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Impact of Cloud, on Fixed Satellite Communication Links on Earth-Space-Path, at Ka, and V-Band in the Africa Continent

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ABSTRACT

The impact of cloud at Ka (30/20GHz) and V (50/40GHz) uplink and downlink frquencies on earth space path for links to Nigerian Communication satellite-2 (NigComsat-II) placed on geostationary orbit slot: 0.0^0N, 42.50^0 E has been investigated for six climatic zones in Africa at 1% , 5% and 10% exceedances of an average year. This investigation is based on recent ITU-RP 840 (2009) and ITU-RP SG3 (2011) data base. The result shows that the impact of cloud at Ka and V bands is highly severe in tropical rain-forest (6.5^0N–6.5^0S, 11.5^0W–30^0E) and the Savannah Western Africa ($8W^0$–12^0N, 11.5^0W–30^0E) climate zones. The estimated values at 1%, 5% and 10% exceedance worst case scenerio is between 1.77 dB to 9.41dB, 0.5 dB to 6.0dB, and 0.1 dB to 2.3dB at Ka and V bands, respectively. The results of cloud attenuation for the six climatic zones in Africa are presented.

Keywords: *Cloud attenuation, Total Cloud liquid water content, Ka and V-band, Satellite look angles, Satellite radiowave propagation*

1. INTRODUCTION

The increasing demand by the end users of telecommunication services such as, multimedia services, high data rates within the Fixed Satellite Service (FSS), has driven satellite providers to use the wider bandwidth available at Ka (20/30GHz) and V (40/50GHz) than C(4/6GHz) and Ku (12/14GHz) band. Although rain has been consider to be the most significant hydrometeor affecting radiowave propagation, the influence of clouds can also be present on an earth-space path and must also be considered [Ippolito, 2008]. The attenuation caused by Cloud becomes significant particularly for systems operating Ka and V bands. This significance becomes more prominent with increasing frequency and decreasing elevation angle [Ippolito, 1999]. Rain can be traced to the formation of clouds. Clouds are a form of condensation best described as visible aggregates of minute droplets of water or tiny crystals of ice particles. The earth's lower atmosphere is typically cloudy. At any instant, about half of the planet's surface is overlain by clouds, varying in thickness from few metres to the full length of troposphere. Clouds are classified on the basis of two criteria appearance and height [Cruz Pol, 2001]. The average liquid water content of clouds varies widely, ranging from 0.05 to over 2 g/m3. Peak values exceeding 5 g/m3 have been observed in large cumulus clouds associated with thunderstorms; however, peak values for fair weather cumulus are generally less than 1 g/m3. [Slobin, 1982].

Many projected Ka-band and V-band services uses small terminals dish Direct to home (DTHM), about 50cm in diameter and, for these, rain effects may only form a relatively small part of the total propagation link margin [Harris, 2002] . Cloud attenuation, cause deep fades levels in these bands therefore this phenomena need to be considered for low availability satellite links owing to its higher probability of occurrence [Mandeep, 2008]. For ease of data analyses in this work, the selected stations in Africa cover six major climatic zones these are:

a. Arid zone (Sahara Desert, 15^0 -30^0 N, 11.5^0W-30^0E)

b. Semiarid regions northern Africa (12^0 –15^0N, 11.5^0W–30^0E),

c. Semiarid Southern Africa (17^0 –22^0S, 17^0W–30^0E),

d. Savanna climate in western Africa ($8W^0$–12^0N, 11.5^0W–30^0E),

e. Savanna climate in southern Africa (6.5^0–17^0S, 14^0–40^0E) and

f. Tropical-rain-forest (Tropical wet) climate (6.5^0N–6.5^0S, 11.5^0W–30^0E).

All the stations used in this study lie within latitude 40^0S–40^0N, and Longitude 20^0W–60^0E. As shown in figure 1.

