APPENDIX V

Anomalous Propagation Removal Algorithm

50. INTRODUCTION

50.1 Background

Occasionally, the NEXRAD composite precipitation products are contaminated by clutter and consequently falsely indicate the presence of precipitation. This drastically reduces the effectiveness of the NEXRAD products for use in Air Traffic control as well as causing errors in other weather information systems that utilize these precipitation products. This document details the algorithm that LL/MIT has developed to identify this clutter, permitting its removal from the precipitation products.

50.2 Algorithm Summary

The NEXRAD Clutter Editor (CE) is designed to detect in NEXRAD data those range gates that are contaminated by ground clutter. The distinguishing characteristics of the ground clutter to be identified by this algorithm are (1) low radial velocity (2) low spectrum width and (3) is most commonly found in scans near the ground. Based on the altitude and downrange distance of the sampling volume corresponding to a given range gate, as well as the radial velocity and spectrum width of the return signal from said volume, the range gate is classified as representing either "weather" or "clutter". Those range gates classified as containing clutter returns are to be ignored during the subsequent generation of NEXRAD precipitation products. A range gate is he herein defined to be the data obtained from a scan at a specific azimuth, elevation and distance. The data in this range gate is considered to be obtained from a sampling volume, that is bounded in range by the pulse duration, and the mein lobe (i.e. between the half power points) of the antenna pattern.

50.3 Conceptual Overview

Studies of NEXRAD clutter performed by LL/MIT indicate that most clutter is found in data from range gates obtained during low elevation scans and from range gates near the radar. The clutter editor therefore first defines regions of space around the radar and then applies a specific set of rules in each region.

Briefly, proceeding radially away from the radar, these zones and rules can be stated as (1) very close to the radar and below a relatively low altitude, all data are rejected as clutter (2) in the next zone where clutter is most often found, data at low altitudes are assumed to be clutter unless proven otherwise, and (3) in the final region, where clutter is not typically found, data are assumed to be representing weather unless the velocity and spectrum width are close to that expected for ground clutter. In cases where ground clutter has been identified based on velocity and spectrum width out to a certain range, but no velocity/spectrum width data exists at longer, adjacent ranges, editing continues if there is continuity of the reflectivity field.

Finally, median averaging may be applied to the final, composite reflectivity products that arc derived from these edited data to remove speckles of "unedited ground clutter".

50.4 References

Doviak & Zmic, "Doppler Radar and Weather Observations", 1984.

51. DETAILED ALGORITHM DESCRIPTION

This algorithm can be divided into four distinct phases, registration, identification, dilation and smoothing. The first phase is the registration of the velocity data and reflectivity date from the lower reflectivity only end velocity only scans. In addition, if the reflectivity and velocity data are of differing spatial resolutions, (typically the reflectivity spatial resolution is 1km and the velocity spatial resolution is 0.2 5 km) , then a mechanism is established to associate a single gate of the low resolution product with multiple gates of the higher resolution product (typically 1 reflectivity gate is associated with 4 velocity/spectrum width gates). After this registration phase is complete, a second phase of range gate classification is performed wherein clutter is identified on a range gate by range gate basis based on criteria described below. In the third phase, certain range gates proximal in range to each previously identified "clutter-contaminated gate" may also be declared as containing clutter if there arc no velocity/spectrum data available to use a discriminant. This is in effect, an extension of the identification of clutter into neighboring range gates. The final processing phase is filtering the final precipitation product derived from these data to remove "speckles" of unedited ground clutter. The procedures to perform these phases are now defined.

51.1 Data Registration

In order to simplify subsequent processing, we assume in this exposition that the separate velocity/ spectrum width only and reflectivity only scans are combined into a single composite scan contain reflectivity, radial velocity and spectrum width. In this registration, two radials having azimuthal angles within 1 degree of each other and having elevation angles within 0.5 degrees of each other are considered a match. Additionally, since the range-resolutions of these scans differ (the reflectivity data has a 1 km resolution and the velocity/spectrum data, has a 0.25 km resolution) one reflectivity gate is associated with 4 velocity/spectrum width values. These composite scans are considered the input to the subsequent phases of this algorithm.

