Turbulence in The Marine Boundary Layer and Air Motions Below Stratocumulus Clouds at the ARM Eastern North Atlantic Site

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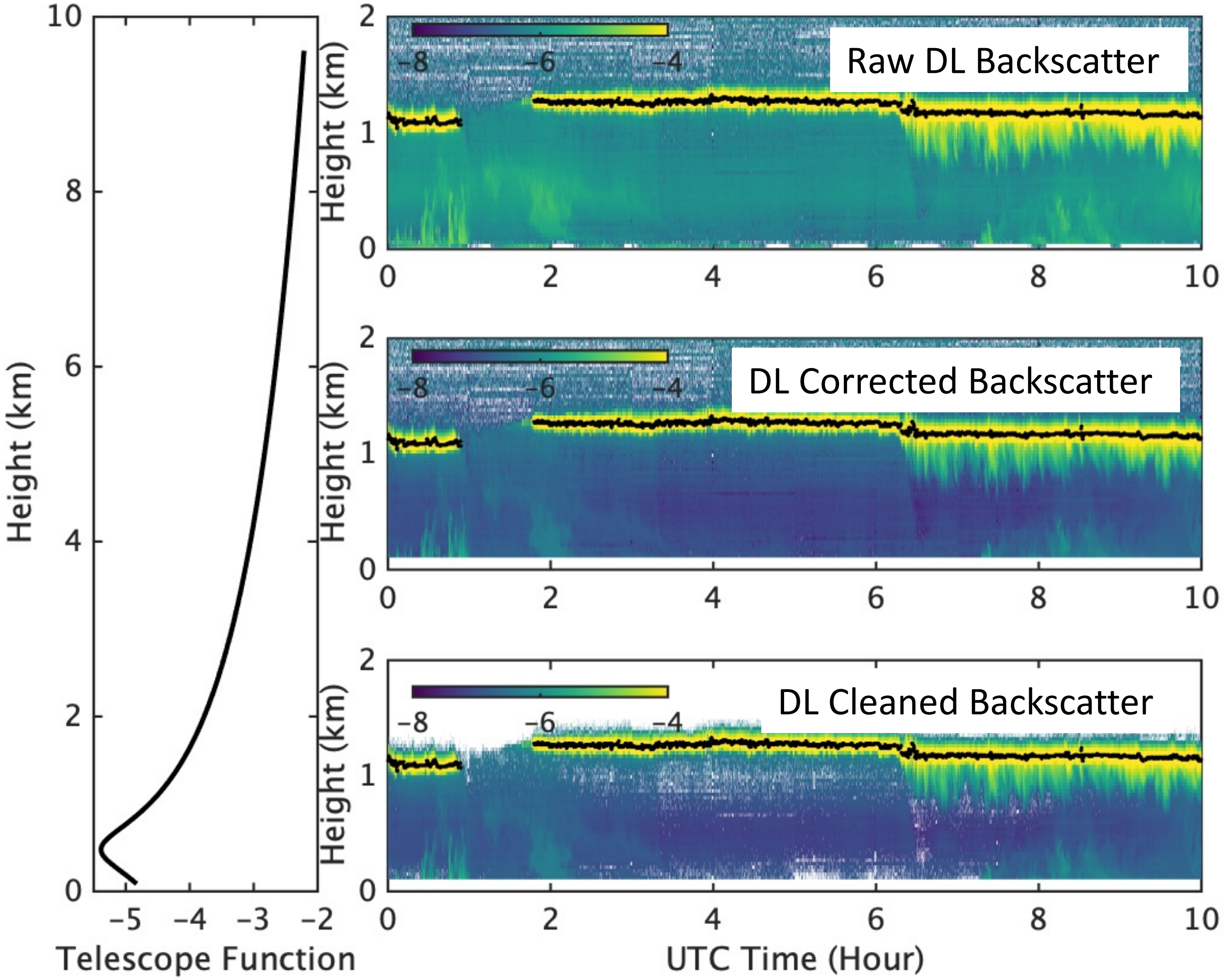
Scientific Objectives

- Radiatively important marine warm low clouds are intimately coupled to the turbulence in the boundary layer.

- Drizzle is known to be ubiquitous below these clouds, with most of it evaporating and thereby affecting turbulence.

