1) Introduction

Mr Vice-Chancellor sir, members of council here present, Principal officers of the University, Distinguished members of Senate, Provosts, Deans, Directors, Heads of Departments/Units, Staff of the University, Highly esteemed Colleagues, Invited Guests, Family members, Friends, Great Ife Students, Gentlemen of the Press, Distinguished Ladies and Gentlemen.

All glory to the Almighty God for making it possible for me to stand before you today to give this 386th Inaugural lecture of the Obafemi Awolowo University, Ile- Ife, Nigeria titled: **Exploring Earth and Space for the Benefits of Mankind.** This is the 10th Inaugural lecture series coming from our Department.

2) Mankind: The Human Race

According to biblical account in the Book of Genesis chapter 1, God decreed and created the heavens (space) and the Earth. In the same book and chapter, in verse 26, man was created in the likeness of God. God blessed man and desired that he should subdue and have dominion over all the Earth and the space that extends from it.

According to Anthony Robbins and Abraham Maslow, both of whom are psychologists, they identified and itemized the needs for the physical and spiritual survival of man. From Geo-scientific perspectives, some of man's needs can be obtained from scientific exploration and the exploitation of the resources available on the Earth and in the space environments for his benefits. The basic needs of man include: **Food, Clothing and Shelter**. Over many centuries and civilizations, the needs of man have grown to include being **able to communicate, security/safety** and **ability to monitor his environment to mitigate against probable natural (or anthropogenic) disasters which may directly or indirectly results from extraneous factors.**

3) My Early days

According to available records, I was born in Mushin Lagos, on the very last day of 1968 to Late Pa Samuel Olusanya and Alhaja

Salimot Ariyibi both from Abeokuta, Ogun State. I had my primary education both at the Ahmadiya (Anwar-ul Islam) Primary School, besides Guinness Plc, Oba Akran, Ikeja, Lagos (1974 to 1978) and at Shiloh Primary School, Okekoto, Agege Lagos (1978-1980). My Secondary education was at Vetland Grammar School, Agege, Lagos from 1980 to 1985. I was admitted to the Obafemi Awolowo University, Ile – Ife, in 1987 to study Physics. My academic experience during the four years for the undergraduate degree was very exciting with good and experienced scholars that impacted in me knowledge that shaped my life for good. Worthy of mention are the likes of Prof J.A. Oyedele, late Prof. O.O. Odundun, Prof. J.B. Aladekomo, late Prof. G.C. Onyedim, Prof. O.A. Alabi, Prof. J.B. Arubayi, Prof. E.E. Balogun, late Prof. S.O. Ogunade, Prof. F.A. Oluwole, Late Prof. F.A.N. Osadebe etc. These senior academics showed and demonstrated dedication, diligence and commitment which serve as inspiration for me among other reasons to decide to have a career in academics. After graduating in 1991, I returned during the 1993/1994 session for my MSc programme under the supervision of Prof Ogunade. For my MSc research, we (myself, Prof Ogunade, Prof Onyedim and Dr Christoff Peter of the Institute For Geophysics, Gottingen) went on a field work in February 1995, around Benue Trough, establishing data stations at Lafia, Makurdi and Oturkpo using the state-of the- art magnetotelluric equipment. This was provided under a funding arrangement made possible by Volkswagen of Germany. After the field work experience and good performance in my MSc course work, my supervisor recommended me to the department for employment as a Graduate Assistant, hence I assumed duty on 5th June 1995. My MSc research was titled: **Magnetotelluric studies of the Middle Benue Trough**. I successfully defended the thesis in November of 1998. With the demise of Prof Ogunade in 2001, I registered for a PhD in Geophysics at the Federal University of Technology, Akure. I completed the programme in 2008 with research focus/title: **Geophysical Investigation for the delineation of potential mineralized zones in southern part of Ilesa area, Southwestern**

Nigeria. The project was jointly supervised by Prof. S.L. Folami, Prof. B.D. Ako and later Prof. J.S. Ojo.

Worthy of note is Prof. M.O. Olorunfemi a renown geophysicist, of the department of Geology here at OAU who started as my academic critic, especially during my PhD programme while on his sabbatical at FUTA. However, he ended up as my academic mentor and father. At various occasions he is always there to instruct and defend me to attain academic excellence.

4) The electromagnetic waves

The discoveries and formulation of the principles of electromagnetic waves by the combined efforts of Andre Marie Ampere (1775–1836), Michael Faraday (1791–1867), James Clerk Maxwell (1831–1879) among others provided a good understanding of this phenomenon. However, it is the interactions of electromagnetic waves with substances or matter that is very relevant and readily find applications in the field of medicine, material science, geoscience, astronomy etc. The electromagnetic spectrum which covers from microwave to gamma ray wavelengths (or frequencies) provides scientific opportunity to probe and characterize various material media. Hence, it is possible to understand the Earth's subsurface using Ground (or aero-) magnetic data, gravity field data, VLF electromagnetic, Electrical Resistivity etc. The heavenly bodies in space can likewise be probed and characterized using the appropriate electromagnetic wavelengths.

Maxwell's equations: Implications

$$\nabla \bullet E = \frac{\rho}{\varepsilon} \qquad (1)$$

$$\nabla \bullet B = 0 \qquad (2)$$

$$\nabla \times E = -\frac{\partial B}{\partial t} \qquad (3)$$

$$\nabla \times B = \mu_o J + \mu_o \varepsilon_o \frac{\partial E}{\partial t} \quad (4)$$

The above expressions are due to Maxwell and can also individually be ascribed to Coulomb, Faraday and Amperes. These are the fundamental equations needed to obtain Magnetotelluric (resistivity) relation when exploring the Earth and the Magnetohydrodynamic (MHD) relation required to describe the plasma motion between heavenly bodies. With this principle on waves, you can travel the universe with me.

