

Fig. 1a- A two-hour period of “stratiform” precipitation during an extra-tropical transition. In these situations the exponents in the Z-R relationships are close to convective cases as shown by the disdrometric relationship in the right panel.

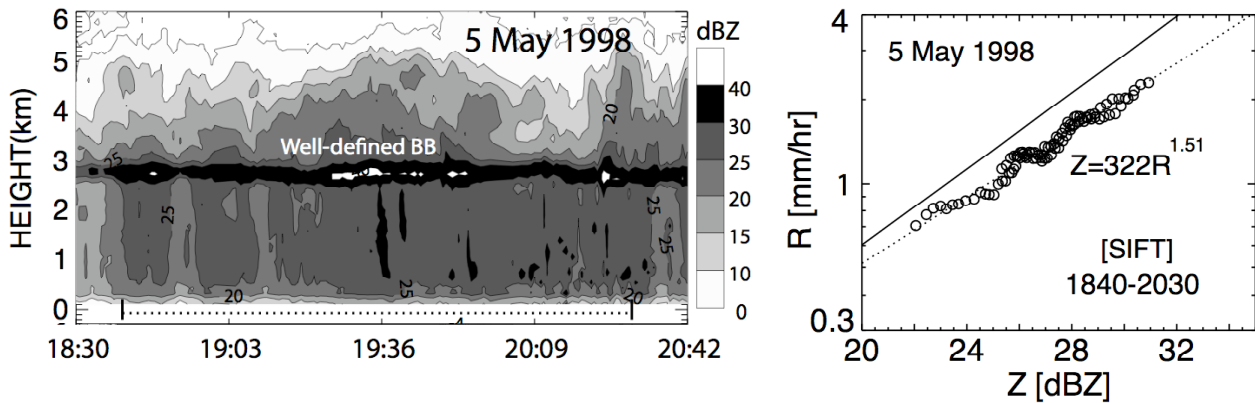


Fig. 1b- A more typical period of summer “stratiform” rain during a large scale uplifting.

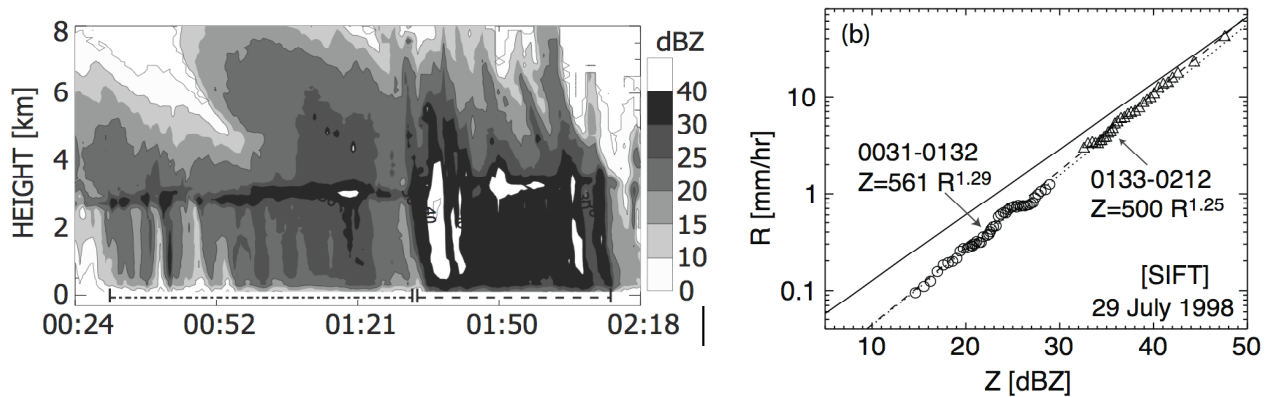


Fig. 1c- The profile of reflectivity as seen by a vertically pointing radar (left) shows two distinctive periods that would be defined as “stratiform” (dash-dot period) and “convective” (dash period) by any commonly used criteria. On the right the two Z-R relationships are shown to be in practice indistinguishable.

