MESOCYCLONE DETECTION

ALGORITHM DESCRIPTION

NX-DR-03-002/34

1.0 PROLOGUE

1.1 FUNCTIONAL DESCRIPTION

The MESOCYCLONE DETECTION algorithm utilizes pattern recognition techniques to detect mesocyclones. This technique defines a process used for searching through Doppler velocity data for symmetric regions of large azimuthal shear. The MESOCYCLONE DETECTION algorithm is based on the extraction of significant attributes which characterize mesocyclones.

The MESOCYCLONE DETECTION algorithm locates mesocyclones where a mesocyclone is defined as a three-dimensional region in a storm which rotates (usually cyclonically), and is closely correlated with severe weather. This algorithm uses the systematic procedure described herein. The first step is to search for a consistent increase of Doppler velocity in the azimuthal direction at a constant range (for clockwise antenna rotation). A consistent decrease of Doppler velocity is required for counterclockwise antenna rotation. (Note: The current AEL is written for clockwise antenna rotation only otherwise a "pattern vector" would be formed when a run of increasing or decreasing Doppler velocity ends.) A "pattern vector" contains seven components: the slant range, the azimuth angles at both ends of the run, the Doppler velocities that correspond to those azimuth angles at the slant range, and the SHEAR (Tangential) and MOMENTUM (Angular). A pattern vector which does not have the magnitudes of angular momentum and azimuthal shear typical of mesocyclones is discarded. The remaining pattern vectors are consolidated to form "features." A "feature" is a set of pattern vectors in a close proximity. If a feature is too small it is discarded. If a feature is sufficiently large and not symmetrical, it is classified as a shear region. Sufficiently large, symmetric shear regions are characteristic of mesocyclones. If these regions are in close vertical proximity, a mesocyclone is identified. Shear regions in close vertical proximity identify 3-D shear regions. The remaining features characterize uncorrelated shear.

1.2 SOURCE

The MESOCYCLONE DETECTION algorithm was developed at the National Severe Storms Laboratory, Norman, Oklahoma, by Larry Hennington. Significant attributes of mesocyclones have been compiled by Hennington and Burgess (1981), referenced below.

REFERENCES

Staff of JDOP, 1979: Final Report on Joint Doppler Operational Project (JDOP) 1976-1978. NOAA Tech. Memo. NSSL-86, March 1979, 84 pp.

Hennington, L.D., and D.W. Burgess, 1981: Automated recognition of mesocyclones from single Doppler radar data. Preprints 20th Conf. Radar Meteor. Boston, Amer. Meteor. Soc., 704-706.

Zrnic', Dusan S., D.W. Burgess and Y. Gal-Chen, 1984: Automated Detection of Mesocyclonic Shear Test Results. NEXRAD JSPO publication, January 1984, 51 pp.

1.3 PROCESSING ENVIRONMENT

Data input to the MESOCYCLONE DETECTION algorithm must be preprocessed for velocity unfolding and elimination of ground clutter. At any time, Doppler velocities for two consecutive radials of data are stored for processing.

2.0 INPUTS

2.1 IDENTIFICATION

AZIMUTH	= Azimuthal position, in radians.
ELEVATION	= Elevation angle, in radians.
RADIUS (Earth)	= The radius of the Earth (6371), in kilometers.
RANGE (Slant)	= The slant range to the center of a SAMPLE VOLUME, in kilometers.
SAMPLE VOLUME	= A data sample volume whose dimensions are 1 degree in azimuth, 0.25 km in range, and 1 degree in depth (perpendicular to the radar beam).
THRESHOLD (Feature Height)	= A value that represents the maximum height of possible mesocyclone FEATUREs (8), in kilometers.
THRESHOLD (High Momentum)	= A value which represents the minimum magnitude of angular momentum expected in a mesocyclone in the presence of low shear (540.0), in km^2/hr.
THRESHOLD (Radial Distance)	= A value which represents the maximum distance in the radial direction between PATTERN VECTORs within the same FEATURE (0.75), in kilometers.
THRESHOLD (Meso-cyclone-High Shear)	= A value which represents the minimum magnitude of shear expected in a mesocyclone in the presence of low angular momentum (14.4), in 1/hr.
THRESHOLD (Low Momentum)	= A value which represents the minimum magnitude of angular momentum in a mesocyclone (180.0), in km^2/hr.
THRESHOLD (Meso-cyclone-Low Shear)	= A value which represents the minimum magnitude of shear expected in a mesocyclone (7.2), in 1/hr.
THRESHOLD (Meso-cyclone Azimuth)	= A value that represents the maximum tangential separation of PATTERN VECTORs to be considered part of the same FEATURE (0.034), in radians.
THRESHOLD (Pattern Vector)	= A value which represents the minimum number of PATTERN VECTORs required to build a FEATURE (10.0).
THRESHOLD (Far Maximum Ratio)	= A maximum value which represents the upper bound of a range of values

