Evaluating the potential of GOME-2 ozone column retrievals in the Chappuis bands

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Introduction

- ozone is one of the most important trace gases in the atmosphere
- UV nadir satellite observations provide very accurate total O_3 amounts and estimates of tropospheric O_3 columns
- currently, all UV/vis nadir ozone products are based on the use of Huggins band information

Why use the Chappuis bands?

- as result of reduced Rayleigh scattering in the visible part of the spectrum, O_3 retrievals in the Chappuis bands are more sensitive to the lower atmosphere and the troposphere
- due to the smaller absorption in the Chappuis bands, the retrieval is much less sensitive to the O_3 vertical distribution and column amount
- in contrast to the O_3 adsorption cross-section in the Huggns bands, the Chappuis bands are not temperature dependent, simplifying the retrieval
- there is more light available in the Chappuis bands (higher solar output, larger surface reflectivity) improving signal to noise ratio
- retrieval in the Chappuis bands would be more consistent with limb / occultation measurements as well as ground-based DOAS observations
- most importantly, combining retrievals in the Huggins and Chappuis bands has the potential for providing tropospheric O_3 columns

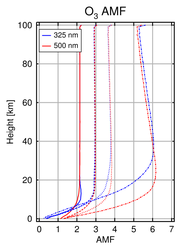

Figure 1: Block airmass factors (weighting functions) for the Huggins and Chappuis bands. Values for SZAs 30°, 50°, 60°, and 80° are shown from left to right. Surface albedo was set to 0.05.

Why not to use the Chappuis bands:

- the differential absorption cross-sections in the Chappuis bands are nearly one order of magnitude smaller than in the Huggins bands
- the Chappuis bands are smoother and less characteristic than the Huggins bands, making the DOAS retrieval less sensitive
- for nadir measurements, there are several strong interferences with the spectral ozone retieval at the wavelengths of the Chappuis bands:
  - strong absorption by water vapour
  - strong absorption by the oxygen dimer O_4
  - liquid water absorption in surface waters
  - spectral dependence of soil reflectance
  - spectral dependence of vegetation reflectance
  - polarisation dependence of instrument

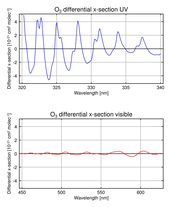

Figure 2: Direct comparison of the differential ozone absorption cross-sections in the Huggins bands (top) and the Chappuis band (bottom)

Acknowledgements

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- GOME-2 lv1 data were provided by EUMETSAT

Selecting the fitting window

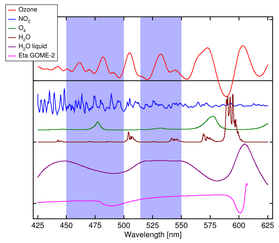


Figure 3: Relevant absorption cross-sections in the Chappuis band. Values are shown in arbitrary units and have been high pass filtered (O_3, NO_2, H_2O_{liquid}). The shaded area is the fitting window used.

- GOME-2 channel 3 ends at around 600 nm
- wavelengths < 450 nm have little O_3 absorption
- wavelengths > 450 nm have large absorptions by H_2O, O_4, and liquid water and extension of the fitting window leads to large biases in O_3
- exclusion of water vapour absorption around 510 nm improves fitting quality and reduces sensitivity to vegetation signal (see below)
- a cubic polynomial was used - polynomials of higher degree improved fitting quality but lead to unstable O_3 retrievals

Impact of Vegetation

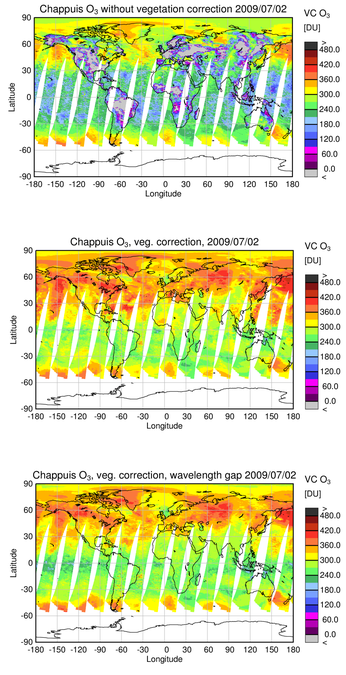


Figure 4: One day of ozone columns retrieved in the Chappuis band without vegetation correction (top), with correction (middle) and with correction and excluding values from 500 - 515 nm (bottom).

- overall pattern of O_3 retrieval in Chappuis looks reasonable but values over some land areas are very low, even negative
- fitting residuals in these areas are large
- areas affected are land surface with vegetation observed under cloud free conditions
- this can be corrected by either using a very large polynomial or by including the logarithm of the ratio of two measurements with and without vegetation in the fit
- in both cases, the fitting residual is much improved and ozone values over vegetation are more realistic, but ozone values increase also in other regions
- use of a wavelength gap reduces the effect
- surface effects have already been reported earlier for GOME observations at wavelengths > 600 nm (Wagner et al.) and for the GOME-2 NO_2 retrieval (Richter et al.)

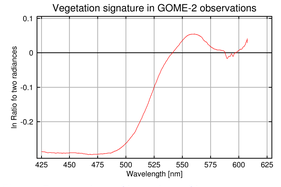
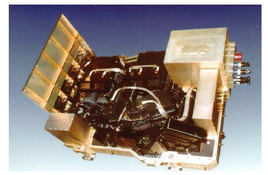


Figure 5: Logarithm of the ration of two measurements, one having a large residual over vegetation and one close by producing a good fit. This ratio has been included in the fit to correct for vegetation effects.

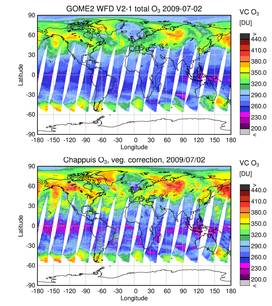
Instrument



GOME-2 Instrument:

- launched on MetOp-A in October 2006
- data since January 2007
- 4 channel nadir viewing UV/visible spectrometer
- first in a series of three identical instruments
- 80 x 40 km^2 pixel size
- global coverage in 1.5 days
- 09:30 LT equator crossing
- launch of next GOME-2 in May 2012

Comparison with UV retrieval



- overall pattern of UV and Chappuis analysis is in good agreement
- Chappuis retrieval has high bias in northern hemisphere
- low bias in the tropics
- random noise of Chappuis data is larger
- thre are several regions with clear artefacts in the Chappuis data, in particular over clear ocean scenes

Figure 6: Comparison of total ozone columns retrieved with the WFD retrieval in the Huggins bands (top) and using the split window and vegetation correction in the Chappuis bands (bottom). The WFD-data are corrected for the effects of clouds and surface albedo and use the TOMS O_3 profile climatology, while the Chappuis analysis does not correct for clouds and, uses the US standard atmosphere and a constant surface albedo of 0.05.

Conclusions

- Ozone retrieval using the Chappuis bands has been demonstrated to be feasible in GOME-2 data
- the signal to noise ratio is clearly lower than for UV fits
- there are spectral interferences from other absorbers and surface spectral reflectance, in particular over vegetation
- the current product is of insufficient accuracy and precision for use in atmospheric studies
- significant improvements are needed in order to make a combined UV/vis retrieval useful

Selected References

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