SECOND STEERING COMMITTEE MEETING (SCM 2)

BLACK SEA AND MIDDLE EAST FLASH FLOOD GUIDANCE (BSMEFFG) SYSTEM

AND FFG TRAINING FOR THE JORDAN METEOROLOGICAL DEPARTMENT (JMD)

(Step-5 Training)

Amman, Jordan

11–13 April 2017

FINAL REPORT

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Second Steering Committee Meeting (SCM 2) of The Black Sea and Middle East Flash Flood Guidance (BSMEFFG) Project and Flash Flood Guidance Training for the Jordan Meteorological Department (JMD)

Amman, Jordan, 11-13 April 2017

1. Executive Summary

In the Black Sea and Middle East region, flash floods account for a significant portion of the lives lost and property damages that result from heavy rainfall. 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 Black Sea and Middle East Flash Flood Guidance (BSMEFFG) System Initial Planning Meeting was held in Istanbul, Turkey on 29-31 March 2010. Six Black Sea and Middle East countries, namely Armenia, Azerbaijan, Georgia, Iraq, Lebanon, and Turkey, were represented in the meeting. Participants expressed their interests to participate in the BSMEFFG system, indicating that flash floods cause considerable human losses and property damages in the Black Sea and Middle East region. At this meeting, the National Meteorological and Hydrological Service (NMHS) of Turkey, graciously offered to host the Regional Centre of the BSMEFFG system, which was accepted by all participating countries. Bulgaria and Jordan have participated in the BSMEFFG project at the later stage. Armenia, Azerbaijan, Bulgaria, Georgia, Jordan, Lebanon, Syria, and Turkey have thus far sent Letters of Commitment (LoC) to WMO to participate in the project. Israel has recently joined the BSMEFFGS and inclusion of it is currently underway.

Based on the BSMEFFG system implementation plan adapted at the Initial Planning Meeting in Istanbul, Turkey, four training activities for the project have been completed. 1) Operational training took place from 8 April to 3 May 2013 at HRC facilities in San Diego, USA. Three hydrometeorlogists from Turkey, one hydrologist from Bulgaria, and one forecaster from

Georgia attended the training. 2) Regional operations training took place on 17-19 December 2013 at the WMO RTC in Antalya, Turkey, in which two forecasters from Armenia, one forecaster from Azerbaijan, one hydrologist from Bulgaria, one forecaster from Georgia, and nine forecasters and hydrometeorologists from Turkey participated. 3) Following the regional operations training, upon requests from the NMHSs of Armenia and Georgia, Mr Sayin provided a one week forecasters training to the forecasts of both countries. 4) The first Steering Committee Meeting (SCM 1) [Step 4 training] of the BSMEFFG system was facilitated by WMO in Tbilisi, Georgia from 28 to 30 June 2016.

As per the implementation plan, the second Steering Committee Meeting (SCM 2) and Step 5 training, which also included experts from the Jordan Meteorological Department (JMD), were held in Amman, Jordan from 11 to 13 April 2017. The objectives of this meeting were to: review the development and implementation status of the BSMEFFG system; use its products in preparation of daily flash flood forecasts and warnings through case study presentations; familiarize participants with the Flash Flood Guidance System Simulator; conduct hands-on exercises for past flash flood events; prepare flash flood bulletins for the issuance of flash flood warnings; perform validation studies; obtain feedback from the participants for possible further development; and evaluate performance of a hydrometeorologist from Turkey, 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 second Steering Committee Meeting, the representatives of Jordan, 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 Mohammed Mfadi Al-Samawi, Director General of the Jordan Meteorological Department, 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 and their impacts do not confine themselves to national borders. He cited occurrences of the flash flood events in Jordan in this year, explaining that flash floods are very dangerous natural phenomenon in the region. He assured participants that forecasters from the JMD will use the BSMEFFG products in preparation of daily flash flood forecasts and warnings. He expressed his pleasure in being able to host the SCM 2 in Amman. He welcomed all the participants to Jordan, and he wished everyone a very successful meeting.

