Exam #2

INEL 5607

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Problems

Comparison	PARSIVEL	2DVD	JW
Characteristics	• laser based optical system • size range for precipitation: 0.3-30mm • size range for particle fall velocity 20 m/s • can measure particles as small as 0.1mm • uses a laser diode to create the horizontal light sheet	• Joins an array for measuring drop size distribution. • Measures raindrop size, shape and velocity. • Composed of optics and line-scan cameras, a computer that records the measurements and the slit images, and another computer that processes the data for analysis and visualization. • Possesses two orthogonal projections that provide 3D raindrop shape information. • Contains real-time data acquisition software • It also has software capable of viewing data "offline", for analysis of previously collected data.	• Drop impact based. • Able to detect drop sizes 0.30-5.3mm • the output voltage relates to the diameter of a raindrop falling at terminal velocity. • it uses a $50cm^2$ styrofoam cone to calculate the displacement. • it is similar in architecture to the 2DVD.

Pros	• Detailed recording and analysis of precipitation type, amount and distribution • Homogeneous laser band guarantees guarantees exact raw data • continuous precipitation measurement without delays. • able to classify the precipitation type • designed for low maintenance and unattended operation • it can provide joint particle size spectra of diverse, simultaneously occurring types.	• Permits measurement of rain, snow and mixed precipitation. • It is capable of providing a lot of information including velocity and shape of individual raindrops. • Under low wind conditions, the 2DVD provides highly accurate data.	• It is not affected by high temperatures. • Can detect several particles at the same time. • Noise can only come from physical, mechanical sources. So areas where insects or other animals that interfere with the optical disdrometers cannot affect this one (unless they impact the styrofoam)

Cons	• Measures maximum diameter of the 1-D projection of the particle • Rain drops that fall at velocities that differ 50% from terminal fall speed are rejected • Fall velocities are underestimated at mid-size drops. • Underestimates the drop concentration at diameters ¡ 1mm • Quantization error due to binning the observed maximum diameter and velocity.	• Malfunctions at high temperatures • Computers attached to it can also overheat. • Water gets collected on the mirrors and smaller drops are formed from these splashes, interfering with measurement.	• because of the dead time, it underestimates the number of drops. • drops lager than 5.0mm are not distinguished by the device. • it assumes that all particles are falling at terminal velocity
Research Objectives and Findings			

2. **a.** For monodisperse, I presumed that

$$N(D) = N_0$$

Then, radar reflectivity is calculated as such:

$$Z = N(D)D^6$$

With values:

- $D = 300\mu m$
- $N = 1L^{-1}$

Results are found in the table

b. Using the equation:

$$Z_e = \int_0^\infty N(D)D^6 dD$$

and the presumption that it is a Marshal-Palmer rain DSD(and therefore $\mu = 0$). We make a MATLAB program to calculate the integral of the drop size distribution

$$N(D) = \frac{N_t}{D_n} e^{\frac{-D}{D_n}}$$

With the following values as:

- $N_t = 1.4e^4 m^{-3}$
- $D_n = 300\mu m$

We use the factor 10^8 to transfer mks units to mm^6/m^3. Results are found in the table below.

c. Using the equation:

$$Z_e = \int_0^\infty N(D)D^6 dD$$

We want to calculate the reflectivity of a Gamma rain DSD, therefore we use:

$$N(D) = \frac{N_t}{\Gamma(3)} \frac{D}{D^n}^2 \frac{1}{D_n} e^{\frac{-D}{D_n}}$$

With the following values as:

- $N_t = 3.8e^4 m^{-3}$
- $D_n = 100\mu m$

CASE	mm^6/m^3	dBZ
A	7.29×10^{-14}	-131.37
B	76.6437×10^9	98.833
C	2.07×10^{10}	103.17

Table 1: Resulsts for all cases of question 2

3. The following three are methods used to measure vertical air velocity:

   - Limiting velocity of fall of the smallest particles that can be detected.
     In this method, the particle size is known and therefore their velocity of fall is also known. With this in mind, the velocity of air corresponds upper limit of the spectrum corrected by this velocity of fall. One flaw on this method is that it always presumes there are small particles in the spectra, which may sometimes not be the case.

