



### South East Europe Flash Flood Guidance System



## The worst flood events in South East Europe, 13-15 May 2014 Case study

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**SEEFFG Steering committee and Training Workshop 31 March-2 April 2015, Skopje, Macedonia**





# 13-15 May 2014 Floods Events

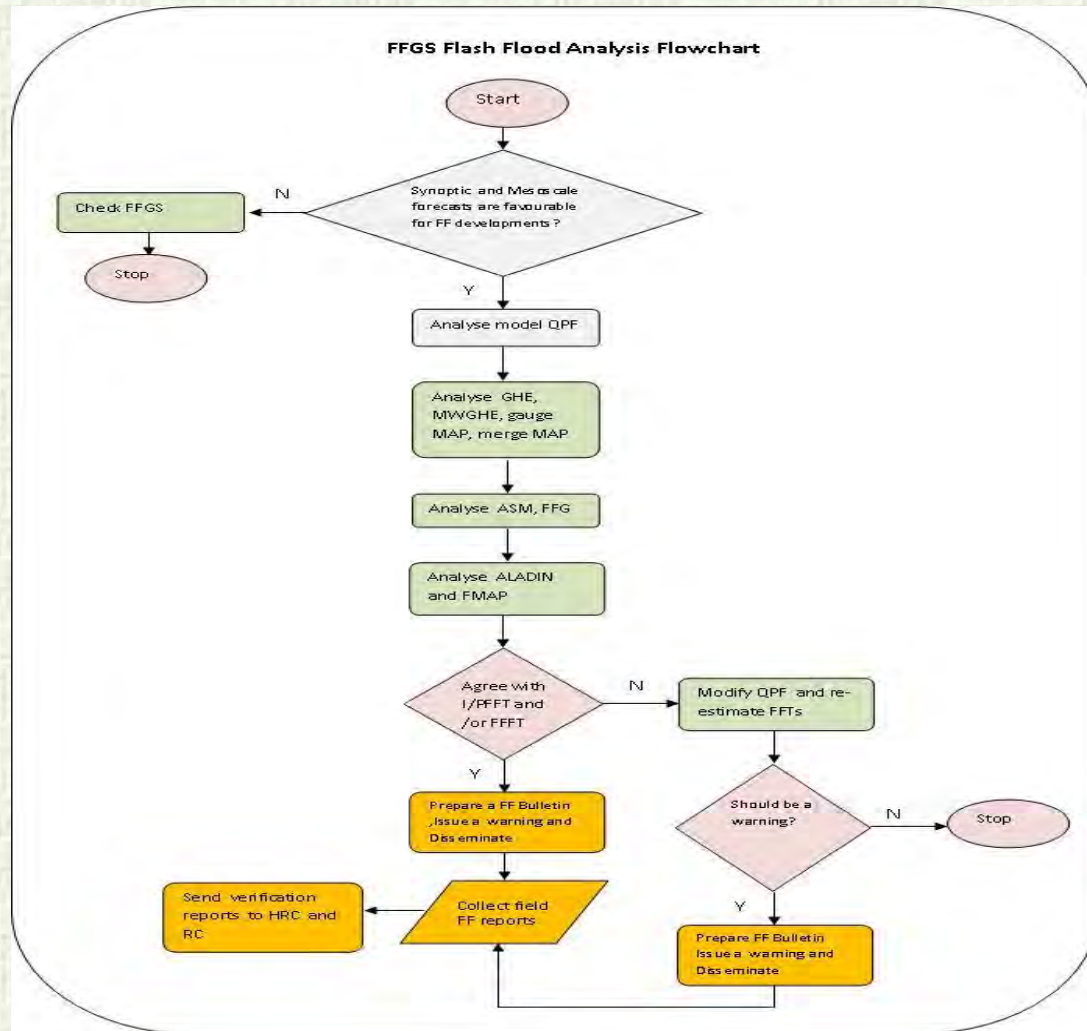


- The worst flood events in more than one hundred year,
- More than 36 people were killed in the SEE region,
- Billions of Dollars of property damages.



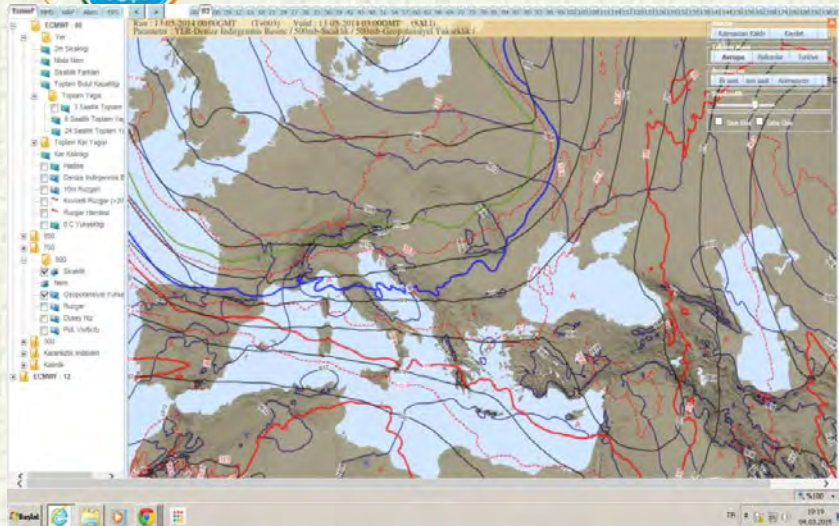


# FFGS Flash Flood Analysis Flowchart



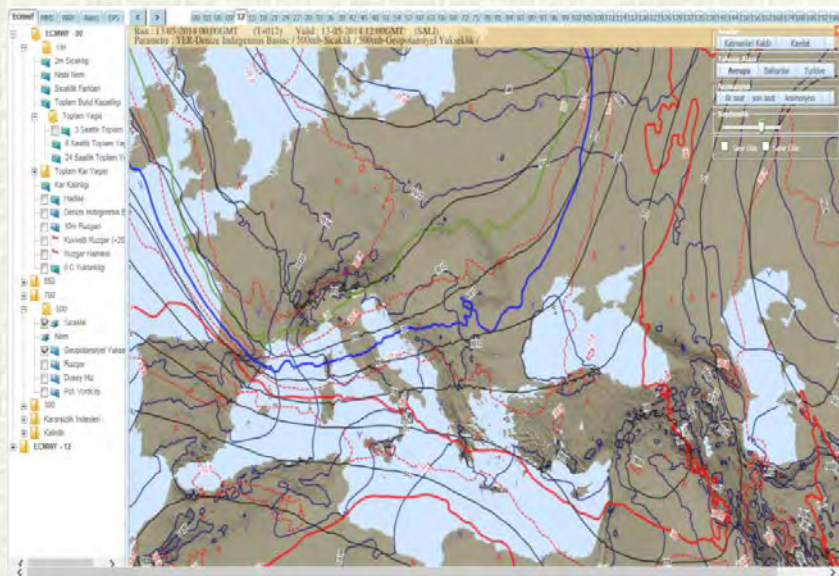


# Synoptic Analysis, 13.05.2014 00UTC: 500 hPa + Surface



For the case study top-down hydrometeorological Analysis from synoptic scale to hydrological scale e.g., sub-basin was conducted.

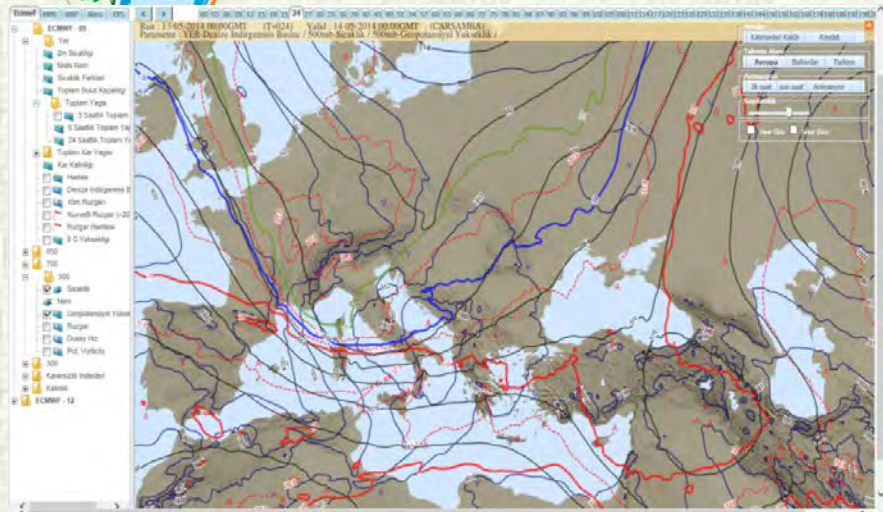
ECMWF 500 hPa geopotential height, temperature, and surface pressure forecasts for +03hr, +12hr were shown from on 13.05.2014 at 00UTC. At 00+03hr (top) a wide trough was located over the central Europe with a value of 558 hPa over the southeast Europe while 500 hPa -25 °C (green) and -20 °C (blue) isotherms were situated over the central and southern Europe indicating existing of upper cold air. On the surface, a low pressure center with a value 1012 hPa of was located in the northern Italy and Adriatic Sea.



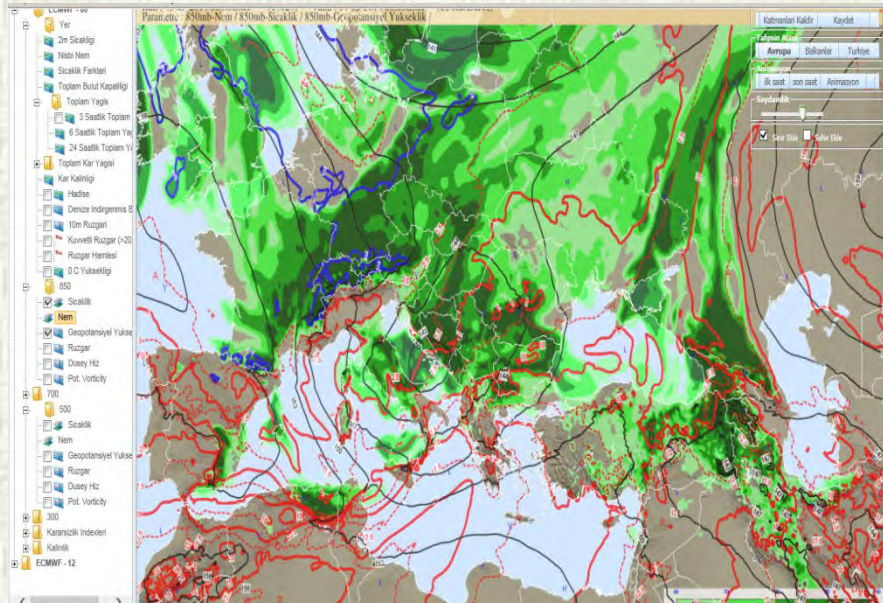
At 00+12h, 500 hPa trough was more pronounced over the southern Europe with a value of 552 hPa while -20 °C (blue) -25 °C (green) isotherms were located over the southern and southeast Europe, respectively. Surface low pressure center had the same value as +3hr but extended eastward.



