Demonstration of Regional FFGS

a planning meeting in Lima, Peru

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Hydrologic Research Center

Definitions of Flash Floods

- World Meteorological Organization - A flood of short duration with a relatively high peak discharge

- American Meteorological Society – A flood that rises and falls quite rapidly with little or no advance warning, usually as the result of intense rainfall over a relatively small area

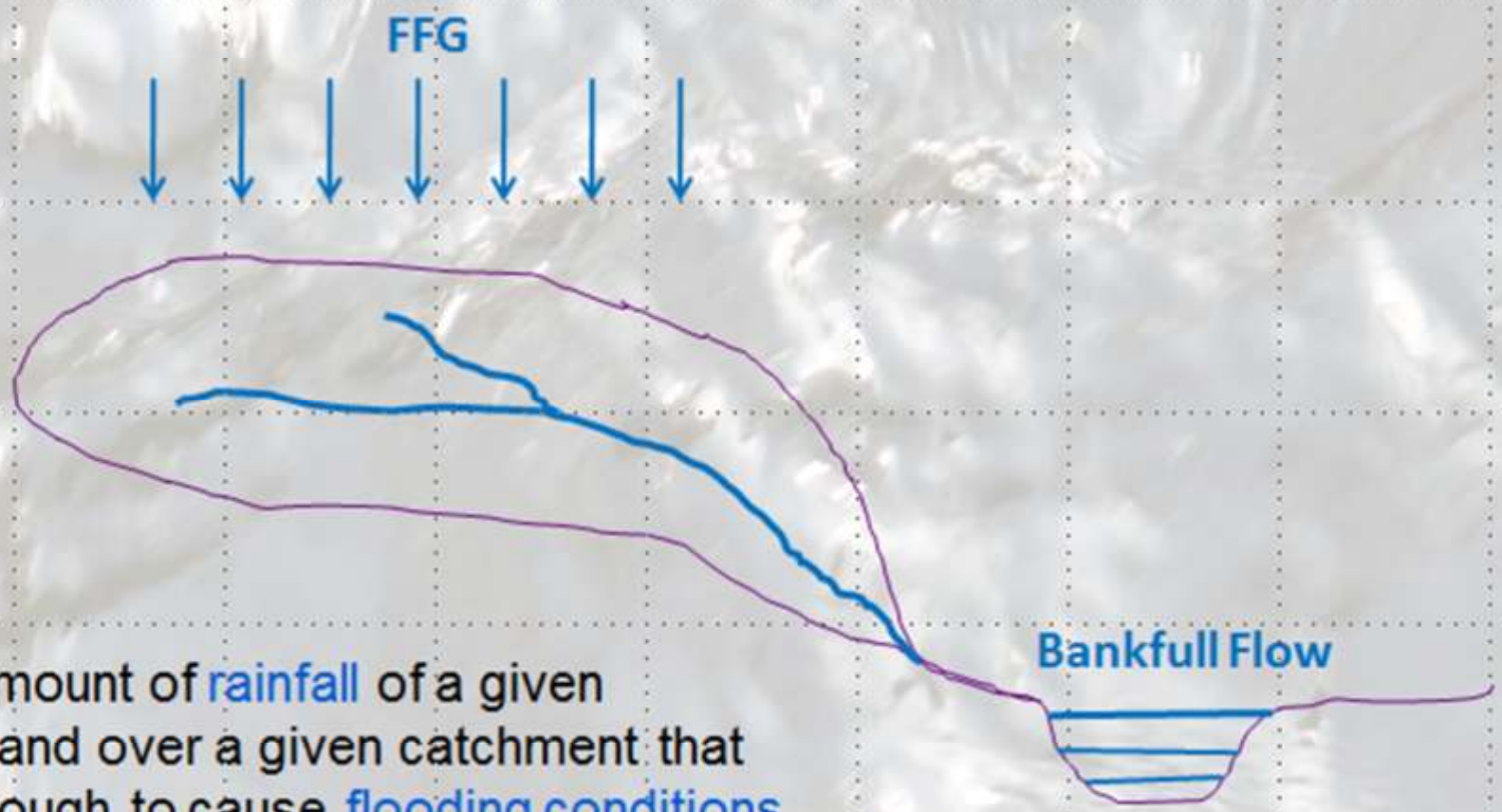
- Response time is 6 hours or less

- A local hydrometeorological phenomenon that requires:
    - BOTH Hydrological and Meteorological expertise for real time forecasting/warning
    - Knowledge of local up to the hour information for effective warning (24 - 7 operation)

Flash Flood Guidance Terminology

- Flood - occurrence of a flow event that overtops the natural or artificial banks in a reach of river channel.
- Flash Flood – a flood that follows shortly after rainfall event.
- Bankfull Flow - a flow in which the water level is at the top of its banks and further rise would result in inundation of the flood plain.
- Flash Flood Guidance (FFG) – the volume of spatially uniform precipitation of a given duration (1-6 hours) over a certain small catchment that is required to cause minor flooding in the draining outlet of the catchment.
- Flash Flood Threat – rainfall of a given duration in excess of the corresponding Flash Flood Guidance value
- Threshold Runoff – rainfall depth in a given duration that is needed for the flow at the basin outlet to exceed bankfull flow when the basin is in near saturation conditions.

Flash Flood Guidance Concept



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

Threshold exceedance concept to estimate occurrence only!

Large River Flooding vs. Flash Flooding

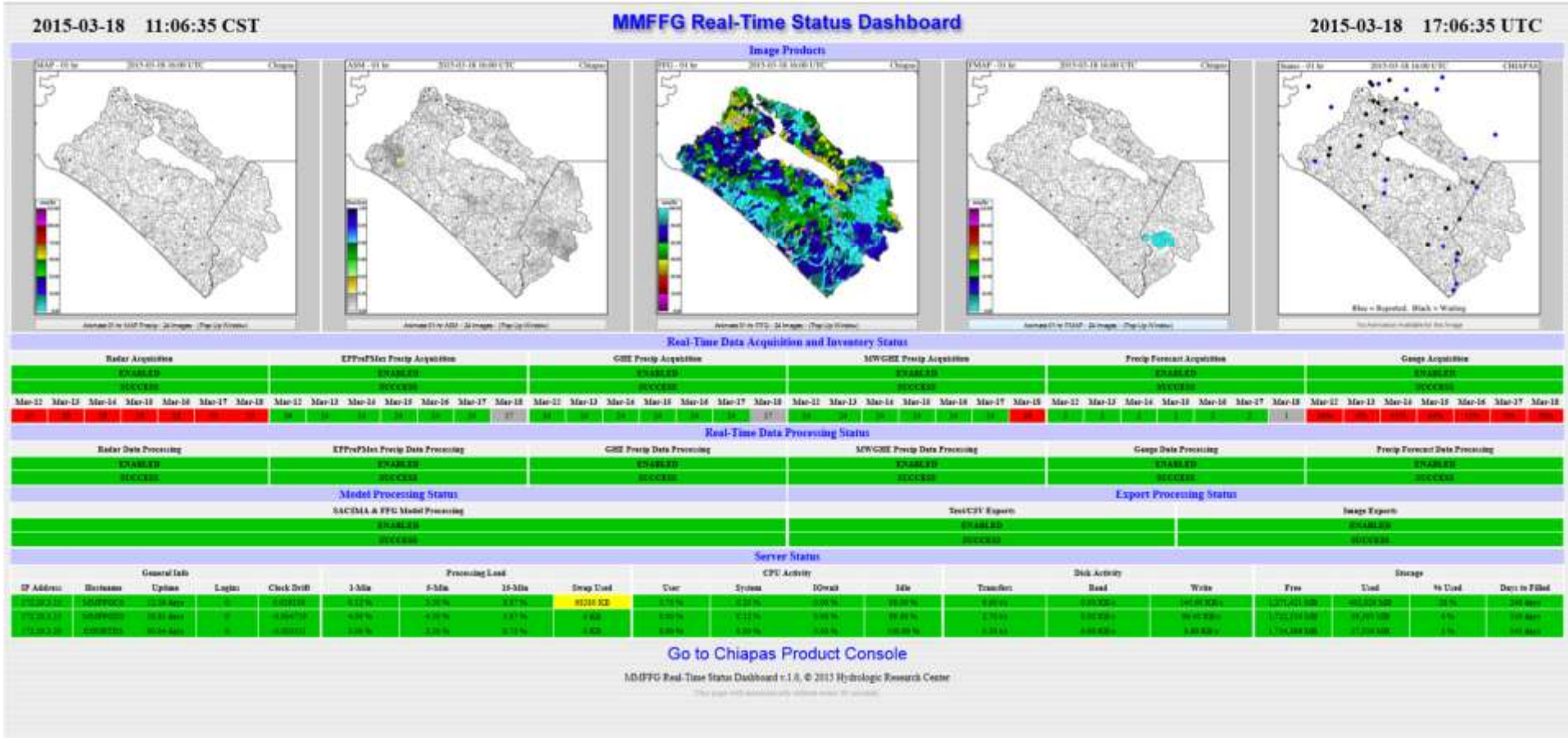
LRF

- Catchment response affords long lead times
- Entire hydrographs can be produced w/ low uncertainty with good quality data
- Local information less valuable
- A hydrologic forecasting problem primarily
- Affords time for coordination of flood response and damage mitigation

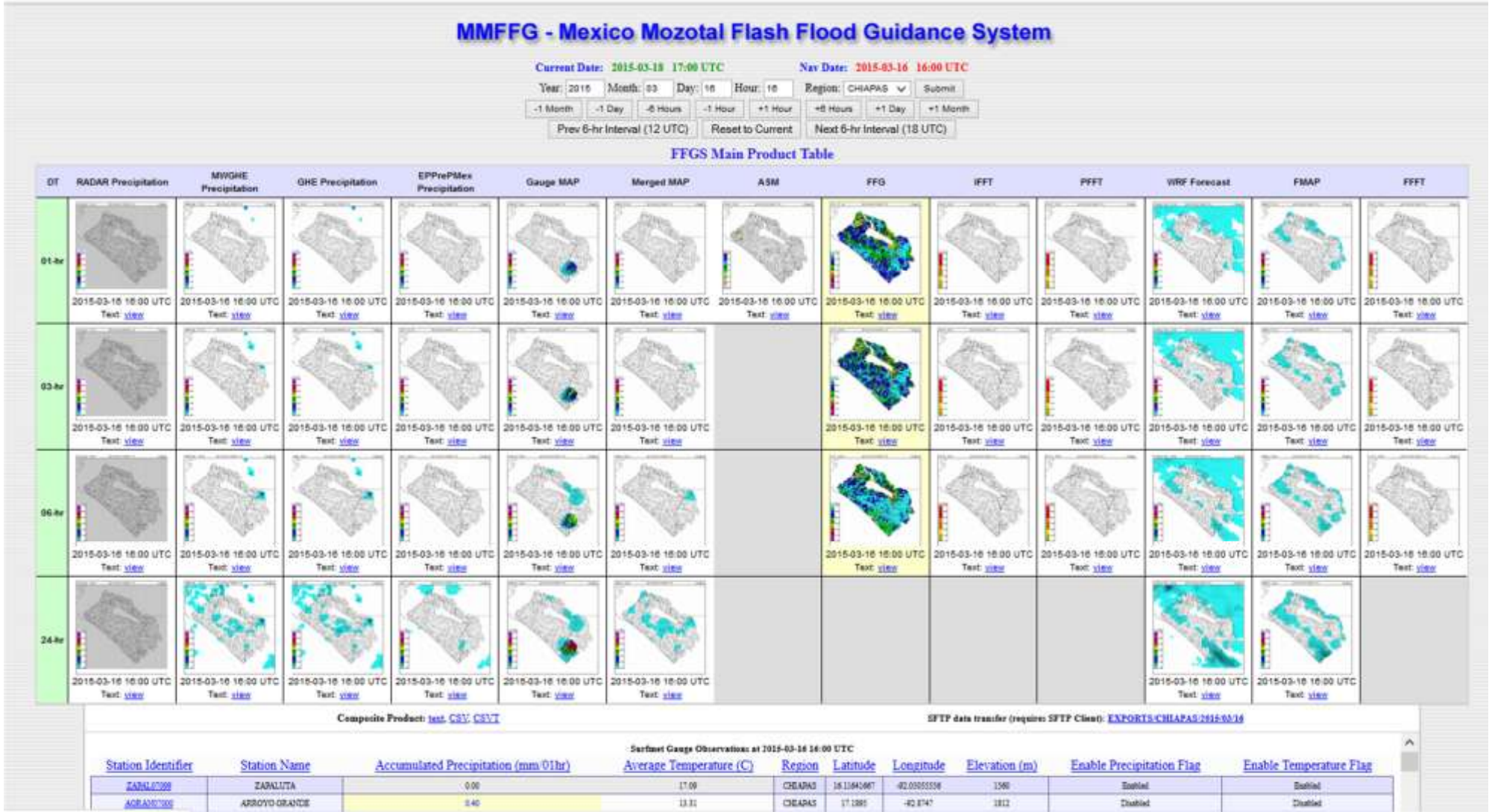
FF

- Catchment response is very fast and allows very short lead times (< 12hrs)
- Prediction of occurrence is of interest
- Local information is very valuable
- A truly hydro-meteorological forecasting problem
- Coordination of forecasting and response is challenging over short times

DASHBOARD


2015-03-18 11:06:35 CST
MMFFG Real-Time Status Dashboard
2015-03-18 17:06:35 UTC
Image Products
Real-Time Data Acquisition and Inventory Status
Real-Time Data Processing Status
Model Processing Status
Export Processing Status
Server Status
Go to Chiapas Product Console

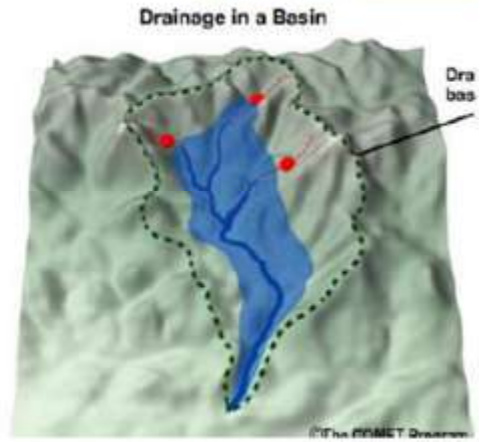
The System Interface

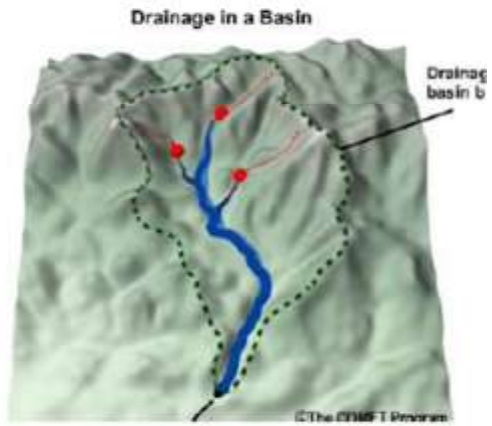


How do you predict a flash flood?

