

BIRA • IASB 1964 • 2014



50 YEARS OF RESEARCH
AT THE BELGIAN INSTITUTE
FOR SPACE AERONOMY



EDITORIAL BOARD

Direction Board

Martine De Mazière, Johan De Keyser and Didier Fussen

Scientific Board

Crist Amelynck, Christine Bingen, Simon Chabrilat,
Frank Daerden, Johan De Keyser, Martine De Mazière,
Didier Fussen, Michel Kruglanski, Karolien Lefever,
Didier Moreau, Jean-François Müller, Eddy Neefs,
Viviane Pierrard, Paul C. Simon, Michel Van Roozendael
and Ann Carine Vandaele.

Editorial Support

Stéphanie Fratta, Sophie Robyns, Umar Sayyed
and Tim Somers

Responsible Editor

Belgisch Instituut voor Ruimte-Aeronomie -
Institut d'Aéronomie Spatiale de Belgique (BIRA-IASB)

FOREWORD

This book was written on the occasion of the 50th anniversary of the Belgisch Instituut voor Ruimte-Aeronomie - Institut d'Aéronomie Spatiale de Belgique (BIRA-IASB). It is intended to present a large part of the scientific studies carried out during 50 years at BIRA-IASB. This is neither an exhaustive activity report nor a scientific textbook on aeronomy.

The addressed topics illustrate the historical evolution of scientific researches in the field of aeronomy since its infancy, in the sixties. Only a minority of topics is not reported.

Special thanks go to all external authors:

Guy Brasseur, Dirk Frimout, Ghislain Grégoire, William A. Lahoz, Marie-Claude Limbourg and Jean-Pierre Pommereau.

Their affiliation is mentioned explicitly in the book. All other authors and contributors are from BIRA-IASB or have been working there until their retirement. The authors are responsible for the content of their chapters and sections..

BIRA-IASB gratefully acknowledges the financial support received for this publication from the Federal Public Planning Service Science Policy, also known as Belgian Science Policy (BELSPO).



TABLE OF CONTENTS

FOREWORD		3
1. PREFACE	Dirk Frimout	12
2. SPACE AERONOMY: A HISTORICAL INTRODUCTION	Paul C. Simon	18
3. THE SUN AND THE EARTH'S ENVIRONMENT	Paul C. Simon	32
INTRODUCTION	Paul C. Simon, Viviane Pierrard and Joseph Lemaire	34
THE SUN	Paul C. Simon	35
ULTRAVIOLET SOLAR IRRADIANCE AND ATMOSPHERIC PROCESSES	Paul C. Simon	38
SOLAR ULTRAVIOLET IRRADIANCE VARIABILITY	Paul C. Simon	40
SOLAR WIND	Viviane Pierrard and Joseph Lemaire	42
4. THE MAGNETOSPHERE: FROM FIRST DISCOVERIES TO CURRENT RESEARCH	Johan De Keyser	46
INTRODUCTION	Johan De Keyser	48
THE MAGNETOSPHERE	Johan De Keyser	49
THE PLASMASPHERE	Joseph Lemaire and Viviane Pierrard	52
THE IONOSPHERE AND ITS COUPLING TO THE MAGNETOSPHERE	Johan De Keyser and Michel Roth	56
ENERGETIC PARTICLES IN SPACE	Norma Crosby	62
5. FROM THE UPPER ATMOSPHERE TO THE TROPOSPHERE: THEORIES AND MODELS	Jean-François Müller and Simon Chabrilat	66
INTRODUCTION	Simon Chabrilat and Guy Brasseur (MPI-M, NCAR)	68
THE UPPER ATMOSPHERE: THE REALM OF SATELLITES	Simon Chabrilat, Guy Brasseur (MPI-M, NCAR) and Paul C. Simon	72

