Cross-verification of the Rapid Developing Thunderstorm and the precipitation products of the Nowcasting and Very short-range forecasting SAF

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Outlines

- Objectives
- Methodology for validation purposes
  - Method used for selection of convective cases
- Quantitative validation – PC, CRR with rain gauges
  - Statistical scores for CRR
  - Statistical scores for PC
  - Cross-validation of CRR and PC
- Subjective validation - RDT, PC, CRR with radar
  - Case studies

A VSA was performed in 2009

- The period of study: 15 May 2009 – 15 September 2009
- Quantitative validation:

  CRR and **PC** products were compared with 10-minute **rain gauge data**
- Qualitative validation:

  PC, CRR and **RDT** products were analyzed through case studies
  They were compared with **radar** data

Data used for the **quantitative** validation

RAIN GAUGE:
101 automatic stations in Hungary – precipitation measurements with Tipping Bucket rain gauges in every *10 minutes*

LIGHTNING DATA:
Lightning reports by LINET network
intra-cloud (**IC**), cloud-to-cloud (**CC**) and cloud-to-ground (**CG**) flashes.

Quantitative validation:

- CRR with rain gauge data
- PC with rain gauge data
- Comparing statistics of CRR and PC

Problems:
CRR – **convective** rain rate (mm/hour intervals)
PC – probability of (**all types of) precipitation** (% interval)
TB -Tipping Bucket rain gauges measures **all types of precipitation** (mm in 10 minutes)

How can we compare CRR with TB, PC with TB, CRR with PC?
- Different types of precipitation
- Different characteristics of precipitation

For CRR –
We had to separate a 'convective' subset of TB, containing only the convective precipitation. We **validated CRR agains tthis 'convective' subset**

For PC -
- We validated **PC against the whole TB dataset**
- For the PC - CRR cross-validation we validated PC against the convective TB subset as well.

Method used to select the convective TB measurements

1. Localization of the meteorological stations on the satellite image
2. **for each slot - we had to decide which stations were in convective situation, measuring convective precipitation.**

Automated method - based on the **CT** and CRR products and **lightning** information.

1. A slots was validated only if at least
   - **15 lightning flashes** in the last hour, or
   - **100 pixels with non-zero CRR** values

2. In these slots the convective TB measurements were selected by studying

   5 x 5 pixel boxes centered on each Tipping Bucket Rain Gauge

   and

   0.5° x 0.5° Grid squares:

   (there must be at least 2 rain gauges in the grid box).

5 x 5 pixels boxes centered on each Tipping Bucket Rain Gauge considered as convective, if

- According to the CT product **80%** of the pixels are **very high or high opaque clouds**. + At least **one pixel must** correspond with **very high opaque cloud**.

or

- According to the CT product **80%** of the pixels are **very high or high opaque clouds**. + There must be **some lightning** activity in the last 30 minutes in the 15 x 15 pixel box centered on the Rain Gauge.

or

- According to the CT product **40%** of the pixels are **very high or high opaque clouds**. + There must be at least **15 lightning flashes** in the last 30 minutes in a 15 x 15 pixels box centered on the Rain Gauge.

or

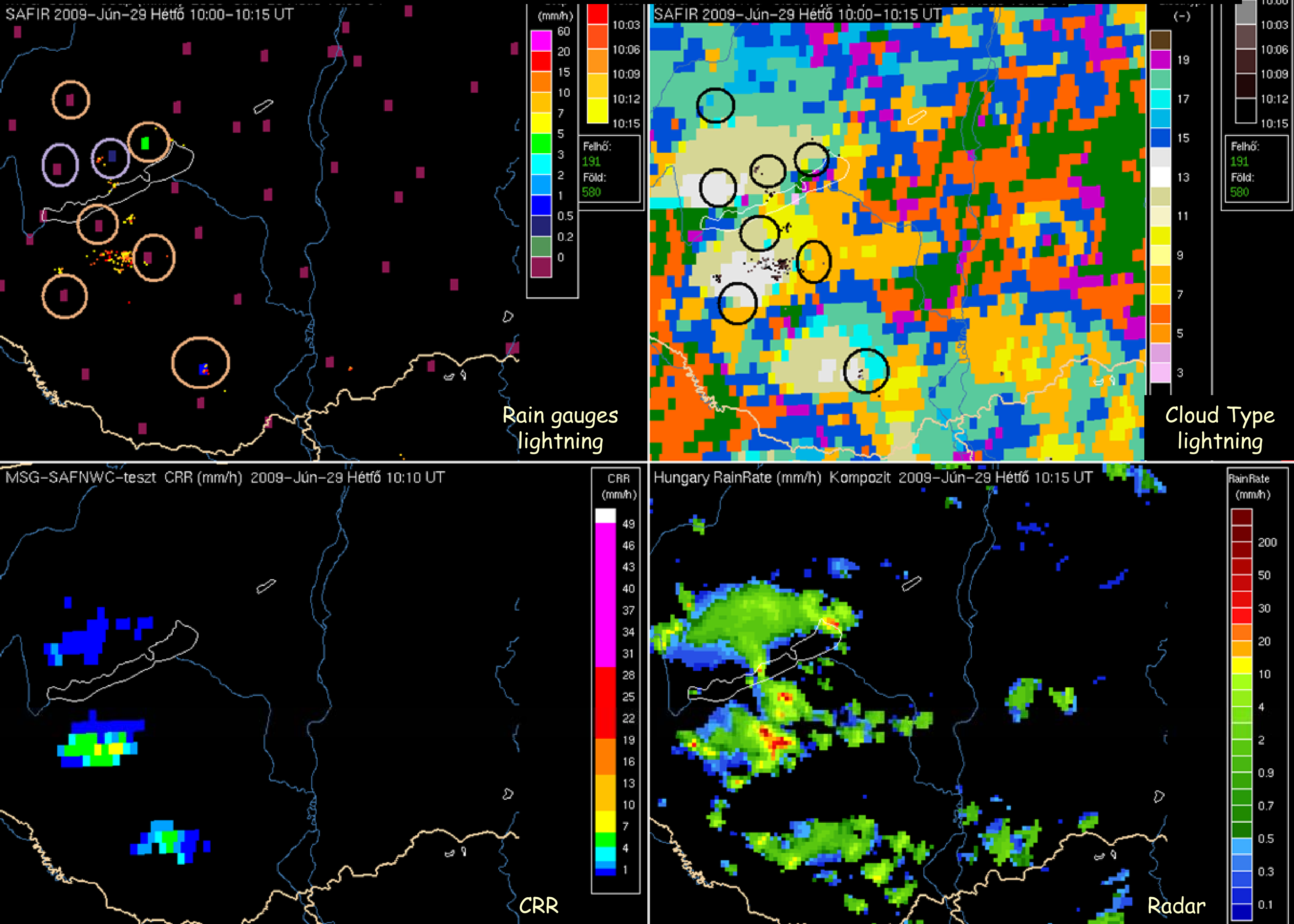
- **Any non-zero CRR** signal has been found in that box.

The 0.5° x 0.5° Grid boxes considered as convective, if

- According to the CT product **60%** of the pixels are **very high or high opaque clouds**. + There should occurred at least **5 lightning** flashes in the last 30 minutes.

- **Any non-zero CRR** signal has been found in that grid.

