STORM CELL SEGMENTS

ALGORITHM DESCRIPTION

NX-DR-Ø3-Ø36/Ø1

1.0 PROLOGUE

1.1 FUNCTIONAL DESCRIPTION

This algorithm defines a radial processing technique which identifies radial sequences of reflectivity, or segments, as part of the processing to identify storm cells. These segments are runs of contiguous sample volumes with reflectivity values greater than or equal to a specified threshold and have a combined length greater than a specified segment length threshold. Also, a segment may contain a specified number of contiguous sample volumes which are within a specified dropout reflectivity value below the reflectivity threshold.

The algorithm has multiple reflectivity thresholds (and a minimum segment length threshold for each reflectivity threshold). For each elevation scan the algorithm searches for segments using each of the reflectivity thresholds as a minimum value.

For each segment, the following attributes are calculated and saved: maximum reflectivity (using a three (adaptable) gate average), mass weighted length, and mass weighted length squared. In addition to those calculated attributes, the following attributes are saved for each segment: azimuth, reflectivity threshold, beginning range, and ending range. These attributes are used as inputs by the STORM CELL CENTROIDS [Ø37] algorithm where radially adjacent segments are combined into storm components.

1.2 SOURCE

This algorithm has been implemented as part of the Storm Cell Identification and Tracking (SCIT) algorithm by the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma (Johnson, 1994). The other parts of the SCIT algorithm are documented in the STORM CELL CENTROIDS [Ø37], the STORM CELL TRACKING [Ø38], and STORM POSITION FORECAST [ØØ8] (Version 26) algorithm descriptions.

REFERENCES

Johnson, J. T., 1994: Enhanced WSR-88D Storm Cell Identification and Tracking Algorithm - Final Documentation Report, NSSL, Norman, OK.

NEXRAD Algorithm Report, 1985: STORM SEGMENTS ALGORITHM DESCRIPTION [Ø22/23], The NEXRAD Joint Systems Program Office (JSPO).

Witt, A., 1994: The NSSL Hail Detection Algorithm - Initial Documentation Report, NSSL, Norman, OK.

1.3 PROCESSING ENVIRONMENT

This algorithm was developed for use on a Weather Surveillance Radar - 1988 Doppler (WSR-88D). For input, the algorithm requires reflectivity data obtained by direct measurement from a weather radar. The reflectivity data must be provided in sample volumes of constant length and approximately one degree in azimuth and depth (perpendicular to the beam) on a radial basis. The radials are collected in a scan of constant elevation angle (or elevation scans). The algorithm requires no more than 360 degrees of radial data per elevation scan. Also, preprocessing to eliminate bad data (e.g. non-meteorological targets), although not a necessity, would be a plus.

The algorithm's statistical performance was evaluated while running as a sub-algorithm of the SCIT algorithm. The SCIT algorithm identifies individual cells within a storm, instead of the entire storm. The SCIT algorithm was developed and tested on NSSL's Radar Analysis and Display Software (RADS) on a 32 bit UNIX based SUN Workstation which ingests live (wideband) or archived (Level II) radial data from a WSR-88D.

2.0 INPUTS

2.1 IDENTIFICATION

AZIMUTH	=	The azimuthal position of a radial or CELL SEGMENT, in degrees.
ELEVATION	=	The angle of the elevation scan, in degrees.
MASS MULTIPLICATIVE FACTOR	=	A multiplicative factor used in computing the PRECIPITATION INTENSITY for the MASS calculation (486), in $(mm^6/m^3)(hr/mm)^{PIE}$.
MASS WEIGHTED FACTOR	=	A factor used in computing the MASS of a SAMPLE VOLUME ($53x10^3$), in $(hr)(kg)/(km^2m^2)$.
PRECIPITATION INTENSITY EXPONENT	=	The power to which the PRECIPITATION INTENSITY is raised in calculating the effective REFLECTIVITY FACTOR (1.37), in dBZe.
RANGE (Slant)	=	Slant range to the center of a SAMPLE VOLUME, in km.
REFLECTIVITY AVERAGING FACTOR	=	The number of SAMPLE VOLUMES used for computing a segment’s maximum (average) REFLECTIVITY FACTOR (3).
REFLECTIVITY FACTOR(Sample Volume)	=	The effective radar reflectivity factor of a SAMPLE VOLUME, in dBZe.
SAMPLE VOLUME	=	A data sample volume whose (half power) dimensions are 1 km in range (or length) and approximately 1 degree in azimuth and depth (perpendicular to the radar beam).
THRESHOLD (Dropout Count)	=	The maximum number of contiguous SAMPLE VOLUMEs with a REFLECTIVITY FACTOR less than the THRESHOLD (Reflectivity) by less than or equal to the THRESHOLD (Dropout Reflectivity Difference) that may be included in a CELL SEGMENT (2).

