GOBIERNO DE ESPAÑA

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

AEMet Agencia Estatal de Meteorología

Satellite Derived Precipitating Products Based on a Principal Component Analysis

EUMETSAT NWC SAF SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

Convection Working Group

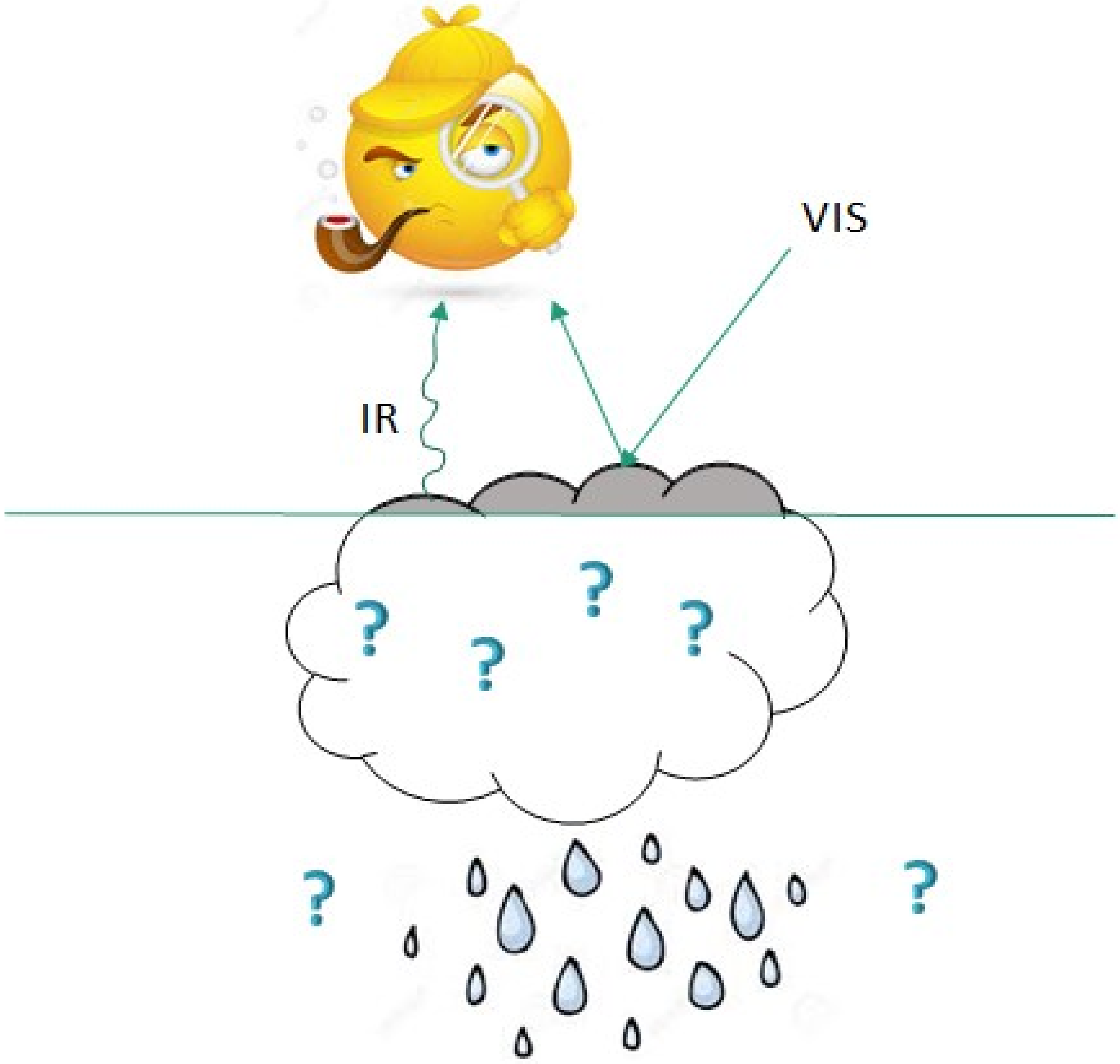
Online meeting 6-8 April

José Alberto Lahuerta García
jlahuertag@aemet.es

OVERVIEW

- CRRPh based on a Principal Component Analyisis
- CRR general view
- Cases of study: CRR vs CRRPh_PCA
- Verification Metric

2. PRECIPITATING PRODUCTS



- Rain drops are not visible from space. Visible and Infrared channels provide information of the upper part of the clouds . There is an indirect estimation of the precipitation.
- Despite this problem, it exits a kind of relation between the high of the cloud (IR channels), the density of the cloud (VIS channels) and the probability of rain and the rain rate.
- It also exits a connection between some microphysical properties such as the water content in the cloud, effective radius …. and precipitation.

NEW PROTOTYPE BASED ON A PRINCIPAL COMPONENT ANALISYS: CRRPh

CRR-Ph based on PCA´s
PC-Ph based on PCA's

¿What does PCA's stand for?

¿Have PCA's been used in other disciplines of meteorology or climatology?

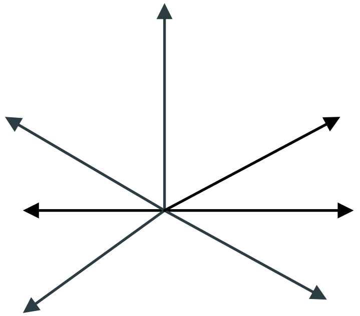
Principal component analysis is a statistical method of **reducing the dimensionality** of a specific dataset that are correlated into a **lower** number of variables **keeping the same information.**

Principal Component Analysis belongs to a family of techniques known as ***unsupervised learning*** due to it doesn't want to predict a variable *(rainfall rate or probability of precipitation) otherwise it want to extract information from the predictors (Visible, infrared and water vapour channels).*

PCA's have **been widely used in weather and climate research** to explain precipitating patterns, climatic variability, to compute climatological indices. It has also been used in remote sensing to extract information of the land , flood mapping, etc.

Large dataset

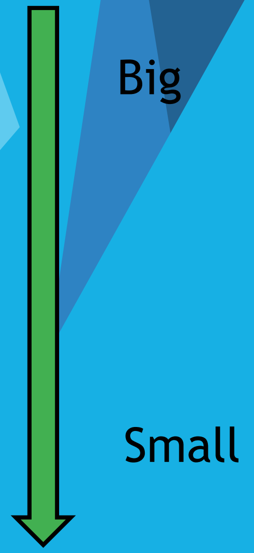
IR10.8	VIS0.6	....	....	...	WV6.2

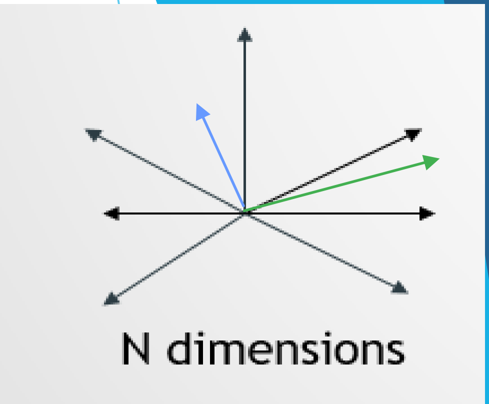


Covariance matrix

$$\begin{pmatrix} * & * & \dots & \dots & * & * \\ * & & & & & * \\ * & & & & & * \\ * & & & & & * \\ * & & & & & * \\ * & * & \dots & \dots & * & * \end{pmatrix}$$

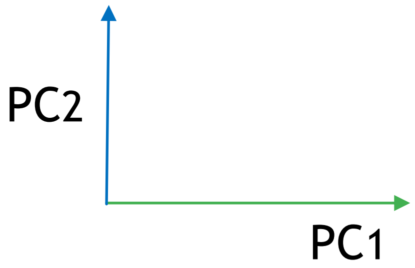
Eigenvectors	Eigenvalues
V1	λ1
V2	λ2
V3	λ3
V4	λ4
…	…
Vn	λn





Reproject

2D-plot



CRRPh_Prototype

DAY TIME

1. Inputs

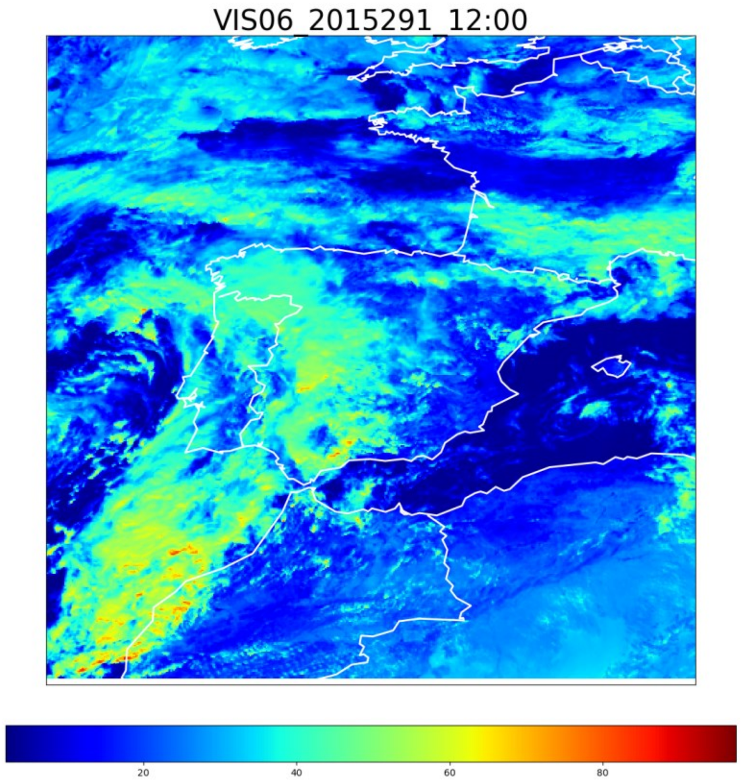
IR10.8	IR12.0	IR13.4	IR8.7	IR9.7	VIS0.6N	WV6.2	WV7.3	CWP

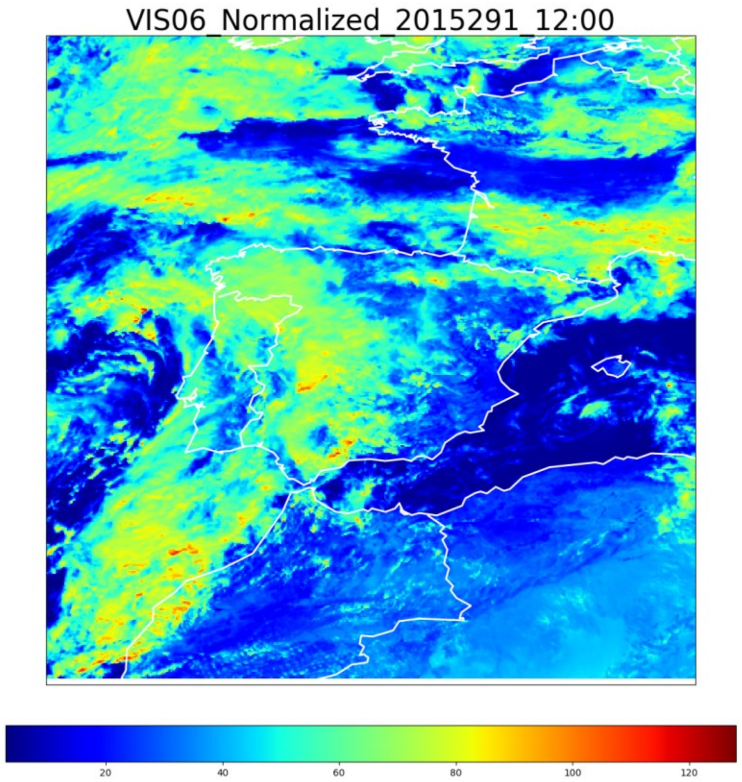
(µm)

COT: The cloud optical thickness is a measure of a **beam atenuation** because of the **absortion and scatering** integrated to a whole column.
It is higly related to the **cloud top reflectances in the VIS0.6µm** and it is low dependent on the cloud size.

