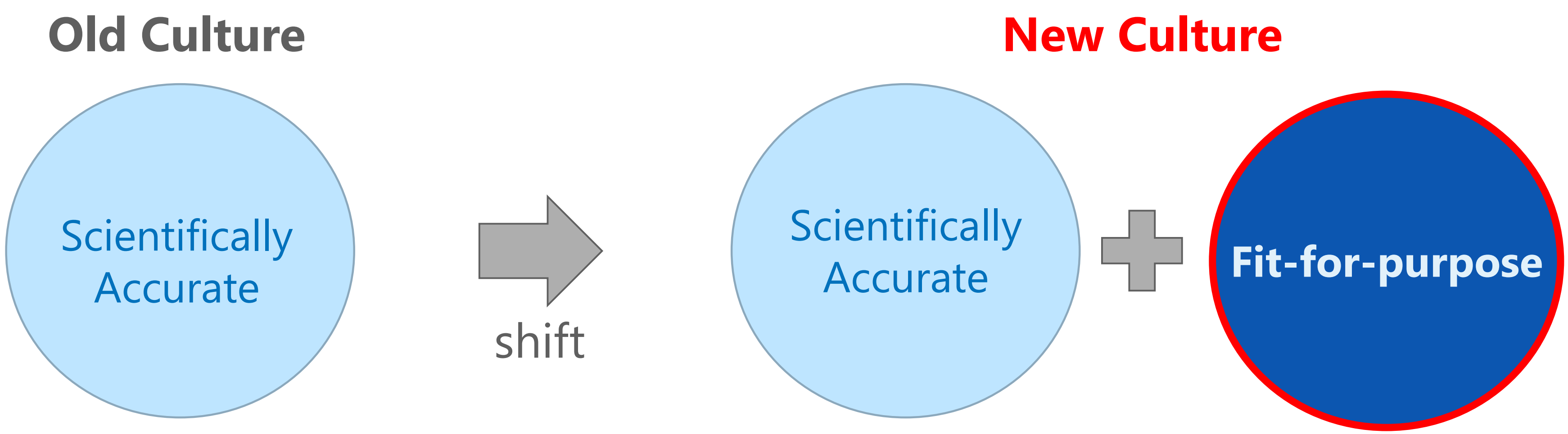
Determination of risk-based warning criteria

Risk-based Warning

Provide Risk-based Information

Users are interested in what the weather might do rather than what the weather might be, no matter how scientifically accurate the information provided is.

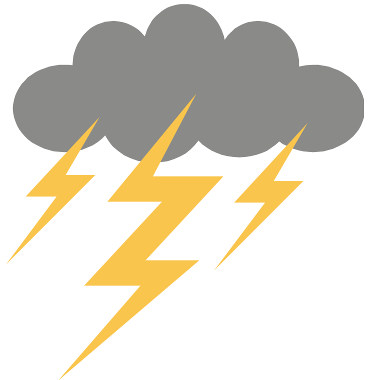


*"What the weather might **be**"*
(General forecast)

*"What the weather might **do**"*
(Impact-based forecast)

DRR-related Terminology (1)

Terminology	Definition
Disaster	**A serious disruption of the functioning of a community or a society** causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources
Hazard	**Potentially damaging physical event** that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.



DRR-related Terminology (2)

Terminology	Definition
Exposure	Exposure is the **total value of elements at-risk**. It is expressed as the number of human lives, and value of the properties, that can potentially be affected by hazards. Exposure is a function of the geographic location of the elements.
Vulnerability	**Physical, social, economic, and environmental factors which increase the susceptibility to be impacted by hazards**. Vulnerability engages resistance and resilience.









based on the 2009 UNISDR Terminology on Disaster Risk Reduction, unless indicated otherwise.
https://www.wmo.int/pages/prog/drr/resourceDrrDefinitions_en.html

In what case does disaster happen?

Disasters do not always happen when hazardous events occur.

Risk = Hazard × Exposure × Vulnerability

- **Hazard**: Potentially damaging physical events
- **Exposure**: Total value of elements at-risk (e.g. number of human lives and properties)
- **Vulnerability**: Physical, social, economic, and environmental factors increasing the susceptibility to hazards

Our recent challenge is to incorporate 'Exposure' and 'Vulnerability' into your warning.

In what case does disaster happen?

Disasters do not always happen when hazardous events occur.

Risk = **Hazard** × **Exposure** × **Vulnerability**

- **Hazard**: Potentially damaging physical events
- **Exposure**: Total value of elements at-risk (e.g. number of human lives and properties)
- **Vulnerability**: Physical, social, economic, and environmental factors increasing the susceptibility to hazards

Statistical Approach

Warning Criteria ← **Weather condition** How's the condition? × **Disaster statistics** Where and in what conditions did disasters occur?

Disaster Risk Levels

Statistical Approach for warning criteria

- JMA adopts a statistical approach to warning criteria using quantitative measurements of weather condition and disaster statistics to identify risk disaster levels and set warning criteria based on risk levels.

quantitative measurements of weather condition

×

Disaster statistics

→ **Warning Criteria**

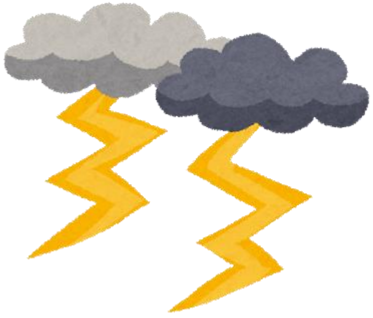
Disaster Risk Levels

- To adopt this method, you need to have
  - ***quantitative measurements of weather condition***
    - *observation data*
    - *various met/hydro indices*
  - ***disaster statistics***
    - *Categorized by weather phenomena*

Disaster statistics associated with weather condition

- Disaster need to be associated with weather condition
  - Kind of damage
  - By rain, wind, snow, Intensity
  - Depression, Typhoon
  - Area
  - Season






Target of Warning

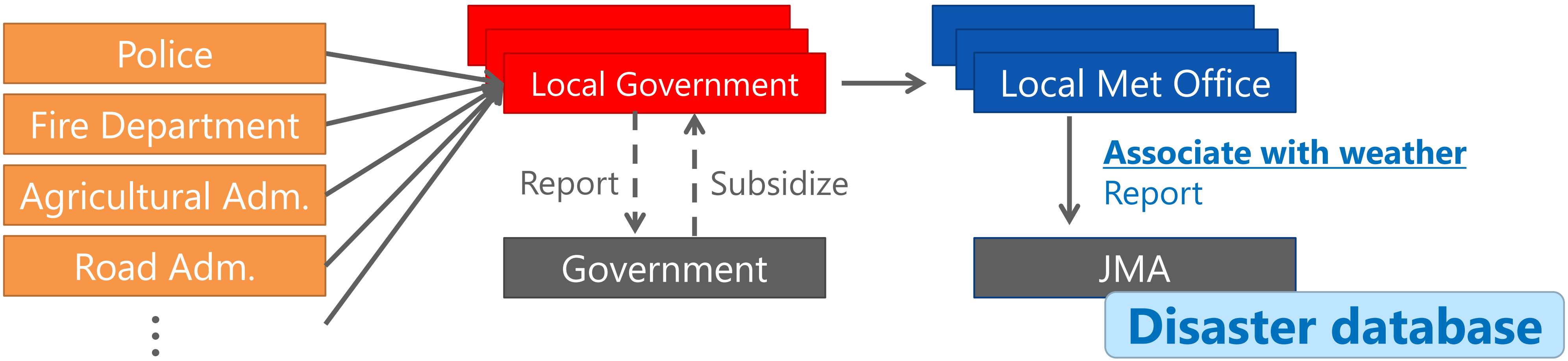
- What kind of damage is to be warn ?
  - Disaster definition would depend on reginal feature.
    - Level of damage (Ex. Flooding on the floor, under the floor)
    - Number (Ex. Over 1 house damaged)

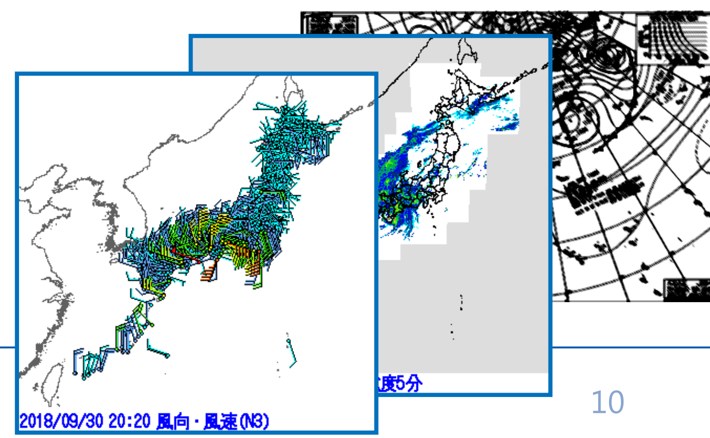
… is need to be sure to issue warning

Collection of Disaster Statistics

Collaboration with Local Governments

In Japan, local governments are responsible for collecting disaster statistics such as economic damages and the number of victims.