# Synoptic Analysis: 850 hPa



At 00+24h (top), 500 hPa trough moved southward over Italy having tighter geopotential contours and pronounced convergence and divergences behind and ahead of the trough while -20 °C (blue) -25 °C (green) isotherms moved over southward indicating that cold polar air was sinking southward. Surface low pressure center, 1008 hPa, was located ahead of the trough in the mid-tropospheric divergence zone over Adriatic Sea.

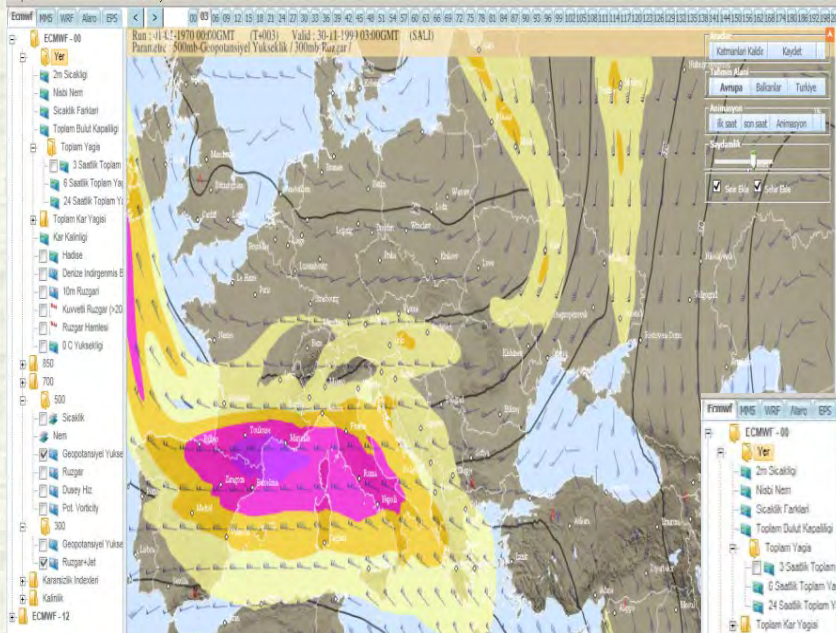


Up to +24h ECMWF forecasts indicated that a strong Mediterranean depressing was formed indicating that it was very likely to produce heavy to very heavy precipitation over the south eastern Europe.

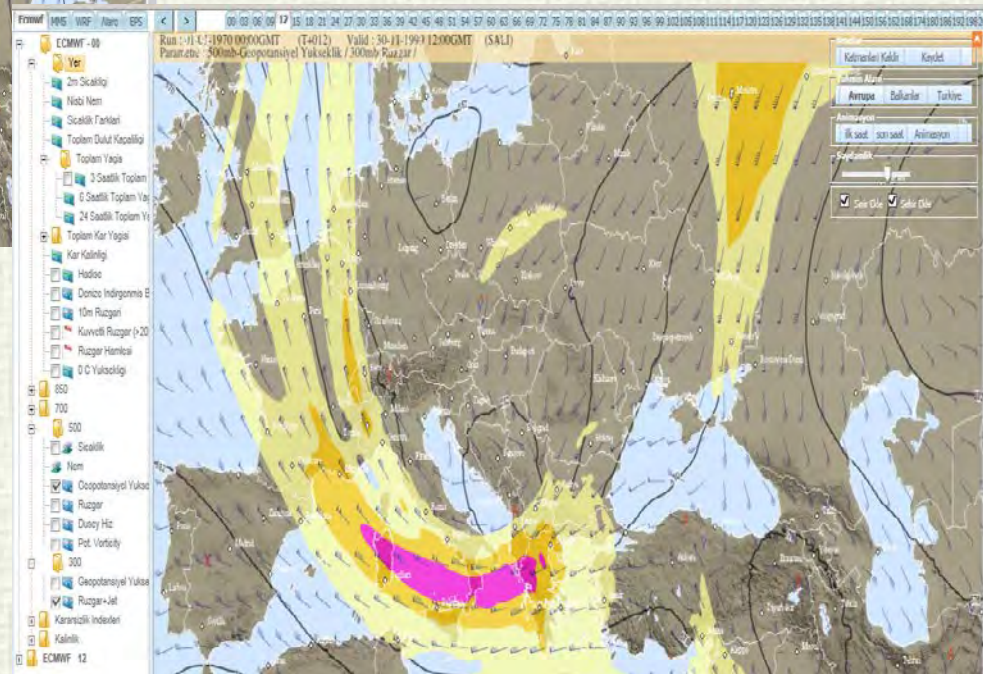
To find out the lower troposphere conditions, 850 hPa fields ( e.g., geopotential, temperature, moisture, advection) should be investigated for the forecasts periods. At 00+24h (bottom), 850 hPa low center with a value of 144 hPa was located over the northern Adriatic Sea. Isotherms show that cold air (5 °C and less) was situated behind the low center while warm air (10 °C an more) was situated ahead of low center. It should be noted that low troposphere was very humid over SEE and central Europe (green).



# Synoptic Analysis: Jet Stream

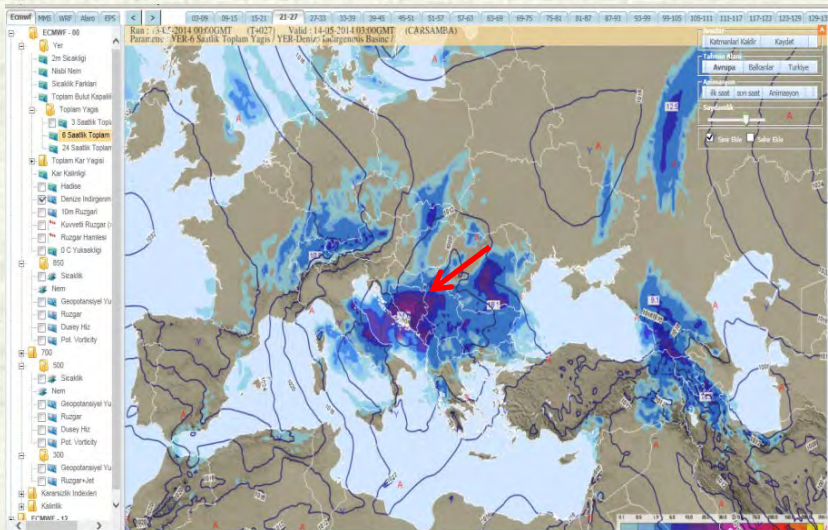
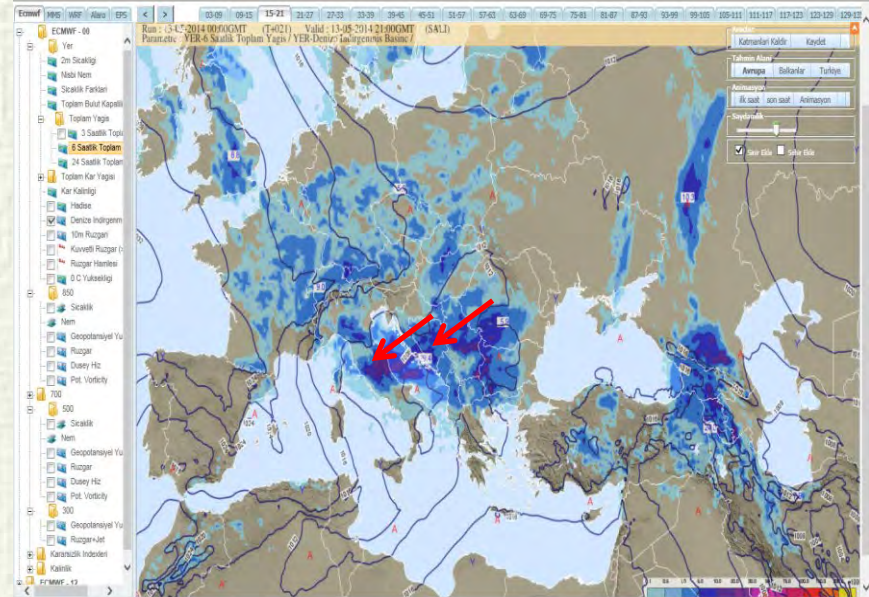
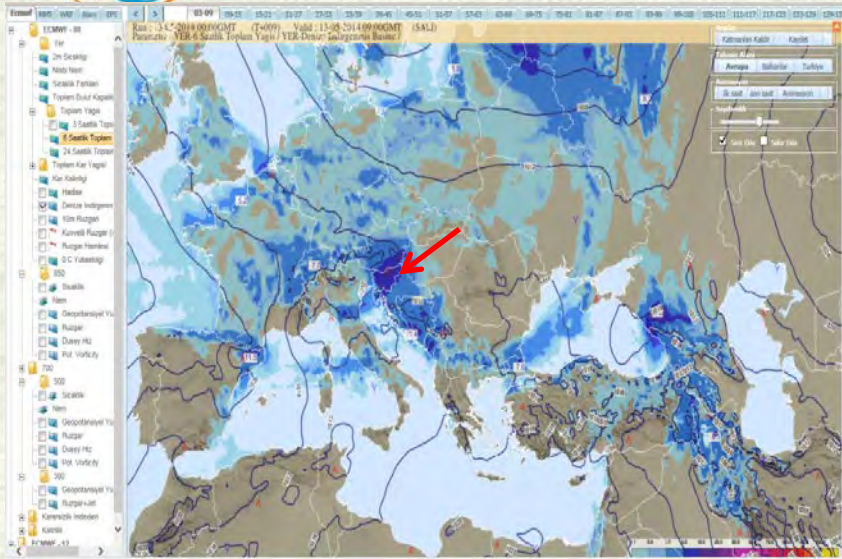


At 00+3h and +24h jet stream analysis shows that jet cores with the values of 120 knots and 100 knots were located over the northern Mediterranean region and southern Italy, bringing cold polar air to the mid-latitudes.





# Synoptic Analysis: ECMWF QPF



At 00 UTC on 13.05.2014, 3-9h (top left), 15-21h (top right), 21-27h (bottom left) ECMWF 6-hr precipitation forecasts show that approximately 30 mm precipitation core was located Slovenia, then moved southward over central Italy and finally to Bosnia Herzegovina with a maximum value of 34mm.

Analysis at 00 UTC, 13.05.2014, depicted that a central Mediterranean depression existed and it was very likely that SEE would be affected by heavy precipitation next 24 hours. Watch out !!!





