Modeling the Rupture Process of the Tokachi-Oki Earthquake using 1-Hz GPS

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Purdue: Jennifer Haase and Gordon Emore

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Outline

- High-Rate GPS
- 1-Hz Observations from Tokachi-Oki
- Model Results
- Implications for Earthscope (PBO) & real-time systems

Traditional GPS

- Sample at 30 sec.
- Edit data.
- Decimate to 5 min.
- Orbits are held fixed.
- Estimate one position per day.

1-Hz GPS

- Sample at 1 Hz
- Edit data.
- No decimation.
- Orbits are held fixed.
- Estimate one position per second.

We use the same software (JPL-GIPSY) to analyze the data.

Traditional GPS

- 24-28 satellites are viewed for 24 hours
- Geometry of the satellites affects position minimally.

1-Hz GPS

- 6-8 satellites will be viewed within 1 hour.
- Geometry of the satellites in the sky determines the precision.

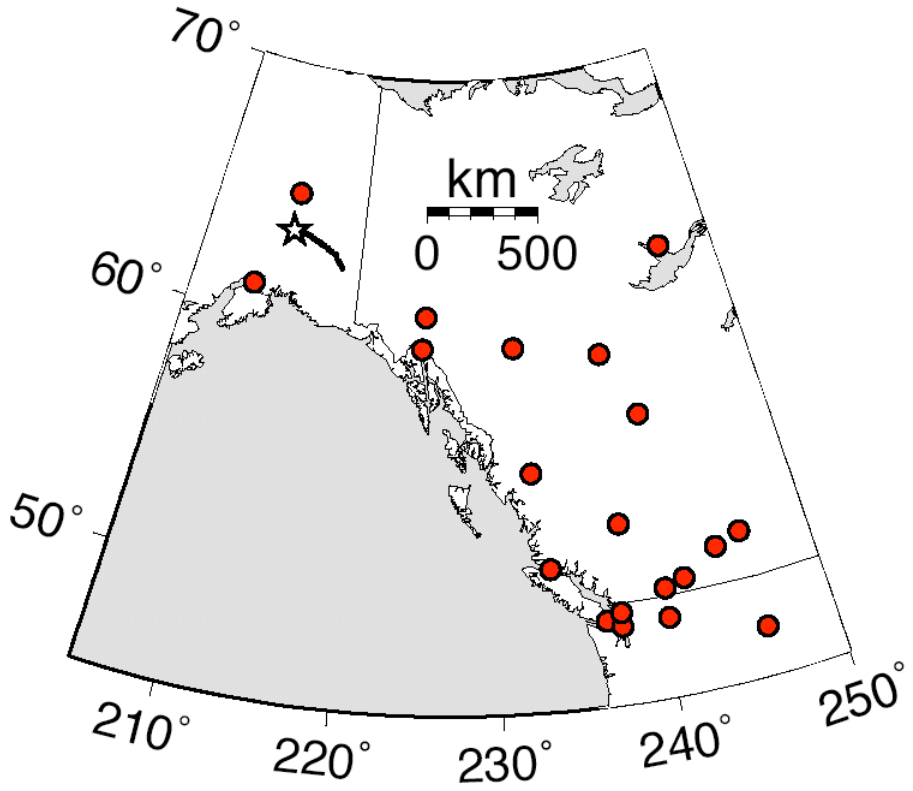
1-Hz GPS

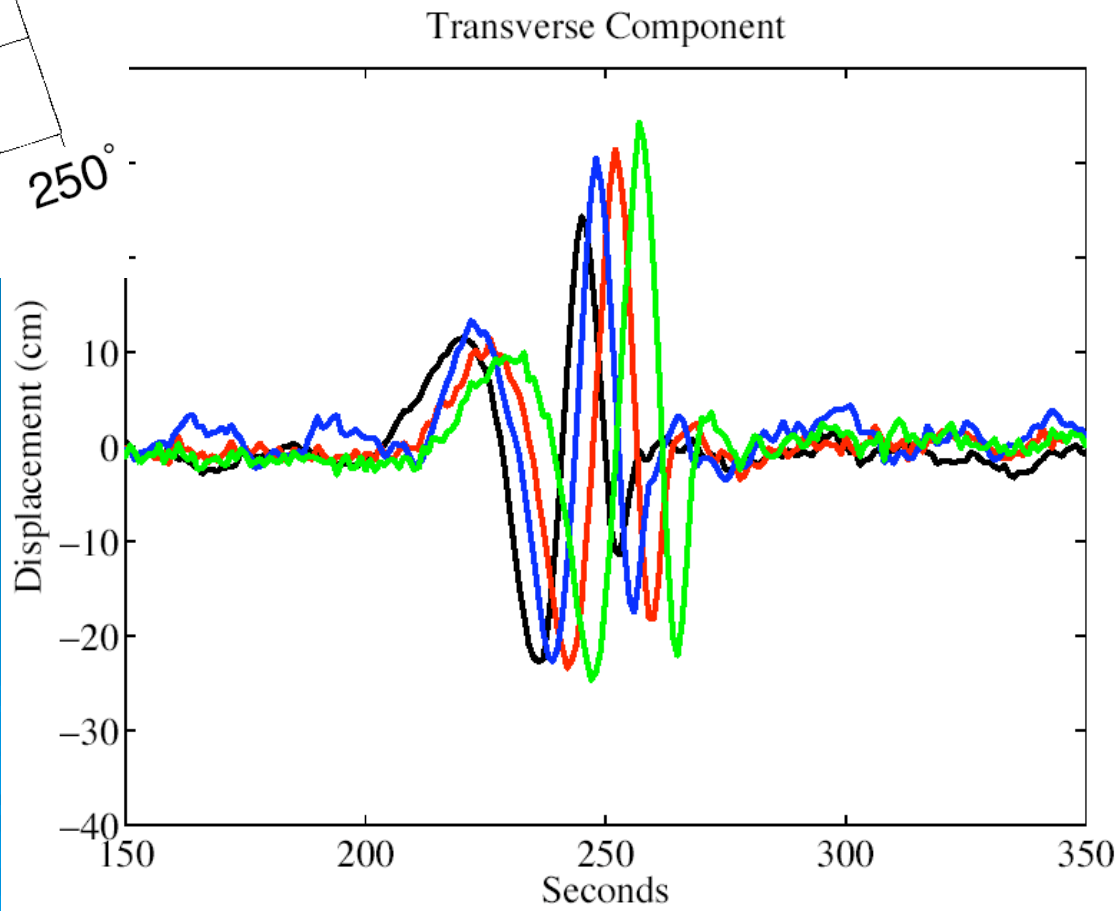
- Relative ground motions [i.e. to a site held fixed]
- *Displacement* estimated
- Insensitive to small ground motions, but no upper limit…

Seismology

- Inertial local reference frame ground motions
- *Acceleration* measured
- Sensitive to small ground velocities or large accelerations