51.2 Initial Clutter Identification Phase

The velocity/spectrum width data from each of the range gates in the composite scan are now examined may be classified as containing clutter or weather according to a rule defined for the region of space within which the sampling volume corresponding to the range gate in question falls. Since the purpose of this algorithm is to prevent high reflectivity ground clutter returns from making their way into the composite reflectivity products, and in the interests of speeding up processing, a minimum reflectivity dBZ_min may be established. Reflectivities lower than this mini mum can be considered as valid with little adverse effect on the resultant composite reflectivity product. Range gates having reflectivity values above this minimum dBZ_min are then classified as weather or clutter according to the following procedure.

51.2.1 Definition Of the Detection Regions and Rules

A given velocity/spectrum width range gate is first located with respect to defined regions of space relative to the radar as given in Figure 2.2-1. In this figure, the NEXRAD is indicated symbolically in the lower left-hand corner; proceeding from lower left to upper right there are three regions, OMIT_ALL, ACCEPT_ IF and REJECT_IF.

Region 1-OMIT ALL: The first region, OMIT_ALL is a region from within which all reflectivity data are declared clutter. This region is bounded by an altitude Z_1, and a down-range distance of D-1. Any range gate whose sampling volume is entirely below the altitude Z_1 and within the distance D_l is considered as containing clutter and the corresponding reflectivity data is considered invalid and not used in forming the composite reflectivity products(s).

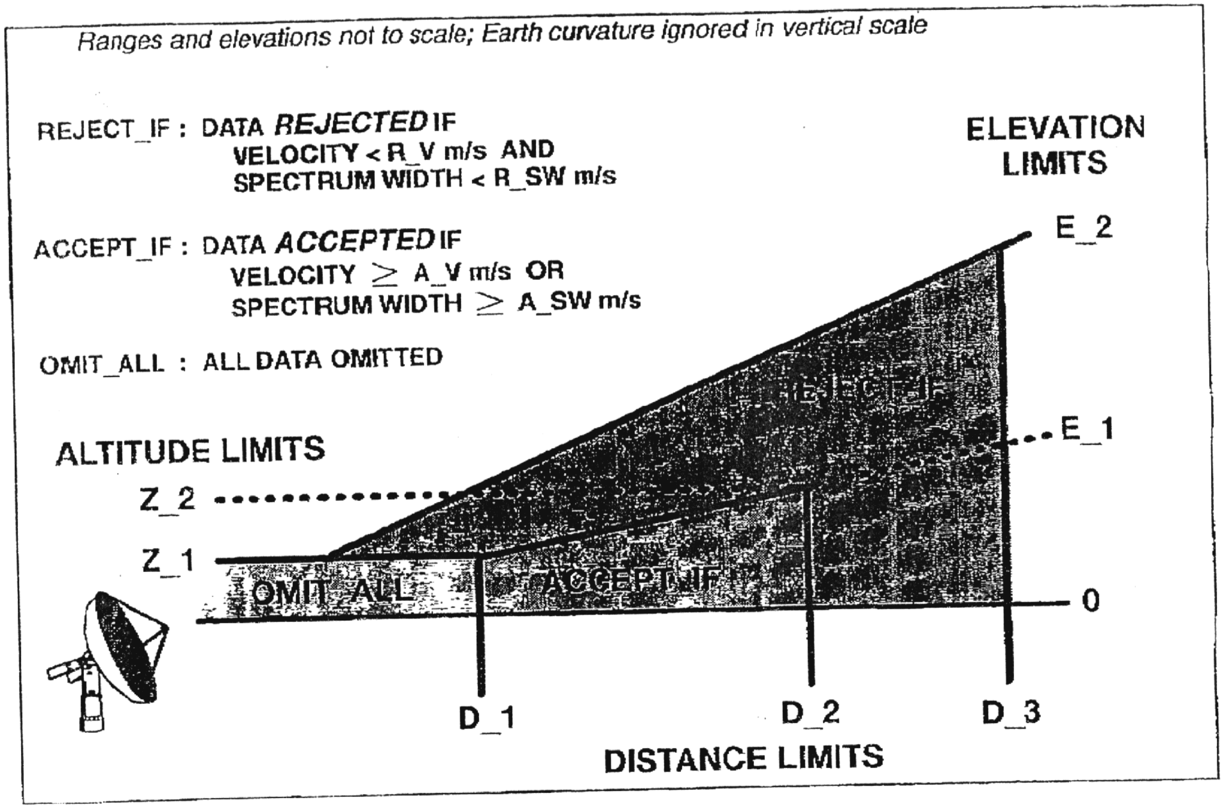


Figure 2.2-1. Region boundaries and names used by the MIT/LL - NEXRAD clutter removal algorithm.

