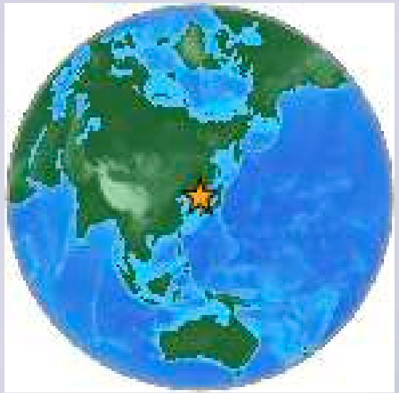
Seismic Aftershock Monitoring system (SAMS) der CTBTO: Status und Erfahrung aus Feldmessungen

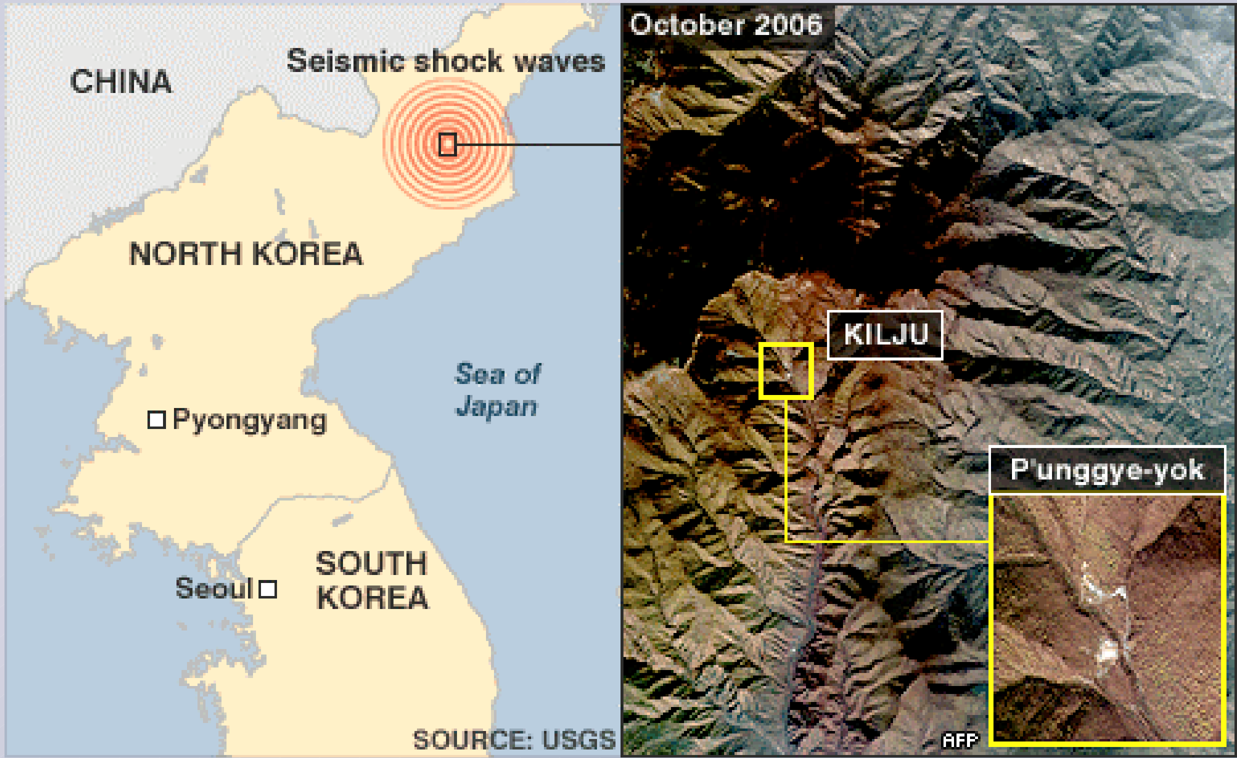
Manfred Joswig
Universität Stuttgart

M5.1 NUCLEAR EXPLOSION - NORTH KOREA

Tuesday, February 12, 2013 at 02:57:51 UTC



At 02:57:51 UTC on February 12, 2013, monitoring stations of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) and many other stations around the world detected a shallow seismic event with explosion-like characteristics in the Democratic People's Republic of Korea (DPRK).



Highlighted is the location of this event which corresponds to a suspected nuclear test site.

Images and location information courtesy USGS and CTBTO

M5.1 NUCLEAR EXPLOSION - NORTH KOREA
Tuesday, February 12, 2013 at 02:57:51 UTC

Naturally occurring seismicity in North Korea is low increasing the likelihood that the event was not an earthquake.

This map shows the earthquakes since 2005.

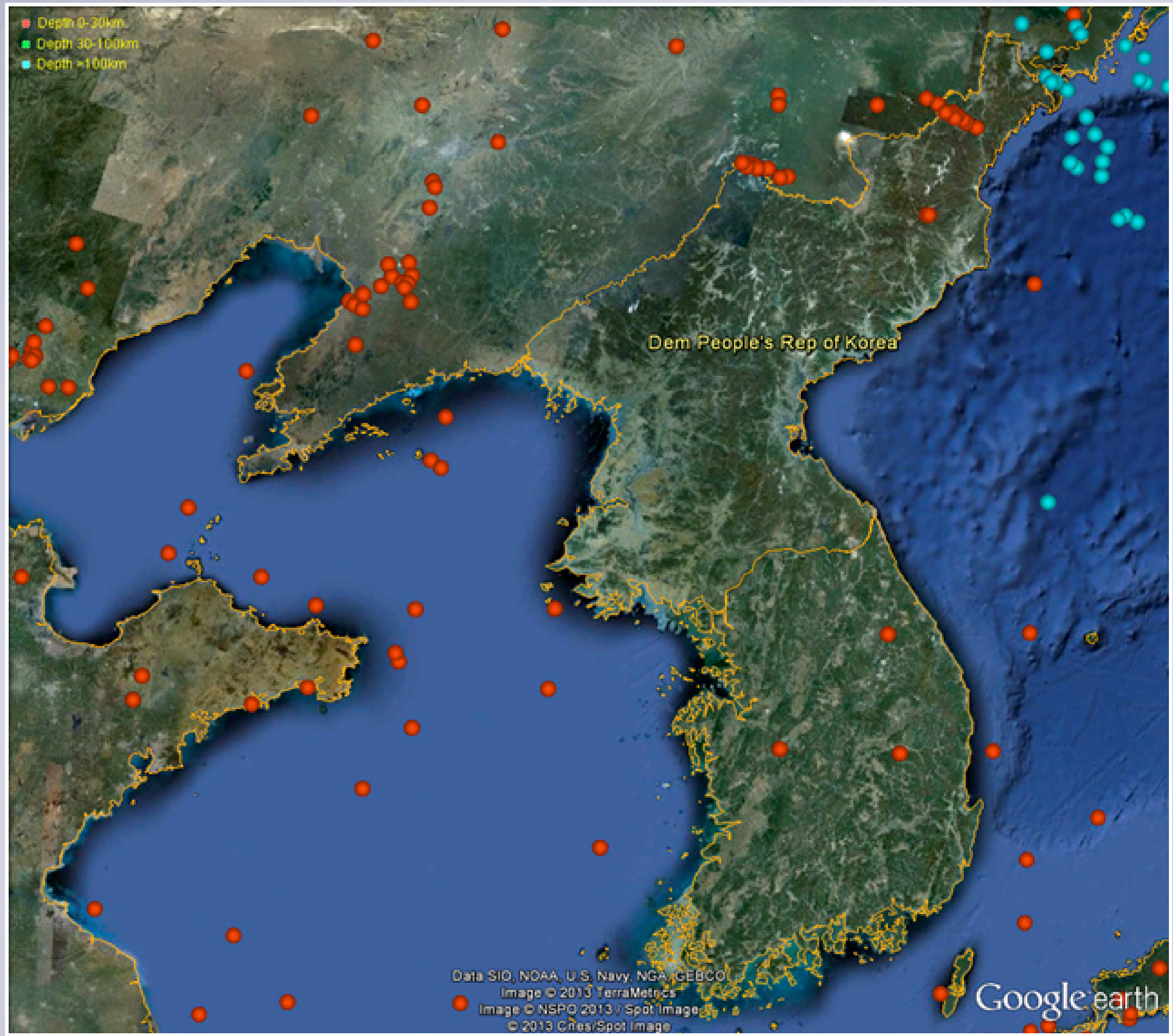
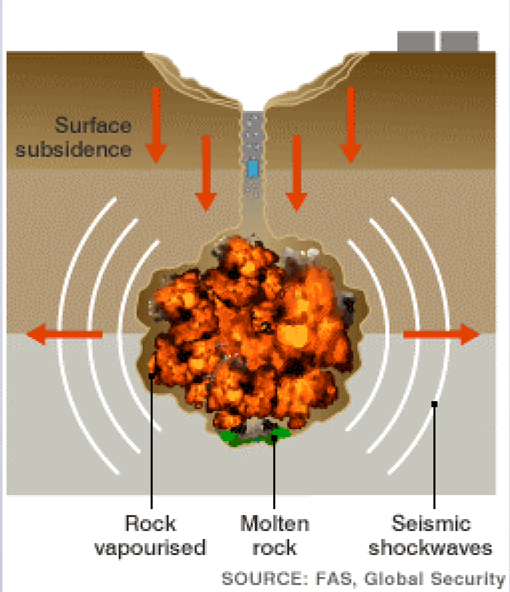


image courtesy CTBTO International Data Centre

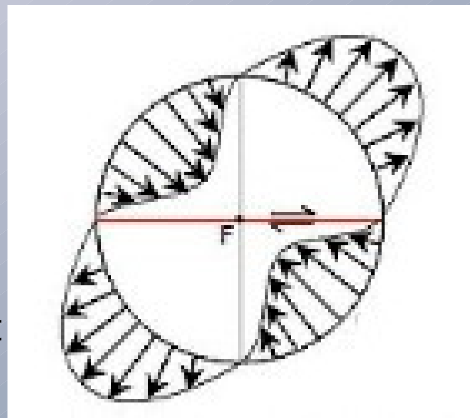
M5.1 NUCLEAR EXPLOSION - NORTH KOREA
Tuesday, February 12, 2013 at 02:57:51 UTC

Analyzing seismograms recorded after an event can discriminate between a natural earthquake or an explosion.



An explosion generates a “sphere” of compressional waves travelling in all directions. A seismogram will show a strong and sudden signal of P-waves, with a similar signal recorded by all the seismometers around the explosion. Additionally, an underground explosion generates surface waves that are smaller than those expected for most earthquakes.

An earthquake is caused by the sliding of rocks along a fracture and will generate both compressional and shear waves concentrated in certain directions.



Schematic diagram showing the direction of initial movement of particles around the focus (F) of an earthquake on a W-E dextral strike-slip fault, viewed from above.

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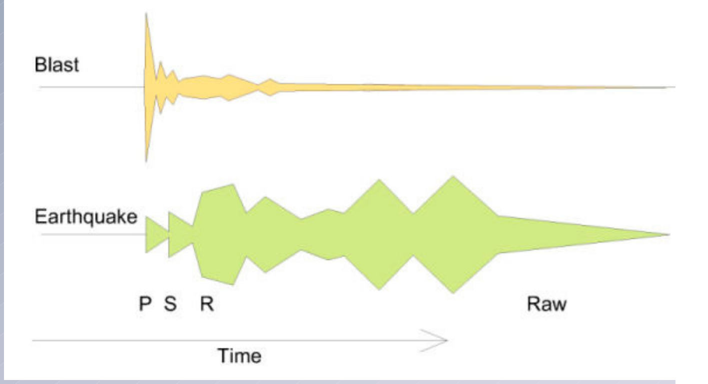
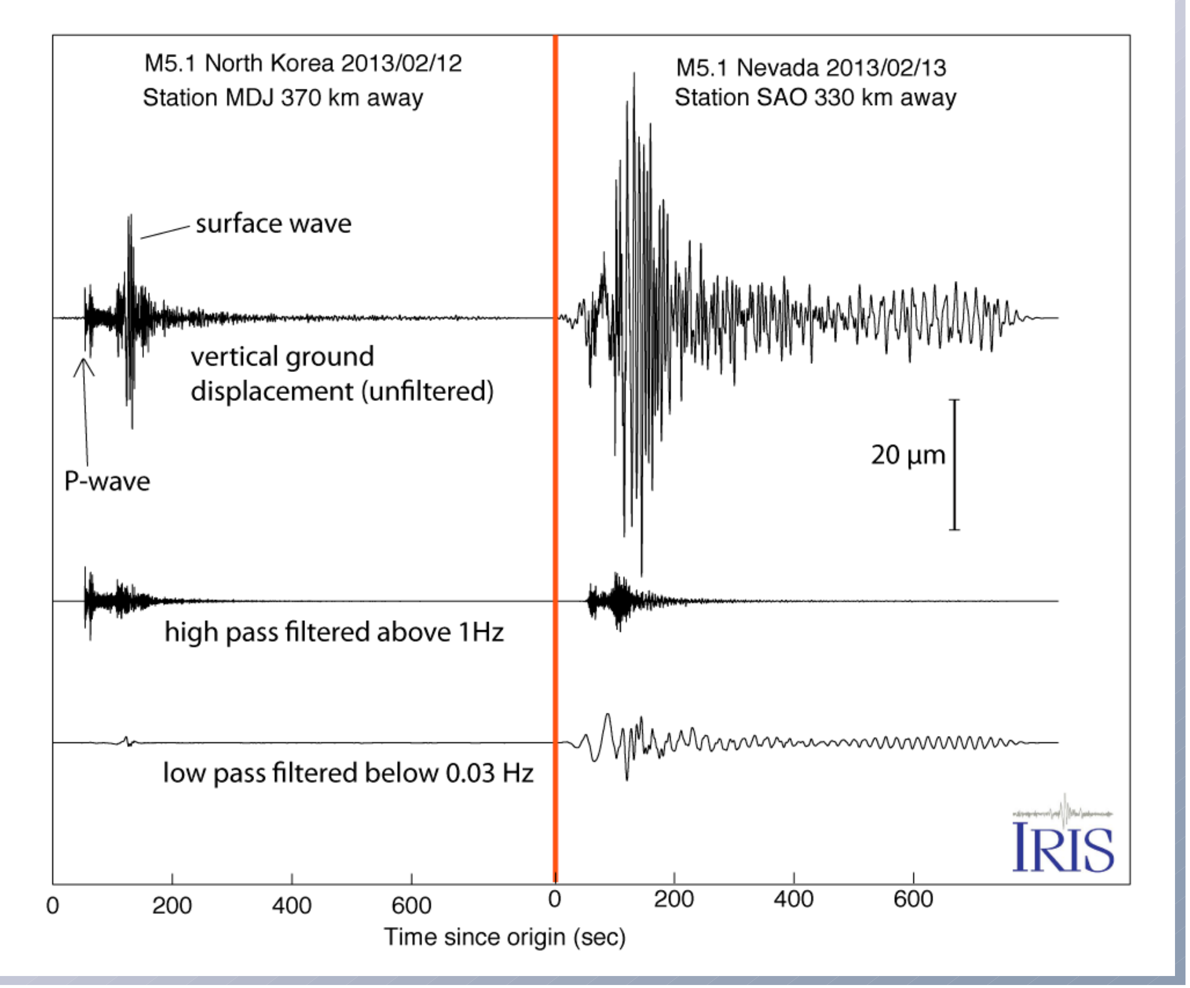
Generalized seismograms showing differences between an explosion and earthquake.





