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SE85 / Earthquake Early Warning, SE85-D3-PM1-201C-003, Invited.

On the Effective Earthquake Early Warning and its Verifications

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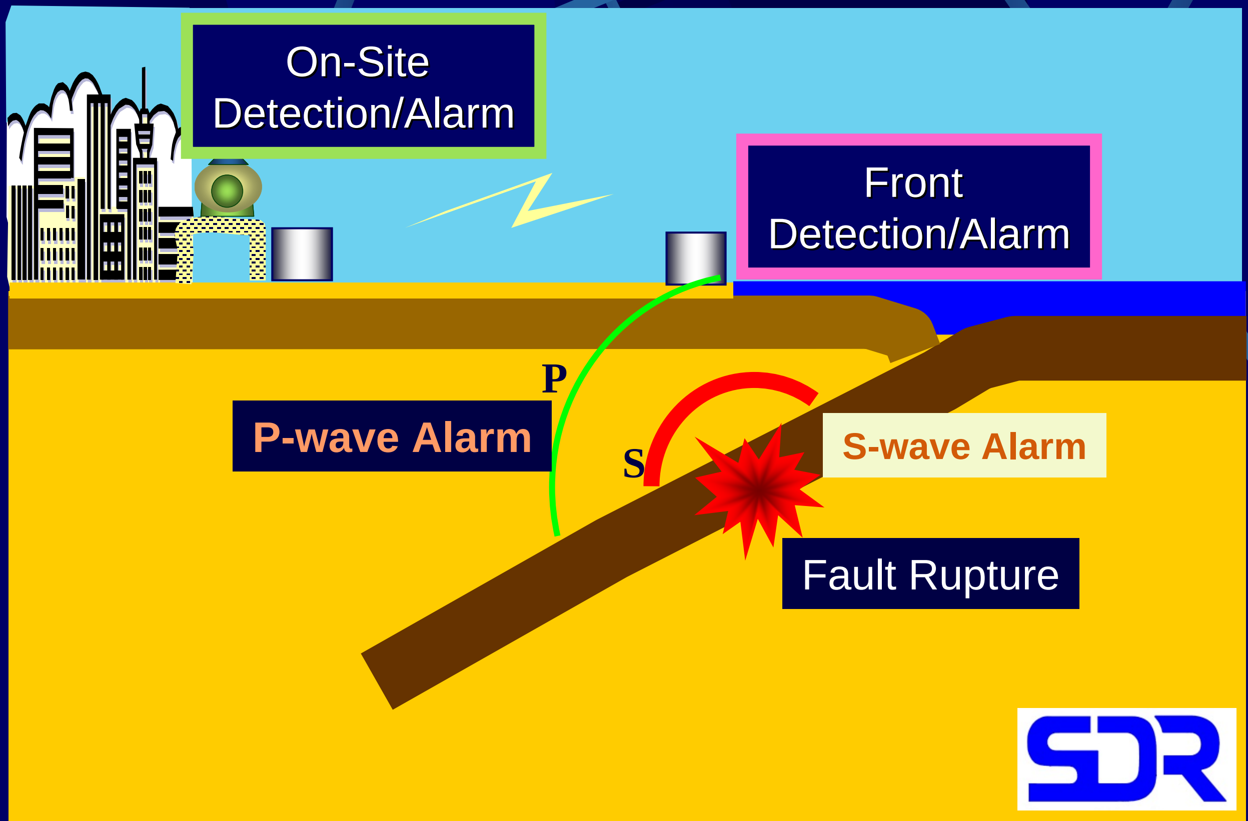
We can see from this video as follows;

- **EEW can get only short time margin.**
- **It is extremely necessary and important to prepare and exercise for EEW in advance.**
- **In any case, only the immediate and proper warning can be useful.**

And one of the lessons from the 3.11 Earthquake is

- **Avoid that Warning becomes crying Wolf.**

Concept of Earthquake Early Warning



There are two kinds of the earthquake alarm. One is "On-site Alarm" which is the alarm based on the observation at the side of the objects to be warned. The other is "Front Alarm" which is the alarm based on the observation near the epicentral area to warn for the possible damaged area.

Both alarm types described can make use of two different triggers, also called "alarms".

One is so-called "S-wave Alarm" or "Triggered Alarm". And the other is "P-wave Alarm".

Concept of the Front Alarm by Dr. Cooper, 1868

In 1972, Dr. Hakuno et al., researchers for earthquake disaster prevention in Japan, advocated the "Strong earthquake alarm system 10 seconds before". Although this was an idea similar to Dr. Cooper's front detection system in 1868, nobody had put in practical use until then.

We have developed a prototype system for EEW as UrEDAS in early 1980's.

Introduction of UrEDAS

UrEDAS, Urgent Earthquake Detection and Alarm System, is the first real time P-wave alarm system over the world in practical use in 1992 for Tokaido Shinkansen.

It is characterized to be able to process digitized waveform step by step without storing waveform.

Amount of procedure is not differ from each other either earthquake occurs or not, so it expected not to be occurred the system down due to the over load.

UrEDAS is able to use not only for the On-site alarm but also for the Front alarm.

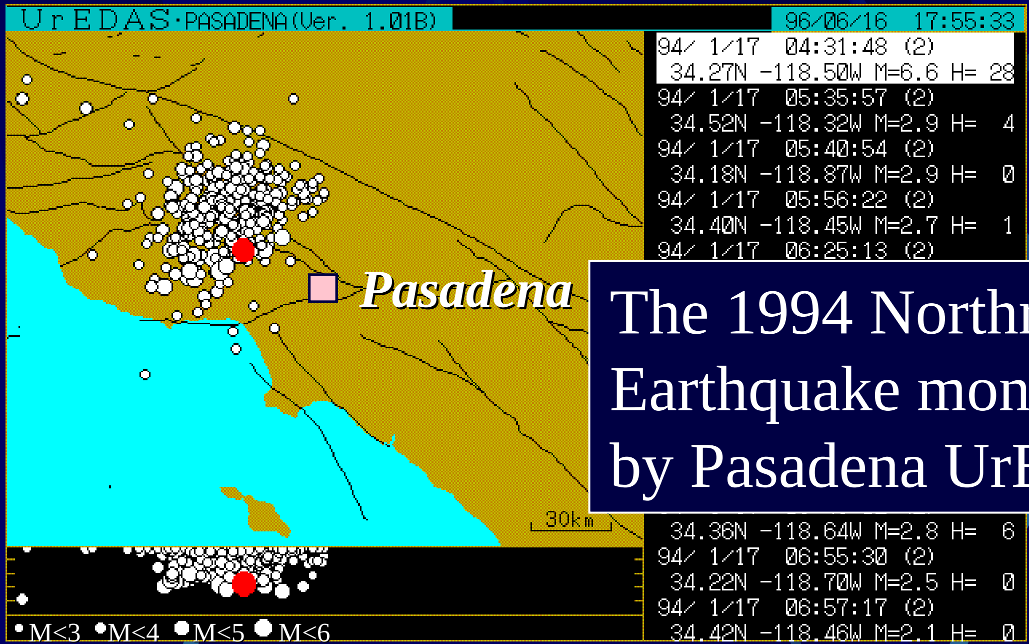
Functions of the UrEDAS

There are two types of UrEDAS; "**UrEDAS**" and "**Compact UrEDAS**".

