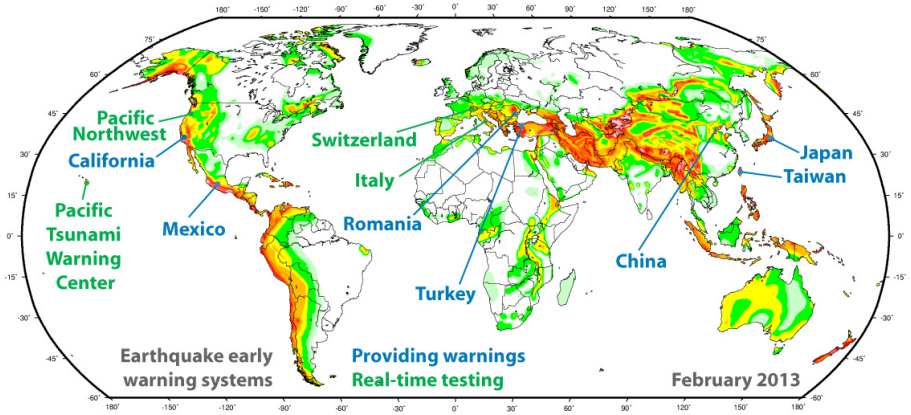
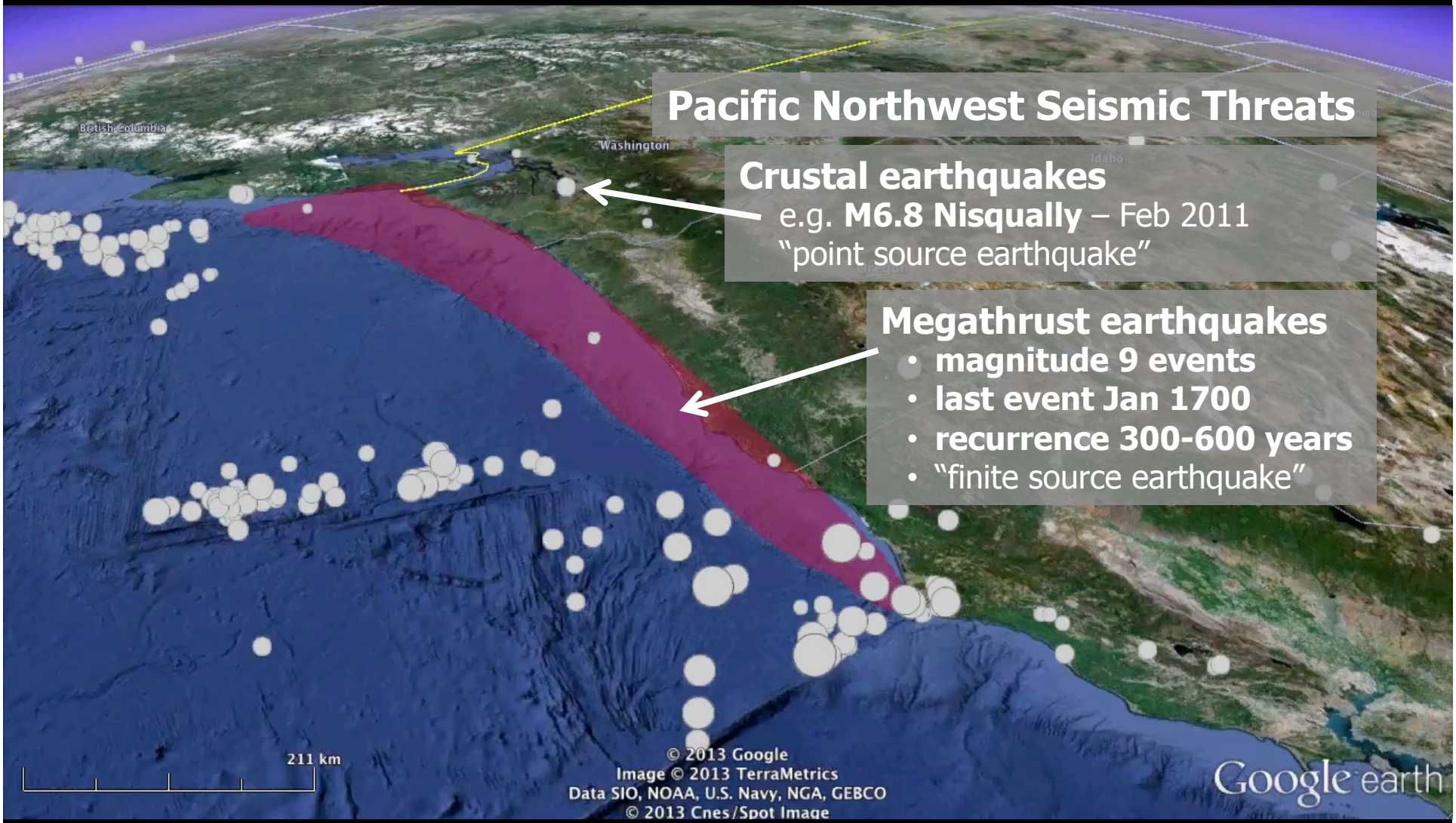
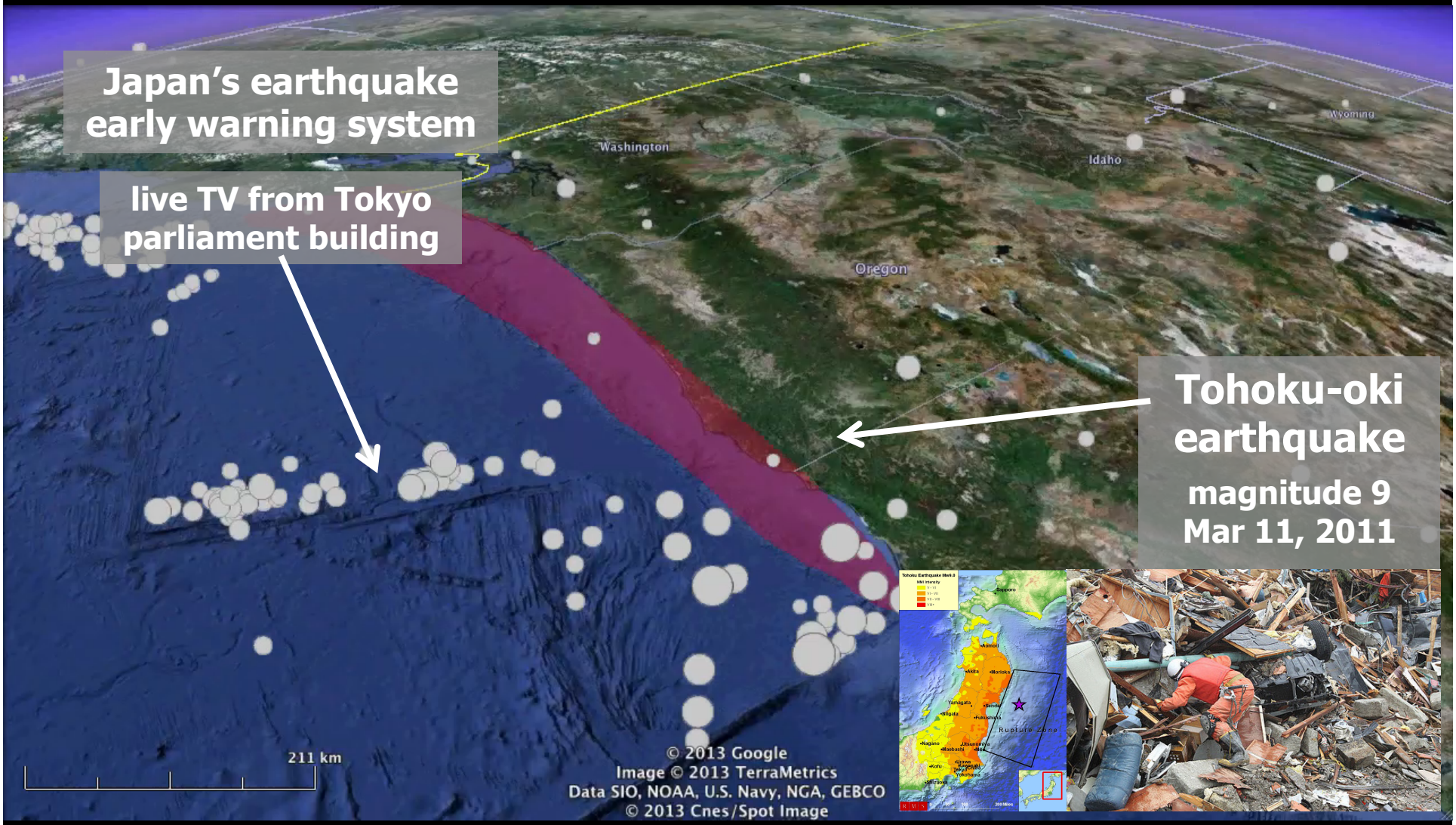


