Predicting Flash Floods: What tools do we have?
Overview of the Flash Flood Guidance System (FFGS)

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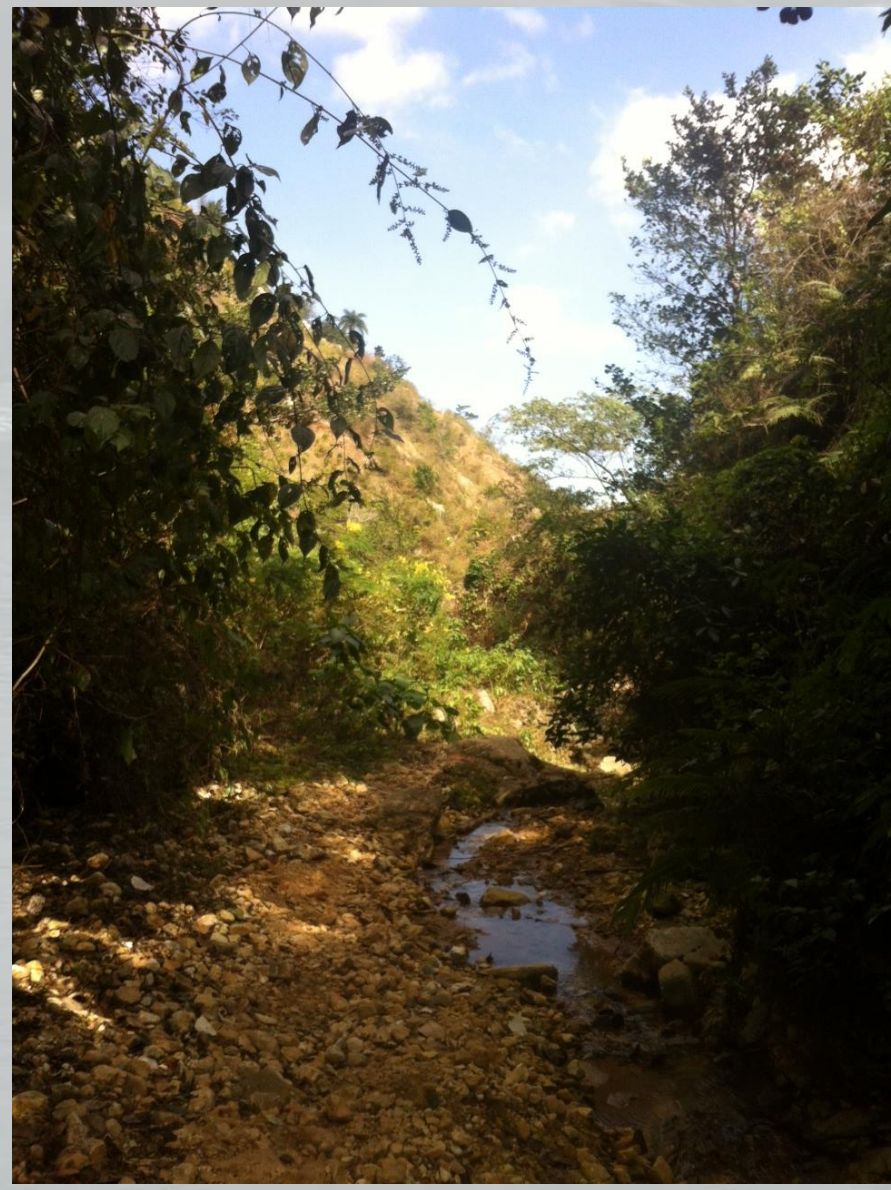
31 October 2019

EMP

Topics Addressed

- What are flash floods and their impacts worldwide?
- What is the flash flood guidance system and what data does it use?
- How do forecasters access and use the system products?
- What type of training and capacity building is in place?
- How good are the real-time products?
- Examples of country use, benefits and requirements
- A few challenges and opportunities for developing countries
- Enhancements



Why Worry About Flash Flooding?

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
- Climatic changes in several regions increase precipitation intensity

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 or earlier

What are natural flash flood causes?

- 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)

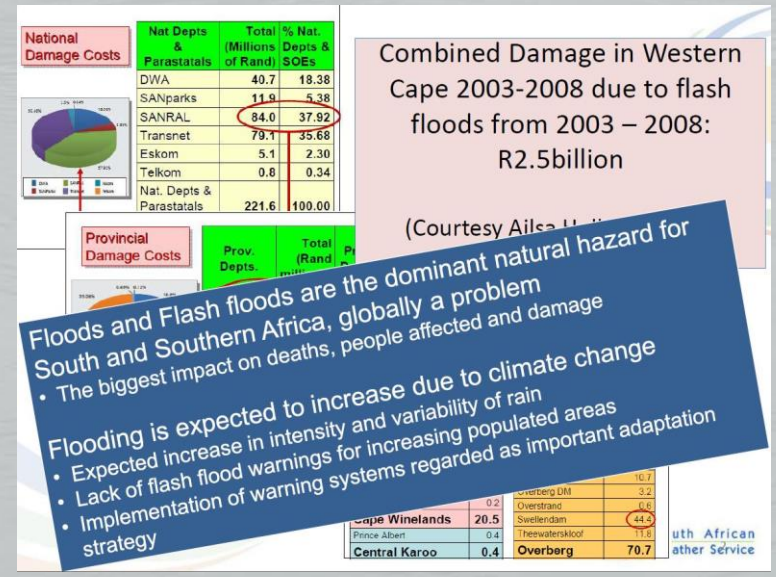
Flash Flood Impacts and Losses

Recent Study United Nations International Strategy for Disaster Reduction (UNISDR):

floods (including flash floods) natural hazards with highest frequency of occurrence (43.4% of total)
floods and flash floods affect most people (about 2 billion over last 20 years; 48% of total affected by all hazards)

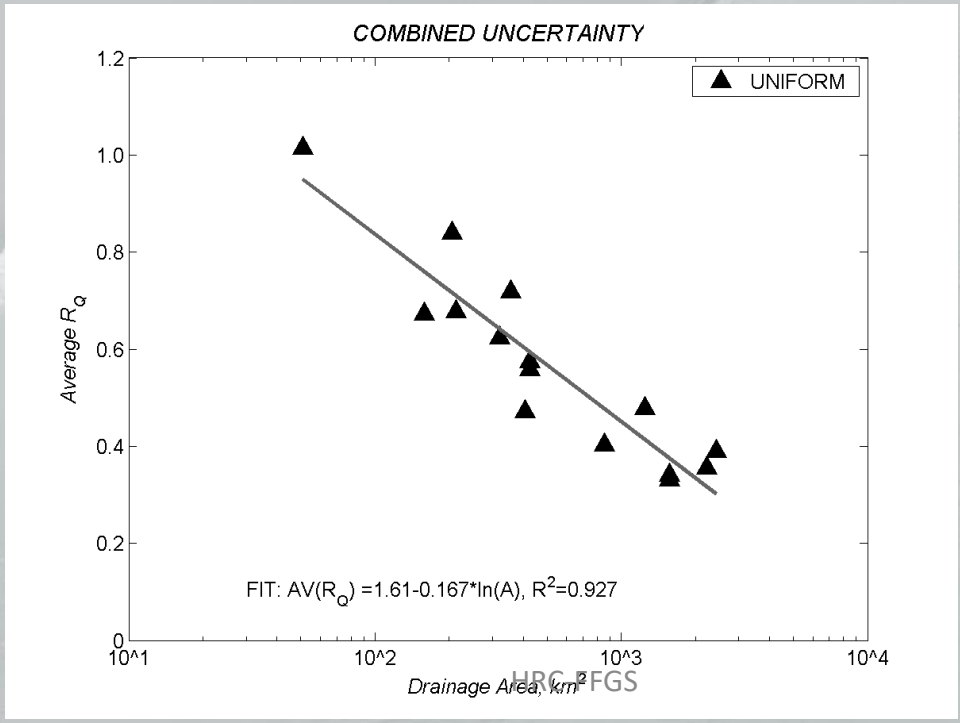
Earlier studies:

more than 5,000 people die from flash floods annually worldwide



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)



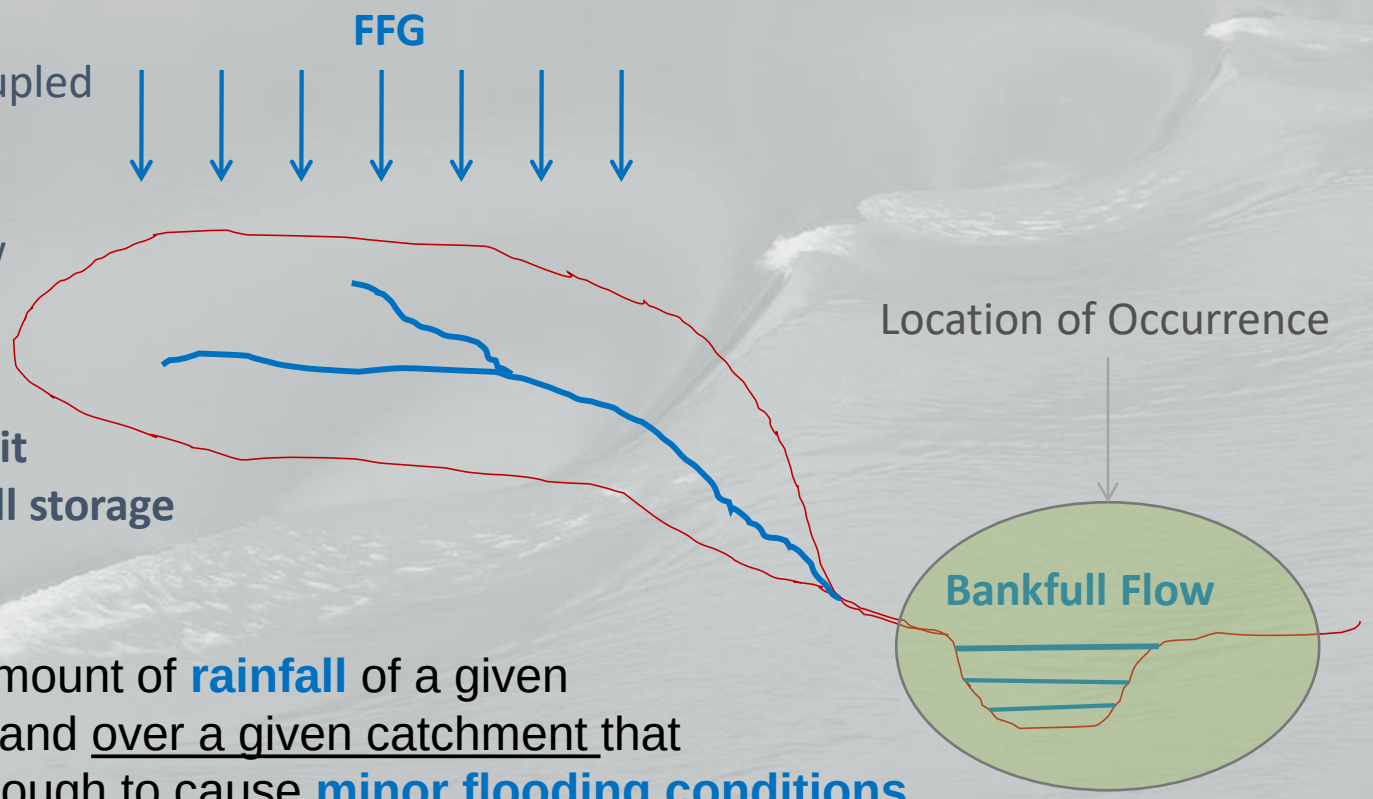
5 BASINS
3 LOCATIONS/BASIN
27 EVENTS/LOCATION

What is flash flood guidance?

Rainfall threshold (familiar concept)

Meteorology and hydrology decoupled for adjustments

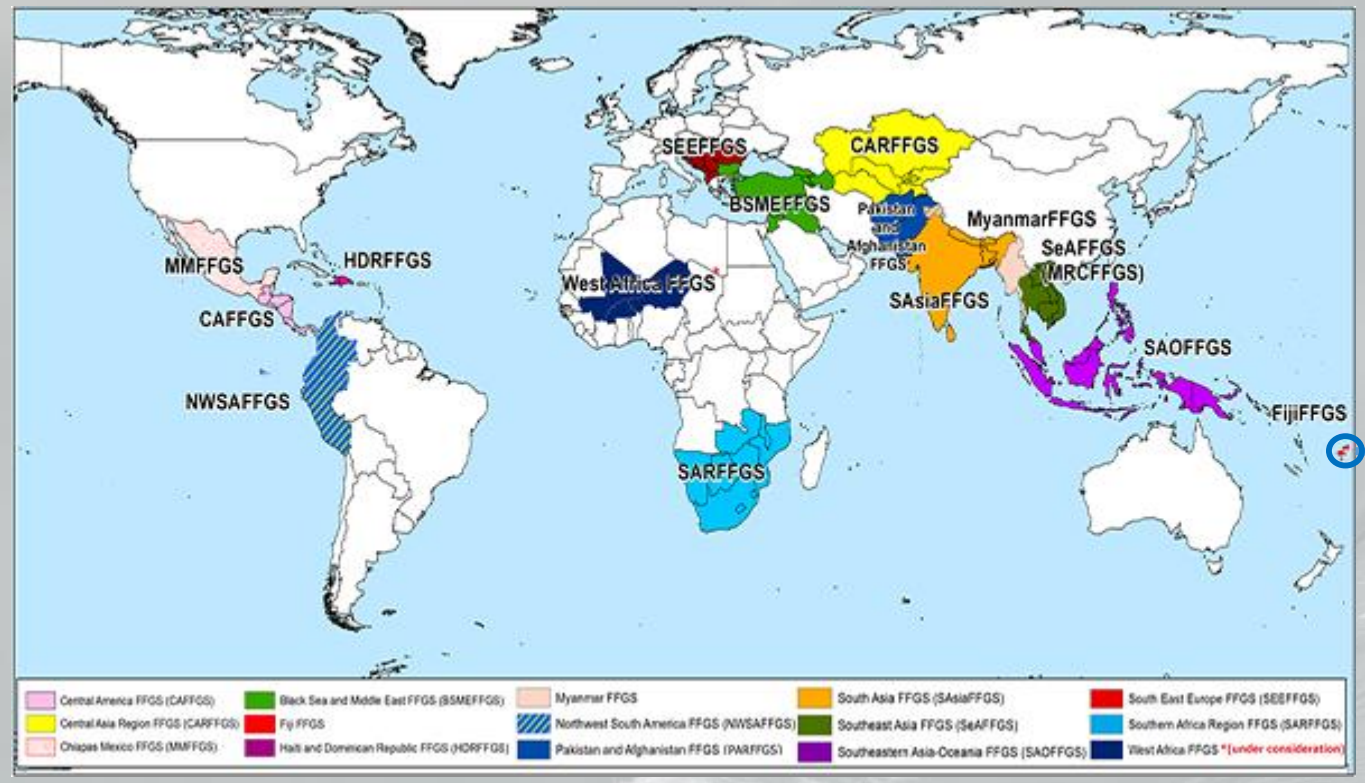
Concerned only with bankfull flow



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

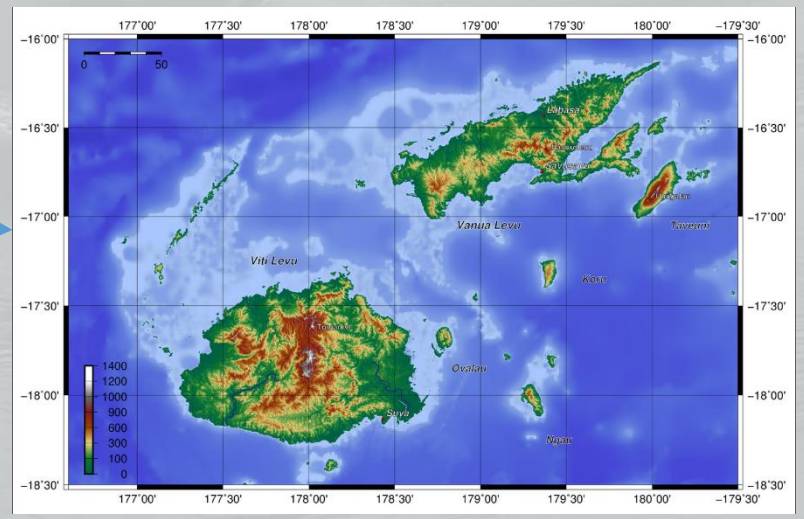
Threshold exceedance concept to estimate occurrence only!

