

Mesocyclone (MD) and Digital Mesocyclone (DMD)

The MD and DMD products are direct outputs of the Mesocyclone Detection Algorithm (MDA). So, before we discuss these products, we will take a look at how the MDA operates. You will only be tested on the MD and DMD products and not the MDA.

Super-Res & Mesocyclone Strength

Recall from previous lessons that super-res velocity data typically allow for easier identification of small-scale features such as mesocyclones because of the finer azimuthal resolution. However, it was first thought that this finer azimuthal resolution would result in velocity magnitudes associated with these features to possibly appear stronger compared to the 1 degree azimuth velocity. Preliminary studies done at WDTD do not show this to be the case. Therefore, nomograms for mesocyclone strength (Fig. 1) that were developed using 1 degree azimuth velocity are still valid with super-res velocity. However, remember that nomograms are not a tool for warning decision making! Their primary purpose is to help a forecaster develop a good sense of what is a strong signature versus a weak signature in a relative sense. Fig. 2 shows an example of what a mesocyclone signature looks like in super-res (left) and 1 degree azimuth resolution (right). Notice how the velocity magnitudes are not all that different, but the texture of the signatures is more defined in the super-res image. While utilizing super-res velocity data, it is wise to check the 1 degree azimuth data to compare/contrast, especially if the super-res products have dealiasing errors. This discussion of course only applies to human identification of mesocyclones. The Mesocyclone Detection Algorithm ingests super-res velocity data on all the split cuts, and 1 deg azimuth data on the rest of the elevation angles.

Process

Let's look at how the MDA uses these operator defined criteria to produce the MD/DMD products. The primary difference between the MD and DMD products is the MD is produced at the end of the volume scan, and the DMD is produced after each elevation scan. So, we will take a look at how the MDA detects circulations on a single elevation scan and for multiple elevation scans.

Processing for a Single Elevation

For a particular elevation angle, MDA searches for shear segments and convergence vectors.

- A shear segment is a string of base velocity bins at a fixed range, where the values increase in a clockwise direction. WSR-88D antennas rotate in a clockwise fashion. This is why the values must increase to be a cyclonic feature.
- A convergence vector is a string of base velocity bins at a fixed azimuth, where the values decrease in a direction away from the radar.

