UNIVERSIDAD DE GRANADA
FACULTAD DE CIENCIAS
DEPARTAMENTO DE FÍSICA APLICADA
GRUPO DE INVESTIGACIÓN DE FÍSICA DE LA ATMÓSFERA - IISTA

Exploring aerosol-cloud interaction in the atmospheric column using improved remote sensing methods

PhD. Dissertation

María Soledad Fernández Carvelo
PhD candidate
Universidad de Granada

Thesis director: Cat. Lucas Alados Arboledas
Catedrático de la Universidad de Granada
Thesis director: Dr. Juan Antonio Bravo Aranda
Profesor Titular de la Universidad de Granada

2026

UNIVERSIDAD DE GRANADA
FACULTAD DE CIENCIAS
DEPARTAMENTO DE FÍSICA APLICADA
GRUPO DE INVESTIGACIÓN DE FÍSICA DE LA ATMÓSFERA - IISTA

Exploring aerosol-cloud interaction in the atmospheric column using improved remote sensing methods

PhD. Dissertation

María Soledad Fernández Carvelo
PhD candidate
Universidad de Granada

Thesis director: Cat. Lucas Alados Arboledas
Catedrático de la Universidad de Granada
Thesis director: Dr. Juan Antonio Bravo Aranda
Profesor Titular de la Universidad de Granada

2026

Tribunal nombrado por el Magfco. y Excmo. Sr. Rector de la Universidad Politécnica de Madrid, el día ___ de _____ de 202X.

Presidente: PhD jury committee 1.

Secretario: PhD jury committee 2.

Vocal: PhD jury committee 3.

Vocal: PhD jury committee 4.

Vocal: PhD jury committee 5.

Suplente: PhD jury committee 6.

Suplente: PhD jury committee 7.

Opta a la mención de "Doctor Internacional"

Evaluadores de organizaciones internacionales:

Reviewer 1, Institution, Country.

Reviewer 2, Institution, Country.

Realizado el acto de defensa y lectura de la Tesis el día ___ de _____ de 202X en la E. T. S. Ingenieros Industriales.

CALIFICACIÓN:

EL PRESIDENTE LOS VOCALES

EL SECRETARIO

The research leading to this doctoral dissertation has received funding from the following programs.

Abstract

Abstract (English version).

Resumen (Spanish)

Resumen (versión en español).

Acknowledgements

Time to say thank you!

Contents

I INTRODUCTION **1**

1 State of the art **3**

2 Objectives of this Thesis **5**

3 Layout of this Thesis **7**

II FUNDAMENTALS **9**

4 Aerosol and climate **11**

5 Atmosphere structure and properties **13**

6 Radiation-atmosphere interaction **15**
6.1 Elastic scattering 15
6.2 Extinction 15
6.3 Raman scattering 15
6.4 Absorption 15
6.5 Radiative transfer equation 15

7 Atmospheric aerosol characterization **17**

8 Atmospheric aerosol properties **19**
8.1 Optical properties 19
8.2 Microphysical properties 19

9 Lidar technique **21**
9.1 Principle and ecuation 21
9.2 Aerosol intensive properties 21
9.3 Depolarization lidar 21
9.4 Fluorescence lidar 21

III INSTRUMENTATION 23

10 ALHAMBRA lidar system 25

11 Setup of the ALHAMBRA lidar system 27
11.1 Overlap function retrieval 27
11.2 Depolarization optical elements adjustment 27
11.3 Vibrational and rotational Raman channels characterization 27
11.4 Bandwidth filter fluorescence channel calibration 27
11.5 Spectrometer coupling fluorescence channel characterization 27

12 Quality Assurance of the ALHAMBRA lidar system 29
12.1 Rayleigh-fit 29
12.2 Telecover test 29
12.3 Depolarization calibration 29
12.4 Zero bin 29

IV METHODOLOGY 31

13 Lidar data preprocessing 33
13.1 Dead time correction 33
13.2 Trigger delay correction 33
13.3 Background subtraction 33
13.4 Overlap correction 33
13.5 Analog and photocounting signals gluing 33
13.6 near- and far-field signals gluing 33

14 Inversion retrievals 35
14.1 Elastic retrieval: Klett method 35
14.2 Inelastic retrieval: Raman method 35

15 Depolarization retrieval 37

16 Fluorescence retrieval 39

V CONCLUSIONS AND FUTURE WORK 41

17 Conclusions 43

18 Future work 45

BIBLIOGRAPHY 47

A APPENDIX 49
A.1 APPENDIX I 49

List of Figures

13.1 Figure caption. 34

List of Tables

14.1 Table caption. 35

Abbreviations

EOA	Example of Abbreviation.

Part I

INTRODUCTION

1 State of the art

Background of your work.

This is an example of a reference (Croff 1983).

2 Objectives of this Thesis

Main goals and contributions arising from this Thesis.

3 Layout of this Thesis

This Thesis is divided into five Parts, with several related Chapters in each of them. Firstly, Part I establishes the framework and background of this Thesis and presents the original contributions and outcomes.

