Overview
GLOBAL FLASH FLOOD GUIDANCE PROGRAM

HYDROLOGIC RESEARCH CENTER

1 December 2015

Distinguishing Characteristics of Flash Floods

1. **Short flood duration**
2. **Small area affected**
3. **Very high mortality rates**

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
3. Prior coordination of warning and disaster-management agencies for effective response

WMO (2008) country-level survey: Among 139 countries, 105 indicated that *flash floods were among the top two most important hazards and require special attention*

The Need

Flash Floods are very significant disasters globally …

- Highest number of deaths per people affected (mortality rate)

… **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

The Response: The Global Initiative for Flash Floods (2008 – Present)

http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php

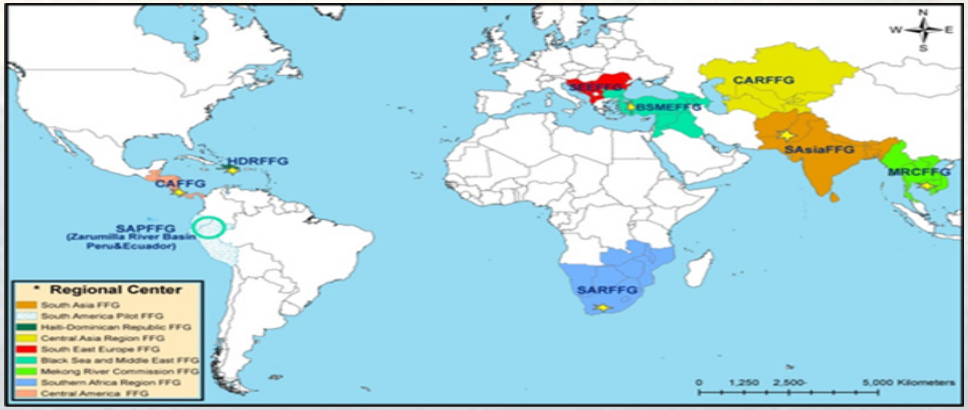
The Hydrologic Research Center (HRC) has signed a joint Memorandum of Understanding to implement regional flash flood guidance systems worldwide with:

the United Nations – World Meteorological Organization (WMO)

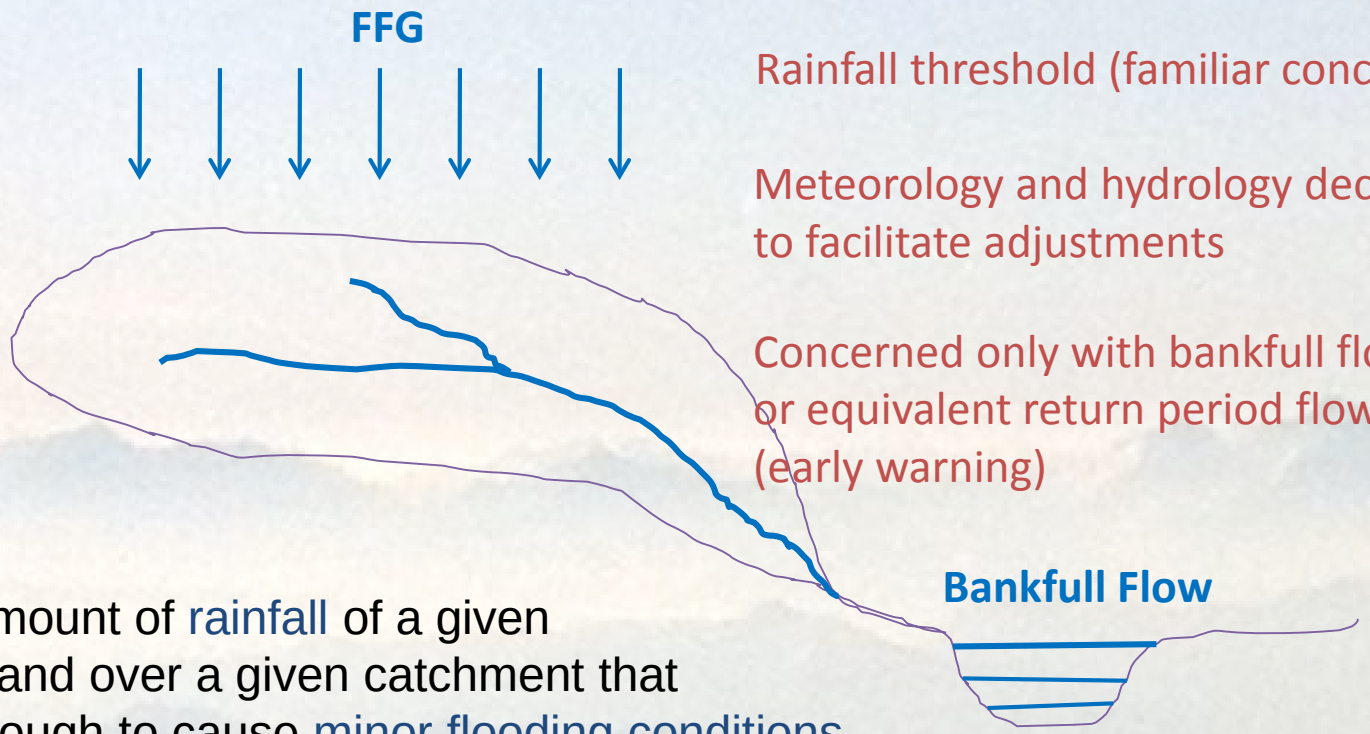
the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA)

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

As of 2015, more than 2.5 billion people are served by these systems



Flash Flood Guidance Concept



Rainfall threshold (familiar concept)

Meteorology and hydrology decoupled to facilitate adjustments

Concerned only with bankfull flow or equivalent return period flow (early warning)

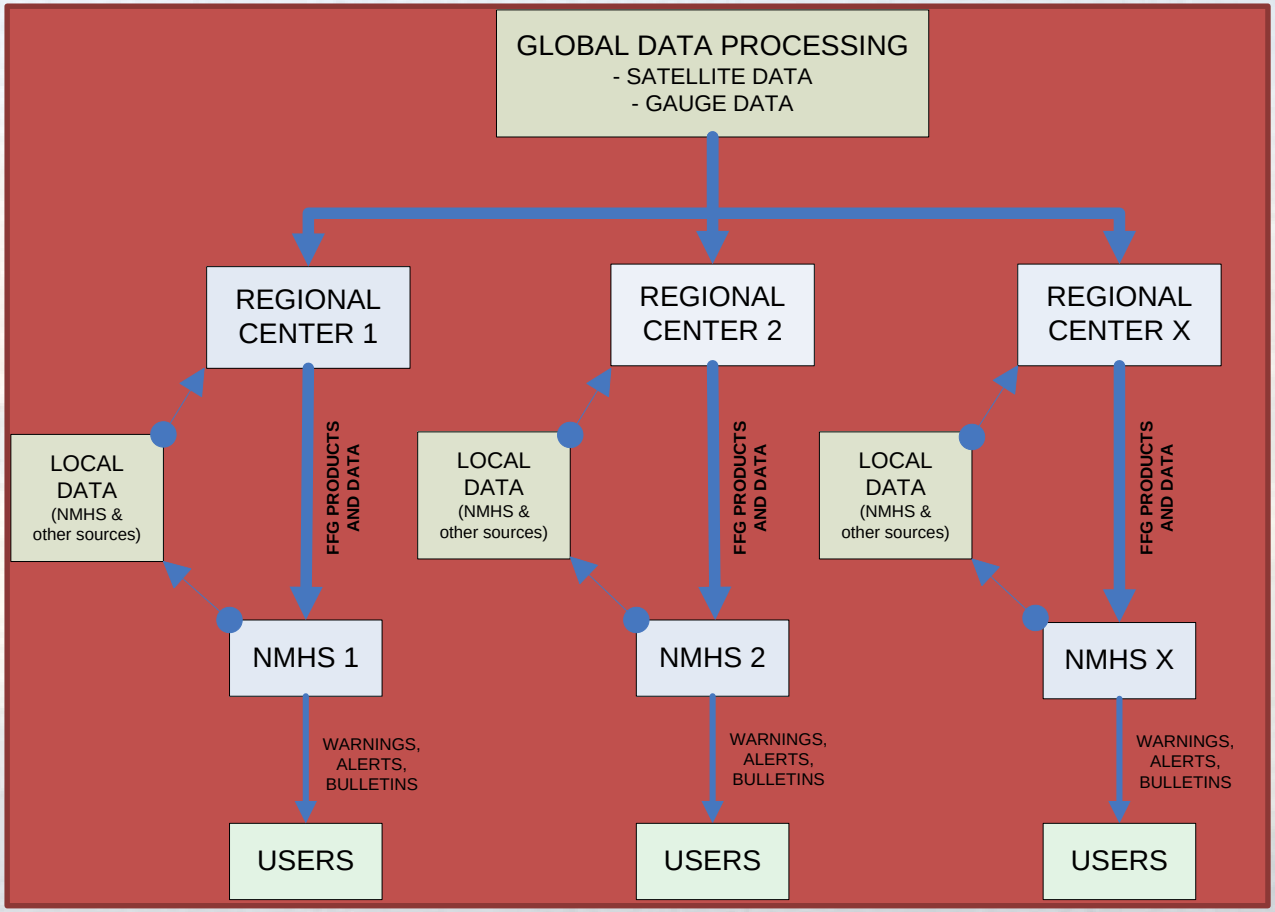
FFG: Amount of rainfall of a given duration and over a given catchment that is just enough to cause minor flooding conditions at the outlet of the draining stream

Threshold exceedance concept to estimate occurrence only!

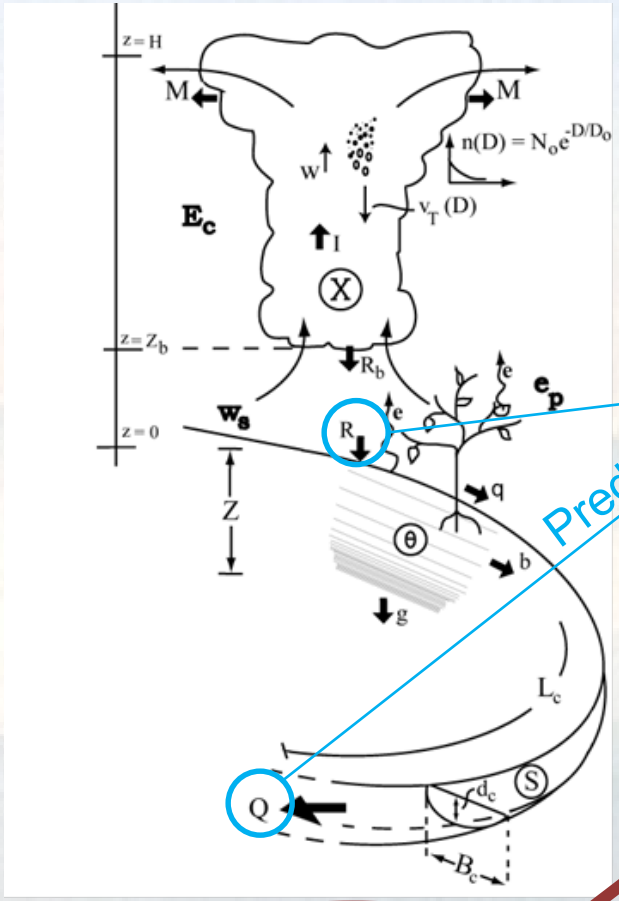
Research and Development History

- **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)**

System for Flash Flood Guidance
(Global-to-Regional-to-Local Components)