REFF: The effective radius is highly related with the cloud top reflectance at 1,6**µm** y 2,25**µm.**
It is well correlated with the probability of rain
CWP: The cloud water path is a measure of the **water content** integrated to a vertical column.

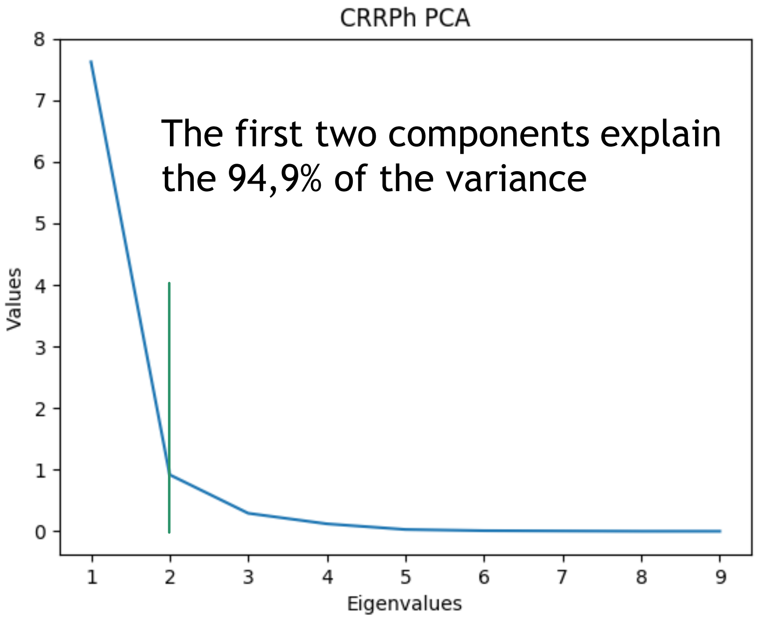
CWP= 2/3 * COT* REFF *(Roebeling and Holleman,* 2009)





2. Normalization

Satellite channel normalization consists of subtracting a fixed value (mean value, previously calculated) from its brightness temperature and dividing it by another fixed value (standard deviation)



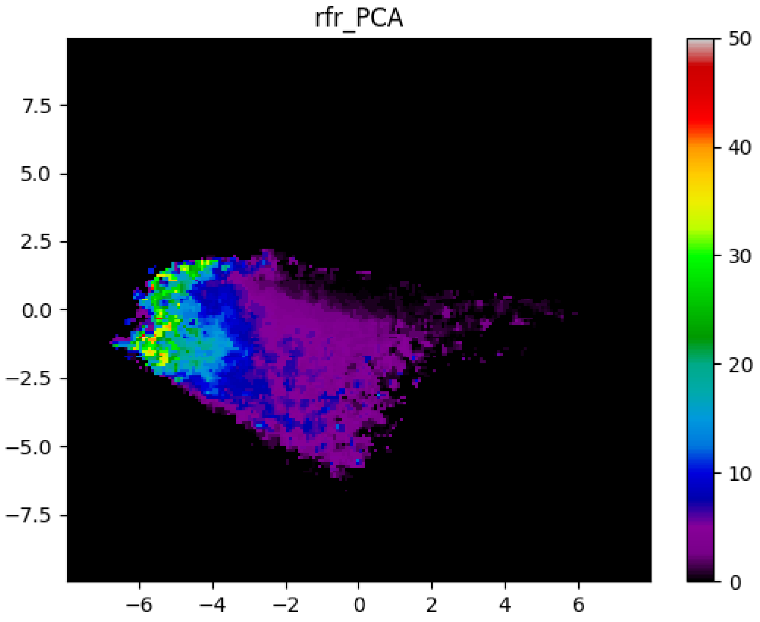
3. Projections

Eigenvector_v1	Eigenvector_v2
v11	v21
v12	v22
v13	v23
v14	v24
v15	v25
v16	v26
v17	v27
v18	v28
v19	v29

$$PC_1 = IR10.8_{normalized} * v_{11} + IR120_{normalized} * v_{12} + \ldots. + CWP_{normalized} * v_{19}$$

$$PC_2 = IR10.8_{normalized} * v_{21} + IR120_{normalized} * v_{22} + \ldots.. + CWP_{normalized} * v_{29}$$

4. Look up table



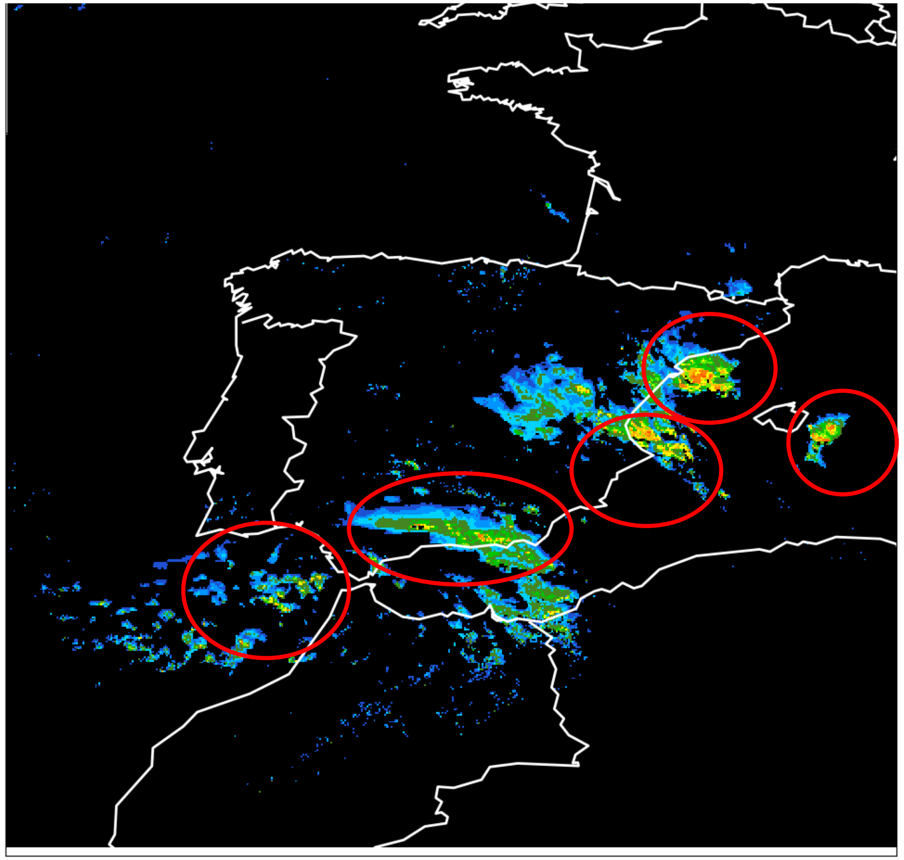
The colour represent the **ninety Percentile** of the Rainfall rate (mm/h)

5. Correction factor

a) **Cloud Water Path Correction**: Since it has been noted this new microphysical version tends to underestimate high rainfall rates in convective cores, it has been **enhanced** the **rainfall rates** by multiplying the rainfall rate output by a correction factor **in terms of the cloud water content**. This way, the more content of water there is in the cloud the bigger the correction factor is.

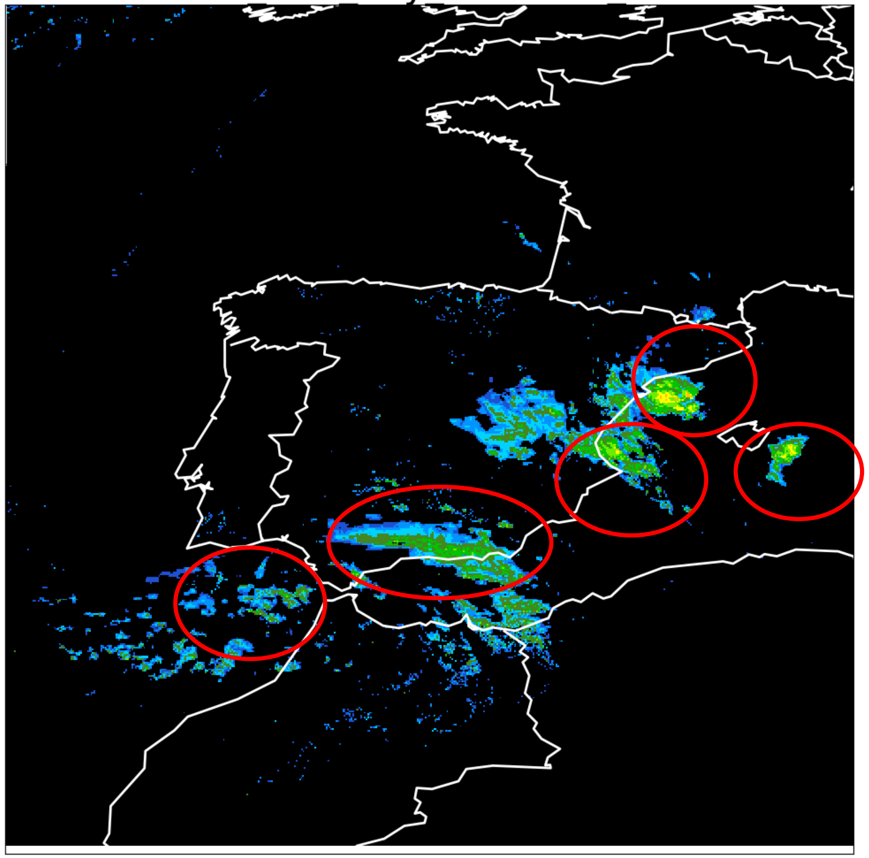
b) **Lightning module.** It has the same lightning module as CRR does.

