Geophysical Research Letters

Supporting Information for

A more general paradigm for understanding the decoupling of stratocumulus-topped boundary layers: the importance of horizontal temperature advection

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Text S1: Automatic detection of atmospheric fronts

The F diagnostic is defined as:

$$F = \frac{\varsigma|\nabla T|}{f|\nabla T|_{ref}}$$

in which ς and $|\nabla T|$ are isobaric relative vorticity and horizontal temperature gradient, both at 900 hPa pressure level. An atmospheric front is characterized by greater values of both parameters. f and $|\nabla T|_{ref}$ are the Coriolis parameter and reference temperature gradient, taken as 0.45 K/(100 km), respectively, which are used to normalize the $\varsigma|\nabla T|$. A threshold F value of 1 is chosen to determine frontal regions. Figure S1 shows an example of frontal systems during the MARCUS field campaign over the Southern Ocean (Zheng and Li, 2019), which illustrates the good performance of the F diagnostic in detecting frontal regions.

Text S2: Description of the mixed-layer model

The mixed-layer model (MLM) is exactly the same with that used in Bretherton and Wyant (1997). It is a 1-D model that treats a stratocumulus-topped boundary layer (STBL), from the surface to the top of the stratocumulus deck, as a bulk layer. There are two prognostic thermodynamic variables: total water mixing ratio and moist static energy, both which are assumed to be conserved in adiabatic moist convection, and are thus vertically uniform in a STBL. The MLM parameterizes the surface fluxes, radiative fluxes, precipitation fluxes, and entrainment rate. The insolation is diurnally averaged. The entrainment closure scheme is based on the amount of STBL-averaged turbulent kinetic energy, in which the entrainment rate is primarily dependent on the convective velocity scale (Turton and Nicholls, 1987). The vertical grid size is set as 10 m.

The initial and boundary conditions are taken from the Table 1 in Bretherton and Wyant (1997). The free-troposphere thermodynamics remain fixed and the underlying sea surface temperature increases gradually by 1.5 K/day. We modify the sea surface temperature increasing rate to 5 K/day and 10 K/day to fulfill our purpose as described in the manuscript.

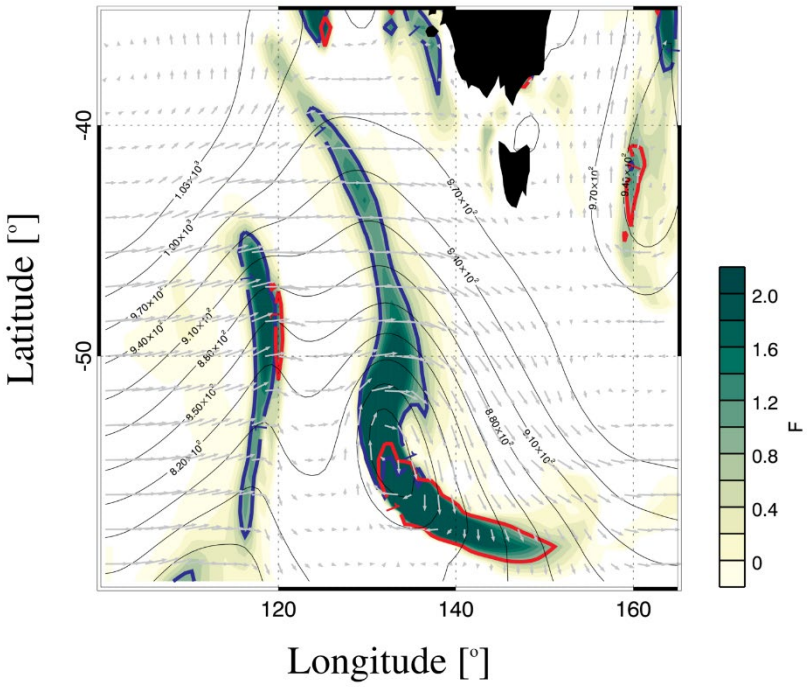

Figure S1: An example of using the *F* diagnostic to identify frontal systems. The date of the case is 1 March 2018 over the Southern Ocean. The blue and red contours mark the identified cold and warm fronts, respectively.