Integrated Systems for Real-Time Warning



Observations or Forecaster Experience

LAST-MINUTE INFORMATION

Forecast

ε

Predictions

Decision to issue warning

Response

Warning Message

Adjustments

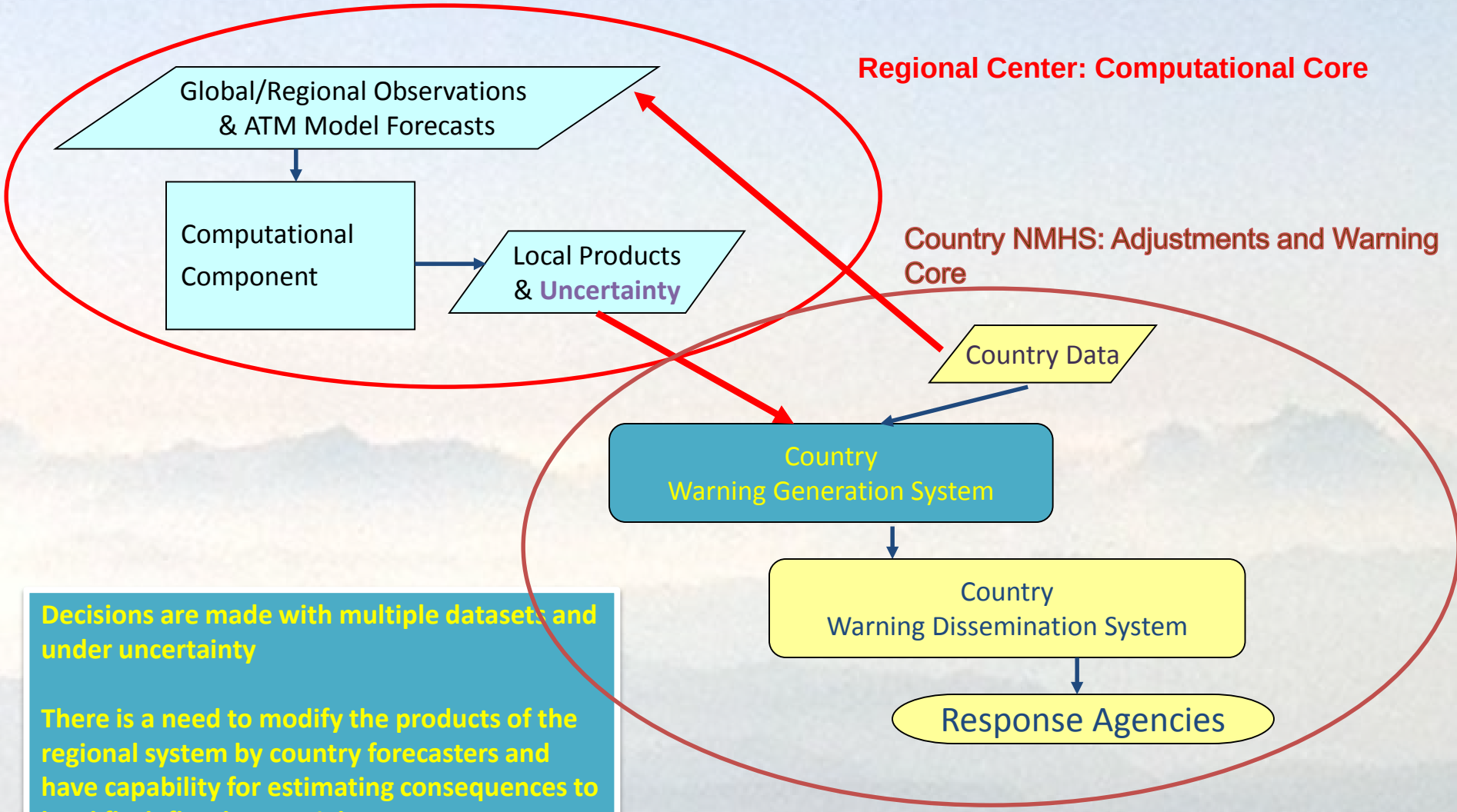
DECISION MAKER GUIDELINES AND PREFERENCES

Agency-Coordination Education Programs

Modeling Systems

Training and Local Experience

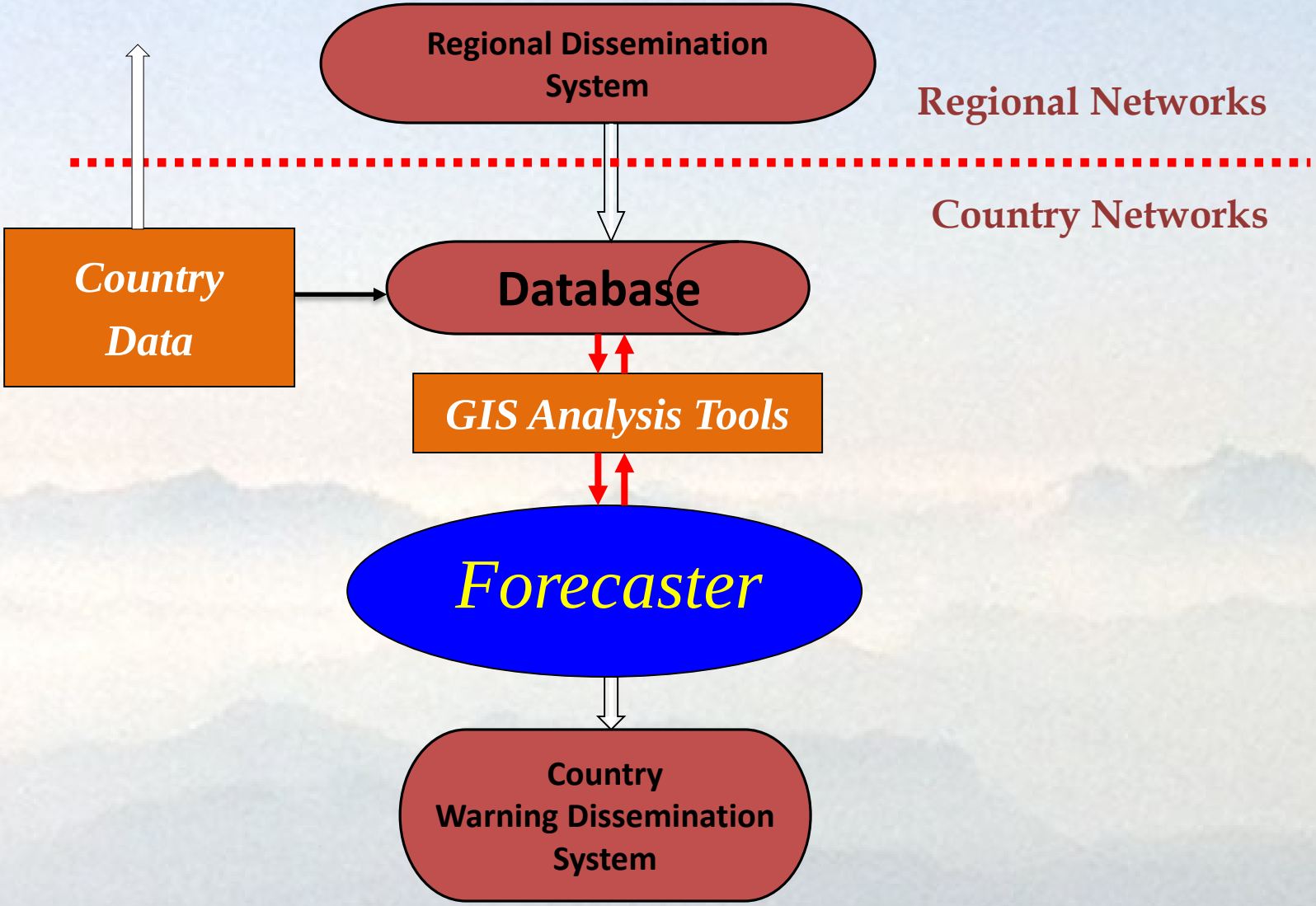
FLASH FLOOD GUIDANCE SYSTEM
From Global Data and Regional Hydrometeorology to Country Data and Warnings



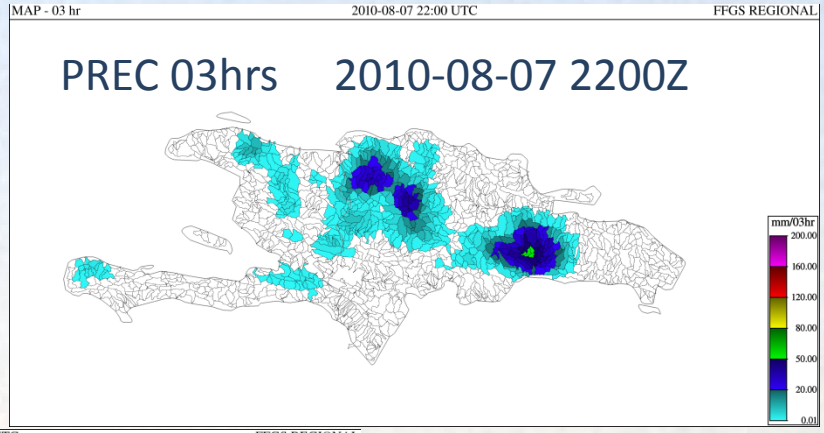
Decisions are made with multiple datasets and under uncertainty

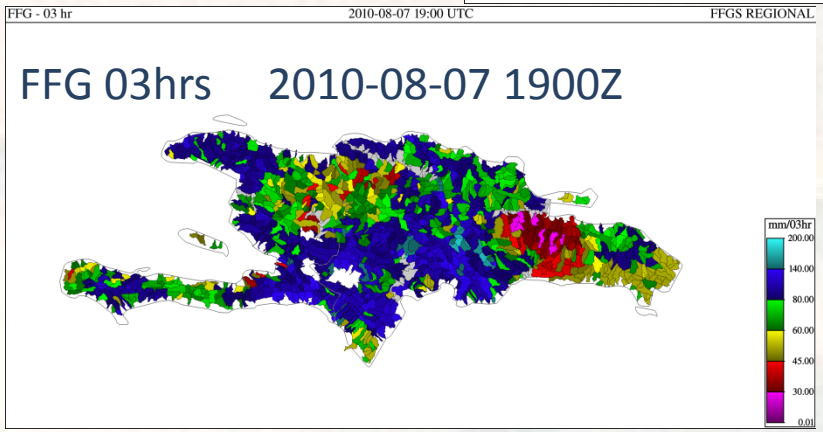
There is a need to modify the products of the regional system by country forecasters and have capability for estimating consequences to local flash flood potential

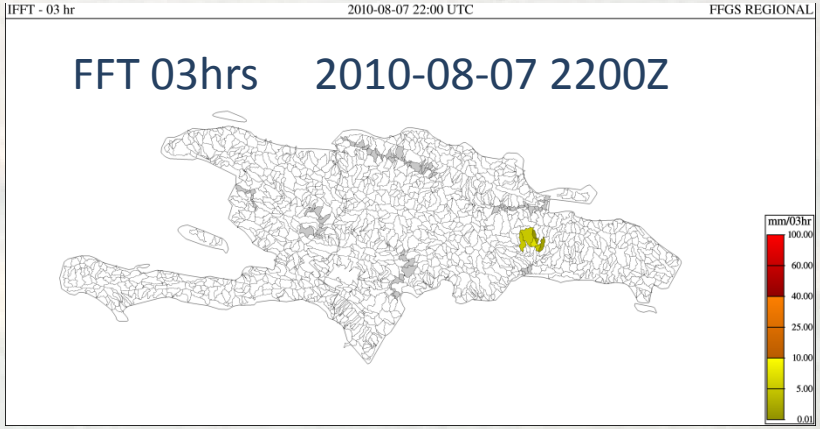
Local System for Warnings



Application of Flash Flood Guidance

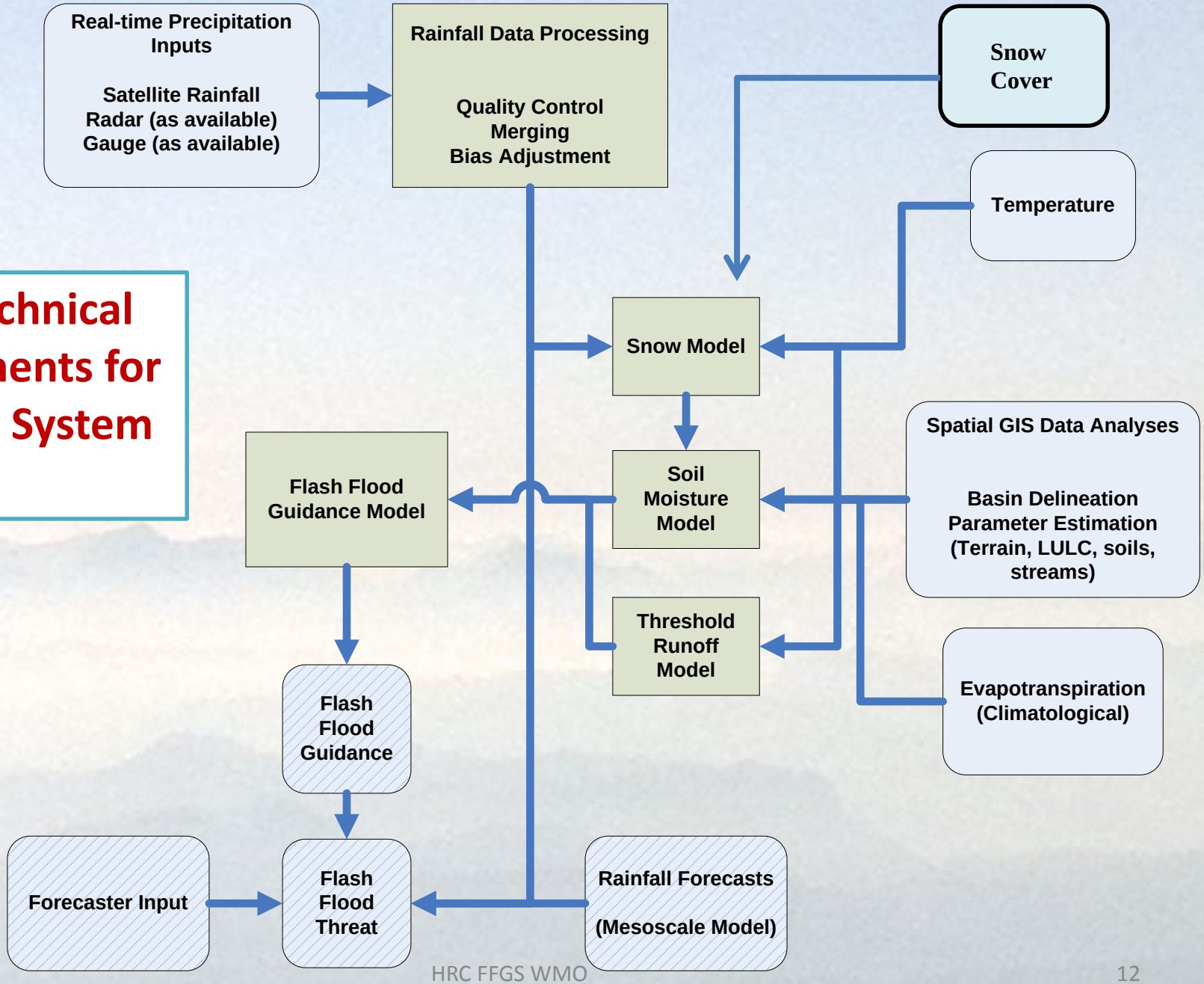






Flash Flood Guidance (FFG): **The amount of actual rainfall of a given duration over a small basin required to generate flooding flows at the outlet of the basin.**

