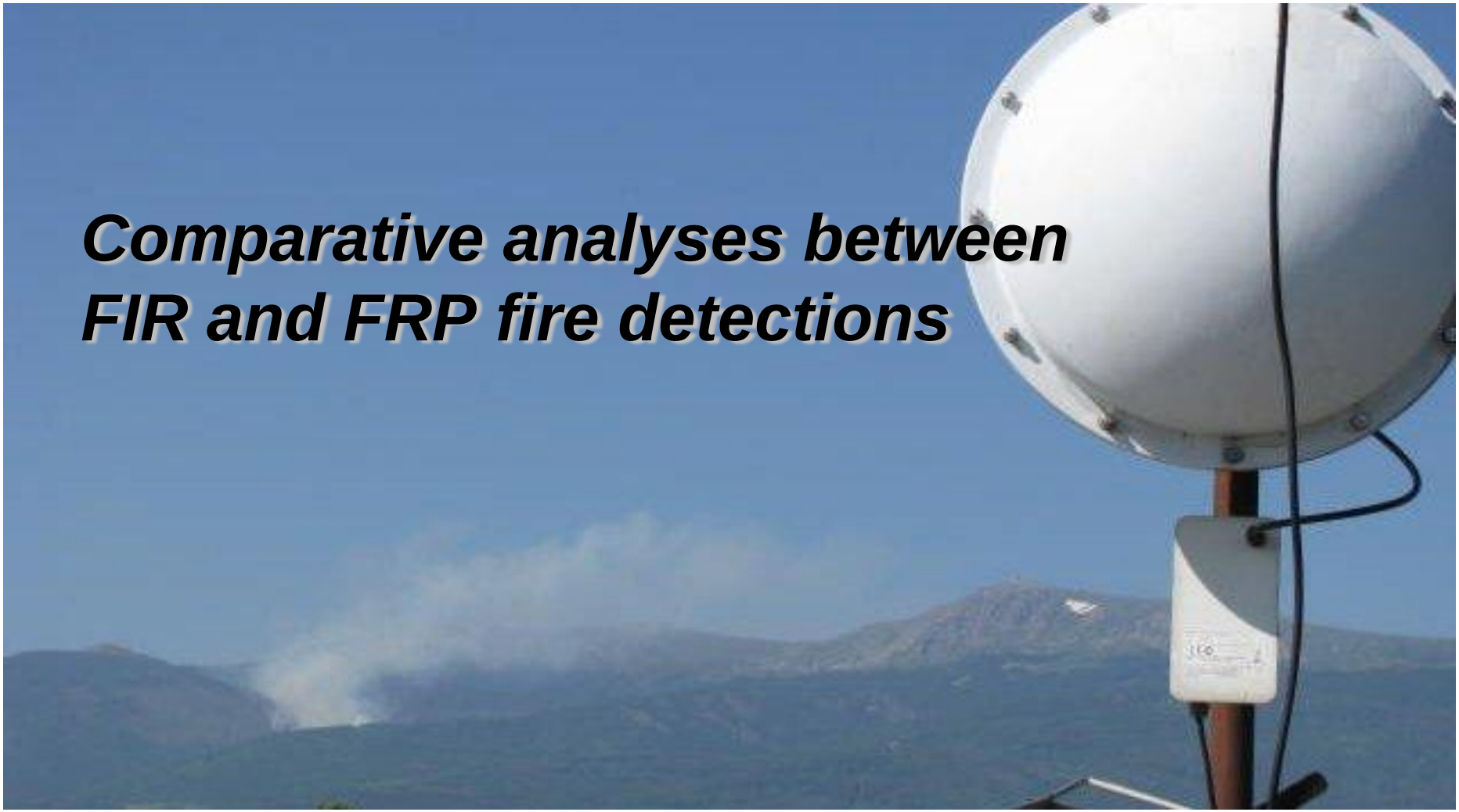

Comparative analyses between FIR and FRP fire detections

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20-21 March 2013, Lisabon/Ericeira, Portugal

Introduction

The aim of this study is to compare the efficiency of the fire detection algorithms based on data from Meteosat Second Generation (MSG) satellites:

- FIR product of Meteosat products Extraction Facilities (MPEF) of EUMETSAT.

  and

- FRP product of Land Surface Analysis (LSA) Satellite Application Facilities (SAF) Programme of EUMETSAT.

Special attention is given to specific synoptic situations, which are favourable for development of both fires and cloudiness aiming to avoid misunderstanding when assessing the performance of fire detection algorithms in such cases as well as to explain some differences/mismatches between the fire products.

MSG Missions and MPEF Fire Products

✓ Two **Active Fire Monitoring (FIR)** products (EUM, 2007) are operationally generated at Meteosat Products Extraction Facilities (MPEF) of EUMETSAT that are derived by using data from the two MSG missions .

The current MSG missions include:

✓**MSG Full Earth** disc scanning generated data every 15 min, image rectification to subsatellite point location 0.0° longitude.

✓ **MSG Rapid Scan,** generates data at 5-minute intervals, scan region from approximately 15° to 70° latitude, subsatellite point location longitude 9.5°E.

LSA SAF FRP Product from SEVIRI Data

The Fire Radiative Power Product (FRP, in MWatts) provides information on the measured radiant heat output of detected fires.

The FRP Product is operationally derived at LSA SAF from satellite observations of SEVIRI data from MSG2 Full Earth disc scanning generated every 15 min and disseminated via EUMETCast.

Fire Detection from SEVIRI Data

The MPEF FIR and LSA SAF FRP products are operational tools for detection of thermal anomalies and vegetation fires, which produce a problem for Southern parts of Europe.

- As all remote sensing methods used for monitoring fires have limitations that tend to cause important biases in the final product.
- For the purpose of near real-time fire risk assessment and fire monitoring, an integration of the existing fire products based on MSG SEVIRI and MODIS satellite systems into a coherent framework is essential.
  - Thermal Anomalies Product (TAP) from MODIS
  - LSA SAF FRP from SEVIRI
  - MPEF FIR from SEVIRI

Fire Products Algorithms

TAP MODIS:

Resolution ~ 1 km at the subsatellite point ~ 1 km
Repeat cycle: 4 overpasses daily

LSA SAF FRP SEVIRI

Resolution ~ 3 km at the subsatellite point (~ 5 km over SEE)
MSG2 Full scanning: every 15 min, subsatellite point at 0.0 longitude
“Contextual" tests are applied whose thresholds are adjusted based on statistics derived from the immediately neighbouring non-fire "background" pixels.

MPEF FIR SEVIRI

Resolution ~ 3 km at the subsatellite point (~ 5 km over SEE)
MSG2 Full scanning: every 15 min, subsatellite point at 0.0 longitude
MSG1 Rapid Scan, at 5-minute intervals, subsatellite point location at 9.5°E.
FIR algorithm does not perform **"contextual" tests**

DATA SET

This study is performed on the base of 31 forest fires in the summer of 2012 reported in the National Data Base, which is maintained by the State Forest Agency of Bulgaria.

Detections by MODIS TAP product are used as a reference for assessing the efficiency of the two SEVIRI algorithms.
The performance of the MPEF FIR and LSA SAF FRP products is studied for these 31 fires regarding the products' capabilities.

- First detection by a product, including early warnings (before fire detection by ground observations as reported in the National Fire Data Base.
- Which of the two SEVIRI algorithms was able to better detect the signals from the fires during the whole duration of the event (as reported in the National Fire Data Base).
- Cases of small fires not detected by one of the SEVIRI algorithms and detected by the other one.

Differences/mismatches between MPEF FIR and LSA SAF FRP

Product/Instrument	Detection Firstly by this product		Better monitoring fire evolution by this product	Number of nights with detections of the fire with this product	Miss to detect by this product	
	Total number of fires detected	Early Warning, before being found out by ground observations			Total number of fires failed to detect	Partially cloudy cases of fires failed to detect
Total number of cases	**31**	**31**	**31**	**31**	**31**	
LSA SAF **FRP/SEVIRI**	**16**	**6**	**9**	**3**	**9**	**2 (of 9)**
MPEF **FIR/SEVIRI**	**10**	**2**	**9**	**3**	**16**	**5 (of 16)**

- FRP is more efficient than FIR in detection of small fires as well as more efficient in providing early warnings including
  - Earlier detection.
  - Detection fires, which are not detected by the other SEVIRI algorithm.
- FRP or FIR can be equally efficient than the other product in detecting signals from some of the fires during the whole duration of the event.

Performance of MODIS TAP algorithm regarding detection by SEVIRI FRP and FIR

Performance of MODIS TAP	Number	Total number of cases
Fires failed to detect by MODIS TAP algorithm	**12**	**31** (all studied)
MODIS failed detections of fires detected by FRP and/or FIR	**10**	
MODIS TAP detections when FRP and FIR failed to detect fire	**4**	**6** (no detected by both FPR and FIR)
MODIS TAP detections prior to FRP and/or FIR fire detection	**2**	**15** (detected by both FPR and FIR)

- Using the same algorithm FRP detected more efficiently small fires than MODIS because its much more frequent observations.
- MODIS managed to detect 2 fires (13 %) earlier than both SEVIRI products when the fire ignition time is very close to an Aqua/Terra overpass. The fire detection products based on MSG (especially the Rapid Scan service) are more efficient than MODIS on Aqua/Terra satellites.

