RADIATIVE CHARACTERIZATION OF ATMOSPHERIC AEROSOLS OVER SELECTED URBAN, RURAL AND MARITIME SITES OF KENYA USING SUN SPECTROPHOTOMETRY

BY

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B.Sc. (Hons)

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science (MSc) in Physics, University of Nairobi.

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Declaration

This thesis is my own work and has not been examined or submitted for examination in any other university.

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156/71197/2007

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This thesis has been submitted for examination with our approval as supervisors.

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Abstract

Atmospheric aerosols modulate the radiative budget and ambient air quality of the atmosphere, thus, there is a need to develop both analytical and computational methodological techniques that determine their physical, chemical and optical properties in order to characterize and model their effects. This thesis embodies the results of the derivation of radiative characteristics of the atmosphere over Nairobi (2006-2008), Mbita (2007) and Malindi (2008) using aerosol data obtained from sun spectrophotometry. Aerosol optical depths (τ), single scattering albedo (ω), angstrom exponent (α), asymmetry factor (g), real (n) and imaginary (k) refractive indices at zero Solar Zenith Angle (SZA) were derived through AErosol RObotic NETwork (AERONET) framework. Temporal and spatial characteristics in τ and α were investigated using multivariate techniques viz. Principal Component Analysis (PCA), Partial Least Squares Discriminant Analysis (PLS-DA), Principal Component Regression (PCR) and Hierarchical Cluster Analysis (HCA). Annual averages of the optical properties together with selected physico-chemical properties i.e. aerosol number densities and extinction cross section were determined. The Coupled Ocean and Atmosphere Radiative Transfer (COART) model was used to solve the radiative transfer equation (RTE) for an atmosphere assumed to be purely impacted by aerosols of different sizes and estimated their radiative impacts.

The use of multivariate chemometric techniques revealed that temporal and spatial characteristics of both τ and α over the study sites are modulated by weekly total rainfall, relative humidity, temperature, aerosol hygroscopic properties, aerosol burden, aerosol mode of generation and composition, both local air circulation and urban heat island effects. There was no significant spectral dependence in ω, g and both n and k at zero SZA over the study sites. Comparison of the measured τ and α from AERONET at λ = 500 nm and 440/675 nm respectively was achieved by utilizing Moderate Resolution Imaging Spectrometer (MODIS) data at 550 nm and 470/660 nm. The values agreed to within 12.4 % and 10.9 % levels of accuracy respectively, showing consistency in the two aerosol remote sensing techniques. There was a declining loss in radiant energy with increasing aerosol particle sizes over the sites of study which is associated to increasing heating effect of the incoming solar radiation. Radiative characteristics (spectral irradiance, integrated fluxes, reflectance) over Nairobi depicted temporal variations as influenced by rainfall distribution. There was an increase in up/down irradiance

ratio of spectral irradiance of 2.6 %, 6.7 %, 7.2 % and 2.4 % and a drop of the ratio by 2.7 %, 12.2 %, 50.6 % and 25.6 % for 2007-2008 for λ = 440 nm, λ = 675 nm, λ = 870 nm and λ = 1020 nm respectively for 2006-2007 across all wavelength channels as impacted on by the total amount of rainfall received. Up/down integrated flux ratio remained virtually constant for time considered over each site. Utilizing these data, radiative forcing due to atmospheric aerosols was estimated, and found to remain relatively constant at $0.46\,K/(\mathrm{W/m^2})$ for all the three sites despite the observed differences in the various aerosol particle properties dominating the sites.