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Abstracts

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Subvisible cirrus detection and parameter retrieval using limb scatter sunlight measured by the OSIRIS imager

Adam Bourassa

Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada

contact: adam.bourassa@usask.ca

The InfraRed Imager (IRI) subsection of the OSIRIS instrument onboard the Odin spacecraft collects limb images of 1.53 micron sunlight scattered from the upper troposphere and lower stratosphere. High altitude thin clouds occurring at or near the tropical tropopause are detected as an enhancement in the line-of-sight radiance profiles. This work attempts to unravel cloud vertical extent and equivalent vertical optical depth from the limb scatter measurements using a radiative transfer model. Due to the long horizontal path lengths provided by the limb viewing geometry, the IRI is capable of detecting cloud layers with vertical equivalent optical depths as low as 10^{-5}. The dusk-dawn orbit of the Odin spacecraft provides global sunlight coverage of the equatorial region throughout the year allowing for the development of a seasonal subvisual cirrus cloud climatology from the IRI dataset.

Odin/OSIRIS global NO_2 climatology

S. M. Brohede[1], C. S. Haley[2], C. E. Sioris[3], D. P. Murtagh[1],
I. C. McDade[2], and E. J. Llewellyn[4]

[1] Chalmers University of Technology, Goteborg, Sweden
[2] York University, Toronto, Canada
[3] Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
[4] University of Saskatchewan, Saskatoon, Canada

contact: cshaley@yorku.ca

A global 'climatology' of stratospheric NO_2 has been created using Odin/OSIRIS NO_2 measurements from the year 2003. The NO_2 profiles are retrieved from the Odin/OSIRIS limb-scattered sunlight measurements using the maximum a posterioir estimator with differential absorption spectroscopy as an intermediate step. The profiles are retrieved between 10 km and 50 km with a vertical resolution of about 2 km and an estimated accuracy of 10% at 30 km. Monthly mean profiles and standard deviations are presented and illustrate both the strengths and weaknesses of the OSIRIS NO_2 data.

Atmospheric tomography from a satellite platform

D. A. Degenstein, A. E. Bourassa, N. D. Lloyd and E. J. Llewellyn

Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada

contact: doug.degenstein@usask.ca

The InfraRed Imager component of the OSIRIS instrument has three vertical imagers that produce a data set used in a two-dimensional volume emission rate retrieval scheme. The technique is a Multiplicative Algebraic Reconstruction Technique adapted from the Maximum Likelihood Expectation Maximization algorithm commonly used in medical imaging. It has been very successful when applied to the OSIRIS limb brightness measurements, but not without a fight. We have learned much about the instrument requirements, both instrument definition and calibration, and how these couple into the retrieval technique. We have also learned much about the variable parameters associated with the retrieval scheme. This tutorial will discuss the closely coupled nature of the measurement set and retrieval algorithm along with the very important observing geometry. The importance of relative calibration and knowledge of the field of view of each measurement will also be discussed. This tutorial is intended to help others avoid the trap we encountered as we implemented our two-dimensional volume emission rate retrieval technique.

Semi-stochastic retrieval algorithm for atmospheric remote sensing

Adrian Doicu

German Aerospace Center, Remote Sensing Technology Institute, Oberpfaffenhofen, Germany

contact: adrian.doicu@dlr.de

In this paper we present a retrieval algorithm for atmospheric remote sensing. The algorithm combines the Tikhonov regularization and the iteratively regularized Gauss-Newton method and is devoted to the solution of multi-parameter inverse problems with simple bounds on the variables. The basic features of the algorithm: the solution of the bound-constrained minimization problem, the selection of the optimal regularization parameter, the derivation of the global regularization matrix and the characterization of the solution (error analysis) are presented. Numerical simulations are performed for ozone retrieval from SCIAMACHY limb scatter measurements.

Retrieval of CO abundance in the middle atmosphere from Odin/SMR limb measurements

Eric Dupuy

Observatoire Aquitain des Sciences de l'Univers, Laboratoire d'Astrodynamique, d'Astrophysique et d'Aéronomie de Bordeaux, Floirac, France

contact: dupuy@obs.u-bordeaux1.fr

The SMR instrument on board the Odin satellite, launched in February 2001, employs four tuneable heterodyne radiometers to measure thermal emission of atmospheric trace gases using the limb sounding technique. The main target constituents are species related to dynamical and chemical processes of the middle atmosphere, such as O_3, H_2O, their isotopes, species playing a part in the atmospheric ozone chemistry such as ClO, HNO_3 and also long-lived tracers for transport such as N_2O or CO.

Among these, CO, as well as water vapor, plays a key role in the observation of dynamical processes throughout the vertical range of the middle atmosphere.

We present the methodology developed to account for a specific instrumental failure affecting the CO observations, as well as the first retrieval results.

CO mixing ratios are compared with former measurements or model results, as well as with the expected properties of atmospheric CO. Preliminary qualitative results show good consistency between the SMR measurements and the other datasets. Possible comparison studies are suggested to validate the CO VMR profiles in the mesosphere and the stratosphere."

ARTS - the first software environment to simulate scattering of thermal emission in limb geometry

Patrick Eriksson[1], Claudia Emde[2], Cory Davis[3] and Stefan Buehler[2]

[1] Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden
[2] Institute of Environmental Physics and Remote Sensing (iup/ife), University of Bremen, Germany
[3] Institute of Atmospheric and Environmental Science, University of Edinburgh, U.K.

contact: patrick@rss.chalmers.se

Improved measurements of the upper troposphere (UT) are urgently needed for a better understanding of the climate system and more detailed predictions regarding feedback mechanisms initiated by increasing levels of CO_2. Currently, modelling these feedbacks is di cult because the present abundance of water vapour and cirrus clouds in the UT is not known accurately. Here tomographic microwave limb sounding can play a central role by providing, for example, observations of UT humidity combining good vertical and horizontal resolution. Microwave instrumentation has an advantage compared to using shorter wavelengths because a much better cloud penetration capability is achieved, but larger cirrus particles can still cause scattering at the wavelengths of consideration (0.75 - 2 mm). A first requirement to analyse existing data and design future instruments optimised for measurement of the UT is that scattering of thermal radiation by cirrus clouds can be simulated, and here we present the first software handling the task without critical simplifications.