Large Fires

Case study:
Differences and mismatches between the LSA SAF FRP and MPEF FIR

Fire Detection and Monitoring fire development

Large Fire

National Fire Data Base: Fire registration 2012/08/26 11:00Z Valchanovo, 42.267 N 27.067 E				
Burned Area Characteristics (ha)				
Total	Forest	Under canopy	At canopy	Grass, Herbs
8000.0	**954.7**	**844.7**	**110.0**	**85.6**

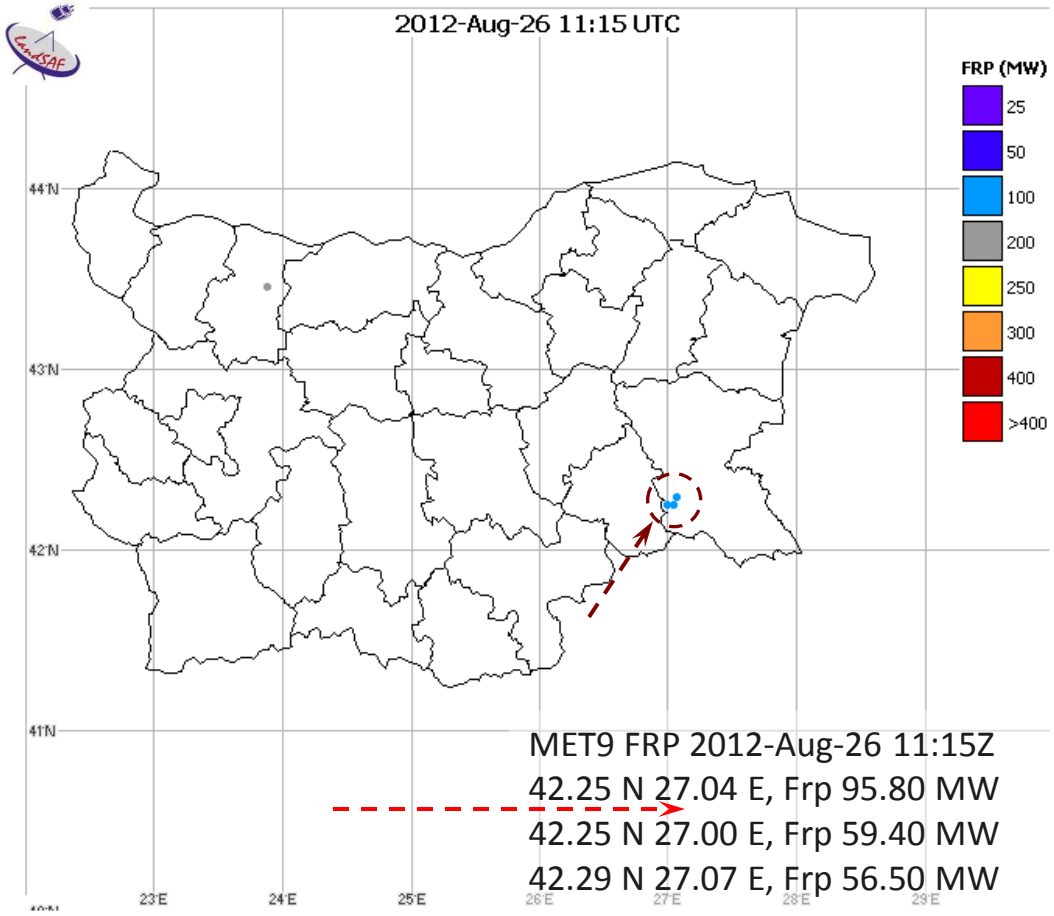
Detected 1st by FRP at 11:15Z and then by FIR and MODIS at 11:45Z

MSG detection: **FRP MET9 2012-Aug-26 11:15Z 42.25 N 27.04 E, Frp 95.80 MW**
FIR 1st MET8 2012-Aug-26 11:45Z 42.27 N 27.04 E

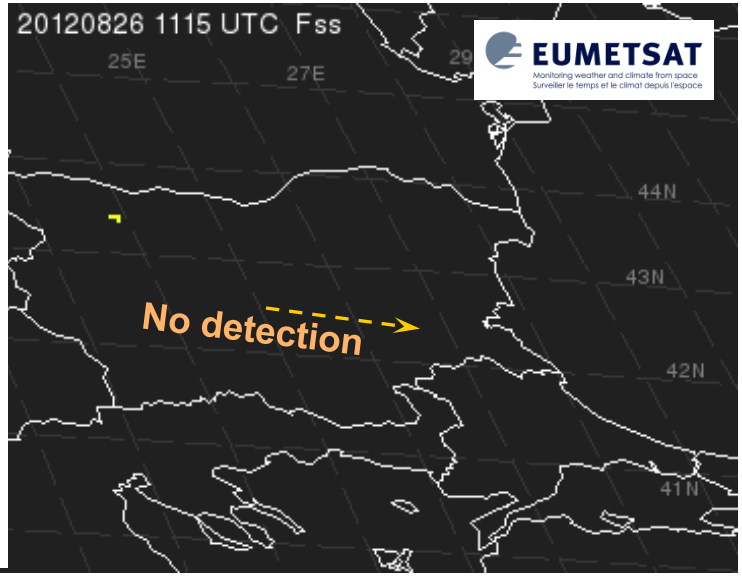
MODIS 1st detection: **Aqua 2012-Aug-26 11:45Z 42.24 N 27.04E, 89 %**
Aqua 2012-Aug-26 11:45Z 42.24 N 27.06 E, 100 %

Fire Detection

26 Aug 2012: **First detection (among the three algorithms) by LSA SAF FRP** at 1115 UTC, while the first signal from the ground observations of State Forest Agency (SFA) is recorded at 1100 UTC (*that is in the same time slot*).

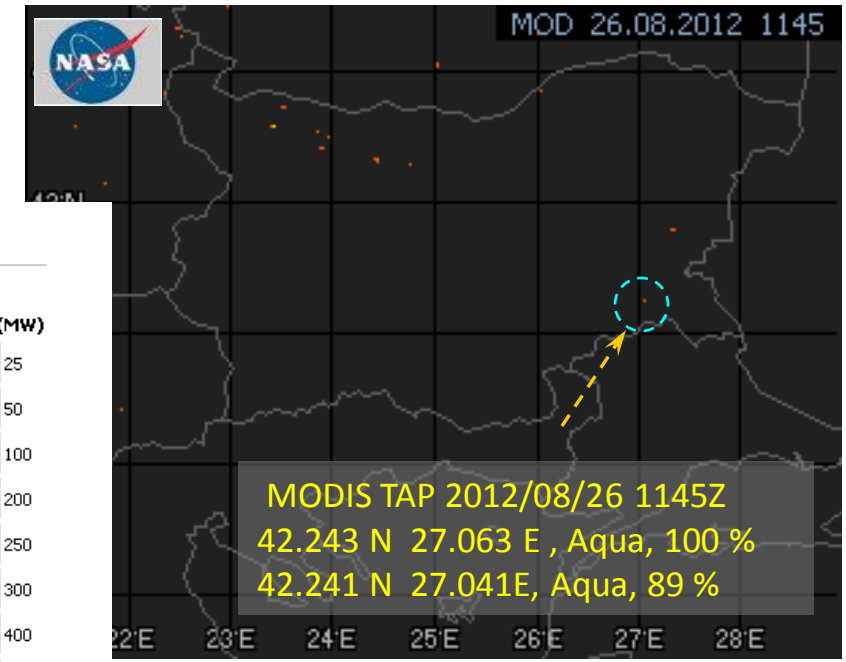


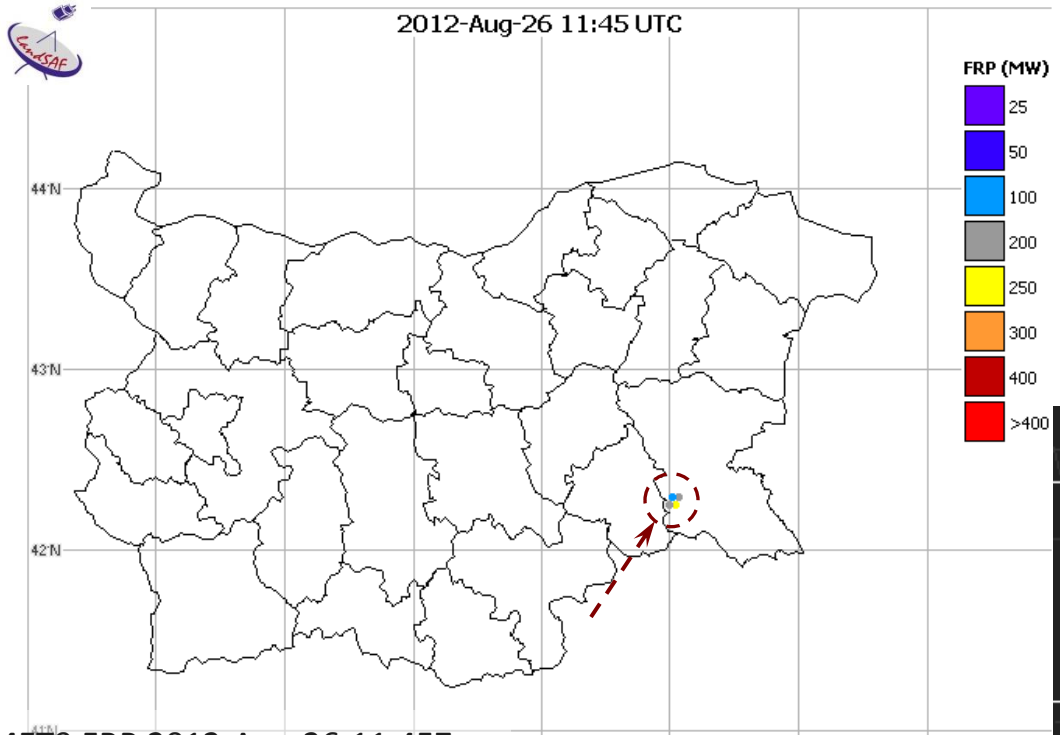
At 1115 UTCMPEF FIR Full Scan did not detect the fire of pixels emitted FRP < 100 MW as derived by LSA SAF FRP product.

