Carbon emissions estimates by SEVIRI FRP product over Eastern Mediterranean

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

LSA SAF
Land Surface Analysis

3rd SALGEE Workshop 'MSG Land Surface Applications: Drought and Fire emissions'
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LSA SAF Fire Radiative Power Applications

Biomass burning is a key process in the Earth system, in particular the terrestrial carbon cycle, and a globally significant source of atmospheric trace gases and aerosols, which impact air quality, atmospheric chemical composition and the Earth radiation budget.

SEVIRI FRP APPLICATIONS

1. **Fire detection and monitoring.**
2. **Assessment of fire activity.**
3. **Climate related issues:**
   - **Estimation of released fire radiative energy.**
   - **Estimation of fire carbon-equivalent emissions.**

AREA OF APPLICATION: *fire-affected regions of Africa, Europe, and part of the eastern South America*

OPERATIONAL ACCES: **Derived at LSA SAF from satellite observations of SEVIRI data from MSG2 Full Earth disc scanning.**

- **Generated every 15 min *(EUM, 2010).***
- **Operationally available through EUMETCast.**

Climate related issues

FUEL COMBUSTION ESTIMATES

The satellite FRP products offer a new way to estimate the location and amount of greenhouse gas and aerosol emissions from fires, as well as reactive gases (ozone precursors particularly), based directly on measures of the actual heat released from these events.

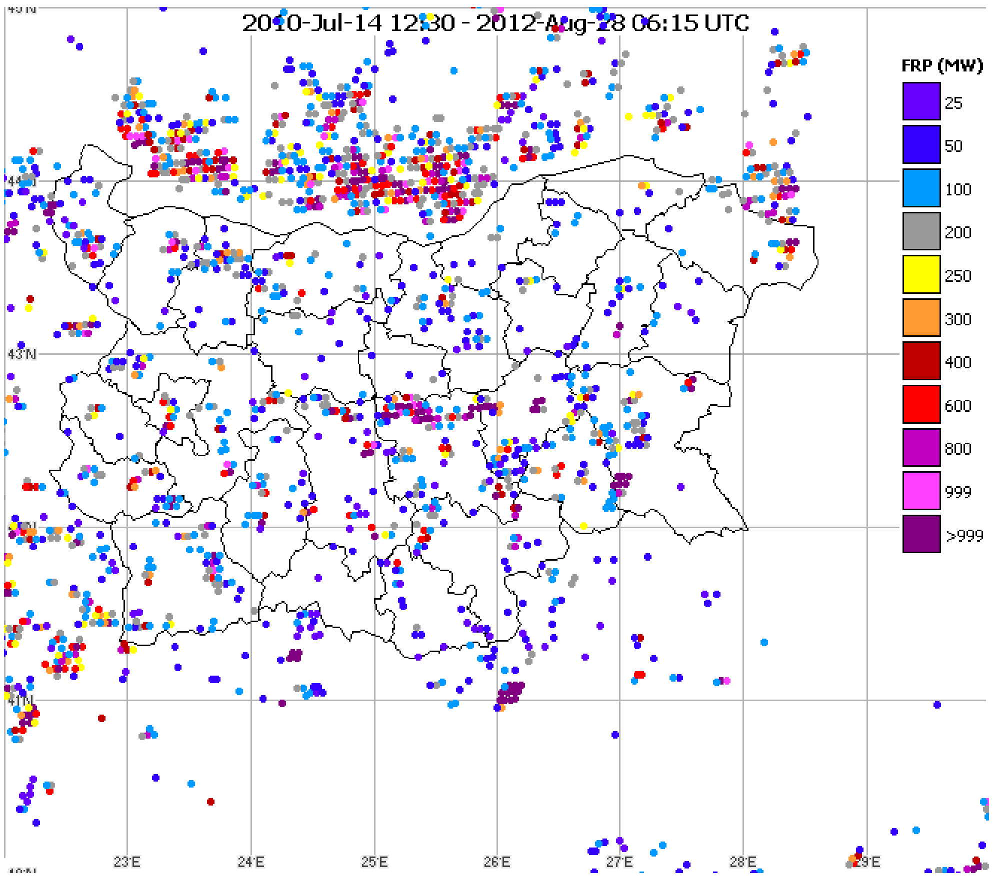
The aim of this presentation is

- To show the applicability of LSA SAF FRP product for estimation of released fire radiative energy and carbon-equivalent emissions over the area of South Eastern Europe.
- To exemplify the dependence of the released emissions by the diversity of the ecosystems injured by the fire.

LSA SAF FRP Product from SEVIRI Data

Operationally derived at LSA SAF from satellite observations of SEVIRI data from MSG2 Full Earth disc scanning every 15 min.

Accumulated FRP, Bulgaria, summer 2010 -2012



Fire Radiative Fire /FRP/ Product

- Detects pixels containing active fires
- Reports time/location of detected fire
- Reports FRP energy for detected fires

