



# **Product User Manual for the “Convective Rainfall Rate” (CRR - PGE05 v4.0)**

SAF/NWC/CDOP2/INM/SCI/PUM/05, Issue 4, Rev. 0.1

*4 December 2014*

*Applicable to SAFNWC/MSG version 2013*

**Prepared by AEMET**

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## DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
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3.0	2 March 2009	30	<p>Initial version (content derived from Software User Manual for PGE05 (Convective Rainfall Rate) of the SAFNWC/MSG: scientific part)</p> <p>Indications and recommendations given by the DRI MSG 2009 have been included.</p>
3.1	11 May 2010	32	<p>Document updated for the SAFNWC/MSG PGE05 v3.1.</p> <p>CRR rain rate algorithm retrieval updated to work using lightning data information (SPR 374 / SMR 352).</p>
3.1.1	1 April 2011	33	<p>Minor changes done according to action MSG-DRI2010-10. No scientific updates, adapted date, issue and rev. to v2011.</p>
3.1.2	15 February 2012	33	<p>Minor changes done according to SPR 485/SMR 457. No scientific updates, adapted date, issue and rev. to v2012.</p>
4.0.1	4 December 2014	29	<p>Modifications for PGE05 v4.0:</p> <ul style="list-style-type: none"> <li>• Calibration matrices have been substituted by analytical functions.</li> <li>• A tuning of the calibration analytical functions has been done.</li> <li>• The CRR classes output includes a new class and colour palette.</li> <li>• The CRR hourly accumulations output provides precipitation accumulations from 0.0 to 51.0 mm with a step of 0.2 mm and includes a new colour palette.</li> <li>• The CRR intensity in mm/h output provides rain rates from 0.0 to 51.0 mm/h with a step of 0.2 mm/h and includes a new colour palette.</li> <li>• Modification of ComputeAccum.c related to SPR 505/SMR 480.</li> </ul> <p>Indications and recommendations given by the NWC SAF SW Package MSG 2013 DRR have been included.</p>


4.0.1	4 December 2014	29	Update of the information about NWP data needed for the running of CRR algorithm.
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## 1. INTRODUCTION

The EUMETSAT “Satellite Application Facilities” (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (<http://www.eumetsat.int>). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, NWC SAF. The main objective of NWC SAF is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the NWC SAF webpage, <http://www.nwcsaf.org>. This document is applicable to the NWC SAF processing package for Meteosat satellites, SAFNWC/MSG.

### 1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual (PUM) for the MSG product PGE05 (CRR) and contains practical information on the characteristics of the product, including the input data and the output product. It also gives information about the algorithm’s implementation and configuration.

### 1.2 SCOPE OF OTHER DOCUMENTS

The Algorithm Theoretical Basis Document contains information about the product objectives, the algorithm scientific description, the needed input data and the output product [AD.1].

The Validation Report version v1.0 of the PGE05 document [AD.2], showing the validation results for PGE05 v4.0, that gives information about the extended validation performed over Spain for a complete year.

The Interface Control Documents ICD/1 [AD.3] describes the External and Internal Interfaces of the SAFNWC/MSG software.

The Interface Control Documents ICD/3 [AD.4] defines the format of the output products generated by the SAFNWC/MSG software.

The Architectural Design Document [AD.5] presents the general architecture of the SAFNWC software, and gives details on each PGE (interface with the SAFNWC software, architecture of each PGE).

### 1.3 SOFTWARE VERSION IDENTIFICATION

This document describes the algorithm implemented in the PGE05 version v4.0 of SAFNWC software package delivery.

### 1.4 IMPROVEMENTS FROM PREVIOUS VERSION

A change has been applied in the algorithm retrieval of rain rates without changing the physical base. Calibration matrices have been substituted by analytical functions. Also, a tuning of the calibration analytical functions has been done against radar data. For this purpose radar data from BALTRAD, Spanish and Hungarian radar networks have been used.

Modification in the outputs:

- A new class has been included in the CRR Classes output. The interval of this new class is from 0.2 to 1 mm/h. The colour palette has been modified accordingly.
- The CRR hourly accumulations output provides precipitation accumulations from 0.0 to 51.0 mm with a step of 0.2 mm. The colour palette of this output has been modified to include values from 0.2 mm.
- The CRR intensities output provides rainfall rates from 0.0 to 51.0 mm/h with a step of 0.2 mm/h and includes a colour palette.

The improvements are shown in the Validation Report [AD.2].

## 1.5 ACRONYMS

ATBD	Algorithm Theoretical Basis Document
CRR	Convective Rainfall Rate
BALTRAD	Baltic Radar Network
CSI	Critical Success Index
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Ratio
HRIT	High Rate Information Transmission
ICD	Interface Control Document
INM	Instituto Nacional de Meteorología
IR	Infrared
MAE	Mean Absolute Error
ME	Mean Error
MSG	Meteosat Second Generation
NWCLIB	Nowcasting SAF Library
OMSZ	Hungarian Meteorological Service
PC	Percentage of Corrects
PGE	Product Generation Element
POD	Probability of Detection
PUM	Product User Manual
PWRH	Moisture Correction Factor
RAINSAT	Rainfall Satellite Technique
RMS	Root Mean Square error
RR	Rain Rate
SAF	Satellite Application Facility
SAF NWC	Satellite Application Facility for Nowcasting
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SUM	Software User Manual
SW	Software



2-V                    2-Variable  
3-V                    3-Variable  
VIS                    Visible  
WV                    Water Vapour

## 1.6 REFERENCES

### 1.6.1 Applicable Documents

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.


