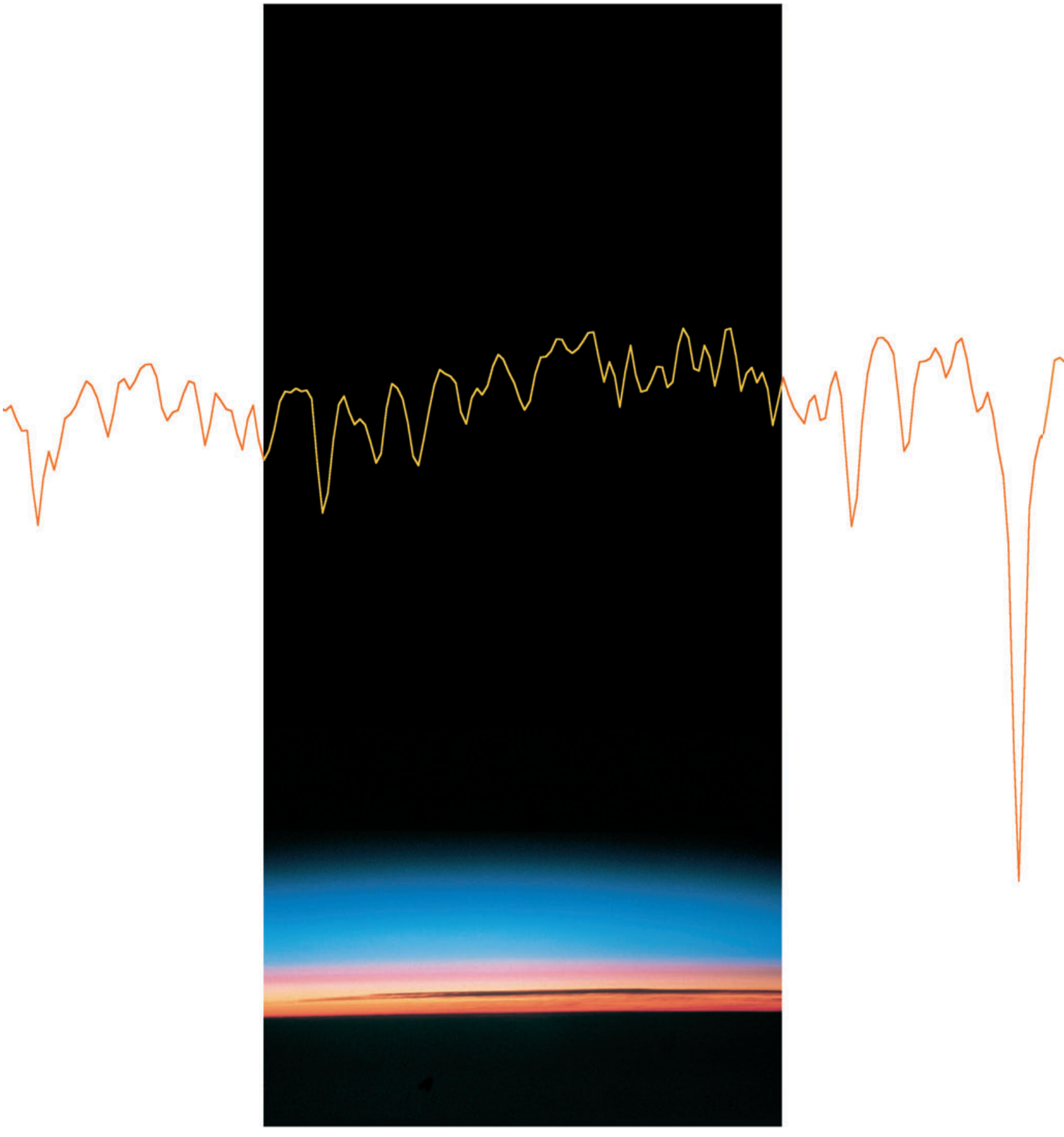