Denali Earthquake





San Simeon Earthquake

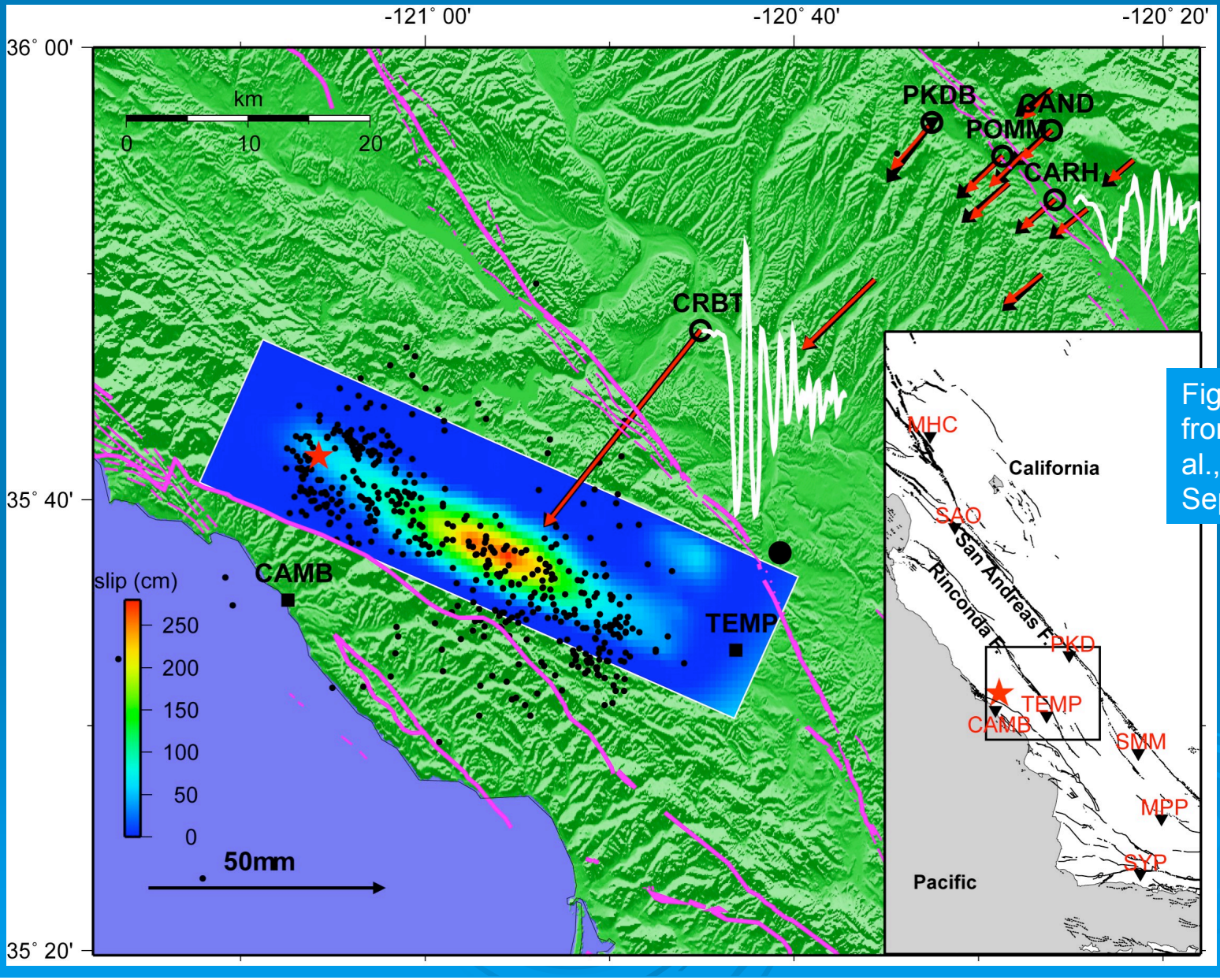
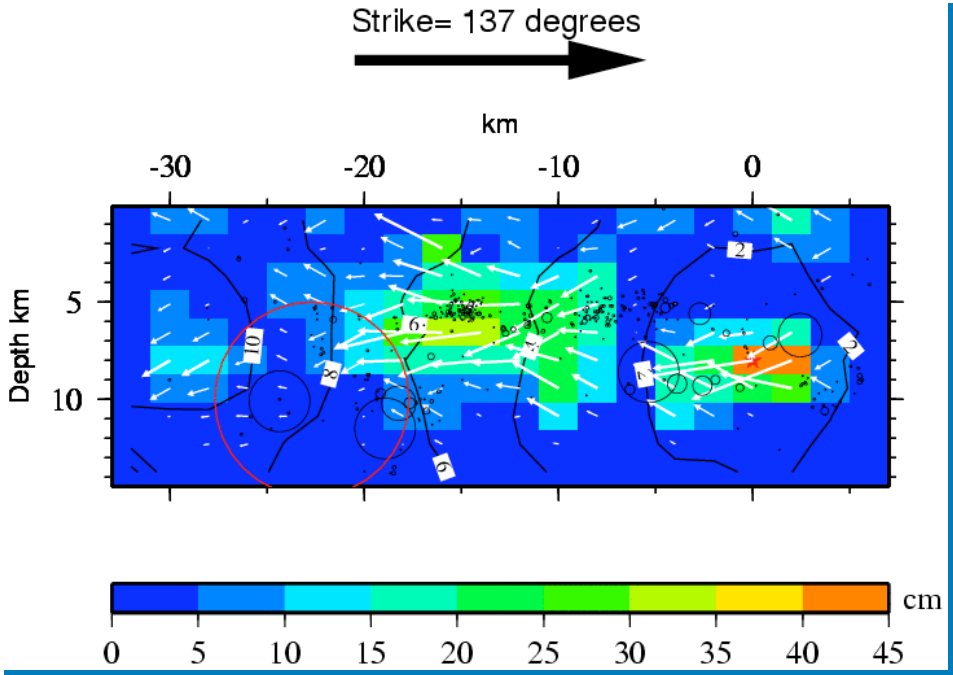
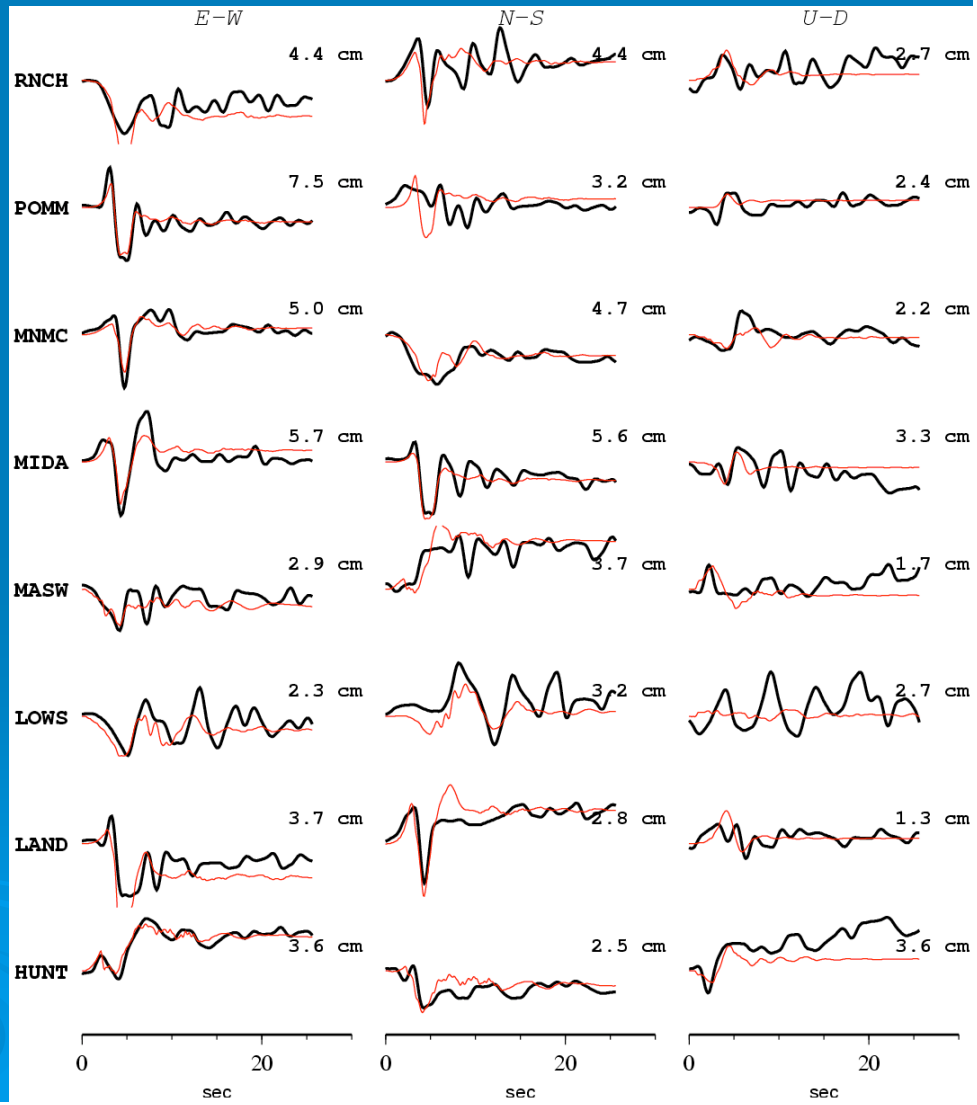