Reference	Title	Code	Vers	Date
[AD.1]	Algorithm Theoretical Basis Document for “Convective Rainfall Rate” (CRR - PGE05 v4.0)	SAF/NWC/CDOP2/INM/SCI/ATBD/05	4.0	15/07/13
[AD.2]	Validation Report for “Convective Rainfall Rate” (CRR-PGE05 v4.0)	SAF/NWC/CDOP2/INM/SCI/VR/12	1.0	15/07/13
[AD.3]	Interface Control Document for the External and Internal Interfaces of the SAFNWC/MSG	SAF/NWC/CDOP2/INM/SW/ICD/1	7.0	15/07/13
[AD.4]	SAFNWC/MSG Output Products Format Definition	SAF/NWC/CDOP2/INM/SW/ICD/3	7.0	15/07/13
[AD.5]	Architectural Design Document for the AEMET- related PGEs of the SAFNWC/MSG	SAF/NWC/CDOP2/INM/SW/AD/4	7.0	15/07/13
[AD.6]	NWC SAF Product Requirements Document	NWC/CDOP2/SAF/AEMET//MGT/PRD	1.2	15/07/13

*Table 1: List of Applicable Documents*

### 1.6.2 Reference Documents

Reference	Title
[RD.1]	
[RD.2]	

*Table 2. List of Reference Documents*

	Product User Manual for the “Convective Rainfall Rate” (CRR -PGE05 v4.0)	<b>Code:</b> SAF/NWC/CDOP2/INM/SCI/PUM/05 <b>Issue:</b> 4.0.1 <b>Date:</b> 4 December 2014 <b>File:</b> SAF-NWC-CDOP2-INM-SCI-PUM-05_v4.0.1 <b>Page:</b> 10/29
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## 2. DESCRIPTION OF THE CONVECTIVE RAINFALL RATE (CRR) PRODUCT

### 2.1 GOAL OF THE CONVECTIVE RAINFALL RATE (CRR) PRODUCT

The CRR algorithm developed within the SAF NWC context estimates rainfall rates from convective systems, using IR, WV and VIS MSG SEVIRI channels and calibration analytical functions generated from both SEVIRI and Radar data.

This product can be obtained for every SEVIRI slot that is every 15 minutes in the normal mode. It is also prepared to run in the Rapid Scan mode with a temporal resolution of 5 minutes.

### 2.2 ALGORITHM OUTLINE OF CONVECTIVE RAINFALL RATE (CRR)

#### 2.2.1 Processing of the Convective Rainfall Rate (CRR)

The basic CRR mm/h value for each pixel is obtained from calibration analytical functions.

Calibration analytical functions are generated by combining SEVIRI and Radar data. Composite radar data are compared pixel by pixel with geographically matched MSG data in the same resolution, and the rainfall rate RR is obtained, as a function of two or three variables (IR brightness temperature, IR-WV brightness temperature differences and normalised VIS reflectances):

$$RR = f(IR, IR-WV, VIS), \text{ for 3-V calibration}$$

$$RR = f(IR, IR-WV), \text{ for 2-V calibration}$$

A filtering process is performed in order to eliminate stratiform rain data which are not associated to convective clouds: the obtained basic CRR data are set to zero if all the pixels in a grid of a selected semisize (def. value: 3pix) centred on the pixel have a value lower than a selected threshold (def. value: 3mm/h). The threshold and the size of the grid can be modified by the user through the model configuration file.


To take into account the temporal and spatial variability of the cloud tops, the amount of moisture available to produce rain and the influence of orographic effects on the precipitation distribution, several correction factors can be applied to the basic CRR value by the users. So that, the possible correction factors are the moisture correction, the cloud top growth/decaying rates or evolution correction, the cloud top temperature gradient correction, the parallax correction and the orographic correction.

At this stage, the CRR precipitation pattern computed in the previous step is combined with a precipitation pattern derived through a lightning algorithm.

At the end of the process the final values of the CRR rainfall rates are used in order to obtain five different outputs as described in section 2.3.

#### 2.2.2 Convective Rainfall Rate (CRR) correction factors

##### Moisture Correction Factor

 <p>NWC SAF Agencia Estatal de Meteorología</p>	<p>Product User Manual for the “Convective Rainfall Rate” (CRR -PGE05 v4.0)</p>	<p><b>Code:</b> SAF/NWC/CDOP2/INM/SCI/PUM/05  <b>Issue:</b> 4.0.1      <b>Date:</b> 4 December 2014  <b>File:</b> SAF-NWC-CDOP2-INM-SCI-PUM-05_v4.0.1  <b>Page:</b> 11/29</p>
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When thunderstorms take place in quite moist environments the computed rainfall rate should be greater than when they occur in dry air masses. To consider this effect a moisture correction factor has been developed. It adjusts the estimates when the air is dry or quite moist. This factor has been defined as the product of the total precipitable water, PW, in the layer from surface to 500 hPa. by the relative humidity, RH, (mean value between surface and 500 hPa. level), obtained from a numerical model.

An environment is considered to be dry if PWRH is significantly below 1.0 and quite moist if PWRH is greater than 1.0.

The PWRH factor decreases rainfall rates in very dry environments and increases them in very moist ones.

#### Cloud Growth Rate Correction Factor

Convective rain is assumed to be associated with growing clouds exhibiting overshooting tops. Consecutive satellite IR images are used to indicate vertically growing and decaying cloud systems.

The cloud growth correction factor, also designated as evolution correction factor, only changes the magnitude of the rain rate through a coefficient if the analysed pixel becomes warmer in the second image. The coefficient value can be modified by the user through the keyword COEFF\_EVOL\_GRAD\_CORR\_00 in the model configuration file (Default value for Normal Mode (0.35) is set in the configuration file. Recommended value for Rapid Scan mode is 0.55).

