F. Hydromet Raingage Correction

F.1 Overview

IRIS/Hydromet is an optional IRIS package for hydrometeorological applications. The standard IRIS features for hydrometeorological applications include:

- Display of rainfall rate in mm/hr or inches/hour for a Z–R relationship selected in the Product Configuration Menus for PPI, RHI, CAPPI, MAX and XSECT. The units selection is made by the color scale selection.
- RAIN1– hourly rainfall accumulation for selectable Z–R relationship. See **Section 2.9** on the RAIN1 product for details.
- RAINN– N-hour rainfall accumulation based on the hourly amounts. See **Section 2.10** on the RAINN product for details.

The additional features provided by the IRIS/Hydromet option are:

- CATCH product to provide precipitation average depth in subcatchment regions for selectable time periods. Subcatchment regions are defined similarly to overlays. CATCH products can be displayed as color-coded regions or as color-coded icons. In the Quick Look Window, you can right-click the mouse on a region or icon to see a bar graph representation of the subcatchment amounts by hour. See **Section 3.1** for details on the CATCH product.
- GAGE product input with raingage calibration. This feature allows the radar RAIN1 hourly accumulations to be calibrated to the actual rain that is measured in gages. The corrected RAIN1 products can then be used by the CATCH and RAINN products. GAGE products may also contain the ZR coefficient and exponent (by site) derived from disdrometer measurement or other source (see **Section 2.1.3**).
- RAIN1 gage correction algorithm F.5
- RAIN1 scheduling with gage correction F.6

In this appendix the features of the Hydromet option are discussed:

F.2 Hydromet Data Flow for Raingage Correction

Figure F–1 shows the data flow for the raingage correction which is described below:

- **Input from External Raingage Network**
  Raingage data are supplied by the customer in the form of files that are transferred automatically by the customer over the network to a directory that is defined by the IRIS **setup** utility (Input section). Each file should contain the total accumulation for the previous hour for all gages. The information that is required is described in **Section F.3** which describes the GAGE product data format.

