PRECIPITATION PRODUCTS

ALGORITHM DESCRIPTION

NX-DR-03-021/26

1.0 PROLOGUE

1.1 FUNCTIONAL DESCRIPTION

The PRECIPITATION PRODUCTS [021] creates Hydrometeorological products from hourly and scan-to-scan accumulations generated by the PRECIPITATION ACCUMULATION [019] algorithm and adjusted by the current BIAS computed by the PRECIPITATION ADJUSTMENT [020] algorithm if FLAG (apply BIAS) is set. Digital, graphical, and alphanumeric products are generated. The digital product is an hourly running total or clock hour accumulation mapped to a 1/40th Limited Fine Mesh (LFM) rectangular (approximately 4 km by 4 km) grid. The graphical products are (1) an hourly running total or clock hour accumulation, (2) a three hour total accumulation generated on the clock hour, and (3) a storm total accumulation. The graphical products are all displayed at a resolution of 2 kilometers by 1 degree.. The alphanumeric Supplemental Precipitation Data product is displayed in ASCII format. The graphical and alphanumeric products are designed primarily for display at the Principle User Processor (PUP), while the digital product is designed for use on external computer systems. (Other products pertaining to the Precipitation Processing Series (PPS), including the Digital Hybrid Scan Reflectivity product, the Digital Storm Total Rainfall Accumulation product, and the User Selectable Precipitation Accumulation product, are described in additional documents, including the RPG/Associated PUP ICD and the Product Specification ICD.)

The hourly running totals or clock hour totals on the 1/40th LFM grid are obtained by determining the mean of all adjusted ACCUMULATION SCAN (Hourly) sample volumes whose polar coordinate centers fall within each 1/40th LFM grid box. At the far ranges where no sample volume centers fall inside a box, the sample volume value at the sample volume whose center is closest to the center of the grid box becomes the value at the grid box. Annotations are automatically added to identify the product and to provide information related to how the data used to generate this product were processed.

The hourly running totals or clock hour totals on the 2 km by 1 degree grid are scaled to 16 levels for use as a display and annotations are added automatically to produce the PRODUCT (Hourly Precipitation).

The three clock hour totals are computed hourly by summing the available individual clock hour totals for the past three hours. At least two of the three hours of data must be available and missing periods should be noted. The data are then scaled to 16 accumulation levels for use as a display, and annotations are added automatically to produce the PRODUCT (Three Hour Precipitation).

The storm total (total precipitation since the last one hour break in significant precipitation) is generated whenever certain scan-to-scan accumulation parameters are exceeded. It is then updated using each ACCUMULATION SCAN (Scan-to-Scan) received until being reset after a one hour break in significant precipitation. If FLAG (apply BIAS) is set, the ACCUMULATION SCAN (Scan-to-Scan) are adjusted using the computed BIAS. The data is then scaled to 16 levels for use as a display and annotations are added automatically to produce the PRODUCT (Storm Total Precipitation).

1.2 SOURCE

The PRECIPITATION PRODUCTS algorithm was developed by the Radar Hydrology Group of the National Weather Service's Hydrologic Research Laboratory. This algorithm is 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 with which weather radar data could be better used for hydrometeorological purposes.

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 Radar Meteor. Conf., AMS, Boston, Mass.

1.3 PROCESSING ENVIRONMENT

The ARRAY PRODUCT (Digital Precipitation) on the 1/40th LFM grid provides hourly running total or clock hour total precipitation accumulation estimates in a digital array format to support hydrometeorological requirements for numerical use of precipitation data in computers external to the NEXRAD RPG. This format is not compatible with PUP displays. In addition to the precipitation array data, an extensive set of annotations (IDENTIFIER INFORMATION and SUPPLEMENTAL DATA) will be included automatically as part of this product. This information is intended for use in higher level (regional/national) processing to identify certain characteristics about the data up to that point in the processing stream. It will be used as part of the information for accomplishing more discriminating quality control functions at the higher level of processing.

