WORLD METEOROLOGICAL ORGANIZATION

WEATHER CLIMATE WATER

Flash Flood Guidance System with global coverage (Res 21, Cg-XV) enhances early warning capabilities of the NMHSs, currently covers fifty two (52) countries and more than two billion people around the world saving lives and decreasing economic losses.

FLASH FLOOD GUIDANCE SYSTEM (FFGS)

with GLOBAL COVERAGE

The Flash Flood Guidance System with global coverage consists of eight regional FFGSs in different stages of development and operational use. Four systems are operational, initial versions were implemented for four, and one is under development.

The main objectives of the Flash Flood Guidance System with global coverage are:

- To enhance NMHSs capacity to issue effective flash flood warnings and alerts;
- To enhance collaborations between NMHSs and Emergency Management Agencies;
- To foster regional developments and collaborations;
- To generate flash flood early warning products by using state of the art hydrometerological forecasting models;
- To provide extensive training including on line training to the hydrometeorological forecasters;
- To support WMO Flood Forecasting Initiative.

Flash floods are among the world's deadliest natural disasters with more than 5,000 lives lost annually and result in significant social, economic and environmental impacts. Accounting for approximately 85% of the flooding cases, flash floods also have the highest mortality rate (defined as the number of deaths per number of people affected) among different classes of flooding (e.g.,riverine, coastal). Flash floods have a different character than river floods, notably short time scales and occurring on small spatial scales, which makes forecasting of flash floods quite a different challenge than forecasting large-river flooding. In forecasting of flash floods, we are concerned foremost with the forecast of occurrence, and herein focuse on two causative events: 1) intense rainfall; and 2) rainfall on saturated soils. Flash floods occur throughout the world, and the development times vary across regions from minutes to several hours depending on land surface, geomorphological, and hydrometeorological characteristics of the region. However, for the majority of these areas, there exists no formal process or capacity for the development of flash flood warnings.

Figure 1: Devastating flash flood events in Turkey

To address the issues associated with flash floods, especially to address the lack of capacity to develop effective flash flood warnings, the Flash Flood Guidance System (FFGS) was designed and developed for interactive use by meteorological and hydrologic forecasters throughout the world. In support of the FFGS programme, a Memorandum of Understanding was signed among the World Meteorological Organization, the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance, the U.S. National Oceanic and Atmospheric Administration/National Weather Service and the Hydrologic Research Center (a U.S. non-profit corporation) to work together under a cooperative initiative to implement the FFGS worldwide. The FFGS programme is a public benefit effort on behalf of the partners.

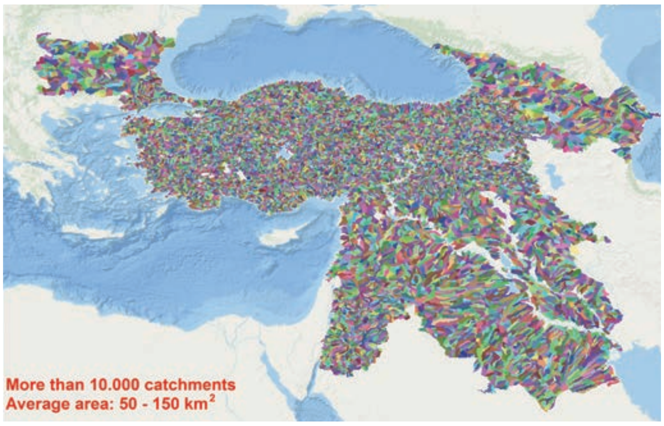

Figure 2: Basin delineations for Black Sea and Middle East FFGS

A system such as the FFGS is an important tool necessary to provide operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of small-scale flash flooding. The FFGS is a robust system designed to provide the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote-sensed precipitation (e.g., radar and satellite-based rainfall estimates) and hydrologic models. To assess the threat of a local flash flood, the FFGS is designed to allow product adjustments based on the forecaster's experience with local conditions, incorporation of other information (e.g., Numerical Weather Prediction outputs) and any last minute local observations (e.g., non-traditional rain gauge data) or local observer reports.

