FOLLOW-UP OPERATIONAL WORKSHOP

SOUTH EAST EUROPE FLASH FLOOD GUIDANCE (SEEFFG) SYSTEM

(Step-4 Training)

Zagreb, Croatia

9–13 May 2016

Final Report

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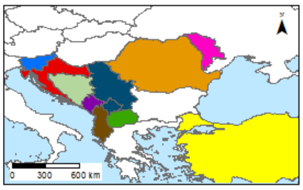
1. Executive Summary



In the South East Europe region, flash floods account for a significant portion of the lives lost and property damages that result from flooding. Given that flash floods can occur at any time or place with disastrous results, there is an urgent need to prioritize efforts that aim to improve early warnings capabilities. Improvements help society to cope with flash flood threats by enabling the mandated national authorities to undertake appropriate measures, thereby contributing to protecting the population at risk from the disastrous effects of flash floods.

As part of WMO's Flood Forecasting Initiative and on the basis of a 4-party Memorandum of Understanding signed by the World Meteorological Organization (WMO); US NOAA National Weather Service (US NWS); the Hydrologic Research Center (HRC), San Diego, USA; and U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA), the signatories have established a cooperative initiative for the Flash Flood Guidance System with Global Coverage Project. To attain global coverage, specific projects are planned and conducted on a regional basis with countries that have committed in writing to participate actively in the implementation and operation of the forecast system.

The South East Europe Flash Flood Guidance (SEEFFG) System Kick-Off Meeting was held in Ankara, Turkey on 22-24 March 2013. Nine South East Europe countries, namely Albania, Bosnia and Herzegovina, Croatia, Moldova, Montenegro, Romania, Serbia, Slovenia, The former Yugoslav Republic of Macedonia, and Turkey, were represented in the meeting. Participants expressed their interests to participate in the SEEFFG system, indicating that flash floods cause considerable human losses and property damages in the South East Europe region. At this meeting, the National Meteorological and Hydrological Service (NMHS) of Turkey, graciously offered to host the Regional Centre of the SEEFFG system, which was accepted by all participating countries. Albania, Bosnia and Herzegovina, Croatia, Moldova, Montenegro, Romania, Serbia, Slovenia, The former Yugoslav Republic of Macedonia have sent Letters of Commitment (LoC) to WMO to participate in the project.

Based on the SEEFFG system implementation plan adapted at the Kick-Off Meeting in Ankara, Turkey, the following project activities have been completed: 1) First Project Steering Committee Meeting took place from 31 March to 2 April 2015 in Skopje, The former Yugoslav Republic of Macedonia; 2) Operational training took place from 5 July to 2 August (12 July – 9 August) 2015 at HRC facilities in San Diego, USA. One forecaster from Albania, two hydrometeorologists from Bosnia and Herzegovina, two hydrometeorologists from Croatia, one forecaster from Moldova, one hydrologist from Serbia, two hydrologists from Slovenia, one hydrologist from The former Yugoslav Republic of Macedonia, and one forecaster from Turkey attended the training.

As per the implementation plan, Follow-Up Operational Workshop and Step-4 training were held in Zagreb, Croatia from 9 to 13 May 2016. The objectives of this workshop were to: review the theoretical basis of the Flash Flood Guidance System; explore in detail, through presentations and discussions, the project products, their development methodology, and the interpretation and validation approaches to provide feedback for their further development; operational use of the SEEFFG products through hand-on exercises; allow a better understanding of the needs of high resolution modelling, including its domains; support the SEEFFGS application; review and evaluate the SEEFFG products for elected past events through case studies; and evaluate the performances of participants who successfully completed FFG Step-2 and Step-3 training to be qualified for the certified WMO FFG Trainer.

2. Opening of the Session

In opening the Follow-Up Operational Workshop, the representatives of Croatia, WMO and HRC, highlighted the importance of improving the timely delivery of flash flood information and guidance to the populations at risk and in the importance of fostering stronger partnerships among countries in the region to strengthen national capabilities to forecast and warn populations at risk from flash flooding and other hydrometeorological hazards.

In his opening remarks, Mr Ivan Cacic, Permanent Representative of Croatia with WMO highlighted the value of regional cooperation particularly given the impacts of climate variability and change on infrastructure and the need for early warning systems to help reduce the risks from hydrometeorological hazards, to promote sustainable development, and to attain and maintain economic prosperity. He also emphasized the need for the international exchange of data and information for improving the provision of forecasts and early warnings, stressing that severe weather events do not confine themselves to national borders. He cited occurrences of the flood and flash flood events in last year, explaining that flash floods are very dangerous natural phenomenon in the South East Europe. He assured participants that Croatia will use the SEEFFG products in preparation of daily flash flood forecasts and warnings. He expressed his pleasure in being able to host the Follow-Up Operational Workshop in Zagreb. He welcomed all the participants to Croatia, and he wished everyone a very successful workshop.

Ms Natasa Strelec Mahovic, the General Director of Meteorological and Hydrological Service of Croatia welcomed the participants to the workshop and Croatia. She emphasized the importance of such workshops in capacity building and improving flash flood forecasting in the region, which is very prone to this hydrometeorological hazard. She also expressed Croatian appreciation for being selected as the venue for this very important workshop.

Mr Borivoj Terek, the Head of Hydrological Department of Croatia said that he was pleased to see progresses that were being made for the implementation of SEEFFGS project as it would assist capabilities of countries within the region to help cope with flash flood events by enhancing their flash flood early warning capabilities. He also welcomed all participants to the workshop and concluded by saying that he is confident the workshop would achieve good outcomes, and looked forward to participating.

Mr Ayhan Sayin (WMO) recalled the objectives of the workshop and its expected results, welcomed the participants, and encouraged them to provide their active inputs into shaping this important regional Flash Flood Guidance system project. He also thanked the Croatian Meteorological and Hydrological Service for all its efforts including hosting the workshop, thereby helping to make a positive atmosphere that would undoubtedly contribute favourably to the success of the workshop.

Ms Theresa Modrick, HRC, welcomed everyone to the workshop and was pleased to see that representatives from the nine South East Europe countries are attending the workshop. She emphasized its importance in enhancing the capacities of NMHSs of the South East Europe countries for timely and accurate early warnings of flash floods. She also expressed her appreciation to the Croatian Meteorological and Hydrological Service for hosting the workshop.

The national press also covered the workshop with several newspaper reporters being present at the opening of the workshop.

3. Organization of the Follow-Up Operational Workshop

Follow-Up Operational Workshop, which was held in Zagreb, Croatia from 9 to 13 May 2016, was attended by representatives of NMHSs from Albania, Bosnia and Herzegovina, Croatia, Moldova, Montenegro, Romania, Serbia, Slovenia, the former Yugoslav Republic of Macedonia, and Turkey. Other participants included representatives from WMO and HRC. The list of participants is provided in Annex I, while the annotated workshop agenda is given in Annex II.

4. Proceedings of the Follow-Up Operational Workshop

Mr Sayin provided a brief overview and purposes of the workshop. He stated goal of the Flash Flood Guidance System was to build capacities at the NMHSs to help society cope with hydrometeorological hazards particularly those of flash floods. The workshop would also allow an opportunity to present and discuss the needs for flash flood forecasting in the Black Sea and Middle East region, including dissemination procedures and coordination between the National Meteorological and Hydrological Services and the Disaster Management Agencies. He provided information about the WMO Flood Forecasting Initiative, stating that FFGS was in-line with the WMO Flood Forecasting Initiative objectives. He also outlined the global FFGS implementation strategy.

Mr Sayin reiterated the roles and responsibilities of the participating NMHSs and the Regional Centre. Participating NMHSs have the following responsibilities, inter alia: to provide historical data to the project developer, HRC; to provide in-situ data to the Regional Centre; to participate in the flash flood hydrometeorological training programme; to issue flash flood warnings and disseminate them to their national Disaster Management Authority; and to cooperate with the Regional Centre on the SEEFFG system issues. Then, he cited the roles and responsibilities of the Regional Centre as being, inter alia: to communicate effectively with WMO, HRC and NMHSs on the SEEFFG system activities; to have computer hardware and software capabilities and good computer network connections; to monitor routinely availability of the SEEFFGS products; and to conduct flash flood validation studies.

He stated that this workshop is the project activity as Step-4 training aimed to: review the SEEFFG products to allow forecasters to become familiar with the SEEFFGS products; promote operational use of the SEEFFG products through hand-on exercises; review and evaluate the SEEFFG products for elected past flash flood events through case studies; evaluate the performance of participants who have successfully completed Step-2 and Step-3 training.

