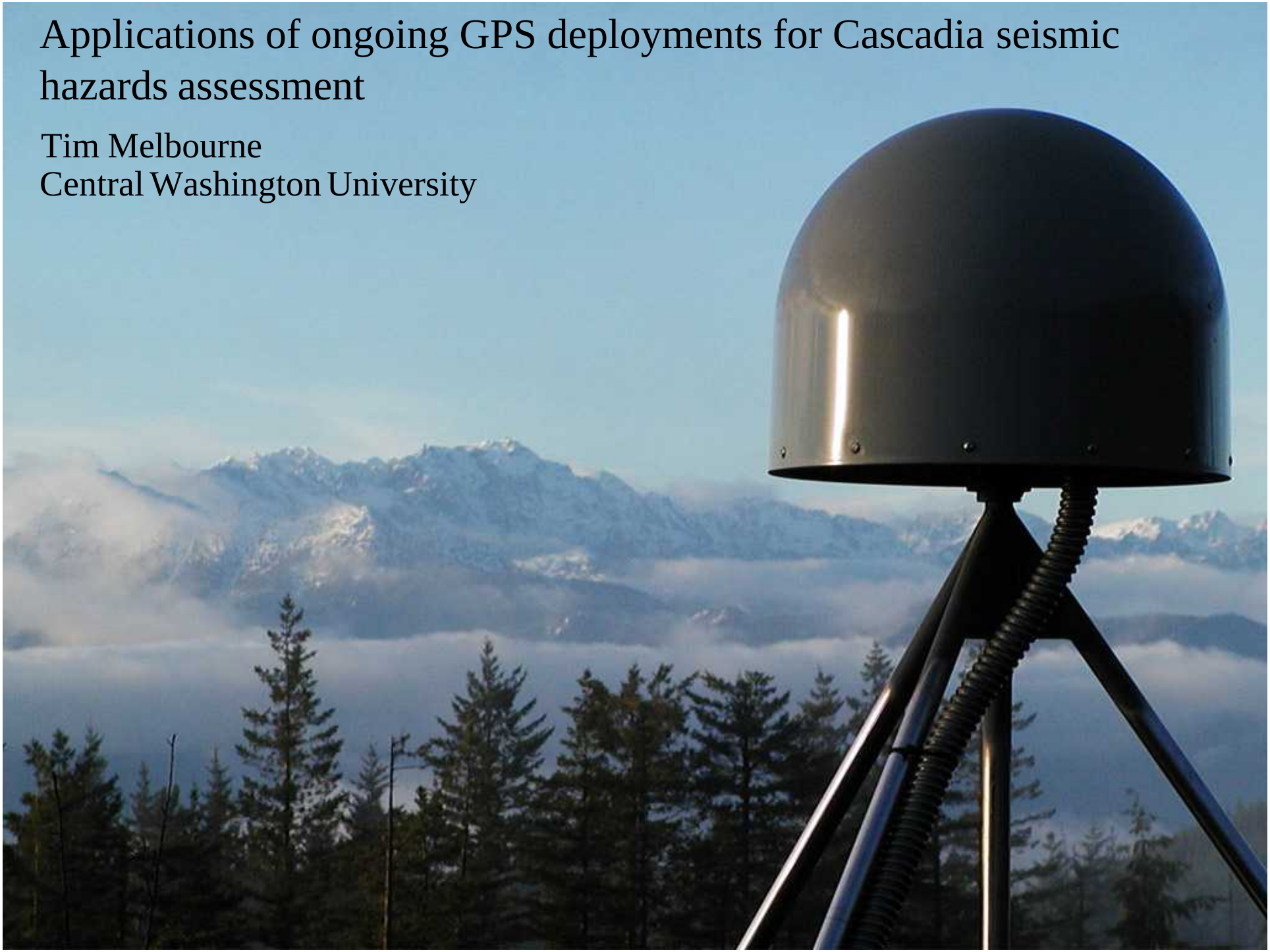
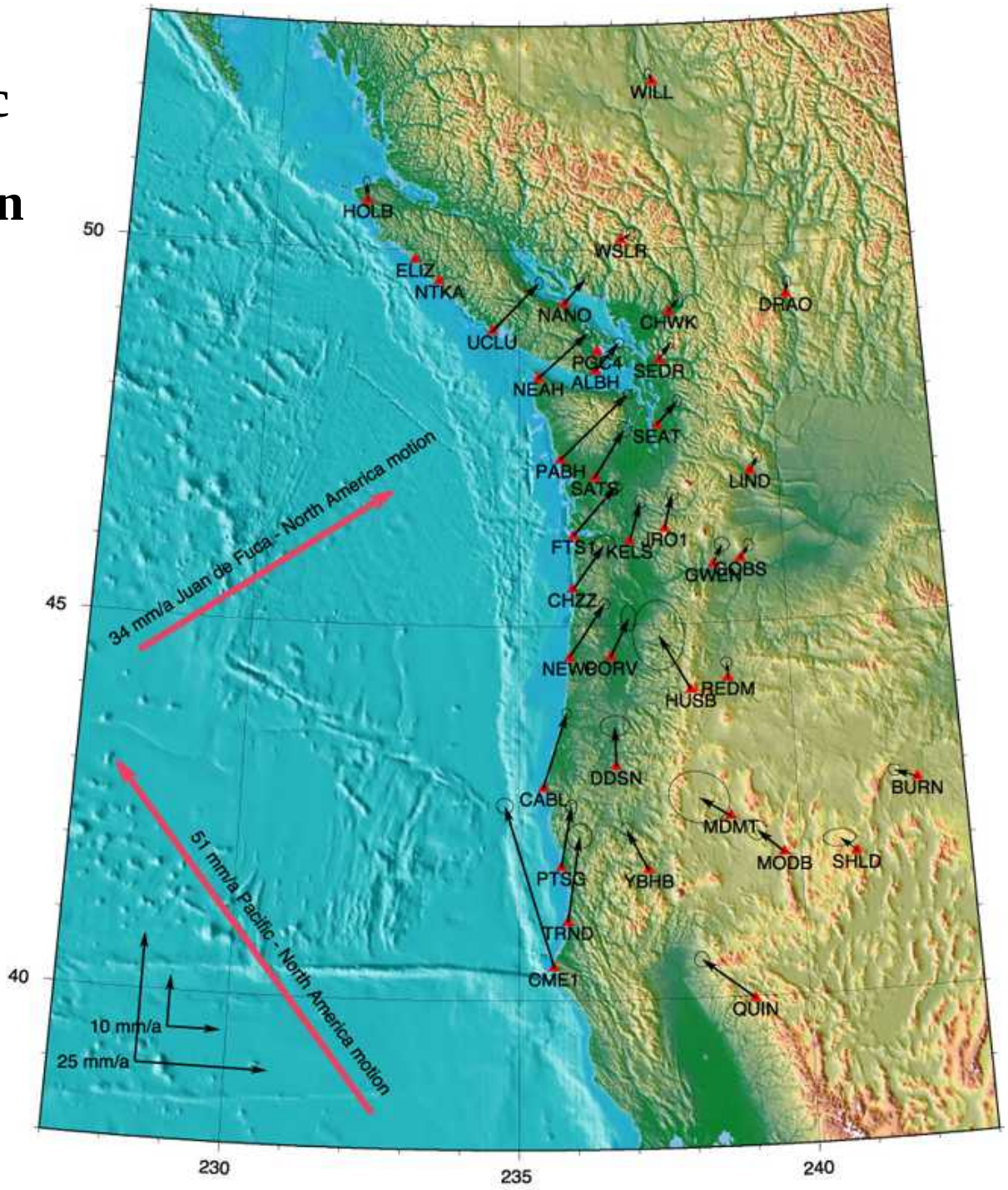
Applications of ongoing GPS deployments for Cascadia seismic hazards assessment

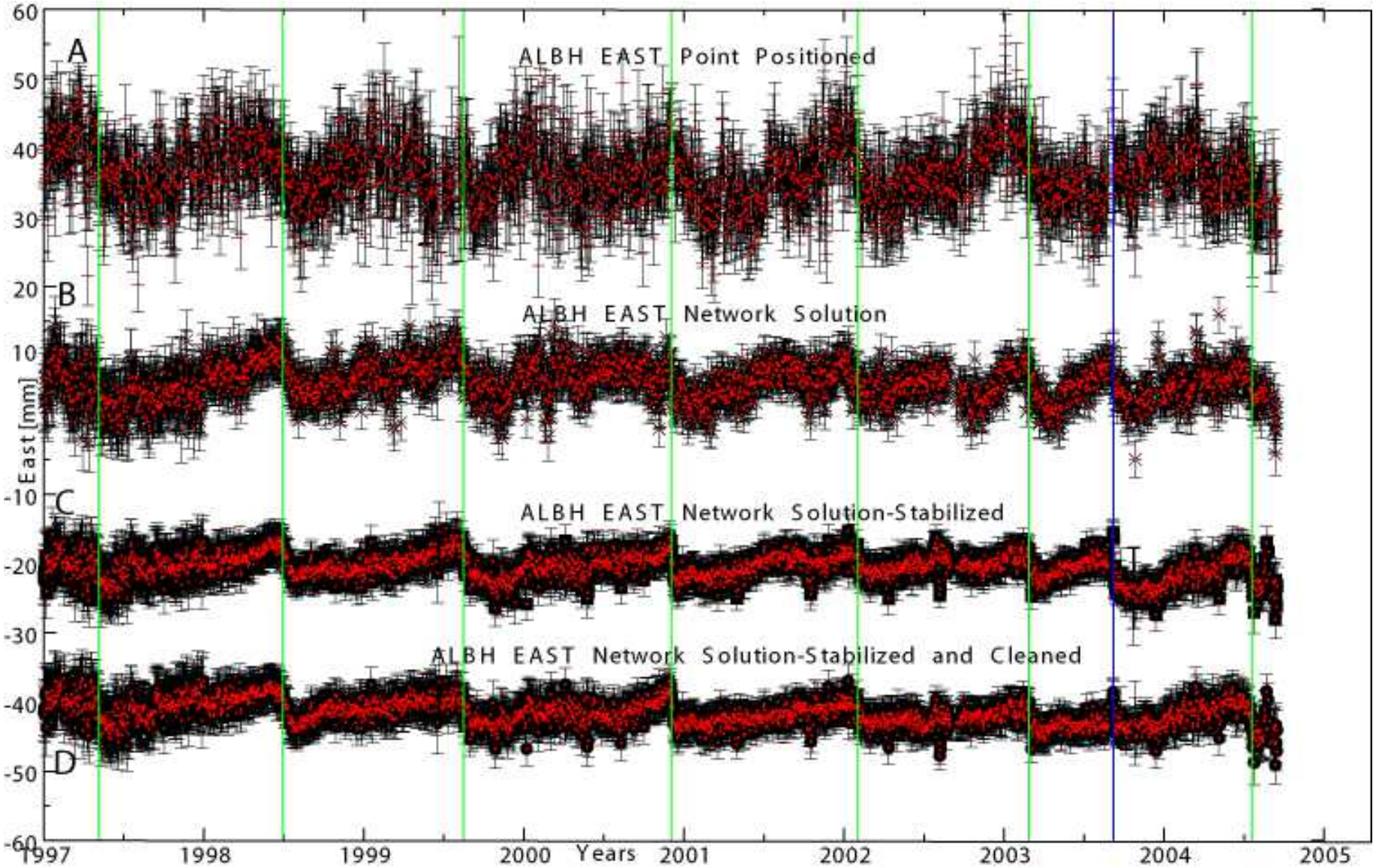
Tim Melbourne
Central Washington University



