No-drizzle segment of rf01- RL2

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A portion of the radar leg, RL2 flown between 11:46 and 12:15 UTC had practically no drizzle fall below cloud base. This portion, by my arbitrary definition, is 11:55 - 12:07, roughly the southern half of the circle. In contrast, the northern half had drizzle reach at least to the middle of the sub-cloud layer. Very little, if any precipitation reached the ocean surface. This situation, for RL2, is illustrated by the radar echo shown in the circle image Fig 1.

This note focuses on the non-drizzling part of RL2, with the idea of presenting a comparison to the observations taken in rf05 and for seeking parallels with modeling results. At this point, the note is going to be pretty rough, mostly just a collection of figures with little commentary. Most figures are in separate but linked PDF files and the majority of them have several pages each.

In accord with this being a no-drizzle area, reflectivity increases with altitude due to increasing LWC and droplet sizes. There is relatively little kilometer or smaller scale structure in the horizontal. The intermittent weak spots evident near cloud top will be discussed later on. There is a large-scale (tens of kilometers) variation in cloud depth, the cloud being thinnest in the middle of this segment and increasing toward the regions where drizzle appears. This variation is manifested in echo top height being near 800 m in the middle, and near 850 m toward the two ends of the 11:55 - 12:07 segment. And, echo top showed further increases in the drizzling region to 880 m. For the segment under discussion, this combination of increasing echo top height and increasing echo depth leads to strong correlation between echo top altitude and vertically integrated reflectivity, VMZ.

The echo top vs. VMZ correlation and the monotonic increase in reflectivity with altitude are consistent with the assumption that cloud base altitude throughout this segment was nearly constant. The validity of that assumption can be examined by looking at the variability of reflectivity as a function of altitude. The 90-percent range of reflectivity values below 750 m altitude is near 4 dBZ. The corresponding factor of 2.5 is much greater than can be reasonably accounted for by variations in LWC, so one has to assume that there are variations in size distributions either due to variations in droplet concentrations, or, more likely, due to variations in settling rates and mixing rates with droplet spectra from higher altitudes.

The vertical velocity field exhibits patchy variation in the horizontal, much like that observed in rf05. Comparing these images with those for reflectivity reveals that the weak spots of reflectivity near echo top can safely be associated with entrainment events. It is also evident that the negative (downward) velocities penetrate deeply into the cloud layer. As for the accuracies of these values, a brief statement is that both with respect to random errors and biases the error band is about ±0.2 m s^{-1}, but further work may show this to be an underestimate.

Statistics of the vertical velocities were evaluated in three different forms: **(a)** with respect to geometrical altitude and **(b)** with respect to the varying echo top altitude. Approach **(b)** was implemented by removing 5-km moving averages of echo top altitude from local values. These 'undulating echo top' results, I think, better reflect patterns with respect the interface but suffer from mild softness in the objective determination of local echo top in the face of residual noise. This weakness can be overcome, and I plan to do that at some time. The great sensitivity of higher moments of the velocity pdf's makes even the displacement of one profile by one rangegate of notable consequence.

(a) The pdf of vertical velocities is shown in Fig. 2. The spread of the distributions increases downward through most of the cloud layer. This is in accord with results from rf05, indicating a greater variation in vertical air velocities closer to cloud base. Of course, one has to be cautious with such conclusions in view of possible variations in reflectivity-weighted fall velocities at any given height. In view of what was said about the variations in reflectivity and its possible causes, it is clear that this ambiguity in not easily resolved (cf. Marie Lothon's ongoing work). At cloud top the increased range of velocities appears to be real, but it also reflects, in this treatment, horizontal variations in cloud top height. (I also should add, that more work needs to be done on the degree of increased noise in velocity that may be associated with reflectivity values close to the noise threshold used in processing these data.)

Vertical profiles of moments of the velocity pdf are given in Fig. 3.

(b) The pdf of vertical velocities at altitudes taken with respect to echo tops adjusted with a 5-km highpass filter is shown in Fig. 4. The general pattern is not that different from that found with geo-altitudes (Fig. 3) except that the depth of larger spread in velocities is now limited to a single rangegate of 15 m below the adjusted echo top. The variance in this layer is less, but skewness is greater. All this makes relatively good sense. Vertical profiles of the moments are given in Fig. 23.

I thought it would also be interesting to see how the pdf moments vary with averaging distance. To this end, for selected altitudes the moments are shown for the full the sample, and for sliding segments of roughly 1/3, 1/10 and 1/30-th of the full sample (roughly 26, 8 and 2.5 km distances) in the figures listed in the table below:

GEO-ALTITUDE				**RELATIVE TO FILTERED ECHO TOP**			
altitude (m)	**26 km**	**8 km**	**2.5 km**	**dist. from mean echo top (m)**	**26 km**	**8 km**	**2.5 km**
810	Fig. 5	Fig. 8	Fig. 11	15	Fig. 14	Fig. 17	Fig. 20
780	Fig. 6	Fig. 9	Fig. 12	45	Fig. 15	Fig. 18	Fig. 21
675	Fig. 7	Fig. 10	Fig. 13	150	Fig. 16	Fig. 19	Fig. 22

The general observation most evident from a perusal of these plots is that there is a great deal of variation in the computed values even at the 26-km scale which includes samples of close to 3000 points. The variability, as expected, increases with reduced sample sizes. Another striking feature is the presence of quite sudden jumps in the higher moments (std. dev and skewness), which result from just one or two outliers. I have proven that this is case by changing, for example, one -3.2 value to 0. So, as already indicated above, these measures of the variability of vertical velocities are, evidently, very sensitive to errors or noise in the data.