Measurements of the Turbulence Master Length Scale Profile in Summertime Eastern North Atlantic Marine Boundary Layer Clouds

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Background

Forecasting transports of heat, moisture, and momentum in models that use first order closure depends upon the specification of eddy exchange coefficients (K-Theory). Many boundary layer models employ parameterizations of these coefficients suggested by Mellor and Yamada (1982) as the underlayment of their boundary layer turbulence physics. They postulated that the K's are products of a stability function, Turbulent Kinetic Energy (TKE), and a turbulence master length scale, l, which is a TKE dissipation length scale. Mellor and Yamada also state that "The major weakness of all of the turbulent closure models probably relates to the turbulent master length scale and, most importantly, to the fact that one sets all process scales proportional to a single scale". A profile of l suggested by Blackadar (1962) is assumed in many models (Bretherton and Park, 2009, for example). Measurements from the ENA Doppler Lidar (DL) at ENA and other ARM sites enable direct measurements of l and, thus, provide a means to determine its variability and, hopefully, the underlying physics that determine its magnitude.

Our Analysis

- Location: Eastern North Atlantic (ENA) ARM Facility
- Study Period: summer 2016 and 2017 (June-August)
- Instruments: Doppler lidar (zenith mode), Wind Profiler
- Averaging Interval: 30 minutes for TKE and Dissipation Rate
- Conditions: wind direction ±75° from north (0°), 75% cloud base detection, cloud base height variability ≤ 200 m during the 30-minute averaging interval.

