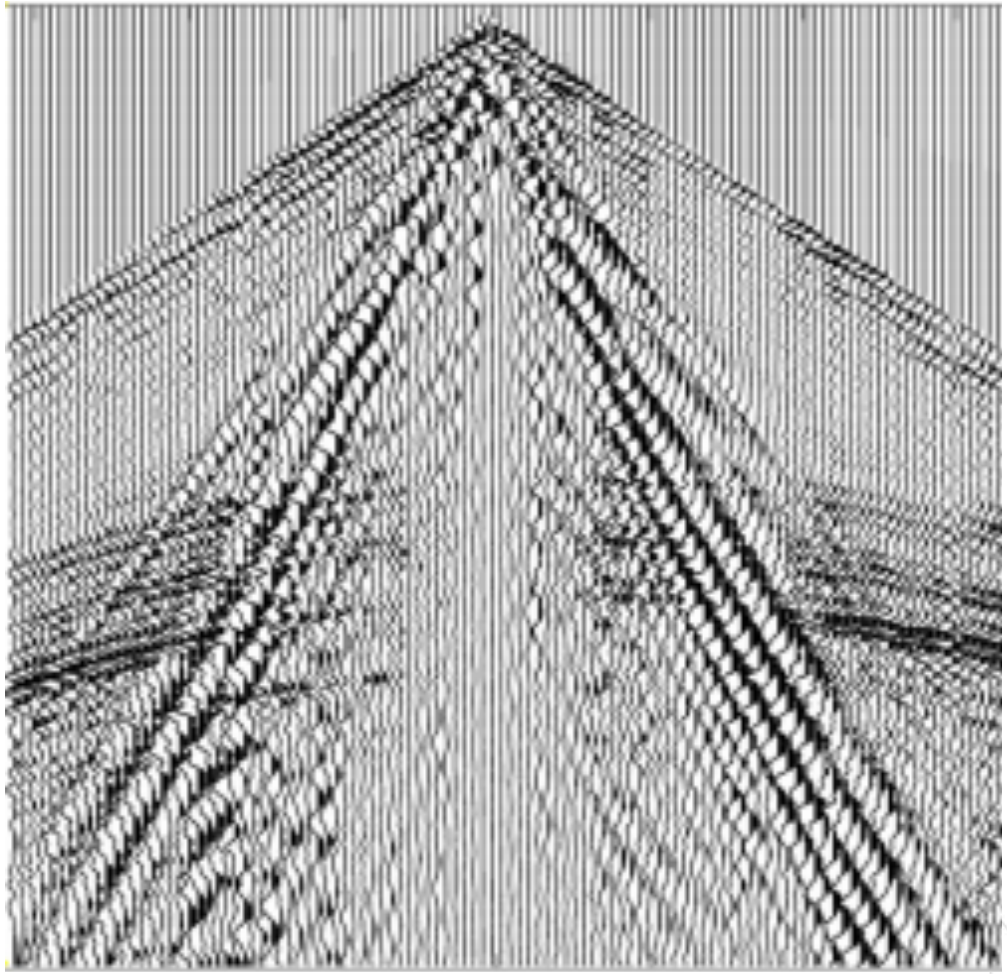
PREPROCESSING IN *DISPLACEMENT SPACE* IN PREPARATION FOR ONSHORE SEISMIC PROCESSING: REMOVING GROUND ROLL AND GHOSTS WITHOUT DAMAGING THE REFLECTION DATA

