WMO RAVI
Hydrological Forum 2016
Workshop on hydrological modelling, forecasting and warnings

Flash Flood Forecasting and Early Warnings in Romania

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Introduction

- In the last decades and especially in the last years a **general increase of the frequency of extreme flash flood events** have been reported, floods that generated significant damages and frequently also loss of lives.

- In particular in Romania, such extreme events occurred in different regions of the country, most of the time having catastrophic effects.

- Taking into account the perspectives of further increase of the frequency of such extremes events as results of the climate changes, **the needs for analysing and simulating the hydrological processes associated with flash floods events become more and more a priority for the scientific hydrological community**.

Introduction

- The Romanian National Hydrologic Forecast Centre is part of the National Institute of Hydrology and Water Management (NIHWM), and is in charge with the operational hydrological short-range, medium and long-range forecasts and flood warnings in Romania.

- At the basin-level (the main 11 River Basins) the short-range forecasts are downscaled by the River Basin Hydrological Forecasts Centres of the eleven branches of the Romanian Water National Administration.

- The methods and procedures used for the hydrological forecasts elaboration are specific to each hydrological forecast category and vary from empirical relations to complex models.

Introduction

The Romanian National Hydrological Forecasting and Modeling System is composed by specialized hydrological modeling modules, adequate for the real-time simulation and forecasting of hydrological processes evolution at different spatial and temporal scales:

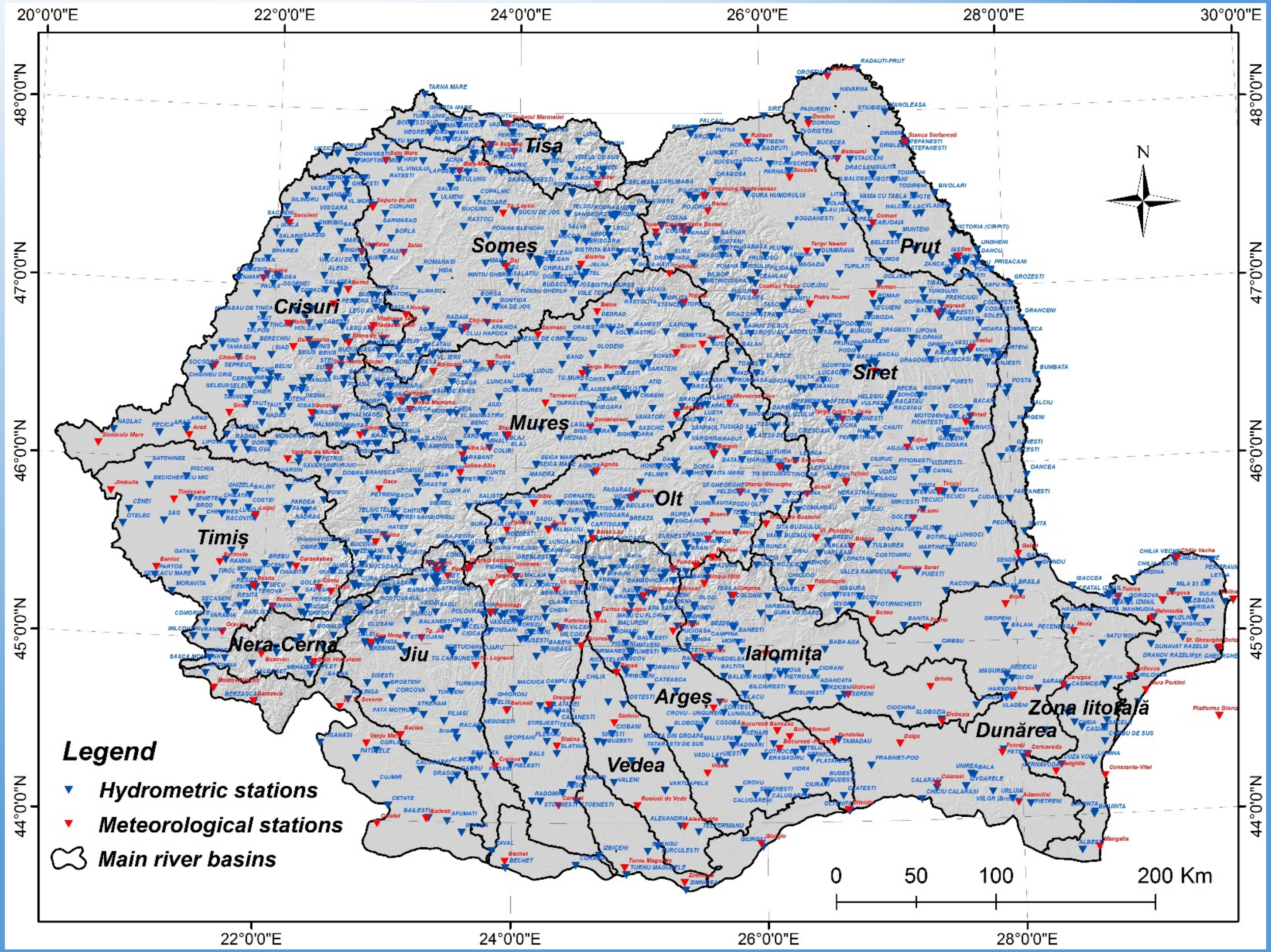
- The first main component of this hydrological modeling system is represented by a complete implementation of the National Weather Service River Forecasting System – USA (NWSRFS), that is used to elaborate hydrological forecasts, in an interactive way, for medium and large scale basins.
- The second component is the distributed modeling component, which is mainly based on the NOAH-R model, model that contains five primary interacting physical process sub-models, with a land surface model (LSM) which runs at the radar-scale (1km), and overland and channel routing model, nested within the LSM, at 100m resolution.
- **The system also includes a Flash-Flood Guidance component, which is an adaptation of the HRC Flash Flood Guidance System used in various regions of the world for operational flash floods warning support.**

Introduction

- Operational procedures for elaborating flash flood warnings are based on Information from the following main sources:
  - Radar products (rain intensities, different period rainfall accumulation products, 5 minutes updates)
  - Manual and automated hydrometric and meteorological stations.
  - Operational numerical meteorological forecasts – different resolutions / sources.
  - Operational hydrological forecasts from the National Hydrological Forecasting System (distributed model NOAH, RFS)
  - Romanian Flash Flood Guidance System (ROFFG)
  - South East Europe Flash-Flood Guidance System (SEEFFG)
  - European Flood Awareness System (EFAS)
  - Other informations/indices related with flash-flood potential / susceptibility.

National hydrometric and meteorologic station networks

- Includes a number of around 1000 manual and automated hydrometric stations, and 160 meteorological stations.
- The stations observations are also used in the operational activity for real time validation of radar precipitation.



General distribution of hydrometric and meteorologic stations in Romania

ROFFG – ROMANIA FLASH FLOOD GUIDANCE SYSTEM

(implemented by Hydrologic Research Center, San Diego, USA, within DESWAT national modernization project)

- **Provides products which contain indicative infomation in real time (with hourly updates) that can help to identify the watersheds where the flash-floods could occur. The watersheds included in ROFFG system have an average area around 30 km². In Romania, for ROFFG system were delineated a number of 8851 watersheds.**

- **the input data for ROFFG system includes:**
  - **hourly precipitations estimated from radar products;**
  - **amount of precipitations recorded at meteorogical and hydrometric stations;**
  - **values of air temperatures recorded at at meteorogical and hydrometric stations;**
  - **additional meteorological informations (snow depth and snow water equivalent).**

