Figure S1. The trajectories of 118 cases, consisting all non-precipitating cases from the "main" set used in Glassmeier et al. (2021), in (a) the $N-L$ plane and (b) the $L-z_i$ plane. The small dots along each trajectory indicate the states from 2 h to 10 h with a 2-h interval. The large symbols indicate the states at 12 h. The 22 cases that are arbitrarily selected to be focused on in the current study are in colors and uniquely identified with the combinations of the color and the shape of the large symbol. Other cases are in gray. In Panel (a), the dash-dotted black line shows a slope of -0.64, the steady state slope reported in Glassmeier et al. (2021); the dashed black line is the precipitation line defined as the line that corresponds to a characteristic cloud-top mean drop radius of 12 μm.
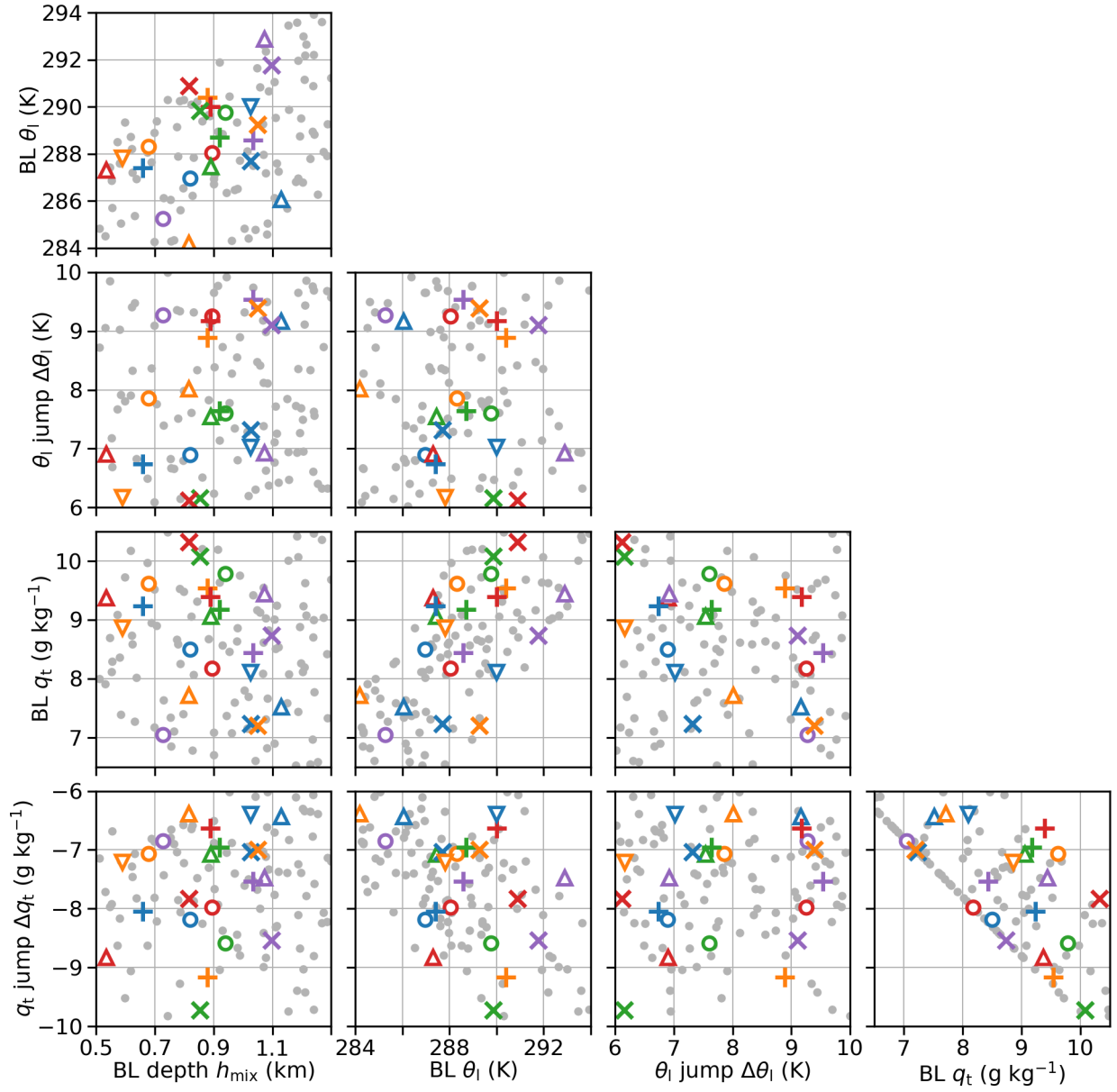
Figure S2. Meteorological conditions (i.e., sets of five parameters that define the initial thermodynamic profiles) for the 22 selected cases. BL stands for boundary layer. Same color and symbol combinations as in Figure S1.