Example of collected disaster statistics

	A	B	C	H	I	J	K
2	Year	Month	Day	The number of flooded houses	R1	R3	R24
3	1991	9	19	346	41	84	276
4	1993	8	27	770	52	137	290
5	2000	7	4	72	80	99	99
6	2001	9	11	113	36	63	126
7	2003	9	3	64	27	27	27
8	2003	10	13	75	61	61	61
9	2004	10	9	202	76	102	259
10	2004	10	20	61	31	69	171
11	2005	9	4	163	59	69	86
12	2000	7	7	11	24	56	189
13	2000	8	9	31	37	37	37
14	2007	8	24	3	47	59	59
15	1996	9	22	0	26	69	234
16	1991	6	24	0	23	31	42
17	1991	8	1	0	22	22	22
18	1991	8	8	0	28	28	28
19	1991	8	20	0	31	44	109
20	1991	9	8	0	26	63	107
21	1991	10	8	0	4	11	108
22	1991	10	11	0	11	23	112
23	1991	10	13	0	2	9	50
24	1992	4	22	0	20	42	42
25	1992	5	20	0	30	30	33
26	1992	6	24	0	4	11	100
27	1992	7	15	0	23	29	29
28	1992	7	16	0	0	0	36
29	1992	9	30	0	30	59	77
30	1992	10	9	0	32	79	142
31	1992	11	20	0	5	21	100

The list of **disaster** occurrence with rainfall data

The list of heavy rain events(**hazard**) with rainfall data

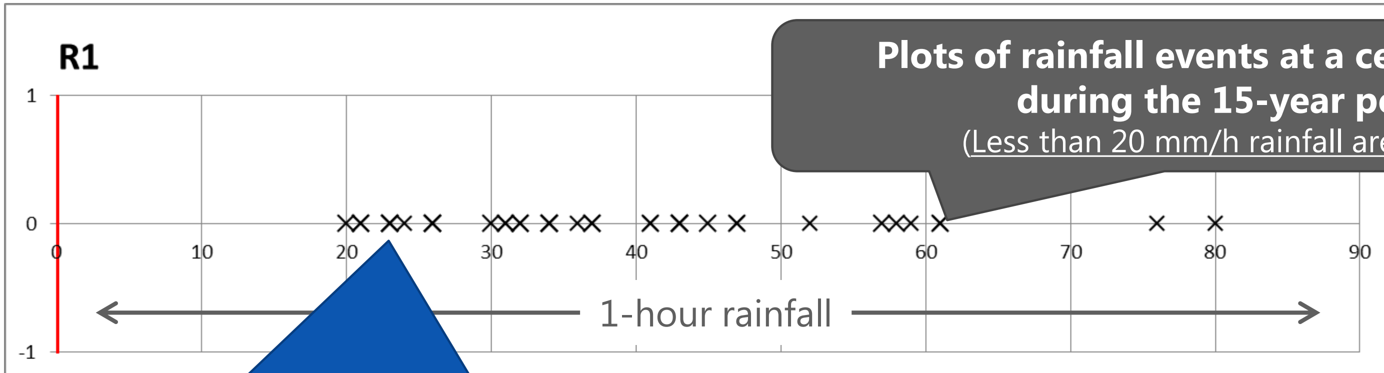
Heavy rain:

- R1 ≥ 20mm
- R3≥ 30mm
- R24≥ 50 mm

Collection of hazard and disaster for statistics

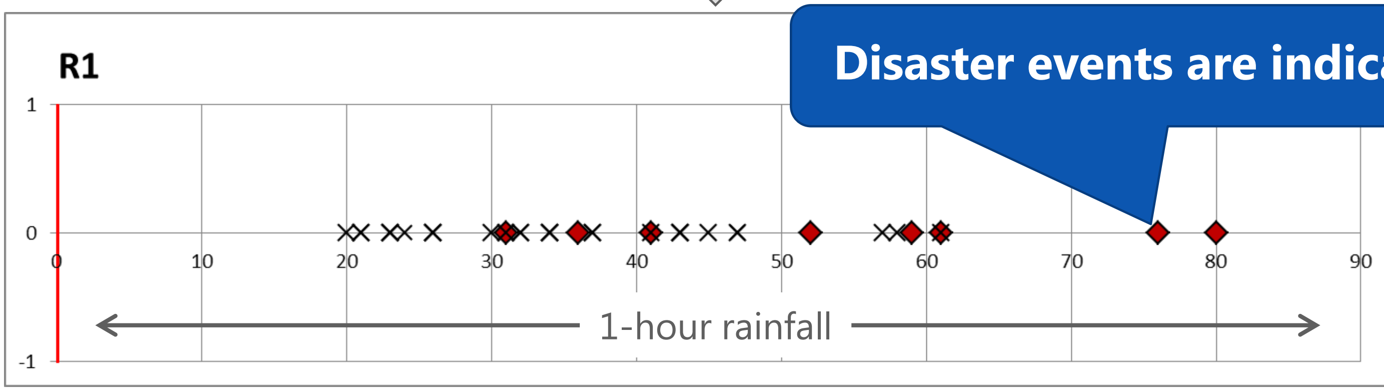
Collect hazard and disaster events for statistics, and visualize the relationship

Plots of rainfall events at a certain station during the 15-year period
(Less than 20 mm/h rainfall are omitted)



Disaster events are indicated as "X"

Disaster events are indicated as "◆"



Verification Indices

Number of warning issuance (NI)

- The number of warning issuances
- This indicates the frequency of warning issuance

Hit Rate (HR)

- The ratio of detected disasters to all disaster events
- This indicates the reliability of warnings

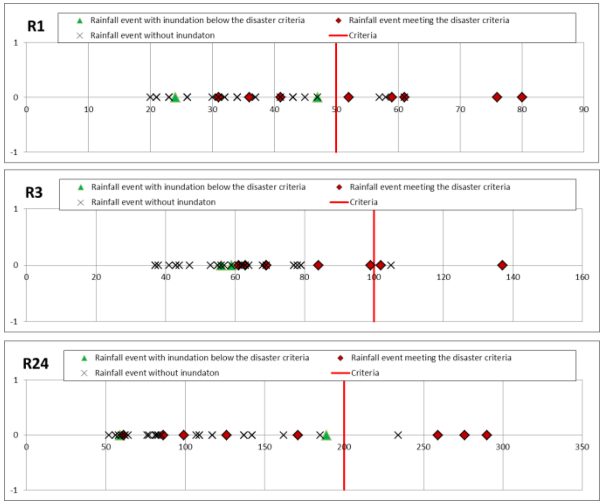
False Alarm Rate (FAR)

- The ratio of no-disaster rainfall event despite of warning issuance to all warning issuances
- The wasted cost for preparation can be estimated

Verification of warning

		Warning issuance		
		YES	NO	TOTAL
Disaster occurrence	YES	A	B	D1
	NO	C		
	TOTAL	W1		

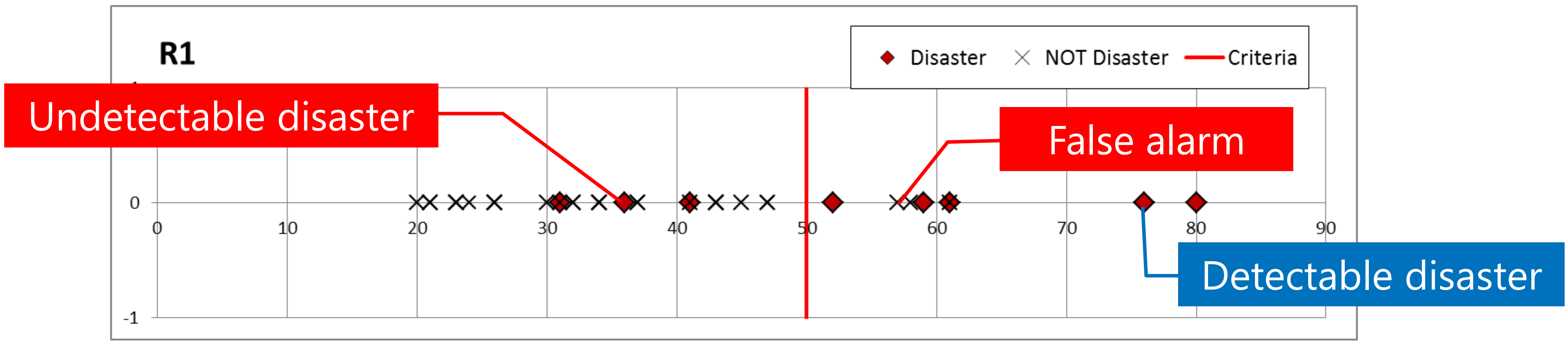
Count



- **Number of Warning Issuance (NI)** = $W1$
- **Hit Rate(HR)** = $\frac{A}{D1}$ $\left(= \frac{\#\ disaster\ occurrence\ above\ criteria}{total\ \#\ disaster\ occurrence}\right)$
- **False Alarm Rate (FAR)** = $\frac{C}{W1}$ $\left(= \frac{\#\ warning\ issuance\ but\ no\ target\ disaster}{total\ \#\ warning\ issuance}\right)$

Trade off on warning criteria

- No perfect criteria (100% detection rate and 0% false alarm rate)