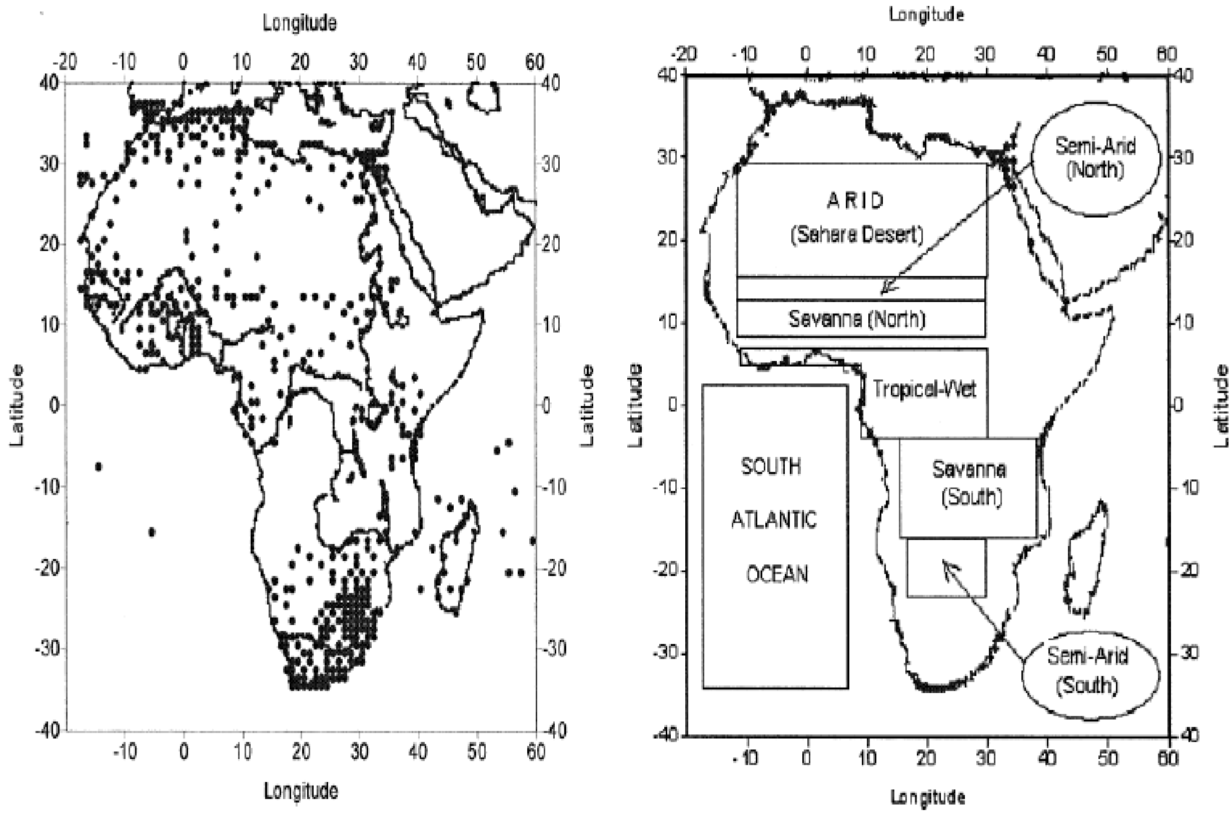

Figure 1: The map of the selected stations and six climatic zones in Africa

2. CLOUD DATA SOURCES

Climatic cloud data from satellite and ground observation from 1929- till date are available from various sources such National Administration and Space Agency (NASA), European Space Agency (ESA), Japan Space Exploration Authority (JAXA), International Telecommunication Union Radiowave propagation study group 3 data bank (ITU-RP-SG3), National Oceanic and Atmospheric Administration (NOAA), European Centre for Medium-Range Weather Forecasts (ECMWF), Japan New ERA 25, to mention few. Table 1 shows type of cloud data that can be retrieve from each of these sources. Cloud liquid water (CLW), Precipitable water (PRW), All relevant Cloud Data (such as; cloud cover, cloud type, cloud horizontal and vertical extent, Cloud top and base Height, Cloud top and base temperature, cloud pressure, and relative humidity).

Table 1: Climatic Cloud data Sources for the computation of Cloud attenuation

Data source	Satellite Name	Cloud Data Available	Date range	Website links working as at January 2011
NASA	TRMM	CLW & PRW only	1997- till date	http://disc2.nascom.nasa.gov/Giovanni/tovas/TRMM_V6.3A12.2.shtml
NASA	AIRS	All relevant Cloud data	1997- till date	http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=AIRS_Level3Month
NASA	CloudSAT	All relevant	2006-	http://gdata1-ts1.sci.gsfc.nasa.gov/daac-

		Cloud data	2010	bin/G3/gui.cgi?instance_id=atrain
NASA	ISCCP	All relevant Cloud data	1983-2008	http://isccp.giss.nasa.gov/products/onlineData.html
MERRA	Muti-satellite	All relevant Cloud data	1979-2010	http://gdata2.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MERRA_MONTH_2D
MIRADOR	Muti-satellite	All relevant Cloud data	1979-2010	http://mirador.gsfc.nasa.gov/
SCOOL	Terra & Aqua	Cloud cover	1997-till date	http://science-edu.larc.nasa.gov/SCOOL/usedata.html http://lance-modis.eosdis.nasa.gov/data_products/
ECMWF-15 & 40 ERA	Muti-satellite	All relevant Cloud data	1953 till date	http://data.ecmwf.int/data/ **you need permission and password**
JAPAN New era	Muti-satellite	All relevant Cloud data	1979-till date	http://ds.data.jma.go.jp/gmd/jra/download/data/MonthFinal/ **you need permission and password**
ITU-RP SG3	In-situ and satellite	CLW & temp profile	1979-till date	http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rsg3-software-ionospheric&lang=en
NOOA	In-situ and satellite	All datrelevant Cloud data	1929-till date	http://www.ncdc.noaa.gov/oa/climate/climatedata.html#daily http://www.ncdc.noaa.gov/oa/wdc/ **You need to purchase some products**

