MIPAS Retrievals using the Oxford Algorithm MORSE

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Anu Dudhia

Atmospheric, Oceanic & Planetary Physics
Dept of Physics, University of Oxford

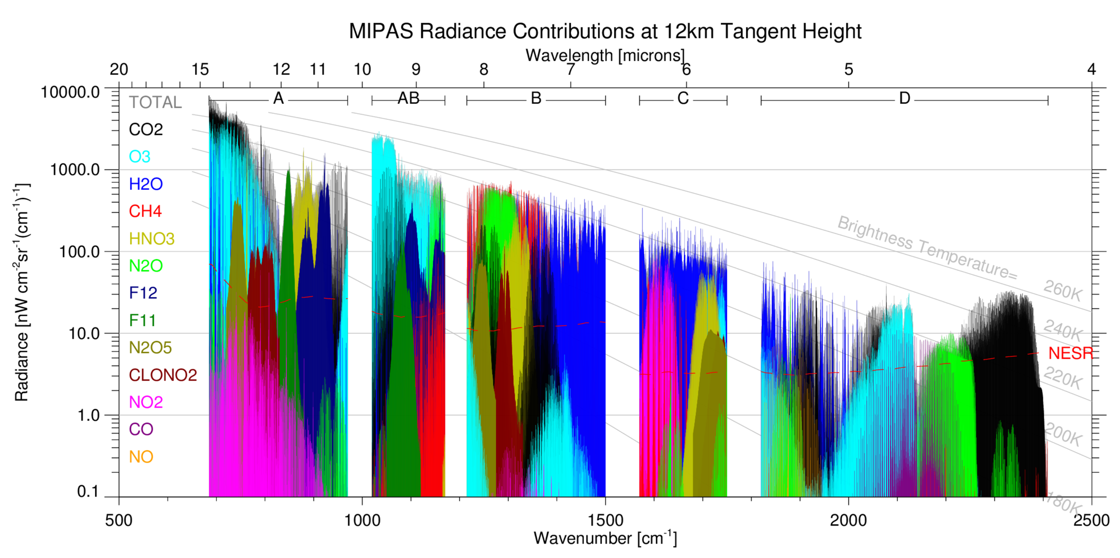
INTRODUCTION

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) was a limb-viewing fourier transform spectrometer which operated on the ESA Envisat satellite from July 2002 - April 2012.

MIPAS made global measurements of infrared atmospheric emission spectra in the range 4-15µm at tangent heights from the mesosphere down to the mid-troposphere. ESA produce calibrated spectra (Level 1B products) and from these derive vertical profiles of atmospheric temperature and composition can be retrieved (Level 2 products).

Using the same ESA L1B spectra, Oxford is one of several groups which also generate their own L2 products [1]. The Oxford MORSE (Multispectral Optimal Retrievals using Sequential Estimation) algorithm uses the same microwindows (ie subsets of the L1B spectra) as the ESA processor, and also retrieves profiles on the measurement tangent point grid, but is based on an optimal estimation scheme rather than a constrained least squares fit.