related to the ratio of radial and azimuthal diameters of a FEATURE at ranges further than THRESHOLD (Range) (4.0).

THRESHOLD (Far Minimum Ratio)	= A minimum value which represents the lower bound of a range of values related to the ratio of radial and azimuthal diameters of a FEATURE at ranges further than THRESHOLD (Range) (1.6).
THRESHOLD (Maximum Ratio)	= A maximum value which represents the upper bound of a range of values related to the ratio of radial and azimuthal diameters of a FEATURE at ranges closer than THRESHOLD (Range) (2.0).
THRESHOLD (Minimum Ratio)	= A minimum value which represents the lower bound of a range of values related to the ratio of radial and azimuthal diameters of a FEATURE at ranges closer than THRESHOLD (Range) (0.5).
THRESHOLD (Range)	= A variable that represents the range at which long range symmetry criteria take effect, in kilometers (140.0 km).
VELOCITY (Doppler)	= Doppler velocities in a SAMPLE VOLUME, in km/hr.

2.2 ACQUISITION

AZIMUTH and ELEVATION are obtained by direct measurement of the radar antenna pointing direction.

VELOCITY (Doppler) is acquired by direct radar measurements.

RADIUS (Earth) is a physical constant.

SAMPLE VOLUME is a direct result of the radar parameters chosen at the time of observation. The sample volumes will still be variable depending on range of observation because the radar beam is diverging.

RANGE (Slant) is acquired by direct radar measurements.

All the thresholds identified in Section 2.1 are site-adaptable parameters used by the algorithm. They are entered by the operator/user as input parameters or are embedded as tables in the algorithm implementation. They are being determined by the research community through further experimentation.

3.0 PROCEDURE

3.1 ALGORITHM

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BEGIN ALGORITHM (MESOCYCLONE DETECTION)

1.0  DO FOR ALL (ELEVATIONS)
     1.1  DO FOR ALL (SAMPLE VOLUMEs of the first two
          adjacent
          radials.)
          1.1.1  COMPUTE (TENDENCY)
          END DO

     1.2  DO FOR ALL (remaining AZIMUTHs)
          1.2.1  DO FOR ALL (SAMPLE VOLUMEs)
                    COMPUTE (TENDENCY)
                    IF (TENDENCY at the previous AZIMUTH is
                       less than or equal to zero AND TENDENCY
                       at the current AZIMUTH is greater than
                       zero)
                    THEN (the VELOCITY (Doppler) at the previous
                         AZIMUTH becomes beginning VELOCITY
                         (Doppler))
                    END IF
                    IF (TENDENCY at the previous AZIMUTH and
                       this RANGE (Slant) is greater than zero
                       AND TENDENCY at the current AZIMUTH at
                       this RANGE (Slant) is less than zero)
                    THEN (the VELOCITY (Doppler) at the previous
                         AZIMUTH becomes ending VELOCITY
                         (Doppler))
                       COMPUTE (MOMENTUM (Angular))
                       COMPUTE (SHEAR (Tangential))
                       IF (MOMENTUM (Angular) is greater
                           than
                          the THRESHOLD (Low Momentum)
                          AND
                          SHEAR (Tangential) is greater
                          than or
                          equal to the THRESHOLD
                          (Mesocyclone-
                          High Shear)) or
                          (MOMENTUM (Angular)
                          is greater
                          than the THRESHOLD (High

            Momentum) AND SHEAR (Tangential)
                          is
                          greater than the THRESHOLD
                          (Mesocyclone-Low Shear))
                          THEN
                             WRITE (PATTERN VECTOR)
                       END IF
                    END IF
                 END DO
           END DO
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1.3  DO FOR ALL (PATTERN VECTORs)
     1.3.1  IF (PATTERN VECTOR centers are within
               THRESHOLD (Mesocyclone Azimuth) AND are
               within THRESHOLD (Radial Distance) of each
               other)
               THEN (Include PATTERN VECTORs as a part of
                    the same FEATURE)
                    (Add PATTERN VECTOR to PATTERN VECTOR
                    List)
            END IF
     END DO

