How Drizzle Evaporation Impacts Below-Cloud Turbulent Kinetic Energy in Transition Marine Stratocumulus

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Background

Turbulence above the ocean surface transports water vapor to the base of marine cloud layers. This turbulence is primarily driven by radiative processes at cloud top, but the impact of evaporating drizzle upon turbulent transport in the sub-cloud layer is less known. The vertical component of the Turbulent Kinetic Energy (TKE) can be measured using a Doppler Lidar. It measures the vertical velocity, w, in the sub-cloud layer every second from which the specific TKE or mean variance can be estimated as $e = 0.5\,\overline{w'w'} = 0.5\,\overline{w'^2}$ (Park and Bretherton, 2009).

Our Analysis

- Location: Eastern North Atlantic (ENA) Graciosa Island ARM Facility (shown below)
- Study Period: summer 2016 (June-August)
- Instruments: Doppler lidar (zenith mode), cloud radar (KAZR; general mode), laser ceilometer
- Averaging Interval: 30 minutes for TKE profile calculations
- Conditions: wind direction ±70º from north (0º), 75% cloud base detection, cloud base standard deviation <250 m, and mean cloud base height <1500 m
- Drizzle: radar effective reflectivity factor >-15 dBZ at least 125 m below the half-hour mean cloud base for >75% of the averaging interval
- Depth Normalization: lidar range normalized from cloud base height such that 1 is cloud base and 0.1 is closest to the surface

