GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 12, NO. 3, 2006: 415 - 420
COPYRIGHT (C) BACHUDO SCIENCE CO. LTD. PRINTED IN NIGERIA. ISSN 1118 - 0579

VERIFICATION OF PREDICTED HEAVY RAIN ON 5TH AUGUST 1998 IN NIGERIA, USING BOTH THE ETA REGIONAL COORDINATE MODEL AND NCEP REANALYSIS MODEL

P. O. EZEMA

(Received 20 May, 2002; Revision Accepted 1 February, 2005)

ABSTRACT

The laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG) of the Institute of Atmospheric Physics (IAP) of Chinese Academy of Science (CAS) developed an Eta regional coordinate model which has used upper air data for 5th August 1998 and predicted heavy rain in Southern and Northern Nigeria, Western part of Cameroon, Eastern part of Benin, Liberia and Southern Mali. The purpose of this paper is to consider the pressure level data and to relate them to the precipitation on 5th August 1998 for Nigeria where data for the rainfall on the day is available. It has been confirmed that the prediction was accurate and that there was heavy rainfall in Lagos (Ikeja), Port Harcourt, Calabar, Kano and Minna. Similar verifications of such predictions in USA have shown a steady rise from 63% in 1975 to 90% in 1999.

KEYWORDS: Numerical Weather Prediction, Eta regional coordinate model, NCEP Reanalysis model.

INTRODUCTION

Numerical Weather Prediction is the process of obtaining an objective forecast of the future state of the atmosphere by solving a set of equations that describe the evolution of variables which define the state of the atmosphere. These variables are pressure, temperature, wind speed, humidity, and geopotential heights. Many thousand observations of the variables are made each day from a variety of observing types such as satellites, aircrafts, ships, buoys, radiosondes and landstations. Since the launch of the first weather satellite in 1960, global observations have been possible even in the remotest areas. Ostby (1999) had reviewed the progress made in tornado and severe thunderstorm forecasting by the Severe Local Storms Unit (SELS) of the National Severe Storms Forecast Center in USA for the past 25 years and showed that the percent of severe weather watches verified rose from 63% in 1975 to 90% in 1999. The SELS Unit was initially established in Kansas City, Missouri in 1954.

Human lives lost to severe weather events throughout the world in 1995 were 8,300 and 8,340 in 1996 respectively. The number of countries that reported weather related events were 42 and 44 in 1995 and 1996 respectively. Table 1 shows the number of reported fatalities from weather events in 1996.

India had the highest causalities because it rained for 12 days consecutively in August 1996 with a total of 12,000mmd^{-1} China followed with a total of 70,000mmd^{-1} leading to the collapse of about 2 million houses and the sinking of about 2000 boats. In USA the low figure of 292 came about because of the high level of sophistication of EARLY WARNING SYSTEMS (EWS) and the accuracy of the NOW CASTING techniques which connect over 1000 radar networks to the Global Telecommunication System (GTS) from which media houses receive their 30-minute broadcasts of the weather.

Table 1: Number of reported fatalities from weather events in 1996 (Conford, 1996)

Country	Number	Principal weather events
India	3,320	Cyclone, tornado, rainfloods, snow rain, avalanches.
China	2,500	Rainfloods, typhoon, snow.
USA	292	Snowstorms, hurricanes, floods, tornados.
Brazil	234	Rainfed landslides, rainfloods.
South Africa	155	Wind, cold, hail, lightning.
Ethiopia	69	Rainfloods, cold, wind, lightning.
Egypt	41	Rainfloods, lightning.
United Kingdom	26	Rainfloods, sandstorm, heat wave, thunderstorm, fog.
Madagascar	21	Cold, fog, blizzards, Cyclone.
Nigeria	14	Rain.
Benin	7	Storm rains.
Algeria	5	Rainfloods.
Mauritius	3	Cyclone.

The same applies to UK where Unified Model is used for both short-term weather forecasts and long-term climate simulations run by the Hadley Center for Climate Prediction and Research. The number reported from Nigeria is not reliable because of bad record keeping, and inability to report to appropriate agency. Air disasters and road accidents due to bad weather would account for a much higher number than what was reported. The loss of property such as collapsed buildings, sinking of boats etc can never be quantified. Therefore, Numerical Weather Prediction of heavy rainfall to avert disaster has been of immense benefit to humanity.

