 <p>NWC SAF Agencia Estatal de Meteorología</p>	<p>User Manual for the Precipitation Product Processors of the NWC/GEO</p>	<p>Code: NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation Issue: 1.0 Date: 21 January 2019 File: NWC-CDOP3-GEO-AEMET-SCI-UM-Precipitation_v1.0 Page: 1/53</p>
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The EUMETSAT
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NWC SAF


Support to Nowcasting and
Very Short Range Forecasting


User Manual for the Precipitation Product Processors of the NWC/GEO

NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation, Issue 1, Rev. 0
21 January 2019

Applicable to


GEO-PC-v154 (NWC-019)
GEO-CRR-v402 (NWC-024)
GEO-PC-Ph-v2.0 (NWC-077)
GEO-CRR-Ph-v2.0 (NWC-081)

 <p>NWC SAF Agencia Estatal de Meteorología</p>	<p>User Manual for the Precipitation Product Processors of the NWC/GEO</p>	<p>Code: NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation Issue: 1.0 Date: 21 January 2019 File: NWC-CDOP3-GEO-AEMET-SCI-UM-Precipitation_v1.0 Page: 2/53</p>
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REPORT SIGNATURE TABLE

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DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
1.0	21 January 2019	53	<p>First version of the User Manual for the Precipitation Product Processors NWC SAF SW Package GEO v2018 DRR.</p> <p>Content derived from the User Manual for the Precipitation Product Processors of the NWC/GEO v2016 NWC/CDOP2/GEO/AEMET/UM/Precipitation</p>




 <p>NWC SAF AEMet Agencia Estatal de Meteorología</p>	<p>User Manual for the Precipitation Product Processors of the NWC/GEO</p>	<p>Code: NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation Issue: 1.0 Date: 21 January 2019 File: NWC-CDOP3-GEO-AEMET-SCI-UM-Precipitation_v1.0 Page: 5/53</p>
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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 geostationary meteorological satellites, NWC-GEO.

1.1 SCOPE OF THE DOCUMENT

This document is the User Manual (UM) for the precipitation products Precipitating Clouds (PC), Convective Rainfall Rate (CRR) and Precipitation products from Cloud Physical Properties (PPh) of the NWC/GEO software package. PPh generates two different products: Precipitating Clouds from Cloud Physical Properties (PC-Ph) and Convective Rainfall rate from Cloud Physical Properties (CRR-Ph).

UM document contains practical information on the characteristics of the products, including the input data and the outputs of the products. It also gives information about the algorithm’s implementation and configuration.

1.2 SOFTWARE VERSION IDENTIFICATION

This document applies to the algorithms implemented in the release 2018 of the NWC/GEO software package (GEO-PC-v1.5.4, GEO-CRR-v4.0.2, GEO-PC-Ph-v2.0 and GEO-CRR-Ph-v2.0).


1.3 IMPROVEMENT FROM PREVIOUS VERSION

Since 2013 release, these technical improvements have been implemented:

- Interface to updated NWCLIB
- New output format
- New PC-Ph and CRR-Ph calibrations with day night algorithms.

1.4 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AEMET	Agencia Estatal de Meteorología
ATBD	Algorithm Theoretical Basis Document
BALTRAD	Baltic Radar Network
CAPPI	Constant Altitude Plan Position Indicator
COT	Cloud Optical Thickness
CRR-Ph	Convective Rainfall Rate from Cloud Physical Properties
CRR	Convective Rainfall Rate
CSI	Critical Success Index
CT	Cloud Type
CWP	Cloud Water Path
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Ratio

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HRIT	High Rate Information Transmission
ICD	Interface Control Document
ICP	Illumination Conditions Parameter
IQF	Illumination Quality Flag
IR	Infrared
KRR	Kernel Ridge Regression
MAE	Mean Absolute Error
CTMP	Cloud Top Microphysical Properties
ME	Mean Error
MRV	Maximum Reflectivity in the Vertical
MSG	Meteosat Second Generation
NIR	Near Infrared
NWCLIB	Nowcasting SAF Library
NWC SAF	Satellite Application Facility for Nowcasting
PC	Percentage of Corrects
PC-Ph	Precipitating Clouds from Cloud Physical Properties
PGE	Product Generation Element
POD	Probability of Detection
PoP	Probability of Precipitation
PPh	Precipitation from Cloud Physical Properties
PWRH	Moisture Correction Factor
R_{eff}	Effective Radius
RLR	Rainfall-Lightning Ratio
RMSE	Root Mean Square Error
RR	Rain Rate
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SW	Software
2-V	2-Variable
3-V	3-Variable
VIS	Visible
VIS-N	Normalized Visible
WV	Water Vapour


1.5 REFERENCES

1.5.1 Applicable Documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X].

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.

Current documentation can be found at the NWC SAF Helpdesk web: <http://www.nwcsaf.org>

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Reference	Title	Code	Vers	Date
[AD 1]	Proposal for the Third Continuous Development and Operations Phase (CDOP-3) March 2017 – February 2022	NWC SAF:CDOP-3 proposal	1.0	11/04/16
[AD 2]	NWCSAF Project Plan	NWC/CDOP3/SAF/AEMET/MGT/PP	1.0	06/03/18
[AD 3]	Configuration Management Plan for the NWC SAF	NWC/CDOP3/SAF/AEMET/MGT/CMP	1.0	21/02/18
[AD 4]	NWCSAF Product Requirements Document	NWC/CDOP3/SAF/AEMET/MGT/PRD	1.0	31/01/18

Table 1: List of Applicable Documents

1.5.2 Reference Documents


The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD.X].

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.

Current documentation can be found at the NWC SAF Helpdesk web: <http://www.nwcsaf.org>

Reference	Title	Code	Vers	Date
[RD 1]	Product User Manual for SAFNWC/MSG “Precipitating Cloud” (PC-PGE04 v1.5)	SAF/NWC/CDOP2/SMHI/SCI/PUM/4	1.5.4	15/07/13
[RD 2]	Data Output Format for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/DOF	1.2.3	23/04/18
[RD 3]	User Manual for the NWC/GEO	NWC/CDOP2/GEO/AEMET/MGT/UM	1.0.1	15/06/17
[RD 4]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/1	1.0	21/01/19
[RD 5]	Algorithm Theoretical Basis Document for the Precipitation Product Processors of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SCI/ATBD/Precipitation	2.1	21/01/19
[RD 6]	Component Design Document for the Precipitation Product Processors of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACDD/Precipitation	2.0	27/02/17
[RD 7]	Scientific and Validation Report for the Precipitation Product Processors of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SCI/VR/Precipitation	1.0	21/01/19

Table 2: List of Referenced Documents

	User Manual for the Precipitation Product Processors of the NWC/GEO	Code: NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation Issue: 1.0 Date: 21 January 2019 File: NWC-CDOP3-GEO-AEMET-SCI-UM-Precipitation_v1.0 Page: 11/53
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2. PRECIPITATING CLOUDS (PC) PRODUCT

2.1 DESCRIPTION OF PRECIPITATION CLOUDS (PC)

2.1.1 Goal of Precipitating Clouds (PC)

Refer to section 2.1 of Product User Manual for SAFNWC/MSG “Precipitating Cloud” (PC-PGE04 v1.5) document [RD 1].

2.1.2 Outline of Precipitating Clouds (PC)


Refer to section 2.2 of Product User Manual for SAFNWC/MSG “Precipitating Cloud” (PC-PGE04 v1.5) document [RD 1].

2.1.3 Description of Precipitating Clouds (PC) output

The content of the PC output (stored in \$SAFNWC/export/PC in netCDF format) is described in the Data Output Format Document [RD 2]. A summary is given below:

NetCDF Common Attributes	
product_completeness	Percentage of pixels within the region containing data
product_quality	Weighted mean of the quality of all pixels with data, using the following weights: 1: Good pixels, 0.5: Questionable quality, 0.0: Bad quality

Container	Content																										
PC	<p>NWC GEO PC Total Precipitation Likelihood:</p> <table> <tr> <th>Class</th><th>Total Precipitation Likelihood (%)</th></tr> <tr><td>0</td><td>0</td></tr> <tr><td>1</td><td>10</td></tr> <tr><td>2</td><td>20</td></tr> <tr><td>3</td><td>30</td></tr> <tr><td>4</td><td>40</td></tr> <tr><td>5</td><td>50</td></tr> <tr><td>6</td><td>60</td></tr> <tr><td>7</td><td>70</td></tr> <tr><td>8</td><td>80</td></tr> <tr><td>9</td><td>90</td></tr> <tr><td>10</td><td>100</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </table>	Class	Total Precipitation Likelihood (%)	0	0	1	10	2	20	3	30	4	40	5	50	6	60	7	70	8	80	9	90	10	100	FillValue	No data or corrupted data
Class	Total Precipitation Likelihood (%)																										
0	0																										
1	10																										
2	20																										
3	30																										
4	40																										
5	50																										
6	60																										
7	70																										
8	80																										
9	90																										
10	100																										
FillValue	No data or corrupted data																										

	<p>User Manual for the Precipitation Product Processors of the NWC/GEO</p>	<p>Code: NWC/CDOP3/GEO/AEMET/SCI/UM/Precipitation Issue: 1.0 Date: 21 January 2019 File: NWC-CDOP3-GEO-AEMET-SCI-UM-Precipitation_v1.0 Page: 12/53</p>
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Geophysical Conditions


Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.
Quality	Parameter	Retrieval Quality 0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

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Another file is generated including statistical information related to the product generation. It contains histograms of precipitation probability and processing flags, and it is generated in ascii format. This file may be useful to get statistics on general algorithm performance.

2.2 IMPLEMENTATION OF PRECIPITATION CLOUDS (PC)

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.

2.2.1 Installation of Precipitating Clouds (PC)

PC product is generated by the GEO-PC component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual [RD 3].

The software installation procedure does not require special resources. It is restricted to decompress the distribution files (a gzip-compressed tar files) and to successfully build the executable GEO-PC-v<version> file to be stored into the \$SAFNWC/bin directory.

Once the GEO-PC-v<version> of the NWC-GEO 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.

2.2.2 Preparation step for Precipitating Clouds (PC)

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. Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4].

The configuration file in charge of the product settings is the PC 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 sun zenith angle threshold to choose between day and night algorithms. More information on this configuration file can be found in section 2.3.2.

In order to run PC product, NWP data (surface temperature) have to be available in \$SAFNWC/import/NWP_data directory.

2.2.3 Execution of Precipitating Clouds (PC)


The GEO-PC execution step consists in the launch of the command:

```
%    GEO-PC-v<version>      <YYYY-MM-DDThh:mm:ssZ>      <region_conf_file>
<model_conf_file>
```

Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4] and model_conf_file is described in section 2.3.2.

GEO-PC requires mainly ten steps:

- Setting the Date/Slot in a UTC structure.