2.1 Cloud Attenuation

There are about nine cloud attenuation models till date [Haris, 2002] The attenuation due to suspended water droplets contained in atmospheric clouds can be determined with a great accuracy, using the Rayleigh model of electromagnetic wave scattering. This physical approach requires the assessment of the cloud vertical profile, that can be derived from radiosonde measurements. Using this approach, the attenuation estimation depends mainly on the accuracy of radiosonde measurements. Therefore, if reliable radiosonde data are available, the results of the Rayleigh model can be used as a reference for testing of the other models or to derive local propagation parameters, such as the mass absorption coefficients of clouds, or cloud liquid water (CLW) content [Louis, 2008]. The ITU-RP, Slobin, Gun and East models are based on the Rayleigh approximation which holds for frequencies up to about 300 GHz for particles under the 100 μm size limit. Cloud liquid water drops in the Rayleigh regime attenuate the radiowave mainly through absorption; scattering effects are negligible in comparison. As a result, the attenuation properties of a cloud can be related to the cloud liquid water (CLW) content rather than the individual drop sizes. The accurate measurement of CLW is an important requirement in determining cloud attenuation. The cloud temperature is also needed to compute the dielectric constant of water. In this work ITU-RP (2009) model and ITU-RP SG3 (CLW) data base have be used to compute cloud attenuation at Ka and V band for the six climatic region in Africa.

2.2 Data Processing

As mention earlier in section 2.0, ITU-RP SG3 cloud liquid water (CLW) content data base for 1%, 5% and 10% exceeded for the year has been re-gridded at 1^o by 1^o latitude and longitude using Bi-linear interpolation as recommended by ITU-R P.1144-5 (2009) as climatic input parameter for the six climatic zones to generate cloud attenuation for 1%, 5% and 10% unavailability in an average year. Figure 2a, 2b and 2c present the maps of Africa (at 1^0 by 1^0 latitude and longitude) CLW for 1%, 5% and 10% exceeded for the year respectively.