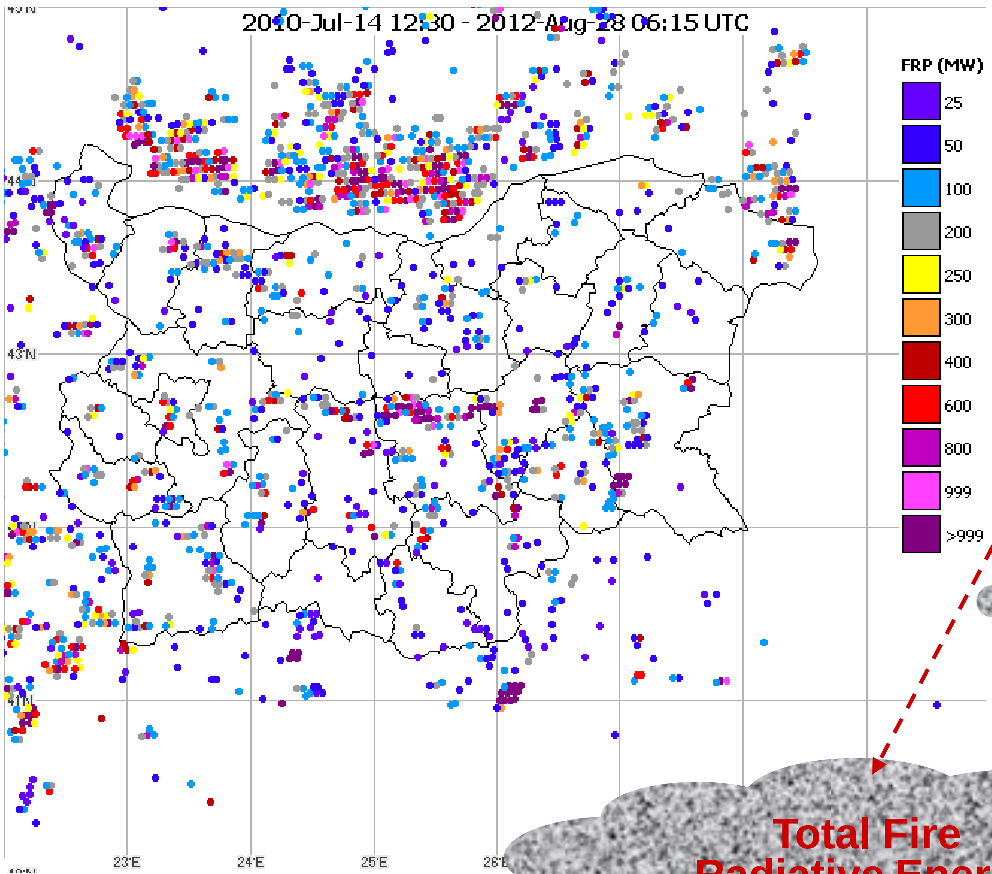
Output

FRP parameter (MWatts) provides information on the measured radiant heat output of detected fires, resulting from the combustion process, whereby carbon-based fuel is oxidised to CO_2 with the release of a certain "heat yield".

LSA SAF FRP Product from SEVIRI Data

Operationally derived at LSA SAF from satellite observations of SEVIRI data from MSG2 Full Earth disc scanning generated every 15 min.

Accumulated FRE, Bulgaria, summer 2010 -2012



- **Fire Radiative Energy /FRE/**

Climate related issues

Output:

- Biomass combustion rate
- Smoke release

- Measuring FRP and integrating it over the lifetime of the fire provides an estimate of the total Fire Radiative Energy (FRE), which for wildfires should be proportional to the total mass of fuel biomass combusted *(Wooster et al. 2003; Govaerts et al., 2010).*

Total Fire Radiative Energy

CO_2 equivalent emissions

CASE-STUDY

A dead-vegetation forest fire in Bulgaria
1- 4 July 2012

- Fire Radiative Power product
    - Radiative energy released to atmosphere
- Fire-CO_2 equivalent emissions

- A wildfire broke out on 1st of July in the eastern parts of Vitosha Mountain, close to Bistritsa, Bistrischko Braniste (announced by UNESKO since 1977 as a biospheric reserve), a suburb of the Bulgarian capital Sofia
  http://www.youtube.com/watch?v=sxRP2AaiweM
- The fire developed at altitudes about 1700 - 1800 m and there is still snow at the northern side of the mountain at altitudes about 2000 m in the beginning of this summer.

Vitosha mountain near Sofia, Bulgaria, 1-4 July 2012

A view from the roof of NIMH

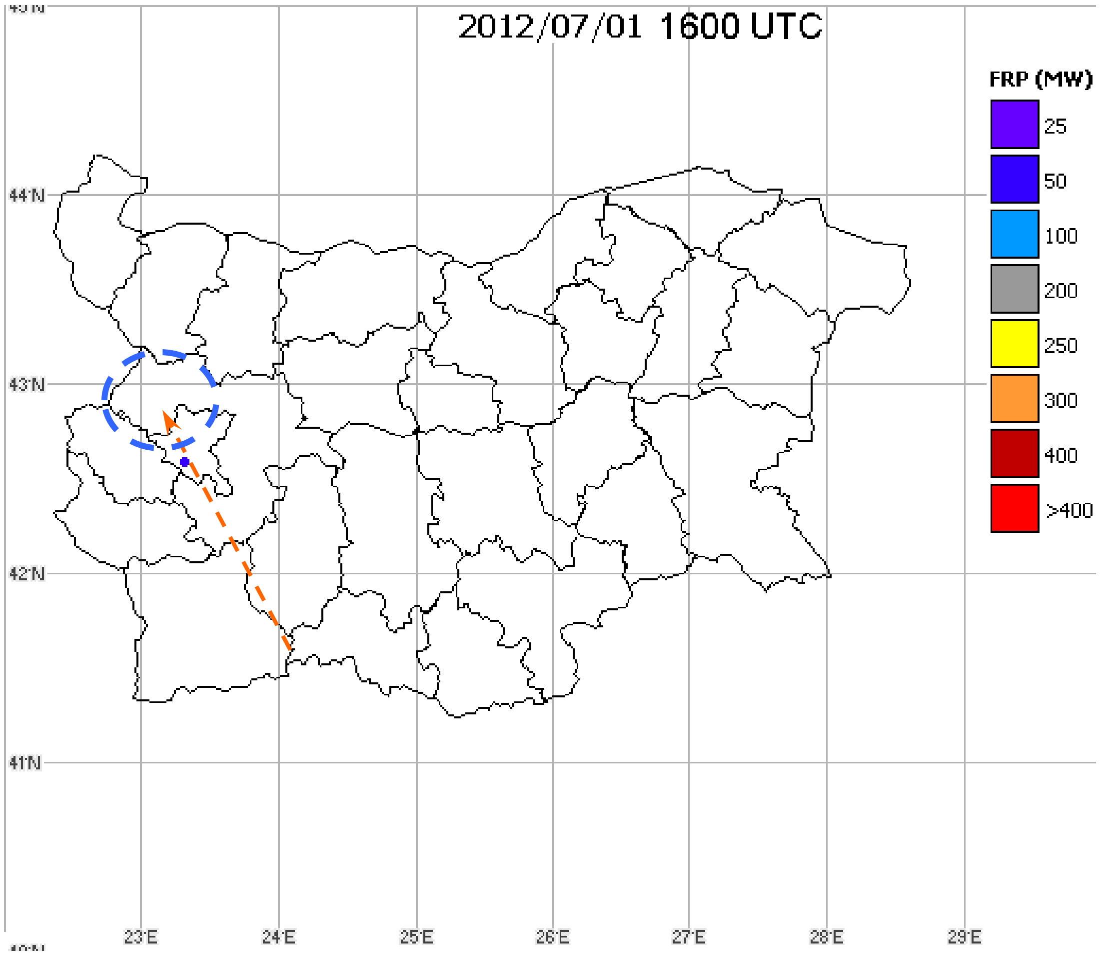
Small fire

A case of a small fire occurred in the centre of an area of a dead-vegetation forest 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 Sofia.