51.2.1 Definition Of the Detection Regions and Rules (Cont'd)

Region 2-ACCEPT IF: The second region, ACCEPT_IF, is a region within which reflective data is considered as representing clutter unless indicated otherwise by either a high radial velocity or a wide spectrum width.

Region Definition : This region is defined to be bounded in down-ranged distance by the distances D_1 and D_2, and is applied to all range gates whose nominal elevation is less than or equal to E_1 and whose sampling volume is below the altitude Z_2 as shown in Figure 2.2-1.

Rule Definition : The rule to apply in this region may be stated in words as "Accept the reflectivity data ONLY IF (1) at least one velocity/spectrum range gate indicates the data is representative of weather and (2) no velocity/spectrum width range gate indicates the data is representative of clutter". In other words, for a reflectivity value to be accepted, the following two statements must both be true.

(1) At least one corresponding velocity/ spectrum width range gate has either (a) a velocity greater than or equal to a certain velocity threshold (A-V meters per second) or (b) a spectrum width greater than or equal to a certain width threshold (A_SW meters per second).

(2) No corresponding velocity/spectrum width range gate has both (a) a velocity less than certain velocity threshold (R_V meters per second) and (b) a spectrum width less than a certain width threshold (R_SW meters per second).

Region 3 - REJECT IF : The final region, REJECT_IF, is a region where reflectivity data is considered as being free of clutter unless indicated otherwise by a small radial velocity and a small spectrum width.

Region Definition : Any range gate whose nominal elevation is less than E_2 and down range distance is less than D_3 and is not in either region OMIT_ALL or ACCEPT_IF is considered to be in this region as shown in Figure 2.2-1.

Rule Definition : The rule to apply in this region may be stated in words as "Reject reflectivity data ONLY IF at least one corresponding velocity/spectrum width range gate has both (1) a velocity less than a certain velocity threshold (R_V meters per second) and (2) a spectrum width less than a certain width threshold (R_SW meters per second)".

51.3 Clutter Bloom/Dilation Phase

After the individual range gates are classified, if the site adaption parameter IF_Extend has the value .TRUE., then the regions identified as containing ground clutter in the region REJECT_IF may be extended as follows:

Beginning at each range gate within the region REJECT IF identified as containing ground clutter, (the initial gate) and proceeding radially outward towards greater distances, continue declaring each range gate as having clutter until at least one of the follow conditions are true.

1) a range gate is encountered with valid velocity and spectrum width data, (ACCEPT_IF) or
2) the reflectivity differs by more than dBZ_diff from the reflectivity of the initial gate, or
3) the range gate in question is more than G_r range gates from the initial gate.

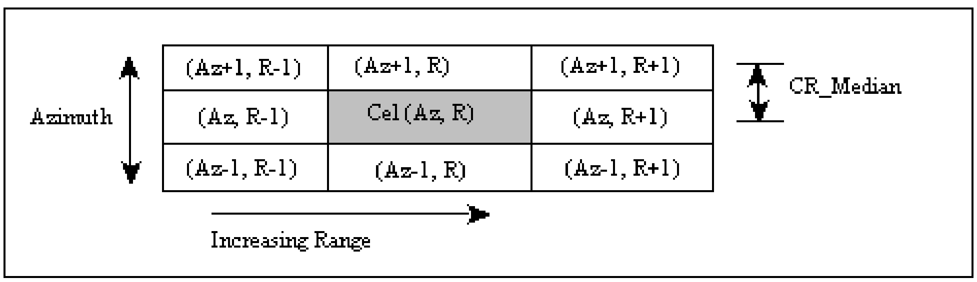
After the radial has been so examined, reject any reflectivity data that has at least one corresponding velocity/spectrum width gated marked as containing clutter.