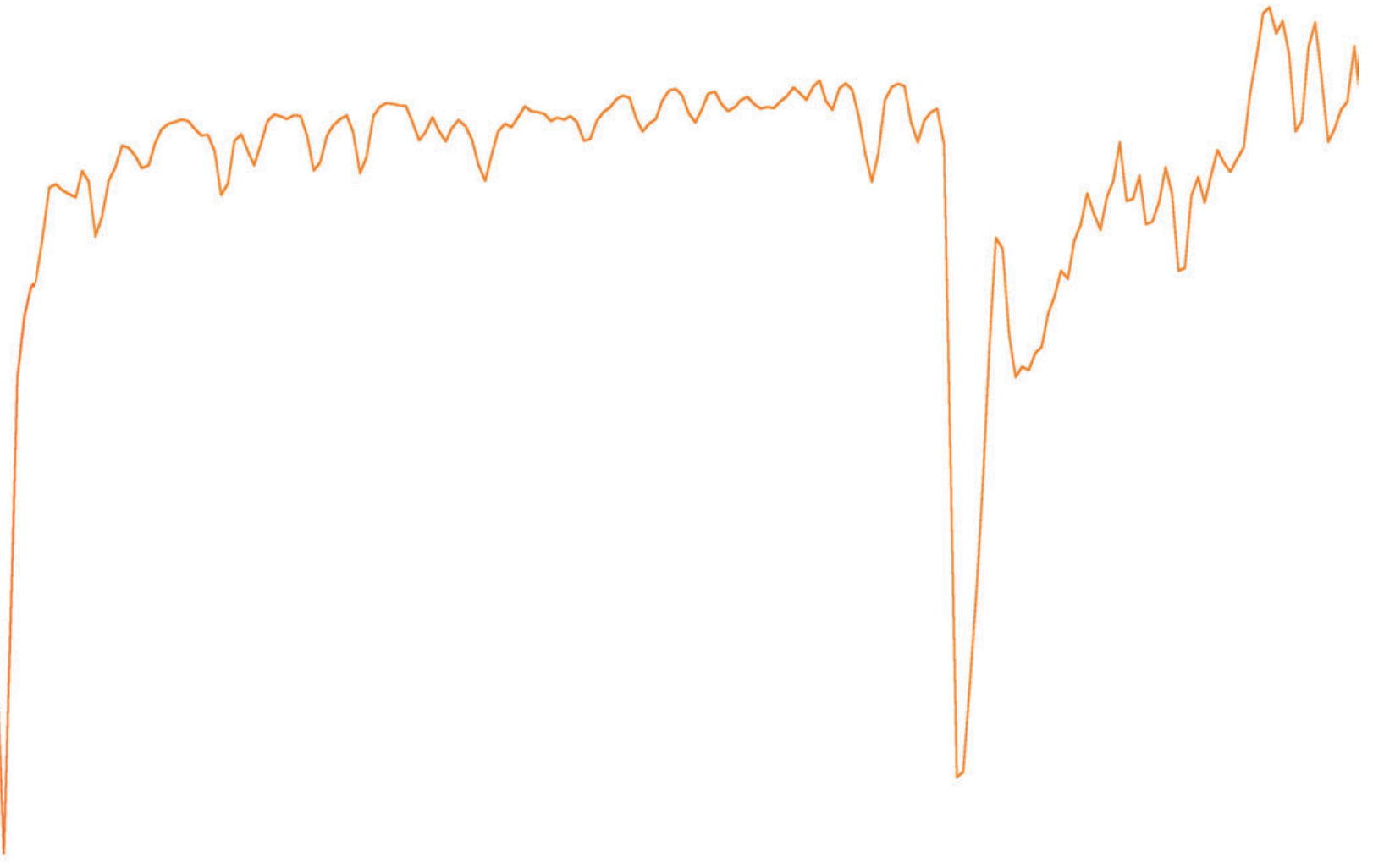
SCIAMACHY



