Optimization of the Number and Location of Tsunami Stations for the Tsunami Warning in South China Sea

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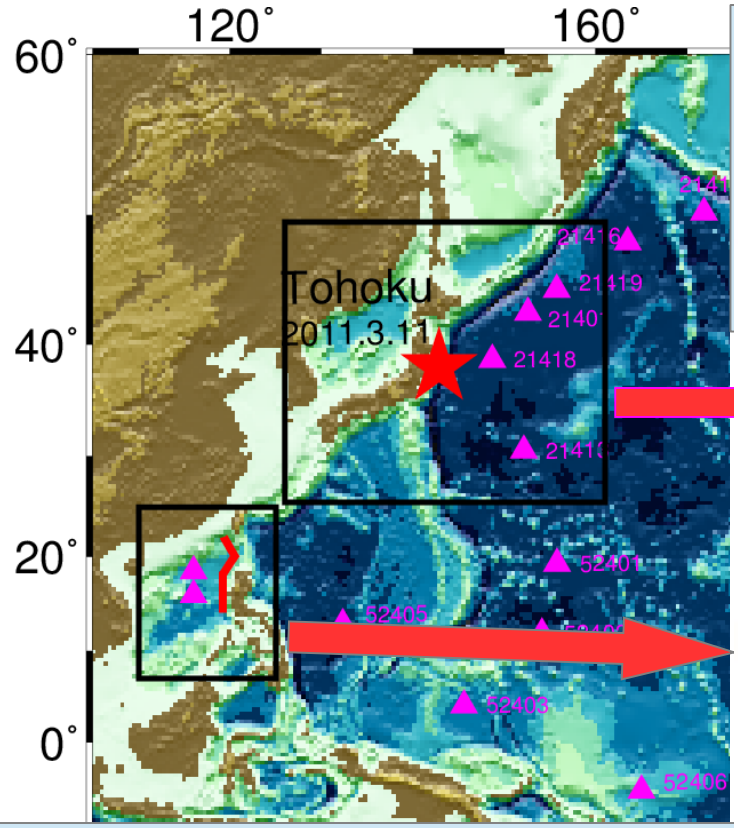
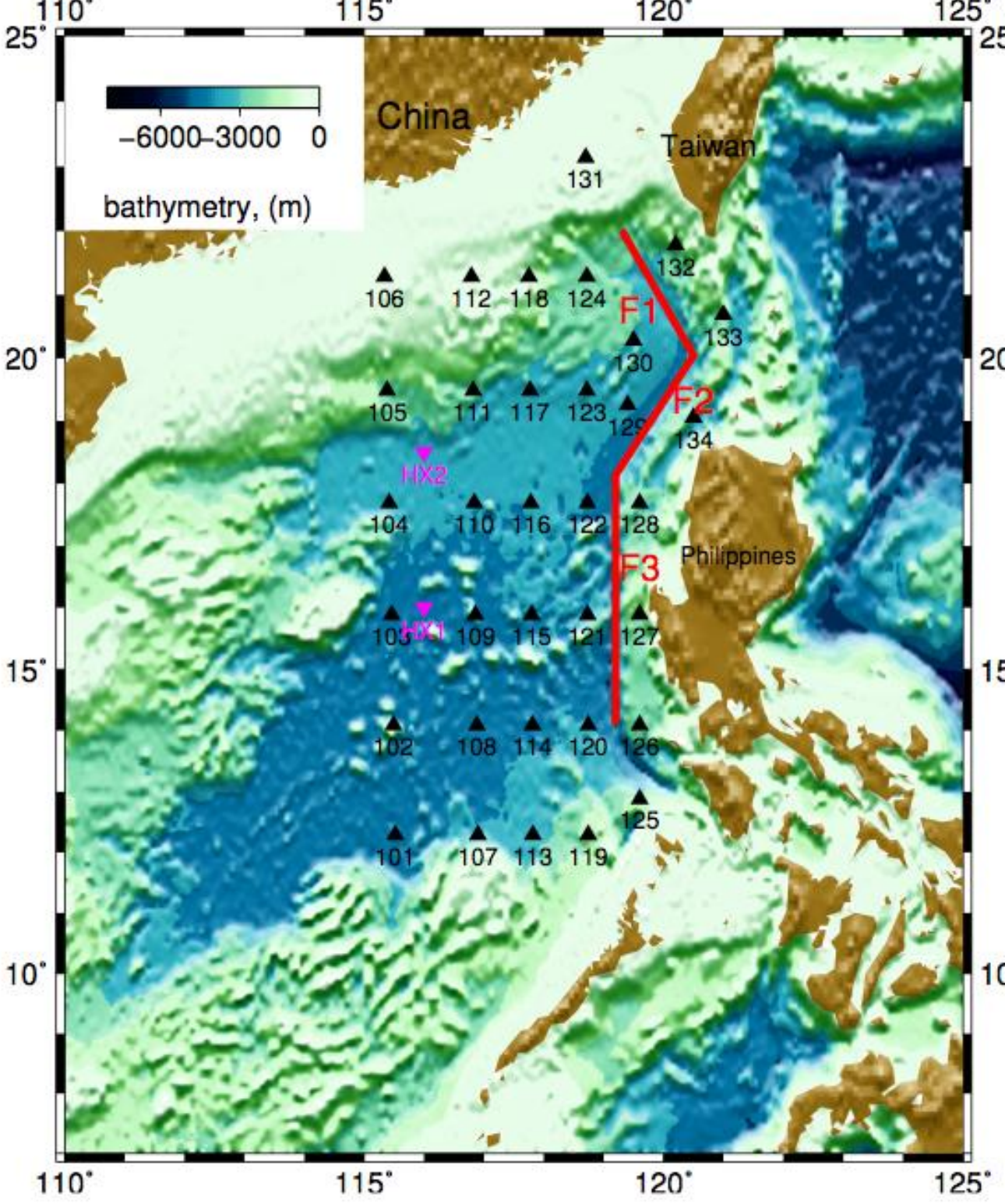


How many buoys?

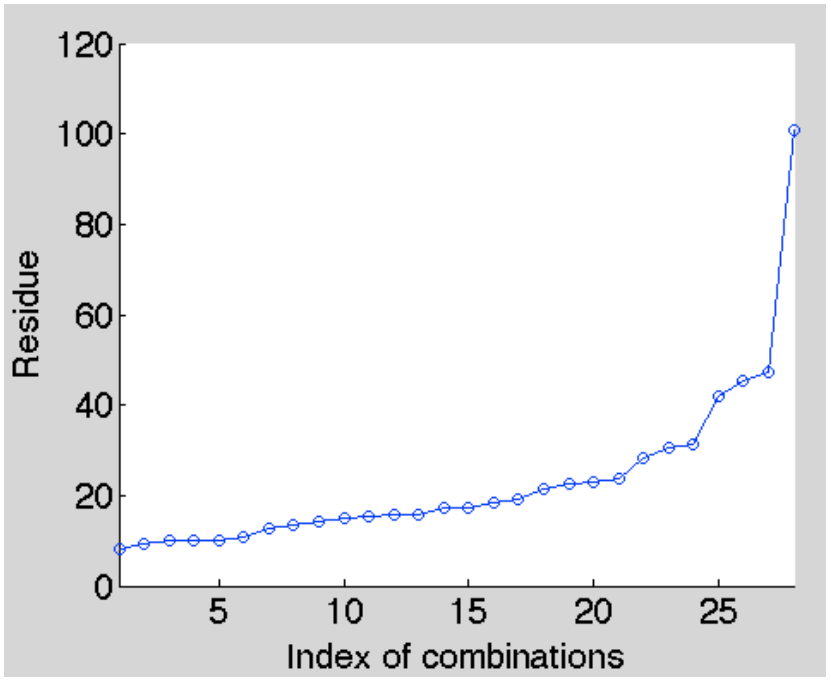
Where to locate?



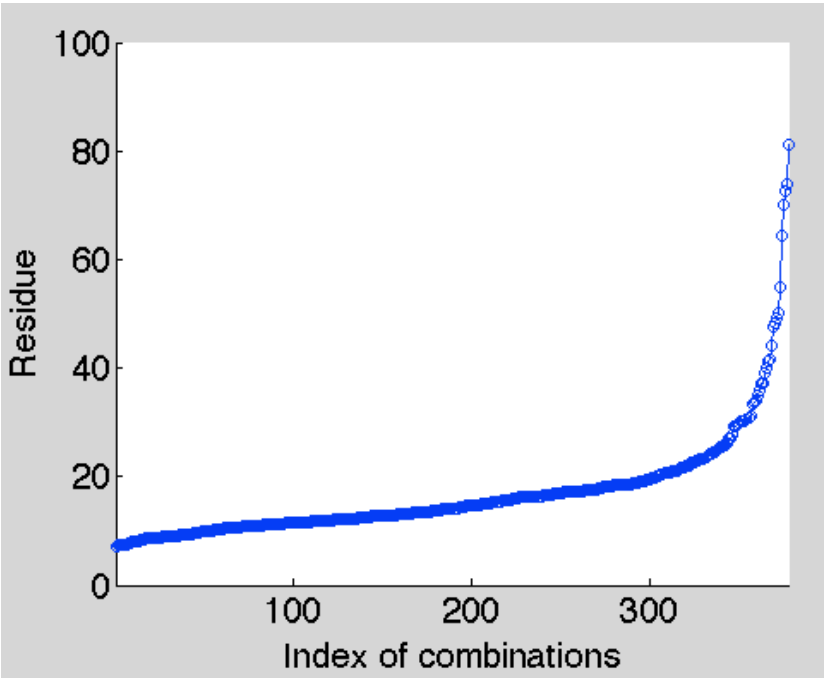
Methodology

- Inversions of tsunami data using every possible combination of tsunami stations:
  - 2011 Tohoku event: 28 tsunami stations
  - 1 station: nchoosek(28, 1) = 28 possibilities
  - 2 stations: nchoosek(28, 2) = 378 possibilities
  - ….
  - 28 stations: use all stations
- Judging criteria: the inverse residue

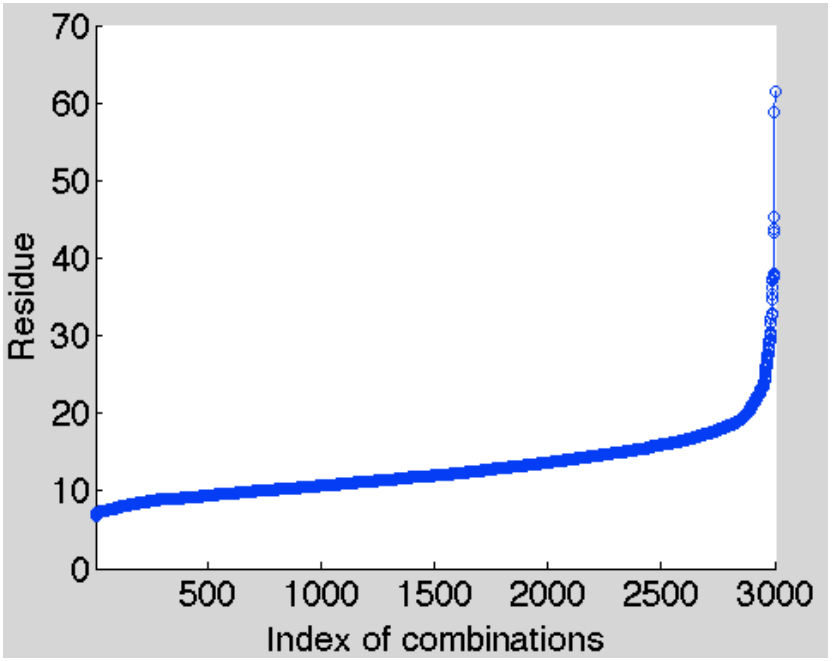
$$\sum_{n=1}^{28} \left[\frac{\text{Prediction} - \text{Data}}{\max(\text{Data})} \right]^2$$