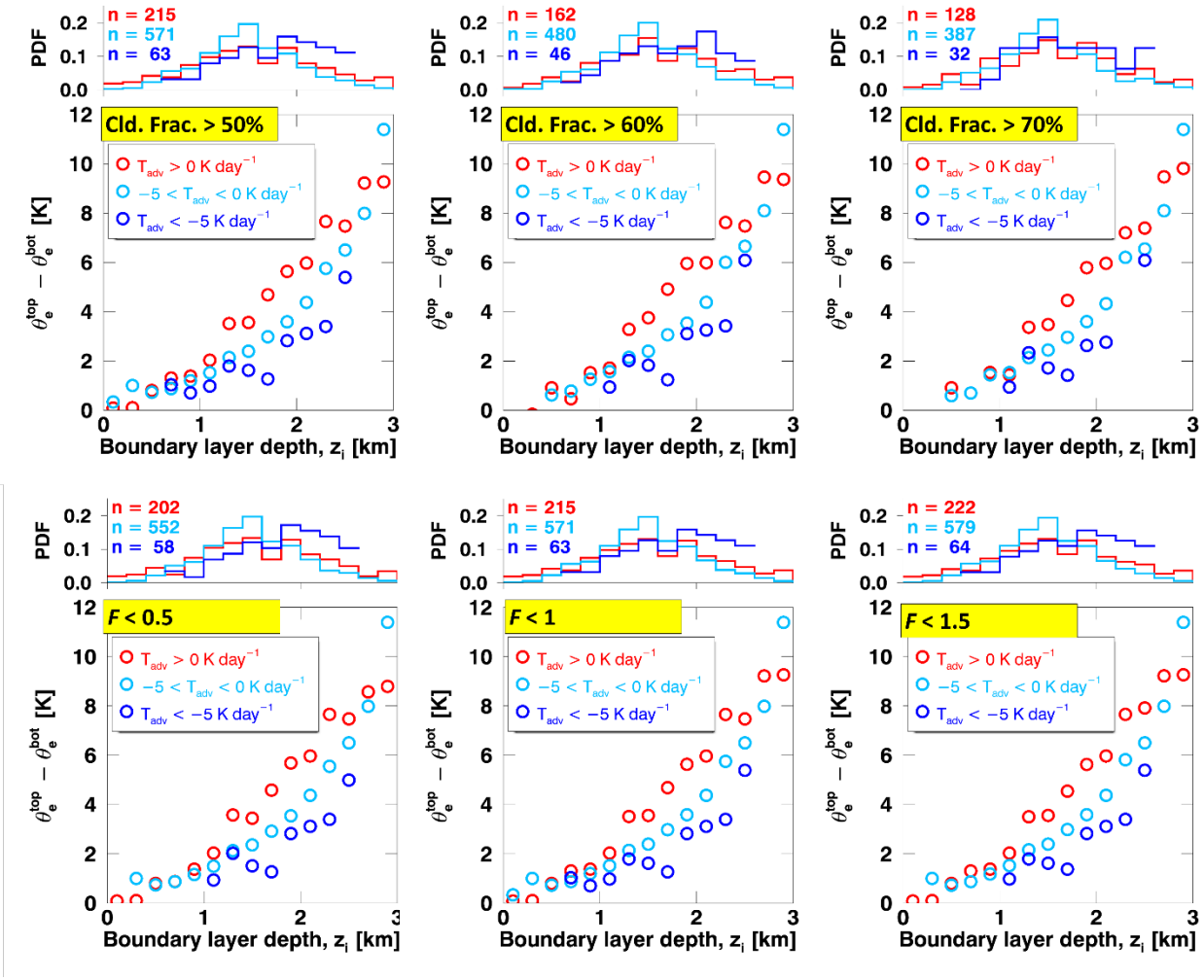

Figure S2: Same with Figure 1a but for STBL cases with cloud fraction greater than 50%, 60%, and 70% (upper panel) and with *F* smaller than 0.5, 1, and 1.5 (bottom panel).