The primary purpose of the FFG systems is to provide real-time informational guidance products for flash floods to trained forecasters. If the system is used frequently, implementation experience has shown that the knowledge and experience of trained forecasters increases and they are able to identify their individual strengths and weaknesses in relation to their abilities in flash flood forecasting and forecast uncertainty. They are also able to identify areas where their local knowledge and the FFGS provide applicable and realistic results, as well as gaining a sense of the meteorological and hydrologic conditions likely to lead to flash flooding for their country.

The Flash Flood Guidance System technical components are depicted in Figure-3. The key model components consist of Threshold Runoff Model (drainage network characteristics) that is computed once for each sub-basin. Estimated precipitation from several sources like satellites, radar as available, and gauges as available are input into a snow model, which estimates snow water equivalent (SWE) and MELT that is inputted into a soil water accounting model to estimate soil water deficit in upper and lower soils. The Flash Flood Guidance component is used to estimate the amount of rainfall that is required to cause bankfull flow for a given duration (e.g., one, three and six hours) at the outlet of each sub-basin taking into account of current soil moisture conditions. The Flash Flood Threat is the amount of mean areal rainfall of a given duration that is greater than the Flash Flood Guidance value of the same duration for a basin.

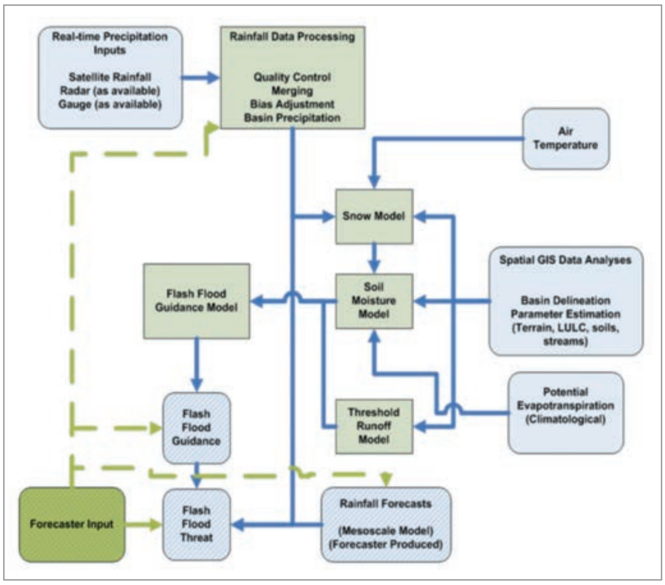

Figure 3: Flash Flood Guidance System technical components

FFGS Products

The FFGS products can be classified into three groups: 1) Diagnostic products such as radar and satellite precipitation, Mean Areal Precipitation, Soil Water, and Flash Flood Guidance; 2) Prognostic products such as Mesoscale Precipitation Forecasts in gridded and mean areal precipitation form; and 3) Warning products such as Flash Flood Threat. In addition, for regions with seasonal snow, products pertinent to snow accumulation and melt are generated. The products are described in the following section.

1. Diagnostic Products

FFGS ingests precipitation estimates from different sources such as those based on weather RADARs, the IR-based satellite Global Hydro Estimator of NOAA/NESDIS, the Microwave-adjusted GHE (MWGHE), and in-situ precipitation gauges in order to estimate bias-adjusted and merged Mean Areal Precipitation (MAP) estimates for each FFGS sub-basin for input into the hydrologic models.

RADAR Precipitation: Weather RADARs provide near real-time two and three dimensional scans of the weather with fine spatial and temporal resolutions so that the local convective storms that produce heavy-rainfall and flash floods can be detected. The FFGS ingests typically CAPPI precipitation products containing gridded precipitation estimates at a constant attitude above the ground surface. The FFGS displays both the gridded mosaic of regional radar CAPPI products and the derived mean areal precipitation for the FFGS basins.