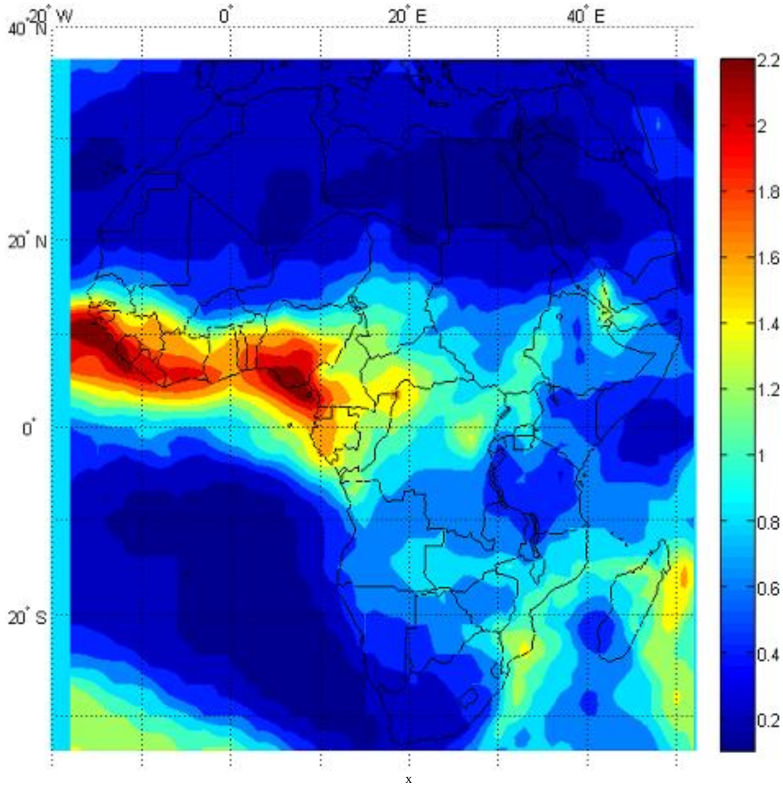

Figure 2a: Normalized CLW for exceeded 1%, of the year in kg/m^2

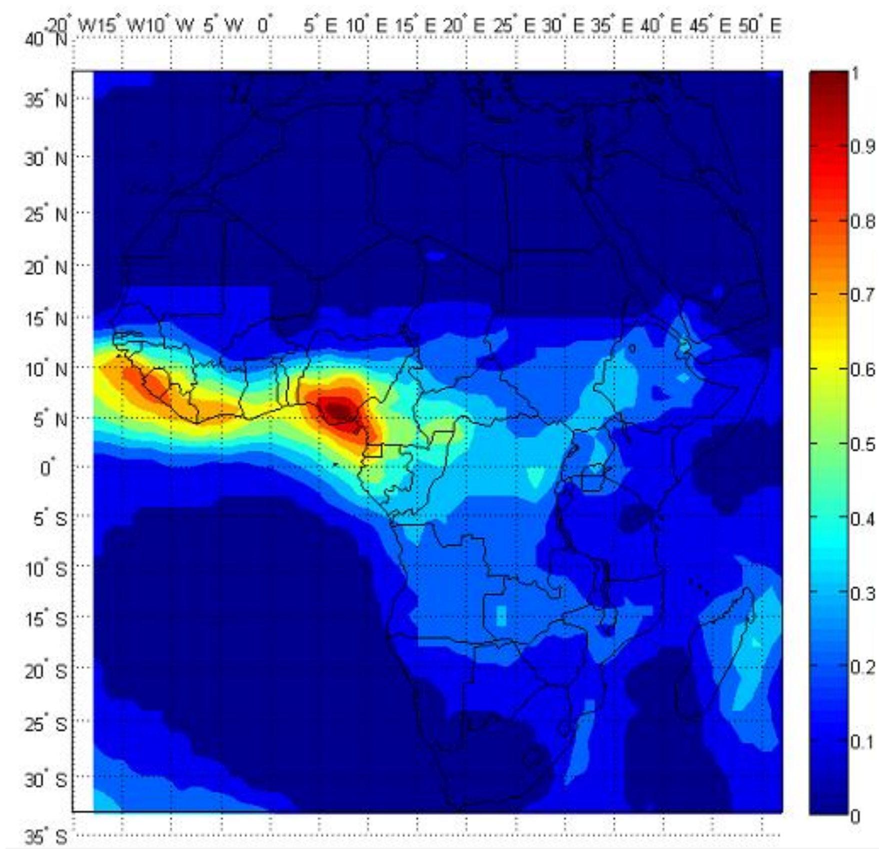

Figure 2b: Normalized CLW for exceeded 5%, of the year in kg/m^2

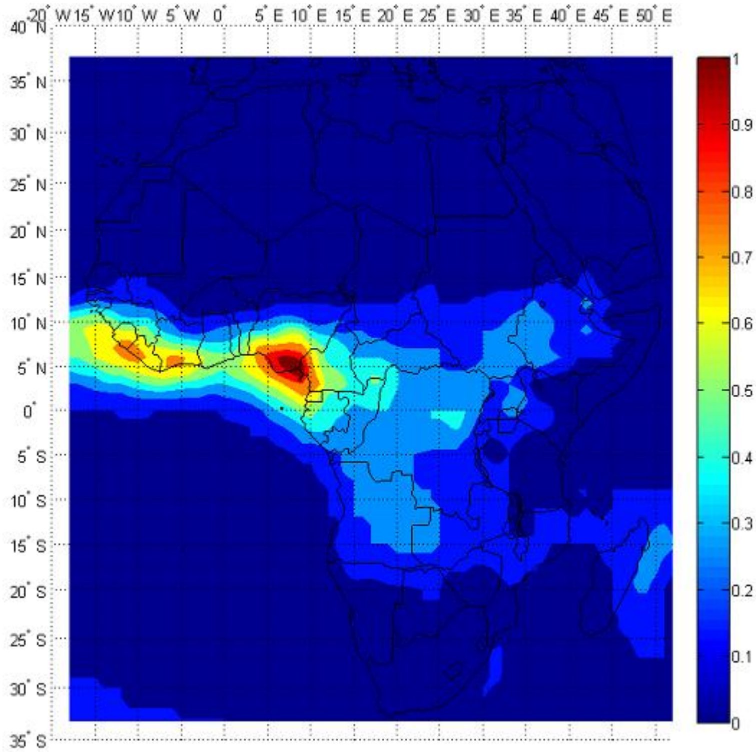

Figure 2c: Normalized CLW for exceeded 10%, of the year in kg/m^2

2.3 Computation of Cloud Attenuation

Nigerian Communication satellite (NigComsat) placed on geostationary orbit slot: 0.0^{0}N, 42.50^0 E. Figure 3 presents the map of calculated look elevation angles in degree for all stations in Africa. The satellite look angles to the NigComsat varies from 13.71^0 to 89 .71^0 for all locations in Africa. Figure 4 present the estimated distance to NigComsat for all stations in Africa and is between 35,786 to 40,194 km.

