

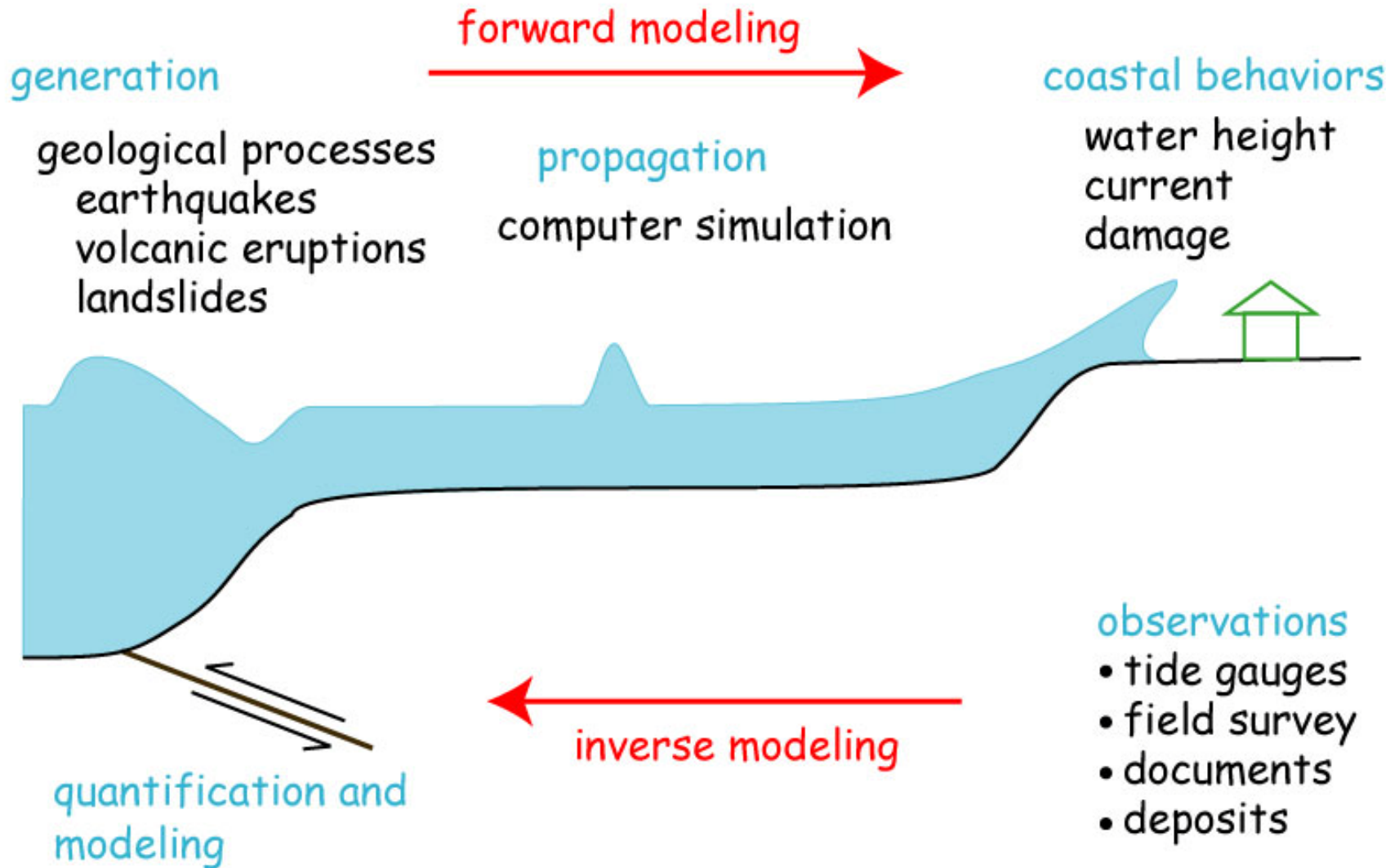
津波波形のリアルタイムインバージョン

東京大学地震研究所

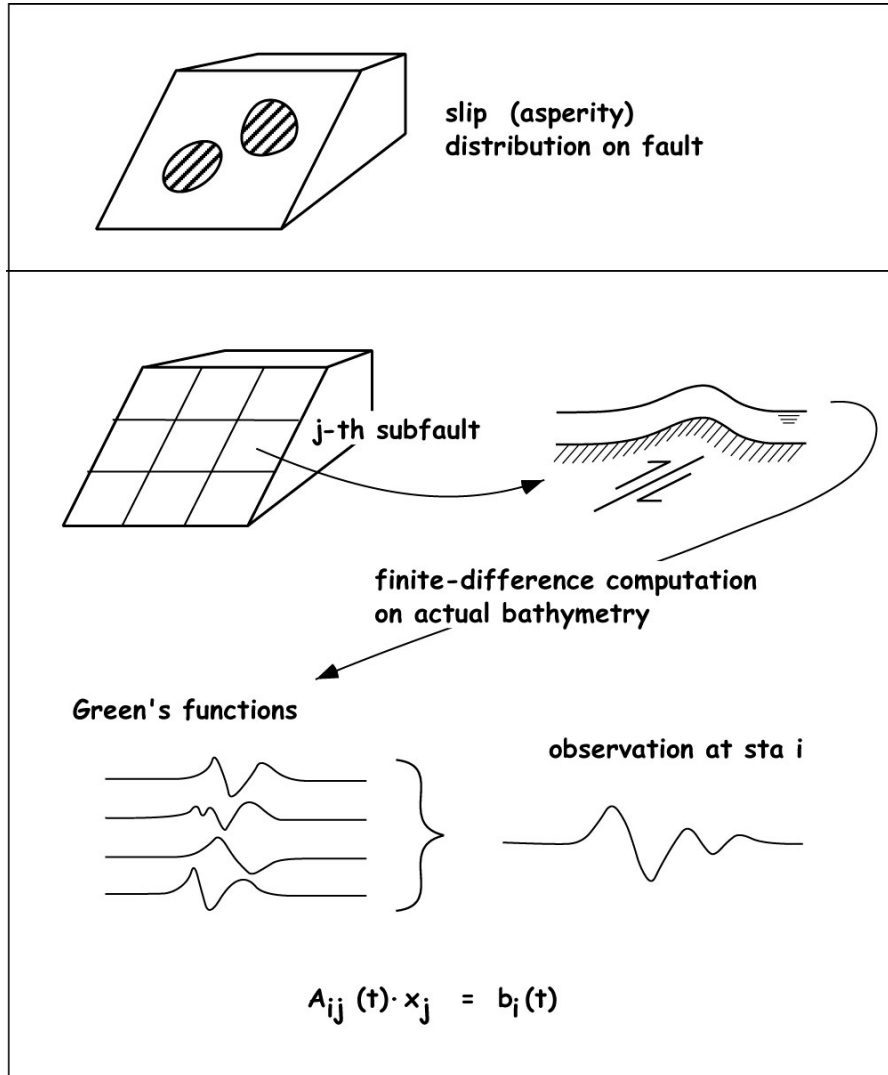
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Forward and Inverse Problems