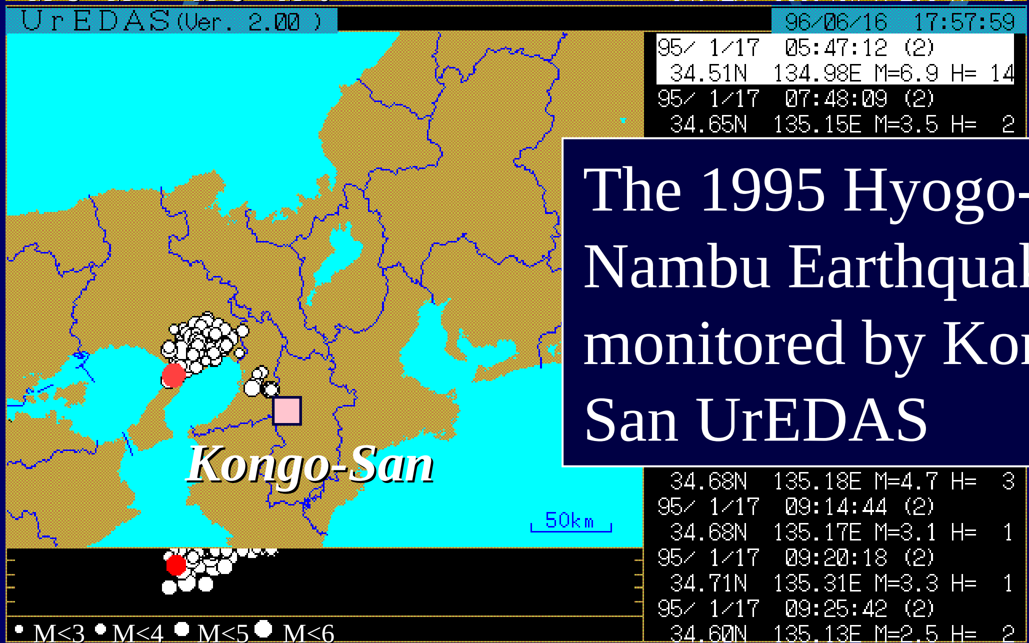
Function of **UrEDAS** (1985) is to estimate the magnitude and the location of detected earthquake in **three seconds** after initial P-wave detection and issuing the alarm for expected damage area.

On the other hand, **Compact UrEDAS** (1998) can evaluate whether the earthquake will be destructive or not using Destructive Intensity **DI** and issues alarm **one second** after **P-wave** detection if needed.

Examples of Monitoring Earthquakes by UrEDAS



The 1994 Northridge Earthquake monitored by Pasadena UrEDAS



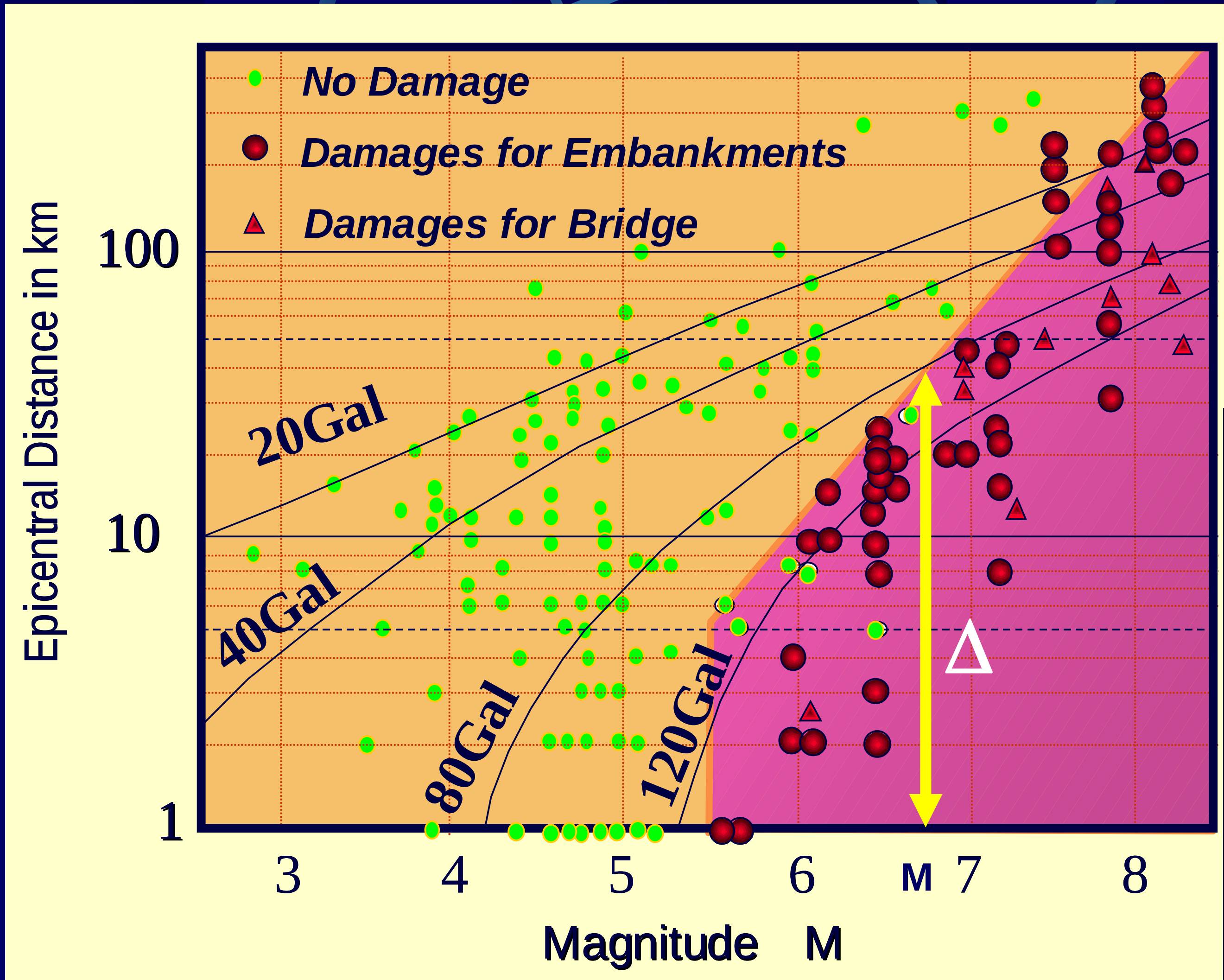
The 1995 Hyogo-Ken-Nambu Earthquake monitored by Kongo-San UrEDAS

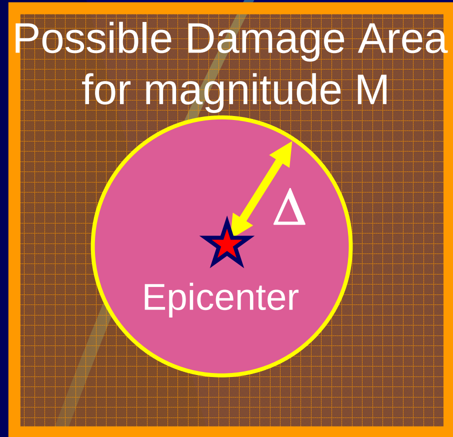
UrEDAS worked at the time of the 1994 Northridge Earthquake and the 1995 Kobe Earthquake.

During the first 24 hours after the Northridge earthquake, UrEDAS in Pasadena detected about 700 aftershocks. The upper figure shows the distribution of the aftershocks. Their magnitude and locations of hypocenter were automatically estimated.

Lower figure shows the result of monitoring the Kobe Earthquake sequence for two weeks after the main shock. Although these figures based on the data of only one UrEDAS station, aftershock activity was almost correctly traced.

UrEDAS Alarm based on M-Δ Diagram
after Bitoh, Nakamura and Tomita (1985)





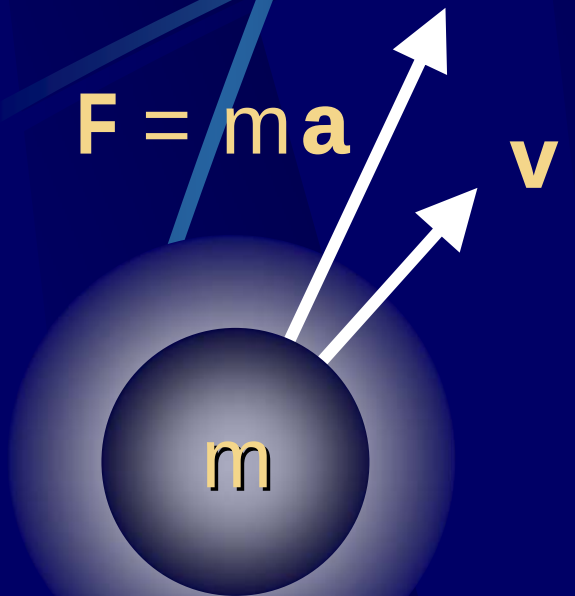
UrEDAS can issue an alarm based on the distribution of the past earthquake damage on magnitude to epicentral distance plane. This alarm is referred to as an M- Δ Alarm.