http

Fire detection by FRP/FIR SEVIRI

FRP SEVIRI: 1600-2215 UTC has 11 earlier detections than FIR SEVIRI



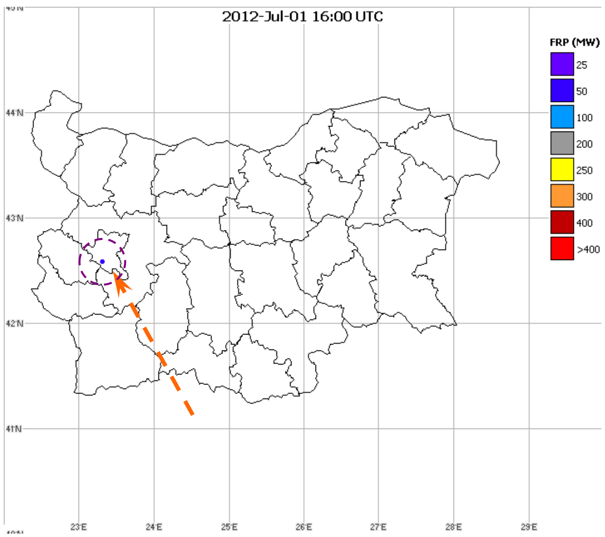
FRP Algorithm detected this event
at low Fire Radiative Energy (~30 MW)

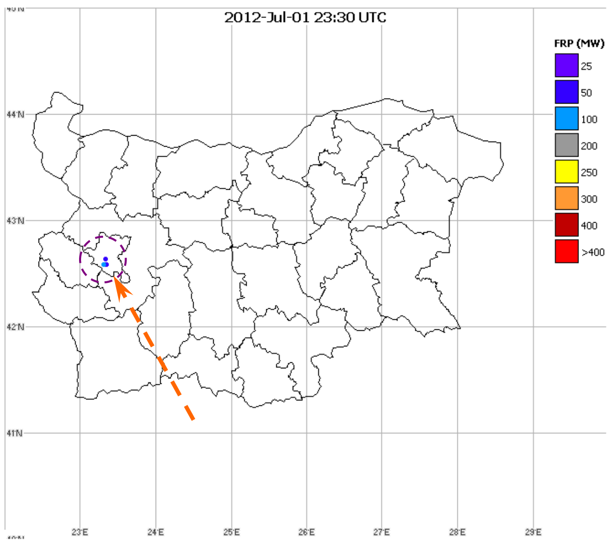
EFFICIENCY OF LSA SAF FRP SEVIRI PRODUCT

FOR ASSESSING FIRE RADIATIVE ENERGY

- Estimation of the FRE is subject to several remote sensing constrains because satellite data are available only at discrete intervals, due to the sensor and satellite orbit geometry and cloud contamination and because FRP is defined only for active fires that have a sufficient size and temperature to enable their detection *(Giglio et al., 2003)*.
- Using a simple method to parameterize the fire diurnal cycle of based on the long-term ratio between Terra and Aqua MODIS FRP *Vermote et al. (2009)* reported an underestimation of FRE from MODIS by about 30 % compared with SEVIRI.
- In the same time, some fire pixels <~100 MW, which are observed by MODIS but may often be missed by SEVIRI due to differences in spatial resolution, do contribute significantly to an overall regional scale FRP estimation regarding fire detection and FRE estimation *(Roberts et al., 2005)*.
- *This case-study exemplifies the limitations due to spatial and temporal sampling issues for SEVIRI and MODIS data.*

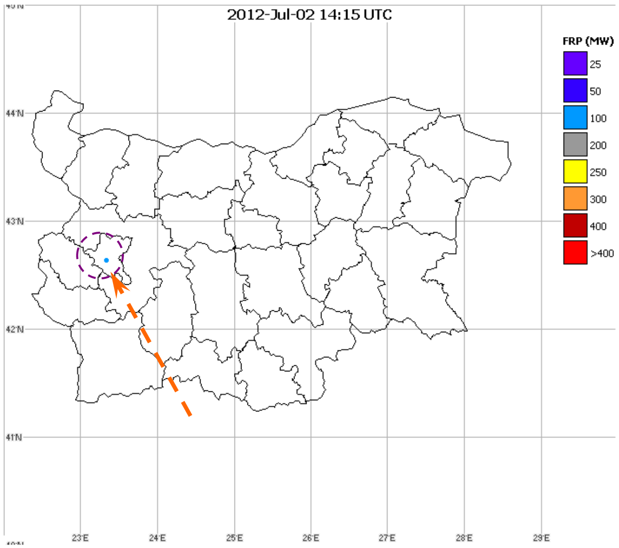
Radiant Energy Emitted by Fire
1-3 July 2012, Vitosha, Bulgaria

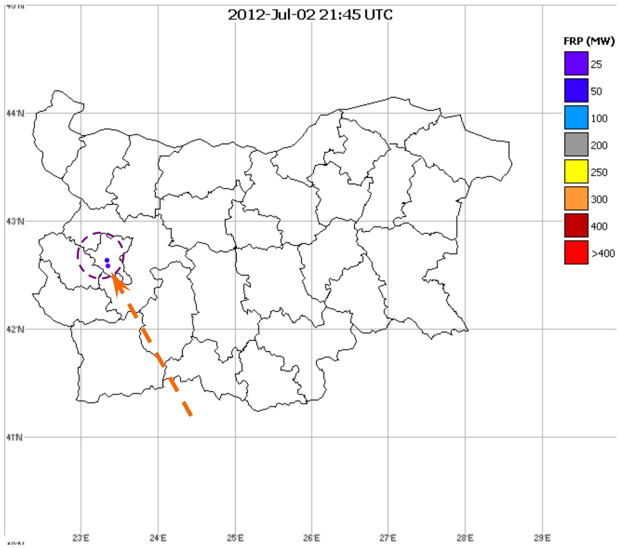




This fire has detected by FRP SEVIRI algorithm

- in 5 pixels
- at 37 discrete slots.