- 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

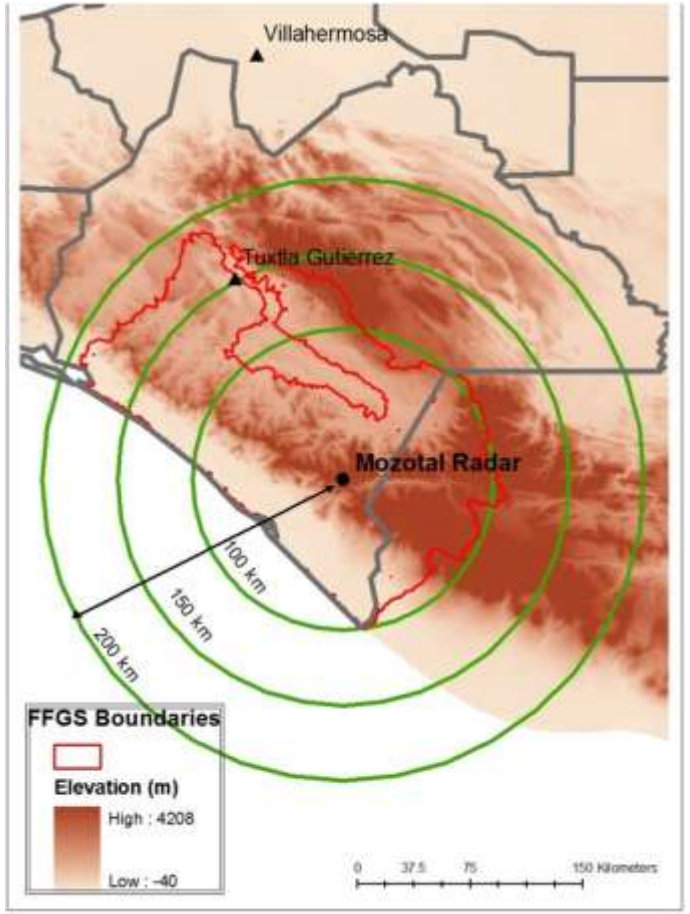
= Hydro-meteorological problem



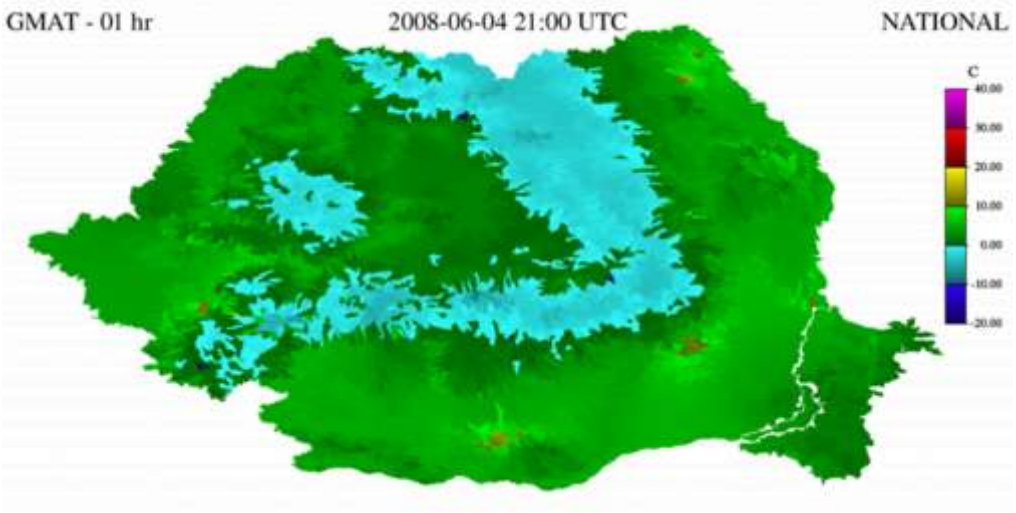


Radar Based FFG Systems

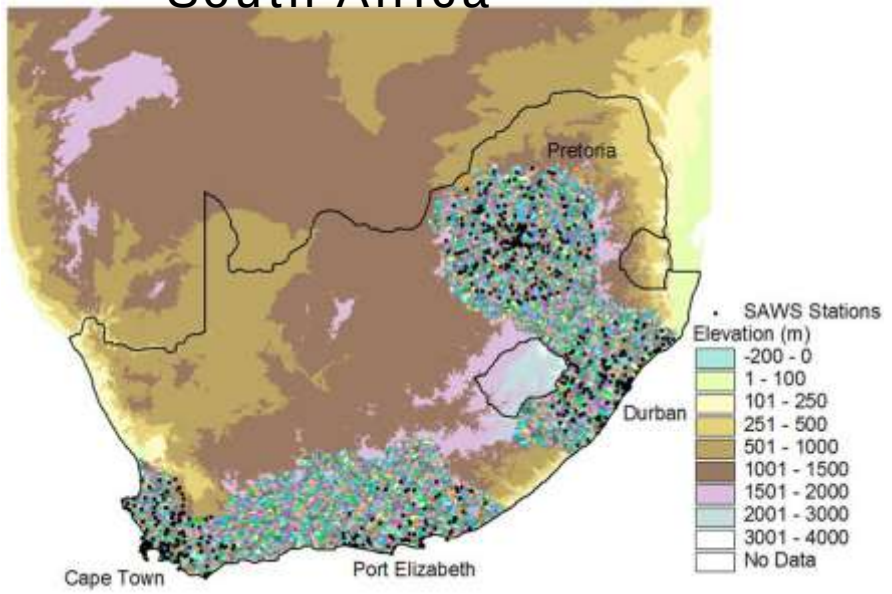
Mexico



Romania

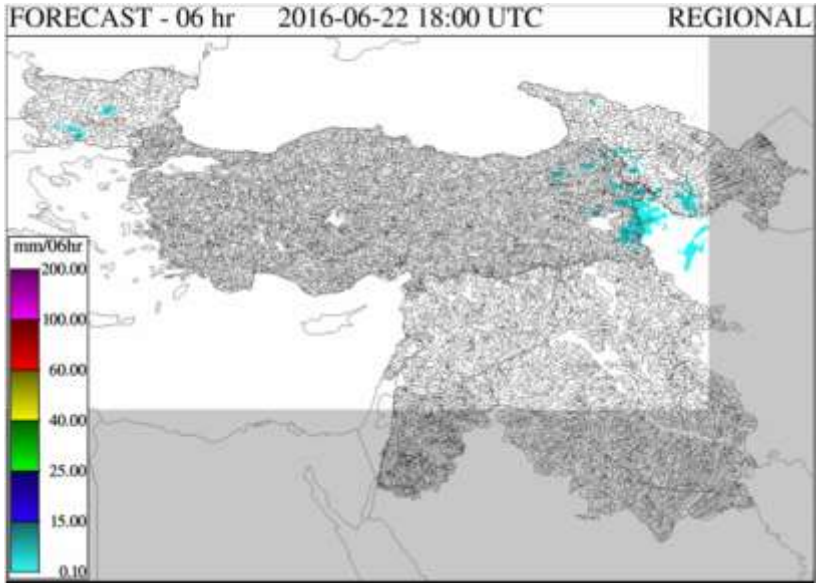


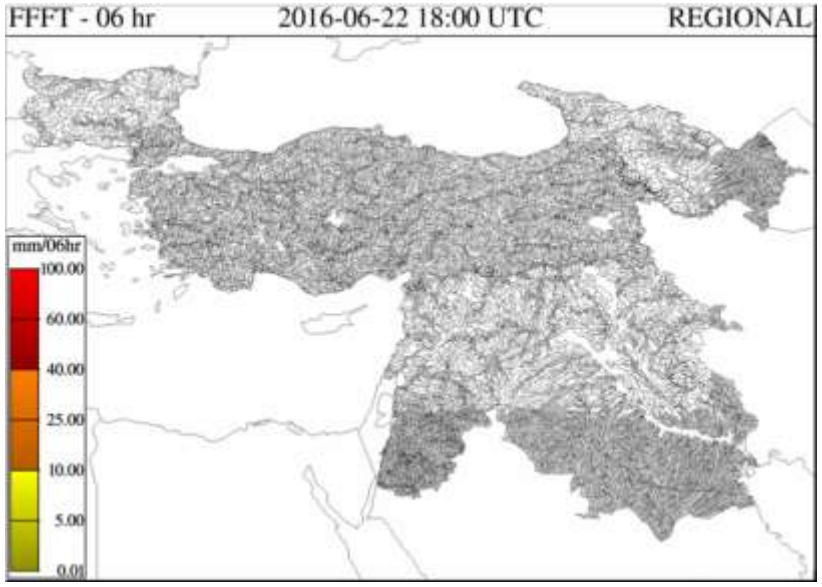
South Africa

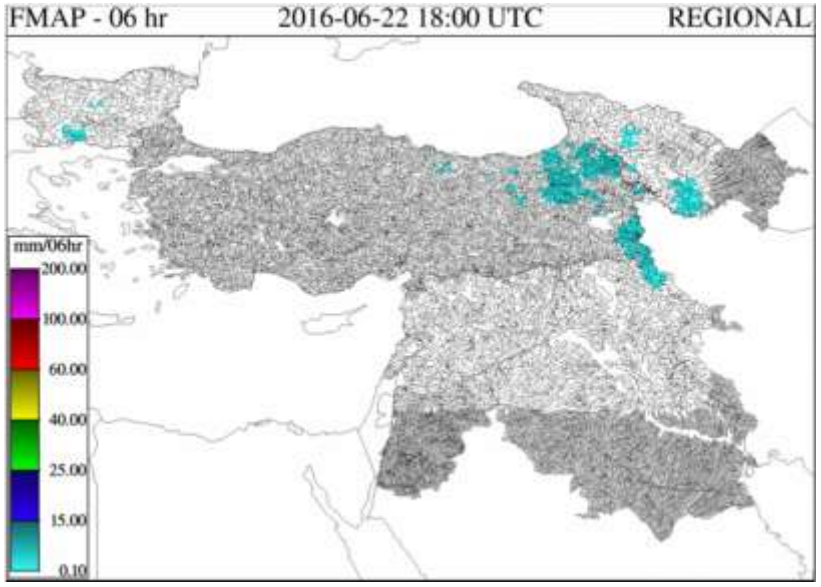


Forecast Precipitation Products

- ALADIN forecast model
  - Turkey (TSMS) Regional Center
- FMAP is computed as average of grids within each basin (*no adjust*.)

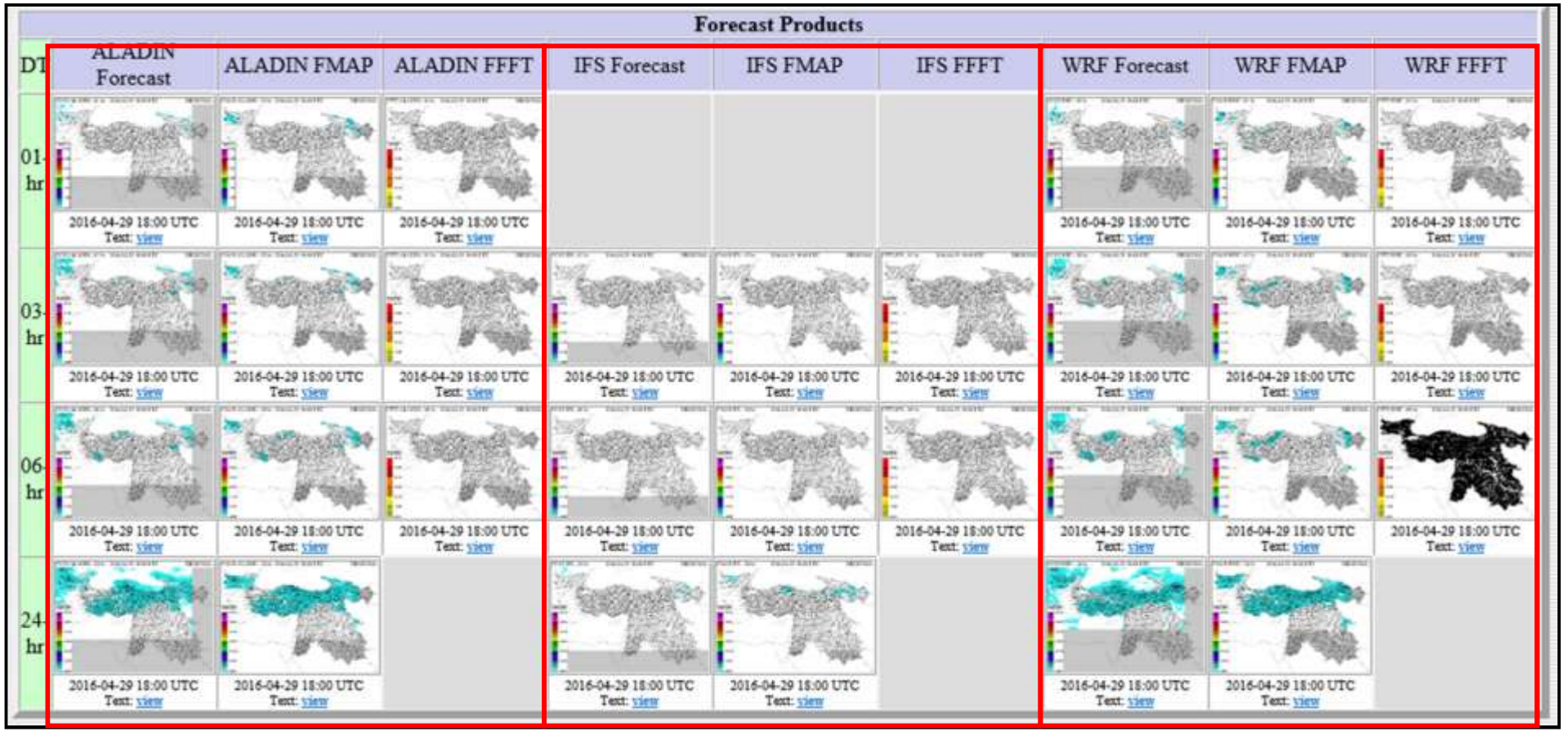




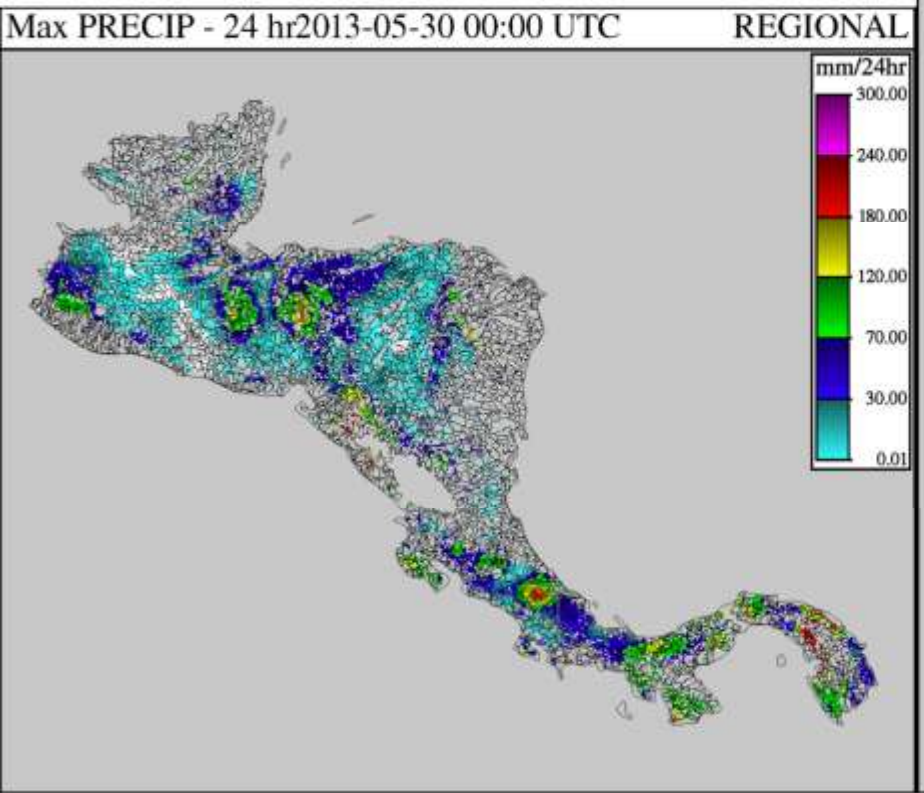


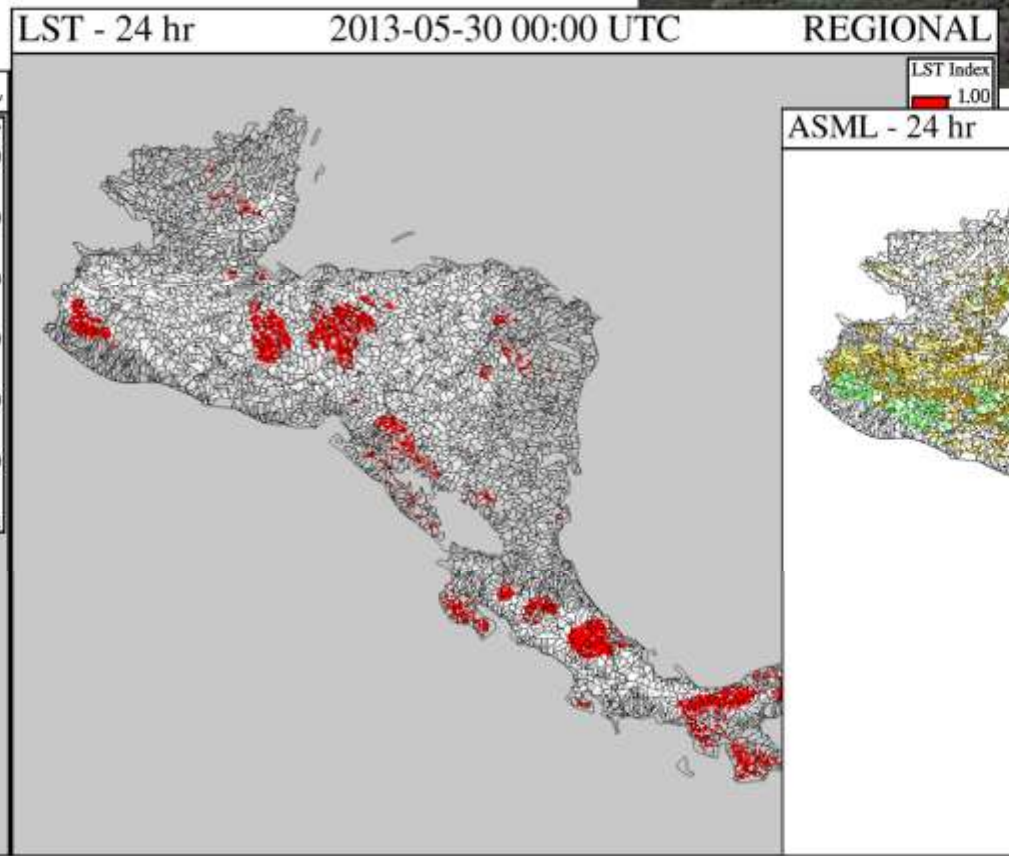
Future: Multi-model Forecast Precipitation

