SURFACE UV-FLUX ESTIMATION FROM GOME : IMPACT OF WAVELENGTH DEPENDENT EFFECTIVE ALBEDO

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1 Introduction

The surface albedo is the ratio between the upward irradiance, reflected from the ground, and the downward irradiance. It is an important parameter in the climate system, since it determines to a large extent the Earth radiation budget. The ground albedo often refers to the average reflectivity over the whole wavelength range of solar radiation. Investigation of the surface influence on radiation in the lower atmosphere at a particular wavelength therefore requires knowledge of the spectral albedo.

Koelemeijer et al. [4] have shown that GOME spectra are useful for this task. Aerosols were neglected in their study and results for different surface types were presented only for wavelengths larger than $425\,nm$. Measurements of spectral reflectivities at ultraviolet wavelengths exist from an airborne platform [7]. Our aim is the estimation of a spectral albedo from GOME experimental data for wavelengths between 315 and $385\,nm$ and its influence on the UV radiation on the ground.

2 GOME

The Global Ozone Monitoring Experiment (GOME) was launched on board the ESA's Second European Remote Sensing Satellite (ERS-2) in April 1995 into a polar sunsynchronous orbit [1]. The nadir-viewing spectrometer measures the Earth's reflectivity and the solar irradiance between $240 - 790\,nm$ at moderate spectral resolution $(0.2 - 0.4\,nm)$. The spatial resolution is about $320 \times 40\,km^2$ for each ground pixel (across $\times$ along track).

3 UV-Index calculation using simulated spectra

With the investigation of theoretical simulated spectra, we demonstrate the effect of a spectral albedo on the determination of the UV radiation on the ground and the UV Index instead of assuming a constant reflectivity over the whole wavelength range.

The UV Index is a unit of measure of UV levels relevant to the effects on human skin. It is defined as the effective irradiance obtained by integrating the spectral irradiance weighted by the CIE reference action spectrum [5] up to $400\,nm$ normalized to 1.0 at $297\,nm$ (see Fig. 1(a)).

Three cloud-free scenarios over different surface types (water, soil and sand) are simulated with the radiative transfer code GOMETRAN++ [6]. Generally the albedo of the surfaces is less than about 10% in the UV; therefore aerosols cannot be neglected. Minimal aerosol loadings with maximum visibility were assumed for each scenario. Fig. 1(b) shows the spectral albedo values up to $800\,nm$ for five surface types which are taken from data sets provided by R. Guzzi. The spectral reflectivity for vegetation is constant in the wavelength range up to $400\,nm$, and the variability for the other surface types is very small.

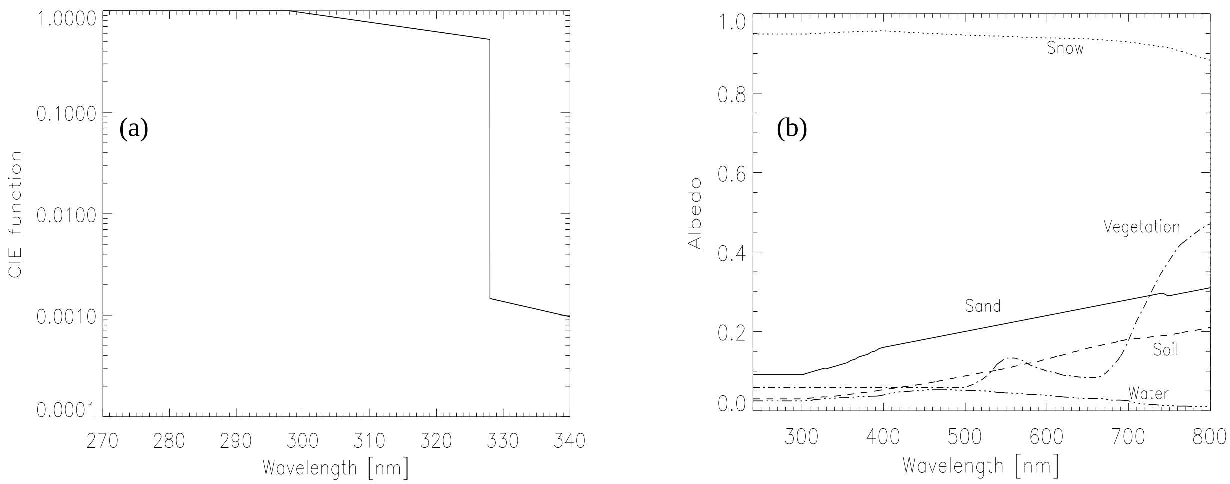

Figure 1: The CIE action spectrum (a) and the spectral albedo for different surface types (R. Guzzi, private communication) (b)

Fig. 2 shows the differences between radiative transfer calculations when assuming a constant albedo and when assuming the spectral albedo for different surface types, except for snow and vegetation. The differences for the wavelength dependent downward flux on the ground is shown. Solid lines indicate calculations with a mean albedo over the wavelength range, and dotted lines indicate a constant albedo at $380\,nm$, which is often taken to be representative. Table 1 gives an overview of the selected values.