He concluded his presentation stating that at the end of this workshop, forecasters should have the following competencies: 1) analyse and monitor the evolving meteorological and hydrological situation; 2) analyse and monitor the SEEFFGS products; 3) forecast meteorological and hydrological phenomena and parameters such as flash floods; 4) prepare flash flood advisories, watches, warnings, and alerts; and 5) communicate flash flood warning information to internal and external users, including Emergency Management Agencies.

4.1. Status of operational flash flood forecasting and early warning capabilities at NMHSs

Experts from each country provided in-depth presentations on the current situation of their national services related to hydrometeorological forecasting capabilities, practices and development plans. The presentations revealed the similarities and differences that exist among the countries regarding their capabilities to deliver weather and flood forecasting and early warnings, especially for those pertaining to flash floods. Countries do not presently have dedicated systems including the use of hydrological modelling to specifically address the provision of flash flood forecasts and warnings.

4.1.1 Albania

Mr Zaimi provided a brief overview of operational flash flood forecasting and early warning system in Albania. He gave an overview of meteorological network stating there are approximately 250 manual and 49 automated stations. For operational forecasting, several Numerical Prediction Models are used such as ALADIN, COSMO, and ECMWF. He stated that tools have been used for flood and flash flood forecasting in Albania are: DEWETRA Platform, South East Europe Flash Flood Guidance System (SEEFFGS), European Flood Awareness System (EFAS), and Drina-Buna Early Warning System. He stated that flood and flash flood warnings are issued by the bulletin, which is prepared every day at 12 o'clock. He concluded his presentation stressing the strong collaboration between the Institute of Geoscience, Energy, Water and Environment, and Civil Protection Agency, which is needed for human loss prevention and disaster risk reduction.

4.1.2 Bosnia and Herzegovina

Ms Djordjevic from Republic Hydro-Meteorological Service of Republika Srpska, provided a brief overview of United Nations Developed Programme (UNDP) for the Vrbas and Bosna Rivers basins. She stated that in the scope of projects, 6 hydrological and 12 rainfall stations were installed in Vrbas River basin, while 9 hydrological stations were installed in Bosna River basin, and showed their geographical locations on the maps. She stated that in the near future, 2 dual-polarized Doppler weather radars will be installed at Borja and Jahorina. She explained early warning system by stating that warnings are issued via Meteoalarm and hydrometeorological bulletins to the public and media.

4.1.3 Croatia

Ms Mutic provided a brief overview of operational flash flood forecasting and early warning system in Croatia. She stressed the collaboration between hydrologists and meteorologists in Croatian Meteorological and Hydrological Service (DHMZ), which was improved after the implementation of the SEEFFGS in Croatia. She stated that after joint detailed hydrometeorological analysis, hydrological and weather forecasters are making decision together for issuing flash flood warnings, which are disseminated to the general public and National Protection and Rescue Directorate. She also provided a flash flood warning verification results for the period from 10 October 2015 to 29 February 2016. She stated that Probability of Detection (PoD) was 95 % while Threat Score was 72 %. She showed the location frequencies of flash flood events in Croatia for the same period, stating that spatial distribution reveals that majority of flash floods occurred along the Adriatic coast which is currently without radar coverage, and below the hilly areas with torrents. She showed some photos of the recent flash flood events. She stated that DHMZ together with Croatian Waters in association with Danish Hydraulic Institute have developed combined hydrological-hydrodynamic MIKE 11 flood forecasting model for the Sava River. Model runs every hour in Hydrological forecasting unit in DHMZ. The operational forecasting system is based on real-time data received from available hydrometeorological stations in Croatia, relevant online data received from Slovenia, and prediction from the NWP models such as ALADIN-HR and ECMWF.

She explained that successful response to flash flood warnings is most likely to occur when people receiving the warning messages have been educated and informed about the particular characteristics of the flash floods, and are familiar with the extent of possible damage that could result. She stated that during the June 2015 at European Space Expo in Zagreb, forecasters from DHMZ informed the public about FFGS satellite products and characteristics of flash floods and their risks. She mentioned that the exhibition was visited by more than 83 thousand of people. She concluded her presentation emphasizing the

SEEFFG system, which proved to be valuable for disseminating warnings in Croatia, and highlighted a great opportunity for enhancement of collaborations with response agencies in disaster risk reduction, and raising community awareness.

4.1.5 Romania

Mr Matreata provided a brief overview of operational flash flood forecasting and early warning capabilities at the National Institute of Hydrology and Water Management in Romania. He emphasized an increase of the frequency of extreme flash flood events in Romania. He stated that The Romanian National Hydrological Forecasts 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. He stated that operational flash flood forecasting and warning system is based on the following main sources: radar products, observations from hydrological and meteorological stations, different numerical meteorological forecasts, operational hydrological forecasts from the National Hydrological Forecasting System (distributed models), Romanian Flash Flood Guidance System (ROFFGS), South East Europe Flash Flood Guidance System (SEEFFGS), and Europe Flood Awareness System (EFAS). He explained hydrometeorological observation network and showed their geographical locations on map. He mentioned that there are more than one thousand manual and automated hydrological stations. He stated that Hydrological Forecasting and Modelling System (HFMS) relies on the gauge-corrected hourly to sub-hourly radar-based quantitative precipitation estimates, which are used as inputs to several real-time hydrological forecasting systems. He briefly described ROFFG system, implemented by HRC and designed to provide flash flood guidance products for sub-basins with an average area of 30 square kilometres. He stated that there are 8,851 sub-basin in ROFFG system. The ROFFG system provides the following products: RADAR (1 km resolution), Merged Mean Areal Precipitation (MAP), Gauge MAP, Average Soil Moisture (ASM), Flash Flood Guidance (FFG), and Forecasted Flash Flood Threat (FFFT). He compared ROFFG system with SEEFFG system, stating that biggest difference is in radar ingestion and, according to that, in the catchment size. He showed maps of Flash Flood Potential Index, Flash Flood Susceptibility Index, and Flash Flood Hazard classes. He concluded his presentation by showing an example of flash flood warning that was issued in Romania.

4.1.6 Slovenia

Mr Petan provided a brief overview of operational flash flood forecasting and early warning capabilities at the Slovenian Environmental Agency (ARSO). He gave an overview of hydrometeorological observation network, which consists of 164 automated hydrological stations, 102 automatic rainfall gauges, and 2 radars. He explained Numerical Weather Prediction (NWP) models which are used for operational forecasting, such as ALADIN and ECMWF. He stated that as an operational nowcasting tool, they are using the Integrated Nowcasting through Comprehensive Analysis (INCA), developed at Austrian meteorological service (ZAMG). The domain with 1 km horizontal resolution covers Slovenia and parts of neighbouring countries. He stated that LACE ALADIN-based Ensemble Prediction System (LAEF) members are used as input data for running the flood forecasting system simulations on Sava and Soča River basins and showed some results. He explained flash flood warning model generated by MIKE11 which are based on rainfall thresholds. He continued by describing early warning process, stating that warnings are disseminated to the public, media, government organizations, including Emergency Management Agency, and neighbouring countries, via Internet, TV, radio, teletext, newspapers, email, fax, ftp, and telephone. He also stated that web site warning notifications include textual warnings, colour coded warning map (Hydroalarm), and downloadable audio clips. At the end, he emphasized the importance of catchment delineation and cross section data which are needed for SEEFFGS improvements.

4.1.7 The Former Yugoslav Republic of Macedonia

Mr Stojov provided an overview flash flood and flood forecasting and early warning system at Macedonian Hydrometeorological Service. He explained operational meteorological and hydrological stations, and showed their geographical location on a map. He described the activities in flood forecasting system which is based on flood peak forecasting by a grapho-analytic technique and SEEFFG system.

4.2. Overview of SEEFFG System Forecaster User Interface

Ms Modrick provided an overview of the SEEFFGS dashboard and forecaster console. She stated that the FFGS user interfaces are secure web-based interfaces to provide overview of the system processing status and current and historical products for IT and forecasting personnel. She explained that functionalities of the dashboard are: 1) display of selected SEEFFGS products with animation tools; 2) real-time data and inventory status; 3) real-time data processing status; 4) computational server status; 5) dissemination server status. She continued to explain the SEEFFGS forecaster console with the following main features: navigation toolbars that allow users to display the products at certain date and time; product table that display full list of the SEEFFGS and products in image formats; and data download buttons in text, CSV, and CSVT formats. She explained the following products in detail:

- **Global Hydro Estimator (GHE) precipitation**, which is produced by US National Oceanic and Atmospheric Administration (NOAA) using Infrared (IR) channel (10.5 micrometre) of geostationary meteorological satellites;

- **Micro Wave adjusted Global Hydro Estimator (MWGHE) precipitation**, which is estimated by correcting GHE precipitation with Micro Wave satellite precipitation;

- **Gauge Mean Areal Precipitation (Gauge MAP)**, which is estimated by using WMO synoptic reports obtained from the GTS network;

- **Merged Mean Areal Precipitation (Merged MAP)**, which is derived from the best available mean areal precipitation estimates from GHE precipitation or MWGHE precipitation or Gauge MAP or Radar estimated precipitation.