Seismograms from two equidistant stations from the (left) 2013/02/12 North Korean M5.1 explosion and the (right) 2013/02/13 Nevada M5.1 earthquake.

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Efforts over a 50-year period to limit and ultimately ban nuclear testing led in 1996 to the signing of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

The CTBT bans all nuclear explosions in all environments.

The Partial Test Ban Treaty from 1963, which banned nuclear tests in the atmosphere, underwater and in space, and the Threshold Test Ban Treaty from 1974, which limited the yield of underground tests to 150 kilotons, represented significant steps towards achievement of the CTBT.

The CTBT will enter into force when it has been ratified by 44 states listed in the Treaty. Of these, 36 states have ratified the Treaty as of October 2012.

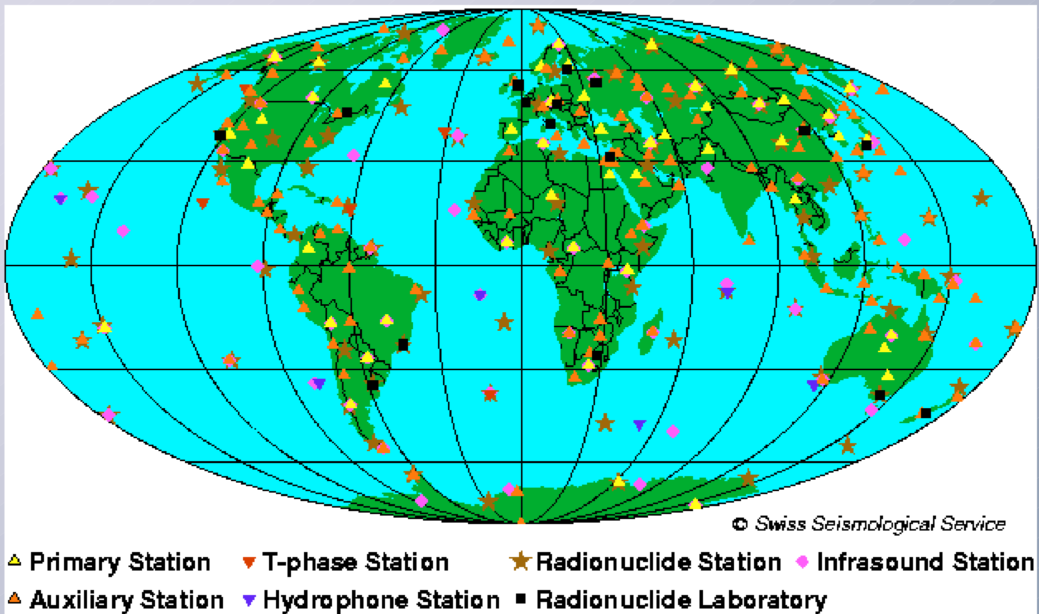
CTBT History and Political Situation

CTBTO Public Information
www.ctbto.org

M5.1 NUCLEAR EXPLOSION - NORTH KOREA
Tuesday, February 12, 2013 at 02:57:51 UTC

Since the Treaty is not yet in force, the organization is called the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) based in Vienna. The CTBTO's main tasks are the promotion of the Treaty and the build-up of the verification regime so that it is operational when the Treaty enters into force.

The International Monitoring System (IMS) will, when complete, consist of 337 facilities worldwide to monitor the planet for signs of nuclear explosions. Over 85 percent of the facilities are already up and running. The IMS uses four state-of-the-art technologies: seismic, hydroacoustic, infrasound and radionuclide. 44 stations of the IRIS/USGS GSN contribute to the IMS as auxiliary or primary stations.



IMS network

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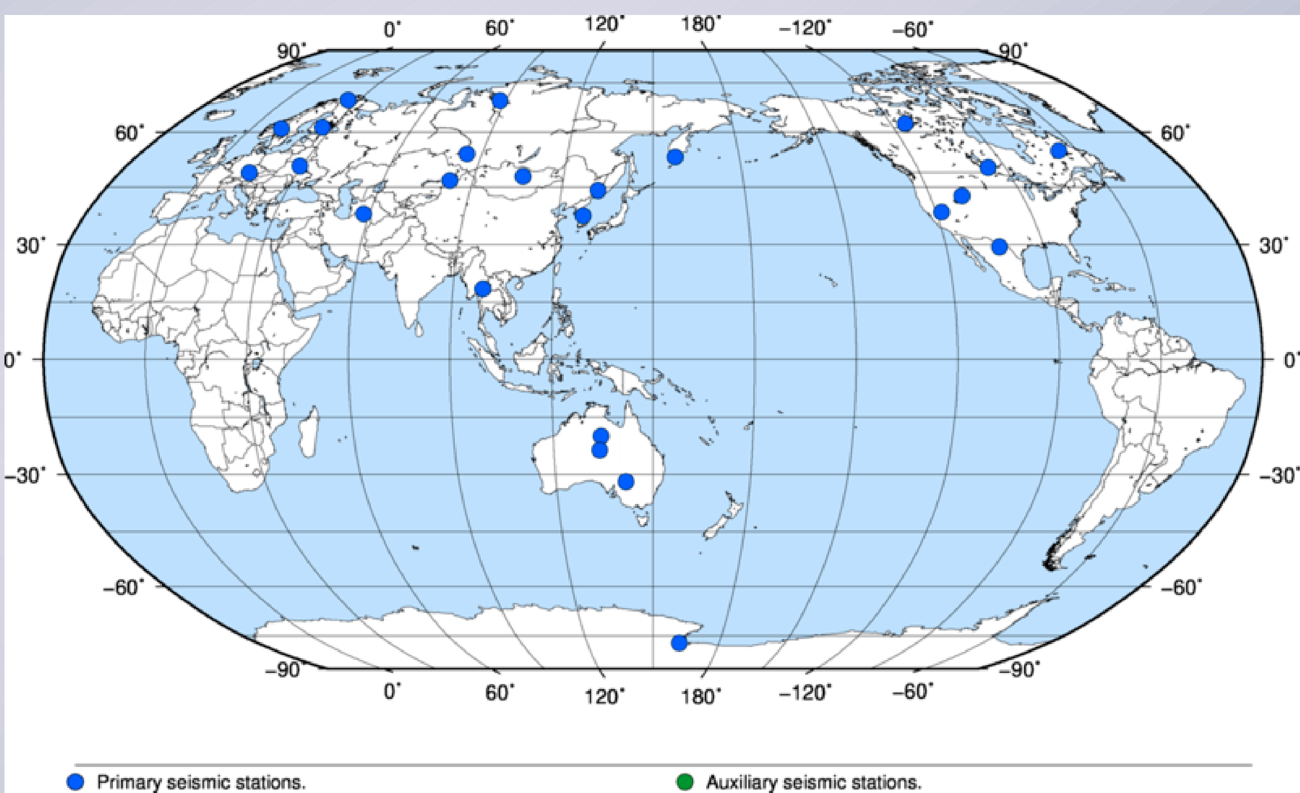
The CTBTO's first and preliminary automatic detections were made by up to 25 seismic stations around the world.

The first data were made available to CTBTO Member States in little more than one hour, and before North Korea announced that they had conducted a nuclear test.



IMS stations shown are just those used in the initial location of this event.

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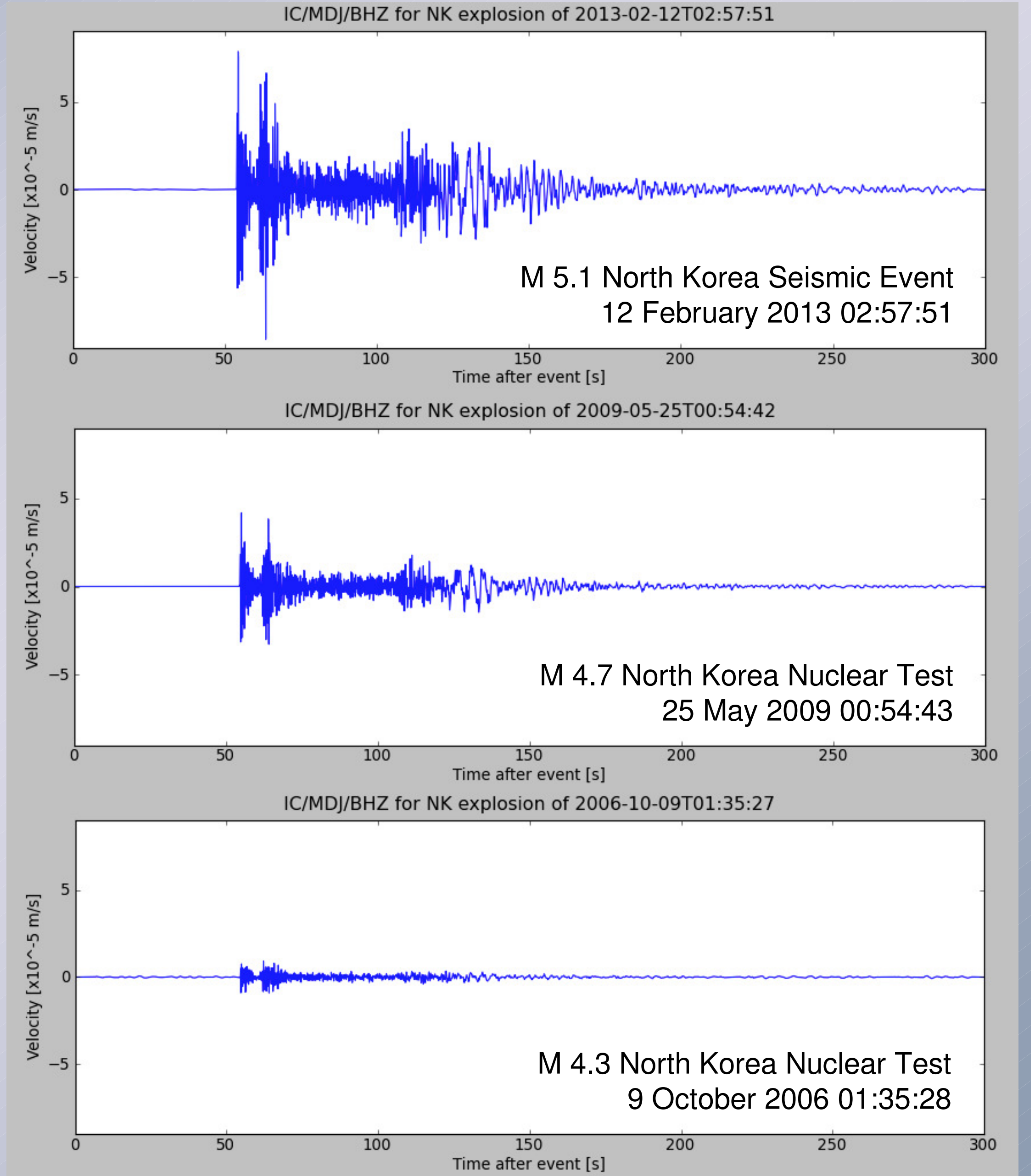
IRIS DMC

Recordings were also available immediately from stations in the Global Seismic Network (GSN).

The plot displays, to a common scale, the 2013, 2009, and 2006 nuclear tests in North Korea on a GSN station MDJ.

MDJ is located a few hundred km north-northeast of the test site



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Comparing the 2006, 2009, and 2013 North Korea nuclear tests, with no filtering or waveform manipulation of the data. The signal is almost identical, except for size, which helps to confirm similar source type and location.

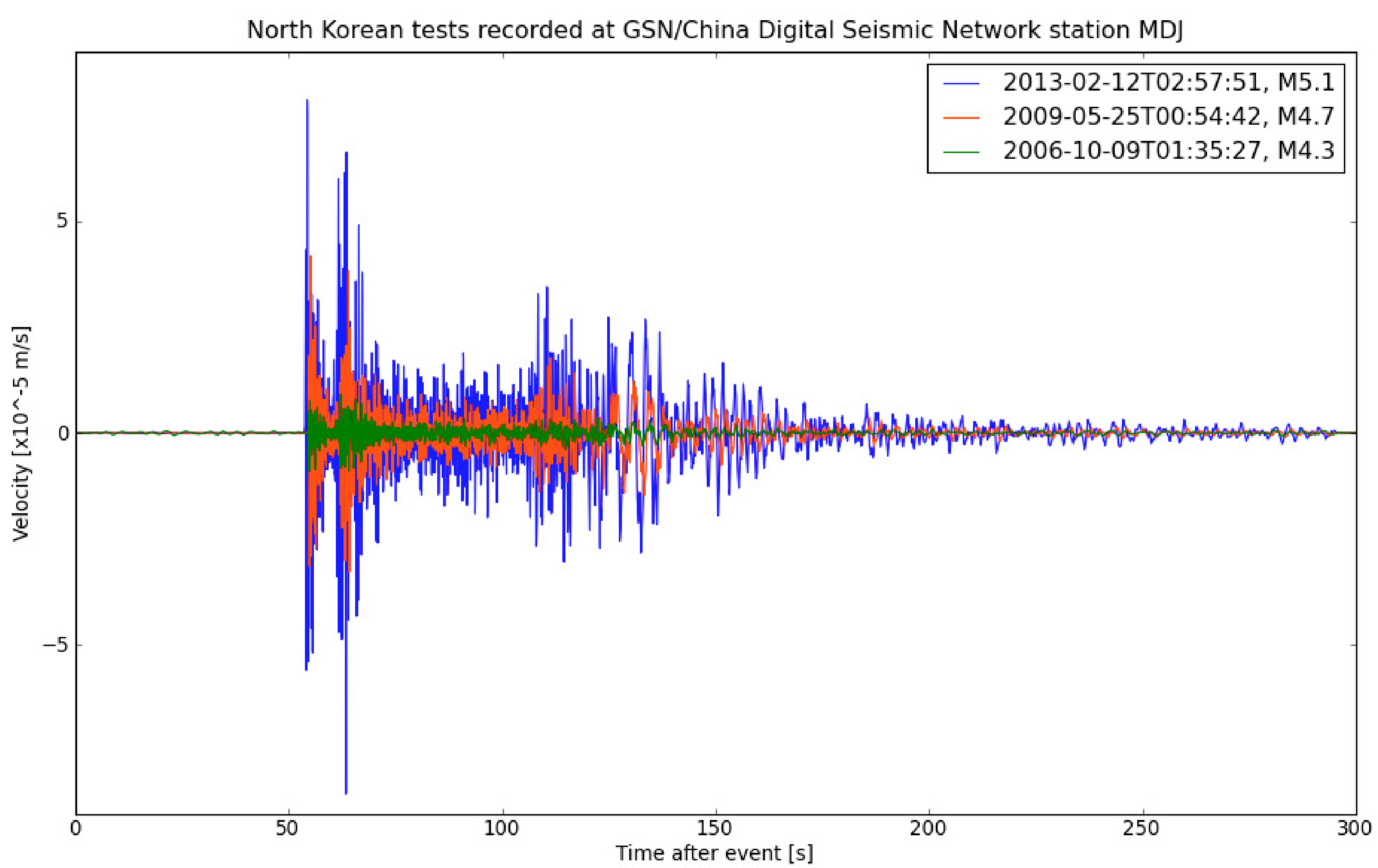

Image courtesy Andy Frassetto

M5.1 NUCLEAR EXPLOSION - NORTH KOREA
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Comparison of the first automatic location estimates of the 2006, 2009 and 2013 nuclear tests by North Korea.

The location accuracy is currently approximately +/- 16.2 km, indicating that the location of today's event is largely identical with the two previous nuclear tests.

