Preliminary analysis on flash floods in the northwestern Pakistan, 2010, using IFAS with satellite-based rainfall and global GIS data

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Flood Disasters in Pakistan

Ali Mardan leads his two donkeys through floodwaters near Sukkur, Sindh province

Extent of the flooding in Sindh province

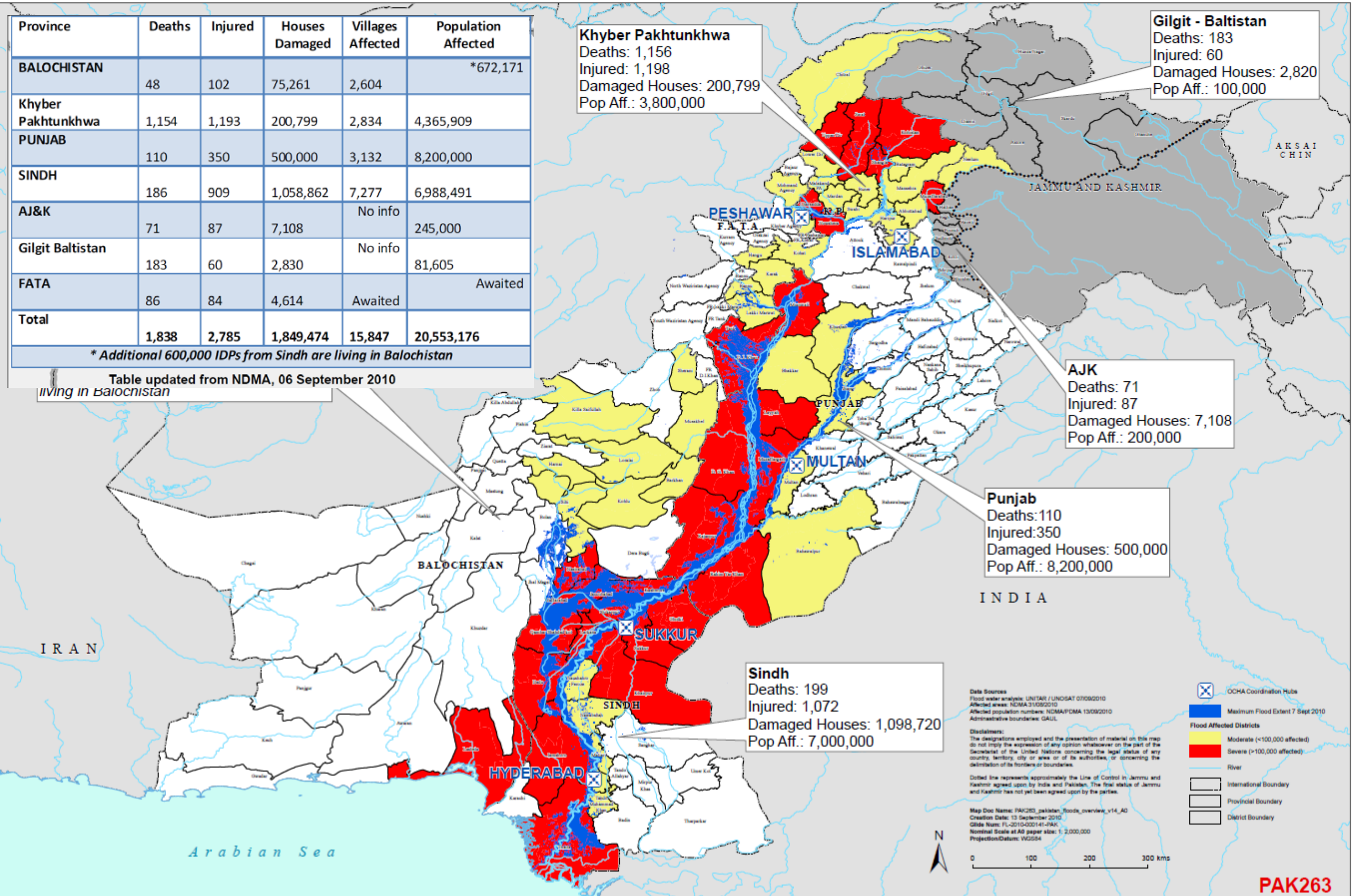
Pakistan - Flood Extent (07 Sept 2010) and Flood Losses (13 Sept 2010)

MapAction | OCHA

Province	Deaths	Injured	Houses Damaged	Villages Affected	Population Affected
BALOCHISTAN	48	102	75,261	2,604	*672,171
Khyber Pakhtunkhwa	1,154	1,193	200,799	2,834	4,365,909
PUNJAB	110	350	500,000	3,132	8,200,000
SINDH	186	909	1,058,862	7,277	6,988,491
AJ&K	71	87	7,108	No info	245,000
Gilgit Baltistan	183	60	2,830	No info	81,605
FATA	86	84	4,614	Awaited	Awaited
Total	1,838	2,785	1,849,474	15,847	20,553,176

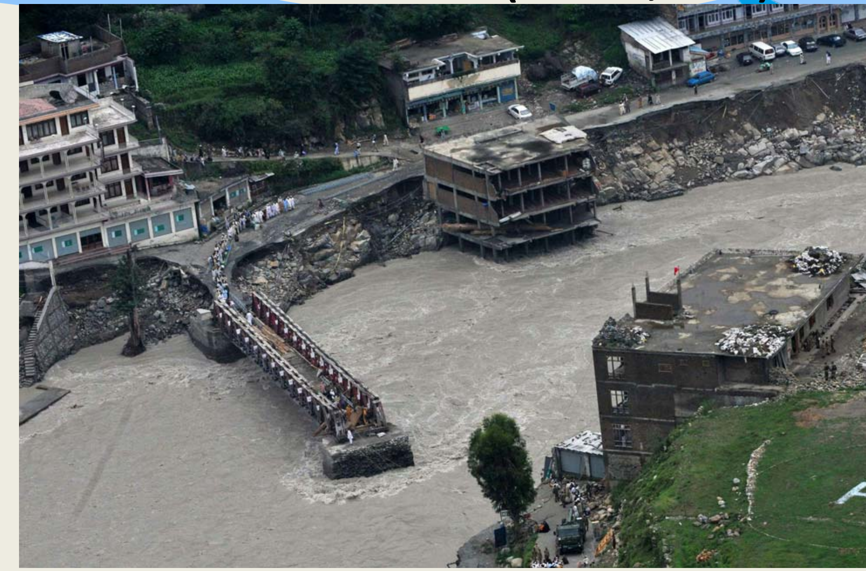
** Additional 600,000 IDPs from Sindh are living in Balochistan*

Table updated from NDMA, 06 September 2010



Flash Flood Disasters in Northwestern Part (7.29, 30)

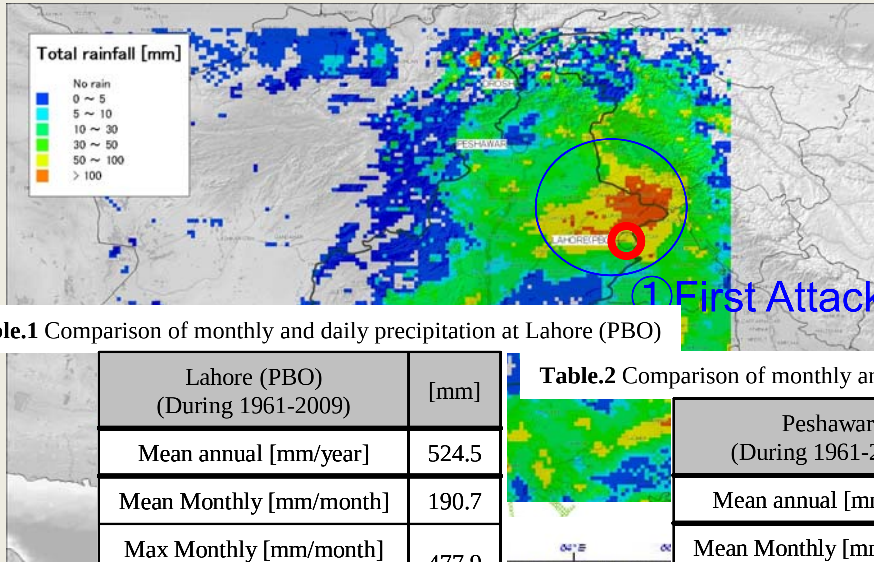
An aerial view shows Nowshera city submerged in flooding caused by heavy monsoon rains in Pakistan on Friday, July 30, 2010. (AP Photo/Mohammad Sajjad)



Pakistani flood survivors cross a bridge near a damaged home in Medain, a town of Swat valley on August 2, 2010. (A Majeed/AFP/Getty Images)

Residents watch water pour through a street on the outskirts of Peshawar, Pakistan on July 28, 2010. (A Majeed/AFP/Getty Images)

Overview of meteorological condition



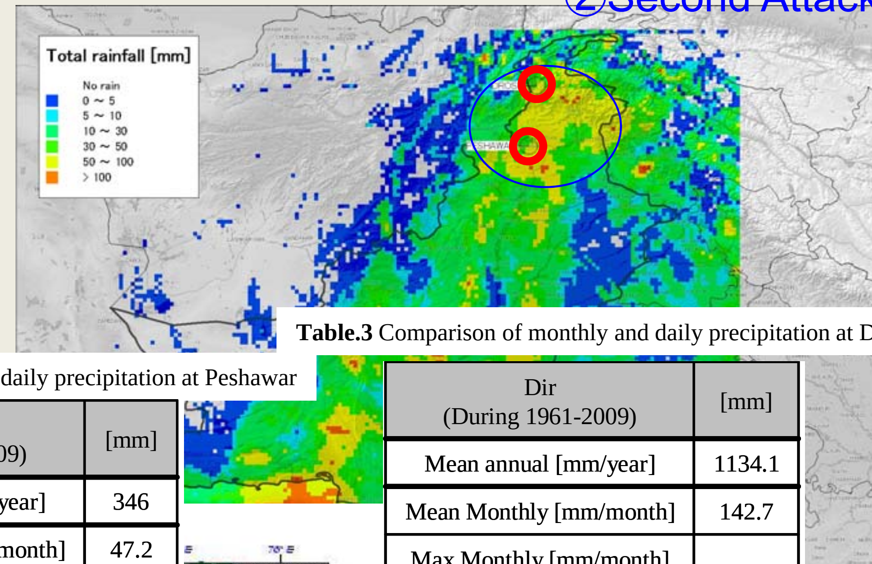


Table.1 Comparison of monthly and daily precipitation at Lahore (PBO)