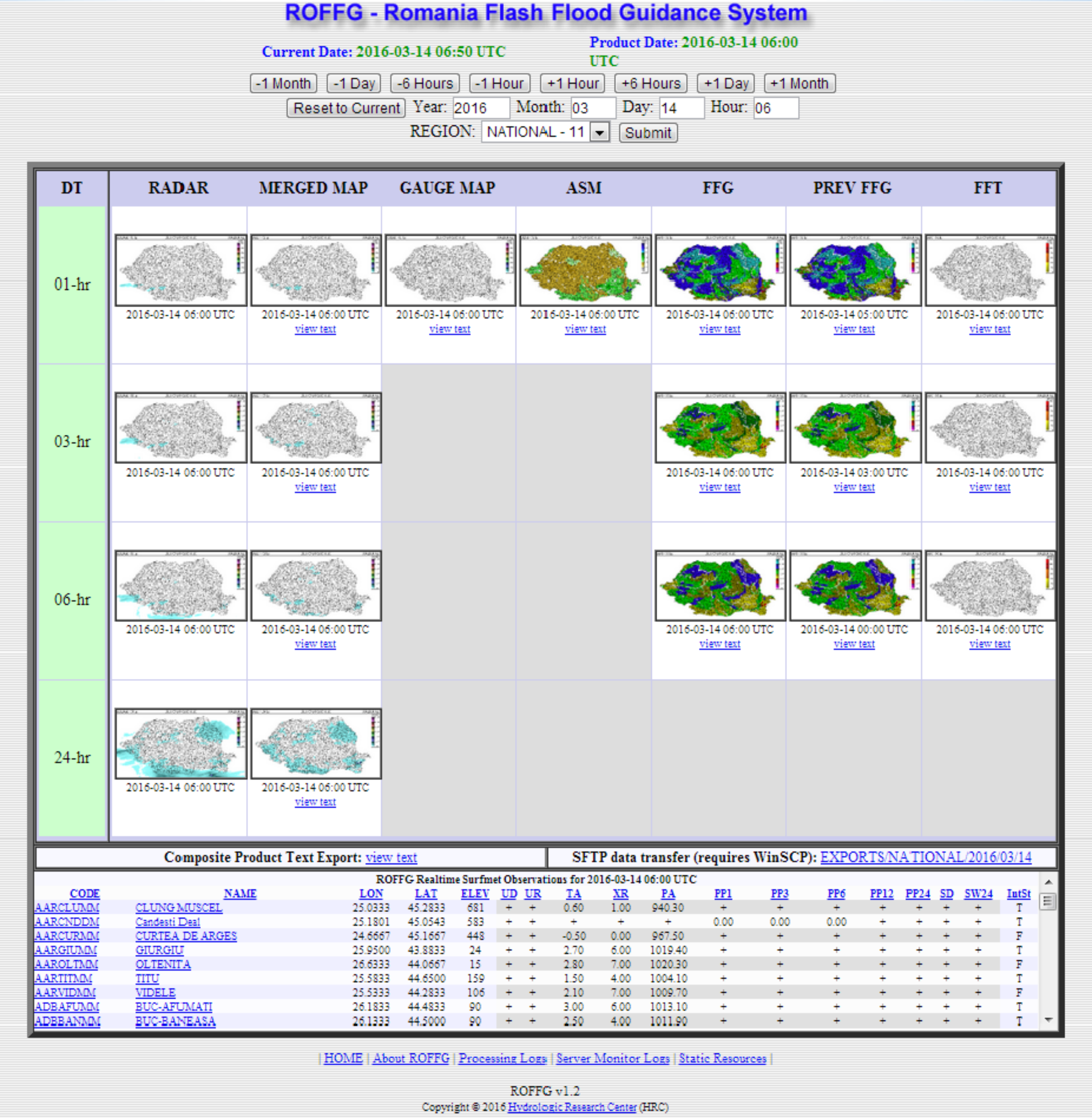
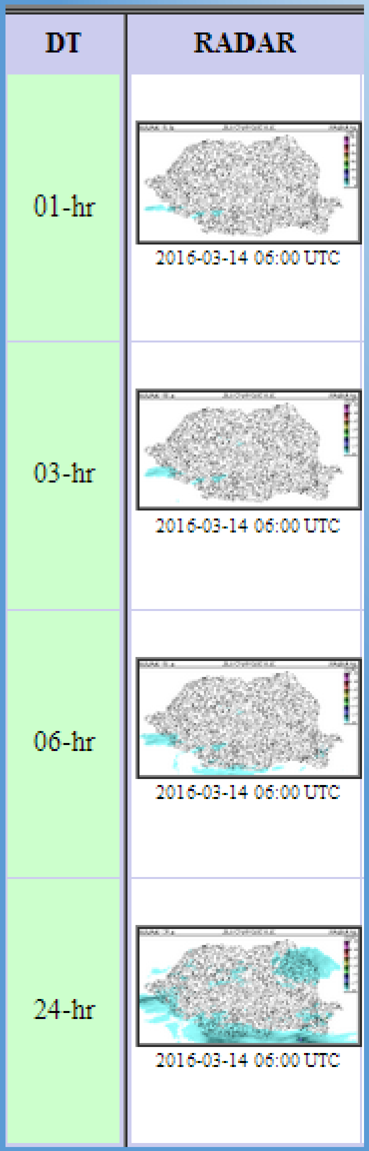


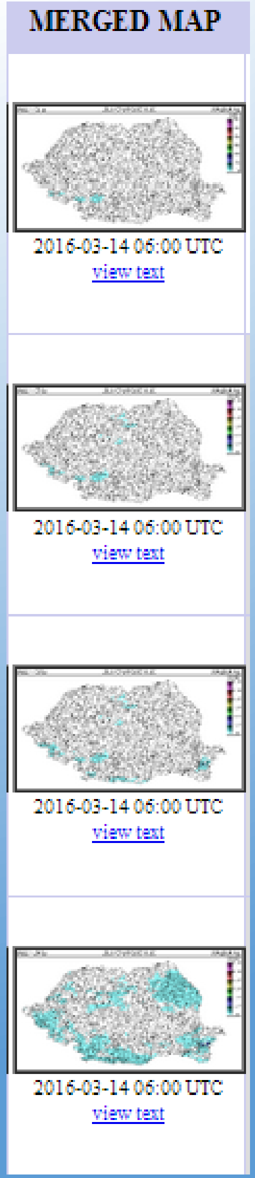
Fig. 2 The web interface of ROFFG system

ROFFG PRODUCTS



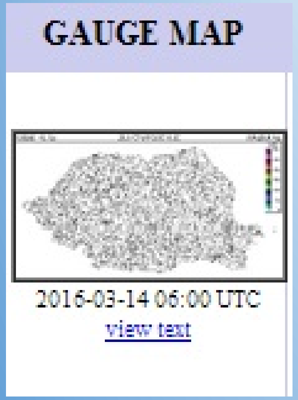
RADAR PRODUCTS

- ➢ Are represented as maps with unadjusted precipitation amounts accumulated in 1, 3, 6 and 24 hours, which are estimated based on radar products in Romania.
- ➢ The maps are in grid format with spatial resolution of 1 km size.
- ➢ This product is unavailable in tabular format.



MERGED MAP
(Mean Areal Precipitation)

- ➢ Represent the average precipitation on the ROFFG catchments, accumulated in 1, 3, 6 and 24 hours.
- ➢ This product is derived based on radar estimations adjusted with the recorded amounts of precipitation from gauge station.
- ➢ This product is also available in tabular format.

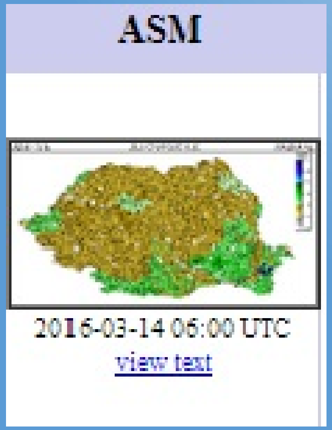


GAUGE MAP

➢Provide accumulations of mean areal precipitation (mm) estimates for each sub-basin produced from interpolation of precipitation gauge data.

➢The Gauge Map data products are updated hourly;

➢The product is available in both graphic and tabular formats.



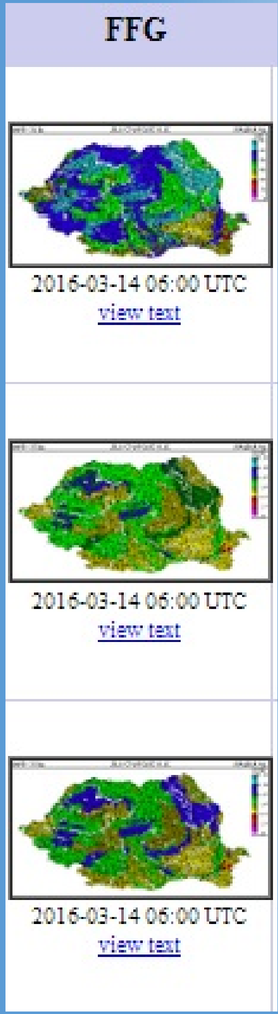
ASM (Average soil moisture)

➢ soil moisture(%);

➢ represents the simulated soil water saturation fraction (dimensionless ratio of contents over capacity) for the upper zone (approximately 20 cm depth) of the Sacramento Soil Moisture Accounting Model for each of the sub-basins.

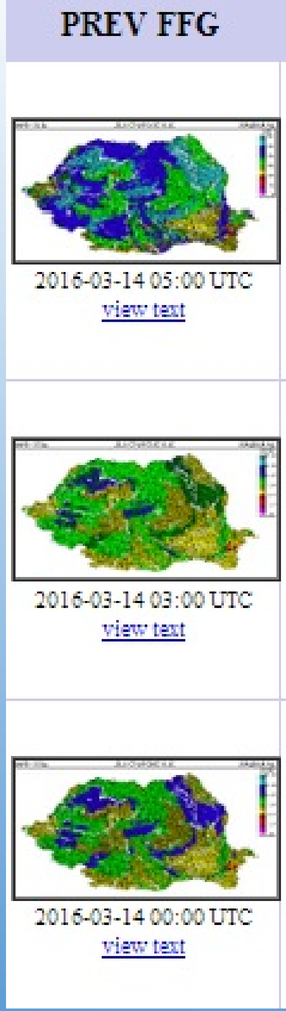
➢ the products are updated hourly;

➢ the product is available in both graphic and tabular formats.



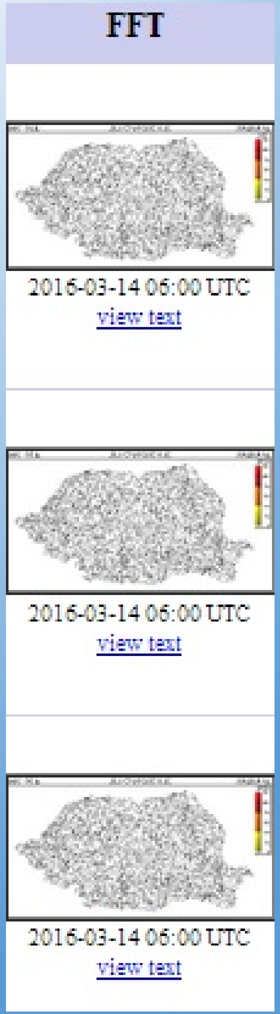
FFG (Flash Flood Guidance)

- For a given sub-basin and duration (1-hour, 3-hour or 6-hour), the FFG value indicates the total volume of rainfall over the given duration which is just enough to cause bankfull flow at the outlet of the draining stream.
- the product is available in both graphic and tabular formats.



