Detecting and locating microseismic events using downhole arrays

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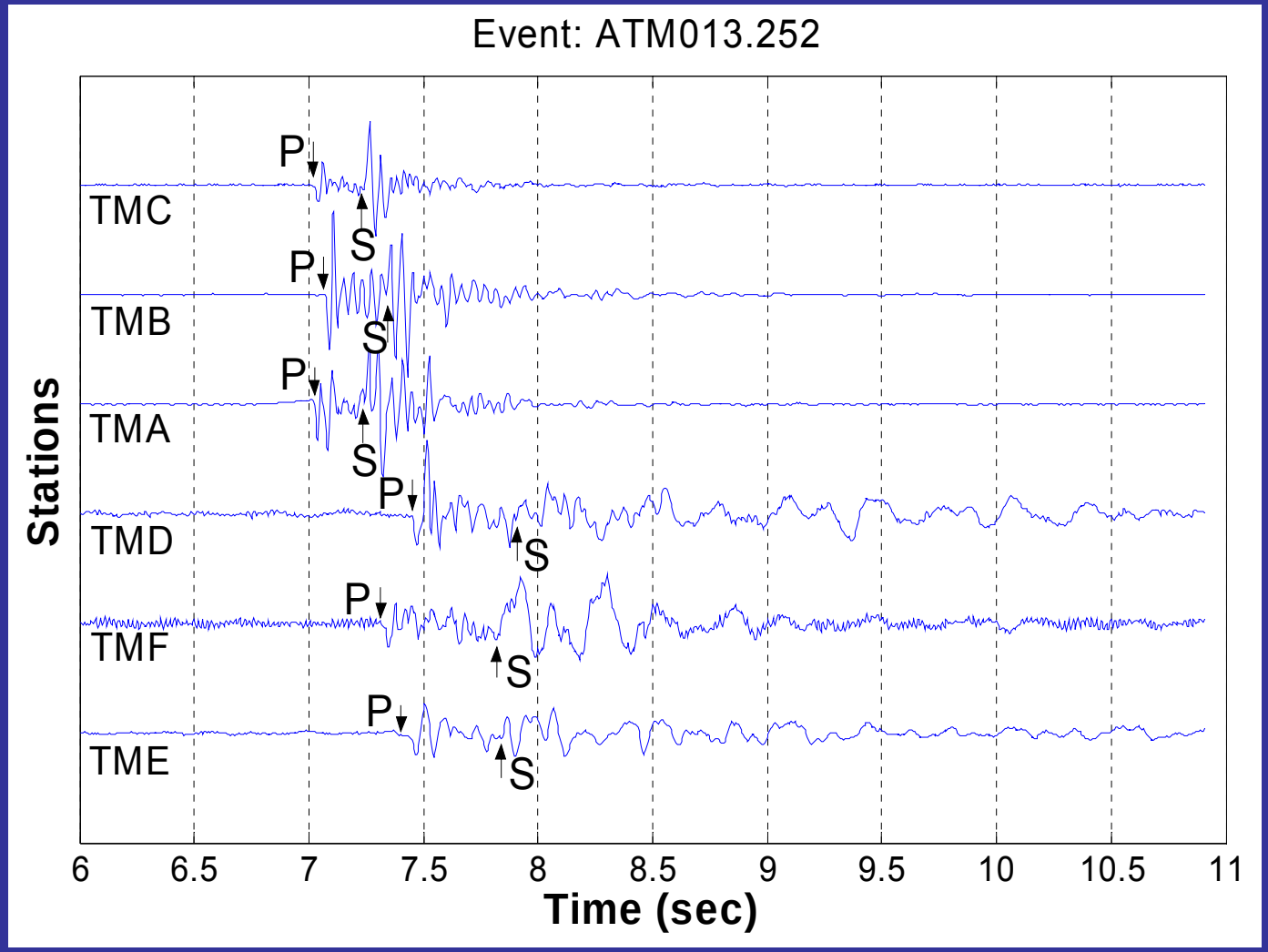
Monitoring & its issues

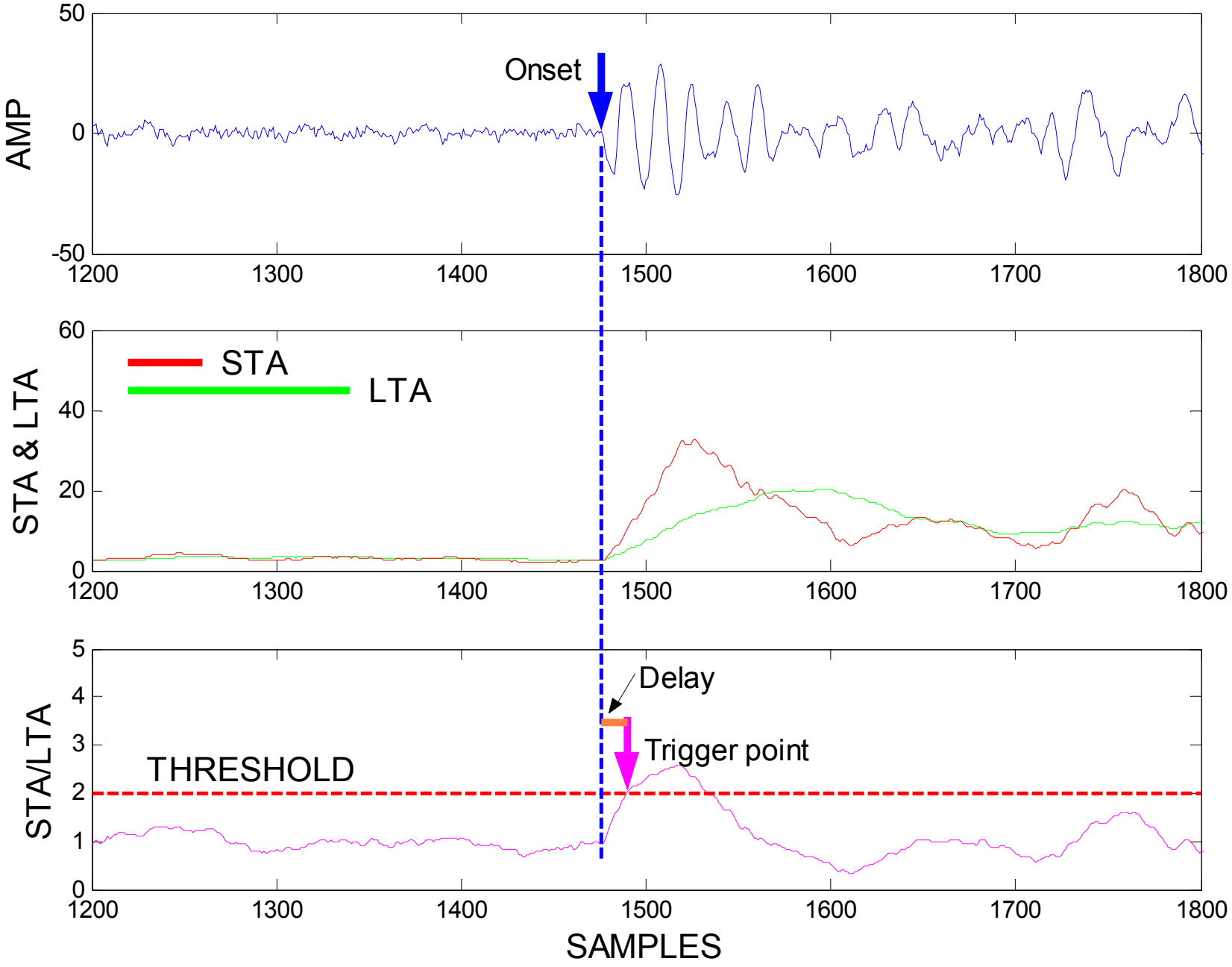
- Petroleum - Effect of injectants, movement of fluids, failures, geologic changes
- Hazards – mass movement prediction & occurence
- Exactly where did events occur? Why?
- What happens if there are poor data, station failures?

