Estimation of errors in modelling of clear-sky direct aerosol radiative forcing in the Arctic due to plane-parallel approach

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Non-uniform properties of the Earth's surface, including highly variable surface albedo, can pose problems in solar radiation modelling in the atmosphere. An application of Independent Column (or Pixel) Approximation approach, widely used in non-uniform situations, may lead to considerable biases in estimates of fluxes and radiances in the atmosphere (Marshak and Davis, 2005). Strong net horizontal photon transport between columns or pixels, neglected in this method, may lead to biased local estimates, especially for small pixels. If pixels are large, the biases are mainly caused by negligence of surface non-uniformity within a pixel.

The main objective of this work is to estimate errors in aerosol radiative forcing modelling, introduced by an application of independent column/pixel approximation (IPA) to clear-sky direct aerosol radiative forcing computation in non-uniform Arctic fjord areas. Using a 3D Monte Carlo RT model (Rozwadowska and Górecka, 2012) for the Hornsund and Kongsfjord regions (Svalbard), we simulated the biases for individual pixels, i.e. the difference between the surface aerosol radiative forcing (ARF) in a given pixel obtained using the plane-parallel model and the 'real' aerosol radiative forcing in that pixel. In both cases mean atmospheric and surface properties were the same. The "real" radiative forcing was computed using 3D Monte Carlo RT model for the real surface topography and the real non-uniform surface albedo. In our simulations, the plane parallel cases were also computed using the Monte Carlo RT model but for the uniform flat surface of the same mean albedo and the same terrain elevation. The simulations were performed for a pixel (grid cell) of the plane-parallel model of 17 km which is in agreement with the horizontal resolution of the tropospheric chemistry model – GEM-AQ (Kaminski et al., 2008) used as a computational tool to derive aerosol properties and distribution over the Svalbard region in iAREA project. Our simulations were performed for various types of pixels, from mostly marine to mostly terrestrial, different surface conditions (summer and early spring), various solar zenith angles (SZA) and aerosol optical thickness (AOT) and for wavelength of 495 nm.

For all the modeled cases aerosol radiative forcing on the surface was negative. An application of IPA to radiative forcing computations for the Arctic fjord region can introduce considerable deviations from the real ARF values. For spring albedo pattern, solar zenith angle 60^o and aerosol optical thickness of 0.04-0.5, the relative error for individual pixels varies from about 5% for a pixel mostly covered with water (99% of water surface) to -23% for mostly terrestrial pixels. A positive relative error means that the IPA modelling overestimates the magnitude (absolute value) of the ARF. Changing surface albedo conditions from spring to summer leads to a reduction in the range of variability in the relative error for individual pixels. For the summer conditions, the error varies from 6% to -13%. Averaging of aerosol radiative forcing over a larger area (several pixels) considerably reduces the biases in the radiative forcing.

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