ARTS, the Atmospheric Radiative Transfer System, is a general and flexible forward model dealing with longwave radiation. A new version was started in 2002 with the aim of incorporating features such as full polarisation, 3D geometry (arbitrary surface model and observation geometry are allowed) and handling of scattering. The inclusion of these features makes ARTS the most advanced software of its kind. The program is fully modular and there exist two modules to solve the scattering problem; a discrete ordinate iterative module and a backward Monte Carlo module. ARTS is developed as an open source project and is publicly available at www.sat.uni-bremen.de/arts, where detailed documentation can be also obtained.

An overview of the implementation of the new ARTS version will be given, and simulation results will be presented. For down-looking geometry cirrus scattering leads throughout to lower observed radiances, but for limb sounding both a radiance increase and decrease can be observed, depending on frequency, cloud position and tangent altitude. It is further shown that scattering can a ect vertical and horizontal polarisation di erently. Critical assumptions here are particle size and shape, and if there exists some preferred direction of particle orientation.

From the Limb Ozone Retrieval Experiment on STS107

David E. Flittner

NASA Langley Research Center, Radiation and Aerosol Branch, Hampton, Virginia, USA

contact: David.E.Flittner@nasa.gov

The next generation (2010-2030) of U.S. satellite based instruments to monitor the vertical profile of ozone concentration will be part of the National Polar-orbiting Operational Environmental Satellite System (NPOESS). As a part of NPOESS, The Ozone Mapping and Profiler Suite (OMPS) will consist of three different instruments: a total ozone mapper (similar to the Total Ozone Mapping Spectrometer, TOMS), a nadir profiler (similar to the Backscatter UltraViolet series of instruments) and a limb profiler. The limb profiler will utilize measurements of light scattered from the limb of the atmosphere and does not have the heritage of the other two sensors. While this technique has been used in the 1980s for mesospheric retrievals with data from the Solar Mesospheric Explorer, its use for the stratosphere and upper troposphere is relatively recent. To increase the scientific experience with this method and its use with limb imagers, the Limb Ozone Retrieval Experiment LORE was flown on-board STS107 in 2003. A significant amount of data from thirteen orbits was down-linked during the mission and exists for analysis, in spite of the Columbia disaster.

LORE was an imaging filter radiometer, consisting of a linear diode array, five interference filters (plus a blank for dark current) and a simple telescope with color correcting optics. The wavelengths for the channels were 322, 350, 602, 675 & 1000 nm, and can be viewed as a minimum set of measurements needed for ozone profiling from 50 km to 10 km. The temporal sampling of the channels, along with the shuttle orbital and attitude (e.g. pitch) motions present a challenge in retrieving precise ozone profiles. This talk illustrates the retrieval algorithms for determination of the channel&#8217s altitude scale, cloud top height and aerosol scattering/extinction profile. Also shown are a sub-set of flight data and the corresponding retrieved ozone profiles. Time permitting, an analysis of the stray light characteristics of the instrument will presented.

Non-LTE retrieval of trace gas abundances and parameters in the middle and upper atmosphere from MIPAS on ENVISAT

Bernd Funke

Instituto de Astrofísika de Andalucía, CSIC, Granada, Spain

contact: bernd@iaa.es

The Michelson Interferometer for Passive Atmosheric Sounding (MIPAS) is a high resolution limb sounder on board ENVISAT which scans the atmosphere at tangent heights from 6 up to 170 km with global coverage. Operational data processing by ESA is limited to the assumption of local thermodynamic equilibrium (LTE) which holds only for a limited number of atmosheric emitters in a restricted altitude range. A dedicated non-LTE data processor has been developed at the Instituo de Astrofísica de Andalucía (IAA) and Institut für Meteorologie und Klimaforschung (IMK) in order to derive a manifold of additional quantities beyond the operational data products relevant to chemistry, dynamics and energetics of the middle and upper atmosphere. The list of atmospheric parameters inferred under consideration of non-LTE includes: (i) NO, NO_2, and CO measured routinely from 6 to 70 km, (ii) pressure, temperature, CO_2, O_3, H_2O, and CH_4 measured in special mode observations up to 100 km, and (iii) various kinetic constants relevant to non-LTE populations of NO_2, CO_2, and H_2O. In this paper, the non-LTE retrieval scheme included in the IMK/IAA non-LTE data processor is presented and the derived data products are characterized. Furthermore, scientific results obtained during the first 2 years of the mission will be highlightened.

Retrieval of stratospheric O_3 and NO_2 profiles from Odin Optical Spectrograph and Infrared Imager System (OSIRIS) limb-scattered sunlight measurements

C.S. Haley[1], S. M. Brohede[2], C. E. Sioris[1,3], E. Griffioen[1,4], D. P. Murtagh[2], I. C. McDade[1], P. Eriksson[2], E. J. Llewellyn[5], A. Bazureau[6], and F. Goutail[6]

[1] York University, Toronto, Canada
[2] Chalmers University of Technology, Goteborg, Sweden
[3] now at Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
[4] now at Juravinski Cancer Centre, Hamilton, Canada
[5] University of Saskatchewan, Saskatoon, Canada
[6] Centre National de la Recherche Scientifique, Verrieres le Buisson, France

contact: cshaley@yorku.ca

In this paper, global number density profiles of O_3 and NO_2 are retrieved from Odin Optical Spectrograph and Infrared Imager System (Odin/OSIRIS) limb-scattered sunlight measurements, using the maximum a posteriori estimator. Differential optical absorption spectroscopy is applied to OSIRIS radiances as an intermediate step, using the wavelength windows 571-617 nm for O_3 and 435-451 nm for NO_2. The method is computationally efficient for processing OSIRIS data on an operational basis. Results show that a 2-3 km height resolution is generally achievable between about 12 km and 45 km for O_3 with an estimated accuracy of 13% at the peak and between about 15 km and 40 km for NO_2 with an estimated accuracy of 10% at the peak. First validations of the retrieved data indicate a good agreement both with other retrieval techniques applied to OSIRIS measurements and with the results of other instruments.