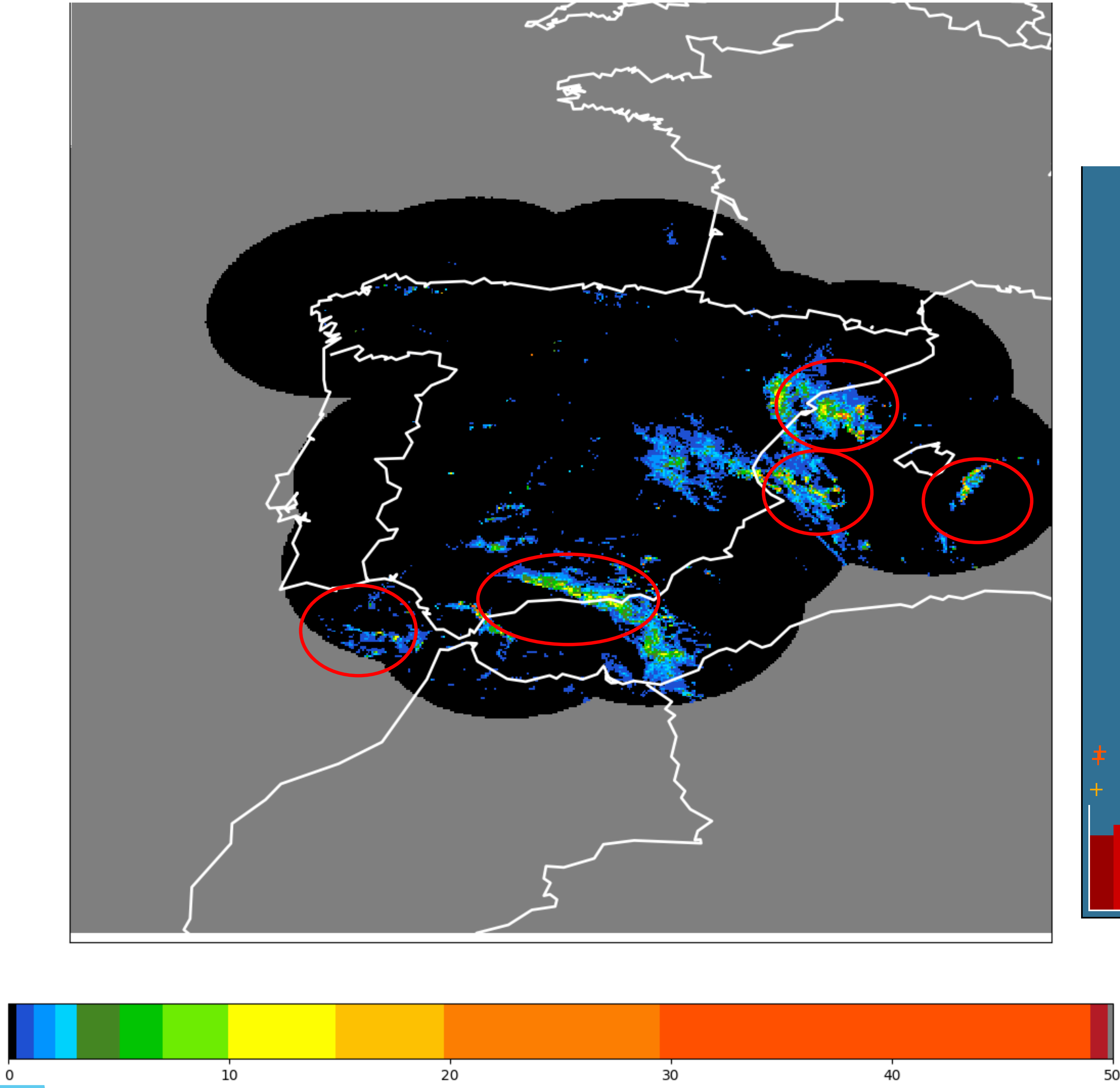
CRRPh PCA the 18th October at 13:30Z



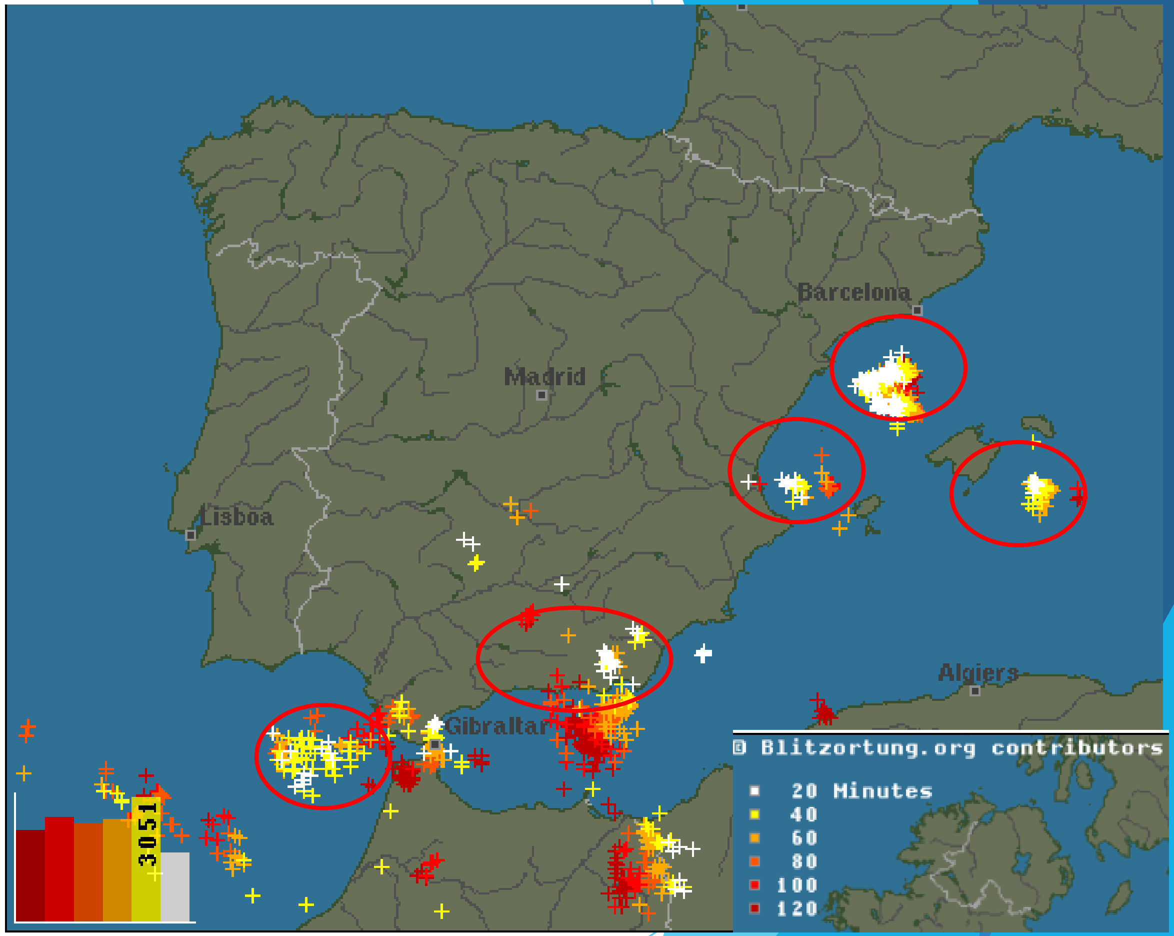
Cloud Water Path correction

CRRPh_PCA_day_2018291_13:30





Spanish radar composite the 18th October at 13:30Z



Two hours lightning activity the 18th October 2018 at 13:30Z

NIGHT TIME

1. **Inputs:**
 The same as day time

IR10.8	IR12.0	IR13.4	IR8.7	IR9.7	VIS0.6N	WV6.2	WV7.3	CWP

Not available at night time

VIS06 and **Cloud Water Path** are needed so they are going to be "predicted" so as to use the same algorithm the whole day.

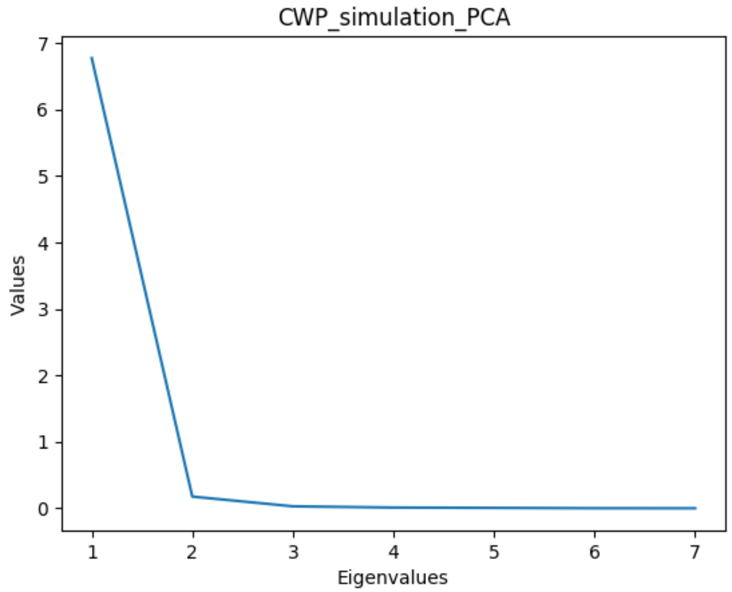
A concept of continuity want to be introduced

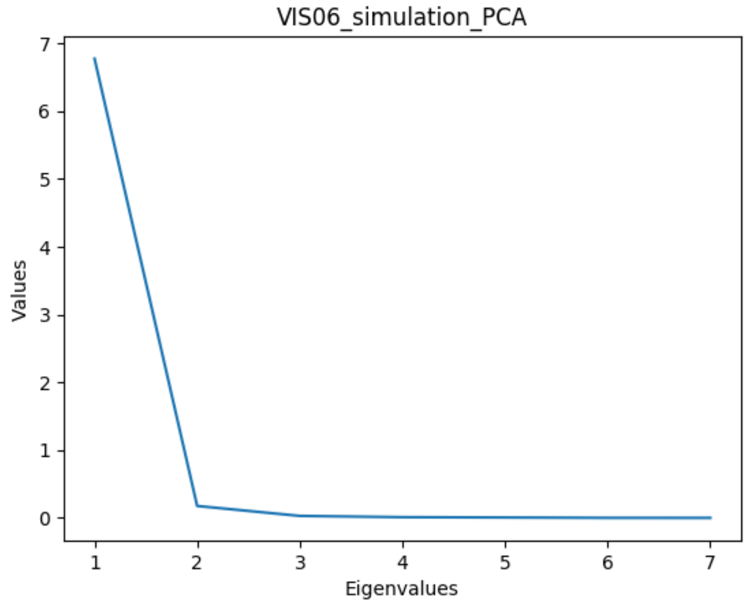
VIS06 and CWP simulation

Since VIS06 and CWP are compulsory at night time to compute the CRR-Ph new prototype, these channels are simulated at day time with the following channels, that are available at night time:

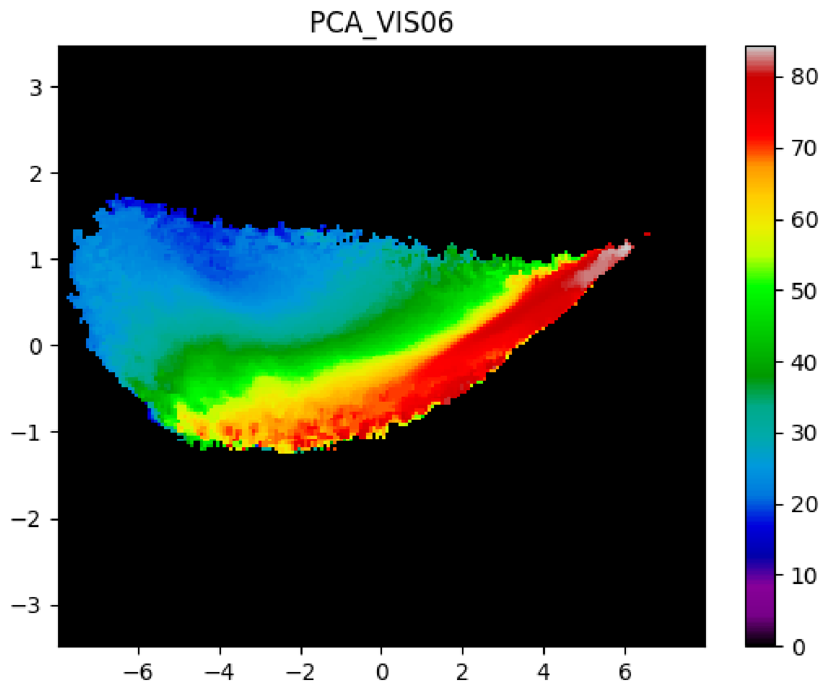
IR10.8 µm	IR12.0 µm	IR13.4 µm	IR 8.7µm	IR 9.7µm	WV6.2 µm	WV 7.3 µm

