Regional monitoring of Cascadia tectonics

Timothy I. Melbourne
Pacific Northwest Geodetic Array (PANGA)
Department of Geological Sciences
Central Washington University

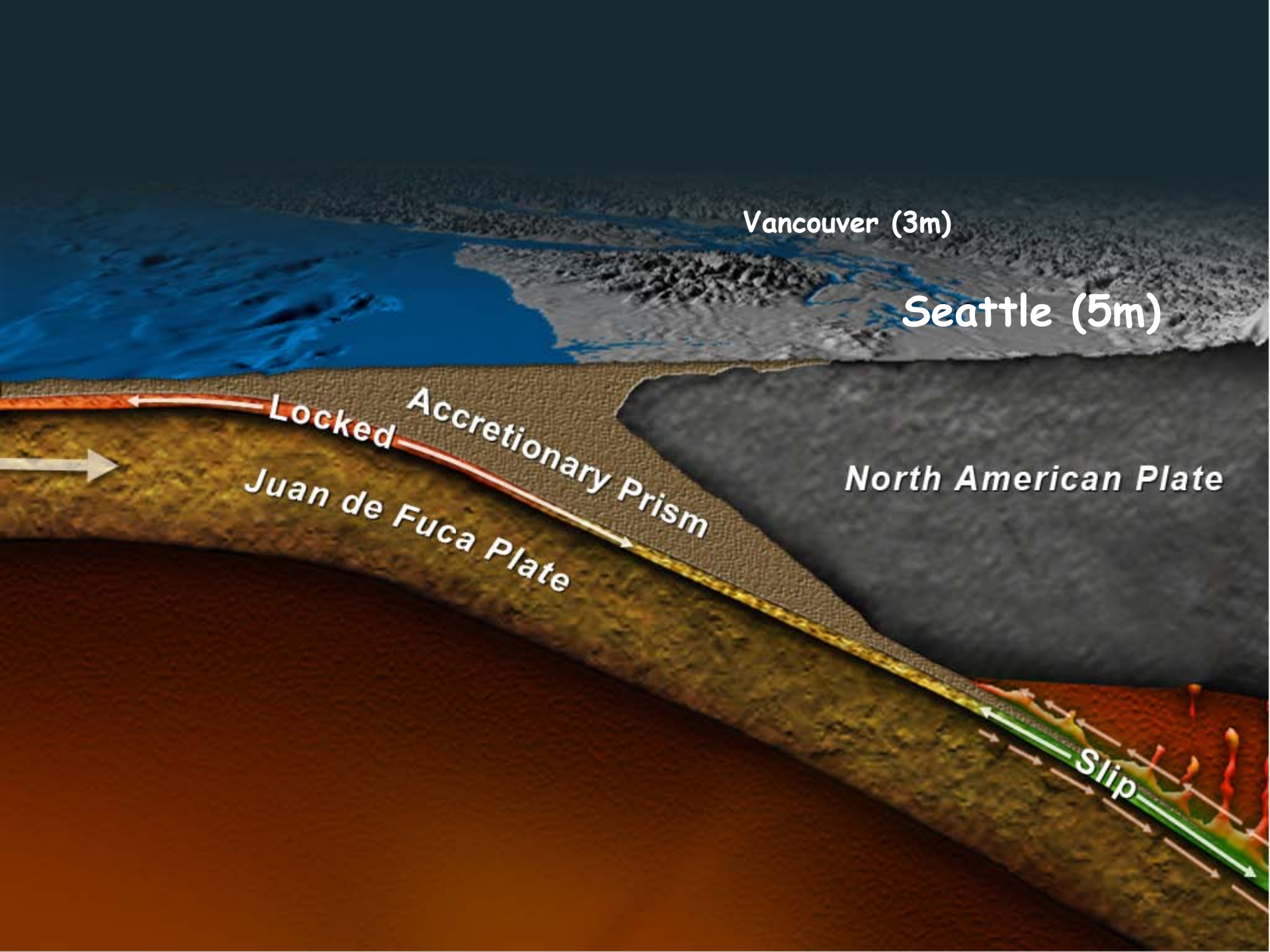
Rex Flake
Andrew Miner
Marcelo Santillan
Craig Scrivner
Walter Szeliga

Aaron Mayfield
Rodger Wilson
Ana Aguiar
James Chapman
Ivan Rabak

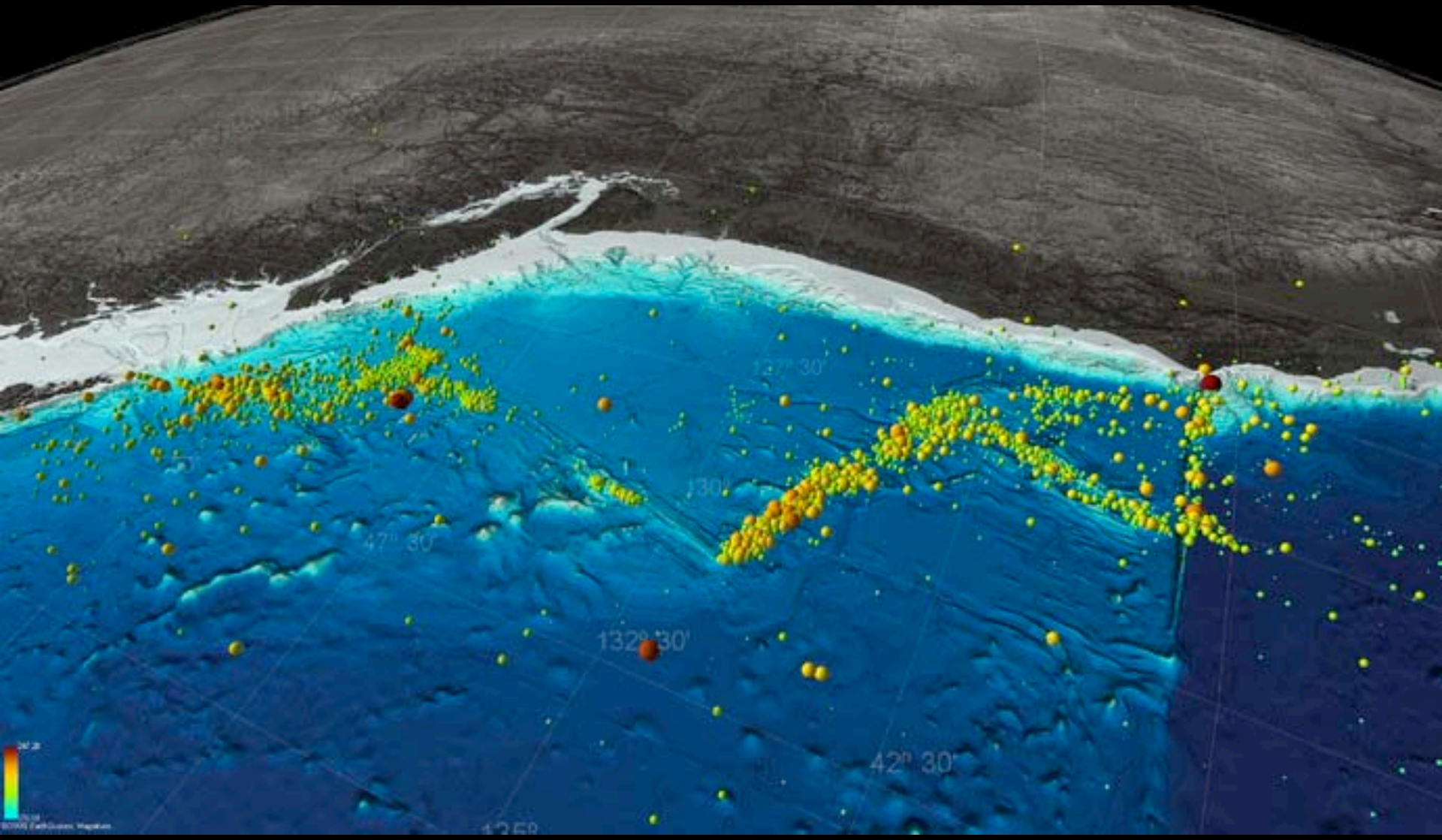
Megan Kostick
Rosie Stahl
Kyle Kinkade
Wendy Stockwell
Sergio Abundiz

Outline

- The Cascadia subduction zone
- Lessons from Japan & the 2011 M9 Tohoku earthquake
- Saving lives with real-time GPS

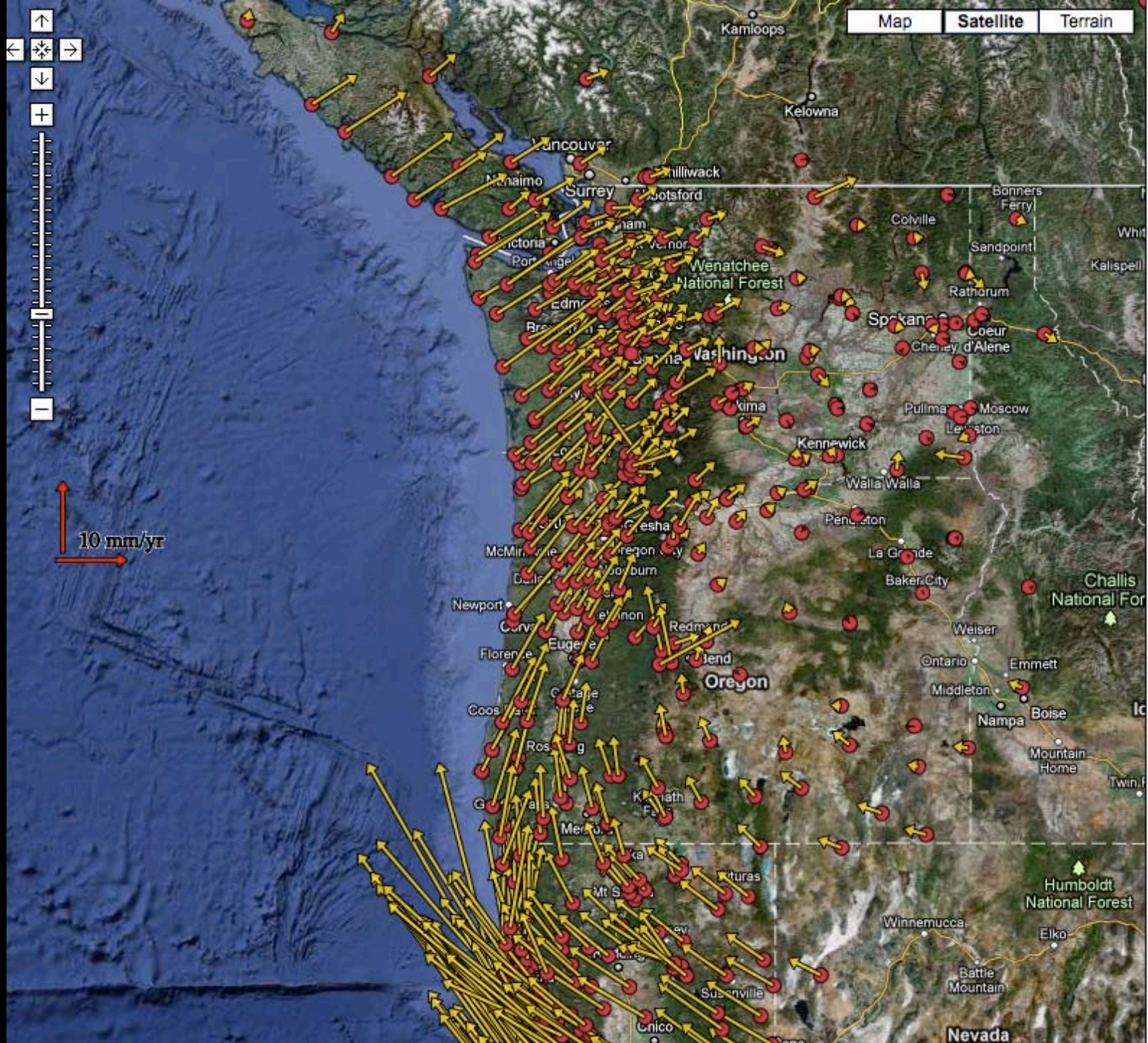

Vancouver (3m)
Seattle (5m)
Locked
Accretionary Prism
North American Plate
Juan de Fuca Plate
Slip

Cascadia Subduction Zone



Earthquake magnitude is proportional to fault size

Cascadia today: 20y of GPS



Cascadia:

36 mm/yr loading rate

Coast moves ~2 cm/yr today

Margin-wide recurrence: 550 years (var ~200 yrs)

