PGE05 CRR
Convective Rainfall Rate

First Joint Training Workshop

14-16 June 2004

Madrid, Spain

A. Rodríguez

Contents of CRR presentation

- Goal of CRR product
- CRR algorithm summary description
- Correction factors description
- List of inputs for CRR
- Coverage and resolution
- Description of CRR outputs
- Example of CRR visualisation
- Actual Status
- Planned activities in 2004

Goal of product

- Convective Rainfall Rate (CRR) product, developed in the SAF NWC context, provides information on convective and stratiform associated to convection rainfall rates coming from MSG-SEVIRI channels.
- This product provides to forecasters some complement to other SAF NWC products related to rain and convection monitoring such as PGE04 (Precipitating clouds) and PGE02 (Cloud type).

CRR algorithm summary description

- **The algorithm developed for the CRR product is based on the empirical relationship: the higher and thicker are the clouds the higher is the probability of occurrence and the intensity of precipitation. Information about cloud top height and about cloud thickness can be obtained, respectively, from the infrared brightness temperature (IR) and from visible reflectances (VIS).**

  (Scofield, R.A., 1987; Vicente,G.A. and Scofield, R.A., 1996)

- **On the other hand, if WV is the water vapour brightness temperature the IR-WV difference is a useful parameter for extracting deep convective clouds with heavy rainfall.**

  (Kurino, T., 1996)

CRR algorithm summary description

- So the rainfall rate is obtained using the **RAINSAT methodology** that tries to establish a **statistic relationship between satellite multi-band imagery and rainfall data.**
- In summary, a **composite radar data** are compared pixel by pixel with a geographically matched **MSG data** set in the same resolution and rainfall rate **R** is calculated as a function of the two or three variables: **IR, IR-WV** brightness temperature during night, plus normalized **VIS** reflectances during daylight.

CRR algorithm summary description

- If a pixel belongs to a day mask R = f (IR,IR-WV,VIS)

  The CRR value is obtained from a 3-D calibration matrix that uses the following bands: IR10.8, WV6.2 and VIS0.6.

- If a pixel belongs to a night mask R = f (IR,IR-WV)

  The CRR value is obtained from a 2-D calibration matrix that uses the following bands: IR10.8, WV6.2.

- Normalised visible reflectances are obtained for all day pixels dividing by the cosine of solar zenith angle.

CRR algorithm summary description

- Then a filter is performed in order to eliminate stratiform rain data that are not associated with convective clouds.
- The obtained CRR data are set to zero if all the nearest pixels in a box of 14x14 do not have an equal or higher value than 3mm/h.

CRR algorithm summary description
Calibration matrices description

- **2-D Matrix**

  This matrix provides Rain Intensity in function of the IR brightness temperature and the IR-WV brightness temperature differences.

  The T10.8 range is divided in 35 classes from -66ºC to 2ºC, every 2.0 °C

- **3-D Matrix**

  The T10.8 range is divided into 18 classes from -66ºC to 2ºC, every 4.0°C

  The IR-WV brightness temperature differences are divided into 19 classes from -11ºC to 25ºC, every 2.0°C

  The normalised visible count range (148-240) is divided in 24 classes, every 4 brightness value.

CRR algorithm summary description
Calibration matrices description

- **Difference Matrix**

  Made with the differences between the Baltic and Spanish matrix elements. The file structure is the same as 2-D matrix.
- **This matrix provides the rainfall amounts that must be added or subtracted to the basic value if the point latitude is higher to 55°N.**
- **For latitudes between 45°N and 55°N the amount to modify the basic value is provided by a linear regression.**
- **For latitudes smaller than 45°N the rainfall amount is the basic value from the Spanish matrix.**

Corrections factors description

- **Users could apply several corrections to the initial estimation of the CRR computed from the calibration matrices. These corrections take into account elements such as 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** (Vicente, G.A. et al.,1998,1999)**;**
- **The possible correction factors are:**
  - **the moisture correction**
  - **the cloud top growth and decaying rates or evolution correction**
  - **the cloud top temperature gradient correction**
  - **the parallax correction**
  - **the orographic correction**

Corrections factors description
Moisture Correction factor PWRH

- To avoid overestimating computed rainfall when thunderstorms occur in quite dry air masses and underestimating in quite moist ones.
- Is defined as the product of Precipitable Water, PW (inch), in the SFC/ 500 hPa layer and the mean Relative Humidity (%), RH, in the same layer. Data obtained from a numerical model.
- The PWRH factor is empirically scaled from 0.0 to 2.0, and the environment is considered dry if PWRH is significantly lower than 1.0 and quite moist if PWRH is greater than 1.0.