- Here we utilize the observations made at the ARM Eastern North Atlantic (ENA) site to
  - Characterize the annual and diurnal cycle of turbulence at the site.
  - Characterize the vertical air motions within drizzle below stratocumulus clouds.

Doppler Lidar (DL) Data Processing



- DL records profiles of backscatter in addition to those of mean Doppler velocity.

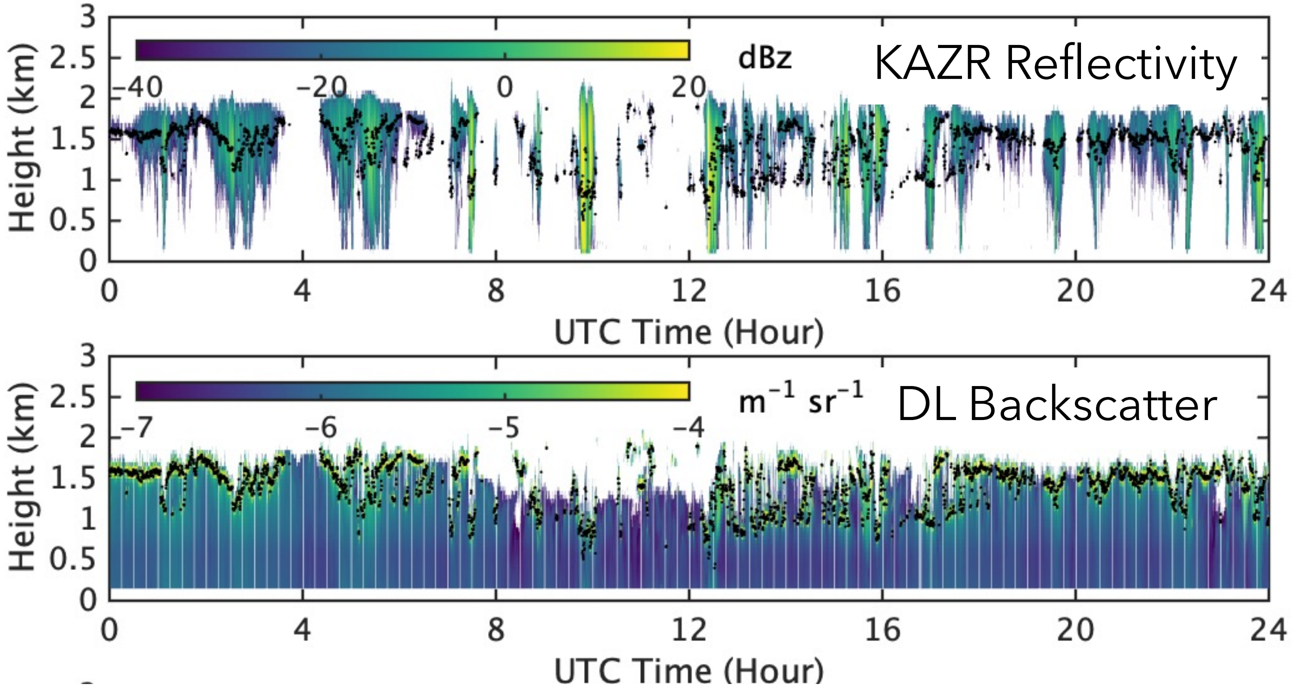
- DL backscatter is corrected for telescope focus function.