Earthquake early warning around the world

Richard Allen
Professor, Director
UC Berkeley
Seismological Laboratory

USGS science for a changing world
CAL EMA
SCEC an NSF+USGS center
Berkeley Seismological Laboratory
Seismological Laboratory California Institute of Technology
ETH
GORDON AND BETTY MOORE FOUNDATION


Pacific Northwest Seismic Threats
Crustal earthquakes
e.g. M6.8 Nisqually – Feb 2011
"point source earthquake"
Megathrust earthquakes
• magnitude 9 events
• last event Jan 1700
• recurrence 300-600 years
• "finite source earthquake"
British Columbia
Washington
Idaho
211 km
© 2013 Google
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Cnes/Spot Image
Google earth


Japan's earthquake early warning system
live TV from Tokyo parliament building
Tohoku-oki earthquake
magnitude 9
Mar 11, 2011
Washington
Oregon
Idaho
Wyoming
211 km
© 2013 Google
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Cnes/Spot Image
Rupture Zone

Automated TV warning

Studio in Tokyo

March 11, 2011

Download mp4: http://seismo.berkeley.edu/~rallen/research/WarningsInJapan/TVwarningNHK_wSubtitles.mp4

Japan

Communicating the warning

TV and radio announcements
- 124 of 127 TV stations (98%)
- 41 AM, 35 FM radio (75%)

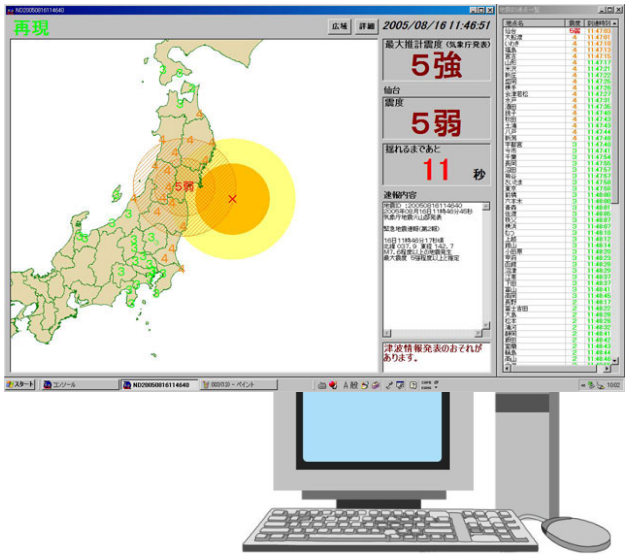
earthquake location and hazard

estimated shaking in your area

J-Alert messages
- 226 municipalities receive the warnings
- 102 announce them with public address systems

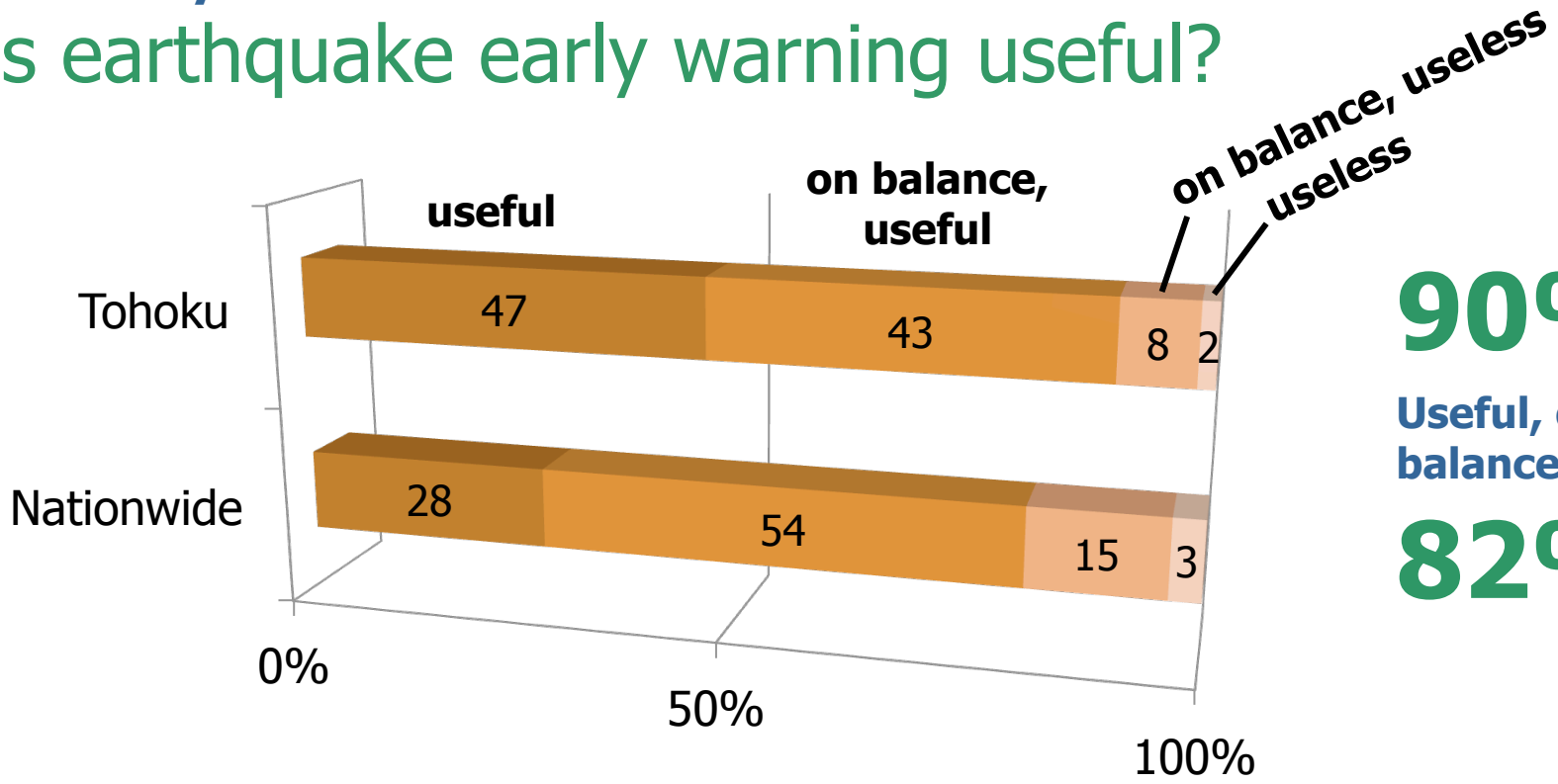
Cell phones
- 3 companies (Docomo, AU, Softbank)
- 52 million can receive them (47%)

