INTRODUCTION TO THE FLASH FLOOD GUIDANCE (FFG) SYSTEM FOR SOUTH ASIA REGION

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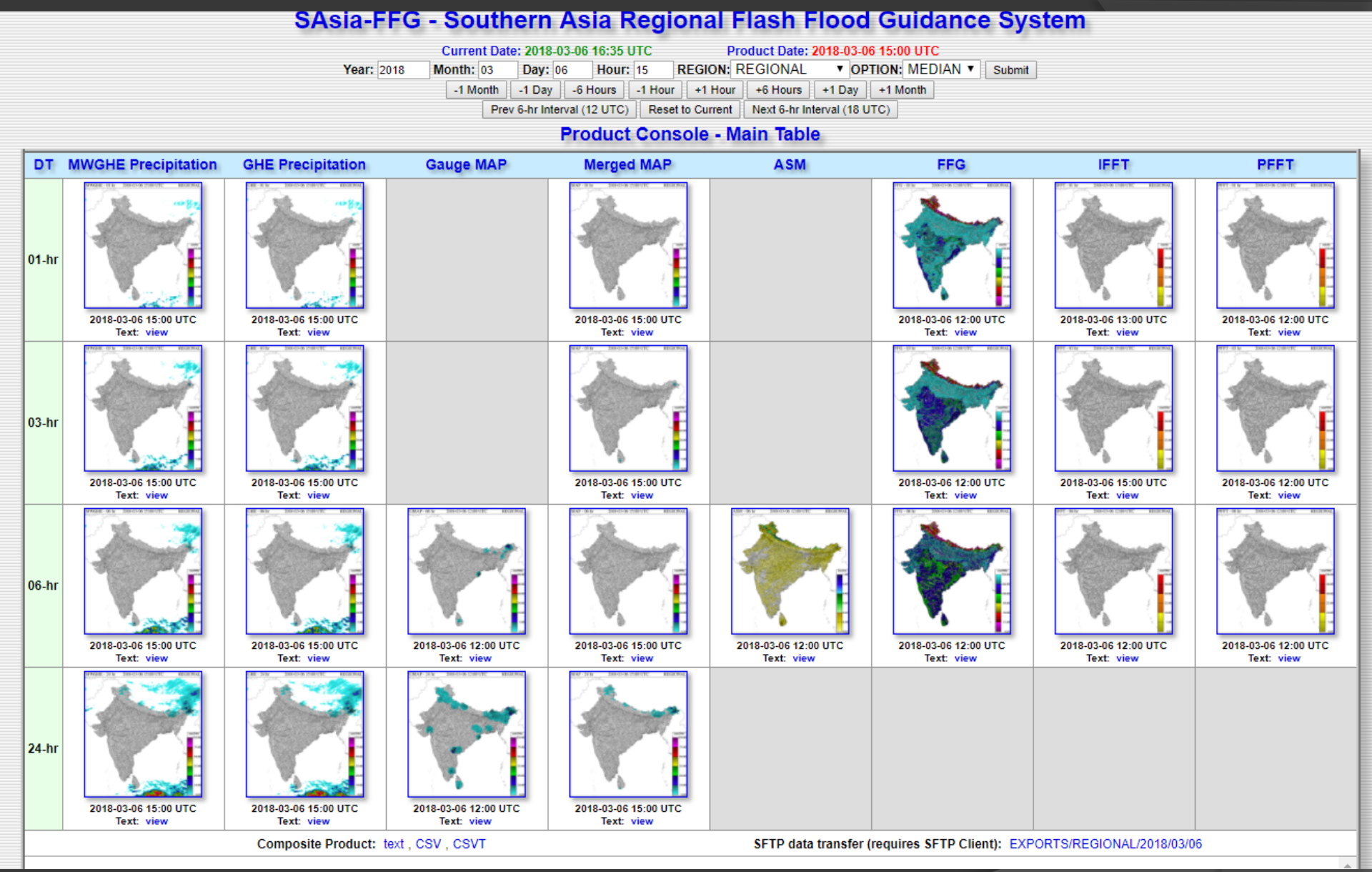
http://www.hrcwater.org

South Asia Region Flash Flood Guidance System

- South Asia Regional program is funded by U.S. Agency for International Development, Office of U.S. Foreign Disaster Assistance (USAID/OFDA)
- Program is in coordination with the U.S. National Weather Service (NWS), and the World Meteorological Organization
- Hydrologic Research Center (HRC) is the technical implementer of the program

Overview

1. Operational Concept And System Design
2. Floods and flash floods in perspective
3. Impacts of Flooding
4. Basic Meteorology of rainfall systems causing flash floods
5. Basic river Hydrology from a flash flooding perspective
6. Forecasting Flash Floods
7. Conclusions

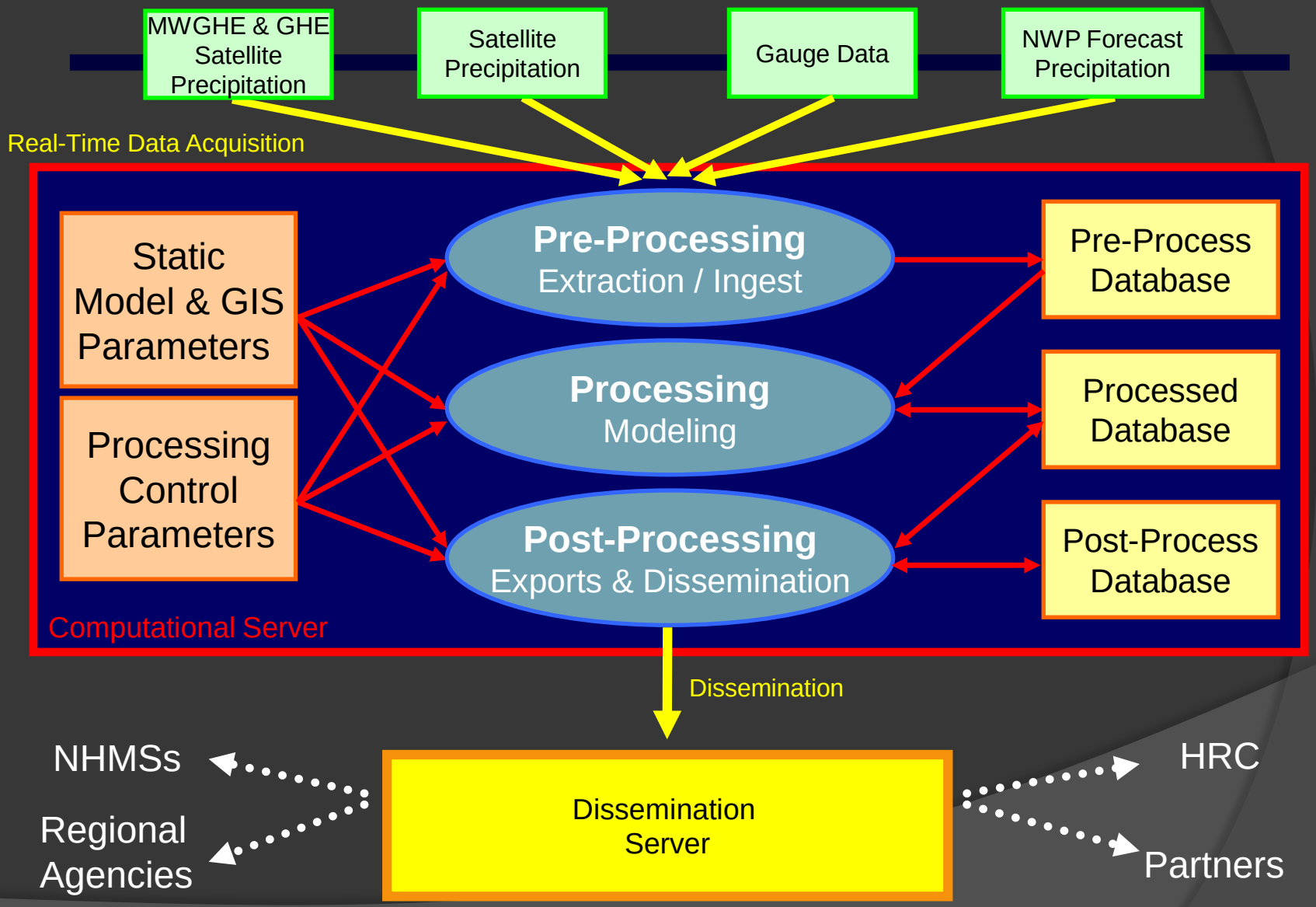


1. Operational Concept And System Design

South Asia Flash Flood Guidance Operational Concept

- SAsia FFG Operational Data Processing Goals
  - Provide fully-automated data acquisition, ingest, processing, modeling, product export and dissemination with various contingency accommodations
  - Establish strategic data acquisition schedules to optimize data availability during SAsiaFFG model processing
  - Establish strategic processing schedules to expedite the availability of FFG results using sustainable processing loads
- SAsiaFFG Operational processing design and automation aims to minimize maintenance responsibilities and demand on staff resources, allowing forecasters to focus on product interpretation and application and allowing IT Staff to focus on critical incidents requiring specific expertise.

SAsiaFFG General Data Flow Processing Design



SAsia-FFG - Southern Asia Regional Flash Flood Guidance System

Current Date: 2018-03-06 16:35 UTC Product Date: 2018-03-06 15:00 UTC

Year: 2018 Month: 03 Day: 06 Hour: 15 REGION: REGIONAL OPTION: MEDIAN Submit

-1 Month | -1 Day | -6 Hours | -1 Hour | +1 Hour | +6 Hours | +1 Day | +1 Month

Prev 6-hr Interval (12 UTC) | Reset to Current | Next 6-hr Interval (18 UTC)

Product Console - Main Table

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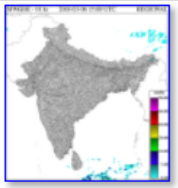
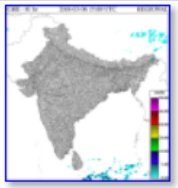
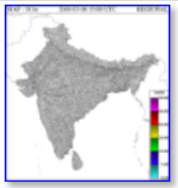
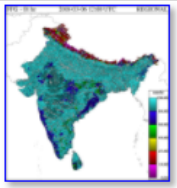
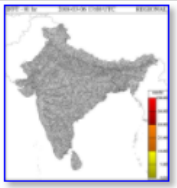
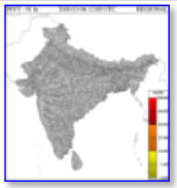
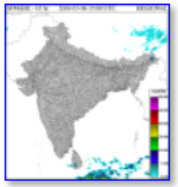
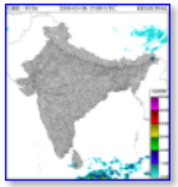
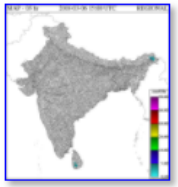
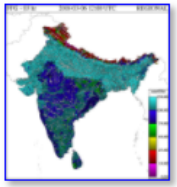
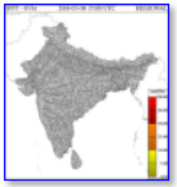
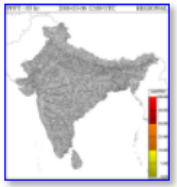
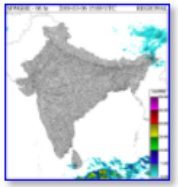
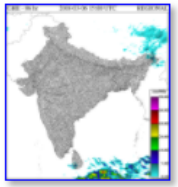
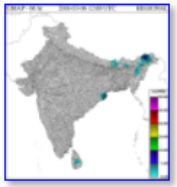
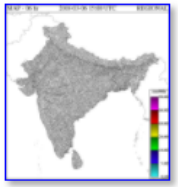
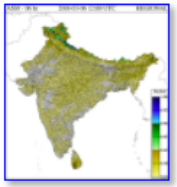
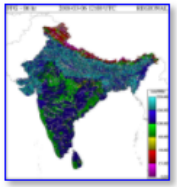
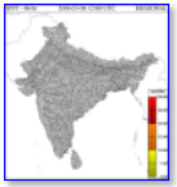
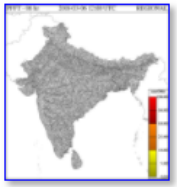
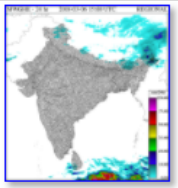
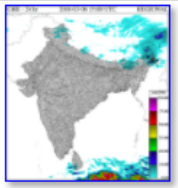
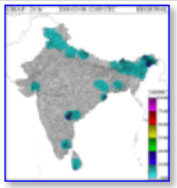
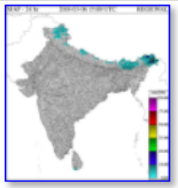
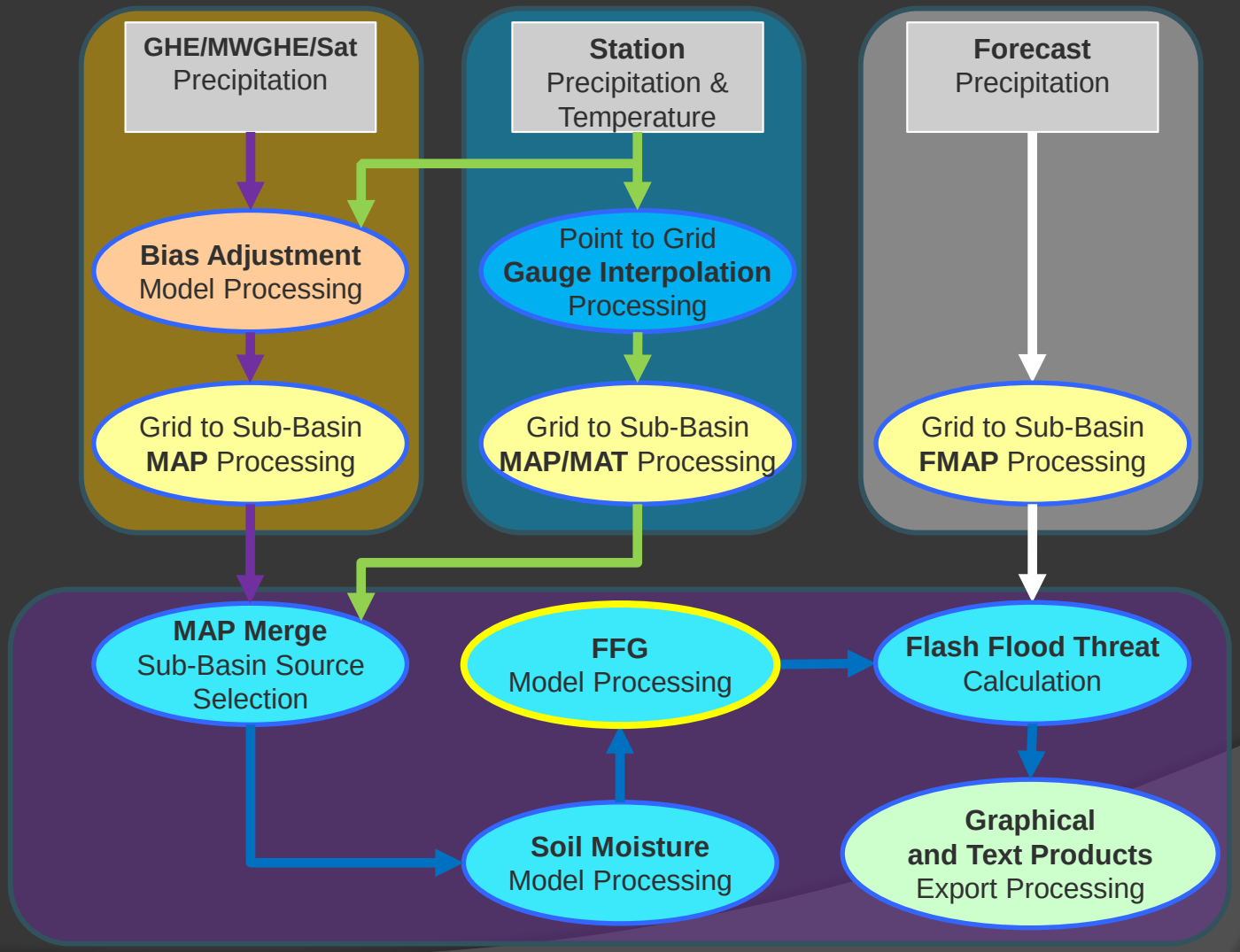
01-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view		 2018-03-06 15:00 UTC Text: view		 2018-03-06 12:00 UTC Text: view	 2018-03-06 13:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
03-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view		 2018-03-06 15:00 UTC Text: view		 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
06-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
24-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view				