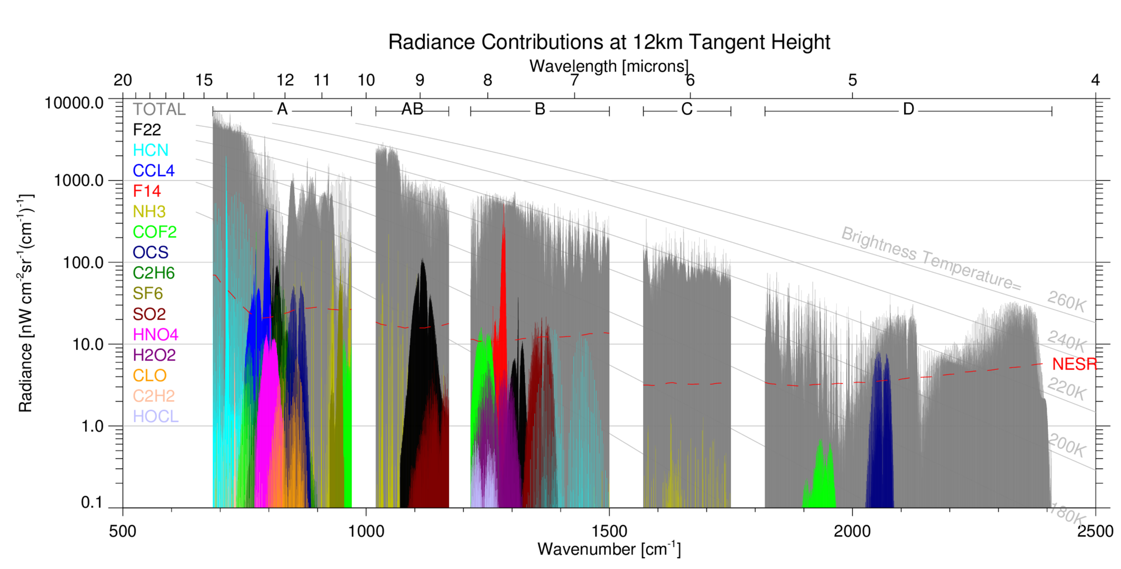
THE INFRARED SPECTRUM



Above is a simulated MIPAS spectrum for a tangent height of 12km showing the spectral features associated with the atmosphere's main infrared emitting species in the 5 MIPAS bands. It is not essential to use a spectrally resolving instrument to retrieve most of these species, although doing so does improve accuracy.

First the temperature and pressure are retrieved using CO2 emission lines (CO2 concentration is assumed known). After this different spectral regions are used to derive concentrations of other molecules in turn: H2O, O3, HNO3, CH4, N2O, NO2, ClONO2, CFC-11, CFC-12, N2O5. Retrievals of CO and NO are more difficult due to a combination of high mesospheric loading and the breakdown of local thermodynamic equilibrium.

In common with most other groups, only small subsets ('microwindows') of the complete L1B spectrum are used for each retrieval – typically 5 microwindows per of up to 3cm^{-1} width per species. This is a compromise between computation speed and accuracy.

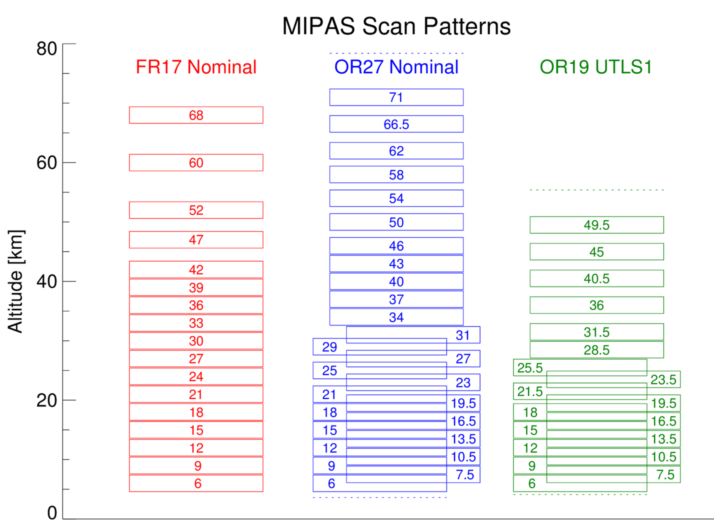


Above is a plot showing spectral signatures of minor species. High spectral resolution *is* essential in order to discriminate emission features of these molecules from the stronger emitters (shown in gray)

The following molecules have recently been added to the Oxford L2 products: CCL4, COF2, CFC-14, HCFC-22, HCN, C2H6, HOCL, OCS, SF6 [2] (the first 5 of these are also being tested for the ESA processor).

