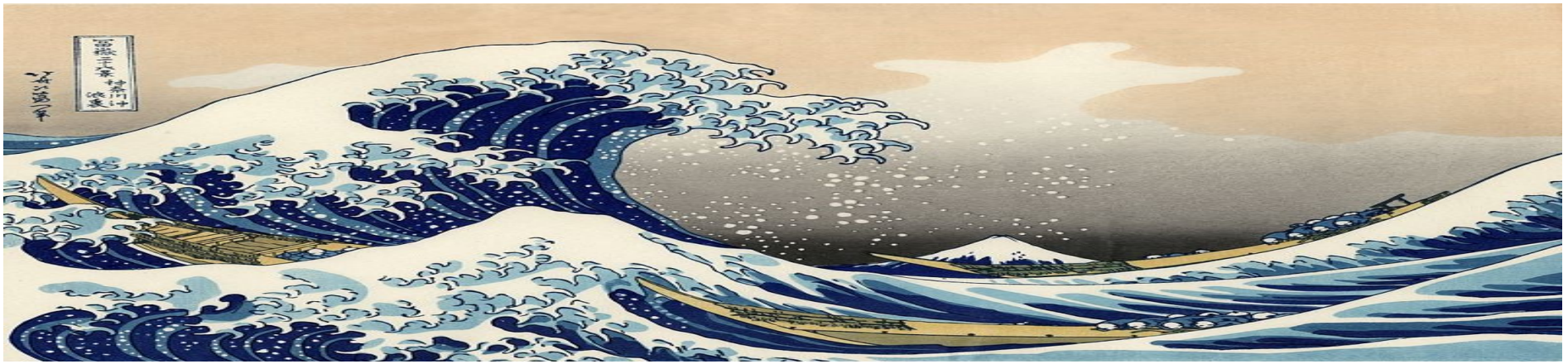


Towards a consistent multi-sensor QPE:

NWC SAF's satellite QPE and AEMET's multi-sensor QPE and FFP

Xavier Calbet (xcalbeta@aemet.es)

Peio Oria, José Alberto Lahuerta, María Pilar Rípodas, Josep Llorenç Lliso, Arantxa Revuelta

Precipitation and Flash Flood Prediction from Minutes to Days
"Berlin", Oct. 2020

Summary

1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

Summary

1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

NWC SAF QPEs

NWC SAF has THREE Convective Rainfall Rate products

1. Convective Rainfall Rate (CRR). Maintained, but with no development. Latest version: 2018
2. Convective Rainfall Rate base on Physical properties (CRR-Ph). Actively developed. Latest version: 2018.
3. Next version of CRR-Ph will be based on Principal Components (CRR-Ph PCA). Being tested as prototype. Developed by José Alberto Lahuerta. We will see this one here.

CRR-Ph PCA

New prototype based on Principal Components Analysis (PCA)

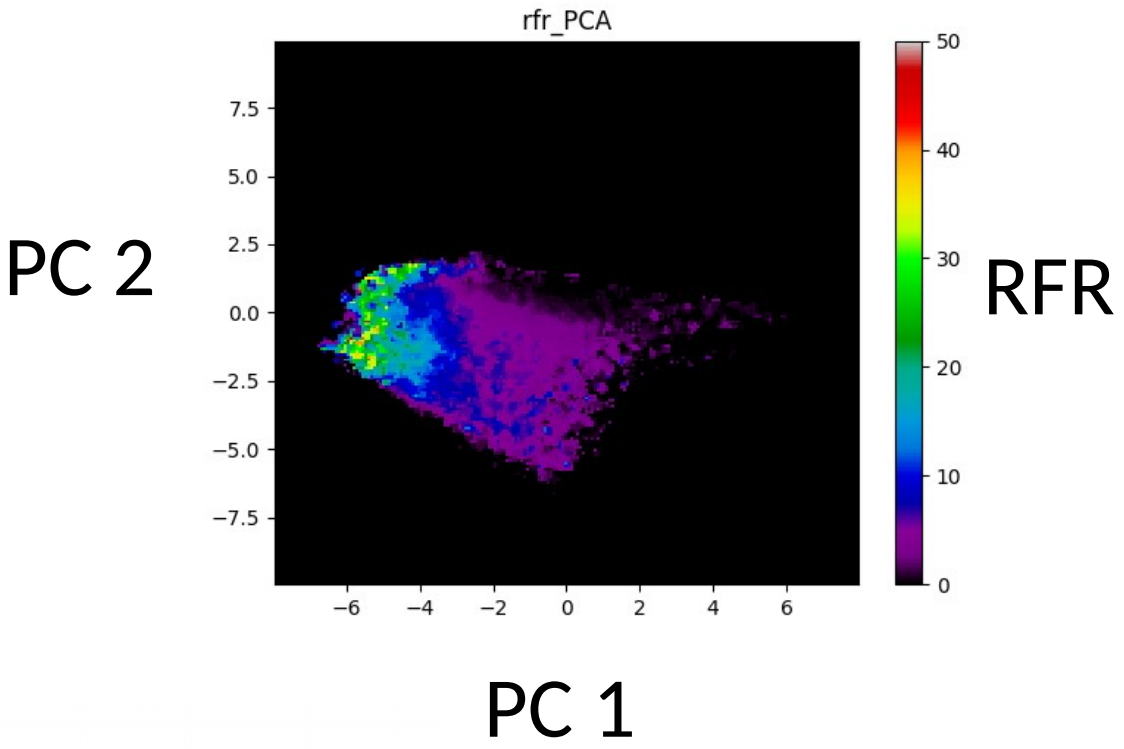
- PCA is a statistical method of reducing dimensionality of a specific dataset into a lower number of variables almost keeping the same information.
- Day Time inputs, with CWP=2/3 * COT*REFF:

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

- The first two PC explain 94.9% of the variance. These are the ones used in the product generation.

CRR-Ph PCA

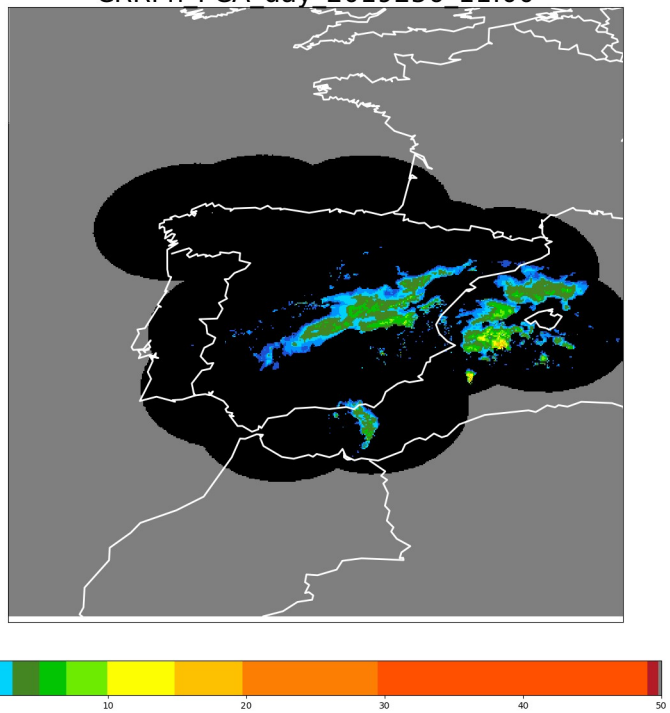
The 90% percentile of the collocated Radar Rainfall Rate can be plotted as a function of PC1 and PC2. This function is latter used as a LUT to derive the product.