Application Worldwide



Fiji

Example of Country Implementation



The Global Initiative for Flash Floods

WMO – USAID/OFDA – NOAA - HRC

To implement regional and flash flood guidance systems worldwide in support of forecasters generating operational flash flood forecasts and warnings

Climate Risk & Early Warning Systems (CREWS)

Environment and Climate Change Canada (ECCC)

Specialized for Fiji Application

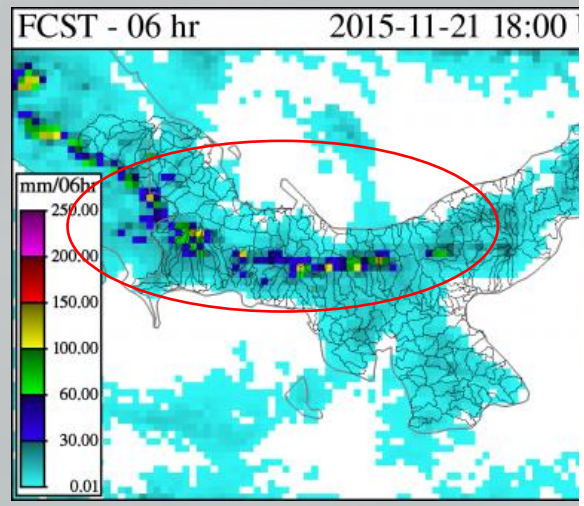
IMAGINE A PANAMA FORECASTER ON 1:00PM LST 21 NOVEMBER 2015 (Saturday)

Panama Time = UTC – 5 hours

It has been raining in Western Panama ….

What is the rainfall fore **land?** **Which small basins are at risk?**

FFG System WRF shows: **ction:** **FFG System Flash Flood Threat shows:**



Home » News » Panama » 12 homes affected in Boquete floods

12 homes affected in Boquete floods

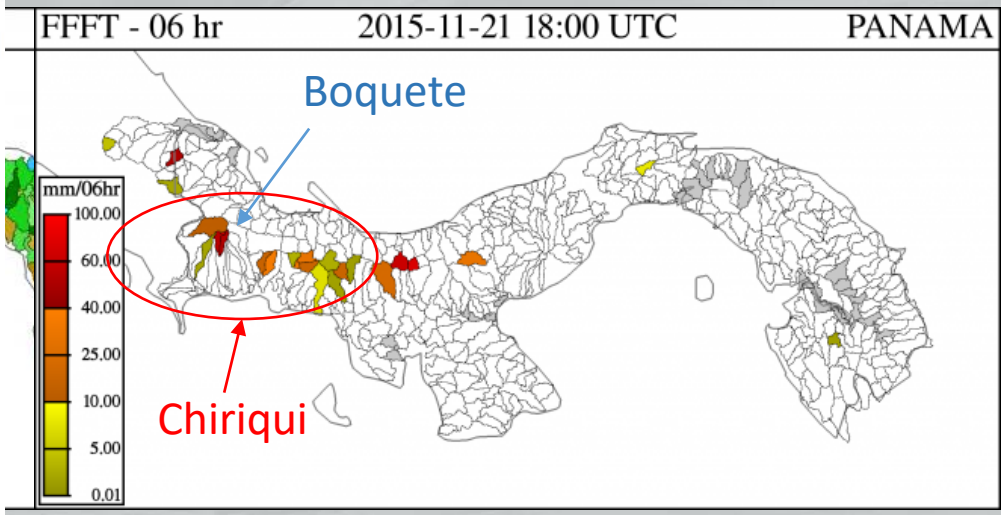
Posted on November 22, 2015 in Panama

HEAVY DOWNPOURS throughout the weekend led to flooding and land slides in Chiriqui and Bocas Del Toro with at least 12 homes affected in the district of Boquete.

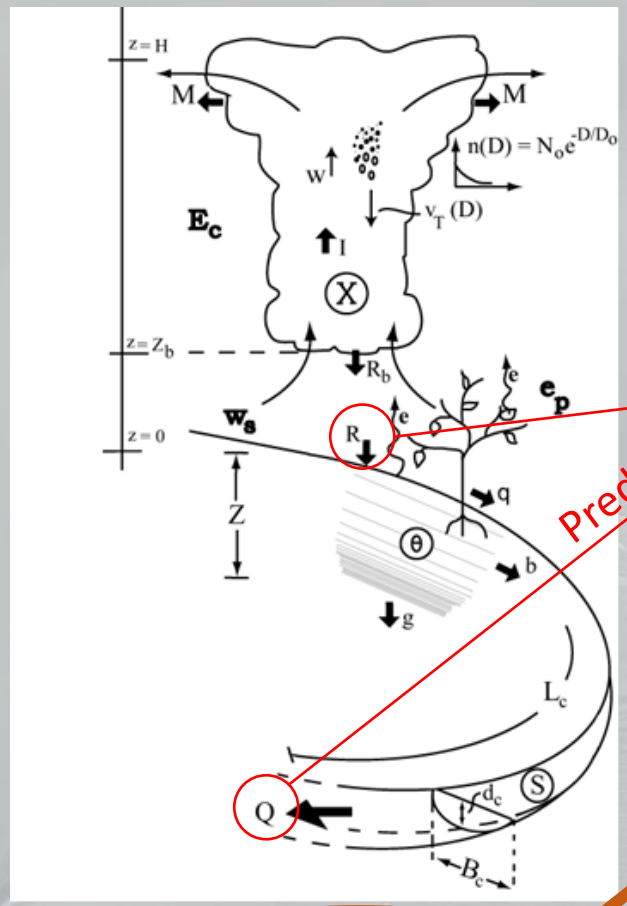
Share:

Post Views: 562

The Joint Task Force (FTC), led by the National Civil Protection System (Sinaproc), said the torrential rain has wreaked havoc in several localities in western Panama, near the border with Costa Rica.



Program Design to Support Integrated Systems Perspective for Real-Time Warning



Observations or Forecaster Experience

Last-Minute Information

Forecast

ε

Predictions

Decision to issue warning

Warning Message

Response

Adjustments

Decision Maker Guidelines and Preferences

Agency-Coordination Education Programs

Modeling Systems

Training and Local Experience

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 flexible to allow forecaster adjustments in real time 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, intercomparison with coupled models, atmospheric forcing quality control, and flexible model structures). The development of **prototype regional systems** using FFG is proposed and accepted in work plan of **WMO CHy Working Group on Applications** (**2002-2003**) and later by the **WMO XV Congress (May 2007) implementation worldwide was approved by all countries present.**

- **2004**: The **Central America Flash Flood Guidance System (first regional system serving 7 countries) becomes operational**.

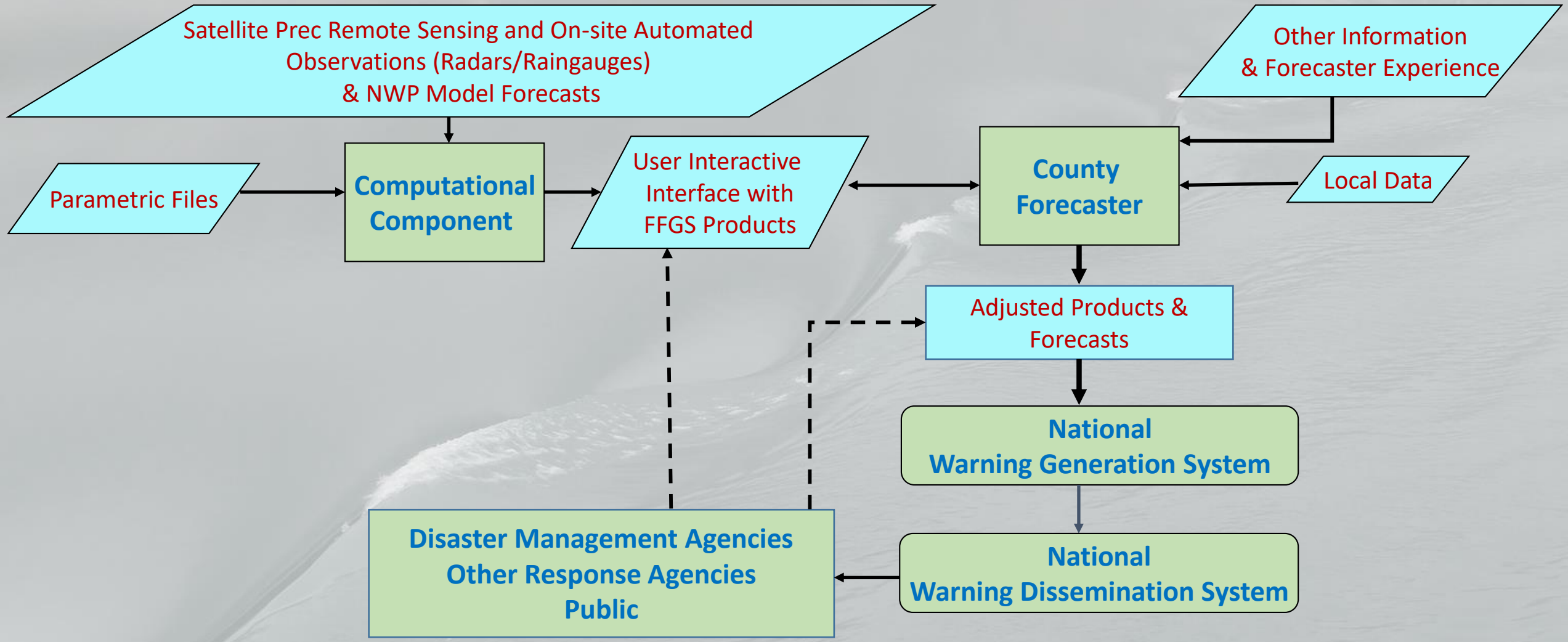
- **2008: WMO, USAID, NOAA, HRC sign a quad-part Memorandum of Understanding to collaborate in the implementation of a global flash flood guidance system (completed a 10-year phase and starting a third 5-year phase)**

Fall 1991

Konstantine Georgakakos (left) confers with graduate students Alex Guetter (seated), Deg Hyo Bae, and Teresa Carpenter; joining the discussion is Jim Cramer (right), data systems coordinator and manager of the Hydrometeorology Laboratory.

