Studies in Support of an Advanced ESA Mission to Sound Atmospheric Composition after Envisat

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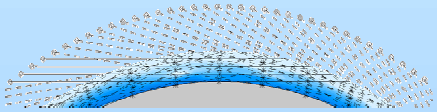
Introduction

During the last three years, two studies have been undertaken in parallel for ESA to consolidate the scientific basis for an advanced future mission to sound atmospheric composition in the period beyond Envisat: An overview is given of the scope and principal findings from these two ESA studies.



Tomographic limb-sounding : The principle of tomographic limb-sounding is to exploit information on horizontal as well as vertical structure in the atmosphere available by viewing a given airmass from different directions. This is accomplished by over-sampling in the horizontal and vertical dimensions and inverting measurements from multiple limb-scans simultaneously to a 2-D atmospheric field

UTLS Study

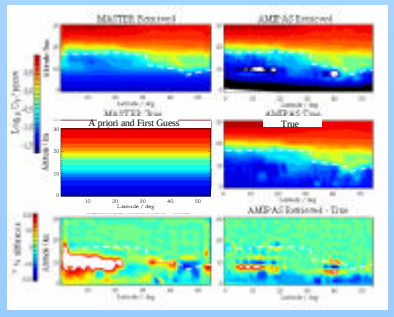
Through the "*Consideration of a Mission Studying Chemistry of the Upper Troposphere and Lower Stratosphere*" the state-of-the-art for limb-sounding of the UTLS region has been advanced in the following ways:

1) Development of tomographic (ie fully 2-D) retrieval schemes for the advanced mm-wave and IR limb-sounders MASTER and AMIPAS and performing iterative, non-linear retrieval simulations for multiple trace gases in the presence of realistic, horizontal (and vertical) structure in temperature, trace gas and cloud fields;

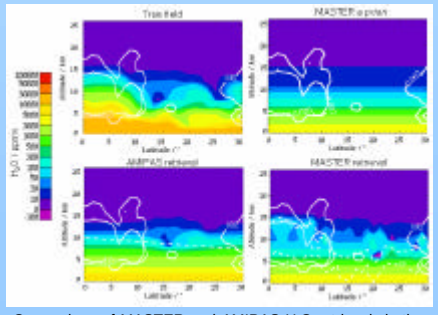
2) Development of a radiative transfer model (ARTS-1.1) to calculate limb radiance spectra rigorously for a multiply-scattering 3-D cloud field

3) Incorporation of cloud scattering into IR and mm-wave radiative transfer models (KOPRA and FM2D) that are fast enough for use in retrievals, through use of approximations

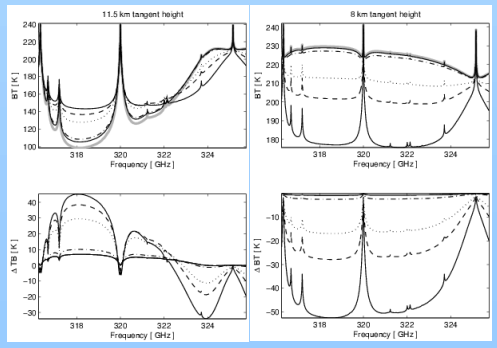
4) Determination of penetration depth into the troposphere for limb-sounding at different wavelengths as a function of latitude, time of year and time of day, on the basis of ECMWF temperature, humidity and cloud fields.



Comparison of MASTER and AMIPAS 2D O_3 retrievals in the absence of cloud (dashed line: tropopause)



Comparison of MASTER and AMIPAS H_2O retrievals in the presence of cloud. (solid lines: location of clouds, dashed lines: lower limit of measurement information). In the AMIPAS case the lower limit is the limb scan range, in the MASTER case the limit is set by attenuation of H_2O itself. The dashed lines correspond to ratio of retrieved to a priori error of 0.1 and 0.9



