Central Asia Regional Flash Flood Guidance System: Introduction to CARFFGS, Design Philosophy, and FFGS Products

Hydrologic Research Center
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CARFFG Steering Committee Meeting
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Kosta Georgakakos – Technical Director/Hydrometeorology

Robert Jubach – Program Management/Disaster Risk Reduction

Rochelle Graham – Education and Training

Theresa Modrick – Mesoscale Modeling and Routing Models

Ari Posner – Land Slides/EOS Data Evaluation

Eylon Shamir – Soil Water and Snow Models

Cris Spencer – IT Engineering/Programming

Jason Sperfslage – IT Systems Engineering
What Do We Call Flash Floods

WORLD METEOROLOGICAL ORGANIZATION (WMO):

“A flood of short duration with a relatively high peak discharge”

AMERICAN METEOROLOGICAL SOCIETY (AMS):

“A flood that rises and falls quite rapidly with little or no advance warning, usually the result of intense rainfall over a relatively small area”

A local hydrometeorological phenomenon that requires:
1. BOTH Hydrological and Meteorological expertise for real time forecasting/warning
2. Knowledge of local up to the hour information for effective warning

Usually, flow crest is reached within 6 hours of causative event (Only consider < 2000km²).
Natural Causes of Flash Floods

• Intense rainfall from *slow moving* thunderstorms or tropical systems

• Orographic rainfall in *steep* terrain

• Soil *saturation or impervious* land surfaces

• Hydraulic *channel* properties

• Sudden release of impounded water (natural dam or human-made dam)
Flash Floods are very significant disasters globally ...

- Highest number of deaths per people affected

... BUT there are no discernible trends for loss reduction

- No flash flood warnings for vast populated areas of the world
- Lack of local expertise and of regional cooperation
- Little in situ data in small regions
- Large-river flood-warning strategies ineffective for flash floods
<table>
<thead>
<tr>
<th><strong>LRF</strong></th>
<th><strong>FF</strong></th>
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</thead>
<tbody>
<tr>
<td>- Catchment response affords long lead times</td>
<td>- Catchment response is very fast and allows very short lead times (&lt; 12hrs)</td>
</tr>
<tr>
<td>- Entire hydrographs can be produced with low uncertainty with good quality data</td>
<td>- Prediction of occurrence is of interest</td>
</tr>
<tr>
<td>- Local information less valuable</td>
<td>- Local information is very valuable</td>
</tr>
<tr>
<td>- A hydrologic forecasting problem primarily</td>
<td>- A truly hydro-meteorological forecasting problem</td>
</tr>
<tr>
<td>- Affords time for coordination of flood response and damage mitigation</td>
<td>- Coordination of forecasting and response is challenging over short times (Careful Planning Needed)</td>
</tr>
</tbody>
</table>
Operational Approaches for Flash Flood Warning

1. Site Specific (data rich catchments with special forecast interests)
2. Area-wide modeling with remotely sensed data and global datasets
   2a. Flash Flood Guidance (data sparse regions for public watches and warnings of flash flood occurrence)
   2b. Full Distributed Hydrograph Modeling (in regions with good data when entire hydrographs are needed) (High Uncertainty on smaller scales)

5 BASINS
3 LOCATIONS/BASIN
27 EVENTS/LOCATION
Importance of Soil Water on Flash Flooding in addition to rainfall rate

Example from south-central United States – Summer Convection

Figure 2. Daily values of rainfall rate (dashed line), flow rate (solid line), and upper soil water (heavy solid line) for Bird Creek near Sperry, Oklahoma, for August and September 1971. Rainfall and flow rates are in millimeters per day and are read on the left ordinate axis. Upper water is in millimeters and is read on the right ordinate axis. Upper water capacity is 135 mm.

Importance of Soil Water on Flash Flooding in addition to rainfall rate

Example from southwestern United States – Winter Mediterranean Rain

20th Century Flash Flood Occurrence

$+$ = all events
$o$ = flash flood events

Modrick & Georgakakos
JHRS 3, 312-336, 2015
Examples of Soil Texture and Infiltration Rates

Soils can infiltrate significant precipitation rates and amount.