Selection of convective precipitation measurements - 5x5 pixel bowes



Quantitative verification of CRR

TB was not compared with the CRR value of just one pixel (containing the rain gauge), but

- **TB was compared with the CRR average and CRR best value in the 5x5 pixel box** around the rain gauge.
- In case of the grid the **average of the TB data** within the grid **was compared with CRR average and CRR best value** in the grid.

(CRR best value - in a given box (or grid) the closest value of CRR to TB is taken.)

The validation of the **best value** was performed in order to compensate the **effect of probably dislocations of rainfall in the CRR** pattern compared to the TB data.

The validation of **grid boxes** is based on the idea to **reduce the discrepancies between point-like and pixel-structured data** for the comparison. This is why grid average values of TBs (2, 3, max. 5 TBs) were compared to CRR averages. It can be good indicator of the ability of CRR to capture large-scale events.

CRR product includes:

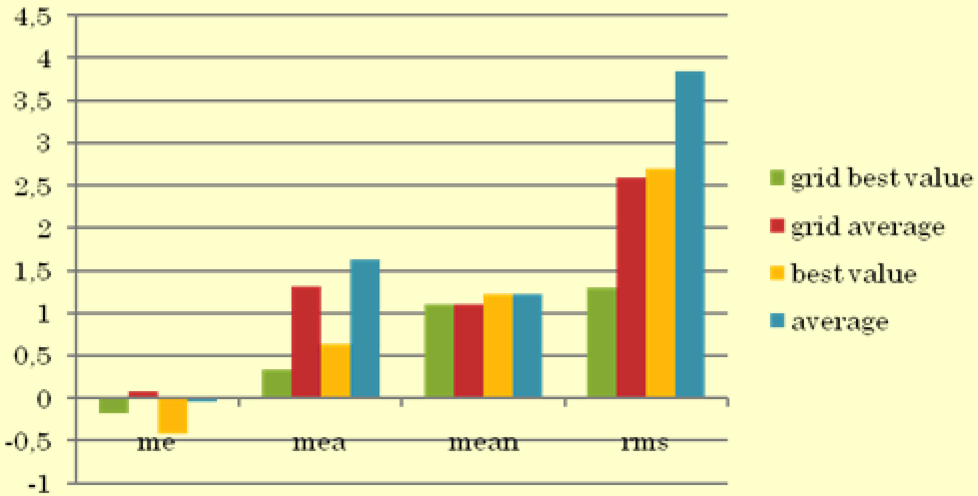
- **CRR - instantaneous** rain rate (interval)
- **CRR_accum - 1 hour accumulated precipitation (**of the previous hour)

Both product were validated:

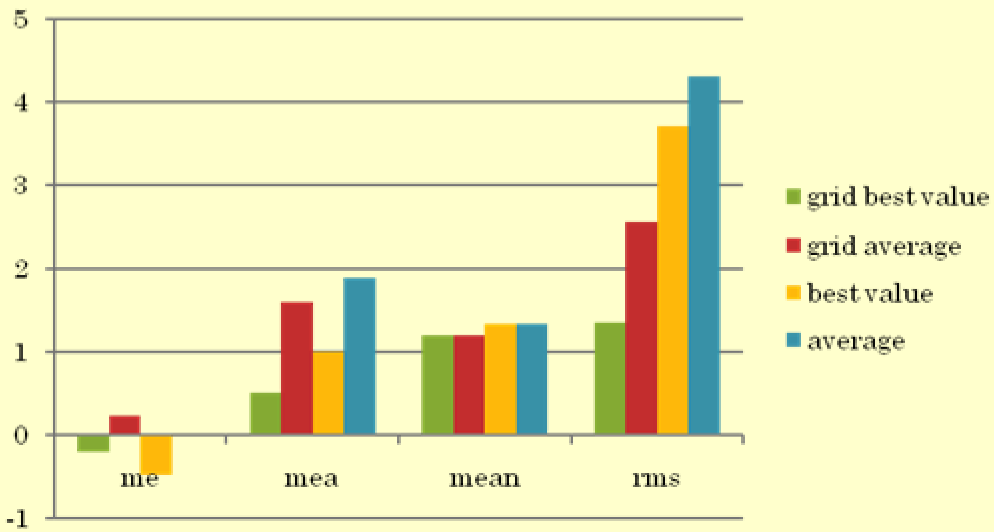
- **CRR** was compared with **30-minute TB** data
- **CRR_accum** was compared with **60-minute TB** data (the scores will be not shown)

Accuracy Statistics for CRR

CRR Accuracy Statistics day



CRR Accuracy Statistics night



- **ME - Underestimation in case of best value** – in case of best value there is hardly any overestimation, meanwhile for 5x5 average in case of TB=0, it is usually overestimation
- **day statistics have slightly lower values** in MAE and RMS than night
- **RMS is lower with grid statistics**
- Day RMS similar for grid average and 5x5 best value
- **MAE and RMS values are lower for best value statistics than for the average st.**
- Grid average is higher in MAE, and lower in RMS than best value 5x5 box => when comparing with grid average, data pairs are smoother than with 5x5 best value (due to discrete values in CRR)

Categorical Statistics.

POD - Probability of Detection:

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

FAR - False Alarm Ratio:

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

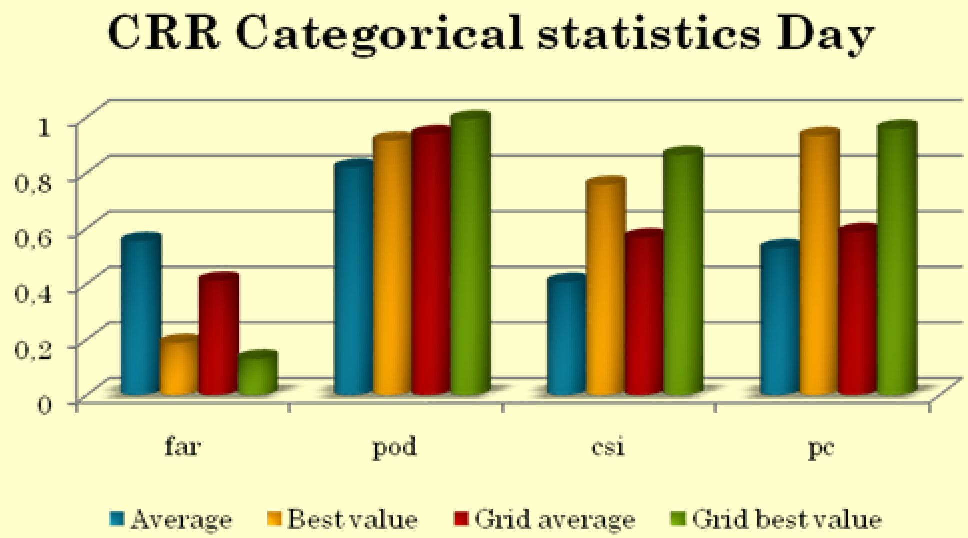
CSI - Critical Success Index:

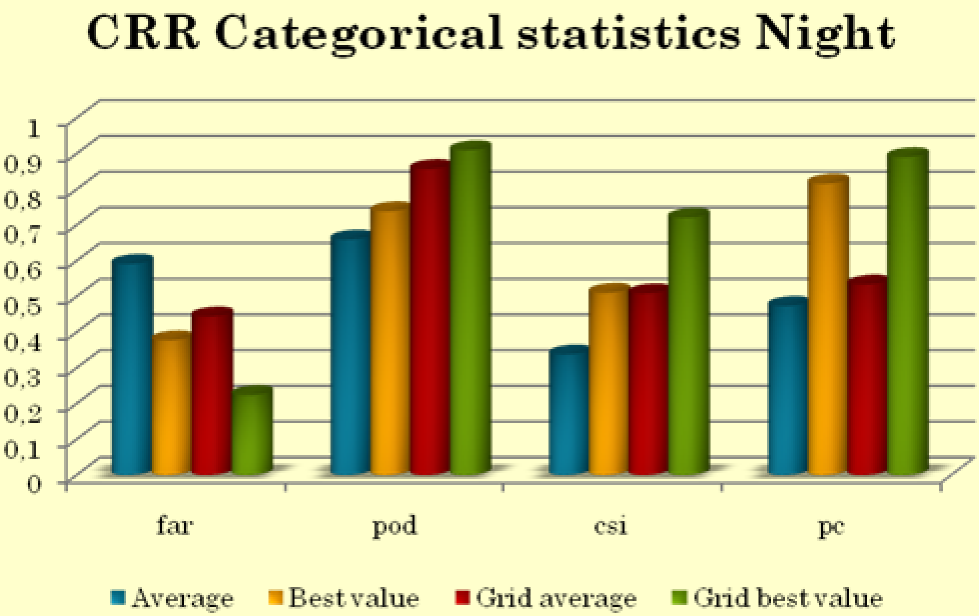
$$CSI = \frac{hits}{hits + misses + false\_alarms}$$

PC -- percentage of corrects

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

Categorical scores for CRR





Rain/no rain statistics

Thresholds:
Box average 0.1mm/h
Box best value 1mm/h
Grid average 0 mm/h
Grid best value 1 mm/h

- **POD is high**
- **FAR is lower for best value than for average method** => if there is no rain, CRR does not give rain in all the surrounding pixels
- PC lower for average
- **biggest difference between day/night in case of FAR best value**

Quantitative verification of PC

PC was verified against the

- Whole data base
- Convective subset

1. **parallax corrected PC product was verified** **(IR10.8 method, without gap filling, we excluded the PC - TB pair from the statistics if Tb is located in a 'gap')**

2. The TB was compared with the PC value of the single pixel containing the rain gauge (not with a bigger area as it was in case of CRR).

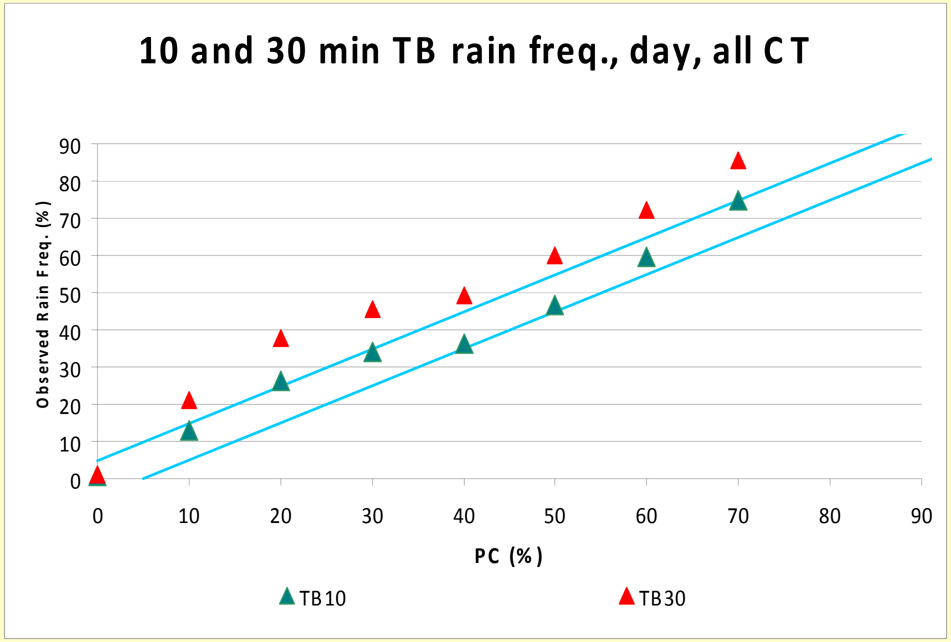
How to compare rain probability with measured rain rate?

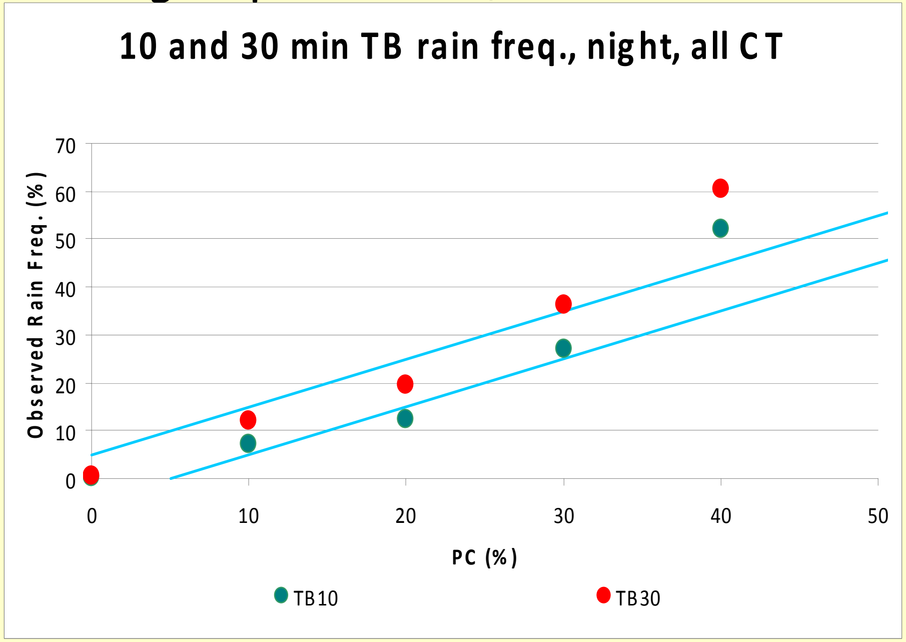
•We compare the PC probabilities with the observed rain frequencies

•we convert the PC probabilities to rain / no rain categories using a threshold (20%)

Comparison between the observed rain frequency and satellite retrieved rain probability

Obsorbed rain frequency was computed from **10- and 30-minute TB** data
The **whole TB dataset** was used, not only the convective one
Results for **day and nighttime** algorithms
Statistics were calculated also for different CT groups (PC sub-algorithms, not shown)

