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RESEARCH ARTICLE

ICT IN THE SERVICE OF ENGINERING, WEATHER AND CLIMATE: THE NIGERIAN ENVIRONMENT APPLICATION AND RESEARCH

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ABSTRACT

The present rapid development in Information and Communication Technology (ICT) all over the world has made life and work much easier for man, but has made accessibility to valuable information cheaper, easier and available for use at any time, and in any part of the world. Man, is an entity of the ecosystem and his survival, way of life, and development to a large extent is determined by how informed he is, about his interaction with the ecosystem and all the processes that go on in it. The present advances in ICT coincides with the era of population explosion which is threatened by weather and climate hazards, and leaves the huge population highly vulnerable to risks associated with such disasters and hazards. The risks have been heightened by human activities of development which have caused increased concentration of greenhouse gases in the atmosphere that has made the earth warmer and increased the frequency of occurrences of extreme weather and climate hazards such as flooding, drought, heat waves, forest fires, hurricanes, landslides etc. Weather service refers to data and information on past weather conditions, present conditions of the atmosphere, surface water or oceans or future weather conditions (forecast, warnings, alerts), advisories or investigations that have been processed for use in making decisions, planning purposes that will optimize production, and ensure preparedness against likely weather disasters. The present advances in ICT coincides with the era of population explosion which is threatened by weather and climate hazards, and leaves the huge population highly vulnerable to risks associated with such disasters and hazards. The risks have been heightened by human activities of development which have caused increased concentration of greenhouse gases in the atmosphere that has made the earth warmer and increased the frequency of occurrences of extreme weather and climate hazards such as flooding drought, heat waves, forest fires, hurricanes, landslides etc. These have claimed lives, destroyed properties, infrastructure, caused loss of farm lands and affected agricultural production in different parts of the world.

INTRODUCTION

Man is an entity of the ecosystem and his survival, way of life, and development to a large extent is determined by how informed he is, about his interaction with the ecosystem and all the processes that go on in it. One of such interactions and processes that affect all areas of man is weather and climate (WMO 2012). Weather and climate information is important to man as it determines what he wears, where he lives, what he produces, when to produce, how he feels, his health condition, what he eats, seasons (wet and dry), availability of water resources, food security, disaster risk level, his comfort, etc. Such information is also considered by the World Meteorological Organization (WMO) as a tool for national development. "Weather, climate and water related data and information can be applied in all countries for the attainment of national, social, economic and cultural goals and sustainable development in nearly all sectors"(WMO 2004). The present rapid development in information and communication technology (ICT) all over the world has made life and work much easier for man, but has made accessibility to valuable information cheaper, easier and available for use at any time, and in any part of the world (Taleshi and Osooli 2007). It has provided a better knowledge and understanding of our environment and enhanced the way such information is communicated or shared for use in decision making about what affects man and his environment as well as what affects development in all facets of life. The present advances in ICT coincides with the era of population explosion which is threatened by weather and climate hazards, and leaves the

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huge population highly vulnerable to risks associated with such disasters and hazards. The risks have been heightened by human activities of development which have caused increased concentration of greenhouse gases in the atmosphere that has made the earth warmer and increased the frequency of occurrences of extreme weather and climate hazards such as flooding drought, heat waves, forest fires, hurricanes, landslides etc. These have claimed lives, destroyed properties, infrastructure, caused loss of farm lands and affected agricultural production in different parts of the world including Nigeria. The increased incidences of floods, drought, hurricanes, forest fires and landslide have caused deaths and destruction of properties all over the world in the last three decades (Sorensen 2000). Among these hazards, flood has proved to be the most destructive (WMO 2004).

Definition of weather and climate

Weather service (Definition, characteristics and products)
Weather

Weather refers to" all physical (and to some extent chemical) processes and phenomena that are manifested in the atmosphere on time scales from seconds to days and weeks (Lam, 2007).

