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Quasi-analytical treatment of spatially averaged radiation transfer in complex terrain

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We provide a new quasi-analytical method to compute the topographic influence on the effective albedo of complex topography as required for meteorological, land-surface or climate models. We investigate radiative transfer in complex terrain via the radiosity equation on isotropic Gaussian random fields. Under controlled approximations we derive expressions for domain averages of direct, diffuse and terrain radiation and the sky view factor. Domain averaged quantities are related to a type of level-crossing probability of the random field which is approximated by longstanding results developed for acoustic scattering at ocean boundaries. This allows us to express all non-local horizon effects in terms of a local terrain parameter, namely the mean squared slope. Emerging integrals are computed numerically and fit formulas are given for practical purposes. As an implication of our approach we provide an expression for the effective albedo of complex terrain in terms of the sun elevation angle, mean squared slope, the area averaged surface albedo, and the direct-to-diffuse ratio of solar radiation. As an application, we compute the effective albedo for the Swiss Alps and discuss possible generalizations of the method.