The application of Numerical Weather Prediction in Communications, aviation industry, navigation, commerce and other areas of human activity has enhanced social and economic values of mankind. Detailed forecasts of winds, thunder storms, tornados, and floods have been achieved and people warned in advance about such catastrophes. Reynolds (1996) reported three major storms which hit California in 1995

P. O. Ezema, Department of Physics & Astronomy University of Nigeria, Nsukka, Enugu State, Nigeria.

and caused damages of more than $3 billion dollars, 27 deaths and over 10,000 houses destroyed (Lott, 1995). The storms and heavy precipitation were diagnosed 5 days before time and the public alerted of the potential danger. Consequently people were evacuated in China, there has been remarkable success in predicting Sea Surface Temperature Anomaly (SSTA), El Nina, La Nina and summer precipitation anomaly. The operational Eta model is run twice daily at the South African Weather Bureau (SAWB) using pressure-coordinate, gridded analyses and forecasts from NCEP'S global spectral model on the GTS. An improvement was made from the initial 80km, 17-level version of the Eta model in 1993 to 48km, 38-level version in 1996. Over South America the Eta model started operation since December 1996 and covers most of South America and part of the Atlantic and Pacific Oceans. It is set up in 40km horizontal resolution and 38 layers in the

$$Eta(\eta) = \left(\frac{P_{rf}(Z_s) - P_t}{P_{rf}(Z_b) - P_t}\right)\left(\frac{P - P_t}{P_s - P_t}\right)$$

where P is pressure, rf, s and t are reference, surface and top of the model respectively; z_b is base elevation or smoothed orography and Z_s is topography height.

In non-mathematical terms the governing equations (Met office, http://www.met office.com) are made up of :

(i) Horizontal equations of motion. The main forces in the atmosphere are the force that acts on air due to differences in pressure and the coriolis force. The coriolis force is an apparent acceleration that air possesses by virtue of the earth's rotation. For an air parcel that moves between two points on the surface of the, its path will not be straight but curved which will be to the right in the northern hemisphere and to the left in the southern hemisphere.

(ii) The hydrostatic equation. This relates the variation in pressure with height. The two main forces in the vertical are the forces of gravity and pressure gradient force. For hydrostatic equilibrium, the gravitational force balances exactly the pressure gradient force.

(iii) The thermodynamic equation. This expresses the principle of the conservation of energy which states that the change in energy within a system is equal to the net transfer of energy across the boundaries of the system. Advection or change of temperature at a point in the atmosphere

Where, V is horizontal wind velocity; ∇ is the 2-D del operator, $\omega = \frac{dP}{dt}$ (vertical velocity), F_H is the horizontal components of friction force, $f = 2\Omega \sin \phi$, is corioles parameter and $f = -fk$, φ is the rate of heat addition or adiabetic heating and $\phi = gz$ is the geopotential

DATA ACQUISITION AND ANALYSIS

The National Centers for Environmental Prediction (NCEP) is an arm of the National Weather Service (NWS) which provides a wide variety of national and international weather guidance products to the government agencies, private sector meteorologist, meteorological organizations and societies throughout the world.

vertical with the initial conditions taken from the NCEP global analysis. The present work is an attempt to use the Eta model in the West African sub-region.

THEORY

The Eta Regional Coordinate Model came into existence to remove distortion or errors in pressure gradients computed over steeply slopping terrain. Mesinger (1983), Zeng (1979), Zeng et al (1986) and Ji (1965) had all worked on the problems posed by topography in weather prediction. Yu (1989, 1994) developed Eta coordinate model to include varied topography so that terrain effects are fully described. The model is normalized by sea level pressure so that Eta surfaces are quasi-horizontal and produce orography in the form of discrete blocks or steps (Mesinger and Black, 1992).

Generally the Eta coordinate is defined by

results from either cooler or warmer air being blown to that point. It could also result from local effects due to evaporation or condensation.

(iv) The continuity equation which is the basic principle of the conservation of mass expressing the fact that matter is neither created nor destroyed.