Weather Service

Weather service refers to data and information on past weather conditions, present conditions of the atmosphere, surface water or oceans or future weather conditions (forecast, warnings, alerts), advisories or investigations that have been processed for use in making decisions, planning purposes that will optimize production, and ensure preparedness against likely weather disasters (Lam 2007). Such services are time dependent and cover short term atmospheric/ocean surface changes in temperature, pressure, humidity, wind speed/direction, precipitation, etc. A standard weather service should therefore have capabilities of acquiring good quality observation data from land based, water based, airborne and outer space platforms and be able to process the data, and communicate timely and reliable information that will satisfy the various needs of the users from all sectors. The information from such services include data that has not been processed which can be used for research purposes by educational and research institutions, derived products based on specific requests, synoptic weather charts (wind, pressure, temperature charts), satellite imageries, radar imageries and forecasts, alerts, or advisories to satisfy specific user needs. In Nigeria, the Nigerian meteorological Agency (NiMet) is mandated by law to offer these services to the people.

Climate service (Definition, characteristics and products)
Climate

Climate is average weather and defined as the measurement of the mean variability of the relevant qualities of certain variables such as temperature, precipitation, or wind over a period of time ranging from months to thousands or millions of years. The base period is 30 years as defined by WMO (UNDP 2016)

Climate Service

The American Meteorological society (AMS) defines climate services as "scientifically based information and products that enhance user's knowledge and understanding about the impacts of climate on their decisions and actions" (AMS 2012)

The products of such services could be past, present, and future climate information and data which may be:

1. Past climate data which may include past data archiving and provision, data rescue, reanalysis, and historical climate summaries (AMS 2012)
2. Present climate observation, monitoring, climate summaries, reports, and research or studies to estimate type, range, and likelihood of how the climate variable will vary which is necessary for planning and adaptation or mitigation at national, state or local level
3. Future climate forecasts and projection of climate conditions also for necessary for planning and adaptation or mitigation
4. Prediction of extreme climatic events such as extreme temperature, heat waves, cold spells, drought, flooding etc.
5. Provision of relevant indices for weather insurance services.

Like the weather services, the climate services are also provided in a timely manner to help address challenges of climate hazards affecting the various sectors or facets of life by taking informed decisions that will prevent, mitigate or enable adaptation to climate variability and change impacts. The science of weather and climate, which has developed over the last century or so, has benefited greatly from the parallel development of ICTs. The use of ICTs such as radio and telecommunication technologies, internet, computers standards and supporting publications have been effectively deployed for weather forecasting, climate monitoring, predicting, detecting and mitigating the effects of natural disasters. There has been appreciable improvements in weather prediction skills due to advances in telecommunications, satellites, computers, internet etc, these have resulted for example in the mitigation of natural disasters, particularly with respect to increased lead time in forecasting. The role of ICTs in weather and climate monitoring is clearly shown in the programmes of the World Meteorological Organization's (WMO) World Weather Watch (WWW), which comprises three integrated core system components as follows:

- The Global Observing System (GOS) provides observations of the atmosphere and the Earth's surface (including oceans) from the globe and from outer space (see Figure 1). The GOS uses remote sensing equipment placed on satellites, aircraft, radiosondes and relay data to environment control centers.
- The Global Telecommunication System (GTS) — radio and telecommunication networks for real-time exchange of a huge volume of data between meteorological centers.

The Global Data Processing System (GDPS) — thousands of linked mini, micro and supercomputers, processes an enormous volume of meteorological data and generates warnings and forecasts. An efficient and effective telecommunication system is necessary to make weather observation data and information available to end users and to meteorological organizations or centers in other countries, regions, and locally in urban and rural areas on real time

(PITEG project 201X). Such a system also enables meteorological data and information sharing, and contribution to WMO programmes such as the world weather web (WWW), WWIS, GOS, GCOS surface network, etc. which have been put in place to facilitate and improve the quality of weather and climate services world-wide. Common communication systems used include remotely installed systems in outer space such as the satellites (satellite technology) and those installed on the ground as receiving and transmitting telecommunication systems. On the ground, communication systems used to share data and information amongst regional, national, and local meteorological centers vary slightly from those used to share data, or provide weather/climate services to clients. Telephones, high frequency radios, log books for land surface observation, high frequency email transceivers, internet facilities and dedicated communications systems such as the GTS, DCPs, and radars are common technologies used for communication between meteorological agencies while communication to the end users could be done using Fax, internet services, television and radio broadcast and GSM or cellular telephones (PITEG project). It is important that all communication disseminated should be timely, and provided whenever and wherever needed, otherwise the essence of the information for use in planning or as early warnings to prepare against weather and climate hazards or disasters will be defeated. These can only be achieved using ICT platforms thus underscoring the relevance of ICT in weather and climate services.