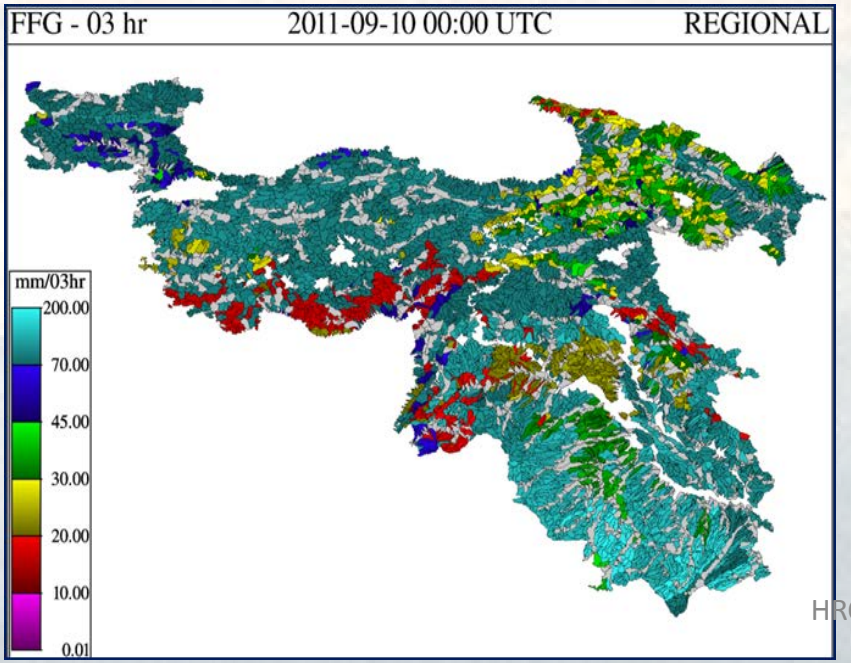
Key Technical Components for the FFG System



Global Flash Flood Guidance Products

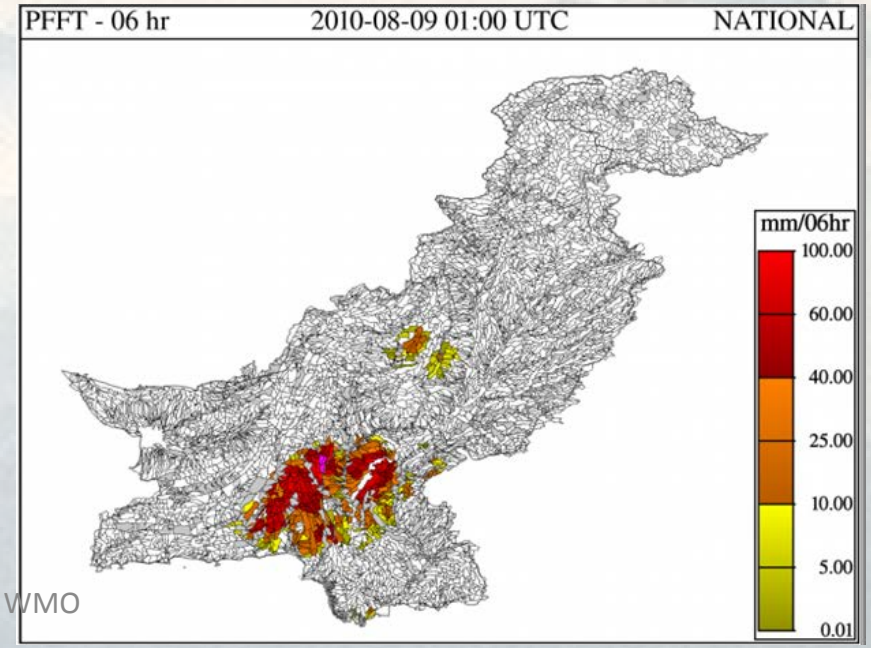
DIAGNOSTIC

Flash Flood Guidance – volume of rainfall of a given duration (1-6 hours) over a given small catchment that is just enough to cause bankfull flow at the outlet



PROGNOSTIC

Flash Flood Threat – rainfall of a given duration in excess of the corresponding Flash Flood Guidance value (existing/past or "forecast" rainfall)



Real-Time Data Forcing

Quality Controlled Multi-Spectral Satellite Rainfall

HE

IR – Based
30-min latency in operations
Based on measurements of top cloud brightness temperature

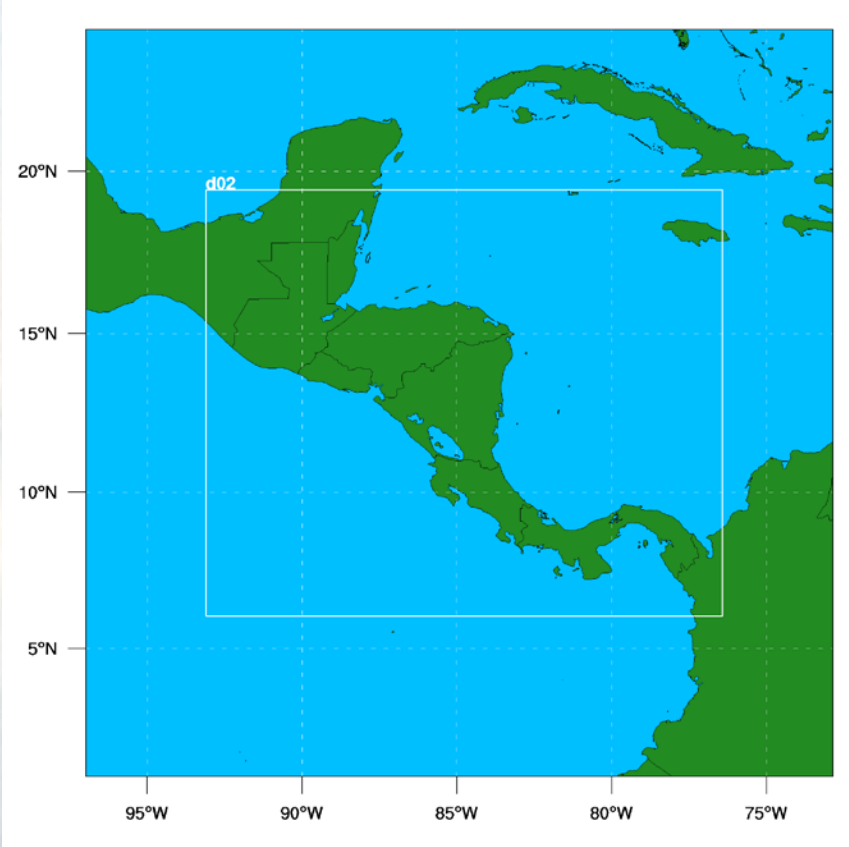
CMORPH

MW – Based
18-26 hour latency in operations
Based on measurements of microwave scattering from raindrops

Global FFGS product combines IR-based HE rainfall with MW-based CMORPH rainfall and with real-time raingauge reports (adaptive Kalman Filtering)

Real-Time Forecasts/Nowcasts Forcing
Mesoscale Numerical Weather Prediction Modeling

- CAFFG (Two Nested Grids)
  - Two way communication
  - Spatial Resolution
    - 18 & 6 km in horizontal
    - 30 layers in the vertical
    - Mesh sizes of 150 x 130 and 256 x 310
  - Temporal Resolution
    - Model time steps of 60 & 20 seconds

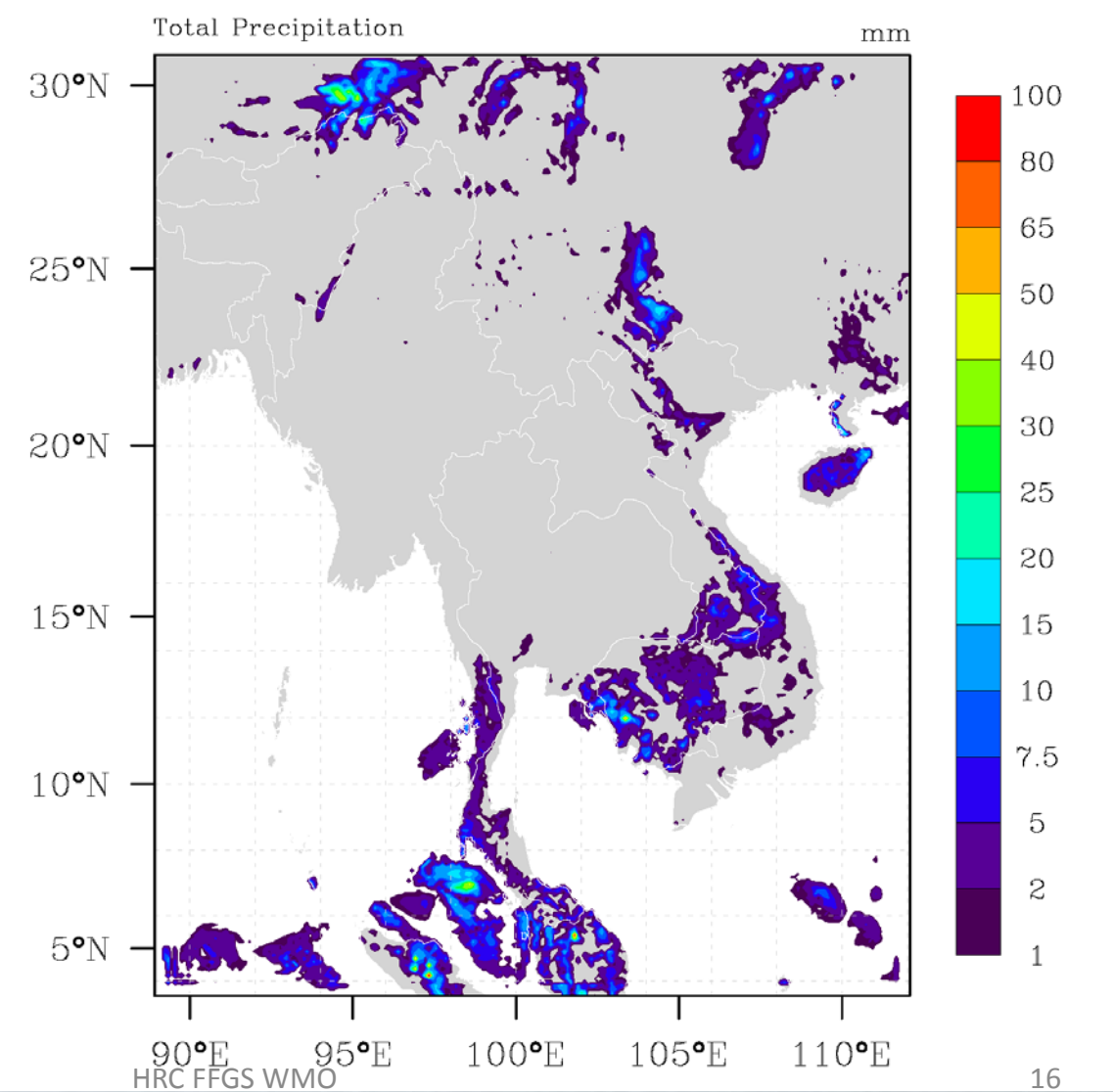


Real-Time Forecasts/Nowcasts Forcing

Mesoscale Numerical Weather Prediction Modeling

- MRCFFG

NCAR ARW v.3.2 Core
Initial Conditions: NCEP GFS (0.5^0)
Final Resolution: 11 km
Forecasts at: 00Z and 12Z
Max Lead Time: 48 hours
Temporal Resolution: 1 hour



