ESCAP/WMO Typhoon Committee

19th INTEGRATED WORKSHOP / AP-TCRC FORUM

Strengthening the Value Chain within the UN EW4All Framework for the Typhoon Committee Region

&

Embracing New Technologies for Achieving Early Warnings for All

19 - 22 November, 2024 - Shanghai, China

End to end flash flood & landside early warning system

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2. General introduction of Flash flood & landslide early warning system
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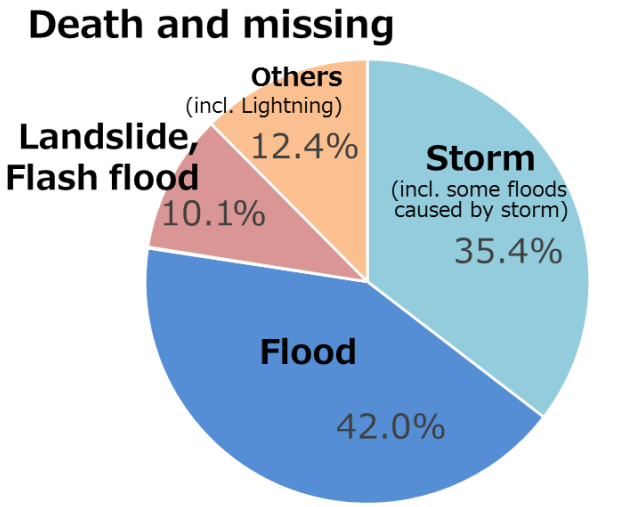
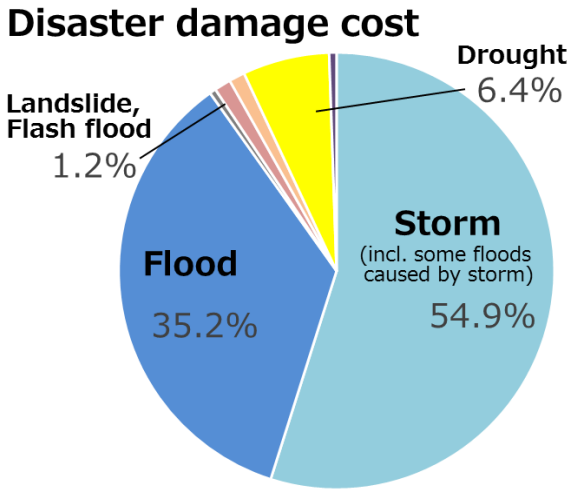
NATURAL DISASTER SITUATION IN VIETNAM

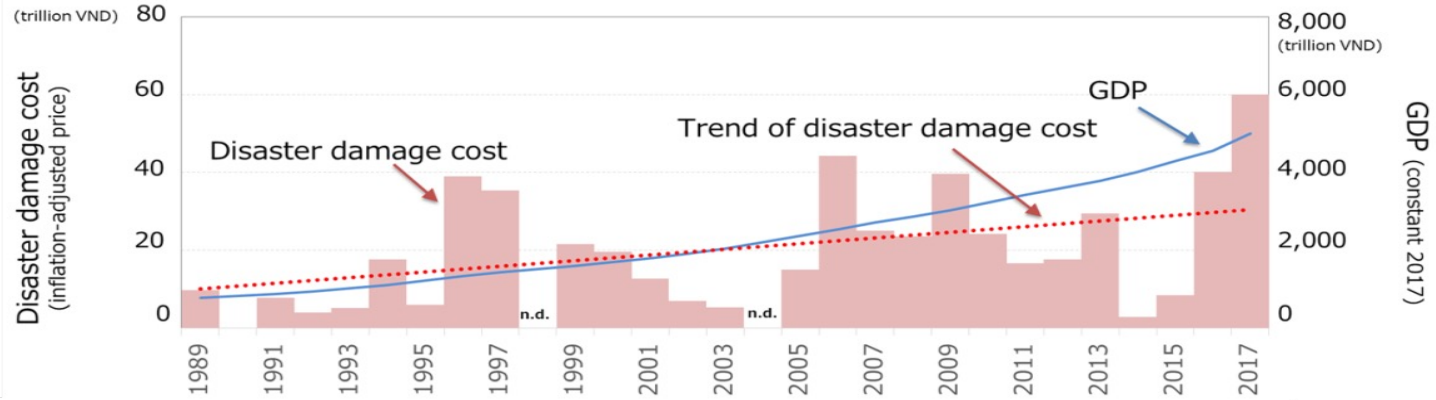
Vietnam – As one of the most natural disaster prone country in the world

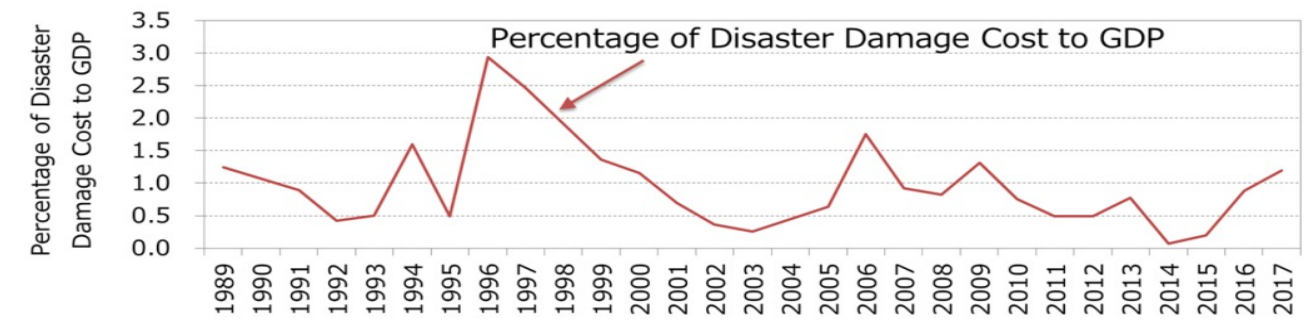




Statistics in the past 30 years shows the disaster situation tends to increasing and unpredictable in both scale and repeat the cycle, especially strong storms, heavy rain, flooding, inundation, extremely cold weather, heat, drought, salinity intrusion.

This is the great challenge in the disaster prevention, control and mitigation in the future.





Natural Hazards in Vietnam

Relative Frequency

High	Medium	Low
Flood	Hail rain	Earthquake
Typhoon	Drought	Frost
Inundation	Fire	
Flash flood	Salinity	
Landslide		

1. Overview information of flashflood & landslide in Viet Nam

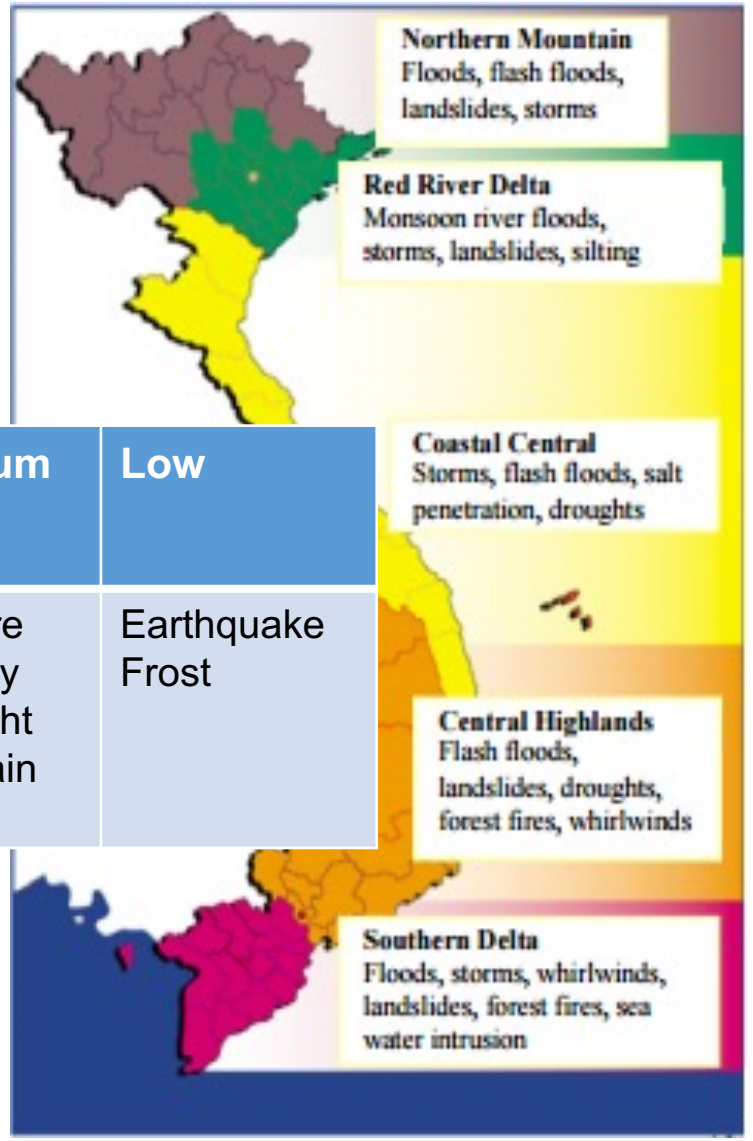
✓ **Flash flood is "A flood of short duration with a relatively high peak discharge" (less than 6 hours) (WMO)**