METHODOLYGY

Data acquisition technology, data processing tools, information products

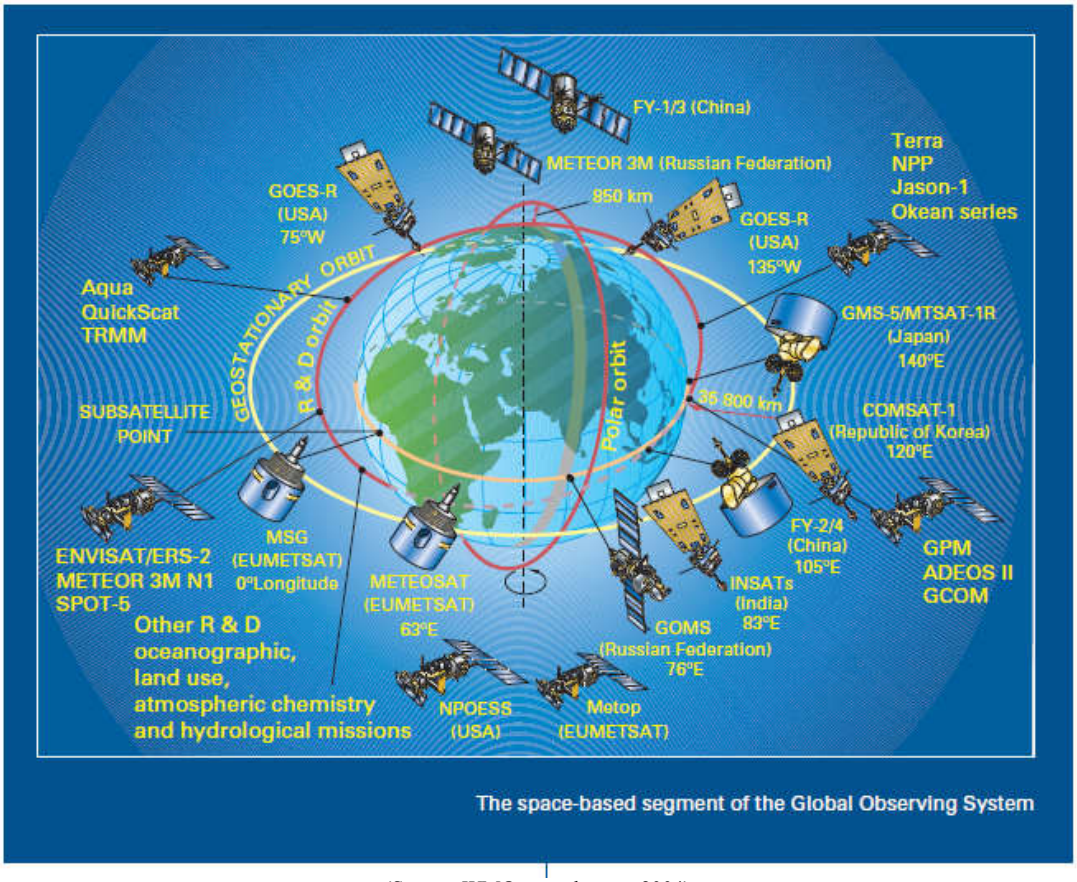
ICT in Data acquisition

The technology and systems or instruments used in acquiring weather and climate data and information on land, sea and air are the same world-wide are expected to meet certain standards as specified and recommended by WMO. However, there still exist slight differences in accuracy and standard of measurements depending on the producer and quality of materials used in producing such equipments. For example, temperature, word-wide is measured using a thermometer while pressure is measured using a barometer, and rain gauge for precipitation whether on land, water or air. Some of these equipments and systems are manually operated while some are automated and installed where human access or monitoring is difficult. A good knowledge of information or data on the surface of the earth and different levels of the atmosphere provides a three-dimensional view, and a better knowledge and understanding of the changes in the atmosphere that are responsible for any given weather over a given place and time. This is why synoptic (land), marine (water), and upper air observations are made to collect data necessary for providing accurate, reliable and good quality information about weather and climate that affect us, threaten our existence and determines our survival and livelihood on any part of the globe. WMO in support of this goal has pioneered and funded several projects in support of making weather and climate data and information such as forecast, alerts and warnings available for all countries cheaply and on time. One of such projects is the WMO Global Observation System (GOS) put in place to make observations and measurements of changes in the atmosphere and surface of the ocean by using instruments/systems installed both on the earth and in space platforms as shown in figure 1 (WMO 2004).

The platforms on land are the manned and automatic weather observation systems, weather radar, upper air stations from where pilot balloons are released, satellite ground station and work stations in national meteorological services are ICT based. Water based platforms (weather ship and ocean data buoy) carry instruments which measure changes in conditions over the ocean surface and at some depth while the airborne platforms (Aircraft, polar orbiting and geostationary satellites) carry instruments which make measurements of weather changes on land, atmosphere and water. common measurements made are air temperature, maximum and minimum temperature, mean sea level pressure, precipitation, cloud, humidity, wind speed and direction, sea