Global Hydro Estimator (GHE) Precipitation: The FFGS is designed to use the NOAA/NESDIS Operational Global Hydro Estimator (GHE) satellite rainfall estimates as a primary precipitation source, because of the data low latency. GHE retrievals use infrared (IR) sensors of geostationary weather satellites estimating cloud top brightness temperatures and establishing statistical relationships between precipitation intensity and brightness temperatures. Adjustments are made based on operational global numerical weather prediction models. 1, 3, 6 and 24-hr GHE precipitation products are available.

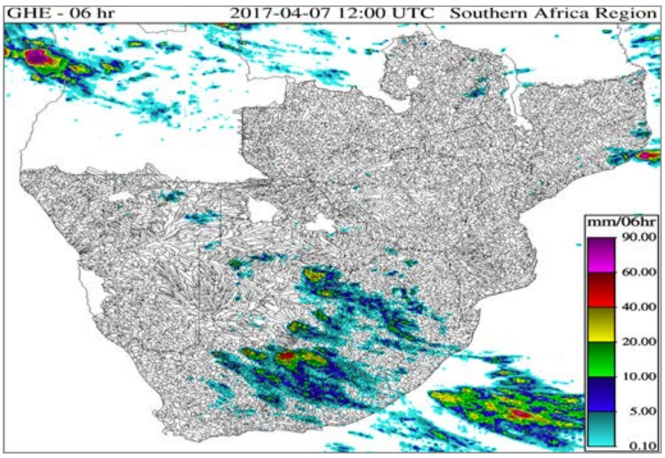

Figure 4: 6-hr GHE precipitation for Southern Africa FFGS

Microwave-adjusted Global Hydro Estimator (MWGHE) Precipitation: The microwave-based estimates use the CMORPH products available from NOAA/Climate Prediction Center. Microwave emissions from hydrometeors compared to those of the background are related to surface rainfall more directly than IR-based brightness temperatures of cloud tops. However, while the GHE products from NOAA have a latency of approximately 20 minutes, the CMORPH products have a much greater latency of one-half day or more. Therefore, GHE precipitation is adjusted by using microwave precipitation data to create MWGHE. 1, 3, 6 and 24-hr MWGHE precipitation products are available.

Merged Mean Areal Precipitation (Merged MAP): It is produced using bias-adjusted RADAR, MWGHE or GHE precipitation using gauge data, depending on the availability of such data for the domain of interest. FFGS provides 1, 3, 6 and 24-hr merged MAP products. The Merged MAP product provides the data that is quality controlled and ingested into the snow and soil water dynamical models and some of the flash flood threat procedures.

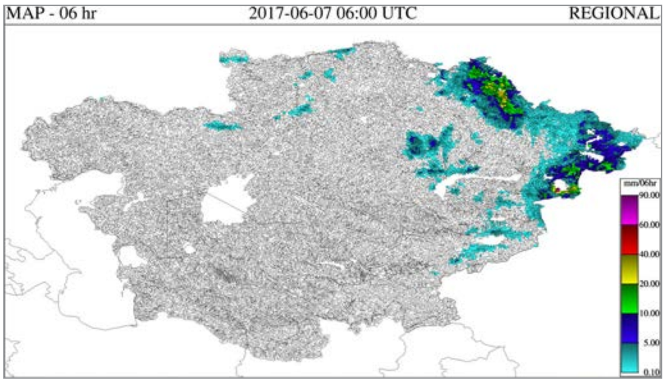

Figure 5: 6-hr merged MAP for Central Asia Region FFGS

Average Soil Moisture (ASM): For each FFGS basin, it is the saturation fraction of the upper soil (20-30 cm). The time-continuous version of the Sacramento Soil Moisture Accounting model is used to estimate the soil water content. For each basin, real time input for this model is the mean areal precipitation while soil, terrain and land cover are used to determine a priori parameters. Typically, ASM is generated and updated every six hours at the model runtimes at 00, 06, 12 and 18 UTC.

