Manfred Gottwald
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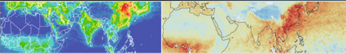
Editors

SCIAMACHY



Exploring the Changing Earth's Atmosphere

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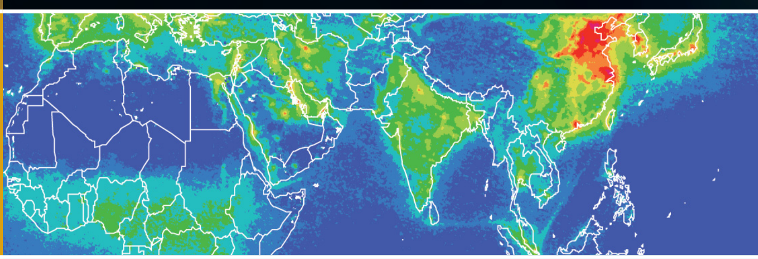

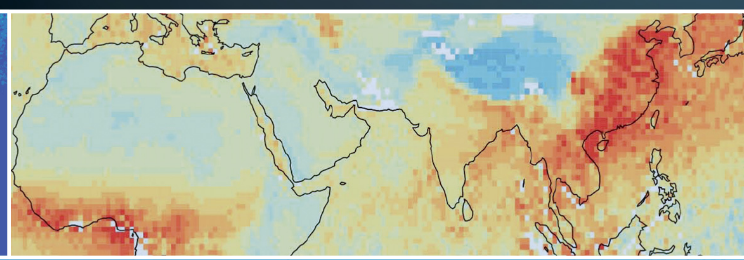

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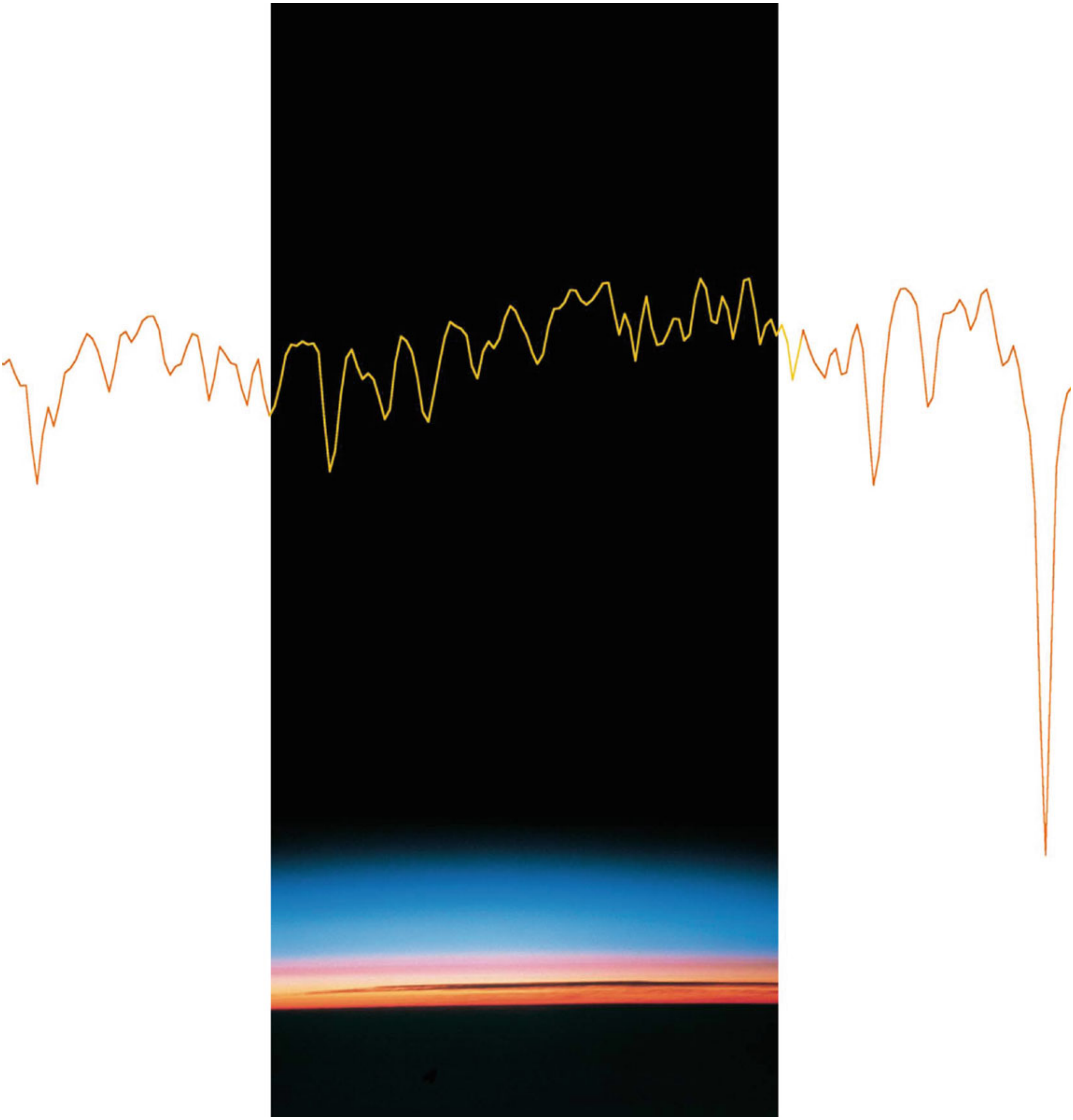

