Total Column Ozone retrieval from multispectral imagers operating in the visible range (ESA Contract 4000112694)

Executive Summary

The depletion of stratospheric ozone due to anthropogenic emissions of long-lived substances containing chlorine and other halogens was first identified as a matter of international concern in the mid-1970s and has received increasing attention since the mid-1980s after the discovery of the ozone hole. Today, in spite of the successful application of the Montreal Protocol and its amendments, the atmospheric halogen loading is still above natural levels and will remain so until the middle of this century. Monitoring of stratospheric ozone therefore remains extremely important, as the ozone layer has yet to recover from the atmospheric halogen loading caused by human action. Moreover, climate change also has an influence on stratospheric ozone while evidences that changing tropospheric ozone levels impact climate are becoming increasingly clear.

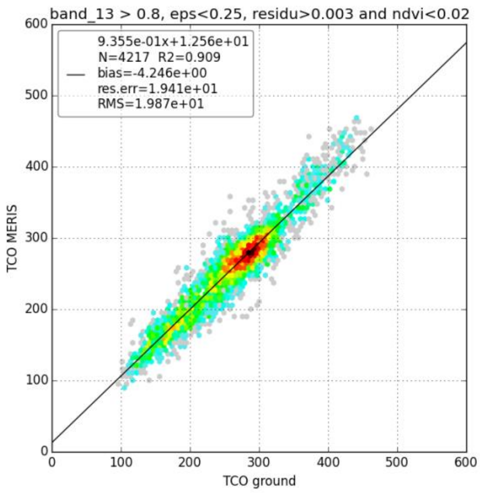
Traditionally, total ozone columns are measured from space from nadir UV hyperspectral instruments. Those measurements are characterized by an accuracy of a few percent and the more recent UV sensors provide observations at a spatial resolution of about 10 kilometres, with a daily global coverage. In this study, we have investigated the potential to exploit observations in the visible spectral range by the multispectral imager MERIS to retrieve total ozone columns, relying on an exploratory study by M. Bouvet (2012)[1]. MERIS has several channels in the ozone Chappuis bands, which can provide information on the ozone atmospheric content. The main difficulty is the proper separation of the ozone absorption signal from the background, which may significantly vary depending on the surface type. Nonetheless, if the ozone columns are retrieved with a sufficient accuracy, the generated data products would benefit from the high spatial resolution of MERIS (05-1 km).

As mentioned before, MERIS channels 3 to 8 are significantly affected by ozone absorption and the algorithm relies on the difference between the measured transmittances at those channels and free absorption transmittances modelled by a 3rd-order polynomial fitted through MERIS channels weakly impacted by atmospheric gases (i.e. 1, 2, 10, 12, 13). In particular, the ozone transmittances at the different MERIS channels have been better modelled in the framework of this project. For bands significantly affected by ozone absorption, ozone transmittances have been calculated using accurate radiative transfer simulations in spherical shell atmosphere and stored in look-up tables for total ozone columns from 25 to 600 Dobson Units. For the other channels, the residual ozone absorption is characterized using a simple parameterization. The retrieved ozone column results from a non-linear least-squares procedure in which the differences between the free-absorption spectrum and the measured transmittances corrected for the ozone absorption are minimized. The correction applied to the measured transmittances is extracted from the look-up tables and depends on the ozone column, which is adjusted as part of the iterative process. The reliability of the method is mostly linked to the assumption that the absorption-free spectrum may be modelled by a simple

[1] Bouvet M., Total column ozone retrieval from MERIS, version 3.1, 15/11/2012 (available from ftp://ftp.estec.esa.int/pub/xe/anonymous/TN_Ozone_Retrieval_Bouvet_v3.1.pdf)

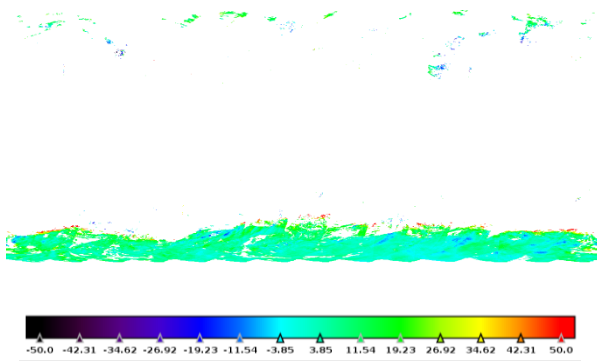
polynomial, which is not always verified in practice. As an outcome of this project, it has been concluded that this assumption is verified mostly above bright surfaces like snow/ice covered scenes or scenes contaminated by optically thick clouds. A series of key parameters have also been identified, which can be used as proxy of the retrieval quality.