Note: At the beginning of a velocity waveform second or third trip, there may be no valid velocity or spectrum width data. This Bloom/Dilation phase, in effect edits ground clutter at the beginning of a subsequent trip if ground clutter was identified at the end of the preceding trip.

51.4 Median Averaging Phase

If the site adaption parameter IF_Median has the value .TRUE., then the computed composite reflectivity product(s) will be median filtered as follows.

Each output composite reflectivity value is set equal to the median of reflectivity values for the range gates that both (a) lie with ± R_Median gates of the range gate in question and (b) whose azimuth is equal to or adjacent to the azimuth of the range gate in question and whose center is no more than the CR_Median meters (measured cross range) from the center of the cell in question. This is illustrated Figure 2.4-1, for which the parameter R_Median has the value 1. As the cross range distance to neighboring cells increases with increasing down range distance, the median filtering is, at some point, applied in range only.



2.5 LL/MIT values of Region Boundaries and Thresholds. (Adaptation Parameters)

Parameter	Nominal Value	Range
dBZ_min	10 dBZ	5-20
Z_1	1 km	0-5
Z_2	3 km	0-10
D_1	45 km	0-100
D_2	103 km	0-300
D_3	230 km	0-300
E_1	0.5 degrees	0-5
E_2	5.0 degrees	0-15
R_V	1.0 m/s	0-5
R_SW	0.5 m/s	0-5
A_V	1.0 m/s	0-5
A_SW	0.5 m/s	0-5
G_r	4 gates	0-20
dBZ_diff	10 dBZ	0-30
IF_Extend	.TRUE.	T/F
IF_Median	.TRUE.	T/F
R_Median	1 gate	0-5
CR_Median	2 km	0-10

Appendix 1.

Minimum spectrum width vs. antenna rotation speed

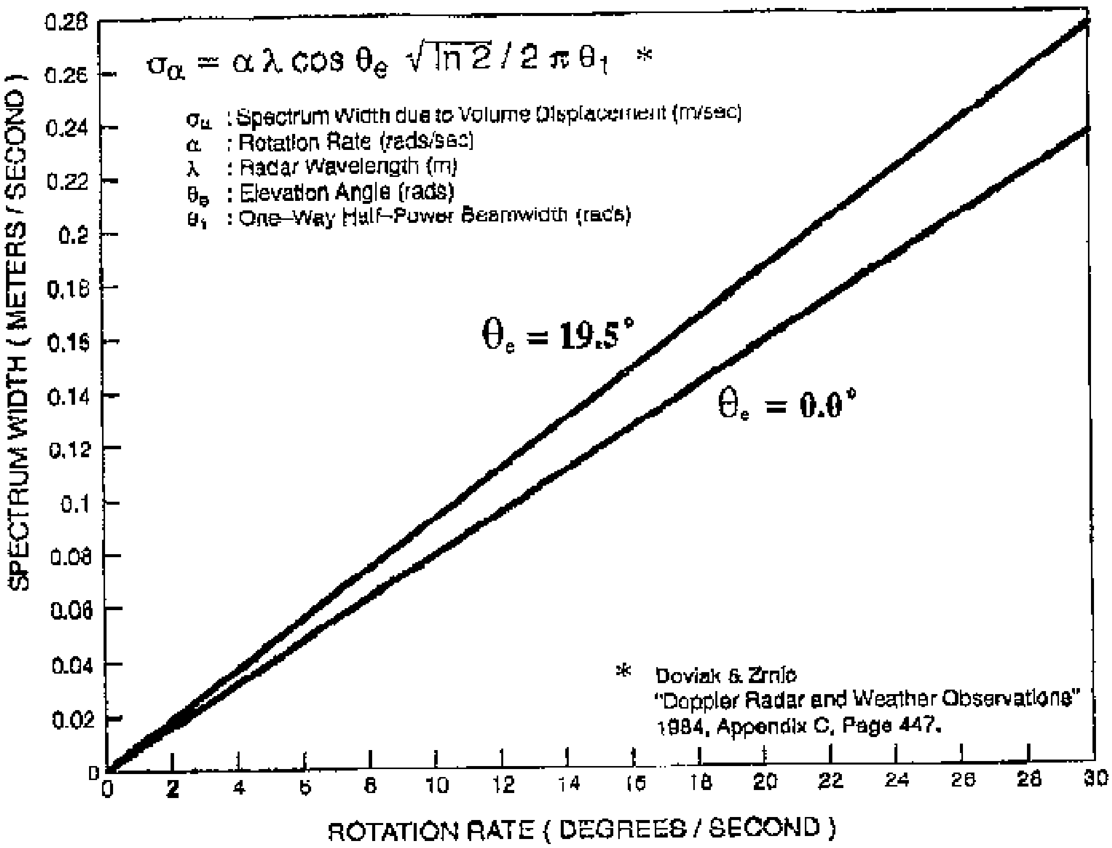
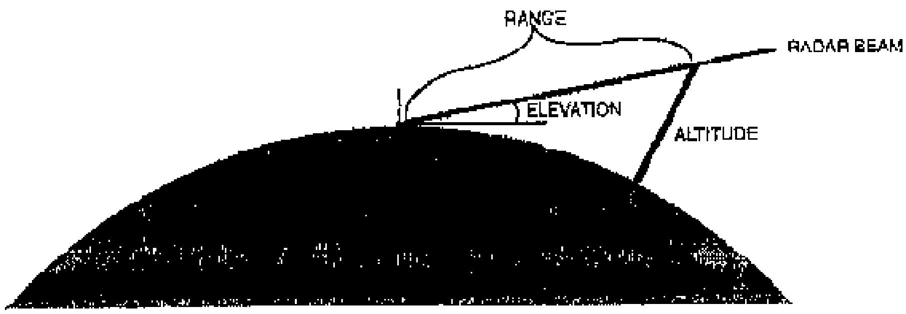