Mr Ayhan Sayin, WMO, recalled the objectives of the meeting 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 Jordan Meteorological Department for all its efforts including hosting the meeting, thereby helping to make a positive atmosphere that would undoubtedly contribute favorably to the success of the meeting. Mr Eylon Shamir, HRC, welcomed everyone to the meeting and was pleased to see that representatives from the four Black Sea and Middle Eastern countries were present. He emphasized the project’s importance in enhancing the capacities of NMHSs of the Black Sea and Middle Eastern counties for timely and accurate early warnings of flash floods. He also expressed his appreciation to the Jordan Meteorological Department for hosting the meeting.

The national press also covered the meeting with several newspaper reporters being present at the opening of the meeting. Mr Mohammed Mfadi Al-Samawi, Director General of Jordan Meteorological Department and Permanent Representative of Jordan with WMO, informed the press about the objectives and possible outcomes of the meeting and positive impacts of the project on the citizens of Joran and other participating countries. Mr Ayhan Sayin also informed reporters about the WMO support being provided for the BSMEFFG system.

3. Organization of the Second Steering Committee Meeting (SCM 2)

The SCM 2, which was held in Amman, Jordan from 11th to 13th April 2017, was attended by representatives of the NMHSs from Bulgaria, Georgia, Jordan, Lebanon, and Turkey. Other participants included representatives from WMO and HRC. The list of participants is provided in Annex I, while the annotated meeting agenda is given in Annex II.

4. Proceedings of the Second Steering Committee Meeting (SCM 2)

Mr Sayin provided a brief overview and purposes of the meeting. 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 meeting 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 BSMEFFG 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 BSMEFFG system activities; to have computer hardware and software capabilities and good computer network connections; to monitor routinely availability of the BSMEFFGS products; and to conduct flash flood validation studies.

Mr Sayin explained the project implementation status, stressing major project milestones. It was stated that after the Initial Planning Meeting; Armenia, Azerbaijan, Bulgaria, Georgia, Syria, and Turkey have sent Letters of Commitment (LoC) to WMO. On the other hand, Jordan and Lebanon participated in the project in 2015. Israel has recently joined the project and its project activities will be carried out in the coming years. It was stated that main project activities that have been completed were: 1) Development and implementation of the BSMEFFG System. 2) Operational Training at HRC, San Diego, USA. 3) Regional training workshop. 4) Country-level training at the NMHSs of Armenia and Azerbaijan. 5) First Steering Committee Meeting (SCM1) [step-4 training].

He stated that this meeting includes the last project activity of Step-5 training and will: review the BSMEFFG products to allow forecasters to become familiar with the BSMEFFGS products; promote operational use of the BSMEFFG products through hand-on exercises; review and evaluate the BSMEFFG products for elected past flash flood events through case studies;

evaluate the performance of a participant from the Turkish State Meteorological Service for the qualification of the certified WMO FFGS trainer, who has successfully completed Step-2 and Step-3 training.

He concluded his presentation stating that at the end of this meeting, forecasters should have the following competencies: 1) analyze and monitor the evolving meteorological and hydrological situation; 2) analyze and monitor the BSMEFFGS Product; 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. BSMEFFG System Operational Concept

Mr Sayin provided an overview of operational capabilities of the Black Sea and Middle East Flash Flood Guidance (BSMEFFG) system and illustrated use of its derived products. He explained the spatial and temporal distribution of flash flood events in Turkey. It was stated that flash floods happen along the coast and in the central and northeastern regions of the county, causing on average forty human losses and hundreds of millions of dollars property damages annually. He described concept of operation FFGS operation at the Turkish State Meteorological Service. He said that hydrometorological division is the core element within the administration structure to maintain the BSMEFFG system 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.

He also provided an overview of verification results for the BSMEFFG system for the years of 2013 and 2014. He stated that Probability of Detection (PoD) was 70% in 2013, while it was 55% in 2014. He concluded his presentation explaining that PoD was lower in 2014 because of the fact that frequency of the convective storms was high and that satellite estimation and numerical weather forecasts of precipitations intensity and amount are relatively poor in comparison with synoptic and mesoscale systems.