SARFFG - Southern Africa Regional Flash Flood Guidance System

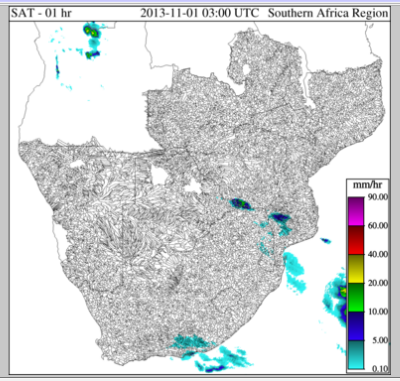
SARFFG Real-Time S ×

https://sarffg.hrc-lab.org/SARFFG/

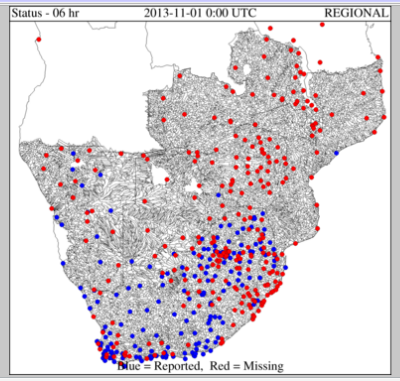
Apps | Google | Imported From IE | REALTIMESYST... | KECK Phase I A... | Patient Surveys ... | CALIFORNIA LA... | Other bookmarks

2013-11-01 06:03:27 SAST — **SARFFG - Real-Time Status Dashboard** — **2013-11-01 04:03:27 UTC**

Image Products



Animate 01-hr Sat Precip - 24 Images - (Pop-Up Window)



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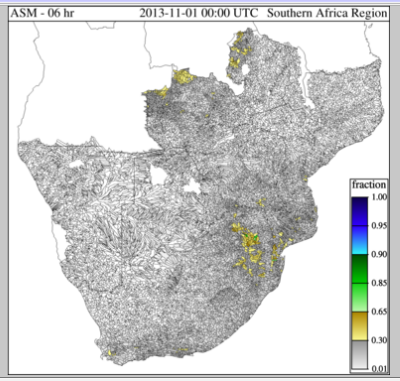
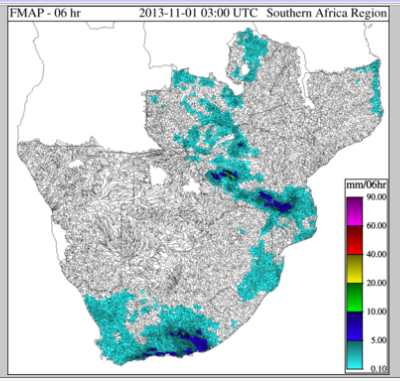


Animate 06-hr ASM - 24 Images - (Pop-Up Window)



Animate Hourly 06-hr FMAP - 24 Images - (Pop-Up Window)

Real-Time Data Download and Inventory Status

SAWS HE Download					HRC MWGHE Download					NESDIS GHE Download					GAUGE Download					UM Forecast Download				
ENABLED					ENABLED					ENABLED					ENABLED					ENABLED				
SUCCESS					SUCCESS					SUCCESS					SUCCESS					PENDING				
Oct-28	Oct-29	Oct-30	Oct-31	Nov-01	Oct-28	Oct-29	Oct-30	Oct-31	Nov-01	Oct-28	Oct-29	Oct-30	Oct-31	Nov-01	Oct-28	Oct-29	Oct-30	Oct-31	Nov-01	Oct-28	Oct-29	Oct-30	Oct-31	Nov-01
11	24	24	24	4	24	24	24	24	3	24	24	24	24	4	15%	14%	36%	51%	39%	72	72	72	72	12

Real-Time Data Processing Status

SAWS HE Data Processing	HRC MWGHE Data Processing	NESDIS GHE Data Processing	GAUGE Data Processing	UM Forecast Data Processing
ENABLED	ENABLED	ENABLED	ENABLED	ENABLED
SUCCESS	PENDING	SUCCESS	SUCCESS	SUCCESS

Model Processing Status

Merged MAP Processing	SMFFG Model Processing
ENABLED	ENABLED
SUCCESS	SUCCESS

Export Processing Status

Text/CSV Exports	Image Exports
ENABLED	ENABLED
SUCCESS	PENDING

Computational Server Status

General Info				Processing Load				CPU Activity				Disk Activity			Storage			
IP Address	Hostname	Uptime	Active Logins	1-Min	5-Min	15-Min	Swap Used	User	System	IOwait	Idle	Transfers	Read	Write	Free	Used	% Used	Days to Filled
184.185.140.77	SARFFGCS	7.15 days	0	137.16 %	109.83 %	111.25 %	733296 KB	23.02 %	2.25 %	56.13 %	18.60 %	333.60 t/s	1,328.80 KB/s	52,218.80 KB/s	134,003 MB	1,629,435 MB	93 %	26 days

Dissemination Server Status

General Info				Processing Load				CPU Activity				Disk Activity			Storage			
IP Address	Hostname	Uptime	Active Logins	1-Min	5-Min	15-Min	Swap Used	System	User	IOwait	Idle	Transfers	Read	Write	Free	Used	% Used	Days to Filled
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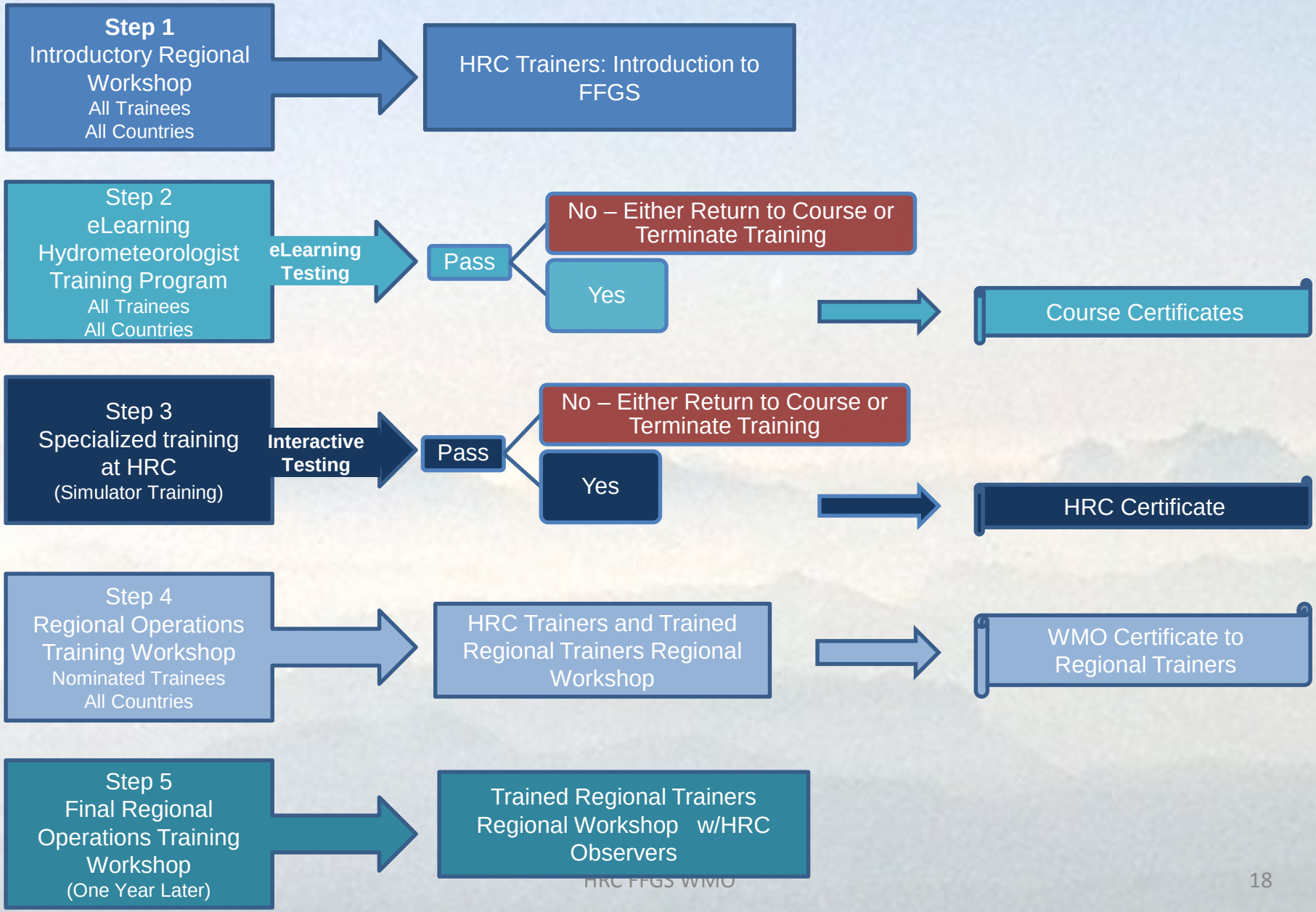
Regional | Botswana | Malawi | Mozambique | Namibia | SouthAfrica | Zambia | Zimbabwe

Surfmet Gauge Precipitation Accumulations ending on 2011-02-12 05:00 UTC

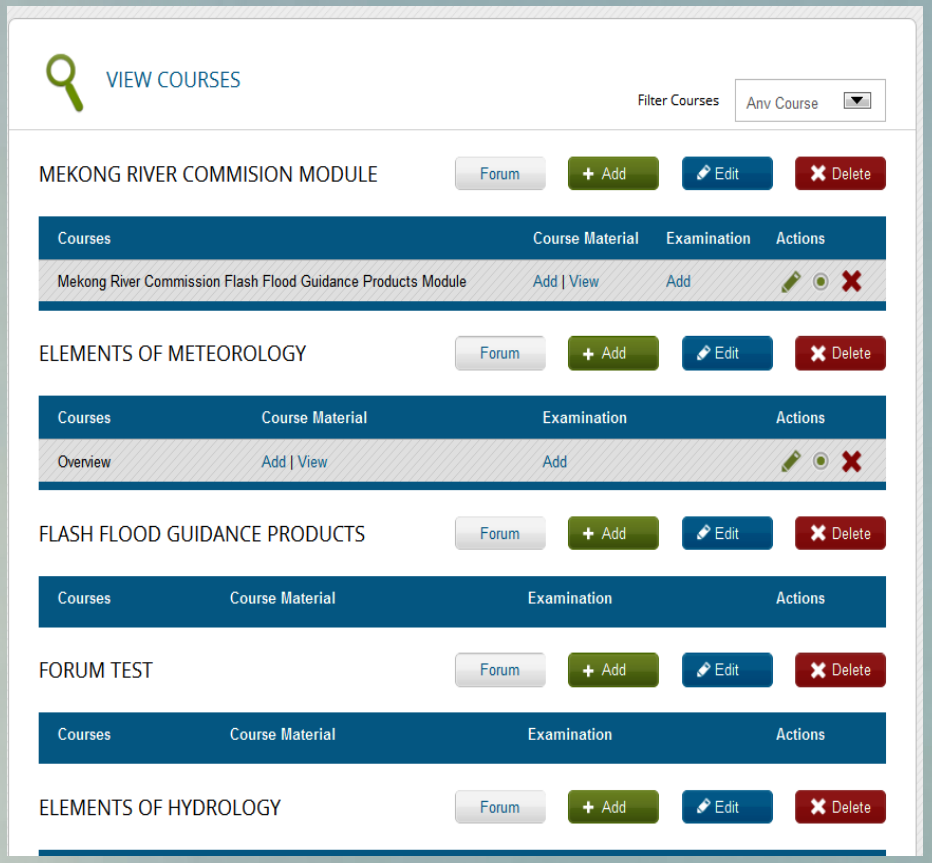
Station Identifier	Station Name	Observation Date & Time	01-hr Precip	01-hr Temp
Missing	Missing	Missing	Missing	Missing

Highlight all | Match case | Phrase not found

Education and Training Activities



Flash Flood Hydrometeorologist Training (FFHT) Program



Five courses

Elements of Meteorology,
Elements of Hydrology,
GIS basics,
Flash Flood Guidance Model Products,
Remote sensing

Forecaster Aid:

Gazette for Forecaster Contributions and Information Exchange Worldwide

Volume I, Issue I April 2011

FLASH FLOOD GUIDANCE GAZETTE

Welcome to the first issue of the Flash Flood Guidance (FFG) Gazette, a semi-annual newsletter bringing users of FFG products all the latest news – operational information, technical advances, case studies and soon introducing the new e-learning environment for the flash flood community.

