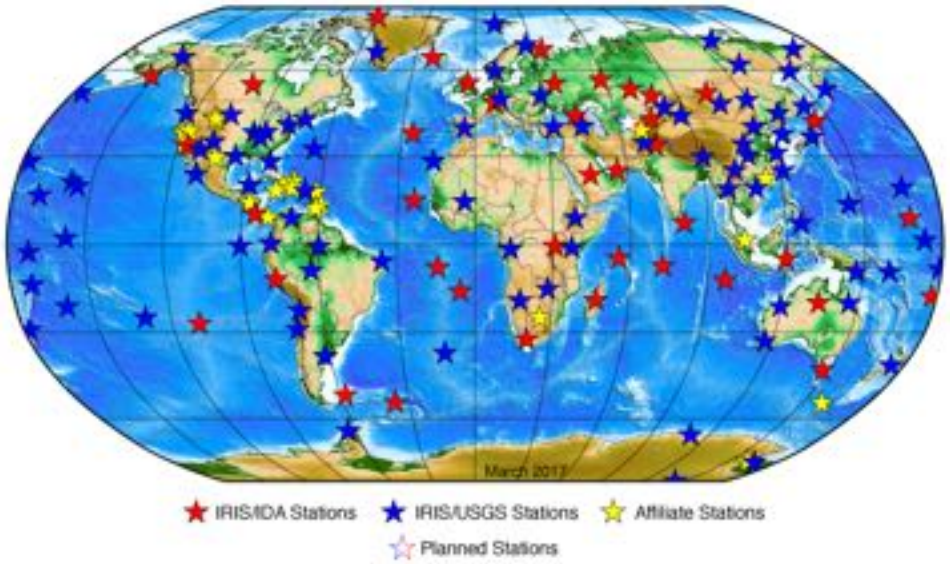
2020 白家瞳分布式光纤实验及地下结构探测研究

尹扶

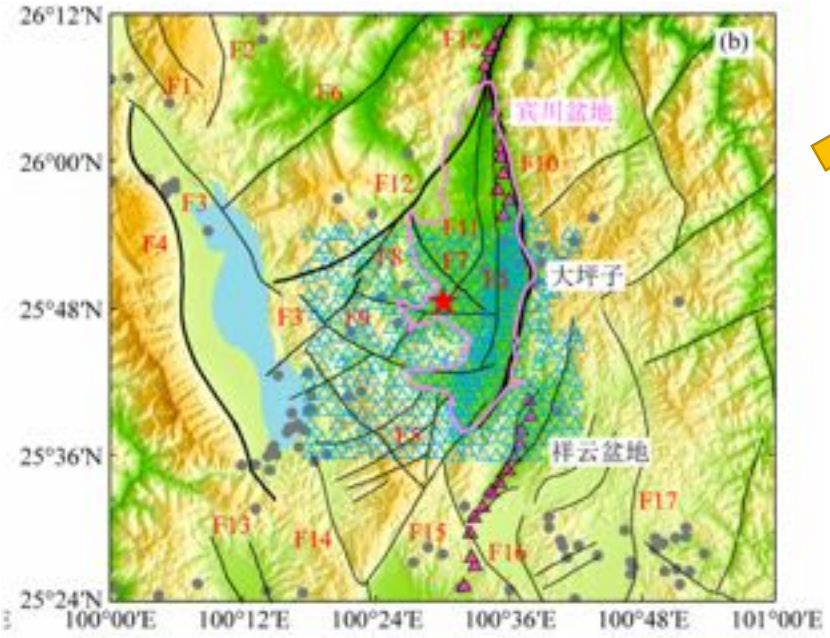
2020

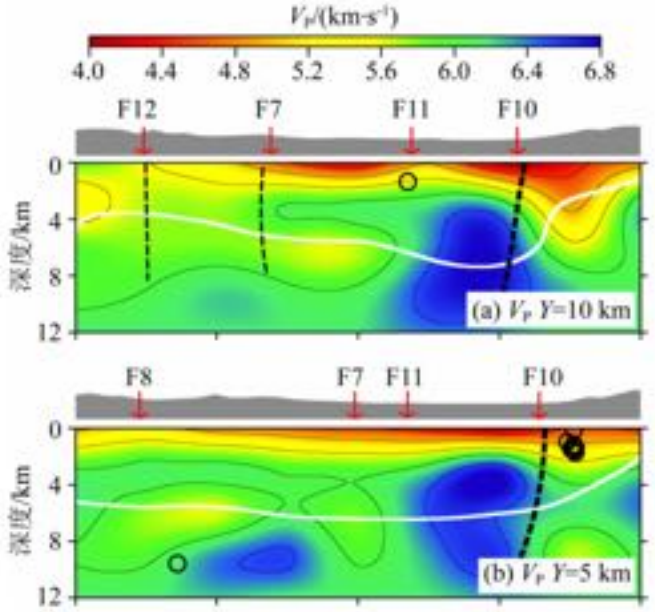
传统的地震观测

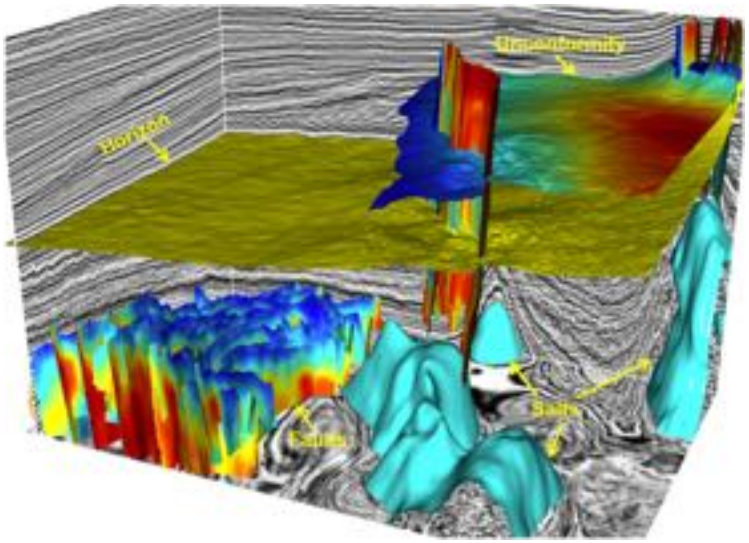

March 2017
IRIS/IDA Stations
IRIS/USGS Stations
Affiliate Stations
Planned Stations


石油圈

密集台阵 地震勘探



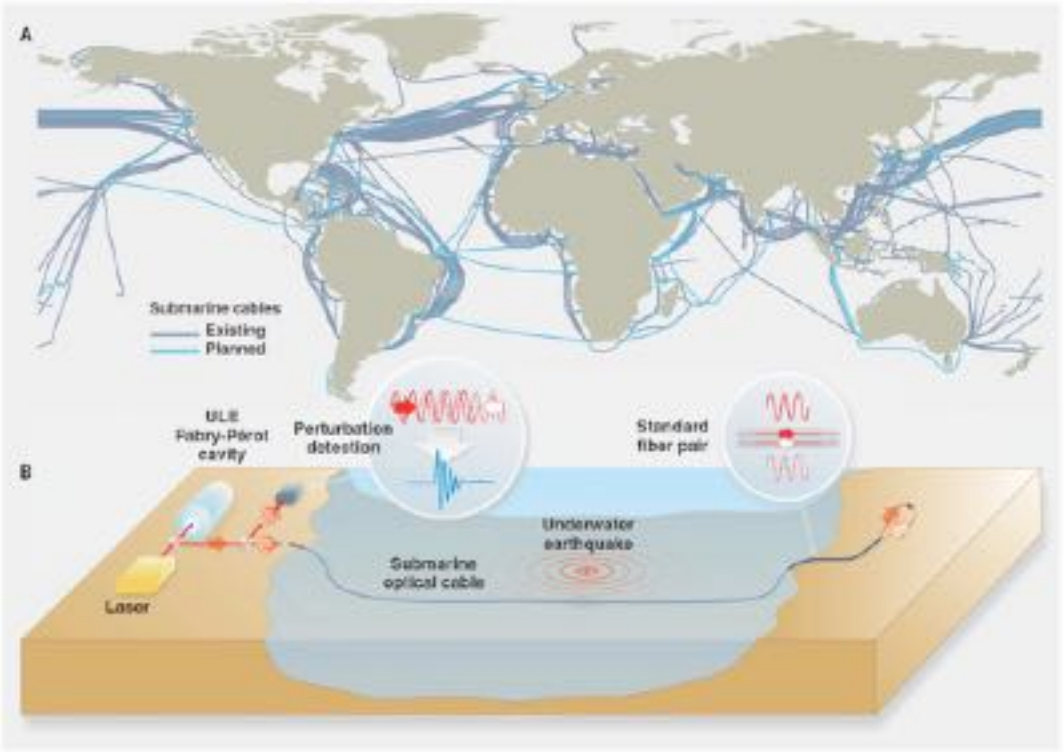




张云鹏，王宝善* 等2020

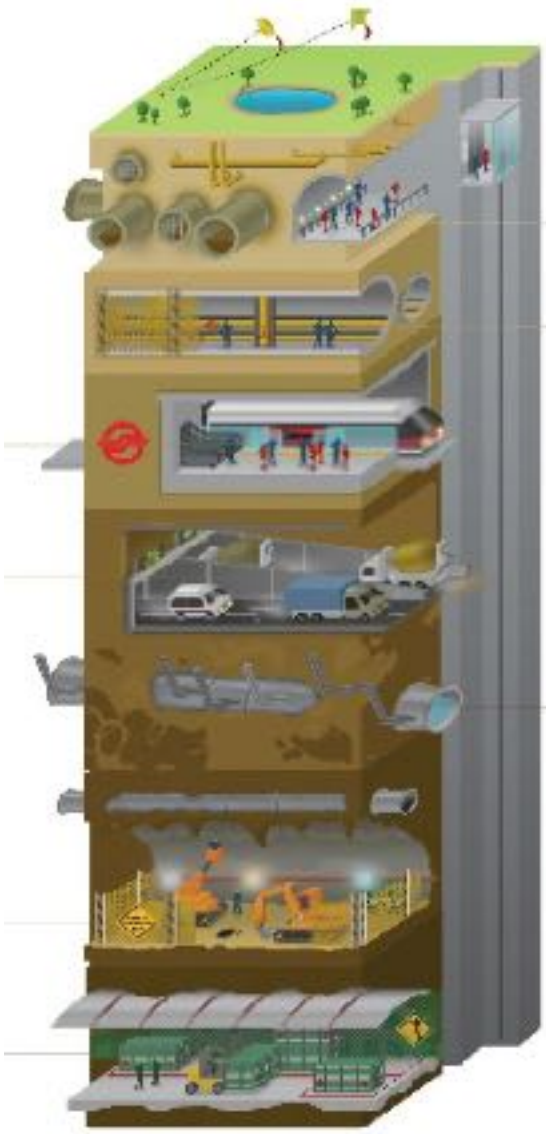
http://cig.ustc.edu.cn/main.htm

特殊情景地震观测



Marra et al., 2018 Science,
海洋地震观测

Imaging of urban underground velocity structure



1m - 3m
- Underground pedestrian links
- Water fiber and sewage pipes

1m - 10m
- Common service Tunnel in Marina Bay

15m - 50m
- MRT systems
- Major roads

20m - 50m
- Deep sewage system
- Transportation to two water reclamation plants

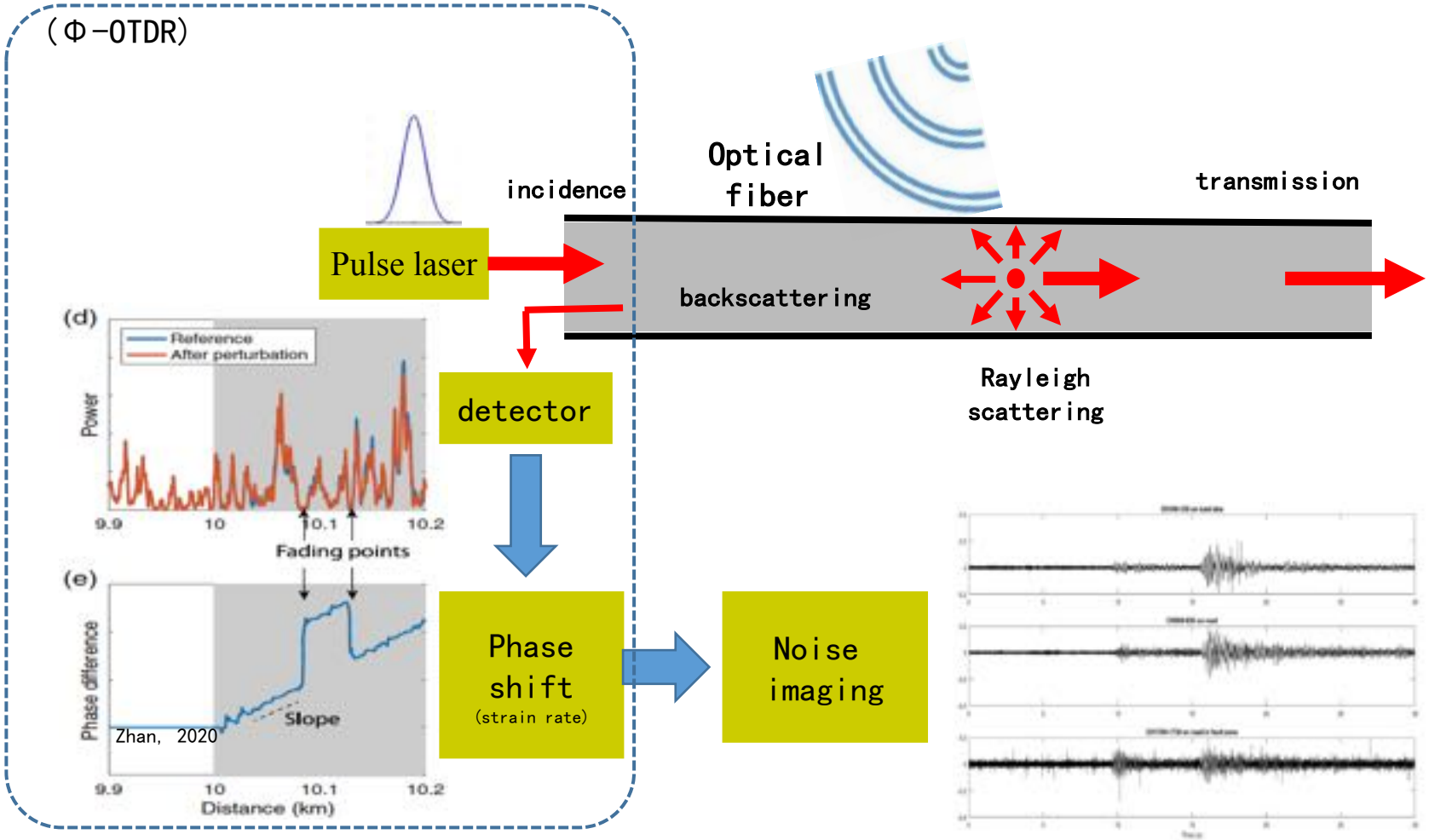
100m onwards
- Underground ammunition facility
- Jurong Rock Caverns for petrochemical storage

http://sgpnus.org/index.html

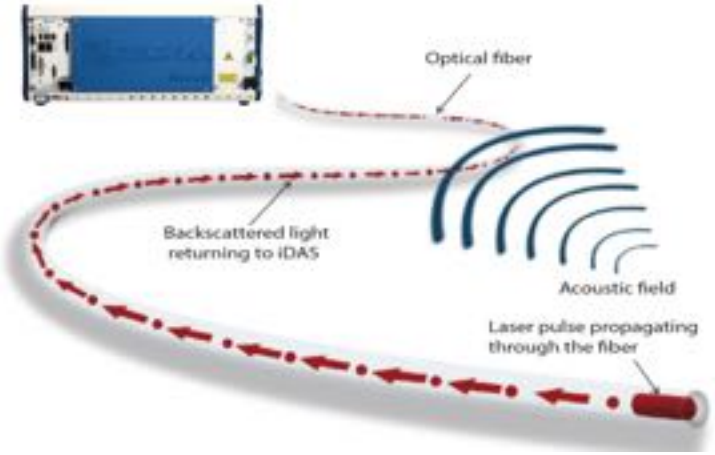
提纲

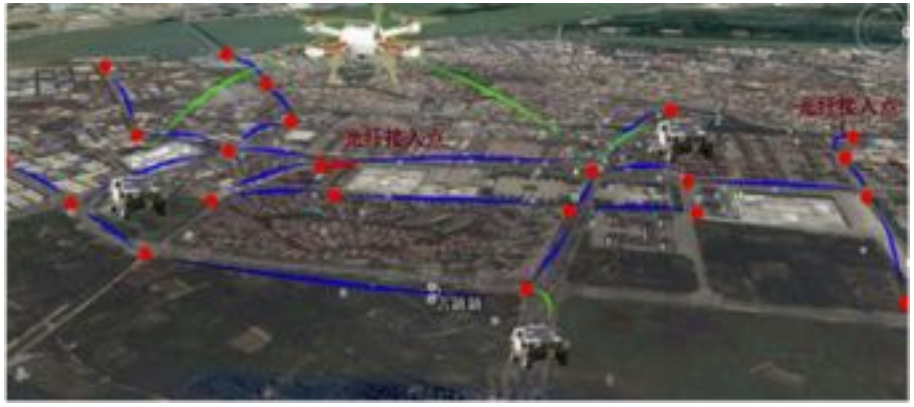
- 分布式光纤声波传感器简介
- 地震学观测实例
- 2020年白家疃观测实验

Distributes Acoustic Sensing Technique(DAS)