Dedicated providers serve
- power plants
- factories
- schools
- hospitals
- shopping malls



JMA Survey of the Public

Is earthquake early warning useful?

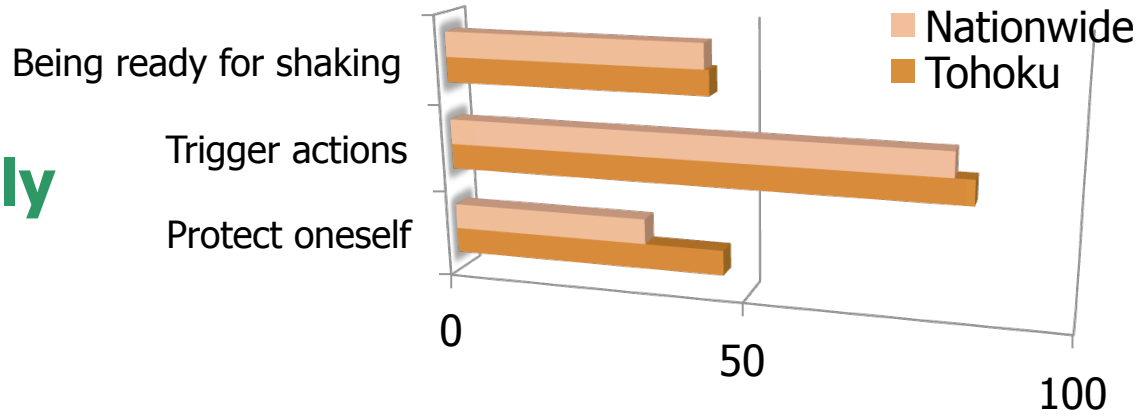


90%

Useful, or, On balance, useful

82%

Why is early warning useful?

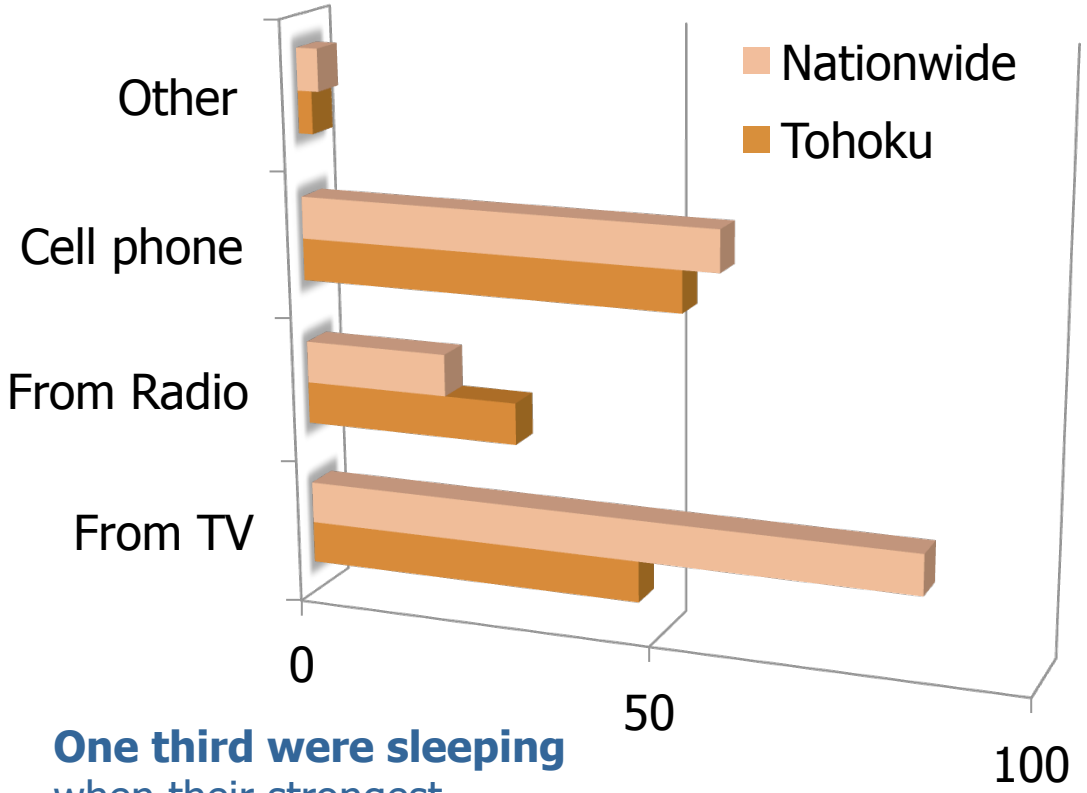


Data provided by Hoshiba

http://www.jma.go.jp/jma/press/1203/22c/manzokudo201203.html

JMA Survey of the Public

How have you received warnings?



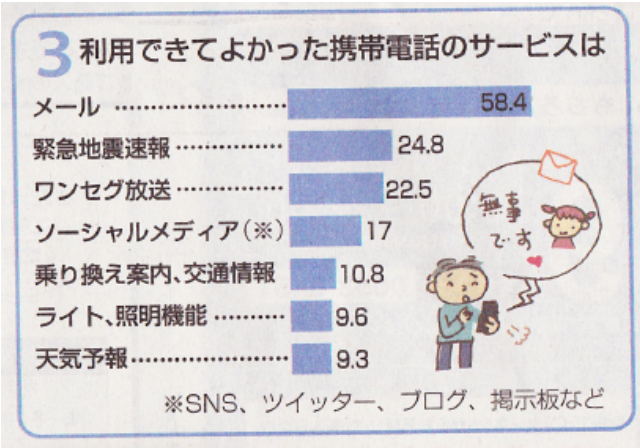
One third were sleeping
when their strongest
earthquake occurred

Of those sleeping
62% in the Tohoku region, and
75% nationwide were
woken by cell phone warning