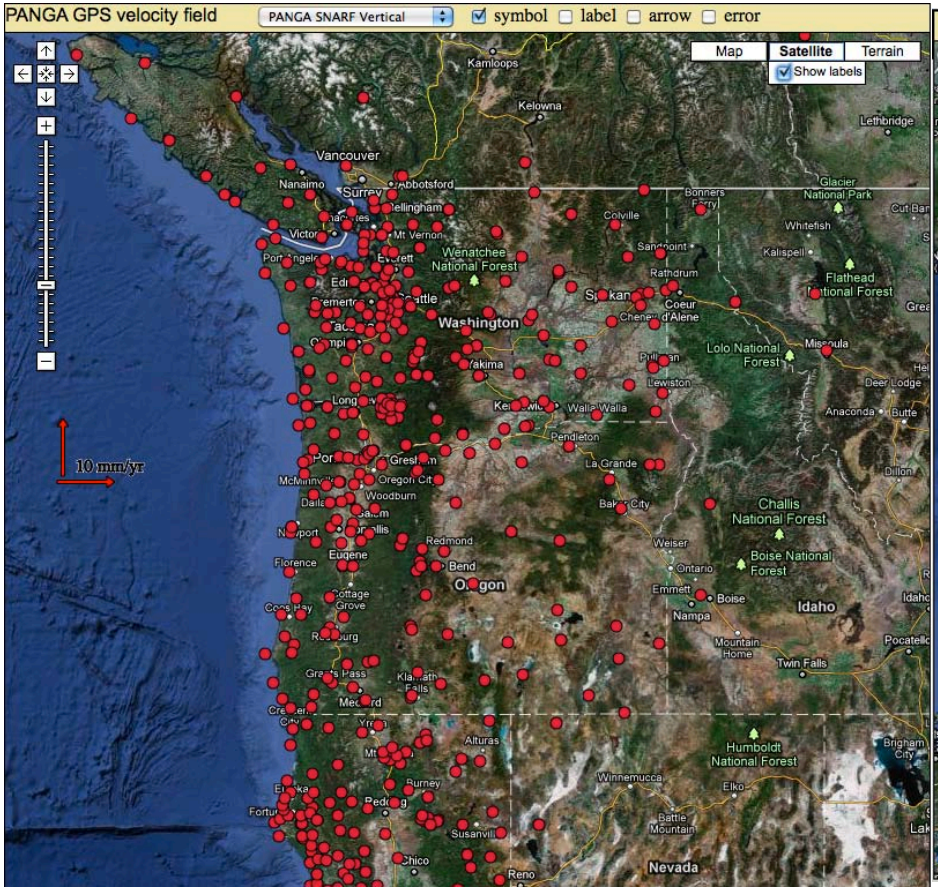
311 years into the eq cycle

10 meters of post-1700 accumulated slip deficit

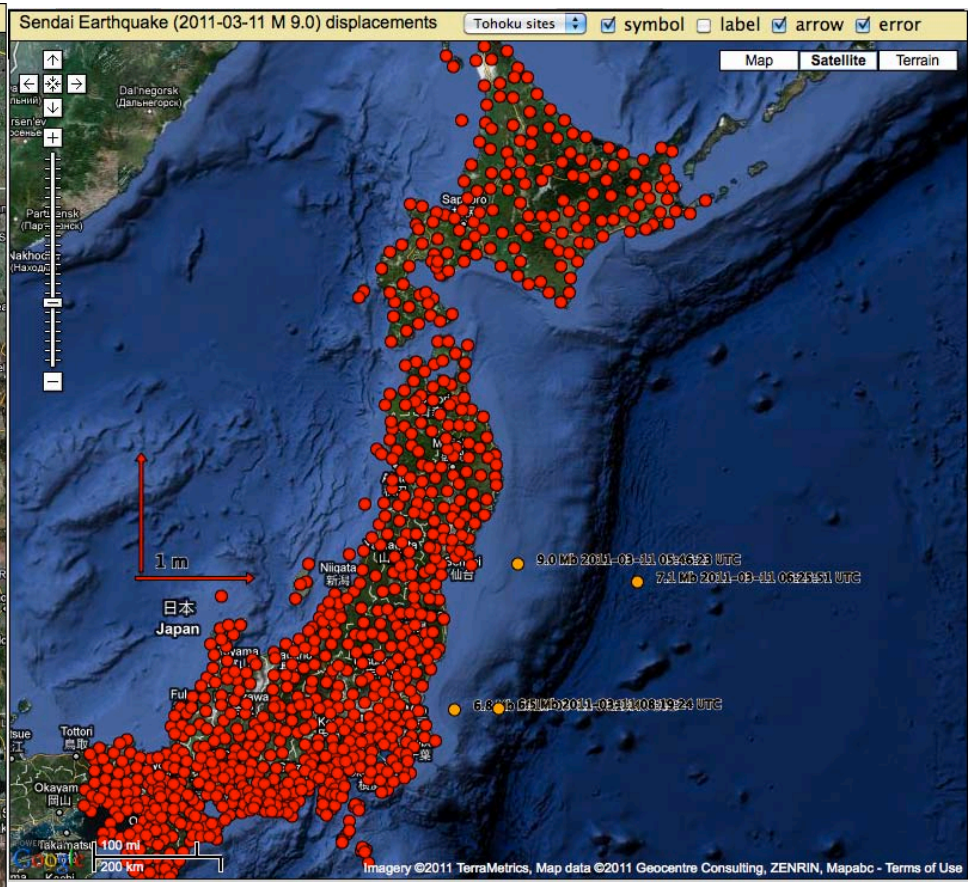
Last eq appears to have been margin-wide (M9)

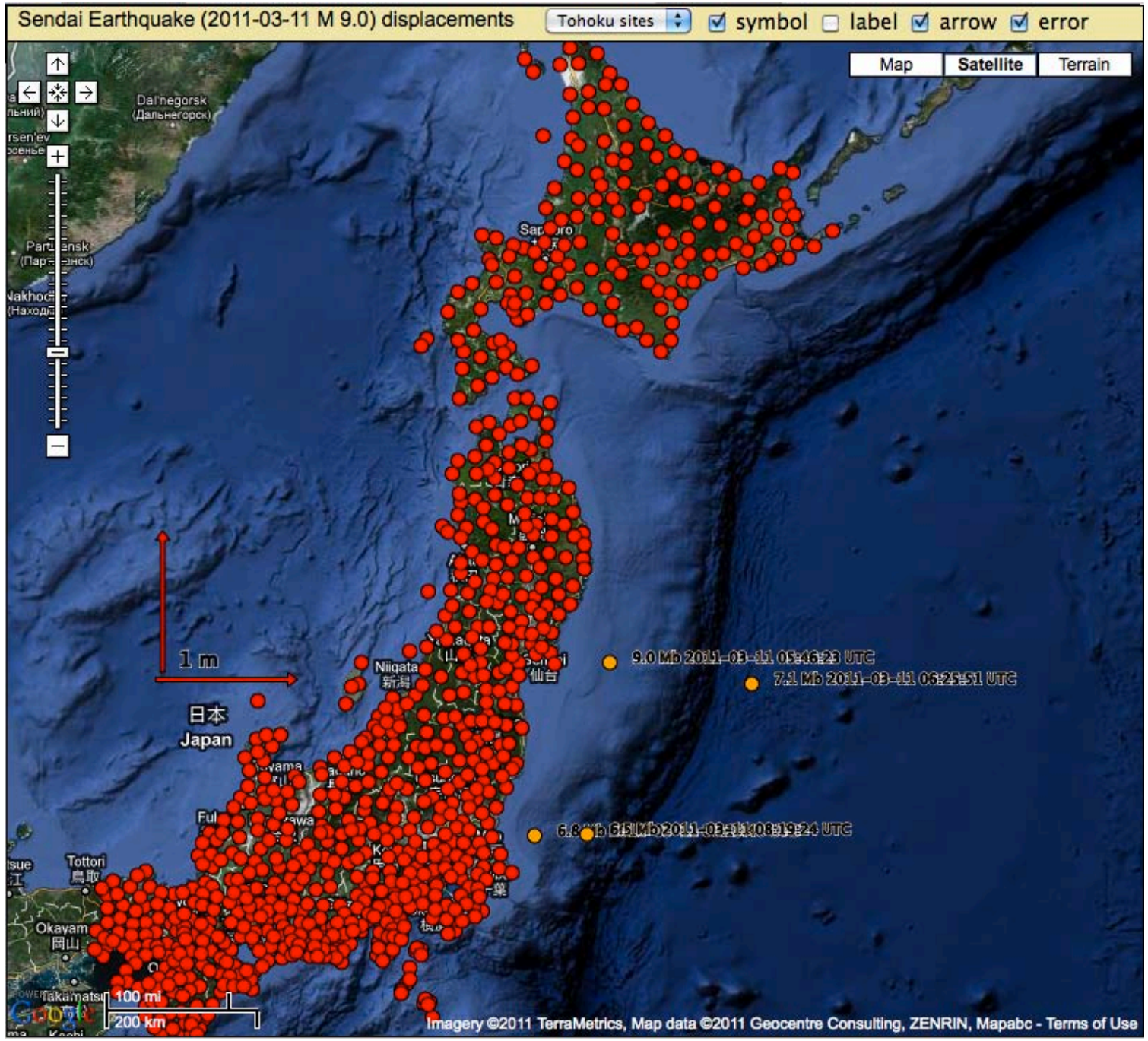
Moment, damage ~ width of seismogenic zone

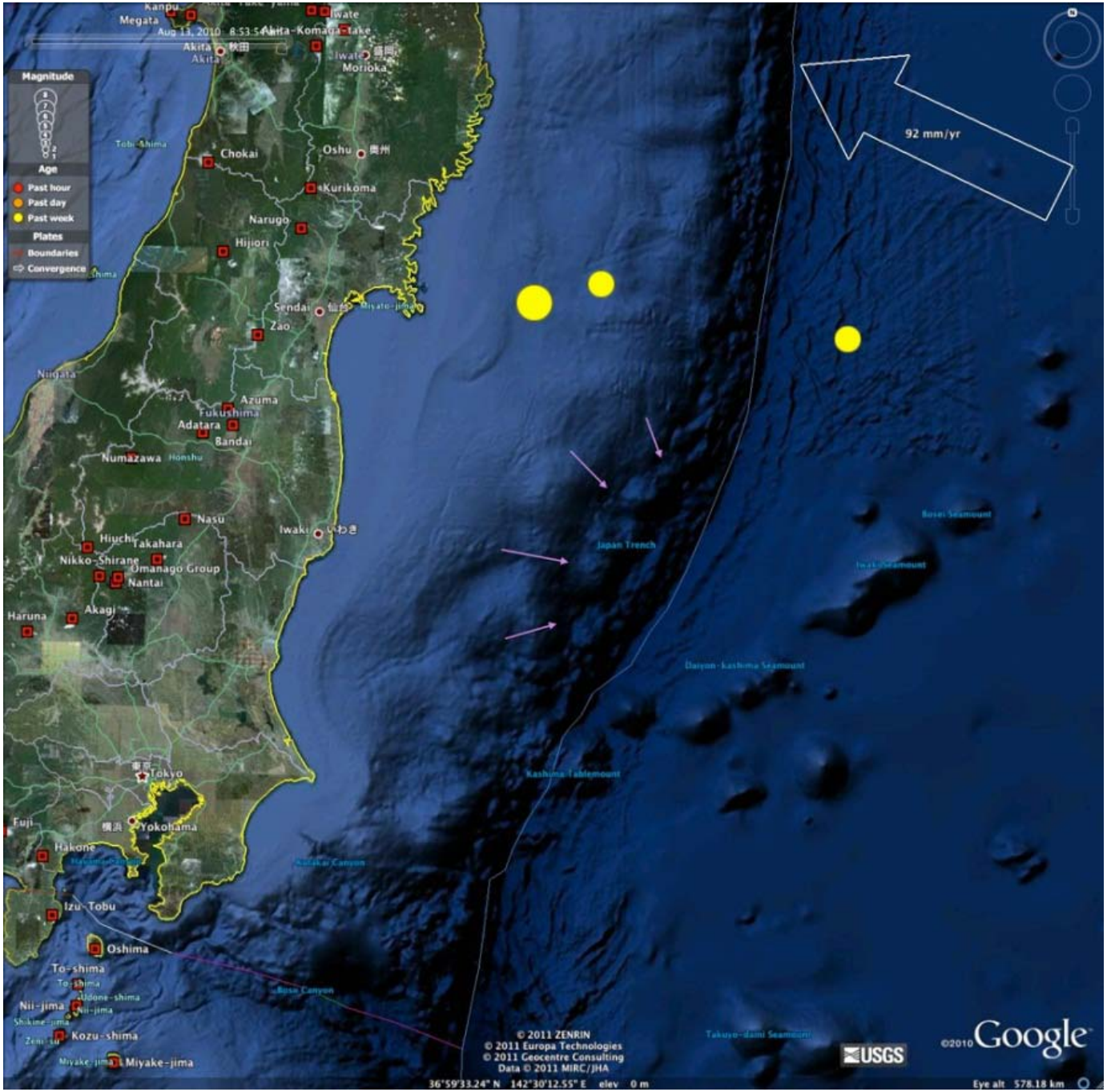
470 Cascadia rtGPS

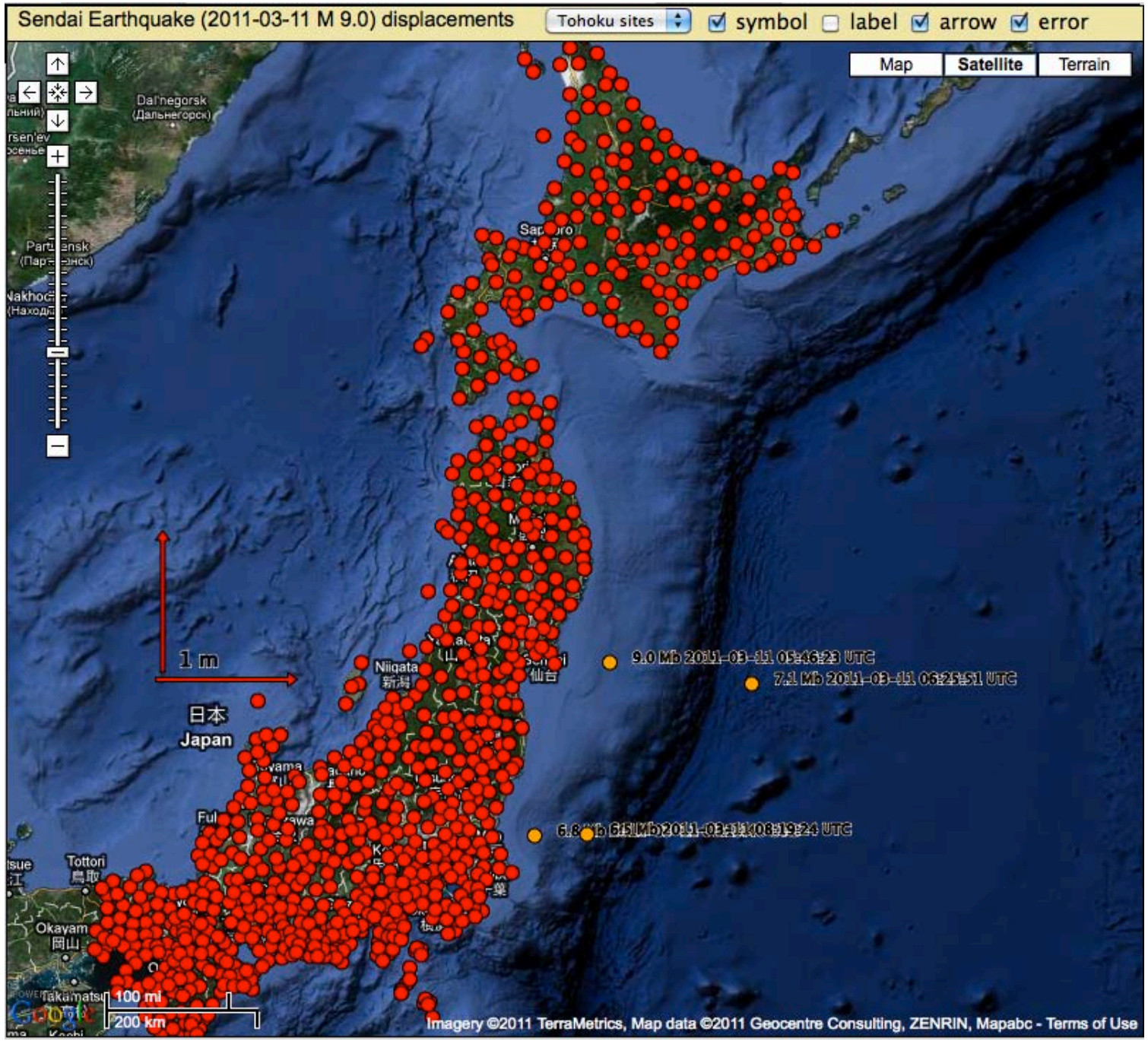


1000 Japanese rtGPS




Sendai Earthquake (2011-03-11 M 9.0) displacements
Tohoku sites
symbol
label
arrow
error
Map
Satellite
Terrain
1 m
日本
Japan
Niigata
新潟
9.0 Mb 2011-03-11 05:46:23 UTC
7.1 Mb 2011-03-11 06:25:51 UTC
Tottori
鳥取
Okayama
岡山
100 mi
200 km
Imagery ©2011 TerraMetrics, Map data ©2011 Geocentre Consulting, ZENRIN, Mapabc - Terms of Use