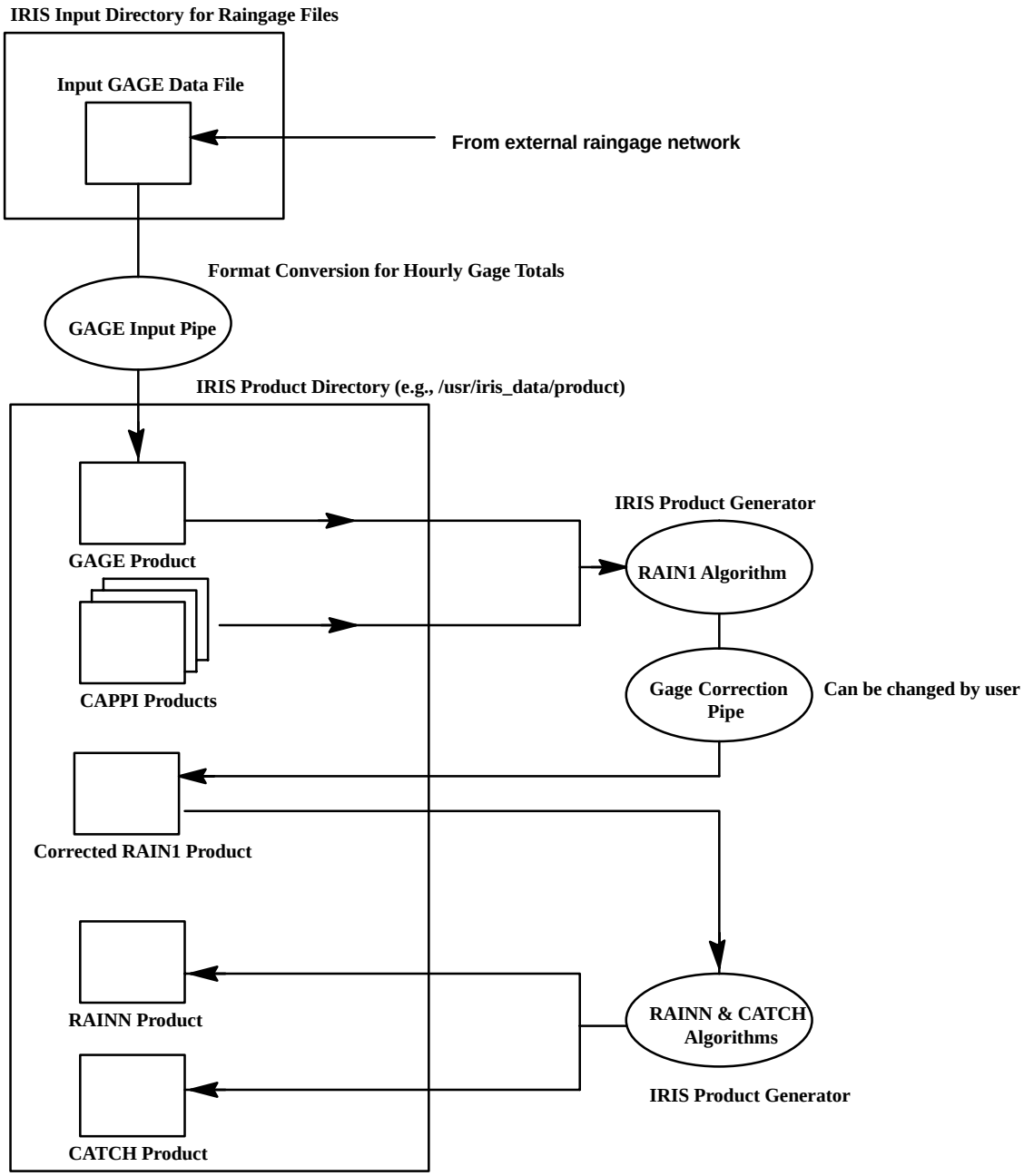
- **Input Pipe for Format Conversion to GAGE Product**
  The "Input Pipe" is a format convertor to reformat the customer data to the GAGE product format. The Input Pipe is specified in the **setup** Input section. It is a software program that will usually be customized for the particular raingage network. Customers can create their own pipes or SIGMET can provide the pipe "AsciiToGage", in which case the pipe source code is also provided so that customers can maintain the pipes in the future. Refer to the ***IRIS Programmers Manual*** for details on Input Pipes for IRIS.

- **GAGE Product**
  This is a product in IRIS that contains the raingage totals for all gages in the network for the last hour. The data format is described in **Section F.3**.

- **Input CAPPI's**
  The IRIS RAIN1 hourly rainfall accumulation product uses CAPPI's as input. the CAPPI's can be in dBZ, dBT or the corresponding rainfall rate according to a default Z–R relationship such as $Z=200R^{1.6}$. Usually a "Filled" pseudo CAPPI is used so that at far ranges the lowest elevation angle will be used to fill-in the data.

- **RAIN1 Processing and Raingage Calibration Process**
  Gage correction is activated when the gage correction button is turned on in the RAIN1 product configuration menu. In this case, the IRIS product generator waits for all of the CAPPI's and the GAGE product for the previous hour and then runs the RAIN1 algorithm. **Section F.6** describes the scheduling considerations for the RAIN1 algorithm with GAGE correction, i.e., how to handle the time delay of the arrival of the GAGE product. The RAIN1 algorithm proceeds normally per the description in **Section 2.9**. The extra step of the GAGE correction is done by a "Product Pipe" algorithm. SIGMET supplies an algorithm based on Brandes and Wilson (1982). Customers can supply their own product pipe correction algorithm in lieu of the one supplied by SIGMET. Refer to the *IRIS Programmers Manual* for details on Product Pipe algorithms.

