



2023-地震学算法与程序培训班

S波接收函数通用提取策略原理及其应用



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2023年07月25日

广告

中国科学院广州地球化学研究所

一级学科博士培养点

2022新增

地质学

环境科学与工程

地球物理学

欢迎老师来指导、交流

欢迎学生报考

深地过程与战略矿产资源
重点实验室（重组）

汇报提纲

一、研究背景

二、方法思路

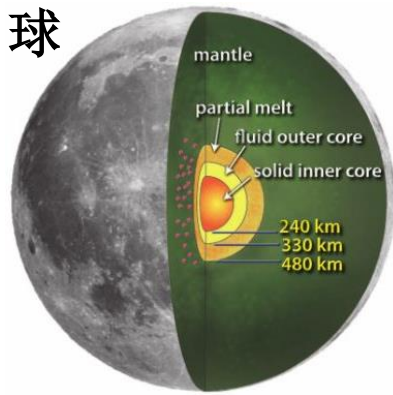
三、应用实例

四、展望

一、研究背景：岩石圈厚度-地质演化过程的钥匙

岩质星球具有圈层结构特征

月球

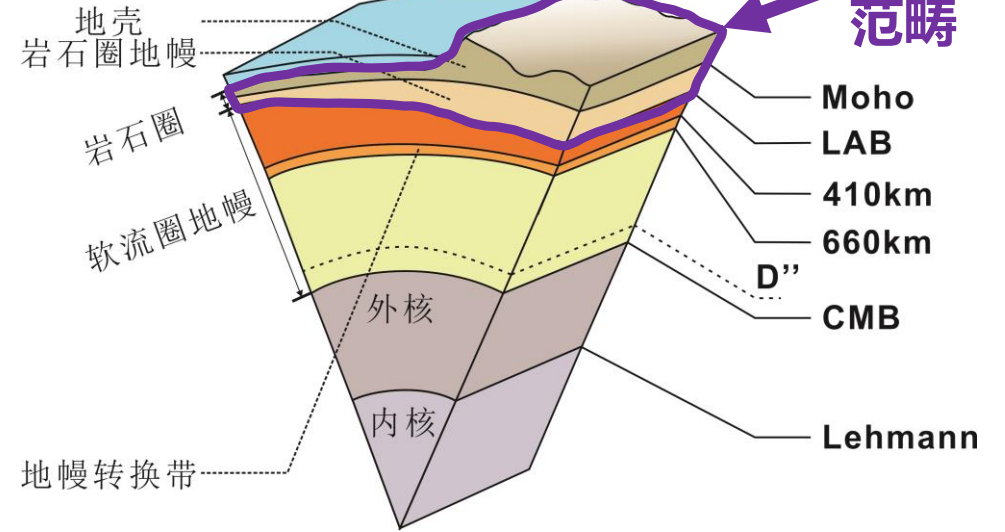


火星

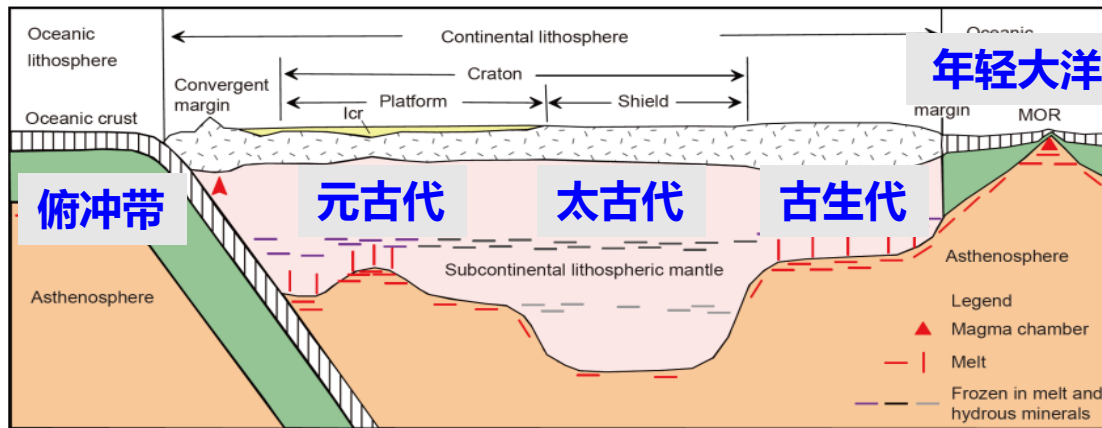


Science.com

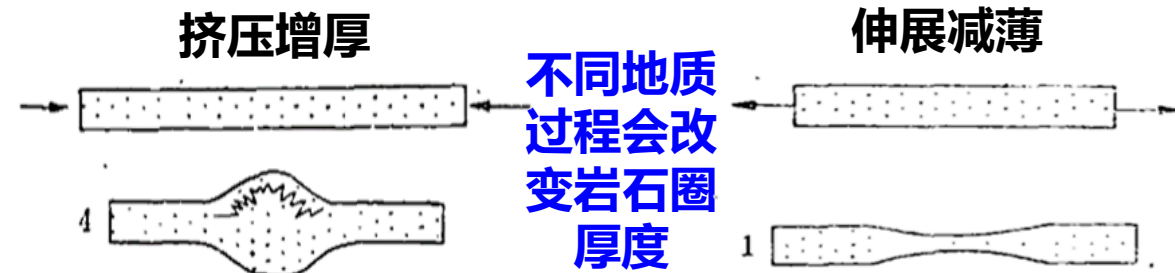
地球的圈层结构



岩石圈厚度 (LAB) 探测—地质演化过程的钥匙

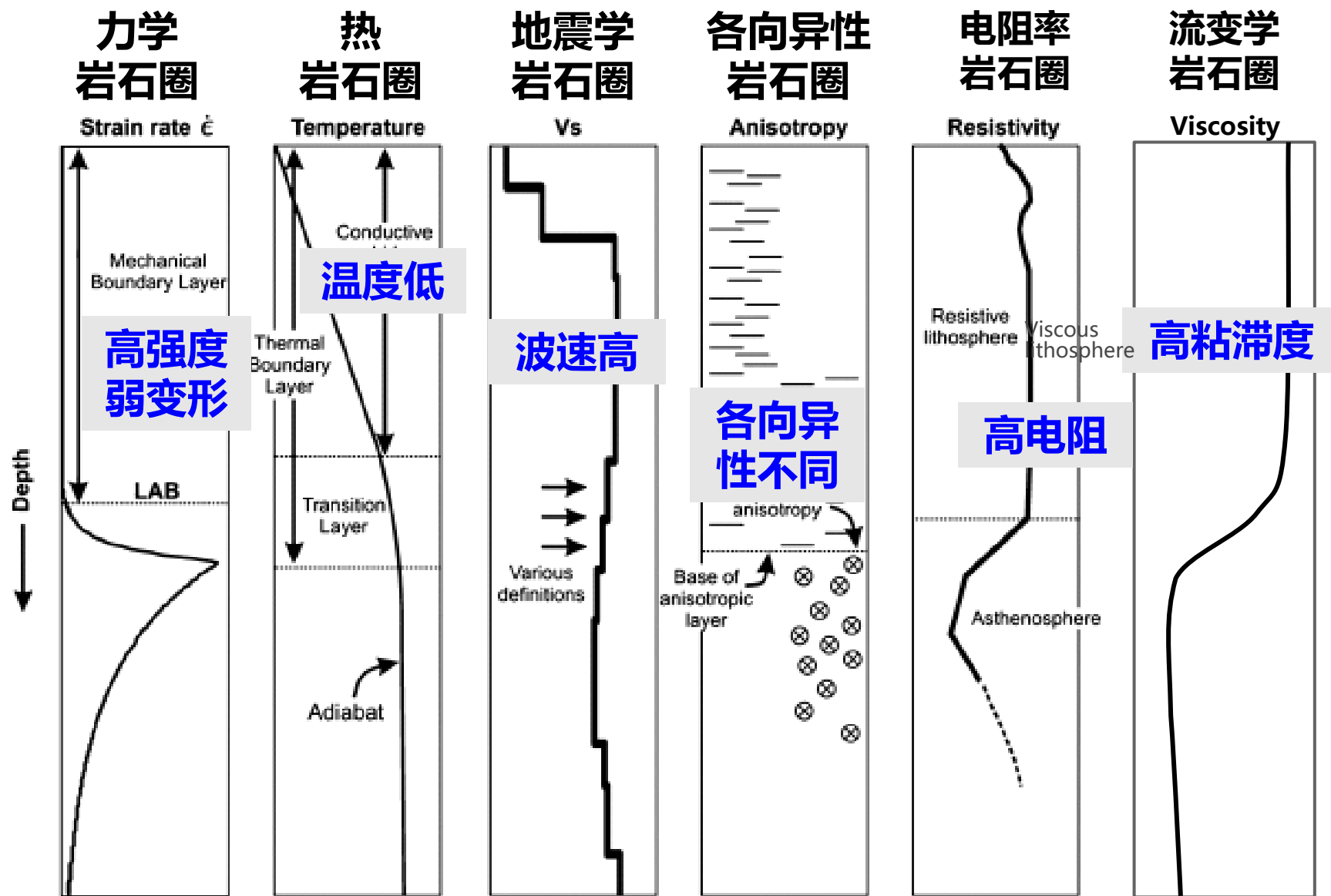


Cawood et al., 2013 不同时期的块体对应不同的岩石圈厚度



马杏垣等, 1983

一、研究背景：不同岩石圈属性的定义



一、研究背景：不同岩石圈属性的定义

力学岩石圈(Mechanical lithosphere): 与对流的软流圈完全隔离的地球最外层刚性部分。在典型地幔应力条件下(1MPa), 经地质时间尺度(10^8 年)其变形不超过1% (板块构造理论) ;

热岩石圈(Thermal lithosphere): 具有热传导温度梯度的地球外壳, 热传导地温线与地幔绝热地温线相交的深度定义为岩石圈底界面, 其中与地幔绝热线对应的地表温度 (地幔潜在温度, potential temperature) T_m 的选取范围为 1200°C - 1450°C , 多为 1300°C ;

地震学岩石圈(Seismic lithosphere): 由地震波速定义, 指位于低速软流圈上的高速盖层;

弹性岩石圈(Elastic lithosphere): 在负载作用下, 百万年时间尺度上表现为完全弹性的地球外层部分;

化学岩石圈(Chemical lithosphere): 由于化学成分上的差别而比软流圈轻的, 同时缺水的, 因而稳定的具有低流变性的地球外壳, 又称为化学边界层;

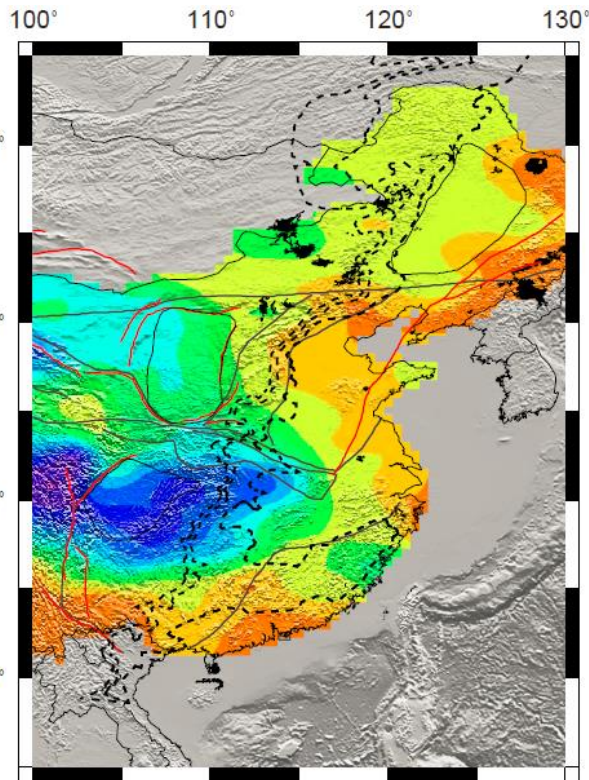
岩石学岩石圈(Petrological lithosphere): 由岩石矿物成分的变化来定义岩石圈和软流圈, 如将元素Y在石榴石中的亏损与富集作为指标, 石榴石中Y含量在10 ppm以下的为岩石圈特征, 否则为软流圈特征;

电性岩石圈(Electric lithosphere): 岩石圈的导电性与温度有着极其密切的关系, 随温度增加而迅速增大。岩石圈在与软流圈的分界面处表现为导电性的迅速增加。

一、研究背景：本课题组有关岩石圈厚度探测的工作

热岩石圈、弹性均衡岩石圈、地震波衰减以及地震学岩石圈数值存在差异性，相互印证，揭示岩石圈底界的强烈不均一性、中国东部具有明显薄的岩石圈。

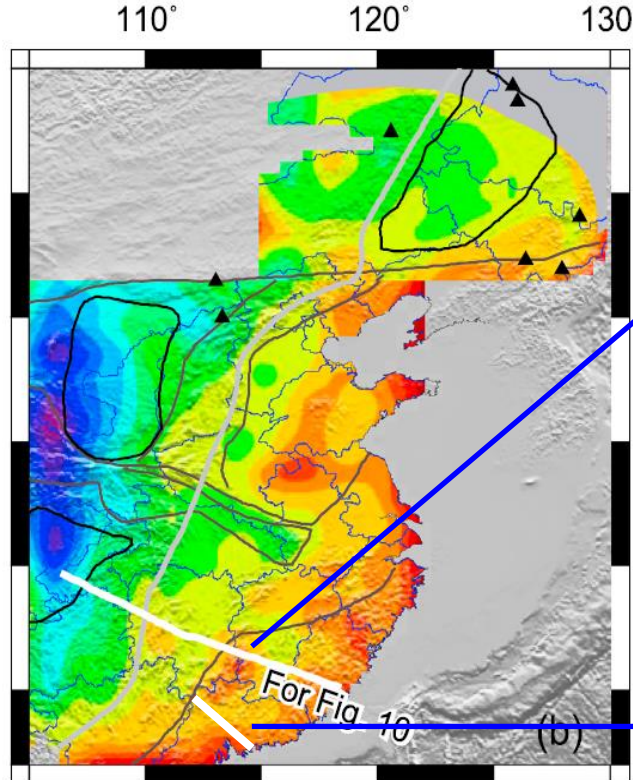
热岩石圈厚度



60 80 100 120 140 160 180 200 km

Deng and Tesauro, 2016

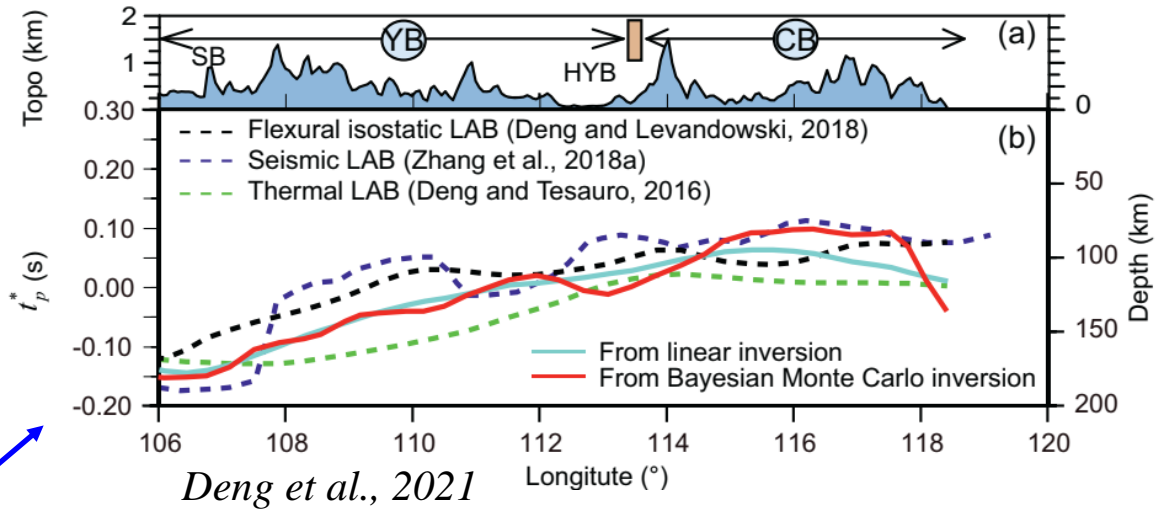
弹性均衡岩石圈厚度



80 120 160 200 km

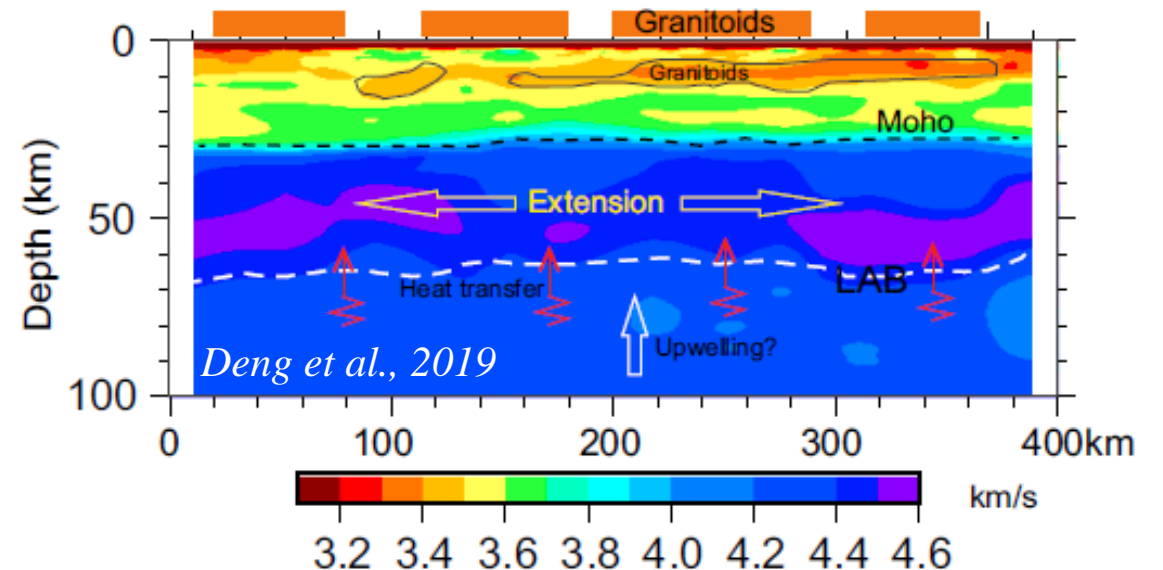
Deng and Levandowski, 2018

远震体波衰减



Deng et al., 2021

地震学联合反演

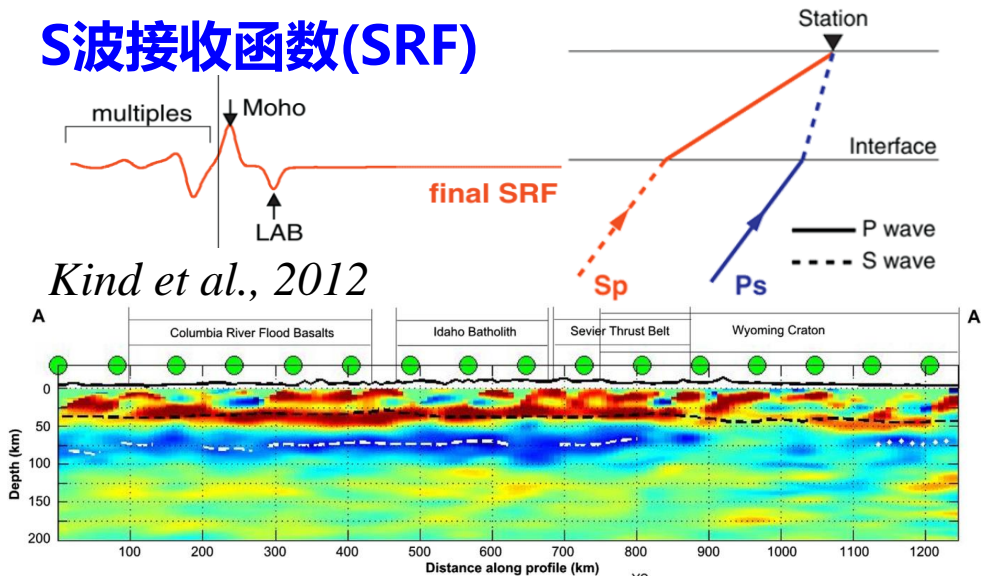


Deng et al., 2019

3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 km/s

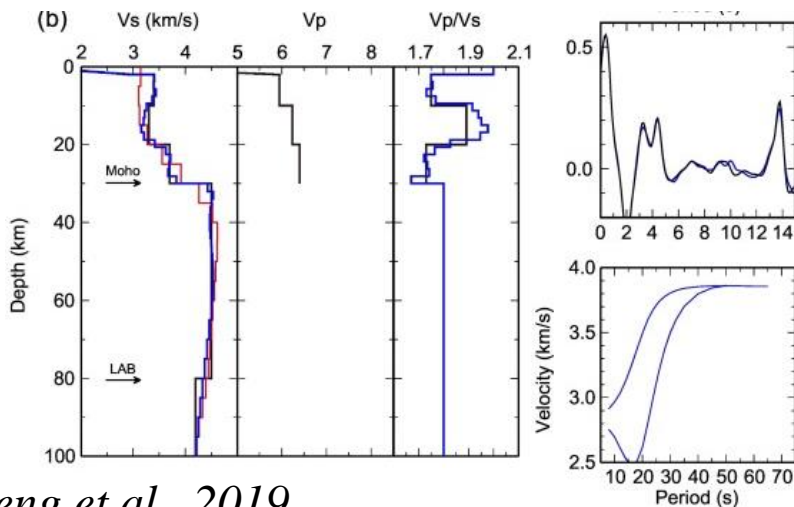
一、研究背景：地震学是岩石圈厚度探测的主要方法

S波接收函数(SRF)