Composite Product: text , CSV , CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2018/03/06

FFGS Model Processing Overview



SAsiaFFG Data Dissemination User Interface

- Purpose and Intent of the Product User Interface (web access)
  - Provide organized and convenient access to downloadable data products for local acquisition to support Forecaster application
  - Facilitate preliminary product review in order to focus forecaster attention on urgent points of interest relating to potential flash flooding
  - Facilitate the collaborative quality control and operational management efforts of Forecasters and IT Staff (system administrators)

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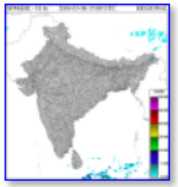
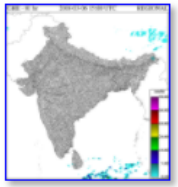
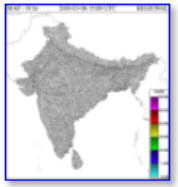
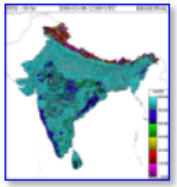
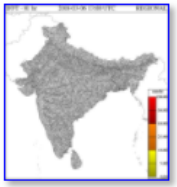
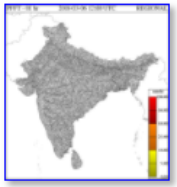
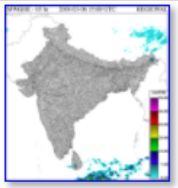
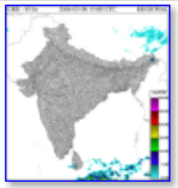
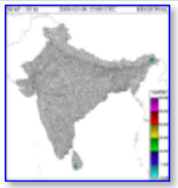
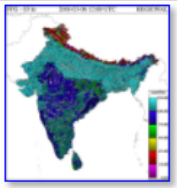
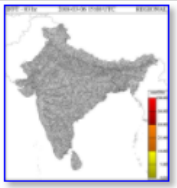
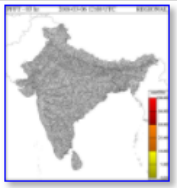
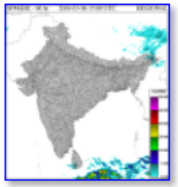
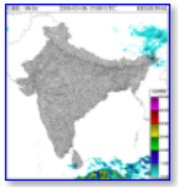
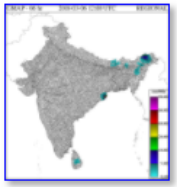
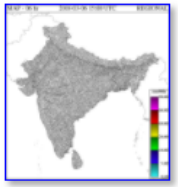
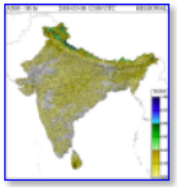
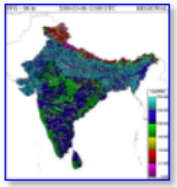
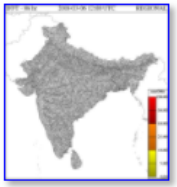
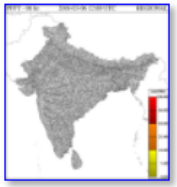
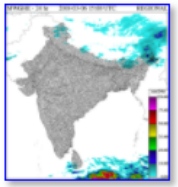
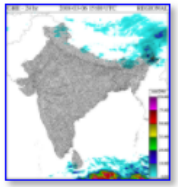
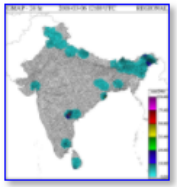
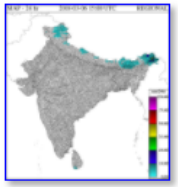
01-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view		 2018-03-06 15:00 UTC Text: view		 2018-03-06 12:00 UTC Text: view	 2018-03-06 13:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
03-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view		 2018-03-06 15:00 UTC Text: view		 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
06-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
24-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view				

Composite Product: text , CSV , CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2018/03/06

2. Floods and flash floods in perspective

Distributed Hydrologic Model

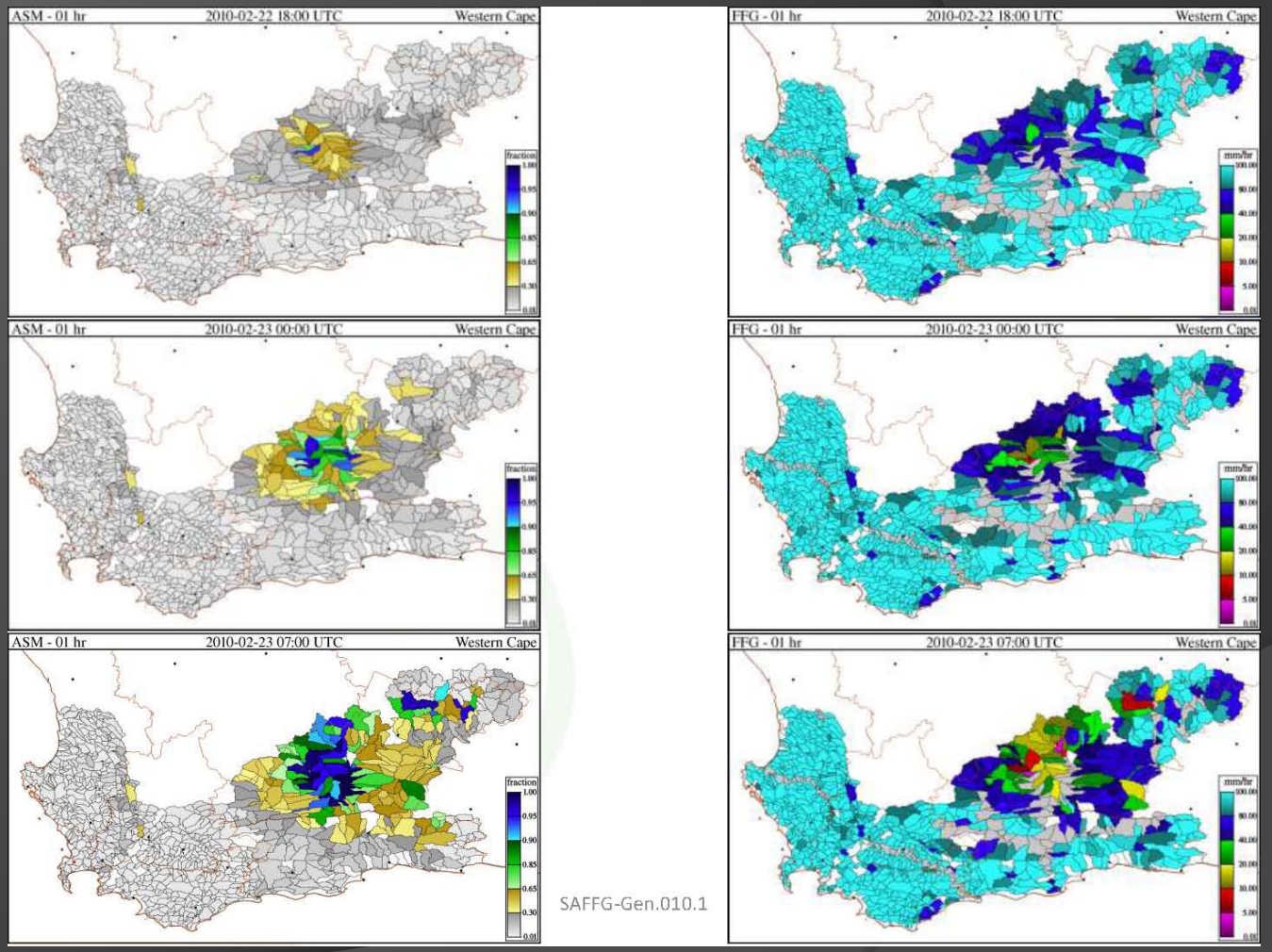
- *Tool for short and long term forecasting of floods*
- *Produces entire hydrographs (w/ high uncertainty on small scales)*
- *Difficult to ingest local precipitation information after model cycle*
- *Awkward for local forecasters to make adjustments, needed for reliable flash flood warning*

Flash Flood Guidance

- *Diagnostic tool useful for quick flash flood occurrence diagnosis and short term prediction*
- *Concerns bankfull flows*
- *Readily ingests local precipitation information*
- *Local forecaster adjustments easy*
- *Promotes Close Collaboration of Hydrologists with Meteorologists*

Large-river flood-warning strategies ineffective for flash floods

- Response time in the range of 1-6 hours.
- As opposed to river floods, flash floods have a quick response to rainfall input.
- Upland basins are most likely killers.



Flash Floods in Perspective

Where as river flood forecasting is generally a *Hydrological* problem, flash flood forecasting is a ***Hydro-meteorological*** problem.

3. Impacts of Flooding

Economic Impacts of Flooding

- Revenue Loss
- Impacts Tourism
- Loss of investment
- Impacts to infrastructure and property
- Loss of jobs

Social Impacts of Flooding

- Water supply disruptions
- Drinking water quality problems
- Drownings and displaced people
- House and dwelling destruction
- Damages to roads leading to communities cut off from aid
- Crop losses
- Epidemics – cholera, diarrhea, malaria outbreaks

4. Basic Meteorology of rainfall systems causing flash floods

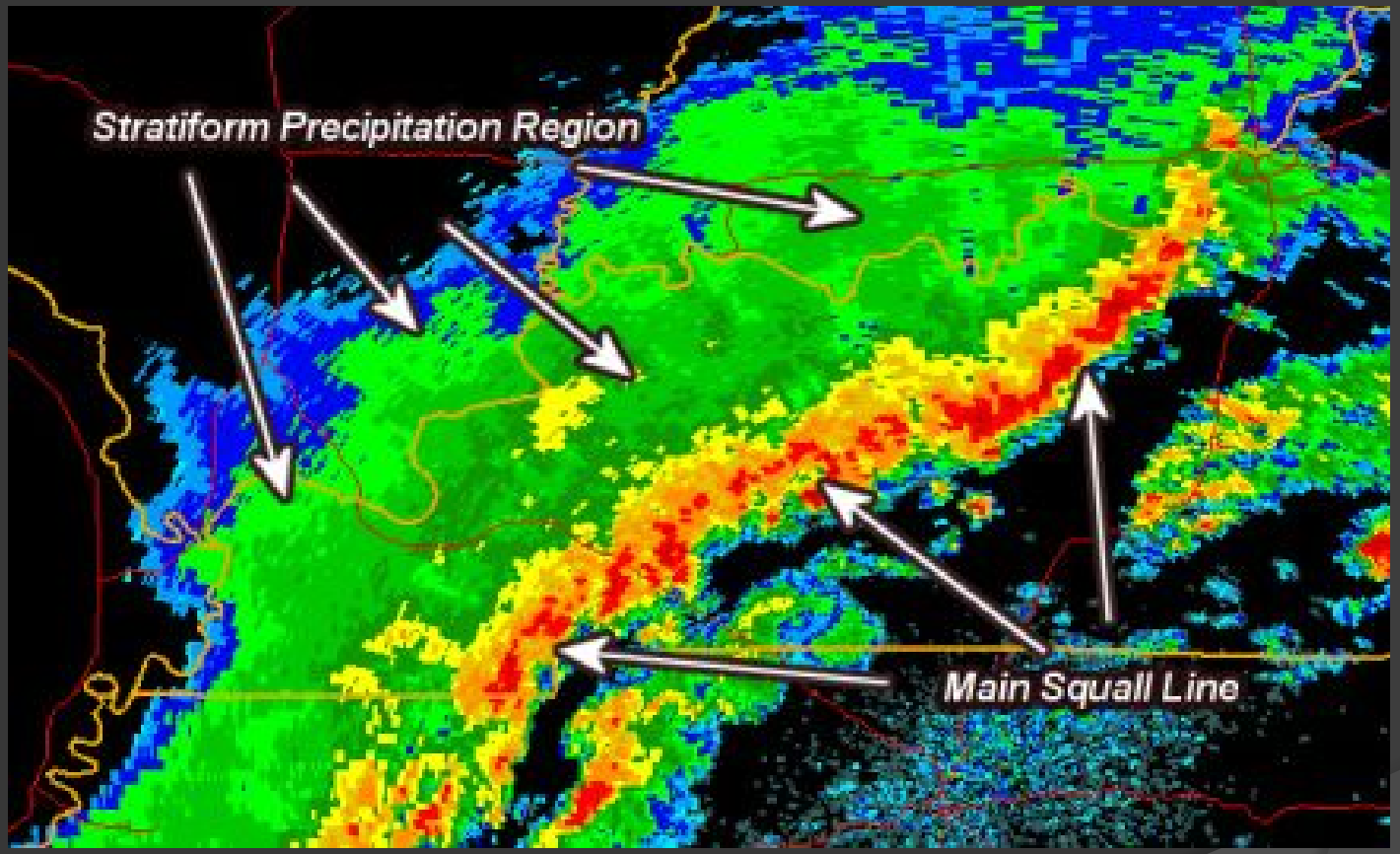
Some Prominent Weather Patterns Causing Weather Related Disasters

Some of the South Asia Region rainfall is caused by the following triggering mechanisms

- Monsoon
- Easterly waves
- Tropical Cyclones
- Thunderstorms

Factors that suggest a rainfall event may lead to a flash flood include. 1) slow movement of a system,

Factors that suggest a rainfall event may lead to a flash flood include. 1) slow movement of a system,



2) prolonged heavy-to-intense rainfall rates,

Factors that suggest a rainfall event may lead to a flash flood include. 1) slow movement of a system, 2) prolonged heavy-to-intense rainfall rates,

3) areal coverage of intense rainfall rates.

