PRECIPITATION ACCUMULATION

ALGORITHM DESCRIPTION

NX-DR-03-019/31

1.0 PROLOGUE

1.1 FUNCTIONAL DESCRIPTION

The PRECIPITATION ACCUMULATION algorithm uses the previous and current precipitation rate (RATE SCAN) data sets output by the PRECIPITATION RATE [018] algorithm to estimate the accumulation during all or parts of the scan to scan period. Accumulation is in millimeters (mm). The period accumulation scan(s) generated during the current pass of this algorithm plus those produced within the hourly period under consideration, are then used to estimate an hourly running total or a clock hour total accumulation scan. This hourly accumulation scan is input to the PRECIPITATION ADJUSTMENT [020] algorithm. The PRECIPITATION ACCUMULATION algorithm also checks the hourly accumulations for suspect values and modifies these under certain conditions.

The technique used to estimate the accumulation during the scan to scan period depends upon the time between scans. If the time between scans is not too large, a simple average precipitation rate is computed for the scan to scan period. This average is computed for each of the one degree by 2 km sample volumes which make up the scan. These averages are then multiplied by the time between scans to construct a period accumulation scan with a 1 degree by 2 km resolution, which gives the estimated scan to scan accumulation. This scan is comprised of 41,400 1 degree by 2 km sample volumes.

If the time between scans is too large to use simple averaging (equivalent to linear interpolation), the precipitation rates for each scan are used separately to compute accumulations for the beginning and ending parts of the scan to scan period. The remainder of the scan to scan period, centered midway between the two scans, is flagged as a missing period. In this case, two 1 degree by 2 km resolution period accumulation scans are constructed.

Next, the beginning and ending times for the hourly accumulation period are established. If a clock hour was passed during the scan to scan period, these times coincide with the beginning and ending of the most recently completed clock hour. If the ending TIME (Gage Accumulation) for the hourly accumulation required by the PRECIPITATION ADJUSTMENT [020] algorithm was passed during the scan to scan period, these times coincide with the beginning and end of the hour ending at the ending TIME (Gage-accumulation). Otherwise, for an hourly running total accumulation the time period extends backward from the current scan time to a time one hour earlier.

Weighting each period accumulation scan by the fraction of it which falls in the hourly accumulation period, a 1 degree by 2 km resolution hourly accumulation scan for the specified hourly period is constructed. However, if too much of the specified hourly period is not covered by period accumulation scans (e.g.,

is missing), no hourly accumulations are constructed and the processing stream continues with the PRECIPITATION ADJUSTMENT [020] algorithm.

Finally, each hourly accumulation scan sample volume value is checked against a threshold to see if it is reasonable. If it is greater than the threshold, (i.e., an outlier) and the values of all neighboring sample volumes are below the threshold, an interpolated accumulation is computed. These changes are made in such a way that subsequent modifications to outliers are not affected by the changes to those previously identified.

1.2 SOURCE

The PRECIPITATION ACCUMULATION algorithm was developed by the Radar Hydrology Group of the National Weather Service's Hydrologic Research Laboratory. This algorithm has been based on experiences gained through the use of real-time rainfall estimation from the D/RADEX system, the GATE project, and other experimental projects, as well as an in-depth analysis of ways which weather radar data could be better used for hydrometeorological purposes.

REFERENCES

Ahnert, P.R., M.D. Hudlow, and E.R. Johnson, 1984: Validation of the on-site Precipitation Processing System for NEXRAD. Preprints, 22nd Radar Meteor. Conf., AMS, Boston, MASS.

Ahnert, P.R., M.D. Hudlow, E.R. Johnson, D.R. Greene, and M.R. Dias, 1983: Proposed "on-site" precipitation processing system for NEXRAD. Preprints, 21st Radar Meteor. Conf ., AMS, Boston, Mass.

Hudlow, M.D., D.R. Greene, P.R. Ahnert, W.F. Krajewski, T.R. Sivaramakrishnan, M.R. Dias, and E.R. Johnson, 1983: Proposed off-site precipitation processing system for NEXRAD. Preprints, 21st Meteor. Conf., AMS, Boston, Mass.