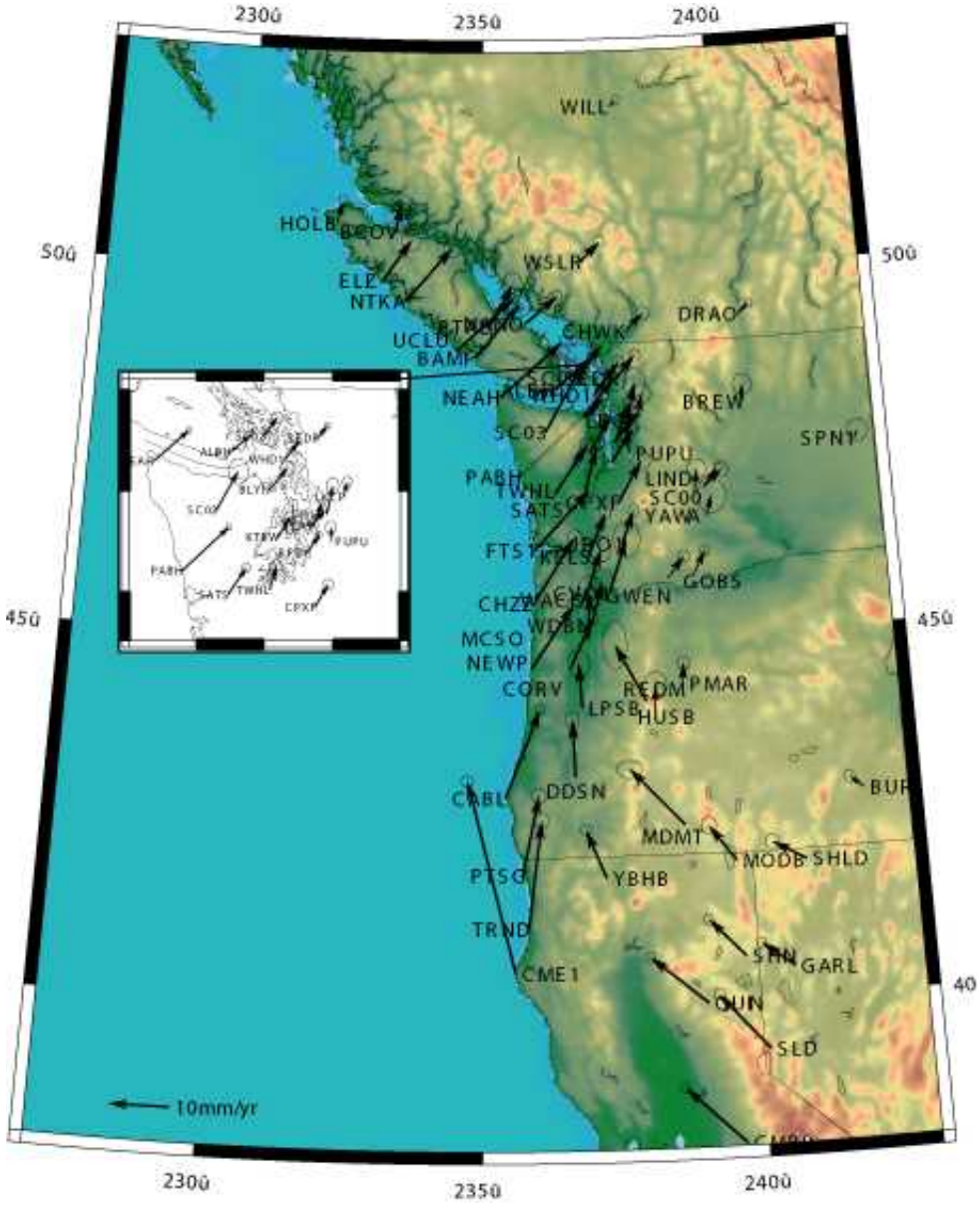
Interseismic Deformation



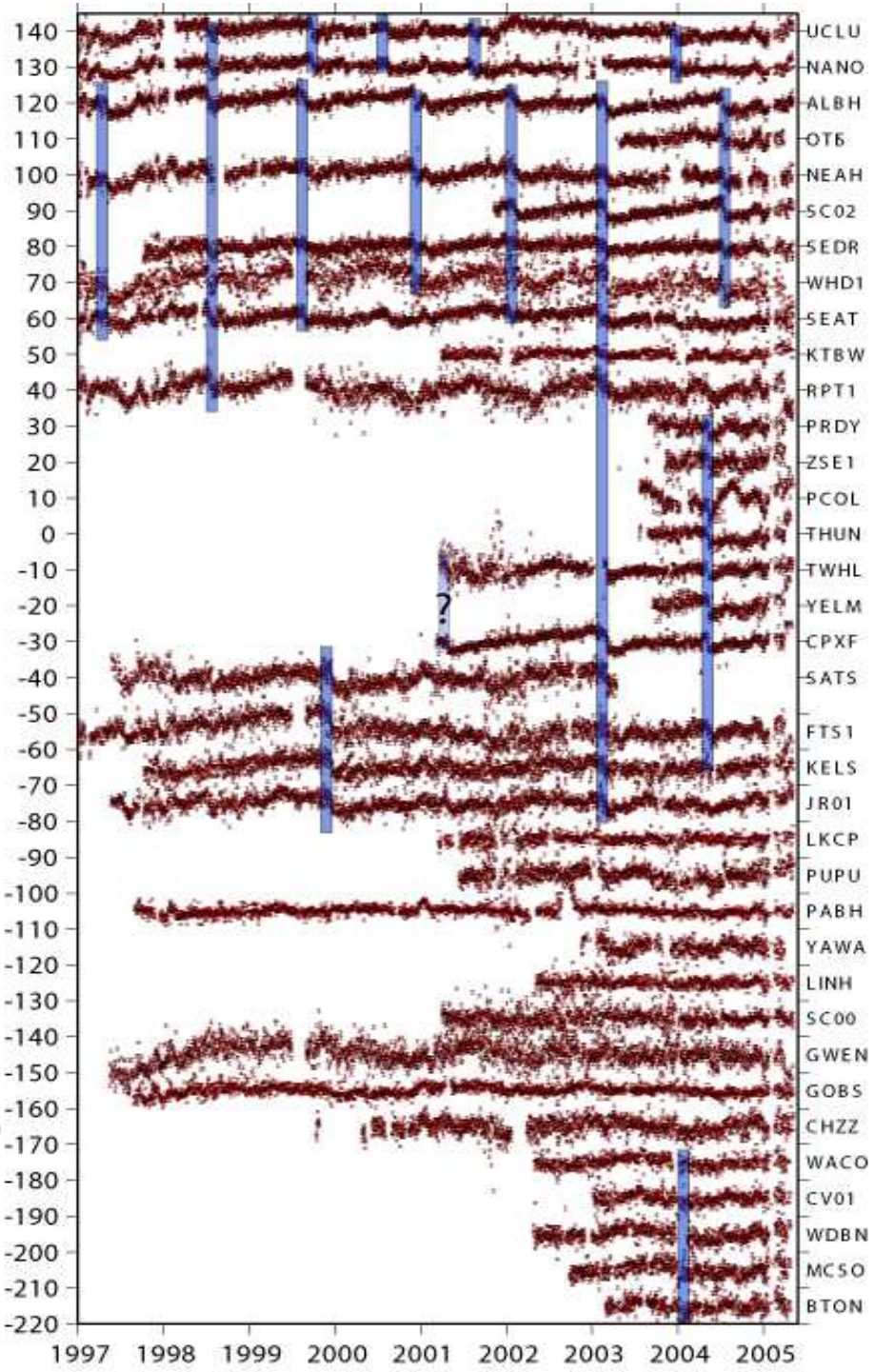
Four levels of GPS Data Analyses



East-West

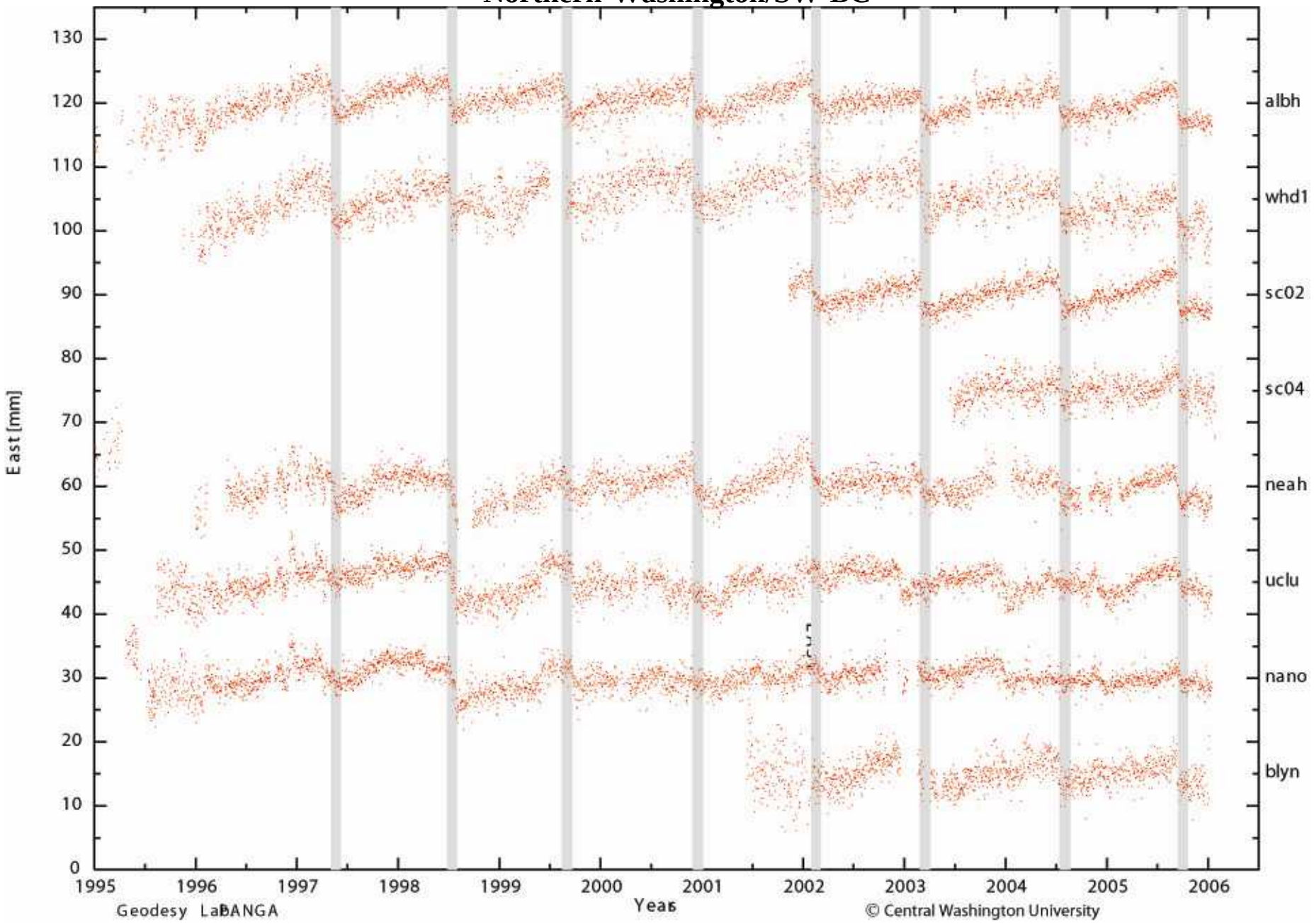


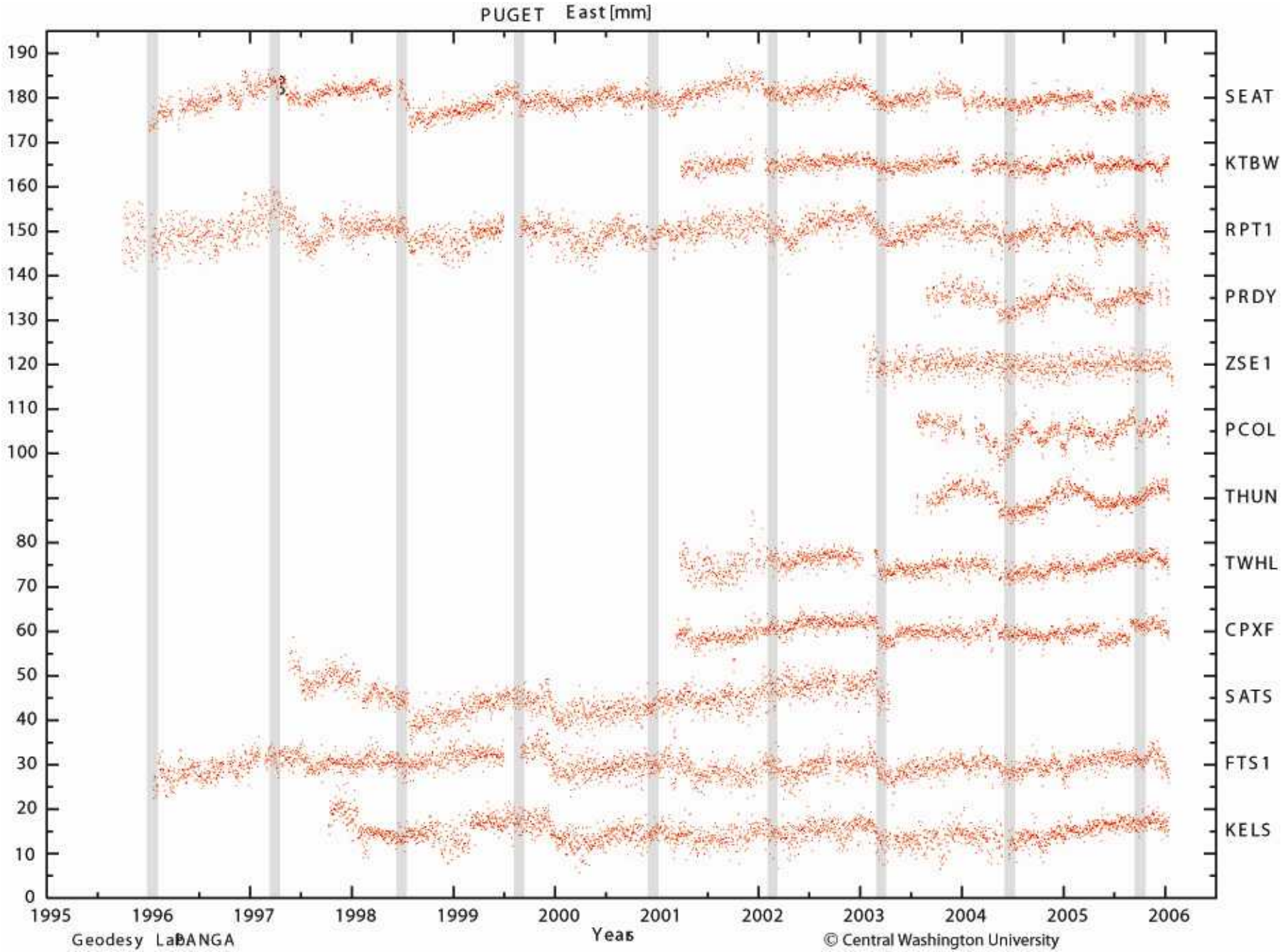
2300
2350
2400
500
450
40
WILL
HOLB
BCOV
ELE
NTKA
WSLR
UCLU
BAMF
CHWK
DRAO
NEAH
BREW
SC03
SPNY
PUPU
PABH
TWHL
LIND
SC00
SATS
YAWA
FTS1
GOBS
CHZZ
GWEN
MCSO
NEWP
CORV
REDM
PMAR
LPSB
HUSB
CABL
DDSN
MDMT
MODB
SHLD
PTSG
YBHB
TRND
SHN
GARL
CME1
GUN
SLD
10mm/yr



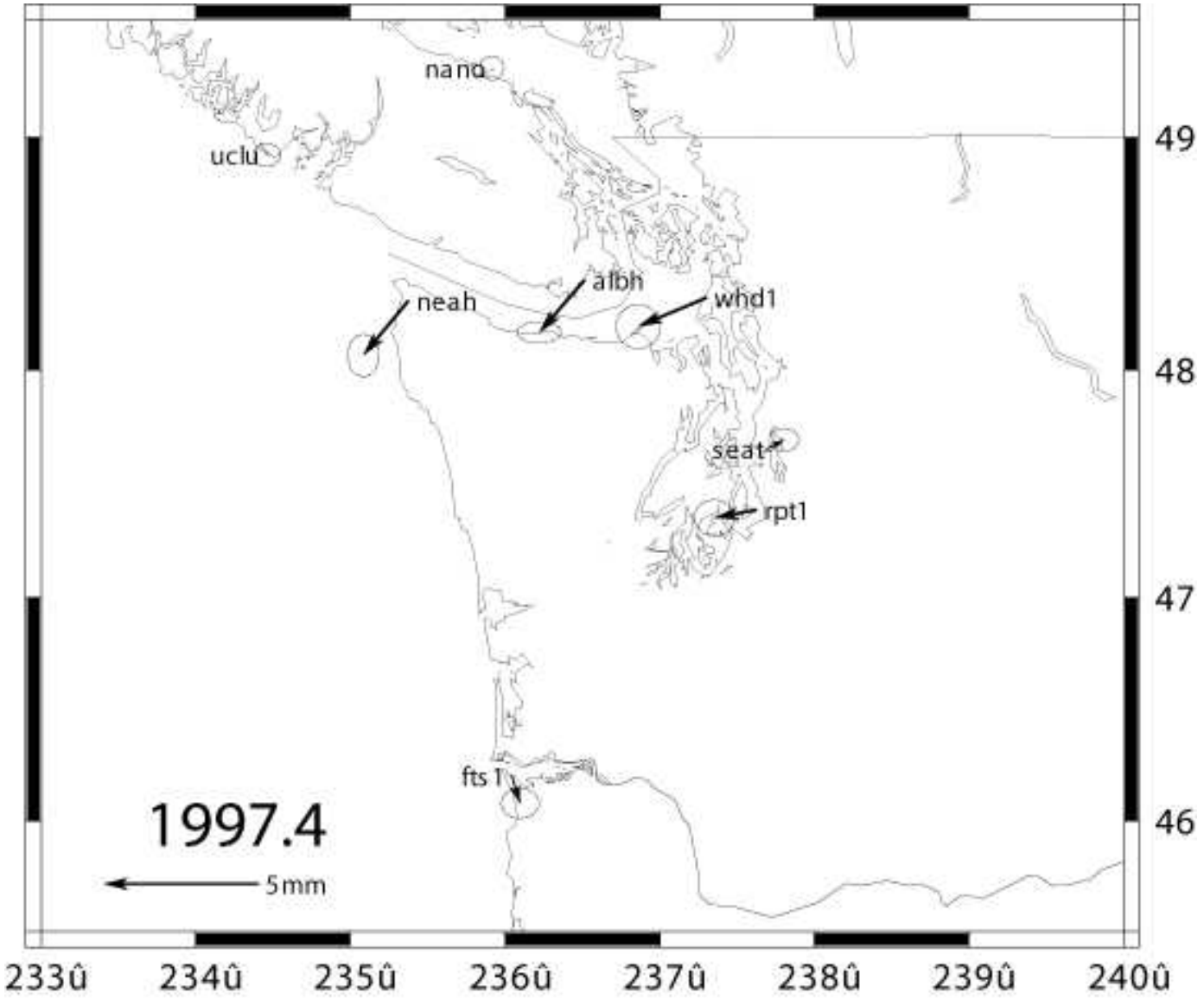
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
1997
1998
1999
2000
2001
2002
2003
2004
2005
UCLU
NANO
ALBH
OTB
NEAH
SC02
SEDR
WHD1
SEAT
KTBW
RPT1
PRDY
ZSE1
PCOL
THUN
TWHL
YELM
CPXF
SATS
FTS1
KELS
JR01
LKCP
PUPU
PABH
YAWA
LINH
SC00
GWEN
GOBS
CHZZ
WACO
CV01
WDBN
MCSO
BTON