Moreover UrEDAS can support restarting operation based on the detailed earthquake parameters.

Captured Video at the time of the 1995 Kobe Earthquake

Motivation of Compact UrEDAS development is the Kobe Earthquake. On the video, they noticed the initial P wave motion as something happening, and then the severe motion attacked them after a few seconds. Although there was only a few seconds between notification of something happening and recognition of earthquake, it was anxiousness and fearful because they could not understand what happened and felt relieved after recognition of the earthquake occurrence. As the counter of this kind of feeling, the earlier earthquake alarm is required and I developed the Compact UrEDAS to make the alarm within one second after P wave arrival.

Definition of DI, Destructive Intensity,and Seismic Intensities RI (corresponding to JMA Instrumental Intensity) and MMI



$$\text{Power} = \mathbf{F}\cdot\mathbf{v} = m\,\mathbf{a}\cdot\mathbf{v}$$

$$\text{DI} = \log_{10}|\mathbf{a}\cdot\mathbf{v}|$$

unit for **a**: Gal (cm/s^2)
unit for **v** : kine (cm/s)

$$\text{Power Density PD} = \text{Power}/m = \mathbf{a}\cdot\mathbf{v}$$

$$\text{LPD} = \log_{10}|\mathbf{a}\cdot\mathbf{v}|$$

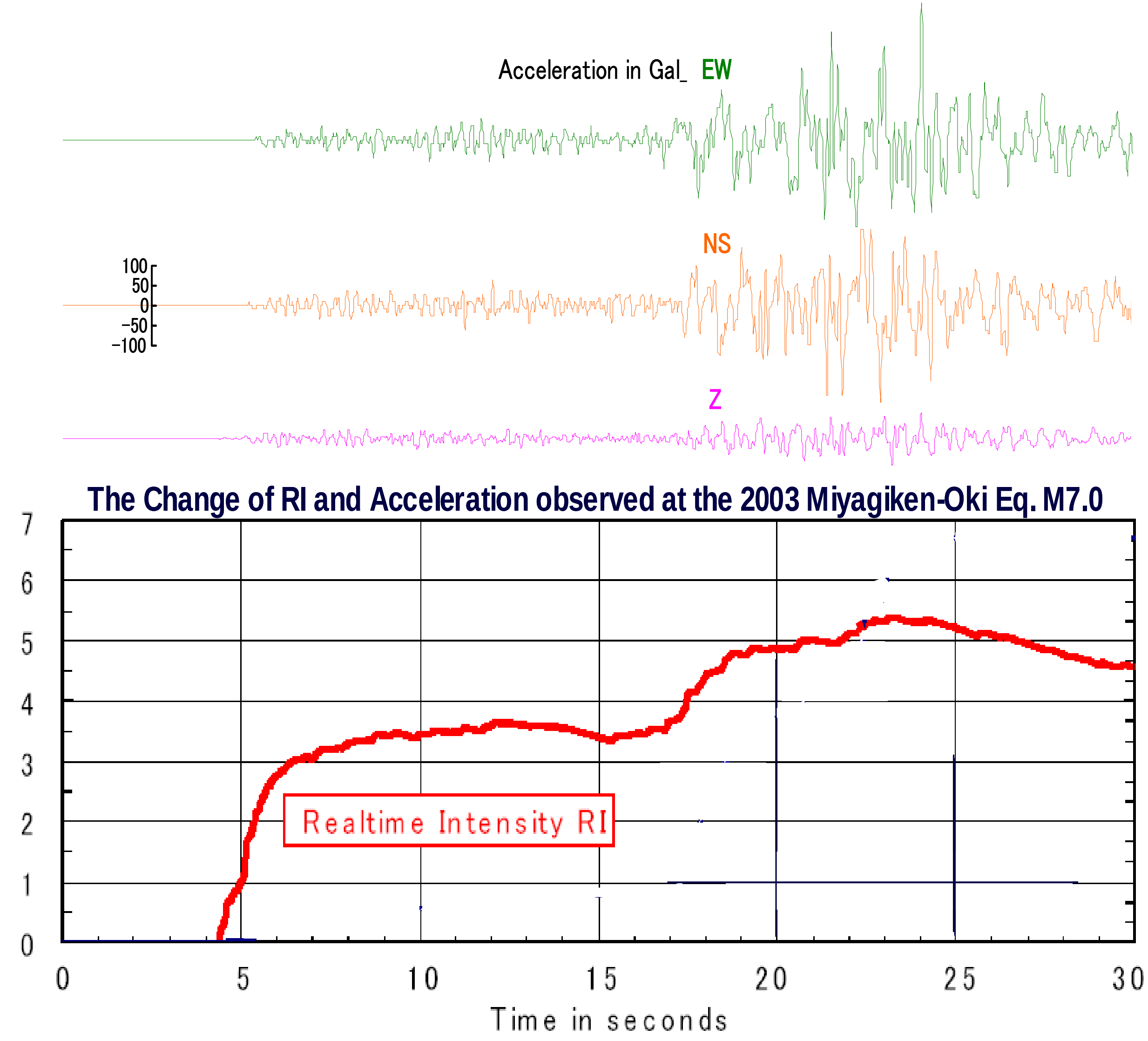
unit for **a**: m/s^2
unit for **v** : m/s

$$\text{RI} = \text{DI} + 2.4 = \text{LPD} + 6.4$$

$$\text{MMI} = (11/7)\cdot\text{RI} + 0.5$$

Compact UrEDAS estimates the destructiveness of the earthquake immediately from the earthquake motion directly, not from the earthquake parameters as UrEDAS, and then issues the alarm if needed. To estimate destructiveness of the earthquake motion, I defined DI, Destructive Intensity, as shown in this slide (1998). Based on the DI, a new seismic intensity, realtime intensity RI, or MMI are defined as this slide (2003).