THE MESOSPHERE AND LOWER THERMOSPHERE: TRANSITION REGIONS AND CURRENT RESEARCH	Simon Chabrilat and Guy Brasseur (MPI-M, NCAR)	75
THEORETICAL AND MODELLING STUDIES OF THE STRATOSPHERE	Sébastien Viscardy and Quentin Errera	78
TROPOSPHERIC MODELLING	Jean-François Müller and Trisseygeni Stavrou	82
6. BALLOON OBSERVATIONS	Crist Amelynck and Paul C. Simon	86
INTRODUCTION	Jean-Pierre Pommereau (LATMOS)	88
SOLAR ULTRAVIOLET RADIATION	Paul C. Simon	91
INFRARED REMOTE SENSING FROM STRATOSPHERIC BALLOONS	Christian Muller	93
BALLOON INTERCOMPARISON CAMPAIGNS	Jean-Pierre Pommereau (LATMOS) and Paul C. Simon	96
MASS SPECTROMETRY	Crist Amelynck and Niels Schoon	99
7. FIRST ORBITAL OBSERVATIONS	Paul C. Simon	102
SPACELAB 1 AND ATMOSPHERIC LABORATORY FOR APPLICATIONS AND SCIENCE MISSIONS	Paul C. Simon	104
THE GRILLE SPECTROMETER	Christian Muller	107
THE SOLAR SPECTRUM EXPERIMENT	Paul C. Simon and Didier Gillotay	109
INVESTIGATION OF ATMOSPHERIC HYDROGEN AND DEUTERIUM THROUGH MEASUREMENT OF LYMAN-ALPHA EMISSION	Paul C. Simon	112
THE EUROPEAN RETRIEVABLE CARRIER	Paul C. Simon	114
REMOTE SENSING OF THE EARTH'S ATMOSPHERE BY THE SPACEBORNE OCCULTATION RADIOMETER	Didier Fussen and Filip Vanhellemont	115
THE SOLAR SPECTRUM INSTRUMENT ON BOARD EURECA	Paul C. Simon	117
8. SATELLITE OBSERVATIONS	Paul C. Simon	118
INTRODUCTION	Paul C. Simon	120
THE GLOBAL OZONE MONITORING EXPERIMENT	Jean-Christopher Lambert and Paul C. Simon	125

THE ENVIRONMENTAL SATELLITE		129
THE SCANNING IMAGING ABSORPTION SPECTROMETER FOR ATMOSPHERIC CHARTOGRAPHY: 10 YEAR MEASUREMENTS OF OUR CHANGING ATMOSPHERE	Jean-Christopher Lambert	131
GLOBAL OZONE MONITORING BY OCCULTATION OF STARS ON BOARD ENVISAT: 10 YEARS OF STELLAR OCCULTATIONS	Didier Fussen, Filip Vanhellemont and Cédric Tétard	133
THE GLOBAL OZONE MONITORING EXPERIMENT-2 ON BOARD METOP: GLOBAL MONITORING OF TOTAL OZONE AND THE TROPOSPHERIC COMPOSITION	Michel Van Roozendael	136
THE INFRARED ATMOSPHERIC SOUNDING INTERFEROMETER	Sophie Vandebussche and Evelyn De Wachter	138
MULTI-SPACECRAFT EXPLORATION OF THE MAGNETOSPHERE WITH CLUSTER	Johan De Keyser	140
THE SOLAR SPECTRUM EXPERIMENT ON BOARD THE INTERNATIONAL SPACE STATION	David Bolsée and William Peetermans	143
THE ATMOSPHERIC CHEMISTRY EXPERIMENT	Martine De Mazière and Didier Fussen	145
THE ENERGETIC PARTICLE TELESCOPE INSTRUMENT	Viviane Pierrard and Ghislain Grégoire (UCL)	147
THE ATMOSPHERIC LIMB TRACKER FOR THE INVESTIGATION OF THE UPCOMING STRATOSPHERE MISSION: THE FIRST BELGIAN SOUNDER OF THE EARTH ATMOSPHERE	Didier Fussen, Emmanuel Dekemper, Didier Pieroux, and Filip Vanhellemont	150
THE PICOSATELLITE FOR ATMOSPHERIC AND SPACE SCIENCE OBSERVATIONS MISSION: TOWARD GEOPHYSICAL MEASUREMENTS FROM MINIATURIZED SPACE SENSORS	Didier Fussen, Didier Pieroux, Sylvain Ranvier and Johan De Keyser	153
9. THE ENDANGERED OZONE LAYER		
INTRODUCTION	Paul C. Simon	156
THE SUPERSONIC AIRCRAFT THREAT TO THE OZONE LAYER	Guy Brasseur (MPI-M, NCAR) and Paul C. Simon	158
THE HALOCARBON THREAT AND POLAR OZONE	Christian Muller	161
OZONE AND CLIMATE CHANGES	Paul C. Simon	163
	Martine De Mazière	168