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SCIAMACHY - Exploring the Changing Earth's Atmosphere

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Cover: Earth's limb at sunrise as seen from the ISS (photo: NASA), global NO_2 (Courtesy: A. Richter, IUP-IFE, University of Bremen) and global CO (Courtesy: Gloudemans et al. 2009) column densities.
Frontispiece: The Earth's stratosphere as seen from the Space Shuttle. Overlaid is a part of an earthshine spectrum as recorded by SCIAMACHY (photo: NASA).

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We dedicate this book to our beloved SCIAMACHY team member Dr. Annemieke Gloudemans, who recently passed away at the age of 35 years. She will always be remembered for her kind personality and through her invaluable contributions to the challenging analysis and interpretation of SCIAMACHY carbon monoxide measurements.

Editorial

In March 2002 the atmospheric science instrument SCIAMACHY was launched on-board ESA's ENVISAT mission into low-Earth orbit. It was, and is still, one of the major current Earth Observation undertakings of Germany, The Netherlands and Belgium, accomplished in cooperation with the European Space Agency (ESA). Having meanwhile successfully monitored and explored the Earth's atmosphere for more than 8 years with SCIAMACHY, the involved scientific institutes and space agencies feel that it is worth to issue a comprehensive publication describing the SCIAMACHY mission – from the very first ideas to the current results. The targeted readership is not only the existing and potentially new SCIAMACHY data users from undergraduate student level up to researchers new in the fields of atmospheric chemistry and remote sensing 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.

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 800 km 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 be launched into space, Chapter 2 takes a closer look at the ENVISAT mission, which hosts SCIAMACHY. The purpose of Chapter 2 is to describe those aspects of ENVISAT being of relevance to the SCIAMACHY mission. The location on and the environment of the platform, together with the ENVISAT orbit, 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 they collect and generate the spectral signals containing the information on geophysical parameters thus being prime responsible for the achieved data quality. In order to provide the reader with an idea about the challenges of instrument development, chapter 3 also outlines the history of how SCIAMACHY was built. Without a flexible operations concept however, all the sophisticated instrument functionalities would have been useless. How SCIAMACHY is operated in-orbit can be found in Chapter 4. The chosen operations 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 in atmospheric and 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 SCIAMACHY's in-orbit mission lifetime, starting with the launch and the Commissioning Phase and illustrates now more than 8 years of routine measurements. Various instrument characteristics, derived from the monitoring activities, are presented and show the excellent in-orbit behaviour. We also outline how in-orbit degradation, a phenomenon common to each long duration space mission, impacts SCIAMACHY's measurements and demonstrate how it can be corrected or compensated.

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. While in the early years of the mission the retrieval methods were mostly relying on standard algorithms, the scientific ingenuity has meanwhile generated a wealth of novel techniques permitting the retrieval of geophysical parameters beyond the original ideas. This chapter can be regarded as the basis for most of the SCIAMACHY data processing and scientific results being described in the next sections.

Operational and scientific 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 and is required, at an adequate level, throughout the mission and even beyond to create long-term datasets of known quality relevant for environmental, atmospheric, and climate change research. Chapter 9 explains the selected validation procedures, associated teams and summarises results acquired so far.

Chapter 10 concludes the publication by presenting SCIAMACHY's unique view of the changing Earth's environment. The capabilities of the instrument permit studying phenomena ranging from the the atmospheric layer where we are living in, i.e. the lower troposphere, up to the mesosphere and lower thermosphere where solar-terrestrial interactions begin to prevail. However SCIAMACHY does no longer stop at the bottom or top of the atmosphere. Even Earth surface parameters like vegetation or phytoplankton properties are now within reach as well as monitoring the solar activity. Finally SCIAMACHY has proven surprisingly successful in acquiring spectral signals from the atmosphere of our neighbour Venus. The content of Chapter 10 nicely illustrates the success achieved up to now and justifies continuing investments in the SCIAMACHY mission and data usage. Although we intended to be as complete as possible in the framework of this book, Chapter 10 is still a summary only. Therefore the interested reader is referred to the references given in this book and the websites listed below allowing a deeper look into SCIAMACHY results:

http://envisat.esa.int/
http://www.sciamachy.de/
http://www.sciamachy.org/
http://www.iup.uni-bremen.de/
http://joseba.mpch-mainz.mpg.de/
http://www.temis.nl/
http://wdc.dlr.de/

The SCIAMACHY project is and has been an important milestone in Earth Observation as it has already yielded unique scientific insights into the working of the Earth system. Many people have contributed to it. With the exception of the Principal Investigator John P. Burrows, who pushed the project since over 25 years, they cannot all be named here but we intended to make clear that the mission is a team effort combining expertise from agencies, industry and science.

The editors would like to thank all involved in the preparation and careful reviewing of this publication. We hope that the result is well received by the readers.

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November 2010

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