Most useful cell phone app

1. Email 58%
2. **Earthquake alerts 25%**
3. TV 23%
4. Twitter, Blog 17%
5. Transportation info 11%

Asahi Shinbun Newspaper – June 2011



Data provided by Hoshiba

http://www.jma.go.jp/jma/press/1203/22c/manzokudo201203.html

Earthquake early warning
Around the world

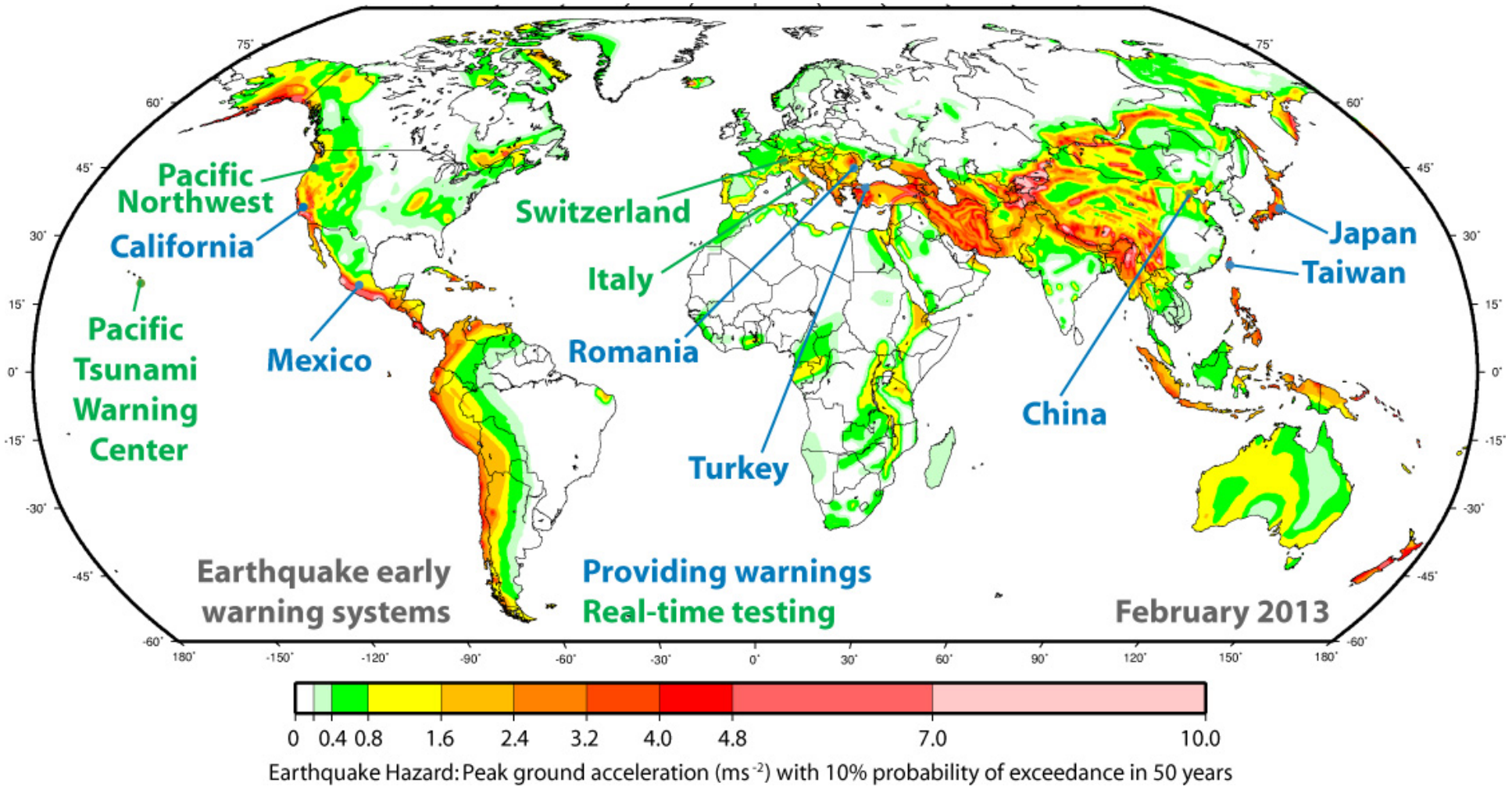
Taiwan: Railroad, hospital, new networks

Turkey: rail, power grid, expanding system, OBS

Mexico: Since 1991, subway, schools

Romania: Nuclear research facility

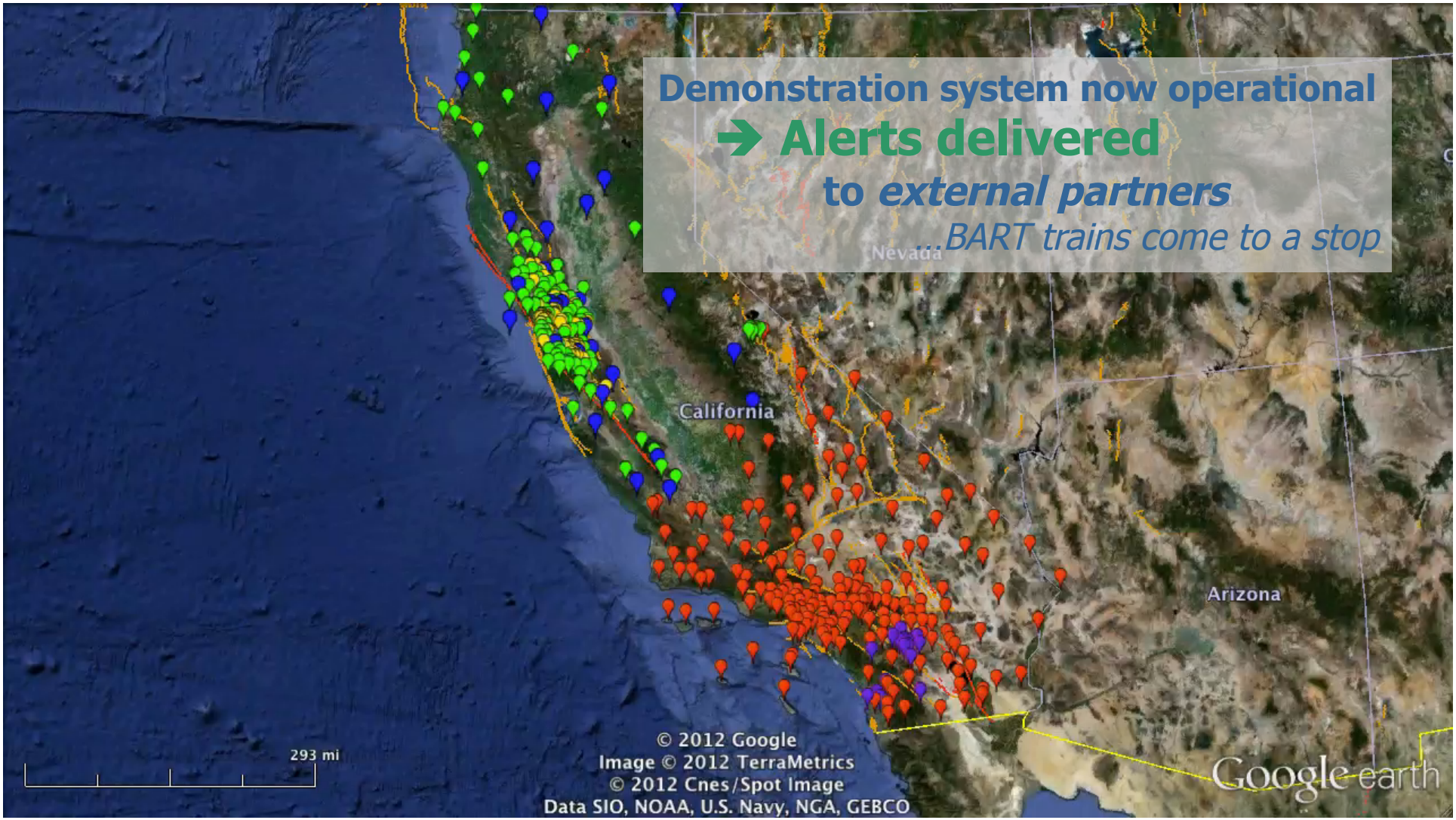
China: multiple regional systems, Twitter release