Magnitude
Age
Past hour
Past day
Past week
Plates
Boundaries
Convergence
92 mm/yr
Kanpu
Megata
Akita
Iwate
Morioka
Tobi-Shima
Chokai
Oshu
Kurikoma
Narugo
Hijiori
Sendai
Zao
Niigata
Azuma
Fukushima
Adatara
Bandai
Numazawa
Honshu
Nasu
Iwaki
Hiuchi
Takahara
Nikko-Shirane
Omanago Group
Nantai
Haruna
Akagi
Tokyo
Yokohama
Fuji
Hakone
Izu-Tobu
Oshima
To-shima
Udone-shima
Nii-jima
Kozu-shima
Miyake-jima
Japan Trench
Bosai Seamount
Daiyon-kashima Seamount
Kashima Tablemount
Boso Canyon
Takuyo-dani Seamount
© 2011 ZENRIN
© 2011 Europa Technologies
© 2011 Geocentre Consulting
Data © 2011 MIRC/JHA
USGS
©2010 Google
Eye alt 578.18 km


Sendai Earthquake (2011-03-11 M 9.0) displacements
Tohoku sites
symbol
label
arrow
error
Map
Satellite
Terrain
1 m
日本
Japan
Niigata
新潟
9.0 Mb 2011-03-11 05:46:23 UTC
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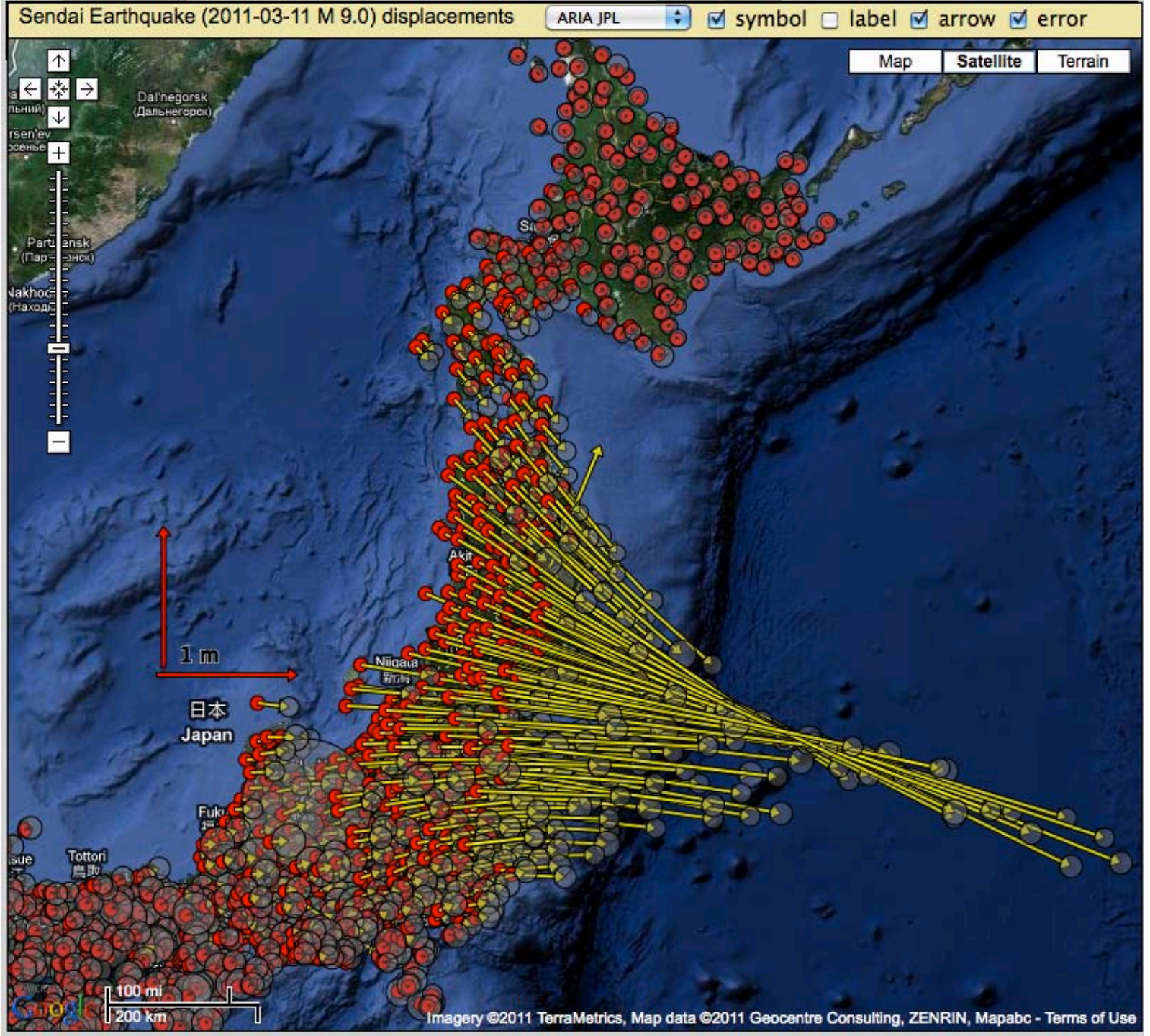
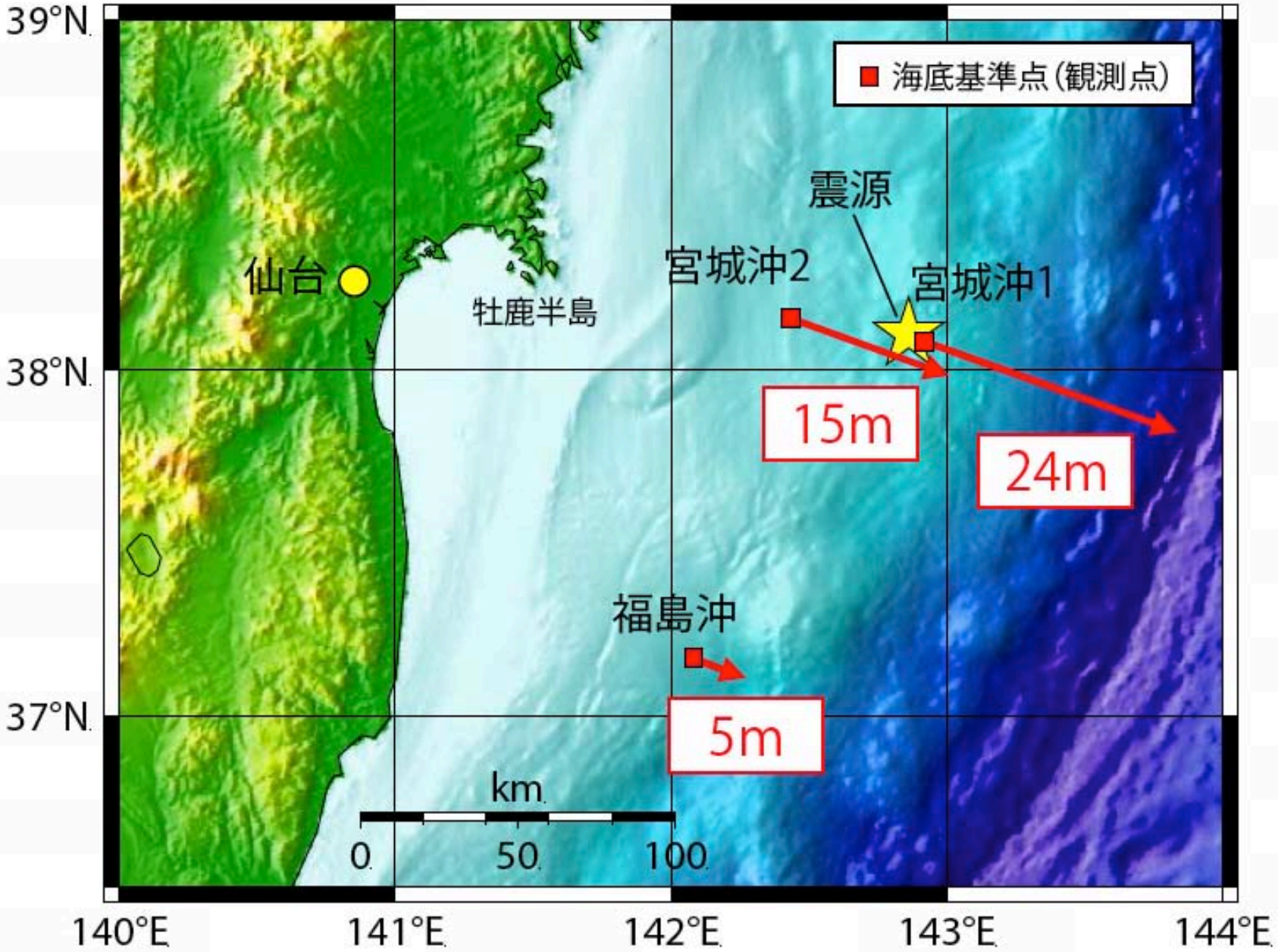
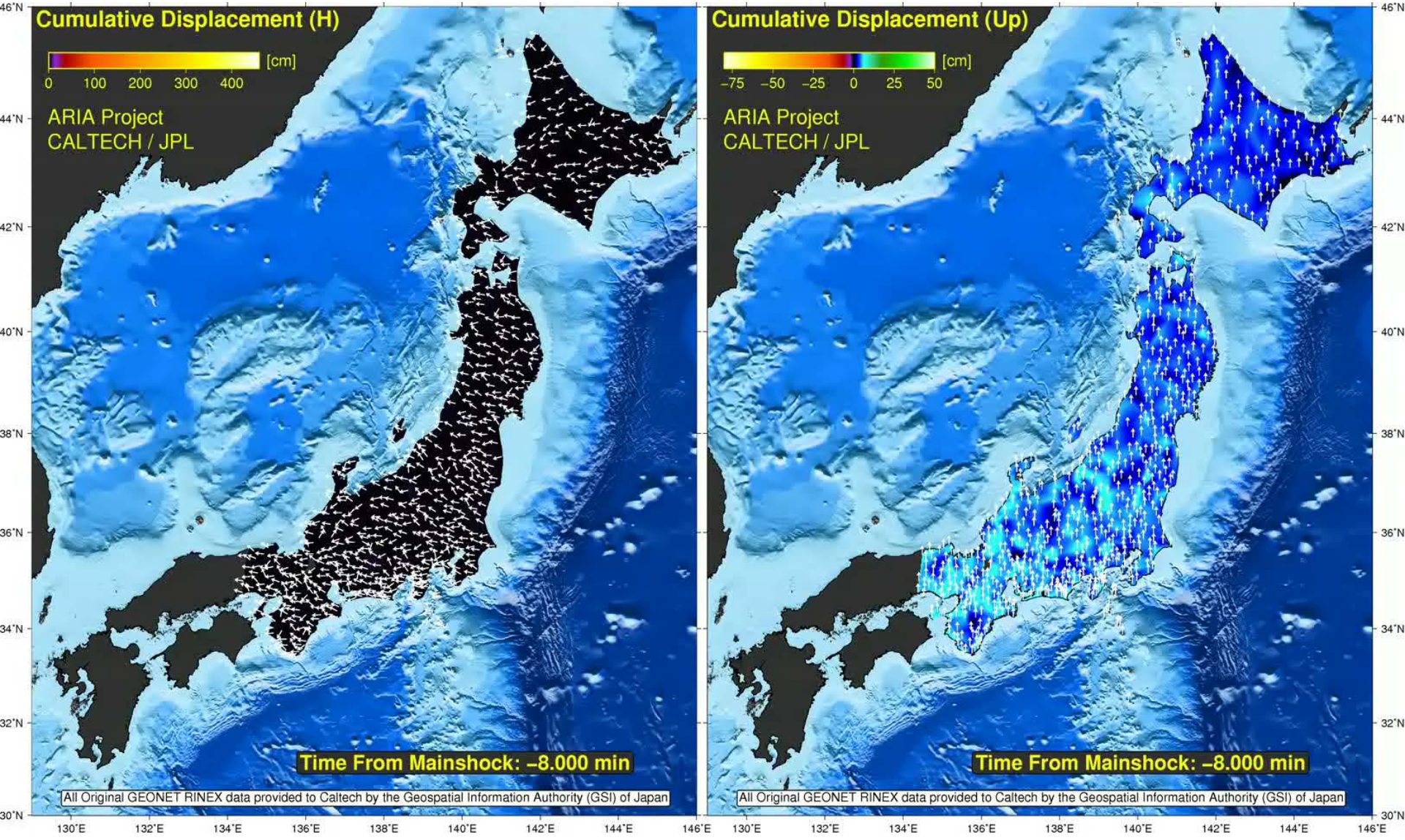
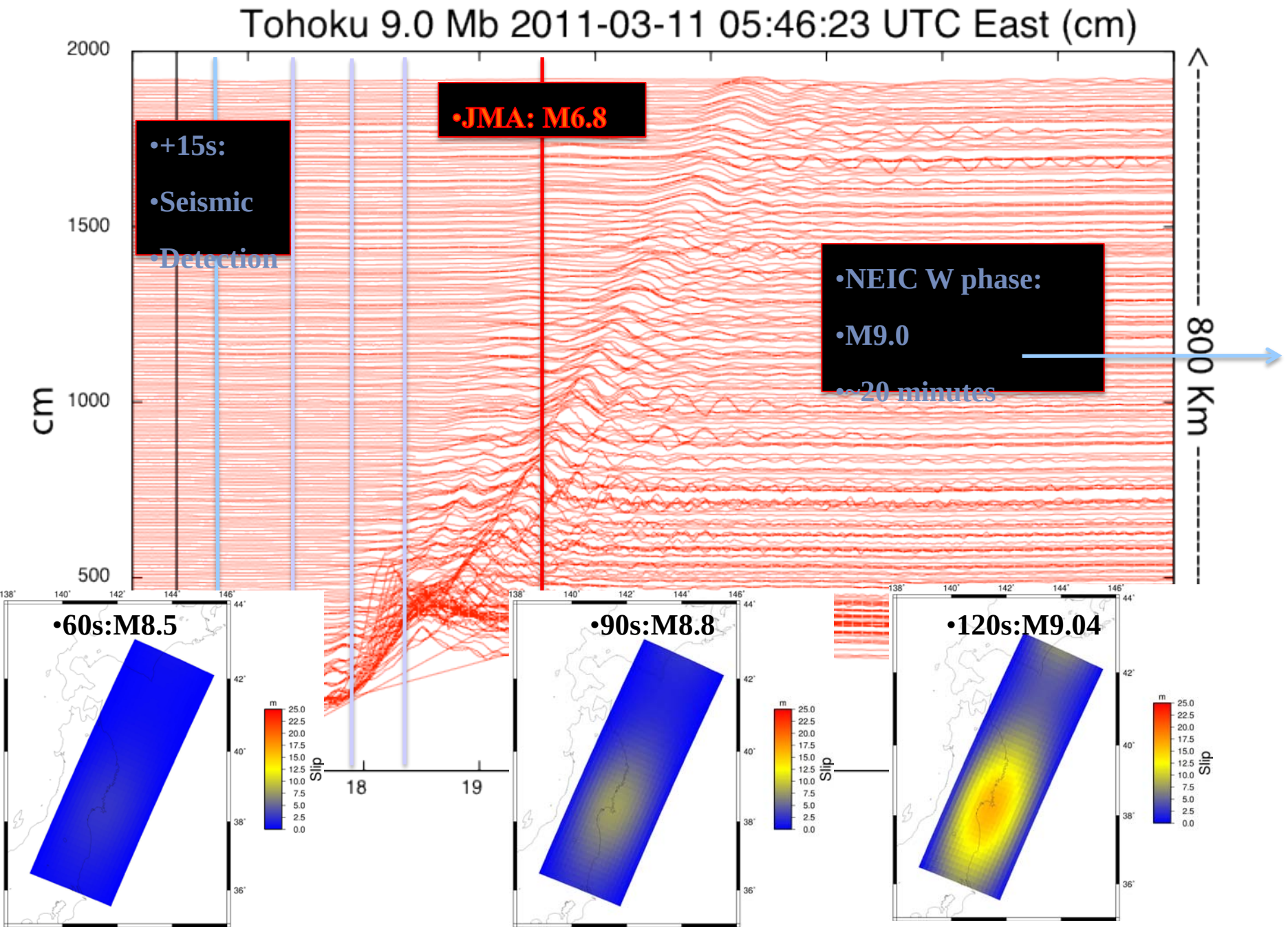
Tottori
鳥取
Okayama
岡山
100 mi
200 km
Imagery ©2011 TerraMetrics, Map data ©2011 Geocentre Consulting, ZENRIN, Mapabc - Terms of Use