Wang 2020 CGU

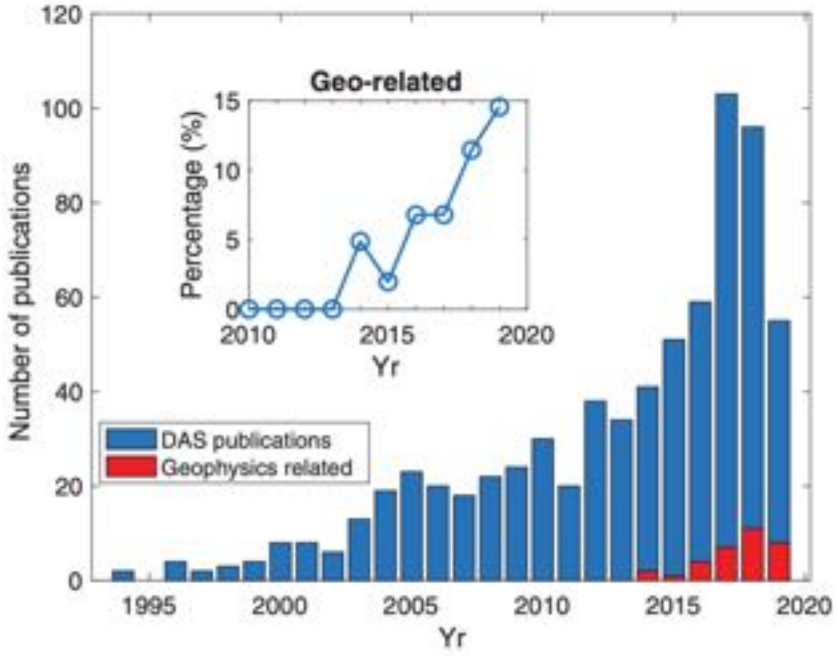




DAS是一种新型地震观测技术,提供超高密度、宽频带观测：

- 台站间距：0.25 -10 m
- 观测长度：0.1 - 10s km
- 信号频段：mHz - kHz

DAS技术在地球物理领域发展迅猛

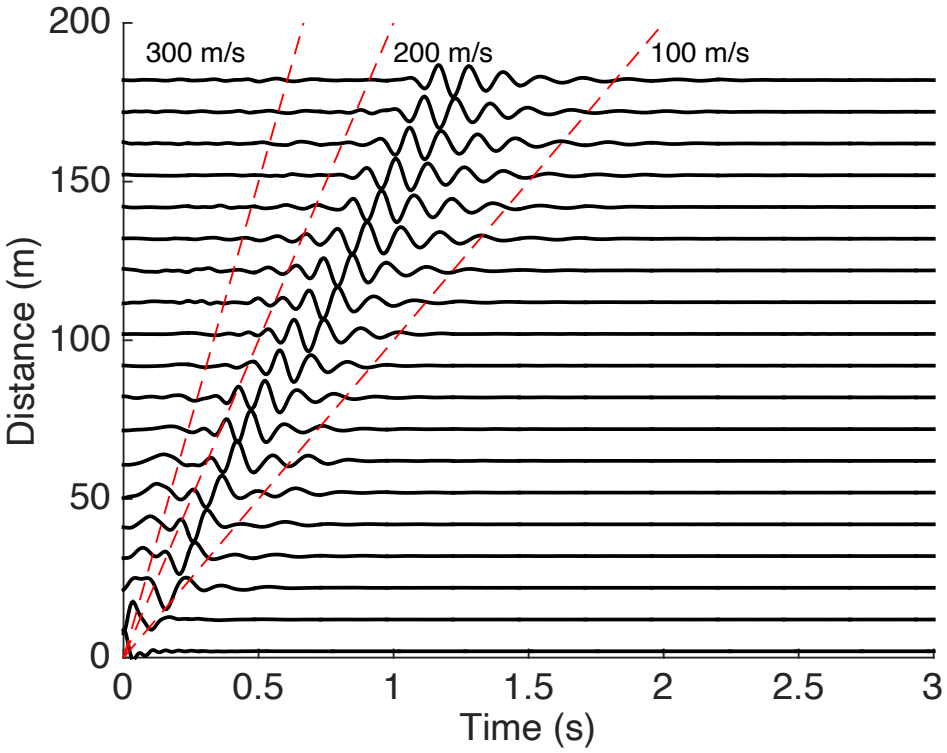


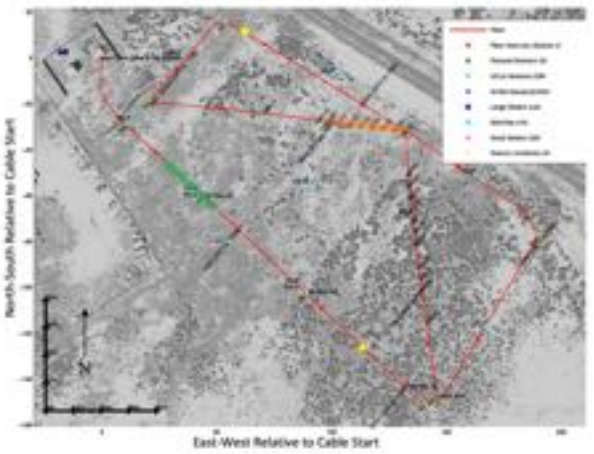
Zhan et al., 2020 SRL

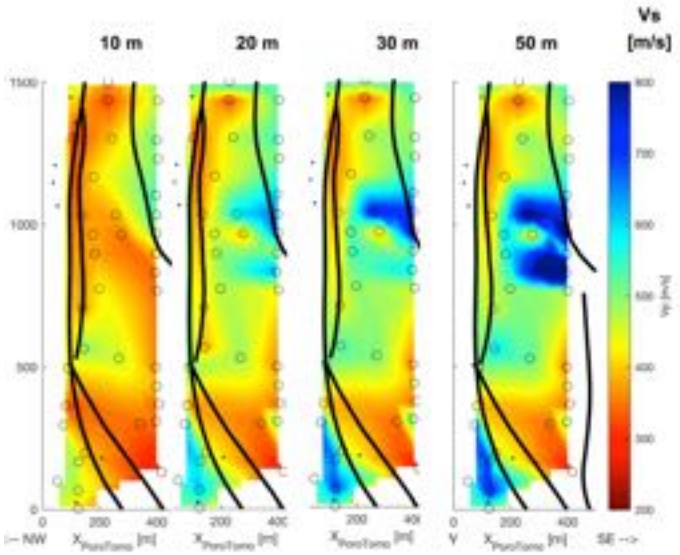
提纲

- 分布式光纤声波传感器简介
- **地震学观测实例**
- 2020年白家疃观测实验

资源勘探实例



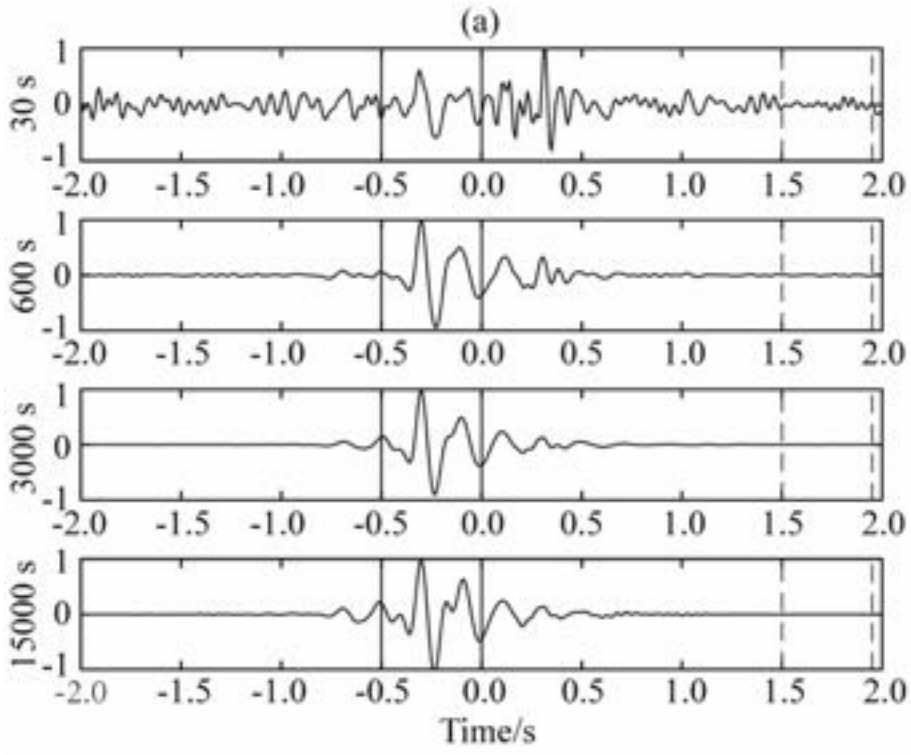


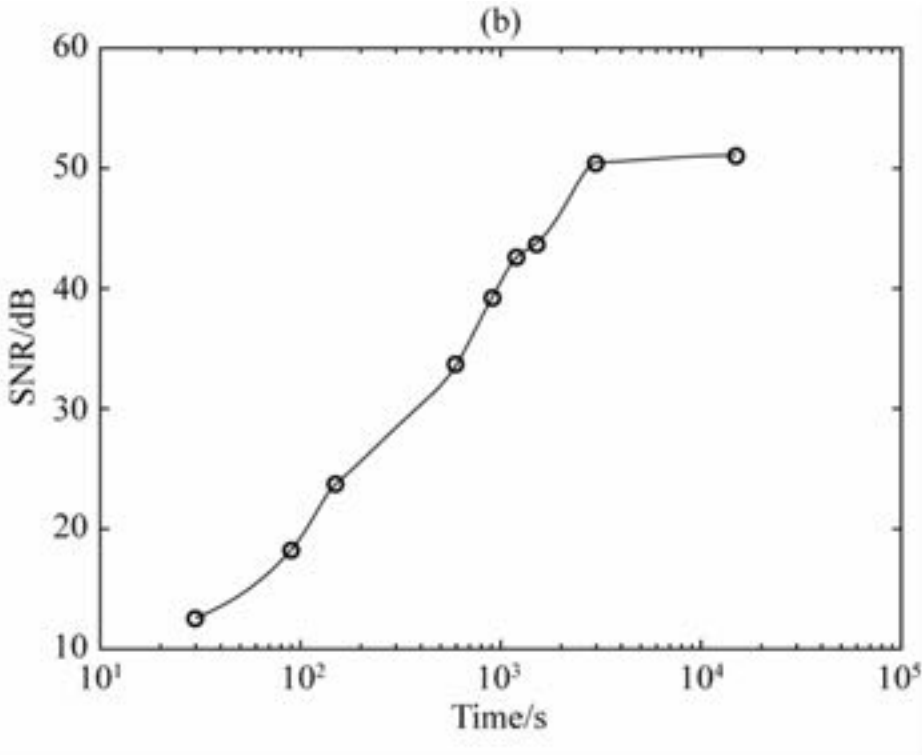


背景噪声成像

Zeng et al., 2017

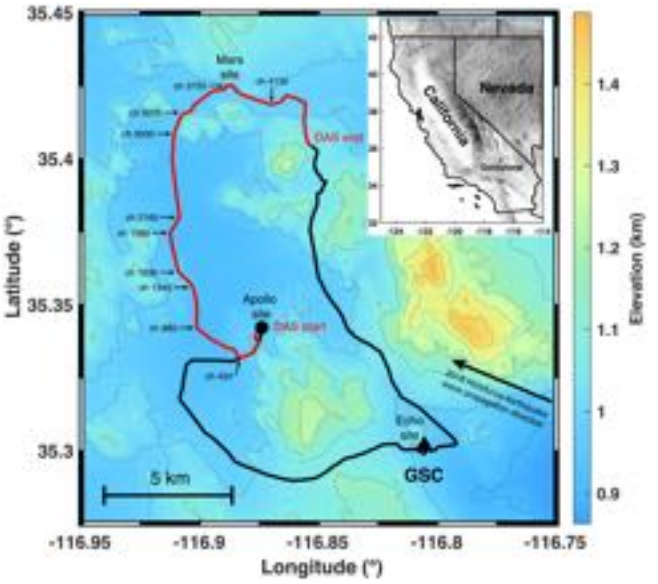
2018年白家疃实验



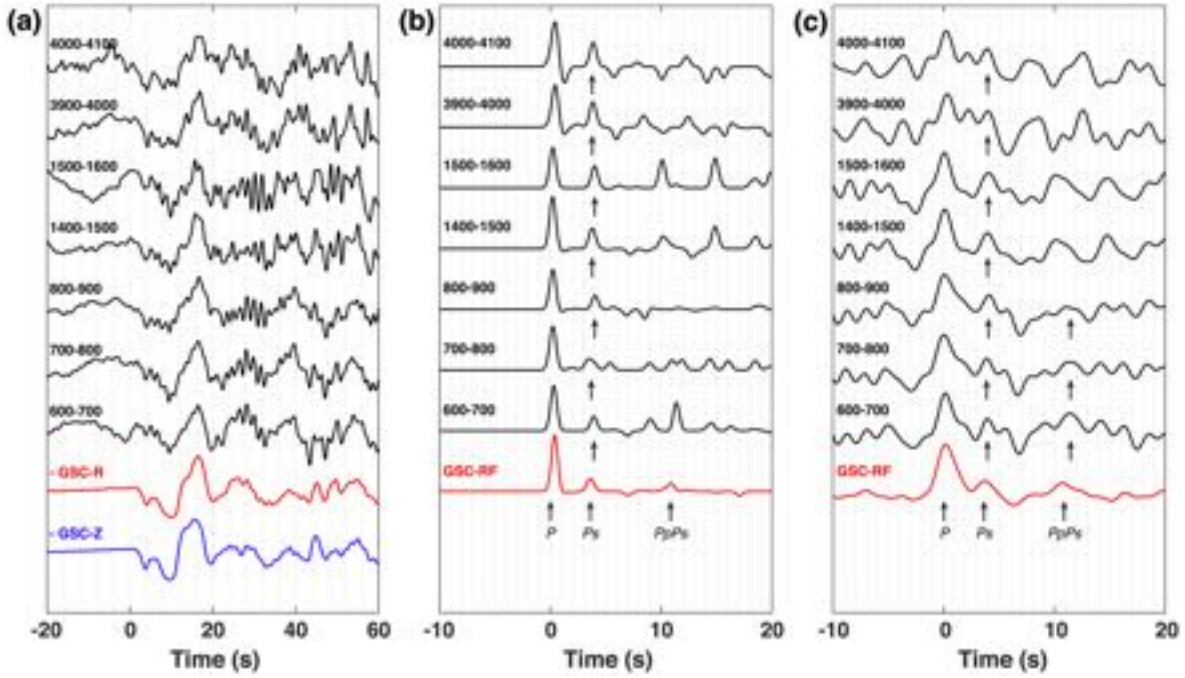


林融冰、宋政宏等.地球物理学报,63(4): 1622-1629

接收函数

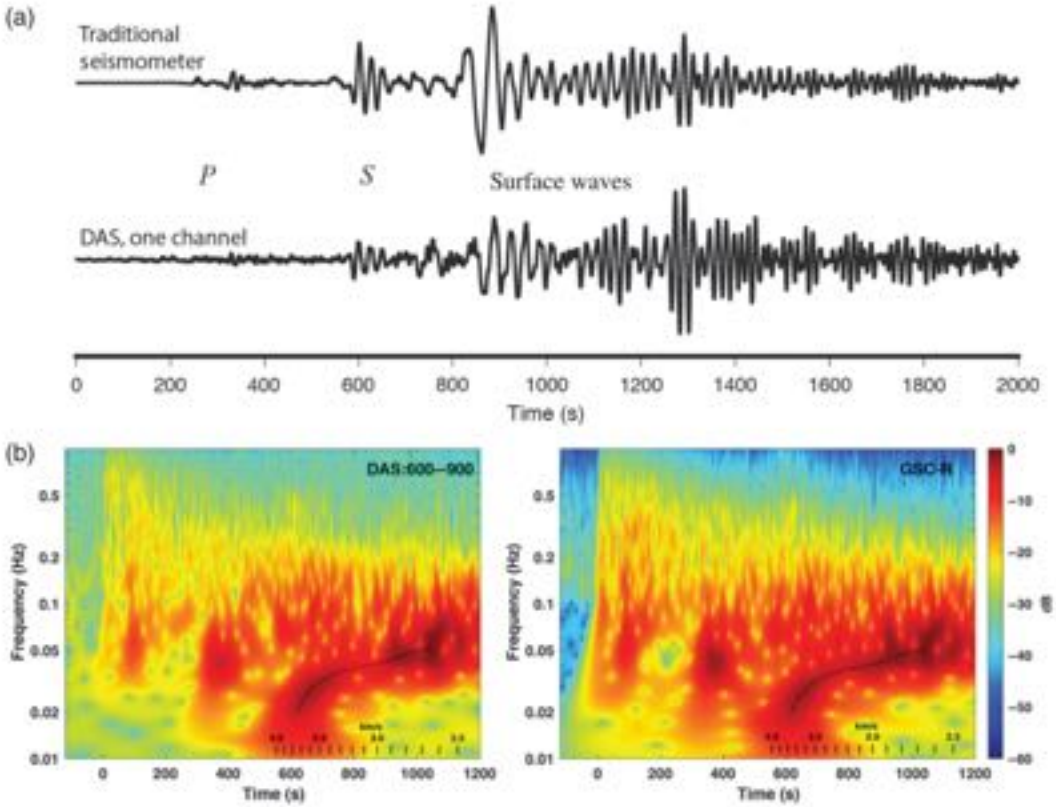


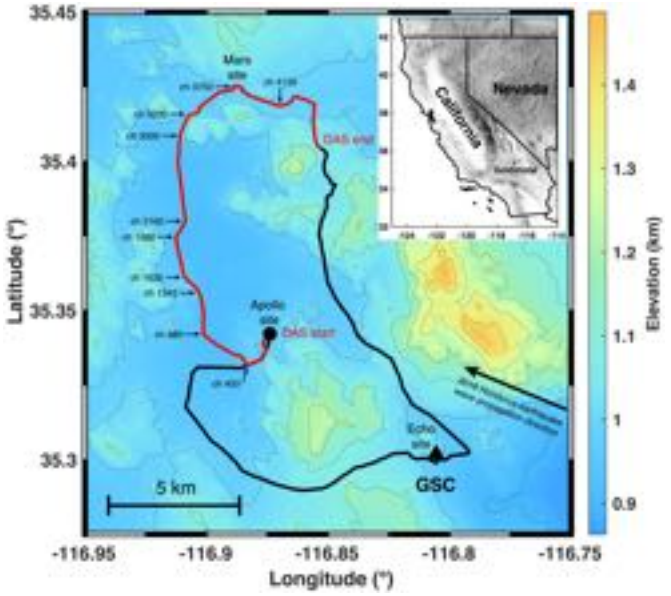
Yu et al., 2019 GRL



天然地震

The 2018 Honduras M7.5 Earthquake