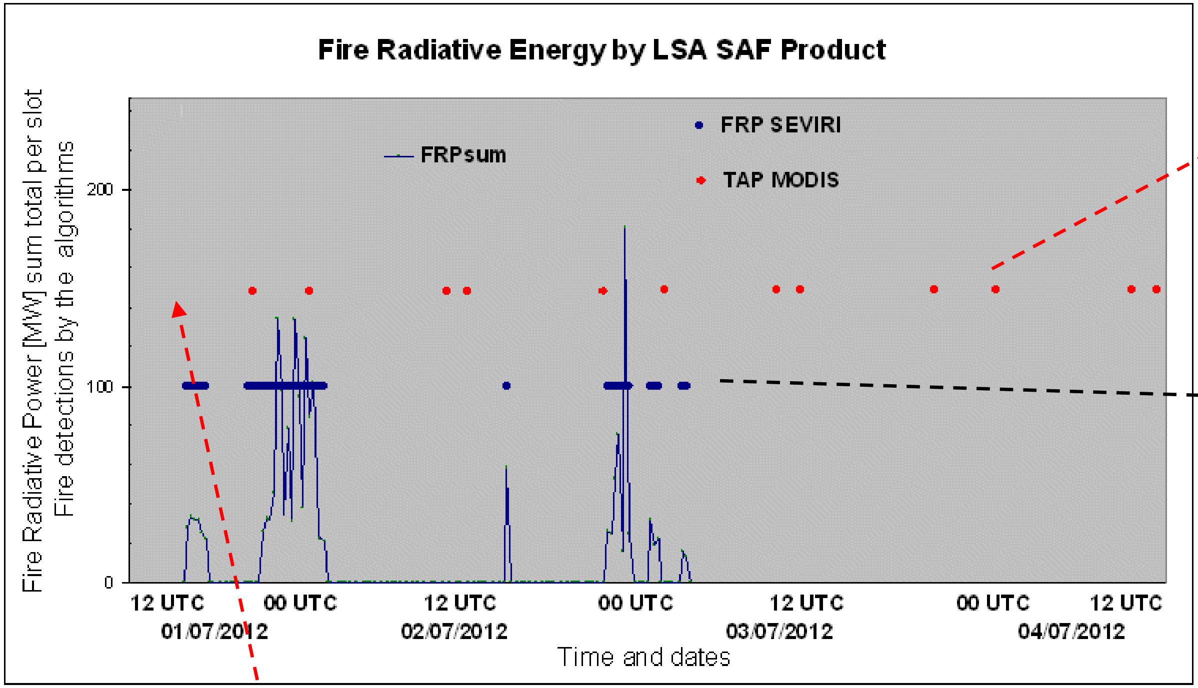




- Measuring this FRP and integrating it over the lifetime of the fire provides a measure of the total Fire Radiative Energy (FRE), which should be proportional to the total fuel mass combusted.

EFFICIENCY OF LSA SAF FRP SEVIRI PRODUCT

FOR ASSESSING FIRE RADIATIVE ENERGY



Detections of TAP MODIS algorithm at 12 overpasses from 1 July 2020 UTC to 4 July 1125 UTC.

Detections of FRP SEVIRI algorithm at 37 slots from 1 July 1600 UTC to 3 July 0245 UTC.

During the last two days of the fire development detected by MODIS, FRP was not able to measure the emitted energy.

During the first 10 hours of fire development the FRP SEVIRI algorithm was efficient to account for FRE, while MODIS algorithm failed to detect the fire due to the gap between the discrete observations.

Therefore all further considerations about the Total Energy and Carbon released, measured by this product are subject to theses constrains.

Climate related issues

FUEL COMBUSTION ESTIMATES

The temporal integration of the FRP measured over the lifetime of the fire provides a measure of the total Fire Radiative Energy (FRE), which should be proportional to the total fuel mass combusted. Simple linear relationships linking FRP, FRE and fuel consumption were first demonstrated in detail by *Wooster et al. (2005).*

– Calculation of Fire Radiative Energy (FRE) per slot:

$$FRE_{slot} = FRP \times 15(min) \times 60(sec)$$

– Rate of biomass consumption (kg.sec-1) = 0.368(± 0.015)xFire Radiative Power (MW)

$$M_{slot} = FRE_{slot} \times 0.368$$

– Calculation of CO_2 released as

$$C_{slot} = M_{slot} \times 0.467$$

Once a biomass combustion rate or total is available, it can simply be multiplied by the fraction of carbon contained in the fuel (usually assumed ~ 0.47) to estimate total carbon release, or by the standard emissions factors of different species, (e.g. CO2, CO, particulate matter) and after integrating over the fire lifetime, the released Total Carbon is calculated.

Climate related issues

Fire energy & Carbon emissions

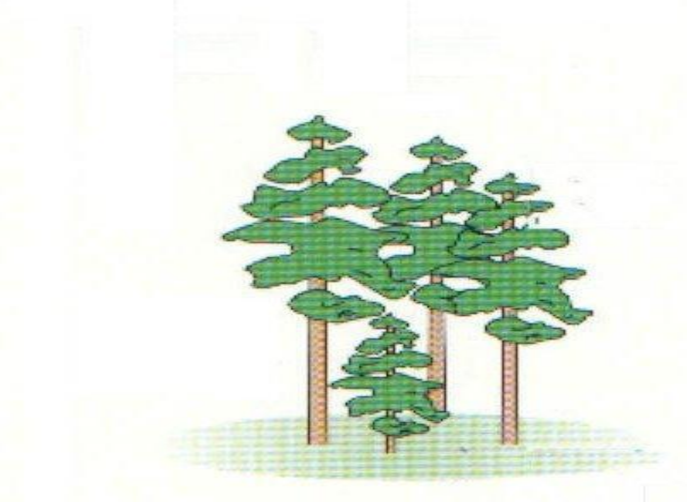
The major components of biomass burning are:

• Forests (tropical, temperate, and boreal)
• Savannas
• Agricultural land after harvest
• Wood for cooking, heating and the production of charcoal.

