FIRST STEERING COMMITTEE MEETING (SCM 1)

SOUTH ASIA FLASH FLOOD GUIDANCE (SAsiaFFG) SYSTEM

New Delhi, India

26–28 April 2016

FINAL REPORT OF THE FIRST STEERING COMMITE MEETING

August 2016

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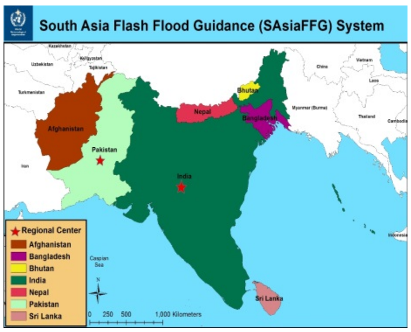
First Steering Committee Meeting (SCM 1) of

The South Asia Flash Flood Guidance (SAsiaFFG) Project

New Delhi, India, 26-28 April 2016

1. Executive Summary



In the South Asia 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 Asia Flash Flood Guidance (SAsiaFFG) System Initial Planning Meeting was held in Katmandu, Nepal on 26-28 November 2012. Representatives of six South Asian countries, namely Bangladesh, Bhutan, India, Pakistan, Sri Lanka, and Nepal were represented in the workshop. Participants expressed their interests to participate in SAsiaFFG project, indicating that flash floods cause considerable human losses and property damages. Major outcomes of this meeting were, participants: 1) considered that flash flood were important hydrometeorological hazards in the region and the SAsiaFFG System would help NMHSs mitigate their adverse impacts; 2) agreed on the development and implementation of SAsiaFFG System; 3) Indian Meteorological Department (IMD) and Pakistan Meteorological Department (PMD) were proposed to host the Regional Centres; 4) agreed on the realization of SAsiaFFG System implementation plan to be completed by June 2014; and 5) agreed that letters of Commitment to be sent to WMO no later than 7 January 2014. Afghanistan has later sent a letter of interest to participate in the SAsiaFFG project. Subsequently, Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, and Sri Lanka have submitted LoC to WMO.

SAsiaFFG System was developed by the Hydrologic Research Center (HRC) and ran one and half years at its premises in San Diego, USA. The servers were shut down after one and half year of operation because of lack of regional collaboration and cooperation to make progress in the regional implementation of the system.

National Meteorological and Hydrological Services (NMHSs) of the regional countries expressed the importance of the project and wished to move forward for the regional implementation. Therefore, first Steering Committee Meeting (SCM1) planned to be held in New Delhi, India from 26 to 28 April 2016.

The objectives of this meeting were to: review the outcomes and status of the SAsiaFFG initial planning meeting to move forward for the development and implementation of the system; review theoretical basis of the Flash Flood Guidance System; explore in detail, through presentations and discussions, the FFG products, their development methodology, and the interpretation and validation approaches to provide feedback for their further development; allow a better understanding of the needs of high resolution modelling, including its domains, to support the SAsiaFFG application; seek the possibility of using the high resolution mesoscale NWP QPF products in SAsiaFFG project; and explore the availability of local historical hydrometeorlogical data to be ingested into the system.

2. Opening of the Session

In opening the first Steering Committee Meeting, the representatives of Ministry of Earth Sciences, India Meteorological Department (IMD), WMO, HRC and USAID/OFDA 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. Although the core aspects of the project focus on the implementation of technology and scientific approaches undertaken mainly by the countries NMHSs, it was highlighted that the guiding indicator for the ultimate success of the project is effective outreach to people and reducing their risk of being affected by flash floods in a disastrous way.

In his opening remarks, Mr Ramesh, Ministry of Earth Sciences, 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 explained that flash floods are very dangerous natural phenomenon in the region particularly in the mountainous regions, emphasizing that availability of local hydrometeorlogical data such as RADAR precipitation would improve the accuracy of the flash flood warnings. He assured participants that India will provide the necessary support for the implementation and operation of the SAsiaFFG project. He expressed his pleasure in being able to host the SCM 1 in New Delhi. He welcomed all the participants to India, and he wished everyone a very successful meeting.

Mr Laxman Singh Rathore, PR of India with WMO, warmly welcomed representatives of the participating countries, WMO, HRC, and USIAD/OFDA. He stressed the constraints of the flash flood forecasting and warnings, mentioning that flash flood events have very short duration and short lead time. He stated that geomorphological characteristics as well as provision of real-time data are quite important for the flash flood modelling. He said that vulnerability assessments are to be performed for impact based flash flood forecasting and that urban flash flood early warning system is to be take into consideration because flash flood events in the urban areas cause fatal casualties and extensive economic damages. He further emphasized the following key points: flash flood products have certain degree of confidence before they are used by the forecasters; warning messages should be in an understandable format; standard operational procedures to be developed for the dissemination of warnings. Ha conclude his speech saying that regional cooperation is the key for the success of the project.

Mr Kostantine Georgakakos, Director of HRC, thanked IMD for organizing such an important meeting and all participants from the NMHSs in the region stressing that SAsiaFFG project shall move forward for the benefits of the all countries in the region. He also mentioned that flash floods are very deadly phenomenon loss of lives and property damages and very difficult to predict. Mr Michael Ernst, Regional Director of USAID/OFDA, welcomed everyone to the meeting and was pleased to learn of the advances being made in the implementation of the SAsiaFFGS. He emphasized its importance in enhancing the capacities of NMHSs of the South Asian Counties for effective early warnings of flash floods. 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 project. He also expressed his appreciations to IMD 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.

3. Organization of the First Steering Committee Meeting (SCM 1)

SCM 1, which was held New Delhi, India from 26th to 28th April 2016, was attended by representatives of NMHSs from Afghanistan, Bangladesh, Bhutan, India, Nepal, and Sri Lanka. Other participants included representatives from WMO, USAID/OFDA, HRC, and International Centre for Integrated Mountain Development (ICIMOD). The list of participants is provided in Annex I, while the annotated workshop agenda is given in Annex II.

4. Proceedings of the Steering Committee Meeting 1 (SCM 1)

4.1 Roles and Responsibilities of the Regional Centre and Participating NMHSs

Mr Ayhan Sayin explained roles and responsibilities of the Regional Centre as being, inter alia: to assist all involved project partners including the HRC for the development and implementation of the SAsiaFFG system; to have sufficient infrastructure, including high speed internet access, WMO Global Telecommunication System (GTS) connection, and human resources to operate the system and provide services to the participating countries; to participate in the flash flood hydrometeorological training programme, including operational training at HRC, San Diego, CA, USA; to lead and evaluate flash flood potentials using SAsiaFFG products and other available tools; to evaluate the SAsiaFFG products from the regional perspective and verify the system products and warnings; to assist the participating NMHSs to issue flash flood watches and warnings; and to provide routine training in collaboration with WMO to the forecasters from participating NMHSs.

He continued to explain roles and responsibilities of the participating NMHSs are to:

- have good cooperation, collaboration, communication with the Regional Centre (RC) for the implementation of the SAsiaFFGS;
- provide historical and in-situ local data to the FFG system developer through the RC as these are specified in Appendix B Data Requirement of SAsiaFFG Implementation Requirements;
- ensure use of the SAsiaFFG system and its products as a part of your operational hydrometeorological forecasting;
- prepare and issue flash flood warnings and alerts to the public and national agencies including Emergency Management Authorities;
- participate in the Flash Flood Hydrometeorological Training Programme-steps 1-5;
- provide training (Steps 4 and 5) on the SAsiaFFG approaches and products to their local duty/shift forecasters to make best use of the system to forecast hydrometeorological hazards;
- have close cooperation and collaboration with the national Disaster Management Authorities and to provide them with flash flood forecasts and warnings so that appropriate actions can be taken; and
- prepare case studies for local flash flood events and conduct verification studies and distributes their results to the RC and HRC.