1.4  DO FOR ALL (FEATUREs)
     1.4.1  IF (The number of PATTERN VECTORs in a FEATURE
               is greater than or equal to THRESHOLD
               (Pattern Vector))
            THEN
                  COMPUTE (FEATURE CENTER POSITION)
                  COMPUTE (DIAMETER (Azimuthal))
                  COMPUTE (DIAMETER (Momentum Azimuthal))
                  COMPUTE (RATIO (Momentum Diameter))
                  COMPUTE (DIAMETER (Radial))
                  COMPUTE (RATIO (Diameter))
                  IF (RATIO (Momentum Diameter) is greater
                     than THRESHOLD (Minimum Ratio) AND
                     less than THRESHOLD (Maximum Ratio))
                     THEN (FEATURE characterizes a
                          mesocyclone)
                     ELSE IF (RANGE (Slant) is greater
                          than or equal to THRESHOLD
                          (Range)
                             AND RATIO (Diameter) is
                          greater than THRESHOLD (Far
                          Minimum Ratio) AND less than
                          THRESHOLD (Far Maximum Ratio))
                          THEN (FEATURE characterizes a
                               mesocyclone)
                          END IF
                  END IF
                  COMPUTE (average SHEAR (Tangential))
                  COMPUTE (HEIGHT (Feature Center))
                  COMPUTE (maximum SHEAR (Tangential))
                  COMPUTE (2-D FEATURE TYPE)
                  COMPUTE (average MOMENTUM (Angular))
                  COMPUTE (FEATURE EXTREMA)
            END IF
      END DO
 END DO
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2.0 DO FOR ALL (ELEVATIONs) FROM (Second) TO (Highest)
2.1 DO FOR ALL (FEATUREs at the current elevation angle whose HEIGHT (Feature Center) is less than or equal to THRESHOLD (Feature Height))
2.1.1 DO FOR ALL (FEATUREs at the first previous elevation angle whose HEIGHT (Feature Center) is less than or equal to THRESHOLD (Feature Height))
UNTIL (a DIFFERENCE (Between Feature Centers) is less than or equal to MAXIMUM FEATURE DISTANCE)
COMPUTE (DIFFERENCE (Between Feature Centers))
COMPUTE (MAXIMUM FEATURE DISTANCE)
IF (DIFFERENCE (Between Feature Centers) is less than or equal to MAXIMUM FEATURE DISTANCE)
THEN (Identify the FEATUREs as belonging to the same vortex)
END IF
END DO

2.1.2 IF (NO DIFFERENCE (Between Feature Centers) of the first previous elevation was less than or equal to MAXIMUM FEATURE DISTANCE and this is not the second elevation angle)
THEN
2.1.2.1 DO FOR ALL (FEATUREs at the next previous elevation angle whose HEIGHT (Feature Center) is less than or equal to THRESHOLD (Feature Height))
UNTIL (a DIFFERENCE (Between Feature Centers) is less than or equal to MAXIMUM FEATURE DISTANCE)
COMPUTE (DIFFERENCE (Between Feature Centers))
COMPUTE (MAXIMUM FEATURE DISTANCE)
IF (DIFFERENCE (Between Feature Centers) is less than or equal to MAXIMUM FEATURE DISTANCE)
THEN (Identify the FEATUREs as

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                belonging to the same vortex)
                             END IF
                             END DO
                     END IF
                END DO
           END DO

      3.0  DO FOR ALL (ELEVATIONs)
           3.1  DO FOR ALL (FEATUREs at the current elevation angle
                           whose HEIGHT (Feature Center) is less than
                           or equal to THRESHOLD (Feature Height))
                IF (FEATURE has not been identified as belonging to a
                   vortex)
                   THEN (identify FEATURE as belonging to a vortex)
                END IF
                END DO
           END DO