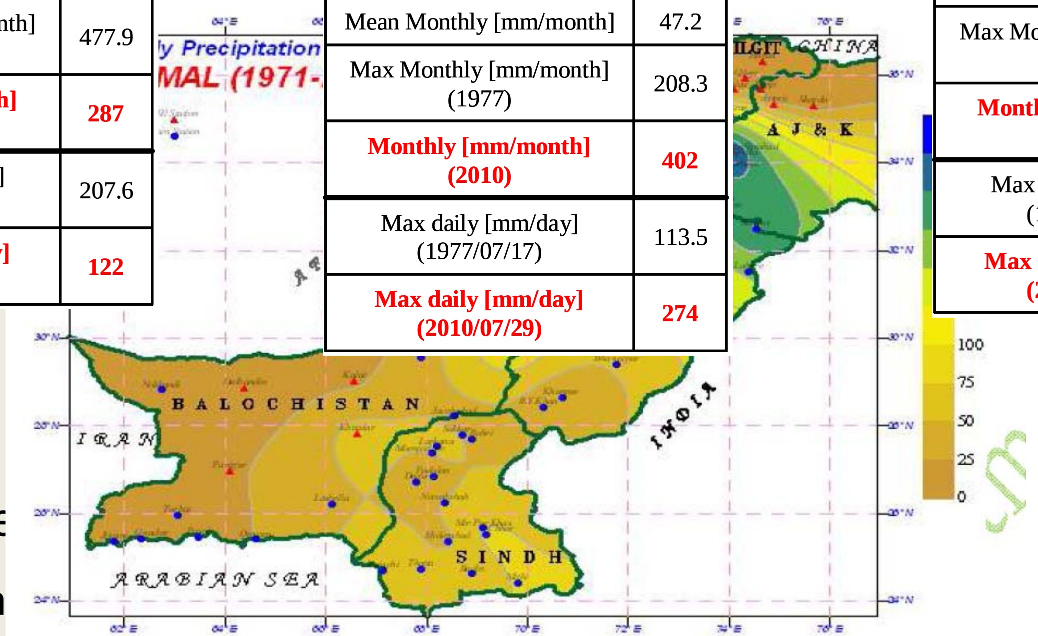
Lahore (PBO) (During 1961-2009)	[mm]
Mean annual [mm/year]	524.5
Mean Monthly [mm/month]	190.7
Max Monthly [mm/month] (1981)	477.9
Monthly [mm/month] (2010)	**287**
Max daily [mm/day] (1980/07/31)	207.6
Max daily [mm/day] (2010/07/22)	**122**

Table.2 Comparison of monthly and daily precipitation at Peshawar

Peshawar (During 1961-2009)	[mm]
Mean annual [mm/year]	346
Mean Monthly [mm/month]	47.2
Max Monthly [mm/month] (1977)	208.3
Monthly [mm/month] (2010)	**402**
Max daily [mm/day] (1977/07/17)	113.5
Max daily [mm/day] (2010/07/29)	**274**

Table.3 Comparison of monthly and daily precipitation at Dir

Dir (During 1961-2009)	[mm]
Mean annual [mm/year]	1134.1
Mean Monthly [mm/month]	142.7
Max Monthly [mm/month] (2008)	274
Monthly [mm/month] (2010)	**317**
Max daily [mm/day] (1989/07/31)	147
Max daily [mm/day] (2010/07/29)	**149**



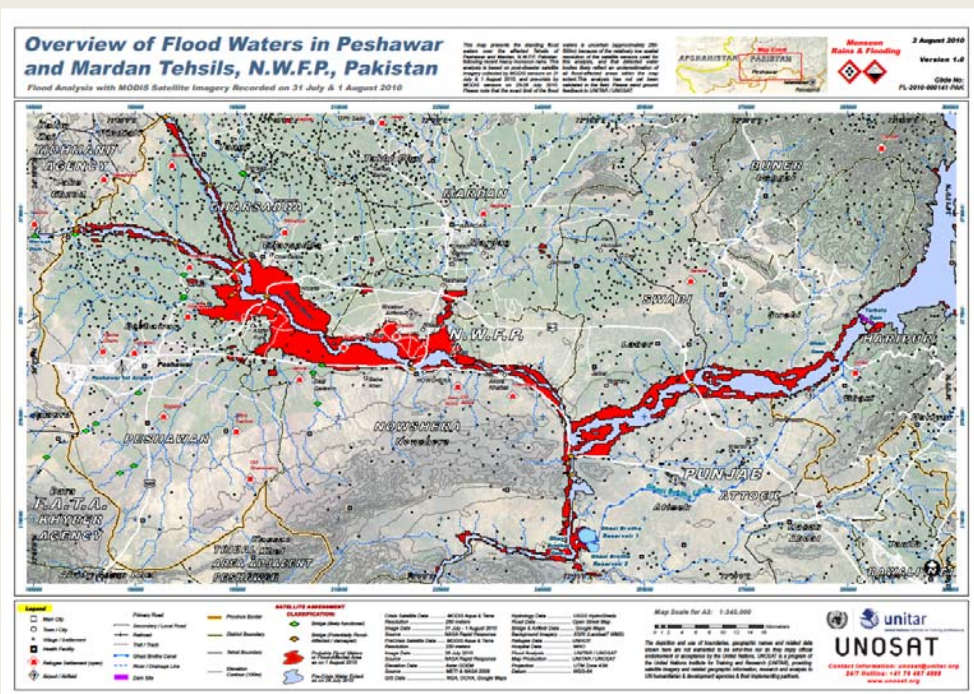
(20 … TC)

- ➤ He… a region secondly.
- ➤There were not … ere is usual.
- ➤There was more … nfall was the heaviest record rain

ICHARM

Hydrologic modeling with satellite-based rainfall data for Emergency Response

- Cannot access to the disaster stricken areas after mega-disasters.
- Remote sensing (+ some local info) are the only sources for estimating the conditions of the disaster (UNOSAT, Dartmouth Flood Observatory, OCHA etc)
- Governments need to rely on the limited information for emergency responses.



<u>Inundated map by UNOSAT</u>

July 29: Flash Flood

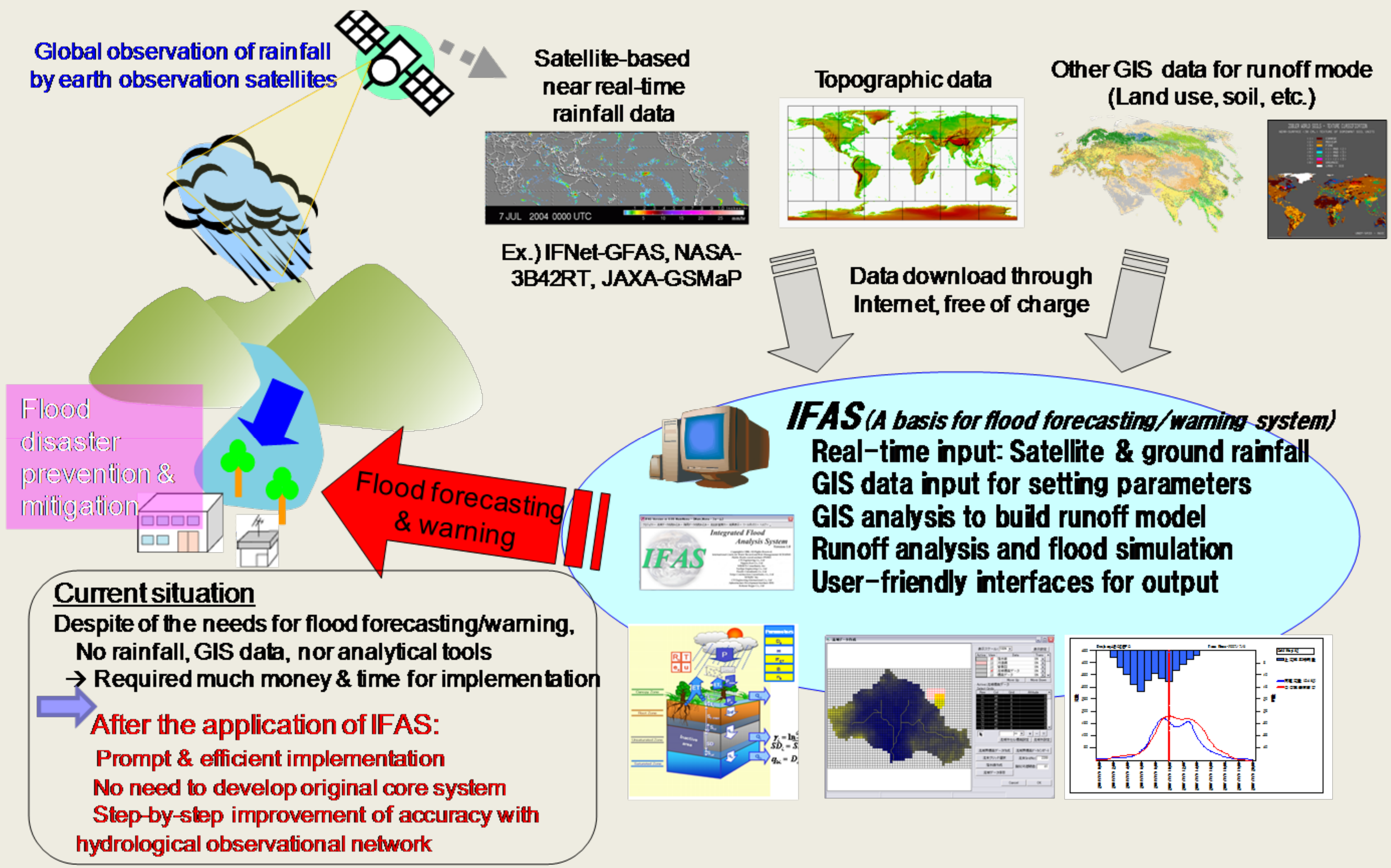
Aug 1: Detected by MODIS satellite

Aug 2: Release the inundation map

- Does a inundation map based on remote sensing detected two days after the flash flood correspond to the damaged area?
- Can a hydrologic model with satellite-based rainfall data provide complementary information?