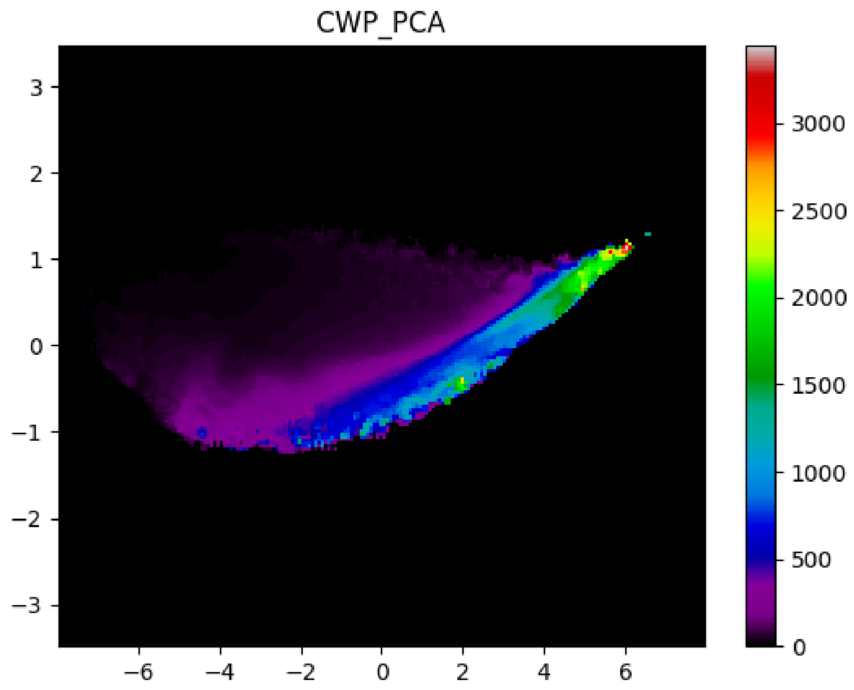
These simulations of the VIS06 channel and the Cloud Water Path are based in a Principal component analysis. To tackle this problem we use 2 eigenvectors that explain the 99,3% of the variance for the both channels.



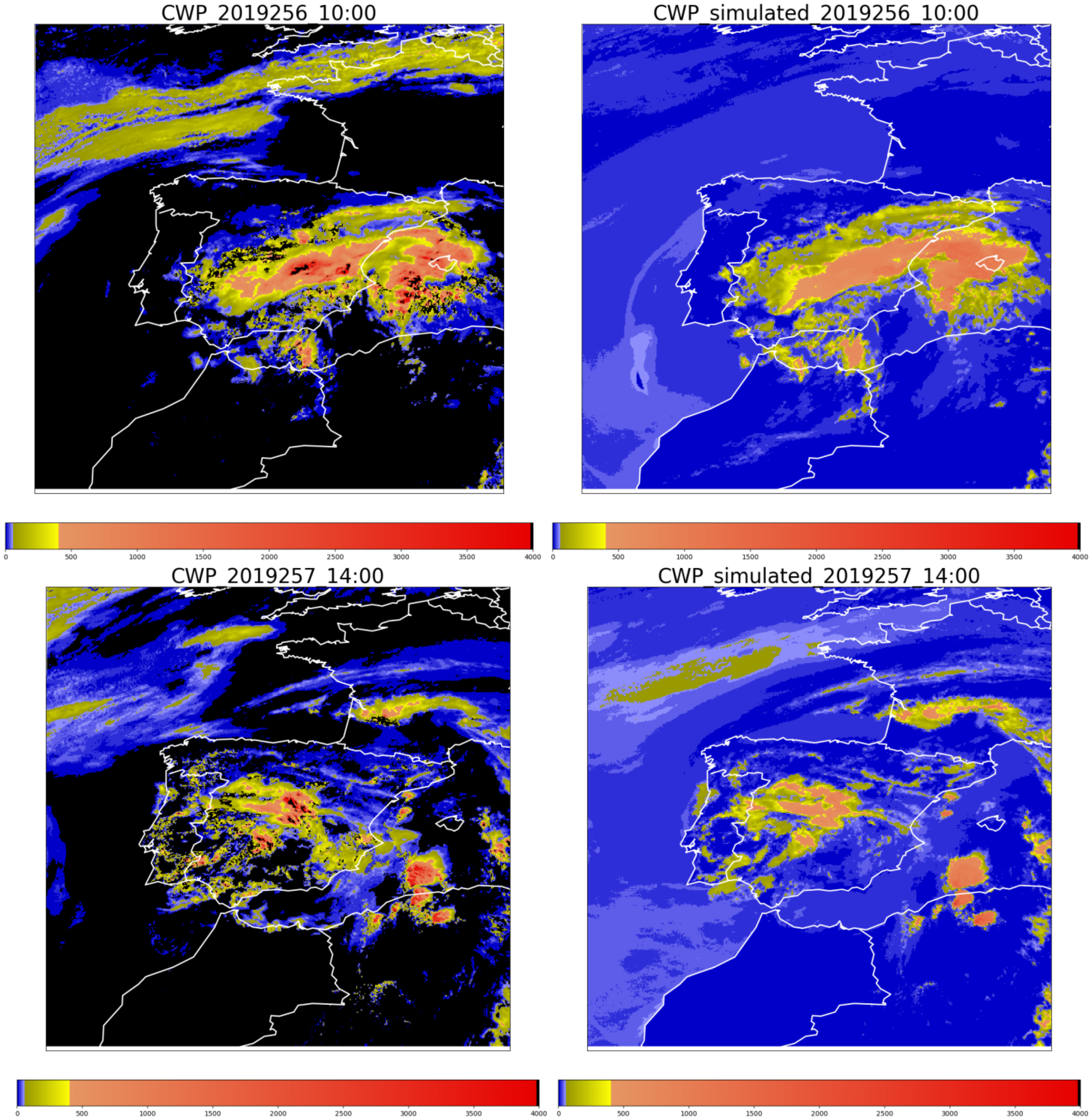


To simplify the problem there have been used the same eigenvectors to simulate the VIS06 channel and the CWP