Eastern North Atlantic Graciosa Island

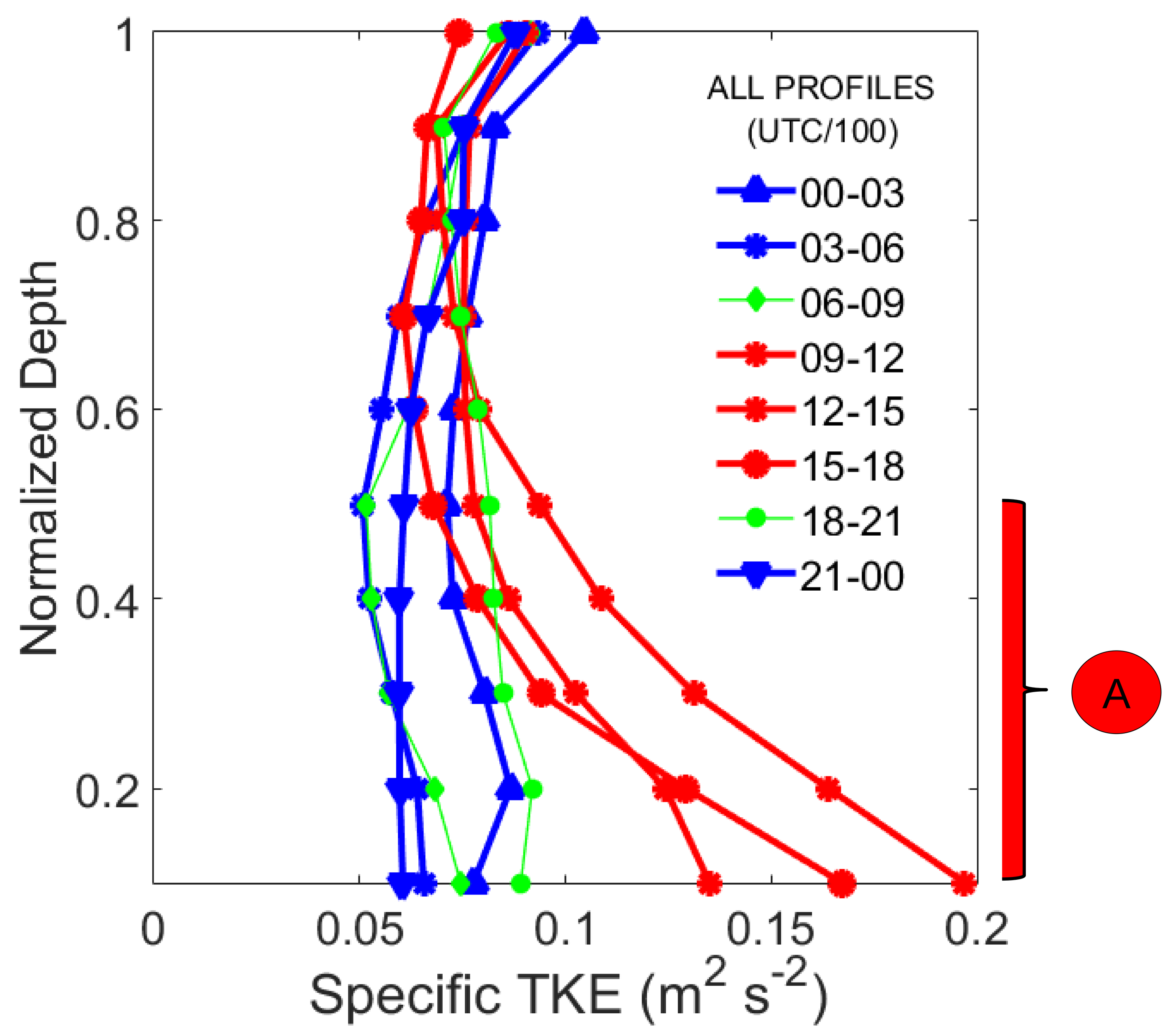

Figure 1: Three hour averages of all half-hour normalized specific TKE profiles meeting the wind direction acceptance conditions. The profiles are predominantly stratocumulus, but occasionally broken clouds and brief clear patches.

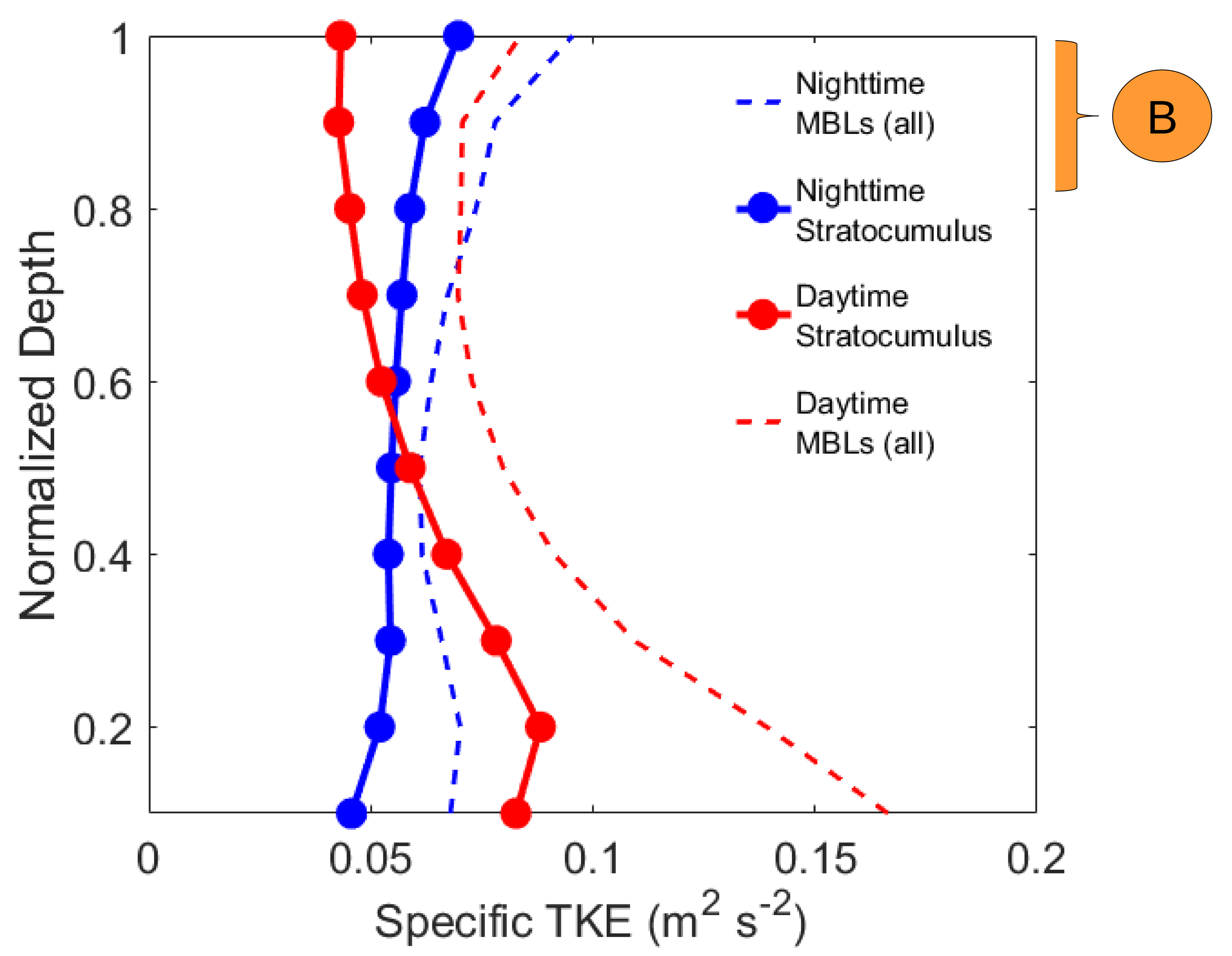

Figure 2: Diurnal composites of half-hour normalized Specific TKE profiles for nine daylight (9am-6pm local) and nine nighttime hours (9 pm-6 am). The dashed lines indicate that the composite utilizes all profiles meeting the acceptance conditions and the solid lines indicate profiles from stratocumulus.

