地震电磁现象及其可能机理

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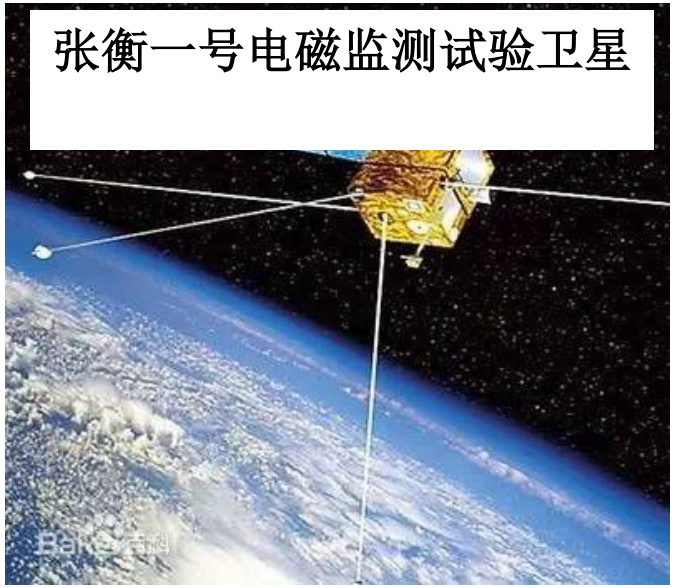
报告提纲

1. 地震电磁现象

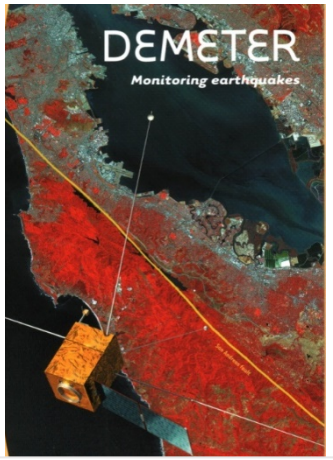
2. 地震电磁机理与数值模拟

3. 讨论

地震电磁监测



Launched on Feb. 2, 2018



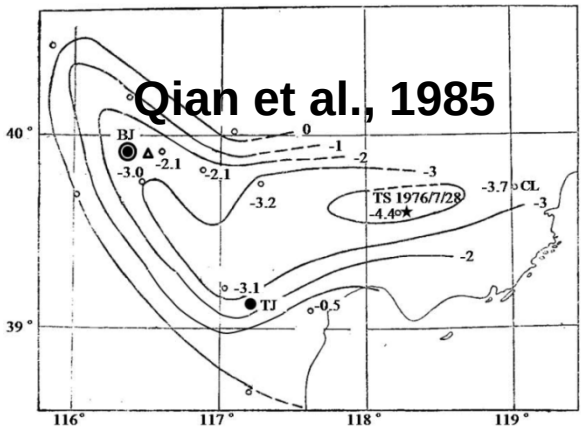
Launched on June 26, 2004

极低频探地工程

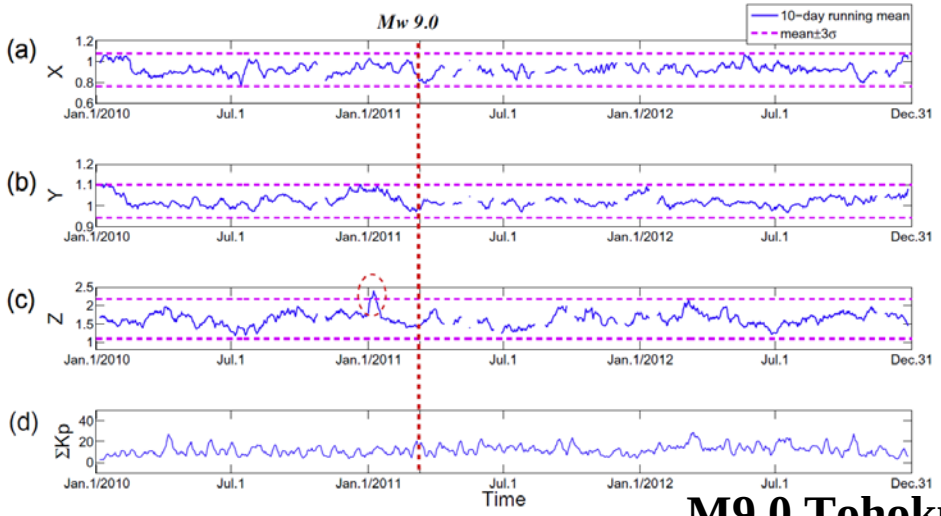
- 电性参量
- 电场
- 磁场
- 电磁扰动

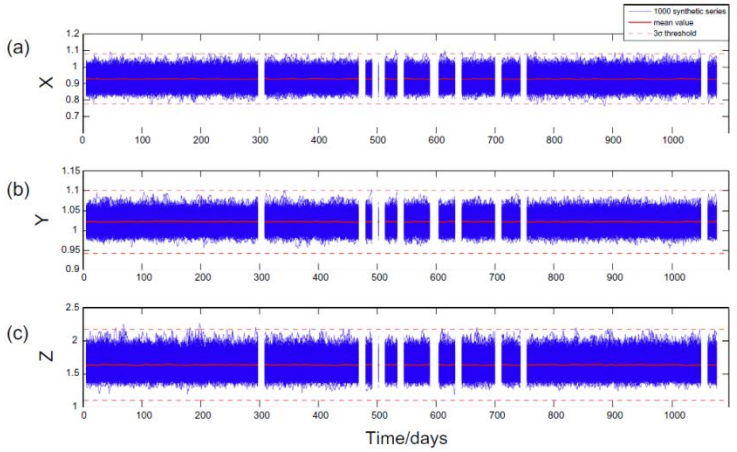
地震电磁现象

- 电性结构变化
- 来自震源区的直接电磁信号(例如，ULF, ELF, VLF, LF, MF, HF, VHF)
- 次生电磁扰动(例如，电离层异常)
- 同震电磁现象