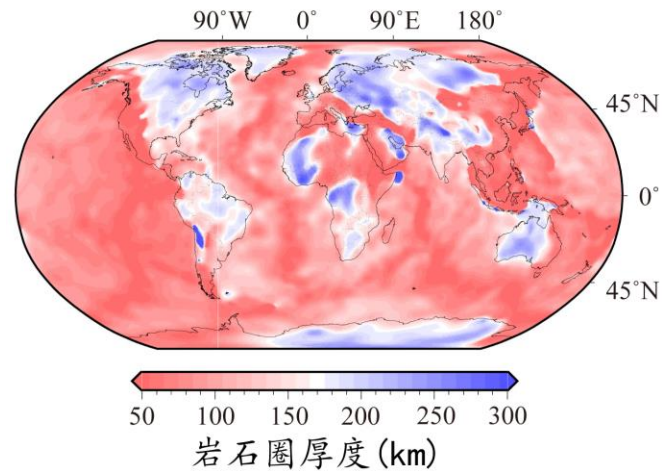


Hopper et al., 2014

联合反演

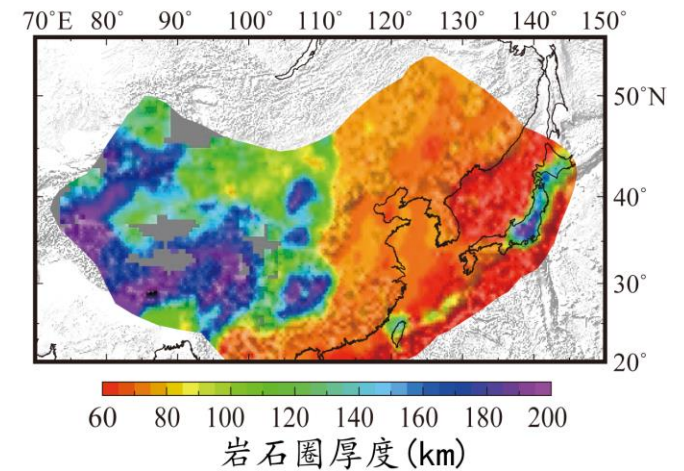


远震面波层析成像



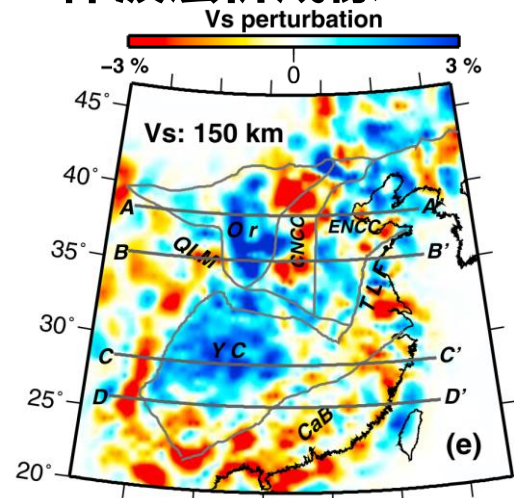
Hoggard et al., 2020

噪声面波层析成像



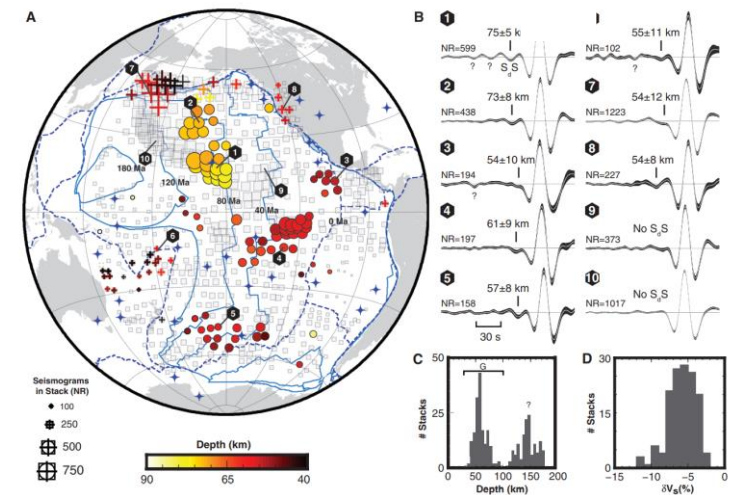
Li et al., 2022

体波层析成像



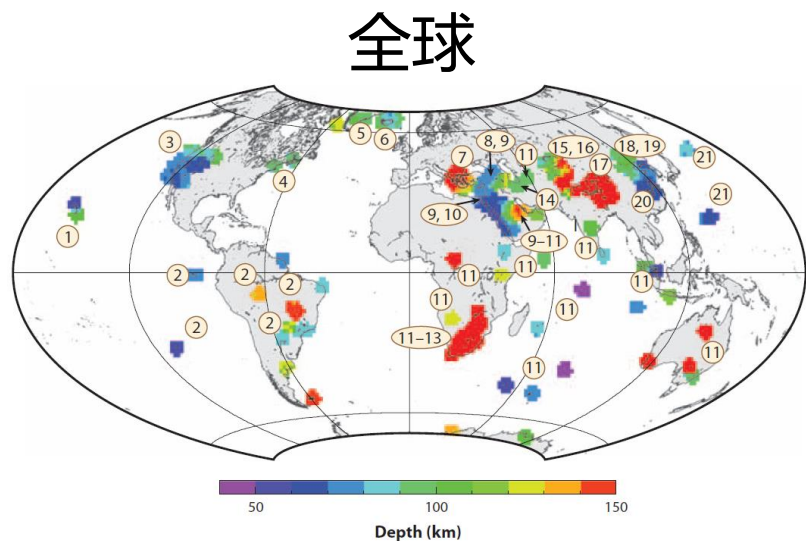
Zhao et al., 2012

SS前驱波



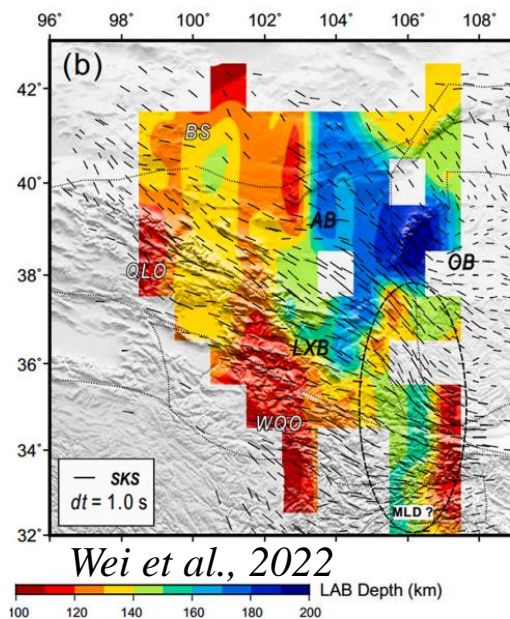
Schmerr, 2012

一、研究背景：S波接收函数是探测地震学LAB的主要方法



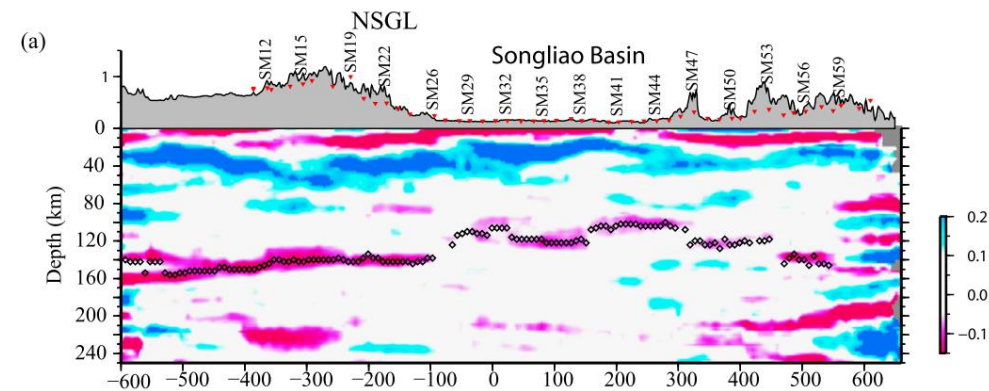
Fischer et al., 2011

青藏高原东北缘



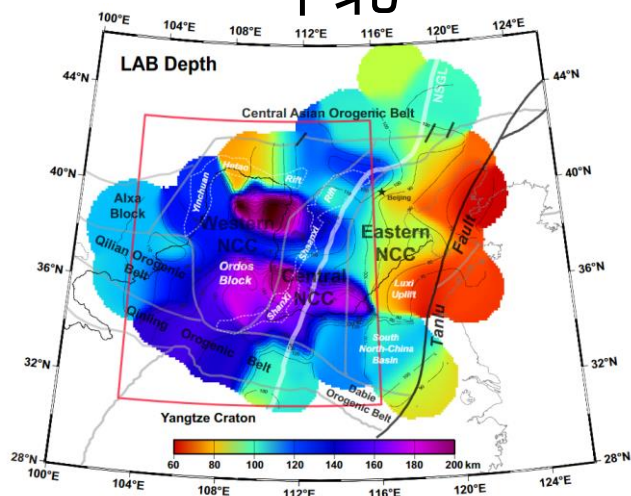
Wei et al., 2022

东北



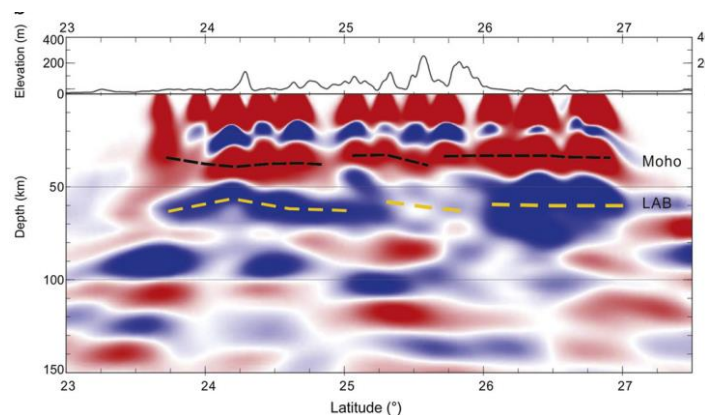
Zhang et al., 2014

华北



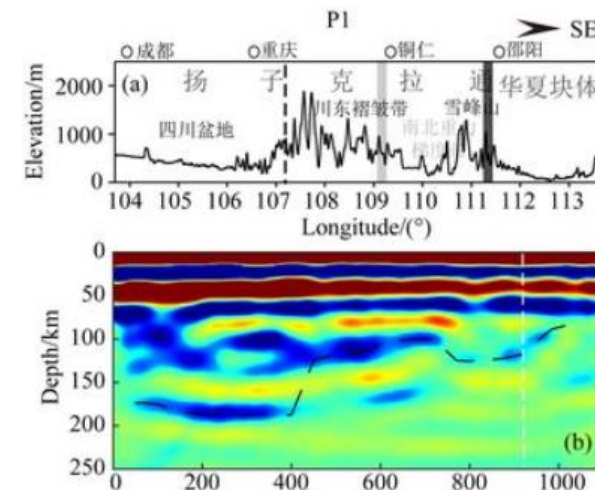
Chen et al., 2019

华南



Li et al., 2013

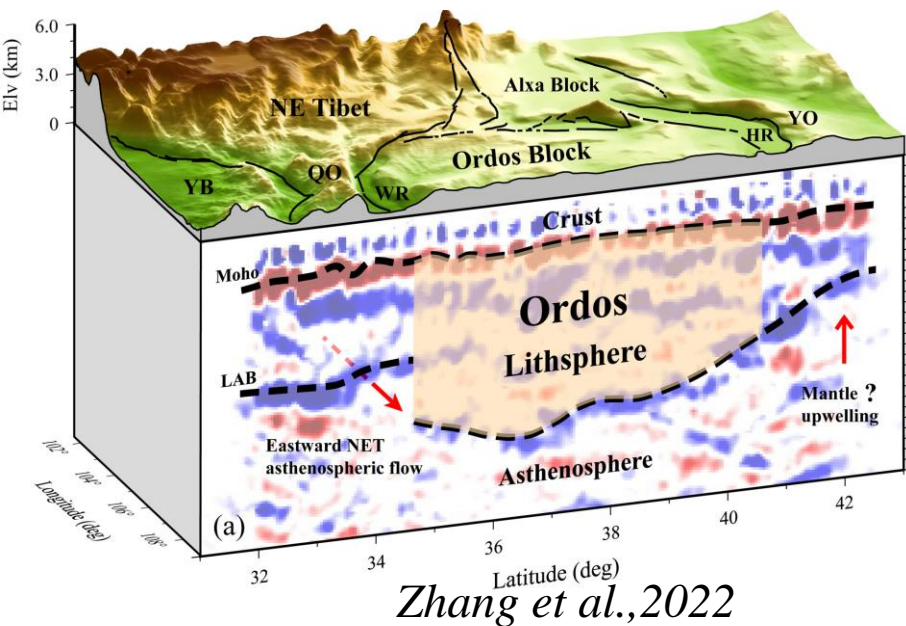
华南



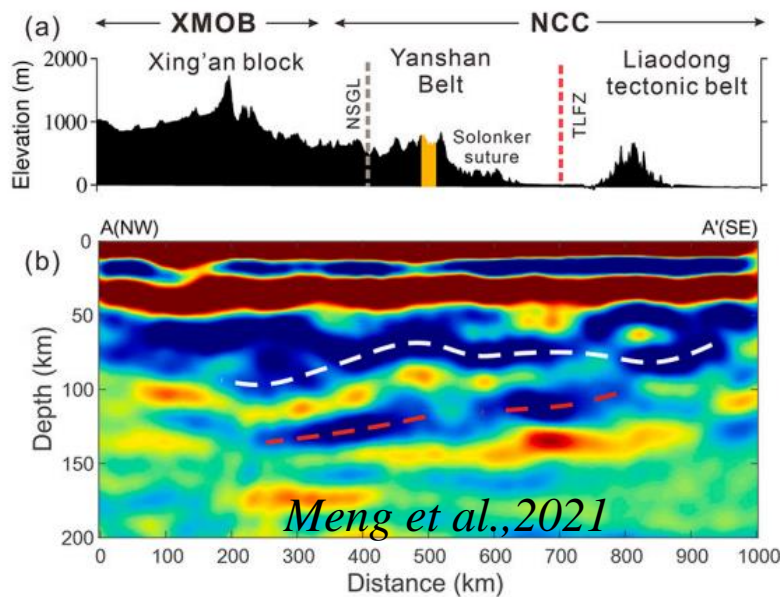
张耀阳等, 2018

一、研究背景：S波接收函数是探测地震学LAB的主要方法

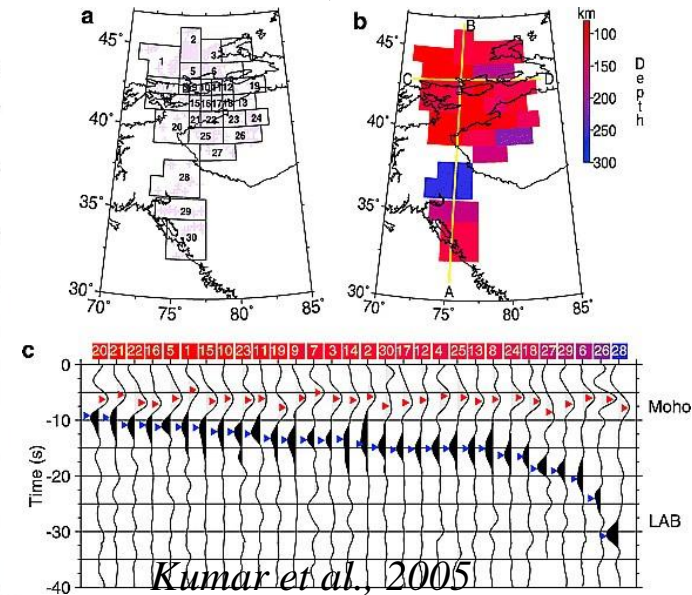
鄂尔多斯



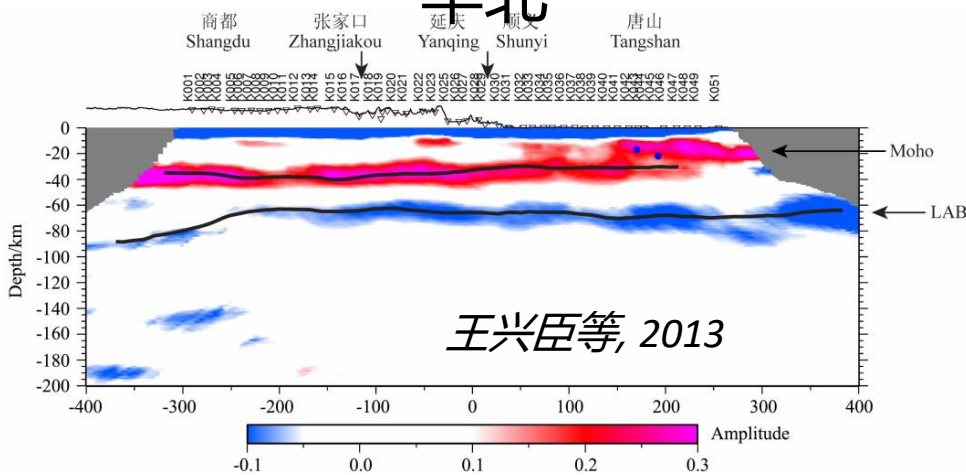
兴蒙造山带



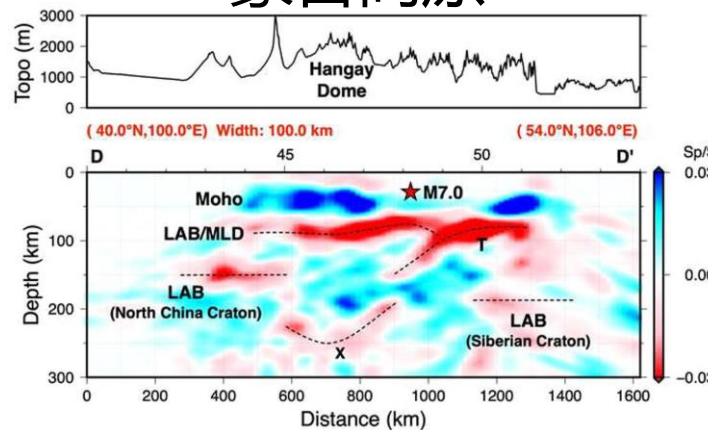
天山



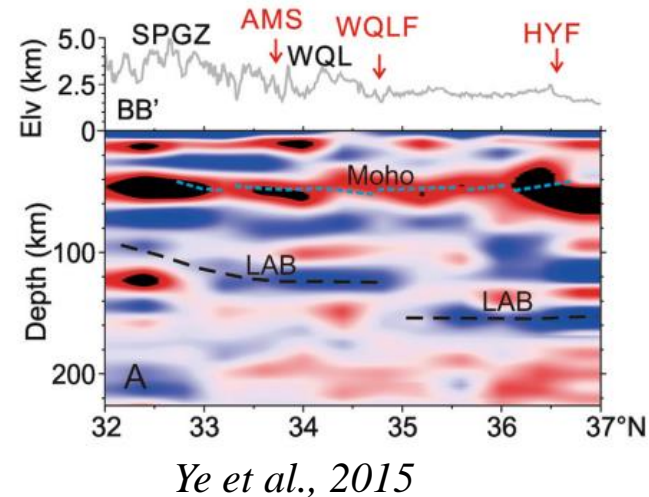
华北



蒙古高原



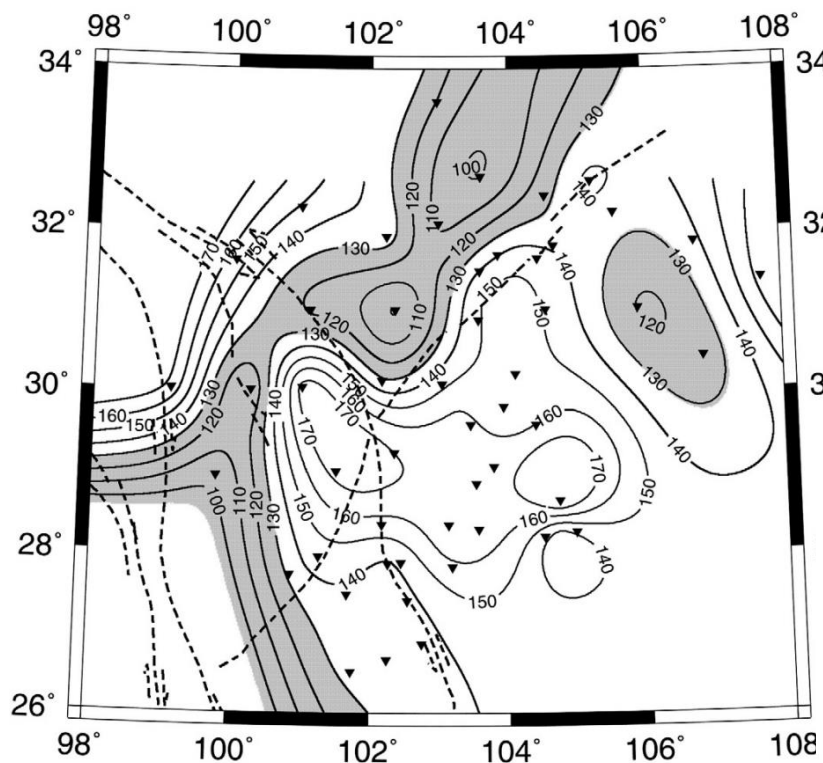
青藏高原东北缘



一、研究背景：不同团队在同一区域的研究结果差异很大

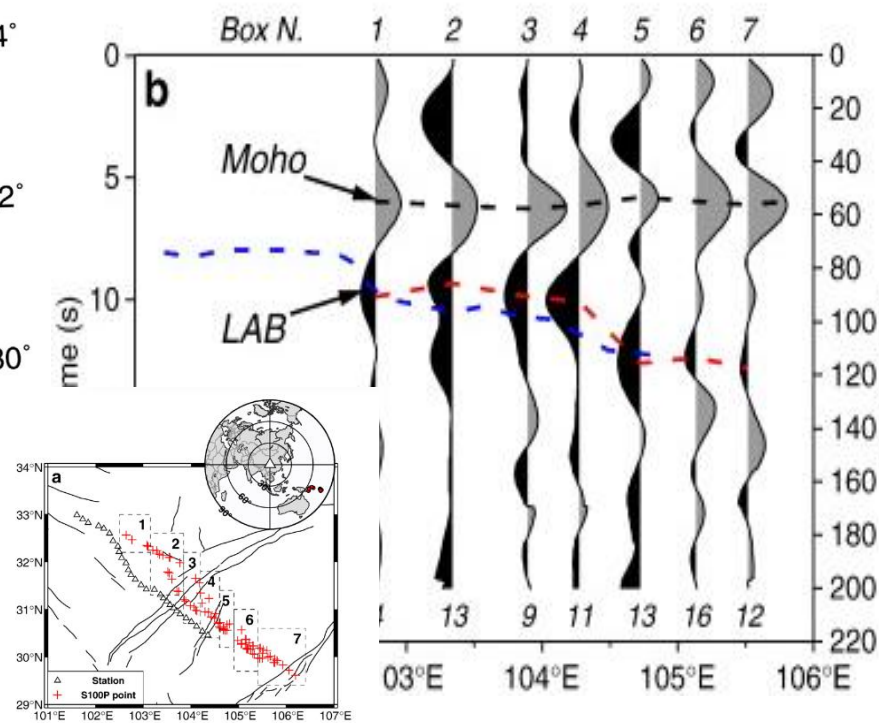
四川盆地

140-170 km



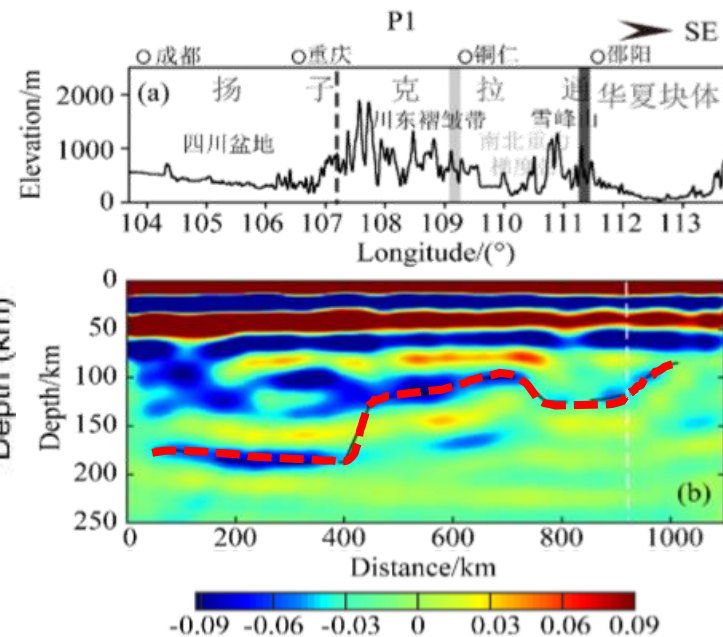
Hu et al. 2011, EPSL

~120 km



Zhang et al. 2010, EPSL

~190 km



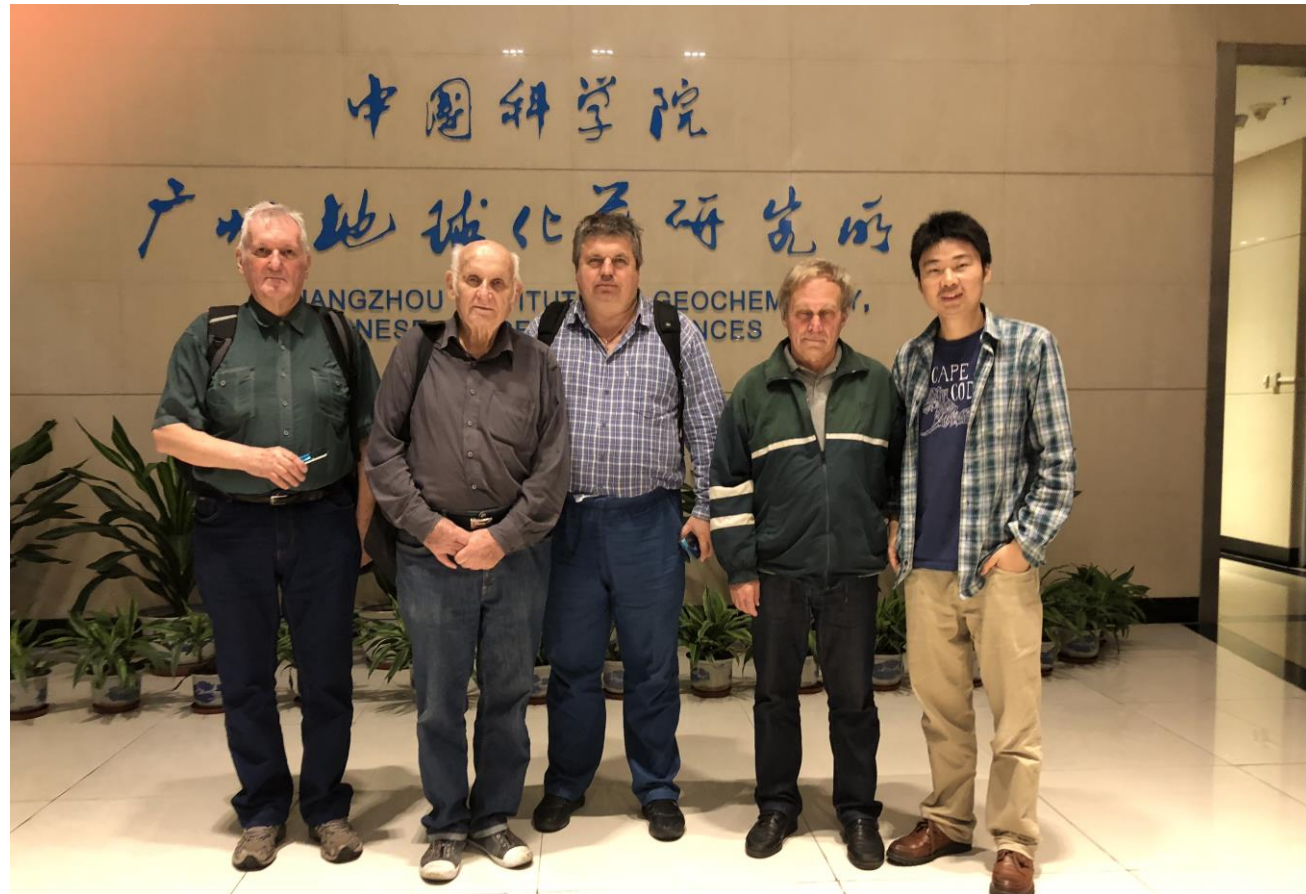
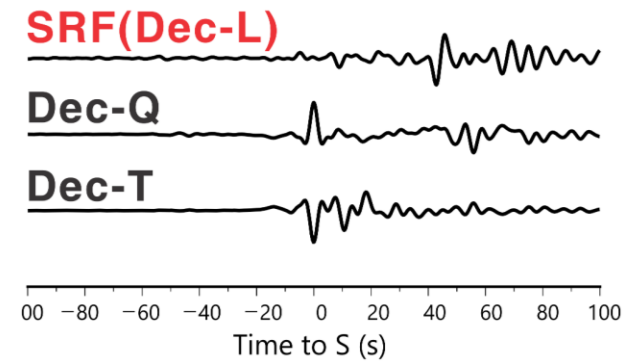
张耀阳等, 2018, 地球物理学报

一、研究背景：不同人同一数据获得的结果也存在差异性

国际合作与交流项目 (2017-2018)

- 提取非常依赖经验
- 好的结果难以复现

Lev Vinnik 团队

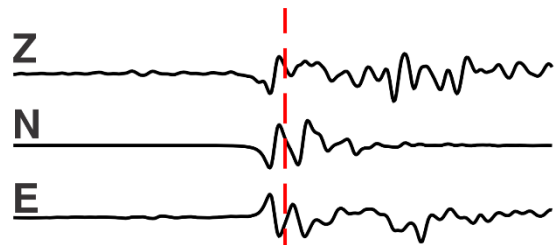


能否提出一种能被有效复现的通用提取策略？

一、研究背景：导致问题的原因

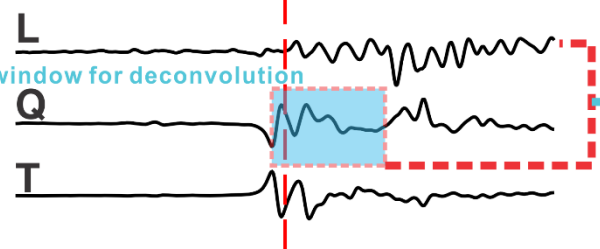
Step 1. 坐标旋转

$$\begin{bmatrix} L \\ Q \\ T \end{bmatrix} = \begin{bmatrix} \cos(i) & -\sin(i) \sin(baz) & -\sin(i) \cos(baz) \\ \sin(i) & \cos(i) \sin(baz) & \cos(i) \cos(baz) \\ 0 & -\cos(baz) & \sin(baz) \end{bmatrix} \begin{bmatrix} Z \\ E \\ N \end{bmatrix}$$

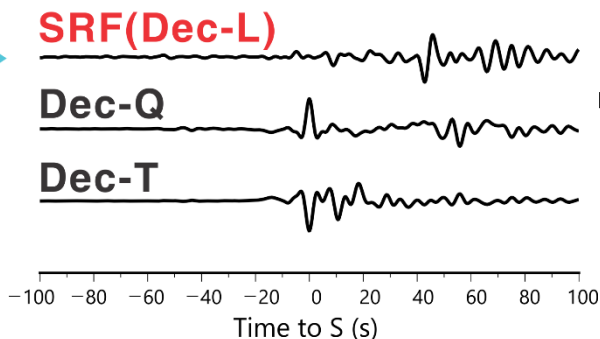


coordinate rotation
[baz(fixed), inci_ang]

window for deconvolution



Spiking
Deconvolution



S波接收函数

常规处理过程易引入人为干预

Step 2. 选定时窗计算反褶积

Step 3. SRF的质量控制

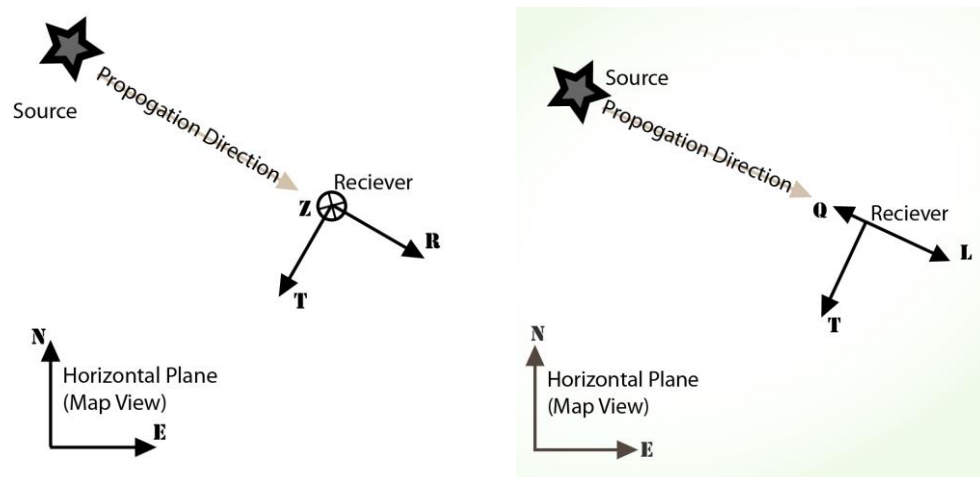
1. 旋转角度？ 波形时窗？

2. 反褶积算法？

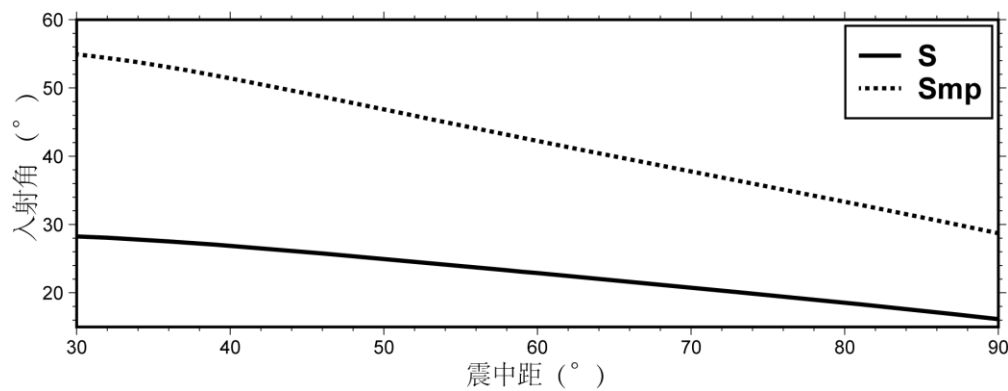
3. 质量控制？

一、研究背景：导致问题的原因1

1 问题1.坐标旋转与时窗选择

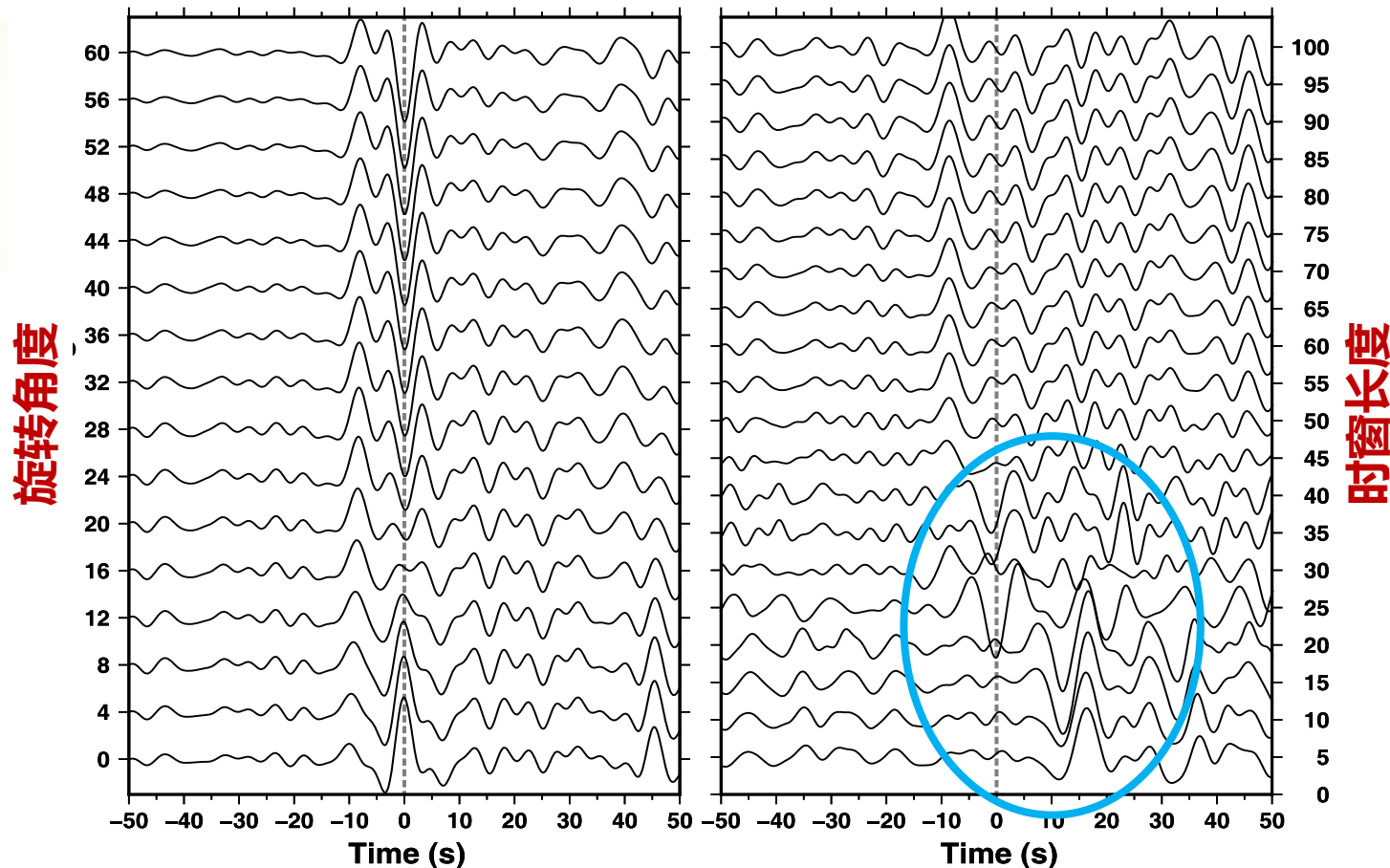


Smp与S的入射角存在较大偏差



Zhang & Deng, 2022, Gcubed

青藏高原台站ST09数据测试 Kumar et al., 2006



Inci_Ang: 从ZRT旋转到LQT坐标系的入射角

Win_Len: 反褶积计算时使用Q分量的波形时窗长度

一、研究背景：导致问题的原因2

2 问题2.反褶积算法的选择

坐标系统:

ZNE/ZRT /LQT/LAB

反褶积算法:

脉冲反褶积

(Robinson, 1954;

Treitel & Robinson, 1966)

时间域迭代反褶积

(Ligorria & Ammon, 1999)

最大熵谱反褶积

(吴庆举等, 2003a)

多道反褶积

(吴庆举等, 2003b)

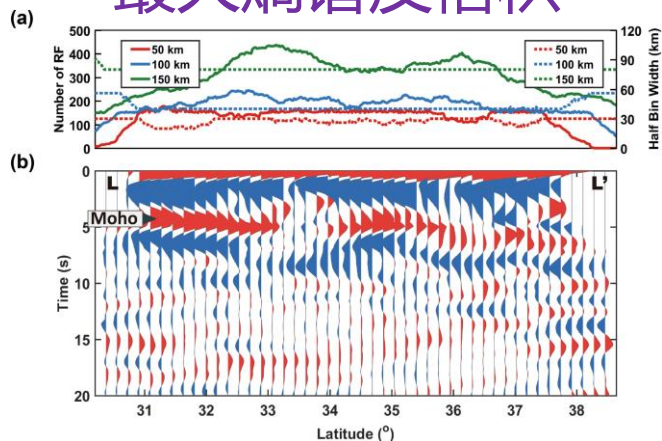
Wiener滤波反褶积

(吴庆举等, 2003c)

MMLD, 最大似然反褶积

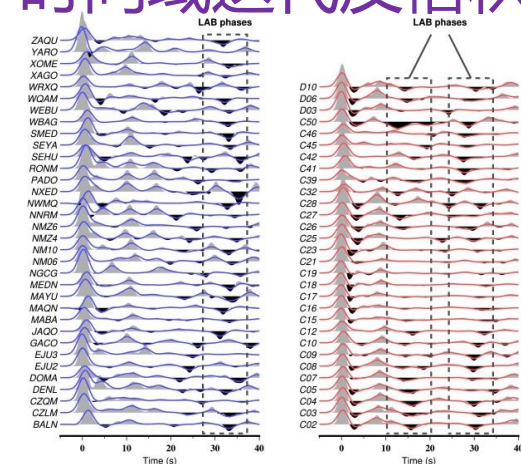
(刘启元等, 2008)

最大熵谱反褶积



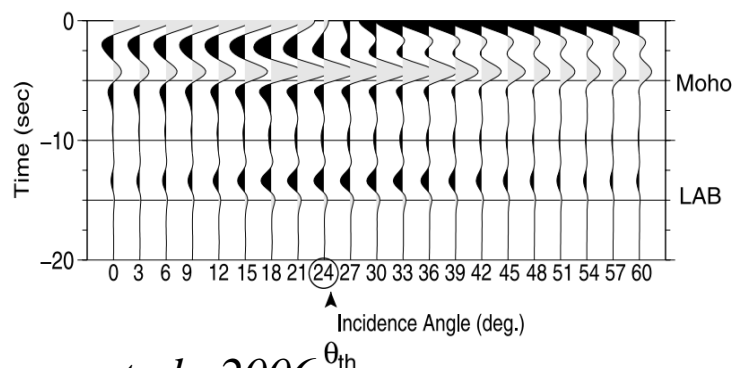
Wu et al., 2020

时间域迭代反褶积

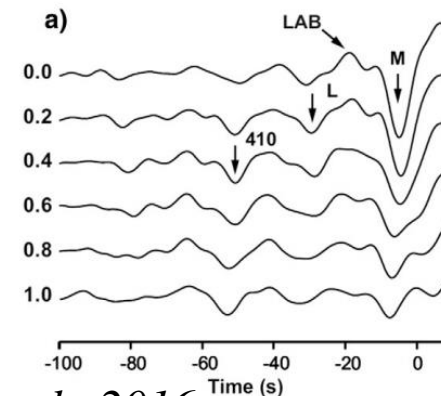


Liu et al., 2020

脉冲反褶积

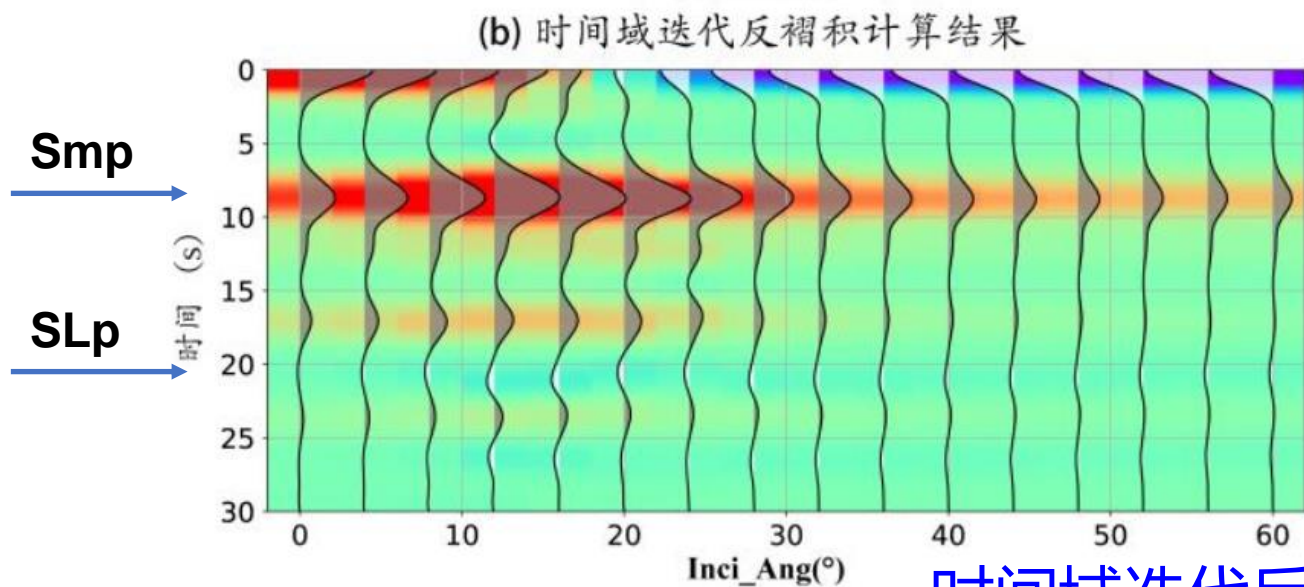
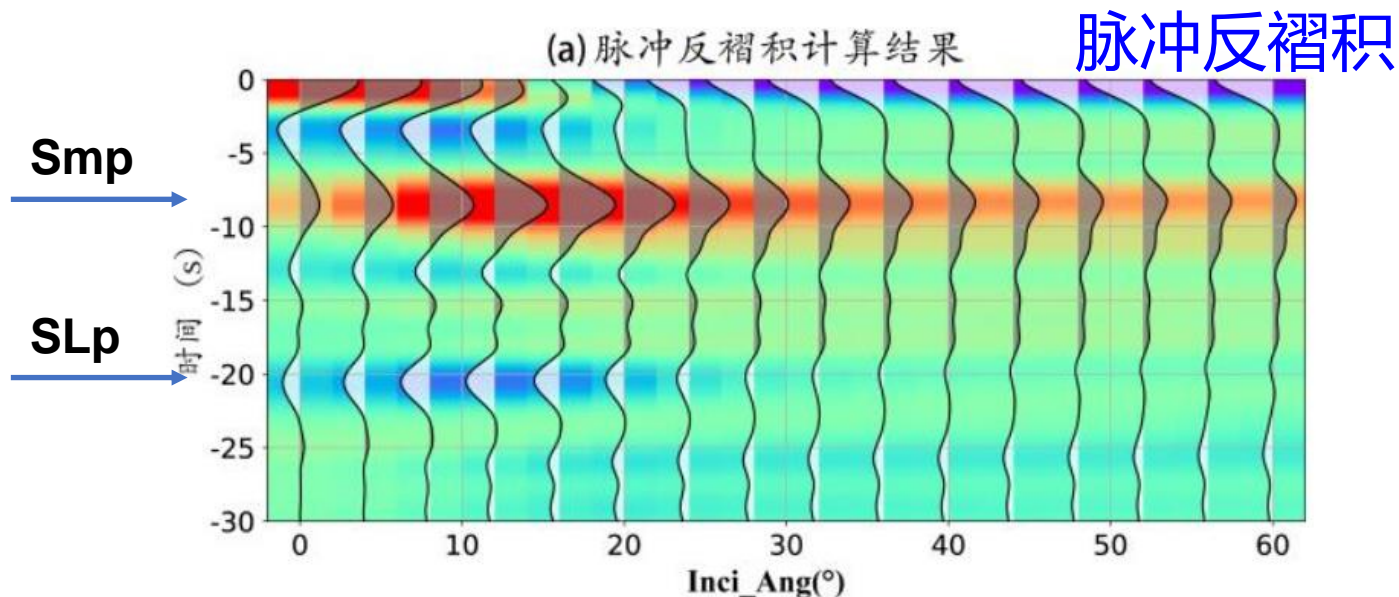