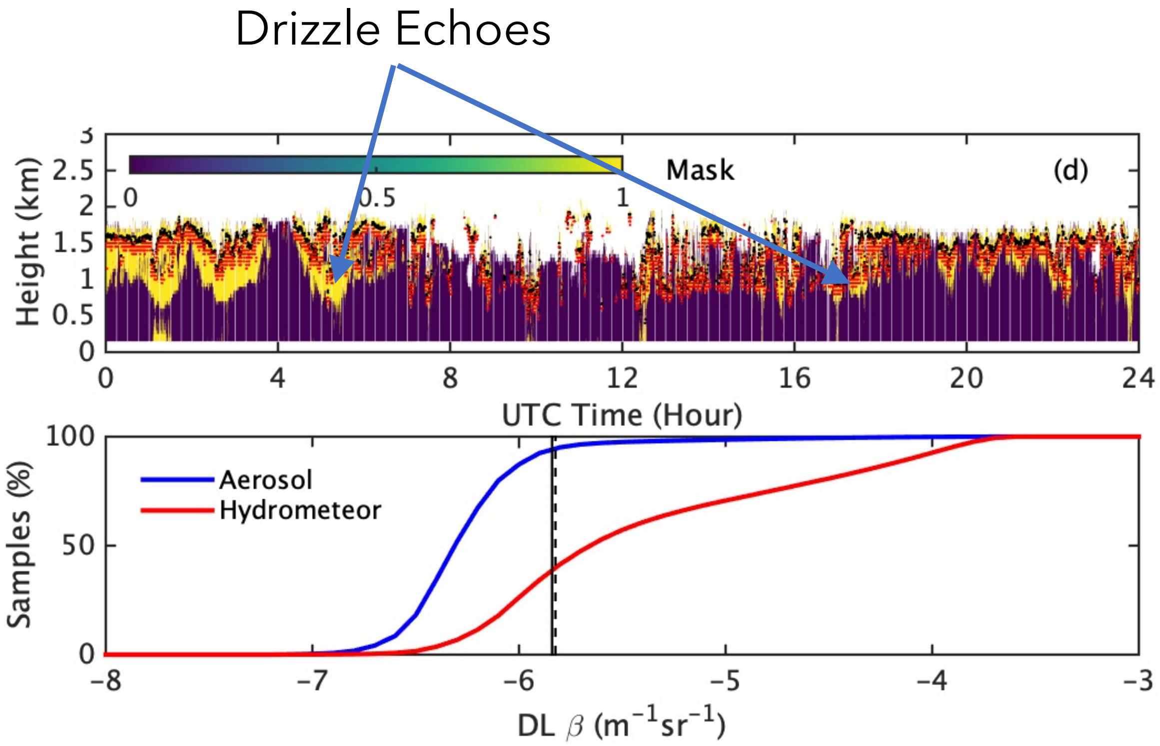
$$\beta(r) = Tf(r)\times(SNR(r) - 1)$$

- Subsequently the DL backscatter is filtered for noise and calibrated.

Pentikainen et al. 2020 Atmos. Meas. Tech.

DL return: Drizzle or Aerosol?