Figure F–1: RAIN1 Raingage Correction Data Flow



- **Corrected RAIN1 Product**
  The raingage calibration process outputs the final corrected RAIN1 product which will then be used by the RAINN and the CATCH products. Note that an uncorrected RAIN1 product can be made by simply running the RAIN1 product (under a different name) with the gage correction button clicked–off. For example, name the uncorrected product HOURLY and the corrected product HOURLY–GAGE.
- **CATCH and RAINN Products**
  The RAIN1 product then serves as the basis for the RAINN and CATCH products. Also, WARN products can be run on the RAIN1. Thus all subsequent products that rely on RAIN1 for input get the benefit of the correction algorithm.

F.3 Gage Data File Format

The customer raingage data files should be sent automatically to a directory specified in IRIS setup/input for the input pipe. Typically, the data can be sent by ftp, rcp or using NFS. The file should contain the hourly gage totals for all of the gages along with other supporting housekeeping information required by the GAGE product such as date and time and raingage location.

The recommended input gage data format is described below. Note that this does not match the format of the GAGE product since the input pipe will reformat the product for IRIS. The basic information needs to be in the file, or in some cases in a separate configuration file for the input pipe. For details on the GAGE product format, refer to the *IRIS Programmer's Manual*. In general, the input pipe must be custom — written either by the customer or by SIGMET. This is the format used by SIGMET's **AsciiToGage** input pipe. Customers who wish to use another format must write their own custom input pipe.

The input data file format is described below:

- Each file is plain text ASCII, and the overall structure is a collection fields consisting of a keyword followed by one or more data values. This makes the format expandable, since new keywords can easily be added in the future, and each software reader can choose which set of keywords it needs to process.
- White space is used to separate the keywords and data values. Quotation marks may be used around a string value if there is a possibility that the string contains white space. Each line of the file is terminated by a "newline" character.
- Each file represents data from any number of stations, but only one data time will be reported in each file. That time is the ending time of the data, and is reported using the "TIME" and "SPAN" keywords in the first lines of the file. The fundamental time resolution is quantized to one-minute intervals.
- Each rain gage station report consists of a line containing at least the "CODE" and "LONLAT" keywords, plus either the "RRATE" or "RFALL" keyword. The "QUAL" and "REM" keywords are optional.

The keywords are as follows:

any comment

Any line beginning with at "#" is ignored, as well as all blank lines.

TIME yyyymmddhhmm

Gives the ending time for all of the stations reported in this file. The string of digits gives the year, month, day, hour, and minute. This keyword should appear only once at the beginning of the file.

SPAN nn

Gives the time span in decimal minutes for all of the data reported in this file. This keyword should appear only once at the beginning of the file. Currently IRIS only supports 60 minute spans.

CODE nnnnnn

Tells the station code for a rain gage. The code is an arbitrary string 15 or less characters long. This field must be present for each reported gage.

LONLAT nn.nnnnn nn.nnnnn

Tells the longitude and latitude of a rain gage. Longitude is a real number from –180 to +180, with positive values representing East longitude. Latitude is a real number from –90 to +90, with positive values representing North latitude. Any number of decimal digits of precision can be used. This field must be present for each reported gage.

RRATE nn.nnn

Tells the rain rate in millimeters/hour for a rain gage. Either the RRATE field or the RFALL field must be present for each reported gage.

RFALL nn.nnn

Tells the rain fall amount in millimeters for a rain gage. Either the RRATE field or the RFALL field must be present for each reported gage.

Z/R ccc.c e.ee

This is an optional field. It is only available from disdrometer type raingages which are capable of calculating a Z/R relationship. The 2 numbers are the constant and exponent in the equation $Z = CR^E$. When there is no rain, or the disdrometer is not

capable of making a measurement, the values of 0.0 should be sent for both numbers. This will be interpreted as a special flag to indicate that the default values should be used.

QUAL nn

Tells the data quality (0:Useless, 10:Best) for a rain gage report. This field is optional; if omitted the data quality is assumed to be "10" (Best).

REM xxxxxxxxxxx

Allows a comment to be inserted in the file. An arbitrary text field follows. Note that quotes should generally be used around comments if the comment itself might include white space.