Remote, Wireless, Permanent Seismic Stations: A Mountain Case

Station locations

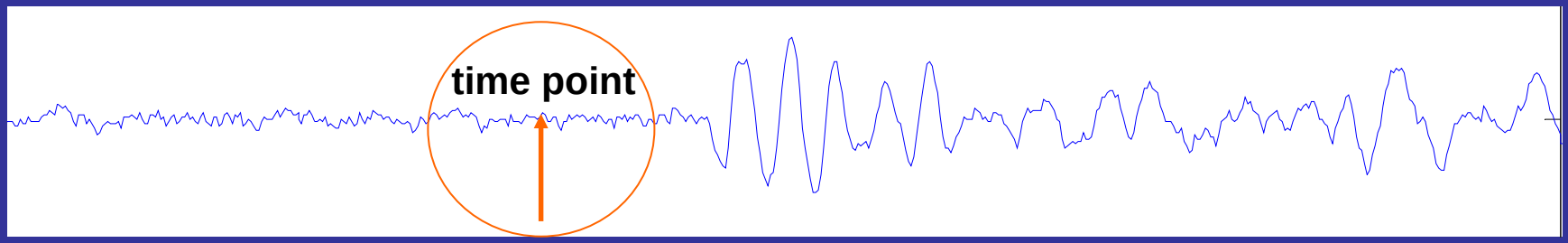
An example of a seismogram recorded




AMP
50
0
-50
Onset
1200
1300
1400
1500
1600
1700
1800
STA & LTA
60
40
20
0
STA
LTA
STA/LTA
5
4
3
2
1
0
Delay
Trigger point
THRESHOLD
SAMPLES

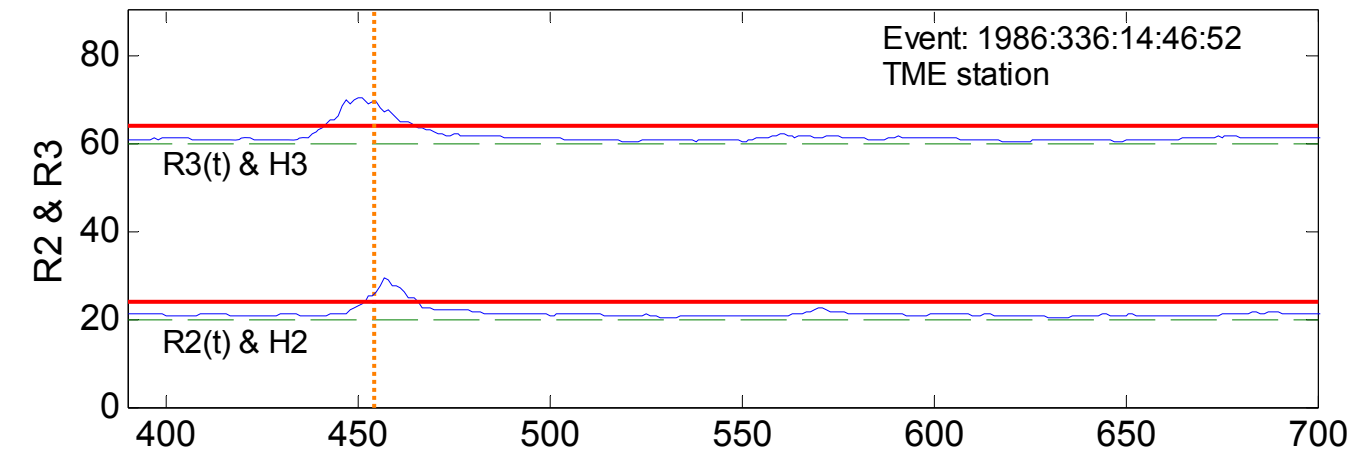
Definitions of multiple time windows

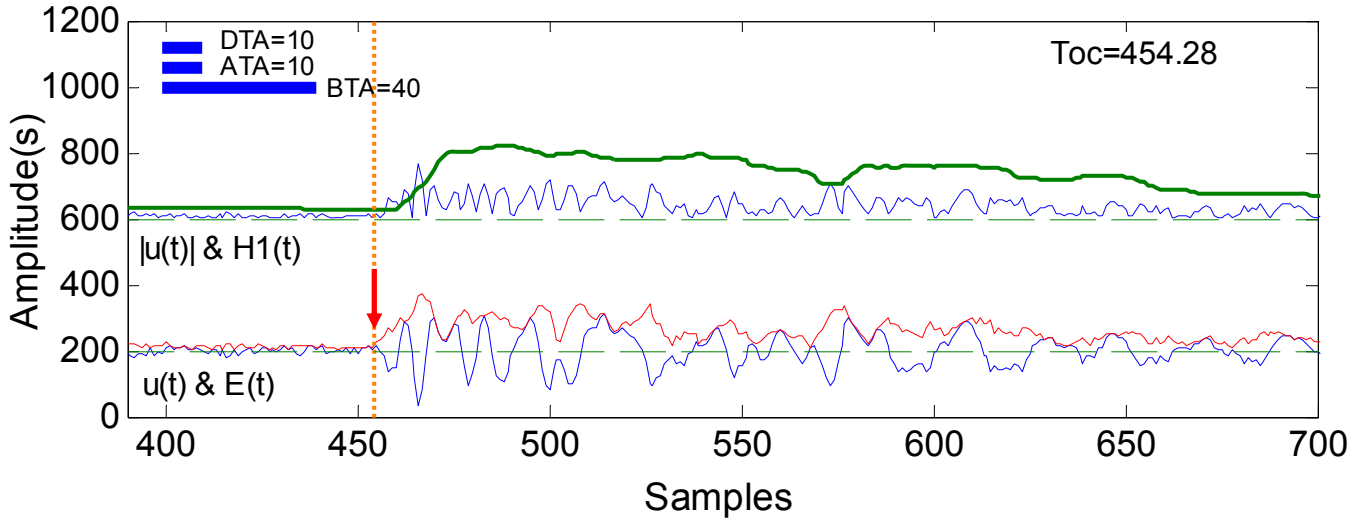
BTA (Before Term Average)
ATA (After Term Average)
DTA (Delayed Term Average)
DLY (Delay of DTA window)