Hydrologic Research Center ~ Linking Science and Society

Flash floods are a world-wide hazard. Unlike other weather related events with specific geographic locations, every location where rain falls is vulnerable, from the tropics to the sub-polar regions. With flash floods being among the most devastating of natural disasters it is essential that flash flood warnings be formulated in a short time with as much specificity in timing and location as possible. As significant rainfall events may cover large areas, this information may be needed for multiple basins at once. This is a very challenging situation for forecasters and some type of guidance is necessary to organize the real-time data and information from multiple sources into easily usable and interpretable products, which are amenable to operational modification in a timely manner.

The HRC flash flood guidance systems aim to provide just that and to assist the forecasters in their effort to provide reliable and timely flash flood watches and warnings. They integrate observed data from remote sensing platforms, on-site automated sensors, and modeled data from atmospheric and land-surface models in an automated FFG software system. Although the use and interpretation of the FFG products requires minimal training, quantifying the uncertainty associated with these products in real time and for specific events requires substantial training of the forecasters.

In an effort to provide a means of communication that will provide forecasters with information on case studies suitable for training, valuable pointers from the field in the use and interpretation of the products, and a forum for the continuing validation of the FFG products and associated warnings, HRC is initiating the publication of a newsletter, the **FFG Gazette**. We would be glad to receive commentary pertinent to the use of the FFG systems from the field for inclusion in the **FFG Gazette**, as well as summaries of interesting FFG applications, validation results and suggestions for system improvements.

On behalf of HRC, I would like to take this opportunity to express our gratitude to those men and women that serve faithfully as forecasters during all hours of day and night in a vigilant effort to reduce life loss from natural disasters throughout the world. To them this effort is dedicated.

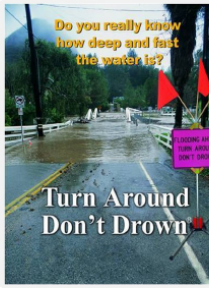
Konstantine P. Georgakakos, Sc.D.
Director - Hydrologic Research Center
San Diego, California, USA

We would like to ask you to share your suggestions, stories, pictures, experiences relating to flash floods and flash flood guidance systems. Please send your information to R. Graham (editor) at rgraham@hrc-lab.org.

In this issue:

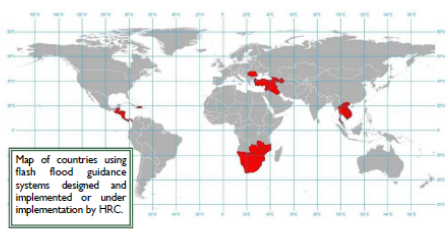
Special points of interest:

- HRC Global Initiative on Fl Floods
- The NEW Sou Africa Regiona Flash Flood Guidance Syst



FLASH FLOOD GUIDANCE GAZETTE

Flash Flood Guidance systems around the World



Map of countries using flash flood guidance systems designed and implemented or under implementation by HRC.

Since 1993 the Hydrologic Research Center (HRC) has led the technical development and application of flash flood guidance systems in thirty different countries.

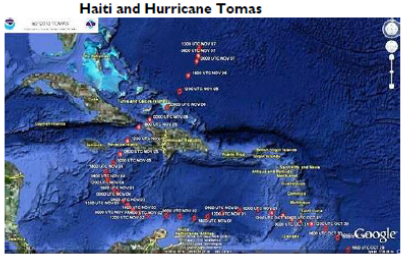
In collaboration with the national meteorological and hydrological services, HRC Flash Flood Guidance systems will serve more than half a billion people worldwide by the end of 2011.

The South Africa Regional Flash Flood Guidance System

The South Africa Regional Flash Flood Guidance (SARFFG) system will be the first fully automated real-time regional flash flood guidance system in the Southern Africa region, in operation in seven countries - South Africa, Botswana, Namibia, Malawi, Mozambique, , Zambia and Zimbabwe in 2011.

The SARFFG system is a diagnostic tool for analyzing weather-related events that can initiate flash floods and is designed to allow the forecaster to add his/her experience with local conditions, incorporate information and any last-minute local observations, to assess the threat of a local flash flood.

Haiti and Hurricane Tomas



Map illustrating the track of Tomas (October 30 to November 7, 2010). Source: U.S. National Weather Service/National Hurricane Center.

On 4th and 5th of November 2010, Haiti was impacted by Hurricane Tomas, with heavy rains and winds over various areas of the country.

Tomas developed from a tropical wave east of the Windward Islands on 29th October and quickly intensified into a hurricane passing near Santa Lucia on 31st October.

During its closest passage to Haiti, Tomas was a Category I Hurricane per the U.S. National Weather Service, National Hurricane Center. See the following discussion to learn how the FFG system was used in Haiti.

For more information on the HDRFFG system see - http://www.hrc-lab.org/right_nav_widgets/realtime_hdrffg/index.php

H FLOOD GUIDANCE GAZETTE

l Solutions-Sharing

ublic Flash Flood Guidance System (HDRFFG)

with Météo-France, has implemented a Flash Flood Guidance system for Haiti and the IDRFFG). The HDRFFG became operational on 1st July, 2010 and was implemented in pacity to the Centre National to develop flash flood warnings, a nuary 2010 earthquake.

or Haiti

Hurricane Tomas, the U.N. me (UNDP) asked HRC to the potential flooding impacts in this, HRC provided UNDP and forecasts of Flash Flood Threat ce of Tomas making landfall.

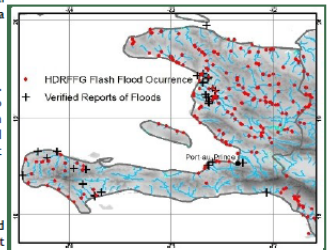


Figure illustrates the HDRFFG Flash Flood Threat Occurrences based on a 36-hour precipitation forecast (for the 36-hour period ending 7 November 2010, 0300 UTC) and compared to locations of verified reports of flash floods.

ce Assessment

and information, HRC assessed the HDRFFG system with respect s/areas impacted by flash floods f the storm.

etailed data were available for this strong indications that the system dentifying impacted basins.

ssment only evaluated the systems accuracy, including the application of rainfall inputs and ether or not warnings were issued and appropriate responses taken, which is the ultimate e of the system.

opical storm Tomas, the use of rainfall forecasts to derive flash flood threat the HDRFFG system) provided valuable results in the identification of areas at his provided useful information to disaster relief agencies on potential flooding r a copy of the report please contact HRC at admin@hrc-lab.org)

ve on Flash Floods:

tal vulnerability and preserve resiliency in basic human needs: livelihoods, agriculture, water stems, and natural resources.

HRC in partnership with U.S. National Weather Service (NWS), U.N. World Meteorological Organization (WMO) and U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA) is involved in an initiative to develop and implement a Global Flash Flood Guidance (GFFG) system designed to be used by weather services and disaster management agencies around the world to develop localized warnings for deadly flash floods. (For more information on the GFFG system see - www.hrc-lab.org/publicbenefit/index.html).

CONGRATULATIONS TO DR THERESA CARPENTER UPON HER COMPLETION AND SUCCESSFUL DEFENSE OF THE DOCTORAL DISSERTATION - 'An Interdisciplinary Approach to Characterize Flash Flood Occurrence Frequency for Mountainous Southern California'.

We are very excited and proud to share this great news! Dr Carpenter, an HRC colleague has defended her Ph.D. dissertation on the 5th of January, 2011 at Scripps Institution of Oceanography, UCSD. (For a copy of her thesis contact Dr Carpenter at tcarpenter@hrc-lab.org).

Operational Utility of Systems with Forecaster Adjustments

- Trained forecaster adjustments have a beneficial effect on warning reliability especially for local bias situations

  (Use of up to the minute information from the field very useful; Real-time cooperation of meteorologists and hydrologists very useful for effective adjustments)

- In-depth training of forecasters in system model behavior is required for sustainability

  (In most cases several-month efforts are required)

- A priori and real-time coordination of forecasters with response agencies necessary for high utility

- Local experience of forecasters invaluable for warnings against short-fuse hydrometeorological phenomena – Validation/Databases

  (Mesoscale model biases; hydrologic model biases; local soil behavior and flooding conditions)

Important Needs

Country data support (e.g., spatial data for soil type and texture, basin delineation verification, historical hydrometeorological data for bias adjustment and snow/soil water model calibration, etc.)

Links of regional center to national real time databases for reduction of uncertainty in precipitation input and increase of reliability

Development of databases of observed flash flood occurrence for validation

Reciprocal training of forecasters and disaster managers and development of well defined a priori plans for response

Enhance public information on flash floods, their perils and the needed response measures