Based on Flash flood characterristics in Viet Nam:

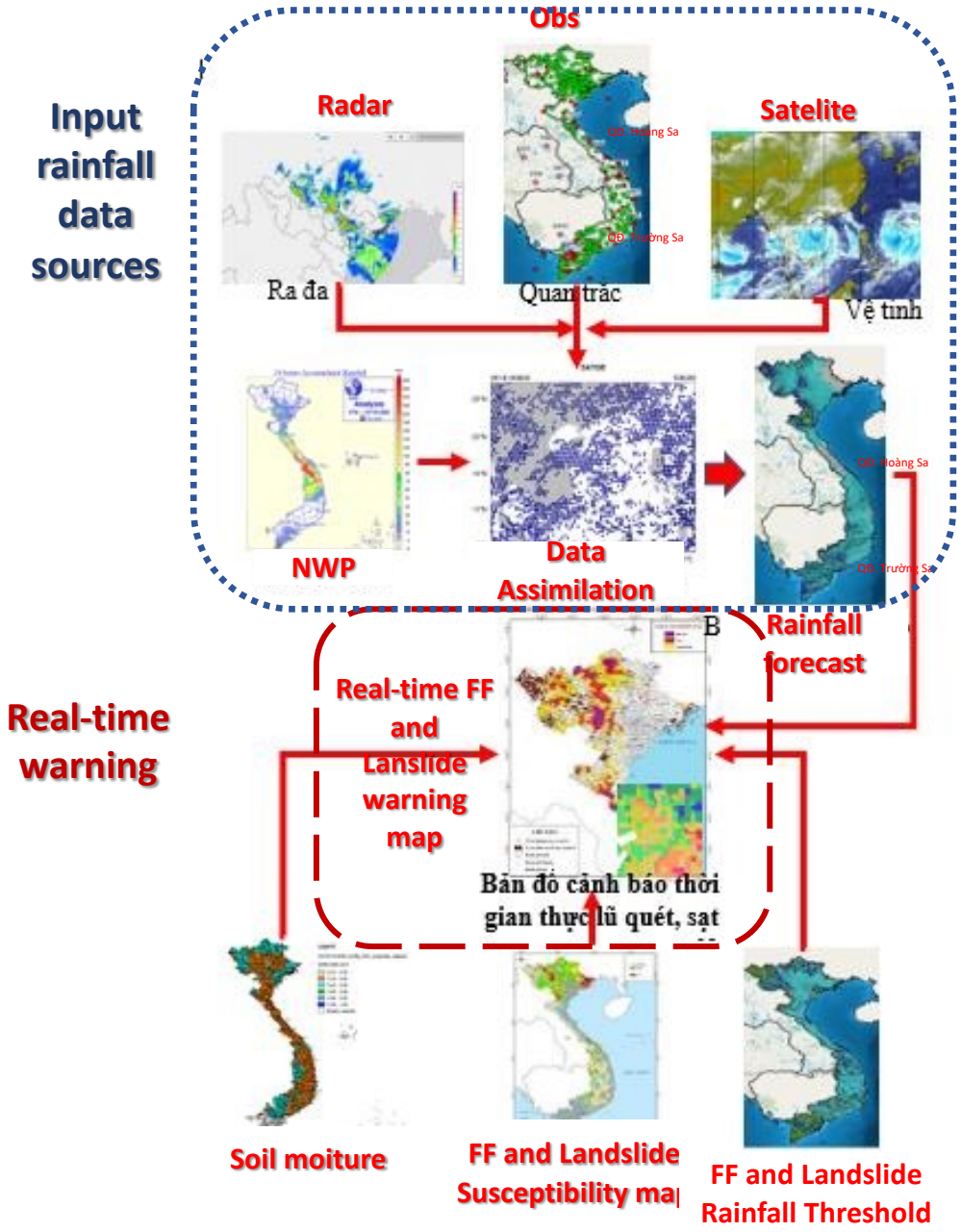
✓ ***Definition***: Flash floods are floods that occur suddenly on steep slopes and small streams in mountainous areas, with rapid flow, often accompanied by mud and rocks; Floods rise and fall quickly, causing great destruction.

✓ Flash floods have occurred and high risk in 33 mountainous provinces in the 4 region in Viet Nam: Mountainous Northern part, Central, Central Highlands and the Eastern part of the South of VN.

High	Medium	Low
Flood Typhoon Flash flood Landslide Inundation	Wildfire Salinity Drought Hail rain	Earthquake Frost



Structure of the system



2. General introduction of Flash flood & landslide early warning system (FFEW)

- ✓ Official launch in operation from the mid of 2024.
- ✓ Integrating many rainfall data sources:
  - *Rainfall estimates from Radar and satellites;*
  - *Observed rainfall from automatic rain gauges;*
  - *Nowcast rainfall 1-3hrs from radar;*
  - *Forecast rainfall NWP 6h - 72hrs (IFS, WRF, WRFDA).*
- ✓ Intergrating the SeaFFGS products.
- ✓ Intergrating the FF & landslide susceptibility map.

- ✓ Development of the system - real-time flash flood and landslide warning orientation.
- ✓ Supporting DMA, Agencies of Search & Rescue to monitor, decision making and timely action taking.
- ✓ Supporting forecast centers for all levels to online monitor near real-time data and information for FF – landslide warning in the operation.