Sendai Earthquake (2011-03-11 M 9.0) displacements
ARIA JPL
symbol
label
arrow
error
Map
Satellite
Terrain
Dal'negorsk
(Дальнегорск)
1 m
日本
Japan
Akit
Niigata
Tottori
100 mi
200 km
Imagery ©2011 TerraMetrics, Map data ©2011 Geocentre Consulting, ZENRIN, Mapabc - Terms of Use

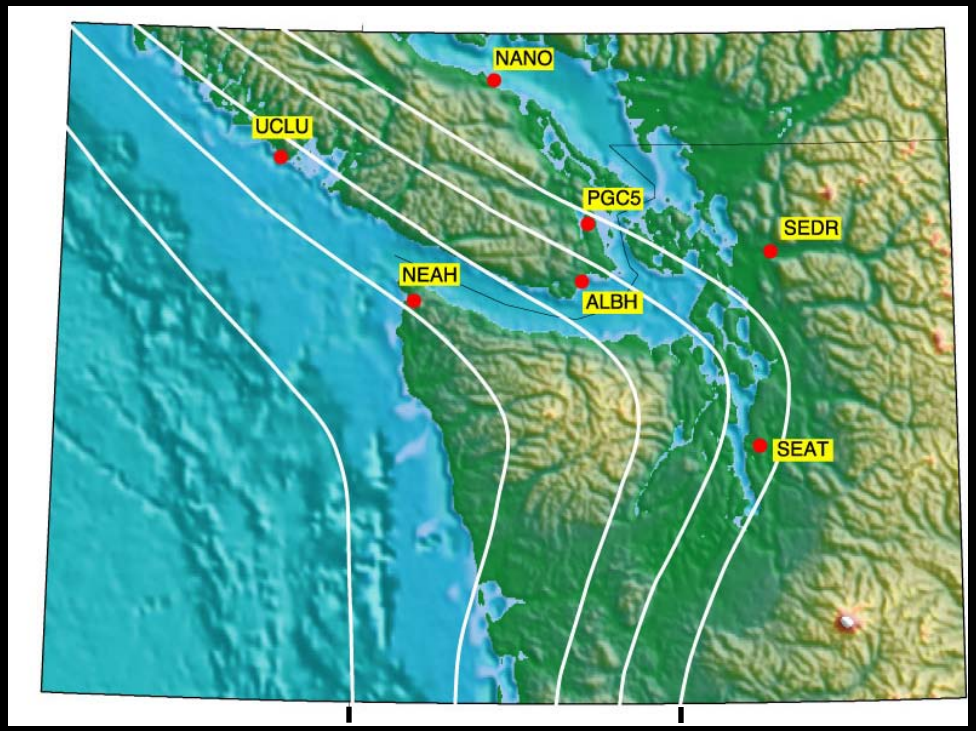


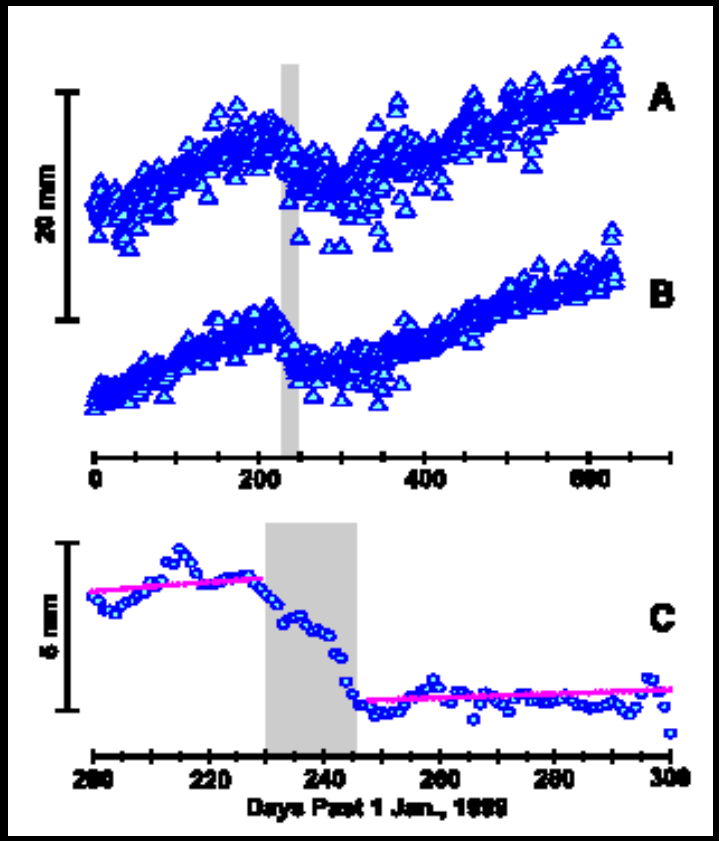
東北地方太平洋沖地震に伴う海底の動き(水平)


Cumulative Displacement (H)
[cm]
0 100 200 300 400
ARIA Project
CALTECH / JPL
Time From Mainshock: –8.000 min
All Original GEONET RINEX data provided to Caltech by the Geospatial Information Authority (GSI) of Japan
Cumulative Displacement (Up)
[cm]
–75 –50 –25 0 25 50
ARIA Project
CALTECH / JPL
Time From Mainshock: –8.000 min
All Original GEONET RINEX data provided to Caltech by the Geospatial Information Authority (GSI) of Japan
46°N
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
130°E
132°E
134°E
136°E
138°E
140°E
142°E
144°E
146°E

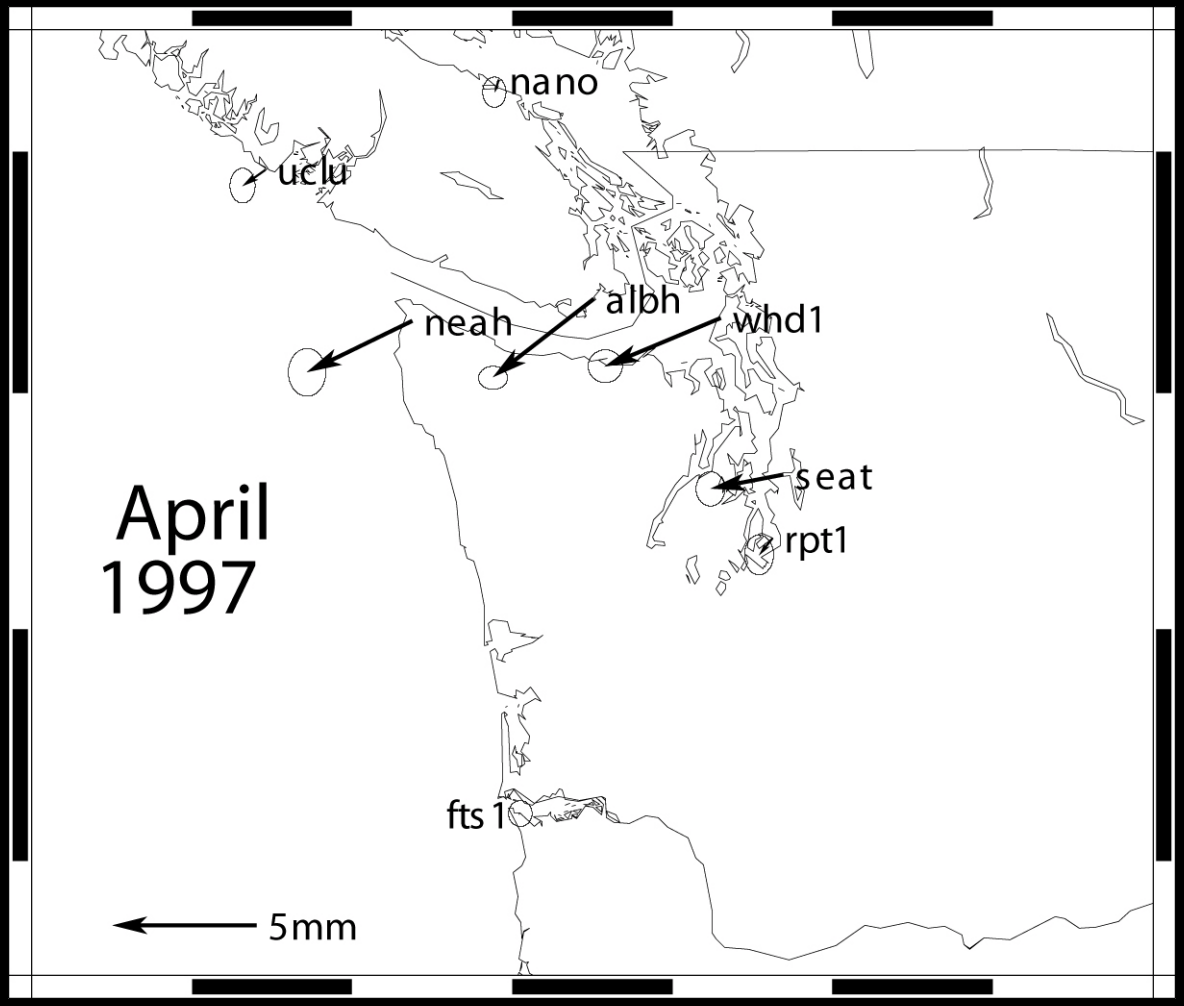

Tohoku 9.0 Mb 2011-03-11 05:46:23 UTC East (cm)
2000
1500
1000
500
cm
800 Km
•+15s:
•Seismic
•Detection
•JMA: M6.8
•NEIC W phase:
•M9.0
•~20 minutes
•60s:M8.5
•90s:M8.8
•120s:M9.04
Slip
m
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
18
19
138°
140°
142°
144°
146°
44°
42°
40°
38°
36°