The Limited Fine Mesh (LFM) grid is a rectangular grid commonly used by the National Weather Service which is based on a polar stereographic projection. An LFM grid box represents an area whose size and shape varies with latitude. Therefore the size and shape of the grid boxes will vary slightly over the area covered by the radar and even more from radar to radar (3.5 to 4.5 km over the conterminous U.S. for the 1/40th LFM grid. The 1/40th LFM grid boxes used here are defined to have 1/40th LFM grid points as their centers and a mesh length of 4.7625 km at 60° N latitude. The information required to generate the grid for each site are the latitude and longitude of the radar, the mesh length at 60° N latitude (the standard latitude), and the standard longitude (105° W)).

In order to cover the radar umbrella out to 230 km even at the lower latitudes of the conterminous United States, a 131 by 131 array of 1/40th LFM grid boxes will be required. This array will always be 131 by 131 regardless of the latitude of the site. This grid should be positioned in such a way that the radar site falls within the grid box (66,66). The ARRAY PRODUCT (Digital Precipitation) must be compacted (e.g., elimination of all 0 rows, run length encoding of rows) to reduce storage and especially communications loadings. Compaction must be done in such a way that the source 131 by 131 array can be reconstructed with the use of nominal computer resources. The 1/4th LFM area averaged precipitation rate data (8 coded precipitation rate levels) for each scan used to generate the ARRAY PRODUCT (Digital Precipitation) will be automatically included as part of the annotations (SUPPLEMENTAL DATA) to the ARRAY PRODUCT (Digital Precipitation). The values for the 13 by 13 1/4th LFM grid were computed by the PRECIPITATION RATE [018] algorithm. These must be compacted subject to the constraints specified above.

The PRODUCT (Three Hour Precipitation) uses the PRECIPITATION TOTALs (Hourly) for the last three clock hours. In order to provide these products on a consistent basis, the method used to save the PRECIPITATION TOTALs (Hourly) must be safe, even from temporary system shutdowns and restarts.

The PRODUCT (Storm Total Precipitation) uses the previous set of PRECIPITATION TOTAL (Storm). Again, the method used to save these data must be safe, even from temporary shutdowns and restarts.

2.0 INPUTS

2.1 IDENTIFICATION

FLAG (apply BIAS) = A set or cleared flag indicating whether the bias should be applied.

Current BIAS = The current BIAS generated by the PRECIPITATION ADJUSTMENT [020] algorithm.

ACCUMULATION Scan (Hourly) = The hourly radar precipitation accumulation SCAN (Hourly) 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 1 mm and a dynamic range of at least 0 to 1600 mm are required. Includes the beginning TIME (Accumulation) and ending TIME (Accumulation).

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 for the period from the previous time to the current time. A precision of at least 0.1 mm and a dynamic range of at least 0 to 400 mm are required. Includes the previous average TIME (Scan) and current average TIME (Scan).

CATEGORY(Precipitation) = The precipitation category currently in effect.

CATEGORY	MEANING
0	No precipitation detected during the past hour
1	significant precipitation detected during the past hour
2	Light precipitation detected during the past hour

TIME (Stamp) = The time at which the Precipitation Detection support function was last executed. A precision of at least 1/1200 hour is required.

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.

TIME (Last Precipitation Detected) = The time at which the Precipitation Detection Function last detected precipitation. A precision of at least 1/1200 hour is required.

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 ACCUMULATION (Zero Interpolated).

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.

BOX (1/40th LFM Grid) = Rectangular grid box centered on 1/40th LFM grid points. At 60 degrees N the mesh length is 4.7625 km. Specifies the scan's sample volumes whose centers fall within each grid box. If