Eastern North Atlantic (ENA) Graciosa Island, Azores

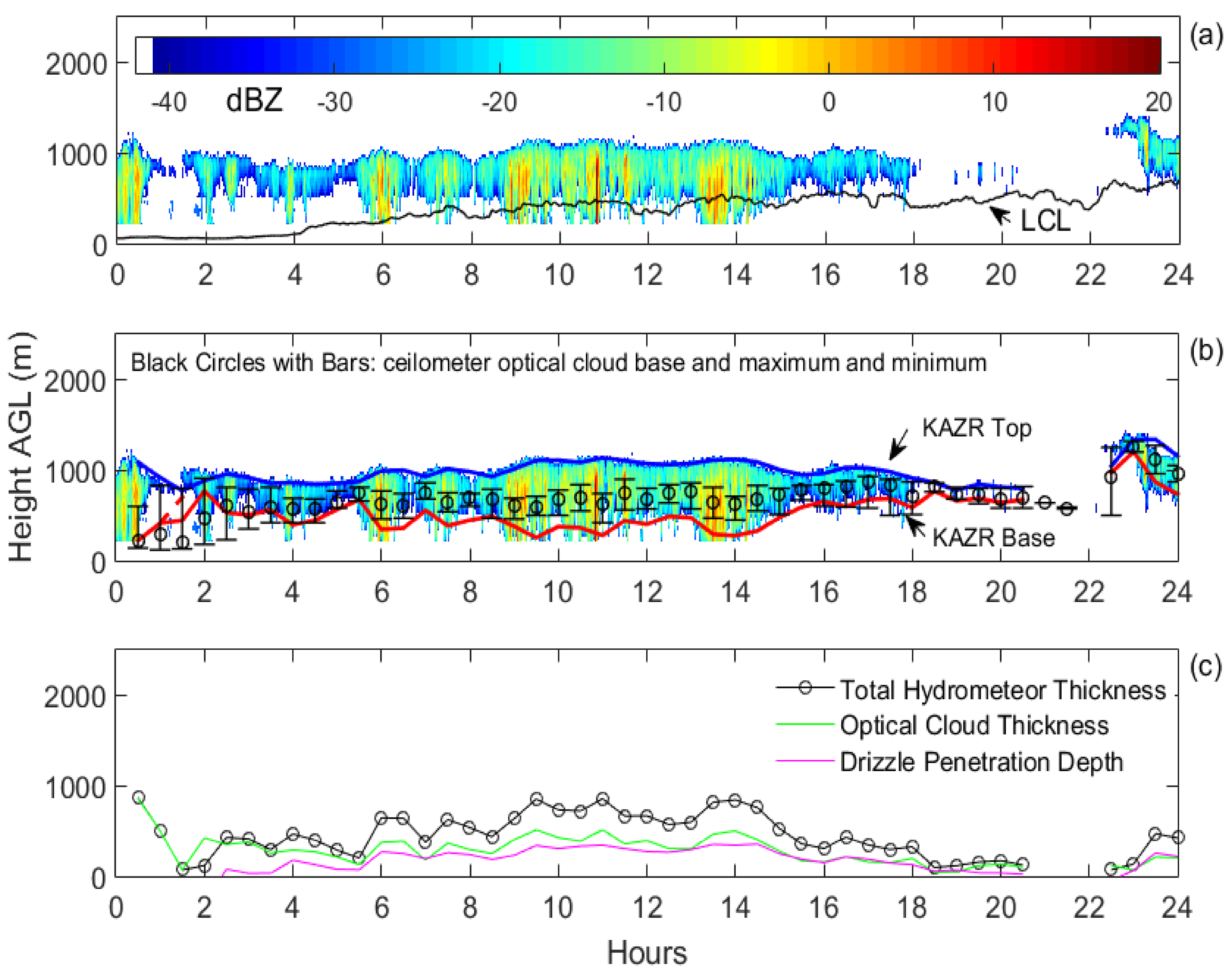

Figure 1: Stratocumulus observed on July 18, 2017 during the first phase of ACE-ENA. Shown are the (a) KAZR reflectivity and island surface Lifting Condensation Level (LCL), (b) half-hour average KAZR hydrometeor boundaries and mean and range of optical cloud base from the laser ceilometer, and (c) cloud structural variables.