The differences are very small for all surface types. Maximum values of $+1.8\%$ (at $310\,nm$) and -1.3% (at $400\,nm$) can be found for sand. The differences for water are negligible. For soil they are not larger than -1.0%. For all surface types the differences are larger using the constant albedo at $380\,nm$, but with opposite signs.

The effect on the derived UV Index can be seen in Fig. 3. The differences between a constant albedo and the spectral albedo for heights up to $13\,km$ are shown. There are no differences above this level. Maximum values of $+1.5\%$ for sand and -1.0% for water can be indicated at the ground and the differences decrease with increasing height. The differences are positive for the whole range, when the mean constant albedo is assumed, that means, the UV Index computed with an albedo held constant is larger than using the spectral albedo, but the variations are obviously small. The mean albedo is smaller than the $380\,nm$ albedo for all surfaces. The differences for sand are both positive and the differences for soil and water switch from positive to negative, when the value at $380\,nm$ is used instead of the mean. A sensitivity study including more simulated spectra or a comparison with groundbased data would give more information. In summary, the weak wavelength dependence of the spectral albedo of various surface types has a rather small influence on the UV surface flux.

In the next section, we will check how the retrieved surface albedo from GOME compare with the Guzzi database often used in various retrieval algorithms for GOME.

Table 1: Values for the constant albedo

Surface	$\alpha =$ mean	$\alpha = \alpha(\lambda = 380nm)$
Water	0.03	0.036
Soil	0.04	0.047
Sand	0.11	0.14

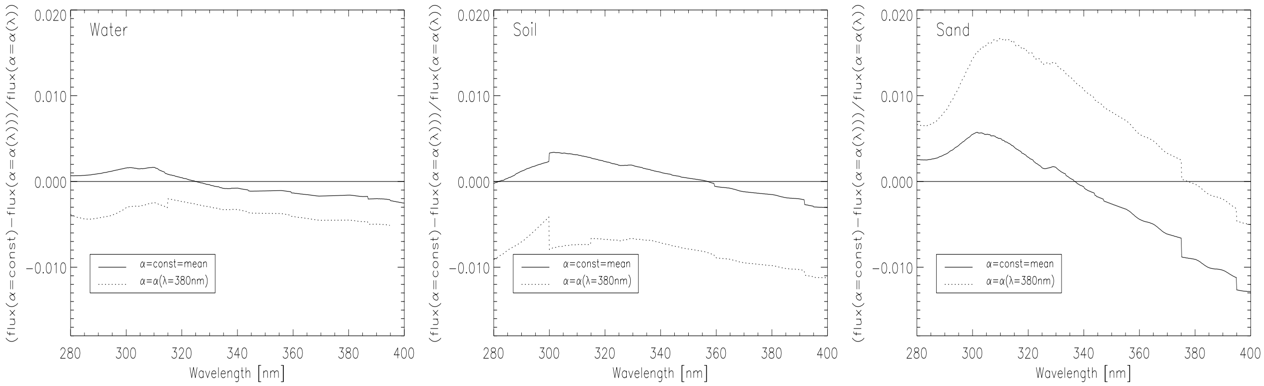

Figure 2: Comparison of downward fluxes at the ground for different surface types calculated with a constant albedo ($\alpha = const$) and with a spectral albedo ($\alpha = \alpha(\lambda)$)