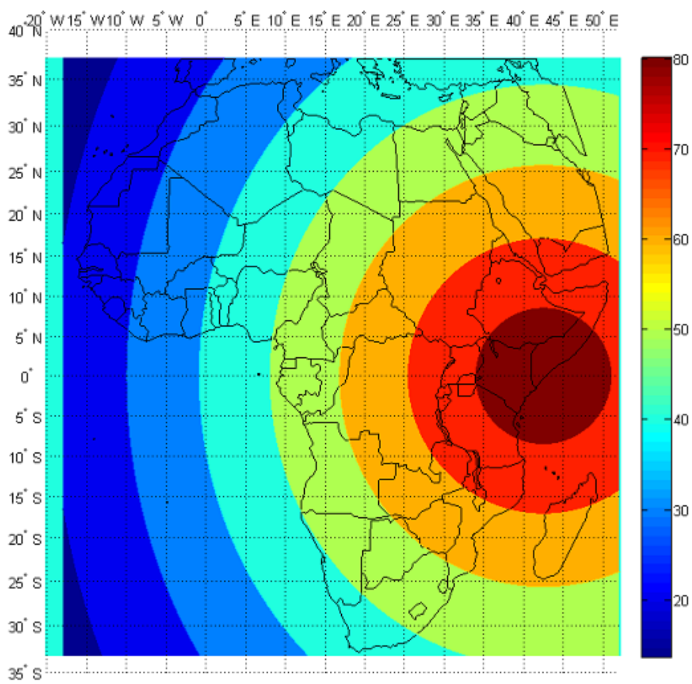

Figure 3: Stations look angles to NigComsat for all locations in Africa.