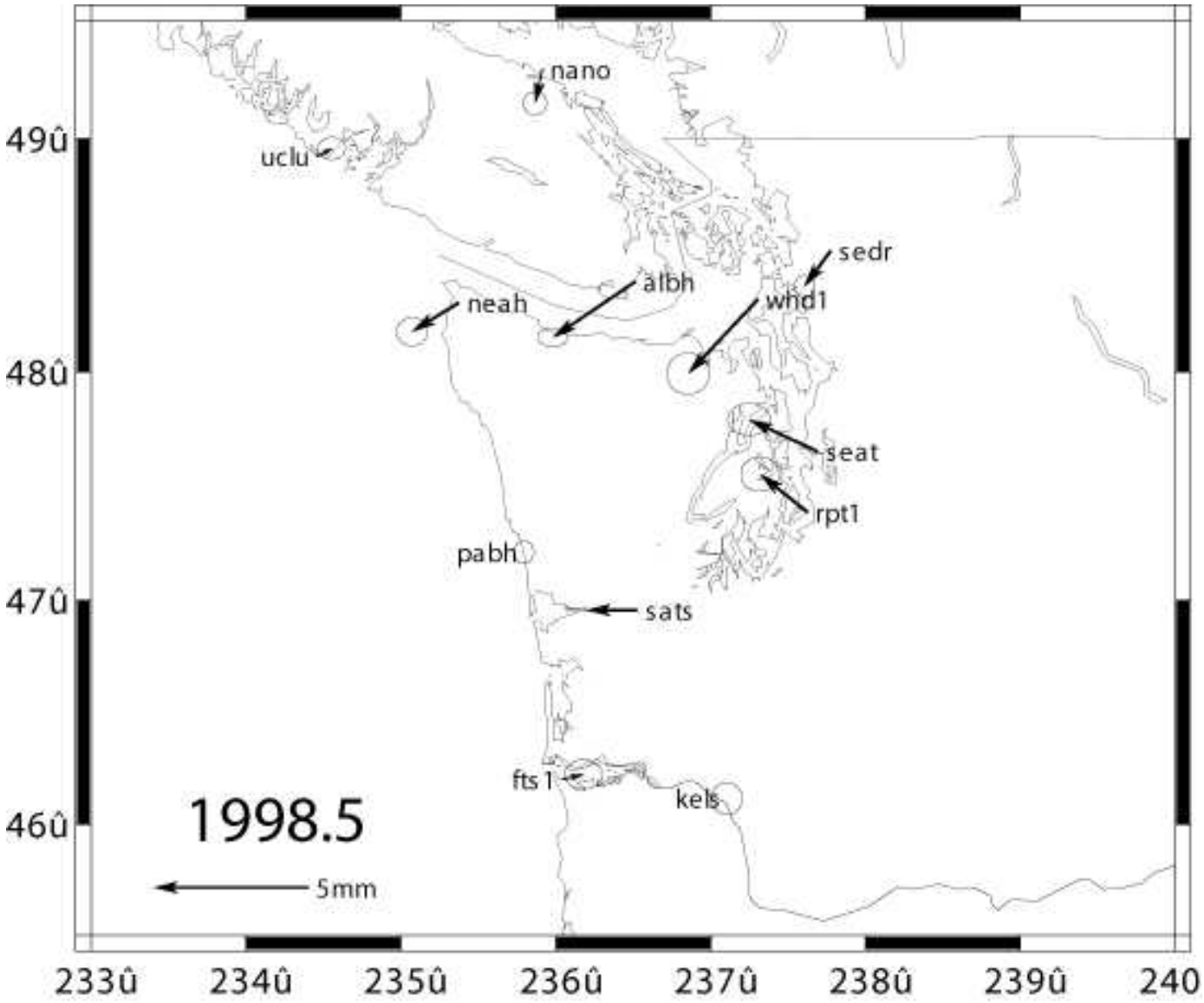
- **Northern Washington/SW BC**

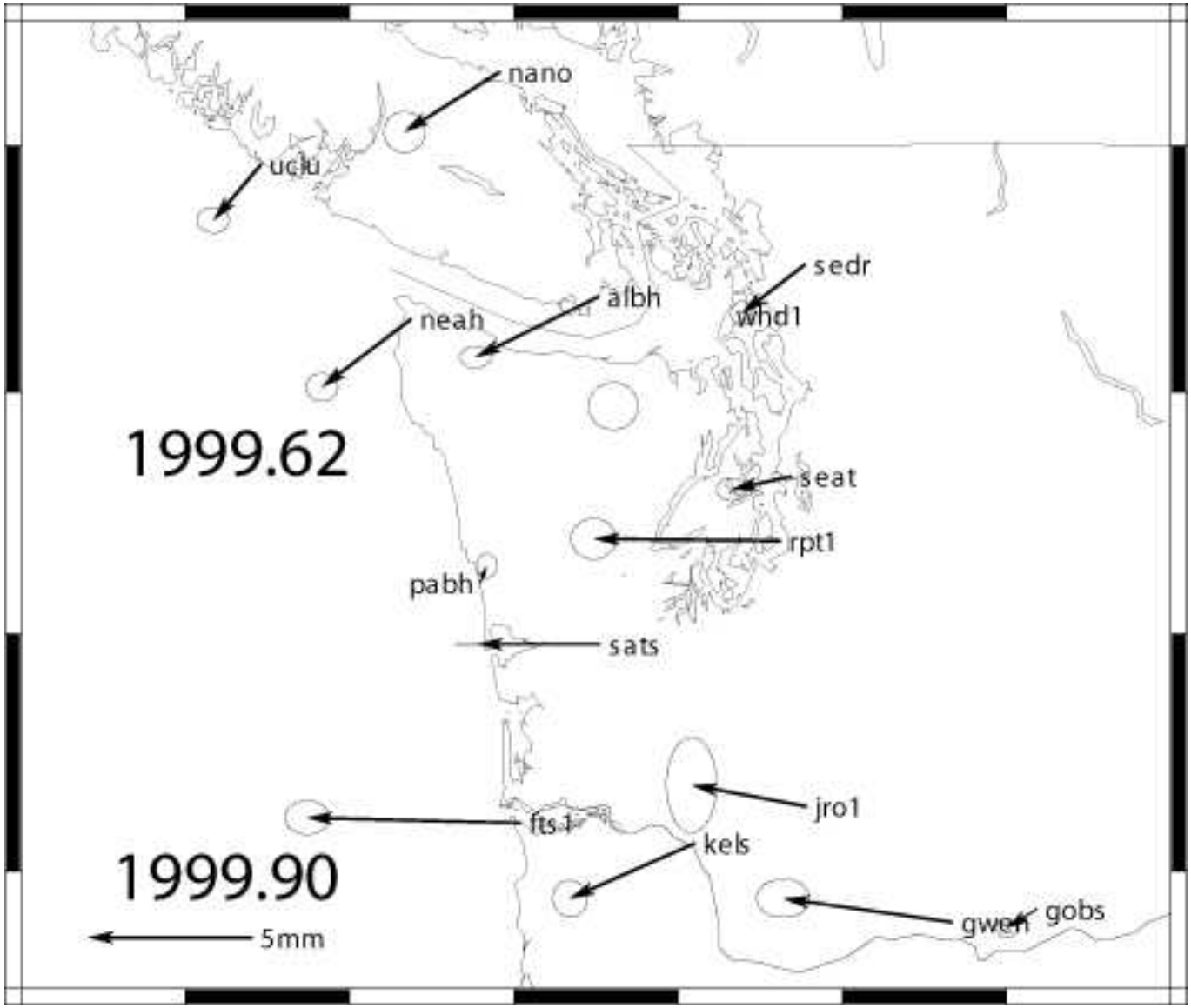


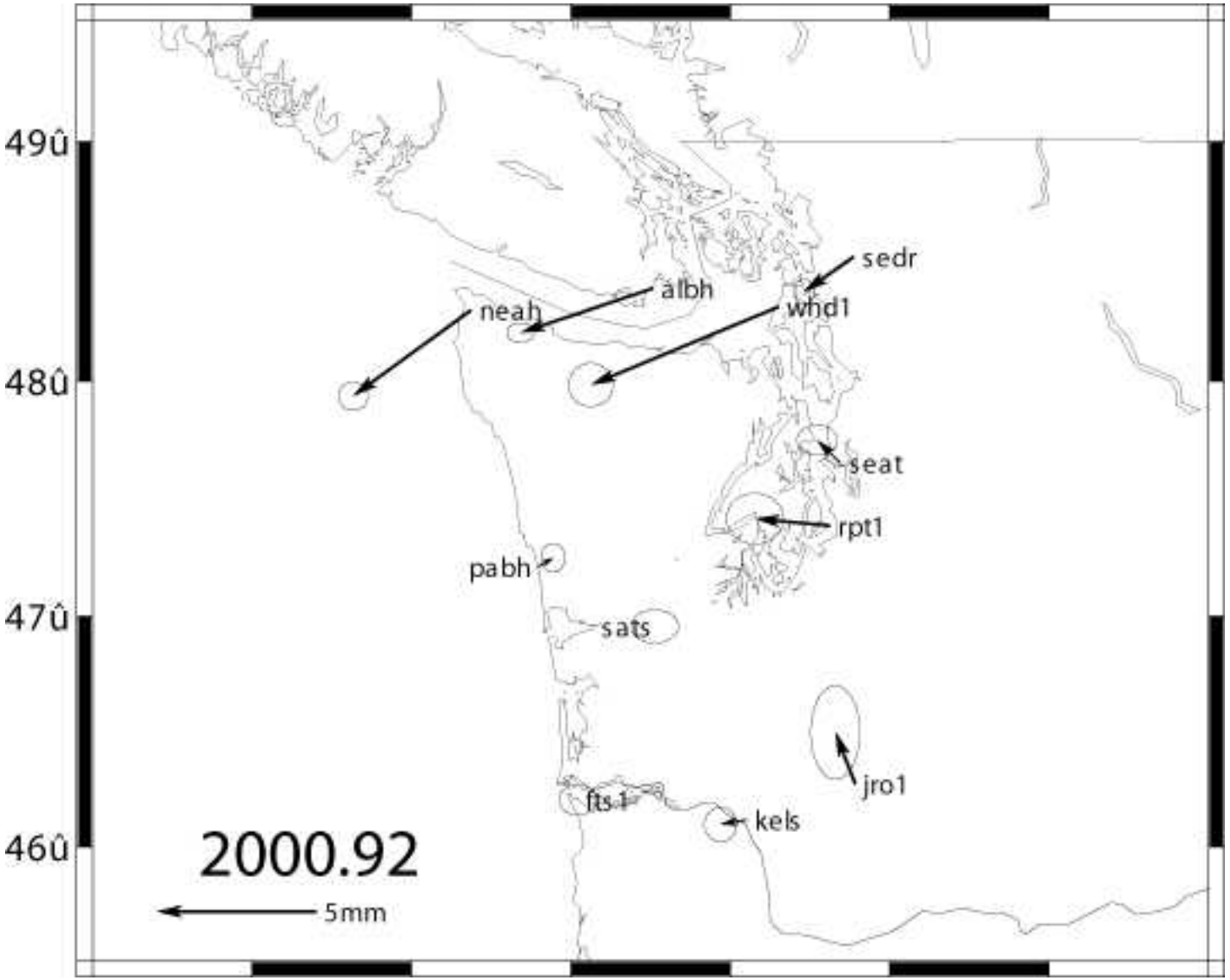

PUGET East [mm]
190
180
170
160
150
140
130
120
110
100
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years
SEAT
KTBW
RPT1
PRDY
ZSE1
PCOL
THUN
TWHL
CPXF
SATS
FTS1
KELS
Geodesy Lab
BANGA
© Central Washington University

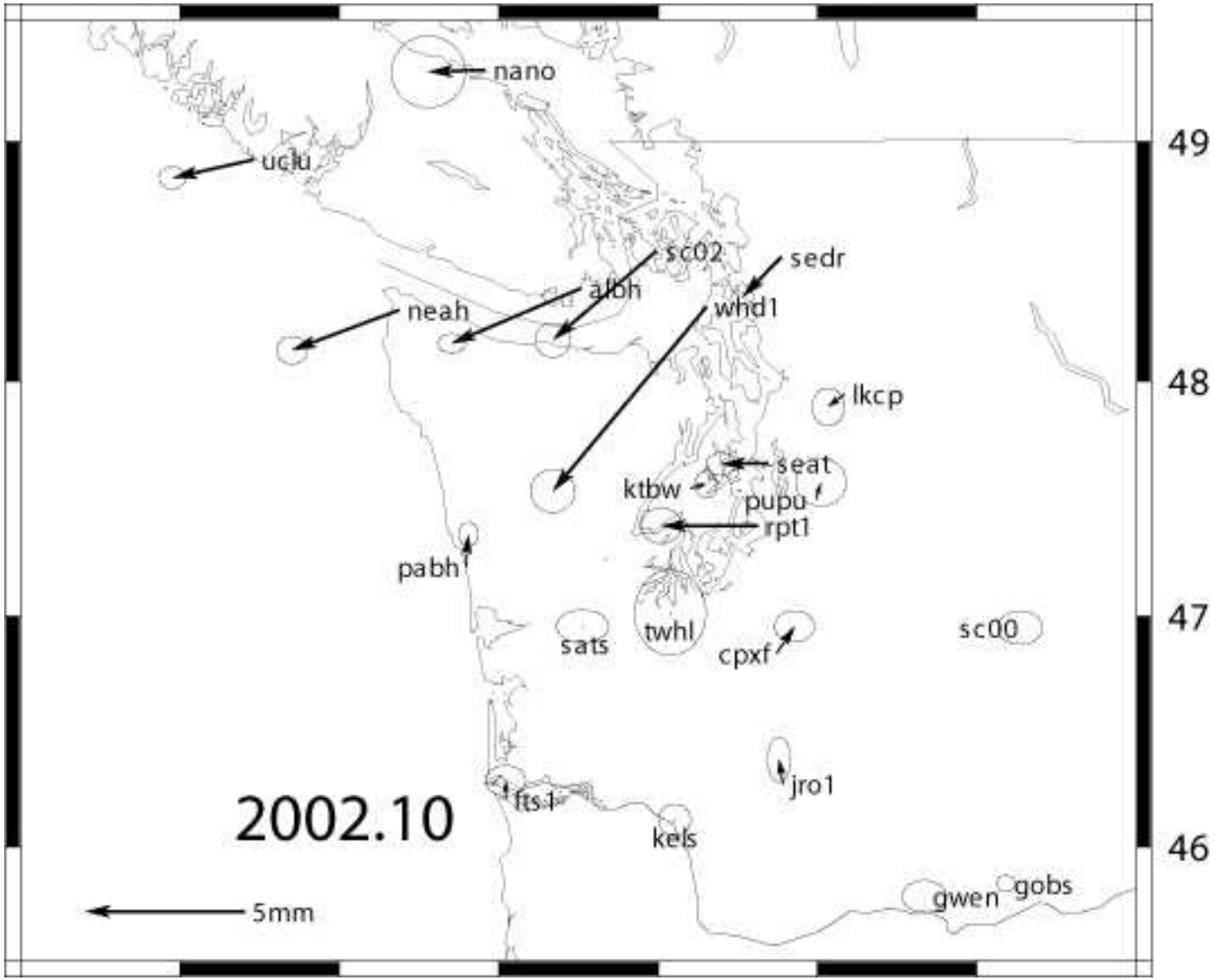
Nearfield deformation from April 1997 creep event

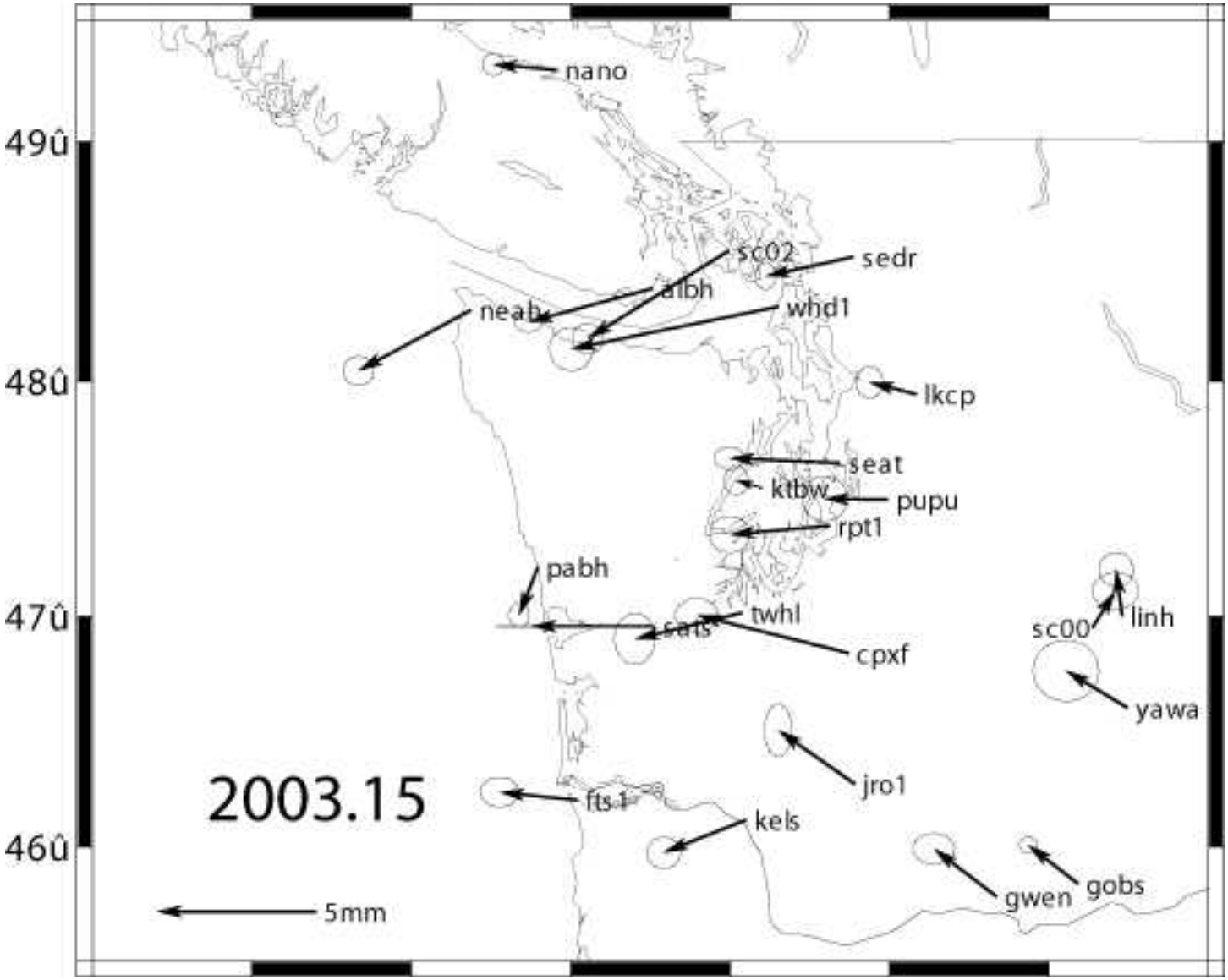


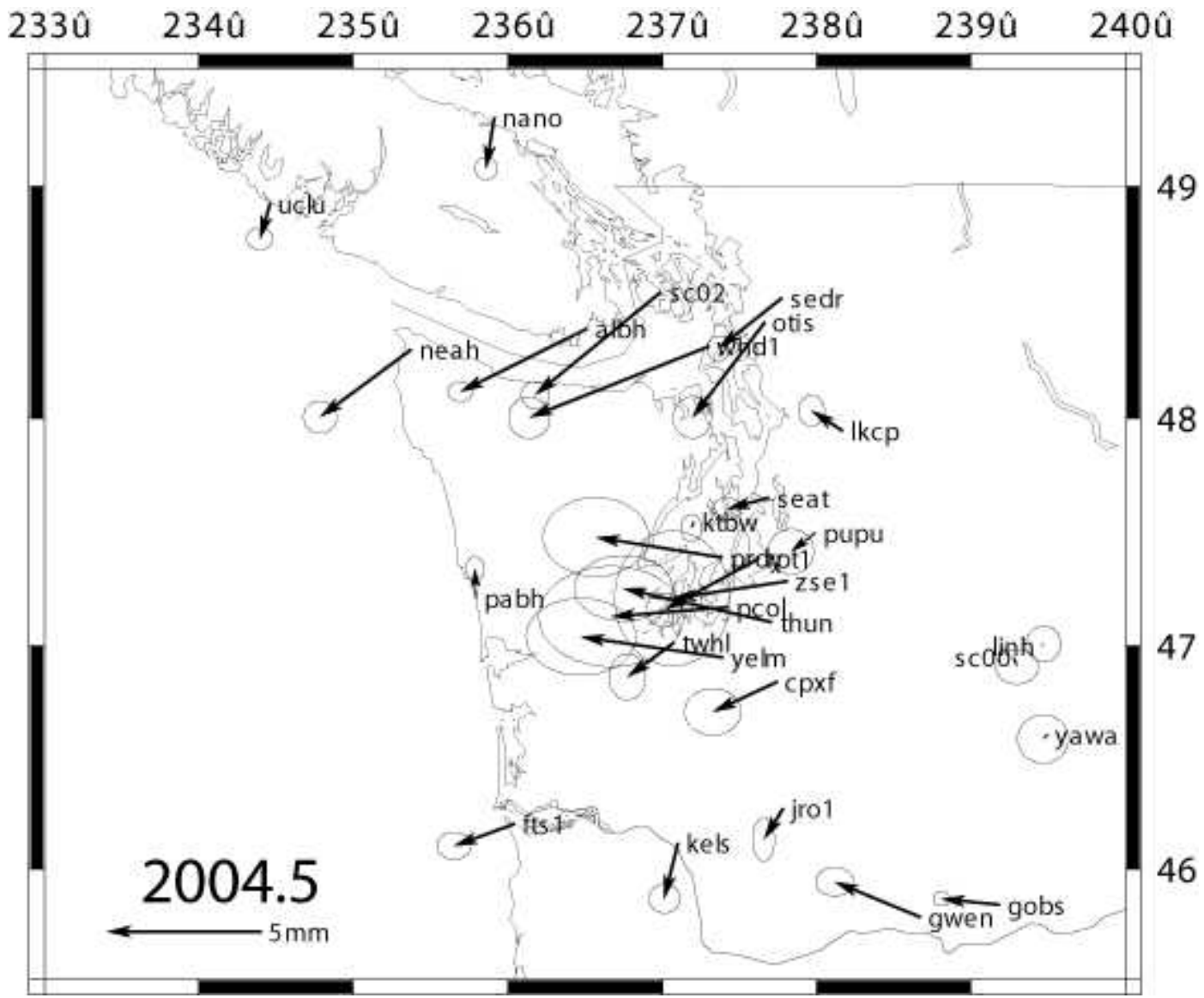

nano
uclu
sedr
albh
neah
whd1
seat
rpt1
pabh
sats
fts1
kels
1998.5
5mm
49û
48û
47û
46û
233û
234û
235û
236û
237û
238û
239û
240