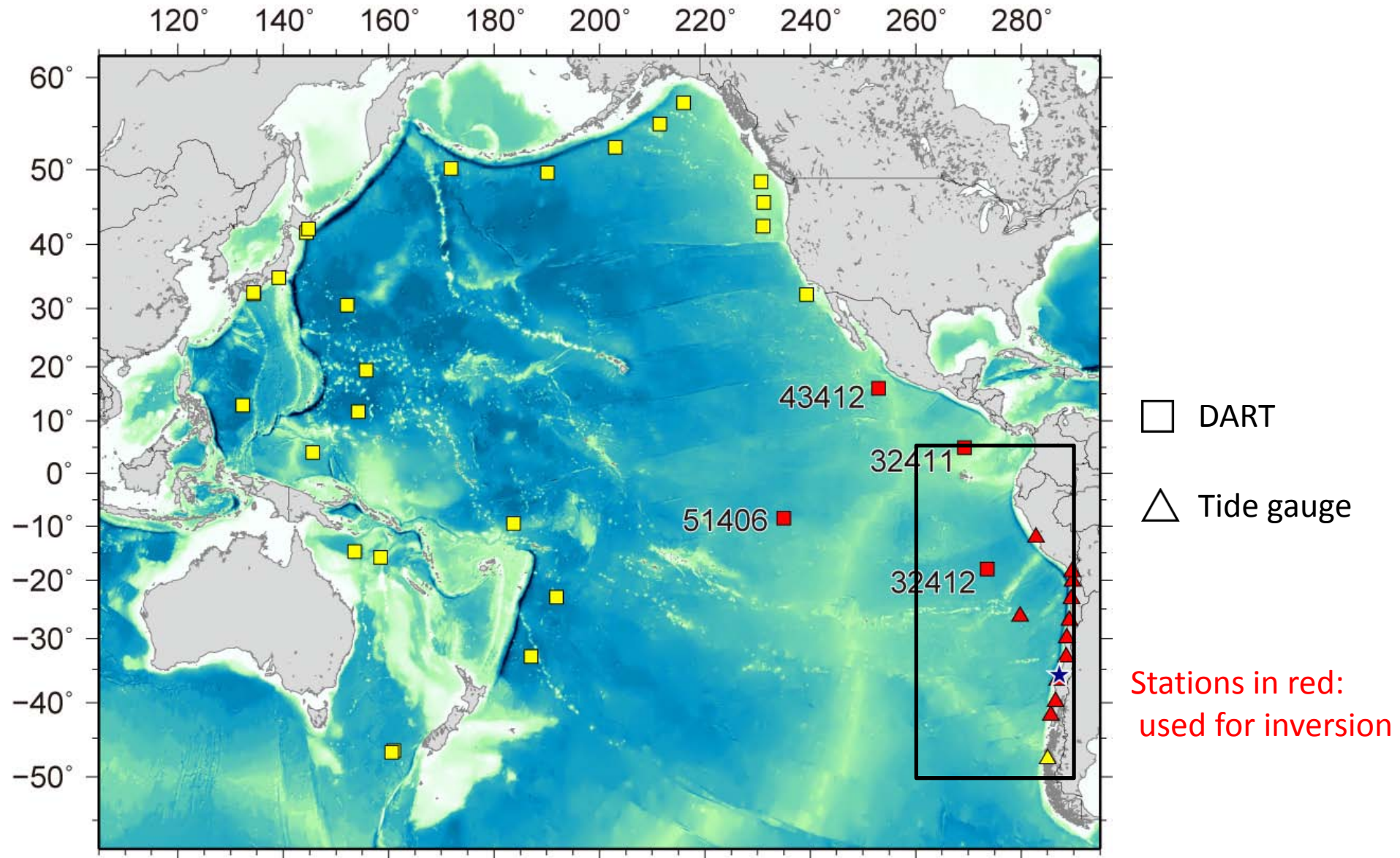
Inversion of Tsunami Waveforms



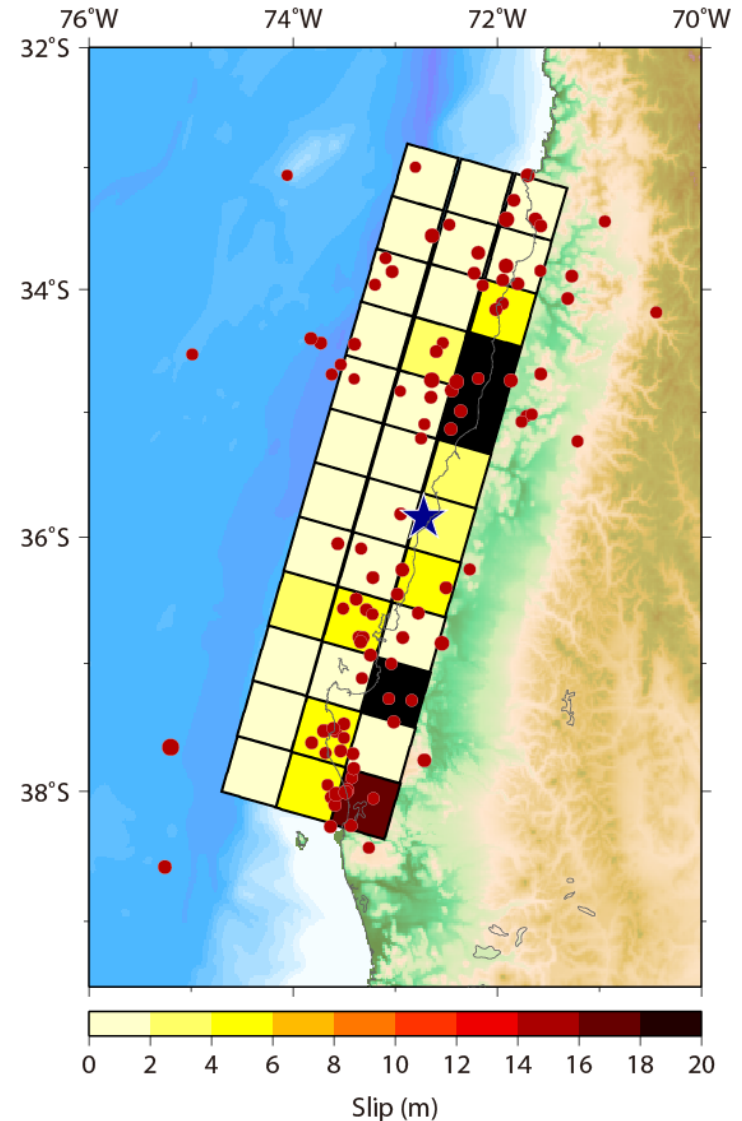
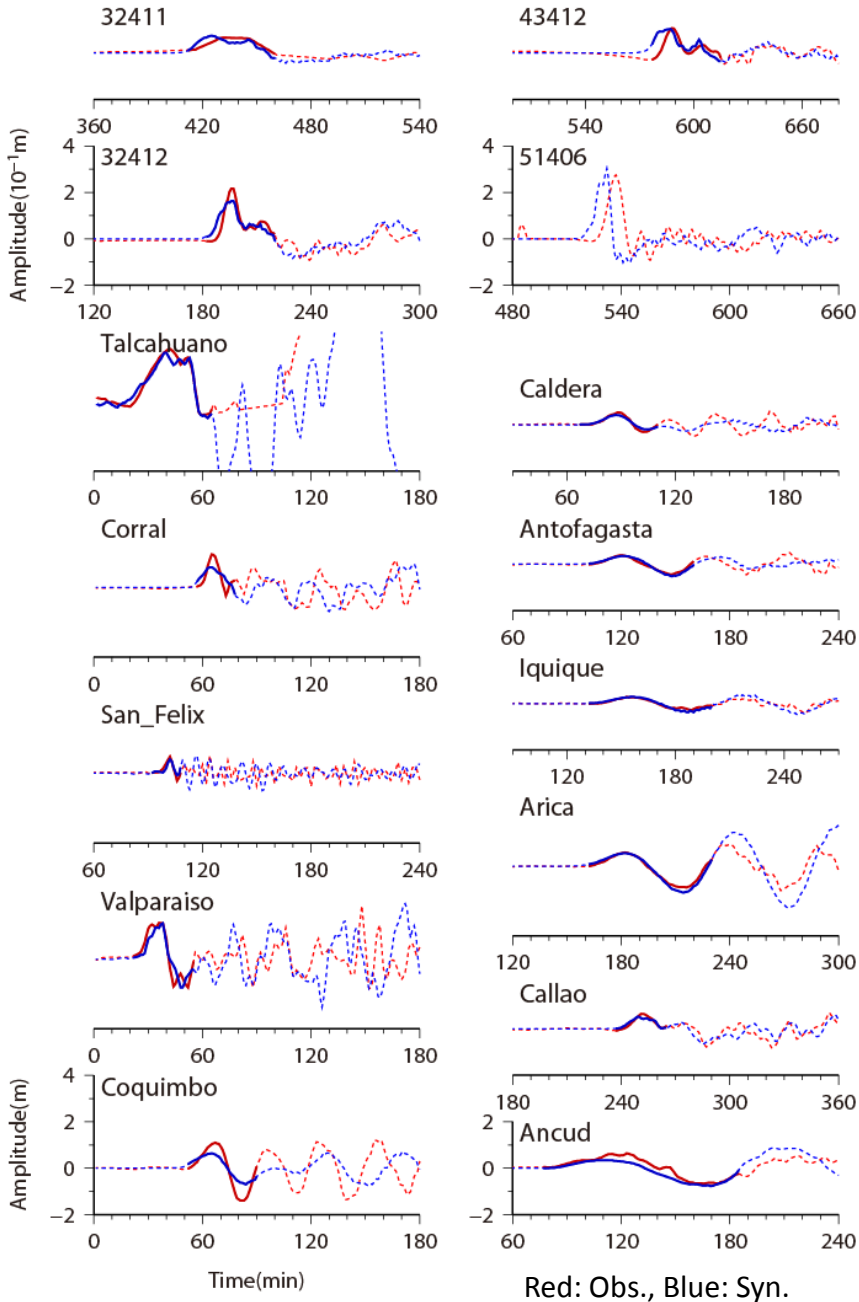
$$\begin{bmatrix}
 \text{computed waveform at station 1} \\
 \text{computed waveform at station 2} \\
 \vdots \\
 \text{computed waveform at station } k
 \end{bmatrix}
 \begin{matrix}
 \text{segment 1} \\
 \text{segment 2} \\
 \vdots \\
 \text{segment } m
 \end{matrix}
 \begin{bmatrix}
 A_{11}(t_1) & A_{12}(t_1) & \dots & A_{1m}(t_1) \\
 A_{11}(t_2) & A_{12}(t_2) & \dots & A_{1m}(t_2) \\
 \vdots & \vdots & \ddots & \vdots \\
 A_{k1}(t_1) & A_{k2}(t_1) & \dots & A_{km}(t_1) \\
 A_{k1}(t_2) & A_{k1}(t_2) & \dots & A_{km}(t_2) \\
 \vdots & \vdots & \ddots & \vdots
 \end{bmatrix}
 \cdot
 \begin{bmatrix}
 X_1 \\
 X_2 \\
 \vdots \\
 X_m
 \end{bmatrix}
 \begin{matrix}
 \text{slip on segment 1} \\
 \text{slip on segment 2} \\
 \vdots \\
 \text{slip on segment } m
 \end{matrix}
 \approx
 \begin{bmatrix}
 \text{observed waveform at station 1} \\
 \text{observed waveform at station 2} \\
 \vdots \\
 \text{observed waveform at station } k
 \end{bmatrix}
 \begin{matrix}
 b_1(t_1) \\
 b_1(t_2) \\
 \vdots \\
 b_k(t_1) \\
 b_k(t_2) \\
 \vdots
 \end{matrix}$$

Satake (1987)