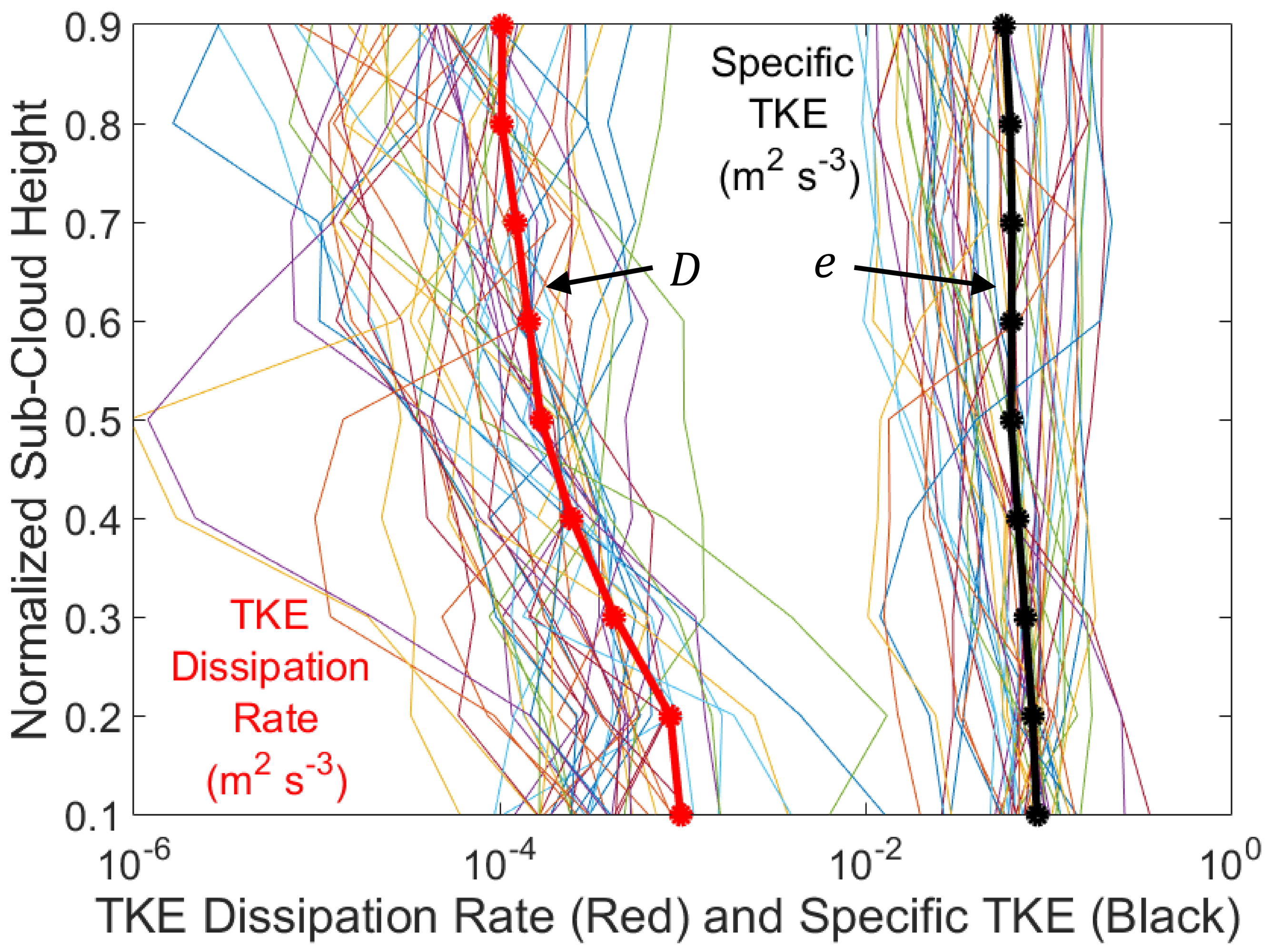

Figure 2: The TKE Dissipation Rate and Specific TKE for July 18, 2017. Individual half-hour profiles for the 24-hour period are indicated by the thin lines and the 24-average profiles as the thicker lines with filled circles (red-dissipation length and black-specific TKE).