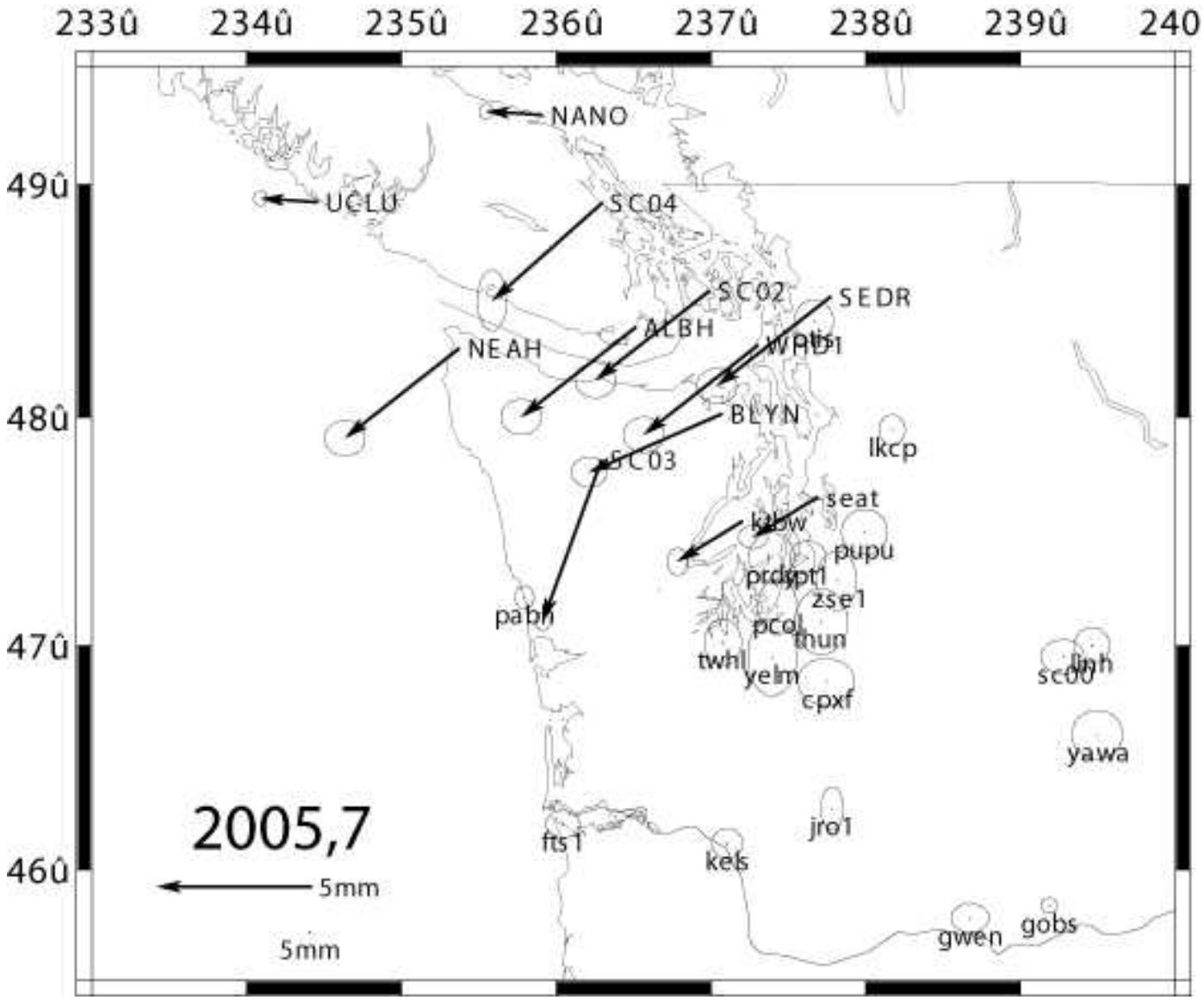

nano
uclu
sedr
albh
whd1
neah
1999.62
seat
rpt1
pabh
sats
jro1
fts1
kels
gwen
gobs
1999.90
5mm


49û
48û
47û
46û
sedr
albh
neah
whd1
seat
rpt1
pabh
sats
jro1
fts1
kels
2000.92
5mm

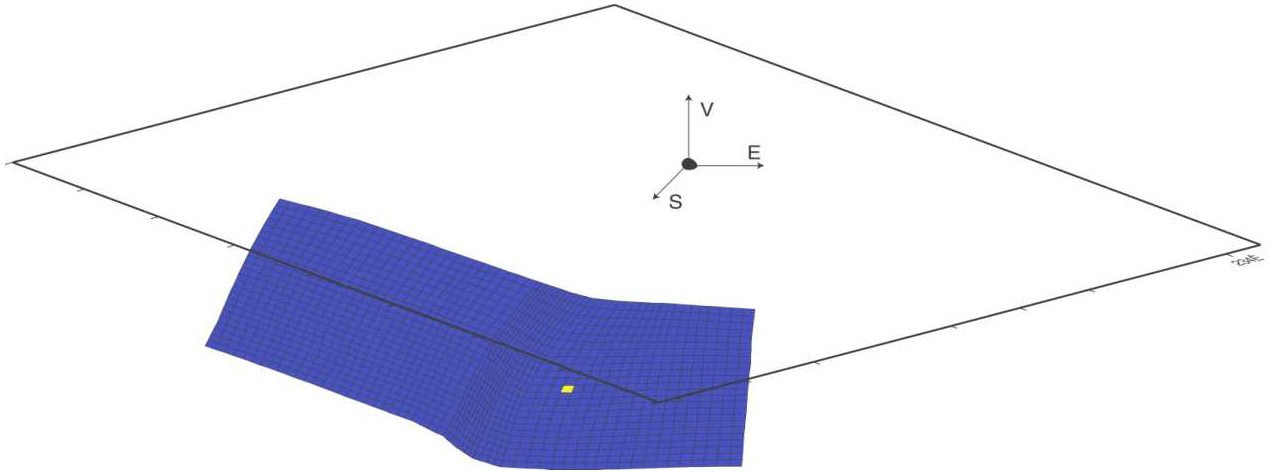

nano
uclu
sc02
sedr
albh
whd1
neah
lkcp
seat
ktbw
pupu
rpt1
pabh
twhl
sats
cpxf
sc00
jro1
fts1
kels
gwen
gobs
2002.10
5mm
49
48
47
46


49û
48û
47û
46û
nano
sc02
sedr
albh
neah
whd1
lkcp
seat
ktbw
pupu
rpt1
pabh
twhl
cats
cpxf
sc00
linh
yawa
jro1
fts1
kels
gwen
gobs
2003.15
5mm


233û
234û
235û
236û
237û
238û
239û
240û
49
48
47
46
nano
uclu
sc02
sedr
otis
albh
whd1
neah
lkcp
seat
ktbw
pupu
pabh
zse1
pcol
thun
twhl
yelm
cpxf
sc00
jnh
yawa
jro1
fts1
kels
gwen
gobs
2004.5
5mm

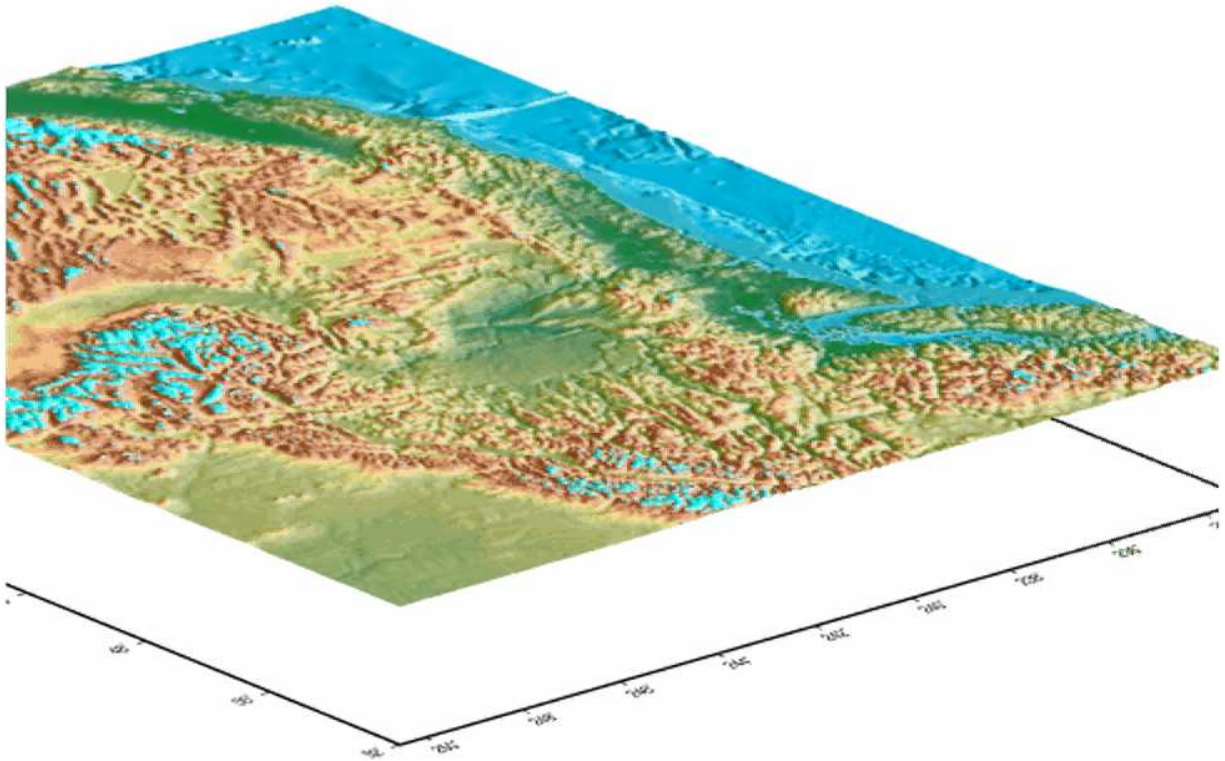

233û
234û
235û
236û
237û
238û
239û
240
49û
48û
47û
46û
NANO
UCLU
SC04
SC02
SEDR
ALBH
NEAH
WHD1
BLYN
lkcp
SC03
seat
kdbw
pupu
prdspt1
zse1
pabh
pcol
thun
twhl
yelm
cpxf
sc00
yawa
jro1
fts1
kels
gwen
gobs
2005,7
5mm
5mm

Spatial inversion of geodetic data:

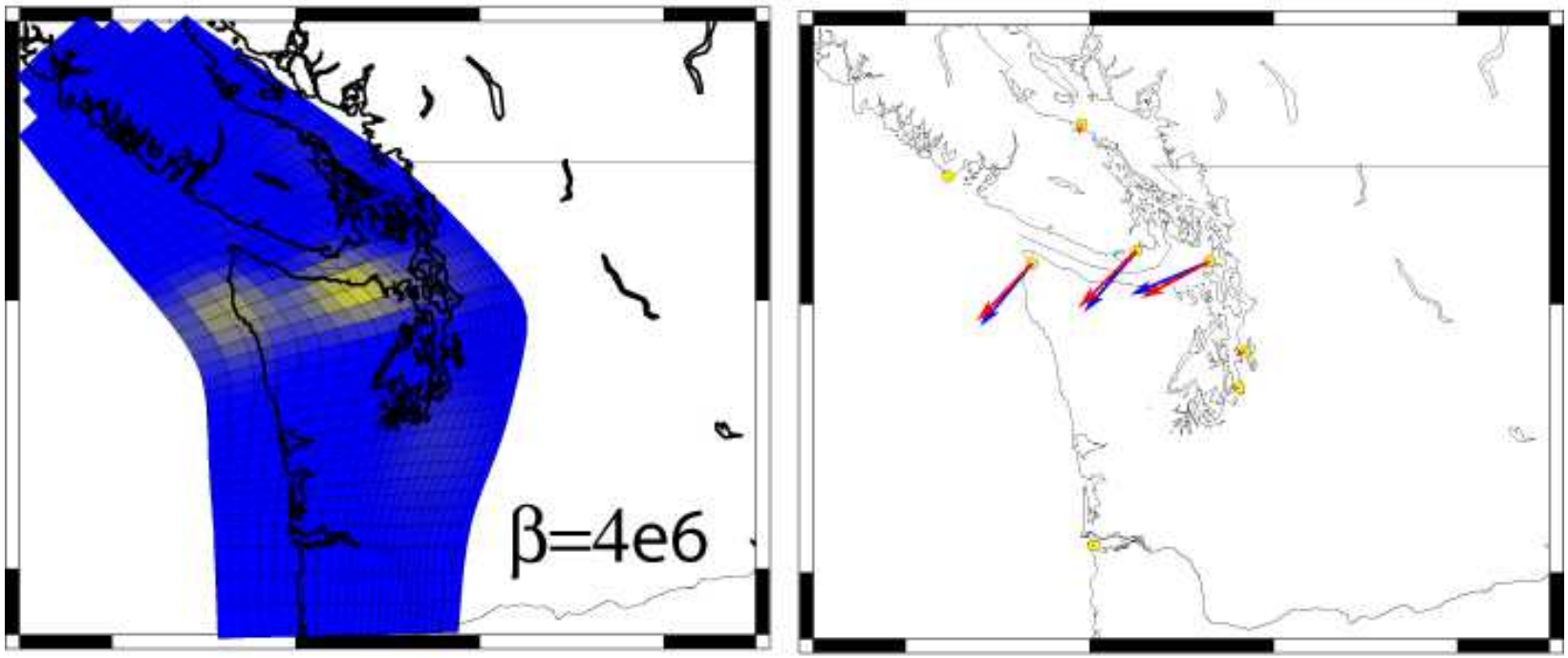


$$R(\mathbf{x},\lambda) = \left\| \sum^{-1/2} (\mathbf{Ax} - \mathbf{b}) \right\|^2 + \lambda^{-2} \left\| \nabla^2 \mathbf{x} \right\|^2$$

