Modelling microphysical and meteorological controls on precipitation and cloud cellular structures in Southeast Pacific stratocumulus

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Microphysical and meteorological controls on the formation of open and closed cellular structures in the Southeast Pacific are explored using model simulations based on aircraft observations during the VAMOS Ocean-Cloud-Atmosphere-Land Study Regional Experiment (VOCALS-REx). The effectiveness of factors such as boundary-layer moisture and temperature perturbations, surface heat and moisture fluxes, large-scale vertical motion and solar heating in promoting drizzle and open cell formation for prescribed aerosol number concentrations is explored. For the case considered, drizzle and subsequent open cell formation over a broad region are more sensitive to the observed boundary-layer moisture and temperature perturbations (+0.9 g kg−1; −1 K) than to a five-fold decrease in aerosol number concentration (150 vs. 30 mg−1). When embedding the perturbations in closed cells, local drizzle and pockets of open cell (POC) formation respond faster to the aerosol reduction than to the moisture increase, but the latter generates stronger and more persistent drizzle. A local negative perturbation in temperature drives a mesoscale circulation that prevents local drizzle formation but promotes it in a remote area where lower-level horizontal transport of moisture is blocked and converges to enhance liquid water path. This represents a potential mechanism for POC formation in the Southeast Pacific stratocumulus region whereby the circulation is triggered by strong precipitation in adjacent broad regions of open cells. A simulation that attempts to mimic the influence of a coastally induced upsidence wave results in an increase in cloud water but this alone is insufficient to initiate drizzle. An increase of surface sensible heat flux is also effective in triggering local drizzle and POC formation.

Both open and closed cells simulated with observed initial conditions exhibit distinct diurnal variations in cloud properties. A stratocumulus deck that breaks up due solely to solar heating can recover at night. Precipitation in the open-cell cases depletes the aerosol to the extent that cloud formation is significantly suppressed within one diurnal cycle. A replenishment rate of cloud condensation nuclei of order 1 mg−1 h−1 is sufficient to maintain clouds and prevent the boundary layer from collapsing the following day, suggesting that some local and/or remote aerosol sources is necessary for POCs to be able to last for days.

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