THRESHOLD (Dropout Reflectivity Difference)	=	The difference below THRESHOLD (Reflectivity) in effective reflectivity that a SAMPLE VOLUME may still be included in a CELL SEGMENT (5), in dBZe.
THRESHOLD (maximum Reflectivity Mass)	=	The maximum REFLECTIVITY FACTOR used in the MASS WEIGHTED LENGTH and MASS WEIGHTED LENGTH SQUARED calculations (80), in dBZe.
THRESHOLDS (Reflectivity)	=	A set of minimum effective reflectivities which the REFLECTIVITY FACTOR of a SAMPLE VOLUME must meet or exceed to be included in a CELL SEGMENT. The REFLECTIVITY FACTOR of the SAMPLE VOLUMEs in a CELL SEGMENT of a THRESHOLD (Reflectivity) must meet or exceed the same THRESHOLD (Reflectivity) (6Ø, 55, 5Ø, 45, 4Ø, 35, 3Ø), in dBZe.
THRESHOLDS (Segment Length)	=	A set of minimum lengths of a CELL SEGMENT for each reflectivity threshold (1.9), in km.

2.2 ACQUISITION

AZIMUTH, ELEVATION, and RANGE (Slant) are directly measured from the radar's instantaneous position. The REFLECTIVITY FACTOR(Sample Volume) is acquired from measurements taken by the radar hardware. The SAMPLE VOLUMEs are a result of radar hardware and parameters at the time of observation.

All other thresholds, coefficients, and exponents are supplied as adaptable parameters whose values have been based on theoretical and empirical studies (See Adaptable Parameter Table Appendix C) and are adjustable at the UCP.

3.0 PROCEDURE

3.1 ALGORITHM

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BEGIN ALGORITHM (STORM CELL SEGMENTS)

1.0   DO FOR ALL (radials of the elevation scan)
      1.1 DO FOR ALL (THRESHOLDS (Reflectivity))
      1.1.1  DO FOR ALL (SAMPLE VOLUMEs of the current radial)
      1.1.2      IF (REFLECTIVITY FACTOR(Sample Volume) is greater than
                    or equal to THRESHOLD (Reflectivity))
                    THEN
      1.1.2.1          Begin or continue POTENTIAL CELL SEGMENT
      1.1.2.2          IF (Beginning POTENTIAL CELL SEGMENT)
                          THEN
      1.1.2.2.1              COMPUTE (beginning RANGE(Segment))
                       END IF
      1.1.2.3          COMPUTE (ending RANGE(Segment))
      1.1.2.4          Reset NUMBER OF DROPOUTS to zero.
      1.1.3      ELSE IF (REFLECTIVITY FACTOR(Sample Volume) is greater
                    than or equal to (THRESHOLD (Reflectivity) -
                    THRESHOLD (Dropout Reflectivity Difference)) AND
                    (continuing POTENTIAL CELL SEGMENT))
                    THEN
      1.1.3.1          COMPUTE (NUMBER OF DROPOUTS)
      1.1.3.2          IF (NUMBER OF DROPOUTS is greater than
                          THRESHOLD (Dropout Count))
                          THEN
      1.1.3.2.1              End POTENTIAL CELL SEGMENT
                       END IF
      1.1.4      ELSE IF (Continuing POTENTIAL CELL SEGMENT)
                    THEN
      1.1.4.1          End POTENTIAL CELL SEGMENT
                 END IF
      1.1.5      IF (POTENTIAL CELL SEGMENT is ended)
                    THEN
      1.1.5.1          COMPUTE (LENGTH(Segment))
      1.1.5.2          IF (LENGTH(Segment) is greater than or equal to
                          THRESHOLD (Segment Length(Reflectivity
                          Threshold)))
                          THEN
      1.1.5.2.1              Label POTENTIAL CELL SEGMENT a CELL SEGMENT
                       END IF
                 END IF
             END DO
          END DO
      1.2 DO FOR ALL (THRESHOLDS(Reflectivity))
      1.2.1  DO FOR ALL (CELL SEGMENTS for this THRESHOLD
                 (Reflectivity))
      1.2.1.1    COMPUTE (maximum REFLECTIVITY FACTOR(Segment))
      1.2.1.2    COMPUTE (MASS WEIGHTED LENGTH(Segment))
      1.2.1.3    COMPUTE (MASS WEIGHTED LENGTH SQUARED(Segment))
      1.2.1.4    COMPUTE (NUMBER OF SEGMENTS(Reflectivity
                    Threshold))
      1.2.1.5    WRITE (maximum REFLECTIVITY FACTOR(Segment))
      1.2.1.6    WRITE (MASS WEIGHTED LENGTH(Segment))
      1.2.1.7    WRITE (MASS WEIGHTED LENGTH SQUARED(Segment))
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    1.2.1.8    WRITE (beginning RANGE(Segment))
    1.2.1.9    WRITE (ending RANGE(Segment))
    1.2.1.10   WRITE (AZIMUTH)
    1.2.1.11   WRITE (THRESHOLD (Reflectivity))
           END DO
    1.2.2  WRITE (NUMBER OF SEGMENTS(Reflectivity Threshold))
        END DO
    END DO
2.0  COMPUTE (average DELTA AZIMUTH)
3.0  WRITE (ELEVATION)
4.0  WRITE (average DELTA AZIMUTH)