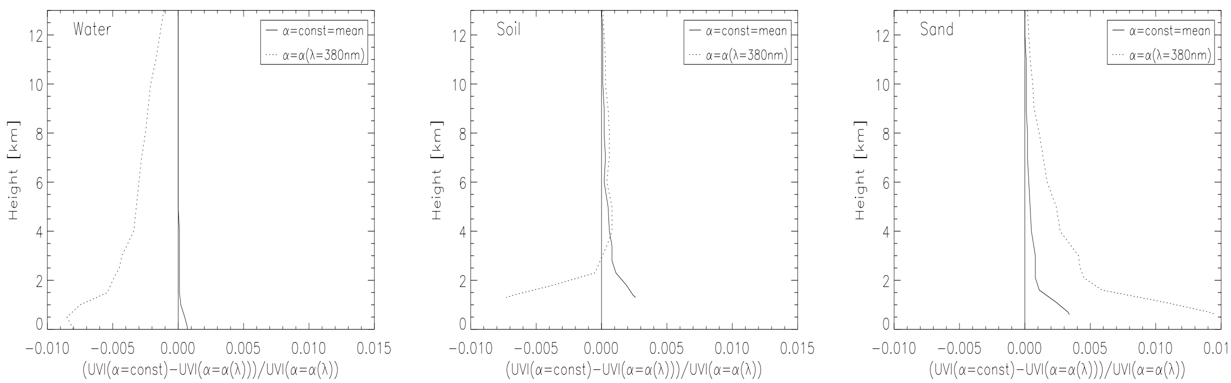

Figure 3: Comparison of the UV Index for different heights and surface types calculated with a constant albedo ($\alpha = const$) and with a spectral albedo ($\alpha = \alpha(\lambda)$)

4 GOME experimental data

For the comparison of the retrieved surface albedo with the Guzzi database, we selected GOME spectra for five cloud-free scenes over the northern Atlantic Ocean. Table 2 gives information about the pixel locations.

All data were acquired in October 1998 and pertain to 'East' pixel which have a line-of-sight of about $23°$. An exception is the last pixel. This is an orbit with a small swath width and scan angle which is taken three times a month from GOME. The solar zenith angle of the measurements was limited to $75°$. The aim was to choose scenarios with minimum albedo to minimize the aerosol and cloud influence.

5 Algorithm description

Evaluation of GOME experimental data requires using the radiative transfer code GOMETRAN++. The first step is to perform radiative transfer calculations in the spectral range from $355 - 385\,nm$. Concentration profiles of the absorbing gases are taken from MPI climatology, temperature and pressure profiles come from UK Meteorological Office, and aerosols are included using the LOWTRAN parametrization. As a first guess for the surface albedo, the Guzzi database is chosen. Output are the modelled sun-normalized radiance R_{mod} and the weighting functions w_i for the atmospheric parameters p_i which are here the Ring-effect, NO_2, O_3 and O_4 columns and the albedo. An estimation of the effective

Table 2: Locations of the selected GOME spectra in the North Atlantic Ocean in October 1998

scene	date	orbit	pixel	latitude	longitude
Ocean	30.10.1998	81030141	481	43 N	46 W
Ocean	25.10.1998	81025132	493	44 N	35 W
Ocean	30.10.1998	81030141	473	44 N	45 W
Ocean	30.10.1998	81030141	465	45 N	45 W
Ocean	24.10.1998	81024135	489	46 N	45 W

spectral albedo requires now the minimum of the residue

$$||R_{exp} - R_{mod} - \sum_{i}^{N} w_i \cdot p_i||^2 \Rightarrow min.$$

For all selected cases the retrieval yielded negative albedo values. As there were no additional parameters such as aerosol loading and cloud fraction which could be changed to obtain physical acceptable results, we attempted to fit an additional parameter that represents the spectral degradation effect of the GOME instrument. The inclusion of the new degradation parameter, here defined as an offset, raised the retrieved albedo to reasonable values. By adding another spectral range (340-350 nm) in the simultanous fit, the degradation function was fitted as a third degree polynomial by varying the albedo in the added spectral range and keeping the albedo value from the earlier fit fixed. This fit was repeated in the same manner by successively adding the spectral windows 325-335 nm and 316-325 nm, whereby only an albedo for the added spectral range was varied while refitting the polynomial. The derived surface albedo in the four spectral ranges provides an estimate of the spectral variation.

6 Results

In Fig. 4 we present our estimation for the wavelength dependent albedo for the first four North Atlantic pixels. The dashed line indicates the mean. The derived values deviate strongly from the literature data. We found a maximum value of 1.5% at $370\,nm$ whereas the Guzzi data sets indicate 3.5% in that range. The albedo values are extremely low. Obviously the values at $320\,nm$ are not very reasonable. Though, the albedo increases with increasing wavelength, which was also found in former studies [7].