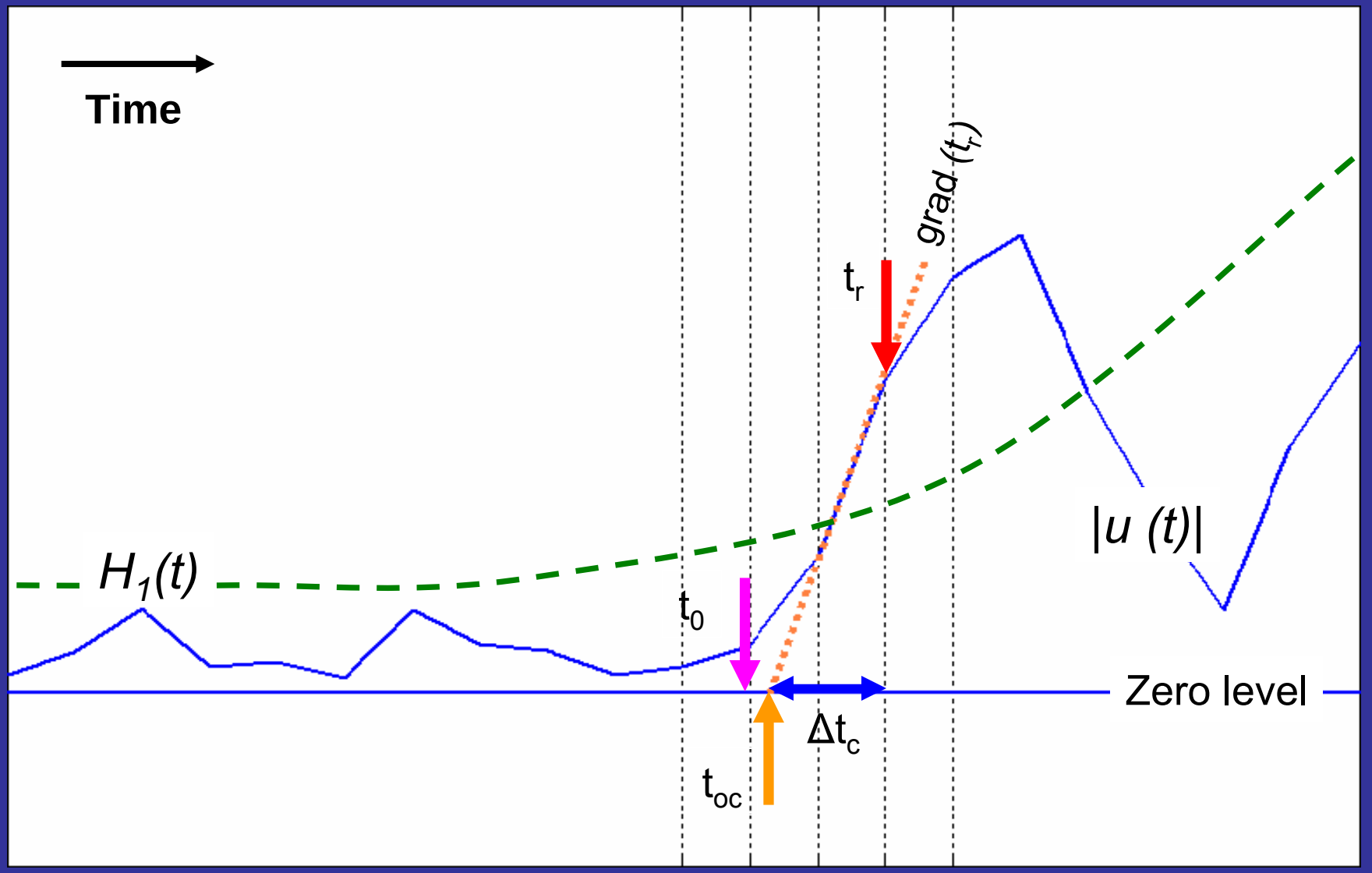
BTA *ATA* *DLY* *DTA*

Picking onset of an event on real seismic data



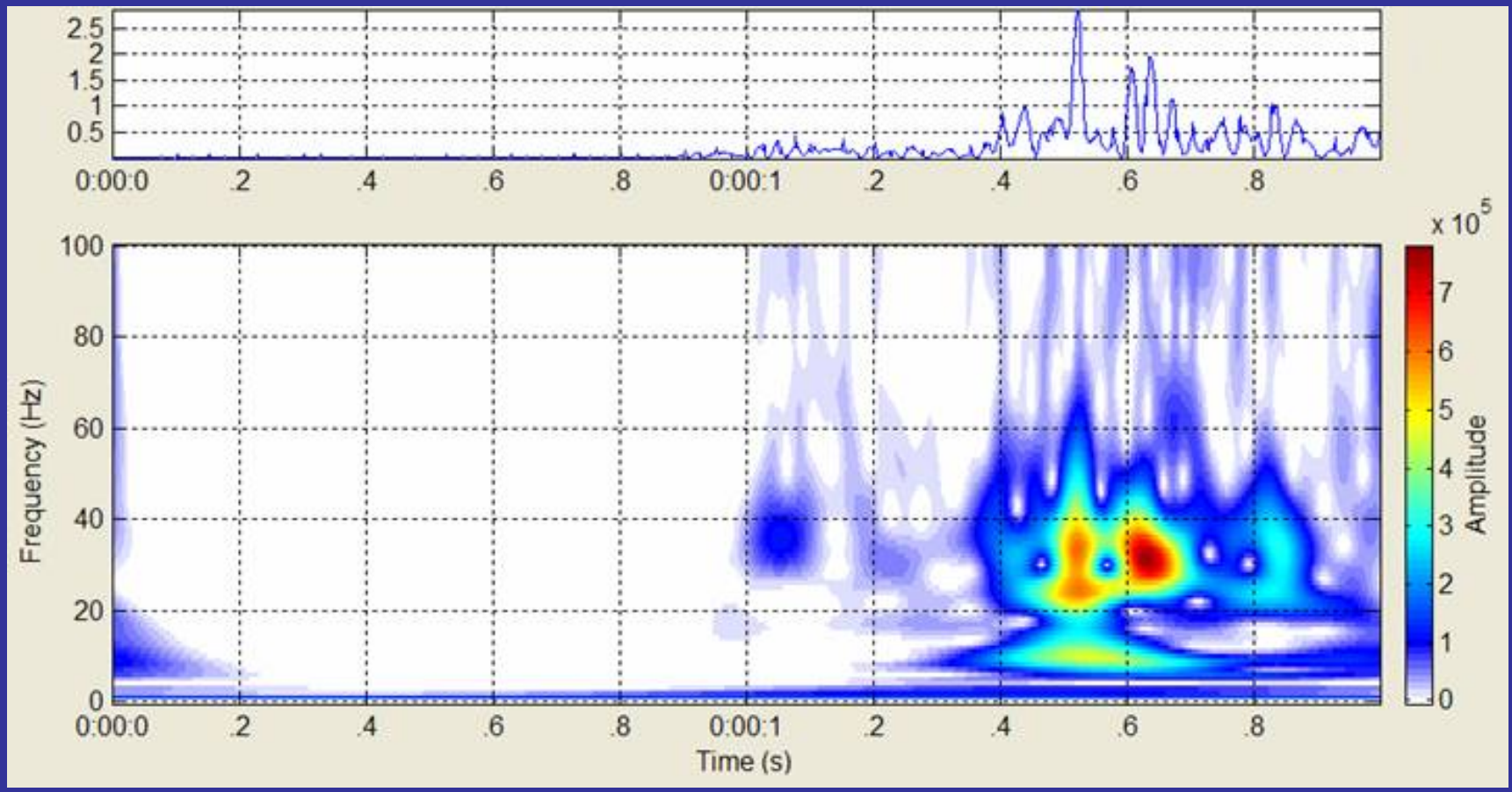


Waveform correction



S-transform methods

(local spectral estimator –Pinnegar, Munro, Stewart, 2006)



Event picking error
(A&R, 1980; Stewart et al., 1984)