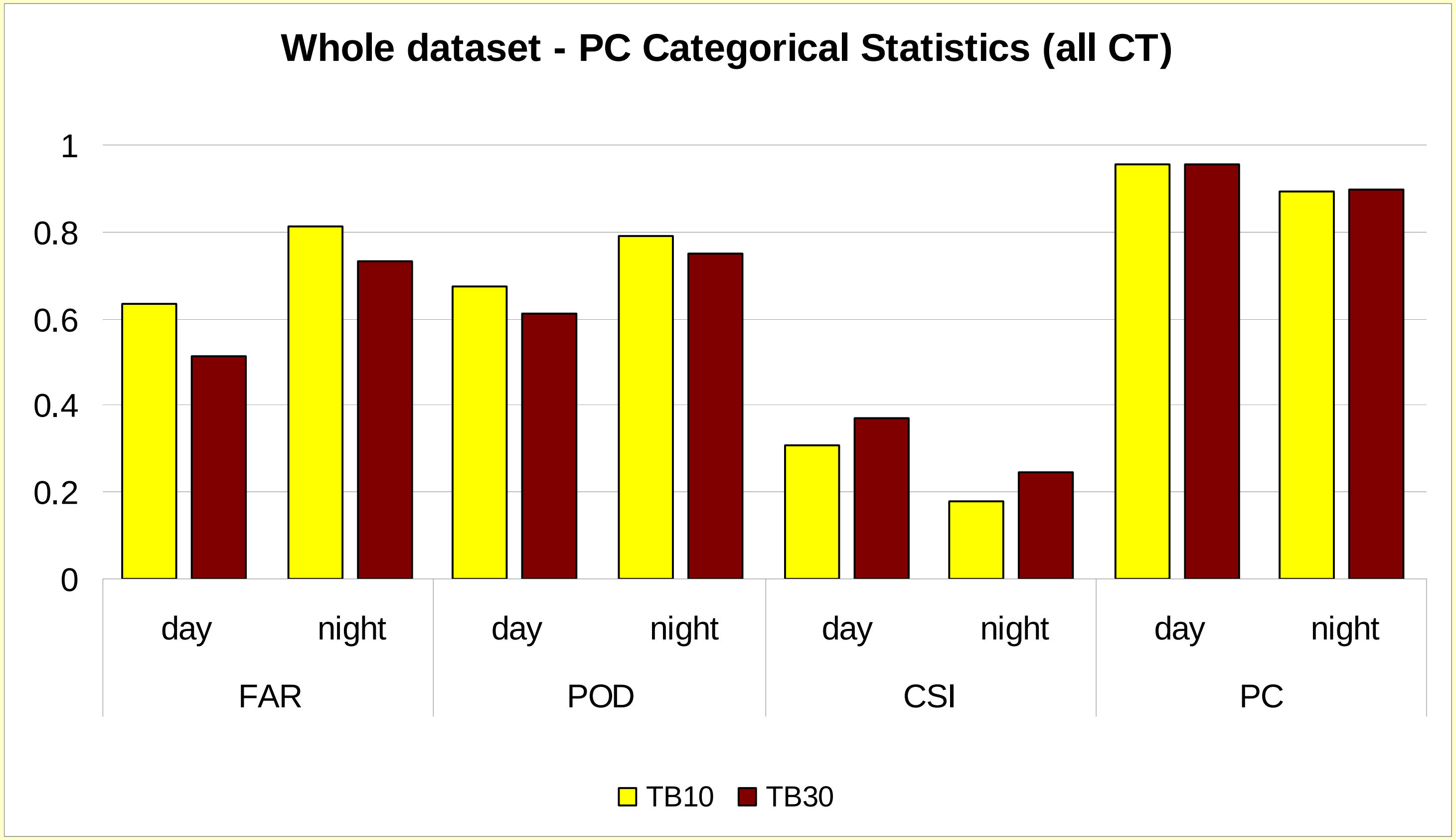




Number of cases

	PC (%)									
	0	10	20	30	40	50	60	70	80	90
day	528680	17881	12349	3691	6438	5595	2083	711	0	0
night	436388	23924	38970	26409	725	0	0	0	0	0

Categorical statistics calculated for the whole TB dataset comparing the PC rain/no rain categories with the 10- and 30-minute TB values



Both POD and FAR is higher for TB10 than TB30

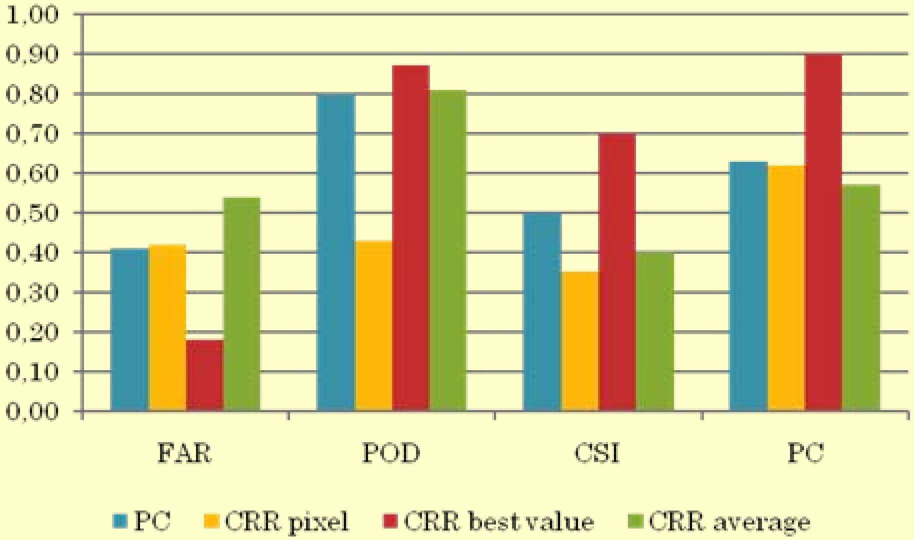
Both POD and FAR is higher for night than for day

CSI, PC - Day algorithm is better than the night algorithm

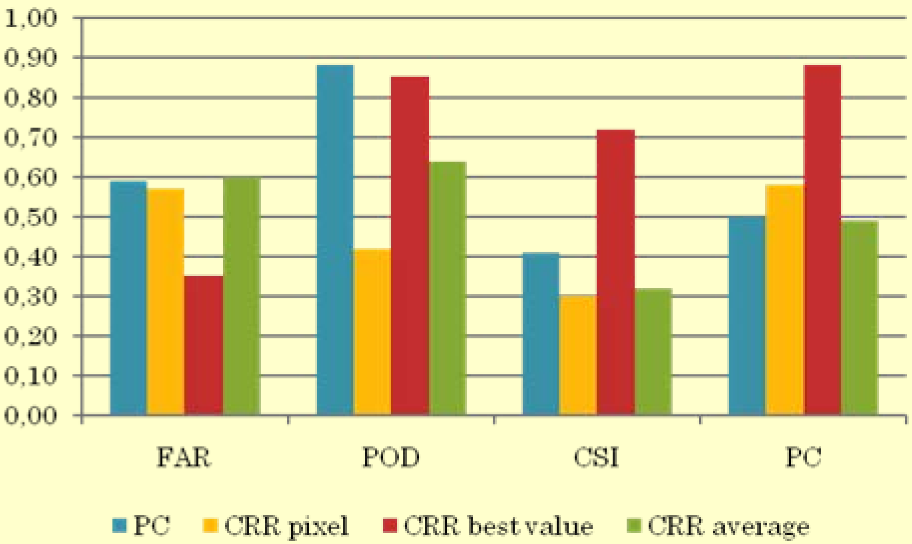
Converting the PC probabilities to rain / no rain categories using a probability threshold of 20%.