Using GOMOS and OSIRIS data in chemical data assimilation

S. Hassinen[1], E. Kyrölä[1], A. Seppälä[1], H. Auvinen[1], C. Haley[2],
J. Damski[3], L. Backman[1]

[1] Finnish Meteorological Institute, Earth Observation, Finland
[2] York University, Centre for Research in Earth and Space Science, Canada
[3] Finnish Meteorological Institute, Meteorological Research, Finland

contact: seppo.hassinen@fmi.fi

The new profiling instruments like GOMOS onboard Envisat and OSIRIS onboard Odin produce novel datasets for chemical data assimilation. GOMOS is an stellar occultation instrument, whereas OSIRIS uses scattered solar light. Both work in limb geometry and therefore both of these instruments have a very good vertical resolution. GOMOS measures mainly over the night side of the Earth and OSIRIS over the day side. Together, these two instruments provide good spatial and temporal coverage.

FASP (FINRose assimilation system for profiles) is an assimilation system developed for OSIRIS and GOMOS data. FASP consists of a global chemistry-transport model FinRose-CTM, an assimilation code based on suboptimal Kalman filter and interfaces to OSIRIS and GOMOS data. The ECMWF analysis fields are used as external dynamics. The aim of FASP is to obtain the full benefit from the new kind of profiling instruments GOMOS and OSIRIS.

The possibilities of profile assimilation will be discussed. The stratospheric ozone development for the year 2003 based on GOMOS and OSIRIS chemical data assimilation will be used as an example. Furthermore, selected dynamical and chemical case studies will be shown to describe the full potential of profile assimilation.

The toolbox SCIARAYS for radiative transfer modelling and atmospheric parameter retrieval in the UV-visible

Johannes Kaiser

Remote Sensing Laboratories, University of Zürich, Switzerland

contact: jkaiser@geo.unizh.ch

The toolbox SCIARAYS contains a radiative transfer model, an instrument model, and inversion routines based on optimal estimation. It has been developed and optimised for the analysis of limb scattering observations. However, arbitrary observational geometry may be simulated in the UV, visible, and near infra-red spectral domains. The radiative transfer model accounts for up to two orders of scattering and surface reflection in a spherical, horizontally stratified, cloud-free atmosphere with refractive bending. The model is optimised for execution speed. It is also fully linearised, i.e. the weighting functions for all atmospheric parameters are calculated quasi-analytically. The toolbox is currently being used, amongst other applications, for the quasi-operational retrieval of ozone profiles from the limb observations by SCIAMACHY aboard Envisat. It is publicly available for download from the internet.

Pointing retrieval with the TRUE knee method

J. W. Kaiser[1], C. von Savigny[2], G. Rohen[2], H. Bovensmann[2], J. P. Burrows[2]

[1] Remote Sensing Laboratories, University of Zürich, Switzerland
[2] Institute of Environmental Physics and Remote Sensing (iup/ife),
University of Bremen, Germany

contact: jkaiser@geo.unizh.ch

We present the TRUE knee algorithm for satellite pointing retrieval from limb scattering in the UV-B spectral range. The algorithm analyzes the shape of the so-called knee feature of the UV-B radiance profiles in a suitable fitting window. Information on the tangent height sequence and the ozone and neutral density profiles may be obtained simultaneously. We characterize the information theoretically contained in a typical UV-B limb observation by SCIAMACHY. Furthermore, a variant of the algorithm is applied to several actual observations and conclusions on the accuracy of the engineering pointing information in the operational Envisat products are drawn.

Callenges in the limb retrieval of noctilucent cloud properties

Bodil Karlsson, J. Gumbel, J. Stegman, G. Witt, and the Odin/OSIRIS Team

Department of Meteorology, Stockholm University, Stockholm, Sweden

contact: bodil@misu.su.se

The limb scanning optical spectrograph onboard the Odin satellite has been used in the study of noctilucent clouds in the summer polar mesopause region. Detailed geographical coverage, planetary wave patterns and seasonal variations can be investigated. The OSIRIS (optical spectrograph and infrared imaging system) instrument is measuring the scattered sunlight in a spectral range from near UV to near IR. This broad coverage is particularly suitable for the performance of spectral analysis. Information about particle sizes can be retrieved from the analysis by comparing with Mie scattering simulations and forward modelling of the limb brightness.

Possibilities to compare OSIRIS measurements and observations from other satellites and ground-based measurements are discussed. A number of challenges turn up when trying to quantitatively compare NLC observations. Challenges discussed in this presentation include Odin's limb viewing geometry, albedo effects as well as the quest for compatible cloud brightness units.

The performance of the JEM/SMILES observation

Y. Kasai[1], C. Takahashi, J. Urban, V. Carmen, S. Buehler, S. Ochiai, J. Inatani, H. Masuko, and the JEM/SMILES Mission Team

[1] Global Environment Division, National Institute of Information and Communication Technology (NICT), Tokyo, Japan

contact: ykasai@nict.go.jp

A new generation of submillimeter-wave instruments employing sensitive SIS (Superconductor-Insulator-Superconductor) detector technology is now being developed. These sensors will provide new opportunities for the precise remote sensing measurements such as stratospheric O_3, its isotopes, HO_2, HOCl, ClO and HCl. We have estimated the observation capabilities of SIS instruments, space-station-borne JEM/SMILES (Japanese Experiment Module / Superconductive Submillimeter-wave Limb Emission Sounder), which is planned for launch in 2008. The precision of the observation of the target species, O_3, HCl, ClO, were found to be within 5% by SMILES observation.

Monthly and seasonal averages of ozone and nitrous oxide derived from the Improved Limb Atmospheric Spectrometer (ILAS/ILAS II)

F. Khosrawi[1,4], R. Mueller[1], M. Proffitt[2], and H. Nakajima[3]

[1] Institute for Stratospheric Chemistry (ICG-I), Forschungszentrum Jülich, Germany
[2] World Meteorological Organization, Geneva, Switzerland
[3] National Institute of Environmental Studies, Iabaraki, Japan
[4] now at: Department of Meteorology, Stockholm University, Stockholm, Sweden

contact: farah@misu.su.se

Northern and Southern hemispheric averaged ozone and nitrous oxide measured by the Improved Limb Atmospheric Spectrometer (ILAS and ILAS II) were used to examine changes in ozone distributions. The ILAS/ILAS II instrument was developed by the Environment Agency of Japan and it was operated on board the Advanced Earth Observing Satellite (ADEOS/ADEOS II) spacecraft of the National Space Development Agency (NASDA). ILAS/ILAS II operated continuously from 30 October 1996 to 30 June 1997 and from 2 April to 24 Oktober 2003, respectively. Measurements about fourteen times per day in high latitude region of both hemispheres were taken. Vertical profiles of e.g. ozone and nitrous oxide were measured in the range of 10 km or cloud top up to 70 km. The high spatial and temporal coverage of ILAS/ILAS II data inside the polar vortex makes these data particularly suitable for studies of Arctic and Antarctic ozone loss. Using correlations of ozone vs. nitrous oxide the ILAS/ILAS II data are organized seasonally and monthly in both hemispheres by partitioning these data into equal bins of altitude or potential temperature. Within these bins the ozone and nitrous oxide data are block averaged over a fixed interval of nitrous oxide (20 ppbv). The resulting families of curves allow to separate ozone changes due to photochemistry from those due to transport.