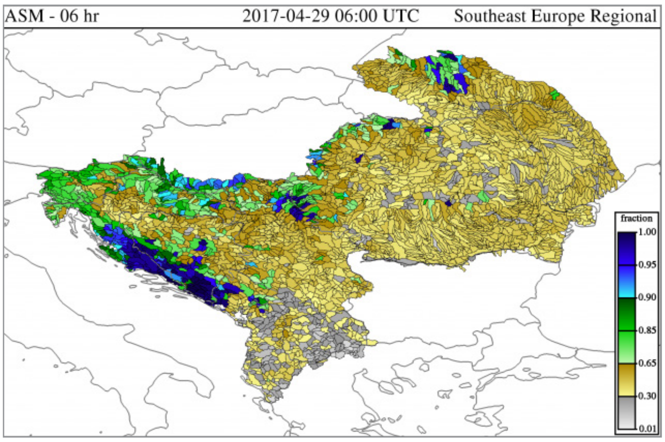

Figure 6: 6-hr Average Soil Moisture for South East Europe FFGS

Flash Flood Guidance (FFG): It is defined as the amount of actual rainfall for a given duration (e.g. 1, 3 and 6 hours) and over a basin that causes bankfull flow at the outlet of the basin. The FFG is calculated and updated every six hours at the model runtimes of 00, 06, 12 and 18 UTC and is valid for the next 1, 3 and 6 hours. One of the parameters for FFG is threshold runoff (FFG when the soil water deficit is zero). Threshold runoff is calculated once from geomorphologic unit hydrograph, drainage channel and catchment characteristics.

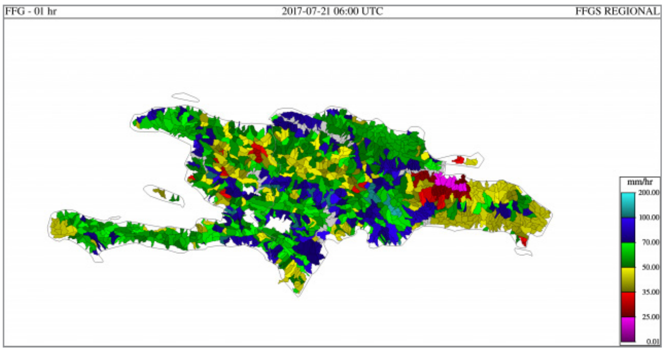

Figure 7: 1-hr Flash Flood Guidance for Haiti and Dominican Republic FFGS

2. Forecast Products

Mesoscale QPF: FFGS incorporates precipitation forecasts from mesoscale numerical weather prediction models to estimate forecast flash flood threat for each basin of the FFGS. 1, 3, 6, and 24-hr mesoscale QPF estimates are available in gridded form.

Forecast Mean Areal Precipitation (FMAP): 1, 3, 6, and 24-hr Forecast Mean Areal Precipitation products are generated from the gridded mesoscale QPF forecasts for each basin.

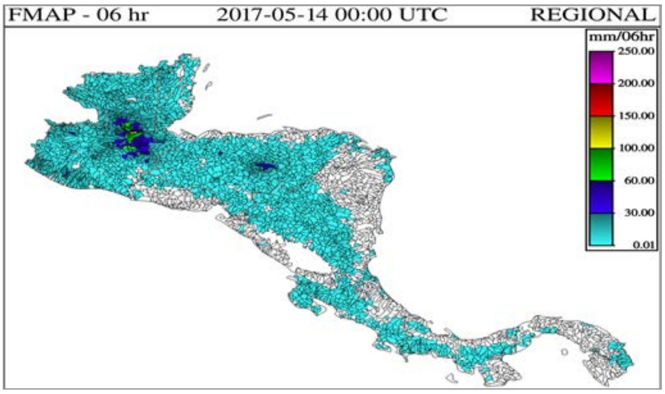

Figure 8: 6-hr FMAP for Central America FFGS

3. Warning Products

FFGS has three flash flood threat products which indicate the likelihood of occurrences of flash floods in a particular sub-basin for a given duration. 1, 3, and 6-hr threat products are generated such that their update times are different.