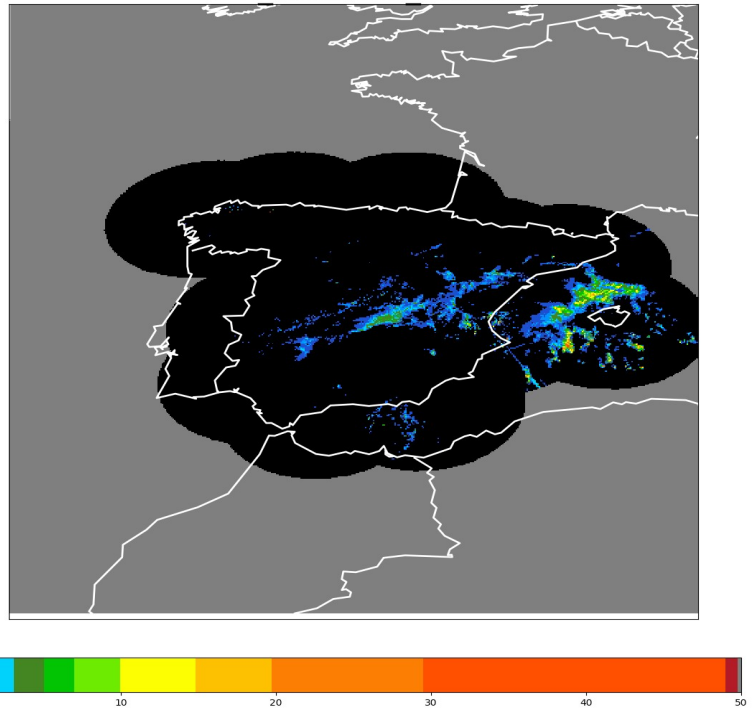
CRR-Ph PCA

Day Time Results, comparison with Radar

CRRPh_PCA_day_2019256_11:00



RFR_2019256_11:00



EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

CRR-Ph PCA

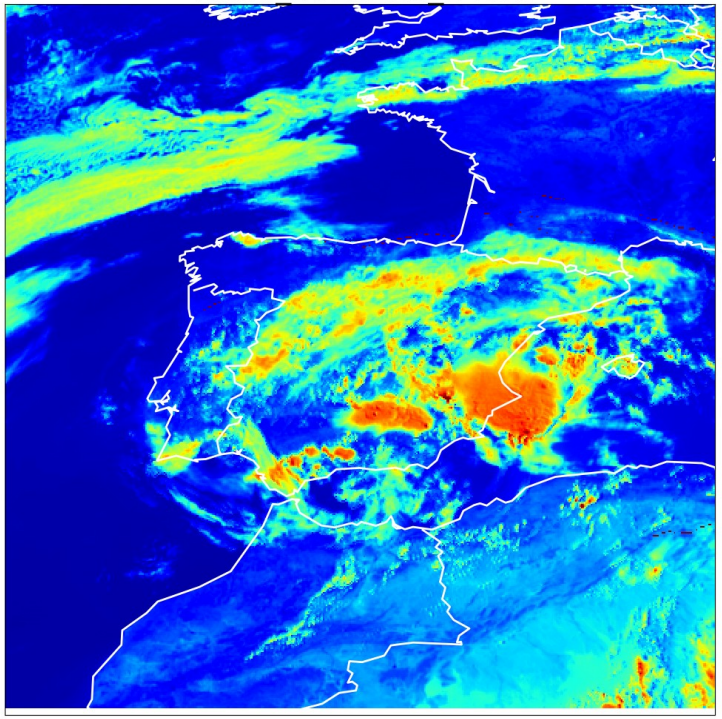
- Night Time same lookup table same as day time to have day/night product continuity
- But, VIS06N and CWP are not available
- VIS06 and CWP will be “predicted” with the actual inputs