Kumar et al., 2006



Vinnik et al., 2016

一、研究背景：导致问题的原因2



时间域迭代反褶积

脉冲反褶积计算SRF的现状

优点:

- SLP震相具有较高的相对振幅
- 在SRF方法发展的早期使用广泛

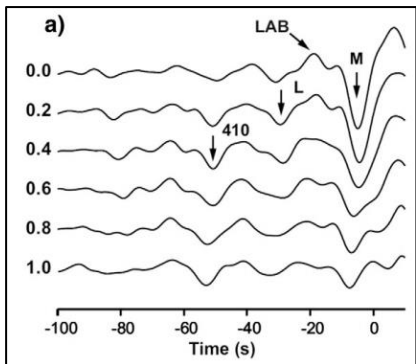
缺点:

- 缺乏维护
- 可移植性差

SeismicHandler

一、研究背景：导致问题的原因3

3 问题3. SRF的质量控制方法



传统质量控制

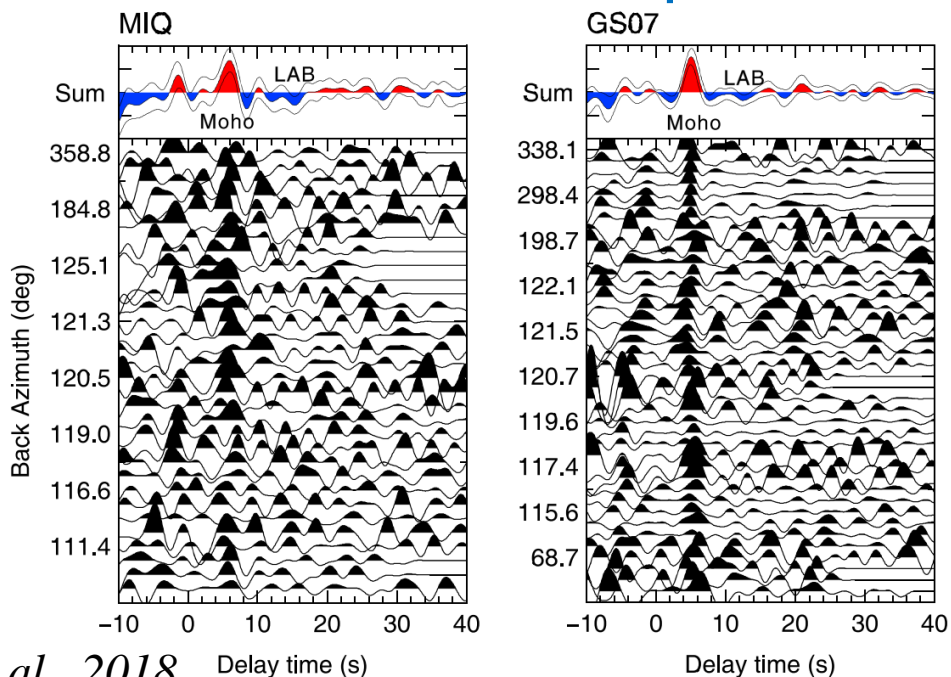
主要依靠手动筛选

至今，SRF的质量控制准则仍待探索

个人经验主导，很难重现

Vinnik et al., 2016

前人探索1: Bootstrap误差估计

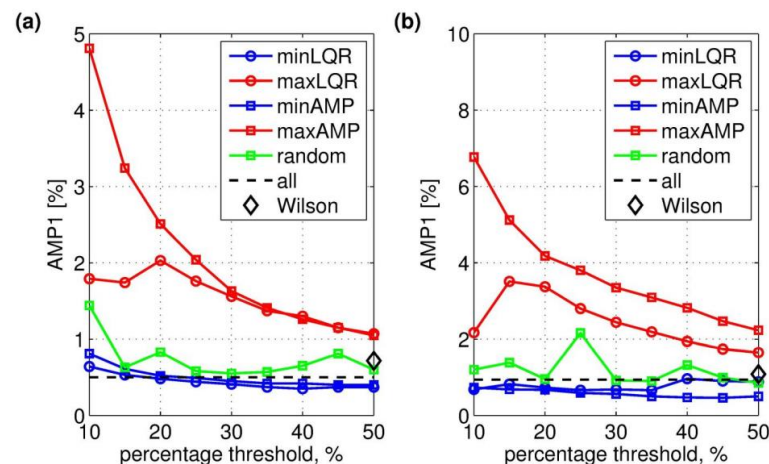


Xu et al., 2018

前人探索2: 振幅比质量控制准则

$$LQR = \text{RMS}(L[t_3 t_4]) / \text{Max}(Q[t_1 t_2]), \quad (1)$$

$$\text{AMP} = \text{RMS}(\text{SRF}[t_5 t_6]), \quad (2)$$



Shen et al., 2019

二、研究思路

1

旋转角度与时窗长度

相关分析
网格搜索

1

解决思路

对旋转角度和时窗长度循环计算，寻找与均值波形互相关系数最高的参数对

2

反褶积算法

程序重制
C++
Python

2

解决思路

重制独立脉冲反褶积程序，使其具有更高可移植性；且能有效重现前人研究结果。

3

SRF的质量控制

相关分析
重排序

3

解决思路

基于RMSE等算法提取数据集主要特征，然后基于波形相似性对单台数据集进行重排序

GC SRF

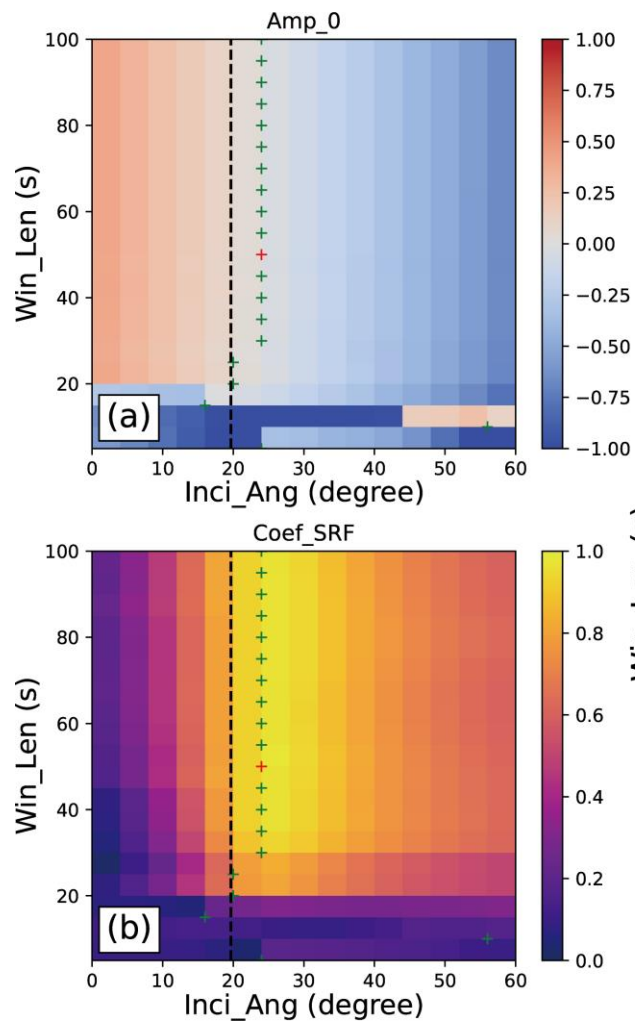
目的：尽量减少人为干预，保证结果完整可重复

二、研究思路

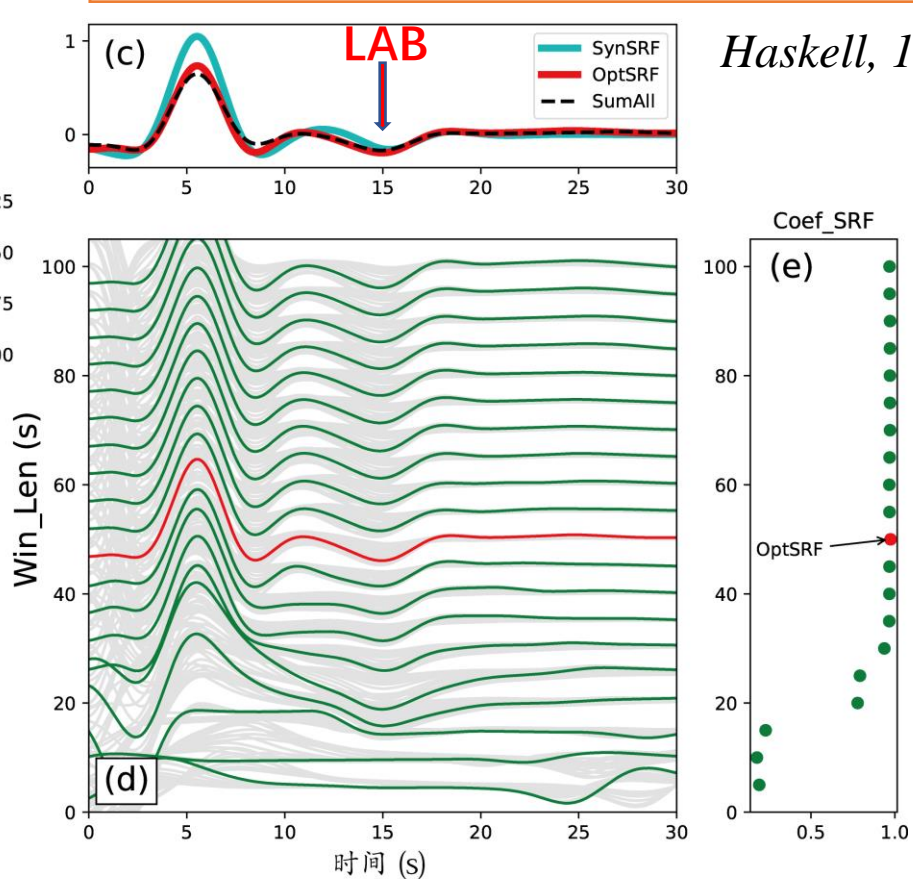
对策：1. 坐标旋转与时窗选择

1

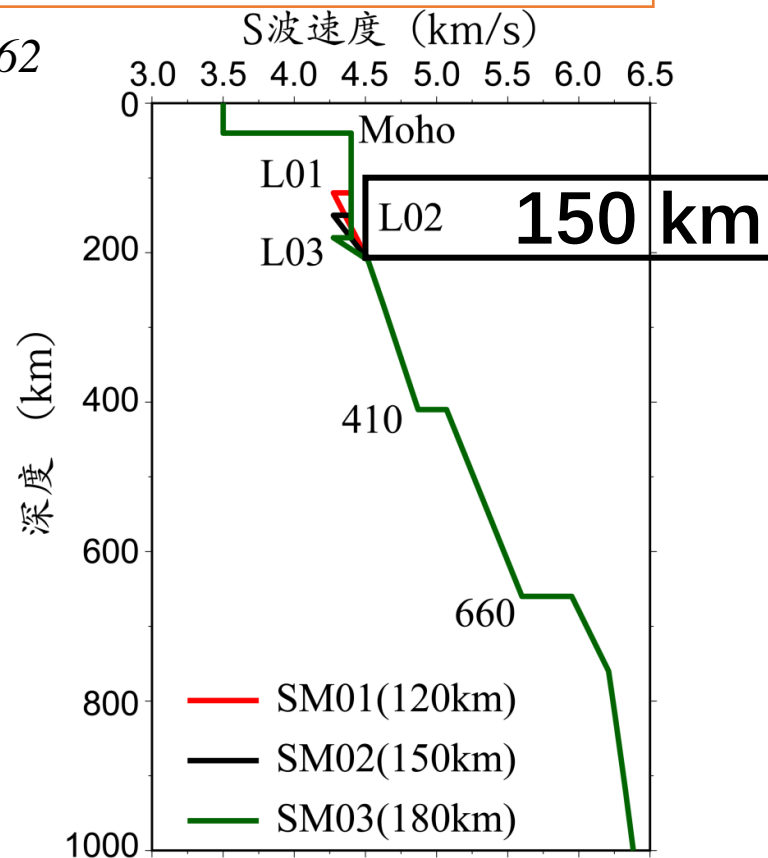
- a) 0时刻L分量振幅最小
- b) 与参考波形互相关系数最高



最佳SRF与直接计算的地层响应相一致



Haskell, 1962



$$\text{Coef}_{\text{SRF}}(\text{Inci_Ang}, \text{Win_Len}) = \text{CC}[\text{SRF}_{\text{ref}}, \text{SRF}(\text{Inci_Ang}, \text{Win_Len})],$$

二、研究思路

对策：2.反褶积算法的选择

2

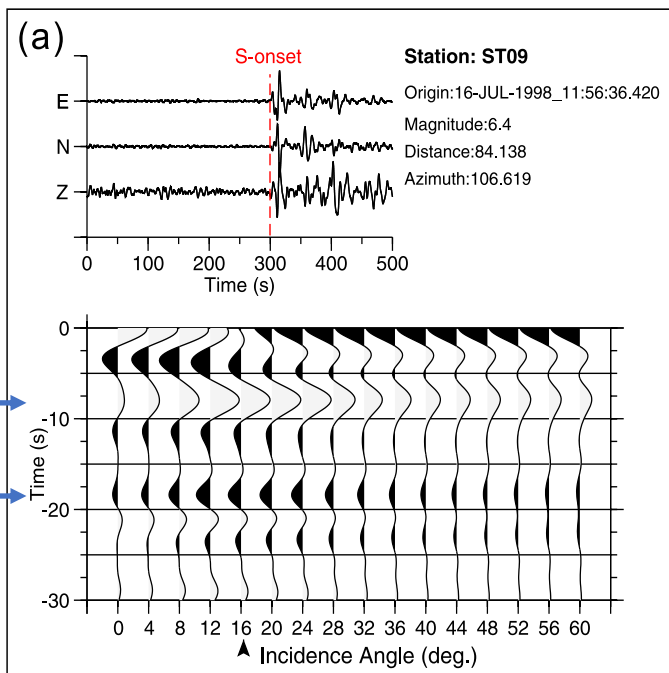
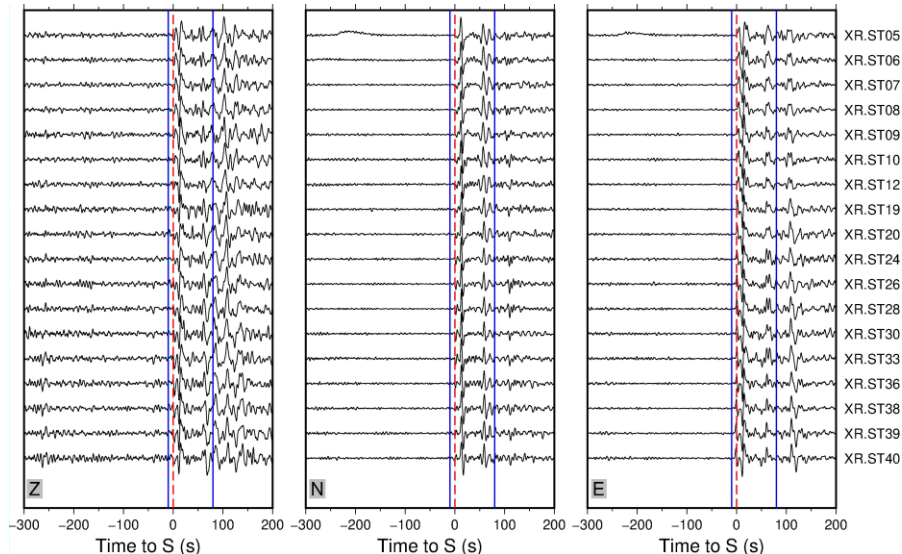
SeismicHandler

缺乏维护
可移植性差

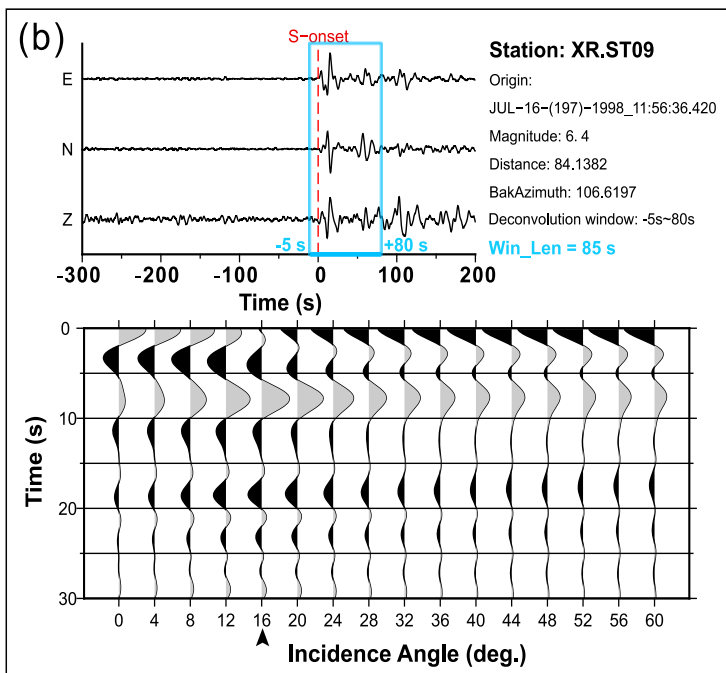
SX_Deconv
基于C++和Python
重制

完全重现前人结果

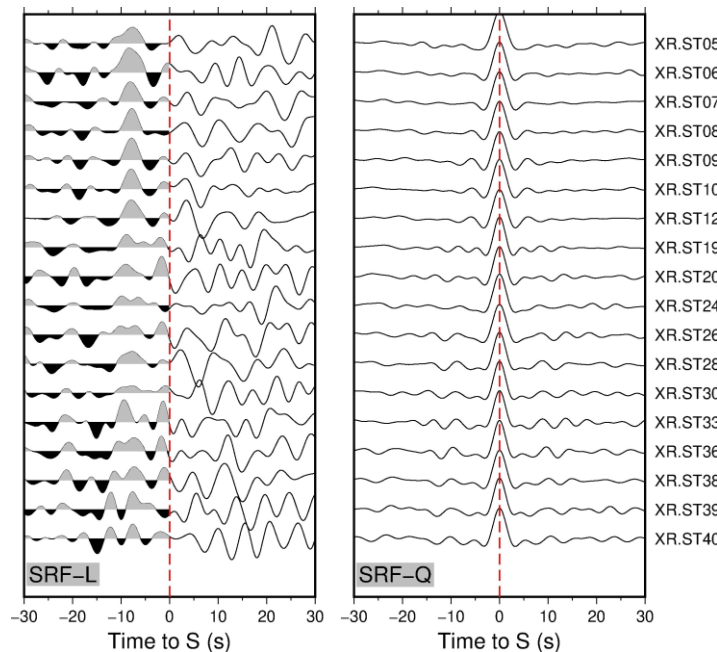
XR台阵单事件测试良好



Kumar et al., 2006



Zhang & Deng, 2022, Gcubed

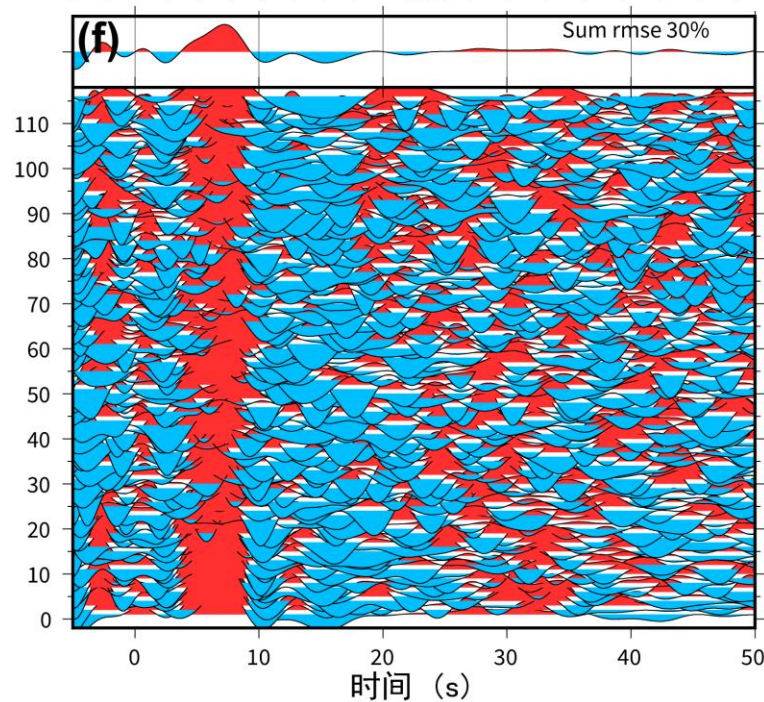
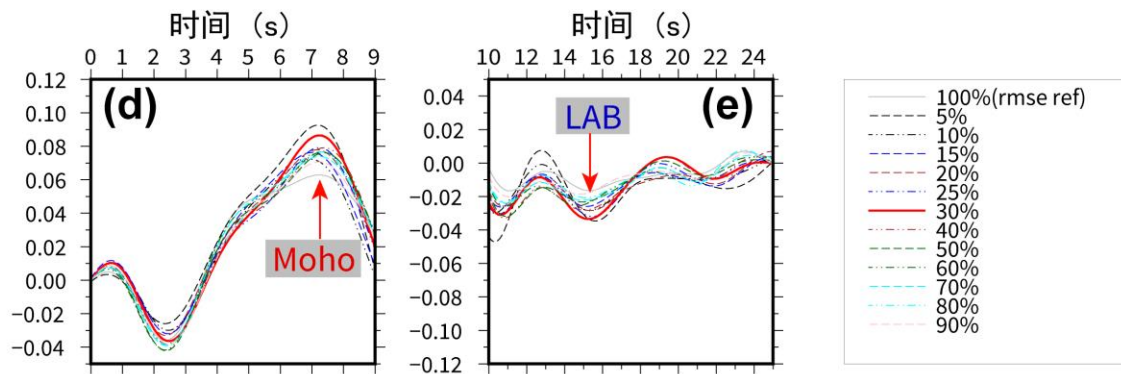
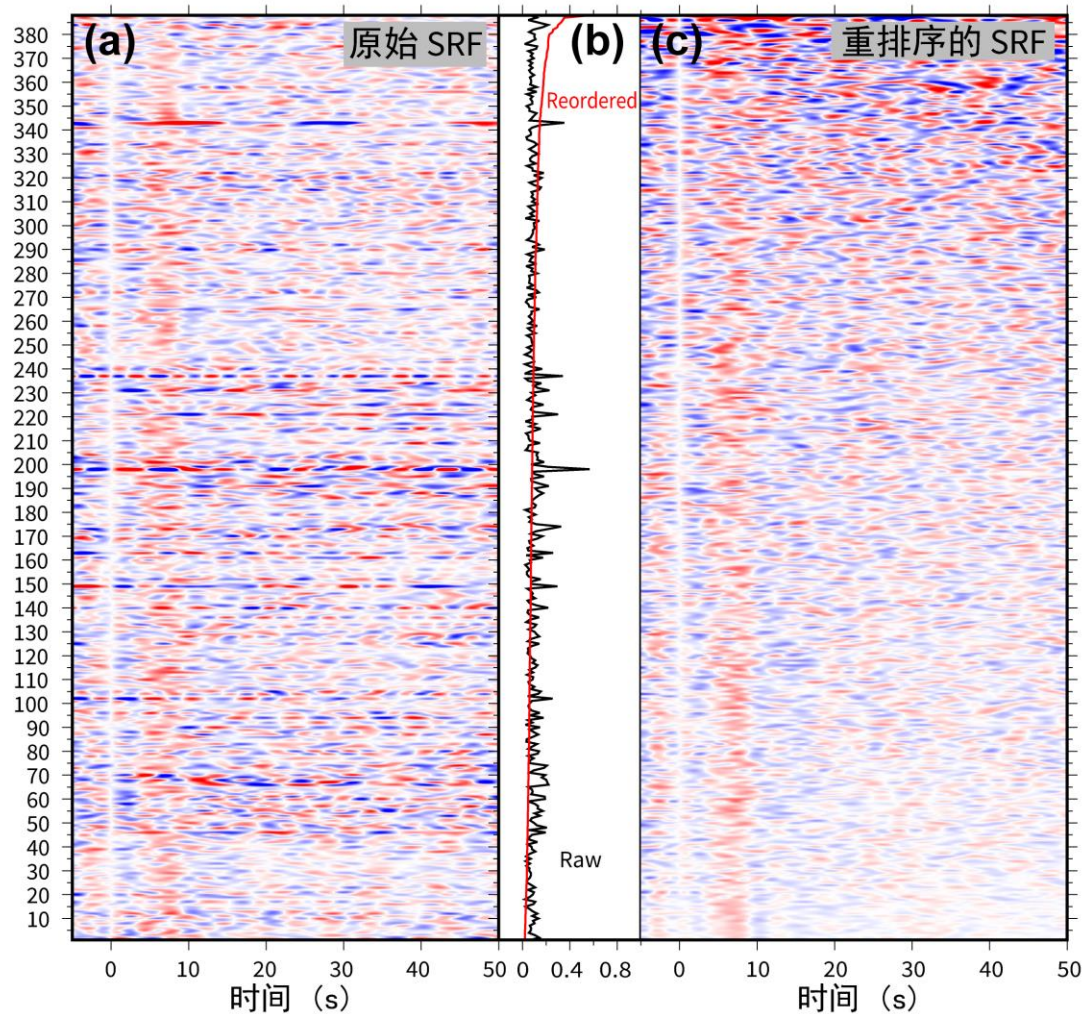


二、研究思路

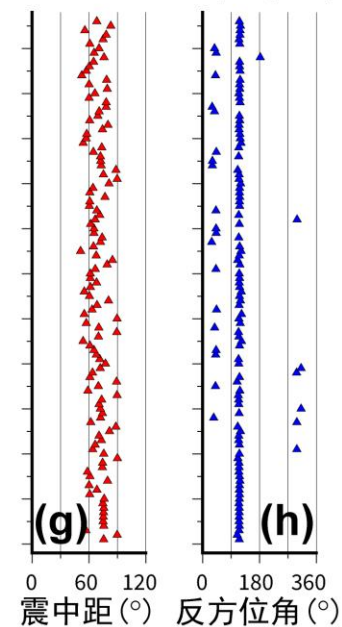
对策： 3. SRF的质量控制方法

3 RMSE: 均方根误差 + 波形重排序

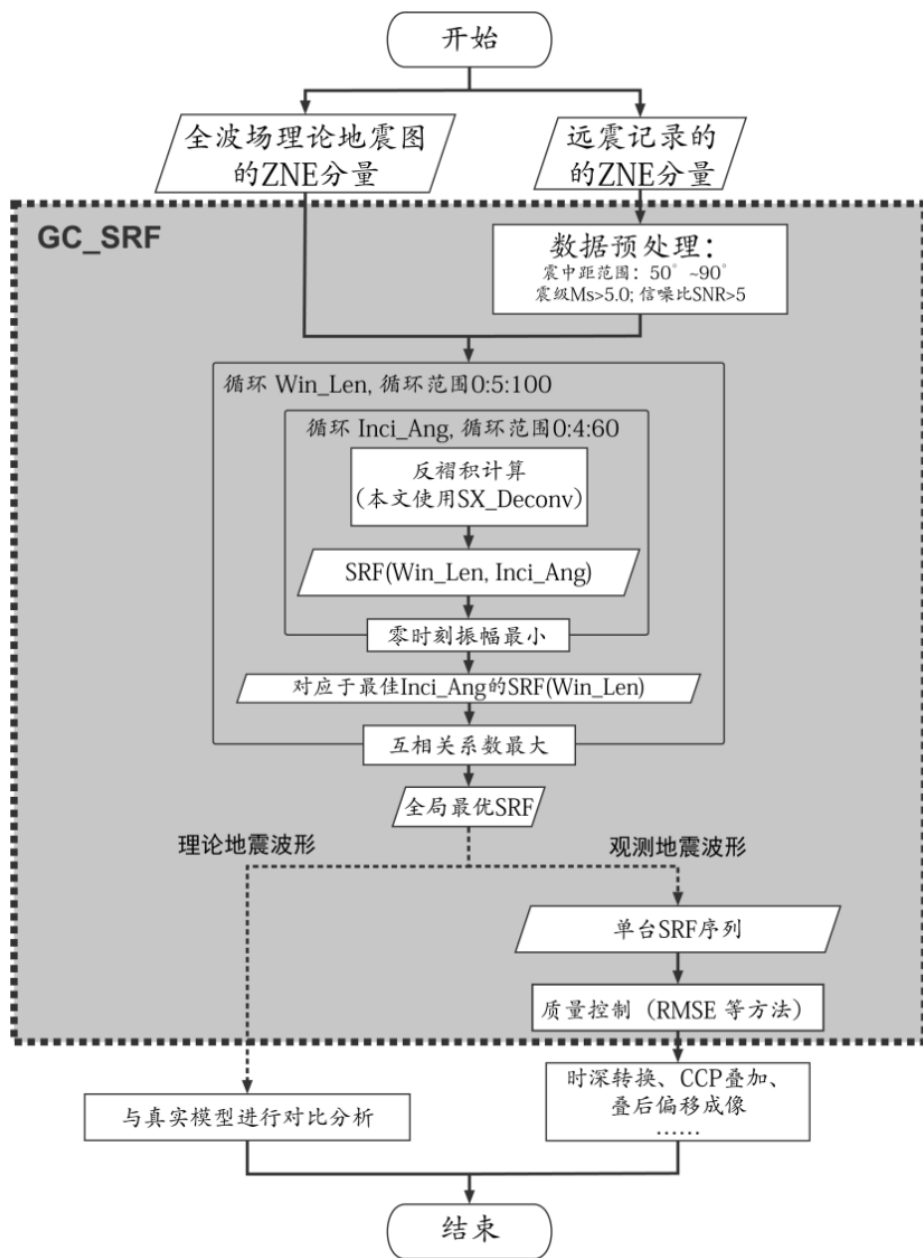
重排序后，
序列前30%具有好的一致性



台站名: SC.MGU
RMSE比例: 30% (116/388)



二、研究思路



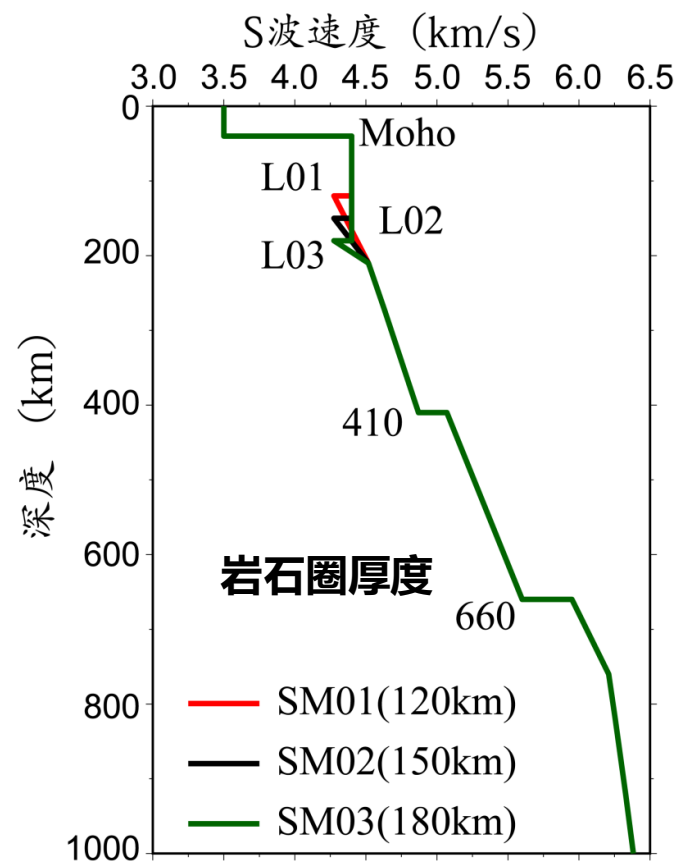
具体操作流程

详见案例展示

二、研究思路：1维模型理论测试

理论测试1:

1-D 速度模型全波场测试



Geophys. J. Int. (2006) 165, 555–564 doi: 10.1111/j.1365-2466.2006.01111.x

Yuan et al., 2006

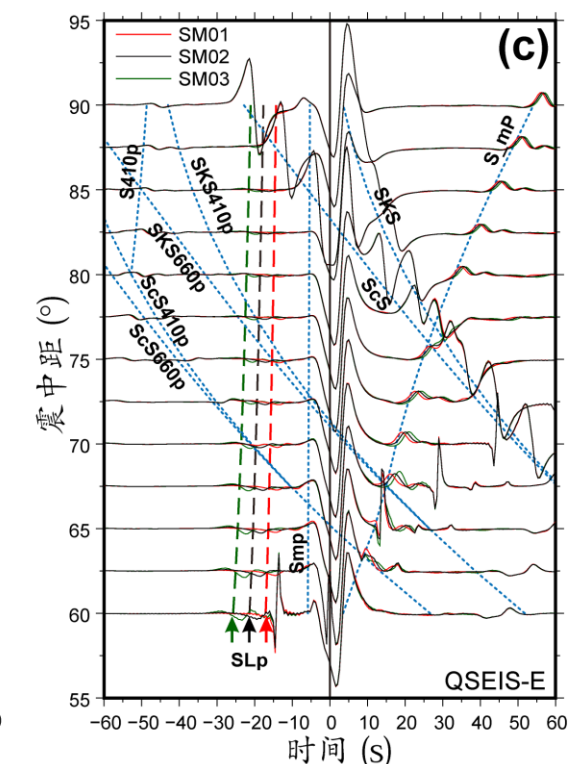
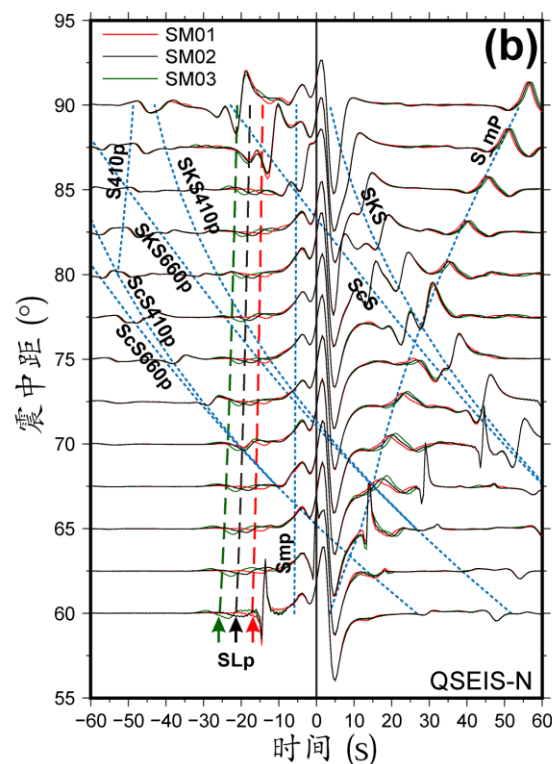
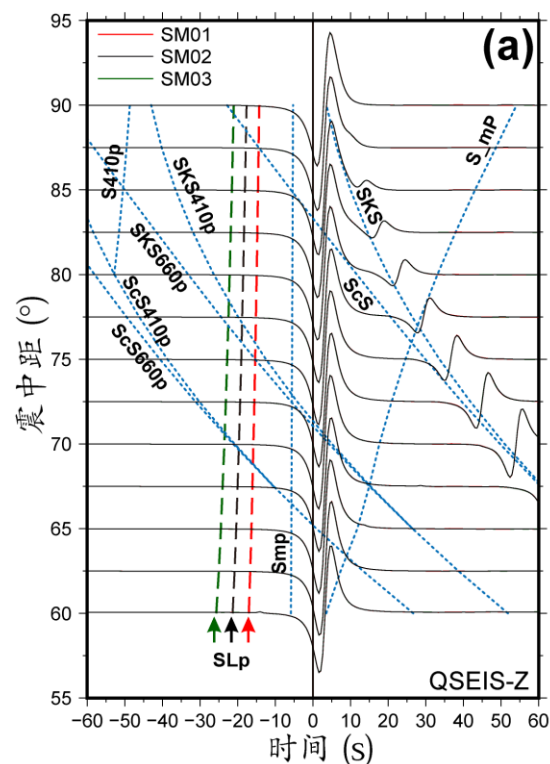
The *S* receiver functions: synthetics and data example

Xiaohui Yuan, Rainer Kind,* Xueqing Li and Rongjiang Wang

GeoForschungsZentrum Potsdam, Telegrafenberg, 14473 Potsdam, Germany. E-mail: yuan@gfz-potsdam.de

Accepted 2005 December 12. Received 2005 November 22; in original form 2005 June 14

Z分量完全看不到Sp震相

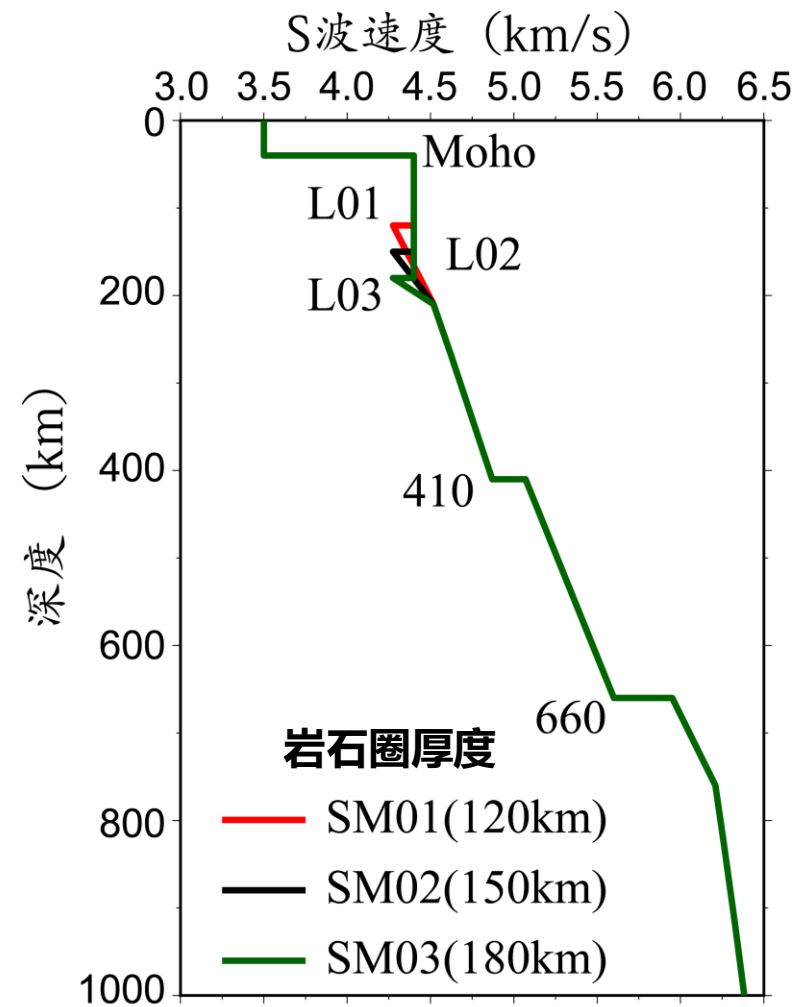


部分波场

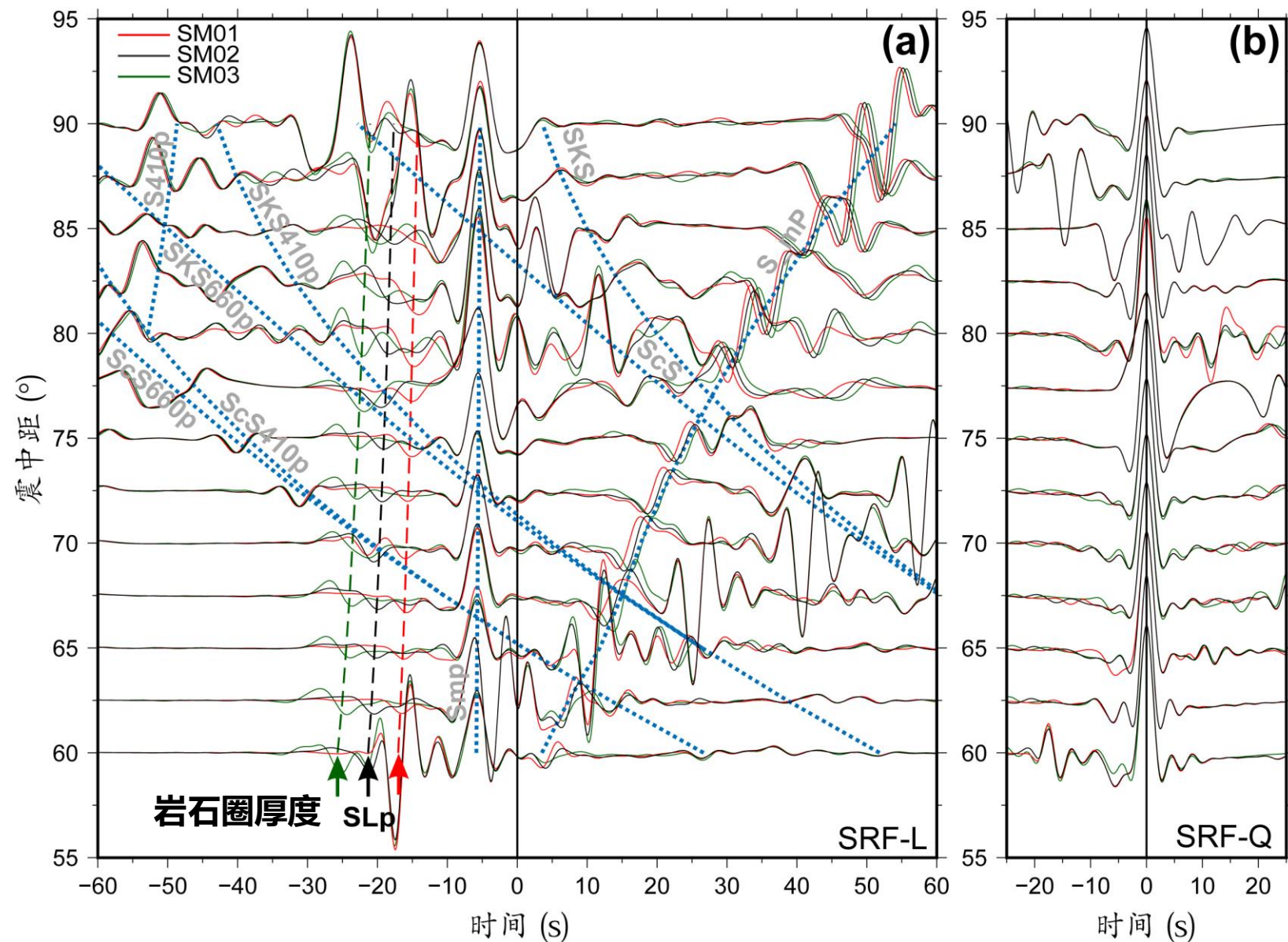
全波场

二、研究思路：1维模型理论测试

理论测试1： 反褶积计算结果



反褶积结果中Sp转换震相清晰可见

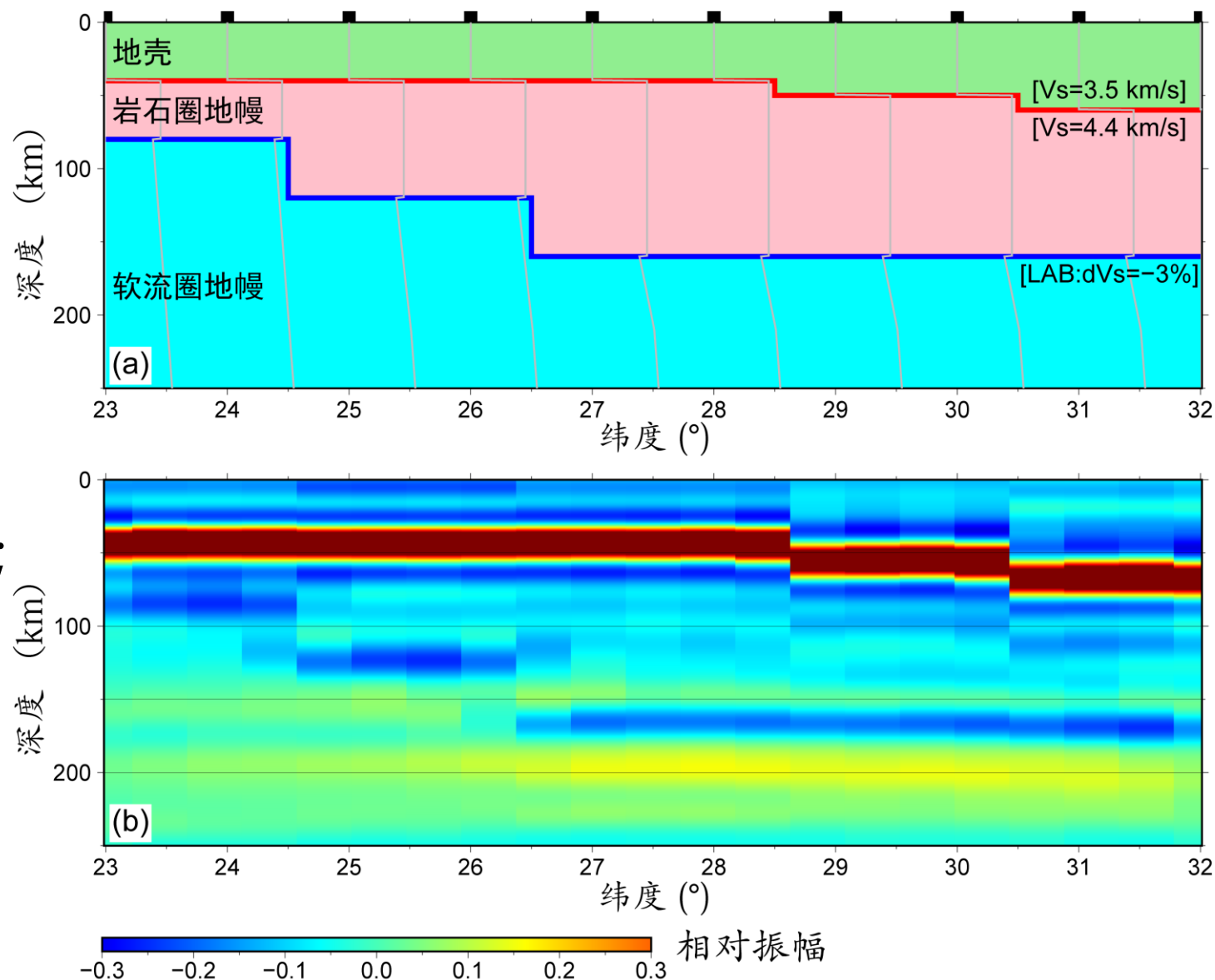


二、研究思路：2维模型理论测试

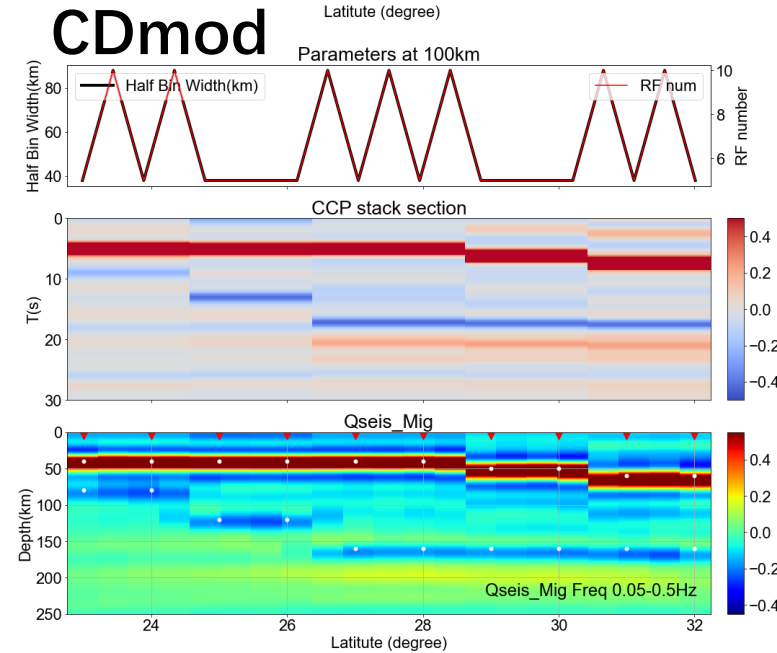
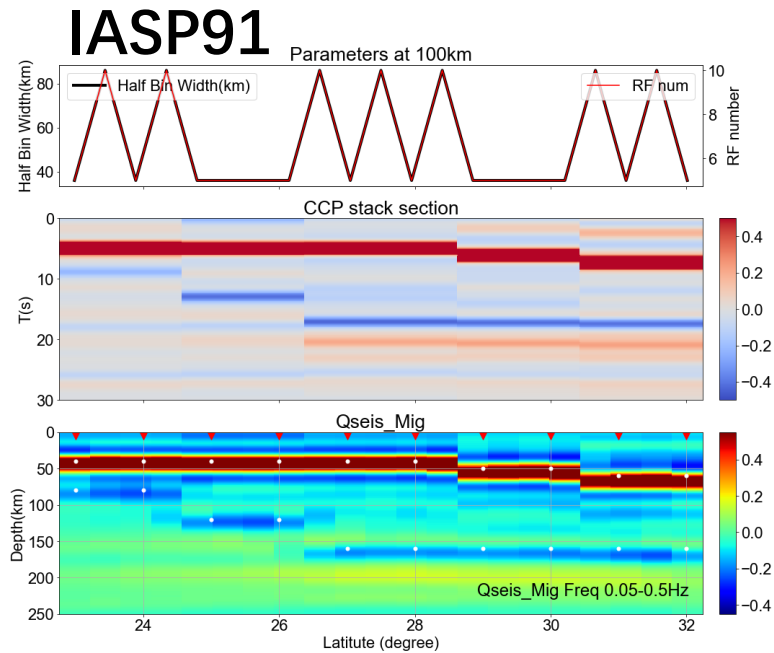
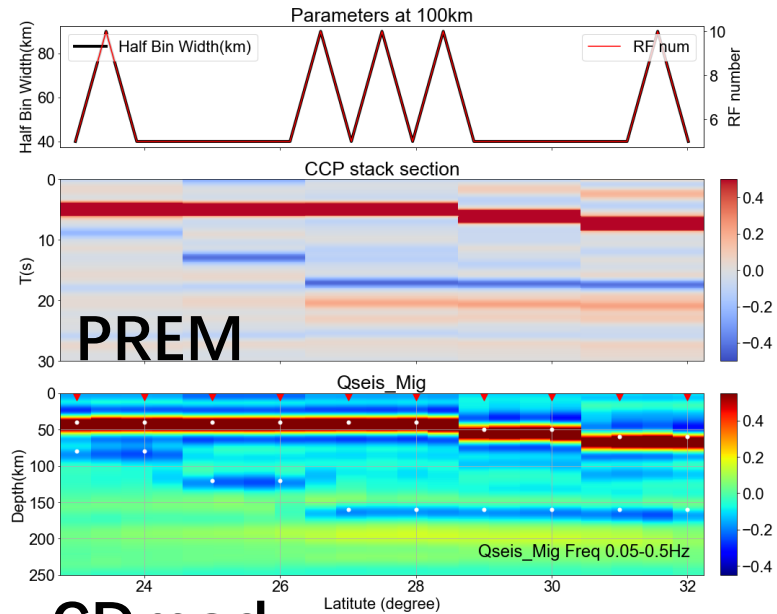
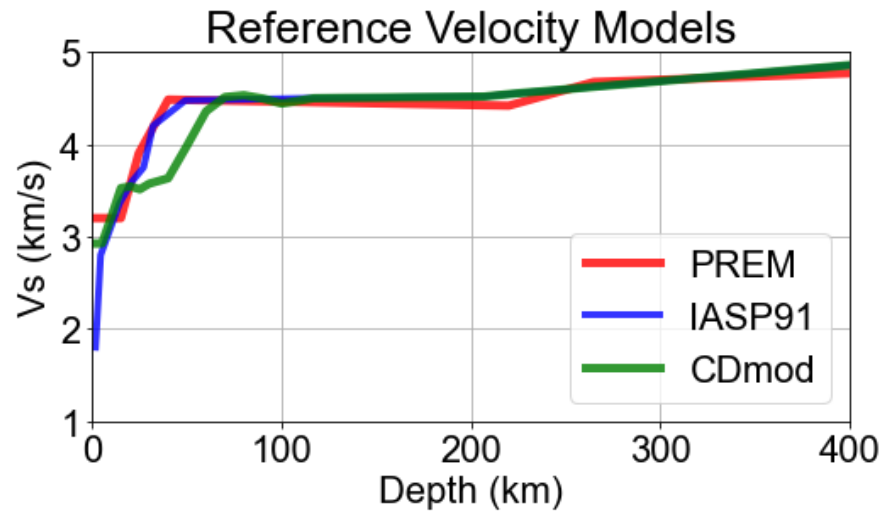
理论测试2： 伪2-D剖面偏移成像 完全重现理论模型

处理流程：

1. 设定10个**虚拟台站**，构建2-D速度模型；
2. 基于QSEIS计算理论地震图；
3. **GC_SRF**获取稳定SRF并使用基于波动方程的成像技术进行**偏移成像**。



二、研究思路：2维模型理论测试，不同速度模型



三、应用实例：青藏高原东南缘

感谢中国地震局地球物理所提供的数据

岩石圈成像争议

体波层析成像: **低波速**

面波层析成像: **高波速**

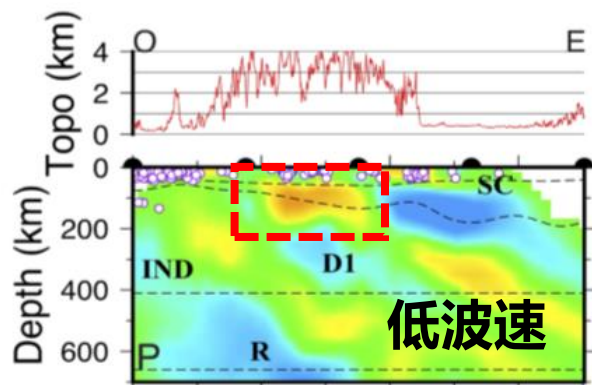
远震衰减成像: **低衰减**

2010年~2015年
691个远震事件
59个台站

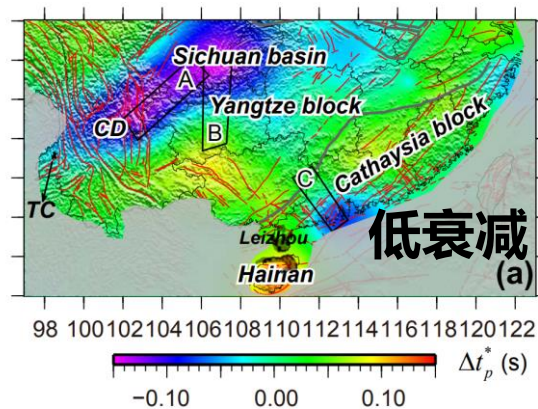
震中距 $55^\circ \sim 90^\circ$
 $SNR_H > 5$

GC_SRF

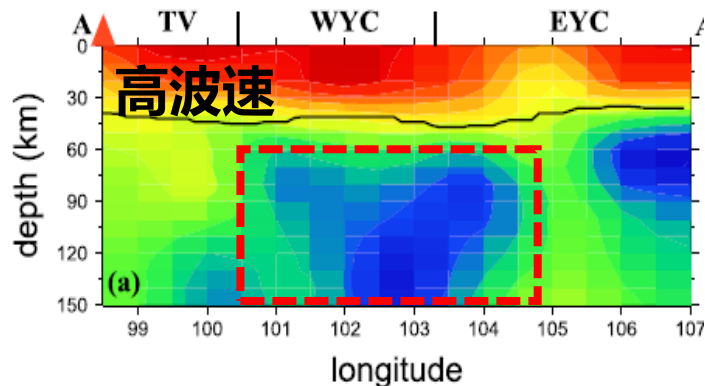
SRF数量
18239条



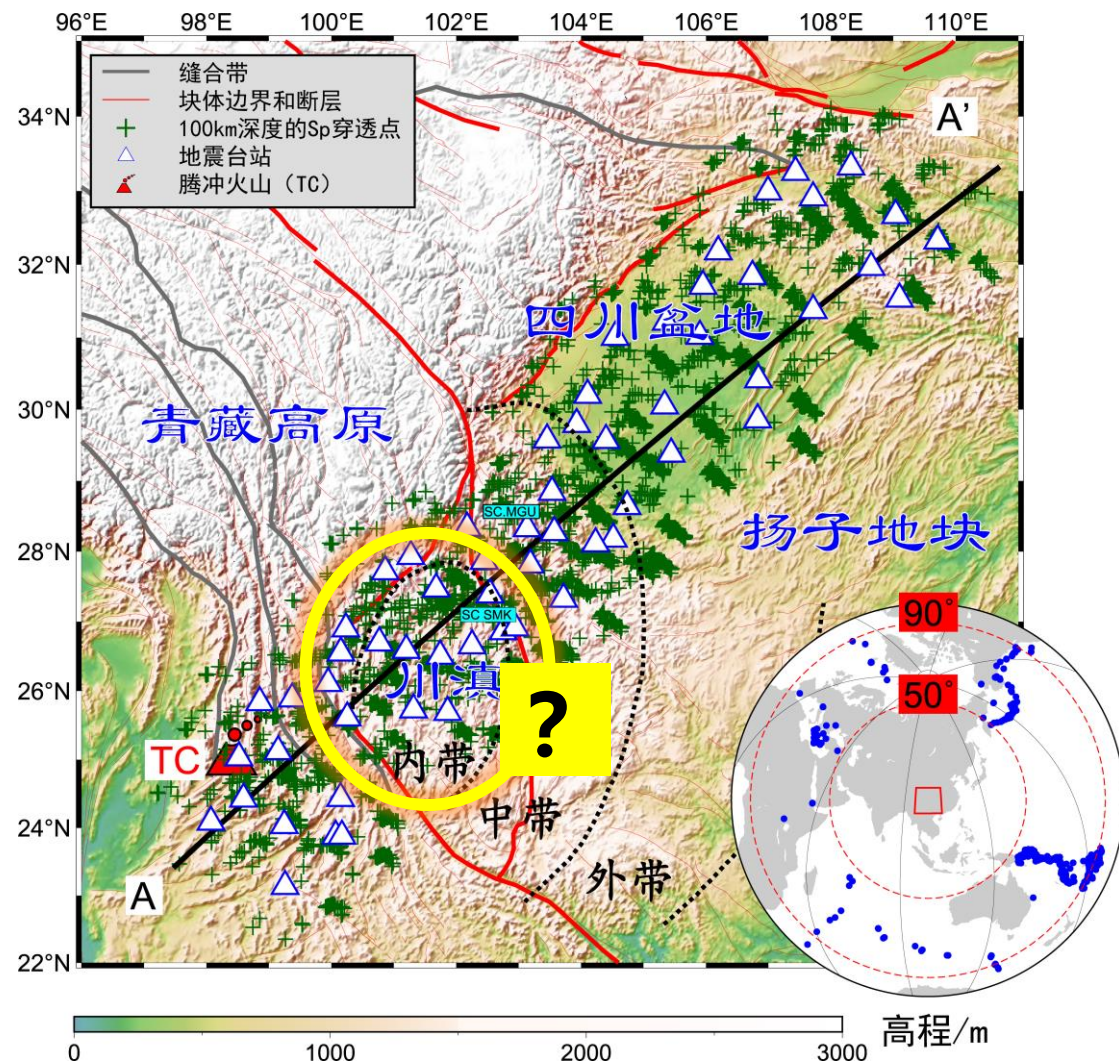
Huang et al., 2019



Deng et al., 2021



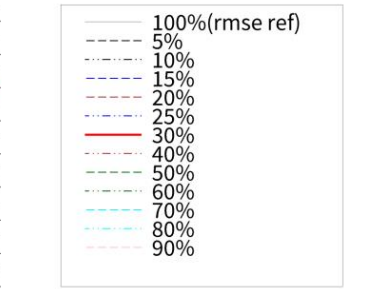
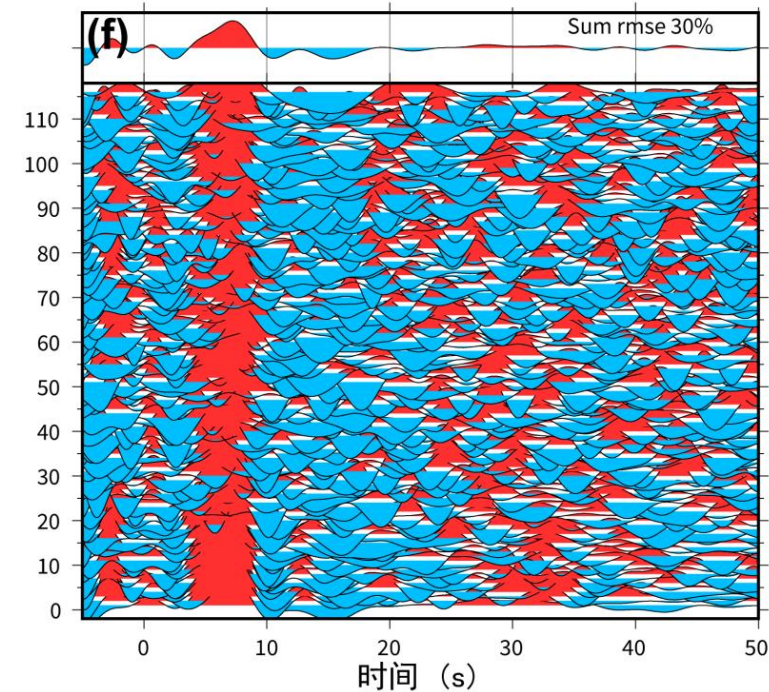
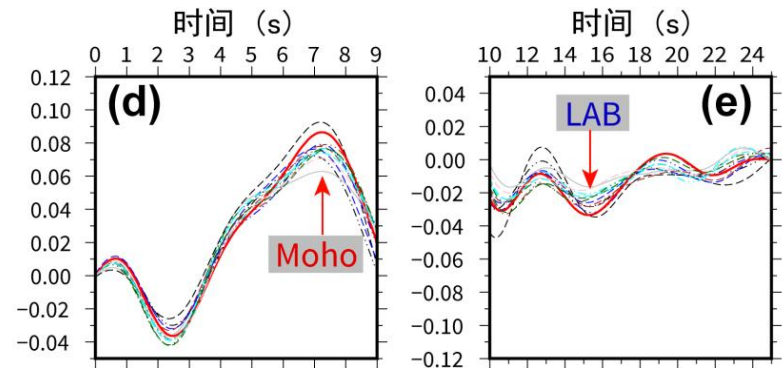
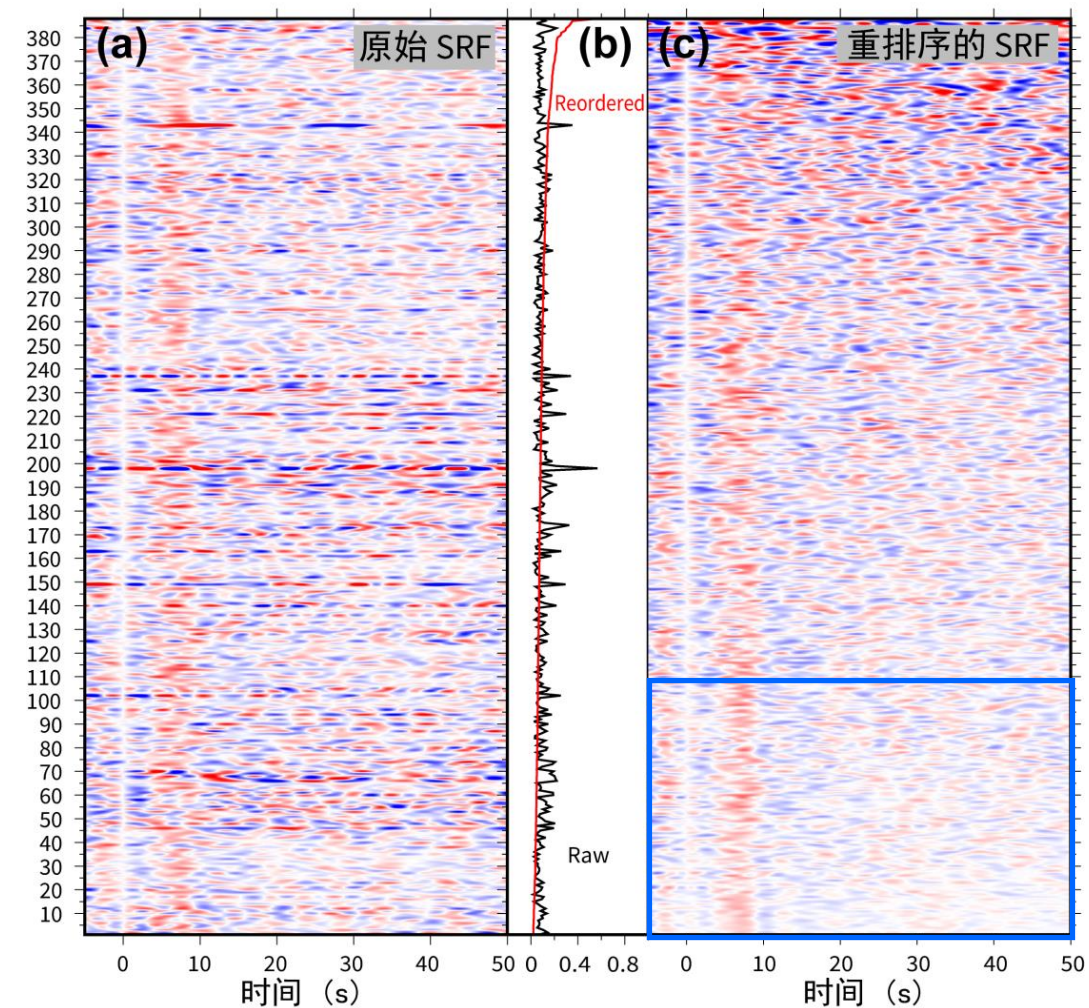
Fu et al., 2016