- ***Active Fire***
  detection & monitoring
- ***Fire carbon emissions***
  Fire Radiative Energy (FRE)
  and
  Fire carbon emitted
  assessed by
  LSA SAF FRP SEVIRI Product

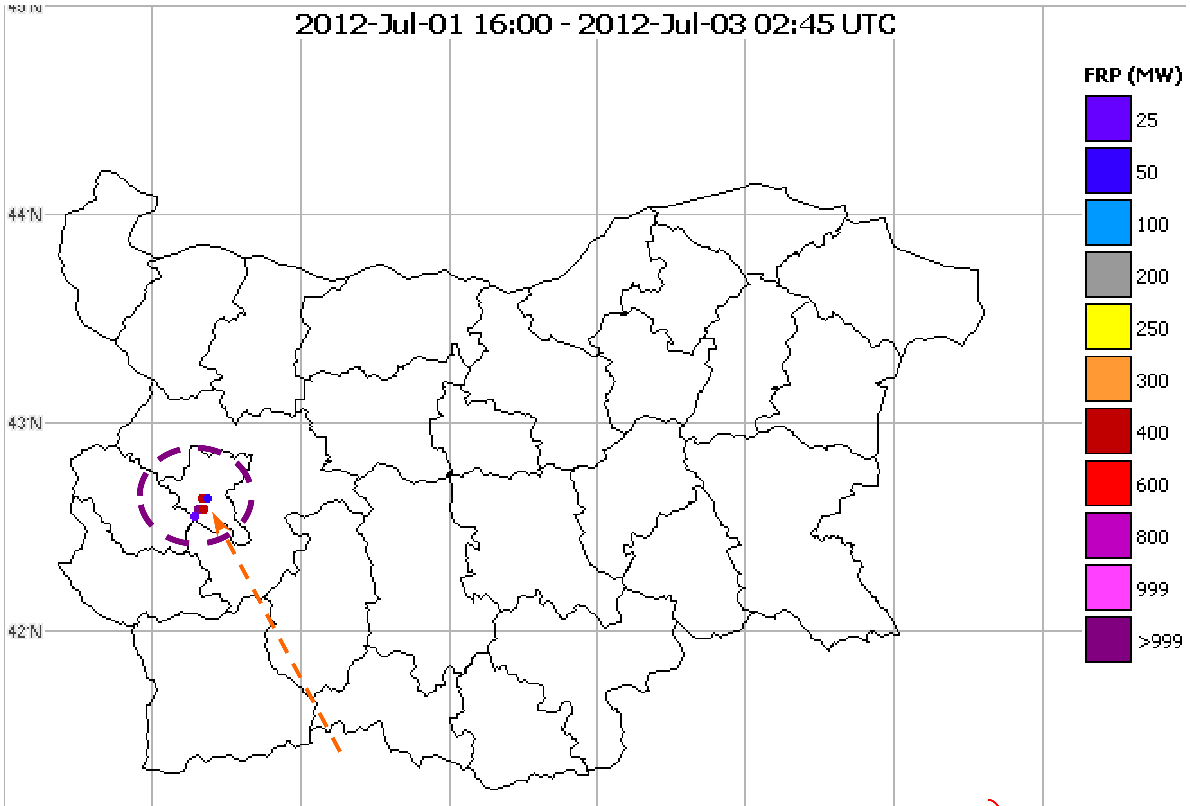
Vegetation Fires
linking both biogeophysical & biogeochemical cycles

Globally, vegetation fires are believed to generate carbon emissions equivalent to between one third and one half of those from fossil fuel combustion, with those from savanna fires responsible for perhaps 50% of this total (Williams et al., 2007).



Wildfire, ecosystems, and climate

Total Fire Radiative Energy (FRE) assessed by LSA SAF FRP SEVIRI Product



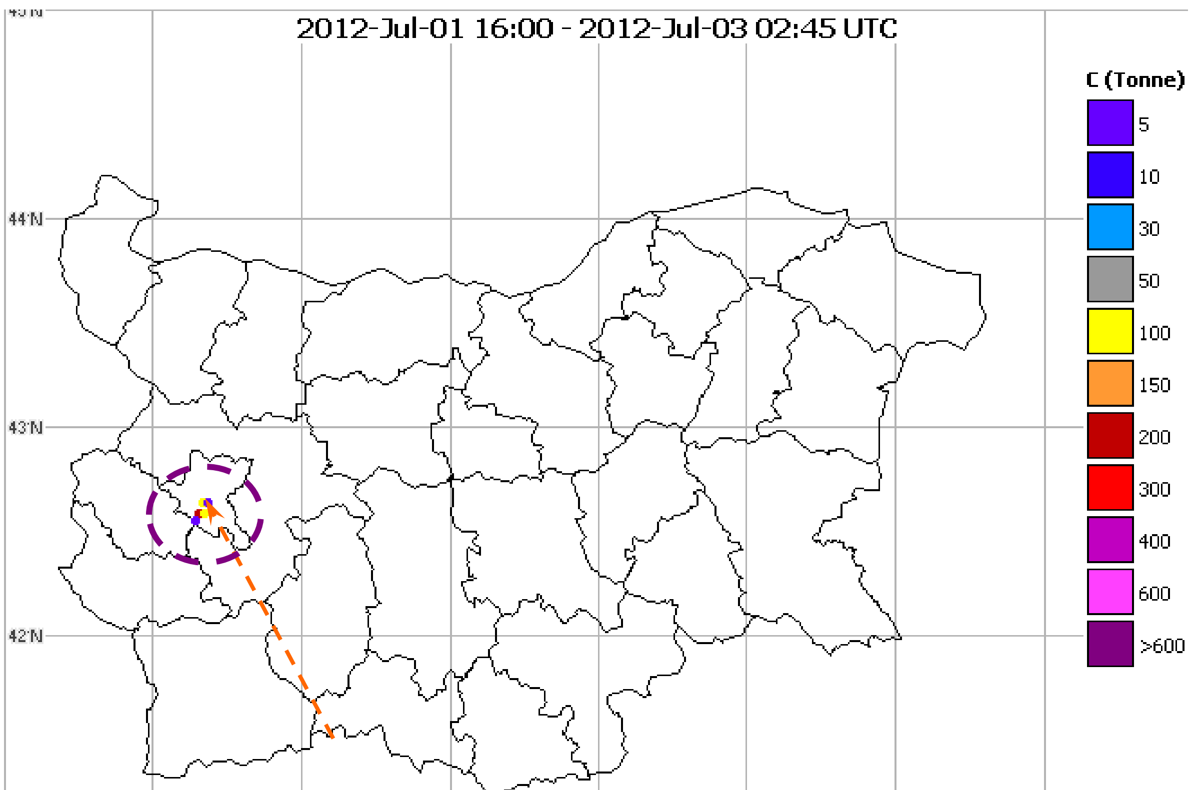
Index,	count,	Lat.,	Lon.,	Frp(MW),	Size(km)
1,	29,	42.59,	23.31,	1036.40,	15.45
2,	1,	42.55,	23.29,	21.40,	15.44
3,	11,	42.59,	23.35,	370.90,	15.46
4,	11,	42.64,	23.33,	330.90,	15.47
5,	1,	42.64,	23.37,	31.90,	15.48