Figure from Ji et al., GRL Sept. 2004

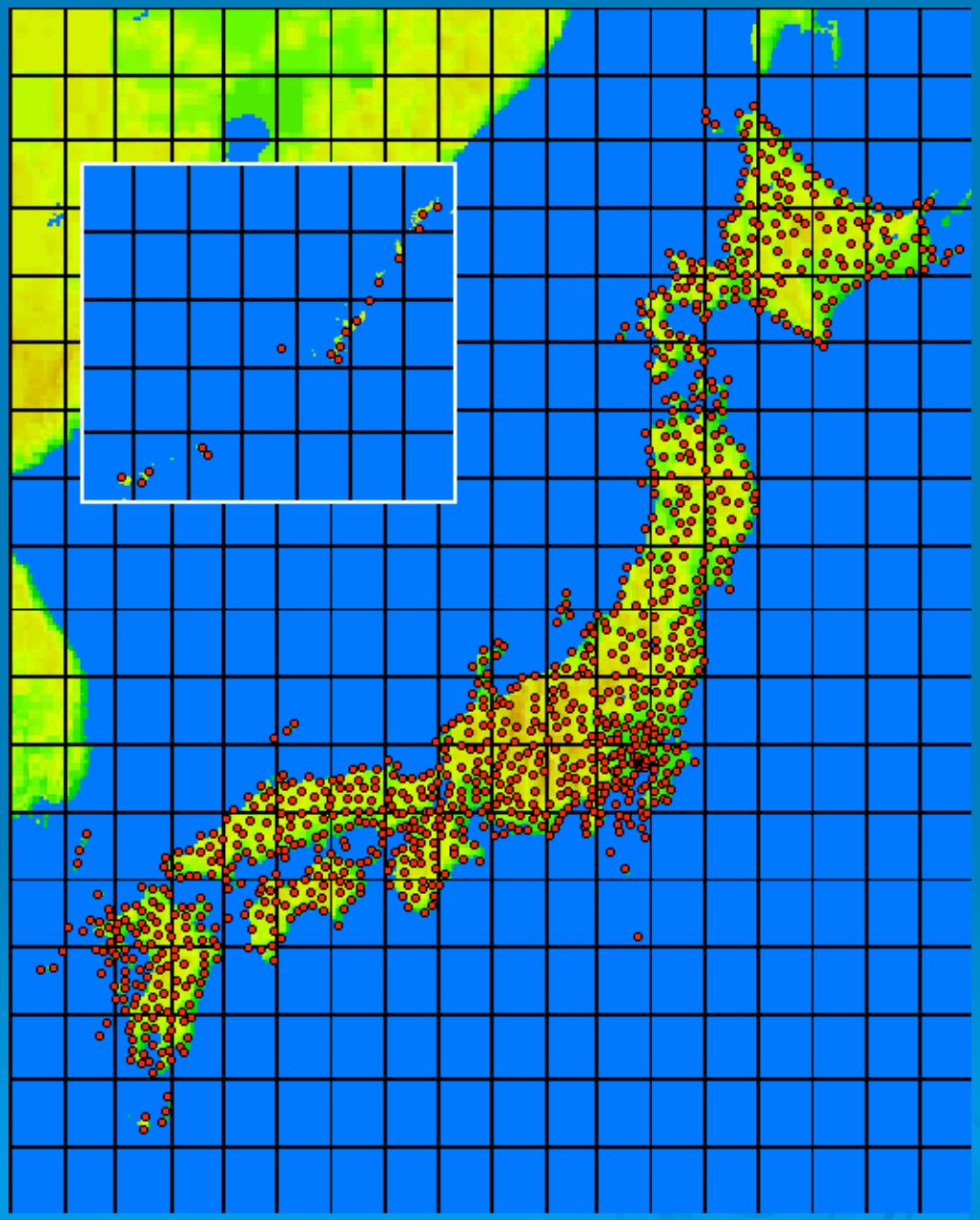


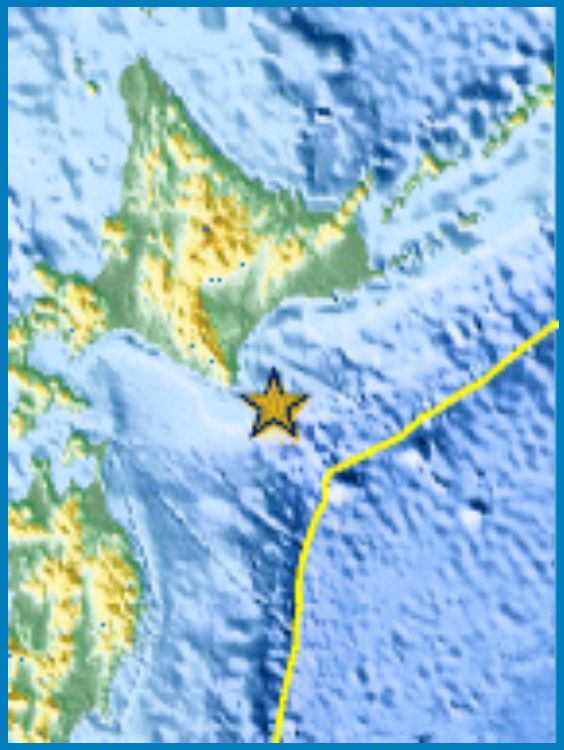
Parkfield Earthquake

Chen Ji's Preliminary Slip Model

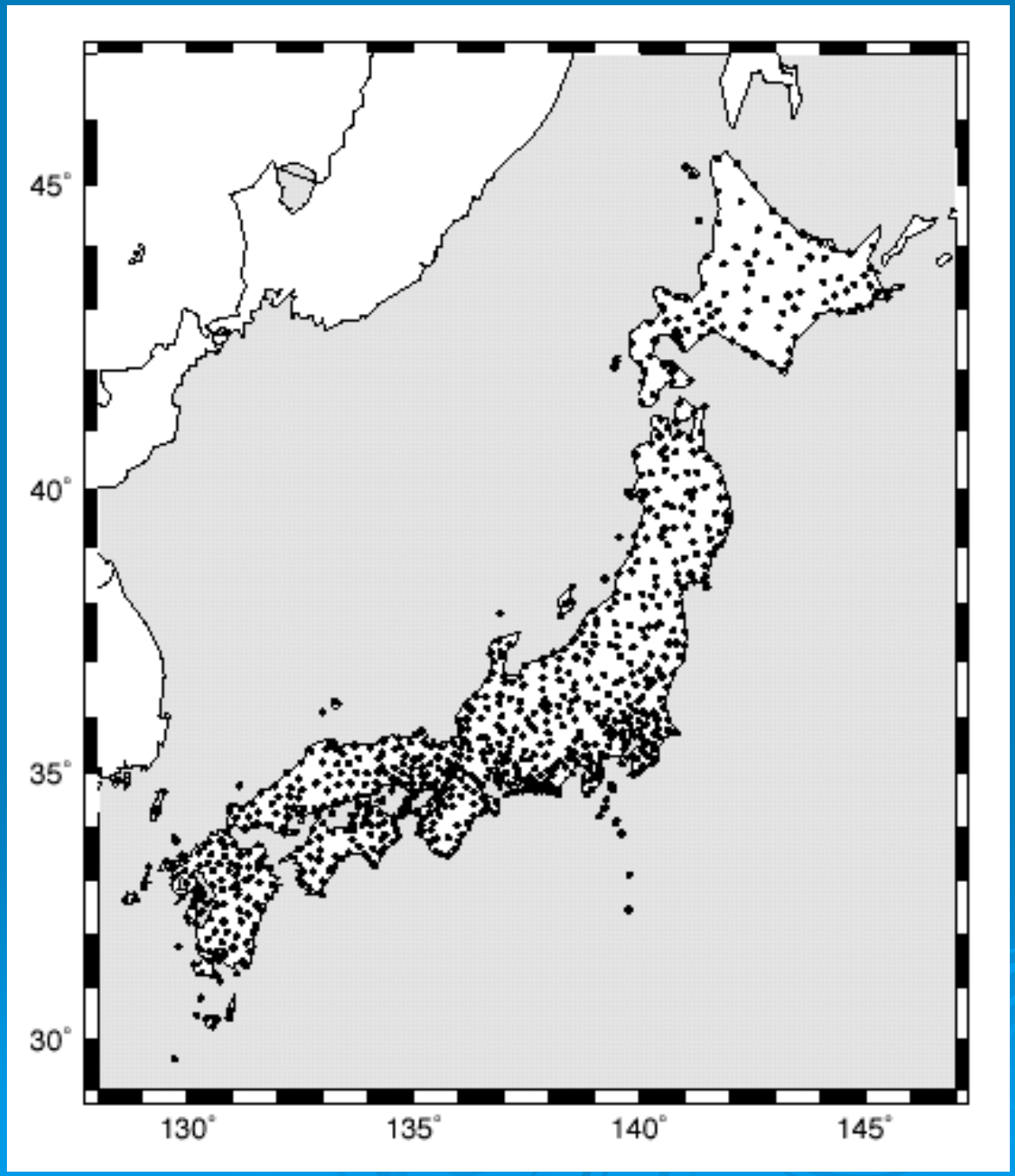


Strong Motion Network





Harvard Mw 8.3

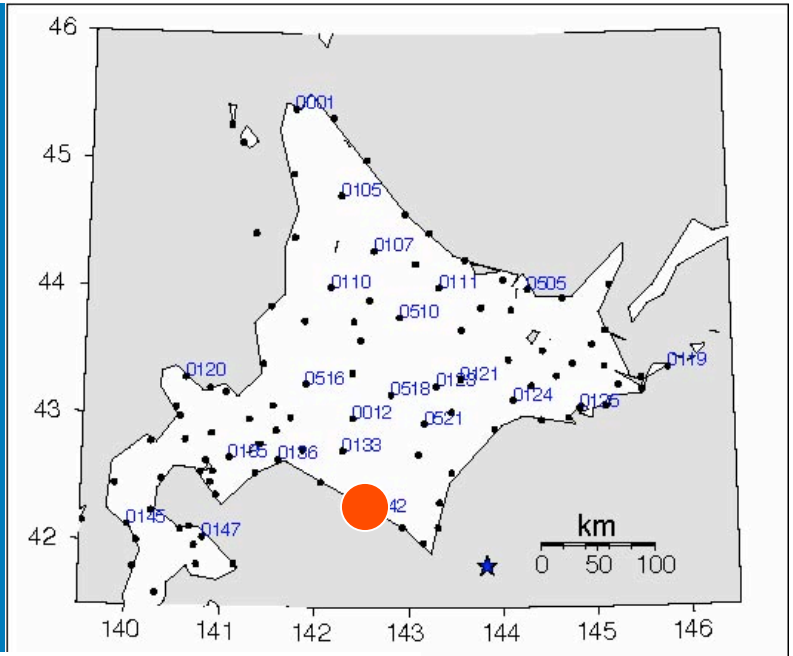


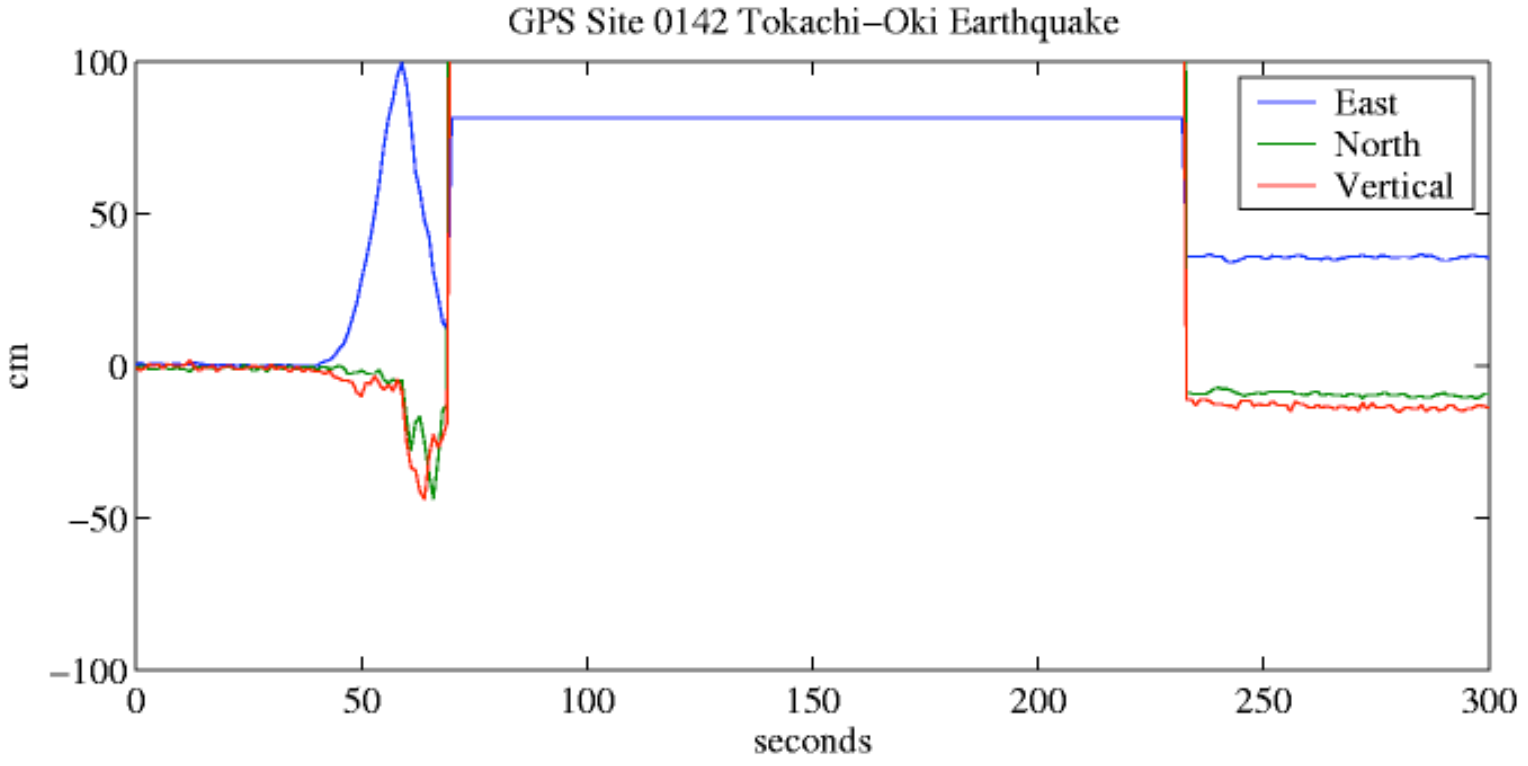
GEONET

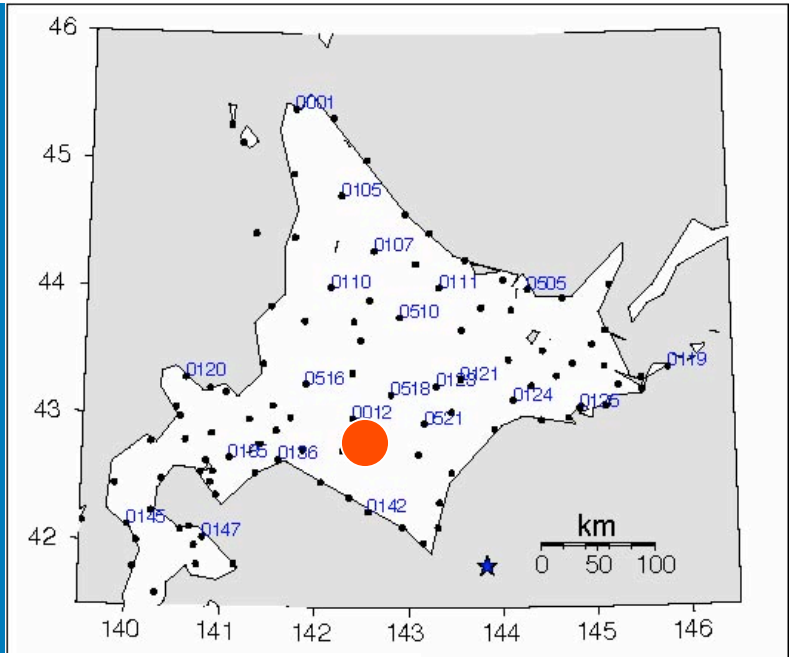
Tokachi-Oki 1-Hz GPS Results

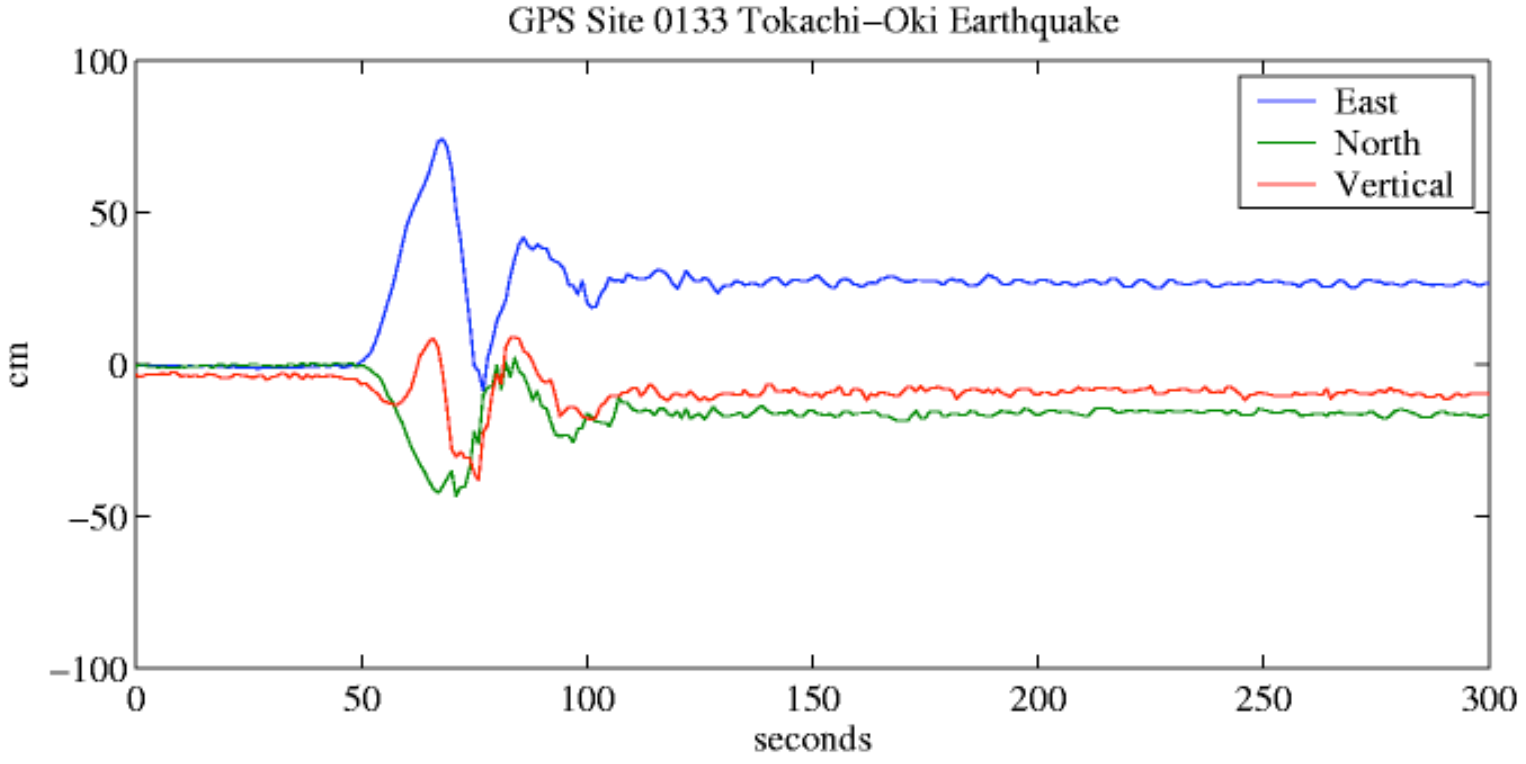
- *Irwan et al*. [2004]
- *Koyama et al*. [2004]
- *Yamagiwa*, this meeting