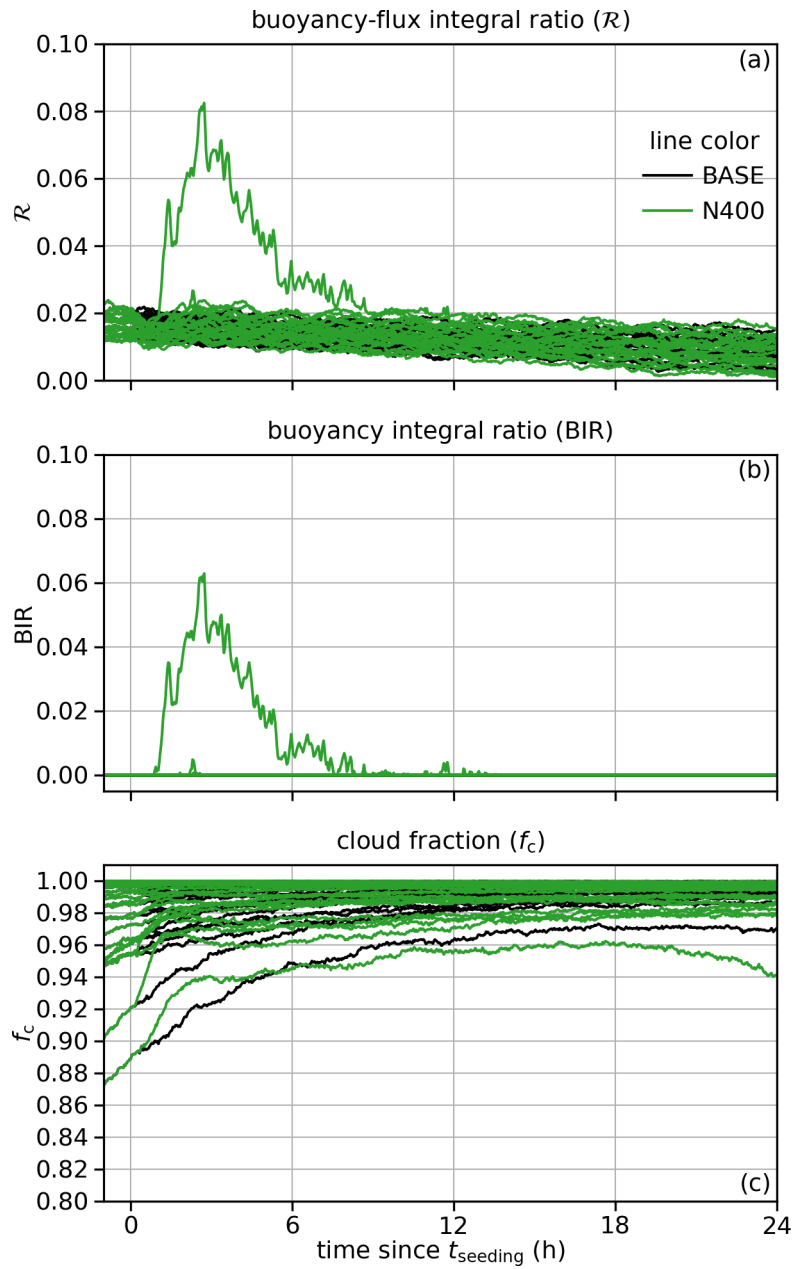
Figure S3. Time series of 22 simulations for BASE and 22 simulations for N400 in MAIN: (a) buoyancy-flux integral ratio ($\mathcal{R}$) as defined in Eq. (1) in Stevens (2000), (b) buoyancy integral ratio (BIR) as defined in Eq. (14) in Bretherton and Wyant (1997), and (c) cloud fraction (f_c) defined as the fraction of domain with cloud optical depth greater than one. Small values in Panels (a) and (b) indicate that the boundary layers are close to well-mixed.