Jing Wu* and Arthur B. Weglein
M-OSRP, University of Houston

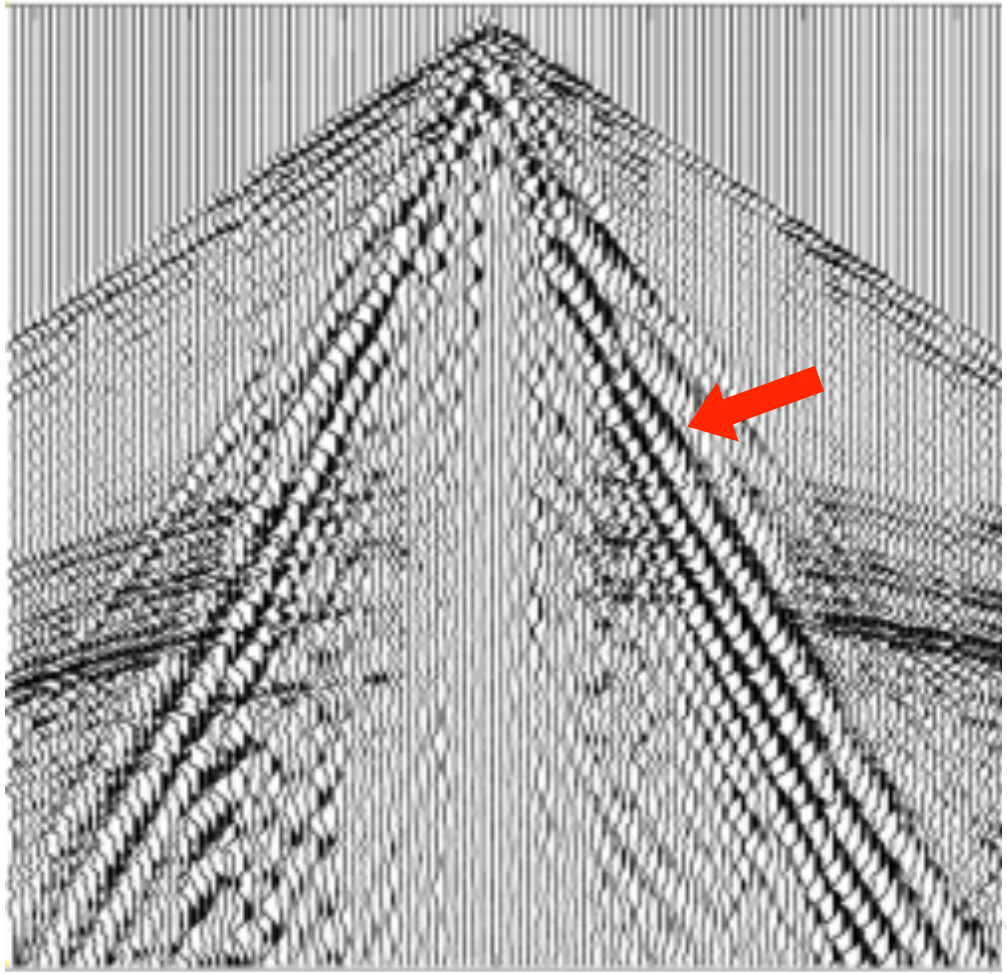
October 19, 2015

MOTIVATION

- Preprocessing
  - ✓ is required for all land seismic data processing