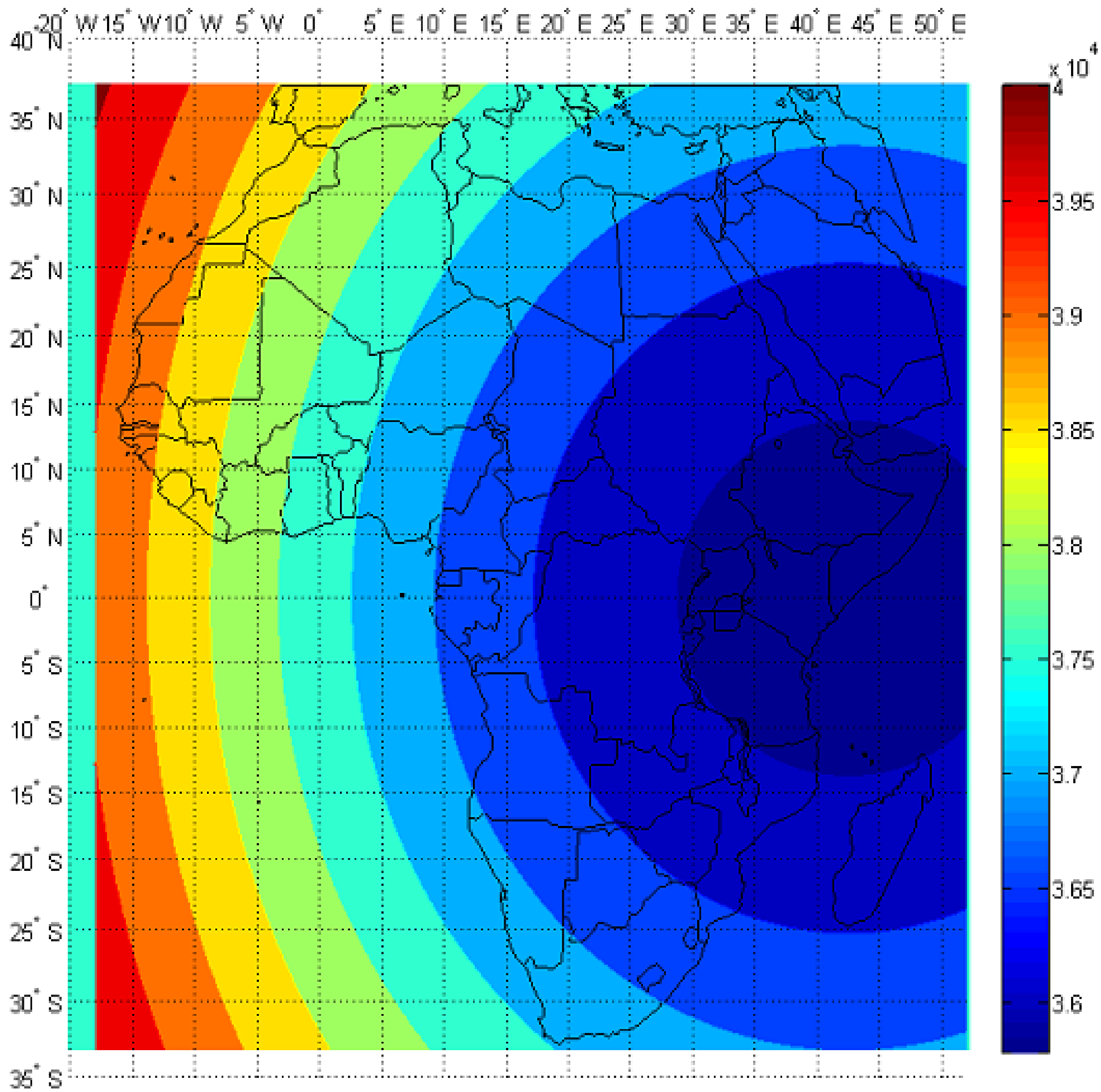

Figure 4: Distance of each station in km to NigComsat

3. RESULTS OF CLOUD ATTENUATION AT KA AND V-BAND

Figure 5a to 5d present the maps of cloud attenuation for 1% unavialability at Ka (30/20 GHz) and V (50/40 GHz) uplink and downlink frequecies respectively. Table 5 summaries the results of cloud attenuation for the six climatic zones of Africa. The impact of cloud at Ka and V band is highly severe in the tropical rain-forest (6.5^0N–6.5^0S, 11.5^0W–30^0E) and the savanna western Africa ($8W^0$–12^0N, 11.5^0W–30^0E) climate zones. This is because of the of high cloud liquid water content and the Inter – Tropical convergent zone in the two regions, follow in descending order by Semi-arid North, Savannah South Africa, Semi-Arid South and lowest in the Arid zone. Cloud attenuation map at 5% and 10% unavilability are not presented but also followed exactly thesame pattern shown for 1% unavilability, this is obvoius from the map of total cloud liquid water content in figures 2a, 2b and 2c, only that the values of attenuation at 5% and 10% are very small compare to the values of attenuation at 1% unavailability and is between 0.5 dB to 6.0 dB, and 0.1 dB to 2.3 dB at 5% and 10% respectively.

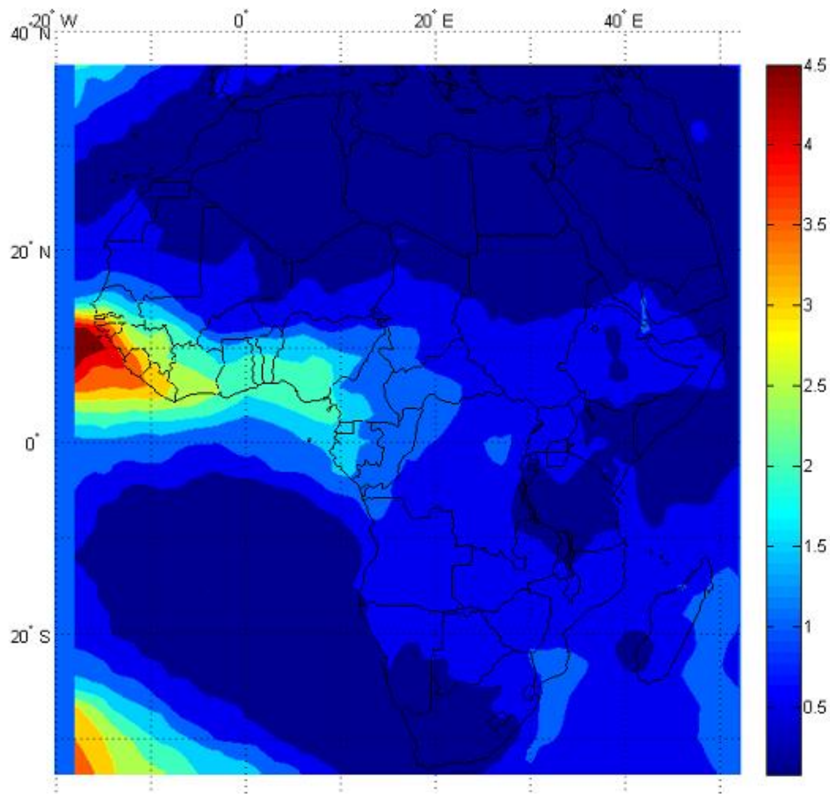

Figure 5a: Cloud attenuation in dB at Ka (30GHz) Uplink exceeded for 1%, of the year in Africa

