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Three-dimensional radiative transfer: Effects of cloud variability on reflected radiances.

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To handle complexity to the smallest detail in radiative transfer models is in practice infeasible. Two main reasons prevent from this: (1) the optical properties of the atmosphere and Earth's surface are not available at an arbitrarily high resolution and (2) time-consuming accurate models for solving the radiative transfer in three-dimensional resolved media are prohibitive for some applications, esp. for climate modeling and operative remote sensing algorithms.

In addition to these restrictions there is, at least, one more conceptual reason of why simplified models are still widespread in use for atmospheric radiation applications: the search for a (mathematical) exact solution and its advantages in the inversion theory.

There are only two cases where the radiative transfer equation has exact solutions: (1) considering a non-scattering medium and no reflection at the boundaries (or allowing reflection but decoupling the upwelling from the downwelling beam) and (2) allowing scattering but considering variability only in the vertical direction. The analyticity of these solutions (or combinations or slight modifications of them) is exploited in practically all operational remote sensing algorithms and climate models. Real clouds, however, are neither perfect black bodies (they scatter radiation) nor horizontally homogeneous.

Three-dimensional (3D) radiation models can account for much more complexity than one-dimensional (1D) ones providing a more accurate solution of the radiative transfer at the cost of renouncing to the desirable exact mathematical solution and considerably increasing the calculation time.

Continuous technology progress has led to an increase of computing power, therefore more sophisticated models can be used e.g. for radiative transfer computations. Accordingly, many three-dimensional models have been developed to study cloud variability and its multi-fractal nature. Furthermore, quantity and quality of input data will be significantly improved with the launch of the Sentinel satellites in the framework of the European Global Monitoring for Environment and Security (GMES) program. So, the actual situation offers a perfect scenario to test the adequacy of the 1D radiative transfer theory and opens the possibility to explore alternatives.

In the framework of this paper, we aim at characterizing cloud heterogeneity effects on radiances, namely: The errors due to unresolved variability (the so-called plane parallel homogeneous (PPH) bias) and the errors due to the neglect of transversal photon displacements (independent pixel approximation (IPA) bias). 3D radiative transfer simulations of nadir reflected radiances in the presence of realistic inhomogeneous cloud fields sampled at different spatial resolutions are going to be performed and compared to their 1D counterparts. Results will be linked to the spatial resolution of different virtual sensors. Further, synergetic use of cloud properties defined at different spatial resolutions are going to be investigated.