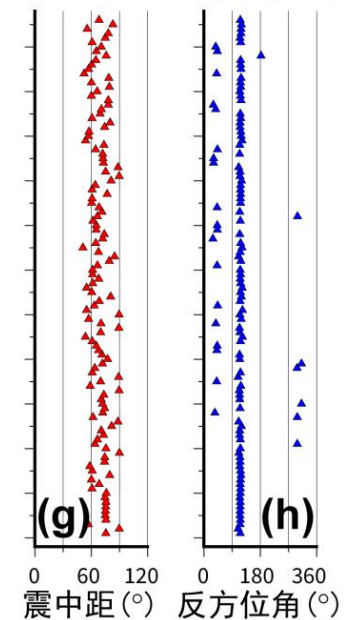
三、应用实例：青藏高原东南缘

基于RMSE大小对道集重排序，RMSE比例为30%

SC.MGU

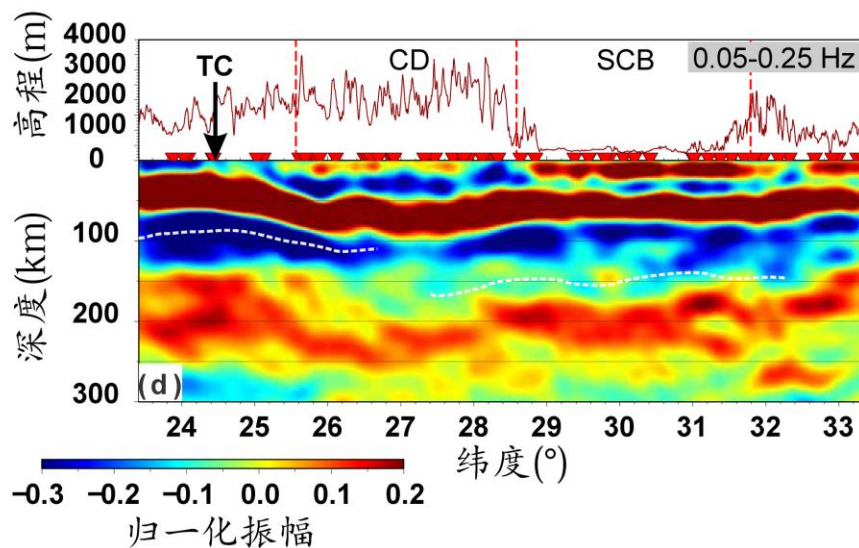
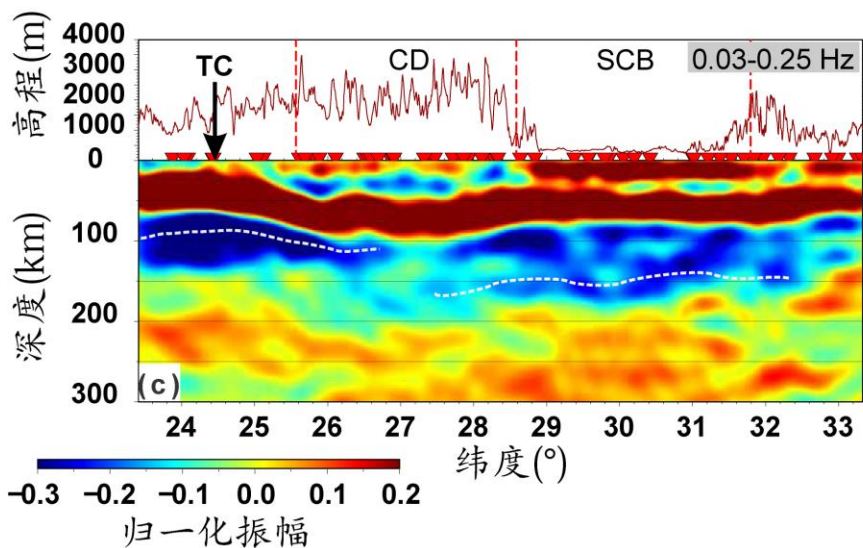
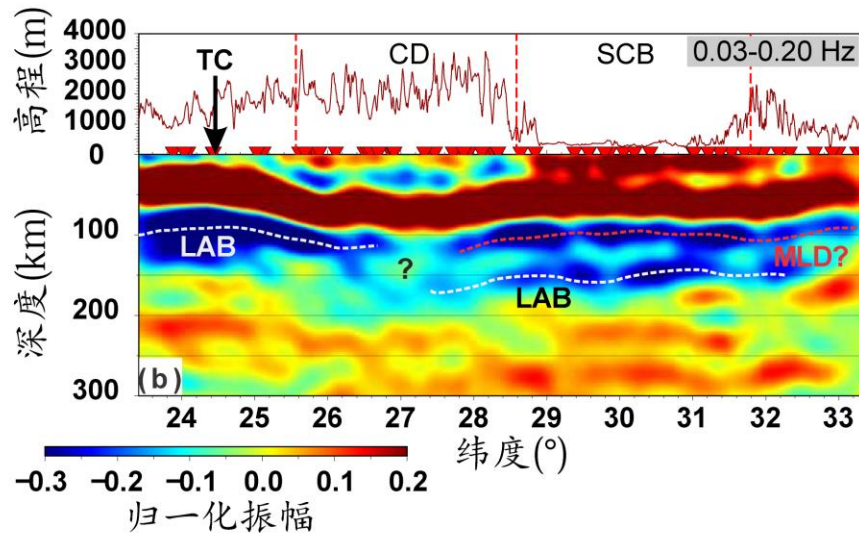
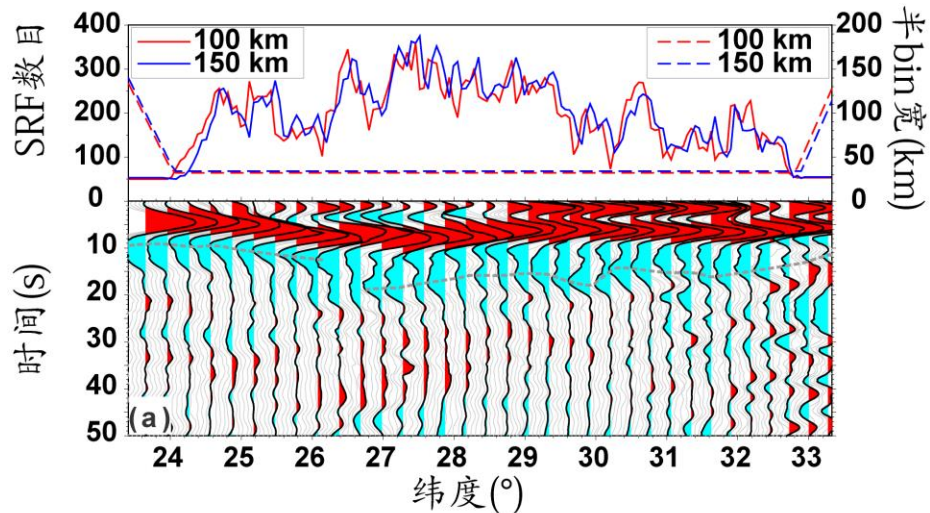


台站名: SC.MGU
RMSE比例: 30% (116/388)



三、应用实例：青藏高原东南缘

扬子西缘GC_SRF的偏移成像结果



基本结果

四川盆地

MLD ~100 km
LAB 150~160 km

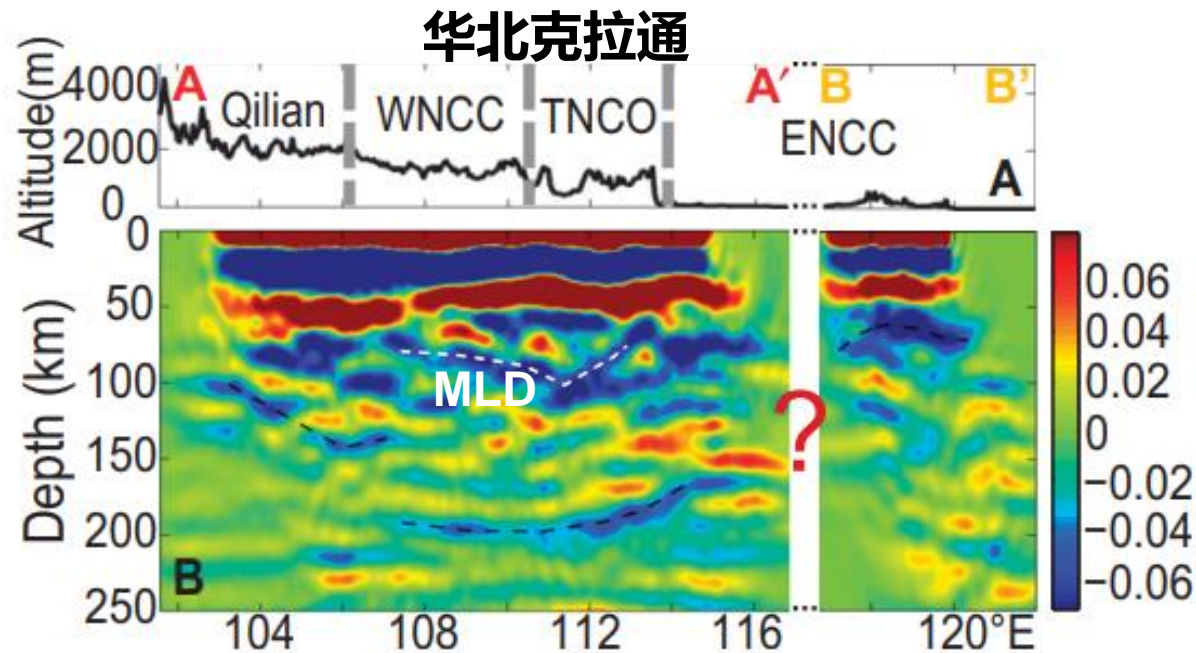
川滇地块

LAB不清晰
难以追踪识别

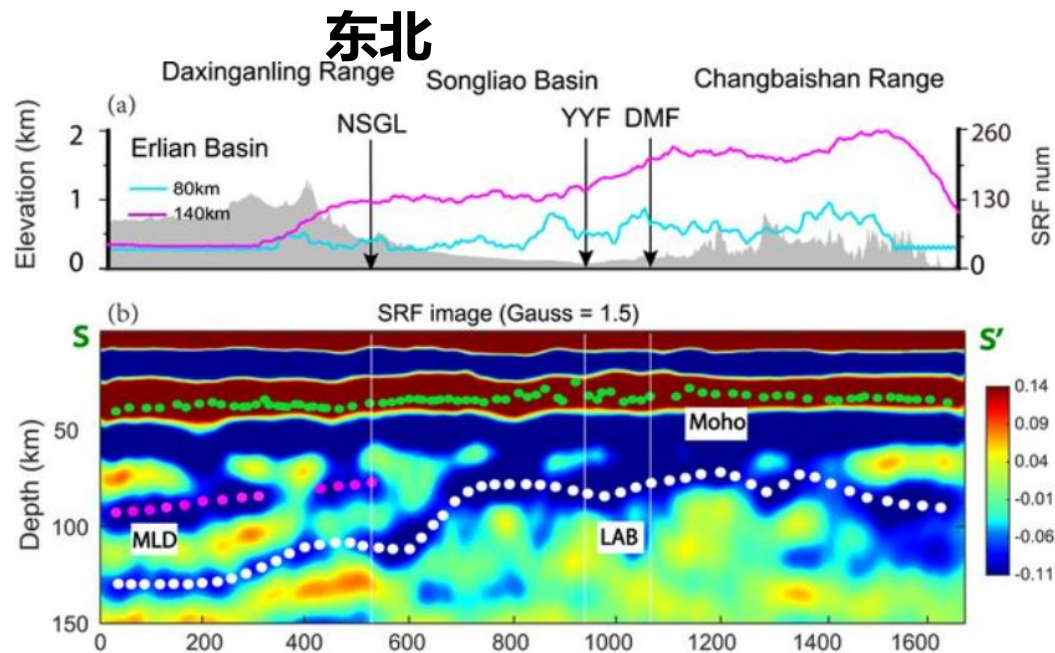
腾冲火山

LAB ~90 km

三、MLD在其他区域的探测



Chen et al., 2014

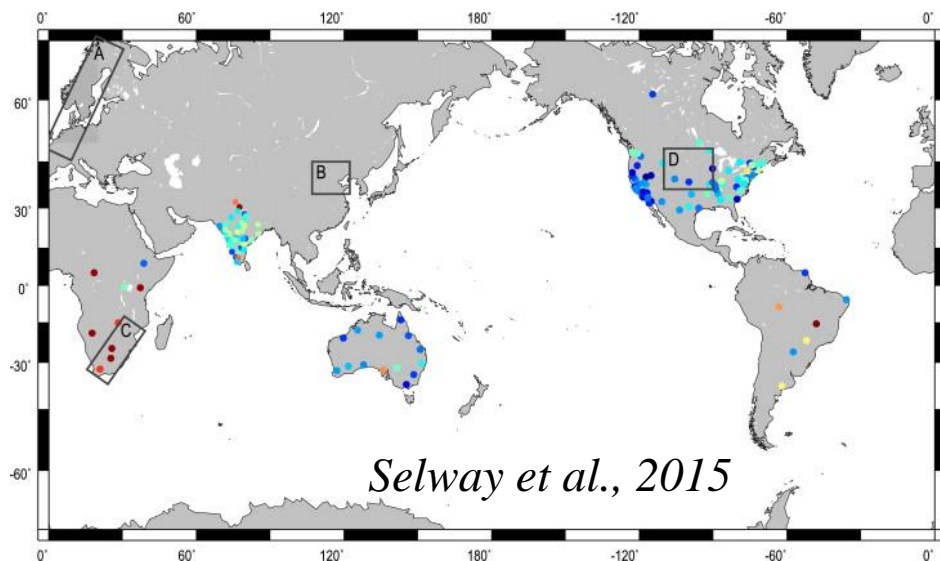


He et al., 2022

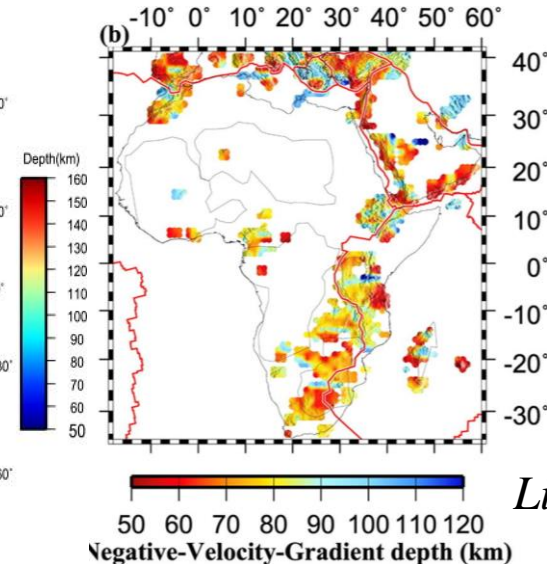
在60~120 km深度
大部分克拉通有看到

- 部分熔融
- 化学组分变化
- 弹性调整的颗粒边界滑动
- 上地幔分层各向异性
- “冻结的” LAB

徐义贤等, 2019



Selway et al., 2015



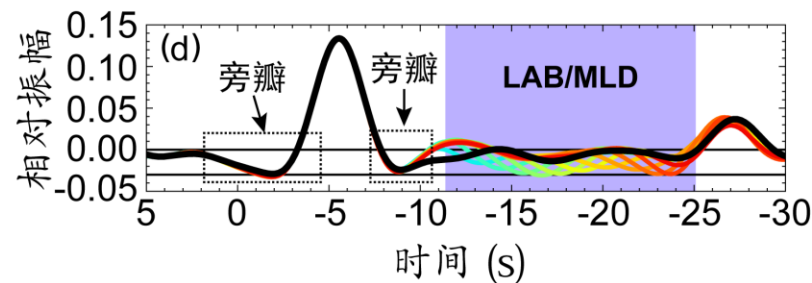
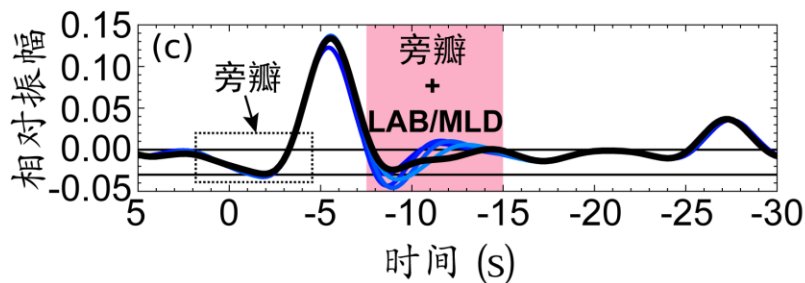
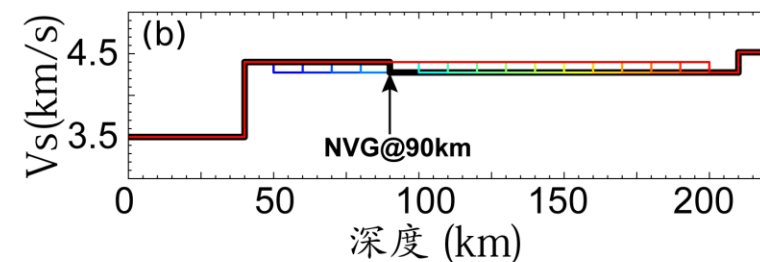
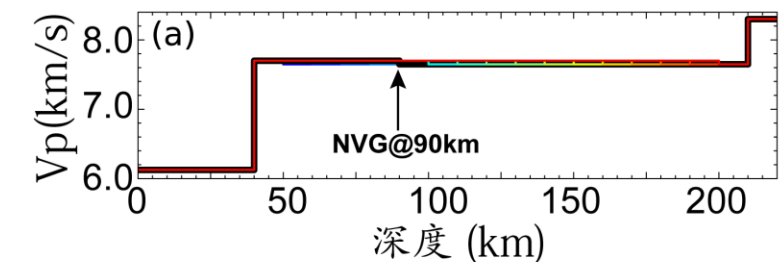
Liu et al., 2021

三、应用实例：青藏高原东南缘

判断是MLD而不是旁瓣

LAB深度 (km)	振幅比: Amp(旁瓣) / Amp(Smp)
90	-0.221201
100	-0.227492
110	-0.236176
120	-0.237383
130	-0.244824
140	-0.247147
150	-0.243042
160	-0.243930
170	-0.247538
180	-0.248319
190	-0.247777
200	-0.243498

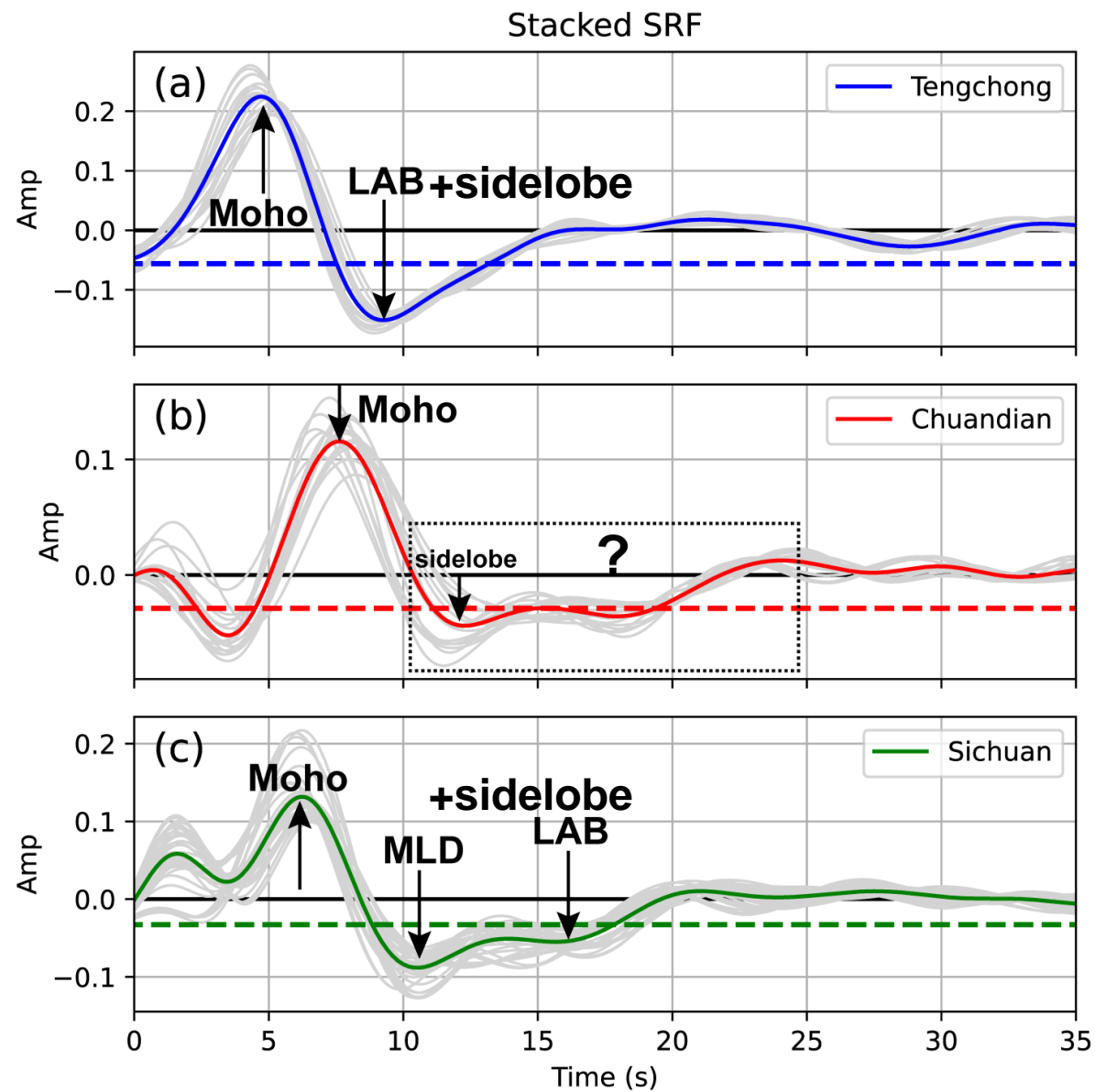
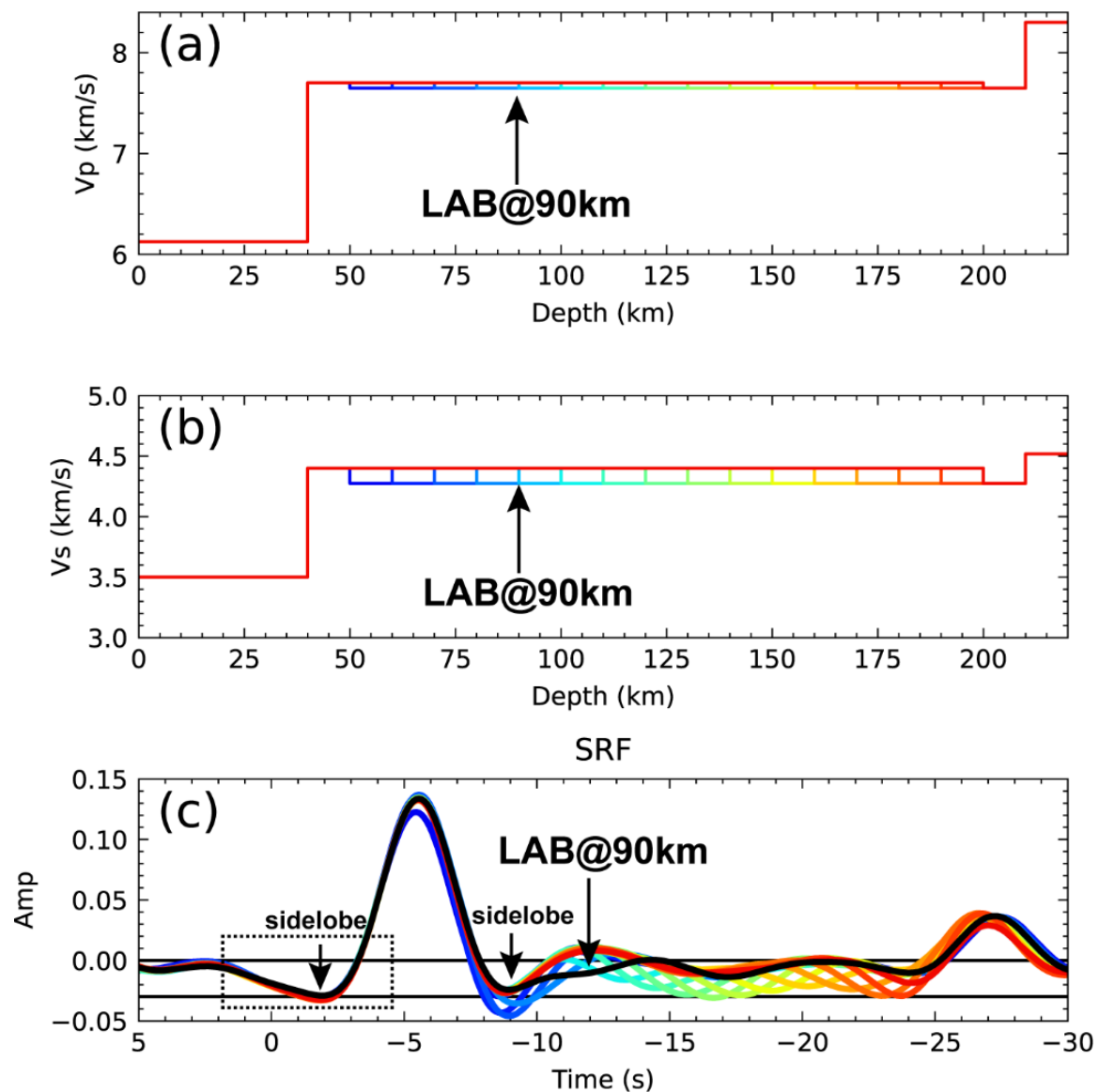
旁瓣与NVG信号的混叠分析 (通过振幅比进行旁瓣测量)



正演

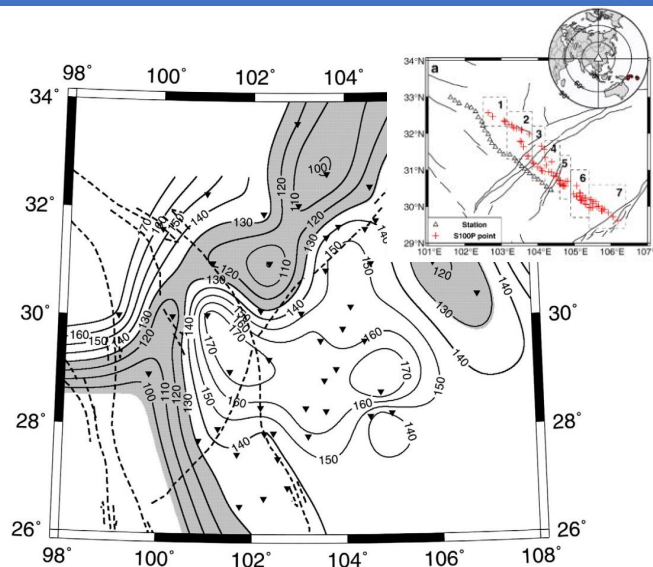
三、应用实例：青藏高原东南缘

判断是MLD而不是旁瓣



三、应用实例：青藏高原东南缘

结果对比

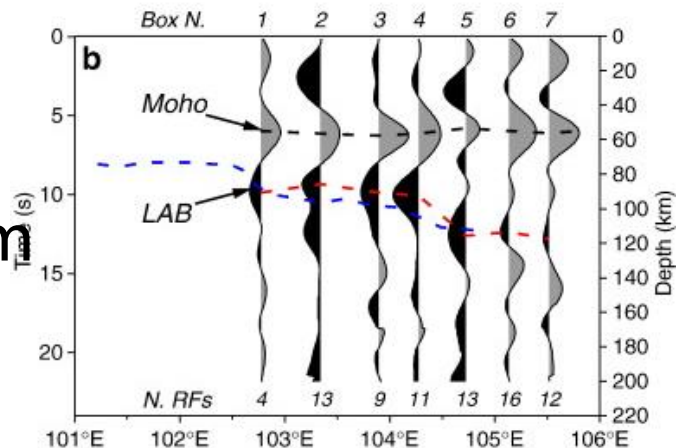


Hu et al., 2011

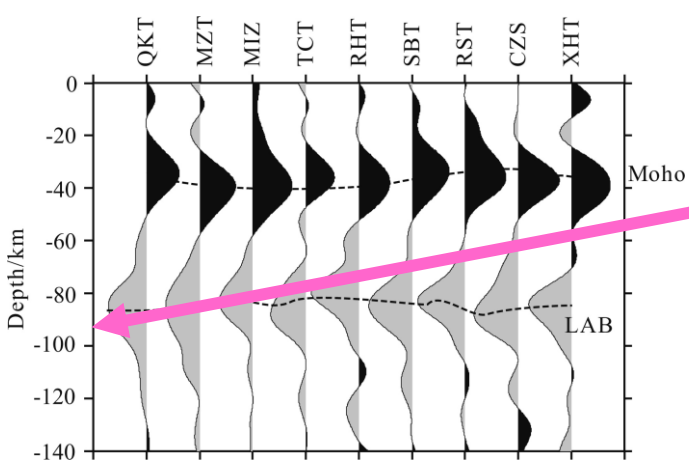
腾冲火山区
LAB应较浅, ~90km
(Hu et al., 2011; Zhang et al., 2015)

四川盆地, 有MLD
LAB应较深, ~160 km
(Zhang et al., 2010; 张耀阳等, 2018)

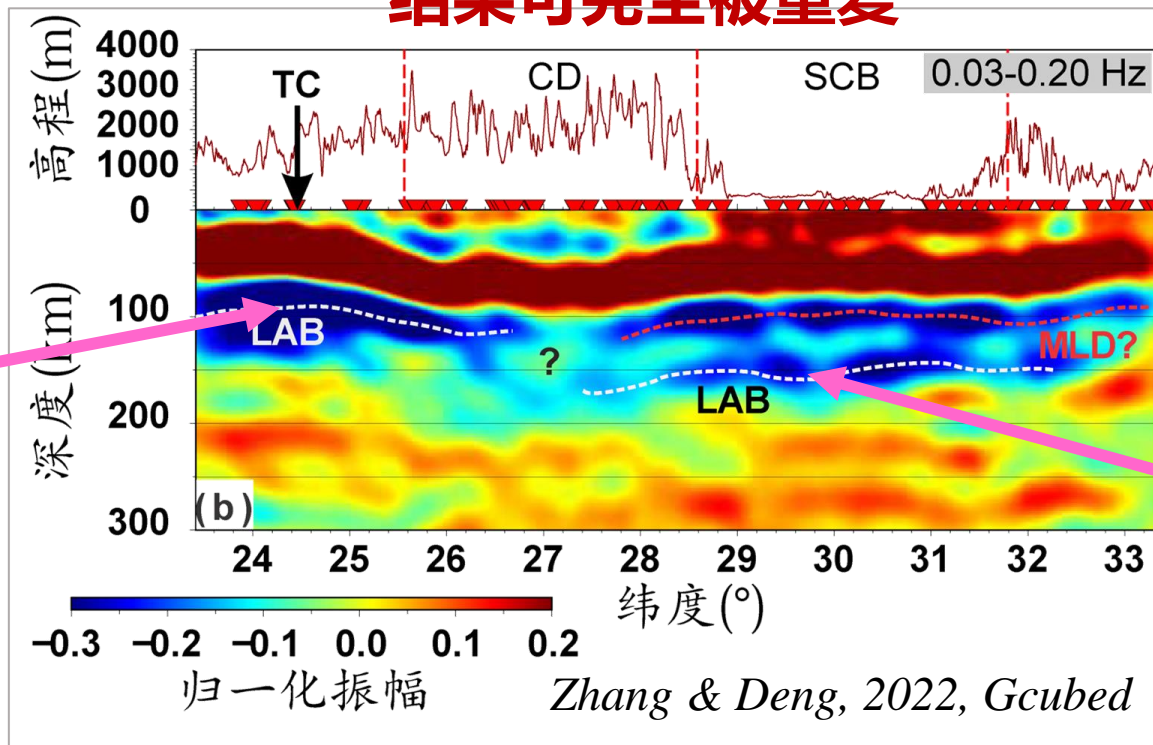
结果可完全被重复



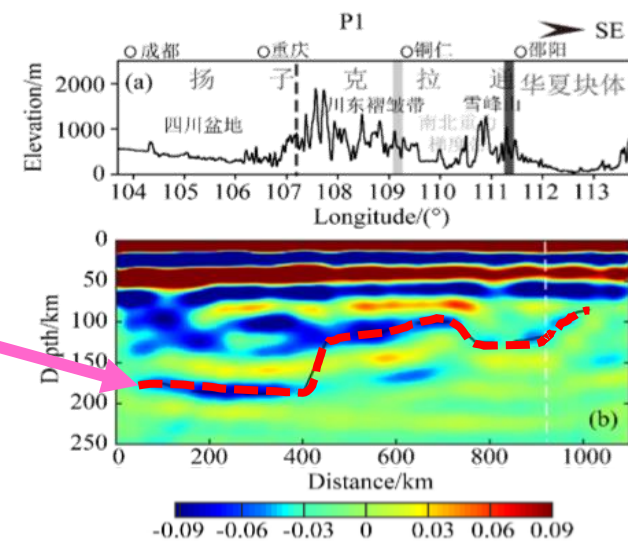
Zhang et al., 2010



Zhang et al., 2015



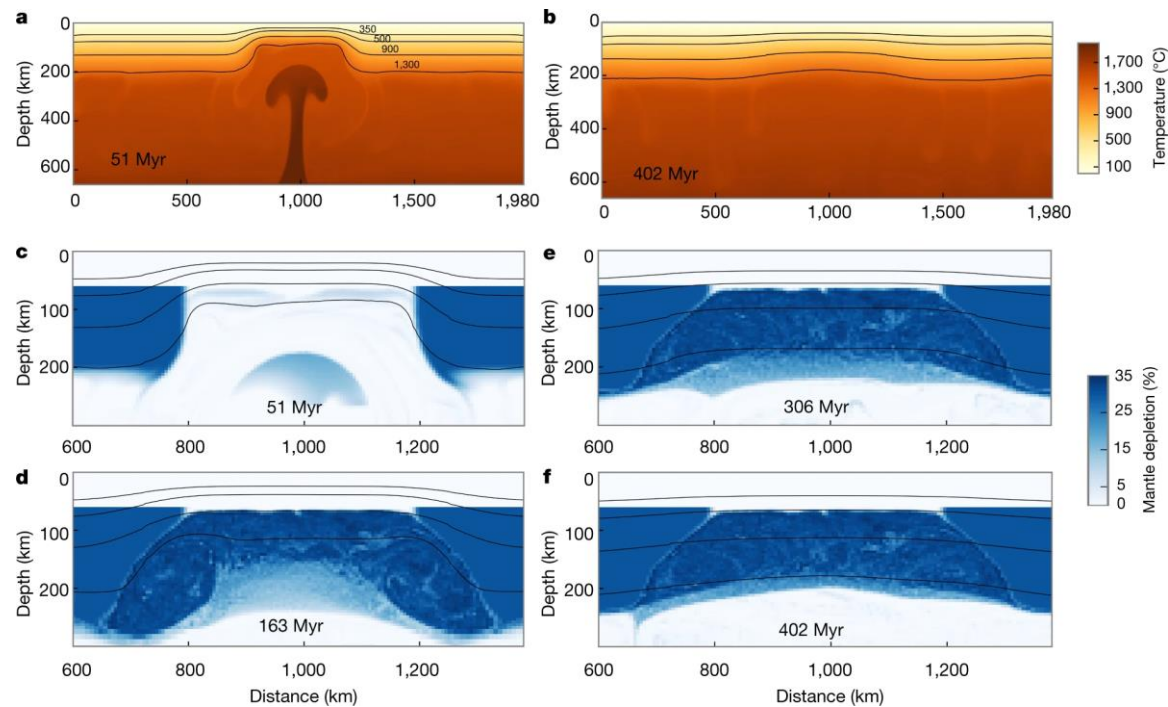
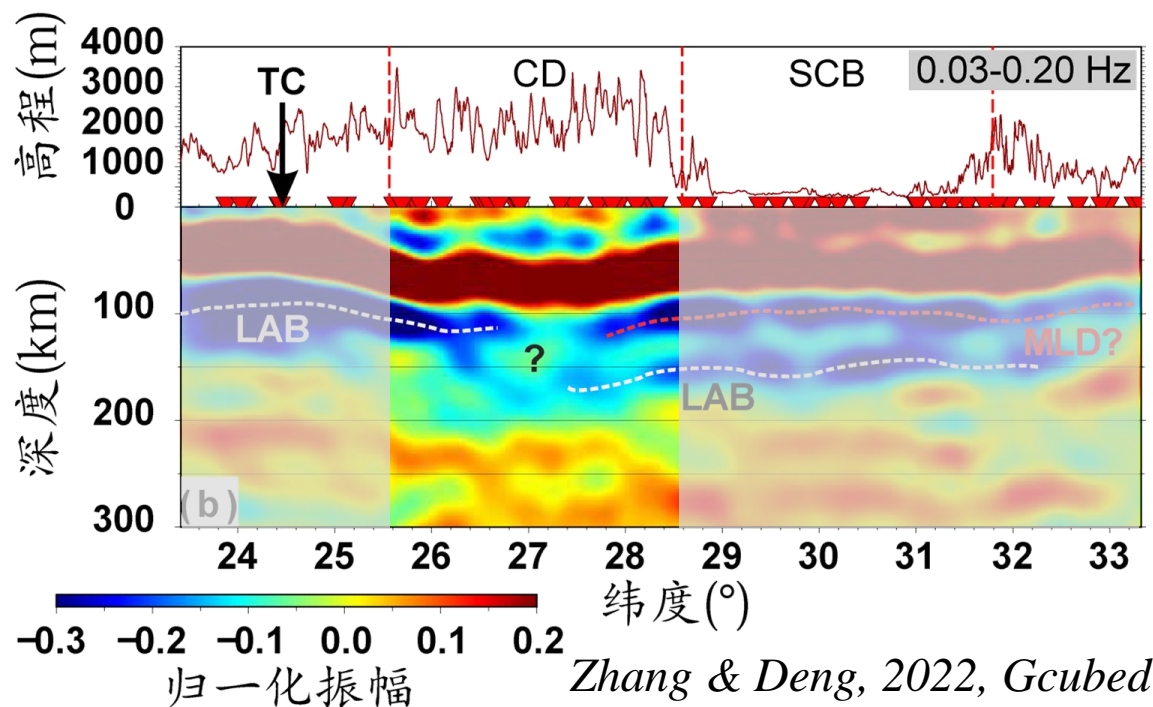
Zhang & Deng, 2022, Gcubed