If lower criteria
(✕) False alarms ↑increase
(〇) Detectable disasters ↑increase

If higher criteria
(〇) False alarms ↓decrease
(✕) Detectable disasters ↓decrease

Use indices to describe it objectively
Continuous verification is required

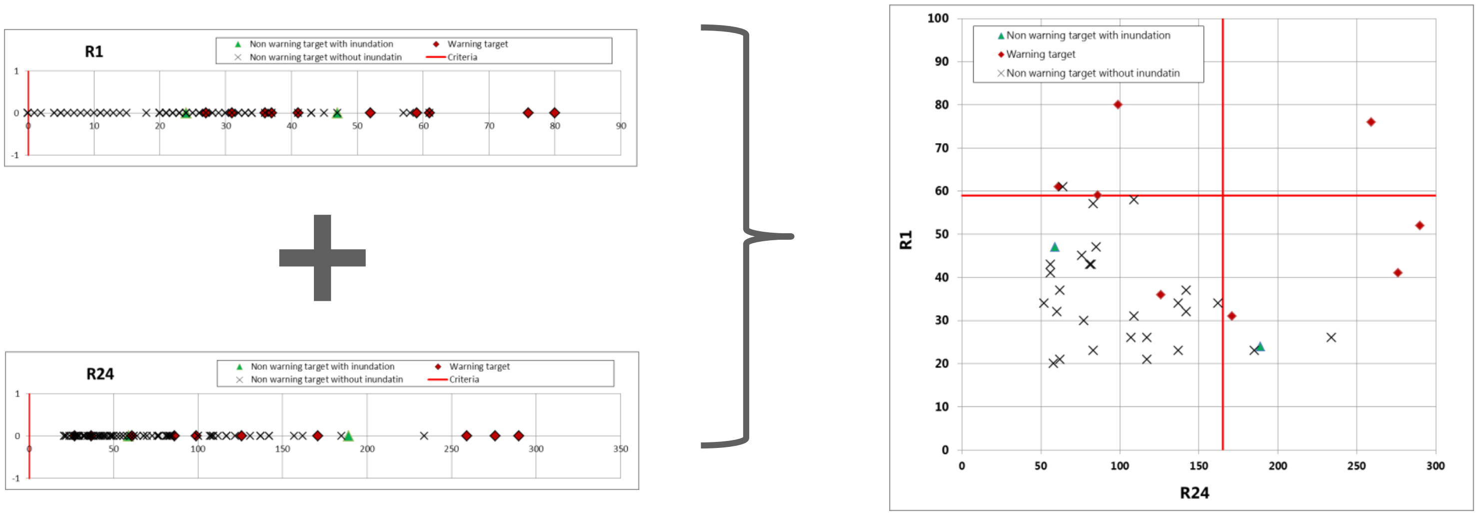
Work flow of warning criteria determination

1. **Collect data**
   - Disaster statistics and Value of indices
2. **Determine the first warning criteria**
   - Set the criteria by comparing severe events with disaster statistics
3. **Verify the criteria with verification indices**
   - Calculate verification indices (e.g. Hit rate, False alarm rate)
4. **Adjust the criteria using the verification indices**
   - Find the most appropriate criteria ("most appropriate" depends on the users' needs)
5. **Determine the final warning criteria**

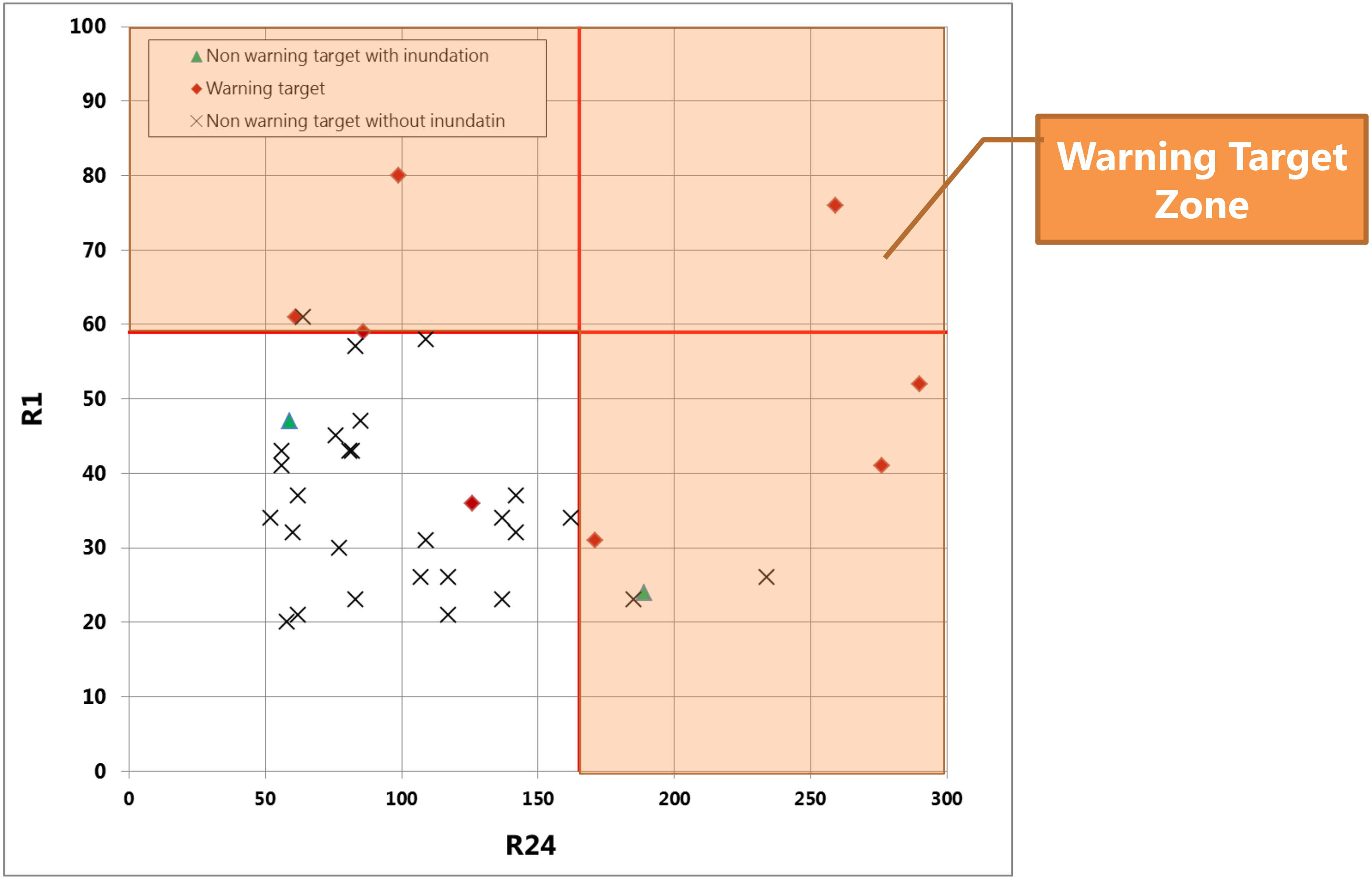
Composite criteria

Composite criteria for each quantitative measurement (R1/R24)

How about compositing these criteria ?



Graph for warning target hazard



Comparison single and composite criteria

- Composite criteria keep FAR, and improve HR and NI
- What does this mean between hazard and disaster ?

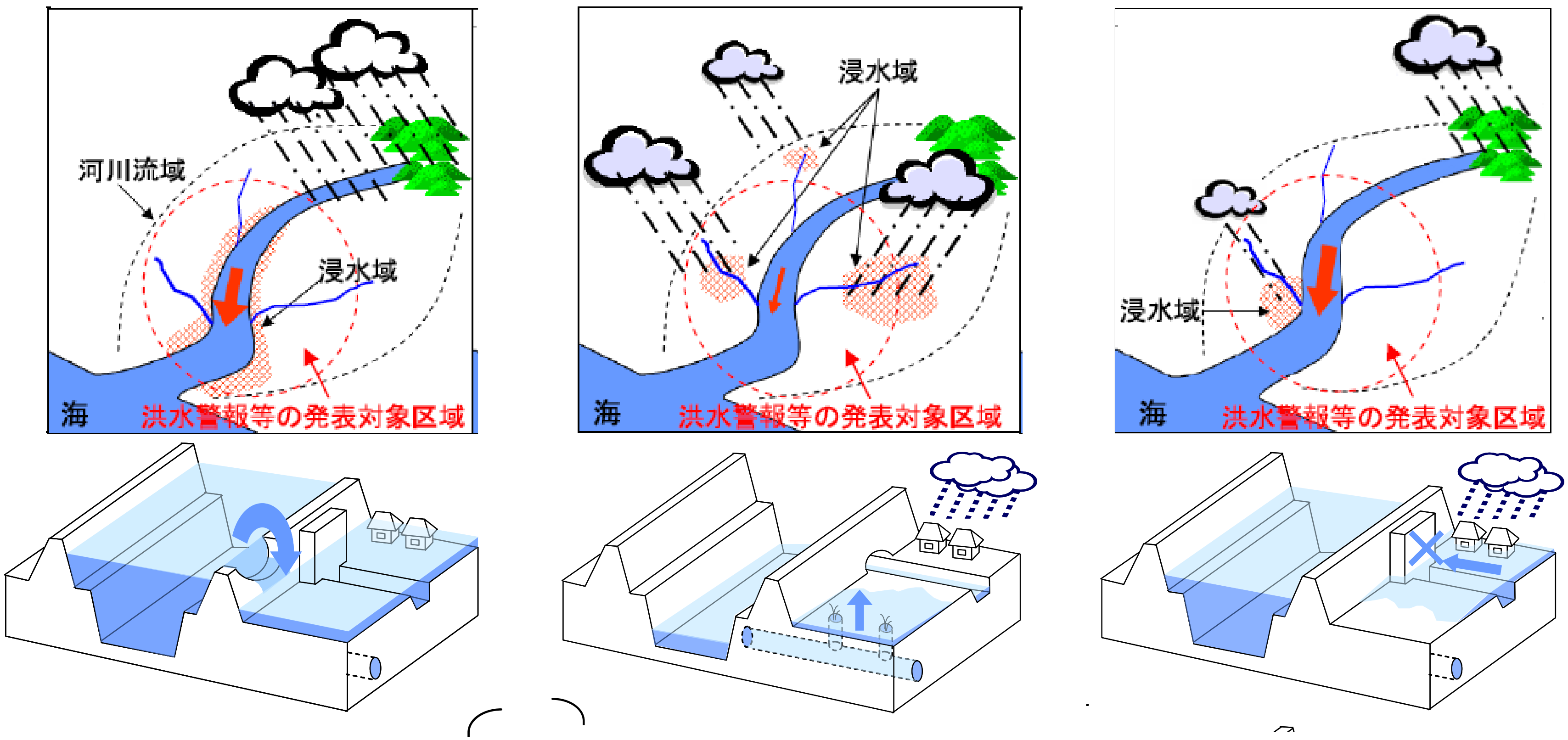
	Criteria	NI	HR	FAR
R1	59	5	40	20
R24	170	7	50	28
R1/R24	59/170	11	80	27

CORRELATION BETWEEN WEATHER FACTOR AND DISASTER INCIDENT

Classify hydrological disasters

Three Types of Hydrological Disasters

Hydrological disasters such as flooding and inundation can be classified into three categories.