For all 37 FRP detections at 5 pixels in the period from 1 July 1600 UTC to 3 July 0245 UTC

Total Fire Radiative Energy: 1791.5 MW

Climate related issues

1-3 July 2012 Vitosha Fire, Bulgaria



Index,	count,	Lat.,	Lon.,	Frp(MW),	Carbon(kg)
1,	29,	42.59,	23.31,	1036.40,	160300
2,	1,	42.55,	23.29,	21.40,	3310
3,	11,	42.59,	23.35,	370.90,	57367
4,	11,	42.64,	23.33,	330.90,	51180
5,	1,	42.64,	23.37,	31.90,	4934

Fire carbon emissions estimated by LSA SAF FRP SEVIRI Product

For all 37 FRP detections at 5 pixels in the period from 1 July 1600 UTC to 3 July 0245 UTC

Total Carbon Emitted: 277091 kg

Emission Factors
Andreae & Merlet (2001)

Fire energy & Carbon emissions at different vegetation types

Fires in diverse ecosystems are very different in the production of gaseous and particulate emissions

CASE-STUDY EXAMPLES

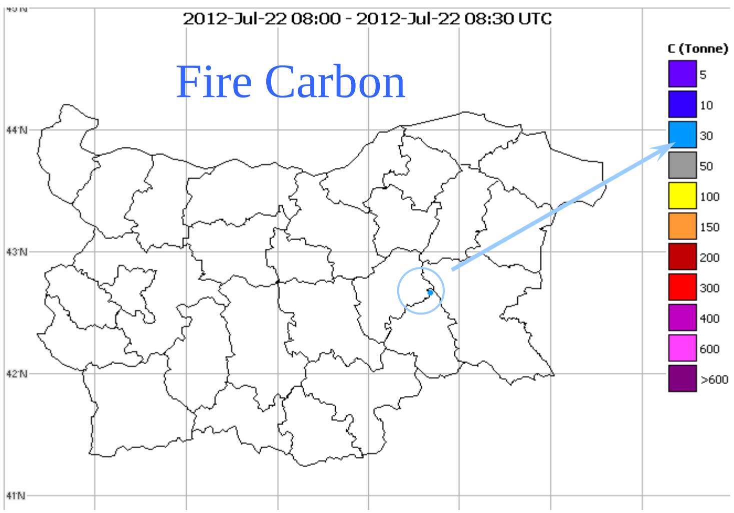
Information for forest fire characteristics in this study are provided by the State Forest Agency /SFA/ of Bulgaria data base.

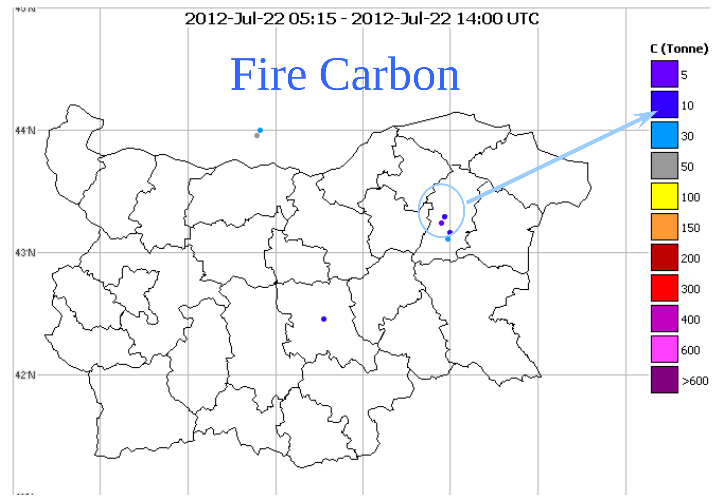
Case-study: 22 July 2012

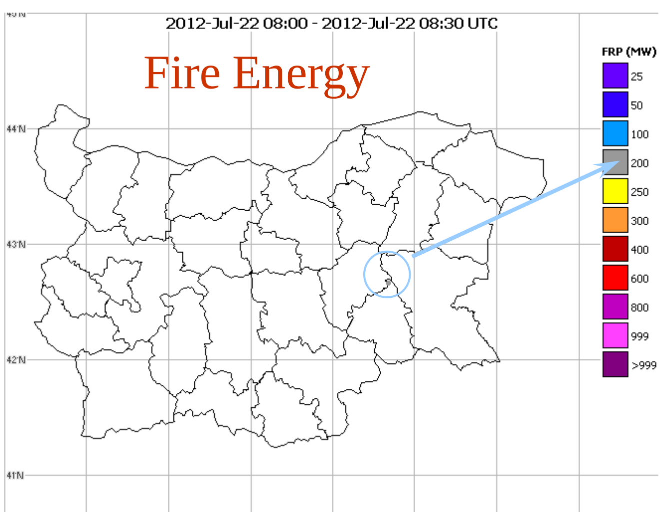
Bulgaria, South Eastern Europe

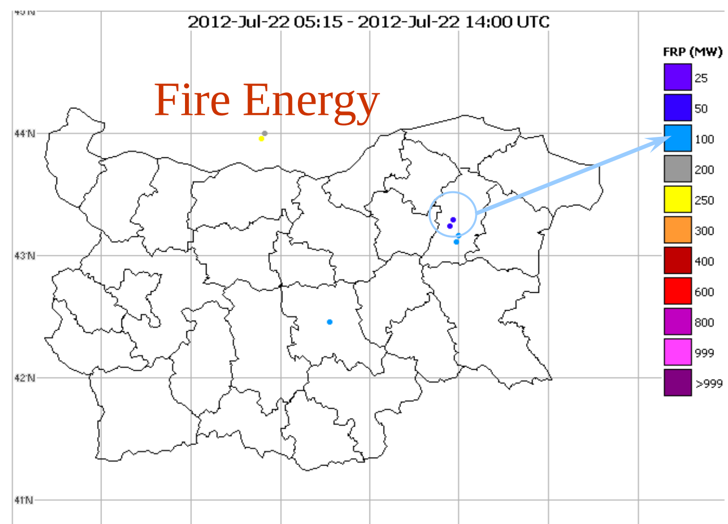
Information for forest fire characteristics are provided by the State Forest Agency /SFA/ of Bulgaria.