So in summary ……

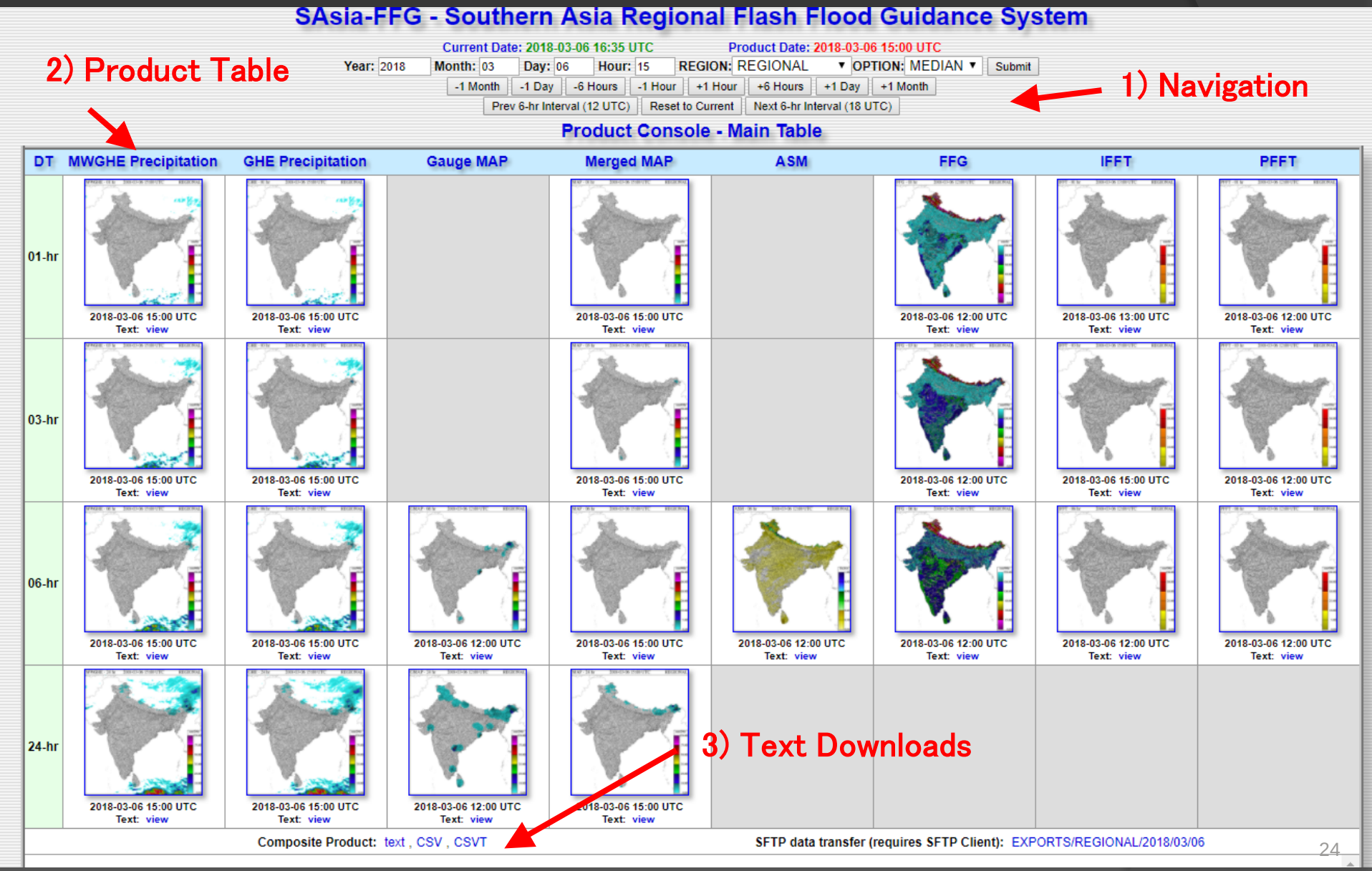
In order for a flash flood to occur, heavy precipitation must fall in a region that has appropriate hydrological ingredients in place.

For heavy precipitation to occur, high rainfall rates must be sustained.

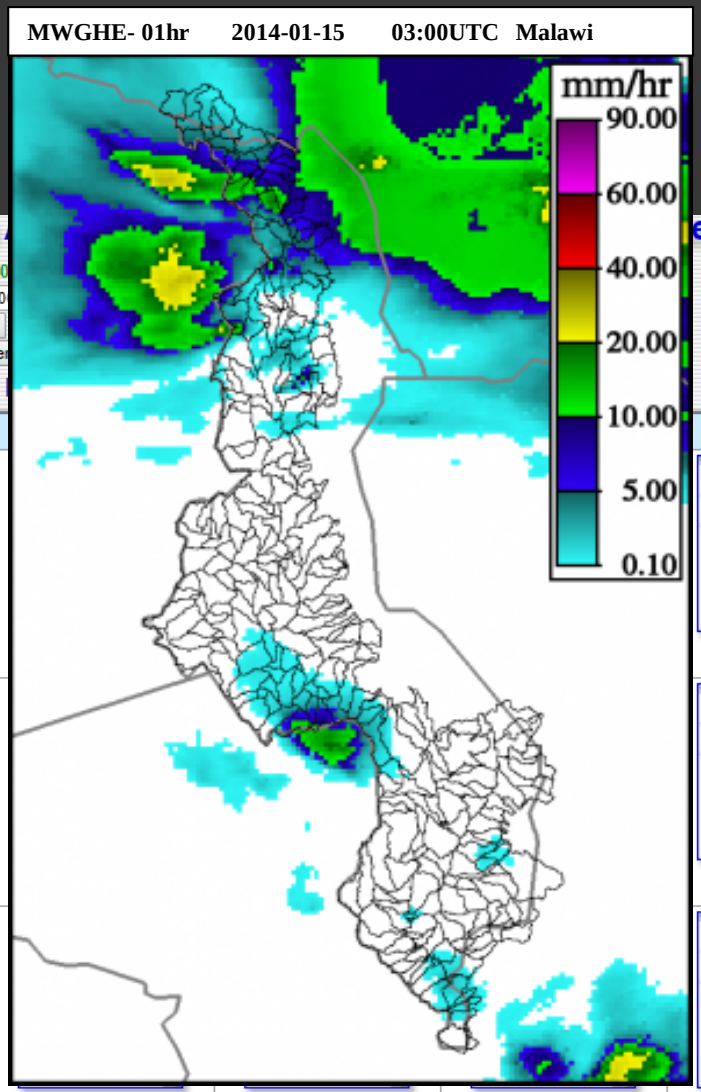
Long duration of high rainfall rates results from slow movement of the rainfall-producing system.

Standardized FFG System Forecaster User Interface

The flash flood guidance system offers products to assist forecasters



Products: Satellite



SAsia-FFG - Southern … em

Current Date: 2018-0…

Year: 2018 Month: 03 Day: 0…

-1 Month -1 Day

Prev 6-hr Inter…

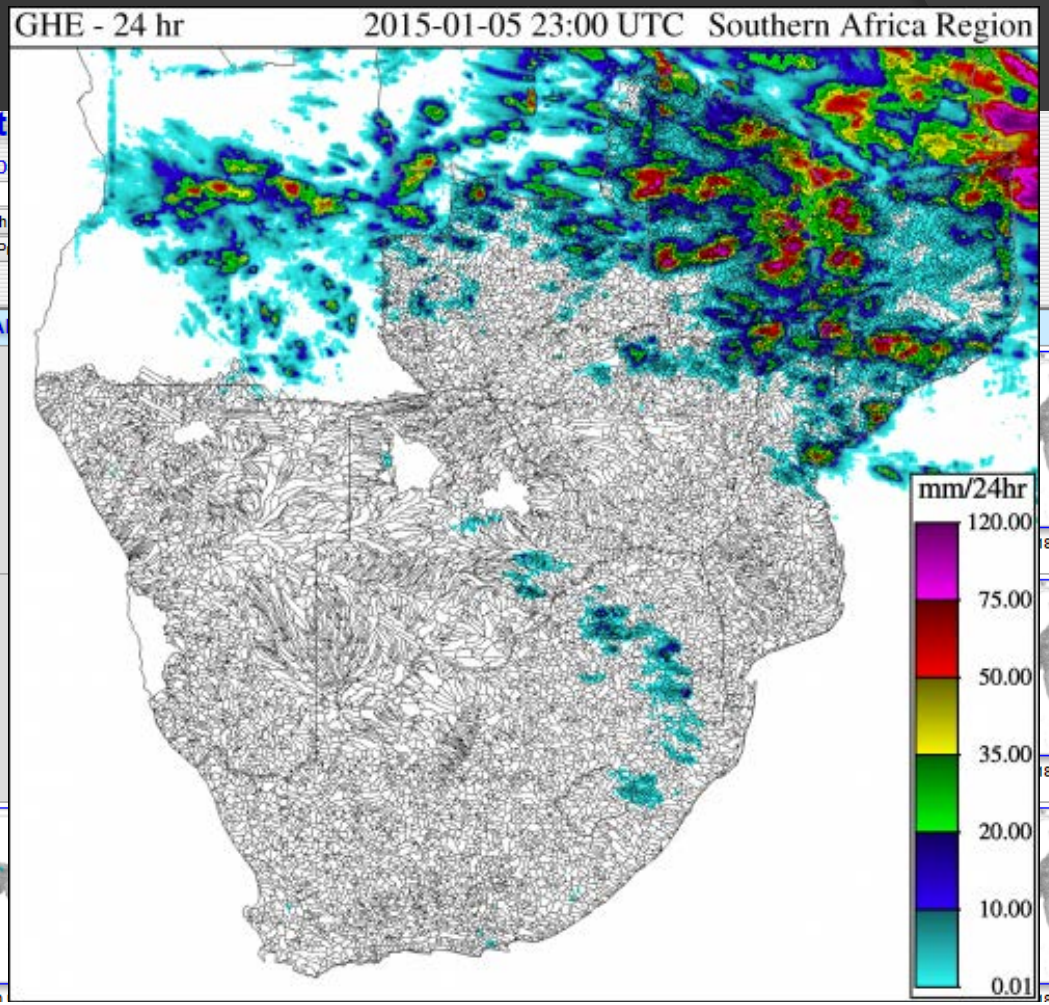
DT	MWGHE Precipitation	GHE Precipitation	Gauge MAP			IFFT	PFFT
01-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view				2018-03-06 13:00 UTC Text: view	2018-03-06 12:00 UTC Text: view
03-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view				2018-03-06 15:00 UTC Text: view	2018-03-06 12:00 UTC Text: view
06-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC	2018-03-06 12:00 UTC	2018-03-06 15:00 UTC	2018-03-06 12:00 UTC	2018-03-06 12:00 UTC	2018-03-06 12:00 UTC
24-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	2018-03-06 12:00 UTC Text: view	2018-03-06 15:00 UTC Text: view			

Composite Product: text , CSV , CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2018/03/06

MWGHE: The Microwave-adjusted Global HydroEstimator satellite-based product provides accumulations of infrared-based precipitation (mm).

Products: Satellite



SAsia-FFG - Sout

Current D

Year: 2018 Month: 03

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P

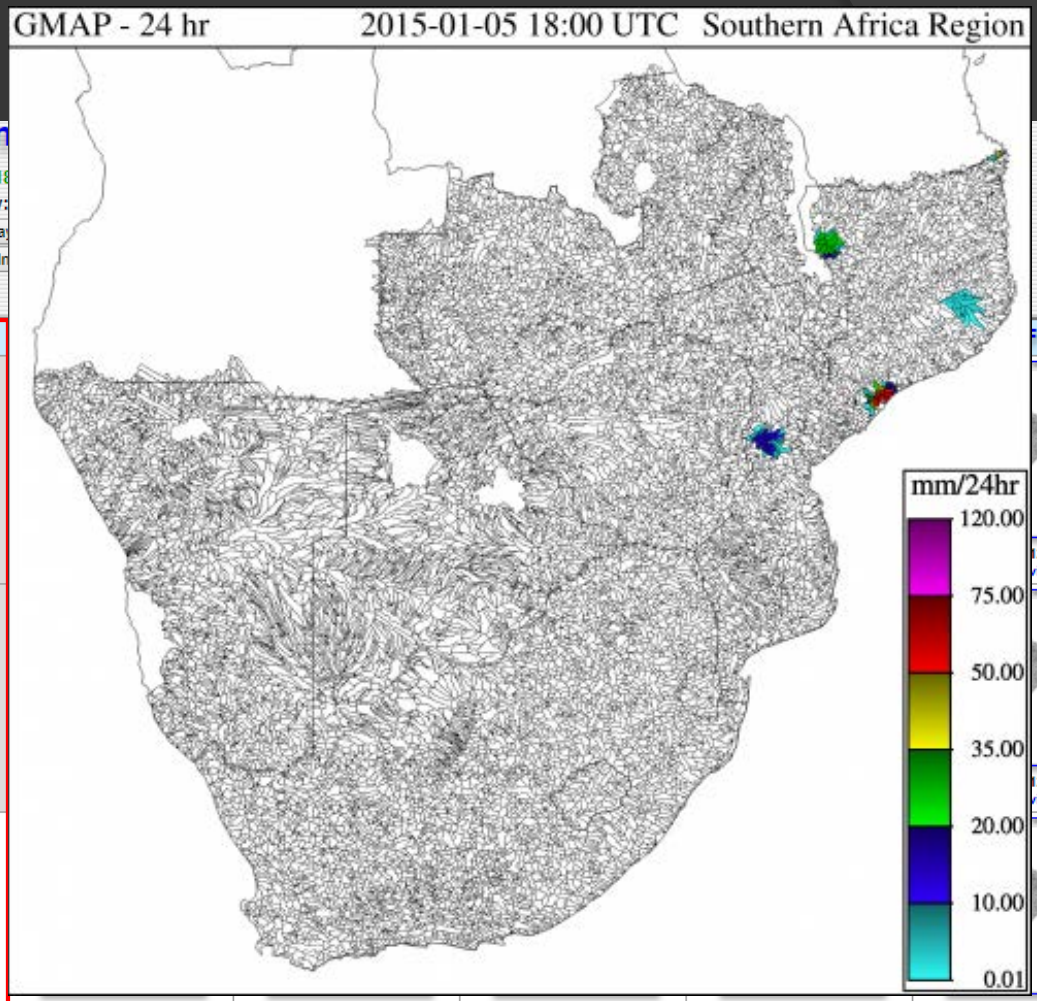
DT	MWGHE Precipitation	GHE Precipitation	Gauge MA		PFFT
01-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view			18-03-06 12:00 UTC Text: view
03-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view			18-03-06 12:00 UTC Text: view
06-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: vie	2018-03-06 12:00		18-03-06 12:00 UTC
24-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	2018-03-06 12:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	

Composite Product: text , CSV , CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2018/03/06

The Global HydroEstimator (GHE) satellite-based product provides accumulations (mm) of satellite-based precipitation.

