Z-R relationship for DYCOMS flights, derived from in situ measurements of droplet spectra.

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Prologue.

As an aid to interpreting the WCR observations in terms of drizzle rate, the in situ probe data were used to generate simple power law equations relating reflectivity Z (mm^6 m^-3) to R (mm h^-1). The approach taken was to first come up with equations that give a reasonable first approximation for the needed transformation for each flight, and for 5-minute segments within the flights.

My approach was guided by the recognition of limitations arising from (i) problems associated with the in situ probe data, (ii) the unknown relationship between spectra measured along the flight line and at other regions sampled by the radar and (iii) the possible influence of air velocities on the actual flux of precipitation at specific locations in or below the cloud.

No direct measurements of drizzle rates, in terms of mass flux, are available for DYCOMS, so this conversion from Z to R cannot be subjected to independent evaluation. A rough estimate of the accuracy of drizzle rates so derived is a factor of 2. Improvements in the estimated accuracy (for better or worse) may come later from comparisons with data from other projects, and from further analyses, possibly involving use of the measured Doppler velocities, which are reflectivity-weighted fall velocities, plus air velocities.

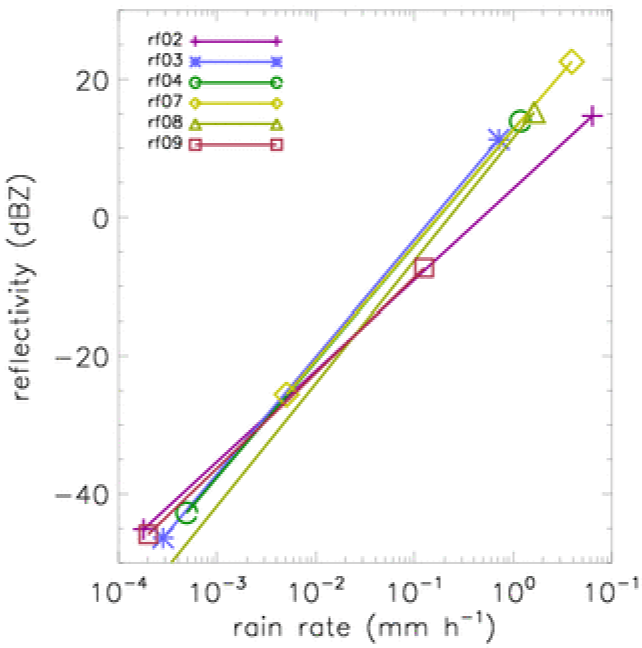
In situ data for hydrometeor size distributions are available for flights rf02, 03, 04, 07, 08, and 09. Analyses to date were done only for these flights. This may be complemented later with data from the Fast-FSSP. The basis for this set of analyses was 1-Hz data archived as C130 variables CS100_LPI, C260X_RWO and C2DC_RWI2.

The following summarizes a set of results I derived using procedures to be detailed later. Other results for Z-R are being generated by Margreet van Zanten at UCLA, by Qing Yang at UW, and possibly by others as well.

Results by day.

The simplest conclusion is that **Z = 18 * R^1.68** is a good descriptor for 4 of the flights (rf03, 04 07 and 08) while a slightly different equation **Z = 3 * R^1.35** is better for flights rf02 and rf09. The difference isn't large, except at high Z and R values.

These results are shown in Fig. 1 (below).