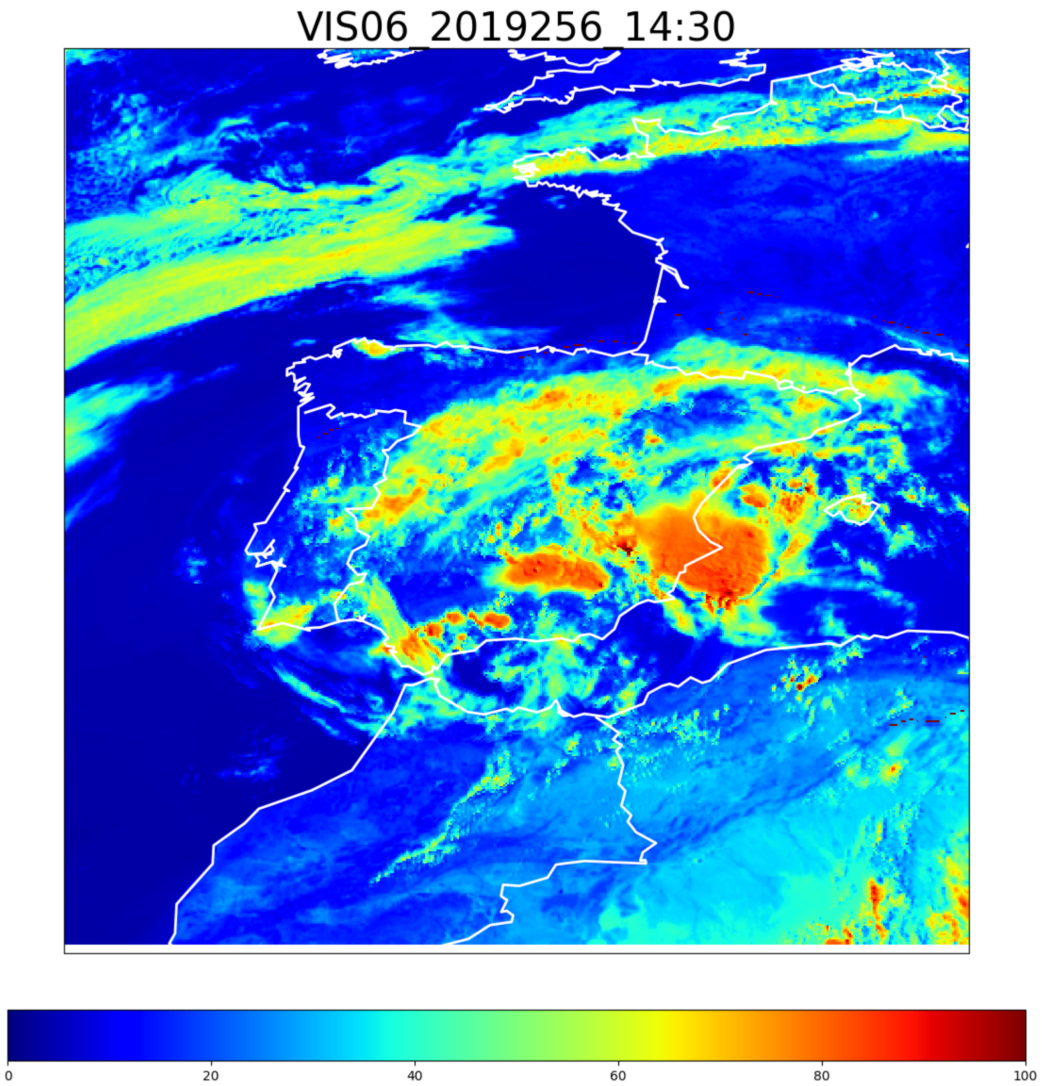


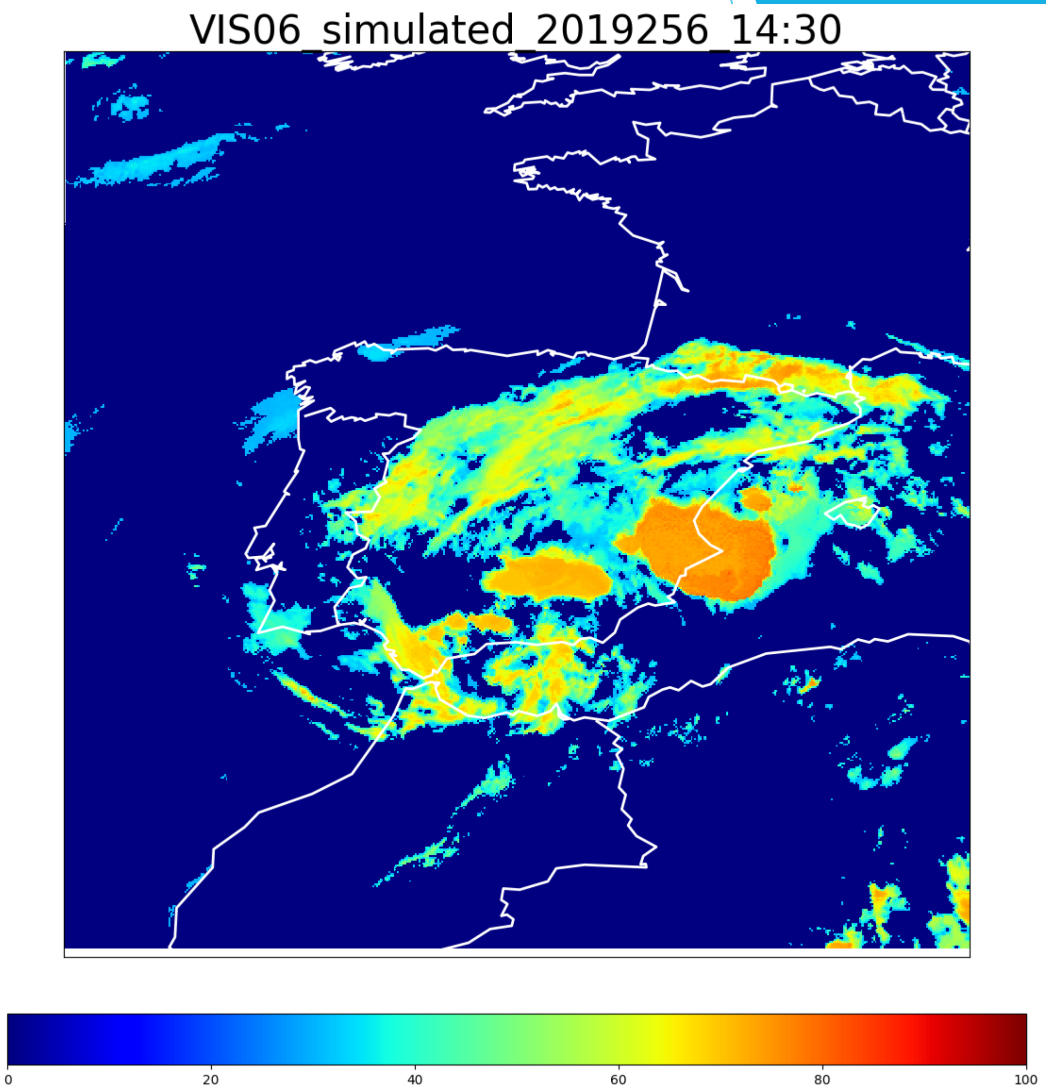


The simulation has been done with the mean value of the VIS06 and CWP. That explains it doesn’t reach so high values than the reality



CWP_2019256_10:00
CWP_simulated_2019256_10:00
0 500 1000 1500 2000 2500 3000 3500 4000
0 500 1000 1500 2000 2500 3000 3500 4000
CWP_2019257_14:00
CWP_simulated_2019257_14:00
0 500 1000 1500 2000 2500 3000 3500 4000
0 500 1000 1500 2000 2500 3000 3500 4000


VIS06_2019256_14:30
0
20
40
60
80
100


VIS06_simulated_2019256_14:30
0
20
40
60
80
100

Restrictions:

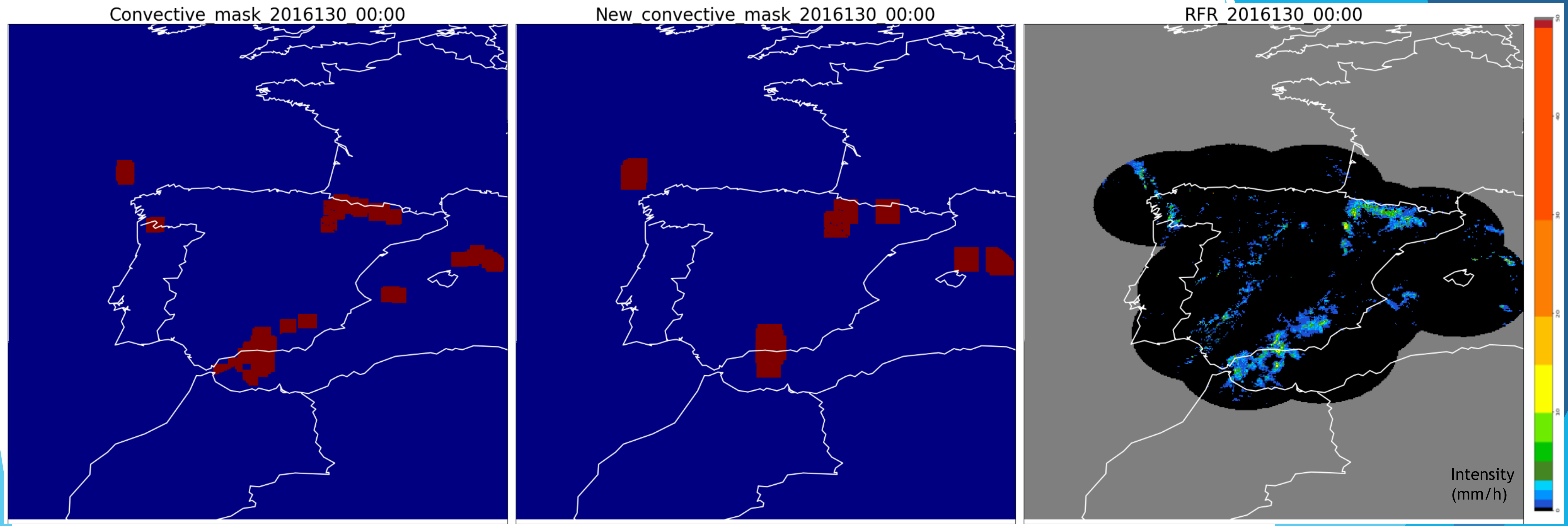
CRRPh is set to zero if:

- CWP(Cloud Water Path) $< 350\ gm^{-2}$
- Cmic_phase == 4 (cloud free)

At night

- $VIS06_{NC(sim)} < 30$
- $VIS06_{NC(sim)} > 100$
- Cloud Water Path Simulated $< 350\ gm^{-2}$

CALIBRATING AREA:



Echotop > 6km
Rainfall rate>3mmh $^{-1}$
Box size = 15pix*15pix

CRR

Echotop>6km
Rainfall rate>10mmh $^{-1}$
Box size = 25pix*25pix

CRRPh_PCA

Spanish radar composite

INPUTS

CONVECTIVE RAINFALL RATE (CRR)

Satellite imagery:
BT IR10.8 μm
WV 6.2 μm
VIS 0.6 μm

NWP:
Surface pressure ,T and dew point.
T at 1000,925,850,700,500 hPa.
HR at 1000,925,850,700,500 hPa.
Geopotencial (pressure levels)

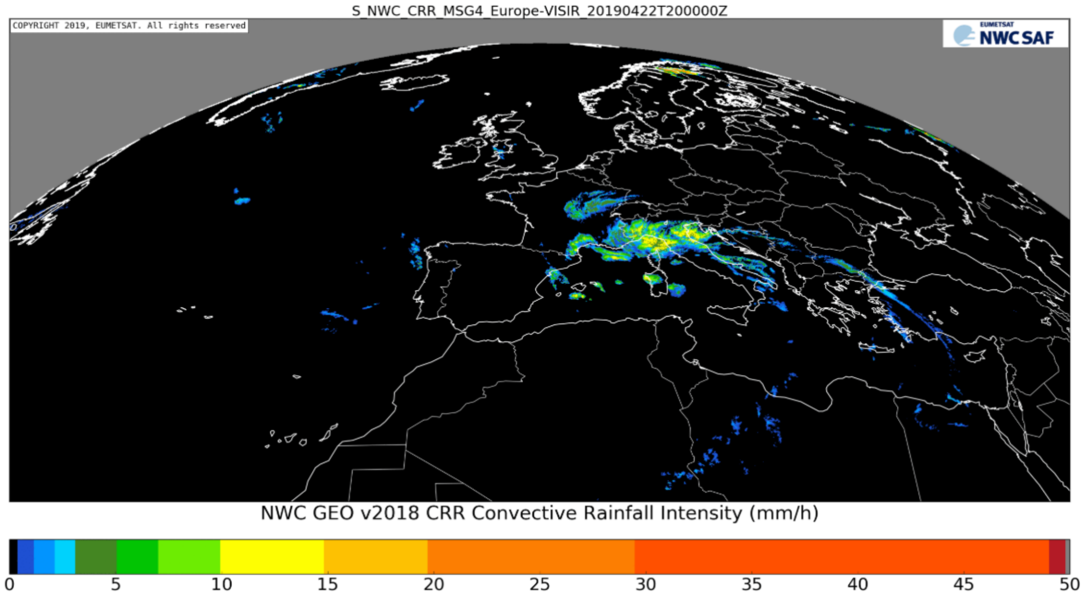
Corrections:

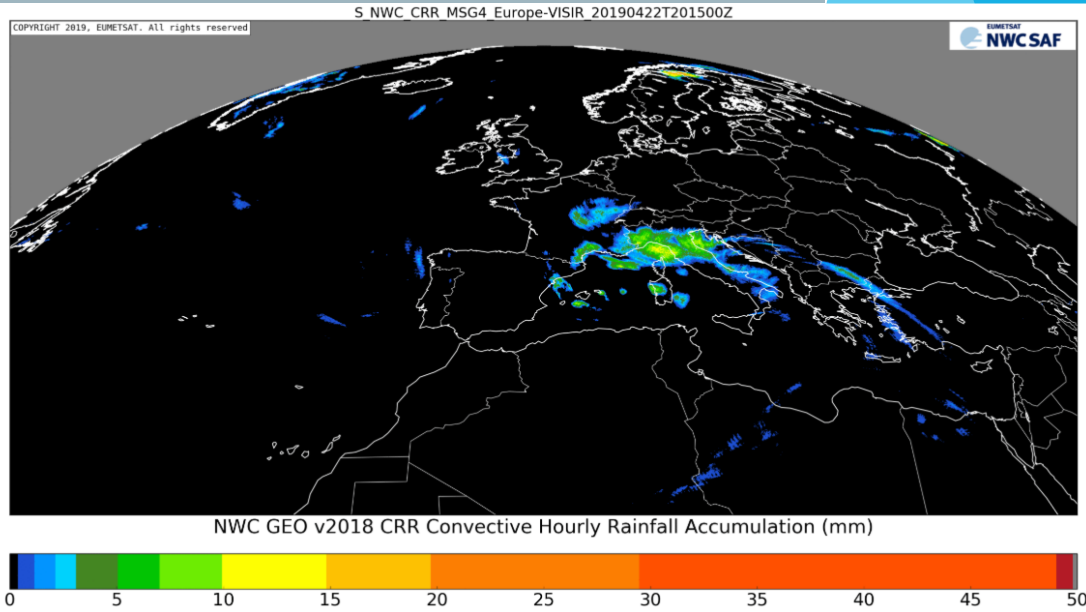
- Parallax (T,Z(mgp) different levels) or climatological profile.
- Orographic correction (u,v in 850hPa)
- Moisture correction (T,HR,p)
- Cloud evolution (2 IR images) or Cloud top Temperature gradient (1 image available)

Auxiliary data:
Sun angles (Normalize VIS)
Saturation Vapour table (Moisture correction)
Terrain elevation (Orographic correction)
Climatological profile

Lighting information is optional

GEO-CRR-v401 2019-04-22T20:00:00Z Spain.cfg safnwc_CRR.cfm





RR(mm/h)=f(IR,IR-WV)

RR(mm/h)=f(IR,IR-WV,VIS-N)