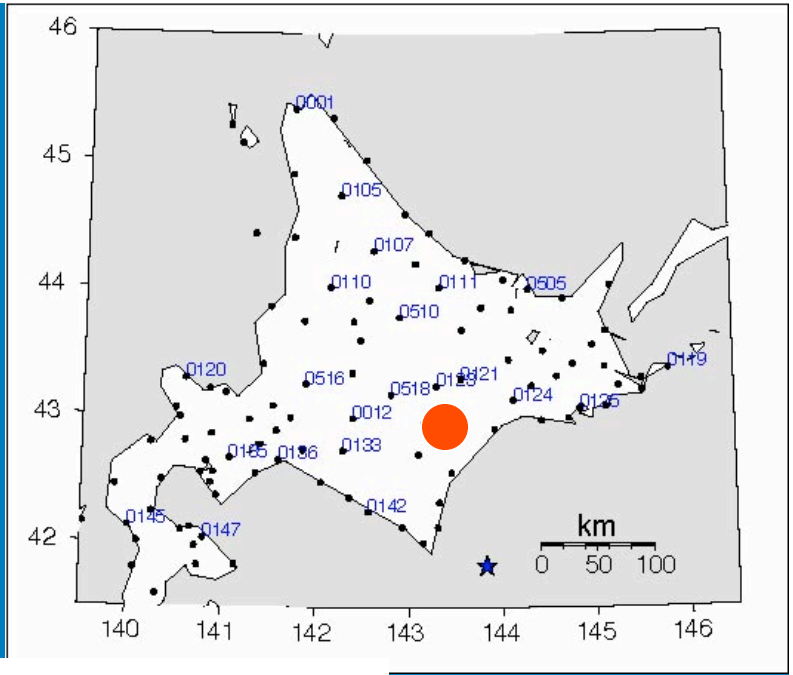
1-Hz GPS Position Estimates

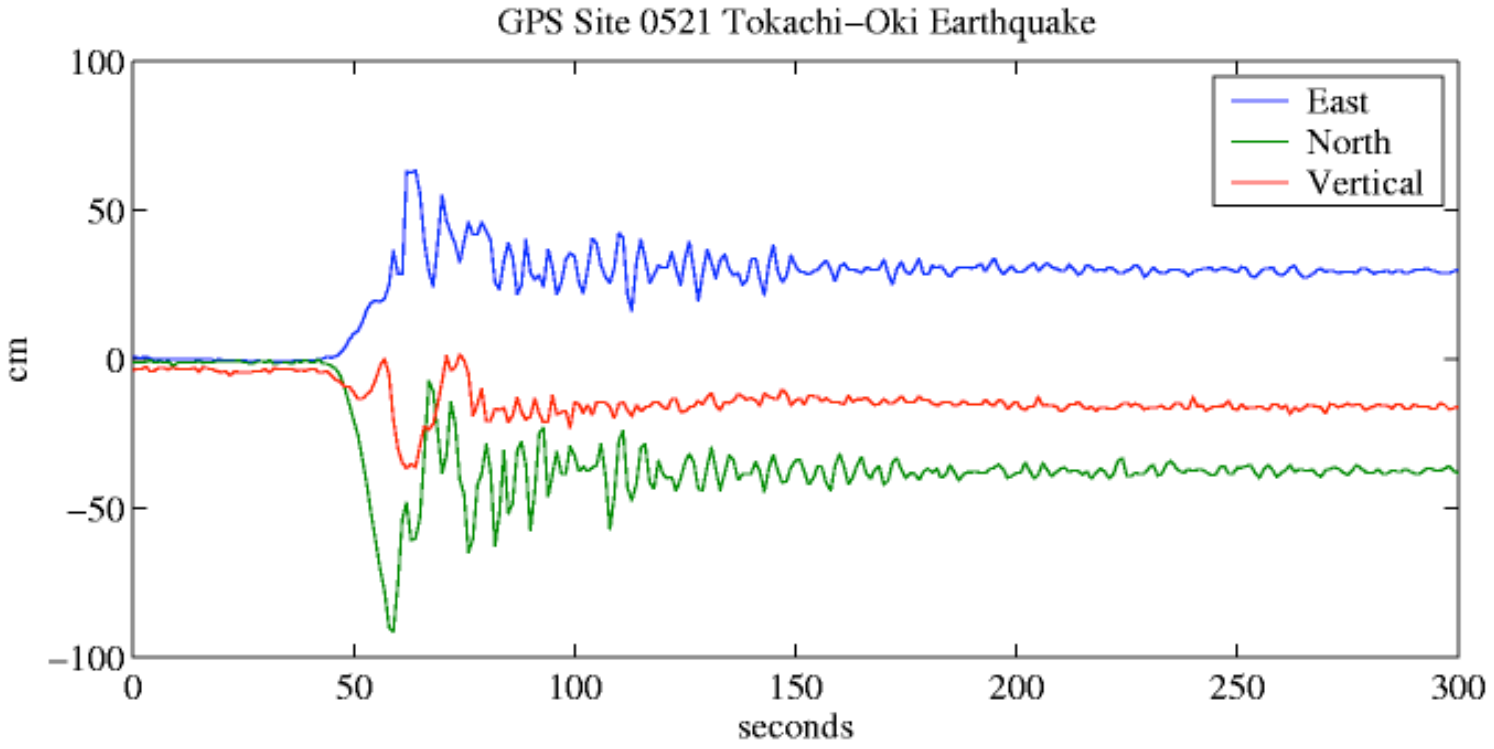


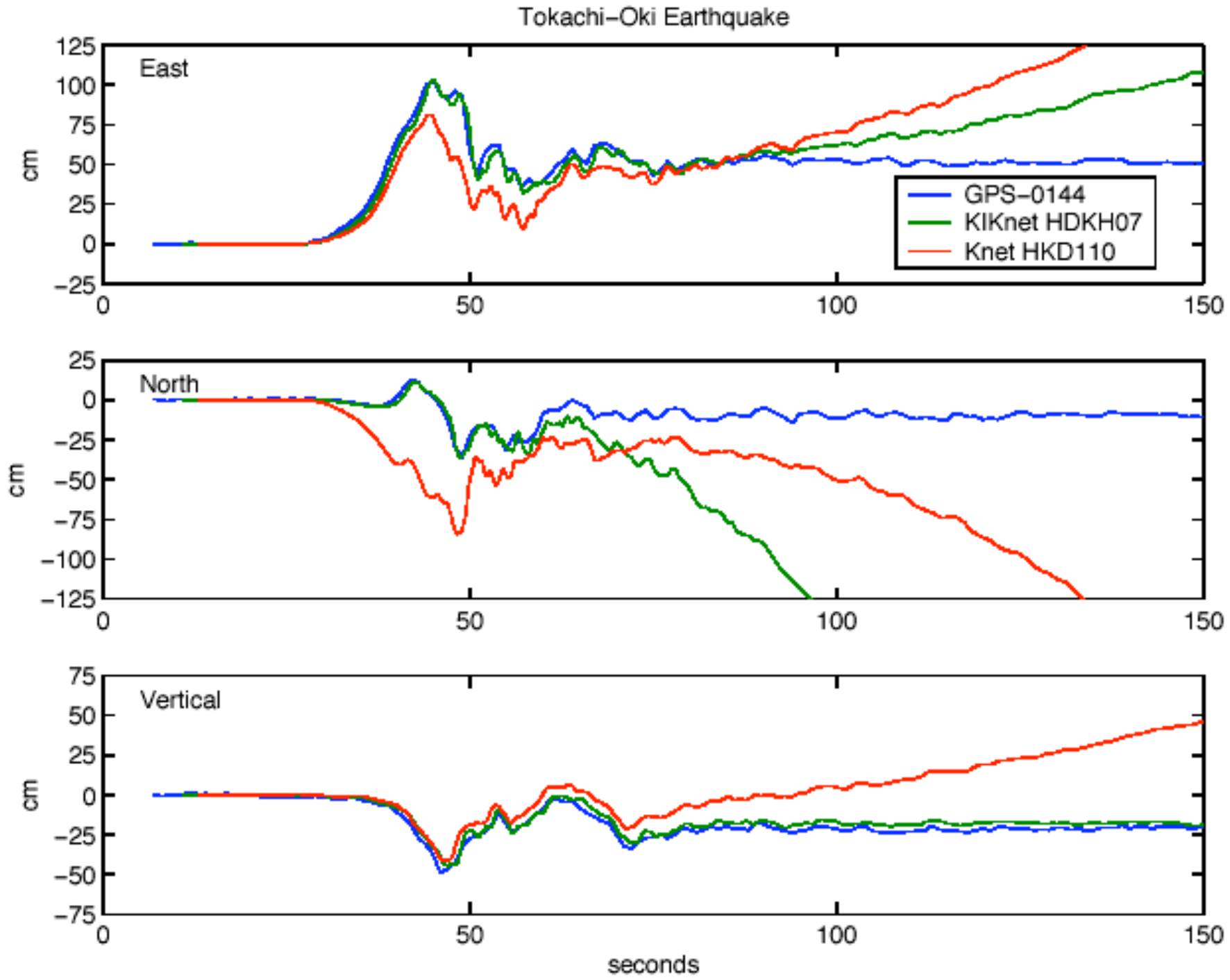


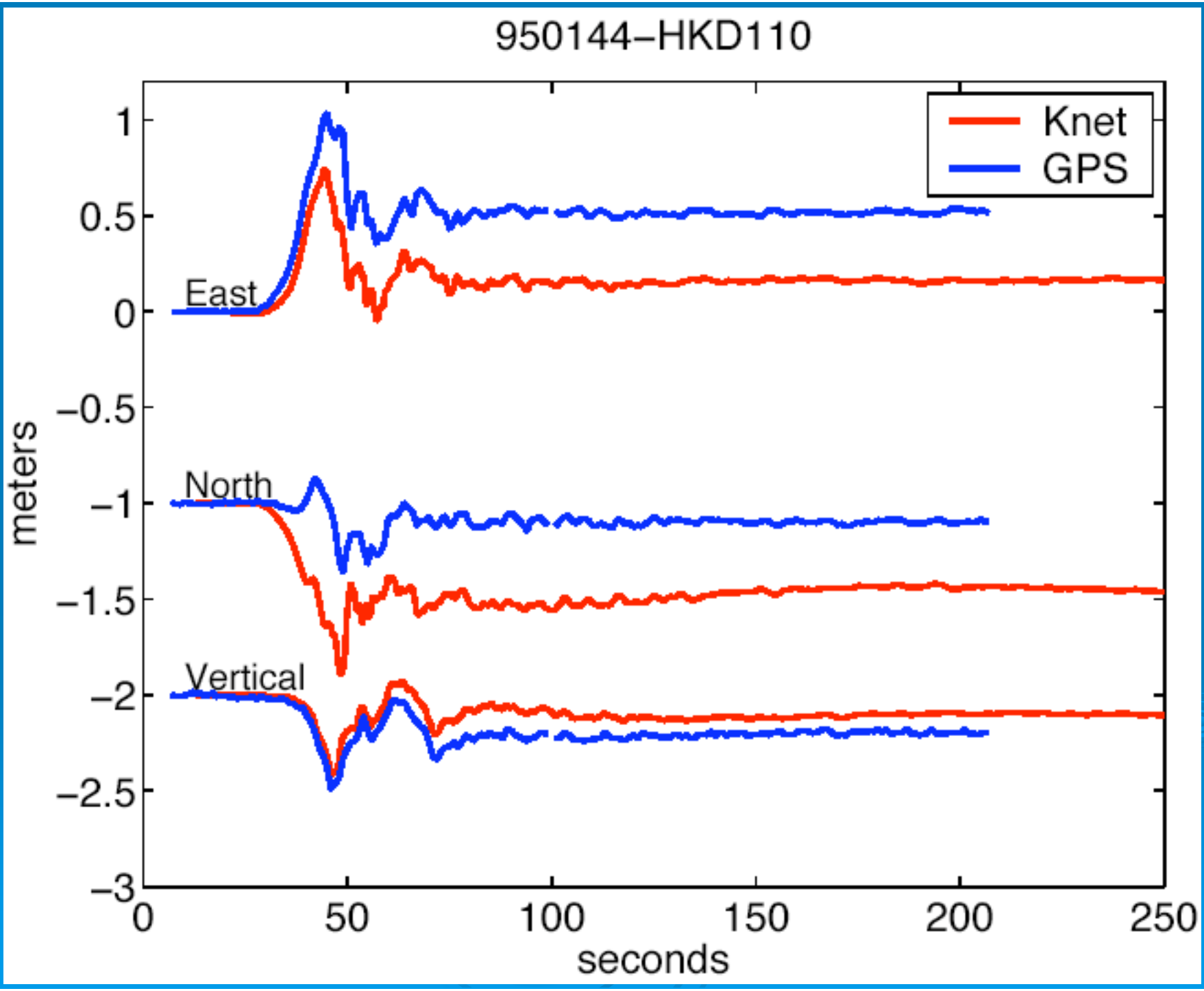

46
45
44
43
42
140
141
142
143
144
145
146
km
0 50 100
0001
0105
0107
0110
0111
0505
0510
0120
0516
0518
0521
0124
0149
0012
0521
0135
0136
0142
0145
0147