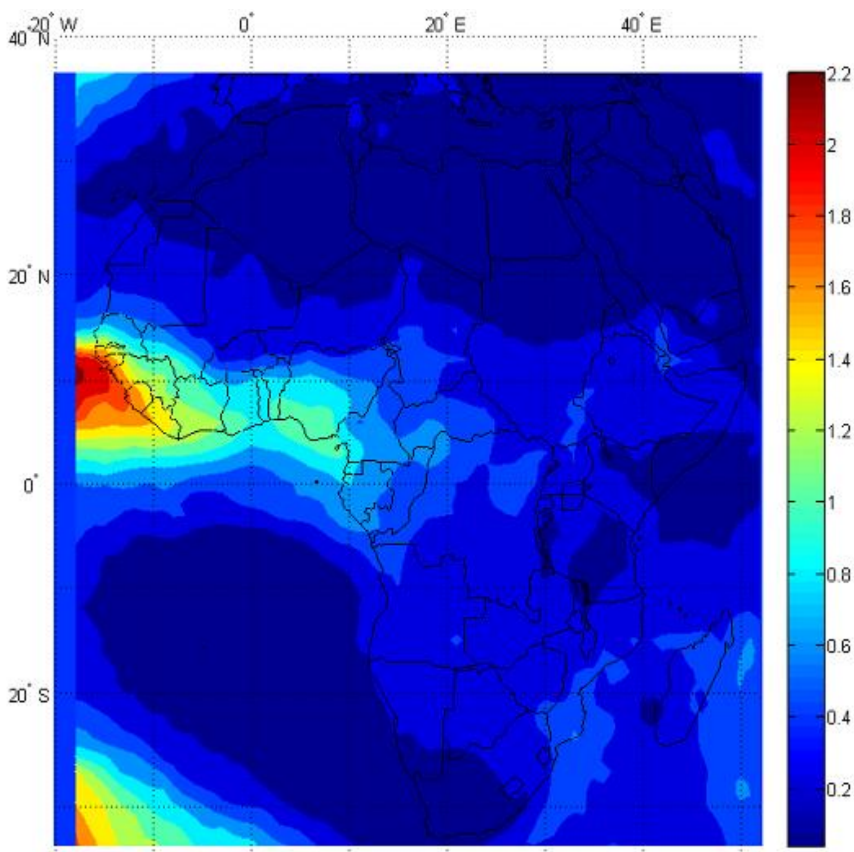

Figure 5b: Cloud attenuation in dB at Ka (20GHz) Downlink exceeded for 1%, of the year in Africa

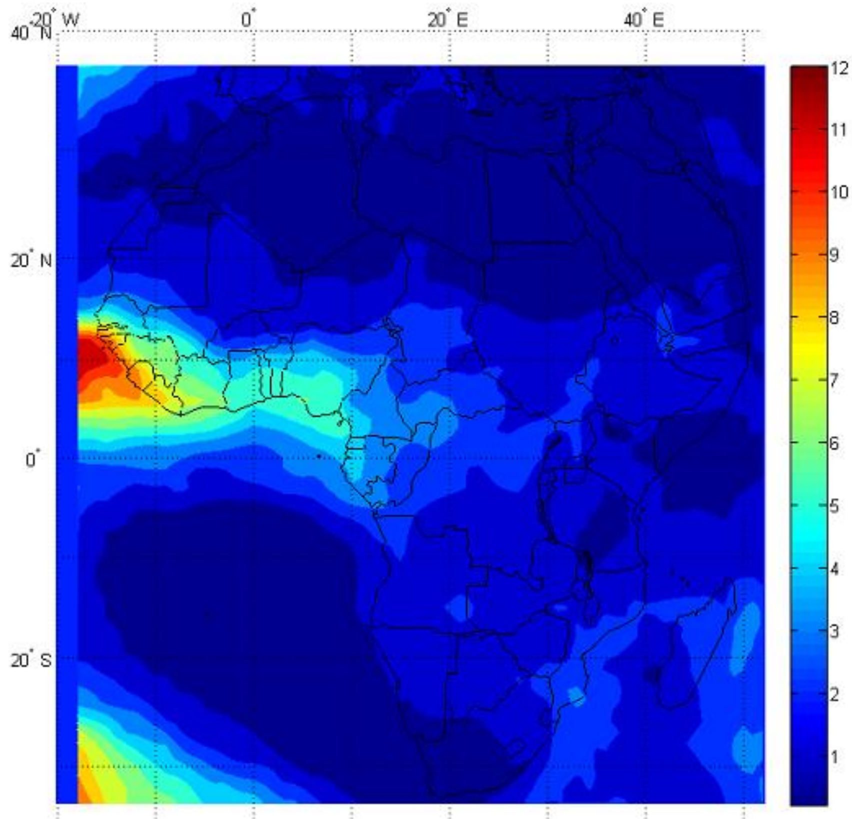

Figure 5c: Cloud attenuation in dB at V (50GHz) Uplink exceeded for 1%, of the year in Africa