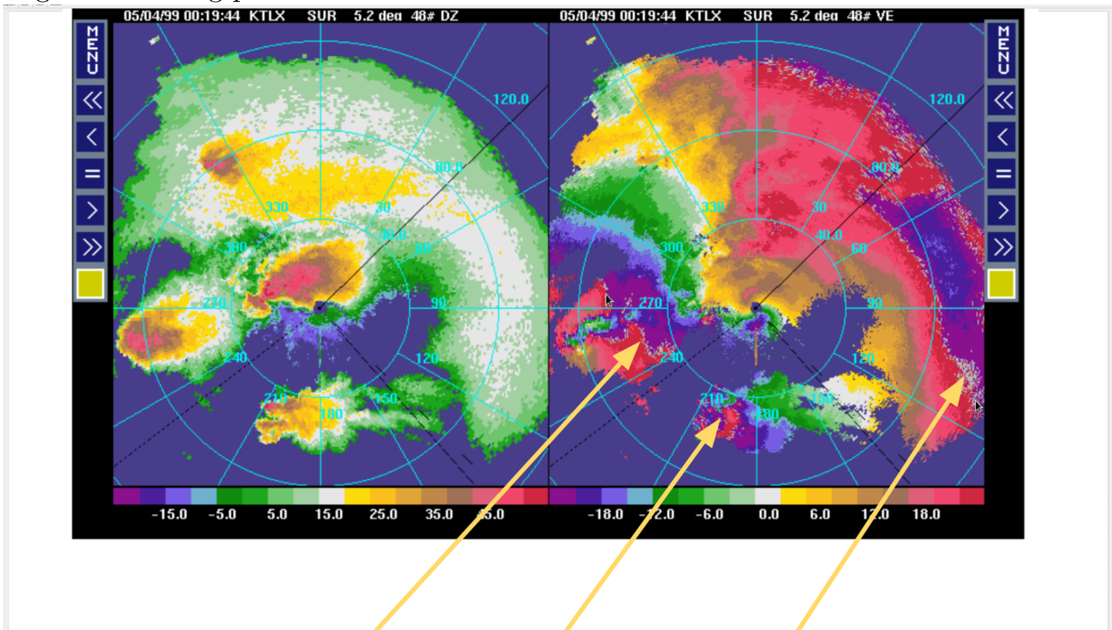
   - Assume the form of the drop size distribution ($N(D)$) and from this derive z-w relations.
     In this more elaborate way, we measure doppler velocity w_d and Z to calculate the air velocity. With our presumed w-Z relationships, we can calculate the mean velocities for doppler and terminal velocity of the particles. In other words, these relationships are generated:

     $$\bar{w}_t = \alpha_t Z^{\beta_t}$$

     However, we can observe that that the limiting factor here are the coefficients, since they change as the rain distribution changes from one measurement to another.

   - Three parameter method.
     This one consists of calculating the parameters w_a, N_0 and λ. The drop size distribution is assumed to be exponential, and N_0 and λ are calculated by using the least square fit method. However, we can already see another limitation in this method: if the DSD does not follow a exponential tendency, this method is bound to fail.

4. **a.** Using the following plots:



The areas indicated by the yellow arrows represent the areas where velocity is folded. Taking the maximum value at the scale as the Nyquist velocity: $24m/s$, we set an aliased velocity $30m/s$. Using the equation:

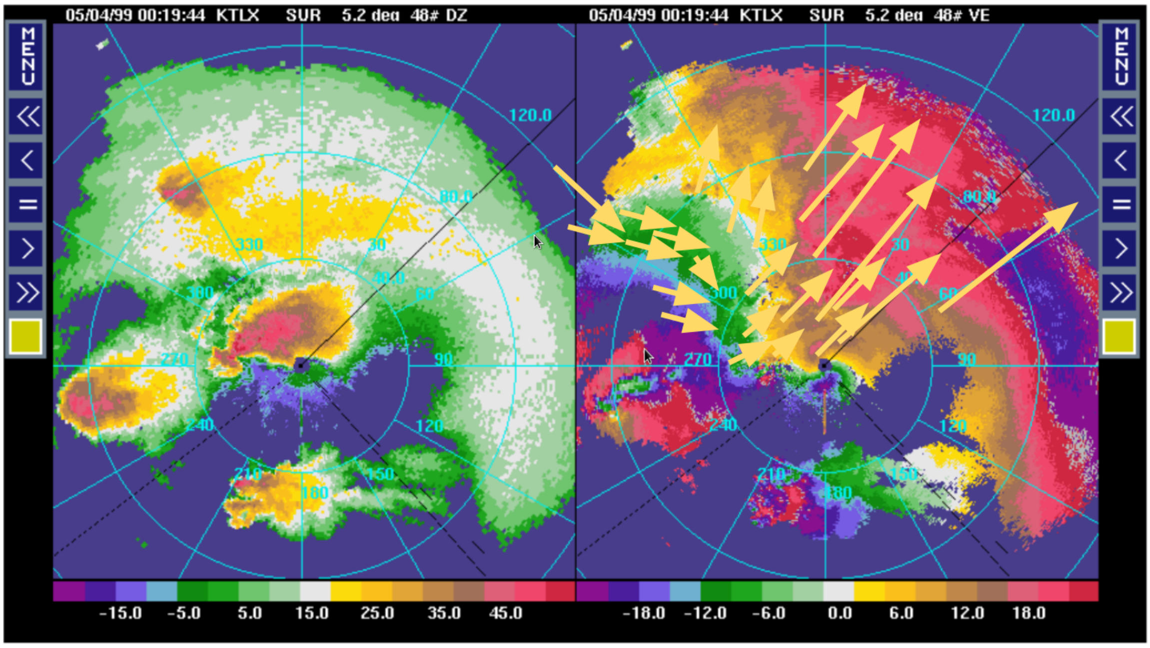
$$V = (-/+)V' \pm 2 * V_{max}$$

We have that:

$$V = 30m/s - 2 * 24m/s$$

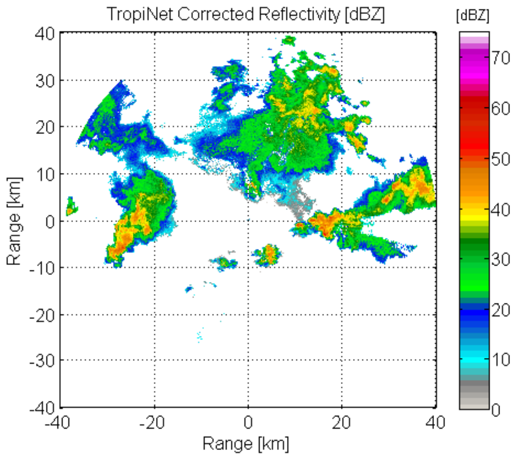
$$V = \pm 18m/s$$

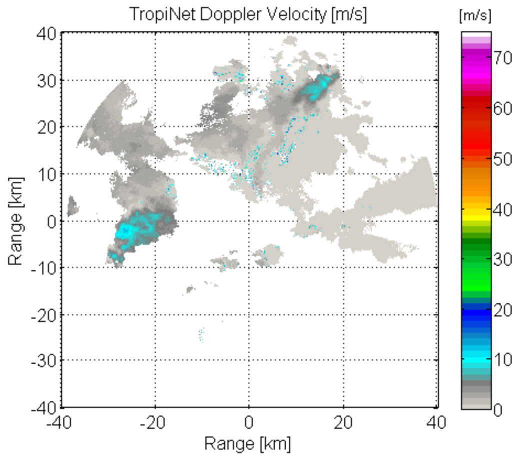
b. In the following figure I have illustrated my interpretation of velocity directions:



The green areas indicate that the flow is going closer to doppler radar, while the redder areas indicate that the flow goes away from the radar.