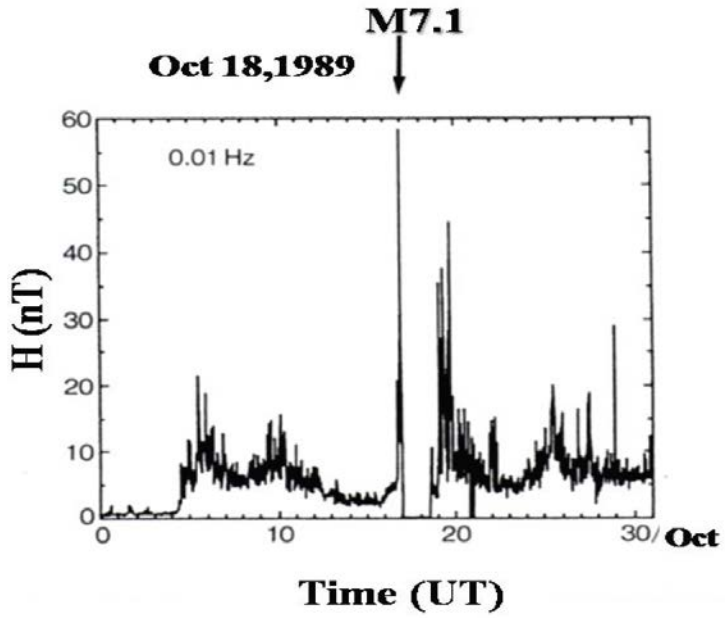


唐山7.8级地震(Qian et al., 1985)





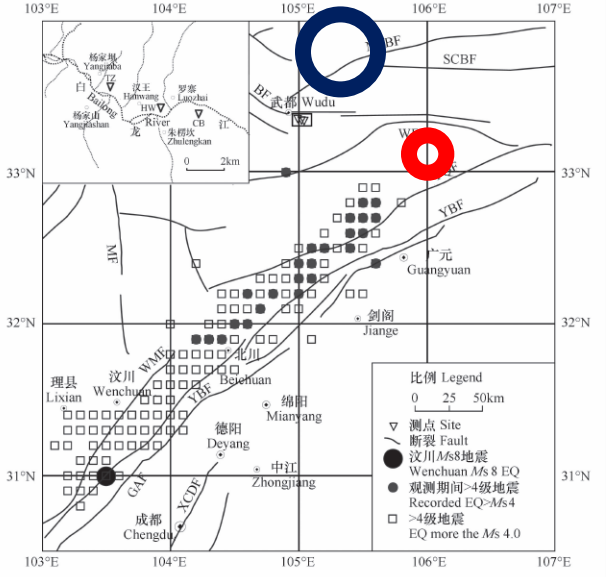
M9.0 Tohoku EQ (Xu et al., 2013)



Loma-Prieta EQ
(Fraser-Smith et al., 1990)