Maximum Daily Rainfall Observed: 187 cm/day – Reunion Island


Flash Flood Guidance (FFG): defines the amount of rainfall of a given duration and over a given catchment that is just enough to cause flooding conditions at the outlet of the draining stream.

- Rainfall Threshold (familiar concept)
- Considers
  - Soil Water Deficit
  - Channel bankfull storage
- Only Bankfull flow (conservative)

Threshold exceedance concept to estimate occurrence only!
Flash Flood Guidance (FFG): defines the amount of **rainfall** of a given duration and **over a given catchment** that is just enough to cause **flooding conditions** at the **outlet of the draining stream**

**Location of Occurrence**

**Urban environment**
- Not represented due to scale
- Not represented due to sewers

**Threshold exceedance concept to estimate occurrence only!**
Regional Application of Flash Flood Guidance

(1) Current Estimate of FFG for small watersheds

(2) Compare with precipitation (obs or forecast)

(3) Identify areas with P > FFG

[Example of the HDRFFG System]
The Hydrologic Research Center (HRC) has signed a joint Memorandum of Understanding to implement regional flash flood guidance systems worldwide with:

the United Nations – World Meteorological Organization (WMO)

the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA)

and the U.S. National Oceanic and Atmospheric Administration (NOAA).

Integrated Systems for Real-Time Warning

Observations or Forecaster Experience

Last-Minute Information

Warning Message

Decision to issue warning

Response

Forecast

Decision Maker Guidelines and Preferences

Agency-Coordination Education Programs

Training and Local Experience

Modeling Systems

Adjustments

Predictions
FFG Research and Development History

- **1970-1988**: US NWS Produces FFG **statistically** for each River Forecast Center. Also, research in adaptive site specific FF prediction systems.

- **1988-1993**: IIHR/HRC develop **physically consistent FFG formulations based on GIS** and create the first operational codes for US NWS.

- **1993-2005**: HRC continues research in various aspects of the FFG process and system (sparsely gauged basins and uncertainty issues, forcing and models). The development of **prototype regional systems** using FFG is proposed and accepted in work plan of **WMO CHy Working Group on Applications (2002-2003)**.

- **2004**: The **Central America Flash Flood Guidance System** becomes operational (serves 7 countries in CA).

- **2008**: **WMO, USAID, NOAA, HRC** sign a quad-part Memorandum of Understanding to collaborate in the development of a **global flash flood guidance system** (currently in second 5-year phase).

- **2015**: Begin development for **Central Asia Regional System**.
Decisions are made with multiple datasets and under uncertainty.

There is a need to modify the products of the regional system by country forecasters and have capability for estimating consequences to local flash flood potential.
Introduction to FFGS Products
Flash Flood Guidance System Forecaster Interface

FFGS forecaster interface was designed to provide visual overview of current (and historical) system products.

**BSMEFFG - Black Sea Middle East Flash Flood Guidance System**

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<tr>
<th>DT</th>
<th>RADAR Precipitation</th>
<th>MWGHE Precipitation</th>
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<th>FFG</th>
<th>IFFT</th>
<th>PFFT</th>
<th>ALADIN Forecast</th>
<th>FMAP</th>
<th>FFTT</th>
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FFG System Products

**DIAGNOSTIC**
- Flash Flood Guidance
- Average Soil Moisture
- Observed Precipitation

**PROGNOSTIC**
- Forecast Precipitation (FMAP)
- Flash Flood Threat
Flash Flood Guidance System Forecaster Interface

Diagnostic Products: ASM, FFG, Merged MAP
Average Soil Moisture (ASM) product provides an estimate of current soil water in the upper soil depth, expressed as a fraction of saturation, based on hydrologic modeling of soil water content. ASM reflects history of prior precipitation. The upper soil depth is most indicative for flash flood production.
Flash Flood Guidance (FFG) is an estimate of the amount of rainfall of a given duration over a given small watershed which is enough to produce bankfull flow in the stream channel at the outlet of the watershed. The system interface provides current FFG values for durations of 1-, 3-, and 6-hours.
## Observed Precipitation

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**GHE: Global HydroEstimator**