DART and Tide Gauge Stations

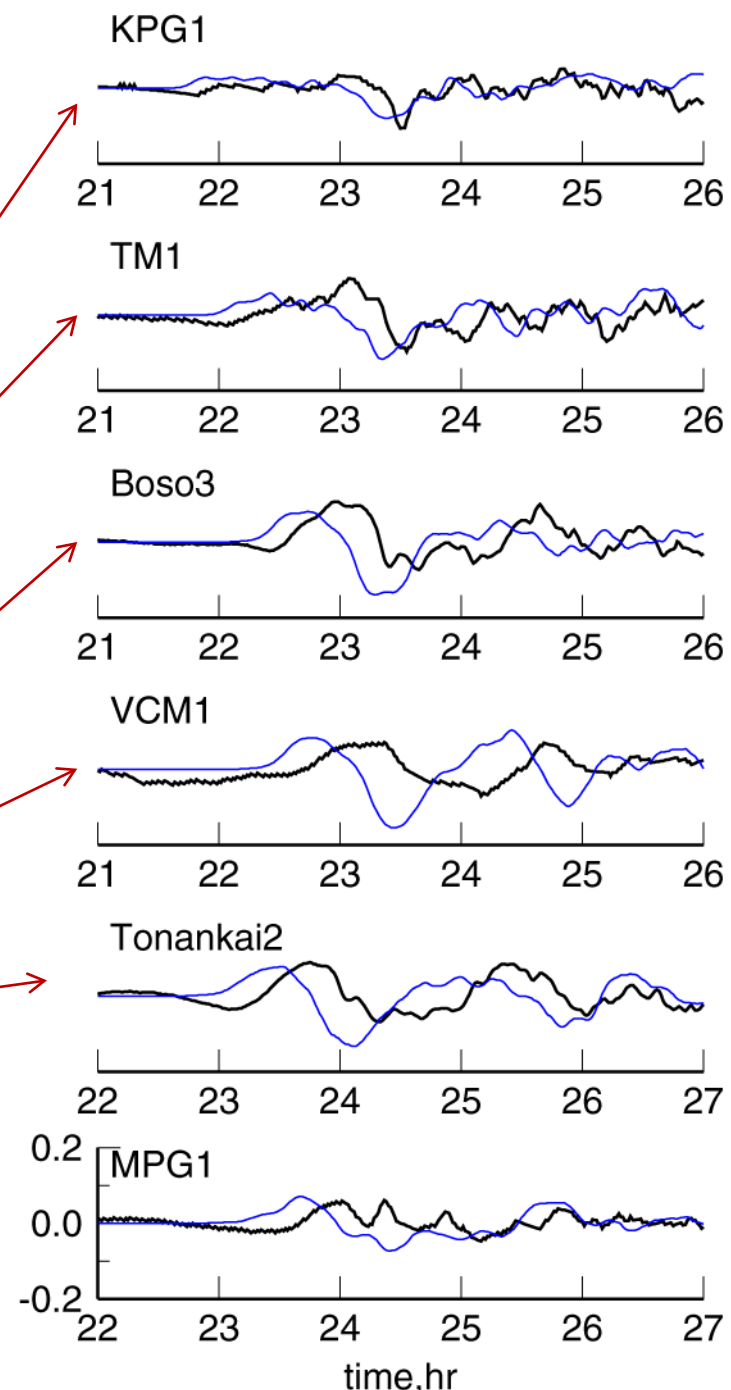
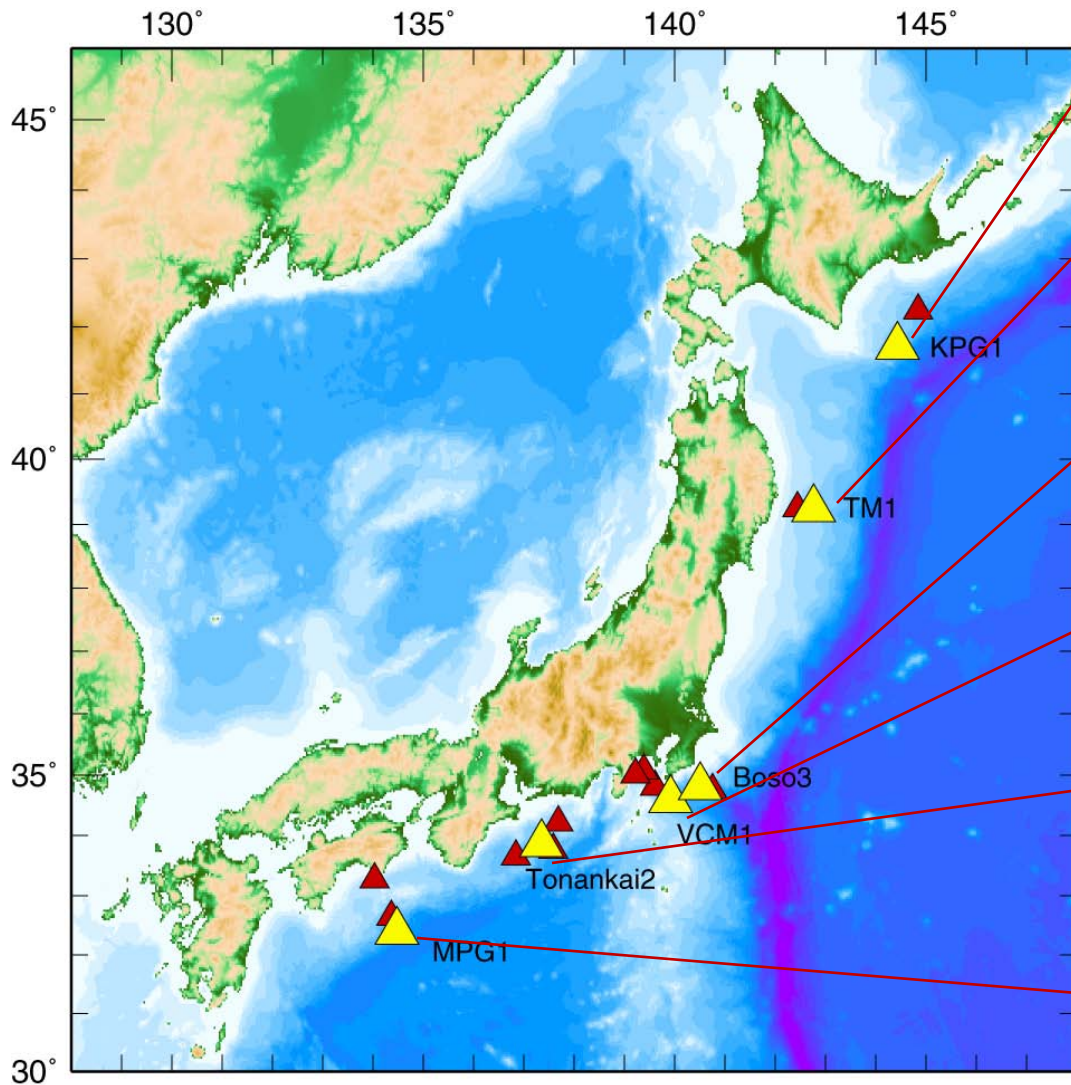


Inversion (TG Data), 36 subfaults

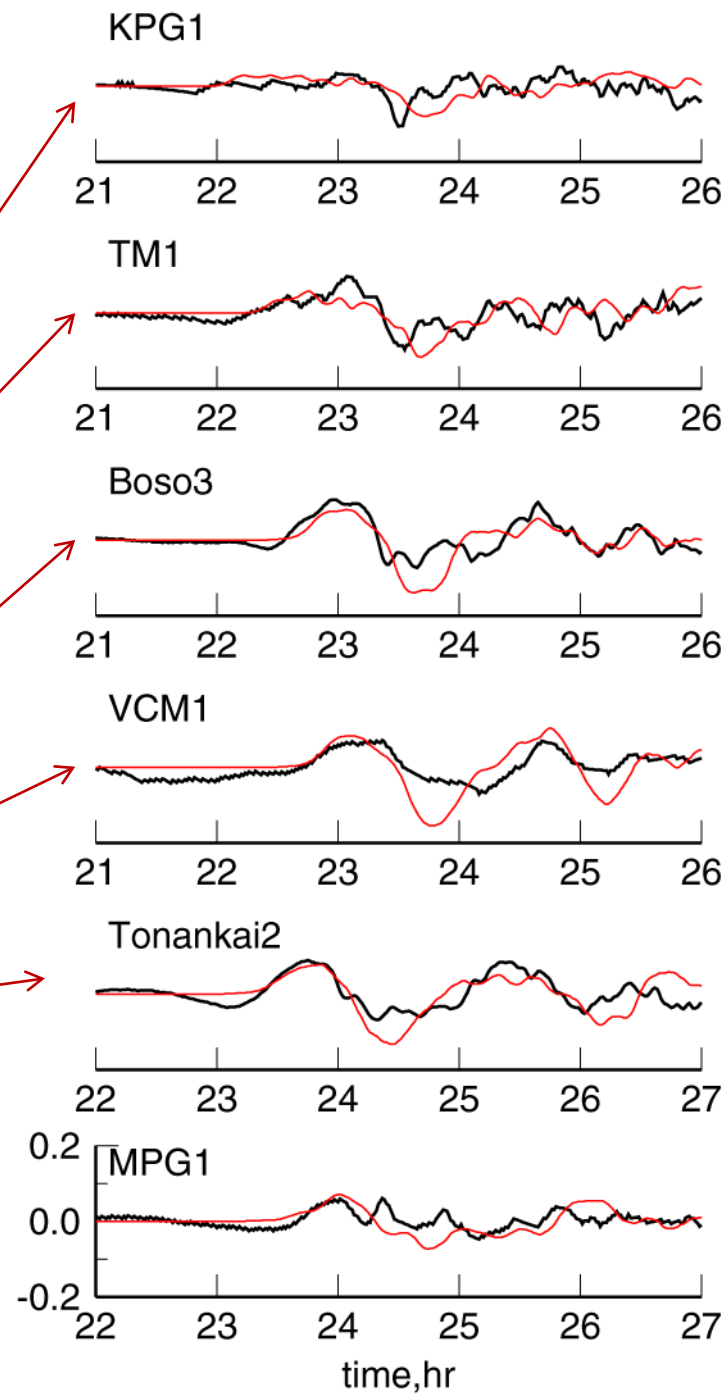
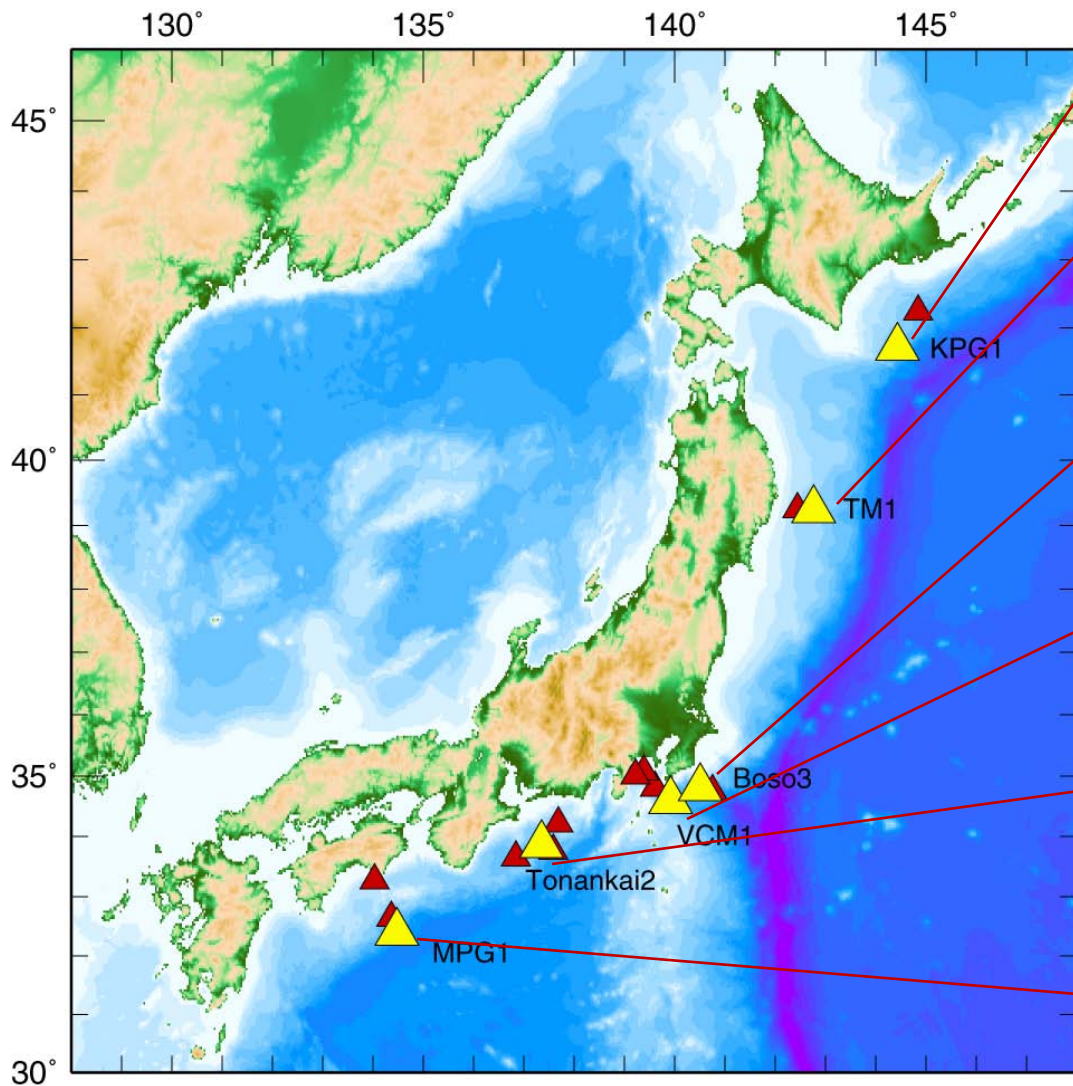