		none, the sample volume whose center is closest to the center of the grid box is specified. Grid boxes whose centers are more than 230 km from the radar are not assigned any sample volumes.
RATE (1/4th LFM Grid Box)	=	Area-average rate (8 level coded value) in eachn each 1/4 LFM grid square. A 13 by 13 grid of values for each RATE SCAN used in constructing the hourly accumulations.
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).
SUPPLEMENTAL DATA	=	A set of varied data, determined during the execution of the precipitation processing series algorithms, which will be included as part of an alphanumeric, PUP-displayable product. Elements of the data will also be included as annotations to the other precipitation products.
IDENTIFIER INFORMATION	=	Consists of annotations such as the radar I.D., product name, time (beginning and ending), date and missing period times. The times must be in hours and minutes GMT (Greenwich Mean Time).
GAGE REPORTs (Accumulator)	=	Reported values of accumulation in mm at each gage and time of occurrence (to the nearest 1/60 hour).
GAGE REPORTs (Incremental)	=	Reported values of incremental accumulation in mm, increment duration (hours to the nearest 1/60 hour) and time of occurrence (to the nearest 1/60 hour).
GAGE-RADAR SET	=	Set of associated pairs of hourly radar and hourly rain gage accumulations.

2.2 ACQUISITION

FLAG (apply BIAS) is a unit adaptation parameter.

Current BIAS is obtained from the PRECIPITATION ADJUSTMENT [020] algorithm.

The following are obtained from the PRECIPITATION ACCUMULATION [019] algorithm:

ACCUMULATION SCAN (Scan-to-Scan) ending TIME (Accumulation)
ACCUMULATION SCAN (Hourly)
FLAG (Zero Hourly Accumulation)
FLAG (Zero Scan-to-Scan)
FLAG (No Hourly Accumulation)

BOX (1/40th LFM Grid) is a unit adaptation parameter file which is automatically generated given the latitude and longitude of the site, mesh length at 60° N (4.7625 km), and the reference longitude (105° W).

SUPPLEMENTAL DATA are assembled from other algorithms within the precipitation processing system.

IDENTIFIER INFORMATION are obtained from a unit adaptation parameter file, assembled from other algorithms within the precipitation processing system (e.g. PRECIPITATION PREPROCESSING [017]), and obtained from system status and calibration files.
TIME (Stamp), PRECIPITATION STATUS MESSAGE, CATEGORY (Precipitation), and TIME (Last Precipitation Detected) are obtained from the Precipitation Detection support function.

RATEs (1/4 LFM Grid Box) are obtained from the PRECIPITATION RATE [018] algorithm.

GAGE REPORTs (Accumulator) and GAGE REPORTs (Incremental) are obtained from the Rain Gage Database maintained by the Gage Data Acquisition support algorithm.

GAGE-RADAR SET is obtained from the PRECIPITATION ADJUSTMENT [020] algorithm.

3.0 PROCEDURE

3.1 ALGORITHM

```
BEGIN ALGORITHM (PRECIPITATION PRODUCTS)

1.0   IF (FLAG (No Hourly Accumulation) not set)
      THEN
         IF (FLAG (Zero Hourly Accumulation) set)
         THEN  Set all ARRAY TOTALs (Digital Precipitation) to zero
         ELSE
            DO FOR ALL  (BOX (1/40th LFM Grid))
               COMPUTE  (ARRAY TOTAL (Digital Precipitation) elements)
            END DO
         END IF
         Combine ARRAY TOTAL (Digital Precipitation) and the RATEs (1/4 LFM
         grid Box) with the appropriate SUPPLEMENTAL DATA and IDENTIFIER
         INFORMATION to produce the ARRAY PRODUCT (Digital Precipitation)
         WRITE (ARRAY PRODUCT (Digital Precipitation))
         IF (FLAG (Zero Hourly Accumulation) set)
         THEN  Set all PRECIPITATION TOTALs (Hourly) to zero.
         ELSE
            COMPUTE  (PRECIPITATION TOTAL (Hourly))
         END IF
      END IF

2.0   IF Clock hour occurred since the previous average TIME (Scan) and before
         or at the current average TIME (Scan) AND PRECIPITATION
         TOTALs(Hourly) exist for at least 2 of the last 3 clock hours)
      THEN
         COMPUTE  (PRECIPITATION TOTAL (Three Hour))
      END IF

3.0   IF (CATEGORY(Precipitation) indicates precipitation has occurred during
         the past 1 hour)
      THEN
         IF (FLAG (Zero Scan-to-Scan) not set)
         THEN
            COMPUTE  (PRECIPITATION TOTAL (Storm))
         END IF
      ELSE
            Set all PRECIPITATION TOTAL (Storm) values to zero
      END IF

4.0   Combine SUPPLEMENTAL DATA, IDENTIFIER INFORMATION, GAGE_RADAR SET
      information and GAGE REPORTs to produce the displayable, alphanumeric
      PRODUCT (Supplemental Precipitation Data)

END ALGORITHM (PRECIPITATION PRODUCTS)
```