10. GROUND-BASED AND IN SITU OBSERVATIONS		
INTRODUCTION	Martine De Mazière and Michel Van Roozendael	170
THE NETWORK FOR THE DETECTION OF ATMOSPHERIC COMPOSITION CHANGE	Martine De Mazière, Michel Van Roozendael, Crist Amelynck and Hervé Lamy	172
THE TOTAL CARBON COLUMN OBSERVING NETWORK	Martine De Mazière and Filip Desmet	174
THE BELGIAN SOLAR UV-VISIBLE MONITORING NETWORK	Didier Gillotay	181
TROPOSPHERIC TRACE GAS MONITORING USING MAXDOAS	Michel Van Roozendael and François Hendrick	184
BIOGENIC VOLATILE ORGANIC COMPOUNDS	Crist Amelynck and Niels Schoon	186
SATELLITE VALIDATION	Jean-Christopher Lambert	189
BELGIAN RADIO METEOR STATIONS	Hervé Lamy	192
MAPPING AIR QUALITY FROM AN UNMANNED AERIAL VEHICLE	Alexis Merlaud and Michel Van Roozendael	194
11. LABORATORY STUDIES		
INTRODUCTION	Ann Carine Vandaele and Crist Amelynck	198
MOLECULAR OXYGEN ABSORPTION CROSS SECTION BETWEEN 175 AND 205 NM	Ann Carine Vandaele and Crist Amelynck	200
HALOCARBONS ABSORPTION CROSS SECTIONS	Paul C. Simon	202
ATMOSPHERIC TRACE CONSTITUENTS	Didier Gillotay and Paul C. Simon	203
CHEMICAL IONIZATION STUDIES OF ATMOSPHERIC COMPOUNDS	Ann Carine Vandaele and Christian Hermans	206
	Crist Amelynck and Niels Schoon	208
12. AEROSOLS, FROM PIONEERING WORK TO GLOBAL SURVEY		
INTRODUCTION	Christine Bingen	211
AEROSOL BALLOON FLIGHTS	Christine Bingen	212
STRATOSPHERIC SATELLITE OBSERVATIONS: OCCULTATION AND IMAGING INSTRUMENTS	Christian Muller and Christine Bingen	214
	Filip Vanhellemont	217

TWILIGHT OBSERVATIONS	Nina Mateshvili	221
CHARACTERIZATION OF STRATOSPHERIC AEROSOLS	Christine Bingen and Christian Muller	224
TROPOSPHERIC REMOTE SENSING OBSERVATIONS BY INFRARED ATMOSPHERIC SOUNDING INTERFEROMETER	Sophie Vandebussche	227
<hr/>		
13. PLANETARY ATMOSPHERES	Ann Carine Vandaele and Frank Daerden	230
INTRODUCTION	Ann Carine Vandaele and Frank Daerden	232
THE PHOBOS OBSERVATIONS	Christian Muller	234
MARTIAN ATMOSPHERE EXPLORATION WITH MARS EXPRESS	Nina Mateshvili and Eddy Neefs	236
VENUS ATMOSPHERE EXPLORATION WITH VENUS EXPRESS	Ann Carine Vandaele and Eddy Neefs	239
NADIR AND OCCULTATION FOR MARS DISCOVERY AND EXOMARS	Ann Carine Vandaele and Eddy Neefs	243
REMOTE SENSING OF AEROSOLS ON MARS AND VENUS	Valérie Wilquet	245
MODELLING OF PLANETARY ATMOSPHERES	Frank Daerden	247
MASS SPECTROMETRY ON ROSETTA	Johan De Keyser and Frederik Dhooghe	249
<hr/>		
14. SCIENCE AND APPLICATIONS	Michel Kruglanski	252
SATELLITE TRAJECTORY FORECASTING	Paul C. Simon	254
SPACE WEATHER	Michel Kruglanski and Neophytos Messios	256
CHEMICAL DATA ASSIMILATION	Quentin Errera, William A. Lahoz (NILU) and Simon Chabrilat	260
DETECTION OF VOLCANIC ERUPTIONS	Nicolas Theys and Hugues Brenot	263
<hr/>		
15. TECHNICAL SUPPORT AND EXPERTISE	Eddy Neefs, Jeroen Maes, Sophie Berkenbosch, and Johan Bulcke	266
INTRODUCTION	Eddy Neefs and Johan Bulcke	268
INFORMATION TECHNOLOGY	Johan Bulcke	269