# Synoptic Analysis, 14.05.2014: 500 hPa + Surface



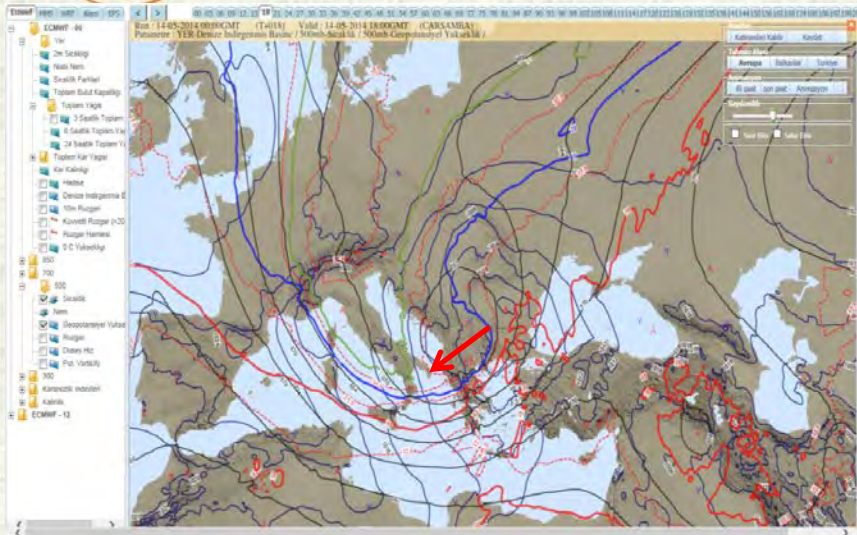
So, we continue to watch weather developments in the region.

ECMWF 500 hPa geopotential height and temperature and surface pressure forecasts for +03h, were shown on the 14<sup>th</sup>, May, at 00UTC. At 00+03h (top) the trough moved southward over southern Italy causing tight geopotential gradients. Low center had a value of 552 hPa and the trough was tilted south west slightly. Cold air associated mid troposphere air mass migrated to the south. Surface low pressure center was located offshore of Bosnia and Herzegovina with a value of 1004 hPa.

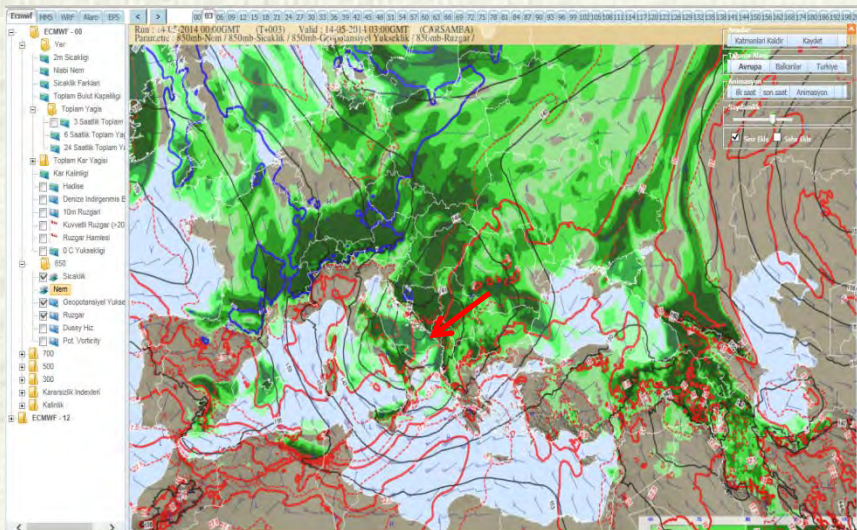
At 00+12h, 500 hPa trough moved over Bosnia and Herzegovina, Albania and Serbia and became cut-off with a low center value of 552 hPa while -20 °C (blue) -25 °C (green) isotherms propagated with the depression over SEE. Likewise, surface low pressure center moved eastward having a value of 1000 hPa.



# Synoptic Analysis: 850 hPa



At 00+18h, 500 hPa trough propagated eastward and located over SEE with a cut-off value of 552 hpa, while -20 °C (blue) isotherm was curving around the low center and -25 °C (green) isotherm was extending over the southern Italy. Surface low pressure center moved eastward over Bulgaria having a value of 1000 hPa.



At 00+03h (bottom), 850 hPa low center with a value of 138 hPa was located over the Bosnia and Herzegovina and Adriatic Sea. Cold Air Advection (CAA) occurred behind the low center while Warm Air Advection occurred ahead of the low center. Moreover, humidity over SEE region was very high (green). Up to +24, the low center propagated over Romania becoming deeper, 132 hPa, and region became more humid.



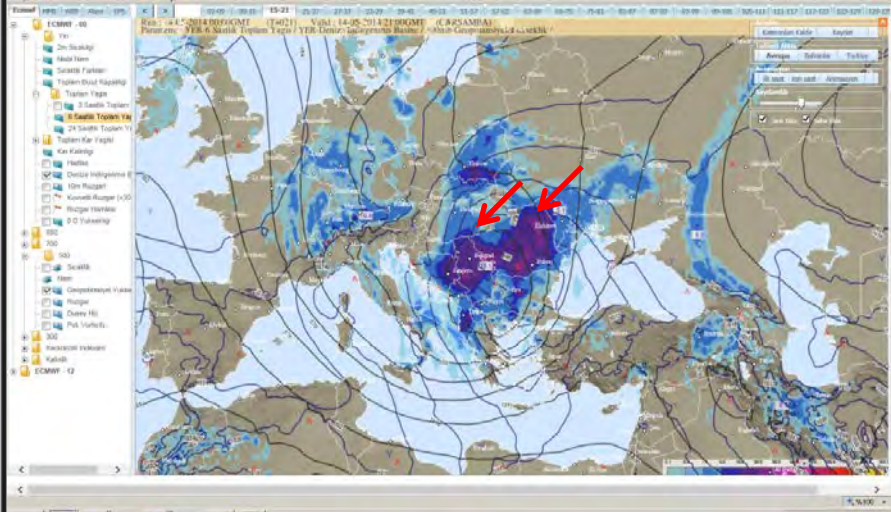
# Synoptic Analysis: ECMWF QPF

At 00UTC on 14.05.2014, +3-9h (top ) ECMWF QPF shows that there are two distinct precipitation cores having a maximum value of more than 30 mm. One of which was located over Bosnia and Herzegovina, Serbia and other one was located over Albania.

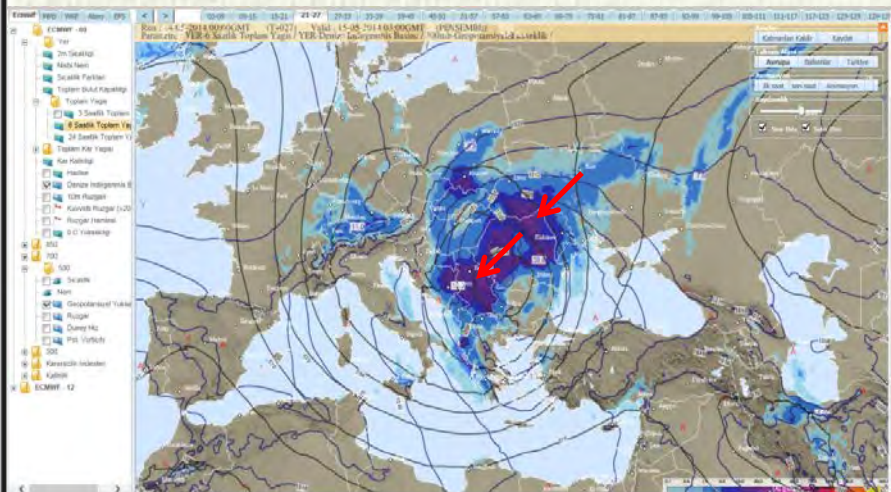
+9-15h QPF shows that precipitation pattern extended west to east from Adriatic Sea to southern Romania and western Bulgaria but the cores with more than 40 mm values remained over Bosnia and Herzegovina, Serbia and Albania.



# Synoptic Analysis: ECMWF QPF



+15-21h (top) and +21-27h QPF show that precipitation pattern extended to the northeast from Bosnia and Herzegovina to Romania having maximum values of 38.1 mm and 25.6 mm, respectively.

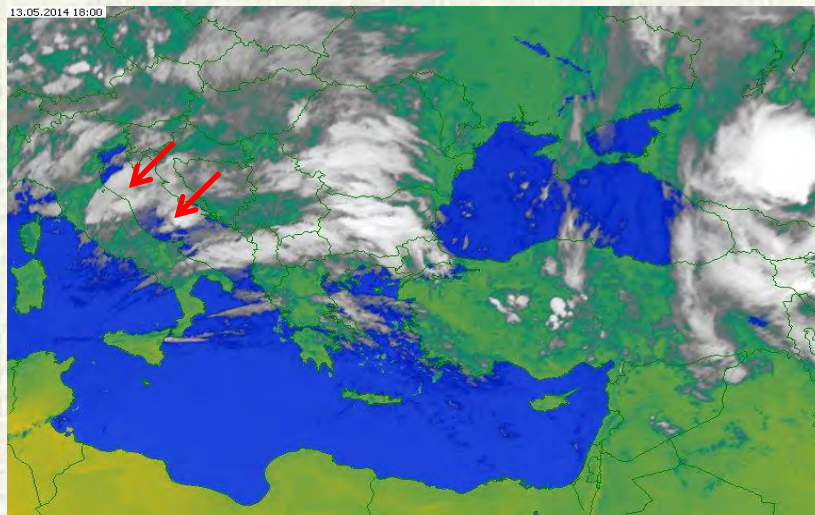
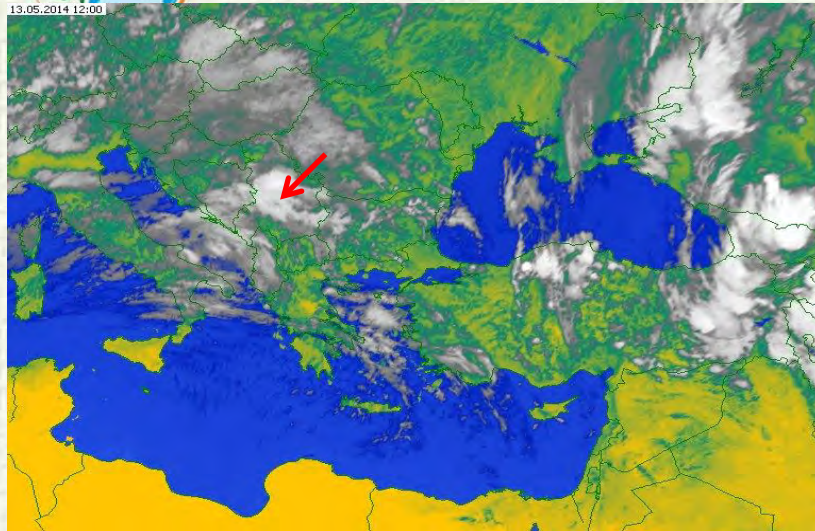


ECMWF forecasts on 13.05.2014 00Z and 14.05.2014 00Z depict that a central Mediterranean depression would affect the SEE region and would produce intensive precipitation in the region up to +24 hours with 6 hourly maximum precipitation values of approximately 50 mm.