Integrated Flood Analysis System IFAS

Toolkit to implement "Global Flood Alert System (GFAS) – Streamflow"



Example of Satellite-based rainfall data disclosed without cost through internet

Product name	3B42RT	CMORPH	QMORPH	**GSMaP_NRT**
Developer and provider	NASA/GSFC	NOAA/CPC	NOAA/CPC	JAXA/EORC
Coverage	N60° - S60°			
Resolution	0.25°	0.25°	0.25°	**0.1°**
Resolution time	3 hours	3 hours	0.5 hour	**1 hour**
Time lag	10 hours	15 hours	2.5 hours	**4 hours**
Coordinate system	WGS			
Historical data	Dec 1997-	Dec 2002-	nearest past 2 days	Dec. 2007～
Sensors	TRMM/TMI Aqua/AMSR-E AMSU-B DMSP/SSM/I IR	Aqua/AMSR-E AMSU-B DMSP/SSM/I TRMM/TMI IR		TRMM/TMI Aqua/AMSR-E ADEOS-Ⅱ/ AMSR SSM/I IR AMSU-B

GSMaP_NRT

JAXA,
JST-CREST
(Prof. Ken'ichi OKAMOTO, Osaka Pref. Univ. et al.)
ICHARM/PWRI

http://sharaku.eorc.jaxa.jp/GSMaP/index.htm

Global Rainfall Map
in Near Real Time

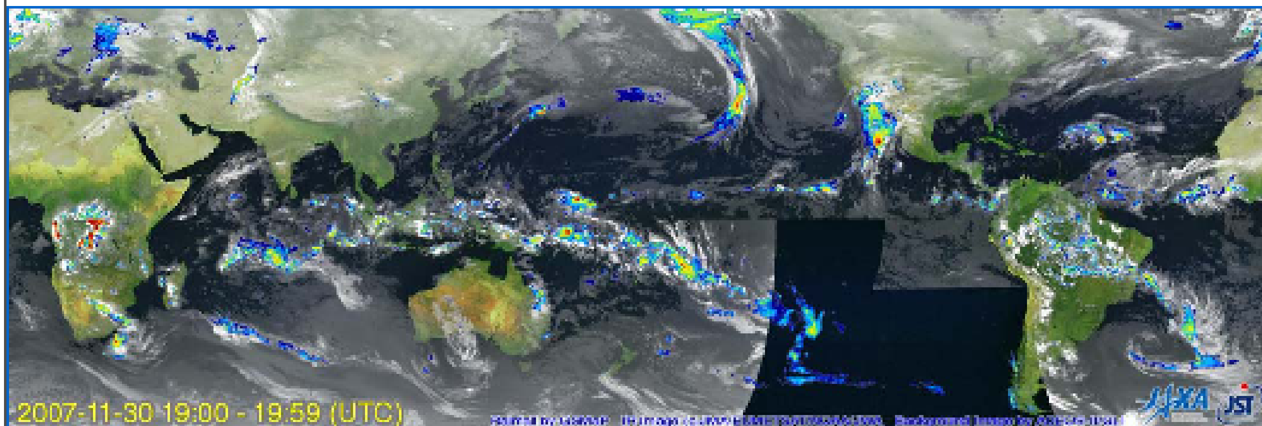
JAXA/EORC

>> Japanese

Last up date: 2007/Dec/01 00:15:02 UTC

Date: 2007 / Nov / 30 19:00-19:59 UTC Submit

Latest 10 Images | 24h Movie | Pre << | Latest | >> Next | MWR Coverage | Google Earth



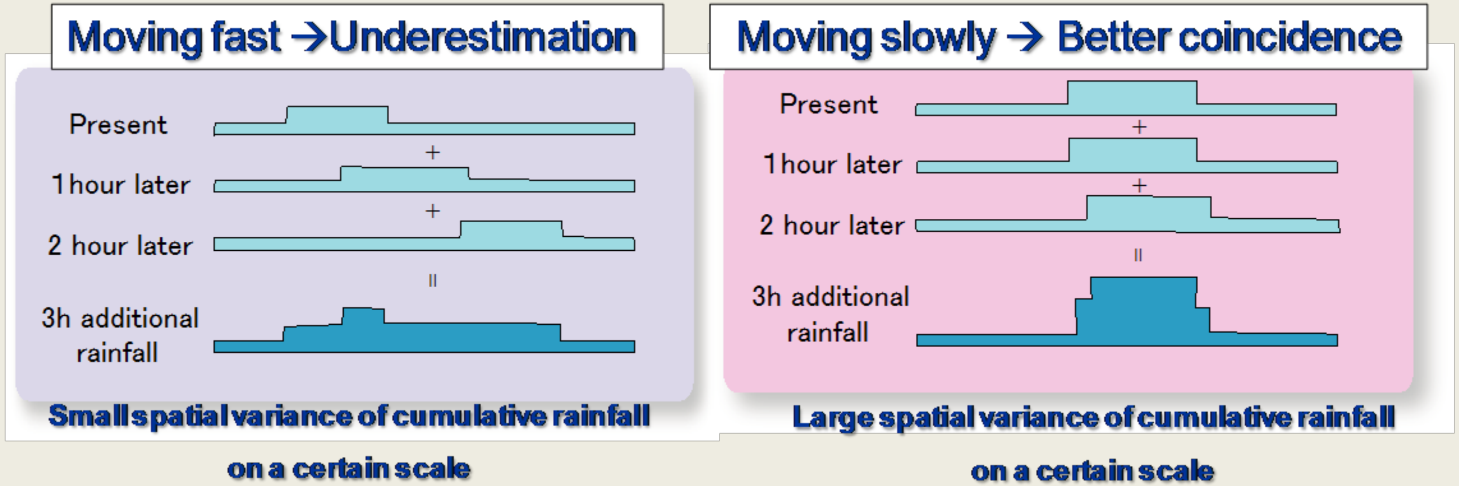
Rain 0.1 0.5 1.0 2.0 3.0 5.0 10.0 15.0 20.0 25.0 30.0 [mm/hr]

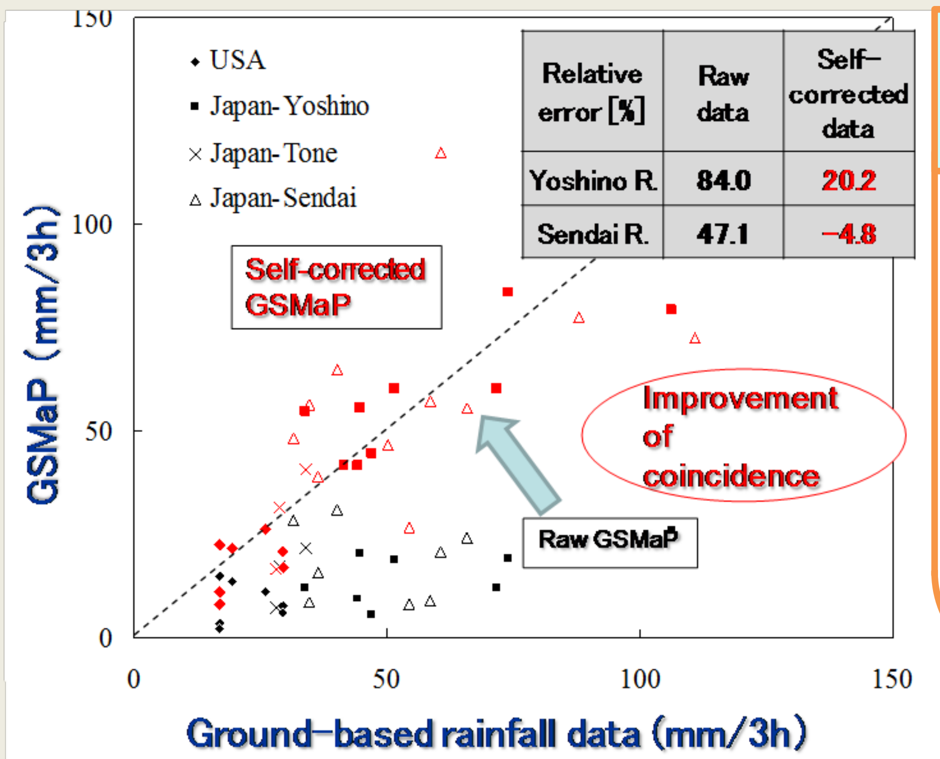
We offer hourly global rainfall maps in near real time (about four hours after observation) using the combined MW-IR algorithm with TRMM TMI, Aqua AMSR-E, DMSP SSM/I and GEO IR data. This system was developed based on activities of the JST-CREST GSMaP (Global Satellite Mapping of Precipitation) project.

Description

Variable	:	Rainfall rate (mm/hr)
Domain	:	Global (60N – 60S)
Grid resolution	:	0.1 degree lat/lon
Temporal resolution	:	1 hour

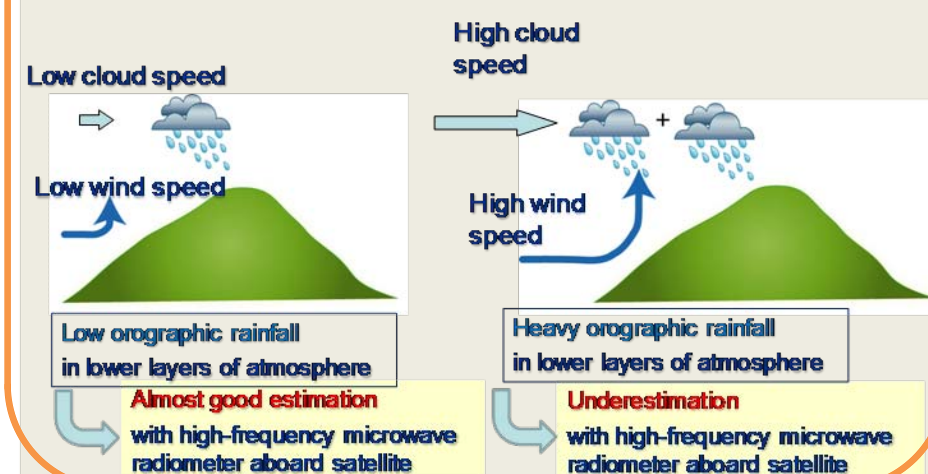
Algorithm for self-correction of satellite-based rainfall data without any ground-based rainfall data





Relative error [%]	Raw data	Self-corrected data
Yoshino R.	84.0	20.2
Sendai R.	47.1	−4.8

A hypothesis on the reason why this self-correction is empirically effective.



Design concept of IFAS

1. To prepare interfaces to get satellite-based rainfall data in addition to ground-based rainfall data, to secure the worldwide availability of input data for flood forecasting/analysis system.

2. To adopt two types of distributed-parameter hydrologic models, the parameters of which can be estimated as the first approximation based on globally-available GIS databases to secure the worldwide availability of hydrologic models for flood forecasting/analysis.

3. To implement GIS analysis modules in the system to set up the parameters for the flood forecasting/analysis model, therefore no need to depend on external GIS softwares.

5. To prepare a series of easy-to-understand graphical user interfaces for data input, modeling, runoff-analysis, and displaying the outputs.