ELECTRONICS, SOFTWARE AND FIRMWARE DEVELOPMENT	Eddy Neefs, Sophie Berkenbosch and Dennis Nevejans	272
MECHANICAL DESIGN AND CONSTRUCTION	Eddy Neefs, Jeroen Maes, Sophie Berkenbosch, Emiel Van Ransbeeck and Dennis Nevejans	274
IMPORTANT CONTRIBUTIONS TO SCIENCE INSTRUMENTATION	Eddy Neefs, Jeroen Maes and Sophie Berkenbosch	275
<hr/>		
16. SPACE OPERATIONS AND KNOWLEDGE MANAGEMENT	Didier Moreau	278
INTRODUCTION	Christian Muller and Didier Moreau	280
THE ATLAS MISSION OPERATIONS: THE SPACE REMOTE OPERATION CENTRE	Didier Moreau and Christian Muller	281
THE BELGIAN USER SUPPORT AND OPERATIONS CENTRE	Didier Moreau and Marie-Claude Limbourg	282
ODISSEA AND CERVANTES MISSIONS	Marie-Claude Limbourg and Didier Moreau	283
SOLAR AND THE ATMOSPHERIC SPACE INTERACTION MONITORING INSTRUMENT	Alice Michel and Nadia This	284
PICARD	Michel Anciaux and Claudio Queirolo	285
MULTI-PURPOSE END-TO-END ROBOTIC OPERATION NETWORK TELEROBOTICS	Karim Litefti and Rachid Abjj	287
PREPARING THE LONG TERM SPACE DATA PRESERVATION	Christian Muller and Didier Moreau	288
<hr/>		
17. CONCLUSIONS AND PERSPECTIVES	Martine De Mazière, Johan De Keyser, and Didier Fussen	290
<hr/>		
LIST BIRA-IASB PERSONNEL		298
ACRONYMS		300



BEIGSCH INSTITUUT VOOR RUIMTE-AERONOME (BIRA) INSTITUTE D'AERONOME SPATALE DE BELGQUE (IASB) BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB) BELGICH INSTITUUT VOOR RUIMTE-AERONOME (BIRA) INSTITUT D'AERONOME SPATALE DE BELGQUE (IASB)

PREFACE

Dirk Frimout



Space Shuttle launch (credit: NASA)

At the time when the Belgian Institute for Space Aeronomy was created, aeronomy was a science relatively unknown to the general public. The term aeronomy was first introduced in 1946 by Professor Sydney Chapman, assigned in 1953 as President of the Special Committee for the International Geophysical Year (IGY) in 1957-58, who defined it as *the science of the upper region of the atmosphere, where dissociation and ionization are important*. Most fittingly, it is during the IGY that the space age begins with the launch of the first artificial satellite, Sputnik, by the USSR.

Located next to the Royal Observatory and the Royal Meteorological Institute in Uccle the Belgian Institute for Space Aeronomy was created in 1964 under the initiative of Professor Baron Marcel Nicolet with the full support of King Baudouin. Professor Nicolet was an internationally well-known scientist of the Meteorological Institute, who in 1953 was assigned as Secretary-General of the IGY and whose achievements in scientific research and administration earned him honors such as the Guggenheim prize.

Professor Nicolet became the first director of the Belgian Institute for Space Aeronomy. The Institute commenced its activities on the 1st of January 1965, provisionally in a building of the Meteorological Institute, but later on it moved into its own buildings. Following the IGY, Professor Nicolet had been able to gather around him a young, ambitious team of collaborators and the closest formed the first core of the scientific personnel. Building on his international experience, he insisted that the Institute be multidisciplinary, meaning, composed of a strong theoretical division, that worked closely together with an experimental group, with the support of a technical division. This approach enabled the Institute to make use of the new space age technologies to perform in situ measurements in the high atmosphere.

As a young engineer, I started my career in this newly created institute. Also to me, aeronomy was an unknown science. All I knew was that it studied the higher atmosphere and that space experiments would be required to fulfill this task. That aspect of the job was very attractive to me. The young Institute started with plenty of ambition, but with a limited budget. Under the leadership of Dr. Baron Marcel Ackerman, we built instruments to perform space experiments, but with our lack of experience and money, we could not make use of sounding rockets or satellites, that had become the international standard at that time. Fortunately, because of the international relations of Prof. Nicolet and Dr. Ackerman and their contacts with the CNES in France, we could perform experiments with stratospheric balloons. These balloons, with a volume of up to 300 000 m³, could carry a payload weighing up to 300 kg to an altitude of 40 km where it could perform measurements in the stratosphere during several hours. Stratospheric balloons were called the “satellites of the poor” but they fitted very well our research which focused on the stratosphere. Our experimental research concerned a priori the study of the ozone layer and the ultraviolet light of the Sun, both not measurable with Earth-based experiments.