- **Average Soil Moisture (ASM)**, which indicates upper soil (20-30 cm) water content, including free and tension water;

- **Flash Flood Guidance (FFG)**, which is an amount of actual rainfall that may cause bankfull flow conditions at the outlet of a sub-basin for a given duration (e.g., 1, 3, or 6 hours);

- **NWP model ingestion,** ALADIN QPF products are ingested to the system;

- **Forecast Mean Areal Precipitation (FMAP),** which is estimated by using ALADIN QPF data;

- **Flash Flood Threat (FFT) products**, which indicate the possibility of flash flood occurrences at the outlet of a particular sub-basin, including Imminent Flash

Flood Threat (IFFT), Persistence Flash Flood Threat (PFFT), and Forecast Flash Flood Threat (FFFT).

- **Gauge Mean Areal Temperature (gauge MAP),** which is estimated using in-situ surface temperature observations from the WMO GTS;
- **Snow Coverage Area (SCA),** which is driven from satellite observations**;**
- **Snow Water Equivalent (SWE)**; and
- **Snow MELT.**

Ms Modrick also explained the Flash Flood Guidance System approach. She stated definitions of flash floods by WMO and American Meteorological Society (AMS) and cited the natural cause of flash floods as intense rainfall from slow moving thunderstorms or tropical systems, orographic rainfall in steep terrain, soil saturation or impervious land surface, and hydraulic channel properties. She explained needs for the FFG system and compared large river flooding with flash floods. She emphasized that it is critical to distinguish them and it is the fundamental concept of the flash flood development and implementation. She continued to explain main components of the FFG system are: runoff modelling; bankfull flow; flash flood guidance; end-to-end process for flash flood warning processes; key components of the FFGS modelling such as precipitation sources and their quality control, snow model, soil moisture model, threshold runoff model, NWP QPF ingestion, and flash flood threat. She showed the diagnostic and prognostic FFG products in stressing that forecasters experiences are fundamental for the issuance of flash flood warnings. She concluded her presentation emphasizing the needs of local data for model calibration and bias adjustments.

4.3. SEEFFG System Development and Theoretical Background

Ms Modrick explained the development and theoretical background of the SEEFFG system in each of the following major categories:1) Special analysis and threshold runoff; 2) Soil moisture, snow and FFG modelling; and 3) Satellite precipitation and bias adjustment. She stated that flash flood basin delineations, which are estimated from quality controlled SRTM-90 m DEM data, are used for model parameterisation, model computations and product displays and have average drainage areas of 150 km^2. She said that results of the delineation are used to compute geometric properties of each watershed, which are used, in turn, for the computation of *Threshold Runoff*[1]. She indicated that this is a constant property of a watershed and that Flash Flood Guidance (FFG) is then estimated from the Threshold Runoff, soil moisture deficit, and evapotranspiration.

She gave an overview of soil moisture, snow and Flash Flood Guidance modelling. She said that the Average Soil Moisture (ASM) product provides an estimate of current soil water in the upper soil depth, expressed as a fraction of saturation. She stated that Sacramento Soil Moisture Accounting (SAC-SMA) model, in which rainfall and snow melt are ingested as input data, is used to estimate ASM. She explained that parameter estimation within the soil model is based on soil texture and soil depth data as provided by the UN Food and Agriculture Organization (FAO). She stated that Snow Accumulation and Ablation Model (SNOW-17) of U.S NWS is employed to estimate Snow Water Equivalent (SWE) and snow melt products for the South East Europe Region. After providing an overview of the snow model, she showed comparisons of modelled SWE and observed snow depth. She then continued to explain the Flash Flood Guidance (FFG) model, specifying that it integrates

[1] Threshold Runoff is defined as the amount of effective precipitation of a given duration which produces the volume of runoff required to cause bankfull flow at the watershed outlet of the draining stream.

Threshold Runoff, soil water content, and current precipitation and that it is updated every six hours.

She continued by explaining that satellite precipitation estimates are derived from geostationary and polar orbiting satellites, providing valuable information for the region where ground-based hydrometeorological observations are sparse. She said that Global Hydro Estimator (GHE) precipitation with 4 km resolution is calculated using the Infra-Red (IR) channel, such that the rainfall rate is correlated with cloud top brightness temperature, while microwave precipitation estimate with 8 km resolution is based on backscattering measurements from raindrops in the microwave spectrum. She also mentioned that there is 18-26 hours latency in operation and that GHE is corrected using microwave precipitation data. She finally articulated that two kinds of bias adjustments were employed. The first one is the climatological bias adjustment to determine the long-term bias in satellite precipitation within a given region using historical precipitation observations, while the second one is the dynamic bias adjustment using in-situ observations disseminated through the GTS.

4.4. SEEFFG System Operational Concept

Mr Turgu provided an overview of operational capabilities of the South East Europe Flash Flood Guidance (SEEFFG) system and illustrated use of its derived products. He described concept of operation FFGS operation at the Regional Centre - Turkish State Meteorological Service. He said that hydrometorological division is the core element within the administration structure to maintain the BSMEFFG and SEEFFG systems and provide products and services to the agencies within the country and participating NMHSs. Its roles and responsibilities are as follows:

- Monitor BSMEFFG and SEEFFG Systems;
- Provide fist level IT maintenance and collaborate with HRC and TSMS IT department to ensure robust operation of the servers;
- Coordination with HRC, WMO, participating countries, national and international organizations;
- Participate in FFG training programme and provide training to the local forecasters;
- Prepare flash flood bulletins and distribute to the weather analysis and forecasting division and executive management;
- Conduct verification studies;
- Promote flash flood products to be used by other national agencies such as agriculture, water management;
- Organize and participate national and international workshops, conferences and meetings on flash floods and floods;
- Prepare user manual, brochures, and other material on Flash Flood Guidance System; and
- Cooperate with universities for the hydro-meteorological capacity development.

4.5. Case studies

Mr Sayin presented a case study on the South East Europe flash flood event that took place on 6-8 March 2016. First of all, he explained the importance of the flash flood case studies that may help forecasters understand responses of the Flash Flood Guidance System (FFGS) under different atmospheric conditions such as storms associated with synoptic and mesoscale depressions and convection in different seasons. Then, he continued to provide an overview of the top-down approach for the preparation of a case study in the following order: 1) analysis of the diagnostic and prognostic synoptic and mesoscale products such as surface, 850, 700, 500 hPa weather charts, as well as jet streams that will allow forecasters to overview there dimensional atmospheric states; 2) Quantitative Precipitation Forecasts

(QPF) of different NWP products such as global ECMWF IFS, and mesoscale ALADIN and WRF models; 3) atmospheric instability analysis including sounding that shows tendency of the air parcels to produce convection and associated cloudiness such as Cumulonimbus clouds; 4) interpretation of satellite and radar images to monitor synoptic and mesoscale scale atmospheric circulation as well as development of local convention; 5) monitoring of in-situ observations, particularly precipitation intensity and accumulation over time and space; 6) analysis of the FFG products; 7) preparation of the FFG bulletins; and 8) issuance of the flash flood warnings and alerts.

He presented an overview of ECMWF IFS surface pressure, 850 hPa, and 500 hPa weather charts from 6 March 2017 at 00 UTC to 7 March 2017 at 12 UTC. He stated that a depression was developed over the central Mediterranean and propagated to the South East Europe in 24 hours, resulting in flooding and flash floods in the region. He explained that a low-pressure centre located over Italy with a value of 1000 mb, while 850 HPa chart showed strong warm air advection ahead of trough and cold air advection behind the trough indicating transition zone between cold air mass and warm air mass and frontal lifting. While the depression was moving toward east, gradients of the 850 hPa isotherms were increased over time between Italy and Turkey. It was stated that 500 hPa low center with a central value of 546 hPa was located over northern Europe and axis of the trough were expanding toward Morocco on 6 March at 00 UTC. The 500 HPa tough propagated eastward until 6 March at 00 UTC. Strong divergence existed ahead the trough over Balkans indicating presence of the low level horizontal divergence and vertical motions in the middle troposphere. -30^{o}C isotherm expanded from England to Spain indicating flow of the polar cold polar air mass into Mediterranean. A well-defined boundary between cold air masses propagating from the north and warm air masses propagating from the south existed over Balkans resulted in the development of steep cold and warm fronts in the region. The depression moved the east overtime and skewed toward east, increasing geopotential gradients over Balkans. The lower and middle atmosphere were unstable ahead of the 500 hPa trough where strong vertical circulation was associated with the frontal lifting. It was stated that there are several prominent instability indices such as K-Index and Convective Available Potential Energy (CAPE) commonly used to measure the atmospheric stability. CAPE field had a maximum value of 2000 over Italy and along the Adriatic coast, indicated strong atmospheric instability that may create favourable conditions for the development of convective storms.