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

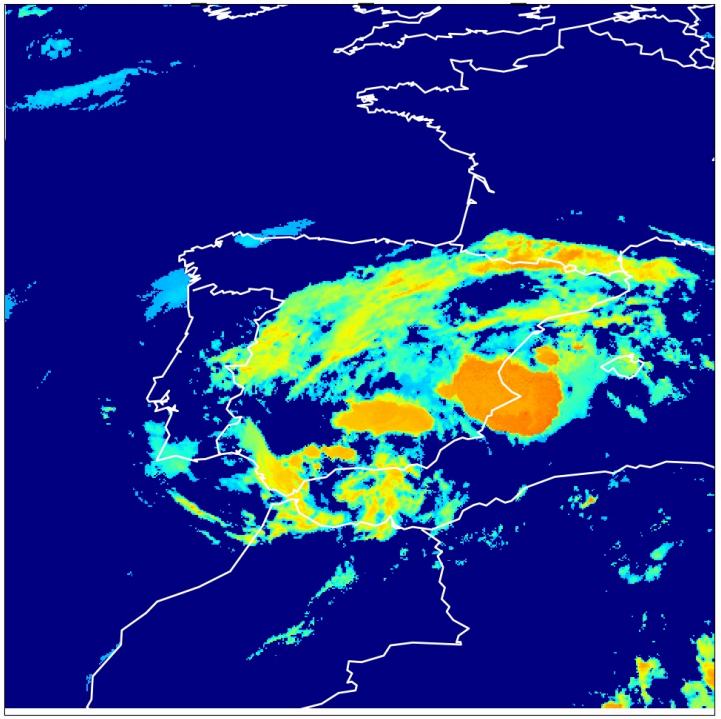
Simulated VIS06 Results

- Measured VIS06 versus simulated VIS06

VIS06_2019256_14:30



VIS06_simulated_2019256_14:30

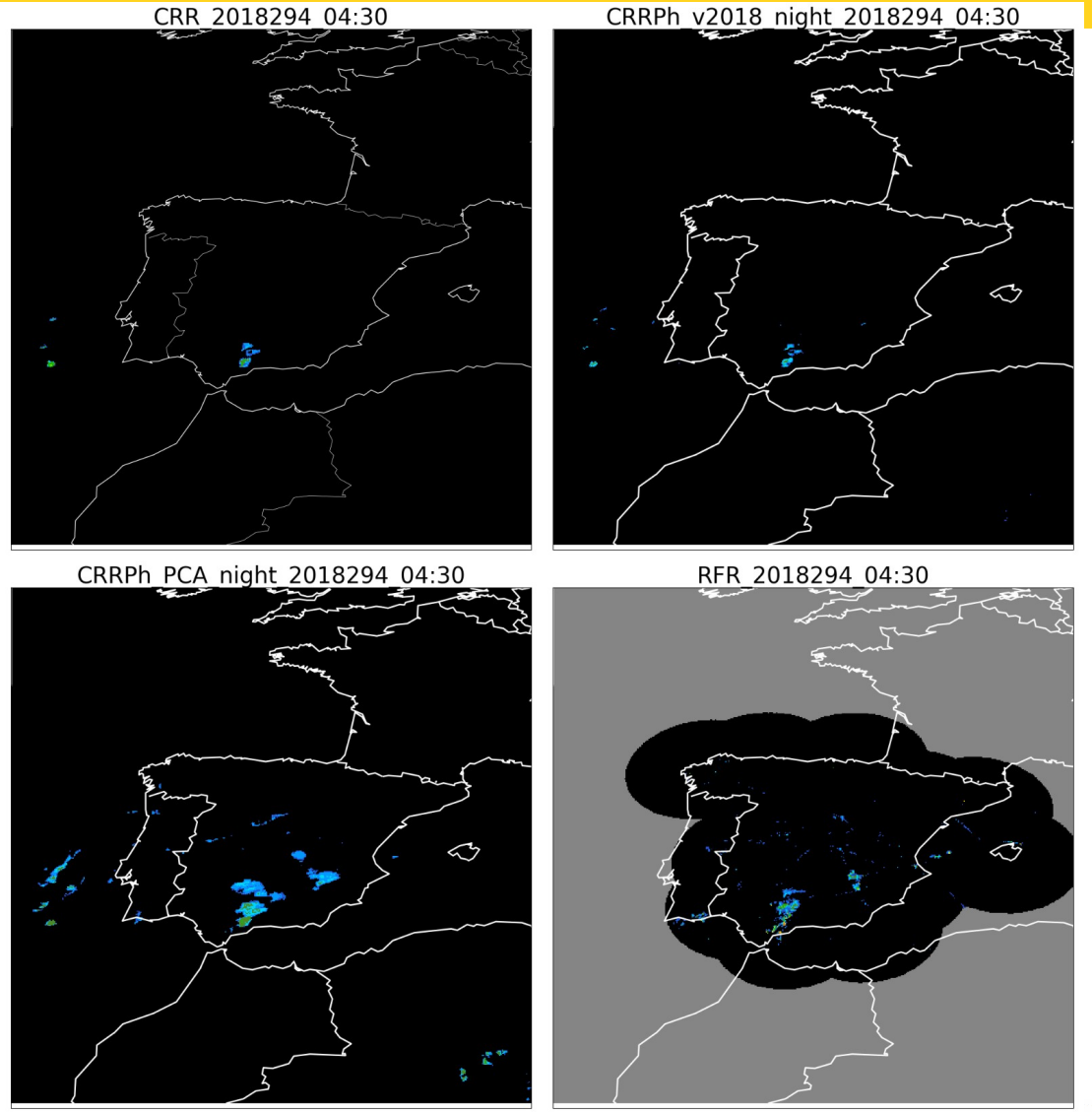


EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

CRR-Ph PCA

Night Time Results, comparison with Radar

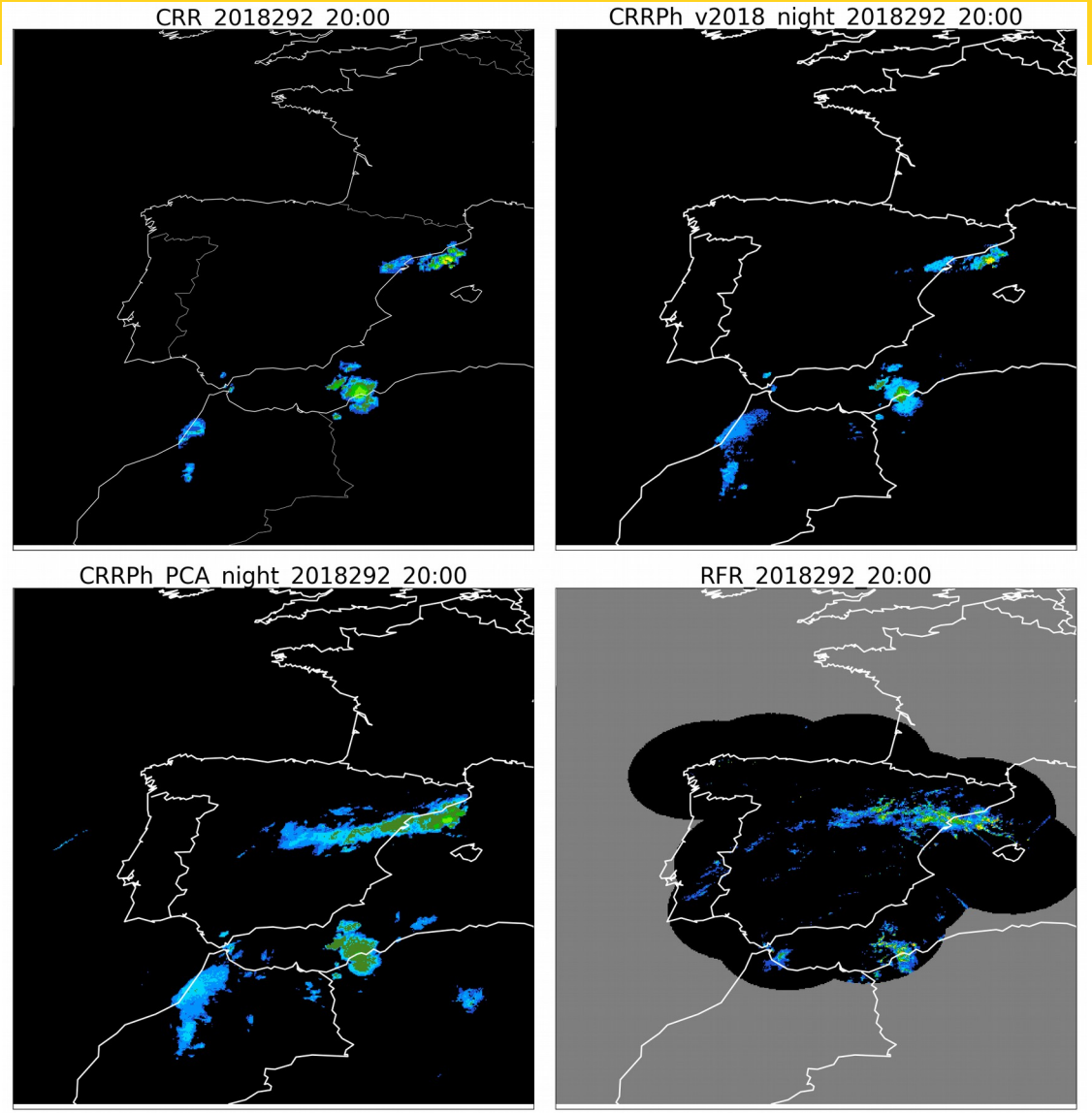


EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

CRR-Ph PCA

Night Time Results, comparison with Radar



EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

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

CRR-Ph	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	1160269	74.24	35.05	53.00	53.00

CRR-Ph PCA prototype	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	1469378	**83.43**	**27.49**	63.38	79.38

REQUIREMENTS

POD (%)	FAR (%)
53	40

POD (%)	FAR (%)
75	35

NIGHT TIME

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

CRR-Ph	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	3397658	42.29	36.42	34.05	34.05

CRR-Ph PCA prototype	N	POD (%)	FAR (%)	CSI (%)	PC (%)
	4374706	**77.48**	**34.85**	54.78	70.16