OPERATING MODES

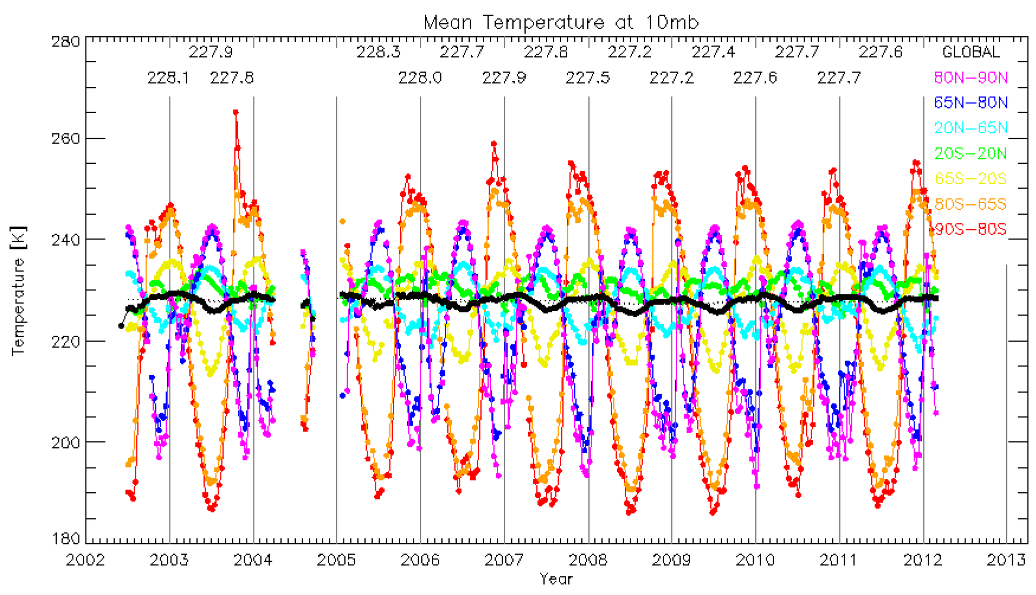
MIPAS was initially operated at full spectral resolution (0.025 cm^{-1} sampling) with 17 measurements for a complete limb scan (FR17). After numerous interferometer anomalies this was suspended in Mar 2004 and operations resumed in Jan 2005 using only 40% of the full interferometer slide movement, hence 0.0625 cm^{-1} sampling. Since the acquisition time for a single spectrum was also reduced by 40%, the number steps in the nominal limb scan was increased to 27 (OR27) to maintain an along-track profile spacing of approx 500 km. However, during 2005-2006 MIPAS was frequently operated in 'UTLS' mode consisting of limb scan sequences of 19 spectra (OR19), with correspondingly reduced profile spacing. From Nov 2007 the instrument also routinely observed 1 day in 5 in either 'Middle Atmosphere' or 'Upper Atmosphere' highe altitude scan modes.