$M_0 = 1.8 \times 10^{22} \text{ Nm}$ (Mw 8.8)

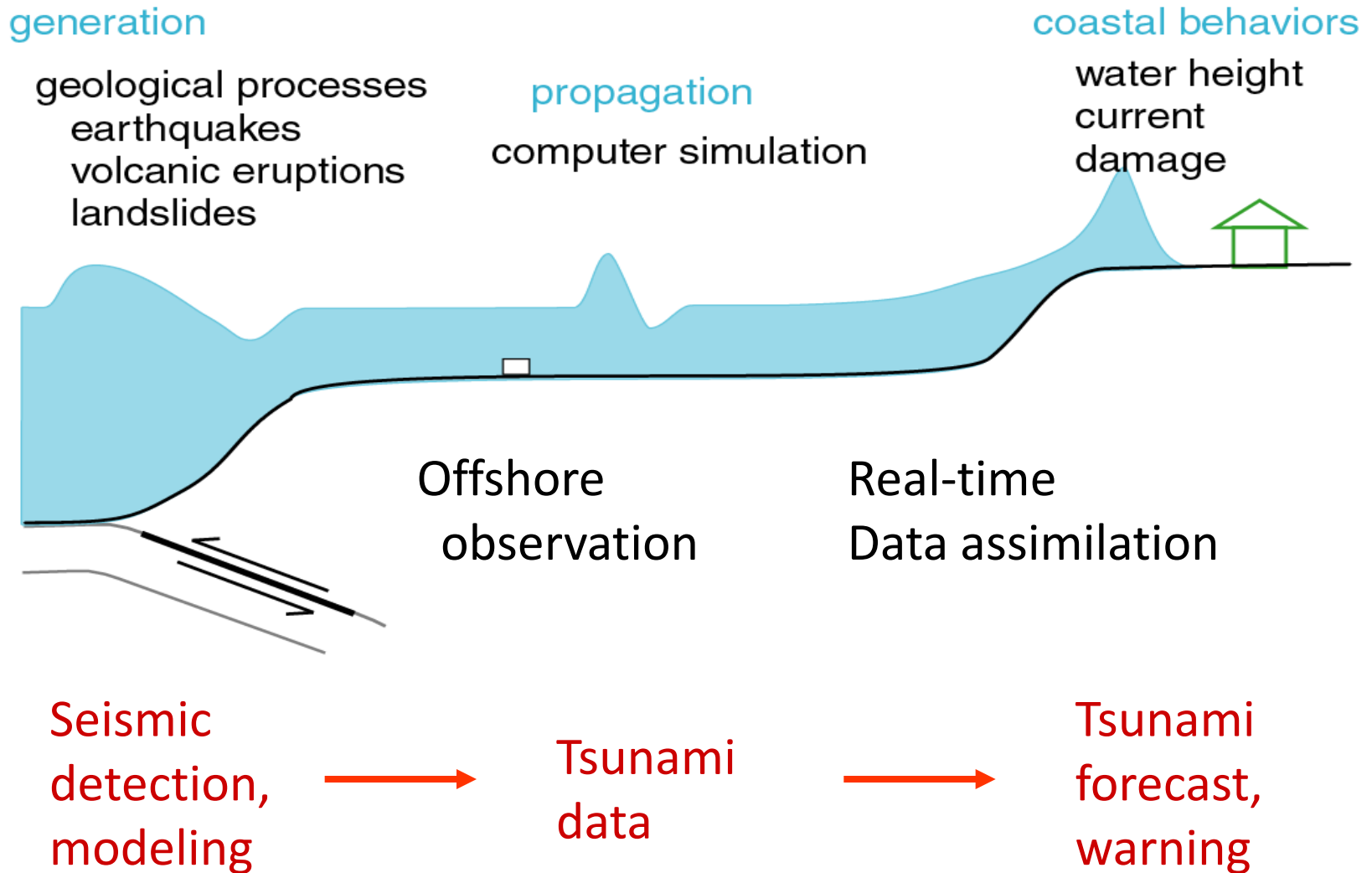
Waveforms around Japan



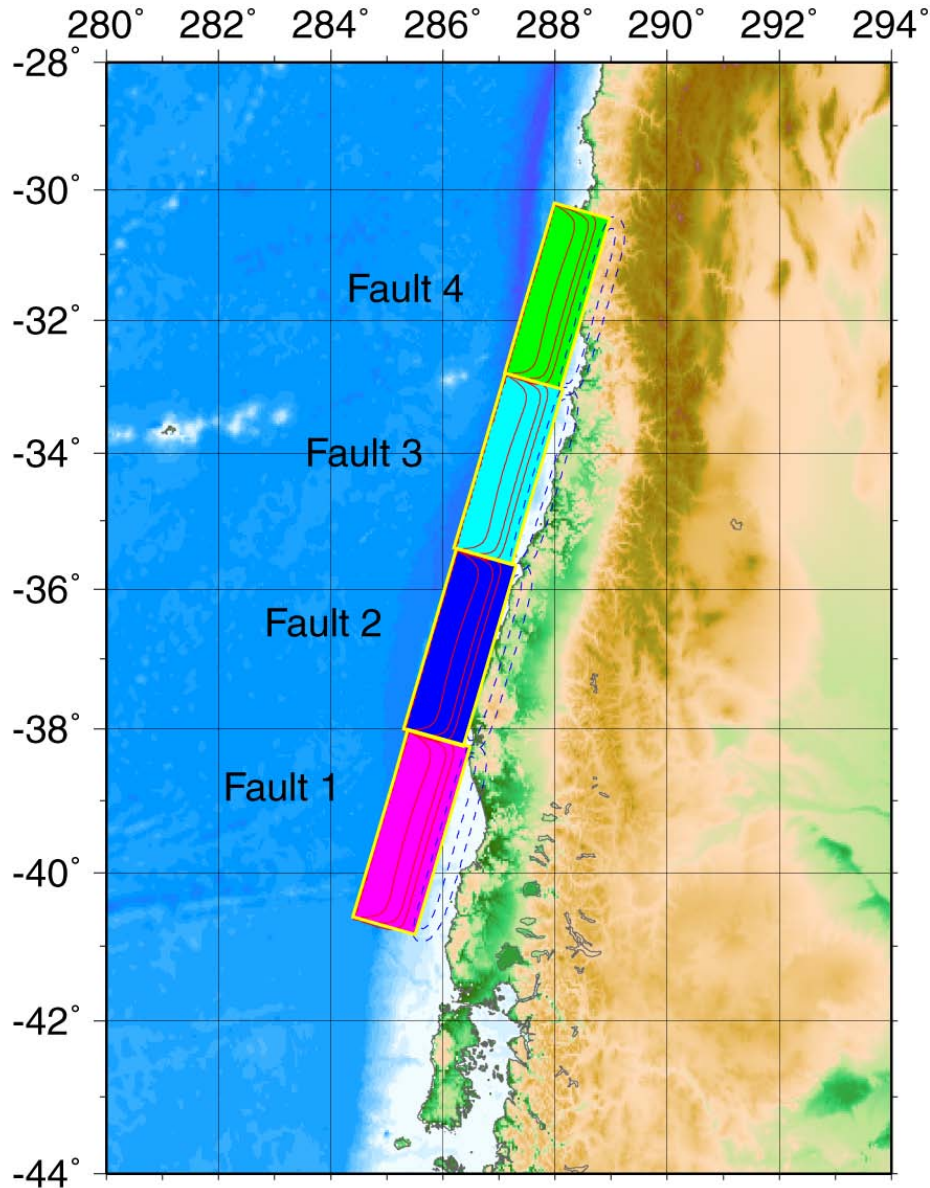
Waveforms around Japan



Real-time Inversion or Data Assimilation



JMA's Fault Models