**MWGHE: Microwave-adjusted GHE**

**Gauge MAP**

Accumulation over the past 1-, 3-, 6- and 24-hours.
Merged MAP

Merged MAP is the **best estimate** of Mean Areal Precipitation over each small watershed for each duration (1-, 3-, 6-, 24-hr)
Flash Flood Guidance System Forecaster Interface

Prognostic Product: Forecast Precipitation and FMAP

BSMEFFG - Black Sea Middle East Flash Flood Guidance System

Current Date: 2015-04-28 18:56 UTC
Nav Date: 2015-04-09 12:00 UTC

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Composite Product: text, CSV, CSVT
Surfnet Gauge Observations at 2015-04-09 12:00 UTC
SFTP data transfer (requires SFTP Client: EXPORTS/REGIONAL, 2015-04-09)
If a forecast precipitation product is available, the system ingests forecast precipitation estimates to calculate forecast MAP (FMAP) for each small watershed for forecast lead times of 1-, 3-, 6-, and 24-hours.
Flash Flood Guidance System Forecaster Interface

Prognostic Products: Flash Flood Threat

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Flash Flood Threat (FFT) products indicate the watersheds where precipitation exceeds the Flash Flood Guidance (FFG) value, based on observed, persisted, or forecast precipitation. FFTs indicate watersheds where the potential for flash flooding is increased.

FFT products are *not* intended to be used for automatic warning generation. Rather, these serve as indicators of regions of potential concern. The role of operational forecasters in evaluating the current situation (observed and forecast precipitation) in these regions is critical.
### Observations

1. **Gauge MAT**
   - Based on real-time temperature stations

2. **IMS Snow Cover**
   - Satellite observation of snow extent (daily)

### Model Output

3. **SWE**
   - Model estimated Snow Water Equivalent

4. **Snow Melt**
   - Melt from snow pack; this contributes to soil water model

### Informational Products: Snow Products

<table>
<thead>
<tr>
<th>Snowpack Products</th>
<th>DT</th>
<th>Latest IMS SCA</th>
<th>SWE</th>
<th>Melt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>06-hr</strong></td>
<td><img src="image1" alt="Map" /></td>
<td><img src="image2" alt="Map" /></td>
<td><img src="image3" alt="Map" /></td>
<td><img src="image4" alt="Map" /></td>
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<td>2015-03-01 12:00 UTC Text: <a href="#">view</a></td>
<td></td>
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<tr>
<td><strong>24-hr</strong></td>
<td><img src="image5" alt="Map" /></td>
<td><img src="image6" alt="Map" /></td>
<td><img src="image7" alt="Map" /></td>
<td><img src="image8" alt="Map" /></td>
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<tr>
<td><strong>4-day</strong></td>
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<td><img src="image10" alt="Map" /></td>
<td><img src="image11" alt="Map" /></td>
<td><img src="image12" alt="Map" /></td>
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Flash Flood Guidance System Forecaster Interface

Informational Products: Real-time gauge data

<table>
<thead>
<tr>
<th>Station Identifier</th>
<th>Station Name</th>
<th>Region</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elevation (m)</th>
<th>Agency</th>
<th>Type</th>
<th>Precipitation Enabled Flag</th>
<th>Temperature Enabled Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>15615</td>
<td>Musala</td>
<td>BULGARIA</td>
<td>42.1797</td>
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<td>7825</td>
<td>Bulgaria</td>
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<td>Enabled</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

Real-time gauge report are critically important for:
- gauge MAP product
- real-time temperature (MAT)
- dynamic precipitation bias adjustment
Preliminary Forecaster Interface Design for CARFFG System
Preliminary Forecaster Interface Design for CARFFG System

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THANK YOU
for your kind attention
Various processes lead to the production of surface runoff and possible flash flooding:

- **SATURATION FROM BELOW** – ALL RAIN INFILTRATES (DOMINANT FOR MOST SOILS)

- **INfiltration Controlled** – RAIN RATES IN EXCESS OF INFILTRATION CAPACITY (CLAY SOILS)

- **COMBINED** – HETEROGENEOUS AREAS AND PROFILES