

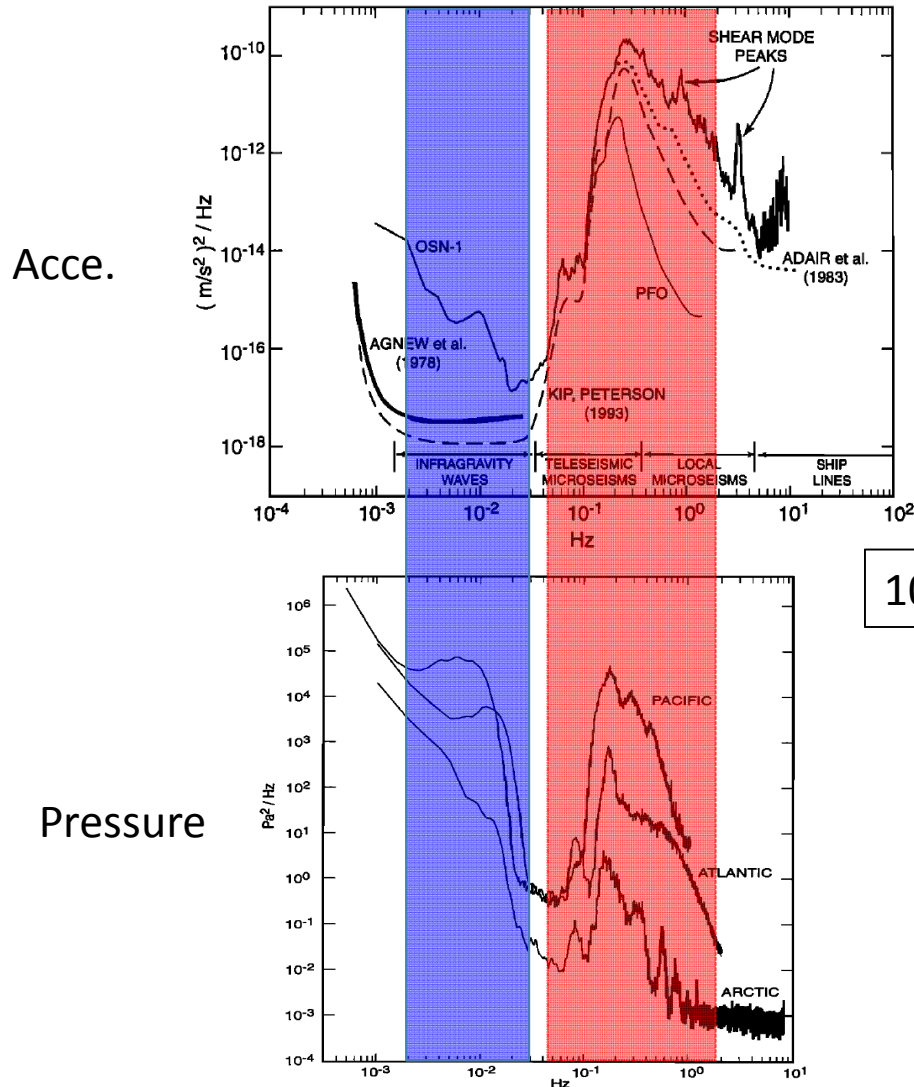
# 海底観測で捉えた常時微動による構造推定

利根川貴志（海洋研究開発機構）

2017/3/29  
東京大学地震研究所

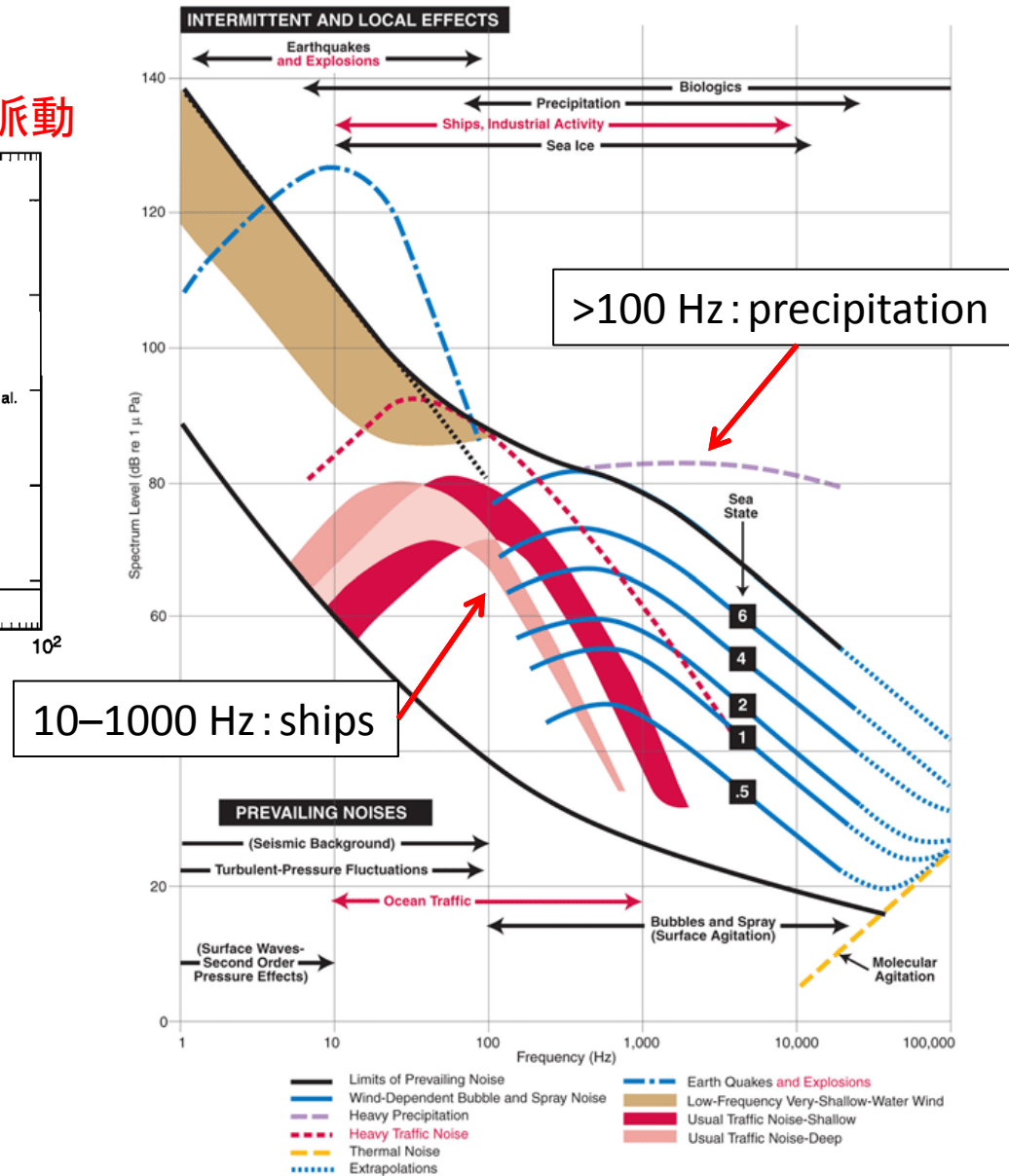
# Seafloor ambient noise

2-30 mHz: 海洋重力波      0.07-2.0 Hz: 脈動



Webb, 1998

Pressure



引用: <http://www.dosits.org/science/soundsinthesea/commonsounds/>

# Outline

本発表：微動を用いた海底下の構造推定

- ・ノイズの窓 (2–5 Hz)