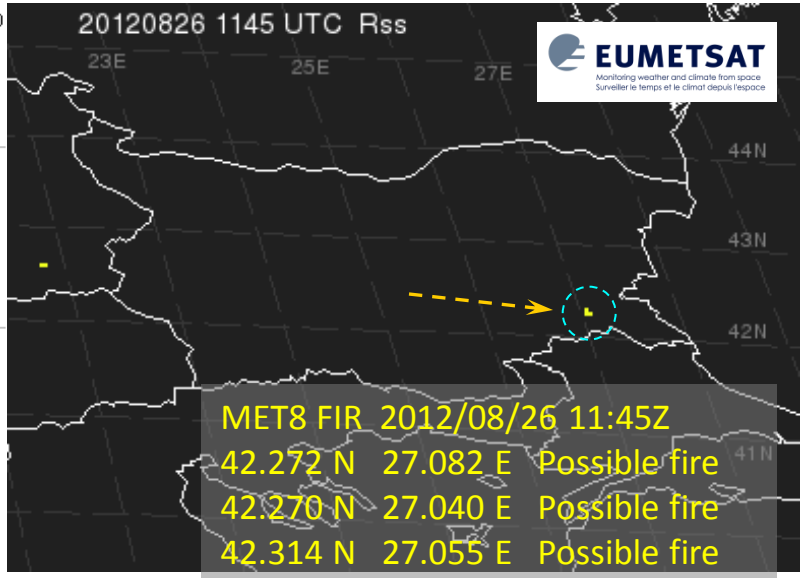


Detection of a Large Fire

Detected by the three algorithms at
26 Aug 2012 1145 UTC





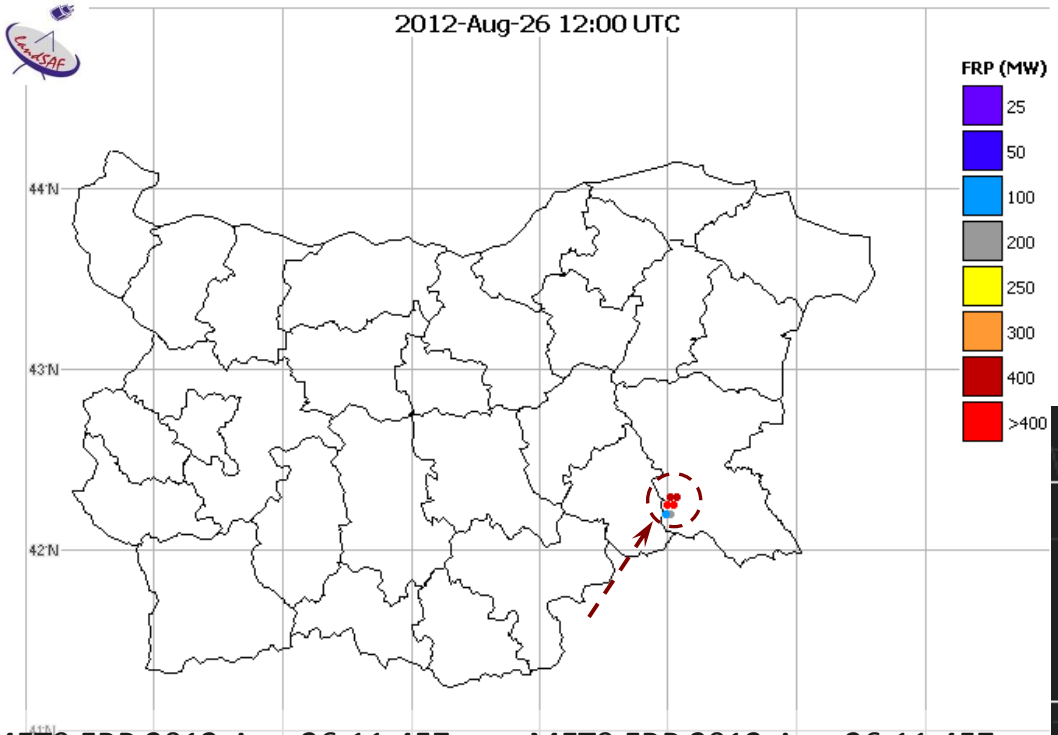


MET9 FRP 2012-Aug-26 11:45Z
42.25 N 27.04 E, Frp 209.00 MW
42.25 N 27.00 E, Frp 156.70 MW
42.29 N 27.07 E, Frp 125.10 MW
42.29 N 27.02 E, Frp 83.70 MW

Fire detection by MPEF FIR only at FRP > 100 MW

Detection of a Large Fire

Detected by the three algorithms at
26 Aug 2012 1145 UTC

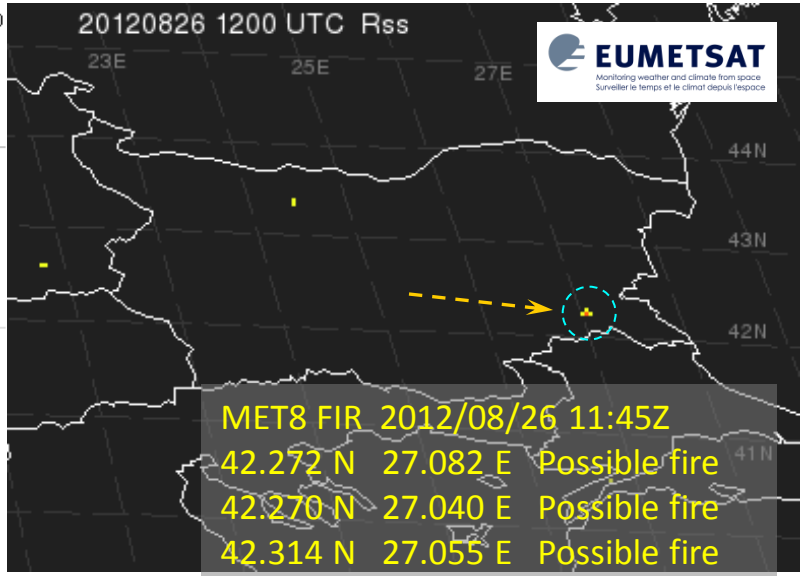


MET9 FRP 2012-Aug-26 11:45Z
42.25 N 27.04 E, Frp 209.00 MW
42.25 N 27.00 E, Frp 156.70 MW
42.29 N 27.07 E, Frp 125.10 MW
42.29 N 27.02 E, Frp 83.70 MW

MET9 FRP 2012-Aug-26 11:45Z
42.25 N 27.04 E, Frp 548.30 MW
42.25 N 27.00 E, Frp 579.40 MW
42.29 N 27.07 E, Frp 325.20 MW
42.29 N 27.02 E, Frp 359.40 MW

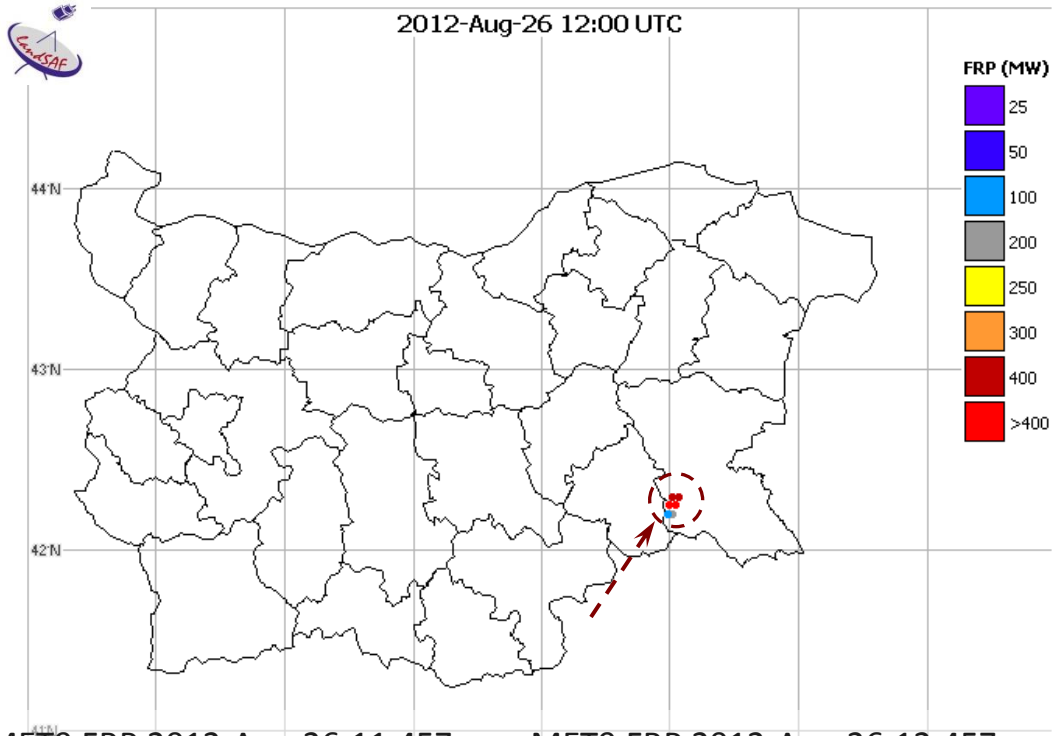
The measured radiant heat output of the detected fires have **increased in a pixel up to FRP > 500 MW .**

At this stage SEVIRI detects the fire only via FIR product from the RSS service of MSG 1 (from sub satellite point of 9.5° N).



Detection of a Large Fire

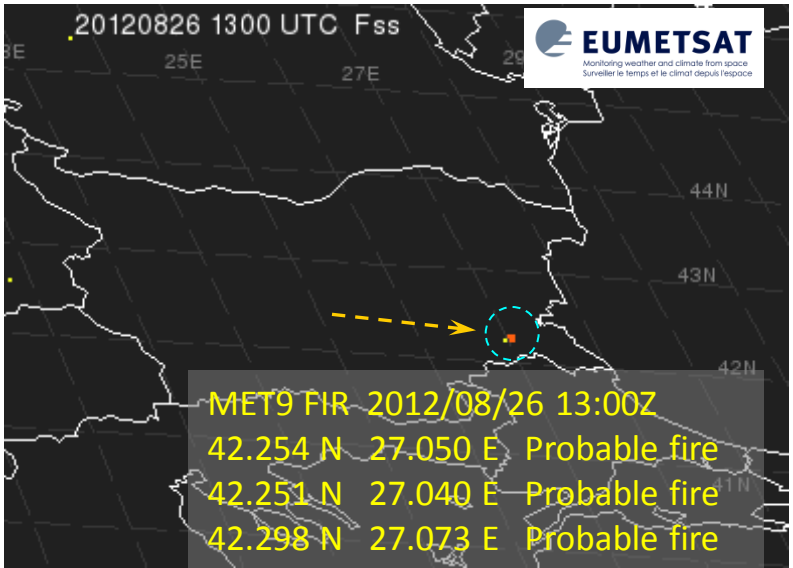
Detected by the three algorithms at
26 Aug 2012 1145 UTC