Corrections factors description
Moisture Correction factor PWRH

- For high latitudes where convective systems can be contaminated by hail (radar rainfall is unrealistically high), if IR cloud top temperature is lower than 215K then it is not needed to increase the rainfall rates, however, when the environment is dry (PWRH<1.0) it is necessary to decrease the rainfall rates.
- So if latitude >55°N, T10.8 < 215 and PWRH >1.0 the computed rainfall rate should not be multiplied by the PWRH correction factor.
- In other case, the computed rainfall rate is multiplied by the PWRH correction factor.

Corrections factors description
Evolution Correction Factor

- When the tops become colder and expand, a convective system is more active and produces the greatest rainfall rates. When the tops become warmer little or no rainfall is produced.
- The detection of active or decaying portions of thunderstorm is performed by searching collocated pixels in two consecutive IR images.
- The evolution factor will be 1 for pixels becoming colder or remaining at the same temperature in the second image and 0 for pixels becoming warmer.
- So this factor acts as a rain mask for the calibration matrices and is used as a rain-no rain discriminator, without any contribution to the magnitude of the rain rate.

Corrections factors description
Gradient Correction Factor

- The Cloud–top Temperature Gradient factor is used when only one IR image is available and the evolution correction can't be applied .
- The concept of finite differences is used to find local maximums and minimums and it assumes that pixels with a local minimum temperature indicate active convection associated with precipitation beneath.
- The CRR data remains the same if the IR temperature is colder than the surrounding pixels, and is divided by 2 or set to zero if the IR temperature is the same or warmer than the surrounding pixels respectively.

Corrections factors description
Parallax Correction Factor

- To use the orographic correction factor, it is important to know the exact position of the cloud tops with respect to the ground below; when one looks away from the sub-satellite point, the cloud top appears to be farther away from the satellite than the cloud base.
- The parallax correction depends on three things: the cloud's height, the cloud's apparent position on the earth, and the position of the satellite. The last two are known and the cloud height is estimated from the cloud top temperature and the latitude from a climatological database.

Corrections factors description
Orographic Correction Factor

- The orographic correction technique uses the interaction between the wind vector and the local ground height gradient in its direction to create a multiplier which enhances or decreases the rainfall estimate, as appropriate.
- An enhancement parameter is defined as $M=1+S*U$, where U is the horizontal wind speed blowing over a surface with a slope of S.

  M is limited to be between 0.2 and 3.5
- Winds are taken from the 850 hPa numerical model and terrain heights are taken from a topographic European image.

List of inputs for CRR

- Satellite imagery (mandatory) :

  The following SEVIRI data is needed at full IR spatial resolution:

  reflectances from VIS 0.6 μm channel

  brightness temperatures from T 6.2 μm T 10.8 μm channels.

- The SEVIRI channels are input by the user in HRIT format and extracted on the desired region by SAFNWC software package.

List of inputs for CRR

- Sun angles associated to SEVIRI imagery:

  Daytime, this information is mandatory for normalizing the VIS image. It is computed by the CRR software using the definition of the region and the satellite characteristics.
- Ancillary data sets:

  Calibration matrices are mandatory.

  Elevation mask is mandatory if orographic correction has to be done
- Numerical model

  This information is mandatory if moisture and orographic correction has to be done

Coverage and resolution

- The software to extract Convective Rainfall Rate (CRR) from MSG SEVIRI imagery has been designed within the EUMETSAT SAF NWC over MSG N region (Europe, North Africa and adjacent seas). One selected sub area must be defined as a rectangular area in satellite projection of numlin x numele SEVIRI IR pixels.
- This product will be derived every 15 minutes on the SEVIRI IR pixel horizontal resolution, i.e. the current resolution will be given by the local pixel size, which depends on the latitude and longitude of the pixel. At the sub-satellite point, the resolution will be 3 km, whereas over Central Europe the resolution will be approximately 5 km.

Description of CRR outputs

- The CRR output is an image that provides parameters on convective rain and is computed for all pixels in the selected region.
- Each pixel in the SAF output contains three parameters:

  Convective Rainfall Rain classes

  CRR correction type

  Flag quality control
- The product is coded in HD5 format and will include a palette to be applied to CRR classes.