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- Definition of the Processing Region Reading read form the Processing Region Configuration File.
- Reading of the Model Configuration File and the Algorithm Configuration.
- Reading of Satellite input data according to the required slot in the required processing region.
- Reading of CT product for the current slot.
- Computation of Navigation data in the processing region.
- Reading of NWP Surface Temperature.
- Implementation of PC algorithm to compute precipitation probability in different classes.
- Writing the PC product file according to the specification provided in the DOF [RD 2].
- Creating and writing Statistics file containing histograms of precipitation probability in different classes.

More information on the GEO-PC execution steps can be found at the Component Design Document for the Precipitation Product Processors of the NWC/GEO document [RD 6].

2.3 INPUTS AND CONFIGURABLE PARAMETERS FOR PRECIPITATION CLOUDS (PC)

2.3.1 List of inputs for Precipitating Clouds (PC)

Satellite imagery:

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

VIS0.6	NIR1.6	IR3.9	IR6.2	IR7.3	IR10.8	IR12.0
Day-time	Day-time	Day-time	Day-time and Night-time	Day-time and Night-time	Day-time and Night-time	Day-time and Night-time

Table 3. PC SEVIRI inputs


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

Cloud type (CT) product output:

CT output, in netCDF format, is mandatory input to PC. This netCDF file must be located in \$SAFNWC/export/CT directory.

NWP parameters:

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

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spatial remapping to the predetermined regions to process on to \$SAFNWC/tmp directory. This avoids spending time in every call to each component to make the remapping process. In off-line operational mode, the “AllMapping” script allows to do the spatial remapping.

Surface temperature is a mandatory input for PC.

Sun and satellite angles associated to satellite imagery

This information is mandatory. It is computed by the PC software itself, using the definition of the region and the satellite characteristics.

2.3.2 Configurable parameters for Precipitating Clouds (PC): Model Configuration File

The PC model configuration file must be placed in the \$SAFNWC/config directory and contains the following information:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the product processor	Chain of characters	GEO-PC
SEV_BANDS	Satellite channels to be used by GEO-PC	Chain of characters	VIS06, NIR16, IR38, WV62, WV73, IR108, IR120
NWP_PARAM	Parameter :Temperature at surface level (K) sampling rate : (=segment size) interpolation method	Chain of characters	NWP_ST 4 BLM
PRODUCT_CONFIG_FILE	PC configuration file	Chain of characters	pge04_algorithm.conf

Table 4. Model configuration file keywords table applicable to PC product

Parameters to be configured by the user, included in the PC configuration file, are the following:


Keyword	Description	Type	Default Value(s)
SUNZEN_ANGLE	Solar zenith angle to select between day and night algorithms (in degrees). It is possible to configure the product to only use the night algorithm by setting the sun zenith angle threshold to 0. This would avoid discontinuities in the product at the day/night transition on the cost of degrading performance during day time	Double	70.0
PROBABILITY_THRESH	If the probability for “no rain” is lower or equal PROBABILITY_THRESH, the pixel will be processed as potentially raining, otherwise the probability of rain is set to zero	Integer	90

Table 5. Parameters to be configured included in the PC configuration file

It is also possible to configure which cloud classes are treated as potentially raining. This can be done through the keyword CLOUDTYPE_DEFINITION: CLOUDTYPES by configuring three values:

CLOUDTYPE (integer)

Used (1) / Not used (0) (integer)

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CT algorithm to be used with this CT class (from 0 to 4) (integer)

PC configuration file is placed at the \$SAFNWC/import/Aux_data/PC directory.

2.4 TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

Refer to section 6 of Product User Manual for SAFNWC/MSG “Precipitating Cloud” (PC-PGE04 v1.5) document [RD 1].

2.5 EXAMPLE OF PRECIPITATING CLOUDS (PC) VISUALIZATION

Examples of both day-time and night-time PC product can be found below:

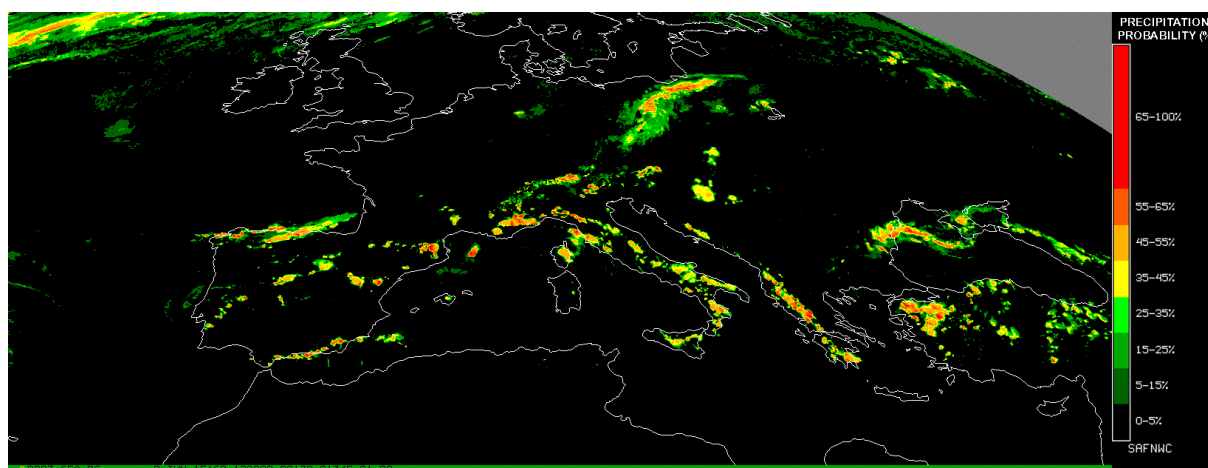


Figure 1. Example of the precipitating clouds product over a day-time scene on 9th June 2015 at 12:00 UTC

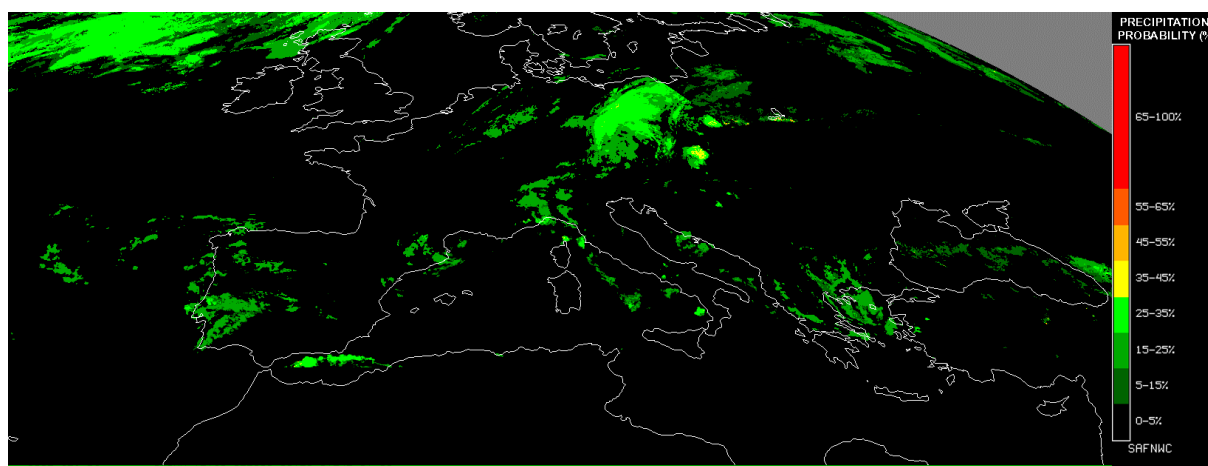



Figure 2. Example of the precipitating clouds product over a night-time scene on 9th June 2015 at 03:30 UTC

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3. CONVECTIVE RAINFALL RATE (CRR) PRODUCT

3.1 DESCRIPTION OF THE CONVECTIVE RAINFALL RATE (CRR) PRODUCT

3.1.1 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 satellite slot, which in case of MSG 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.

This product does not distinguish the phase of the estimated precipitation.

3.1.2 Outline of Convective Rainfall Rate (CRR)

3.1.2.1 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 reflectance):

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

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

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 semi-size (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 3.1.3.

3.1.2.2 Convective Rainfall Rate (CRR) correction factors

3.1.2.2.1 Moisture Correction Factor

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

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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.

3.1.2.2.2 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 cannot be applied when consecutive images are not available. In this case the alternative method of Cloud-top Temperature Gradient Correction is applied.

3.1.2.2.3 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 [RD 5]. 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.

3.1.2.2.4 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.

3.1.2.2.5 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.

3.1.2.3 Lightning algorithm

As lightning activity is related with convection, an option to use this information to improve precipitation estimates 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. To carry out the tuning of the lightning algorithm for a specific lightning network, the following steps should be performed:

- A representative set of convective storms should be chosen. Radar data and lightning data for each storm is needed.

- For each storm, the total amount of rainfall (in mm) according to the radar and the total number of lightning strokes occurred along the event should be measured. With this information the Rainfall-Lightning Ratio (RLR), which is the ratio between the total amount of mm of rainfall and the number of lightning strokes occurred, can be computed for each storm.
- The average of the RLR for the chosen set of storms should be computed. With this information the following keywords can be computed and updated in the model configuration file for CRR:
 $Z1 = 0.228 * RLR$ (RAIN_LIGHTNING_RATE_1 in Model configuration file for CRR)
 $Z2 = 0.074 * RLR$ (RAIN_LIGHTNING_RATE_2 in Model configuration file for CRR)
 $Z3 = 0.025 * RLR$ (RAIN_LIGHTNING_RATE_3 in Model configuration file for CRR)
 $Z4 = 0.010 * RLR$ (RAIN_LIGHTNING_RATE_4 in Model configuration file for CRR)
- For the same set of storms, and using the lightning information measured, a rain field should be computed for each storm at the same time that radar images were taken. To do this, since the tuning was done taking as ground truth the radar rain rates, each lightning stroke has to be allocated to a radar pixel. For each lightning stroke precipitation has to be spread, at and around the pixel allocated to it, in the following way:


$Z4$	$\frac{Z3+Z4}{2}$	$Z3$	$\frac{Z3+Z4}{2}$	$Z4$
$\frac{Z3+Z4}{2}$	$\frac{Z2+Z3}{2}$	$Z2$	$\frac{Z2+Z3}{2}$	$\frac{Z3+Z4}{2}$
$Z3$	$Z2$	$Z1$	$Z2$	$Z3$
$\frac{Z3+Z4}{2}$	$\frac{Z2+Z3}{2}$	$Z2$	$\frac{Z2+Z3}{2}$	$\frac{Z3+Z4}{2}$
$Z4$	$\frac{Z3+Z4}{2}$	$Z3$	$\frac{Z3+Z4}{2}$	$Z4$

At the same time, to take into account the temporal influence of the lightning occurrence, these rain amounts ($Z1$, $Z2$, $Z3$ and $Z4$) should be multiplied by $COEF_{\tau}$:

$$COEF_{\tau} = -1 * 10^{-7} (\Delta\tau)^4 - 3 * 10^{-3} (\Delta\tau)^2 + 1$$

Where $\Delta\tau$ is the time interval (in minutes) between the time of occurrence of the lightning stroke and the radar image.