The following example file gives rain gage data for five different sites during a 60-minute time span ending at 22:00 on 10 July 2000. Note that the exact columns and the numerical precision are allowed to vary, as are the order of keywords on each line.

```
REM "Example format of an IRIS Rain Gage input file"
TIME 200007102200  SPAN 60
CODE 001213  LONLAT 127.312533 38.172512 RRATE 4.5
CODE 000223  LONLAT 127.2223 38.2155 RRATE 2.2
CODE 000095  LONLAT 127.31 38.2283 RFALL 0.083
LONLAT 127.1214 38.1825 QUAL 0 RRATE 1.2 REM "Gage broken" CODE 000122
CODE 000109    RRATE 1.1 LONLAT 127.2884 38.1277
```

F.4 Configuration of RAIN1 with Raingage Correction

The configuration steps necessary to generate RAIN1 products with gage correction are detailed below.

1. Configuration of Input CAPPI Products

The RAIN1 algorithm starts with CAPPI products. Please refer to **Section 2.4** on the CAPPI product configuration for more information. Here are some considerations in how to optimize the CAPPI products for RAIN1 with GAGE correction:

- **CAPPI data type set to R based on Z**
  The input CAPPI should be made in rainfall rate units. This causes the CAPPI interpolation to be done on rainfall rate rather than on dBZ. Thus the weighting of the interpolation is linear in rainfall rate units. Use the corrected reflectivity factor "Z" (as opposed to the uncorrected reflectivity factor "T") so that you have the benefit of clutter correction and cancelation.
- **CAPPI resolution of approximately 1 km**
  The resolution of the RAIN1 product will be identical to that of the input CAPPI

product. SIGMET recommends that the maximum range for the CAPPI and the number of pixels be set to yield a resolution of approximately 1 km. For example, for a 240 maximum range, a 480 X 480 product would have 1 km resolution.

- **CAPPI height of approximately 1 km, Fill set to Yes (Pseudo CAPPI)**
  Select a single-level CAPPI height of approximately 1 km depending on the height of the surrounding terrain. Note that CAPPI heights are defined as height above a reference level that is usually set to sea level (in IRIS Setup/RCP). Enable the CAPPI Fill so that the CAPPI will be defined for near and far ranges where it is not possible to interpolate to 1 km.
- **Use default Z–R relationship of $Z=200R^{1.6}$**
  SIGMET recommends that the customer initially use a default $Z=200R^{1.6}$ as the default Z-R relationship in the CAPPI product. After some experience, the customer may choose to modify this to match their precipitation more closely. This relationship can be adjusted seasonally as well.

2. RAIN1 Product Configuration

For the RAIN1 product configuration select the input CAPPI's configured above. Use the same Z-R relationship in the RAIN1 product as was used for the CAPPI's. Click the gage correction button to on if you will be using gage correction.

3. GAGE Correction Configuration File (Rain1GageCor.conf)

The raingage correction algorithm uses a configuration file called Rain1GageCor.conf in the /usr/sigmet/config. A template can be found in /usr/sigmet/config_template/init directory and should be copied to /usr/sigmet/config at installation. An example is shown in figure F–2.