The parameters have the following information:

Description of CRR outputs
Convective Rainfall Rain classes

- **5 bits for Convective Rainfall Rain classes.**

  For daytime:

CLASSES	RAINFALL RATE (MM/H)
0	0.0
1	1.0
2	2.0
3	3.0
4	5.0
5	7.0
6	10.0
7	15.0
8	20.0
9	30.0
10	>50.0

Description of CRR outputs
Convective Rainfall Rain classes

For night time:

CLASSES	RAINFALL RATE (MM/H)
0	0.0
1	1.0
2	2.0
3	3.0
4	5.0
5	7.0
6	>10.0

Description of CRR outputs
CRR correction type

- 5 bits for CRR correction type:
  - 1 bit for moisture correction:
    - 0 No correction, 1 Corrected by PWHR factor
  - 1 bit for cloud growth rate correction:
    - 0 No correction, 1 Corrected by IR data from previous slot
  - 1 bit for cloud top temperature correction:
    - 0 No correction, 1 Corrected by IR temperature gradient
  - 1 bit for parallax correction:
    - 0 No correction, 1 Corrected by parallax
  - 1 bit for orographic effect correction:
    - 0 No correction, 1 Corrected by orographic effects

Description of CRR outputs
Flag quality control

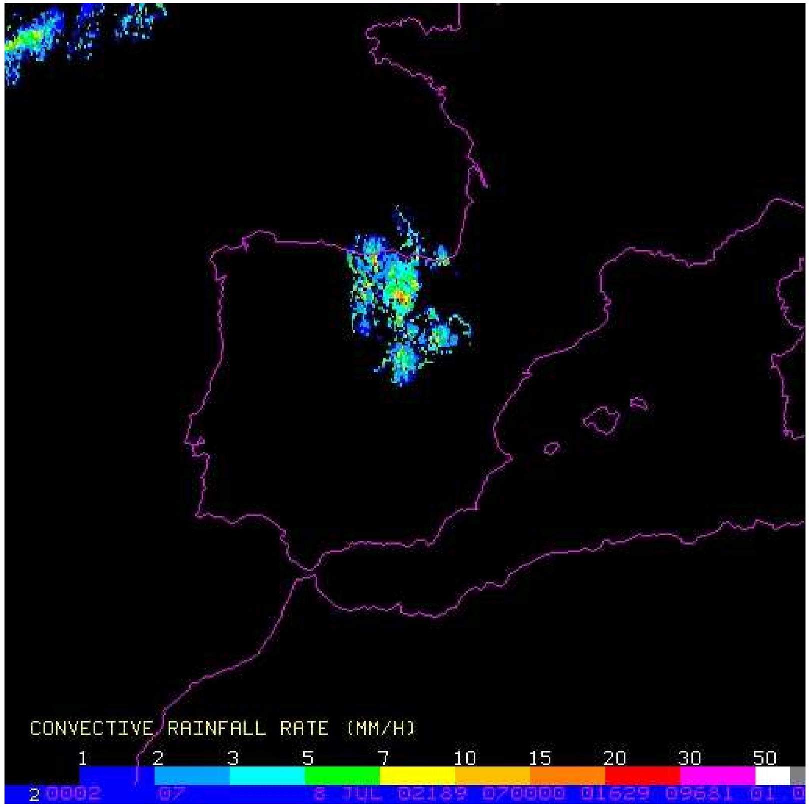
- 2 bits for automatic quality control:
  - 0 No error
  - 1 IR10.8, WV6.2 or VIS0.6 data missing
  - 2 Out of range in calibration matrices
  - 3 Mathematical error in normalization, error in zenith angle.