- To tune the spatial density of lightning occurrence algorithm part, the rain rates obtained through the lightning information (RR_{light}) should be compared with the radar rain rates (RR_{radar}) pixel by pixel. For each pixel $F(N) = RR_{radar} / RR_{light}$ should be computed. Also, the spatial density of lightning occurrence for each pixel, N , should be computed in the image time interval. The time image interval is chosen as the time interval between two satellite images. In the case of MSG, this time interval in the normal mode is 15

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minutes. N is computed at each pixel as the number of lightning strokes occurred in the time interval in a 11x11 pixels box centred on that pixel. With the pairs of values (F(N), N) for each pixel, the following function should be adjusted, and coefficients a and b should be obtained:

$$F(N) = a * (1 - b^N)$$

To include this information in the model configuration file for CRR it should be taken into account that:

COEFF_N_LIGHTNING_A = a


COEFF_N_LIGHTNING_B = b

3.1.3 Description of the Convective Rainfall Rate (CRR) outputs

The content of the CRR output (stored in \$SAFNWC/export/CRR in netCDF format) is described in the Data Output Format Document [RD 2]. A summary is given below:

NetCDF Common Attributes	
product_completeness	Percentage of pixels within the region containing data
product_quality	Weighted mean of the quality of all pixels with data, using the following weights: 1: Good pixels, 0.5: Questionable quality, 0.0: Bad quality


Container	Content																												
crr	<p>NWC GEO CRR Convective Rainfall Rate Class:</p> <table border="1"> <thead> <tr> <th>Class</th><th>Rainfall Intensity (mm/h)</th></tr> </thead> <tbody> <tr><td>0</td><td>[0.0, 0.2)</td></tr> <tr><td>1</td><td>[0.2, 1.0)</td></tr> <tr><td>2</td><td>[1.0, 2.0)</td></tr> <tr><td>3</td><td>[2.0, 3.0)</td></tr> <tr><td>4</td><td>[3.0, 5.0)</td></tr> <tr><td>5</td><td>[5.0, 7.0)</td></tr> <tr><td>6</td><td>[7.0, 10.0)</td></tr> <tr><td>7</td><td>[10.0, 15.0)</td></tr> <tr><td>8</td><td>[15.0, 20.0)</td></tr> <tr><td>9</td><td>[20.0, 30.0)</td></tr> <tr><td>10</td><td>[30.0, 50.0)</td></tr> <tr><td>11</td><td>[50.0,)</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </tbody> </table>	Class	Rainfall Intensity (mm/h)	0	[0.0, 0.2)	1	[0.2, 1.0)	2	[1.0, 2.0)	3	[2.0, 3.0)	4	[3.0, 5.0)	5	[5.0, 7.0)	6	[7.0, 10.0)	7	[10.0, 15.0)	8	[15.0, 20.0)	9	[20.0, 30.0)	10	[30.0, 50.0)	11	[50.0,)	FillValue	No data or corrupted data
Class	Rainfall Intensity (mm/h)																												
0	[0.0, 0.2)																												
1	[0.2, 1.0)																												
2	[1.0, 2.0)																												
3	[2.0, 3.0)																												
4	[3.0, 5.0)																												
5	[5.0, 7.0)																												
6	[7.0, 10.0)																												
7	[10.0, 15.0)																												
8	[15.0, 20.0)																												
9	[20.0, 30.0)																												
10	[30.0, 50.0)																												
11	[50.0,)																												
FillValue	No data or corrupted data																												
crr_intensity	<p>NWC GEO CRR Convective Rainfall Intensity:</p> $\text{crr_intensity(mm/h)} = \text{scale_factor} * \text{counts} + \text{add_offset}$ <p>where:</p> <p><i>scale_factor</i> = 0.1</p> <p><i>add_offset</i> = 0.0</p>																												

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Container	Content
crr_accum	<p>NWC GEO CRR Convective Hourly Rainfall Accumulation:</p> $\text{crr_accum(mm)} = \text{scale_factor} * \text{counts} + \text{add_offset}$ <p>where:</p> $\text{scale_factor} = 0.1$ $\text{add_offset} = 0.0$
crr_status_flag	<p>13 bits indicating Applied Corrections:</p> <ul style="list-style-type: none"> Bit 0: Humidity correction applied Bit 1: Evolution correction applied Bit 2: Gradient correction applied Bit 3: Parallax correction applied Bit 4: Orographic correction applied <p>Use of optional data:</p> <ul style="list-style-type: none"> Bit 5: Solar channel used Bit 6: Lightning data used <p>Processing information</p> <ul style="list-style-type: none"> Bit 7: crr_intensity set to 0 due to filtering process Bit 8: crr_intensity was a hole because of the parallax correction, and then was filled by the median filter Bit 9,10, 11: Use of bands for accumulation <ul style="list-style-type: none"> 1: All required bands were available 2: One previous CRR band is missing 3: At least two previous CRR bands are missing (no consecutive) 4: At least two previous CRR bands are missing (some are consecutive) Bit 12: Accumulation quality flag. Set to 1 if: <ul style="list-style-type: none"> not all crr values are available to perform the accumulation, OR any of the crr_intensity values was set to 0 due to filtering process OR Any of the crr_intensity values was a hole because parallax correction

Geophysical Conditions

Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	<p>Defines the illumination condition</p> <ul style="list-style-type: none"> 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	<ul style="list-style-type: none"> 0: N/A (space pixel) 1: Land 2: Sea 3: Coast

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Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing


Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.
Quality	Parameter	Retrieval Quality 0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

3.2 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 NWC-GEO software package.

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3.2.1 Installation step for Convective Rainfall Rate (CRR)

CRR product is generated by the GEO-CRR component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual [RD 3].

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

Once the GEO-CRR-v<version> of the NWC-GEO 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.

3.2.2 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. Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4].

The configuration file in charge of the product settings is the CRR 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. More information on this configuration file can be found in section 3.3.2.

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 CRR” (*Convective Rainfall Rate (CRR) dynamic inputs*) have to be available in \$SAFNWC/import/Obs_data/Lightning directory.

3.2.3 Execution step for Convective Rainfall Rate (CRR)


The GEO-CRR execution step consists in the launch of the command:

```
%   GEO-CRR-v<version>      <YYYY-MM-DDThh:mm:ssZ>      <region_conf_file>
<model_conf_file>
```

Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4] and model_conf_file is described in section 2.3.2.

GEO-CRR requires mainly six steps:

- Initialise all variables and data structures according to input data. This includes computation of navigation data in the processing region read from the Processing Region Configuration File.
- Reading the input data required to execute the requested CRR processing in the processing region including Satellite input data, IR band for previous slot and previous CRR products (required to compute the hourly rainfall accumulation)

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- Implementation of the algorithm to compute the base CRR values and filtering data to eliminate stratiform rain.
- Application of CRR corrections to base CRR data values computed in the previous step. Corrections to be applied are configurable and defined in the CRR Model Configuration file.
- Computation of the hourly rainfall accumulations using rainfall intensities from previous CRR slots
- Computation of CRR classes from CRR intensities as well as quality and processing information, and writing the CRR product file according to the specification provided in the DOF [RD 2].

More information on the GEO-CRR execution steps can be found at the Component Design Document for the Precipitation Product Processors of the NWC/GEO document [RD 6].

3.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CONVECTIVE RAINFALL RATE (CRR) PRODUCT

3.3.1 List of inputs for Convective Rainfall Rate (CRR)

3.3.1.1 Convective Rainfall Rate (CRR) dynamic inputs

Satellite imagery:

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

T10.8 μ m	TPrev10.8 μ m	T6.2 μ m	VIS0.6 μ m
Mandatory	Optional*	Mandatory	Optional

Table 6. CRR SEVIRI inputs


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

* If TPrev10.8 μ m is not available, the Cloud Growth Rate Correction Factor cannot 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-GEO package has predefined tools (coordinated by the NWC-GEO 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 product processor 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.

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

The NWP model fields used by CRR corrections are 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

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 CRR:

A file with information on every lightning stroke occurred in a time interval is mandatory to choose the option of adjusting the CRR precipitation pattern with the lightning information provided by ground based lightning detection networks. Information about this lightning information file structure can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO [RD 4]. This file must be located in the \$SAFNWC/import/Obs_data/Lightning directory.

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.

3.3.1.2 Convective Rainfall Rate (CRR) static inputs

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

Sun angles associated to satellite imagery

This information is mandatory for normalising the VIS image when the solar channel is used. It is also used to choose whether to run day-time or night-time algorithm.

Ancillary data sets:


Saturation Vapour table is mandatory for Humidity correction and is located in the \$SAFNWC/import/Aux_data/CRR directory.

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

Elevation mask is mandatory for orographic correction and is located in the \$SAFNWC/import/Aux_data/Common directory.

Model configuration file for CRR:

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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. A complete list of these parameters and the explanation of the most useful ones can be found in section 3.3.2.

3.3.2 Configurable parameters for Convective Rainfall Rate (CRR): Model Configuration File

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


The CRR model configuration file needed for the execution of CRR 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).

3.3.2.1 Keywords table for Convective Rainfall Rate (CRR)

Model Configuration File, located in the \$SAFNWC/config directory and identified by the extension “.cfm”, contains the following information applicable to CRR product:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the product processor	Chain of characters	GEO-CRR
SAT_BANDS	Satellite channels to be used by CRR	Chain of characters	VIS06 WV62 IR108
DAY_NIGHT_ZEN_THRESHOLD	Solar zenith angle to select between day and night cases (in degrees)	Double	70
USE_SOLAR_CHANNEL	Indicator whether the day-time algorithm should be used or not by indicating if the satellite solar channel has to be used in the computation of the CRR basic value (1 yes; 0 no)	Integer	1
WIN_FILTER_SEMISIZE	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
FILTER_THRESHOLD	Threshold for filtering process	Integer	3
APPLY_HUMIDITY_CORR	Indicator whether the Humidity correction should be applied or not (1 yes; 0 no)	Integer	1
APPLY_EVOL_GRAD_CORR	Indicator whether the Evolution/Gradient correction should be applied or not (1 yes; 0 no)	Integer	1
APPLY_PARALLAX_CORR	Indicator whether the Parallax correction should be applied or not (1 yes; 0 no)	Integer	1
APPLY_OROGRAPHIC_CORR	Indicator whether the Orographic correction should be applied or not (1 yes; 0 no)	Integer	1
APPLY_LIGHTNING_CORR	Indicator whether the Lightning information should be used or not (1 yes; 0 no)	Integer	0
COEFF_EVOL_GRAD_CORR_00	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
COEFF_EVOL_GRAD_CORR_01	Coefficient used when the Evolution/Gradient	Real	0.25