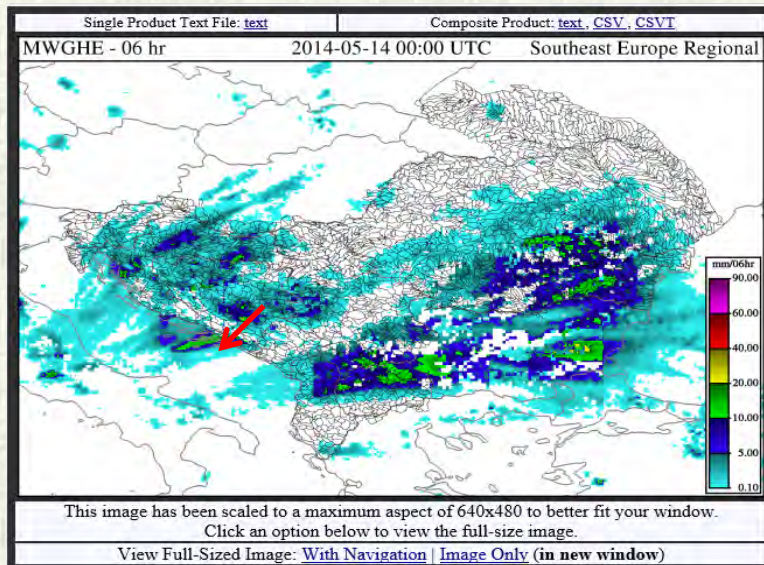
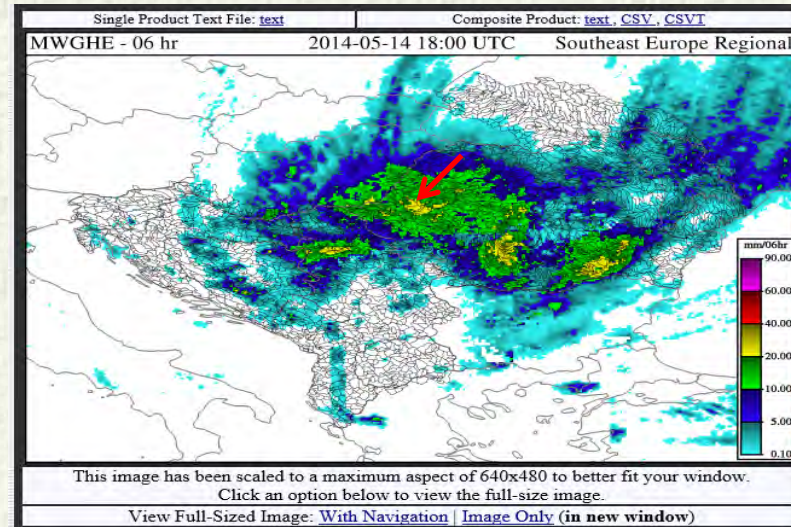
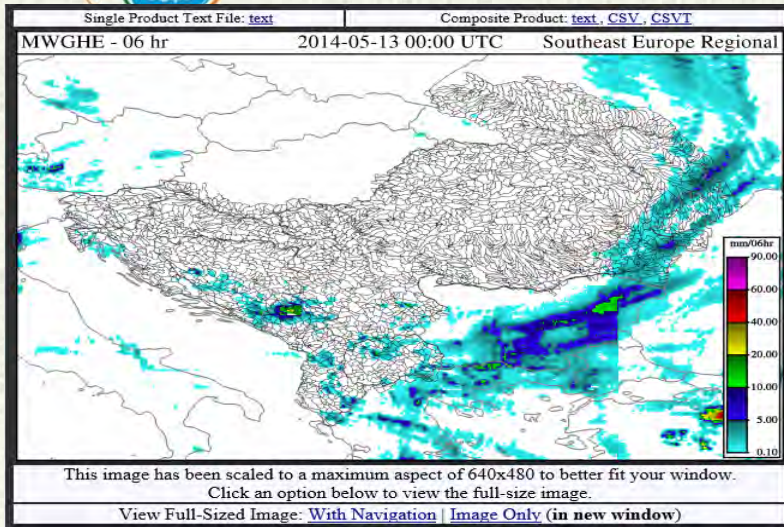
# Synoptic Analysis: Satellite Images



EUMETSAT MSG images on 13.05.2014 at 12UTC (top) and at 18 UTC (bottom) show cloudiness over SEE in grey scale. It should be noted that Cb (Cumulonimbus) clouds that are associated with convection exist along the Adriatic Sea coasts of Albania, Bosnia and Herzegovina and Croatia could be due to both frontal and orographical lifting.



# SEFFG Products: MWGHE (Satellite Precipitation)

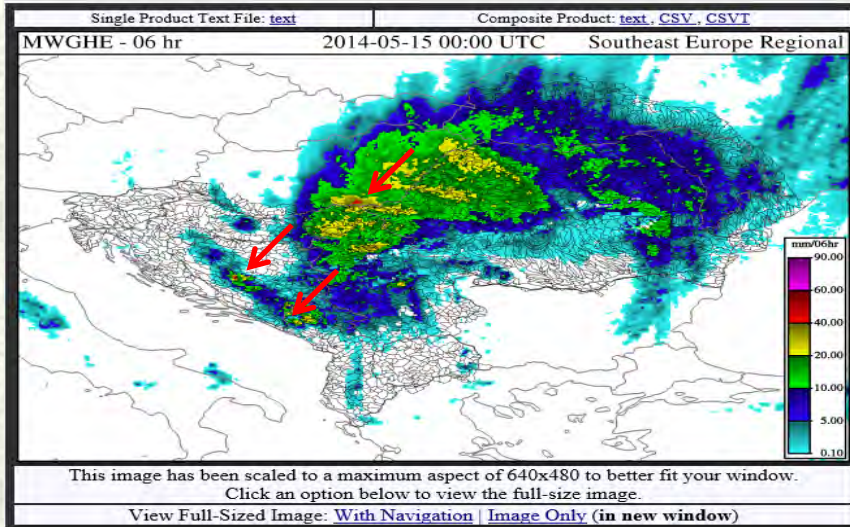


Now SEFFG diagnostic products are to be investigated to find out hydrological responses of catchments.

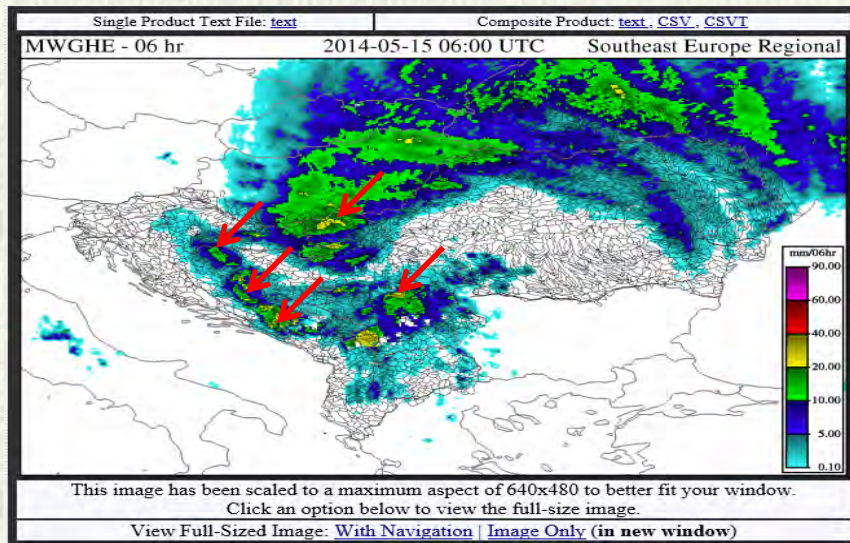
6-hr microwave adjusted GHE is a global satellite precipitation retrievals by NESDIS shows that on 13.05.2014, 00UTC (upper left) there was very little rainfall in SEE. On the other hand, 14.05.2014 00UTC (bottom left) maximum precipitation accumulation was up to 10-20 mm and then at 18UTC (upper right) it was 20-40 mm.



# SEEFFG Products: WMGHE



On 15.05.2014 00UTC (top) precipitation area extended to the northeast having maximum values of **40-60 mm** over Bosnia and Herzegovina and Serbia (red).

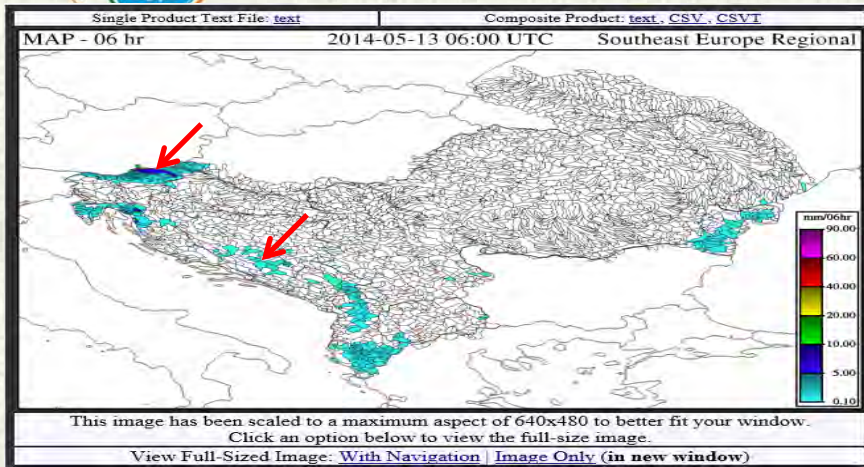


At 06UTC (Bottom), 6-hr precipitation intensity reduced over last six hours but rainfall continued in a patchy way over Bosnia and Herzegovina and Serbia (red arrows) having maximum values of **40-60 mm**.

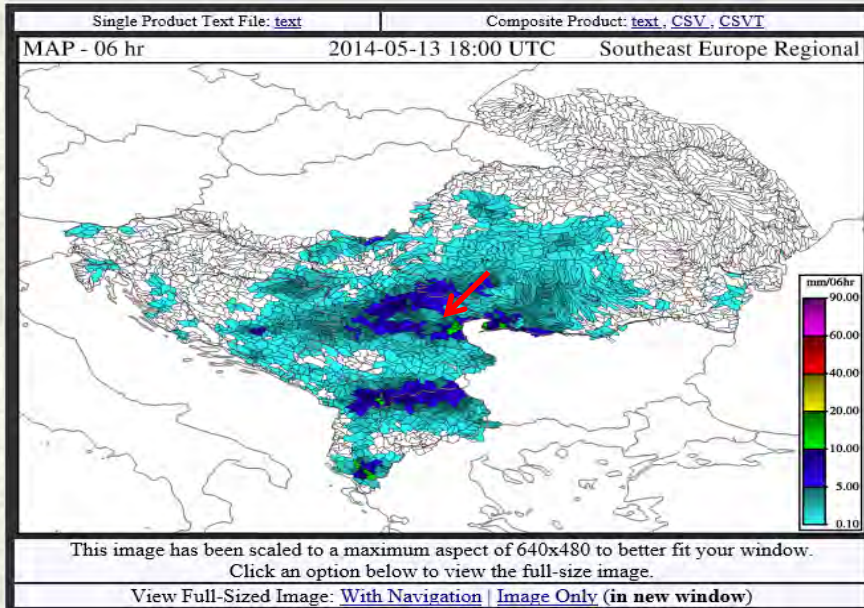
As it is obviously seen that MWGHE precipitation temporal and spatial distributions were in line with the ECMWF QPF forecasts with varying precipitation intensity.