  - 海底堆積物の異方性構造と時間変化

- ・脈動の低周波側 (0.09–0.2 Hz)

  - 付加体の速度構造と時間変化・地震活動との比較

海底下・構造推定

  - 地震による表面波 (Isse et al. 2009; 2010)

  - 微動+地震による表面波 (Takeo et al. 2013; 2014; 2016)

  - レシーバ関数 (Kawakatsu et al. 2009; Kumar et al. 2011)

本発表

  - 微動を活用した単一観測点下の構造推定

    - ・海洋重力波

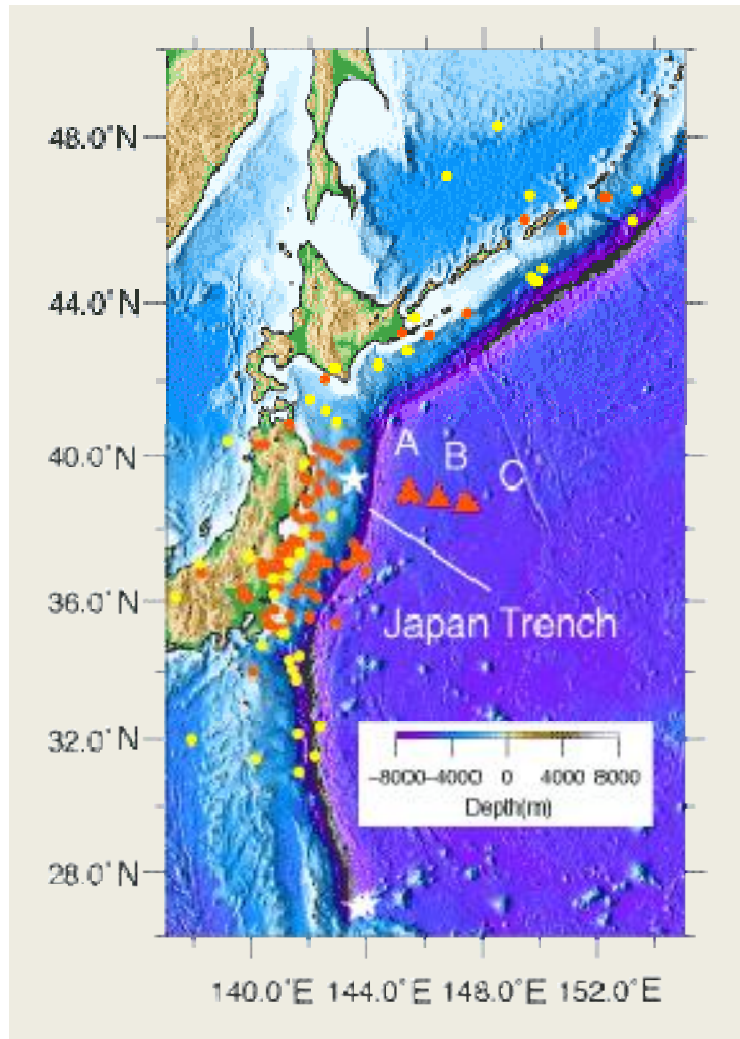
      - JpGU(大気海洋セッション)

      - 「太平洋を横断する海洋外部重力波の発生場所とその季節変化」

      - 利根川・深尾・塩原・杉岡・伊藤・山下

# (1) 海底堆積物の異方性

Anisotropy and its temporal variation on the marine sediment



3 BBOBS CMG-3T (Guralp System Ltd.)

Observation period

• 2010/7 – 2011/8

• The M9.0 Tohoku-Oki eq. on Mar. 11, 2011

Frequency band

2–5 Hz : noise notch ~2–10 Hz

Tonegawa, Fukao, Nishida, Sugioka, Ito (2013, JGR)