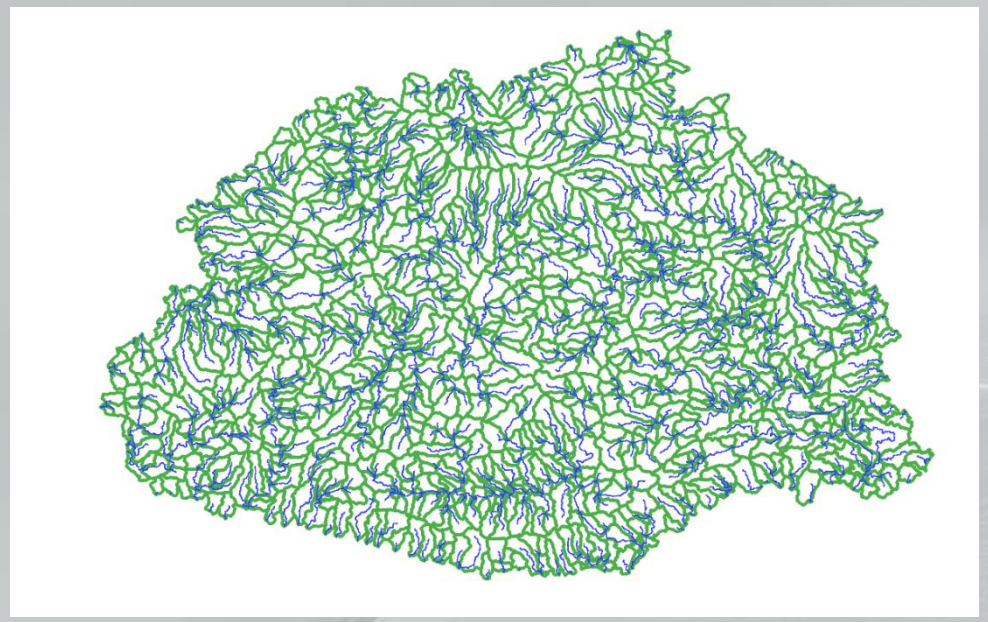
FLASH FLOOD GUIDANCE SYSTEM

From Global Data and Regional Hydrometeorology to National Data and Warnings

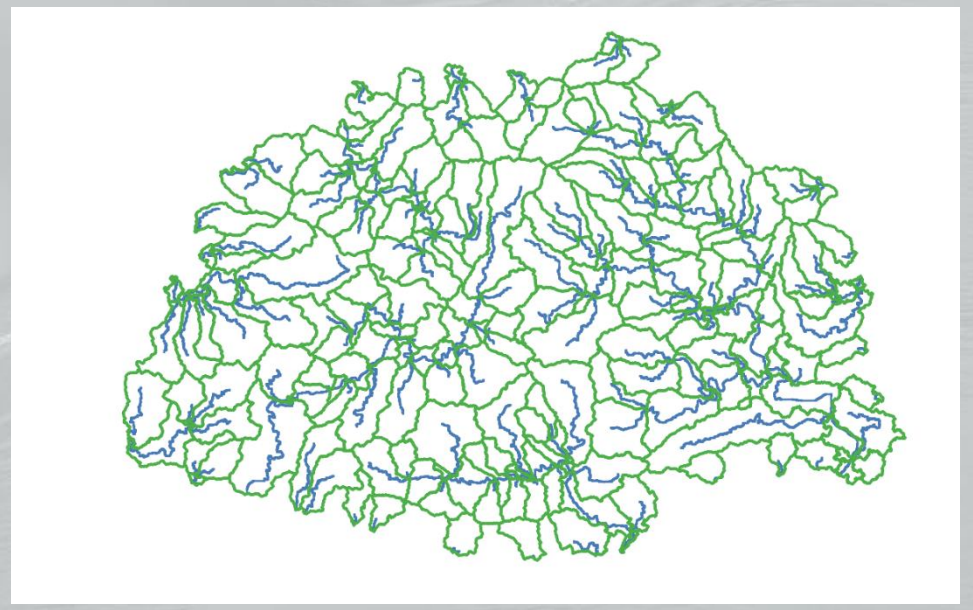


Watershed Area used in Delineation Commensurate with the Precipitation Forcing

Used a Threshold of 5 km^2 Watershed Area



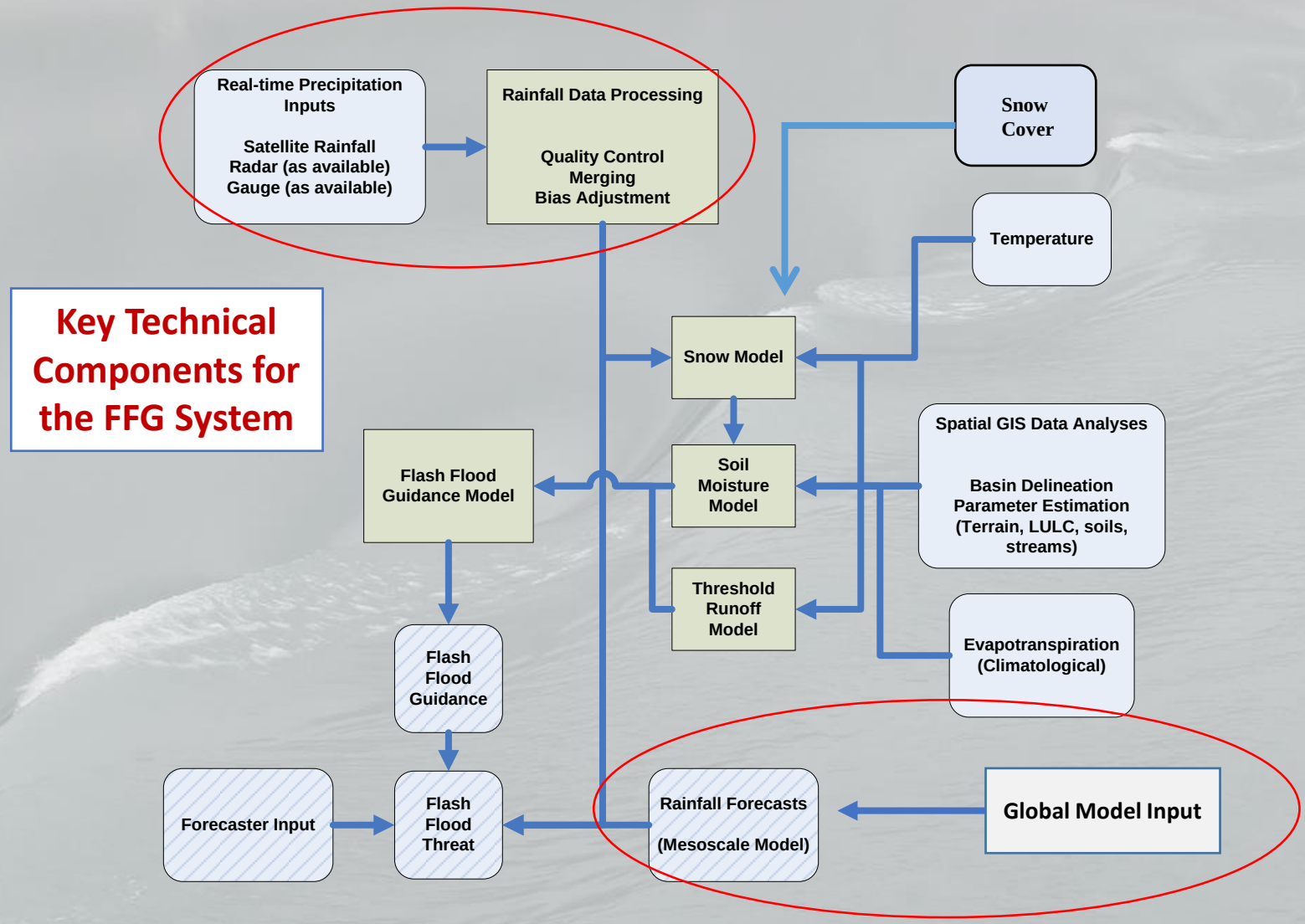
Used a Threshold of 25 km^2 Watershed Area



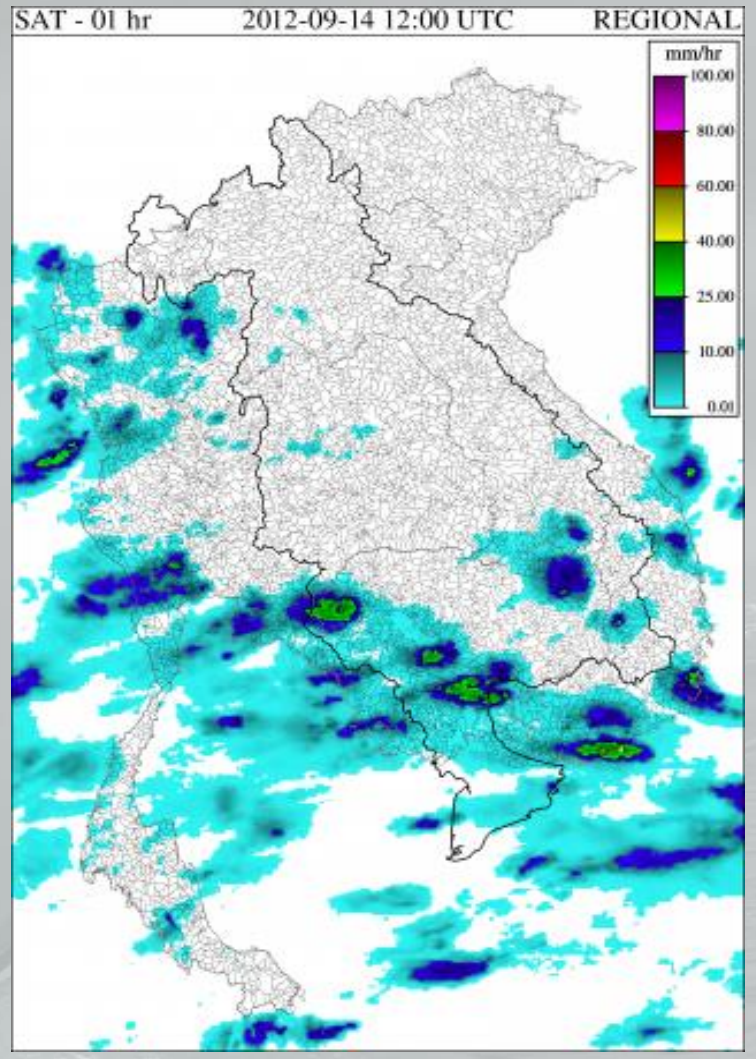
Depending on the availability and quality of the gauge-adjusted real-time satellite and radar data, the configuration with the more reliable products for each country is identified in the context of the system.

SOURCES OF INFORMATION FOR THE FFGS

Individual Watershed Operations



Satellite Rainfall - Hydroestimator



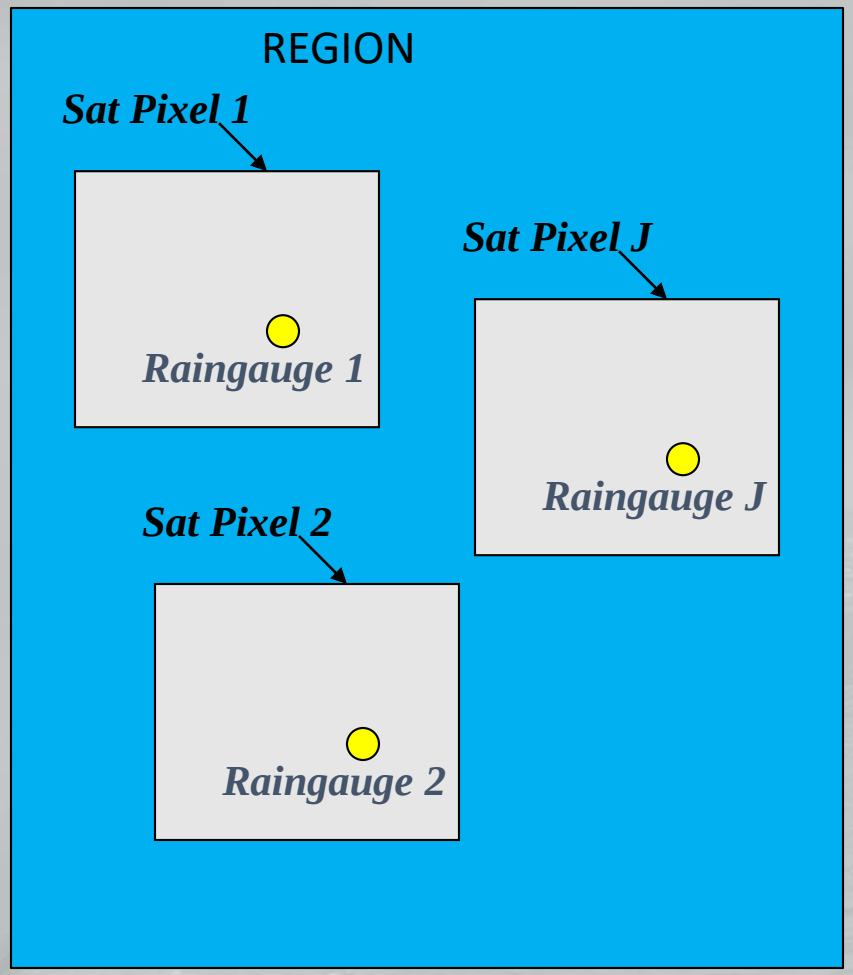
- **IR based (10.7 μm)**
- **Short latency**

Rain Rate =
Function of brightness temperature

Enhanced for:

1. Atmospheric moisture effects
2. Orography (upslope/downslope)
3. Convective Eqlb. Level (warm-top convection)
4. Local pixel T difference with surroundings
5. Convective core/no-core region

Bias and Log-Bias Factors



$$\beta_t = \ell n \left[\frac{\sum_{j=1}^{N_g} R_g(t, j)}{\sum_{j=1}^{N_g} R_s(t, j)} \right]$$

Log-Bias

Bias (B)

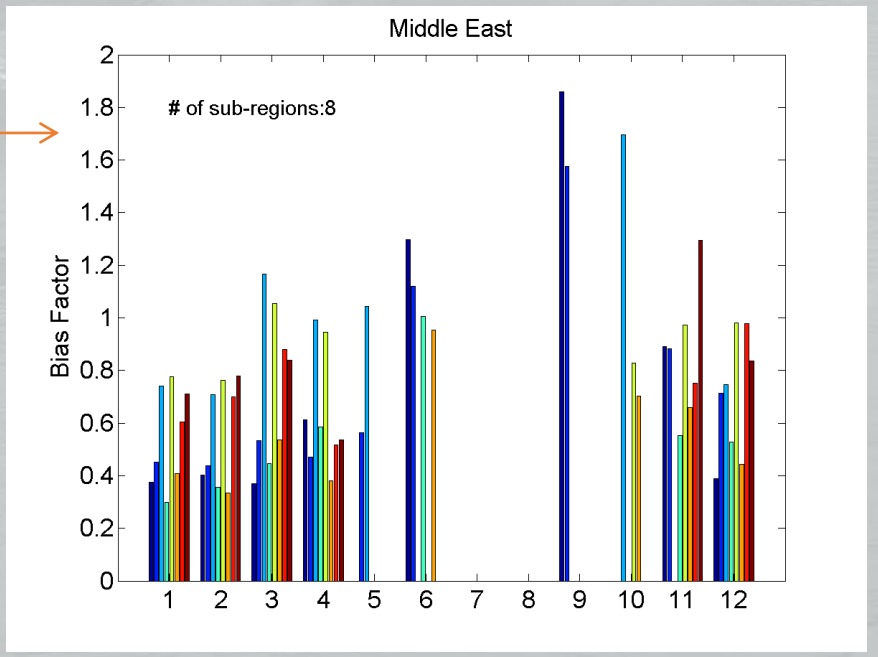
Climatological Adjustment Using Gauges and Corresponding Satellite Pixel Data

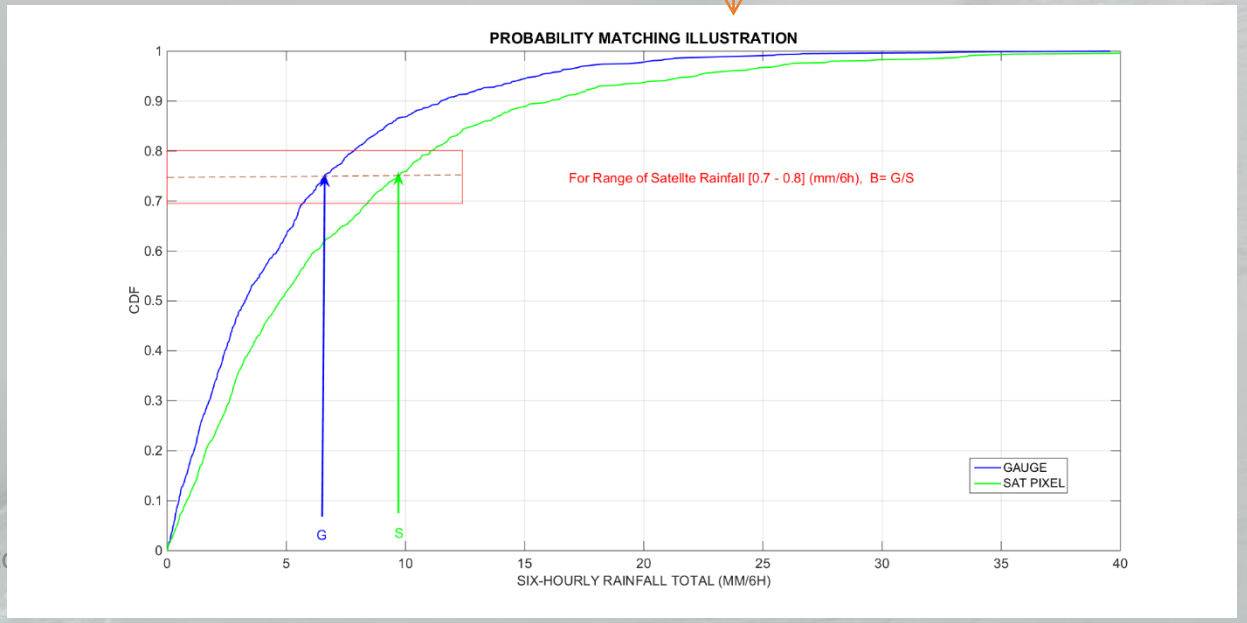
- Historical Data for regions of uniform hydroclimatology, terrain and gauge density
- Usually done for an given month or season
- Result is bias factor for each region and month/season

Bias Factor computed from:

(1) Mean values

(2) Probability matching considerations





Dynamic Bias Adjustment Basics

$$\beta_t = \ell n \left[\frac{\sum_{j=1}^{N_g} R_g(t,j)}{\sum_{j=1}^{N_g} R_s(t,j)} \right]$$

$$\beta_{t+1} = \beta_t + w_{t+1}$$

$$z_{t+1} = \beta_{t+1} + v_{t+1}$$

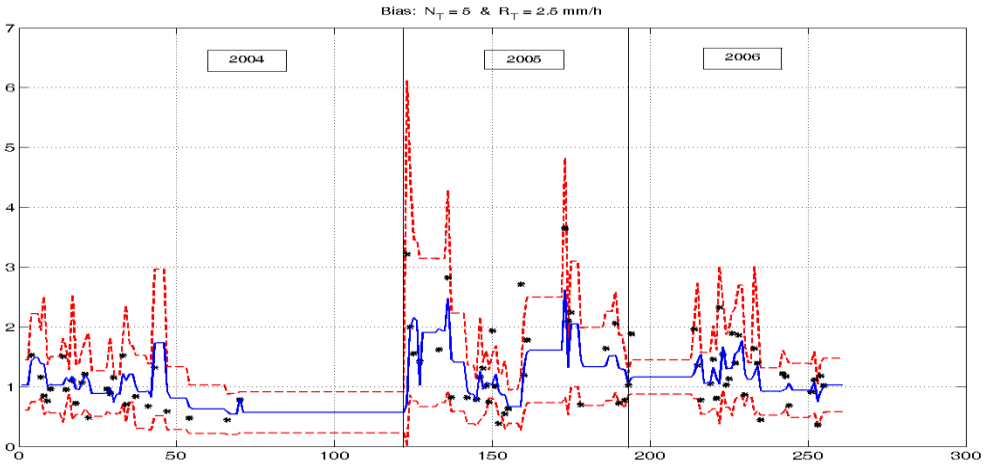
Kalman Filter
Stochastic Approximations

- N pairs of consecutive values
- At least 20% raingauges with rain
- Conditional Mean > Threshold (mm/h) (satellite/radar and gauge)

Bias (B)

Important issue:
Gauge data quality control

3-Year Bias Trace from CEFFGS



Multi-Spectral Satellite Rainfall

HE

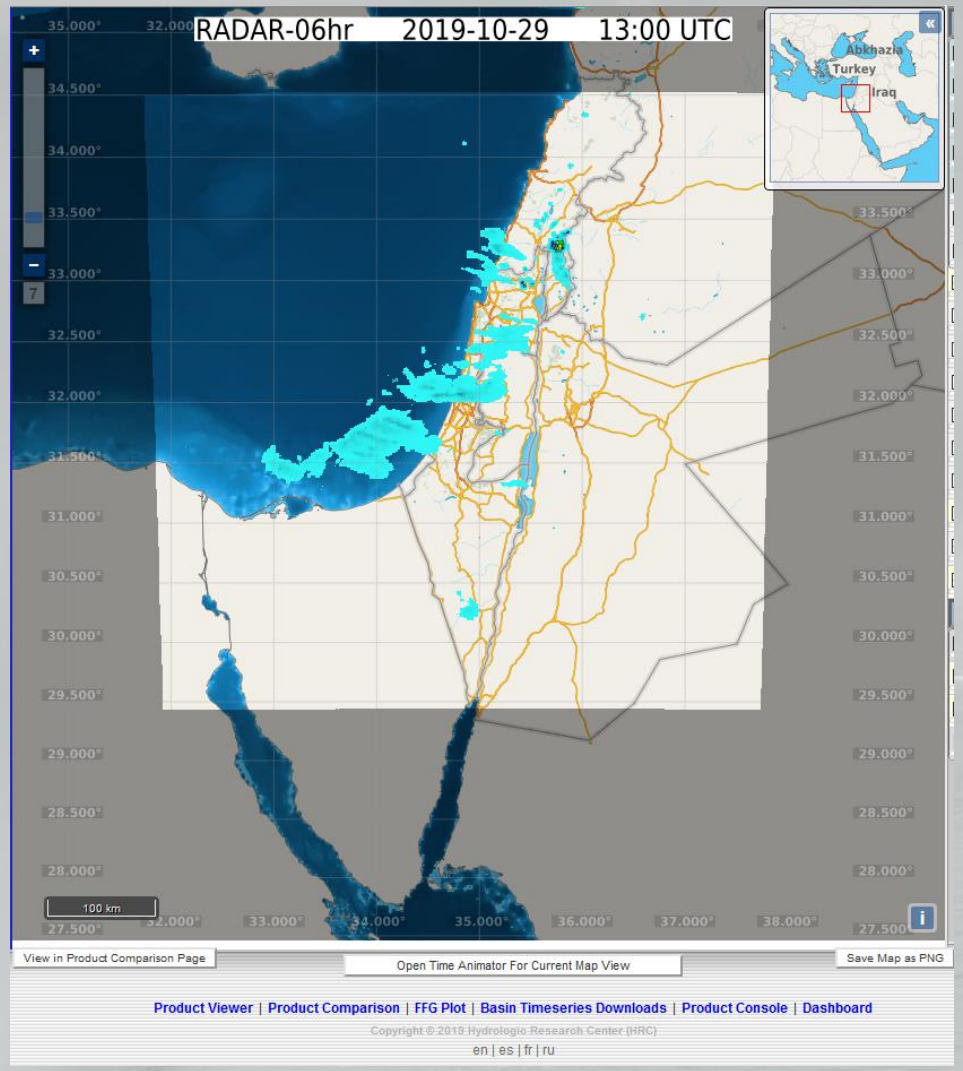
IR – Based
30-min latency in operations
Based on measurements of top cloud brightness temperature

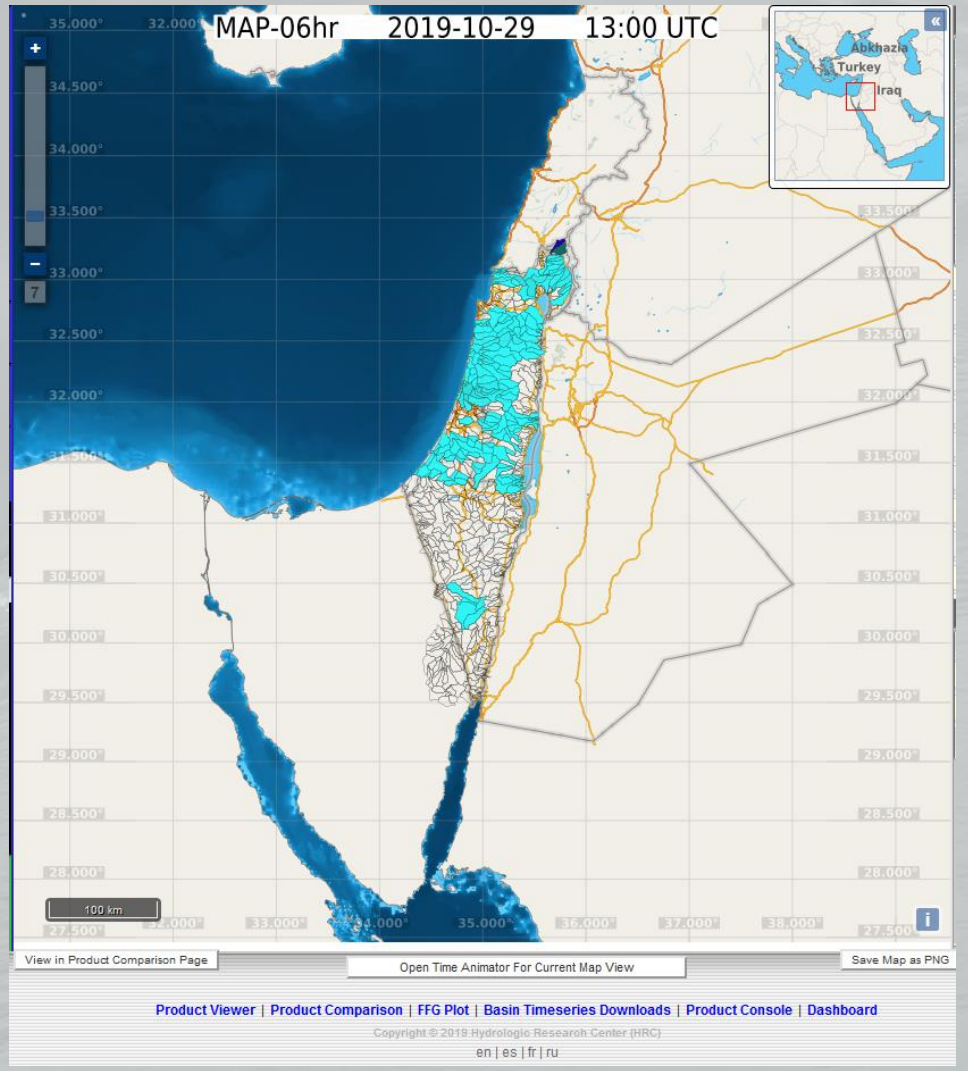
CMORPH

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

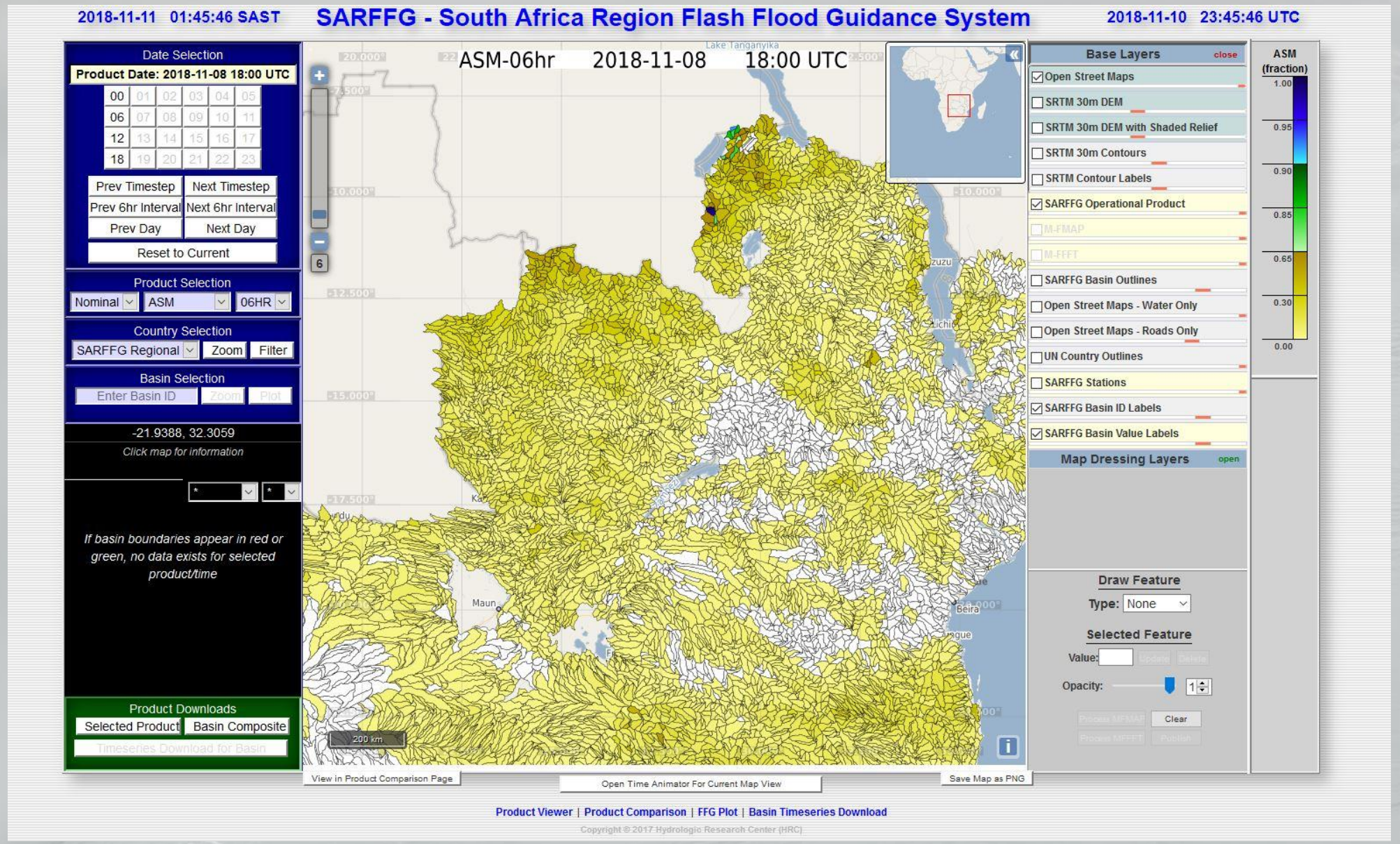
Global FFGS product combines IR-based HE rainfall with MW-based CMORPH rainfall

Use of Radar Data





Forecaster Interface based on Mapserver Technology



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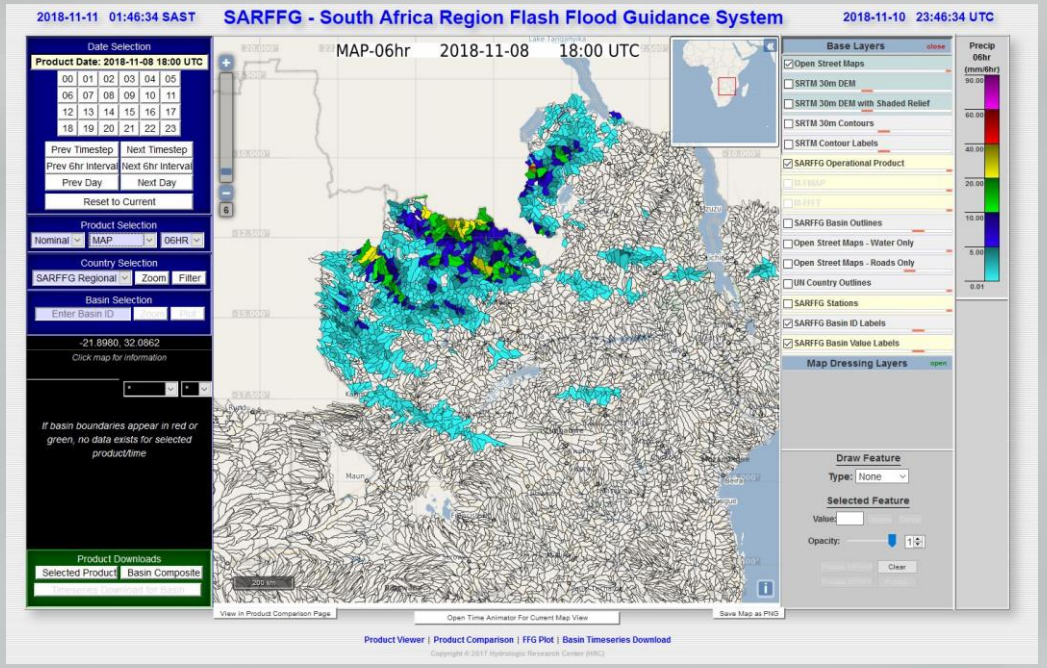