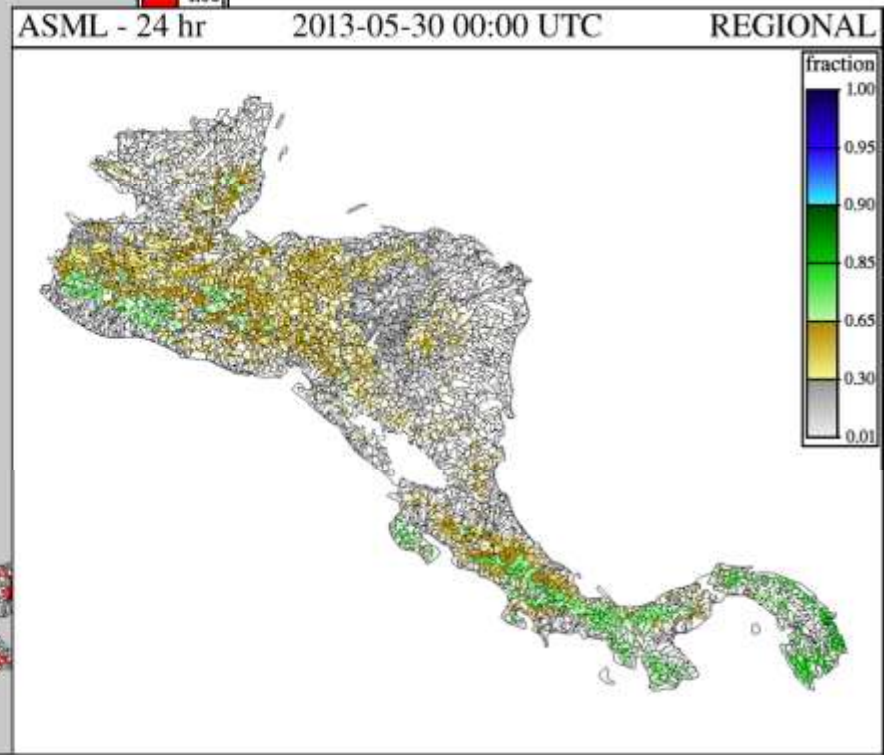
Currently under development, capability to ingest precipitation forecasts from multiple NWP models and generate FMAP and FFFT products (prototyped in BSMEFFGS).



Upcoming FFGS new product: Land Slide Threat [LST]







Review of the System Technical Background

Flash Flood Guidance Terminology

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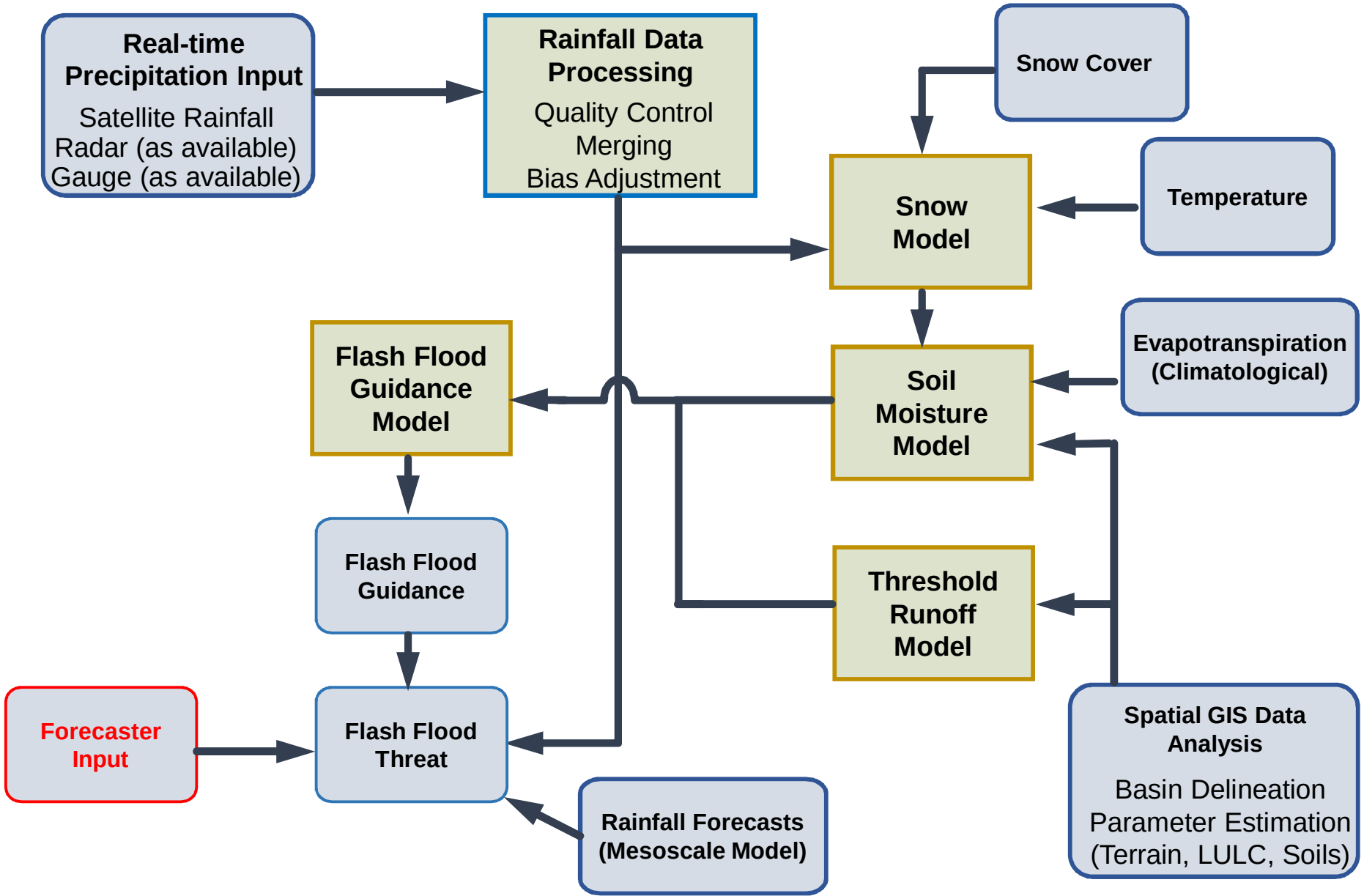
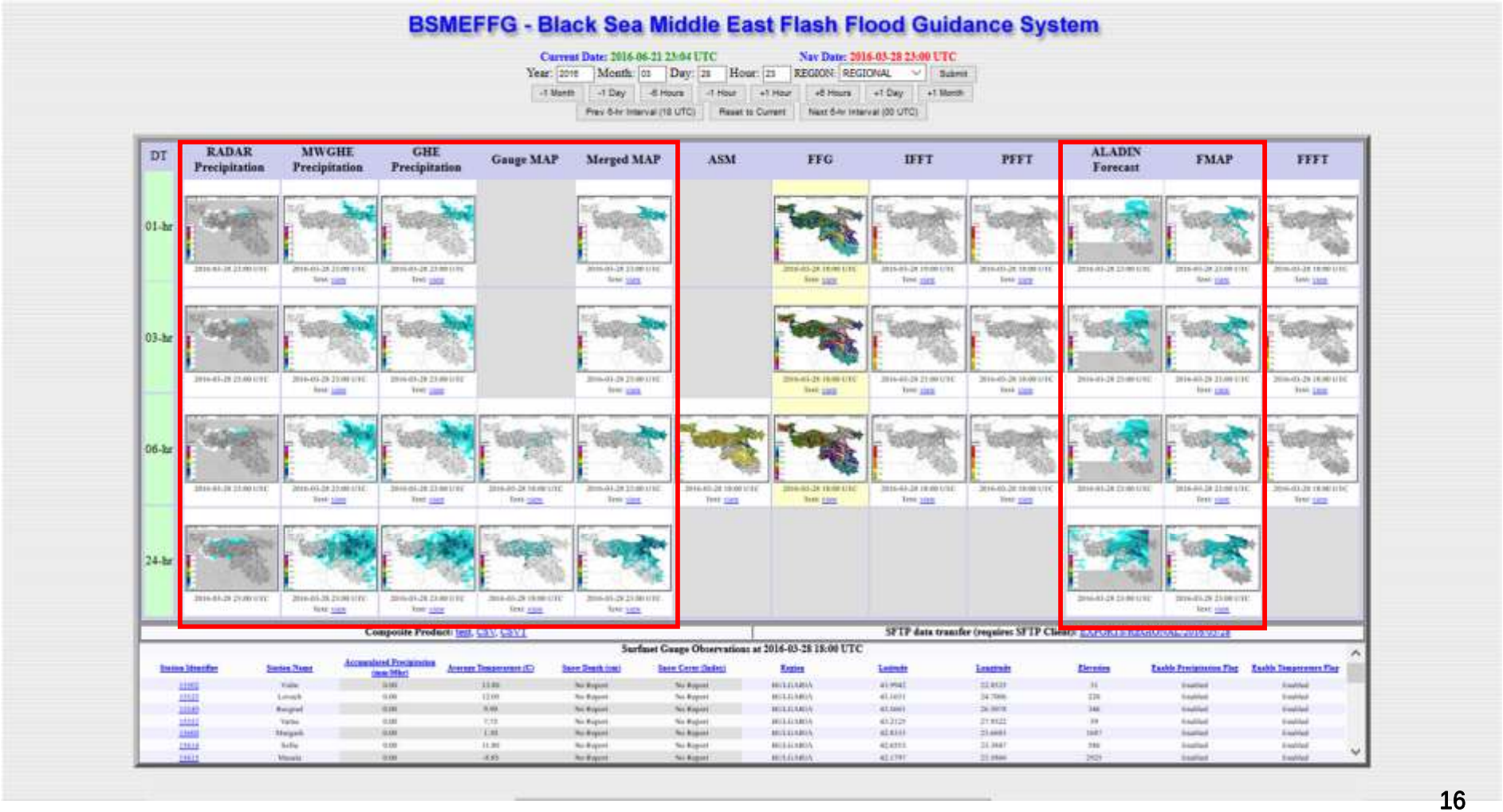
Key Technical Components for Flash Flood Guidance Systems



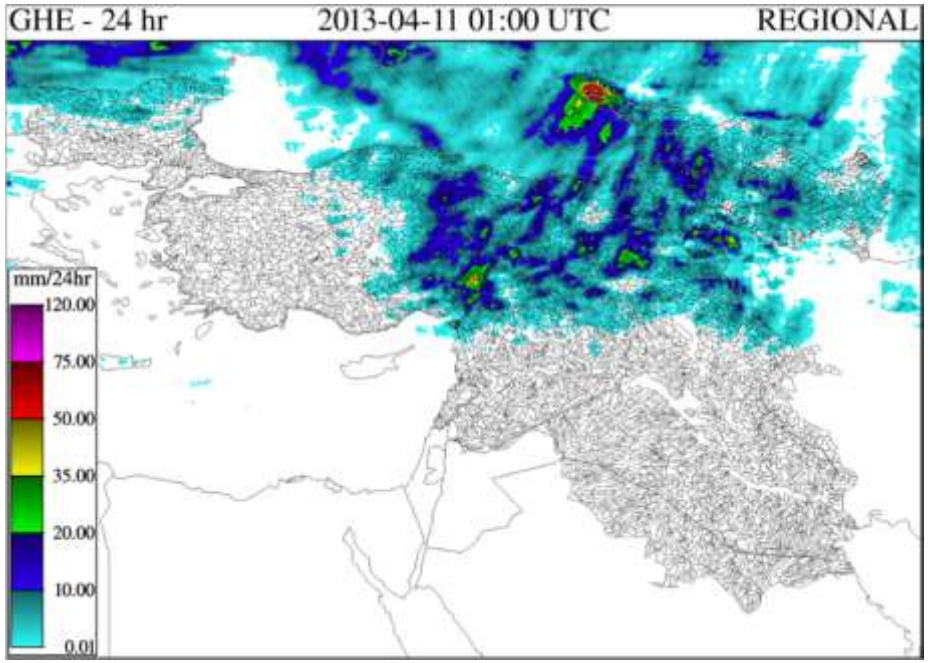
EEFFG Precipitation Products

Flash Flood Guidance Systems need up-to-date high-quality estimates of precipitation to assess current flash flood potential.