Enhancements for FFGS improved operations

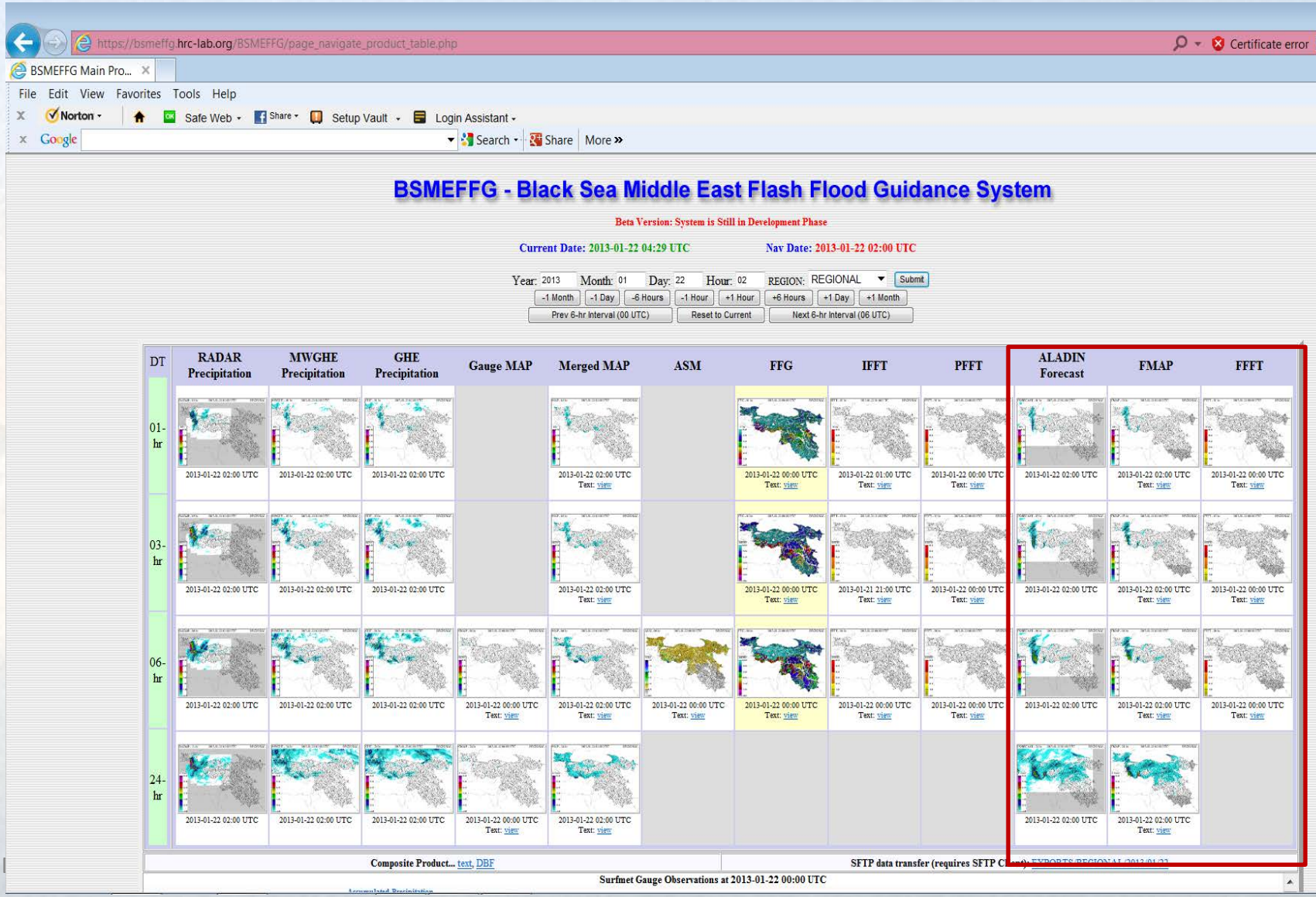
Hydrologic Research Center

21 July 2015

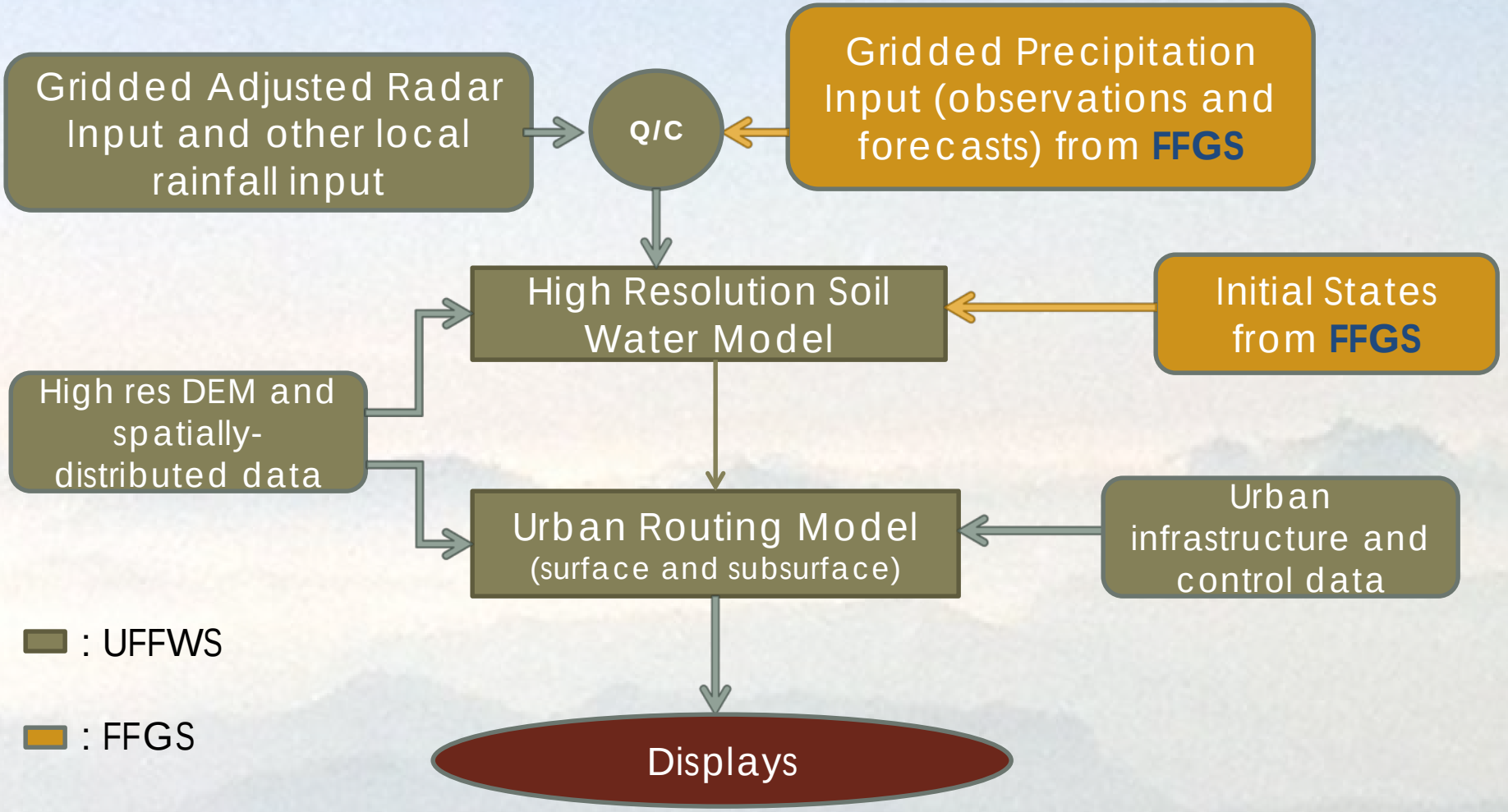
Advances to be discussed

- A. Multiple Mesoscale Model Input
- B. Urban Flash Flood Warning
- C. Use of satellite inundation mapping and surface soil moisture observations to correct FFGS soil water
- D. Landslide occurrence prediction
- E. Riverine discharge ensemble prediction

A. Multiple Mesoscale Mode Input

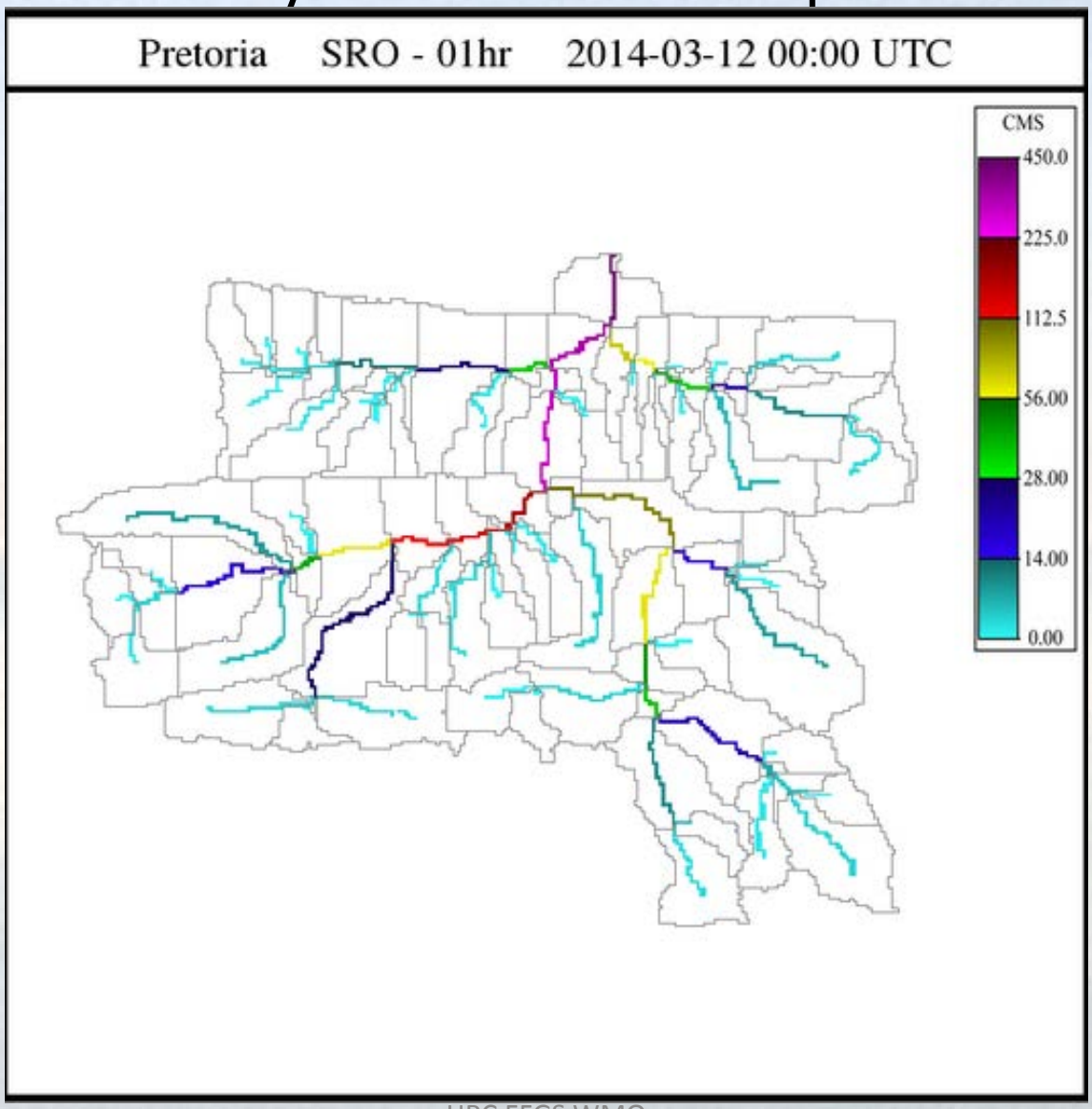


B. Urban Flash Flood Warning



Surface Drainage Flow

City of Pretoria Example

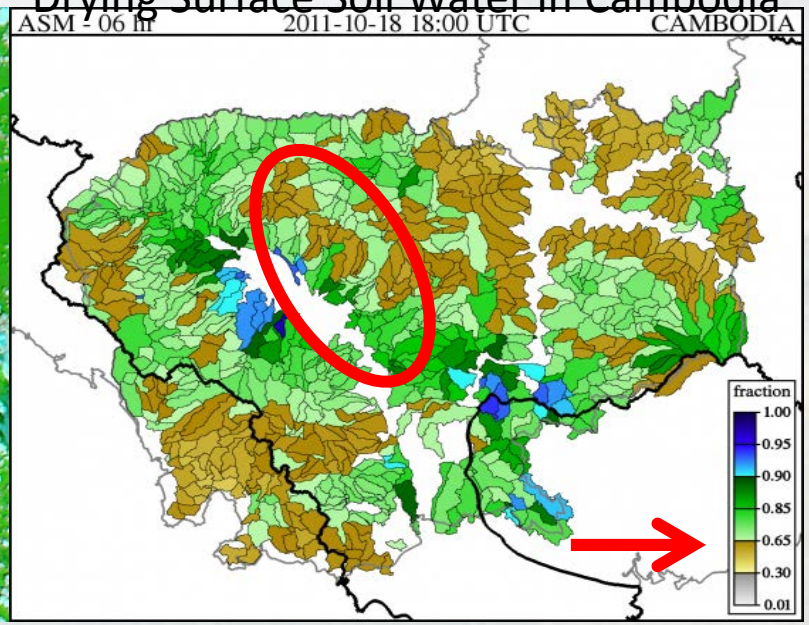


C1. Inundation Mapping for Soil Water Estimation

STANDING WATER CORRECTIONS TO MODEL SOIL WATER FROM NASA PRODUCTS

MODIS-Based
Observed Inundation Area in Cambodia

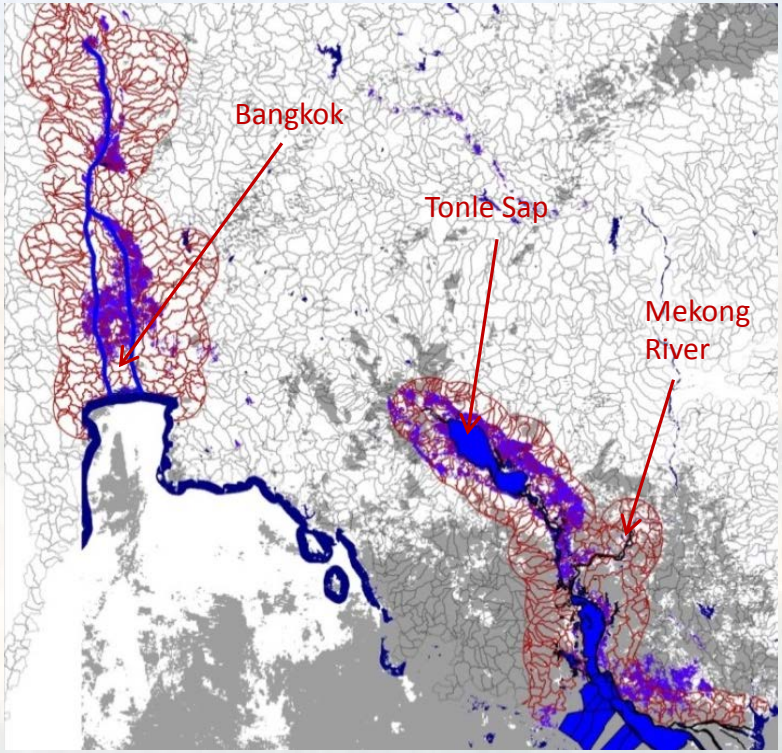
MRCFFG Modeled
Drying Surface Soil Water in Cambodia

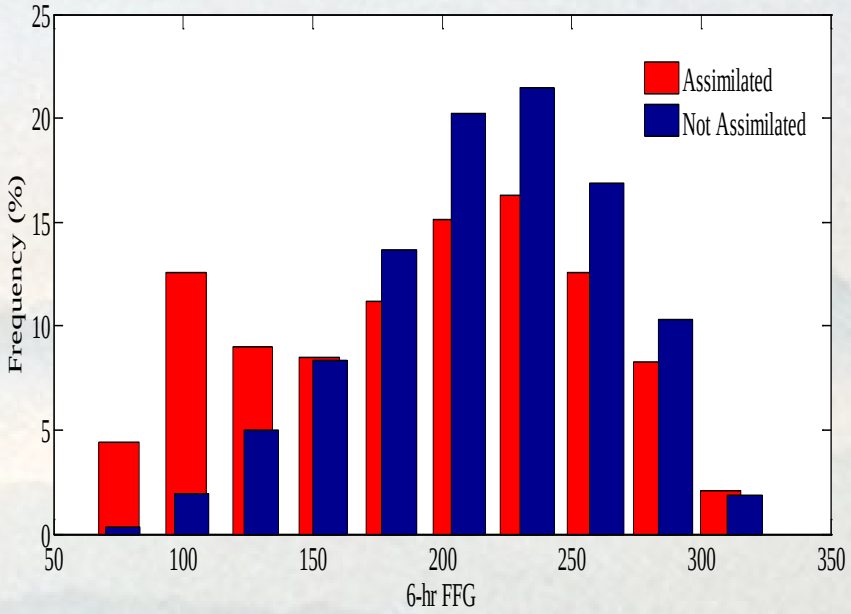


HRC Current Work: *Feasibility and Effectiveness of Correcting Operational Model Soil Water with MODIS Inundation Information in Real Time for Nonlocal Precipitation forcing*