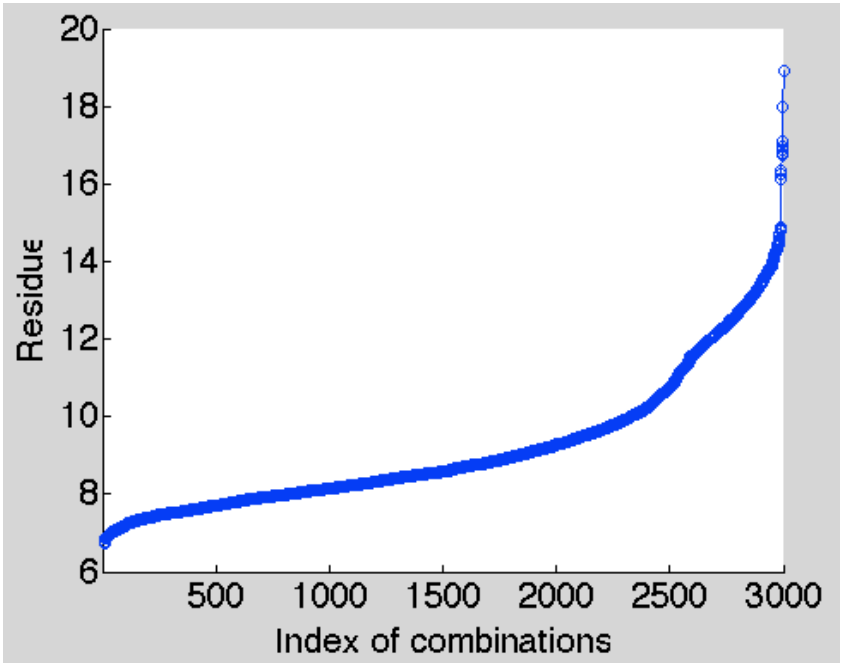
1 station: 28 possibilities



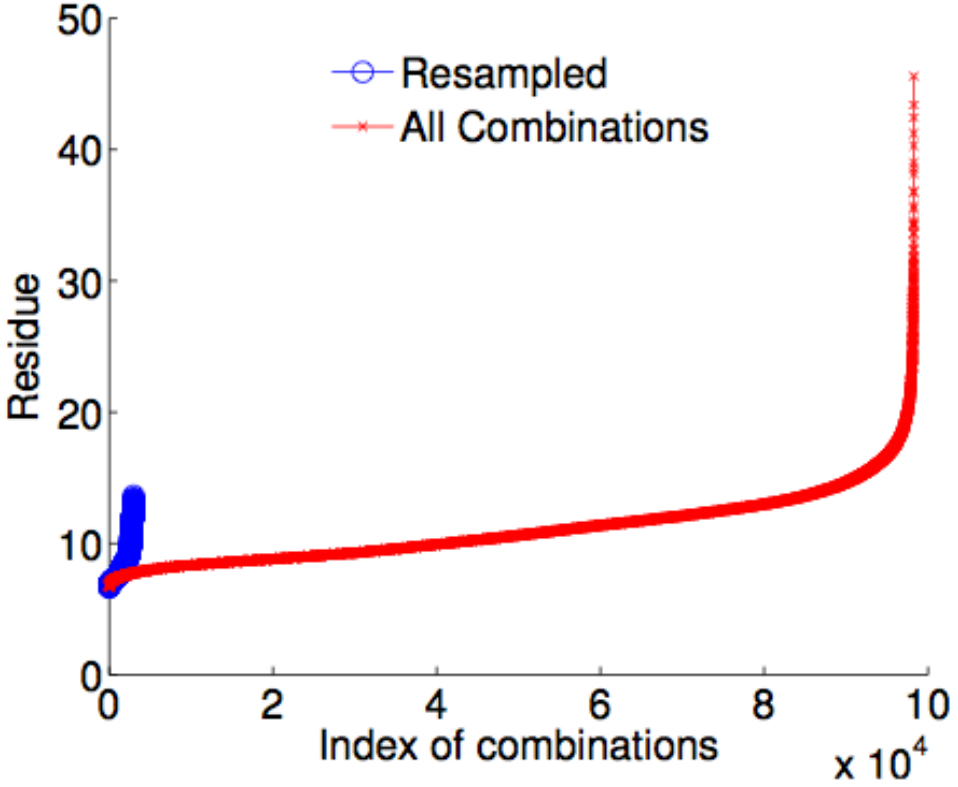
2 stations: 378 possibilities

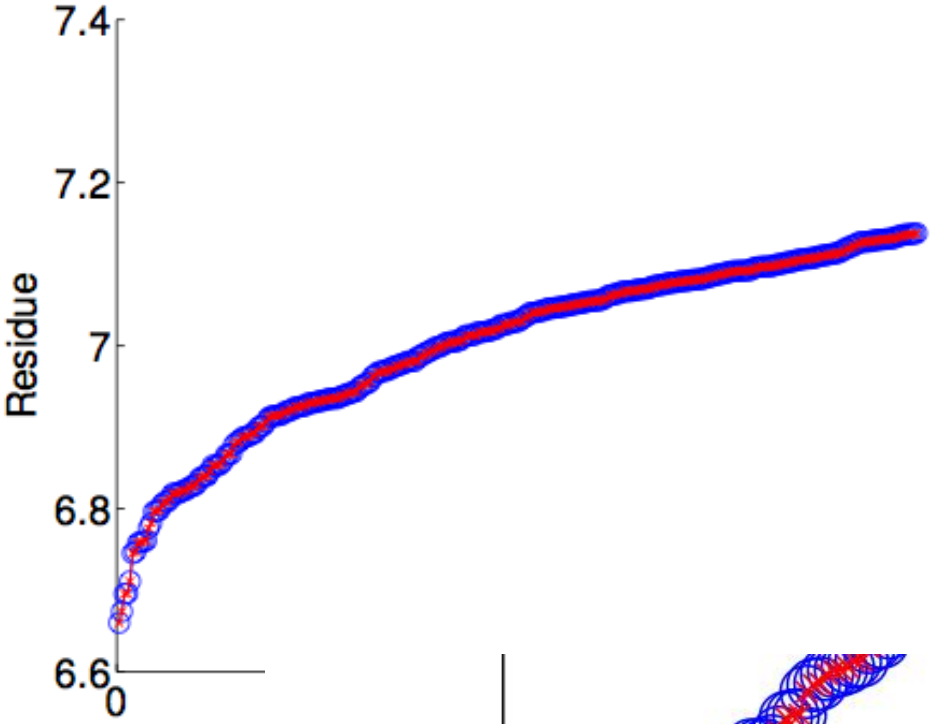


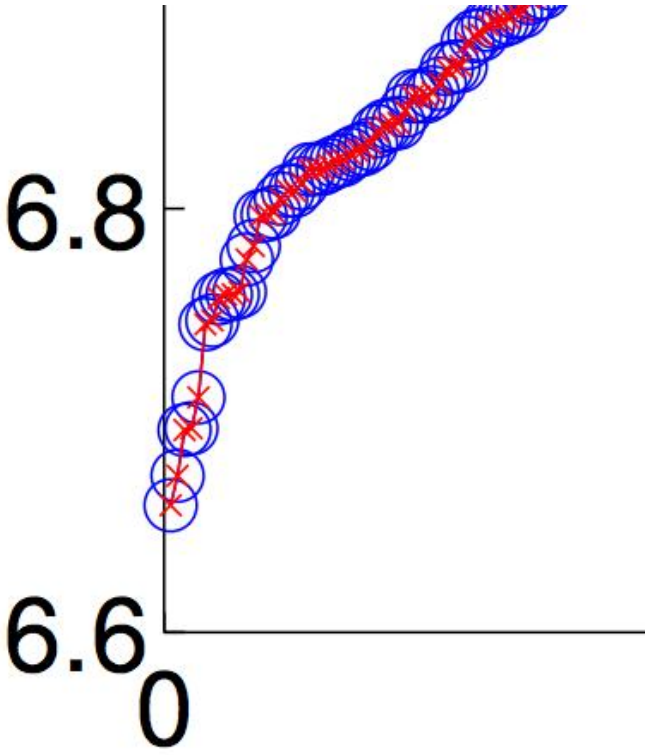
3 stations: 3000 possibilities (upper bound)



4 stations: 3000 possibilities (upper bound)