       4.0  DO FOR ALL (identified vortices)
              IF (Vortex has more than one FEATURE)
                     THEN IF (Two or more FEATUREs characterize a
                             mesocyclone)
                             THEN (VORTEX TYPE is mesocyclone)
                             ELSE (VORTEX TYPE is 3-D shear)
                          END IF
                     ELSE  (VORTEX TYPE is uncorrelated shear)
              END IF
           WRITE (VORTEX TYPE)
           WRITE (Number of FEATUREs)
           Identify FEATURE with maximum average SHEAR (Tangential)
           IF (VORTEX TYPE is a mesocyclone)
              THEN
              COMPUTE (POSITION (Mesocyclone))
              WRITE (POSITION (Mesocyclone))
              ELSE
              WRITE (FEATURE CENTER POSITION)
           END IF
           WRITE (DIAMETER (Azimuthal))
           WRITE (maximum average SHEAR (Tangential))
           WRITE (DIAMETER (Radial))
           WRITE (average MOMENTUM (Angular))
           END DO

       5.0  DO FOR ALL (mesocyclone VORTEX TYPEs)
           Assign MESOCYCLONE ID
           5.1  WRITE (MESOCYCLONE ID)
           5.2  DO FOR ALL (FEATUREs)
                5.2.1  Identify the FEATURE with the highest maximum
                       SHEAR (Tangential)
                5.2.2  COMPUTE (POSITION MAXIMUM SHEAR (Tangential))
                5.2.3  Identify the FEATURE with the lowest HEIGHT
                       (Feature Center); i.e., HEIGHT (Feature
                       Center) is the mesocyclone base.
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            5.2.4  Identify the FEATURE with the highest HEIGHT
                   (Feature Center); i.e., HEIGHT (Feature
                   Center) is the mesocyclone top
            5.2.5  COMPUTE (average SPEED (Rotational))
            5.2.6  COMPUTE (FEATURE EXTREMA)
            END DO
      5.3   WRITE (POSITION MAXIMUM SHEAR (Tangential))
      5.4   WRITE (highest value of maximum SHEAR (Tangential))
      5.5   WRITE (lowest HEIGHT (Feature Center))
      5.6   WRITE (highest HEIGHT (Feature Center))
      5.7   WRITE (average SPEED (Rotational))
            WRITE (average SHEAR (Tangential))
       END DO

END ALGORITHM (MESOCYCLONE DETECTION)
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3.2 COMPUTATION

3.2.1 NOTATION

TCY = TENDENCY, the trend in Doppler velocities (increasing (+), decreasing (-)) in the azimuthal direction.

VD = VELOCITY (Doppler), the Doppler velocities in a SAMPLE VOLUME, in km/hr. Precise to .36 km/hr.

j = INDEX (Azimuth), the index for AZIMUTH.

AZIMIN = AZIMUTH MINIMUM, the smallest azimuth found within a FEATURE in radians. Precise to 1.75×10^{-3} radians.

AZIMAX = AZIMUTH MAXIMUM, the largest azimuth found within a FEATURE, in radians. Precise to 1.75×10^{-3} radians.

PI# = A mathematical constant (3.1416), unitless.

MFD = MAXIMUM FEATURE DISTANCE, a value representing the horizontal distance (formed by projecting one FEATURE diameter into the other's plane) limiting vertical correlation of two FEATUREs at consecutive elevation angles, in kilometers. Precise to 10^{-4} km.

PVE = PATTERN VECTOR, a vector which is formed when a run of increasing Doppler velocity ends. A PATTERN VECTOR contains seven components: the slant range, the azimuth angles at both ends of the run, the Doppler velocities that correspond to those azimuth angles at the slant range, and the SHEAR (Tangential) and MOMENTUM (Angular).

FEX = FEATURE EXTREMA, a set of four parameters (beginning RANGE (Slant-Feature), ending RANGE (Slant-Feature), beginning feature AZIMUTH and ending feature AZIMUTH). These are the maximum and minimum AZIMUTHs of its PATTERN VECTOR LIST, and the maximum and minimum ranges from the PATTERN VECTOR LIST.

FEA = FEATURE, a set of PATTERN VECTORs which have passed spatial proximity.

PVL = PATTERN VECTOR LIST, the set of all PATTERN VECTORs in a FEATURE.

TDFT = 2-D FEATURE TYPE, assigns an unique value to indicate that a 2-D FEATURE characterizes a MESOCYCLONE and another if it does not.

M = MOMENTUM (Angular), angular momentum, in km^2/hr. Precise to 3.6 x 10^{-5} km/hr.