6. To distribute the executable program, free of charge, from the ICHARM/PWRI website

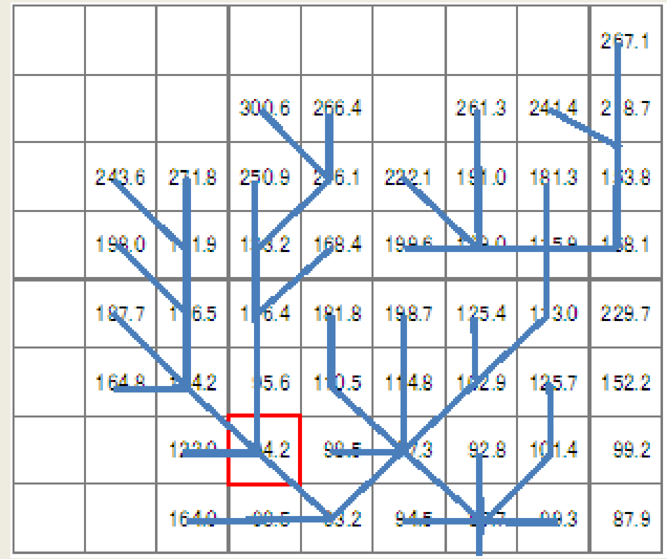
Flood runoff analysis model creation using global GIS data

ICHARM

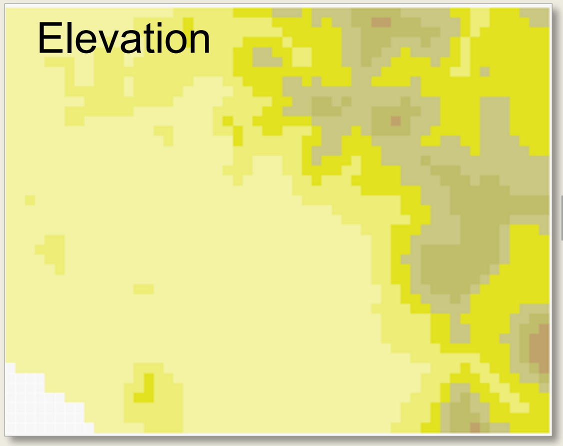
Import data

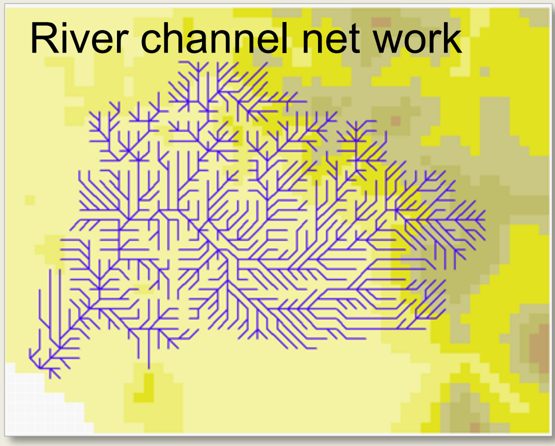
Type	Product	Provider
Elevation	Global Map(Elevation data)	ISCGM
	GTOPO30	USGS
	Hydro1k	USGS
Land use	GLCC	USGS
	Global Map(Land cover)	ISCGM
	Global Map(Land use)	ISCGM
Geology	Geology	CGWM
Soil type	Soil Texture	UNEP
	Soil Water Holding Capacity	UNEP
	Soil Depth	GES

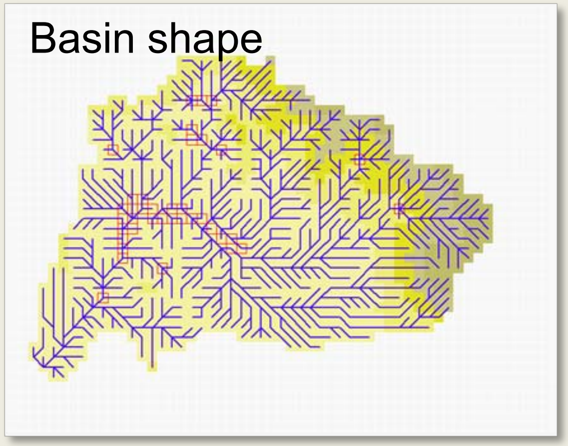
Example of elevation data of a each cell and a river channel network



Creation of River channel net work and basin shape based on elevation data





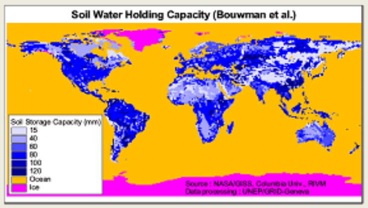


Parameter estimation using global GIS data

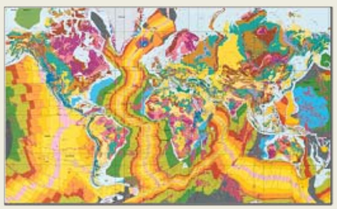
GIS data

Land use, Land cover

Soil



Geology



Parameter

Roughness
Surface permeability

Soil permeability
Soil thickness

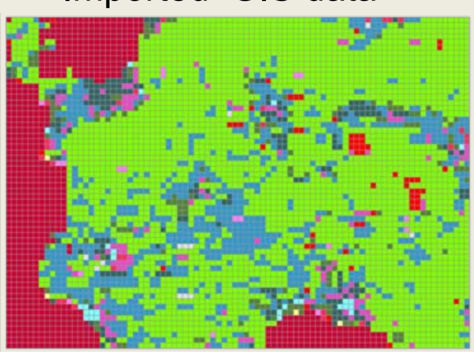
Rock permeability

Relation between land-use classification and parameters

Land use classification	Parameter classification
Broadleaf Evergreen Forest	1
Broadleaf Deciduous Forest	1
Needleleaf Evergreen Forest	1
Needleleaf Deciduous Forest	1
Mixed Forest	1
Tree Open	1
Shrub	2
Herbaceous	2
Herbaceous with Sparse Tree/Shrub	2
Sparse vegetation	2
Cropland	3
Paddy field	3
Cropland / Other Vegetation Mosaic	3
Mangrove	3
Wetland	3
Bare area,consolidated(gravel,rock)	2
Bare area,unconsolidated (sand)	2
Urban	4
Snow / Ice	5

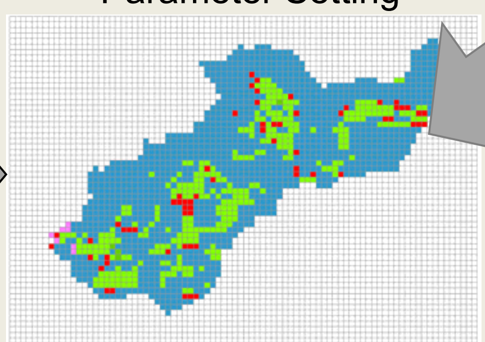
The parameter values of each classification are set up at basins which can obtain hydrological data beforehand

Imported GIS data



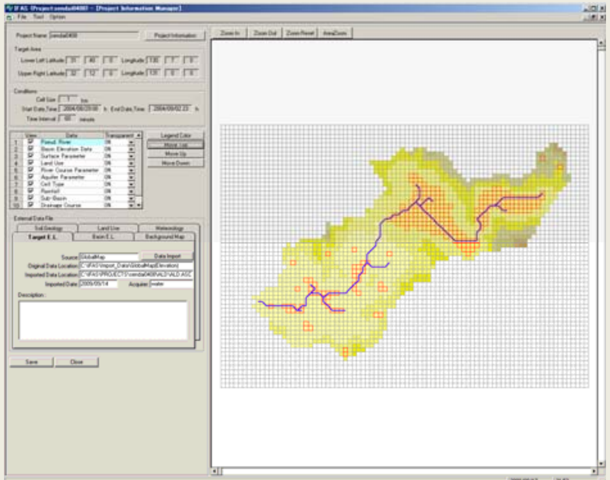
GIS analysis function

Parameter Setting

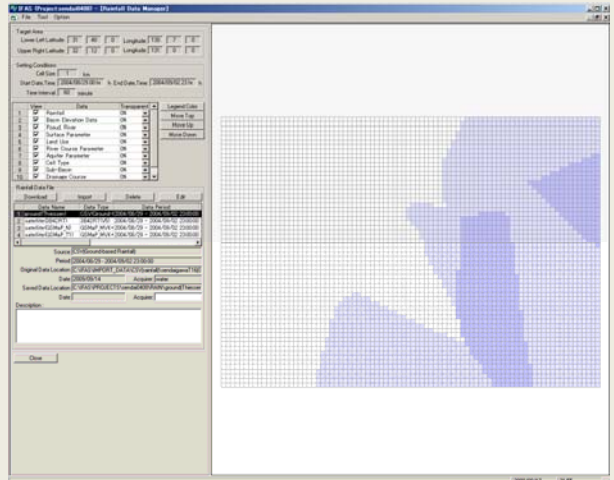


Interface display

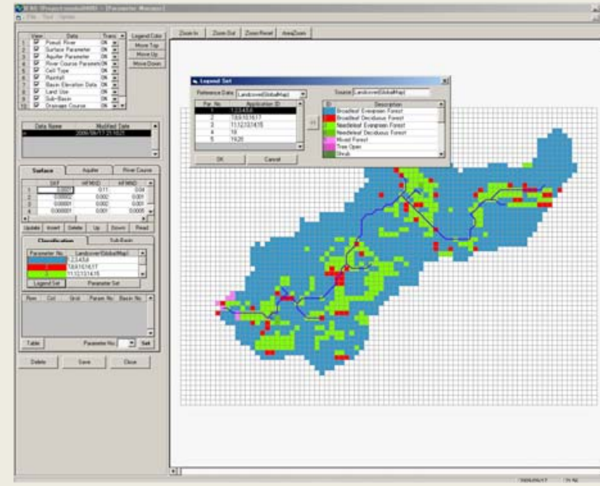
Main display



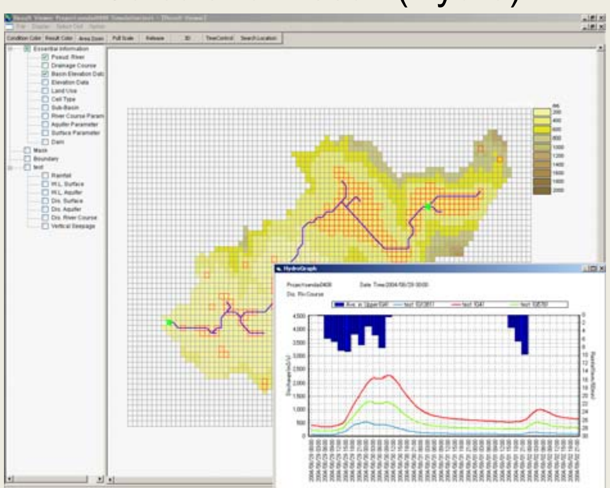
Edit display of rainfall data



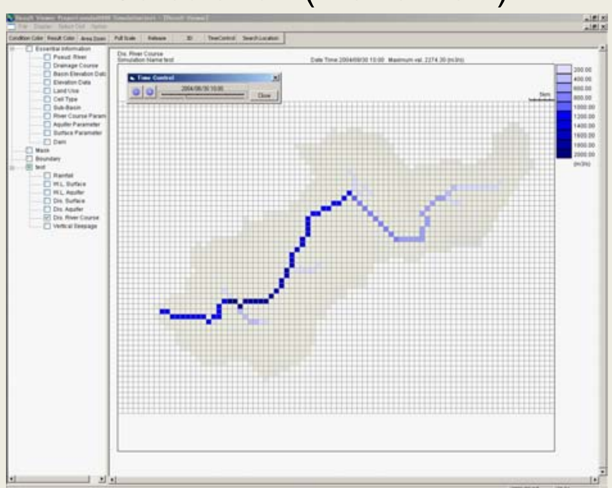
Setting display of parameter



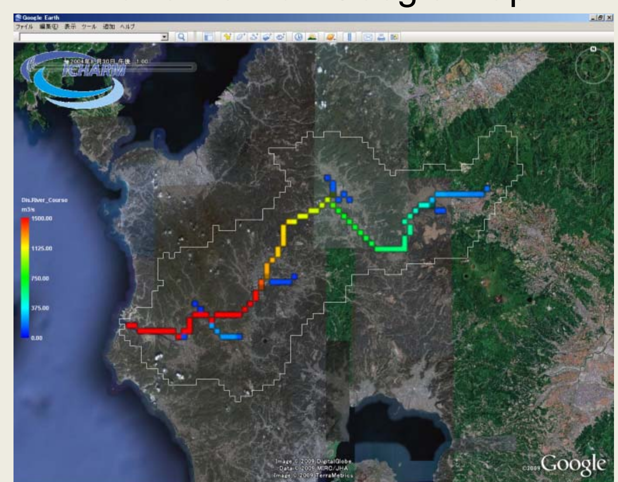
Calculation result (Hydro)