1.3 PROCESSING ENVIRONMENT

This algorithm requires precipitation rate scans from both the previous and current outputs of the PRECIPITATION RATE [018] algorithm. Only scans flagged as good in the PRECIPITATION RATE [018] algorithm are used (i.e. previous scan means previous good scan). Zero rate scans (scans not actually generated but assumed to be zero everywhere) can be good scans. The algorithm is sufficiently flexible so that it can provide accumulation information for as much of the scan-to-scan period as possible even when the time between scans is larger than 5 minutes. However, the error associated with the accumulation will grow rapidly as the time between scans increases. Therefore, in order to provide, to the maximum extent possible, uninterrupted precipitation record, the method used to save the previous

precipitation rate scan must be safe, even from temporary system shutdowns and restarts.

Whenever the current precipitation rate scan is the first scan in a new clock hour, clock hour accumulations are computed instead of computing running hourly accumulations (note: the only difference between clock hour and running hourly accumulations are the starting and ending times for the one hour accumulation period). Since the time between scans may be large if a system problem occurs, the clock hour accumulation period could be set to begin up to 2 hours before the current scan time. In addition, missing periods must be taken into account so that hourly integration criteria can be checked. Therefore, all scan-to-scan period accumulation scans for periods ending any time after 1 hour prior to the previous scan time must be saved. The previous scan time is the last good scan collected prior to the current scan. The method used to save these period accumulation scans must be safe, even from temporary system shutdowns and restarts.

2.0 INPUTS

2.1 IDENTIFICATION

RATE SCAN	=	Precipitation rate data on a 1 degree by 2 km polar grid from 1 to 230 km, in dBR. A precision of at least 0.1 mm/hr and a dynamic range of at least 0 to 1600 mm/hr are required (not generated for times when FLAG (Zero Rate) or when FLAG (Bad) are set).
average TIME (Scan)	=	The average scan time of the four elevation scans used to construct the HYBRID SCAN. This is a time of occurrence, not duration.
FLAG (Zero rate)	=	A set or cleared flag for each average TIME (Scan) indicating, if set, that all precipitation rate values can be assumed to be zero .
maximum TIME (Interpolation)	=	The maximum period over which a period accumulation scan can be computed using two precipitation rate scans, in hours (approximately 0.5 hours).
minimum TIME (Period)	=	The minimum period of time during an hourly accumulation period for which ACCUMULATION SCAN (Period) data are required in order to estimate the hourly accumulation in hours (approximately 0.90 hours).
ACCUMULATION SCAN (Period)	=	Interpolated or extrapolated period precipitation accumulation data on a 1 degree by by 2 km polar grid from 1 to 230 km, in mm.
TIME (Last precip-itation detected)	=	The time at which the Precipitation Detection support function last detected precipitation.
PRECIPITATION STATUS MESSAGE	=	An alphanumeric message which includes the radar ID, TIME (Stamp), current radar status, current operational mode, current scan strategy, TIME (Last Precipitation Detected), CATEGORY (Precipitation), number of gages in data base, and time since last update to the gage data base.
THRESHOLD (Hourly	=	The maximum hourly rainfall amount

Outlier)		allowed in an hourly accumulation scan sample volume (400), in mm. A precision of at least 0.1 mm is required.
ending TIME (Gage accumulation)	=	The time, each hour, when hourly radar and gage accumulations are required by the PRECIPITATION ADJUSTMENT [020] algorithm. A precision of at least 1/1200 hour is required.

2.2 ACQUISITION

RATE SCANs and FLAG (Zero Rate) are obtained from the PRECIPITATION RATE [018] algorithm.

Average TIMEs (Scan) for each RATE SCAN are obtained from the PRECIPITATION PREPROCESSING [017] algorithm.

Maximum TIME (Interpolation) and minimum TIME (Period) are system adaptation parameters and are based on empirical/theoretical studies.