surface temperature, etc (Anuforom 2016) which is then processed, analyzed and used to produce relevant weather and climate information for the end users for decision making. In space, different satellites have been installed by different satellite companies from different parts of the world (figure 2). Popular among these satellites are the Meteorological Second Generation (MSG) and Meteosat European meteorological satellites (EUMETSAT) used in most European, Asian and African National Meteorological services including NiMet. This technology has helped, particularly on providing weather data and information about places that are not habitable and accessible. Another advantage is the sufficiency (volume) of all types of real time data, the wide coverage (spatial extent) and high frequency and rate of time (temporal) at which data is acquired. A major disadvantage however is the low resolution of the data (Inness 2010). The introduction of these technologies in acquiring data and information particularly in the last 3 decades has significantly improved the quality and quantity of weather forecast, alerts and warnings issued from national weather agencies like NiMet and global weather centers such as EUMETSAT, UKMET office, Meteo France, NOAA etc. and from regional centre like ACMAD.

Data processing tools

Supercomputers, Workstations, Personal Computers (PC's), Laptops, numerical weather prediction models, and trained forecasters are all tools employed to produce good and reliable weather and climate information (forecast, alerts, warnings) in weather prediction centers world-wide. Supercomputers are however seen only in global weather prediction centers like EUMETSAT, UKMET office, Meteo-france, Korea Met. Administration, NOAA etc. because of the high cost of procuring such high capacity and fast computers for use in running numerical weather prediction models to produce forecast and other weather products. The use of NWP models has become indispensable because of advancement in technology and a shift from the conventional way of analyzing surface observation data and making forecast manually. This old method takes time and its limited in prediction over large domains (global and regional). Work stations like Meteo Second Generation (MSG), RETIM synergy, PUMA synergy later AMESD and presently MESA assemble different products and vast information from satellites in real time and also provide global model forecast products for easy, comparison, evaluation, and use to produce local and specific purpose forecasts, alerts or warnings in service of weather and climate. These workstations and regional NWP models are common in most forecast centers including NiMet.