POD (%)	FAR (%)
47	50

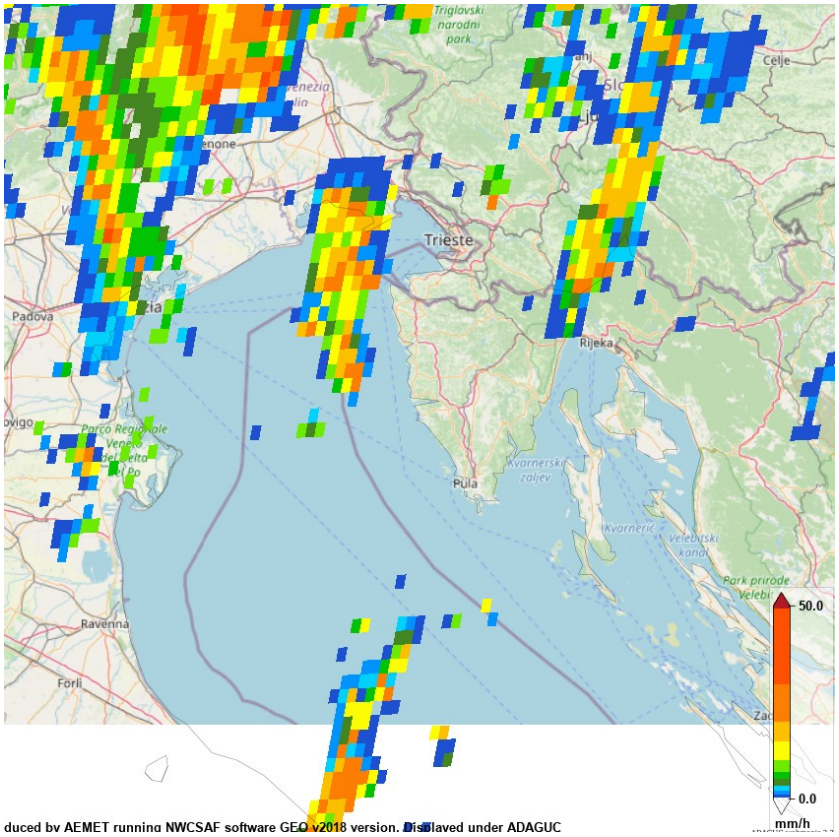
POD (%)	FAR (%)
47	50

Summary

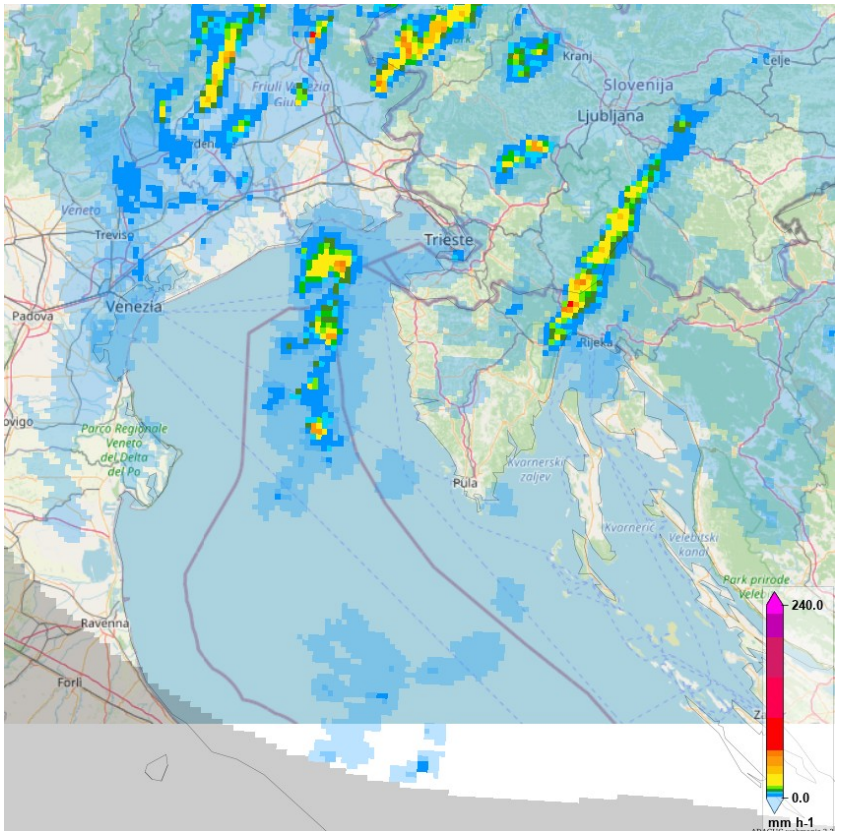
1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

Satellite CRR and Radar RFR Inconsistency

CRR



RFR

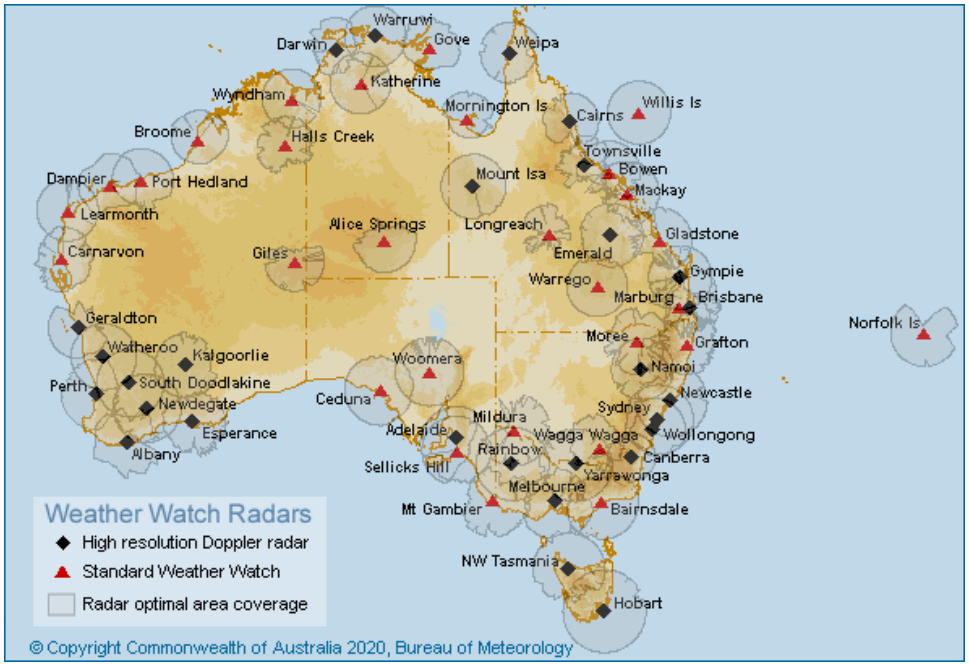


EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Satellite CRR and Radar RFR Inconsistency

- Consistency is needed if merging regions with radar and with satellite coverage
- This is common over the ocean or in big countries



EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

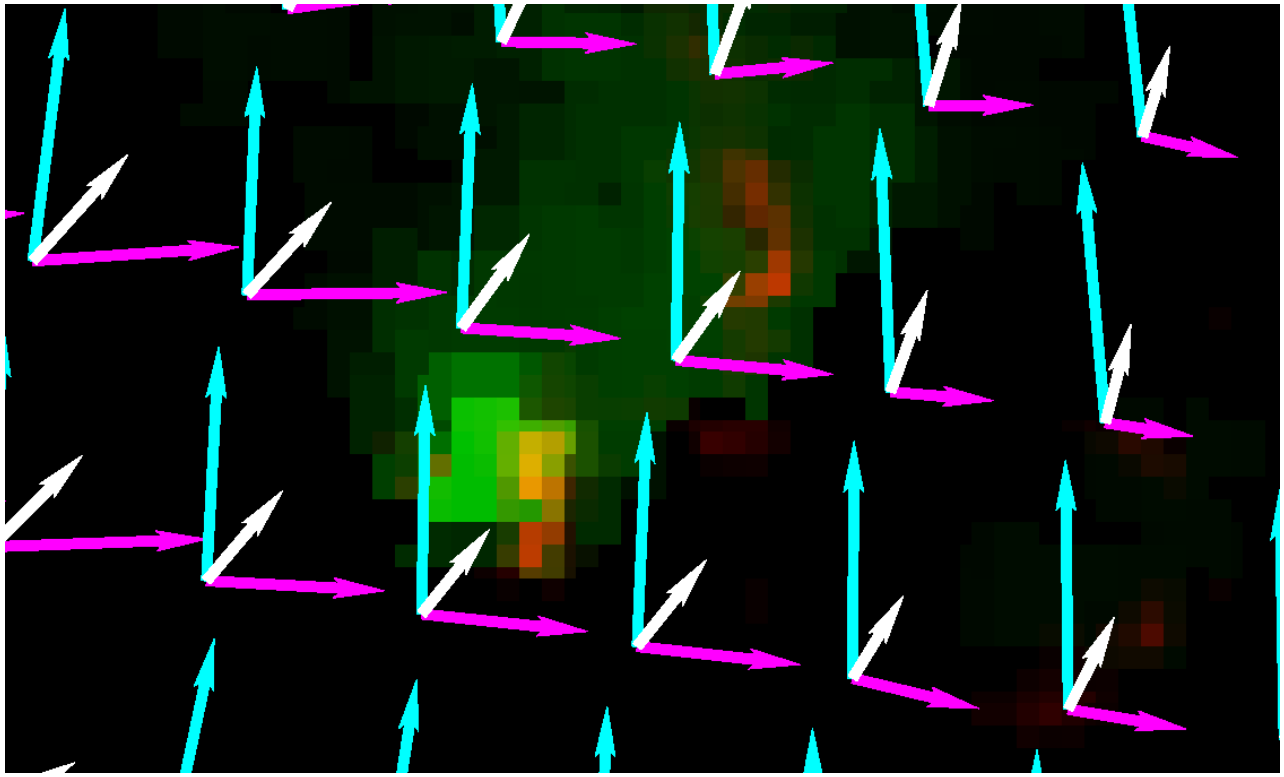
Summary

1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

Search for Consistency

- At AEMET we are looking at what are the physical and measuring principles behind the inconsistency between radar and satellite rainfall rate
- Not only the signal should be measured but also some kind of uncertainty or probability associated with it
- This will ideally permit the merging of both radar and satellite measurement products
- Long term goal of finding the dynamics of convection via satellite data
- In the meantime we just merge data the “best we can” or plot both products on different layers

Combining Radar and Sat Rain



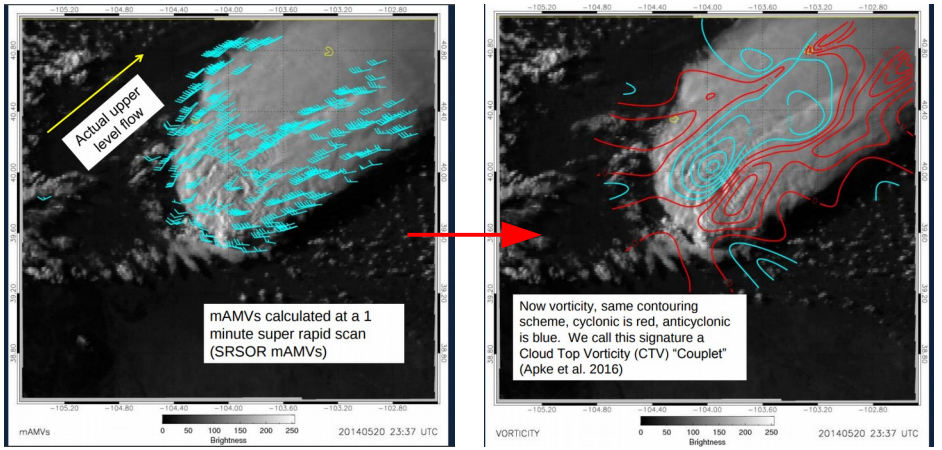
- Satellite precipitation in green
- Radar precipitation in red
- Three velocities: wind mean, right and left Bunkers

Dynamics from Satellite?

Could a more precise determination or modelling of cloud dynamics from satellite data help in these situations?

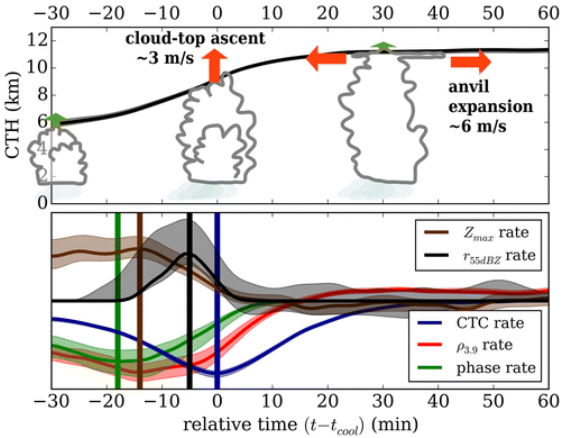
- Winds from RSS:

  → Potential to determine kinematics at cloud top (Apke et al., CWG 2016)



- Determination of updraft strengths:

  → From anvil or cloud top area determination (Senf and Deneke, CWG 2018)

