FLUID DYNAMICS MODELLING OF THE IMPACT OF CLIMATE CHANGE ON SOLAR RADIATION IN NIGERIA

OHUNAKIN, OLAYINKA SOLEDAYO

(B.Sc (Ife); M.Sc (Ibadan))

MATRIC. NUMBER: CUGP070205

A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES OF COVENANT UNIVERSITY, OTA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN MECHANICAL ENGINEERING

JUNE, 2014

DECLARATION

I hereby declare that I carried out the work reported in this thesis in the Department of Mechanical Engineering, School of Engineering and Technology, College of Science and Technology, Covenant University, Ota, Nigeria under the supervision of Prof. R. O. Fagbenle, Dr. O. M. Oyewola and Dr. M. S. Adaramola.

I also solemnly declare that no part of this report has been submitted here or elsewhere in a previous application for award of a degree. All sources of knowledge used here have been duly acknowledged.

Engr. OHUNAKIN Olayinka Soledayo **Date**

(CUGP/07/0205)

Prof. F. A. Oyawale **Date**

Head, Department of Mechanical Engineering

CERTIFICATION

This is to certify that this thesis is an original research work undertaken by **OHUNAKIN Olayinka Soledayo (CUGP070205)** and approved by:

1. Name: **Prof. R. O. Fagbenle**

Supervisor

Signature: R.L.Fagbenle Date: 14th. March, 2014

2. Name: **Dr. O. M. Oyewola**

Co-Supervisor

Signature: ..... Date:

3. Name: **Dr. M. S. Adaramola**

Co-Supervisor

Signature: ..... Date:

4. Name: **Prof. F. A. Oyawale**

Head of Department

Signature: ..... Date:

DEDICATION

This thesis is dedicated to THE ALMIGHTY GOD. THE SOURCE OF ALL TRUE KNOWLEDGE.

ACKNOWLEDGEMENTS

Unto the Almighty God goes my eternal gratitude for His mercies over me and for helping me to finish the study successfully. I also testify to His grace at every stage of my life particularly during the period of this research. If not for HIS GRACE, this work would be impossible. For all His enablement, for Divine wisdom and Divine strength, I return all praises to Him.

I deeply appreciate Dr. David O. Oyedepo, the Chancellor of Covenant University and the visioner of Living Faith Commission for answering to the call of God. Also, special thanks goes to the Management Staff of the university: the Vice Chancellor, Prof. Charles K. Ayo, the Registrar, Mr. Muyiwa Oludayo, the Deans of the Colleges, for their commitment to the pursuit of excellence and sound academic scholarship.

My profound gratitude goes to my supervisor Prof. R.L. Fagbenle, for his untiring efforts, guidance, unconditional supports, and immense contributions to the thesis. Many thanks go to my co-supervisors, Dr. O. M. Oyewola and Dr. M. S. Adaramola for their enormous contributions, support and encouragement throughout the period of this study. I equally want to thank them for their fatherly disposition to me, their genuine concern both academically and spiritually. Their leadership style is unparalleled and worthy of emulation.

I also appreciate Dr. Laura Marriotti (ICTP, Trieste, Italy) and CORDEX project on Africa. Dr. Adejare Adejuwon and family (Director, Special Climate Change Unit, Abuja), Dr. Conrad & Esse Omohinmin and family, Dr. Nsikak Benson and family, Engr. R.O. Leramo and family, Dr. Oluseyi Ajayi and family, Prof. C.A. Loto and family, Engr. & Prof. (Mrs.) Tokunboh Obayan, Engr. Wole Olunlade, Prof. E. N. Kwofie, Dr. & Mrs. Christopher Nkiko and the entire FGBMFI, Iyana-Iyesi Chapter, Mr. John and Rose Agbo, Mr. Etiosa and Nosa Uyigue, Ogbemudia Godfrey, Ero-Edevbaro Agharese and the entire Staff of Community Research and Development Centre (CREDC), Edo State, Nigeria.

I appreciate the entire Department of Mechanical Engineering, the Head of Department, Prof. F. A. Oyawale for his leadership style, Prof A. O. Inegbenebor, Prof C. A. Bolu,

Engr. Ayodeji and Tayo Abidakun, Engr. Samson Aasa, Engr. P. O. Babalola, Engr. J. O. Okeniyi, Engr. Seun Kilanko, Engr. S. O. Oyedepo, Engr. O. A. Omotosho, Engr. (Mrs) Funmi Joseph, Mr. Femi Babarinde, Mr. Damola Adelekan, Dr. Tolulope and Tutu Loto, Mr. Peter Abioye, Mr. David Olugboye. I also appreciate the following personalities for their untiring effort to make sure this work becomes a reality: Dr. S. J. Ojolo (UNILAG), Dr. B. S. Ogunsina (OAU, Ife), Dr. R. R. Dinrifo (LASPOTECH, Lagos), Dr. K. M. Odunfa (UI, Ibadan) and Dr. A. O. Odior (UNIBEN).