(v) The equation of state relates the three primary thermodynamic variables namely: pressure, density and temperature for a perfect gas. The atmosphere is a mixture of gases but it is assumed to obey the equation of state.

(vi) The water vapour equation. The amount of water vapour in a parcel of air can change as a result of advection and of condensation or evaporation.

The basic hydrodynamical equations expressed by Haltiner and Williams (1980) from which numerical integrations are carried out are:

$$\frac{dV}{dt} = -\nabla_p \phi + fK \times V + F_H$$

$$\nabla . V + \frac{\partial \omega}{\partial P} = O$$

$$\varphi = Cp\frac{dT}{dt} - \frac{RT}{P}\omega$$

$$and \quad \frac{\partial \phi}{\partial P} = -\frac{RT}{P}$$

Data were collected from the National Center for Environmental Prediction (NCEP) through the internet from National Oceanic and Atmospheric Administration (NOAA), NOAA-CIRES Climate Diagnostics Center FTP Server. The gridded data were downloaded and decoded from Gridded Binary (GRIB) format using software contained in the General Meteorological Package (GEMPAK). The decoded data were processed by the model and the output passed to the Grid Analysis and Display System (GrADs) for display of graphics. The model has a horizontal resolution of 75km and 11 vertical layers.

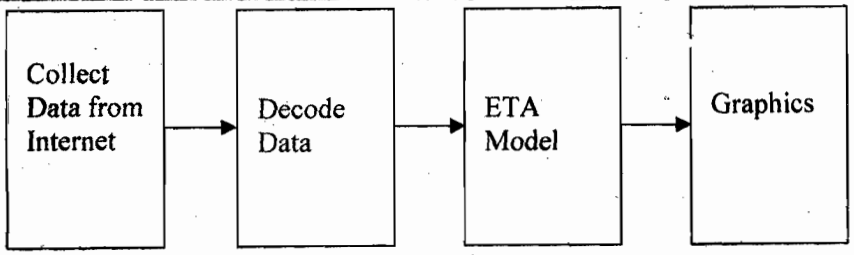

Figure 1 Stages of Analysis

Figure 1 is the block diagram of the stages of analysis. The documentation of LASG-REM is obtained from the Institute of Atmospheric Physics (IAP).

DISCUSION OF RESULTS

Figure 2 shows the West African region where predicted rainfall would take place on 5th August 1998 with the Eta

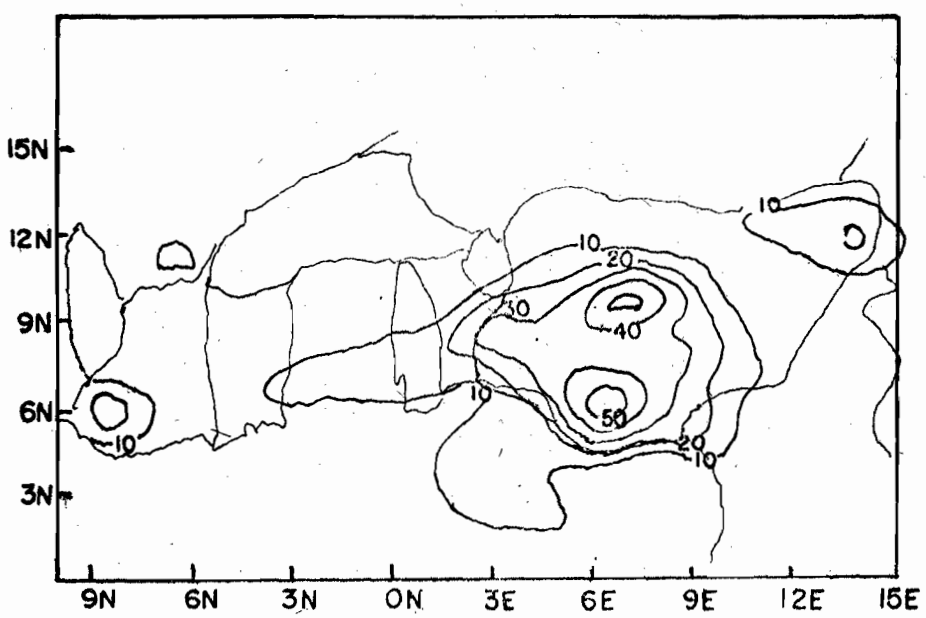

Figure 2 Predicted rainfall on 5th August 1998.