END ALGORITHM (STORM CELL SEGMENTS)
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3.2 COMPUTATION

3.2.1 NOTATION

AZ	=	The AZIMUTH, the azimuthal position of a radial, in degrees.
DBZE	=	The REFLECTIVITY FACTOR(Sample Volume), the effective radar reflectivity factor of a SAMPLE VOLUME, in dBZe.
DBZEavg	=	The average reflectivity factor of a group of SAMPLE VOLUMEs, in dBZe.
DBZEmax	=	The maximum REFLECTIVITY FACTOR(Segment), the maximum average reflectivity factor in a CELL SEGMENT, in dBZe.
DELAZ	=	The difference in horizontal azimuthal position of two adjacent radials on the elevation scan, in degrees.
DELAZave	=	The average DELTA AZIMUTH, the average difference in horizontal azimuthal position of the adjacent radials on the elevation scan, in degrees.
j	=	An index for SAMPLE VOLUMEs.
k	=	An index for SAMPLE VOLUMEs.
l	=	An index for THRESHOLD (Reflectivity).
MMF	=	The MASS MULTIPLICATIVE FACTOR, a multiplicative factor used in computing the PRECIPITATION INTENSITY (486), in $(mm^6/m^3)(hr/mm)^{PIE}$.
MRM	=	The THRESHOLD (maximum Reflectivity Mass), the maximum REFLECTIVITY FACTOR used in the MASS WEIGHTED LENGTH and MASS WEIGHTED LENGTH SQUARED calculations (80), in dBZe.
MWF	=	The MASS WEIGHTED FACTOR, a factor used in computing the mass of a SAMPLE VOLUME (53×10^3), in $(hr)(kg)/(km^2m^2)$.
MWL	=	The MASS WEIGHTED LENGTH(Segment), the mass density weighted length of a CELL SEGMENT, in kg/km^2.
MWLS	=	The MASS WEIGHTED LENGTH SQUARED(Segment), the mass density weighted length squared of a CELL SEGMENT, in kg/km.
NAZ	=	The number of radials in an elevation scan.