In 1970, the scientific emphasis moved worldwide to the problem of global pollution in the stratosphere, especially the chlorofluorocarbons and nitric oxides. This was partly triggered by an economic interest as big airplane producers like Aérospatiale in France and Boeing in USA, planned the construction of supersonic airplanes, intended to fly in the stratosphere. People were afraid that soon a large flotilla of supersonic airplanes, such as the Concorde, would fly daily over the ocean between Europe and America and that the exhaust of nitric oxides would attack the ozone layer. This would have a major impact on our atmosphere. With the experience of stratospheric balloons, the Belgian Institute for Space Aeronomy was in a good position to perform the required measurements and so, the Institute added the measurement of vertical profiles of a number of important minor constituents by absorption measurements in the near infrared part of the spectrum to its experimental program. A close collaboration was started with ONERA in France, who had developed an instrument, specially adapted for this purpose: the Grille Spectrometer. With this instrument, vertical profiles of several minor constituents could be measured at different latitudes. This allowed us to acquire quite some data, important for verification of the mathematical models developed by the theoreticians in the Institute. All these results contributed to the study of the greenhouse effect and the global warming of the Earth. The arrival of the Space Shuttle allowed for the first time to perform global measurements, and hence, the Grille Spectrometer was proposed to fly on the joint NASA-ESA mission Spacelab I.



Dirk Frimout presenting the mockup of the Space Shuttle and Spacelab in the cargo bay.



Dirk Frimout during the Atlas 1 mission.

In collaboration with CNRS in France, the Belgian Institute for Space Aeronomy had also developed two other instruments, SOLSPEC and ALAE, both of which performed measurements of the Sun, and that were selected for the Spacelab 1 mission as well. In this way, the Institute was involved in three experiments on the Spacelab 1 flight in November 1983. They all were successful and brought a quantity of good data for the modelling of the stratosphere. All three experiments flew a second time on the ATLAS 1 mission in 1992. I was proud to have these experiments on board and to be able to control their good functioning during the flight.

Since then, the Belgian Institute for Space Aeronomy has evolved and has become more and more international. Many new groups were created within the Institute and have contributed to its international recognition. The activities and the research results related to the magnetosphere and plasma physics, to mass spectrometry, to planetary atmospheres and to so many other subjects, are all discussed in this publication.

The success behind this young institute is due to many factors, first of all the well-chosen multidisciplinary composition of the team of scientists, technicians and support teams, all delivering high-quality work. From the beginning, there was contact and collaboration with leading institutes from all over the world. The Institute got involved in and contributed to many international projects. It was a homogeneous team of young scientists with an experienced leadership and most of all with the necessary commitment and sense of adventure. This policy continued with the new generation of young scientists that took the torch from the first generation. The research has extended towards the atmospheres of the planets Mars and Venus. There are continuously new challenges, which will always attract young scientists.

I personally have many reasons to thank the Belgian Institute for Space Aeronomy. Specifically, I had the opportunity to expand my talents, which included preparing a doctoral thesis and spending a postdoctoral year at the University of Colorado in the United States. For many years, I was lucky to work in a highly qualified team of scientists, with dedicated technicians and with good administrative support. Together we got to know the sweetness of success during the launch campaigns, but also the deceptions of failures.

The Belgian Institute for Space Aeronomy was also my springboard to space. Thanks to their support, I got the unique opportunity to become a candidate to participate in the ATLAS 1 mission, and this support never ceased. Even when I left the Institute, I still felt closely linked to it. I continued to follow their successes. I still admire their creativity, their dedication and their scientific performances. I know that I can always count on their expertise when I need information. On the occasion of this 50th anniversary, I want to thank them all for the help they have given. Congratulations to the young, dynamic team that is taking care of the continuity and future of the Institute.



Dirk Frimout working in the upper deck of the Shuttle during the ATLAS 1 mission.