4.2 Individual Country Presentations

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 are available on the WMO website (www.wmo.int)[1]. 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.

4.2.1 Afghanistan

The expert from Afghanistan, Mr Mohammad Nasim Muradi, firstly provided an overview of the climate and geomorphology of Afghanistan, specifying that it is located on the high plateau and high mountains span in the northern and eastern part of the country with their peak height of more than seven thousand kilometers at the Hindi Kush Mountain. He explained that Afghanistan has a continental climate with large seasonal and diurnal temperature variations; weather conditions of Afghanistan is mainly influenced by Mediterranean, Gulf, and Siberian depressions and Indian Monsoon Cyclones; annual average precipitation distribution shows great variations from desert regions to the mountainous regions with values of 250 mm to 1212 mm. He stated that Indian Monsoon affects the weather conditions and precipitation pattern over Afghanistan from July to September, causing floods and flash floods. He cited the most devastating natural disasters as earthquake, drought, floods and flash floods, and landslides, showing spatial distribution of the flood prone areas across Afghanistan where most floods occur in the northern and eastern mountainous regions and NWP QPF maps. He also showed flood forecasting bulletin and provided information on the previous flood/flash flood events that were caused by heavy rainfall such as Qala-E-Naw flood event took place on 17 April 2016 killed 23 people. He concluded his presentation citing gaps and challenges for the flash flood forecasting at Afghanistan Meteorological Department (AMD) as: 1) lack of sufficient meteorological stations and equipment; 2) security problems; 3) shortage of technical staff; 4) lack of cooperation between Hydrological Organization and IMD; 5) lack of flood forecasting and meteorological models.

4.2.2 Bangladesh

The expert from Kyrgyzstan, Mr Meer Abul Hashem, provided an overview of flash flood occurrences in the country. He explained that flash floods mostly happen from the period of April to May in the Haor Region, south eastern hilly regions, and Teesta Basin in northwest, causing substantial damages to the rice crops. He stated that there is not flash flood forecasting tools are available, but flash flood predictions are based on satellite images, long-range weather forecast, and warnings are disseminated only to the water authority through SMS and e-mail. He showed existing hydrological stations in Kalni, Kangsha, Surma, and Kurshiyara rivers as well as hydrological stations that will be installed within the scope of the HILIP project, citing that four hydrological stations have been installed under HKH-HYCOS project and four stations installed under the World Bank project of WMIP. He stated that flash flood forecasting is a complex problem, requires closer cooperation between hydrologists and meteorologists. He stressed that Quantitative Precipitation Forecast (QPF) is essential for the flash flood forecasting but not available in Bangladesh. He then cited flash flood events that had taken place in last thirteen years, killing hundreds of people and inflicting considerable amount of economic damages. He explained elements of flash flood warning system with the end-to-

[1] The link to the material is http://www.wmo.int/ffgs

end forecasting concept. He showed the riverine flood forecasting applications in various rivers. He stated that a number of training activities have been conducted within the scope of RIMES project to enhance the flood forecasting capabilities. He articulated that a flash flood forecasting pilot study was conducted in 2008 in the northeastern region by using precipitation data of the European Centre for Medium-Range Weather Forecasts (ECMWF) and stated the main findings of the pilot project as: 1) precipitation measurement network is not sufficient; 2) more data are needed from the Indian territory of the basin; 3) ECMWF QPF data is not suitable for the flash flood forecasting. He concluded his presentation stating that flash flood guidance system may improve flash forecasting capabilities in Bangladesh once implemented.

4.2.3 Bhutan

The expert from Bhutan, Mr.Pema Wangdi, provided an overview of flood forecasting and early warnings system, including hydrometeorlogical network and NWP modelling. He stated that there are of 15 principal hydrological stations, 9 secondary hydrological stations, and 15 flood warning stations; while there are of 81 class A and B meteorological stations and one radiosonde station located in Paro international airport, showing spatial locations of the stations across the country superimposed on the DEM data. He said that some historical hydrometeorlogical data such as precipitation, pan evaporation, and snow data have been available since 2012, while rain gauge, surface weather observations, and snow data are available in real-time. He then explained weather forecasting and now casting capabilities at the Department of Hydromet Services (DHMS), showing charts and images of temperature forecasts, weather satellite products, and WRF forecast products. He emphasized that Himawari-8 data reception stations has been recently installed. He mentioned that there are two different kinds of database software used for the storage of the hydrometeorlogical data-Climsoft and Hydata. He stated that weather observation data are transferred to GTS via New Delhi and Bangkok. He stressed that Cyclone Alia in 2009 caused flooding with widespread damages, inflicted 17 million USD economical losses. He then explained existing flood early warning system of GLOF and Rainstorm Early Warning System operational in three sub-basins. He articulated the information flow of early warning system through the government administrative structure that is responsible for the flood and water management related issues and responses. He explained the existing challenges as: 1) low density hydrometeorlogical network and rain gauges; 2) lack of real-time telemetry of the hydrometeorlogical observation network; 3) lack of trained personnel; 4) lack of flood forecasting system; 5) lack of hazard maps; and 6) lack of standard operating procedures. He concluded his presentation saying that SAsiaFFG system will enhance local capabilities in issuance of the flash flood warnings but “black-box” modelling approach should be avoided.

4.2.4 India

The expert from India, Mr Naresh Kumar, provided an overview of the meteorological observation network, forecast and warning products of IMD. He stated that hydrometeorological observation network of IMD consists of, inter alia: 23 Doppler Radars; 725 AWOS stations; 1124 automatic rain gauges; 39 upper air radiosonde stations; 62 pilot balloon observations; 559 surface observations; 701 hydrometeorological stations; 21 snow gauges; 219 agrometeorological observations; 222 evaporation stations; 49 soil moisture stations; and 6 ozone stations. He stated that cold waves, fog, heavy snow, frost, cyclonic disturbances, heat waves, thunderstorms, hail storms, squalls, tornadoes, heavy rainfall, floods and flash floods, and droughts are the main hydrometeorlogical hazards in India. He explained that there are six meteorological regions, nineteen meteorological centres, and six cyclone centres across the country. He continued to explain weather forecasting system components from observation to dissemination of forecasts and warnings. He showed forecasting workstation and various products such as surface observations charts, plotting, T-Phaigram, and plane trajectories. He articulated the forecasts structure of Nowcasting, short-range, medium range, extended-range and long-range provided at the national, regional, and local levels; showing forecast and warning products. He cited the specialized divisions, inter alia, as hydrometeorology, instrumentation, satellite meteorology, agrometeorology, aviation meteorology, regional climate centre, and training. He stated that Regional Specialized Meteorological Centre located in New Delhi provides cyclone advisories, daily outlooks, and training to member countries. He showed skill scores of forecasts and warnings. He conclude his presentation explaining future investment plan as: 9 DWRs (Doppler Weather Radar), 18 MRRs (Micro Rain Radar), 12 compact severe weather detection systems, 230 surface observation systems for the North Region; and 270 surface observation stations, 14 DWRs, 40 MRRs, 10 lightening detection systems, 8 micrometer radiometers, 8 Doppler Wind Lidars for the North East Region.