Imminent Flash Flood Threat (IFFT): It is the difference between the corresponding merged MAP and FFG for the same duration, indicating that flash flood is happening now or is about to happen very soon. It should be noted that IFFT is estimated and updated by using current precipitation. Thus, it represents an "nowcast" weather situation.

Persistence Flash Flood Threat (PFFT): The concept is that previous precipitation of a given duration will persist for the same duration into the future. Therefore, the PFFT is considered a "forecast" flash flood threat using persistence forecast for the rainfall.

Forecast Flash Flood Threat (FFFT): Contrary to IFFT and PFFT that use merged MAP generated from bias adjusted radar and satellite measurements or gauge data, FFFT estimation uses forecast mean areal precipitation generated from mesoscale-model precipitation forecasts. For a given duration, it is the differences between forecast mean areal precipitation (FMAP) and FFG.

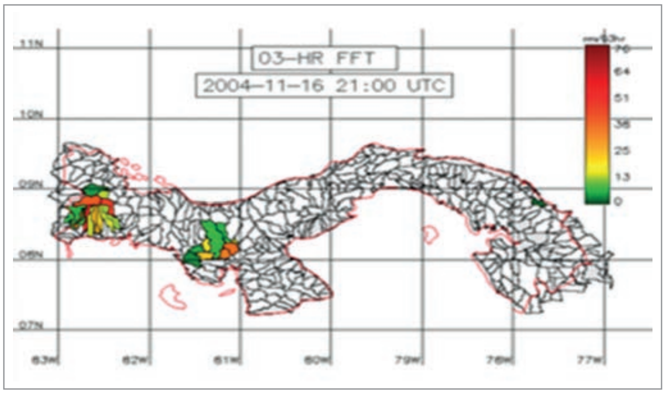

Figure 9: Flash Flood Threat for Central America FFGS

Snow Products

Latest IMS SCA: Multi-sensor snow and ice mapping analysis for the northern hemisphere is performed by NOAA /NESDIS using polar and geostationary satellites sensors.

Snow Water Equivalent (SWE): It is the direct output of SNOW accumulation and ablation model. It is estimated at 00, 06 , 12 and 18 UTC .

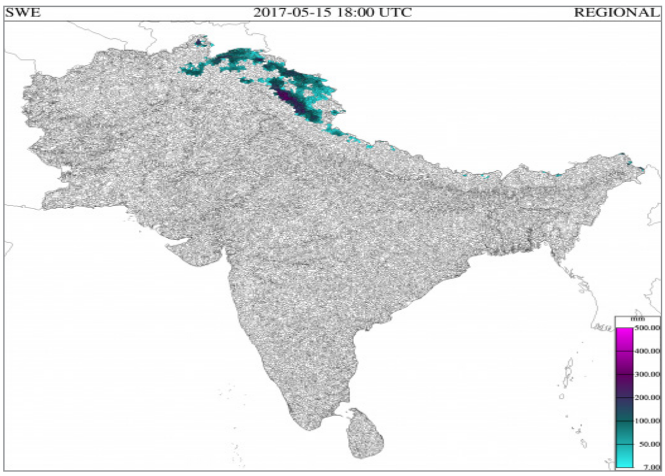

Figure 10: Snow Water Equivalent (SWE) for South Asia FFGS

Snow Melt (MELT): It is an estimate of melt volume and is a direct output of the SNOW model. The product provides cumulative melt over periods of 24 and 96 hours.

More information about FFGS is available at the following WEB sites:

www.wmo.int/ffgs and www.hrcwater.org

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