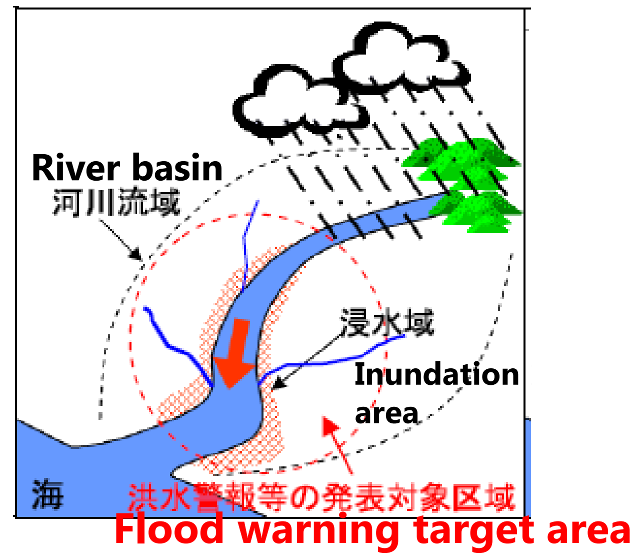


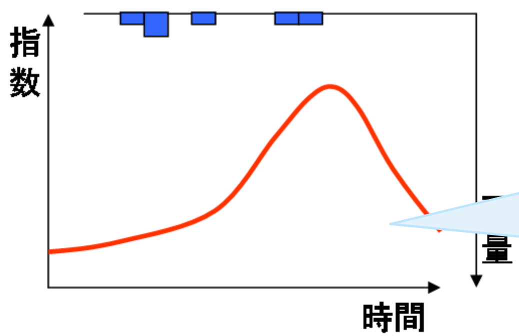
1. Flooding

① Heavy rain at the upstream of the river..

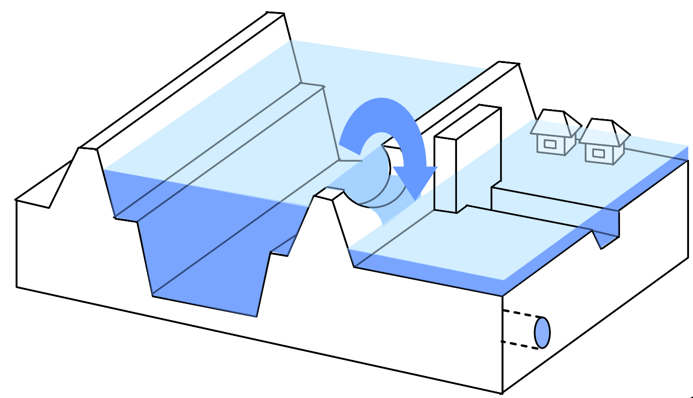
② Water level of the river increases gradually.

③ Finally, it causes flooding at the downstream area.





Good correlation with **long term rainfall (R24)**

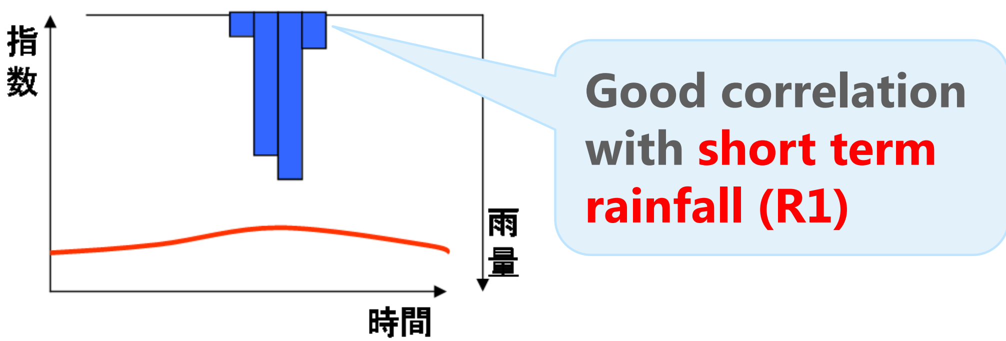


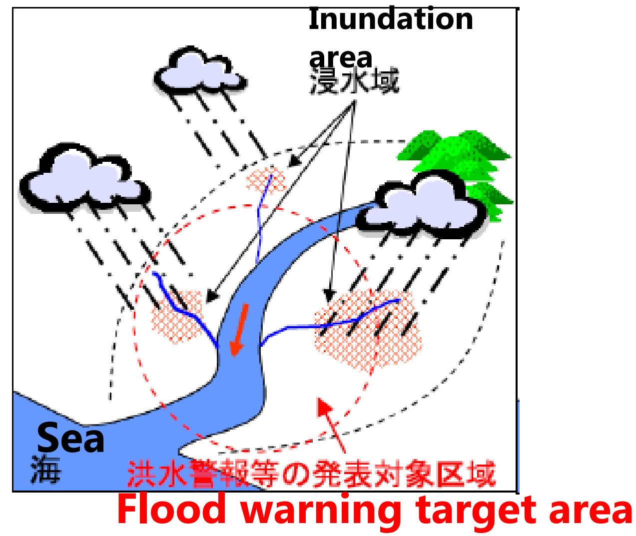
Rain in the upstream
take time to reach downstream area

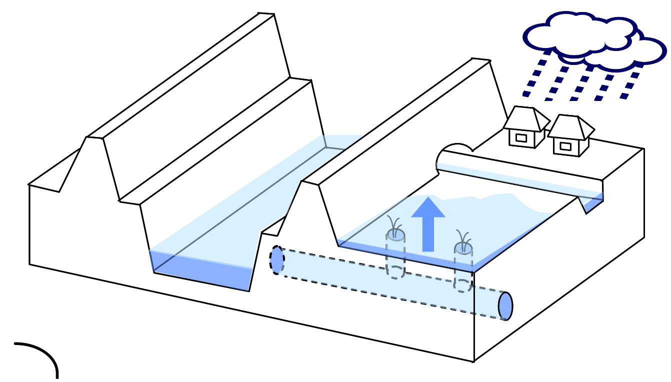
2. Inland Flooding

① **Heavy rain at a certain area over drainage system capacity.**

② **It causes inundation at the area.**







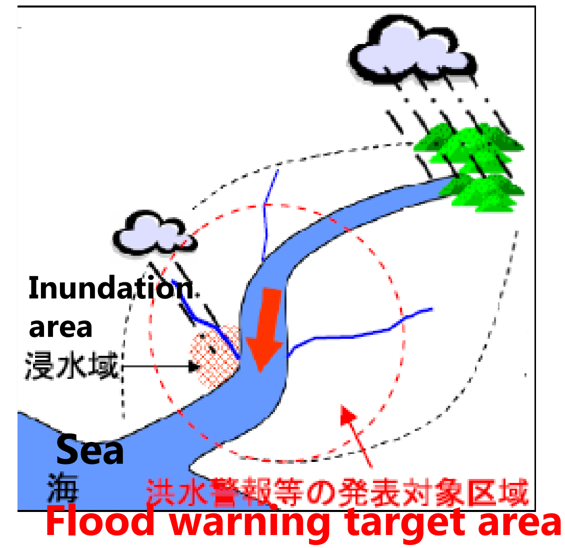
3. Composite-type Flooding

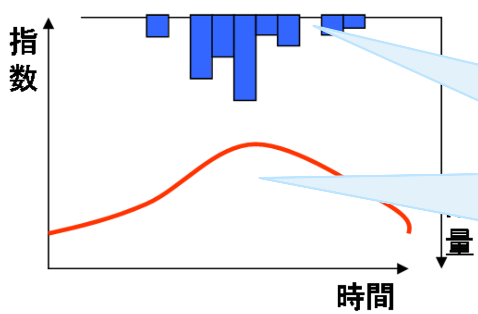
① Heavy rain at the downstream area

① Heavy rain at the upstream area

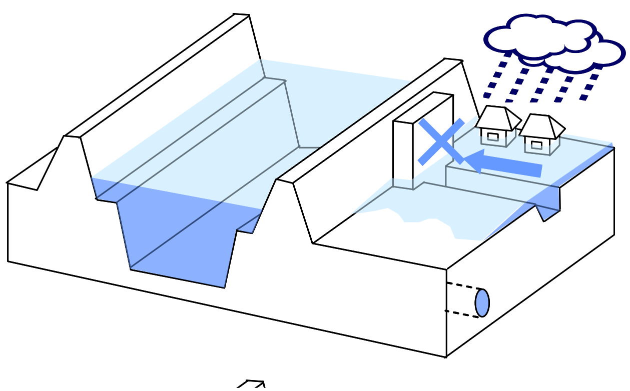
② Drainage system capacity fulfilled by water from upstream, and heavy rain at downstream does not be drained.