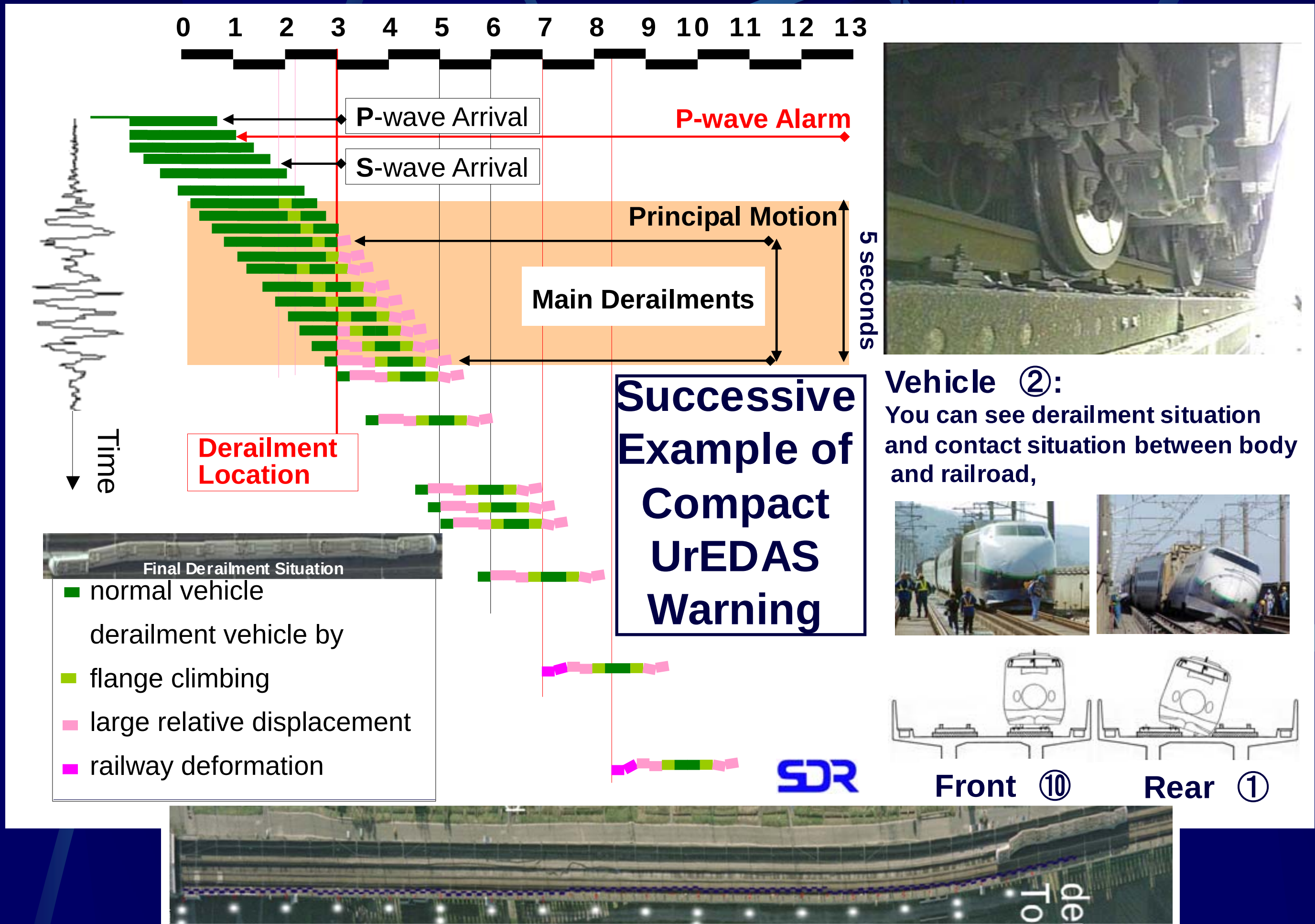
The Change of RI for Earthquake Motion



When P wave arrives, RI increases drastically. After initial P wave, RI keeps almost same value until the S wave arrival. After the arrival of S wave, it reaches to its maximum value. This value can be related on damage and Instrumental Seismic Intensity of JMA or other scales like MMI.

Instrumental JMA Intensity scale is defined to calculate artificially only after the earthquake termination. On the other hand, RI can be calculated in realtime with physical background. This can be concluded as, with the continuous observation of RI, earthquake alarm can be issued efficiently and damage can be estimated precisely.

The P wave alarm of Compact UrEDAS demonstrates the effectiveness as making the derailment not catastrophic (the 2004 Niigataken-Chuetsu Earthquake M6.8)



This railway track is built on many viaducts, and viaducts with different characteristics are joined at 300m. The train derailed passing at the 300m point. The alarm was issued about 2.5 seconds before the arrival of the S-wave at the location of the train. The large motion started one more second after that. So the P-wave alarm preceded the large motion by about 3.5 sec. If FREQL was installed, the P-alarm issued 0.8 sec earlier.

Without the emergency breaking triggered by the alarm the train would have arrived at the 300m point earlier and more vehicles would have passed that point during the large motion. With the very high possibility of the rail buckling, this would have caused more serious derailment and overturning.

FREQL

(Fast Response Equipment against Quake Load)

- FREQL is developed for the earthquake warning system based on the experiences of development and operation of the world first P wave alarm system UrEDAS.
- FREQL integrates the functions of UrEDAS, Compact UrEDAS and AcCo.
- P wave alarm is available 0.2 seconds in minimum after P wave detection (the fastest time was shortened to 0.1 seconds in 2009).
- S wave alarm is also available. (Based on acceleration and realtime seismic intensity RI)

FREQL is toward to the new field, as for the Hyper Rescue Team under the risk of aftershocks


朝日新聞（夕刊）
1 4版
2008年（平成20年）5月17日

病院職員宿舎の倒壊現場で、機器を使って調べる日本の国際緊急援助隊＝16日午後、四川省青川県喬荘、樫山晃生撮影


Rescue Activity of Hyper Rescue Team

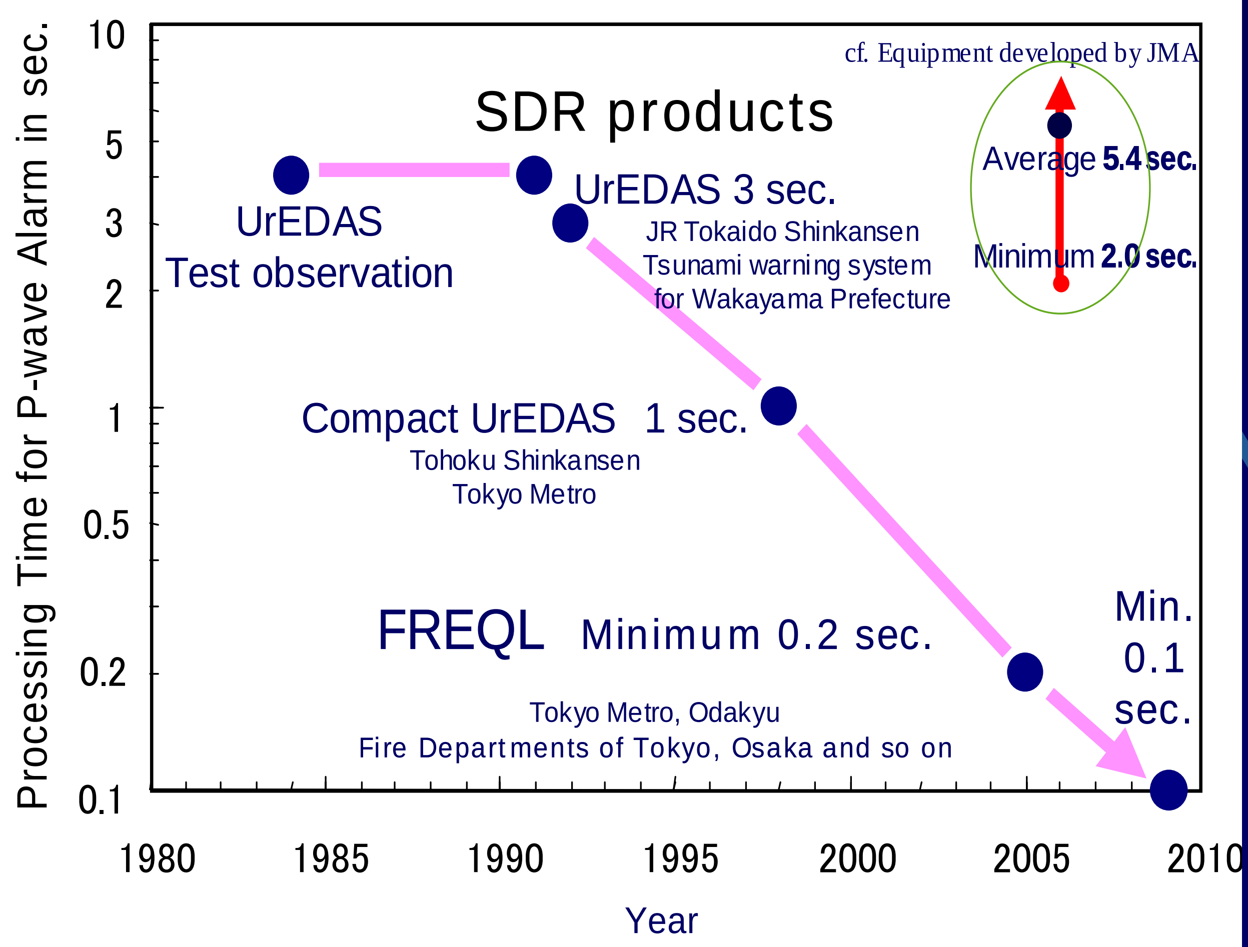
-

Hyper rescue team acts under a risk of large aftershocks.