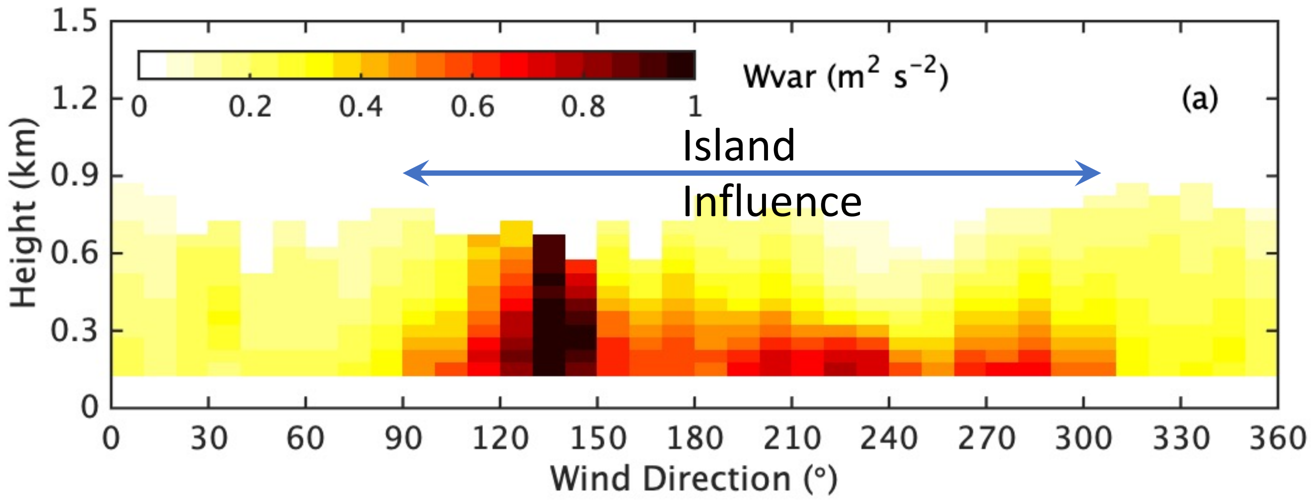


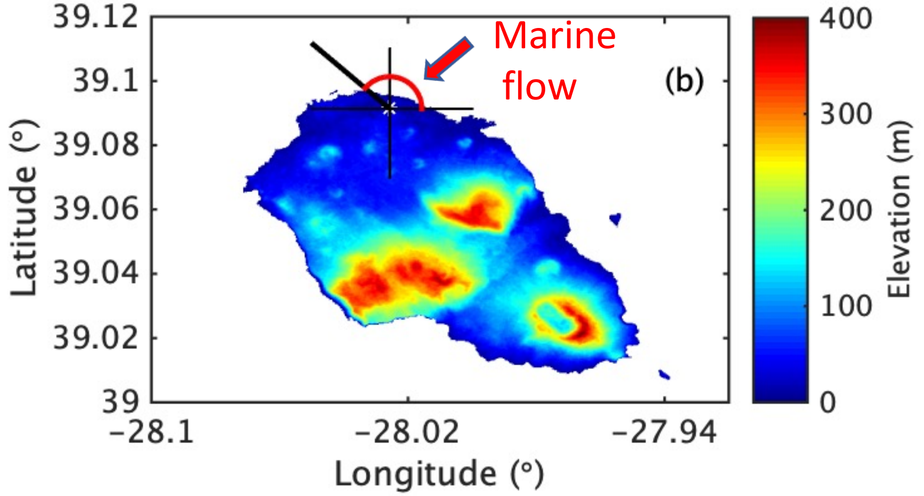


- Produce distribution of DL calibrated backscatter below the cloud base for within and outside the drizzle shafts as identified by the cloud radar.
- Use 95th percentile value of the DL backscatter outside the drizzle shafts as a threshold for distinguishing DL returns as aerosols or hydrometeors.