He compared 6-hr ECMWF IFS and WRF Quantitative Precipitation Forecasts (QPF) accumulation from 6 March at 00 UTC to 7th March at 18 UTC. It was stated that there were big differences in the QPF fields of two models at 06 UTC, 12 UTC, and 18 UTC such that maximum values of the ECMWF IFS QPF were of 46.4 mm, 44.1 mm, and 39.9 mm; while WRF values were of 68.3 mm, 92.3 mm, and 90.6 mm. It was clearly shown that WRF QPF values were as twice high as ECMWF IFS QPF. That´s why, multi-model NWP model QPF ingestion was quite important to compare QPFs of different models and to monitor their performances during various seasons and months under different weather conditions.

He provided an overview of the SEEFFG products from 5 March at 00 UTC to 6 March at 18 UTC. He stated that satellite precipitation products (GHE and MWGHE) showed that 6-hr precipitation accumulation had a maximum value of 60 mm over Serbia, Croatia, and western Romania on 5 at 00 UTC. Average Soil Moisture (ASM) values over the same region were one, indicating that top soil was completely saturated due to accumulation of the rainfall over last six hours. On the other hand, Flash Flood Guidance (FFG) values were quite low ranging from 15 to 30 mm/6-hr. This indicates that if rainfall intensity continues at the same rate or more bankfull condition will be met resulting in flooding at the outlets of the catchments. Therefore, 6-hr and 24-hr QPF values of ALADIN mesoscale model were analysed to find out spatial and temporal distribution of precipitation forecasts over next 24 hours. 24-hr ALADIN QPF was 75 mm over Croatia and the Adriatic Sea. Once the depression moved the southeast to the Adriatic Coast, maximum precipitation intensity reached 75mm/24-hr over Montenegro and Albania where precipitation intensified due to moisture influx from the sea and orographic lifting attaining 120 mm/24-hr rainfall accumulation at 18 UTC. 6-hr ASM from 5 March 00 UTC to 6 March 00 UTC showed that top soil was saturated in Croatia, Bosnia and Herzegovina, and Montenegro, while 6-hr FFG values decreased to 15 mm for the same period. Forecast Flash Flood Threat (FFFT) values which shows access amount of rainfall ranged from 15 mm to 25 mm/6-hr over Montenegro, indicating high possibility of occurrences of flash floods. The system propagated to the northeast from Montenegro to Bosnia and Herzegovina, and Serbia with 90 mm/6-hr rainfall intensity. Spatial coverage of FFFT expanded toward the northwest in Montenegro and had a maximum value of 60 mm/6-hr at 6 March at 06 UTC. It was stated that two people were killed and extensive property damages accrued due to flash floods from 6 to 7 of March in the region. He showed a template for the flash flood warning messages that may be used by the duty forecasters to submit them to the concern authorities through various media such as email, SMS, and fax. He emphasized that central Mediterranean depressions, which associated with fronts and propagate southeast Europe through Adriatic Sea, produce heavy rainfall causing flash floods.

4.5.1 Albania

Mr Zaimi gave his presentation on the flash flood event that occurred in Albania on 11 October 2015. First, he provided an overview of the weather analysis on 11 October at 00 UTC, emphasizing that flash floods were caused by the Mediterranean depression coupled with the orographic lifting. He showed European Storm Forecast Experiment (ESTOFEX) and European Flood Awareness System (EFAS) products from 10 October 2015, which indicated severe weather over Albania.

He provided an overview of the SEEFFGS products from 10 October 00 UTC to 11 October 12 UTC. He stated that Merged Mean Areal Precipitation (MAP) had a maximum value of 120 mm over the western and central Albania on 11 October at 00, 06, and 12 UTC. Average Soil Moisture (ASM) vales over the same part were 1.00, indicating saturation of the top soil in Albania. The 6-hr Flash Flood Guidance values were with 15 mm very low over the almost all the country. 6-hr Imminent Flash Flood Threat (IFFT) on 11 October existed over the northern, western, and central Albania, with values up to 100 mm at 00 UTC, indicating very high probability of accordance of the flash floods. The 24-hr Forecast Mean Areal Precipitation (FMAP) on 10 October at 12 UTC that is generated by ALADIN mesoscale precipitation forecast, showed values up to 120 mm, while the 6-hr FMAP had a maximum value of 90 mm at 18 UTC over the western part of Albania. 6-hr Forecast Flash Flood Threat (FFFT) on 10 October existed over the northern, southern and central Albania, while on the 11 October high FFFT value were attained in the same region. Taking into consideration of FFG, ASM, Merged MAP, and FFFT products, he stated that flash floods were predicted and warnings issued in advance.

4.5.2 Bosnia and Herzegovina

Ms Babic and Ms Djordjevic presented a case study for the flash flood event that took place on 14 and 15 October 2015 in Bosnia and Herzegovina. At the beginning, it was stressed that Bosnia and Herzegovina (BiH) has two National Meteorological and Hydrological Services with the same responsibilities, but for the different entities. First, Ms Djordjevic provided an overview of the weather analysis on 14 and 15 October. She showed 500 hPa weather charts and stated that 500 hPa low centre with a central value of 543 hPa was located over Germany and axis of the trough were expanding to the south. She showed EUMETSAT Airmass RGB overlaid with 500 hPa geopotential height images stressing cyclogenesis over north Italy which resulted in flash flooding in the region. She also showed

ECMWF 24-hr Quantitative Precipitation Forecast (QPF) on 13 October at 00 UTC with maximum values up to 100 mm over coastal Croatia and western BiH.

Ms Babic provided an overview of the SEEFFG products from 14 October at 06 UTC to 15 October at 12 UTC. She stated that forecasters noted high soil moisture saturation on 14 October in the western and central part of the country, and this high level propagated southward across the mountains during the event. During the 15 October, 6-hour Average Soil Moisture (ASM) showed total saturation of the upper soils in the central, western, and southern BiH. The 6-hr Flash Flood Guidance (FFG) estimates were very low (10-25 mm/hr) for many sub-basins in the same regions. She stated that 6-hr and 24-hr Quantitative Precipitation Forecast (QPF) values generated by ALADIN on 14 October at 18 UTC showed maximum values up to 90 mm/6-hr and 120 mm/24-hr. The system estimated 6-hr Imminent Flash Flood Threat (IFFT) on 15 October at 06 UTC in the central and southwestern BiH with maximum values up to 100 mm, indicating that that flash floods could be happening in the region. On the other hand, 6-hr Forecast FFTs were estimated over the same areas such that some catchments attained a maximum value of 40 mm. Considering current states of the weather conditions, forecasts, and analysis of the SEEFFGS products, she stressed that flash flood warnings were issued well in advance to the public and Disaster Management Agencies.

4.5.3 Croatia

Ms Mutic and Mr Jurlina presented a case study on the flash flood event that took place in Peljesac peninsula in southern Croatia on 10 October 2015. First, Ms Mutic provided a brief overview of climatological analysis and wildfires that had impact on this event. The average monthly air temperature for June, July, and August 2015 in southern Croatia was above the multi-annual average (1961-1990) as indicated by positive anomalies of average monthly air temperature. According to percentile ranks and classification ratings, thermal conditions in southern Croatia for all three months dominantly fall under the extremely warm category. Extremely high temperature as well as lower precipitation averages have contributed to the several wildfires in Peljesac, after which severe flash floods events occurred. She explained the impacts of heavy rainfall on the land affected by fires stating that wildfires can alter soil properties, so that burn areas become hydrophobic, and tending to repel and not absorb water, for weeks or even years following a fire. She stressed that indeed, some of the greatest flash flood risks in the Mediterranean area, occur after high-intensity fires in coniferous forests. She stated that the time required for a flash flood to begin depends on how severe the fire was and how steep the terrain is, combined with the rainfall rate. She also stated that wildfires increase the flash flood risk by increasing the runoff volume and the potential for sediment transport (debris flow) within the runoff. She showed photos of wildfires over steep slopes in Peljesac and satellite images that captured smoke of these events: NASA’s natural-colour geostationary satellite image collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument that flies aboard the Aqua satellite, EUMETSAT’s MSG Seviri High Resolution Visible (HRV) and RGB Night Microphysical. She concluded her part of presentation by saying that although rainfall is often considered the most important factor for forecasting flash floods, what happens to the rain when once it is on the ground can sometimes be of greater importance.