b data
x slip
A Green's fns
λ misfit/roughness
Σ data covariance



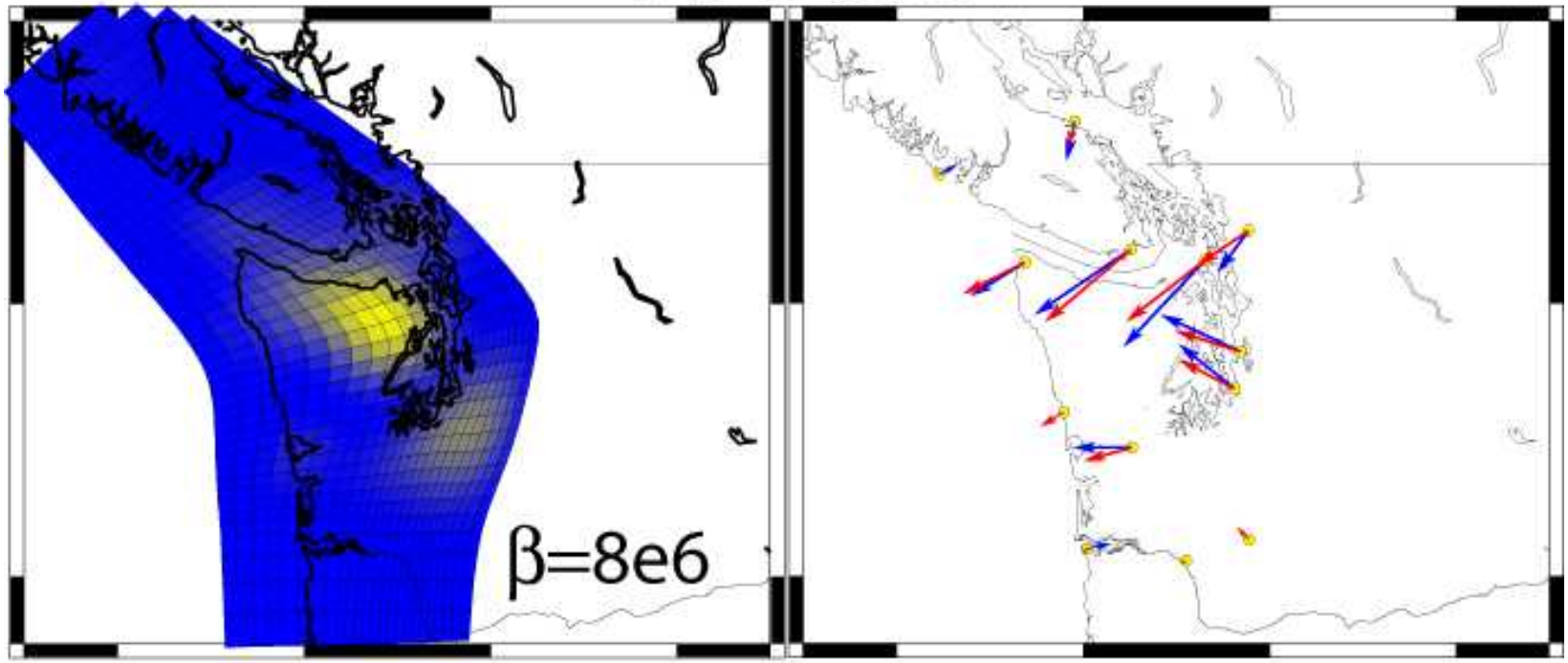
1997.4



Mw=6.4;max=1.6cm

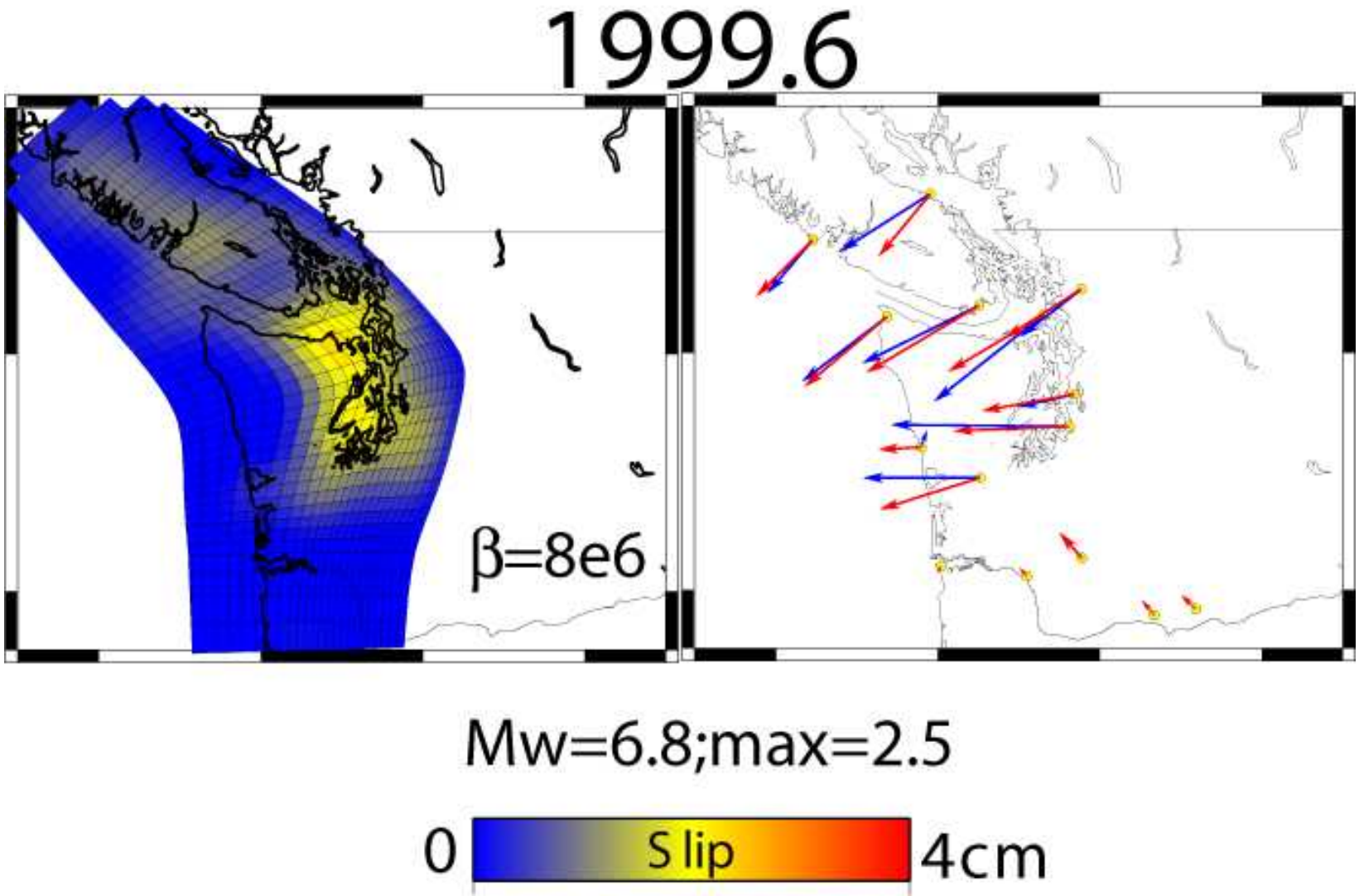
0 Slip 4cm

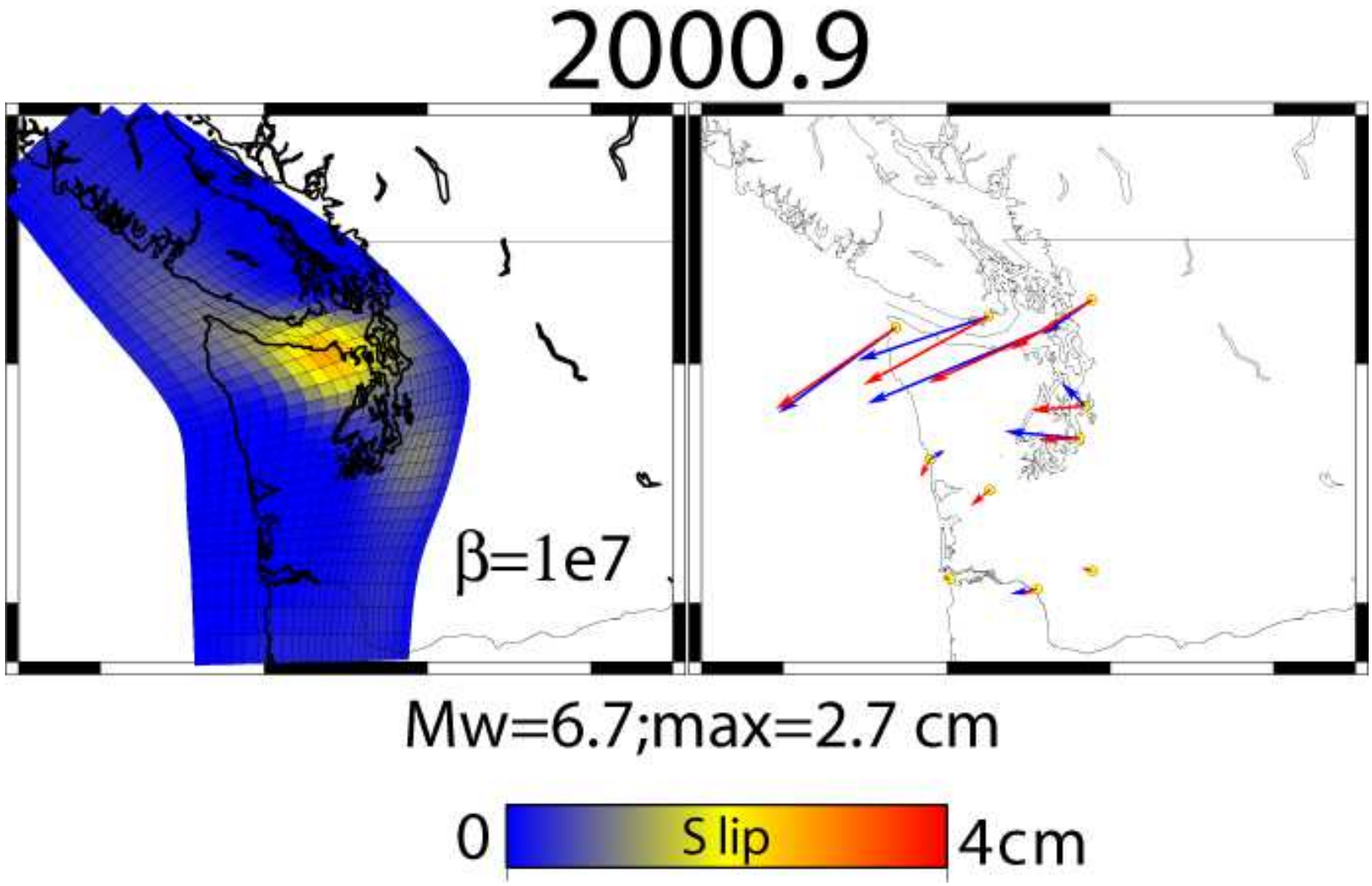
1998.5

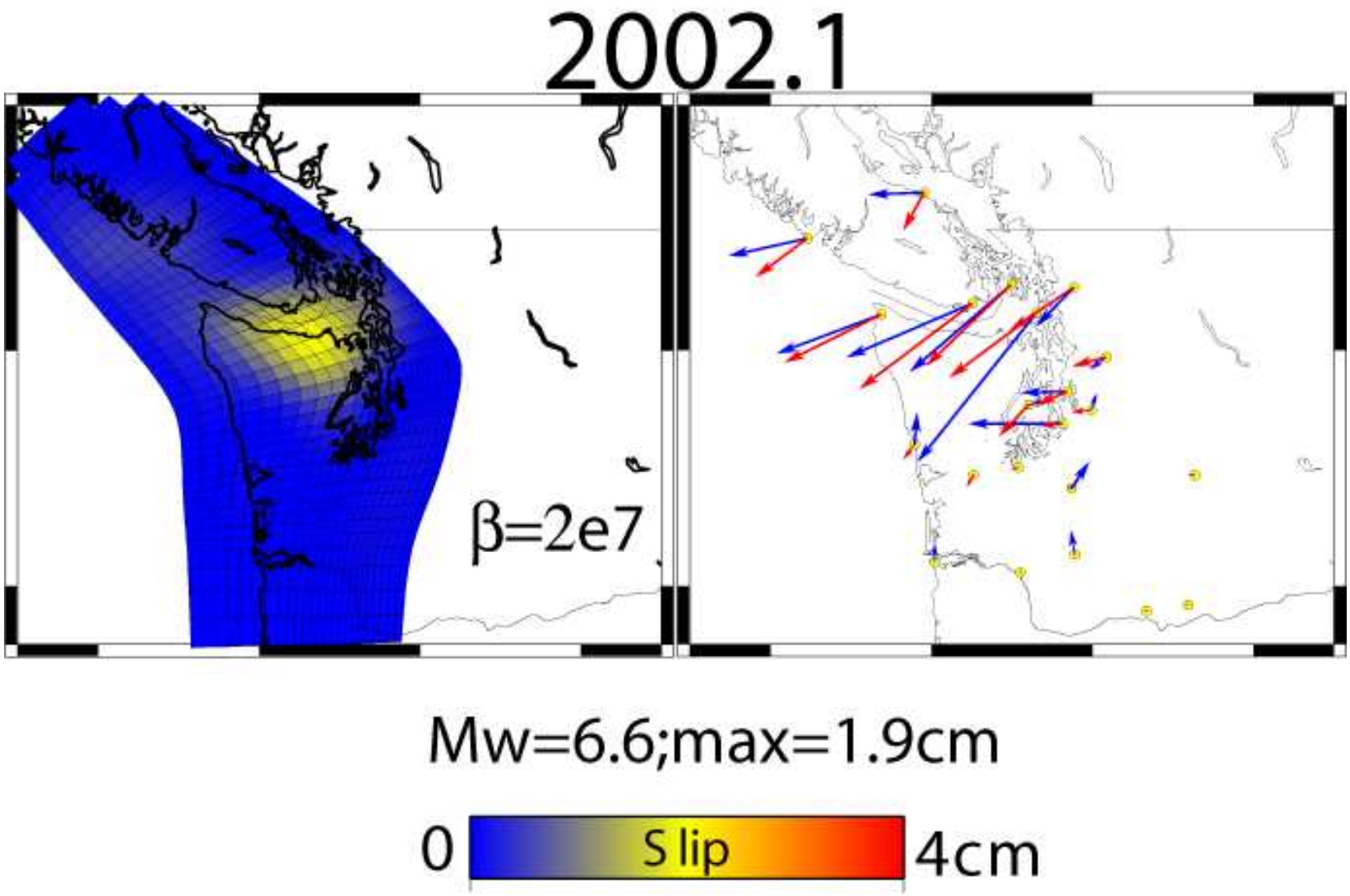


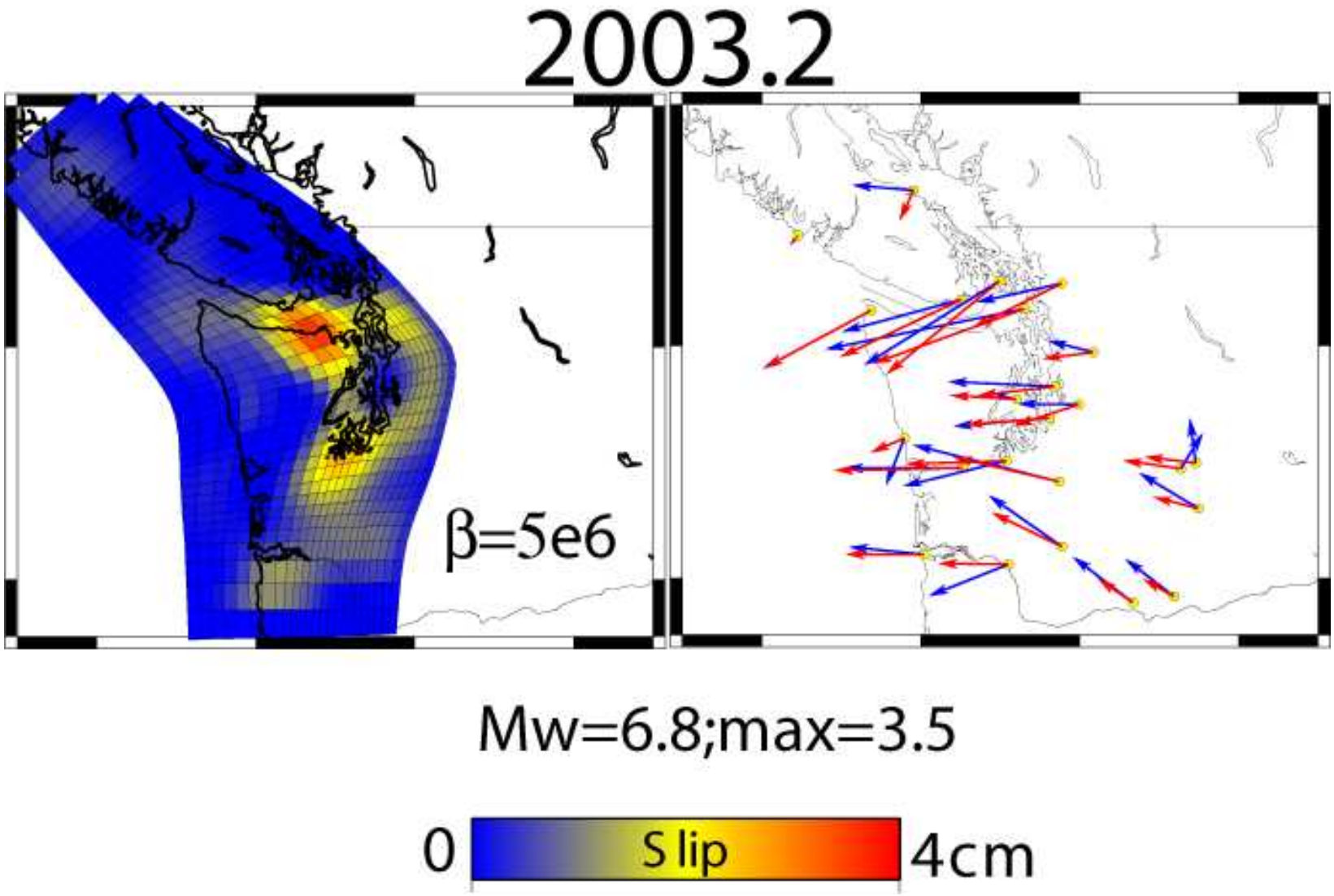
Mw=6.6;max=2cm

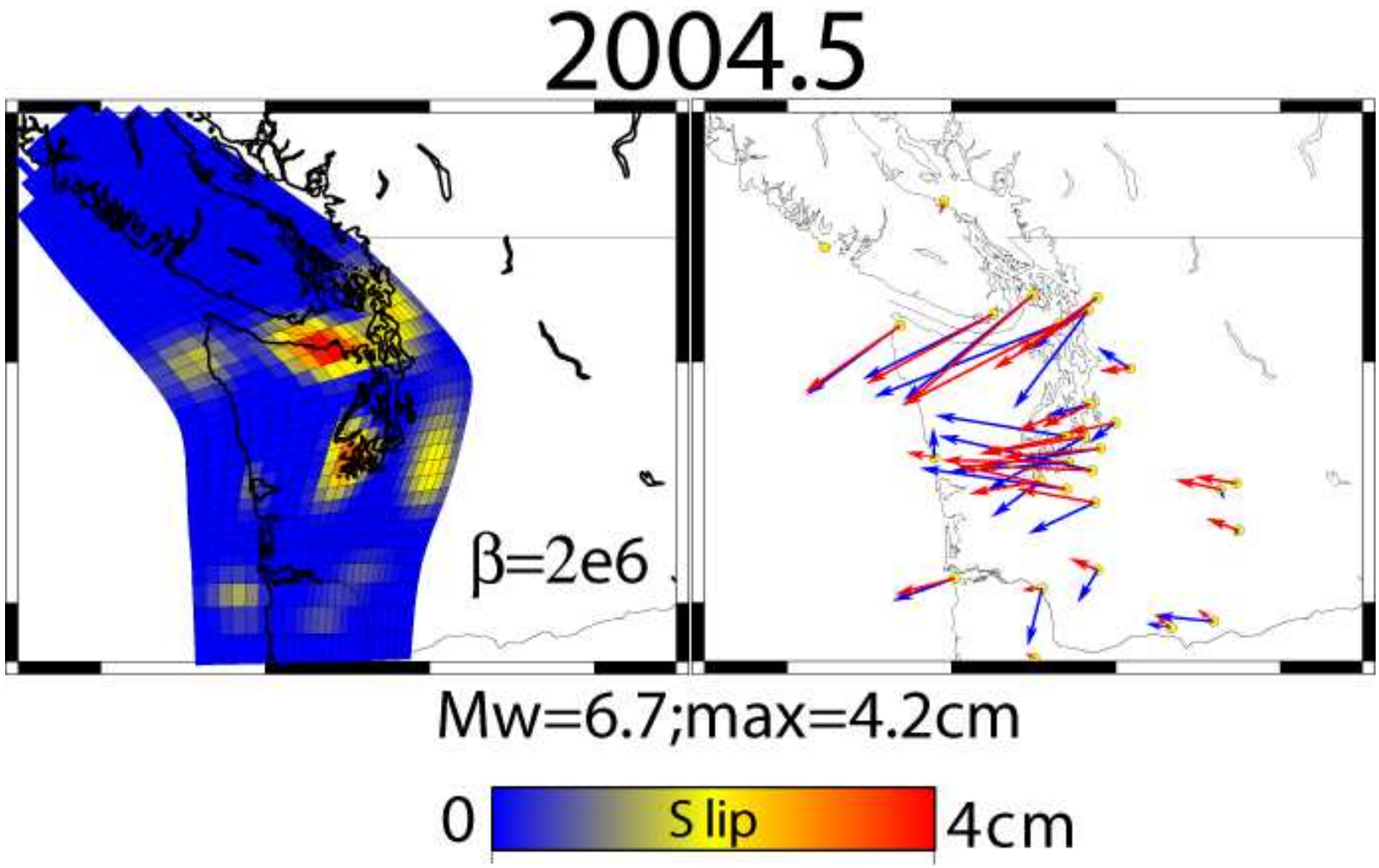
0 Slip 4cm

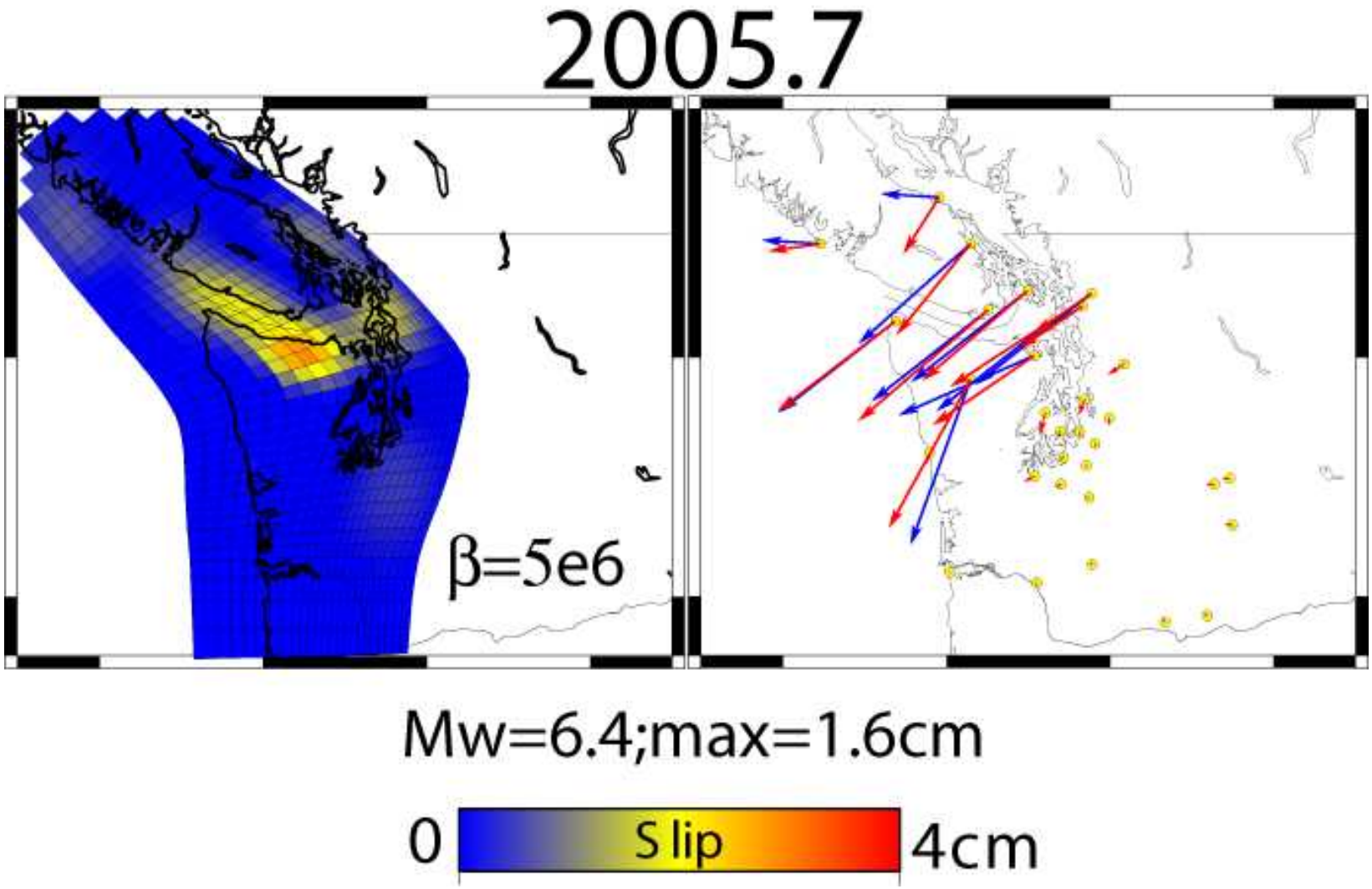

1999.6
β=8e6
Mw=6.8;max=2.5
0
Slip
4cm


2000.9
β=1e7
Mw=6.7;max=2.7 cm
0
Slip
4cm

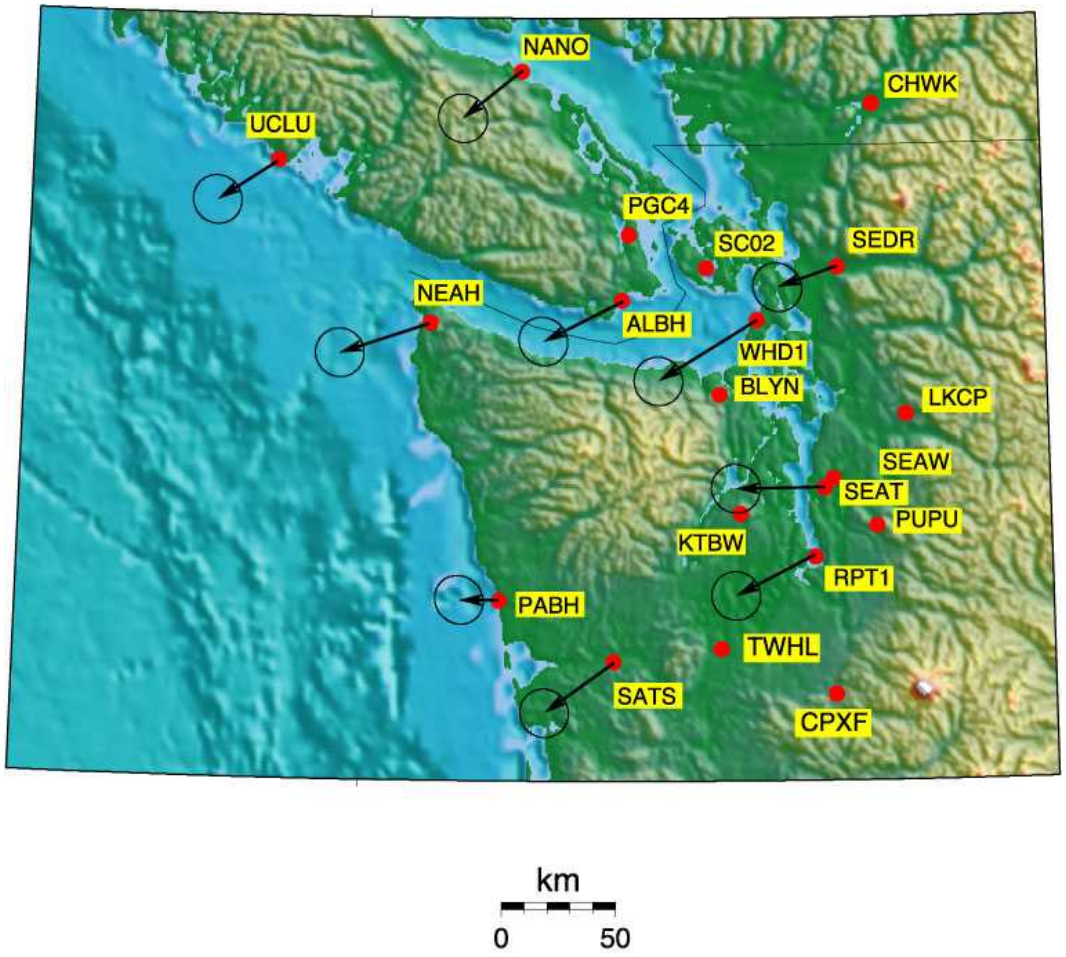

2002.1
β=2e7
Mw=6.6;max=1.9cm
0
S lip
4cm

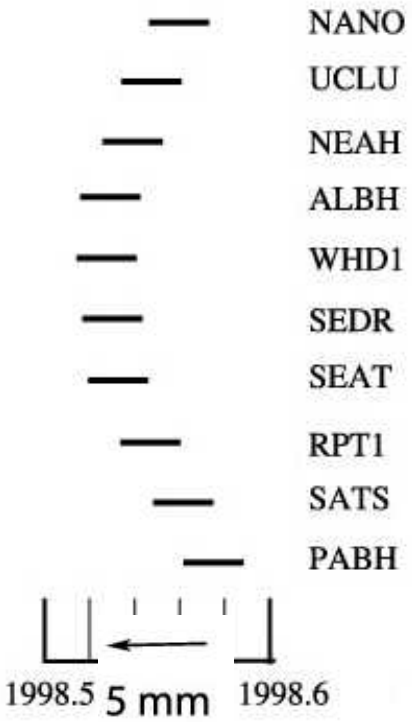

2003.2
β=5e6
Mw=6.8;max=3.5
0
Slip
4cm


2004.5
β=2e6
Mw=6.7;max=4.2cm
0
Slip
4cm

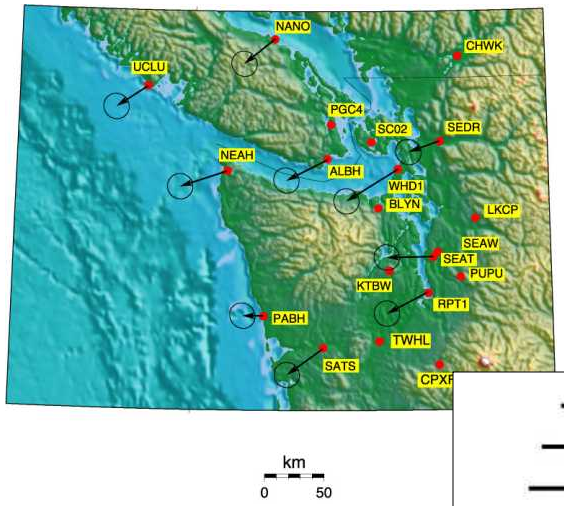