(Source: WMO annual report 2004)

Figure 1. Part of WMO Global Observing System showing installations in outer space platforms for acquiring and processing and transmitting meteorological data and information

ICT in Production of Weather and Climate Products and Services

Weather and climate products and services common in local, regional and international hydro meteorological organizations are forecast, alerts, advisories and warnings. The forecast could be short ranged (1 to 48hours), medium ranged (3-10 days) or long ranged (months to years). It is then disseminated to various users either in coded or plain formats according to standards specified by WMO, and other regulatory bodies such as the International Civil Aviation Organization (ICAO) for aviation purposes. Products for aviation include terminal aerodrome forecast (TAF), METAR (Route forecast), flight folders, severe weather alerts, advisories and warnings. In the public weather services, products and services include data archiving and sharing, 1-5 days forecast for the electronic and print media and for other sectors weather outlooks, climate outlook, recorded videos and audios, charts, graphs, bulletins, reviews, advisories and products tailored towards specific needs of the sectors such as transportation, oil exploration and drilling, engineering construction, agriculture, disaster management, water resource management, policy makers. Others are seasonal and sub-seasonal forecast and advisories for planning and decision making. Training, workshops or seminars are also services organized for specific users to enhance productivity and reduce disaster risk from weather and climate hazards. The generation of these products are made possible by the evolution of ICT which are composed of fast computers, access to internet facilities radios, TVs, telephones, Fax machines, social media, etc.

National Meteorological and Hydrological Services (NMHSs)

Weather and climate services are provided in most countries by the National Meteorological Service (NMS) or agencies, and in some countries by the National Meteorological and Hydrological Services (NMHSs). Several technologies are employed and collaborations necessary to communicate the end products (forecast, alerts, advice, warnings) to the users from various sectors. Figure 3 shows the structure of typical meteorological service, its products, partnerships, procedure, and role in providing useful weather and climate data/ information to the users

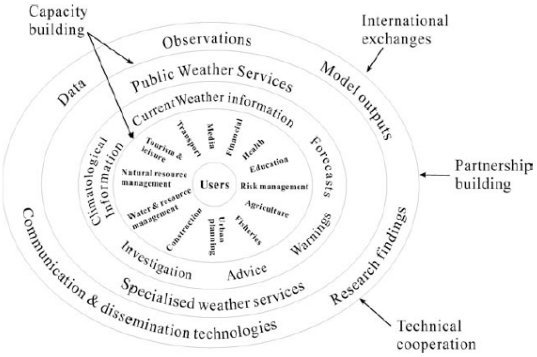


Figure 2. Model Structure of a National Meteorological Service, partnership, collaboration and users (Source: Lam 2007: WMO Technical Document no. 1385

Progression of ICT in NiMet

First is data acquisition technology which covers all technologies/tools and facilities used in acquiring weather data and information, secondly is the data processing technology which covers all technologies used in NiMet to process data and information, and thirdly, data and information communication technology involving all equipment/tools employed in NiMet to share weather data and information amongst the various meteorological stations and between the weather service agencies and the end users.

instruments found in the weather enclosures are: rain gauges for measuring precipitation, wind vane and anemometer (Figure 3) for measuring wind direction and speed, wet and dry bulb thermometers, maximum and minimum thermometers for measuring air temperature. Others are soil thermometers at 5, 10, 20, 30, 50, and 100cm depths for measuring temperature of the soil at different depths, sunshine recorder, etc. Dew point, relative humidity, and cloud information are also measured at these stations (Figure 3). Most of the synoptic stations are located at the airports while others are in remote areas, farms, schools and related organizations. How many