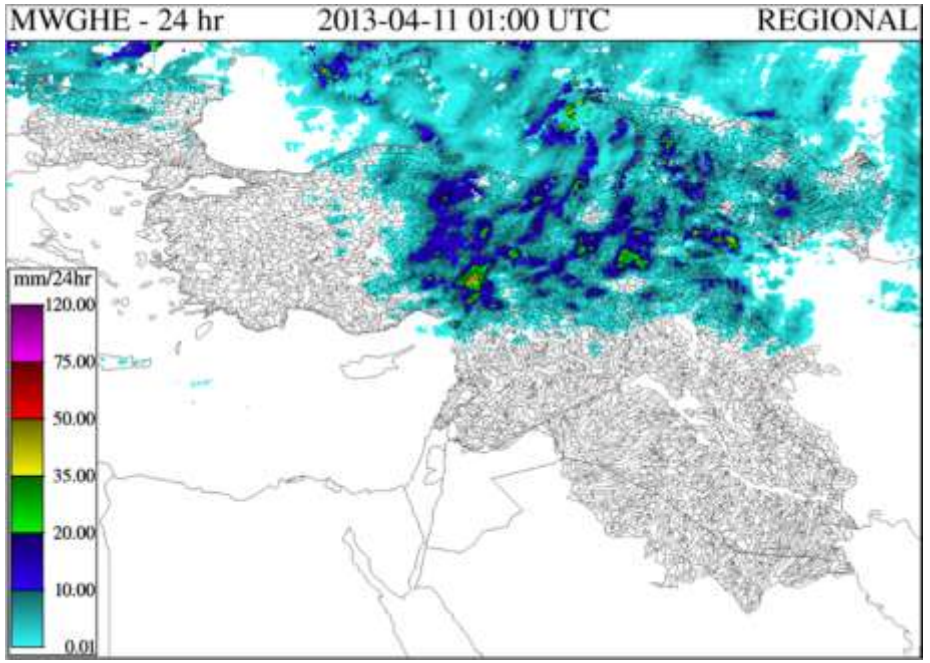


Satellite Precipitation

Original GHE



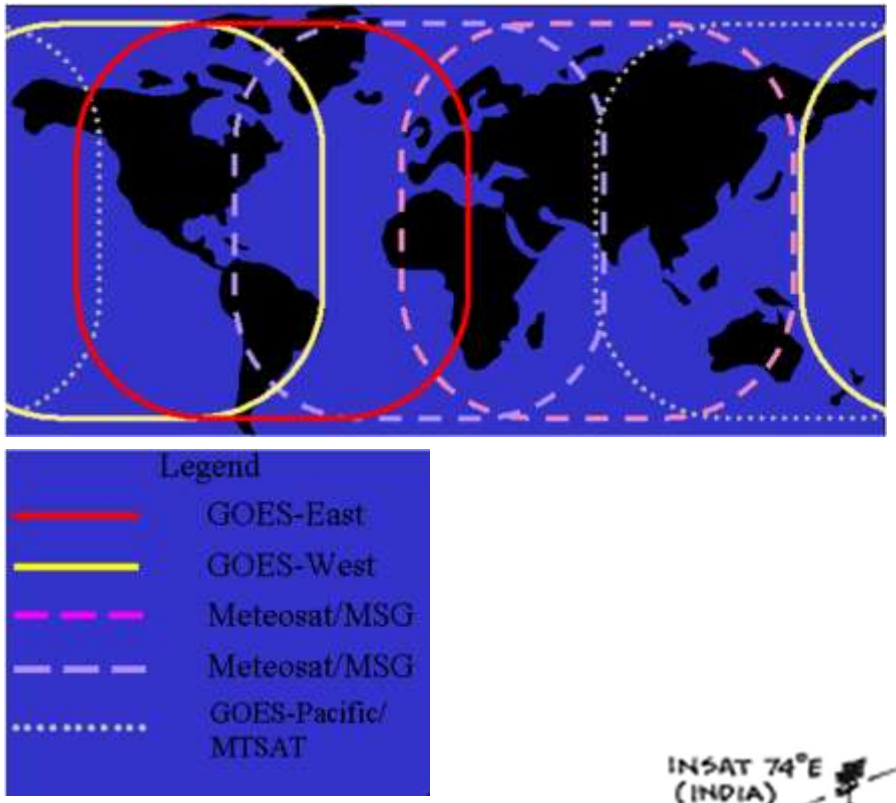
Adjusted GHE



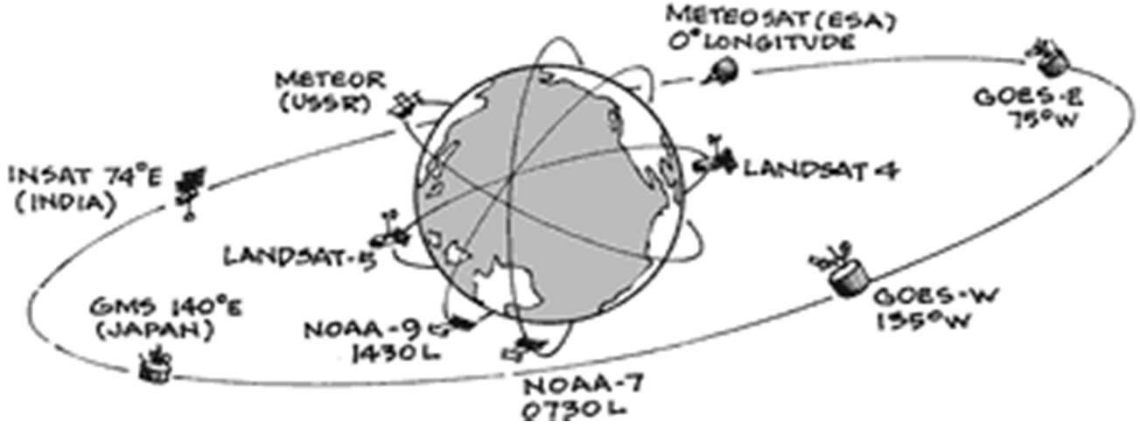
Remotely-sensed precipitation estimates provide good spatial coverage and detail.
- indirect measurement of precipitation

In situ observations (rain gauges) provide “ground truth” but often have sparse coverage.

Hydro- Estimator National Environmental Satellite, Data, and Information Service (NESDIS) (NOAA)

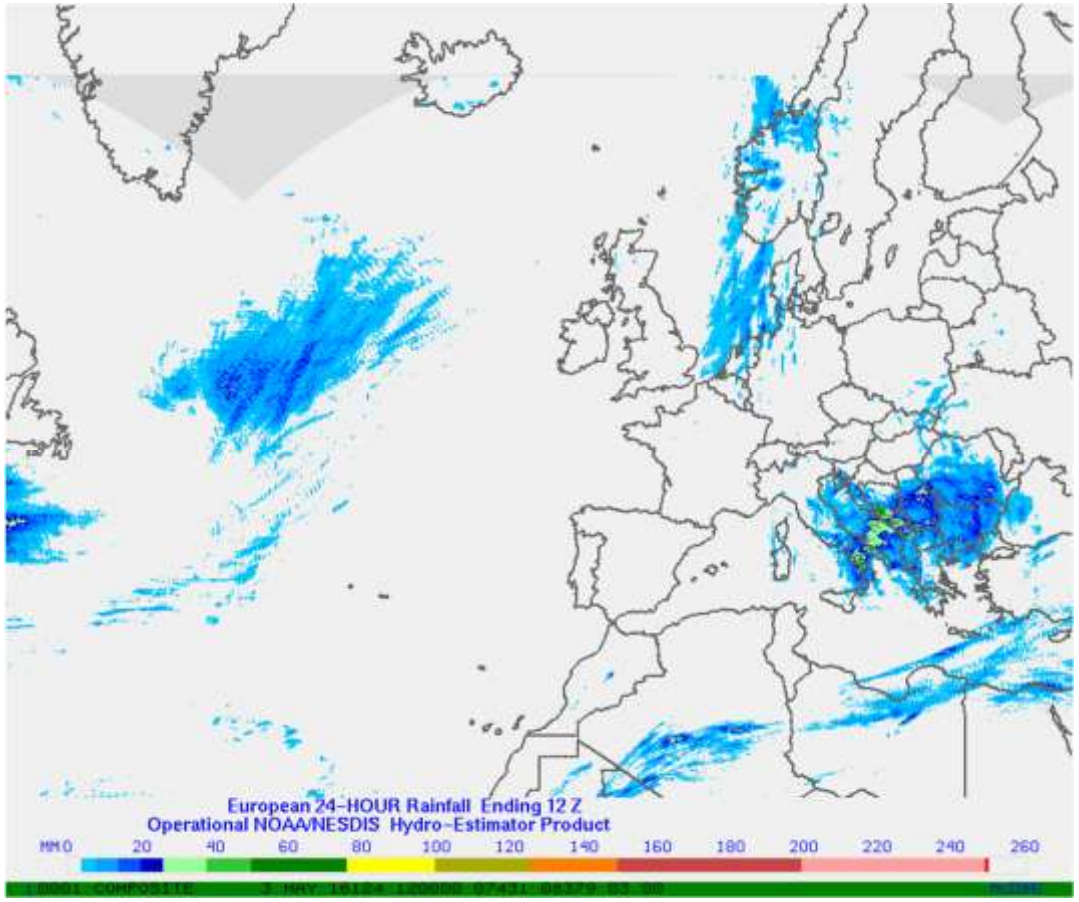


- **Real-time operational since August 2002**
- **Available globally (60N-60S)**
- **Hourly values for about 4 km.**
- **geo-stationary GOES satellites IR 10.7 micron.**
-
- **Data are produced at the full instrument resolution and are updated whenever new imagery becomes available, with a latency of less than 15 minutes.**



Global Hydro-Estimator

GHE: Rainfall rate based on Cloud Top Brightness Temperature (*indirect measurement*)



- Produced by NOAA/NESDIS
- Research on satellite precipitation
  - since late 1970s;
  - Hydro-Estimator since 2002;
  - GHE Operational in 2012.
- Infrared (IR)-based, 10.7 mm
- ** Short latency **(< ½ hour)
- ~4km resolution

Enhanced for:

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

Multi-Spectral Satellite Rainfall for FFG Systems

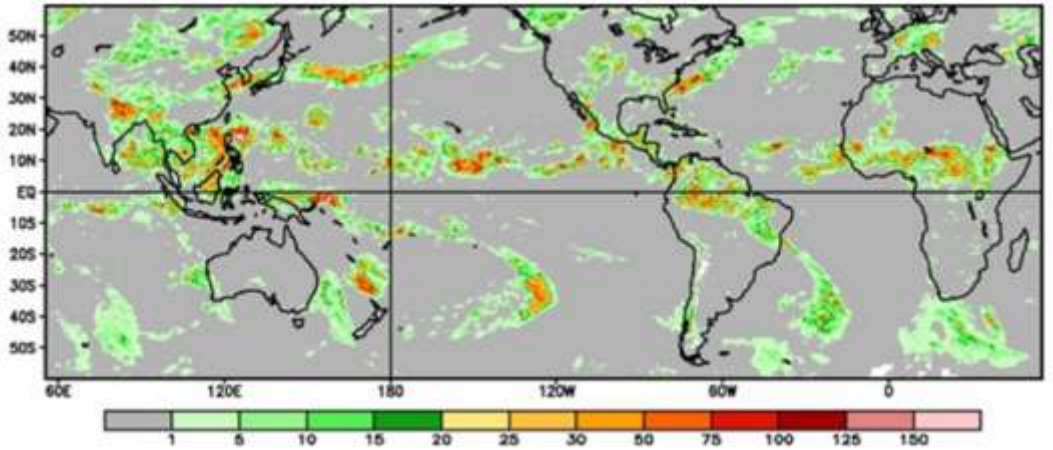
HRC effort to combine IR-based GHE rainfall with MW-based CMORPH rainfall

CMORPH is based on measurements of microwave scattering from raindrops.

- measure of the hydrometeors in clouds
- still not observation of rainfall at surface

High-Resolution Satellite Estimates

- CMORPH : CPC Morphing technique (Joyce et al. 2004
  - Combined use of satellite PMW and IR data
  - 8kmx8km / 60°S-60°N;
  - 30-min interval / from September 2000 / Real-time
  - Project on the way to back-extend the CMORPH to 1998
  - Sample for August 18, 2003



Multi-Spectral Satellite Rainfall for FFG Systems

GHE

- Infrared – based
- Measurements of brightness temperature at the top of the cloud
- 30-min latency in operations
- ~4km resolution

CMORPH

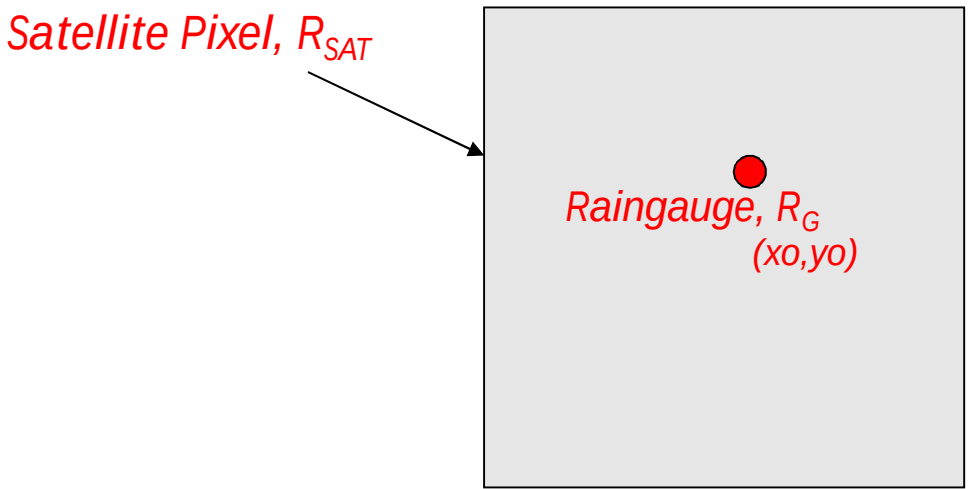
- Microwave – based
- Measurements of microwave scattering from raindrops
- 18-26 hour latency in operations
- ~ 8km resolution
- No estimation over snow

FFGS Product combines IR-based GHE with MW-based CMORPH: MWGHE

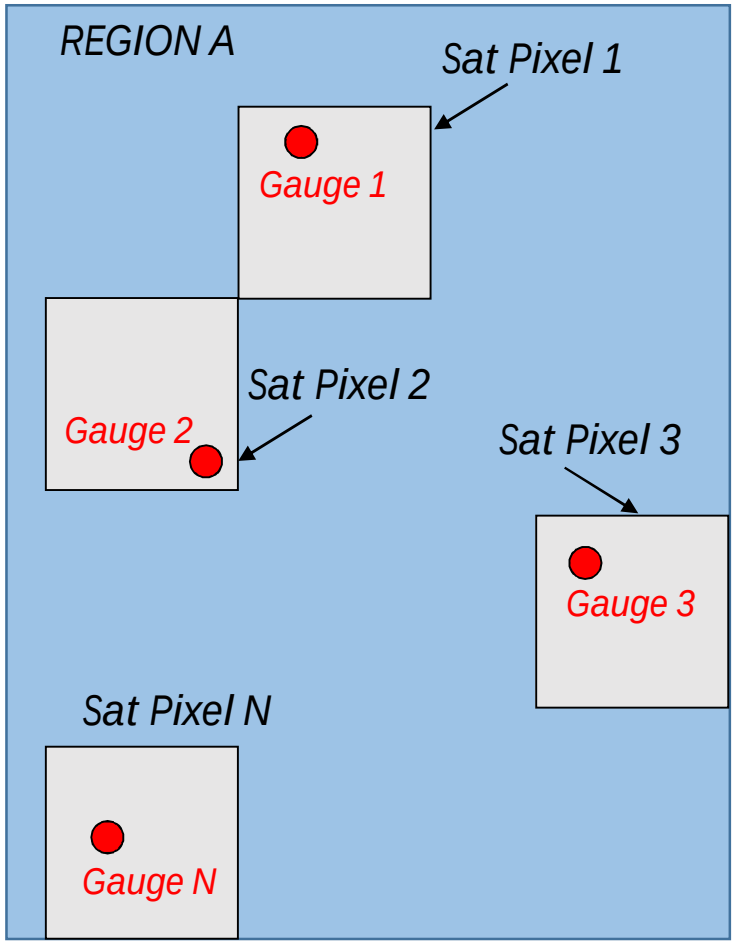
Reasons for Satellite Precipitation Bias

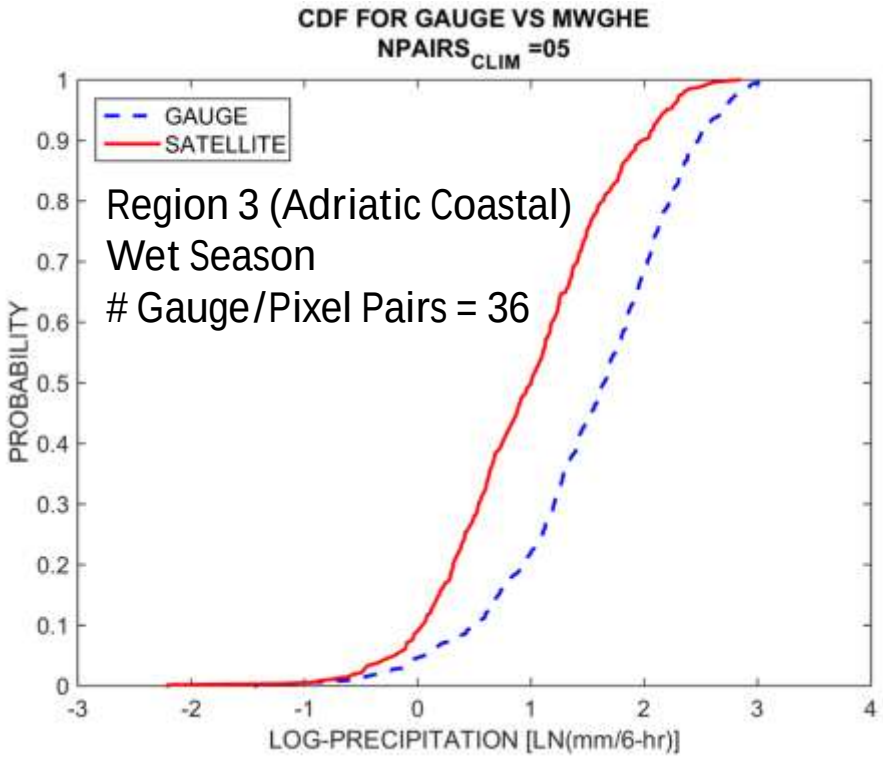
Bias may exist in the remotely sensed precipitation estimates relative to gauges. This should be removed before inputting to hydrologic models.