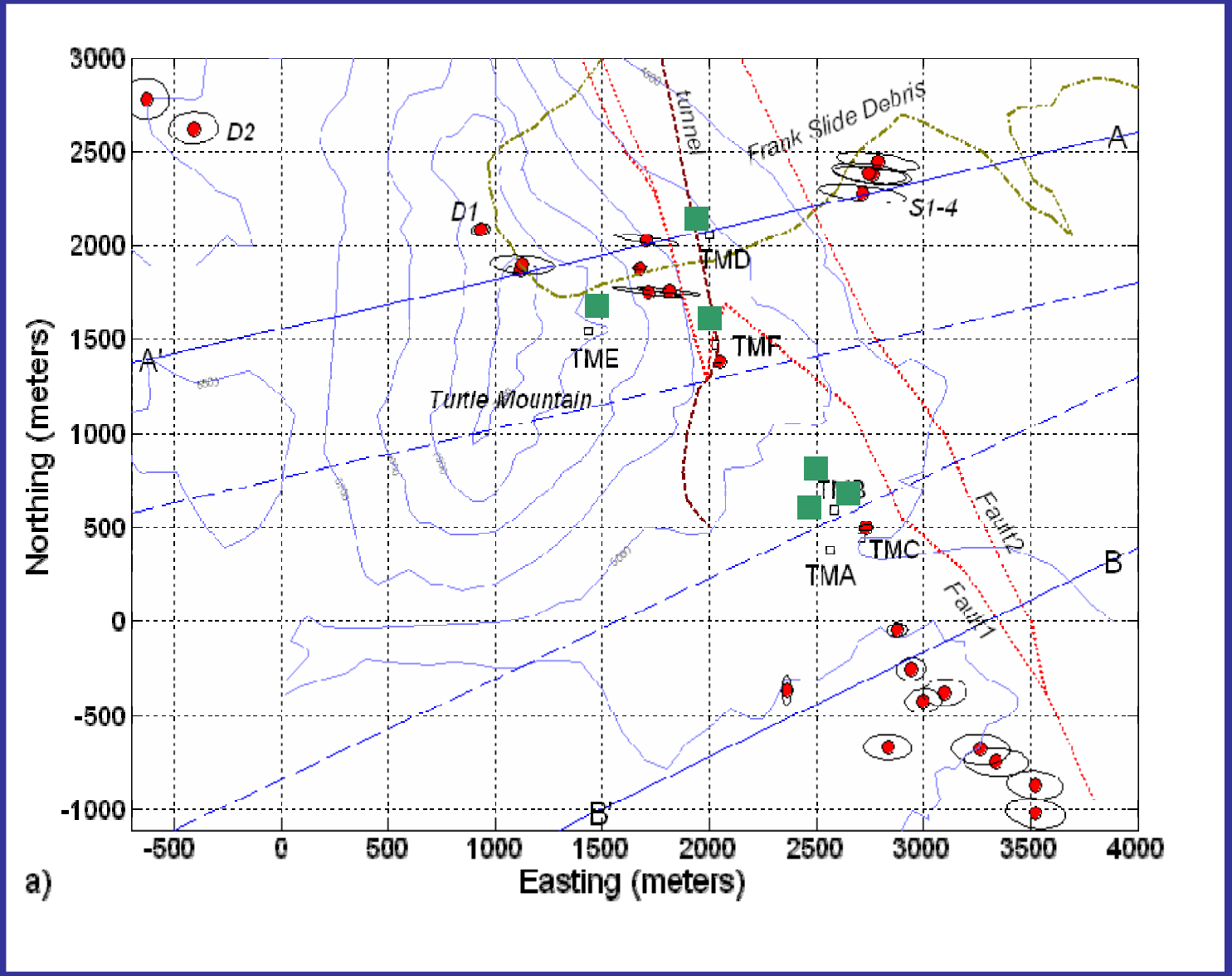
- Single seismogram/channel pick error:

$$\Delta t = 1/f_{max} \log_2 (1 + (S/N)^2)$$

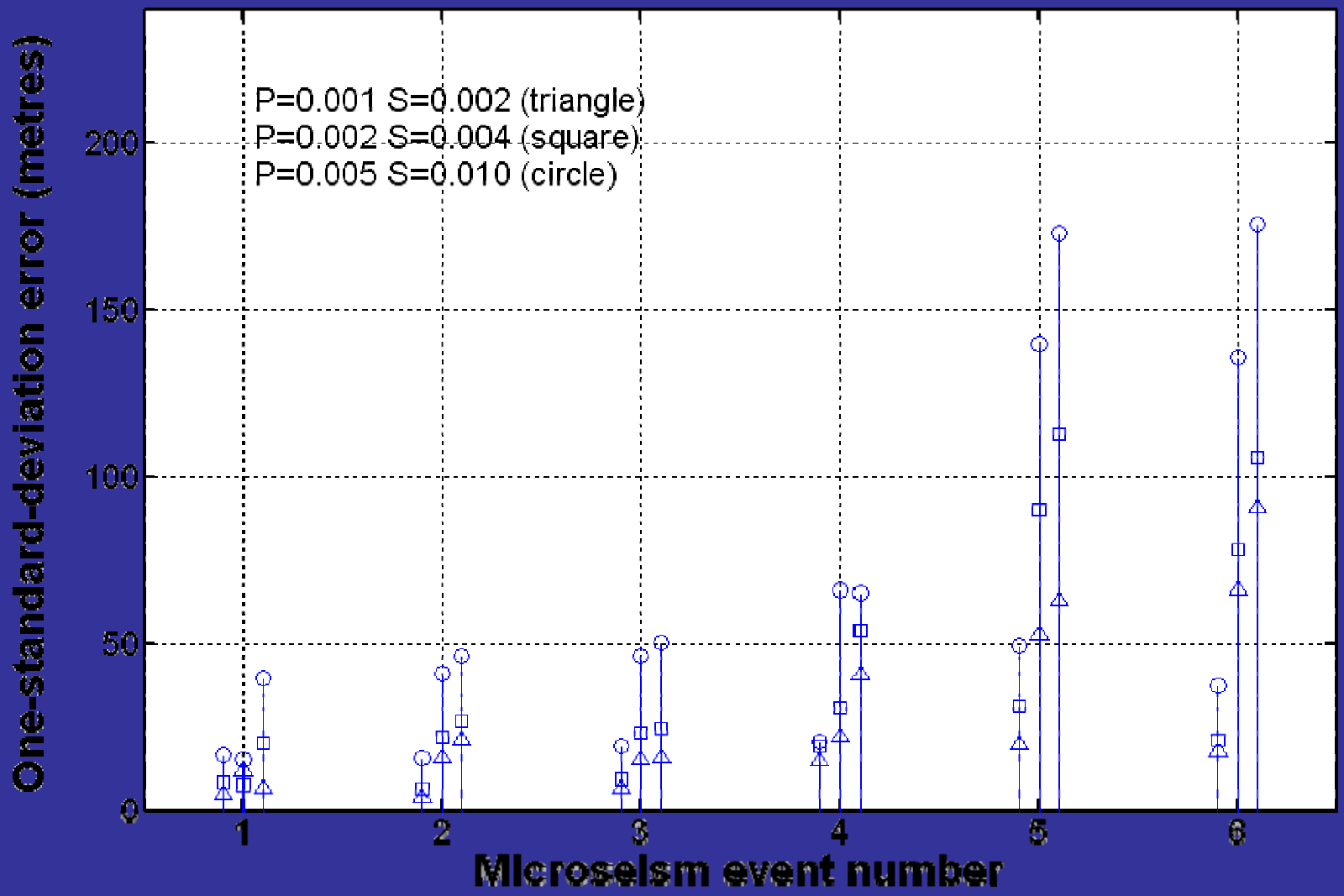
for example, if f_{max} = 100Hz, S/N = 5