Comparison of limb radiances from OSIRIS and GOMOS

E. Kyrölä[1], S. Hassinen[1], A. Seppälä[1], J. Tamminen[1], G. W. Leppelmeier[1], J. L. Bertaux[1], A. Hauchecorne[2], G. Barrot[3], D. Murtagh[4], J. Stegman[5], G. Witt[5], E. J. Llewellyn[6], D. A. Degenstein[6], R. L. Gattinger[6], I. McDade[7], C. S. Haley[7], B. Solheim[7], W. Evans[8]. K. Strong[9], J. Burrows[10]

[1] Finnish Meteorological Institute, Helsinki, Finland
[2] Service d'Aéronomie du CNRS, Verrieres le Buisson Cedex, France
[3] ACRI-ST,Sophia Antipolis, France
[4] Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden
[5] MISU, Department of Meteorology, Stockholm University, Stockholm, Sweden
[6] ISAS, University of Saskatchewan, Saskatoon, Canada
[7] EATS, York University, North York, Canada
[8] Physics Department, University of Toronto, Toronto, Canada
[9] Physics Department, Trent University, Peterborough, Canada
[10] Institute of Remote Sensing, University of Bremen, Bremen, Germany

contact: erkki.kyrola@fmi.fi

OSIRIS on board Odin and GOMOS on board Envisat measure scattered sunlight in the limb viewing direction. These measurements are used to derive vertical profiles of various trace gases. In this work we compare radiances and retrieved trace gas profiles from the two instruments. This work is part of the Envisat AO-project LIMBVAL.

GOMOS on ENVISAT: an overview

E. Kyrölä[1], J. Tamminen[1], V. Sofieva[1], S. Hassinen[1], A. Seppälä[1], P. Verronen[1], G. W. Leppelmeier[1], J. L. Bertaux[2], A. Hauchecorne[2], F. Dalaudier[2], D. Füssen[3], F. Vanhellemont[3], O. Fanton d'Andon[4], G. Barrot[4], A. Mangin[4], B. Théodore[4], M. Guirlet[4], P. Snoeij[5], R. Koopman[6], L. Saavedra[6]

[1] Finnish Meteorological Institute, Helsinki, Finland
[2] Service d'Aéronomie du CNRS, Verrieres le Buisson Cedex, France
[3] Institut d'Aeronomie Spatiale de Belgique, Brussels, Belgium
[4] ACRI-ST,Sophia Antipolis, France
[5] ESA/ESTEC, Noordwijk, The Netherlands
[6] ESA/ESRIN, Frascati, Italy

contact: erkki.kyrola@fmi.fi

GOMOS (Global Ozone Monitoring by Occultation of Stars) on ESA's Envisat-satellite measures ozone, NO_2, NO_3, H_2O, O_2, aerosols, neutral air density, and temperature in the stratosphere and mesosphere using the stellar occultation method. GOMOS has an UVIS spectrometer at 248-690 nm and two IR spectrometers at 750-776 nm and 916-956 nm. The spectrometers use 0.5 sec integration time which provides 1.6 km or better vertical sampling frequency. Two fast photometers (1 KHz) record fast fluctuations (scintillations) in the stellar light. GOMOS measures during night and day but the quality of day measurements suffers from limb scattered solar light. The limb scattered light is recorded independently of the occultation signal and also it can be used for constituent retrieval. During one orbit GOMOS measures 300-500 occultations leading to a good global coverage. We will present here an overview of the GOMOS mission so far.

Middle atmosphere data assimilation: what is the added value from MIPAS?

William Lahoz

Data Assimilation Research Center, Department of Meteorology, University of Reading, U.K.

contact: wal@met.reading.ac.uk

Odin/SMR global measurements of water vapour and its isotopes in the middle atmosphere.

N. Lautié, J. Urban, D. Murtagh, and the Odin/SMR Retrieval Group

Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden

contact: nicolas@rss.chalmers.se

Water vapour, the strongest greenhouse gas, is not only a good tracer of the dynamics in the middle atmosphere, but is also linked to many chemical processes like the natural destruction of ozone (through the HO_x family). Improving our knowledge of the amount of water and its variability in the stratosphere and in the mesosphere is thus of primary importance.The Sub-Millimetre Radiometer (SMR) onboard the Odin satellite, launched in February 2001, measures the thermal emission from the Earth s limb in the 485-580 GHz spectral range. In particular, two bands around 489 and 557 GHz are used to study water vapour and its isotopes, on the basis of 4 days per month. Using a forward model and an inversion code based on the OEM, vertical profiles of H_2O-16, H_2O-18, and HDO are retrieved between roughly 20 and 70 km at 489 GHz, whilst H_2O-16 is retrieved from the mid-stratosphere to the lower thermosphere (35-100 km) at 557 GHz. In addition to the interesting picture of water vapour provided in the entire middle atmosphere, the unique and original measurements of HDO and H_2O-18 between 20 and 60 km allow the study of isotopic depletion/enrichment of water, supplying information on the origin of air masses (tropospheric or stratospheric).

UV Remote sensing of the mesosphere with OSIRIS

E. J. Llewellyn, R. L. Gattinger, D. A. Degenstein, and N. D. Lloyd

Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada

contact: edward.llewellyn@usask.ca

The OSIRIS instrument on the Odin satellite includes an optical spectrograph that makes limb measurements of both scattered sunlight and the airglow in the wavelength range 280-800 nm. While the scattered sunlight in the mesosphere is quite bright (typically 10^4 R/Å at 70 km) it is possible to identify airglow features that are excited through the resonant absorption of sunlight. In this paper we present new mesospheric observations in the wavelength region 300-325 nm and suggest that the airglow feature at 308 nm is due to emission from the OH (A-X) system. With this identification we can determine the mesospheric profile of OH in the ground vibrational state. The possibility of detecting the NO Gamma bands in this wavelength region is also discussed.