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	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 temperature maximum.		
COEFF_EVOL_GRAD_CORR_02	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
LIGHTNING_DELTA_TIME	Time interval to consider lightning data files	Integer	15
RAIN_LIGHTNING_RATE_1	Rain rate parameter 1 linked to observed lightning	Real	2.3
RAIN_LIGHTNING_RATE_2	Rain rate parameter 2 linked to observed lightning	Real	0.75
RAIN_LIGHTNING_RATE_3	Rain rate parameter 3 linked to observed lightning	Real	0.25
RAIN_LIGHTNING_RATE_4	Rain rate parameter 4 linked to observed lightning	Real	0.1
COEFF_N_LIGHTNING_A	Coefficient "a" to be applied during the lightning adjustment function	Real	0.45
COEFF_N_LIGHTNING_B	Coefficient "b" to be applied during the lightning adjustment function	Real	0.7
INT_PRODUCT	Indicator whether intermediate products have to be written (Y yes; N no)	Chain of characters	N
NWP_PARAM	Parameter : Wind velocity (u-component) (ms ⁻¹) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_UW 1 BILIN
NWP_PARAM	Parameter : Wind velocity (v-component) (ms ⁻¹) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_VW 1 BILIN
NWP_PARAM	Parameter : Relative humidity (%) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_RH 1 BILIN
NWP_PARAM	Parameter : 2m dewpoint temperature (K) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_2D 1 BILIN
NWP_PARAM	Parameter : 2m air temperature (K) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_2T 1 BILIN
NWP_PARAM	Parameter : Temperature (K) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_T 1 BILIN
NWP_PARAM	Parameter : Surface pressure (Pa) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_SP 1 BILIN
NWP_PARAM	Parameter : Geopotential (m ² s ⁻²) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_GEOP 1 BILIN


Table 7. Model configuration file keywords table applicable to CRR product

3.3.2.2 Keywords description for Convective Rainfall Rate (CRR)

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

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- **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 70°. It is possible to configure the product to only use the night algorithm by setting the day night zen threshold to 0. This would avoid discontinuities in the product at the day/night transition on the cost of degrading performance during day time.
- **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 and so 3-V calibration functions will be used during day-time).
- **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 semi-size (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_CORR:** To decide whether the lightning information will be used (keyword set to 1) or not (keyword set to 0) to improve the CRR precipitation pattern. By default this keyword is set to 0.
- **COEFF_EVOL_GRAD_CORR_00:** When two consecutives IR images are available and the Evolution correction is applied, if the IR brightness temperature increases in a pixel, 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).
- **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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (Default value: 2,30 mm).
- **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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (Default value: 0,10 mm).

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- **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).

3.4 TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

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.
- The limited availability of radar data at the time of carrying out the CRR calibration caused that three different radar datasets, with different radar products, had to be used. In the case of the Spanish radar data, PPI product were used and a quality control, taking advantage of a quality image generated for the radar national composite products (Gutierrez and Aguado, 2006), was used. In the case of the Hungarian radar data, rain rates based on Maximum reflectivity in the vertical were used, while in the case of Baltrad network, pseudo-CAPPI at 2Km were used to derive rain rates. It should be borne in mind that no quality control methods were used for Baltrad and Hungarian radar datasets.
- Data from the radar networks in different areas were not compared to an independent reference.

Regarding the lightning algorithm:

- The CRR lightning algorithm in CRR v4.0.1, 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.

This product does not distinguish the phase of the estimated precipitation.

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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.

3.5 EXAMPLE OF CONVECTIVE RAINFALL RATE (CRR) PRODUCT VISUALISATION

3.5.1.1 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.

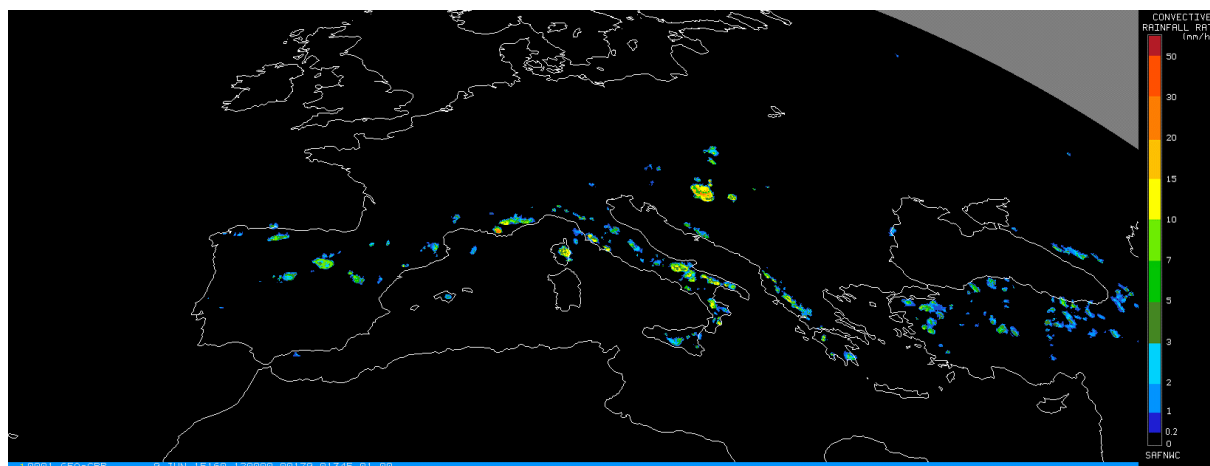


Figure 3. CRR instantaneous intensities output corresponding to 9th June 2015 at 12:00Z

3.5.1.2 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.

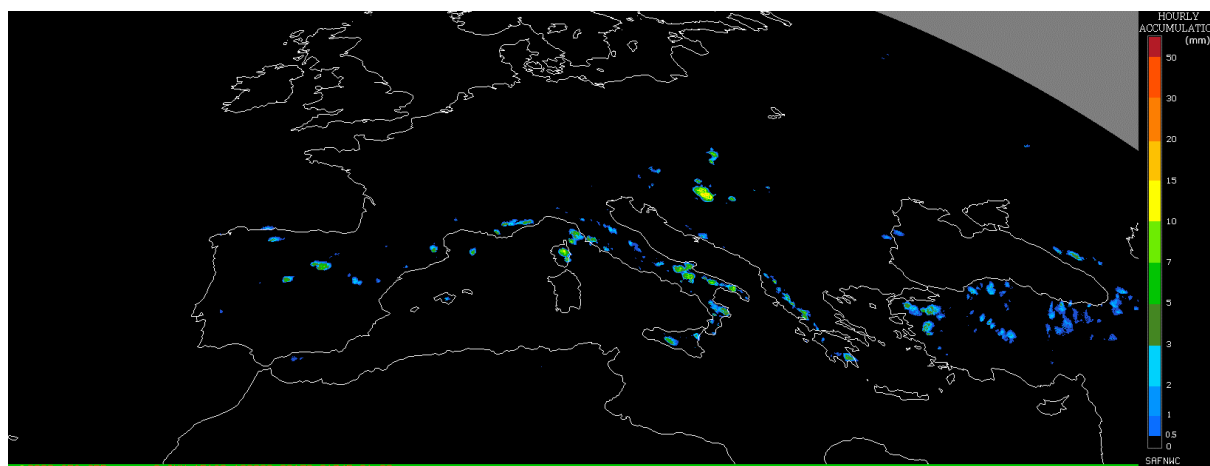



Figure 4. CRR hourly accumulations output corresponding to 9th June 2015 at 12:00Z.

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4. PRECIPITATING CLOUDS FROM CLOUD PHYSICAL PROPERTIES (PC-PH) PRODUCT

4.1 DESCRIPTION OF PRECIPITATING CLOUDS FROM CLOUD PHYSICAL PROPERTIES (PC-PH)

4.1.1 Goal of Precipitating Clouds from Cloud Physical Properties (PC-Ph)

Precipitating Clouds from Cloud Physical Properties (PC-Ph) product, developed within the NWC SAF context, is a Nowcasting tool that provides estimation on the probability of precipitation (PoP) occurrence. In this context, PoP is defined as the instantaneous probability that a rain rate greater than or equal to 0.2 mm/h occurs at the pixel level.

This product can be obtained for every satellite slot, which in case of MSG 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.

4.1.2 Outline of Precipitating Clouds from Cloud Physical Properties (PC-Ph)

4.1.2.1 Day time

The PoP estimation is done using information on the cloud physical properties, Effective Radius (R_{eff}) and Cloud Optical Thickness (COT). Using these two parameters the Cloud Water Path (CWP) is computed. The following step connects CWP with PoP for each pixel, through the following relationship:

$$PoP = 33.0 * Ln(CWP) - 149.6$$

Where PoP is the Probability of Precipitation occurrence (%) and CWP is the Cloud Water Path (gm^{-2}).

To eliminate parallax effects, a parallax correction can be applied (see section 3.1.2.2.4 Parallax correction).

The graph of this function can be observed below.

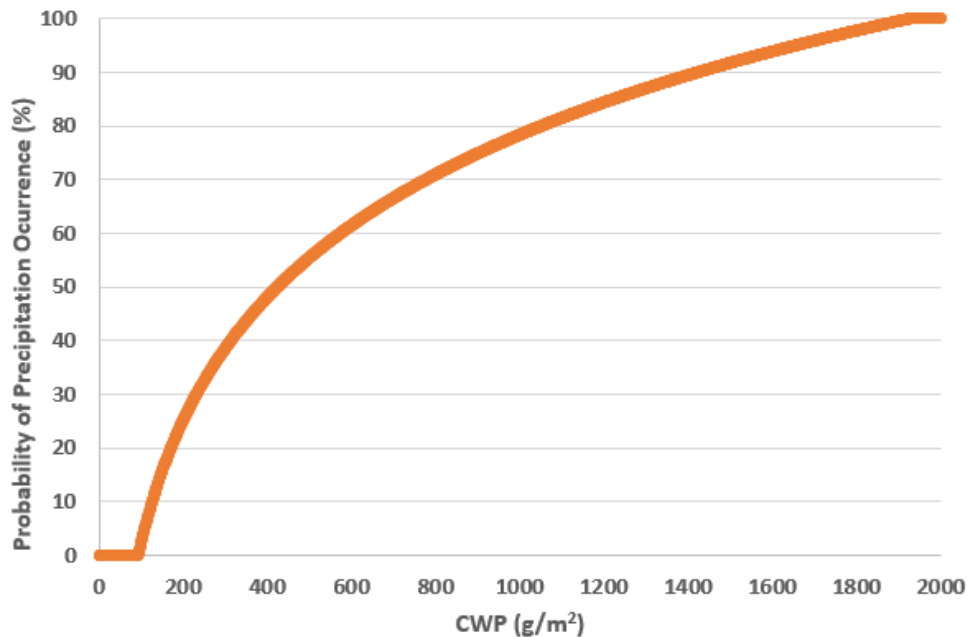


Figure 5. Function that connects Probability of Precipitation with CWP

4.1.2.2 Night time


The PoP estimation is computed whenever the CMIC phase is defined. A nonlinear regression, the Kernel Ridge Regression (KRR), is applied to establish a relationship between SEVIRI brightness temperatures and rainfall intensities.