Figure F–2: Example of Rain1GageCor.conf file

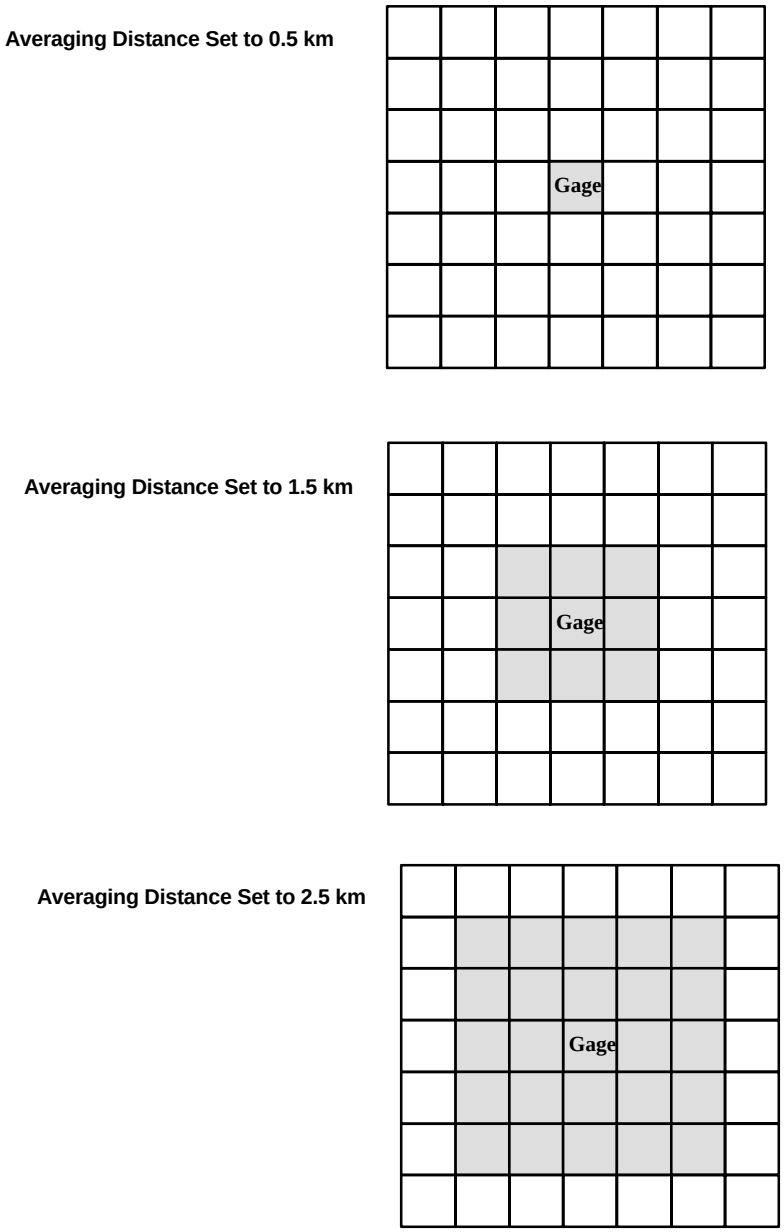
```
# Rain1GageCor.conf for the Rain1/GAGE correction program
LOG NONE
# OVERRIDE_PRODUCT_NAME JOE
# VERBOSE

MIN_VALID_GAGE 1.00

MIN_VALID_RADAR 1.00

MIN_CORRECTION  0.20
MAX_CORRECTION  5.00
```

The various fields are described here:

- **LOG**
  Configures where logging information goes to. Choices are NONE, TERM, FILE, or BOTH. FILE means place in the ${IRIS_LOG}/Rain1GageCor.log file.

- **MAX_CORRECTION**
- **MIN_CORRECTION**
  The maximum and minimum gage correction factors prevent large, possibly erroneous corrections from contaminating the data. The numbers are entered as factors such as 3 and 0.3 for the max and min respectively. In the event that the limit is exceeded, the algorithm will use the value of the limit, i.e., the correction factors will be saturated at the limit.
- **MIN_VALID_GAGE**
  This is the minimum amount of rainfall hourly accumulation for a gage to be considered as having a valid amount of rainfall. This will depend to some extent on the accuracy of the gages. A value of 3 mm would be typical. Note that this corresponds to approximately a one hour average reflectivity factor of 21 dBZ.
- **MIN_VALID_RADAR**
  This is the minimum RAIN1 accumulation, averaged about a gage that is valid. Radar precipitation accumulations less than this are considered invalid and no gage correction is calculated. This is similar to the Minimum Valid Gage Accumulation, except that in this case it is for the radar. A value of 3 mm would be typical.
- **MIN_VALID_COVERAGE**
  When the radar RAIN1 pixels about a gage are averaged (1, 9, 25, 49 pixels, etc.) to make a gage correction, not all of the pixels will generally be valid. If the percentage of valid pixels is less than this value, than a gage correction is not calculated. For example, if the Minimum Percentage is set to 50%, and averaging about a gage is over 3 X 3 pixels, then at lease 5 pixels must be valid for a gage correction to be generated.
- **OVERRIDE_PRODUCT_NAME**
  Use this command if you wish to change the product name of the RAIN1 product.
- **RADAR_AVERAGE**
  This is the distance in km around the raingage where the radar reflectivities shall be averaged. In the case where the input CAPPI resolution is 1 km (e.g., maximum range of 240 km and 480 X 480 pixels), setting the Averaging Distance to 1.5 km would result in averaging over 3 X 3 pixels centered about the pixel containing the gage. Examples are shown in **Figure F–3** below.