http://luquetsatlo.nchmf.gov.vn/

System Interface

Administrative warning

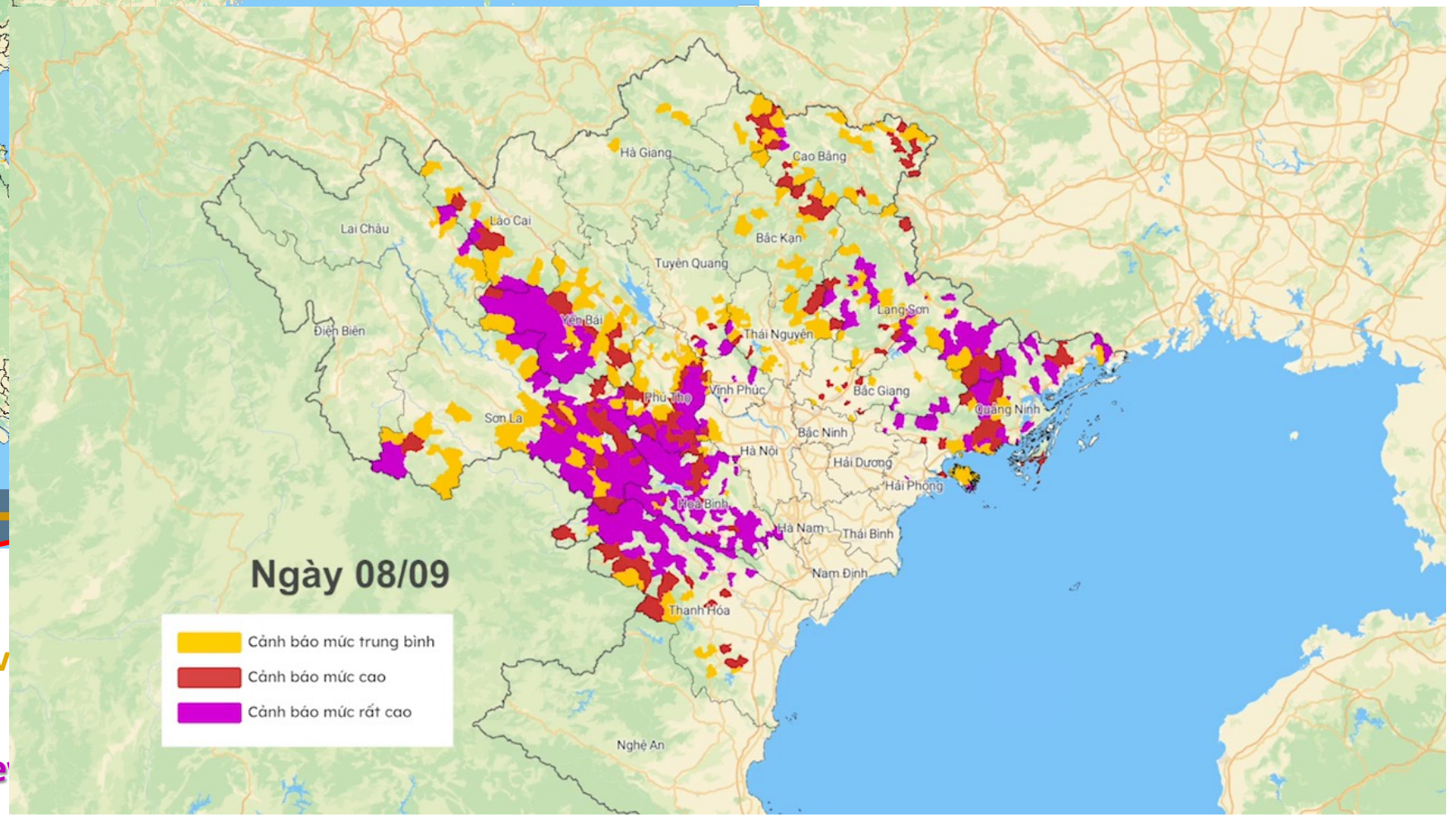
List of warning area

Medium Lev

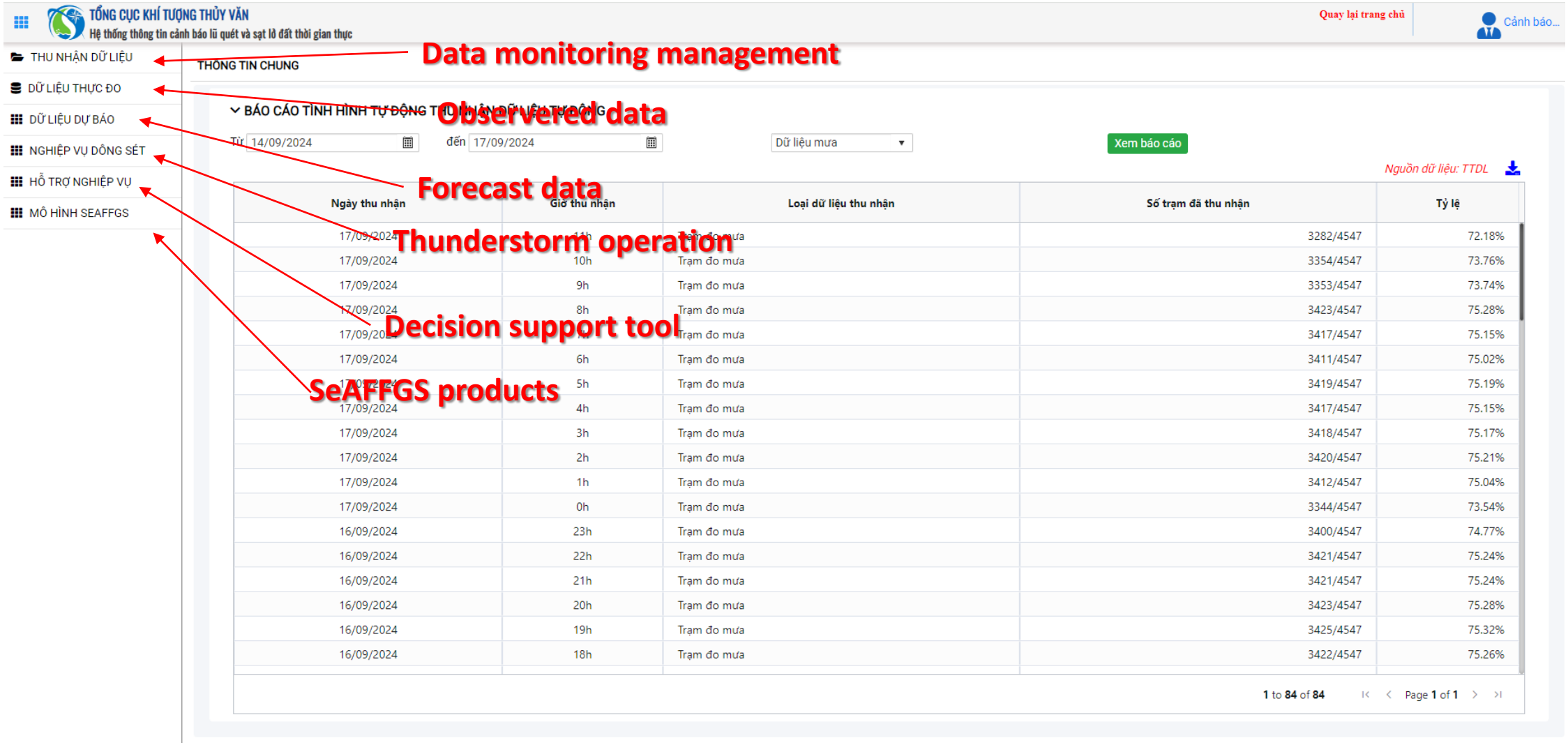
High Level

Very high Le

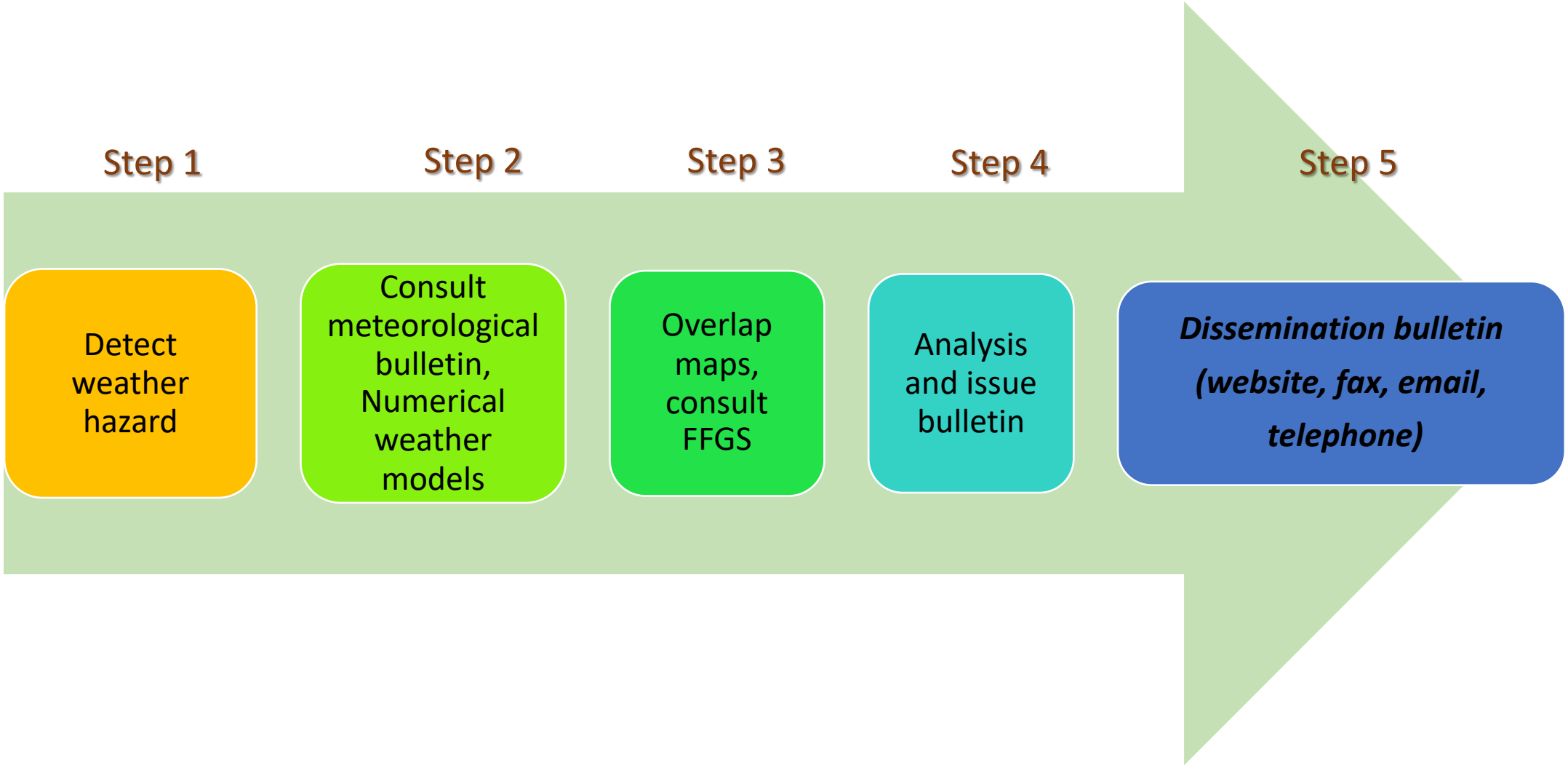
High risk position



Main Functions



3. End to end flash flood & landslide warning procedure



The capacity for flash flood forecasting and warning: before 3-6 hour or more

Step 1 - Step 2

PROCEDURE OF HEAVY RAINFALL PREDICTION →FLOOD, FLASH FLOOD, LANDSLIDE WARNING

RAINFALL FORECAST

- Preparing heavy rain scienarios in 24, 48hrs

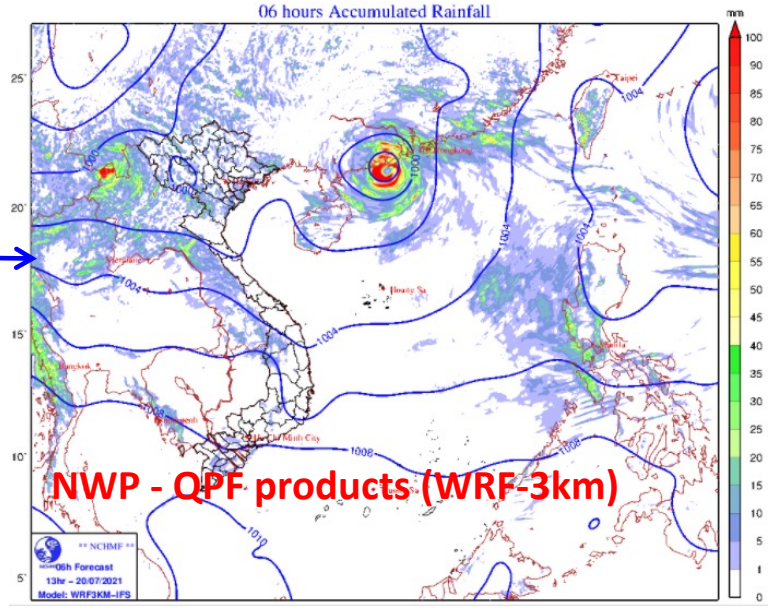
- Rainfall situation analysis;
- Providing precipitation. mapping of 6h, 12hrs, 24hrs, 2-3 days as extreme critical situation
- Estimating radar rainfall via

Quantitative forecast rainfall

DỰ BÁO ĐỊNH LƯỢNG MƯA PHỤC VỤ DỰ BÁO, CẢNH BÁO THIÊN TAI THỦY VĂN KHU VỰC BẮC BỘ

Từ 20210818 07h đến 20210819 07h

TT	Khu vực mưa			Lượng mưa (mm)										Ghi chú
				07h-10h		10h-13h		13h-19h		19h-01h		01h-07h		