Mavg = average MOMENTUM (Angular), average MOMENTUM (Angular) determined from the PATTERN VECTORs comprising a FEATURE, in km^2/hr. Precise to 3.6 x 10^{-5} km/hr.

SRT = SHEAR (Tangential), the change in Doppler velocity for a PATTERN VECTOR divided by its length, in 1/hr. Precise to 3600 1/hr.

SRTmax = maximum SHEAR (Tangential), the maximum SHEAR (Tangential) of all the PATTERN VECTORs in a FEATURE, 1/hr. Precise to 3600 1/hr.

SRTavg = average SHEAR (Tangential), the average SHEAR (Tangential) determined from the PATTERN VECTORs comprising of a FEATURE, in 1/hr. Precise to 3600 1/hr.

SRTmaxavg = maximum average SHEAR (Tangential), the largest of all the average SHEAR (Tangentials), in 1/hr. Precise to 3600 1/hr.

VDend = ending VELOCITY (Doppler), the Doppler velocity at the end of a PATTERN VECTOR, in km/hr. Precise to .36 km/hr.

VDbeg = beginning VELOCITY (Doppler), the Doppler velocity at the beginning of a PATTERN VECTOR, in km/hr. Precise to .36 km/hr.

RS = RANGE (Slant), the slant range to the center of a SAMPLE VOLUME, in kilometers. Precise to 10^{-4} km.

AZendpv = ending pattern vector AZIMUTH, ending azimuthal position of a PATTERN VECTOR, in radians. Precise to 1.75 x 10^{-3} radians.

AZbegpv = beginning pattern vector AZIMUTH, ending azimuthal position of a PATTERN VECTOR, in radians. Precise to 1.75 x 10^{-3} radians.

FCP = FEATURE CENTER POSITION, the FEATURE center position in range, elevation and azimuth.

i = INDEX (Elevation), the index for ELEVATION.

DAA = DIAMETER (Azimuthal), azimuthal diameter of a FEATURE, in kilometers. Precise to 10^{-4} km.

MESID = MESOCYCLONE ID, an ID assigned to a mesocyclone when the MESOCYCLONE Algorithm identifies a mesocyclone.

HFClow = lowest HEIGHT (Feature Center), the lowest ELEVATION of a FEATURE center (mesocyclone base), in kilometers. Precise to 10^{-4} kilometers.

HFChigh = highest HEIGHT (Feature Center), the highest ELEVATION of a FEATURE center (mesocyclone top), in kilometers. Precise to 10^{-4} kilometers.

DMA = DIAMETER (Momentum Azimuthal), the momentum weighted azimuthal diameter of a FEATURE, in kilometers. Precise to 10^{-4} km.

DAR = DIAMETER (Radial), radial diameter of a FEATURE, in kilometers. Precise to 10^{-4} km.

ROD = RATIO (Diameter), the ratio of the azimuthal diameter to the radial diameter of a FEATURE.

RMD = RATIO (Momentum Diameter), the ratio of the momentum weighted azimuthal diameter to the radial diameter of a FEATURE.

HFC = HEIGHT (Feature Center), the ELEVATION of a FEATURE center, in kilometers. Precise to 10^{-4} km.

PHI# = ELEVATION, elevation angle, in radians. Precise to 1.75×10^{-3} radians.

RE = RADIUS (Earth), radius of the Earth (6371), in kilometers. Precise to 10^{-4} km.

RSFEbeg = Beginning RANGE (Slant-Feature), the beginning slant range of a FEATURE, in kilometers. Precise to 10^{-4} km.

RSPV = RANGE (Slant Pattern Vector), the RANGE (Slant) of a
PATTERN VECTOR, in kilometers. Precise to 10^{-4} km.

RSFEcen = Center RANGE (Slant-Feature), the slant range of a FEATURE center, in kilometers. Precise to 10^{-4} km.

RSFEend = Ending RANGE (Slant-Feature), the ending slant range of a FEATURE, in kilometers. Precise to 10^{-4} km.

DIF = DIFFERENCE (Between Feature Centers), the horizontal distance between FEATURE CENTER POSITIONs (at adjacent elevation angles), in kilometers. Precise to 10^{-4} km.

VTY = VORTEX TYPE, designates whether vortices composed of one or more FEATUREs represent a mesocyclone, 3-D shear, or uncorrelated shear, unitless.

