



Ain shams university

**Optical characteristic of the atmosphere over Cairo
from sunphotometer measurements**

A thesis

Submitted to faculty of science
Ain shams university
for
The degree of Ph.D.
(Physics)

by

Eman Gaber Hamza

**(B. Sc. Physics, Faculty of Science, south valley
University 1997)**

(M. Sc. Meteorology, Cairo University 2004)

Supervised by

Prof. Dr. M. M. Abdel-Wahab

Astronomy and Meteorology Dept.,

Faculty of Sci. Cairo Univ.

(Egypt)

Dr. M.M. Abdel aal

Ass. Prof. Dr. of Phys.

Phys. Dpt.

Faculty of Girls, for Arts, Sci. and Edu.

Ain shams Univ.

Dr A. Zakey

ICTP Trieste.

Italy



Ain shams university

Approval sheet

Name: ***Eman Gaber Hamza Hassan***

Title: “Optical characteristic of the atmosphere over
Cairo from sunphotometer measurements “

Degree: Ph.D

Supervisors :

1. Dr. M. M. Abdel-Wahab

Prof. Dr. M. M. Abdel-Wahab
Astronomy and Meteorology
Dept.
Faculty of Sci.
Cairo Univ.
(Egypt)

2- Dr. M. M. Abdel aal

Prof. Dr of Phys. Dpt. (Egypt)
Faculty of Girls, for Arts, Sci.
and Education.
Ain shams Univ

3-Dr. A. Zakey

ICTP Trieste Italy

Examiners :

1-

2-

3-

Abstract

This study is based on an analysis of available meteorological data from ground stations in addition to AERONET data.

Recent studies using year (2004–2005) satellite (including Moderate Resolution Imaging Spectroradiometer (MODIS) and ground Aerosol Robotic Network (AERONET) data show strong seasonal variability of aerosol optical depth (AOD) with maximum aerosol loading ($1 > \tau_a > 0.3$) during spring season. A number of major dust storms, originating from western arid and desert regions (west Desert), affect the whole during the season (March–May). Pronounced changes in the aerosol optical parameters, derived from AERONET, have been observed over Cairo University ($30^{\circ} 01' N$, $31^{\circ} .12' E$) during dust storm events (2004–2005). These measurements were recorded by sunphotometer that measures direct sunlight over a narrow range of wavelengths, some sunphotometer use "interference filters" to make a sharp cut off to ensure the measurement at selected of wavelength.

Monthly average values of aerosol optical depth (AOD) showed a pronounced temporal trend, with a maximum AOD during winter and the transition season (spring) at two sites urban areas.

Abstract

Variation of Angstrom exponent (α) with the AOD was clear and the α - value depends on the spectral range used in its determination.

The number of occurrence distribution measurements are carried out at seven stations in Egypt some of these stations are urban/industrial areas, and other is an agricultural area covering the period from Jan 1968 to Dec 2005.

The dust model includes dust emission as a function of (vegetation cover- soil type and texture – soil wetness – friction velocity), dust deposition (wet and dry), horizontal and vertical advection and vertical diffusion through an improved formulation of PBL. One case with very remarkable sandstorms has been described and investigated through this study. The model output for 72 hours were validated and verified with satellite images and visibility as actual data. In addition, the aerodynamic parameters (friction velocity, wind speed and vertical motion for compression) are the main factors in the dust emission. The author concludes that:

- 1) The model had an excellent performance in predicting dust over Egypt during the forecast period when compared with the satellite images and actual visibility.
- 2) The dust storm events are extremely associated with the cold front.

Abstract

- 3) The dust emission start to increase sharply when friction velocity u^* reaches over 0.5 m/s.
- 4) The downward motion was needed to make excitation for the dust to liberate from the soil and then upward motion was the main factor in lifting the dust to different heights according to its intensity and the weight of the parcel.

Acknowledgments

First of all my deep thanks are for Allah who helped and supported me. Special thanks are to my parents and husband for their encouragement, support and love. I am especially grateful to **Prof. Dr. M.M Abdel-Wahab** Professor of Meteorology physics (Cairo Univ.) not only for offering me the chance to work in his lab., but also for his acknowledge for many helpful discussions and for patiently fielding and answering my numerous questions.