Washington
Oregon
Idaho
North Dakota
Minnesota
South Dakota
Iowa
Nebraska
Kansas
Missouri
Colorado
Nevada
California
Arizona
New Mexico
Oklahoma
Texas
Arkansa
Louis
?
Earthquakes
since 1970

CISN California Integrated Seismic Network

ShakeAlert



CISN California Integrated Seismic Network

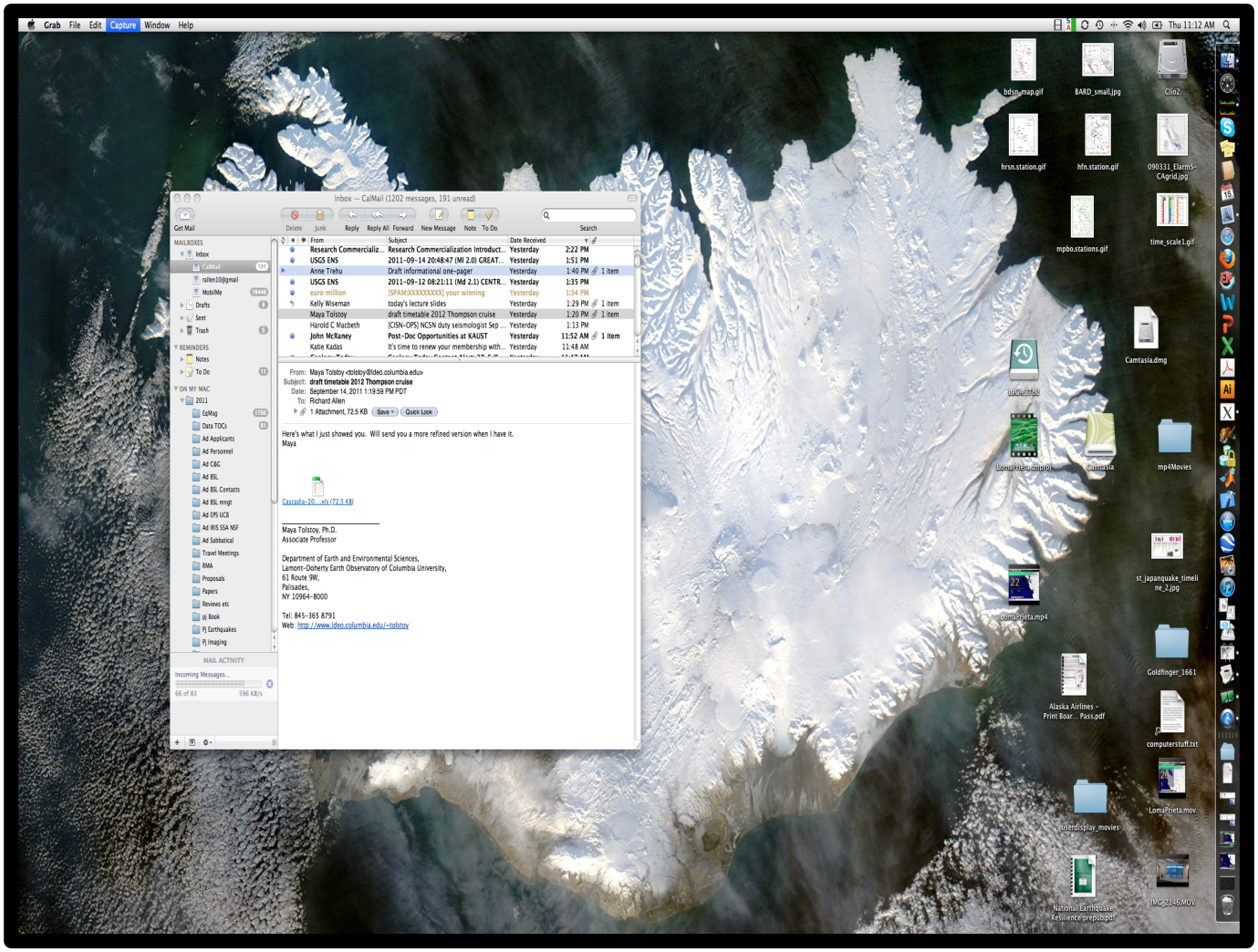
ShakeAlert

Status today: Demonstration system

M3.5 Aromas Earthquake

...near the epicenter of Loma Prieta

My desktop →



CISN California Integrated Seismic Network

ShakeAlert