Mr Jurlina first explained meteorological conditions that resulted in producing heavy precipitation. He showed DWD surface analysis and EUMETSAT Airmass RGB overlaid with 500 hPa geopotential height images from 10 October 00 UTC to 11 October 12 UTC. He explained that Croatia and western Bosnia and Herzegovina were most of the time under the influence of southerly and southwesterly flow, which was bringing moist air from the Mediterranean. In this flow regime surface cyclone from the Tyrrhenian Sea entered the Adriatic Sea bringing extreme amounts of heavy rainfall that triggered multiple flash flood events. It was also shown that 24-hr ALADIN-HR Quantitative Precipitation Forecast (QPF) was more than 100 mm over southern Croatia, Bosnia and Herzegovina, and Montenegro.

Then, he provided an overview of the SEEFFGS products on 11 October at 00, 06, 12, and 18 UTC. First of all, he showed spatial and temporal distribution of various FFGS diagnostic products, such as Average Soil Moisture (ASM), indicated that upper soil became completely saturated along Adriatic at 18 UTC, while 6-hr Flash Flood Guidance (FFG) values were with 15-30 mm low over the same areas. 1-hr, 3-hr, and 6-hr Imminent Flash Flood Threat (IFFT), and 1-hr, 3-hr, and 6-hr Persistent Flash Flood Threat (PFFT) existed over the central and southern Adriatic regions, with values up to 40 mm. Forecasted Mean Areal Precipitation (FMAP) showed that 24-hr precipitation accumulation was up to 120 mm. He showed that also there were a number of sub-basins with Forecast Flash Flood Threats (FFFT) in the analysed area, while maximum FFFT reached 60 mm/6r over southern Croatia. He showed some photos and video records of the event, saying that the most affected areas were the exact locations where wildfires occurred. He concluded his part of presentation emphasizing that FFGS products are very valuable and useful for the issuance of flash flood forecasts and warnings in Croatia.

4.5.6. Moldova

Mr Gherman presented a case study on the flash flood event that took place in northern Moldova in 2015. He provided an overview of meteorological analysis on 26 May and 15-16 June 2015 by showing radar images, precipitation accumulation and soil moisture conditions. He concluded his presentation by showing a video records of the flash flood events.

4.5.6 Romania

Mr Matreata presented a case study on the multiple flash flood events that took place in Romania on 9 and 11 April 2016. First, he provided an overview of SEEFFG products on 9 April at 6 and 12 UTC. He stated that satellite precipitation products (GHE and MWGHE) showed that 24-hr precipitation accumulation had a maximum value of 35 mm over northwestern part of Romania, while 6-hr precipitation accumulations were up to 10 mm over central Romania at 06 UTC. He showed an Average Soil Moisture (ASM) map that indicates that catchments had ASM values ranging from 0.30 to 1.00 over central, northern and western Romania, showing completely saturation. He stated that Flash Flood Guidance (FFG) values for the same areas were quite low ranging from 0.01 to 30 mm/6-hr. The 6-hr and 24-hr Quantitative Precipitation Forecast (QPF) values of ALADIN mesoscale model had values up to 35 mm. He stated that based on results generated by SEEFFGS, ROFFGS, EFAS, and radar products, flash flood warnings were issued well in advance on 9 April at 19 EET.

He continued to explain the SEEFFGS products from 11 April at 06 and 12 UTC. He stated that satellite precipitation accumulation indicated a precipitation band expanding over Romania with a maximum core value of 75mm/24-hr. He stated that MAP had maximum values of 40 mm/6-hr and 50 mm/24-hr at 06 UTC over the central Romania. ASM values at 06 UTC in the same area were ranging from 0.85 to 1.00, indicating that upper part of soil had reached complete saturation, making that area vulnerable for the possible flash flood occurrences. He showed FFG chart and stated that values reached their minimums with 0-15 mm over the same areas. The 6-hour FMAP showed values up to 40 mm, while 24-hr precipitation accumulation was up to 100 mm. There were a number of basins with Forecast Flash Flood Threats (FFFT) in the region, while maximum FFFT reached 10 mm/6-hr over central part of Romania. 6-hr Imminent Flash Flood Threat (IFFT) at 12 UTC existed over the same areas with the values up to 25 mm, indicating high probability of occurrence of flash flooding. For that part of the country, National Institute of Hydrology and Water Management issued another flash flood warning. He concluded his presentation by showing a video record and photos of a flash floods events and stating that FFG system is very useful tool for forecasters to issue timely and accurate flash flood watches and warnings.

4.5.6 Serbia

Mr Vladikovic provided a brief overview of flood and flash flood event that took place from 7 to 14 March 2016 in Serbia. He stated that torrential rainfall triggered flash floods and led to large scale flooding along Zapadna Morava, Juzna Morava, Ibar, Kolubara, Drina, Lim, and Jadar Rivers, and their tributaries. He continued to provide a weather analysis, saying that the period from 6 to 8 March was characterized by prevalence of the cyclone circulation formed in the Genoa Bay, atmospheric front in southwesterly upper level flow, and low-level jet stream, with scattered rain and showers across the country. He stated that highest amounts of precipitation were recorded in western and southwestern Serbia. He showed water level hydrographs stressing the water level, which rose very rapidly, causing large economic losses and effecting thousands of people.

Ms Jerinic provided an overview of the SEEFFG products from 5 to 7 March 2016. She stated that 6-hr Merged Mean Areal Precipitation (Merged MAP) had a maximum value of 75 mm over the western Serbia on 7 March at 12 UTC. She showed temporal and spatial distribution of 6-hr Average Soil Moisture (ASM) from 5 March at 00 UTC to 7 March at 12 UTC. She explained that upper soil was completely saturated rapidly over northern, western, and southwestern Serbia, while 6-hr Flash Flood Guidance (FFG) values reached their very low values, from 0-30 mm, over the same areas. She showed 24-hr ALADIN QPF on 6 March at 12 UTC, with 120 mm in the southwestern Serbia, Montenegro and Albania, indicating high possibility of flash flood occurrence. 6-hr Imminent Flash Flood Threat (IFFT) on 6 March at 18 UTC existed over north and central Serbia, and on 7 March at 00 UTC expanded on the western Serbia with the values up to 40 mm, indicating high probability of accordance of flash flood in the region. She stated that on 7 March, due to heavy rainfalls, flooding, and flash flooding, an emergency situation has been declared for 14 cities and municipalities in the central and western parts of Serbia. On 8 March, approximately 200 persons were evacuated and more than 700 households have been flooded. She concluded her presentation stating that SEEFFG System is a very valuable supplementary tool for forecasting flash floods events in Serbia.

4.5.7 Slovenia

Mr Golob presented two case studies on the flash flood events that occurred on 1-2 May 2016, and 11-18 May 2015. At the beginning of the first presentation, he stated that heavy local precipitation in combination with snow melt, resulted in flash flooding in the northeastern Slovenia. Then, he commenced to provide an overview of the SEEFFGS products from 1 May at 00 UTC to 2 May at 12 UTC. It was stated that 96-hr MELT on 1 May at 00 had a maximum value up to 30 mm, while there were a lot of sub-basins that had soil moisture fraction higher than 0.65 (light green) so they must have been monitored for possible flash flood occurrences. He stated that Quantitative Precipitation Forecast (QPF) showed that 24-hr precipitation accumulation exceeded 75 mm over some catchments in the northeastern Slovenia. 6-hr Gauge Mean Areal Precipitation (GMAP) at 18 UTC had a maximum precipitation accumulation of 40 mm, while merged Mean Areal Precipitation (MAP) had a maximum value of 10 mm over the same areas. He explained that underestimation of satellite precipitation estimates resulted in lower MAP and higher Flash Flood Guidance (FFG) values. The Forecast Flash Flood Threat (FFFT), which is an index showing the possible occurrences of flash floods, had value of 5 mm and existed over one catchment in the northeastern Slovenia.