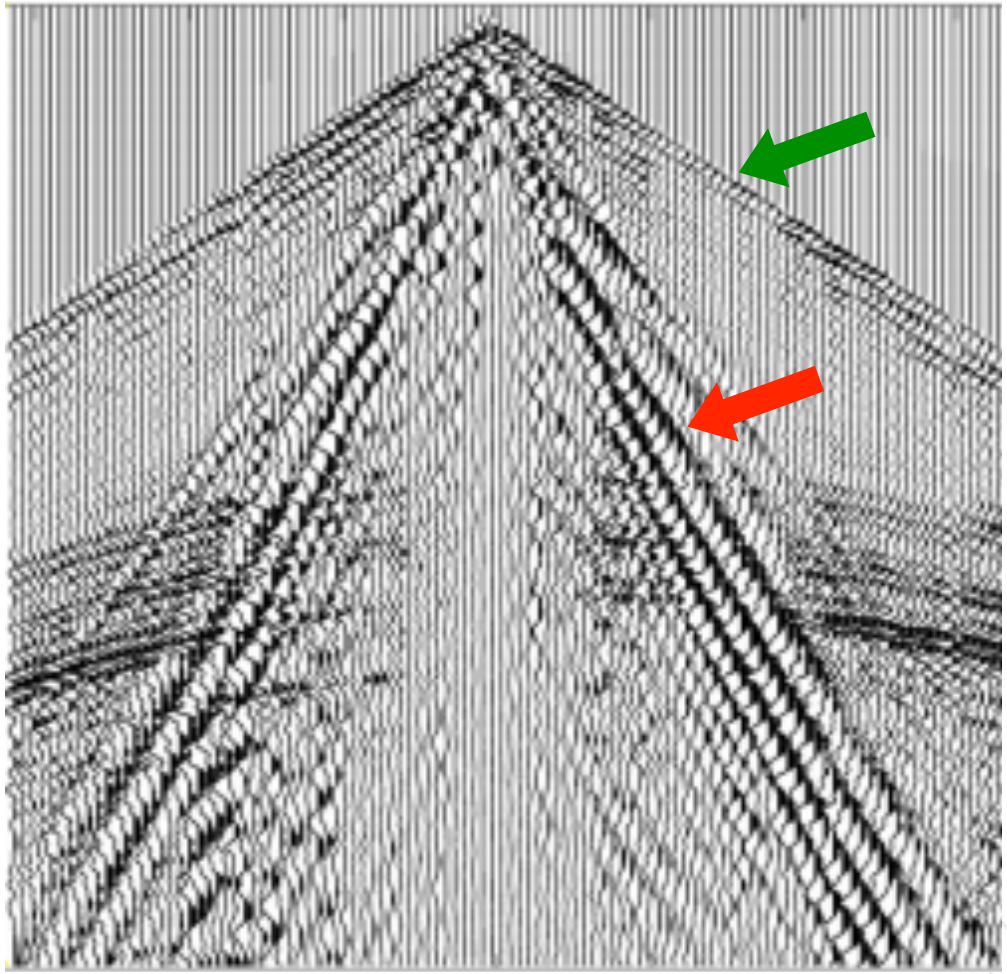


Boustani et al., 13



Ground roll
(Rayleigh wave)

Boustani et al., 13



Direct wave

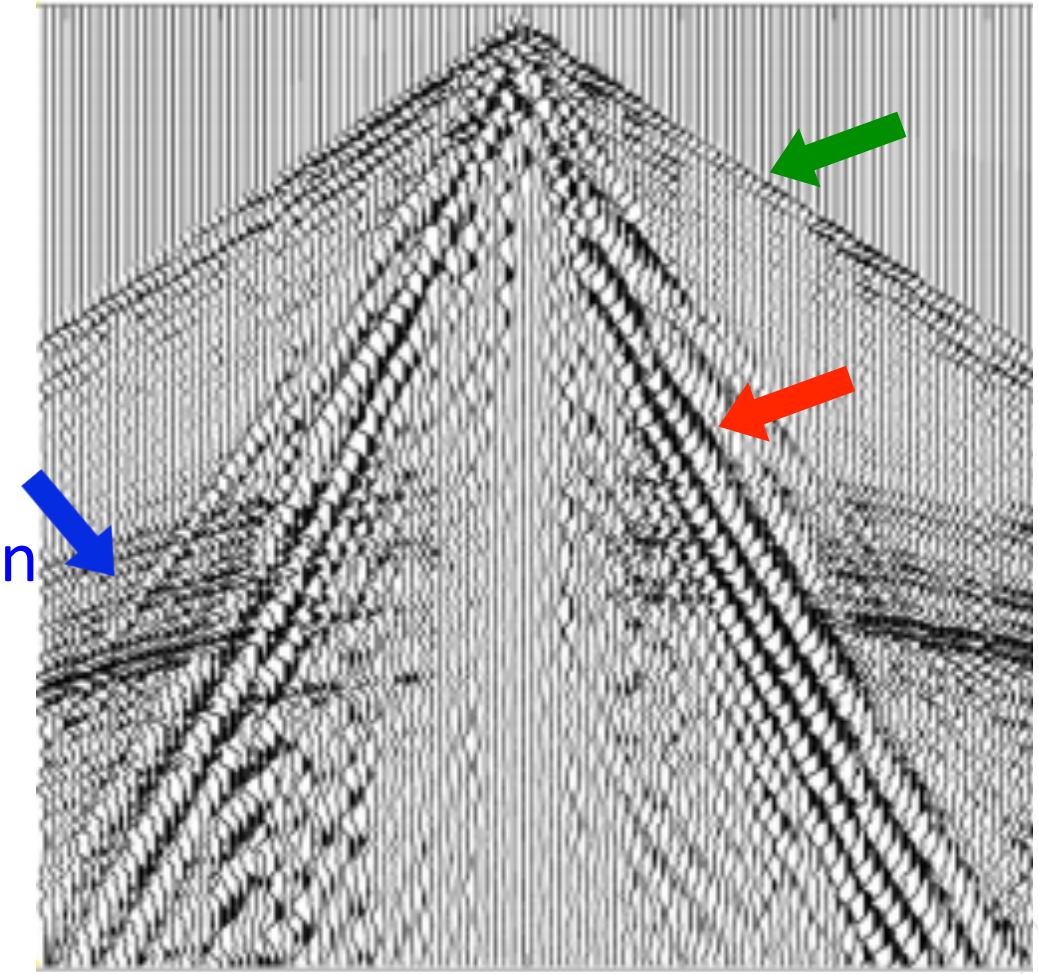
Ground roll
(Rayleigh wave)