- Vastly different scales of satellite pixel and rain gauge area
- Orography organizes surface rainfall according to prevailing winds
- Satellite estimates do not directly measure rainfall at surface
- There may be significant misregistration errors in satellite data



Bias Adjustment for Satellite Precipitation





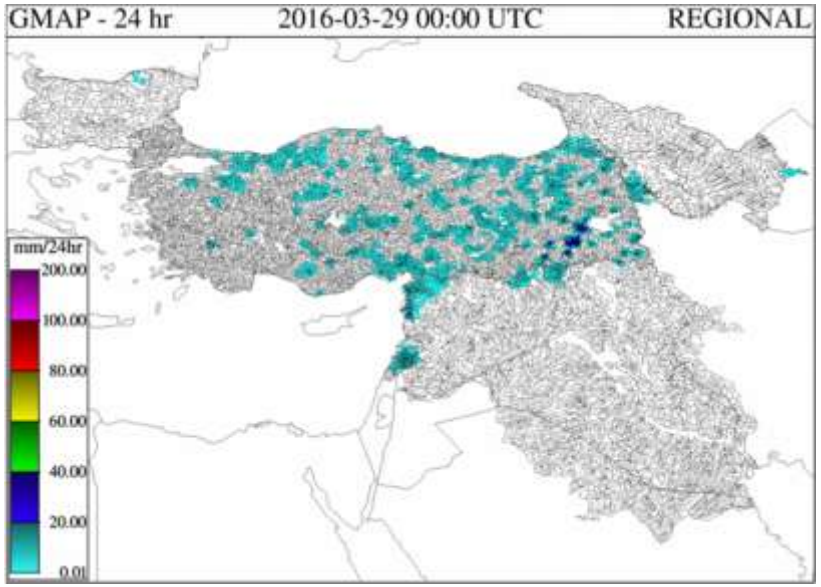
Log Bias:

$$\beta_t = \ln\left\{\frac{\sum_{j=1}^{N_G} R_G(j,t)/NG}{\sum_{j=1}^{N_G} R_{SAT}(j,t)/NG}\right\}$$

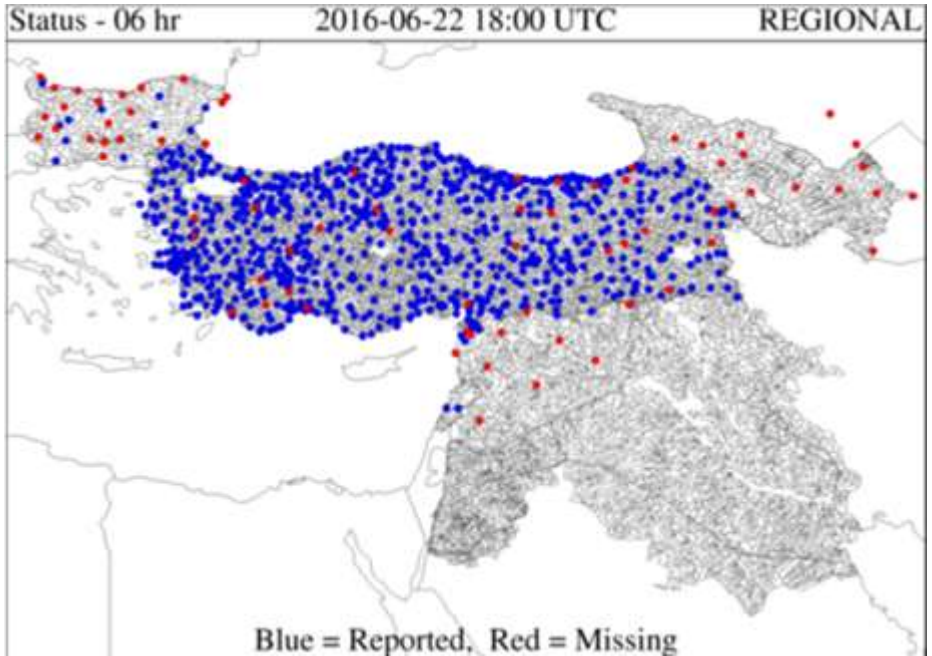
Approach for both climatological and real-time bias.

Gauge MAP

GMAP is interpolation of real-time gauge precipitation to flash flood basins. Updated every 6 hours.

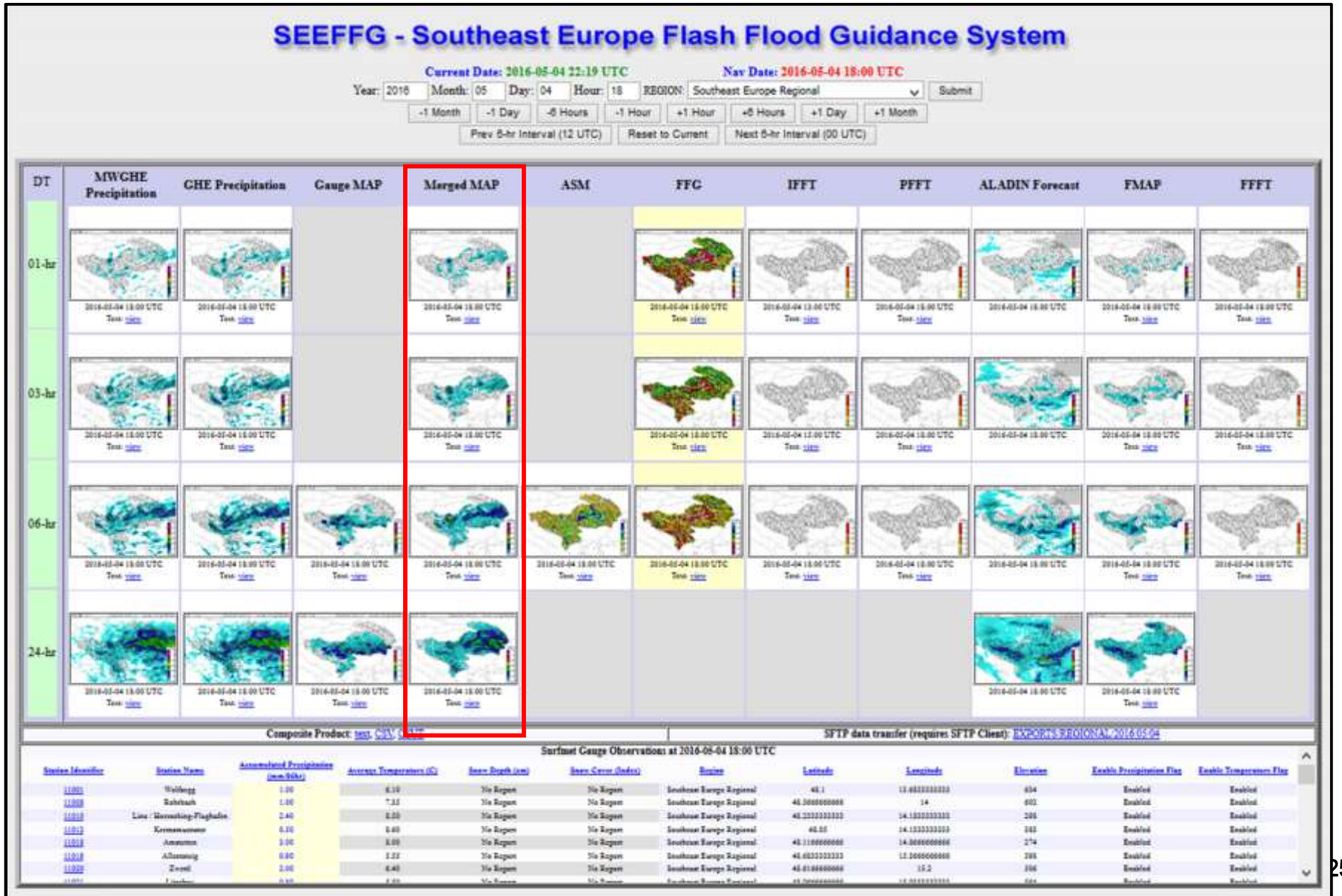


Real-time data quality is important!



The dashboard shows status of stations reporting to system in real-time.
- notify RC if stations are erroneous
- always working to add more stations if available in real-time.

Precipitation Products

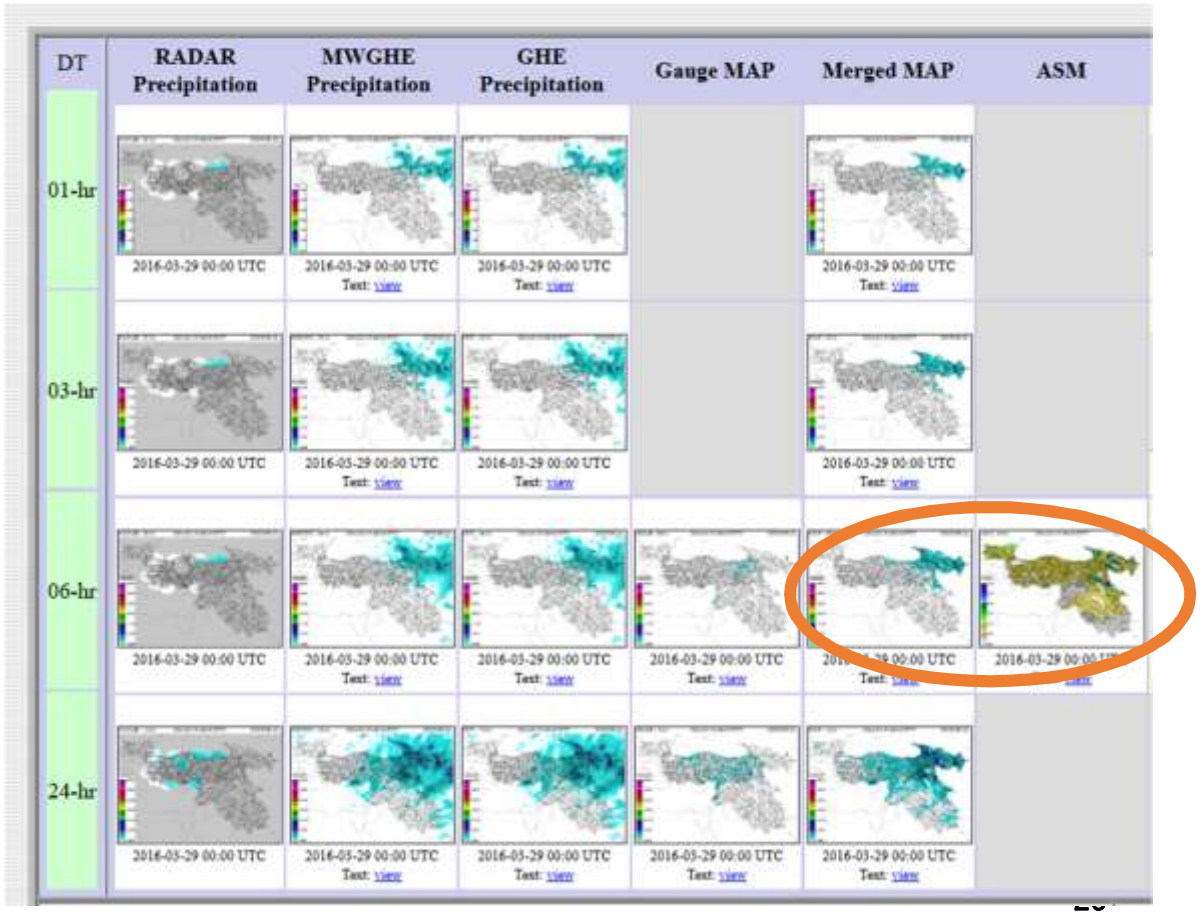


Merged MAP

Merged MAP:
The “best estimate” of current mean areal precipitation over each watershed
- Radar
- MWGHE
- GHE
- real-time gauges

Accounts for ‘long-term’ bias (climatological bias applied) as well as event-specific (real-time) bias.

6-hour Merged MAP is input to hydrologic modeling components 1, 3, 6- hour are used for Calculation of IFFT/PFFT.



Review of Technical Background
2. Spatial Analysis / GIS and Soil Model Components

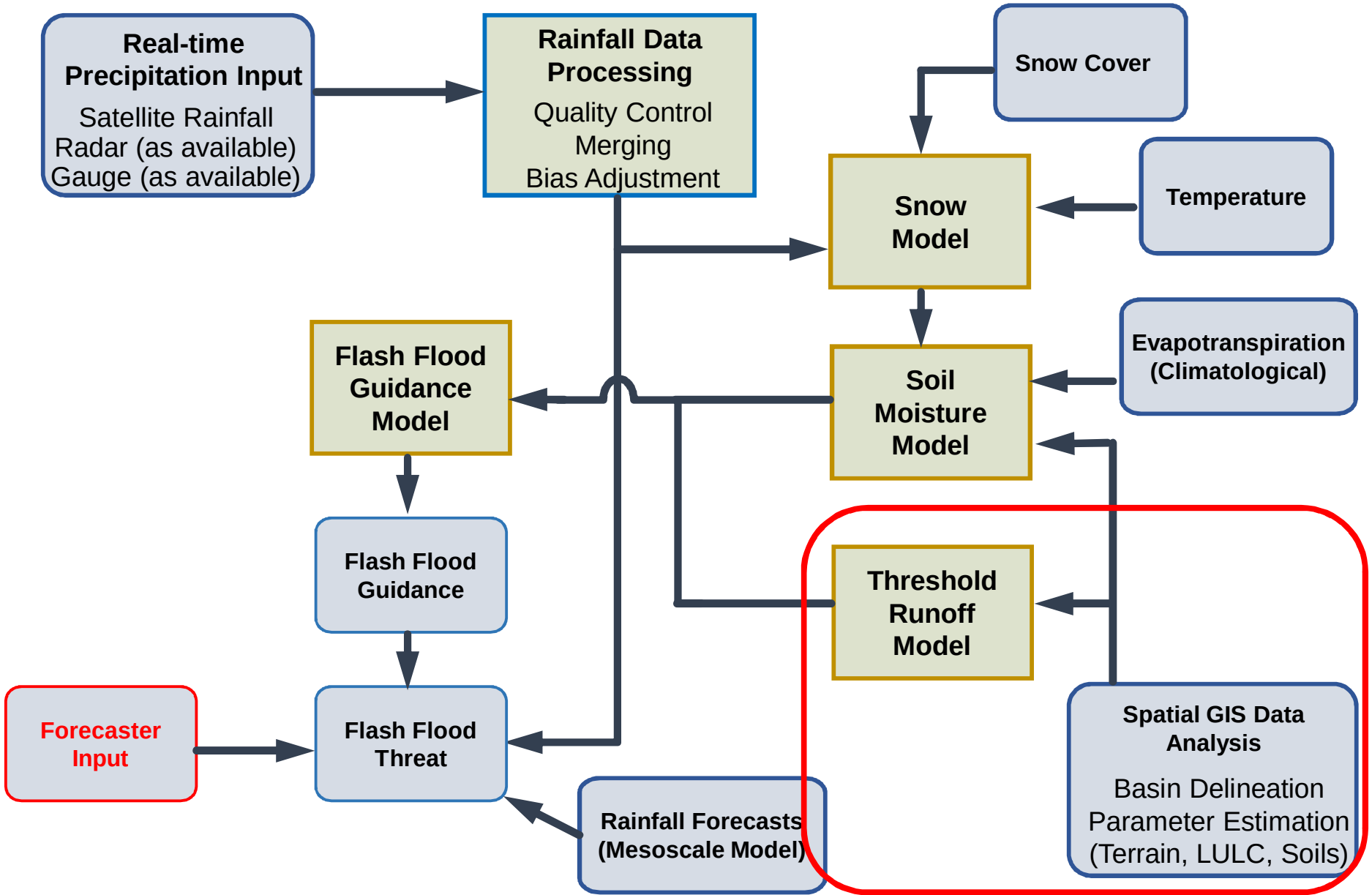
Southern California mountain stream

Motivation

Hydrologic Components of BSMEFFG System account for land surface processes in production of flash floods.