3.2 COMPUTATION

3.2.1 NOTATION

Bcur = Current BIAS generated by the PRECIPITATION ADJUSTMENT [020] algorithm.

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 for the period from the previous time to the current time. A precision of at least 0.1 mm and a dynamic range of at least 0 to 400 mm are required.

Includes the previous average TIME (Scan) and current average TIME (Scan).

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).

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

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.

PTHadj = PRECIPITATION TOTAL (Hourly) adjusted, the adjusted hourly precipitation total. If FLAG (apply BIAS) not set, the adjusted hourly total is set equal to the ACCUMULATION SCAN (Hourly).

PT3 = PRECIPITATION TOTAL (Three Hour), the three hour precipitation total.

SUP = SUPPLEMENTAL DATA, a set of data which will be included as annotations to the four precipitation products.

ID = IDENTIFIER INFORMATION, consists of annotations such as the radar I.D., product name, time (beginning and ending), date and missing period times. The times must be in hours and minutes GMT (Greenwich Mean Time).

APDP = ARRAY PRODUCT (Digital Precipitation), the hourly running total or clock hour total on a 1/40th LFM Grid out to 230 km in a 256 data level (8 bit) format. Product includes appropriate supplement data.

PSTcur = Current PRECIPITATION TOTAL (Storm), the current storm precipitation total, in mm. A precision of at least 0.1 mm and dynamic range of at least 0 to 1600 mm are required.

PSTpre = Previous PRECIPITATION TOTAL (Storm), the precipitation total computed previously, in mm. Precise to 0.1 mm.

Note: Precision will be units specified unless otherwise stated.

3.2.2 SYMBOLIC FORMULAS

COMPUTE (ARRAY PRODUCT (Digital Precipitation))

```
IF (FLAG (apply BIAS) set THEN
      APDP = (Sum of N (ASH * Bcur) / N
ELSE
      APDP = (Sum of N ASH) / N
ENDIF
```

where sum is over N ACCUMULATION SCAN (Hourly) sample volumes specified for a particular BOX (1/40th LFM Grid). Values of N may range from 0 to 360

depending on the location, size, and shape of the BOX (1/40th LFM Grid). When N = 0, APDP = 0.

COMPUTE (PRECIPITATION TOTAL (Hourly) adjusted)

For each ASH

```
IF (FLAG (apply BIAS) set) THEN
      PTHadj = ASH * Bcur
ELSE
      PTHadj = ASH
END IF
```

then use PTHadj to build PRECIPITATION TOTAL (Scaled Hourly) product.

Note. Reference Federal Meteorological Handbook, Number 11, Part C, Appendix A for all product data levels.

COMPUTE (PRECIPITATION TOTAL (Three Hour))

```
IF (FLAG (apply BIAS) set THEN
      PT3 = (Sum of N (ASH * Bcur)
ELSE
      PT3 = (Sum of N ASH)
ENDIF
```

where sum is over all N available clock hour PRECIPITATION TOTALs (Hourly) from the last three clock hours with ACCUMULATION SCAN (Hourly) values greater than zero.