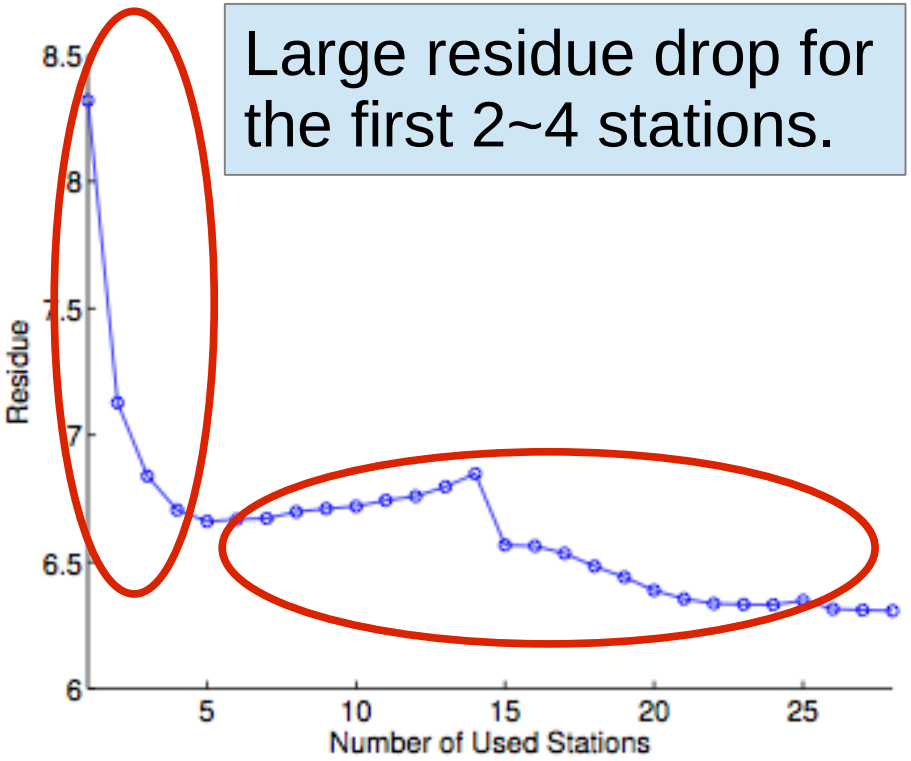




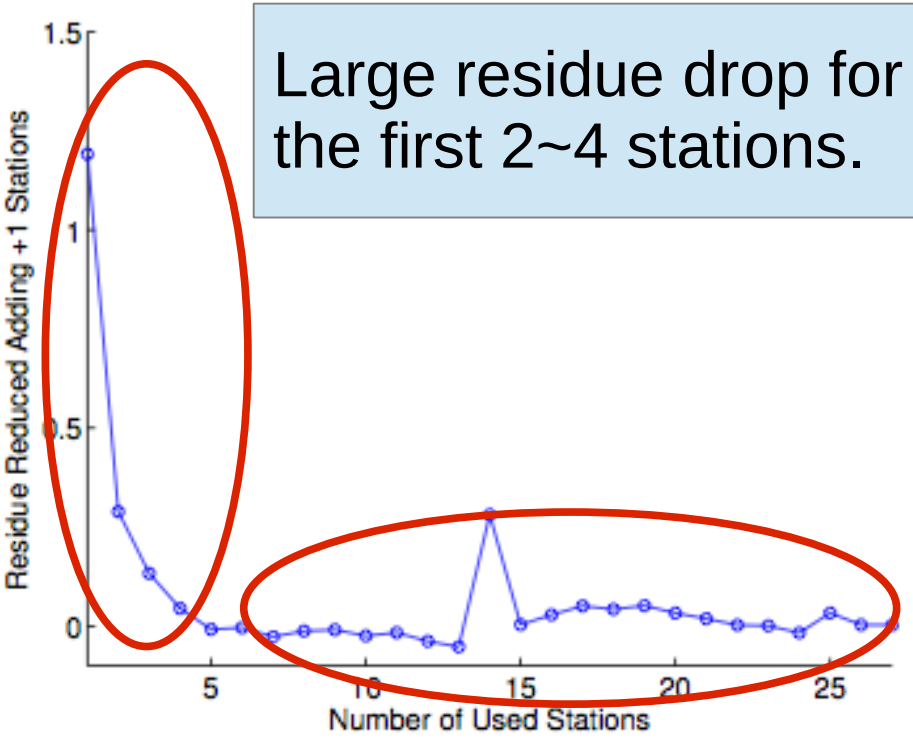
Using 5 stations:

nchoosek(28,5) = 98,280
Resampled = 3,000

Results for 2011 Tohoku



Large residue drop for the first 2~4 stations.



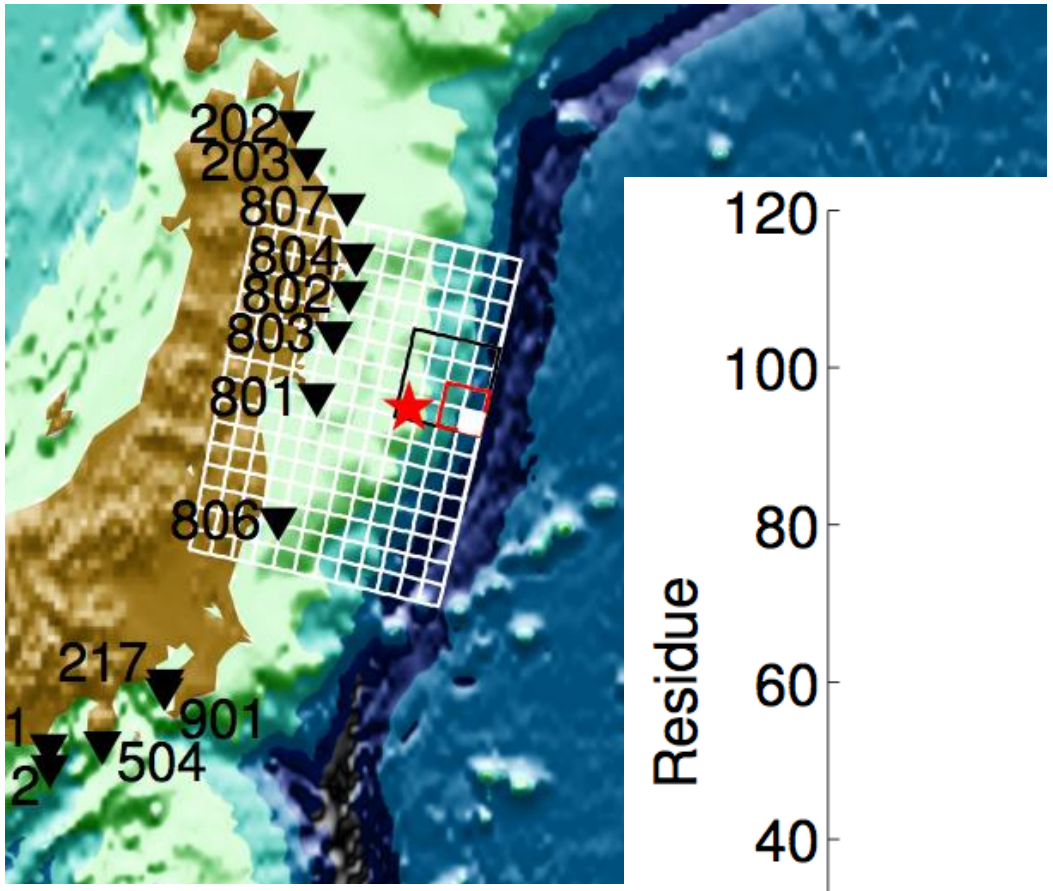
Large residue drop for the first 2~4 stations.

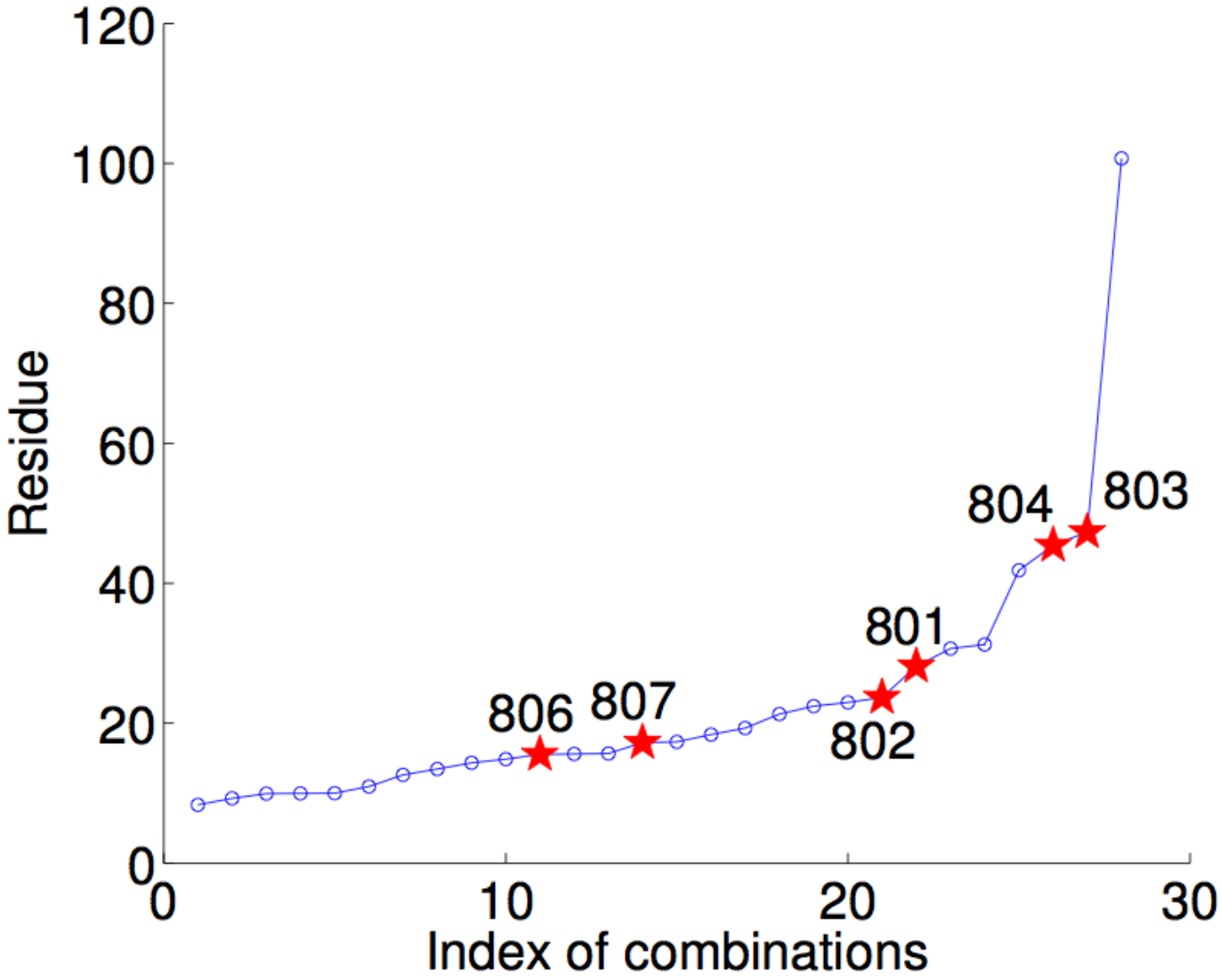
Minor residue drop for the rest.

Residue increases due to 3000 maximum inversions – failure to capture the least residue

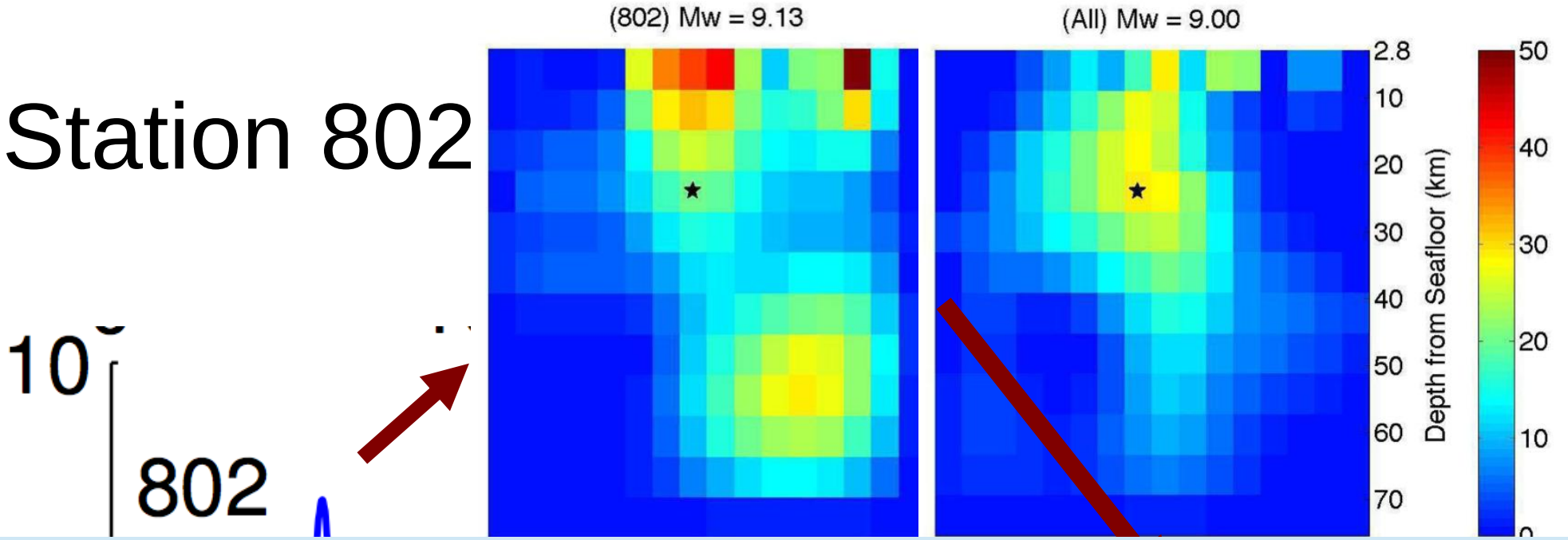
Almost zero residue drop for the rest.