Figure F–3: Radar Data Averaging about a Raingage Location
(Input CAPPI pixel resolution set to 1 km for example)



4. IRIS Setup Configurations

- **Setup/Input to Configure the Raingage Input**
  Specify the input characteristics of the user raingage files including the directory where the files will arrive and the name of the Input Pipe that will be used to reformat the data into the IRIS GAGE product. Refer to the *IRIS Utilities Manual* section on setup/input for details. Note that depending on your system there may also be a ".conf" file for the Input Pipe. The input pipe will be stored in /usr/sigmet/config/pipes.

- **Setup/Product to Configure Default Z-R Relationship**
  Typically this is set to $Z=200R^{1.6}$ (input 200 and 1.6). However, you can set it differently based on local experience. Note that you can override this in the RAIN1 product configuration.

- **Setup/Product to Configure the GAGE Wait Time**
  This is the time required after the end of the hour for the GAGE product to be generated. The delay will be primarily caused by the delay in the arrival of the user raingage data over the network.

F.5 Algorithm for RAIN1 Gage Calibration

The raingage correction algorithm provided by SIGMET is modeled after Brandes and Wilson (1982). The algorithm uses a basic time step of one hour, i.e., GAGE totals for each hour are compared to the hourly radar totals (based on a default Z–R relationship) for the same hour. The ratio (1-hour gage accumulation/1-hour radar accumulation) is the correction factor for a gage. The RAIN1 product is then corrected by interpolating the correction factors for all of the gages to each pixel in the RAIN1 product and multiplying the radar pixel value by the correction factor. The basic algorithm steps are described below.

1. Gage Correction Factor Calculation for Each Gage

The gage correction is the ratio of the (1-hour gage accumulation)/(1-hour radar accumulation.

- The gage accumulation is taken from the GAGE product. It must be greater than the Minimum Valid Gage Accumulation for a gage correction factor to be calculated.
- The radar accumulation for the gage is calculated by first making an uncorrected RAIN1 product for the hour and then averaging the pixels surrounding the gage (according to the Averaging Distance, see **Figure F–3**). The pixels are averaged by summing only the valid (non-thresholded) pixels and then dividing by the number of valid pixels. For a gage correction to be calculated, the average rainfall accumulation must be greater than the Minimum Valid Radar Accumulation, and the number of valid (non-thresholded) pixels must be greater than the Minimum Percentage Radar RAIN1 Coverage.
- If both the gage and radar 1-hour accumulations are valid, then a gage correction is calculated for the gage. Otherwise, the gage is flagged as invalid.
- The maximum and minimum correction factor limits are then applied.
- This procedure is repeated for each gage.

2. Gage Correction Interpolation for Each Pixel

The gage correction factors are then applied to the uncorrected RAIN1 product to yield the final corrected RAIN1 output product. The technique is that the rainfall accumulation value at each pixel in the uncorrected RAIN1 product is multiplied by an average correction factor.

The average correction factor for a pixel is calculated from all gages by weighting the correction factor for each gage inversely with its distance from the pixel, i.e.,

$$\overline{C} = \frac{\sum \frac{C_i}{D_i}}{\sum \frac{1}{D_i}}$$

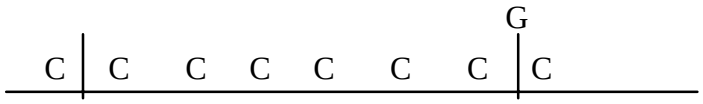
where $\overline{C}$ is the average gage correction for a pixel, C_i is the correction at a gage and D_i is the distance between the gage and the pixel. Note that the minimum value of D_i is fixed at 1 km.