张耀阳等, 2018

三、应用实例：青藏高原东南缘

结果对比



川滇地区

LAB不清晰，难以追踪识别

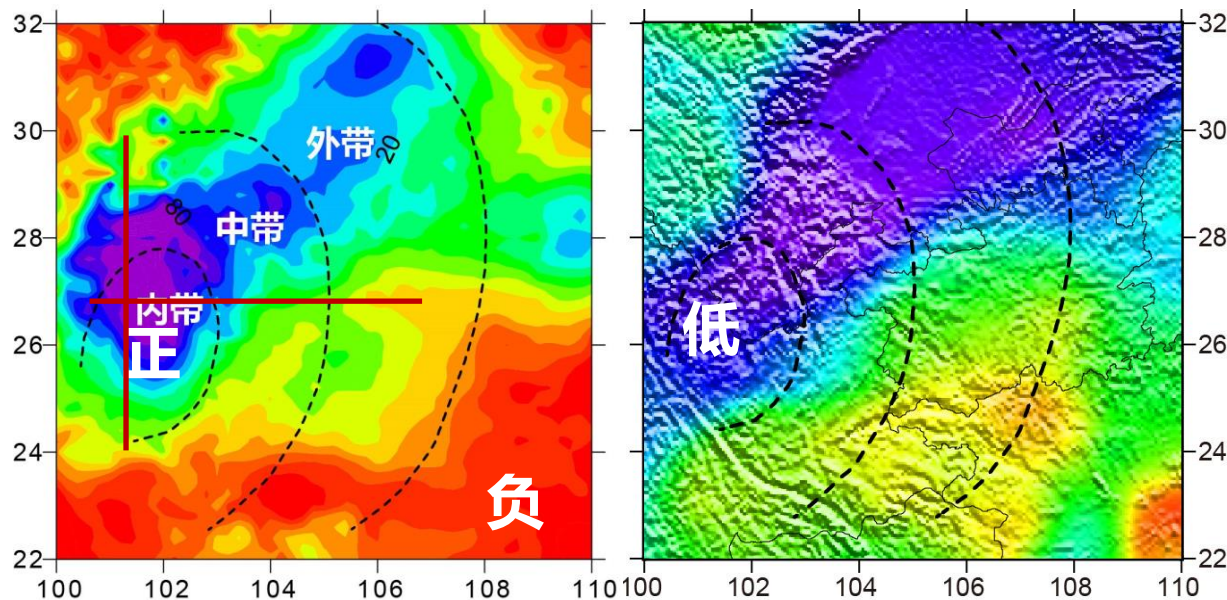
- 地幔柱作用撤离之后重新生长岩石圈响应
- 克拉通边缘所可能产生的拆沉作用 (Feng, Yao et al., 2022)

数值模拟研究表明：

地幔柱上涌导致在克拉通的薄弱点(thin spot)区域发生减薄破坏

地幔柱作用撤离后岩石圈将重新克拉通化(recratonization)

三、应用实例：青藏高原东南缘峨眉山大火成岩省地球物理特征



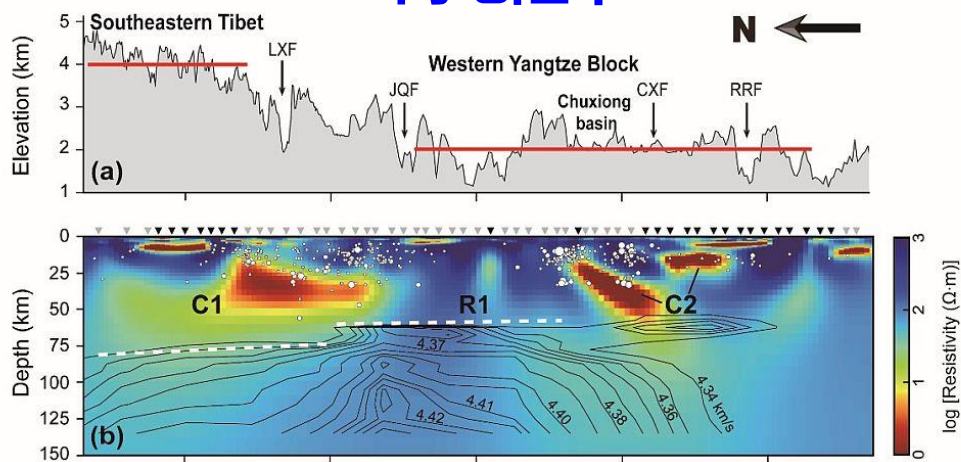
正剩余布格重力异常

Deng et al., 2014

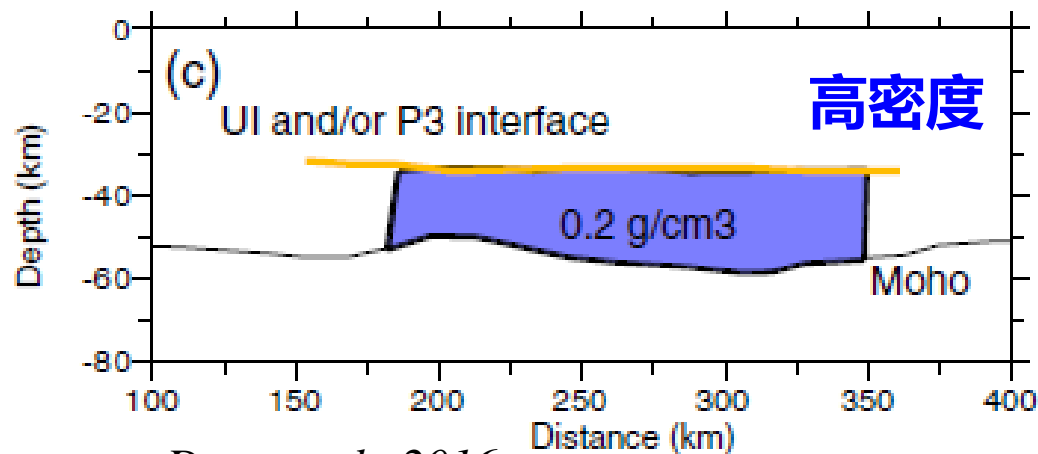
低衰减结构

Deng et al., 2021

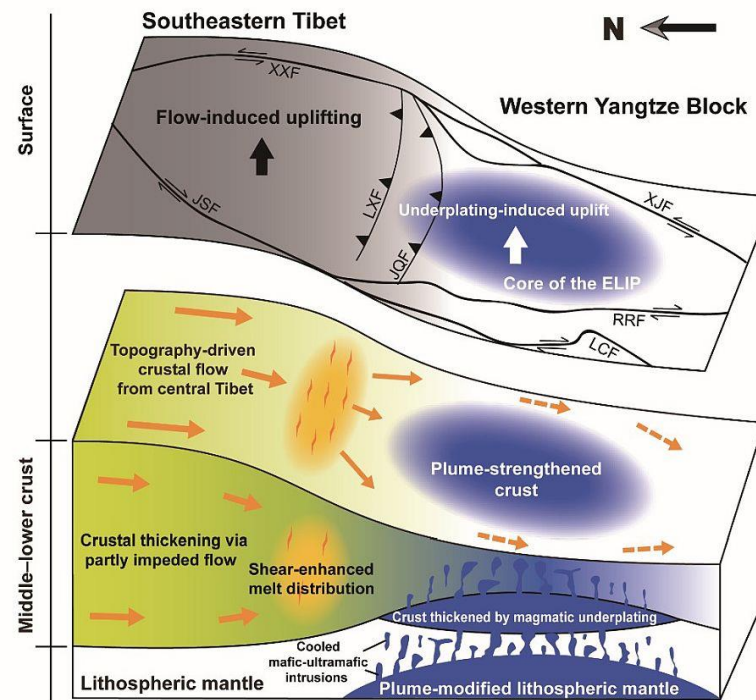
高电阻率



Li et al., 2020



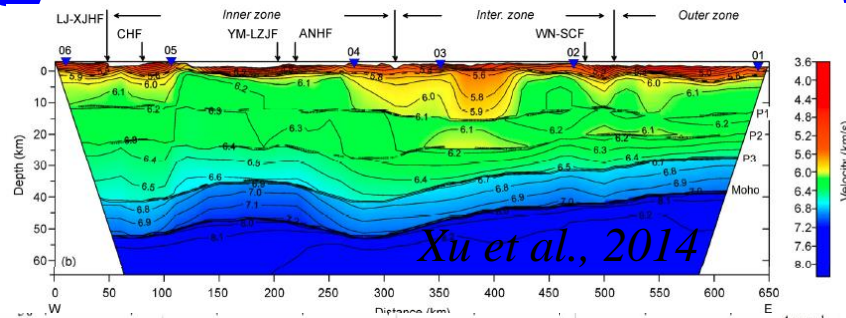
Deng et al., 2016



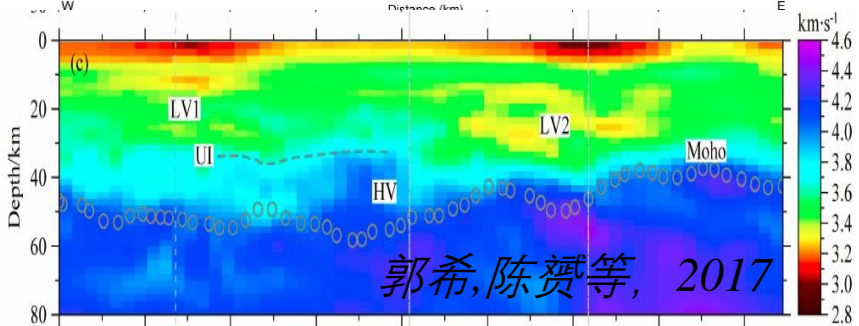
三、应用实例：青藏高原东南缘峨眉山大火成岩省地球物理特征

高波速

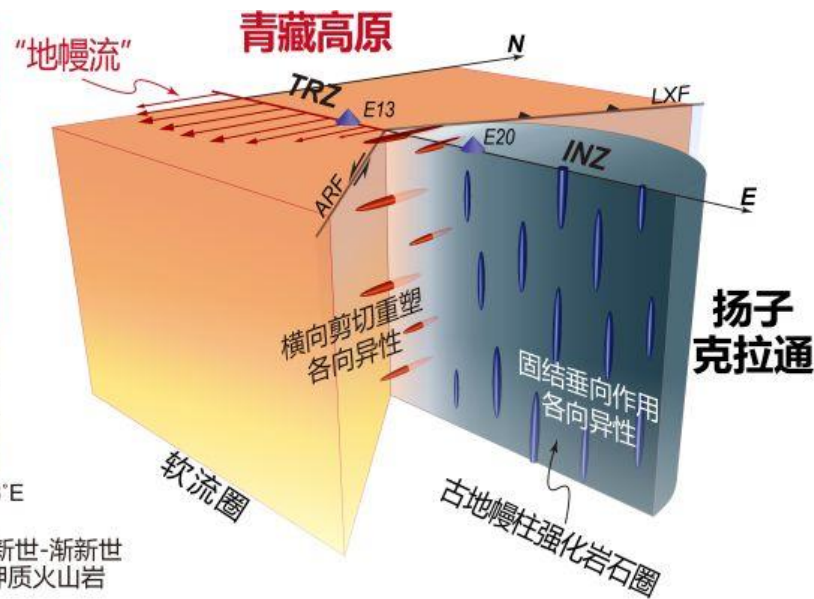
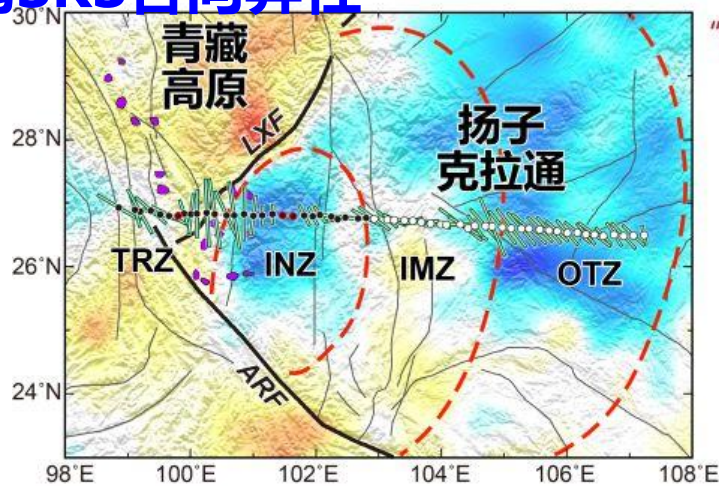
Vp



Vs

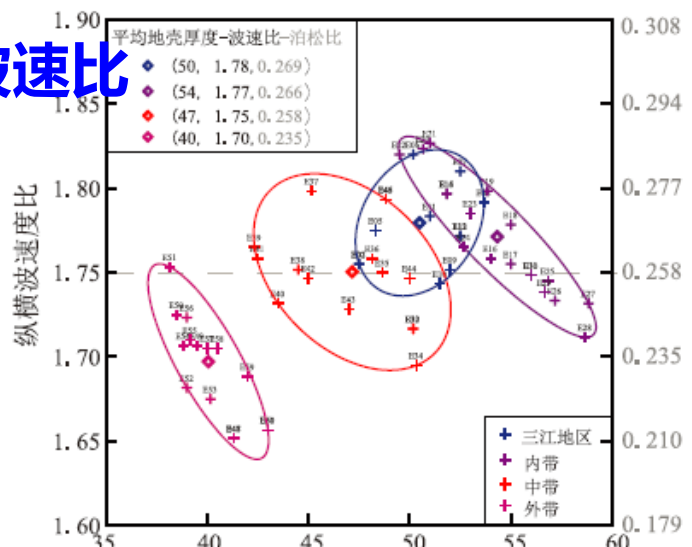


弱SKS各向异性



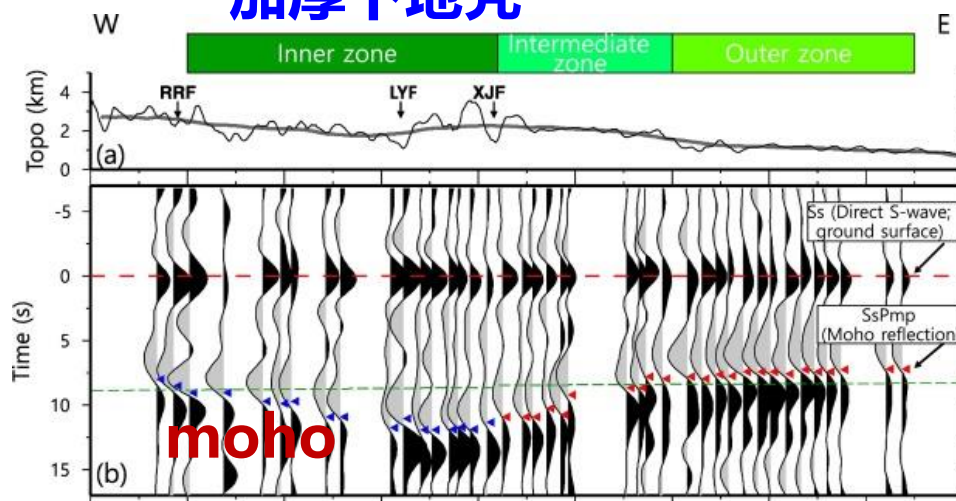
Li, Chen et al., 2021a

高波速比



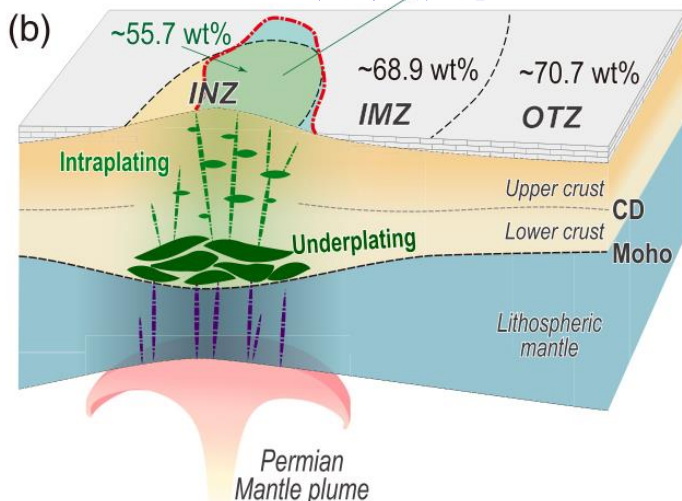
Chen et al., 2015

加厚下地壳



Liu, Tian et al., 2017

高铁镁质含量



Li, Chen et al., 2021b

四、展望：单台岩石圈厚度估计ML-k

GC_SRF策略

无人干扰，可完全重复

特点：得到稳定的S波接收函数
偏移成像之后得到岩石圈厚度

缺点：1.需要台阵；2.需要速度模型

Zhang and Deng, 2022, Gcubed



克服第一个缺点，少量台站：
火山区，火星，月球？

ML - κ 扫描叠加

特点：单台同时获得岩石圈厚度，
地壳厚度，地壳波速比，岩石圈地
幔波速比

Moho depth variation in southern California from teleseismic receiver functions

L Zhu, H Kanamori - Journal of Geophysical Research: Solid ... , 2000 - Wiley Online Library

The number of broadband three-component seismic stations in southern California has more than tripled recently. In this study we use the teleseismic receiver function technique to determine the crustal thicknesses and V_p/V_s ratios for these stations and map out the lateral variation of Moho depth under southern California. It is shown that a receiver function can provide a very good "point" measurement of crustal thickness under a broadband station and is not sensitive to crustal P velocity. However, the crustal thickness estimated only from ...

★ Save 99 Cite **Cited by 1728** Related articles All 16 versions

Ps 转换震相： $H - \kappa$ 方法获得地壳厚度，地壳平均波速比

改进

加入Sp转换震相
(S波接收函数)

ML - κ 扫描叠加

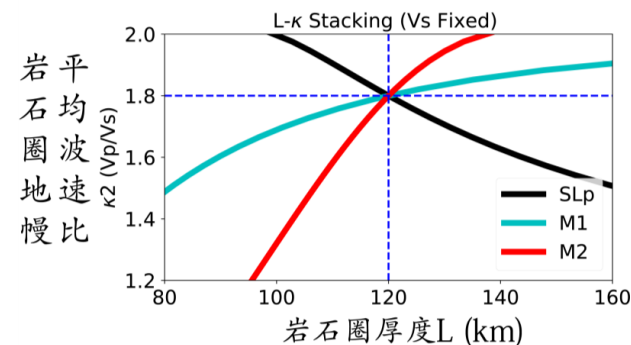
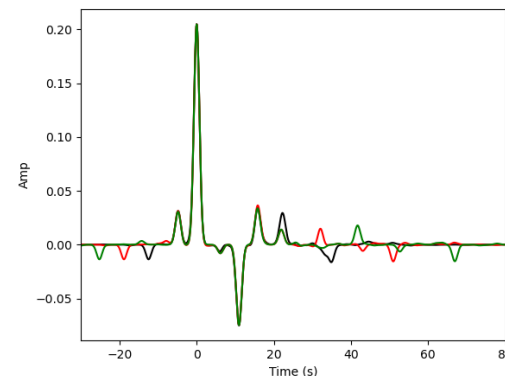
1.证明正支震相的存在性

正演显示其存在且成组出现

2.推导走时解析表达

3.解析式的图像表示

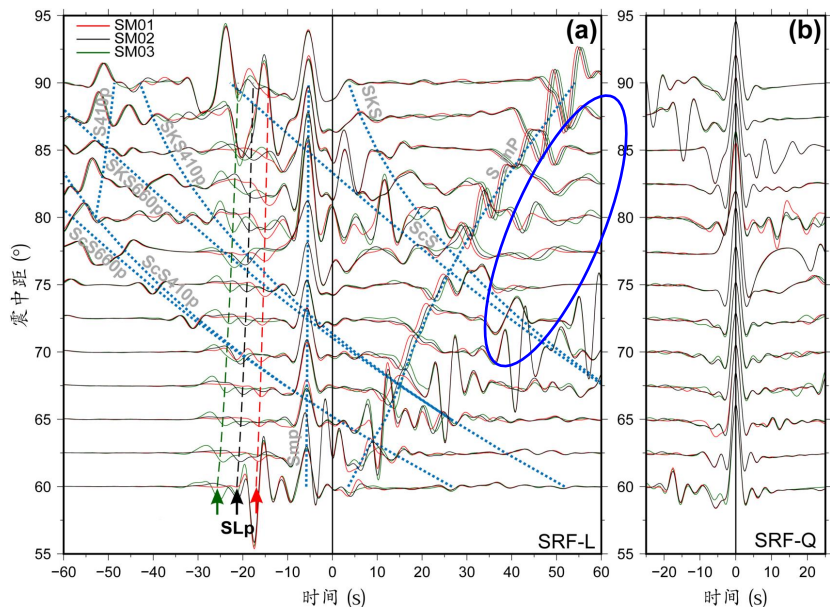
Zhang and Deng, 2023, Prepared



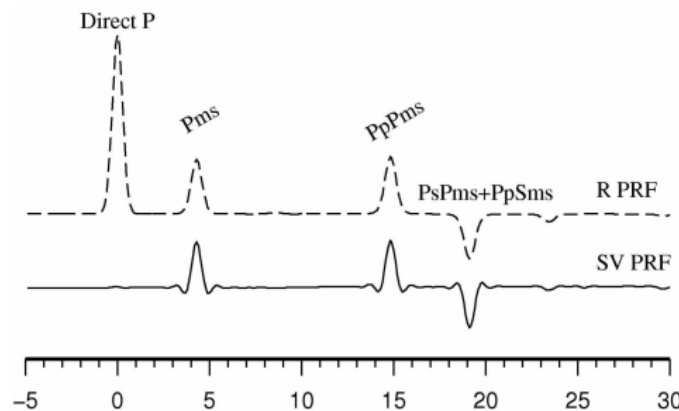
四、展望：单台岩石圈厚度估计ML-k

1.证明正支震相的存在性

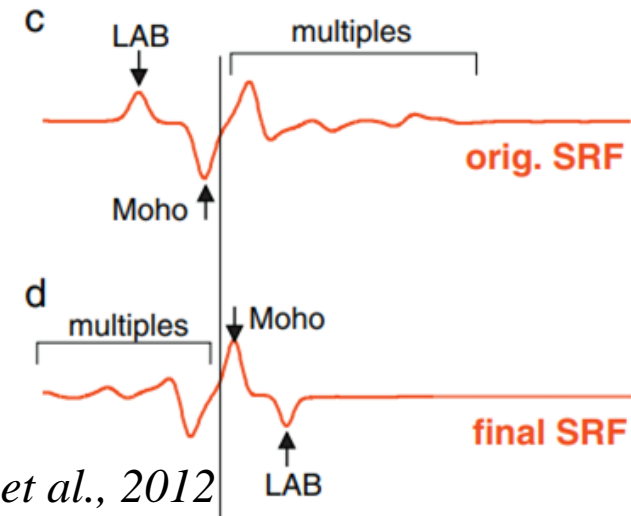
1-D理论测试显示正支存在与LAB深度相关的震相



现有研究中一般不讨论正支震相



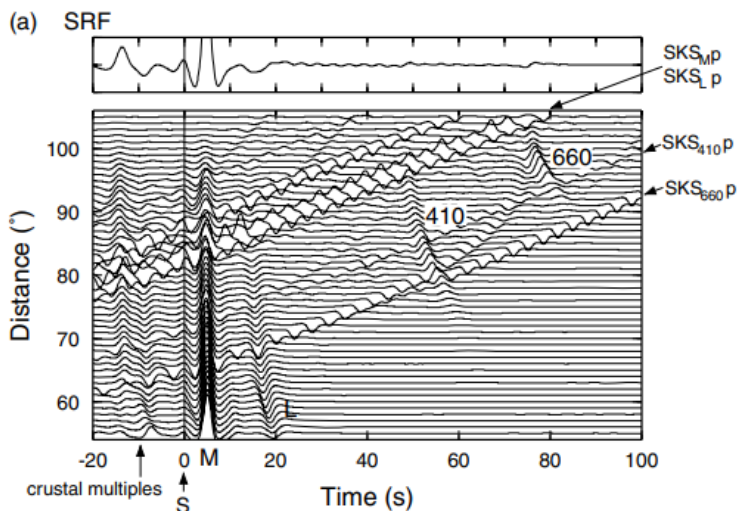
徐强等, 2008



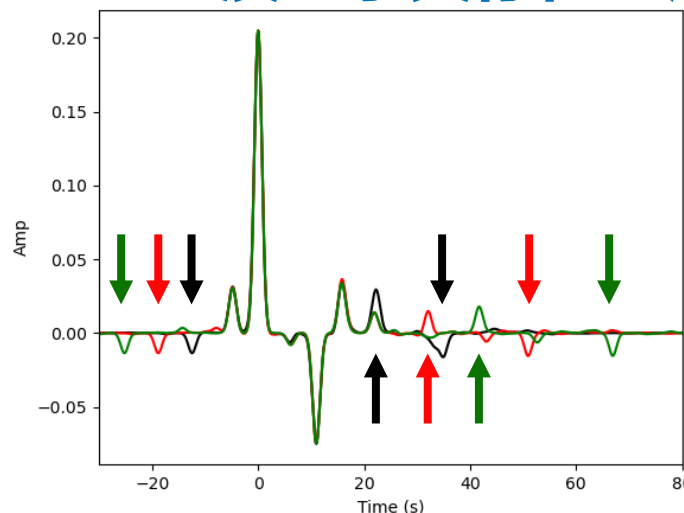
Kind et al., 2012

正演显示其存在且成组出现

一般标记为地壳多次波

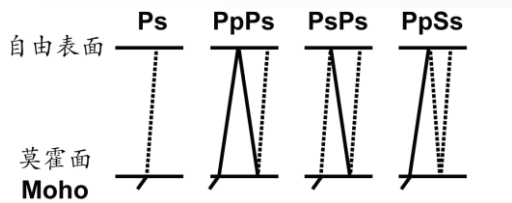


Yuan et al., 2006

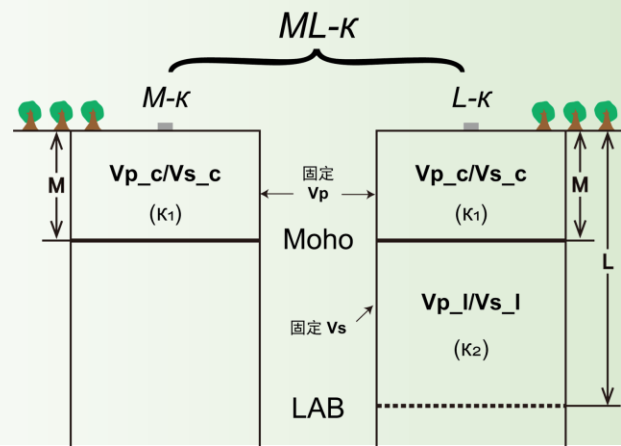


LAB 100km
LAB 150km
LAB 200km

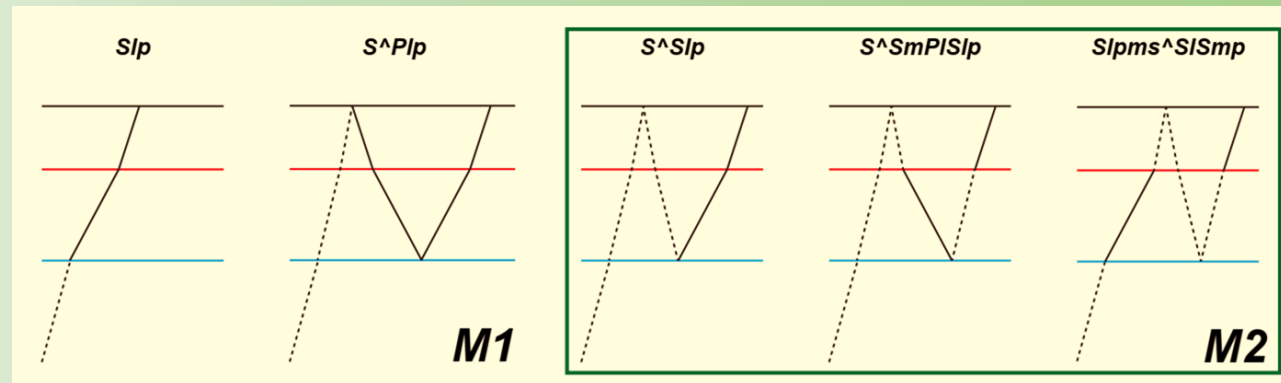
经典的H - κ方法的震相组合



模型构建



ML - κ所用震相的震相组合



震相走时的解析表达式

$$H = \frac{t_{Ps}}{\sqrt{\frac{1}{V_S^2} - p^2} - \sqrt{\frac{1}{V_P^2} - p^2}}$$

$$H = \frac{t_{PpPs}}{\sqrt{\frac{1}{V_S^2} - p^2} + \sqrt{\frac{1}{V_P^2} - p^2}}$$

$$H = \frac{t_{PpSs+PsPs}}{2\sqrt{\frac{1}{V_S^2} - p^2}}$$

Zhu and Kanamori, 2000



t_{SLp}

t_{M1}

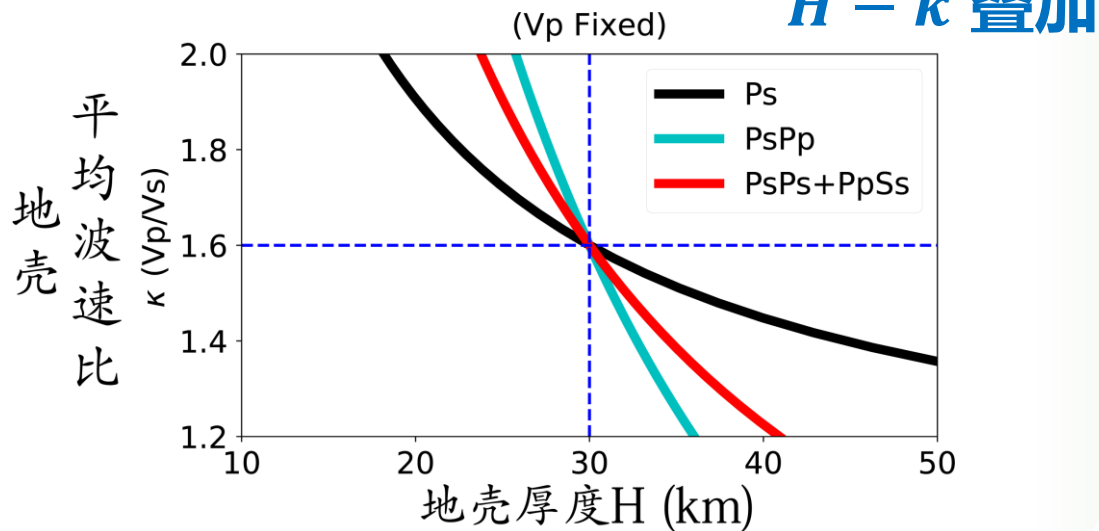
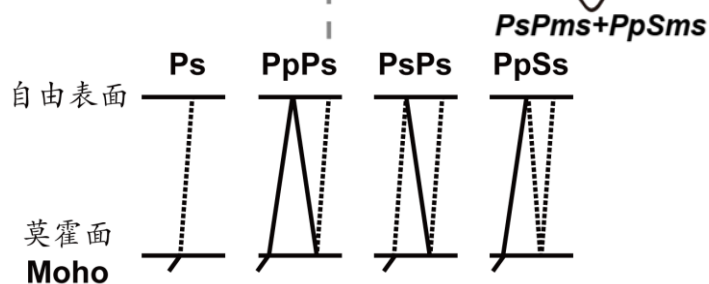
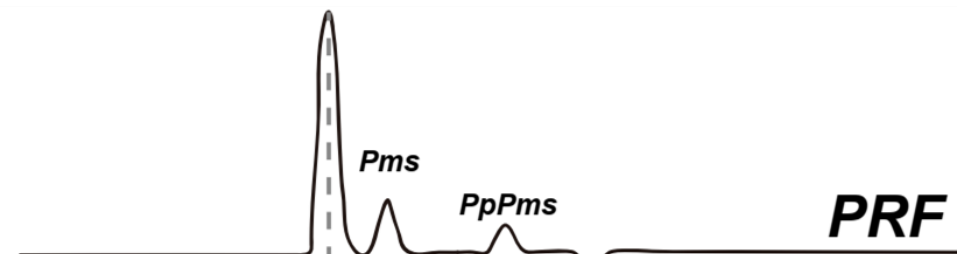
t_{M2}