In second part of presentation, he gave an overview of the SEEFFGS products from 14 October at 00 UTC to 15 October at 00 UTC. He stated that low pressure system over the

Adriatic Sea caused intensive precipitation which resulted in flash flooding in the central and southern Slovenia. It was stated that bankfull conditions exceeded at several catchments due to heavy rainfall intensity, and limited capacity of karstic underground aquifers. He showed GMAP and MAP charts with a maximum values up to 40 mm. Soil Moisture (ASM) chart indicated that top soil in most of the catchments were saturated. Spatial distribution of 6-hr Flash Flood Guidance (FFG) field showed that FFG values were low in a range between 1 to 30 mm, indicating that occurrence of the bankfull conditions was very likely over the next 6 to 24 hours if current precipitation intensity persists. 6-hr Forecast Flash Flood Threat (FFFT), which is the difference between 6-hr Forecast Mean Areal Precipitation (FMAP) and 6-hr FFG, existed over western and southern Slovenia having a maximum value of 50 mm. He concluded by saying that flash flood warnings were issued in advance, and that in this case SEEFFG system was precise and useful.

4.5.6 The former Yugoslav Republic of Macedonia

Mr Stojov presented a case study on flash flood event that occurred in Shipkovica, in the northern The former Yugoslav Republic of Macedonia, on 3 August 2015. At the beginning, he cited that according to witnesses, the rain started around 13:00 UTC, as a normal or common rainfall, and progressed into precipitation with strong intensity for approximately an hour. At 15:30 UTC, water started to flow through the gully in the middle of the village, and after only 10-15 minutes, large amount of dirt, sand and stones were being carried by the water, and were crashing between and through the houses.

He then continued to provide an overview of weather analysis on 2 August stating there were intrusion of upper level low from north over the Balkans with advection of little colder air in the centre of system (-10°C), indicating unstable atmosphere with potential for developing thunderstorms. EUMETSAT geostationary satellite images showed a cloud band with associated medium and high clouds over and the southern part of the region, including The former Yugoslav Republic of Macedonia on 3 August at 12 UTC.

He gave an overview of the SEEFFGS products on 3 August from 12 UTC to 18 UTC. He stated that 6-hr Merged Mean Areal Precipitation (Merged MAP) had a maximum value of 20 mm at 15 UTC. Average Soil Moisture (ASM) was fairly low throughout the country prior to the event (12:00 UTC), but changed quickly to high saturation for some basins by 18:00 UTC. It was explained that during the summer and when soil is dry, soil crusts can be formed, which can significantly reduce soil infiltration rate and subsequently the utilization of water resources, and increase surface runoff, especially during intense summer convective rainfall. He stated that 1-hr Flash Flood Guidance (FFG) at 12 UTC were with 25 mm low, while 3-hr FFG indicated that 25-40 mm of rainfall over the Shipkovica catchment is needed to cause bankfull condition at the outlet of the catchment. The 6-hr Forecasted MAP at 15 UTC had maximum precipitation accumulation of 60 mm, located southern of Shipkovica, where ALADIN QPF was around 20 mm. He concluded his presentation by showing the photos of flash flood consequences, and saying that knowledge of local conditions and the location of heavy precipitation (both observed and forecast) were critical in assessing the situation for this event.

4.6. Technical Background on the Flash Flood Verification

Ms Modrick provided a presentation on technical background on the flash flood verification. At the beginning, she stressed different aspects of the SEEFFG system which can be validated, including: diagnostic products (observed MAP, soil moisture), forecast products (mesoscale model, FMAP), and validation of flash flood warnings issued by forecasters. She stated if persistent biases are found in certain regions, they can be corrected by post-processing the system results before estimating FFFT and deciding whether to issue a warning. To identify strengths and challenges in the end-to-end process of warning-response, flash flood events should be collected and archived in database. She showed evaluation of the Probability of Detection (POD) and False Alarm Rate (FAR) sample frequencies for 20 years for discharge at the catchment outlet exceeding a given threshold (mm/hr). She explained that POD reached 83 % for the flow of a 2-year return period with a corresponding FAR frequency of 7 %. She continued to explain that the system can perform well under good quality of data. Reduction of POD and increase of FAR may happen because of system-input data quality degradation in different regions and locations (e.g. satellite or radar data quality, and rainfall nowcast or forecast quality). She continued by explaining initial validation of FFG system products, which were made for the Central America FFG (CAFFG) system implemented in 2004. She stated that for 3 months training, system operators from Costa Rica and El Salvador were in daily communication with Country Agencies to receive community information regarding local flooding. The evaluation considered the success of the system-produced FFFT and the forecaster-adjusted FFT during the period from September to November 2004. The ground truth data used to evaluate FFT were local reports of flash flood occurrence (or non-occurrence). The metrics used in this case were number of hits, false alarms, and number of misses. She showed the results of operational evaluation of CAFFG FFT explaining that when system is used as intended by the forecaster and forecaster adjustments are made, significant skill is added in both predicting events that occurred and minimizing the warnings for the events that did not occurred. Ms Modrick also showed an example of contingency table for the flash flood bulletins developed by Turkish State Meteorological service (TSMS) for the period from 21 May 2012 to 17 June 2013. She concluded stressing the importance of SEEFFG system validation and advising participating countries to develop a database of observed flash flood events, and statistical measurements for assessing performance of warning generation process.

4.7. BSMEFFG System Verification Results and Challenges

Mr Turgu presented BSMEFFG system verification results and challenges. At the beginning, he stressed the definition of verification process given by WMO, citing that the main goal of verification process is to constantly improve the quality (skill and accuracy) of the services including: Establishment of a skill and accuracy reference against which subsequent changes in forecast procedures or introduction of new technology can be measured; Identification of the specific strengths and weaknesses in a forecaster's skill and the need for forecaster training and similar identification of a model's particular skill and the need for model improvement; and Information to the management about a forecast program past and current level of skill to plan future improvements; information can be used in making decisions concerning the organizational structure, modernization and restructuring the National NMHSs. After describing the verification process, he showed an example of TSMS Extreme Event Observation (FEVK) Records. He explained that flash flood records include data such as: latitude and longitude of the event, start/finish date and time of event, precipitation amount, remarks, location of event, photos, and whether flash flood bulletin was issued or not. He stated that all records are stored in Excel sheet. He stressed that verification process in Turkey is very challenging because Turkey has more than 11,800 sub-basins, with an average drainage area of 64 km^2. He showed and compared maps of location frequencies of flash flood events in 2014 reported by TSMS, State Hydraulic Affairs (DSI) and press. He continued by showing and explaining the contingency table of flash flood warnings for 2014. He stated that Probability of Detection (PoD) was 55 %, False Alarm Ratio was 15 % and Critical Success Index 0.4 %. After presenting flash flood warnings in 2014, he also showed and compared maps of location frequencies of flash flood events in 2015 reported by TSMS, DSI, and press. In 2015, TSMS reported 276, DSI 94, and press 82 flash flood events in different locations across Turkey, respectively. Spatial distribution reveals that majority of the flash floods occurred along the coastal regions. He showed a graph presenting monthly distribution of TSMS extreme event observation and flash floods hits in 2014. He stressed June as a month with the most extreme event observations (47) in 2014, and stated that 15 of them were flash floods. He also showed a monthly distribution of flash flood events in 2015, which also revealed that most of flash floods occurred in June (80), and emphasized the seasonality of flash flood occurrence in Turkey. At the end, he stressed the importance of flash flood verification process, which is necessary to evaluate the performance of the FFG system.

4.8. Hands-on Exercises

As hands-on exercises, three flash flood events were studied by the participants collectively.

Ms Mutic presented a case study as a part of hands-on exercise for the flash flood event that took place on 14 October 2015 in Croatia. She used the Flash Flood Guidance Simulator to interpret the SEEFFFGS products for the issuance of flash flood warnings in combination with weather analysis, nowcasting, and local hydrometeorlogical data. The FFGS Simulator has the following features:

- Synoptic (ECMWF) Analysis: Geopotential height 500 hPa, Mean Sea Level Pressure (MSLP), Convective Available Potential Energy (CAPE), 3-hr and 24-hr Quantitative Precipitation; Forecast (QPF), Wind fields, SYNOP reports, and Radio sounding data;
- Mesoscale ALADIN NWP Analysis: 3-hr and 24-hr Quantitative Precipitation Forecast (QPF), and Wind fields;
- Weather Satellite images: RGB air mass analysis, enhanced IR colour, EUMETSAT Satellite Application Facility (SAF) Convective Rainfall Rate (CRR), and Lighting data;
- FFGS Diagnostic products: Global Hydro Estimator (GHE) precipitation, Micro Wave adjusted Global Hydro Estimator (MWGHE), Gauge Mean Areal Precipitation (Gauge MAP), Merged Mean Areal Precipitation (Merged MAP), Average Soil Moisture (ASM), and Flash Flood Guidance (FFG);
- FFGS Forecast products: Forecasted Mean Areal Precipitation (FMAP) based on ALADINNWP model;
- FFGS Warning products: Imminent Flash Flood Threat (IFFT), Persistence Flash Flood Threat (PFFT), and Forecasted Flash Flood Threat (FFFT); and
- Other data: Average slope map, Hydrological Soil Group (HSG) map, Dominant land cover and land use map, population density map as such all data were calculated and presented for each sub-basin in Croatia.