Forest / Grass







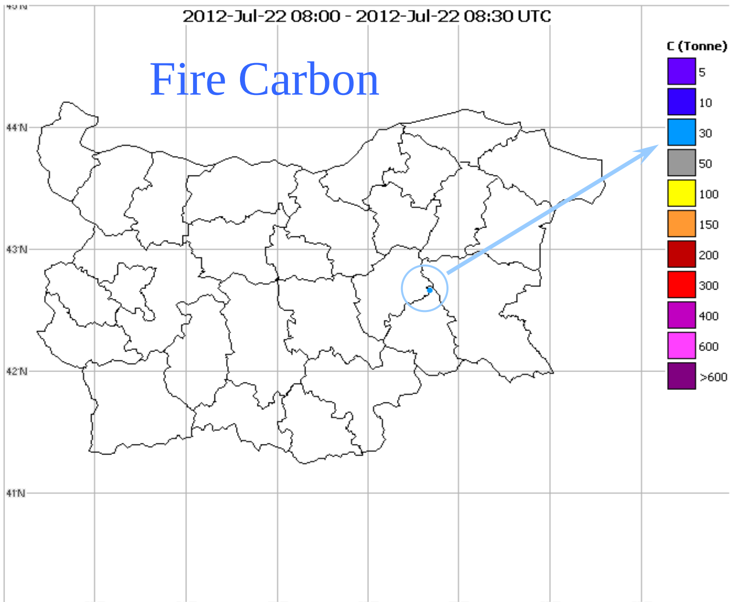


Beach forest: 0.5 ha, under canopy
Total area 15 ha; Total C = 26.05 T
1 pixel FRE = 168.4 MW

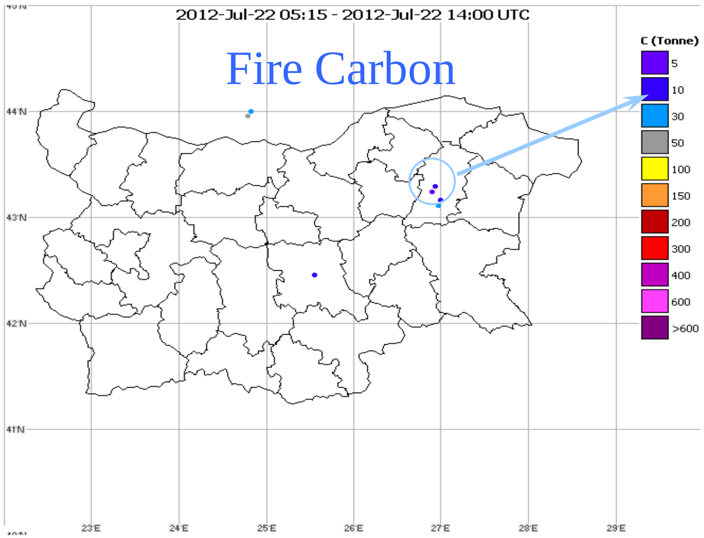
Grass/bushes:
Total area 6.6 ha; Total C = 10.3 T
2 pixels FRE = 66.6 MW

Case-study: 22 July 2012 *Bulgaria, South Eastern Europe*

Forest / Grass



Beach forest: 0.5 ha, under canopy
Total area 15 ha; Total C = 26.05 T
1 pixel FRE = 168.4 MW



Grass/bushes:
Total area 6.6 ha; Total C = 10.3 T
2 pixels FRE = 66.6 MW

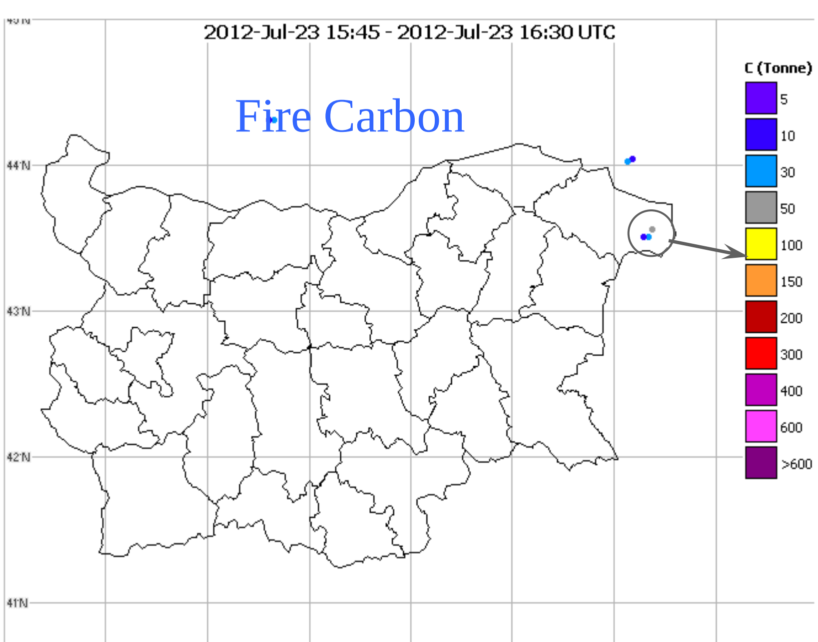
✓ Comparing **small** forest fires (under canopy) *vs*. grass/bushes burning.
✓ 1 pixel FRP detecting 0.5 ha broadleaved deciduous forest burning corresponds to more than twice FRE released comparing to the grass burning.
✓ Accordingly, 1 pixel FRP detecting 0.5 ha broadleaved deciduous forest burning release more than twice total C (eq.) comparing to the grass.