In particular **Dr. M.M. Abdal aal** Assistant Prof. of solid state physics (Ain shams Univ.) gave frequent assistance and effective contribution in this work.

I'd like to extend my thanks to **Dr. A. Zakey** Dr of physics (ictp. trieste Italy) for suggesting the work of Optical characteristic and for his overall directions and also for his assistance in the progress of the work during the experimental part.

I gratefully acknowledge **Darwish Prof.** of Meteorology, (Egypt Meteorology authority) not only for his departmental facilities, but also for his keen encouragement, aduices and support throughout the different stages of this work.

Thanks to Abdelhamid alawdi Prof of metrology, (Egypt metrology authority) for his true help and solving many problems.

Eman

Contents

	<i>Subject</i>	<i>Page</i>
	Abstract	
	<u>CHAPTER 1</u> <i>Introduction</i>	
1-	Introduction	1
1-1	Aerosol origins, size Distribution, and Chemical Composition	5
1-2	Aerosol parameter classification	6
1-3	Refractive Indices	7
1-4	Interactions of light and the atmosphere	8
1-4.1	Mass Scattering and Absorption Efficiencies	13
1-5	Influence of hygroscopic growth on light scattering	15
1-6	Impacts of light attenuation by aerosols	16
1-6.1	Visibility reduction	16
1-6.2	Direct radiative forcing by aerosols	17
1-7	Mineral dust	19
1-8	Instrumentation and methodology	20
1-8.1	Data Set Description	27
	<u>CHAPTER 2</u> <i>The system of Reg CM-dust Production</i>	30
2-1	RegCM physics – initial and boundary conditions	31
2-2	Dust parameterizations into RegCM	32
2-2.1	Soil characterizations (soil texture and aggregation)	34
2-2.2	land-surface properties	34

2-2.3 The horizontal mass flux of dust	39
2-2.4 The vertical mass flux of dust	40
2-3. The desert depressions (Sahara cyclones)	42
2-4 Program operation	45
2-5 Program speed	46
2-6 The size distribution	47
2-7 Optical properties of the size distribution	49
2-8 Particles and their growth	52
2-9 Optical indices	54
2-10 Particle concentration	60
2-11 Test cases	60
<u>CHAPTER 3</u> Estimating aerosols from numerical models	69
3-1 Forecasting for dust storms over Egypt from numerical models	
3-2 model description	71
3-2.1 The Time Integration Scheme	74
3-2.2 The Horizontal (Semi-LaGrange) Advection Scheme	76
3-3 Module of the Atmospheric Dust Cycle	79
3-3-1 Dust emission	
3-3-2 Dust Sink	83
3-4 Validation of the dust model	86

CHAPTER 4 *The properties of dust aerosol and reducing tendency of the dust storms in Egypt*

4- 1 The properties of dust aerosol in <i>Egypt</i>	97
4-2 Situation of measurements and instruments in <i>Egypt</i>	100
4-3 Data analysis method	103
4-3.1 The temporal variation of dust aerosol mass concentration and the tendency of the intensity of dust storm in <i>Egypt</i>	103
4-3.2 The optical properties and radiation effects of the dust storms	106
4-3.3. Spatial distributions of various types of dust storm events in all of <i>Egypt</i>	109
4. 4 Dust storm events changes in various regions	116
4-4.1 The stages of dust storm events in each region and their inter annual changes	116
4-4.2. The monthly average of dust aerosol for dust storms from 1968 to 2004 in each region	120
4-5. Effect of wind direction and speed	123
<u>Chapter 5</u> <i>Changes in aerosol parameters during major dust storm events (2004–2005) over Cairo using AERONET</i>	125
5-1 mineral dust and their properties, transport and dynamics.	125