5. **a.** Using the matlab program, we arrive to the following plots:





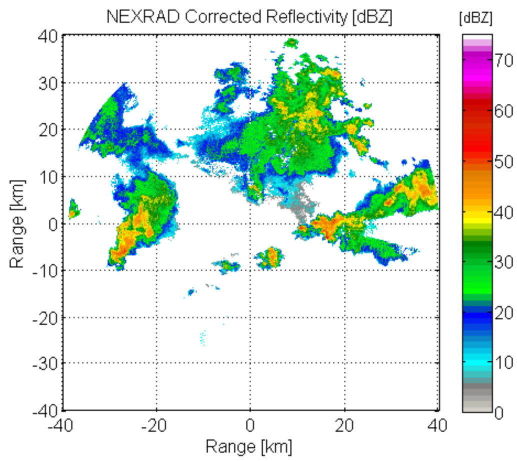
In the Corrected Reflectivity graph is seen that there is not much activity going on there. Most of high reflectivity areas are around the 0km in the y axis. Also, reflectivity isn't any greater than 40-50 dBZ approximately. There is also not that much movement as shown in the Doppler velocity graph. Velocity is not any greater than 10 m/s approximately. There is no observable or evident correlation between the two quantities, since there are regions of high reflectivity with low speed and also relatively high speed.

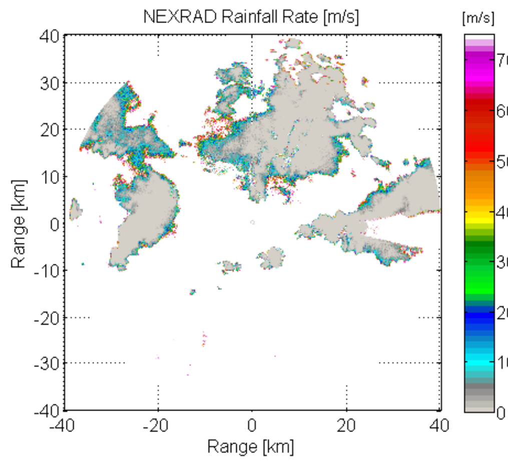
b. Using NEXRAD's standard relationship

$$Z = 300 * R^{1.4}$$

We solve for R to obtain how the rainfall rate varies according to reflectivity

$$R = (\frac{Z}{300})^{1/1.4}$$





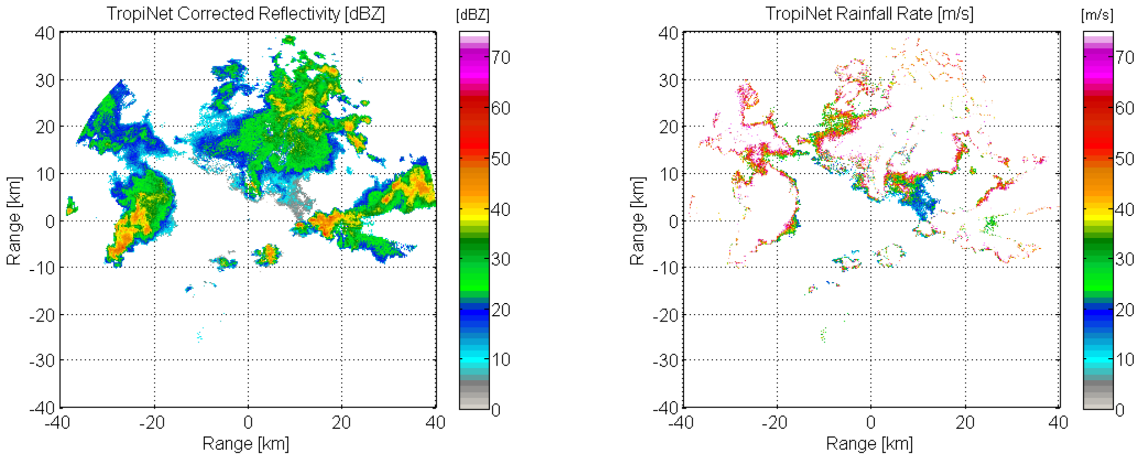
Using NEXRAD's standard relationship, we can see that there is not a good fit. According to the equation for NEXRAD's standard relationship, they are both supposed to increase in a "overdamped" fashion. However looking at both graphs, we can see that in areas where there is high reflectivity, the rainfall rate for that same area is not particularly impressive.

