Converting weather radar data to Cartesian space: A new approach using DISPLACE averaging

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Abstract

Volume-scan radar data can be processed to display radar rainfall fields on constant altitude planes. These displays are called CAPPIs. A new interpolation method is described and the CAPPIs so produced are compared to those obtained using conventional schemes. The new method is called DISPLACE Variate Averaging or DVA and is computationally efficient, requiring only half the computer time of other interpolation methods. DVA avoids division and multiplication and many of the conversions between units. It therefore provides new possibilities for real-time CAPPI processing. The method's output is used to compile rain fields for convective showers and general rain conditions which occurred during February 1996, using the data from an S-band radar.

Introduction

Constant Altitude Plan Position Indicators (CAPPIs) are an important radar-data derived product in the field of hydrometeorology. A large portion of South Africa's rainfall is produced by convective storms which are characterised by rainfall fields with high spatial and temporal variability. The representativeness of point measurements provided by rain gauges becomes very limited for convective rainfall. Doviak and Zrnic (1984) commented on the problem indicating the inverse relationship between the percentage error in using rain gauges to estimate area rainfall and the true areal mean rain depth. Seed (1993) noted that the rain-gauge measured rainfall is at best representative of a 10 km^2 area. Astute water resource management is required to meet the growing demands of the community. This need has focused attention on the use of area rainfall estimation, since the nationwide rain-gauge network is too sparsely distributed for simple extrapolation methods to provide accurate area estimates. Radar provides a means to scan large volumes of the atmosphere at high resolution and to capture information on the intensity of the precipitating scatterers in real time. As rainfall stimulation research in South Africa (Mather and Terblanche, 1994) moves towards area experiments, away from individual convective cells as experimental units, the use of radar to verify the outcome becomes even more important.

Radar is often operated in volume-scan mode whereby a three-dimensional image of the precipitation scatterers is obtained by consecutively scanning the atmosphere at higher elevations for complete azimuthal rotations. However, the data captured during this process are in spherical co-ordinates which is not ideal for the purpose of data analyses. CAPPI-processing techniques can be classified into two broad groups, viz. projection and interpolation methods. The radial distance from the radar determines the elevation step(s) from which data will be utilised, i.e. data from progressively lower elevations will be used as the distance from the radar increases. This inverse relation holds irrespective of CAPPI height and method, although the data usage transition between elevations is abrupt in projection methods, and more gradual and smooth in interpolation methods.

The projection method, where data from a slant elevation plane are projected onto a horizontal plane parallel to the earth's surface has been very popular due to its relative simplicity. However, the method does have drawbacks. Discontinuities appear at ranges where the data-use transition between different elevations occur. These discontinuities are always present but are most evident in the presence of data collected in stratiform precipitation.

In the sections that follow, a brief background to radar meteorology with reference to the MRL5 dual-wavelength radar, the rain-gauge network in the Bethlehem area and the interpolation CAPPI procedures in use in South Africa, is given. This is followed by the derivation of the CAPPI equations with emphasis on the new DVA method of interpolation. Finally, the advantages and use of the procedure in compiling rainfall maps from the S-band section of the MRL5 radar, verified against surface measurements, are shown in a case study.

Equipment

Radar data processing and the MRL5 radar

The background to radar and its uses in meteorology is well described by Atlas (1990), Battan (1973) and Doviak and Zrnic (1984). A short summary of some of the relevant aspects is given below.

Conventional weather radars generally use logarithmic receivers to accommodate the large range of received powers (>10^6) from precipitation echoes. A range correction term introduces a further 10^2 increase to the received power range that has to be provided for. In addition, the returned power from precipitation echoes exhibits a large sample-to-sample variance, necessitating averaging over a large number of samples to obtain accurate estimates of the mean received power. Before averaging, the analog signal from the logarithmic receiver (known as the video signal), is digitised to derive video processor (VP) counts. These are integer values reflecting the resolution of the analog to digital converter used (e.g. 12 bits). The averaged VP counts - which should be corrected for the bias (-2.5 dB) introduced by averaging the logarithms of the received power from precipitation echoes - can then be related back to the average received power (in dBm) through the calibration slope of the specific radar

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