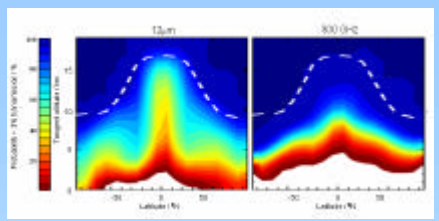
Simulated limb spectra (MASTER – Band C) for a cloud with ice mass content 1.6x10^{-3}g/m^3 at altitude 10-12 km. Left panel: 11.5 km tangent altitude. Right panel: 8 km tangent altitude. Clear sky spectrum (grey line), other lines correspond to different particle sizes: 21.5 µm (solid), 34.0 µm (----), 68.5 µm (·····), 85.5 µm(----), 128.5 µm (solid). The top plots show absolute brightness temperatures and the bottom plots differences between the cloudy and the clear-sky spectra

MASTER millimetre-wave emission sensor designed specifically for UTLS limb-sounding

AMIPAS mid-infrared emission sensor designed specifically for UTLS limb-sounding

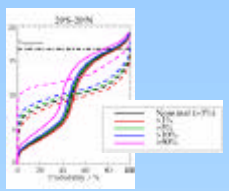
MASTER H_2O, O_3, CO, HNO_3, N_2O, ClO

AMIPAS H_2O, O_3, HNO_3, N_2O, CH_4, temperature



Annual mean probability of limb transmittance > 3%, as estimated from ECMWF fields of temperature, water vapour, water and ice clouds sampled globally 1 day in 10 over a year. It has been shown within this study that retrievals of useful quality can be obtained down to a transmittance of 3%. Dashed white line shows climatological tropopause.

- penetration into upper troposphere for *mm-wave limb sounding* in tropics: low cirrus extinction and capability to retrieve trace gases when cirrus extinction coefficient is low
- penetration into middle troposphere for *IR limb sounding* in cloud-free scenes



Annual mean probability of exceeding limb transmittance thresholds for the tropics (average over latitude band 20 S to 20 N):

UTLS STUDY PRINCIPAL FINDINGS:

The study has confirmed that the MASTER and AMIPAS limb-sounders offer:

1) Retrieval of UTLS structure with higher fidelity than preceding missions, through use of tomographic limb-sounding and advanced instrument design (~100 km horizontal resolution along-track achievable)

2) Complementary information from mm-wave and IR emission in respect to:

- Depth and frequency of penetration into troposphere for H_2O, O_3, CO
- Sensitivity to aerosol, PSC and cirrus
- The additional trace gases measured

ACOR-2 Study

The "*Atmospheric Chemistry Observational Requirements Study - 2nd Extension*" focused on refining the specifications of new instruments in polar orbit for limb-sounding of the UT/LS and nadir-sounding of the troposphere at near-IR wavelengths. These instruments were selected in the original ACOR study to extend and complement the observational capabilities of the future operational missions MetOp and NPOESS.

Key elements were:

- 2-D radiative transfer and retrieval models to determine error sensitivities and to define instrument specifications of limb sounders (**MASTER**, **AMIPAS**)
- quantitative investigation of the potential value of a **limb cloud imager (LCI)** to support UTLS trace gas retrievals from the limb FTIR emission sensor.
- refining the specifications of **near-IR nadir-sounding spectrometers** (Fourier transform and grating) by means of detailed retrieval simulations and comparison against (externally specified) requirements for worthwhile satellite observations of CO_2, CO, CH_4 and other hydrocarbons.

SOME FINDINGS FROM ACOR-2 STUDY :

This study has led to a number of recommendations for changes to instrument specifications which do not detract from the ACECHEM scientific objectives. Examples of instrument simplifications are:

- AMIPAS: spectral resolution is less critical than previously anticipated - relaxation of requirement
- LCI: Two near-IR channels are needed to distinguish aerosol/cloud. One could replace the 12µm channel - reduction in size and complexity
- MASTER: High spectral resolution spectrometers found not to be needed and some reduction in bandwidth allowable

Full details in:

Consideration of Mission Studying Chemistry in the UTLS, Kerridge et al., Final Report, ESTEC Contract No 15457/01/NL/MM, 2004

Definition of Mission Objectives and Observational Requirements for an Atmospheric Chemistry Explorer Mission Study 2nd Extension, Kerridge et al., Final Report, ESA Contract 13048/98/NL/GD, CCN4, 2004

Acknowledgements

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