M8 faults

L: 300 km

W: 100 km

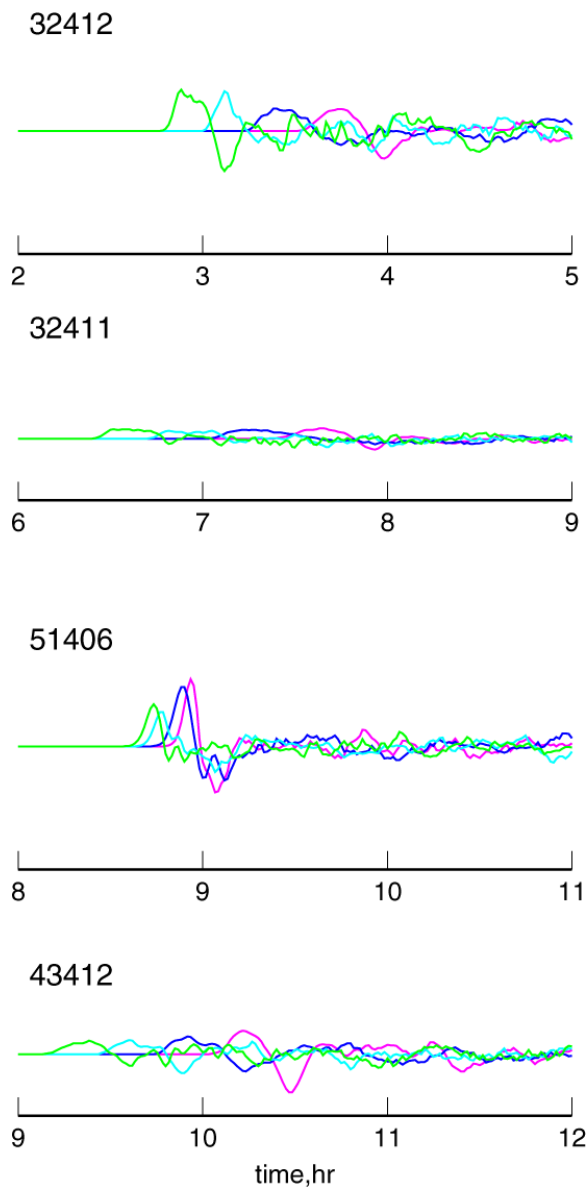
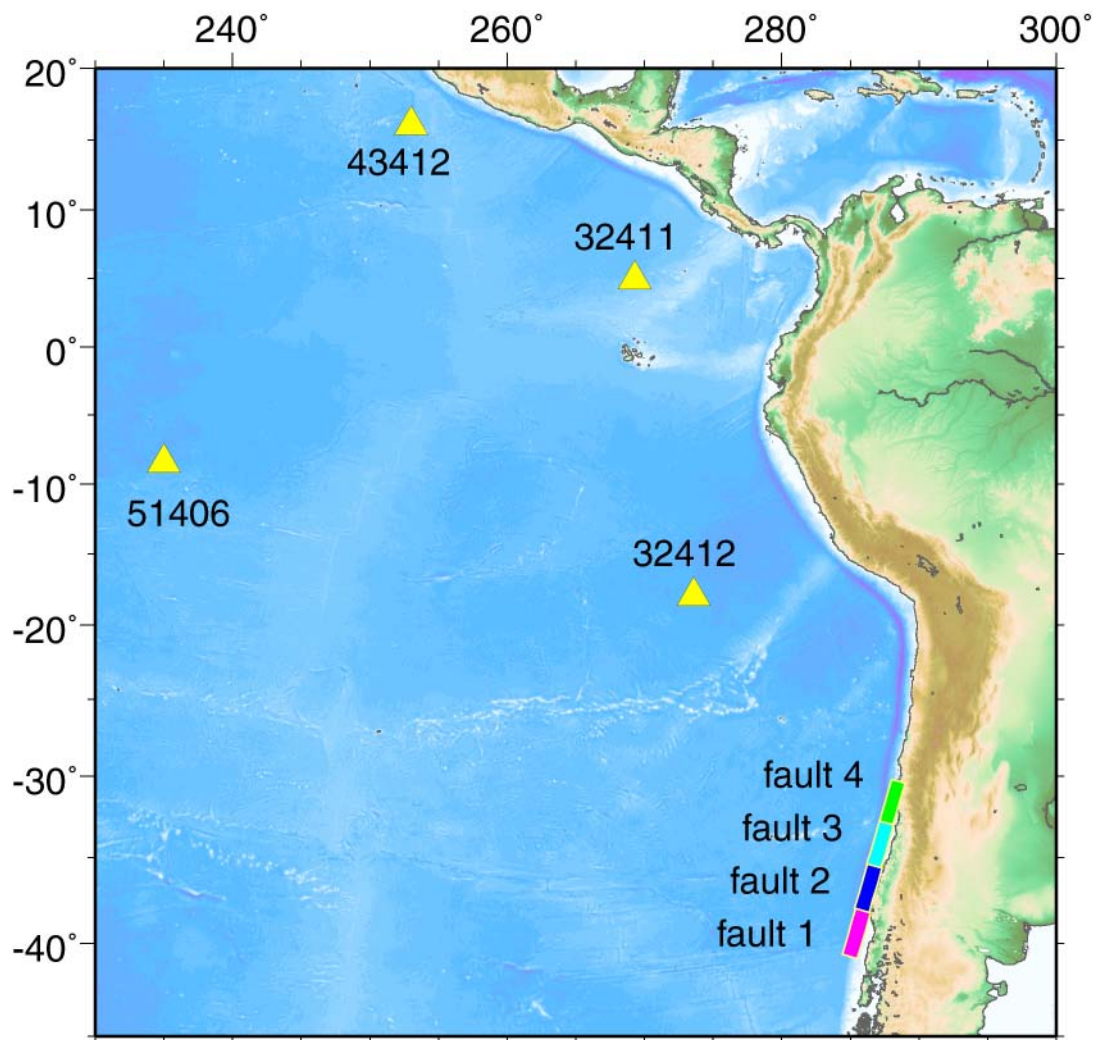
Slip: 7 m

Depth: 0 km

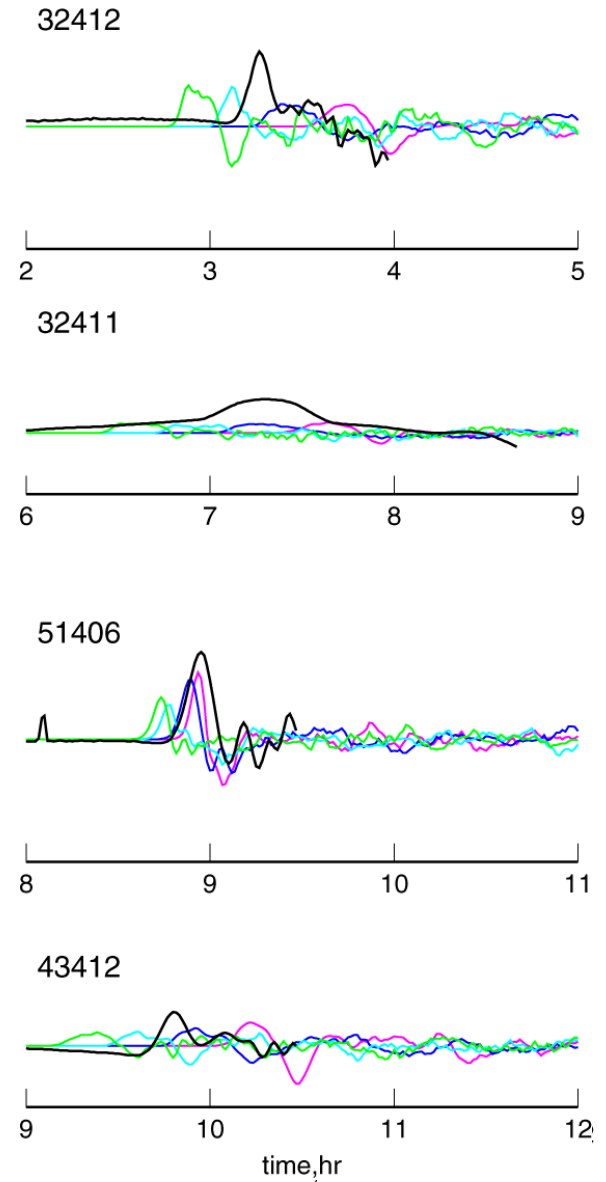
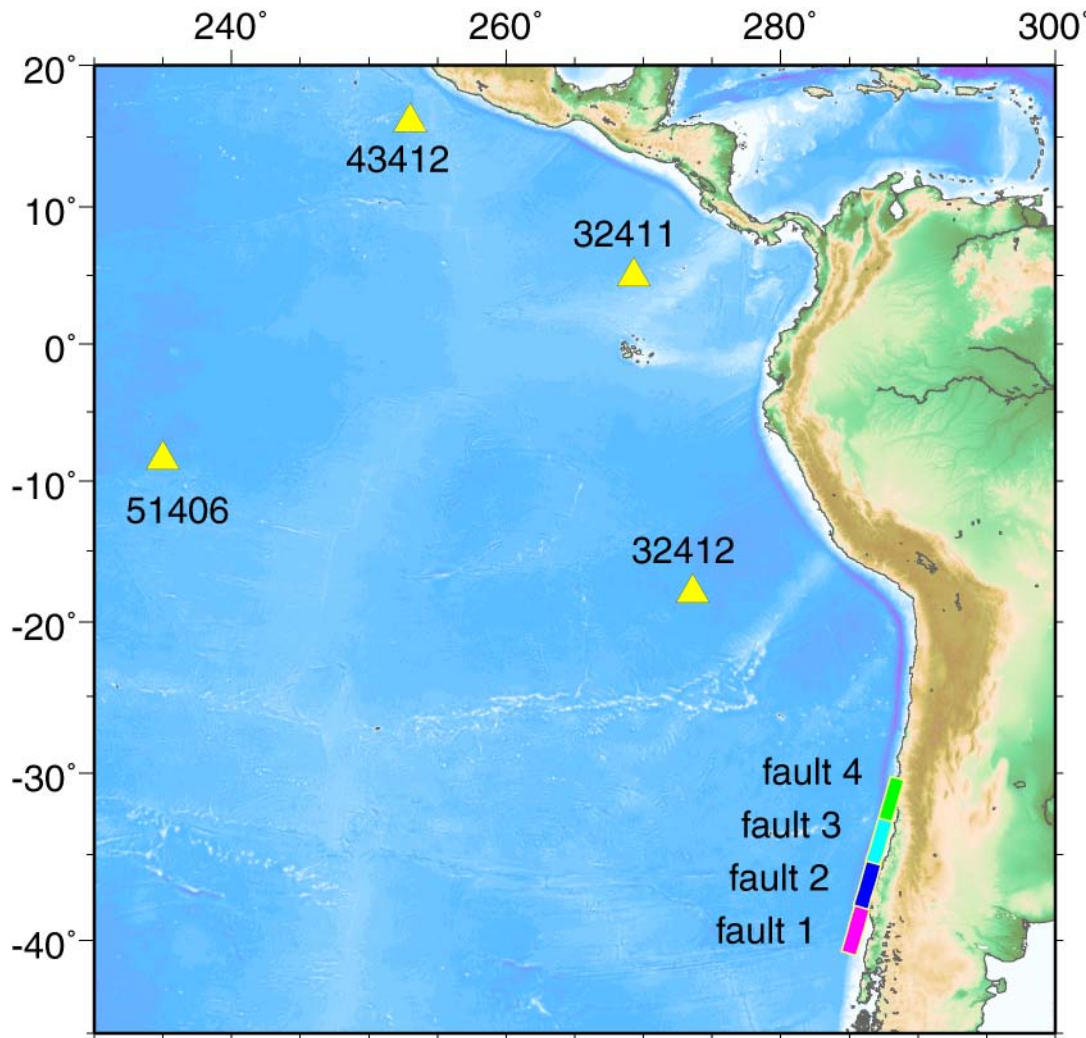
Dip: 14 degree

