Forecasting and Nowcasting of Severe Storms and their preferred tracks across West Africa

A.O.B Udogwu [1], J.B Omotosho [2], S.O Gbuyiro [2], I. Ebenebe [1], G.C Osague [1], E. Olaniyan[1]

[1]*Nigerian Meteorological Agency,Plot 507 Pope John Paul Street, Maitama, Abuja,Nigeria, metosa3@yahoo.com*
[2]*The Federal University of Technology, Akure,P.M.B 704, Akure,Nigeria, president@nmets.org*
(Dated: 11 September 2009)

I. INTRODUCTION

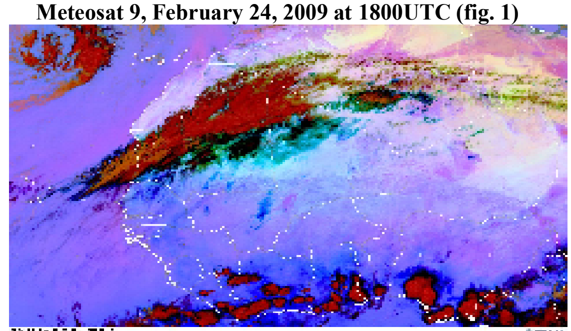
There are two distinct seasons in West Africa – the rainy season in northern summer and the dry season in northern winter. The two seasons are clearly defined by the movement of the Inter Tropical Discontinuity (henceforth ITD) which usually oscillates from the West African coast northwards with the northern summer to about 22° N and back again with northern winter. As the ITD moves northwards, moisture-bearing winds from southern Atlantic penetrate West Africa. The most destructive storms in Nigeria occur just before the onset of the rainy season (February-May) and just before the cessation of the rains (September-October). Omotosho (1990) noted that the rains cannot start until the deep convective systems (Thunderstorms and Squall lines) that deliver most of the precipitation has started to develop and organize. Therefore squall lines and thunderstorms are the major contributors to West African and in particular Nigerian rainfall. A number of very high impact weather have been observed in the sub-region. A severe storm occurred on the 22nd of September 1952 producing very high rainfall amounts for the three rainfall stations in Lagos Metropolis at the time (Lagos Roof, 159mm; Oshodi, 159mm and Ikeja, 134mm). This is over 94% of the monthly normal of 160mm in just one day. Another severe storm developed over the south west coast of Nigeria, around Lagos in the early hours of September 20, 2000; just becoming visible on the Meteosat 7 satellite imagery at 0530UTC. The progressive development of the storm was accompanied by very intense rainfall not observed in Lagos since the 1952 rains, producing very high rainfall amounts in the four rainfall stations in the Lagos Metropolis within just 6 hours of its occurrence (Lagos Roof, 280mm; Lagos Marine, 177mm; Ikeja 140mm; and Oshodi, 81mm). This is an average of about 106% of the monthly normal within just 6 hours. October 18, 2003 was the last day of the Commonwealth Games being hosted by Nigeria in Abuja. A powerful storm of 80kts hit the city between 1700 and 1745hours local time ripping apart the Velodrome and other facilities being used for the games with unconfirmed loss of three lives. A similar storm had occurred at Abuja airport on March 27, 2002 with maximum gust over 80kts and causing severe damage to parked aircrafts particularly light aircrafts. An unusual dust storm gusting 60kts brought total darkness (zero visibility) for nearly 2hrs to Maiduguri and its neighbouring cities of north east Nigeria at 1600UTC (1700LT) on 30th May 1988. This phenomenon is a regular occurrence to that part of the country (being in the arid region) during the onset of the rainy season in May/June (Omotosho, 1995) most of which are not accompanied by rainfall. The list is endless and the story is similar in many West African cities and communities at these periods of the year.

This paper attempts to use these two storms in 2009 as case studies:

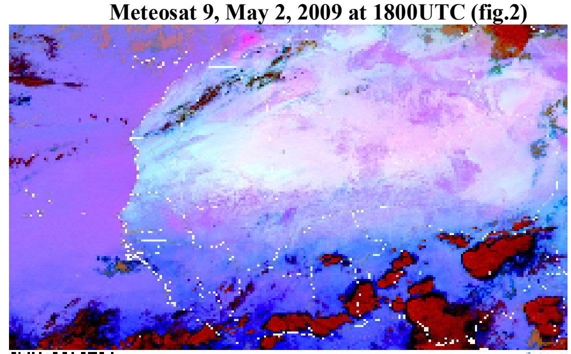
- To highlight the role of the progressive northward advance of the ITD (ITCZ) with the onset of the rainy season in West Africa by comparing two events.
- To use surface thermodynamic properties to infer important mid-tropospheric conditions necessary for storm development and intensity in the face of dearth of upper air sounding.
- To see whether analysis of surface conditions can be used to infer storm severity.
- To see to what extent relief features contribute to violent storms usually experienced during onset of rains.
- To ascertain how surface conditions contribute in determining the tracks of storms.
- To compare morning and afternoon conditions to see how much they contribute in the overall storm formation scenario.

II. DATA AND COMPUTATIONS

Meteosat 9, February 24, 2009 at 1800UTC (fig. 1)



Meteosat 9, May 2, 2009 at 1800UTC (fig.2)



Equivalent Potential Temperature (Θ_e)

This is the temperature a parcel of air would reach if it is lifted dry adiabatically until all the water vapour in the parcel condenses out releasing its latent heat and the parcel is brought down to a pressure of 1000hpa. It is usually approximated to the static energy of the atmosphere.