Zhan et al., 2020 SRL

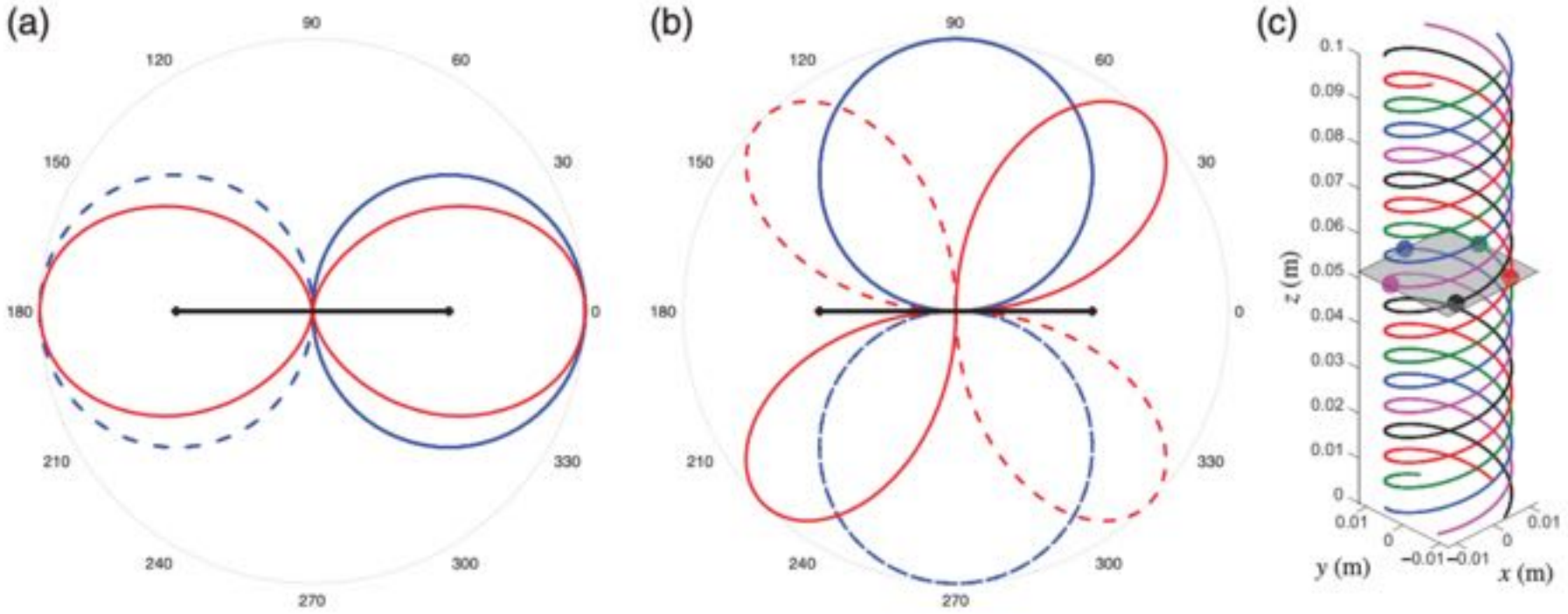
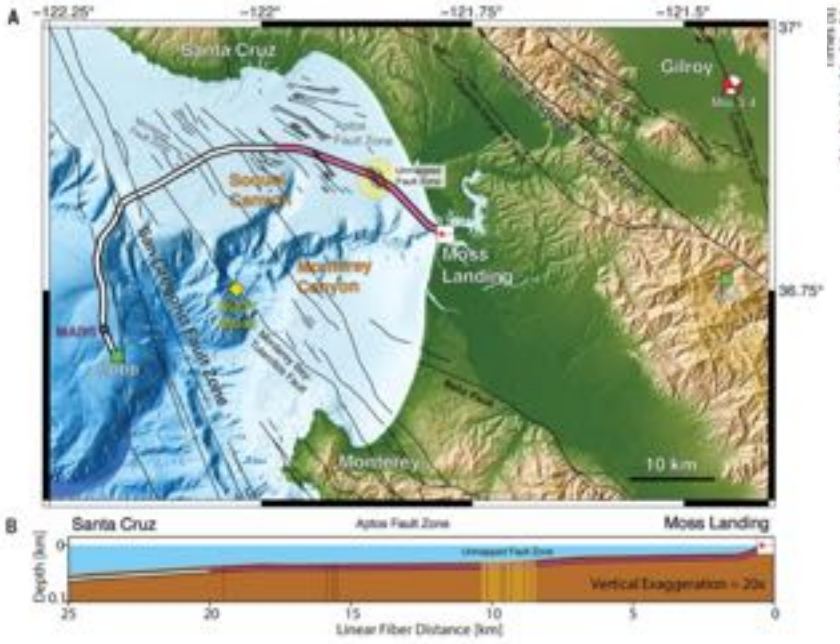
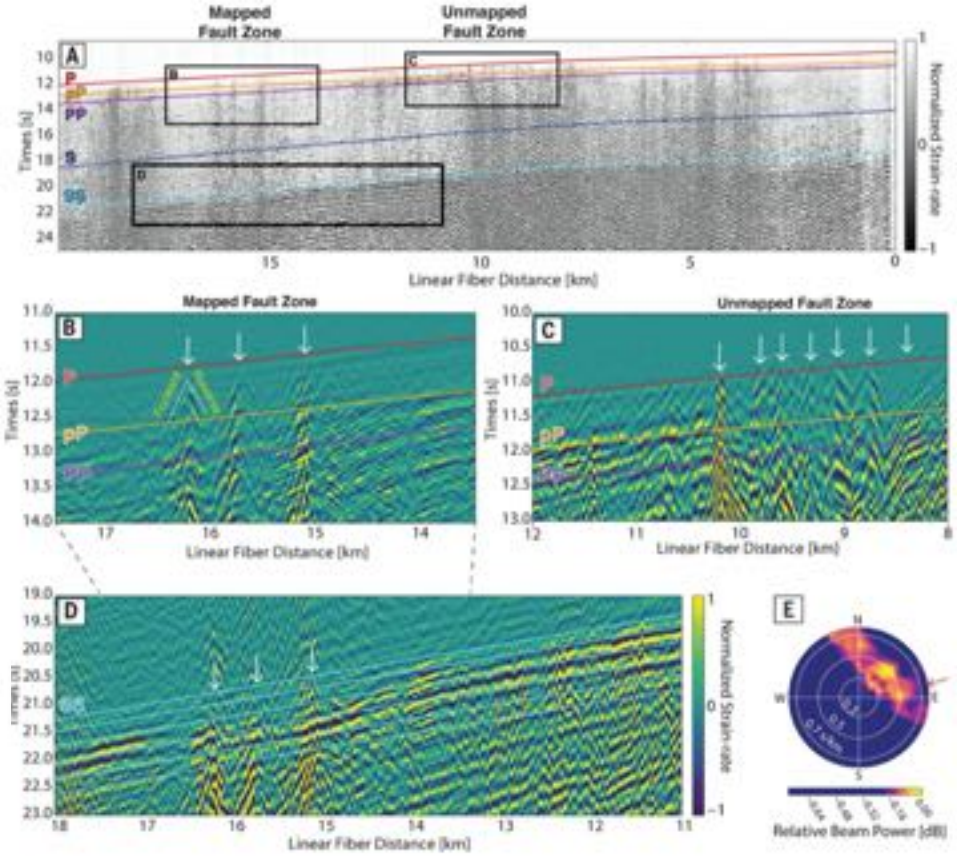


Figure 4. (a) Red lines show directional sensitivity of DAS, or linear strainmeter in general, to P wave for a straight fiber section aligned along the horizonal axis (black lines). Solid and dashed lines mean positive and negative, respectively. Reproduced based on Benioff (1935). The directional sensitivity of a conventional seismometer’ s horizontal component is shown in blue lines as references. (b) Same as (a) but for S waves. (c) A helically wound fiber-optic cable design that can provide better broadside DAS sensitivity than straight fibers. Figure from Lim Chen Ning and Sava (2018).

