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Spatio-temporal variability, dynamics and parameterization of organized precipitating convection

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Precipitating convection strongly affects the atmospheric state at both weather and climate time scales. Latent heat is released during phase changes of water (vapor-to-liquid, liquid-to-ice). Heat absorbed by evaporating precipitation and melting ice drives downdrafts in the mid-to-low troposphere which strongly affect surface-atmosphere exchange. Cloud-radiative interaction is affected by the redistribution of humidity and condensate. The heating-cooling couplet causes an upscale evolution of precipitating convection into larger-scale systems (organized convection) that affect the large-scale circulation of the atmosphere differently from cumulus convection per se. In climate models, both cumulus convection and organized convection are sub-grid-scale processes (i.e., require parameterization). However, traditional parameterizations were not designed to represent convective organization. In a sheared environment propagating mesoscale convective systems (MCS) – populations of cumulus embedded in a convectively-driven mesoscale circulation – are represented explicitly by cloud-system resolving models (CRM; grid-length about a km). A dynamical model of MCS-type organization provides an observationally validated analog simple enough to be applied in a parameterization of convective organization (hybrid representation; Moncrieff and Liu 2007). The heating couplet is approximated by a first-baroclinic (cumulus) mode and a second-baroclinic (mesoscale circulation) mode. Mesoscale momentum transport is represented similarly.

Convective organization strongly affects the statistical properties of the atmosphere, measured as spatio-temporal patterns of precipitation (Hsu et al. 2006) Time series of measurements (radar and rain gages) of natural MCSs over the continental US, as well as CRM simulations, show that the precipitation rate exhibits distinct temporal periodicity and power-law scaling. Fourier decomposition shows two distinct power-law exponents in the rain-rate spectra: -4/3 and -2/3 at scales smaller and larger than 20 km, respectively. This scale-break corresponds to the lower bound of meso-convective organization. The rain-rate features distinctive temporal variability at approximately 1/2, 1, 4, 11 and 25 days. The eastward- propag ating patterns with periods $<$ 5 days are consistent with MCS-type organization. Lower-frequency ($>$ 5 day) patterns that propagate westward suggest the influence of large-scale disturbances (e. g., Rossby waves). It is conceivable that the above statistical variability could be represented in stochastic physics parameterizations.

References

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