同震电磁现象

观测证据： 天然地震



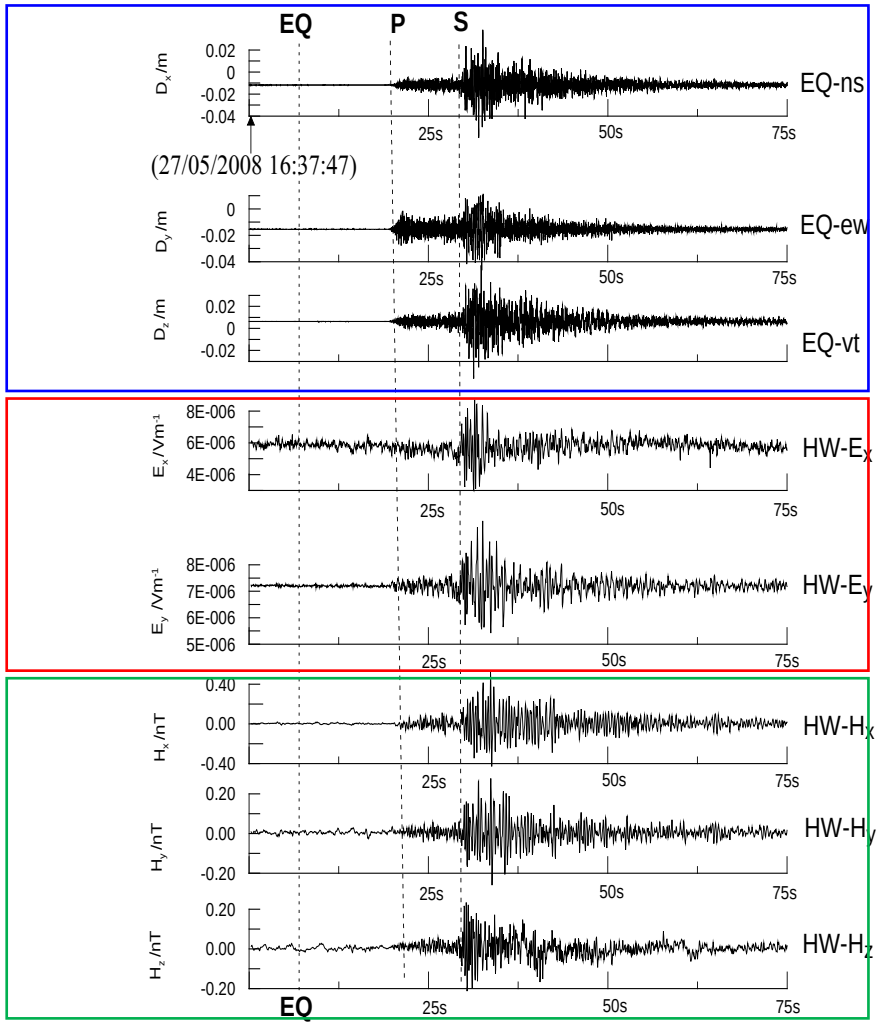
Aftershock of Wenchuan EQ

Ningqiang Ms5.7

2008-5-27

16:37:51.3

Tang et al., 2010



地震电磁现象的客观存在性

机 理 ？ 难！

如何入手？（突破口） （同震）震电现象

报告提纲

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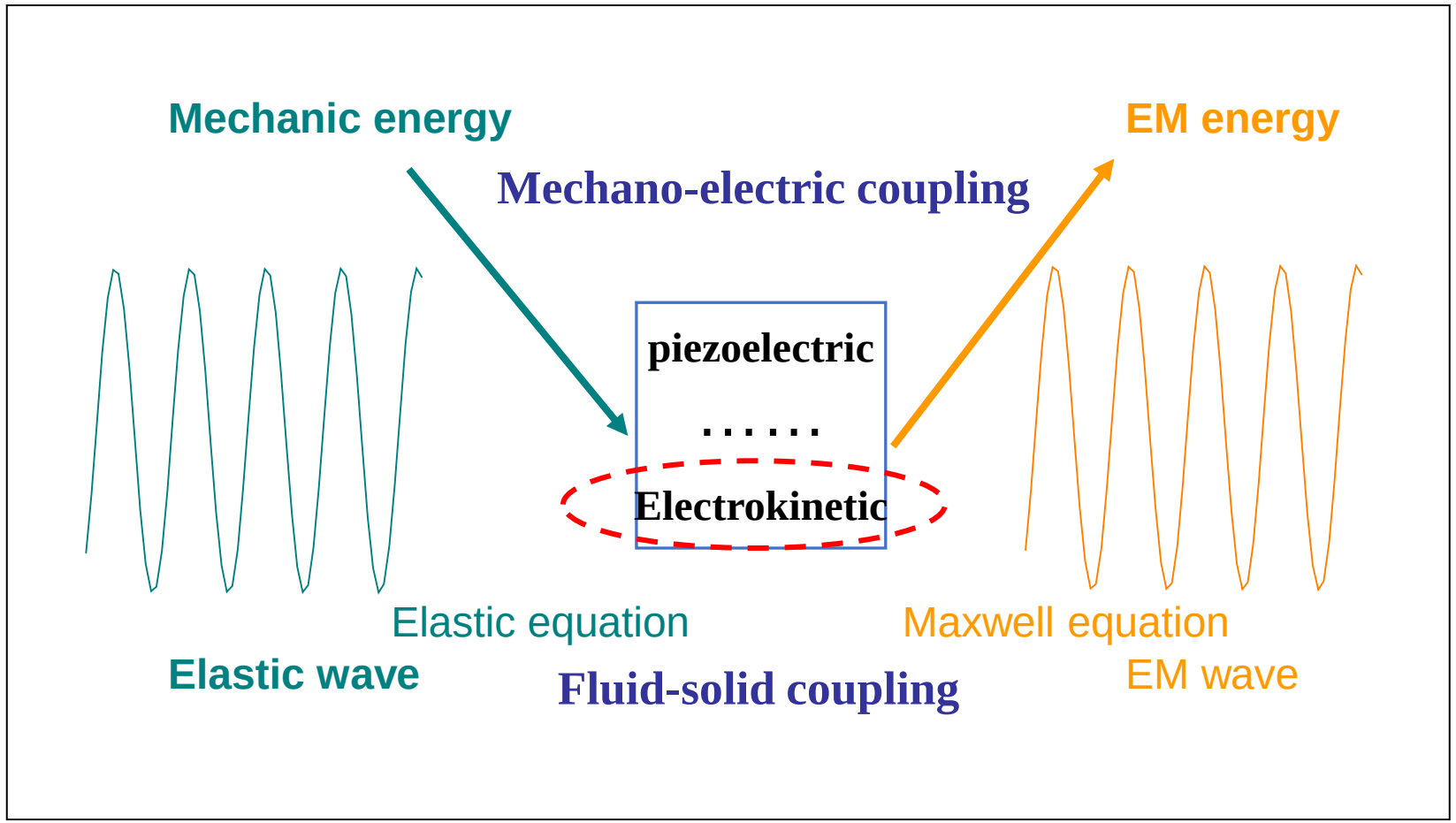
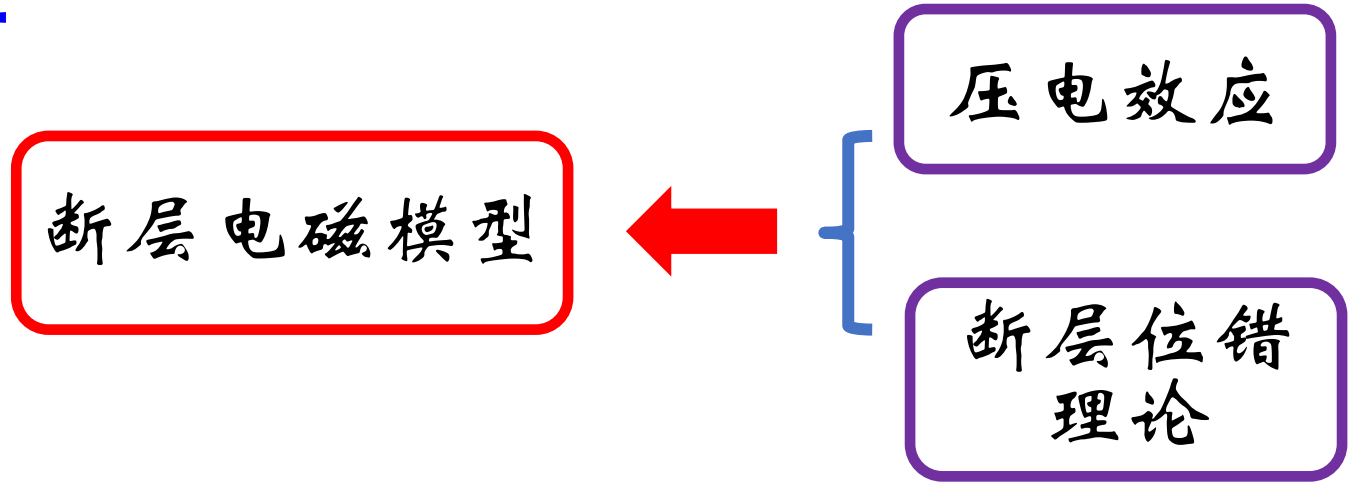
Assumption?