2005.7
β=5e6
Mw=6.4;max=1.6cm
0
Slip
4cm

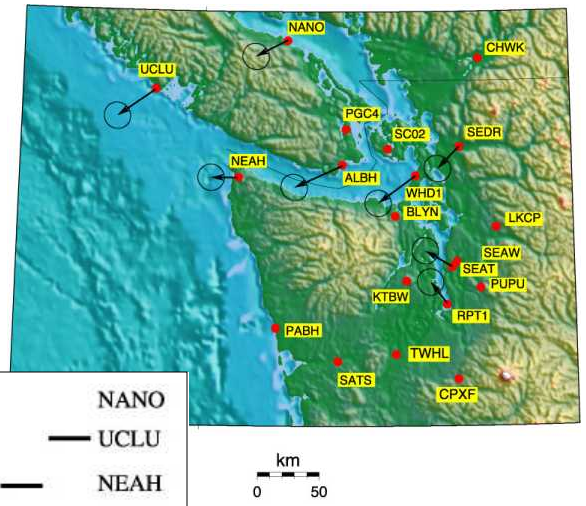
Slip propagation through time

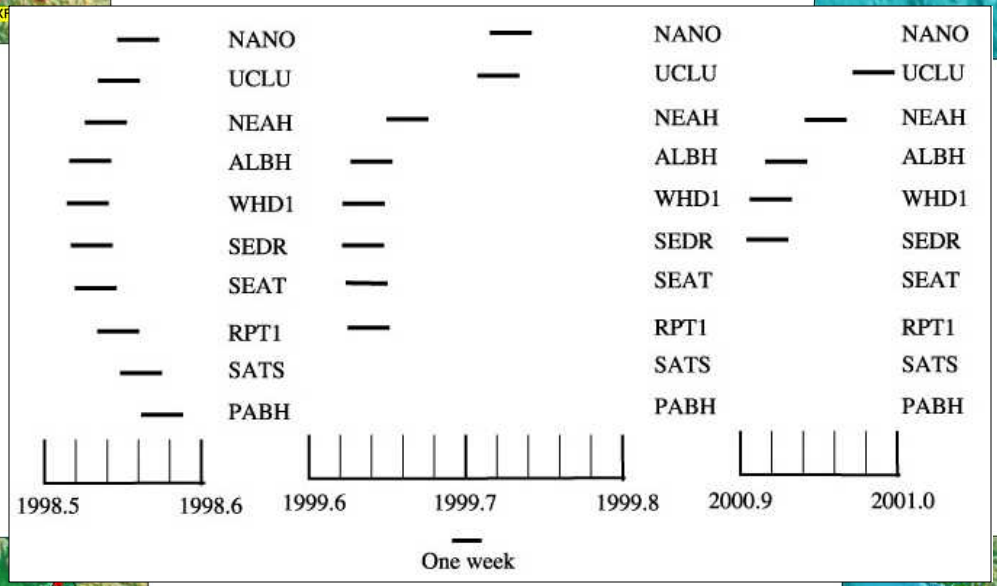


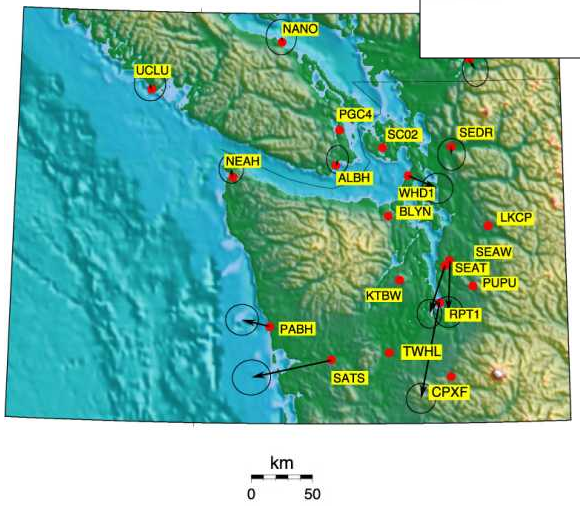


1998.5

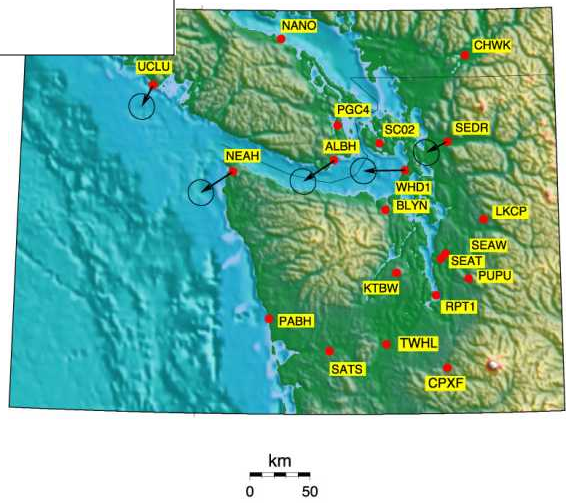

NANO
CHWK
UCLU
PGC4
SC02
SEDR
NEAH
ALBH
WHD1
BLYN
LKCP
SEAW
SEAT
PUPU
KTBW
RPT1
PABH
TWHL
SATS
CPXF
km
0
50


NANO
CHWK
UCLU
PGC4
SC02
SEDR
NEAH
ALBH
WHD1
BLYN
LKCP
SEAW
SEAT
PUPU
KTBW
RPT1
PABH
TWHL
SATS
CPXF
km
0
50

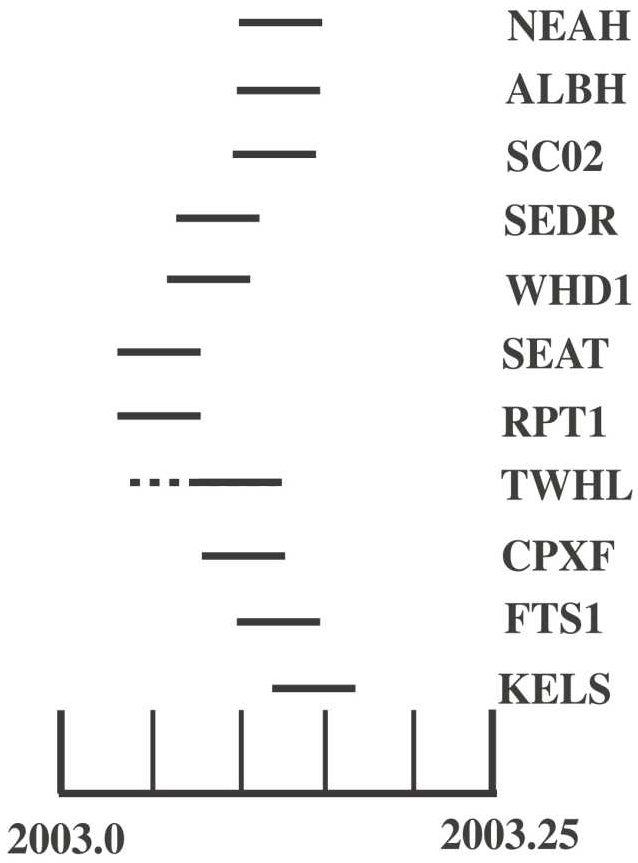

NANO
UCLU
NEAH
ALBH
WHD1
SEDR
SEAT
RPT1
SATS
PABH
1998.5
1998.6
1999.6
1999.7
1999.8
2000.9
2001.0
One week

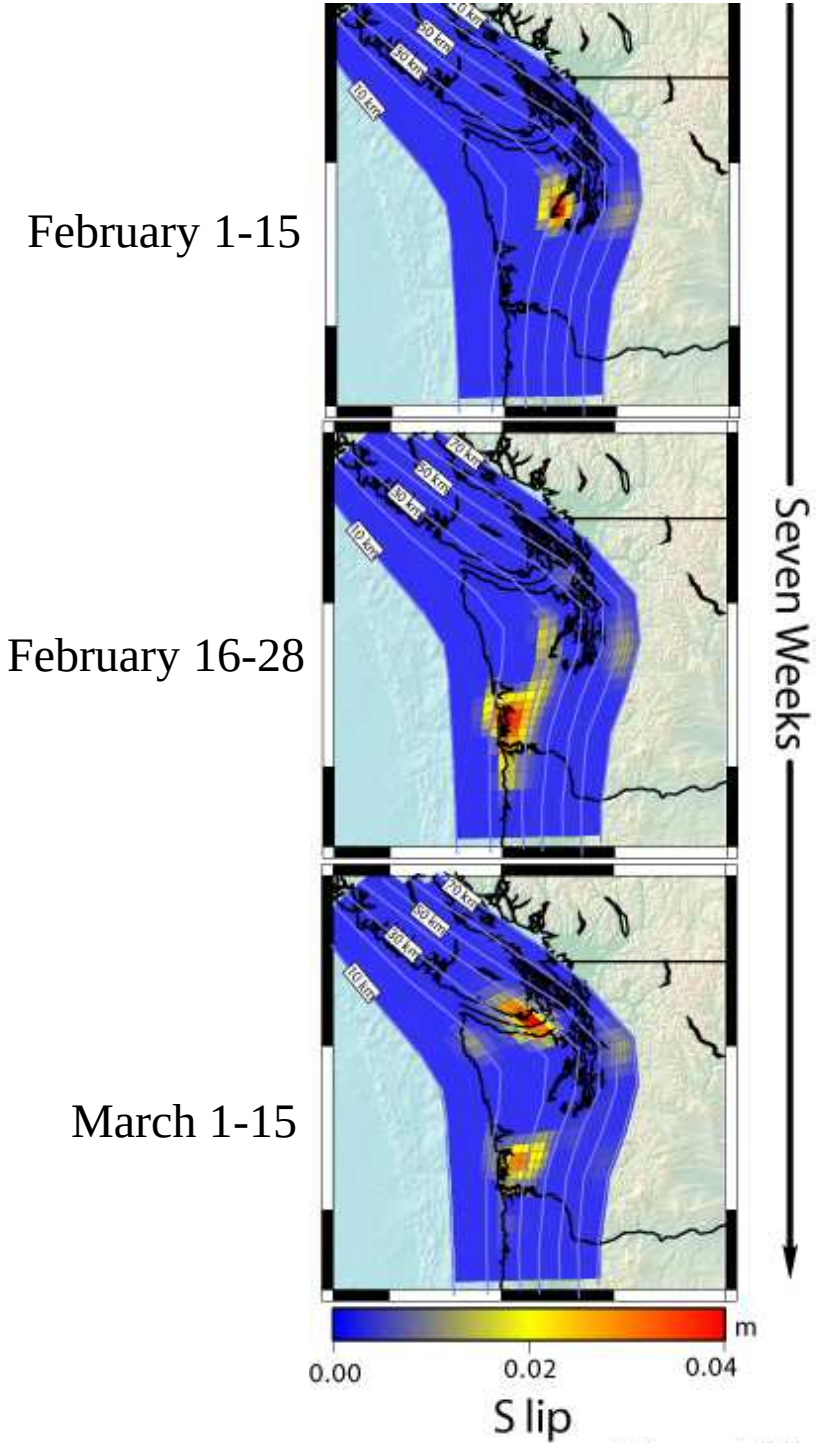

NANO
UCLU
PGC4
SC02
SEDR
NEAH
ALBH
WHD1
BLYN
LKCP
SEAW
SEAT
PUPU
KTBW
RPT1
PABH