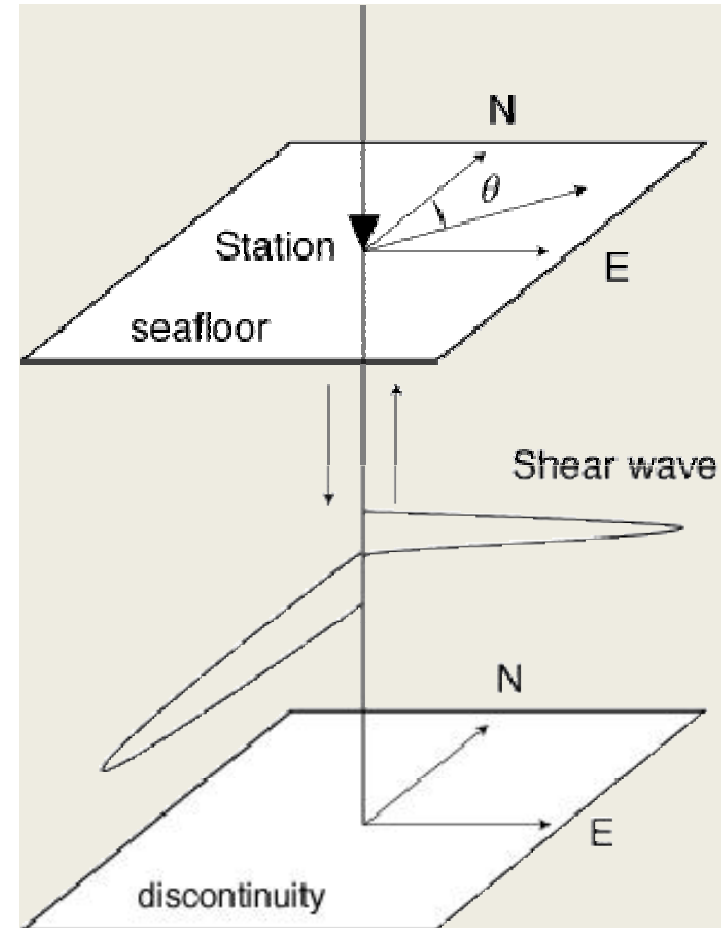
# Detection of anisotropy

Auto correlation function (ACF)  
of ambient noise

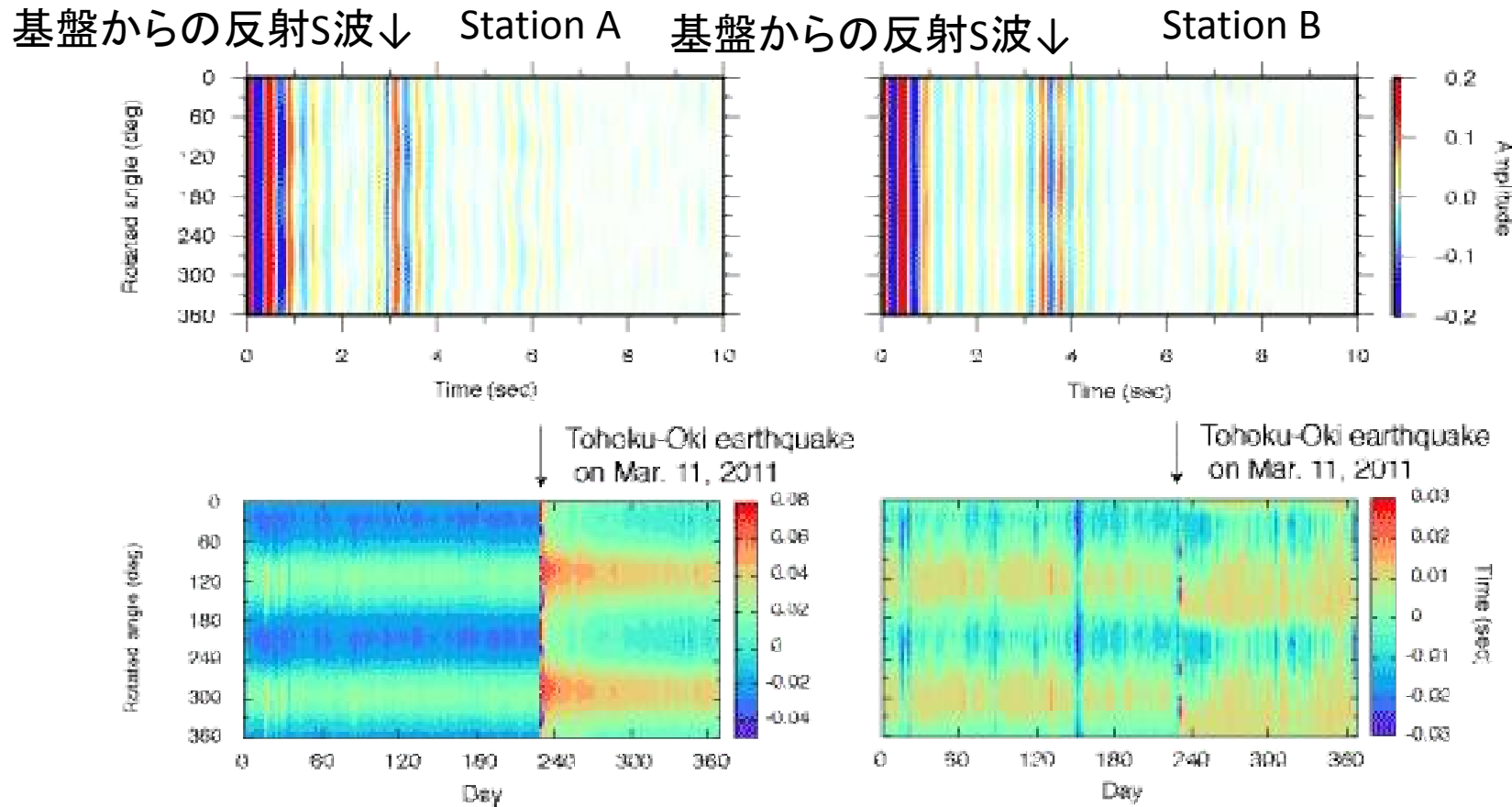
ACF using the NS polarized noise  
→the NS polarized S reflection

ACF using the EW polarized noise  
→the EW polarized S reflection

a differential travel time btw. the NS  
and EW polarized S reflections  
→anisotropy btw. the seafloor and  
seismic discontinuity



# Temporal variation of travel time



Fast direction : N25°E (Trench parallel)

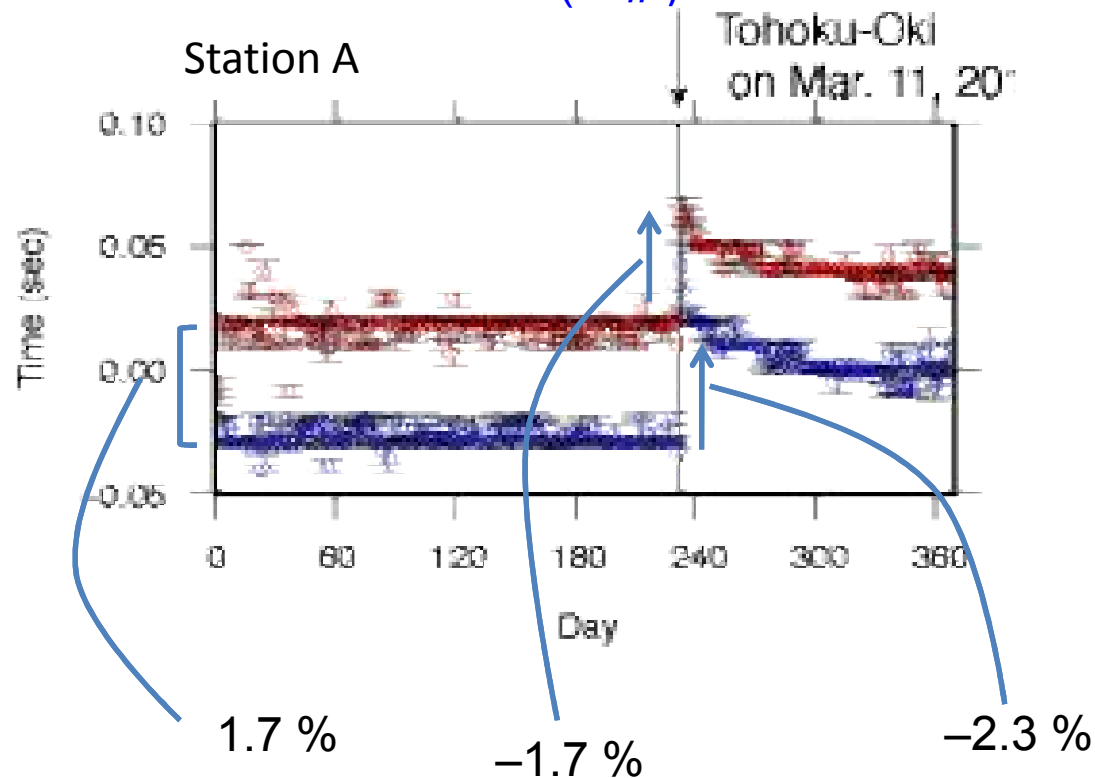
Slow direction : N115°E

Travel time delay: ~0.05 s @ station A,  
N/A @ station B

# Temporal variation of anisotropy

Red : Slow direction N115°E ( $V_s \perp$ )

Blue : Fast direction N25°E ( $V_s \parallel$ )