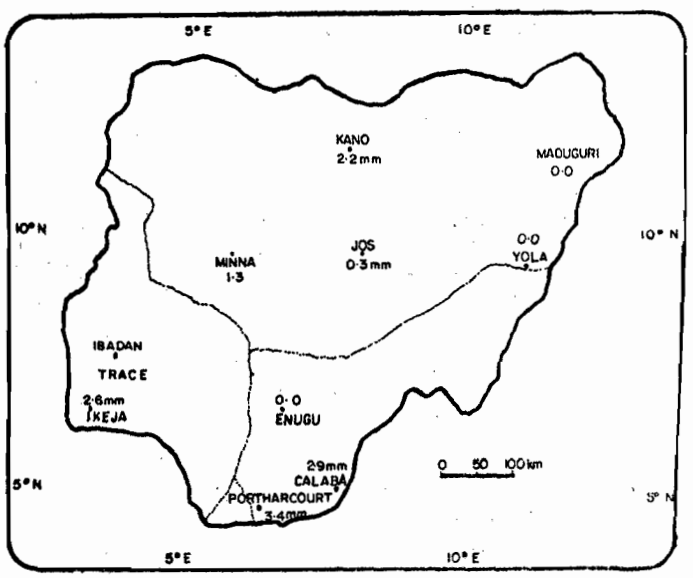

Figure 3 Location of rainfall on 5th August 1998

Table 2 Verified precipitation on 5th August 1998 indicating cities and locations.

Town	Rainfall (mm)	Lat.^{0}N	Longitude ^{0}E
Ikeja	2.6mm	06^{0}35	03^{0}20
Ibadan	Trace	07^{0}22	03^{0}59
Kano	2.2mm	12^{0}03	08^{0}32
Jos	0.3mm	09^{0}38	08^{0}51
Minna	1.3mm	09^{0}37	06^{0}32
Calabar	2.3mm	04^{0}58	08^{0}21
Port Harcourt	3.4mm	05^{0}01	06^{0}57
Maiduguri	0.0	11^{0}51	13^{0}05
Enugu	0.0	11^{0}51	13^{0}05
Yola	0.0	09^{0}14	12^{0}28