4.2. Overview of the BSMEFFGS Products

Mr Shamir provided an overview of the BSMEFFGS dashboard and forecaster console. He 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. He explained that functionalities of the dashboard are: 1) display of selected BSMEFFGS 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. He continued to explain the BSMEFFGS 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 BSMEFFGS and products in image formats; and data download buttons in text, CSV, and CSVT formats. He 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**, 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);

- **Multi- NWP model ingestion,** ALADIN, ECMWF IFS , and WRF QPF products are ingested to allow forecasters to compare different FFGS products resulted from these models.

- **Forecast Mean Areal Precipitation (FMAP),** which is estimated by using WRF 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.**

Mr Shamir also explained the Flash Flood Guidance System approach. He 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. He explained needs for the FFG system and compared large river flooding with flash floods. He emphasized that it is critical to distinguish them and it is the fundamental concept of the flash flood development and implementation. He 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. He showed the diagnostic and prognostic FFG products in stressing that forecasters experiences are fundamental for the issuance of flash flood warnings. He concluded his presentation emphasizing the needs of local data for model calibration and bias adjustments.

4.3. Case Studies

Mr Sayin presented a case study on the South East Europe flash flood event that took place on 6-8 March 2016 causing loss of lives and extensive economical losses in Montenegro and Serbia. 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 center 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 favorable conditions for the development of convective storms.

He compared 6-hr ECMWF IFS and WRF Quantitative Precipitation Forecasts (QPF) accumulation from 6th 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 is 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 5th March at 00 UTC to 6th 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 5th 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 analyzed 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 5th March 00 UTC to 6th 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. FFFT expanded toward the northwest in Montenegro and had a maximum value of 60 mm/6-hr at 6th March at 06 UTC. It was stated that two people were killed and extensive property damages accrued due to flash floods from 6th to 7th 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.

In his second presentation, he presented a case study on a flash flood event that took place in Georgia on 12-14 June 2015 in which more than forty people were killed and millions of dollars economical damage were inflicted according to the UNDP report. He stated that the flash flood was caused by the occurrence of severe convective storms during the night. He said that there were two important lessons learned from this case study: firstly, convective rainfall may not be detected neither by FFG system nor NWP models. If this is the case, weather satellite and/or weather RADAR nowcasting products, depending on the availability of them, are very useful tools to be used in flash flood forecasting. Secondly, 24/7 working hours are extremely important because flash flood may happen at any time, which was the case in this event.

Jordan Flash Flood Event

Mr Elryalat presented a case study on the flash flood event that took place on 26-28 March 2016 in the city of Azraq in the eastern Jordan. He showed synoptic analysis of surface chart and 500 hPa geopotential height on 26 March 2016 at 06 UTC. He stated that a high pressure centre with 1016 hPa value was located over the northern and eastern parts of Jordan, while low pressure centre with 1012 hPa was located over the southern Jordan. It was stated that surface pressure tendencies had negative values in the north and east parts of the surface trough, indicating that the surface low pressure centre will propagate towards this region. He explained 500 hPa analysis in detail, stressing that a deep upper low depression with 536 hPa value was located over Ukraine and associated trough expended southward to the eastern Mediterranean and Jordan. He stated that the surface low pressure centre associated with upper low formed instable conditions in the middle troposphere. Then, he showed Skew-T Log-P diagrams of Bet Dagan and Mafraq sounding stations on 26 March 2016 at 00UTC and stated that instability indices showed weak or no instability in the middle troposphere. IR geostationary weather satellite image showed a cloud band with associated medium and high clouds over the eastern Mediterranean and that convective clouds developed over Egypt, Saudi Arabia, and southern Jordan on 26th of March at 10:15 UTC.