The cloud growth rate correction factor can not be applied when consecutive images are not available. In this case the alternative method of Cloud-top Temperature Gradient Correction is applied.

#### Cloud-top Temperature Gradient Correction Factor

This alternative correction method is based on the fact that much information can be extracted from the cloud-top structure on a single IR image.


This correction factor, also designated as gradient correction factor, is based on a search of the highest (coldest) and lowest (less cold) cloud tops. The idea is to search for the pixels that are below the average cloud top surface temperature (local temperature minima) and assume these pixels indicate active convection associated with precipitation beneath.

The hessian of the temperature field is analysed for each pixel with a temperature lower than 250K, in order to search for those pixels with extreme values as is explained in the Algorithm Theoretical Basis Document [AD.1]. Rain rate corresponding to those pixels which have a maximum (meaning that are warmer than its surroundings) is modified by multiplying a coefficient. The value of that coefficient can be selected by the user through the keyword COEFF\_EVOL\_GRAD\_CORR\_01 in the model configuration file (Default value: 0.25). In those pixels which have neither a local IR temperature maximum nor minimum, the rain rate is modified through a coefficient controlled by the keyword COEFF\_EVOL\_GRAD\_CORR\_02 (Default value: 0.50). Otherwise rain rate is not modified.

#### Parallax correction

To apply the orographic correction factor is necessary to know the exact cloud position with respect to the ground below. This is not a problem when a cloud is located directly below the satellite; however, as one looks away from the sub-satellite point, the cloud top appears to be farther away from the satellite than the cloud base. This effect increases as you get closer to the limb and as clouds get higher.

The parallax correction depends on three factors: a) the cloud height, b) the apparent position on the earth of that cloud and c) the position of the satellite.

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The last two factors are known, but the first one has to be estimated. Two height estimation methods have been studied: numerical model and climatological profile obtained from the 1962 standard atmosphere model. Both of them are based on the conversion of each IR10.8 brightness temperature to height. By default, height is estimated using NWP data.

When the Parallax Correction is working, a spatial shift is applied to every pixel with precipitation according to the basic CRR value. If in this re-mapping process two pixels of the original image are assigned to the same pixel of the final image, the algorithm takes the maximum value of the rainfall rate, and if a pixel of the final image is not associated to any pixel of the original image (a “hole” appears in the final image), the software identifies the pixels with “hole” and assigns to them a value of the rainfall rate that is the result of applying a 3x3 median filter centred on the hole pixel.

### Orographic correction factor

Local topography has long been recognised to have an effect on the distribution and intensity of precipitation. However, the rain induced by orographic forcing is a complex process associated with complicated flows. Rainfall amounts are dependent on the atmospheric flow over the mountains and on the characteristics of the flow disturbances created by the mountains themselves.

This correction factor uses the interaction between the wind vector (corresponding to 850 hPa level from the NWP) and the local terrain height gradient in the wind direction to create a multiplier that enhances or diminishes the previous rainfall estimate, as appropriate.

### **2.2.3 Lightning algorithm**

As lightning activity is related with convection, this information has been added to the product. Only Cloud-to-Ground lightning flashes provided by ground based lightning detection networks are used by this algorithm.

To incorporate this information into the product a rain rate has been assigned to every lightning depending on:

- the time distance ( $\Delta\tau$ ) between the lightning event and scanning time of the processing region centre.
- the location of the lightning
- the spatial density of lightning in a time interval

Once the precipitation pattern has been computed, it is compared to the CRR precipitation pattern in order to obtain the final product. This final product contains the highest rain rate of the two.

The CRR lightning algorithm and the coefficients applied have been derived for Spain using the lightning information from the AEMET lightning detection network.

Ground based lightning detection networks provide information with different performances in detection efficiency and location accuracy. For this reason, the keyword APPLY\_LIGHTNING in the model configuration file is set to 0 and by default the lightning information is not used.

Before to use the lightning algorithm it is highly recommended to the user to adapt the lightning coefficients to the specific performances of the used lightning detection network through the appropriate keywords in the model configuration file.

## 2.3 DESCRIPTION OF THE CONVECTIVE RAINFALL RATE (CRR) OUTPUTS

CRR product is coded in HDF5 format. The available outputs are the following:

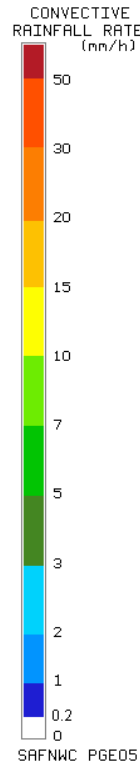
CRR:

The rainfall rates obtained by the CRR algorithm expressed in mm/h are converted into twelve classes as it is shown bellow:

CLASSES	RAINFALL RATE (mm/h)
0	rate < 0.2
1	0.2 = rate < 1
2	1 = rate < 2
3	2 = rate < 3
4	3 = rate < 5
5	5 = rate < 7
6	7 = rate < 10
7	10 = rate < 15
8	15 = rate < 20
9	20 = rate < 30
10	30 = rate < 50
11	rate ≥ 50

*Table 3. CRR classes*

This output includes the following palette:



*Figure 1. CRR palette*

***CRR\_ACCUM:***

Rainfall rates from the images in the last hour are used in order to compute the hourly accumulations. This output provides precipitation accumulations from 0.0 to 51.0 mm with a step of 0.2 mm and includes a palette that uses the same thresholds and colours as the classes output palette.

***CRR\_INTENSITY:***

Rainfall rates in mm/h are necessary to calculate the hourly accumulations. This output provides rainfall rates from 0.0 to 51.0 mm/h with a step of 0.2 mm/h and includes a palette that uses the same colours as the classes output palette.