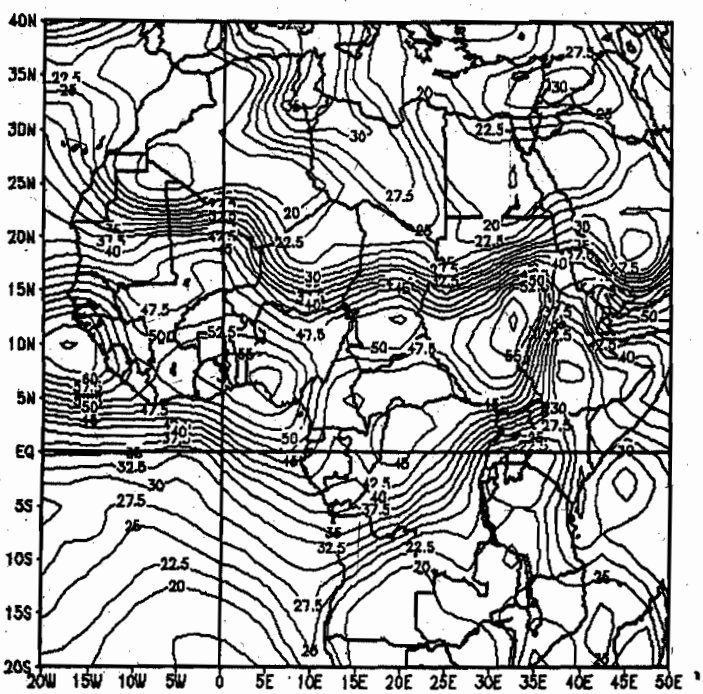

Figure 4 : SURFACE PRECIPITABLE WATER(kg/m^2) 01-DAY MEAN FOR:
Wed AUG 05 1998
NCEP OPERATIONAL DATASET

Regional Model Prediction. The countries are Nigeria, Benin, Togo, Ghana Liberia and Southern Mali. Verified prediction could only take place in Nigeria as shown in Table 2 and Figure 3. Port Harcourt and Calabar recorded the highest precipitation of 3.4mm and 2.3mm in the South Eastern Nigeria while Ikeja in the South West recorded 2.6mm. In the North Central, Jos and Minna recorded 0.3mm and 1.3mm respectively while Kano recorded 2.2mm. It is surprising that Enugu and Maiduguri in the Lake Chad region had no rainfall that day which was at variance with the prediction. The NCEP Reanalysis Model is shown in Figure 4 which displays global surface precipitable water in kg/m^2. The West Africa Region had the highest surface precipitable water ranging from 50-60 kg/m^2 leading to the heavy downpour verified. Also Figure 5 shows the NCEP global relative humidity for the 5th August 1998. The West African region had 85-95% relative humidity.

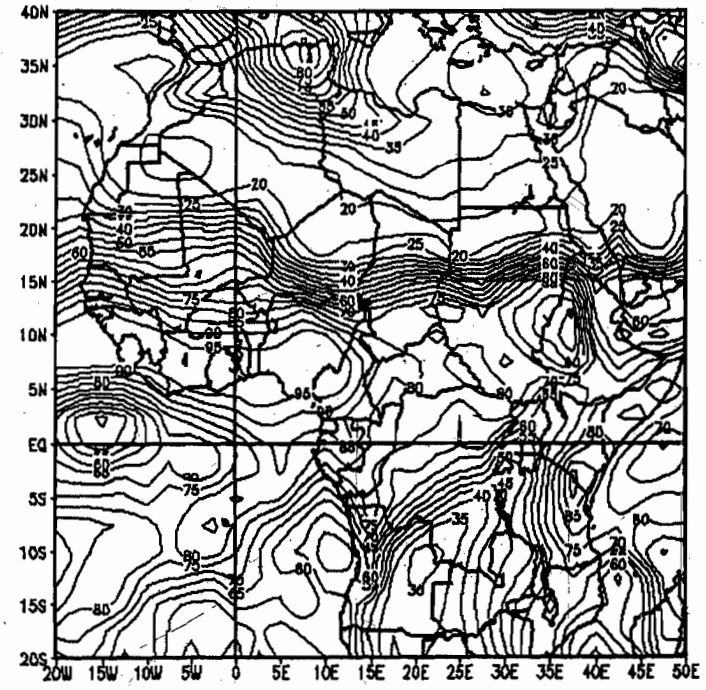

Figure 5 850mb REL. HUMIDITY (%) 01-DAY MEAN FOR:
Wed AUG 05 1998
NCEP OPERATIONAL DATASET

Figure 6 shows the total moisture on that day. The West African region ranged from between 45 and 50 because the Southwest maritime airmass sweeping across the Atlantic Ocean moves inland moisture laden.

The Tropical Rainfall Measuring Mission (TRMM) could not be accessed for the prediction and verification for the present work. The Tropical rainfall Measuring Mission satellite is a joint venture between National Aeronautics and Space Administration (NASA); and National Space Development Agency of Japan (NASDA). It measures typhoons (including hurricanes and cyclones) and rainfalls within the tropics.