After the Niigataken Chuetsu Earthquake, the hyper rescue team approached us to adopt FREQL as a supporting system for the rescue activity.

Tokyo fire department and other departments in nation wide have adopted the portable FREQL as equipment to keep the safety against the risk of the second hazards caused by aftershocks during their rescue activity, not only in Japan but also in Pakistan, China and New Zealand.

Change of processing time for EEW

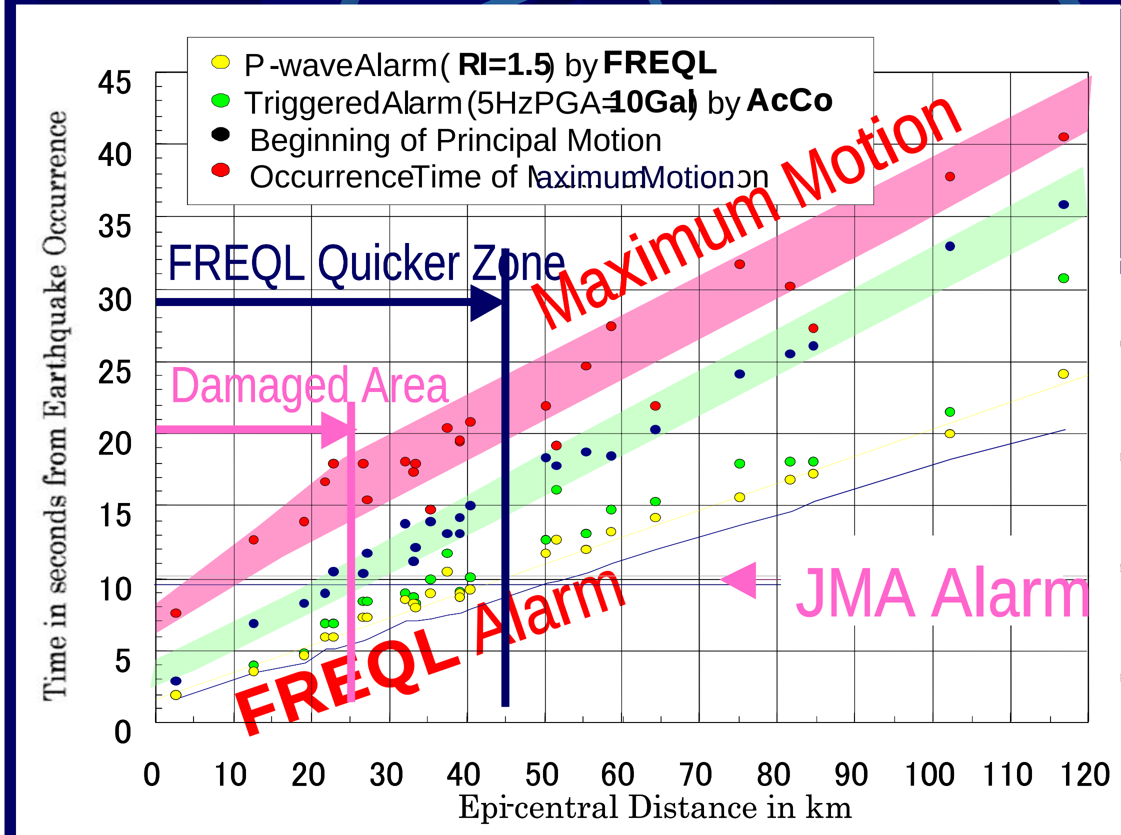


Development of Processing Time

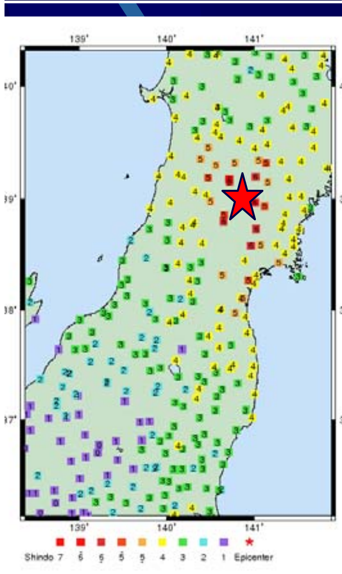
This figure shows the change of the processing time for EEW.

While JMA system performs every one second for the alarm processing intermittently with stored data, UrEDAS and FREQL perform the procedure continuously in every sampling time.

Actual Example with Simulated Results of FREQL or AcCo for Recent Damaged Earthquake in JAPAN