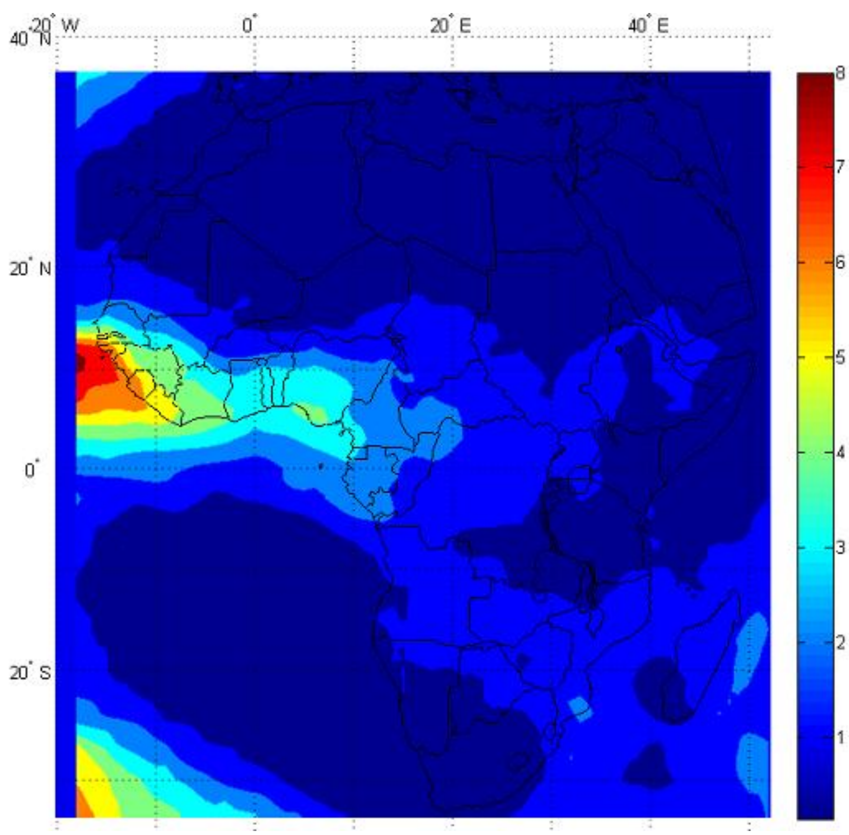

Figure 5d: Cloud attenuation in dB at V (40GHz) Downlink exceeded for 1%, of the year in Africa

Table 2: Summaries of Cloud attenuation at 1% unavailability at the six climatic zones of Africa

Africa Regional Climate zones	Ka_up 30GHz Att dB	Ka_down 20GHz Att dB	V_up 50GHz Att dB	V_down 40GHz Att dB
Arid zone	0.09 - 1.47	0.04 - 0.68	0.22 - 3.60	0.15 - 2.46
Semi-Arid North	0.34 - 2.58	0.16 - 1.20	0.61 - 3.78	0.57 - 4.34
Semi-Arid South	0.45 - 1.04	0.21 - 0.48	1.11 - 2.56	0.76 - 1.75
Savanna west Africa	0.51 - 3.83	0.24 - 1.77	1.26 - 9.41	0.86 - 6.44
Savanna South Africa	0.32 - 1.17	0.15 - 0.54	0.77 - 2.87	0.53 - 1.96
Tropical-Rain forest	0.16 - 3.82	0.07 - 1.77	0.39 - 9.38	0.27 - 6.42
Very High	High	Medium	Low	Lowest

4. SUMMARY AND CONCLUSION

The paper examines the impact of cloud at Ka (30/20GHz) and V (50/40GHz) uplink and downlink frquencies on earth space path for links to Nigerian Communication satellite (NigComsat) placed on geostationary orbit slot: 0.0^0N, 42.50^0 E , for six climatic zones in Africa at 1% , 5% and 10% exceedances of the year. The recent ITU-RP SG3 (2010) Total culumnar cloud liquid water data have been used. The results shows that the impact of cloud at Ka and V bands is highly severe in the tropical rain-forest (6.5^0N–6.5^0S, 11.5^0W–30^0E) and the savanna western Africa ($8W^0$–12^0N, 11.5^0W–30^0E) climate zones and the values is between 0.15 and 1.77 dB and 0.39 and 9.41dB at Ka and V bands respectively. Further research work based on cloud cover statistics measured from ground observation (from 1951 to 1996) and satellite data (1979 to 2010) for the six climatic zones in Africa are needed to compared the present result based on ITU-RP Study Group 3 data to validate the accuracy and suitability of the ITU-RP cloud liquid water data base for the African continent.

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