	Đài khu vực	Tỉnh		Lượng mưa phổ biến	Lượng mưa max	Lượng mưa phổ biến	Lượng mưa max	Lượng mưa phổ biến	Lượng mưa max	Lượng mưa phổ biến	Lượng mưa max	Lượng mưa phổ biến	Lượng mưa max	
1	Khu vực Tây Bắc	Lai Châu		2-7	20	0-5	15	10-15	40	10-25	60	10-25	70	
		Điện Biên		2-7	20	0-5	15	10-15	40	10-25	60	10-25	70	
		Sơn La		2-7	15	0-5	10	10-15	40	10-25	60	10-25	65	
		Hòa Bình		2-7	15	0-5	10	5-15	35	10-25	60	10-25	65	
2	Khu vực Việt Bắc	Lào Cai		5-10	25	2-7	20	5-10	30	10-30	70	10-30	70	
		Yên Bái		2-7	20	0-5	15	5-10	30	10-30	70	10-30	70	
		Phú Thọ		2-7	20	0-5	15	5-10	30	10-30	70	10-30	70	
		Hà Giang		2-7	30	0-5	20	5-10	30	10-30	70	10-30	70	
		Tuyên Quang		2-7	20	0-5	15	5-10	30	10-30	70	10-30	70	
		Thái Nguyên		2-7	20	0-5	15	0-5	20	10-30	70	10-30	70	
		Bắc Cạn		2-7	20	0-5	15	5-10	30	10-30	70	10-30	70	
		Vĩnh Phúc		2-7	20	0-5	15	5-10	30	10-25	50	10-25	50	

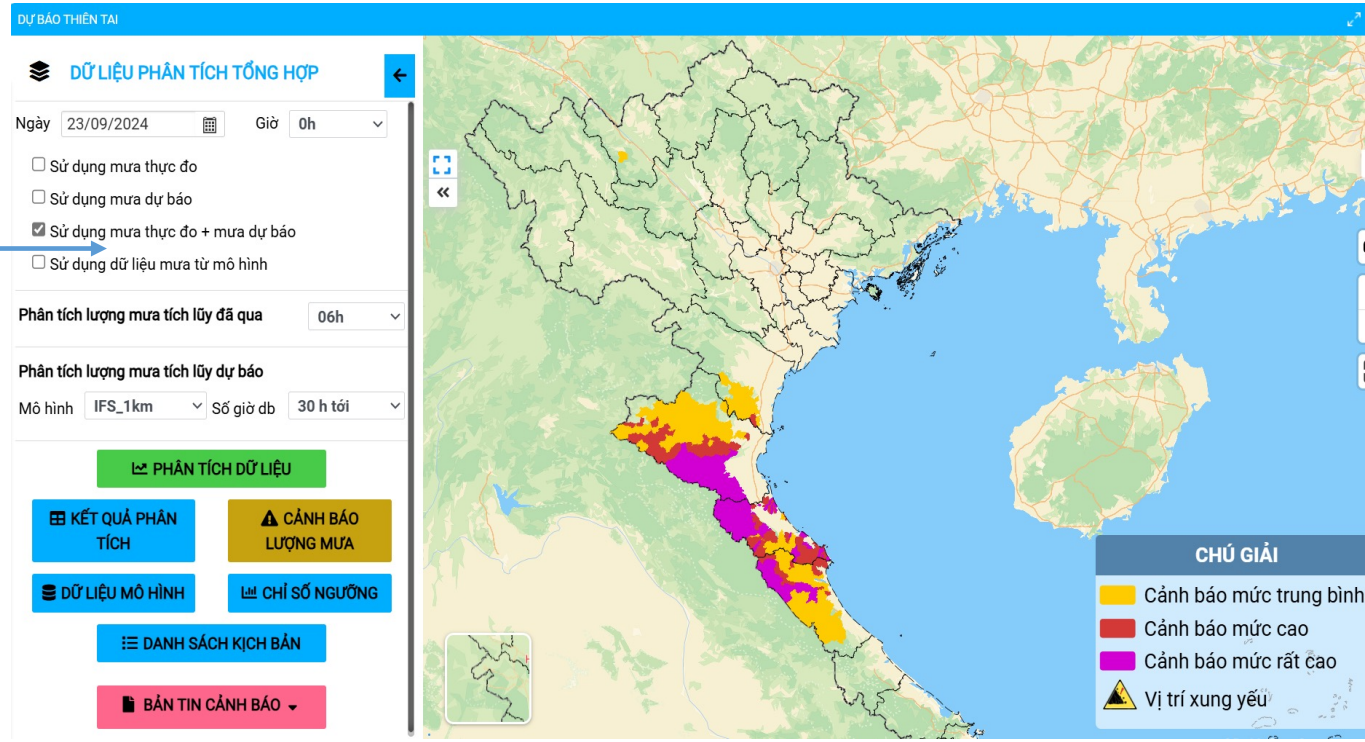


NWP - QPF products (WRF-3km)

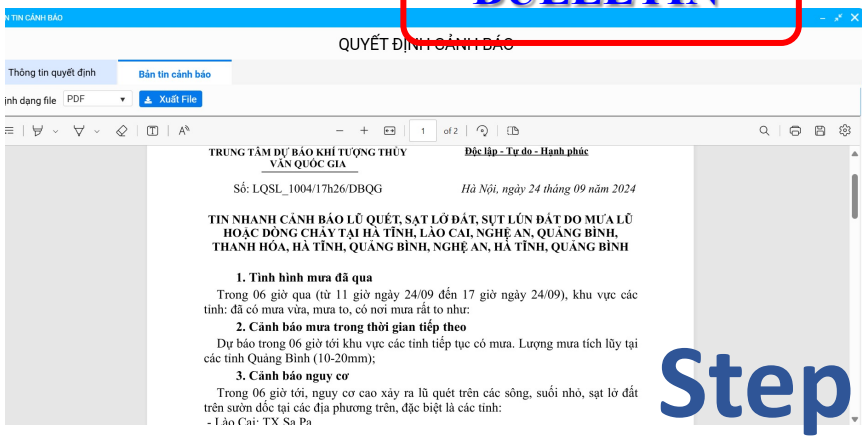
- Developing flash flood + landslide risk maps for every 6hrs (24hrs, 48hrs as requiment) based on difference forecast rainfall scienarios