Possible Mechanisms of seismic EM phenomena



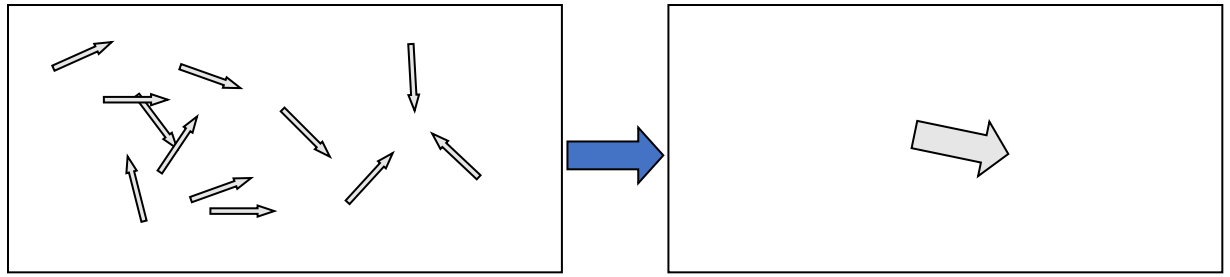
（1） 压电效应



➢**Effective piezoelectricity** **(Rock/Piezo-crystal)**

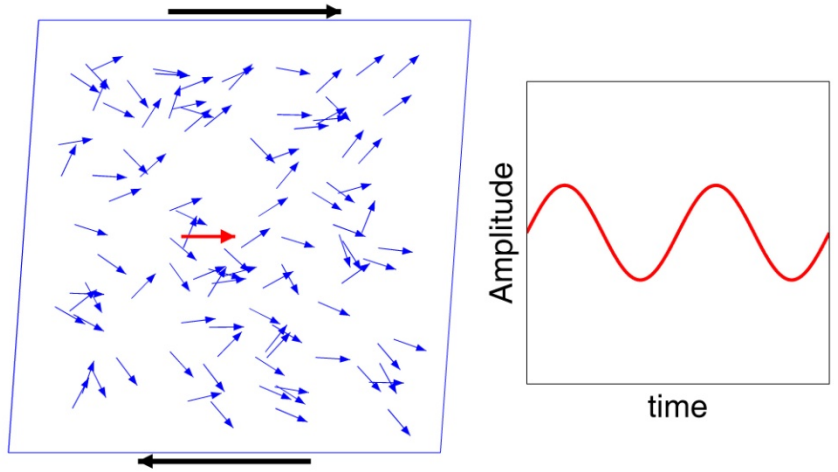
$\alpha_{eff} = n^{1/2} / N \, \alpha_{qz} = \eta \, / n^{1/2} \, \alpha_{qz}$ （η :volume fraction of quartz)

$\alpha_{eff} = (\varsigma n + n^{1/2}) / N \, \alpha_{qz}$ （ς :fraction of preferred orientation)



地震作用下岩石压电效应产生的条件

从理论上证明了微小的优势排列可产生与观测值相当的信号



通过理论和模拟分析发现：当岩石内部晶体完全随机分布时，压电效应难以被检测到；当岩石内部晶体呈现微弱优势排列，压电效应就可被电磁台站观测到。这一成果加深了我们对“地震作用条件下岩石压电效应”的认识。

Huang et al., 2002, 2011

(2) 动电效应

震电波场数值算法 ← 动电效应 + 理论地震图算法

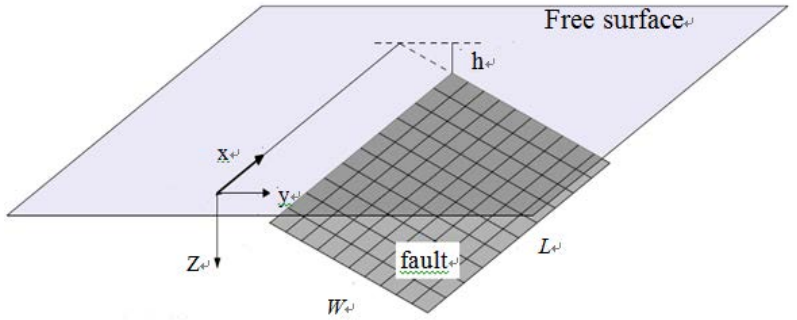
- 应用广义反透射系数方法发展了一套层状孔隙介质中点源激发震电波场的数值模拟新方法(Ren et al., 2010)
- 利用点源叠加方法(point source stacking method)和广义反透射系数方法，开发了有限断层破裂模型震电波场数值模拟算法(Ren et al., 2012)

Geophysical Journal International

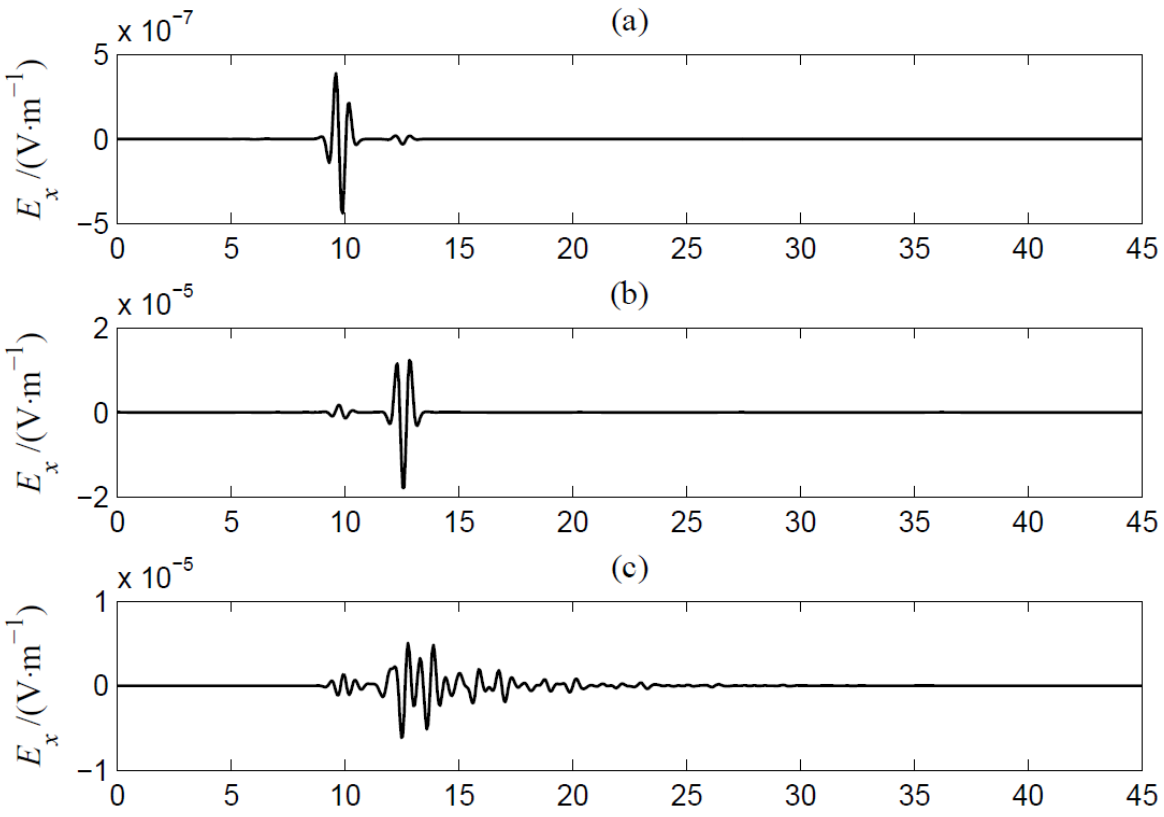
Geophys. J. Int. (2012) **188**, 925–944 doi: 10.1111/j.1365-246X.2011.05309.x