Products: Gauge MAP



SAsia-FFG - Southern

Current Date: 2018

Year: 2018 Month: 03 Day:

-1 Month -1 Day

Prev 6-hr In

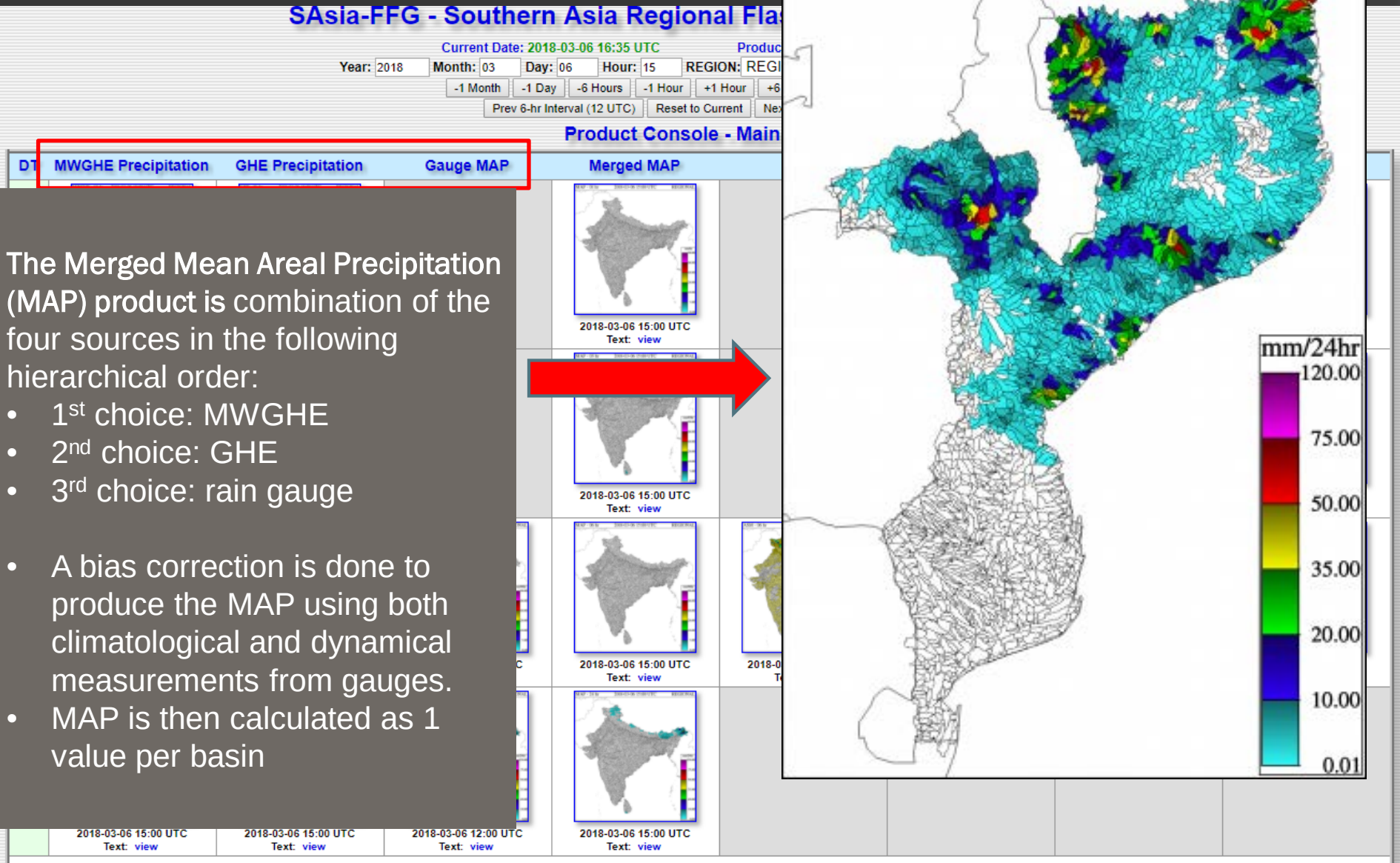
DT	MWGHE Precipitation	GHE Precipitation	Gauge MAP
01-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	
03-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	
06-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	2018-03-06 12:00 UTC Text: view
24-hr	2018-03-06 15:00 UTC Text: view	2018-03-06 15:00 UTC Text: view	2018-03-06 12:00 UTC Text: view

Composite Product: text , CSV , CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2018/03/06

The Gauge MAP data products are updated every six hours and reflect accumulations of basin-average precipitation of a given duration

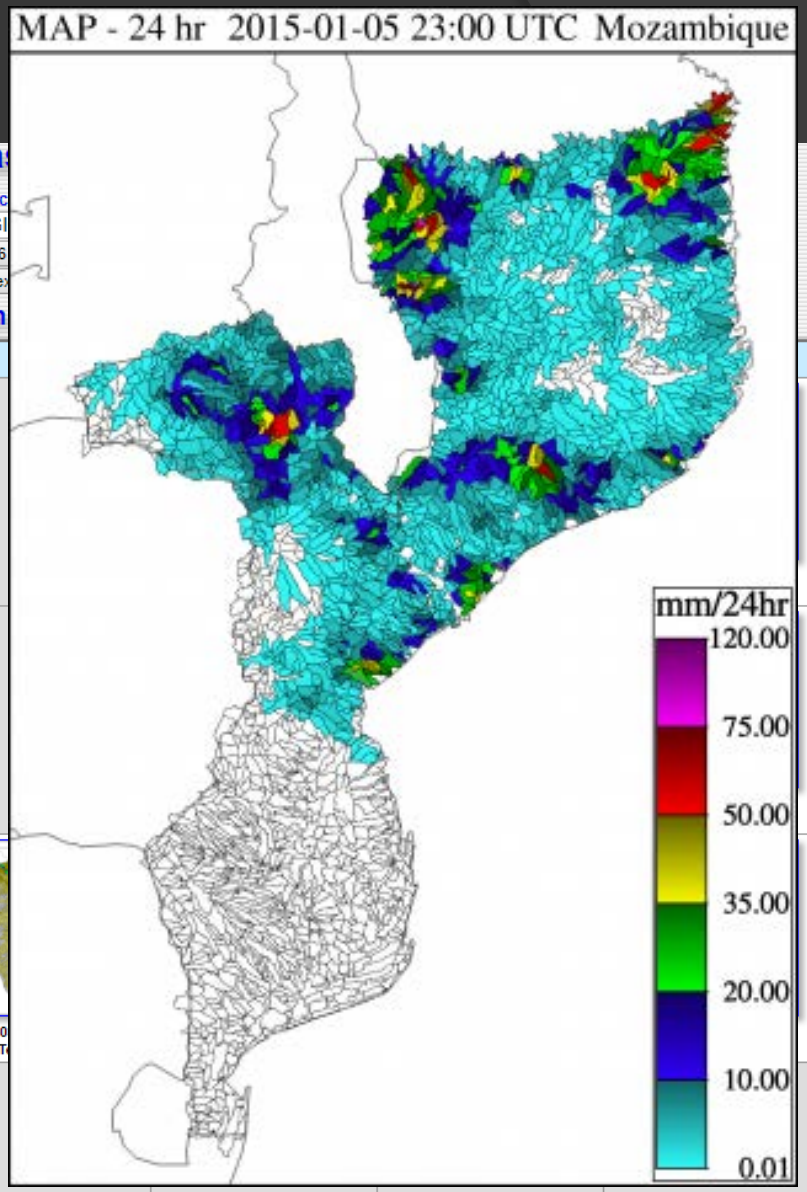
Products: Merged MAP



The Merged Mean Areal Precipitation (MAP) product is combination of the four sources in the following hierarchical order:

- 1st choice: MWGHE
- 2nd choice: GHE
- 3rd choice: rain gauge

- A bias correction is done to produce the MAP using both climatological and dynamical measurements from gauges.
- MAP is then calculated as 1 value per basin



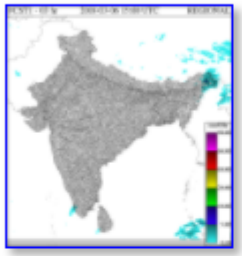
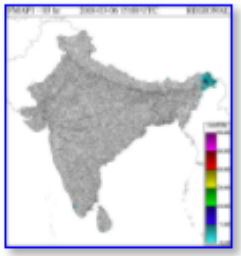
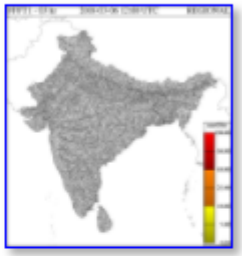
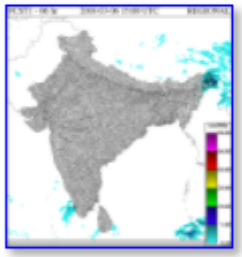
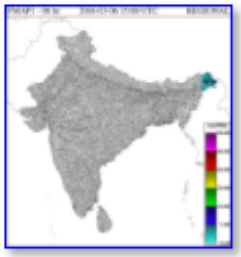
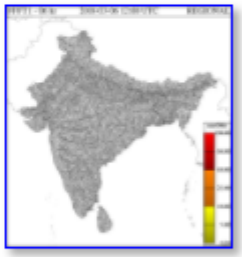
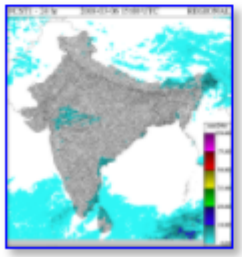
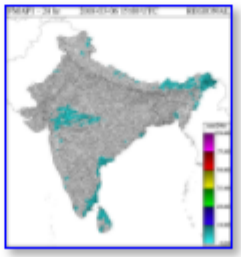
How to interpret MAP

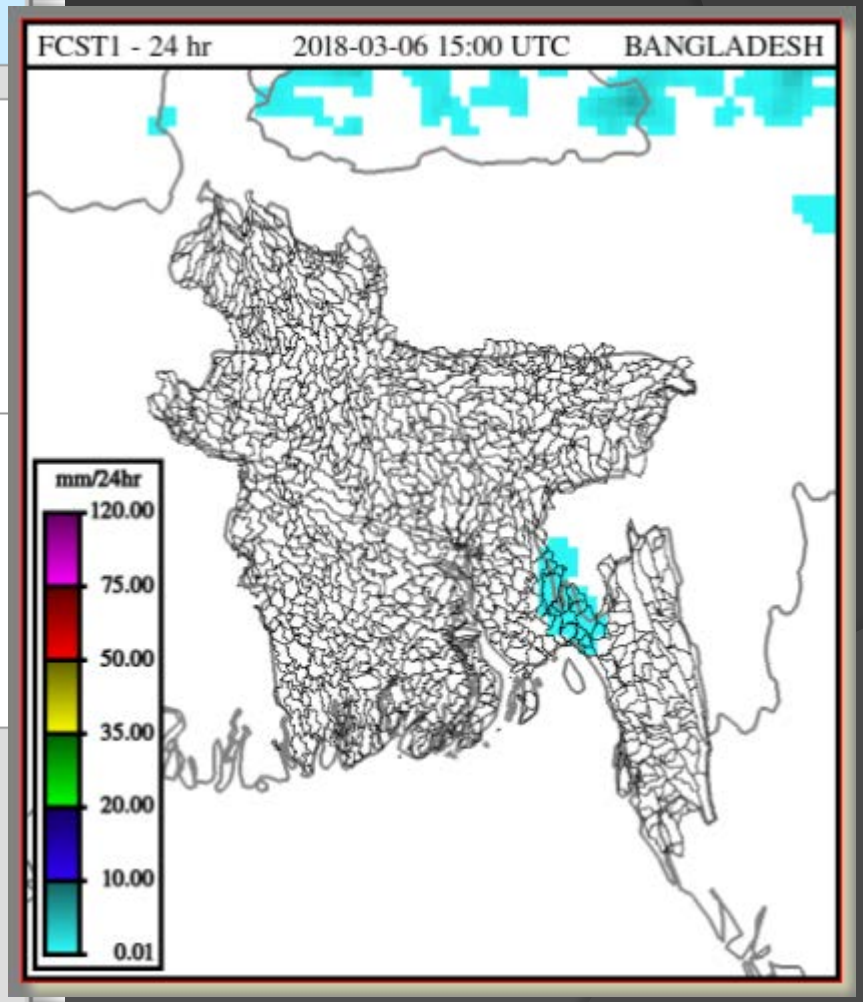
- MAP is NOT a prediction!
- MAP is "historical" rain, i.e. that HAS fallen in the past 1 hour, or over the past 3 hours, or the past 6 hours
- It provides 1 average rainfall value per basin, so it will be a lower value than any single rainfall station
- Provides an indication of the rainfall distribution

Products: Forecast

The forecast precipitation product is produced by using numerical forecasts from the Unified Model.

Product Console
Model Forecast Products

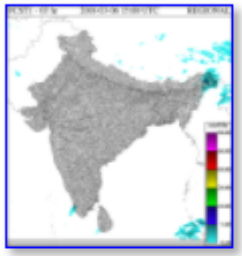
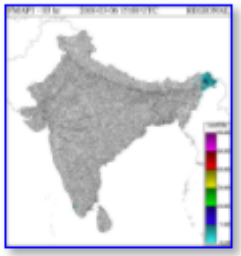
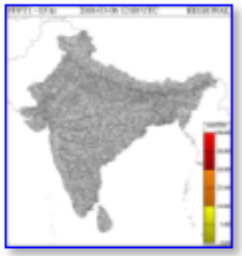
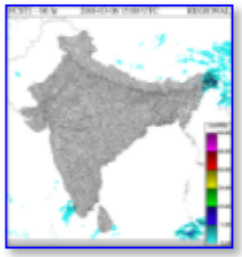
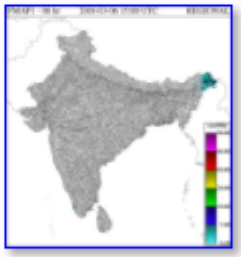
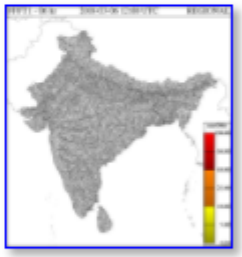
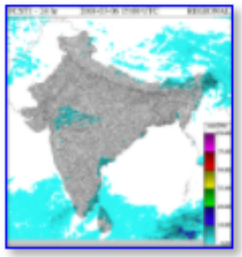
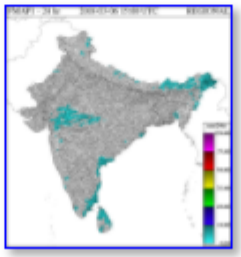
DT	WRF Forecast Precipitation	WRF FMAP	WRF FFFT
01-hr			
03-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
06-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
24-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	

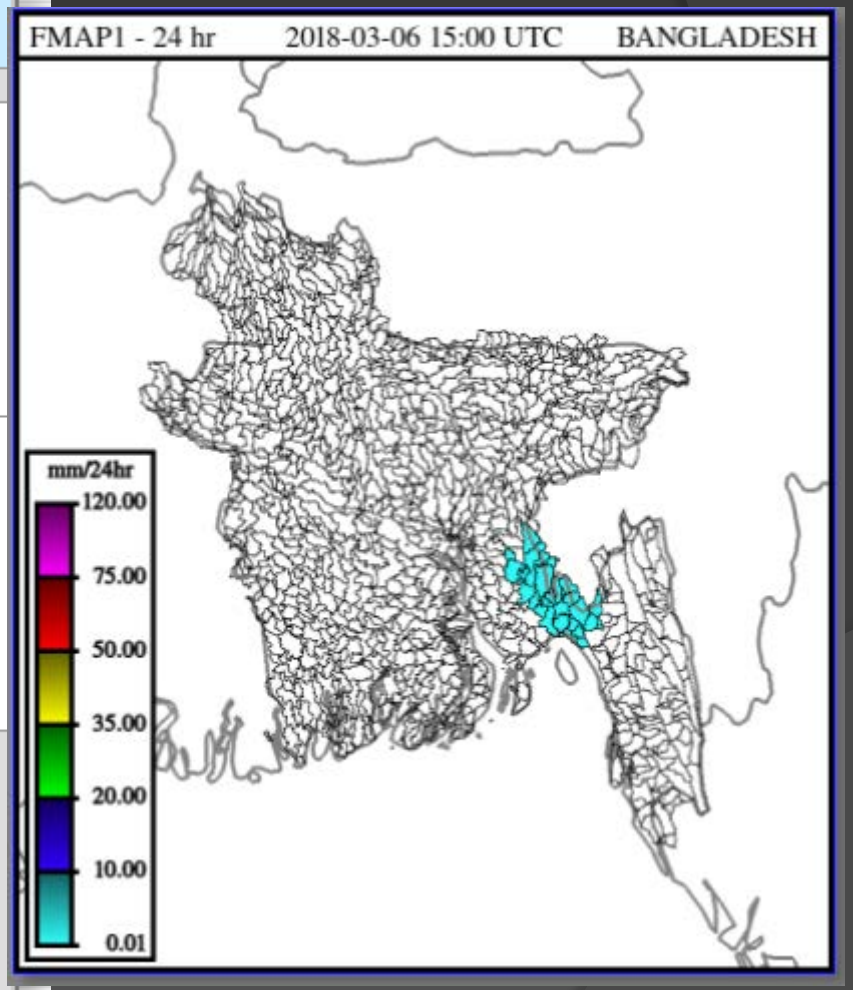


Products: Forecast MAP

The Forecast Mean Areal Precipitation (FMAP) product reflects rainfall accumulations produced using numerical forecasts from the Unified forecast Model of basin-average precipitation.

Product Console
Model Forecast Products

DT	WRF Forecast Precipitation	WRF FMAP	WRF FFFT
01-hr			
03-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
06-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	 2018-03-06 12:00 UTC Text: view
24-hr	 2018-03-06 15:00 UTC Text: view	 2018-03-06 15:00 UTC Text: view	



5. Basic river hydrology from flooding perspective

Flash floods are not generated purely by intense rainfall but also by the hydrologic processes of the land surface on which the rainfall occurs.