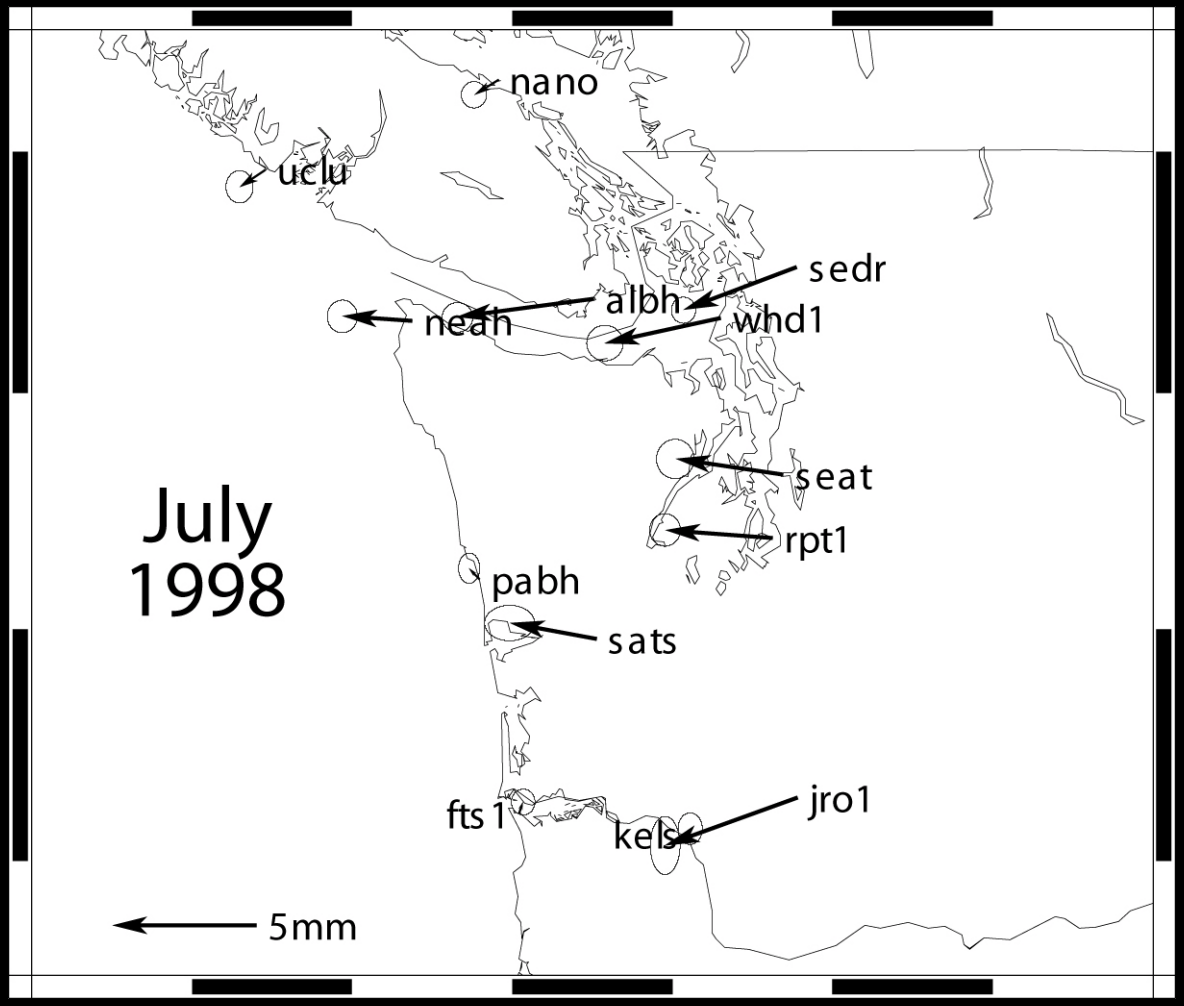
Slow Slip





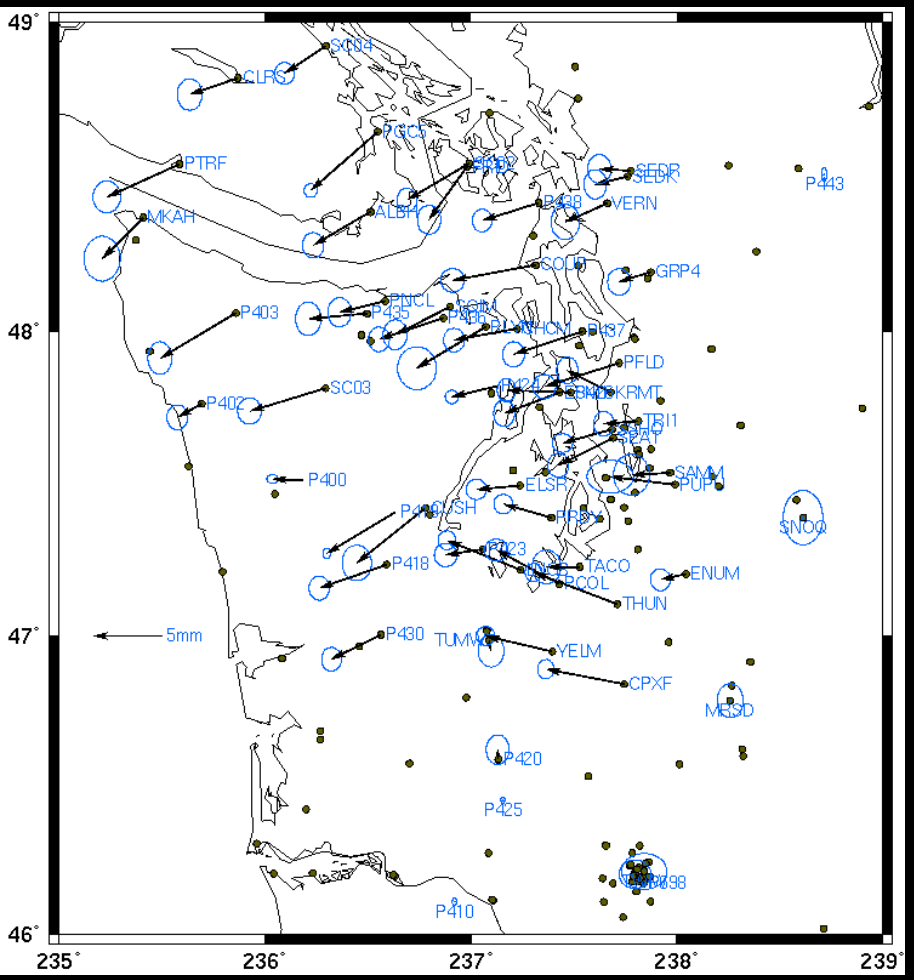
Dragert, Wang and James, 2001


nano
uclu
albh
neah
whd1
seat
rpt1
fts1
April
1997
5mm

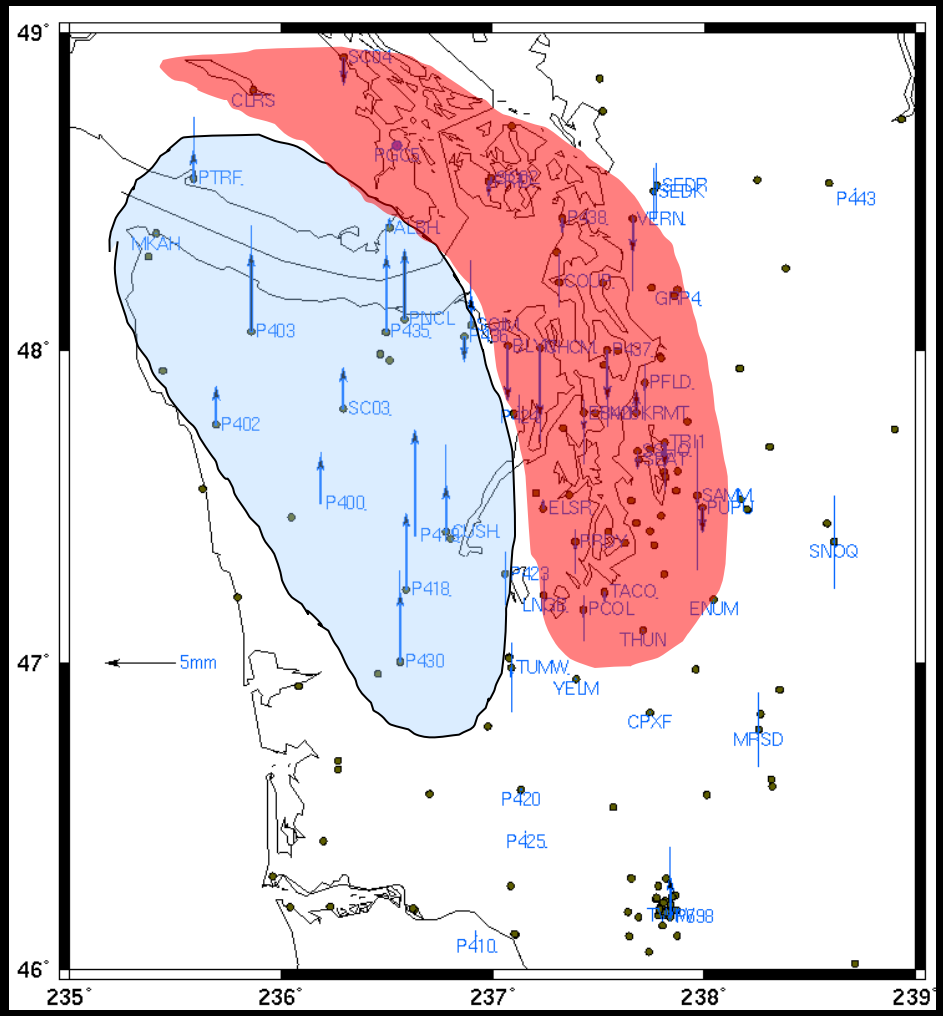

nano
uclu
sedr
albh
neah
whd1
seat
rpt1
July
1998
pabh
sats
fts1
jro1
kels
5mm

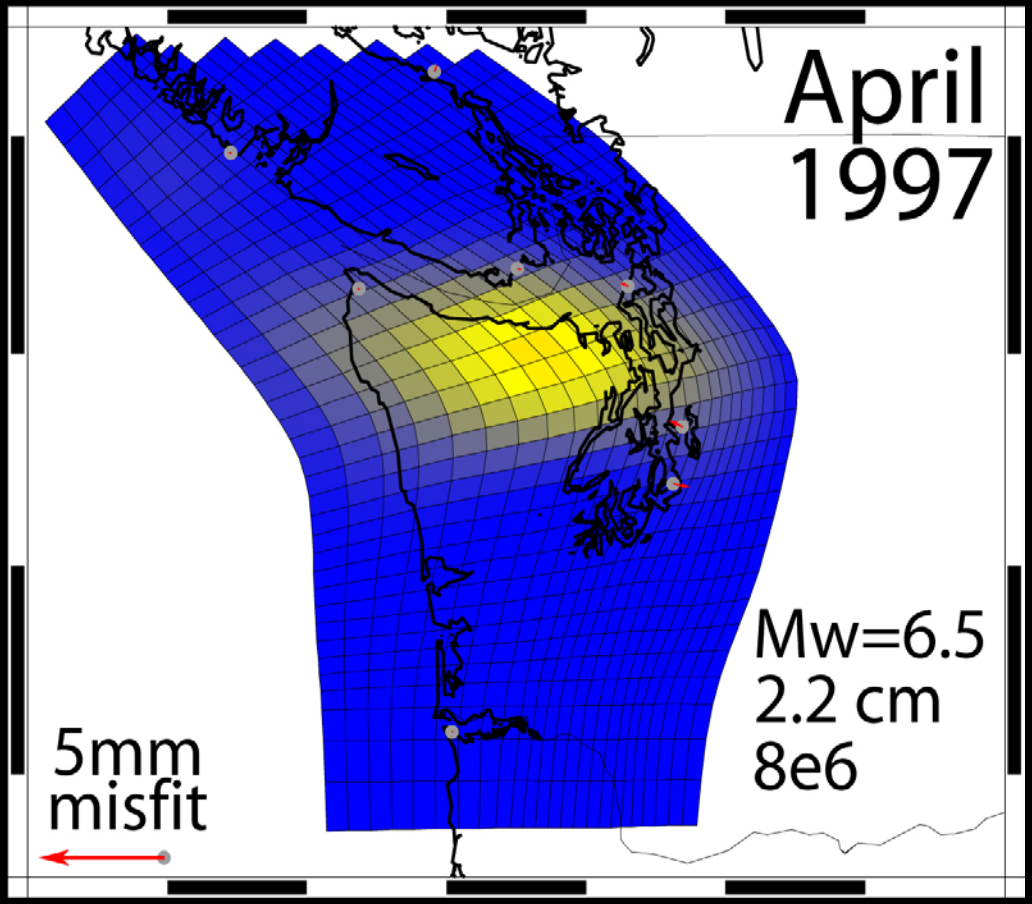
August 2010 GPS Displacements

Horizontal

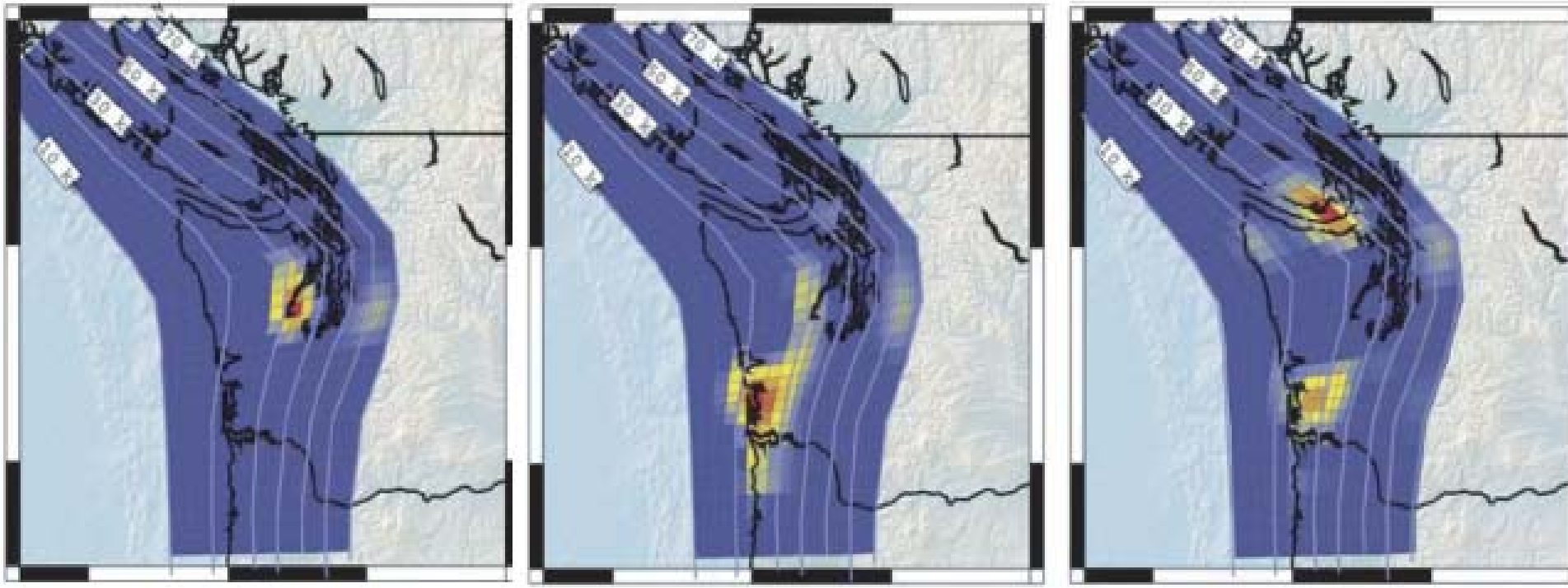


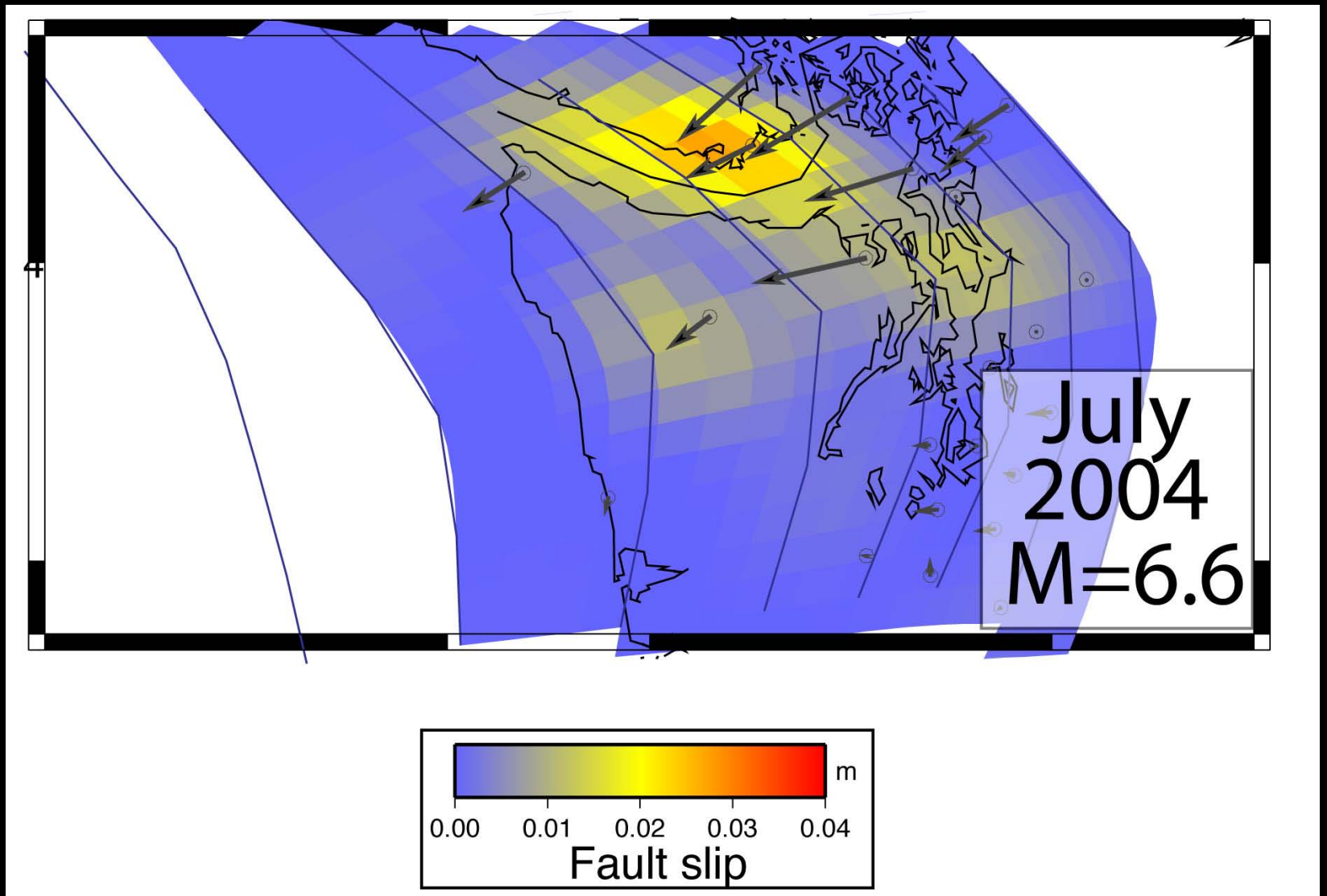