2

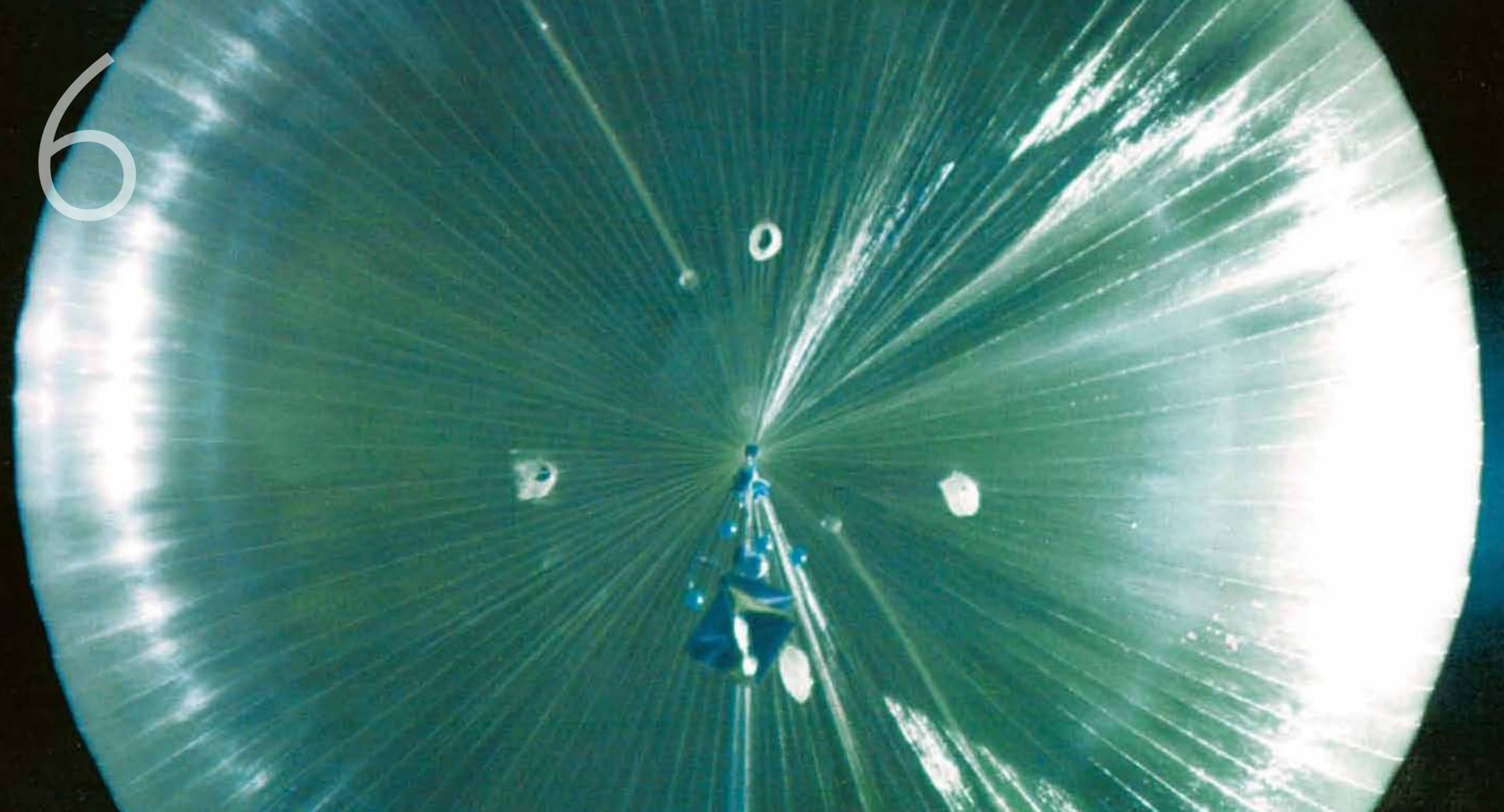


BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB) BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB) BELGIECH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB)

“If we long for our planet to be important, there is something we can do about it. We make our world significant by the courage of our questions and the depth of our answers”
(Carl Sagan)