# SEFFFG Products: Merged MAP



Merge MAP, which is the final precipitation product that is ingested into various FFGS models e.g., SNOW-17, SAC-SMA, FFG, estimated from bias adjusted MWGHE or bias adjusted GHE or the gauge interpolations. MAP is mean areal precipitation for each sub-basin.

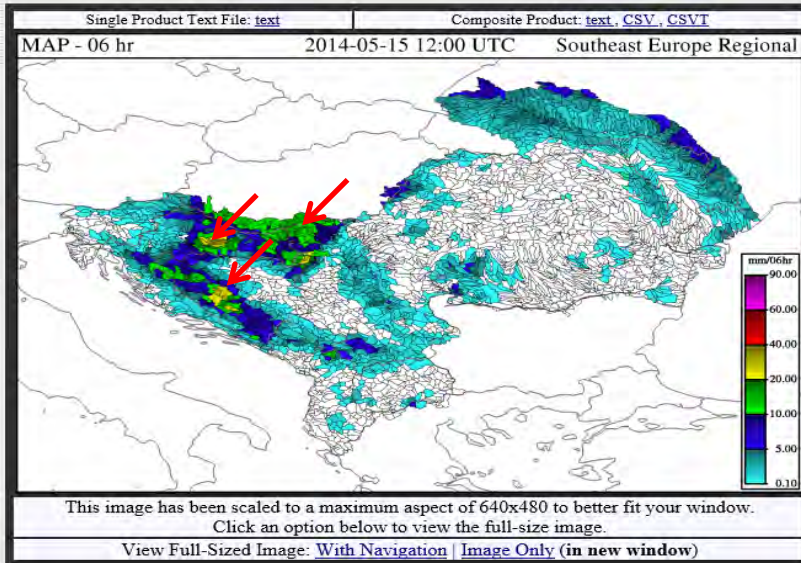
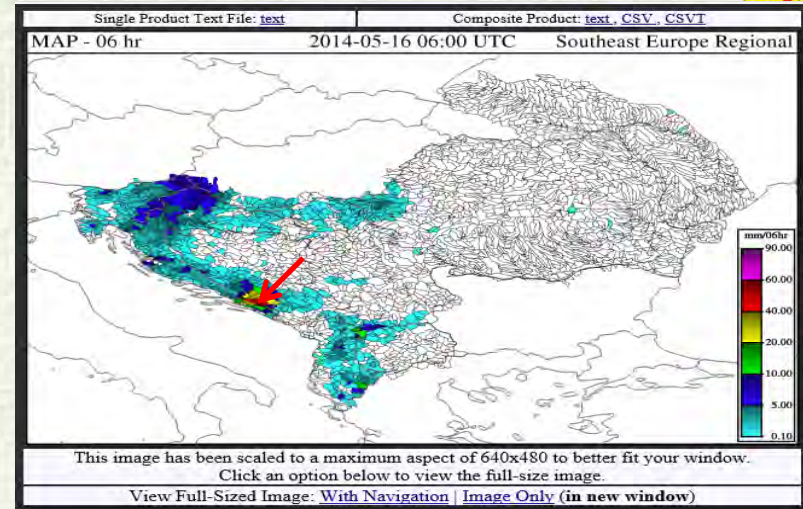
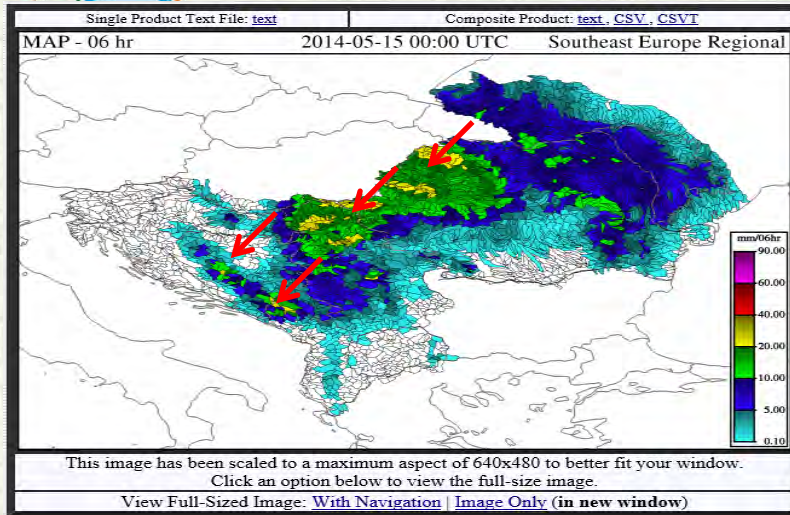


On 13.05.2014 at 06UTC (top), **5-10 mm** MAP (dark blue) existed over Croatia and **0-5 mm** (light blue) MAP existed over Bosnia and Herzegovina and Albania and southeast Romania.

On the other hand, 13.05.2014 at 18UTC (bottom), precipitation pattern moved to the east and spatial distribution was extended over central SEE having maximum values of **10-20 mm** over Serbia (green).



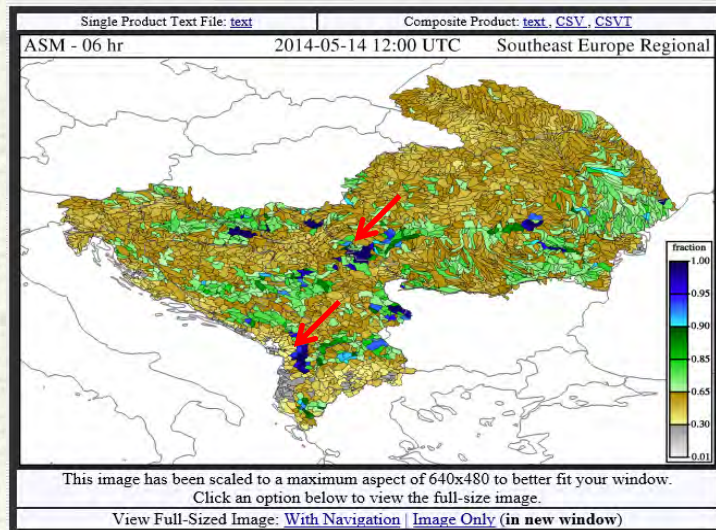
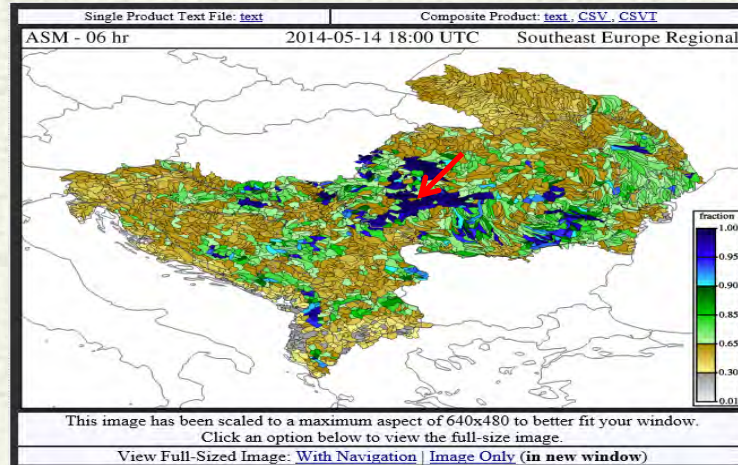
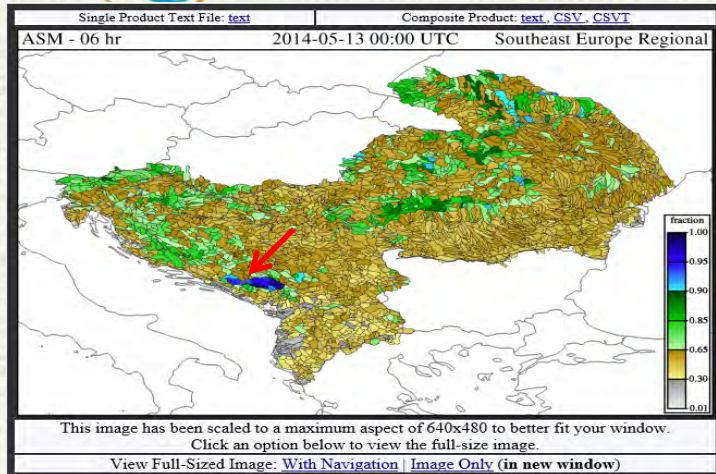
# SEEFFG Products: Merged MAP



15.05.2014 at 00UTC (top left), **20-40 mm** MAP (yellow) existed over Bosnia and Herzegovina, Serbia and western Romania, while at 12 UTC (bottom left) MAP remained over the same region except western Romania and had the same magnitude. On the other hand, 16.05.2015 at 00UTC (top right), MAP diminished in Serbia and Romania and move to Croatia and to the Adriatic coast of Bosnia and Herzegovina having maximum MAP values of **40-60 mm** (red).



# SEEFFG Products: ASM

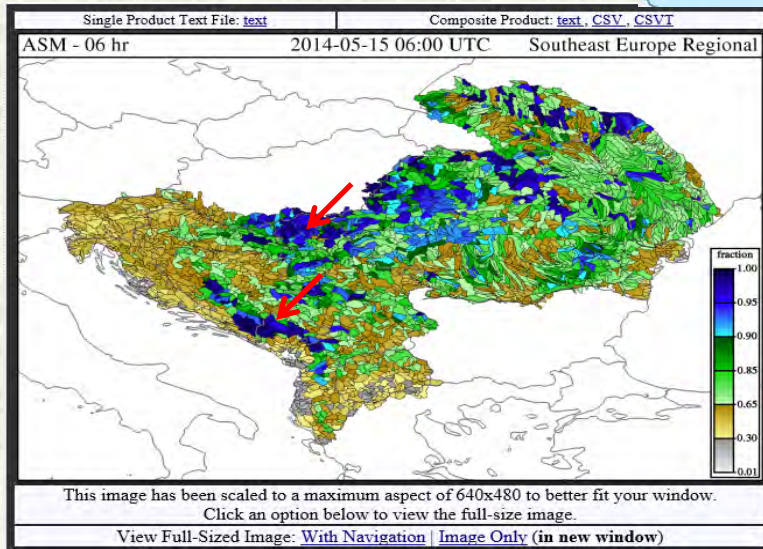
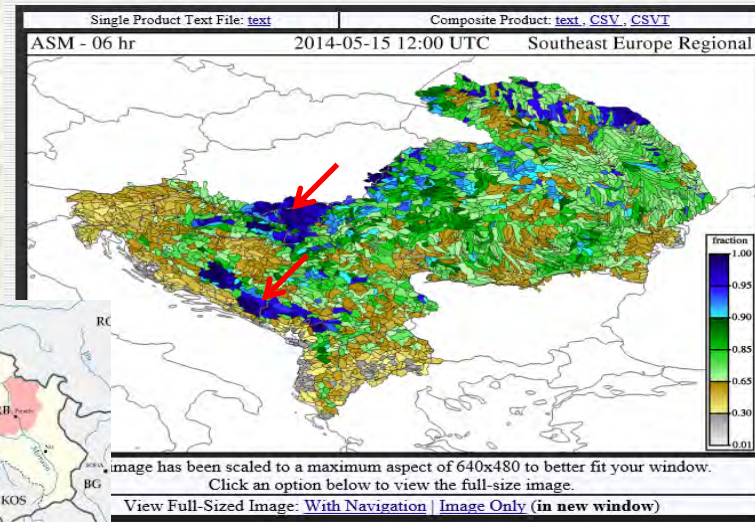
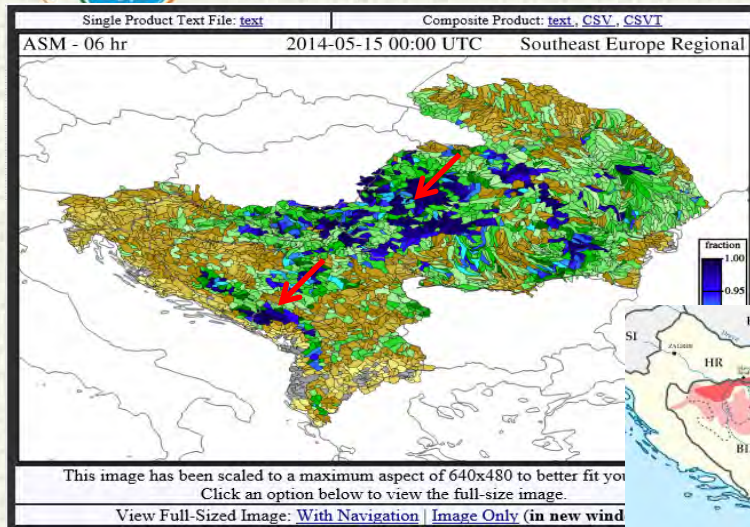