As with the two previous nuclear tests, the signal was emitted from close to the surface.

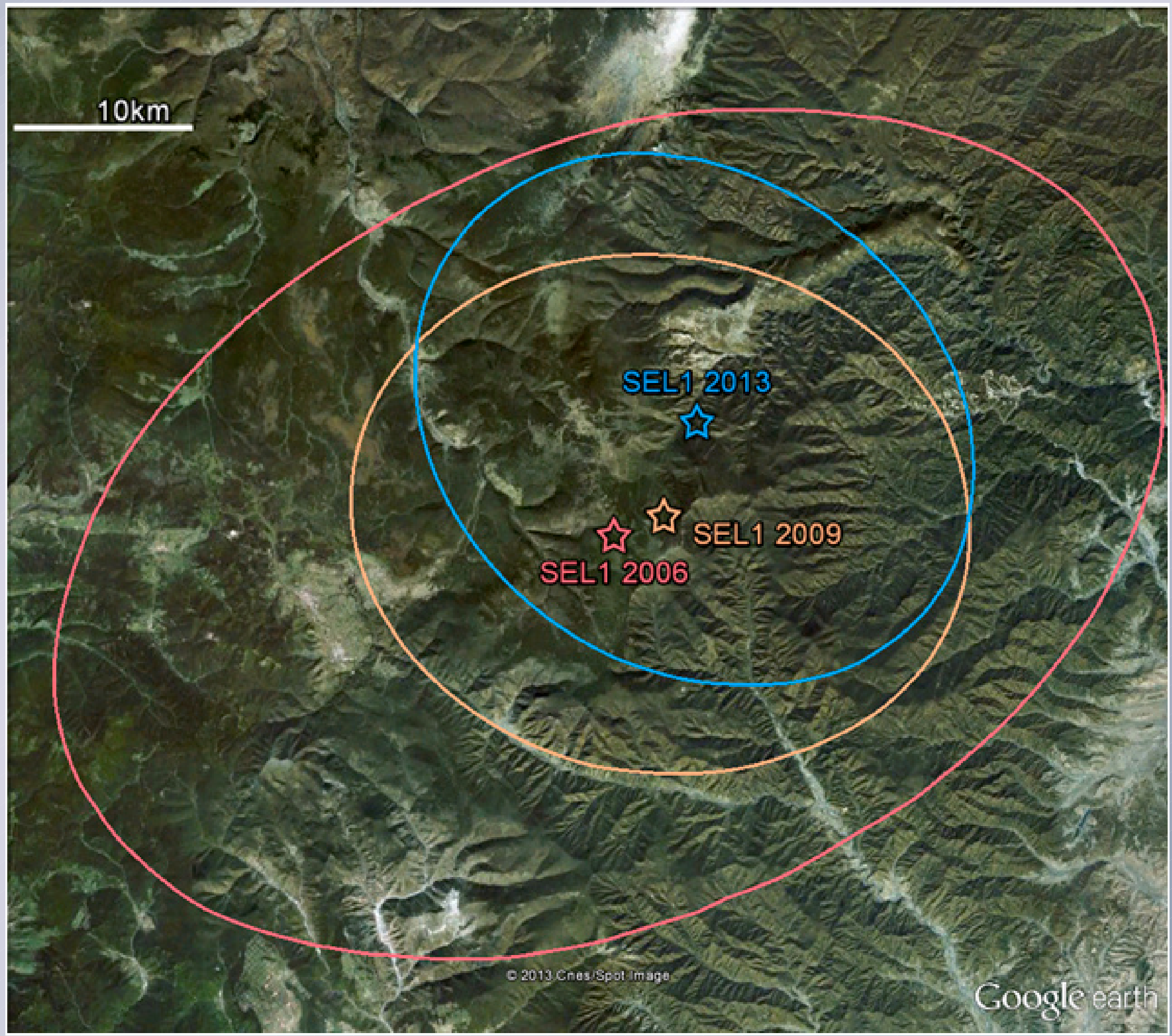


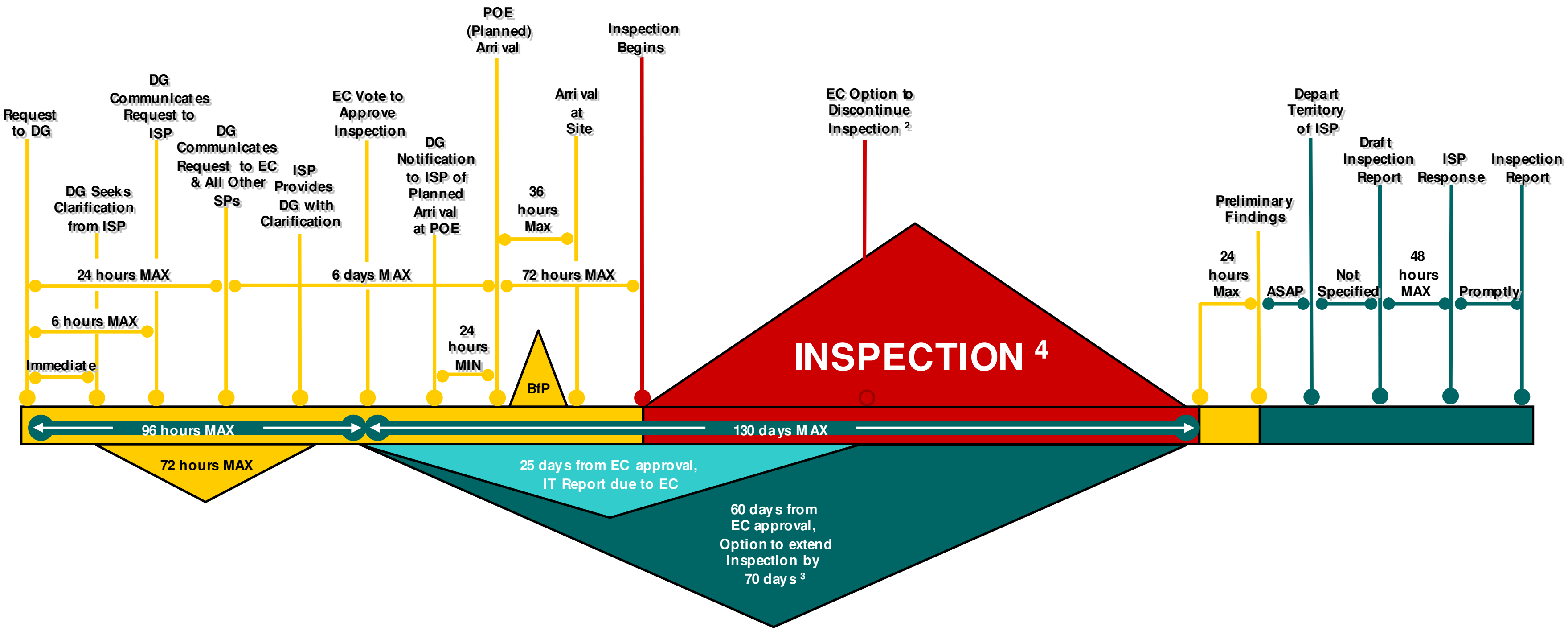
image courtesy CTBTO International Data Centre

OSI – On Site Inspection

- to clarify whether a nuclear weapon test explosion or any other nuclear explosion has been carried out in violation of Article I of CTBT

- to gather any facts which might assist in identifying any possible violator
(Article IV, Para. 35)

CTBT OSI Timelines

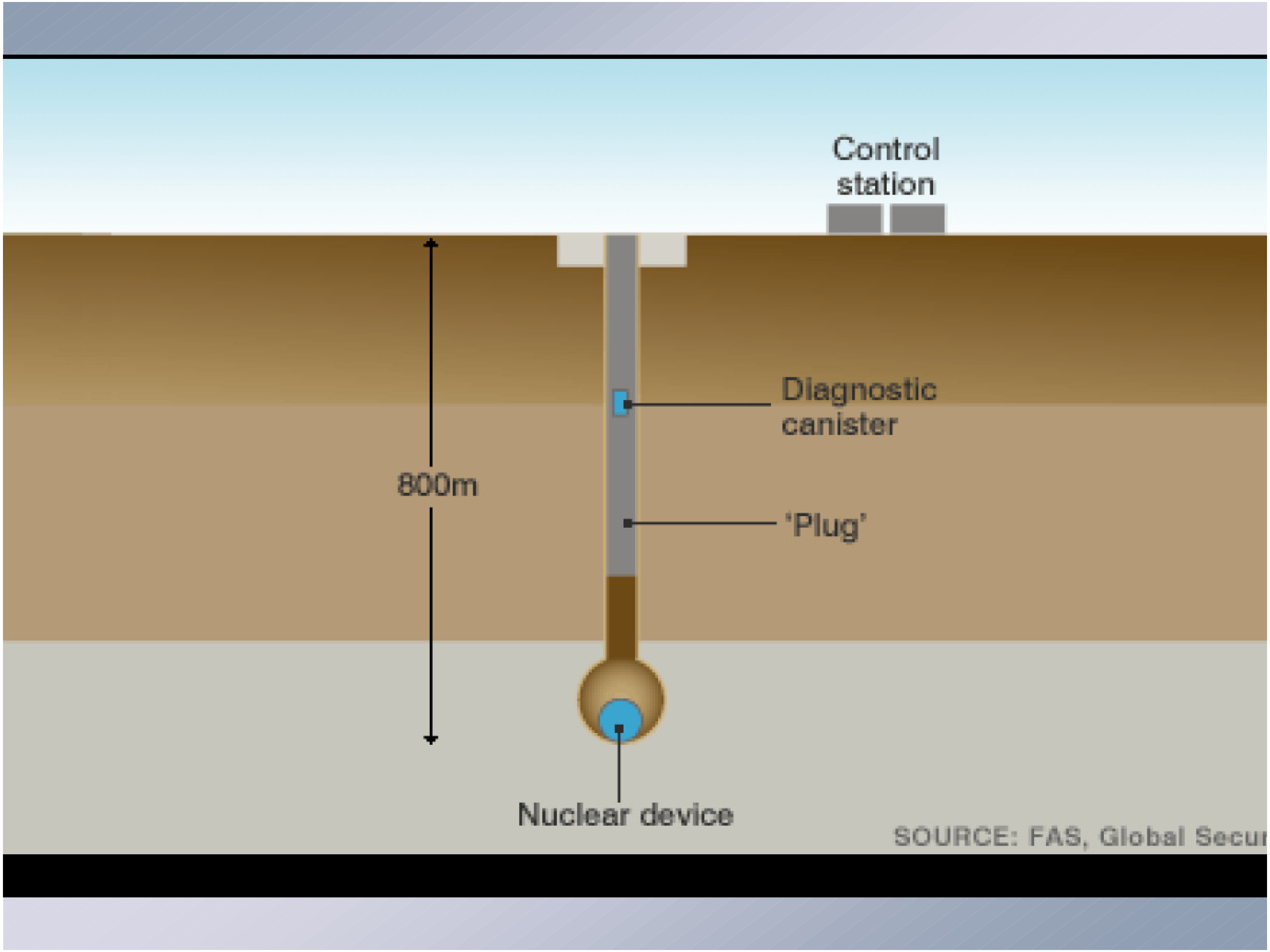


1 The decision to conduct an inspection requires an affirmative vote of 30 members (the Executive Council (EC) is composed of 51 members)

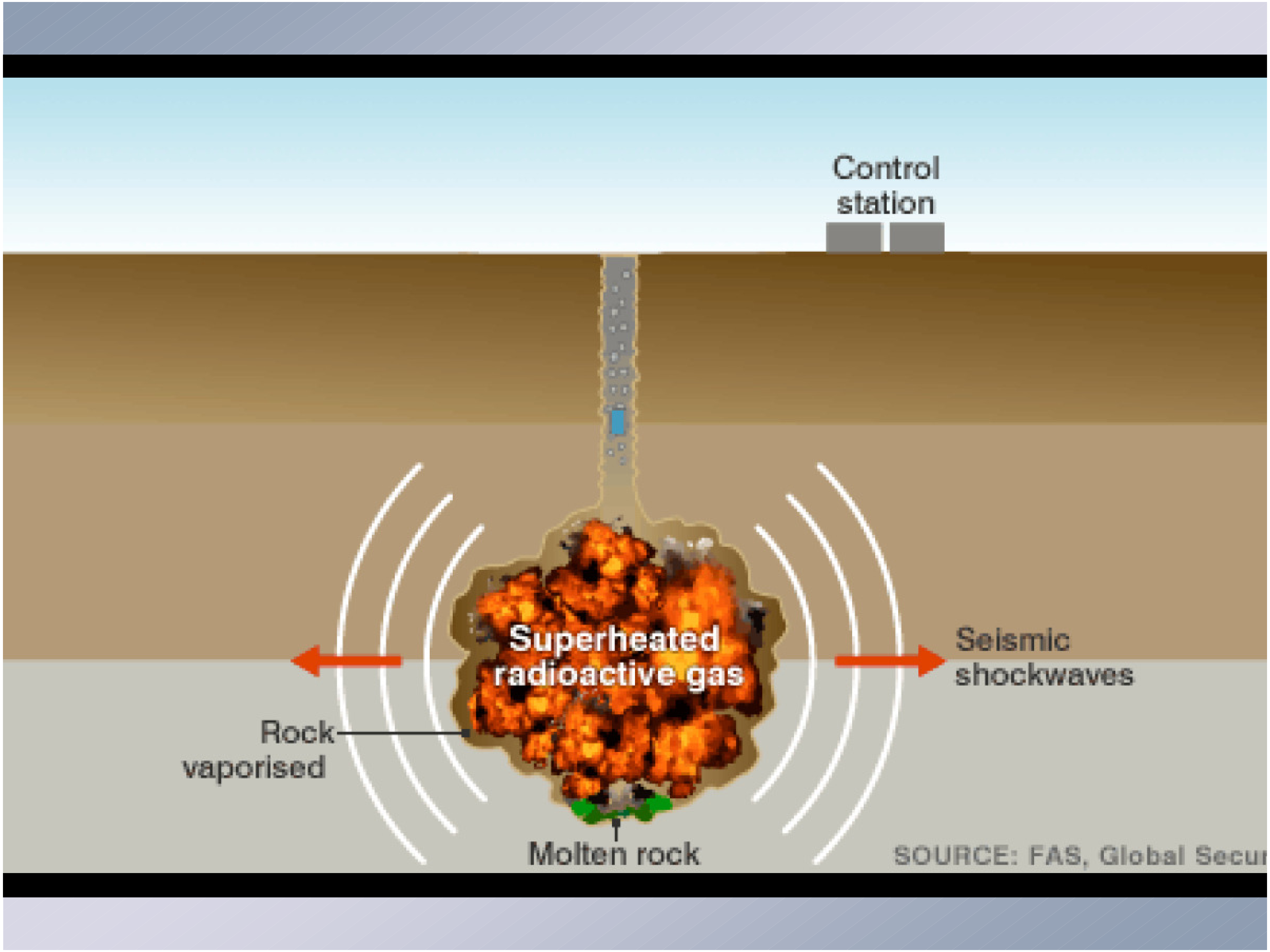
2 The inspection shall proceed automatically unless the EC, no later than 24 hours after receipt of the progress inspection report, votes by a majority of all it´s members not to continue the inspection