A crack model

(Jakobsen et al. 2000, JGR)

- water saturated crack
- biconnected

the degree of anisotropy  
(before the earthquake)

$\Delta T$ s at fast direction

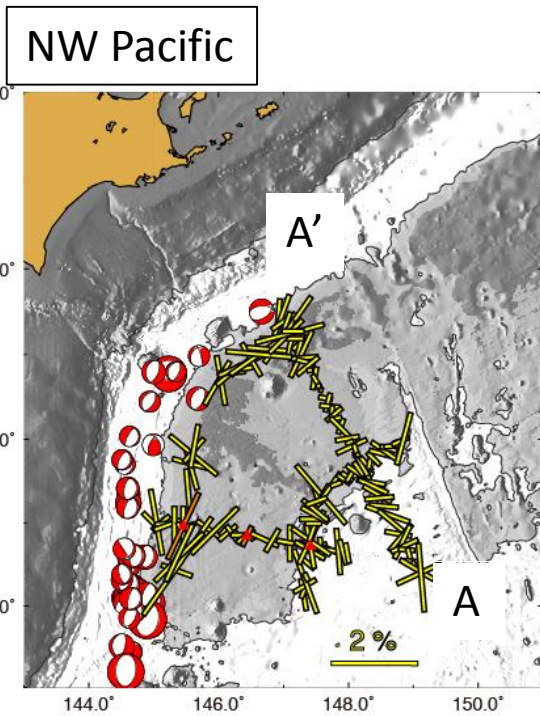
$\Delta T$ s at slow direction



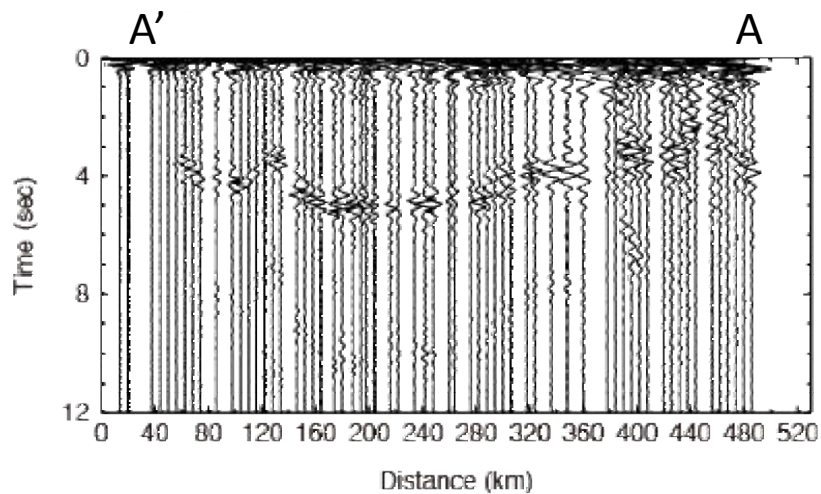
increases of aspect ratio and  
porosity

infiltration of water  
close to spherical cracks

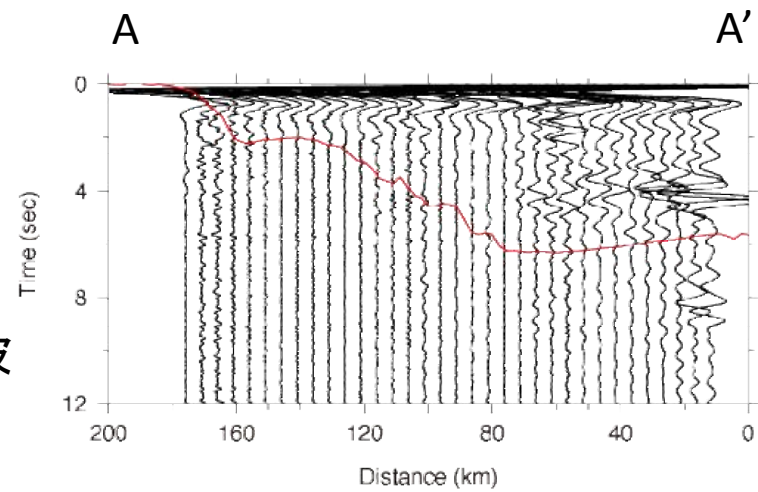
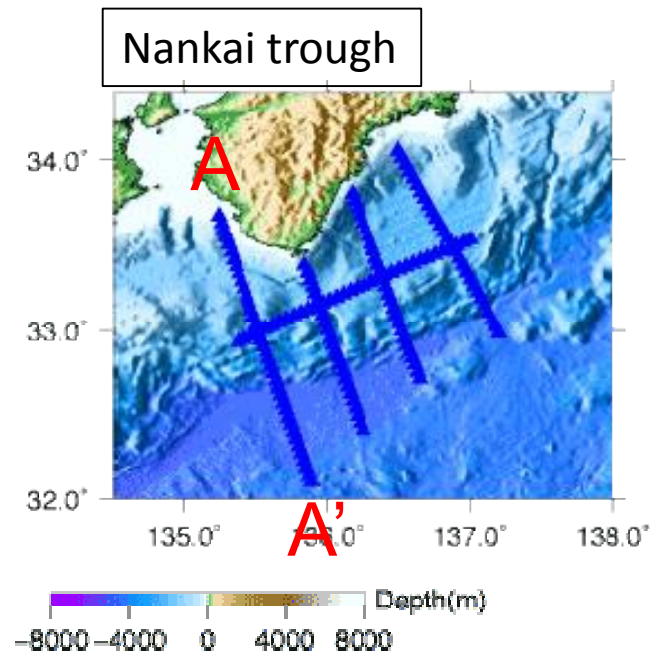
# 構造探査データのノイズ部分



Tonegawa, Fukao, et al. 2015, PEPS



←  
基盤からの  
反射S波



遠洋性の海底堆積物: 基盤がフラット



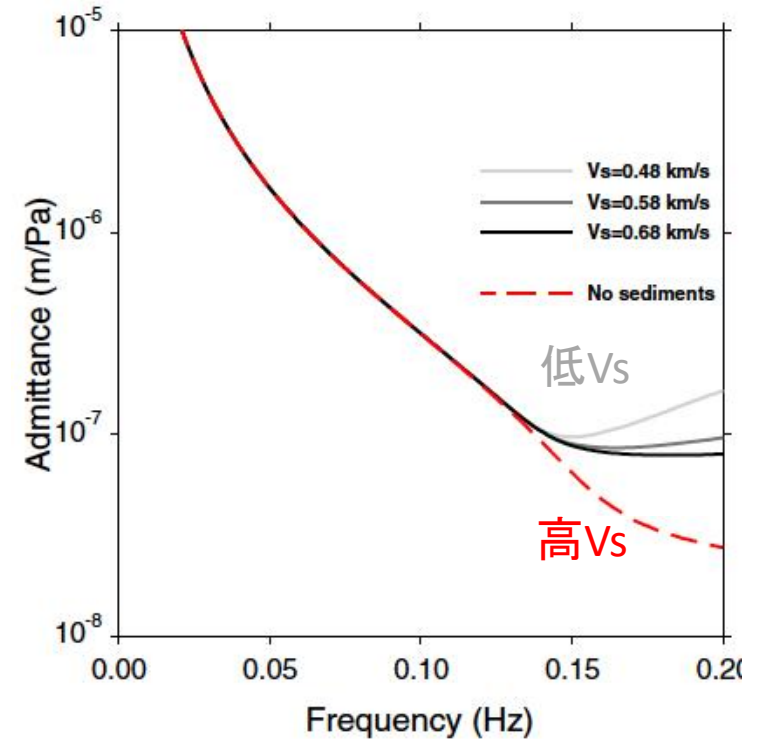
## (2) 付加体の速度構造

Rayleigh admittance (Ruan et al. 2014, JGR)