5) Why study the Earth and Space?

We rely on the Earth for valuable resources such as soil, water, metals, industrial minerals, and energy, and we need to know how to explore and exploit these resources sustainably. Equally we can use our knowledge of the Earth to understand other planets in our solar system, as well as those around distant stars.

The simple answer to the question above is that the Earth is our home — our only home for the foreseeable future — and in order to ensure that it continues to be a great place to live, we need to understand it. Additionally, there is more to it than that:

- We can study rocks and the fossils they contain to understand the evolution of our environment and the life within it.
- We can understand how to mitigate our risks from earthquakes, volcanoes, slope failures, and damaging storms (including rainstorms and geostorms).
- We can use our knowledge of Earth to understand other planets in our solar system, as well as those around distant stars.
- We can learn how and why Earth's climate has changed in the past, and use that knowledge to understand both natural and man-induced climate change.

  Earth science explores land surface and natural resources (ground, water, metals, soil and stones) as well as their husbandry. We also study the structure, processes, and properties of the planet, along with nearly 5 billion years of

biological evolution. The term “earth sciences” includes the study of the atmosphere (meteorology), water flowing on or beneath continental surfaces (hydrology), and the oceans and seas (oceanography).

- Ongoing developments in earth sciences provide an understanding of changing environments, the natural distribution of energy resources, and provide various methodologies for mitigating and predicting the effects of geological disasters such as earthquakes, floods, volcanic eruptions, and landslides.

6) We Are Explorers

Man by nature tries to explore his immediate environment for reasons that may be for economic and even for survival purposes. That explains why in medieval times, Amerigo Vespucci discovered the new worlds (North /South America) which were later populated by migrants in large numbers more than the original owners.

Similar instincts in man is also responsible for space exploration. Exploring space is an opportunity not only to discover new worlds and build advanced technologies, but also to work together towards a larger goal irrespective of nationality, race, or gender. If we stop exploring, we stop being human.

Studying the solar system, for example, has brought us insights into such phenomena as gravity, the magnetosphere, the atmosphere, fluid dynamics and the geological evolution of other planets.

Speaking of saving lives, space exploration could save *all* our lives. The solar system has calmed down a lot since the early eons, but there are still an unknown number of big asteroids and comets out there that could smack into the planet. Such collision with the Earth can have a devastating consequences. A robust space program is the only hope we have of deflecting such an object. If we are not working toward that goal, humanity already has an expiration date.

About 120 years ago, the world population is less than 2 billion and currently we now have over 8 billion humans on Earth. This population figure was attained with no corresponding increase in Earth's landmass. The need to find other areas of the Earth and other planets habitable to man is very important to lessen the conflicts over economic and political agitations for lands utilization.

Colonizing other bodies in the solar system (or building our own orbiting habitats) is a way to create a "backup" of humanity that will survive no matter what happens to Earth including a possible nuclear war conflagration. Maybe future humans will be Martians who will never set foot on Earth. Commercial space flights, currently operated by SPACEX of Elon Musk is already providing passengers with the experience of life for some period outside of our Earth just like Astronauts who are regularly on board the International Space Station (ISS).

7) Research Efforts

With good training and knowledge in geomagnetism and applied geophysics and a PG Diploma in Computer Science, I am well prepared to explore the Earth and the space environments. However, self-development was also necessary for me to advance in the academic profession. The fact that the geomagnetic field summed from the crustal field, main field and secondary field stimulated my interest in space studies especially to study the variations arising from external field sources. My first set of papers were a review articles on solar activity and the occurrence of magnetic storms and its disruptive effects (2003a, 2003b) alongside the article on Magnetotelluric studies on the middle Benue trough (2004). These initial efforts were very helpful as it provided me an opportunity to get research sponsorship and travel grants fellowships to Romania (1998), South Africa (2004), USA (1999) and Italy (1998, 2004 – 2011).

8) The Geomagnetic Field (Earth's magnetic Field)

The Earth is like a magnetic dipole (Figure 1) similar to the Earth's field. The geomagnetic field extends from the Earth's inner core to where it meets the solar wind, a stream of energetic particles emanating from the sun. The geomagnetic field is used to explore the dynamics of the Earth's interior and its surrounding space environment (Space weather), and geomagnetic data are used for geophysical mapping, mineral exploration, risk mitigation, navigation and other practical applications.

8a) The geomagnetic storm

A geomagnetic storm (or a solar storm) is a major disturbance of Earth's magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding the Earth**.** These storms result from variations in the solar wind that produces major changes in the currents, plasma, and fields in Earth's magnetosphere. The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several minutes to many hours) periods of high-speed solar wind, and most importantly, a southward directed solar wind magnetic field (opposite the direction of Earth's field) at the dayside of the magnetosphere. This condition is effective for transferring energy from the solar wind into the Earth's magnetosphere (Space weather).

During storms, the currents in the ionosphere, as well as the energetic particles that precipitate into the ionosphere add energy in the form of heat that can increase the density and distribution of density in the upper atmosphere, causing extra drag on satellites in low-earth orbit. The local heating also creates strong horizontal variations in the ionospheric density that can modify the path of radio signals and create errors in the positioning information provided by GPS. While the storms create beautiful aurora, they also can disrupt navigation systems such as the Global Navigation Satellite System (GNSS) and create harmful geomagnetic induced currents (GICs) in the power grid and pipelines.

