). The characteristics of the south-westerly winds, which bring the moisture to the sub-continent are in turn determined by the nature of the sea surface temperature of the South Atlantic Ocean (Adedokun, 1978). It is thus logical that the conditions of the south-westerly winds as determined by the SSTA and its associated ITD would be least modified near the coast. As the ITD advances and the southerly winds progress further inland, their thermodynamic transformations become more pronounced. The changes in the nature of south-westerly winds and other rainfall-associated factors are thus a function of space and time. Thus the space connection between rainfall over the land and the activities over the Atlantic Ocean weakens with distance between a location over the land and the sea. It is therefore not surprising that a prediction model based on sea surface temperature anomalies is more skillful in the south, near the ocean, that in the interior of the continent.

CONCLUSIONS

The forecast skills of the various organizations appear not to have witnessed any significant improvement between 1996 and 2000. Overall the proportion of the forecasts falling into the "low skill" category is not discouraging. However the relatively high percentage of the "moderate skill" and low percentage of the "high skill' categories suggest that there is considerable room for improvement. It has been established in this study that better rainfall forecasts could be achieved with a higher resolution SSTA data and the inclusion of more predictor variables especially those of a synoptic nature. The paper discusses forecasts for the five years 1996 – 2000 which appear to be a short period to make significant deductions about forecast skills. This means that one has to give the various organizations more time to perfect the existing forecast tools. However, it is our considered view in concluding this paper that this review has not come too early because it is the type of feedback needed to hasten the emergence of more skillful forecasts.

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TABLES

Table 1: Types and Methods of Forecasts: 1996 – 2000

ORGANIZATIONS	TYPES OF FORECASTS			YEARS				
	CATEGORY	METHOD	MONTHS	1996	1997	1998	1999	2000
Met Office	Quint	Statistical	JAS	xxx	xxx	xxx		xxx
	Quint	Dynamic	JAS		xxx			
NOAA	Tercile	Statistical	JAS	xxx	xxx		xxx	
CNRS	Quint	Statistical	JAS					xxx
CFO	Tercile	Statistical/ Synoptic	JJAS		xxx		xxx	xxx

Table 2a: Skill Assessment of Quint Forecast Categories

FORECAST	VERY WET	WET	AVERAGE	DRY	VERY DRY
Observations					
Very Wet	High	Moderate	Low	Low	Low
Wet	Moderate	High	Moderate	Low	Low
Average	Low	Moderate	High	Moderate	Low
Dry	Low	Low	Moderate	High	Moderate
Very Dry	Low	Low	Low	Moderate	High

Table 2b: Skill Assessment of Tercile Forecast Categories

FORECAST	ABOVE NORMAL	NEAR NORMAL	BELOW NORMAL
Observations			
Above Normal	High	Moderate	Low
Normal	Moderate	High	Moderate
Below Normal	Low	Moderate	High

Table 3a: Observations for the Quint Categories for July, August and September, 1996-2000 (using 1961 – 1990 climatological average)

STATIONS	MEAN	1996		1997		1998		1999		2000	
		OBS	CA	OBS	CA	OBS	CA	OBS	CA	OBS	CA
Maiduguri	434							761	V. Wet	520	V. Wet
Kano	502	907	V. Wet	957	V. Wet	1589	V. Wet	1240	V. Wet	872	V. Wet
Bauchi	668					812	V. Wet	1046	V. Wet		
Kaduna	645	825	Average	754	Average			856	Wet	824	Average
Minna	740			615	V. Dry	641	V. Dry	624	V. Dry	633	V. Dry
Jos	699					600	Dry	777	Wet	820	V. Wet
Ilorin	579	498	Average	524	Average	882	V. Wet	586	Wet	548	Average
Lokoja	701			506	Dry			837	V. Wet	504	Dry
Ibadan	533	733	V. Wet	240	V. Dry	416	Average	745	V. Wet	580	Wet
Enugu	904					612	V. Dry	503	V. Dry	970	Wet
Ikeja	469	557	Wet	465	Average	230	V. Dry			617	Wet
Benin	901					990	Average	1013	Average	878	Average

Table 3b: Observations for the Quint Categories for July, August and September, 1996-2000 (using 1951 – 1980 climatological average)