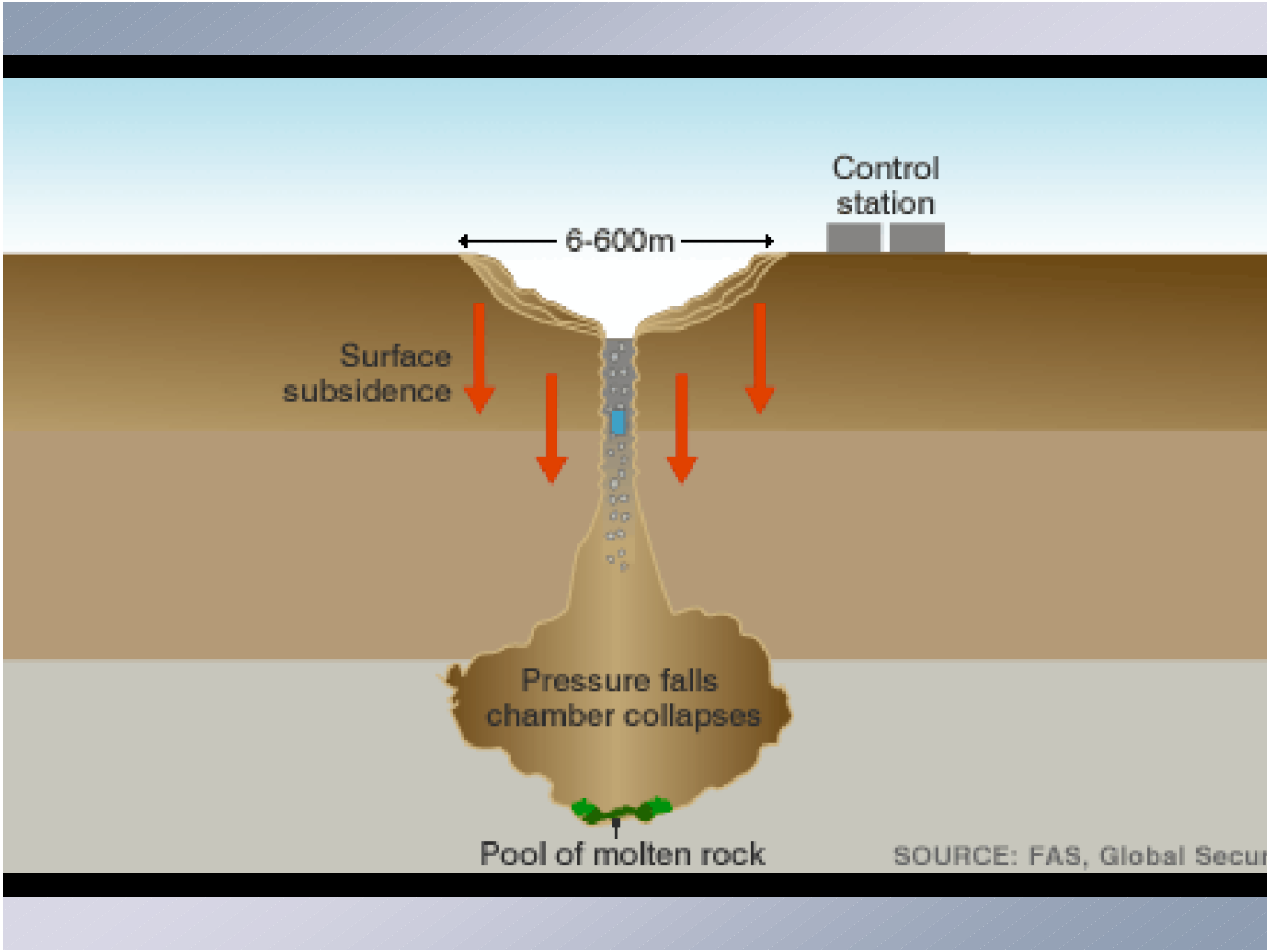
3 The inspection may be extended beyond 60 days by a maximum of 70 days if the EC, by a simple majority, approves a request by the IT within 72 hours of receipt of such a request

4 The IT may request the termination of an inspection at any time; such a request will be considered approved unless the EC, by a 2/3 majority vote, blocks such a request within 72 hours of receipt of the request



Control station
Diagnostic canister
800m
'Plug'
Nuclear device
SOURCE: FAS, Global Secur


Control station
Superheated radioactive gas
Seismic shockwaves
Rock vaporised
Molten rock
SOURCE: FAS, Global Secur


Control station
6-600m
Surface subsidence
Pressure falls chamber collapses
Pool of molten rock
SOURCE: FAS, Global Secur

Introduction

- An OSI is conducted in an inspection area (IA)

  - it has to be a continuous area
    and can not exceed 1000 km^2

  - there shall be no linear distance greater that
    50 km in any direction

- Inspection team (IT)
  - up to 40 inspectors

  - Logistic/Administration
  - Seismic
  - Visual Observation
  - Radionuclide
  - (Continuation Period)

Passive seismological monitoring for aftershocks

- aftershocks

  - 2 basic types for an underground nuclear explosion (UNE)
    - rock fall in the cavity
    - stress release from the surrounding geological environment

  - size and frequency of the occurrence depend on:
    - size of an UNE
    - geological conditions
    - time after an UNE

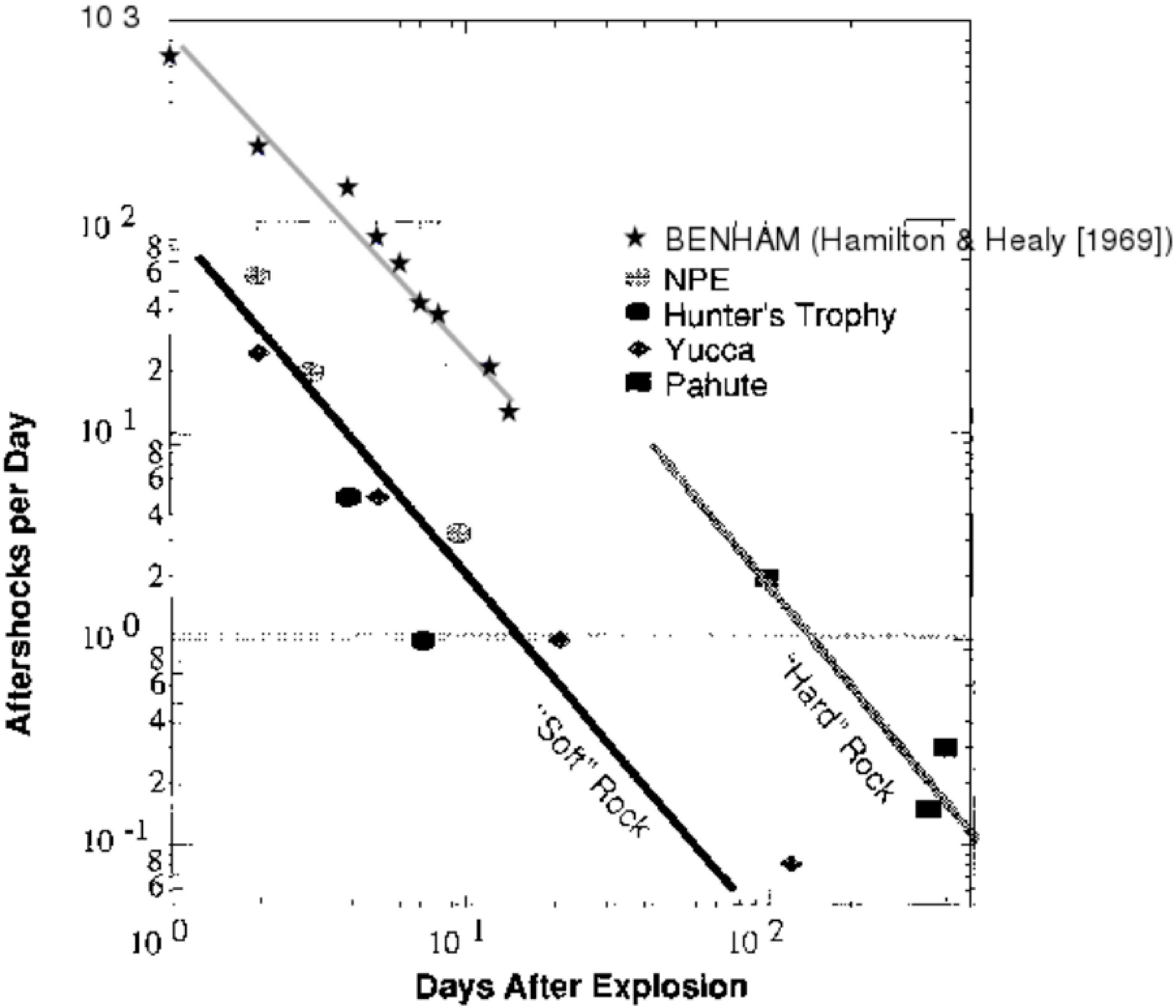
Passive seismological monitoring for aftershocks

- aftershocks (cont.)

  - expected size can be, however, as low as ml = -2 (nanoevents)

  - expected frequency in the initial phase: probably not more than one or few events per day

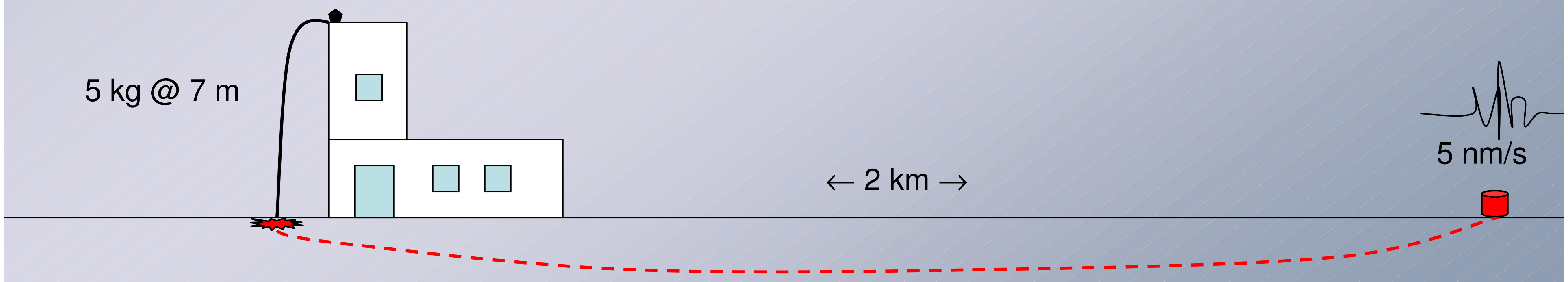
  - not necessarily close to UNE hypocenter



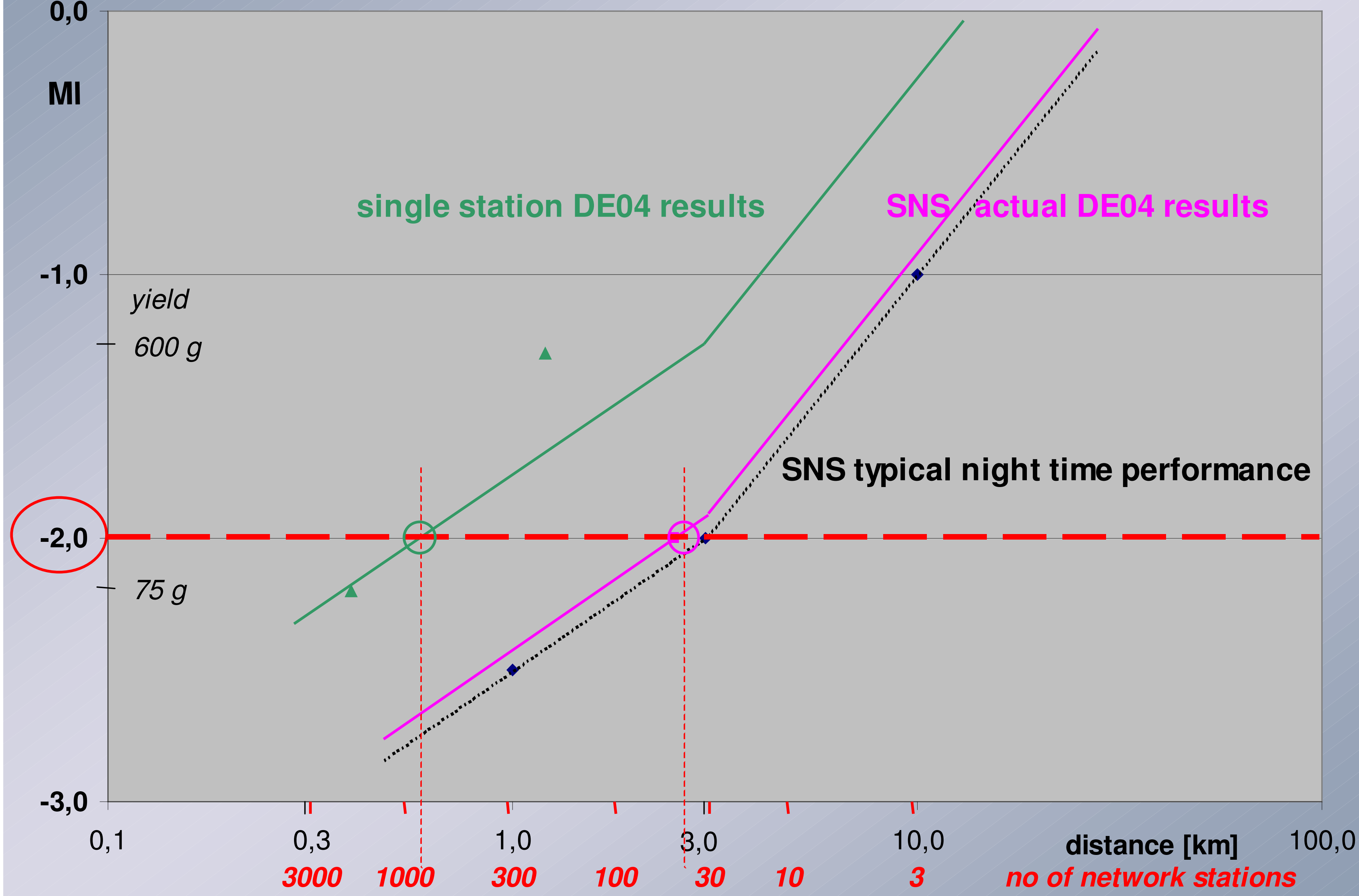
BENHAM (Hamilton & Healy [1969])
NPE
Hunter's Trophy
Yucca
Pahute
"Soft" Rock
"Hard" Rock
Aftershocks per Day
Days After Explosion