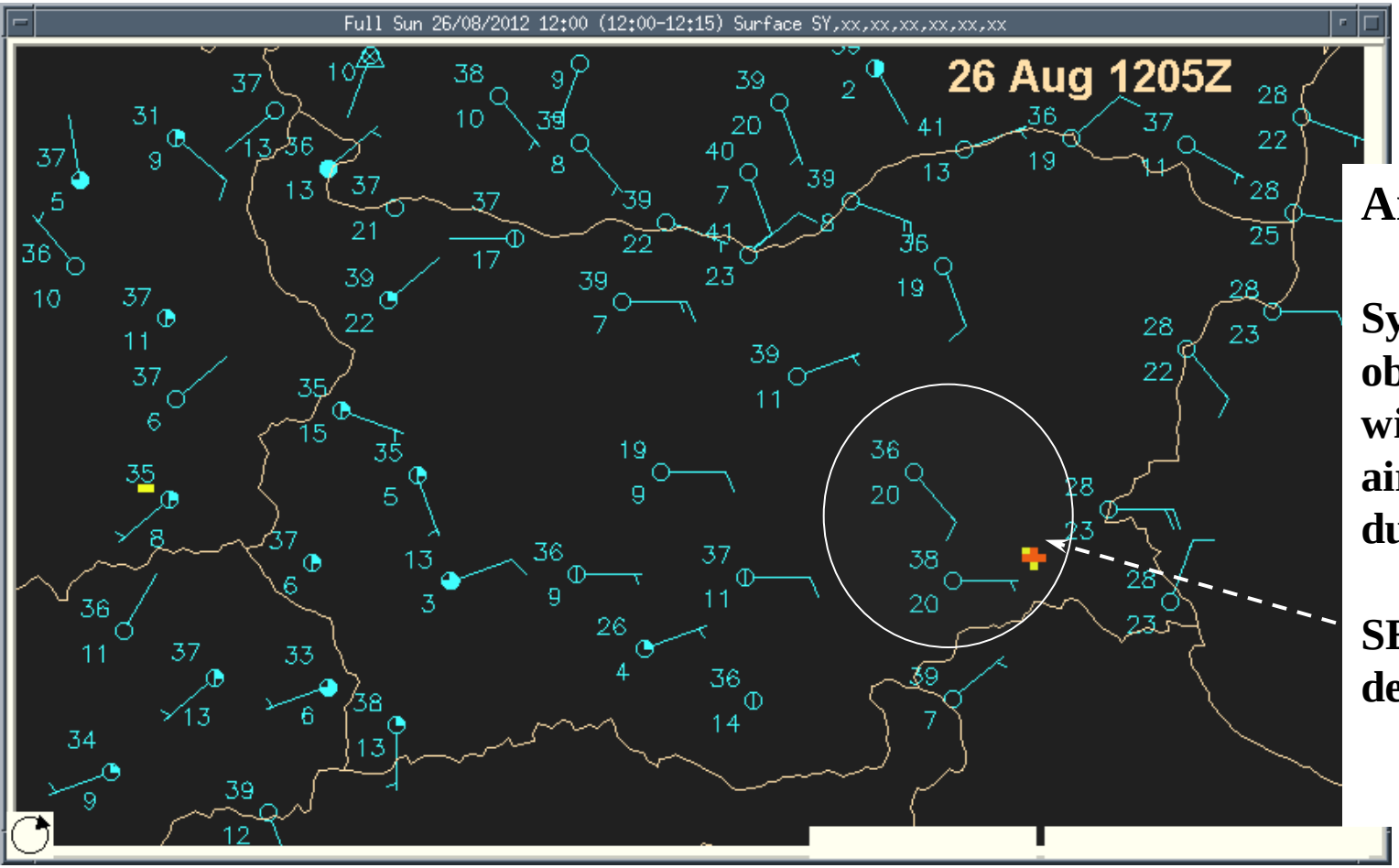
MET9 FRP 2012-Aug-26 11:45Z
42.25 N 27.04 E, Frp 548.30 MW
42.25 N 27.00 E, Frp 579.40 MW
42.29 N 27.07 E, Frp 325.20 MW
42.29 N 27.02 E, Frp 359.40 MW

MET9 FRP 2012-Aug-26 12:45Z
42.25 N 27.04 E, Frp 446.30 MW
42.25 N 27.00 E, Frp 915.10 MW
42.29 N 27.07 E, Frp 357.40 MW
42.29 N 27.02 E, Frp 456.20 MW

After the measured radiant heat output of the detected fire has **increased in a pixel up to FRP > 900 MW .**
Only at this stage SEVIRI FIR product detects the fire also from data of the Full Scan service of MSG 2 (from sub satellite point of 0°) that provide a lower resolution than the RSS FIR.



Synoptic evolution and Monitoring fire development



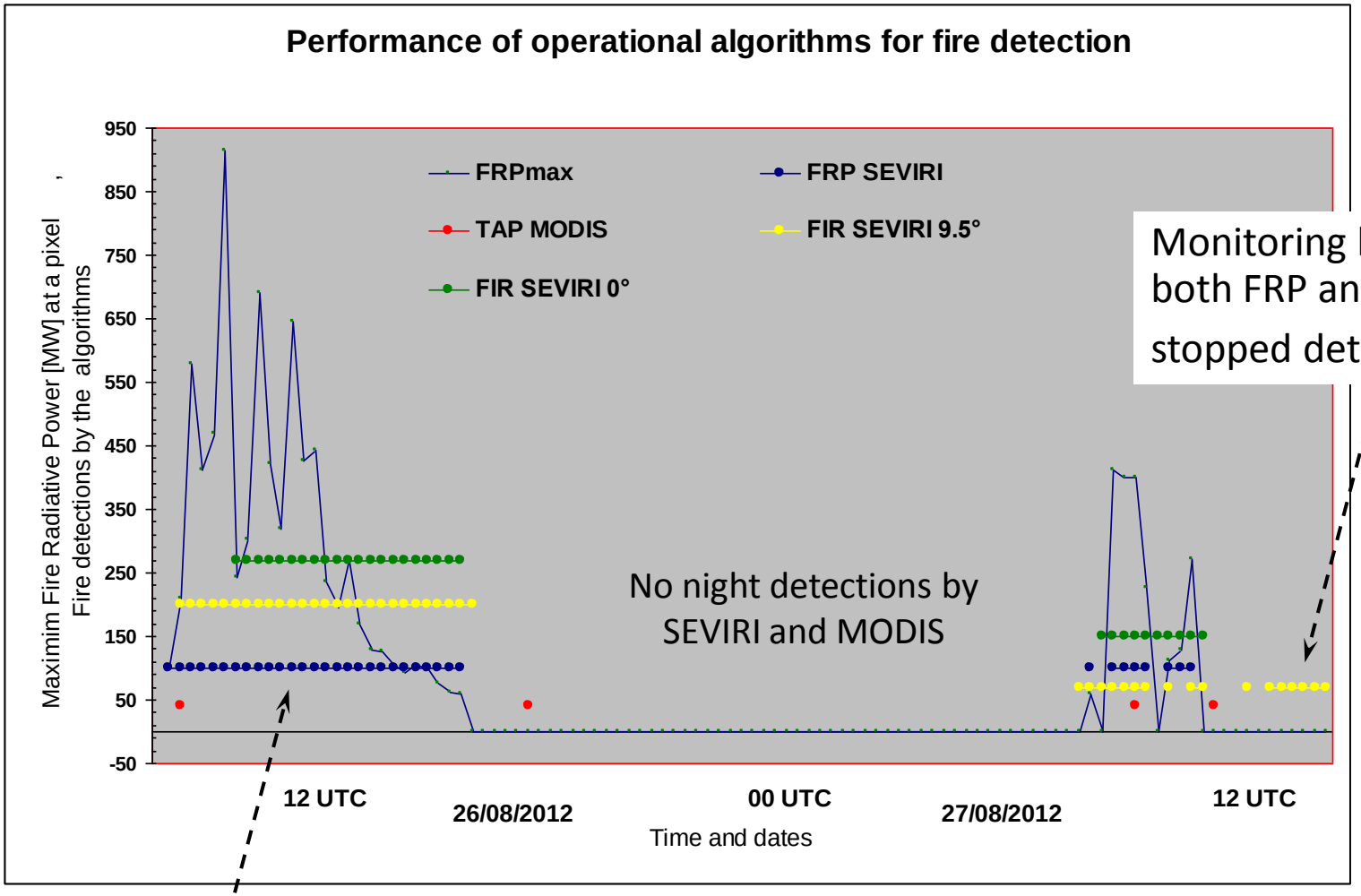
Animation:

Synoptic observations:
wind
air temperature
due point

SEVIRI MPEF FIR detections

- **Decreasing fire activity at night due to decreasing air humidity: dew point depression (from 15-18 °C to 0-5 °C) and no wind.** **No detections by SEVIRI and MODIS.**
- **On 27 Aug the cyclonic field at the surface leading to increase of wind and change direction that reinforce the fire development.**

Monitoring fire development



Monitoring by FIR RSS after both FRP and FIR Full Scan stopped detection.

Fire detection by all products at the beginning of fire development and high Fire Radiative Energie (up to 900 MW) as measured by FRP product.

For South Eastern Europe, the Rapid Scan FIR product from 9.5° E , because of its higher spatial resolution, may provide more efficient fire monitoring than FRP, which is based on Full Scanning from 0°.