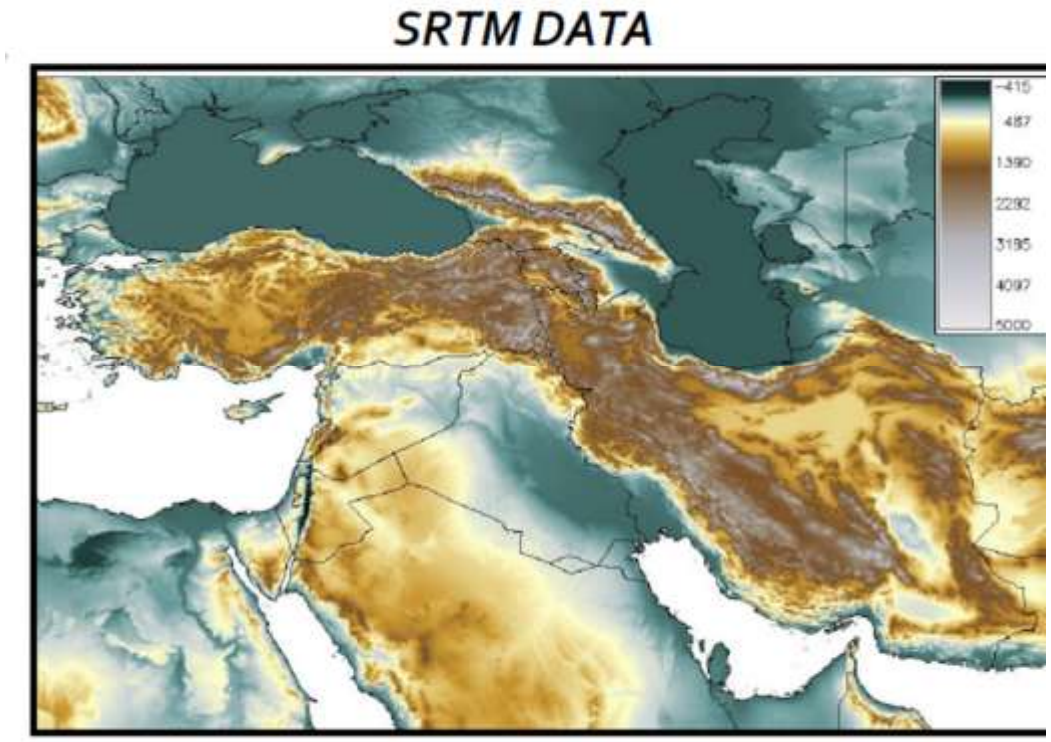
- *infiltration of rainfall into soil and storage of moisture in soil*
- *Accumulation and ablation of snow, and snow melt contribution to soil*
- *Frozen ground*
- *production of runoff into channels*
- *evapotranspiration*

Key Technical Components for Flash Flood Guidance Systems



GIS Processing to Delineate Small Flash Flood Watersheds

- *GIS processing of digital elevation data (SRTM)*
- *Define watershed boundaries*
- *Estimate watershed characteristics (A, L, S) used in calculations*
- *Spatial analysis for model parameterizations and MAP calculations*



GRASS GIS software

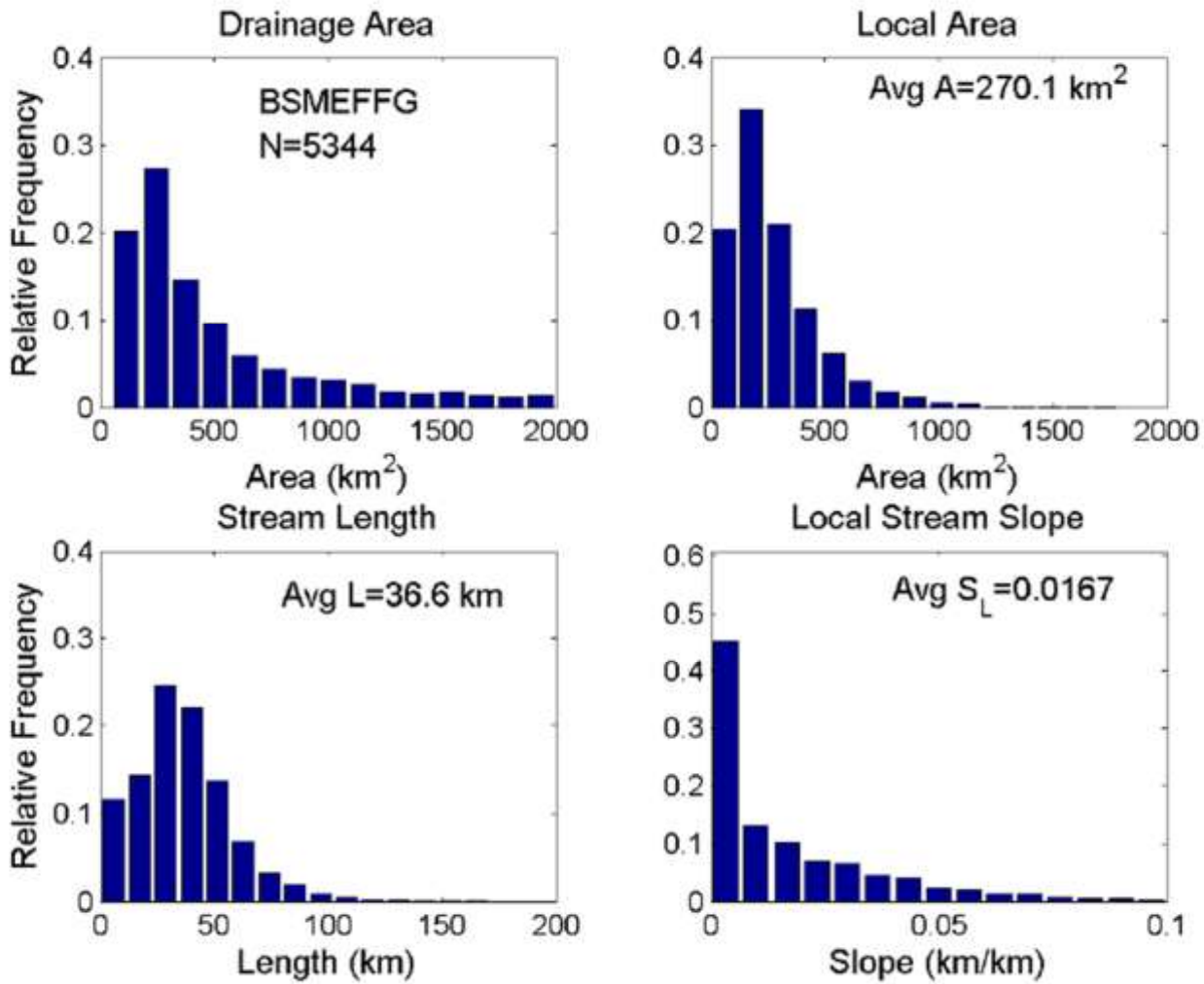
- *r.watershed routine*

SRTM 90-m DEM

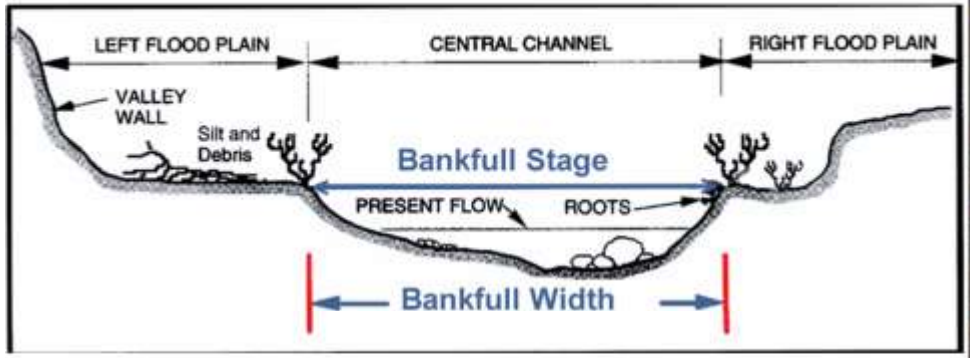
- *satellite-observed*
- *near global*
- *quality controlled*

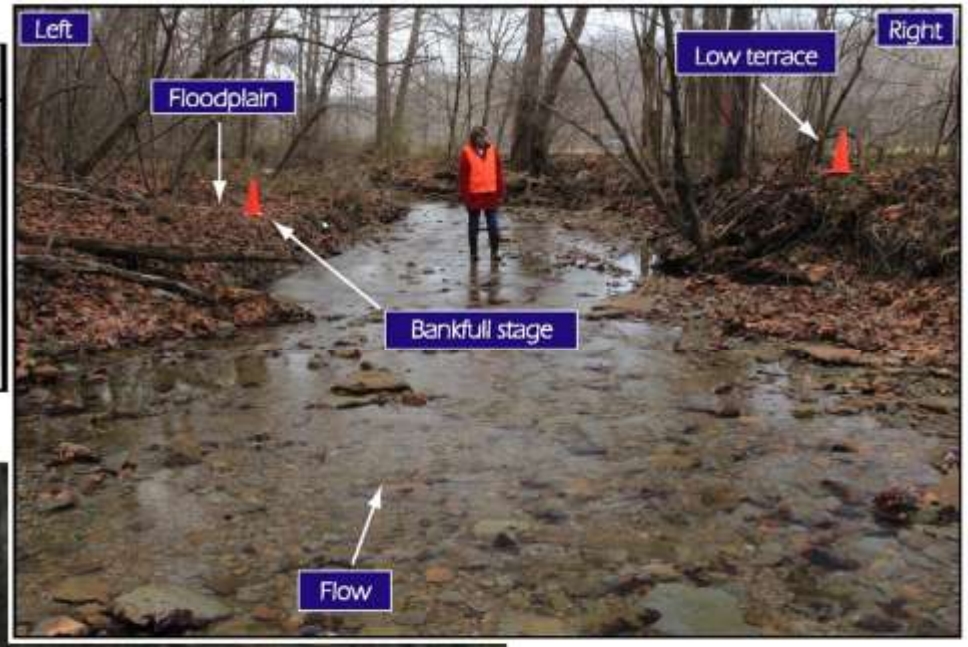
Characteristics of BSMEFFG Basins

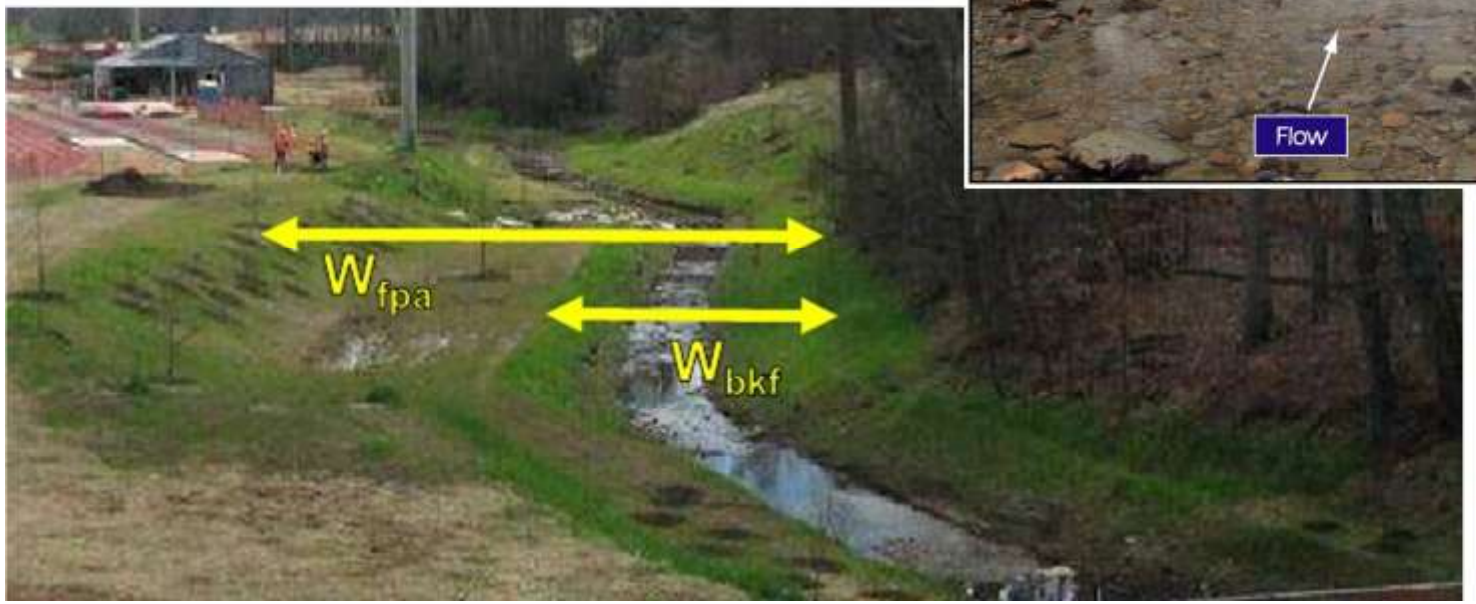
For Accumulated Drainage Area < 2000km²



Definition of Threshold Runoff

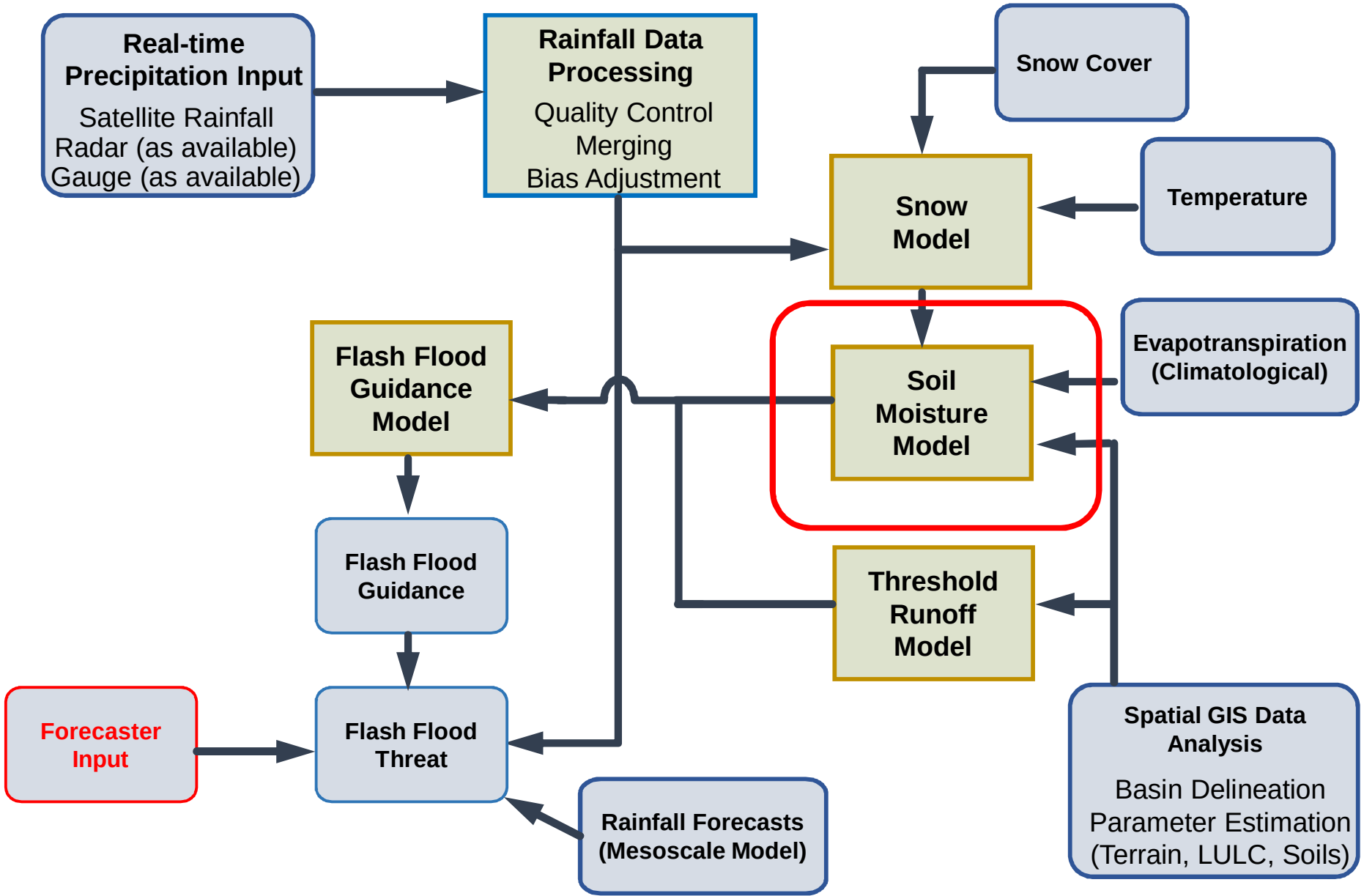






Threshold runoff represents the storage capacity of the stream to accept runoff at a level of minor flooding.