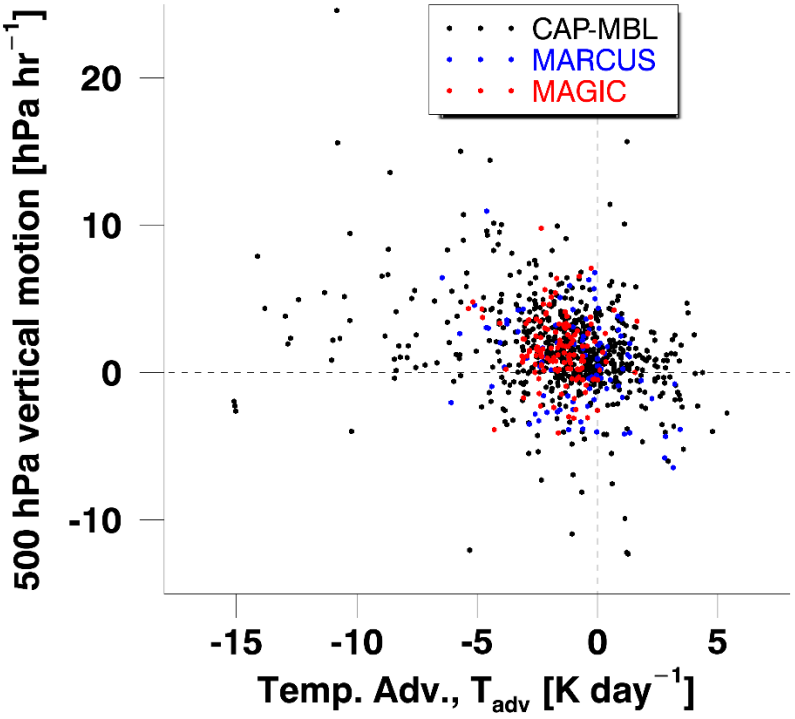

Figure S3: Scatterplot of the selected cases in the two-dimensional space of temperature advection and 500 hPa vertical motion.

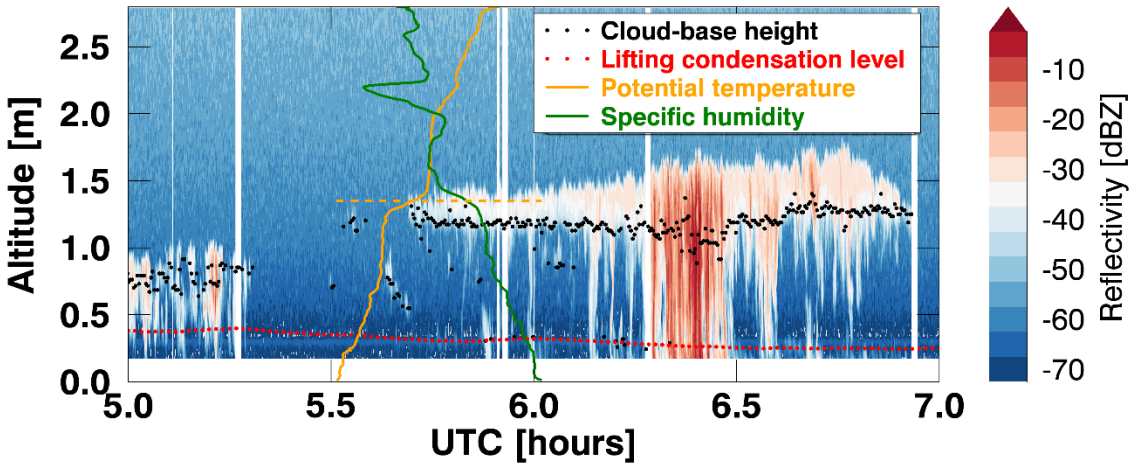

Figure S4: (a) Height-time plot of WACR image of clouds during the CAP-MBL on May 19 2010. The sampled clouds were under the influence of warm air advection. The red and black dots mark the lifting condensation level and ceilometer-measured cloud-base heights, respectively. Orange and green lines are profiles of radiosonde-measured potential temperature and specific humidity scaled by ± 0.5 hrs. The horizontal dashed orange line marks the identified z_i.