More information about the KRR can be found in the Algorithm Theoretical Basis Document for the Precipitation Product Processors of the NWC/GEO, section 4.2.1.2.1 [RD 5]


4.1.3 Description of Precipitating Clouds from Cloud Physical Properties (PC-Ph) outputs

The content of the PC-Ph output (stored in \$SAFNWC/export/PC in netCDF format) is described in the Data Output Format Document [RD 2]. A summary is given below:

NetCDF Common Attributes	
product_completeness	Percentage of pixels within the region containing data
product_quality	Weighted mean of the quality of all pixels with data, using the following weights: 1: Good pixels, 0.5: Questionable quality, 0.0: Bad quality

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Container	Content																																																														
pcph	<div>NWC GEO PC-Ph Precipitating Clouds from cloud Physical Properties</div> <table><tr><th colspan="4">DAY ALGORITHM</th></tr><tr><th>GEO-CMIC-PHASE INPUT</th><th>GEO-CMIC-PHASE PHASE INPUT CLASS</th><th>COTT OR REFF FROM CMIC</th><th>PC-PH OUTPUT</th></tr><tr><td rowspan="2">Liquid</td><td rowspan="2">1</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td rowspan="2">Ice</td><td rowspan="2">2</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td rowspan="2">Mixed</td><td rowspan="2">3</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td>Cloud-free</td><td>4</td><td>NOT APPLICABLE</td><td>0</td></tr><tr><td>Undefined</td><td>5</td><td>NOT APLLICABLE</td><td>NO DATA</td></tr><tr><td>No data or corrupted data</td><td>FillValue</td><td>NOT APPLICABLE</td><td>NO DATA</td></tr></table> <div><table><tr><th colspan="3">NIGHT ALGORITHM</th></tr><tr><th>GEO-CMIC-PHASE INPUT</th><th>GEO-CMIC-PHASE PHASE INPUT CLASS</th><th>PC-PH OUTPUT</th></tr><tr><td>Liquid</td><td>1</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td>Ice</td><td>2</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td>Mixed</td><td>3</td><td>pcph(%) = scale_factor * counts + add_offset</td></tr><tr><td>Cloud-free</td><td>4</td><td>0</td></tr><tr><td>Undefined</td><td>5</td><td>NO DATA</td></tr><tr><td>No data or corrupted data</td><td>FillValue</td><td>NO DATA</td></tr></table><div>pcph(%) = scale_factor * counts + add_offset</div><div>where: scale_factor = 1.0 add_offset = 0.0</div></div>	DAY ALGORITHM				GEO-CMIC-PHASE INPUT	GEO-CMIC-PHASE PHASE INPUT CLASS	COTT OR REFF FROM CMIC	PC-PH OUTPUT	Liquid	1	NO DATA	NO DATA	DATA AVAILABLE	pcph(%) = scale_factor * counts + add_offset	Ice	2	NO DATA	NO DATA	DATA AVAILABLE	pcph(%) = scale_factor * counts + add_offset	Mixed	3	NO DATA	NO DATA	DATA AVAILABLE	pcph(%) = scale_factor * counts + add_offset	Cloud-free	4	NOT APPLICABLE	0	Undefined	5	NOT APLLICABLE	NO DATA	No data or corrupted data	FillValue	NOT APPLICABLE	NO DATA	NIGHT ALGORITHM			GEO-CMIC-PHASE INPUT	GEO-CMIC-PHASE PHASE INPUT CLASS	PC-PH OUTPUT	Liquid	1	pcph(%) = scale_factor * counts + add_offset	Ice	2	pcph(%) = scale_factor * counts + add_offset	Mixed	3	pcph(%) = scale_factor * counts + add_offset	Cloud-free	4	0	Undefined	5	NO DATA	No data or corrupted data	FillValue	NO DATA
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Ice	2	pcph(%) = scale_factor * counts + add_offset																																																													
Mixed	3	pcph(%) = scale_factor * counts + add_offset																																																													
Cloud-free	4	0																																																													
Undefined	5	NO DATA																																																													
No data or corrupted data	FillValue	NO DATA																																																													
pcph_status_flag	<div>5 bits indicating</div> <div>Data Availability: Bit 0: R_{eff} or COT not computed (out of cloud, night time or undefined phase) Bit 1: Phase not computed or undefined Bit 2: IR band missing (used in parallax correction)</div> <div>Applied Correction: Bit 3: Parallax correction applied</div> <div>Other information Bit 4: pc_intensity was a hole because of the parallax correction, and then was filled by the median filter</div>																																																														

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Geophysical Conditions


Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.
Quality	Parameter	Retrieval Quality 0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

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4.2 IMPLEMENTATION OF PRECIPITATING CLOUDS FROM CLOUD PHYSICAL PROPERTIES (PC-Ph)

Previous condition and licences:

The right to use, copy or modify this software is in accordance with EUMETSAT Policy for the NWC-GEO software package.

4.2.1 Installation of Precipitating Clouds from Cloud Physical Properties (PC-Ph)

PC-Ph product is generated by the GEO-PPh component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual [RD 3].

The software installation procedure does not require special resources. It is restricted to decompress the distribution files (a gzip-compressed tar files) and to successfully build the executable GEO-PPh-v<version> file to be stored into the \$SAFNWC/bin directory.

Once the GEO-PPh-v<version> of the NWC-GEO 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.

4.2.2 Preparation of Precipitating Clouds from Cloud Physical Properties (PC-Ph)

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. Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4].


The configuration file in charge of the product settings is the PPh 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 whether the parallax correction should be applied or not. Since GEO-PPh component is in charge of computing both PC-Ph and CRR-Ph products on demand, to obtain PC-Ph output, it should be indicated in PPh model configuration file through OUTPUT_PRODUCT keyword. More information on this configuration file can be found in section 4.3.2.

In order to apply parallax correction, NWP data required have to be available in \$SAFNWC/import/NWP_data directory.

4.2.3 Execution of Precipitating Clouds from Cloud Physical Properties (PC-Ph)

The GEO-PPh execution step consists in the launch of the command:

```
%    GEO-PPh-v<version>    <YYYY-MM-DDThh:mm:ssZ>    <region_conf_file>
<model_conf_file>
```

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Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4] and model_conf_file is described in section 4.3.2.

GEO-PPh, to compute PC-Ph product, requires mainly five steps:

- Initialise all variables and data structures according to input data. This includes computation of navigation data in the processing region read from the Processing Region Configuration File.
- Reading the input data required to execute the requested PPh processing in the processing region including required CMIC product and IR Satellite band.
- Implementation of the algorithm to compute the base PC-Ph values and some other quality and processing information.
- Application of parallax correction, if required in the PPh Model Configuration file, to the base PC-Ph values computed in the previous step.
- Writing the PC-Ph product file according to the specification provided in the DOF [RD 2].

More information on the GEO-PPh execution steps can be found at the Component Design Document for the Precipitation Product Processors of the NWC/GEO document [RD 6].

4.3 INPUTS AND CONFIGURABLE PARAMETERS FOR PRECIPITATING CLOUDS FROM CLOUD PHYSICAL PROPERTIES (PC-PH)

4.3.1 List of inputs for Precipitating Clouds from Cloud Physical Properties (PC-Ph)

CMIC product physical properties:

- CMIC Phase, COT and R_{eff} parameters are mandatory inputs to PC-Ph day algorithm.
- CMIC Phase is mandatory input to compute the PC-Ph night algorithm

These parameters will be read from CMIC NetCFD file which must be located in \$SAFNWC/export/CMIC directory.

Satellite imagery:

IR10.8 and WV6.2 are mandatory inputs to compute the PC-Ph night algorithm.


IR10.8 SEVIRI brightness temperature at full IR spatial resolution is a mandatory input to compute Parallax Correction. It must be placed by the user in HRIT format in the \$SAFNWC/import/Sat_data directory. Then it will be extracted on the desired region by NWC-GEO software package.

Numerical model:

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

The NWP files must be located in \$SAFNWC/import/NWP_data directory. In real time operational mode, the NWC-GEO package has predefined tools (coordinated by the NWC-GEO

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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 product processor to make the remapping process. In off-line operational mode, the “AllMapping” script allows to do the spatial remapping.

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

Ancillary data sets:

Climatological profile is necessary as a backup for Parallax correction in case NWP is not available. This information is included in the software package and is located in the \$SAFNWC/import/Aux_data/CRR-Ph directory.

Model configuration file for PPh:

PPh model configuration file contains configurable system parameters in the generation process of both PC-Ph and CRR-Ph products. This file is placed in the \$SAFNWC/config directory. The PC-Ph product related parameters refers to ancillary datasets, numerical model data and parallax correction. The complete list of these parameters and the explanation of the most useful ones is available on section 4.3.2.

Region configuration file (region.cfg):

This file set the dimensions and positions where PPh products will be obtained and is located in \$SAFNWC/config directory.

4.3.2 Configurable parameters for Precipitating Clouds from Cloud Physical Properties (PC-Ph)

Model configuration file contains configurable items in the product generation process such as corrections to be run, NWP parameters to be used by the PPh product processor, etc.


The PPh model configuration file needed for the execution of PPh 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).

4.3.2.1 Keywords table for Precipitating Clouds from Cloud Physical Properties (PC-Ph)

The PPh model Configuration File, located in the \$SAFNWC/config directory and identified by the extension “.cfm”, contains the following information applicable to PC-Ph product:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the product processor	Chain of characters	GEO-PPh
SEV_BANDS	Satellite channels to be used by PPh	Chain of characters	IR108
DAY_NIGHT_ZEN_THRESHOLD	Solar zenith angle to select between day and night cases (in degrees). It is possible to configure the product to only use the night algorithm by setting the sun zenith angle threshold to 0. This would avoid discontinuities in the product at the day/night transition on the cost of degrading performance during day time	Double	70
APPLY_PARALLAX_CORR	Indicator whether the Parallax correction should be applied or not (1 yes; 0 no)	Integer	1

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OUTPUT_PRODUCT	Products to be generated: ALL : Both CRR-Ph and PC-Ph netCDF products are generated CRR-Ph : Only CRR-Ph netCDF product is generated PC-Ph : Only PC-Ph netCDF product is generated	Chain of characters	ALL
NWP_PARAM	Parameter : Temperature (K) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_T 1 BILIN
NWP_PARAM	Parameter : Geopotential (m ² s ⁻²) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_GEOP 1 BILIN

Table 8. Model configuration file keywords table applicable to PC-Ph product

4.3.2.2 Keywords description for Precipitating Clouds from Cloud Physical Properties (PC-Ph)

Below there is a description of the most useful keywords defined in PPh model configuration file and applicable to PC-Ph product in order to make easier the user exploitation:

- **APPLY_PARALLAX_CORR:** To decide whether the Parallax correction should be applied to PC-Ph basic values or not (1 yes; 0 no)
- **OUTPUT_PRODUCT:** To decide which products are to be generated:
ALL: Both CRR-Ph and PC-Ph netCDF products are generated
CRR-Ph: Only CRR-Ph netCDF product is generated
PC-Ph: Only PC-Ph netCDF product is generated

4.4 TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

For undefined phase pixels, R_{eff} and COT values are not computed by CMIC, in these cases the PC-Ph day algorithm assigns NO DATA value.