③ It causes inundation.





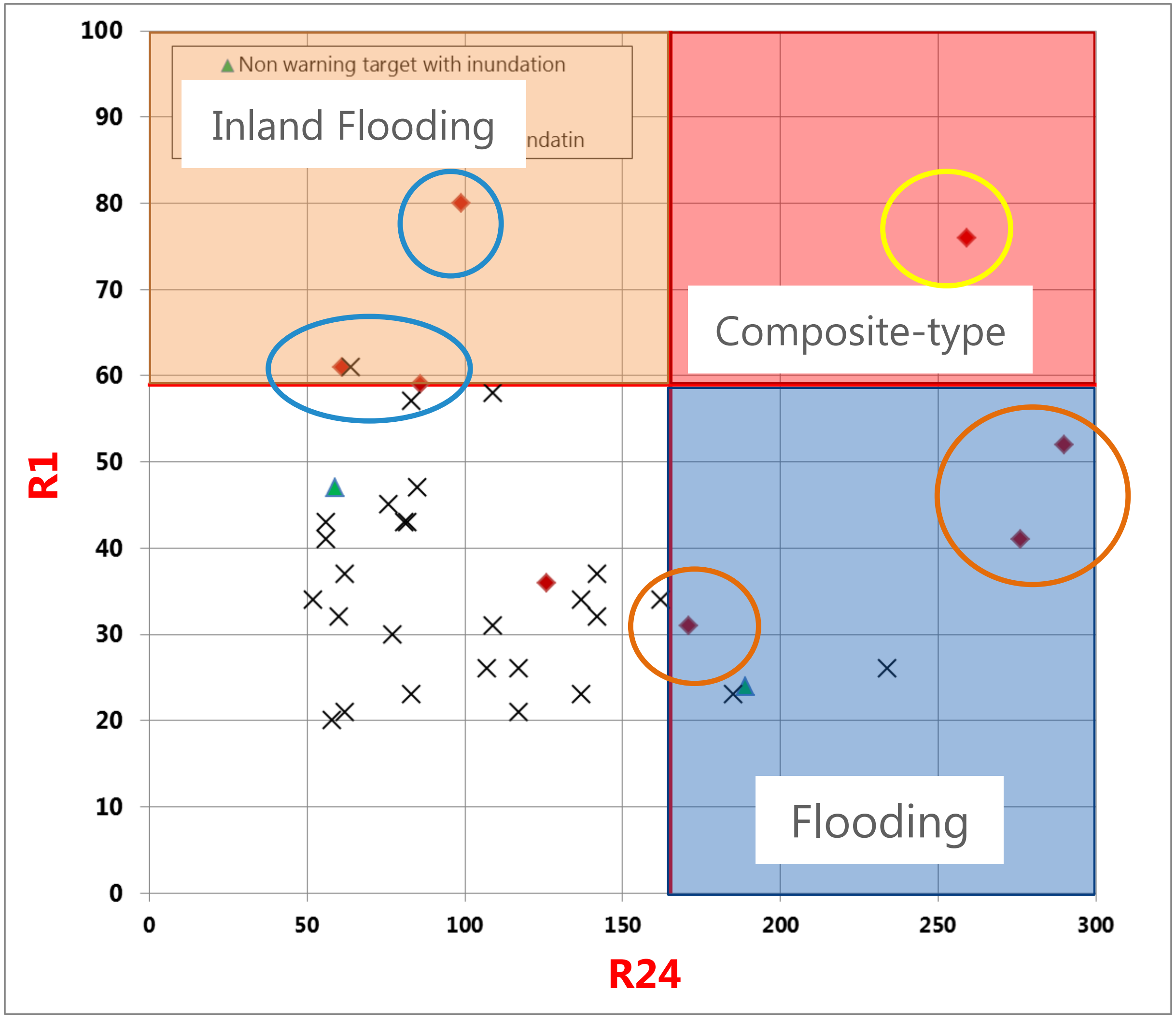
Good correlation with both **short term rainfall (R1)** and **long term rainfall(R24)**



Criteria from R1 and R24

1. **Flooding**
   Long term rainfall (R24)
2. **Inland Flooding**
   Short term rainfall (R1)

3. **Composite-type**
   Both



Warning Criteria and Disaster incentive

- Understanding
  - What kind of disaster happen
  - What made that disaster

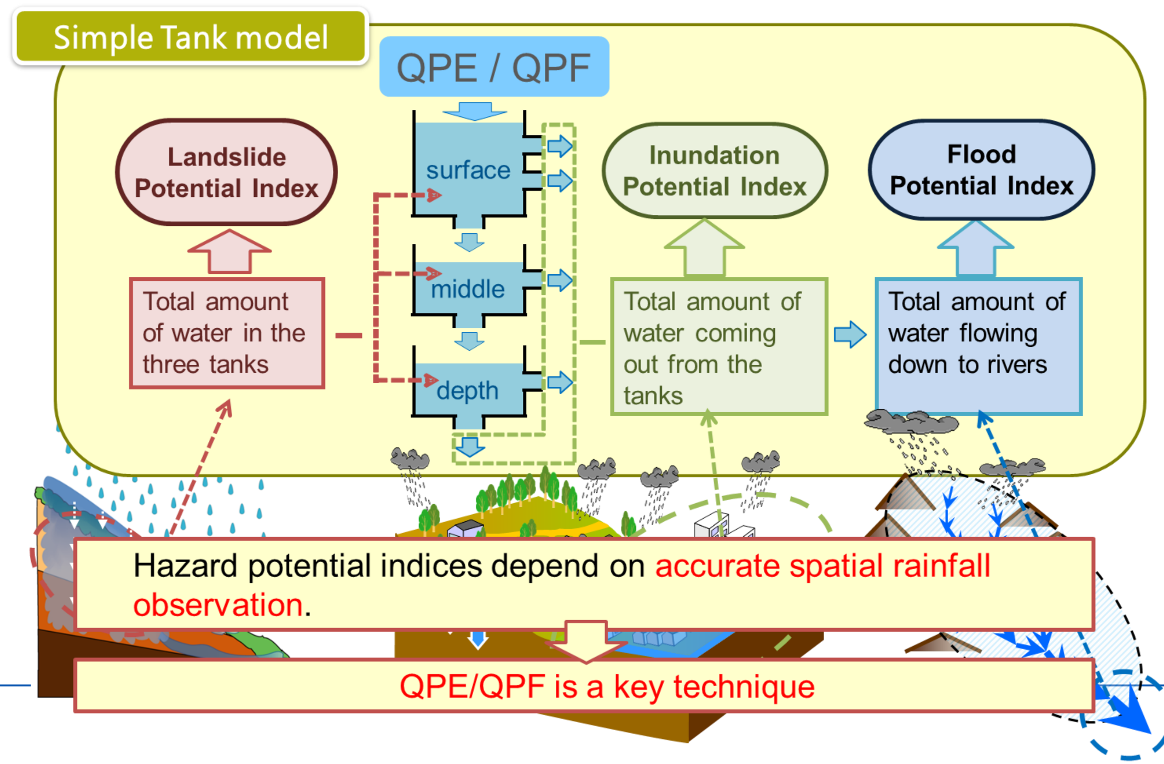
makes **proper warning criteria**.

- HR and FAR is trade off, but advanced method, like composite method, makes more proper warning criteria.
  - **Disaster statistics** is basic for these work.