Boustani et al., 13

Direct wave

Ground roll
(Rayleigh wave)

Ghosts
exist in reflection



Boustani et al., 13

Direct wave

Ground roll
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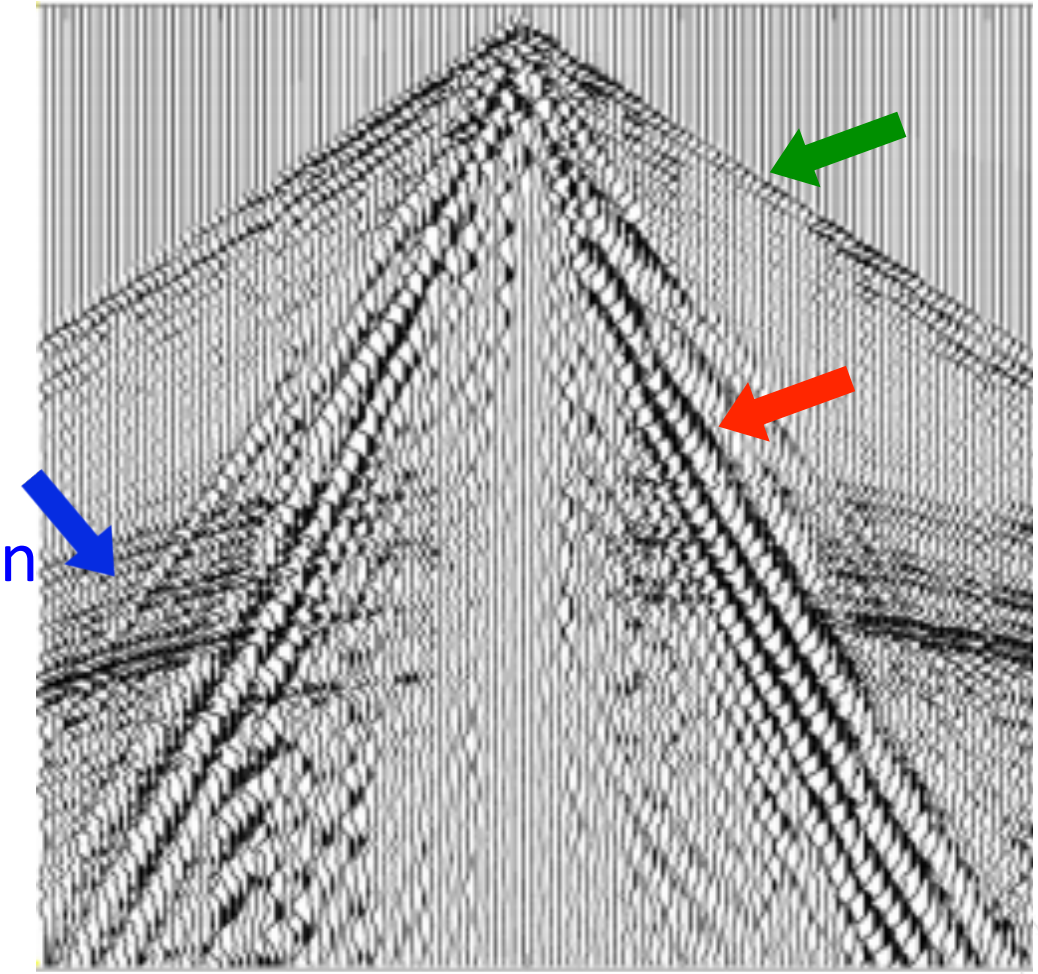