海洋地震





Lindsey et al., Science, 2019

提纲

- 分布式光纤声波传感器简介
- 地震学观测实例
- **2020年白家疃观测实验**

白家疃观测实验

2018 → 2020

地震观测系统

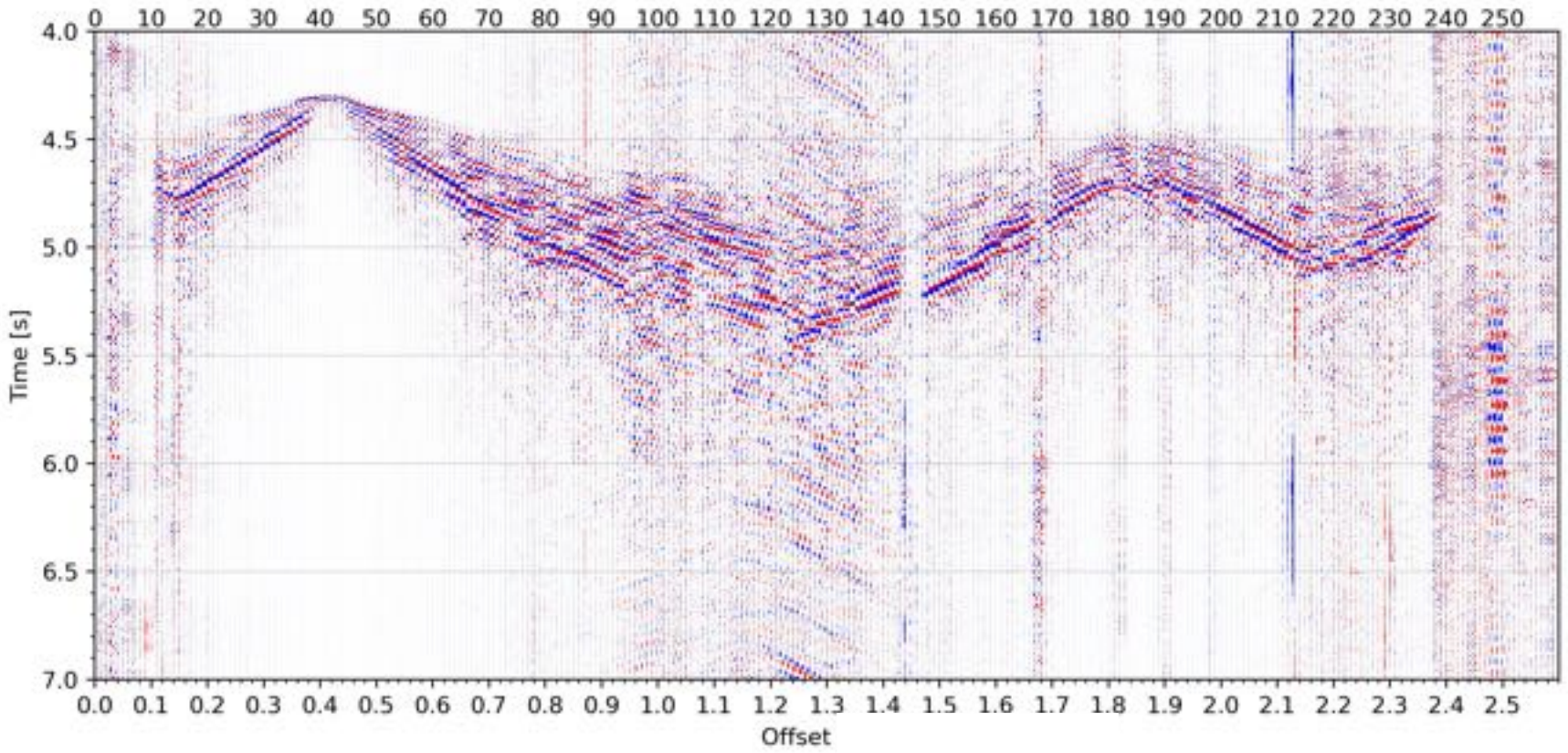
红色点：人工落锤

蓝色曲线：光纤

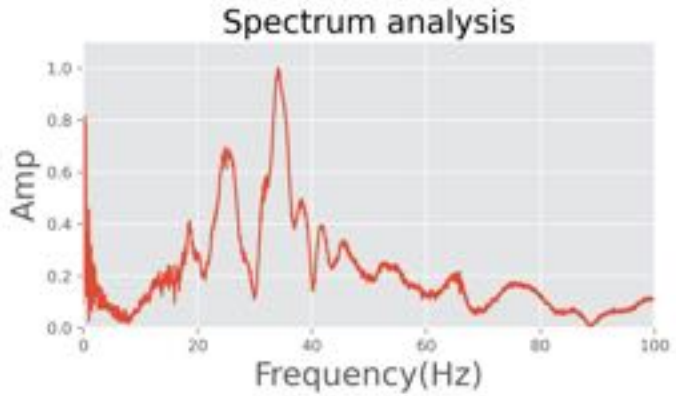
小型震源车

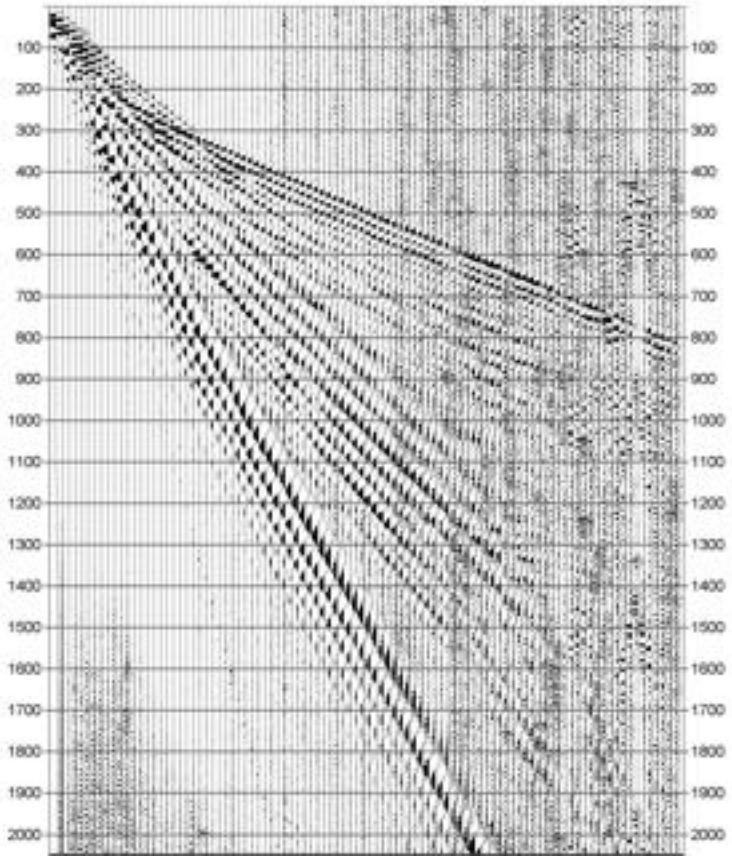
人工落锤信号

走时层析成像

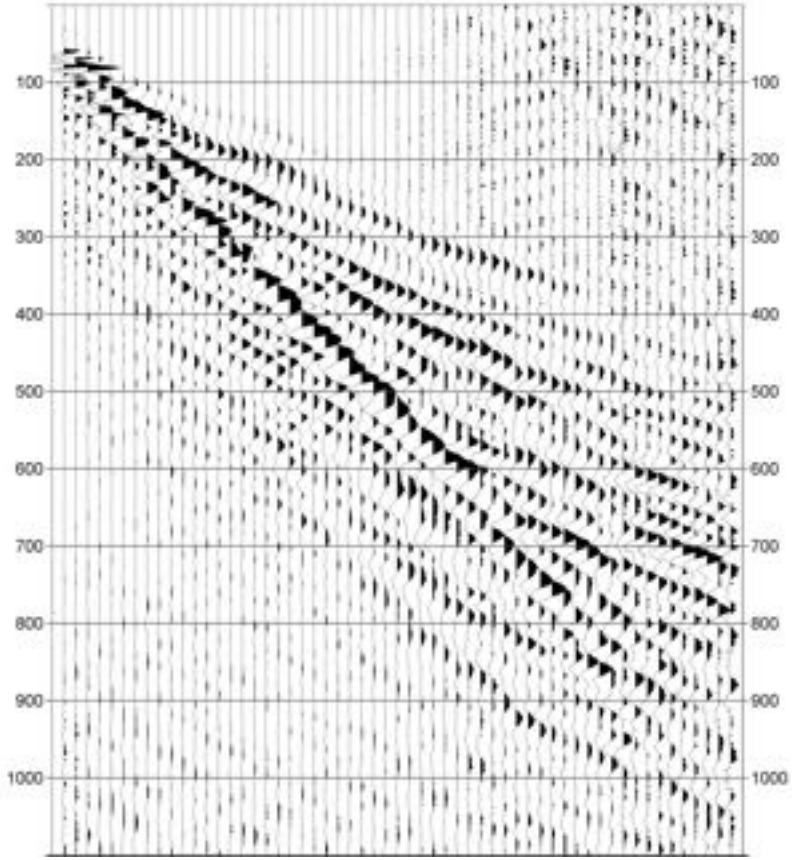


DAS 信号比较



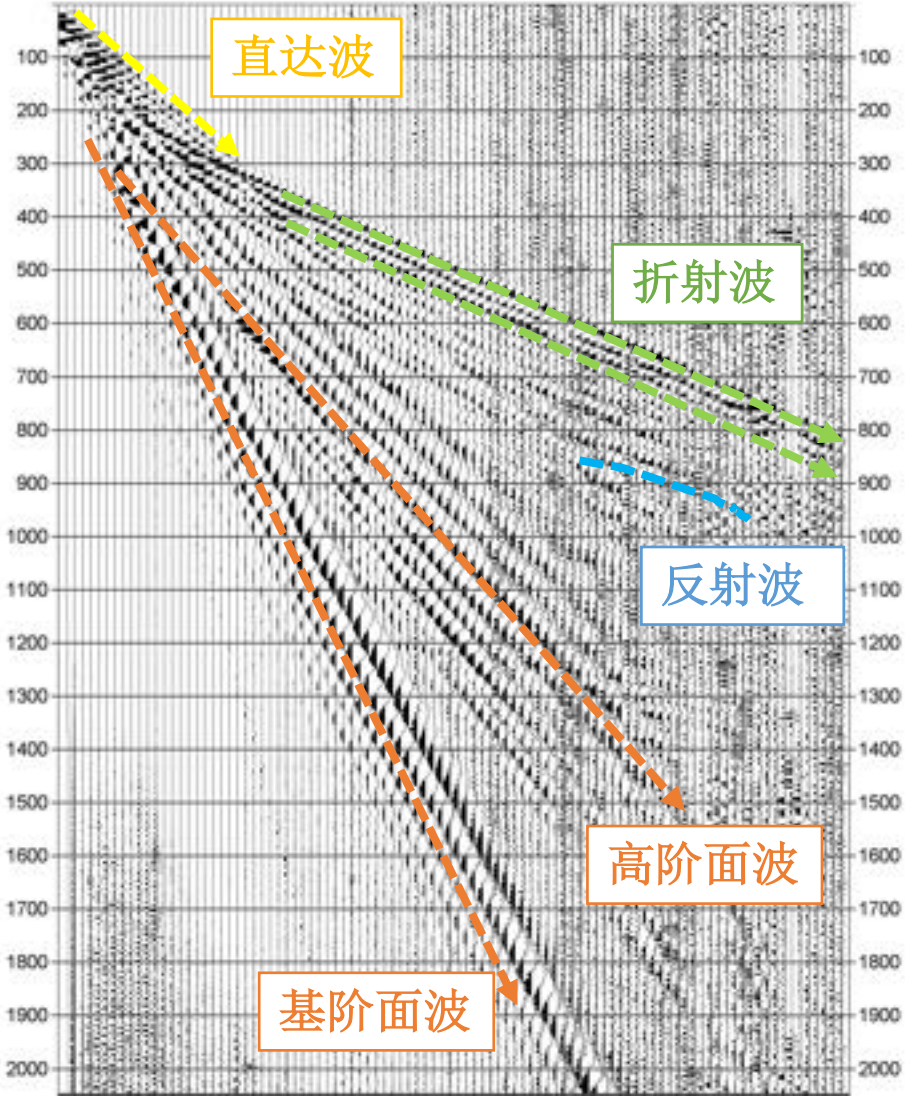


野外地震勘探信号



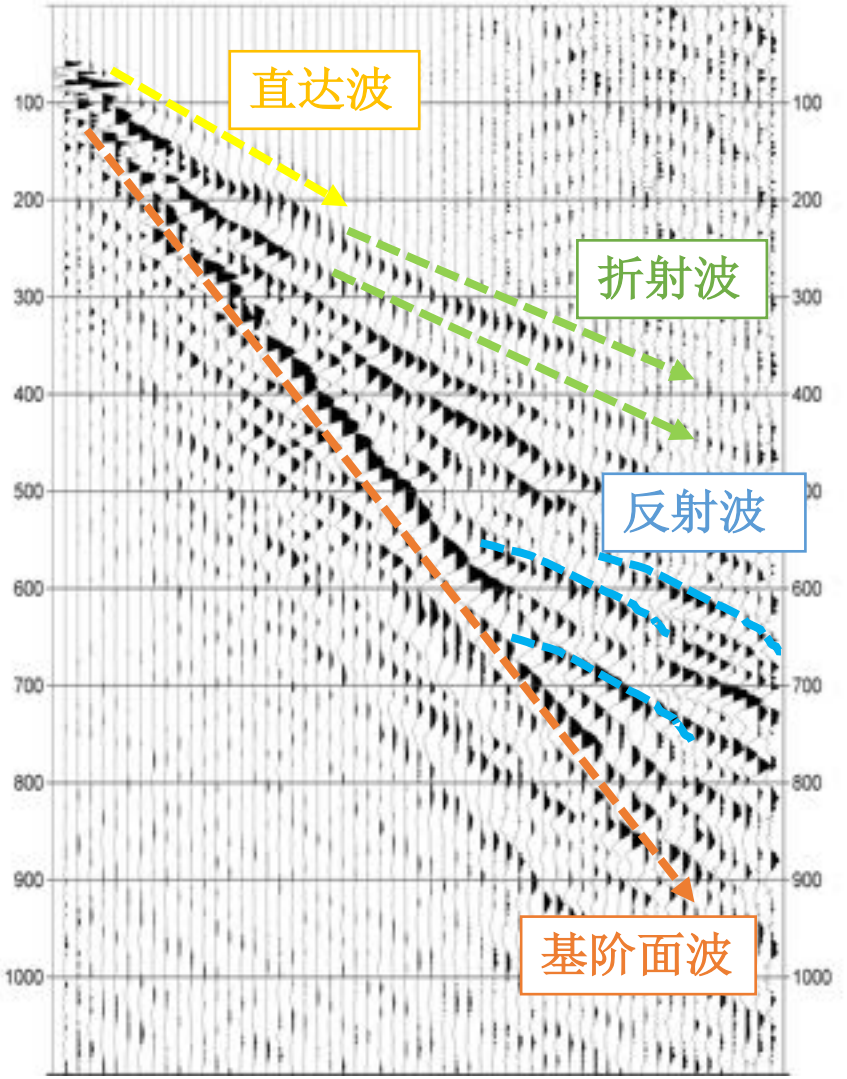
DAS 信号

野外地震勘探信号

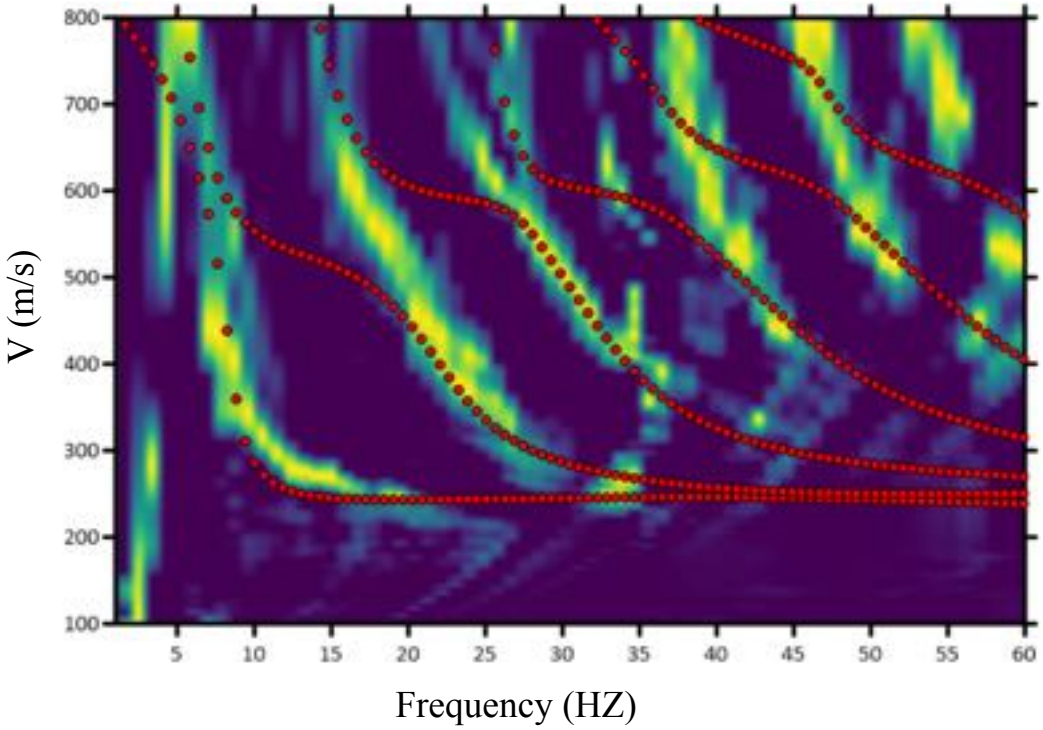


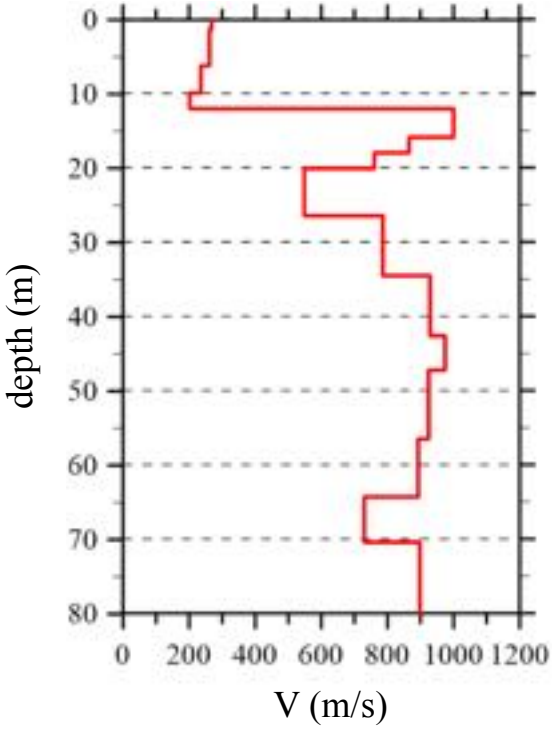