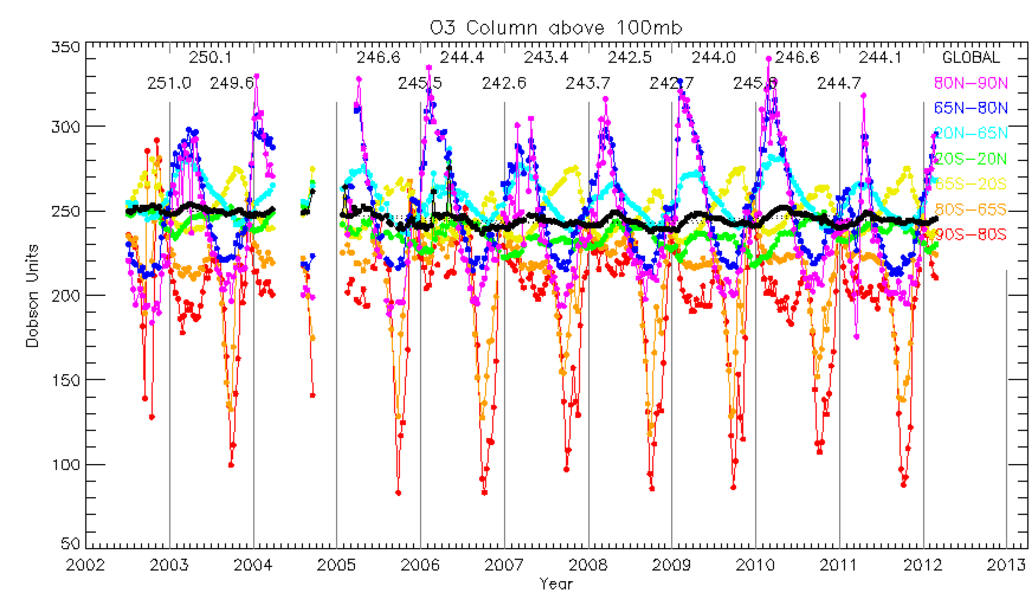


Projection of various MIPAS scan patterns onto the atmospheric limb. Rectangles represent the MIPAS effective field-of-view (30x10km), shown to scale. Numbers indicate the nominal tangent heights. The OR27 and OR19 scan patterns included a latitude-dependent altitude offset (dotted lines showing max/min range) following the tropopause shape. Although the limb is sampled at 1.5km spacing, the achievable vertical resolution in the L2 data is approx 2km at best.

10-YEAR TRENDS

MIPAS data extend for a decade but, given the different operating modes, some care is required if the data are to be used to establish trends on this timescale [3]. The figures below show summaries of the Oxford L2 data for temperature at 10mb, where the dataset appears self-consistent, and for the ozone column above 100mb, where there is a clear offset between the FR data before 2005 and the subsequent OR data.

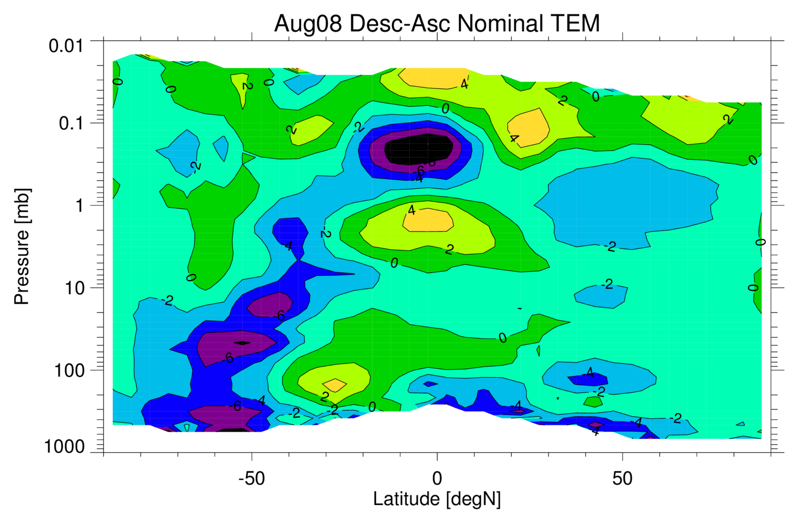




Long term trends in the Oxford MIPAS L2 temperature at 10mb (top) and ozone above the 100mb surface (bottom). Black lines represent the global average, other colours are different latitude bands. Each point represents a 10 day mean of MIPAS data. Numbers along the top are the 1 year global average values. Note in particular the stability of the temperature annual mean – within a few tenths of a K – compared to the obvious offset in the ozone – 5 DU – after the change in instrument resolution in 2005.