TWHL
SATS
CPXF
km
0
50

5 mm

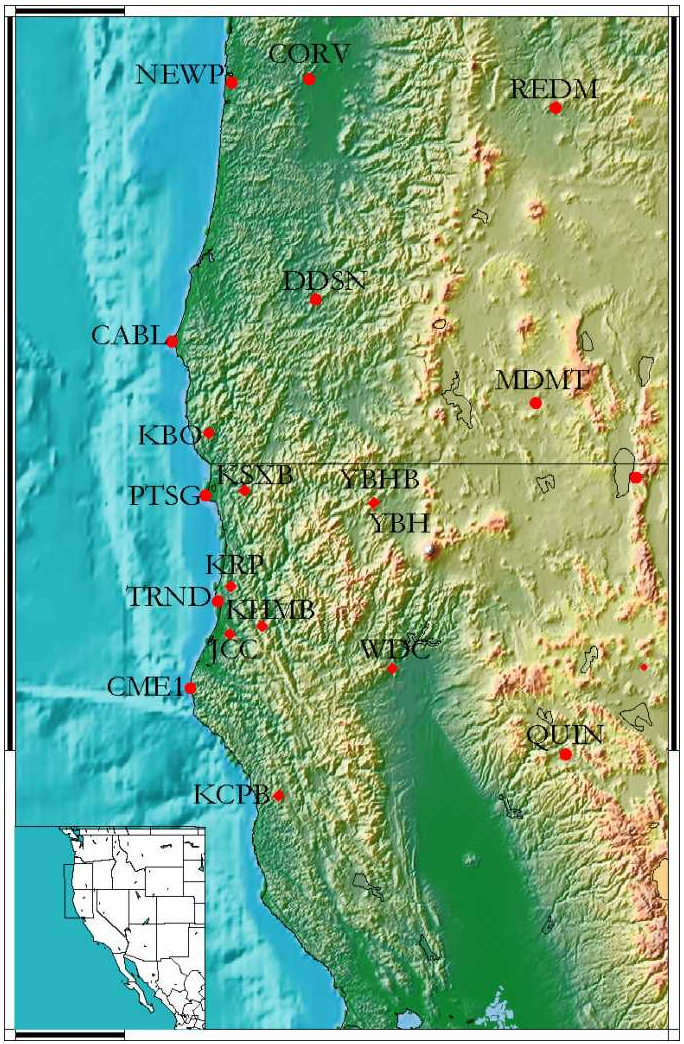

NANO
CHWK
UCLU
PGC4
SC02
SEDR
ALBH
NEAH
WHD1
BLYN
LKCP
SEAW
SEAT
PUPU
KTBW
RPT1
PABH
TWHL
SATS
CPXF
km
0
50

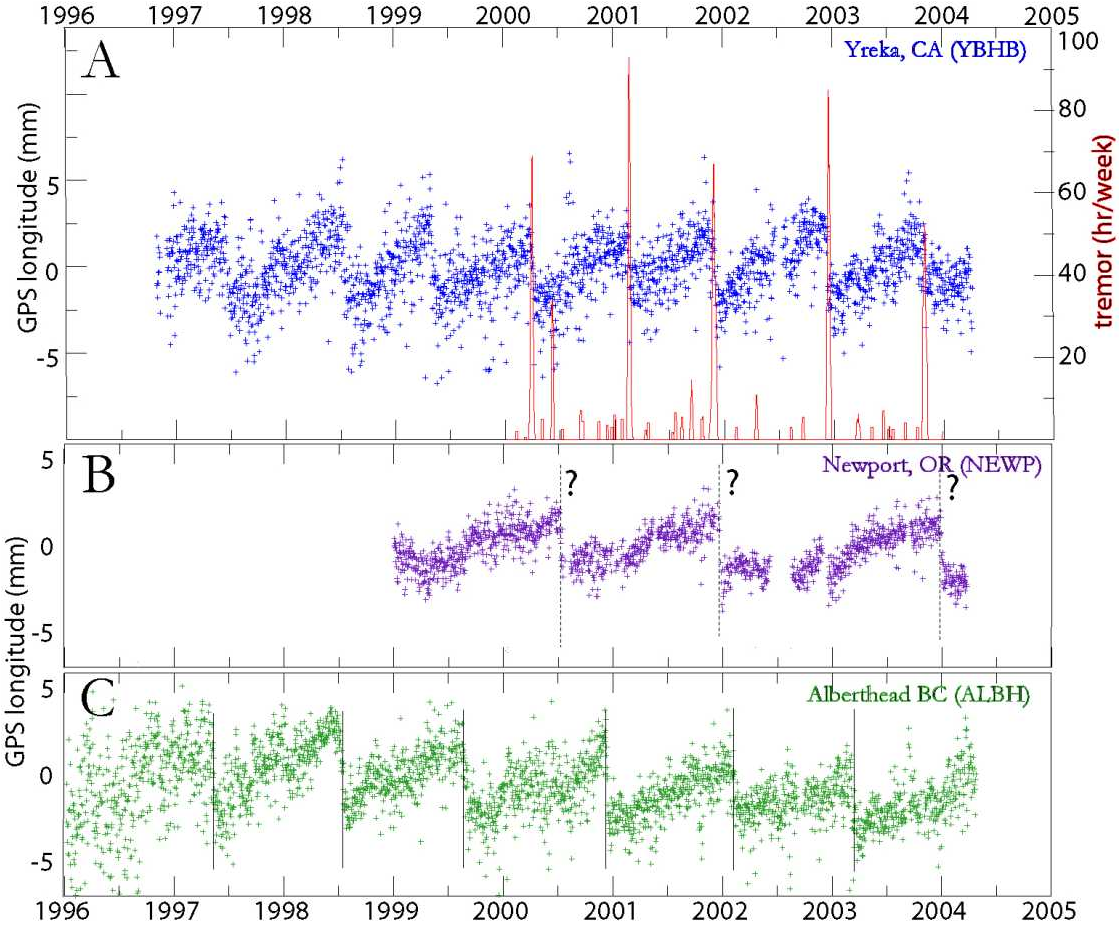
2003-Largest event so far



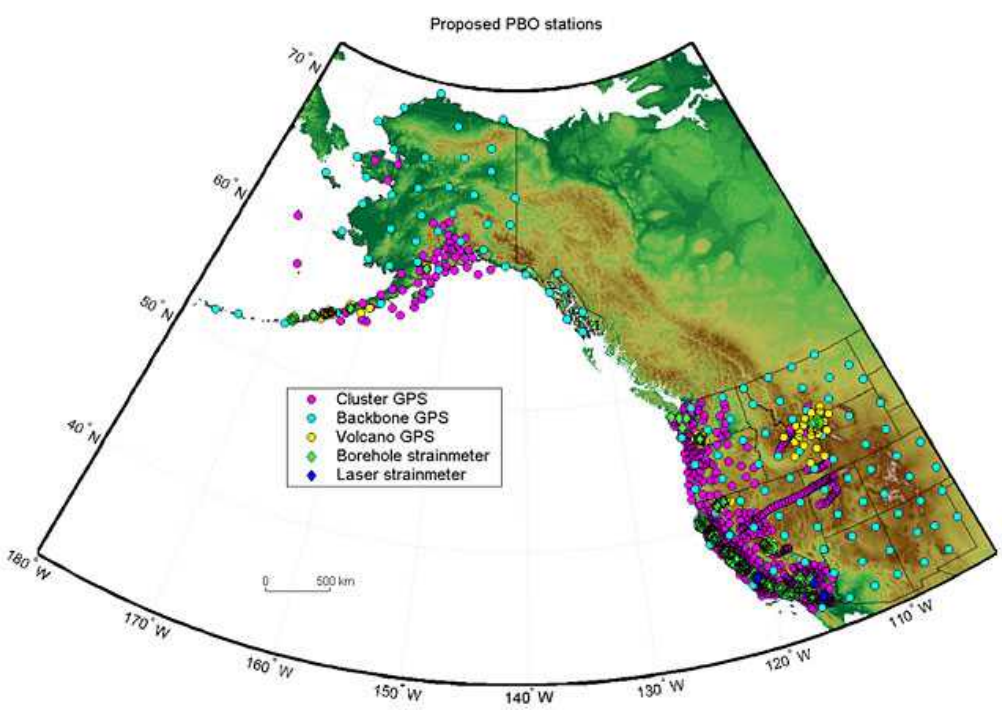


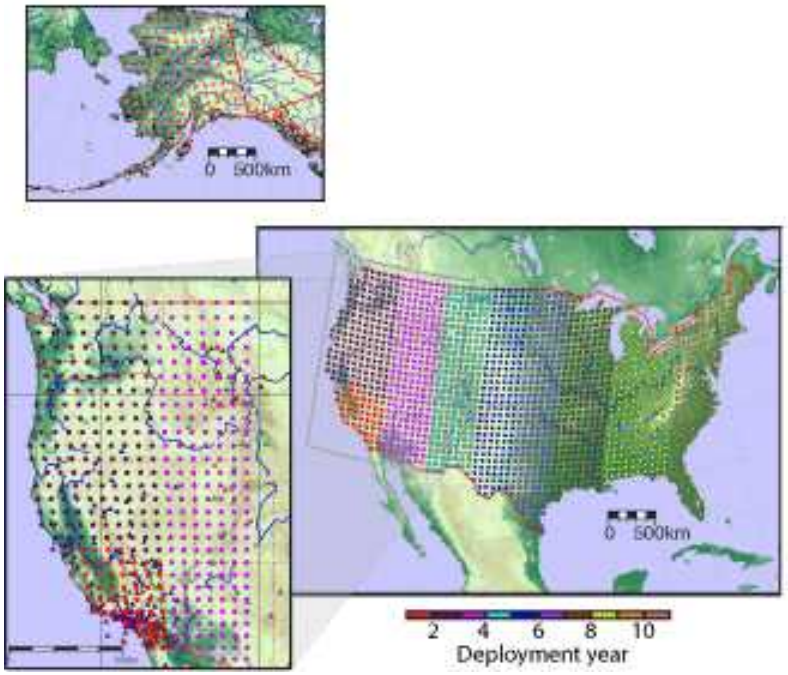
Central Oregon and Northern California



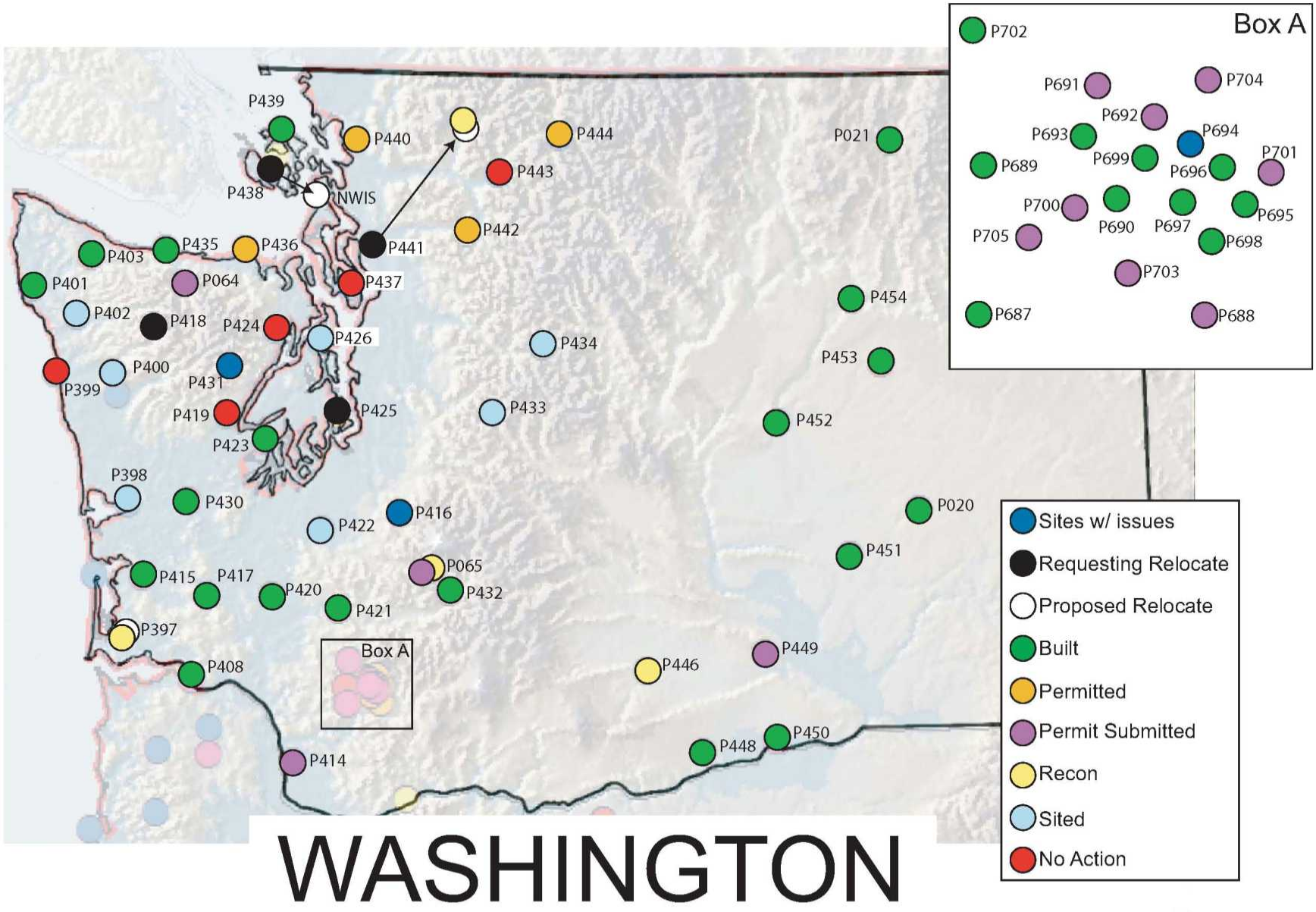


Real-time GPS Data available for tsunami warning systems

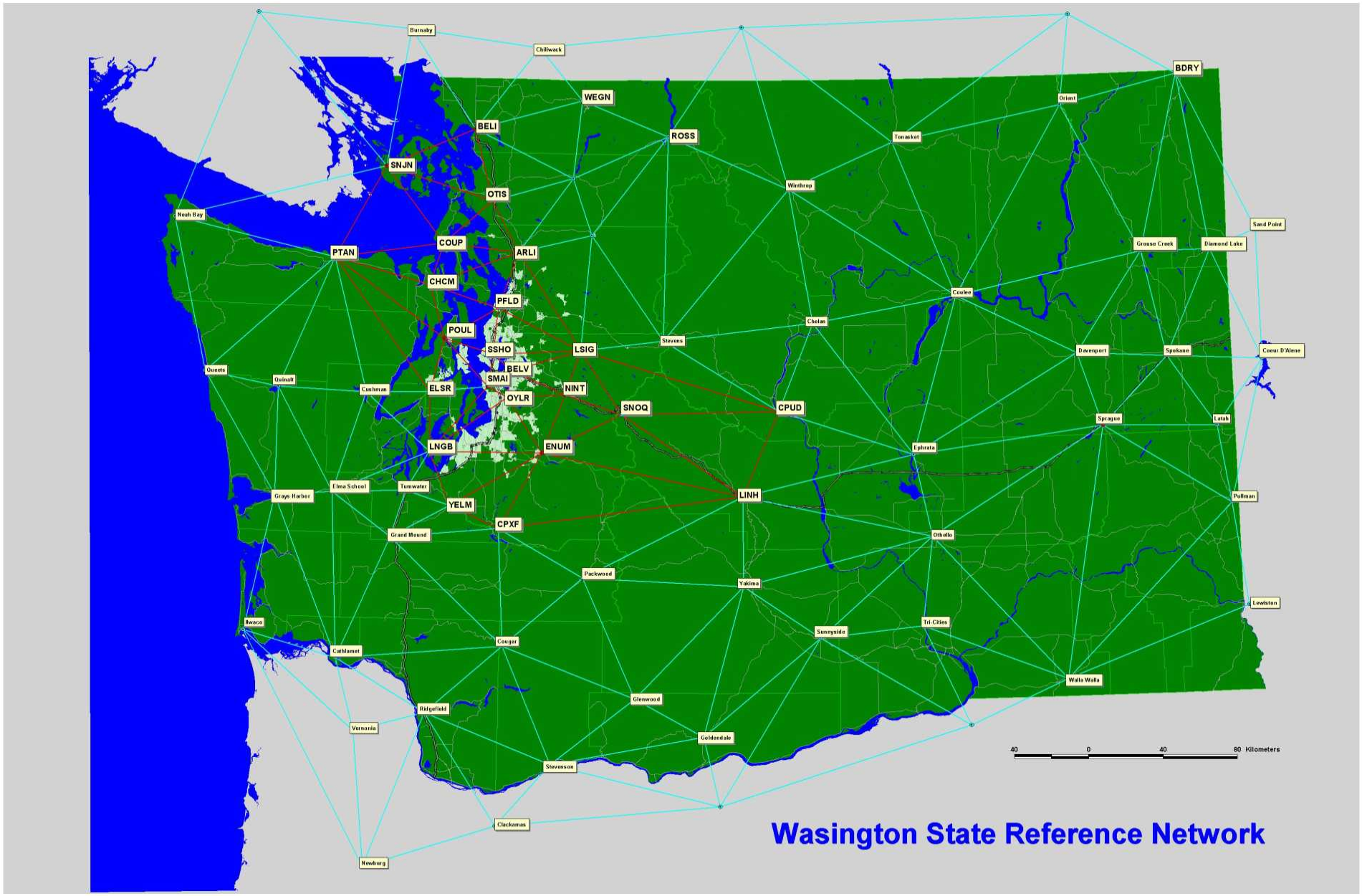




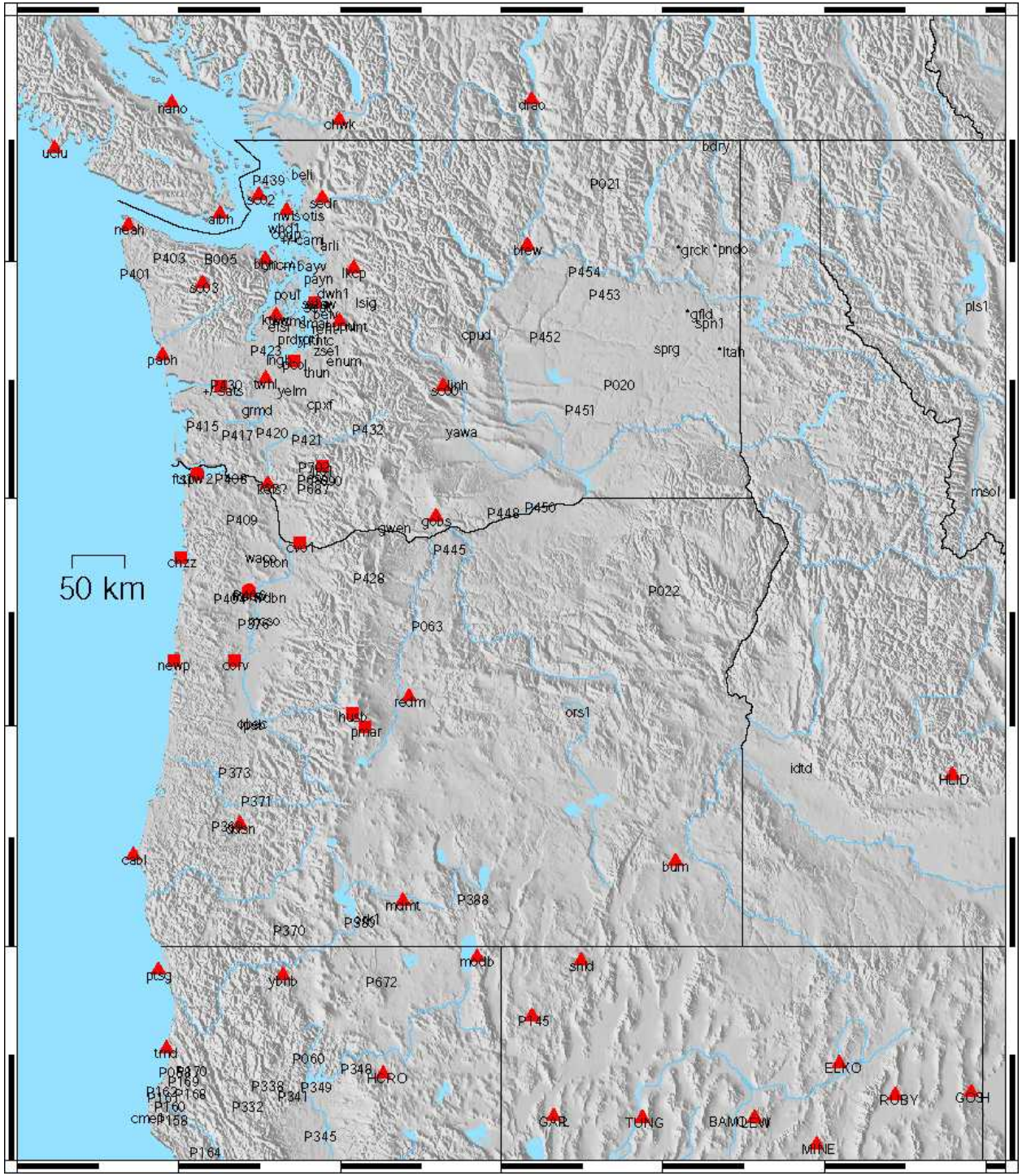
New Plate Boundary Observatory GPS deployments



~150-~190 non-PBO GPS deployments



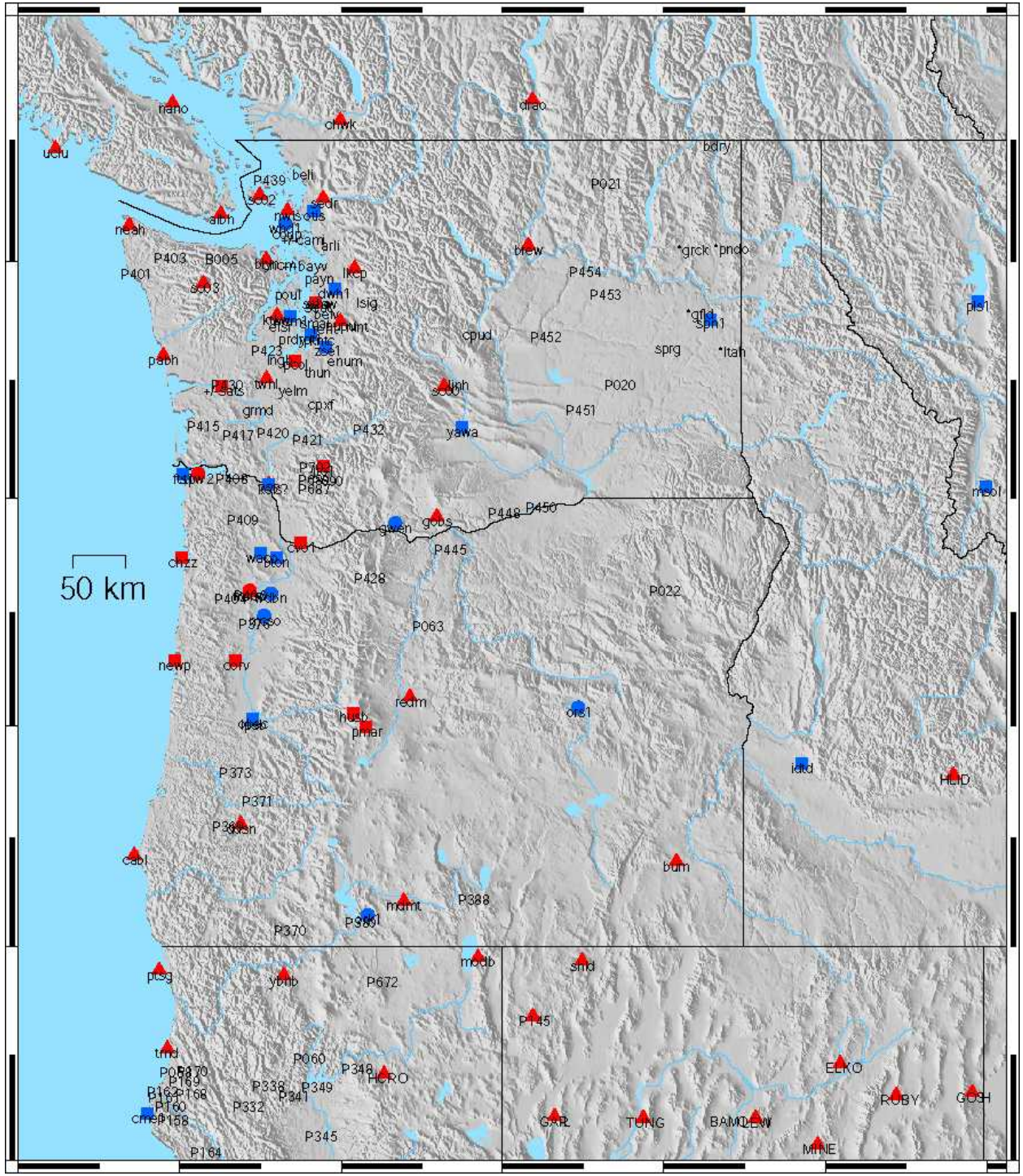
PANGA 2002


50 km
nano
chwk
drao
uclu
bdry
P439
beli
P021
sedr