Calculation (Plane view)



Plane view on Google Map



GSMaP_NRT as an input data for Simulation

	GSMaP_NRT [mm/day]							Ground-gauged [mm/day]						
day	PESHAWAR	AIDU_SHARI	CHERAT	ISLAMABAD	CHILAS	ARACHINAI	DROSH	PESHAWAR	AIDU_SHARI	CHERAT	ISLAMABAD	CHILAS	PARACHINAR	DROSH
27	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	4.0	1.0	0.0	0.0	2	0.0
28	3.0	1.5	7.6	3.3	3.3	1.3	15.9	0.0	44.0	33.0	68.0	2.0	20	23
29	31.5	35.5	43.5	8.0	0.0	2.2	24.1	274.0	187.0	257.0	31.0	8.0	21	61
30	14.3	32.9	15.7	17.6	3.1	15.9	4.5	59.0	103.0	81.0	120.0	26.0	20.0	15
31	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0	0.0
Total_R	48.8	69.8	68.2	28.9	6.5	19.5	44.5	333.0	338.0	372.0	219.0	40.0	63	99

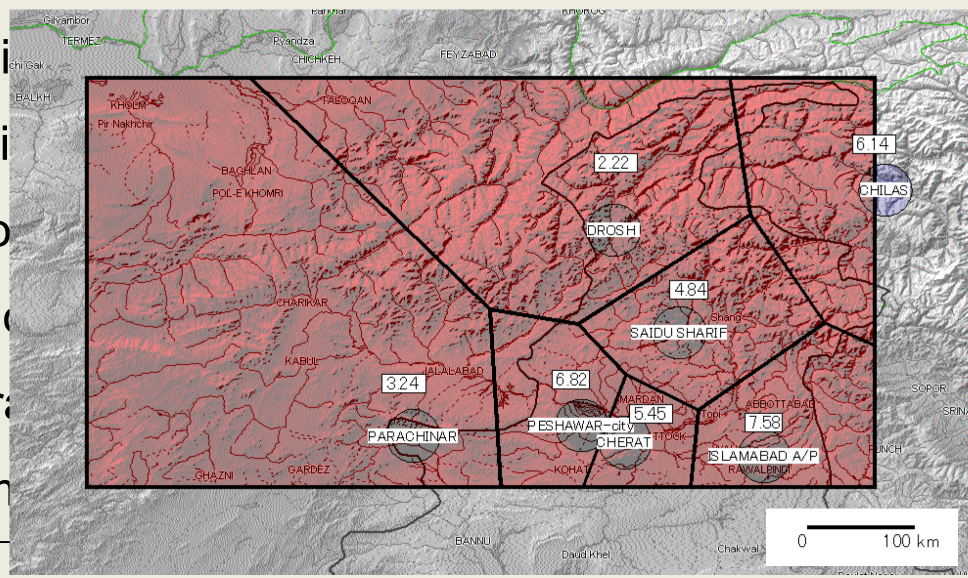
	(GG/GSMaP_NRT)[倍]									
day	PESHAWAR	AIDU_SHARI	CHERAT	ISLAMABAD	CHILAS	ARACHINAI	DROSH	average	ave-thiesen	
27	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.1	0.0	no-rain
28	0.0	30.3	4.4	20.5	0.6	15.5	1.4	10.4	11.1	
29	8.7	5.3	5.9	3.9	0.0	9.4	2.5	5.1	6.0	
30	4.1	3.1	5.2	6.8	8.3	1.3	3.3	4.6	3.2	
31	0.0	0.0	0.0	0.0	35.9	0.0	0.0	5.1	3.1	
Total_R	6.82	4.84	5.45	7.58	6.14	3.24	2.22			

(Most of heavy rai … a region from July 27th to 31st which i …

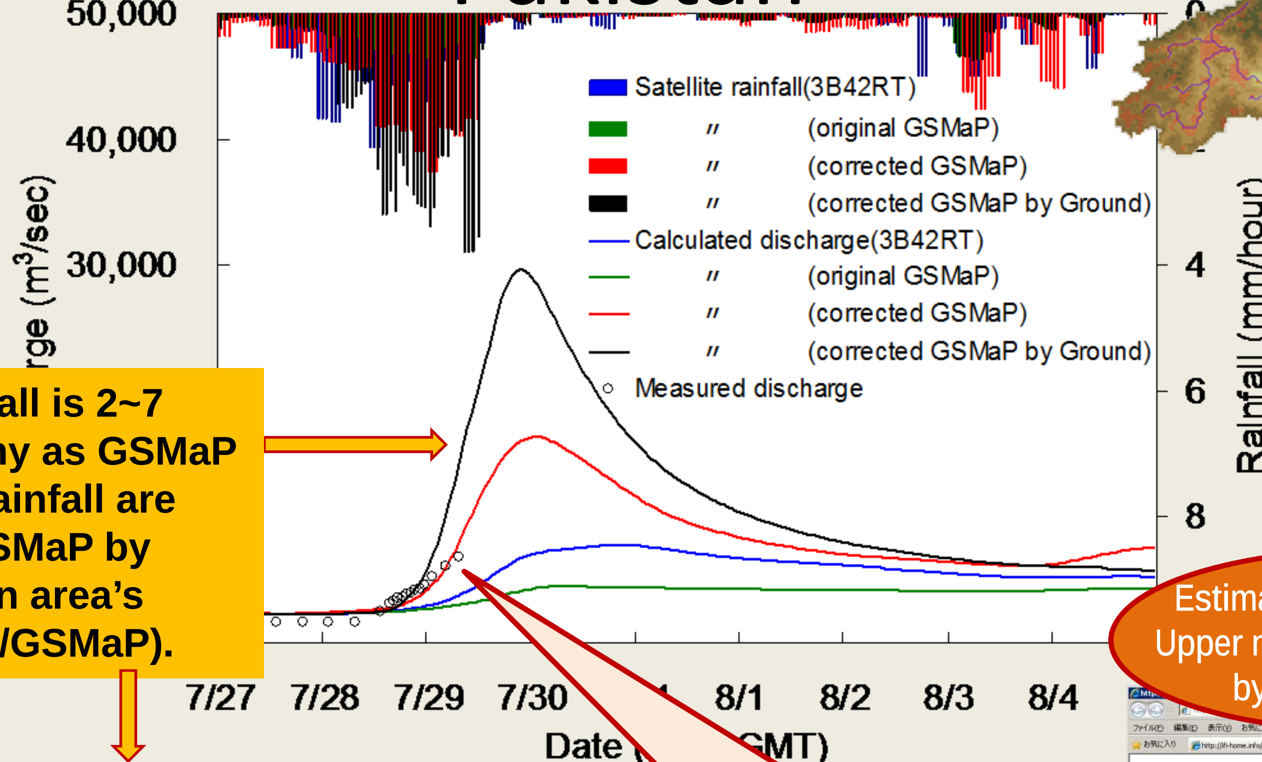
➤Calculating ratio … 31st in each Thiessen polygin …

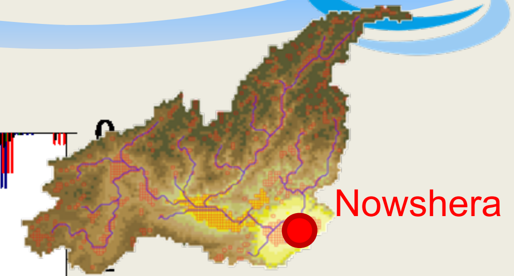
➤Multiplying the r … .

➤Self-correction n …



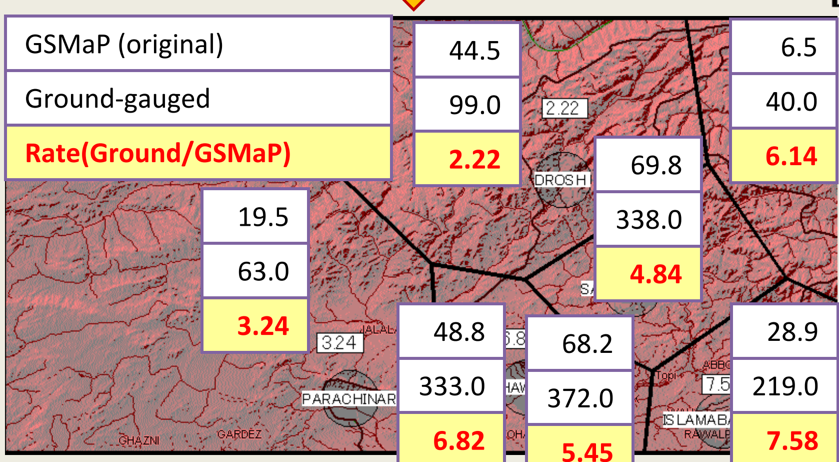
Calculation results : Kabul river in Pakistan





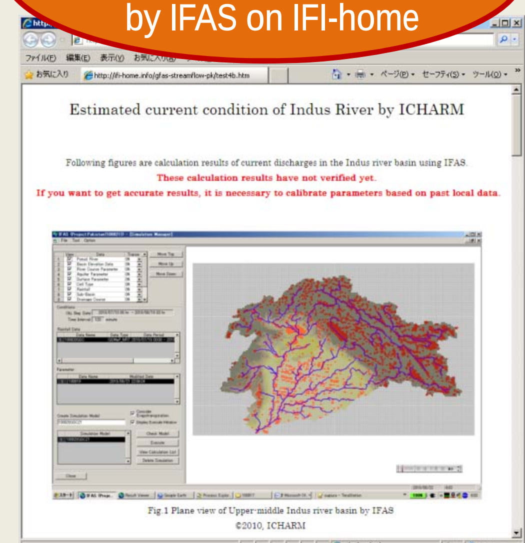
Calculated by Default parameter

Ground rainfall is 2~7 times as many as GSMaP one. These rainfall are multiplied GSMaP by each thiessen area's ratio(Ground/GSMaP).



Though measured discharge broke off before peak, we can guess a certain extent of flood scale and duration by using IFAS.