1 Station, Near- or Far-Field?



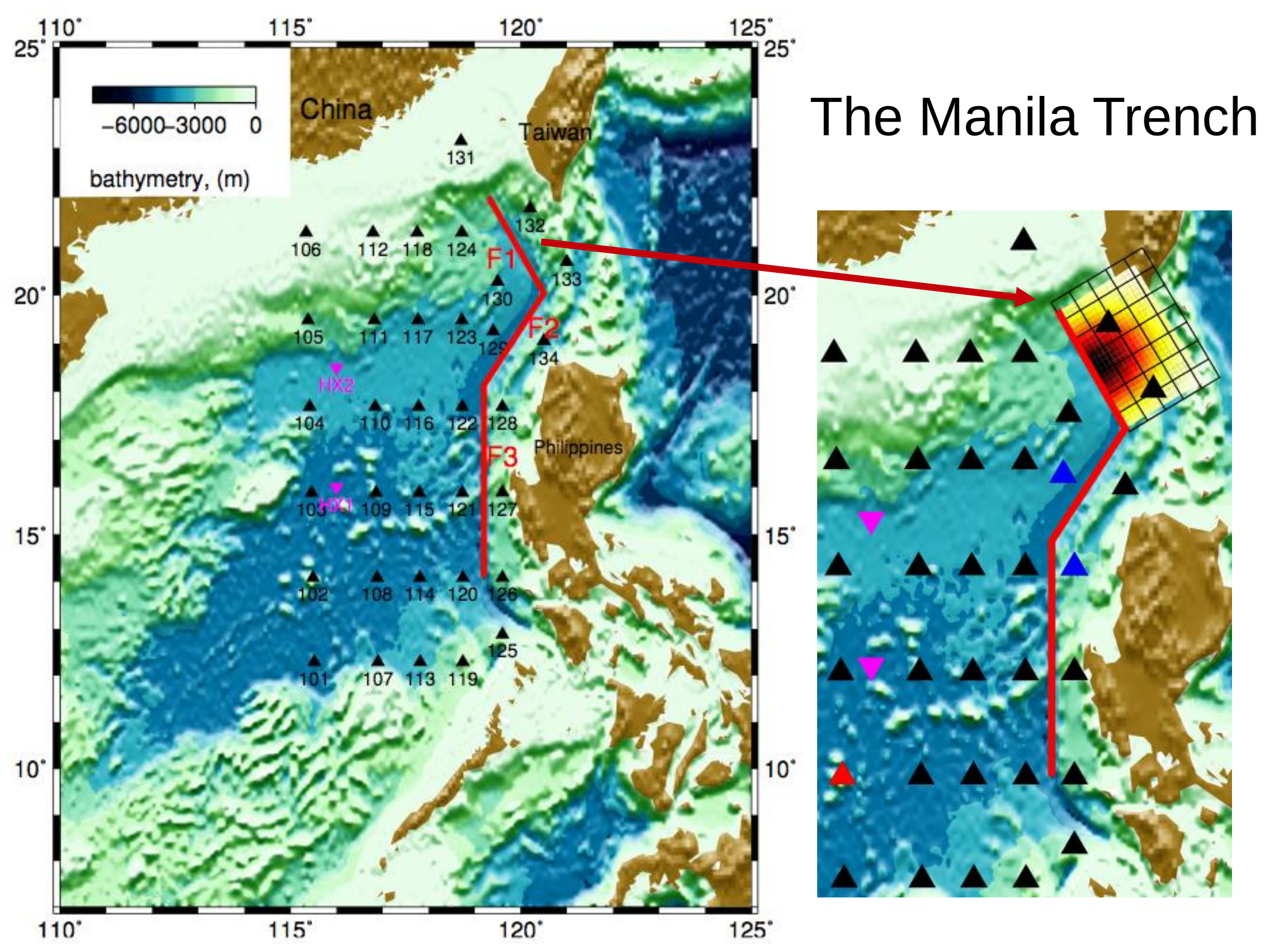


Station 802

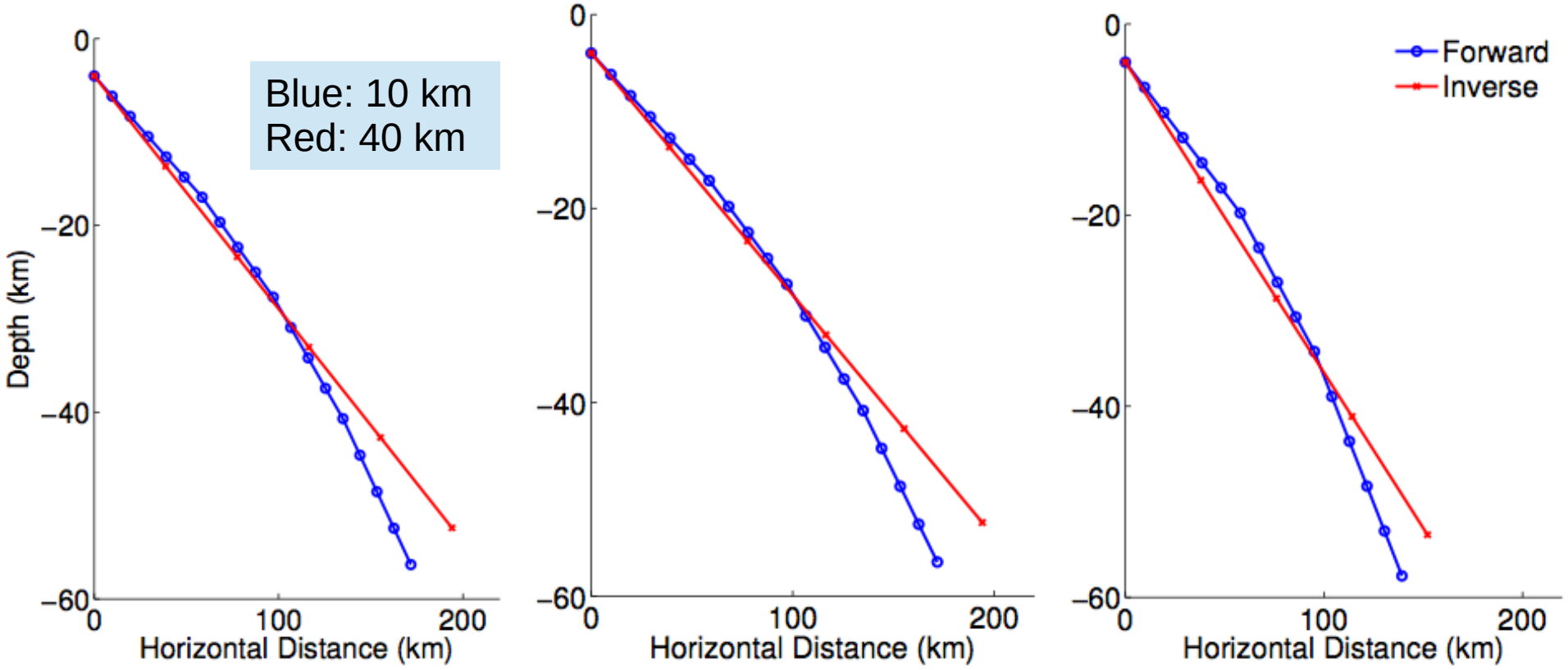


2~4 buoys are sufficient for inversion of tsunami to constrain earthquake source if they are optimally located.

Some near-field stations with short and high-amplitude leading waves give bad predictions.


The Manila Trench
110°
115°
120°
125°
25°
20°
15°
10°
−6000–3000 0
bathymetry, (m)
China
Taiwan
Philippines
F1
F2
F3
HX2
HX1
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134