CRR has operational status

$$RR = H(IR) * \exp\left[-0.5 * \left(\frac{(IR - WV) - C(IR)}{W(IR)} \right)^2 \right]$$

$$H(IR) = 8 * 10^8 \exp[-0{,}082 * IR]$$

C(IR)=0,2*IR-45,0

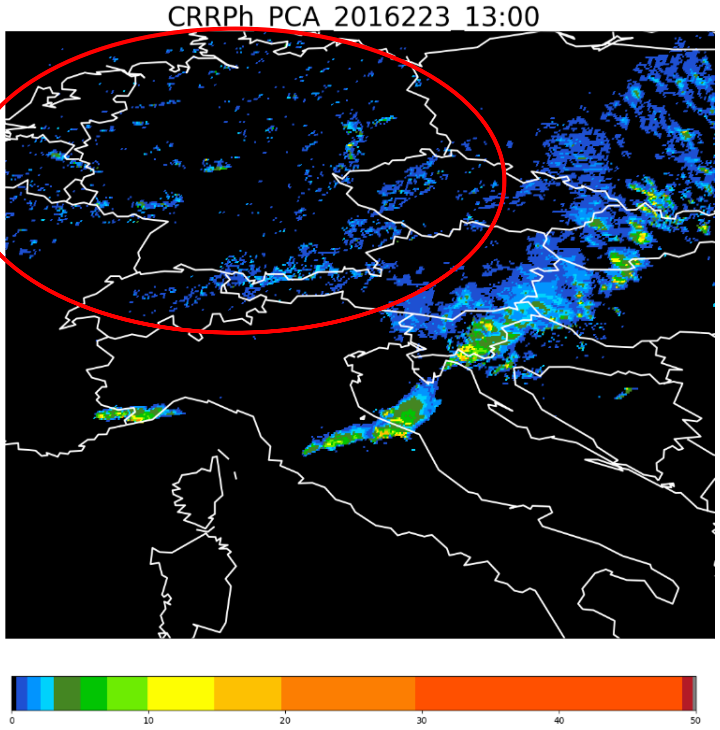
$$W(IR) = 1{,}5 * exp\left[-0{,}5 * (\frac{IR - 215{,}0}{3{,}0})^2 + 2{,}0 \right]$$

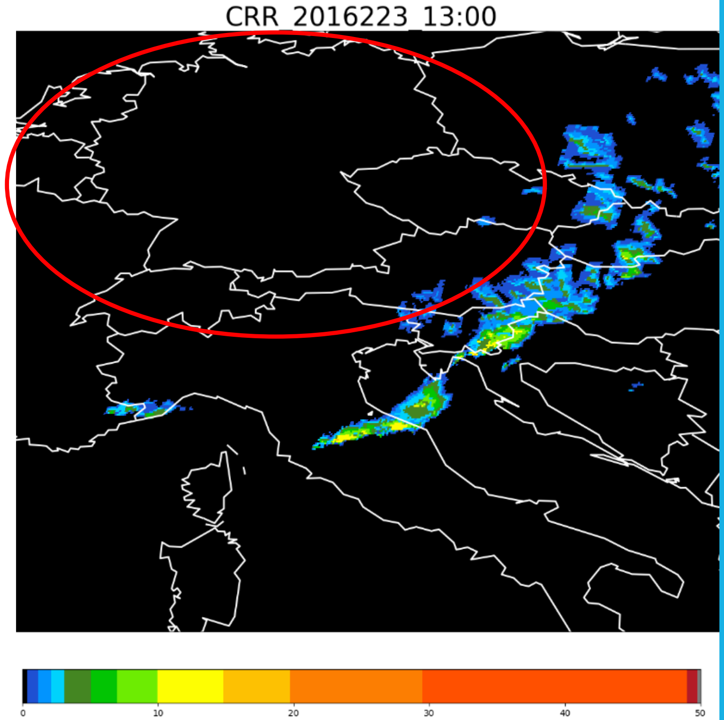
Study Cases:
CRRPh vs CRR

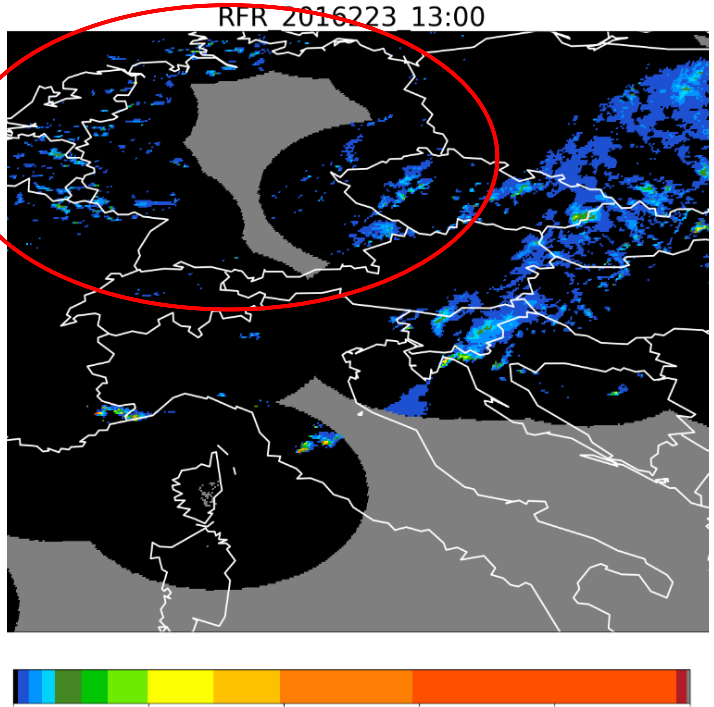
10th August 2016

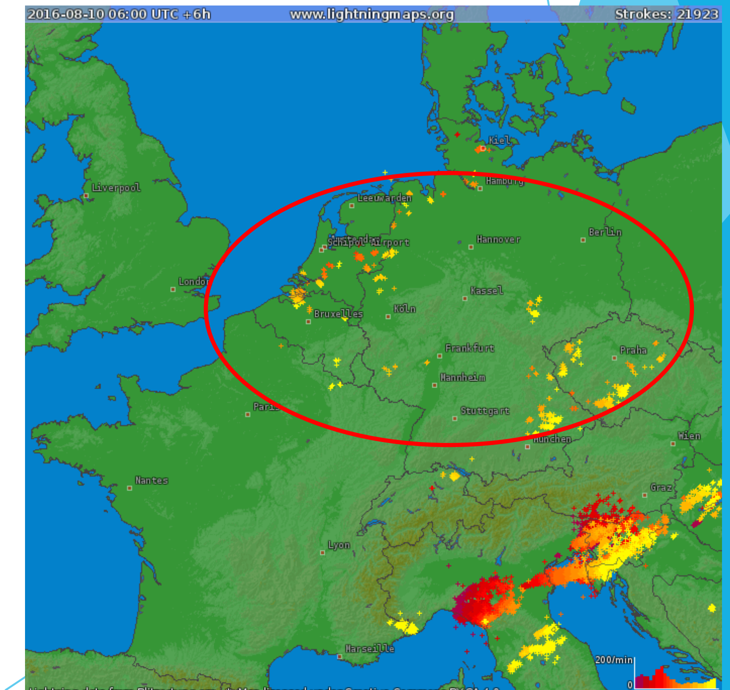
Day time

As it can be appreciated looking at lightning flashes (bottom right) and OPERA radar composite (bottom left) inside the oval red line, there was shallow convection after the front passage over a big extension of Germany, Netherlands and Check Republic that the CRRPh new prototype was able to detect, by contrast the CRR product was not.