The largest recorded geomagnetic storm in recent time is in **1989, a geomagnetic storm** that energized ground induced currents that disrupted electric power distribution throughout most of Quebec (Canada) and caused aurorae as far south of Texas.

8b) Geomagnetic Storm Indices

A geomagnetic storm is defined by changes in the Dst (disturbance – storm time) index. The Dst index estimates the globally averaged change of the horizontal component of the Earth's magnetic field at the magnetic equator based on measurements from a few magnetometer stations. Dst is computed once per hour and reported in near-real-time. During quiet times,

The Planetary K (Kp index) measures the global strength of a geomagnetic event ranging n values from 0 to 9, respectively for quiet and extreme storm.

Other solar activity indices include the Ap, AE, Sunspot numbers and solar radio flux

8c) Geomagnetic storm effects

i) Disruption of electrical systems

ii) Communication

High frequency communication systems use the ionosphere to reflect radio signals over long distances. Ionospheric storms can affect radio communication at all latitudes. Some frequencies are absorbed and others are reflected, leading to rapidly fluctuating signals and unexpected propagation paths. Radio operators using HF bands rely upon solar and geomagnetic alerts to keep their communication circuits up and running.

iii) Navigation systems

The Global Navigation Satellite System (GNSS), and other navigation systems are adversely affected when solar activity disrupts their signal propagation. Airplanes and ships used the very low frequency signals from these transmitters to determine their

positions. During solar events and geomagnetic storms, the system can give navigators inaccurate information of their position by as much as several miles. The navigators can however shift to backup autonomous system if there was an alert that a geomagnetic storm was in progress.

iv) Satellite hardware damage

v) Geophysical survey
Earth's magnetic field is used by geophysicists to determine subsurface rock structures. This is possible only when the Earth's field is quiet, so that true magnetic signatures can be detected.

For these reasons, many surveyors themselves use geomagnetic alerts and predictions to schedule mapping activities.

vi) Pipelines
Rapidly fluctuating geomagnetic fields can produce geomagnetically induce currents in pipelines.

This can lead to many leakage points.

vii) Radiation hazards to humans

vii) Effect on animals
Some scientists in the area of geomagnetobiology have speculated that migrating animals which use magnetoreception to navigate, such as birds, fish and honey bees, might also be affected during storms.

9) ICTP Fellowship: Earth and Space Physics Research
I have so far presented the importance of geomagnetic field and the possible effects its variations (Geomagnetic storms) may have on physical and biological systems. Our review paper Ariyibi et al.(2003a,b) and Ariyibi et al. (2004) were the main papers that defined my academic career. With these papers and others, I was able to win a travel grant to University of Kwazulu Natal, South

Africa in 2004 and also won the prestigious Regular Associateship of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy (2004 – 2011). With the assistance of ICTP and Boston College USA, our laboratory was provided with the NovAtel GSV 4004B GPS model in 2009 (Fig.2). This facility together with the available GSM-19 T Proton Precision Magnetometer (PPM) formed the nucleus of equipment available for the Earth and Space Physics Research Laboratory (ESPRL).

a) Postgraduate students Supervision: Earth and Space Physics Research Laboratory (ESPRL)

Thanks to the postgraduate (PG) college and the PG committee of my Department that provided me with very good and brilliant students who were able to share in my research vision, mission and aspirations in the field of Earth and Space Physics (ESP). I have a privilege of having about 10 master students and 4 PhD students under my supervision during the period of 2010 and 2017. With them the ESPRL became very active and vibrant and we jointly published research articles in many reputable journals. I wish to briefly present some of these research results which are of immense benefits to mankind in many respects.

10) Earth and Space Research at ESPRL: Benefits to Mankind

a) Groundwater

Water is one of the most important natural resources which man cannot do without. Groundwater is the water occupying the spaces between rocks and in the tiny inter-connected spaces between individual grains in rock. It is free from suspended matter and bacteria. It can be said to be pure, clear and colourless. It has greater quality than surface water and so useful for domestic and industrial purposes. Public water supply is not readily available in most urban /semi –urban cities of Nigeria, hence, individuals, local authorities or donor agencies result to drilling of boreholes for groundwater to meet the water needs of the people. However, groundwater development in the crystalline basement complex areas is problematic and is characterized by spate of failures of

boreholes arising from poor understanding of the basement complex hydrogeologic setting.

Awosika *et. al*. (2020) carried out the Evaluation of groundwater potential zones using integrated geophysical approach in Obun‑Ewi, Ondo East local government, Southwestern Nigeria. Obun- Ewi is an area that suffers from a shortage of freshwater and the main source of water is rainwater. Groundwater provides an alternative solution to face the gap between water demand and available water in this area.

The groundwater potential map revealed that about 69.6% of the study area fell within the poor groundwater potential rating, about 21.7% constituted the moderate groundwater potential rating while the remaining 8.7% constituted high groundwater potential rating. The study concluded that the groundwater potential of Obun-Ewi, Ondo town is generally poor, with areas around central South (around VES 9) and far Northern part of the study area (around VES 21) has good groundwater potential, suitable for siting boreholes.

In another work, **Dasho *et al.*, (2017)** carried out satellite remote sensing to groundwater potential modeling in Ejigbo area, Southwestern Nigeria. Landsat-7 EMT+ and ASTER GDEM image of Ejigbo area, Osun State Nigeria were processed to generate composite lineament map and lineament-intersection map. (Fig.3).

The study concluded that the groundwater potential of areas around Ejigbo, Osun state is of poor to moderate level rating. There are however very few areas with good to very good groundwater potential.