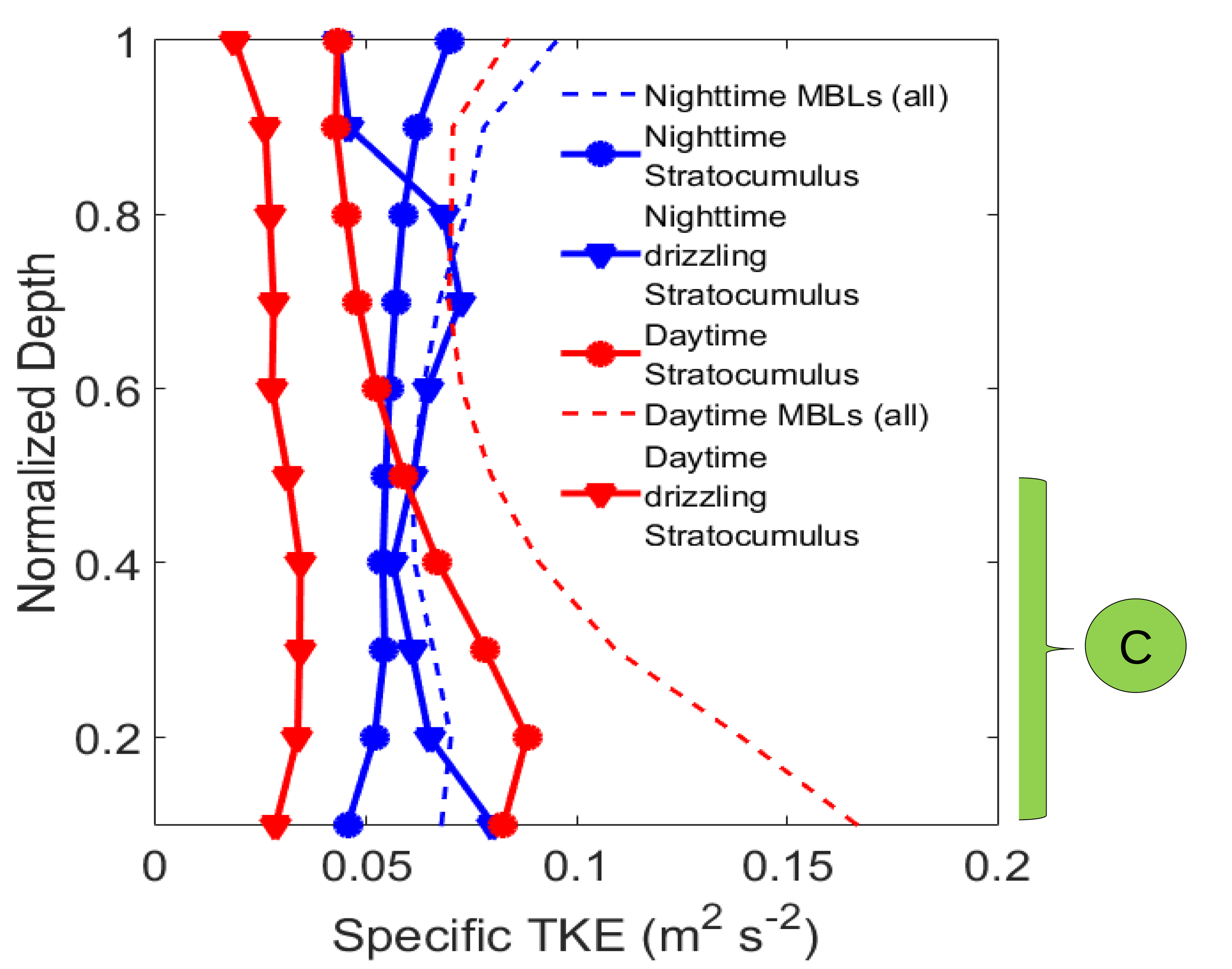

Figure 3: Added to the profiles shown in Figure 2 are the profiles of periods that contain drizzling stratocumulus. Clouds are classified as drizzling stratocumulus if they contain echoes of > -15 dBZ that are >125 m below mean cloud base for at least 75% of the half-hour averaging interval.