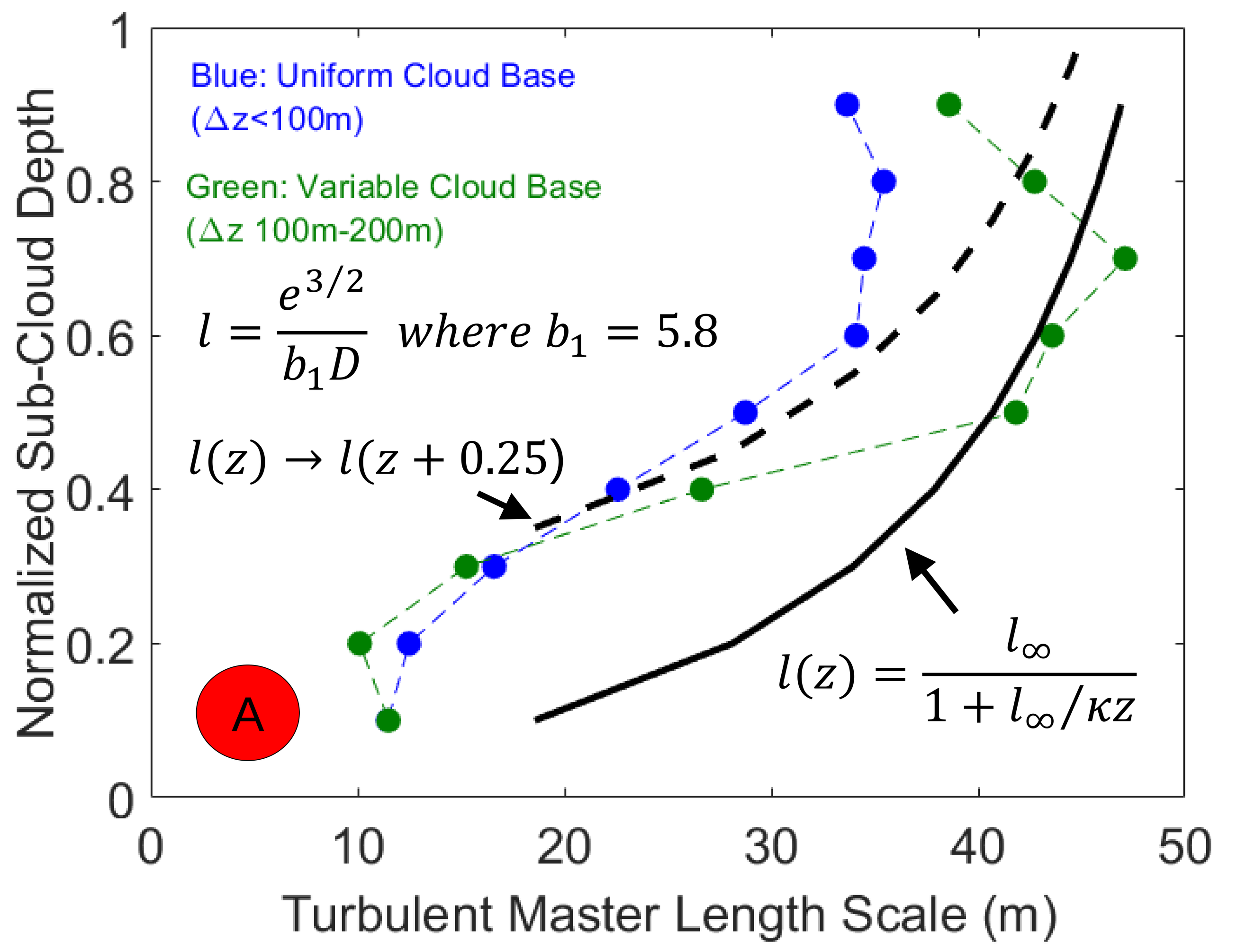

Figure 3: Measurements of the average Turbulence Master Length scale profile for July 18,2017. The blue and green lines represent different levels of variability in the optical cloud base height measured by the laser ceilometer, which may be due to increased mixing at cloud top. The black line is the Blackadar (1962) parameterization and the black dashed line represents a constant offset to z in the parameterization.