In yet another regional work, **Dasho et al. (2021)** carried out a Tracking of Total Water Storage (TWS) over River Basins in Nigeria Using Grace Satellite. Regional monitoring of available water resources across Nigeria for effective management is

becoming very important with the encroaching desertification in the northern part of the country. Deploying a ground-based monitoring network across the country is not feasible due to the huge financial cost. GRACE satellite provides cost-effective means of regional-scale monitoring of water resources.

The study concludes that the increase in TWS, in most of the basins, is likely due to changes in groundwater recharge quantities and therefore suggests that increasing access to improved groundwater sources is likely to be highly successful in mitigating the adverse effect of climate change in Sub-Saharan Africa.

b) Waste Management

Indiscriminate disposal of domestic and industrial wastes not only have adverse effect on the environment but also can create a breeding ground for diseases. Waste disposal and sanitation habits in sub – Saharan Africa, Nigeria inclusive, have not been encouraging. Lack of established waste disposal sites have compelled people to dump wastes in open spaces, market places, on sidewalks and even in streams thereby turning such places to breeding ground for vectors of typhoid fever, cholera and other infectious diseases particularly as it affects the degradation of natural groundwater quality.

Adebayo *et al.*, (2014) carried out an Environmental Assessment of Old Domestic Dump – Site Using 2D Electrical Resistivity Imaging: A Case Study from Olubonku dumpsite Ede, Osun State, Southwestern, Nigeria.

The 2D resistivity structures show that the topsoil has virtually merged with the weathered layer because of overlapping relatively low resistivity values of (<10 ohm-m) with a depth range of 1.0->5 m for topsoil and weathered layer which were suspected to be due to high metal contents and thus leachate saturation(Fig.4). It was also observed that the weathered layer constitute the aquifer unit in the study area. Due to the observed relatively shallow water table

of 2.1-3.5 m around the dump site, the groundwater around the dump site is suspected to have been polluted.

In another work by **Adebayo *et al,* (2015**) we try to delineate the contamination Plumes at Olubonku Dump Site using geophysical and geochemical Approach (Ede Town, Southwesten Nigeria).

The elemental concentrations of K, Ca, Mn, Zn, Ni, Cu, Cr and Fe in the soil samples located at the periphery of the dump site are much higher than those of the control sample point indicating pollution while water quality analysis from existing hand dug wells showed increase in concentrations of nitrate exceeding the permissible WHO limits. It can be concluded that the soils and the groundwater in the vicinity of investigated dump site had been polluted.

Olagunju *et al.*, (2017) carried out a geochemical and geophysical approach to environmental impact assessment: a case study of Emirin active open dumpsite,

The 2-D resistivity structure shows migration of leachate to a depth of 0.5–12.5 m along Traverse 3 and 1 → 25 m along traverse 1, 2 and 4. These deductions are corroborated by the geoelectric sections with the correspondingly low weathered layer resistivity values of 11–37 Ωm and thickness ranges of 4.8–8.7 m beneath the dumpsite. It can be concluded that the groundwater, river and soil within the vicinity of the investigated dumpsite have been contaminated to an estimated extent of about 25 m and leachate flow along the south western direction of the waste site..

c) Mineralization

Nigeria is endowed with vast but largely untapped solid mineral resources especially for maximum economic advantage. These minerals include tin ores, iron ores, clay, talc, lithium among others. Particularly, the schist belt regions of Ilesa and NW Nigeria are known to be mineralized especially, with the existence of sulphide minerals such as gold and other precious stones.

However, the occurrence of these minerals are structurally controlled and required geo-scientific investigation to determine their economic viability for their exploitation.

Ariyibi (2011a) carried out a geophysical study around the Ilesa area within the schist belt of Southwestern Nigeria aimed at delineating the mineralization potential.

The geophysical methods engaged have helped to map the structural complexity such as evidence of faulting, mineralized fractures, joints and dykes in the study area. In addition, it is now evident that mineralization is not limited to within the amphibolites, but also exist in the other rock types. Additionally, there is an improved delineation of the rock contacts which has hitherto been difficult to map as a result of dearth of outcrops and the presence of overburden.

Furthermore, **Ariyibi *et al*., (2011)** applied a multivariate technique, the Principal Component on geochemical data: A case study of the basement in southern Ilesa area, Nigeria. The study is aimed at clarifying the potential source of mineralization dealt with before in regional studies.

The principal components U_4, U_5, U_6, U_7, and U_8 have smaller variability and exhibit the following eigenvalues 0.6653, 0.3033. 0.2008. 0.0034, and 0.0000.

The analysis identified the metallic associations of Fe-Mn, Pb-Cr, and Cd-Zn within the amphibolites, schist and epidiorite complex, quartzite, and quartz schist.

Adegoke et al., (2021) carried out a Geophysical Interpretation of Magnetic Data over Mineralized Zone of Itagunmodi, Southwestern Nigeria. This was with a view to providing information on the depth to basement rocks, the subsurface geologic layers, and essentially how these geologic structures serve as indicators for the occurrence of minerals and also its possible

contribution/influence to the deposition and disposition of minerals in Itagunmodi town.

The Ifewara and other major fault zones were delineated. Itagunmodi, the study area was observed to be associated with two minor faults that offset the Ifewara fault at about 30° and 45°. This suggested possible migration of minerals from the Ifewara fault into the deformed structures via the Itagunmodi area inferred faults over geological time. The study concluded that the mineralization in the Itagunmodi area is structurally controlled.

d) Regional geologic structures

According to Wright (1968), over Nigeria and part of West Africa the formation of a regional (main) geologic structure resulted from the inter-cratonic rift in which the release of torsional stresses is associated with the separation of Africa from South America. These major structures are of significance to understand the subsurface geologic setting of the country and should also guide in the construction of critical infrastructural such as dams, interstate roads, bridges, etc.