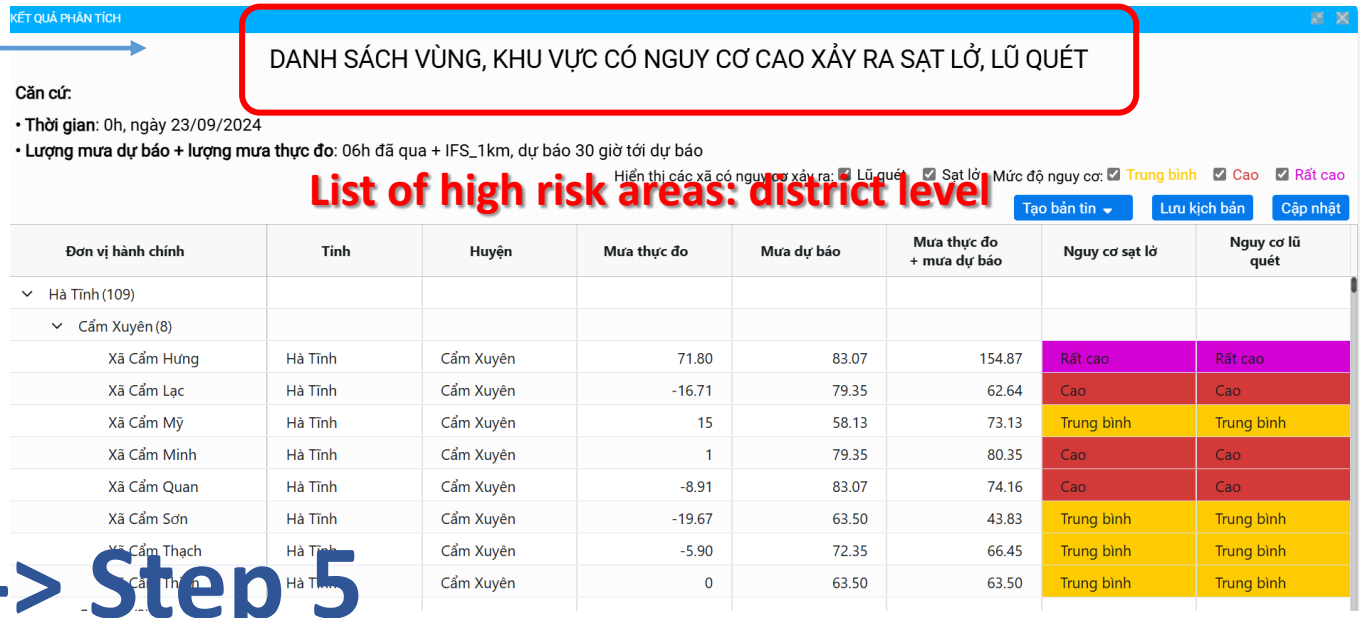
- Analysis: SEAFFGS production references; historical & rainfall forecast information; landslide risk maps.

- Bulletin preparation and dissimination



BULLETIN



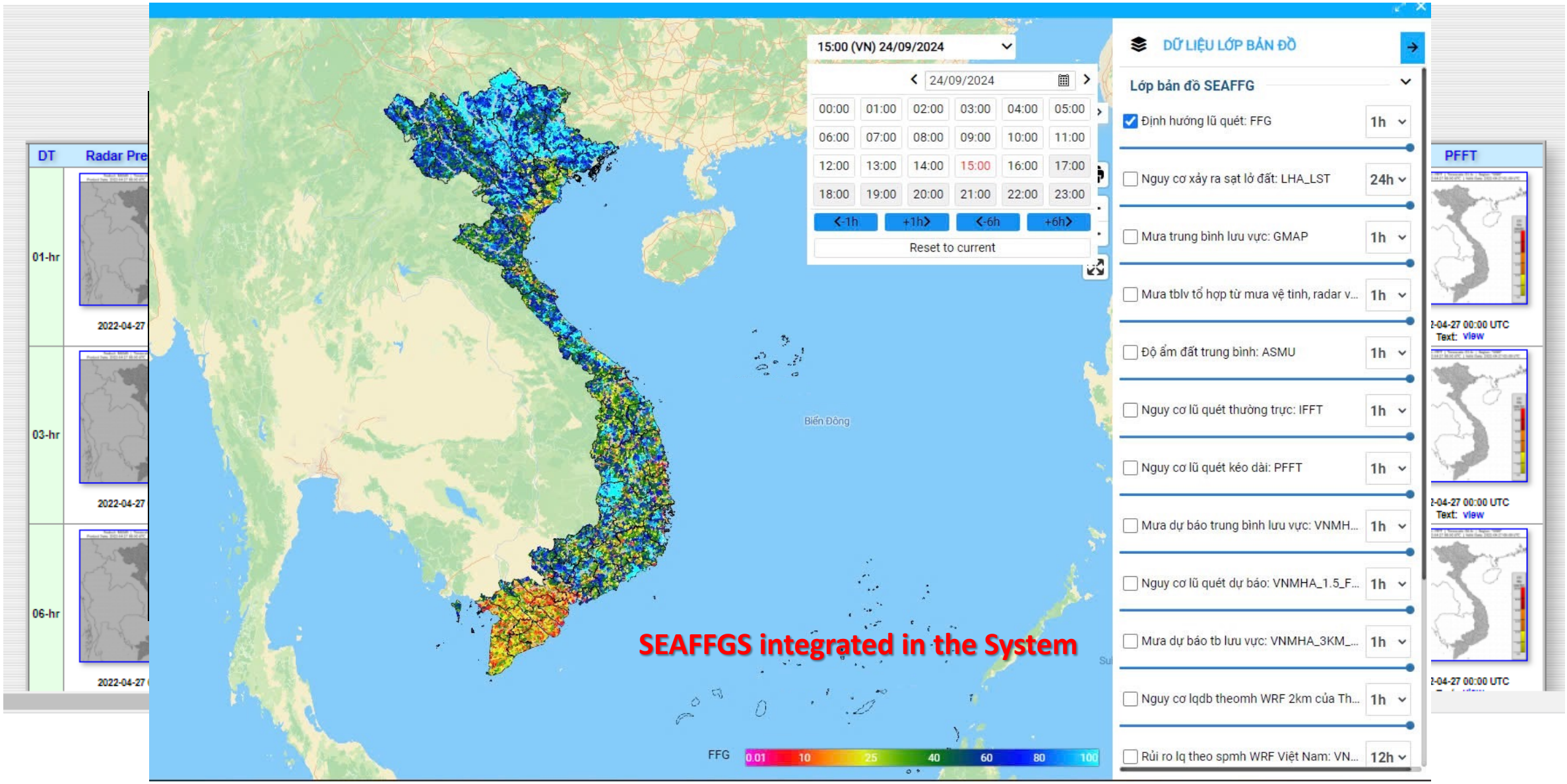


List of high risk areas: district level

Đơn vị hành chính	Tỉnh	Huyện	Mưa thực đo	Mưa dự báo	Mưa thực đo + mưa dự báo	Nguy cơ sạt lở	Nguy cơ lũ quét
Hà Tĩnh (109)							
Cẩm Xuyên (8)							
Xã Cẩm Hưng	Hà Tĩnh	Cẩm Xuyên	71.80	83.07	154.87	Rất cao	Rất cao
Xã Cẩm Lạc	Hà Tĩnh	Cẩm Xuyên	-16.71	79.35	62.64	Cao	Cao
Xã Cẩm Mỹ	Hà Tĩnh	Cẩm Xuyên	15	58.13	73.13	Trung bình	Trung bình
Xã Cẩm Minh	Hà Tĩnh	Cẩm Xuyên	1	79.35	80.35	Cao	Cao
Xã Cẩm Quan	Hà Tĩnh	Cẩm Xuyên	-8.91	83.07	74.16	Cao	Cao
Xã Cẩm Sơn	Hà Tĩnh	Cẩm Xuyên	-19.67	63.50	43.83	Trung bình	Trung bình
Xã Cẩm Thạch	Hà Tĩnh	Cẩm Xuyên	-5.90	72.35	66.45	Trung bình	Trung bình
[illegible]	Hà Tĩnh	Cẩm Xuyên	0	63.50	63.50	Trung bình	Trung bình

Step 3 -> Step 5

The products from SEAFFGS in the NCHMF for reference



4. The system improvements for strengthening flash flood and landslide early warning capacity

The first FFEW system based on:

+ SEAFFGS – official launched into the operation from June, 2022

+ Flash flood - landslide susceptibility maps

Theory of flash flood warning in FFGS

Soil moisture accounting model

SAC-ASM

❑ Model classification

+ Continuous
+ Lumped
+ Deterministic

❑ Inputs

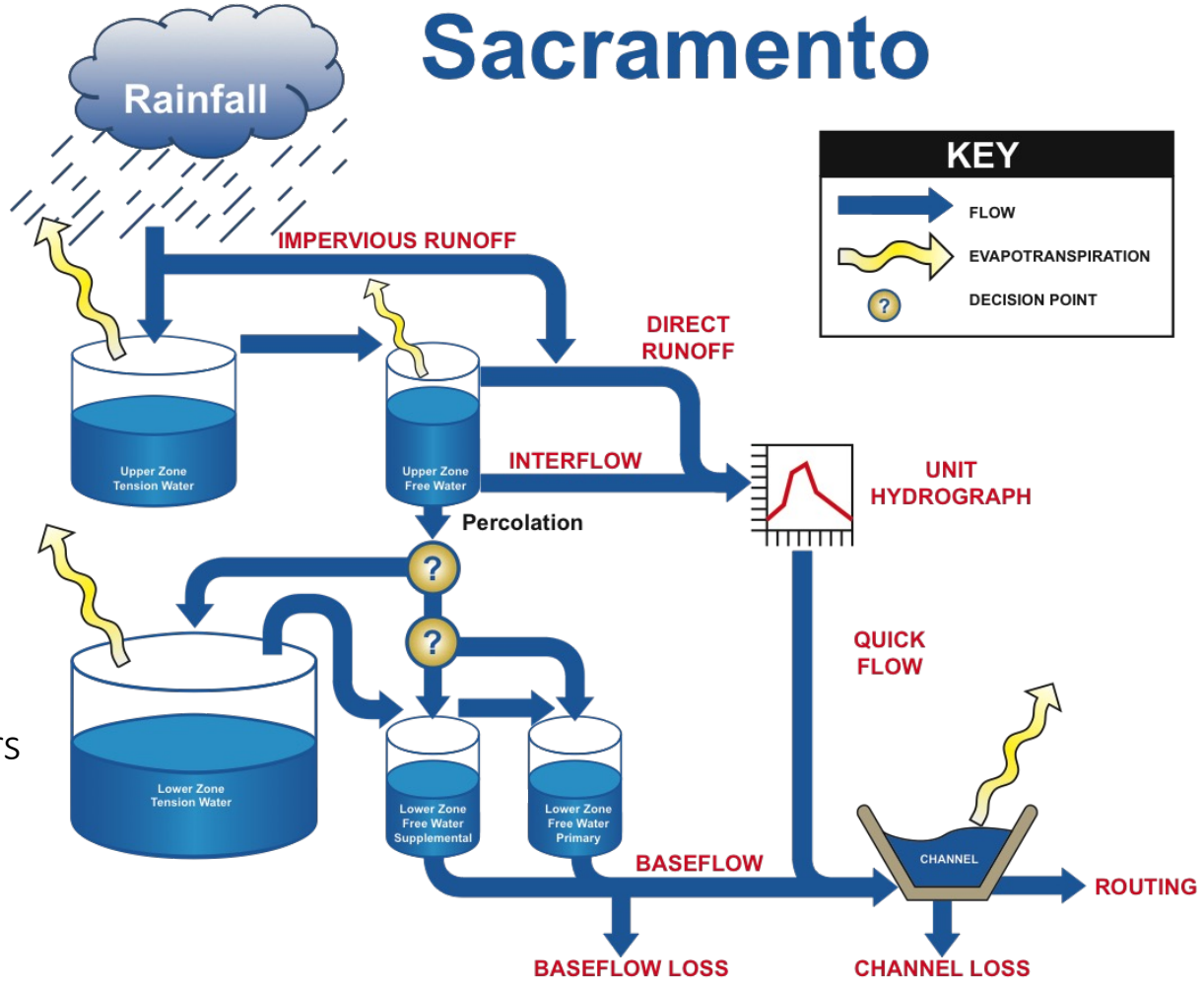
+ Rainfall
+ Evapotranspiration (temperature, humidity, wind speed, sunshine duration)

❑ Main outputs

+ Soil moisture
+ Discharge

❑ **Model parameters**:16 parameters

+ Physical: estimated from surface data (land, DEM, soil)
+ Calibrated: determined by calibration and validation processes



Theory of flash flood warning in FFGS

Runoff threshold

Bankful flow

Runoff threshold

$Q_P = q_{pR} R A$

Unit hydrograph

Basin area

$R = \frac{Q_P}{q_{pR} A}$

*q_{pR}

Geomorphologic Unit Hydrograph (GHU)

$Q_P = 2.42 RA/\Delta^{0.4}(1 - 0.218 t_R/\Delta^{0.4})$

$\Delta = L^{2.5}/(iAR_L\alpha^{1.5})$

Effective rainfall time

River length

Effective rainfall

Horton length rate

$\alpha = S_c^{0.5}/nB^{2/3}$

Physical method

River width

Hydraulic depth

$Q_P = Q_{bf} = B_b D_b^{5/3} S_c^{0.5}/n$

Surface slope

Maning

$n = 0.43 S_c^{0.37}/D_b^{0.15}$

In case of no cross-section data, B, D, S can be identified by A

Regional relationships for flow and cross-sectional parameters

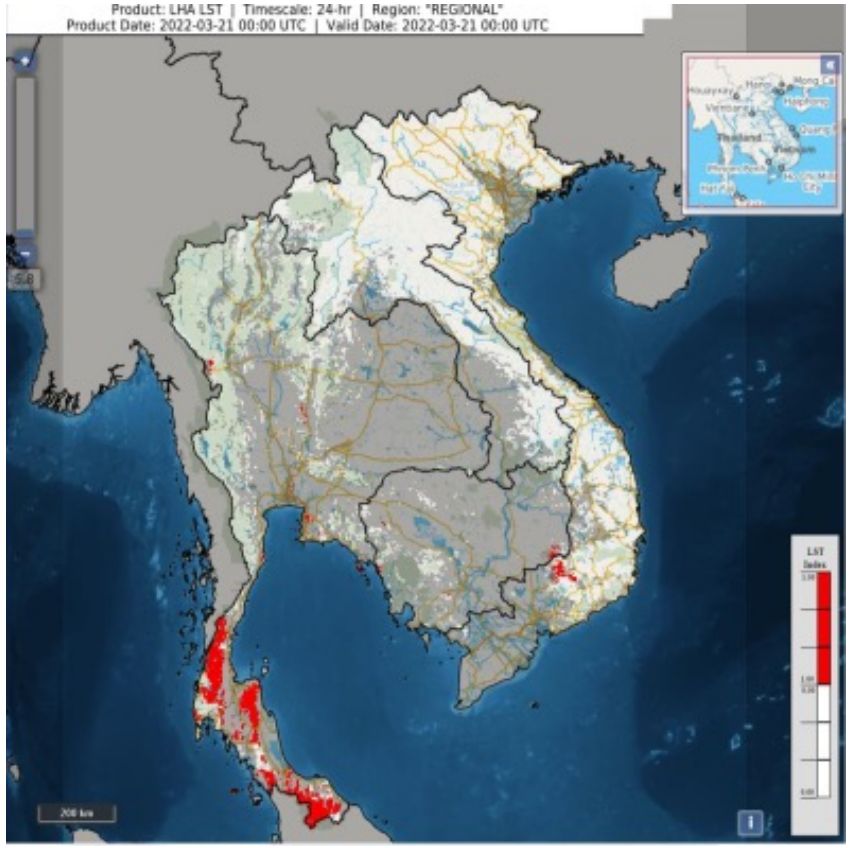
Parameter	California	Iowa	Oklahoma
Q_2	–	$Q_2 = 20.4A^{0.0607} S^{0.440}$, $R = 85\%$	$Q_2 = 0.03A^{0.59} P^{1.84}$ (Tortorelli and Bergman, 1985)
B_b	$B_b = 3.29A^{0.3714}$ (Leopold, 1994)	$B_b = 2.80A^{0.363}$, $R = 91\%$	$B_b = 2.33A^{0.542}$, $R = 82\%$
D_b	$D_b = 0.3A^{0.261}$ (Leopold, 1994)	$D_b = 0.82A^{0.160}$, $R = 50\%$	$D_b = 1.03A^{0.198}$, $R = 40\%$
S_c	$S_c = 0.006A^{-0.385}$	$S_c = 0.045A^{-0.203} S^{0.564}$, $R = 65\%$	$S_c = 0.006A^{-0.385}$, $R = 66\%$

Statistical method

2-year return period of flow $Q_p = Q_2$

Theory of landslide warning in FFGS

- **Type of warning:** rain-induced landslide, not include debris flow, trigged by human activities
- **Method:** a statistical method, rainfall threshold is defined based on historical record of landslide events and soil water content
- **Spatial resolution**: 4x4 km
- **Updated every 6 hours**
- **Yes/No warnings**