Small Fires

Case study:
Differences and mismatches between the LSA SAF FRP and MPEF FIR

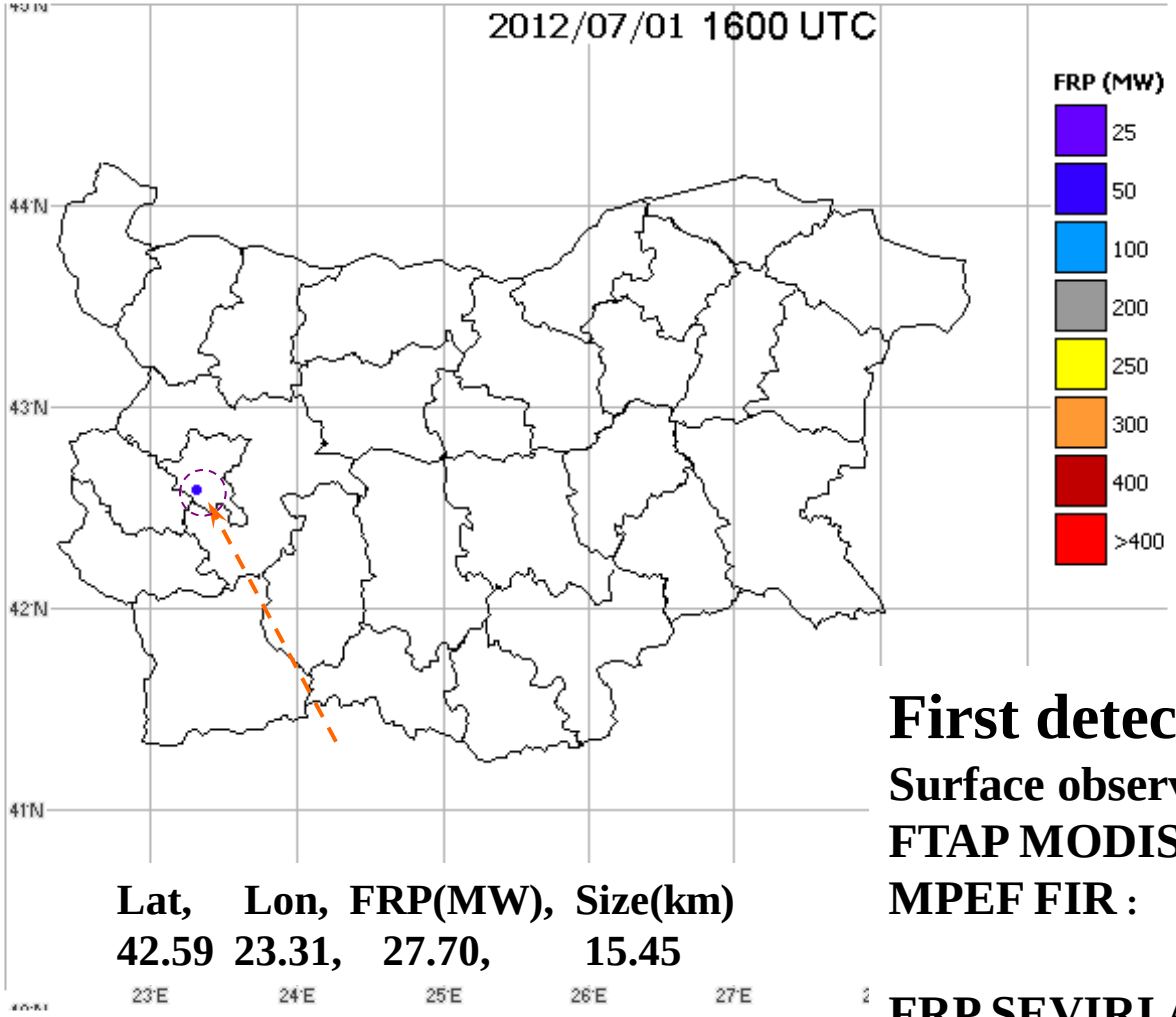
Small fire

A case of a small fire occurred in the centre of an area of a dead-vegetation forest in a nature reserve (under the aegis of UNESCO since 1977) where numerous age-old trees felled by a wind storm in 2001. This fire produced high **combustion rate of the fuel in a wood mass of dead forest and the absence of forest canopy:** 1st July 2012 in Vitosha Mountain, close to the Bulgarian capital Sofia**.**

http://www.vesti.bg/index.phtml?tid=40&oid=4952471

Detection of a Small Fire

Earliest detection by FRP SEVIRI: 1600 UTC



Lat, Lon, FRP(MW), Size(km)
42.59 23.31, 27.70, 15.45

FRP SEVIRI Algorithm detected the fire at radiant heat of 28 MW

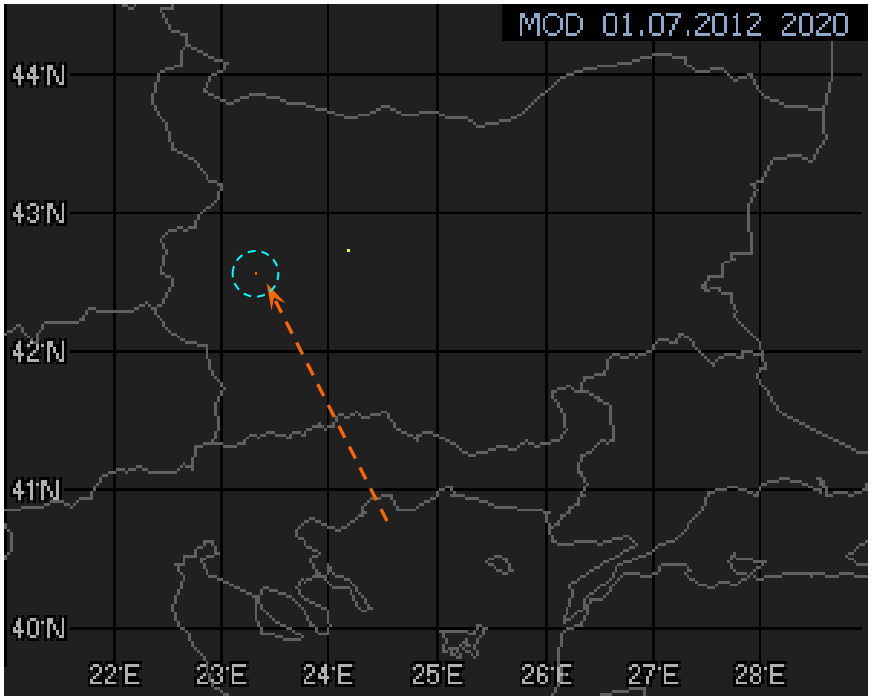
First detection: 1 July

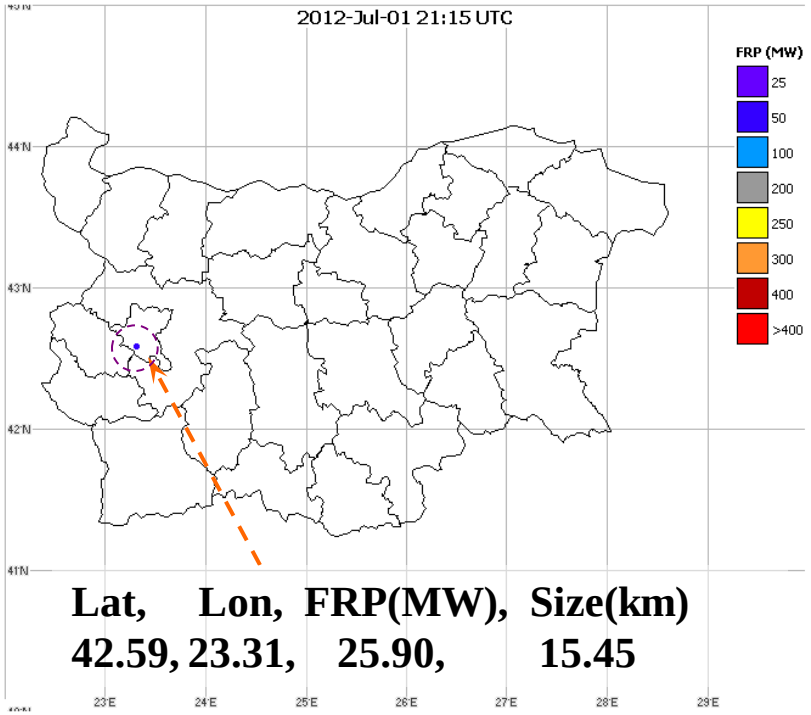
Surface observations: ~ 1100 UTC
FTAP MODIS: 2020 UTC
MPEF FIR : 2225 UTC

FRP SEVIRI Algorithm: 1600 UTC
4 hours and 20 min earlier than MODIS
6 hours and 25 min earlier than MPEF FIR

Detection of a Small Fire

A later detection by MODIS FTAP: 2020 UTC
FRP does not detect the fire from 17 to 21:15 UTC



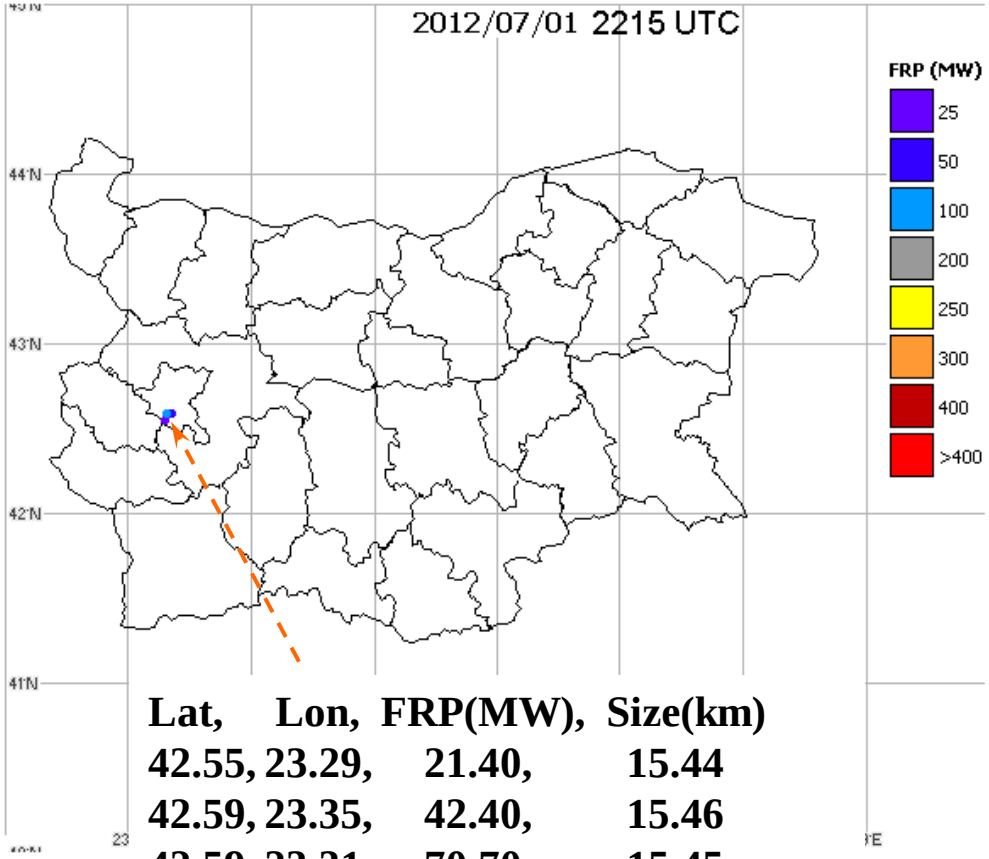


MODIS fire pixels
Lat-,_Lon___-_Date_-_-,UTC,SAT,P%
42.565, 23.326, 01.07.2012,2020,T,66
42.563, 23.314, 01.07.2012,2020,T,100

LSA SAF FRP re-detects the fire at 21:15 UTC **at radiant heat of 26 MW.**

Detection of a Small Fire

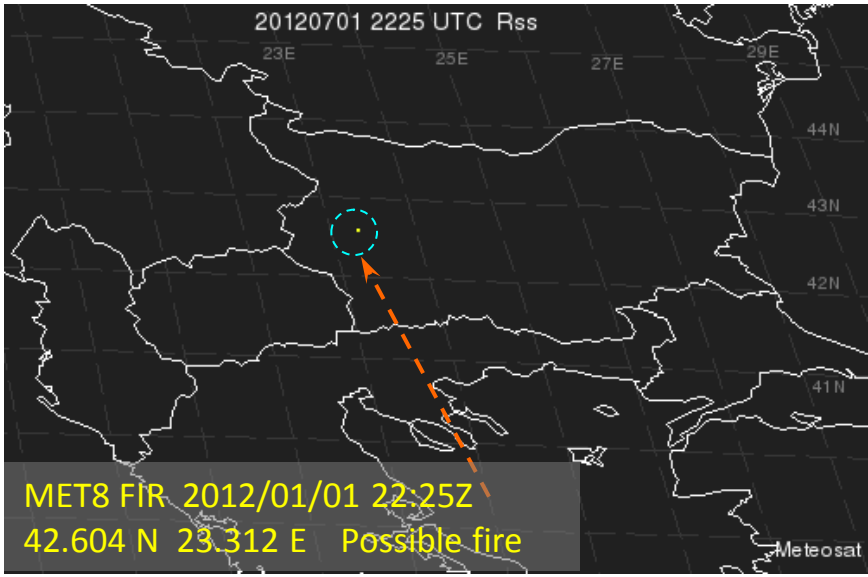
by SEVIRI MPEF FIR



Lat,	Lon,	FRP(MW),	Size(km)
42.55,	23.29,	21.40,	15.44
42.59,	23.35,	42.40,	15.46
42.59,	23.31,	70.70,	15.45