Ms Surinder Kaur provided an overview of hydrometeorlogical observation network and services, including rainfall monitoring and analysis. She showed flood prone regions and basins as Assam, Bihar, West Bengal, UP, Odisha and Andhra, and Pradesh; and Gangna, Brahmaputra and Mahanadi, respectively. She said that floods and flash floods are caused by heavy rainfall with short duration, glacial outburst, change in river morphology, and failure of dams. She explained that flood forecasting in India performed in collaboration with the Central Water Commission such that Flood Meteorological Office (FMO) provides Quantitative Precipitation Forecast (QPF) to the Central Flood Forecasting Division (CFFD) to ingest it into flood models. She explained how QPF products are generated by using NWP models, RADARs, and Satellite data. She concluded her presentation citing the challenges in QPF estimation.

Mr M.P. Singh, Central Water Commission (CWC), gave an overview of flood forecasting and warning in India. He stated that there are 176 flood forecasting stations and 878 hydrological observation sites, which are installed in 9 major river basins with 71 sub-basins. He mentioned that on average annually 6.000 forecasts are issued with the accuracy level of 96 percent and continued to explain concept of operation of flood forecasting and warning. He articulated that for the major rivers forecasts are prepared based on the water level data at 08:00 and 09:00 am local time and issued once a day at 10:00 am local time from 24 to 36 hours; while for the medium size rivers forecasts are prepared based on the water level data at 06:00 and 18:00 hours local time and issued twice a day at 07:00 and 19:00 hours local time from 12 to 24 hours; and multiple flash flood warnings are prepared daily with a lead time less than 12 hours. He stated that flood forecasting models are based on statistical and hydrodynamic methods. The former is the correlation between gauge data, discharge, Antecedent Precipitation Index 8API), while the latter is of MIKE-11. He said that warning messages are disseminated to the concern people and organizations via e-mail, SMS, WEB portal, phone, and fax. He concluded his presentation showing WEB portal and standard operating procedure.

Mr Rahul Saxena, provided an overview of Numerical Weather Prediction (NWP) modelling studies. He explained the definitions for the weather forecasts as: Nowcasting less than six hours; short-range forecasting up to 3 days; medium-range forecasting 3-10 days; extended-range forecasting 10-30 days; and long- range forecasting more than 30 days. He stated that National Centre for Medium Range Weather Forecasting (NCMRWF) develops advanced numerical weather prediction systems, while Indian Institute of Tropical Meteorology (IITM) conducts basic research in Ocean-Atmosphere and Climate Systems, and IMD is responsible for meteorological observations and forecasts. He mentioned that 350 Tepa Flop high performance computing system with more than two thousand computing nodes and three Peta Byte storage are installed at NCMRWF. He explained seamless modelling concept with spatial domain ranging from 25 km resolution GFS global model to 3 km resolution regional WRF model. After explaining new features and migration to upgraded high performance computer system, he gave detailed information on the new version of Hurricane Weather Research and Forecasting (HWRF) model and its regional domain with 3 km horizontal resolution. He then informed the audience on the GFS model and its technical features. He continued to explain weather dropper Radar network and Radar and satellite products. He concluded his presentation

explaining future plans on Nowcasting, short-range forecasting, medium-range forecasting, extended-range forecasting, and special services.
Mr Virendra Singh provided an overview of the meteorological satellites of India. He stated that currently Kalpana-1 located at 74 degree east, INSAT-3A located 93.5 degree east, and INSAT-3D geostationary satellites are operational, providing earth images at different spectral channels such as Visible and Infra-Red. He gave detailed information on the payloads of the satellites such that INSAT-3D with half an hour temporal resolution is the most advanced satellite amongst three with its imaging and sounding capabilities. He showed the products that are driven from the satellite data are, inter alia: Sea Surface Temperature (SST), Upper Tropospheric Humidity (UTH), Cloud Motion Winds (CMW), Cloud Mask, Snow Coverage, and QPE. He explained sounding products driven from the INSAT-3D satellite sounder data are, inter alia: temperature profile, humidity profile, Lifted Index, and Total Ozone. He showed case studies comparing satellite driven rainfall with the observations. He stated that satellite images and products are available on the dedicated WEB portal through RAPID (Real-Time Analysis of Products and Information Dissemination) system. He concluded his presentation explaining RAPID system features and its functionalities.

4.2.5 Nepal

The expert from Nepal, Mr Rajendra Sharma, explained the status of flood forecasting and early warning system. He stated that flash flood have the highest mortality rate and damages amongst the top five hydrometeorlogical hazards from 1990 to 2015. He cited the roles and responsibilities of flood forecasting section of DHM are to: 1) establish hydrological stations and operate them;2) asses hazards and vulnerabilities and create risk maps in major river basins;3)develop flood forecasting models for the major rives; 4) establish flood warning system; 5) prepare guidelines and manuals for flood early warning system. He showed meteorological and hydrological stations network with equipment details such as sensors, communication infrastructure. He stated that three weather RADAR will be installed in the coming years funded by the World Bank and that WRF model provides QPF forecasts up to three days. He depicted several statistical values such as number of days exceeding the pre-determined threshold water levels and showed stage hydrographs of different rivers. He explained the flood early warning system in different basins such as Kankai River Basin and showed response images. He concluded his presentation explaining Glacier Lake monitoring system.

4.2.6 Sri Lanka

The expert from Sri Lanka, Ms P. Hettiarachchi, provided an overview of hydrological services in the country. First, she stated that there are 103 rivers and associated 94 coastal basins, while six of them experience floods very often, namely Attanagalu Oya, Kelani, Kalu, Gin, Nilwala, and Mahaweli. Second, she mentioned that there are 122 hydrological stations across the country, citing their types and selection criteria. She showed the hydrometeorlogical sensors installed along the rivers, reservoirs, irrigation channels. She said that data are transferred via GPRS and Satellite and stored in a database. Third, she articulated that HEC-HMS and MIKE-11 software are used for the flood forecasting and riverine modeling. She then stated advantages and disadvantages of flood forecasting based on meteorological forecasts and continued to explain the present forecast practices for the issuance of flood warnings. She concluded her presentation showing inundation maps of Kelani River flooding.

Second expert from Sri Lanka, Ms A.R.Warnasooriya, provided an overview of meteorological services in the country. She stated that Sri Lanka located in the tropics and under the influence of monsoon climate regime, specifying climatological and topographical features as annual average rainfall of 1860 mm and mean temperature of 27.5 ºC, while the highest mountain peak is of 2524 meters. She stated the major hydrometeorlogical hazards as Cyclones, Landslide, Drought, Tornado, Lightening, and floods, stressing that floods are the major hydrometeorlogical hazards in the country. After explaining roles and responsibilities of the department of meteorology, she cited that there are 23 principle meteorological stations, 38 agro-meteorological stations, approximately 520 rain gauges, one Radisonde, and 5 pilot balloon stations. She stated that Meteorological Department provides public weather and aeronautical services to the different sectors such as fishery, shipping and aviation. She explained that provision of Agro-meteorological services started in 1973, includes prediction of evaporation, precipitation, relative humidity, sunshine duration, max and min temperatures, while climatological services include precipitation analysis, seasonal weather prediction, EL-Nino and La-Nina outlook. She articulated that severe weather forecasts and early warning services consist of tropical storms, heavy rain, thunderstorm, lightening, tornado, strong winds and Tsunami forecasts and warnings; and explained standard operating procedure and early warning dissemination system. She showed the satellite data and products used in weather forecasting such as weather satellite images from HIMAWARI, METEOSAT, INSAT, and FY satellites. She stated that two WRF mesoscale NWP model domains runs in the meteorological department at 15 km and 5 km resolutions, while global and regional NWP model are also used in weather forecasting. She concluded her presentation explaining organizational structure and human resources.