地震剖面图片来自 雷宇航博士

DAS 信号



高阶面波信号



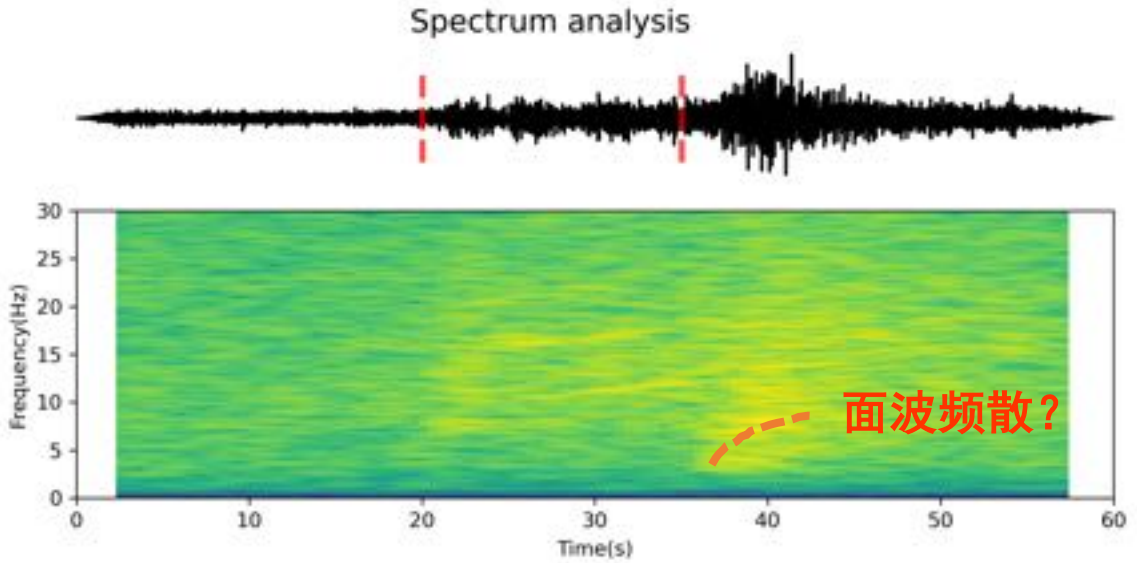


图片来自 雷宇航博士

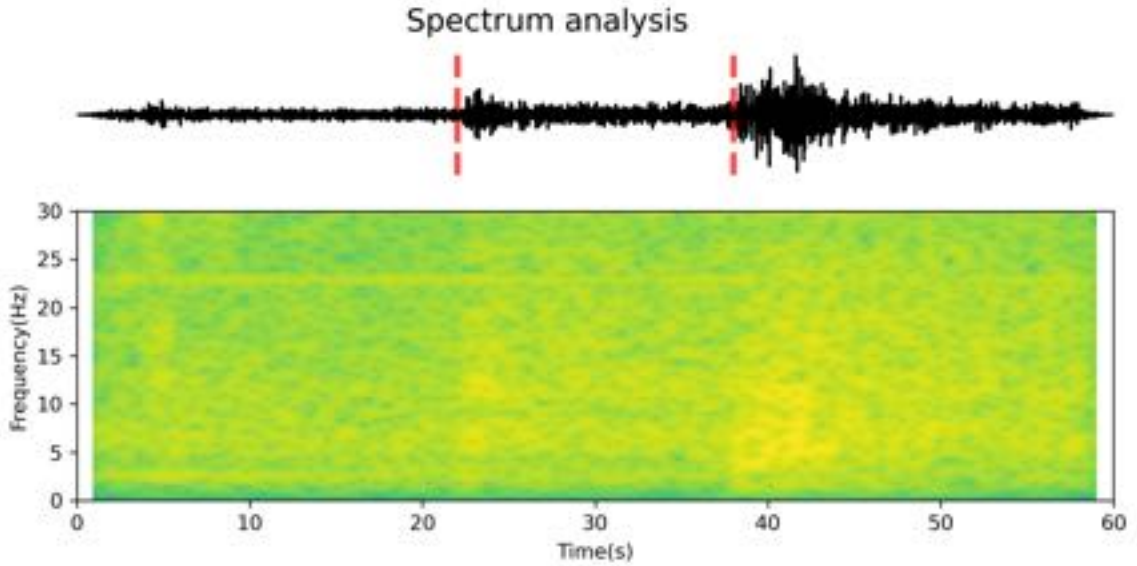
天然地震信号

事件：20201003111007

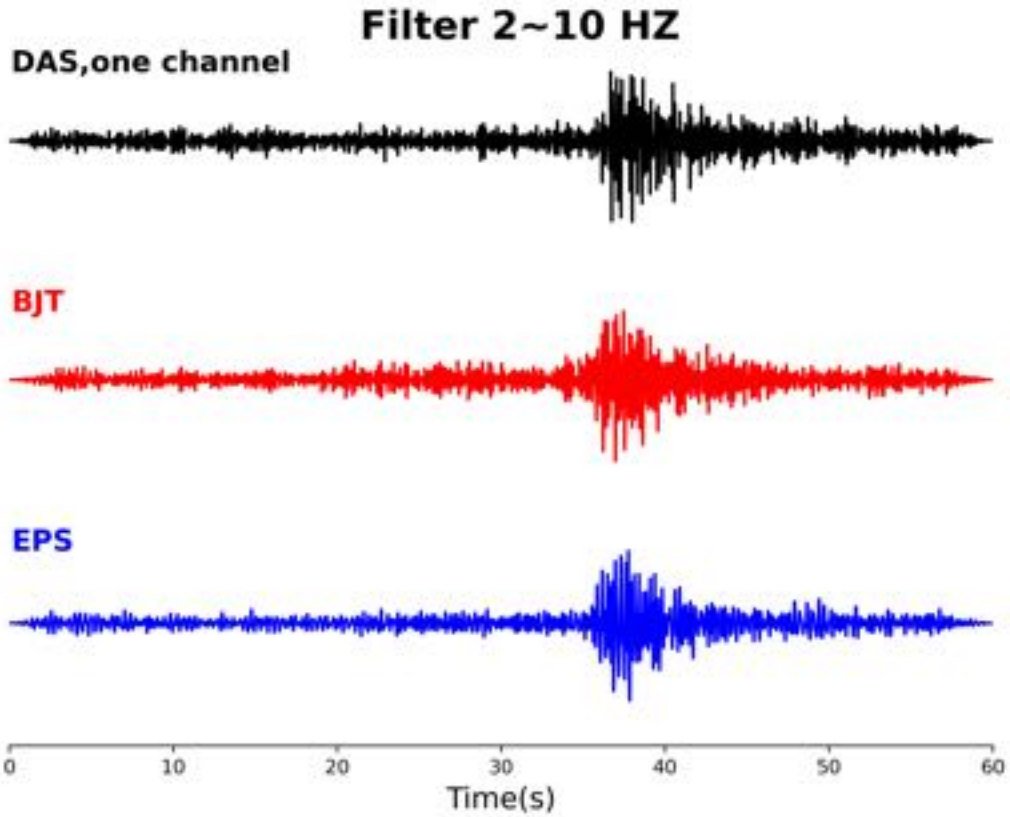
DAS, one channel

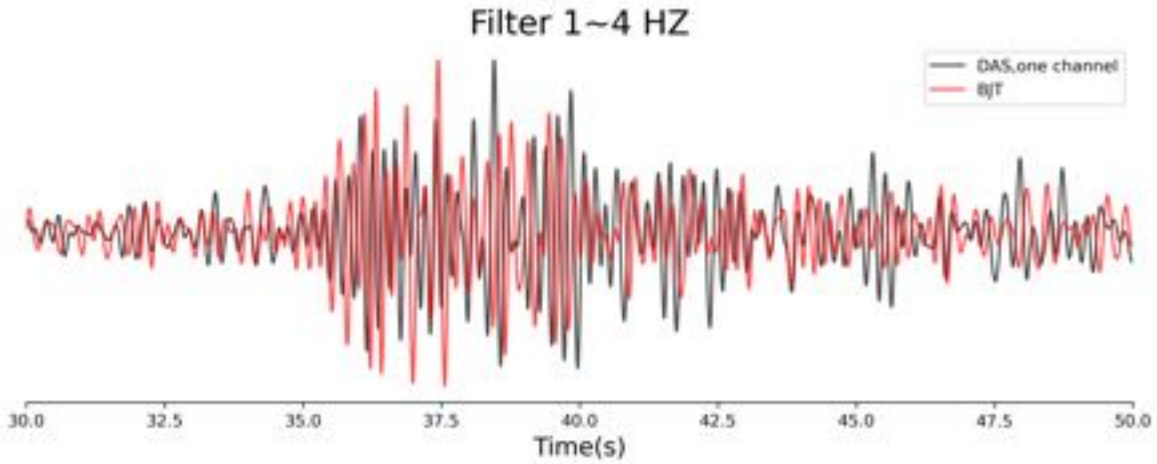


XX.BJT03.01.001.D



波形对比：

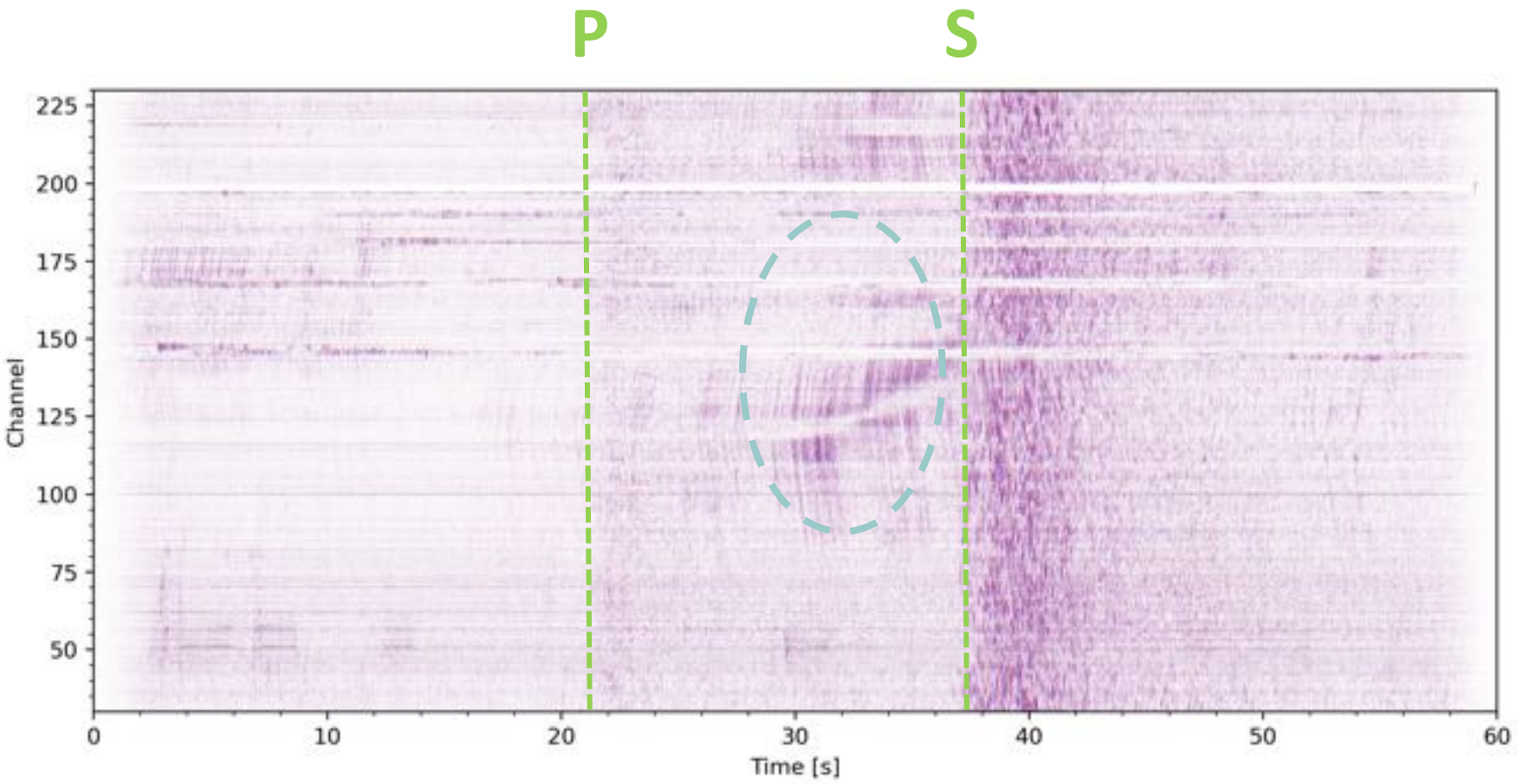

Filter 2~10 HZ
DAS,one channel
BJT
EPS
0
10
20
30
40
50
60
Time(s)

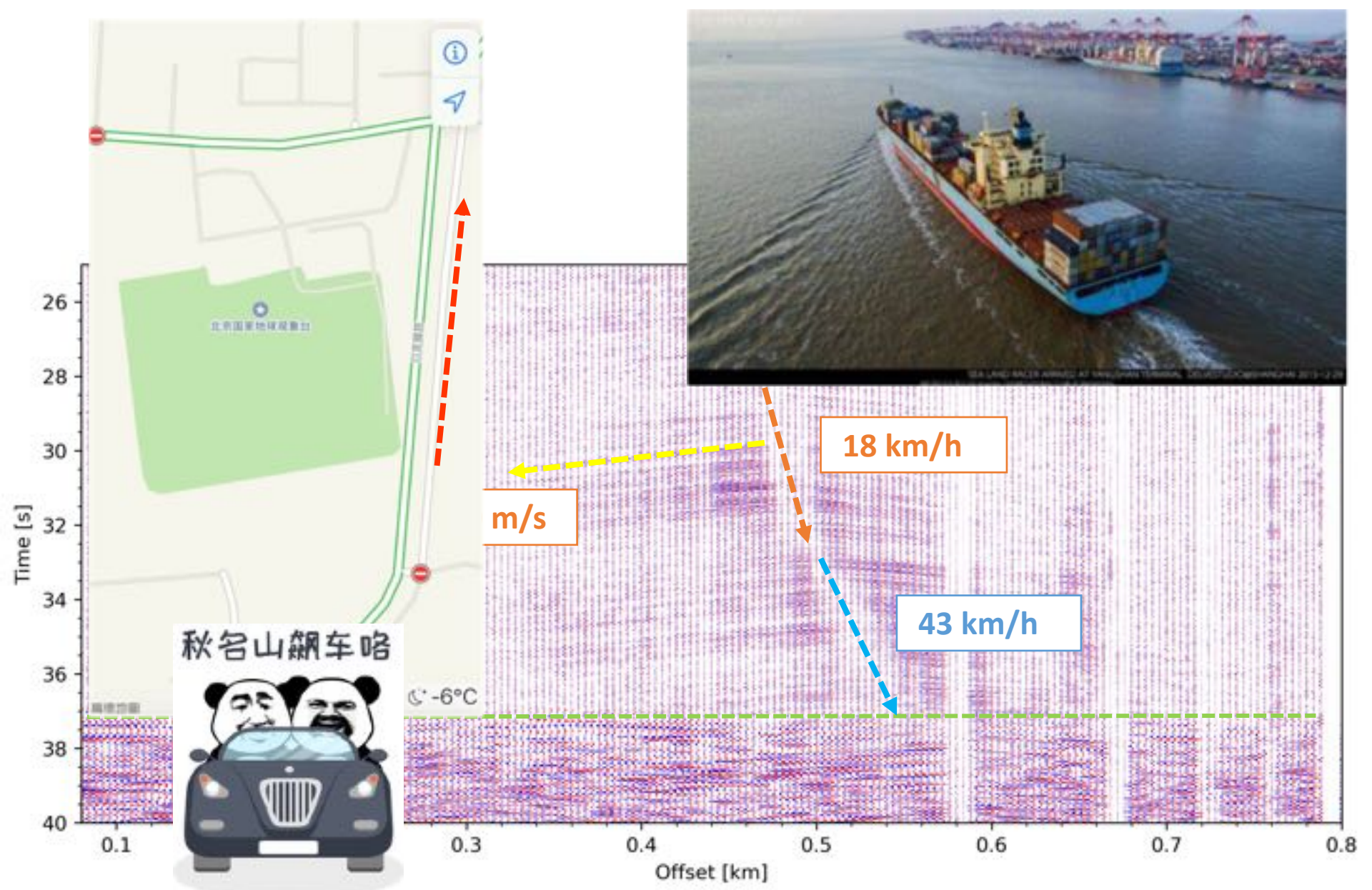

Filter 1~4 HZ
DAS,one channel
BJT
30.0
32.5
35.0
37.5
40.0
42.5
45.0
47.5
50.0
Time(s)