Examination of the SOLSE/LORE-2 limb scattering data

Robert Loughman[1], Kristie V. Lee[1], Michael Hill[1], David Flittner[2], Didier Rault[2], Richard McPeters[3], Ernest Hilsenrath[3], Scott Janz[3], Tammy Brown[3], and P.K. Bhartia[3]

[1] Center for Atmospheric Sciences, Hampton University, Hampton, Virginia, USA
[2] Radiation and Aerosol Branch, NASA Langley Research Center, Hampton, Virginia, USA
[3] Atmospheric Chemistry and Dynamics Branch, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

contact: robert.loughman@hamptonu.edu

The Shuttle Ozone Limb Scattering Experiment (SOLSE) and Limb Ozone Retrieval Experiment (LORE) instruments were re-flown in January 2003 to test the potential of limb scattering ozone retrievals. In this paper, we discuss some remaining challenges associated with the SOLSE/LORE data set. Assigning the proper altitude scale to the data is complicated by the poor temporal sampling obtained from the LORE 350 nm channel, as well as frequent shuttle attitude adjustments and maneuvers during the measurements. Characterization of the stray light observed in the measured radiance profiles has also proven difficult. We outline the strategy pursued to overcome these obstacles and validate the measured ozone profiles, confirming the accuracy and robustness of the limb scattering ozone retrieval method.

Retrieval of kinetic temperature, CO_2, and H_2O from satellite infrared limb emission measurements under non-local thermodynamic equilibrium conditions

Christopher J. Mertens

NASA Langley Research Center, Atmospheric Sciences Division, Chemistry and Dynamics Branch, Hampton, Virginia, USA

contact: c.j.mertens@larc.nasa.gov

The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) experiment was launched onboard the TIMED satellite in December 2001. SABER has been designed to provide measurements of the key radiative and chemical sources and sinks of energy in the mesosphere and lower thermosphere (MLT), in order to achieve major advances in understanding the structure, energetics, chemistry, and dynamics of the MLT region from 60-180 km. SABER measures Earth limb emission in 10 broadband radiometer channels ranging from 1.27 μm to 17 μm. Measurements are made both day and night over the latitude range from 54°S to 87°N with alternating hemisphere coverage every 60 days. The continuous sounding of SABER provides 2200 vertical scans of limb radiance per channel per day, which are used to retrieve vertical profiles, with 2 km altitude resolution, of kinetic temperature (T_k), O_3, H_2O, and CO_2 volume mixing ratios (vmr), and volume emission rates from $O_2(^1\Delta)$, OH(ν=3-5), OH(ν=7-9), and NO.

MLT infrared limb emissions are in non-local thermodynamic equilibrium (non-LTE), requiring complex non-LTE radiation transfer algorithms and novel retrieval approaches to derive the key data products. In this paper we concentrate on T_k, CO_2 and H_2O. T_k/CO_2 are retrieved simultaneously from SABER's 15 μm and 4.3 μm radiometer channels, respectively. We show SABER T_k/CO_2 results at mid-latitudes and during polar summer and winter seasons, along with T_k comparisons with ground-based and in-situ measurements. SABER-lidar T_k comparisons at Fort Collins, CO provide an indirect validation of the SABER-retrieved CO_2 profiles. We show preliminary H_2O results, which are retrieved from SABER's 6.3 μm radiometer channel.

SABER - an experiment to explore and characterize the non-LTE terrestrial upper atmosphere

Marty Mlynczak, and the SABER Science Team

Atmospheric Sciences Division, NASA Langley Research Center, Hampton, Virginia, USA

contact: m.g.mlynczak@nasa.gov

SABER, the Sounding of the Atmosphere using Broadband Emission Radiometry experiment, was launched in December 2001 on the NASA Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite. SABER began routine operations in January 2002 and has operated flawlessly since that time. The SABER experiment is focused on studying the energy balance of the terrestrial mesosphere and lower thermosphere. This region of the atmosphere is unique in that all of the energetically significant processes relating to solar energy deposition and radiative cooling require consideration of non-local thermodynamic equilibrium (non-LTE). SABER exploits the occurrence of non-LTE to provide a comprehensive suite of measurements including atmospheric temperature, chemical composition, and rates of heating and cooling. In this talk we will review the SABER measurements with particular emphasis on the concepts and methods that enable accurate derivation of the SABER data products.

Future missions STEAM and SWIFT

Donal Murtagh

Department of Radio and Space Science, Chalmers University of Technology,
Göteborg, Sweden

contact: donal@rss.chalmers.se

On the conditions for PMC formation: comparison of Odin/OSIRIS PMC brightness with coincident TIMED/SABER kinetic temperatures

Svetlana Petelina

Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada

contact: svetlana@osirus.usask.ca

The Optical Spectrograph and InfraRed Imager System (OSIRIS) on the Odin satellite detects Polar Mesospheric Clouds (PMC) by measuring the limb-scattered sunlight over the broad wavelength range of 280 nm - 800 nm with the spectral resolution of about 1 nm. When in aeronomy mode, Odin typically scans the stratospheric region from 6 km to 60 km, and extends these scans to 100 km every 7th or 8th day. However, during the NH Summers of 2002 and 2003, there were special summer-mesospheric campaigns (from 1st to 15th of July) when Odin performed continuous mesospheric observations rotating between mesospheric scans (65 km to 100 km) and strato-mesospheric scans (6 km to 100 km). As a result, more than 1500 PMCs were detected by OSIRIS during the NH Summer of each year.

To better understand the conditions for PMC formation and existence, simultaneous measurements of the mesospheric water vapor and temperature are required. Since the accurate retrieval of these parameters from the Odin data is still an ongoing work, we decided to perform the PMC - mesospheric temperature analysis using the coincident measurements from the SABER instrument on TIMED. SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) is one of the four instruments on the NASA's TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) satellite that regularly measures many key atmospheric parameters (including the mesospheric kinetic temperature, KT) since the beginning of 2002. Presently, SABER Level 2A data are freely available at http://saber.larc.nasa.gov.