***CRR\_QUALITY:***


8 bits mask indicating which corrections have been applied for each pixel. Moreover, it indicates whether the product is latitude dependant or not, and if the SEVIRI solar channel and the lightning information have been used during the computation of the CRR:

1 bit for moisture correction:

- 0: No correction
- 1: Corrected by PWHR factor

1 bit for cloud growth rate correction:

- 0: No correction
- 1: Corrected by IR data from previous slot

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1 bit for cloud top temperature correction:

0: No correction

1: Corrected by IR temperature gradient

1 bit for parallax correction:

0: No correction

1: Corrected by parallax

1 bit for orographic effect correction:

0: No correction

1: Corrected by orographic effects

1 bit for latitude dependant:

set always to 1 since dependency on latitude is always taken into account

1 bit for solar channel used:

0: No solar channel used

1: Solar channel used

1 bit for lightning information used:

0: No lightning information used

1: Lightning information used

### ***CRR\_DATAFLAG:***

8 bits mask indicating the processing status of each pixel:

1 bit for IR10.8, WV6.2 or VIS0.6 data missing:

0: All the channel data required are available

1: There is a missing data in some channel

1 bit to indicate if the set of SEVIRI data is out of the calibration matrices range:

set always to 0 since calibration matrices are not used.

1 bit to identify mathematical errors:

0: No mathematical error

1: A mathematical error has occurred

1 bit for the convective filter:

0: The CRR value remains the same

1: The CRR value has been set to zero because of the filtering process


1 bit for the filled holes after parallax correction:

0: No hole due to the parallax correction

1: Hole due to the parallax correction filled by a median filter

2 bits the hourly accumulation CRR band status:

0: All required bands were available

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1: One previous CRR band is missing

2: At least two previous CRR bands are missing (no consecutive)

3: At least two previous CRR bands are missing (some are consecutive)


1 bit for the status of the CRR pixels used to compute the hourly accumulation:

0: All the pixels used in the computing of the hourly accumulation have their CRR\_DATAFLAG bits set to 0

1: At least one of the pixels used in the computing of the hourly accumulation has at least one of its CRR\_DATAFLAG bits set to 1

The HDF-5 output files are stored in \$SAFNWC/export/PGE05. Detailed information on the HDF-5 format file can be found in [AD.4].



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### 3. IMPLEMENTATION OF THE CONVECTIVE RAINFALL RATE (CRR) PRODUCT

#### Previous condition and licences

The right to use, copy or modify this software is in accordance with EUMETSAT Policy for the SAFNWC/MSG software package.

#### 3.1 INSTALLATION STEP FOR CONVECTIVE RAINFALL RATE (CRR)

The software installation procedure does not require special resources. It is restricted to decompress the distribution file (a gz-compressed tar file) and to successfully build the executable PGE05 file to be stored into the \$SAFNWC/bin directory.

Once the PGE05 of the SAFNWC/MSG is installed and configured in the system, its operational use requires the definition of some Configuration files in order to select the regions to be processed and some needed configurable parameters.

The automatic set of pre-defined time scheduling (of the preparation step) is in Programmed Task Definition Files.

#### 3.2 PREPARATION STEP FOR CONVECTIVE RAINFALL RATE (CRR)

The configuration file in charge of the region where the product is going to be run, has an optional name and the “.cfg” extension. This file contains the region centre location and the size image. When the application is installed, some region configuration files appear in \$SAFNWC/config. Each of them corresponds to a different region; nevertheless users can create their own region configuration file.

The configuration file in charge of the product settings is the PGE05 model configuration file that has an optional name and the “.cfm” extension. Through this file the user can configure the way the product is going to be run choosing options such as the type of calibration or the corrections to be used.

In order to apply some corrections, NWP data (*Convective Rainfall Rate (CRR) dynamic inputs*) have to be available in \$SAFNWC/import/NWP\_data directory.


In order to use the lightning information, the “Lightning information file for PGE05” (*Convective Rainfall Rate (CRR) dynamic inputs*) have to be available in \$SAFNWC/import/Obs\_data directory.

#### 3.3 EXECUTION STEP FOR CONVECTIVE RAINFALL RATE (CRR)

The execution step is the real-time process of the SEVIRI images over the region. This process consists of the launch of the command PGE05 along with the required parameters: slot, region configuration file name and model configuration file name.

PGE05 requires mainly six steps:

- First step consists of an initialisation, which performs the environment settings for a given region, and the Day/Night mask for all the pixels processed.
- Second step is intended to read the external data as SEVIRI bands.
- Third step is to normalise the VIS image, in case the solar channel is used.

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- Fourth step holds the core process for the computation of the CRR product. For each pixel the next parameters are calculated: CRR mm/h basic values, Quality and Data flags.
- Fifth step develops those corrections that have been chosen to be applied using the output data from the previous step. CRR mm/h values, Quality and Data flags are updated.
- Sixth step computes rain rates from lightning information if this option has been chosen. This data are combined with the output data from the previous step. CRR mm/h values, Quality and Data flags are updated.
- Last step converts the mm/h CRR values into classes, computes the hourly accumulations and writes the product outputs in SAFNWC format.