Ariyibi *et al.*, (2004) carried out a magnetotelluric survey around the Benue trough. The Magnetotelluric (MT) data was acquired simultaneously at three sites namely: Lafia, Makurdi and Oturkpo in the Middle Benue Trough.

The orientations of the induction vectors at Makurdi and Lafia confirm the existence of faults and shear zones at the flanks of the trough and these probably coincide with the Chain and Charcot lineaments. The study also revealed the presence of narrow fault zones within the trough as shown by the induction vectors at Oturkpo at all the periods. The MT data from the three sites: Oturkpo, Makurdi and Lafia in the Middle Benue trough have been interpreted in terms of a one dimensional model of the subsurface structure. The MT model indicates the presence of a conducting crustal structure in the middle Benue trough.

Ariyibi *et al.*, (2003c) also presented Geomagnetic induction vectors on sites located near the coast, basement and the middle Benue trough covering essentially part of the southwest and the middle Benue trough of Nigeria. The results show that coastal effect was evidence as the magnitude of the induction vectors for night events at Ikorodu (IKO), Awa (AWA), Igbado (IGB) and Okitipupa (OKI) were larger when compared to the basement-sites. Since only night events were considered, the influence of the equatorial electrojet was not responsible for the enhancement of the induction response noticed in Lafia (LAF) and Makurdi (MAK) but are rather due to the existence of a prominent fault that mark the structural boundary of the trough. The orientation of the induction vectors especially at the basement sites indicate more, the existence of inland anomaly oriented roughly in the East-West direction rather than the inferred extension of the oceanic fractures into the continent.

The probable continental extension of the mid-Atlantic oceanic fracture zones (St. Paul's, Romanche, Chain and Charcot) adapted from Ajakaiye *et.al.*(1986,1987) is as shown in Fig.6 The induction vectors at the coastal site indicate coastal magnetic anomaly, due largely to the mid-Atlantic fracture zones. Also the induction vectors at the middle Benue trough indicate fault zones both within and at the boundaries of the trough.

Onyedim *et al*, (2005, 2006a,b) examined the Aeromagnetic imaging of the basement morphology in part of the Middle Benue Trough, Nigeria. This study employed aeromagnetic data to investigate the morphology of the sediments in part of the middle Benue trough Nigeria.

The results are important as these basement features are vital structures due to evolution of the trough in general serve as indication of suitable structural targets in the exploration for groundwater, solid minerals and oil in the area investigated.

Other regional structures of geologic significance identified were as elucidated in Awoyemi et al., (2005,2016) on basement fault propagation in the Chad Basin of Nigeria which shows that the sedimentary section was affected by the tectonics of the underlying basement, with faults propagating from the basement upwards into the sedimentary cover. These faults constitute potential structural traps for oil accumulation or conduit for oil migration.

e) Building/Infrastructural development

There has been reported cases of roads, bridges and building failures which are traceable to lack of adequate geologic information about the overburden thickness and its competences to support the structural loads.

Adenika *et al.* (2018) carried out a geophysical survey along Ibadan-Ife Highway (around Akinlalu/ Ipetumodu) located in the Precambrian Basement Complex of Southwestern Nigeria to examine the geological factors responsible for Highway pavement failure.

This was with the view to detailing the subsurface geoelectric sequence, mapping the subsurface structural features within the sub-grade soil and delineating the bedrock relief as a means of establishing the cause(s) of the road pavement failure.
The failed portions of the road are probably precipitated by very thick and low resistive substratum (clay) beneath the highway pavement and the identified suspected linear features are the major geological factors responsible for the highway pavement failure. Thick and low resistive substratum (< 100 Ωm, clayey sub-grade soil). The soil type absorbs water, swells and collapses under imposed traffic load stress and thereby leading to road pavement failure.

Dasho *et al.* (2020) carried out a seismotectonic analysis of parts of Togo-Benin-Nigeria shield by delineating and characterising crustal discontinuities using gravity bouguer anomaly data. This

was with a view to understand the significance of the discontinuities to the seismicity of the area. .

The prominent N-S trend pattern aligns with the general N-S foliation strike emplacement across the shield. The Lagos-Ibadan-Ijebu-Ode fault line was identified in this map as having close proximity to locations of previous earth tremors and therefore might be associated to those events.

f) Heliophysical studies at Low latitudes to improve International Reference Ionosphere (IRI) model

Heliophysics involves the study of the Sun and its effects on the Earth and other bodies within the solar system. It is concerned with the magnetosphere, ionosphere, thermosphere, mesosphere of the Earth and other planets .The ionosphere is a shell of electrons and electrically charged atoms and molecules that surrounds the Earth, between 80 and about 600 km where Extreme Ultra-Violet (EUV) and x-ray solar radiation ionizes the atoms and molecules thus creating a layer of electrons. The ionosphere is important because it reflects and modifies radio waves used for communication and navigation. It also protects organisms on Earth by absorbing those harmful extreme ultraviolet rays. Also, large geomagnetic storms triggered by solar flares and coronal mass ejections from the Sun can create severe temporary disruptions in the ionosphere (Figure 7). The International Reference Ionosphere (IRI) is the internationally accepted standard for the ionosphere (by COSPAR and URSI in late 1960s) and is officially certified as such by the International Standardization Organization (ISO). The IRI model is continually upgraded as new data and new modeling approaches become available and this process has resulted in several major milestone editions of IRI. The work by our research group at Ife used the GPS data to provide results which would also serve as input to improve the IRI model adaptable to low-latitude ionosphere locations in Africa, a region where there is paucity of data and the occurrence of complex phenomenon such as the Equatorial Electrojet.