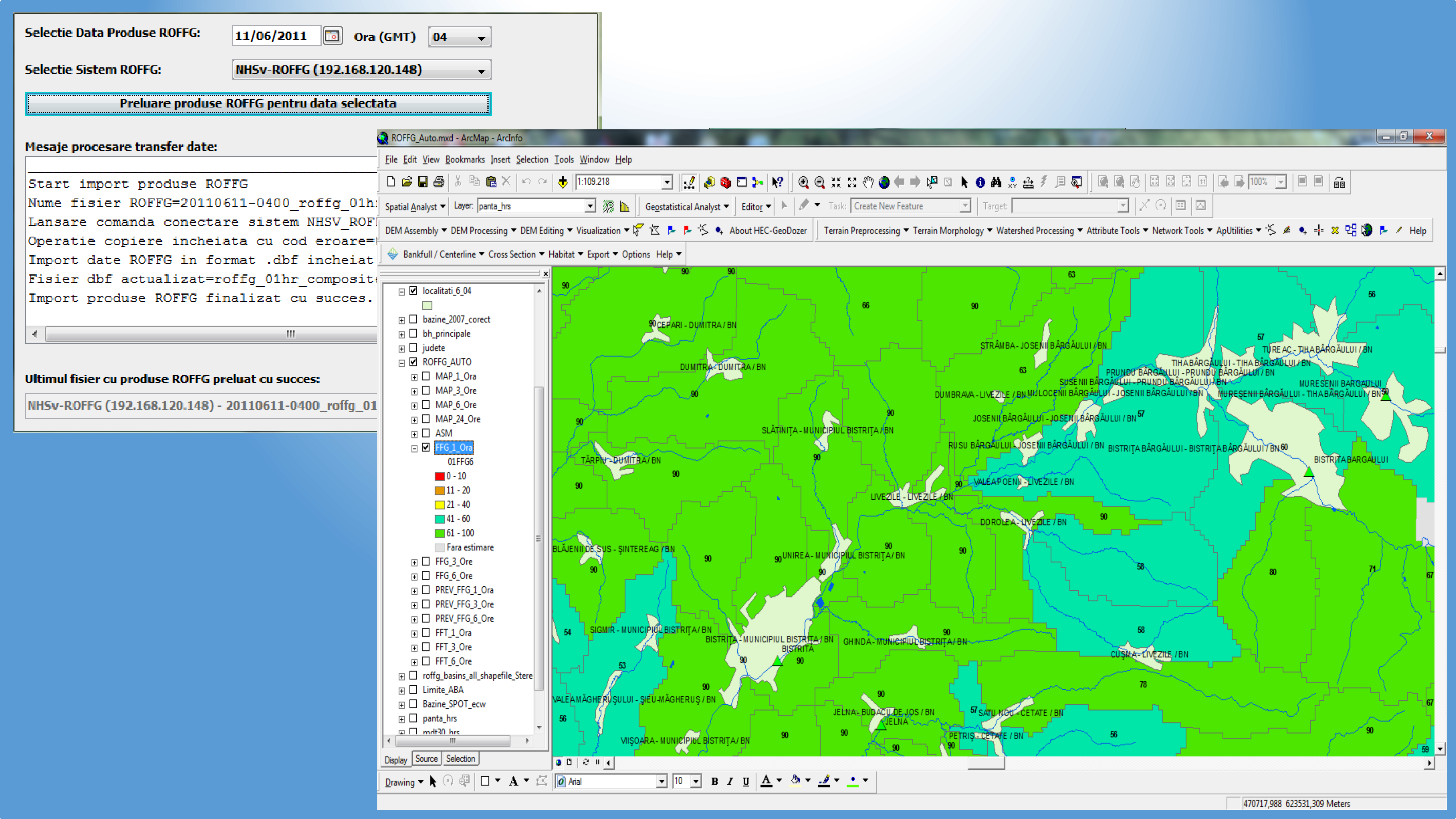
PREV FFG

- Represent the FFG values calculated at a previous time step (previous hour).
- The product is available in both graphic and tabular formats.



FFT

- FFT products include text, tables and images of hourly, 3-hourly and 6-hourly flash-flood threat (mm) for each ROFFG catchment.
- The values indicate the difference of observed mean areal rainfall of the given duration and the corresponding past FFG of the same duration for a given ROFFG subbasin.


Selectie Data Produse ROFFG:
11/06/2011
Ora (GMT)
04
Selectie Sistem ROFFG:
NHSv-ROFFG (192.168.120.148)
Preluare produse ROFFG pentru data selectata
Mesaje procesare transfer date:
Start import produse ROFFG
Nume fisier ROFFG=20110611-0400_roffg_01h
Lansare comanda conectare sistem NHSV_ROF
Operatie copiere incheiata cu cod eroare=
Import date ROFFG in format .dbf incheiat
Fisier dbf actualizat=roffg_01hr_composite
Import produse ROFFG finalizat cu succes.
Ultimul fisier cu produse ROFFG preluat cu succes:
NHSv-ROFFG (192.168.120.148) - 20110611-0400_roffg_01
ROFFG_Auto.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Tools Window Help
1:109.218
Spatial Analyst
Layer: panta_hrs
Geostatistical Analyst
Editor
Task: Create New Feature
Target:
DEM Assembly DEM Processing DEM Editing Visualization
About HEC-GeoDozer
Terrain Preprocessing Terrain Morphology Watershed Processing Attribute Tools Network Tools ApUtilities Help
Bankfull / Centerline Cross Section Habitat Export Options Help
localitati_6_04
bazine_2007_corect
bh_principale
judete
ROFFG_AUTO
MAP_1_Ora
MAP_3_Ore
MAP_6_Ore
MAP_24_Ore
ASM
FFG_1_Ora
01FFG6
0 - 10
11 - 20
21 - 40
41 - 60
61 - 100
Fara estimare
FFG_3_Ore
FFG_6_Ore
PREV_FFG_1_Ora
PREV_FFG_3_Ore
PREV_FFG_6_Ore
FFT_1_Ora
FFT_3_Ore
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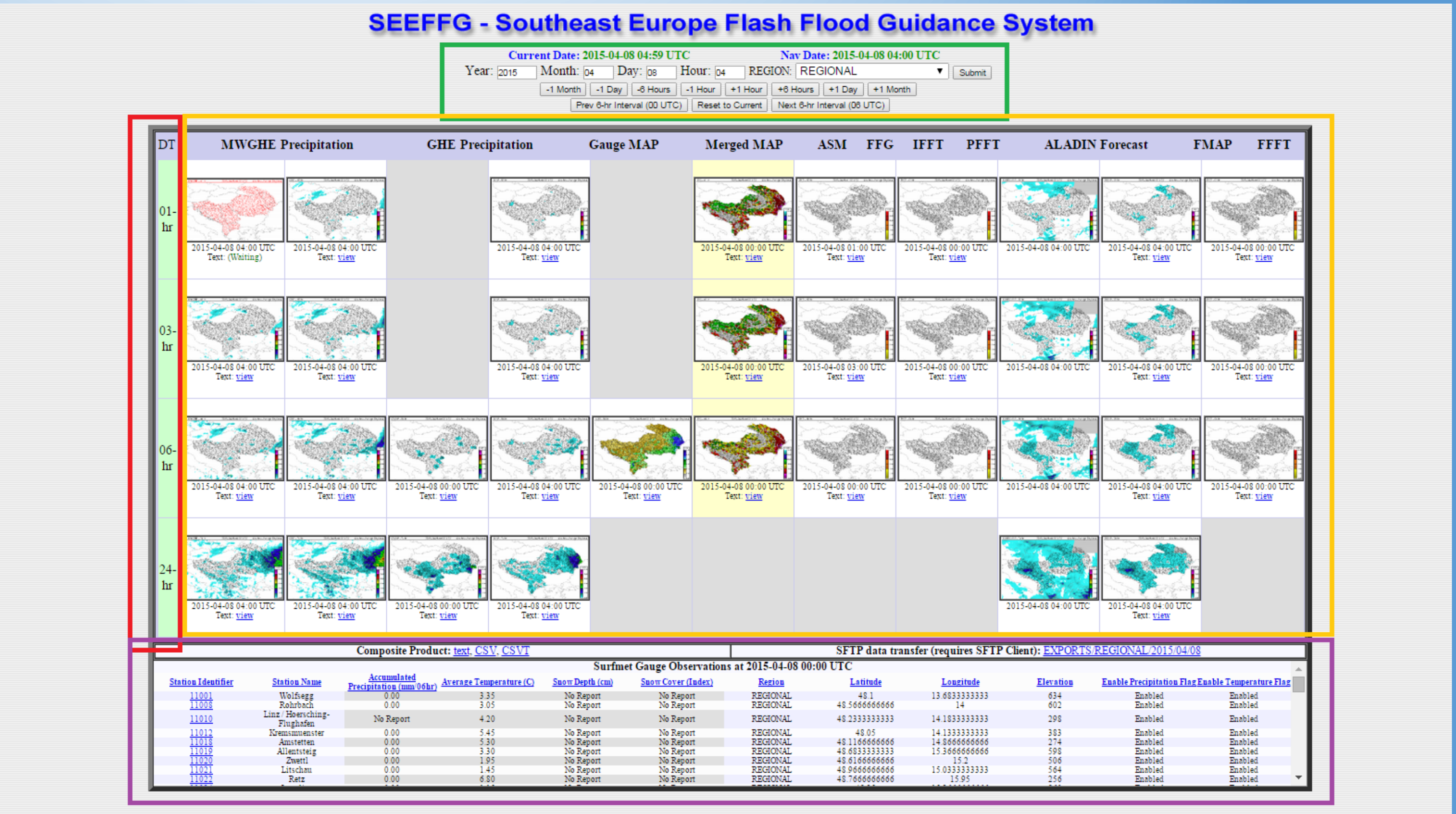
roffg_basins_all_shapefile_Stere
Limite_ABA
Bazine_SPOT_ecw
panta_hrs
Display Source Selection
CEPARI - DUMITRA / BN
DUMITRA - DUMITRA / BN
STRÂMBA - JOSENII BÂRGĂULUI / BN
TURE AC - TIHA BÂRGĂULUI / BN
TIHA BÂRGĂULUI - TIHA BÂRGĂULUI / BN
PRUNDU BÂRGĂULUI - PRUNDU BÂRGĂULUI / BN
DUMBRAVA - LIVEZILE / BN
MIJLOCENII BÂRGĂULUI - JOSENII BÂRGĂULUI / BN
MURESENII BÂRGĂULUI - TIHA BÂRGĂULUI / BN
JOSENII BÂRGĂULUI - JOSENII BÂRGĂULUI / BN
SLĂTINIŢA - MUNICIPIUL BISTRIŢA / BN
RUSU BÂRGĂULUI - JOSENII BÂRGĂULUI / BN
BISTRIŢA BÂRGĂULUI - BISTRIŢA BÂRGĂULUI / BN
BISTRIŢA BARGAULUI
TĂRPIU - DUMITRA / BN
VALEA POENII - LIVEZILE / BN
LIVEZILE - LIVEZILE / BN
DOROLEA - LIVEZILE / BN
BLĂJENII DE SUS - ŞINTEREAG / BN
UNIREA - MUNICIPIUL BISTRIŢA / BN
SIGMIR - MUNICIPIUL BISTRIŢA / BN
BISTRIŢA - MUNICIPIUL BISTRIŢA / BN
BISTRIŢA
GHINDA - MUNICIPIUL BISTRIŢA / BN
CUŞMA - LIVEZILE / BN
VALEA MĂGHERUŞULUI - ŞIEU-MĂGHERUŞ / BN
JELNA - BUDACU DE JOS / BN
JELNA
SATU NOU - CETATE / BN
PETRIŞ - CETATE / BN
VIŞOARA - MUNICIPIUL BISTRIŢA / BN
Drawing
Arial
10
470717,988 623531,309 Meters