Cross-verification of PC and CRR

Day



night



CRR and **PC**
categorical statistics
(rain/no rain)

day- and nighttime

Convective TB subset
30-minute TB data

PC, CRR pixel –
TB compared with the PC, CRR value of the **single pixel** containing the rain gauge

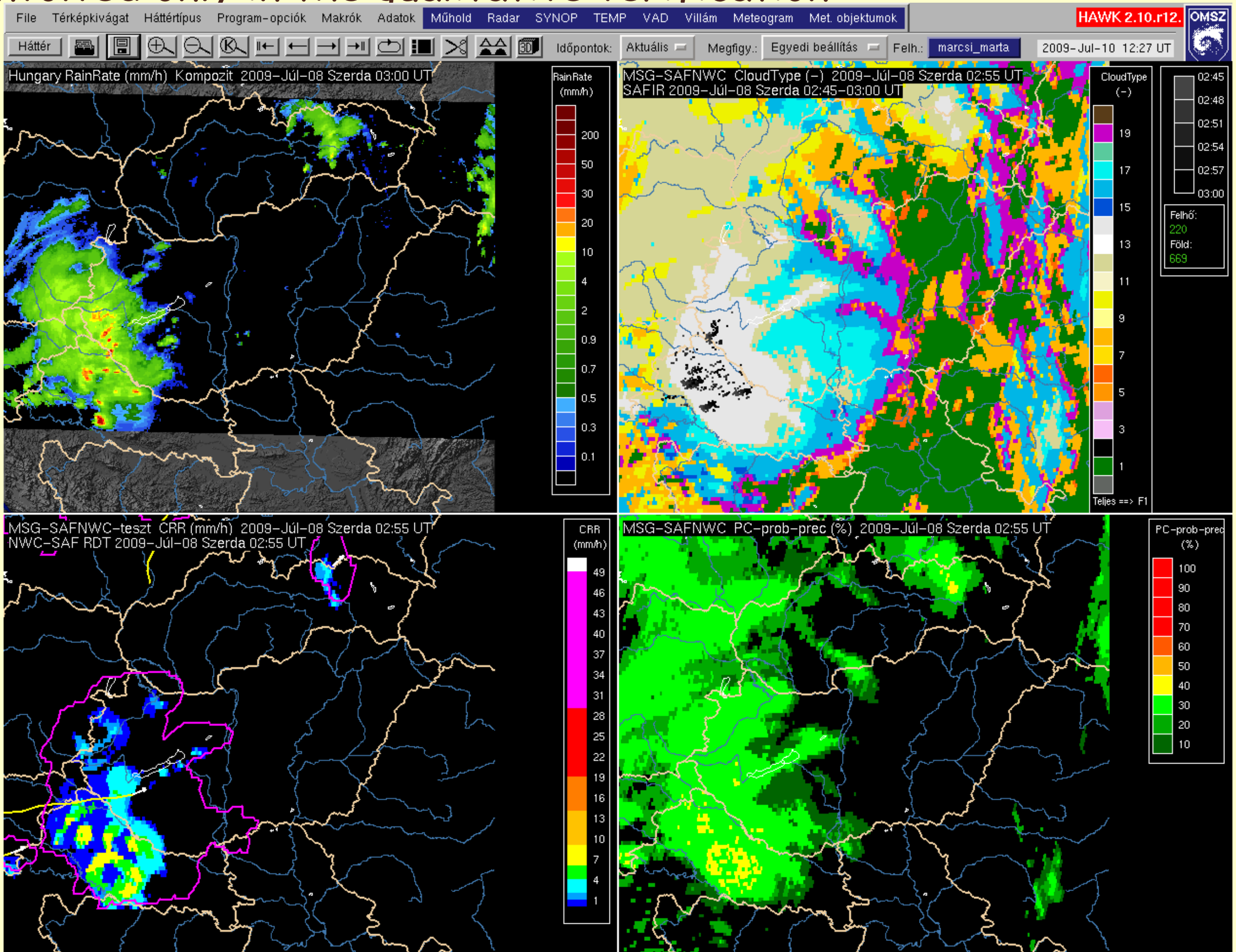
CRR best value, CRR average –
TB compared with (more) CRR value(s) in the 5x5 pixel box

Qualitative validation, case studies

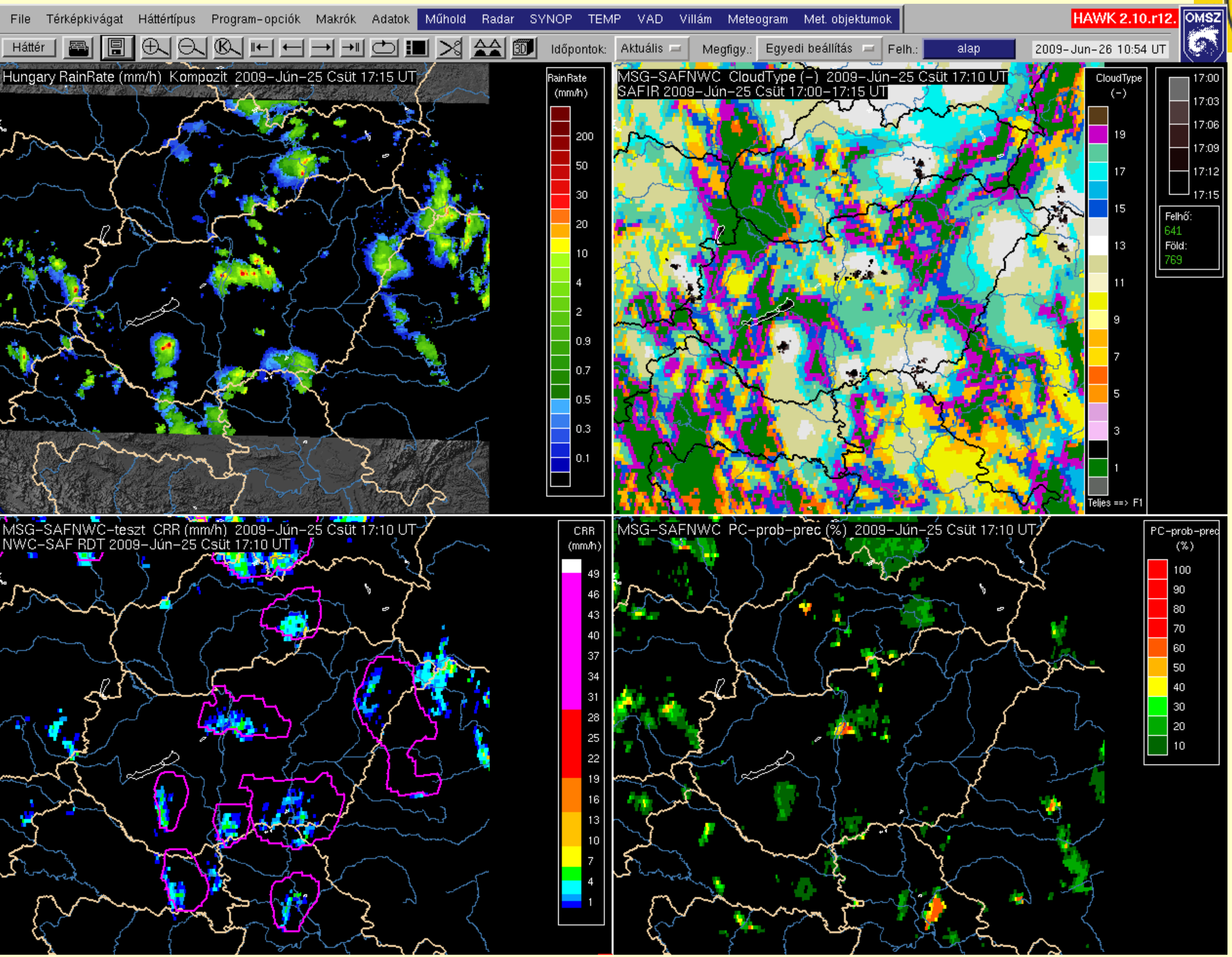
Parallel visualization of
CRR, RDT, PC, RGBs, IR10.8, radar, lightning,
+ satrep analysis, surface charts (+ help of a forecaster)

