ECHO TOPS

ALGORITHM DESCRIPTION

NX-DR-03-013/18

1.0 PROLOGUE

1.1 FUNCTIONAL DESCRIPTION

The Echo Tops algorithm estimates echo (non-zero reflectivity category) top heights for 4 kilometer (east-west) by 4 kilometer (north-south) grid boxes. A grid box represents the area on the earth where a single value of reflectivity will be assigned. The height of the echo top is measured from ground level to the mid-point of the radar radial beam for the highest non-zero reflectivity category per grid box.

1.2 SOURCE

The Echo Tops algorithm described herein was supplied by Mr. Robert Saffle of the NWS's Techniques Development Laboratory. It represents the implementation used on the D/RADEX radars.

1.3 PROCESSING ENVIRONMENT

The Echo Tops algorithm only requires reflectivity data. This algorithm does not use the "raw" reflectivity factor data obtained from the radar. Several preprocessing steps are carried out before the data are input to the algorithm. The NWS preprocessing performed on the data is described by the following operations.

First, the standard $1/r^2$ range correction is performed on the data. A correction is then made for oxygen absorption of microwave energy. The linear attenuation correction of 6.5 x 10^{-3} dB/km for a 10 cm radar is then performed. The resulting reflectivity factor data values for each sample volume are assigned a number representing fifteen categories as shown in the Operational Threshold column of Table 1. If the return power is less than 18.5 dBZe it is assigned a value of zero. The data are also filtered to remove any spurious data. A data point must have at least two adjacent points with a category value of at least one, otherwise the isolated point is removed. That is, at least two of the four possible sample volumes at a particular elevation with adjoining sides to the sample volume in question must be in category one or above. This final data set is the one used as input to the Echo Tops algorithm.

2.0 INPUTS

2.1 IDENTIFICATION

AZIMUTH	=	Azimuthal position, in radians. Precise to 10^{-3} radians.
CATEGORIES	=	Categorized effective reflectivity factor data for each SAMPLE VOLUME.
ELEVATION	=	Elevation angle, in radians.
RANGE (Slant)	=	The slant range to the center of a SAMPLE VOLUME, in kilometers.
BOX (4 km x 4 km Grid)	=	Square grid boxes which are 4 km on a side and cover ranges from 0 to 230 km.

2.2 ACQUISITION

AZIMUTH, ELEVATION, and RANGE (Slant) are quantities measured directly during the radar data acquisition process.

CATEGORIES are obtained from the NWS preprocessing algorithm as described in Section 1.3.

BOX(4 km x 4 km Grid) is a system supplied parameter.

3.0 PROCEDURE

3.1 ALGORITHM

```
BEGIN ALGORITHM (ECHO TOPS)

1.0  DO FOR ALL (ELEVATIONs)
     1.1  DO FOR ALL (AZIMUTHs)
          1.1.1  DO FOR ALL (RANGEs (Slant))
                 1.1.1.1 IF (CATEGORIES value is not equal
                         to zero)
                         THEN COMPUTE (HEIGHT (Echo Tops))
                            Map polar position of HEIGHT
                            onto the BOX (4 km x 4 km Grid).
                         END IF
                 END DO
          END DO
     1.2  DO FOR ALL (BOXes (4 km x 4 km Grid))
          1.2.1  COMPUTE (TOP (Echo))
          1.2.2  WRITE (TOP (Echo))
          1.2.3  IF (TOP (Echo) is found at the highest
                    ELEVATION)
                    THEN
                      Mark the TOP (Echo) as being at the
                      highest ELEVATION.
                 END IF
          END DO
     END DO

2.0  WRITE (TOPs (Echo))

END ALGORITHM (ECHO TOPS)
```

3.2 COMPUTATION

3.2.1 NOTATION

HTOP = HEIGHT (Echo Tops), the height of non-zero values in CATEGORIES for each SAMPLE VOLUME, in kilometers. Precise to 10^{-4} kilometers.

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

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

TOP = TOP (Echo), the greatest height of an echo computed for a BOX (4 km x 4 km Grid), in kilometers. Precise to 10^{-4} kilometers.

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

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

3.2.2 SYMBOLIC FORMULAS

COMPUTE (HEIGHT (Echo Tops))

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

COMPUTE (TOP (Echo))

$$TOP = HTOP_n \text{ if } HTOP_n > TOP$$

where n is the number of height values within a BOX(4 km x 4 km Grid)

4.0 OUTPUTS

4.1 IDENTIFICATION

TOPs (Echo) are estimates of Echo Top heights for each 4 x 4 kilometer grid box. The product may be converted to thousands of feet for display purposes.

4.2 DISTRIBUTION

These echo top values could be used directly for display or used as input to other algorithms.

5.0 INFERENCES

5.1 LIMITATIONS

The precision for measuring the height decreases with range because of beam broadening. At a range of 230 kilometers the one-half beam width is 4040 meters.

The algorithm does not correct for data contamination from side lobes. The height of echo tops could be overestimated from this effect.

The echo tops may be undetectable by the radar at close range with a limited range of elevations.

5.2 FUTURE DEVELOPMENTS

No future developments have been identified for this algorithm.