c. Due to the fact that Puerto Rico is a tropical island, the tropical Z-R relationship is chosen:

$$Z = 31R^{1.71}$$

Which is Blanchard's relationship for Hawaii, a tropical place like Puerto Rico. Solving for R we get:

$$R = (Z/31)^{1/1.71}$$



While I thought that this relationship would have worked pretty well, the graphs tell otherwise. A similar problem to the one encountered in part b is also encountered here. For areas with high reflectivity, we can see in the other graph that rainfall rate is too high. The same can be said for some areas where the reflectivity is not that impressive either. This Z-R relationship did not prove to be a good one for this dataset even though common sense would tell us that it could be a good approximation.

Appendix

0.1 References

The following references were used for completing the table:

- Ali Tokay: `http://pmm.nasa.gov/sites/default/files/document_files/parsivel_Tokay_c3vp_case.pdf`
- M. Thurai et al: `http://www.adv-geosci.net/30/3/2011/adgeo-30-3-2011.pdf`
- OTT Parsivel^2: `http://meteo-tech.co.il/e-Catalog/pdf/parsivel.pdf`
- Anton Krueger and Witold F. Krajewski: `http://journals.ametsoc.org/doi/pdf/10.1175/1520-0426%282002%29019%3C0602%3AТDVDAD%3E2.0.CO%3B2`
- M. Loffler-Mang: `ftp://goes.gsfc.nasa.gov/EASMITHWebSite/03.%20GPM%20Folder/03e.%20GPM%20Workshop%20Materials/06.1st%20GV&CalVal%20WS/GV%20Workshop%20White%20Papers/LoefflerMangYuter.pdf`
- C. R. Williams et al: `http://rain.atmos.colostate.edu/research/pubs/williams2000.pdf`
- Ali Tokay et al: `https://ams.confex.com/ams/pdfpapers/64350.pdf`

0.2 MATLAB Code

The following is the matlab code used for calculating values and plots:

This one was used to calculate the values of the first table.

```
syms D;

Nt1 = 1;
Dn = 300*10^(-6);

resultA = Nt1*Dn^(6)*10^8;
resultA = double(resultA)
10*log10(resultA)

Nt2 = 1.4*exp(4);
resultB = int((Nt2/Dn)*exp(-D/Dn), D, 0, inf)*10^8;
resultB = double(resultB)
10*log10(resultB)

Nt3 = 3.8*exp(4);
Dn1 = 100*10^(-6);
resultC = int((Nt3/gamma(3))*((D/Dn1)^(2))*(1/Dn1)*exp(-D/Dn1), D, 0, inf
resultC = double(resultC)
10*log10(resultC)
```