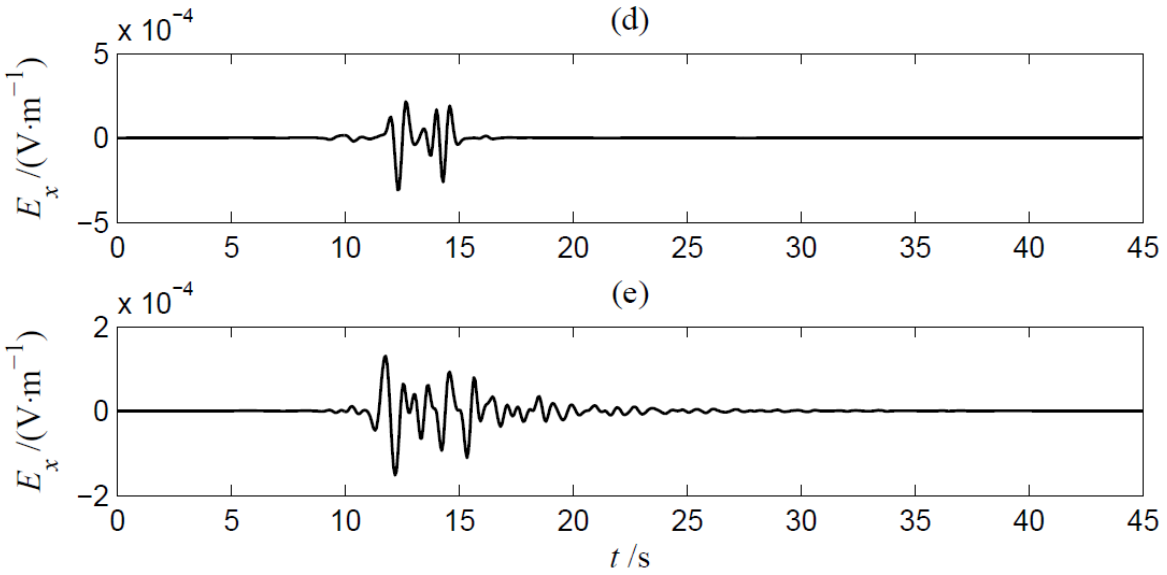
Numerical simulation of coseismic electromagnetic fields associated with seismic waves due to finite faulting in porous media

Hengxin Ren,[1] Xiaofei Chen[1] and Qinghua Huang[2]



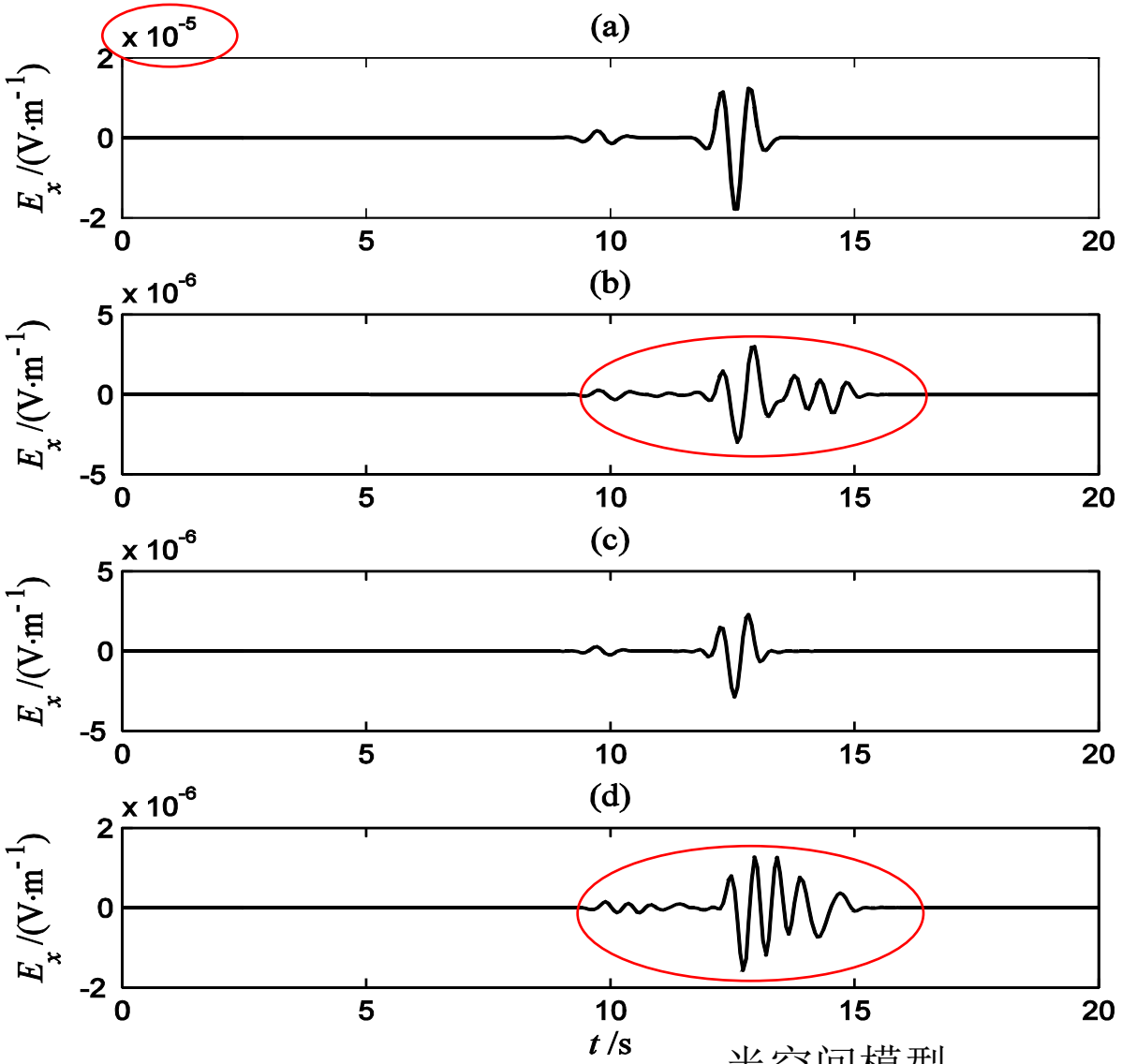
Effect of media structures and source types