5-2 Optical Characteristics of Dust Storms over Cairo	129
5-3 Statistical Distribution of AOD and α, and their correlation	129
5-4 Diurnal Variation of AOD and Angstrom Exponent	131
5-5 Aerosol characteristics during summer campaign 2005	132
5-6 Characterization of the Aerosol Individual Components	134
5-7. Volume Size Distributions	136
<u>CHAPTER 6</u> <i>summary and discussion</i>	
6-1 Synoptic of the chosen dust-storm case study	149
6-2 Spatial and temporal variation of dust concentration during the case study	155
6-3 Relation of dust emissions with boundary layer height and ventilation index	160
6-4 Comparison of the predicted dust load with both Satellite Images from NOAA and TOMS	165
6-5 Source and Transport of the Dusts	169
<u>7- References</u>	175
<u>8- conclusion</u>	203
<u>9- Arabic abstract</u>	209

Nomenclature

Symbol	Notation
σ_{ep}	Aerosol light extinction coefficient
σ_{sp}	Aerosol light scattering coefficient
σ_{ap}	Aerosol light absorption coefficient
τ	Aerosol optical depth
ω	Aerosol single scattering albedo
σ_{sg}	scattering by gases
σ_{ag}	absorption by gases
I_λ	The light intensities at wavelength λ
$N_m(D_p)$	The mass size distribution function
E_{ext}	mass extinction efficiency
D_p	function particle diameter
ri	refractive index
Q_{scat}	Mie scattering efficiencies
Q_{abs}	Mie absorption efficiencies
X_v	The visual length
D	the fractional day length
T_{at}	the atmospheric transmission
A_c	fractional cloud cover
B	the scatter fraction
$n(D_p)$	the cumulative particle number distribution
D_i	the mean particle radius
$\log \sigma_i$	a measure of particle poly dispersity
Z_h	The roughness element
R_d	the roughness density
$u_t^*(D_p)$	threshold friction velocity

ρ_p	particle density
ρ_a	air density
\mathcal{G}	is gravitational acceleration
u_{ts}^*	the threshold friction velocity
σ_i	standard deviations
e_i	binding energies
K	radius index
P_s	surface pressure
η	vertical velocity
T_V	virtual temperature
q_{DW}	the specific total water content
R_a	the aerodynamic resistance
R_s	the surface layer
R_t	the transfer resistance

- Fig (1.1) : An idealized illustration showing total suspended particles (TSP), as well as fine (PM_{2.5}) and coarse (TSP-PM_{2.5}) particle modes , with their major chemical mass components .
- Fig (1.2) : Mie scattering efficiency (550 nm) for a purely scattering aerosol ($r_i = 1.53$), and the absorption and scattering efficiency for an aerosol that has both scattering and absorbing components ($r_i = 1.53 - 0.66i$).
- Fig (1.3) : Mass scattering efficiency (550 nm) for a purely scattering aerosol ($r_i = 1.53$), and the mass absorption and scattering efficiency for an aerosol that has both scattering and absorbing components ($r_i = 1.53 - 0.66i$)
- Fig (1.4) : The global mean radiative forcing of the climate system for the year 2000, relative to 1750
- Fig (2.1) : The log normal size distribution and its second moment. They are drawn for a distribution with a mode of 0.24 μm , a shape parameter of $\sigma = 1/\sqrt{2}$, and a concentration of 1 particle per cm^3 .
- Fig (2.2) : Optical properties of spherical particles as a function of particle radius according to Mie

theory. The optical indices pertain to a particle made from a mixture of sea salt and water at 80% relative humidity. The optical wavelength is 3.5 μ m.

Fig (2.3) : Growth factors, given by equation (16) and table (2-4), for three particles in the Navy Aerosol Model that change size in response to changes in the relative humidity. The dashed lines indicate the neutral condition.

Fig (2.4) : The real part of the optical index for dust as a function of optical wavelength. The solid circles are tabulated values from the literature, and the lines connecting them were generated by linear interpolation within the NAM6 code

Fig (2.5) : The imaginary part of the optical index for dust as a function of optical wavelength. The solid circles are tabulated values from the literature, and the line connecting them were generated by linear interpolation with the NAM6 code.

Fig (2.6) : The real part of the optical index for B1 aerosol.

Fig (2.7) : The imaginary part of the optical index for B1 aerosol.

Fig (2.8) : The real part of the optical index for sea salt.