4.2.7 ICIMOD

The expert from ICIMOD, Ms Mandira Singh Shrestha, provided an overview of ICIMOD activities, including flood occurrences in the Himalayan region, HKH HYCOS achievements, development of the regional flood outlook, and possible roles of ICIMOD in the SAsiaFFG System. She described ICIMOD as an intergovernmental, knowledge, learning and enabling centre and stated that Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan are the member countries. She explained that flood, storm, earthquake, landslide, epidemic, extreme temperature, and drought are the major disasters in the region, on average annually killing more than 24 thousand people and affecting more than 160 million people. She stressed that one-third of these disasters is of floods and that frequency and magnitude of them have considerable increased over the years. She explained the End-to-End flood early warning system components, including observations, data dissemination, and modeling, preparation of warning and dissemination, and responses. She stated the goals of the global WMO WHCOS framework, and explained HKH-WHCOS project in detailed, including various project components such as enhancement of existing hydrometeorological observation network, establishment of the regional flood information system, and capacity building. She articulated flood forecasting modeling and tools and showed their applications in several river basins. She stated that TRMM satellite precipitation data are used in the flood forecasting models after being corrected by the historical data. She showed flood outlook and evaluation of flood forecasting in Koshi River. She stated that data and products are disseminated via dedicated WEB portal. She explained the challenges and opportunities. She concluded her presentation, suggesting the followings for possible role of ICIMOD in the SAsiaFFG project:

- ICIMOD could participate at a technical level by being a part of the validation of the satellite based rainfall estimates;
- ICIMOD could hold regional trainings and workshops for the representatives of the national hydrometeorological services;
- ICIMOD would like to be a part of the trainings (online courses on the flash flood guidance system as well as at the HRC training programs); and
- ICIMOD could work with the regional and international partners to forge cooperation in the region and provide a regional platform.
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4.4. Linkage between Severe Weather Forecasting Demonstration Project (SWFDP)-Bay of Bengal and SAsiaFFG System

Mr M.Mohapatra of IMD provided information about the current status of the SWFDP-Bay of Bengal (SWFDP-BoB) saying that it will strengthen capabilities of the participating National Meteorological and Hydrological Services in the region for issuance of the severe weather warnings. He mentioned that SWFDP is a cascading forecasting process from the global scale to the regional scale. He explained that global NWP Centres provide NWP/EPS and satellite based products in the project window frame. Regional Centres in turn interpret the information received from the Global Centres to prepare daily guidance products for the participating NMHSs, run mesoscale NWP model, and maintain RSMC WEB portal. On the other hand, NMHSs access to all products available on the RSCM web portal to issue advisories, warnings, and alerts in liaison with user communities, and provide feedback to the Regional Centres. He said that Indian Meteorological Department (IMD) is the Regional Centre for SWFDP-BoB. He stated that SWFDP-BoB focus on the following severe weather events: 1) flooding caused by heavy rain produced by tropical cyclones, thunderstorms, monsoon; 2) strong winds; 3) drought; 4) high waves and swells; 5) storm surge; 6) heat waves and cold waves; and 7) fog. He explained the threshold values for heavy rain, strong winds, high waves and swells. He said that IMD, NCEPT, ECMWF, UKMO, and JMA as the Global Centres will provide products to the Regional Centre. He explained the roles and responsibilities of the Global Centres, RSMC, and the participating NMHSs. He showed SWFDP-BoB WEB portal, warning products provided by IMD, link to the participating NMHSs, and forecast guidance products. He mentioned that extensive training will be provided to forecasters from the participating NMHSs. He concluded his presentation saying that linkage between SAsiaFFG System and SWFDP-BoB may be beneficial to the participating NMHSs in a way that SAsiaFFG system may use high resolution QPE and QPF products provided by the SWFDP-BoB.

4.5 South Asia Flash Flood Guidance (SAsiaFFG) System Training (Step 1 Training)

4.5.1 Flash Flood Guidance System Key Components and Data Requirements

Mr Konstantine Georgakakos of HRC provided an overview of South Asia Flash Flood Guidance (SAsiaFFG) products and data needs. He showed the SAsiaFFGS user interface console and touched upon the products by naming them and saying that details will be presented in the following presentations. Then, he continued to explain the key technical components of the SAsiaFFG system: 1) Precipitation data sources, namely satellite and gauge; 2) Snow model; 3) Soil moisture model; 4) Threshold runoff model; 5) Flash Flood Guidance model; 6) Flash flood threat; 7) Forecasters input; and 8) Mesoscale modelled QPF.

He explained the real-time rainfall processing scheme and merged Mean Areal Precipitation (merged MAP), specifying that the objective is to produce the best estimate of mean areal precipitation over each watershed to be ingested into soil and FFG models. She then articulated real-time and historical bias corrections by using in-situ observations and past precipitation data records. He stated that Flash Flood Guidance (FFG) product is computed by using several hydrological models, namely threshold runoff modelling, snow modelling, and soil water modelling.

He concluded her first presentation summarizing the local data received and local data needs for the development and operation of the SAsiaFFGS, emphasizing that the following data must be provided to HRC for the development of the system:

- Historical precipitation, temperature and soil data;
- In-situ precipitation and temperature via GTS;
- Local soil and land use data.

SAsiaFFG system data requirements and data priorities are provided in ANNEX IV and V.

4.5.2 SAsiaFFG System Development and Theoretical Background

Mr Georgakakos explained the development and theoretical background of the SAsiaFFG 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. He stated that flash flood basin delineations, which are estimated from quality controlled SRTM-90 meter DEM data, are used for model parameterization, model computations and product displays and have average drainage areas of 150 square kilometers. He 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*[2]. He 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.

He gave an overview of soil moisture, snow and Flash Flood Guidance modelling. He 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. He 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. He 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). He 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 Asia Region. After providing an overview of the snow model, she showed comparisons of modelled SWE and observed snow depth. He then continued to explain the Flash Flood Guidance (FFG) model, specifying that it integrates Threshold Runoff, soil water content, and current precipitation and that it is updated every six hours.

He 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. He 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. He also mentioned that there is 18-26 hours latency in operation and that GHE is corrected using microwave precipitation data. He 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.

4.5.3 Advances in FFGS Functionalities

Mr Kostantine Georgakakos presented current enhancements for the FFGS improved operations. He touched upon the following four major topics:

- Multiple Mesoscale Model Input;
- Urban Flash Flood Warning;
- Use of satellite inundation mapping to correct soil moisture; and
- Landslide occurrence prediction.

First of all, he further articulated each topic saying that it was forecasters demand to include multiple mesoscale model input display on the FFGS forecaster console because each model behaves

[2] 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.

differently in different seasons event in months. Secondly, he explained that there is a grooving demand for a urban flash flood early warning system to be incorporated into FFG because occurrences of urban flash floods have recently increased due du climate change and climate variability. Hs continued saying that a demonstration project for the urban flash flood early warning has been conducted for the city of Pretoria, South Africa and second one to be conducted in Istanbul, Turkey. Thirdly, he showed a case study to correct soil moisture in the inundated regions in northern Viet Nam by using MODIS satellite images. Last but not least, he showed an demonstration case study of Landslide prediction using FFGS outputs conducted in El Salvador includes landslide susceptibility mapping, real-time occurrence prediction based on FFGS rainfall and soil moisture data, and susceptibility class.