SEEFFG – South East Europe Flash-Flood Guidance System
(implemented by Hydrologic Research Center under International Program coordinated by WMO)

- Provides in great measure the same informations as ROFFG system.

Differences between SEEFFG and ROFFG:

- The larger area for catchments: SEEFFG – around 100-150 km² vs. ROFFG – around 30 km².
- The estimated rainfall using satellite products.
- Include rainfall forecast component based on ALADIN model.
- Use 6 hours rainfall accumulation and air temperature from stations;
- Products regarding the snow layer:
    - Fraction of basin snow cover area;
    - Snow water equivalent (mm);
    - Snow melt (mm).



The web interface of SEEFFG system

General assessment of the ROFFG System

- HRC is recommending a period of at least 2 years of experimental use for FFG type Systems.
- Main objective for this general assessment: estimate the ROFFG System flash flood events detection capability, based on the data available in real time, with no user intervention and/or adjustments.
- We analyzed the available data and information from the period 2011 – 2012, when the ROFFG System was running in real time, with the same parameters configuration.

We selected flash flood events based on the following two type of historical information:

  – Inventory of floods events in gauged small basins, generated by concentrated rain events, and with the maximum recorded level exceeding the flood level threshold.
  – Official inventory of damages reports, for the damages generated by flooding from small streams.

General assessment of the ROFFG System

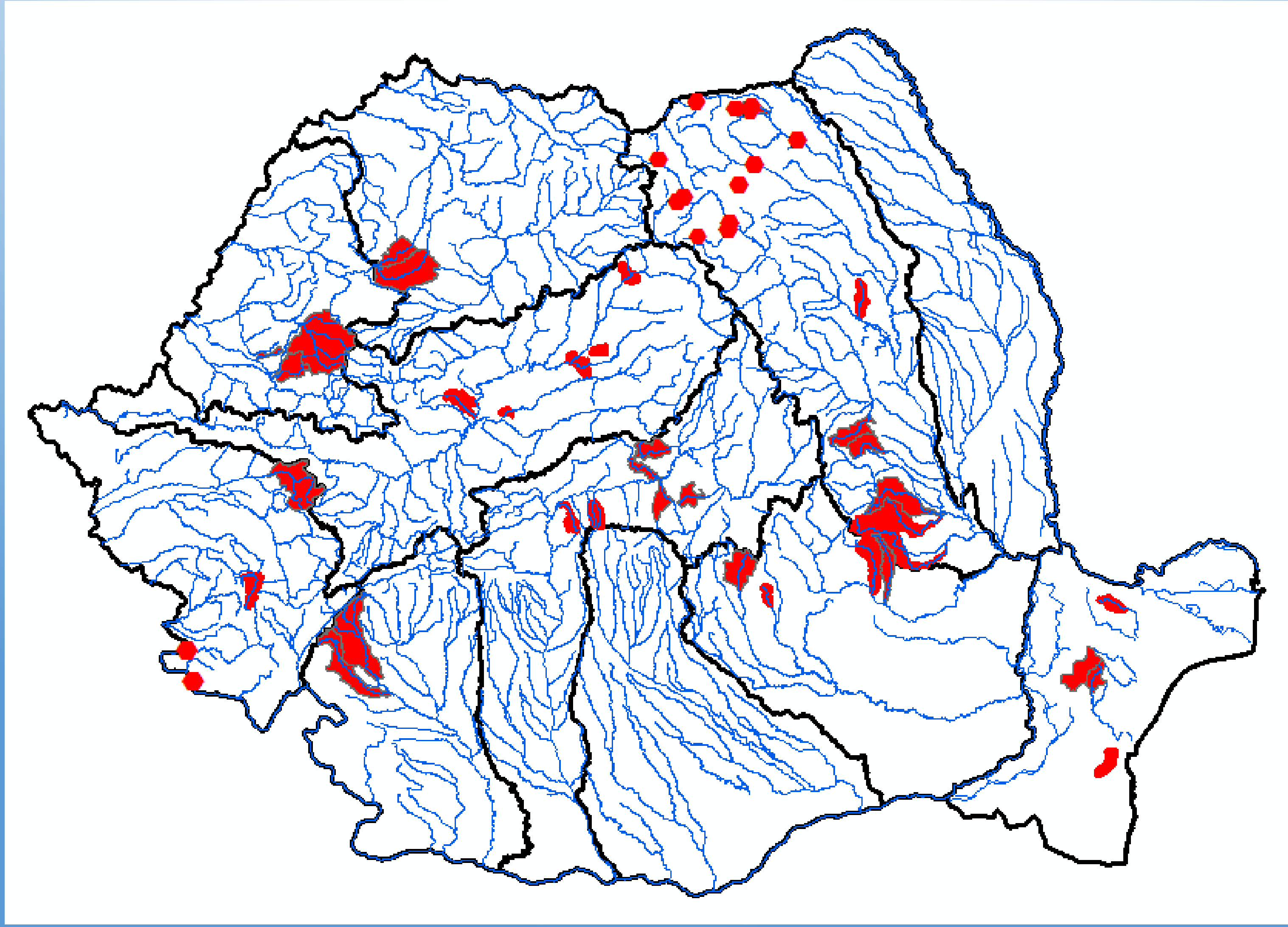
For the selected events, we analyzed:

- The FFT products, for the small basins configured in the ROFFG System within the identified gauged and/or ungauged basins, to check if the system detected a flash flood event in the area;

- The Radar and MAP products, for different accumulation periods;

- The recorded precipitations at stations situated in the basin or close to the basin;

- The official real time precipitation maps, for 24 hours, and for 10 days before the events, maps generated in real time by the Romanian Meteorological Administration, from the meteorological and hydrometrical stations data, available in real time.