He indicated that Radar images, provided by the Israel Meteorological Service (IMS), showed moderate to heavy rainfall over the southern, central and eastern Jordan, resulted in flash flooding, particularly in the urban areas. He provided an overview of the BSMEFFG products from 26 March to 27 March 2016. He stated that 6-hr Merged Mean Areal Precipitation (Merged MAP) had a maximum value of 45 mm over the central and northern Jordan on 26 March at 18 UTC and 27 March at 00 UTC. Average Soil Moisture (ASM) values over the same parts were 0.85 or 1.00, indicating saturation of the top soil in the region. The 6-hr Flash Flood Guidance (FFG) values, which were with 0-15 mm, and were considered to be very low over the northern and western Jordan. 6-hr Imminent Flash Flood Threat (IFFT) on 27 March at 00 UTC existed over northern Jordan with the values up to 40 mm, indicating high probability of occurrence of flash flooding in the region. He concluded his presentation showing a video record of a flash flood event that occurred in the city of Azraq on 26 March 2016. Moreover, during the facilitated discussions, forecasters from the Jordan Meteorological Department stated that the BSMEFFG System is a very valuable supplementary tool for forecasting flash floods events.

During the facilitated discussions, it was stated that if forecasters see any deficiencies in the system, they should communicate them to the system developer, HRC, and WMO so they may consider taking corrective action. Mr Elryalat stated that Jordanian forecasters noticed that 6-hr FFG values were unrealistically high with values of 150 mm in some catchments. He said that he immediately informed HRC about it and the need to modify the model parameters. He indicated that now the FFG estimates are more reasonable. He stressed that communication is the key for improving the system.

Bulgaria Flash Flood Event

Mr Koshinchanov gave his presentation on the flash flood event that occurred in Bulgaria from 16 to 17 January 2016. First, he provided an overview of the weather analysis on 16 January at 06 UTC and on 17January 2016 at 00 UTC, emphasizing that flash floods were caused by the Mediterranean depression associated with frontal system and coupled with the orographic lifting. Then, he provided an overview of the BSMEFFGS products. The 6-hour Microwave adjusted Global Hydro Estimator (MWGHE) and 6-hour Global Hydro Estimator (GHE) on 16 January 2016 at 18 UTC showed that maximum precipitation accumulation was up to 30 mm, while 24-hr MWGE and GHE had maximum values up to 50 mm in the southern Bulgaria. The 6-hr and 24-hr Merged Mean Areal Precipitation (Merged MAP) estimates had a maximum value of 30 mm over the same area. Average Soil Moisture (ASM) values on 16 January at 18 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 indicated that the 6-hr Flash Flood Guidance (FFG) values reached their minimums with 0-15 mm over the same areas. The 6-hour Forecast Mean Areal Precipitation (FMAP) that is generated from ALADIN mesoscale precipitation forecasts showed values from 30 and 47 mm, while Forecast Flash Flood Threat (FFFT) values showed access amount of rainfall ranged from 5 mm to 40 mm/6-hr in the southern and central part of the Bulgaria. Considering the FFG, ASM, Merged MAP, and FMAP products, he stated that flash floods were predicted and warnings issued in advance. He continued to explain the BSMEFFGS products on 17 January at 00 UTC, showed that depression had first become stationary in the areas where flash flooding had occurred the previous day, and then it propagated eastward. The ASM product indicated that more catchments in the east were saturated, with as low as 15 mm/6-hr FFG values being attained in the same region. 6-hr FFFT still existed in the same areas with its increased values up to 50 mm, indicating high possibility of flash flood occurrence. He concluded his presentation providing results of estimated peak discharge for a catchment where flash flood occurred, using the rational method and stressed that BSMEFFGS products are very useful for the prediction of flash floods.

Turkey Flash Flood Event

Mr Turgu presented a case study on the multiple flash flood events that took place in the Aegean Rea Region in the western Turkey on 17 January 2016. First he explained meteorological condition that resulted in producing heavy precipitation. He stated that a deep low pressure centre with 998 hPa value located over Greece, subsequently propagated eastward producing heavy rainfall in the western Turkey along the Aegean Sea coast. It was stated that 850 hPa chart indicated a strong cold air advection over Athens from southwest and Low Level Jet (LLJ) from southeast, bringing humid and warm air towards Çeşme town. It was mentioned that there were strong winds at the mid troposphere with maximum core values of 50-70 kt between Athens and Çeşme. He stated that there was a big temperature gradient between surface and 500 hPa as an indication of instability as such surface temperature was 16^{o}C and -19^{o}C at 500 hPa level on 17 January at 00 UTC. He showed that Polar Jet Stream with the core speed of 100 Knot over France, was associated with the frontal system, cyclonically curved in the south of Italy and moved to the western Turkey. It was also shown that 24-hr ECMWF Quantitative Precipitation Forecast (QPF) was 151 mm over Çeşme. EUMETSAT MSG WV channel image indicated a dry band behind 500 hPa trough and widespread cloudiness ahead of the trough associated with the frontal lifting on 17 January at 00:00 UTC. Radar PPI reflectivity images on 17th of January at 03, 06, 09, 12 and 15 UTC shoved reflectivity values of more than 40 dBz over Çeşme, Dikili, İzmir, and Manisa, implying the existance of severe thunderstorms with heavy precipitation. He showed Izmir (WMO Station No: 17095) radiosonde station skew-T log-P diagram on 17th January at 00 and 12 UTC that indicated moist and instable lover troposphere with veering winds at the lover troposphere and very close dew point temperature and air temperature.