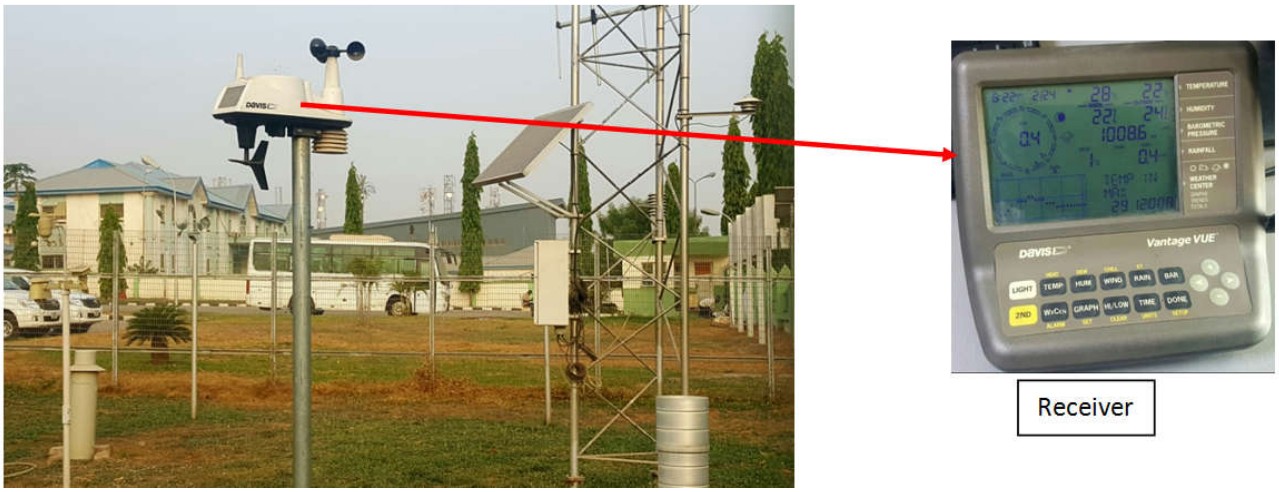


Figure 3. An Automatic weather station at the Abuja international Airport with sensors which measure pressure, wind speed and direction, dew point and humidity and displays the data/ weather information on the receiver to the right of the enclosure

Figure 4. Low Level Wind Shear Alert System (LLWAS) recently installed by NiMet at the

RESULTS AND DISCURSION

NiMet in collaboration with WMO and other United Nation bodies have continued to invest great resources in providing necessary equipment, technologies and manpower needed to make good weather observation possible around the world and in Nigeria. One of such is the contribution made towards installation of a network of ground based synoptic stations, marine stations, upper air stations and ground receiving satellite stations for ~~use in~~ data acquisition and transmission across the different states of the Federation. A total of 54 (at least one in each state) synoptic weather observations equipped with different manual and automatic weather observation instruments (Figure 3), and communication equipments have been installed by NiMet for measuring and sharing weather data and information. The common

marine stations, upper air stations, Agromet stations, hydrometer stations and those installed with automatic stations. Are there any with automatic transmission enabled facility to send observed data to data processing centre.

Table 1. Progression of NiMet synoptic stations

Period	Number of synoptic stations	Location/states
1900 - 1960	-	-
1961 - 1980	28	28
1981 - 2000	36	36
2001 - 2017	60	80

At the airports, particularly the international airports (Lagos, Kano, Abuja and Port Harcourt) special instruments to monitor thunderstorms, lightning and wind shear are installed in

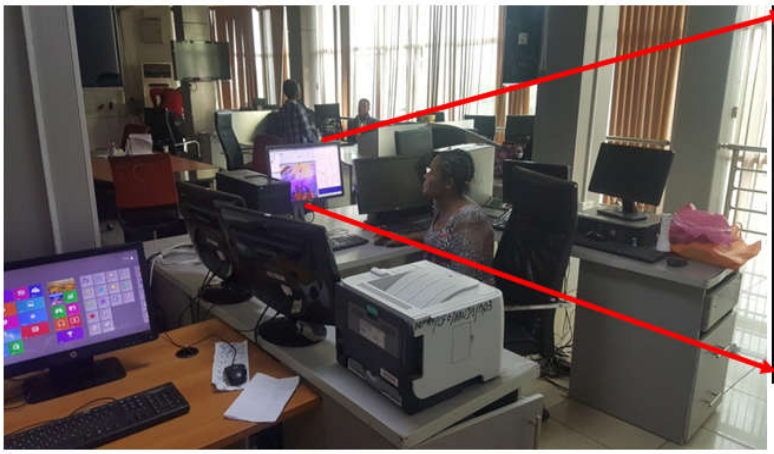


Figure 5: Newly Installed PUMA 2015 workstation at Central forecast office of NiMet, Abuja, installed in February 2017

Products (Real time imagery and forecast charts) displayed and analyzed by meteorologist on duty

