Abstract

Cloud and drizzle microphysics and vertical velocity statistics are remotely sensed with millimeter cloud radars. Different methods are available to separate rain drop gravitational settling fall speed from air velocity.

The motion-stabilized NOAA-W band Doppler cloud radar was deployed on a ship in the southeastern tropical Pacific in the VOCALS (VAMOS Ocean Cloud Atmosphere) experiment. In CAP-MBL (Clouds, Atmospheric Radiation, and Precipitation in the Marine Boundary Layer) the ARM mobile facility (AMF) WACR Doppler cloud radar was deployed at Graciosa, Azores in 2009-2010.

We retrieve vertical air velocity from stratocumulus clouds in these locations using radar reflectivity and mean Doppler vertical velocity moments. The empirical separation technique uses the constraint that gravitational settling of hydrometeors is independent and uncorrelated to air vertical motion (Pinsky et al. 2010).

Method

1. The Pinsky et al. (2010) air vertical velocity retrieval first constructs a lookup table of mean fall speeds $V_f(Z,h)$ as a function of reflectivity and height in the cloud.

$$V = V_f(Z, h) + U$$

We find that the mean fall speed dependence on height and reflectivity is variable, changing slightly with variation of the cloud drizzle microphysics.

Longer-averaged lookup tables may be more robust, but less representative of clouds observed in a local neighborhood. Our objective is make $V_f(Z,h)$ both representative and robust.

The first step separates Doppler velocity into mean fall speed and a residual velocity $U$. The second part of the Pinsky et al. (2010) retrieval separates the residual velocity into two parts

$$U = U_1 + W$$

with air vertical velocity $W$. The relative partition between $W$ and $U$ is assumed $W$ and $V_f$ are uncorrelated. $U_1$ depends on the standard deviation of $U$ in each lookup table bin $h_0=U_1(Z,h)$ a more bin standard deviation $V_f$ more of $U$ assigned to $V_f$ and less to $W$.

Cloud-top dissipation

Dropout fall speeds are relatively small at cloud top. In a preliminary calculation from the VOCALS stratocumulus cloud radar Doppler vertical velocity data, we assumed velocities in the highest range gate had negligible contribution from droplet fall speed, and interpreted the Doppler velocity as air velocity. Using a slowly-varying horizontal wind and Taylor’s hypothesis we computed the turbulence kinetic energy (TKE) dissipation at cloud top from velocity spectra. The time series from VOCALS cruise leg 2 (upper axis) has diurnal variability and extreme outliers. We computed the time series on the local time of day (below), computed the histogram (shaded), and the median dissipation (bold line) in each hour.

The retrieved air velocity $W$ depends mostly on the lookup table $V_f(Z,h)$, $V_f$ is small and $W=U$.

Deeper clouds have downward retrieved $W$ below cloud. Do deeper rain shafts induce true air downdrafts? Or are they artifacts of $V_f(Z,h)$ underestimating rain fall speed in rain shafts below deeper clouds?

To define cloud top estimate and construct lookup table with vertical coordinate relative to cloud top height.

References