4.5.4 Black Sea and Middle East Flood Guidance (BSMEFFG) System User Interface and Dashboard

Mr Ayhan Sayin explained the Dashboard and BSMEFFGS user console. He stated that Dashboard is designed as a quick-look facility to check and monitor server processes that are located at the Regional Centre (RC) as part of regional implementation of the global FFGS. He explained that Dashboard was composed of five major sections:

- Quick-look Product Windows showing selected products such as Global Hydro Estimator (GHE); Global Telecommunication System (GTS) data dissemination status, showing status of those station that are reporting to GTS; Average Soil Moisture (ASM); and Forecast Mean Areal Precipitation (MAP);
- Real-Time data downloads and inventory status;
- Real-Time Data processing status;
- Computational server status; and
- Dissemination server status.

He continued to explain in detail BSMEFFGS Forecaster Console, saying that the console has the following main windows for the product display and selection:

- Products navigation toolbar to select regional and country-level products, time and date, and time interval;
- FFG products window to display user-selected products;
- Snow products window to display snow products such as Snow Water Equivalent (SWE), snow MELT, Snow Coverage, and Mean Areal Temperature (MAT);
- Surface Meteorological Observations Window to display in-situ data transmitted through GTS and received by the BSMEFFGS for further processing such as real-time precipitation bias adjustment;
- Product description and system monitoring tools that provide complementary tools for the further data processing and information to the users.

He reiterated the natural causes of flash floods as being: 1) intensive rainfall from slow moving thunderstorms or tropical systems; 2) orographic rainfall in steep terrain; 3) soil saturation or impervious land surface; and 4) hydraulic channel properties and continued to explain brief definitions of the products and showed how to display products and data. Finally, he articulated in detail how the BSMEFFG products should be used by the forecasters in operation to prepare flash flood bulletins and warnings:

- Weather RADAR precipitation estimation;

- **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);
- Quantities Precipitation Forecast (QPF) from High Resolution Mesoscale Numerical Weather Prediction Model, ALADIN;
- **Forecast Mean Areal Precipitation (FMAP),** which is estimated by using gridded LAM QPF of ALADIN; and
- **Flash Flood Threat (FFT)** products, which indicate the possibility of flash flood occurrences at the outlet of a particular sub-basin, includes Imminent Flash Flood Threat (IFFT), Persistence Flash Flood Threat (PFFT), and Forecast Flash Flood Threat (FFFT).

Mr sayin concluded his presentation by explaining the snow products generated by the FFGS, namely snow water equivalent (SWE), snow coverage, the contribution of snow melt (snow MELT), and mean areal temperature (MAT). He also showed how to access to the products data for off-line processing.

4.5.5 Case Study-Operational FFG products usage

Mr Ayhan Sayin presented a case study on the South East Europe flash flood event that took place on 13-15 May 2014. Firstly, he explained the importance of the flash flood case studies that may help forecasters to understand the behavior 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 explain the top-down approach for the preparation of a case study, given in the following order: 1) analysis of the diagnostic and prognostic synoptic and mesoscale products such as surface, 850, 700, 500 hPa charts, as well as jet streams; 2) precipitation forecasts of different NWP products such as ECMWF, ALADIN and WRF; 3) instability analysis including instability indices; 4) satellite and radar images; 5) monitoring of in-situ observations, particularly precipitation intensity and accumulation over time; 6) analysis of the FFGS products in detail; 7) preparation of FFG Bulletins; and 8) issuance of the flash flood warnings and alerts.

He explained that the worst flood and flash flood event occurred in South East Europe killing more than 36 people and inflicting widespread economic damages that ware worth of billions of dollar. The event effected whole South East Europe particlularly Serbia, Bosnia and Herzegonia, Montenegro, and Romania.

He continued to explain synoptic analysis at different levels such as surface, 850 hPA, 700 hpa, and 500 hPa from 13 May 2014 to 15 May 2014 that showed a trough developed over the central Mediterranean and moved south and southeast over the next couple of days. Pronounced surface pressure center with 1008 hPa was located over the Adriatic Sea and became deeper in the next 24 hours. 850 HPA chart showed a strong cold air advection behind the trough and warm air advection ahead of the trough. Jet core was located over the southern Italy with a core value of 120 knots.

Analysis showed that at 00 UTC, 13.05.2014, a central Mediterranean depression existed and it was very likely that SEE would be affected by heavy precipitation next 24 hours. ECMWF 6 hour precipitation forecast showed that 6-hr QPF values increased from 20mm to 50 mm from 13 May 00 UTC to 14 May 00 UTC. Satellite images showed widespread cloudiness including convective clouds along the Adriatic Sea.

He then explained Now SEEFFG diagnostic products are to be investigated to find out hydrological responses of catchments. 6-hr microwave adjusted GHE is a global satellite precipitation retrievals by NESDIS shows that on 13.05.2014, 00UTC there was very little rainfall in SEE. On the other hand, 14.05.2014 00UTC maximum precipitation accumulation was up to **10-20 mm** and then at 18UTC it was **20-40 mm**. On 15.05.2014 00UTC (top) precipitation area extended to the northeast having maximum values of **40-60 mm** over Bosnia and Herzegovina and Serbia .At 06UTC, 6-hr precipitation intensity reduced over last six hours but rainfall continued in a patchy way over Bosnia and Herzegovina and Serbia having maximum values of **40-60 mm**. As it is obviously seen that MWGHE precipitation temporal and spatial distributions were in line with the ECMWF QPF forecasts with varying precipitation intensity. He continued to explain the spatial and temporal changes in soil moisture and Flash Flood Guidance (values). Finally he showed the 24-hr ALADIN QPF value of 120 mm over Bosnia and Herzegovina and Serbia. He said that taking into account of FFG, ASM, merged MAP, and FMAP products and his/her own local forecasting experiences, one may conclude that occurrences of the flash floods in the region was highly likely. He concluded his presentation showing flash flood bulletin, warning text, and precipitation measurements, and flood images in the region.

4.5.6 BSMEFFGS Verification Results

Mr Ayhan Sayin's presentation built upon that of Mr Kosntantine Georgakakos`s presentation that he demonstrated the operational capabilities of the Black Sea and Middle East Flash Flood Guidance (BSMEFFG) system and illustrated the use of its derived products. 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 were high and that satellite estimation and numerical weather forecasts of precipitations intensity and amount are relatively poor in comparison with synoptic and mesoscale systems.

4.6 SAsiaFFGS Hydrometeorological Training Programme

As a part of the facilitated discussions, Mr Georgakakos 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.

He then explained that it was planned to hold Step 3 specialized training course at HRC, San Diego, CA, USA in February 2017 and that Step 2 eLearning hydrometeorological training (on line course) is a prerequisite for the Step 3 specialized training at HRC. He mentioned that countries should nominated several trainees to take on line courses because they must complete them and pass on-line exams and an exit interview; and that a trainee with the highest score from each NMHS will attend the Step 3 training.

He stated that within the scope of FFG-Pakistan project, three forecasters from the Pakistan Meteorological Department (PMD) took operational training course at HRC, San Diego, USA in 2013.

All country representatives agreed that training of the forecasters from the participating NMHSs is very important for the successful operation of the SAsiaFFG system. ICIMOD representative Ms Mandira Singh Shrestha made an intervention saying that ICIMOD would like to be involved in the capacity building activities because it has very extensive experiences for providing training to the forecasters from Afghanistan, Bangladesh, Bhutan, Myanmar, and Nepal in various topics including hydrometeorlogical forecasting and water management. Participant appreciated and welcome offer of ICIMOD to be engage in the capacity building activities.