then Δt = 2ms

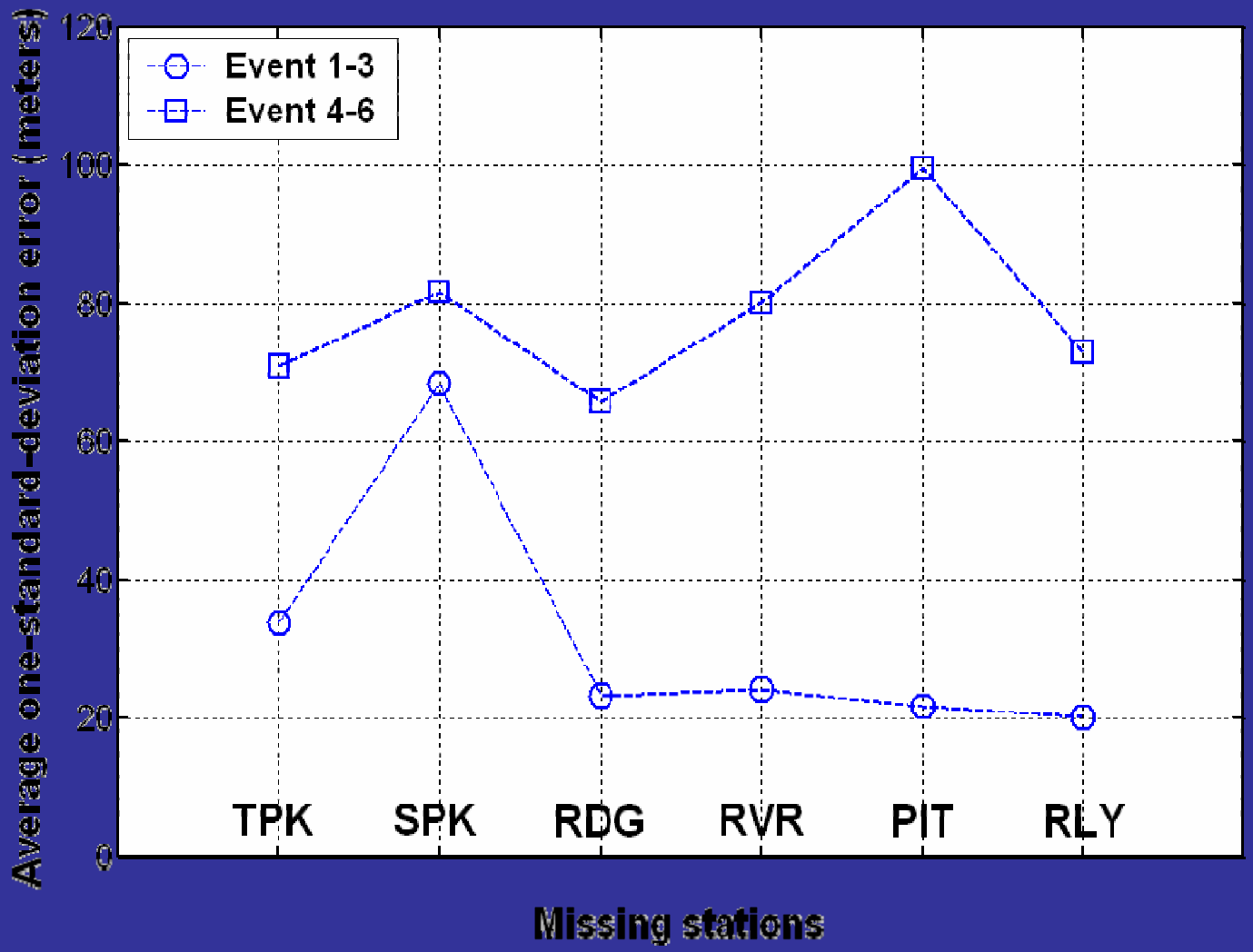
Error estimates by a surface array



Error in hypocentre location

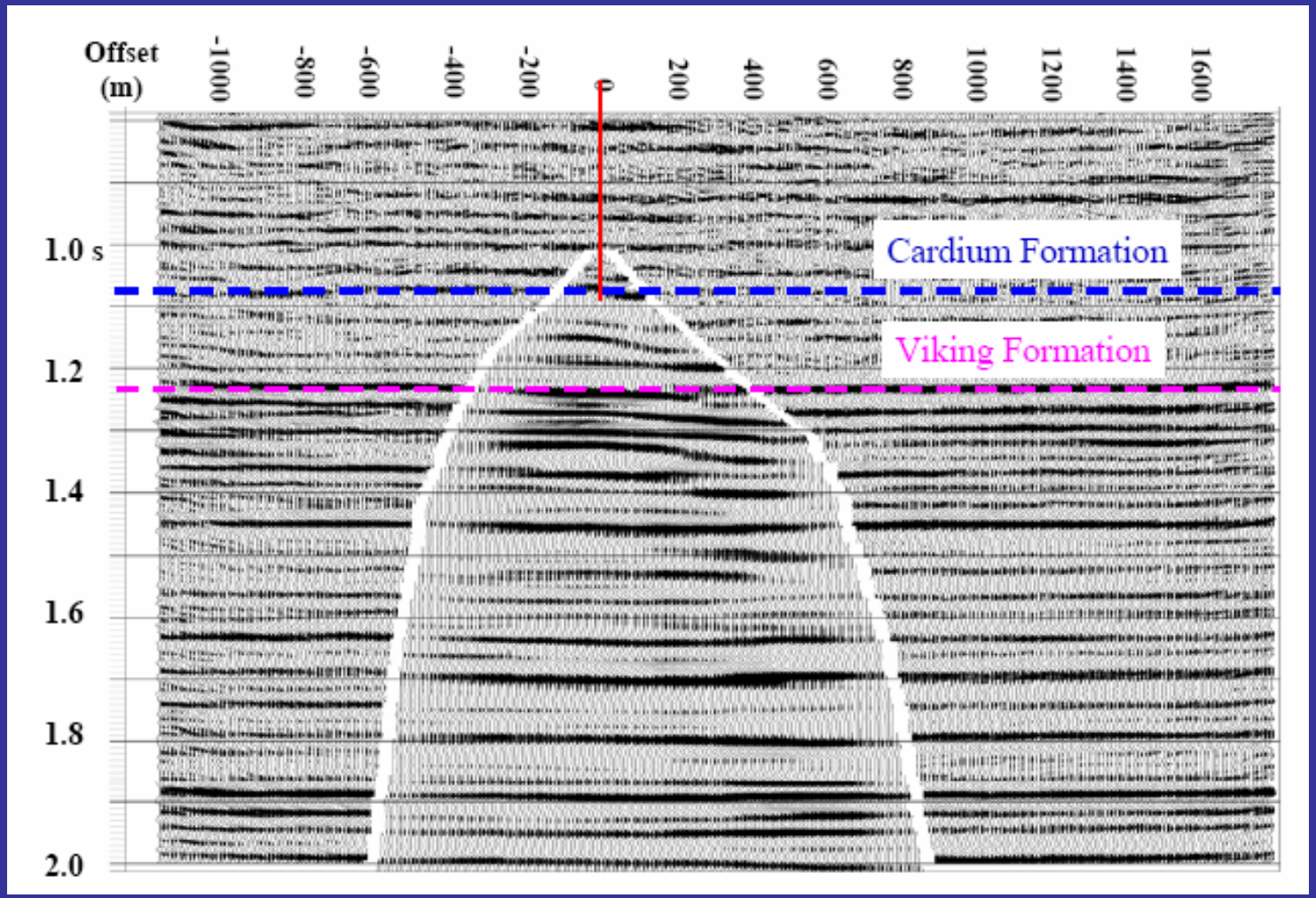


Overall sensitivity to station loss

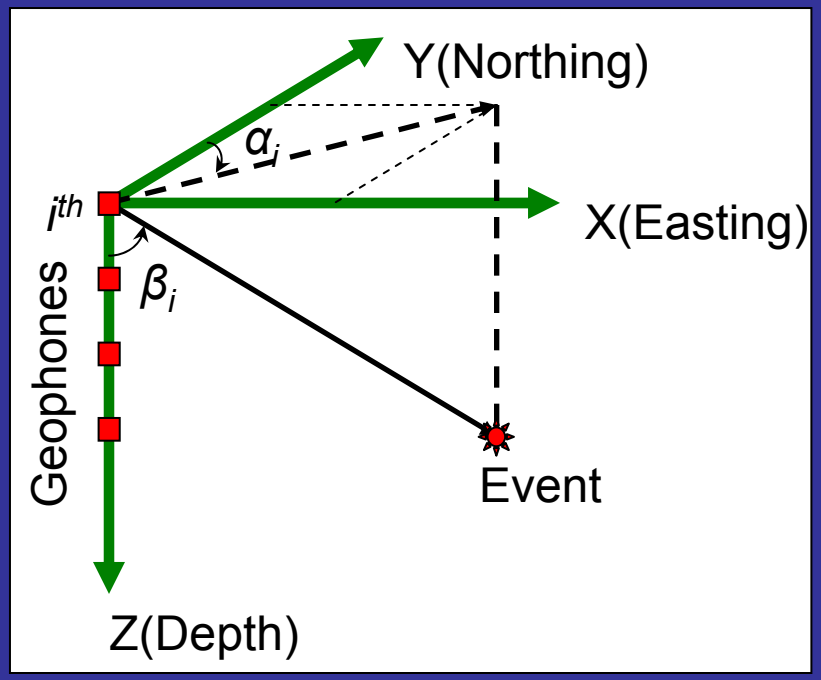


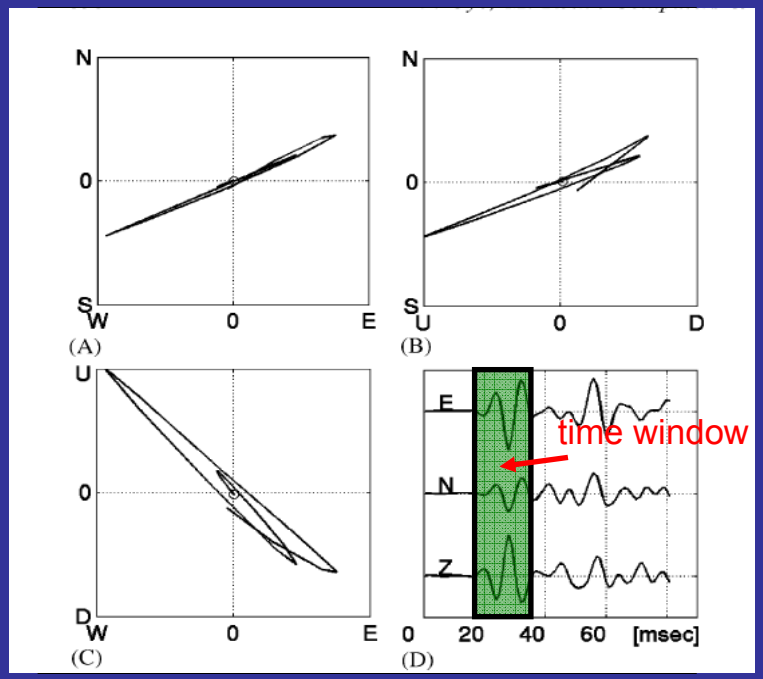
Installation of eight-level 3C geophone string in the well at Violet Grave

Violet Grove CO_2 EOR/sequestration Project (Coueslan et al., 2006)