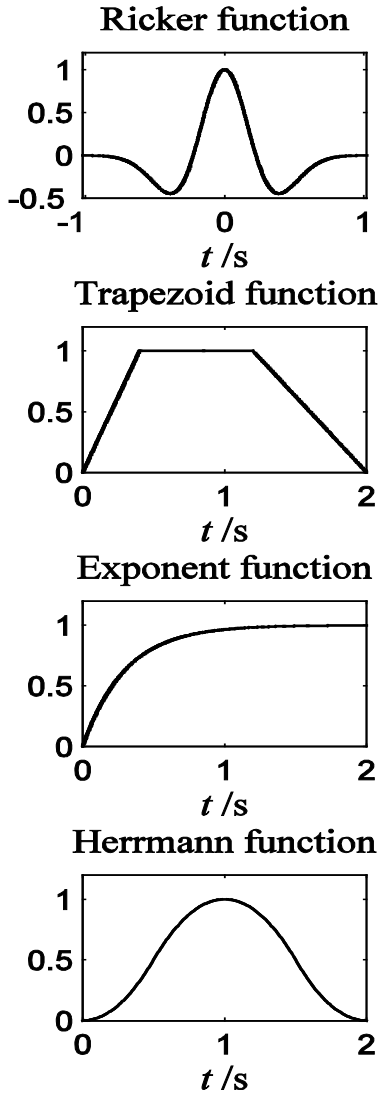
Zhang et al., 2013

Effect of source time function



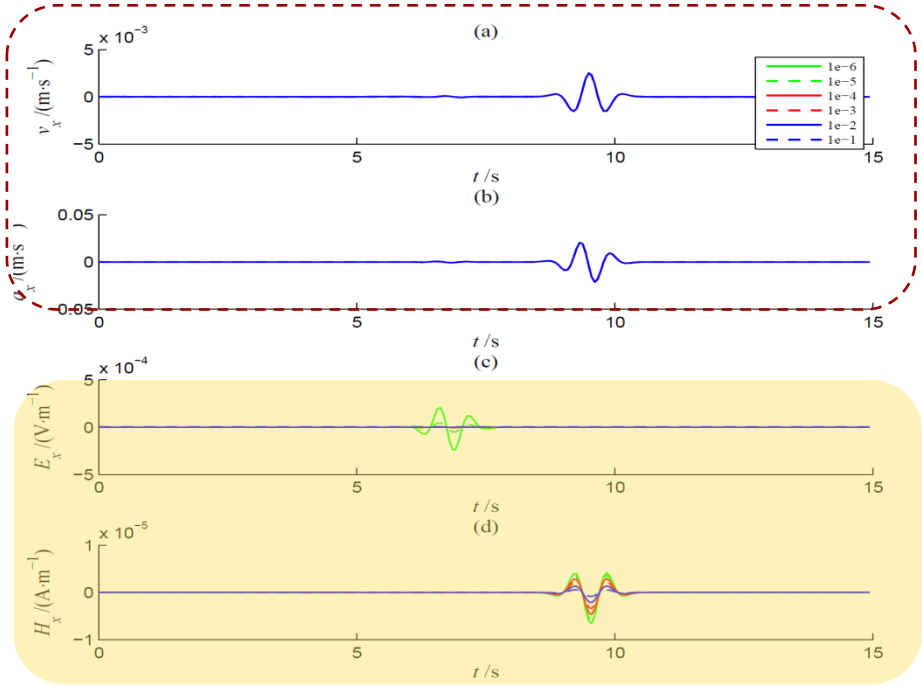
半空间模型

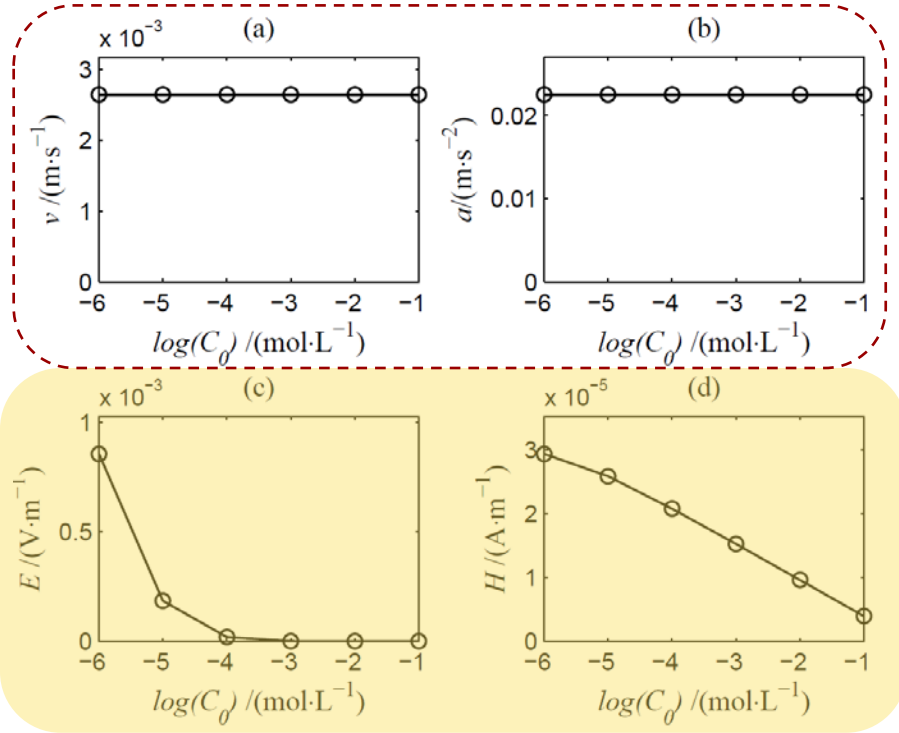