Vertical

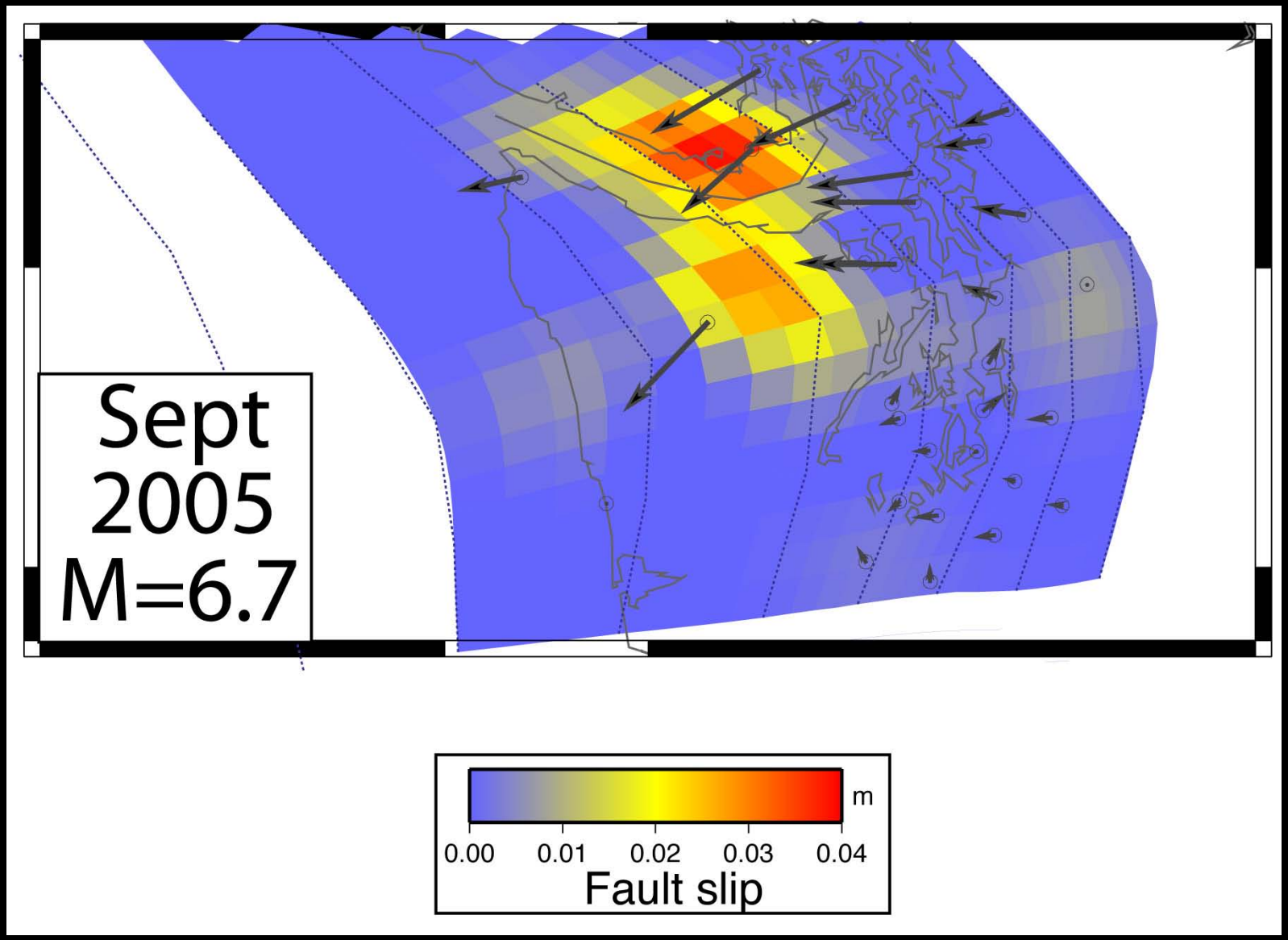


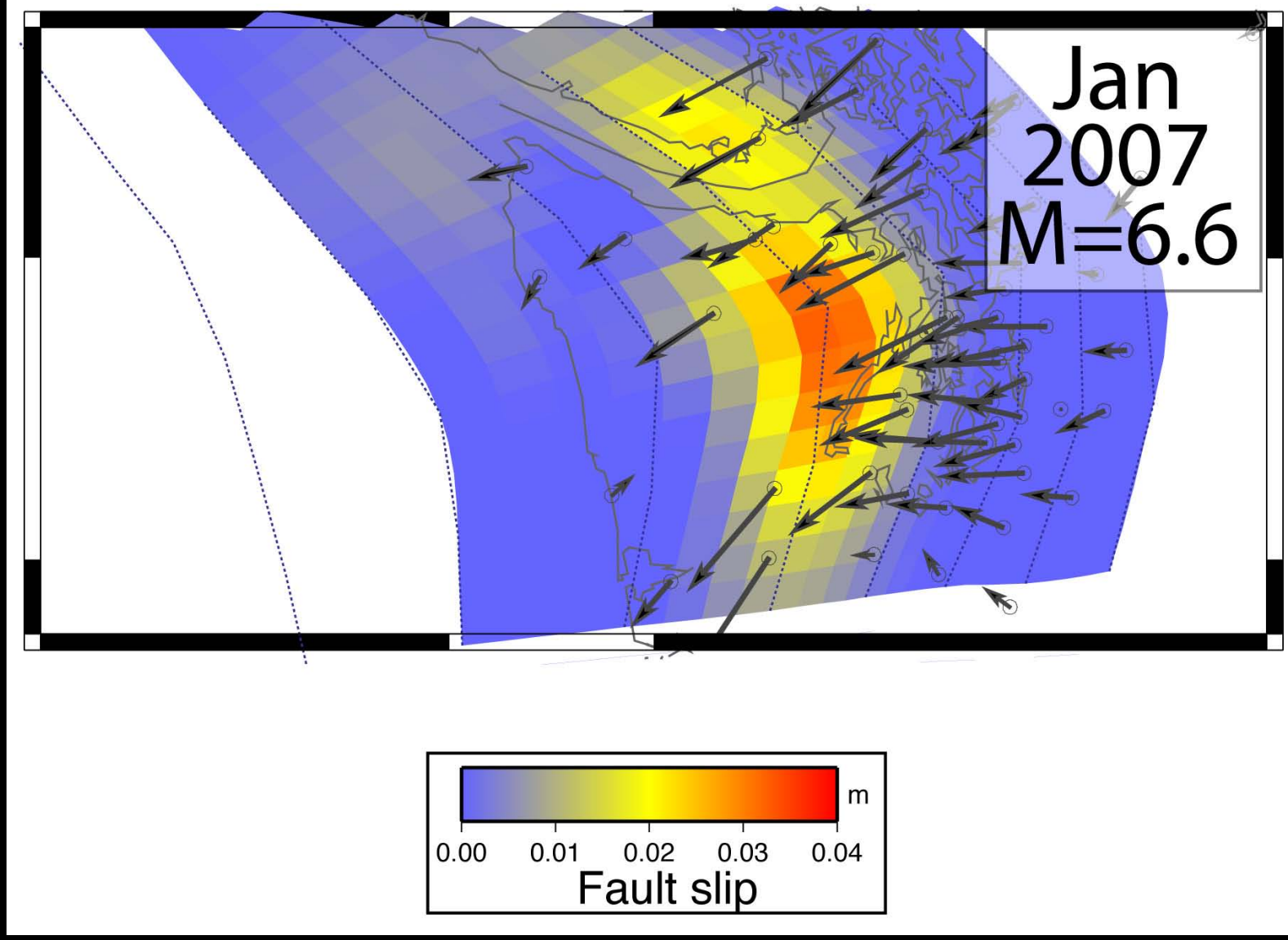

April
1997
Mw=6.5
2.2 cm
8e6
5mm
misfit

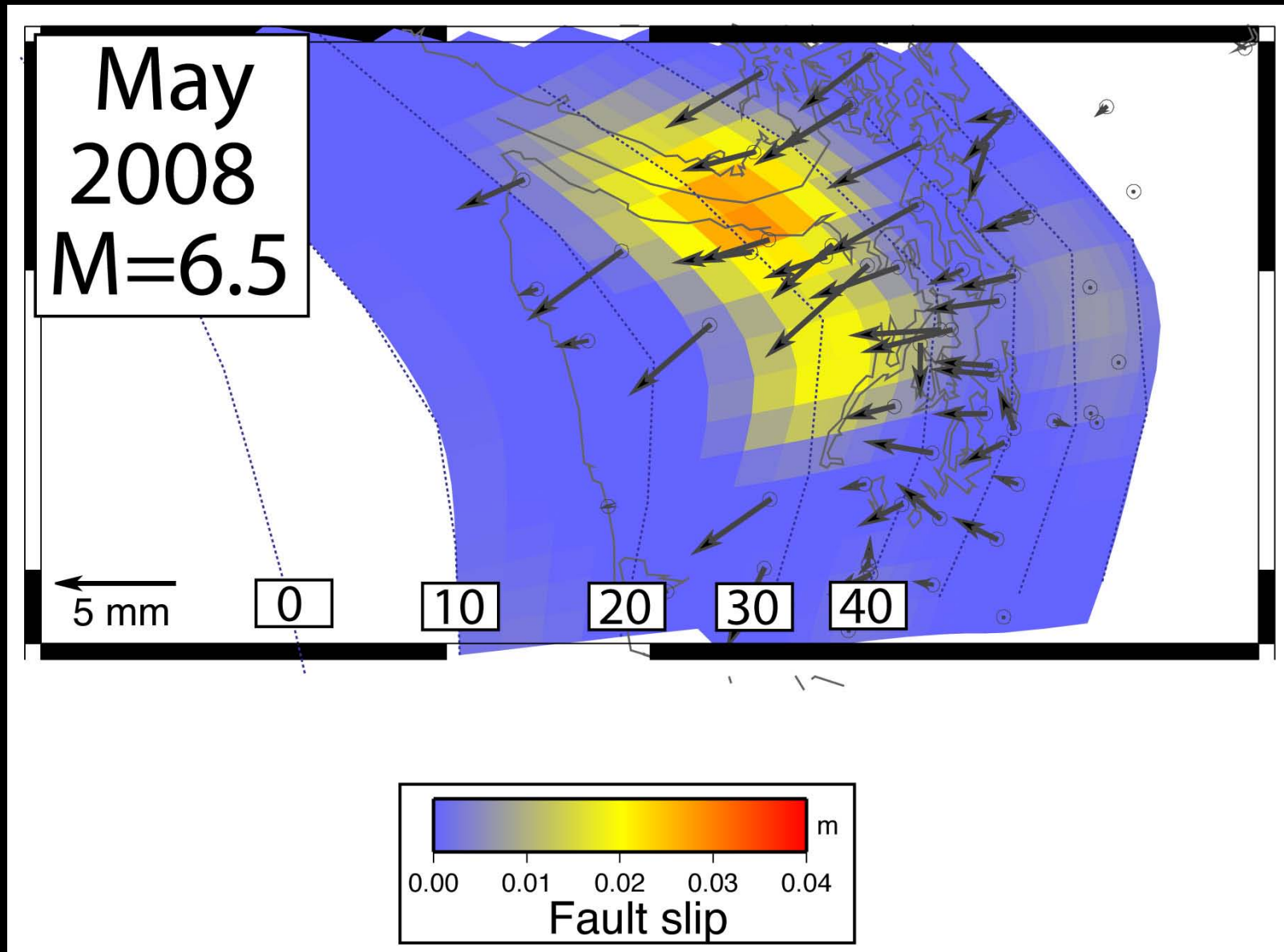
~February 5 2003 through ~March 15 2003



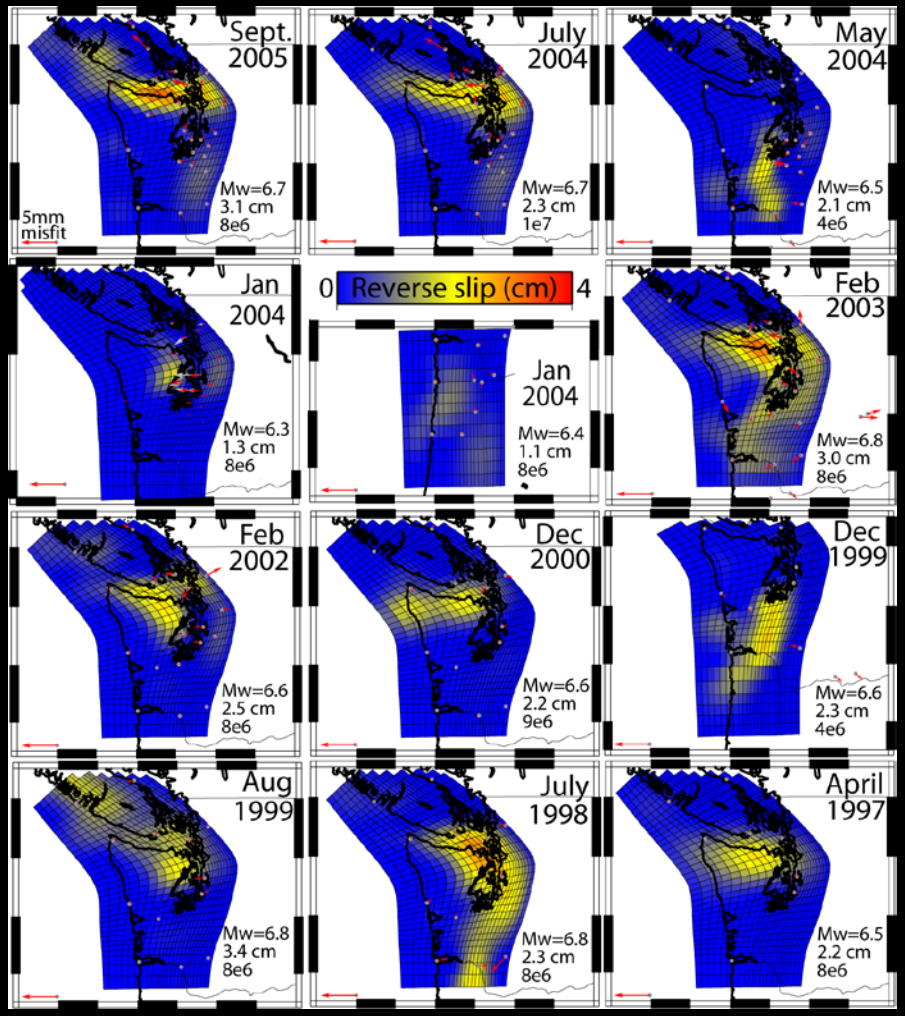

July
2004
M=6.6
m
0.00
0.01
0.02
0.03
0.04
Fault slip


Sept
2005
M=6.7
m
0.00
0.01
0.02
0.03
0.04
Fault slip


Jan
2007
M=6.6
m
0.00
0.01
0.02
0.03
0.04
Fault slip