Indices of JMA

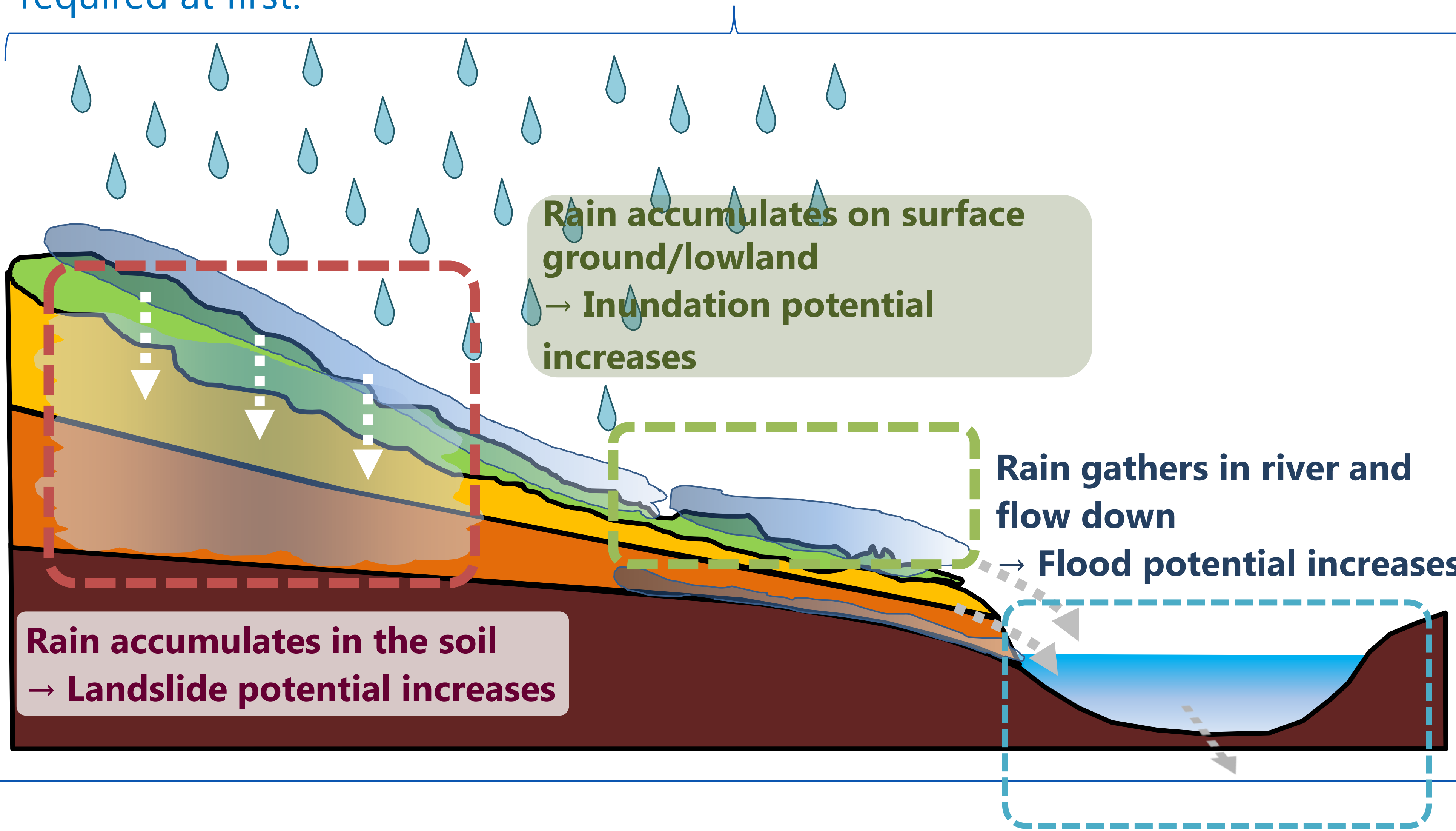
- JMA used rainfall as warning criteria, and studied
  - R1 have good correlation with Inland flooding, but sometimes don’t match to overflow of drainage capacity
  - R24 have good correlation with flooding, but it does not consider the rainfall at upstream

So Indices were developed for waning criteria to catch disasters correctly

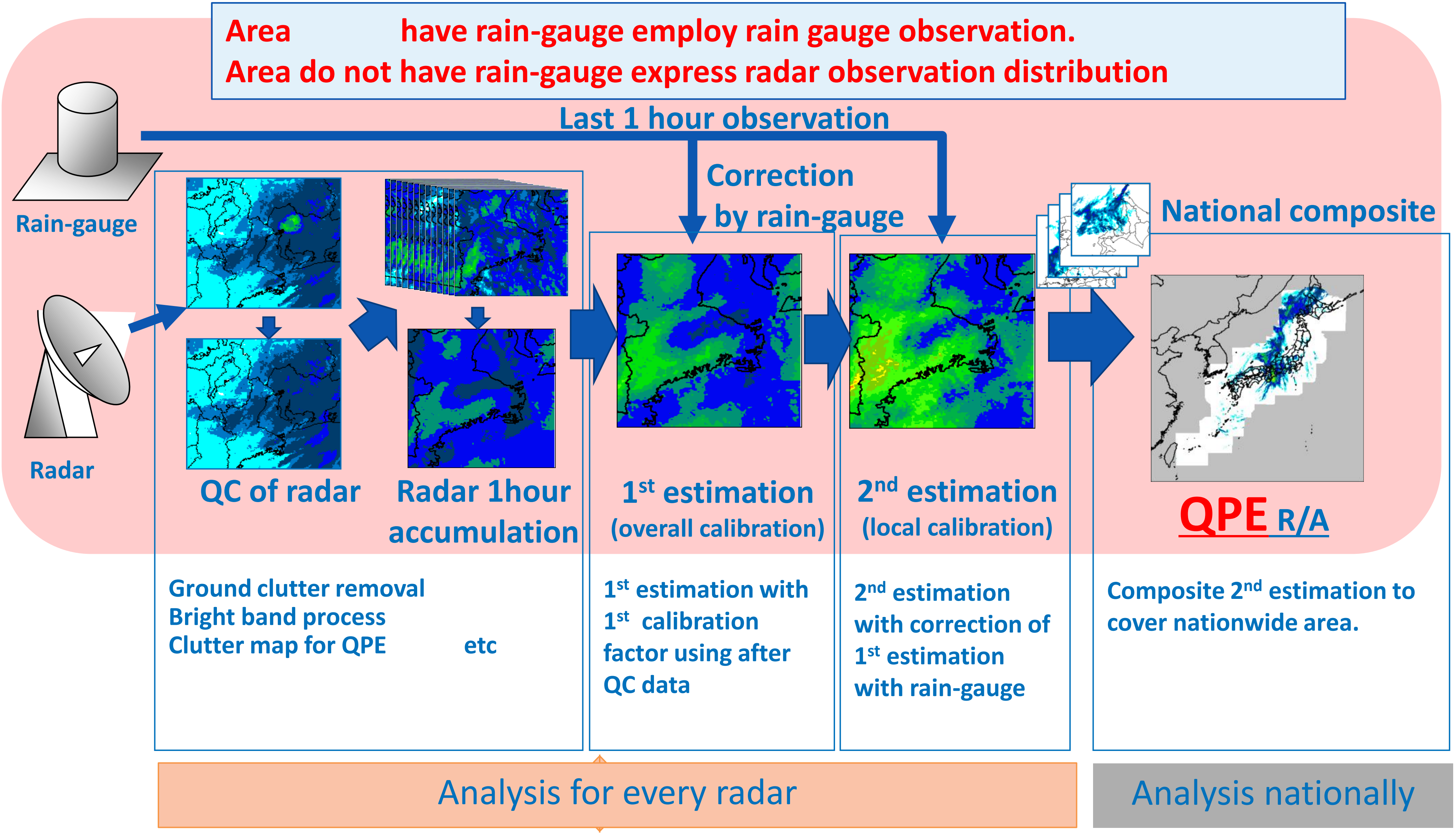


Developing hydrological indices

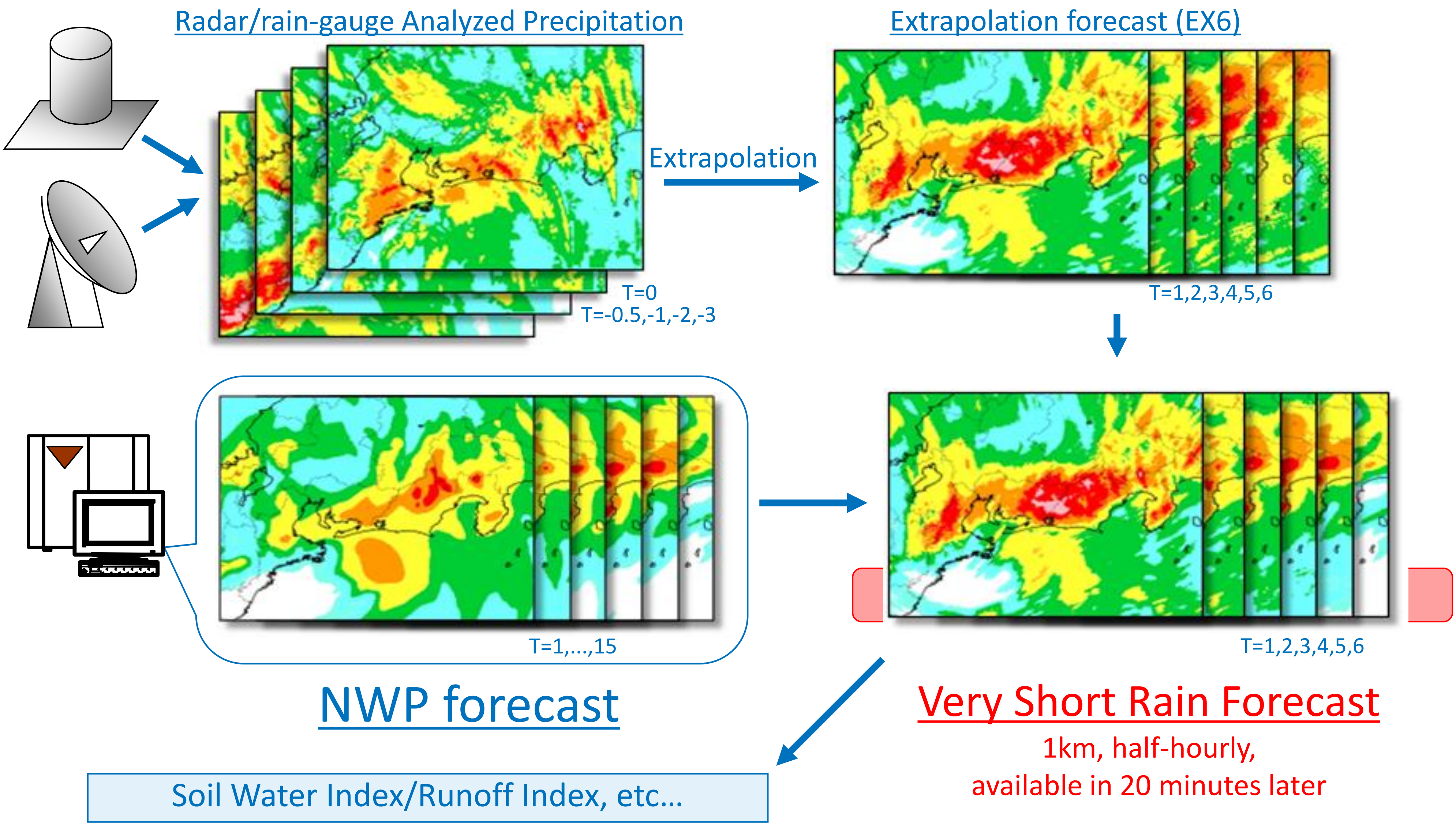
Spatially spread analysis(QPE) and forecast(QPF) of precipitation mount is required at first.