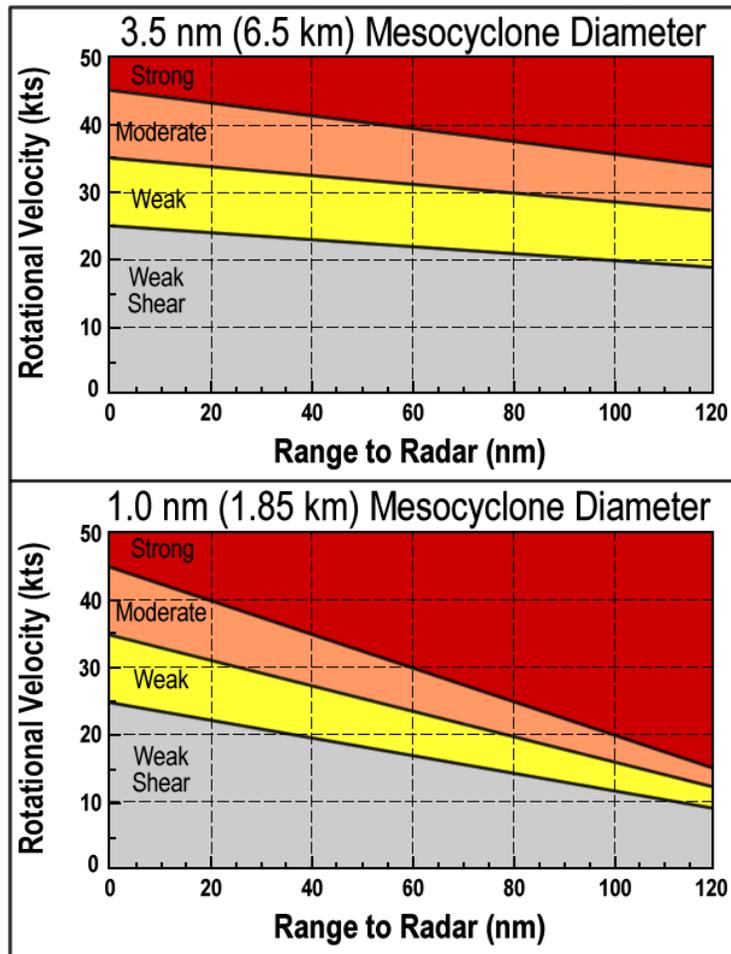


Figure 1. Mesocyclone Recognition Guidelines for a mesocyclone diameter of 3.5 nm (top) and 1.0 nm (bottom) as a function of range from radar for 1 degree azimuth velocity data.

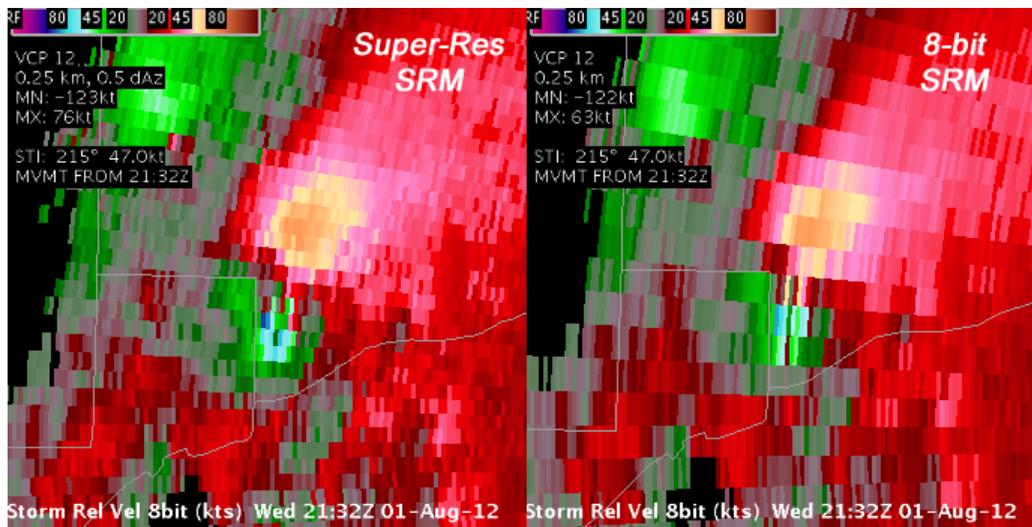


Figure 2. Super-res (left) and legacy, 1 degree azimuth (right) storm-relative velocity images for a mesocyclone at the 0.5 degree tilt.

Algorithms		
Close Save Undo		
Baseline: Restore Update		
Adaptation Item MDA		
Name	Value	Range
Minimum Reflectivity	0	-25 <= x <= 35, dBZ
Overlap Display Filter	Yes	No, Yes
Minimum Display Filter Rank	5	1 <= x <= 5

Figure 3. MDA Adaptable Parameters at the RPG HCI.

Minimum Reflectivity Threshold

Candidates for shear segments or convergence vectors must have corresponding reflectivity values above a threshold. This threshold is a URC adaptable parameter called the “Minimum Reflectivity”. The default setting is 0 dBZ (Fig. 3). Lowering this threshold would result in many more false detections.