Selected FF events spatial distribution

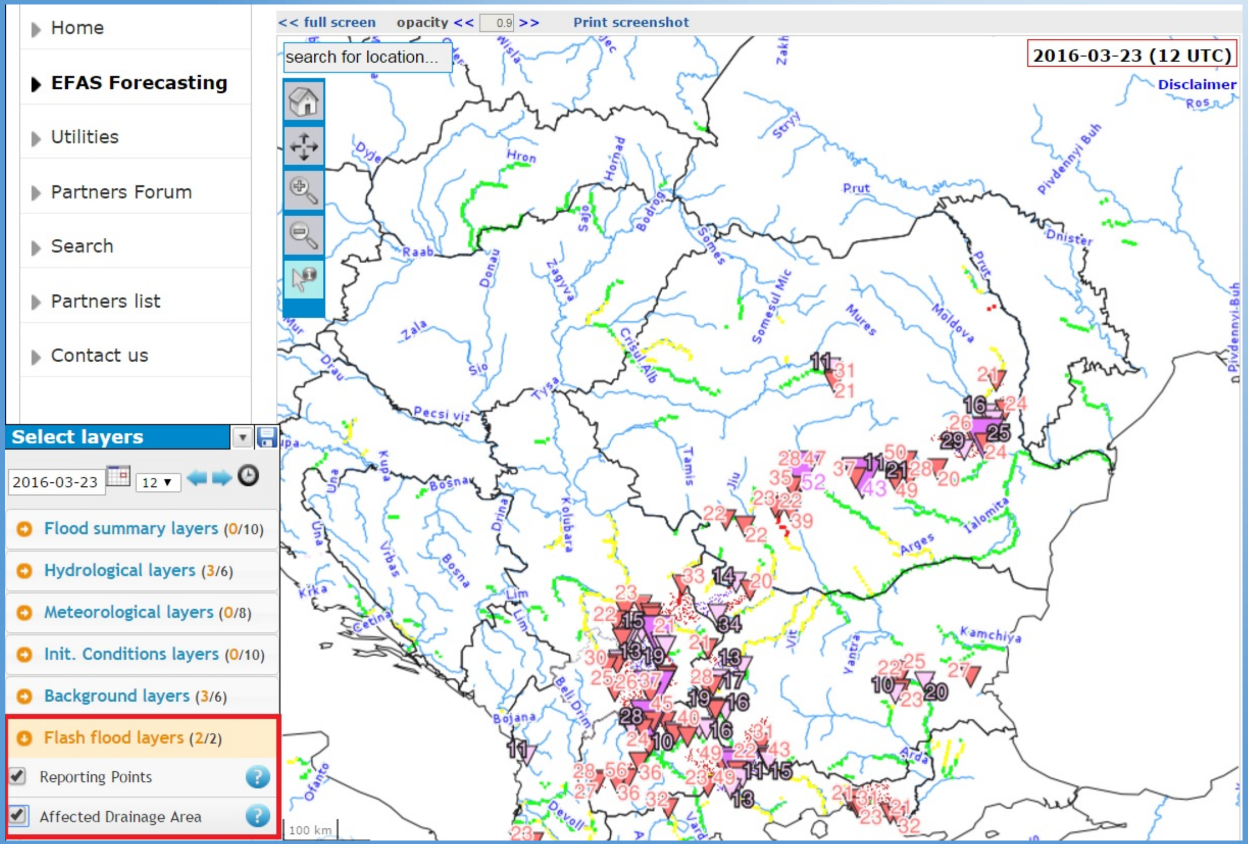
Assessment results:

- From a total of 40 selected flash flood events, 33 events where detected by the ROFFG System, based on the real time available data and estimates, with no forecaster intervention (FFT system generated products), representing 82.5 %.

- Based on the analysis of the hydrometeorological evolution and the ROFFG System generated products, for the 7 undetected events, the main conclusion was that the precipitation was underestimated by the system.

European Flood Awareness System (JRC together with partners from EU countries)

- Is the first monitoring and forecast operational system for floods at european level.
- EFAS was designed in the first instance for medium and large size river basins and lead time up to ten days.
- The dedicated flash-floods component from EFAS includes 2 products: *Reporting points and Affected Drainage Area.*

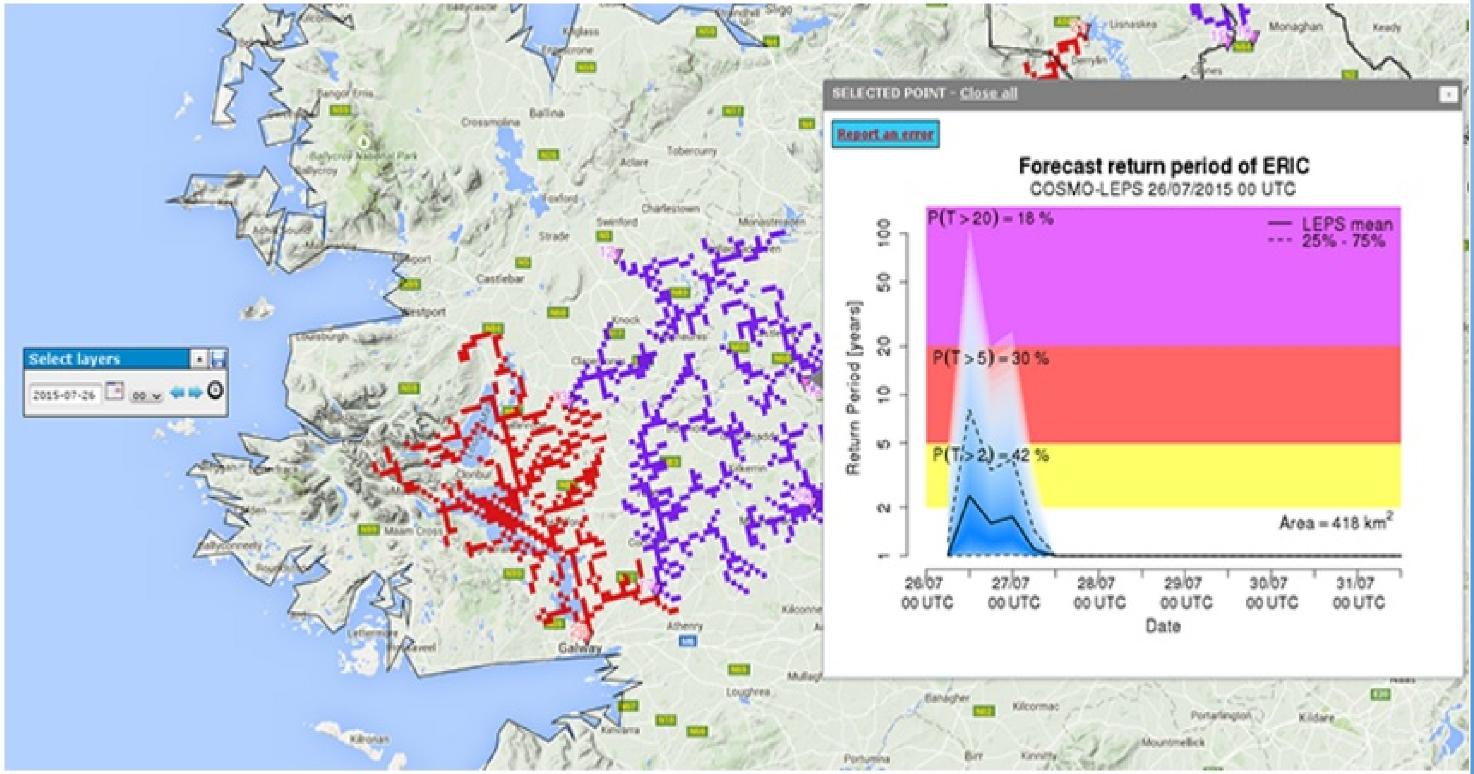


The web interface of EFAS with flash-floods component highlighted

- Reporting points showing the forecasted probability [%] of surface runoff index to exceed a 5 or 20 year return period magnitude.
- A red warning point is generated when the probability of an event to exceed the 5-year return period is greater than 20%.
- A purple reporting point is generated when the probability of an event to exceed a 20-year return period is greater than 10%.
- These warning points are displayed on the web interface as colored triangles. By selecting one of these points a graph showing the corresponding probabilistic ERIC (*Raynaud et al., 2014, A dynamic runoff co-efficient to improve flash flood early warning in Europe: evaluation on the 2013 central European floods in Germany*) return period forecast will appear. It displays the forecasted ERIC values for the following 5 days.

European Flood Awarness System

- A separate layer entitled 'Affected Drainage Area' highlights the upstream river network which contributes to each reporting point, i.e. the areas of the network which may be at risk from flash flooding. These river pixels are colored in the same scheme as their corresponding warning points (red = high and purple = severe).
- EFAS flash flood informations are useful mainly when the probability of exceeding a 20 year return period magnitude of the surface runoff index is greater than 35% and the forecasted start of the event is < 72 hours.



