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A High Performance Computing approach to model multiple Rayleigh scattering in the Earth atmosphere

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The retrieval of atmospheric trace gases and aerosols in the Earth atmosphere from light scattering measurements typically involves an iterative inversion algorithm. A key part of this algorithm is its forward model, which takes care of calculating the amount of light that the remote sensing instrument will see, for any assumed atmosphere composition. The forward model is usually an atmospheric radiative transfer code.

It is a serious challenge for a radiative transfer code to be, at the same time, sufficiently accurate and sufficiently fast, so that it can be included in the iterative retrieval loop of an operational service. An accurate code must be able to calculate multiple Rayleigh scattering (important in the UV and/or at lower altitudes) by the air in a spherical atmosphere. This is something that currently only a Monte Carlo algorithm can do. However, any Monte Carlo code is far too slow to be included in the retrieval loop, even if we make use of the currently available HPC power.

We report some first results that were obtained by a new solution to this old problem. We first use a HPC cluster to tabulate multiple Rayleigh scattering in a standard Earth atmosphere, using a Monte Carlo code, as function of 6 parameters (albedo, view zenith angle, solar zenith angle, relative azimuth angle, altitude and wavelength). Then, a well chosen empirical function is fitted on the tabulated data. From this function, correction factors are derived and appropriately inserted in a fast single scattering algorithm, which so effectively becomes a multiple scattering algorithm. Since the evaluation of the empirical function is also very fast, we end up with a radiative transfer code that is both accurate and sufficiently fast for operational data production.

Our conclusion is that commonly available and affordable HPC systems can still not directly solve the retrieval problem with sufficient accuracy in real time. However, the above described two step approach now becomes feasible. Indeed, a HPC system is necessary and sufficient to tabulate the atmospheric multiple Rayleigh scattering over the required higher dimensional data space in a reasonable time (typically a few months).

The above devised forward model will be used in the retrieval loop of a proposed operational O_3 service, driven by a forthcoming space-borne remote sensing instrument, called ALTIUS. This instrument is a spectral imager, currently under development at BISA and in collaboration with external partners. It will be installed on a micro-satellite of the PROBA class and will observe in limb scattering as well as solar and stellar occultation modes. The objectives of the mission are the retrieval of high resolution vertical profiles of key atmospheric trace gases such as O_3, NO_2, CH4, BrO and also water vapor and aerosols.