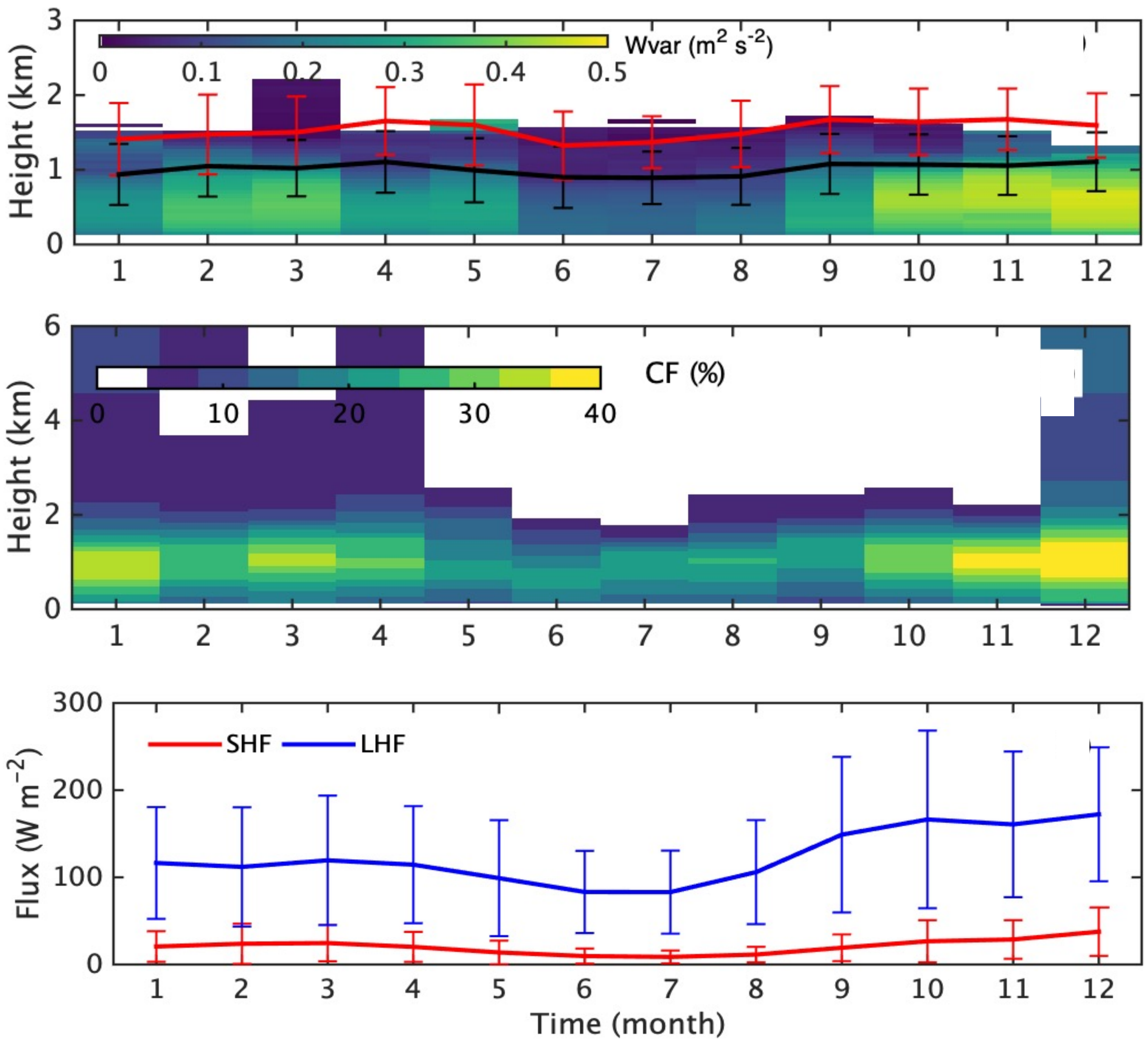
Effect of Island Heating on Turbulence

- Observations at the site were used to identify clear-sky (cf<20%) convective (SHF>25 Wm^{-2}) hours.
- Averaged profiles of variance of vertical air motion binned by the wind direction during clear-sky convective hours were used to identity wind directions during which data was affected by the island.
- Data collected during wind directions between 90-310 are affected by the island.