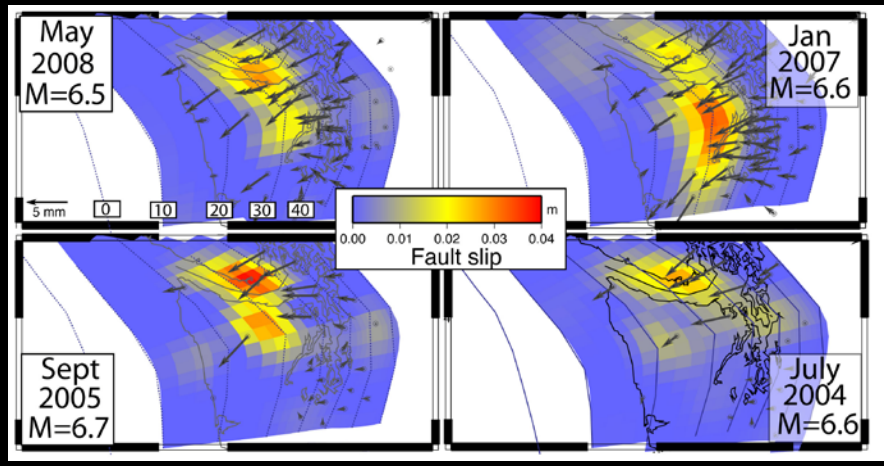

May
2008
M=6.5
5 mm
0
10
20
30
40
m
0.00
0.01
0.02
0.03
0.04
Fault slip

Many magnitude 6s

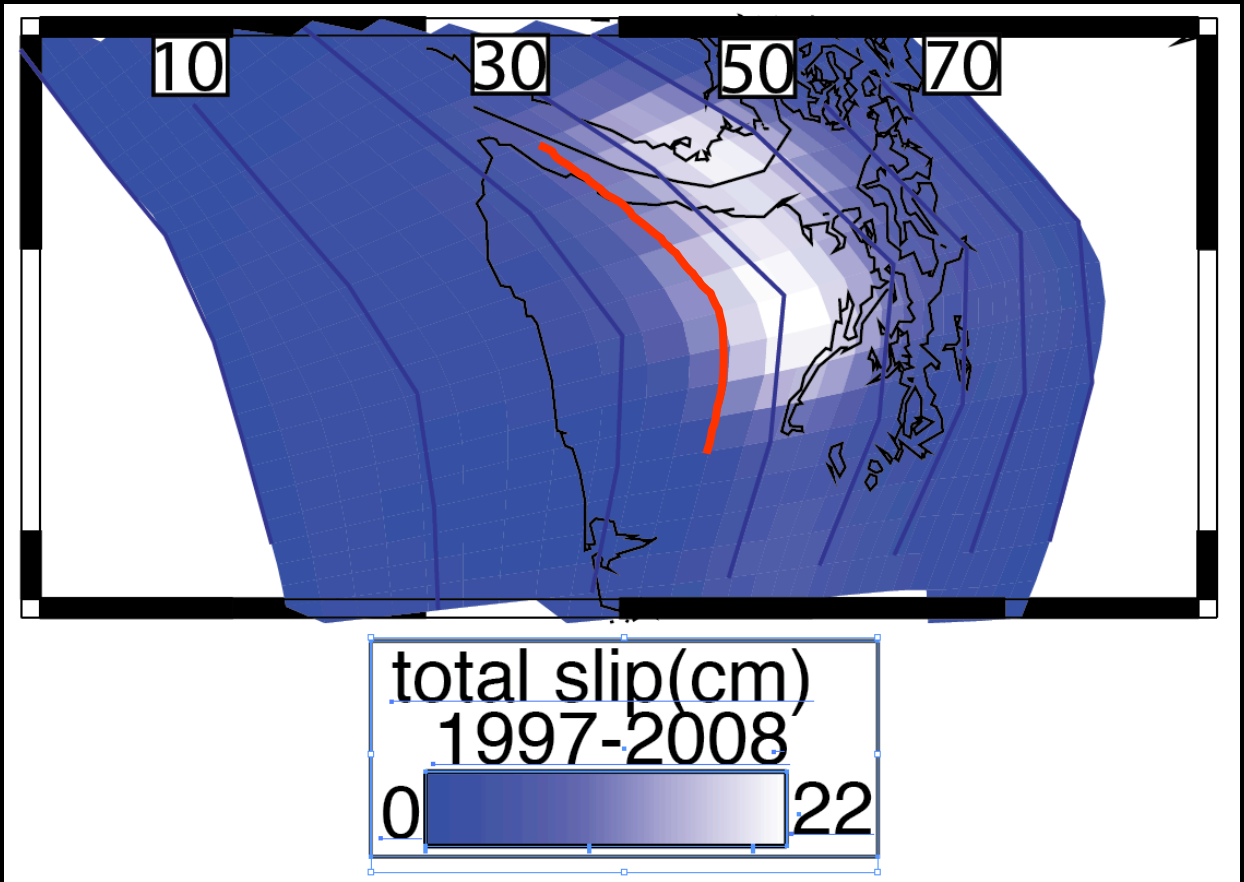


Szeliga et al., 2008

+

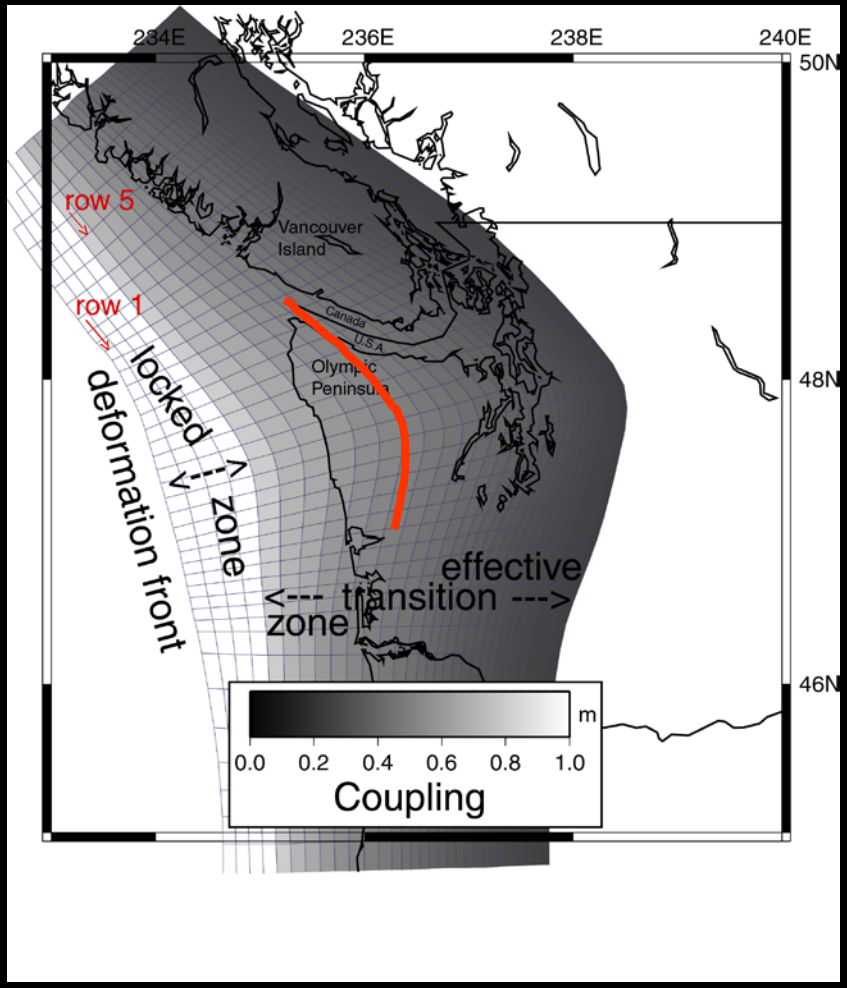


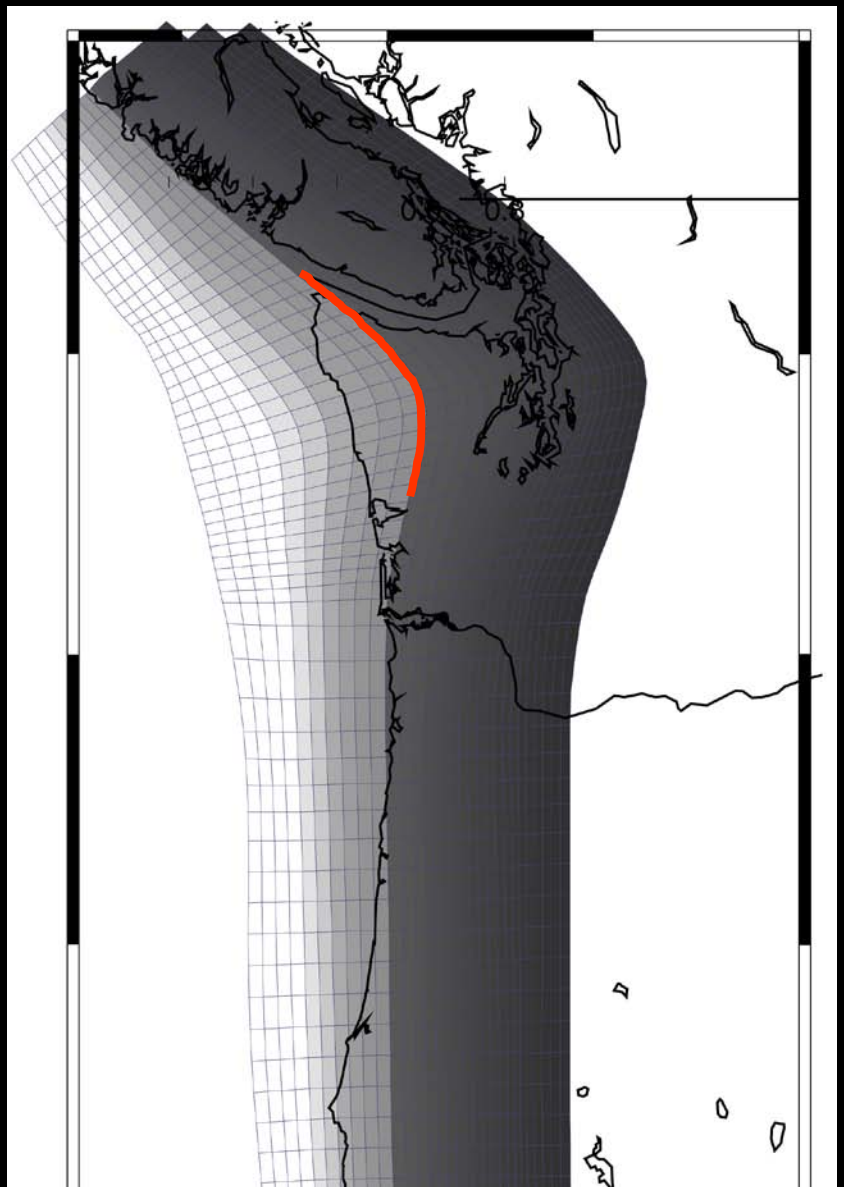
Chapman and Melbourne., 2009



- ~Half of convergence is accommodated by large ETS events
- All imaged slip occurs below 25 km depth, above 40 km
- But max slip ~ 1/smoothing