DAS记录信号

事件：20201003111007

震中距：134 km



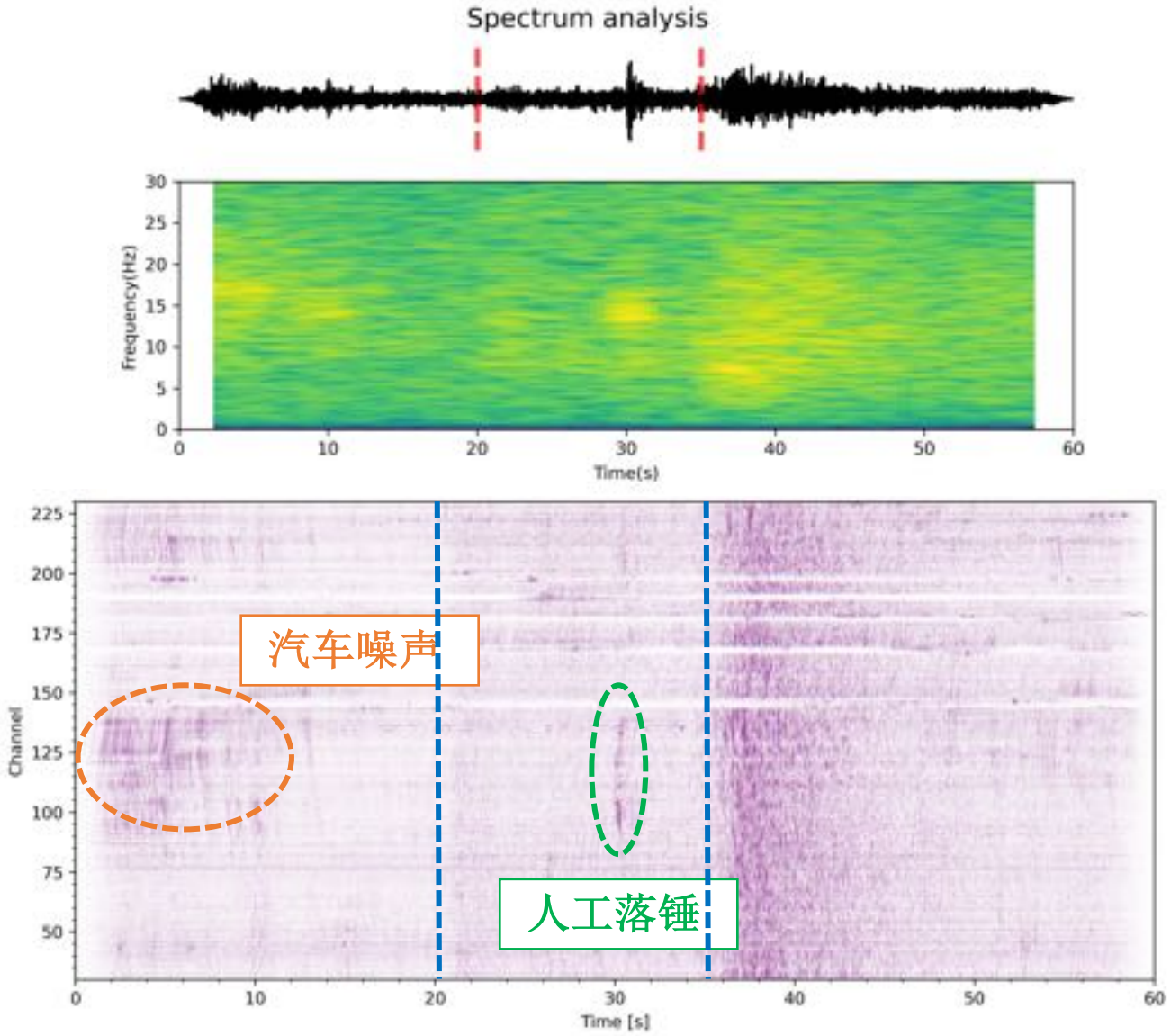

18 km/h
m/s
43 km/h
秋名山飙车咯
-6°C
Time [s]
Offset [km]
26
28
30
32
34
36
38
40
0.1
0.3
0.4
0.5
0.6
0.7
0.8

交通监测

天然地震信号

事件：20201002121230

震中距：122 km

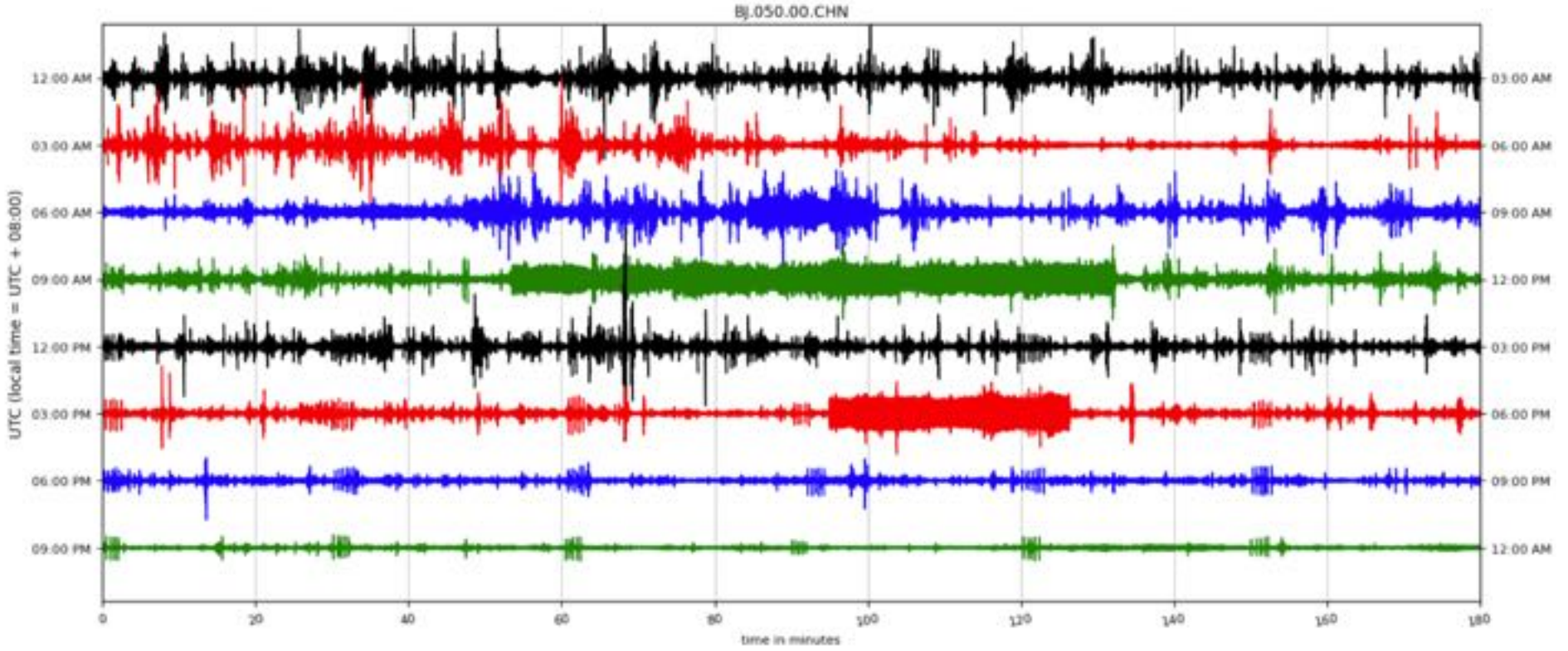


周边噪声信号

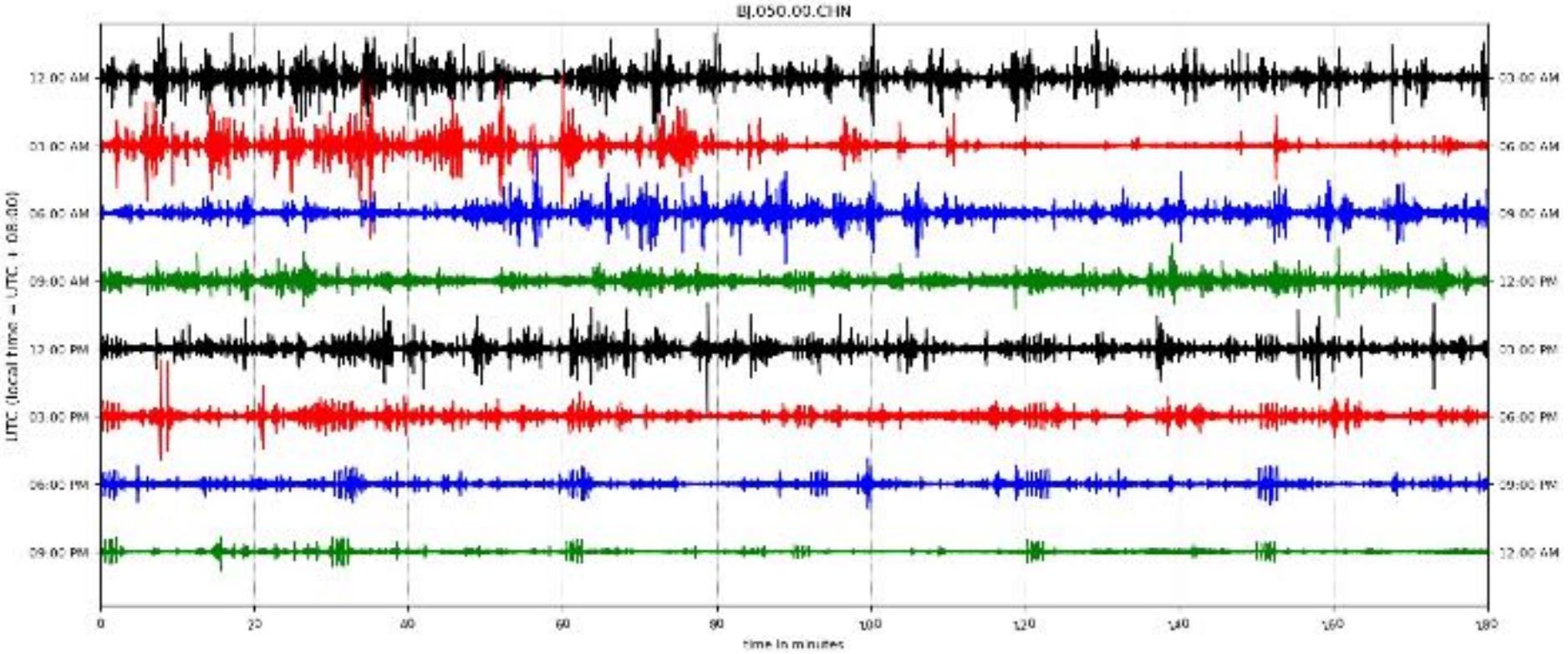
日期：10月04日

DAS道号：050

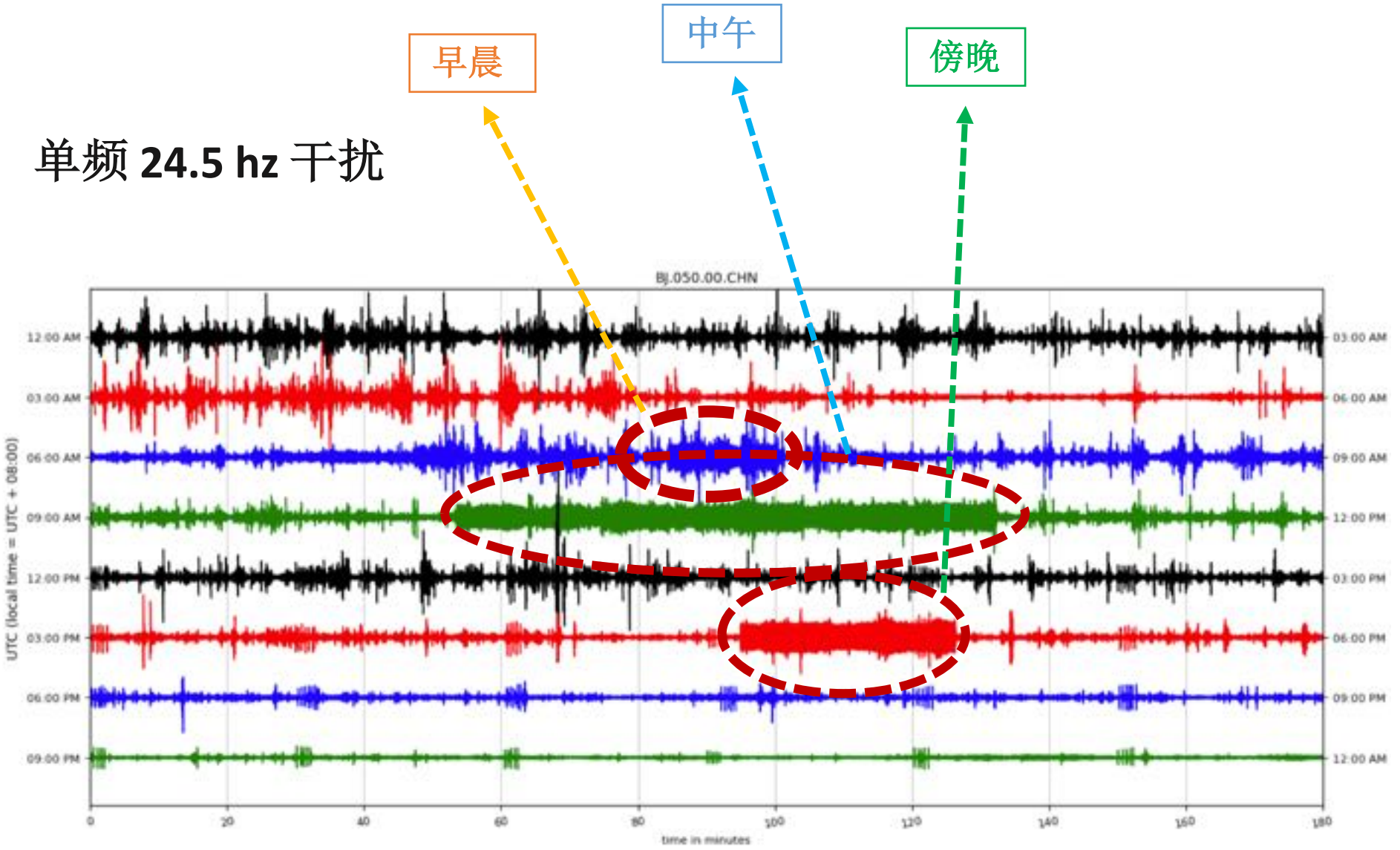
原始记录



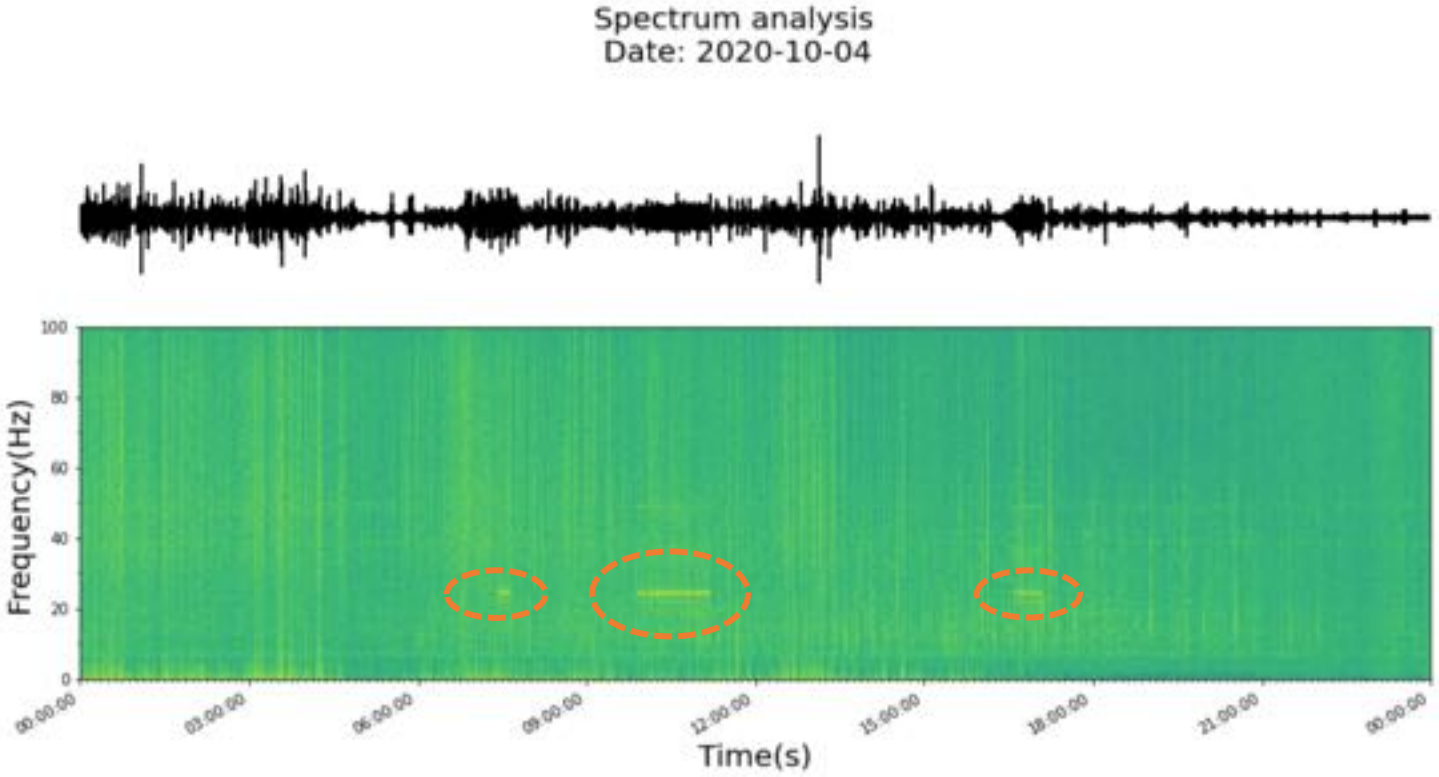
滤波 0–20 Hz 后


BJ.050.00.CHN
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
UTC (local time = UTC + 08:00)
0
20
40
60
80
100
120
140
160
180
time in minutes