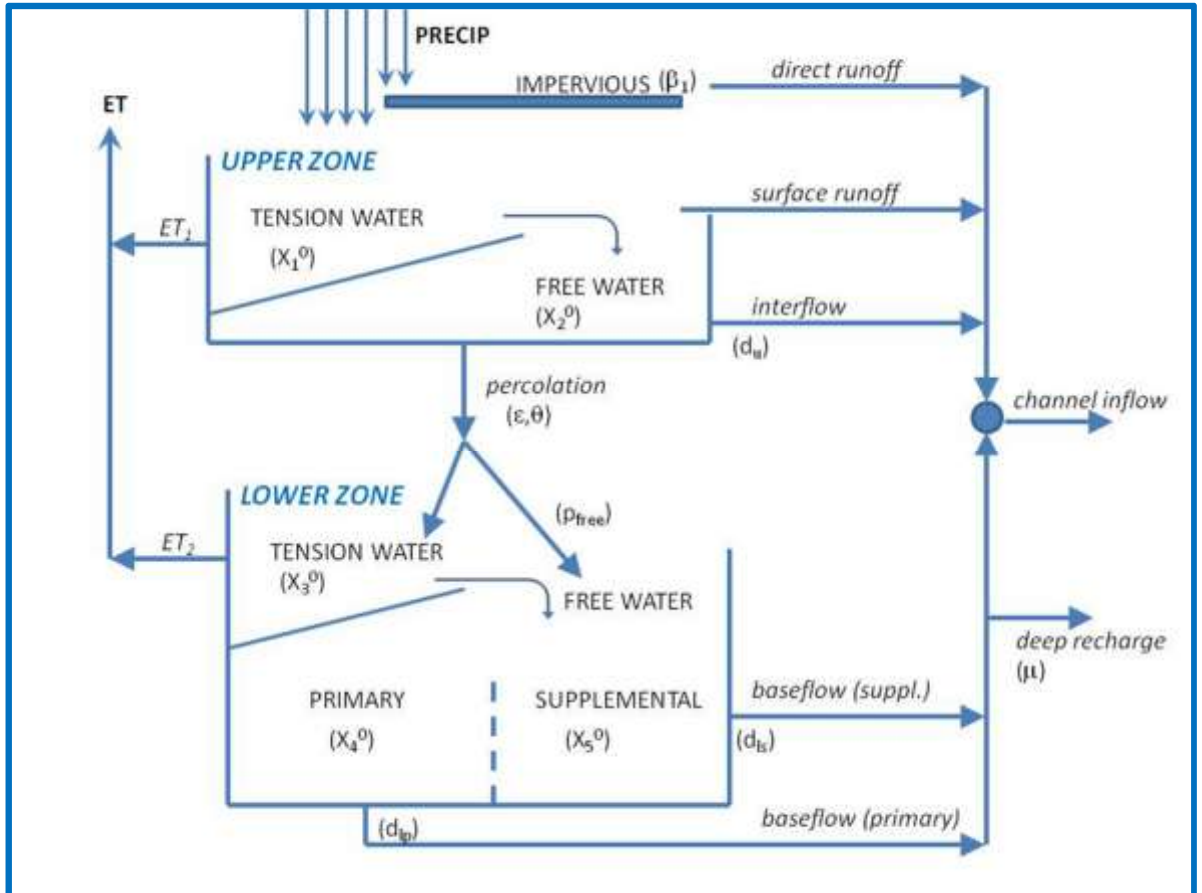
Key Technical Components for Flash Flood Guidance Systems



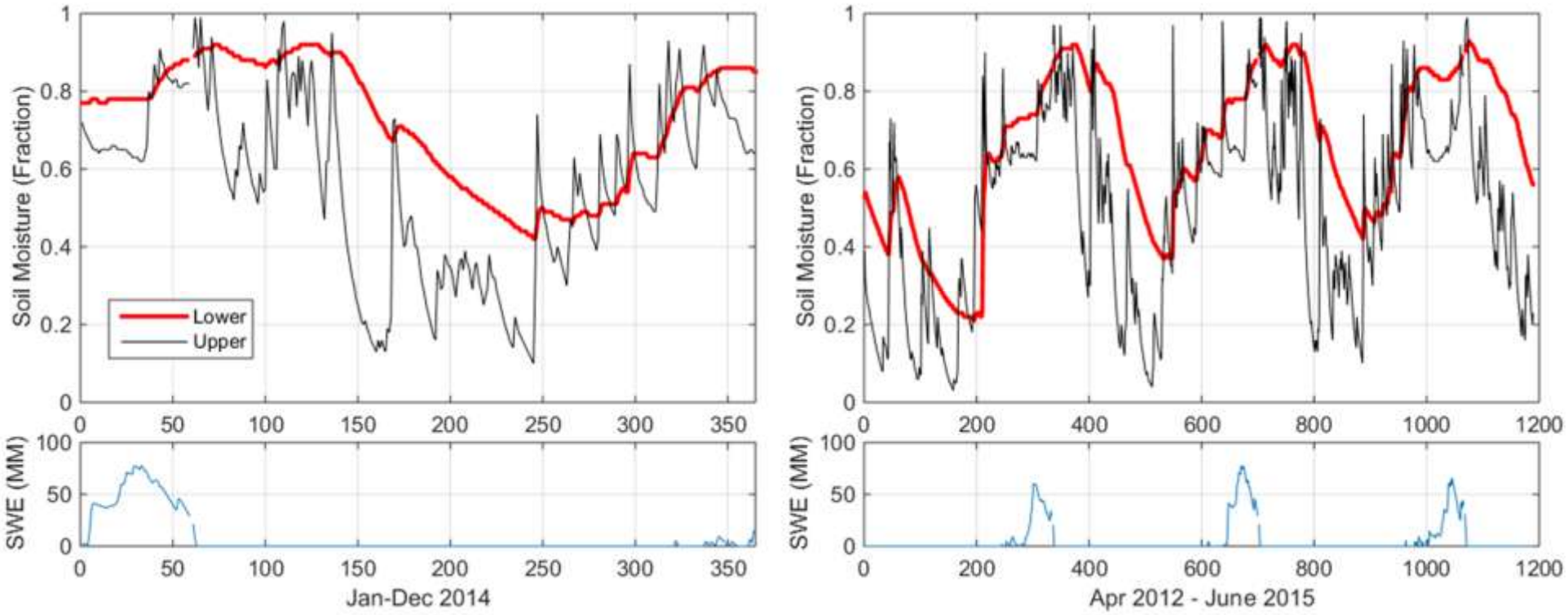
SAC-Soil Moisture Accounting Model

- A Conceptual hydrologic model is used for soil water modeling: Sacramento Soil Moisture Accounting Model (SAC-SMA) to estimate ability of land surface to absorb and hold moisture.

A two-layer conceptual model representing the movement of soil water through a vertical, homogeneous soil column

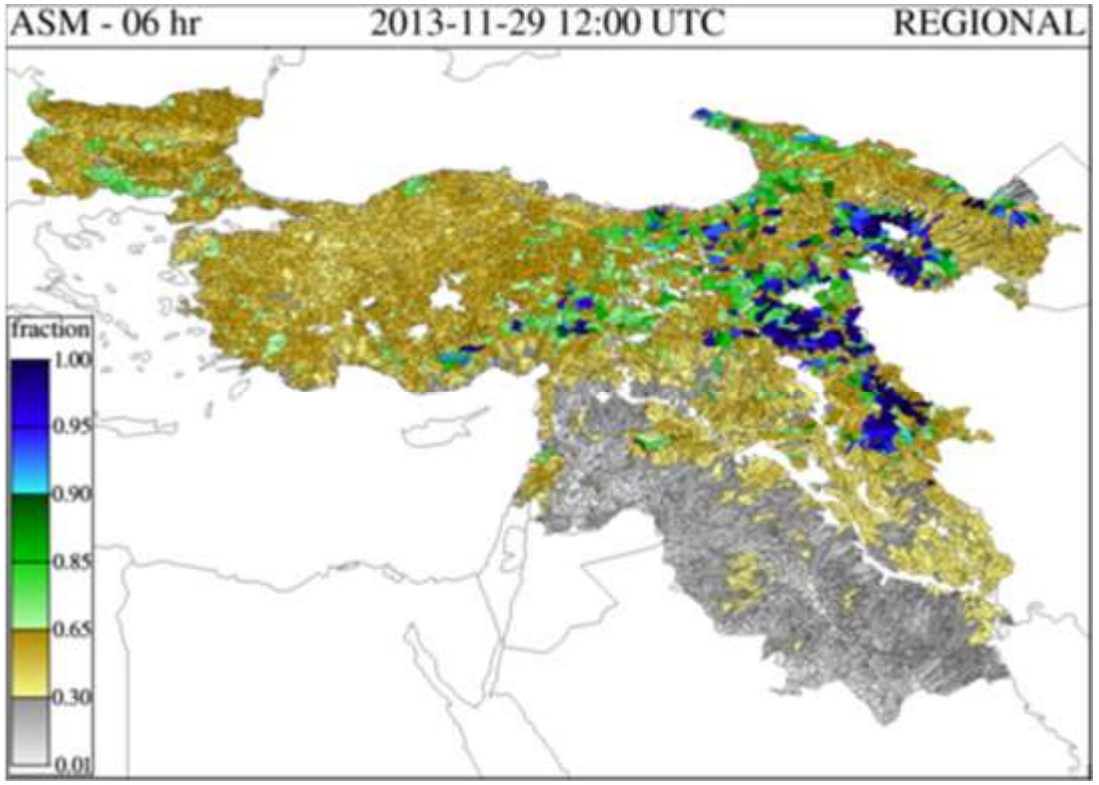


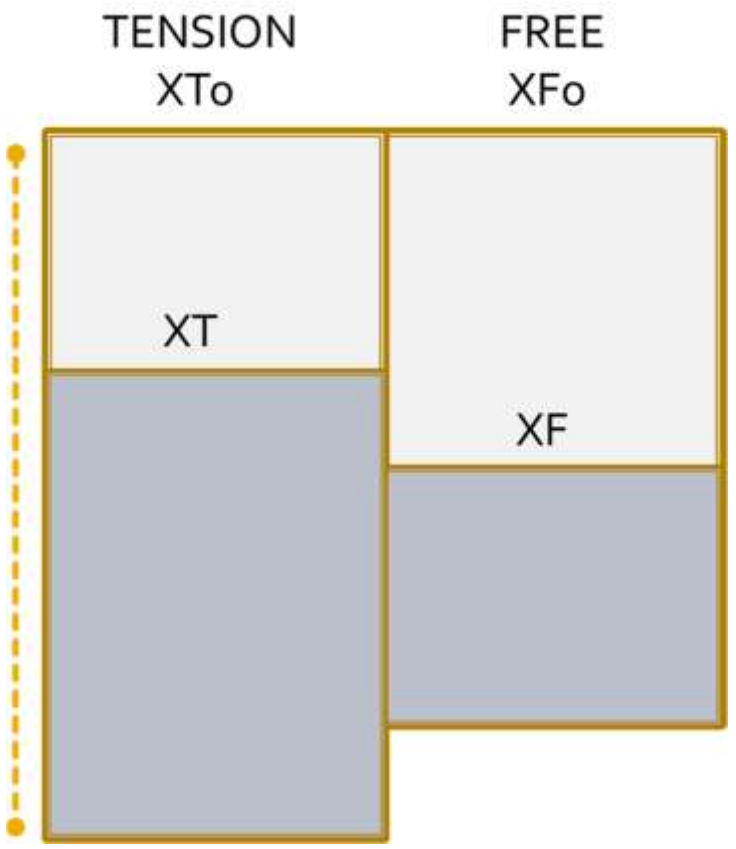
Time series of Soil Moisture



Average Soil Moisture

Upper Zone Soil Moisture

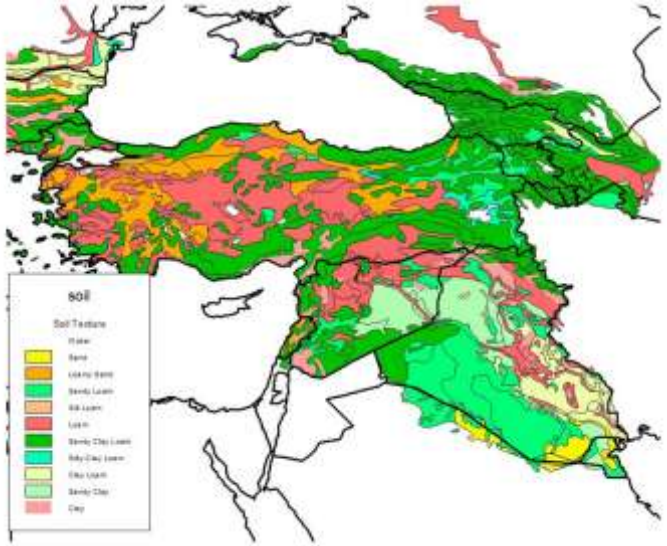




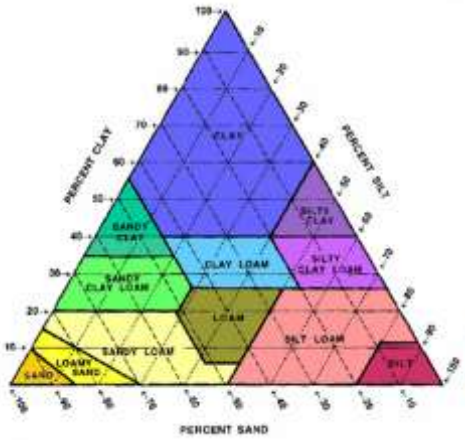
ASM = (XT + XF) / (XTo + XFo)