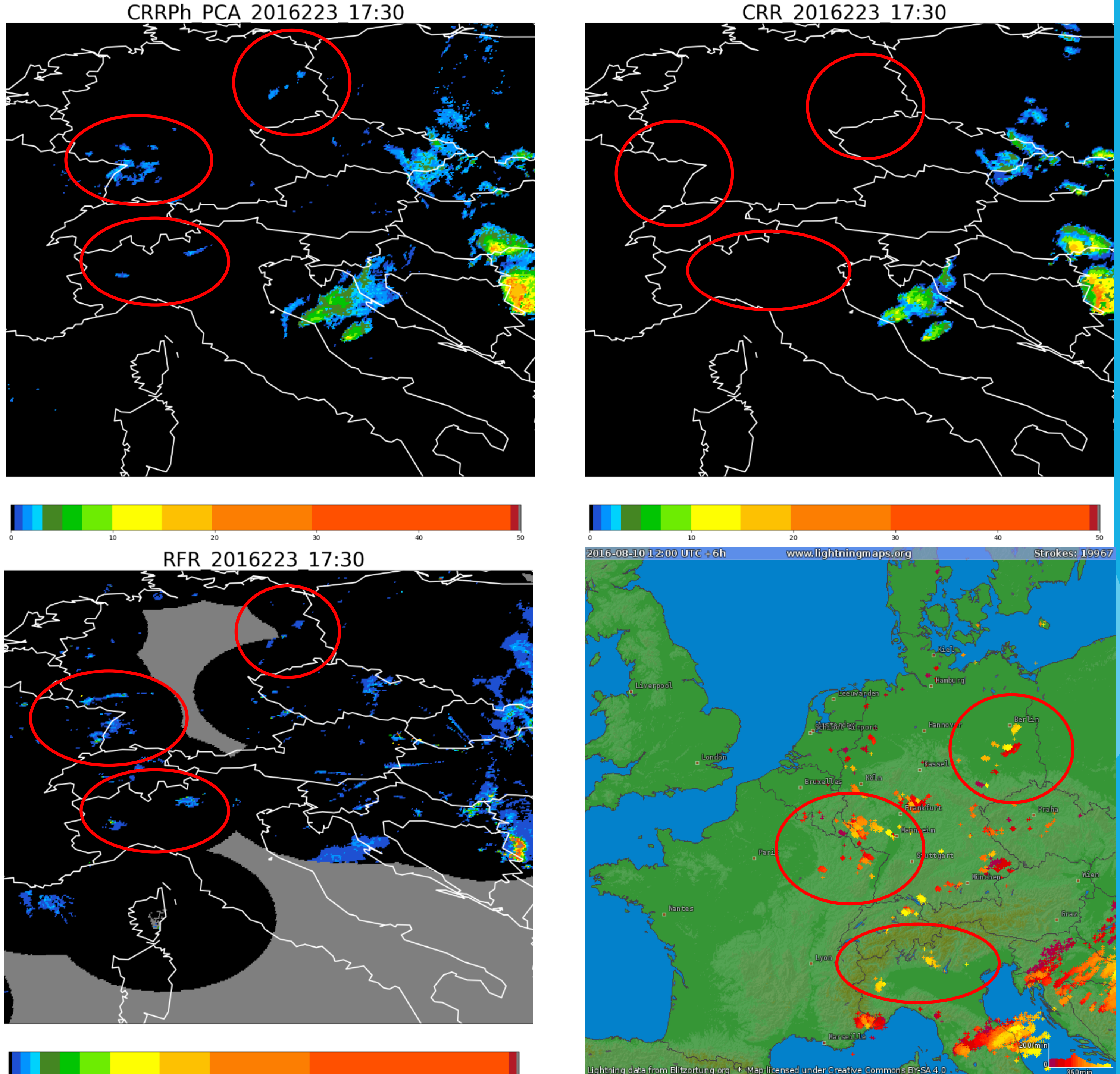




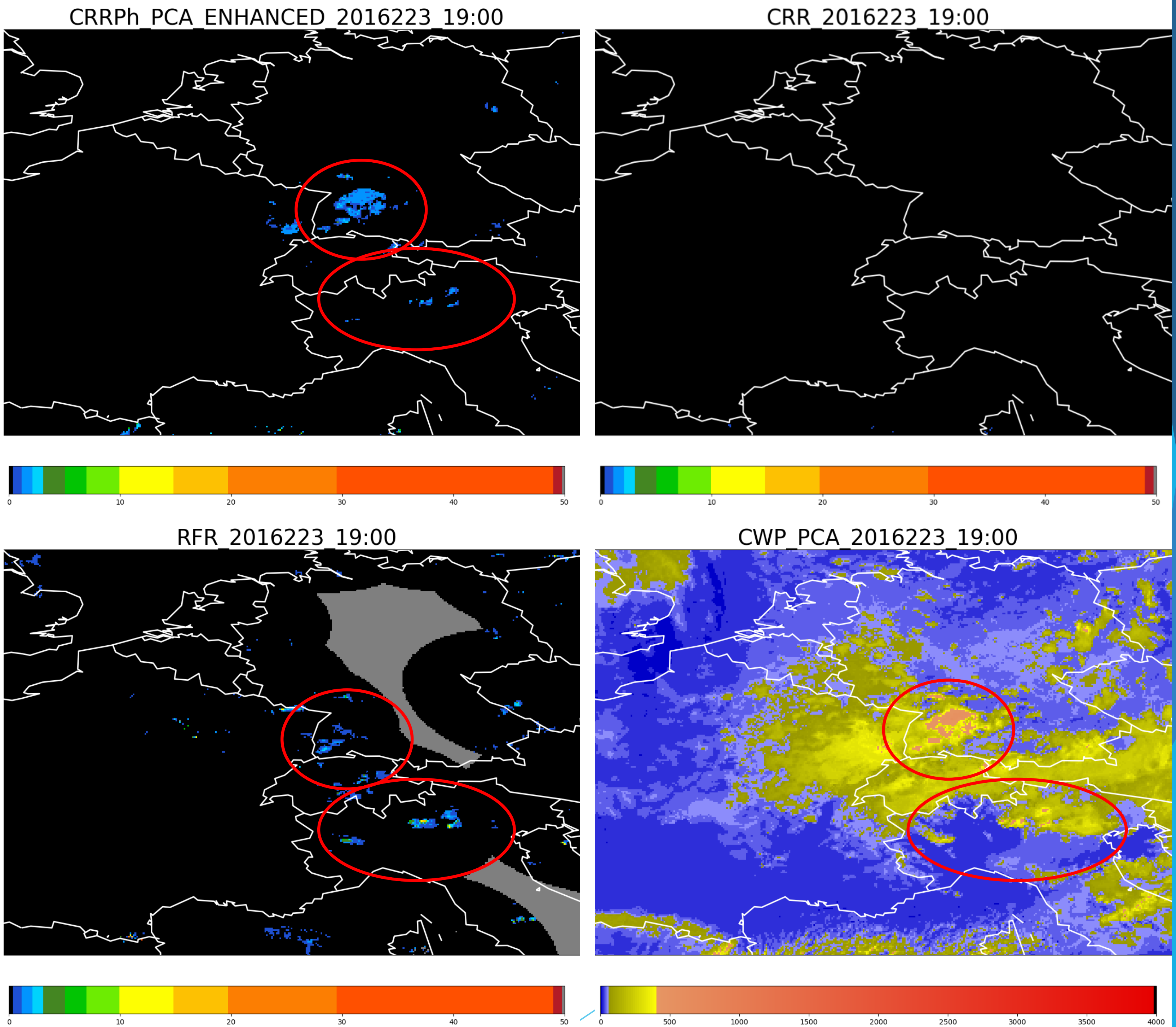


Night time algorithm

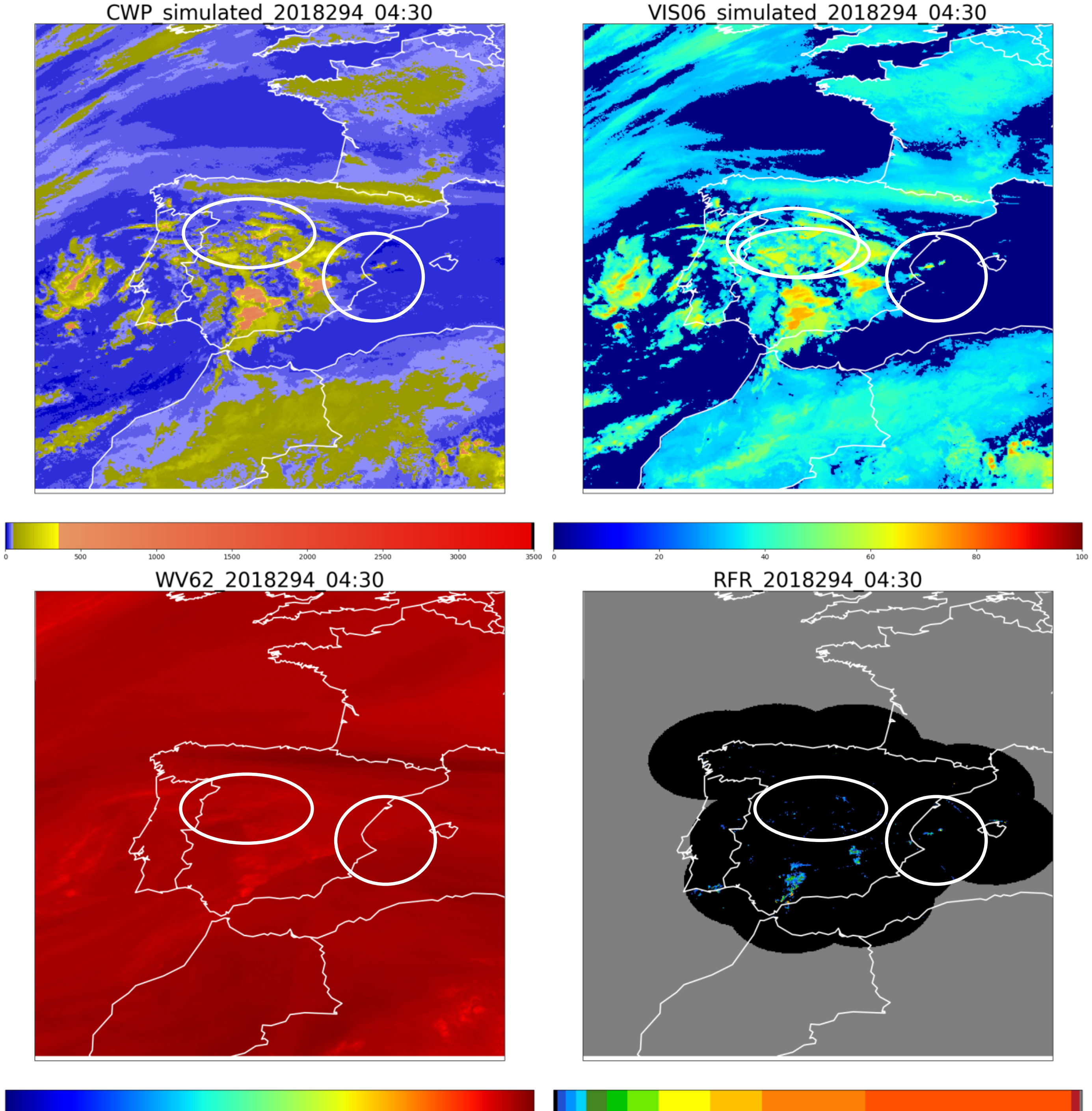
With respect to the night algorithm, CRRPh is also able to detect early stages of convective cores as it can be appreciated looking at the three red circles that have been highlighted. The storms inside these red circles have lightning activity.