COMPUTE (PRECIPITATION TOTAL (Storm))

```
IF (FLAG (apply BIAS) set) THEN
      PSTcur = PSTpre + (ASS * Bcur)
ELSE
      PSTcur = PSTpre + ASS
ENDIF
```

4.0 OUTPUTS

4.1 IDENTIFICATION

DATA ARRAY--

- The ARRAY PRODUCT (Digital Precipitation) providing, in compressed form, the hourly running total or clock hour total on a 131 by 131 1/40th LFM grid is output from this algorithm. The appropriate SUPPLEMENTAL DATA are: total number of isolated sample volumes, total number of replaced and interpolated outliers (reflectivity factor), mean percent area reduction and mean bi-scan ratio of all scans during the accumulation period, the number of bad scans during the accumulation period, the area-averaged precipitation rate in each 1/4 LFM grid box for each scan during the accumulation period, the number of interpolated outliers (hourly accumulations), the FLAG (apply Bias), the computed bias estimate and its estimation error variance.

GRAPHICAL--

- The PRODUCT (Hourly Precipitation) gives the hourly running total or clock hour total out to 230 km in a 16 level display compatible format. The appropriate SUPPLEMENTAL DATA are: radar bias estimate, the error variance of bias estimate and the FLAG (apply Bias).

- The PRODUCT (Three Hour Precipitation) gives the 3-hour total over the past 3 clock hours out to 230 km in a 16 level display compatible format. The appropriate SUPPLEMENTAL DATA are: the values of the three computed biases and the three error variances, and the FLAG (apply Bias).

- The PRODUCT (Storm Total Precipitation) depicts the total accumulations since the last one hour break in significant precipitation out to 230 km in a 16 level display compatible format. The appropriate SUPPLEMENTAL DATA are: the mean of bias estimates applied since the storm began and the mean estimation error variance occurring during the storm.

ALPHANUMERIC--

- The PRODUCT (Supplemental Precipitation Data) provides, in display-compatible, alphanumeric format, the following SUPPLEMENTAL DATA parameters for the current volume scan: number of isolated sample volumes, number of replaced and interpolated outliers (reflectivity factor), number of interpolated outliers (hourly accumulation), percent area reduction, bi-scan ratio, flag (bad scan), missing period indicator (with beginning and ending times if missing period present), computed bias estimate and its error variance, and flag (apply bias).

  It also provides GAGE-RADAR SET information, including the number of gage-radar pairs and, for each pair, the gage ID, its azimuth and range (from the radar), the hourly gage accumulation estimate and matching radar accumulation estimate (in inches, to nearest .01"), and an indicator as to whether the pair used in the BIAS determination.

  Furthermore, the product provides data from the RAIN GAGE DATABASE, including the present number of reporting gages, the date & time of last data base update, the ID, latitude, longitude, azimuth, range, gage type (accumulator or incremental) and number of reports for each gage and, for each report, the timestamp, value (in inches, to nearest .01"), and, for incremental-type gages, the duration (in minutes).

4.2 DISTRIBUTION

Rainfall estimates from this algorithm will be distributed to user sites and used as input to subjective and objective hydrometeorological forecast procedures for flash-flood watches and warnings, river stage monitoring, and water management information applications. Products derived by this algorithm will be distributed as follows:

The ARRAY PRODUCT (Digital Precipitation) will be transmitted automatically, once per hour (possibly as often as twice per hour), to the River Forecast Centers (RFCs) and as required to the Weather Forecast Office (WFOs) for input into computer based hydrometeorological models. Distribution will be directly from the Radar Product Generator (RPG) and from the Principal User External System (PUES) port at the Principal User Processor (PUP).

Graphical Display Products (PRODUCT (Hourly Precipitation), PRODUCT (Three Hour Precipitation), PRODUCT (Storm Total Precipitation)), as well as Alphanumeric Display Product (PRODUCT (Supplemental Precipitation Data)) - Distributed to WSFOs and RFCs through the PUP.

5.0 INFERENCES

5.1 LIMITATIONS

This algorithm does not provide sufficient intelligence required to distill and integrate heavy precipitation information into a flash flood alert map.

5.2 FUTURE DEVELOPMENTS

The addition of the capability to generate a flash flood alert map will be an important enhancement to consider for the future.

Also, current plans are to develop, based on the SUPPLEMENTAL DATA, IDENTIFIER INFORMATION, and possibly other data processing/quality information, a one or two digit quality status code which would always be displayed with the graphical products. This code would provide the viewer with important information on the processing and quality of the data.