3. The Vertical Profile of Reflectivity

Another much used ambiguous concept is “The Vertical Profile of Reflectivity”. Of course, we can measure reflectivity as a function of height but this does not necessarily define an object we are entitled to denote as VPR. Figure 2 shows a time height profile of reflectivity in a situation where trails can be well differentiated. In these trails the larger particles are to the left of each trail. In a continuous precipitation at each level there is a mixture of particles coming from different origins and having undergone different histories. It is clear that the VPR has no well-defined physical meaning. It is naïve to expect the VPR to contain information that can be used to deterministically extrapolate a measurement aloft to ground.

Figure 3 shows an observed set of profiles and illustrates how rapidly information on reflectivity at one height becomes fuzzy when we use it as information on precipitation intensity at another height. It is clear that the vertical profile of reflectivity is a probabilistic concept and must be used as such. An example of a climatological probabilistic VPR is given in Fig. 4, where the lines are iso-probabilities of having a given reflectivity on the x-axis at the y-axis height. Thus, an equi-probability climatological VPR correction (by probability matching) for an observation of 17.5 dBZ at 1 km above the bright band peak corresponds to a reflectivity of 25 dBZ one kilometer below the peak. A correction with the mean profile gives 23 dBZ at -1km. Perhaps a better climatological correction can be obtained by conditioning the statistics to observed values. Figure 5 shows the mean profiles stratified in 2 dB intervals at 1 km above the BB peak. For the same observation of 17.5 dBZ at 1 km the extrapolation to -1 km now gives 27 dBZ, that is, a 4 dB difference with respect to a climatological average profile.

Using climatological VPR corrections is like using a climatological Z-R relationship. It is acceptable if large errors are tolerable.

The alternative is an adaptable VPR correction, necessary for QPE if Q stands for quantitative (as opposed to qualitative). However, to derive a VPR that is representative of a situation (that is, a time-space interval) we must first quantify the time-space variability of the VPR. This can be formulated as: given a measured value at a point in the volume scan at ranges long enough so that the ground values are not seen, what is the optimal time-space domain at short ranges that will give us the VPR profile that will minimize the residual errors after the VPR correction. For this we must know

the time-space correlation structure of the values at ground given the value measured at the particular height. Or, in other words what is the decorrelation time and decorrelation distance of the residual errors after a particular VPR correction. Moreover, since this variability is very large we must condition the statistics to some obvious parameters that determine the change of reflectivity in height and its variability. All this is not easy, but absolutely necessary.

In fact, the two main problems in radar QPE, the correction for the vertical profile of reflectivity and the adjustment of the Z-R relationship require similar approach and may benefit by stratification by the same parameters, namely height of the bright band (which we use to some extent); depth of precipitation; profile of vertical air motion; hodograph.

4. Adjustment by gages

What is the purpose of gage adjustment? Correct for the residual variability of the VPR before or after some mean correction was applied? Correct for the variability of the Z-R relationships? Calibrate the radar? Or sweep under the rug all the shortcomings of the system?

Depending on our objectives different requirements are needed, all related with the space-time variability of the uncertainties in QPE. The spacing of raingages and their spatial coverage must be matched to the decorrelation distance of the residuals of the Z-R relationship used and the residual of errors after VPR correction. The fact that both may be correlated makes the problem more interesting.

A cluster of gages within a domain smaller than the decorrelation distance of residuals will adjust radar to this particular domain but will result in large biases outside.

The success in gage adjustment depends on the success in understanding the VPR correction and the adjustment of the Z-R relationship and the structure of the residual uncertainties. And I don't know of any shortcut!