It is the interaction between meteorology and hydrology of a location - where the complex interrelationships between:

- atmospheric moisture,
- the terrain,
- soil moisture content,
- and geomorphology

can result in the enhancement of the runoff potential of a given rainfall event, increasing the likelihood of a flash flood event.

Dependent on two factors:

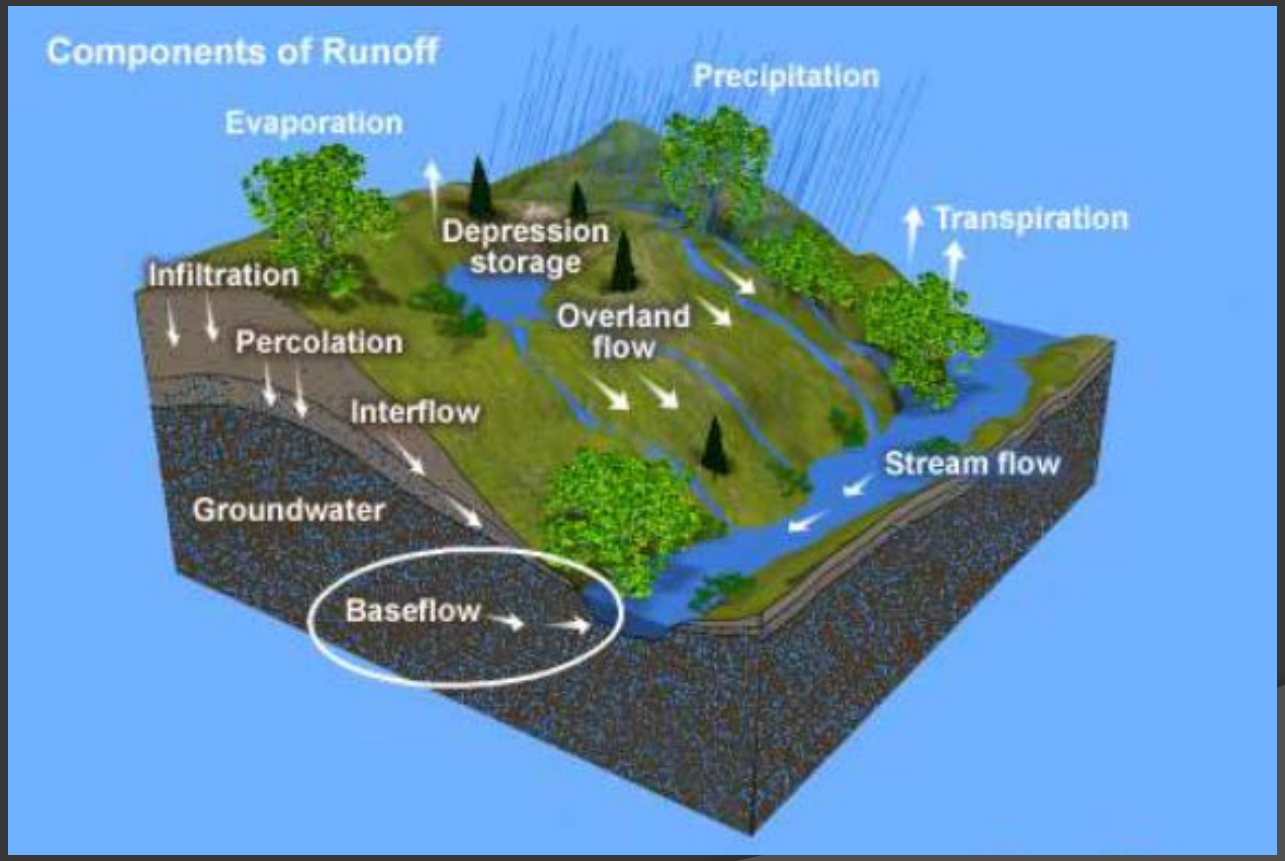
1) is the rainfall rate and the ability for the ground, rivers and streams to absorb the water and

2) the amount of water that is already stored in the ground or moving through the rivers and streams.

Hydrologic modeling of flash floods includes information on:

Hydrological process including components of the hydrologic cycles, rainfall-runoff processes, evaporation, infiltration and groundwater flow, water budgets, surface and sub-surface hydrology.

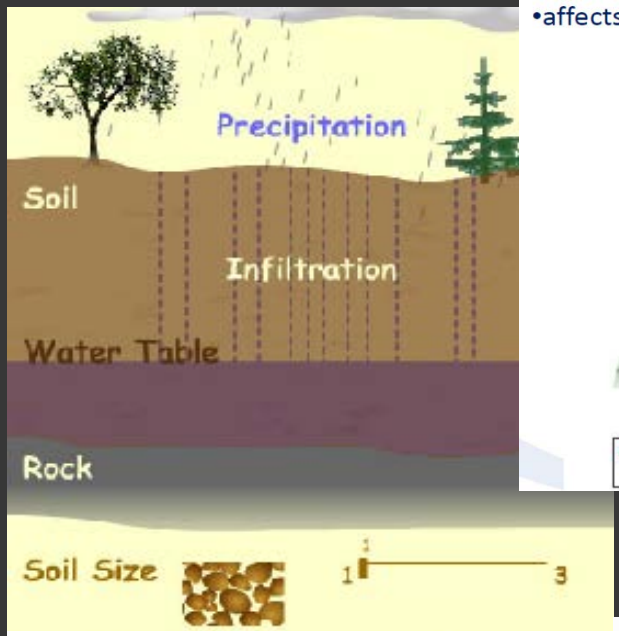
Volume = inflow – outflow of a system



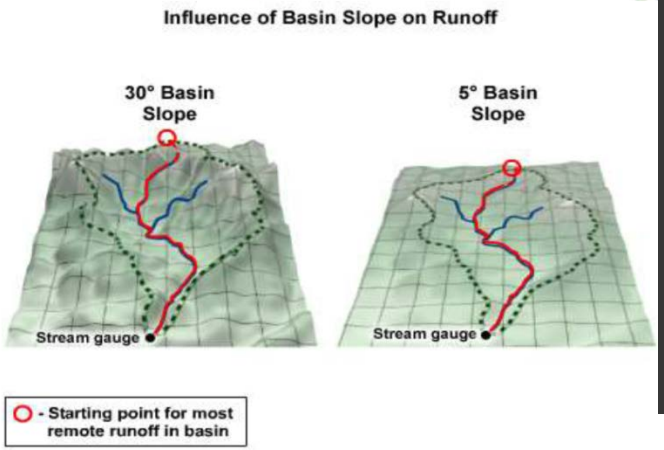
THIS IS KEY INFORMATION FOR FLOOD AND FLASH FLOOD FORECASTING

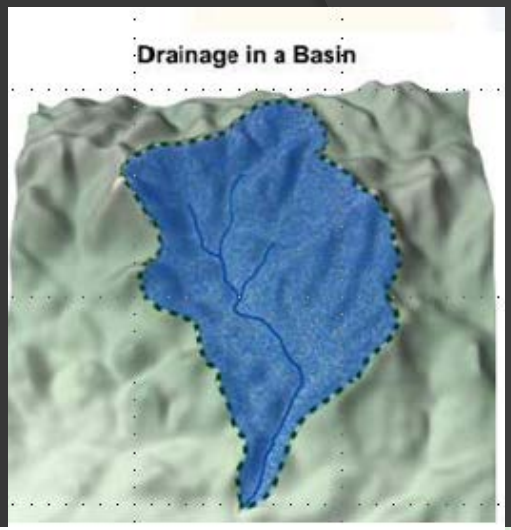
Hydrologic modeling of flash floods includes information on:

Also needed is information on stream flow data networks, and detailed descriptions of the river basins, including vegetation types, soil types, topography, basin size, shape, slope.

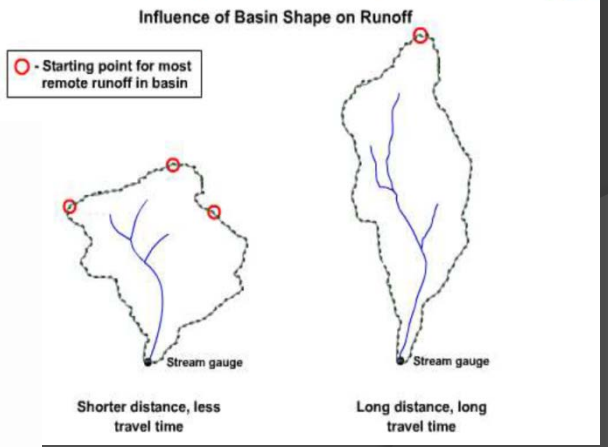


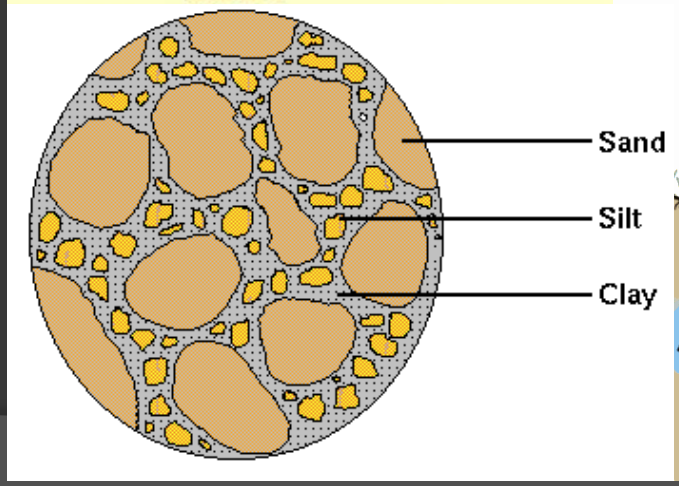
•affects amount and timing of runoff

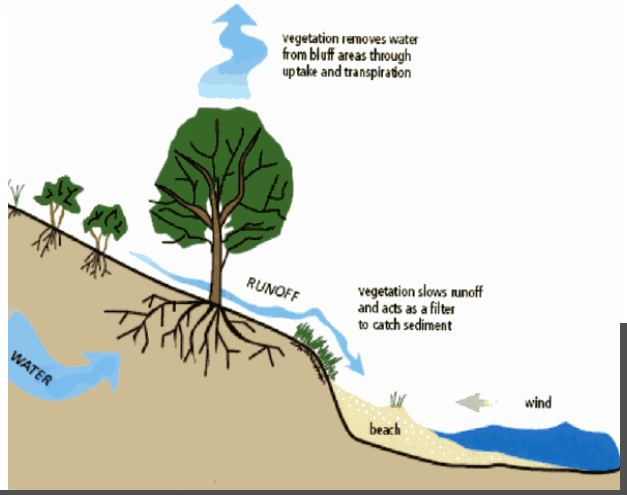




influences magnitude and timing of peak flow



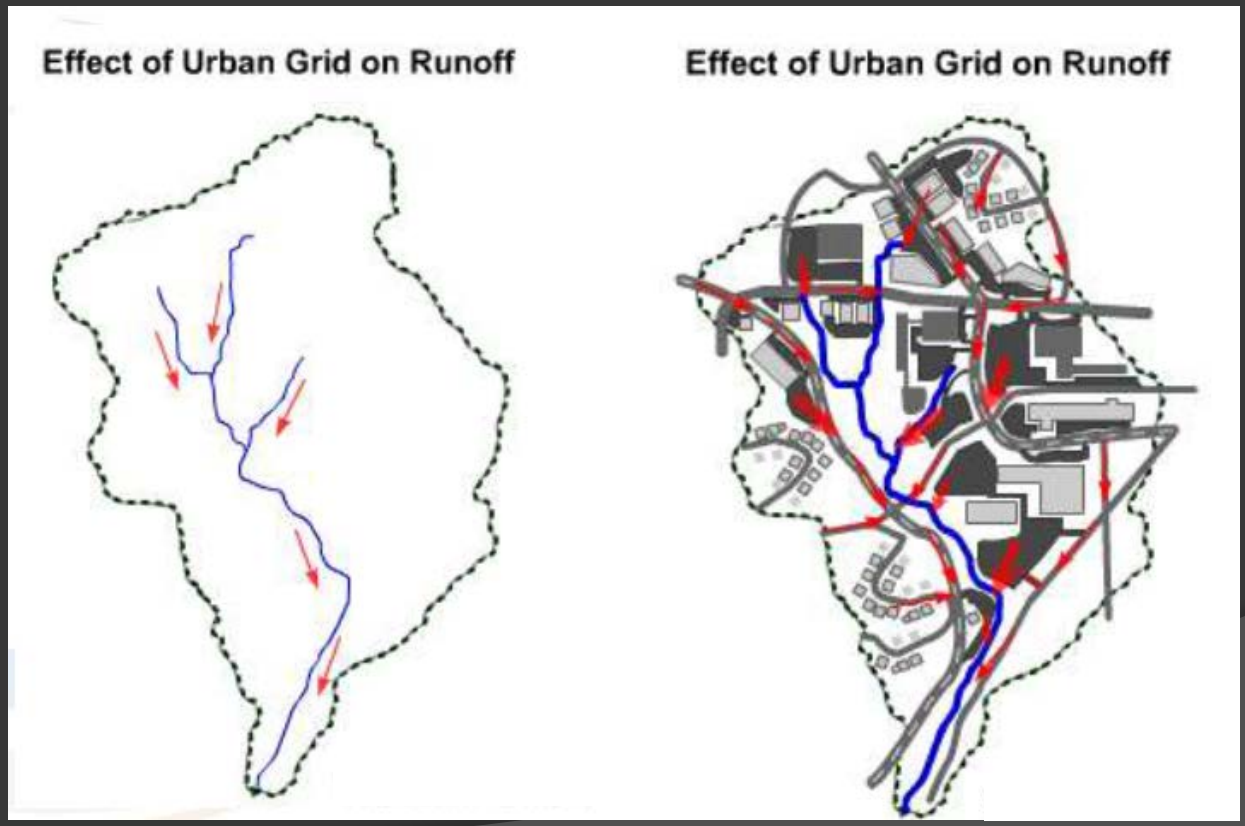




Urbanization

Results in changes of the natural ground surfaces and stream channels of the basin, permeability, roughness, etc.