ACCUMULATION SCANs (Period) are computed during PRECIPITATION ACCUMULATION algorithm passes and saved for periods ending any time after 1 hour prior to the previous average TIME (Scan). The previous average TIME (Scan) is the average scan time of the last good scan successfully collected prior to the current scan.

THRESHOLD (Hourly Outlier) is a seasonally dependent unit adaptation parameter based on empirical/theoretical studies.

PRECIPITATION STATUS MESSAGE including the TIME (Last Precipitation Detected) is obtained from the Precipitation Detection support function.

Ending TIME (Gage Accumulation) is a site adaptation parameter specified by the PRECIPITATION ADJUSTMENT [020] algorithm.

3.0 PROCEDURE

3.1 ALGORITHM

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BEGIN ALGORITHM  (PRECIPITATION ACCUMULATION)

1.0  COMPUTE (average TIME (Scan) difference)

     Clear FLAG (Zero Scan-to-Scan)

2.0  IF   (average TIME (Scan) difference) is less than maximum
          TIME (Interpolation)
       THEN
          IF   Current FLAG (Zero Rate) set
          AND  previous FLAG (Zero Rate) set)
             THEN
                Set FLAG (Zero Scan-to-Scan)
                Set all interpolated ACCUMULATION SCAN (Period)
                values to zero
          ELSE
             COMPUTE   (Interpolated ACCUMULATION SCAN (Period))
             Set ACCUMULATION SCAN (Scan-to-Scan) to interpolated
             ACCUMULATION SCAN (Period)
             WRITE  (ACCUMULATION SCAN (Scan-to-Scan))
          END IF
     ELSE
       COMPUTE   (beginning TIME (Missing Period))
       COMPUTE   (ending TIME (Missing Period))
       WRITE  (TIME (Missing Period))
       IF   (previous FLAG (Zero Rate) set)
          THEN Set all forward extrapolated ACCUMULATION SCAN
               (Period) values to zero
       ELSE
          COMPUTE   (forward extrapolated ACCUMULATION SCAN
                    (Period))
       END IF
       IF   (current FLAG (Zero Rate) set)
          THEN Set all backward extrapolated ACCUMULATION SCAN
               (Period) values to zero
       ELSE
          COMPUTE   (backward extrapolated ACCUMULATION SCAN
                    (Period))
       END IF
       IF   (last FLAG (Zero Rate) set AND current FLAG (Zero
            Rate) set)
          THEN Set FLAG (Zero Scan-to-Scan)
       ELSE
          COMPUTE   (ACCUMULATION SCAN (Scan-to-Scan))
          WRITE  (ACCUMULATION SCAN (Scan-to-Scan))
       END IF
     END IF

3.0  WRITE (FLAG (Zero Scan-to-Scan))
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4.0  Replace ending TIME (Accumulation) with current average TIME
     (Scan)

5.0  IF   (ending TIME (Gage Accumulation) has occurred since the
          previous average TIME (Scan) AND before or at the
          current average TIME (Scan))
       THEN Replace ending TIME (Accumulation) with the ending
            TIME (Gage Accumulation)
     END IF

6.0  IF   (End of clock hour occurred since the previous average
          TIME (Scan) AND before or at the current average TIME
          (Scan))
       THEN Replace ending TIME (Accumulation) with the end time
            of the most recently completed clock hour
     END IF