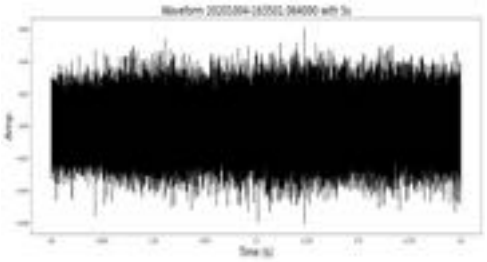
单频 24.5 hz 干扰

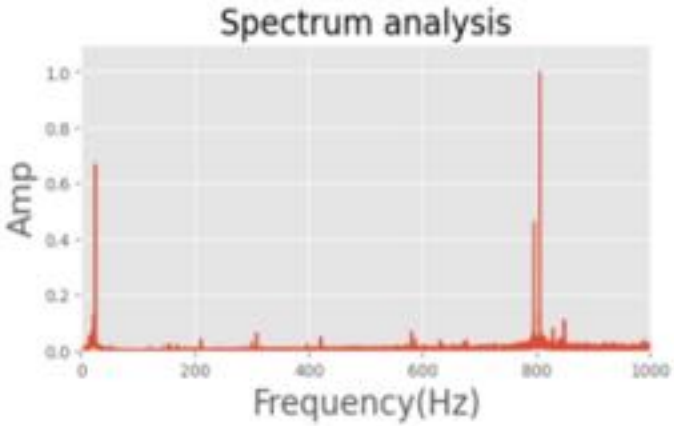

早晨
中午
傍晚
BJ.050.00.CHN
UTC (local time = UTC + 08:00)
12:00 AM
03:00 AM
06:00 AM
09:00 AM
12:00 PM
03:00 PM
06:00 PM
09:00 PM
12:00 AM
0
20
40
60
80
100
120
140
160
180
time in minutes

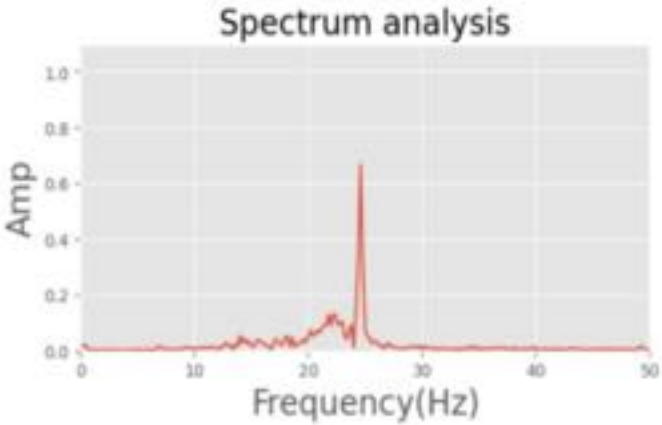
时频分析：



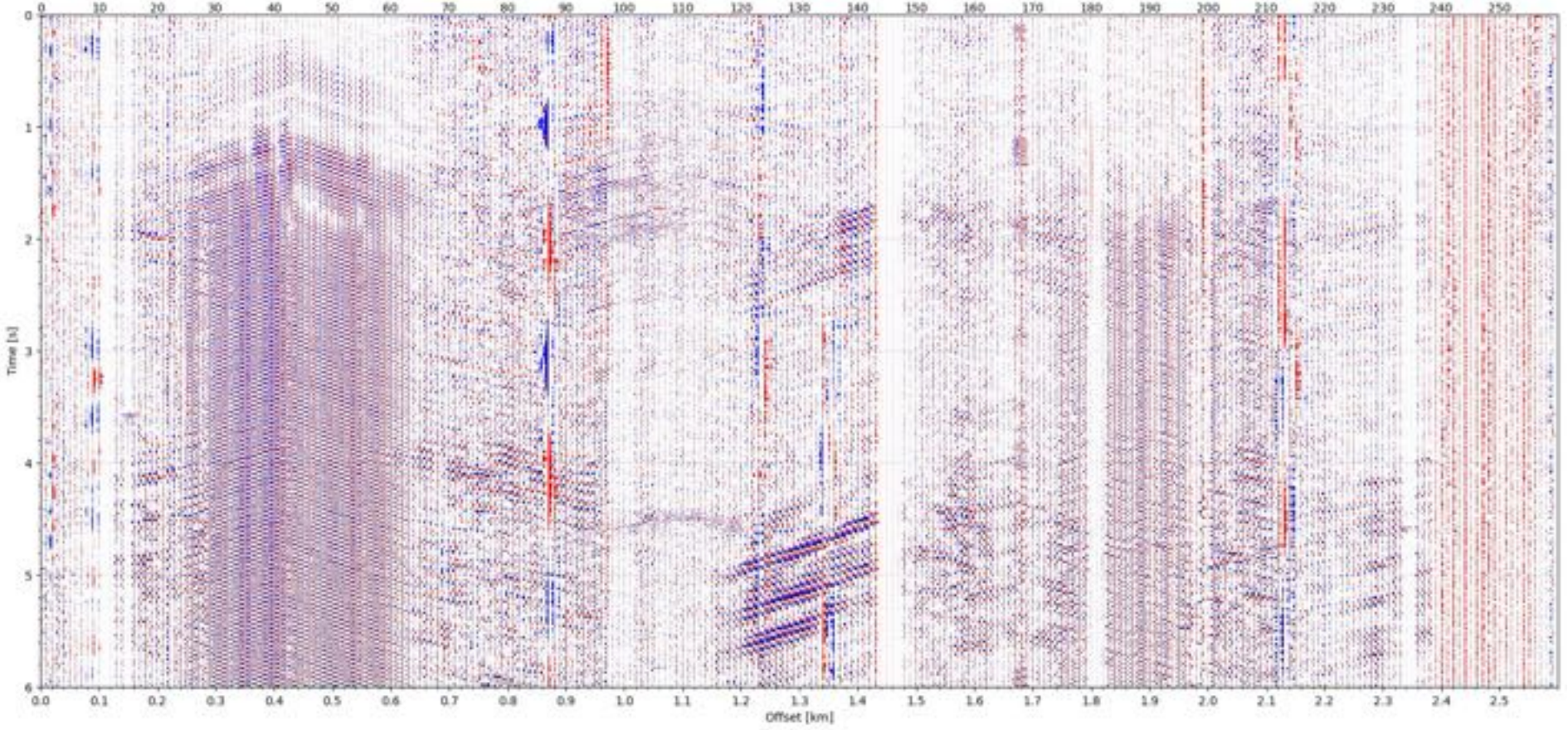
20k 采样数据





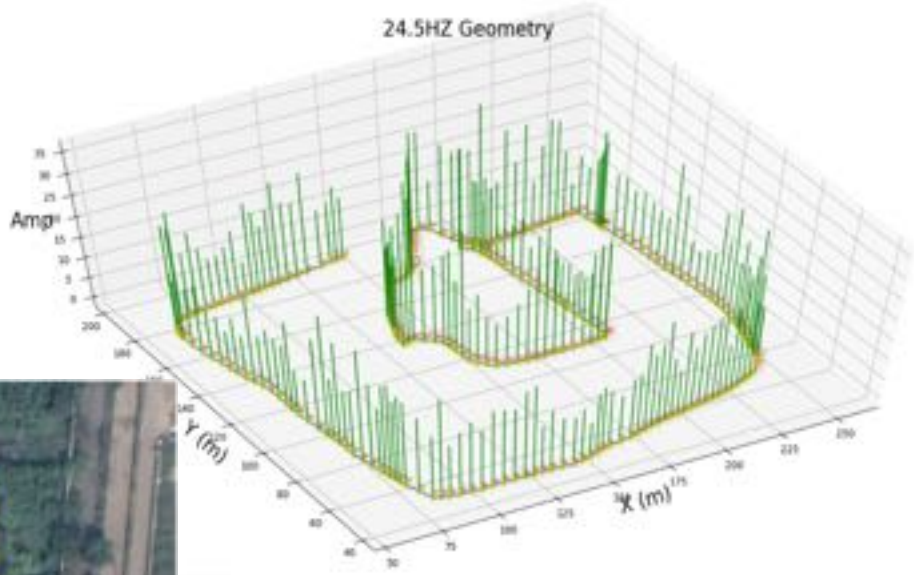


- 单频 **24.5 hz** 干扰波形
- 记录长度 **6** 秒

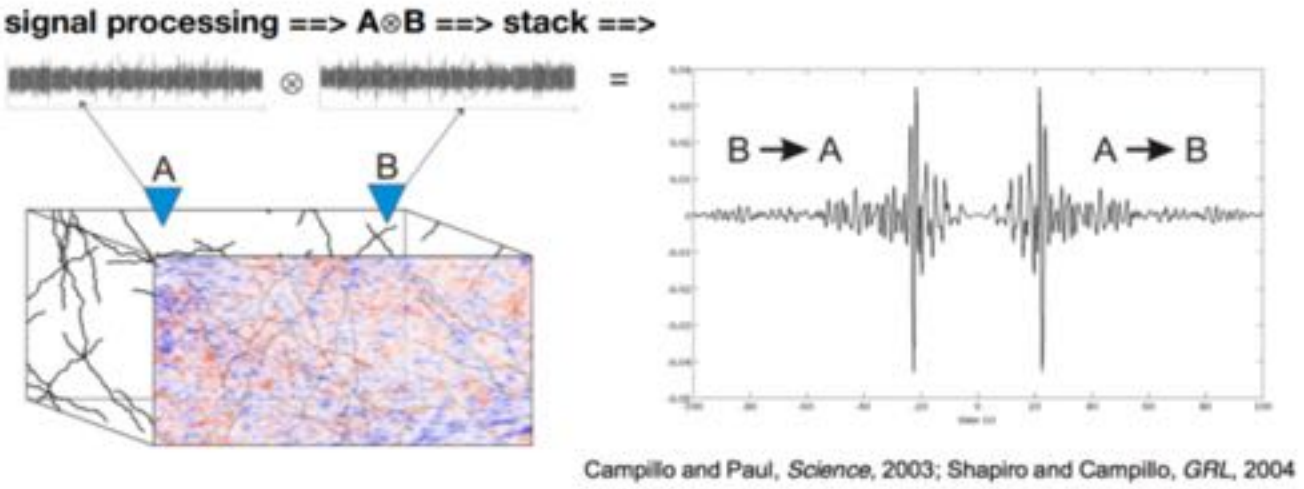


- 单频 **24.5 hz** 干扰时空强度

厨房抽油烟机/固定转速水泵？？

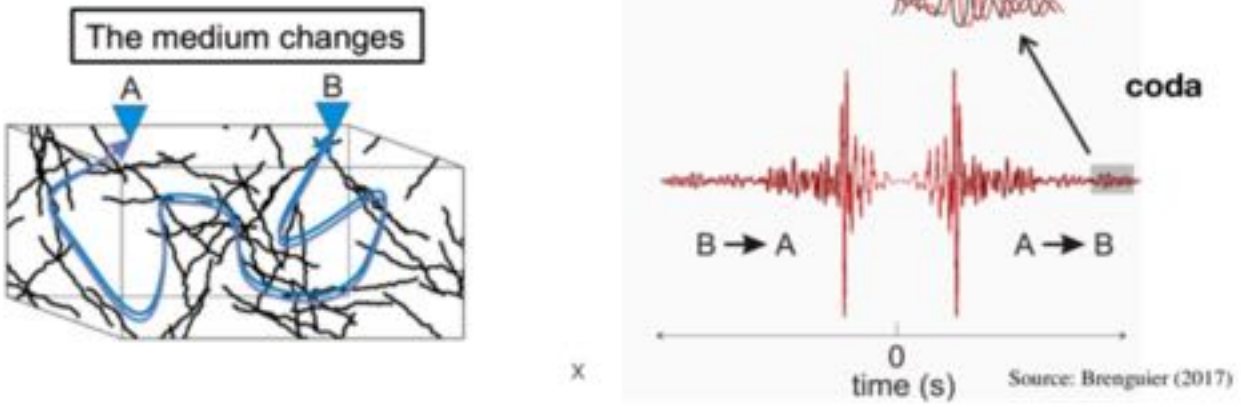


背景噪声面波成像

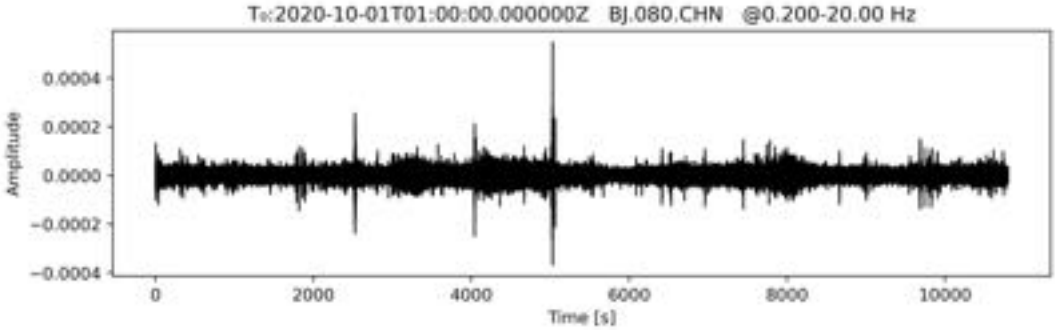


Campillo and Paul, *Science*, 2003; Shapiro and Campillo, *GRL*, 2004

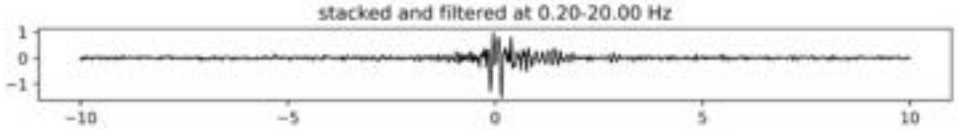
Temporal changes of seismic wave velocity at depth ==> characterize the deformation rate?



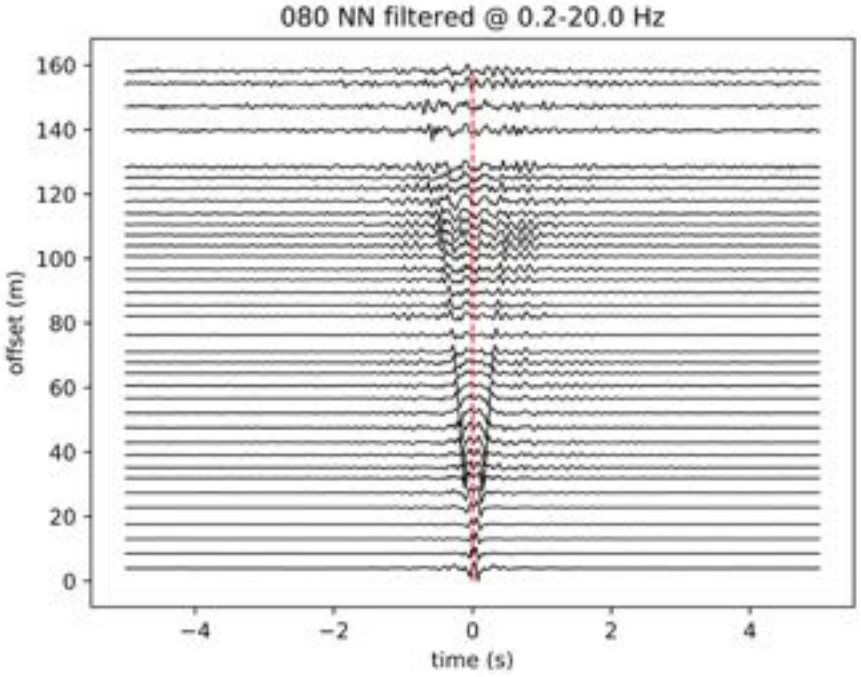
a.