We performed the detailed analysis of the OSIRIS PMC - SABER mesospheric KT correlation in the height range of 82 km - 84 km under the different space/time coincidence criteria. It has been shown that due to the high spatial and temporal variability of the mesospheric KT, the coincidence criteria in this case must be very 'narrow', namely 3 hours or less in time and 2° or less in latitude/longitude. Under such criteria, no PMCs were found in the analyzed altitude range (82 km to 84 km) when the mean KT in this range was larger than 142 K, and no bright PMCs were found for the mean KT larger that 136 K. It has been also shown that poleward of 80°N PMC KT is on average 5-8 K lower than that for latitudes 68°N - 75°N.

Ozone, NO_2 and aerosol retrieval from SAGE III limb scatter measurements

Didier F. Rault

NASA Langley Research Center, Hampton, Virginia, 23681, USA

contact: didier.f.rault@nasa.gov

The ability of SAGE III to retrieve ozone, NO_2 and aerosol vertical distribution within Earth atmosphere from limb scatter measurements is being investigated. The sunlight scattered by atmospheric gases and particulates (aerosol, clouds) and the Earth's surface is measured and spectrally dispersed by SAGE III spectrometer. It will be shown that Ozone density vertical profiles can be retrieved from 10 km (or cloud top) to 50 km at a resolution of about 1 km and a precision of less than 10 % using Chappuis and Huggins ozone absorption bands. NO_2 vertical density profiles can be retrieved from 15 to 40 km at a resolution of about 1 km and a precision of 20% using the NO_2 absorption features in the 430-450 nm spectral range. Aerosol extinction vertical profiles (from 15 to 30 km) can be retrieved using a series of non absorbing channels. Retrieved products will be compared with available correlative data (ozone sondes, SAGE III in occultation, OSIRIS).

Upper stratospheric/ lower mesospheric ozone profiles retrieved from SCIAMACHY limb spectra: Theory, first validation and ozone depletion at the solar proton event in Oct./ Nov. 2003

G. J. Rohen[1], C. v. Savigny[1], E. J. Llewellyn[2], J. W. Kaiser[3], K.-U. Eichmann[1], A. Bracher[1], H. Bovensmann[1], J. P. Burrows[1]

[1] Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany
[2] Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada
[3] Remote Sensing Laboratories (RSL), University of Zurich, Zurich, Switzerland

contact: rohen@iup.physik.uni-bremen.de

Ozone density profiles between 35 and 65 km altitude are derived from scattered sunlight limb radiance spectra measured by the SCIAMACHY instrument on the Envisat satellite. The method is based on the inversion of normalized limb radiance profiles in the Hartley absorption bands of ozone at selected wavelengths in the UV between 250 and 310 nm. It employs a non-linear Newtonian iteration version of Optimal Estimation coupled with the raditive transfer model SCIARAYS. The technique delivers reliable results as shown by a first comparison with MIPAS. An overview of the methodology is given and an initial error analysis. As an application the ozone depletion during the solar proton storm between 28 October and 6 November 2003 is shown.

Assimilation of Odin ozone data in the DIAMOND model

John Rösevall, and Donal Murtagh

Department of Radio and Space Science, Chalmers University of Technology,
Göteborg, Sweden

contact: donal@rss.chalmers.se

BrO and OClO vertical profile retrieval from SCIAMACHY limb measurements.

A. Rozanov, V. Rozanov, and J. P. Burrows

Institute of Environmental Physics/Institute of Remote Sensing (iup/ife),
University of Bremen, Germany

contact: Alexej.Rozanov@iup.physik.uni-bremen.de

The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) launched on board the European Environment Satellite (ENVISAT-1) in March 2002 is one of the newest space-borne instruments intended to improve our knowledge of the atmospheric physics and chemistry. The SCIAMACHY instrument measures the scattered and reflected spectral radiance in nadir and limb geometry and the spectral radiance transmitted through the atmosphere in solar/lunar occultation geometry in the spectral region 240 - 2380 nm.

First retrievals of SCIAMACHY measurements in limb viewing geometry demonstrate a huge information content of the measured data. Despite remaining problems due to imperfect data calibration and pointing knowledge newly developed retrieval algorithms were shown to provide vertical distribution of such atmospheric trace gases as ozone, NO_2, and BrO with a reasonable accuracy.

This contribution is aimed to investigate an information content of SCIAMACHY limb measurements with respect to BrO profile retrievals, i.e., sensitivity of the differential spectra as they used by the retrieval procedure to trace gas number density variations in different altitude ranges, especially in the lower stratosphere and upper troposphere (UTLS) region. Another investigated aspect is a possibility to retrieve OClO vertical profiles from the SCIAMACHY limb measurements.

Validation of the FMI L2 OSIRIS products.

A. Seppälä[1], S. Hassinen[1], E. Kyrölä[1], H. Auvinen[2], A. Karpetchko[3], C. S. Haley[4]

[1] Finnish Meteorological Institute, Earth Observation, Finland
[2] University of Helsinki, Department of Mathematics, Finland
[3] Finnish Meteorological Institute, Arctic Research Center, Finland
[4] York University, Centre for Research in Earth and Space Science, Canada

contact: annika.seppala@fmi.fi

The Odin satellite launched on February 2001 carries two instruments, OSIRIS (Optical Spectrograph and InfraRed Imaging System) and SMR (Sub-Millimeter Radiometer). Both instruments use the limb scanning technique to retrieve vertical profiles of minor constituents in the middle atmosphere. Odin is a Swedish-led satellite project funded jointly by Sweden (SNSB), Canada (CSA), Finland (Tekes) and France (CNES).

The Level 1 processing of the OSIRIS measurement data is done in Canada by University of Saskatchewan. The Level 2 processing is done separately by teams in Canada and Finland using different retrieval methods. In Finland the Level 2 processing is done by the Finnish Meteorological Institute (FMI) using the Modified Onion Peeling (MOP) method. The aim of the processing is to simultaneously retrieve vertical profiles of ozone, NO_2, BrO, OClO and aerosols. The profile of neutral air density is also retrieved. The processing takes place at Sodankylä processing center.

We present the results from the validation done against the products processed in Canada with the Flittner method. The FMI ozone results will be compared also against other satellite instruments, like POAM and GOMOS, and various soundings.