YFCP = Y-POSITION (Feature Center), Y-position of the FEATURE CENTER after conversion from polar to Cartesian coordinates, in kilometers. Precise to 10^{-4} kilometers.

XFCP = X-POSITION (Feature Center), X-position of the FEATURE CENTER after conversion from polar to Cartesian coordinates, in kilometers. Precise to 10^{-4} kilometers.

PM = POSITION (Mesocyclone), the mesocyclone position using Cartesian coordinates, in kilometers. Precise to 10^{-4} kilometers.

SPRavg = average SPEED (Rotational), half the momentum weighted diameter of a FEATURE times the average SHEAR (Tangential), in km/hr. Precise to .36 km/hr.

AZcenfe = AZIMUTH (Center Feature), the center azimuth of a 2-
dimensional FEATURE, momentum weighted, in radians.
Precise to 1.75 x 10^{-3} radians.

PMST = POSITION MAXIMUM SHEAR (Tangential), the RANGE (Slant), beginning pattern vector AZIMUTH and ending pattern vector AZIMUTH where the maximum SHEAR (Tangential) is found in a feature classified as a mesocyclone vortex, in kilometers, radians and radians. Precise to 10^{-4} kilometers, 1.75 x 10^{-3} radians.

NOTE: Precision is equivalent to the units unless otherwise stated.

3.2.2 SYMBOLIC FORMULAS

COMPUTE (TENDENCY)

$$TCY = Sign\ of\ VD_j - VD_{j-1},\ or\ 0$$

COMPUTE (MOMENTUM (Angular))

$$M = ABS\ [(VDend - VDbeg)\ (RS)\ (AZend - AZbeg)]$$

COMPUTE (SHEAR (Tangential))

$$SRT = ABS\ [(VDend - VDbeg)\ /\ (RS)\ (AZendpv - AZbegpv)]$$

COMPUTE (average (MOMENTUM (Angular))

$$Mavg = \sum_n ABS \frac{[\ (VDend_n - VDbeg_n)\ (RSPV)\ (AZend_n - AZbeg_n)\ ]}{n}$$

COMPUTE (FEATURE CENTER POSITION)

FCP_i (AZcenfe,RSFEcen)

where,

$$AZcenfe = \sum_n [\ [AZbegpv_n + (DAZ_n/2)\ ]\ (VM_n)\ ]\ /\ \sum_n VM_n$$

where, $DAZ_n = ABS\ (AZbegpv_n - AZendpv_n)$

and $VM_n = ABS\ [\ (DAZ_n)\ (VDendpv_n - VDbegpv_n)\ ]$

NOTE: Corrections for crossing 360° or counterclockwise rotation are not accounted for here.

$$RSFEcen = [\ \sum_n \{ABS\ [VDend_n - VDbeg_n)\ (AZendpv_n - AZbegpv_n)\ (RSPV_n\ ]\ \}\ ]\ /$$
$$[\ \sum_n \{ABS\ [VDend_n - VDbeg_n)\ (AZendpv_n - AZbegpv_n)\ ]\ \}\ ]$$

and n is the PATTERN VECTOR number.

COMPUTE (DIAMETER (Azimuthal))

$$DAA = \left[\sum_n \{ [(AZendpv_n - AZbegpv_n)^2] \} (RSFEcen) \right] / \left[\sum_n \{ ABS\ (AZendpv_n - AZbegpv_n) \} (\pi/4) \right]$$

and n is the PATTERN VECTOR number.

COMPUTE (DIAMETER (Momentum Azimuthal))

$$DMA = (3\pi/8) \left[\sum_n \{ ABS\ [(AZendpv_n - AZbegpv_n)^2 (VDend_n - VDbeg_n)] \} (RSFEcen) \right] / \left[\sum_n \{ ABS\ [(VDend_n - VDbeg_n) (AZendpv_n - AZbegpv_n)] \} \right]$$

where n is the PATTERN VECTOR number.