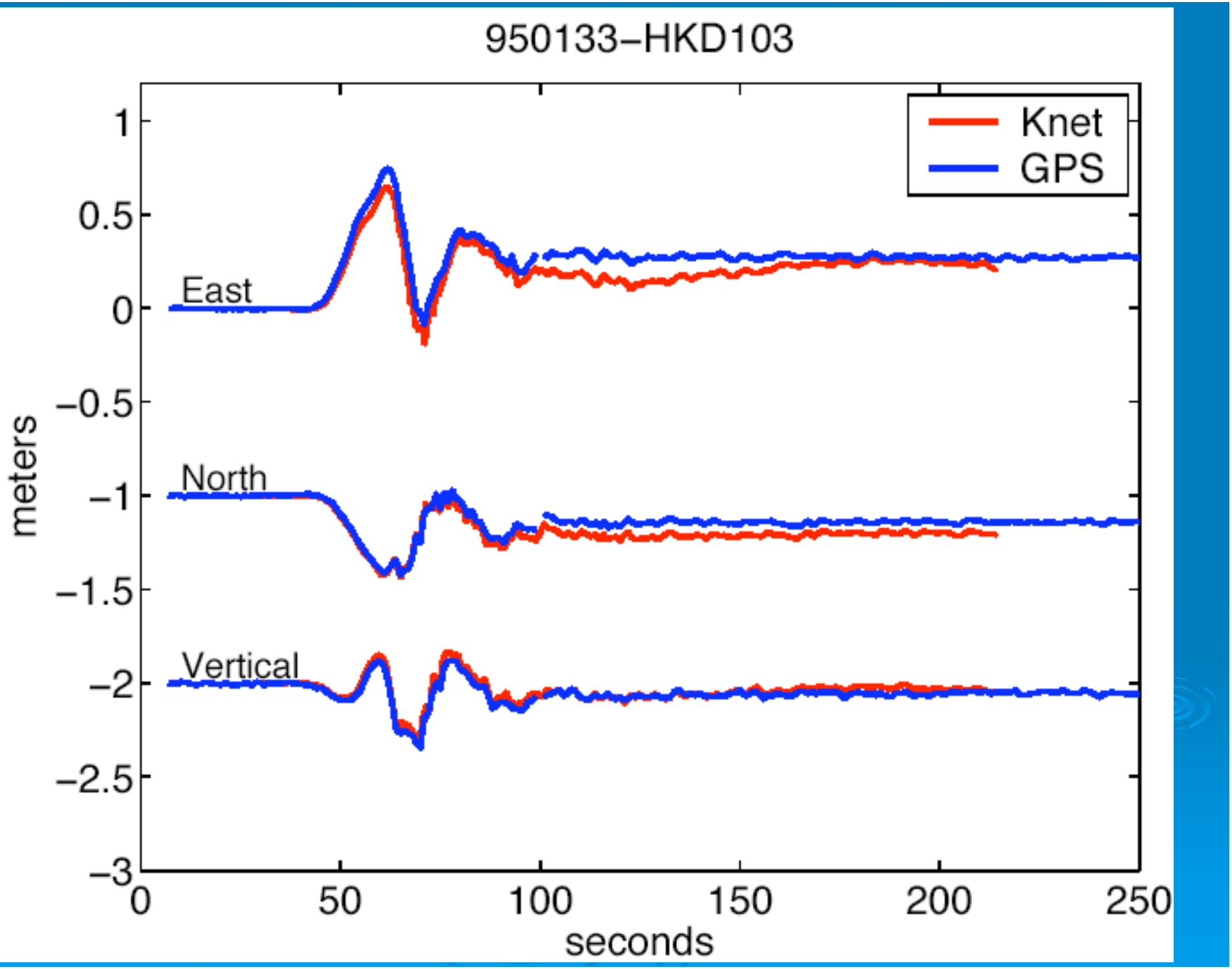

GPS Site 0133 Tokachi–Oki Earthquake
East
North
Vertical
cm
seconds
100
50
0
−50
−100
0
50
100
150
200
250
300

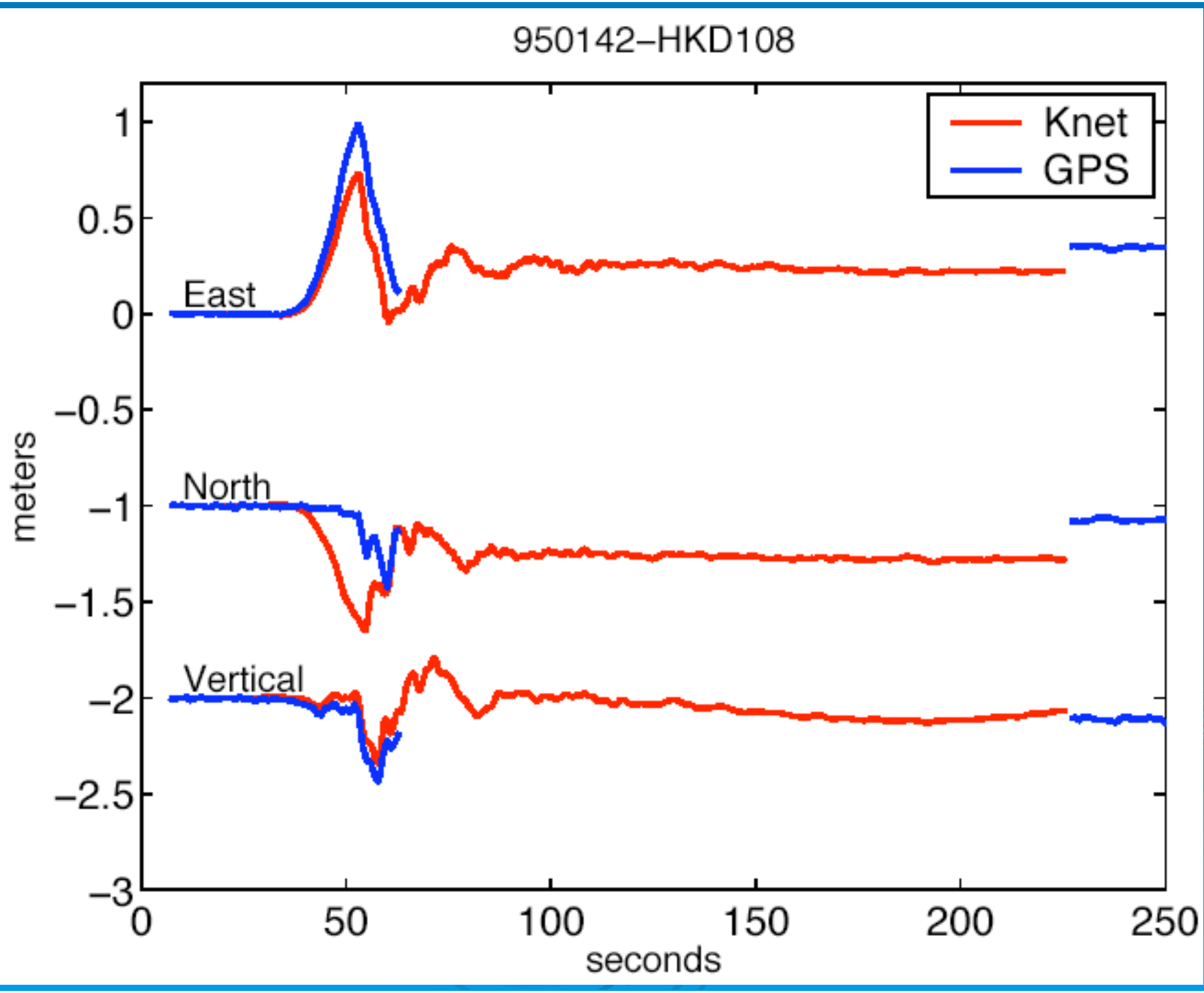

46
45
44
43
42
140
141
142
143
144
145
146
0001
0105
0107
0110
0111
0505
0510
0120
0516
0518
0521
0124
0125
0129
0012
0133
0135
0136
0142
0145
0147
km
0
50
100