Solar proton events of October-November 2003 as seen by GOMOS/Envisat

A. Seppälä[1], P.T. Verronen[1], E. Kyrölä[1], S. Hassinen[1], L. Backman[1], A. Hauchecorne[2], J.-L. Bertaux[2], D. Fussen[3]

[1] Finnish Meteorological Institute, Earth Observation, Finland
[2] Service d'Aeronomie du CNRS, France
[3] Institut d'Aeronomie Spatiale de Belgique, Belgium

contact: annika.seppala@fmi.fi

Through a large solar disturbance like flare or coronal mass ejection a vast amount of protons and other ions with very high energies can be emitted from the Sun. If these particles reach Earth they evoke an occasion called Solar Proton Event (SPE). The charged particles enter the Earth's atmosphere causing ionization in the middle atmosphere. Ion chemistry leads to increased production of odd nitrogen (NO_x) and odd hydrogen (HO_x). These gases participate in several chemical reactions that decrease the amount of ozone in the middle atmosphere. Because of the effect that the Earth's magnetic field has on charged particles the effects of enhanced ionization are greatest in the polar cap regions.

Observations of O_3 and NO_2 made by the GOMOS (Global Ozone Monitoring by Occultation of Stars) instrument on board the Envisat satellite have been used to monitor the increase of NO_2 and depletion of ozone due to the great SPEs of October-November 2003. For the first time this phenomenon was monitored in polar winter conditions by a satellite instrument. We will present results showing NO_2 enhancement of several hundred per cent and tens of per cent ozone depletion, an effect which lasts several months after the events.

Constraints on the global distribution of stratospheric Br_y from simultaneous measurements of BrO, NO_2, and O_3 with SCIAMACHY

Chris Sioris

Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, USA

contact: csioris@cfa.harvard.edu

The observed global distributions of BrO (15-30 km) and NO_2 (11-41 km) from SCIAMACHY are shown along with a brief description of the retrieval approach. The volume mixing ratio profile of inorganic bromine (Br_y) is inferred from SCIAMACHY measurements of the vertical distribution of BrO, NO_2, and O_3 by using these observations to constrain a photochemical model and give the local bromine partitioning. Comparisons are made with previous Br_y profile estimates from inorganic and organic methods. Possible sources of Br_y in the tropical tropopause layer are discussed.

Cirrus clouds in the infrared – early results from the ACE mission

James Sloan

Department of Chemistry, University of Waterloo, Canada

contact: sloanj@uwaterloo.ca

MCSCIA: a Monte Carlo model for studies of limb measurements

Francesco Spada, and Maarten C. Krol

IMAU, Utrecht University, The Netherlands

contact: f.spada@phys.uu.nl

A 3D spherical radiative transfer model has been developed to study limb measurements at the UV/Vis. wavelengths. The model uses a backward (adjoint) Monte Carlo approach (McScia) and we investigate several possibilities that make a Monte Carlo radiative transfer calculation useful for the analysis of satellite data.

With McScia the photon path-length distribution can be obtained easily. This distribution, calculated in a non-absorbing atmosphere, can then be convoluted with trace gas profiles. The use of this so-called Equivalence Theorem enables a fast calculation for different absorber profiles. Since the scattering properties of the atmosphere vary slowly with wavelength, these trajectories are a good approximation for a narrow spectral interval in which a molecular absorption feature is present. Thus, the method can be used to retrieve profiles of trace gases using a variation of the DOAS method.

While the focus of the research is on limb measurement, the method can be applied to any geometrical setup (e.g also nadir).

In this presentation some first results of McScia will be presented. Apart from validation with a plane parallel radiative transport model, equivalent photon trajectories (Feigelson [1984], Radiation in a Cloudy Atmosphere, Kluwer) will be presented for limb and nadir viewing geometries.

Odin/SMR limb observations of stratospheric trace gases: level-2 processing of ClO, N_2O, HNO_3, and O_3

J. Urban[1], N. Lautié[1], E. Le Flochmoën[2,6], C. Jiménez[1,5], P. Eriksson[1], J. de La Noë[2], E. Dupuy[2], L. El Amraoui[2,7], U. Frisk[3], F. Jégou[2], D. Murtagh[1], M. Olberg[4], and P. Ricaud[2,6]

[1] Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden
[2] Observatoire Aquitain des Sciences de l'Univers, L3AB, Floirac, France
[3] Swedish Space Corporation, Solna, Sweden
[4] Onsala Space Observatory, Chalmers University of Technology, Göteborg, Sweden
[5] now at School of GeoSciences, The University of Edinburgh, U.K.
[6] now at Laboratoire d'Aérologie, Toulouse, France
[7] now at Météo France, Toulouse, France

contact: jo.urban@rss.chalmers.se

The Sub-Millimetre Radiometer (SMR) on board the Odin satellite, launched on 21 February 2001, observes key species with respect to stratospheric chemistry and dynamics such as O_3, ClO, N_2O, and HNO_3 using two bands centered at 501.8 and 544.6 GHz. The adopted retrieval methodology for level-2 processing is described and the achieved in-orbit measurement capabilities of the SMR radiometer for these species are presented in terms of altitude range, altitude resolution and measurement precision. The characteristics of the relevant data versions are discussed and differences are evaluated. The sensitivity to systematic spectroscopic and instrumental uncertainties is also investigated.

Validation of Odin/SMR limb observations of stratospheric nitrous oxide

J. Urban, and the Odin/SMR Retrieval and N_2O-Validation Groups

Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden.

contact: jo.urban@rss.chalmers.se

The Sub-Millimetre Radiometer (SMR) on board the Odin satellite, launched on 20 February 2001, performs regular measurements of the global distribution of stratospheric nitrous oxide (N_2O) using spectral observations of the $J = 20 \rightarrow 19$ rotational transition centered at 502.296 GHz. Roughly 3 years of data have been accumulated so far. N_2O is a very useful tracer for global transport processes since it is chemically inert in the lower stratosphere with a lifetime of more than one year.

The global Odin/SMR N_2O data set is described and the quality of the retrieved N_2O profiles (level-2 product) is assessed by comparison with independent balloon- and aircraft-borne validation measurements.Odin/SMR data are also compared with preliminary results from the Improved Limb Atmospheric Spectrometer-II (ILAS-II) on board the Advanced Earth Observing Satellite-II (ADEOS-II) and from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on the Envisat satellite.

Odin is a Swedish-led satellite project funded jointly by Sweden, Canada, Finland and France.

Ozone profile retrieval from SCIAMACHY limb measuments.

J. I. van Gent, R. van Oss

KNMI Royal Netherlands Meteorological Institute, De Bilt, The Netherlands

contact: gentjvan@knmi.nl

We present vertical ozone profiles retrieved from limb radiances measured by SCIAMACHY.