The web interface of EFAS with the graph of Forecast return period of ERIC

Example of Flash-Flood Warning issued in Romania

ADMINISTRAŢIA NAŢIONALĂ "APELE ROMÂNE"
INSTITUTUL NAŢIONAL DE HIDROLOGIE ŞI GOSPODĂRIRE A APELOR
Şos. Bucureşti - Ploieşti 97, Bucureşti, cod 013686, ROMÂNIA
Tel.: +40-21 - 3181115 Fax: +40-21-3181116 E-mail:relatii@hidro.ro

-INH/A

ATENŢIONARE HIDROLOGICĂ PENTRU FENOMENE IMEDIATE
NR. 4 DIN 09.04.2016

Sursa: INSTITUTUL NAŢIONAL DE HIDROLOGIE ŞI GOSPODARIRE A APELOR, BUCURESTI		
Ziua/luna/anul: 09.04.2016	**Ora: 19:55**	**Numărul mesajului: 4**

Către:
Ministerul Mediului, Apelor şi Pădurilor, Inspectoratul General pentru Situaţii de Urgenţă, Administraţia Naţională Apele Române, Ministerul Administraţiei şi Internelor, S.C. Hidroelectrica S.A., Administraţiile Bazinale de Apă: Crişuri

FENOMENELE VIZATE:
Scurgeri importante pe versanţi, torenţi, pâraie cu posibile efecte de inundatii locale şi creşteri de debite şi niveluri cu posibile depăşiri ale COTELOR DE ATENŢIE
Bazine afectate:
Râurile mici din bazinul superior al râului Cigher (afluent al Crișului Alb) – județul Arad

ATENŢIONARE HIDROLOGICĂ PENTRU FENOMENE IMEDIATE
COD GALBEN

MOMENTUL PRODUCERII FENOMENELOR VIZATE:
Data: 09.04.2016 ora 20:10 – 09.04.2016 ora 24:00

Ca urmare a precipitaţiilor lichide înregistrate în ultimele ore, a celor prognozate, şi propagării, se pot produce scurgeri importante pe versanţi, torenţi, pâraie cu posibile efecte de inundaţii locale şi creşteri de debite şi niveluri cu posibile depăşiri ale **COTELOR DE ATENŢIE** pe râurile mici din bazinul superior al râului Cigher (afluent al Crișului Alb) **– județul Arad.**

Fenomenele menţionate se pot produce cu probabilitate mai mare în bazinele Timercea, Nadăș și Pustaciu.

În funcţie de evoluţia fenomenelor hidrometeorologice vom reveni cu actualizarea prognozei hidrologice.

Se impune urmărirea evoluţiei situaţiei hidrometeorologice în conformitate cu „Regulamentul privind gestionarea situaţiilor de urgenţă generate de inundaţii, fenomene meteorologice periculoase, accidente la construcţii hidrotehnice, poluări accidentale pe cursurile de apă şi poluări marine în zona costieră".

Romulus-Dumitru COSTACHE		**Aprobat, Director C.N.P.H. Dr. ing. Marius MATREATA**

General inventory of the flood watch and flood warning messages, issued by the National Hydrologic Forecast Center in the period April – October 2014

	WARNINGS MESSAGES > 6 hours lead time (medium and large scale floods, including local flash floods)		WARNINGS MESSAGES < 6 hours lead time (short term warnings for local flash floods)	
	Warnings	**Watch**	**Warnings**	**Watch**
APRILIE	9	4	1	0
MAI	14	1	11	14
IUNIE	2	5	2	20
IULIE	6	6	21	28
AUGUST	8	2	7	31
SEPTEMBRIE	2	4	2	7
OCTOMBRIE	4	-	2	2
TOTAL	**45**	**22**	**46**	**102**

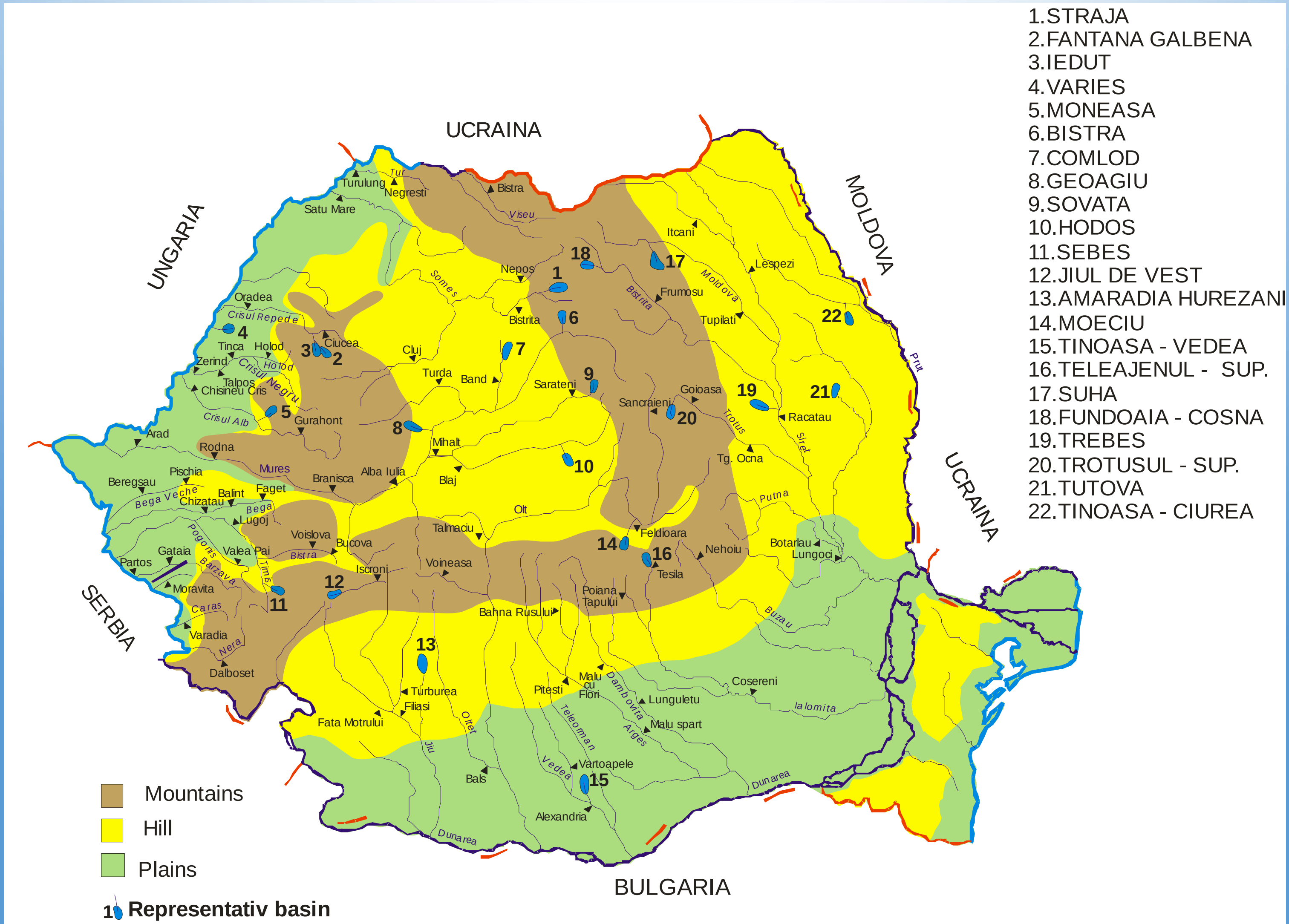
ASSESSMENT OF FLASH FLOOD HAZARD MAPS USING DIFFERENT THRESHOLD VALUES AND INDICES METHODS

- Flood mapping is a crucial element of flood risk management (Directive 2007/60/EC on the assessment and management of flood risks).
- Flash Flood mapping is a special case, as it is mentioned also in the Handbook of good practices in flood mapping produced by "EXCIMAP" (European Exchange Circle on Flood Mapping").
- According to this good practices handbook, several aspects can be highlighted in relation to flash-flood hazard and risk map delineation:
  - Flash-flood prone areas can be identified in a first approach by using meteorological criteria, in terms of rainfall amounts and intensities above a threshold that have impacted the same area in the past.
  - Geomorphologic criteria are of primary importance in flash-flood prone areas, since water in most of these rivers do not flow for most of the year.
  - Classical 1-D hydraulic modelling for hazard delineation may not be useful in small to medium flash-flood prone areas. Modelling of solid transport is particularly important, since it highly affects the extent of the flood.

ASSESSMENT OF FLASH FLOOD HAZARD MAPS USING DIFFERENT THRESHOLD VALUES AND INDICES METHODS

- In order to enable the accuracy of hydrological / hydraulic modelling as well as for producing the final flood hazard map detailed and accurate digital maps and digital elevation models (DEM) are required.
- General recommended minimum requirements are 10 m*10 m (possibly 5 m*5 m) horizontal and minimum 0.5 m vertical resolution.
- Taking into account all of these aspects and the need for a Flash Flood Hazard Map at national level, for all the territory of Romania, we used as a first general practical approach the following methodology:
  - Use the threshold runoff values from the actual ROFFG operational system configuration.
  - Compute the runoff for selected precipitation scenario using the runoff coefficients based on the data from the representatives small basins in Romania.
  - Define and check the flash flood hazard severity classes using information from the existing hydrometric stations in small basins, and Flash Flood Potential index.
  - Estimate the potential flooded area using specific GIS processing, taking into consideration the influence of the main physical -geographical factors on the runoff generation processes.