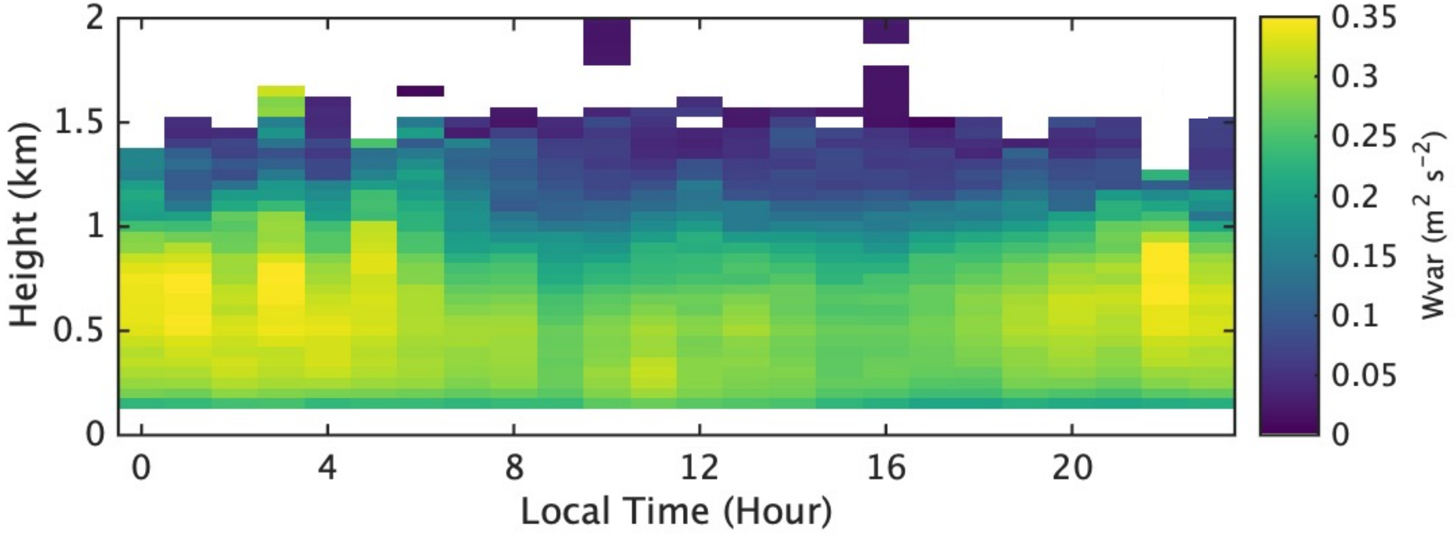


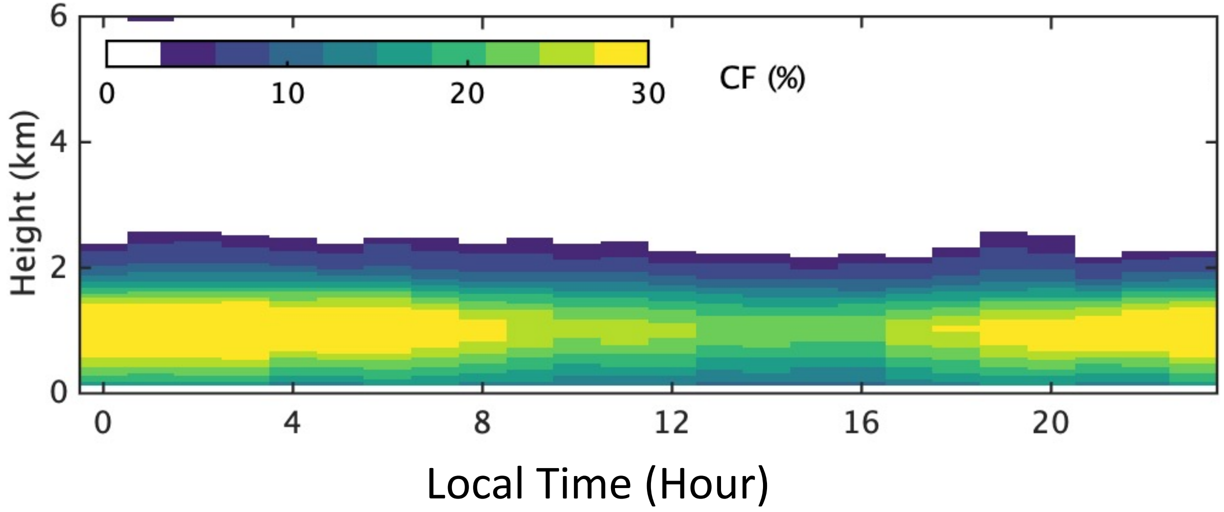
Annual Cycle



- On average ~30% of the observations are unaffected by the island.
- Boundary layer is deeper with higher turbulence in the winter than during the summer.
- Cloudiness, winds, and surface fluxes are higher during the winter months than during the summer months.

