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Stochastic parameterization of vertical velocity and cloud droplet activation using subgrid cloudy columns in ECHAM-HAM

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A stochastic treatment of cloud activation and CDNC is implemented in ECHAM5.5-HAM2. The parameterization is built on top of a Stochastic Cloud Generator (SCG; Räisänen et al. 2004; 2007) and the Monte Carlo Independent Column Approximation (McICA) radiative transfer scheme (Pincus et al. 2003; Barker et al. 2008), allowing explicit representation of subgrid cloud properties using a specified number of subcolumns.

The Tompkins cloud cover scheme (Tompkins, 2002) is employed in this configuration, as it provides information about the subgrid distribution of total water content inside GCM grid-cells, based on a semi-prognostic probability distribution (beta distribution). The information about the subgrid variability is then used by the SCG to generate the subcolumns. In each subcolumn level, cloud cover (cloud fraction is 0 or 1 for each subgrid point) and cloud condensate amount are defined by applying certain decorrelation and overlap assumptions. However, with the parameterizations used until now, a horizontally uniform CDNC has to be assumed for all the subcolumns.

Hence, a probability density function is defined for vertical velocity (PDFw) in each GCM grid-cell, allowing the calculation of maximum water vapor supersaturation as in the cloud droplet activation parameterization by Abdul-Razzak & Ghan (2000) through random sampling of the PDFw. This yields unique CDNC for each of the cloudy subcolumns. The radiative effects of the resulting cloud columns with two-moment non-uniform microphysical properties are finally explicitly treated by the McICA radiation parameterization.

Model runs show encouraging results in cloud top CDNC when compared to observations; the GCM-scale mean CDNC is mostly reduced with the new subgrid parameterization compared to the standard approach by Lohmann et al. (2007). Moreover, even without the subgrid treatment of cloud activation, implementing SCG and McICA reduces a positive bias in net shortwave radiation (SW) seen in parts of the tropical ocean regions, but introduces new negative SW biases in trade wind regions. This is probably an issue with the Tompkins cloud cover scheme in conjunction with the current model configuration. Introducing the subgrid cloud activation decreases these biases slightly but does not completely eliminate them.

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