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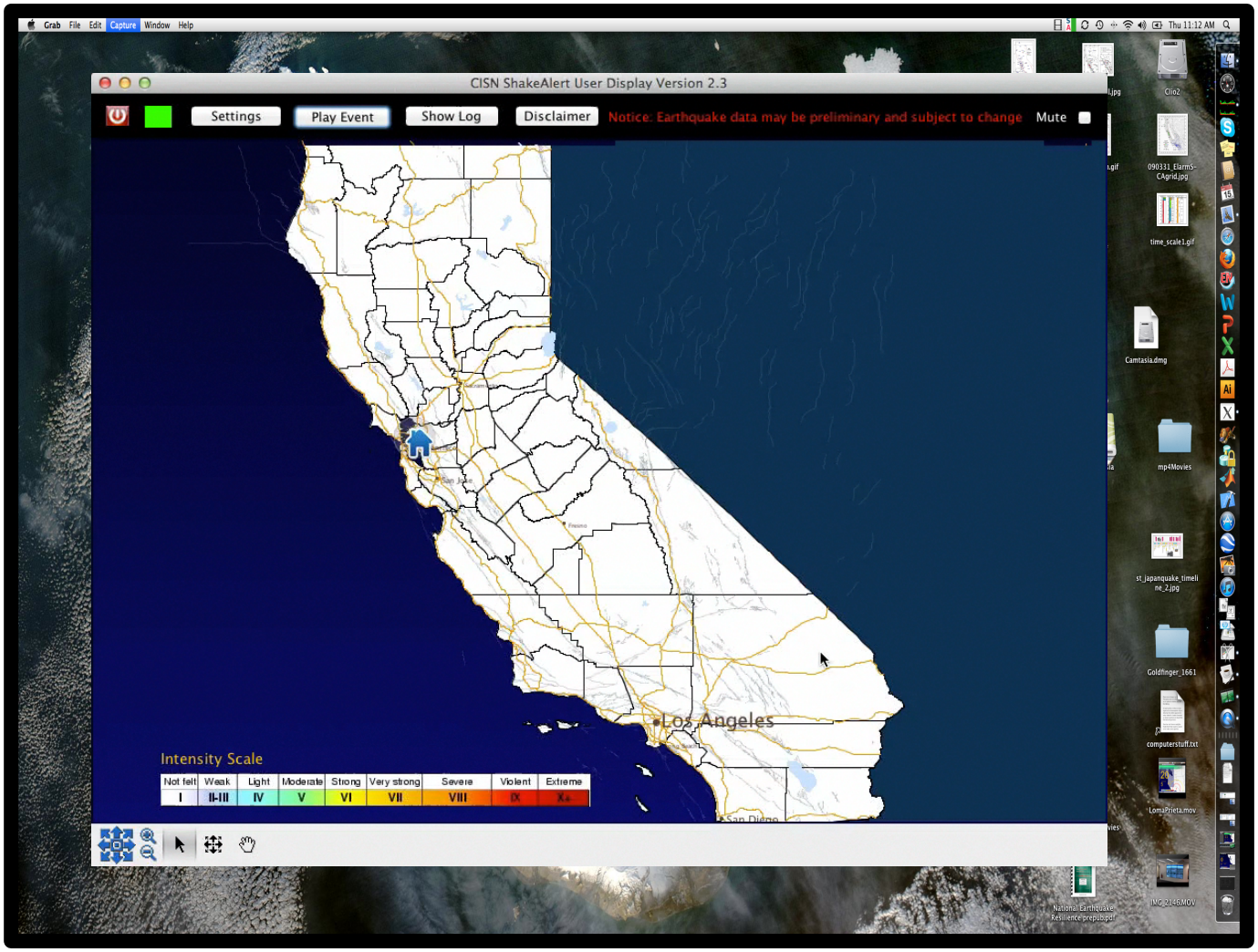


Challenges: The Big One

M5

M6

M7

M8

M9

Point source solution

- **Operational:** Japan, US, etc.
- **Seismic methods** using few sec of P-wave

Finite source solution

- **Developmental:** US
- Seismic and/or **GPS methods**
- Iterative updates to warnings

Example

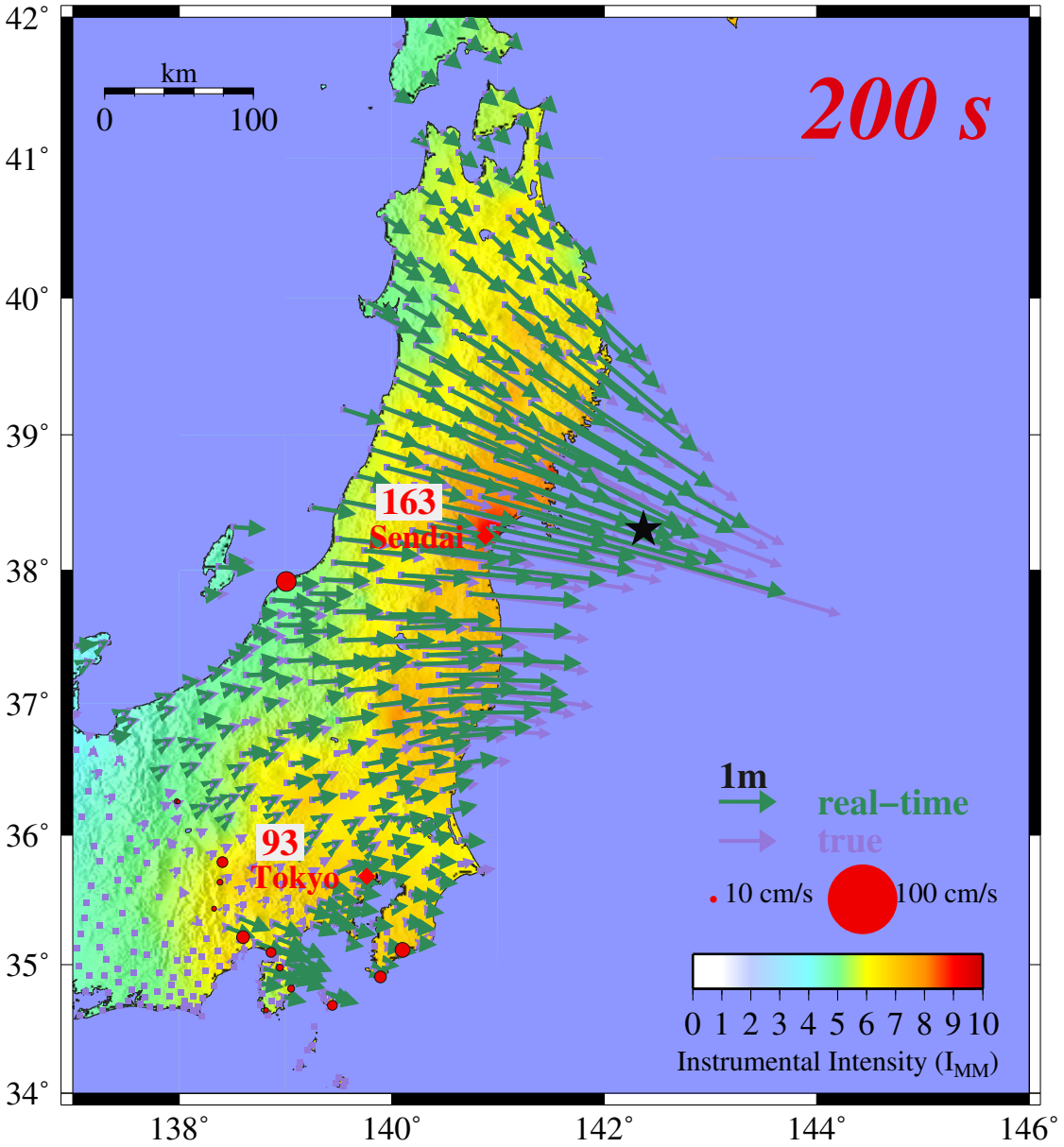
M9 Tohoku-oki

Success: Warning issued in Sendai

But: Underestimated the magnitude and the shaking at greater distances e.g. Tokyo