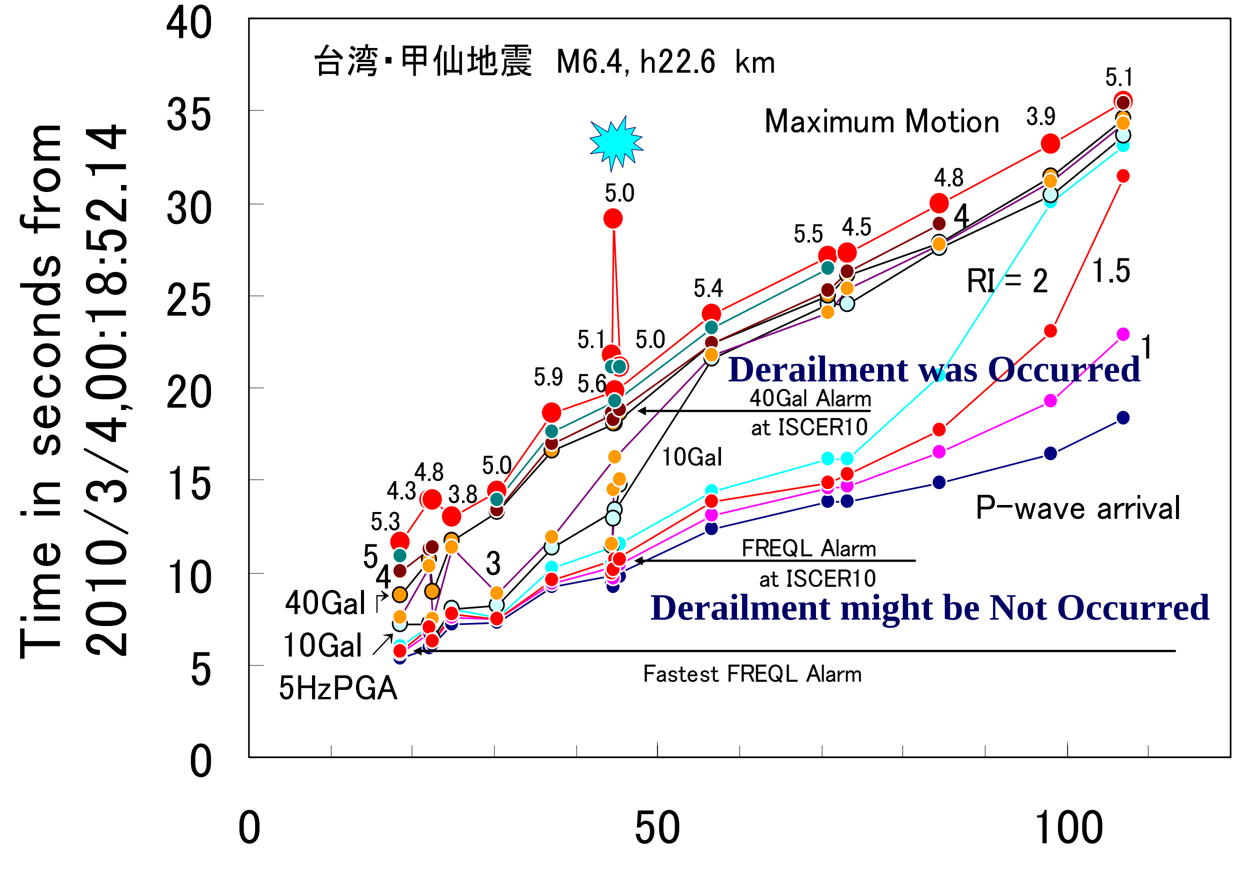
2008.6.14, Mjma 7.2, Depth8km

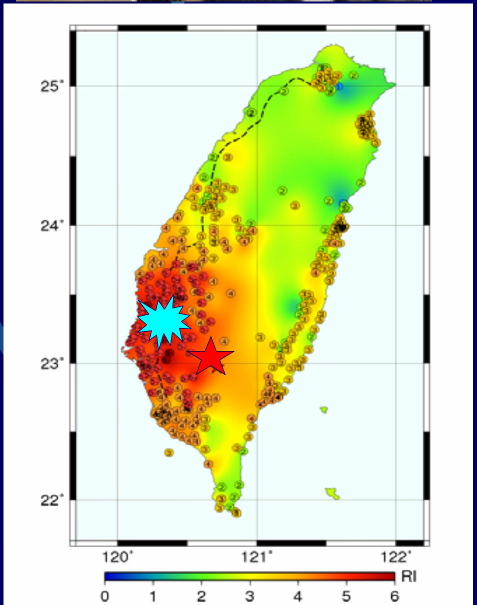


This figure compares the EEW by JMA and the simulated on-site alarm of FREQL and AcCo using strong motion records. Horizontal axis is epicentral distance, Vertical axis is time from occurrence of Earthquake. Solid line shows P-wave arrival.

JMA alarm spread after the strong motion in damaged area. In contrast this, the time margin by FREQL alarm is several seconds before the beginning of strong motion, even at the epicenter itself.

Early Warning Simulation For the 2010 Jiansian Earthquake（M6.4, h22.6km）

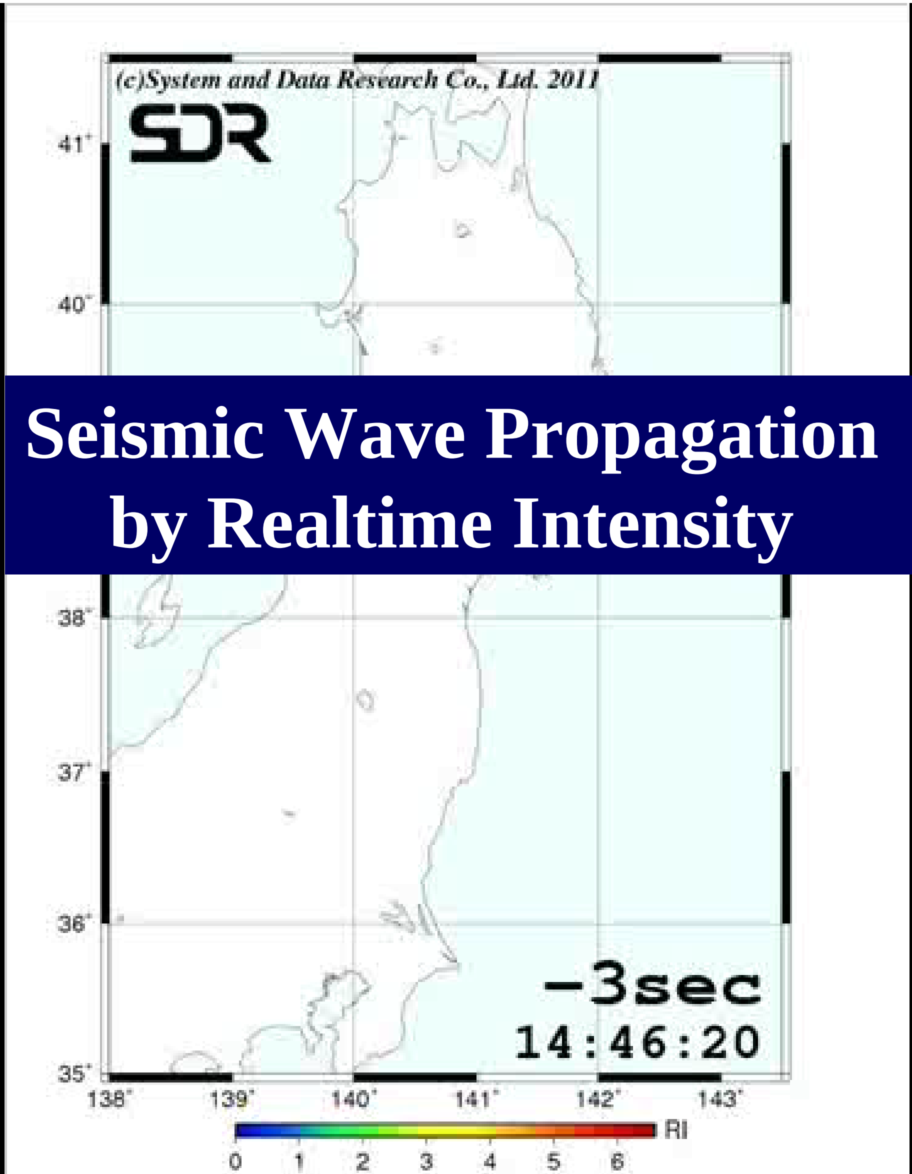


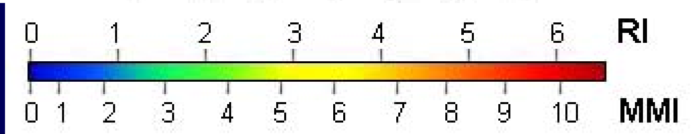


Realtime Intensity RI

This figure shows a result of simulation using strong records with changing of the RI. The 40 Gal alarm near the derailment point was issued 18 seconds after the occurrence. FREQL on-site alarm should be issued at 10 seconds after the occurrence, or 8 seconds earlier than the 40 Gal alarm. It is clear that the FREQL alarm proceeding to the strong motion with over three seconds at even the focal area.