Akintufede *et al.* (2016) carried out a Total Electron Content Variations during Different Geomagnetic Activities in Ile-Ife, Nigeria.

Comparative result between GPS- and IRI- derived TEC showed similar pattern of diurnal variations. The results of the research revealed the need for adjustment in the IRI-2012 for better representation of low-latitude ionosphere, more especially over Ile-Ife, Nigeria.

Another work by **Olatunbosun *et al.* (2019)** observed discrepancies in International Reference Ionosphere Model Predictions at a Nigerian Low - Latitude Stations. Day–to–day, monthly, seasonal and annual variations of TEC were observed, with IRI prediction values consistently higher than the GPS measured TEC values at all segments, especially during the day-time plateau and decay region. The relative deviation of measured TEC from the modeled TEC showed appreciable difference, about 70% in most cases. IRI–2016 therefore, over– estimates GPS–derived TEC in low–latitude station.

A fairly recent work by **Olabode and Ariyibi (2020)** examined the geomagnetic storm main phase effect on the equatorial ionosphere over Ile–Ife as measured from GPS observations. The effect of the main phase of two intense geomagnetic storm events which occurred on August 6 and September 26, 2011 on the equatorial ionosphere was investigated
A maximum TEC value of 55.8 TECU was recorded during the main phase of the September 26, 2011 storm event depicting TEC enhancement. Significant scintillation index value of 0.57 was observed when the main phase started on August 6, 2011 followed by a prolonged suppression while there was less significant scintillation impact on September 26, 2011 with a maximum value of 0.33. The study showed rapid energy input from solar wind during geomagnetic storm events and effect large variations in TEC and significant scintillation phenomenon in the equatorial ionosphere over Ile–Ife, Nigeria.

g) Ionospheric Studies at Low latitudes: Implications for navigation / communication

Magnetic storm is a recurring phenomenon and is established to have a relationship with the solar cycle. The induced current during such storm have tremendous impact on life on the planet earth. In order to guide against economic and other losses that may result from poor navigation and the possible disruption in signals, data, messages and utilities supplies, it is very necessary to have geomagnetic observatories that can supply accurate data in near real-time to issue alerts when magnetic storms or disturbances are likely to occur. Big corporations such as Telcos, Power, Oil companies among others can benefit from such data.

Ariyibi *et al* (2003) worked on the variation of solar activity and the occurrence of magnetic storms. The solar activity as measured by sunspot number predicts on 11 year solar cycle, for the number of sunspots to be maximum. It was established that few years after this maximum, high magnetic activity (i.e. magnetic storm occurrence) arises. During a (geo) magnetic storm, which is a global phenomenon, elements of Geomagnetic Field (GMF) are affected and the rapid field changes induce electrical currents called Geomagnetically Induced Currents (GIC) into space, atmosphere and the Earth's (sub) surface. .

Ariyibi *et al* (2013a) used the dual frequency SCINDA NovAtel GSV 4004B GPS receiver installed at Ile-Ife [on geographical latitude 7^{o}33/N and Longitude 4^{o}33/E and geomagnetic dipole (coordinate) of latitude 9.84^{o}N and longitude 77.25^{o}E)

The vertical TEC in this study showed that the values vary widely from as low as 0 TEC about sunrise to about 35 TEC during the day. Depletion in TEC was also noticed about sunset and marked by the occurrence of scintillation with a maximum index value of 0.3. Results of the IRI models and the observed TEC differ considerably; hence, the need to improve IRI models for its adaptability to the Africa Ionospheric conditions.

Ariyibi *et al* (2013b) also carried out a study of Ionospheric variations during geomagnetic activities at a low-latitude station, Ile-Ife, using the dual frequency SCINDA NovAtel GSV 4004B GPS receiver at the Ile-Ife (a low -latitude station)..
From the interpreted data, the occurrence of geomagnetic storm does not necessarily suggest an increase in the level of scintillation at a low-latitude region. Also, there is a remarkable difference between the IRI 2007 model and the observed TEC values, as the daytime TEC peak differs in magnitude and time of occurrence from the observed TEC.

Ariyibi (2014a) also worked on the Estimation of Ionospheric slab thickness (τ) during the period of low geomagnetic activity at a low-latitude station, Ile-Ife, Nigeria.

Generally, the estimated slab thickness ranged between 240 km and 300 km, attaining a maximum value during 12.:00LT and 14:00LT. Also the diurnal and seasonal (summer and winter) variation clearly validated the linear relationship existing between the TEC and τ over the African ionosphere.

However, the equinox season was exceptional, as an abnormal rise in ´τ value reaching 2,800 km between the hours of 14:00 and 18:00 LT was observed. This abrupt change in τ of the ionosphere was probably due to the intensification by the solar wind-magnetosphere coupling.

Additionally, **Ariyibi** (2014b) examined NmF2 and TEC of the equatorial ionosphere during the period of geomagnetic storms as observed from GPS data at Ile-Ife, Nigeria,

This result showed that, for a geomagnetic storm of comparable order of magnitude (in Dst and kp), the maximum electron density and TEC values varied markedly.

Jimoh *et al.* (2016) also investigated the ionospheric response to two intense geomagnetic storms on 9 March and 1 October 2012 over a Low_latitude station, Ile-Ife, Nigeria.

The change of Ionospheric range delay, which is directly proportional to change of TEC during geomagnetic storms, is a potential limitation in precise positioning using radio waves from GPS, hence, have an adverse effect on navigation and communication systems.

Olatunbosun *et al.* (2020) examined HF Propagation during geomagnetic storms at a low latitude station of Guam (Lat. 13.62^{o}N and Long. 144.86^{o}E).