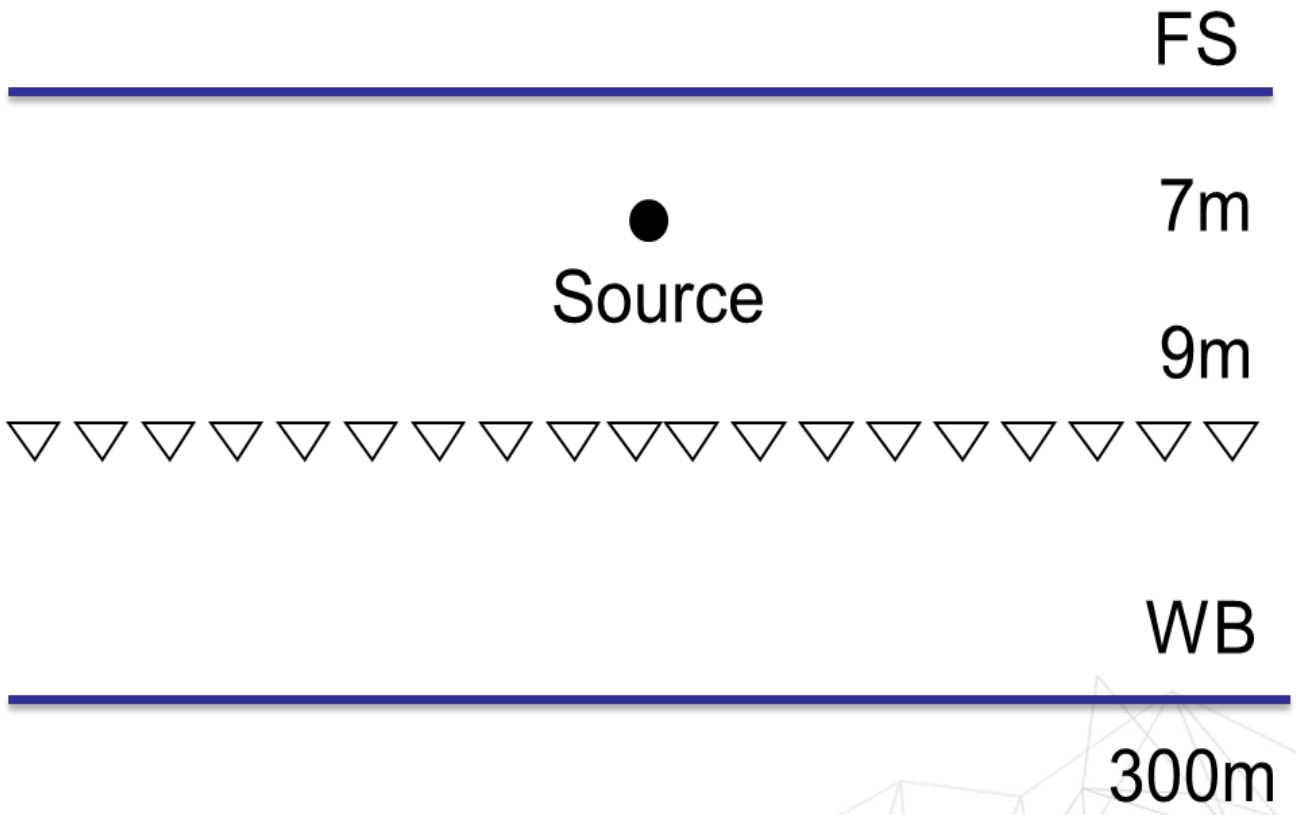
Boustani et al., 13

Preprocessing to separate these events from upgoing reflection

MOTIVATION

- Preprocessing
  - ✓ is required for all land seismic data processing