2-D Shear Features

Shear segments from a single elevation and constant range are first combined into two-dimensional (2-D) features. The 2-D feature creation is a complicated process, whereby numerous parameters are computed and saved for subsequent use. Rotational velocity is calculated using the max inbound and outbound velocities in all shear segments (not necessarily from the same shear segment). Fig. 4 shows how 2-D mesocyclones are constructed from 1-D shear segments. Once the 2-D shear features are computed, the MDA also builds 1-D convergence segments (peak inbound and outbound velocities along a single azimuth) that are used to compute average convergence within a 2km buffer outside the mesocyclone base (Fig. 5). No divergence is calculated; only convergence velocity differences are calculated. Unique cores of rotation are extracted from large areas of rotation to define the 2-D features for a given radar tilt. Small features less than 1km (or less than 4 shear segments) are thrown away (Fig. 6). In addition, non-circular features (such as shear along linear gust fronts) are thrown away if the aspect ratio of $D_r/D_a > 2$ (Fig. 7).

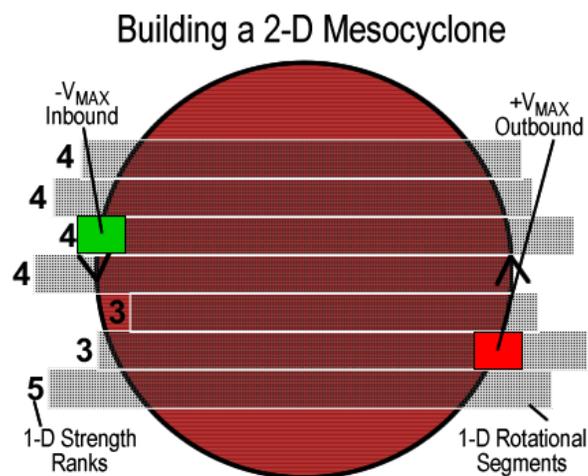


Figure 4. Shear segments combined into 2-D Features.

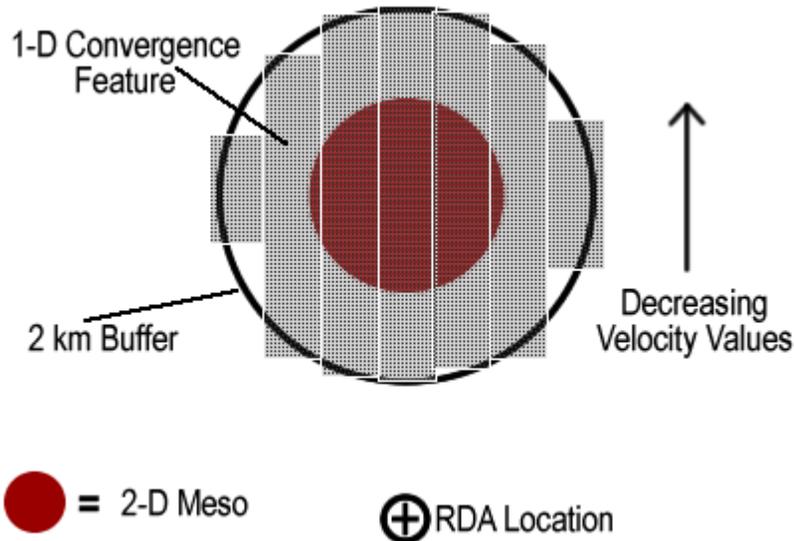


Figure 5. Convergence segments used to calculate convergence velocity differences.

2-D Circulation Sorting and Strength Rank

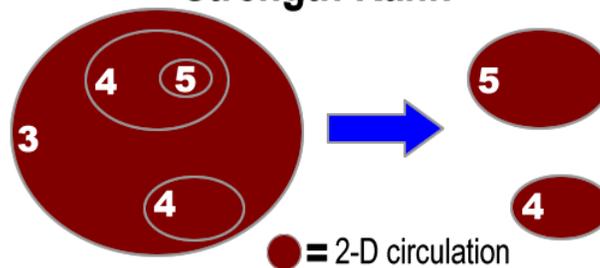


Figure 6. 2-D Features are sorted based on size and location relative to one another. On the left the bottom circulation with strength rank 4 is assumed to be greater than 1 km from the top circulations. On the right, these two circulations are preserved. The strength rank of 5 is preserved for the top feature since it is nearly collocated with the broader circulation.