albh
neah
brew
grck
pndo
P403
B005
P401
P454
P453
pls1
cpud
P452
sprg
ltah
pabh
P423
enum
thun
P020
P451
yelm
grmd
cpxf
P415
P417
P420
P421
P432
yawa
P409
gwen
gobs
P448
P450
msol
P445
chzz
waco
bton
P428
P022
P063
newp
corv
redm
ors1
idtd
HLID
P373
P371
cabl
burn
mdmt
P388
P370
modb
smd
ptsg
ybnb
P672
P145
trnd
P060
P348
HCRO
ELKO
P338
P349
P341
P332
ROBY
GOSH
GAR
TUNG
BAMD
DEW
P345
MINE
P164

PANGA +

Surveyors

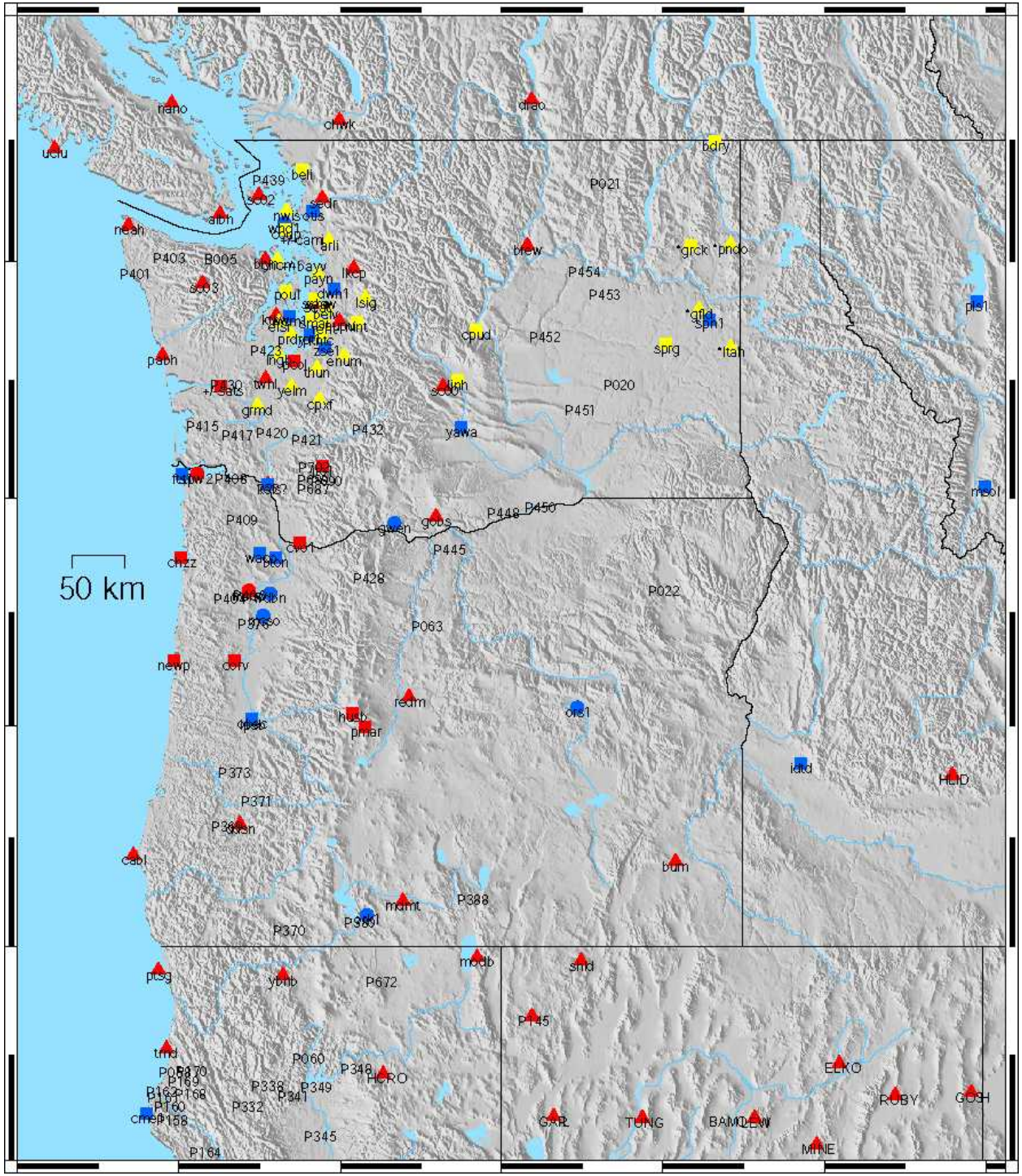
2002



Stations processed

by CWU- 2005

(plus 450 PBO)



By end of next year:

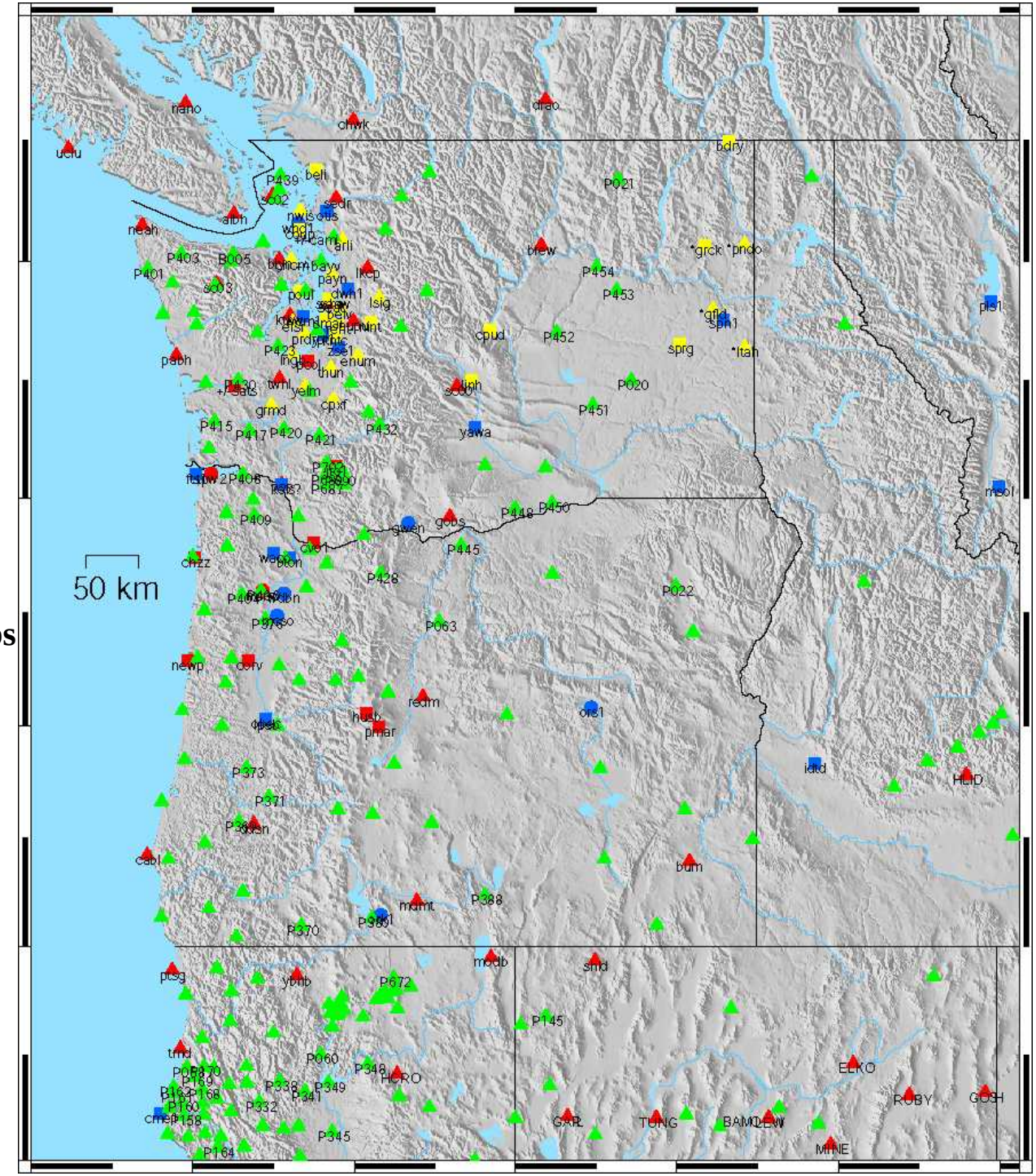
250+ cGPS instruments

Variable monumentation

Current interseismic strain:

Puget/forearc hazards

YFB N-S convergence

SSE moment budgets

Real-time data feeds-tsunami apps