SCIAMACHY

MONITORING THE CHANGING EARTH'S ATMOSPHERE



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Cover:
Earth's atmosphere geophysical parameters as seen by SCIAMACHY. Overlaid on a global NO_2 distribution are examples of tropospheric maps. The corresponding results can be found in chapter 10 together with their references.

Frontispiece:
The Earth's stratosphere as seen from the Space Shuttle. Overlaid is a part of an Earthshine spectrum as recorded by SCIAMACHY (Shuttle photo: NASA, graphics: DLR-IMF)

Editorial

The atmospheric science instrument SCIAMACHY on ESA's ENVISAT mission was one of the major spaceflight developments in Germany, The Netherlands and Belgium in the past decade. With its launch in 2002 on-board ENVISAT, SCIAMACHY began to yield new insights into the Earth's atmosphere.
Instrument providing agencies, principal investigators and the science team decided that – based on SCIAMACHY's success – it is well justified and an appropriate time to report about the SCIAMACHY mission to the interested scientific and general public. This publication is intended to tell the story of SCIAMACHY – from the very first ideas to its present in-orbit status. The targeted readership are not only the existing and potentially new SCIAMACHY data users but anyone who is keen to learn about SCIAMACHY's efforts to study the atmosphere and its responses to both, natural phenomena and anthropogenic effects. This includes managers, politicians, students, the press and the general public.

The first chapter explains briefly why it is necessary to make measurements from low-Earth orbit to study the atmosphere. The global views from an altitude of several hundred kilometers open new windows to observe large-scale phenomena which are of prime importance to understand today's changing atmosphere and climate. This introductory chapter sets the stage for the rest of the publication. Having summarised why SCIAMACHY was selected to fly in orbit, chapter 2 takes a closer look at the ENVISAT mission, which hosts SCIAMACHY. The purpose of chapter 2 is also to describe those aspects of ENVISAT's ground segment which are of relevance to the SCIAMACHY mission. The location and environment on the platform determines many aspects of the instrument's design and operation. Similarly the concepts for data downlink and handling in the ground segment specify how measurement data is received, processed and disseminated in general.

A detailed description of the instrument concept is the subject of chapter 3. It permits insight into optical, thermal and electronic subsystems. Main emphasis is given to the optical paths since these collect and generate the spectral signals containing the information on geophysical parameters. In order to provide the reader with an idea about the challenges of instrument development, chapter 3 also outlines the history of the development of SCIAMACHY. Without a flexible operations concept however, all the functionalities built into the instrument would have been in vain. How SCIAMACHY is operated in-orbit can be found in chapter 4. The selected approach allows, despite the instrument complexity, full exploitation of its capabilities in a well structured operations environment thus supporting the need for long, stable measurements as required for relevance to climate research. In chapter 5, the various steps necessary to calibrate the instrument, on-ground and in-orbit, are presented. Calibration is required to fully characterise the optical paths. Additionally, chapter 5 also addresses optical performance monitoring which permits quantification of the degradation of optical components. Calibration and monitoring together ensure that the recorded signals are transformed into well calibrated spectra – a prerequisite for retrieving geophysical parameters with high accuracy over the full mission lifetime.

Chapter 6 brings the more technical part of the publication to a close. It describes the first years of SCIAMACHY in space, starting with launch and the Commissioning Phase and ending with more than 3 years of routine measurements. Several instrument characteristics, as derived from the monitoring activities, are presented and show the excellent in-orbit behaviour. We also outline which non-conformances have been detected and how they, fortunately, could be corrected or are accommodated.

With chapter 7 the science related information is introduced by summarising the principles and methods for the derivation of geophysical parameters from the measured spectra. It can be regarded as the basis for most of the SCIAMACHY data processing and scientific results being described in the next chapters. Scientific and operational data products are the subject of chapter 8. The reader learns which products are generated under ESA responsibility and which are provided by research institutions involved in SCIAMACHY. For the ESA generated products, the strict requirements and implementations of the operational processing environment are outlined. As every geophysical parameter retrieval requires well calibrated measurements, we also report on how calibration and monitoring information is used to derive Earthshine, extraterrestrial radiance and irradiance data products from the raw signals. Retrieved geophysical parameters do not necessarily immediately translate into atmospheric science results. It has to be proven first that the data products are of sufficient quality. This process of product validation, subject of chapter 9, was an enormous effort in the first years of the mission. It will be required, at an adequate level, throughout the mission and even beyond to create

long term datasets of known quality relevant for climate change research. Chapter 9 explains the selected validation procedures, associated teams and provides results acquired so far.

Chapter 10 concludes the publication by presenting some first results – SCIAMACHY's unique view of the Earth's atmosphere. The capabilities of the instrument enable investigation of many regions of the atmosphere – from troposphere up to mesosphere and above. Analysis of the solar observations yields significant information about the sun. The content of chapter 10 nicely illustrates the success achieved up to now and justifies the continuing investment in the SCIAMACHY mission.