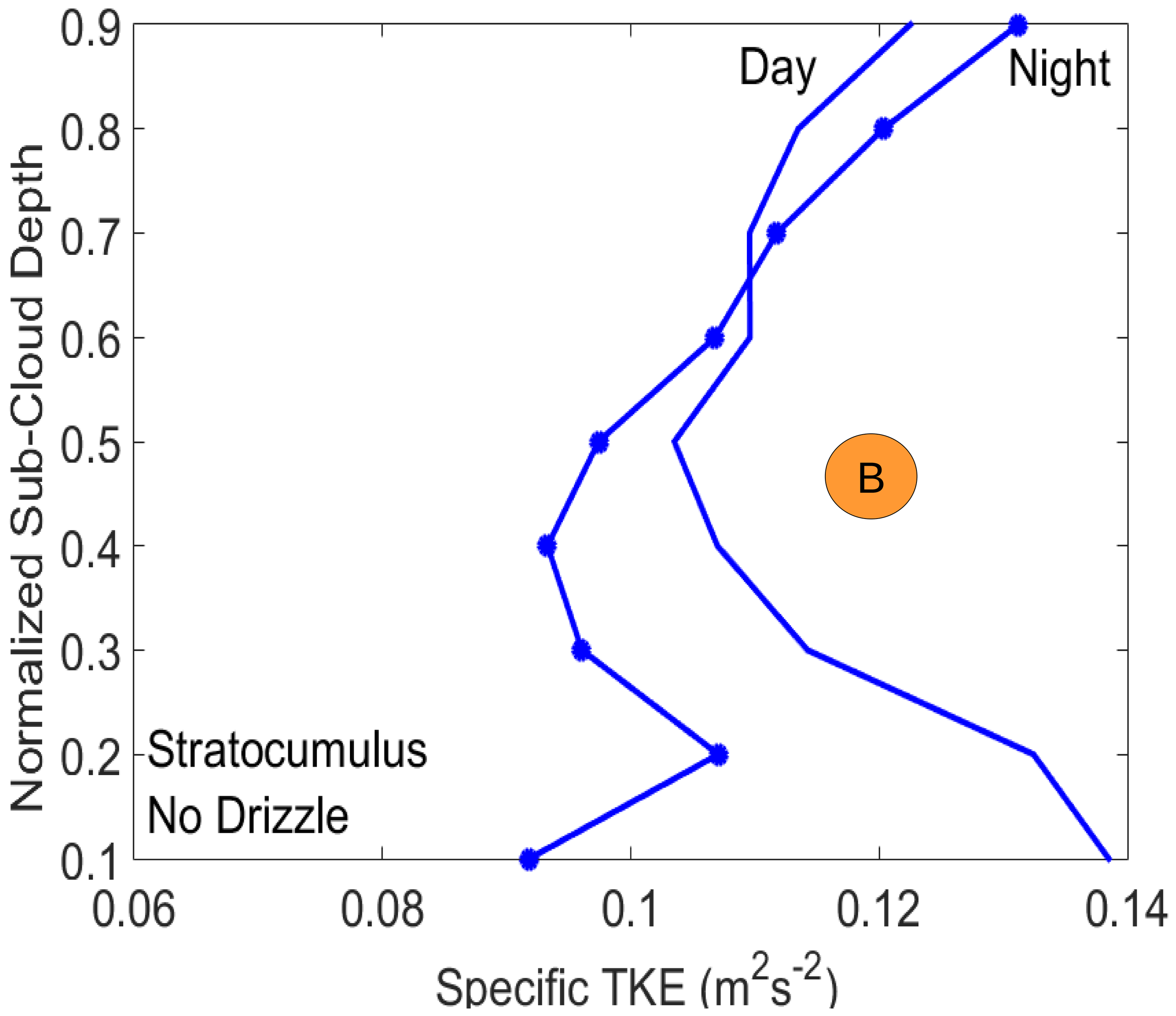

Figure 4: A comparison of the daytime and nighttime specific TKE profiles in non-drizzling stratocumulus.