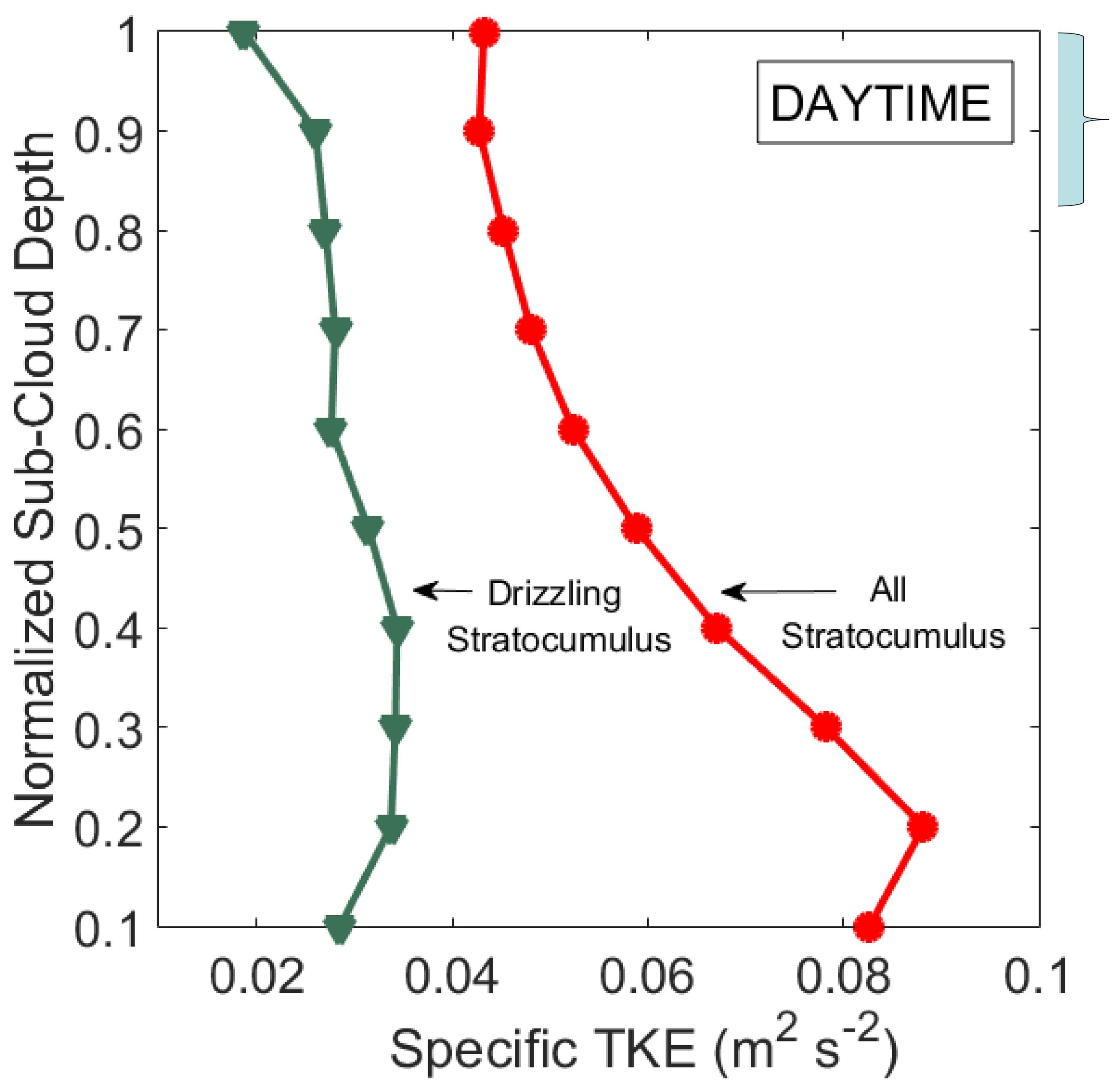

Figure 4: A comparison of the daytime composite specific TKE profiles in all stratocumulus and drizzling stratocumulus.