Road and storm sewer systems add to stream density, resulting in more rapid runoff to stream channels (also because of decreased roughness)



So in summary ……

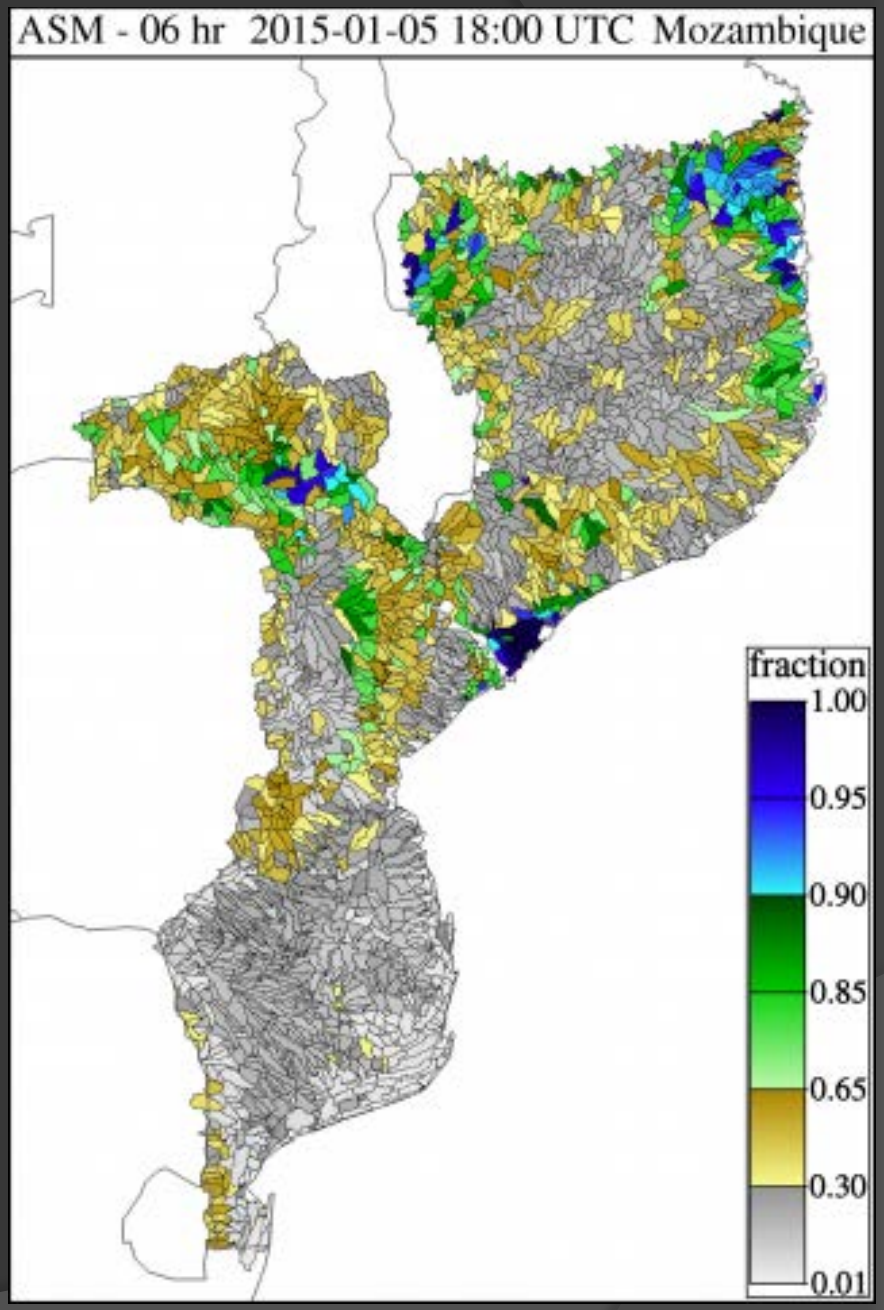
Flash floods are phenomenon in which the important hydrologic processes are occurring on the same spatial and temporal scales as the intense precipitation.

These include components of the hydrologic cycle, rainfall-runoff processes, evaporation, infiltration and groundwater flow, water budgets, surface and sub-surface hydrology, and properties unique to flash floods.

Products: ASM

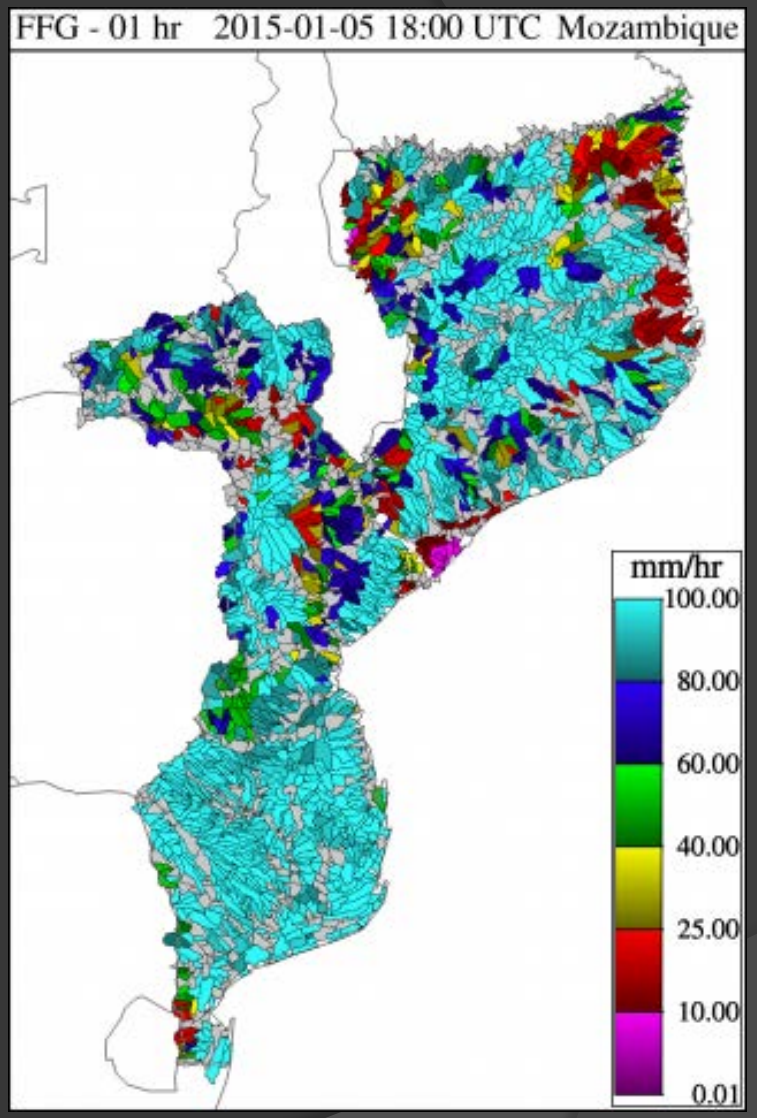
How to interpret ASM

- ASM is a model interpretation of soil moisture fraction, not real soil moisture!
- It is an instantaneous value, i.e. valid for that time and not an accumulation like the other variables
- Provides an indication of the average soil saturation in the basin
- The higher the value, the closer to saturation, so less rainfall is able to infiltrate the soil, and more rain will run off.



How to interpret FFG

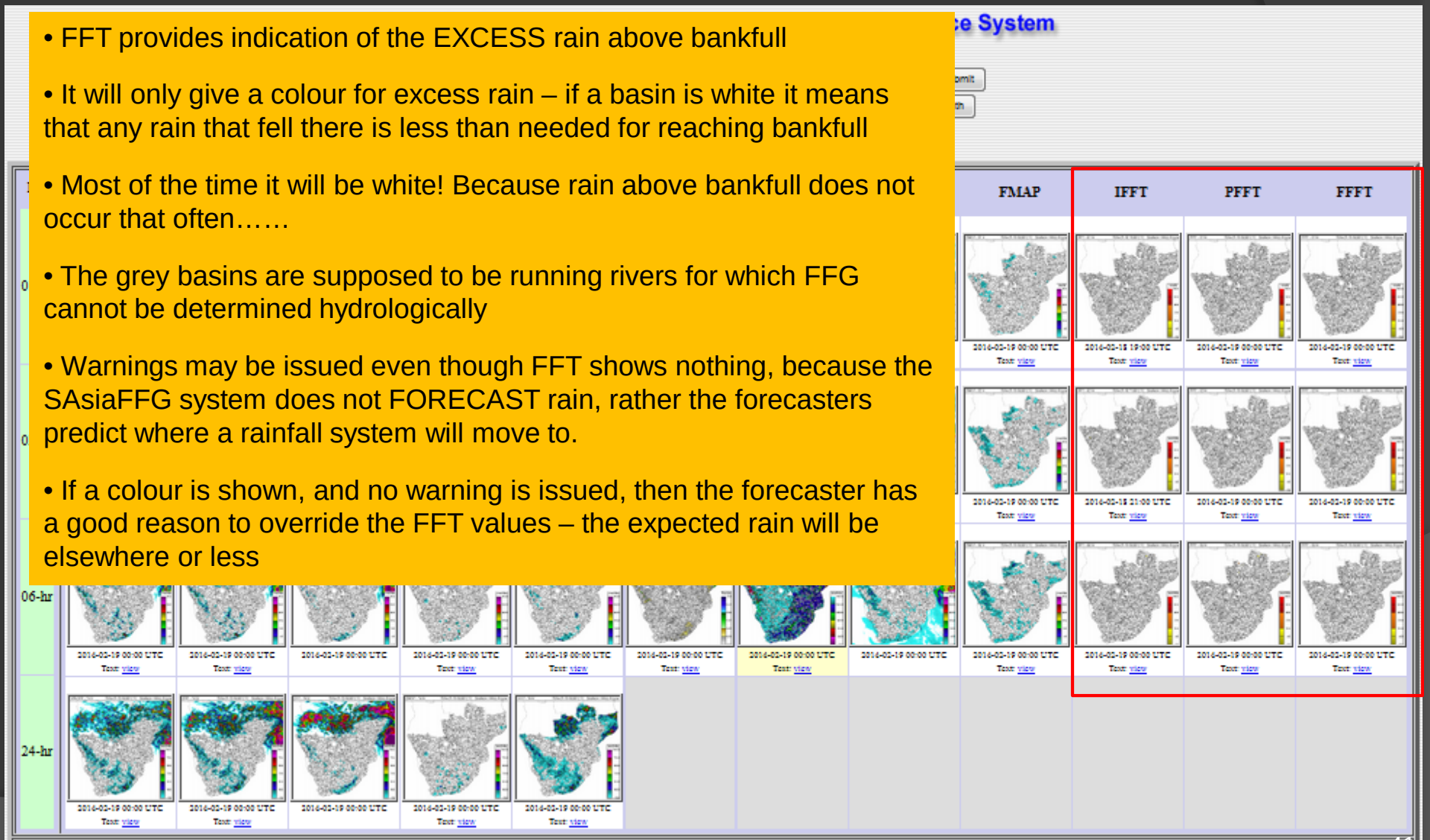
- Provides indication of total amount of rain NEEDED in the next 1 hour or next 3 hours, next 6 hours to reach bankfull at outlet of the basin.
- It is thus a FORECAST of the rain NEEDED
- It does not say where flooding is occurring, but only how much rain is needed
- Flooding will only occur if that amount of rain falls in the next 1, 3 or 6 hours
- It is useful to identify areas vulnerable to flooding
- It is a conservative value
- The lower the FFG value, the more dangerous it is (the less rain needed for bankfull)



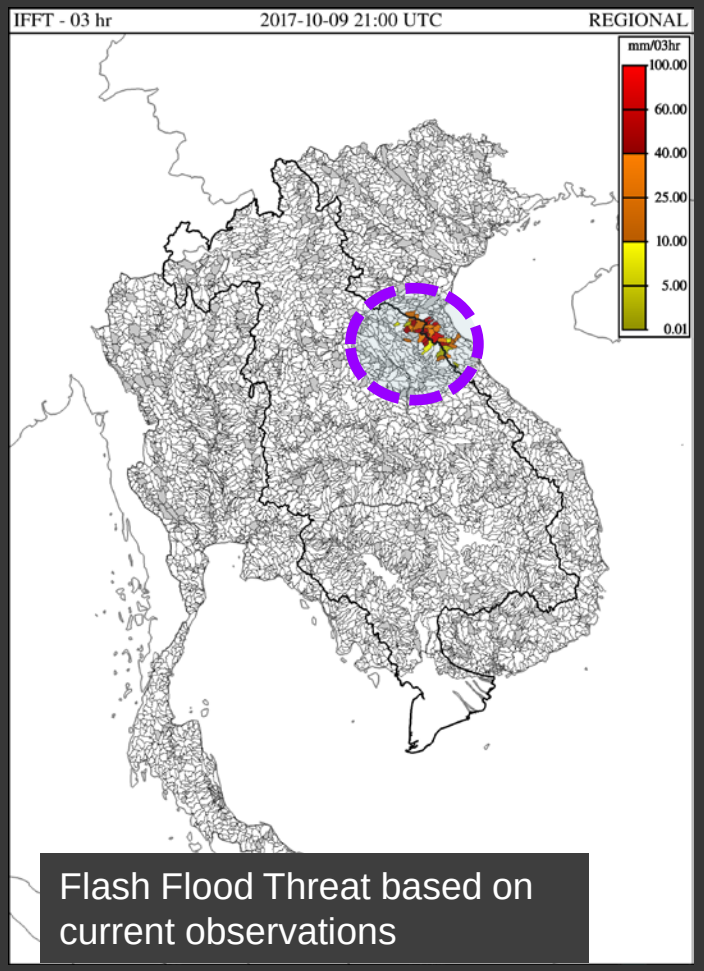
SAsiaFFG System Interface

How to interpret FFT

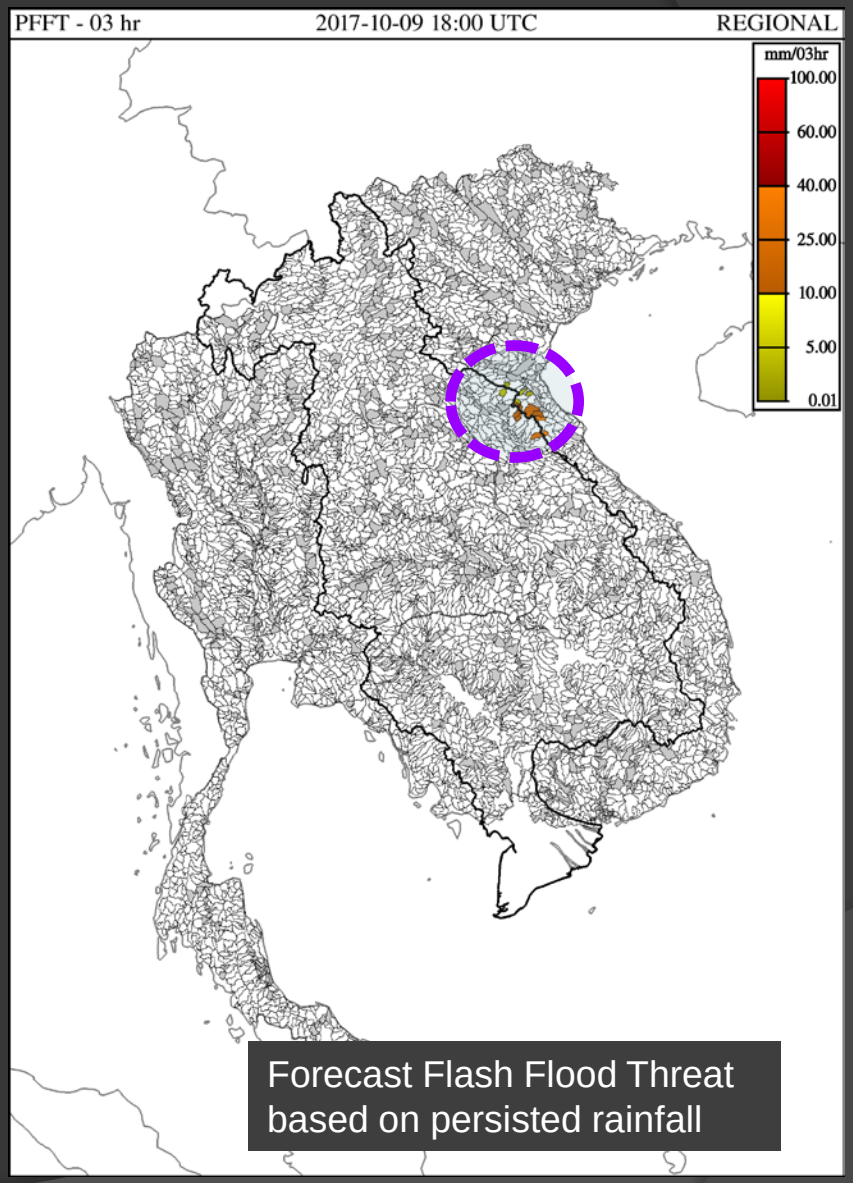
- FFT provides indication of the EXCESS rain above bankfull
- It will only give a colour for excess rain – if a basin is white it means that any rain that fell there is less than needed for reaching bankfull
- Most of the time it will be white! Because rain above bankfull does not occur that often……
- The grey basins are supposed to be running rivers for which FFG cannot be determined hydrologically
- Warnings may be issued even though FFT shows nothing, because the SAsiaFFG system does not FORECAST rain, rather the forecasters predict where a rainfall system will move to.
- If a colour is shown, and no warning is issued, then the forecaster has a good reason to override the FFT values – the expected rain will be elsewhere or less