Comparative results between the ionogram of disturbed and undisturbed ionosphere showed that geomagnetic storms lead to increased foF2, MUF values and NmF2. The results also revealed that the strength of the refracted signals were particularly good, strong enough to rebound from the earth and refract again.

Olatunbosun *et al.* (2017) investigated the occurrence of scintillation during intense geomagnetic storms at low latitude stations with a view to knowing the contribution of geomagnetic storms on scintillation occurrence..

The GPS receivers can then be designed to operate in scintillating environments. Comparative result between scintillation occurrence during storm and that during quiet time showed that scintillation was more pronounced during quiet periods over all stations.

Owolabi *et al.* (2019) also considered the Diurnal and Seasonal Variations of Equivalent Slab thickness over Low- and Mid-Latitude regions

Sao Luis (**Brazil)** and **Chilton** (**United Kingdom)** from January 2013 to December 2015 were used in the study.

The monthly variation also indicate a seasonal variation with highest daytime values (400 km) during winter months and lowest (below 300 km) during summer months for the low latitude station (Sao Luis). However, the nighttime values are of the same order (about 200 km) for the low latitude station (Sao Luis). Also, highest daytime values (above 250 km) are observed during summer months and the nighttime values are below 200 km over the years for the mid latitude station (Chilton).

h) Information about deep Space

The term outer space refers to anything beyond the Earth, including things very close to home in low-Earth orbit, which begins as low as 100 miles (160 kilometers) above the planet. Deep space, on the other hand, starts a bit further out: It is often considered to be anything further away from the Earth than our moon and can refer to things beyond our solar system entirely(Plate 1). The objectives of Our studies of deep space can help to unravel: (i) if there are other life elsewhere, (ii) if there are other habitable planets out there for humans and (iii) if there are other resources out there that can be helpful here on Earth. We must note that our present studies may not be able to locate the "paradise (or heaven) or hell in a religious sense" as this may only be visible in a spiritual sense/wavelength and not available on the electromagnetic spectrum.

Ariyibi (2009) presented a Preliminary observations of the Chandra data were made in order to study the Pulsar Wind Nebula in the Supernova Reminant IC443.

The observed density numbers and the normalized counts of both the point source and the diffuse source were used to describe the X-ray source. The fractional reduction in the normalized counts /s/keV noticed in the diffuse source can be the explanation for the bow-shock nebula around the supernova remnant IC443. The fact that the ejecta never comes out smoothly reveals that the shape of the X-ray point source is non-uniform and undergoes non-rigid body rotation.

Ariyibi (2016a) investigated simultaneous multi-satellite observations of a solar quiet wind condition and the energy rate estimation of the associated currents using Magnetic data from the INTERBALL-TAIL and GEOTAIL satellites.

The result from this work showed that more magnetic energy is available at the magnetotail. This magnetic energy is part of the energy responsible for driving the plasma flow, eddy currents and plasma instabilities after magnetic reconnection at the dusk side of the noon-midnight meridian plane. Such energy rate can be more during a magnetic storm and the often associated substorms.

In another paper, **Ariyibi (2016b)**, on the quiet solar wind conditions with magnetic Data from the Wind and Geotail Satellites which are at apogees of $240R_E$ respectively were considered for the already identified quiet solar wind condition which extends from 8 March to 10 March 1997.

From the magnetic records on the satellites and the corresponding measurement from a ground – based magnetometer at the southern pole it was established that during period of solar quiet variations the horizontal components of the fields are responsible for the observed current cell on the sun-lit southern hemisphere which goes clockwise.

11) CONCLUSIONS AND RECOMMENDATIONS

Mr Vice Chancellor sir, from the foregoing, our research experience have afforded us the knowledge of the interior of the Earth to identify geologic structures suitable for the occurrence of groundwater, its mineralization, and the existence of linear features which have great implications on critical infrastructural development. Our research effort have also provided valuable data and interpretation for the complex nature of the Earth's Ionosphere, particularly over parts of Africa where there is paucity of data and where there is a dominant effect of Equatorial Electrojet (EEJ).

Quality and potable water is very essential to man. This ordinarily should have been suitably provided by public water works to cater adequately for the water needs of the populace in our semi-urban, urban, towns and cities. However, the failures on the part of governments to provide this basic needs in most part of Africa, Nigeria inclusive, have made Non-Governmental Organizations (NGOs), individuals and even some government agencies to embark on sinking of boreholes to ameliorate inadequate water supply or out rightly serve as alternative to public water supply in many of our communities and individual homes. The number of boreholes that would be sunk to cater for the greater part of a nation/state water needs will in no doubt have aggregate adverse effect on the stability/equilibrium of the Earth's subsurface. Therefore, it is very important that provision of water by public water works should be mandatory, encouraged, sustained, modernized and properly networked to reach all our communities.

In most cases, dumpsites are originally located on the outskirt of towns. However, the increase in rural-urban population migration coupled with limited land availability makes the erstwhile lands on outskirt of town to become residential areas. This is the case with Olubonku and Emirin dumpsites. Additionally, the amount of waste generated is ever increasing and are often disposed inappropriately. In the basement terrain, the physico-chemical analyses as reported in Adebayo *et al*., (2014, 2015) and Olagunju *et.al.*, (2017) showed that the contaminants in the waste can leach into available water bodies (surface and groundwater) and also have adverse effects on environmental health of humans and animals . In these our studies, groundwater pollution were observed in the vicinity of the dumpsites. Provision of pipe-borne water by the public water works should be mandatory and planned for, especially in areas where dumpsite are to be sited or already existing. This, among other reasons can be advanced, advocated for and demanded by the people living in areas near such dumpsites.