Figure A-1. NEXRAD SPECTRUM WIDTH DUE TO VOLUME DISPLACEMENT

Appendix 2.

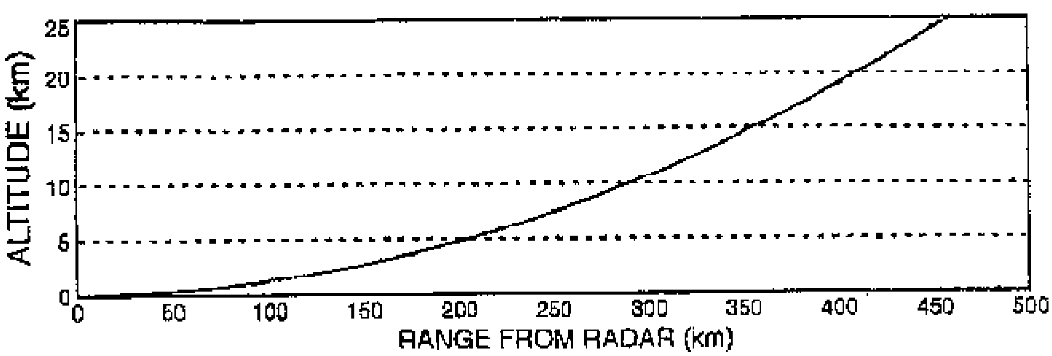
Altitude vs. Down range distance

ITWS ALTITUDE COMPUTATION ACCOUNTING FOR EARTH CURVATURE

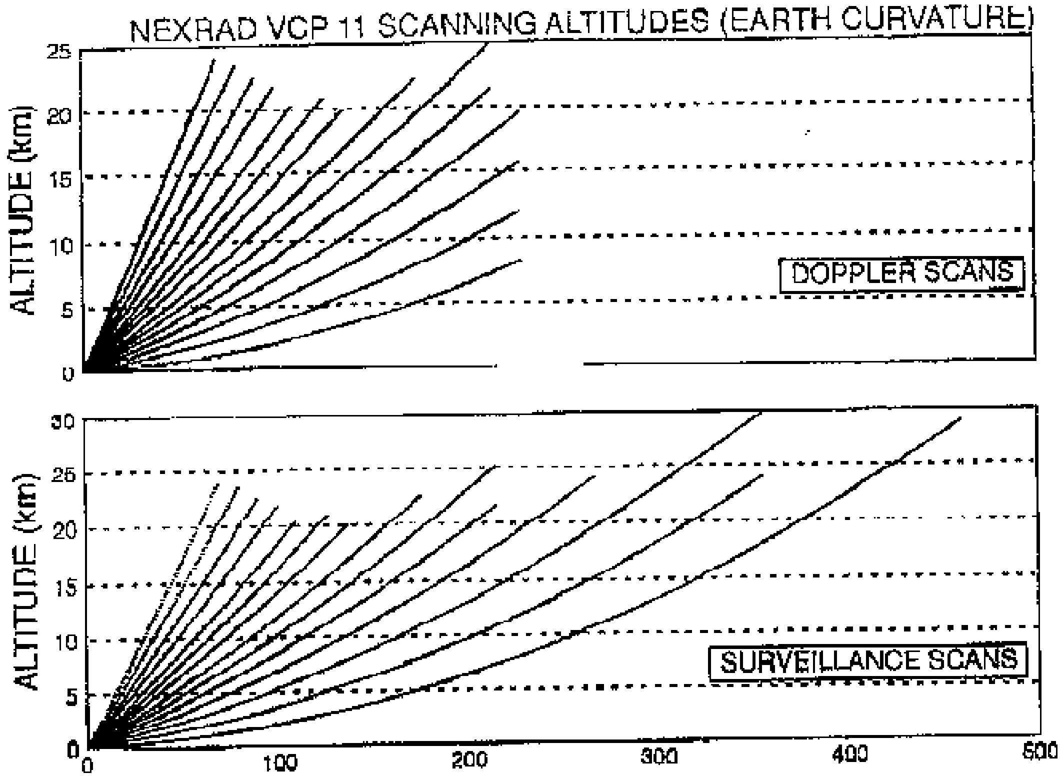


$$\text{ALTITUDE} = \text{RANGE} \times \sin(\text{ELEVATION}) + \frac{\text{RANGE}^2 \times \cos^2(\text{ELEVATION})}{(4/3) \times \text{DIAMETER}_{\text{EARTH}}}$$

1.21



Appendix 3. NEXRAD scan patterns.