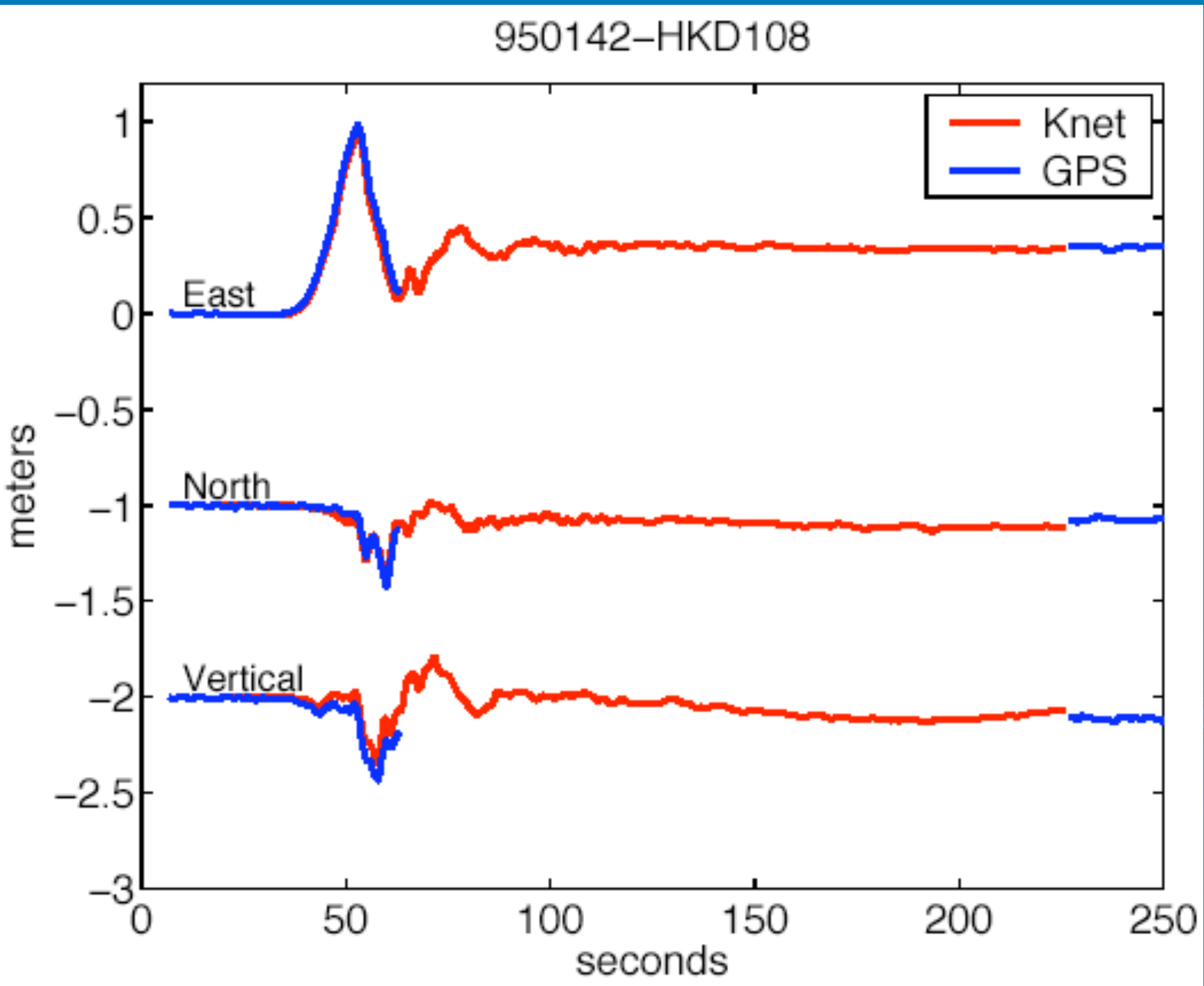

GPS Site 0521 Tokachi–Oki Earthquake
East
North
Vertical
cm
100
50
0
−50
−100
0
50
100
150
200
250
300
seconds


Tokachi−Oki Earthquake
East
North
Vertical
cm
seconds
GPS−0144
KIKnet HDKH07
Knet HKD110
125
100
75
50
25
0
−25
−50
−75
−100
−125
0
50
100
150

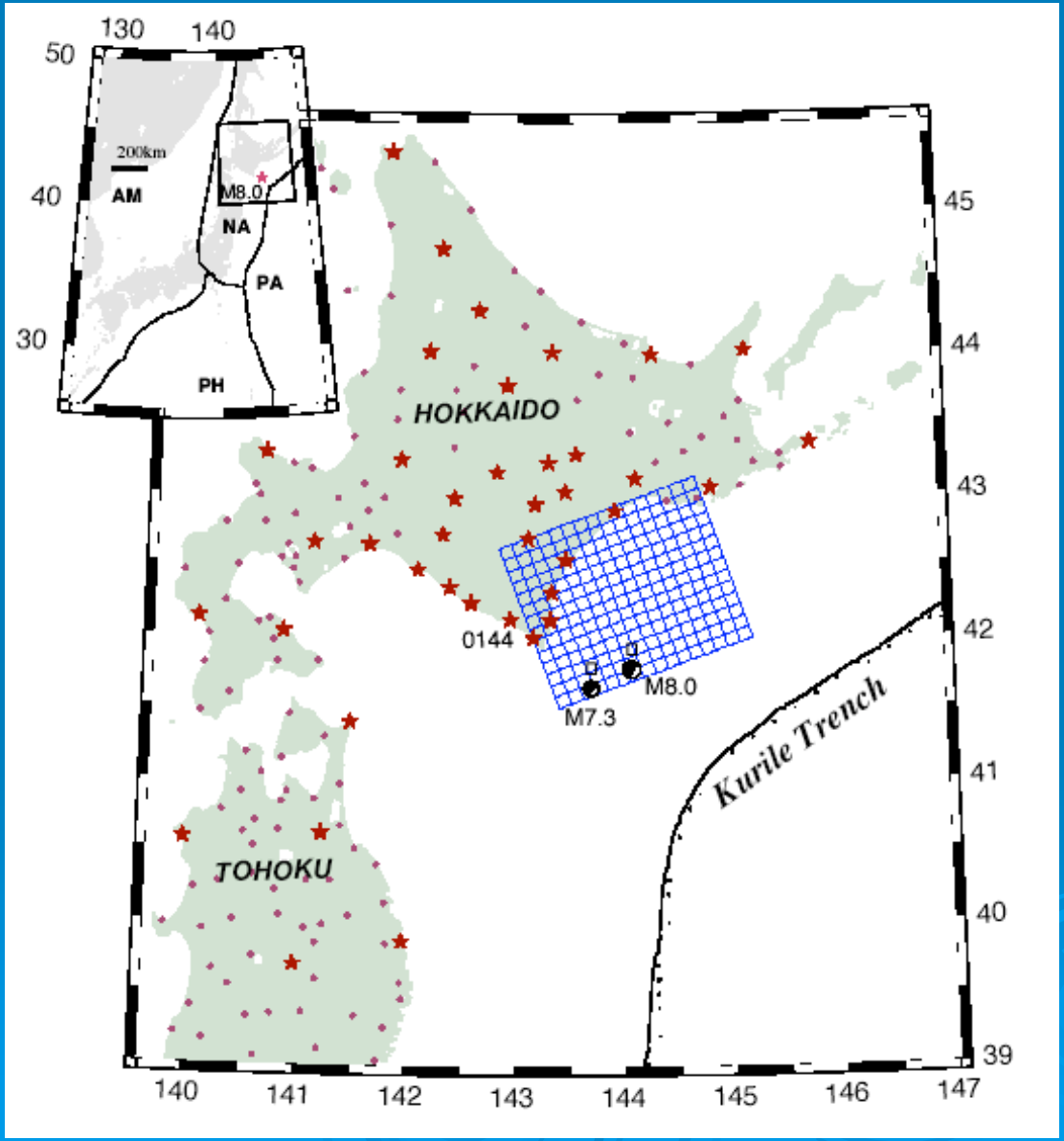

950144–HKD110
Knet
GPS
East
North
Vertical
meters
seconds
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
0
50
100
150
200
250


950133–HKD103
Knet
GPS
East
North
Vertical
meters
seconds
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
0
50
100
150
200
250


950142–HKD108
Knet
GPS
East
North
Vertical
meters
seconds
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
0
50
100
150
200
250

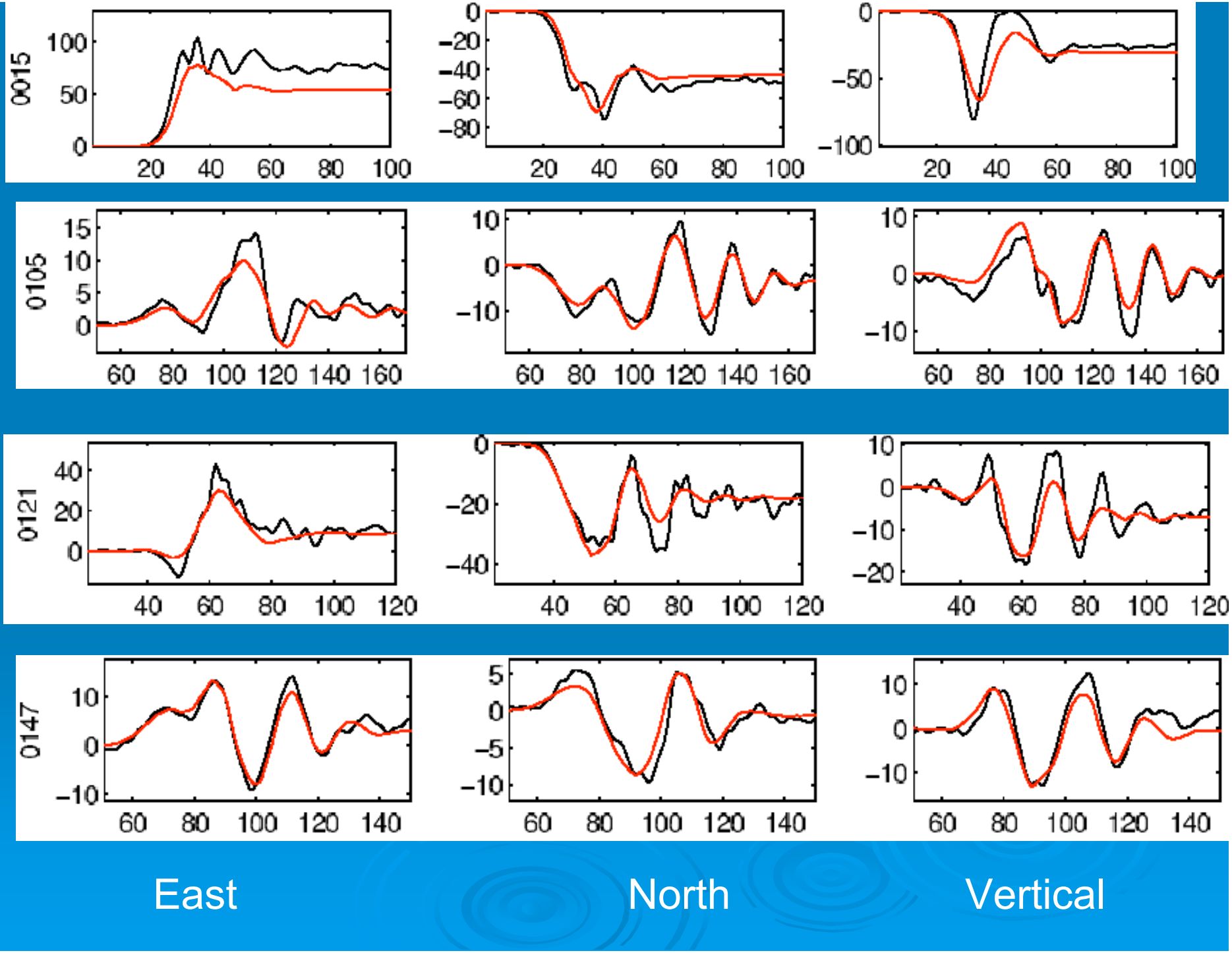

950142–HKD108
Knet
GPS
East
North
Vertical
meters
seconds
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
0
50
100
150
200
250