Many states in Nigeria have valuable minerals which can be mined in commercial quantity. Following from our studies (among others) as reported in Ariyibi (2011), Ariyibi *et.al.* (2011b), Adegoke et al (2021), Adebayo (2018), there has been an upsurge in mining activities in many areas of Osun State. However, many of these mining sites are operated by illegal (artisan) miners who deploy manpower with less capital to carry out their activities. Oftentimes these activities involve unscientific guess work with random or indiscriminate pitting with associated pollution of water bodies, environmental/land degradation accompanied by communal conflicts as is the case in parts of Ifewara/ Ilesa areas in Osun State. Much greater communal conflicts are reported in Zamfara, Plateau, Niger, Kogi, Nassarawa etc. However, Recent mineral (aerial) survey and mapping exercise carried out by the Nigerian Geological Survey Agency (NGSA) and the Federal Ministry of Solid Minerals in partnership with the sub - national governments will largely addressed these issues following standard procedures and practice on mining (rules and regulations) activities by registered/licensed miners.

The regional geologic structures over Nigeria and part of West Africa as shown by some of our results in Ariyibi et al. (2003), Ariyibi et al, (2004), Onyedim et al (2005, 2006a,b) and in Dasho *et al*. (2020) have provided information which must be considered before the planning and construction of critical infrastructures such as dams, roads, bridges, nuclear power stations, high-rise buildings etc. The deep oceanic fractures zones including the Chain, Charcot, Romanche and St Paul are known to extend into the lithosphere in parts of West Africa, Nigeria inclusive. Likewise, the Ifewara faults and the predominantly N - S lineaments identified over the Togo - Benin - Nigeria Shield are worthy of consideration. Such will help to mitigate against possible damage which may arise from tremors as the African plate become increasingly unstable due to the active Cameroon Volcanic Line (CVL) and the East African rift systems among others.

Mr. Vice Chancellor sir, the sun has extremely important influences on our planet as it is the main driver of weather, ocean currents, seasons, and climate, and makes plant life possible through photosynthesis. Can we just imagine the life on Earth without the Sun? Additionally, the Space weather condition driven by the Sun via the solar wind has a strong impact on the ionosphere. The ionosphere is very important because it reflects and modifies radio waves used for communication and navigation. The study of ionospheric condition over Nigeria and parts of Africa during different periods of geomagnetic storm events near EEJ were reported in Ariyibi *et al* (2003), Ariyibi *et al* (2013), Akintufede *et al.* (2016), Jimoh *et al.* (2016), Olatunbosun et al.(2015, 2019, 2022), Olabode and Ariyibi (2020) and so on. These are very valid contributions on the subject matter from low-latitude Africa and were published in reputable journals. Mr.Vice Chancellor, sir, I wish to state that these output from ESPRL has provided valuable data used to improve the IRI model adaptable to low- latitude ionosphere in parts of Africa which are readily useful in navigation and communication systems over the region.

The ESPRL group is still vibrant and with adequate funding for the acquisition of relevant equipment can provide expert services that can be financially supportive to the University. Acquisition of relevant equipment including : High Density Professional MT Electrometer, All-Channel Speedy Groundwater Detector, Pipeline Leakage Detector, ADMT C3Electromagnetic probe, DPS-4D digital Ionosonde, SQUID magnetometer SRM-755 etc would enabled members of the group to make positive contribution in this regard.

Mr Vice Chancellor sir, our University, through the Department of Physics and Engineering Physics, is an active player in the international space research community. This was recognized with the sitting of Africa Regional Centre for Space Science and Technology Education in English (ARCSSTE- E) by the United Nation Office Of Outer Space (UNOOSA) in 1998. The centre was hosted, naturally, by the Physics and Engineering Physics

Department where it actually belongs. As former Head of Department (2019-2022) and working with colleagues, we developed and got senate approval for relevant curriculum for courses in Astrophysics, Space Physics, Stellar Physics, Geomagnetism etc at our undergraduate level with a view to producing knowledgeable manpower in these areas for our overall national growth and development. We must note that no nation develops technologically beyond its space program!

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As Head of the ESPRL, I wish to formally appreciate the contributions by many of my former and present graduate/undergraduate students who have worked with the group to achieve results. After completing their training, many of these former students are currently employed as academics in Nigerian Higher Institutions/Universities while others are in Canada, USA, Europe and Asia making positive contributions in the field of Earth and Space research.

My gratitude to my Late dad, Pa Samuel Olusanya Ariyibi. He was an inspiration to me right from childhood. The void left by him since 2002 (at age 74) have been very difficult to fill in my life. He believed so much in me and was always there to encourage and support me. My appreciation also to my mother, Alhaja Salimot Ariyibi, who was my first teacher, who despite her limited education, taught me good writing and good conduct. They are both precious gifts of God to me as they jointly ensured I have good and balanced upbringing with a positive view of life. My Siblings: Pastor (Engr.) Ola Ariyibi (RCCG), Pastor (Mrs) Yemisi Orekoya(RCCG), Deaconess Jumoke Adebimpe (LFC), Mr. Ibrahim Bello and Mr Taju Bello (Late) together with my extended Ariyibi-Akinbami family are all there to support me always. The Obawole Family of Ile - Ife who are my in -laws are a special gift of God to bless my life, worthy of mention is my mother in-law, Pastor (Mrs) Aderonke Obawole. My uncles: Mr Ola Sobande representing all Sobandes, Chief Ade Sab representing all Sulaimons, Alhaji Mujib Abioye representing the Abioyes family members are very supportive and also serve as inspiration for my success in life.

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