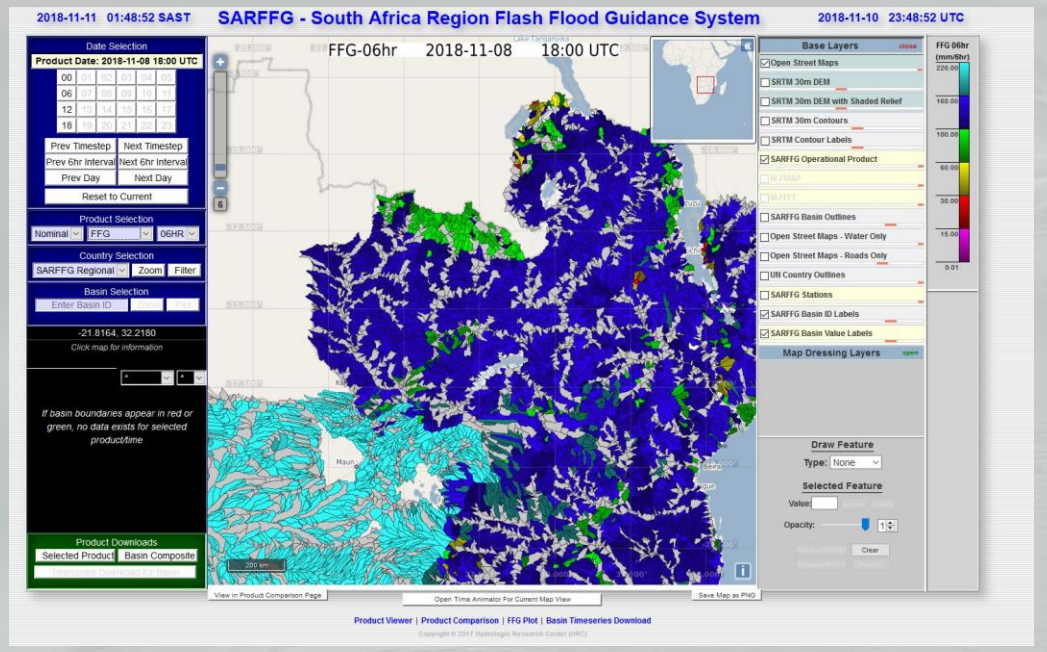

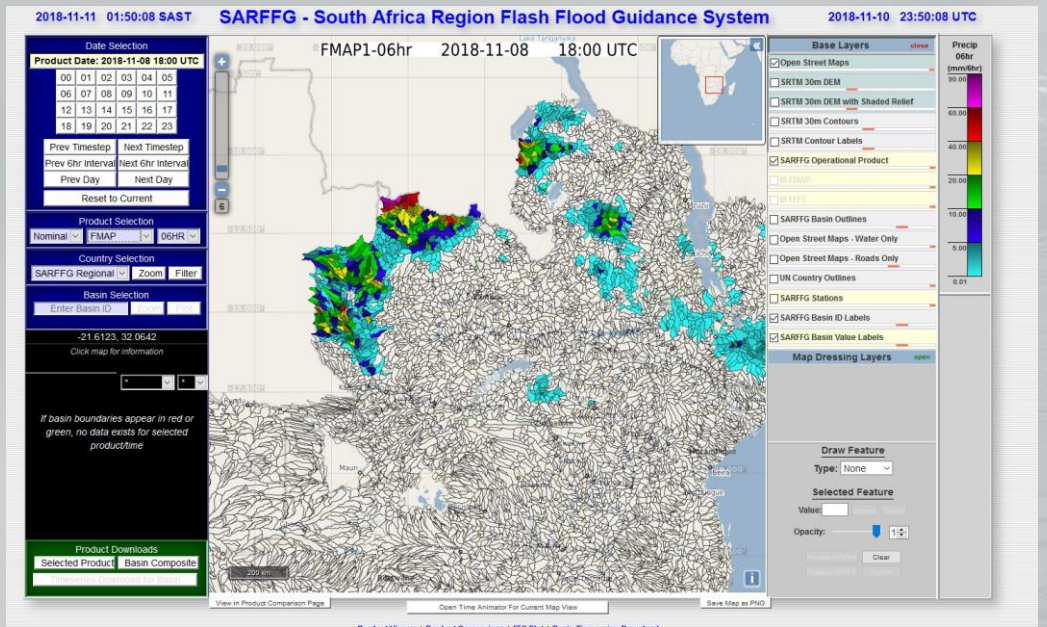

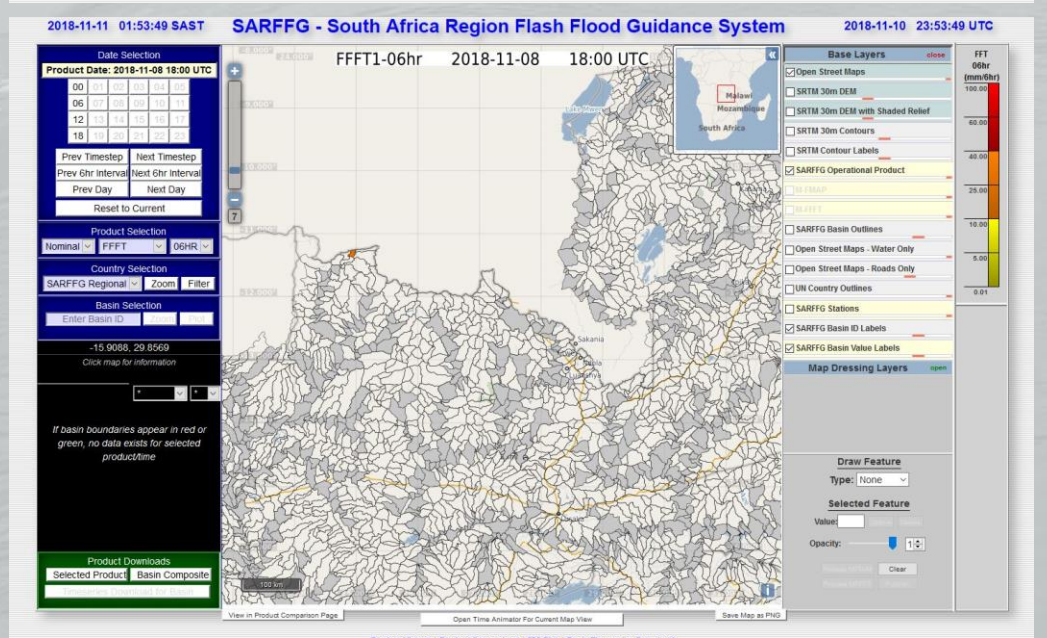

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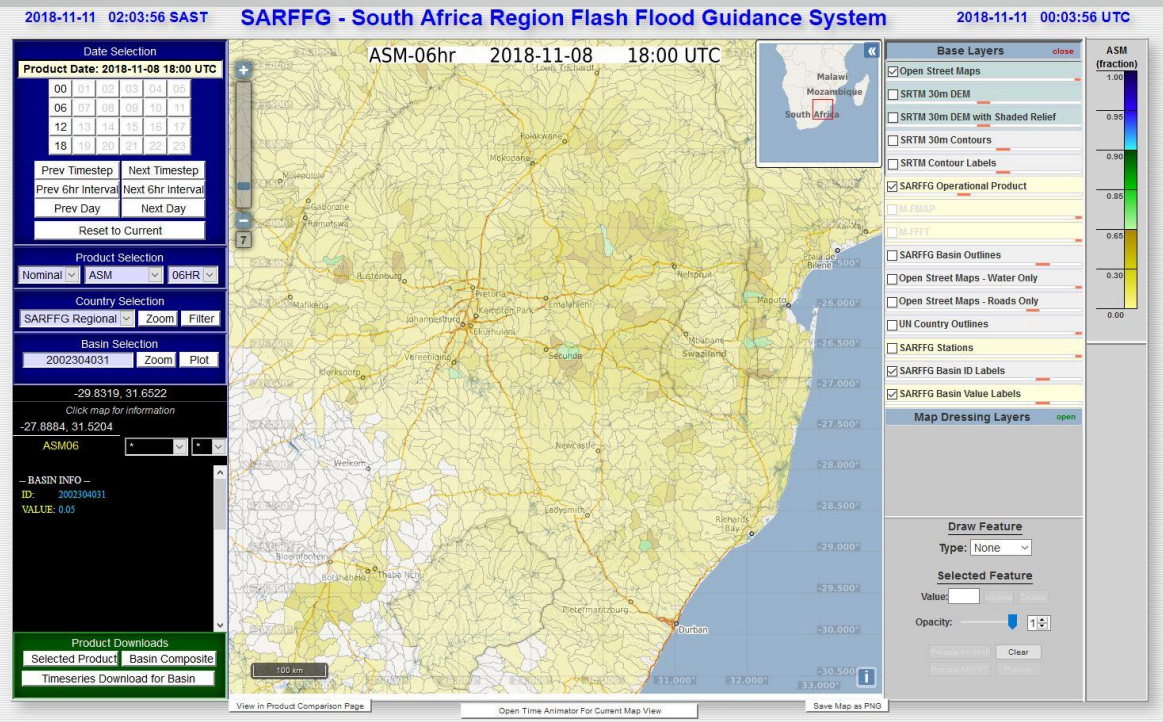

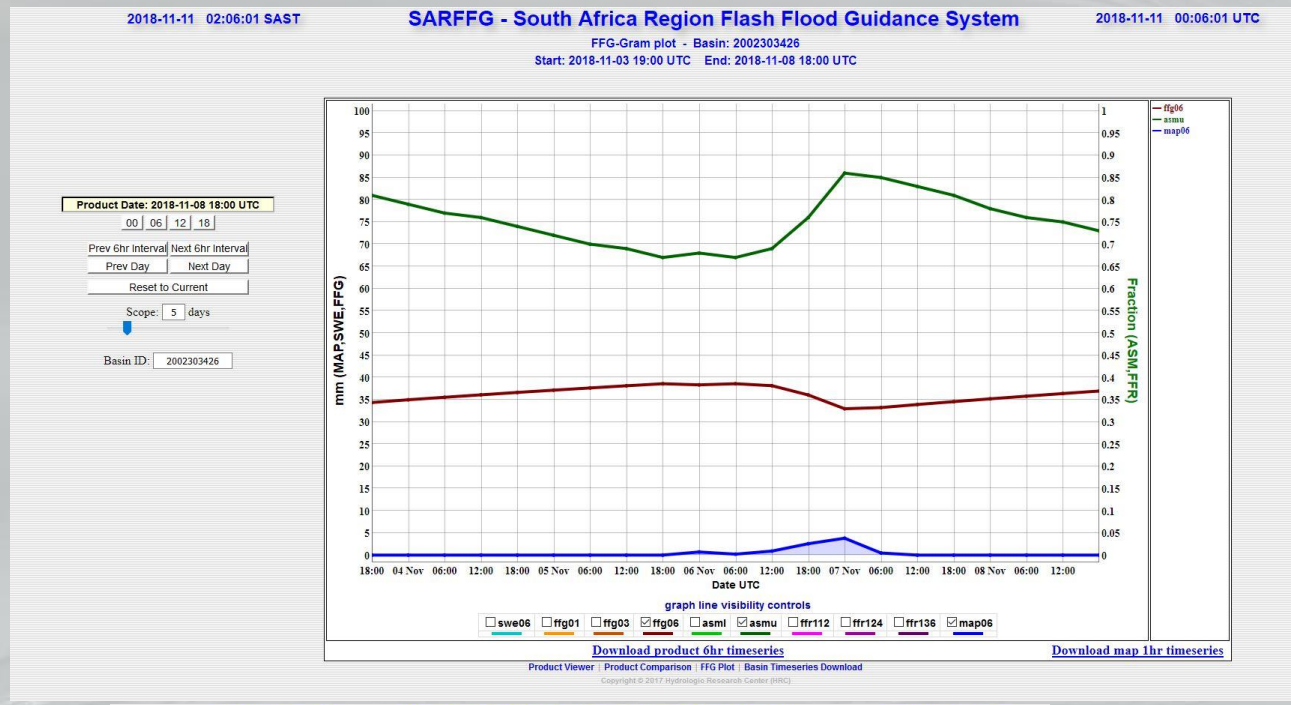

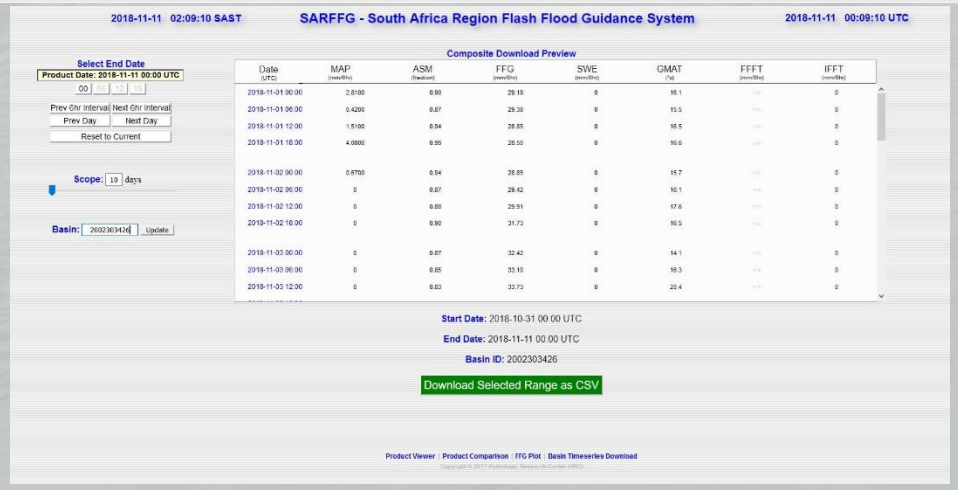

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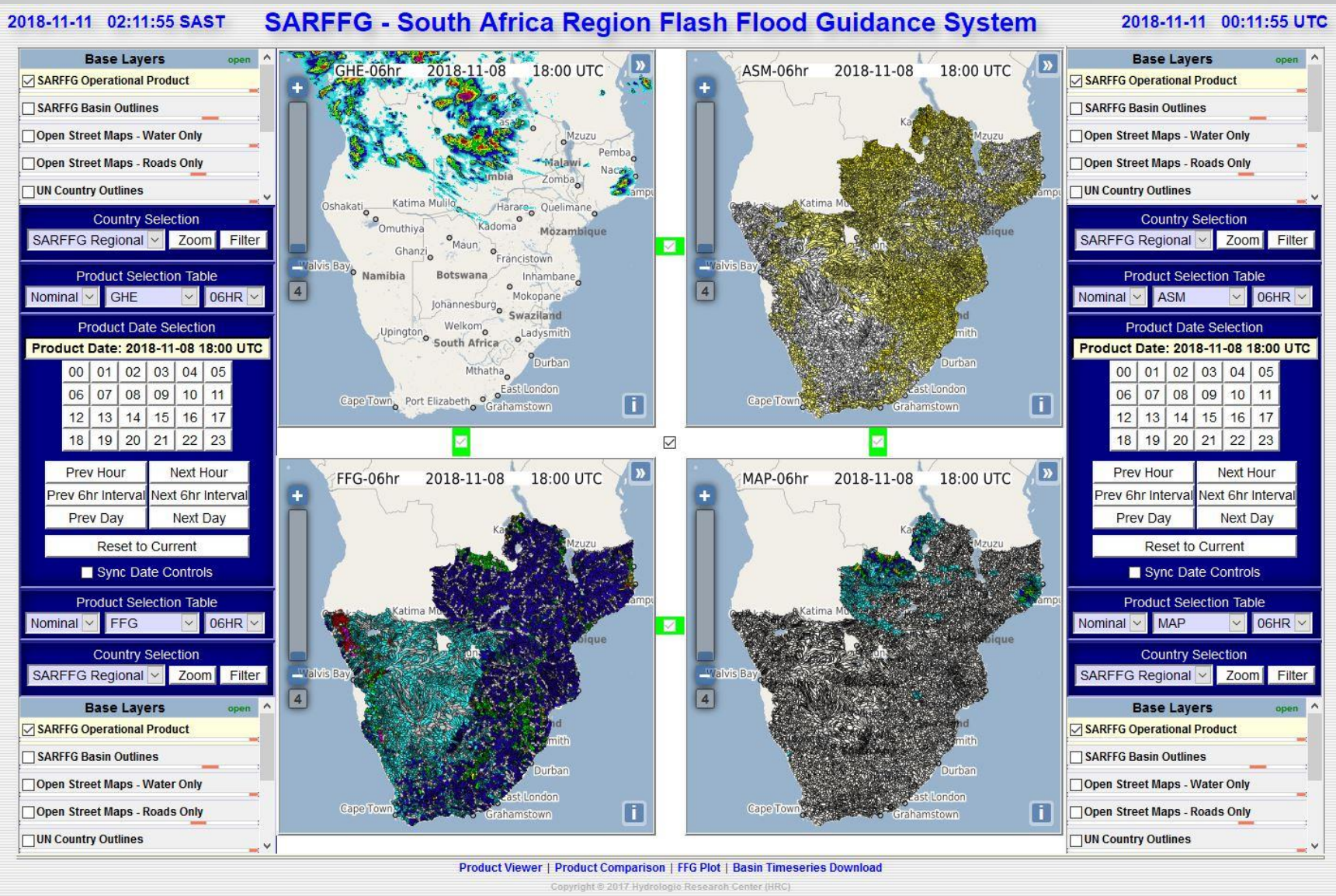