ASM (Average Soil Moisture) is a direct output of SAC-SMA model and shows upper soil (20-30 cm) moisture deficit fraction. Saturation of the upper soil is critical for the flash floods occurrences depending on other parameters e.g., topography, slope, vegetation.

Spatial and temporal distribution of 6-hr ASM are shown on 13.05.2014 at 00UTC (upper left), 14.05.2014 at 12UTC (bottom left) and 18UTC (upper right), indicating that upper soil was saturated (dark blue) rapidly in Bosnia and Herzegovina, Albania, Serbia and western Romania.



# SEFFG Products:ASM

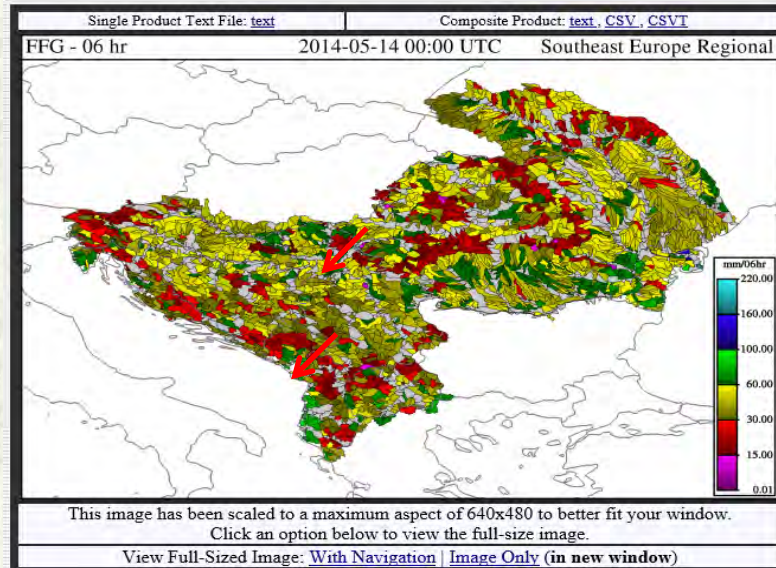
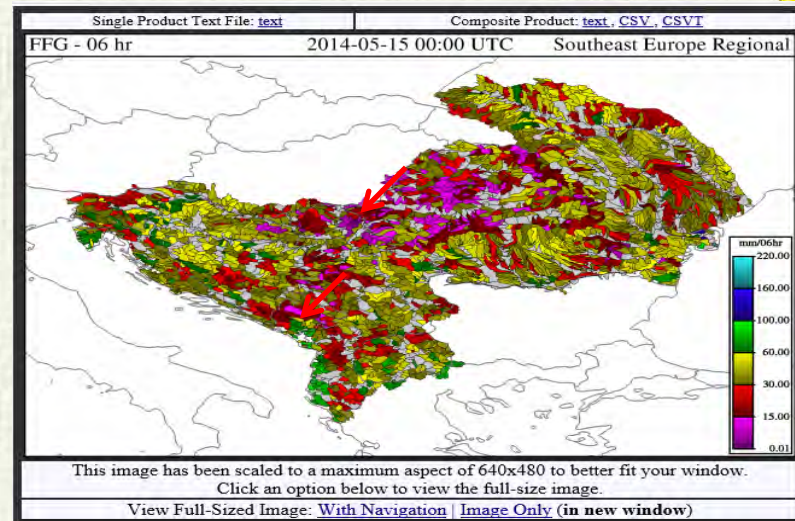
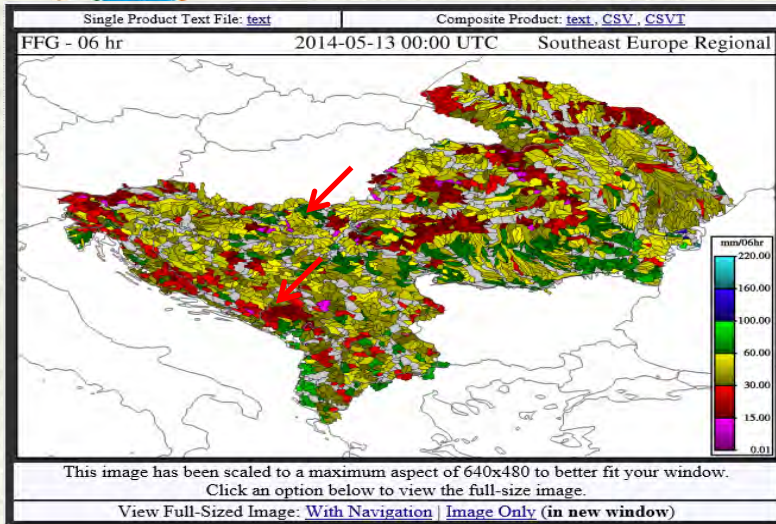


On 15.05.2014 at 00UTC (upper left), 06UTC (bottom left), and 12UTC (upper right), ASM images show that more sub-basin upper soil saturated associated with continues rainfall in the region. Particularly, sub-basins in Bosnia and Herzegovina and northern Serbia were remained saturated up to 24 hours making the region very vulnerable to flash flood occurrences.

Just to show the correlation between soil saturation for flash floods, the most effected regions are shown in the middle image obtained from a newspaper overlap with the saturated sub-basins.



# SEEFFG Products: FFG

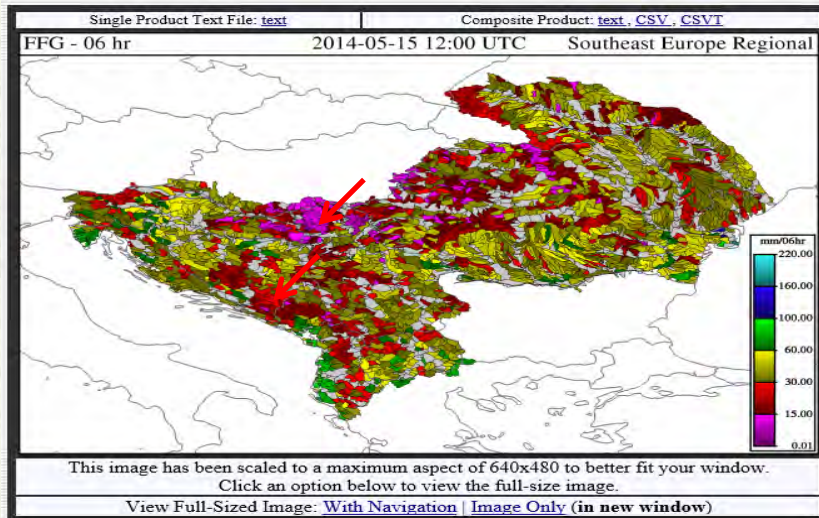


Flash Flood Guidance (FFG) is the actual rainfall that may cause just bankfull at the outlet of a sub-basin for a given duration. 1-hr, 3-hr and 6-hr FFG values are estimated at model runtimes 00, 06, 12 and 18 UTC. It is a function of threshold runoff, and soil moisture deficit. The lower FFG, the higher the occurrences of flash floods.

6-hr FFG products show that FFG values significantly decreased from 13.05.2014 00UTC (upper left) to 15.05.2014 00UTC from predominantly 30-60 mm (yellow) to 0-15 mm (purple).

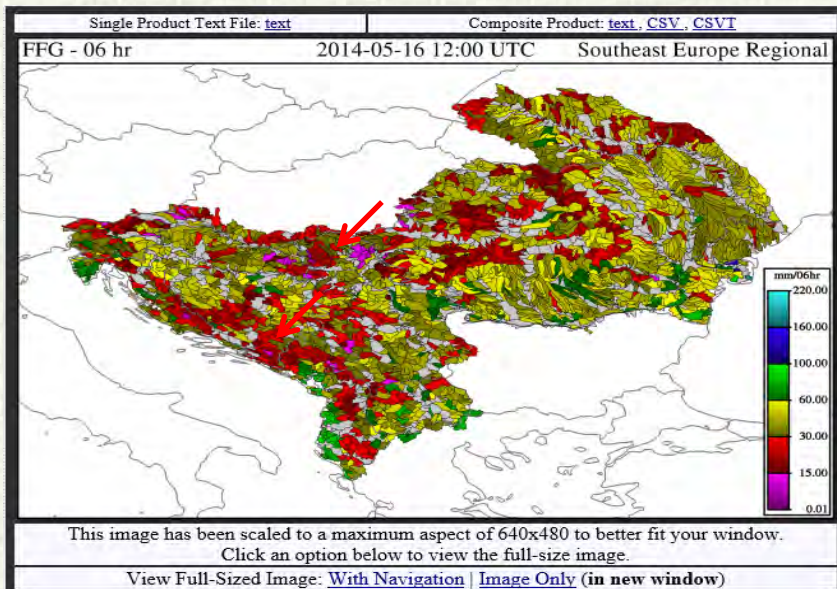


# SEEFFG Products: FFG



15.05.2014 at 12UTC (top), 6-hr FFG values reached their minimums with **0-15 mm** (purple) and **15-30 mm** (red) over the northern Serbia, Bosnia and Herzegovina, and western Romania, respectively.

On the other hand, 6-hr FFG values increased significantly on 16.05.2014 at 12UTC (bottom) indicating that precipitation was reduced considerable in the region.