FRP Detection Algorithm detected 3 fire pixels, total intensity fire (134 MW)

EUMETSAT, Satellite: MET8, 2012/07/01 22:25Z
Lat: 42.604 Lon: 23.312 Possible fire



2215 UTC

Total fire radiant heat : 134 MW

This results in the First detection by MPEF FIR at 2225 UTC

Small fires not detected by LSA SAF FRP and detected by MPEF FIR

Date, period Time of finding out at the ground location	Affected area characteristics				MODIS detection Time Location Confidence	**MPEF FIR detection**	
	Total burned (ha)	Forest (ha)	Forest at canopy (ha)	Forest herbs grass (ha)		Rapid Scan MSG-1 9.5°E. number, time/ location	Full Scan MSG-1 0°E.
26/08/2012 1200Z 43.291N, 24.795E	268.8	18.6	13.8	4.8	No detection at: 0810Z, 0950Z, 1030Z	early warning 10:35Z 43.270N, 24.783E	early warning 10:30 Z 43.293, 24.776
17/10/2012 1200Z 43.700N 27.750E	4.7 ha	4.7 ha	0	0	0935Z 43.539, 27.919,76%	early warning 0855Z 43.621N, 27.872E 0935Z 43.533N, 27.882E	0915Z 43.534N, 27.937E

Two small fires detected by both FIR RSS and FIR Full Scan while FRP was not able to detect the fires. These fires are small/medium and have short duration (~ 8h) being detected by the FIR product only at 1/2 slots.

Small fires (< 10 ha total) detected by LSA SAF FRP not detected by MPEF

Date, period Time of finding out at the ground location	Affected area characteristics				MODIS detection Time Location Confidence	**LSA SAF FRP detection**	
	Total burned (ha)	Forest (ha)	Forest at canopy (ha)	Forest herbs grass (ha)		Number of slots with detections, Time and location of maximum FRP	Maximum FRP measured at a pixel
08/07/2012 0855 Z 42.60N, 25.6E	7.9	1.9	0	6.0	No detection	1 slot, early warning 0800 Z, 43.63N, 25.51E	54.8 MW
08/07/2012 1100 Z 41.717N, 23.767E	1.5	1.5	0	0	No detection	4 slots 1130 Z 41.75, 23.70	106.4 MW
22/07/2012 0900 Z 43.283N 26.93E	6.8	6.8	0	6.8	0930 Z 43.296, 26.923, 66%	5 slots, early warn 0515Z 43.29,26.93 0900Z 43.16, 26.99	60.50 MW
06/08/2012 1440 Z 42.367N 25.2E	7.3	7.3	0	0	No detection	2 slots 1515 Z 42.40, 25.22	60.20 MW

For very small fires (FRP < 10 ha total burned area),

- FRP product may more efficiently detect the fire than SEVIRI FIR and MODIS TAP.

Small fires (10 – 50 ha total) detected by LSA SAF FRP not detected by MPEF

Date, period Time of finding out at the ground location	Affected area characteristics				MODIS detection Time Location lat., lon, Confidence	**LSA SAF FRP detection**	
	Total burned (ha)	Forest (ha)	Forest at canopy (ha)	Forest herbs grass (ha)		Number of slots with detections, Time and location of maximum FRP	Maximum FRP measured at a pixel
22/07/2012 1110Z 42.883, 26.45	14.1	0.5			0930 Z 42.629, 26.694, 81%	3 slots Early Warn 0800 Z 42.66, 26.68	69.80 MW
21/08/ 2012 0740 Z 42.65, 22.80	43.8	43.8	10.4	9.2	0945Z 42.658, 22.837, 97%	1 slot 0930Z 42.69; 22.79	62.5 MW

For small fires (FRP < 50 ha total burned area),

- SEVIRI FIR algorithm may fail to detect fires detected by MODIS.
- SEVIRI FRP product may provide more efficient fire detection than FIR.

Small fires (50 – 150 ha total) detected by LSA SAF FRP not detected by MPEF

Date, period Time of finding out at the ground location	Affected area characteristics				MODIS detection Time Location lat., lon, Confidence	**LSA SAF FRP detection**	
	Total burned (ha)	Forest (ha)	Forest at canopy (ha)	Forest herbs grass (ha)		Number of slots with detections, Time and location of maximum FRP	Maximum FRP measured at a pixel
08/07/2012 1210 Z 41.983N, 26.75E	130.8	46.9	73.9	9.9	2050 Z- 41.979, 26.709, 25%	5 slots 1630 Z, 42.01, 26.70	76.50 MW
22/07/2012 1310Z 42.433, 25.65Z	54	3	0.5	0.2	No detection	6 slots 1515Z 42.46, 25.55	105.40MW
23/072012 1435 Z 43.483, 28.333	90	0.5			No detection	7 slots 1600Z 43.56, 28.37	110.70 MW

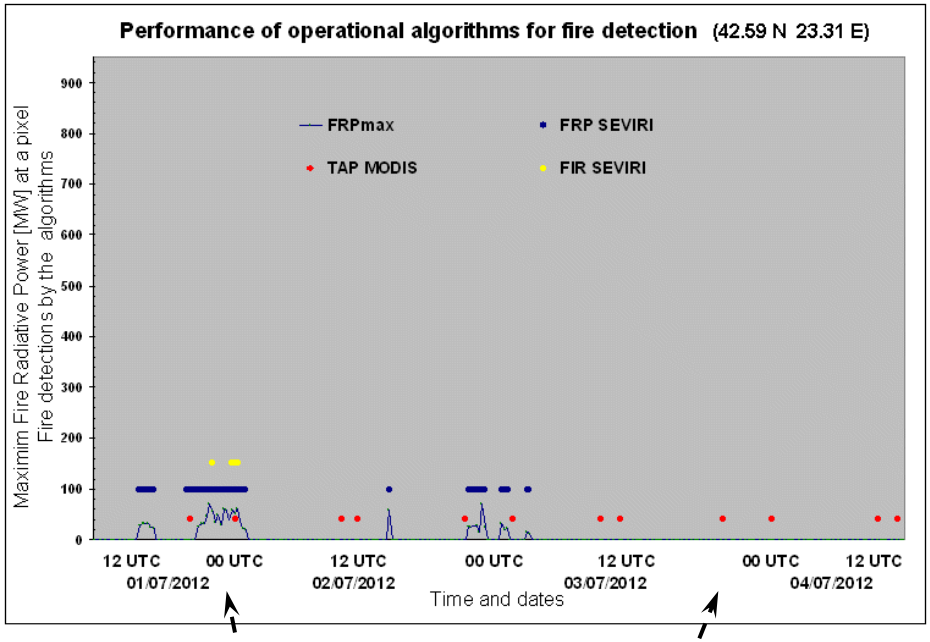
For small fires (FRP < 150 ha total burned area),

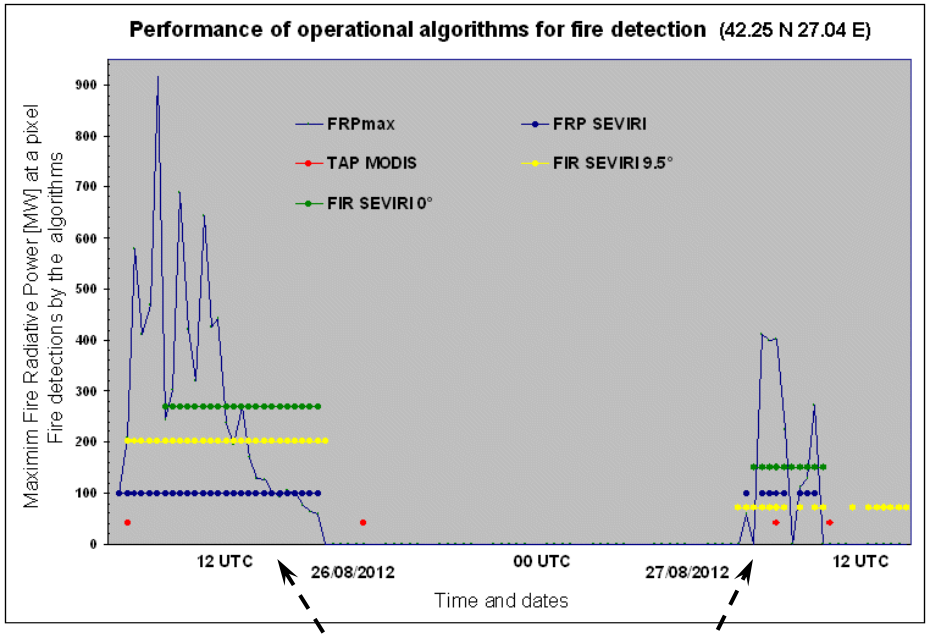
- SEVIRI FIR algorithm may fail to detect fires detected by MODIS.
- SEVIRI FRP product may provide more efficient fire detection than SEVIRI FIR as well as than MODIS TAP.

Monitoring fire development

SEVIRI and MODIS Products

Small fires vs. *Large fires*





For small fires (FRP < 100 MW per pixel), at different stages of fire development:

- FRP product may provide more efficient fire monitoring than FIR.
- SEVIRI algorithms may fail to detect fires detected by MODIS.

For Large fires (reaching FRP > 200 MW per pixel, measured by SEVIRI),

- SEVIRI FRP and FIR (both from Full Scanning from 0° and Rapid Scan from 9.5° E) can be equally efficient for fire detection.
- As some stages SEVIRI FIR from RSS may be most efficient in fire detection.