Zhang and Deng, 2023, Prepared

四、展望：单台岩石圈厚度估计ML-k

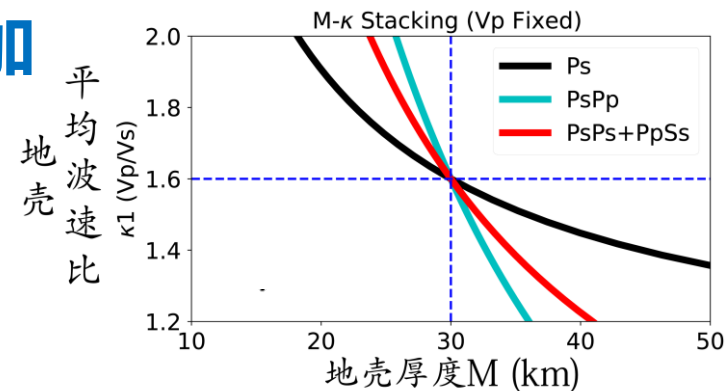
3. 解析式的图像表示

经典的H- κ 方法

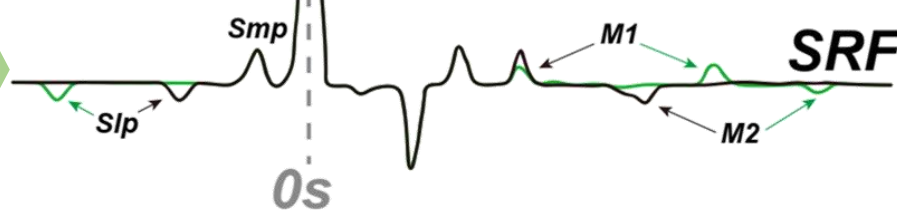


ML- κ 叠加方法

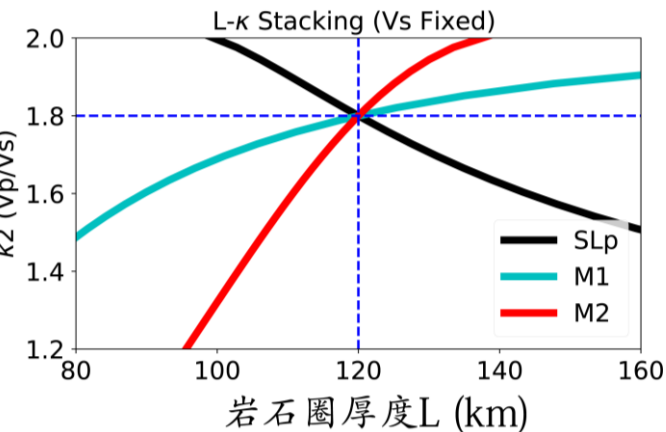
第一步：M- κ 叠加



第二步：L- κ 叠加



岩石圈平均波速比 κ_2 (Vp/Vs)



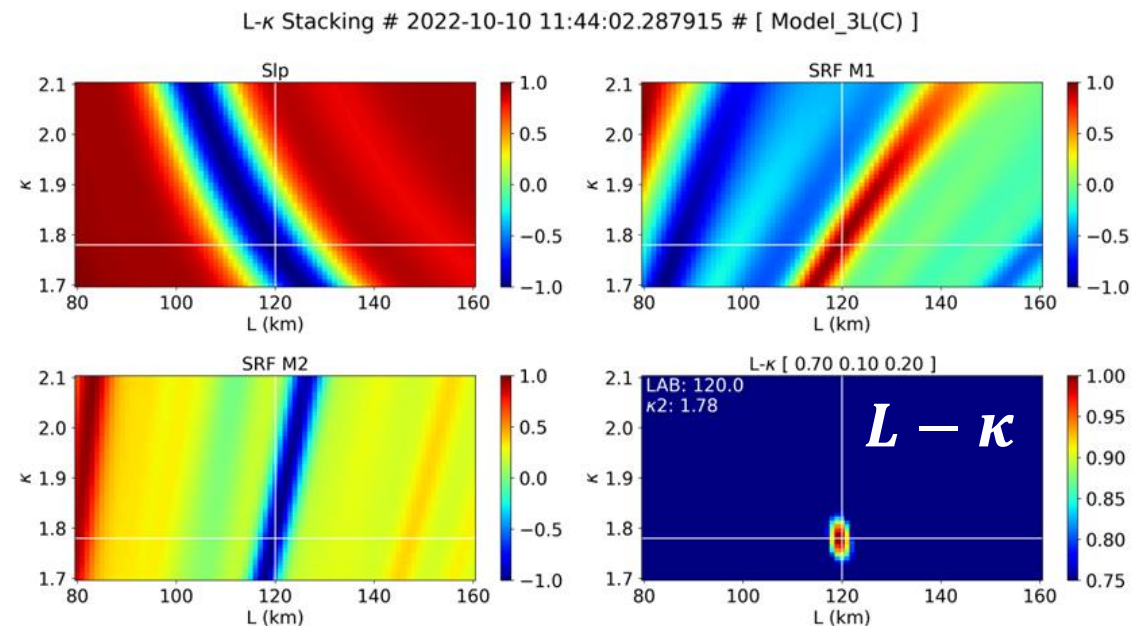
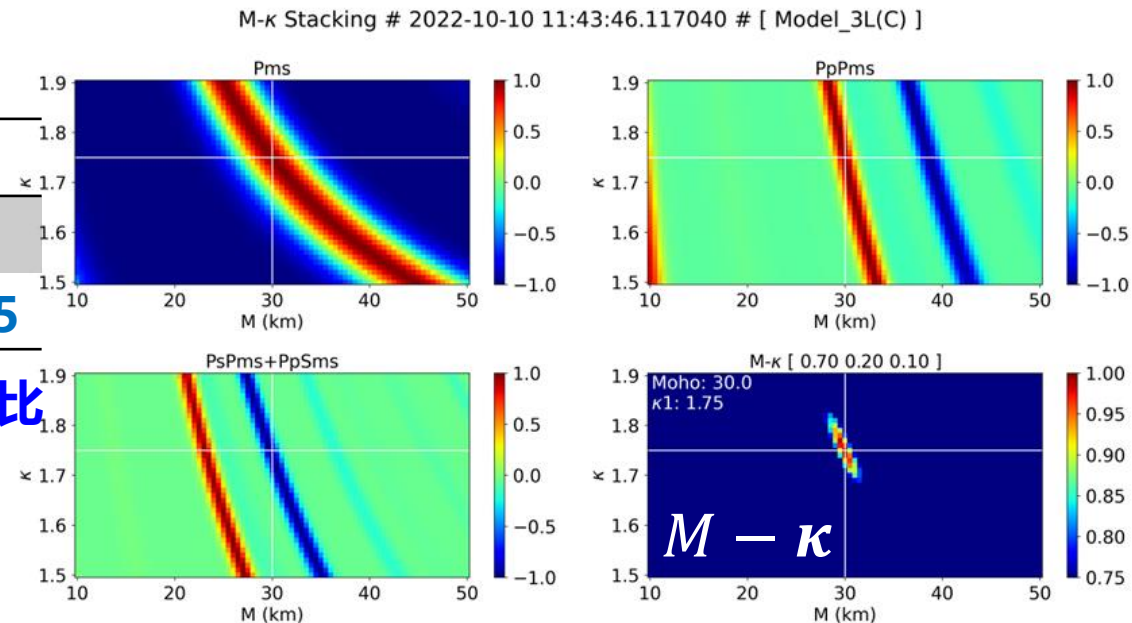
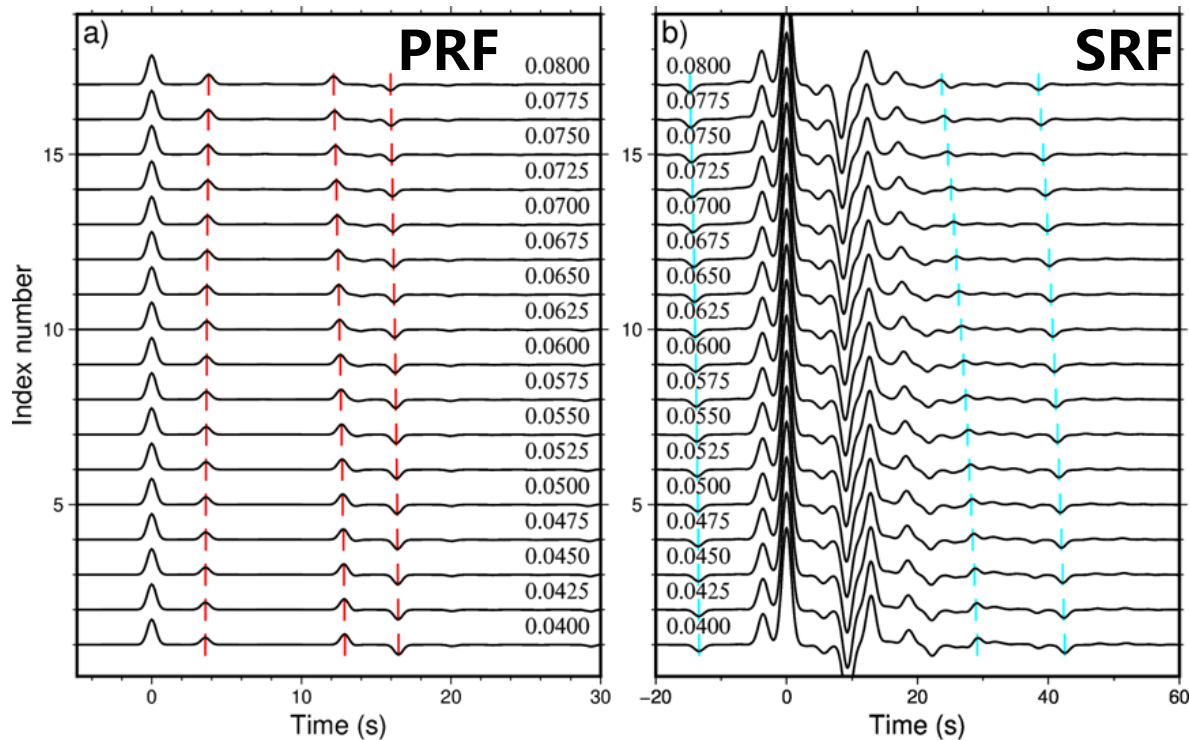
四、展望：单台岩石圈厚度估计ML-k理论测试

理论模型测试:Model_3L

	M (km)	κ_1	L (km)	κ_2
理论值	30	1.73	120	1.80
$ML - \kappa$	30/0.839	1.75/0.03	120/1.126	1.780/0.055

地壳厚度, 地壳波速比, 岩石圈厚度, 岩石圈地幔波速比

理论接收函数慢度剖面



四、展望：单台岩石圈厚度估计ML-k理论测试

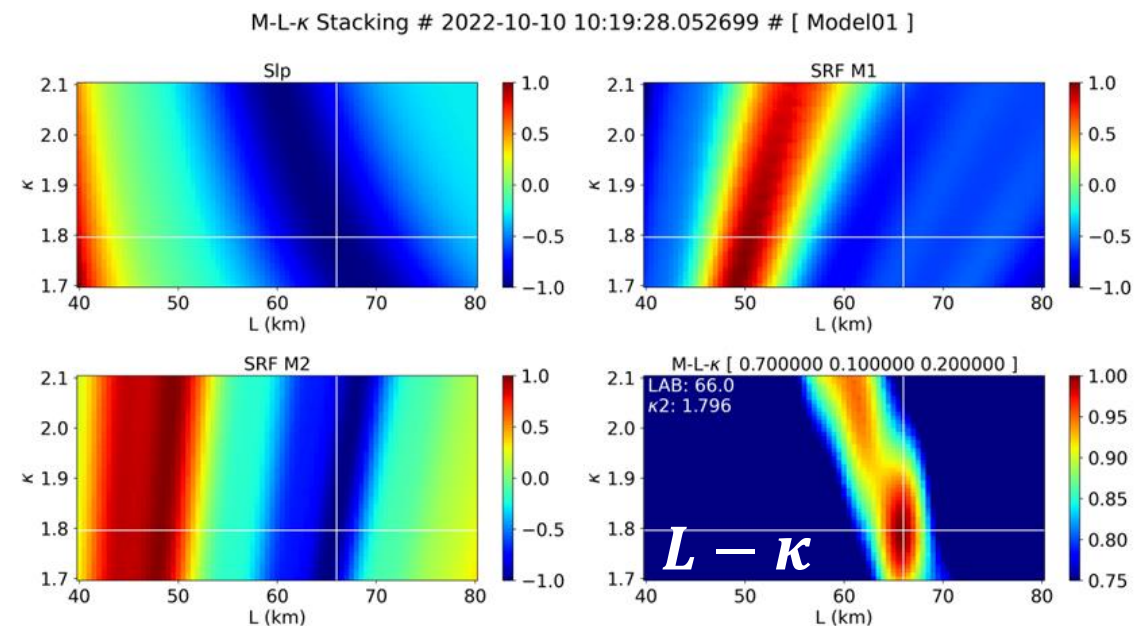
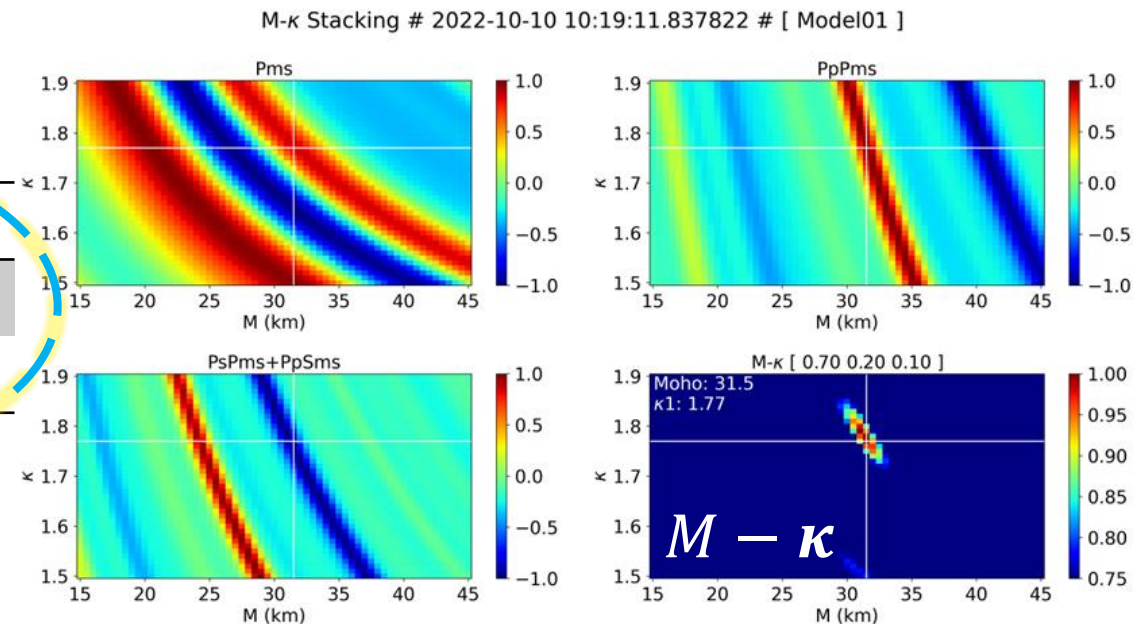
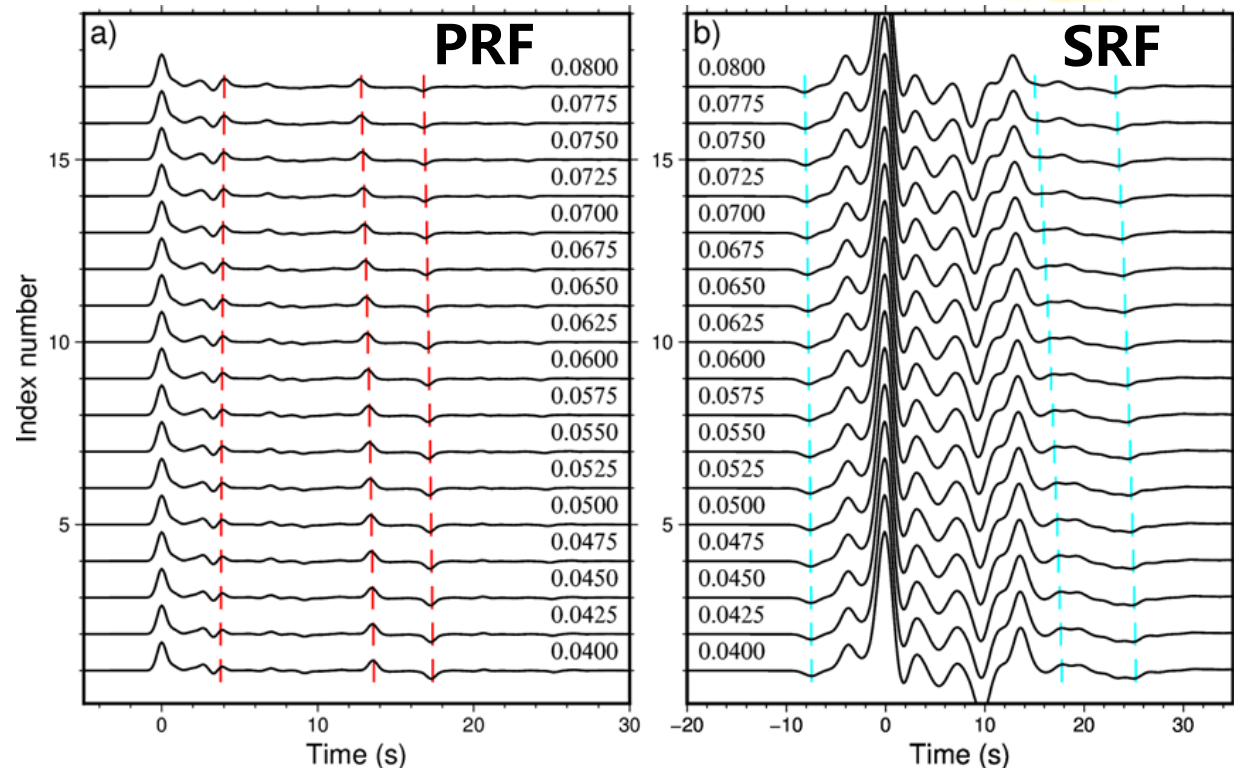
理论模型测试: Model_01 (南加州参考模型)

模型参数参考 *Zhu & Kanamori, 2000*

	M (km)	κ_1	L (km)	κ_2
理论值	31	1.731	67	1.85

$ML - \kappa$ 31.5/0.753 1.77/0.027 66/2.479 1.796/0.2

理论接收函数慢度剖面

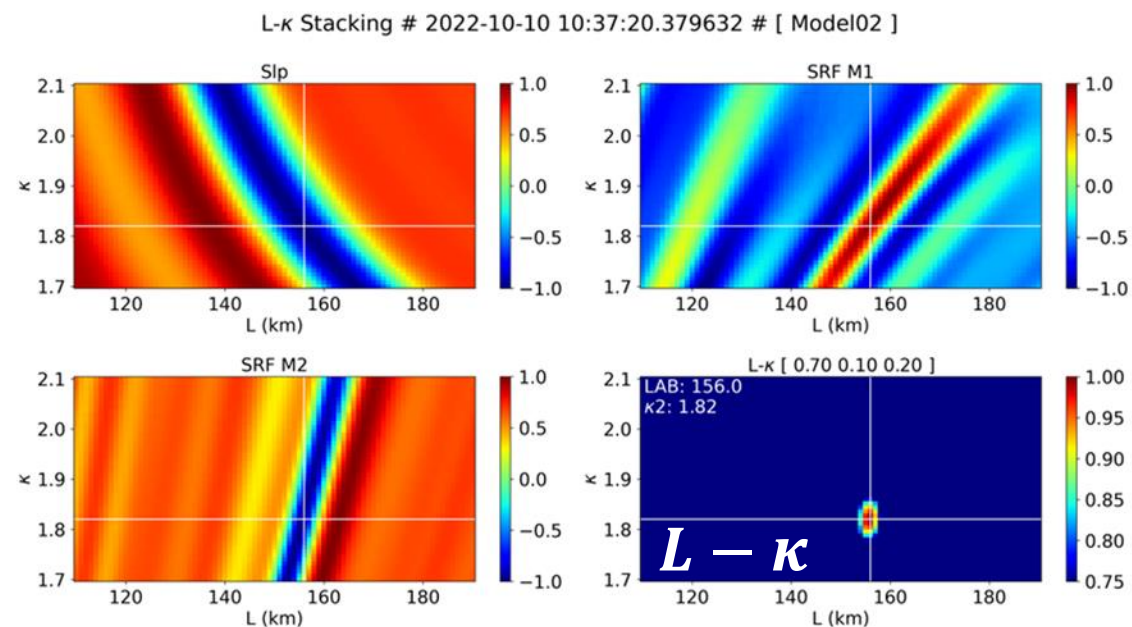
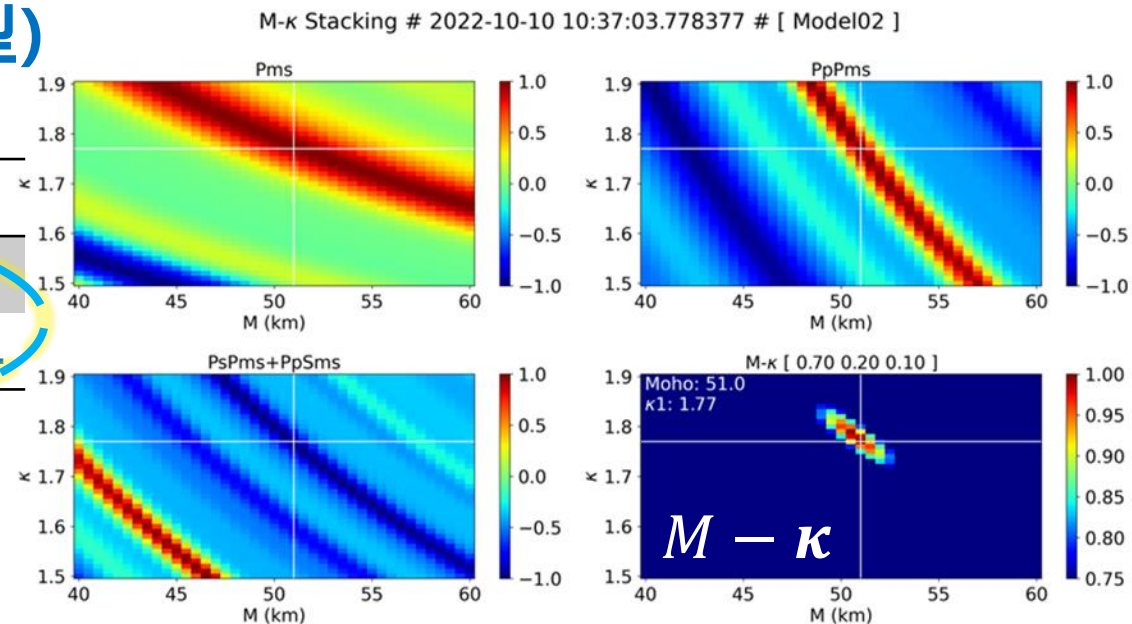
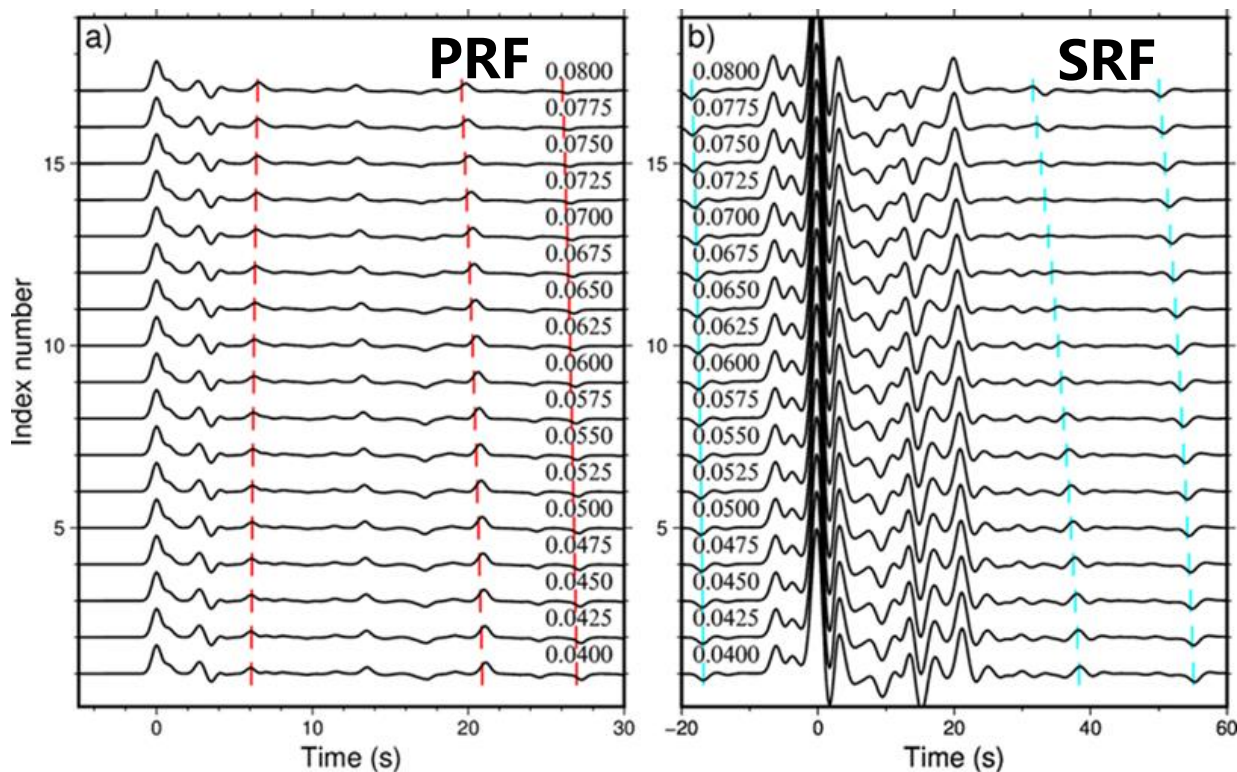


理论模型测试: Model_02 (四川盆地参考模型)

模型参数参考 *USTClitho2.0, Han et al., 2022*

	M (km)	$\kappa 1$	L (km)	$\kappa 2$
理论值	51	1.77	155	1.83
$ML - \kappa$	51/0.665	1.77/0.019	156/0.925	1.82/0.044

理论接收函数慢度剖面



四、展望：岩石圈速度反演Joint_RFSW

GC_SRF策略

无人为干扰，可完全重复

特点：得到稳定的S波接收函数
偏移成像之后得到岩石圈厚度

缺点：1.需要台阵；2.需要速度模型

Zhang and Deng, 2022, Gcubed

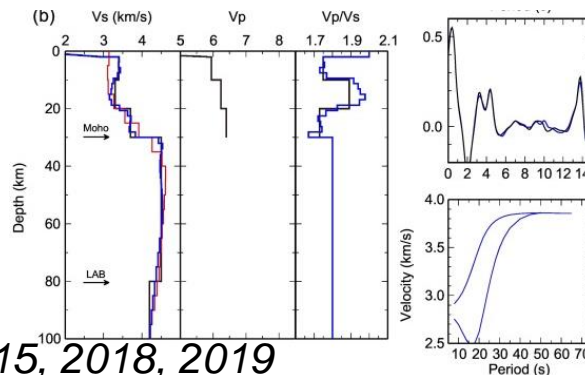


克服第一个缺点，少量台站：
火山区，火星，月球

ML - κ 扫描叠加

特点：单台同时获得岩石圈厚度，
地壳厚度，地壳波速比，岩石圈地
幔波速比

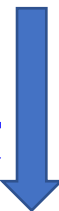
Zhang and Deng, 2023, Prepared



Deng et al., 2015, 2018, 2019

Joint: P波接收函数与面波频散联合反演

改进
加入S波接收函数



克服第二个缺点

joint_RFSW联合反演

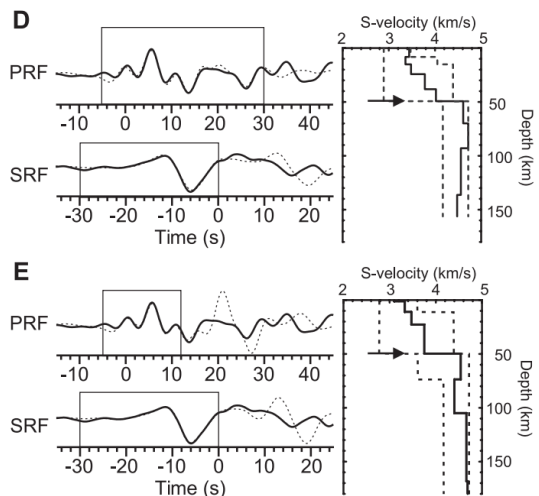
P波接收函数、S波接收函数与面波频散联合反演

特点：同时获得不同深度速度、
速度比，岩石圈厚度，地壳厚度

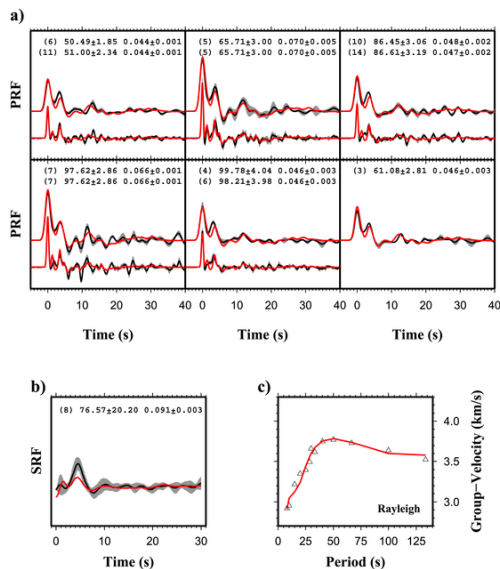
Zhang and Deng, 2023, Prepared

四、展望：岩石圈速度反演Joint_RFSW前人研究

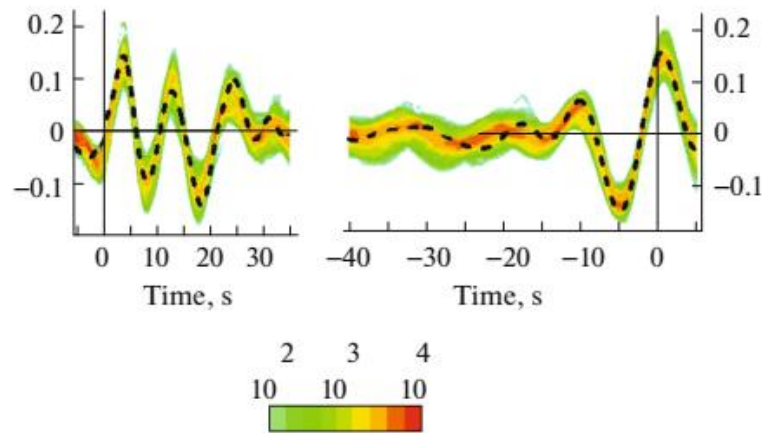
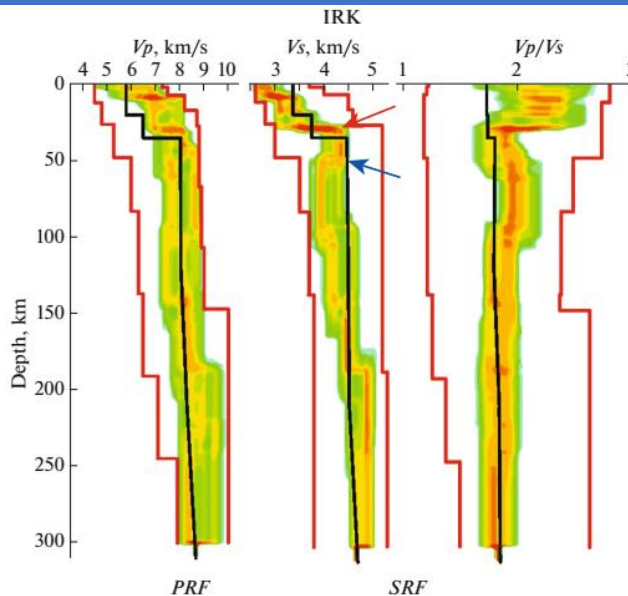
与SRF有关的联合反演