C1. Inundation Mapping for Soil Water Estimation

Posner et al. Remote Sens. **2014**, *6*, 10835-10859 – Open Access



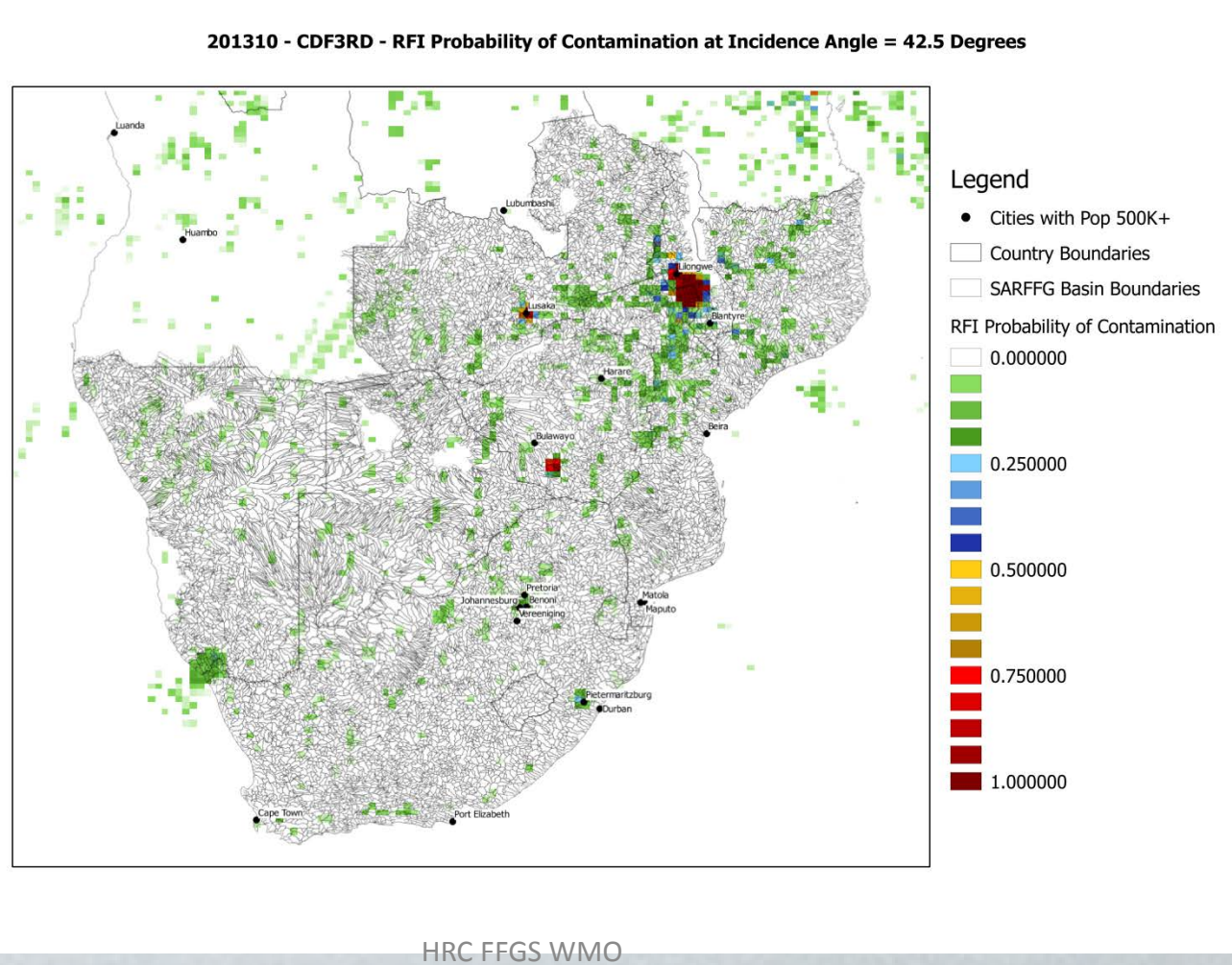


Method: Assimilation of saturation of upper soil in catchments with inundation greater than 85% and use of soil model to adjust lower soil water.

C2. Feasibility of using SMOS Data

Working with WMO(Bijinski), ESA(Drusch), CESBIO(Kerr) and UGent(Verhoest) to develop a project for HRC to examine the utility of incorporating SMOS in FFG systems

Radio Frequency Interference -RFI



D. Landslide prediction using FFGS output

- D.1 Susceptibility map development in a region with an adequate database (El Salvador, Central America) (completed)
- D.2 Real Time landslide prediction using FFGS rainfall and soil water thresholds in El Salvador (completed)
- D.3 Generalization for Central America and implementation in CAFFG (on going)

D.1 Susceptibility Mapping
(hillslope scale)

Parameter

(e.g. Slope)

Classes

Low

Medium

High

Landslide Class Density

$$\frac{N_{pixels}(with\ Landslides\ in\ Parameter\ Class)}{N_{pixels}(in\ Parameter\ Class)}$$

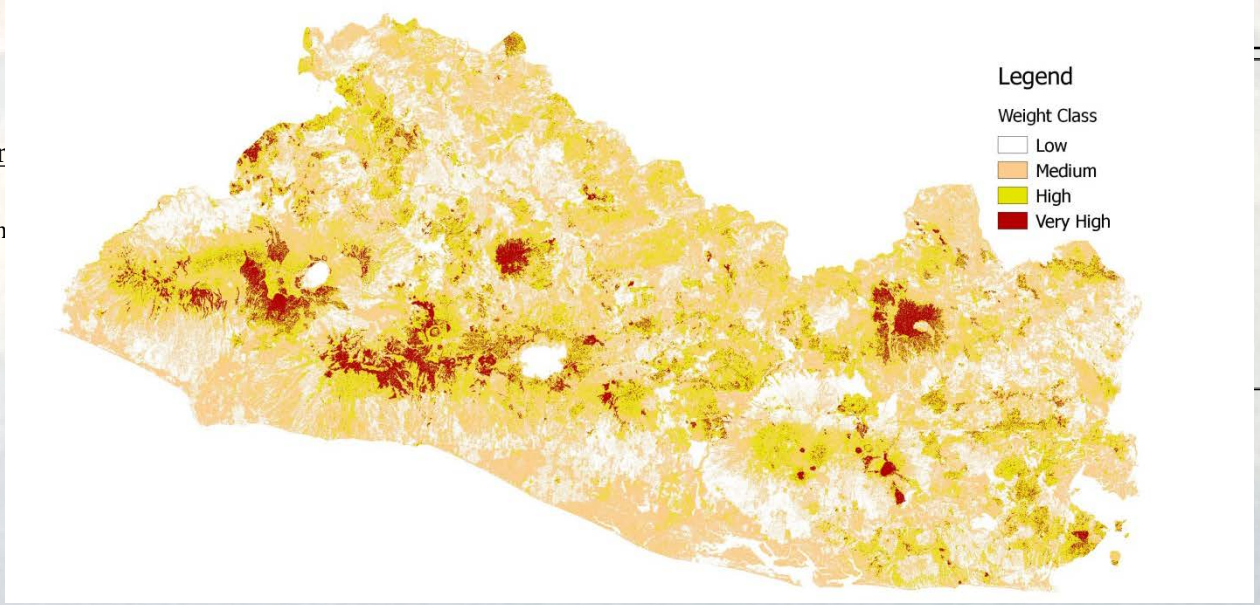
Landslide Map Density

$$\frac{Total\ N_{pixels}(with\ Landslide)}{Total\ N_{pixels}(in\ region)}$$

Landslide Inventory Map

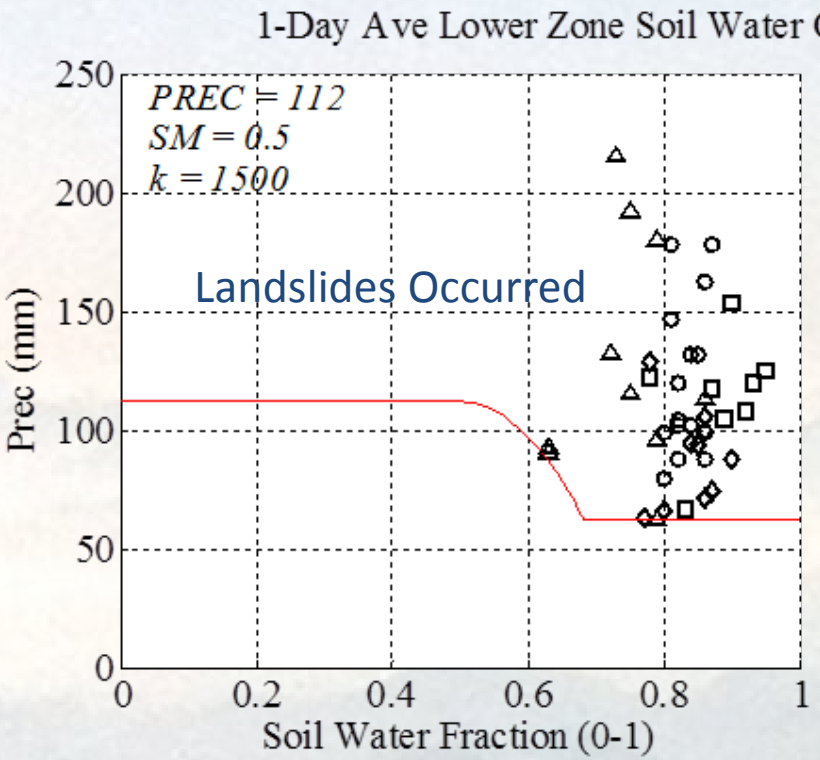
Factor

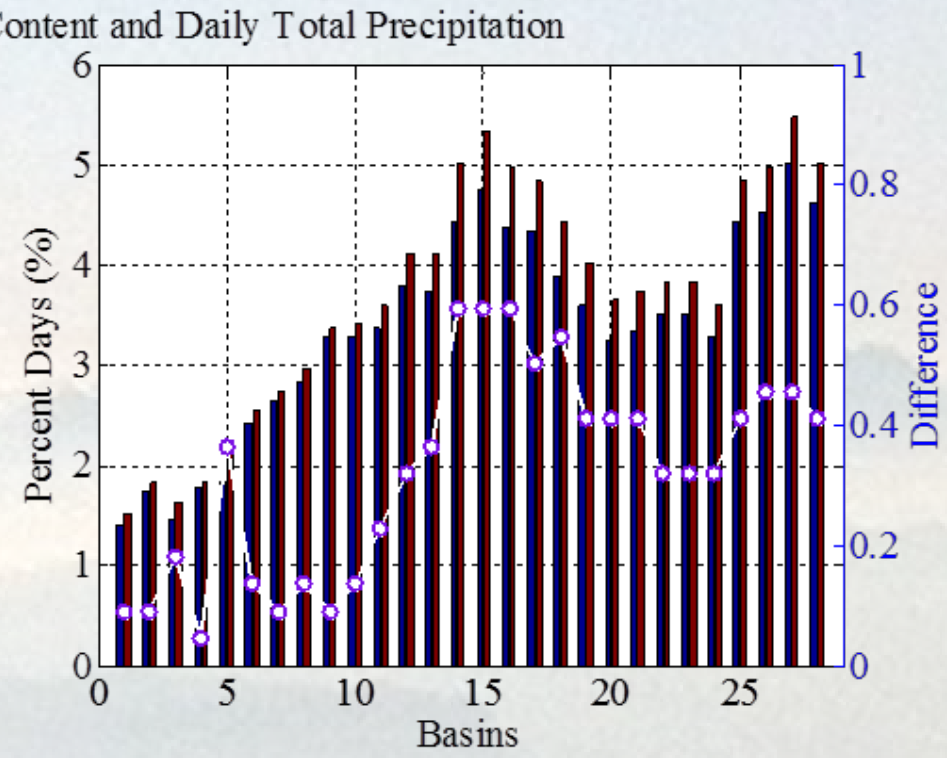
$W_i = \ln$



Continuous Susceptibility Weight Values to Discrete Classes

D.2 Real-time Occurrence Prediction based on FFGS Rainfall and Soil Water





E. Operational Riverine Routing

Real-Time Prototype implemented in Panama (CAFFG)

- **Ensemble Prediction**
- **Lake operations included**
- **Interface operational supporting forecasters**