Rake: 90 degree

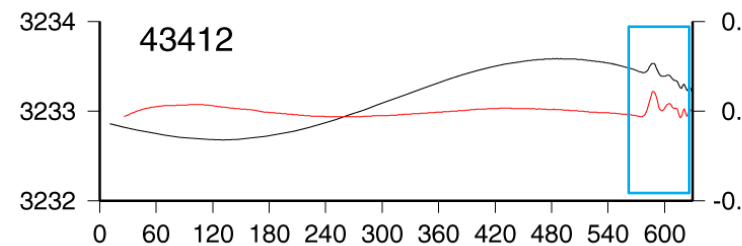
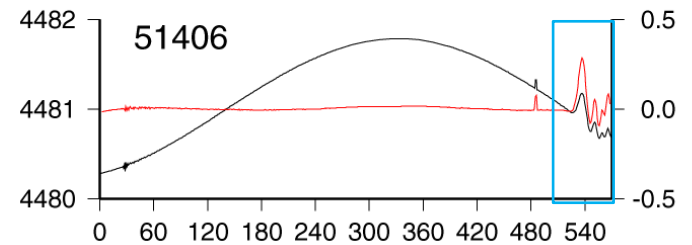
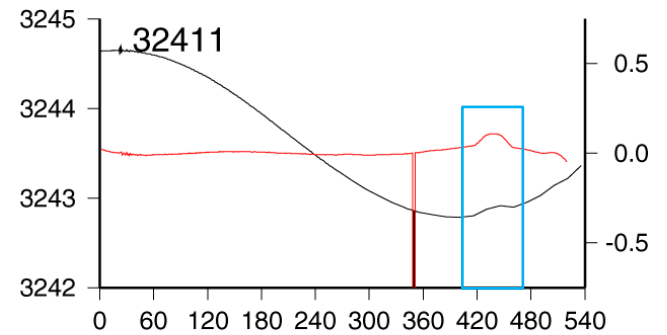
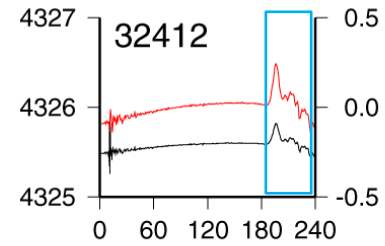
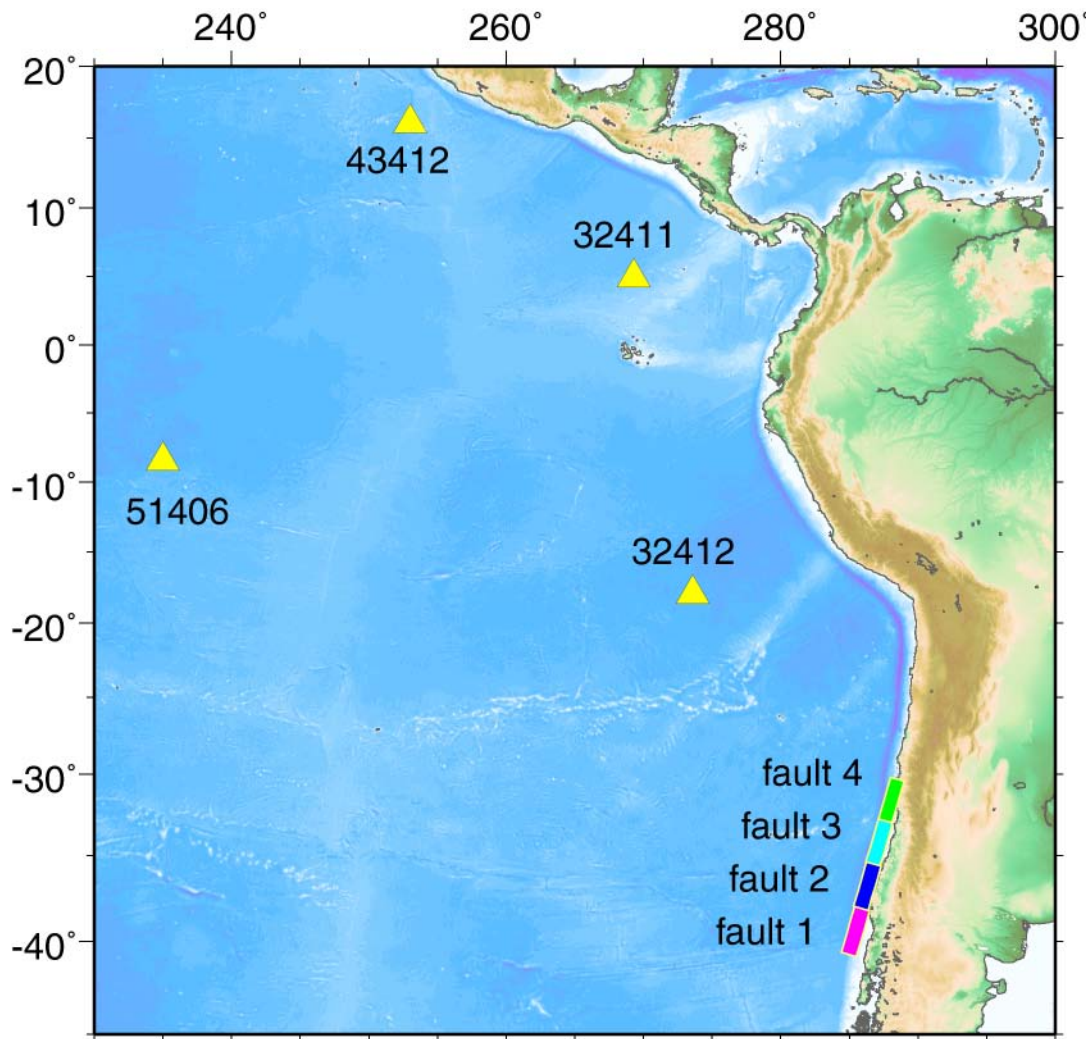
Green's functions



Green's functions and Observed waveforms



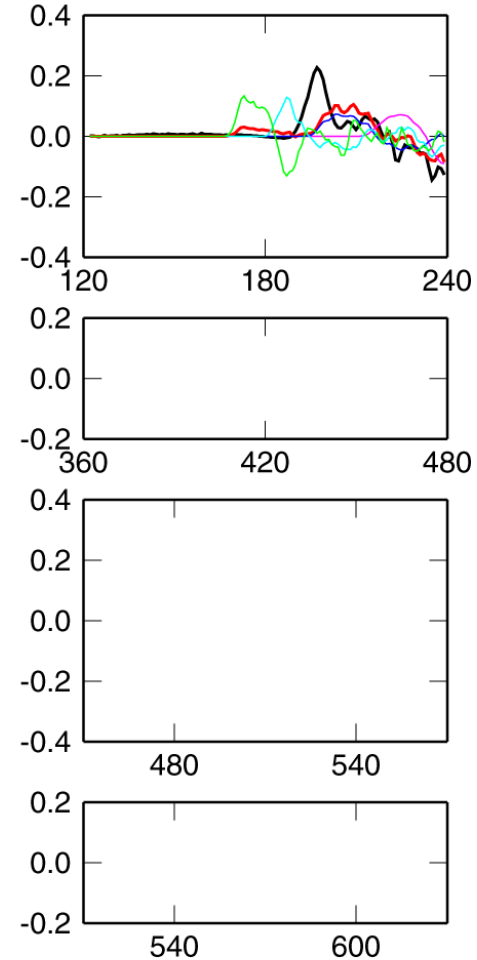
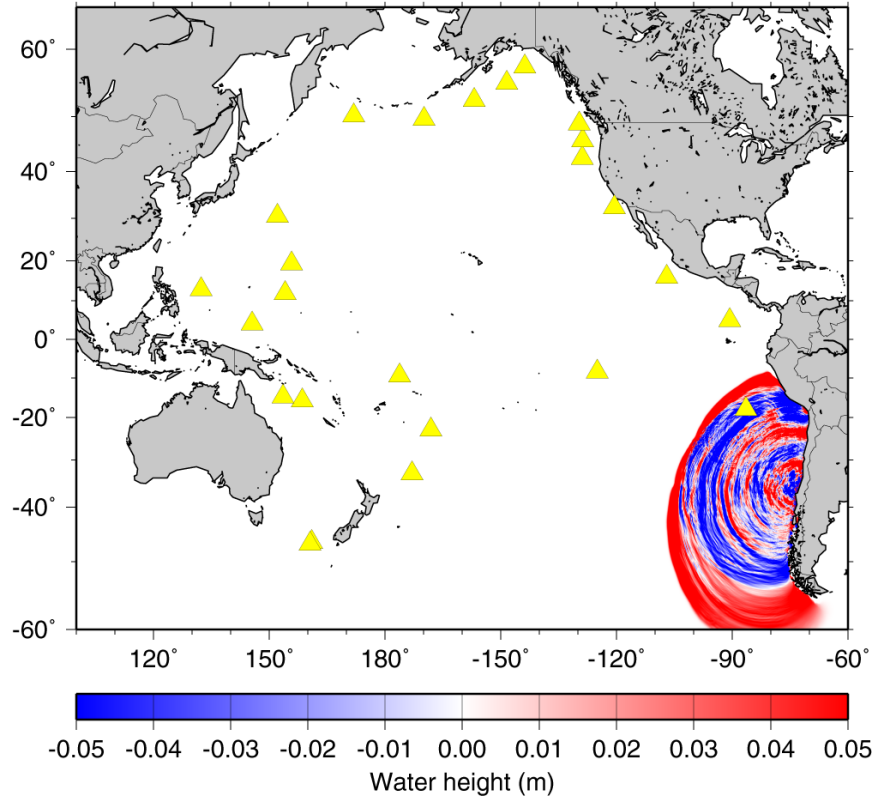
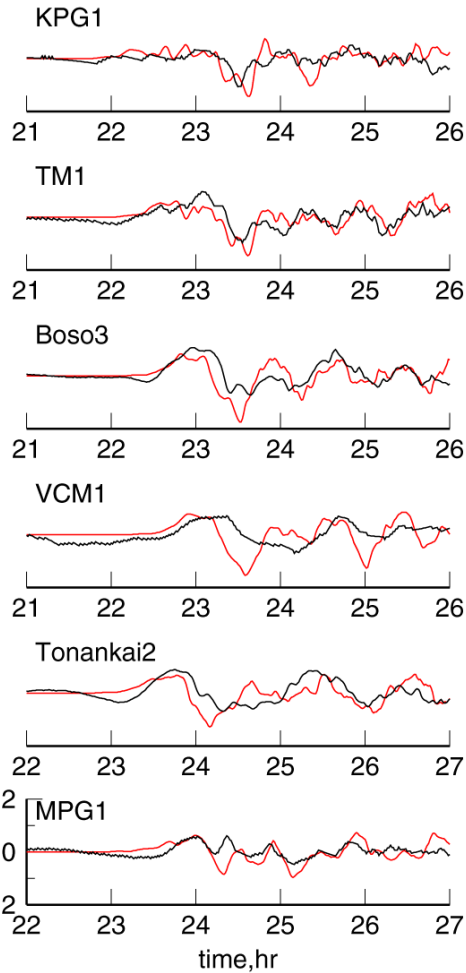
Observed waveforms