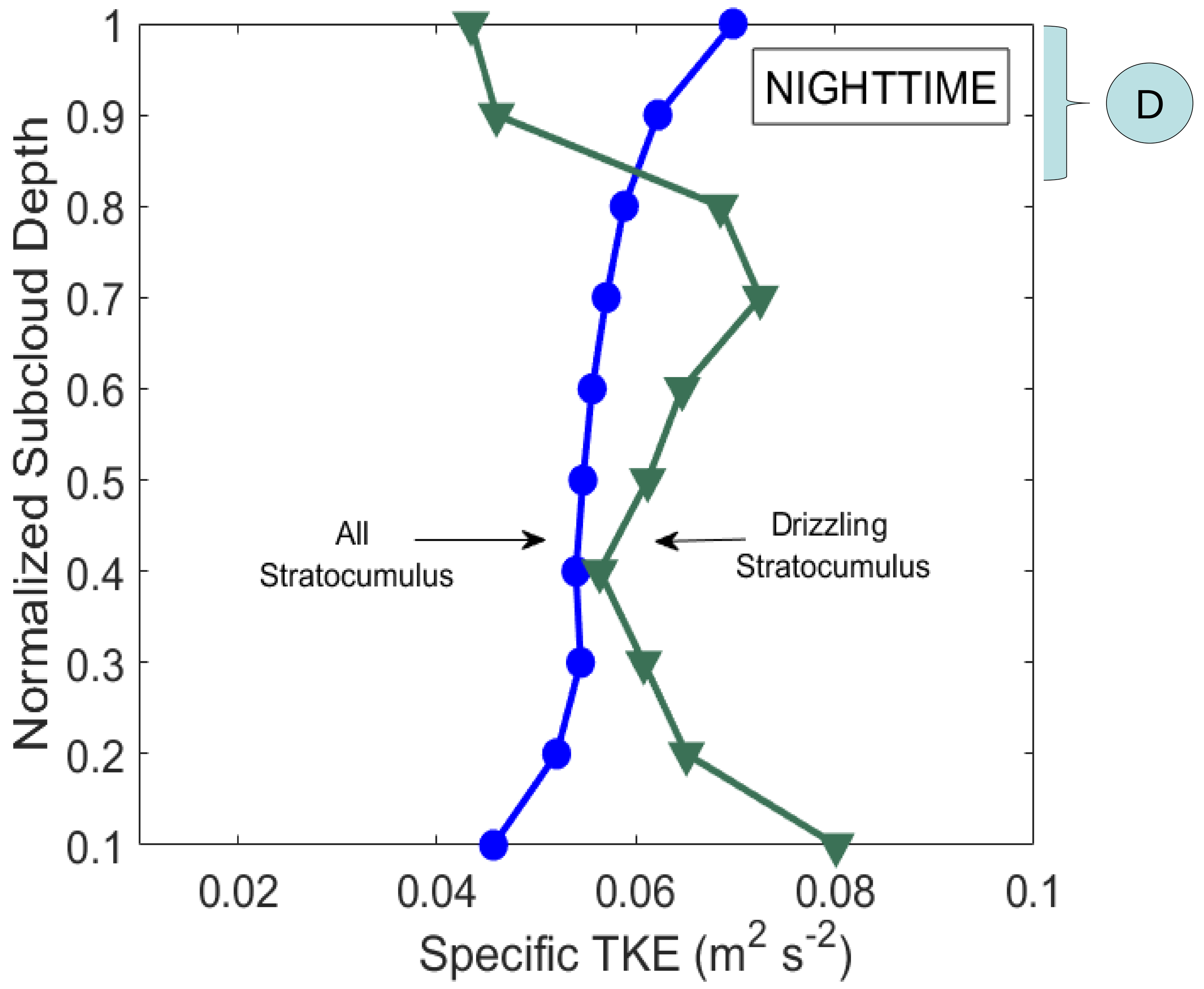

Figure 5: A comparison of the nighttime composite specific TKE profiles in all stratocumulus and drizzling stratocumulus.

Notable Features

Region A: Elevated values of specific TKE in the lower half of the sub-cloud layer during the daytime hours are indications of island effects (when all profiles are included).

Region B: Reduced specific TKE near cloud base is consistent with radiative decoupling.

Region C: Daytime drizzling stratocumulus appears to effectively mitigate island effects.

Region D: Drizzling stratocumulus reduces specific TKE near cloud base during the daytime and the nighttime.

Perspective

- Drizzle may have opposite impacts upon the specific TKE during the daytime and nighttime.
- Nighttime drizzle evaporation increases the specific TKE in the lower ~80% of the MBL, potentially through increased negative buoyancy due to evaporative cooling.
- Daytime drizzle evaporation decreases specific TKE throughout the sub-cloud layer, but island effects may exaggerate this reduction in the lower half of the MBL.

Reference: Park, S. and C. Bretherton, 2009: The University of Washington Shallow Convection and Moist Turbulence Schemes and Their Impact on Climate Simulations with the Community Atmosphere Model. *J. Climate,* **22**, 3449–3469, doi: 10.1175/2008JCLI2557.1.