Project Accomplishments

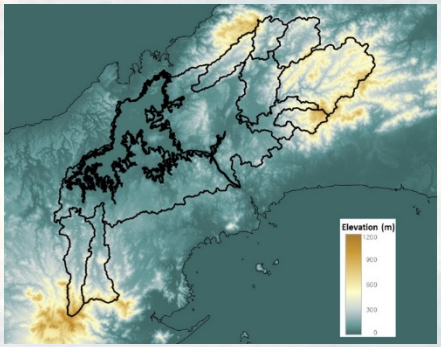
- Demonstrated the feasibility for an operational distributed modeling application for the Rio Chagres.
- Generate table of ensemble forecasts for the Chagres River Inflow to Madden Lake and specified upstream flow points
- Also, generated initial graphical interface for user review of ensemble forecasts and simulations
- Included Madden Lake operations and estimates and forecasts Madden Lake levels
- Target lead times for ensemble prediction will be 36 hours with hourly resolution and 20 ensemble members (as available)
- Twice daily starts with average spatial resolution of 2 km^2 for sub-basins.
- Estimate model parameters from existing operational model parameters with historical data for initial adjustments

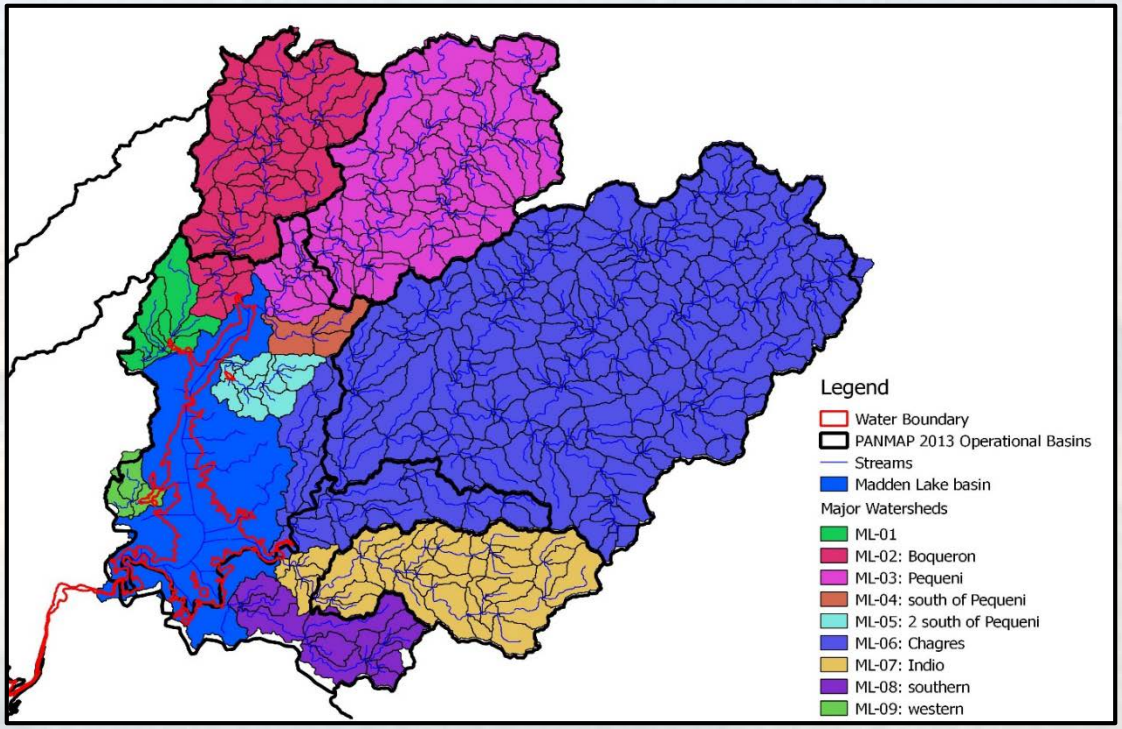
Geospatial Analysis

Subbasin Av. Resolution: 2 km^2

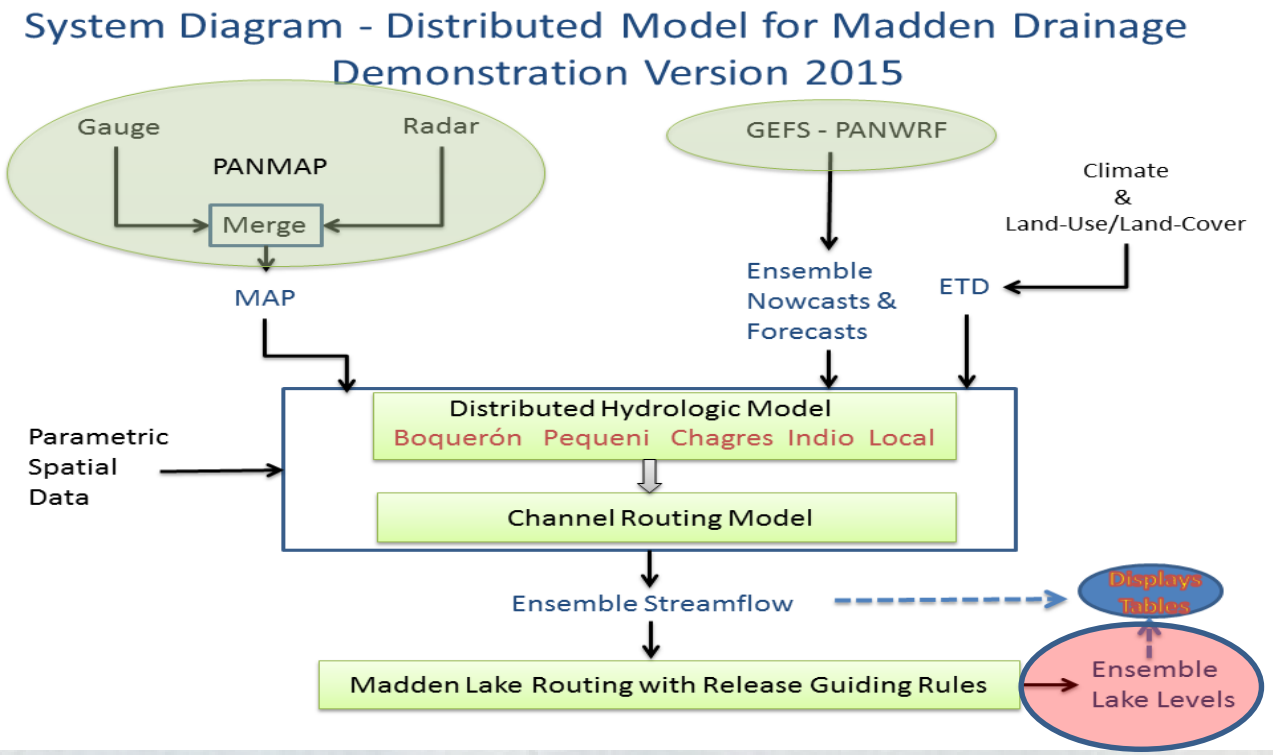
SRTM 30m

Madden Lake boundary
(SRTM water boundary &
Google Earth Adjustments)





Distributed Model Diagram – PANDHM V.2015



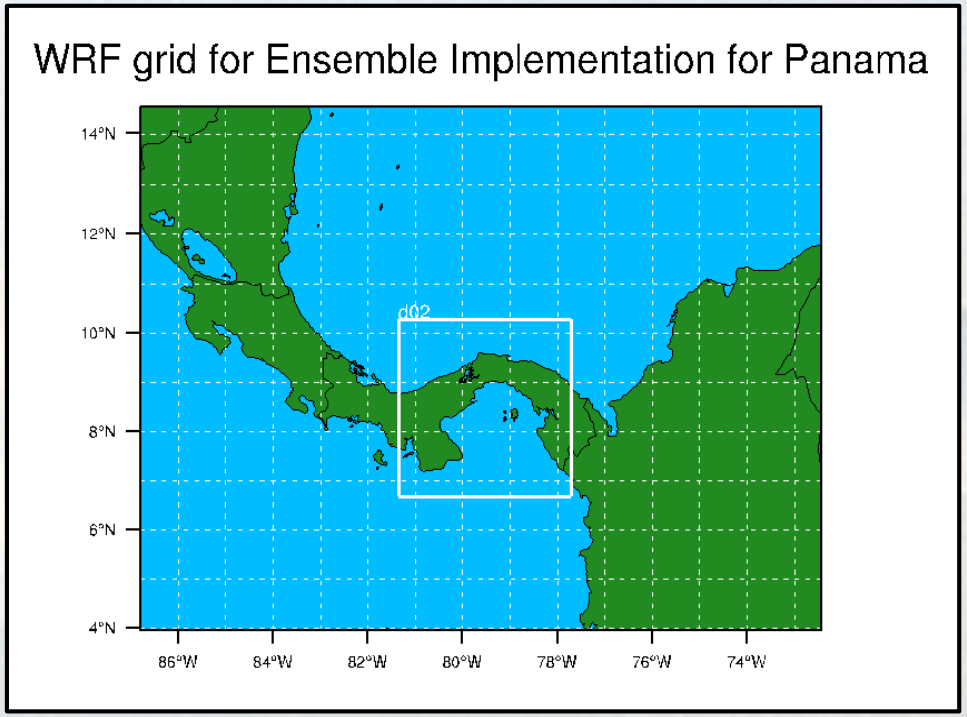
PANWRF Ensemble Run Configuration

20-Member Ensembles

4-km resolution

00 UTC and 12 UTC starts

NCEP GEFS forcing



Example Forecast Products

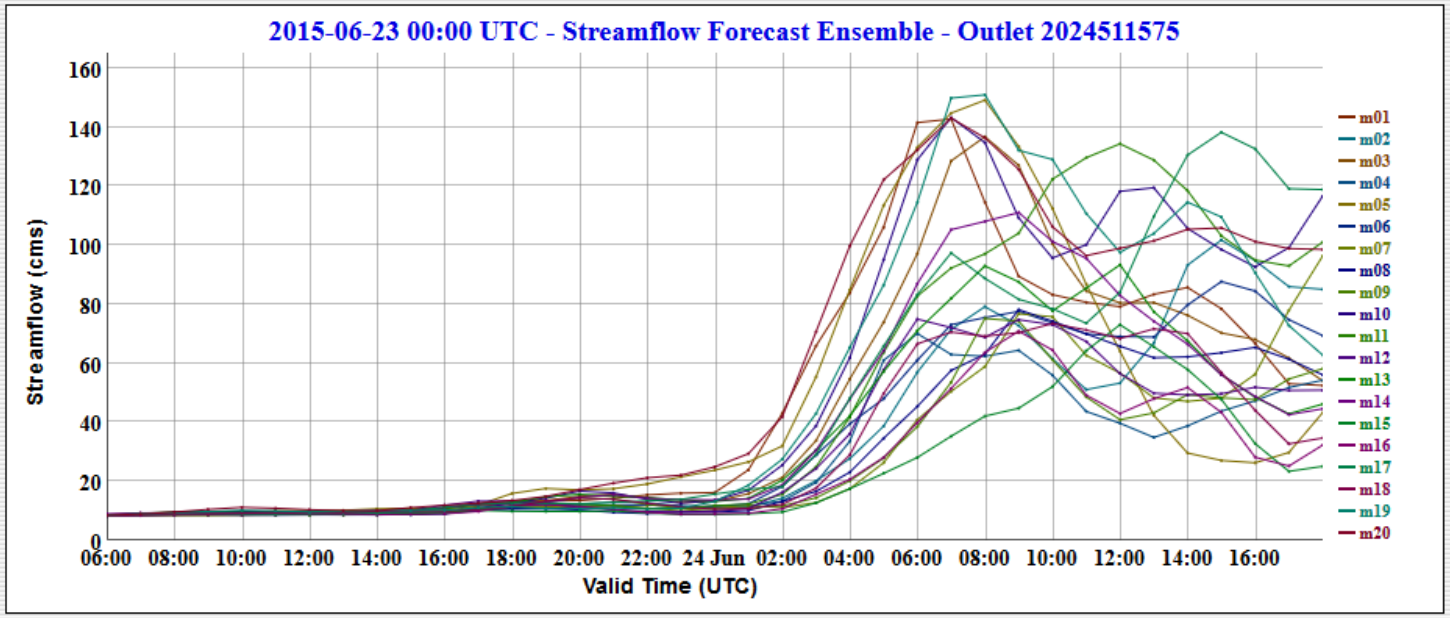
PANDHM v1.0p - Panama Distributed Hydrologic Model System

Experimental Interface of the Hydrologic Research Center

2024511575 - Chico

Reset to Current | **Year:** 2015 | **Month:** 06 | **Day:** 23 | **Hour:** 00 | Submit

-1 Year | -1 Month | -1 Day | -12 Hour | +12 Hour | +1 Day | +1 Month | +1 Year



FFG Development Team at HRC

Kosta Georgakakos – Technical Director/Hydrometeorology

Robert Jubach - Progr. Management/Disaster Risk Reduction

Jason Sperfslage - IT Systems Engineering

Theresa Carpenter - Mesoscale Modeling and Routing Models

Eylon Shamir – Soil Water and Snow Models

Cris Spencer – IT Engineering/Programming

Aris Posner – Land Slides/EOS Data Evaluation

Rochelle Graham – Education and Training