Inversion at 240 min

4 hour 0 min

inversion at 240 min



Weights 1: 0.75, 2: 1.60, 3: 0.32, 4: 0.23

Slip: 1: 5.3m, 2: 11m, 3: 2.2m, 4: 1.6m

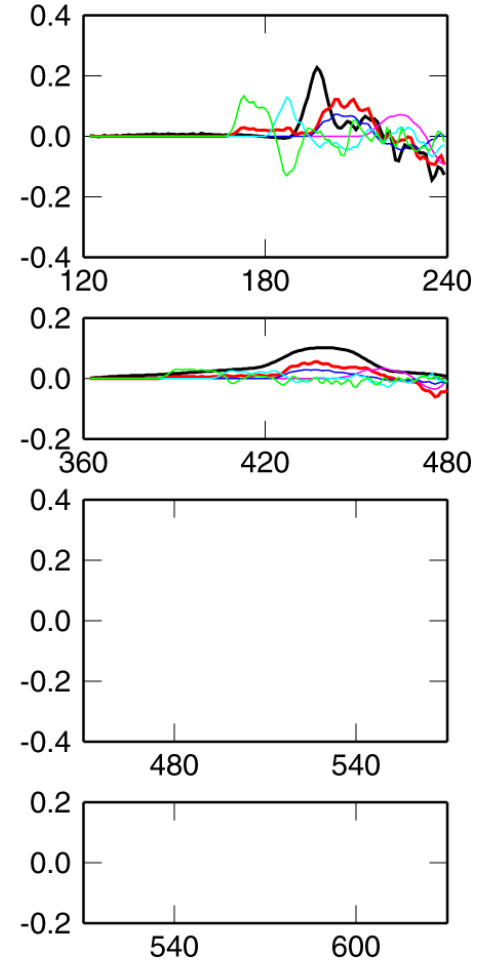
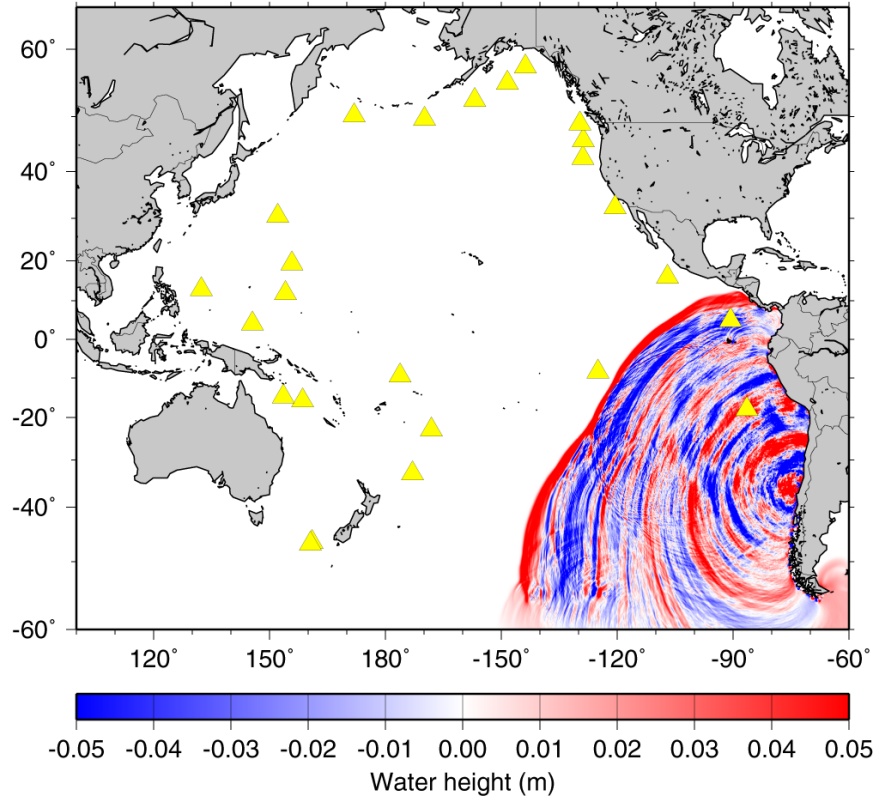
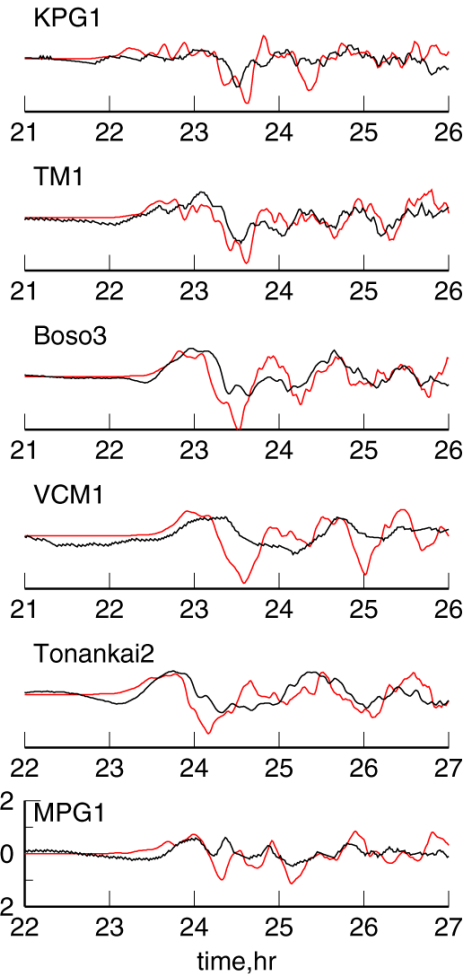
Total moment : 2.1×10^{22} Nm

