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Treatment of autoconversion in climate models: implications for the second indirect aerosol effect

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Global estimates of the indirect aerosol effect that are much larger than 1 W m^{-2} in magnitude are difficult to reconcile with observations, yet recent global climate models (GCMs) give estimates between –1.0 and –4.4 W m^{-2}. These results include a substantial contribution by the second indirect effect, whereby an increase in cloud droplet concentration leads to suppression of autoconversion (coalescence of cloud droplets to form small raindrops). The resultant increase of liquid-water path with aerosol loading is a feature of GCM simulations, but has mostly not been found in observational studies, e.g., [1]. Although several explanations for this discrepancy have been proposed, this talk will focus on the treatment of autoconversion in GCMs.

Most existing GCM simulations have used the threshold-based autoconversion scheme of Tripoli and Cotton [2], even though this scheme is based on some crude assumptions, such as the use of a constant collection efficiency for droplet coalescence. Recently, Liu and Daum [3] introduced a new threshold-based autoconversion scheme, which replaces the assumption of constant collection efficiency with the Long collection kernel [4]. Other features of the new scheme are an autoconversion rate that responds to changes in the dispersion of the cloud droplet spectrum, and an autoconversion threshold that depends on the mean radius of the sixth moment of the droplet spectrum [5].

A new estimate of the second indirect aerosol effect is calculated, using the Liu and Daum scheme in a low-resolution version of the CSIRO GCM [6]. The new scheme gives a global-mean value of –0.28 W m^{-2}, compared to –0.71 W m^{-2} when the Tripoli and Cotton scheme is used. Although there is some impact from the modified treatment of the autoconversion threshold in the new scheme, the main reason for the smaller value is the smaller autoconversion rate (R) in the new scheme. This results

in smaller *absolute* changes in R when cloud droplet number concentration (N) is increased. This occurs even though the *relative* changes in R are larger in the new scheme ($R \propto N^{-1}$) than in the old scheme ($R \propto N^{-1/3}$).

This result shows that it is crucial to accurately simulate autoconversion in GCMs, since errors in the autoconversion rate will affect estimates of the second indirect effect. A few existing studies give insights into the merits of these and other autoconversion schemes, although the results are limited and somewhat conflicting. These studies will be briefly discussed, along with suggestions for further work.

References

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