

## **Representing 3D effects in atmospheric radiation schemes.**

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In this talk I will discuss the representation of 3D cloud radiative effects in the radiation schemes of large-scale atmospheric models, and hence the prospects for estimating the global impact of 3D radiation on the Earth system. I will start by outlining the principle of the "SPARTACUS" solver for accounting for 3D effects in an approximate but affordable way, which is available as an option in the open-source ecRad radiation scheme used at ECMWF. An improvement following from comparison to benchmark shortwave Monte-Carlo calculations is the careful inclusion of the mechanism of "entrapment", which tends to make scenes darker compared to equivalent calculations in which 3D effects are neglected. Observational evaluation of shortwave SPARTACUS will also be presented from a long-term analysis of the ratio of direct-to-total fluxes at the surface. More recent comparisons to longwave Monte-Carlo calculations imply that SPARTACUS tends to overestimate 3D radiative effects in the longwave. A mechanism to explain this is currently under investigation, and relates to the limitations of the two-stream approximation underpinning SPARTACUS, but could be improved by adding more streams. Lastly, I will summarize a new approach to using machine learning for atmospheric radiative transfer: rather than trying to emulate the entire radiation problem, which is very difficult with sufficient accuracy for NWP, we run a fast 1D radiation scheme and emulate the "3D correction" training on the difference between SPARTACUS and the 1D scheme. This achieves close to the accuracy of SPARTACUS without incurring the 4-5 times greater computational cost.