The map of the representative basins from Romania



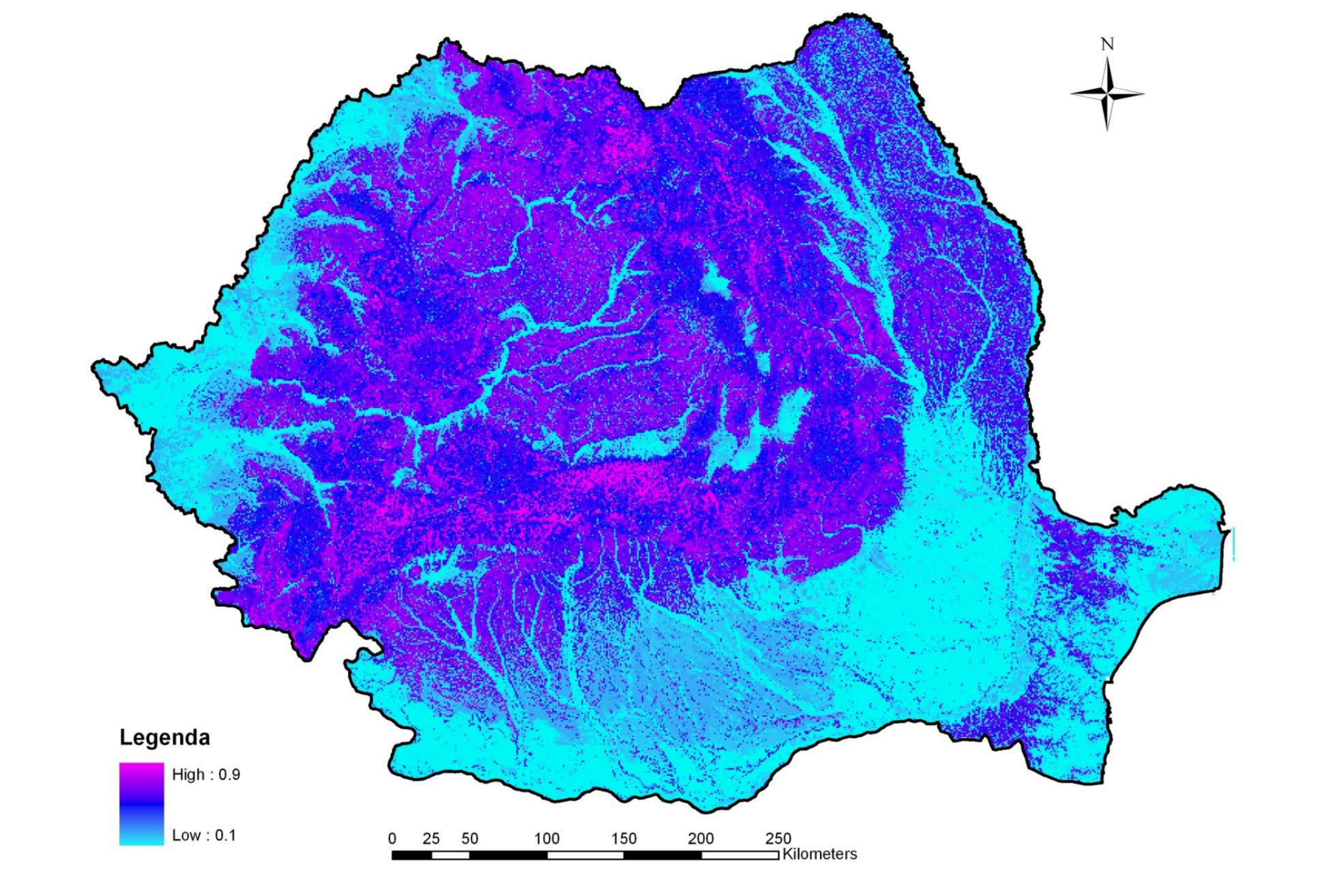
Located in different physical – geographical areas of the country, the representative basins offer a great diversity of conditions regarding the geology, soil, relief, vegetation, etc..

Slope, forest and soil texture influence

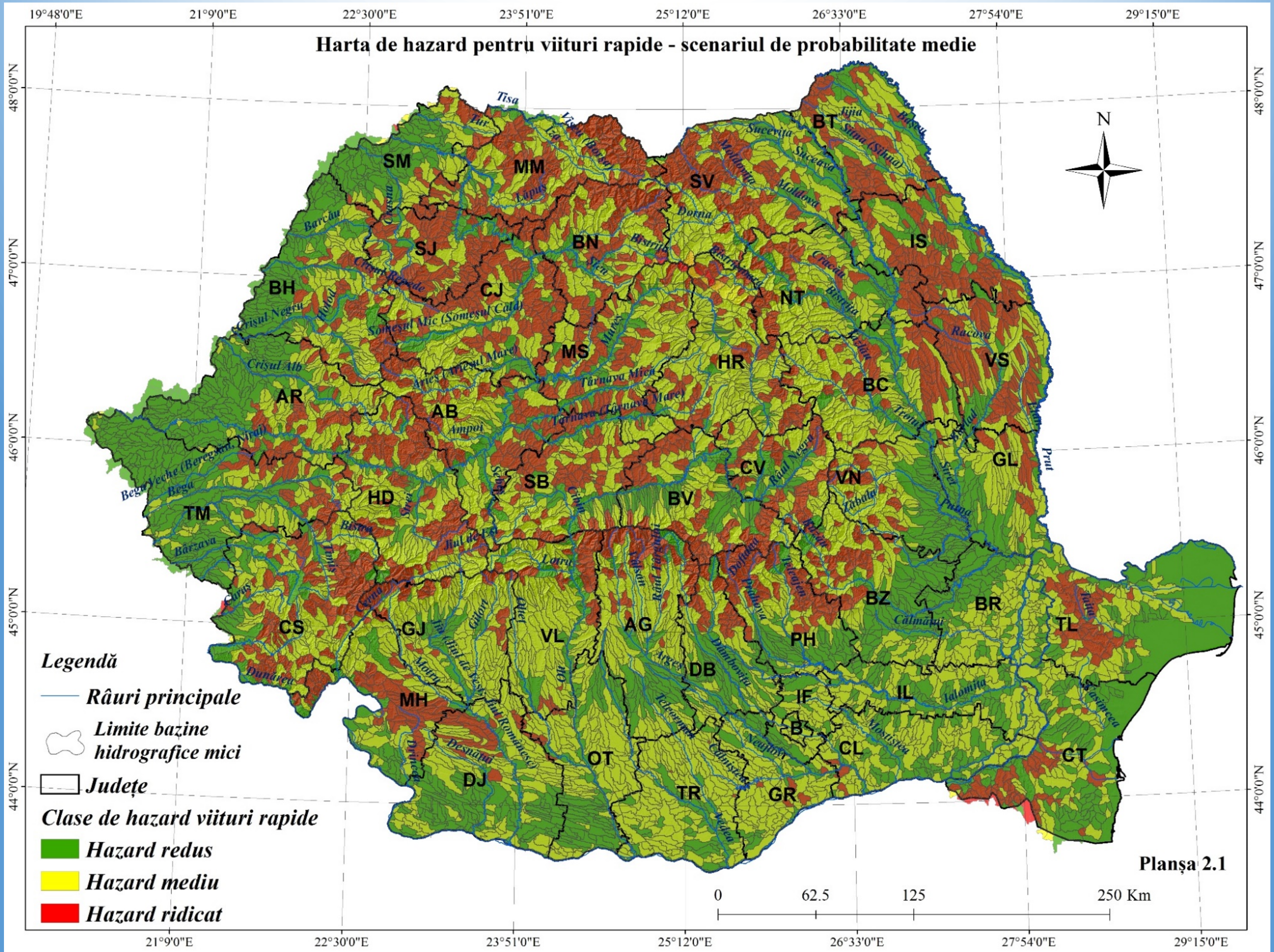
Cp(%)/ I_b(%)/	0-20	20-40	40-60	60-80	80-100
Soils with high infiltration capacity					
5-10	0.44	0.42	0.40	0.38	0.36
10-20	0.46	0.44	0.42	0.40	0.38
20-30	0.48	0.46	0.44	0.42	0.40
30-40	0.50	0.48	0.46	0.44	0.42
40-50	0.52	0.50	0.48	0.46	0.44
Soils with mean infiltration capacity					
5-10	0.55	0.53	0.51	0.49	0.47
10-20	0.57	0.55	0.53	0.51	0.49
20-30	0.59	0.57	0.55	0.53	0.51
30-40	0.62	0.60	0.58	0.55	0.53
40-50	0.64	0.62	0.60	0.57	0.55
Soils with low infiltration capacity					
5-10	0.66	0.63	0.61	0.58	0.56
10-20	0.69	0.66	0.63	0.60	0.57
20-30	0.73	0.69	0.66	0.63	0.60
30-40	0.75	0.72	0.69	0.65	0.63
40-50	0.78	0.75	0.72	0.68	0.65

Runoff coefficient values as function of forestation coefficient, basin slope, and soil type, for a precipitation event of 125mm and previous 5 days API of 40mm (source P. Miță, 1996)

Values of the maximum runoff coefficient, 1 km grid, obtained using a fuzzy model approach