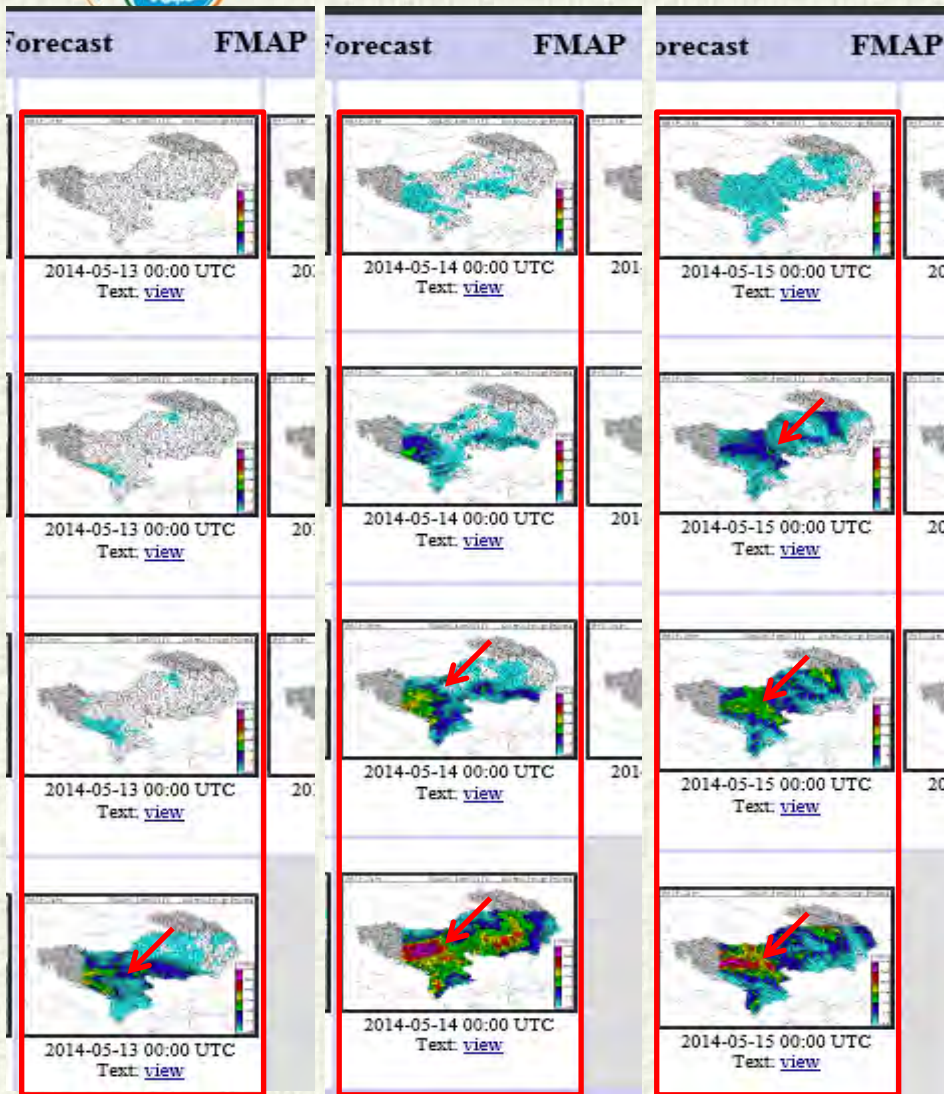


So, forecasters must monitor and compare spatial and temporal distribution and variation of FFG with mean areal distribution of rainfall e.g., merge MAP or forecast MAP which are generated from different QPF models like ALADIN or WRF to find out whether or not excess amount of rainfall to occur in a particular sub-basin such that;

merged MAP – FFG= I/P Flash Flood Threats  
OR  
forecast MAP - FFG= Forecast Flash Flood Threat



# SEEFFG Products: Forecast MAP



So, let's investigate forecast MAP estimated from ALADIN QPF of TSMS, which was available at that time but currently merged ALADIN QPF from Croatia and Turkey are used, to find out QPF spatial and temporal variations from 13th May to 15th May.

13.05.2014 at 00UTC (first column), FMAP shows that 24-hr precipitation accumulation was **35-50 mm** (yellow).

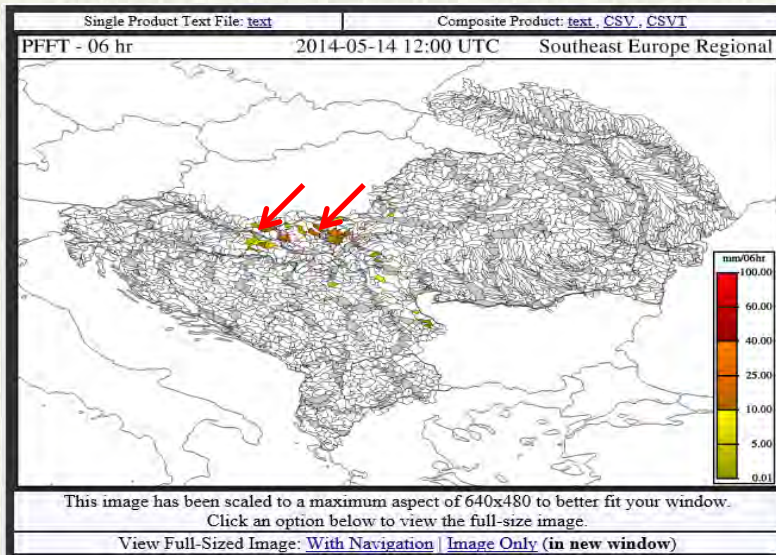
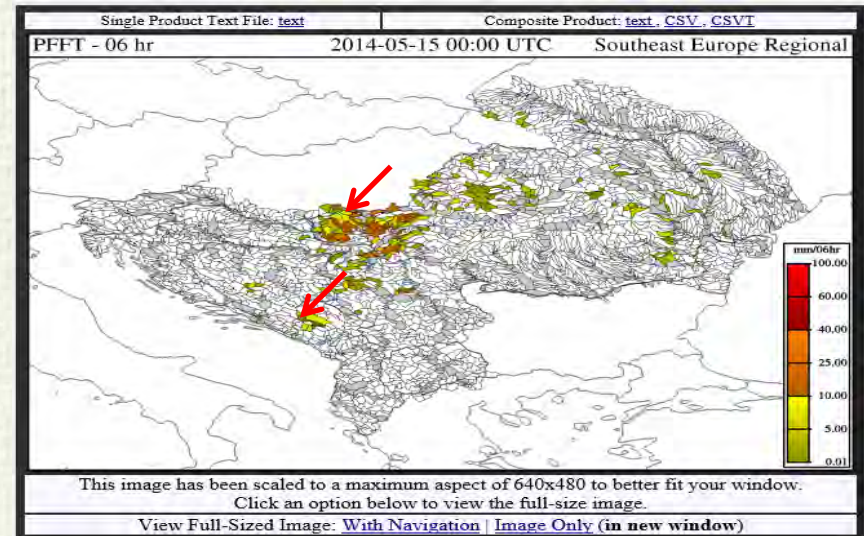
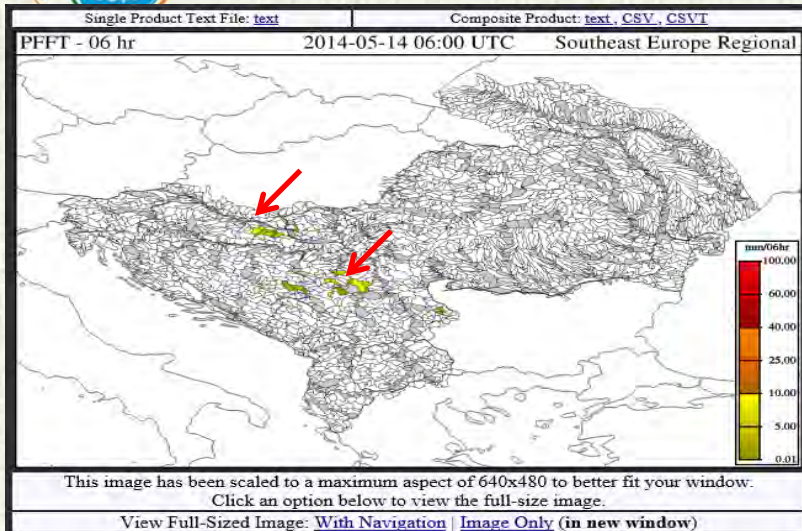
However, on 14.05.2014 at 00UTC (second column), 6-hr FMAP values were **20-40 mm** (yellow) and 24-hr FMAP values were **75-120 mm** (purple) over Bosnia and Herzegovina and Serbia.

On 15.05.2014 at 00UTC (third column), 6-hr FMAP values were **20-40 mm** (yellow) and 24-hr FMAP values were **75-120 mm** (purple) over Bosnia and Herzegovina and Serbia.

**Thus, taking into account of FFG, ASM, merged MAP, and FMAP products and his/her own local forecasting experiences, one may conclude that occurrences of the flash floods in the region was very likely.**