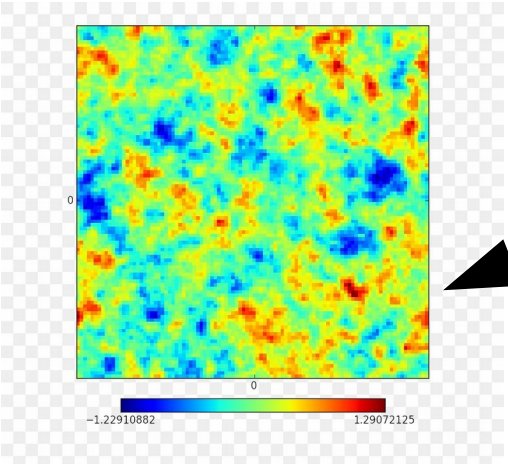


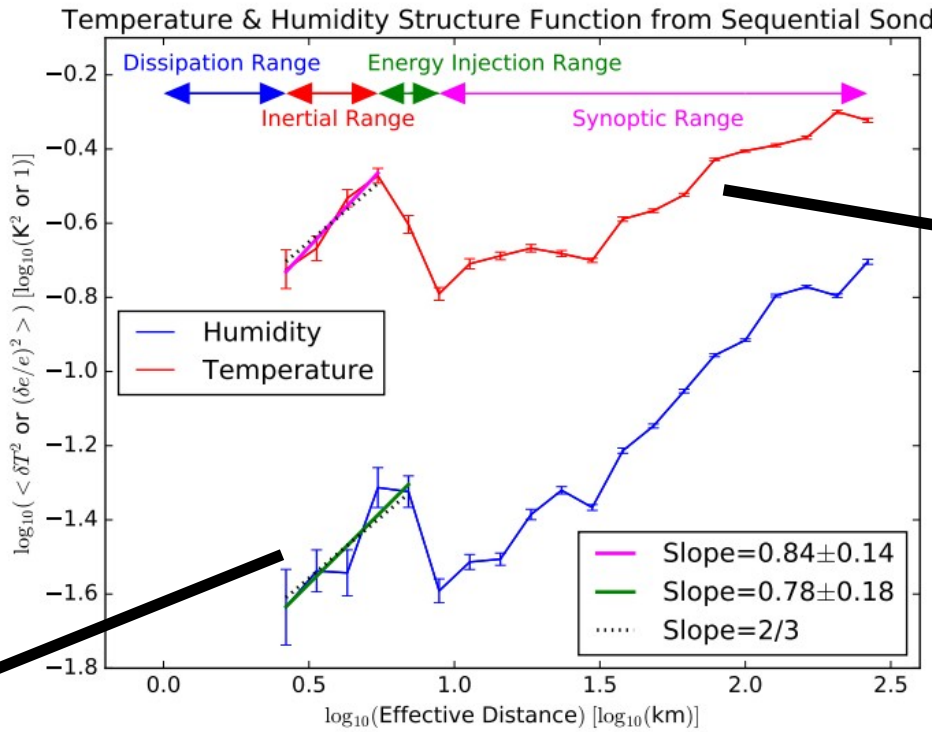
GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Different scales

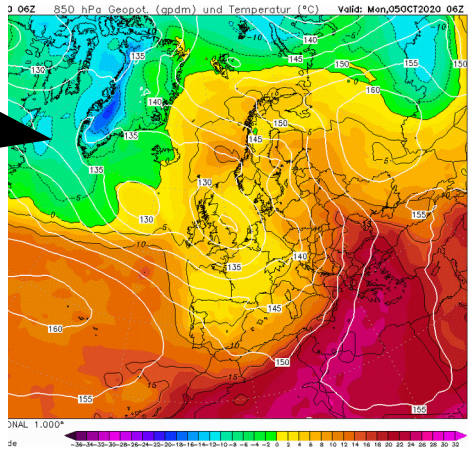
When searching for consistency for temperature and water vapour we find two different scales (Calbet et al. 2018, AMT). This could be important for other Nowcasting effects.

Scales < 6 km
Random
Gaussian Field





Scales > 10km
Smooth Field



GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet
Agencia Estatal de Meteorología

Summary

1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Prototype AEMET QPE for FFP

Main items:

- Based on merging measurements from radar, satellite and rain gauges
- Currently being developed in AEMET and tested for some FF situations
- Uses geostatistical technique (KED) and Cross-Validation to select an “optimal” QPE field
- Preliminary focused on a region with a high-density mesoscale rain gauge network
- Includes crowdsourced data
- Resolution: 1 km^2 / 1 hour (but 10 minutes is planned)
- Obtained PCP fields can be further applied to NWC (e.g STEPS)
- Provides a precipitation field for hydrological purposes (flash-flood forecast, early-warnings …)
- Developed by Peio Oria

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Prototype AEMET QPE for FFP

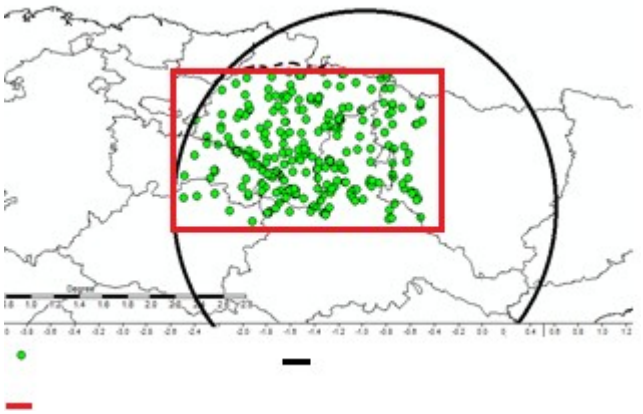
Input Data:

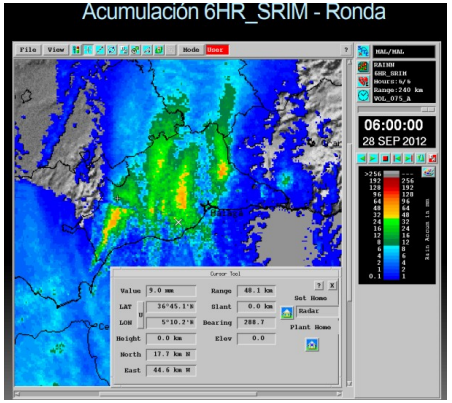
1. Local approach: PCP field is obtained through the use of as many as possible rain data (density is about 150 / 10000 km^2). **Rain gauge** networks belong to:

- Official institutions: NWS (AEMET), hydrological, agriculture, regional ~ 100
- Crowdsourcing ~ 50

Data should be available with minimum-delay

Preliminary QC over rain gauge data

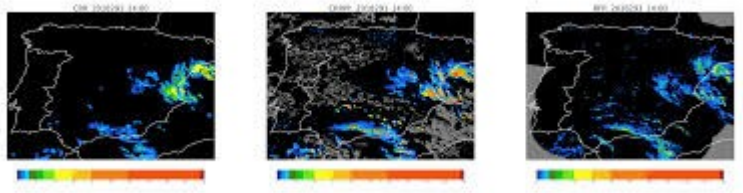




2. Pcp **Radar** field based on operational *SRI* product:

- Identification of ground clutter
- Reflectivity-to-rain-rate conversion using the Marshall–Palmer Z–R relationship
- Correction for vertical profile of reflectivity (VPR)

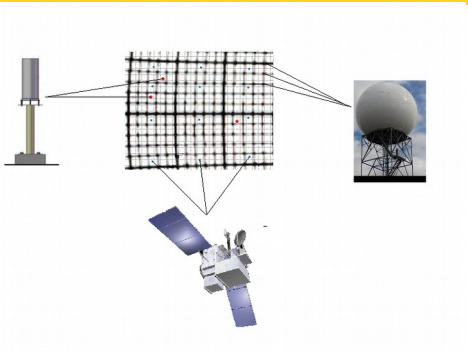
3. Satellite-based product (*CRR-Ph* from NWC SAF) is also used



GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Prototype AEMET QPE for FFP. Algorithm (I)

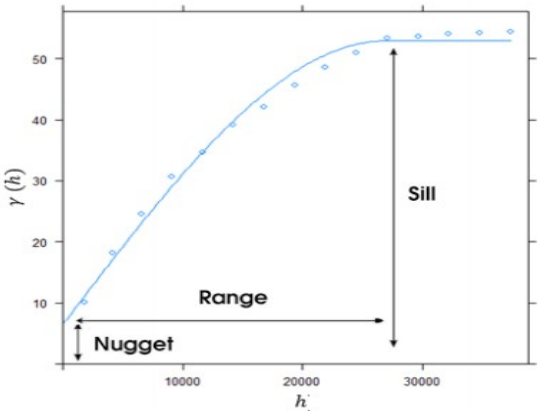
Projection change and CRS transformation of remote-sensing products to common grid in *aeqd* projection



Merging all data through geostatistical technique:
Kriging with External Drift (KED).