STATIONS	MEAN	1996		1997		1998		1999		2000	
		OBS	CA	OBS	CA	OBS	CA	OBS	CA	OBS	CA
Maiduguri	462							761	V. Wet	520	Wet
Kano	590	907	V. Wet	957	V. Wet	1589	V. Wet	1240	V. Wet	872	V. Wet
Bauchi	730					812	V. Wet	1046	V. Wet		
Kaduna	795	825	Wet	754	Average			856	Wet	824	Wet
Minna	721			615	V. Dry	641	V. Dry	624	V. Dry	633	V. Dry
Jos	823			615	V. Dry	600	V. Dry	777	Dry	820	Average
Ilorin	525	498	Average	524	Average	882	V. Wet	586	Wet	548	Average
Lokoja	580			506	Dry			837	V. Wet	504	Dry
Ibadan	402	733	V. Wet	240	V. Dry	416	Average	745	V. Wet	580	V. Wet
Enugu	757					612	Dry	503	V. Dry	970	Wet
Ikeja	525	557	Wet	465	Average	230	V. Dry			617	Wet
Benin	950					990	Average	1013	Average	878	Average

Table 3c: Observations for the Tercile Categories for July, August and September, 1996-2000

STATIONS	MEAN	1996		1997		1998		1999		2000	
		OBS	CA	OBS	CA	OBS	CA	OBS	CA	OBS	CA
Maiduguri	434							761	A. Norm	520	A. Norm
Kano	502	907	A. Norm		A. Norm	1589	N. Norm	1240	A Norm	872	N. Norm
Bauchi	668					812	N. Norm	1046	A Norm		
Kaduna	645	825	N. Norm	754	N. Norm			856	A. Norm	824	N. Norm
Jos	740			615	B. Norm	641	B. Norm	624	B. Norm	633	B. Norm
Minna	699					600	B. Norm	777	A. Norm	820	A. Norm
Ilorin	576	498	N. Norm	524	N. Norm	882	A. Norm	586	A. Norm	548	N. Norm
Lokoja	701			506	N. Norm			837	A. Norm	504	N. Norm
Makurdi	742									65 7	
Ibadan	533	733	A. Norm	240	B. Norm	416	B. Norm	745	A. Norm	580	A. Norm
Enugu	904					612	B. Norm	503	B. Norm	970	A. Norm
Ikeja	469	557	N. Norm	465	N. Norm	230	B. Norm			617	N. Norm
Benin	901					990	N. Norm	1013	N. Norm	878	B. Norm

Table 3d: Observations for the Tercile Categories for June, July, August and September, 1996-2000

STATIONS	MEAN	1996		1997		1998		1999		2000	
		OBS	CA	OBS	CA	OBS	CA	OBS	CA	OBS	CA
Maiduguri	474			143	B. Norm			844	A. Norm	677	A. Norm
Kano	625			1119	A. Norm			1392	A. Norm	1172	A. Norm
Kaduna	935							1286	A. Norm		
Enugu	904			834	A. Norm						
Ikeja	817			1083	A. Norm						

Table 4: Annual Forecasting Skill Performance Assessment

	PERCENTAGE CONTRIBUTION OF EACH SKILL CATEGORY		
Year	Skill High	Skill Moderate	Skill Low
1996	29%	42%	29%
1997	23%	59%	18%
1998	0%	33%	67%
1999	57%	29%	14%
2000	25%	49%	26%

Table 5: Organizational Skill Performance Assessment

FORECASTING ORGANIZATION	PERCENTAGE CONTRIBUTION OF EACH SKILL CATEGORY		
	Skill High	Skill Moderate	Skill Low
MO (all)	2 1%	44%	35%
NOAA	56%	22%	22%
CNRS	18%	55%	27%
CFO	20%	70%	10%

Table 6: Regional Disparities in the Forecasting Skill Performance Assessment

STATIONS		PERCENTAGE CONTRIBUTION OF EACH SKILL CATEGORY		
		Skill High	Skill Moderate	Skill Low
Maiduguri	Sahel	17%	33%	50%
Kano	Sudan	17%	17%	66%
Kaduna	N. Guinea	20 %	60%	20%
Minna	S. Guinea	25%	25%	50%
Jos	Plateau	17%	50%	33%
Ilorin	S. Guinea	17%	83 %	0%
Lokoja	D. Savanna	50%	25%	25%
Ibadan	Dry Forest	29%	71%	0%
Enugu	Dry Forest	33%	33%	34%
Ikeja	Rain Forest	29%	57%	14%
Benin	Rain Forest	33	6 7	0%