Example of CRR visualisation

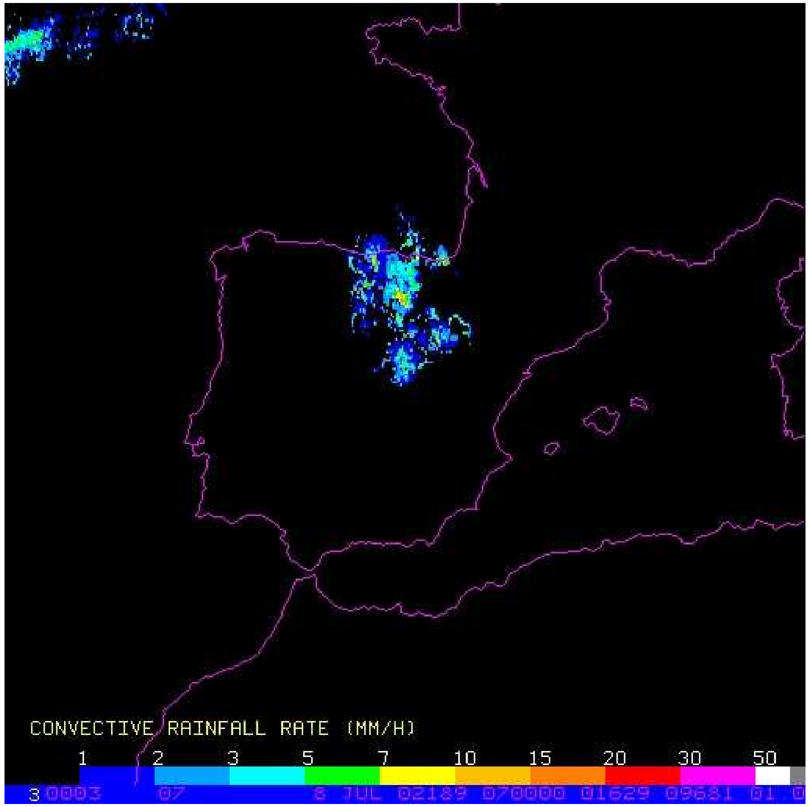
- The images displayed in Figures 1-3 have been obtained using 3-D calibration matrices and MTP data, 4 km resolution and Lambert Conformal re-projected. The equivalence between colours and the CRR values is shown at the bottom scale. The figure 4 is the radar rainfall rate image.