4.7 Project Implementation Plan

Mr Konstantine Georgakakos described the revised project implementation plan, showing the major tasks, milestones, and schedule. It was stated that Afghanistan, Bangladesh, Bhutan, Pakistan and Sri Lanka have sent Letters of Commitment (LoC) to WMO to participate in the project. Participants urged India to join the SAsiaFFG as the Regional Centre by submitting its LoC to WMO as soon as possible. The following main activities were mentioned and had focused discussions on how the process may be sped-up: 1) historical hydrometeorological data to be provided by the end of August 2016; 2) on-line courses to be completed by the end of November 2016; 3) SAsiaFFG system to be completed by the end of December 2016; and 4) operational training at HRC to be conducted in February, 2017. Participants unanimously agreed on the implementation of the CARFFG system, saying that they would do their utmost to comply with the plan. SAsiaFFGS implementation plan is provided in ANNEX VI of this document.

4.8 Visit to the India Meteorological Department (IMD)

During the workshop, participants visited the offices of IMD to see first-hand the available facilities and infrastructure. Various departments and divisions, including numerical weather prediction, meteorological data processing, weather analysis and forecasting, and satellite data reception and processing divisions were visited. It was obvious that IMD has made significant investments on new technology for the modernization of its observational network; data reception, processing and dissemination; numerical weather prediction; climatological modelling, and weather RADARs, and training of its staff.

5. Conclusions of the Steering Committee Meeting 1

Participants discussed the concept and expected results of the project agreed in line with the Flash Flood Guidance System with global coverage and its regional implantations. The conclusions of the meeting are:

1. Noted that flash floods and landslides are important hydrometeorlogical hazards in the region, and the SAsiaFFG System would help NMHSs to mitigate their adverse impacts;

2. Agreed to move forward on the development and implementation of SAsiaFFG System;

3. Agreed with the fast-tracking of the SAsiaFFG implementation plan that was presented at the meeting;

4. Agreed on the implementation of landslide susceptibility maps in the SAsiaFFG system;

5. Reiterated the agreement to establish two Regional Centres (RCs), one at the India Meteorological Department (IMD) and another one at the Pakistan Meteorological Department (PMD), as two separate systems which is consistent with the conclusions of initial planning workshop that took place in Kathmandu, Nepal in November 2016;

6. Noted that representatives of Bangladesh, Bhutan and Sri Lanka expressed their interests, subject to concurrences of their Permanent Representatives (PRs), to work with IMD as their RC, while Afghanistan expressed his interest, subject to concurrence of his PR, wo work with PMD as its RC;

7. Agreed that the Regional Centres will provide products and services for their respective participating countries (one example is very high resolution mesoscale Numerical Weather Prediction (NWP) Quantitative Precipitation Forecast (QPF) products);

8. Expressed their appreciation concerning significant contributions that will be made by IMD and PMD in leading provision of flash flood products and services to the participating NMHSs;

9. Urged IMD to submit as soon as possible its Letter of Commitment (LoC) to WMO reading its participation in the SAsiaFFG project and hosting the RC;

10. Agreed to provide historical and real-time hydrometeorlogical and landslide data, when such data exist, to the Hydrologic Research Center (HRC) through the appropriate RC;

11. Agreed on the inclusion of weather RADAR precipitation estimation in SAsiaFFG;

12. Recognized that trained meteorological and hydrological experts are needed for the effective production of early warning of flash floods by the SAsiaFFG System;

13. Agreed on the design and implementation of the flash flood hydrometeorlogist training programme and recognized for the effective and efficient use of the SAsiaFFG System;

14. Agreed that the International Centre for Integrated Mountain Development (ICIMOD), as a knowledge partner, should consider contributing to the implementation of SAsiaFFG System through capacity building and other activities; and

15. Recommended strengthening the linkages between the SAsiaFFG project and SWFDP Ban of Bengal project.

6. Closing of the Steering Committee Meeting 1

Closing remarks were made by WMO, HRC, IMD. ICIMOD, 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

FIRST STEERING COMMITTEE MEETING (SCM 1)

SOUTH ASIA FLASH FLOOD GUIDANCE (SAsiaFFG) SYSTEM

New Delhi, India

26–28 April 2016

List of Participants

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ANNEX II

FIRST STEERING COMMITTEE MEETING (SCM 1)

SOUTH ASIA FLASH FLOOD GUIDANCE (SAsiaFFG) PROJECT

New Delhi, India

26–28 April 2016

Final Agenda

Day I

09:00 *Registration*

09:15-09:45 Opening Ceremony

Welcome speeches by the IMD, Ministry of Earth Sciences, WMO, USAID/OFDA, and HRC representatives

09:45–10:00 *Photo session*

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

10:30–10:45 Selection of the session chair and review of the agenda

- Participants self-introductions (All)

10:45-11:15 Review of outcomes of SAsiaFFG Initial Planning Meeting (WMO)

11:15-11:45 Status of SAsiaFFG System (modeling, training etc.) (HRC)

11:45–12:30 Overviews of existing flash flood forecasting and warning infrastructures of NMHSs of the South Asia (Country presentations);

- Local capacity for the provision of flash flood early warnings,
- Local capacity for weather forecasting and nowcasting (Global and limited Area Models, meteorological data processing and visualization software),
- Current hydrometeorological networks (number and types of meteorological and hydrological stations, data dissemination methods, GTS reporting, radiosonde stations, databases),

- Organizational structure and human resources (7/24 working, number of trained forecasters, forecasting department,
- Availability of systematically observed hydrometeorological data (availability of the data, data types, digital or paper, periods of coverage) since May 2012,
- Collaborations with emergency management agencies other governmental and non-governmental (private sector, TV, Radio etc.) organizations.
    - Overview of products and services provided.

12:30–14:00 Lunch Break

14:00–14:30 Overviews of existing flash flood forecasting and warning infrastructures of NMHSs of the South Asia (Country presentations) (Continued)

14:30–15:00 Responsibilities of the Regional Centre(s) (WMO)

15:00-15:30 IMD capacities in weather and hydrometeorological forecasting, IT, communication etc. (IMD)

15:30–15:45 Responsibilities of the participating National Meteorological and Hydrological Services (NMHSs) (WMO)

15:45-16:15 Tea Break

16:15–16:45 Local data requirements & transmission to the Regional Centre (WMO)
Feedback on requirements (NMHSs)

16:45-17:00 Project Management Issues (WMO)

17:00-17:30 *Status* of SWFDP-Bay of Bengal (IMD)

DAY II

09:00 – 09:30 Overview of Day I presentations and discussions (All)

09:30 – 11:00 Overview of the South Asia Flash Flood Guidance products (HRC):

- Diagnostic precipitation products (GHE, MWGHE, Merged MAP),
- Prognostic precipitation products (NWP QPF, FMAP),
- Soil Moisture (ASM),
- Flash Flood Guidance (FFGS),
- Threats (IFFT, PFFT, FFFT),
- Snow Products (SCA, SWE, MELT).

11:00 – 11:30 Tea Break

11:30 – 12:00 SAsiaFFG system development and review of theoretical background (HRC):

- Design Philosophy and Introduction to Modelling Components,
- Data Used for Development.

12:00 – 12:30 SAsiaFFG system development and review of theoretical background (HRC) (Continued):

- Spatial GIS Analysis,
- Runoff Estimation.