Scaling of Earthquake Signals

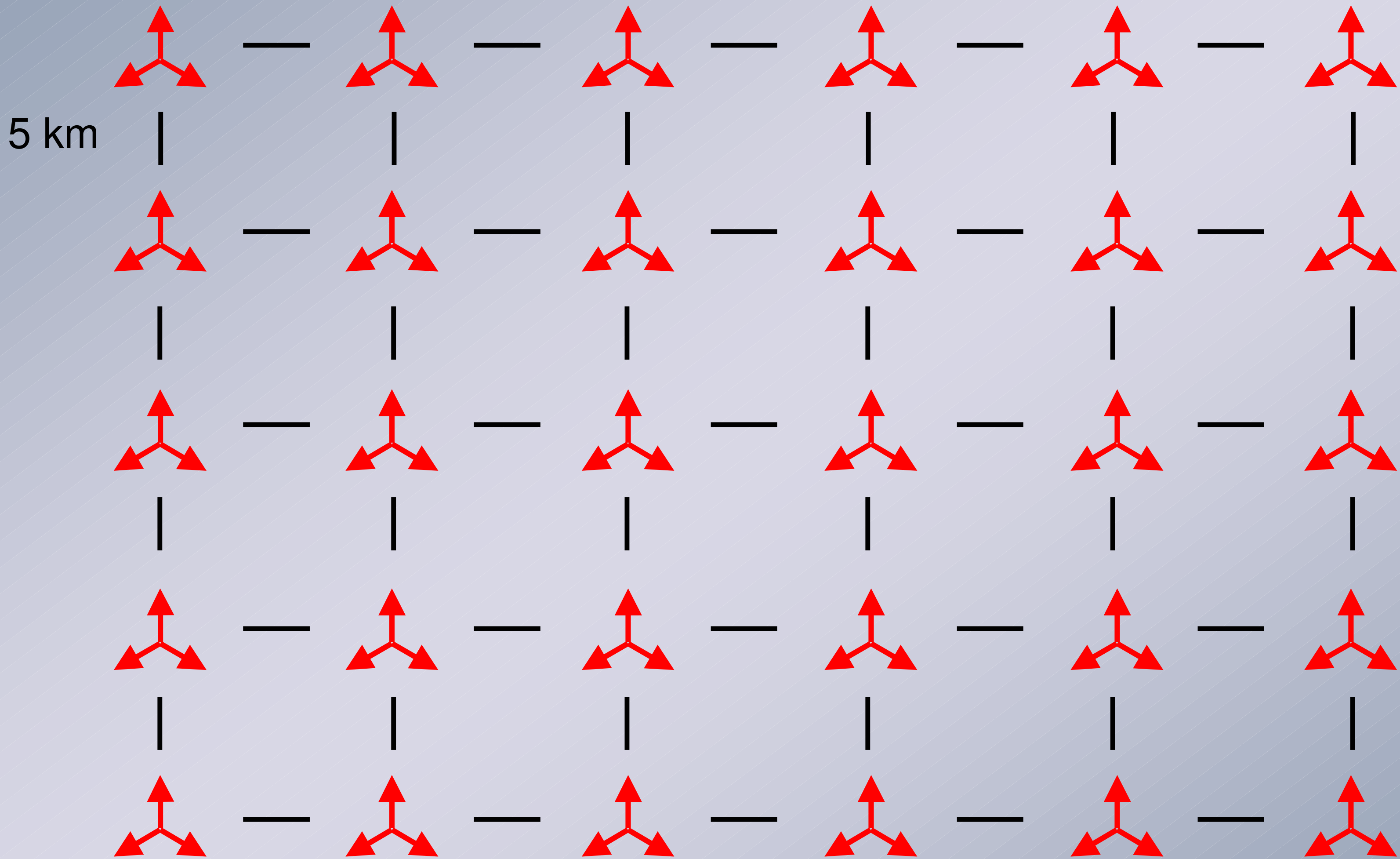
Magnitude	rel. Energy Release	typical Effects or Examples
7.0	1	Izmit Quake 8/99
5.0	0,001	chimney breaks
3.0	0,000.001	smallest felt earthquake
1.0	0,000.000.001	minor quarry blast
-1.0	0,000.000.000.001	aftershock from nuclear explosion
-2.0	0,000.000.000.000.03	limit of OSI monitoring