$$\eta(f) = \left| \frac{u_z(f)}{\Delta P(f)} \right|$$

$u_z(f)$  : displacement at the seafloor

$\Delta P(f)$  : differential pressure at the seafloor



レーリー波の変位に対する水圧の(振幅の)伝達関数

- 脈動(0.09–0.15 Hz付近)
- 地震(0.01–0.15 Hz付近)
- (基本モード)

# DONET data

Period of the used data

DONET1

Jan., 2011–Dec., 2016

DONET2

Mar., 2016–Dec., 2016

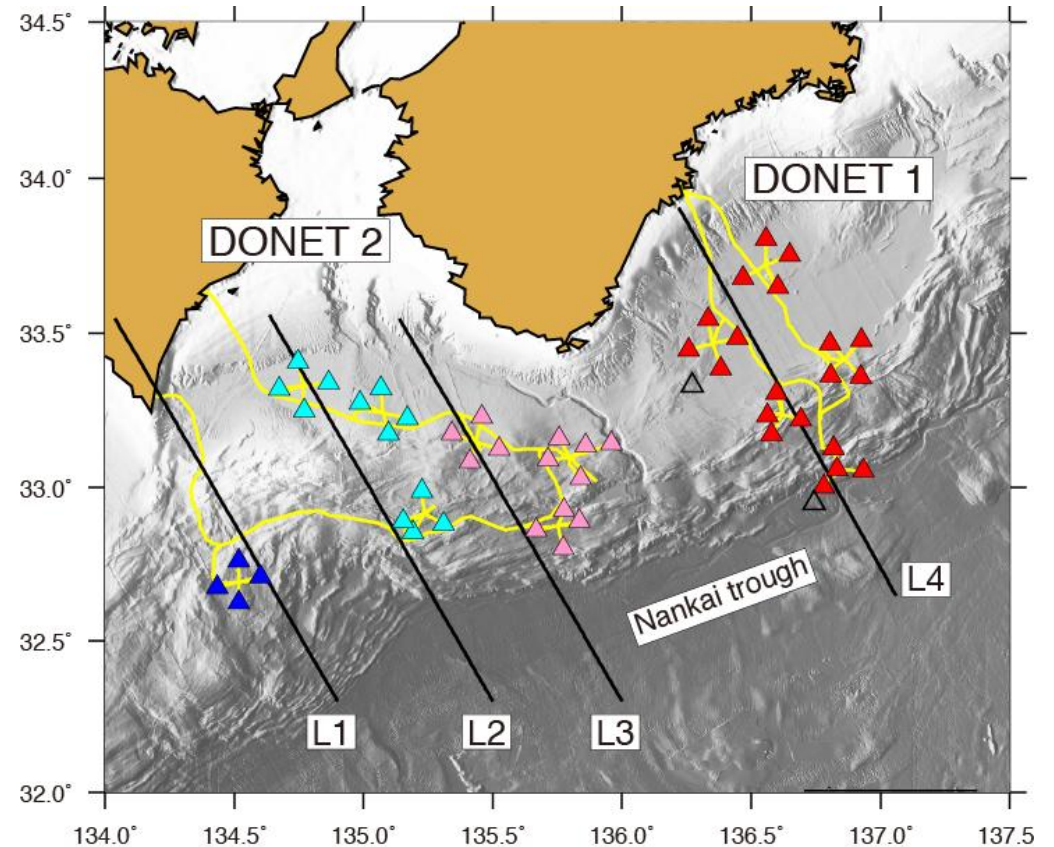
No. station : 51

22 : DONET 1 → 20のみ使用

29 : DONET 2

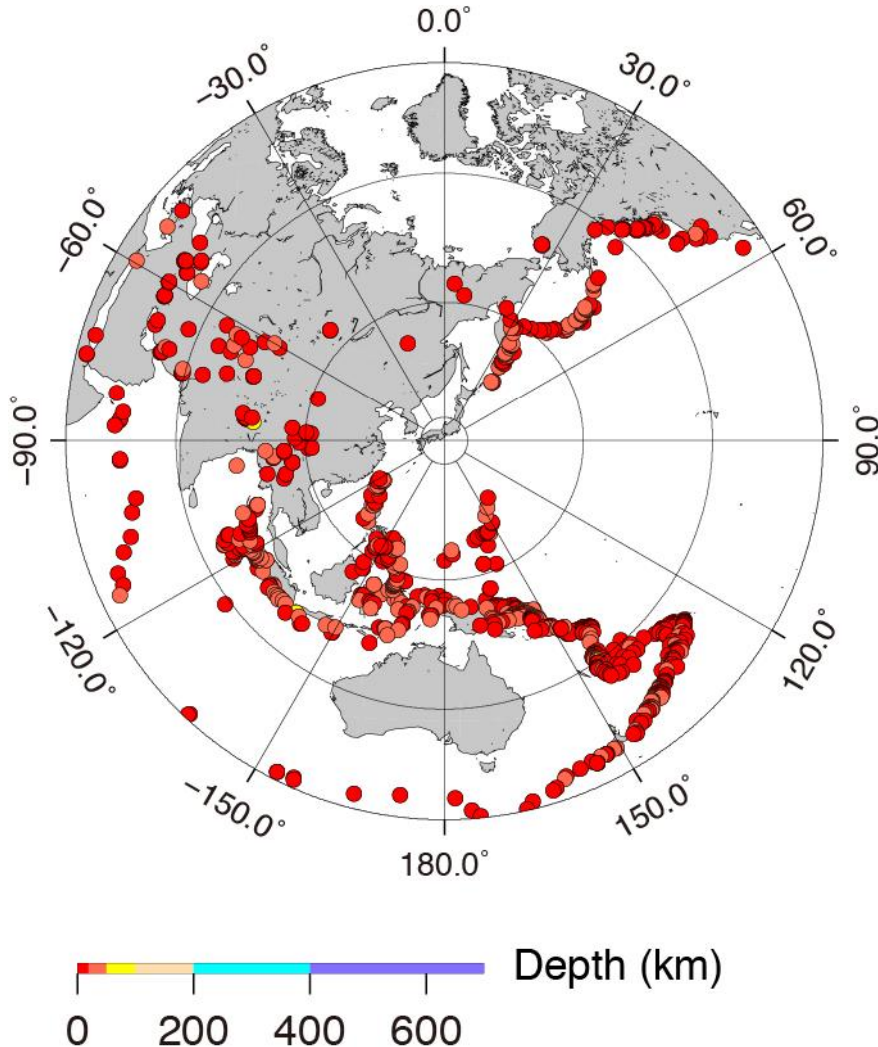
Records

- UD displacement
- pressure records



# 長周期側：地震のレーリー波

地震によって励起されたレーリー波を使用



2011/1/1–2016/12/31

Magnitude: >5.0

Depth: < 50 km

Epi. Distance:  $15^\circ < \Delta < 90^\circ$

S/N > 1.5 (0.04–0.1 Hz)