Example of CRR visualisation

CRR

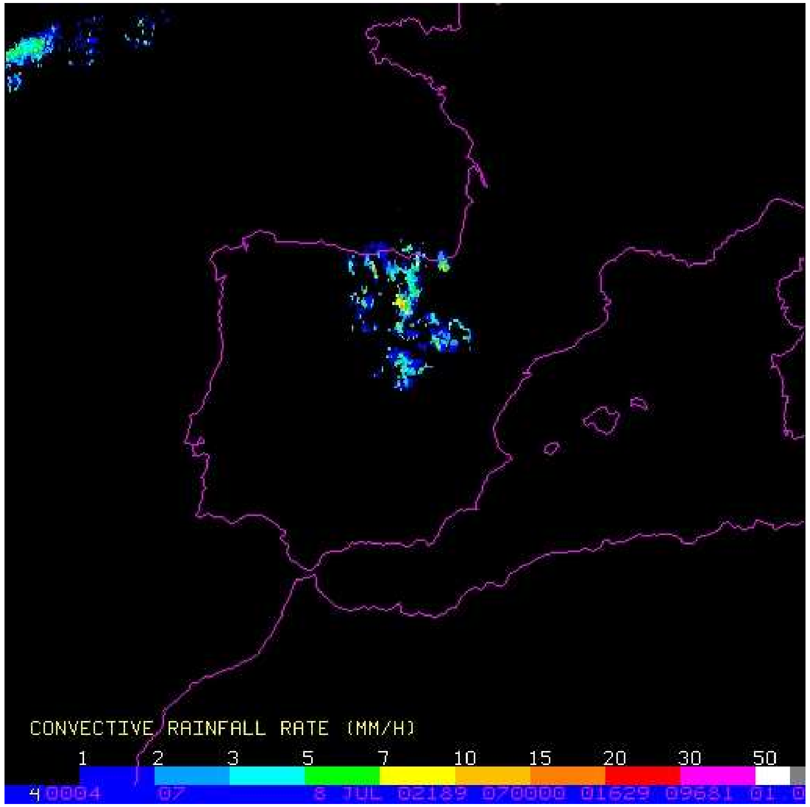


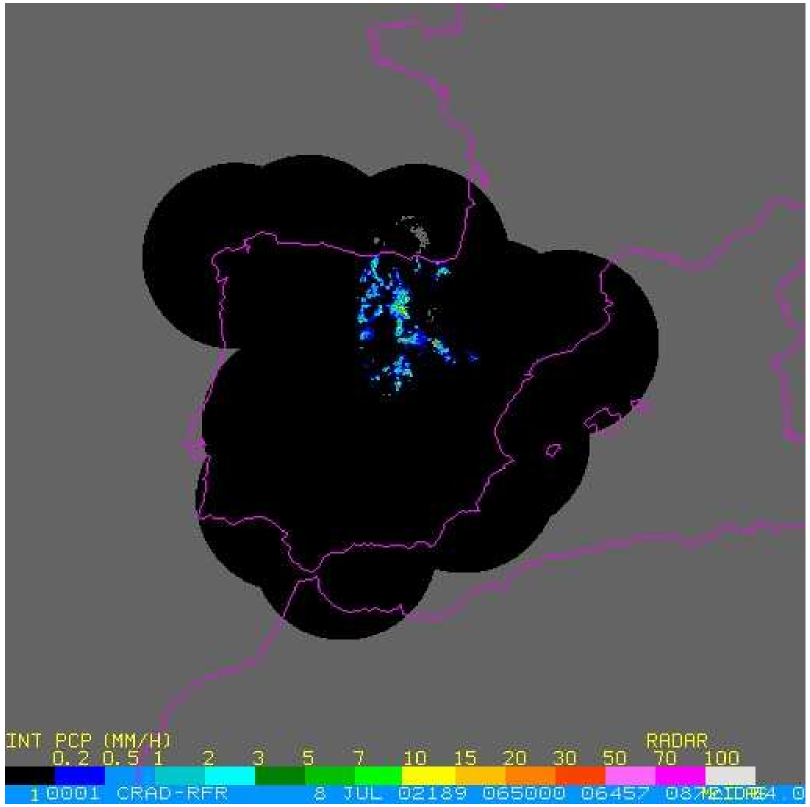
CRR+Moist Corr



Example of CRR visualisation

CRR+MC+EvolCorr+ParCorr Radar-data





Example of CRR visualisation

- Description of the example

  A Meteosat sub-area of 512x512 pixels centered at 40º N 3º W is processed and projected to a Lambert Conformal projection with standard latitudes 33.5º N & 46.5º N and 0º standard longitude at 4 km resolution.

  The first image is the CRR output.

  The second one is the result of applying the moisture correction factor using HIRLAM numerical model to the first one.

  The third image is the result of applying the evolution correction factor and the parallax correction to the second one.

- To compare the results with radar data it is important to take into account the different scales.

Actual Status

- The PGE05 CRR included in SAFNWC/MSG v1.0 is the same as the CRR from SAFNWC/MSG v0.1.
- The calibration matrices within PGE05 v0.1 are based on Meteostat-7 using the VIS06 channel information as "normalised visible count" classes because of the heritage of INM prototype.
- There are 2-D and 3-D Spanish matrices computed from case studies with MET-7 and Spanish Radar and 2-D Baltic matrix obtained from MET-7 and the NORRAD data.
- The file structure of the difference matrix is the same as 2-D matrix.
- The v0.1 has a software bug that affects the moister correction.
- The corrections are set to 0 in the safnwc_pge05.cfm configuration file.

Planned activities in 2004

- 2-D and 3-D Spanish matrices have been computed with Real SEVIRI and INM Radar data. For this, selected episodes have been used (up to 62 days). For SEVIRI, normalized visible reflectances for the 3-D matrix are now used instead of the visible counts (for MET-7).
- The checking and tuning phase using the new matrices is not completely finished and new cases of convective situations occurring during 2004 will be studied for improvements.
- Case studies with Real SEVIRI and NORRAD data are needed in order to obtain new Baltic matrices in both 2D and 3D dimensions and the corresponding difference matrices.
- To modify the PGE05 code according to the new use the VIS06 channel information and correct the SW bug that affects the moisture correction for the SAFNWC/MSG v1.0.

Planned activities in 2004

- **List of the 62 days of 2003 used to compute the 2-D and 3-D Spanish matrices from 15-Jul-2003 to 28-Dec-2003 in Julian date:**

  196,210,211,215,217,218,222,223,224,229,231,233,234,235,246,247,
  248,249,250,264,265,266,272,273,274,275,279,280,283,284,285,286,
  287,288,289,290,291,292,294,295,296,297,298,299,301,304,311,312,
  318,319,323,326,327,334,335,337,338,339,340,342,361,362.