F.6 RAIN1 Scheduling with Gage Product

The scheduling algorithm for generation of the RAIN1 product is different from the standard RAIN1 scheduling since the product generator must await the arrival of both the CAPPI's and the GAGE product for the previous hour. To account for the delay in the arrival of the GAGE product, a Gage Wait Time is input into IRIS **setup**/product. In the figures below this is noted as "WaitG".

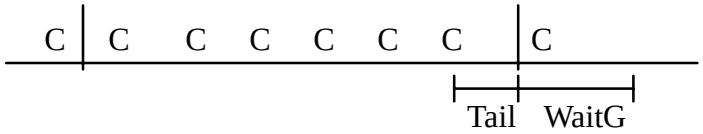
The notation shows a time line which represents the data time, i.e., in the case of a CAPPI, this is the time that the volume scan was started based on the clock on the radar computer which may be different than the clock on the computer where RAIN1 is being generated. In the case of a GAGE product this is the time exactly on the hour, at the end of the accumulation hour. Vertical bars show even hours.

Case 1A: Normal Case, CAPPI's and GAGE arrive



This is the normal case when both the CAPPI and the GAGE products arrive. The GAGE product actually arrives sometime after the hour, but in "Data Time" it is plotted exactly on the hour. The RAIN1 product is run as soon as the GAGE product arrives and the first CAPPI from the next hour arrives.

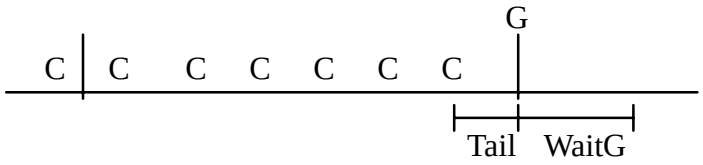
Case 1B: CAPPI'S arrive, but GAGE does not



Here the GAGE product does not arrive. The RAIN1 product will run (without GAGE correction) when the local time on the product computer is past the arrival time of the last input CAPPI plus the Tail and WaitG times. The Tail time is difference between the data time of the last input and the next integer hour. The WaitG time is the "Raingage Arrival Wait Time" from **setup**/product.

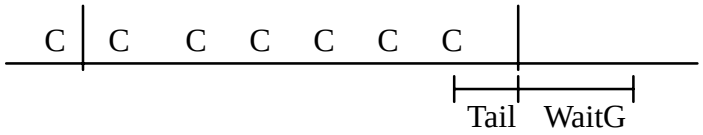
Note that if the GAGE product eventually arrives, it will be ignored.

Case 2A: GAGE arrives, but the first CAPPI in the next hour does not



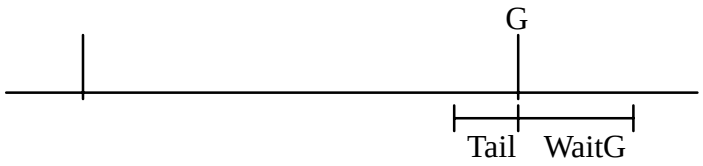
This is similar to the previous case. In this case, after the Tail and WaitG times have elapsed, the product runs using the available CAPPI's in the prior hour. There will be a GAGE correction and the RAIN1 algorithm will use all of the available CAPPI's in the hour.

Case 2B: Neither GAGE nor the first CAPPI in the next hour arrive



This is nearly identical to the Case 2A, i.e., after the Tail and WaitG times have elapsed, the product runs using the available CAPPI's in the prior hour except that there will be no GAGE correction.

Degenerate Case: No CAPPI's ever arrive



In this case, no RAIN1 product is generated.

F.7 References

Brandes, E. A. and J. W. Wilson, 1982: Thunderstorms: A social, Scientific and Technological Documentary; Vol 3: Instruments and Techniques for Thunderstorm Observation and Analysis. E. Kessler, Editor. U.S. Department of Commerce, NOAA Environmental Research Laboratories.