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A New Cloud Properties Parameterization Implemented in the Fast Radiative Transfer Code sigma-FORUM

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In this study we investigate the level of accuracy of scaling methods, and analytical approximations, commonly used in fast radiative transfer routines of weather and climate models. Specifically, we focus on Chou's approximation (Chou et al., 1999), and a simple scaling method based on the similarity principle. The former one is widely implemented in existing fast radiative codes to solve the radiative transfer problem in the infrared spectral region. At this regard, updated Chou backscatter parameters are computed based on realistic particle size distributions of liquid water and ice particles and by exploiting state of the art optical properties databases.

The assessment of the accuracy of approximate methodology all over the infrared spectrum is obtained by considering a widespread collection of atmospheric scenarios. Top of the atmosphere synthetic spectral radiances are computed for each scenario by considering alternatively an accurate and time-consuming methodology, such as the discrete ordinate solution (DISORT), or the approximate methodologies. The residuals are evaluated at far- and mid-infrared wavelengths and compared with the goal noise of the future 9th Earth Explorer FORUM satellite sensor (Palchetti et al., 2020). Results are discussed and analyzed in terms of geometrical, microphysical, and optical properties of the clouds layers (Martinazzo et al., 2021). In case of both water and ice cloud scenarios, the approximate solutions perform well in the mid infrared for most of the cases studied. When the far infrared region is considered, not negligible inaccuracies are observed.

To reduce the computational errors of basic scaling methods, a correction term is modelled and computed using the solution proposed by Tang et al. (2018) which assumes a downward radiance term not necessarily equal to the blackbody radiance, as it is done in Chou's approximation. The Tang methodology, originally implemented for flux computations, is here adapted to the simulation of radiance fields, and refined by computing the appropriate multiplicative coefficients in the far and mid-infrared separately. Results show that the range of validity of the new methodology is extended with respect to Chou's approximation and covers most of the cloud cases encountered in nature. It represents an accurate solution for the computation of radiance fields in presence of cirrus clouds which are one of the targets of the FORUM mission.

Finally, the whole set of radiative parameters needed to solve the radiative transfer equation using the Chou and Tang approximations is parametrized by mean of polynomial functions of the

effective dimension of the cloud particle size distribution. The parametrized parameters are then implemented in the sigma-FORUM code a forward model designed for the fast calculation of radiance and its derivatives with respect to atmospheric and spectroscopic parameters of nadir-looking hyperspectral instruments. The σ-FORUM model is an updated version of sigma-IASI model (Amato et al., 2002), a monochromatic radiative transfer model based on a look-up table of optical depths parametrized as a polynomial concerning the atmospheric temperature and constituents. The strategy enables fast, accurate radiance and analytical derivatives calculations.