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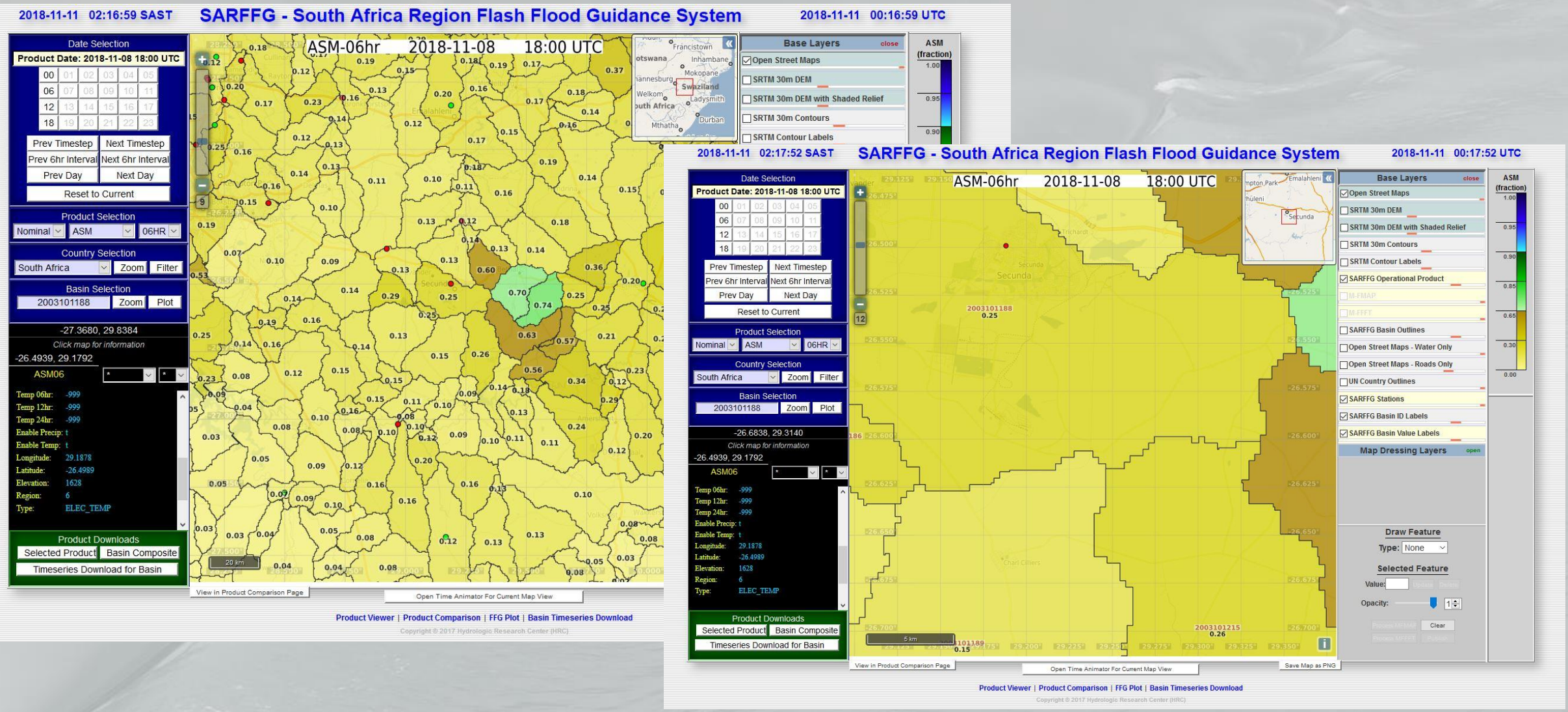


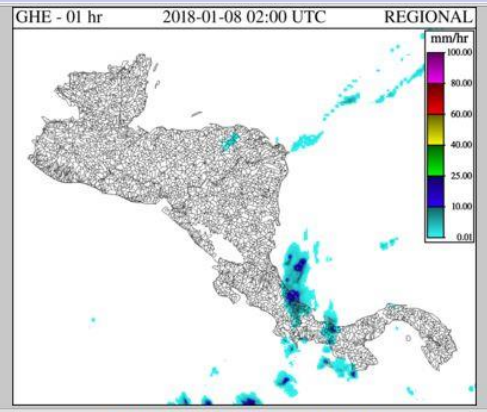
FFGS Dashboard for IT Staff and Forecasters

2018-01-07 21:31:03 CST

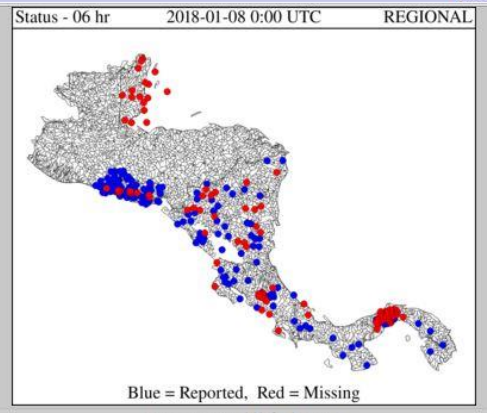
CAFFG - Real-Time Status Dashboard

2018-01-08 03:32:03 UTC

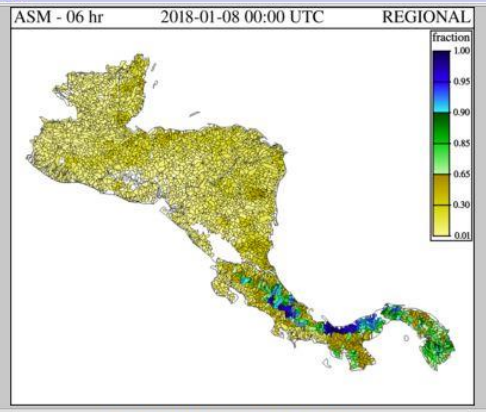
Image Products



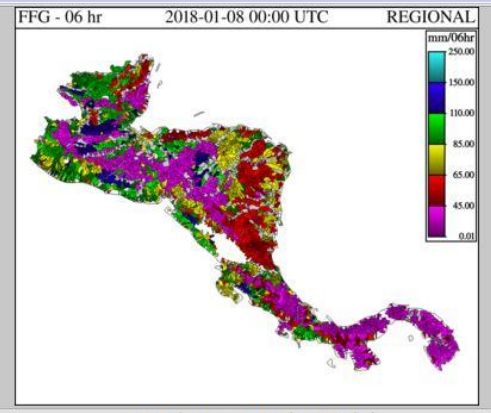
Animate 01-hr Sat Precip - 24 Images - (Pop-Up Window)



No Animation Available for this Image



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



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

Real-Time Data Download and Inventory Status

HRC MWGHE Download				
ENABLED				
SUCCESS				
Jan-04	Jan-05	Jan-06	Jan-07	Jan-08
24	24	24	24	3

NESDIS GHE Download				
ENABLED				
SUCCESS				
Jan-04	Jan-05	Jan-06	Jan-07	Jan-08
24	24	24	24	4

GAUGE Download				
ENABLED				
SUCCESS				
Jan-04	Jan-05	Jan-06	Jan-07	Jan-08
65%	68%	78%	69%	66%

CAWRF Download				
ENABLED				
SUCCESS				
Jan-04	Jan-05	Jan-06	Jan-07	Jan-08
0	0	0	0	0

Real-Time Data Processing Status

HRC MWGHE Data Processing
ENABLED
SUCCESS

NESDIS GHE Data Processing
ENABLED
PENDING

GAUGE Data Processing
ENABLED
PENDING

CAWRF Data Processing
ENABLED
PENDING

Model Processing Status

SACSMA & FFG Model Processing
ENABLED
SUCCESS

Export Processing Status

Text/CSV Exports
ENABLED
SUCCESS

Image Exports
ENABLED
SUCCESS

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
192.168.0.6	CAFFG-CS	390.41 days	0	77.87 %	48.25 %	52.62 %	1316636 KB	86.59 %	2.26 %	0.00 %	11.15 %	236.20 t/s	0.40 KB/s	10,869.60 KB/s	843,093 MB	1,116,166 MB	57 %	165 days

Dissemination Server Status

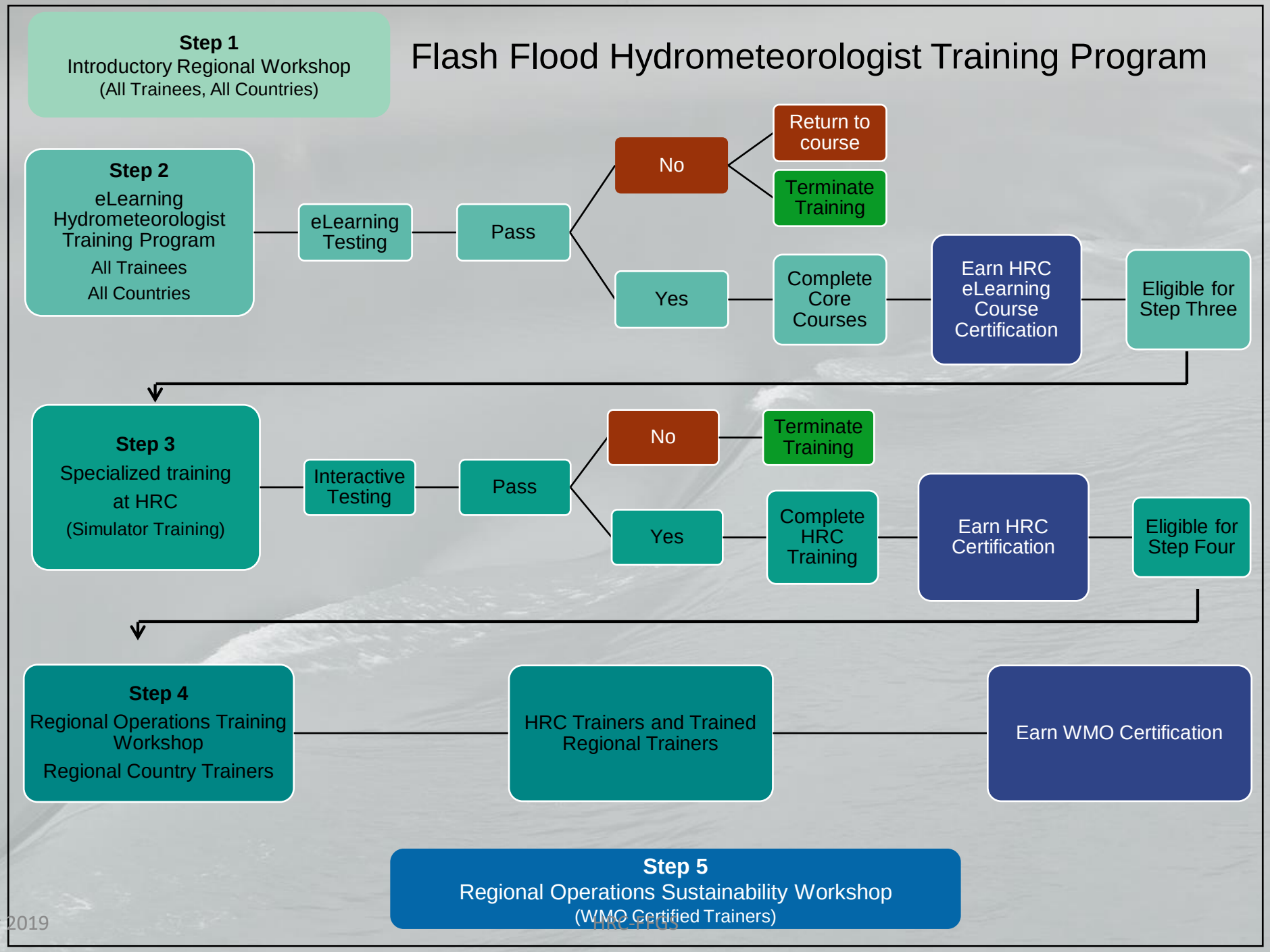
General Info				Processing Load				CPU Activity				Disk Activity			Storage			
IP Address	Hostname	Uptime	Active Logins	1-Min	5-Min	15-Min	Swap Used	System	User	IOwait	Idle	Transfers	Read	Write	Free	Used	% Used	Days to Filled
192.168.0.7	CAFFG-DS	380.25 days	0	10.87 %	10.25 %	10.62 %	86656 KB	24.75 %	0.25 %	0.12 %	74.88 %	4.60 t/s	0.00 KB/s	89.60 KB/s	213,847 MB	1,538,080 MB	88 %	42 days