Sacramento SMA Model Parameterization

1. Soils Information: texture /depth



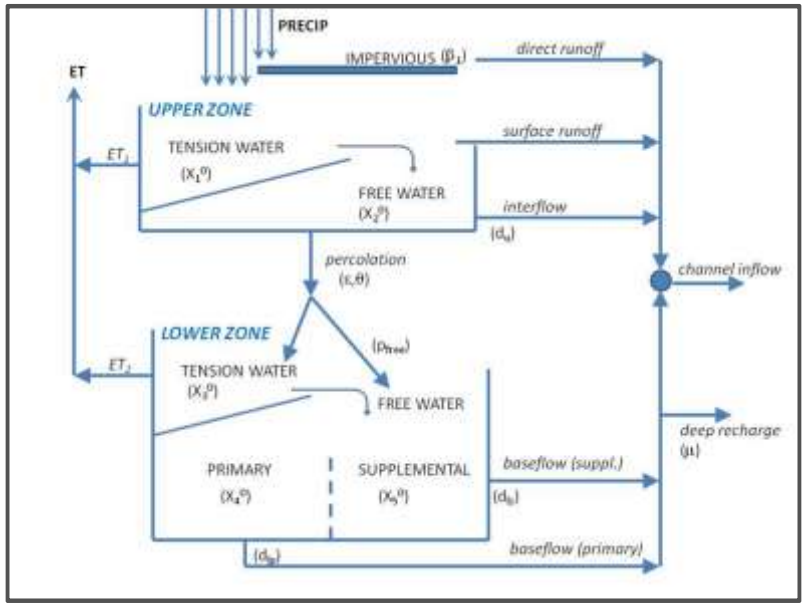
2. Soils Texture



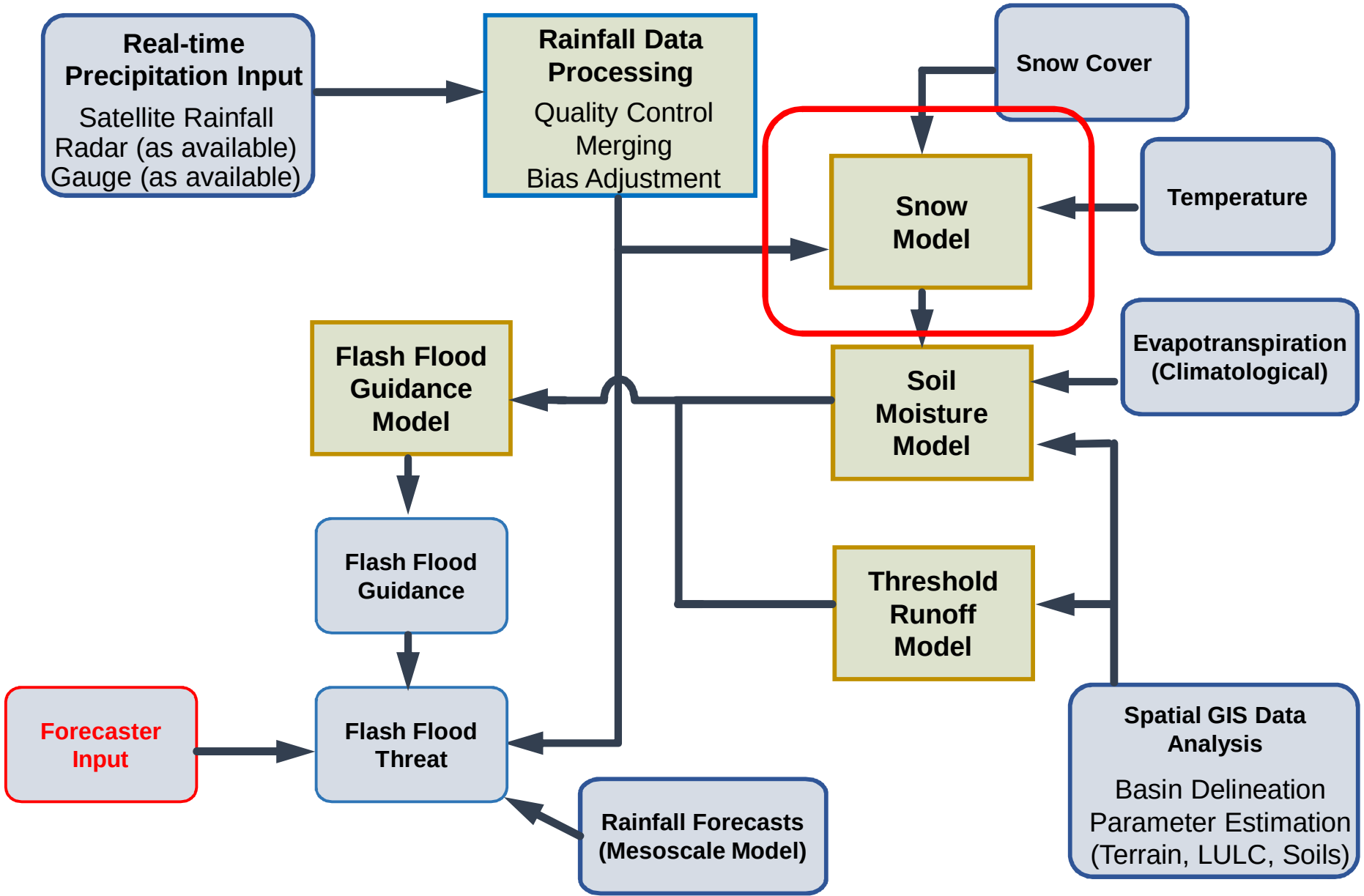
3. Hydraulic Properties

Soil Class	θ_s(m^3/m^3)	θ_r(m^3/m^3)	θ_m(m^3/m^3)	K_s(m/h)	α	σ_{Ks}(m/h)
Sand	0.34	0.09	0.015	0.168	2.79	0.062
Loamy Sand	0.42	0.16	0.05	0.050	4.26	0.082
Sandy Loam	0.43	0.21	0.07	0.019	4.74	0.119
Loam	0.44	0.25	0.095	0.012	5.25	0.108
Silty Loam	0.48	0.29	0.11	0.010	5.33	0.090

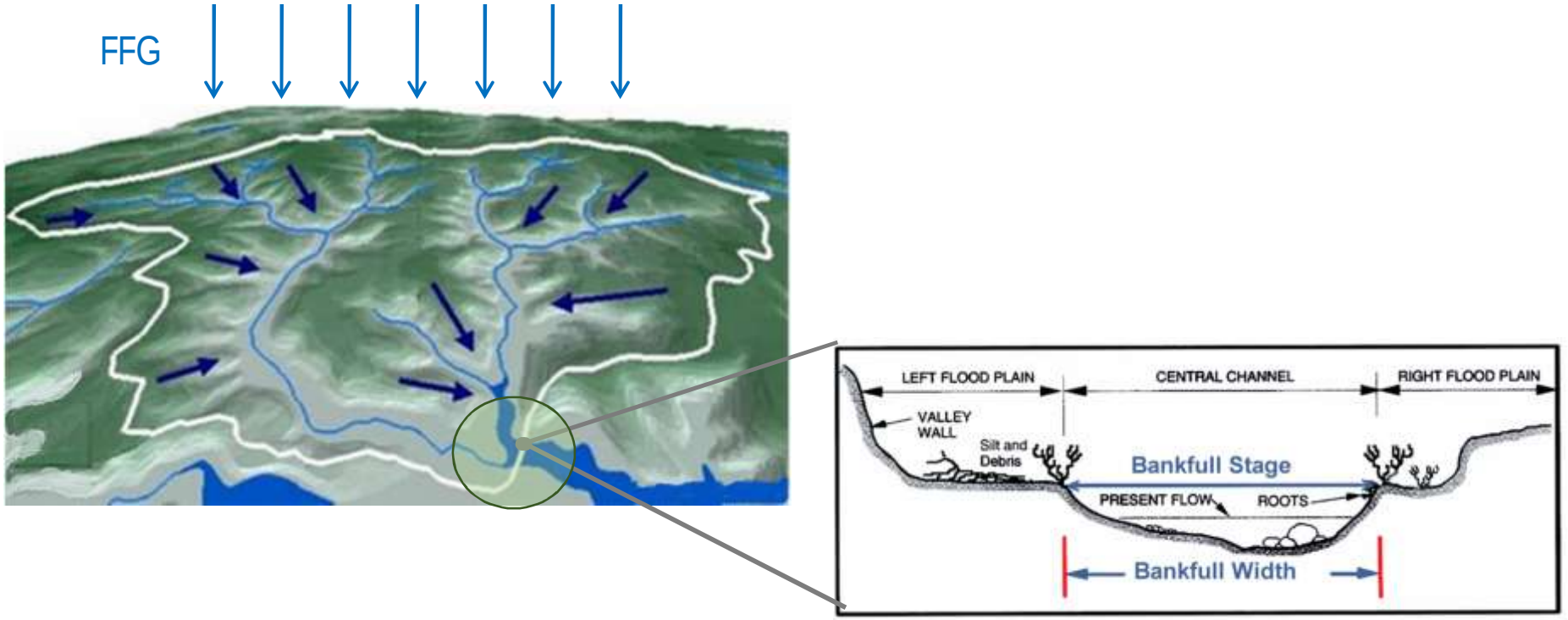
4. Parameters of SAC-SMA



Key Technical Components for Flash Flood Guidance Systems



Review of Technical Background
4. Flash Flood Guidance and Flash Flood Threat Products

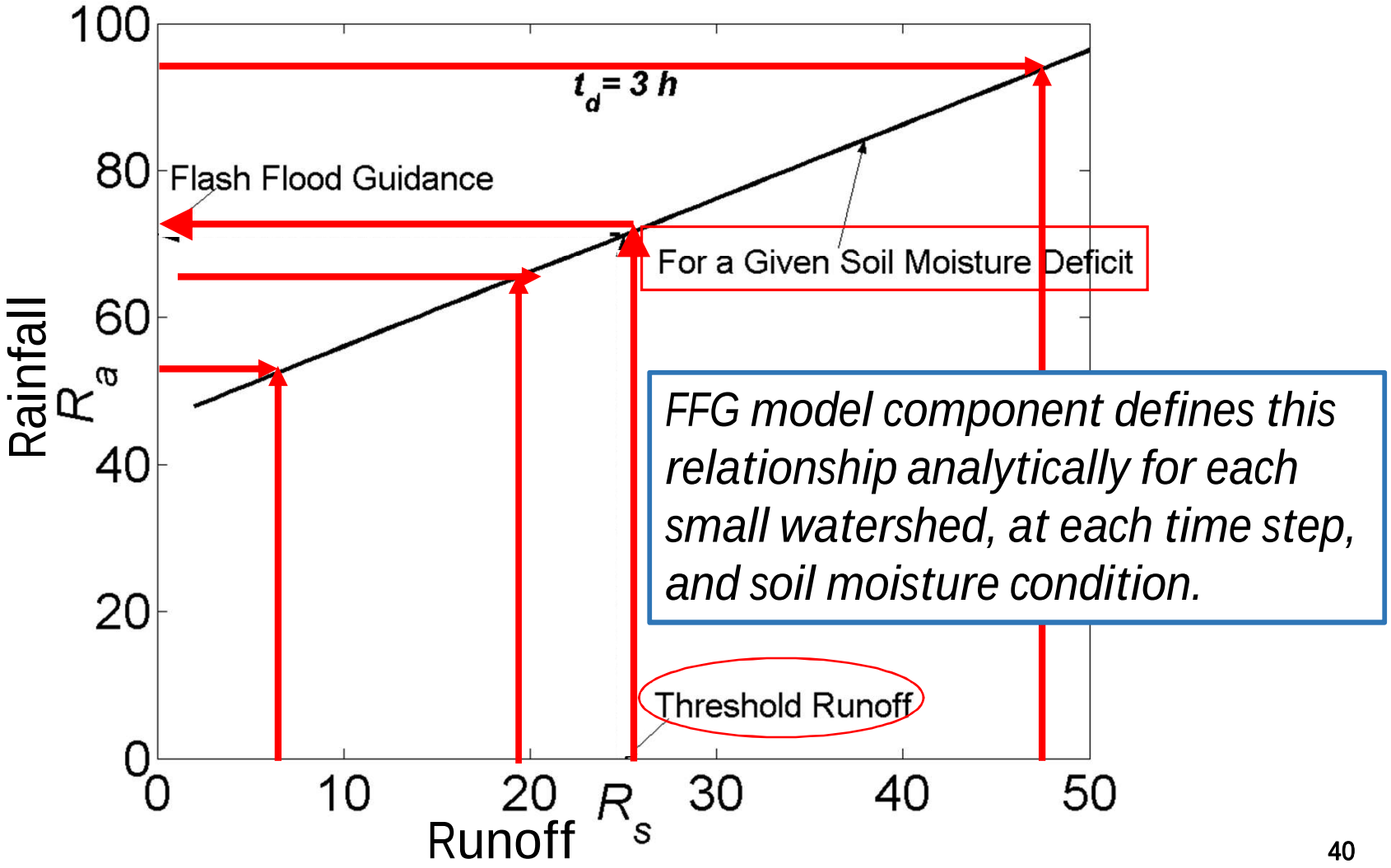


Flash Flood Guidance (FFG): The amount of **rainfall** of a given duration and over a given catchment that is just enough to cause **flooding conditions** at the outlet of the draining stream

Relationship of Threshold Runoff to FFG

A) "What if" scenario

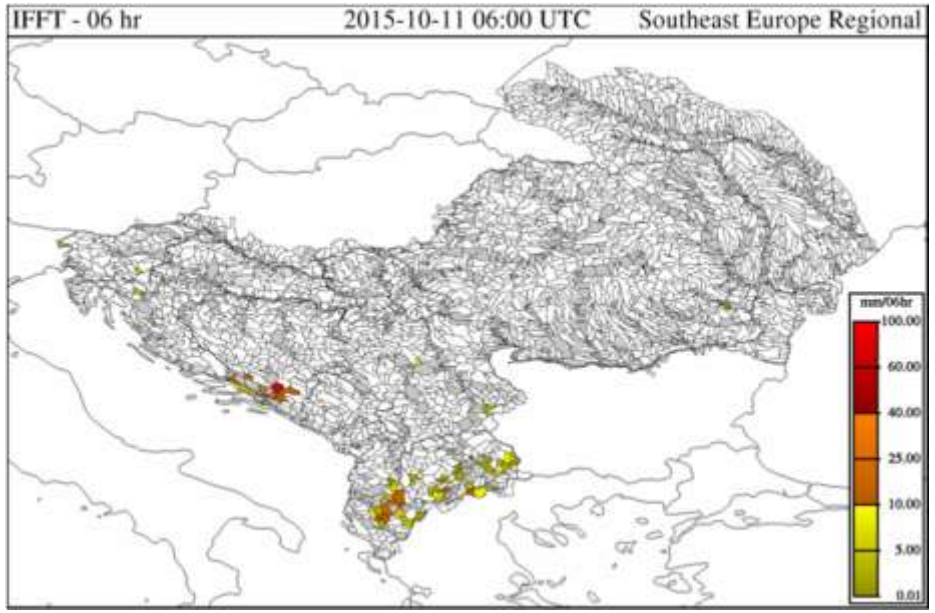
For a given watershed



FFG model component defines this relationship analytically for each small watershed, at each time step, and soil moisture condition.

Flash Flood Threat Products

Potential for flash flooding is increased when *PRECIPITATION > FFG*.



Flash Flood Threat, FFT, defined:
FFT = MAP - FFG

FFT provides indication of regions of potential concern.

Color bar provides magnitude of FFT.

Like FFG, FFT products are computed for 1-, 3-, and 6- hour durations and updated every 6 hours.

Flash Flood Threat Products

IFFT: Imminent
- based on *observed* precipitation (merged MAP) and prior FFG
- Flash flooding may be occurring!

PFFT: Persistence
- most recent *observed* precipitation (merged MAP) and current FFG
- forecast of persistence: *IF* rainfall continues at current rate

FFFT: Forecast
- based on *forecast* precipitation (FMAP) and current FFG
- Forecaster must evaluate in FMAP


THANK YOU