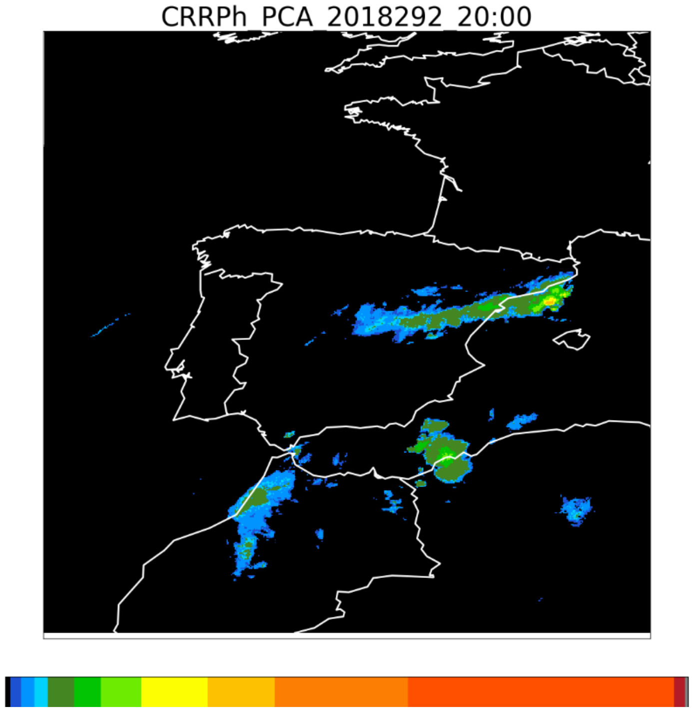
1:30 hours later

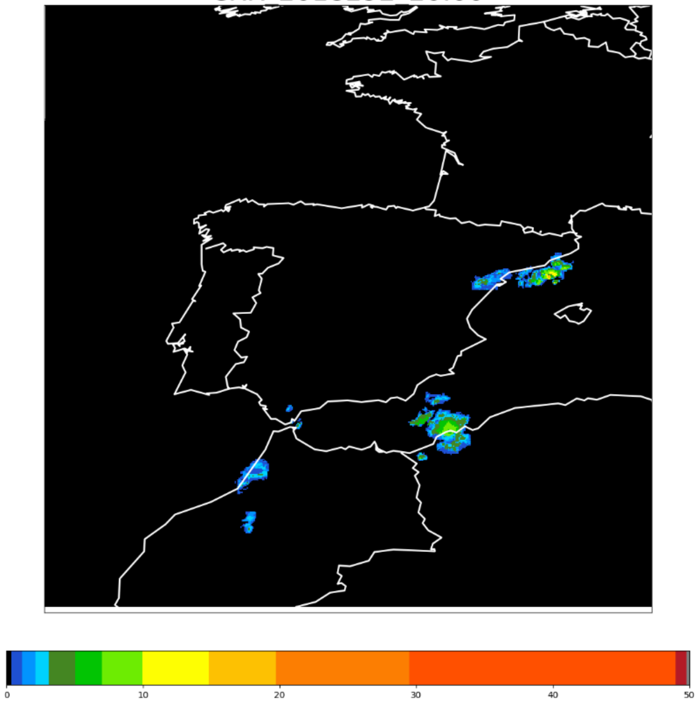


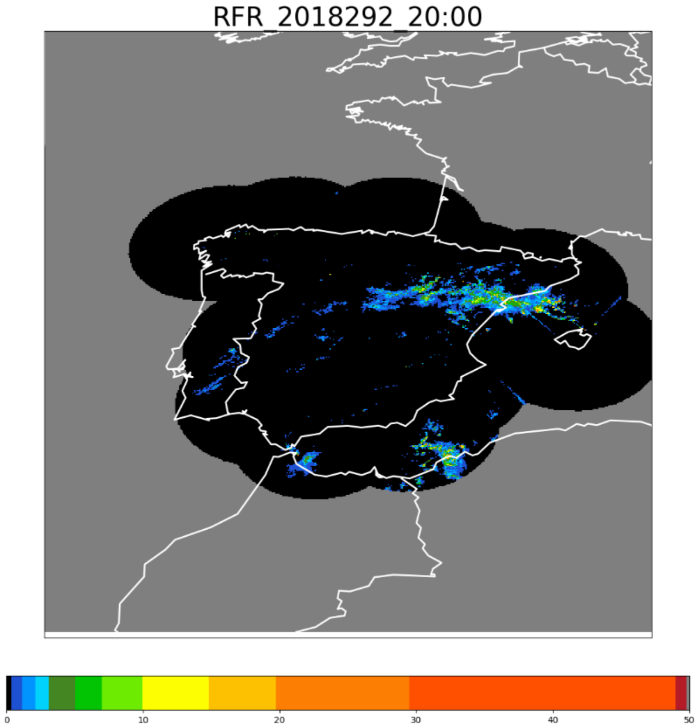
21th October
2018 at 04:30Z

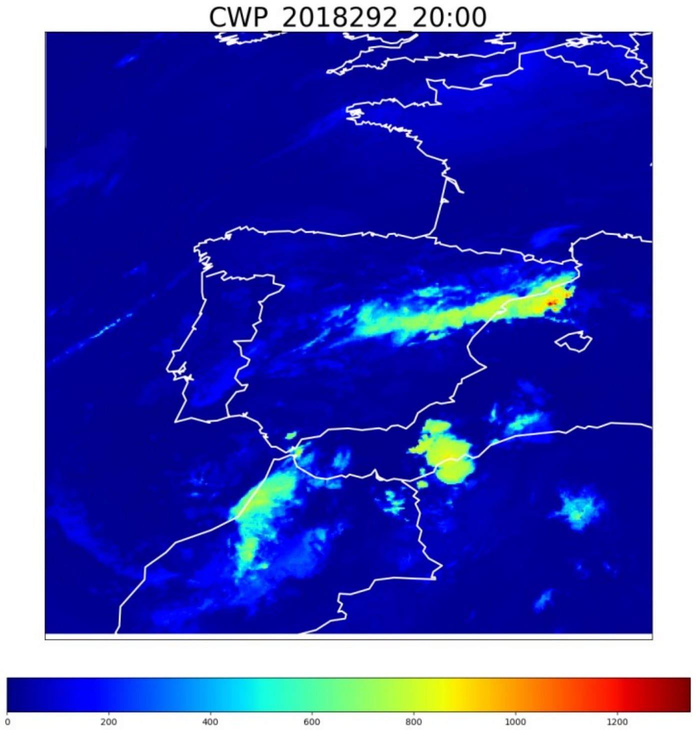


19th October 2018

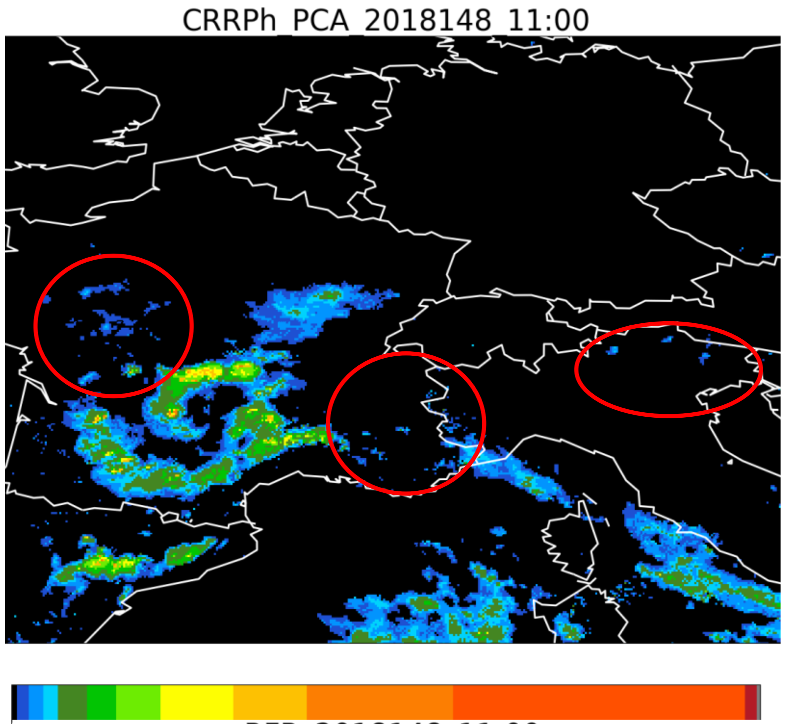


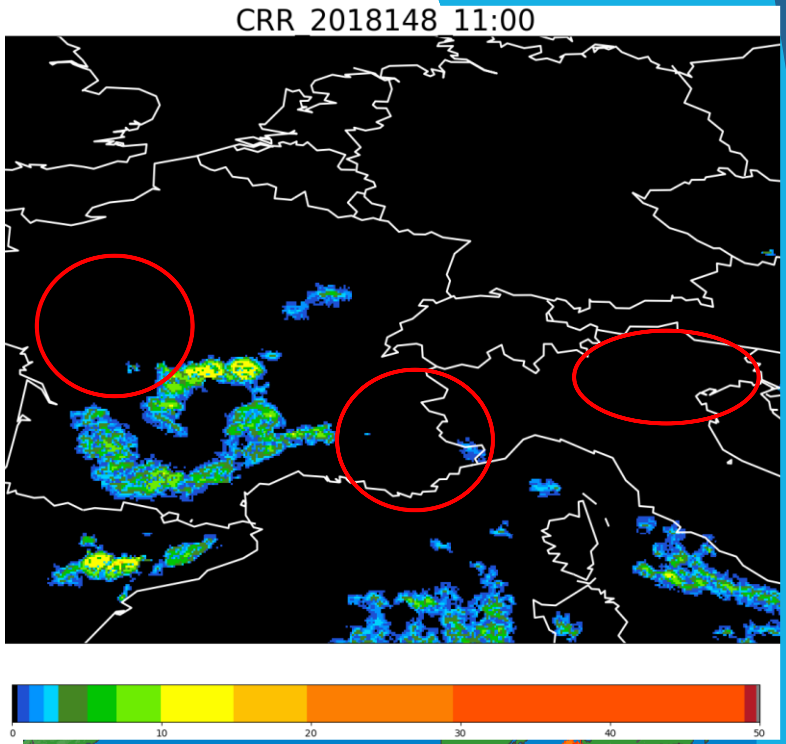


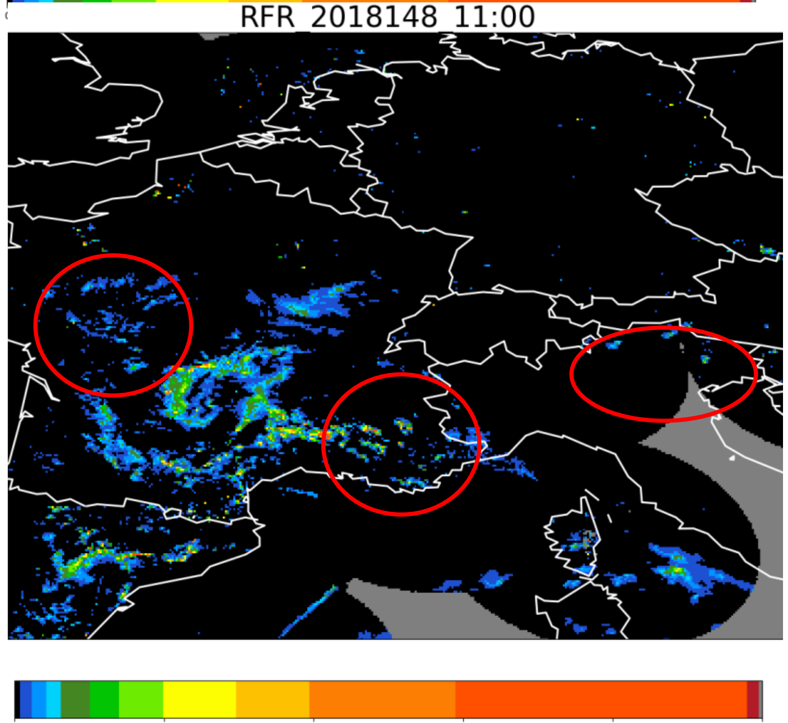


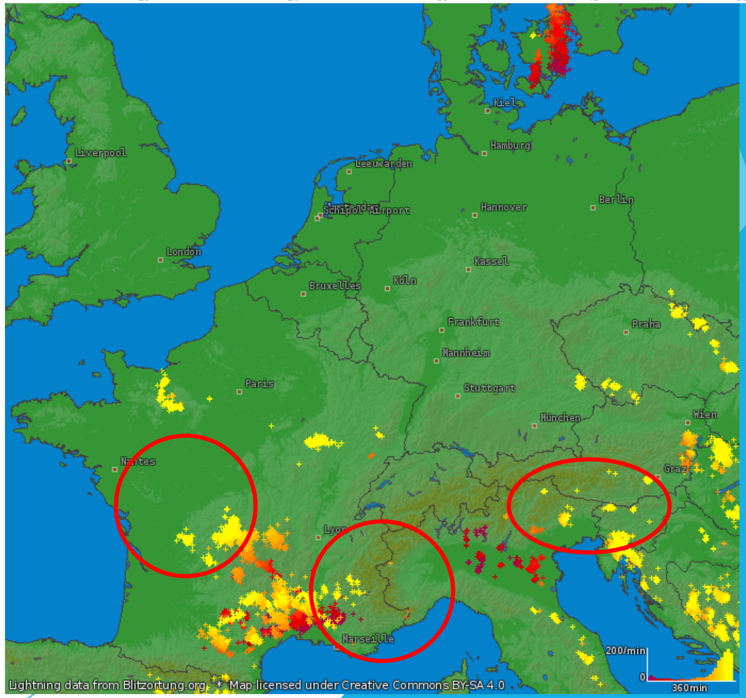


28th May 2018









CATEGORICAL VALIDATION IN **CONVECTIVE AREAS**

CALIBRATING : 2015
VALIDATING : 2016

DAY TIME

CRR	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	--------	62.82	34.13	47.64	64.55

CRRPh prototype	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	1469378	**83.43**	**27.49**	63.38	79.38

NIGHT TIME

CRR	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	--------	53.74	45.53	37.08	54.57

CRRPh prototype	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	4374706	**77.48**	**34.85**	54.78	70.16

REQUIREMENTS

POD (%)	FAR (%)
53	40

POD (%)	FAR (%)
75	35

POD (%)	FAR (%)
47	50

POD (%)	FAR (%)
47	50

Preliminary validation results in Spain

•False Alarm Ratio:

$$FAR = \frac{false\_alarms}{hits + false\_alarms}$$

•Probability of Detection:

$$POD = \frac{hits}{hits + misses}$$

•Critical Success Index:

$$CSI = \frac{hits}{hits + misses + false\_alarms}$$

•Percentage of Corrects:

$$PC = \frac{hits + correct\_negatives}{hits + misses + false\_alarms + correct\_negatives}$$

		Estimated (CRR-Ph,PC-Ph) occurred[1]	Estimated (CRR-Ph,PC-Ph) no occurred
Observed (Radar)	occurred*	hits	misses
	no occurred	false alarms	correct negatives

Conclusions

- ✓ New propotype based on a Principal Component Analysis is going to be available soon.
- ✓ It uses the same calibration function during the whole day.
- ✓ It provides with a Cloud Water Path Correction Factor and a Lightning module.
- ✓ Better preliminary validation results in Spain compared with the operational CRR at day time and at night time.

More information about the CRRPh product can be found in the “Algorithm Theoretical Basis Document for the Precipitation Product Processors of the NWC/GEO MTG-I day-1” available in the following website: nwcsaf.org

Thank you very much for your attention