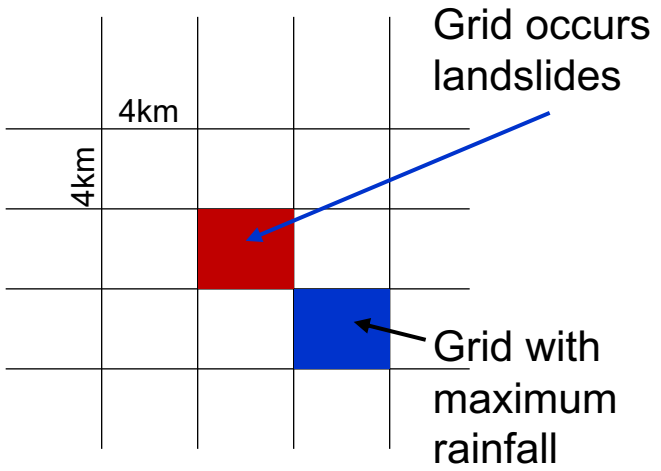


Theory of landslide warning in FFGS

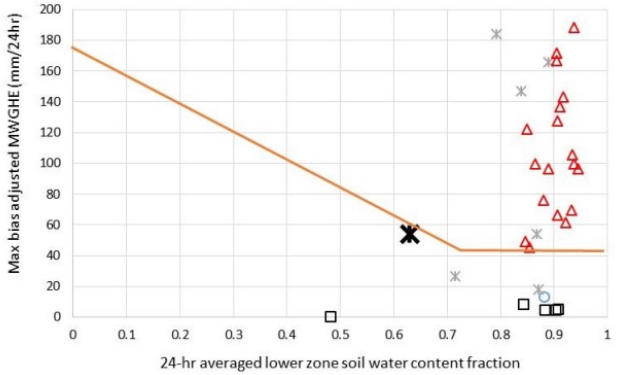
Inputs: total rainfall of the last 24 hours, soil moisture at lower zone, location and time of landslide events

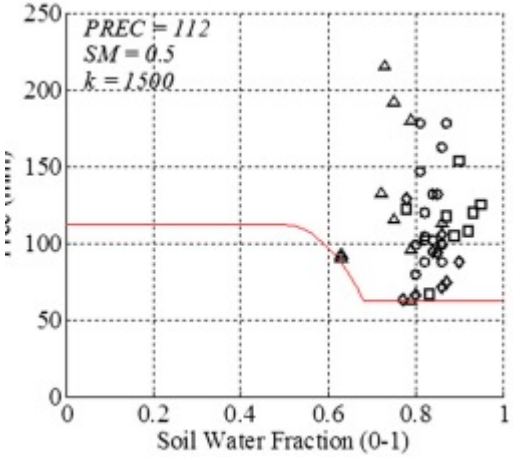
$$y = \begin{cases} PREC & \text{if } x \le SM \\ -k * (x - SM)^2 + PREC & \text{if } x > SM \text{ và } y > P_{min} \\ P_{min} & \text{if } y \le P_{min} \end{cases}$$

$$PREC = \frac{1}{n}\sum_{i=1}^{n} R_i^{99th}$$



- n: number of landslide events,
- R^{99th}: 99th rainfall at the grid that has the highest value;
- P_{min}: minimum rainfall among all landslide events
- SM: soil moisture at lower zone

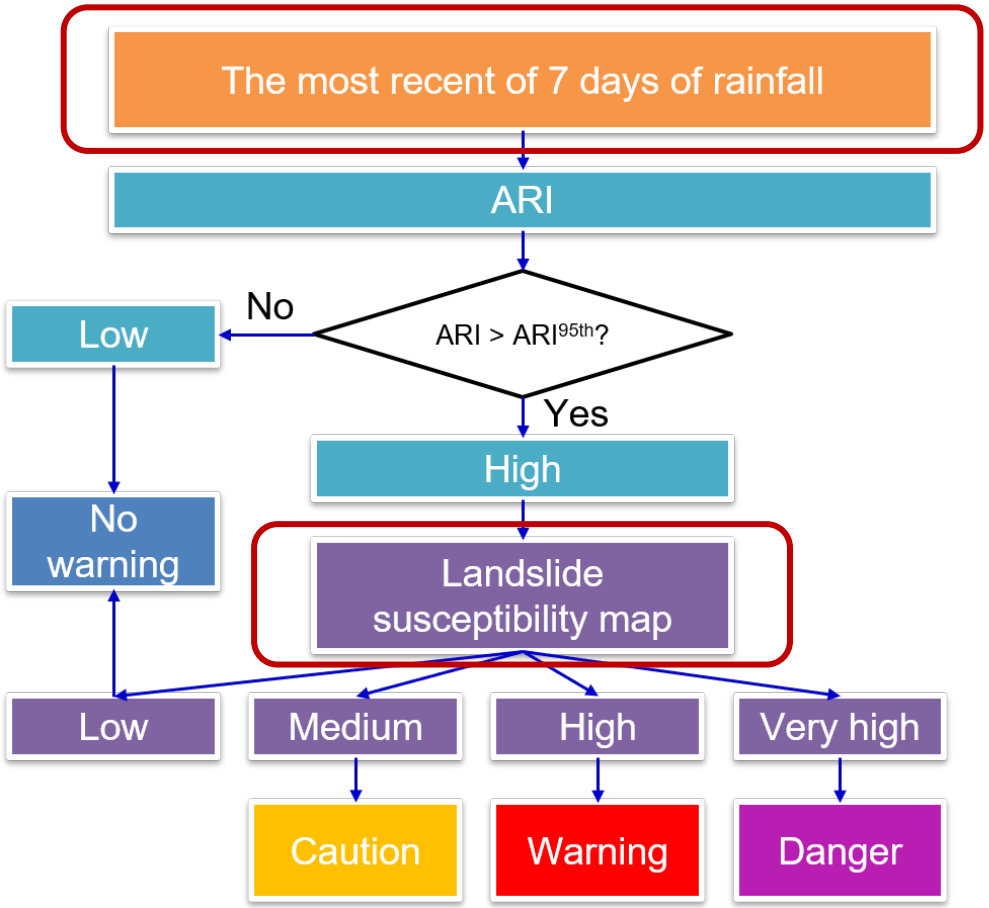




FFEW System

ARI: Antecedent Rainfall Index

$$ARI = \frac{\sum_{t=0}^{6} w_t P_t}{\sum_{t=0}^{6} w_t} \qquad w_t=(t+1)^{-2}$$



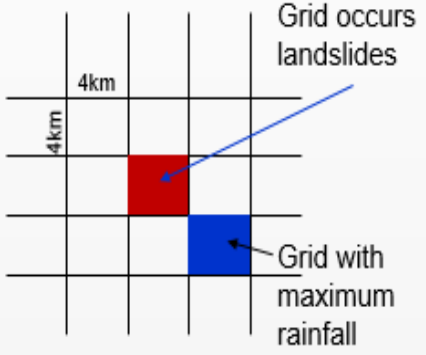
SEAFFGS

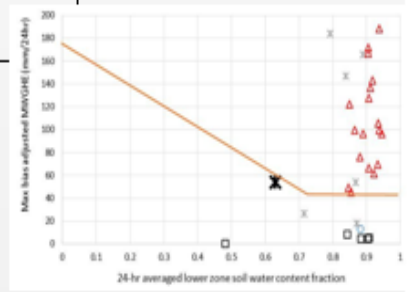
Inputs: total rainfall of the last 24 hours, soil moisture at lower zone, location and time of landslide events

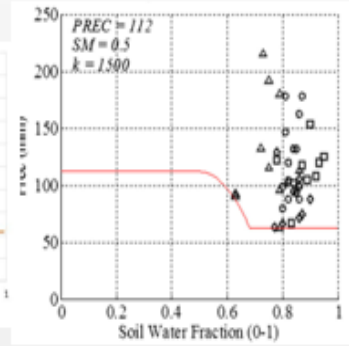
$$y = \begin{cases} PREC & \text{if } x \le SM \\ -k * (x - SM)^2 + PREC & \text{if } x > SM \text{ và } y > P_{min} \\ P_{min} & \text{if } y \le P_{min} \end{cases}$$

$$PREC = \frac{1}{n}\sum_{i=1}^{n} R_i^{99th}$$

- n: number of landslide events,
- R^{99th}: 99th rainfall at the grid that has the highest value;
- P_{min}: minimum rainfall among all landslide events
- SM: soil moisture at lower zone







In mountainous areas, after days of prolonged heavy rain, the soil and rocks were saturated, it is still faced a high risk of landslide when it was not raining.