JMA **QPE** algorithm

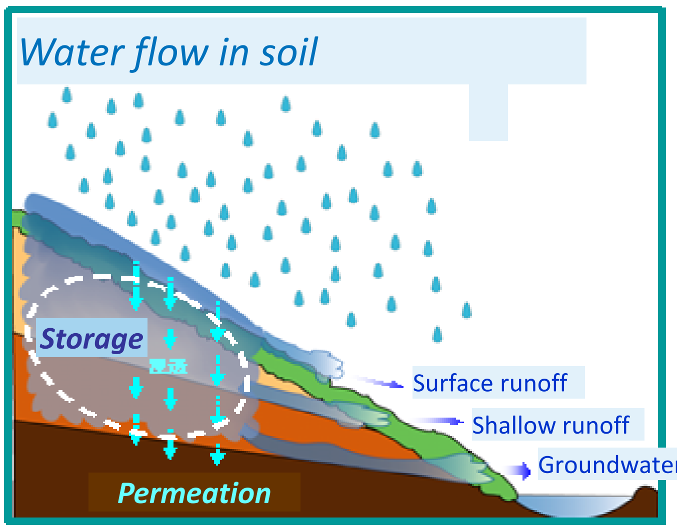


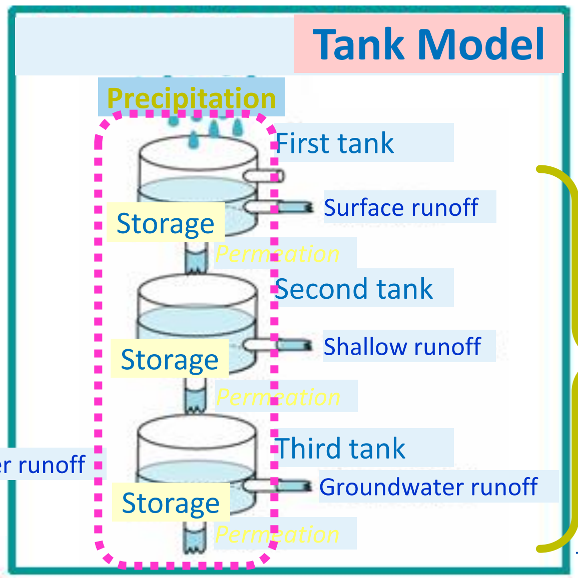
QPF Concept of Very Short Range Forecast of Precipitation

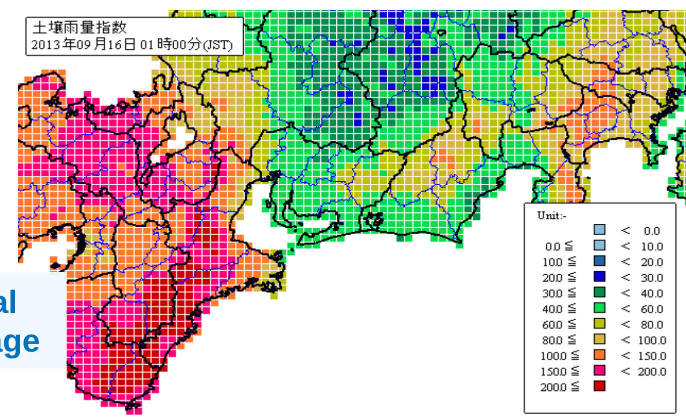


Land slide Potential Index

- “Land slide potential index” is equivalent to the total storage volume of three serial tanks.
- Known good correlation with landslide incident statistically
- Capable to keep disaster potential from proceeded rainfall, so cover disaster long term rainfall cases, cases after rainfall finished.

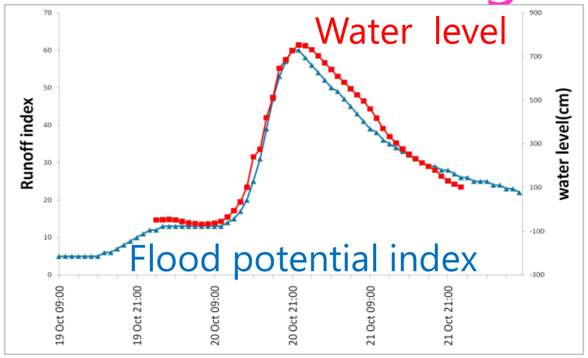


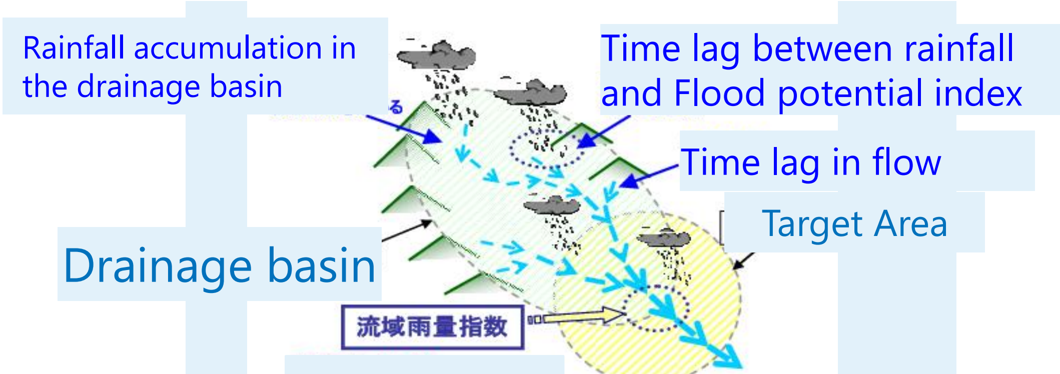


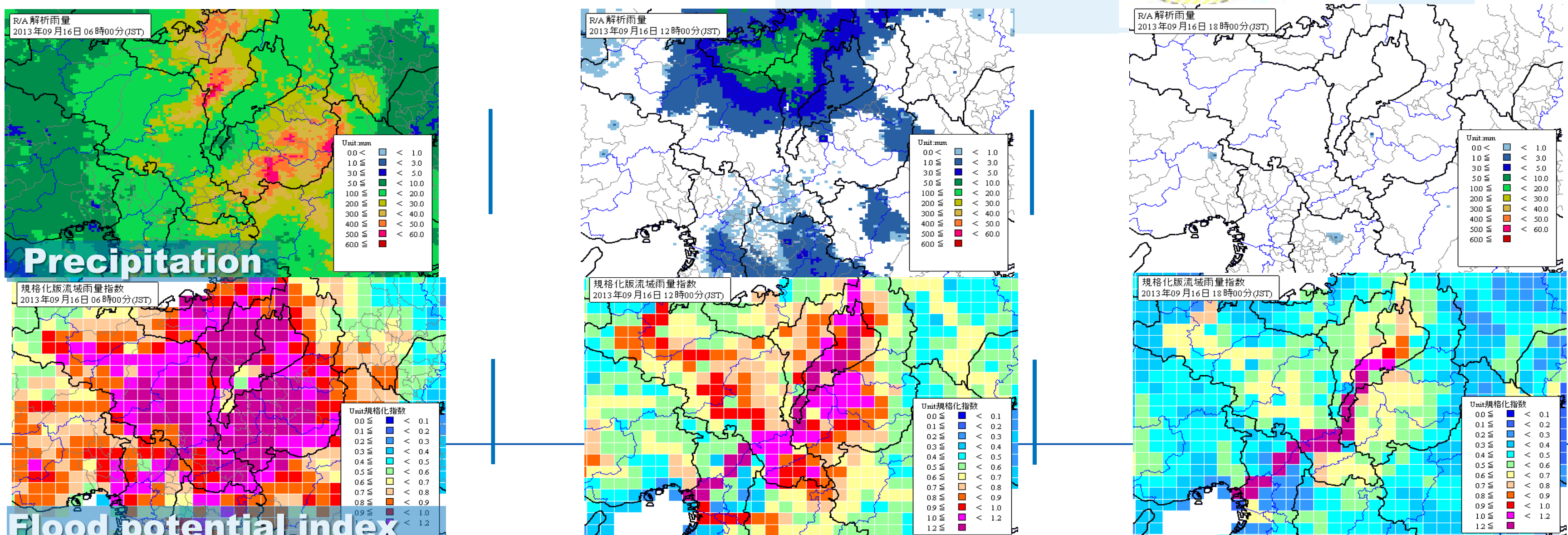


Flood Potential Index

- Water amount around drainage basin should be considered to estimate the risk of flood disaster.
- Flood Potential Index is calculated from outflow from tank model and flowing down at the river.