Zhang et al., 2013



震源时间函数类型

Salinity effect

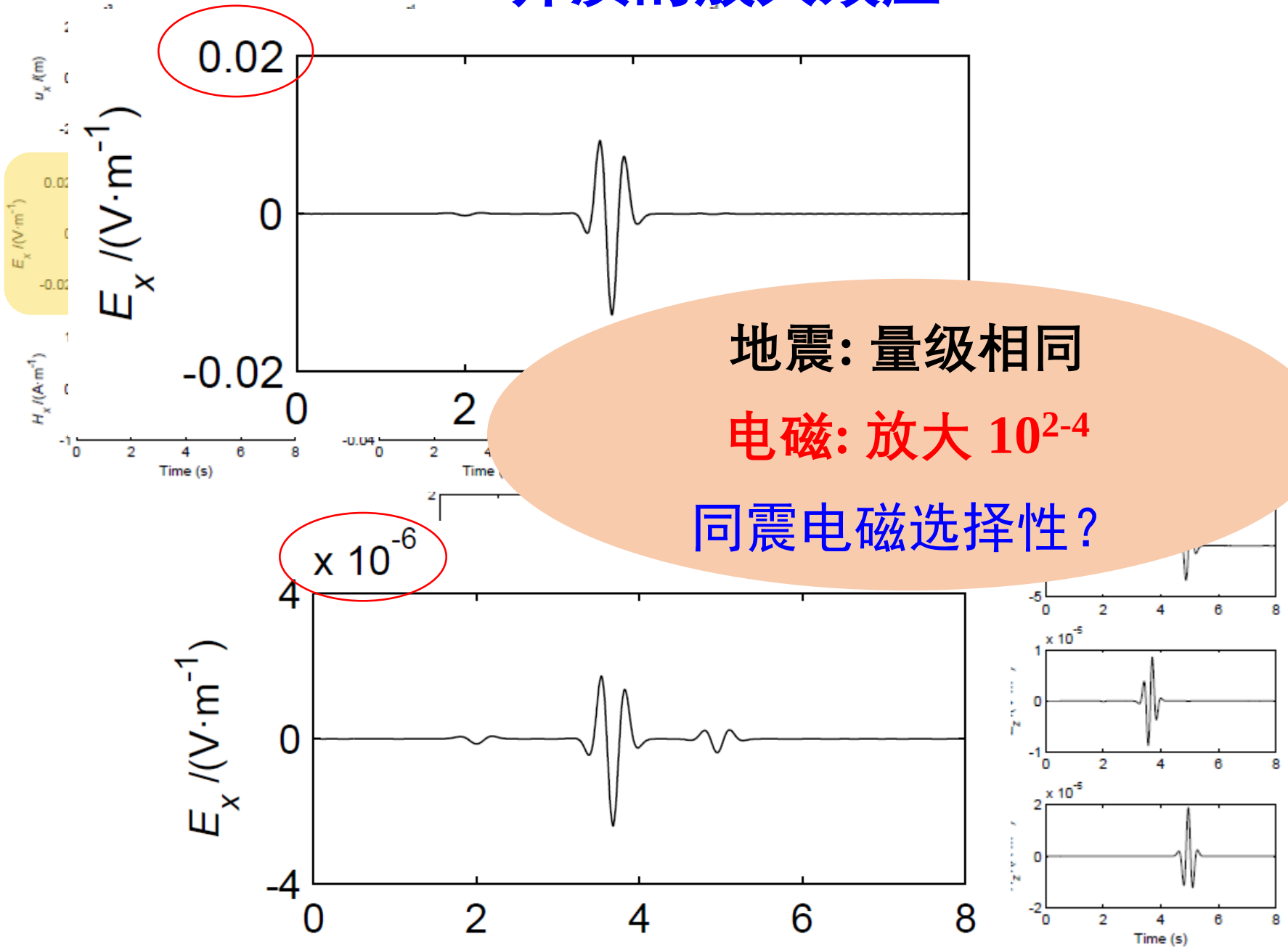




EM signals are sensitive to salinity, but seismic signals are not.