COMPUTE (DIAMETER (Radial))

DAR = RSFEend - RSFEbeg

COMPUTE (RATIO (Diameter))

ROD = DAA/DAR

COMPUTE (RATIO (Momentum Diameter))

RMD = DMA/DAR

COMPUTE (HEIGHT (Feature Center))

$$HFC = \{ RSFEcen^2 + 2\ [(4/3)\ (RE)\ (RSFEcen)\ (\sin\ (\phi))] \} / \{ 2\ (4/3)\ RE \}$$

COMPUTE (maximum SHEAR (Tangential))

SRTmax = SRT if SRT $\geq$ SRTmax

where;

$$SRT = ABS\ [(VDend - VDbeg) / [(RS)\ (AZendpv - AZbegpv)]]$$

COMPUTE (average SHEAR (Tangential))

$$SRTavg = \frac{\sum_n ABS\ [(VDend_n - VDbeg_n)\ (RSPV_n)\ (AZendpv_n - AZbegpv_n)]}{n}$$

where n is the PATTERN VECTOR number.

COMPUTE (DIFFERENCE (Between Feature Centers))

DIF = $\{[XFCP_i - XFCP_{i-1}]^2 + [YFCP_i - YFCP_{i-1}]^2\}^{1/2}$

where,

$XFCP = RSFEcen[\sin(AZcenfe)]\ [\cos(\phi)]$

$YFCP = RSFEcen[\cos(AZcenfe)\ ]\ [\cos(\phi)]$

COMPUTE (MAXIMUM FEATURE DISTANCE)

MFD = $\{[\ (DAA_i + DAR_i)\ /2\ ] + [\ (DAA_{i-1} + DAR_{i-1})\ /2\ ]\}/2$

where i is the current elevation angle of the vertical correlation.

COMPUTE POSITION (Mesocyclone)

The X-POSITION (Feature Center) and Y-POSITION (Feature Center) of the FEATURE with the maximum average SHEAR (Tangential).

COMPUTE (POSITION MAXIMUM SHEAR (Tangential))

This includes the RANGE (Slant), beginning pattern vector AZIMUTH and ending pattern vector AZIMUTH of the pattern vector containing the maximum SHEAR (Tangential).

COMPUTE (average SPEED (Rotational))

SPRavg = SRTavg (DMA/2)

COMPUTE (2-D Feature Type)

Assign an unique value to indicate that a 2-D FEATURE characterizes a mesocyclone and another if it does not.

COMPUTE (FEATURE EXTREMA)

A set of four parameters. Determine the maximum and minimum AZIMUTHs in the PATTERN VECTOR LIST, and the maximum and minimum ranges in the PATTERN VECTOR LIST.

Note: These may belong to separate PATTERN VECTORs.

4.0 OUTPUTS

4.1 IDENTIFICATION

For each vortex found by this algorithm, the following are outputted:

- VORTEX TYPE
- number of FEATUREs in vortex

For the FEATURE with the maximum average SHEAR (Tangential), the following are outputted:

- FEATURE CENTER POSITION
- HEIGHT (Feature Center)

- DIAMETER (Azimuthal)
- DIAMETER (Radial)

- maximum average SHEAR (Tangential)
- maximum SHEAR (Tangential)
- average MOMENTUM (Angular)

For each vortex classified as a MESOCYCLONE ID, these additional values are outputted:

- highest HEIGHT (Feature Center)
- lowest HEIGHT (Feature Center)
- POSITION (Mesocyclone)
- average SPEED (Rotational)
- FEATURE EXTREMA for each FEATURE in MESOCYCLONE ID
- average SHEAR (Tangential)
- highest value of maximum SHEAR (Tangential)

4.2 DISTRIBUTION

Output from the MESOCYCLONE DETECTION algorithm can be used as input to a mesocyclone tracking algorithm and a mesocyclone forecast algorithm. The output can also be used for severe weather warning procedures. FEATURE EXTREMA, FEATURE and MESOCYCLONE ID are input to the TVS (026) algorithm.

5.0 INFERENCES

5.1 LIMITATIONS

The MESOCYCLONE DETECTION algorithm does not consider meso-anticyclones. Before a FEATURE can be classified as a mesocyclone, time continuity must be established. The successful detection of mesocyclones by the MESOCYCLONE DETECTION algorithm depends upon the selection of optimum high and low shear thresholds and high and low momentum thresholds, and upon the distance threshold for vertical correlation. Also, bad data can artificially end a pattern vector.

5.2 FUTURE DEVELOPMENTS

The MESOCYCLONE DETECTION algorithm remains under development. Optimum high and low momentum thresholds, high and low shear thresholds, as well as more refined range dependent symmetry criteria, will be determined. The results of algorithm testing may affect the values assigned to other constants.