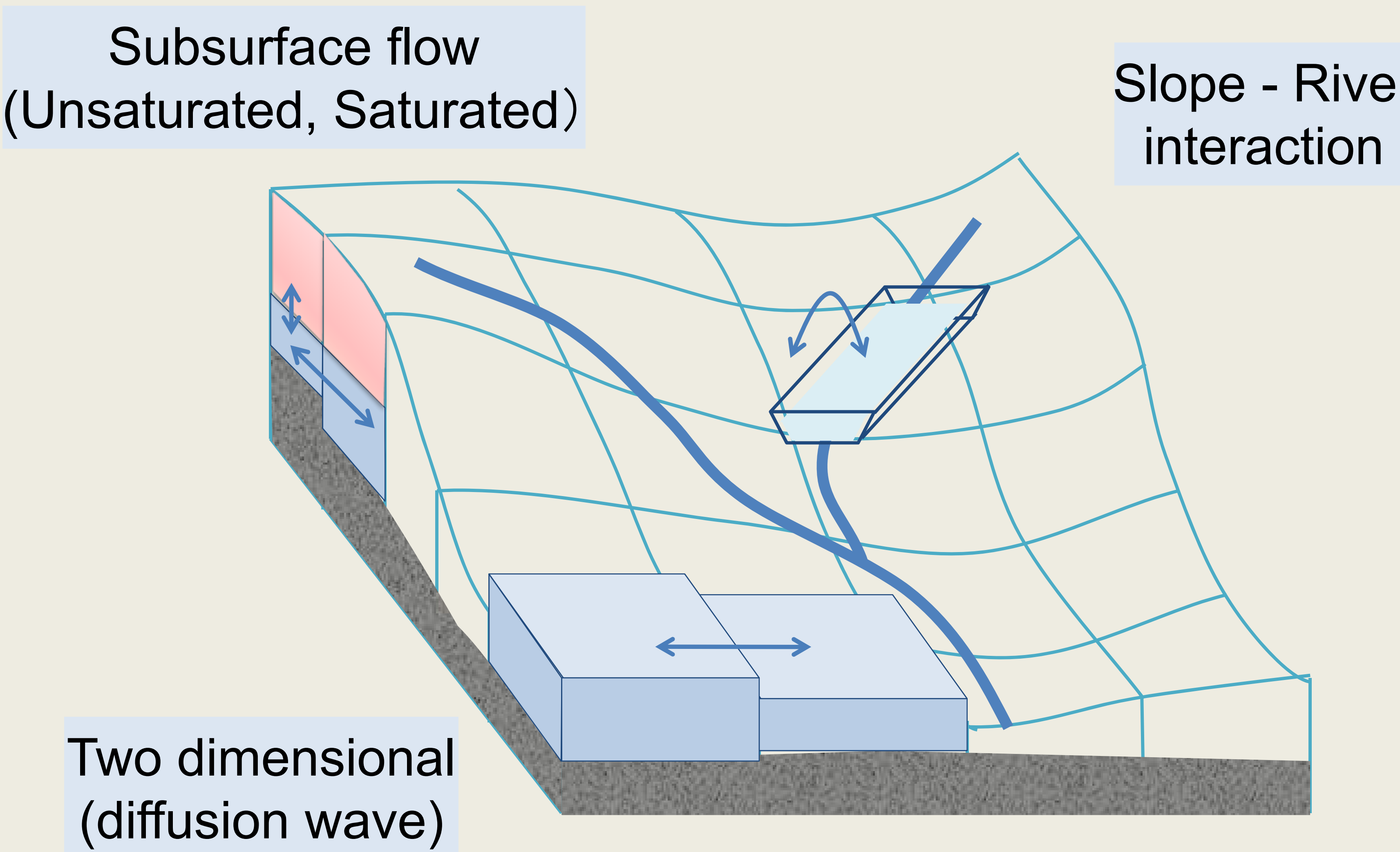
Estimated river discharge in Upper middle Indus river basin by IFAS on IFI-home



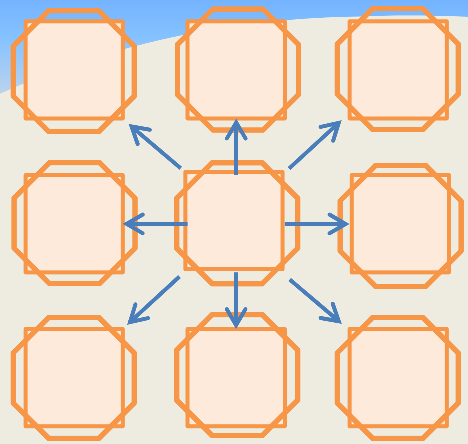
Another new approach:
Rainfall-Runoff-Inundation Model

- Both river discharge and inundation are simulated simultaneously with rainfall input.
- The model is being developed for real-time flood predictions and/or quick estimations of flood extent immediately after flood disasters.
- It also utilizes globally available dataset; model application can be completed in a short time.

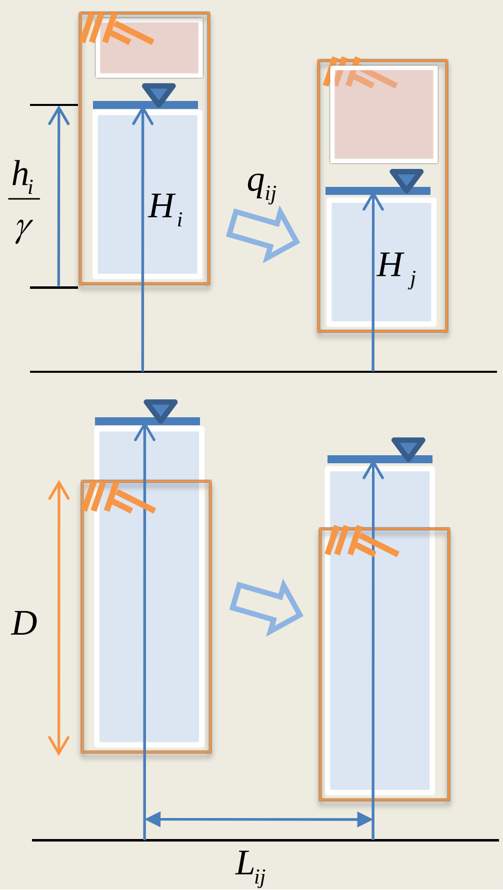
2D Rainfall-Runoff-Inundation Model



SLOPE CALCULATION



Octagon Grid: Quinn, Beven etal, Vol.5, 59 - 79, HP1991



Mass balance

$$\frac{dh_i}{dt} = r_i - \frac{1}{A_i}\sum_j q_{ij} b_{ij}$$

r_i : Rainfall, h_i : Water depth, b_i : Width, A_i : Area

Saturated subsurface : Darcy Flow

$$q_{ij} = K_{eff} I_e h_i$$

K_{eff} : Saturated hydraulic conductivity

$I_e = \frac{H_i - H_j}{L_{ij}}$: Hydraulic gradient

Saturated subsurface, surface : Darcy + Manning Flow

$$q_{ij} = K_{eff} I_e h_i + \frac{1}{n}\sqrt{I_e}\left(h - d_A\right)^{5/3}$$

n : Surface roughness

d_A : Effective soil depth (D x γ)

Simulation conditions

Simulation Period
July 27 0:00 – Aug 2 0:00 (GMT) : 6 days (144h)

Simulation Domain
(~92,605 km^2)

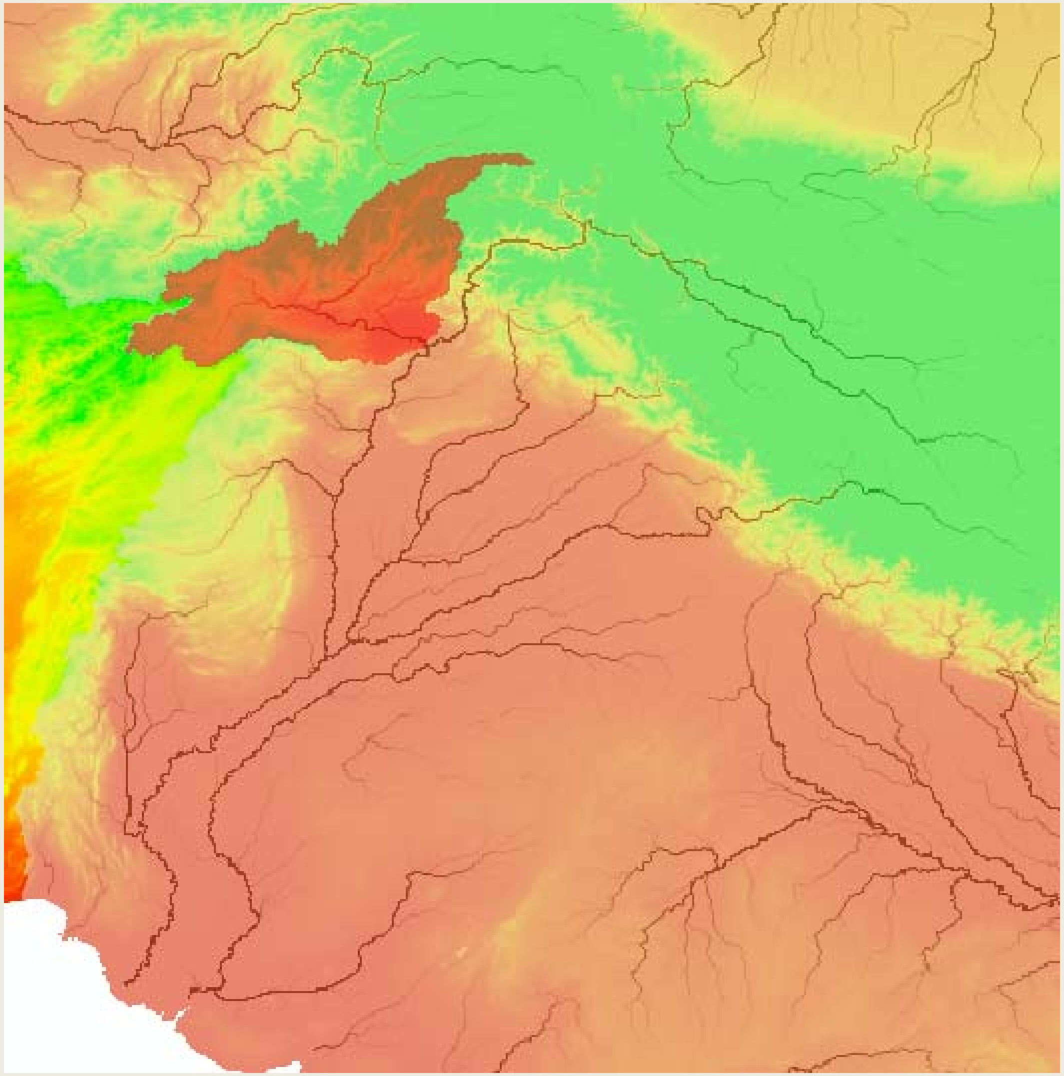
Grid cell size: 30 sec
(761 m x 924 m)