Detection threshold

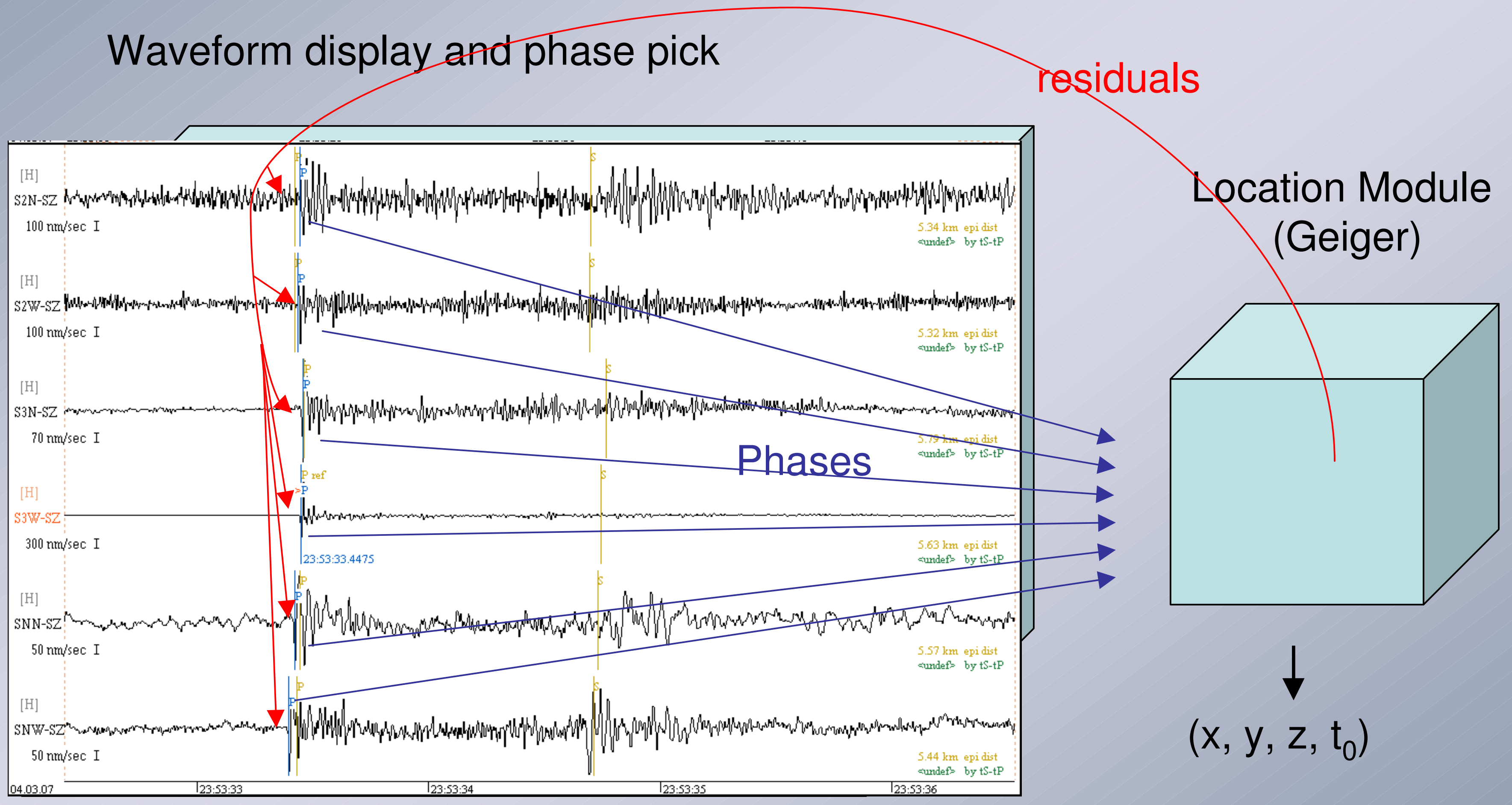


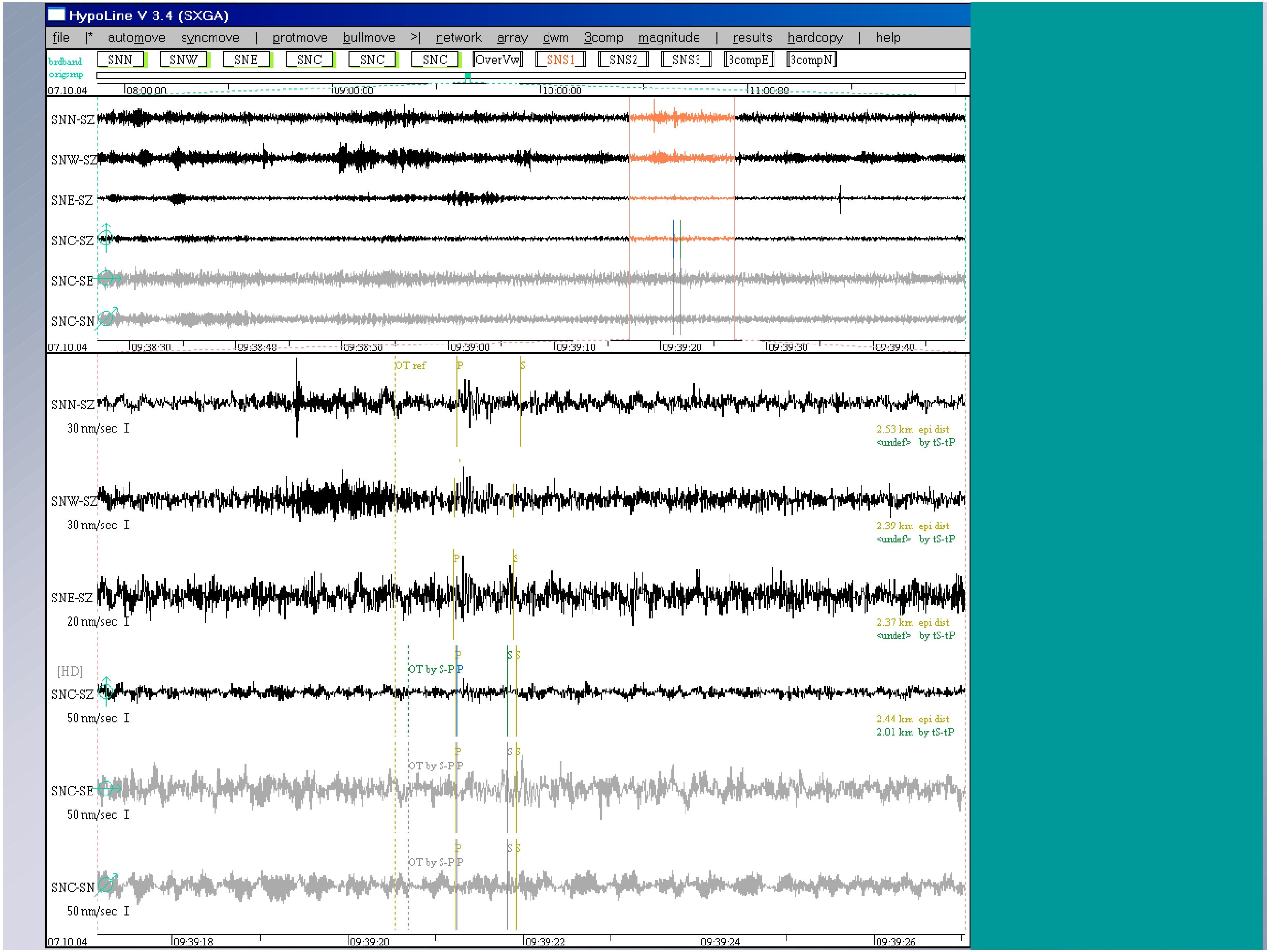
IFE08: ~30 small arrays

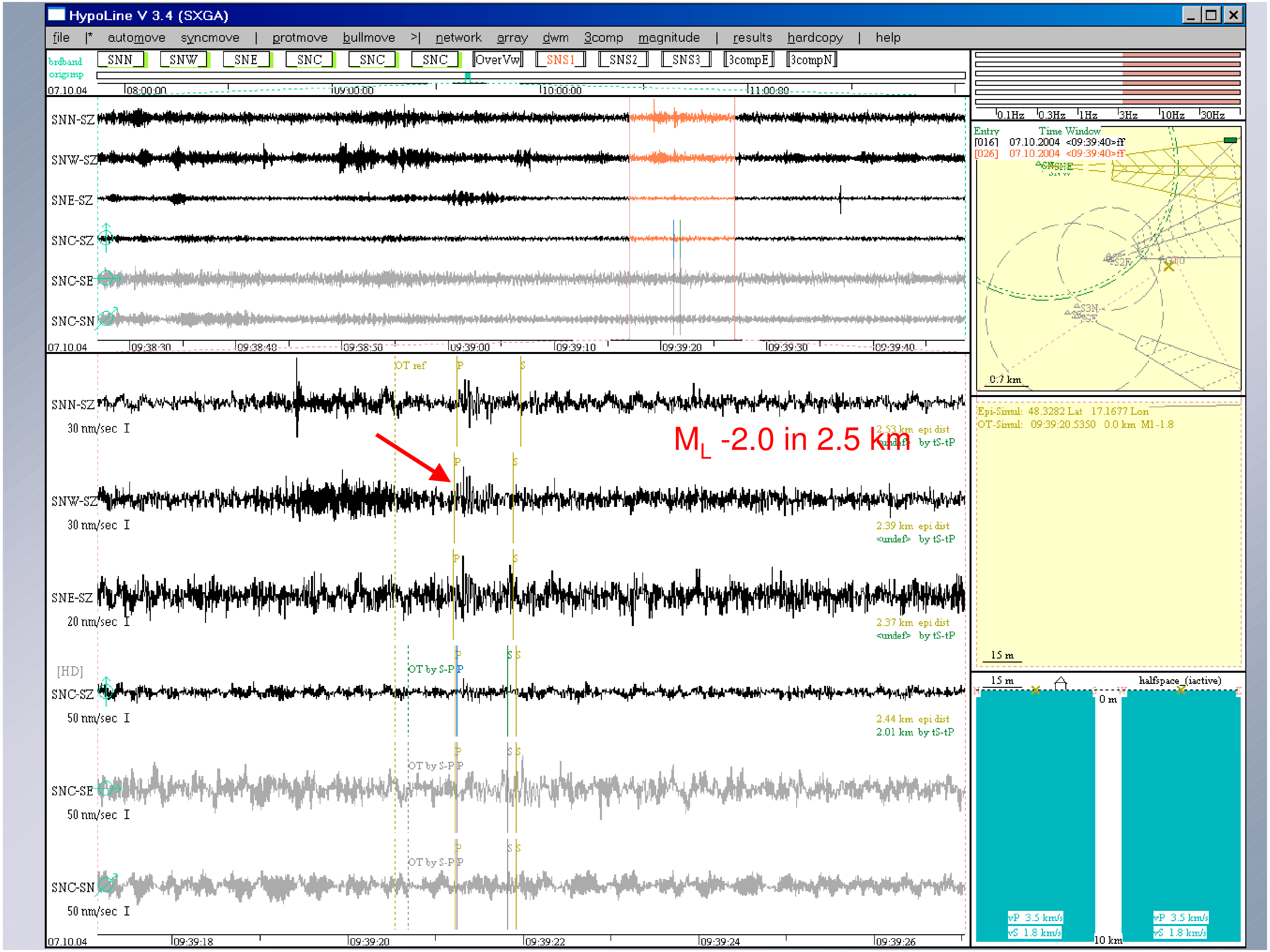


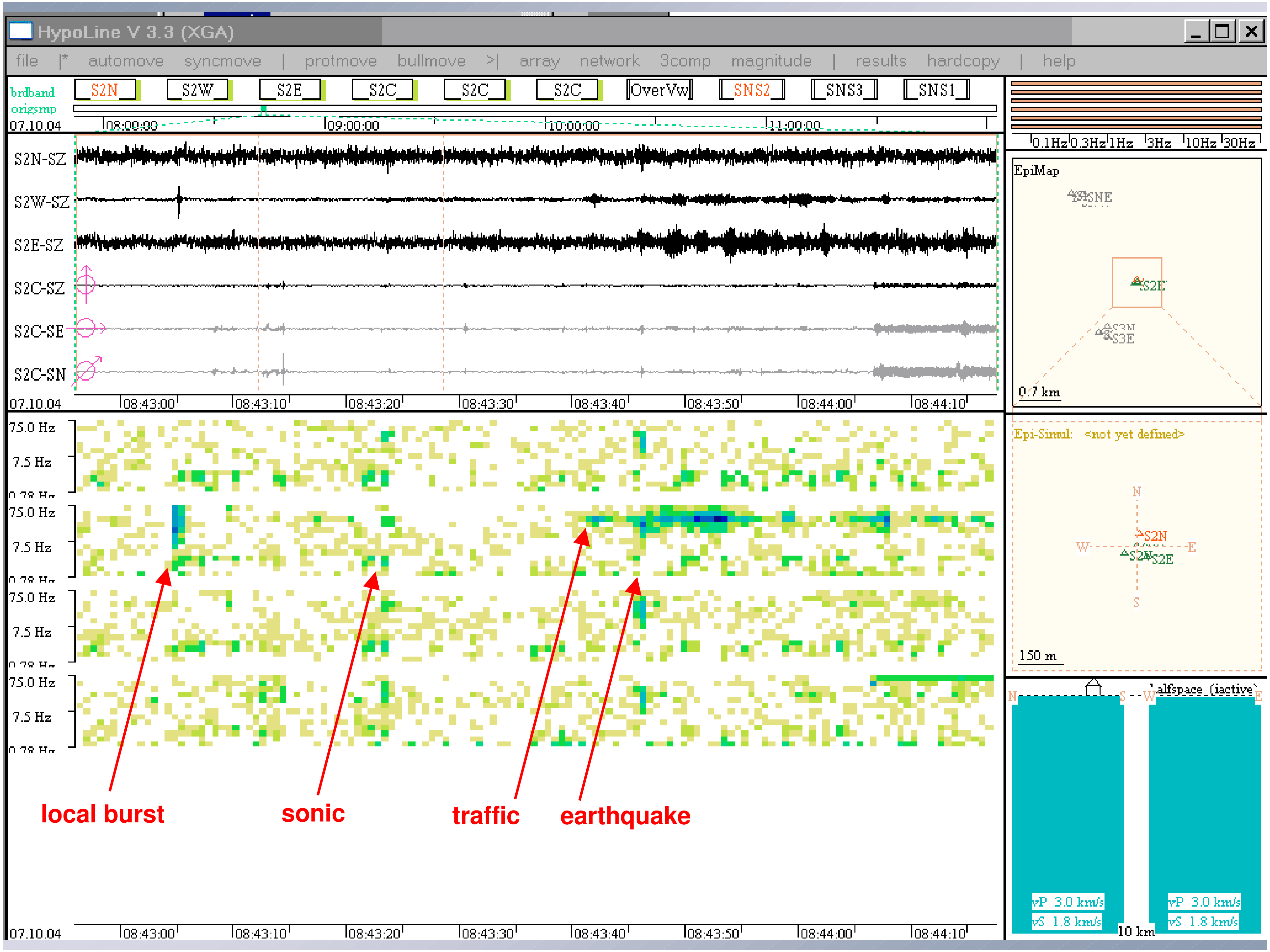
=> ~ 750 km^2 (1000 km^2 IA)

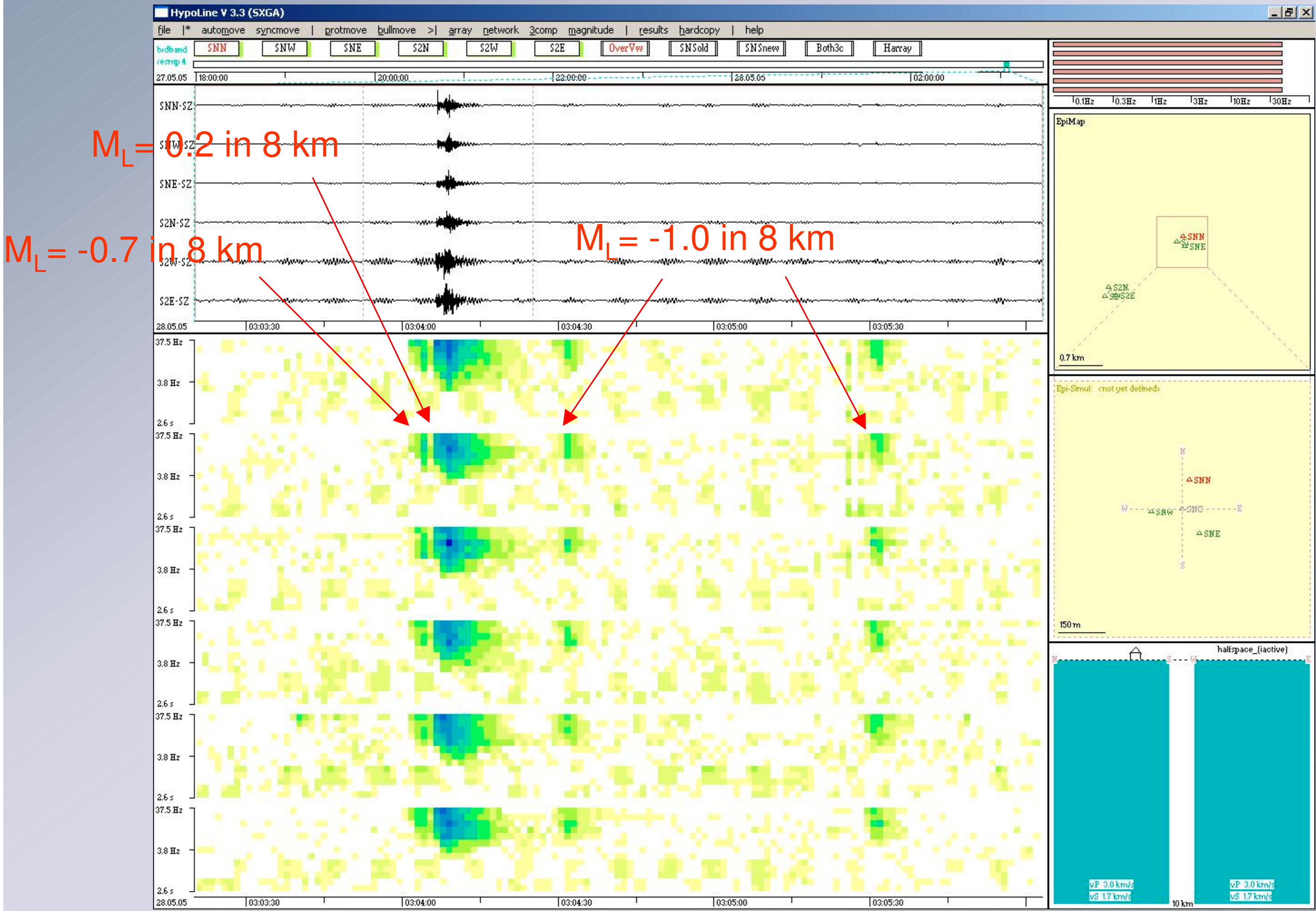
Standard Earthquake Location Procedure




HypoLine V 3.4 (SXGA)
file |* automove syncmove | protmove bullmove >| network array dwm 3comp magnitude | results hardcopy | help
SNN SNW SNE SNC SNC SNC OverVw SNS1 SNS2 SNS3 3compE 3compN
brdband
origsmp
07.10.04
08:00:00
09:00:00
10:00:00
11:00:00
SNN-SZ
SNW-SZ
SNE-SZ
SNC-SZ
SNC-SE
SNC-SN
09:38:30
09:38:40
09:38:50
09:39:00
09:39:10
09:39:20
09:39:30
09:39:40
OT ref
P
S
30 nm/sec
2.53 km epi dist
<undef> by tS-tP
2.39 km epi dist
20 nm/sec
2.37 km epi dist
[HD]
OT by S-P
50 nm/sec
2.44 km epi dist
2.01 km by tS-tP
09:39:18
09:39:20
09:39:22
09:39:24
09:39:26


HypoLine V 3.4 (SXGA)
file |* automove syncmove | protmove bullmove >| network array dwm 3comp magnitude | results hardcopy | help
SNN SNW SNE SNC SNC SNC OverVw SNS1 SNS2 SNS3 3compE 3compN
SNN-SZ
SNW-SZ
SNE-SZ
SNC-SZ
SNC-SE
SNC-SN
0.1Hz 0.3Hz 1Hz 3Hz 10Hz 30Hz
Entry Time Window
[016] 07.10.2004 <09:39:40>ff
[026] 07.10.2004 <09:39:40>ff
0.7 km
Epi-Simul: 48.3282 Lat 17.1677 Lon
OT-Simul: 09:39:20.5350 0.0 km Ml -1.8
15 m
halfspace_(iactive)
0 m
10 km
vP 3.5 km/s
vS 1.8 km/s
OT ref
OT by S-P
30 nm/sec
20 nm/sec
50 nm/sec
2.53 km epi dist
2.39 km epi dist
2.37 km epi dist
2.44 km epi dist
2.01 km by tS-tP
ML -2.0 in 2.5 km
09:39:18 09:39:20 09:39:22 09:39:24 09:39:26


HypoLine V 3.3 (XGA)
local burst
sonic
traffic
earthquake



M_L= 0.2 in 8 km
M_L= -0.7 in 8 km
M_L= -1.0 in 8 km
HypoLine V 3.3 (SXGA)

eoph.pdf - Adobe Reader

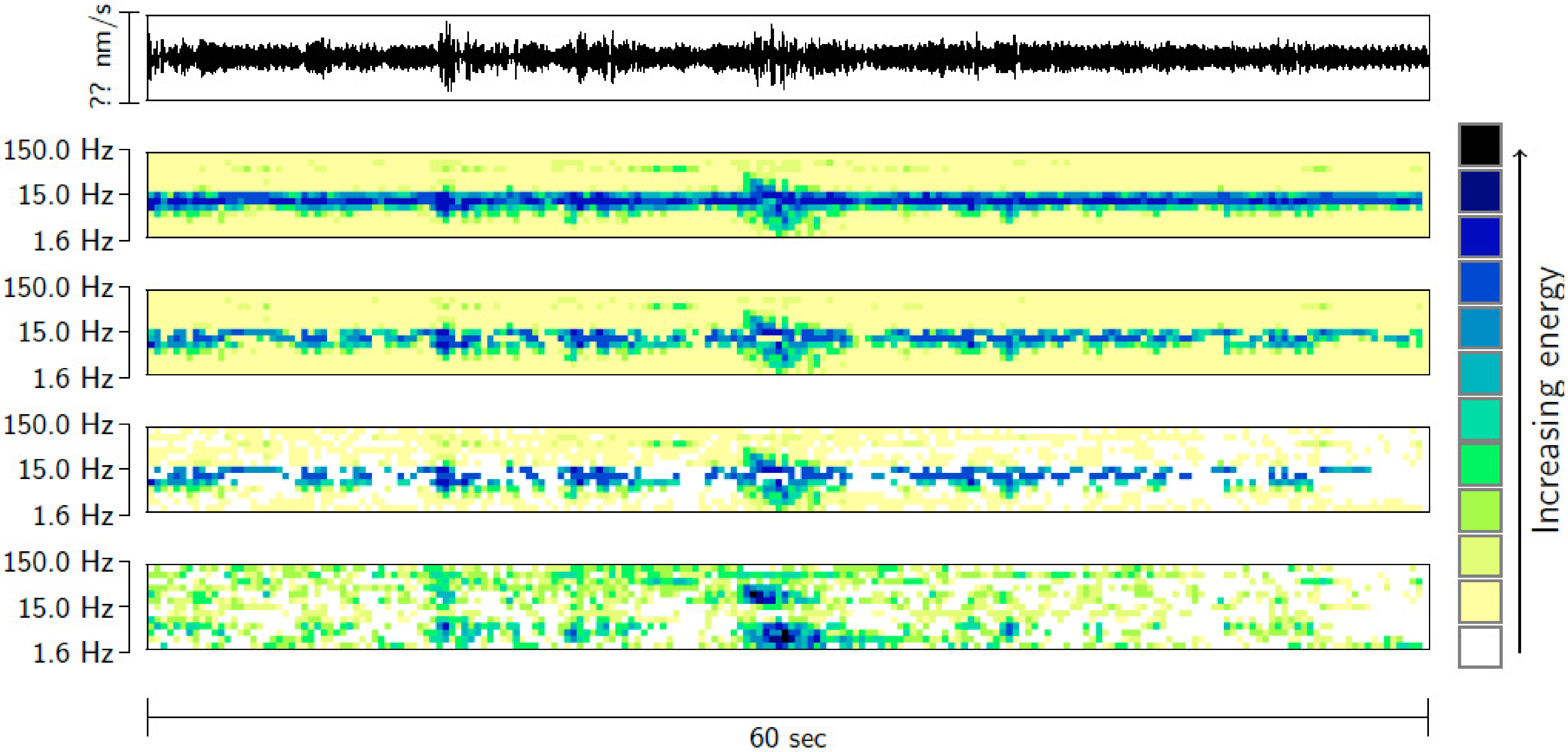


Figure 3: Processing steps of sonogram calculation for a local earthquake: Seismogram, power spectral density spectrogram with logarithmic amplitudes and half-octave frequency bands, noise adaptation, blanking and prewhitening.