Processing for Multiple Elevations

The 2-D features are then vertically correlated and initially classified as “circulations”. Each circulation is assigned an ID number, with numbers cycling from 0 to 999.

Strength Rank

One of the foundations of the MDA is the strength rank. Strength rank is a dimensionless number from 1 to 25 directly tied to the rotational strength of a 2-D MDA-identified circulation (see Fig. 8). The 3-D strength rank is a measure of the overall rotation through a certain depth of the storm (see Fig. 9). The 3-D feature depth, base, and strength are considered for the two different classes of circulations:

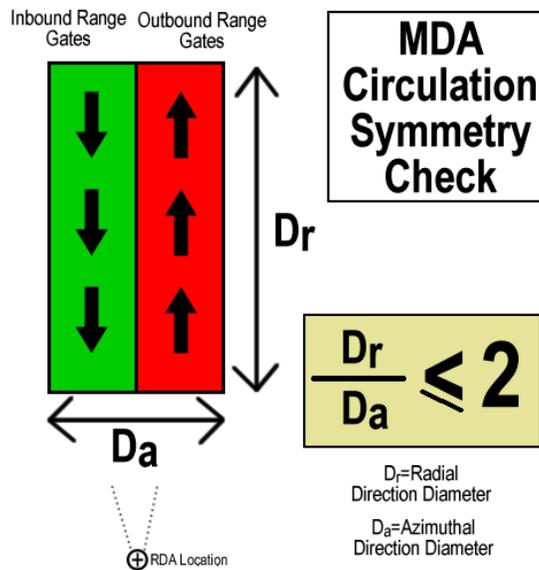


Figure 7. To ensure mesocyclones have a circular shape, a 2-D aspect ratio $D_r/D_a < 2$ is applied to each 2-D circulation. If this criterion is not met, the circulation is discarded from the algorithm.

Strength Rank	ΔV (kts)	V_r (kts)	Shear (m/s km)	Description
3	40	20	4.5	~Weak Rotation
5	60	30	6.0	~Minimal Mesocyclone
7	80	40	7.5	~Moderate Mesocyclone
9	100	50	9.0	~Strong Mesocyclone
↓	↓	↓	↓	
25	270	135	21.75	

Figure 8. Table showing the 2-D strength ranks given delta-V, V_r , and shear values.

2 Circulation Classes

- Traditional mesocyclone (default).
- Low core (L),

The default classification for any circulation that reaches a 3-D strength rank of 5 or greater is mesocyclone. When the strength rank of the vertical profile of 2-D features is 5 or greater through a depth of at least 3 km (~10 kft), and the base of the lowest 2-D feature is at an altitude of less than 5 km (~16 kft), it is classified as a mesocyclone. To account for mesocyclones identified only close to the