I will want to acknowledge Dr. Olaniran J. Matthew, you have been a wonderful man. Prof. A.T. Salami, I am grateful sir, and all the staff of Space Applications and Environmental Science Laboratory (SPAEL), Atmospheric Studies and Space Applications Unit, Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. I equally want to thank Engr. A. T. Oyeniran and his wife (Mrs. Yemisi Oyeniran) and his entire family for all the supports. They have always being there for me.

Many thanks to Miss. Esther Ajiboye for providing editorial assistance, Dr. (Mrs) Inegbenebor and also Tolu Alao, Bolaji Abidoye, Seun Alabi and Akin Adejuwon. They all put long hours so that I can come up with a perfect report. You are deeply appreciated. I am highly indebted to the entire library staff particularly Mrs. Ify Osinulu, Mrs. Egbe Odeshi, Chijoke Ohaegbulam, Chidi Isiakpona, Mr. Goodluck Ifiji.

I wish to appreciate the following people: my parents, Mr. and Mrs. Akinbode Ohunakin, for their prayers and blessings in the course of this study and my profound siblings, Dr. Afolabi, Olayide, Akinlolu and Abiola for their support and encouragement. My in-laws, in particular Chief Komolafe and Mrs. Komolafe, Jibola, Wale for their prayers, supports, love and constant encouragement.

Finally, I am indebted and grateful to my wife, Mrs. Folakemi Ohunakin and my son for their prayers, kindness and understanding during the period of writing this work. They bore the burden of my long hours at work and even at home during the period of this study and without whose tolerance the work could hardly have been successfully completed.

ABSTRACT

Solar energy applications being developed to assist in limiting the extent of climate change through low-carbon technologies, rely on the natural environment that may be sensitive to changes in the climate, resulting from rising carbon emissions. Climate models are essential to predict the future of solar irradiance fields needed for long range planning of solar energy use. Despite the wide use of numerial models on precipitation and agriculture, their applications on measuring the effect of changing climate on renewable energy resources and weather parameters that contribute to building comforts are very sparse. In this study, the nature of seasonal and interannual variability of solar radiation is investigated alongside global solar radiation climatologies. The International Centre for Theoretical Physics regional climate model (ICTP-RegCM3) driven by European Centre/Hamburg 5 general circulation model (ECHAM5-GCM) and based majorly on the fundamental principles of Newton's second law, the conservation of mass, the equation of state and the first law of thermodynamics was generated for Nigeria under an enhanced atmospheric CO_2 level for the period 1981 to 2100. The model was validated using 11-year solar radiation and mean atmospheric temperature data from two observatories (Nigerian Meteorological Agency (NIMET) and the National Aeronautic and Space Administration (NASA)). Data were analysed using descriptive statistics and Fisher test ($p<0.01$). The model performed reasonably well when compared with the observed data. The best simulations for seasonal cycle of global solar radiation was obtained over the North having $\sigma' = 1.45$, $R = 0.84$ and $\sigma' = 0.97$, $R = 0.98$ whereas the worst simulations occur over the South with $\sigma' = 0.93$, $R = 0.62$ and $\sigma' = 0.85$ and $R = 0.87$ for the NIMET and NASA respectively. RegCM3 was also found to indicate a fair prediction of the interannual variability of solar radiation and mean air temperature over the climatic zones. Correlations for the solar radiation range from $-0.12\ to\ 0.64$ (NIMET) and $0.07\ to\ -0.41$ (NASA) reflecting that the simulated interannual variability over the South and North climatic zones fairly agree with the observed, but more consistent with that observed in the Middle-belt zone ($NIMET: R = 0.64$). The simulated seasonal global solar radiation bias for the RegCM3 with NIMET and NASA observed datasets in the control period (1981–2010) are of similar magnitudes and showed a mixture of persistent positive and negative biases ranging between –10 and 30%. The seasonal potential future changes in period 1 (2011–2040), showed a reduction in the range of 0 (North) to 3.27% (South) whereas more reduction in global solar radiation is observed in period 2 (2041–2070), having general decrease ranging from 0.11 (Middlebelt) to 3.39% (South). Potential changes in period 3 (2071–2100), is generally characterized with mixed increase and decrease in global solar radiation across the country than the previous two periods. The model has predicted well, the potential effect of changing climate on solar radiation over Nigeria. It was also observed that the finer the resolution in grid spacing, the better the model in representing the observed data.