Extensive comparisons of the total ozone columns retrieved from MERIS observations with independent measurements from both ground and space have allowed to identify thresholds for these key parameters which define a domain of validity for the MERIS total ozone column product. Within this domain, the MERIS retrievals are assumed to be reliable and relatively accurate. The reference ground-based measurements used in this study originate from UV spectrophotometers (Brewer and Dobson instruments) and from UV-Visible DOAS spectrometers which are routinely archived in the World Ozone and Ultraviolet Radiation Data Centre (WOUDC - http://www.woudc.org),) and in the Data Host Facility (DHF) of the Network for the Detection of Atmospheric Composition Change (NDACC). The reference satellite data sets are those generated as part of the ESA Ozone_CCI project with the GODFIT algorithm applied to the nadir UV sensors GOME, SCIAMACHY, GOME-2 and OMI[2]. Within the domain of validity defined by the key parameters, a general good agreement is found between ground-measurements and MERIS ozone columns in co-location with 26 selected stations. The comparison is characterized by a correlation coefficient of 0.91and a general bias of only -4 DU.



MERIS TCO versus TCO measured from ground (in Dobson Unit) for 26 stations. All MERIS pixels co-located with the ground-stations over the full mission (2002-2012) and belonging to the domain of validity defined by the quality indicators have been considered in this comparison.

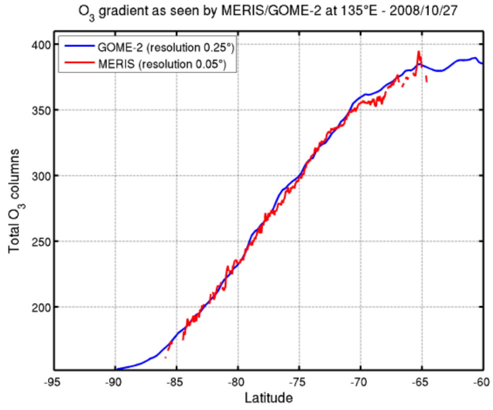
Intercomparison of the MERIS total ozone column product with UV data products has clearly shown that MERIS retrievals are not physical out of the defined domain of validity. However, within this domain, which corresponds roughly to bright surfaces, the MERIS TOCs are generally in reasonable agreement with the GOME-2A TOCs as illustrated on the figure hereby. When considering comparisons with GOME-2 for 18 days distributed over the seasons in 2008, a mean bias of 1.5% and a standard deviation of 3.3% are found for pixels over Antarctica while, outside of Antarctica, a larger mean bias of 4.4% with a standard deviation of 4.8% are observed,



Absolute TCO differences between MERIS and GOME-2A for the 15 October 2008. Only regions where the MERIS quality parameters indicate reliable retrievals are considered.

[2] Lerot, C., et al., 2014, Homogenized total ozone data records from the European sensors GOME/ERS-2, SCIAMACHY/Envisat and GOME-2/MetOp-A, J. Geophys. Res., 119, 3, 1639-1662, *doi:10.1002/2013JD020831*

indicating a low-bias of the MERIS ozone columns. Further investigations have been carried out to better understand the origin of the low bias in the MERIS retrievals. It has been clearly shown that this bias is particularly clear when the ozone absorption is low, e.g. in case of low ozone columns or limited effective atmospheric light path. This underlines the difficulty of the
method to separate a low ozone absorption signal from an absorption-free background by the method. However, we have clearly shown that the method leads to relatively reliable total ozone columns in case of strong O_3 signature in the radiances and over bright surfaces presenting relatively wavelength-independent spectral response. Those conditions are for example often met over Antarctica and the figure hereby nicely illustrates the O_3 gradient along longitude 135°E as seen by GOME-2 and MERIS for one day of the ozone hole season in 2008. The two instruments see consistent large scale spatial variation of the total ozone field. The high-frequency variations in the MERIS observations agree roughly with the estimate of the level of noise in the MERIS product (1-2%).



O_3 gradient in Southern Pole seen by MERIS and GOME-2A along the longitude 135°E for one day of the ozone hole season 2008.