$Q_{bf} = bA^{a}$

$Q_{bf} = bA^{a1}R^{a2}$

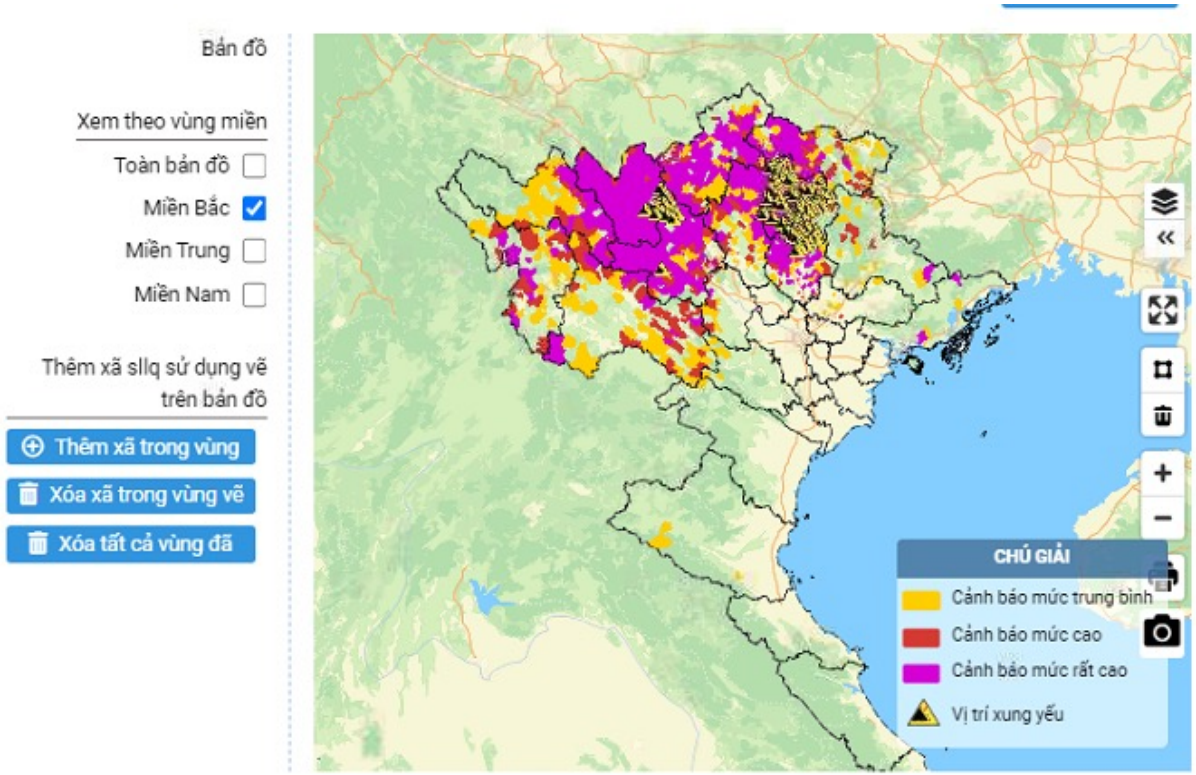
$Q_{bf} = bA^{a1}S^{a3}$

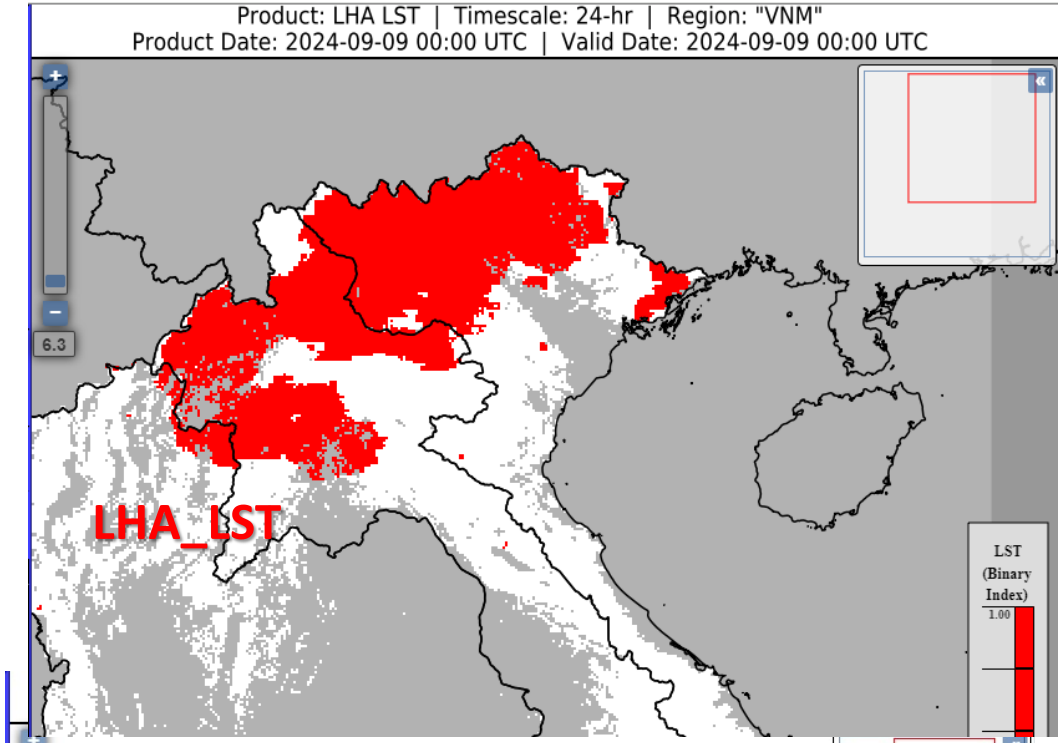
State	Correlation function
Iowa	$Q_{bf} = 20{,}4 * A^{0{,}0607} S^{0{,}44}$
Oklahoma	$Q_{bf} = 0{,}03 * A^{0{,}59} R^{1{,}84}$

Applying Statistical Method in the FFGS to determine Qbf for each regions in Viet Nam Sub-catchment

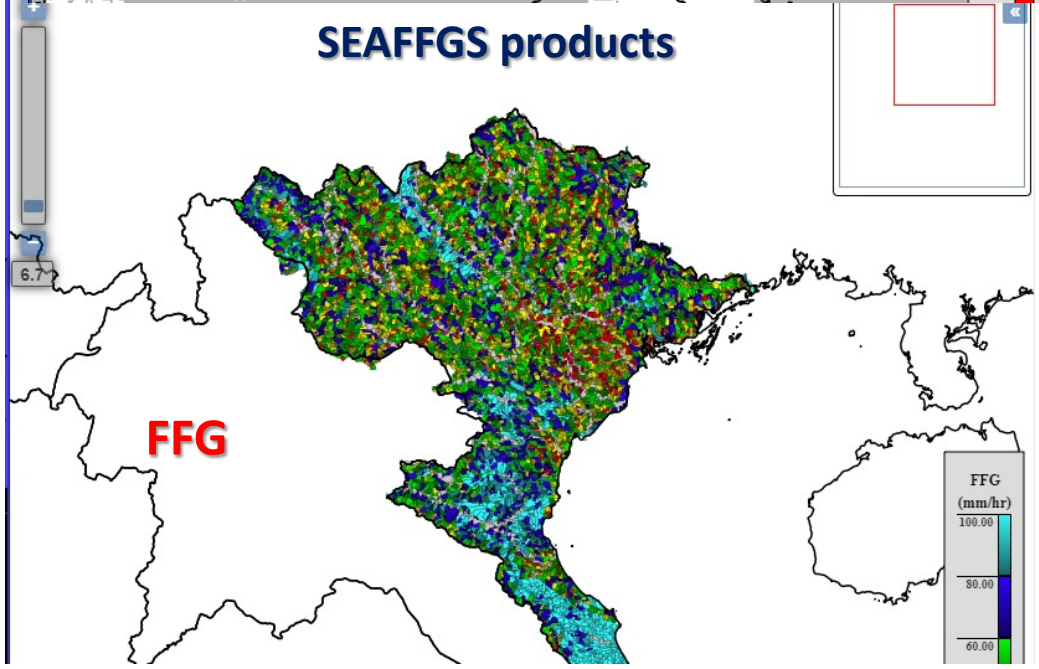
Region	No station	$Qbf = bA^{a}$			$Qbf = bA^{a1}S^{a2}$				$Qbf = bA^{a1}R^{a3}$			
		a	b	R^2	a1	a2	b	R^2	a1	a3	b	R^2
Whole VN	60	0.844	2.44	0.616	0.0790	0.40	18	0.670	0.9	1.9	0.31	0.725
Northern	34	0.765	3.60	0.600	0.0760	0.33	15	0.602	0.9	2.0	0.26	0.737
North East & Middle North	14	0.768	6.01	0.724	0.0778	0.45	20	0.796	0.9	1.4	0.44	0.810
NorthWest	20	0.721	2.27	0.536	0.0770	0.47	15	0.537	0.9	3.1	0.38	0.768
Central & Highland	27	0.871	4.90	0.729	0.0629	0.47	16	0.735	0.9	1.1	0.27	0.772

All products in the FFEW system can be able to refer in the FF – LSD warning operation





SEAFFGS products



5. Conclusion and recommendation

- ✓The FFGS has been approached to the mordernest methodology and technology in flash flood warning.
- ✓The FFEW has been updated and adjusted in order to be suitale for the actual condition in Viet Nam; provided end to end procedure in daily operation FF - LSD warning.
- ✓Forecasters have an important role in analyzing and using products from FFEW to make decisions about the level and scope of flash flood and landslide warnings in the bulletin.
- ✓The increase of automatical rain gauge network and improvement of NWP products need to be considered to enhance the result of FFEW.

THANK FOR YOUR LISTENING!