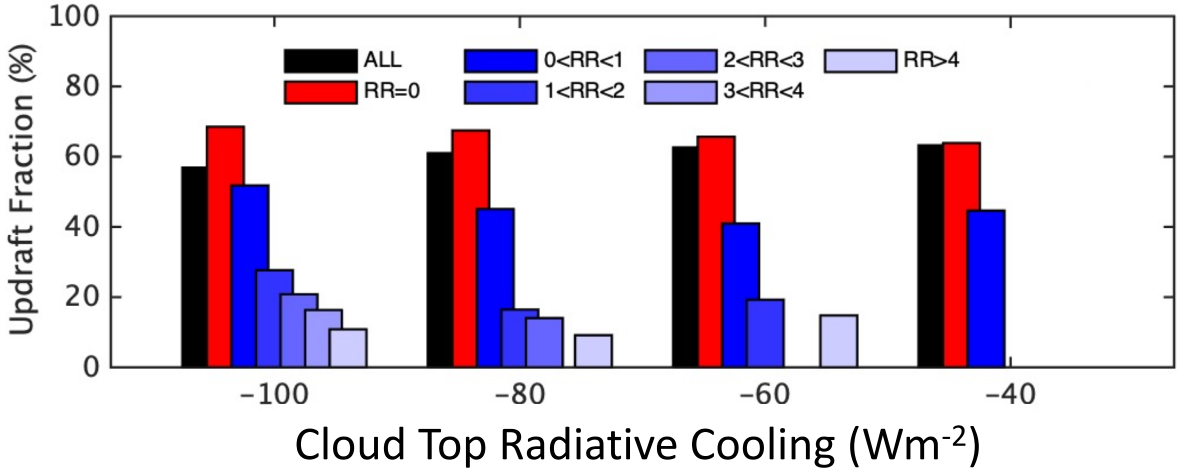
Diurnal Cycle

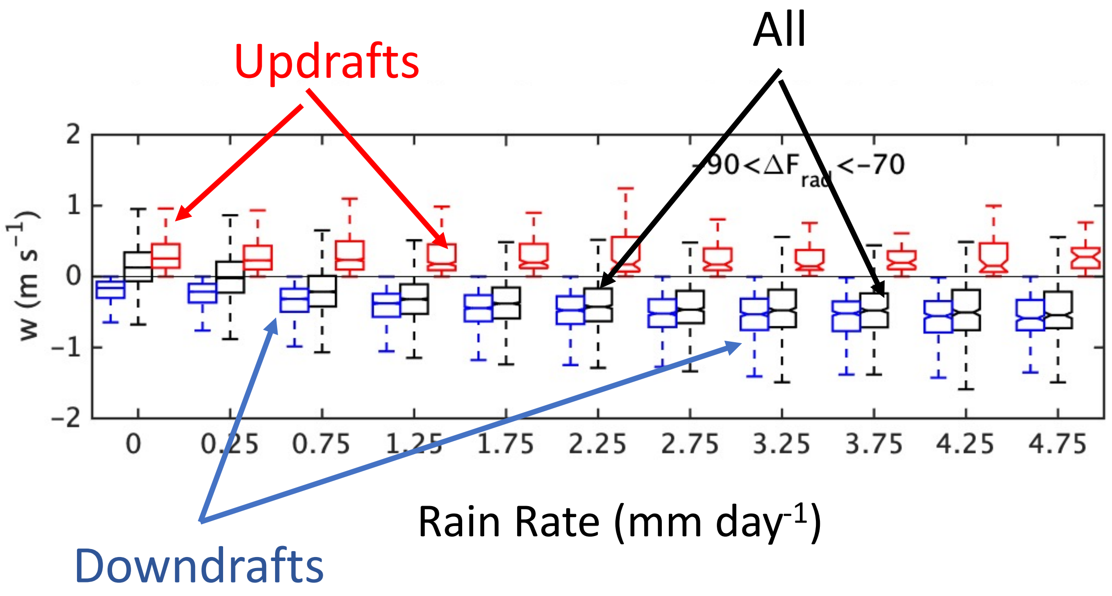




- Variance of vertical velocity is higher during the nighttime as compared to the daytime.
- Cloud fraction (CF) and rain fraction exhibited a distinct diurnal cycle with higher values during the nighttime than during the daytime.
- Winds, surface fluxes, PBL depth didn’t exhibit a diurnal cycle.

Air Motions Within Drizzle Below Stratocumuli





- For a similar amount of radiative cooling at the cloud top, drizzle increasingly falls in downdrafts. For weak rain rates (<2 mm day^{-1}), drizzle might fall within updrafts or downdrafts.

- For a similar amount of radiative cooling at the cloud top, the downdraft strength increased with rain rates, while the updraft strength remained unchanged.

Summary and Conclusion

- The turbulence observations made at the site are affected by the island during wind directions between 90 and 310.
  - About 30% observations made at the site correspond to marine conditions that are unaffected by the island heating.
  - Implications for climatological and model evaluation studies.
- On average turbulence is higher during the winter months than during the summer months, due to higher surface fluxes, stronger winds and greater cloud cover.
- Turbulence and boundary layer cloud cover was higher during the nighttime than during the daytime.
- In marine stratocumuli, for a similar amount of radiative cooling at the cloud top
  - Drizzle increasingly falls within downdrafts with increasing rain rates
  - The strength of the downdraft increased with increasing rain rates.

Poster Session 3: Wednesday 2-3 pm Eastern Time

Ceilometer and Doppler Lidar Calibration