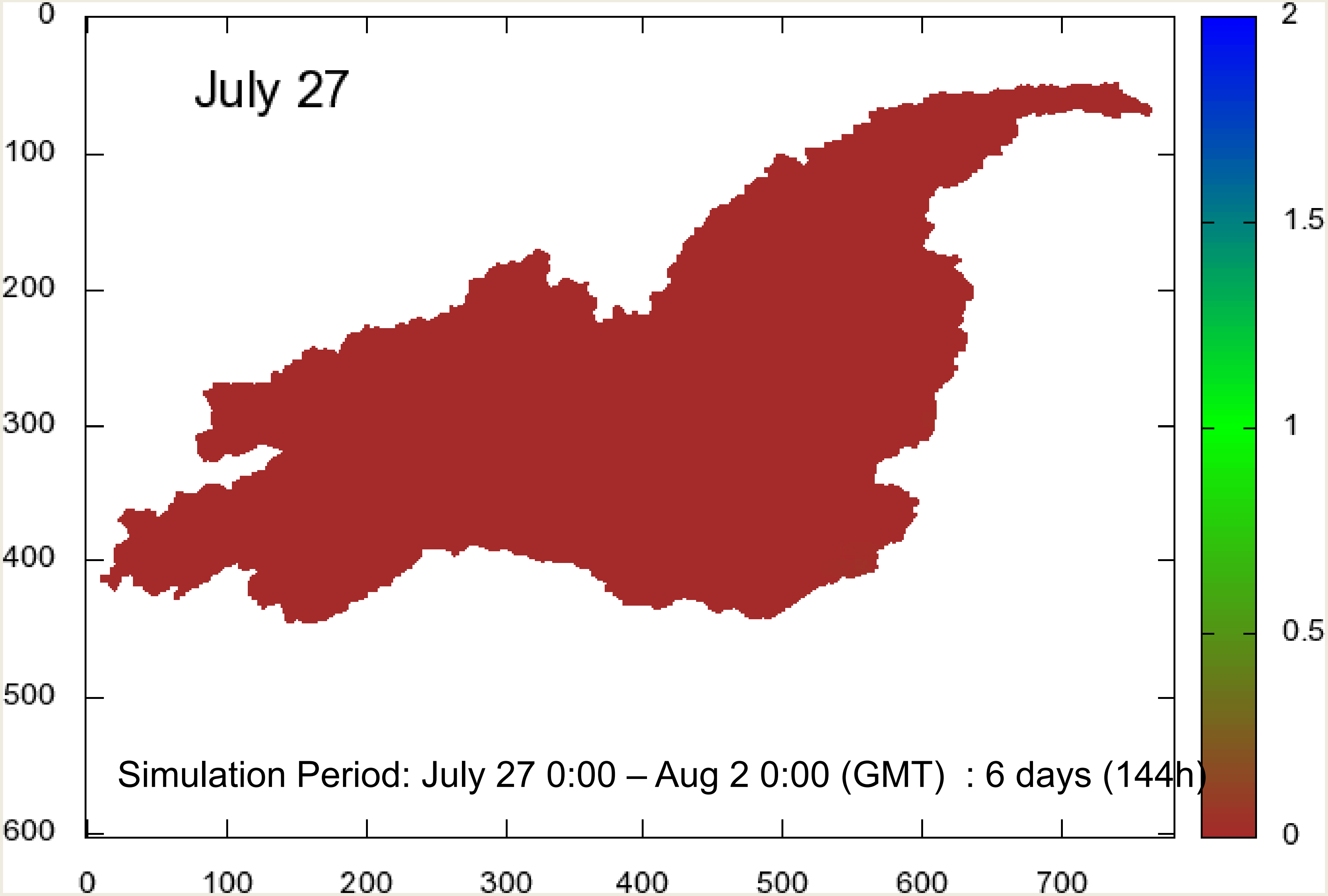
Number of grids inside the basin
: 131,489

River width
$= 2.5\ A[km^2]^{0.4}$

River depth
$= 0.1\ A[km^2]^{0.5}$

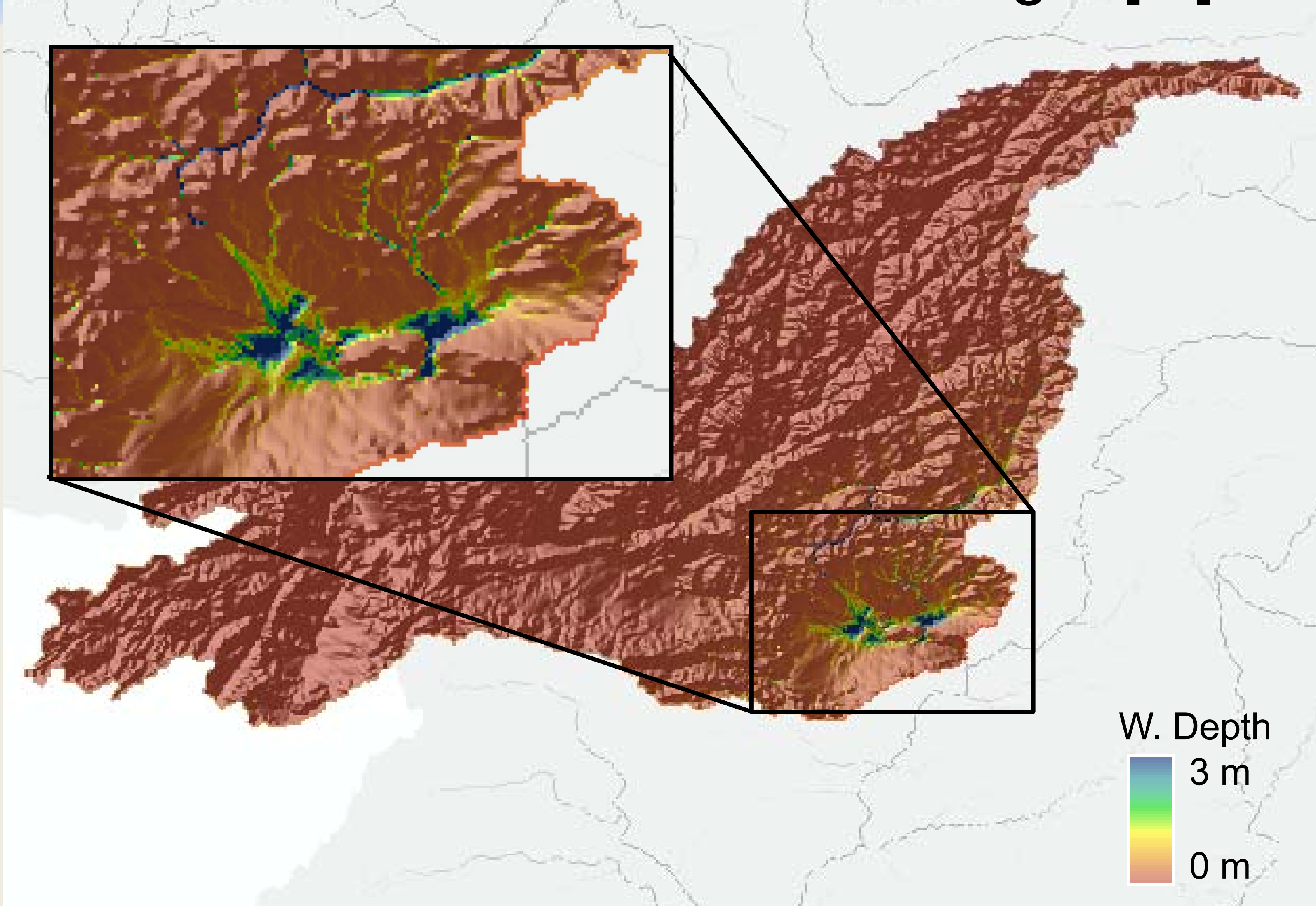
Sim. Time: ~ 10 hrs



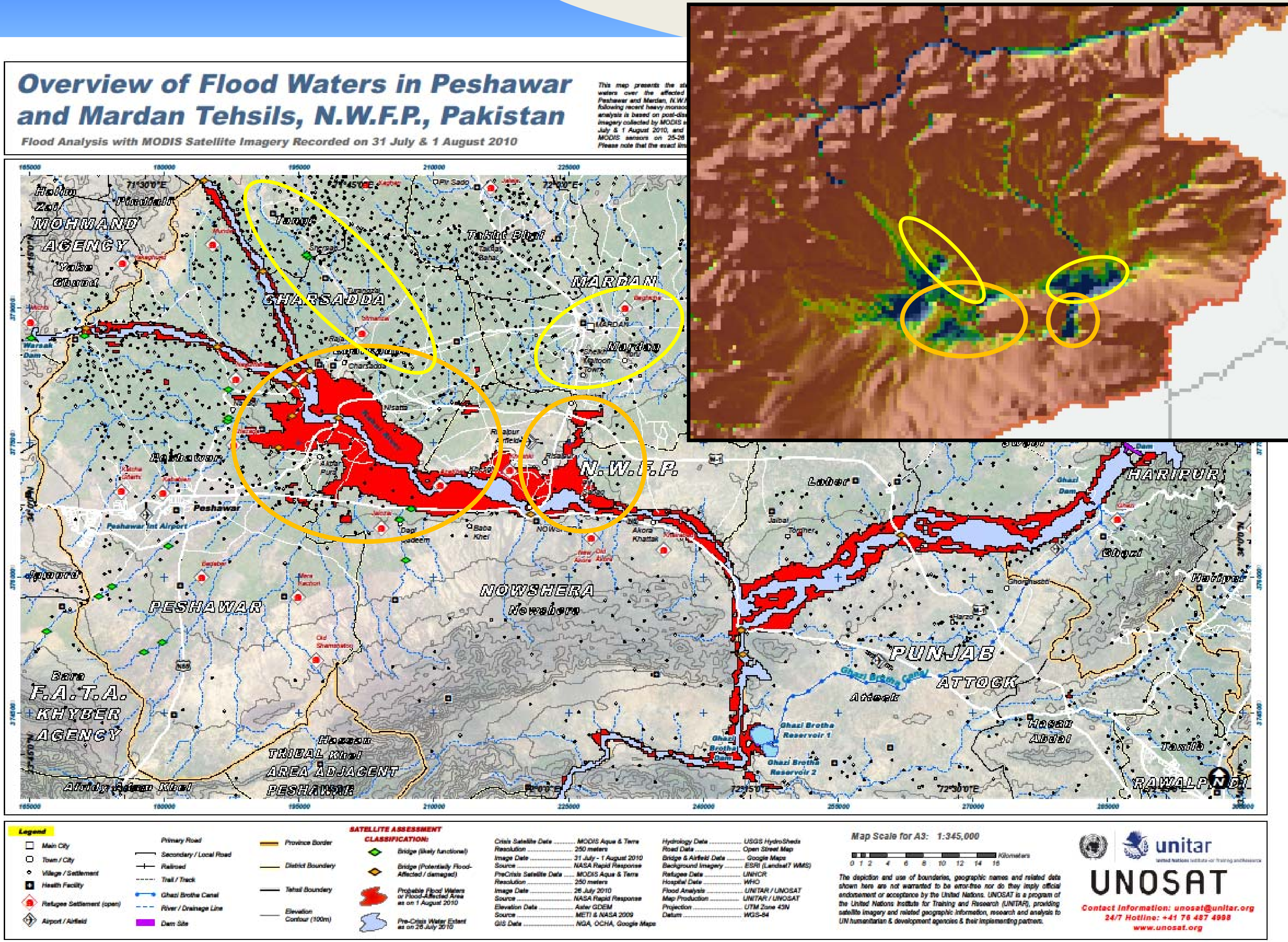


July 27
Simulation Period: July 27 0:00 – Aug 2 0:00 (GMT) : 6 days (144h)
0
100
200
300
400
500
600
700
2
1.5
1
0.5