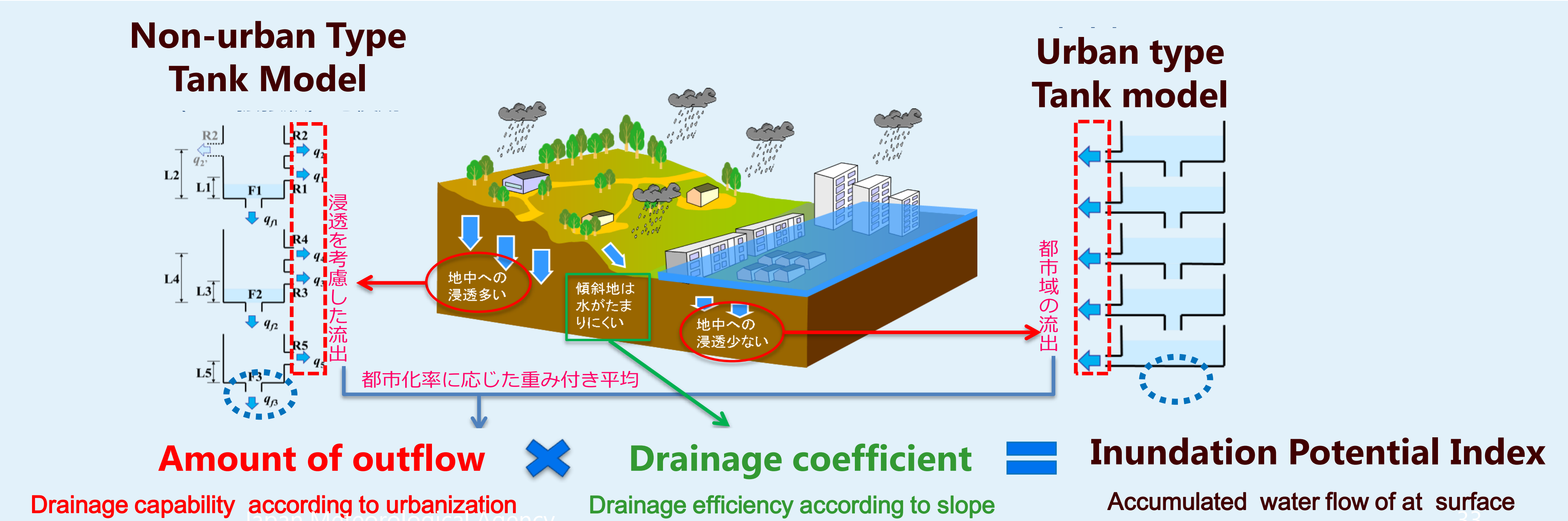




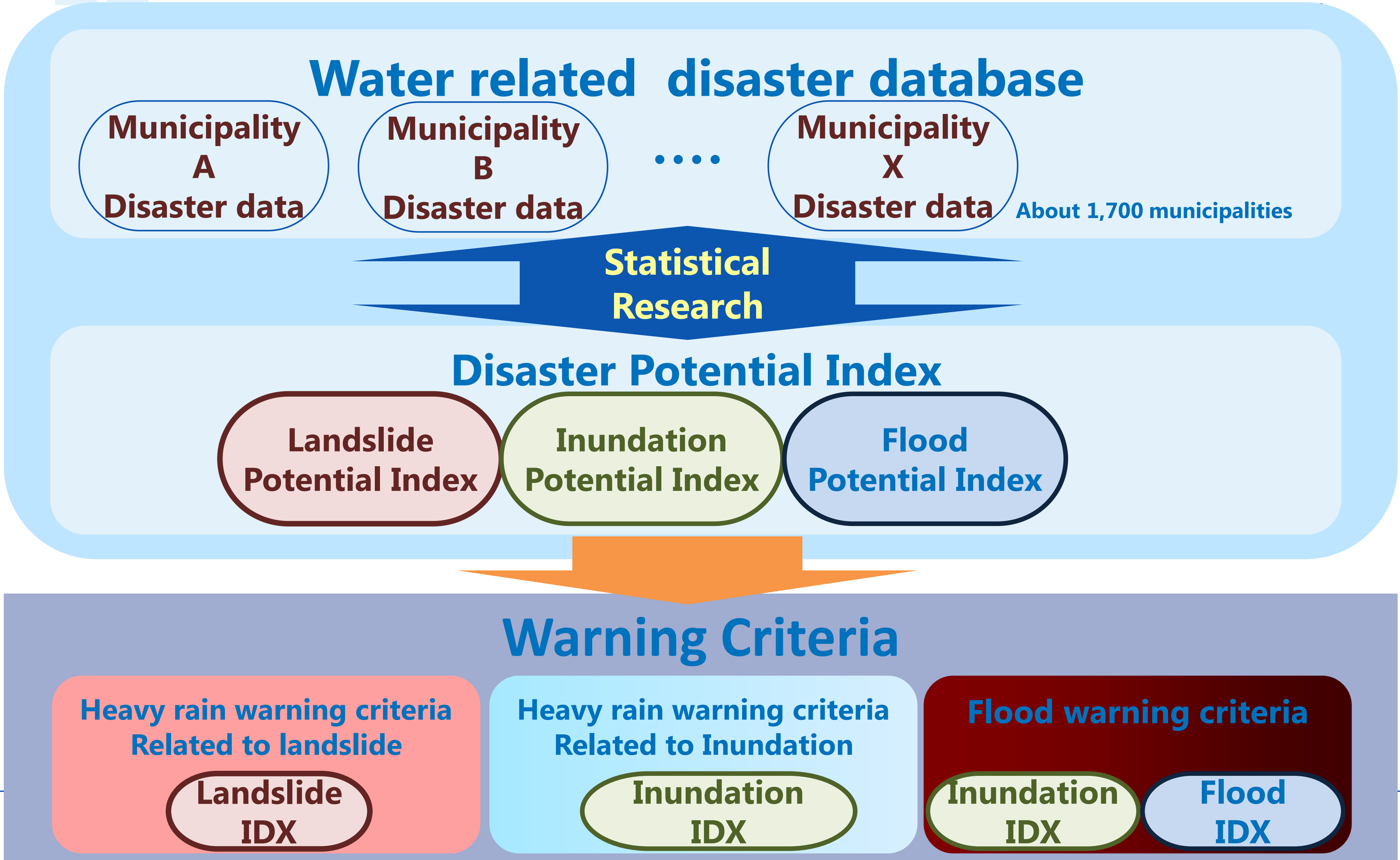


Inundation Potential Index

- Target is inundation caused by amount of rainfall over drainage capacity.
- Inundation Potential Index consider urbanization to cover the difference of infiltration.
- Low land is in danger for Inundation, and Inundation occur at area far from river.



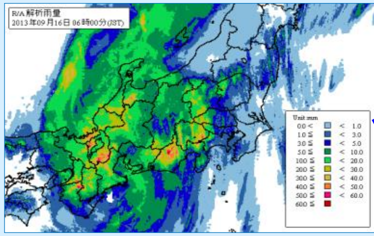
Waning Criteria Determination



Early Warning System in JMA

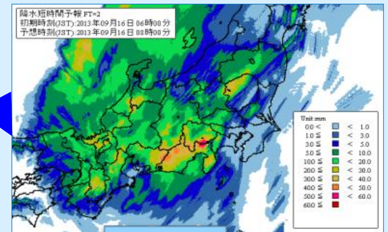
Quantity

QPE



Estimates amount of rainfall

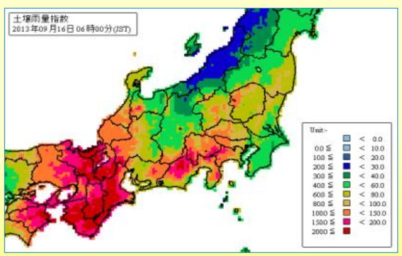
QPF



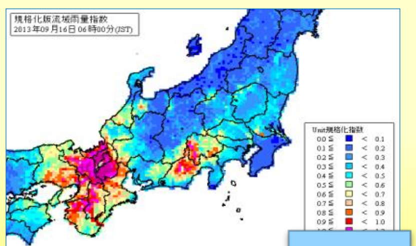
Forecast amount of rainfall

Index

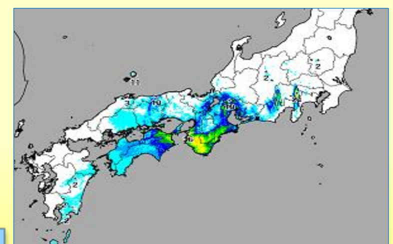
Landslide Potential Index



Inundation Potential Index

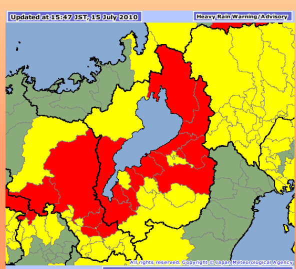


Inundation Potential Index



Disaster risk
Analysis/Prediction

Warning / Advisory



Use each index as criteria

Summary on Determination of risk-based warning criteria

- **P**ublic **W**eather **S**ervice need to publish warning with considering the risk of severe weather
- For impact based warning, proper **warning criteria** is essential
  - **Target of warning** should be determined clearly
  - Users opinion is also considered to determine warning criteria
- **Disaster database** is key to determine proper warning criteria
  - **Classification** of disaster sometimes makes new indices
- Continuous **verification** of warning criteria is important
- **Disaster-risk estimation** by **quantitative measurement** is key for **I**mpact **B**ased **F**orecast

Thank you for your attention