  - ✓ provides necessary prerequisite for Inverse Scattering Series (ISS) multiple removal, which is the most capable method available today and does not need any subsurface information

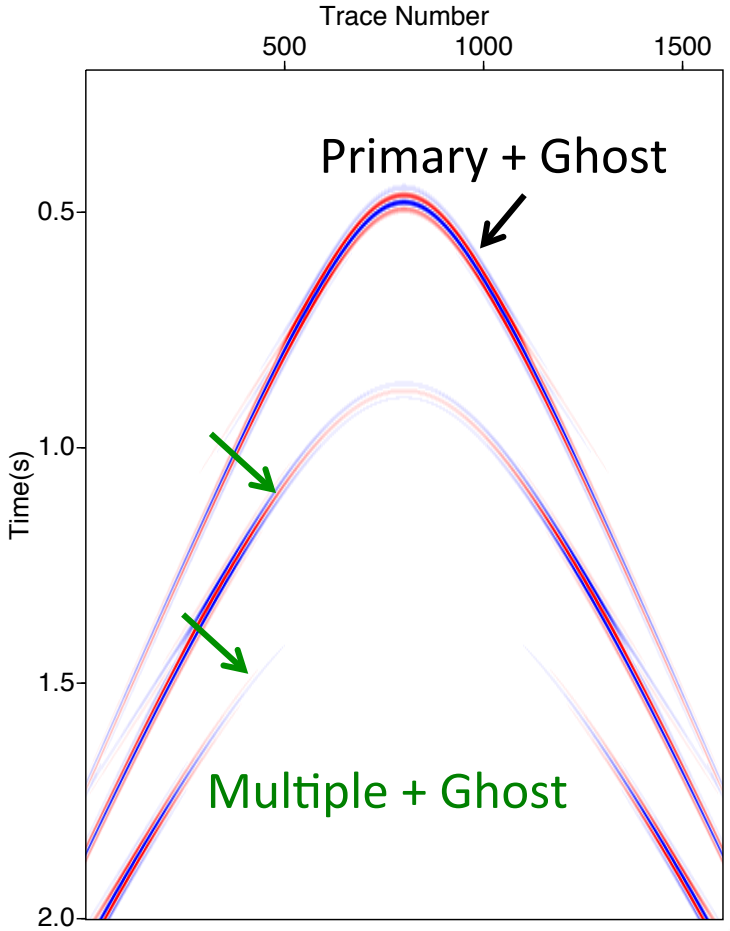
IMPACT OF DEGHOSTING ON ISS MULTIPLE REMOVAL