He then provided an overview of the BSMEFFGS products for the same period. First of all, he showed spatial and temporal distribution of various FFGS products such as 6-hr Average Soil Moisture (ASM), indicated that upper soil became completely saturated at 18 UTC, while 6-hr Flash Flood Guidance (FFG) values varied from 1 mm to 60 mm. Forecast Mean Areal Precipitation (FMAP) showed that 24-hr precipitation accumulation was up to 100 mm. There were a number of basins with Forecast Flash Flood Threats in the region, while maximum FFFT reached 60 mm/6-hr over Çeşme. He concluded his presentation emphasizing that FFGS products are very valuable and useful for the issuance of flash flood forecasts and warnings.

He also showed an application that was developed by the Turkish State Meteorological Service to display the BSMEFFGS snow products such as Snow Water Equivalent (SWE), snow MELT, and Snow Coverage Area (SCA) time series in graphical format, tables, and google Earth for each big river basins in Turkey. He stated that this application was developed upon request from the State Water Authority (DSI) for their reservoir management studies. A screenshot of this application is presented in ANNEX III.

Croatia Flash Flood Event

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. It was stated that the FFGS Simulator is written in Hypertext Processor (PHP), Java, and HTML language 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 color, 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. 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.

Georgia Flash Flood Event

Mr Loladze provided an overview of BSMEFFGS products for Georgia on 7 April 2017 at 06 UTC. He showed an Average Soil Moisture (ASM) map that indicates that some catchments had ASM values ranging from 0.30 to 1.00 on the top of mountains in the Black Sea Region. He stated that this was not realistic because there had not been any precipitation in the region for two days. Mr Shamir responded saying that the soil model uses not only precipitation data but also snow melt for the estimation top soil moisture as such top soil of some catchments on the mountains was saturated due to snow melt. Mr Loladze also showed Snow Water Equivalent (SWE) values with a maximum value of 500 mm on the mountains of the Black Sea Region, claiming that it is unrealistic situation to have this amount of SWE in the region. Mr Shamir responded that SCA product should be looked at to see fractional snow coverage in the sub-basins. SCA map at 06 UTC on 7 April 2017 showed that some catchments in which there were high SWE values were totally covered with snow. He reiterated that 500 mm SWE estimation by the snow model was realistic and that verification should be done by conducting local in situ measurements to confirm the actual conditions. Mr Loladze showed that 6-hr and 3-hr Flash Flood Guidance (FFG) values varied between 10 and 35 mm and between 10 and 45 mm, respectively. He requested clarification saying that for some catchments FFG values were not estimated and shown as grey on the FFG map. Mr Shamir said that FFG model does not estimate the FFG values for the catchments in which snow coverage is greater than 40%. Mr Loladze mentioned that the BSMEFFGS does not generate products for the larger river basins. Mr Shamir responded clarifying that larger river catchments are not represented in the FFGS nor its estimation of products because the FFGS concept reflects small basins with drainage area that is smaller than 2,000 km2.