Regarding the night time, the PC-Ph product also assigns NO DATA value to those pixels with undefined phase according to the phase output of the CMIC product, which means that no information on whether the cloud consists of water or ice is available.


As the main inputs of the product are computed by CMIC, there exists the need to run CMIC previous to run PPh.

It has been observed that pixels located in the surroundings of snow according to CMIC take sometimes high values of CWP, so a probability of precipitation higher than 0% is assigned erroneously.

It is highly recommended to apply parallax correction for a better location of precipitation areas with respect to the ground below.

This product obtains the best results for convective events in terms of a categorical validation

4.5 EXAMPLE OF PRECIPITATING CLOUDS FROM CLOUD PHYSICAL PROPERTIES (PC-PH) VISUALIZATION

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Below is shown an example of the PCPh product. According to the PCPh output format described in section 4.1.3, cloud-free pixels appear in black and NO DATA values are plotted in grey, for both day and night algorithm.

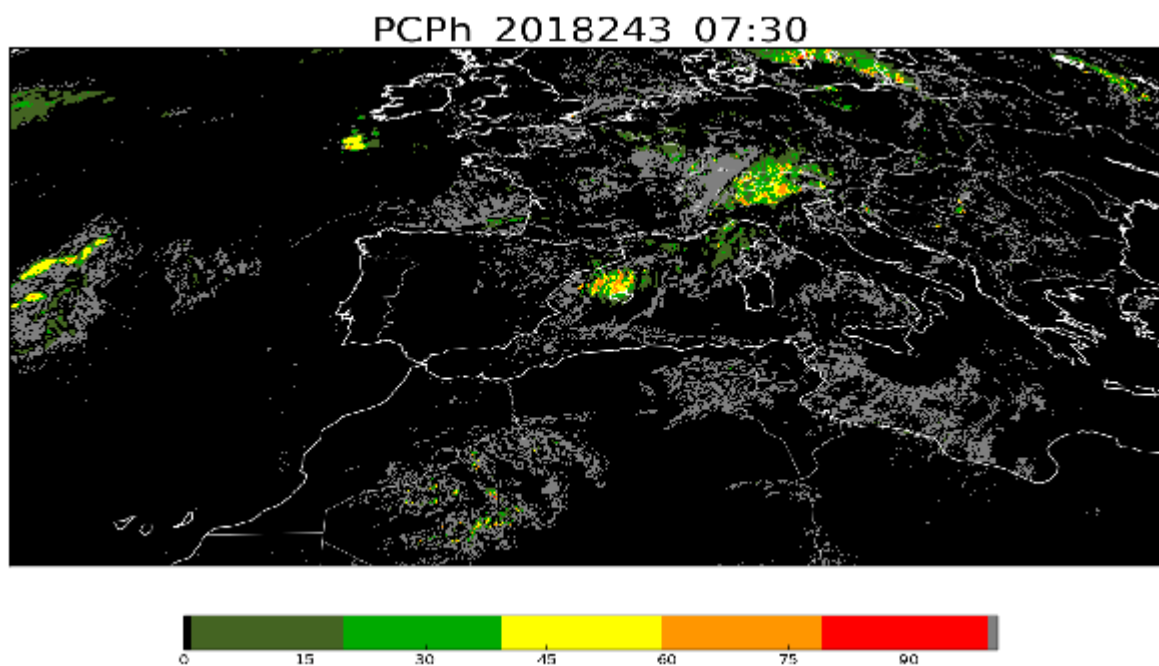



Figure 6. PC-Ph probability of precipitation for 31th August 2018 at 7:30 UTC over Europe and North Africa

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5. CONVECTIVE RAINFALL RATE FROM CLOUD PHYSICAL PROPERTIES (CRR-PH) PRODUCT

5.1 DESCRIPTION OF CONVECTIVE RAINFALL RATE FROM CLOUD PHYSICAL PROPERTIES (CRR-PH)

5.1.1 Goal of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph) product, developed within the NWC SAF context, is a Nowcasting tool that provides information on convective, and stratiform associated to convection, instantaneous rain rates and hourly accumulations.

This product can be obtained for every satellite slot, which in case of MSG 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.

5.1.2 Outline of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

5.1.2.1 Day time

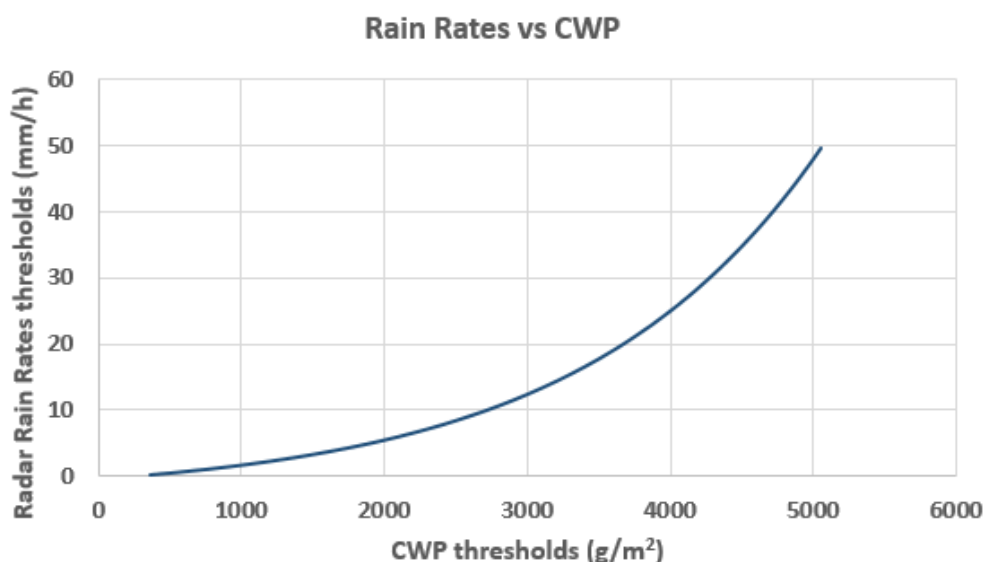
The convective rainfall rate estimation is done using information on the cloud physical properties, Effective Radius (R_{eff}) and Cloud Optical Thickness (COT). Using these two parameters the Cloud Water Path (CWP) is computed. Depending on some R_{eff} and CWP thresholds, the precipitation area is enclosed. Only in those pixels belonging to the precipitation area, the rain rate is computed.

To assign an instantaneous rain rate to each pixel, the following relationship between CWP and precipitation intensity is applied:

$$RR = 2.0 * \exp(6 * 10^{-4} (CWP + 400.0)) - 3.02$$

Where RR is the Rainfall Rate (mmh^{-1}) and CWP is the Cloud Water Path (gm^{-2}).

The graph of this function can be observed in the following figure.




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Figure 7. Function that connects Rain Rates with CWP

Rain rates estimation from geostationary satellite data cannot be very accurate so trying to estimate rain rates higher than 50 mm/h using this type of data is not realistic. For this reason a maximum limit of 50 mm/h has been established.

It has been seen that, under some conditions, rain rates assigned by this product are erroneously high. In order to provide the user with information about the reliability of the estimated rain rates an illumination quality flag (CRPh_IQF) has been developed.

CRR_IQF (%) is included as an output of the product and it must be understood as an indicator of the confidence that a forecaster can have on the rain rates estimated by the product.

For a better location of the precipitation area, the parallax correction can be applied to this product (see section 3.1.2.2.4 Parallax correction). This option is chosen by the user through the product model configuration file and it is applied by default.

Since lightning activity can provide valuable information about convection, a lightning algorithm can be applied to derive a precipitation pattern that will be combined with the CRR one computed in the previous step in order to complement it (see section 3.1.2.3 Lightning algorithm).

At the end of the process the final values of the CRR-Ph rainfall rates in mm/h are used in order to obtain hourly accumulations and four different outputs as described in section 5.1.3 are completed.

5.1.2.2 Night time


The convective rainfall rate estimation is computed whenever the CMIC phase is defined. A nonlinear regression, the Kernel Ridge Regression (KRR), is applied to establish a relationship between SEVIRI brightness temperatures and rainfall intensities.

More information about the KRR can be found in the Algorithm Theoretical Basis Document for the Precipitation Product Processors of the NWC/GEO, section 5.2.1.2.1 [RD 5]


5.1.3 Description of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph) outputs

The content of the CRR-Ph output (stored in \$SAFNWC/export/CRR in netCDF format) is described in the Data Output Format Document [RD 2]. A summary is given below:

NetCDF Common Attributes	
product_completeness	Percentage of pixels within the region containing data
product_quality	Weighted mean of the quality of all pixels with data, using the following weights: 1: Good pixels, 0.5: Questionable quality, 0.0: Bad quality