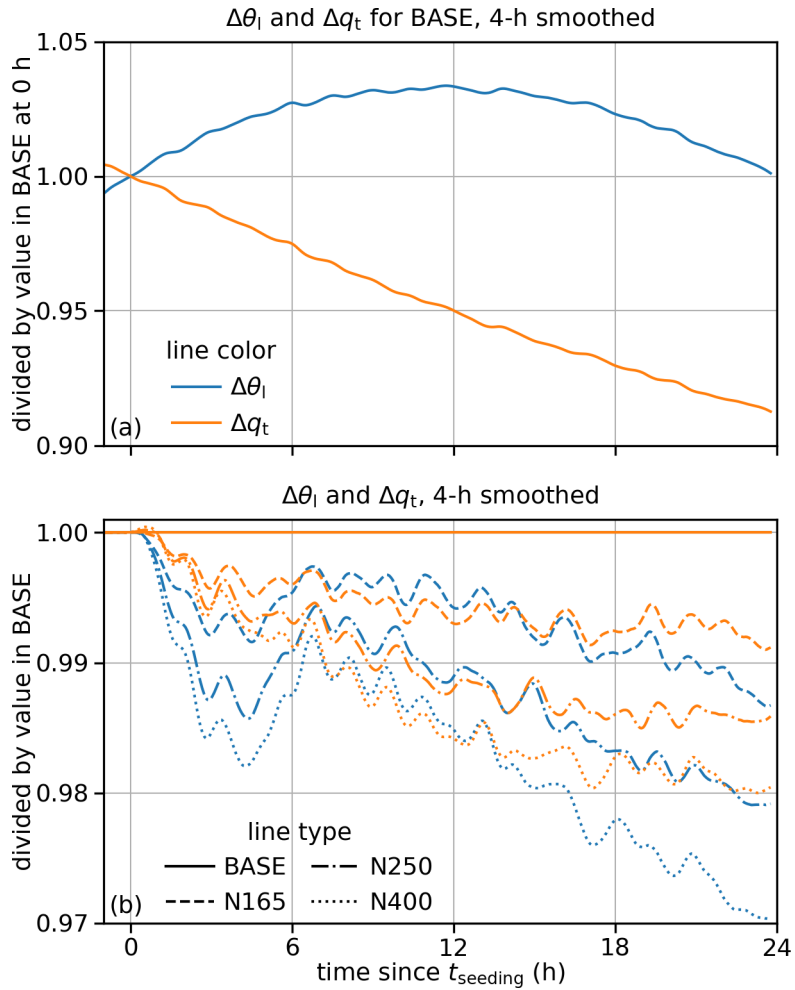
Figure S4. Four-hour smoothed time series related to θ_l and q_t jumps across the inversion base ($\Delta\theta_l$ and Δq_t) averaged across simulations for BASE, N165, N250, and N400. Panel (a): normalized by values in BASE at 0 h. Panel (b): normalized by values in BASE.

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