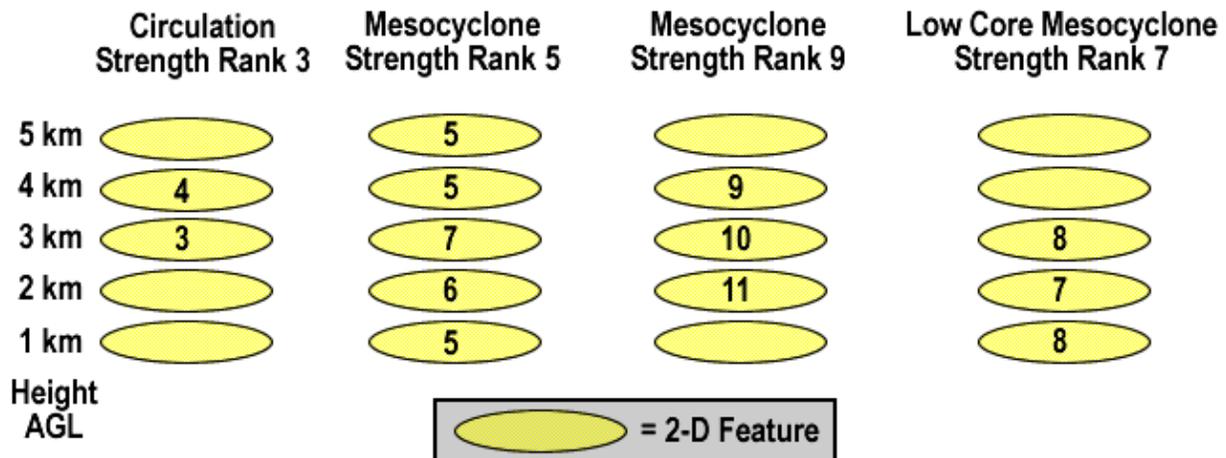


Figure 9. MDA defines a strength rank based on rotation intensity through a minimum depth. 4 examples are provided to demonstrate how the MDA assigns a rank to a 3-D feature. The first circulation on the left would receive a rank of 3 and not be considered a mesocyclone because the strength rank is not high enough through the required depth of 3 km. The three remaining examples on the right are assigned Strength Ranks of 5, 9, and 7 respectively. These 3-D strength ranks are assigned because the circulation strength rank met or exceeded this value continuously throughout a depth of 3 km for the strongest circulation in the storm. Note that the last circulation was identified using the “Low Core” classification guidelines.

surface or perhaps for low-topped supercells, a low core classification is applied to MDA logic. For a mesocyclone to be labeled “Low Core” three constraints are applied:

1. total depth of the 3-D feature is 3 km (~10 kft) ARL or less
2. base height of the 3-D feature is 3 km ARL or lower
3. depth of the 3-D circulation is at least 25% of the storm depth as determined by the SCIT algorithm.

Strength Ranks range from 1 as the weakest possible to 25 as the strongest. Any circulation with a Strength Rank of 5 or greater is classified as a mesocyclone. Typical strength rank values for well-defined mesocyclones are between 5 and 9, and values exceeding 13 are exceptionally rare. The following thresholds are approximate out to 54 nm (100 km), with thresholds reduced from 54 to 108 nm (100 to 200 km):

- Strength Rank 3 ~ 20 kt Vr - Weak Shear
- Strength Rank 5 ~ 30 kt Vr - Minimal Meso
- Strength Rank 7 ~ 40 kt Vr - Moderate Meso
- Strength Rank 9 ~ 50 kt Vr - Strong Meso

Final “Sanity” Check

In order to cut down on the number of clearly false detections, which might occur in areas of little or no significant meteorological echo, a final check is performed by the MDA. Any identified circulation that is

NOT within 20 km of a SCIT identified cell is discarded. This final check eliminates MDA detections in areas of weak signal, not near any SCIT identified storms, and thus should reduce the number of false detections.

Adaptable Parameters

In addition to the Minimum Reflectivity, there are two other MDA adaptable parameters that are editable; the minimum display filter rank and overlap display filter.

Minimum Display Filter Rank

The Minimum Display Filter Rank (Fig. 3) identifies which circulations are displayed on the end of volume scan MD product. The default setting is 5, which means that all circulations with a Strength Rank of 5 or greater would be displayed on the MD product. If this parameter was set to 5 and the strongest circulation detected had a Strength Rank of 4, no circulations would be displayed. However, the DMD product can display ALL identified circulations regardless of strength rank, even those with ranks below the Minimum Display Filter Rank.

Overlap Display Filter

This parameter addresses the possibility of two circulations being displayed on a graphical product in the same location, i.e. the circles overlap. If the "Overlap Display Filter" parameter is set to the default value of "Yes" (see Fig. 3), the 3D circulation that is detected over lower elevation angles is the one displayed.