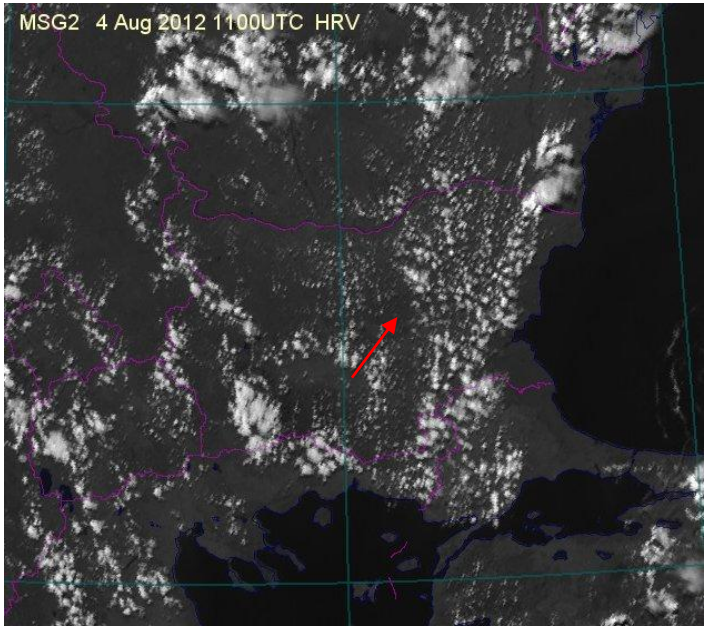
LIMITATIONS

Cloudiness in fire weather situations

- A significant fire remote sensing constrain is the presence of cloudiness in fire weather situations.
  - The algorithms could not detect existing fires due to elimination of cloudy pixels or assuming some detections in partially cloudy pixels as "false" fire detections based on "contextual" tests .
  - False alarms are also possible in cases of sun glint reflection from undetected small clouds .
- There are various instances of differences/mismatches between SEVIRI MPEF FIR, SEVIRI LSA SAF FRP and MODIS TAP products.

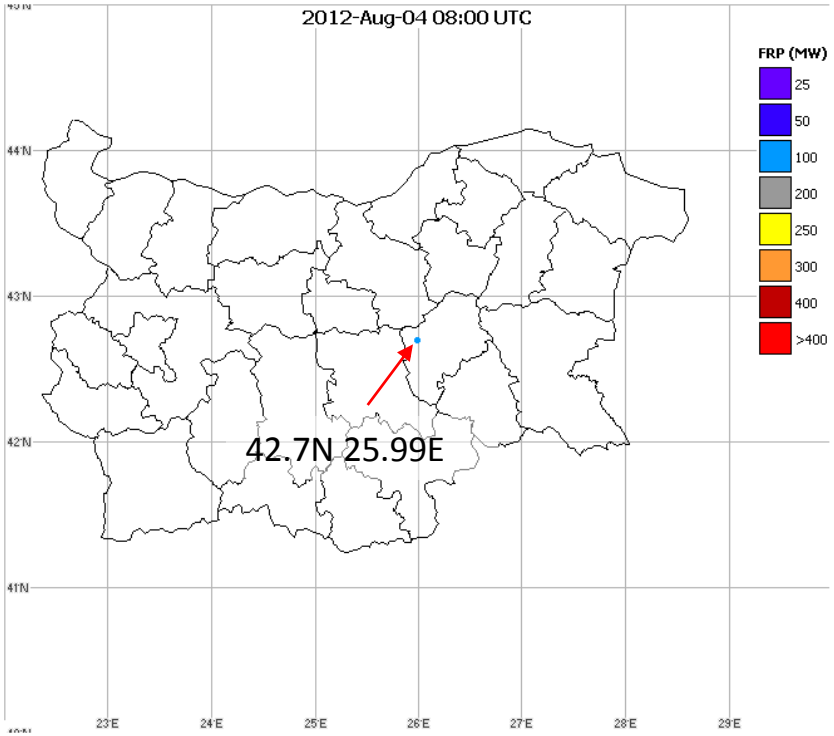
Cloudiness in Fire Weather situations
Failure detection by Satellite Products

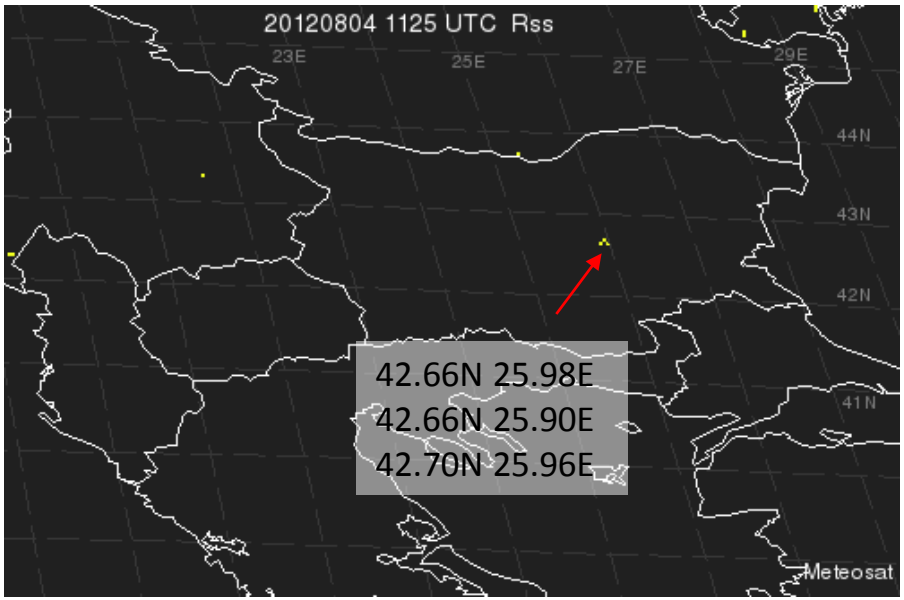
- In some cases of partial cloudiness the SEVIRI fire products may be able to detect a fire in single slots due to its higher frequency of observations, while MODIS does not detect the fire because of cloudy conditions at satellite overpassing the fire location.



4 August 2012, Fire at 42.66N 25.95E

- Detections in single pixels by FRP and FIR RSS
- No detection by MODIS

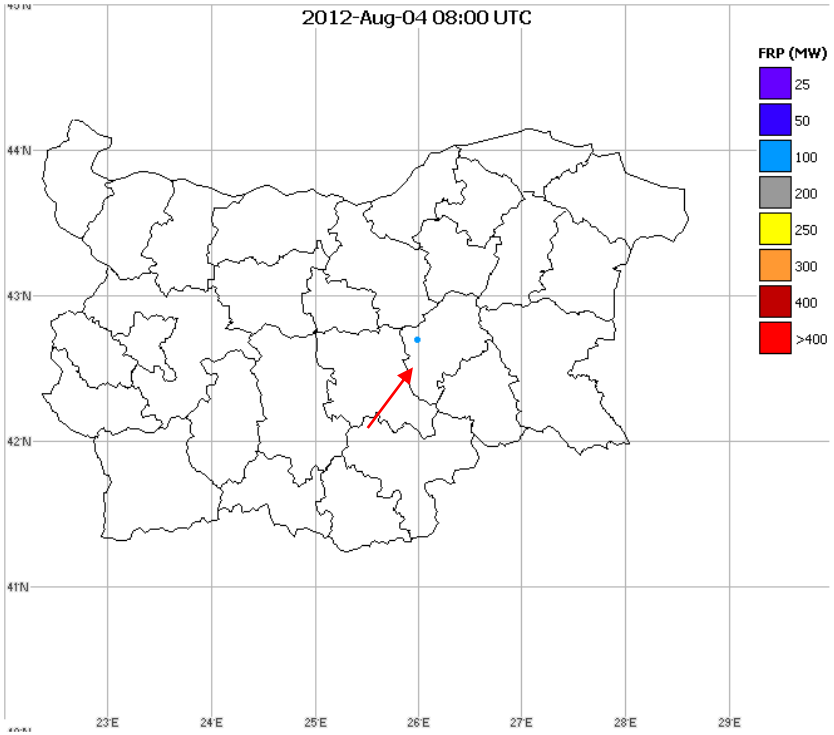




Cloudiness in Fire Weather situations
Failure detection by Satellite Products

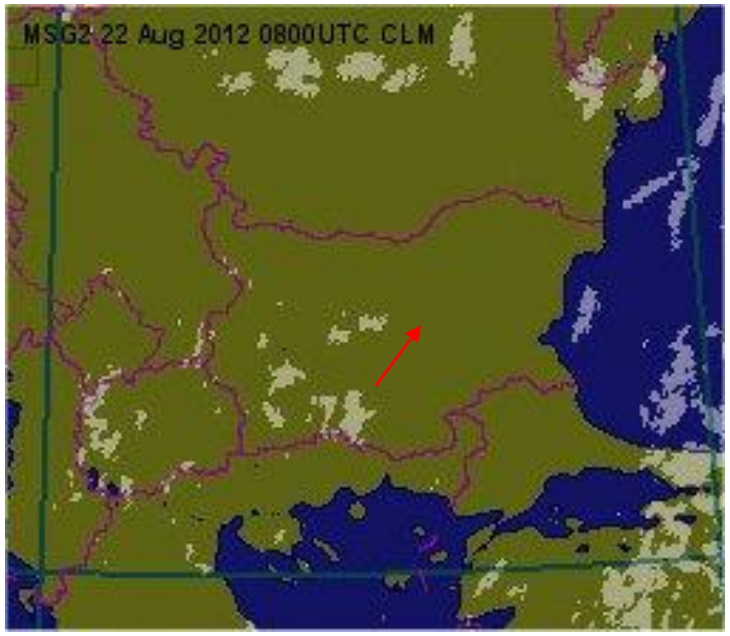
4 August 2012, Fire at 42.66N 25.95E

- Early Warning by FRP at 0800 UTC **42.70,25.99E**,
- Found out at the ground at 1055 UTC,
- No detection by MODIS TAP.



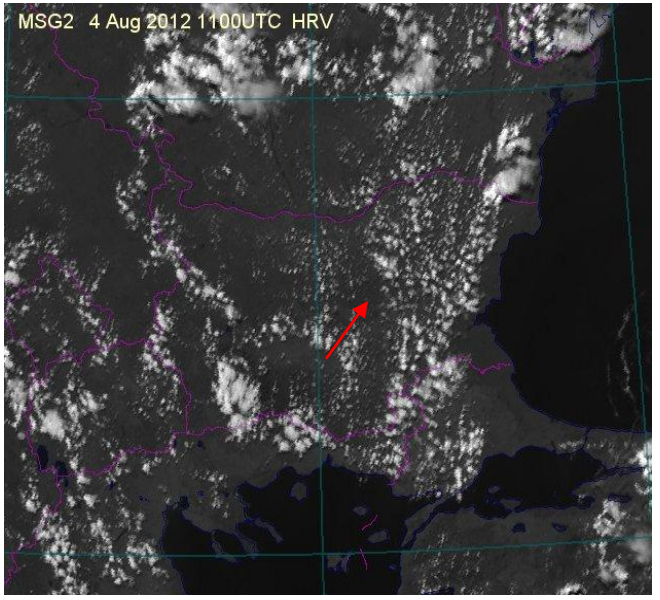
- No cloudiness at the time of fire ignition.
- The LSA SAF FRP product detects the fire due to its efficiency to detect small fires better than MPEF FIR algorithm.