Huang et al., 2015

介质的放大效应



地震: 量级相同

电磁: 放大 $10^{2\text{-}4}$

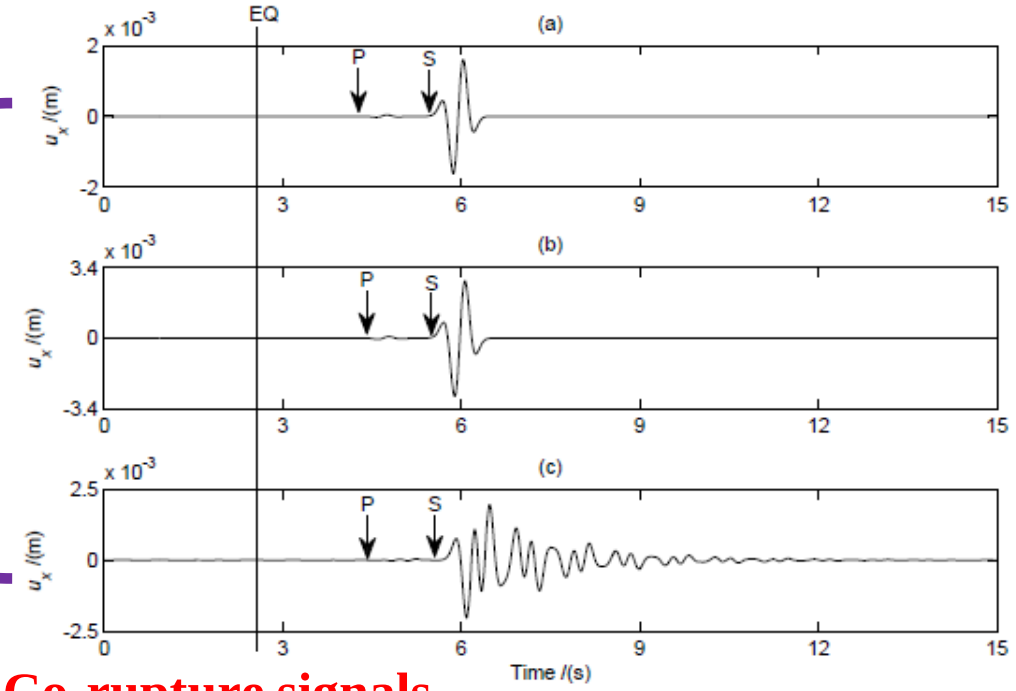
同震电磁选择性？

Huang et al., 2015

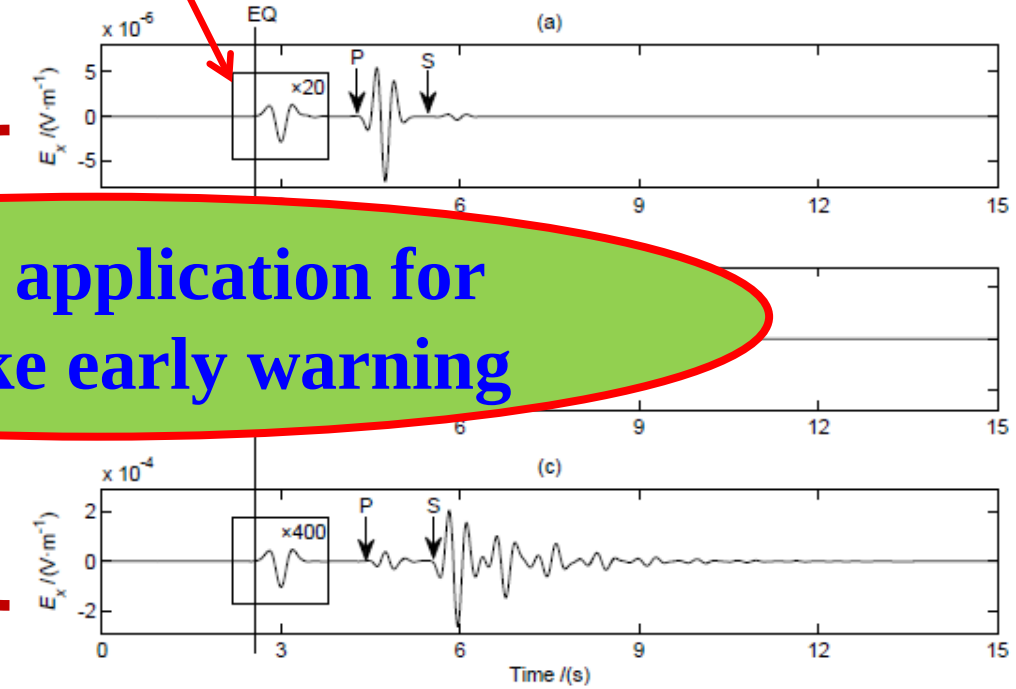
同震电磁信号分类

Effect of medium structures

Seismic signals



Co-rupture signals



Potential application for earthquake early warning

Huang et al., 2015

Geophysical Journal International

Geophys. J. Int. (2015) **200,** 835–848
GJI Geomagnetism, rock magnetism and palaeomagnetism
doi: 10.1093/gji/ggu435

Electrokinetic effect combined with surface-charge assumption: a possible generation mechanism of coseismic EM signals

Hengxin Ren,[1,2,3] Jian Wen,[1,2,3] Qinghua Huang[4] and Xiaofei Chen[1,2,3]

幅度 + 波形

Geophysical Journal International

Geophys. J. Int. (2016) **204,** 147–166
GJI Geomagnetism, rock magnetism and palaeomagnetism
doi: 10.1093/gji/ggv400

Existence of evanescent electromagnetic waves resulting from seismoelectric conversion at a solid–porous interface

Hengxin Ren,[1,2,3] Qinghua Huang[4] and Xiaofei Chen[1,2,3]

Geophysical Journal International

Geophys. J. Int. (2016) **206,** 205–220
Advance Access publication 2016 April 13
GJI Geomagnetism, rock magnetism and palaeomagnetism
doi: 10.1093/gji/ggw144

Numerical simulation of seismo-electromagnetic fields associated with a fault in a porous medium

Hengxin Ren,[1,2] Qinghua Huang[3] and Xiaofei Chen[1,2]

Geophysical Journal International

Geophys. J. Int. (2019) **218,** 1961–1982
Advance Access publication 2019 June 05
GJI Marine Geosciences and Applied Geophysics
doi: 10.1093/gji/ggz263

2-D poroelastic wave modelling with a topographic free surface by the curvilinear grid finite-difference method

Yao-Chong Sun,[1,2] Hengxin Ren,[1] Xu-Zhen Zheng,[1] Na Li,[3] Wei Zhang,[1] Qinghua Huang[4] and Xiaofei Chen[1]

报告提纲

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存在的问题与展望

- 野外电磁观测

  地震电磁现象的客观存在（经验阶段） √

  疑似早于地震波的信号 √？

  破裂时的同震信号 ？？？

  可控源+天然源 ？？？

- 数据处理方法

  仪器观测精度的提高；电磁环境干扰的加剧；

  如何从强干扰背景中提取弱信号？成像精度？

- 电磁观测资料的物理解释?

  室内实验；理论模型

致谢

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Thank you!