# SEFFG Products: Persistence FFT

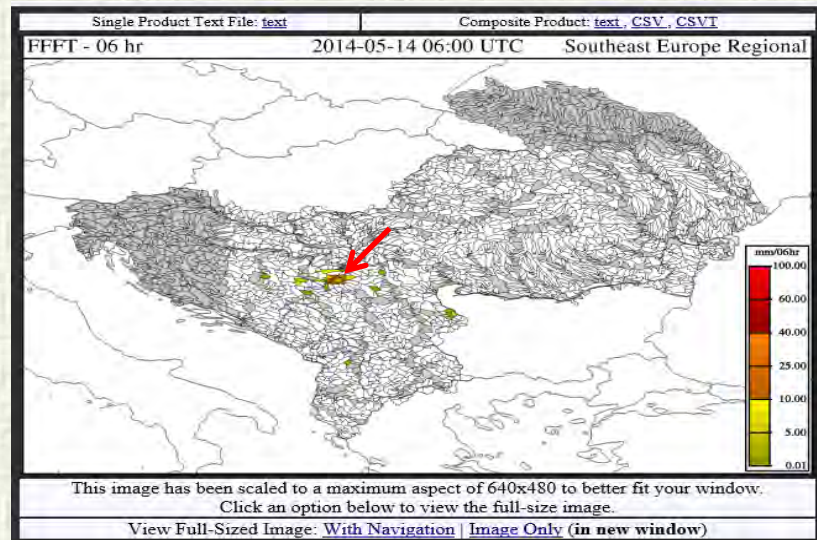
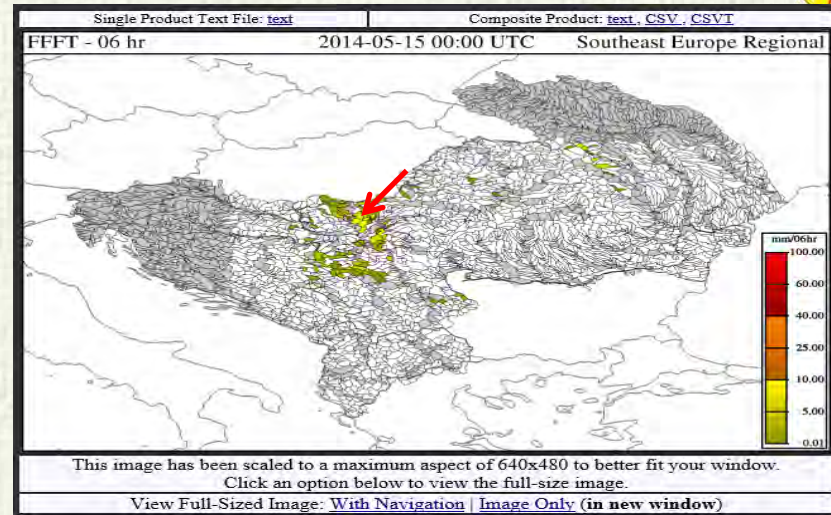
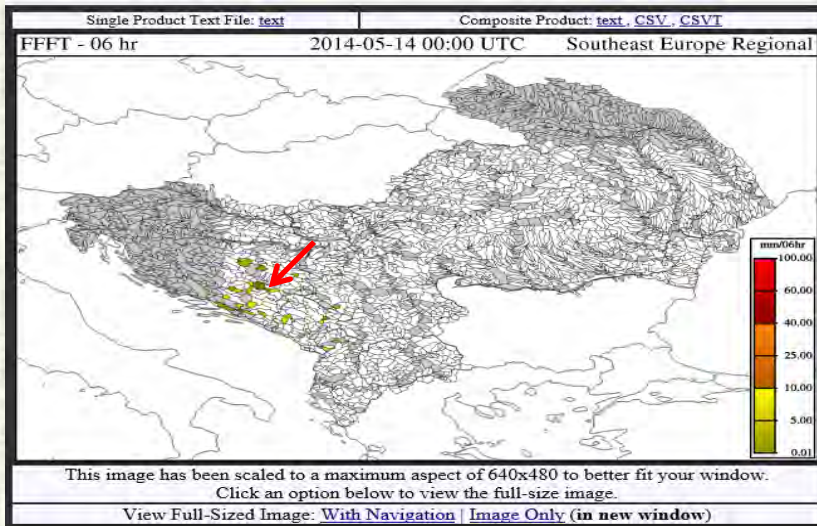


After reminding that,  
merged MAP – FFG= I/P Flash Flood Threats  
or  
forecast MAP - FFG= Forecast Flash Flood Threat

On 14.05.2014 at 06UTC (upper left), 6-hr PFFT existed over Bosnia and Herzegovina and Serbia and spatially extended and strength in the next 24 hours having maximum values of 0-10 mm (yellow), 10-40 mm (orange).



# SEFFFG Products: Forecast FFT



6-hr FFFT existed over Bosnia and Herzegovina on 14.05.2014 at 00UTC (upper left) having maximum values of **10-40 mm** (orange). On 14.05.2014 at 06UTC (bottom left), it propagated toward the east with the same maximum values and then moved to Serbia on 15.05.2014 at 00UTC, expanding its spatial coverage.





# FFG Summary Matrix



Products	Date: 14.05.2014		Time: 00 UTC	
	Status			
	1-hr	3-hr	6-hr	24-hr
GHE (Max , mm)	10-20	20-30	40-60	50-75
Merged MAP (Max, mm)	5-10	10-20	10-20	20-35
FMAP	0-5	10-20	20-40	75-120
ASM (compare last several periods)			Increasing (+)	
FFG (Region and amount (mm))	Adriatic Coast, Central Romania: 10-25 North and southern Romania : 40-60	Adriatic Coast, Central Romania: 10-25 North and southern Romania : 40-70	Adriatic Coast, Central Romania: 15-30 North and southern Romania : 30-60	
I/PFFT (mm)			+ (Romania) 0-10	
FFFT (mm)			+ (Bosnia and Herzegovina) 10-40	
Forecasters Opinion	FF watch/warning is advice for next 6 hours. In the next 24 hours heavy to very heavy precipitation is expected in the region.			

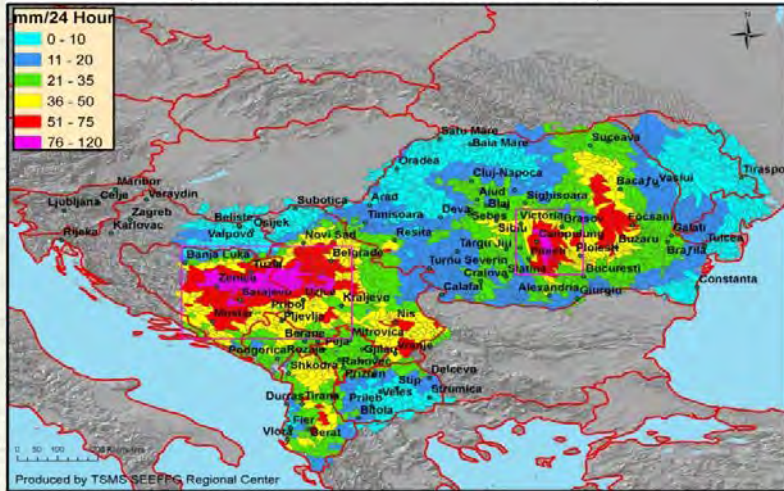




# SEEFFG Flash Flood Bulletin



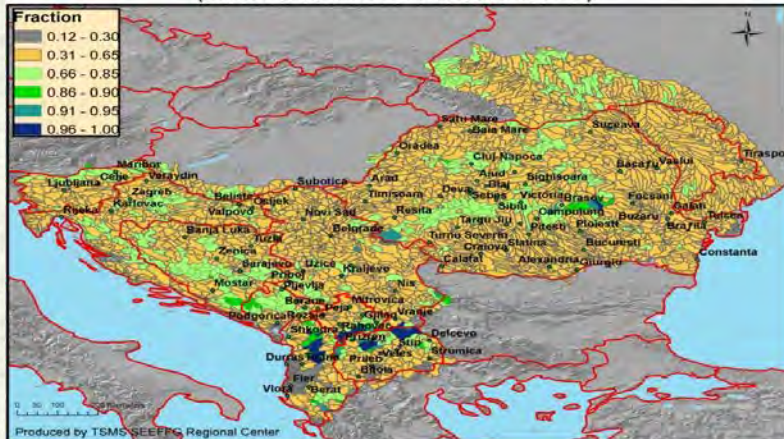
South East European Flash Flood Guidance System  
(FMAP 14.05.2014 00:00 UTC )



South East European Flash Flood Guidance System  
(FFFT 14.05.2014 00:00 UTC )



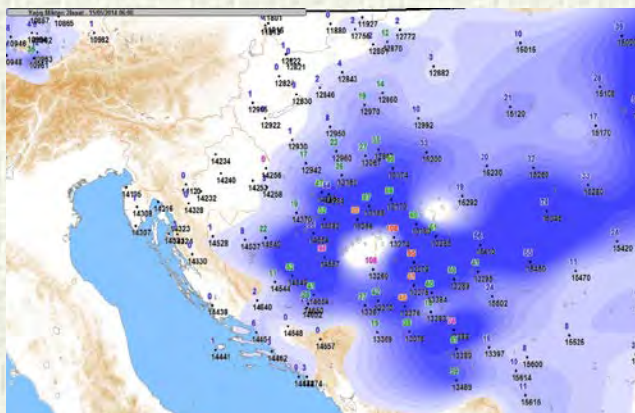
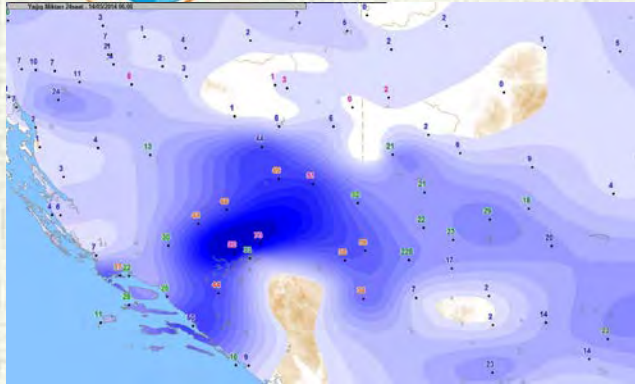
South East European Flash Flood Guidance System  
(ASM 14.05.2014 00:00 UTC )



It was advised to issue flash flood warning so that a SEEFFG flash flood Bulletin was to be prepared by using one of GIS tools and available raw data on the user interface page. For the 13-15.05.2014 flood events in SEE, Partial content of SEEFFG flash flood bulletin are shown. Then, Bulletin and/or warning text must be distributed to responsible organizations e.g., emergency management, municipality.



# Observations



24 Hour precipitation accumulation of some synoptic stations in Bosnia and Herzegovina

Location	13.May.14	14.May.14	15.May.14	16.May.14	17.May.14	18.May.14	Total
Tuzla	0,0	<b>49,2</b>	<b>107,0</b>	<b>89,6</b>	15,0	0,0	<b>260,8</b>
Zenica	0,1	<b>47,9</b>	<b>40,0</b>	<b>31,9</b>	4,9	0,8	<b>125,6</b>
Sarejevo	0,1	<b>72,6</b>	<b>32,0</b>	<b>13,4</b>	2,9	1,2	<b>122,2</b>
Ivan Sedlo	0,0	<b>79,7</b>	<b>20,0</b>	<b>7,1</b>			<b>106,8</b>
Banja Luka	1,4		<b>25,0</b>	<b>32,1</b>	36,0	0,4	<b>94,9</b>
Bihac	1,1	<b>4,1</b>	<b>1,0</b>	<b>25,4</b>	49,2	0,1	<b>80,9</b>
Bugojno	0,7	<b>43,7</b>	<b>14,0</b>	<b>14,3</b>	1,6	0,4	<b>74,7</b>
Bjelasnica	1,4	<b>33,2</b>	<b>21,0</b>	<b>11,4</b>	2,4	4,6	<b>74,0</b>
Mostar	0,0	<b>43,9</b>	<b>0,0</b>	<b>0,3</b>	0,6	0,4	<b>45,2</b>
Gradadac	0,0		<b>28,0</b>		13,3	0,0	<b>41,3</b>
Livno	0,0	<b>29,7</b>	<b>1,1</b>	<b>1,2</b>	0,3	0,0	<b>32,3</b>
Sanski Most	2,1	<b>12,7</b>	<b>10,0</b>				<b>24,8</b>
Neum	0,1	<b>0,0</b>	<b>0,1</b>	<b>0,0</b>	0,0	0,0	<b>0,2</b>

24-hr precipitation accumulations were shown in the images on 14.05.2014 at and 15.05.2014 at 06UTC, having maximum values of **80 mm** (upper left) and **108 mm** (bottom left). Moreover, 24-hr precipitations accumulation of some synoptic stations in Bosnia and Herzegovina were presented in the table indicating that Tuzla city received the most precipitation.



# Results: The most sever flood events in the last century



Would SEEFFG system be helpful to issue warnings and alerts in advance?  
Certainly Yes...





**Thank you for your kind Attention...**