ND	=	The NUMBER OF DROPOUTS, the number of contiguous SAMPLE VOLUMEs with a REFLECTIVITY FACTOR less than the THRESHOLD (Reflectivity) by less than or equal to the THRESHOLD (Dropout Reflectivity Difference).
NS	=	The NUMBER OF SEGMENTS(Reflectivity Threshold), the number of CELL SEGMENTS found with each reflectivity threshold.
PIE	=	The PRECIPITATION INTENSITY EXPONENT, the power to which the PRECIPITATION INTENSITY is raised in calculating the effective REFLECTIVITY FACTOR (1.37), in dBZe.
PIN	=	The PRECIPITATION INTENSITY, precipitation intensity, in mm/hr (liquid equivalent).
RA	=	The REFLECTIVITY AVERAGING FACTOR, the number of SAMPLE VOLUMEs used for determining the maximum (average) reflectivity factor (3).
RS	=	The RANGE(Slant), the slant range to the center of a SAMPLE VOLUME, in km.
RSbeg	=	The beginning RANGE(Segment), the RANGE(Slant) to the front (closest to the radar) of the first SAMPLE VOLUME of a CELL SEGMENT, in km.
RSend	=	The ending RANGE(Segment), the RANGE(Slant) to the back of the last SAMPLE VOLUME of a CELL SEGMENT, in km.
SVbeg	=	The first SAMPLE VOLUME of a CELL SEGMENT.
SVend	=	The last SAMPLE VOLUME of a CELL SEGMENT.
SVL	=	The length (in slant range) of a SAMPLE VOLUME, in km.
ZE	=	The REFLECTIVITY FACTOR(Sample Volume), the effective radar reflectivity factor of a SAMPLE VOLUME, in mm^6/m^3.

3.2.2 SYMBOLIC FORMULAS

<u>COMPUTE</u> (beginning RANGE(Segment))

RSbeg = SVbeg*SVL - SVL/2

<u>COMPUTE</u> (ending RANGE(Segment))

RSbeg = SVend*SVL + SVL/2

<u>COMPUTE</u> (NUMBER OF DROPOUTS)

ND = ND + 1

<u>COMPUTE</u> (LENGTH(Segment))

LEN = RSend - RSbeg

<u>COMPUTE</u> (maximum REFLECTIVITY FACTOR(Segment))

$$DBZEavg_k = \left[\sum_{j=k - INT(RA/2)}^{j=k + INT(RA/2)} DBZE_j \right] / RA$$

where INT is a function whose magnitude is the largest integer that does not exceed the magnitude of the argument. Index j is constrained to the interval [SVbeg,SVend].

$DBZEmax = DBZEavg_k$ if $DBZEavg_k \geq DBZEmax$

<u>COMPUTE</u> (MASS WEIGHTED LENGTH(Segment))

$$MWL = \sum_k [(MSV_k)(RS_k)]$$

where MSV = (MWF)(PIN),

where PIN is computed from the relation $ZE = (MMF)(PIN)^{PIE}$,

and $ZE = 10^{(DBZE/10)}$.

If DBZE > MRM, DBZE = MRM

COMPUTE (MASS WEIGHTED LENGTH SQUARED(Segment))

$$MWLS = \sum_{k} [(MSV_k)(RS_k)^2]$$

where MSV is defined as above.

COMPUTE (NUMBER OF SEGMENTS)

$$NS_l = NS_l + 1$$

where l is index for the different reflectivity thresholds.

COMPUTE (average DELTA AZIMUTH)

$$DELAZ = ABS(AZ_i - AZ_{i-1})$$

if DELAZ > 180, then DELAZ = 360 - DELAZ

$$DELAZavg = [\sum_{i} (DELAZ)]/NAZ$$

4.0 OUTPUTS

4.1 IDENTIFICATION

For each cell segment the algorithm will output the following attributes: the beginning RANGE, ending RANGE, maximum REFLECTIVITY FACTOR, MASS WEIGHTED LENGTH, MASS WEIGHTED LENGTH SQUARED, AZIMUTH, and the reflectivity threshold with which it was found. Additional outputs include, the angle of the ELEVATION scan on which the algorithm was run; the average DELTA AZIMUTH of the radials; and the NUMBER OF SEGMENTs found with each reflectivity threshold.

4.2 DISTRIBUTION

The outputs of this algorithm are inputs to the STORM CELL CENTROIDS [Ø37] algorithm.

5.0 INFERENCES

5.1 LIMITATIONS

One consideration is the potentially large number of (cell) segments. The STORM SEGMENTS [Ø22/23] algorithm detects (storm) segments using only one reflectivity threshold. This algorithm uses seven reflectivity thresholds; therefore, there could comparatively be seven times the number of segments.

Another limitation is that the algorithm makes no attempt to prevent non-meteorological targets (e.g. anomalous propogation or clutter) in the reflectivity data from being considered segments. Clutter filtering is being applied in the WSR-88D, but it is not always adequate or correctly applied. When non-meteorological targets are identified as segments, this may lead to falsely identified storm cells or parts of storm cells in the STORM CELL CENTROIDS [Ø37] algorithm.