30 s before P arrival

30 s after Rayleigh arrival

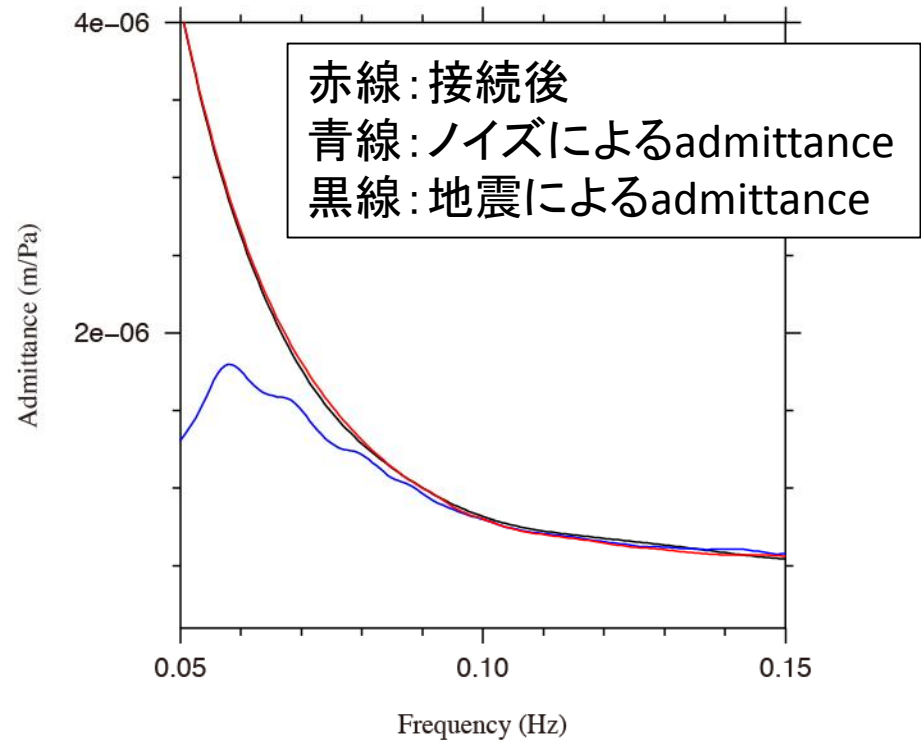
coherence 圧力 v.s 変位

> 0.9 (0.03–0.1 Hz)

Total No. of events: 890/~1900

# Processing

- 1) displacement records  
removal of instrument response
- 2) Calculation of Rayleigh admittance  
2 sets :  
noise (microseisms) and earthquake
- 3) Smoothing  
Parzen window (0.01 Hz width)
- 4) Stack
- 5) Connection of the two sets  
The connected frequency is determined by  
coherence ( $> 0.9$ )



# Non-linear inversion: simulated annealing

Cost (objective) function

$$E = w_1 \sum_i^N \overset{\text{microseisms}}{\underset{\text{obs}}{|\eta(f_i) - \eta_0(f_i)|}} + w_2 \sum_j^M \overset{\text{earthquake}}{\underset{\text{predict}}{|\eta(f_j) - \eta_0(f_j)|}}$$

synthetic admittance:  
DISPER80 (Saito, 1988)

$$w_1=0.6, w_2=0.4$$

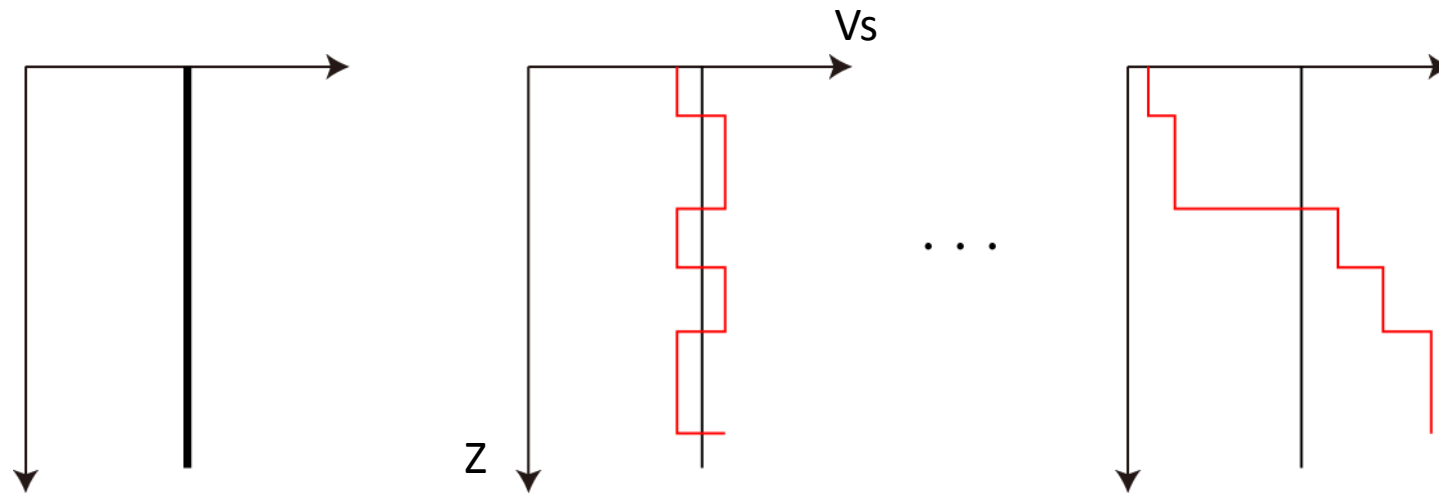
Iteration 3000 times  
(1500-2000 → convergence)