Number of Detections Vs. Weaker Circulations

Tornadoes are sometimes produced from small, weak circulations. The default setting of 5 for the Minimum Display Filter Rank is based on MDA performance with large, deep supercells. For environments where mini-supercells are favored, setting the Minimum Display Filter Rank to 3 or 4 is a consideration. The smaller circulations will be displayed on the MD product. However, the total number of circulations displayed will increase significantly as the value of this parameter is lowered.

Tracking Features

MDA has a process that attempts to track 3D circulations from one volume scan to the next. At the end of a volume scan, all 3D features are assigned an extrapolated position for the subsequent volume scan based on previous positions. The locations projected from the previous volume scan are then used to try to match to 3D features detected from the current volume scan.

If There Is a Match

If a 3D feature is matched for more than one volume scan, the past positions and forecast positions will be displayed. This is very similar to the past and forecast positions for a storm centroid generated by the SCIT algorithm. Past and forecast tracks computed by MDA apply to the 3D feature. Circulations are

tracked for up to 10 previous volume scans and up to six forecast positions are computed in 5 minute intervals. The number of forecast positions will never exceed the number of past positions.

Once matched, 3D features will appear on both the MD and DMD products.

If There Isn't a Match

A 3D feature from a previous volume scan is retained until there is a match to the subsequent volume scan. However, the search to obtain a match does not persist for the entire volume scan. For a 3D feature detected from a previous volume scan, the search persists until the height of the radar beam is 3 km above the base of the feature. Once the radar beam reaches that height, the feature is removed.

Unmatched features will not be shown on the MD product. They may appear on some elevations of the DMD output while the search for a match is ongoing.

Enough of the algorithm! The next section will discuss more characteristics of the DMD product that is produced by this algorithm.

Digital Mesocyclone Characteristics

Cursor Readout

A nice feature of the DMD product is the ability to utilize cursor readout, which you cannot do with the MD product. As you move the cursor over the circulation with sampling turned on you will see several of the attributes of that feature. The cursor readout can include various attributes including radar id, circulation id, closest storm ID, strength rank, speed/direction of movement, base, depth, etc. (see Fig. 10).

Dynamic Progressive Disclosure

Display of DMD in the main pane of CAVE has a very unique zooming feature, termed dynamic progressive disclosure. That is a fancy term that essentially means the more you zoom in, the greater the number of circulations you will see. Zoomed out as far as possible with a DMD graphic loaded in the main pane will display only the strongest circulations. As you zoom in, you will notice that weaker circulations will display in addition to the strongest circulations already visible. Continued zooming results in the appearance of even more weaker circulations, up to circulations with a strength rank of 1, if applicable.

Volume Browser Options

The Volume Browser is another way to display DMD data, although this method takes a lot of practice and can take an appreciable amount of time to set up. The Volume Browser can display the following attributes of up to 10 identified mesocyclones simultaneously for comparison:

- Feature Strength (i.e., Strength Rank)

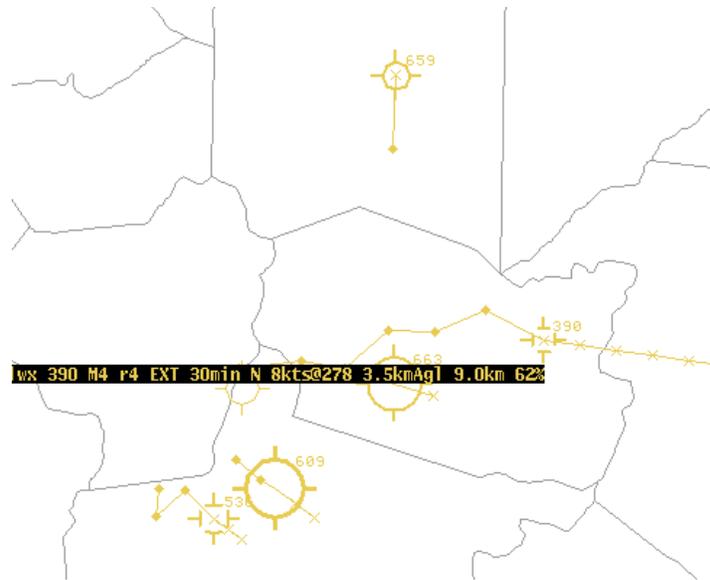


Figure 10. This DMD example displays the cursor readout as the cursor was over circulation 390 at the far right of the graphic. There are two extrapolated features in this particular DMD product.