A **poster** is presented during the workshop about the case studies

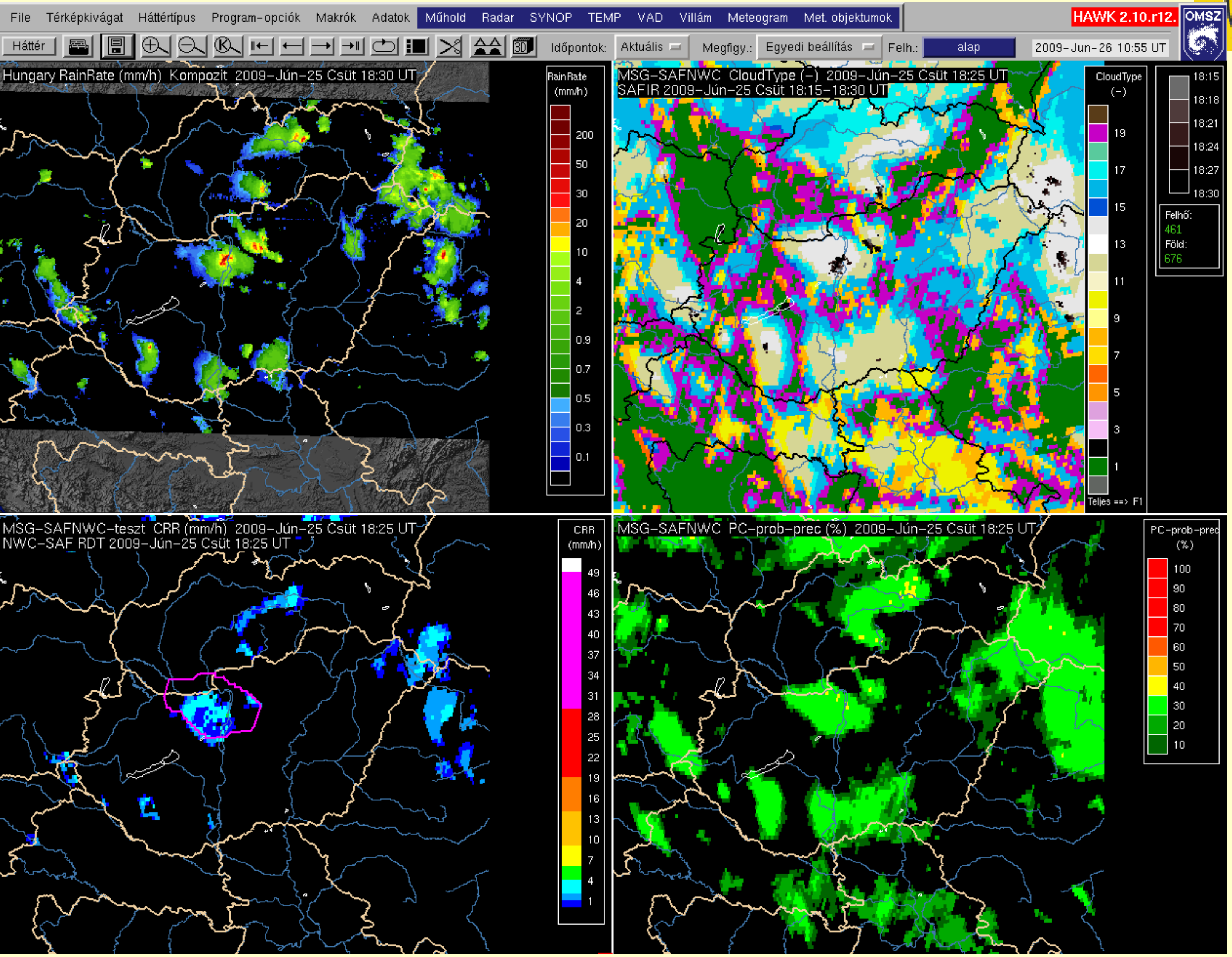
RDT is involved only in the qualitative verification