Fault Geometry



F1: 12.5deg ~ 23deg

Inverse: 14.0 deg

F2: 12.5deg ~ 23deg

Inverse: 14.0 deg

F3: 15.3deg ~ 35.5deg

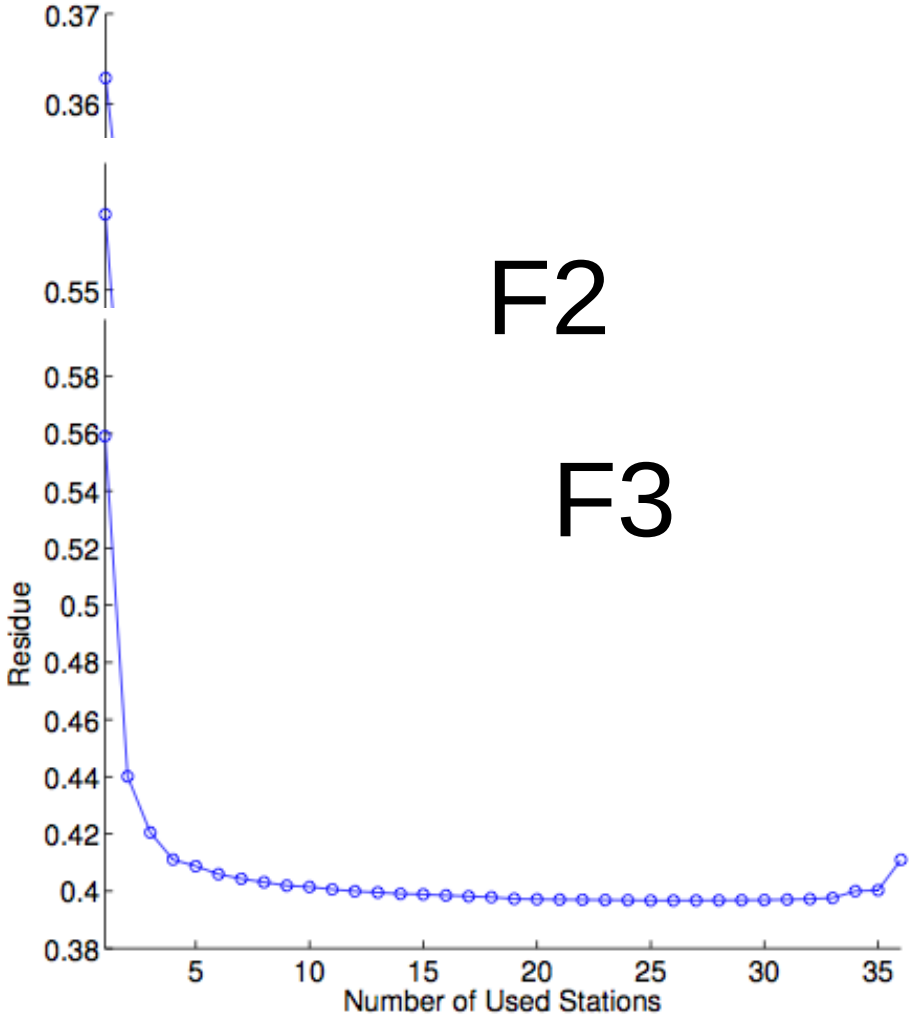
Inverse: 18.0 deg

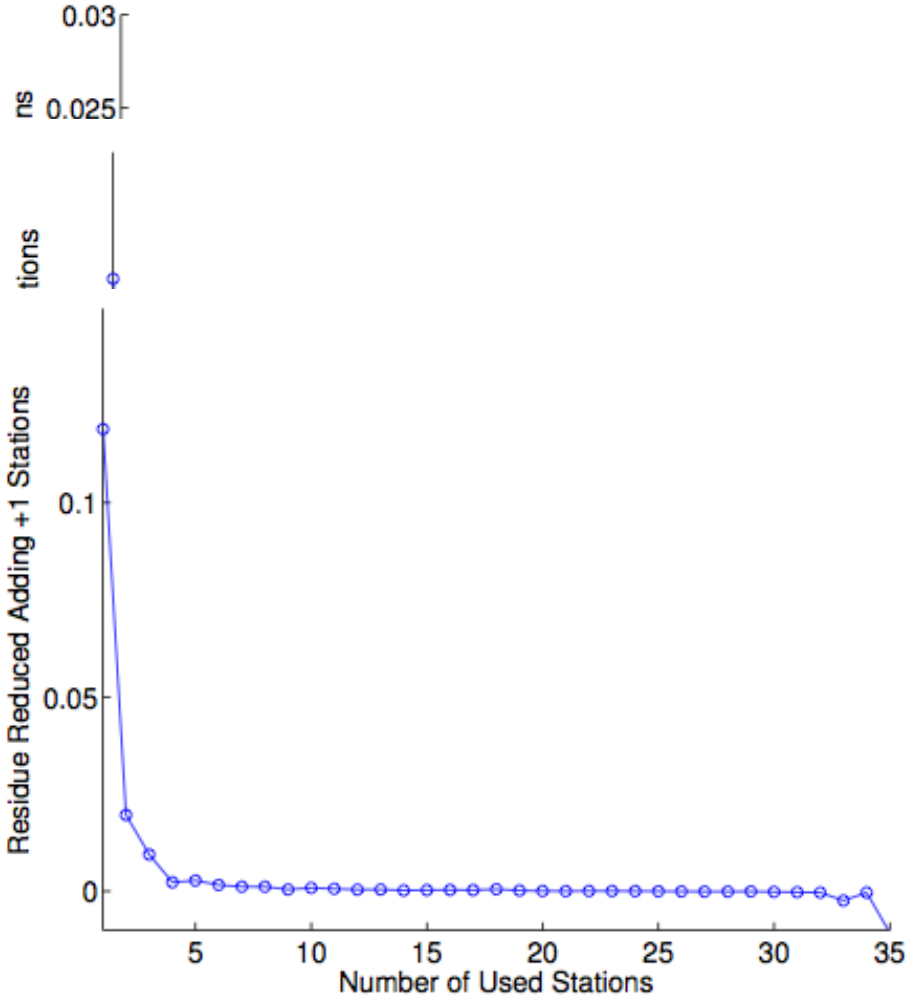
(Hsu et al. 2012)

Results for the Manila Trench

F2

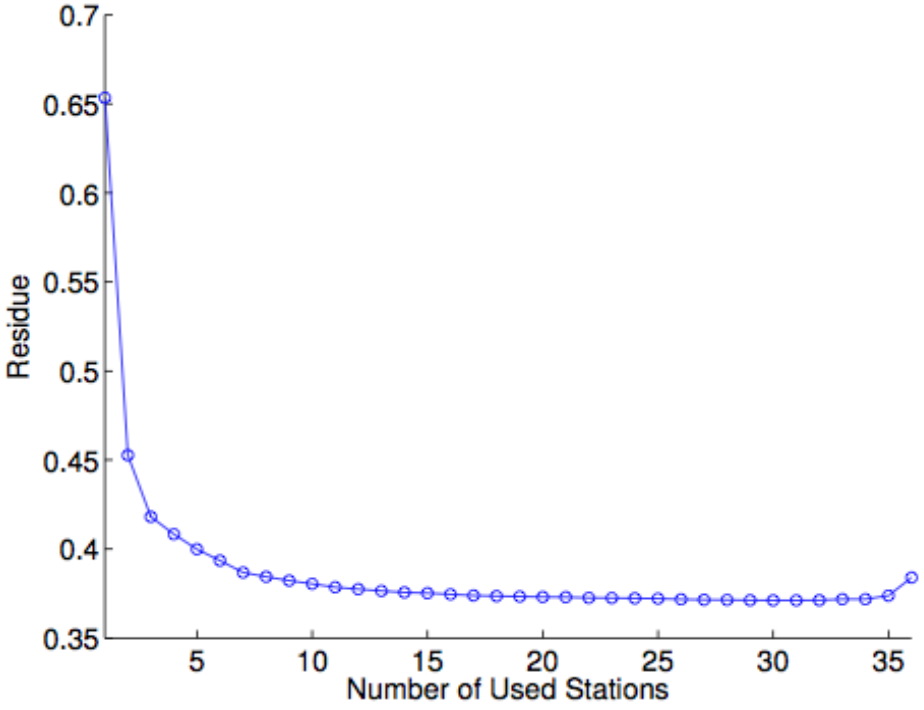
F3

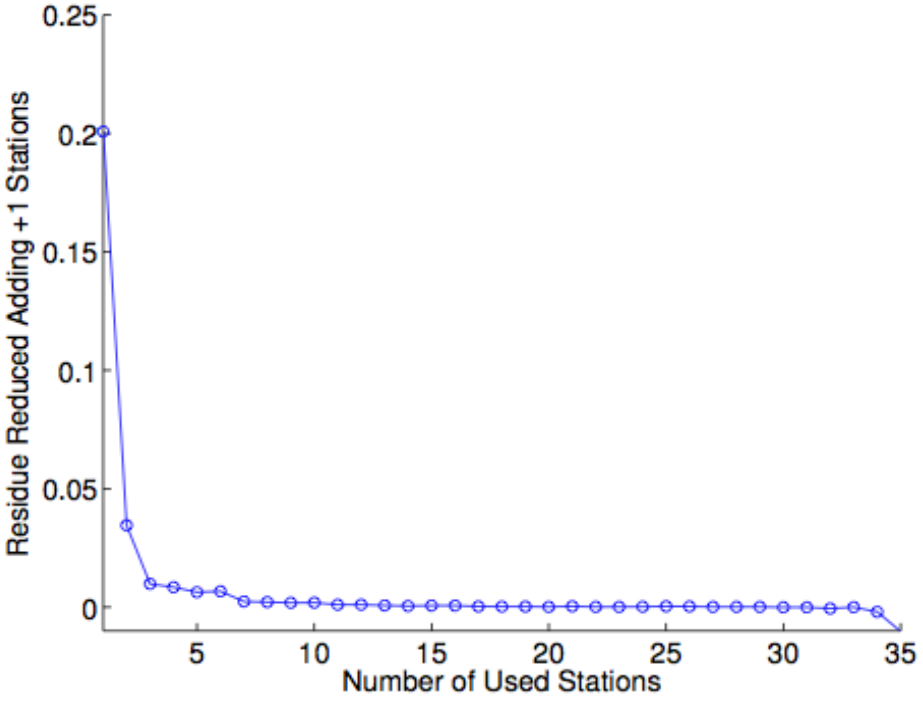




Results for the Manila Trench

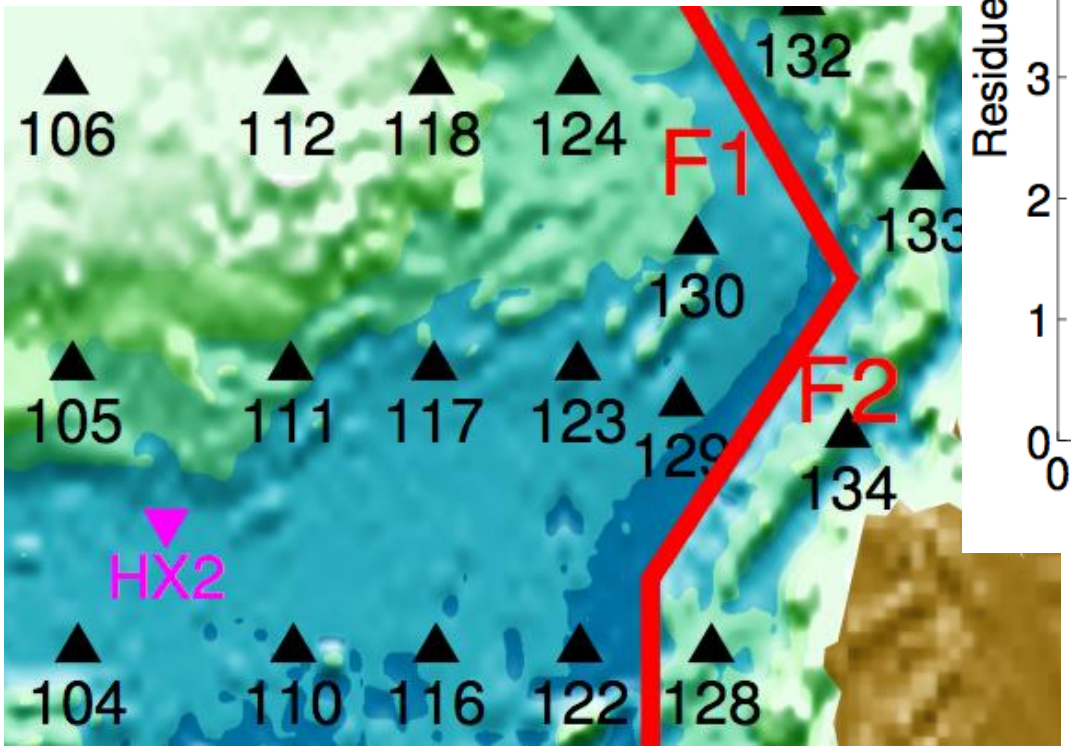
Averaged Residue over Three Faults:

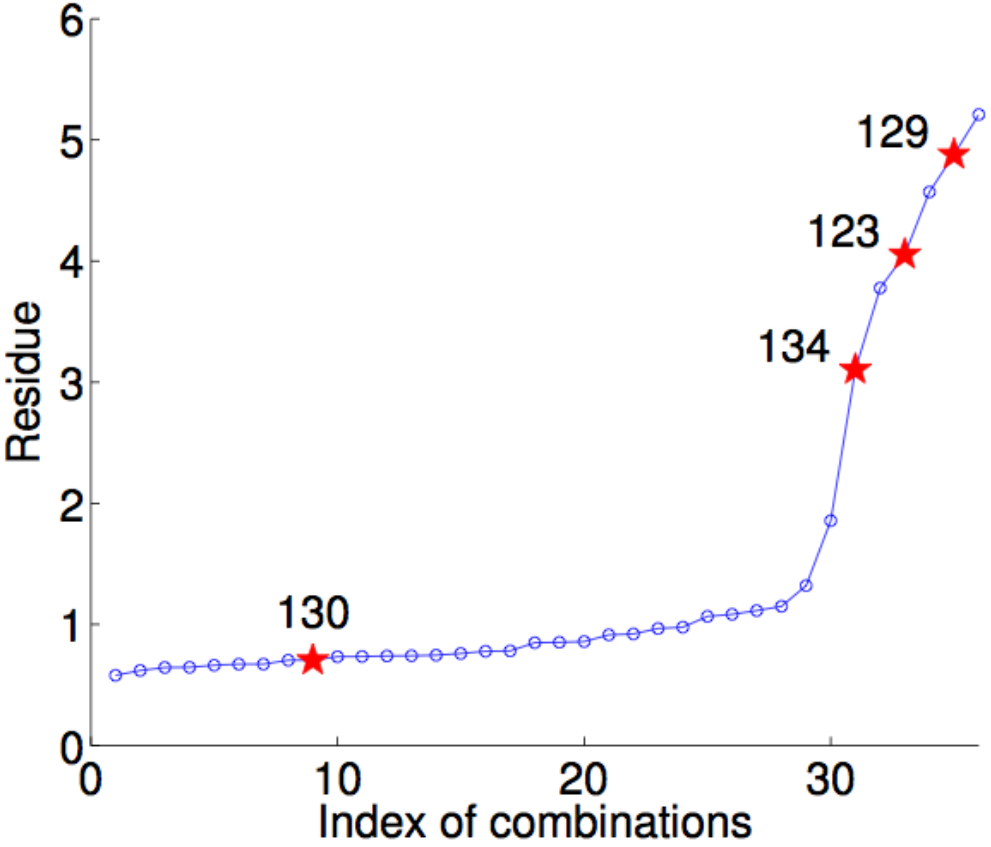




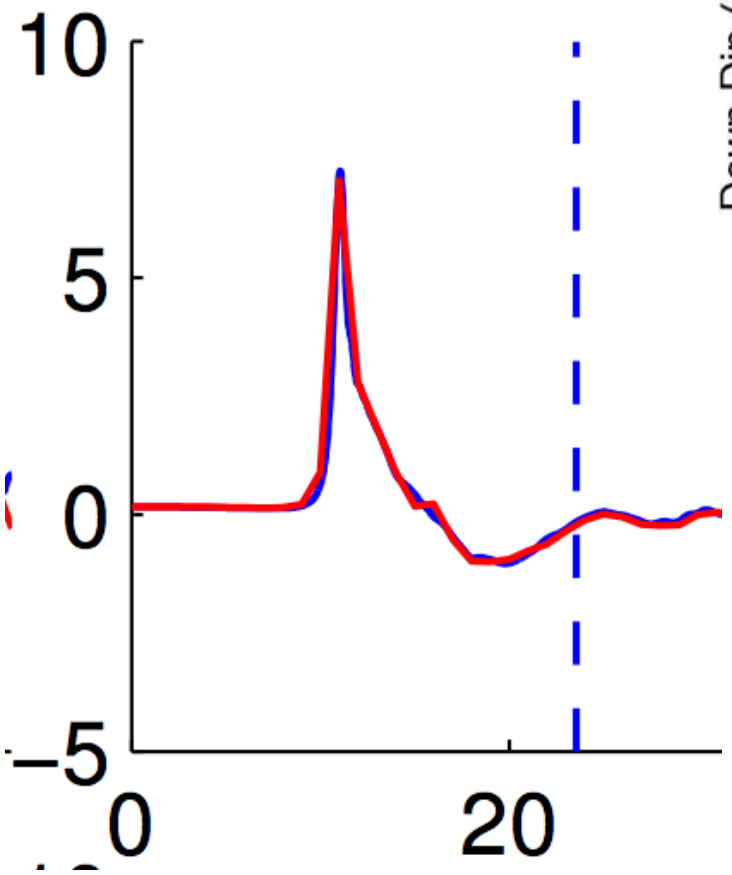
Near- or Far-Field?