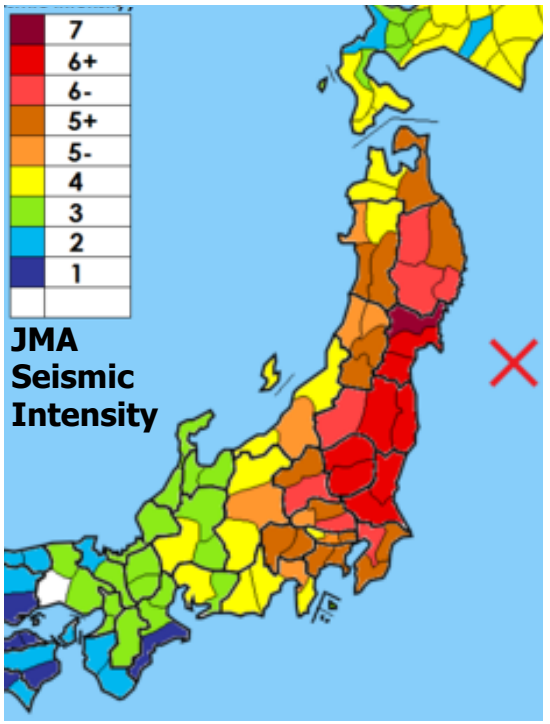
***Because:* Point source only system**

M9 Tohoku-Oki ...what to expect in the Pacific Northwest



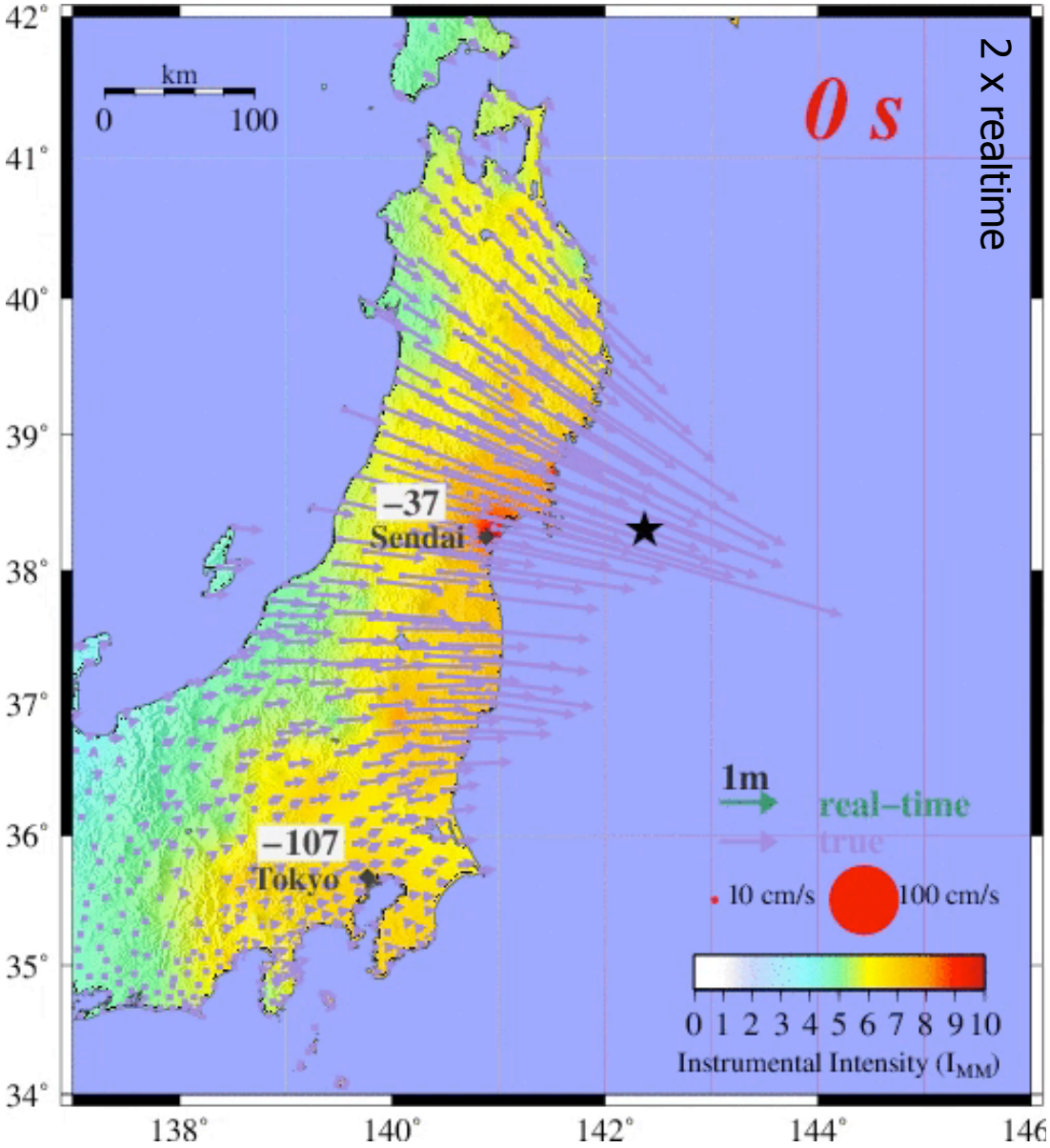
100 sec
rupture duration

5 meters
permanent displacement



Colombelli and Allen, in review

M9 Tohoku-Oki ...what to expect in the Pacific Northwest



Timeline

37s	S-wave at Sendai
40s	Detect GPS signal
50s	1st phase displacement observable: 2m
95s	Strongest shaking along coast
95s	2nd phase displacement observable: 5m
110s	S-wave at Tokyo
170s	Strongest shaking in Tokyo