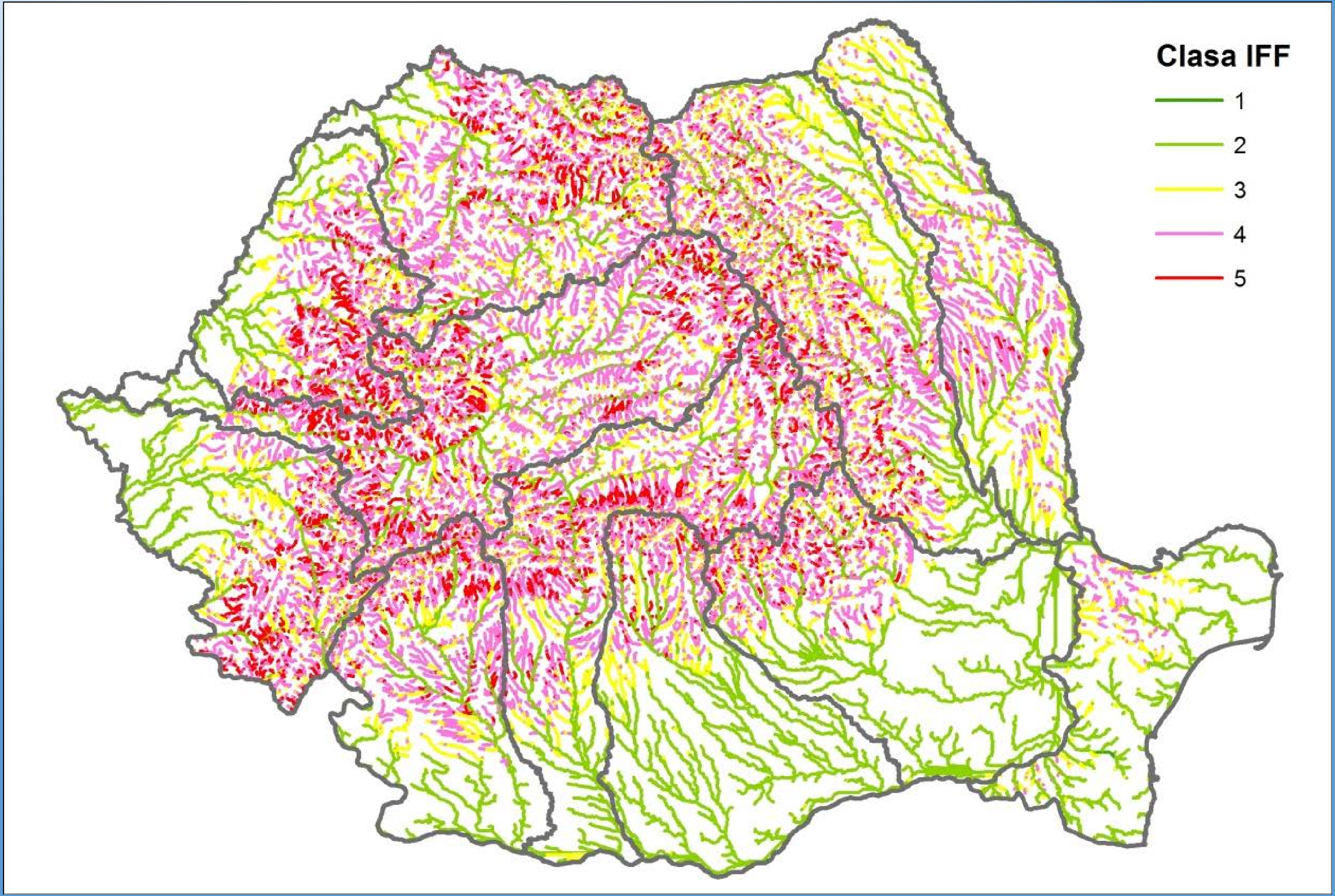


Flash Floods hazard map



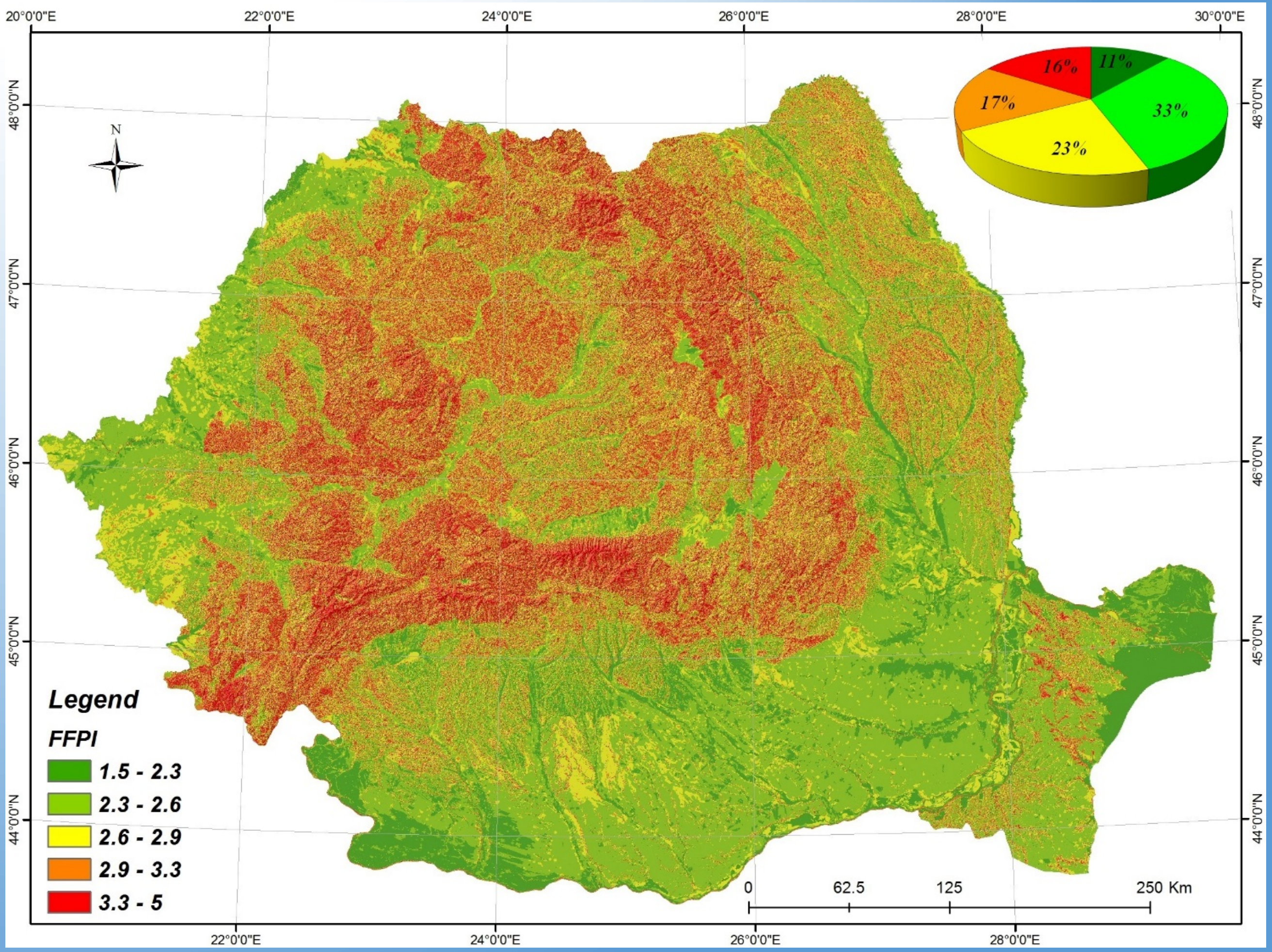
Flash Floods susceptibility index - preliminary version

Using a methodology based on a detailed analysis at the river network cells level, by specific GIS processing for assessing the flash flood susceptibility (this development was done within the national VULMIN and RORISK Projects).



Flash-Flood Potential Index

- Is a dimensionless index which was obtained by overlapping multiple layers (lythology, slope, land cover, profile curvature and hydrological soil groups) in the GIS environment.
- The FFPI values shows the potential of different terrain surfaces to generate the rapid surface runoff and further to trigger the flash-flood. At the same amounts of rainfall, according to their characteristics, the terrain surfaces, can trigger or not flash-floods.
- Spatially modelling of the values of FFPI at national scale is very useful for the decision to issue or not a flash-flood warning .



FFPI values in Romania

General final observations:

- ➢ We could consider that nowadays we (almost) reached a general agreement that we have an unavoidable uncertainty associated with any hydrological warning and forecast in real time, especially if we try to have a minimum useful lead time for our warning and/or forecast.

- ➢The recommended approach to deal with this uncertainty is to go for probabilistic hydrological warnings and forecasts.

- ➢Flash Flood forecasting and warning is … again a special case, due to the specific very short lead time a probabilistic warning is really the best approach, but still very difficult to be accepted by the main users.

Next steps:

- The first priority is to improve the rain gauge correction algorithm, and in general to optimize the procedure of mean areal precipitation estimation, by a data fusion approach.
- Reconfigure the operational distributed model NOAH-R configuration to be able to run the model based on what-if scenarios.
- Optimize and finalize the real time procedure for using ROFFG products together with distributed model NOAH-R, SEEFFG, EFAS and other systems/information for flash floods warning activities, bring all the important products in a common GIS framework.
- Adapt the real time FF warning elaboration procedure in order to generate and add detailed maps together with the actual text message, based on an improved ROFFG configuration for the sub-basins delineation.
- National Hydrologic Forecast Center – organizational structure adaptation:
  - Since 2015 a new forecaster team, dedicated to Flash Flood Forecasting and Warnings, have been added.
  - We have now 4 young peoples in this dedicated team, and according to our strategy the forecaster number will be increased in two steps, in the next 3 years.

Next steps for FF hazard mapping:

- **The next step will be to add a detailed distributed modeling step, based on cellular automata approach, using general accepted hydrological principle for infiltration and routing.**
- **Depending on the results, this approach will be also used/included in the operational, FF warning real-time activity.**

- **We think that in the near future, a general agreement will be reached also in accepting that for any flood hazard mapping method / result there is always an associated uncertainty.**
- **And most probably, the next step will be to produce and use … probabilistic flood hazard maps.**

Thank you very much for your attention!