Case-study: 23 July 2012 *Bulgaria, South Eastern Europe*
‘Small’ fires under canopy at different forest types/total area affected

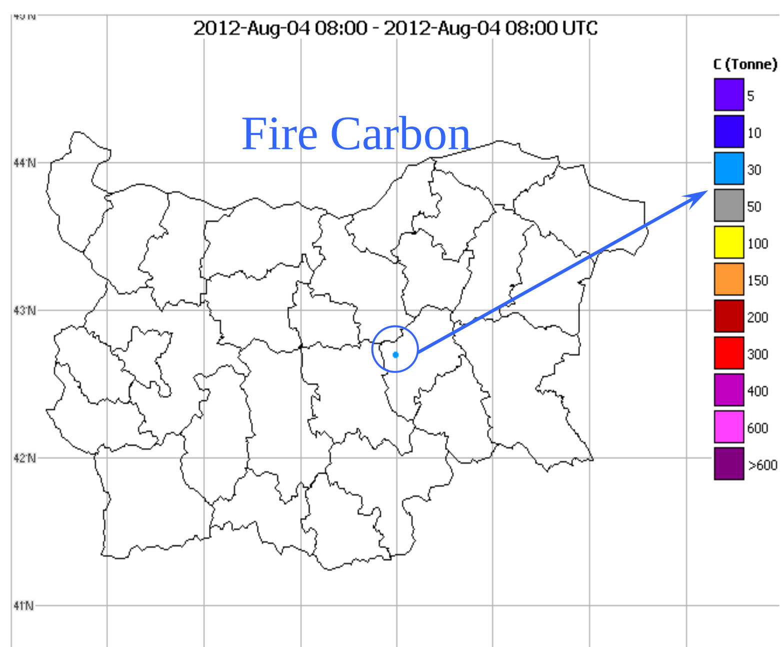
✓ There is much more FRE released from mixed broadleaved forest due to:

- Differences in total area affected
- Differences in forest species: mixed broadleaved release more FRE, correspondingly more fire Carbon eq. is emitted.
- The age of the forest, i.e. the C-accumulated

✓Significant differences in C eq. release between two cases of different broadleaved spp. and also depending on the total area affected by the fire.



Broadleaved forest: 0.5 ha under canopy
Total area 90 ha; Total C = 73.2 T
3 pixels FRE = 473.6 MW



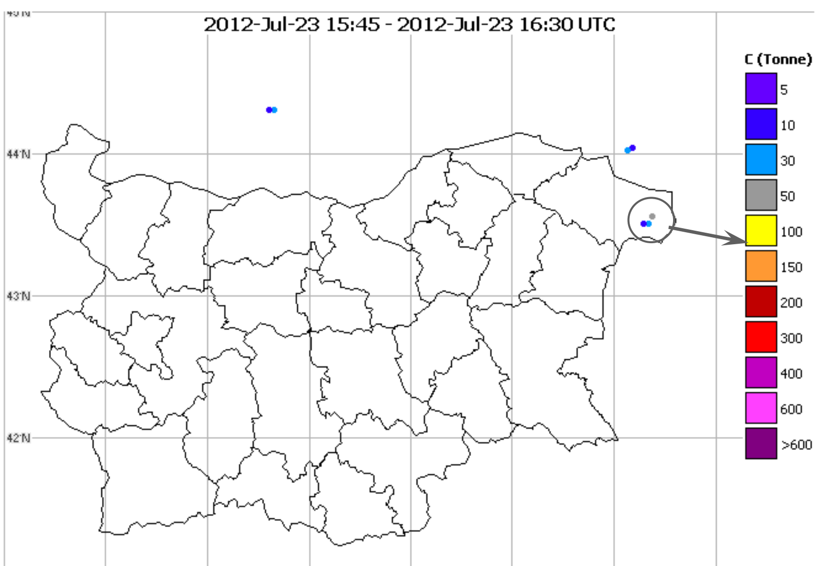
Acacia forest:3 ha under canopy
Total area 15 ha; Total C = 11.0 T
1 pixel FRE = 70.9 MW

Case-study: 23 July vs. 26 August 2012, *Bulgaria, South Eastern Europe*
‘Small’ fire under canopy vs. ‘Large’ fire at canopy
broadleaved forest fires of quite different total area affected

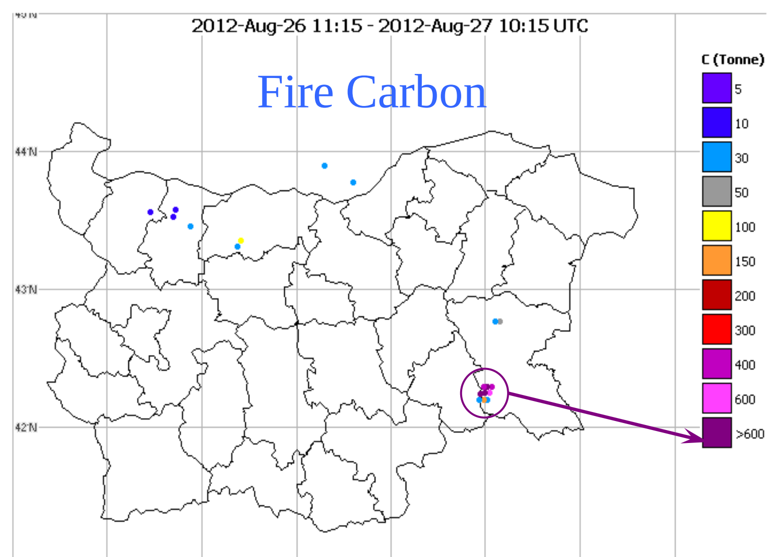
- On 23 Jul 2012: *0.5 ha forested area*, 0.5 ha under canopy
- On 26 Aug 2012: *954.7 ha forested area*, 844.7 ha under canopy, **110.0 ha at canopy**
- 90 vs. 8000 ha non forested area.

✓ Much more Carbon release from the ’large’ forest fire .

✓ Significant Carbon release from non forested area of the ’small’ forest fire .



Broadleaved forest: 0.5 ha under canopy
Total area 90 ha; Total C = 73.2 T
3 pixels FRE = 473.6 MW



Broadleaved forest: 954.7 ha under canopy, 110ha at canopy.
Total area 8000 ha; Total C = 4 377.3 T
9 pixels FRE = 28 300.6 MW

Conclusion

Estimation of emissions from fires in diverse ecosystems by SEVIRI FRP product depend on a set of factors:

- ✓ Total area affected and its partitioning between forest, grass, shrubs.
- ✓ The type of ecosystem (forest species age, closure, etc.)
- ✓ The moisture content of the vegetation and
- ✓ The nature and behavior, and characteristics of fire.
- ✓ *Remote sensing capabilities of MSG, that are due to the sensor and satellite orbit geometry, and that FRP is defined only for active fires, which have a sufficient size and temperature to enable their detection* .

Operational generation of FRP product by data from RSS of MSG is strongly recommend. Such a product will be much more useful for South Eastern Europe and this could be one of the recommendation from 3rd SALGEE Workshop.

Acknowledgments

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