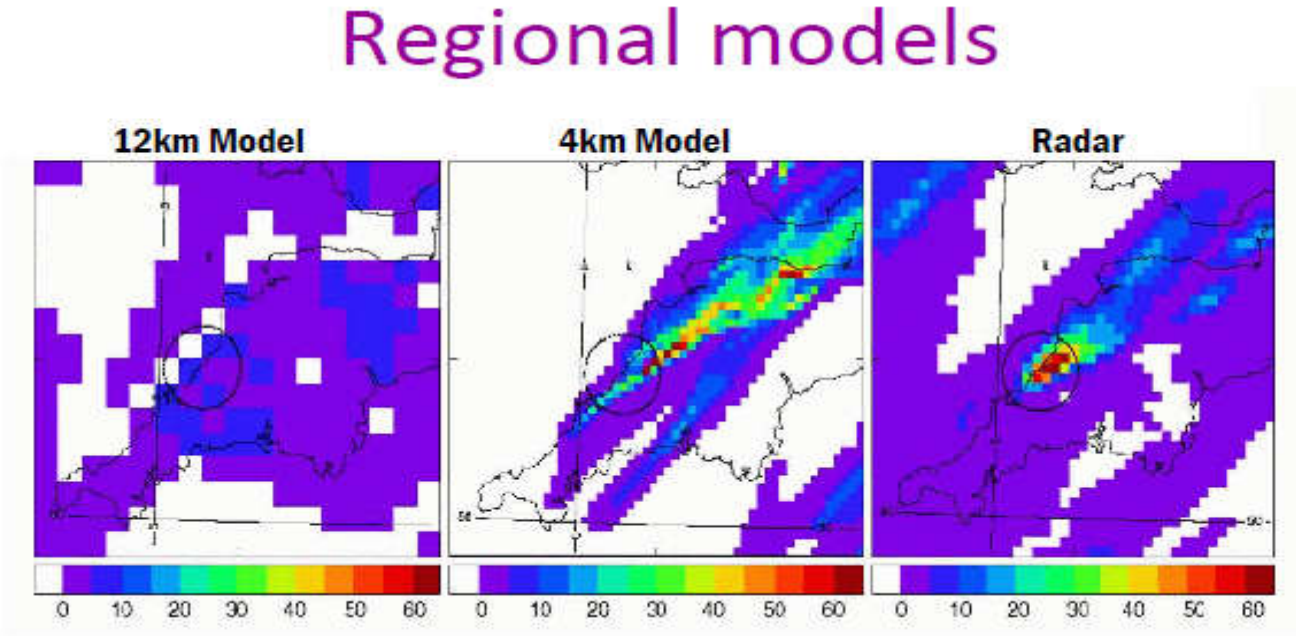


Figure 6. Comparing observed precipitation on the radar with forecast output from same model at 12km and 4km resolution and shows that model with smaller grid spacing captures small scale weather processes better than larger grid space (lower resolution) models. (Source: Met Office Forecasting Research Technical Report 466)

addition to the basic weather measuring instruments. These instruments transmit their data via a wireless radio transmission connection to the forecast office where the data are processed. Satellite receiving and work stations (MSG, RETIM, PUMA) and radars are also installed at the international airports for measuring and tracking real-time weather phenomena such as thunderstorm and line squall, for low resolution forecast, and for relevant information such as CAPE, cloud, vortices, wind convergence, divergence, etc.

Katsina International airport on 7th January 2017

12 Marine observation stations have been installed along the coast line for measuring weather changes over the sea and covering about 800km and 8 Upper air stations located in Abuja, Lagos, Kano, Enugu, Calabar, Yola, Jos, Maidugiri have also been installed for upper atmosphere observations. Measurements over the ocean are done in-situ using ship or offshore platforms while drifting buoys, stationary buoys, radars and satellites are used for remote measurements. The 12 marine stations are located along the coastal areas in Nigeria namely "Victoria Island Lagos, Exon mobil at Ibeno- Akwa Ibom state, Marina Calabar, Onne wharf in Port Harcourt, Koko wharf in Delta state, Aiyetoro in Ondo state, Nigerian Institute of Oceanography and Marine Research Lagos, Nigerian Ports Authority ports in Warri, Apapa-Lagos, Calabar, River states. NiMet presently uses a regional model of about 7Km resolution called the NiMet-COSMO (Consortium for Small-scale Modeling) model in combination with other global models (grid size 55km) from EUMETSAT, UKMet, NOAA, and Meteo-france (ARPEGE model) for its operational weather forecasting services. The real-time satellite imageries and forecast products from these workstations are made available using computers (hardware and software) specifically designed to satisfy this need.