We have developed an "optimal estimation" scheme for the retrieval of vertical ozone profiles from SCIAMACHY limb measurements. The limb measurement technique aims at an improved vertical sampling of vertical trace gas profiles, as well as a better estimate for the tropospheric column. An important component in the retrieval scheme is an accurate forward radiative transfer model (RTM). Based on the LIDORT discrete ordinate method, the RTM is fast enough to meet the requirements for operational use.

In this presentation we present a validation of the newly developed RTM by comparing its results with those of the existing model LIMBTRAN, for a variety of solar position scenarios. Furthermore, we present and discuss the first vertical ozone distributions obtained with our retrieval scheme.

Global measurements of OH rotational temperature from space

C. von Savigny, K.-U. Eichmann, E. J. Llewellyn, H. Bovensmann, and J. P. Burrows

Institute of Environmental Physics and Remote Sensing (iup/ife),
University of Bremen, Germany

contact: csavigny@iup.physik.uni-bremen.de

Retrievals of mesopause OH rotational temperatures from satellite-borne Meinel band emission measurements are presented. The nighttime measurements of the OH (3-1) Meinel band near 1.5 micron were performed with the SCIAMACHY instrument on the European Space Agency's environmental satellite Envisat. The derived OH (3-1) rotational temperatures were previously shown to be in reasonable agreement with the CIRA-86 atmosphere temperatures for the seasons and latitudes considered and in good agreement with ground-based OH rotational temperature measurements at different locations. This contributions presents results of the first 2 years of OH temperature data derived from SCIAMACHY. The SCIAMACHY limb nighttime observations provide a unique data set of near-global OH rotational temperature to study seasonal and geographical variations, dynamical processes and possibly long-term temperature trends, if an extended data set becomes available in the future.

Vertical variation of NLC particle sizes retrieved from Odin/OSIRIS limb scattering observations

C. von Savigny[1], S. V. Petelina[2], E. J. Llewellyn[2], D. A. Degenstein[2], N. D. Lloyd[2], and J. P. Burrows[1]

[1] Institute of Environmental Physics and Remote Sensing (iup/ife), University of Bremen, Germany
[2] Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada

contact: csavigny@iup.physik.uni-bremen.de

The vertical variation of noctilucent cloud (NLC) particle sizes is derived from limb scattering observations in the UV-B spectral range performed with the Optical Spectrograph and InfraRed Imager System (OSIRIS) on the Swedish-led Odin satellite. The particle sizes are determined under the assumptions that NLC particles can be treated as Mie-particles with known refractive index, and that their size distribution can be approximated by a log-normal distribution. A sample data set of 16 bright NLCs observed during the 2003 northern hemisphere NLC season and the 2003/2004 southern hemisphere NLC season was selected for this study. In almost all the cases the derived NLC particle sizes increase with decreasing altitudes. This is in agreement with the standard assumption of larger particles sedimenting out of the cloud bottom. The derived particle sizes fall within the range from 25 to about 80 nm.

Mapping of PSCs during Austral spring with SCIAMACHY

C. von Savigny, P. Ulasi, K.-U. Eichmann, H. Bovensmann, and J. P. Burrows

Institute of Environmental Physics and Remote Sensing (iup/ife),
University of Bremen, Germany

contact: csavigny@iup.physik.uni-bremen.de

SCIAMACHY performs spectroscopic measurements of solar radiation scattered by the Earth's limb, covering the tangent height range from about 0 km to 95 km. Scattering occurs in the presence of molecular atmospheric constituents, but is also due to aerosols such as stratospheric sulphate aerosols and polar stratospheric clouds (PSCs). Solar radiation scattered by PSCs in the NIR spectral range, where the lower stratosphere can be remotely sensed in limb geometry, is a sensitive indicator of the presence of PSCs. PSCs are detected with a color ratio approach employing two weakly absorbing NIR wavelengths, i.e., 750 nm and 1090 nm. A priori knowledge is required in terms of the latitude and altitude ranges where PSCs typically occur in order to avoid false PSC identification due to, e.g., cirrus clouds. This contribution describes the PSC detection technique employed, and presents SCIAMACHY PSC observations during the austral springs 2002 and 2003. The majority of the detected PSCs fall within the area, where UKMO temperatures are below 195 K, but there are also several exceptions. Future activities will address the question as to whether the different PSC types can be distinguished with SCIAMACHY limb scattering observations.

Linearization of radiative transfer in spherical geometry with the forward-adjoint perturbation theory

Holger Walter and Jochen Landgraf

National Institute for Space Research (SRON), Utrecht, The Netherlands

contact: h.walter@sron.nl

Satellite observations of the UV/VIS backscattered radiance in limb-viewing geometry offer the possibility to determine atmospheric trace gas profiles with a high vertical resolution. This requires the simulation of the backscattered radiance with radiative transfer models, which take the multiple scattering of radiation in a spherically bended atmosphere into account. Most inversion methods need in addition the sensitivity of the backscattered radiance with respect to changes of the trace gas density. This corresponds to the linearization of the radiative transfer problem.

We present a general approach for an analytical linearization of radiative transfer models in spherical geometry based on the forward-adjoint perturbation theory. This method employs the formulation of the radiative transfer equation in its forward and adjoint operator form. As a result, the presented approach enables the linearization of the radiative transfer model with the help of only two radiative transfer calculations. Compared to a finite difference scheme this approach is very efficient and allows a fast and accurate retrieval of the atmospheric composition. Furthermore, the linearization approach itself is independent from the solution method of the radiative transfer equation.

In order to demonstrate the application of the developed linearization principles, we consider a simplified spherical radiative transfer problem. Here, we assume a homogeneous spherical shell atmosphere, which is illuminated by a radial-symmetrically external radiation source. For this scenario, we calculate the derivative of the backscattered radiance with respect to the absorption properties of ozone. The verification of the calculated derivatives are performed with a finite difference scheme. Thus, the presented method enables the efficient linearization of radiative transfer models in spherical geometry, which are needed for a remote sensing of the atmospheric composition with measurements of the backscattered radiance in limb-viewing geometry.

The ACE mission on SciSat

G. Witt[1], and the ACE Team

[1] Department of Meteorology, Stockholm University, Stockholm, Sweden

contact: gwitt@misu.su.se