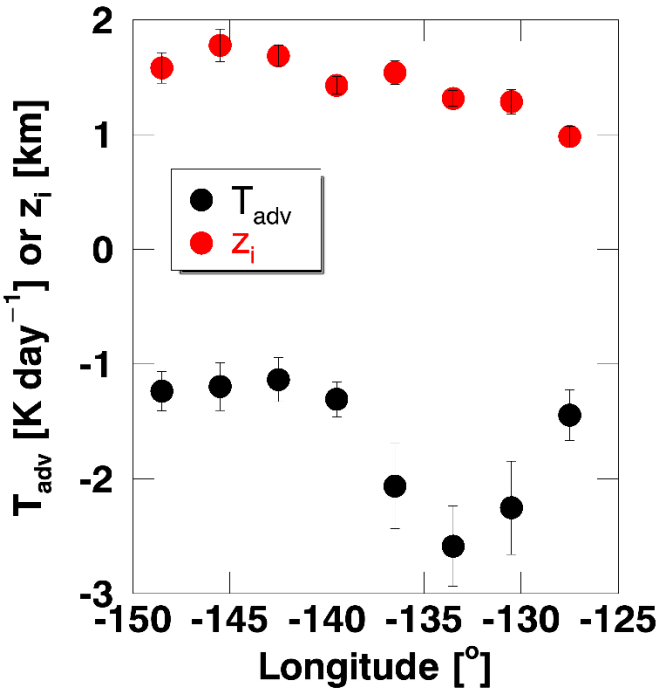

Figure S5: Variations of T_{adv} and z_i with the longitude during the MAGIC.

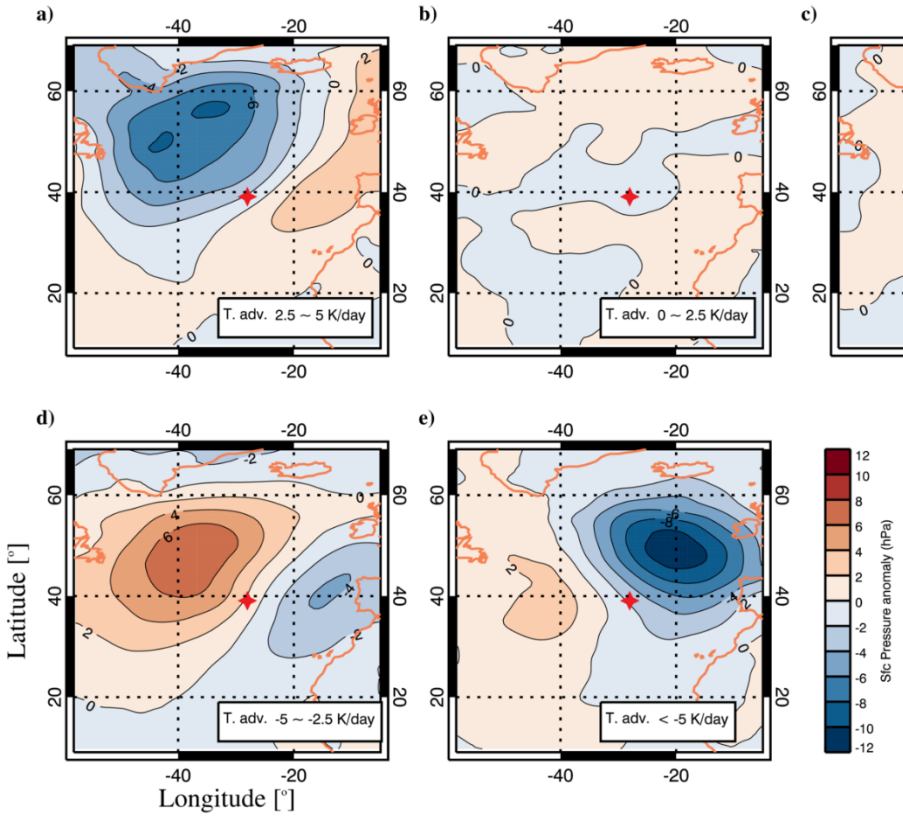

Figure S6: The composite surface pressure anomalies (relative to the monthly mean) around the observational site on the Graciosa Island during the CAP-MBL (red star) under the influence of temperature advection with different strengths and directions.

Reference:

Bretherton, C. S., & Wyant, M. C. (1997). Moisture transport, lower-tropospheric stability, and decoupling of cloud-topped boundary layers. *Journal of the atmospheric sciences*, *54*(1), 148-167.

Turton, J. D., & Nicholls, S. (1987). A study of the diurnal variation of stratocumulus using a multiple mixed layer model. *Quarterly Journal of the Royal Meteorological Society*, *113*(477), 969-1009.

Zheng, Y., & Li, Z. (2019). Episodes of Warm-Air Advection Causing Cloud-Surface Decoupling During the MARCUS. *Journal of Geophysical Research: Atmospheres*.