- Feature Diameter
- Shear Magnitude
- Gate-to-Gate Shear

The Volume browser allows for time-height displays of those DMD attributes. Loading the data is not straightforward, so it's a good idea to practice the method on the WES machine rather than during any live severe event. Loading DMD attributes using the volume browser must be done based on one or more meso ID number(s), thus the first step is to choose a mesocyclone ID of interest.

- Load the Volume Browser and select "Time height" from the top left drop down menu.
- Select "DMD" under the "Sources" heading from the "Other" menu.
- In Fields, select from the "Other" menu "Feature Strength", "Feature Diameter", "Shear Mag", and "Gate2Gate Shr"
- Click the "Tools" Menu and select "Choose by ID". Enter next to the letters A through J any mesocyclone IDs you want to examine. Which meso ID you associate with which letter is irrelevant. If you want the Volume Browser to remember these meso IDs, click the lock button next to the label Points in the top left. You can close the "Choose by ID" window before moving onto the next step.
- Once you have entered your meso ID(s), go back to the volume browser window and select the "Tsect" letter from the "Points" drop down menu under the "Planes" heading. You can select multiple "Tsects", and these will correspond to the Meso ID(s) you entered in the "Choose by ID" window.
- Click Load and your CAVE window should load the DMD data.

An example of how your volume browser should look in order to load time-height plots of DMD is given in Fig. 11. In the graphic, clicking the “Load” button would result in a timeheight plot of all 4 attributes for mesocyclone IDs 904 since it was entered into the “Choose by ID” window as “A”, and in the Volume Browser window Tsect A was selected.

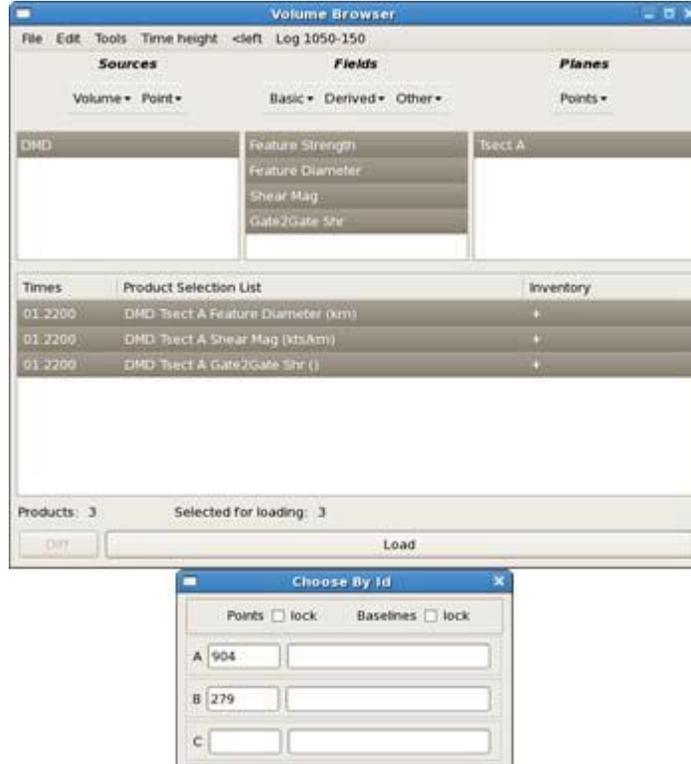


Figure 11. The Volume Browser and Choose by ID windows set up to display DMD time-height plots of the mesocyclone IDs 904 and 279. All that is left to do is click the “Load” button from the Volume Browser window.