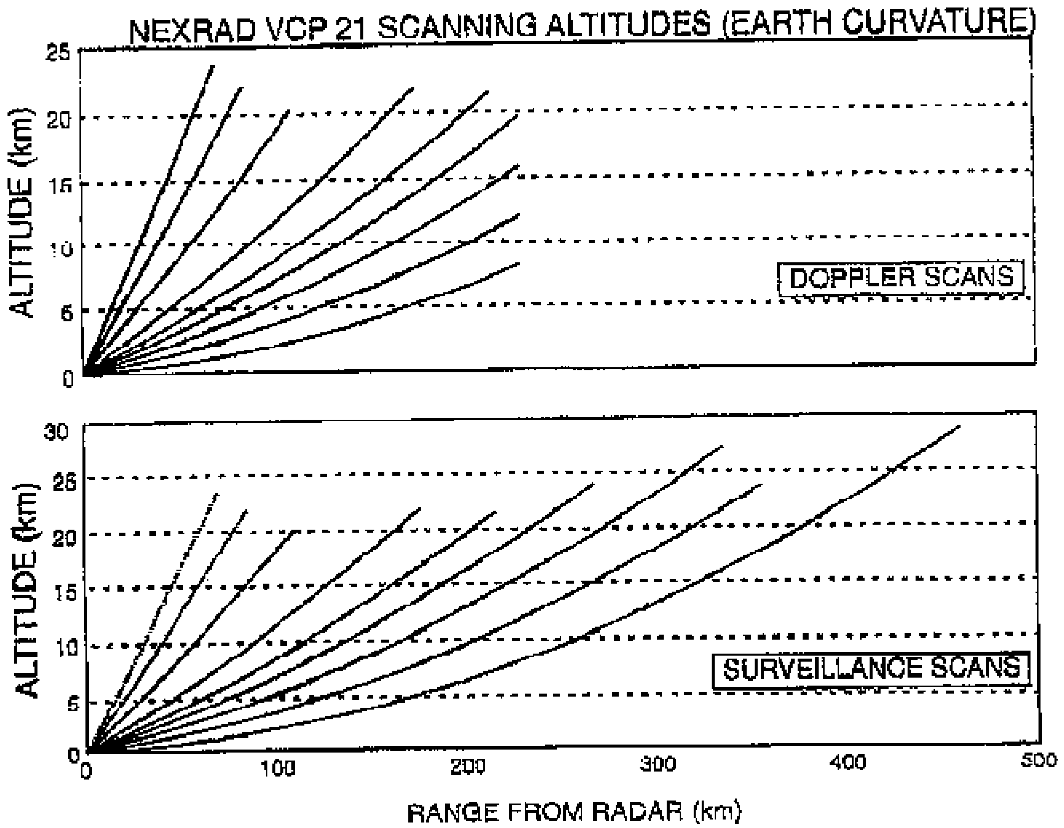


RANGE FROM RADAR (km)

Tilt	Elevation	Surv	Dopp
1	0.5°	460	0
2	0.5°	0	920
3	1.45°	356	0
4	1.45°	0	920
5	2.4°	356	920
6	3.35°	268	920
7	4.3°	216	860
8	5.25°	216	860
9	6.2°	176	700
10	7.5°	137	548