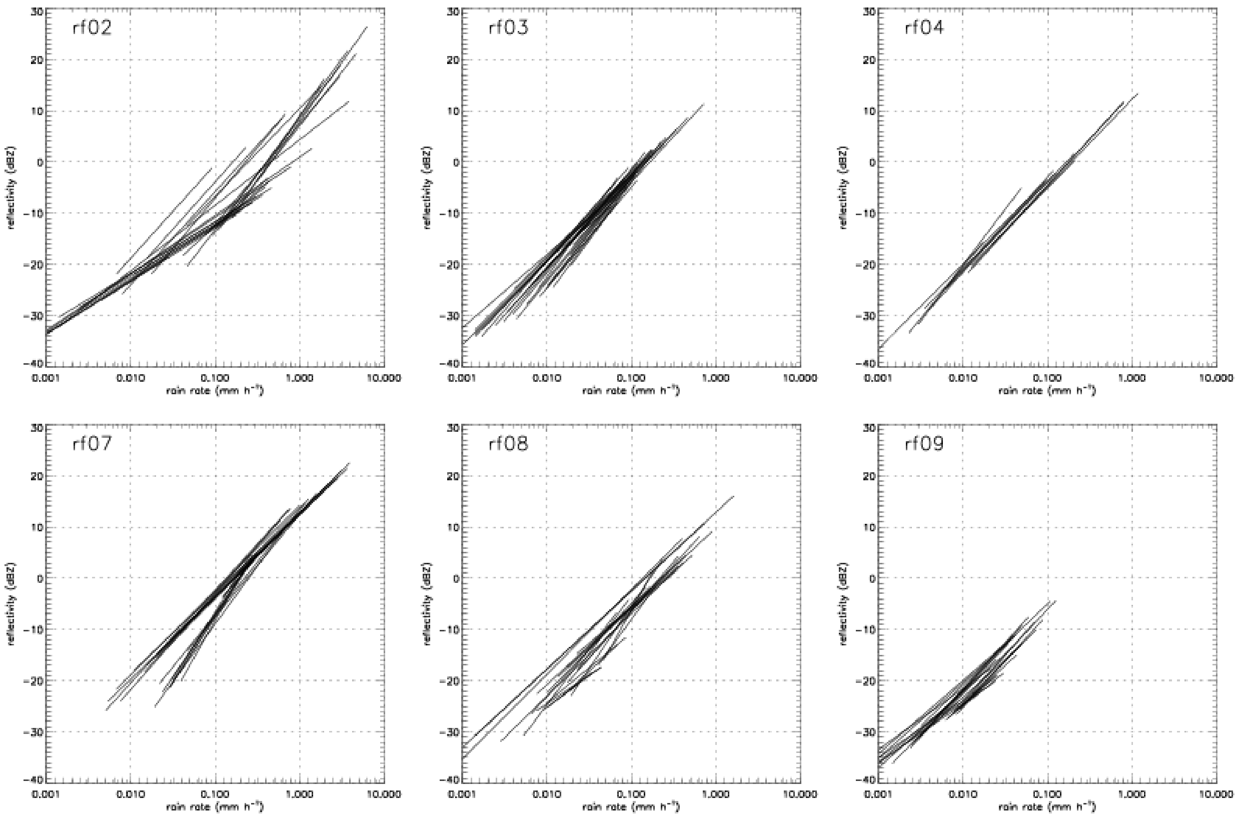
Numerical definitions of the equations are shown in the table below with **a** designating the pre-factor, **b** the exponent, **c t**he correlation coefficient, and **rmin** and **rmax** define the range of values for the data of given flight.

rf02 26 legs: a = 2.58 b = 1.32 c = 0.96 rmin = 0.0002 rmax = 6.3367
rf03 29 legs: a = 23.56 b = 1.70 c = 0.98 rmin = 0.0003 rmax = 0.7160
rf04 11 legs: a = 18.57 b = 1.68 c = 1.00 rmin = 0.0005 rmax = 1.1810
rf07 24 legs: a = 18.49 b = 1.67 c = 0.98 rmin = 0.0051 rmax = 3.9131
rf08 25 legs: a = 13.95 b = 1.77 c = 0.96 rmin = 0.0002 rmax = 1.6294
rf09 27 legs: a = 3.21 b = 1.38 c = 0.97 rmin = 0.0002 rmax = 0.1246

The number of legs in this table refers to the number of flight segments, each roughly 5-min in duration, for which independent Z-R equations were fit. No stratification of these legs by location, altitude, etc. is involved at this point.

Results by flight leg.

More detailed results are given in the next figure. Separate panels show the Z-R relationship for each flight, with one line per 5-min flight leg. The lines are shown extending over the range of values observed in the
leg.



The leg by leg data are also available in tabular form via [this link.]

Data processing

There are innumerable details about how the data were treated in this analysis. As a means of providing some detail for the curious, I am attaching an admittedly somewhat arcane description via [this link.]
As the reader will discover, there are several arguable steps in the processing; my approach was that outlined in the prologue. I was trying to get at a relationship that gives the best estimate, in my opinion, not necessarily one that would be considered the optimal representation of the data from which the information is extracted. For example, the numbers of points in the source data with different R-values wasn't considered to be of dominant relevance and wasn't allowed to influence the resulting Z-R unduly.

Use and next steps

For now, the results can be used as is to provide estimates of drizzle fluxes. The $Z = 18 * R^{1.68}$ equation yields drizzle rates, for given Z that is about a factor of 2 lower than $Z = 4.0 * R^{1.37}$ which I used up to this point. That equation was derived from data collected off the Oregon coast in 1995 and 1999 using the Wyoming King Air. Whether the difference between the two sets of data reflects some underlying difference, or not, has not yet been examined to any degree of detail. But, the magnitude of the difference is of the same order as the spread found for the DYCOMS data, so .....

Some of the flights show possible groupings of legs with discernible differences in Z-R. This is the case for rf02 and rf07, the two heavy drizzle cases. Other stratifications may also emerge as the results are further scrutinized.

Clearly, more can be done, but there is also a clear limit to how much is worth investing in this effort. With that in mind, I will be glad to receive all sorts of inputs on the issue, specially good insights regarding patterns in droplet and drizzle size distributions which might show some orgnization of the Z-R relationships too.