This one was used to make the plots for the 5th problem.

```
%% Plotting TropiNet Data
% INEL5607 SPRING 2015
% EXAM#2

%% Opening file and accesing variables from file

%Open file - edit the name
File_name='Aguirre.netcdf'; ncid = netcdf.open(File_name,'NC_NOWRITE');%R

%% Retrieve variables and filter
CR_id=netcdf.inqVarID(ncid,'CorrectedReflectivity'); %Reflectividad Corre
CorrectedReflectivity=double(netcdf.getVar(ncid,CR_id));

Vel_id=netcdf.inqVarID(ncid,'Velocity'); %velocity
Velocity=double(netcdf.getVar(ncid,Vel_id));
```

```
%Filter data for accepted range of values
PHV_id=netcdf.inqVarID(ncid,'CrossPolCorrelation'); %for filtering purpos
RHVX=netcdf.getVar(ncid,PHV_id);
 CorrectedReflectivity(CorrectedReflectivity ==-99900) = NaN;
 CorrectedReflectivity(CorrectedReflectivity<0) = NaN;
 CorrectedReflectivity(RHVX < 0.6) = NaN;
 Velocity(isnan(CorrectedReflectivity))=NaN;

%Getting Azimuth, Elevation and Range Gate info

 A_id=netcdf.inqVarID(ncid, 'Azimuth'); az_set=netcdf.getVar(ncid,A_id); %
 Elevation_id=netcdf.inqVarID(ncid,'Elevation');
 Elevation=netcdf.getVar(ncid,Elevation_id); elevX=Elevation(2);

 GateWidth_id=netcdf.inqVarID(ncid,'GateWidth');
 GateWidth=netcdf.getVar(ncid,GateWidth_id);

 RangeToFirstGate=0; drX=GateWidth(1)/1000000;
RngX=(drX*RangeToFirstGate):drX:(40.161-drX);

 aziX=az_set;
 aziXr = -(aziX-90)*pi/180;
 [RngXM,aziXrM]=meshgrid(RngX,aziXr);
X = RngXM.*cos(aziXrM); Y = RngXM.*sin(aziXrM);

%% Reflectivity Plot
% Reflectivity Plot
 cr= figure(1); pcolor (X,Y,CorrectedReflectivity');
 axis equal tight; shading 'interp';
 caxis ([0 75]); %Plot Legend of possible values
 colorbar('FontSize',12); load('MyColormaps','mycmap');
 set(cr,'Colormap',mycmap); set(gca,'FontSize',12);
 title('TropiNet Corrected Reflectivity [dBZ]','FontSize',12);
 xlabel('Range [km]','FontSize',12); ylabel('Range [km]','FontSize',12);
 grid on; h = colorbar; hTitle = get(h,'Title'); set(hTitle,'String','[dBZ

%Velocity plot
 vv= figure(2); pcolor (X,Y,Velocity');
 axis equal tight; shading 'interp';
 caxis ([0 75]); %Plot Legend of possible values
 colorbar('FontSize',12); load('MyColormaps','mycmap');
 set(vv,'Colormap',mycmap); set(gca,'FontSize',12);
 title('TropiNet Doppler Velocity [m/s]','FontSize',12);
 xlabel('Range [km]','FontSize',12); ylabel('Range [km]','FontSize',12);
```

```
grid on; h = colorbar; hTitle = get(h,'Title'); set(hTitle,'String','[m/s

reflectivity = 10.^(CorrectedReflectivity/.10)

rainfall = (reflectivity/.300)^.(1/1.4)

%Nexrad rainfall rate plot
vv= figure(3); pcolor (X,Y,rainfall');
axis equal tight; shading 'interp';
caxis ([0 75]); %Plot Legend of possible values
colorbar('FontSize',12); load('MyColormaps','mycmap');
set(vv,'Colormap',mycmap); set(gca,'FontSize',12);
title('NEXRAD Rainfall Rate [m/s]','FontSize',12);
xlabel('Range [km]','FontSize',12); ylabel('Range [km]','FontSize',12);
grid on; h = colorbar; hTitle = get(h,'Title'); set(hTitle,'String','[m/s

rainfall = (reflectivity/.31)^.(1/1.71)

%Puerto Rico rainfall rate
vv= figure(5); pcolor (X,Y,rainfall');
axis equal tight; shading 'interp';
caxis ([0 75]); %Plot Legend of possible values
colorbar('FontSize',12); load('MyColormaps','mycmap');
set(vv,'Colormap',mycmap); set(gca,'FontSize',12);
title('NEXRAD Rainfall Rate [m/s]','FontSize',12);
xlabel('Range [km]','FontSize',12); ylabel('Range [km]','FontSize',12);
grid on; h = colorbar; hTitle = get(h,'Title'); set(hTitle,'String','[m/s


%%
```