Ordinary Kriging (OK) only takes rain gauge data (primary variables) for constructing a linear estimator which is a weighted sum of *n* observations of neighboring points. A semivariogram model needs to be constructed. However, in KED:
- The semivariogram is obtained from (real-time) radar data and fitted to a spherical model every time the algorithm runs.
- Additionally some external variables, in this case radar and satellite-based QPEs, are used as auxiliary information (secondary variables) since better capture the spatial variability of rainfall fields.

Semivariogram obtained using radar data. A spherical model has been fitted.



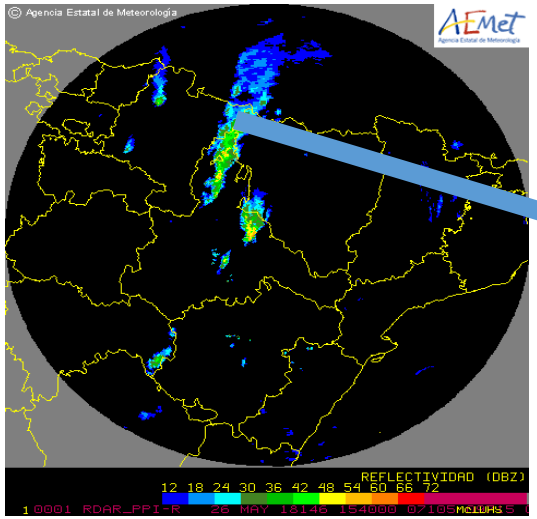
GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet
Agencia Estatal de Meteorología

Prototype AEMET QPE for FFP. Algorithm (II)

- Depending on the auxiliary field (*SRI* or *CRR-Ph*) chosen in the KED different combinations for the PCP field can be generated.
- In addition logarithmic transformations of the KED variables are also considered and included as possible combinations for QPE fields : first taking log only in the primary variable and then both in primary and secondary variables.
- Then the resulting six different KED-based precipitation fields (3 using SRI and 3 using CRR-Ph) are constructed.
- To verify which combination gives the best result a real-time cross-validation (CV) routine is performed:
- Remove an observation (in this case a rain-gauge)
- Construct the KED model with the remaining observations
- Compare predicted value by the model with the observation
- Iterate process for all observations
- Compute RMSE for assessing the skill
- Finally the combination with less RMSE is selected and taken as “optimal QPE”

QPE product for FFP: Case Studies

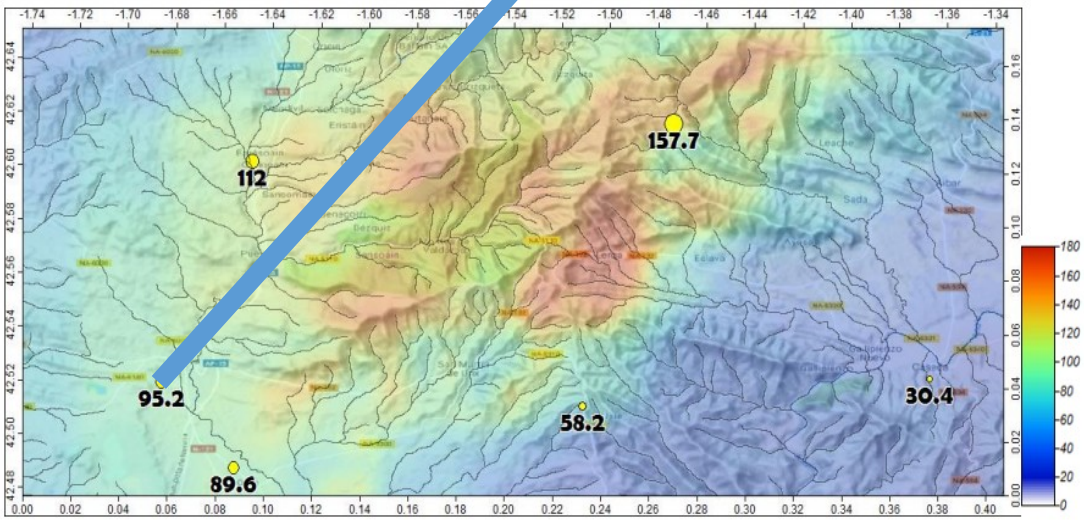
Product has been tested in different convective episodes (scales from 1 to 10 hours) with associated FF risk: Supercells, squall-lines, convective trains, quasi-static cells



Example of obtained QPE field for the extreme flash-flood event which took place in middle Navarre (8th July 2019). Accumulations over the whole episode are shown.

Numbers correspond to precipitations measured in rain-gauges.

River network is also displayed.



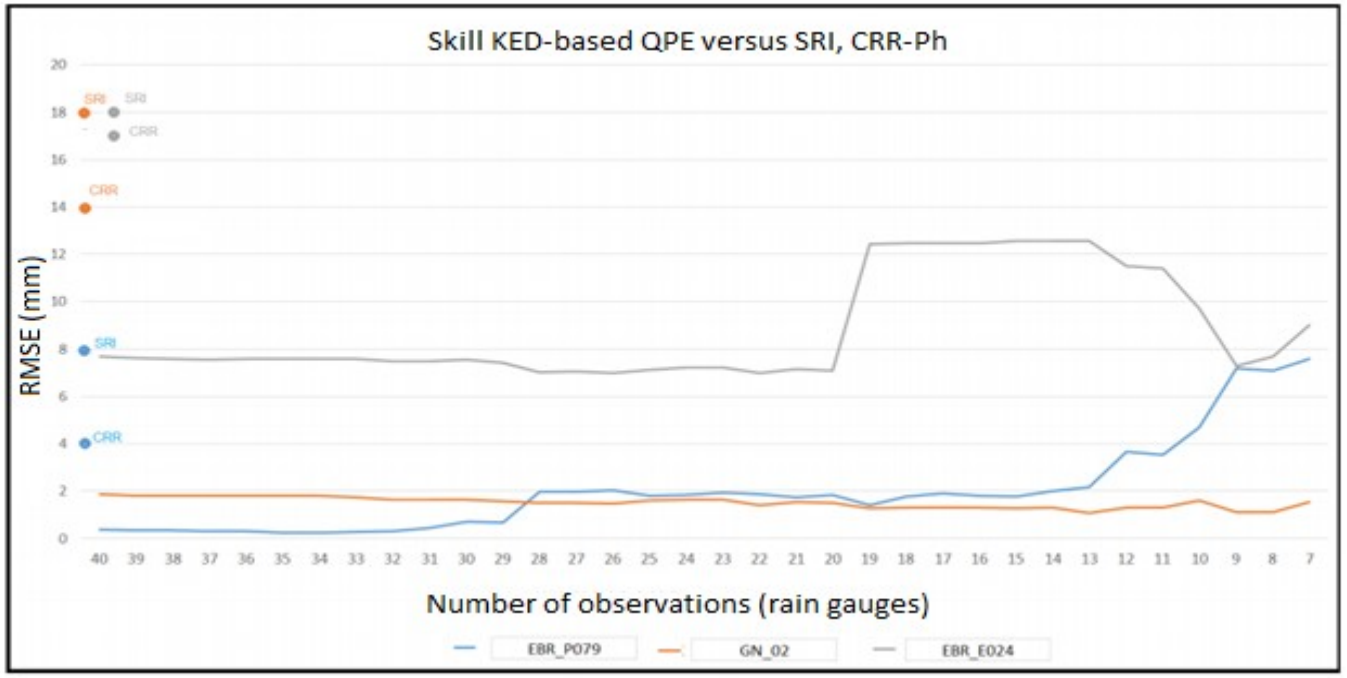
QPE product for FFP: Some Results

Example of the observed and estimated precipitation quantities in a convective event (03-06-2018 (15-16 UTC)) for different rain-gauges. Observations larger tan 15 mm/hour are in red.