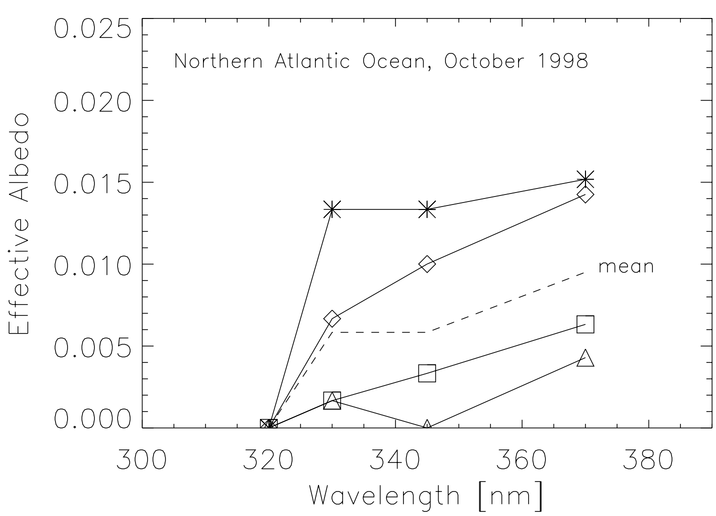

Figure 4: Estimation of the spectral albedo in the four wavelength ranges for four North Atlantic pixels (solid lines with symbols). The dashed line indicates the mean.

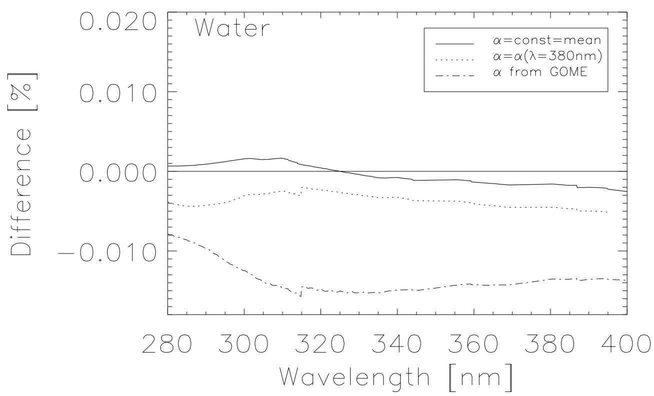

Figure 5: Same as Fig. 2 but additionally the new comparison with the estimated albedo from GOME data

Another GOMETRAN flux calculation was then derived assuming a new constant albedo of $\alpha = 0.0059$ (average of our estimation). The differences between these results and the flux derived with a wavelength dependent albedo from Guzzi database is shown in Fig. 5 (dot-dashed line). They are only about -1.5%, although the value of the estimated albedo deviates strongly from the literature data (0.58% instead of 3.0%).

The results for the 3rd order polynomial are shown in Fig. 6 (solid curves) for all five pixel. They are in good agreement, except for the last pixel which is taken from an orbit with a smaller maximum scan angle (10° instead of 31°) and a smaller swath width. The polynomial can be considered as an estimation of the degradation effect. It is about 3.5% and seems to depend on the scan mirror angle. For comparison, differences of radiances between collocated GOME and SBUV/2 (Solar Backscattered Ultra Violet Instrument, launched on NOAA-14, [3]) radiances are plotted. SBUV/2 values were predicted using the retrieved SBUV/2 ozone profile in a radiative transfer calculation [2]. They are indicated with symbols and dotted lines and show a reasonable agreement with our results except for one value near $320\,nm$ which was taken from the NOAA-11 satellite.

7 Discussion

It was shown for some selected examples and three surface types, that the UV flux calculation is not very sensitive to the spectral variation of the surface albedo. The differences between a constant albedo and a wavelength dependent albedo are rather small. The estimation of a spectral albedo from GOME experimental data over the North Atlantic Ocean has shown large deviations from the literature. The results have to be checked for other surface types, and other seasons.

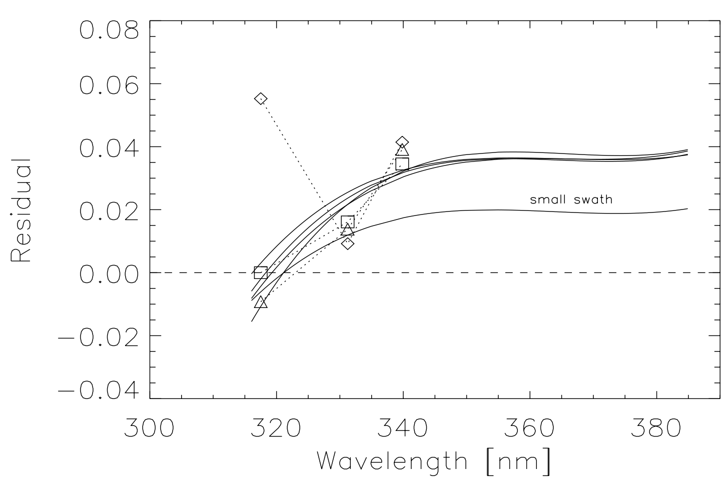

Figure 6: Estimation of the polynomial representative for the degradation effect for five North Atlantic pixels (solid lines) in comparison with SBUV/2 data (dotted lines with symbols)

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