The flash flood guidance system offers products to assist forecasters

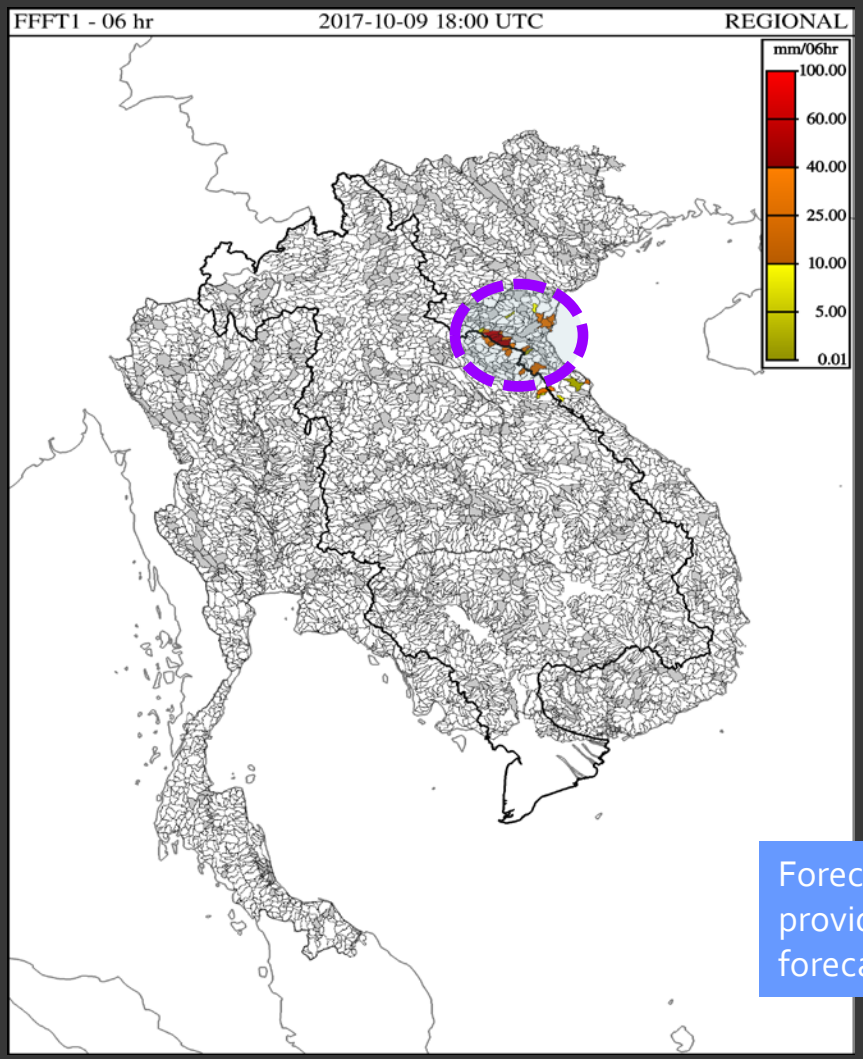


Flash Flood Threat based on current observations

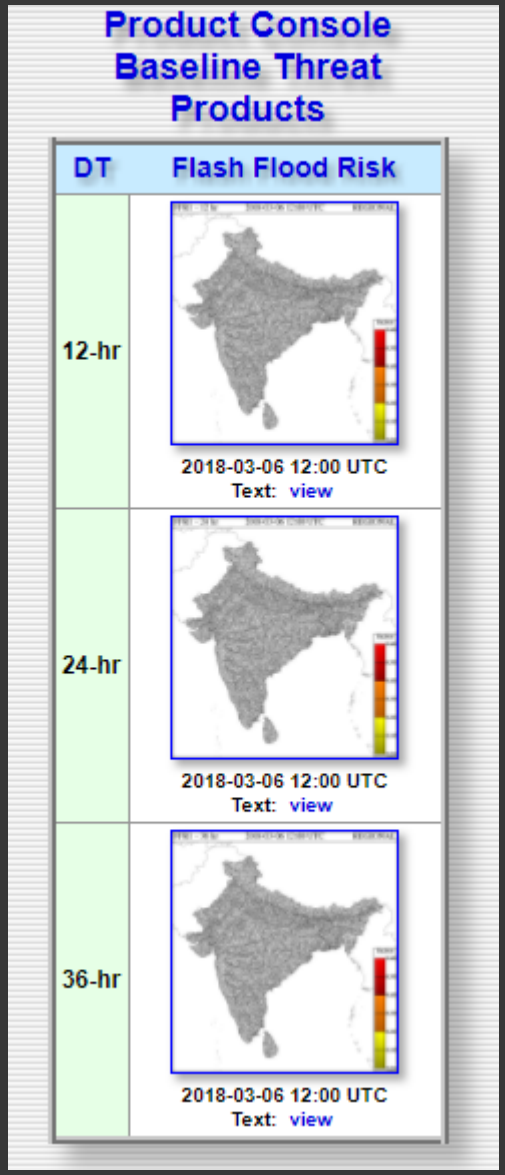


Forecast Flash Flood Threat based on persisted rainfall

The flash flood guidance system offers products to assist forecasters



Forecast Flash Flood Threat (FFFT) Product provides the forecaster with an idea of regions forecasted to be of concern for flash flooding.

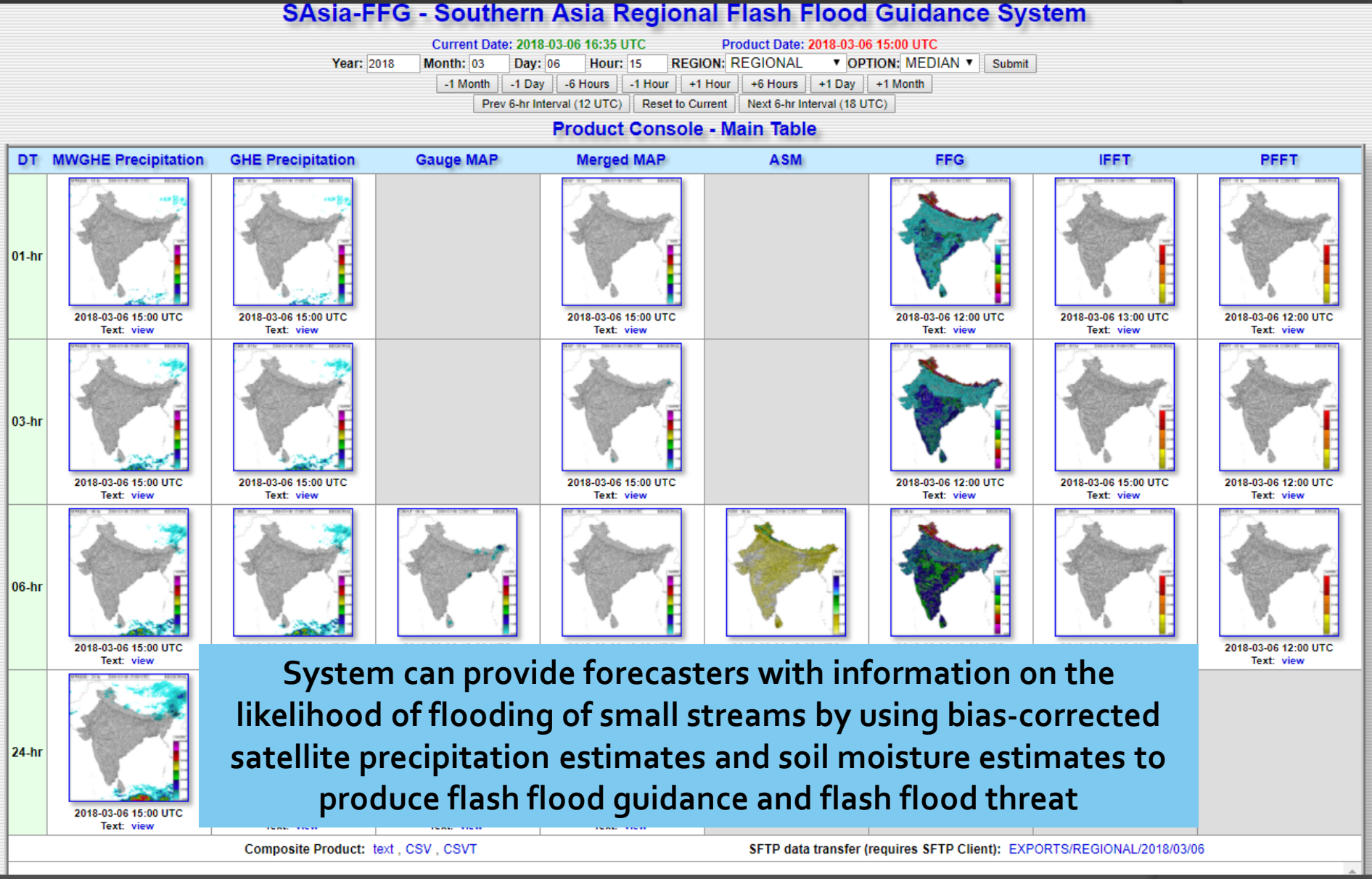


This is a measure of the forecast flash flood occurrence frequency. For example what is the relative frequency of positive flash flood threat for the entire forecast lead time interval that is due to forecast rainfall of 3-, or 6-hour duration from WRF Model Forecast.

SAsiaFFG System Interface

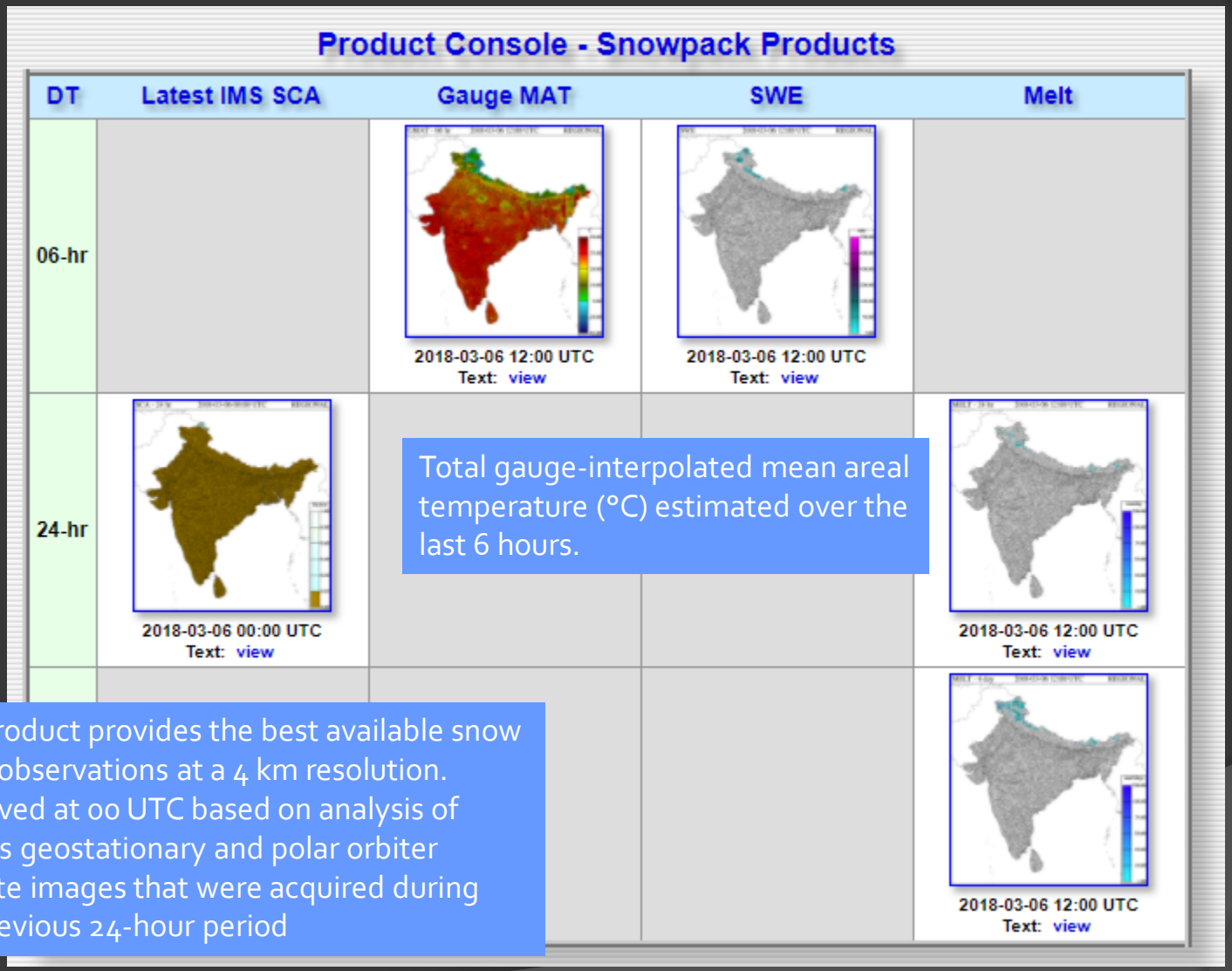
Informational Products: Links

Operational Approaches for Flash Flood Guidance

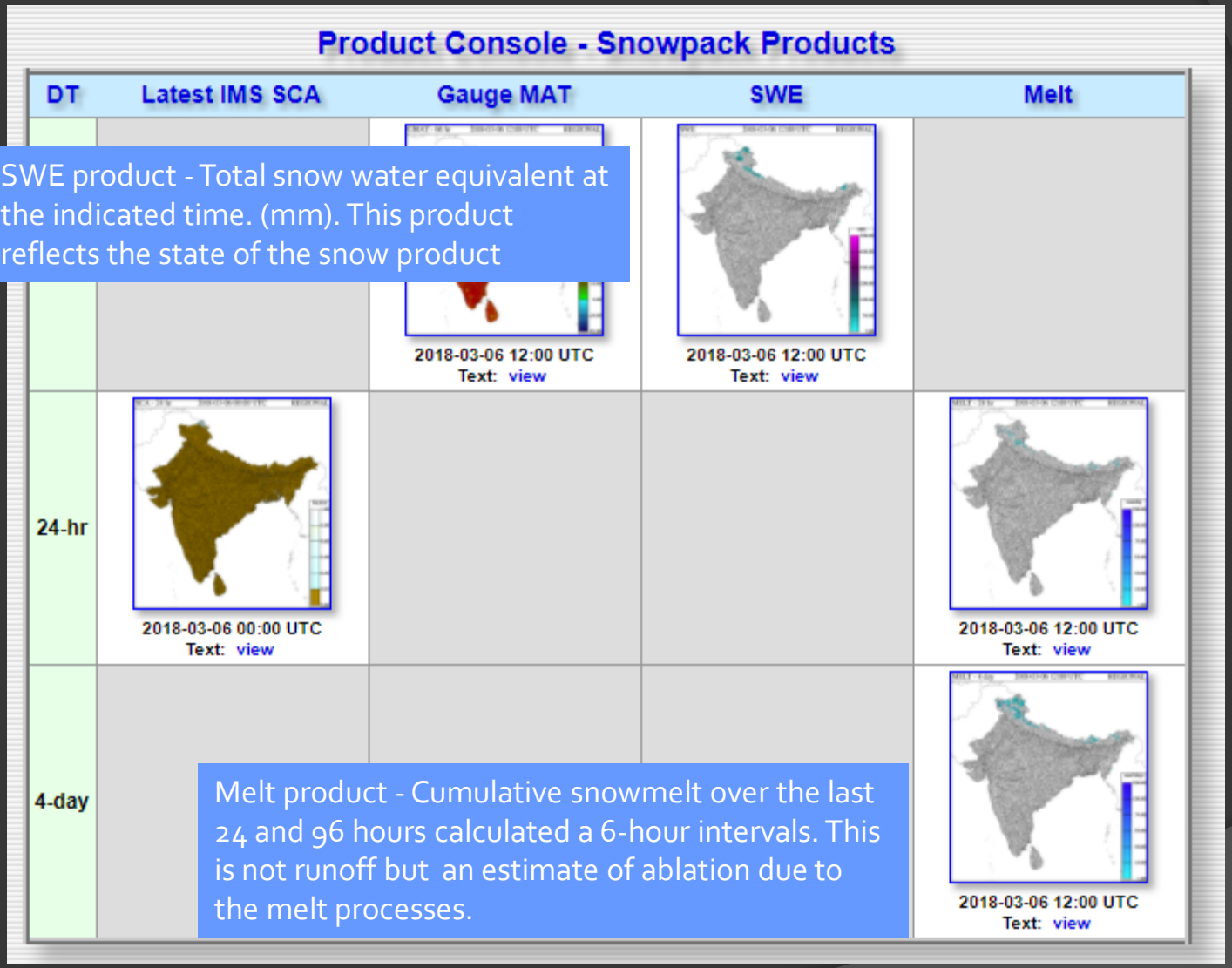


System can provide forecasters with information on the likelihood of flooding of small streams by using bias-corrected satellite precipitation estimates and soil moisture estimates to produce flash flood guidance and flash flood threat