# Velocity updates

Initial velocity model: Nakanishi et al. (2008)  $V_p \rightarrow V_s, \rho$

$$v'(z_k) = \begin{cases} v(z_k) - \Delta v & \text{if } \alpha < 0.5 \\ v(z_k) + \Delta v & \text{if } \alpha > 0.5 \end{cases} \quad \begin{array}{l} \alpha: \text{random number } (0 \leq \alpha \leq 1) \\ \Delta v: 0.01 \text{ km/s in } V_s \end{array}$$

a velocity increment,  $\Delta v$ , at a depth interval of 0.1 km

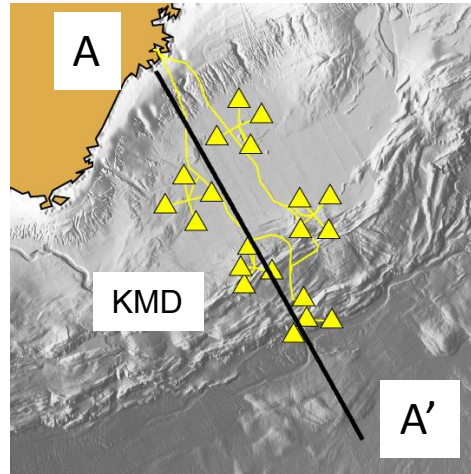


velocity gradient

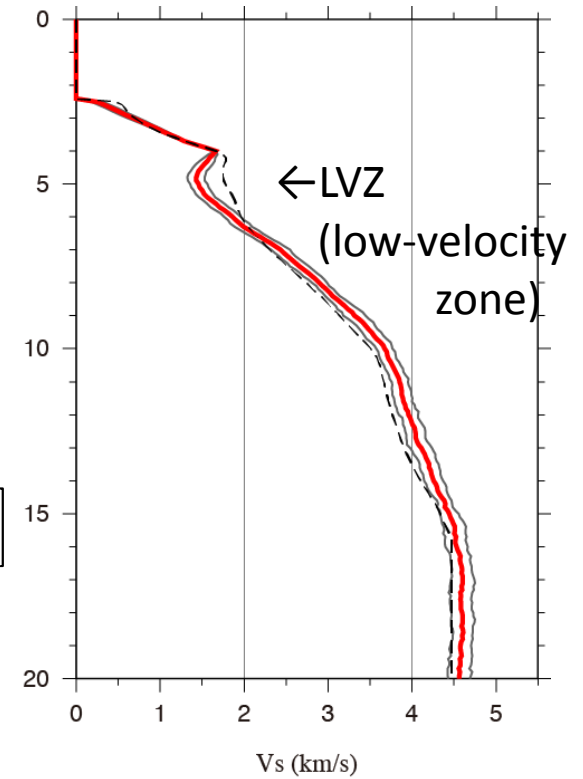
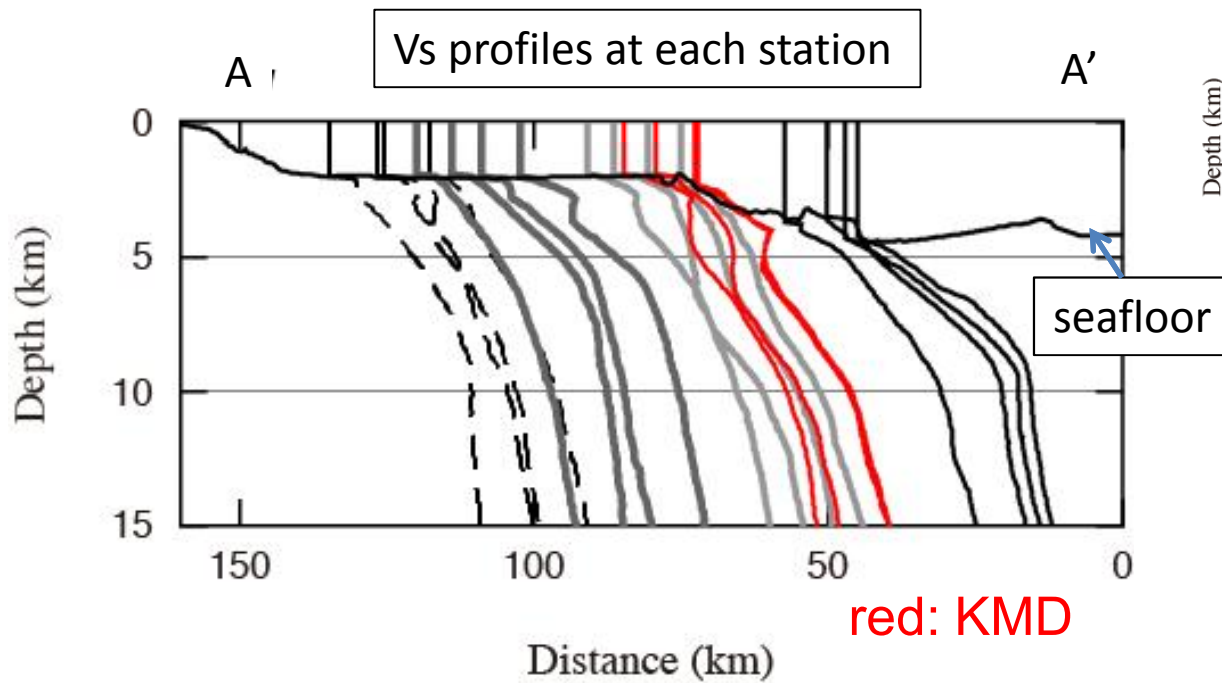
differential velocity (above or below the layer) exceeds 0.1 km/s

