

UNIVERSITY OF NAIROBI



**SIMULATION OF RADIATIVE FORCING DUE TO AEROSOLS OVER SOME
COUNTIES IN KENYA**

BY

GODFREY SHEM JUMA

I54/63045/2013

**A RESEARCH DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE
IN CLIMATE CHANGE OF THE UNIVERSITY OF NAIROBI**

JULY, 2015

Declaration

This dissertation is my original work and has not been presented for the award for any degree in this University or any other academic institution.

Mr. Godfrey Shem Juma
Department of Meteorology	Signature	Date
University of Nairobi		

This dissertation has been submitted for examination with our approval as University Supervisors

Prof. J. N. Muthama
Department of Meteorology	Signature	Date
University of Nairobi		

Mr. B. K. Mutai
Department of Meteorology	Signature	Date
University of Nairobi		

Dedication

This dissertation is dedicated to my father, Wilfred Daniel Owino and My Mother, Fridah Owino for their prayers and unwavering support during my course work.

Abstract

Anthropogenic emissions of aerosols and their precursors contribute to a reduction of solar radiation at the surface. The Coupled Ocean and Atmosphere Radiative Transfer (COART) model was used to solve a radiative transfer equation using aerosol optical thickness data derived from Moderate Resolution Imaging Spectroradiometer (MODIS) spanning 2000 to 2015.

Trajectory modeling was carried out using Hybrid Single Particle Lagrangian Model (HYSPLIT) to trace the possible sources of aerosols. Integrated fluxes were generated from COART model and their spatial and temporal patterns specified. Counties investigated are Mombasa, Lamu, Nairobi, Kakamega, Bungoma, Nyeri, Meru, Machakos, Turkana, Transoia, Baringo, Nakuru, Narok, Kisumu, Kisii, Nyamira and Busia. Simulation of future warming was also done using Model for the Assessment of Green House Gas-Induced Climate Change, A Regional Climate SCEnario GENerator (MAGGICC SCENGEN).

Results of the spatial characteristics of aerosols revealed that Turkana, Garrisa, Mombasa and Lamu Counties had higher aerosol optical depth while Kisii County had low aerosols 'optical depths respectively across all seasons. It was also observed that aerosol loading was highest during the JJA season. Results from the temporal characteristics of aerosols showed that Garrisa County had the highest interannual variability of aerosols. The study indicated that aerosol loading across all Kenyan Counties is reducing and that long distance transport and dispersion of aerosols was facilitated by low level winds.

Results from spatial variation of radiative forcing due to aerosols revealed that Kisii County had high radiative forcing while Marsabit, Wajir, Mombasa, Lamu and Turkana Counties had relatively lower radiative forcing. Results from temporal analysis revealed that forcing over Kenya is reducing and is in the range of -0.187 to -0.05 w/m^2 .

Model simulation results revealed a warming of 0.17 $^{\circ}\text{C}$, 0.45 $^{\circ}\text{C}$, and 2.96 $^{\circ}\text{C}$ by the year 2000, 2015 and 2100 respectively, due to aerosols. Results also reveal sulphates-induced warming of 0.1 $^{\circ}\text{C}$ and 0.25 $^{\circ}\text{C}$ under reference and policy scenarios respectively. Detailed investigation of dominant radiative processes corresponding to individual aerosols in each county is recommended.

Table of Contents

Declaration.....	ii
Dedication.....	iii
Abstract.....	iv
List of tables.....	viii
List of Figures.....	ix
List of Acronyms.....	xi
List of Chemical Symbols.....	xiii
CHAPTER ONE.....	1
1.0 INTRODUCTION.....	1
1.1 Background of the Study.....	1
1.2. Problem Statement.....	2
1.3 Objectives of the Study.....	2
1.4 Justification of Study.....	3
1.5. Area of Study.....	3
CHAPTER TWO.....	5
2.0. LITERATURE REVIEW.....	5
2.1 Green House Gases and Aerosols.....	5
2.2. Radiative Forcing.....	8
2.3 Climate Change Scenarios.....	17
CHAPTER THREE.....	18
3.0. DATA AND METHODOLOGY.....	18
3.1. Data Type and Source.....	19
3.2. Limitations.....	19
3.3 Methodology.....	19

3.3.1. Theoretical Framework	20
3.3.1.1. Radiative Forcing	20
3.3.1.2 The Radiative Transfer Equation (RTE).....	20
3.3.1.3 Beer’s Law	24
3.3.1.4. Radiation Balance Equation.....	25
3.3.1.5 MODIS Framework.....	26
3.3.1.6. Lagrangian Modeling	27
3.3.1.7: Structure of MAGGIC-SCENGEN.....	29
3.3.2. COART Modeling.....	31
3.3.2.1 COART Model Assumptions.....	33
3.3.2.2. Estimation of Radiative Forcing using COART Model.	33
3.3.4. Time Series Analysis.....	35
3.3.5. HYSPLIT Trajectory Modeling	35
3.3.6. MAGGIC SCENGEN Modeling	36
3.3.7. Data Analysis via GIOVANNI	37
CHAPTER FOUR.....	39
4.0 RESULTS AND DISCUSSION.....	39
4.1. Limitations of Study	39
4.2. Spatial-Temporal Characteristics of Aerosols.	39
4.2.1. Spatial Characteristics of Aerosols.	39
4.2.2. Temporal Characteristics of Aerosols	46
4.3. Spatial –Temporal Characteristics of Radiative Forcing due to Aerosols.....	57
4.3.1. Spatial Characteristics of Radiative Forcing.....	57
4.3.2. Temporal Characteristics of Radiative Forcing	59
4.4. Warming Projections over Kenya	65
CHAPTER FIVE.....	70