Many people have contributed to SCIAMACHY. With the exception of the Principal Investigator John P. Burrows, who pushed the project since over 20 years, they cannot all be named here but we intended to clearly state that the mission is a team effort combining expertise from agencies, industry and science. Writing this publication involved many people as well. For its preparation main authors were selected for each chapter. Given the trilateral nature of SCIAMACHY, they had to ensure that contributions from all relevant parties were combined to result in the final version of each chapter.

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References to photos, images and graphics are given wherever required. All other figures have been specifically generated for this publication. The Earth in several graphics was modelled by using the publicly available web resource *Earth and Moon Viewer*.

The editor would like to thank all involved in the preparation and careful reviewing of this publication. The review team included, in addition to the authors, I. Aben, J. Carpay, C. Chlebek, F. Diekmann, A. Doicu, A. Goede, J. How, R. Koopman, E. Krieg, P. Lützow-Wentzky, C. Muller, P. Stammes and T. Trautmann. Generating this publication was a significant extra effort. We hope that the result is well received by the readers.

M. Gottwald
March 2006

Contents

Foreword

The challenge of understanding the complex Earth-atmosphere system has been a driver for scientific development since the time of the ancient Greeks (*Aristotle: "Meteorology", 350 B.C.E., translated by E. W. Webster and available via http://classics.mit.edu/Aristotle/*). In order to understand how the system is coupled together, including non linear feedbacks, detailed knowledge about the components of the system are required. In the past three decades mankind has realised that the growth in population and its standard of living is such that anthropogenic activity modulates both climate and weather. Scientific consensus recognises that global measurements of key atmospheric constituents and parameters are required to assess accurately global climate change.

SCIAMACHY, a national contribution to ESA's ENVISAT programme, was proposed to address such needs. The ambitious goal of SCIAMACHY is to observe the Earth's atmosphere with unprecedented detail in order to understand how the system functions and how the environment of our home planet responds to change. Currently SCIAMACHY has and is providing an important and significant step in our ability to gather the necessary knowledge about the Earth's atmosphere and thereby facilitate good management and governance of life on Earth.

This project has been one of the most important investments in space engineering and environmental science in Germany, The Netherlands, Belgium and Europe over the past two decades. Its development occupied many teams in Europe's space agencies, industries and scientific community. Since the launch of ENVISAT more than 4 years ago, SCIAMACHY has more than met its agreed scientific objectives and continues to operate with excellent performance. The instrument delivers data of high scientific quality, which will be a source of study and investigation for the forthcoming decade. SCIAMACHY represents a pathfinder towards the provision of a global observing system capable of meeting the need to provide global sustainable development. The instrument demonstrates that space based measurements are able to provide results needed not just by scientists but also by national, European and international environmental policy maker.

Projects like SCIAMACHY, whilst intending to make objective measurements of our environment, depend on the subjective efforts of a large group of individuals. There are many fathers of this success, too many to mention by name. The original proposers and science team members and the younger scientists, who are now exploiting the scientific data are essential contributors to the mission. Similarly the agencies and industry, who have invested in the objectives of SCIAMACHY, were taking on risk as well as potential gain.

SCIAMACHY's management and industrial consortium solved many challenging problems during the life of the instrument thus far. The effective interaction of a team, comprising a fluctuating group of scientists, engineers and administrators from research, agencies and industry, who designed, built and now maintain SCIAMACHY, is a prerequisite to have any chance of success. The ability of such teams to work effectively together across both disciplinary and national borders for a common goal is an achievement in itself. So in this context thanks go to all, who have made and who will continue to make the SCIAMACHY project a success.

This publication represents an overview of the objectives, the development and some of the results from SCIAMACHY. It aims to inform the interested reader and will hopefully be complemented by future volumes documenting the further development of SCIAMACHY and the exploitation of the data products. From a technical stand point ENVISAT and SCIAMACHY are able – barring unforeseen problems – to deliver data well beyond 2010. Hopefully ENVISAT and the SCIAMACHY mission will be extended to enable SCIAMACHY to maintain its current performance and thereby provide data of unique value well into the next decade. *Hunting light and shadows* to exploit for Earth System Science and environmental policy is one key element in providing sustainable development for the Earth's environment in the 21st century.

J.P. Burrows
SCIAMACHY Principal Investigator
March 2006