Current microseismic monitoring method

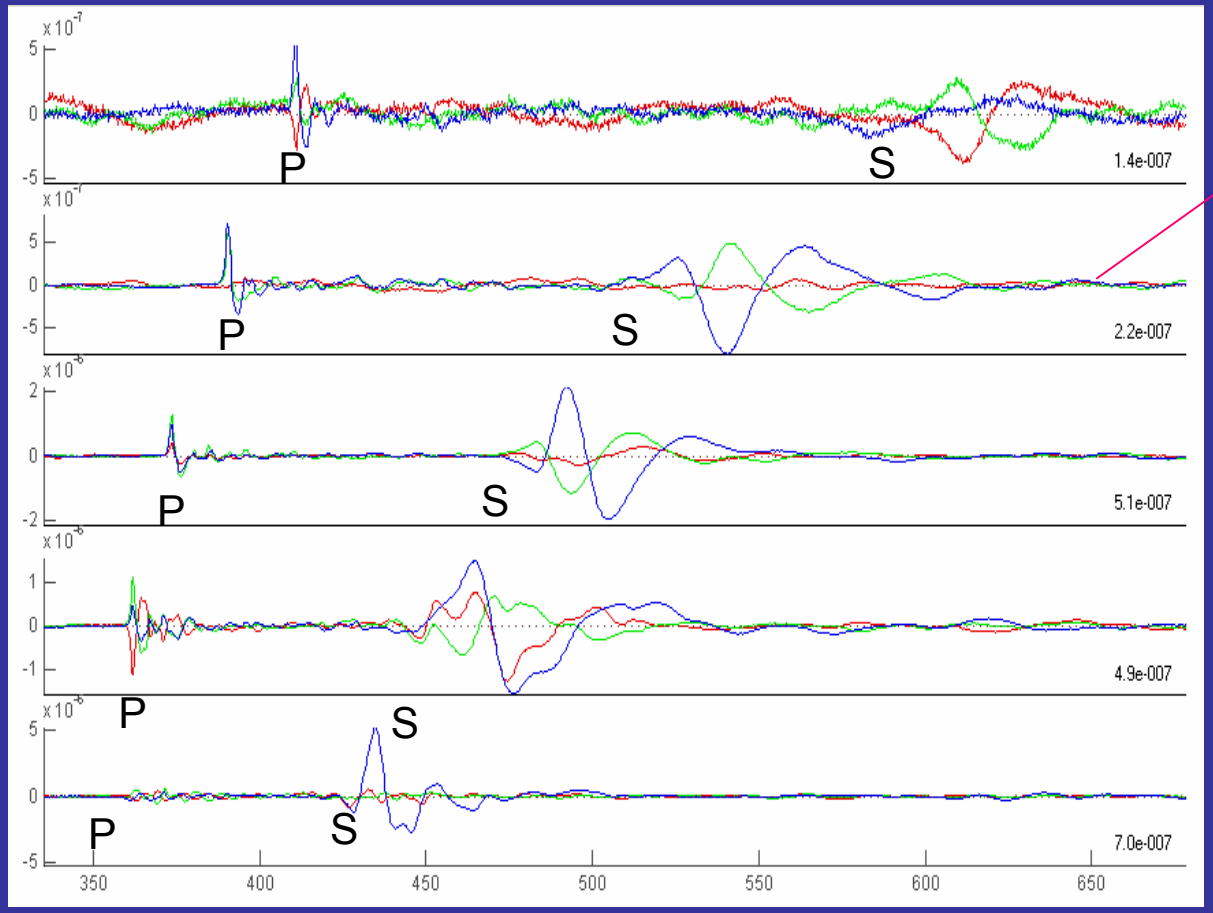


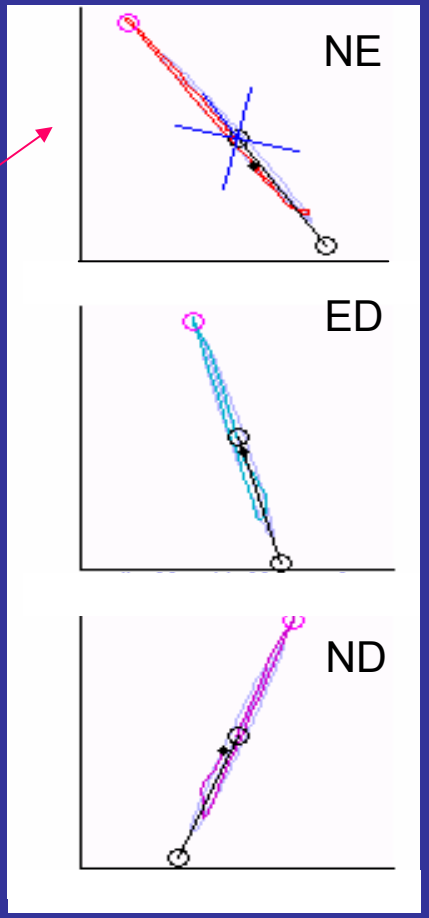


α_i: azimuth of i^{th} geophone
β_i: angle of incidence of i^{th} geophone

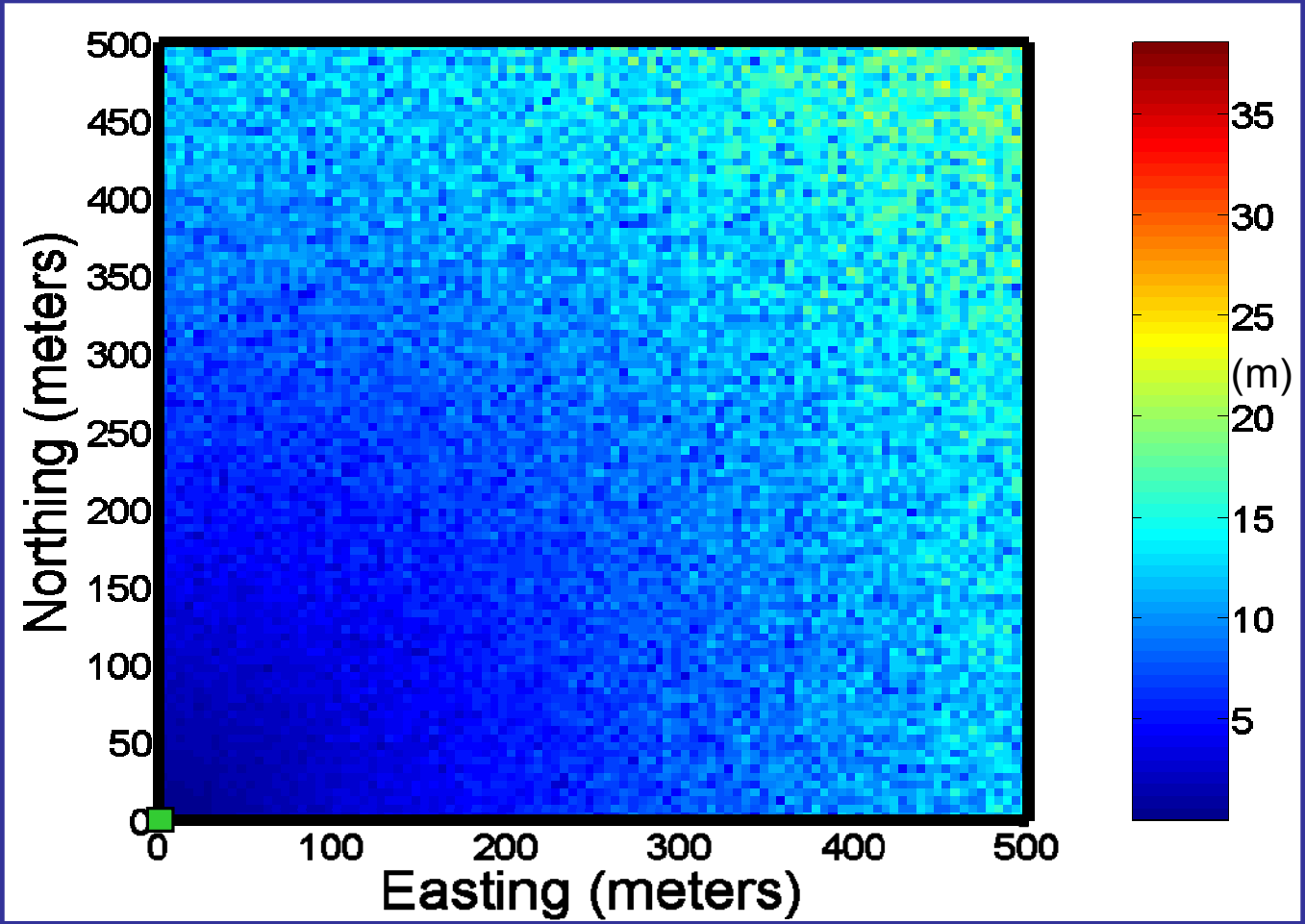
Measurements of the azimuth and angle of incidence

An example of seismograms and hodograms of an event recorded in Cold Lake VSP monitoring