New SAsiaFFG System Forecaster User Interface Products



New SAsiaFFG System Forecaster User Interface Products



7. Forecasting Flash Floods

Flash Flood Forecasting

Flash floods are difficult to forecast:

- **Combination of high rainfall rate and**
- **Rapid and efficient runoff is common to flash flood events**

• Many countries warnings for flash floods: "heavy rain with potential for flash floods"

• Ignore underlying hydrological conditions, so there is a need to know accurately the rainfall rate over a river basin

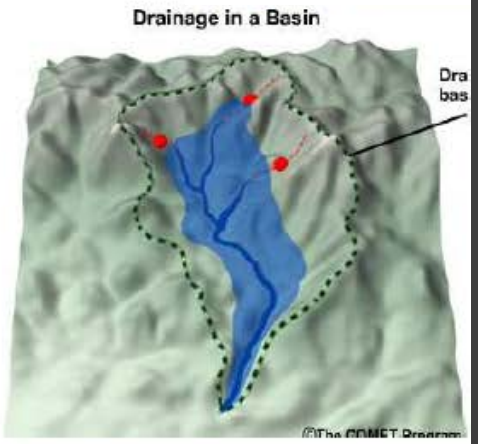
• Compared to a river flood, a flash flood is a true hydrometeorological problem

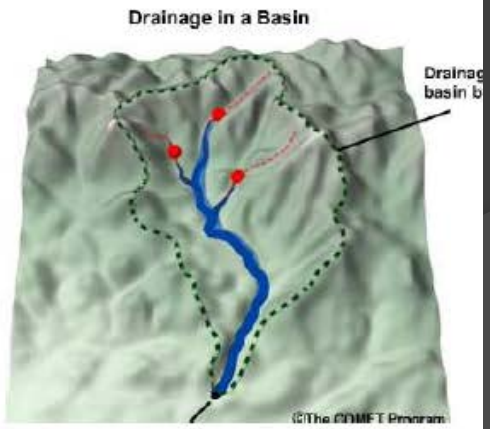
• Need for a meteorological & hydrological based flash flood forecasting system at time of flood to determine basins in danger

How do you predict a flash flood?

- Forecaster's question:
  - How much rain will cause a flood in this particular area?
- What do you need to know to answer this question?
  - How much water will run off?
  - How full is the stream?
  - What about recent rain?
  - ➢ How river basin responds - Hydrology
- How much rain am I expecting over this area?
  - ➢ Weather forecasting – Meteorology

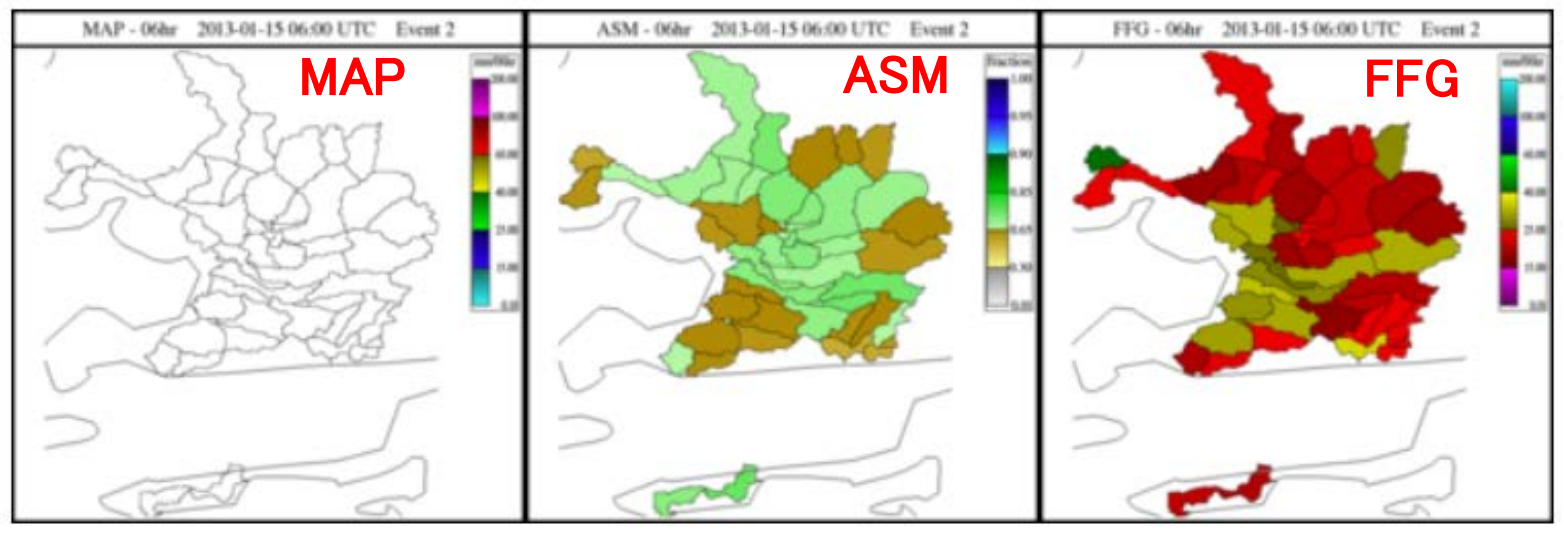
= Hydro-meteorological problem



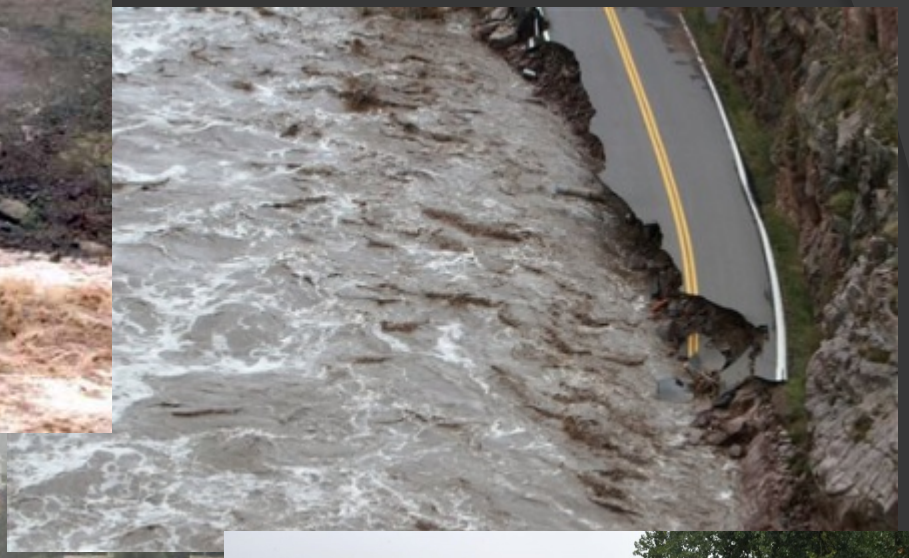


Flash Floods

A flash flood is a rapid onset flood (<6 hours) following the causative event (heavy rain, dam failure) "*too much water, too little time*"



Flash flood forecasting is becoming more and more important worldwide

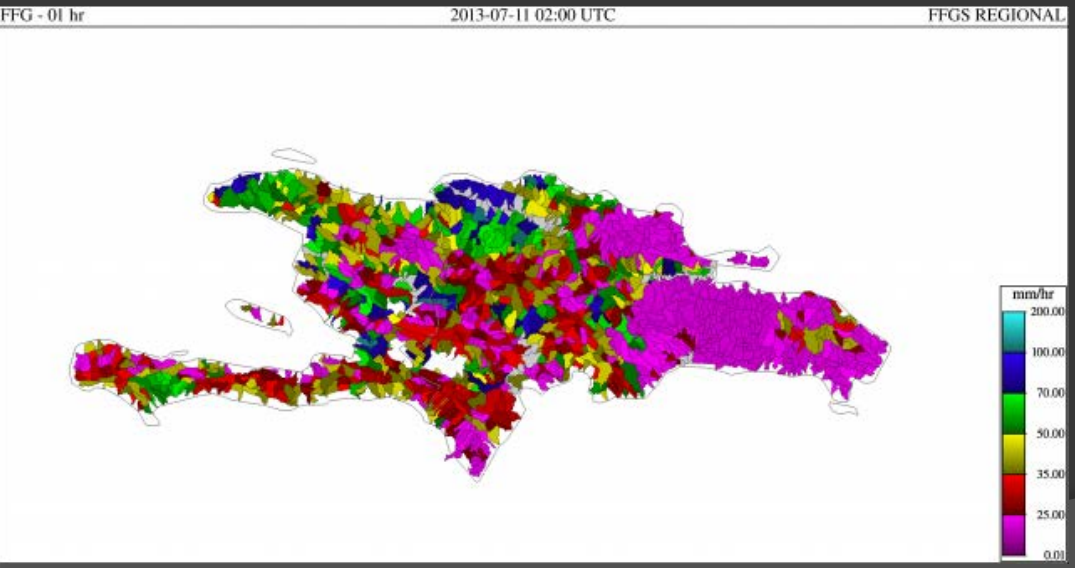


7. Conclusions

Performance of FFGS so far

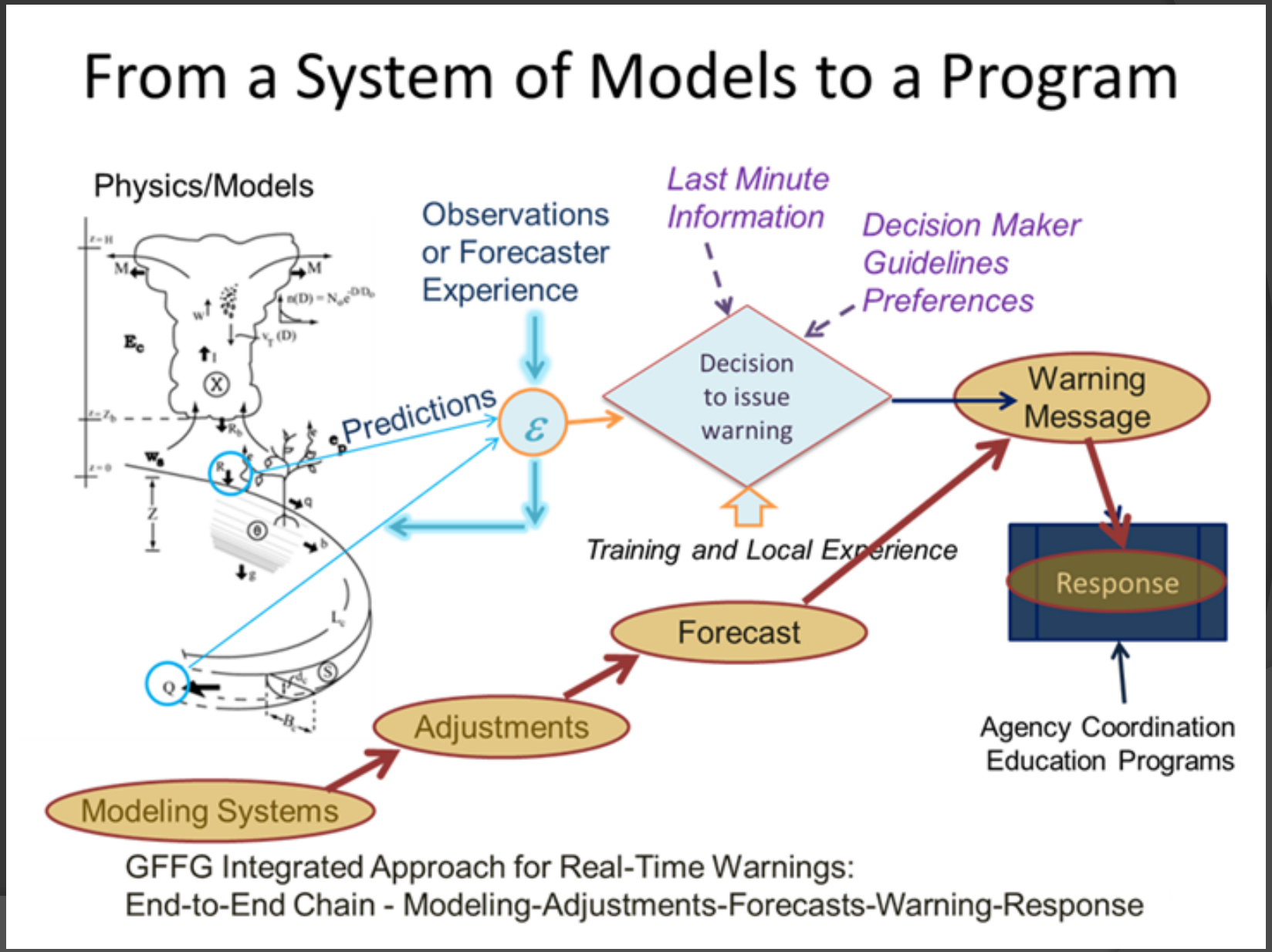
SAsiaFFG provides useful guidance particularly for larger scale systems on potential flooding over South Asia Region.

- The FFGS systems in the region using satellite rainfall estimation
- Deal well with larger scale events (TCs, MCSs)
- Struggles with small scale high intensity events (individual T/S)
- Will struggle with heavy rain from stratiform clouds (however this is mostly a problem for southern and south-western coastal regions of South Asia)
- 6-hour update time implies no new FFG information available in-between main synoptic hours



However, SAsiaFFG still provides very valuable guidance to forecasters of a hazard that had no information on in the past.

INSTITUTIONAL COLLABORATION IMPORTANT



However, if the warning does not reach the community at risk, the best system will be worthless.

Challenges

- Emphasis needs to be on enhancing institutional collaboration
- Stakeholders needs must be understood
- Routine incorporation of the FFG by operational forecasters
- Formalized communication platform of flash flood advisories, watches and warnings with key stakeholders

In the South Asia Region , extreme weather and climatic events including droughts, flash floods and floods have and will continue to have significant impacts on economic sectors, natural resources, ecosystems, livelihoods, and human health (IPCC 2014).