Colombelli and Allen, in review

M9 Tohoku-Oki

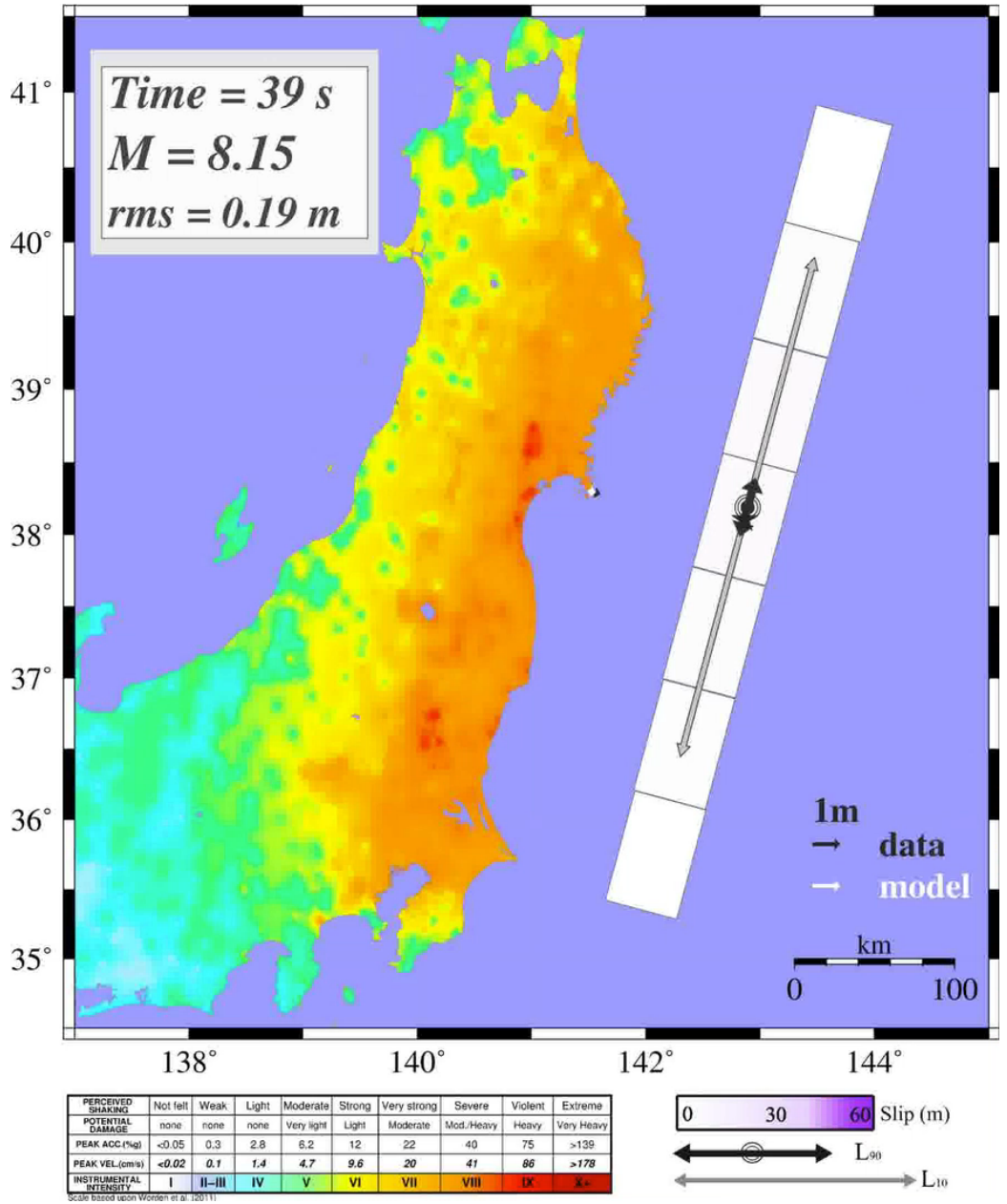
OT+

31s *First seismic alert 8 s before shaking in Sendai*
JMA estimate: M7.1
GPS estimate: **n/a**

39s *S-waves reach Sendai*
JMA estimate: M7.6
GPS estimate: **M8.2**

60s *15s before peak shaking in Sendai*
JMA estimate: M7.6
GPS estimate: **M8.4**

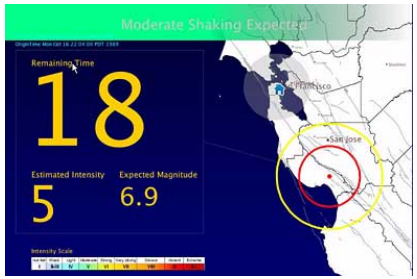
130s *35s before peak shaking in Tokyo*
JMA estimate: M7.6
GPS estimate: **M8.9**



Colombelli and Allen, in review

Conceptual

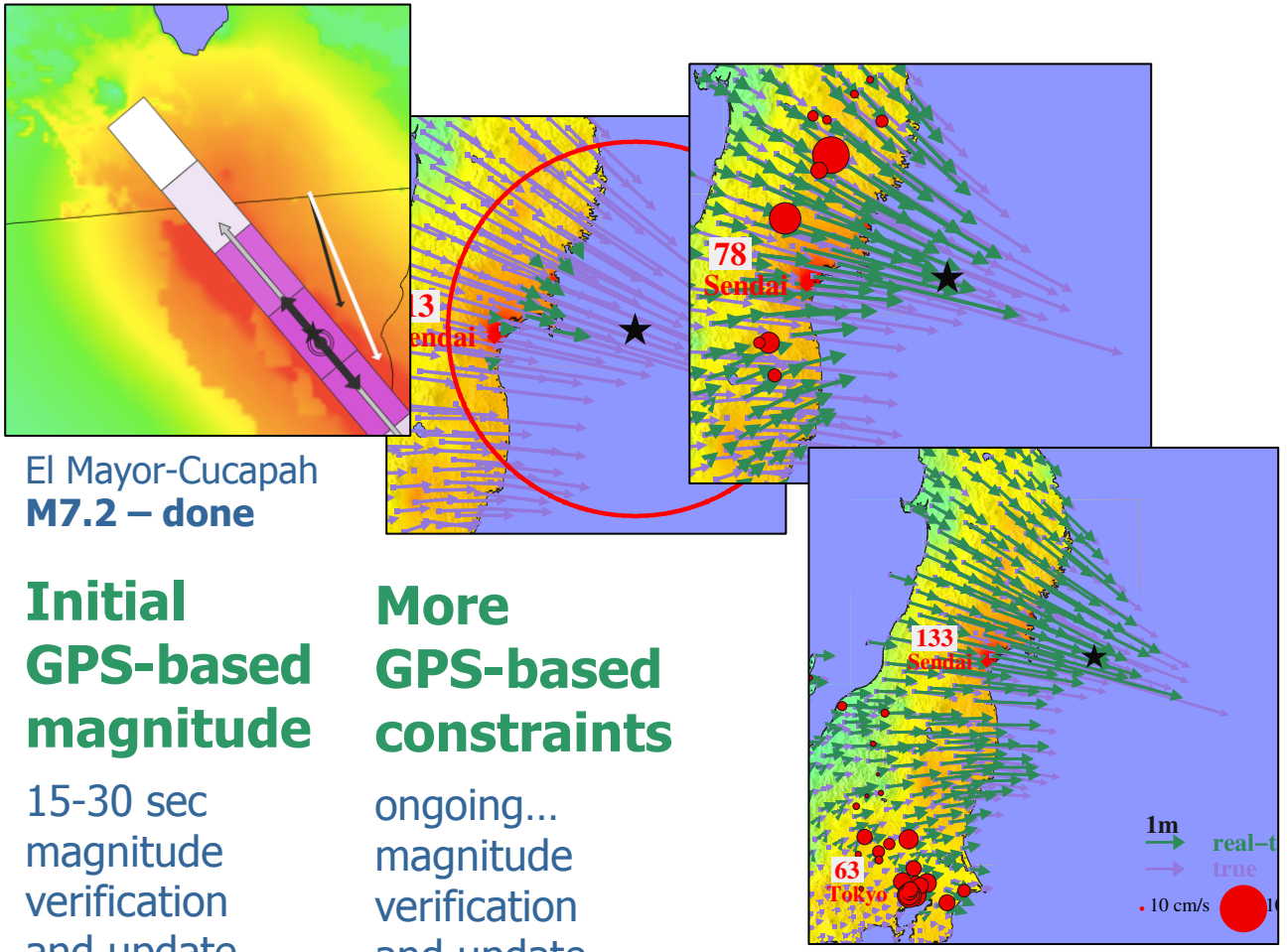
Alert timeline



P-wave based alerts

CISN *test system*

5-15 sec location, magnitude



El Mayor-Cucapah
M7.2 – done

Initial GPS-based magnitude

15-30 sec magnitude verification and update

More GPS-based constraints

ongoing… magnitude verification and update

Tokyo strong shaking in Tohoku-oki

origin time

Strong shaking near epicenter

Strong shaking at greater distances

0 5 15 … 170 time seconds

Outlook

Earthquake early warning is experiencing rapid growth and development around the world

Driven by rapid development of
- earthquake source science
- distributed sensor technologies
- communication connectivity

At a time of

Increasing complexity and fragility of our infrastructure

big data + science + connectivity = opportunity

Prediction: The US will build an early warning system.

Will it be before, or immediately following the next big earthquake?