7.0  Set Beginning TIME (Accumulation) equal to Ending TIME
     (Accumulation) minus one hour

8.0  COMPUTE   (total TIME (Period))

9.0  Clear FLAG (No Hourly Accumulation)

10.0 IF   (total TIME (Period) is greater than minimum TIME
          (Period))
       THEN Clear FLAG (Zero Hourly Accumulation)
       IF   (TIME (Last Precipitation Detected) is before
            beginning TIME (Accumulation))
         THEN Set FLAG (Zero Hourly Accumulation)
       ELSE
         COMPUTE   (ACCUMULATION SCAN (Hourly))
         DO FOR ALL  (SAMPLE VOLUMEs)
           IF   (SAMPLE VOLUME value from ACCUMULATION SCAN
                (Hourly) is greater than THRESHOLD (Hourly
                Outlier) AND all eight adjoining SAMPLE VOLUME
                values are less than the THRESHOLD (Hourly
                Outlier))
             THEN
               COMPUTE   (interpolated ACCUMULATION (Hourly))
                         for that SAMPLE VOLUME
               Replace Accumulation SCAN (Hourly) for that
               SAMPLE VOLUME with interpolated Accumulation
               (Hourly)
               Keep count of the NUMBER (Interpolated
               Accumulation Outlier)
           END IF
         END DO
         WRITE   (NUMBER (Interpolated Accumulation Outlier))
         WRITE   (ACCUMULATION SCAN (Hourly))
       END IF
       WRITE  (FLAG (Zero Hourly Accumulation))
     ELSE
       Set FLAG (No Hourly Accumulation)
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END IF

11.0 WRITE (Flag (No Hourly Accumulation))

END ALGORITHM (PRECIPITATION ACCUMULATION)

3.2 COMPUTATION

3.2.1 NOTATION

TSavgdif	=	average TIME (Scan) difference, the difference in time at which scans were taken, in hours to the nearest 1/1200 hour.
TSavgcur	=	current average TIME (Scan), the average TIME (Scan) time of the current RATE SCAN (or implied zero RATE SCAN if FLAG (Zero Rate) set), to at least 1/1200 hour.
TSavepre	=	previous average TIME (Scan), the average TIME (Scan) of the last good RATE SCAN (or implied zero RATE SCAN if FLAG (Zero Rate) set), to at least 1/1200 hour.
AHint	=	interpolated ACCUMULATION (Hourly), the interpolated hourly radar precipitation accumulation using the eight neighboring sample volume accumulation values, in mm. Precise to at least 0.1 mm.
ASP	=	ACCUMULATION SCAN (Period), interpolated or extrapolated period precipitation accumulation on a 1 degree by 2 km polar grid from 1 to 230 km, in dBA. A precision of at least 0.1 mm and a dynamic range of at least 0 to 400 mm.
FHA	=	FLAG (Zero Hourly Accumulation), a set or cleared flag indicating, if set, that all current ACCUMULATION SCAN (Hourly) values can be assumed to be zero .
ASPint	=	interpolated ACCUMULATION SCAN (Period), the precipitation accumulations for the period from previous average TIME (Scan) to current average TIME (Scan) obtained by interpolation from the previous and current RATE SCANs, in mm. Precise to at least 0.1 mm.
ASPfwdext	=	forward extrapolated ACCUMULATION SCAN (Period), the precipitation accumulations for the period from previous average TIME (Scan) to beginning TIME (Missing Period) obtained

by extrapolation from the previous RATE SCAN, in mm. Precise to at least 0.1 mm.

ASPbacext = backward extrapolated ACCUMULATION SCAN (Period), the precipitation accumulations for the period from ending TIME (Missing Period) to current average TIME (Scan) obtained by extrapolation from the current RATE SCAN, in mm. Precise to at least 0.1 mm.

RSPcur = current RATE SCAN, the current precipitation rate data on a 1 degree by 2 km polar grid from 1 to 230 km, in mm/hr. A precision of at least 0.1 mm/hr and a dynamic range of at least 0 to 1600 mm/hr are required.

FNA = FLAG(No Hourly Accumulation), a set or cleared flag indicating, if set, that no hourly accumulations were computed for the hour ending at the current ending TIME (Accumulation).

FZS = FLAG (Zero Scan-to-Scan), a set or cleared flag indicating, if set, that all current ACCUMULATION SCAN (Scan-to-Scan) values can be assumed to be equal to zero.

RSPpre = previous RATE SCAN, the previous precipitation rate data on a 1 degree by 2 km polar grid from 1 to 230 km, in mm/hr. A precision of at least mm/hr and a dynamic range of at least 0 to 1600 mm/hr are required.

TMP = TIME (Missing Period), the beginning and ending times of any missing periods between the previous scan time and current scan time. Precise to 1/1200 hr.