Seismic Wave Propagation by Realtime Intensity





14:46:46
FREQL Alarm estimated

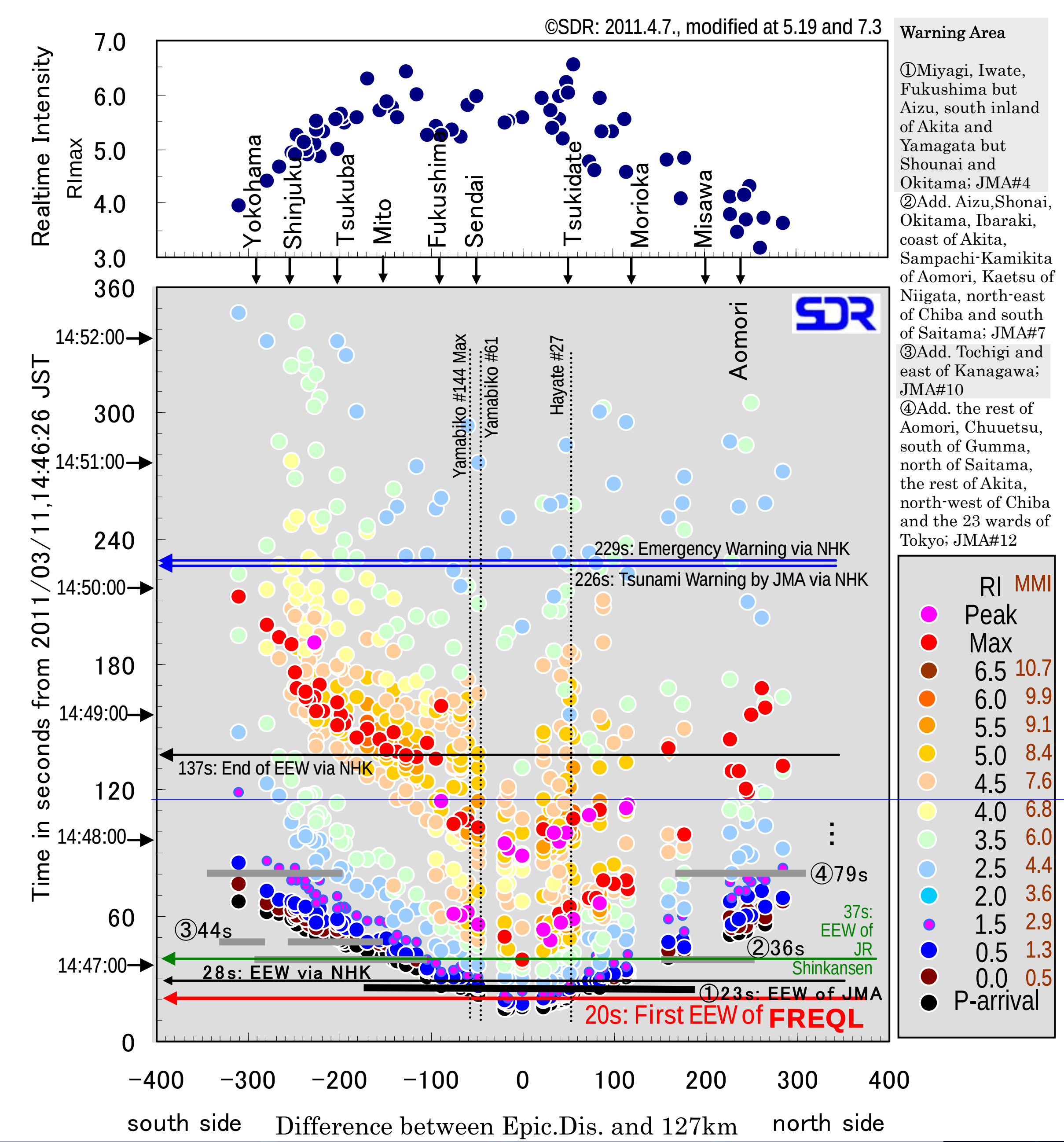
14:46:49
JMA EEW

14:46:54
JMA EEW on TV screen

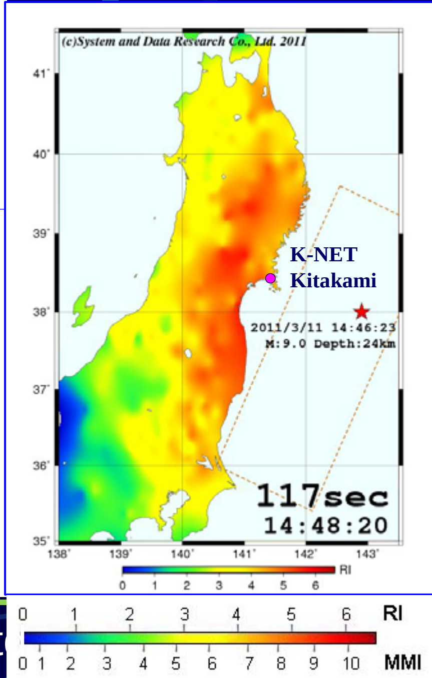
14:47:03
JR Alarm

14:47:06
JR Emergency Braking started

The 2011.3.11 East Japan Eq. M9.0



This figure shows the Realtime Intensity RI varied in time and space.
The first EEW of FREQL is three seconds faster than that of JMA.
At any places, on-site FREQL alarm leads more than 20 seconds.
For Kanto region including Tokyo metropolitan area, more than one minute are expected as lead time.



The 2011.3.11 East Japan Eq. M9.0
(continue)

The timings of the warning by several systems as EEWs by FREQL, JMA and JR are summarized as follows.

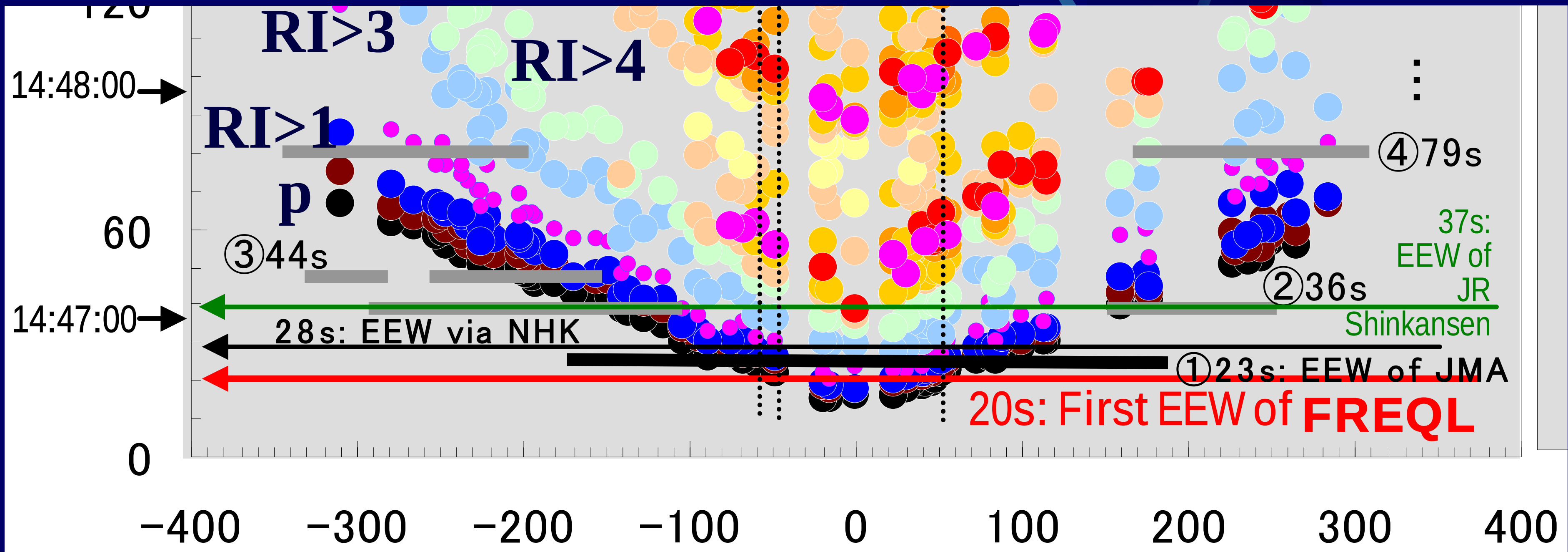
The fastest FREQL warning is estimated to be issued at 14:46:46 (20) simulated with the data of K-NET Kitakami station, MYG008.

JMA issued EEW at 14:46:49 (23) and it appeared on the NHK-TV screen at 14:46:54 (28) or on cellular phones between 14:46:54 and 14:46:59.

Comparison EEWs

	Onsite FREQL	Network JMA	Onsite JR
14:46:46	⊛(estimated)		
14:46:49		⊛	
14:46:54		NHK-TV, celler phone	
		Many people felt this earthquake themselves	
14:46:59		cellular phone	
14:47:03			⊛
14:47:06			Emergency Breaking

⊛) Time of issuing alarm



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The 2011.3.11 East Japan Eq. M9.0

(continue)

JR issued EEW at 14:47:03 (37) for all the Shinkansen operated by JR-East, and then an emergency brake started at 14:47:06 (40).