So far, the MIPAS full-resolution data (2002-2004) has only been processed (both by ESA and Oxford) using a limited set microwindows that were selected pre-launch to meet strict computing budgets. A new, unrestricted, set of FR microwindows has now been selected and is used in Oxford v1.4 data (also the next version of ESA data). This is expected to improve the precision of the FR part of the MIPAS dataset and *may* also reduce the offsets associated with the change in MIPAS resolution

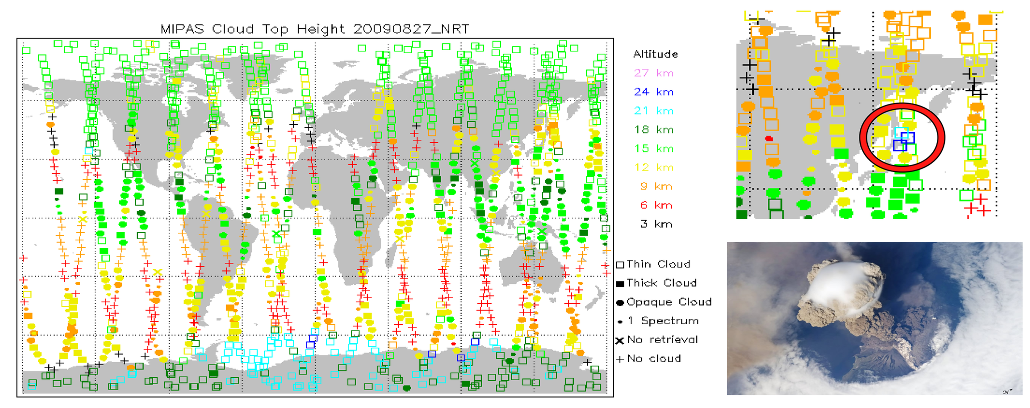
DAY-NIGHT



The plot above shows the difference in zonal mean temperature for August 2008 between the descending (day-time) and ascending (night-time) orbits. The oscillating structure over the equator is the (real) diurnal tide. However the differences at mid-latitudes are thought to arise from neglecting horizontal temperature gradients in the retrieval forward model. Similar artefacts can be seen in the day-night differences of most species in the Oxford (and ESA) data.

CLOUD & AEROSOL

A separate part of Oxford processing is the retrieval of cloud top height, temperature and extinction by observing the continuum emission between the CO2 lines in the 900-1000cm^{-1} region (10µm window). This also seems to be a more robust cloud detection method than the widely-used Cloud Index and will be incorporated into future L2 processing. Meanwhile, a more conventional aerosol extinction retrieval is being tested as a candidate for adding to the list of L2 products [4].



The main plot above shows the cloud retrieval results for 27 Aug 2009. Apart from the expected Polar Stratospheric Clouds at high altitude in the Antarctic, this also shows a uniform 'thin cloud' coverage at around 15km altitude throughout the Arctic. Working backwards this can be traced to the eruption of the Sarychev volcano in the Kuril islands (just north of Japan) in mid-June 2009. The upper right plot shows a detail of the retrievals for 18 June where the circled area shows cloud detected at 24km above the volcano. The photograph, taken from the ISS, shows an earlier eruption on 12 June.

RELATED POSTERS

The following posters at this meeting include results from the Oxford L2 processor

[1] Comparison of the MIPAS products obtained by four different L2 Processors, P. Raspollini et al. - *compares L2 products obtained from Bologna, IFAC, KIT/IAA and Oxford.*

[2] Analysis of new species retrieved from MIPAS, S. Cai. - *initial evaluation of new molecular species retrieved with the Oxford processor*

[3] Merged Ozone Product from four MIPAS Processors, A. Laeng et al - *describes the construction of an ozone dataset for climate change studies*

[4] Aerosol Extinction and Classification using MIPAS, A. Smith et al – *retrievals of aerosol extinction profiles at different wavelengths used to discriminate between aerosol types*

For further information see
www.atm.ox.ac.uk/group/mipas
or Google 'MIPAS' and 'Oxford'