## 4. INPUTS AND CONFIGURABLE PARAMETERS FOR CONVECTIVE RAINFALL RATE (CRR) PRODUCT

### 4.1 LIST OF INPUTS FOR CONVECTIVE RAINFALL RATE (CRR)

#### 4.1.1 Convective Rainfall Rate (CRR) dynamic inputs

##### Satellite imagery:

The following SEVIRI brightness temperatures and visible reflectances are needed at full IR spatial resolution:

T10.8 $\mu\text{m}$	TPrev10.8 $\mu\text{m}$	T6.2 $\mu\text{m}$	VIS0.6 $\mu\text{m}$
Mandatory	Optional*	Mandatory	Optional

*Table 4. CRR SEVIRI inputs*

The SEVIRI channels are input by the user in HRIT format and extracted on the desired region by SAFNWC software package. These data must be located in the \$SAFNWC/import/SEVIRI\_data directory.

\* If TPrev10.8 $\mu\text{m}$  is not available, the Cloud Growth Rate Correction Factor can not be computed but the Cloud-top Temperature Gradient Correction Factor is computed instead as an alternative.

##### Numerical model:

The NWP files must be located in \$SAFNWC/import/NWP\_data directory. In real time operational mode, the NWC SAF package has predefined tools (coordinated by the NWC SAF Task Manager daemon) which check every minute for new NWP data making automatically the spatial remapping to the predetermined regions to process on to \$SAFNWC/tmp directory. This avoids spending time in every call to PGE to make the remapping process. In off-line operational mode, the “AllMapping” script allows to do the spatial remapping.

NWP information is used by default for parallax correction. In case of lack of NWP parameters parallax correction will be run using a climatological profile.

NWP information is mandatory for moisture and orographic corrections. When this information is not available, CRR is computed without applying these two corrections.

There are no studies on the impact of NWP data horizontal and temporal resolutions on estimated rain rates throughout those corrections at this time. Some studies are expected to be done in this line for the future. NWP vertical resolution required by the corrections is the following:


For moisture correction:

Relative Humidity at 1000, 925, 850, 700 and 500 hPa

Dew Point temperature at 2 m

Temperature at 2 m

Temperature at 1000, 925, 850, 700, 500 hPa

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## Surface Pressure

For parallax correction:

Temperature at 1000, 925, 850, 700, 500, 400, 300, 250 and 200 hPa

Geopotential at 1000, 925, 850, 700, 500, 400, 300, 250 and 200 hPa

For orographic correction:

U and V wind components in 850 hPa

### Lightning information file for PGE05:

A file with information on every lightning stroke occurred in a time interval is mandatory to choose the option of adjusting the CRPh precipitation pattern with the lightning information provided by ground based lightning detection networks. Information about the “Lightning information file for CRPh product” structure can be found in the Interface Control Document [AD.3]. This file must be located in \$SAFNWC/import/Obs\_data.

The CRR lightning algorithm and the coefficients applied have been derived for Spain using the lightning information from the AEMET lightning detection network.

Ground based lightning detection networks provide information with different performances in detection efficiency and location accuracy. For this reason, the keyword APPLY\_LIGHTNING in the model configuration file is set to 0 and by default the lightning information is not used.

Before to use the lightning algorithm it is highly recommended to the user to adapt the lightning coefficients to the specific performances of the used lightning detection network through the appropriate keywords in the model configuration file.

## **4.1.2 Convective Rainfall Rate (CRR) static inputs**

The following information is included or computed by the software package:

### Sun angles associated to SEVIRI imagery

This information is mandatory for normalising the VIS image when the solar channel is used. It is computed by the CRR software itself using the definition of the region and the satellite characteristics.

### Ancillary data sets:

Saturation Vapour table is mandatory for Humidity correction and is located in the \$SAFNWC/import/Aux\_data/PGE05 directory.


Saturation Vapour Polynomial Coefficients table is mandatory for Humidity correction and is located in the \$SAFNWC/import/Aux\_data/PGE05 directory.

Climatological profile is necessary as a back up for Parallax correction in case NWP is not available. This information is located in the \$SAFNWC/import/Aux\_data/PGE05 directory.

Elevation mask is mandatory for orographic correction and is located in the \$SAFNWC/import/Aux\_data/TOPO directory.

### Model configuration file for PGE05:

The CRR model configuration file, located in the \$SAFNWC/config directory, contains configurable system parameters in the product generation process related with algorithm thresholds, ancillary datasets, numerical model data, corrections to be applied, etc. The complete

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list of these parameters and the explanation of the most useful ones is available on *List of configurable parameters* of this manual and in the Interface Control Document [AD.3]

## 4.2 LIST OF CONFIGURABLE PARAMETERS FOR CONVECTIVE RAINFALL RATE (CRR)

Model configuration file contains configurable items in the product generation process such as algorithm thresholds, SEVIRI channels to be used by the PGE, coefficients, etc.

The CRR model configuration file needed for the execution of PGE05 must be placed at the \$SAFNWC/config directory.


The only constraint in the use of any name is the key used to specify the parameters to be used from NWP models: NWP\_PARAM. The use of this keyname is mandatory, and will be used by a pre-processing task in charge of remapping NWP incoming files (in GRIB format).

### 4.2.1 Keywords table for Convective Rainfall Rate (CRR)

The CRR model configuration file contains the following information:

Keyword	Description	Type	Default Value(s)
<b>PGE_ID</b>	Identifier of the PGE	Chain of characters	PGE05
<b>SEV_BANDS</b>	SEVIRI channels to be used by PGE05	Chain of characters	VIS06 WV62 IR108
<b>DAY_NIGHT_ZEN_THRESHOLD</b>	Solar zenith angle to select between day and night cases (in degrees)	Double	80
<b>WIN_FILTER_SEMISIZE</b>	Semi-size of the window used to filter the Basic CRR image (in pixels).  Window_Size=(2*WIN_FILTER_SEMISIZE +1) *(2*WIN_FILTER_SEMISIZE +1)	Integer	3
<b>FILTER_THRESHOLD</b>	Threshold for filtering process	Integer	3
<b>APPLY_HUMIDITY_CORR</b>	Indicator whether the Humidity correction should be applied or not (1 yes: 0 no)	Integer	1
<b>APPLY_EVOL_GRAD_CORR</b>	Indicator whether the Evolution/Gradient correction should be applied or not (1 yes: 0 no)	Integer	1
<b>APPLY_PARALLAX_CORR</b>	Indicator whether the Parallax correction should be applied or not (1 yes: 0 no)	Integer	1
<b>APPLY_OROGRAPHIC_CORR</b>	Indicator whether the Orographic correction should be applied or not (1 yes: 0 no)	Integer	1
<b>COEFF_EVOL_GRAD_CORR_00</b>	Coefficient used when the Evolution/Gradient correction is applied.  When two consecutives IR images are available and the Evolution correction is applied, if in a pixel the IR brightness temperature increases, the CRR value computed in that pixel is multiplied by this coefficient.	Real	0.35
<b>COEFF_EVOL_GRAD_CORR_01</b>	Coefficient used when the Evolution/Gradient correction is applied.  When the previous IR image is not available and the Gradient correction is applied, this coefficient multiplies the previous computed CRR value if the analysed pixel has a local IR	Real	0.25

	temperature maximum.		
<b>COEFF_EVOL_GRAD_CORR_02</b>	Coefficient used when the Evolution/Gradient correction is applied.  When the previous IR image is not available and Gradient correction is applied, this coefficient multiplies the previous computed CRR value if the analysed pixel has not a local IR temperature maximum or minimum.	Real	0.50
<b>USE_SOLAR_CHANNEL</b>	Indicates if the SEVIRI solar channel has to be used in the computation of the CRR (1 yes: 0 no)	Integer	1
<b>APPLY_LIGHTNING</b>	Indicator whether the Lightning information should be used or not (1 yes: 0 no)	Integer	0
<b>LIGHTNING_DELTA_TIME</b>	Time interval to consider lightning data files	Integer	15
<b>RAIN_LIGHTNING_RATE_1</b>	Rain rate parameter 1 linked to observed lightning	Real	2.3
<b>RAIN_LIGHTNING_RATE_2</b>	Rain rate parameter 2 linked to observed lightning	Real	0.75
<b>RAIN_LIGHTNING_RATE_3</b>	Rain rate parameter 3 linked to observed lightning	Real	0.25
<b>RAIN_LIGHTNING_RATE_4</b>	Rain rate parameter 4 linked to observed lightning	Real	0.1
<b>COEFF_N_LIGHTNING_A</b>	Coefficient “a” to be applied during the lightning adjustment function	Real	0.45
<b>COEFF_N_LIGHTNING_B</b>	Coefficient “b” to be applied during the lightning adjustment function	Real	0.7
<b>NWP_PARAM01</b>	Parameter : Wind velocity (u-component) (ms <sup>-1</sup> ) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_UW 1 BILIN
<b>NWP_PARAM02</b>	Parameter : Wind velocity (v-component) (ms <sup>-1</sup> ) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_VW 1 BILIN
<b>NWP_PARAM03</b>	Parameter : Relative humidity (%) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_PR 1 BILIN
<b>NWP_PARAM04</b>	Parameter : 2m dewpoint temperature (K) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_2D 1 BILIN
<b>NWP_PARAM05</b>	Parameter : 2m air temperature (K) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_PT 1 BILIN
<b>NWP_PARAM06</b>	Parameter : Temperature (K) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_PT 1 BILIN
<b>NWP_PARAM07</b>	Parameter : Surface pressure (Pa) sampling rate : (=segment size) interpolation method.	Chain characters	of NWP_SP 1 BILIN
<b>NWP_PARAM08</b>	Parameter : Geopotential (m <sup>2</sup> s <sup>-2</sup> ) sampling rate : (=segment size)	Chain characters	of NWP_GEOP 1

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	interpolation method.	BILIN
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Table 5. Model configuration file keywords table

## 4.2.2 Keywords description for Convective Rainfall Rate (CRR)

Below there is a description of the most useful keywords defined in PGE05 model configuration file in order to make easier the user exploitation:

- **DAY\_NIGHT\_ZEN\_THRESHOLD:** to choose the solar zenith angle that selects between 2-V and 3-V Calibrations. By default this keyword is set to 80°.
- **USE\_SOLAR\_CHANNEL:** to choose whether the Software will use the solar channel (only for day time) or not. By default this keyword is set to 1 (the solar channel is going to be used).
- **COEFF\_EVOL\_GRAD\_CORR\_00:** When two consecutives IR images are available and the Evolution correction is applied, if in a pixel the IR brightness temperature increases, the CRR value computed in that pixel is multiplied by this coefficient. (Default value for Normal Mode (0.35) is set in the configuration file. Recommended value for Rapid Scan mode is 0.55).
- **COEFF\_EVOL\_GRAD\_CORR\_01:** When the previous IR image is not available and the Gradient correction is working, this coefficient multiplies the initial CRR value if the analysed pixel has a local IR temperature maximum. (Default value: 0.25).
- **COEFF\_EVOL\_GRAD\_CORR\_02:** When the previous IR image is not available and the Gradient correction is working, this coefficient multiplies the initial CRR value if the analysed pixel has neither a local IR temperature maximum nor minimum. (Default value: 0.50).
- **WIN\_FILTER\_SEMISIZE:** The obtained basic CRR data are set to zero if all the pixels in a grid with a WIN\_FILTER\_SEMISIZE pixels semisize (default value: 3pix) centred on the pixel have a value lower than a selected threshold. The size of this window will be:  