Moment magnitude (Mw): 8.8

Inversion at 480 min

8 hour 0 min

inversion at 480 min



Weights 1: 0.80, 2: 1.60, 3: 0.42, 4: 0.21

Slip: 1: 5.6m, 2: 13m, 3: 2.9m, 4: 1.5m

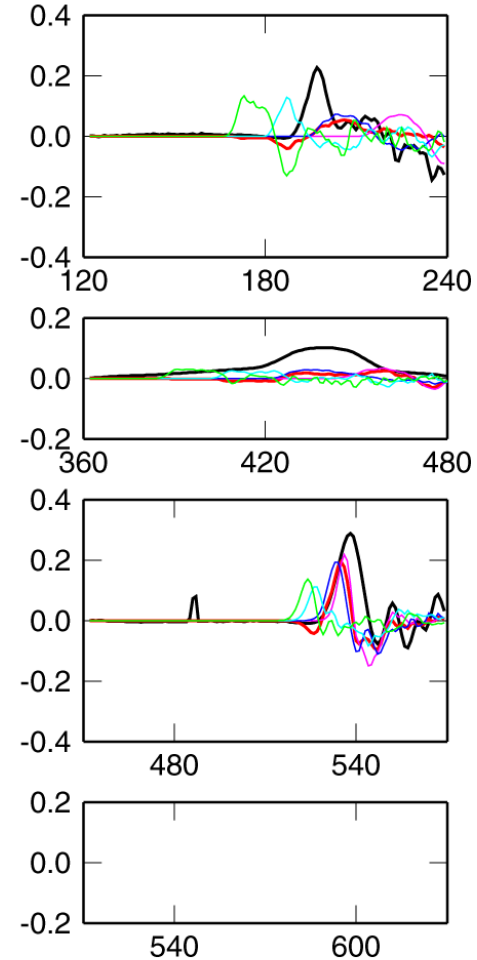
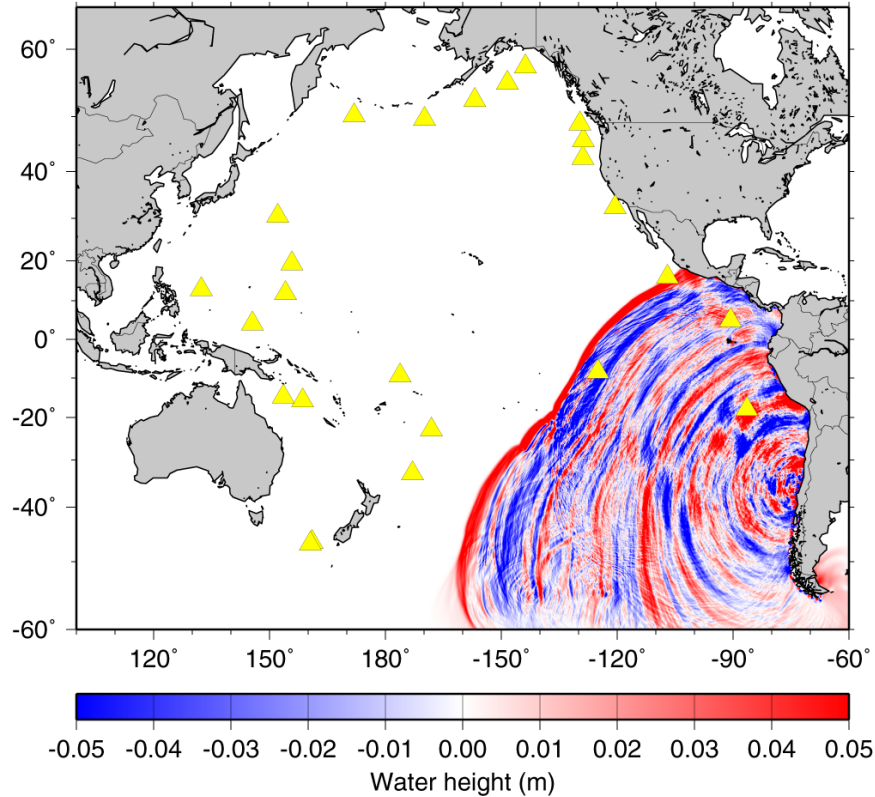
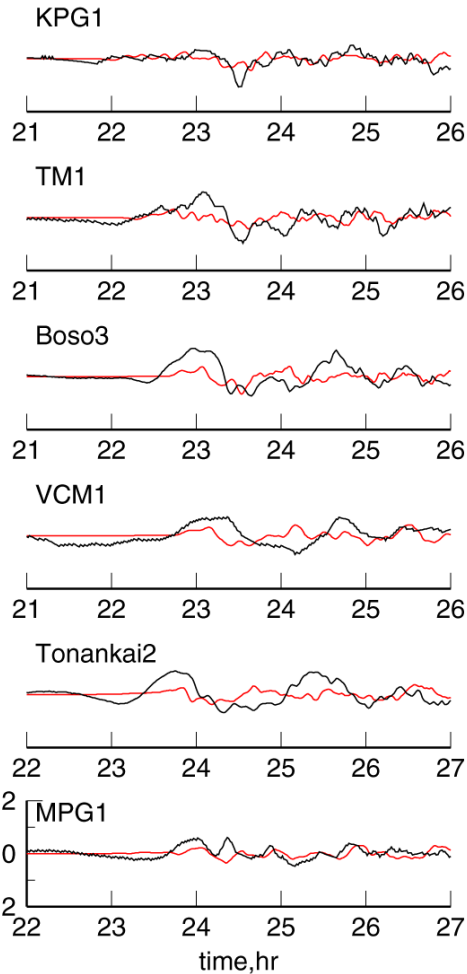
Total moment : 2.4×10^{22} Nm

Moment magnitude (Mw): 8.8

Inversion at 570 min

9 hour 30 min

inversion at 570 min



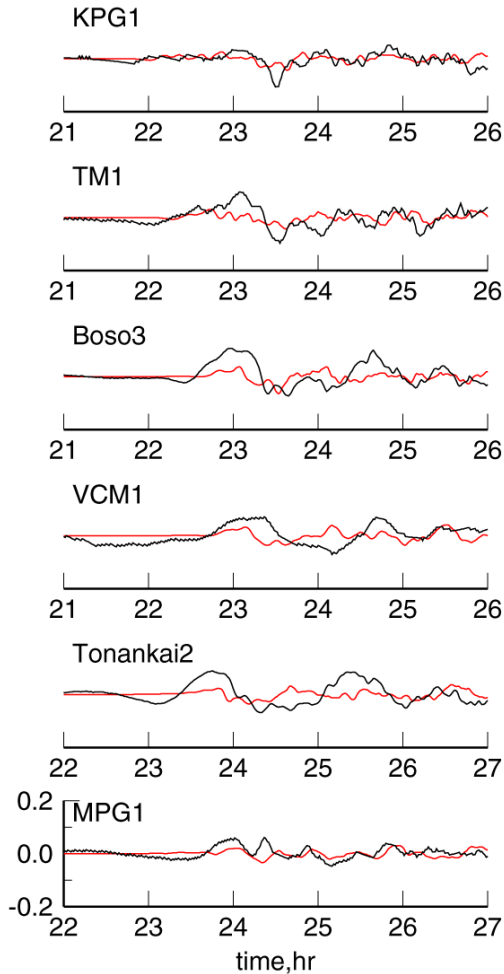
Weights 1: 0.53, 2: 0.52, 3: -0.38, 4: -0.05

Slip: 1: 3.7m, 2: 3.6m, 3: 2.7m, 4: 0.4m

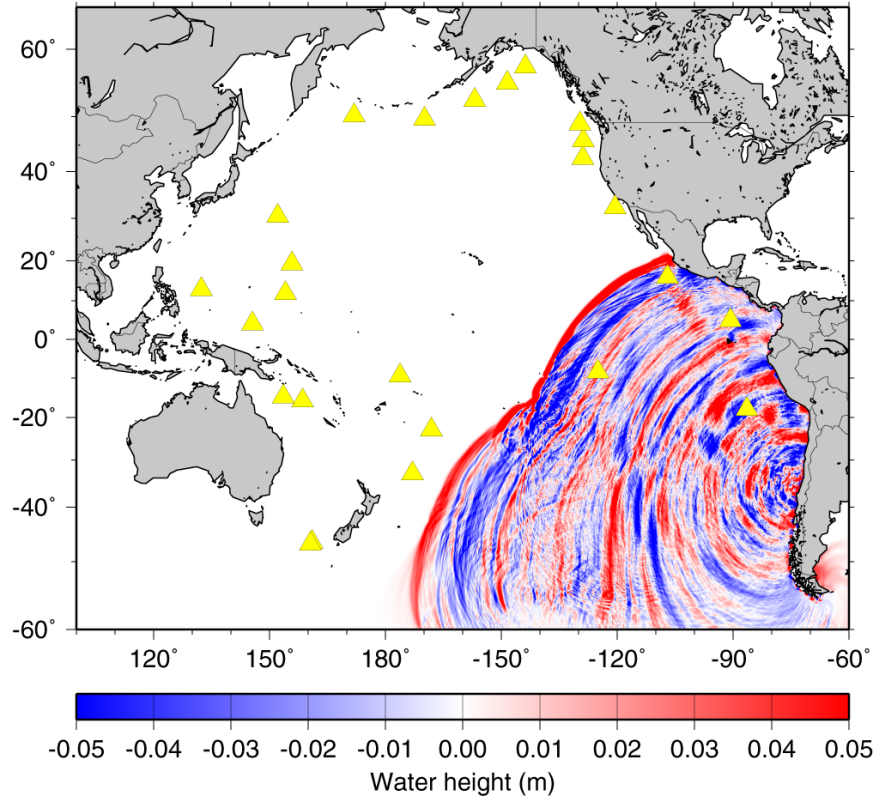
Total moment : 1.0×10^{22} Nm

Moment magnitude (Mw): 8.6

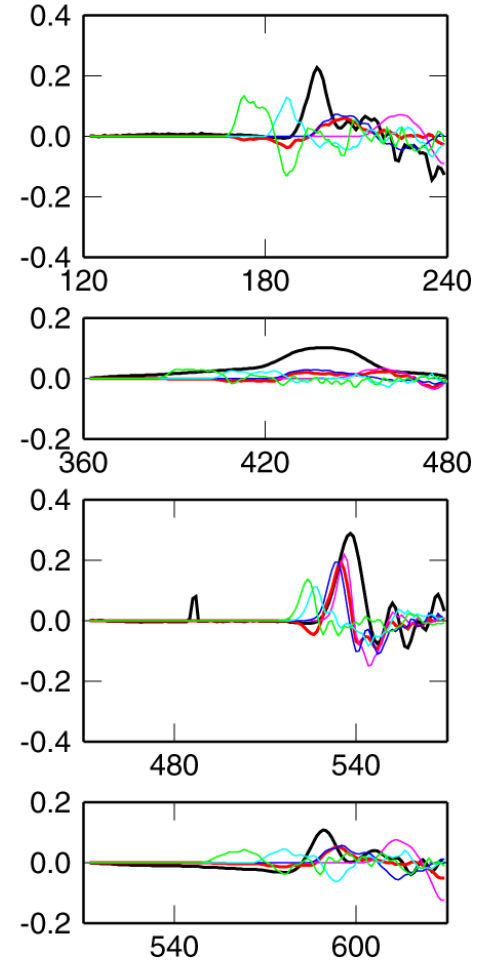
Inversion at 630 min



10 hour 30 min



inversion at 630 min



Weights 1: 0.46, 2: 0.57, 3: -0.38, 4: -0.09

Slip: 1: 3.2m, 2: 4.0m, 3: 2.7m, 4: 0.6m

Total moment : 1.1×10^{22} Nm

Moment magnitude (Mw): 8.6

リアルタイムインバージョン

- DARTデータから潮汐を除くなどの処理が必要
- 小断層からの津波波形を計算してあれば、ごく短時間で可能
- 日本沿岸での波形の予測も同時にできる

解決すべき問題

1. 日本への到着時刻の遅れ
 - 2010年観測データとの比較から20分遅れとした
 - 地域ごとの補正量が必要
2. 小断層の長さ
 - 今回はM 8.5モデルを利用したが、波形が合わない
 - 短い小断層を利用すべき
3. 沖合の水圧計から沿岸への増幅