11	8.7°	127	508
12	10.0°	110	440
13	12.0°	100	400
14	14.0°	90	360
15	16.7°	80	320
16	19.5°	70	280

Number of range gates for various scans

Appendix 3. NEXRAD scan patterns.

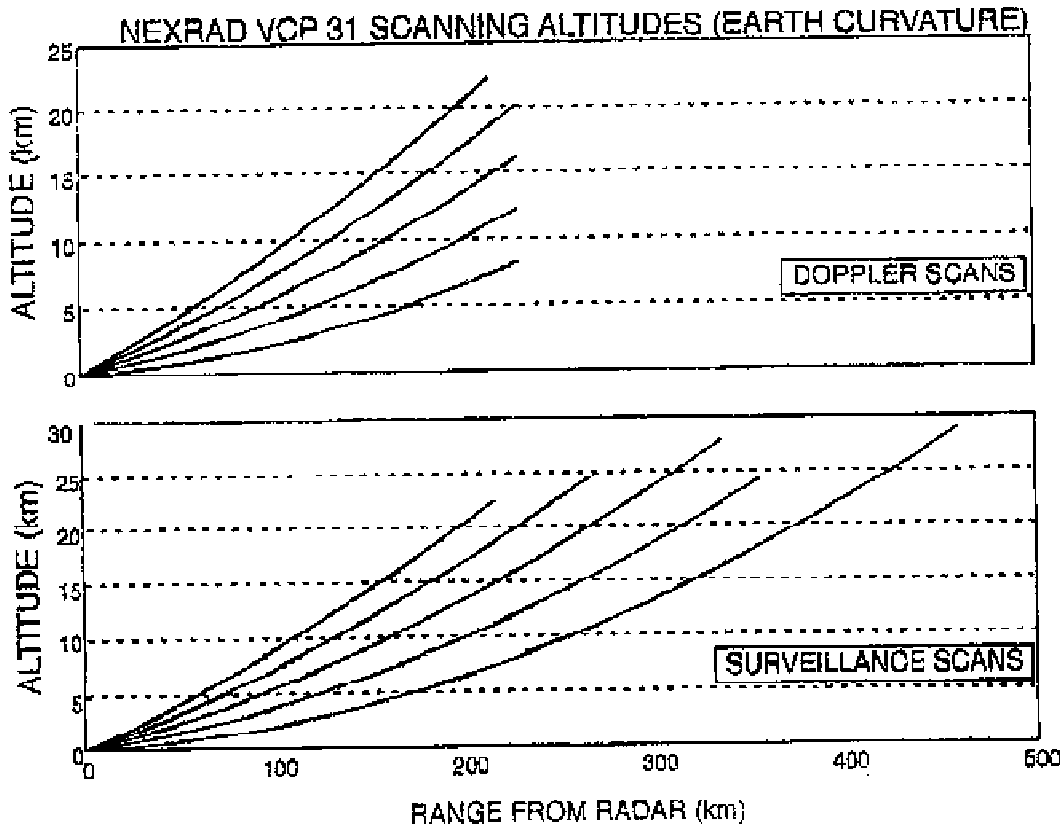


RANGE FROM RADAR (km)