$$(WIN\_FILTER\_SEMISIZE*2+1) \times (WIN\_FILTER\_SEMISIZE*2+1)$$
- **FILTER\_THRESHOLD:** The basic CRR data obtained from the functions are set to zero if all the pixels in the selected window filter centred on the pixel have a value lower than FILTER\_THRESHOLD. (Default value: 3 mm/h).
- **APPLY\_LIGHTNING:** To decide whether the lightning information will be used (keyword set to 1) or not (keyword set to 0) to combine the CRR precipitation pattern. By default this keyword is set to 0.
- **LIGHTNING\_DELTA\_TIME:** Time interval before the scanning time of the processing region centre, where the lightning occurrences will be taken into account by the lightning algorithm. (Default value: 15 min).
- **RAIN\_LIGHTNING\_RATE\_1:** Rain amount assigned to the pixels corresponding to the Z1 area according to the lightning algorithm. A detailed description of the lightning algorithm can be found in the Algorithm Theoretical Basis Document for PGE05 [AD.1]. (Default value: 2,30 mm).

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- **RAIN\_LIGHTNING\_RATE\_2:** Rain amount assigned to the pixels corresponding to the Z2 area according to the lightning algorithm. A detailed description of the lightning algorithm can be found in the Algorithm Theoretical Basis Document for PGE05 [AD.1]. (Default value: 0,75 mm).
- **RAIN\_LIGHTNING\_RATE\_3:** Rain amount assigned to the pixels corresponding to the Z3 area according to the lightning algorithm. A detailed description of the lightning algorithm can be found in the Algorithm Theoretical Basis Document for PGE05 [AD.1]. (Default value: 0,25 mm).
- **RAIN\_LIGHTNING\_RATE\_4:** Rain amount assigned to the pixels corresponding to the Z4 area according to the lightning algorithm. A detailed description of the lightning algorithm can be found in the Algorithm Theoretical Basis Document for PGE05 [AD.1]. (Default value: 0,10 mm).
- **COEFF\_N\_LIGHTNING\_A:** Coefficient “a” of the equation that modifies the rain rate according to the density of lightning around each pixel in the lightning algorithm. (Default value: 0,45).
- **COEFF\_N\_LIGHTNING\_B:** Coefficient “b” of the equation that modifies the rain rate according to the density of lightning around each pixel in the lightning algorithm. (Default value: 0,7).



## 5. SUMMARY OF CONVECTIVE RAINFALL RATE (CRR) PRODUCT VALIDATION RESULTS

The following tables summarize the validation results of this CRRv4.0. More details can be obtained from the Scientific report on improving NWCSAF/MSG Precipitation Products [AD.2].

Green colour values in tables mean that FAR or POD values obtained in that validation fulfill the FAR and POD target values defined in the NWC SAF Product Requirements document [AD.6].

### 5.1 INSTANTANEOUS RATES

#### 5.1.1 Accuracy statistics

Algorithm	N	Mean (mm/h)	ME (mm/h)	MAE (mm/h)	RMSE (mm/h)
3-V function	846153	0,60	0,47	1,18	2,81
2-V function	868860	0,63	0,81	1,55	3,19

Table 6. Accuracy statistics for instantaneous rates

#### 5.1.2 Categorical statistics

Algorithm	FAR (%)	POD (%)	CSI (%)	PC (%)
3-V function	30.6	58.1	45.9	65.4
2-V function	44.6	54.4	37.8	55.1

Table 7. Categorical statistics for instantaneous rates

### 5.2 HOURLY ACCUMULATIONS

#### 5.2.1 Accuracy statistics


Algorithm	N	Mean (mm/h)	ME (mm/h)	MAE (mm/h)	RMSE (mm/h)
3-V function	576334	0,39	0,38	0,79	1,99
2-V function	602462	0,41	0,54	0,97	2,15

Table 8. Accuracy statistics for hourly accumulations

## 5.2.2 Categorical statistics

<b>Algorithm</b>	<b>FAR (%)</b>	<b>POD (%)</b>	<b>CSI (%)</b>	<b>PC (%)</b>
<b>3-V function</b>	<b>49.0</b>	<b>63.8</b>	<b>39.3</b>	<b>63.9</b>
<b>2-V function</b>	<b>58.2</b>	<b>58.6</b>	<b>32.3</b>	<b>55.4</b>

Table 9. Categorical statistics for hourly accumulations

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## 6. CONVECTIVE RAINFALL RATE (CRR) PRODUCT ASSUMPTIONS AND LIMITATIONS

The CRR product is based on a calibration method which requires the availability of a training set of precipitation data derived from radar information, to be used as ground truth to derive the relationship between satellite information and rainfall rate.

Regarding the radar data:

- The drop size distribution, used to obtain the radar rainfall rates (mm/h) from the radar reflectivity (Dbz), has been assumed to be the Marshall Palmer type throughout the calibration and validation procedures.
- No online operational method has been applied in order to adjust the radar rainfall intensities using rain gauge measurements.

Regarding the lightning algorithm:

- The CRR lightning algorithm in CRR v4.0, and the coefficients applied, have been derived for Spain using the lightning information from the AEMET lightning detection network. Concerning this particular, it is important to highlight that ground based lightning detection networks provide information with different performances in detection efficiency and location accuracy. For this reason, in the model configuration file the keyword APPLY\_LIGHTNING is set to 0 and by default the lightning information is not used.
- Before to use the lightning algorithm it is highly recommended to the user to adapt the coefficients to the specific performances of the lightning detection network serving that information.
- This issue could be solved in a satisfactory manner in the future with the use of lightning information provided by MTG Lightning Imager which will be able to provide lightning information with uniform and controlled performances all around the coverage area.