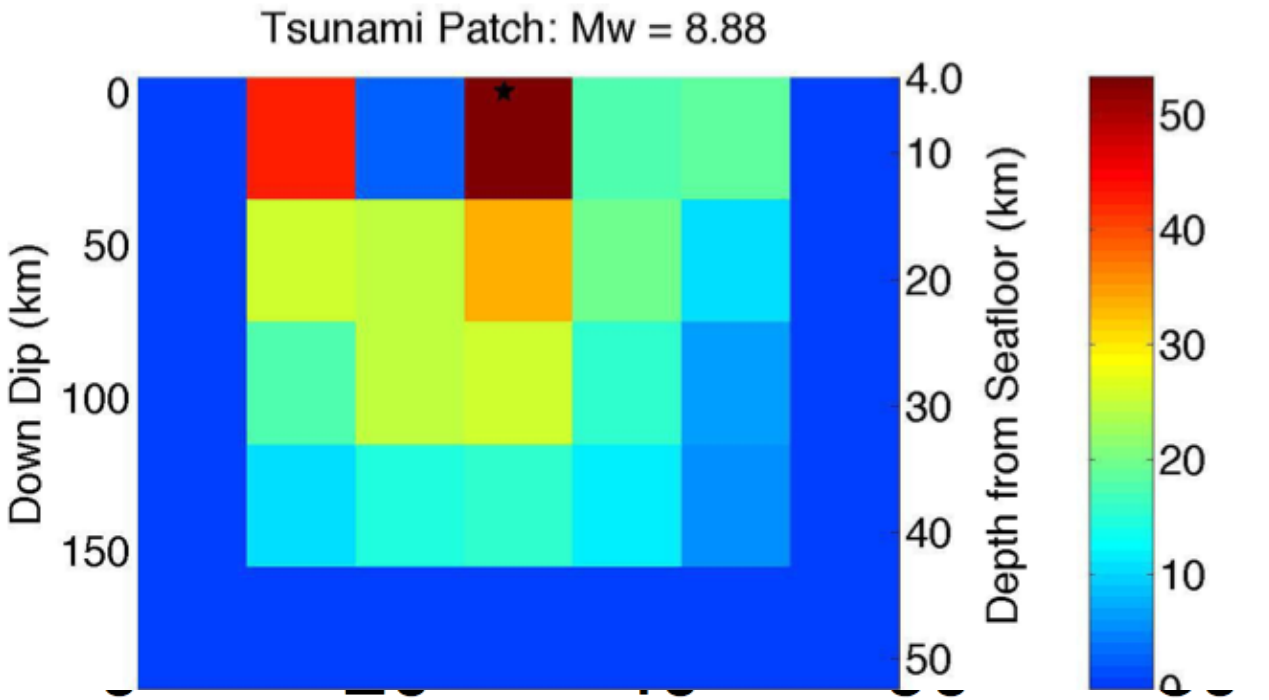
Example: F2

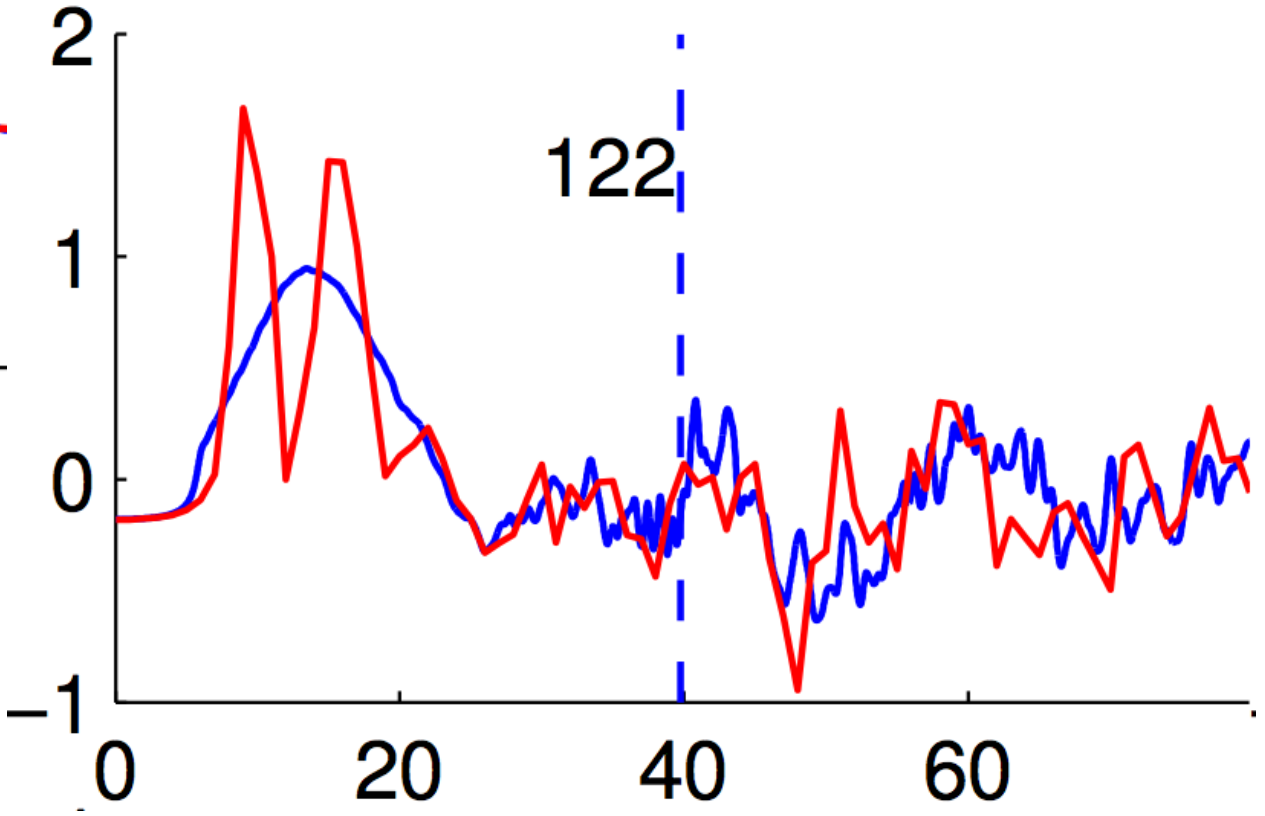




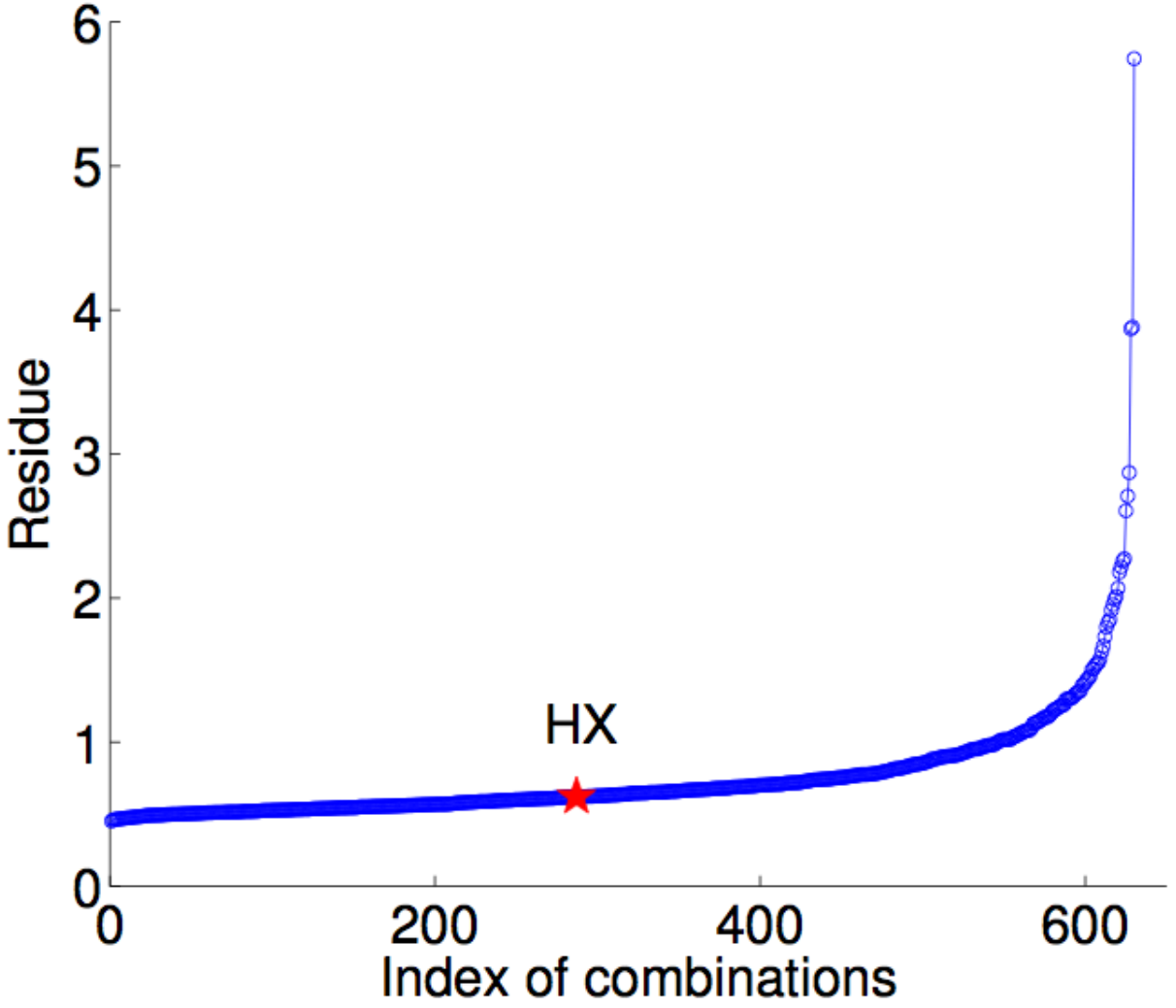
Station 123


10
5
0
−5
0
20


Tsunami Patch: Mw = 8.88
Down Dip (km)
0
50
100
150
4.0
10
20
30
40
50
Depth from Seafloor (km)
50
40
30
20
10


2
1
0
−1
122
0
20
40
60

Buoys of HX



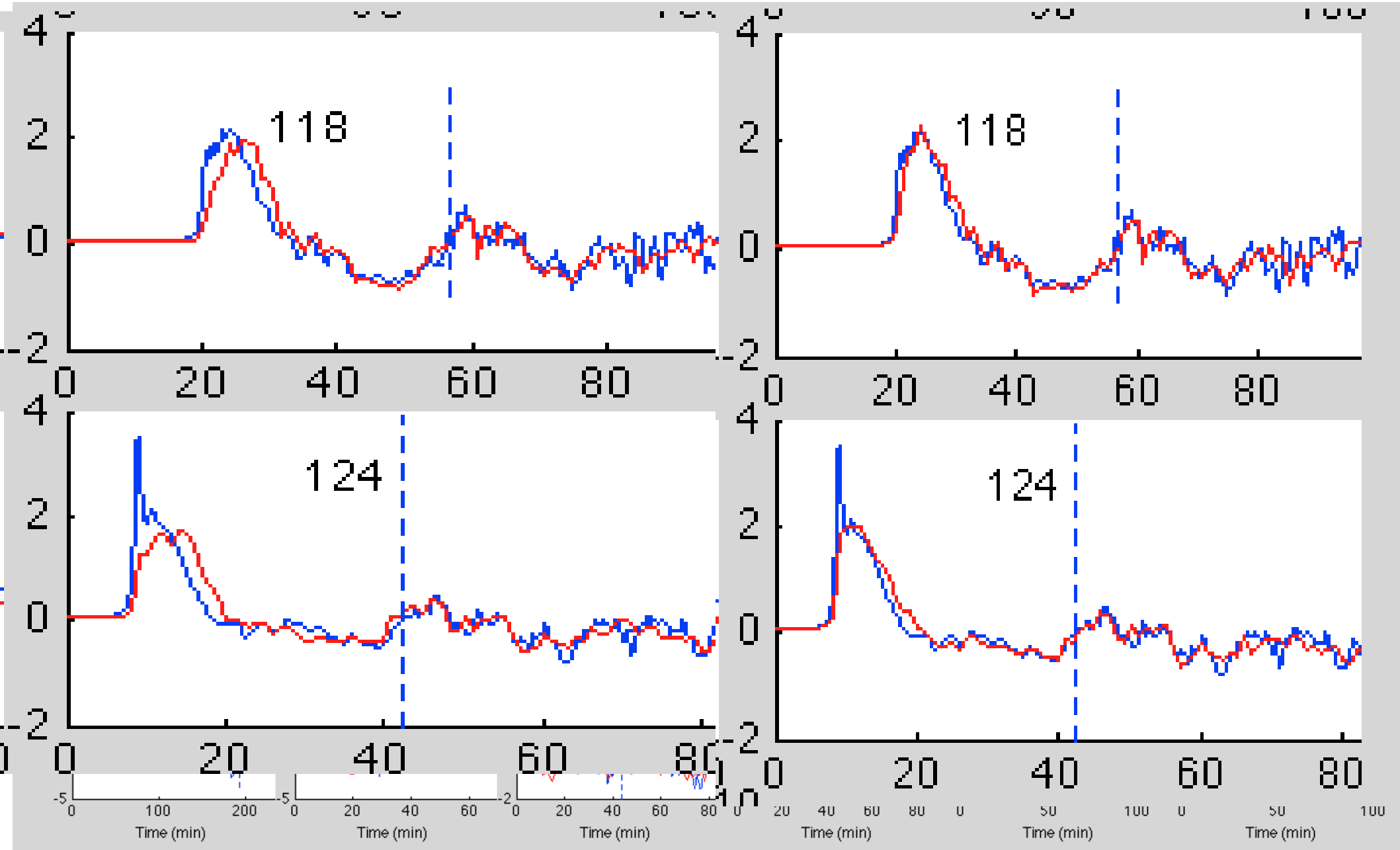
Residue =

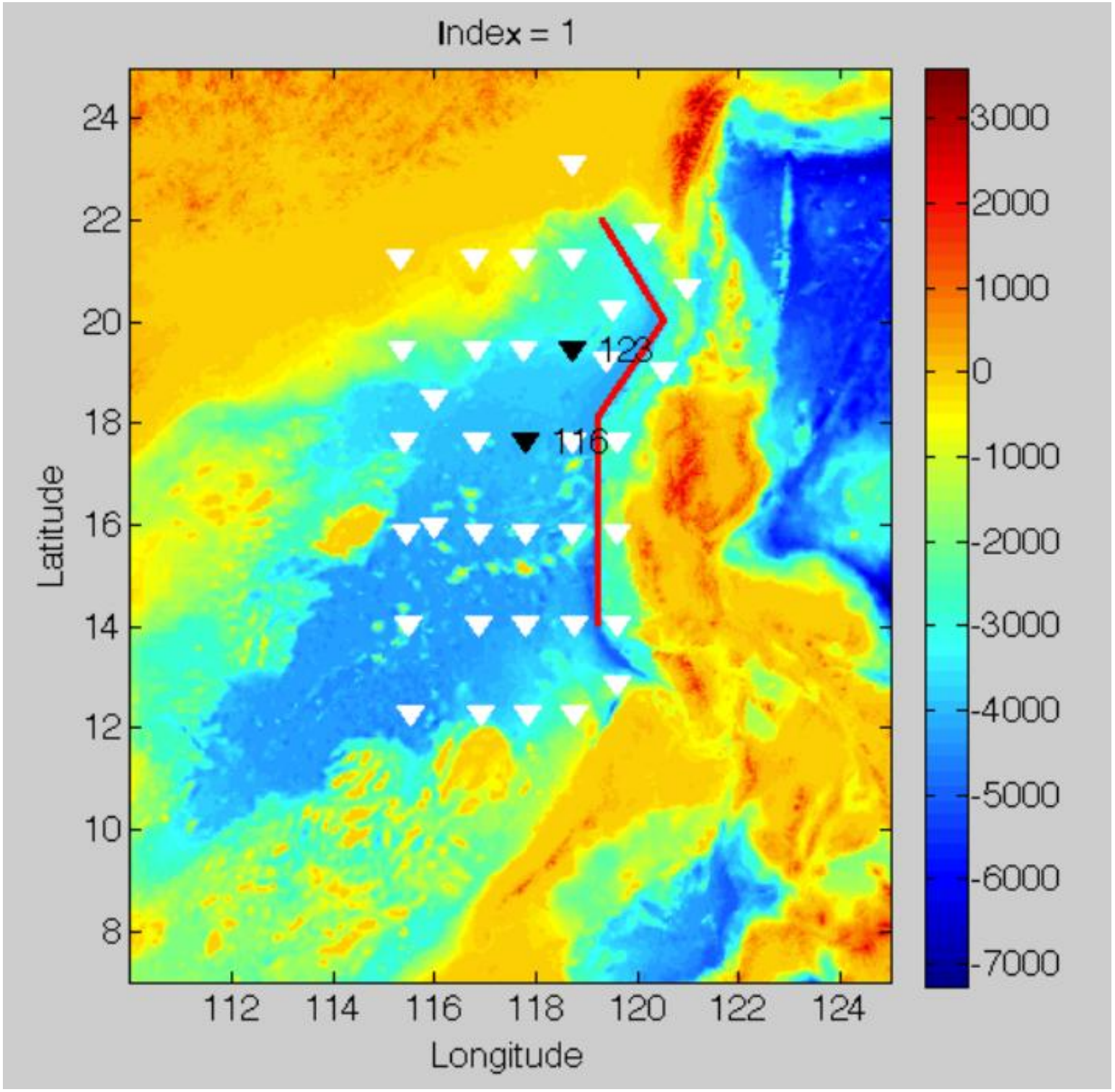
0.62

Min Residue =

0.45

HXs for F1


118
118
124
124
Time (min)
Time (min)
Time (min)
Time (min)
Time (min)
Time (min)



Best: 123, 116

Top 30 in video.

