Influence of variability in aerosol vertical profile on retrievals of aerosol optical thickness from NOAA AVHRR measurements

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Upward radiances at the TOA are the main source of information on the atmosphere and the Earth’s surface. Therefore the precise modelling of the atmospheric component of these radiances is an essential problem in remote sensing algorithms. Atmospheric aerosols control variability of TOA radiances over clear sky for given positions of the sun and a satellite. Vertical distribution of type and concentration of aerosol particles varies in time and space. Typically, variability of aerosol profiles is not included in remote sensing algorithms for AOT. Neither they are taken into account in sensitivity analysis of the algorithms. However, some works indicate that in some cases variability in aerosol profile may have significant impact on the TOA radiances (e.g. Meloni et al., 2005, Mitchell et al., 2006).

In the present study we analyse the possible influence of variability in atmospheric aerosol profiles on angular distributions of the TOA upward radiances, focusing on its possible impact on AOT retrievals. We do not intend to analyse any particular case but rather estimate the maximum uncertainty to be expected, and specify the conditions for which a maximum uncertainty may be expected.

The analysis is based on simulations by means of MODTRAN code (Berk et al., 1999). The following tropospheric aerosol models were used in the study: urban/industrial, polluted maritime and clean maritime (d’Almeida et al., 1991). TOA radiances were modelled for three kinds of vertical profiles of aerosol attenuation coefficient for $\lambda=550$ nm. Profiles similar to those included in MODTRAN were used in the retrieval algorithm. „Real” TOA radiances in NOAA AVHRR channels 1 and 2 were calculated for the extreme cases when all aerosol is concentrated (profile 0) near the surface (0-1 km) and (profile 1) in a layer 5-7 km above the surface. Aerosol optical thickness retrieved from the simulated TOA radiances by means of the algorithm was compared to the actual AOT used in the modelling of the TOA radiances. The biases, i.e. the differences between the retrieved and the actual AOT, were calculated for various values of AOT, water vapour content (WV), solar zenith angle (SZA) satellite zenith angle and relative azimuth between the satellite and the sun. Atmospheric conditions and solar and satellite angles used in the bias simulation are similar to those in the Baltic region.

In the case of channel 1, concentration of the aerosol in the near-surface layer practically does not influence AOT retrievals under the assumption of constant aerosol profile. The bias is negligible regardless of AOT, solar zenith angle, water vapour content and aerosol model. However, an appearance of a dominating aerosol layer at the altitude of several kilometres may result in a considerable bias in AOT retrievals from AVHRR radiances in channel 1. The maximum bias, $\varepsilon=0.14$, is found for AOT=1, SZA=65°, WV=0.5 g cm$^{-1}$ and absorbing aerosols, that is for urban and polluted maritime models. In the case of AOT=0.2 the maximum absolute value of the bias is about 0.02.

In channel 2, the bias is considerably higher than in channel 1. Generally, the bias is negative for the profile 0 and positive for the profile 1, regardless of the aerosol model, aerosol optical thickness, water vapour content, and sun-pixel-satellite geometry. Its absolute value increases with an increase in AOT, SZA and water vapour content, reaching its maximum value at AOT=1, SZA=65° and WV=3.0 g cm$^{-1}$ in these simulations. For profile 1 the maximum absolute value of the bias amounts to 0.4 for AOT=1 and about 0.04 for AOT=0.2, while for profile 0 it does not exceed 0.02 for AOT=0.2 and 0.06 for AOT=1.0 in our simulations.

Even though actual biases may vary from the values presented above, they should fall within the range of magnitude determined in his paper. Given that in the present bias estimation simplified “exaggerated” cases were considered and that AOT over the Baltic Sea typically is below 0.2 and only very rarely exceeds 0.5, the expected aerosol profile bias is negligible for channel 1 of NOAA AVHRR, while for channel 2 it may be significant.