$\Theta_e = \Theta \exp (L_v q / C_p T_v)$ where T_v = virtual Temperature, q = Specific humidity

L_v = the Latent heat of vapourization (2.253×10^6 J kg^{-1})

C_p = 1004 J kg^{-1}deg.$^{-1}$

$T_v = T (1 + 0.608 q)$

$\Theta = T (1000 / p)^k$ where $k = R/ C_p$, $R = R_d$ = 287 J kg^{-1}deg.$^{-1}$, k = 0.286 ,

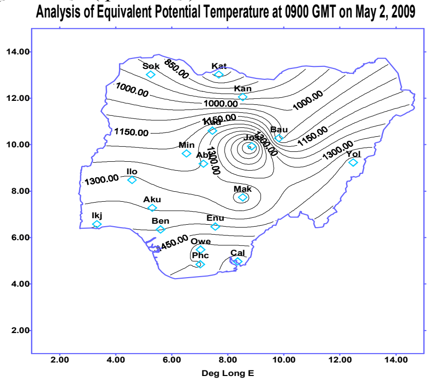
T = Temperature, p = pressure

$q = q_s RH / 100$ where RH = relative humidity in percent,

q_s = Saturation Specific Humidity

$q_s = \epsilon_1 e_s / (p - \epsilon_2 e_s)$ where $\epsilon_1 = 0.622$ and $\epsilon_2 = 0.378$

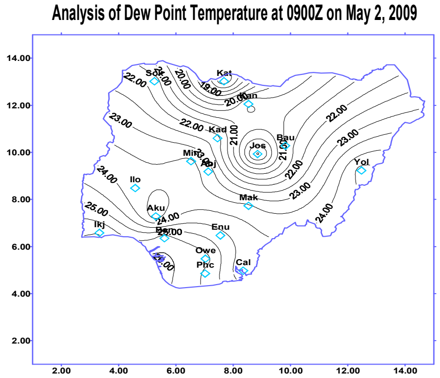
Analysis of Equivalent Potential Temperature at 0900 GMT on May 2, 2009



Dew point Temperature (T_d)

This is the temperature to which air must be cooled at constant pressure until saturation is reached, at which point liquid water condenses out. Dew point temperature is an absolute measure of how much water vapour is in the air (i.e how humid it is). Hence highest dew point temperatures correspond to highest humidity.

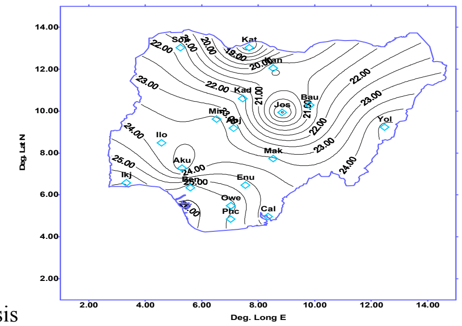
Analysis of Dew Point Temperature at 0900Z on May 2, 2009



Pressure Tendency(P_{24})

Refers to the net change in station level pressure over the last 24 hours. Its analysis is referred to as isallobaric analysis

Analysis of Dew Point Temperature at 0900Z on May 2, 2009



III. RESULTS AND CONCLUSIONS

Two storm events of February and May 2009 were studied in this work to highlight the role of the ITD (ITCZ) during the onset of the rains and the predisposing thermodynamic conditions at the surface.

The analysis of the winds at (10m AMSL, 850 and 700hpa) on the affected days was carried out in order to trace moisture transport into the sub-region. Surface analysis of some thermodynamic variables (theta-e and dew point temperature) were carried out in addition to isallobaric analysis for both morning (0900UTC) and afternoon (1500UTC) conditions to ascertain which periods present more tell-tale signals for the formation of these storms and perhaps their severity as well.

It was found that areas of high theta-e values (above 1, 340K) that coincide with areas of high dew point (≥23.2°C for the south and ≥21.1°C for the north) were highly probable zones for afternoon storm formation especially near high elevation areas. It is important to note that morning conditions of these variables tend to be more significant for the afternoon storm conditions hence it is therefore possible to determine where afternoon storms would form well ahead of time knowing the morning situation. Results also showed that more stations have higher values of theta-e during the morning hours than the afternoon which may be due to a convectively unstable atmosphere. While the storms formed near areas of tight pressure gradients in the north with the storms being driven by 700hpa winds, storms appear to propagate along negative morning tendency in conjunction with mid-tropospheric flow in the south. The storms move along West Africa in an East –West direction as reflected by the cold clouds on the satellite images (Figures 1 and 2).

IV. AKNOWLEDGMENTS

The authors are indebted to Mr Odule, Mrs M.O Iso, Mrs Oyeshile and Mrs Afuye for providing the vital data for this work.

V. REFERENCES

Omotosho J.B (1985): The Separate contributions of Squall Lines, thunderstorms and the Monsoon to the total Rainfall in Nigeria. J.Climatol.5: 476-488

Omotosho et al (2000): Predicting Monthly and Seasonal Rainfall, Onset and Cessation of the Rainy Season in WesAfrica using only Surface Data. Int. J. Climatol. 20: 865-880.

Eumetsat: www.eumetsat.com