She provided an overview of the weather conditions by using the simulator. She explained the following key weather features in her briefing: development and propagation of the low pressure centres, troughs, ridges, cold and warm air advections, divergence and convergence fields, and associated weather patterns. It was stated that Croatia was under the influence of a low-pressure system situated over the Gulf of Genoa, and a strong jet streak was curved along the cut-off low resulting in high values of deep layer shear (DLS) and significant low-level shear (LLS). That is why, mid and lower troposphere zones were instable with high Convective Available Potential Energy (CAPE) that overlapped with strong DLS, LLS, and orographic lifting, resulting in organized and long-lived convections. EUMETSAT geostationary satellite images showed development of cumulonimbus clouds with high cloud tops over Italy, Croatia, and Bosnia and Herzegovina which produced heavy rain along the coastline and subsequently flash floods in the region. She then continued by providing an overview of the SEEFFGS products.

First, FFGS Diagnostic products were analysed to investigate hydrological response of the catchments. The 6-hr GHE and MWGHE products on 14 October 2015 at 00 UTC showed that precipitation was very low over the central parts of the Adriatic coast and on the islands. On the other hand, 6 hours later, at 06 UTC, 6-hr GHE had a maximum value of 20-40 mm along the Adriatic coast, while 6-hr Gauge MAP (GMAP) at 06 UTC had a maximum precipitation accumulation of 60 mm. She reiterated that Merged MAP is a bias corrected precipitation product that was ingested into various hydrological models such as Snow-17 and Sacramento Soil Moisture Accounting Model (SAC-SMA). It was stated that at 06 UTC, the precipitation pattern spread across the country with a maximum Merged MAP value of 40 mm in the central parts of the coastal region. She emphasized that forecasters should pay attention to spatial and temporal variation of soil moisture. It was stated that the 6-hour Average Soil Moisture (ASM) product showed that upper soil in the coastal and mountainous regions were completely saturated. She stated that 1-hr FFG values were as low as 10-25 mm in many basins in the south and coastal regions, indicating suitable conditions for the occurrences of flash floods. She mentioned that the depression had become stationary over the region and that 24-hr ALADIN QPF was more than 120 mm, while 6-hr FMAP at 12 UTC had maximum precipitation accumulation of 90 mm. It was shown that Forecast Flash Flood Threat (FFFT) products indicated positive values with possibility of flash flood occurrence in the mountainous region in the southern coasts as such 6-hr FFFT had maximum values of 40 mm and 100 mm at 06 UTC and at 12 UTC in the central part of the coastal region.

Ms Mutic stated that Croatian media and Disaster Management Agency (DMA) reported flash flood events with widespread property damages and considerable economical losses. She mentioned that the Croatian MHS issued several flash flood warnings in advance to the national DMA, the public, and media that helped to prevent loss of life. She showed post-event verification results that probability of detection (PoD) was 90% and probability of false alarm rate was 10%. It was also stated that bedsides the flood events, approximately 100 landslides occurred in the same region. She emphasized that the short lead time is the biggest constraint to issuing flash flood warnings. To issue then in a timely fashion and with the greatest accuracy, forecasters should use all available tools and their products, including FFGS and assess these using their expert judgement and skill. She concluded her presentation, saying that it was critical for the forecasters of the national service to collaborate with Disaster Management Agency (DMA) of Croatia to prevent loss of life and minimize economic damages.

Second hands-on exercise was led by the Ms Renko who provided a daily weather briefing depicting surface, 850 hPa, 500 hPa, satellite images, and precipitation analysis on 12 May, including 24 and 72 hours forecasts. Development and propagation of the low-pressure centres, troughs, ridges, cold and warm air advections, divergence and convergence fields and associated weather patterns were also explained in detailed. After the weather briefing, facilitated discussion took place amongst participants who expressed their views on the interpretation of the SEEFFGS products and possible occurrences of flash floods in the region.

As a part of facilitated discussion, Ms Samper Hiraldo provided an overview of flash flood event that took place in Biescas, in Spainish Pyrnees on 7 August 1996. Eighty-seven people were killed as a result of the catastrophic flash flood, which hit a campsite located on the alluvial fan at the outlet of the 19 km^2 catchment. She stressed rainfall intensity which was estimated at 500 mm/hr. She concluded by emphasizing destructive power of flash flood events.

4.9. Post-processing of SEEFFG products with QGIS and preparations of Operational Flash Flood Bulletins and Warnings: Hands-on Exercises

Mr Akbaş presented post-processing of SEEFFG products with Quantum Geographical Information System (QGIS), as a part of hands-on exercises. He stated that for the preparation of a Flash Flood Early Warning Bulletin, forecaster can use Forecast Flash Flood Threat (FFFT) products. The web page for QGIS software download and installation instructions were provided. He also reiterated and stressed that all SEEFFG participating countries have sub-basin boundaries in the shapefile format under the “Static Resources” tab of SEEFFG Interface. These files can be opened by every GIS software after unzipping them. Because flash flood often occurs in small areas, forecasters would like to see not only the SEEFFG products, but also additional layers that can be displayed with the products, so that precise location can be determined. He showed where and how to download additional free vector GIS layers, such as cities, roads, railways, rivers, lakes, administrative boundaries, land use, soil data, and raster layer such as digital elevation model. During the hands-on exercise, each participant downloaded all required shapefiles and tab-delimited hourly SEEFFGS output data from the Product console, and created its own map for the Flash Flood Guidance Bulletin. At the end, he showed an example of the bulletin created and disseminated by Turkish State Meteorological Service.

4.10. Overview of Advances of the International SAVA River Basin Commission

Mr Sarac from the International Sava River Basin Commission provided an overview of the advances such as Sava Geographical Information System (Sava GIS) and Sava Hydrological Information System (Sava HIS). He stated that Sava HIS will provide a tool for collecting storing, analysing and reporting a sufficiently high-quality data hydrological and meteorological data. Those data and information will be used in decision-making system in all aspects of water resources management, while Sava GIS is designed to support sharing and disseminating of data and information among the Sava River basin countries.

4.11. SEEFFG Hydrometeorological Training

As a part of the facilitated discussions, Mr Sayin stated that training was an integral part of the project, and extensive training would be provided to the participant countries' forecasters. He showed the schematic diagram outlining the FFGS hydrometeorological training programme, which is contained in ANNEX III of this report. He explained that it consisted of five steps:

- Step 1 introductory regional workshop;
- Step 2 eLearning hydrometeorological training;
- Step 3 specialized training at HRC;
- Step 4 regional operations training workshop; and
- Step 5 regional operational sustainability workshops.

He further articulated that once the training was completed, forecasters should be confident and competent to use FFGS products for flash flood forecasting and the provision of early warnings. Forecasters recommended that WMO should facilitate more regional operational sustainability trainings (Step-4) for the forecasters.

4.12 Evaluation of the trainees

This workshop corresponds to the step-4 training of the flash flood hydrometeorologist training programme. One of the main goals of this workshop is to evaluate trainees who have successfully completed SEEFFGS step-2 and 3 training to be qualified for the WMO certified FFG trainers. That is why, Mr Klodian Zaimi from Albania**,** Ms Petra Mutic and Toni Jurlina from Croatia, Ms Azra Babic and Ms Milica Djordjevic from Bosnia and Herzegovina, Mr Gherman Bejenaru from Moldova**,** Ms Jelena Jerinic from Serbia, Mr Saso Petan and Mr Andrej Golob from Slovania presented flash flood case studies and took a written exam. The results will be evaluated by the WMO and HRC representatives.

5. Conclusions and Outcomes of the Follow-Up Operational Workshop

1. There was agreement among participants that the SEEFFG System is a useful tool to enable forecasters to issue timely and accurate flash flood warnings in combination with other available tools such as weather analysis and forecasts and nowcasts;

2. Participants agreed that more regional operational trainings should be facilitated by the project partners.

3. Participants became familiar with the SEEFFGS operational concept.

4. Participants developed competencies to be able to access to the SEEFFGS servers to use its products.

5. Participants become familiar the key technical and scientific backgrounds of the SEEFFGS developments, including bias adjustments with historical and dynamic precipitation data, soil moisture modelling, threshold runoff modelling, snow modelling and flash flood guidance modelling.