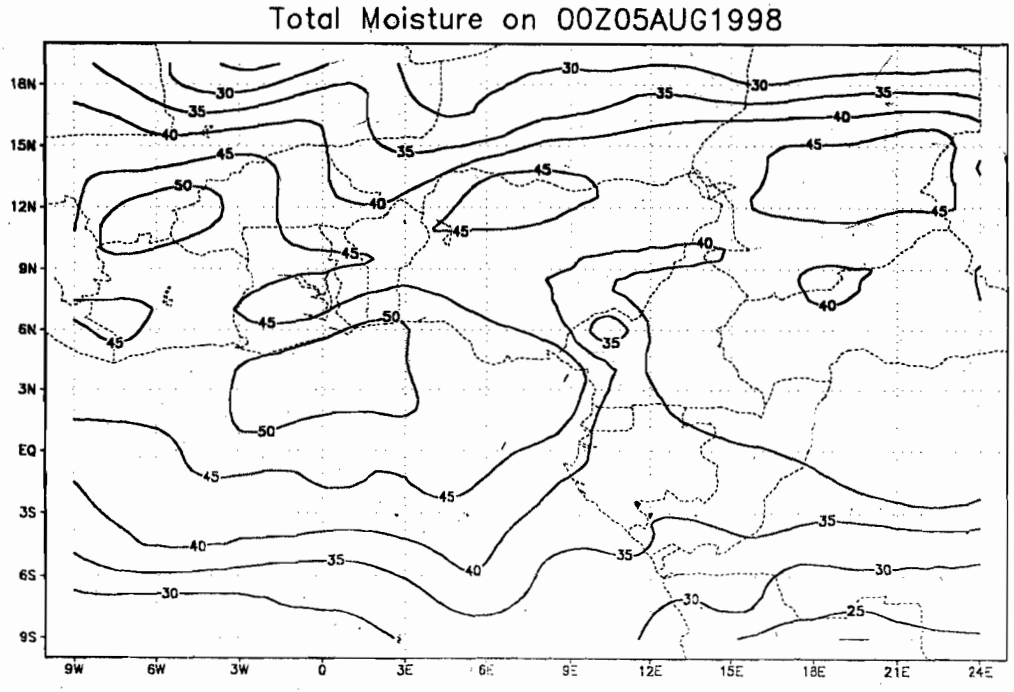

Figure 6. Total moisture on 00Z05AUG1998.

CONCLUSION

Both the Eta coordinate model and NCEP reanalysis model have been used to verify heavy rain predicted for August 5th 1998. It has been pointed out that prediction success has reached 90% and that informs the recorded results from many parts of the country. Perhaps the 10% failure accounts for non-availability of rainfall at Enugu and Maiduguri. The model is being used in South Africa and South America, and has great potential for use in Nigeria. Active collaboration will be sought with these centers to have a strong base in the country for future prediction to improve aviation, agriculture and tourism. It was not possible to collect data from countries outside Nigeria for verification.

ACKNOWLEDGMENT

The author is grateful to the Third World Academy of Sciences for sponsoring his trip to China where the Chinese Academy of Sciences played host in ICCES, IAP Beijing where this work was done.

REFERENCES

Haltiner, G.J. and Williams, R.T., 1980. Numerical Prediction and Dynamic Meteorology. Second edition. New York, John Wiley and Sons.

Ji Liren,, 1965. Numerical Analysis of the Process of a low shear line formation over China, Acts Meteorological Sinica, 35 (1): 18-33 (Chinese)

Lott N. and M. Sittelm,, 1995. January and March 1995: A California Cloudburst NCDC Tech. Rep. 95-01; http://www.ncdc. noaa.gov Met office: Governing equations, http://www. Met office.com

Mesinger F., 1983. A blocking technique for representation of mountains in atmospheric models, Riv. Meteor. Aeronautical, Vol.43.

Mesinger F. and Black, T., 1992. On the impact of forecast accuracy of the steep-mountain (ETA) versus sigma coordinate. Meteor. Atmospheric Physics, 50,47-60

NCEP OPERATIONAL DATASET. Image provided by the NOAA-CIRES Climate Diagnostics Center, Boulder Colorado from their Web site at http://www. cdc. noaa.gov/.

Ostby, F.P., 1999. Improved Accuracy in Severe Storm Forecasting by the Several Local Storms Unit during the Last 25 years: Then versus Now. Weather and Forecasting. 14 : 526-534

Reynolds W. David,, 1996. Similarities of three major precipitation events in California during 1995. Preprints 15th Conference on Weather Analysis and Forecasting, August 19-23, Norfolk, VA

Yu Rucong,, 1989. Design of the Limited Area Numerical Prediction Model with Steep mountains, Chinese Journal of Atmospheric Sciences, 13(12): 145-158

Yu Rucong., 1994. The Testing Operational Numerical Weather Prediction for China Flood Season Precipitation in 1993 by a regional ETA. Coordinate Model, Chinese Journal of Atmo. Sciences, 18(3):

Zeng Qiugcun., 1979. The Physical and Mathematical Basic of Beijing.