Mr Loladze continued his presentation showing relief maps of Georgia and noted that there are more than 700 glaciers, mainly located on the Greater Caucasus Mountain Ranges with the highest peak being more than five thousand meters above MSL. He showed the various climatic zones of Georgia and some weather Radar images. He stressed that flash floods are very common hydrometeorological hazards in Georgia due to heavy precipitation and rapid snow melt. He concluded his presentation showing a video on the landslide event in the village of Akhaldaba, about 20 km southwest of Tbilisi that carried millions of cubic meter of land, mud, and trees into Tbilisi.

4.4. Hands-on Exercises

Hands-on exercises of four flash flood events were collectively studied by the participants. The first one was the flash flood event that occurred on 28 October 2016 in the city of Aqaba located on the coast of the Red Sea in southern Jordan. After the weather briefing, a facilitated discussion took place among participants who expressed their views on the interpretation of the BSMEFFGS products and possible occurrences of flash floods in Aqaba. Participants predicted flash floods in Aqaba where flash floods actually happened on 28 October 2016 due to heavy rainfall. The second hands-on exercise was led by the forecasters from Lebanon who explained in detail the weather conditions and BSMEFFGS products for the flash floods that occurred in southern Lebanon on 2 April 2017. Similarly, flash flood events that occurred on 8 November 2016 in Jordan and on 13 April 2017 in Jordan and Lebanon were studied by the participants.

4.5. Advances in the FFG System

Mr Shamir presented enhancements being developed for the FFGS to improve operations and to extend its functionality. He touched upon the following four items:

- Multi-model QPF use in the FFGS;
- Landslide Susceptibility Mapping;
- Urban Flash Flood Warning; and
- Riverine Routing.

He articulated each topic saying that it was forecasters demand to include multiple mesoscale model input in the display on the FFGS forecaster console because each model behaves differently in different seasons even in different months. Then, he showed multiple NWP ingestion examples from the BSMEFFGS and explained their impacts on the accuracy of the FFGS products. Secondly, he stated that there is a growing demand for a urban flash flood early warning system to be incorporated into FFG because occurrences of urban flash floods have recently increased due to climate change and climate variability. He further stated that a demonstration project for the urban flash flood early warning system has been conducted for the city of Pretoria, South Africa, and second one is underway to be implemented in Istanbul, Turkey. Finally, he showed a demonstration case study of landslide prediction using Central America Flash Flood Guidance System (CAFFGS) products conducted in El Salvador including landslide susceptibility mapping, real-time occurrence prediction based on FFGS rainfall and soil moisture data, and susceptibility class.

4.6. BSMEFFGS Hydrometeorologist Training

Mr Shamir provided an overview of the FFGS Hydrometeorlogist Training Programme. He stated that training was an integral part of the project, and extensive training would be provided to the forecasters from the participating NMHSs. He showed the schematic diagram outlining the FFGS hydrometeorological training programme. 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 said that on-line training (Step-2), which is a prerequisite for the specialized training (Step-3) at the HRC premises in San Diego, USA, comprises of five modules:

- Elements of Meteorology;
- Elements of Hydrology;
- Flash Flood Guidance Products;
- Geographical Information System (GIS); and
- Remote Sensing.

During the facilitated discussions, participants expressed their appreciations with the quality of the training and its content, thanking to WMO and HRC for facilitating and providing such excellent training. It was mentioned that one forecaster from Turkey, one forecaster from Lebanon, and one forecaster from Jordan have successfully completed Step-3 and Step-4 training and have become certified WMO FFG trainers. It was also mentioned that Mr Ertan Turgu from Turkey, who has successfully completed Step-3 training, will be evaluated during this meeting towards the qualification of certified WMO FFG trainer. Forecasters from Lebanon recommended that WMO should facilitate more regional operational sustainability training (Step-5) for the forecasters.