Part **??** corresponds to the description of the fundamentals that applies to this work...

Part II

FUNDAMENTALS

Aerosol and climate

4

5 Atmosphere structure and properties

6 Radiation-atmosphere interaction

6.1 Elastic scattering

6.2 Extinction

6.3 Raman scattering

6.4 Absorption

6.5 Radiative transfer equation

7

Atmospheric aerosol characterization

8 Atmospheric aerosol properties

8.1 Optical properties

8.2 Microphysical properties

9 Lidar technique

9.1 Principle and ecuation

9.2 Aerosol intensive properties

9.3 Depolarization lidar

9.4 Fluorescence lidar

Part III

INSTRUMENTATION

10 ALHAMBRA lidar system

11 Setup of the ALHAMBRA lidar system

11.1 Overlap function retrieval

11.2 Depolarization optical elements adjustment

11.3 Vibrational and rotational Raman channels characterization

11.4 Bandwidth filter fluorescence channel calibration

11.5 Spectrometer coupling fluorescence channel characterization

12 Quality Assurance of the ALHAMBRA lidar system

12.1 Rayleigh-fit

12.2 Telecover test

12.3 Depolarization calibration

12.4 Zero bin

Part IV

METHODOLOGY

13 Lidar data preprocessing

13.1 Dead time correction

13.2 Trigger delay correction

13.3 Background subtraction

13.4 Overlap correction

13.5 Analog and photocounting signals gluing

13.6 near- and far-field signals gluing

Let's include Figure 13.1 as an example.

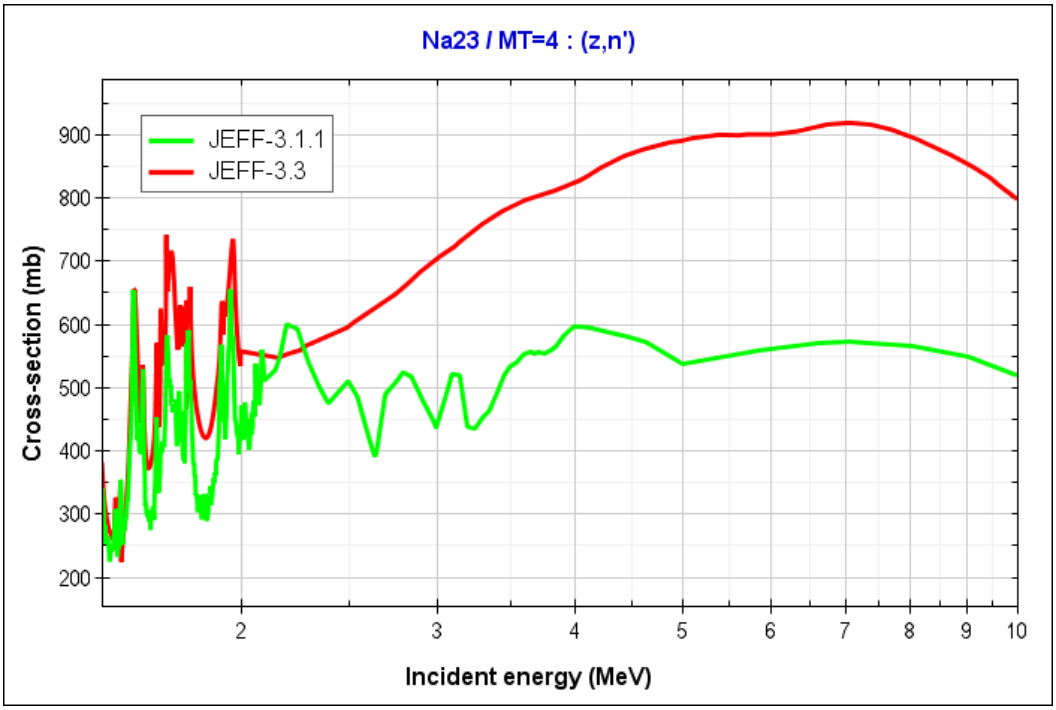

Fig. 13.1.: Figure caption.

14 Inversion retrievals

14.1 Elastic retrieval: Klett method

14.2 Inelastic retrieval: Raman method

Let's include Table 14.1 as an example.

Tab. 14.1.: Table caption.

X1	X2	X3	X4	X5
Y1	XY1	XY2	XY3	XY4

15 Depolarization retrieval

16 Fluorescence retrieval

Part V

CONCLUSIONS AND FUTURE WORK

17 Conclusions

Conclusions and main outcomes of work carried out in this Thesis.

18 Future work

As a continuation of the work carried out in this Thesis, the following lines are identified for further research.

Bibliography

Croff, A. G. (1983). “ORIGEN2: A Versatile Computer Code for Calculating the Nuclide Compositions and Characteristics of Nuclear Materials”. In: *Nuclear Technology* 62.3, pp. 335–352. DOI: 10.13182/NT83-1 (cit. on p. 3).

APPENDIX A

A.1 APPENDIX I