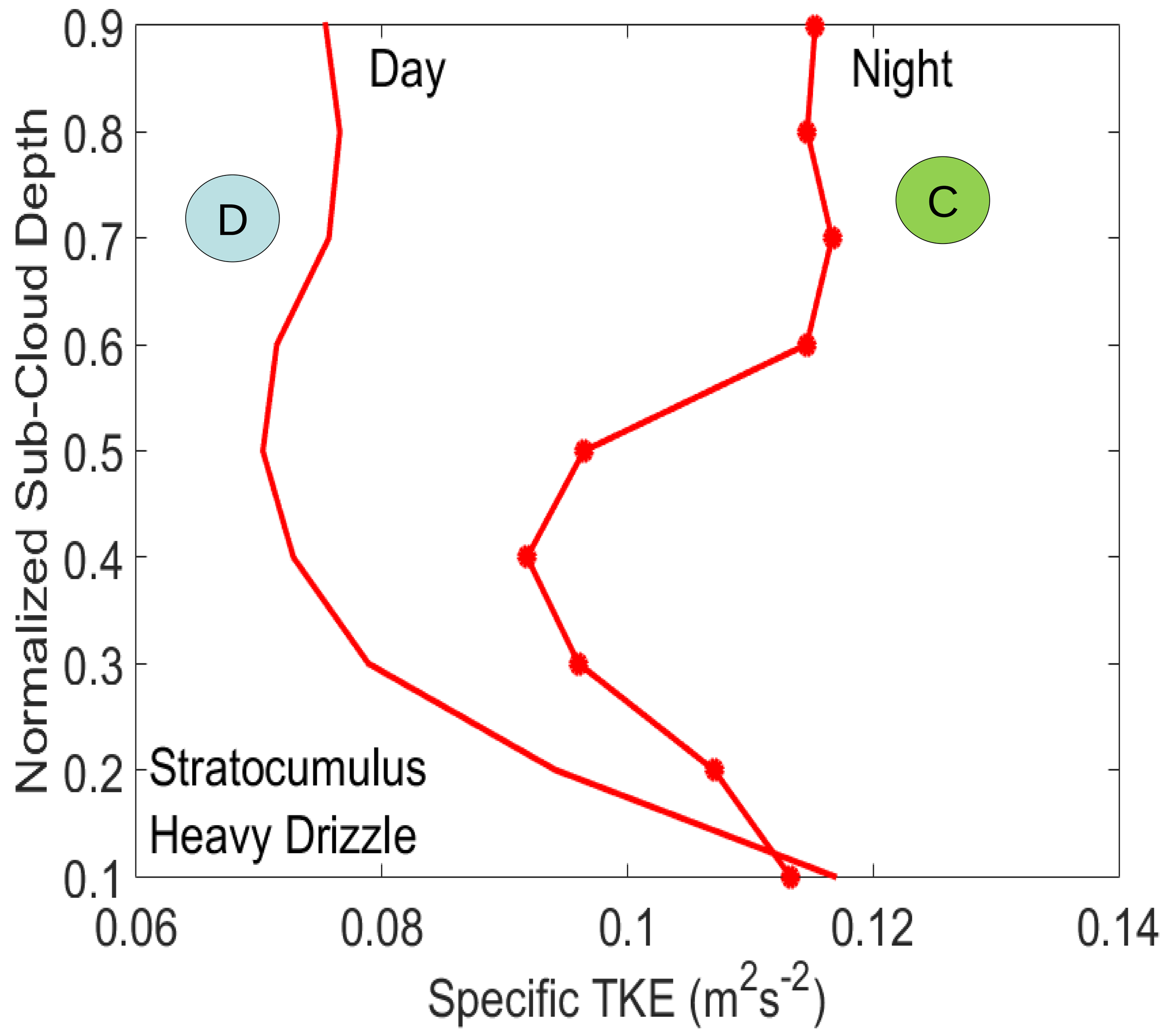

Figure 5: As in Figure 4, but for stratocumulus with heavy drizzle, which is defined as drizzle located to a depth of at least 250 m below the optical cloud base.

Perspective

Region A: Magnitudes of the measured Turbulence Master Length Scale agree well with Blackadar (1962) on July 18, 2017, although the profile is offset.

Region B: A TKE minimum indicating decoupling is observed near the center of the sub-cloud layer during both day and night.

Region C: Nighttime heavy drizzle produces a well-mixed region in the upper one-third of the sub-cloud layer.

Region D: Heavy drizzle significantly decreases specific TKE in the daytime stratocumulus-topped MBL.

References

Blackadar, A.K., 1962: The vertical distribution of wind and turbulent exchange in a neutral atmosphere, J. *Geophys. Res.*, **67**, 3095-3101.

Bretherton, C. and S. Park, 2009: A new moist turbulence parameterization in the community atmosphere model, *J. Climate*, **22**, 3422-3448.

Mellor and Yamada, 1982: Development of a turbulence closure model for geophysical fluid problems, **20**, *Rev. Geophys. and Space Physics*, 851-875.