Communication of weather data and information between NiMet weather stations in Nigeria during the 1960 - 1980 period, was done using analogue technologies such as, MUFAX,Fax, Telex, SSB radio, tele-printer, RACA system,

Table 4. Progression of ICT in NiMet

Technology/Equipment	Period	Function
Fax	pre-1960s	Used to scan weather information (text documents or images) which are then sent to others using a telephone line. The messages are decoded back to text and image formats at the receiving end.
Telex	1960s	used to exchange weather data and information over long distances through a network of teleprinters .
SSB radio	1960s - 2010	Used to exchange weather data and information between stations
Tele-printer	1960s	Used to key in messages from SSB and send to other countries
Radio RACA system	1970s - 1990s	Mufax
GTS		Used for world-wide communication of meteorological data and information
GSM	late 80s- present	Used to communicate weather information through mobile phone network, SMS and to access the internet via modems.
MDD	90s	
PDUS	1992-1996	
Internet	Early 2000	Used for distribution of alpha-numeric Met data carry and transmit primary data, satellite imageries and charts on hourly basis
MSG satellites, sat	Late 90s - 2008	A satellite receiving station which provides real timeweather information from meteorological imageries, weather forecast charts from global NWP models, etc.
RETIM/SADIS	2000s	Upgraded version of MSG workstation with more channels for more weather information
RANET	2003	For transmitting weather information to farmers in rural and urban areas through radion FM frequency (88.8MHz
PUMA	2010-2017	Upgraded version of the RETIM and MSG workstation with more channels which provide more information on clouds, winds, pressure, convergence, thunderstorms, deep convective systems, vorticity, air and sea surface temperature, humidity, forest fires, snow, NDVI etc.
AMESD		Developed for Agricultural purposes
MESA		Monitoring for Environment and Security for Africa provides relevant information on Agriculture, fisheries, hydrology, weather etc
LLWAS		

Fax → Telex → SSB → Teleprinter → Mufax → GTS → GSM → Internet → MDD → PDUS → MSG → RETIM/SADIS → PUMA → AMESD → MESA

MUFAX, etc. The introduction of satellite and GSM telecommunication system paved way for the upgrade to communication equipments such as Meteorological Data Distribution (MDD), Primary Data User System (PDUS), MSG, RETIM, PUMA, GTS, Internet, mobile phones, SMS etc. for use in sharing meteorological data and information between Met stations. The progression of these technologies from the early to recent period (top - bottom) shown in table 4.

Modern weather observation data and forecast information is shared or communicated using digital satellite and communication technologies which receive the raw data and information sometimes in coded formats before it is further processed to produce weather related products that will satisfy the needs of the users. The satellite technologies include ground receiving and work stations such as the RETIM, PUMA or MSG which receive and display information from the meteorological satellites such as the EUMETSAT Meteo Second Generation (MSG). MetOp, and GOES, located in outer space. In conclusion, Man, is an entity of the ecosystem and his survival, way of life, and development to a large extent is determined by how informed he is, about his interaction with the ecosystem and all the processes that go on in it. The present advances in ICT coincides with the era of population explosion which is threatened by weather and climate hazards, and leaves the huge population highly vulnerable to risks associated with such disasters and hazards. The risks have been heightened by human activities of development which have caused increased concentration of greenhouse gases in the atmosphere that has made the earth warmer and increased the frequency of occurrences of extreme weather and climate hazards such as flooding, drought, heat waves, forest fires, hurricanes, landslides etc

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