Rain gauge	Observed accumulation	Optimal estimation by Cross-Validation
9198X	1.4	1.7
9321X	4.4	7
9228J	2.8	1.1
EBR_A264	2.2	5
EBR_EM75	3.6	2.5
GN_02	3	2
MAP_5	1.6	1.8
GN_10	16.4	11.8
GN_14	3.8	9.4
GN_17	30.6	27
GN_21	0.7	0
GN_26	2	1.4

Improvement wrt existing rain estimation products (raw rain-gauge interpolation, SRI, CRR-Ph).

Skill of different products in a convective episode. Every color represents the comparation in an (arbitrary) rain gauge for an (arbitrary) hourly period of one of the analyzed situations. The y-axis is the RMSE (obs. vs estimation via CV) and the x-axis is the number of observations (i.e. rain gauges) taken in the KED.



GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología

Summary

1. Nowcasting SAF's QPE (CRR-Ph)
2. Inconsistency between sat and radar QPE
3. The search for consistency
4. AEMET's multi-sensor QPE
5. Future

Combination/Simplification of products

- Too many products for a forecaster!!!
- Need to simplify or combine products
- For this, consistency is necessary
- In AEMET we are searching for this consistency, also determining uncertainties or using probabilities
- Also, products improve if surface based data is added
- In the meantime, the NWC SAF is making a big effort in making software available to plot all the data together

Visualization/Distribution with ADAGUC

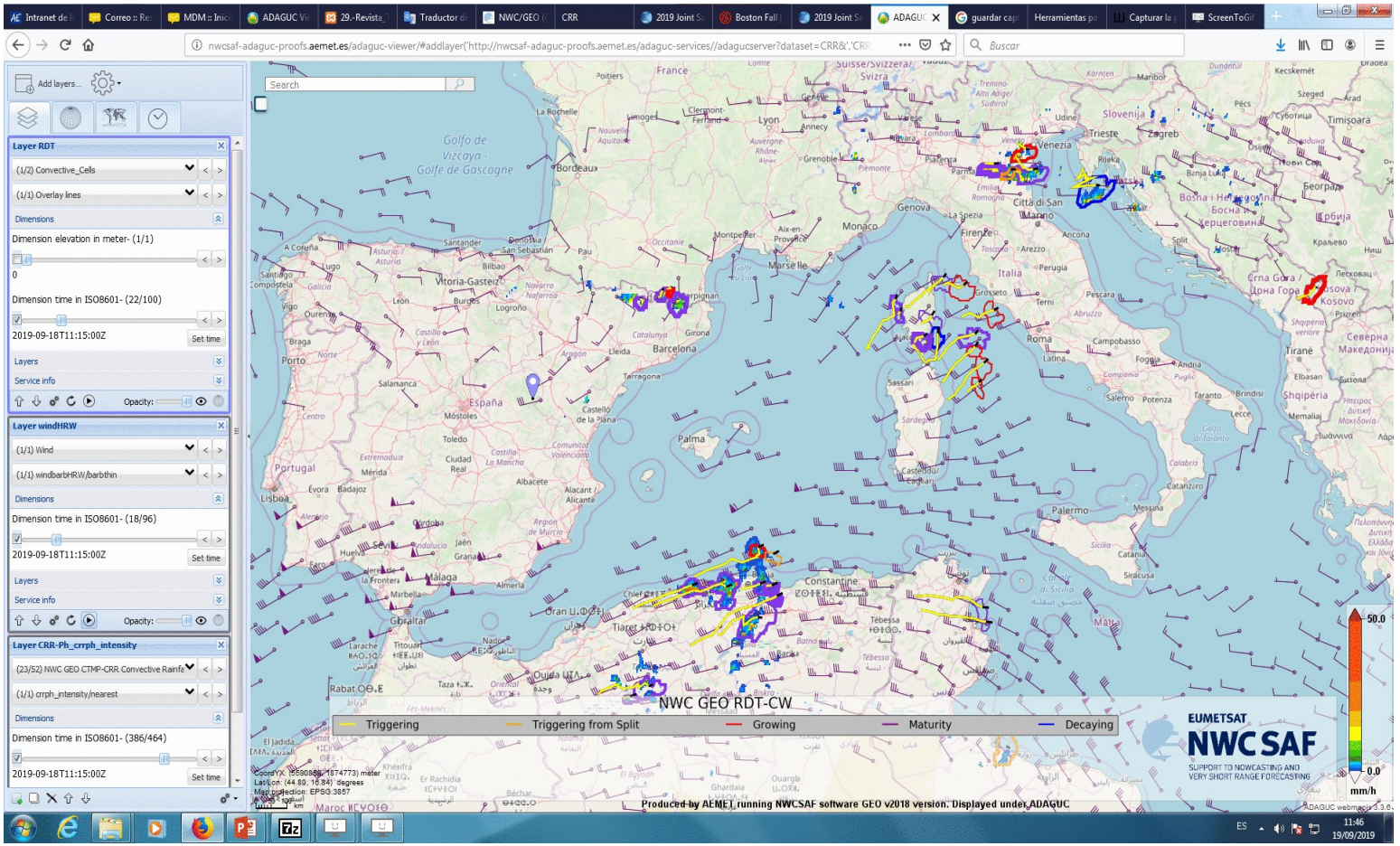
18th September 2019

Three products

- RDT-CW
- CRR-Ph
- HRW

On OpenStreetMap

nwc-saf.eumetsat.int



http://nwcsaf-adaguc-proofs.aemet.es/adaguc-viewer/

EUMETSAT NWC SAF

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

AEMet Agencia Estatal de Meteorología

Visualization/Distribution with ADAGUC

- Developed by KNMI (Netherlands)
- Completely Open Source
- Has two server components: ADAGUC services and ADAGUC server
- Has two clients which are web visualizers: ADAGUC viewer and GeoWeb
- Will be operational for NWC SAF in a few weeks
- Inputs are HDF5, NetCDF4, GeoJSon and CSV
- Outputs are Web Mapping Services (WMS) for online visualization, Web Feature Services (WFS) for downloading vector data, Web Coverage Services (WCS) for downloading raster data and OpenDAP

KNMI ADAGUC - http://adaguc.knmi.nl/

Summary

- Merging and appropriate plotting of products will be key in the future
- Products in near real time at http://nwcsaf-adaguc-proofs.aemet.es/adaguc-viewer/
- More information of NWC SAF products at

  nwc-saf.eumetsat.int
- The NWC SAF provides software to generate the products and also tools to use an open source software to display them (ADAGUC)
- It would be beneficial, especially for smaller countries, to have a common development platform for Nowcasting based on open source software