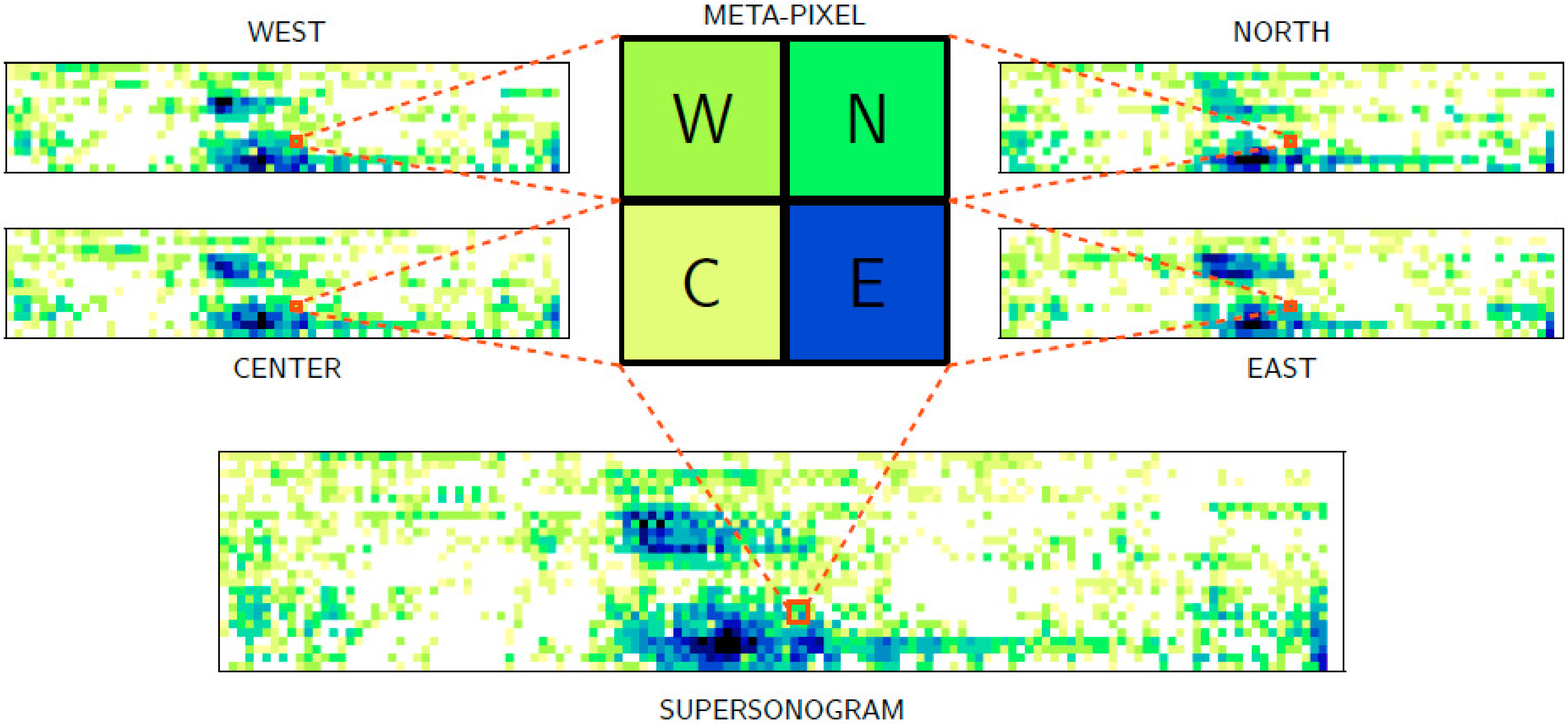
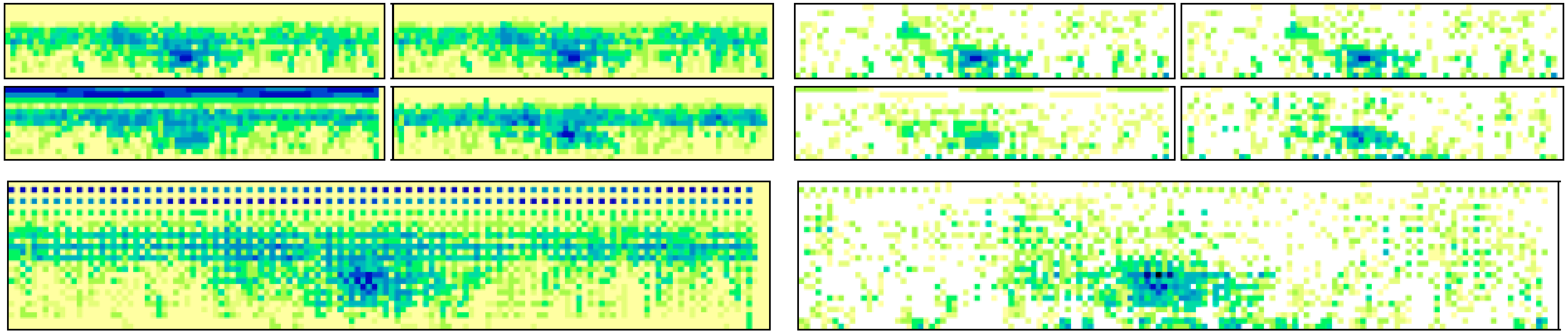
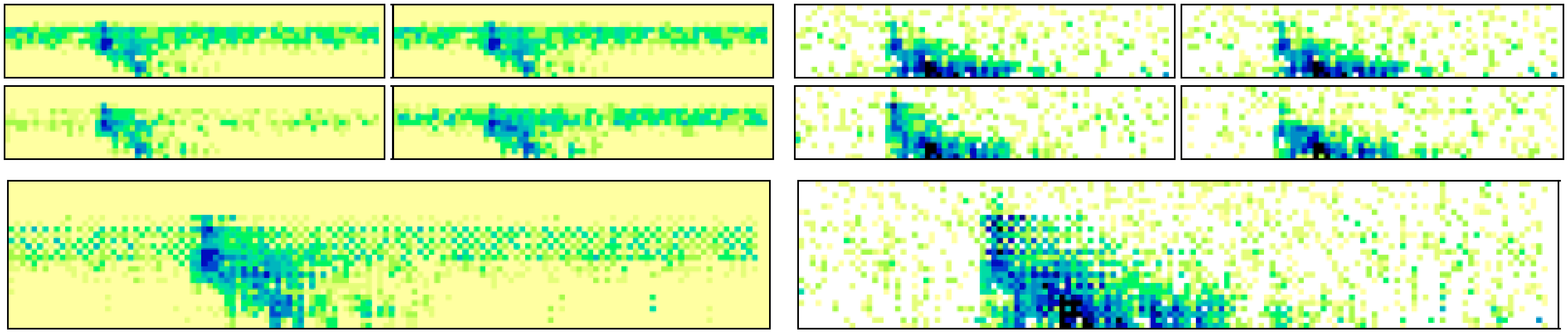


Figure 4: Compilation of a super-sonogram from four sonograms of a mini-array. The pixels of each single sonogram create the meta-pixels of the super-sonogram.

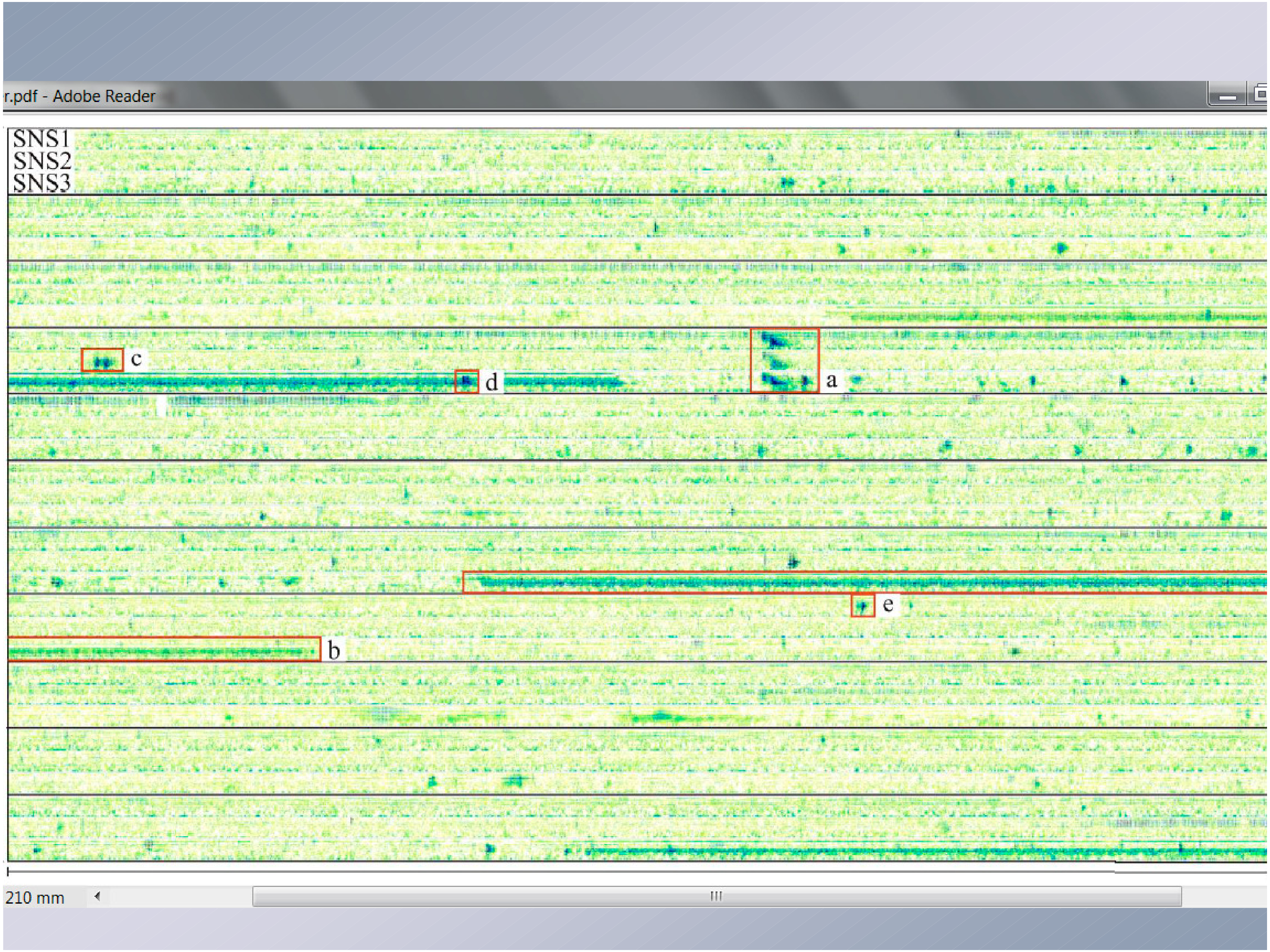


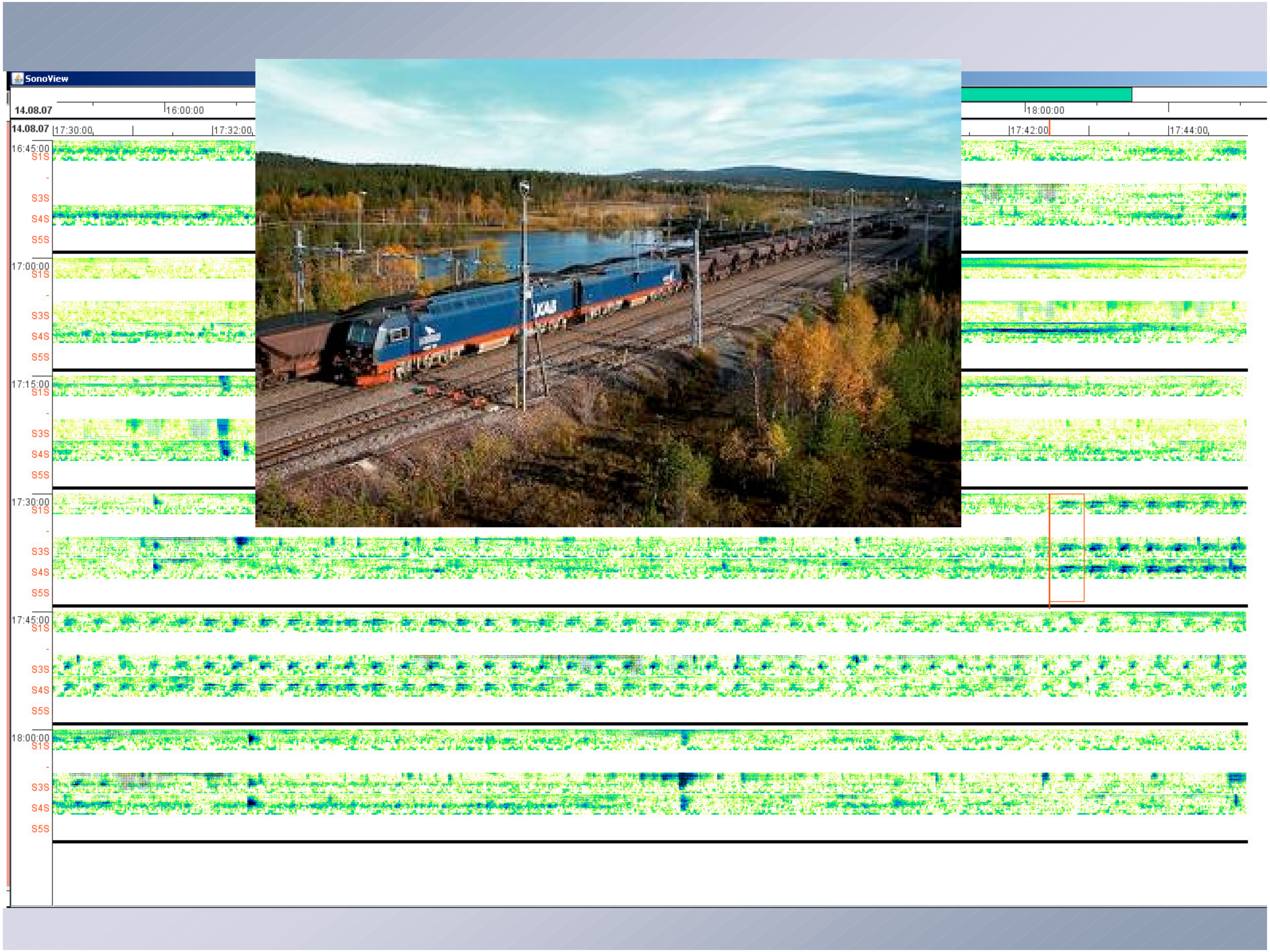
(b) The almost not visible event in the spectrograms on the left gets visible by lifting it from noise in the sonograms and the resulting super-sonogram (local event 27.10.2010 04:35:15).



(c) Example of an improvement of a P-onset through better contrasts and completion of energies of lower frequencies of the impulsive i.e. broadband onset (local event 23.03.2010 15:58:50).

Figure 5: Comparison of super-sonogram compilation of ordinary spectrograms without sonogram steps (left) versus sonograms (right). Figures on each side consist of the four spectrograms/sonograms in the order given in figure 4 plus the resulting super-sonogram on the bottom and show each 20 second time duration.


r.pdf - Adobe Reader
SNS1
SNS2
SNS3
c
d
a
e
b
210 mm

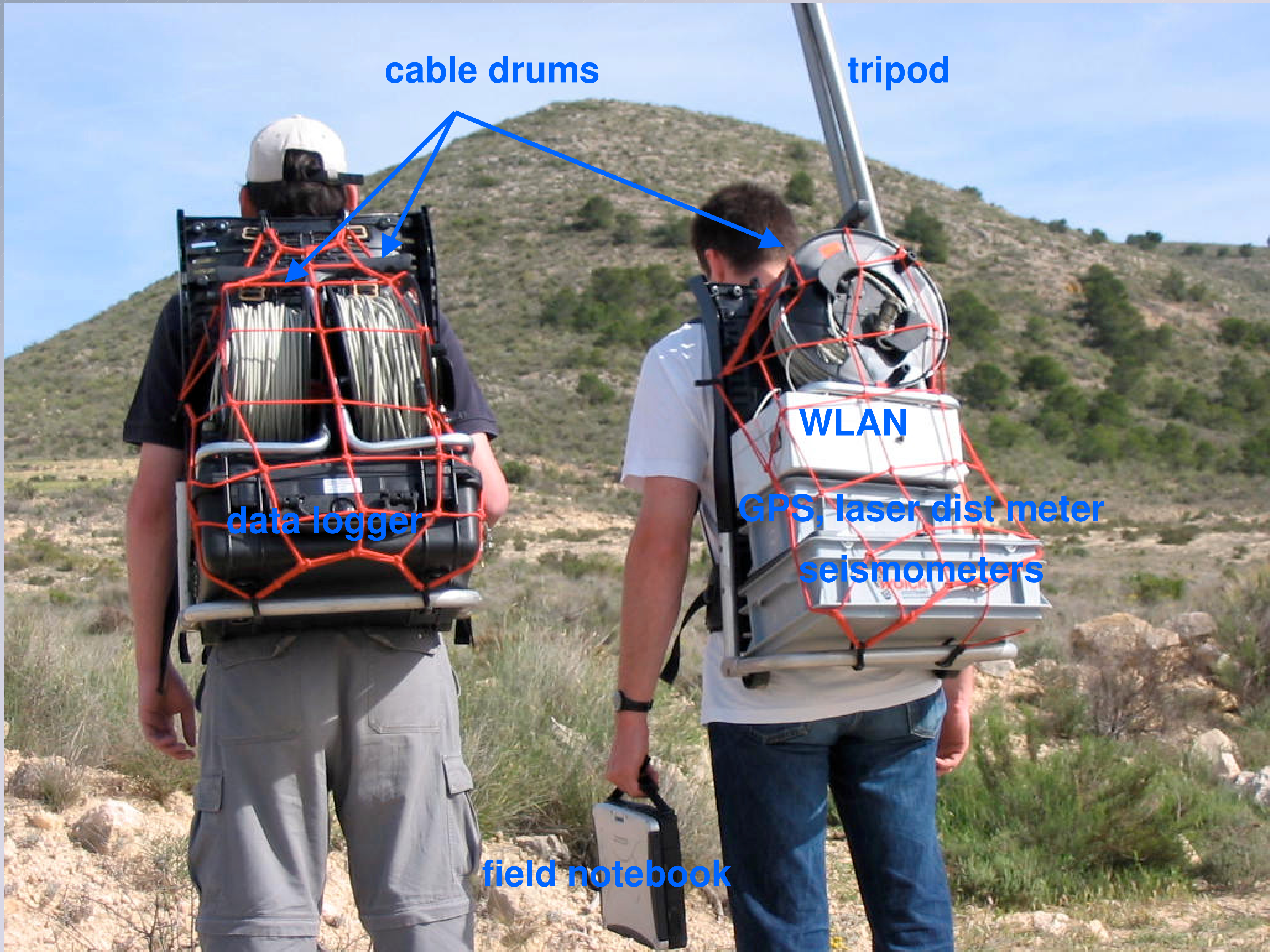

SonoView
14.08.07
16:00:00
18:00:00
14.08.07
17:30:00
17:32:00
17:42:00
17:44:00
16:45:00
17:00:00
17:15:00
17:30:00
17:45:00
18:00:00
S1S
S3S
S4S
S5S