Vinnik et al., 2004

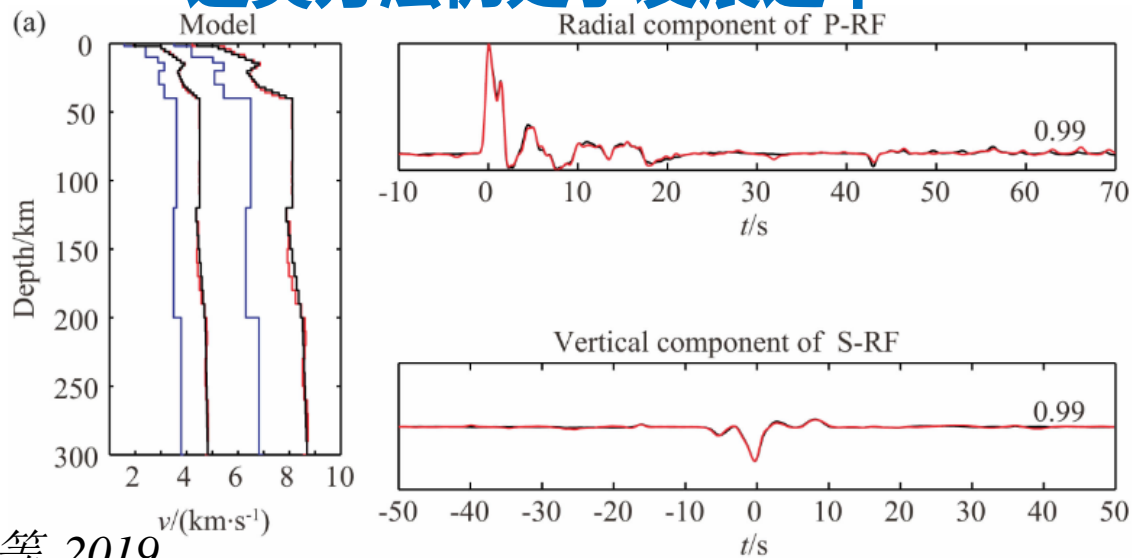


Tang et al., 2019



Vinnik et al., 2019

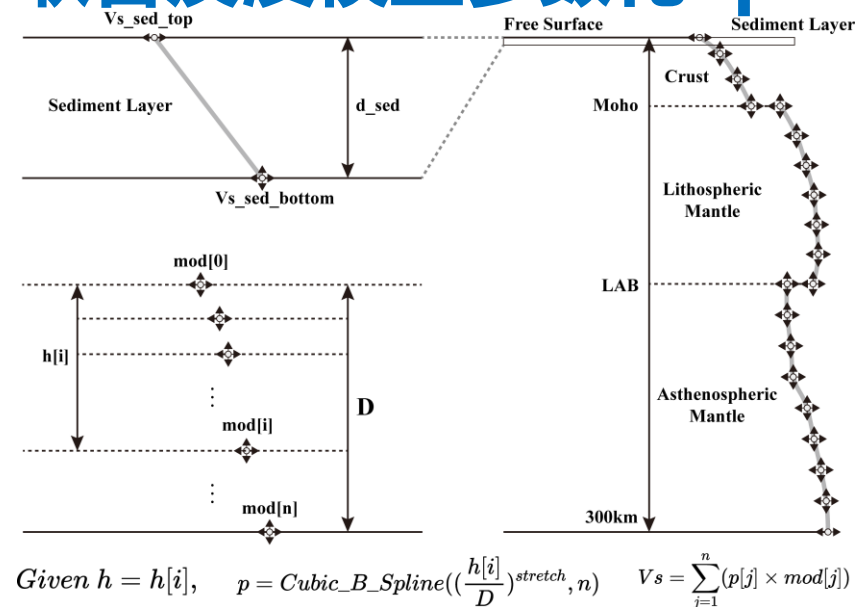
同时获得moho, LAB, Vs, Vp/Vs 这类方法仍处于发展之中



王峻等, 2019

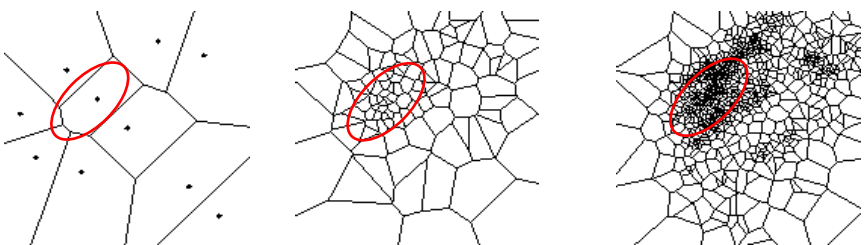
三、展望：岩石圈速度反演Joint_RFSW

联合反演模型参数化Spline



最优化算法：邻域算法
Neighbourhood Algorithm

Sambridge, 1999



1. 联合反演数据体

面波群速度

面波相速度

P波接收函数

S波接收函数

Pms走时

SLp走时

目标函数构建

$$\begin{aligned}
 &w_1 |D_{grp}^{obs} - D_{grp}^{pred}| \\
 &+ w_2 |D_{phs}^{obs} - D_{phs}^{pred}| \\
 &+ w_3 |D_{prfs}^{obs} - D_{prfs}^{pred}| \\
 &+ w_4 |D_{srfs}^{obs} - D_{srfs}^{pred}| \\
 &+ w_5 |tps^{obs} - tps^{pred}| \\
 &+ w_6 |tsp^{obs} - tsp^{pred}| \\
 &+ \lambda |m - m_0| \\
 &+ \varphi |Lm|
 \end{aligned}$$

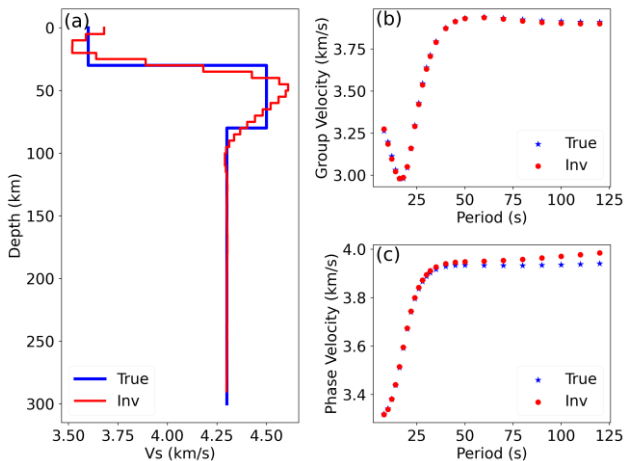
Li, Song, Zhu, Deng, 2017, JGR

Zhang and Deng, 2023, Prepared

四、展望：岩石圈速度反演Joint_RFSW理论测试

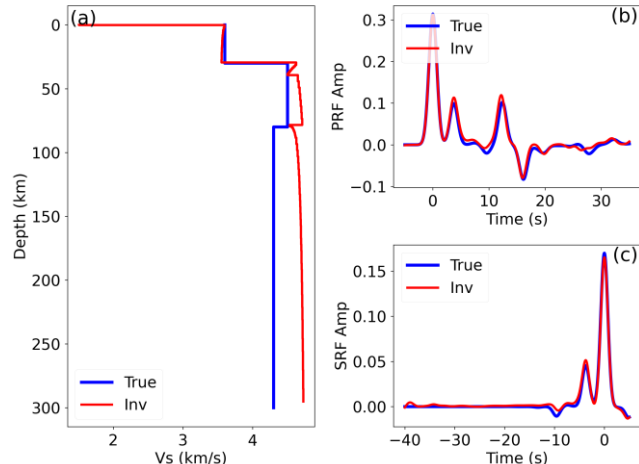
单独面波频散反演

Dispersions Inversion



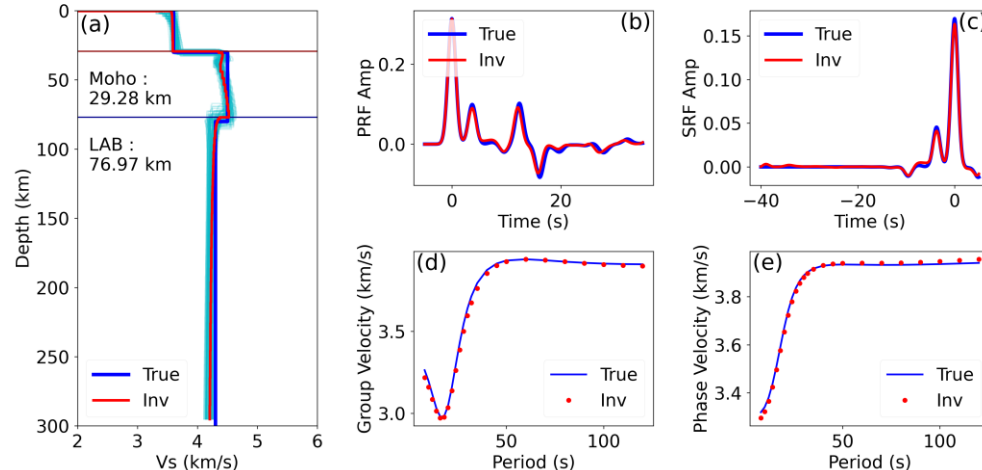
单独接收函数反演

RFs Only Inversion



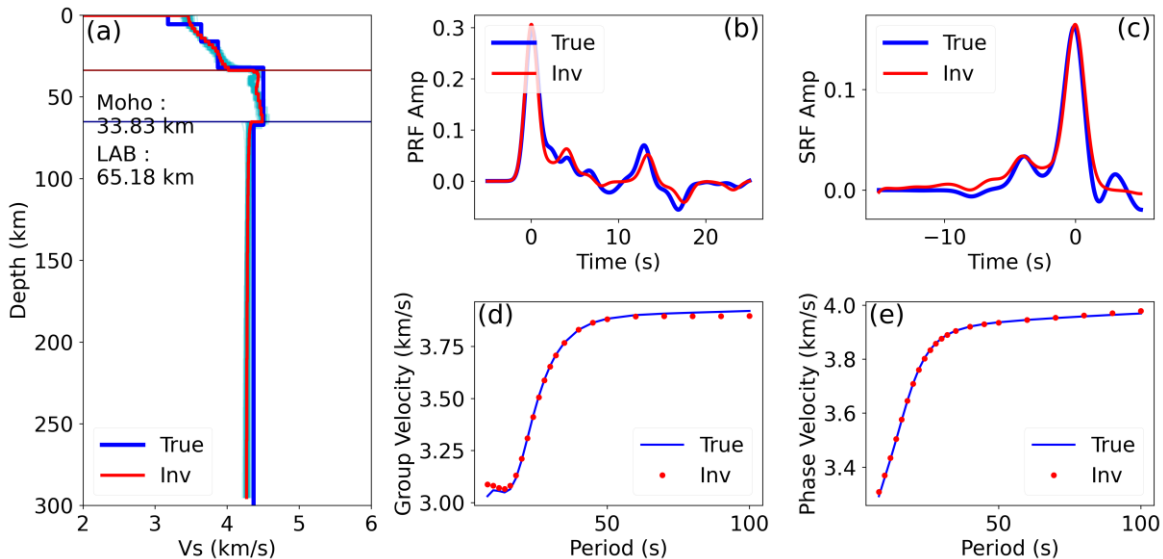
Model_3L(A)联合反演

Joint inversion test # 2022-10-12 14:18:40.968834



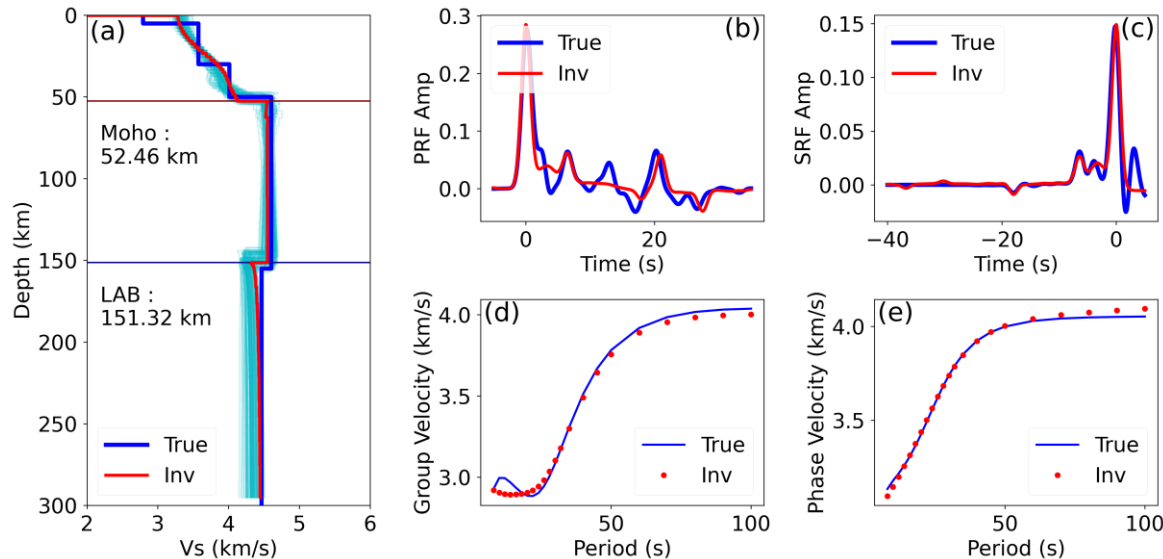
Model_01联合反演 (南加州参考模型)

Joint inversion test # 2022-10-12 18:28:21.152749



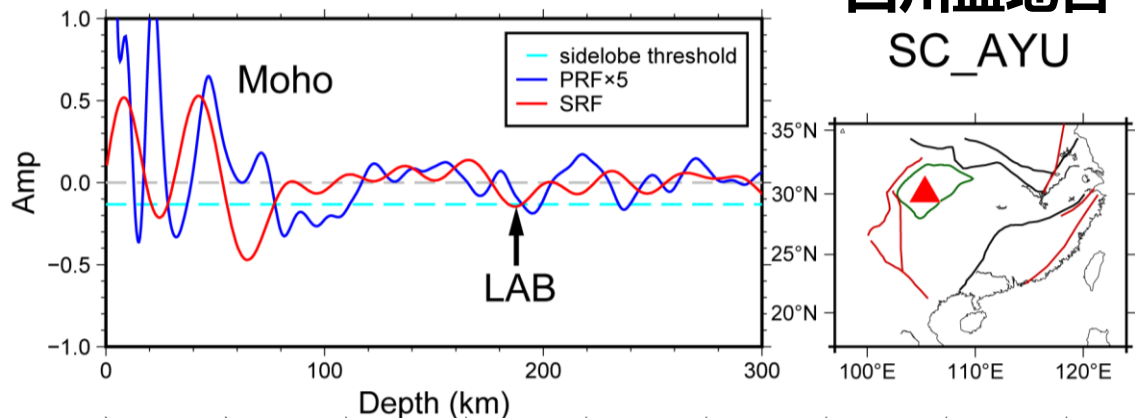
Model_02联合反演 (四川盆地参考模型)

Joint inversion test # 2022-10-12 19:15:25.482501

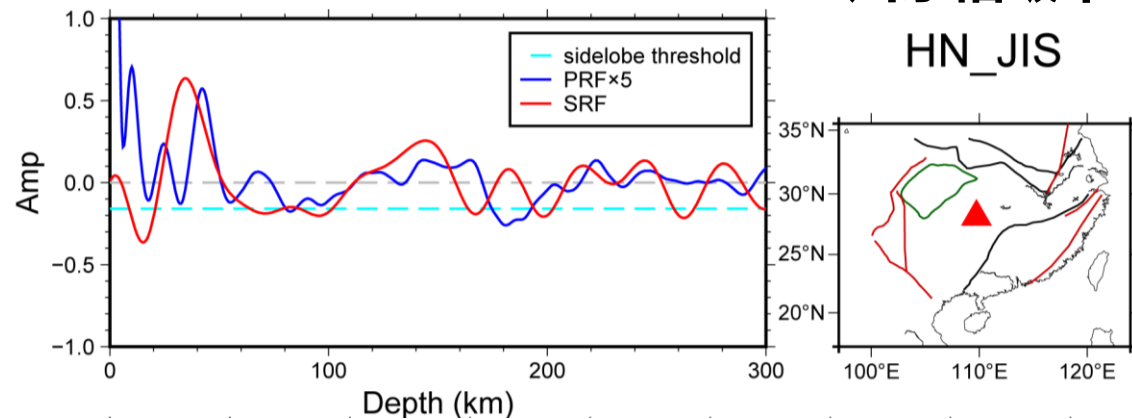


四、展望：岩石圈速度反演Joint_RFSW实际数据测试

慢度叠加->时深转换结果

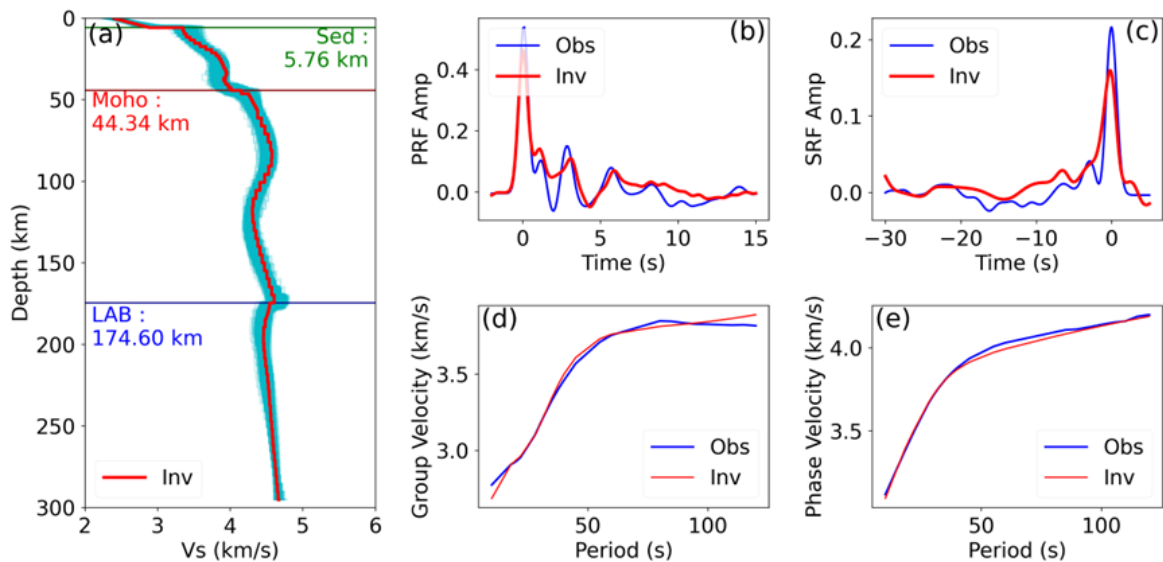


慢度叠加->时深转换结果



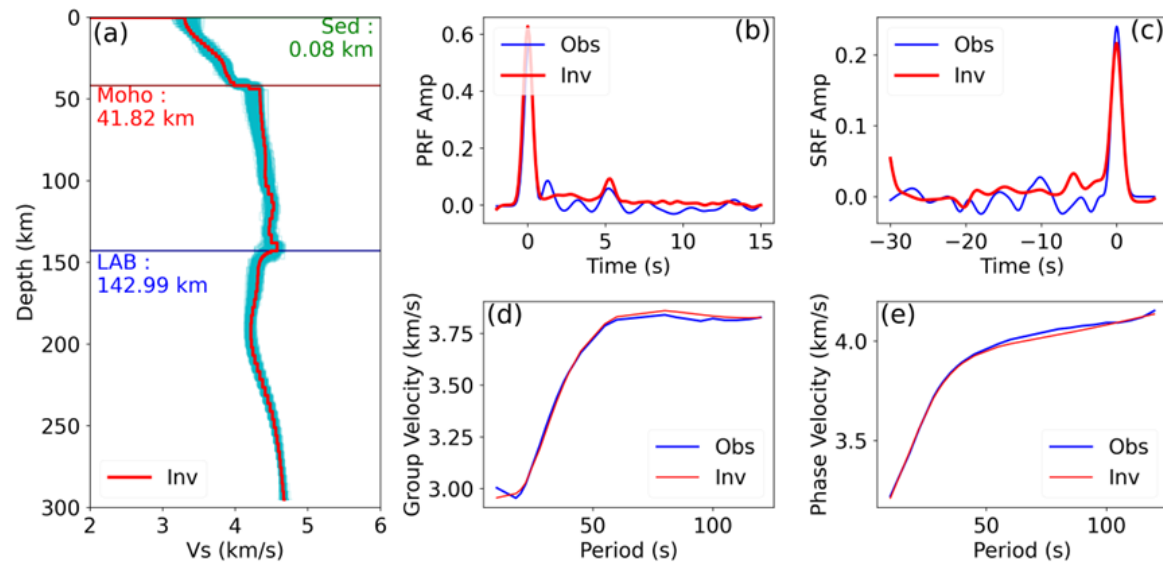
联合反演结果

Joint inversion test @ SC_AYU # 2022-10-30 13:46:40.425557



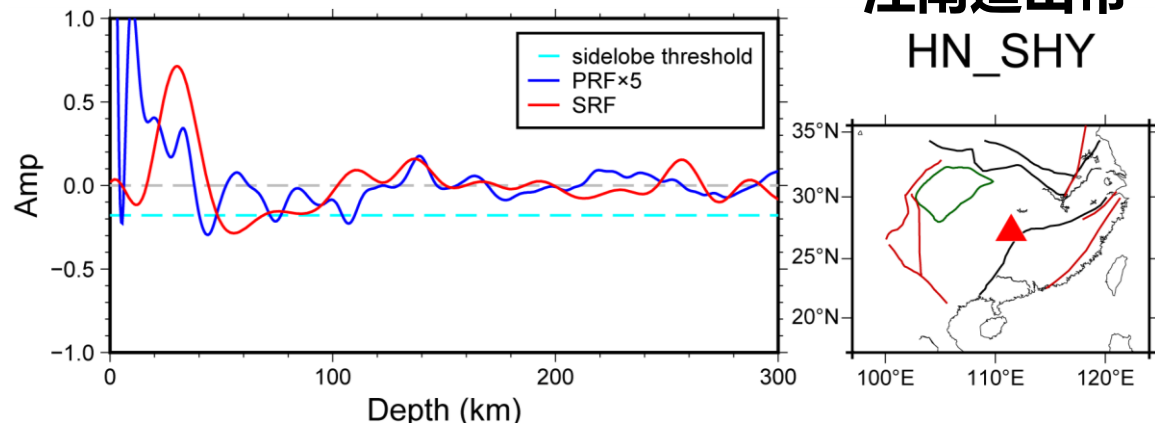
联合反演结果

Joint inversion test @ HN_JIS # 2022-10-29 07:16:16.141104

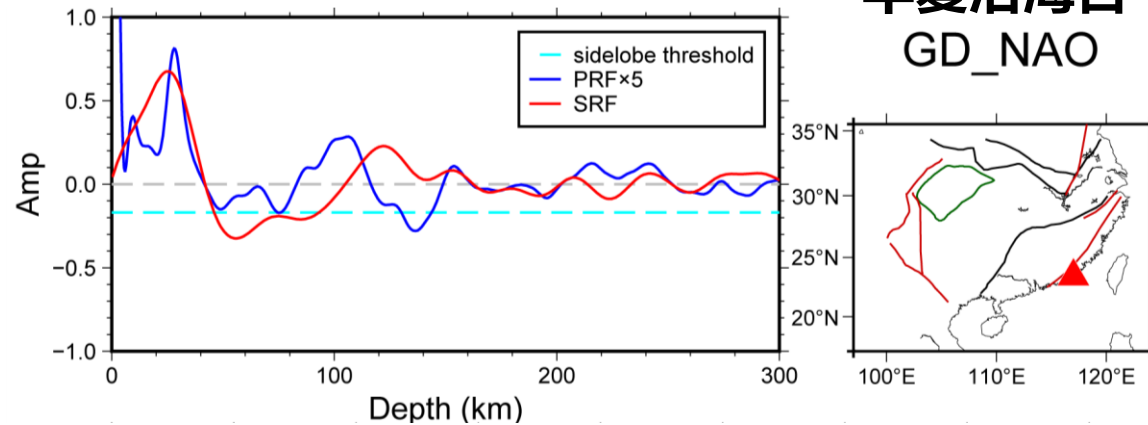


四、展望：岩石圈速度反演Joint_RFSW实际数据测试

慢度叠加->时深转换结果

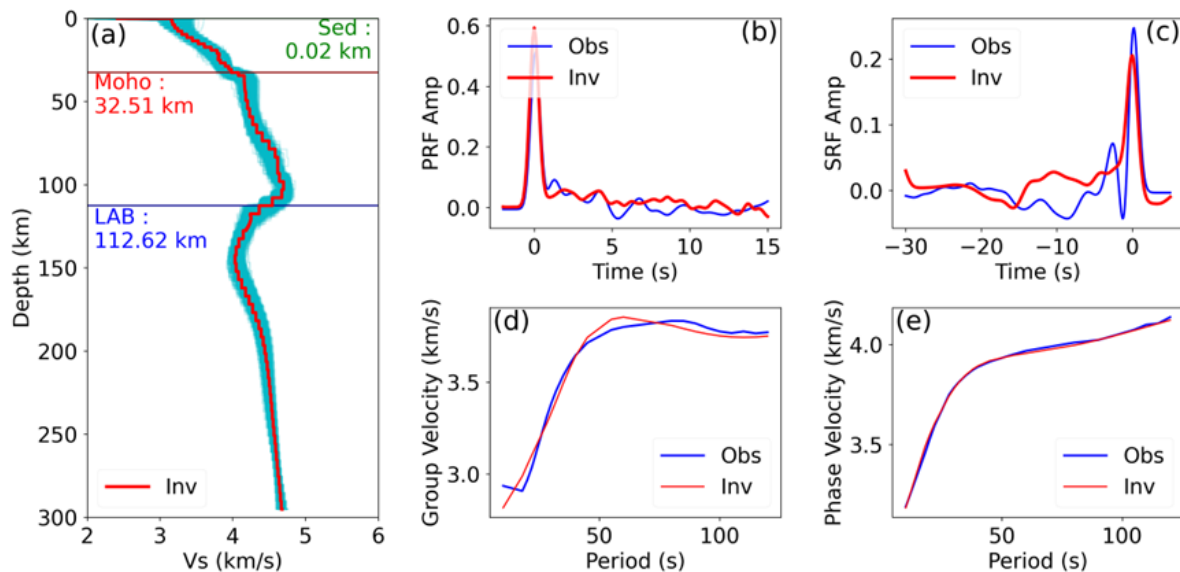


慢度叠加->时深转换结果



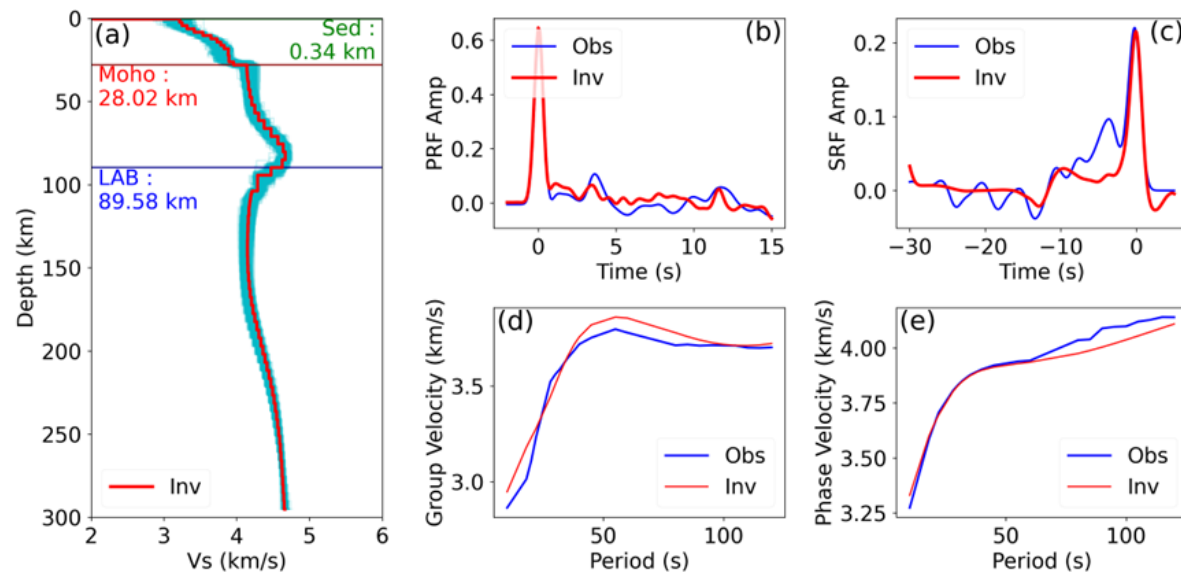
联合反演结果

Joint inversion test @ HN_SHY # 2022-10-29 11:50:15.258422



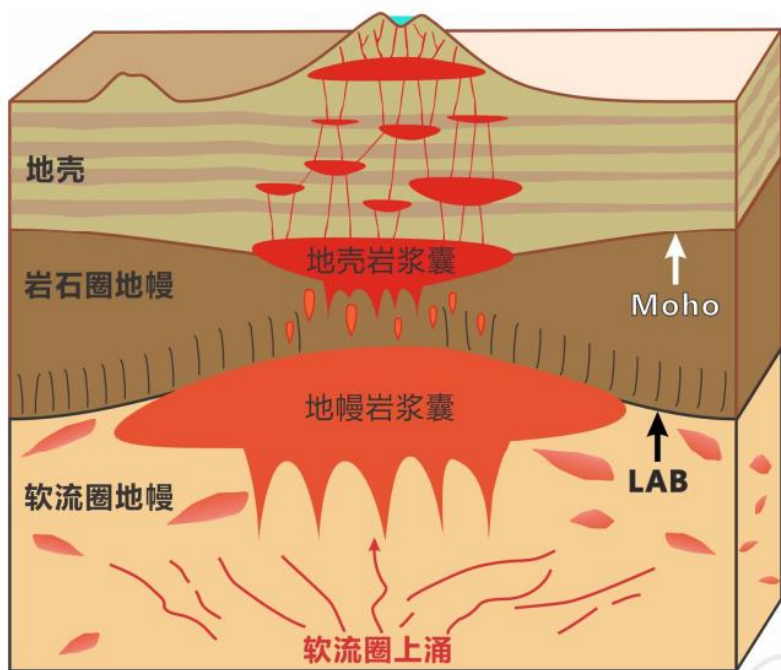
联合反演结果

Joint inversion test @ GD_NAO # 2022-10-29 07:28:51.692328

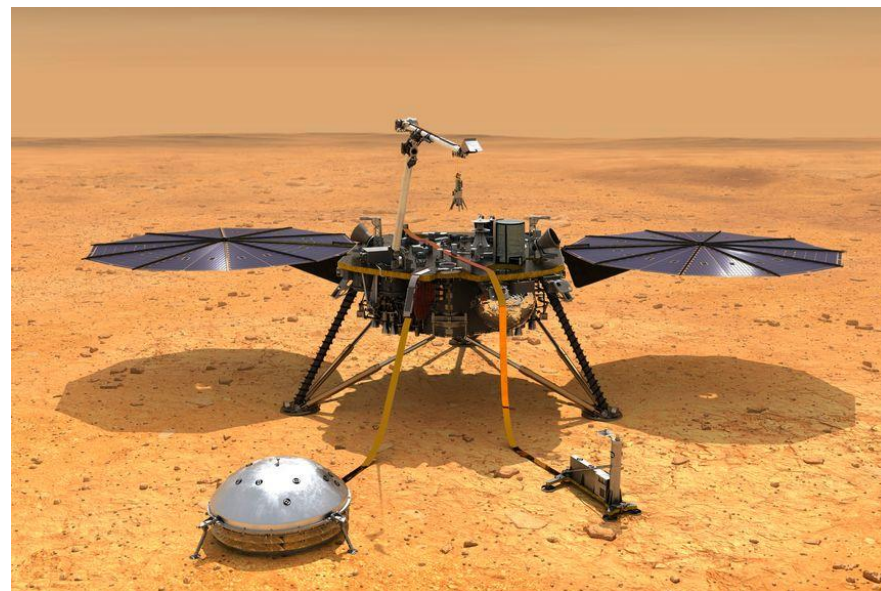


四、展望：单台站地区的应用

长白山火山区



火星InSight SEIS数据



未来会给出更详细的报道

小结

- 提出了一种基于波形互相关的S波接收函数提取策略GC_SRF，该策略可以避免人为因素的干扰。后期会在该基础上进一步发展ML-k，和Joint_RFSW方法，未来有机会再详细展示结果和算例。
- S波接收函数偏移成像结果显示四川盆地下方LAB可能达到160km处，且有MLD；腾冲火山下方的LAB在90km附近，而川滇块体下方的岩石圈界面特征并不显著，推测与地幔柱作用后岩石圈增生有关。
- GC_SRF主要缺点：需要长期观测数据（短周期台站很难应用）；如果数据都很差，也会得到一个结果，可能就不对了。

谢谢!
敬请批评指正!

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张周: zhangzhou3@gig.ac.cn