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Fast forward modelling of radar and lidar depolarization subject to multiple scattering

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Lidar depolarization contains useful information on cloud phase, but when the receiver footprint on the cloud is large, as is the case of a satellite lidar, the depolarizing effect of multiple scattering can also become important. In liquid clouds, where we may assume that the single-scattering depolarization is negligible, the measured depolarization is directly related to the degree of multiple scattering which in turn is related to the extinction of the cloud. In the case of spaceborne cloud radar, multiple scattering can become dominant in precipitating clouds, which makes it very difficult to interpret the returns quantitatively. Simulations have shown that if depolarization were measured by such a spaceborne radar then its magnitude could provide information on the degree of multiple scattering and so assist in its interpretation in terms of cloud and precipitation properties. Previously we have demonstrated that our fast forward model for simulating multiply scattered lidar and radar signals can be incorporated into a variational retrieval scheme for optimally estimating cloud properties. The challenge addressed by this presentation is how to incorporate depolarization into this model, which would enable measured depolarization signals to be used rigorously in microphysical retrievals.

Our fast forward model is divided into two parts. The first employs the "photon variance-covariance" (PVC) method and considers single and small-angle multiple scattering. The second employs the "time-dependent two stream" (TDTS) method and considers wide-angle multiple scattering. Note that in the case of radar, small-angle scattering is not important and so we may use single scattering plus the TDTS method. To simulate the effect on depolarization on small-angle multiple scattering, we recognise that small-angle diffraction does not in itself depolarize the light, but it does lead to backscattered returns resulting from scattering slightly at an angle to the exact backscatter direction. While exact backscattering from spheres does not depolarize, slightly "off-backscatter" returns do, in a way that we can parameterize and hence incorporate in our forward model. For wide-angle multiple scattering, we take a more heuristic approach and assume that each order of scattering randomizes the polarization by a fixed fraction, to be determined empirically.

We have performed comparisons between our new fast forward model and a Monte Carlo model. In the simple case of a Rayleigh phase function, our model works extremely well when applied with a value of 0.25 for the degree of randomness introduced in the polarization for each order of wide-angle multiple scattering. In the case of a Mie phase function, the degree of depolarization depends more on the receiver field of view and it is necessary to make the degree of randomness a function of the fraction of the radiation that remains within the receiver field of view. Prospects for incorporating this new model in a retrieval algorithm will be discussed.