ETS delineates a 25 km lower limit to interseismic strain accumulation

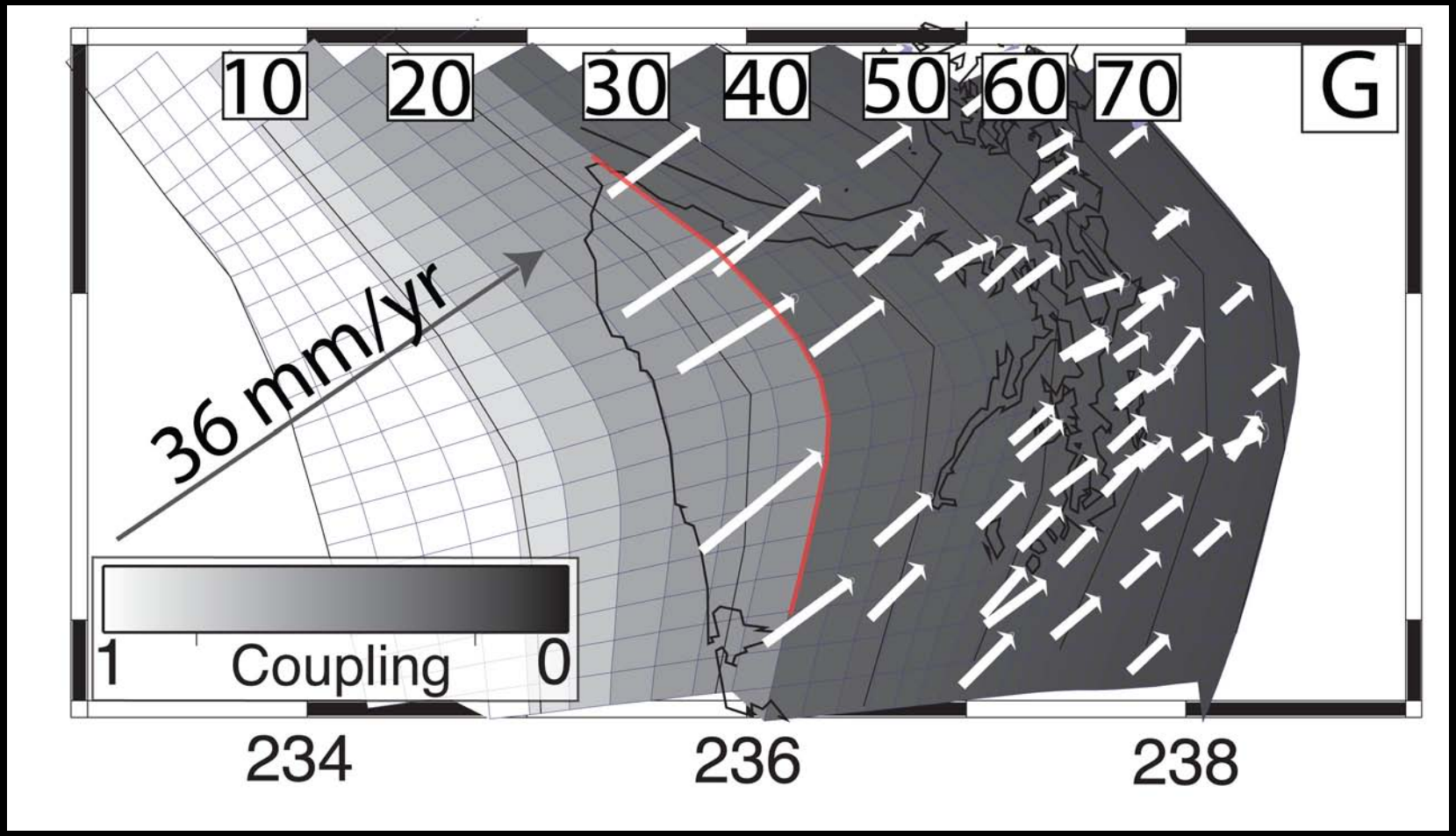




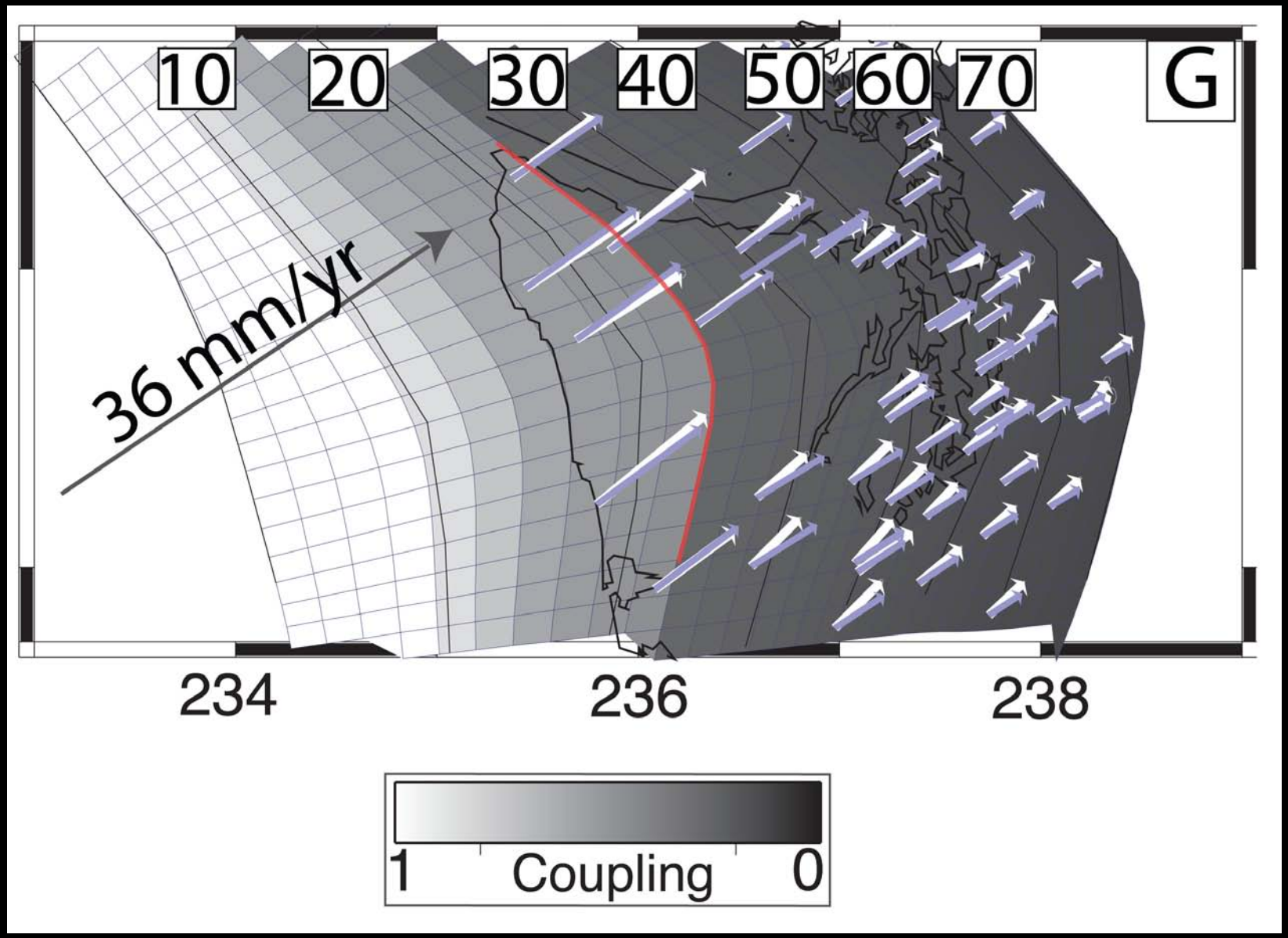
After Hyndman, Dragert, Wang, etc, 1992-2003

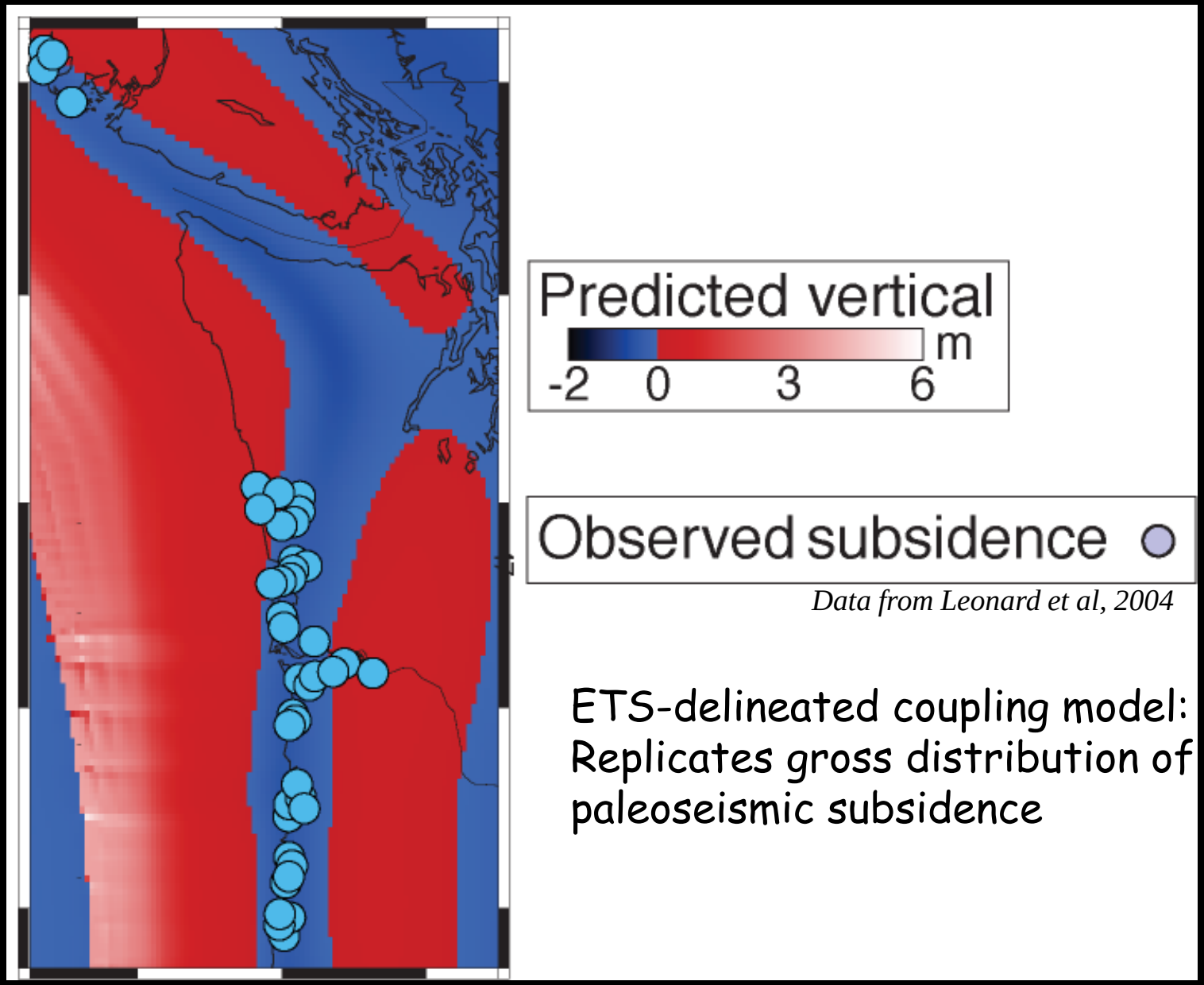
Testing this model:

- It should replicate current GPS data (which has many new stations)
- Run in reverse, it needs to satisfy paleoseismic constraints



Test 1: comparison with current interseismic deformation:



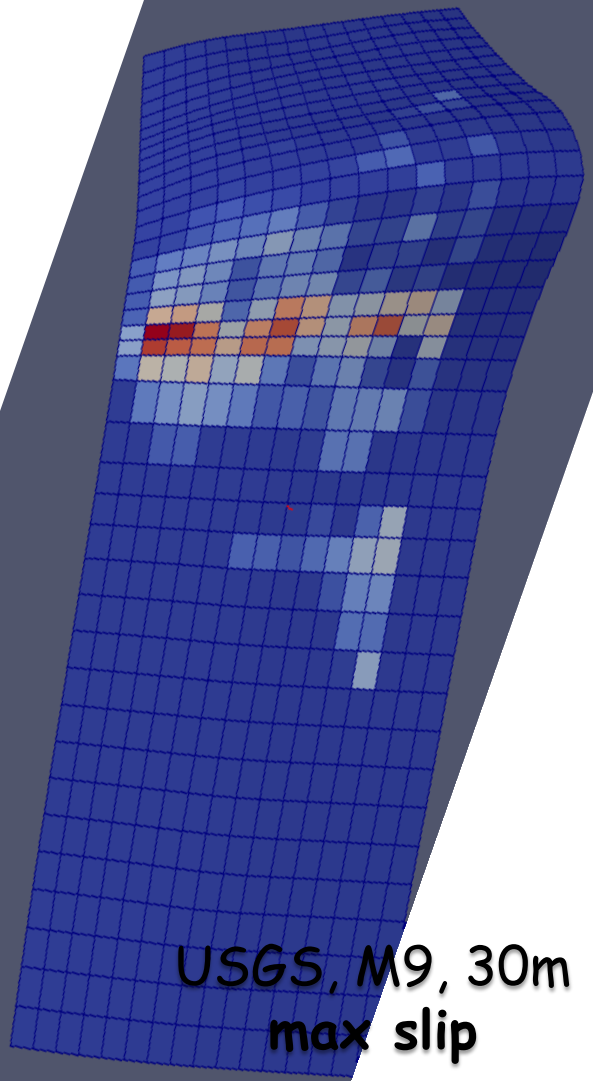


Data from Leonard et al, 2004

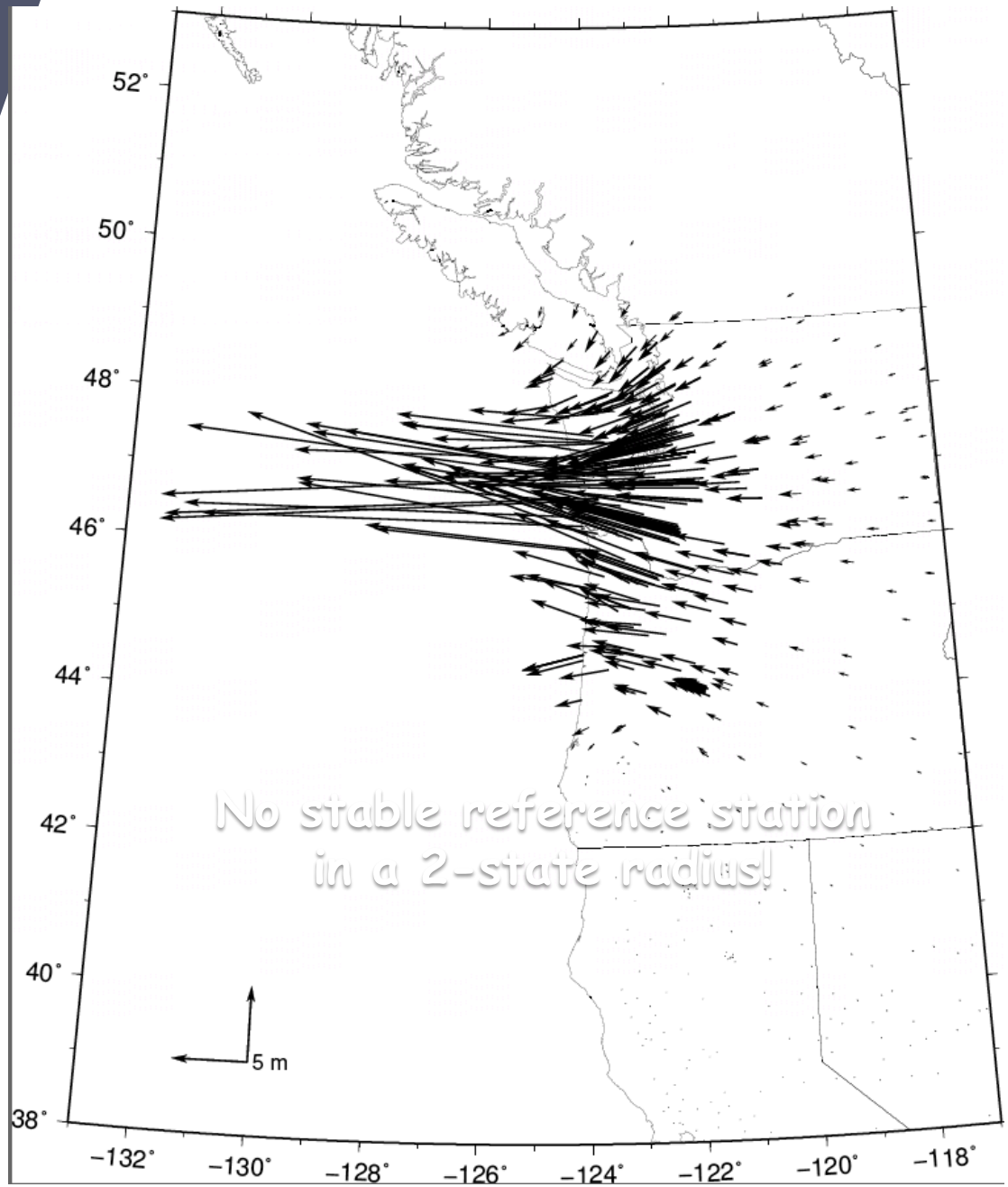
ETS-delineated coupling model:
Replicates gross distribution of paleoseismic subsidence

A rough forecast of future slip after full recurrence interval

Why rtGPS? Tohoku in Cascadia



USGS, M9, 30m
max slip



Concluding thoughts

- The Cascadia subduction zone will have great earthquakes
- Real-time GPS network is in place
- Data analyses are evol
- Saving lives with real-time GPS