Trade-off:

Residue

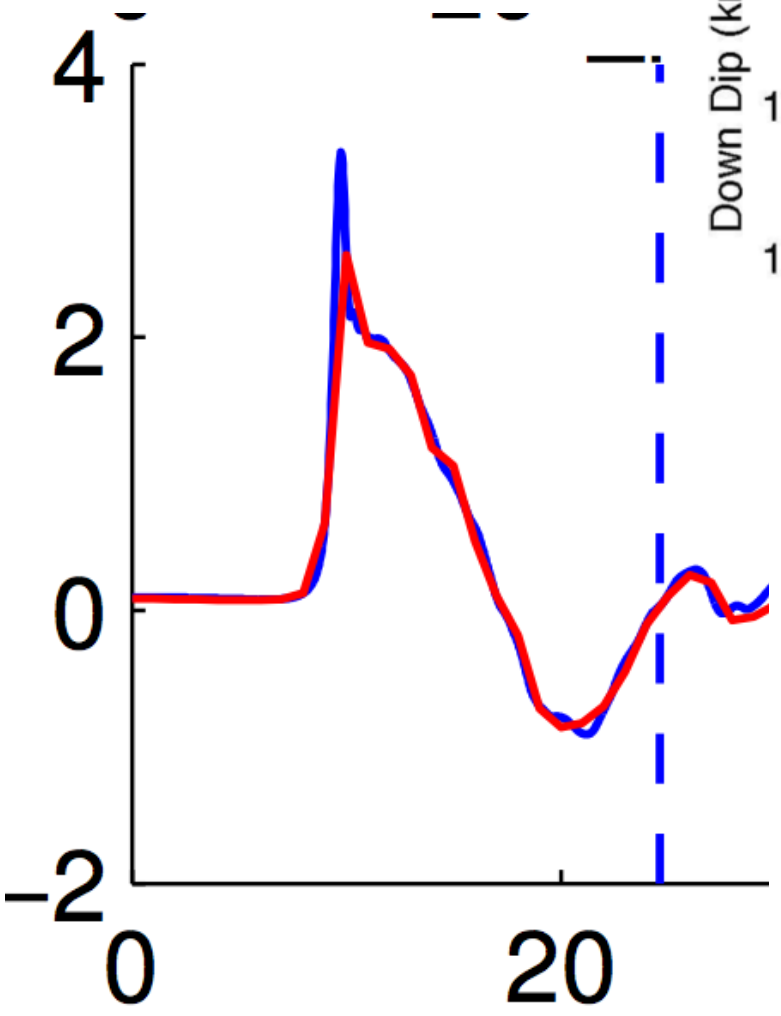
Distance.

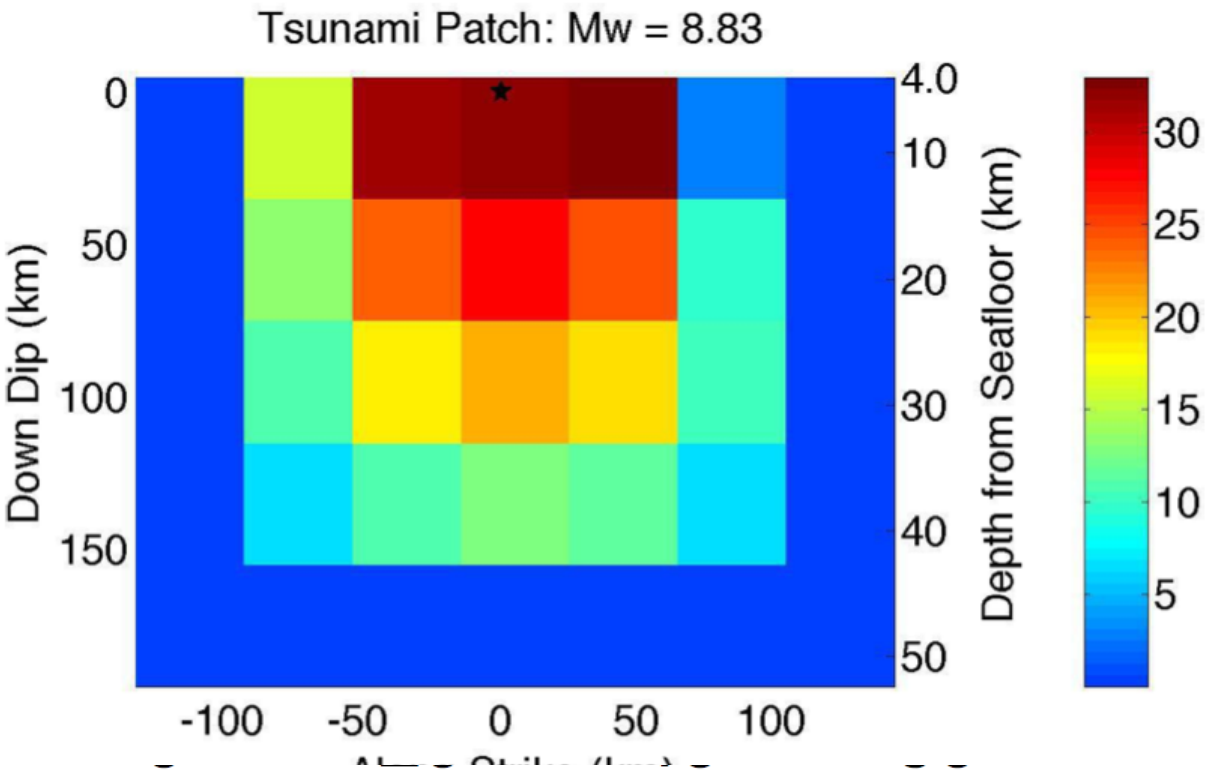
Conclusions

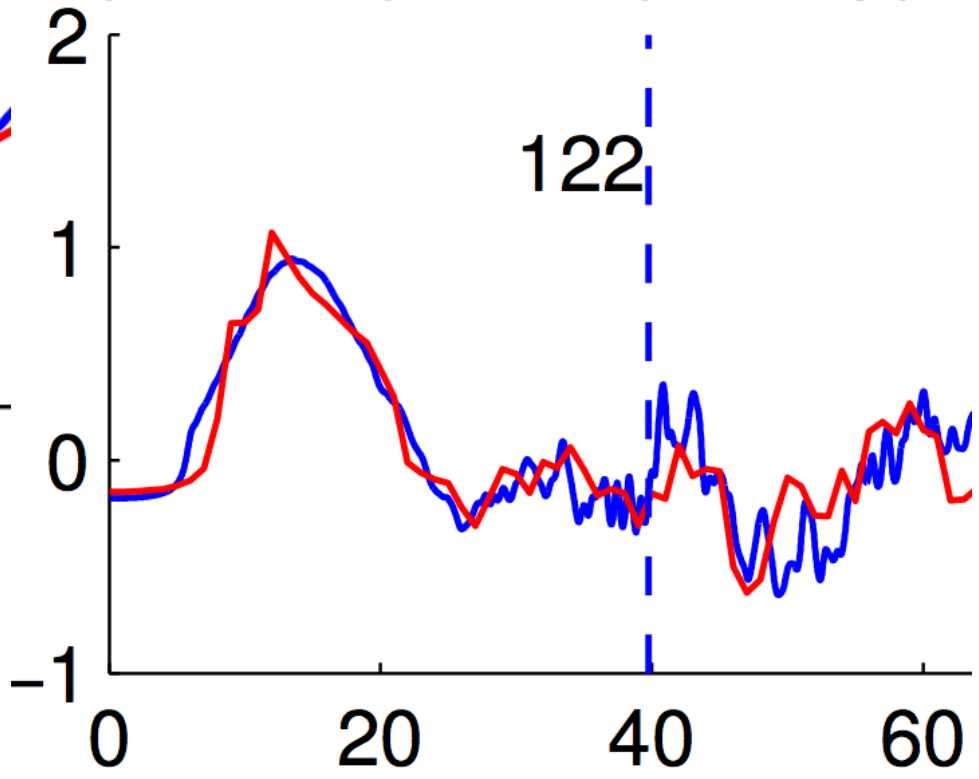
- 2~4 buoys are sufficient for inversion of tsunami to constrain earthquake source if they are optimally located; adding more data does not significantly improve the results.
- Some near-field stations with short and high-amplitude leading waves tend to exaggerate model error, and thus give bad predictions.
- HX buoys have small residue in the inversions; the location can be further optimized.

Thank you!

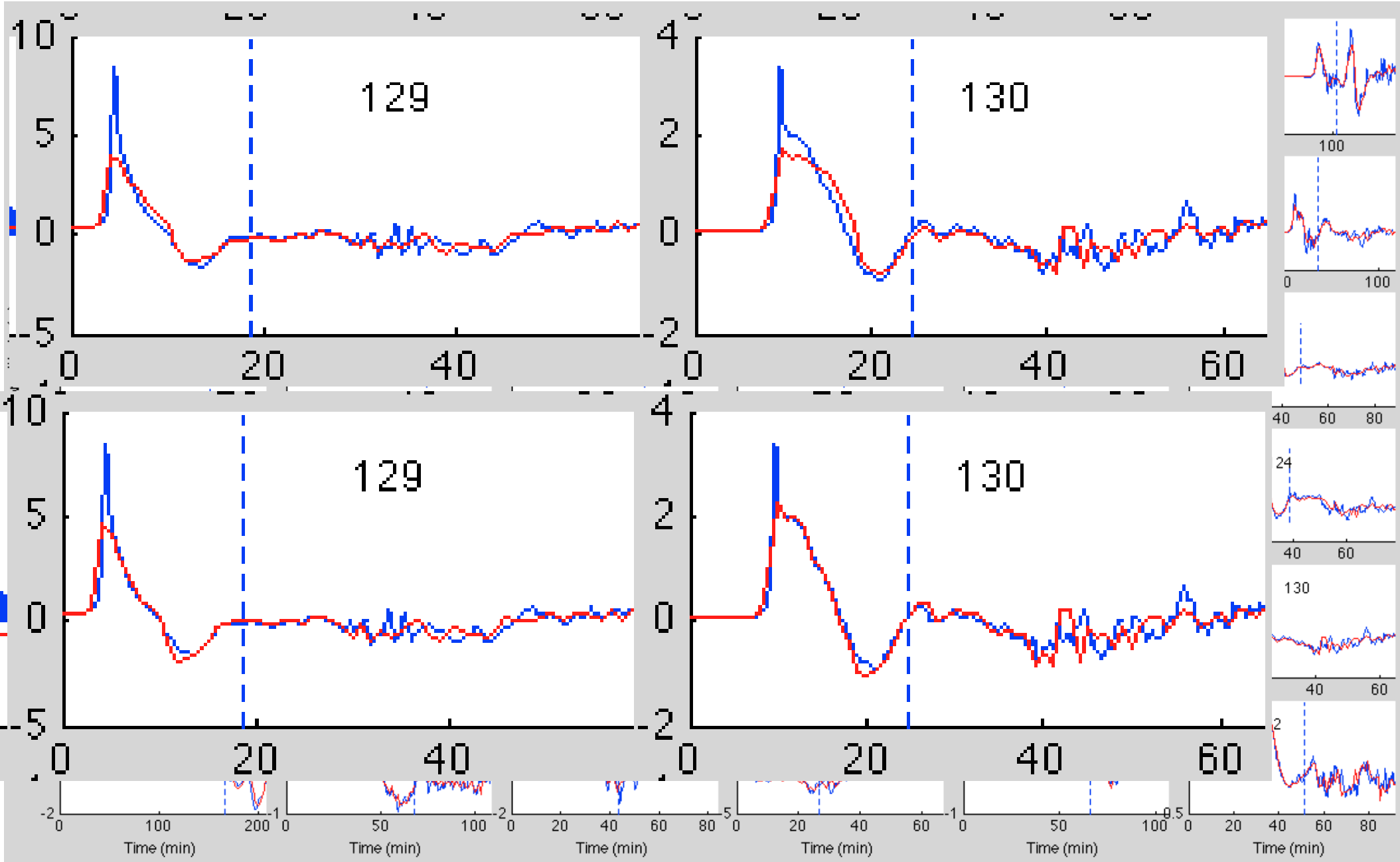
Station 130, F2







HXs for F2


129
130
129
130
Time (min)
Time (min)
Time (min)
Time (min)
Time (min)
Time (min)

HXs for F3