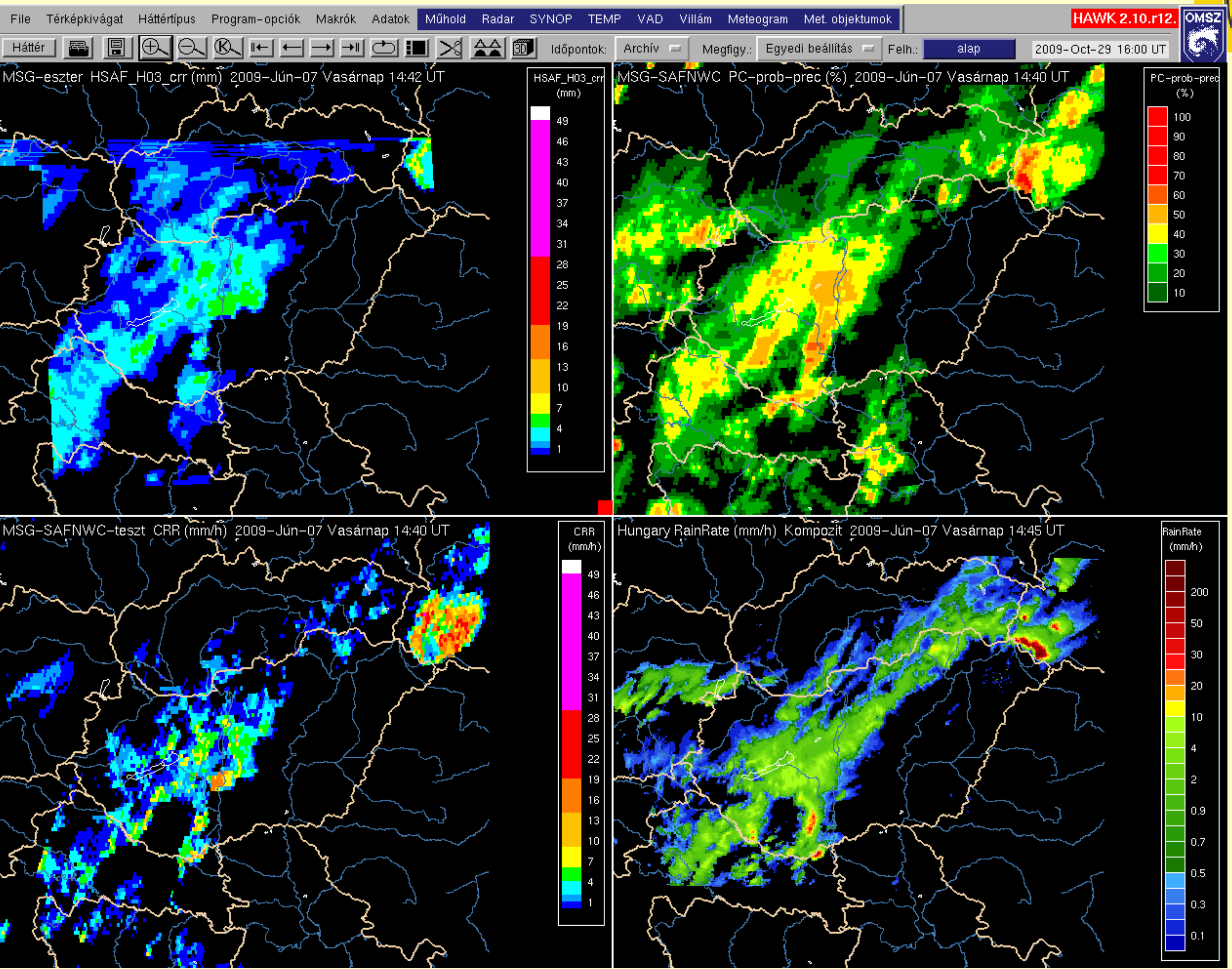
Case study: 25 June 2009



Case study: 25 June 2009



Cross-validation with HSAF



Conclusions from subjective validation

- **RDT without lightning input**:
- the RDT product is **much more reliable** now. It detects the **majority of the mature phase convective clouds**.
- the **time stability improved**.
- It detects **mainly mature phase** convective clouds, developing convective cells are more often missed. Decaying phase convective clouds are not detected in this version.
- The **small and/or warm cells are often missed**.
- **Better** performance in **'pure' convective situation** (Cbs, MCSs and no front), than in frontal situation. Sometimes a huge part of a **front** is detected as convective.
- in some cases the **contour is too 'loose'**, This happens more often at the beginning of the detection. Later the algorithm finds better the edge of the cloud/tower.
- The trajectory is not smooth
- some **high level Lee clouds detected** by RDT as convective. However their time stability was low.

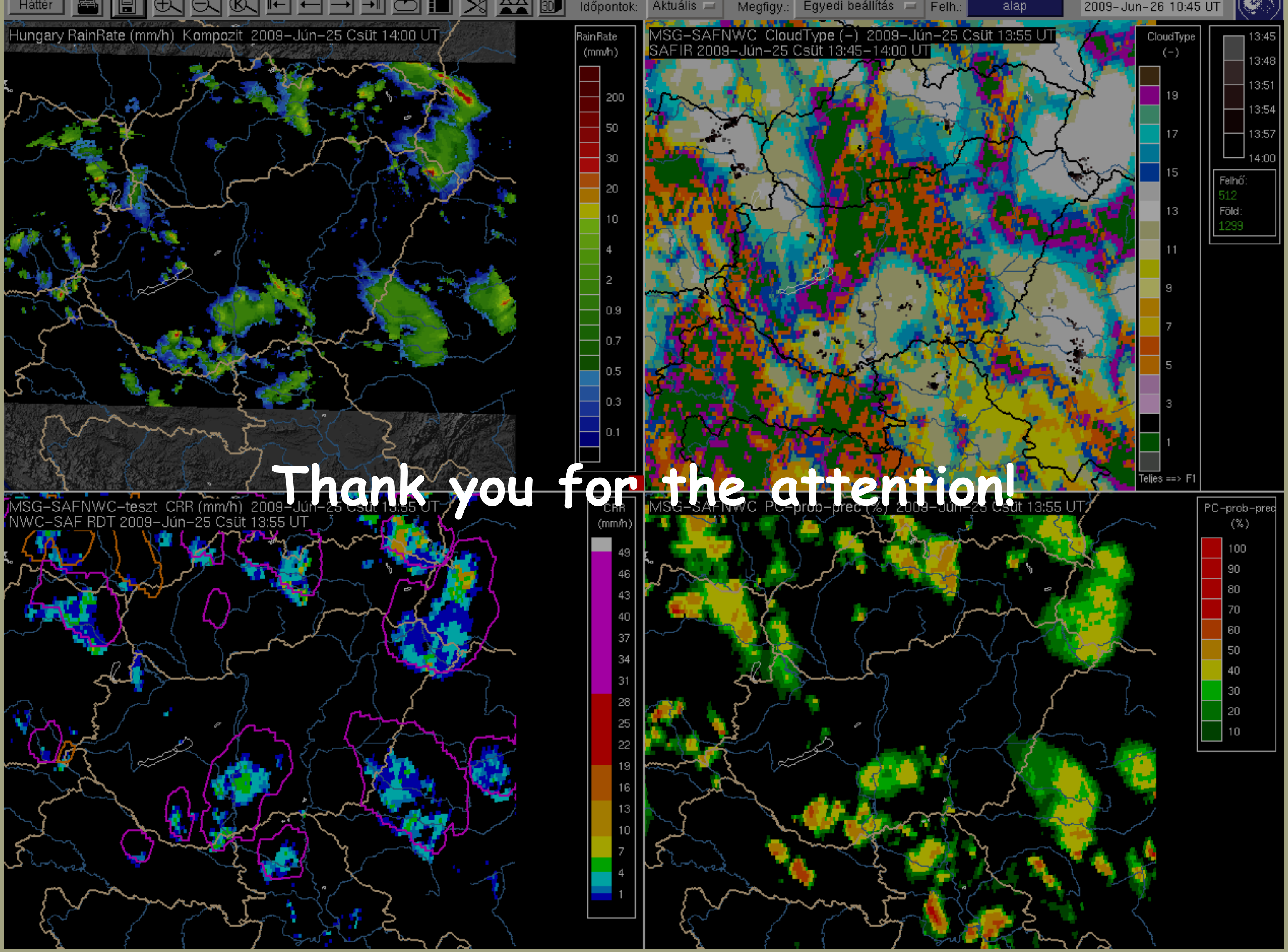
Conclusions from case studies

CRR and PC provide **useful information on precipitation in lack of radar data**. no microwave information, only cloud top parameters. They are usually more similar to satellite than to radar image.

CRR is useful in areas/seasons where the convection is typical. We recommend using it first of all in **pure convective situations.** Sometimes problems with separation of convective from non-convective situation/clouds/precipitation (Problem for automatic applications) Fronts with cold tops – can have CRR values
CRR **often misses precipitating cells** if they are relatively **warm/small.** The CRR performance is better for big, intense convection. We recommend **overlaying lightning on CRR image**. So one could have an impression about the missing small warm objects/rain.
CRR usually **overestimates the area** of the precipitation, unless it is relatively warm/small cell
CRR underestimates the radar maxima
we can **often** see the **cold ring shape** in the CRR image

PC **often reflects well the overall pattern of the radar image**, mainly the daytime PC at high or medium sun elevation and in case of isolated Cbs, Cb clusters.
PC misses less small/warm cells than CRR.
PC is quite good for **weak frontal precipitation**. It is good at detecting the precipitation falling from mid-level clouds.
PC seems to **depend on the solar elevation**. At **low solar elevation** the daytime PC patches become smaller. Sometimes they can almost vanish
The **nighttime PC algorithm is less informative**. There is a strong **discontinuity** between the day- and nighttime PCs. The discontinuity for PC is stronger than for CRR.