SPACE AERONOMY: A HISTORICAL INTRODUCTION

Paul C. Simon

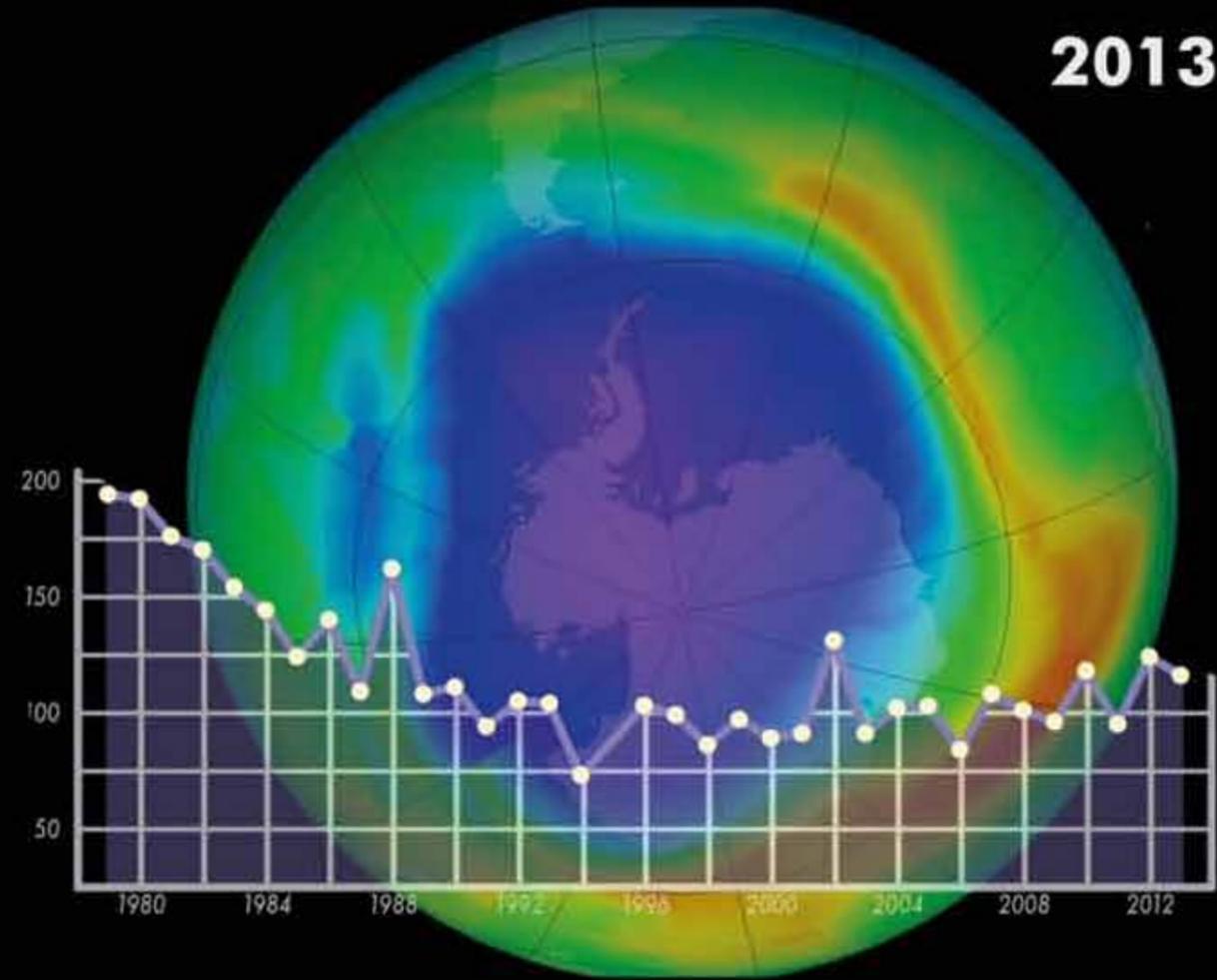


BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB) BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB) BELGIECH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB)

BALLOON OBSERVATIONS

Christ Amelinck and Paul C. Simon

Ozone Concentration



BELEGCH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB) BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB) BELGIECH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) INSTITUUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB)

THE ENDANGERED OZONE LAYER

Paul C. Simon



BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) / INSTITUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB) / BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB) / BELGISCH INSTITUUT VOOR RUIMTE-AERONOMIE (BIRA) / INSTITUT D'AERONOMIE SPATIALE DE BELGIQUE (IASB)

TECHNICAL SUPPORT AND EXPERTISE

Eddy Neefs, Jeroen Maes, Sophie Berkenbosch and Johan Bulcke

Science is moving from one astonishment to another. Aristoteles