Number of range gates for various scans

Tilt	Elevation	Surv	Dopp
1	0.5°	460	0
2	0.5°	0	820
3	1.45°	356	0
4	1.45°	0	920
5	2.4°	336	920
6	3.35°	268	920
7	4.3°	216	860
8	6.0°	176	700
9	9.9°	110	440
10	14.6°	85	340
11	19.6°	70	280

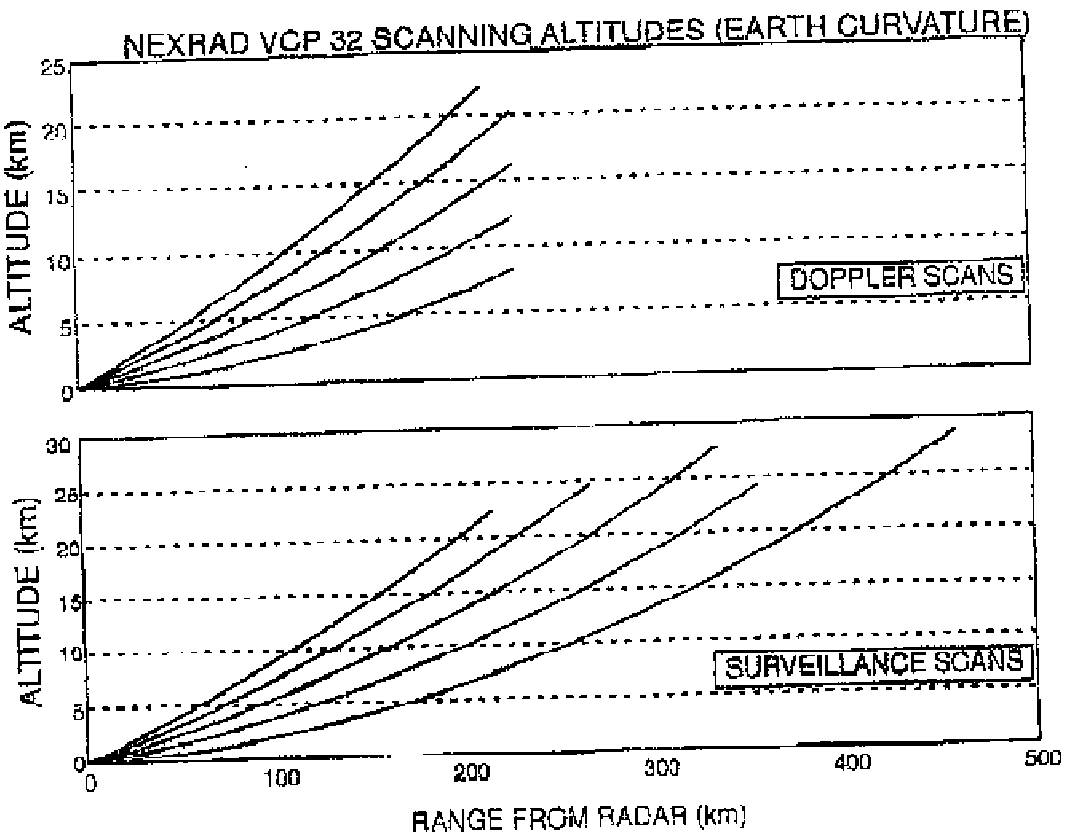
Appendix 3. NEXRAD scan patterns (cont'd)



Tilt	Elevation	Surv	Dopp
1	0.5°	460	0
2	0.5°	0	920
3	1.5°	356	0
4	1.5°	0	920
5	2.5°	336	920
6	2.5°	336	920
7	3.5°	268	920
8	4.5°	216	860

Number of range gates for various scans

Appendix 3. NEXRAD scan patterns (cont'd)



Tilt	Elevation	Surv	Dopp
1	0.5°	460	0
2	0.5°	0	920
3	1.5°	356	0
4	1.5°	0	920
5	2.5°	336	920
6	3.5°	268	920
7	4.5°	216	860

Number of range gates for various scans