MSG MPEF Cloud mask

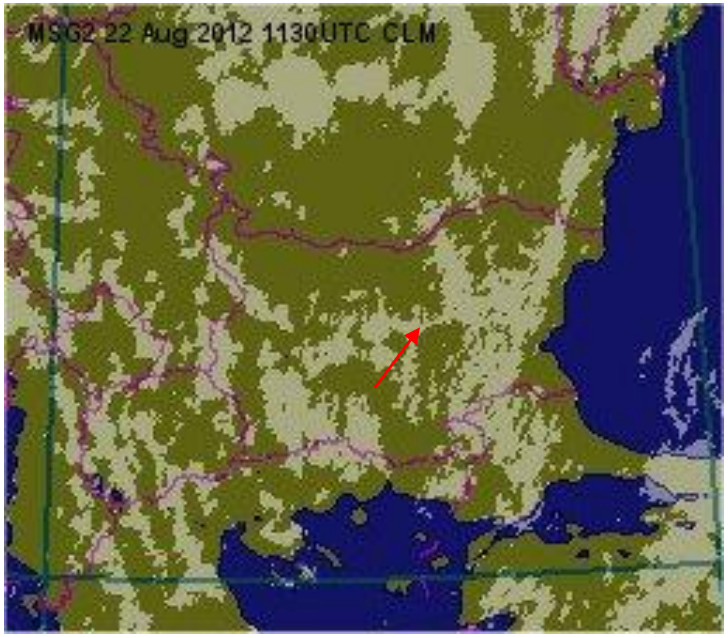


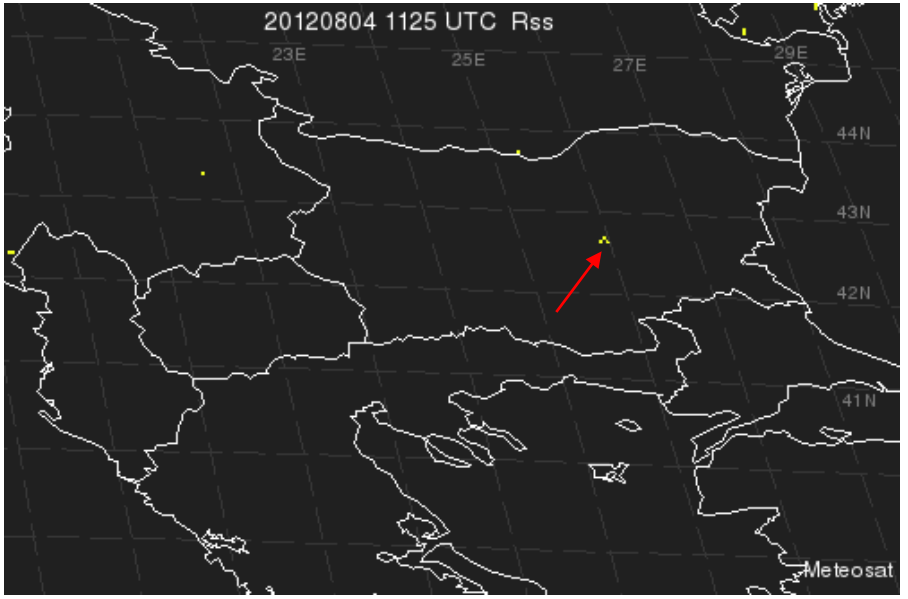
Cloudiness in Fire Weather situations
Failure detection by Satellite Products

- At a later stage of fire activity, convective clouds develop, then LSA SAF FRP and MODIS TAP failed in detection.
- The MPEF FIR product based on MSG RSS detected the fire (**1125 UTC, 42.659, 25.984**) in any cloud gap due to:
  - higher spatial resolution for this region from sub satellite point at 9.5° E than FRP from MSG2 Full Scan at 0°.
  - higher time frequency at 5 min interval than 15 min for FRP.



4 August 2012, Fire at 42.66N 25.95E



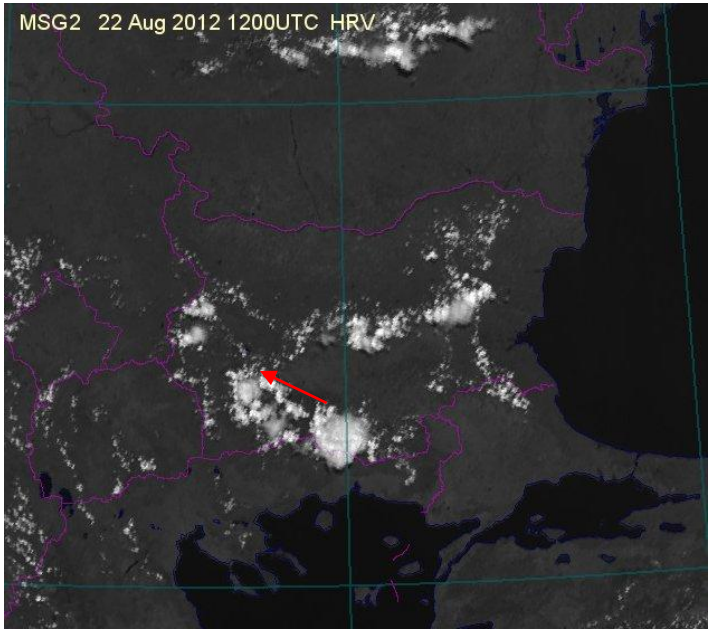


Cloudiness in fire weather situations:

Satellite products fail to detect fires

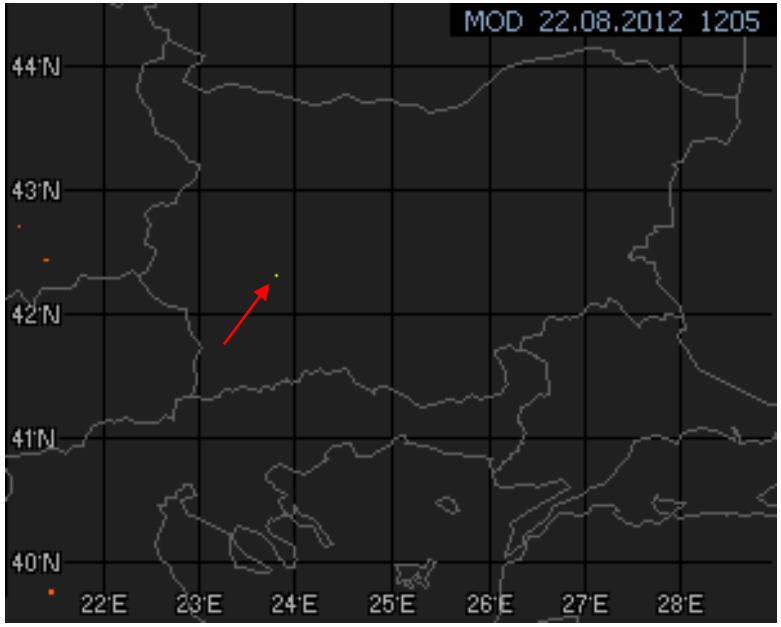
- In some partially cloudy cases, fires are detected by MODIS because of higher spatial resolution while the SEVIRI algorithms classify the corresponding pixel as cloudy and do not detect the fire.

MSG HRV channel image

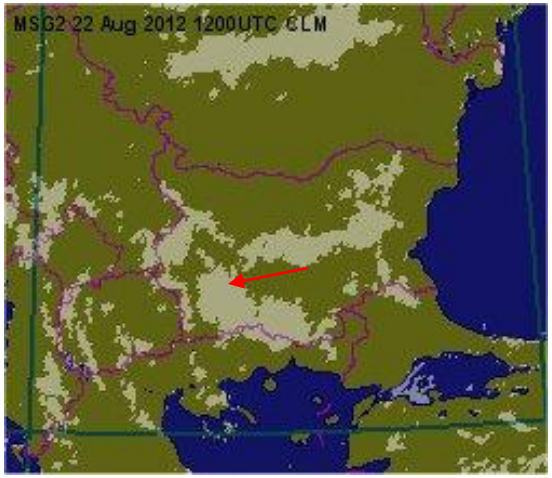


22 August 2012: Fire at 42.3N 23.767E

- No detections by FRP and FIR



MSG MPEF Cloud mask



SUMMARY
Differences/mismatches between MPEF FIR and LSA SAF FRP

- For small fires (FRP < 150 ha total burned area),
  - SEVIRI FIR algorithm may fail to detect fires detected by MODIS.
  - SEVIRI FRP product may provide more efficient fire detection than SEVIRI FIR as well as than MODIS TAP.
- In synoptic situations which are favourable for development of both fires and cloudiness.
  - SEVIRI fire products may be able to detect a fire in single slots due to its higher frequency of observations, while MODIS does not detect the fire because of cloudy conditions at satellite over passing the fire location.
  - In other partially cloudy cases, fires may be detected by MODIS because of higher spatial resolution while the SEVIRI algorithms classify the corresponding pixel as cloudy and do not detect the fire.

SUMMARY
Differences/mismatches between MPEF FIR and LSA SAF FRP

- FRP is more efficient than FIR in detection of small fires as well as more efficient in providing early warnings, including
  - Earlier detection.
  - Detection of fires, which are not detected by the other SEVIRI algorithm.
- For small fires (FRP < 100 MW per pixel),
  - SEVIRI algorithms may fail to detect fires detected by MODIS.
  - FRP product may provide more efficient fire monitoring than FIR.
- For Large fires (reaching FRP > 200 MW per pixel, measured by SEVIRI),
  - SEVIRI FRP and FIR (both from Full Scanning from 0° and Rapid Scan from 9.5° E) can be equally efficient for fire detection.
  - For the South Eastern Europe, the Rapid Scan FIR product from 9.5° E may provide more efficient fire monitoring than FRP, which is based on Full Scanning from 0° because of the higher spatial resolution.

PERSPECTIVES

Use of SEVIRI MPEF FIR and LSA SAF FRP in a synergetic way for fire detection

For an efficient fire detection, various available sources of information can be used in order to avoid as mush as possible the remote sensing constrains due to the sensor and satellite orbit geometry and cloud contamination.

Further activities:

- Validation studies of LSA SAF FRP product, regarding the false fire detection alarms over South Eastern Europe are needed.
- In validation studies the situations favourable for development of both fires and cloudiness have to be carefully monitored that will help to avoid misunderstanding when assessing the performance of fire detection algorithms.

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Monitoring weather and climate from space
Surveiller le temps et le climat depuis l'espace

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