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Structure and covariance of cloud and rain water in marine stratocumulus

Mikael Witte, Hugh Morrison, and Andrew Gettelman
National Center for Atmospheric Research, Boulder, Colorado, United States (mkwitte@ucar.edu)

Many state of the art cloud microphysics parameterizations in large-scale models use assumed probability density functions (pdfs) to represent subgrid scale variability of relevant resolved scale variables such as vertical velocity and cloud liquid water content (LWC). Integration over the assumed pdfs of small scale variability results in physically consistent prediction of nonlinear microphysical process rates and obviates the need to apply arbitrary tuning parameters to the calculated rates. In such parameterizations, the covariance of cloud and rain LWC is an important quantity for parameterizing the accretion process by which rain drops grow via collection of cloud droplets. This covariance has been diagnosed by other workers from a variety of observational and model datasets (Boutle et al., 2013; Larson and Griffin, 2013; Lebsock et al., 2013), but there is poor agreement in findings across the studies. Two key assumptions that may explain some of the discrepancies among past studies are 1) LWC (both cloud and rain) distributions are statistically stationary and 2) spatial structure may be neglected. Given the highly intermittent nature of precipitation and the fact that cloud LWC has been found to be poorly represented by stationary pdfs (e.g. Marshak et al., 1997), neither of the aforementioned assumptions are valid. Therefore covariance must be evaluated as a function of spatial scale without the assumption of stationary statistics (i.e. variability cannot be expressed as a fractional standard deviation, which necessitates well-defined first and second moments of the LWC distribution). The present study presents multifractal analyses of both rain and cloud LWC using aircraft data from the VOCALS-REx field campaign to illustrate the importance of spatial structure in microphysical parameterizations and extends the results of Boutle et al. (2013) to provide a parameterization of rain-cloud water covariance as a function of spatial scale without the assumption of statistical stationarity.