Acknowledgments

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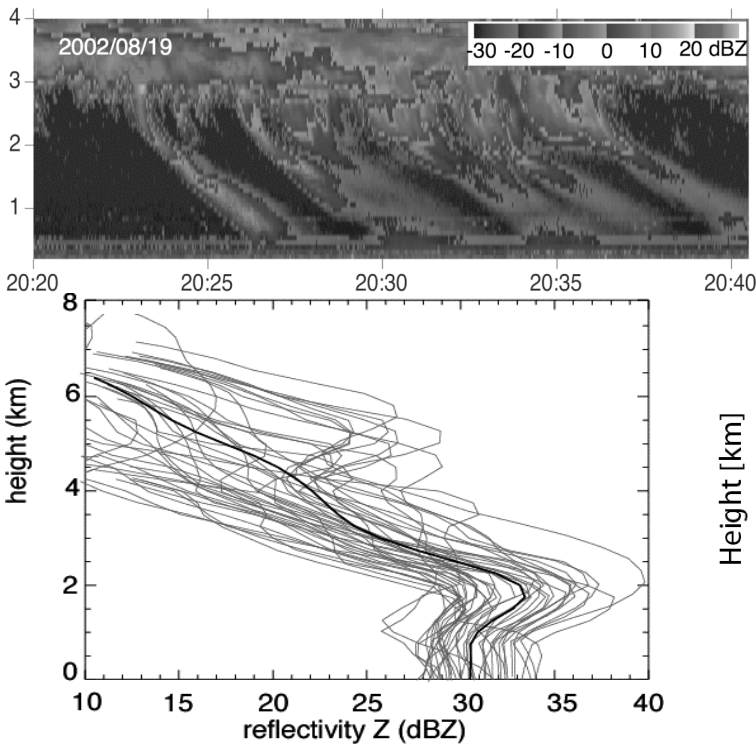


Fig. 2- This time-height profile illustrates that through horizontal drift and size sorting the precipitation at a given height is composed of particles having very different microphysical history.

Fig. 3- The left figure illustrates the variability in VPR encountered in any situation defined by tens of minutes and tens of kilometers. This leads to the rapid decorrelation of reflectivity in height: for a distribution of ± 1 dB at any level there is a five-fold broader distribution at one kilometer apart.

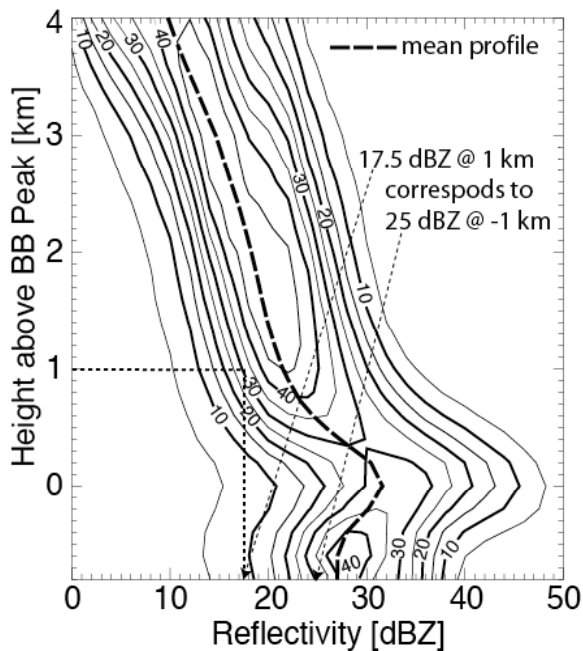


Fig. 4- Probabilistic VPR

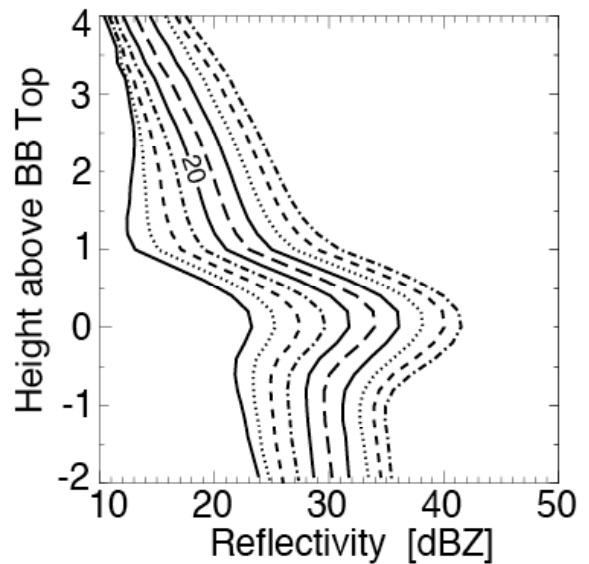


Fig. 5- Mean climatological profiles stratified at 1 km above the BB every 2 dB from 12 to 30 dBZ