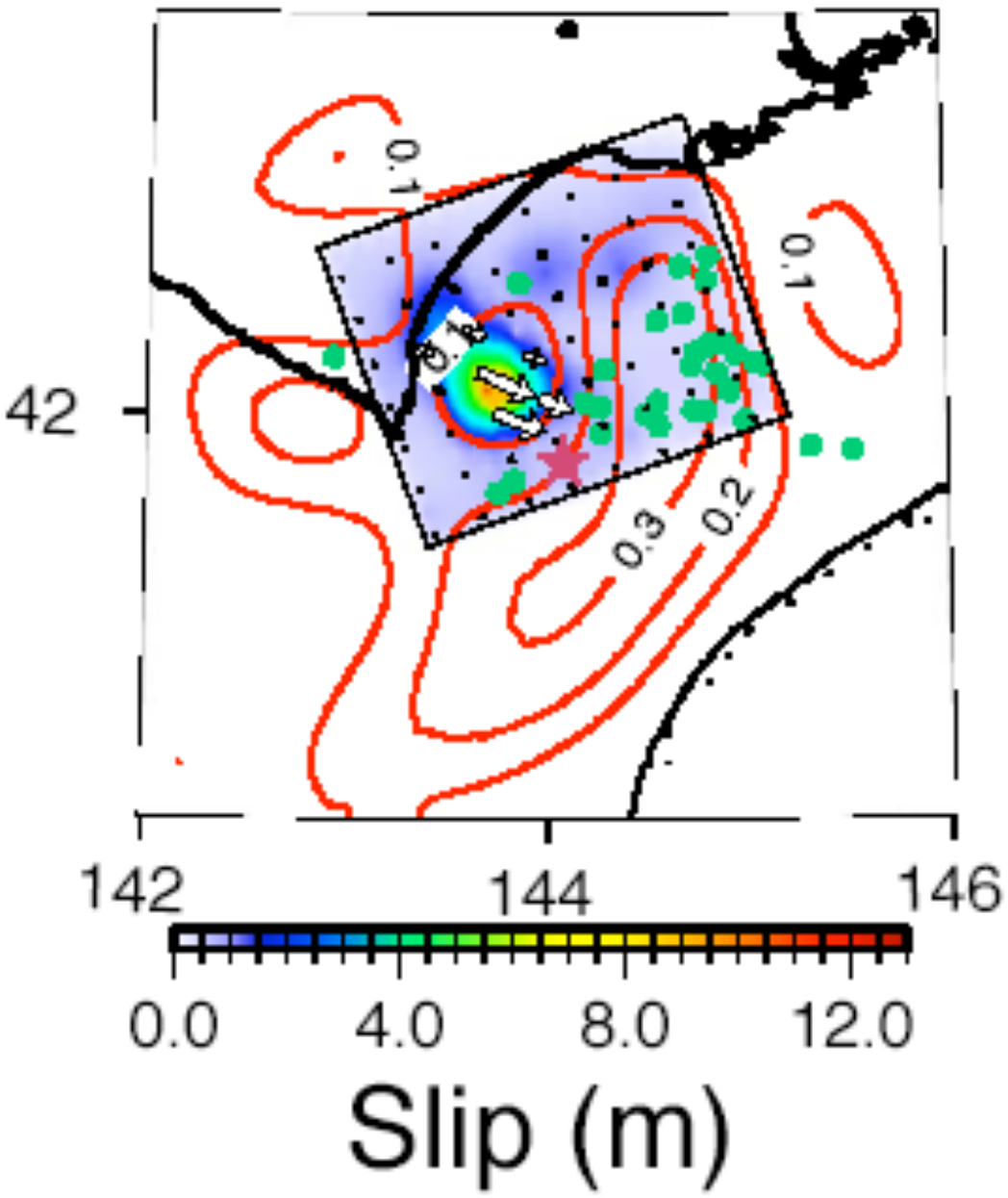
1-Hz GPS Sites Used



Methodology

- Multiple time window inversion
- Fault plane 10 x 10 km segments
- Frequency-Wavenumber (FK) of *Zhu & Rivera* [2003].
- Smoothness & positivity constraints.
- Velocity structure after *Yagi* [2004].