TMPbeg = beginning TIME (Missing Period), the beginning times of any missing periods between the previous scan time and current scan time. Precise to 1/1200 hr.

TMPend = ending TIME (Missing Period), the ending times of any missing periods between the previous scan time and current scan time. Precise to 1/1200 hr.

TIPmax = maximum TIME (Interpolation), the maximum period over which a period accumulation scan can be computed using two precipitation rate scans, in hours. Approximately 0.5 hours with

a precision of at least 1/60th hour is required.

TPE = TIME (Period), the beginning and ending times for all ACCUMULATION SCAN (Period) data which are available, in hours. Precise to 1/1200 hr.

WFP = WEIGHT FACTOR (Period Accumulation), the time between the beginning of a period and the end of a period which covers a particular ACCUMULATION SCAN (Period), in hours. Precise to 1/1200 hr.

TPEbeg = beginning TIME (Period), the beginning time for a particular ACCUMULATION SCAN (Period). Precise to 1/1200 hr.

PEend = ending TIME (Period), the ending time for a particular ACCUMULATION SCAN (Period). Precise to 1/1200 hr.

TPEmin = minimum TIME (Period), the minimum period of time during an hourly accumulation period for which ACCUMULATION SCAN (Period) data are required in order to estimate the hourly accumulation, in hours. Precise to 1/60th hr. (approximately 0.90 hours).

ASS = ACCUMULATION SCAN(Scan-to-Scan), the total scan-to-scan accumulation data on a 1 degree by 2 kilometer polar grid from 1 to 230 kilometers. A precision of at least mm and dynamic range of at least 0 to 400 mm are required. Includes the previous average TIME (Scan) and current average TIME (Scan).

TAbeg = beginning TIME (Accumulation), the beginning time of an ACCUMULATION SCAN (Hourly). Precise to 1/1200 hr.

TAend = ending TIME (Accumulation), the ending time of an ACCUMULATION SCAN (Hourly). Precise to 1/1200 hr.

ASH = ACCUMULATION SCAN (Hourly), the hourly radar precipitation accumulation data for an hourly running period or clock hour on a 1 degree by 2 kilometer polar grid from 1 to 230 kilometers. A precision of at least 0.1 mm and a dynamic range of at least 0 to 1600 mm are required. Includes the beginning TIME (Accumulation) and ending TIME (Accumulation).

ACR = ACCUMULATION (Rainfall), the rainfall accumulation for a sample volume within a particular ACCUMULATION SCAN (Period), in millimeters. A precision of 0.01 mm and a dynamic range of 0 to 400 mm are required.

NAO = NUMBER (Interpolated Accumulation Outliers), the number of hourly accumulation sample volumes that contained hourly outliers which could be removed by interpolation.

TLD = TIME (Last Precipitation Detected), the time at which the Precipitation Detection support function last detected precipitation. Precise to 1/1200 hr.

Note: Precision will be units specified unless otherwise stated.

3.2.2 SYMBOLIC FORMULAS

COMPUTE (average TIME (Scan) difference)

TSavgdif = (TSavgcur - TSavgpre)

COMPUTE (interpolated ACCUMULATION SCAN (Period))

$$ASPint = 10.0 \log \left\lfloor \frac{TSavgdif\left(10^{RSPpre/10.0} + 10^{RSPcur/10.0}\right)}{2.0} \right\rfloor$$

for ranges 1 to 229 by 2 and azimuths 0 to 359 by 1.

where, TSavgdif is defined above and the quantities $10^{RSPpre/10.0}$ or $10^{RSPcur/10.0}$ are considered zero if the previous or current FLAG (Zero Rate) are set, respectively.

COMPUTE (beginning TIME (Missing Period))

$$TMPbeg = \left(TSavgpre + \frac{TIPmax}{2.0} \right)$$

COMPUTE (ending TIME (Missing Period))

$$TMPend = \left(TSavgcur - \frac{TIPmax}{2.0} \right)$$

COMPUTE (forward extrapolated ACCUMULATION SCAN (Period))

$$ASPfwdext = 10.0 \log \left\lfloor \frac{TIPmax}{2.0} \left(10^{RSPpre/10.0} \right) \right\rfloor$$

for ranges 1 to 229 by 2 and azimuths 0 to 359 by 1.