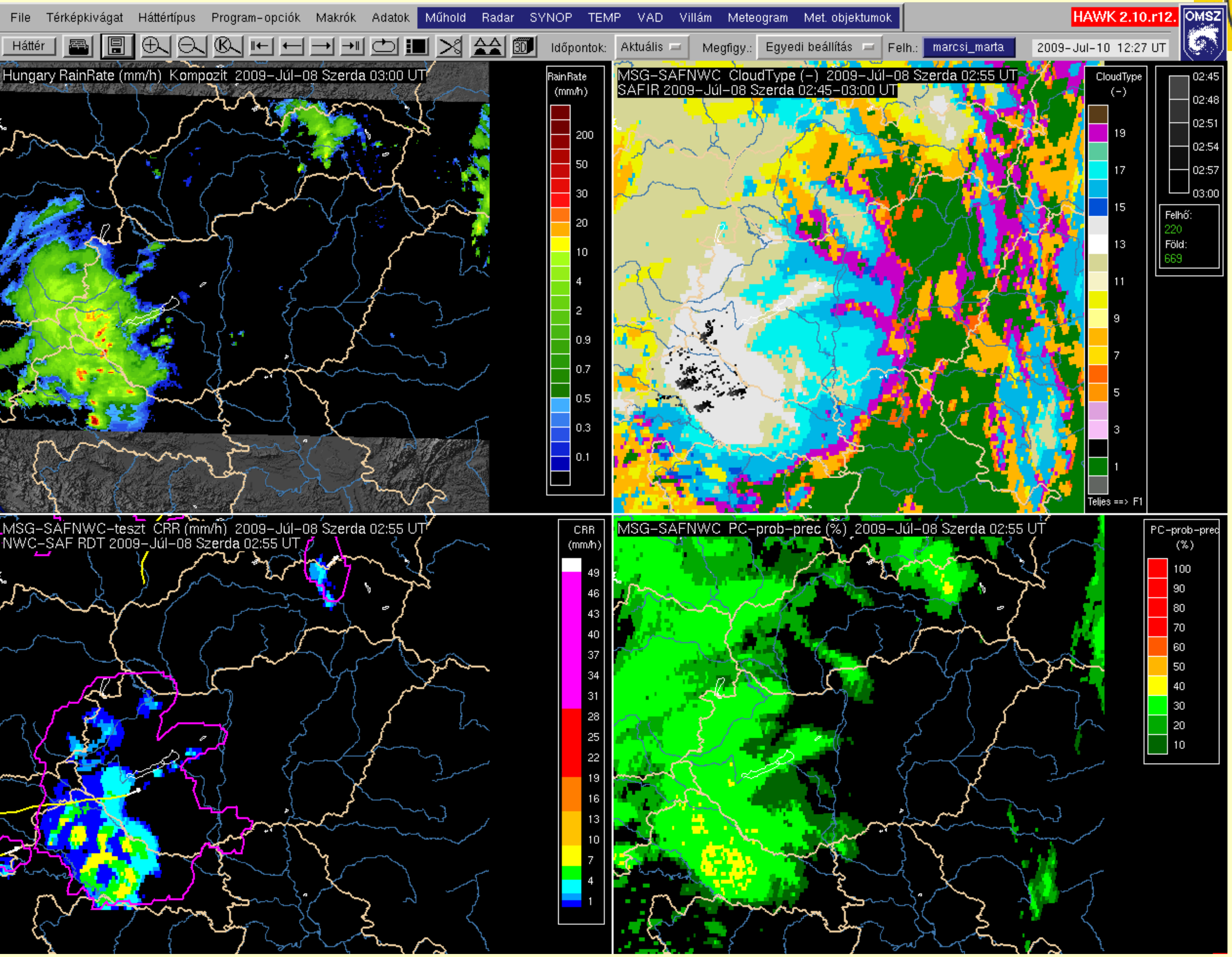
Neither PC nor CRR **can reflect the inner precipitation distribution** of a severe MCS, e.g. can not see the location of a squall line.



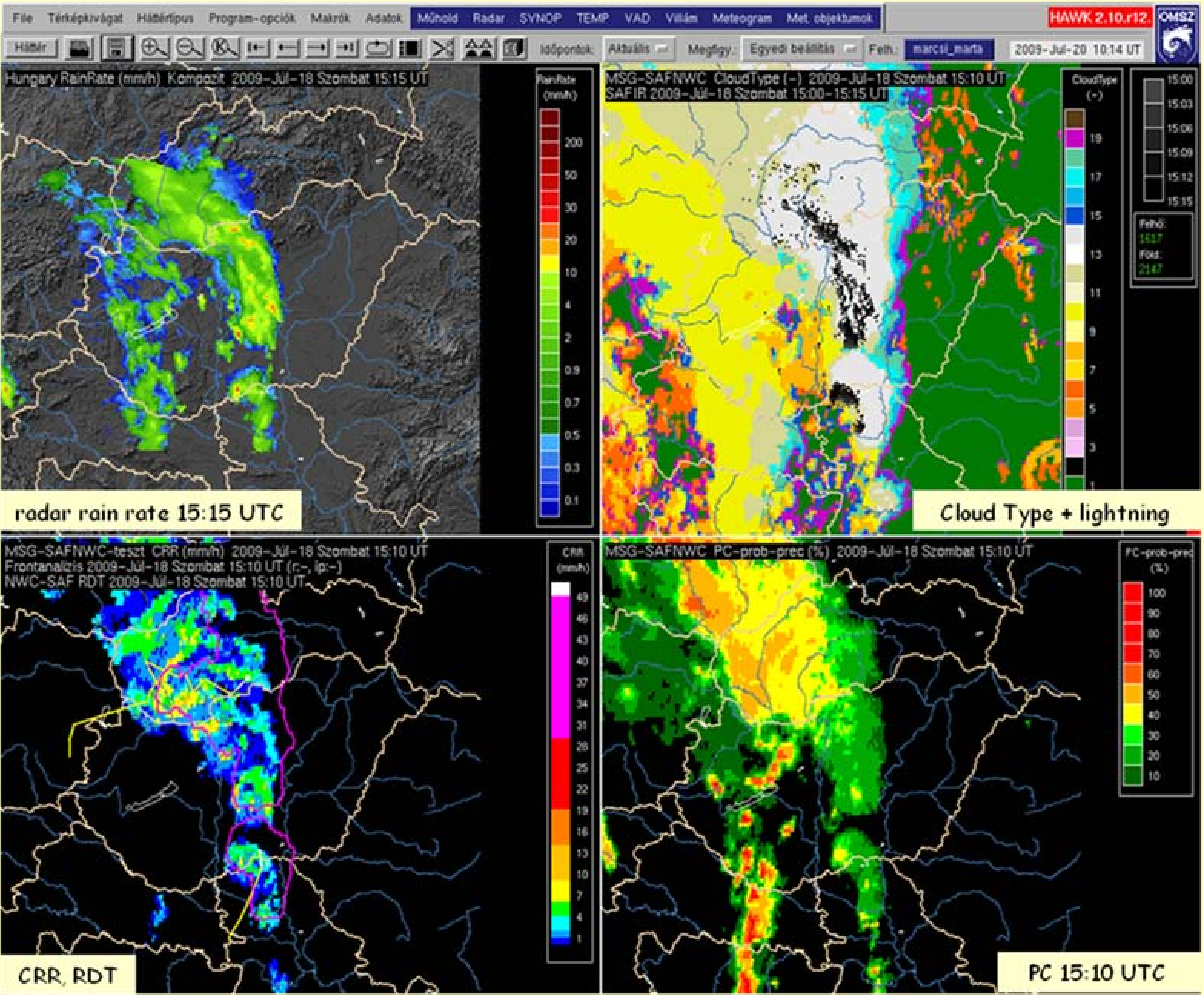
VSA report on the PC CRR RDT cross-verification is available at
http://nwcsaf.inm.es/VSA/report_cross_verif_2009.pdf

A poster was presented about the case studies on the EUMETSAT conference in Bath, conference paper is available at EUMETSAT homepage
http://www.eumetsat.int/idcplg?IdcService=GET_FILE&dDocName=PDF_CONF_P55_S2_12_PUTSAY_P&RevisionSelectionMethod=LatestReleased

Prefrontal activity



Prefrontal activity



Prefrontal activity