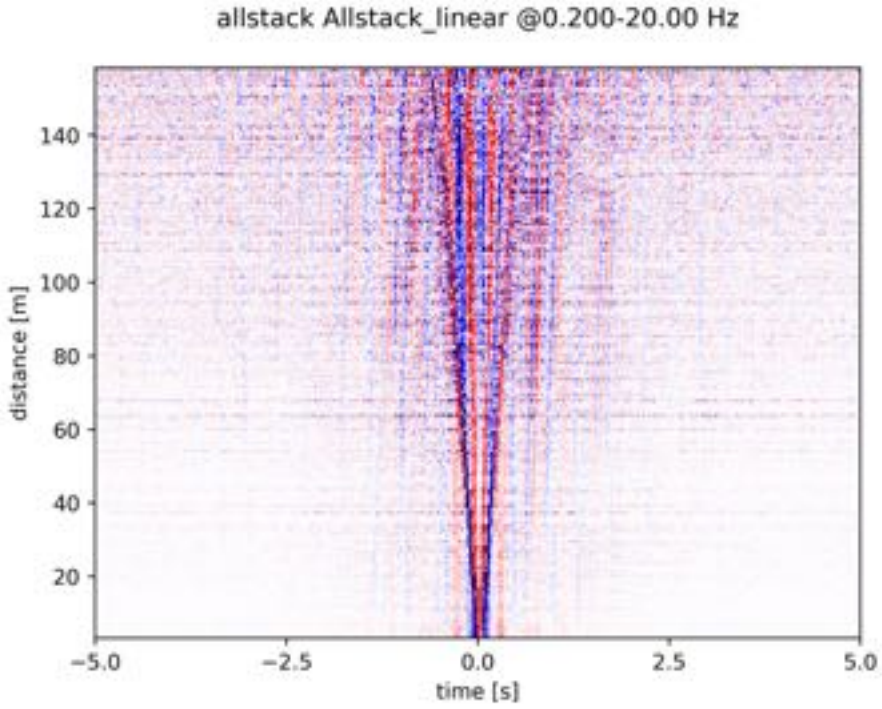

T0:2020-10-01T01:00:00.000000Z BJ.080.CHN @0.200-20.00 Hz
Amplitude
0.0004
0.0002
0.0000
−0.0002
−0.0004
0
2000
4000
6000
8000
10000
Time [s]

b.

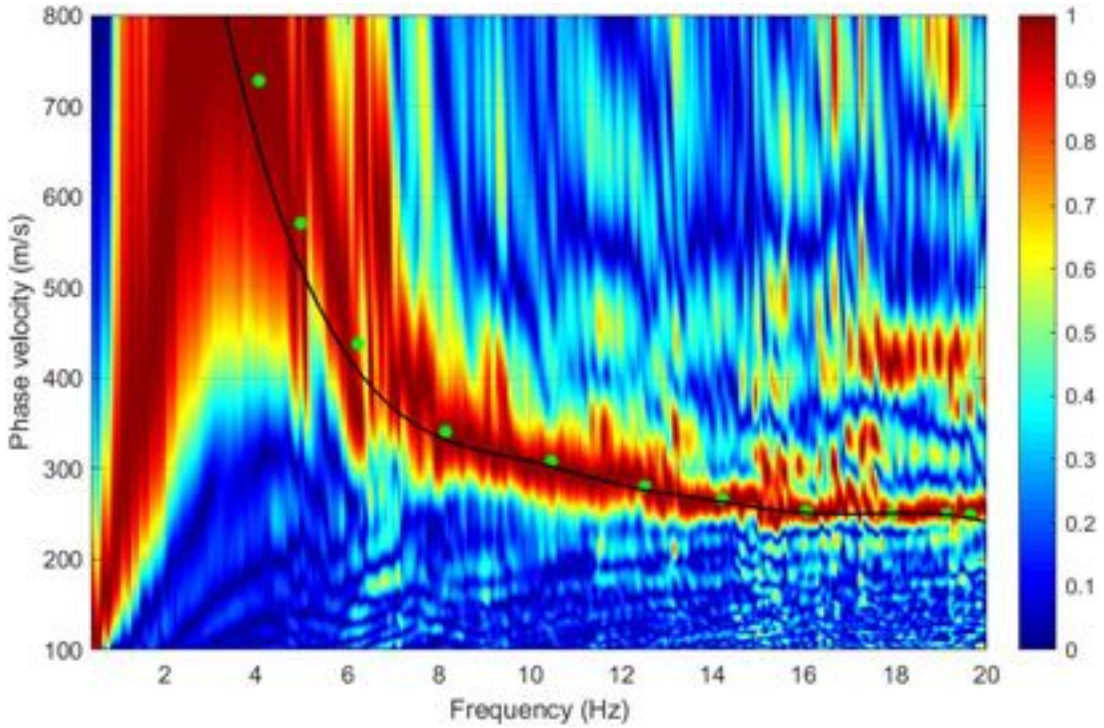

stacked and filtered at 0.20-20.00 Hz
1
0
−1
−10
−5
0
5
10

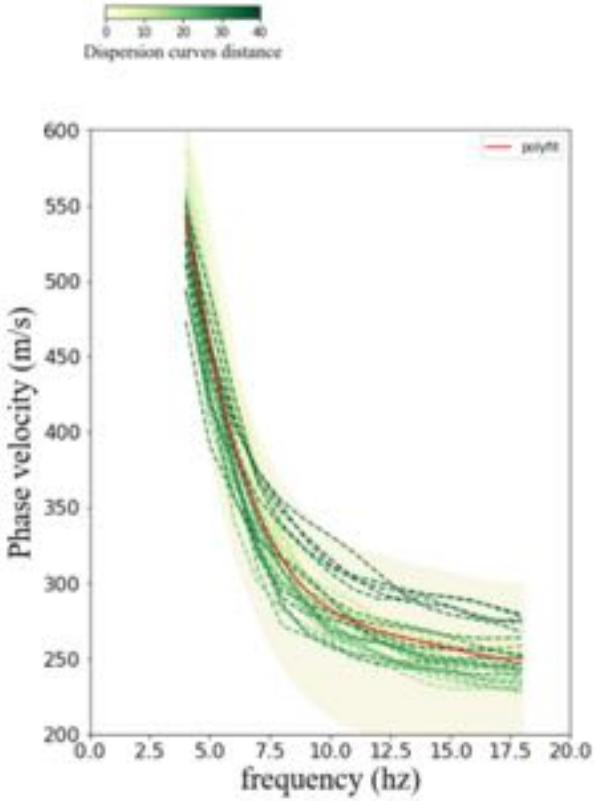
c.


080 NN filtered @ 0.2-20.0 Hz
offset (m)
160
140
120
100
80
60
40
20
0
−4
−2
0
2
4
time (s)

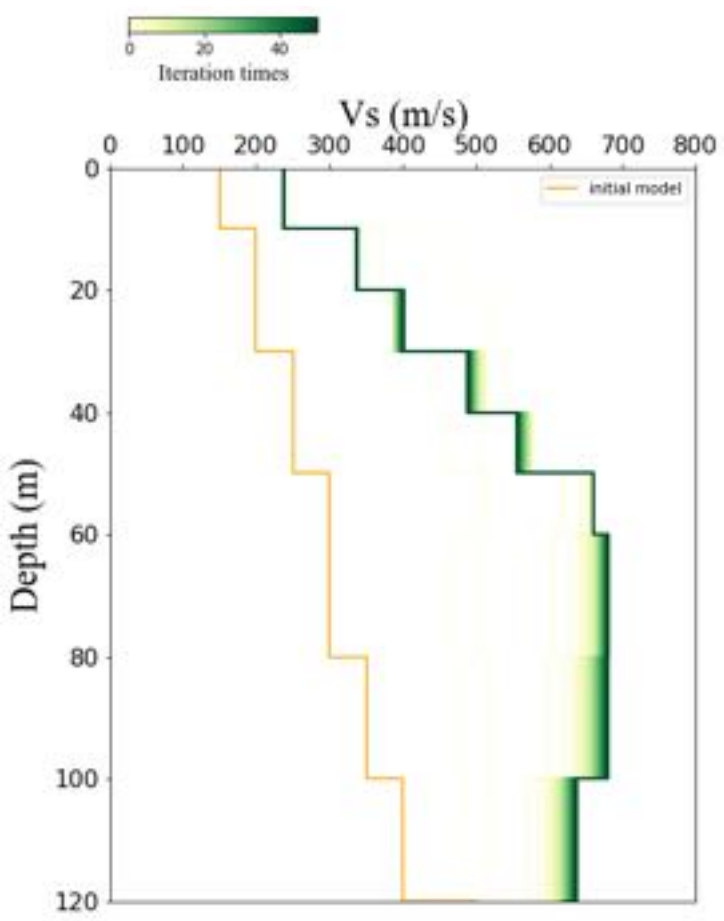

allstack Allstack_linear @0.200-20.00 Hz
distance [m]
140
120
100
80
60
40
20
−5.0
−2.5
0.0
2.5
5.0
time [s]

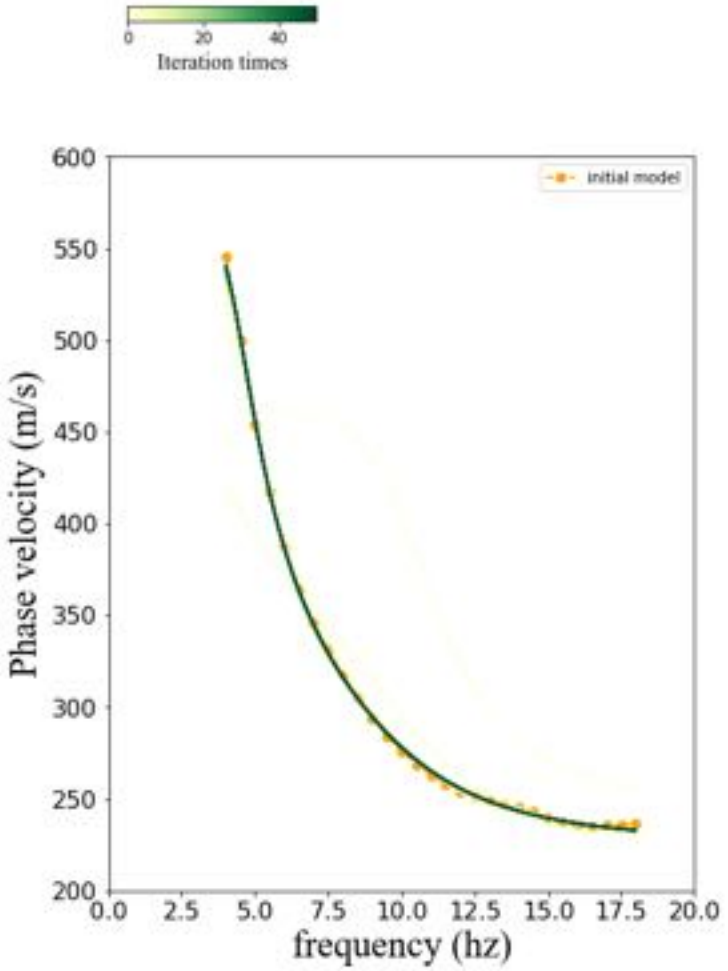
频散曲线提取


Phase velocity (m/s)
Frequency (Hz)

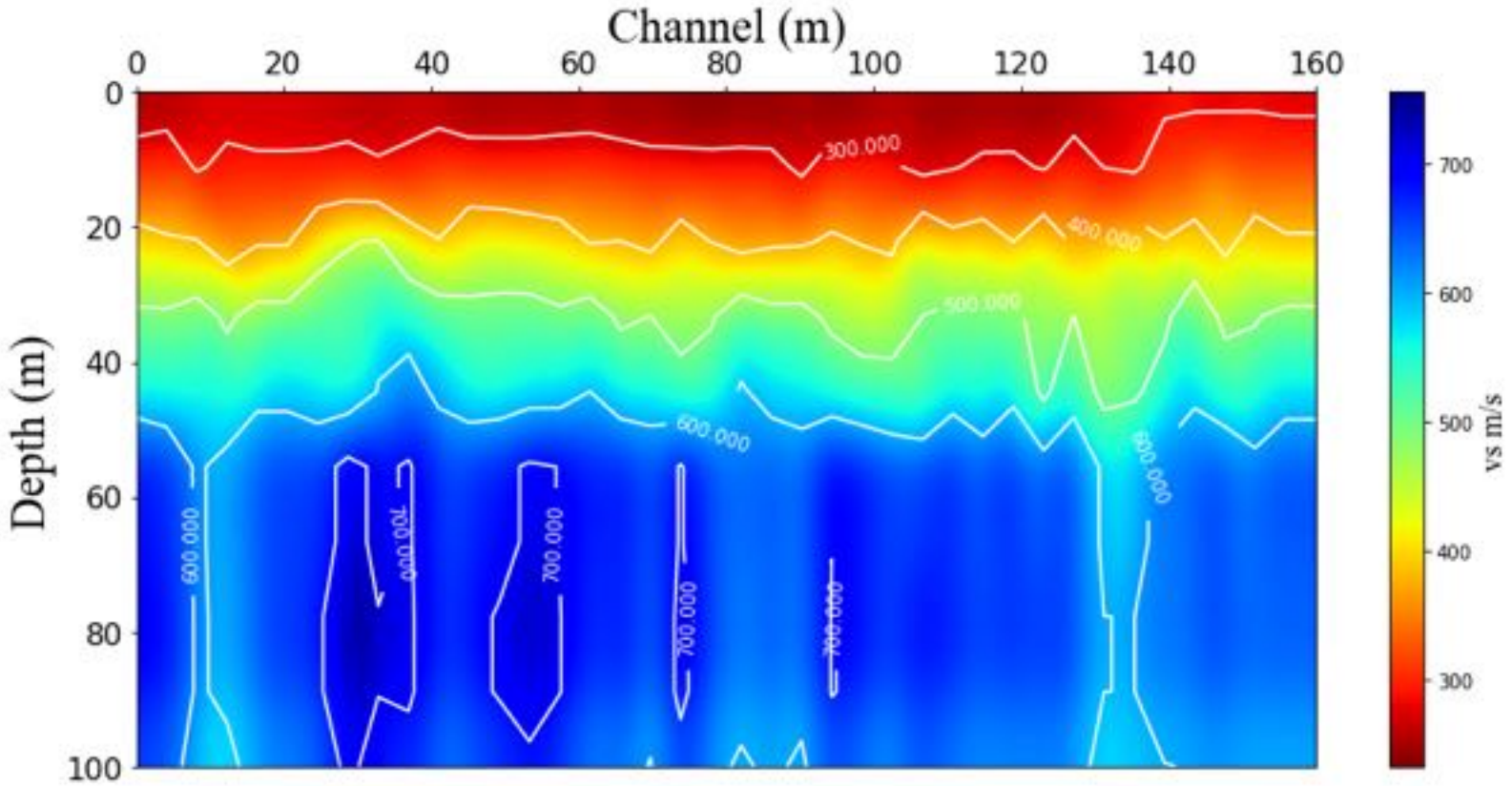

Dispersion curves distance
Phase velocity (m/s)
frequency (hz)
polyfit

S波速度反演


Iteration times
0
20
40
Vs (m/s)
0
100
200
300
400
500
600
700
800
Depth (m)
0
20
40
60
80
100
120
initial model


Iteration times
0
20
40
Phase velocity (m/s)
600
550
500
450
400
350
300
250
200
frequency (hz)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
initial model

DAS测线下方 S波速度剖面



总结

- 观测到交通、锤击和天然地震等信号
- 利用DAS技术和光纤可以为城市地下结构探测提供新手段

Thanks !