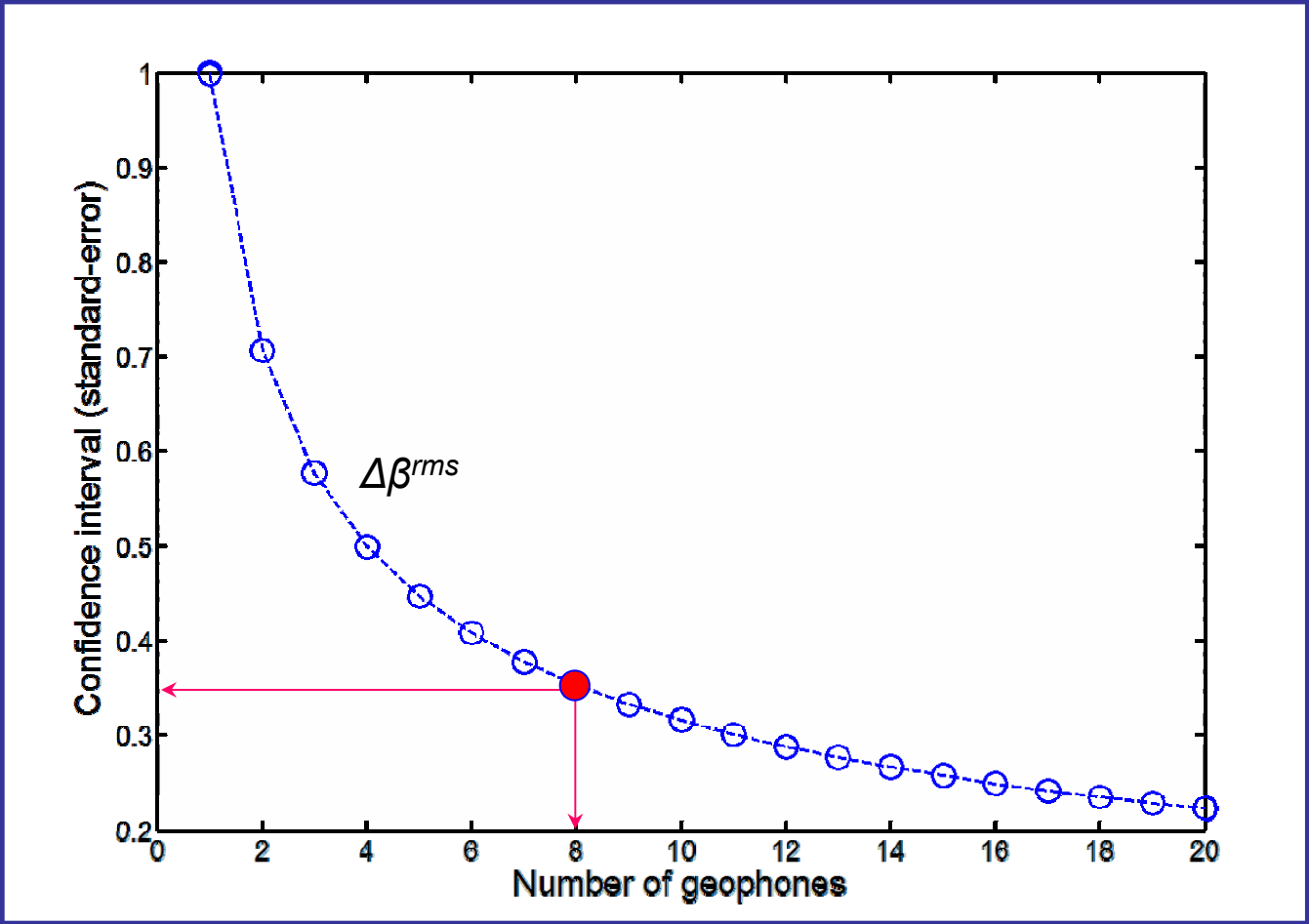




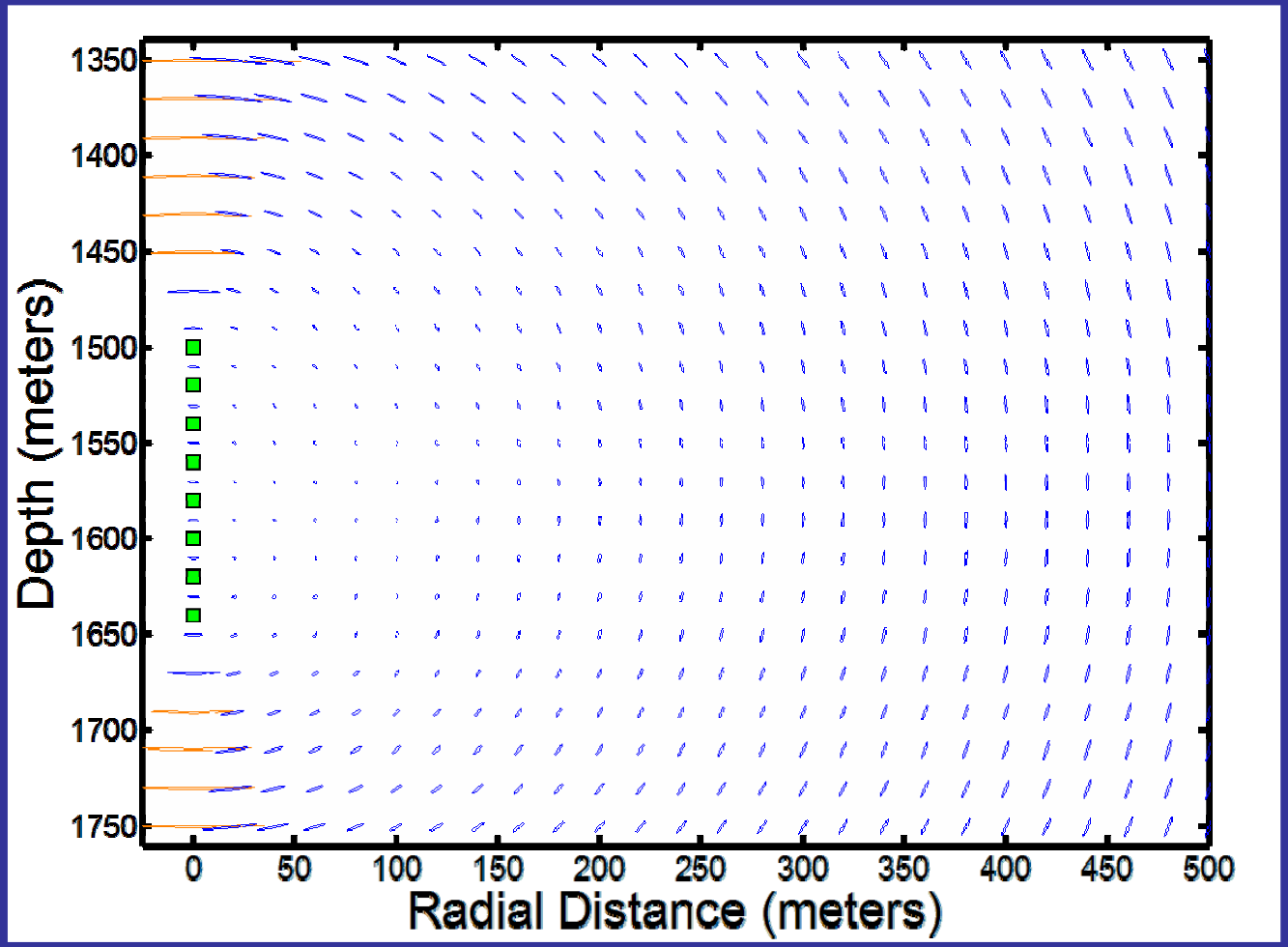
Results of transverse error in a numerical experiment



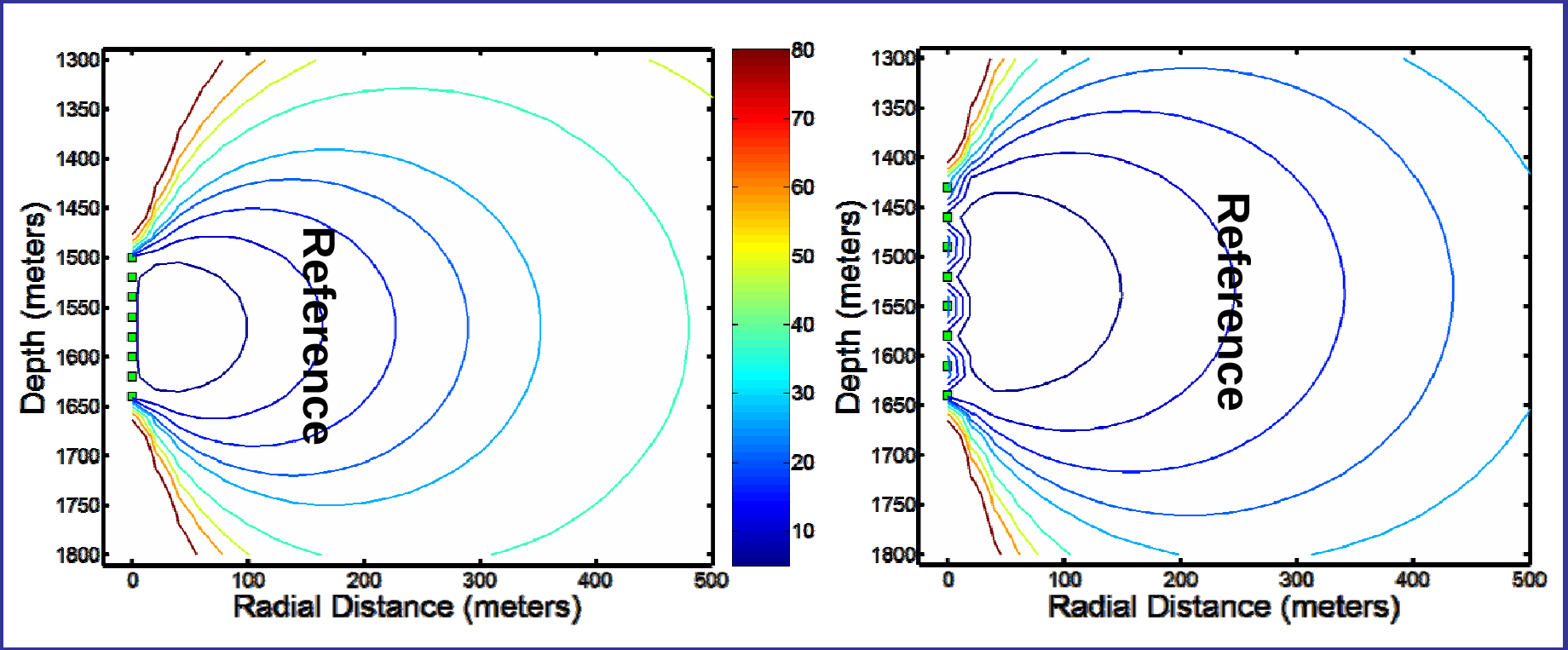
Effects of the number of geophones in a VSP array



Position errors in the vertical plane (geophone spacing interval 20 meters)



Comparison of the maximum angular error (contour maps) in vertical plane



Conclusions

- Applications of seismic monitoring are rapidly increasing
  - New event detectors under development – more sensors help
- Hypocentre location is key in passive seismic monitoring
- Event picking error can cause hypocentre misplacement
  - Azimuthal estimates assisted by more sensors
- Radial errors reduced by larger aperatures

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