12:30 – 14:00 Lunch Break

14:00 – 14:30 SAsiaFFG system development and review of theoretical background (Continued) (HRC):

- Soil Moisture Model and Parameterization,
- Snow Model,
- Flash Flood Guidance.

14:30 – 15:00 SAsiaFFG system development and review of theoretical background (continued) (HRC):

- Satellite Precipitation Estimation,
- Precipitation Bias Adjustment Principles.

15:00-15:30 BSMEFFG User Interface and Dashboard (Ayhan Sayin, WMO):

- Walk-through of Products (view system in real-time),
- Real-time Data Use.

15:30-16:00 Overview of HKH-HYCOS and its benefits to SAsiaFFG System (Mandira Singh Shrestha, ICIMOD)

16:00-17:30 *Visit* to IMD facilities such as weather analysis and forecasting and telecommunication divisions (to be confirmed).

19:00 Welcome dinner

Day III

09:00–09:30 Overview of previous day presentations/discussions (All)

09:30–10:00 Operational FFG products usage-Case study (Participants will be involved) (WMO).

- Synoptic and mesoscale analysis,
- FFG products and preparations of bulletins,
- Detailed discussion of examples,
- Validation Methodology and BSMEFFG System 2015 validation results.

10:00-10:30 PMD Experiences on the operational FFG products usage (Case Study) (Muhammad Hanif). Participants will be involved.

10:30–11:00 Tea Break

11:00-12:00 Advances in FFGS Functionalities (HRC):

- Landslides,
- Urban flash flood early warning system,
- Riverine Routing,
- Ensemble.

12:00– 12:30 Possible points of collaborations between SWFDP- Bay of Bangal and SAsiaFFGS (All)

12:30–14:00 Lunch Break

14:00–15:30 Project planning and implementation-work plan development (WMO)

- Adjustments and next steps

15:30-16:00 ***Tea Break***

16:00-16:30 Review of decisions and recommendations (All)

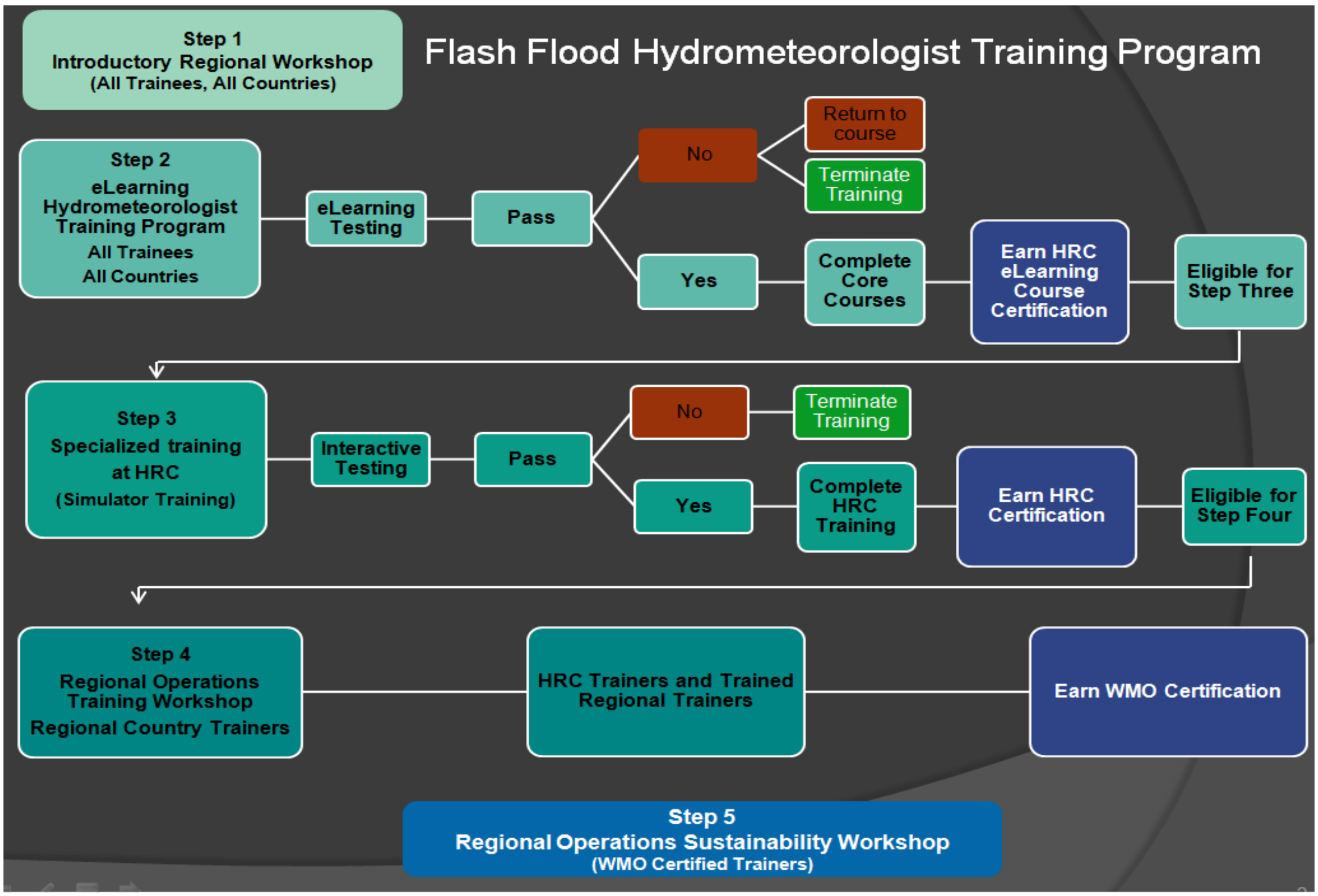
16:30–17:00 Final Discussion and recommendation (All)

17:00-17:30 Closing statements & closure of the meeting

-End of Workshop-

Flash Flood Hydrometeorological Training Programme

An ongoing regional training program involving the Regional 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).



ANNEX IV

Data Requirements

For the development and operation of Flash Flood Guidance System, local historical and/or climatological hydrometeorological and geomorphologic, and real-time data are required. They are used for, among others, model parameterizations, calibrations, bias adjustments. Use of the higher resolution spatial and temporal local data in the FFG models is critical for the system performances. At the absence of local data, they will be obtained from international organizations like soil data from FAO (Food and Agricultural Organization). Therefore, participant countries are advised to collect, arrange and provide the following data types in required formats, depending on the availability of them.

A. NMHS Capacity Information

Institutional capacities, responsibilities:

- Hydrometeorological observation network, data processing and visualization tools;
- River and flash flood forecasting and early warning tools;
- Nowcasting tools;
- QPE/QPF tools and models;
- IT capabilities; and
- Organization structure (forecasting department, regional offices etc.,).

B. Spatial GIS Data, Maps

- Digital terrain elevation data (quality controlled);
- Stream network;
- Lakes/reservoirs/wetlands;
- Soil type, texture and depth;
- Vegetation cover, and land usage; and
- Monthly climatological maps of precipitation, temperature and potential evapotranspiration.