	microseismic networks	*nanoseismic monitoring*	*passive seismic*
typical application area, completeness magn.	perm. local network 10000 km^2 M_L 1.0	temp. fault mapping 100 km^2 M_L -1.0	instrumented oil field 1 km^2 M_L -3.0
#stations (typical)	30 single 3c	3 SNS arrays	100+ array traces
select analysis segment	STA/LTA & voting	Sonograms & PR	(continuous)
noise forensics	optional	essential	none
Signal-to-Noise Ratio > +15 dB	(5:1) > 0 dB	(1:1) > -15 dB	(1:5)
status of onset phases	clear	questionable	not visible
process solution	pick all ⇒ batch	pick ⇒ live update	automated stack
test/improve solution	new run	slide any parameter*	(not applicable)
solution info	hypo, t_0, M_L, **M**	hypo, t_0, M_L statistics	
improve by master event	possible	possible	(not applicable)
identify effects of single parameter* to joint solution	indirect by time residuals to LMS solution	fully resolved in location domain by jack-knifing	(not available)

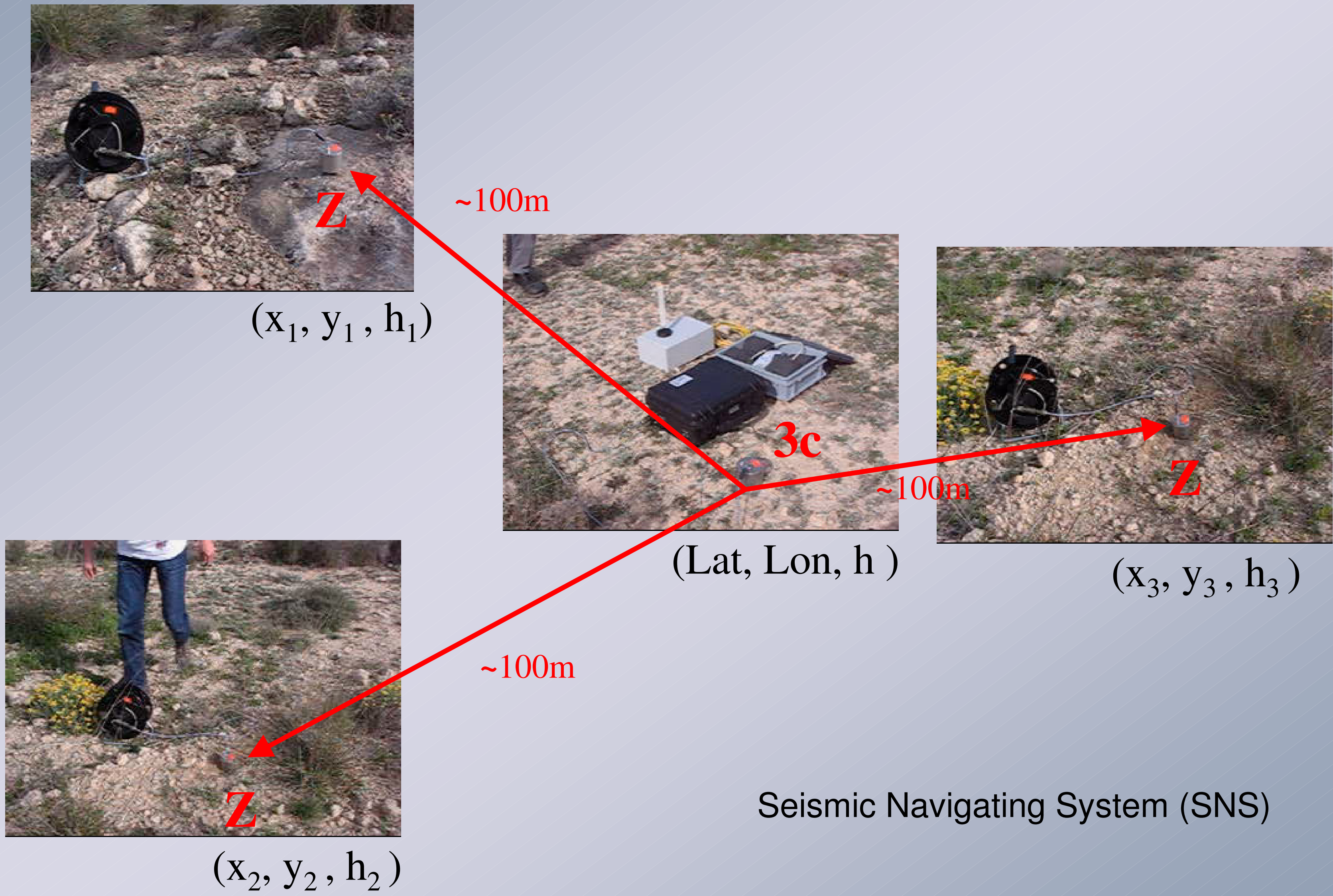
* phase picks, forced depth, layer model

Integrated Field Exercise 2008 - Travel

Be Portable !


cable drums
tripod
WLAN
data logger
GPS, laser dist meter
seismometers
field notebook

Tripartite, Equilateral Array with 3-Comp Center Station



Seismic Navigating System (SNS)

Field activities - Zusammenfassung

Installation

- 27 Kleinarrays sowie 2*3c Seismometer eines Kleinarrays in IA zwischen 4.9 – 8.9.2008
  (manpower: 4 Feldteams a 2 Teammitglieder)

- 3*3c Einzelstationen am 11.9.2008

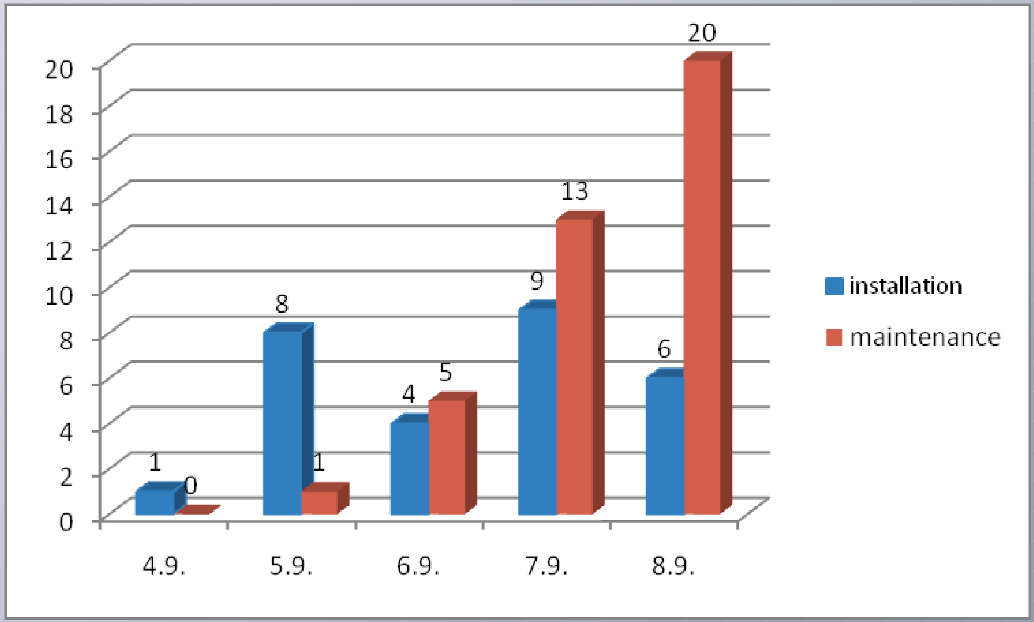
Instandhaltung

- ab 9.9.2008: routine maintenance (data collection, battery exchange)

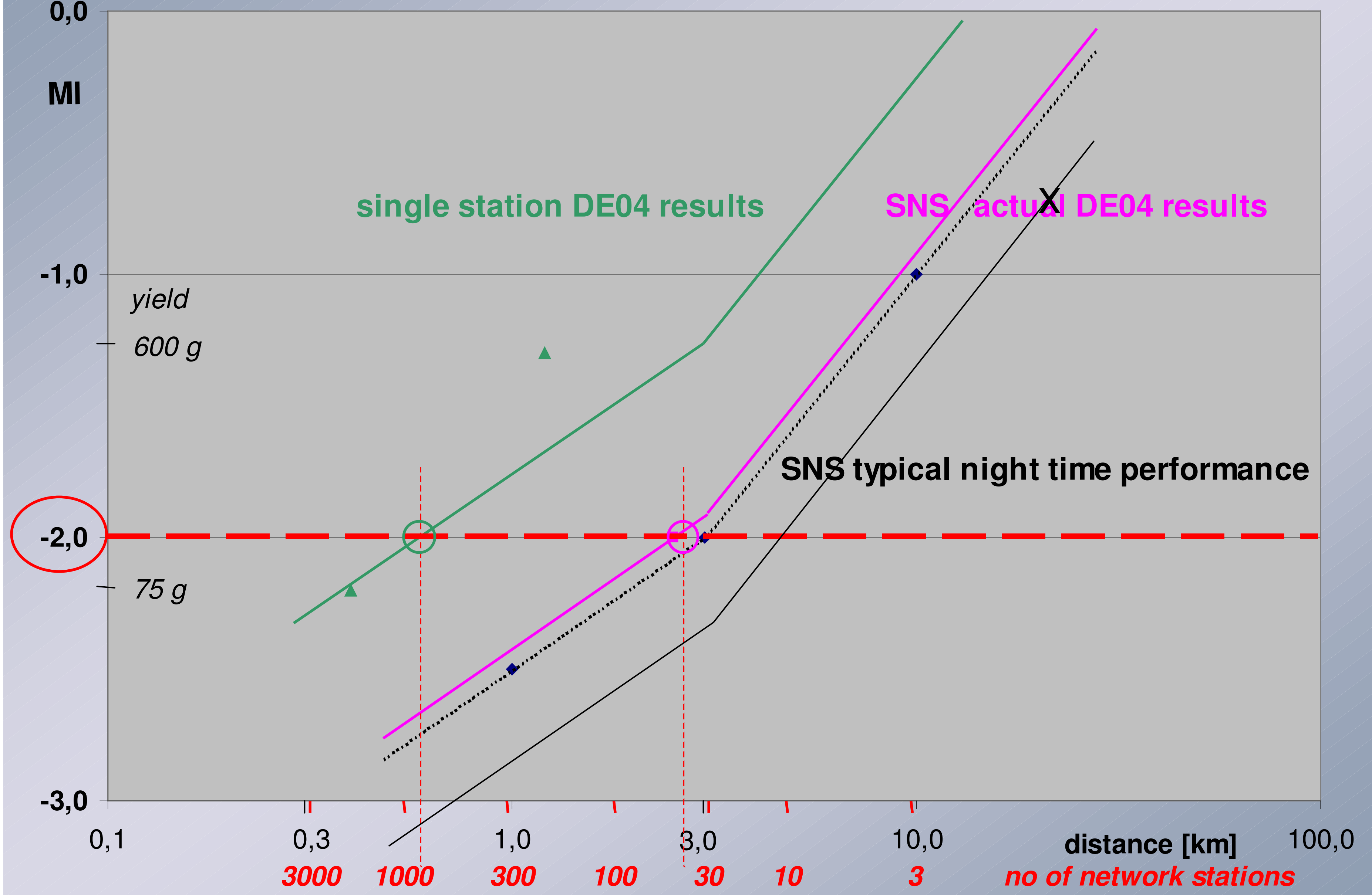
Decommission

- alle Stationen 17.-19.9.2008

Ausführliche schriftliche Dokumentation sämtlicher Operationen (installation, maintenance, decomission)



Detection threshold



Results

- Unfavorable weather conditions in the period 5.-7.9 (heavy rain and strong wind) =>reduced detection capability for this time period.

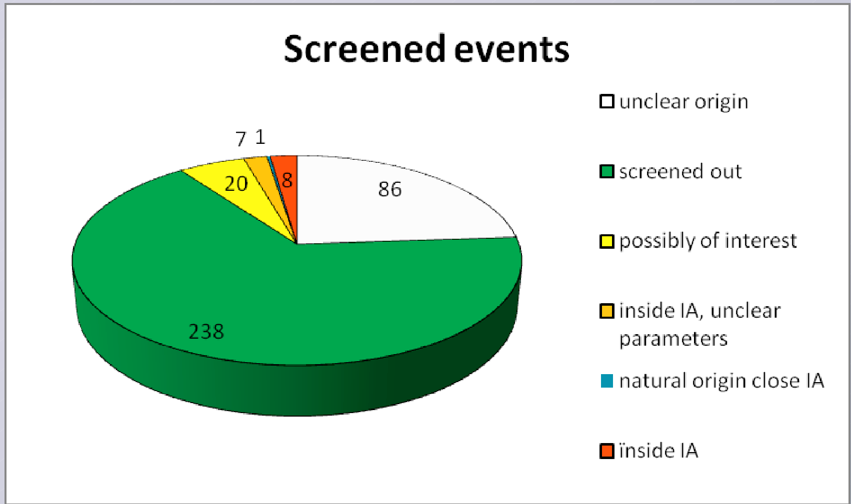
- Weather conditions improved for the period 8.-13.9

- Sensitivity of SAMS network was high in the period 8.-13.9. This is demonstrated by detection and location of natural event M_L -0.7 on 11.9 at 18:43:25h SW of IA with epidist ~20 km
  => detection sensitivity estimation of network: M_L -2 in 3-4 km during certain periods

- Data were fully screened for the period 5.-13.9. Teleseismic, regional, local activity outside IA and local activity inside IA were recorded by the network.

- 360 events were identified during the screening. Teleseismic and regional outside IA were not analyzed.

- Final catalogue: 15 events identified inside, or potentially inside, IA. Epicenters are inside IA, however, error ellipses include also area outside IA in some cases



Screening results for the period 5.9-13.9