→no update for velocity model

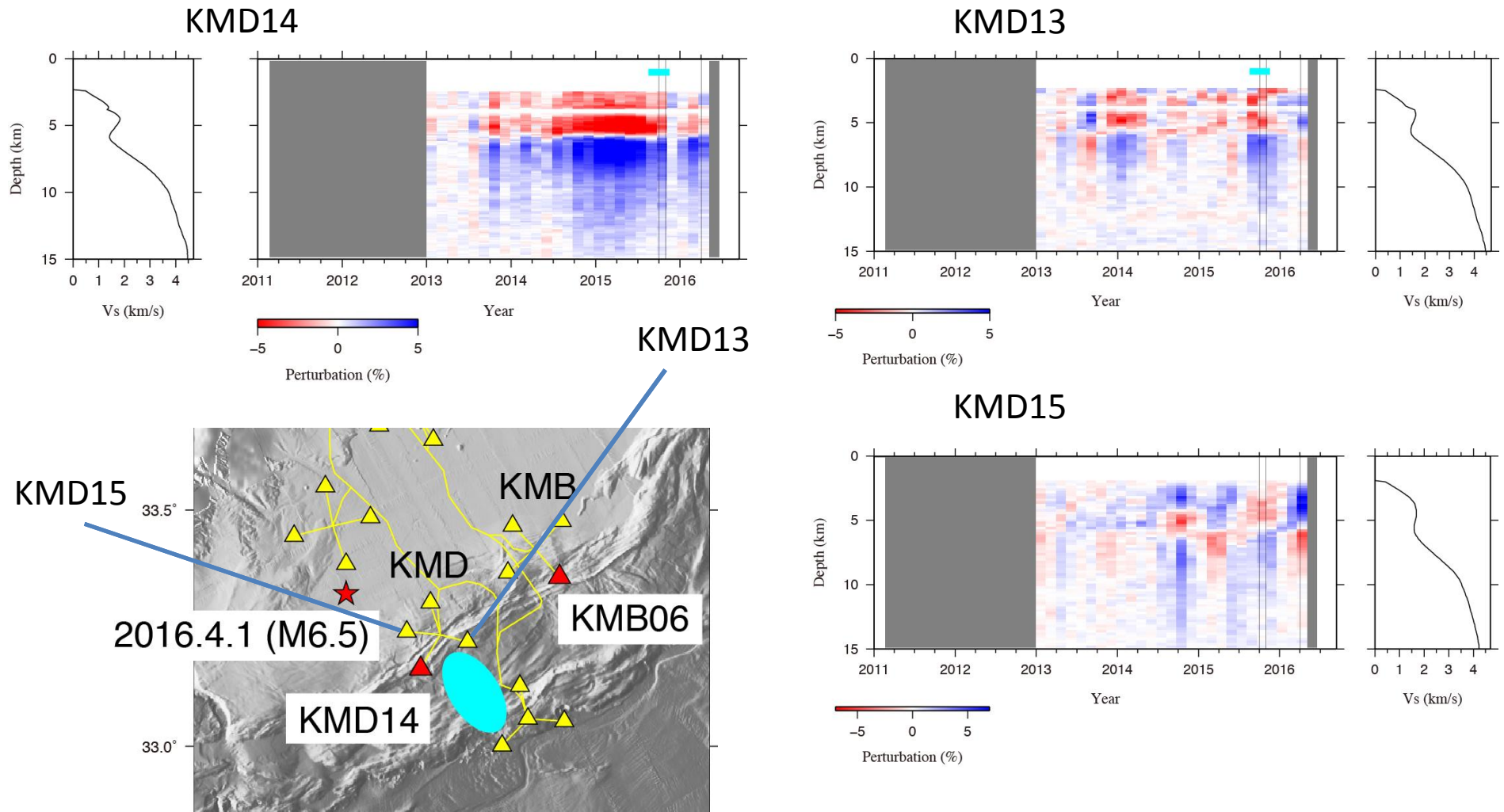
# DONET 1



dash : Initial vel.  
red: result  
gray:  $1\sigma$  (50 times)  
KMD13

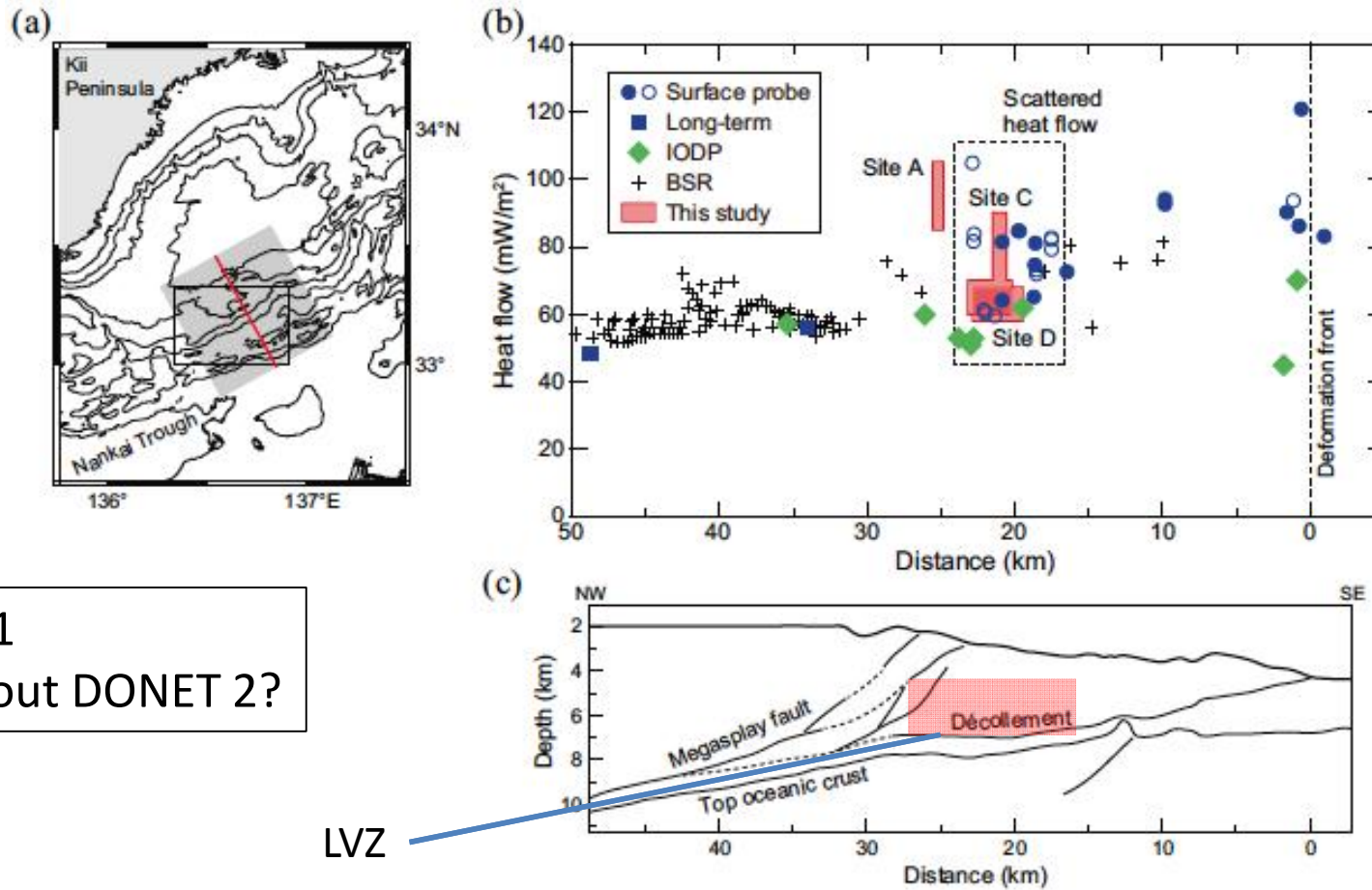


# Temporal variation of LVZ





# LVZ v.s heat flow



DONET 1  
How about DONET 2?

Yamano et al. 2014  
Hamamoto et al. 2011

# まとめと今後の展望

## 本発表

単一観測点での解析

微動を活用した構造推定

- ・海底堆積物の異方性構造とその時間変化
- ・付加体内部の構造
  - 1) LVZとsVLFE活動
  - 2) 構造の時間変化
  - 3) 熱流量との関連

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## 今後の展望

微動: 深部の構造推定への橋渡しの役割

浅部構造 ← 微動解析で抑える

- ・ Ambient noise correlation (S波のtwo-way走時)
- ・ Rayleigh admittance (S波速度の絶対値)

↓より深部への接続

レシーバ関数解析