C. Spatial GIS Data, Maps

Channel cross-sectional Information for natural channels with drainage areas less than 2,000 km^2. The following hydrometeorological data, 5-20 years in record length, preferable in digital format:

- Precipitation (hourly, daily, monthly), covering at least past 5 years as much as available;
- Surface air temperature (hourly, daily, monthly);
- Top soil moisture (daily, weekly, monthly);
- Streamflow discharge for local streams with drainage areas less than 2000 km^2 (hourly, daily, monthly);If streamflow discharge data are unavailable, stream stage data (hourly, daily, monthly) and associated stage-discharge curves (rating curves), also for local streams;

- Snow depth, snow water equivalent (SWE) and snow coverage (hourly, daily monthly);
- Flood frequency analysis (regional and local);
- Flash flood occurrences (regional and local);
- Stream geometry studies for small streams;
- Climatological precipitation and flood studies; and
- Karst flow measurement studies.

If above data are unavailable, such hydro-meteorological and climatological data as monthly precipitation; surface air temperature; pan-evaporation/evapotranspiration; soil moisture; stream flow; radiation; wind and humidity; snow depth and coverage and SWE should be provided.

D. Real-Time Data Requirements

FFG system uses real-time meteorological observations in WMO synop format that are disseminated through WMO GTS, including the following parameters, among others:

- Precipitation;
- Surface temperature, humidity, wind speed/direction, pressure, solar radiation;
- Snow depth and SWE; and
- Soil moisture.

Besides the synoptic reports, if additional hydrometeorological observations are available, that would be transferred to the regional centre through ftp services, may improve the system performances.

NMHS Observation Network Metadata Requirements

The following metadata for the rain gauges, weather stations, and stream gauges are to be provided:

- Geographical locations (latitude and longitude in decimal degrees);
- Elevation in meters;
- Type of stations and WMO station numbers(synoptic, climate);
- Current operational status (Automatic, Manuel);
- Observation interval (hourly, 3-hourly, 6-hourly etc);
- Available sensors (Precipitation, Temperature, Humidity, Soil Moisture, Dew Point, Snow, SWE etc.);
- Total number of stations and number of synoptic stations that reports to GTS;
- Data transmission type (HF/VHF radio, wide area network, GPRS, satellite etc.);
- Data quality control applied (y or n); and
- Existing database (Oracle, Informix etc.).

ANNEX V

Data Priorities for the CARFFG System

REAL-TIME DATA

Real-time data is considered the highest priority for the operational FFG System.

Priority	Data Type	Time Resolution
1	Meta data for all gauges+	
1	Precipitation*	Hourly or 6-hourly preferred -OR- 3-hourly or daily
1	Surface temperature*	Hourly or 6-hourly preferred
2	Snow depth / snow water equivalent	6-hourly or daily
3	Stream flow	6-hourly or daily
4	Soil moisture measurements	6-hourly or daily
5	Humidity, wind, solar radiation	6-hourly or daily

+ Meta data includes station name &/or identifier, coordinates in LAT/LON, and elevation
** Precipitation, temperature, and snow observations may be used directly by system. Soil moisture, stream flow and other meteorological observations (frequent less available)*
are provided as information through system interface and may be used by forecaster to evaluate certain system output products.

HISTORICAL DATA

Historical data is necessary for model development and evaluation of FFG System components. The items listed below in Section 1 are higher priority, and considered equal level of priority as the corresponding priority levels of real-time data. Additional information requested in Section 2 and 3 may be during development as such data is available. The priority assignments are grouped together for Sections 2 and 3, and follow the priority level of Section 1.

(1) FOR ANALYSIS PERIOD OVERLAPPING SATELLITE ESTIMATES:
1.a) PRECIPITATION BIAS ANALYSIS

Priority	Data Type	Time Resolution	Period of Record
1	Gauge Precipitation*	Hourly preferred -OR- 3- or 6- hourly -OR- Daily	2012 - current
1	Meta data for all gauges+		

** Gauges with good spatial coverage and relatively uniform density across country. Quality*
controlled data is required. Typically, most information is available from daily reporting stations.
+ Meta data includes station name &/or identifier, coordinates in LAT/LON, and elevation.

1.b) Hydrologic Model Calibration

Priority	Data Type	Time Resolution	Period of Record
1	Meta data for all gauges		
2	Surface air temperature	Hourly or Daily preferred -OR- 3- or 6- hourly	2012 - current
3	Stream flow data++	Hourly or Daily	2012 - current
4	Pan evaporation / evapotranspiration	Daily preferred -OR- weekly or monthly	2012 - current
4	Snow depth, snow water equivalent (SWE)	Daily preferred -OR- weekly or monthly	2012 - current
4	Measured soil moisture	Daily preferred -OR- weekly or monthly	2012 - current
5	Radiation, wind & humidity	Hourly or Daily	2012 - current

++ if stream flow data is unavailable, stream stage (height) data plus rating curve may be used.

1.c) Hydrologic Model Calibration – Spatial Data

Priority	Data Type	Resolution	Period of Record
1	Soil type, soil texture, soil depth		
1	Land cover/vegetation cover/ Land use		
2	Stream survey reports / channel geometry information	For small streams, draining < 2000 km^2	Surveys within recent 10-15 years
3	Return period flow estimates&	For small streams, draining < 2000 km^2	
4	Spatial coverage of karst regions		

& if return period flows are unavailable, stream flow data for 10-20 years may be used to derive these estimates.

(2) ADDITIONAL HISTORICAL DATA (NOT OVERLAPPING SATELLITE ESTIMATES, BUT RECENT TIME PERIOD PREFERRED*

Priority	Data Type	Time Resolution	Period of Record
1	Precipitation	Hourly or Daily	5-20 years
1	Surface air temperature	Hourly or Daily	5-20 years
1	Stream flow data++	Hourly or Daily	5-20 years
2	Pan evaporation / evapotranspiration	Hourly or Daily preferred -OR- weekly or monthly	5-20 years

3	Snow depth, snow water equivalent (SWE)	Daily preferred -OR- weekly or monthly	5-20 years
3	Measured soil moisture	Daily preferred -OR- weekly or monthly	5-20 years
5	Radiation, wind & humidity	Hourly or Daily preferred -OR- weekly or monthly	5-20 years

** spatial and period of record correspondence between meteorological (P,T,Evap,SWE) and hydrological (Q, soil moisture) observations is desired for hydrologic model calibration. If corresponding time series are unavailable, data is used to evaluate climatological response.*

++ if stream flow data is unavailable, stream stage (height) data plus rating curve may be used.

[&] if return period flows are unavailable, streamflow data for 10-20 years may be used to derive these estimates.

(3) ADDITIONAL HISTORICAL STUDIES

Priority	Data Type	Resolution	Period of Record
4	Location of reservoirs		
4	GIS layers of watershed boundaries or stream network[%]		
5	Historical flash flood occurrences or reports		
6	Flood frequency studies		
6	Karst flow measurements or studies		

[%] digital GIS layers based on digitization of topographic map preferred and used to evaluate automated watershed delineation results.

ANNEX VI

Milestones for the SAsiaFFG System Implementation Plan

TASK NAME	2016									2017							
	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Initial Planning Meeting	DONE																
Server Purchase - Regional Centers																	
Letters of commitment and focal points to be provided by India Meteorological Department																	
Obtain static and historical hydromet data																	
Obtain real-time data information - data availability/access																	
Training Workshop - Step 1 (Steering Committee Meeting #1)	DONE																
National/Regional Centers complete online courses - Step 2																	
Complete system development																	
Regional Center develop and provide real-time data format																	
Regional Center operational (to collect real-time data)																	
National Centers operational and provide real-time data access																	
Steering Committee Meeting #2																	
Complete operational training at HRC - Step 3																	
Onsite system installation at Regional Center																	
Operations workshop - Step 4 (Steering Committee Meeting #3)																	