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Container	Content																																																														
crrph_intensity	<div>NWC GEO CTMP-CRR Convective Rainfall Intensity</div> <div><table><tr><th colspan="4">DAY ALGORITHM</th></tr><tr><th>GEO-CMIC-PHASE INPUT</th><th>GEO-CMIC PHASE INPUT CLASS</th><th>COTT OR REFF FROM CMIC</th><th>CRR-PH OUTPUT</th></tr><tr><td rowspan="2">Liquid</td><td rowspan="2">1</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td rowspan="2">Ice</td><td rowspan="2">2</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td rowspan="2">Mixed</td><td rowspan="2">3</td><td>NO DATA</td><td>NO DATA</td></tr><tr><td>DATA AVAILABLE</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td>Cloud-free</td><td>4</td><td>NOT APPLICABLE</td><td>0</td></tr><tr><td>Undefined</td><td>5</td><td>NOT APPLICABLE</td><td>NO DATA</td></tr><tr><td>No data or corrupted data</td><td>FillValue</td><td>NOT APPLICABLE</td><td>NO DATA</td></tr></table></div> <div><table><tr><th colspan="3">NIGHT ALGORITHM</th></tr><tr><th>GEO-CMIC-PHASE INPUT CLASS</th><th>GEO-CMIC PHASE INPUT CLASS</th><th>CRR-PH OUTPUT</th></tr><tr><td>Liquid</td><td>1</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td>Ice</td><td>2</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td>Mixed</td><td>3</td><td>crrph_intensity(mm/h) = scale_factor * counts + add_offset</td></tr><tr><td>Cloud-free</td><td>4</td><td>0</td></tr><tr><td>Undefined</td><td>5</td><td>NO DATA</td></tr><tr><td>No data or corrupted data</td><td>FillValue</td><td>NO DATA</td></tr></table></div> <div><div>crrph_intensity(mm/h) = scale_factor * counts + add_offset</div><div>where:<div><div>scale_factor</div><div>= 0.1</div></div><div><div>add_offset</div><div>= 0.0</div></div></div></div>	DAY ALGORITHM				GEO-CMIC-PHASE INPUT	GEO-CMIC PHASE INPUT CLASS	COTT OR REFF FROM CMIC	CRR-PH OUTPUT	Liquid	1	NO DATA	NO DATA	DATA AVAILABLE	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Ice	2	NO DATA	NO DATA	DATA AVAILABLE	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Mixed	3	NO DATA	NO DATA	DATA AVAILABLE	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Cloud-free	4	NOT APPLICABLE	0	Undefined	5	NOT APPLICABLE	NO DATA	No data or corrupted data	FillValue	NOT APPLICABLE	NO DATA	NIGHT ALGORITHM			GEO-CMIC-PHASE INPUT CLASS	GEO-CMIC PHASE INPUT CLASS	CRR-PH OUTPUT	Liquid	1	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Ice	2	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Mixed	3	crrph_intensity(mm/h) = scale_factor * counts + add_offset	Cloud-free	4	0	Undefined	5	NO DATA	No data or corrupted data	FillValue	NO DATA
DAY ALGORITHM																																																															
GEO-CMIC-PHASE INPUT	GEO-CMIC PHASE INPUT CLASS	COTT OR REFF FROM CMIC	CRR-PH OUTPUT																																																												
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Liquid	1	crrph_intensity(mm/h) = scale_factor * counts + add_offset																																																													
Ice	2	crrph_intensity(mm/h) = scale_factor * counts + add_offset																																																													
Mixed	3	crrph_intensity(mm/h) = scale_factor * counts + add_offset																																																													
Cloud-free	4	0																																																													
Undefined	5	NO DATA																																																													
No data or corrupted data	FillValue	NO DATA																																																													
crrph_accum	<div>NWC GEO CTMP-CRR Convective Hourly Rainfall Accumulation</div> <div><div>crrph_accum(mm) = scale_factor * counts + add_offset</div><div>where:<div><div>scale_factor</div><div>= 0.1</div></div><div><div>add_offset</div><div>= 0.0</div></div></div></div>																																																														

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Container	Content
crrph_iqf	<p>NWC GEO CTMP-CRR Confidence based on illumination conditions</p> $crrph_iqf(\%) = scale_factor * counts + add_offset$ <p>where:</p> <p><i>scale_factor</i> = 1.0 <i>add_offset</i> = 0.0</p>
crrph_status_flag	<p>10 bits indicating</p> <p>Data Availability:</p> <p>Bit 0: R_{eff} or COT not computed (out of cloud, night time, phase not defined) Bit 1: Phase not computed or undefined Bit 2: IR band missing (used in parallax correction)</p> <p>Applied Correction:</p> <p>Bit 3: Parallax correction applied</p> <p>Use of optional data:</p> <p>Bit 6: Lightning data used</p> <p>Other information</p> <p>Bit 8: crr_intensity was a hole because of the parallax correction, and then was filled by the median filter</p> <p>Bit 9, 10, 11: Use of bands for accumulation</p> <p>1: All required bands were available 2: One previous CRR band is missing 3: At least two previous CRR bands are missing (no consecutive) 4: At least two previous CRR bands are missing (some are consecutive)</p> <p>Bit 12: Accumulation quality flag. Set to 1 if: not all crr values are available to perform the accumulation, OR any of the crr_intensity values was set to 0 due to filtering process OR Any of the crr_intensity values was a hole because parallax correction</p>

Geophysical Conditions

Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	<p>Defines the illumination condition</p> <p>0: N/A (space pixel) 1: Night 2: Day 3: Twilight</p>
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	<p>0: N/A (space pixel) 1: Land 2: Sea 3: Coast</p>

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Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing


Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.
Quality	Parameter	Retrieval Quality 0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

5.2 IMPLEMENTATION OF CONVECTIVE RAINFALL RATE FROM CLOUD PHYSICAL PROPERTIES (CRR-PH)

Previous condition and licences:

The right to use, copy or modify this software is in accordance with EUMETSAT Policy for the NWC-GEO software package.

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5.2.1 Installation of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

CRR-Ph product is generated by the GEO-PPh component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual [RD 3].

The software installation procedure does not require special resources. It is restricted to decompress the distribution files (a gzip-compressed tar files) and to successfully build the executable GEO-PPh-v<version> file to be stored into the \$SAFNWC/bin directory.

Once the GEO-PPh-v<version> of the NWC-GEO 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.

5.2.2 Preparation of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

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. Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4].

The configuration file in charge of the product settings is the PPh 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 whether the parallax correction should be applied or not. Since GEO-PPh component is in charge of computing both PC-Ph and CRR-Ph products on demand, to obtain CRR-Ph output, it should be indicated in PPh model configuration file through OUTPUT_PRODUCT keyword. More information on this configuration file can be found in section 4.3.2.

In order to apply parallax correction, NWP data required have to be available in \$SAFNWC/import/NWP_data directory. And to run Lightning algorithm, lightning data must be placed in the \$SAFNWC/import/Obs_data/Lightning directory.

5.2.3 Execution of Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)


The GEO-PPh execution step consists in the launch of the command:

```
%    GEO-PPh-v<version>      <YYYY-MM-DDThh:mm:ssZ>      <region_conf_file>
<model_conf_file>
```

Information on the region_conf_file can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO document [RD 4] and model_conf_file is described in section 4.3.2.

GEO-PPh, to compute CRR-Ph product, requires mainly six steps:

- Initialise all variables and data structures according to input data. This includes computation of navigation data in the processing region read from the Processing Region Configuration File.

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- Reading the input data required to execute the requested PPh processing in the processing region including required CMIC product, IR Satellite band and previous CRR-Ph products in the requested processing region (required to compute the hourly rainfall accumulation).
- Implementation of the algorithm to compute the base CRR-Ph values and some other quality and processing information.
- Application of parallax correction and lightning correction, if required in the PPh Model Configuration file, to the base CRR-Ph values computed in the previous step.
- Computation of the hourly rainfall accumulations using rainfall intensities from previous CRR-Ph products
- Writing the CRR-Ph product file according to the specification provided in the DOF [RD 2].

More information on the GEO-PPh execution steps can be found at the Component Design Document for the Precipitation Product Processors of the NWC/GEO document [RD 6].

5.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CONVECTIVE RAINFALL RATE FROM CLOUD PHYSICAL PROPERTIES (CRR-PH)

5.3.1 List of inputs for Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

CMIC product physical properties:

- CMIC Phase, COT and R_{eff} parameters are mandatory inputs to CRR-Ph day algorithm.
- CMIC Phase is mandatory input to compute the CRR-Ph night algorithm.

These parameters will be read from CMIC NetCFD file which must be located in \$SAFNWC/export/CMIC directory.

Satellite imagery:

IR10.8 and WV6.2 are mandatory inputs to compute the CRR-Ph night algorithm


IR10.8 SEVIRI brightness temperature at full IR spatial resolution is a mandatory input to compute Parallax Correction. It must be placed by the user in HRIT format in the \$SAFNWC/import/Sat_data directory. Then it will be extracted on the desired region by NWC-GEO software package.

Numerical model:

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

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

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avoids spending time in every call to product processors to make the remapping process. In off-line operational mode, the “AllMapping” script allows to do the spatial remapping.

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

Ancillary data sets:

Climatological profile is necessary as a backup for Parallax correction in case NWP is not available. This information is included in the software package and is located in the \$SAFNWC/import/Aux_data/CRR-Ph directory.

Lightning information file for CRR-Ph product:

A file with information on every lightning stroke occurred in a time interval is mandatory to choose the option of adjusting the CRR-Ph precipitation pattern with the lightning information provided by ground based lightning detection networks. Information about this lightning information file structure can be found in the Interface Control Document for Internal and External Interfaces of the NWC/GEO [RD 4]. This file must be located in the \$SAFNWC/import/Obs_data/Lightning directory.

The CRR-Ph 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.

Model configuration file for PPh:

PPh model configuration file contains configurable system parameters in the generation process of both PC-Ph and CRR-Ph products. This file is placed in the \$SAFNWC/config directory. The CRR-Ph product related parameters refers to ancillary datasets, numerical model data, parallax correction and lightning correction. The complete list of these parameters and the explanation of the most useful ones is available on section 5.3.2.

Region configuration file (region.cfg):


This file set the dimensions and positions where PPh products will be obtained and is located in \$SAFNWC/config directory.

5.3.2 Configurable parameters for Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

Model configuration file contains configurable items in the product generation process such as corrections to be run, NWP parameters to be used by the PPh product processor, etc.

The PPh model configuration file needed for the execution of PPh 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).


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5.3.2.1 Keywords table for Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)

The PPh model Configuration File, located in the \$SAFNWC/config directory and identified by the extension “.cfm”, contains the following information applicable to CRR-Ph product:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the product processor	Chain of characters	GEO-PPh
SEV_BANDS	Satellite channels to be used by PPh	Chain of characters	IR108
DAY_NIGHT_ZEN_THRESHOLD	Solar zenith angle to select between day and night cases (in degrees). It is possible to configure the product to only use the night algorithm by setting the sun zenith angle threshold to 0. This would avoid discontinuities in the product at the day/night transition on the cost of degrading performance during day time	Double	70
APPLY_PARALLAX_CORR	Indicator whether the Parallax correction should be applied or not (1 yes; 0 no)	Integer	1
OUTPUT_PRODUCT	Products to be generated: ALL : Both CRR-Ph and PC-Ph netCDF products are generated CRR-Ph : Only CRR-Ph netCDF product is generated PC-Ph : Only PC-Ph netCDF product is generated	Chain of characters	ALL
APPLY_LIGHTNING_CORR	Indicator whether the Lightning information should be used or not (1 yes; 0 no)	Integer	0
LIGHTNING_DELTA_TIME	Time interval to consider lightning data files	Integer	15
RAIN_LIGHTNING_RATE_1	Rain rate parameter 1 linked to observed lightning	Real	2.3
RAIN_LIGHTNING_RATE_2	Rain rate parameter 2 linked to observed lightning	Real	0.75
RAIN_LIGHTNING_RATE_3	Rain rate parameter 3 linked to observed lightning	Real	0.25
RAIN_LIGHTNING_RATE_4	Rain rate parameter 4 linked to observed lightning	Real	0.1
COEFF_N_LIGHTNING_A	Coefficient “a” to be applied during the lightning adjustment function	Real	0.45
COEFF_N_LIGHTNING_B	Coefficient “b” to be applied during the lightning adjustment function	Real	0.7
NWP_PARAM	Parameter : Temperature (K) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_T 1 BILIN
NWP_PARAM	Parameter : Geopotential (m^2s^{-2}) sampling rate : (=segment size) interpolation method.	Chain of characters	NWP_GEOP 1 BILIN

Table 9. Model configuration file keywords table applicable to CRR-Ph product

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5.3.2.2 *Keywords description for Convective Rainfall Rate from Cloud Physical Properties (CRR-Ph)*

Below there is a description of the most useful keywords defined in PPh model configuration file applicable to CRR-Ph product in order to make easier the user exploitation:


- **APPLY_PARALLAX_CORR:** To decide whether the Parallax correction should be applied to CRR-Ph basic values or not (1 yes; 0 no)
- **OUTPUT_PRODUCT:** To decide which products are to be generated:
ALL: Both CRR-Ph and PC-Ph netCDF products are generated
CRR-Ph: Only CRR-Ph netCDF product is generated
PC-Ph: Only PC-Ph netCDF product is generated
- **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-Ph 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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (Default value: 2,30 mm).
- **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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (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 the Precipitation Product Processors of the NWC/GEO [RD 5]. (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).