COMPUTE (backward extrapolated ACCUMULATION SCAN (Period))

$$ASPbacext = 10.0 \log \left\lfloor \frac{TIPmax}{2.0} \left(10^{RSPcur/10.0} \right) \right\rfloor$$

for ranges 1 to 229 by 2 and azimuths 0 to 359 by 1.

Note: Time from TMPbeg to TMPend is to be flagged as a missing period.

COMPUTE (ACCUMULATION SCAN (Scan-to-Scan))

$$ASS = 10.0 \log \left\lfloor 10^{ASPfwdext/10.0} + 10^{ASPbacext/10.0} \right\rfloor$$

for ranges 1 to 229 by 2 and azimuths 0 to 359 by 1.

COMPUTE (total TIME (Period))

$$TPE = \sum_n WFP_n$$

where,

sum is over all n ACCUMULATION SCAN (Period) which have end times (TPEend) after the beginning TIME (Accumulation).

WFP_n = MAX (0,(MIN(TPEend,TAend) - MAX(TPEbeg,TAbeg)))

COMPUTE (ACCUMULATION SCAN (Hourly))

$$ASH = 10.0 \log \left\lfloor MAX \left[10^{AZH/10,} \sum_n \frac{WFP_n}{TPEend_n - TPEbeg_n} \cdot ACR_n \right] \right\rfloor$$

where,
for ranges 1 to 229 by 2 and azimuths 0 to 359. The summation and WFP_n are defined above.

COMPUTE (interpolated ACCUMULATION (Hourly))

$$AHint = 10.0 \log \left\lfloor \frac{\sum_{n=1}^{8} 10^{ASH_n/10.0}}{8.0} \right\rfloor$$

where, sum (n) is over all eight neighboring ACCUMULATION SCAN (Hourly) sample volumes.

4.0 OUTPUTS

4.1 IDENTIFICATION

The ACCUMULATION SCAN (Hourly) (including the beginning TIME (Accumulation) and ending TIME (Accumulation)) is output unless the FLAG (Zero Hourly Accumulation) or FLAG (No Hourly Accumulation) is set. This scan contains an hourly running total or clock hour total precipitation accumulation scan set.

An ACCUMULATION SCAN (Scan-to-Scan) (including the previous average TIME (Scan) and current average TIME (Scan)) is output unless the FLAG (Zero Scan-to-Scan) is set.

A FLAG (Zero Scan-to-Scan), FLAG (Zero Hourly Accumulation), and FLAG (No Hourly Accumulation) are output.

Additionally, TIME (Missing Period), the beginning and ending times of any missing periods between the previous average TIME (Scan) and current average TIME (Scan) and NUMBER (Interpolated Accumulation Outliers), the number of outliers which were interpolated in the ACCUMULATION SCAN (Hourly), are included in SUPPLEMENTAL DATA.

4.2 DISTRIBUTION

The ACCUMULATION SCAN (Hourly), ending TIME (Accumulation), and ACCUMULATION SCAN (Scan-to-Scan) are input to the PRECIPITATION ADJUSTMENT [020] algorithm.

The FLAG (Zero Scan-to-Scan), FLAG (Zero Hourly Accumulation), and FLAG (No Hourly Accumulation) are input to the PRECIPITATION ADJUSTMENT [020] algorithm and the PRECIPITATION PRODUCTS [021] algorithm.

The FLAG(Zero Scan-to-Scan) is output to the FLASH FLOOD PRECIPITATION PROJECTION [030] algorithm.

5.0 INFERENCES

5.1 LIMITATIONS

Missing periods of data will reduce the accuracy of the accumulations.

5.2 FUTURE DEVELOPMENTS

Parameter values will be "fine tuned" using actual NEXRAD data.