6. Participants noted the necessity of real-time data reception through the GTS to allow real-time bias precipitation adjustment and use of other surface data in model calculations such as surface temperature data ingestion into snow accumulation and ablation model.

7. Participants became familiar with the SEEFFGS forecaster console, dashboard, and its products such as Global Hydro Estimator (GHE), Microwave adjusted GHE, gauge Mean Areal Precipitation (MAP), merged MAP, Average Soil Moisture, Flash Flood Guidance (FFG), Flash Flood Threats (FFT), Forecast Mean Areal Precipitation (FMAP), Snow Water Equivalent (SWE), Snow MELT, Mean Areal Temperature (MAT), and satellite snow coverage.

8. Participants developed basic competencies to be able to make synoptic, mesoscale, and nowcasting analysis and interpret the SEEFFGS products to prepare flash flood warnings.

9. Participants agreed that country-level verification studies shall be conducted on the flash flood warnings and FFGS products to improve the performance of the SEEFFG System and that a verification guideline should be available to the participating countries,

10. Participants agreed that implementation of the advance modules such as multi-NWP QPF ingestion is very beneficial to NMHSs. They noted radar data ingestion in Turkey and recommended that it should be implemented for the other participating countries where weather Radar network have already been installed.

11. Participants developed competencies to post-process SEEFFGS products with QGIS, and to prepare clear and understandable flash flood warning messages.

12. Participants took a written exam on the FFGS technical and scientific background and gave a presentation of a flash flood event that took place in their countries for the qualification of certified WMO FFG trainers.

13. There was an agreement that participants from Croatia, Bosnia and Herzegovina, and Slovenia, who have participated in Step-3, will prepare SEEFFGS User Guide.

6. Closing of the Follow-Up Operational Workshop

Closing remarks were made by WMO, HRC, Croatian Meteorological and Hydrological Service, and participants. Thanks were also extended to all attendees for their active participation in the workshop and spirited involvement in the discussions, which contributed to the successful conclusion of the workshop.

ANNEX I

FOLLOW-UP OPERATIONAL WORKSHOP

SOUTH EAST EUROPE FLASH FLOOD GUIDANCE (SEEFFG) SYSTEM

Zagreb, Croatia

9–13 May 2016

List of Participants

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ANNEX II

Follow-Up Operational Workshop South East Europe Flash Flood Guidance (SEEFFG) System

Zagreb, Croatia, 9-13 May 2016

Workshop Agenda

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Day 1

09:00-09:15 Registration of participants
09:15-09:45 Opening of the workshop (DHMZ, WMO, HRC)
09:45-10:15 Introduction of participants *(All)*
10:15-10:30 Overview and Purpose of the Workshop (WMO)

10:30-11:00 Tea Break

11:00-12:30 Status of Operational flash flood forecasting and early warnings capabilities at the NMHSs
(Country presentations and Discussions)

12:30-14:00 Lunch Break
Interactive session-participants to be engaged in discussions to demonstrate their comprehension of the system.

14:00-14:30 Overview of SEEFFG System Forecaster User Interface (HRC)

- Forecaster Console
- Dashboard

14:30-15:00 Review of the SEEFFG System Design/Theoretical Background
Precipitation Components (HRC)

- Satellite/Radar Precipitation Estimation and bias adjustment
- Precipitation Observations
- Merged Mean Areal Precipitation (merged MAP)
- NWP Rainfall Forecasts

15:00-15:30 Review of the SEEFFG System Design/Theoretical Background
System's Hydrological Model Components (HRC)

- Spatial GIS Analysis
- Threshold Runoff Estimation
- Soil Moisture
- Snow Model

15:30-16:00 Tea Break

Interactive session-participants to be engaged in discussions to demonstrate their comprehension of the system

16:00-16:30 Review of the SEEFFG System Design/Theoretical Background
Flash Flood Guidance (HRC)
- Flash Flood Guidance (FFG)
- Flash Flood Threats (IFFT, PFFT, FFFT)

16:30-17:00 Review of the SEEFFG System Design/Theoretical Background
Snow Products (HRC)
- Snow Water Equivalent (SWE)
- MELT

16:00-17:30 SEEFFG System Operational Concept (RC)
- Computational Server
- Dissemination Server
- Status of RC Operations

17:30-18:00 Discussions on the SEEFFG System Design/Theoretical Background (All)

Day 2

09:00-09:30 Review of Day 1

09:30-10:30 How to prepare flash flood warnings: Methodology (WMO)
- Interpretation of weather analysis and forecasts
- Mesoscale and Nowcasting Analysis
- Weather RADAR and Satellite images
- Interpretation of SEEFFG Products

10:30-11:00 Tea Break

11:00-11:30 A Case Study: Flash Floods Associated with Mediterranean Depressions (WMO)

11:30-12:00 A Case Study: Flash Floods Associated with Convections (WMO)

Country-presentations to be provided by those who attended Operational Workshop at HRC

12:00-12:30 A Flash Flood Case Study and Discussions (Croatia)

12:30-14:00 Lunch Break

14:00-14:30 A Flash Flood Case Study and Discussions (Slovenia)

14:30-15:00 A Flash Flood Case Study and Discussions (Serbia)

15:00-15:30 A Flash Flood Case Study and Discussions (Romania)

15:30-16:00 Tea Break

16:00-16:30 A Flash Flood Case Study and Discussions (Moldova)

16:30-17:00 A Flash Flood Case Study and Discussions (Bosnia and Herzegovina)

17:30 *Sightseeing Tour*

19:00 *Welcome Dinner hosted by DHMZ*

Day 3

09:00-09:30 Review of Day 1

09:30-10:00 Technical Background on the Flash Flood Verifications (HRC)

10:00-10:30 BSMEFFG System Verification Results and Challenges (RC-TSMS)

10:30-11:00 **Tea Break**

11:00-12:30 Hands-on Exercise for Past Events in the region (Guided by HRC, All) (example “daily operations”)

- Daily Weather Briefing
- Hydrologic Output
- SEEFFG Product Analysis
- Flash Flood Threats
- Discussion

12:30-14:00 Lunch Break

14:00-15:00 Hands-on Exercise for Past Events in the region (Guided by HRC, All) (example “daily operations”)

- Daily Weather Briefing
- Hydrologic Output
- SEEFFG Product Analysis
- Flash Flood Threats
- Discussion

Day 4

09:00-09:30 Review of Day 3

09:30-10:00 A Flash Flood Case Study and Discussions (Albania)

10:00-10:30 A Flash Flood Case Study and Discussions (the Former Yugoslav Republic of Macedonia)

10:30-11:00 Tea Break

11:00-12:30 Post-processing of SEEFFG products with QGIS: Hands-on Exercises (guided by RC-TSMS, All)

12:30-14:00 Lunch Break

14:00-15:00 Hands-on Exercise for Past Events in the Region (Guided by WMO, All) (example “daily operations”)

- Daily Weather Briefing
- Hydrologic Output

- BSMEFFG Product Analysis
- Flash Flood Threats
- Discussion

15:00 *Technical Visit to DHMZ*

Day 5

09:00-09:30 Review of Day 4

09:30-10:30 Preparations of Operational Flash Flood Bulletins and Warnings: Country-level Experiences (All)

10:30-11:00 Tea Break

11:00-11:30 Example of Flash Flood Bulletins and Warnings (RC-TSMS)

11:30-12:00 Dissemination of flash flood Warnings and Emergency Management Agency (EMA) Needs (All)

12:00-12:30 Overview of Advances of the International SAVA River Basin Commission (Mirza Sarac)

12:30-14:00 Lunch Break

14:00-15:00 How to improve Service Delivery of Flash Flood Warnings to EMA and Public (All)

15:00-15:30 Forecasters Expectations and Recommendations on the Best Use of SEEFFG products (All)

15:30-16:00 Tea Break

16:00-16:30 Local Capacity Building: Forecasters Training, Cooperation with Universities and Other Organizations, Preparation of User Guide for SEEFFG System (All)

16:30-17:00 Sustainability of the SEEFFG System: Cooperation with the RC and NMHSs, Feedbacks, and Step-5 Training (WMO)

17:00-17:30 Final Discussions and Closure (All)

Flash Flood Hydrometeorological Training Programme

An ongoing regional training program involving the Centres will be developed to maintain proficiency with system operations, ensure continued system validation, and ensure continued system use and ownership. This will involve continual engagement with the community of users. Tools will be developed to build capacity to improve the system and handle more complex contingency scenarios (e.g. key data missing, failure in "normal" operations, communications, or other such events).