5.4 TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

This algorithm can be run only over daytime.

For undefined phase pixels, R_{eff} and COT values are not computed by CMIC, so a NO DATA value is assigned in these cases by the algorithm.

As the main inputs of the product are computed by CMIC, there exists the need to run CMIC previous to run PPh.

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It has been observed that pixels located in the surroundings of snow according to CMIC take sometimes high values of CWP, so a probability of precipitation higher than 0% is assigned erroneously.

It is highly recommended to apply parallax correction for a better location of precipitation areas with respect to the ground below.

The relatively weak coupling between spectral features in the visible and infrared channels with precipitation rate for all situations except for convection makes it in most cases doubtful to try to assign precipitation rates from GEO data alone. For this reason, this product has been calibrated only for convective events, and so, it obtains the best results for convective events. For other type of precipitation, like the stratiform one, serious underestimation, overestimation or unforecasted events are likely to occur. There exists a high dependence on illumination conditions for this product.

This product does not distinguish the phase of the estimated precipitation.

It must be borne in mind that these kind of cloud top based precipitation indirect methods necessarily have uncertainties. Although not found during the calibration and validation processes, according to the literature it is possible to find small ice particles in high-level strong updrafts of deep convective clouds (Rosenfeld et al., 2008). This could cause erroneous rain rate estimations.

5.5 EXAMPLE OF CONVECTIVE RAINFALL RATE FROM CLOUD PHYSICAL PROPERTIES (CRR-PH) VISUALIZATION

An example of the CRR-Ph instantaneous rain rates is shown below. It has been obtained at full resolution. According to the CRR-Ph output format described in section 5.1.3, cloud-free pixels appear in black and NO DATA values are plotted in grey, for both day and night algorithm.

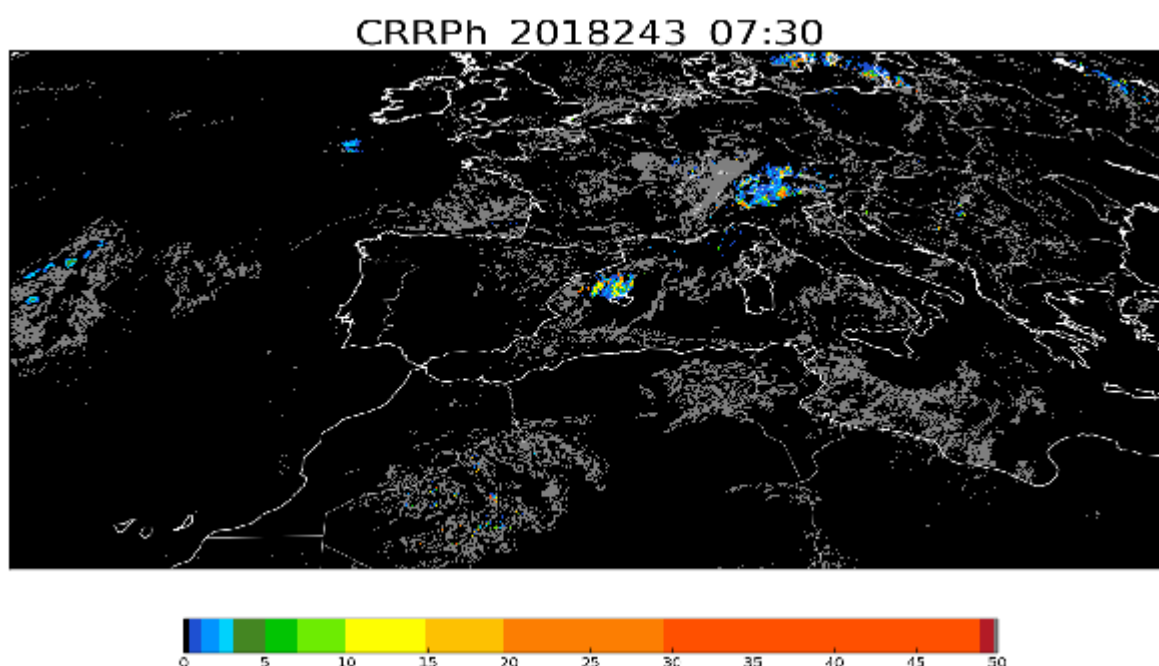


Figure 8. CRR-Ph instantaneous rain rates for 31th August 2018 at 07:30 UTC over Europe and North Africa

An example of the CRR-Ph hourly accumulations is shown below. It has been obtained at full resolution.

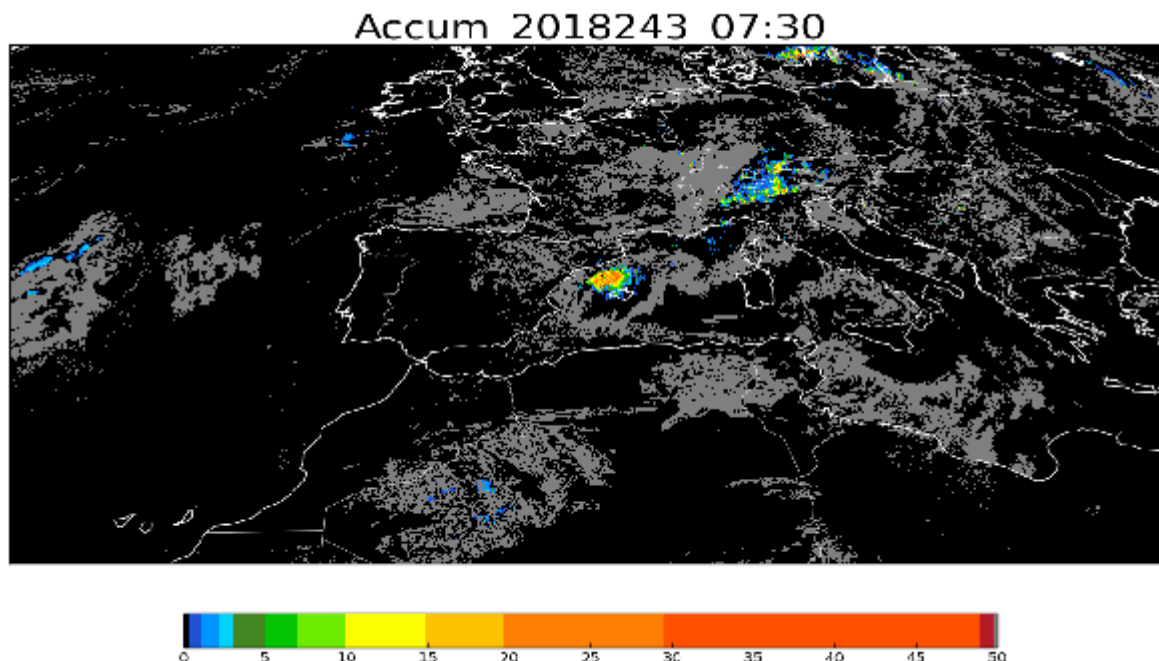


Figure 9. CRR-Ph hourly accumulations for 31th August 2018 at 07:30 UTC over Europe and North Africa

An example of the CRR-Ph illumination quality flag is shown below.

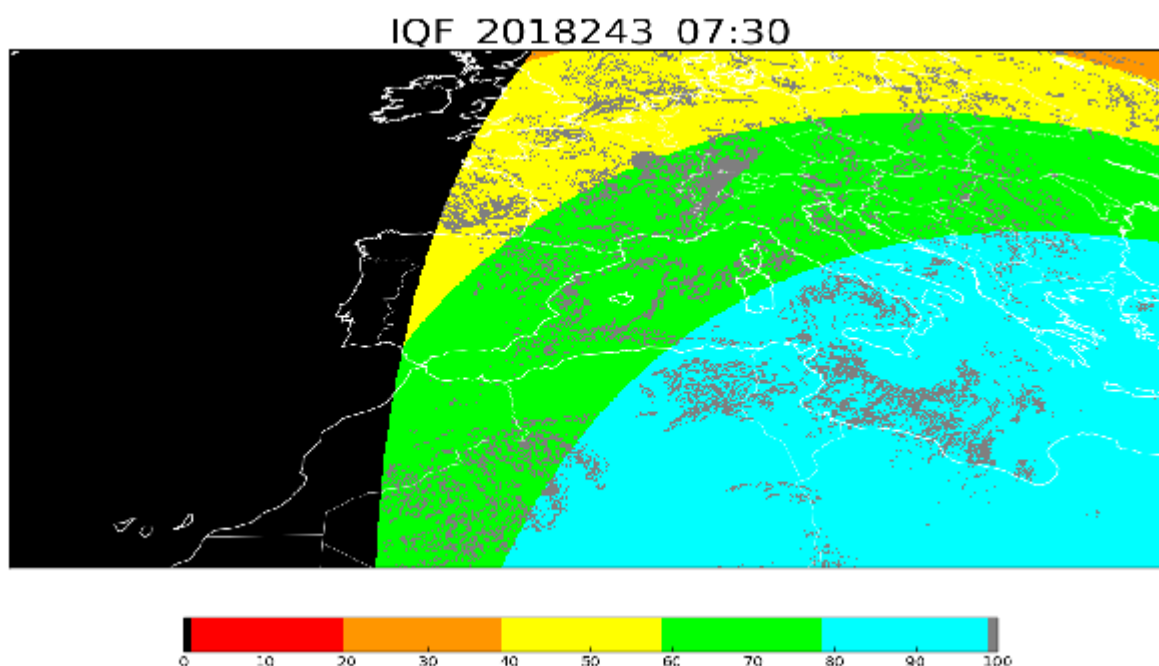



Figure 10. CRR-Ph illumination quality flag for 31th August 2018 at 07:30 UTC over Europe and North Africa

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6. REFERENCES

Daniel Rosenfeld, William L. Woodley, Amit Lerner, Guy Kelman, Daniel T. Lindsey, 2008. Satellite detection of severe convective storms by their retrieved vertical profiles of cloud particle effective radius and thermodynamic phase. J. Geophys. Res. D4, 113.