5. Conclusions and Outcomes of the Meeting

1. There was agreement among participants that the BSMEFFG 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 from Lebanon and Jordan noted that in addition to the WMO GTS data, more AWOS data can be provided to the BSMEFFG System through FTP,

3. Participants agreed that more regional operational suitability training (Step-5) should be facilitated by the project partners,

4. Participants noted that inclusion of Israel into the BSMEFFGS will be beneficial for the regional counties such as Lebanon and Jordan through provision of high resolution of NWP mesoscale model products and weather Radar images,

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

6. Participants agreed that implementation of the advance modules such as multi-NWP QPF ingestion is very beneficial to NMHSs. They noted implementation of Riverine Routing in Turkey and recommended that it should be implemented in other participating countries,

7. Participants became familiar with the BSMEFFGS operational concept,

8. Participants developed competencies to be able to access to the BSMEFFGS servers to use its products,

9. Participants became familiar with the BSMEFFGS 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,

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

11. Participants developed basic competencies to prepare clear and understandable flash flood warning messages,

12. Mr Ertan Turgu from the Turkish state Meteorological Service took a written exam on the FFGS technical and scientific background and gave a presentation of a flash flood event that took place in the western Turkey for the qualification of certified WMO FFG trainer.

6. Closing of the Meeting

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

ANNEX I

Second Steering Committee Meeting (SCM 2) of the Black Sea and Middle East Flash Flood Guidance (BSMEFFG) System and FFG Training for the Jordan Meteorological Department (JMD)

Amman, Jordan
11-13 April 2017

List of Participants

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ANNEX II

Second Steering Committee Meeting (SCM 2) of the Black Sea and Middle East Flash Flood Guidance (BSMEFFG) System and FFG Training for the Jordan Meteorological Department (JMD)

Amman, Jordan, 11-13 April 2017

Agenda

Day 1

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

10:30-11:00 Tea Break

11:00-11:30 Overview of BSMEFFGS Forecaster Console and Dashboard (WMO)

11:30–12:30 Overview of BSMEFFGS Products: Precipitation (HRC)

- Satellite/Radar Precipitation Estimation
- Bias adjustments
- Merged Mean Areal Precipitation (merged MAP)
- Multi model NWP Precipitation Ingestion
- Forecast Mean Areal Precipitation (FMAP)

12:30-14:00 Lunch Break

14:00-14:30 Overview of BSMEFFGS Products (Continued) (HRC, WMO)

- Average Soil Moisture (ASM)
- Flash Flood Guidance (FFG)
- Flash Flood Threats (IFFFT, PFFT, FFFT)

14:30-15:00 Overview of BSMEFFGS Products (Continued): Snow Products (HRC)

- Snow Water Equivalent (SWE)
- MELT

- Snow Coverage

15:00-15:30 BSMEFFG System Operational Concept (WMO)

15:30-16:00 Tea Break

16:00-16:30 Guidance for Preparation of flood warnings (WMO)
- Interpretation of weather analysis and forecasts
- Mesoscale and Nowcasting Analysis
- Weather RADAR and Satellite images
- Interpretation of BSMEFFG Products

16:30-17:00 A case Study: Flash Floods Caused by Frontal System (WMO)

16:00-17:30 A Case Study: Flash Floods Caused by Convective System (WMO)

<u>Day 2</u>

09:00-09:30 Review of Day 1

09:30-11:00 FFGS Simulator (Petra Mutic)

11:00-11:30 Tea Break

11:30-12:30 A Flash Flood Case Study for Jordan (Dafi Alryalat)

12:30-14:00 Lunch Break

14:00-15:30 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

15:30-16:00 Tea Break

16:00-17:30 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

19:00 *Welcome Dinner hosted by Jordan Meteorological Department*

Day 3

09:00-09:30 Review of Day 2

O9:30-11:00 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

11:00-11:30 Tea Break

11:30-13:00 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

12:30-14:00 Lunch Break

14:00-14:30 A Flash Flood Case Study and Discussions (Ertan Turgu, Turkey)

14:30-15:00 Preparations of Operational Flash Flood Bulletins and Warnings (TSMS)

15:00-16:00 An overview of the BSMEFFG system operations and recommendations for further applications (All)

16:00-16:30 Tea Break

16:30-17:00 Dissemination of flash flood Warnings and Emergency Management Agency (EMA) Needs and How to Improve Service Delivery of Flash Flood Warnings to EMA and Public (All)

17:00-17:30 Forecasters Expectations and Recommendations (All)

17:30-18:00 Final Discussions and Closure (All)

-End of Meeting -

ANNEX III

Snow MELT Time Series (2016-2017) of the BSMEFFG System for Tigris and Euphrates River Basin in Turkey