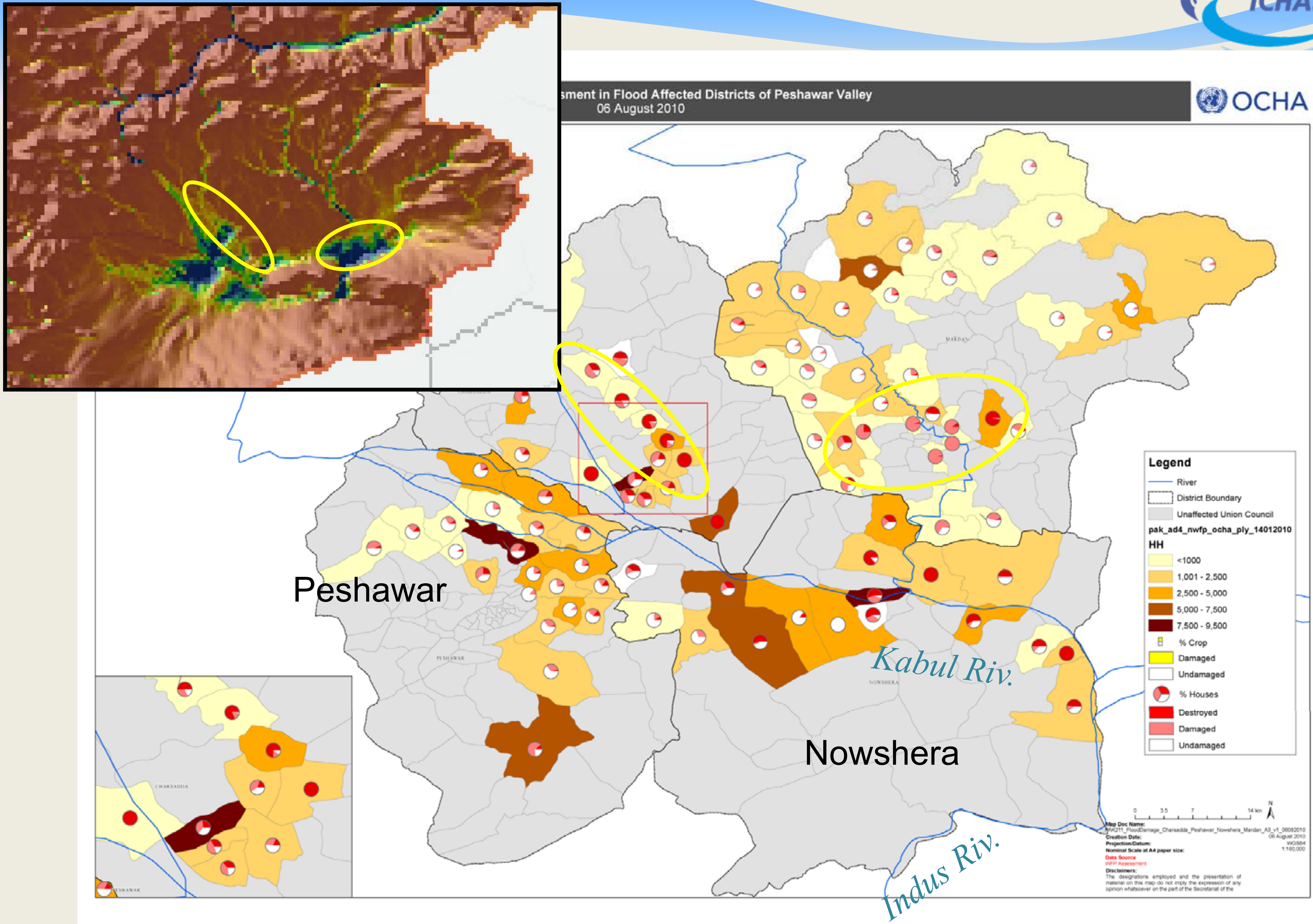
Simulated Peak Water Height [m]



Simulation Period: July 27 0:00 – Aug 2 0:00 (GMT) : 6 days



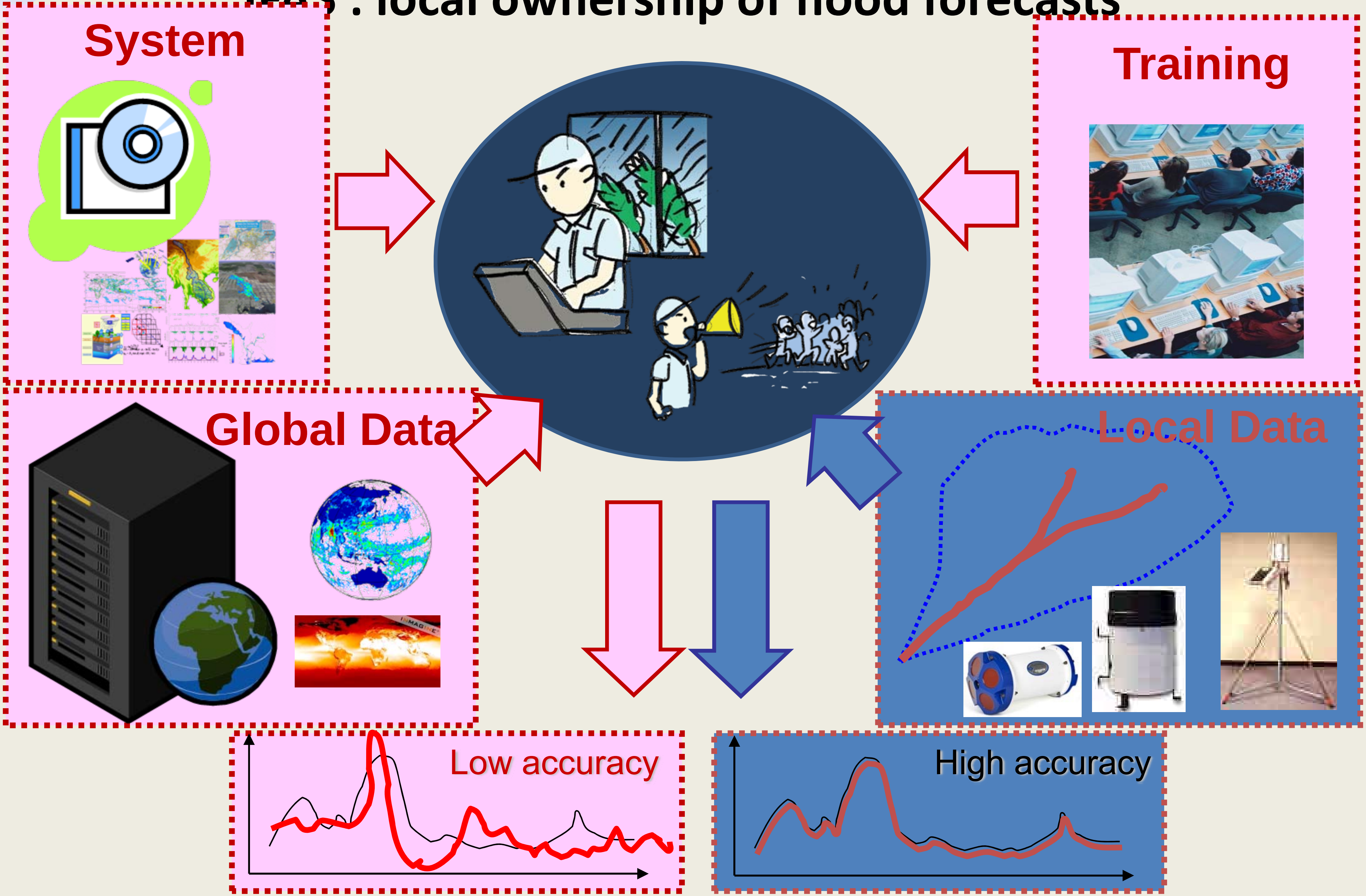
Overview of Flood Waters in Peshawar and Mardan Tehsils, N.W.F.P., Pakistan
Flood Analysis with MODIS Satellite Imagery Recorded on 31 July & 1 August 2010
MOHMAND AGENCY
CHARSADDA
MARDAN
Mardan
Takht Bhai
Peshawar
PESHAWAR
Peshawar Int Airport
N.W.F.P.
NOWSHERA
Nowshera
PUNJAB
ATTOCK
Attock
HARIPUR
Haripur
Ghazi
Hasan Abdal
Taxila
RAWALPINDI
F.A.T.A.
KHYBER AGENCY
TRIBAL AREA ADJACENT PESHAWAR
Ghazi Brotha Reservoir 1
Ghazi Brotha Reservoir 2
Ghazi Brotha Canal
Legend
SATELLITE ASSESSMENT CLASSIFICATION:
Map Scale for A3: 1:345,000
UNOSAT
unitar
Contact information: unosat@unitar.org
24/7 Hotline: +41 76 487 4998
www.unosat.org



http://www.reliefweb.int/rw/fullmaps_sa.nsf/luFullMap/1063BC946E3800968525778800 6FF75B/$File/map.pdf?OpenElement

ICHARM

IFAS : local ownership of flood forecasts



Conclusion

- The combination of satellite-based rainfall information, global GIS data and IFAS (Integrated Flood Analysis System), a practical toolkit for local users, especially for developing countries to integrate all those global information, has a very high potential to make prompt flood analyses even in poorly-gauged river basins.
- The application of a new Rainfall-Runoff-Inundation model was also successful to interpolate missing satellite-based information on flood inundation area caused by flash flood.
- On the other hand, it should be also noted that, without any in-situ (ground-truth) data, such integrated information & analysis cannot be assured, verified nor improved.
- It is, therefore, indispensable to couple satellite & global GIS data with in-situ (geographical, geophysical and hydrologic) data in order to improve the quality (accuracy) of the integrated information & analysis and to upgrade the range & depth of application. The importance of in-situ hydrologic data is everlasting.

Thank you for your attention!

http://www.icharm.pwri.go.jp/

Fukui City on the left bank side of the Asuwa River (photographed on July 18)

Fukui City on the left bank side of the Asuwa River (photographed on July 18)

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