REGIONAL BELIZE COSTARICA ELSALVADOR GUATEMALA HONDURAS NICARAGUA PANAMA

Go to REGIONAL Product Console

CAFFG Real-Time Status Dashboard v.1.0, © 2016 Hydrologic Research Center

Flash Flood Hydrometeorologist Training Program



Verification and Validation Activities

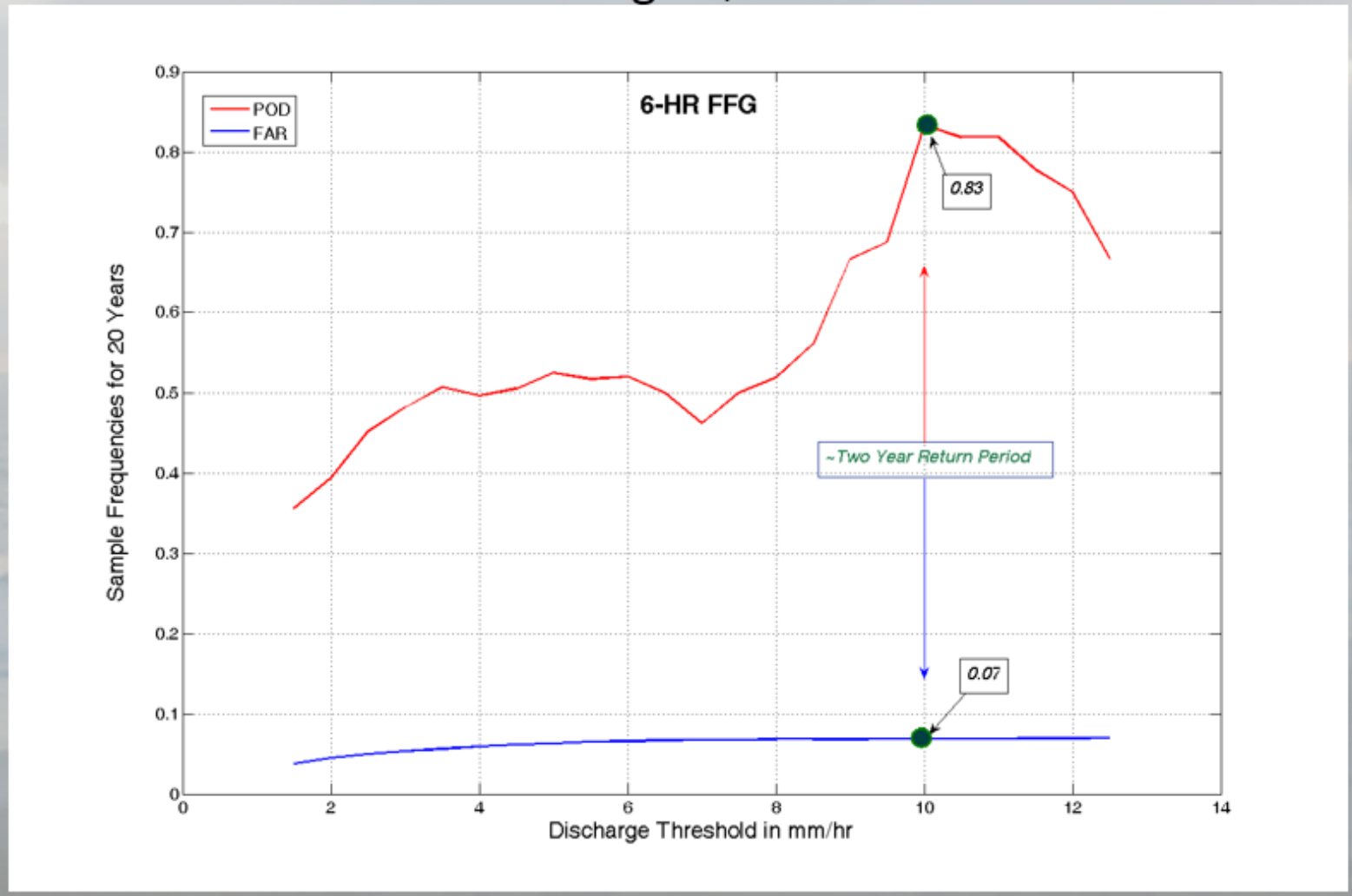
QPE Validation SARFFG

MWGHE:	BEFORE	AFTER	GHE:	BEFORE	AFTER
DJF					
Res Mean	0.5 mm/d	0.03 mm/d	0.8 mm/d		0.12 mm/d
Obs Mean	1.7	1.7	1.9		1.9
Res St Dev	2.7	2.9	3.2		3.4
Obs St Dev	3.3	3.3	3.6		3.6

MWGHE:	BEFORE	AFTER	GHE:	BEFORE	AFTER
JJA					
Res Mean	2.4 mm/d	0.06 mm/d	2.4 mm/d		0.17 mm/d
Obs Mean	3.2	3.2	4.0		4.0
Res St Dev	3.4	3.2	3.7		4.1
Obs St Dev	4.6	4.6	4.8		4.8

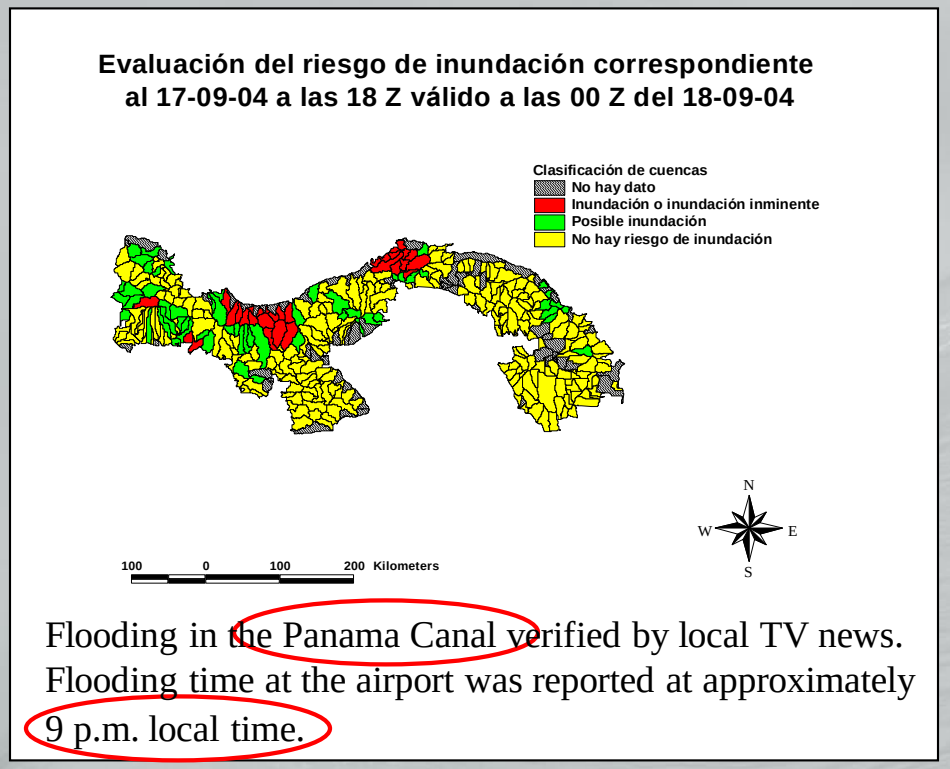
Single Data-Rich Basin Validation

Rio Chagres, Panama



Example of Warning Validation

System operators from Costa Rica and El Salvador were in daily communication with Country Agencies to receive community information regarding local flooding



3-Hourly FF Threat (*adjst*):
Hits: 57% (*63 – 100%*)
False: 30% (*0 - 21%*)
Misses: 13% (*0 - 16%*)

Other Examples of Warning Validation

CROATIA

a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	21 (a)	7 (b)	28
	No	1 (c)	113 (d)	114
	Total	22	120	142

Contingency table of flash flood warnings for Croatia in the period from 10 of October 2015 to 29 of February 2016

Hit Rate (POD): a/(a+c)	0.95
False Alarm Ratio (FAR): b/(a+b)	0.25
False Alarm Rate (POFD): b/(b+d)	0.058
Threat Score: a/(a+b+c)	0.72

The scores for flash flood warnings for Croatia in the period from 10 of October 2015 to 29 of February 2016

EL SALVADOR

MARN disaster management agency (2018):

"In El Salvador, the system as a whole (including the FFGS) achieved a decrease in casualties caused by intense storms from more than 300 people between 2004 and 2009, to around 12 between 2009 and 2018."

Desired Prerequisites for Effective System Implementation and Use

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

Challenges and Opportunities for Implementation in Developing Countries

SOME CHALLENGES

Communications links and PC availability for accessing the secure-internet FFGS interfaces
Continued availability of high resolution quality controlled satellite precipitation data at regional centers to provide the main forcing in lieu of extensive and well maintained on-site observation networks
Continuing cooperation between forecast and disaster management agencies
Continuing capacity building in the hydrometeorology of flash flood events, their precursors and uncertainties
Continuing pubic education on the perils of flash floods and preparedness

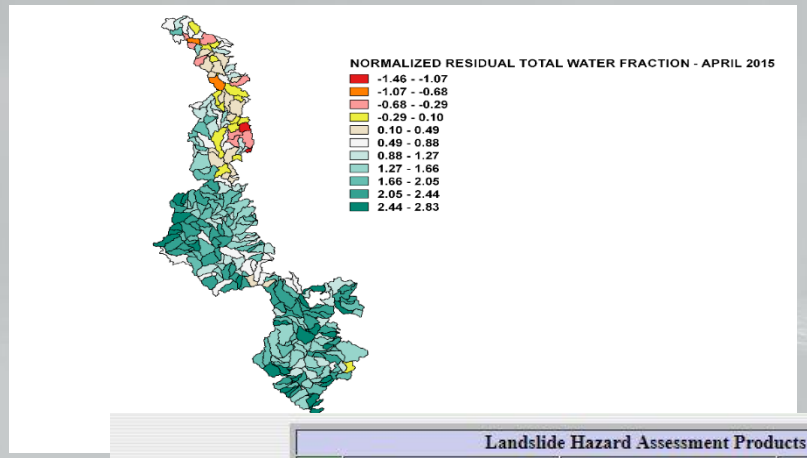
SOME OPPORTUNITIES

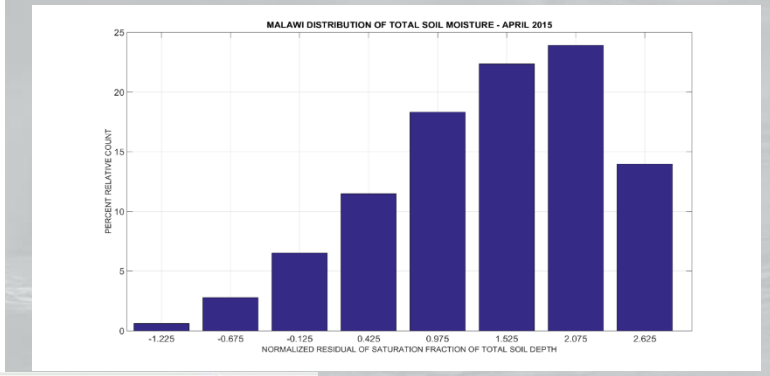
Develop a cloud version of the system for countries without a viable regional center
Maintain a center to provide high resolution satellite precipitation information to countries and regions
Develop decision support products to link uncertain forecasts to evacuation decisions
Encourage the Met&Hyd agencies to use system products for agriculture, water resources management and transportation for long-term support and sustainability of operations
Develop materials for public education targeting sectors of the society (e.g., school children, drivers, low-income housing dwellers by the river, etc.

Social Media Forecaster Communication in Regions

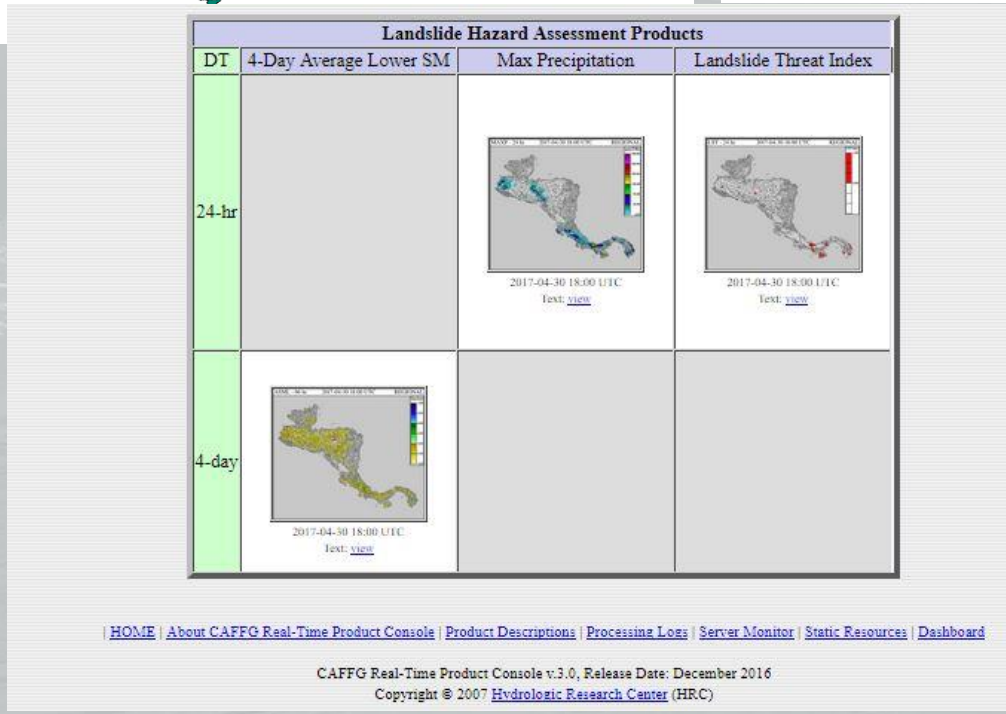
Additional Useful Products of the FFGS

Soil Moisture for Agriculture:



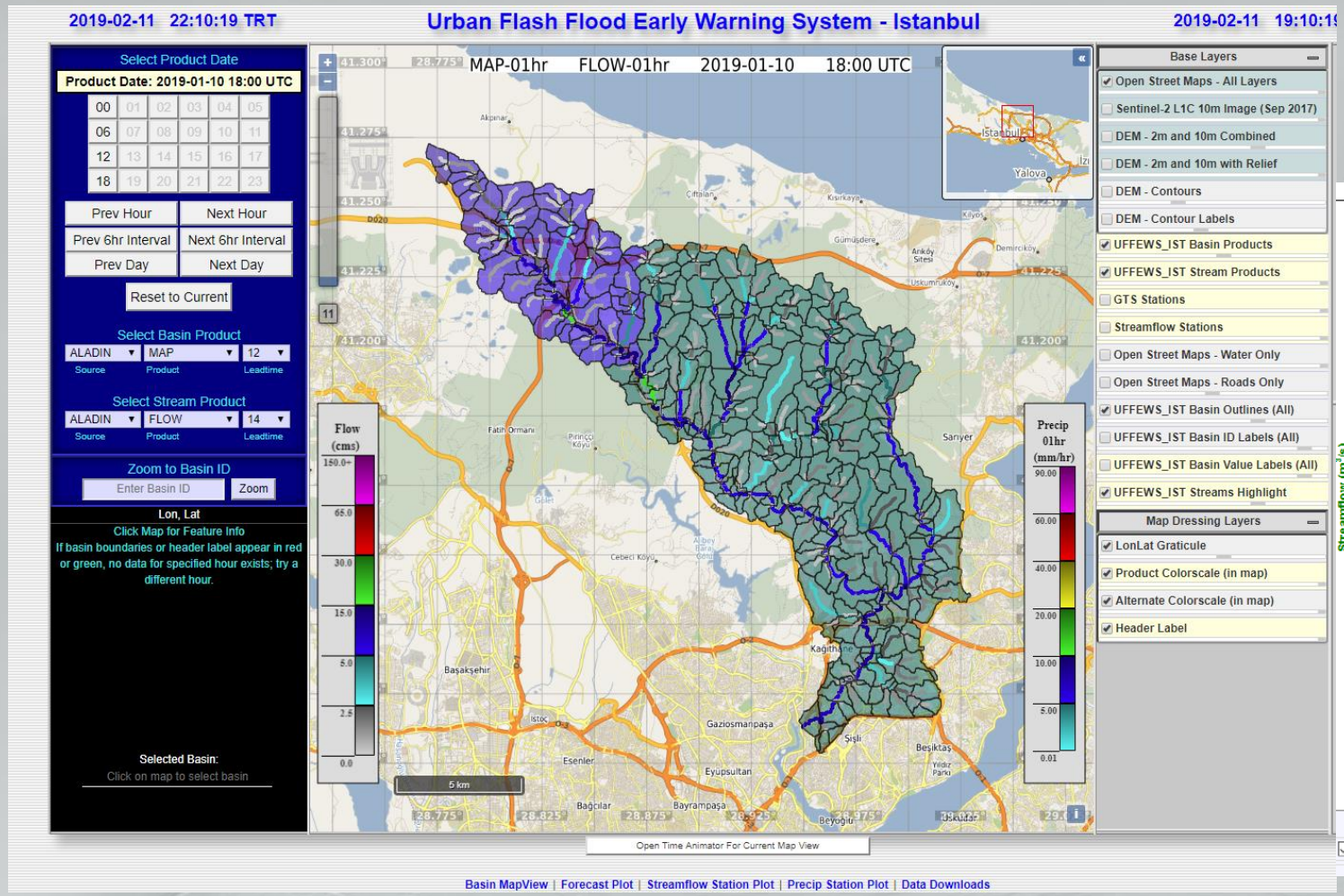


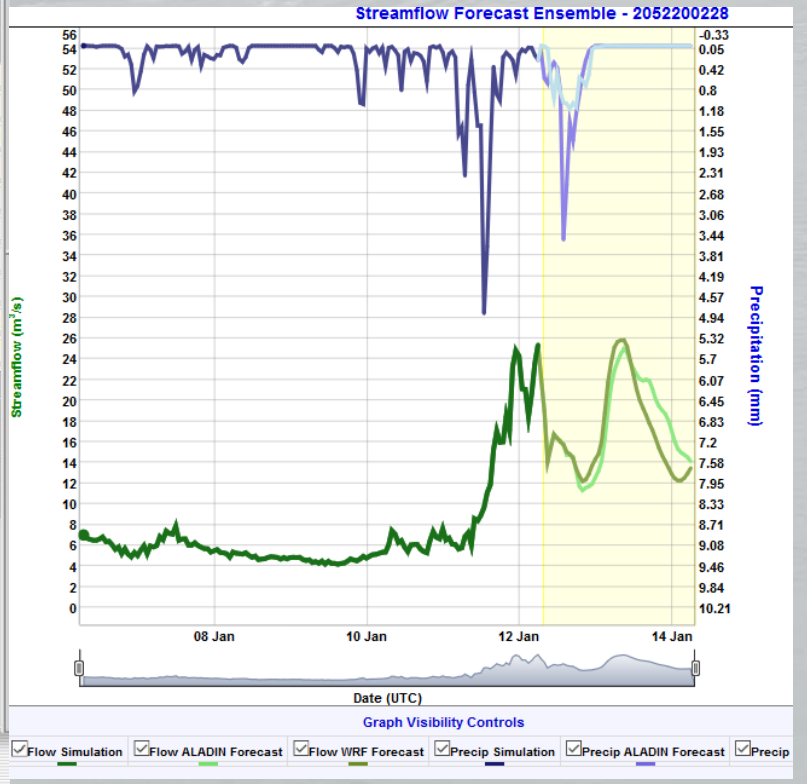
Landslide Occurrence Assessment:



Additional Useful Products of the FFGS

Channel Routing and Urban Products:

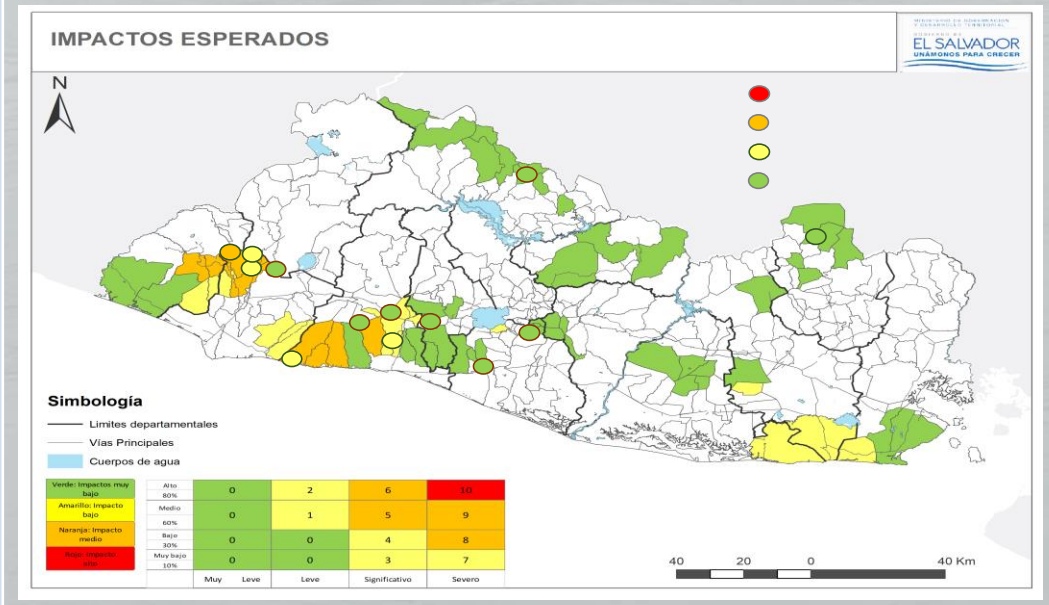




Additional Useful Products of the FFGS

Strong Links to Impact Based Forecasting Program:

GOALS	MEANS	OUTCOME
Strengthen Country preparedness for flash floods (and other weather-related events)	FFGS products and uncertainty Guided Workshops that bring together forecasters, disaster managers, first responders, other stakeholders Developing decision support tools to link uncertain forecasts with decisions to issue evacuation statements	Capacity building of national met/hyd agencies, disaster management agencies. Improved reliability and lead time of effective forecasts Improve communication of forecast information to responders and disaster management agencies



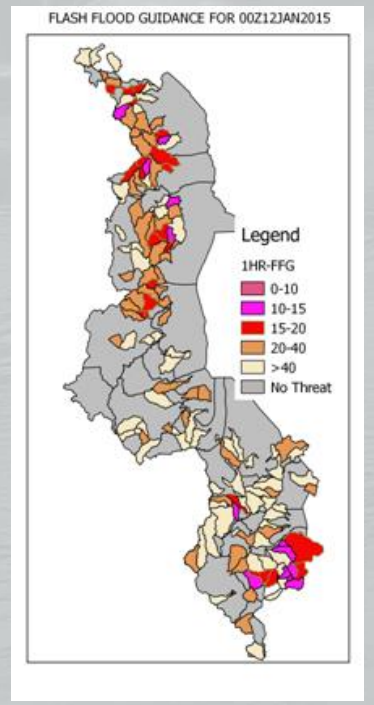
Example of use of the FFGS in Malawi

JANUARY 2015 – Thunderstorms caused flash floods, worst in decades

The Department of Climate Change and Meteorological Services (DCCMS) monitored and issued flash flood warnings continuously through both print and electronic media (DCCMS: Flash floods produce most fatalities annually in Malawi)

DCCMS Warning issued:

"Take note that we still have low FFG values marked RED in Northern Malawi. This translates to high risk of flash flooding if 0.01 to 30mm in the next 6 hours is attained in those areas. We expect the southern areas to pick the low FFG signal in the next 24 hours as a low pressure area deepens in the Mozambique Channel to enhance Congo air mass over most areas of Malawi. Monitoring of flash floods continues."

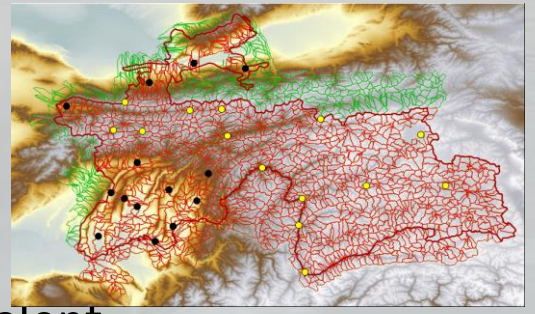


12th January 2015 for 00UTC – 18UTC.

Agency Cooperation and Post Assessment:

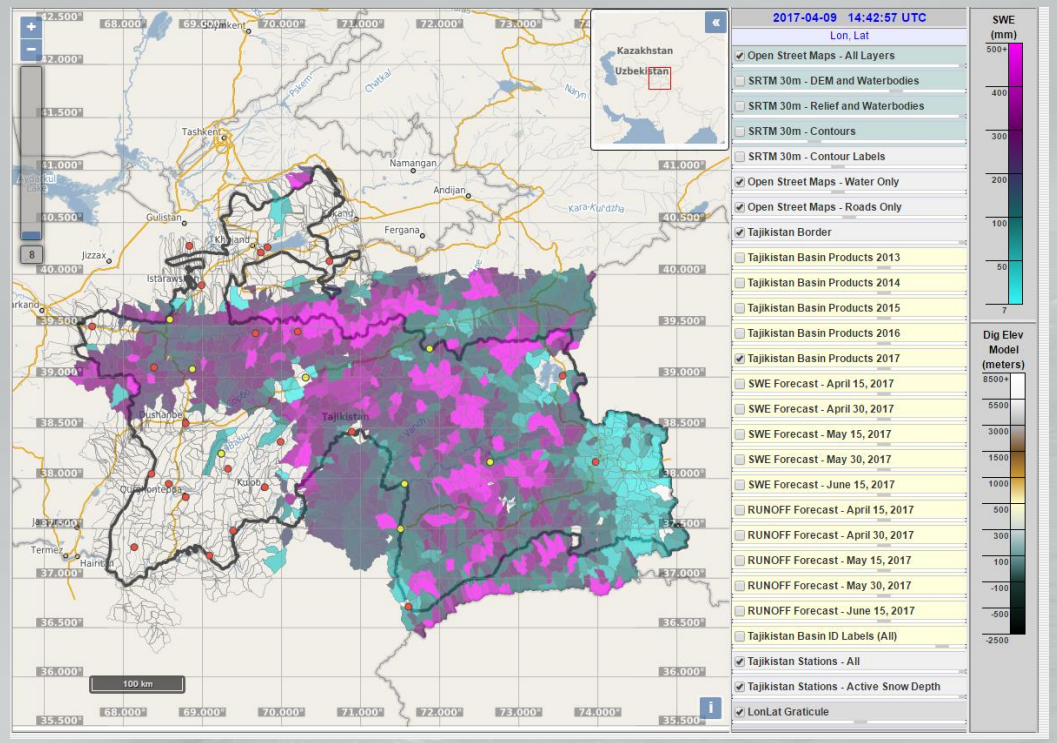
The DCCMS worked closely with the Department of Disaster Management Affairs (DoDMA) through the worst disaster in decades, affecting millions of Malawians in 15 out of 28 Districts. The DCCMS timely flash flood forecasts and warnings supported by the **SARFFG system** reduced casualties, damage to properties, and enhanced public preparedness.

Example of use of FFGS in Tajikistan

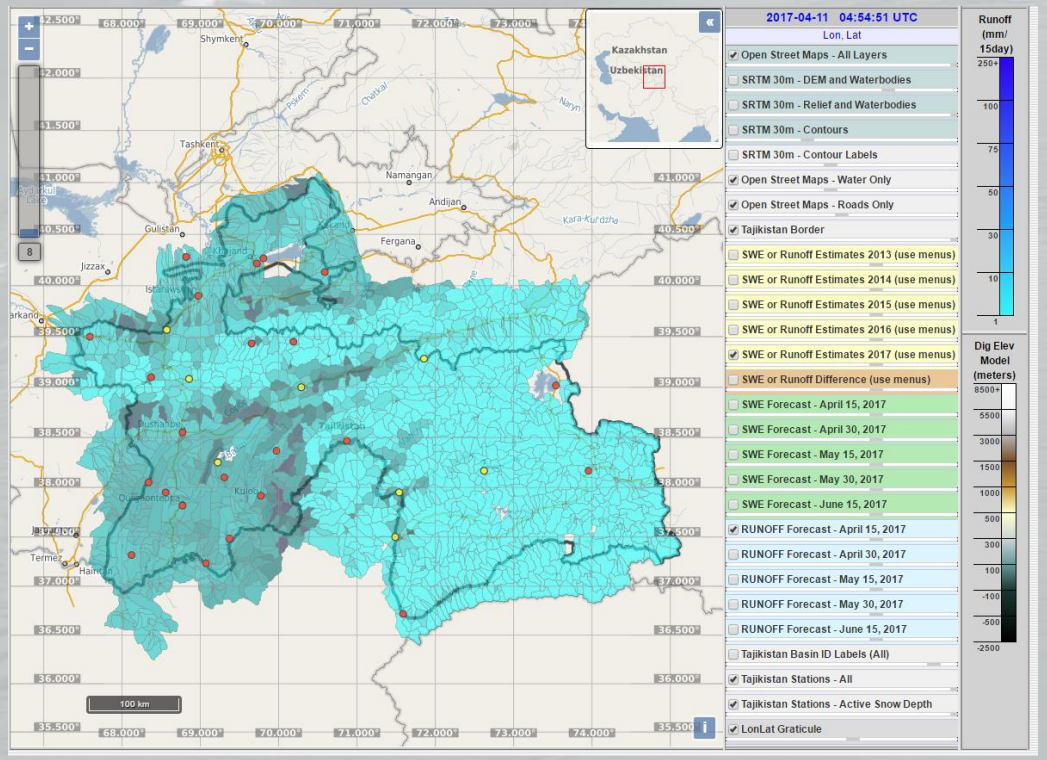


Use the CARFFG system infrastructure to provide timely estimates of snow water equivalent, and of snowmelt and rain runoff for the Tajikistan Basins using the available data and CARFFG system models (World Bank Funding) Close collaboration with Tajikistan Hydromet and promoted enhanced collaboration between forecast and disaster management agencies

1 April 2017 Snow Water Equivalent



Seasonal to sub-seasonal prediction of snowmelt runoff out to 5 months



FFG Development Team at HRC

Konstantine Georgakakos – Managing Technical Director/Hydrometeorology/Uncertainty Characterization

Robert Jubach - General Management/Disaster Risk Reduction

Jason Sperfslage - IT Systems Engineering

Theresa Modrick-Hansen - Hydrometeorological Modeling

Eylon Shamir – Soil Water and Snow Models

Cris Spencer – IT Engineering/Programming

Randall Banks – IT Engineering/Programming

Zhengyang Cheng – Fluvial Hydraulics and Flood Routing

Rochelle Campbell – Education and Training/Links to Disaster Management

FFGS Gazette: https://www.hrcwater.org/flash-flood-guidance-systems/
Country contributions and experiences of using FFGS