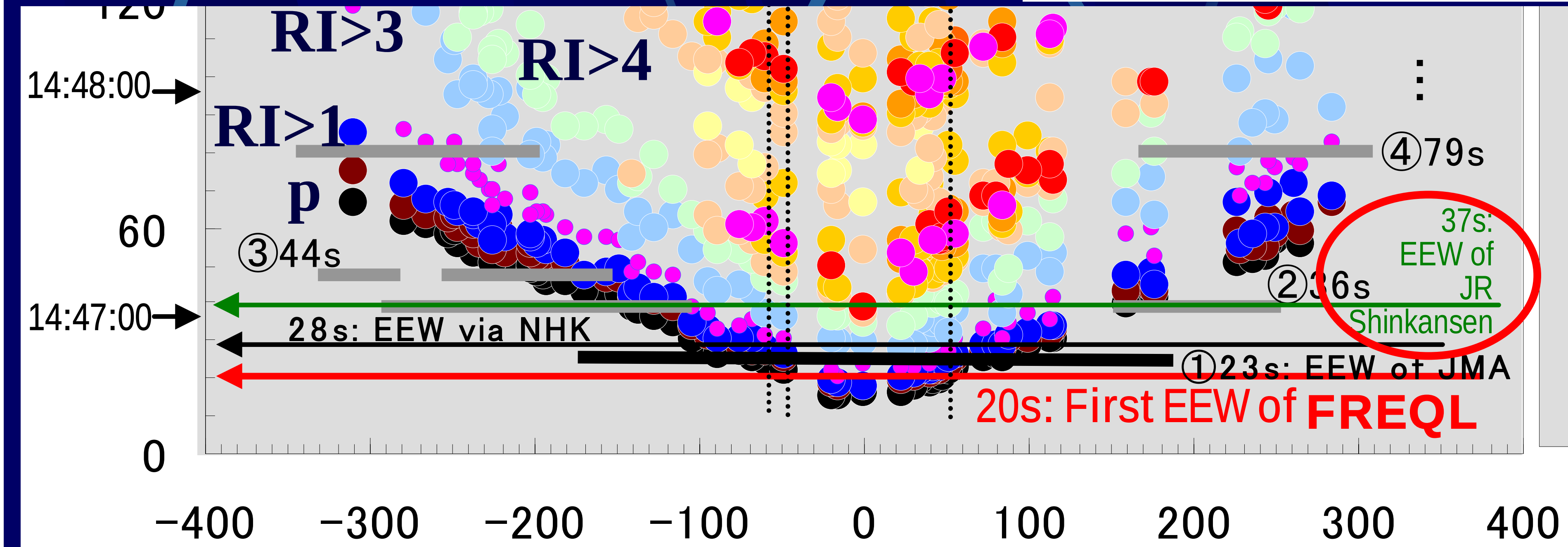
First destructive wave arrived at the Shinkansen lines around Sendai at 14:47:15 (49), and second wave attacked around at 14:48:00 (94).

Fortunately, there is no death and no injured for Shinkansen, only one bogie of the vehicle for test running was derailed.

Comparison EEWs

	Onsite FREQL	Network JMA	Onsite JR
14:46:46	⊛(estimated)		
14:46:49		⊛	
14:46:54		NHK-TV, celler phone	
		Many people felt this earthquake themselves	
14:46:59		cellular phone	
14:47:03			⊛
14:47:06			Emergency Breaking

⊛) Time of issuing alarm



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The 2011.3.11 East Japan Eq. M9.0

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On the system of JR-East, their instruments for early warning has been replaced some other system based on JMA system instead of our Compact UrEDAS.

The early warning system of JR could not issue alarm and they were failed. Only ordinal 40Gal alarm systems along Shinkansen or 120Gal alarm system for front detection sites were issued alarm.

This is a reason of too late alarm of JR.

Comparison EEWs

	Onsite FREQL	Network JMA	Onsite JR
14:46:46	⊛(estimated)		
14:46:49		⊛	
14:46:54		NHK-TV, celler phone	
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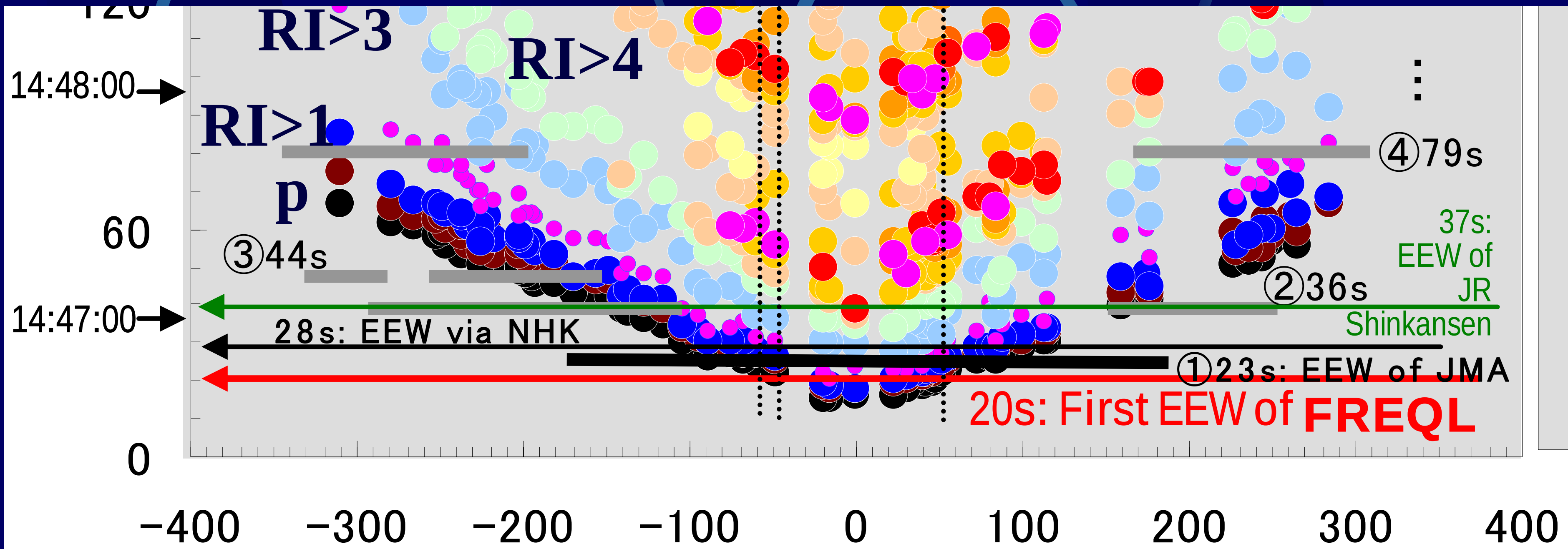
14:47:03			⊛
14:47:06			Emergency Breaking

⊛) Time of issuing alarm



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What is necessary for earthquake disaster prevention?

Before and During Quake

Quick Response
Using On-Site Alarm
against Sudden Quake

Escape to Safety Zone based on Each Feeling or On-Site Alarm

Check the Safety Zone Constantly

Imagine and Train to Escape actually

It is clear that the primary preventative action by the people at the time of the earthquake is to keep away from places where they could be hit by falling or loose objects. Obviously to make possible this requires a timely and immediate warning to be issued.

What is necessary for earthquake disaster prevention?

After Quake

Imagination for Disaster
is required

National organizations should specify the area of expected catastrophic damage accurately and initiate rescue operations without delay based on the information from responsible and capable organizations in realtime.

Quick Rescue at the Possible Damage Area is based on the Exact Earthquake Information by Authorized Organizations

EEW and Earthquake Disaster Mitigation

Damage Examples of the 3.11 Earthquake (Mw 9.0)

- The Basic Countermeasure is Strengthening the Facilities
- EEW is only a Trigger for Quick Response against Quake
- It is important for EEW to avoid Overestimation and Crying Wolf
- Accurate Information is Extremely Important for Quick Response after the Event

Problems of JMA warning

Tsunami warning by JMA is quite early for the 3.11 Earthquake, three minutes and a half after detecting the P-wave, but is including many problems such as low accuracy for height estimation:

>Crying Wolf caused by frequent unnecessary warnings,
>Loss tension and knowledge from both residences and local governors, because JMA has prohibited Tsunami warning by local governors after the Kobe earthquake.

The earthquake motion of the 3.11 Earthquake seems very strange and very long by all people themselves in unusually. This is the best signal for quick response against the tsunami. But almost all the people thought that the tsunami warning must be issued by JMA, just as JMA intend. But in practice, many people who could not receive warning took no action, then their evacuation delayed fatally. This is very important lesson from this event.

These problems are appeared not only for Tsunami warning but also for EEW .

Urgent Craving for JMA

at 2011 AOGS in Taipei

JMA must quit all restriction for warnings on earthquake, EEW and Tsunami warnings.

JMA must issue
exact and detailed information
for main shock and aftershocks immediately,
to support quick response.

END

Thank you for your kind attention!

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