As a summary, according to the feedback of the users, the CRR product provides useful information as a complement to Radar products allowing the forecasters to identify convective areas.

## 7. EXAMPLE OF CONVECTIVE RAINFALL RATE (CRR) PRODUCT VISUALISATION

### 7.1.1 Instantaneous Rates

Below is shown an image corresponding to CRR classes output. It has been obtained at full resolution and all corrections have been applied.

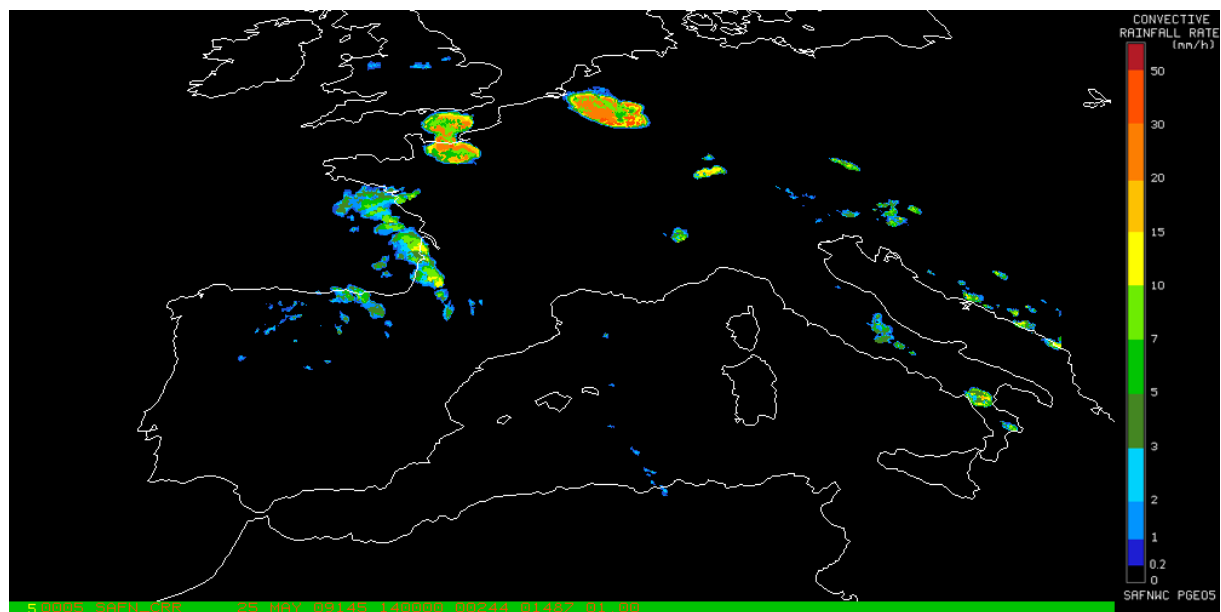


Figure 2. CRR instantaneous intensities output corresponding to 25<sup>th</sup> May 2009 at 14:00Z

### 7.1.2 Hourly Accumulations

Below is shown an image corresponding to CRR hourly accumulations output. It has been obtained at full resolution and all corrections have been applied.

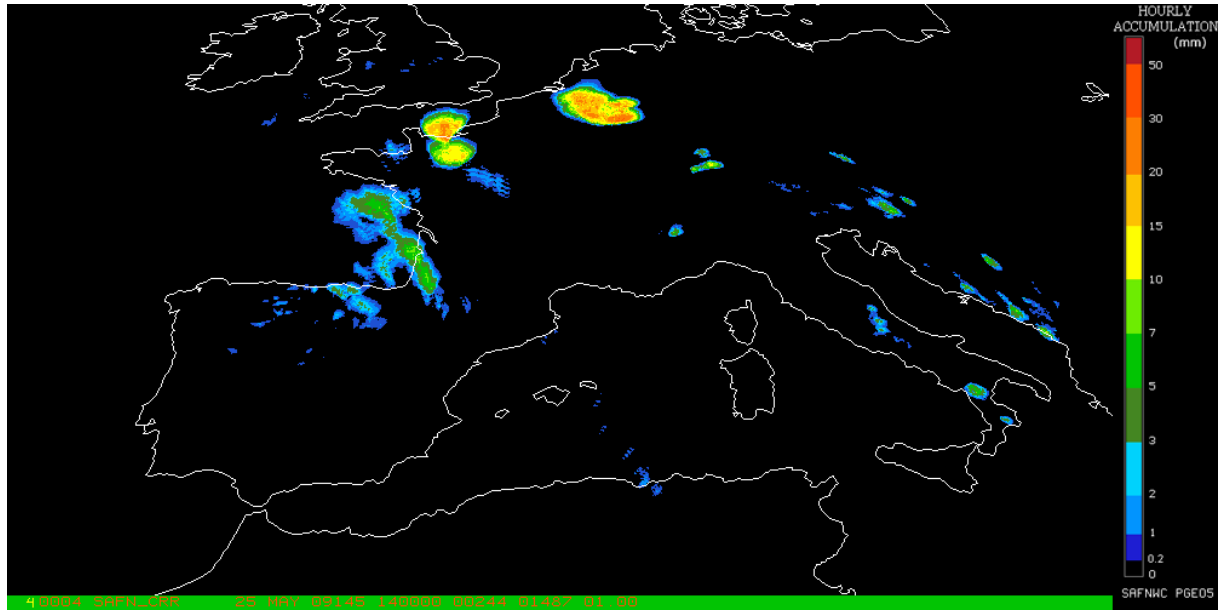


Figure 3. CRR hourly accumulations output corresponding to 25<sup>th</sup> May 2009 at 14:00Z.