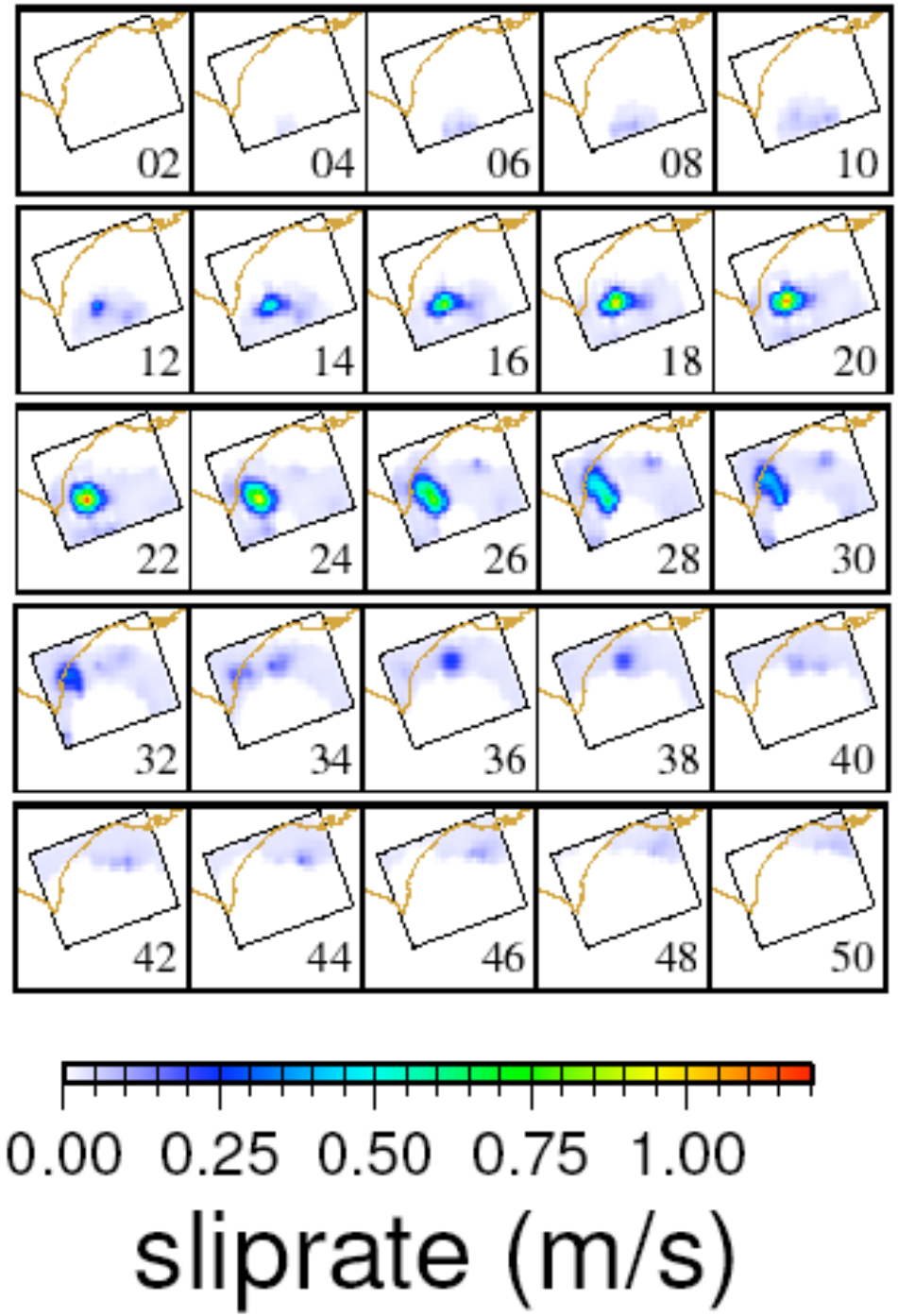

0015
0105
0121
0147
East
North
Vertical



Mo=1.7×10^{21}Nm
（Mw8.1）
Peak Slip ~ 9.0m

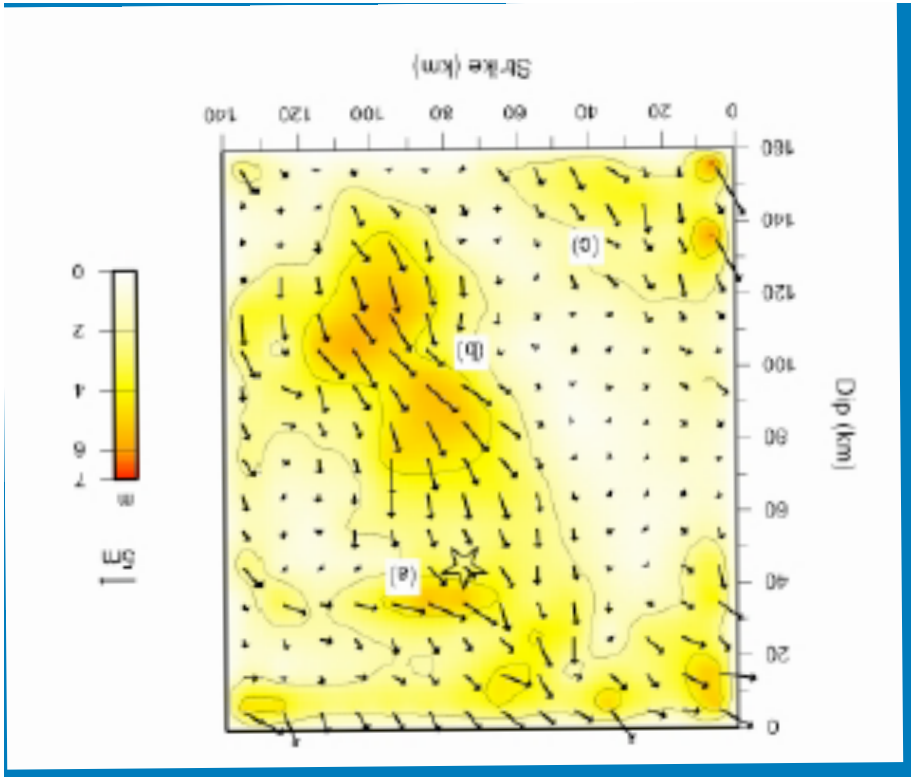
Aftershocks

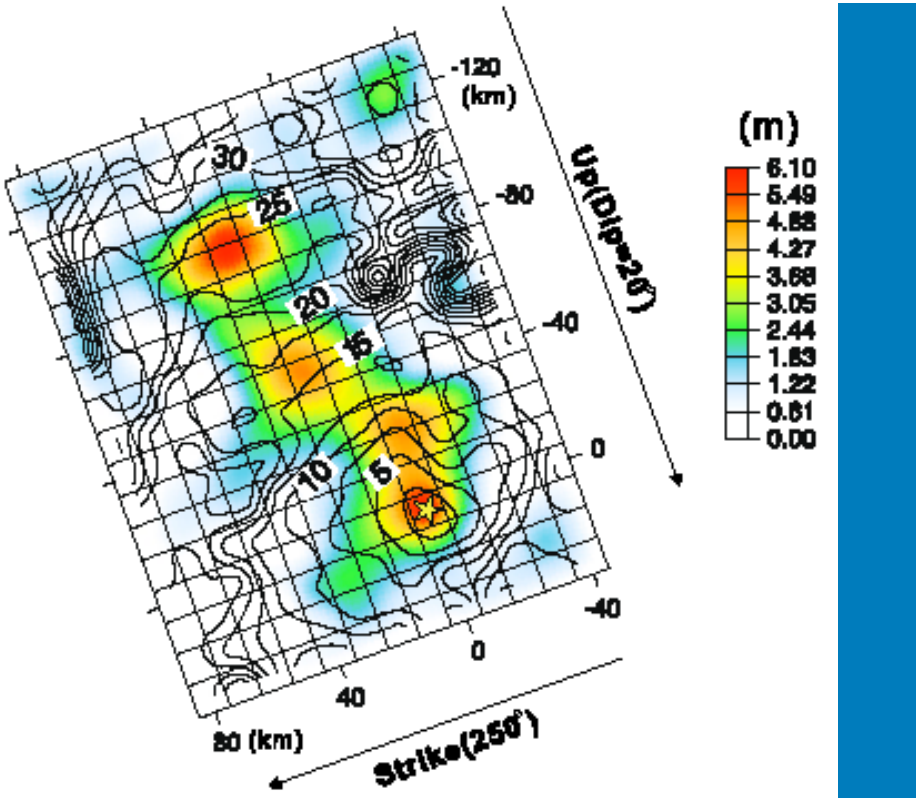
Ito et al. [2004]

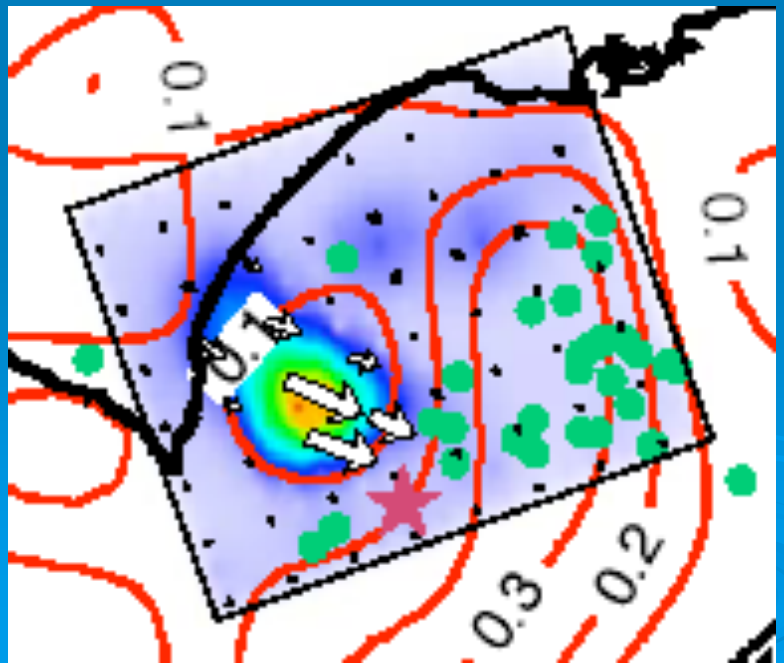

02
04
06
08
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
0.00 0.25 0.50 0.75 1.00
sliprate (m/s)

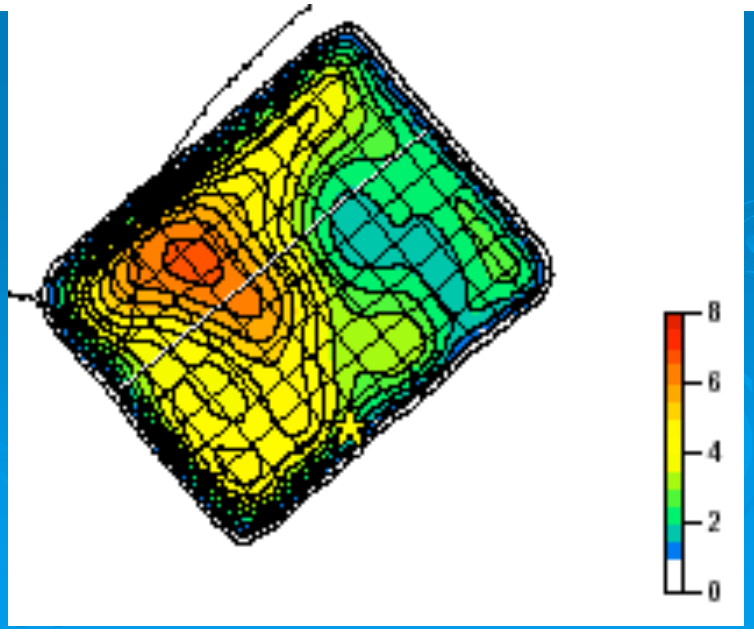
Model Results from Seismic Data

- *Yamanaka & Kikuchi* [2003]
- *Honda et al.* [2004]
- *Yagi* [2004]
- *Koketsu et al.* [2004]
- This presentation

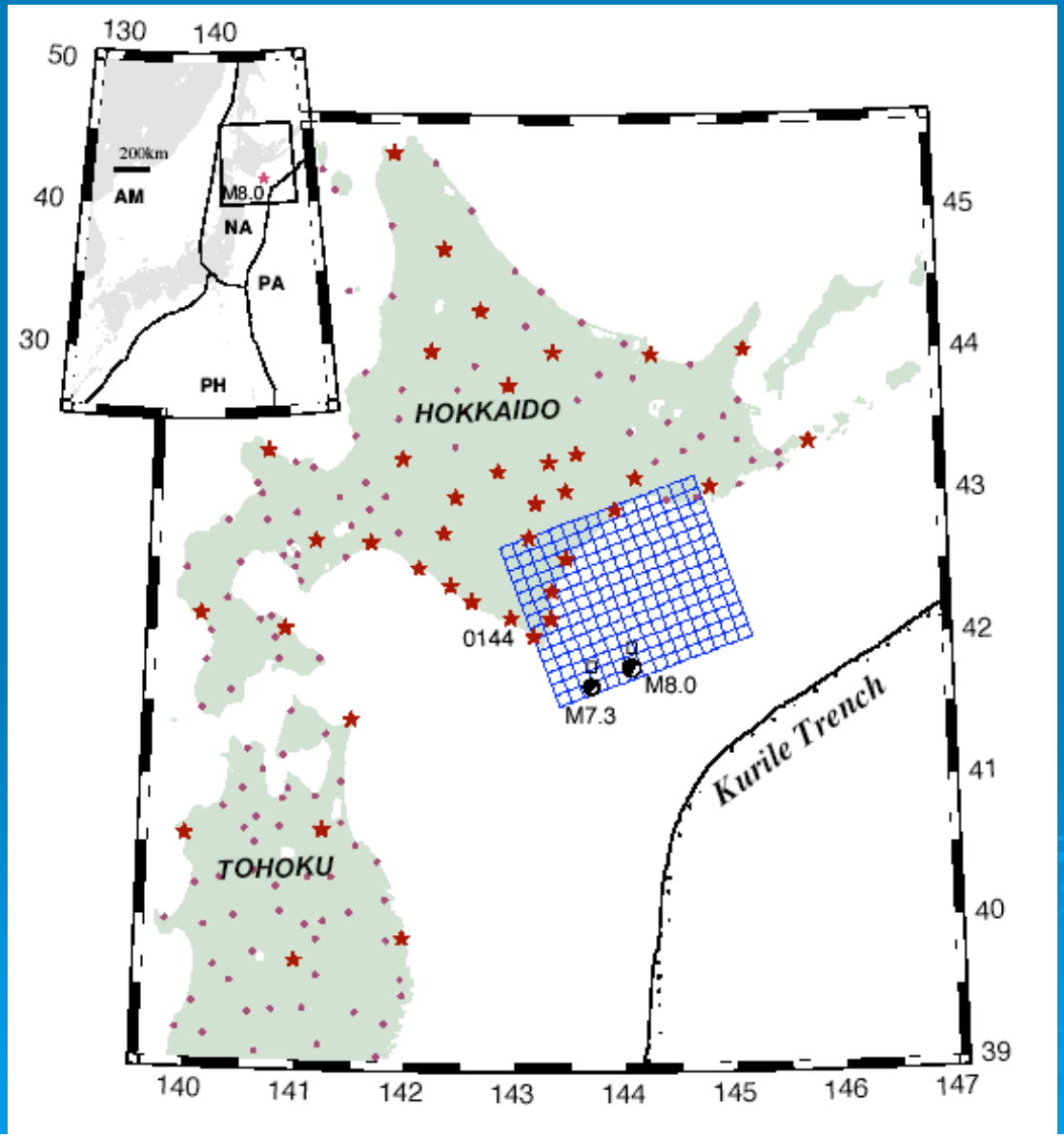

Strike (km)
Dip (km)
(a)
(b)
(c)
5m


(m)
6.10
5.49
4.88
4.27
3.66
3.05
2.44
1.83
1.22
0.61
0.00
Up(Dip=20°)
-120 (km)
-80
-40
0
-40
0
40
80 (km)
Strike(250°)
30
25
20
15
10
5


0.1
0.2
0.3
0.2
0.1


8
6
4
2
0

What Next?


130
140
50
40
30
200km
AM
M8.0
NA
PA
PH
HOKKAIDO
45
44
43
42
41
40
39
0144
M8.0
M7.3
Kurile Trench
TOHOKU
140
141
142
143
144
145
146
147

Implications for Earthscope

- High-frequency GPS provides a useful measurement of large ground displacements during earthquakes.
- Existing GPS and seismic networks in Japan provide invaluable information for developing PBO.
- Results from Tokachi-Oki influenced UNAVCO's choice of 5 Hz as a sampling interval for PBO.

Implications for Real-Time

- Real-time GPS will “never” be better than post-analysis.
- Nevertheless, we know how to build a real-time GPS positioning system. In practice, it will take time and effort to build an high-precision GPS real-time system with error checking.
- Much of the GPS hardware is already installed. Software and communications are needed.

Acknowledgements

- GSI
- NIED
- NSF EAR
- UNAVCO
- Orbits: IGS
- GIPSY: JPL
- Archives: CDDIS, SOPAC
- Comments: J. Savage, L. Zhu, R. Graves, R. Burgmann, A. Venkataraman, K. Hirahara, D. Wald