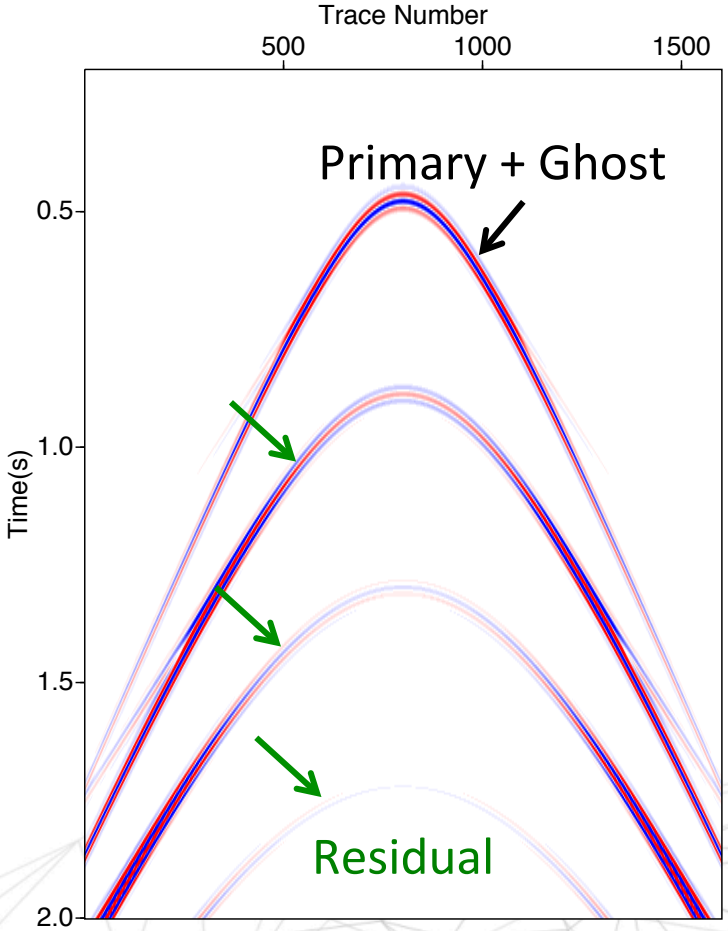
(*Jinlong Yang, 14; P. Carvalho and A. Weglein, 92; Jingfeng Zhang, 05, 06, 07*)

IMPACT OF DEGHOSTING ON ISS MULTIPLE REMOVAL

Input data with ghosts



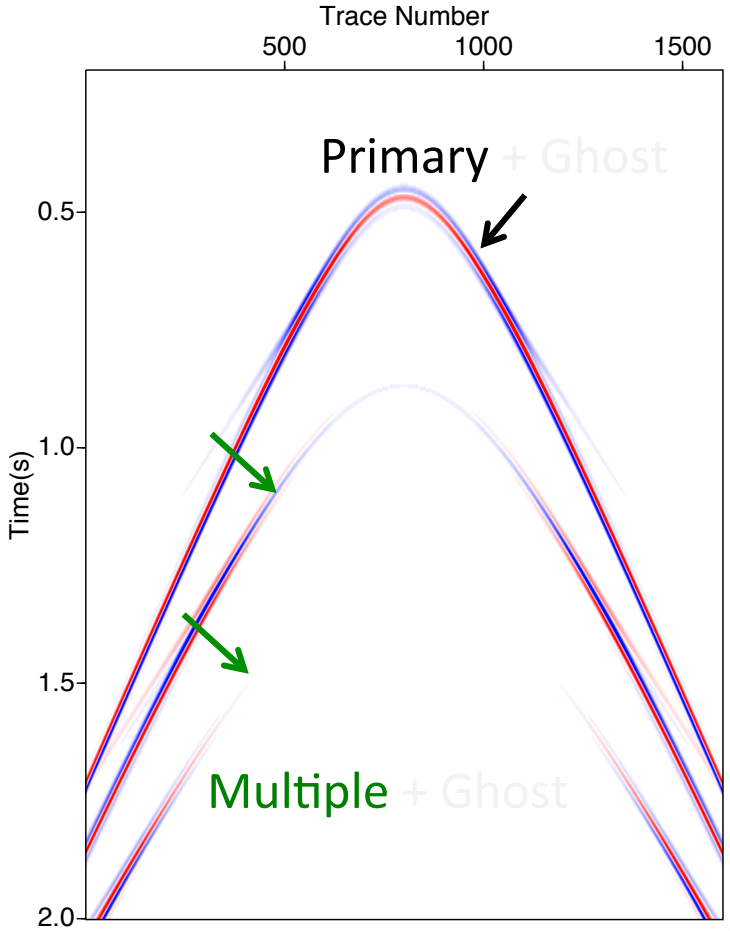
Multiple removal result



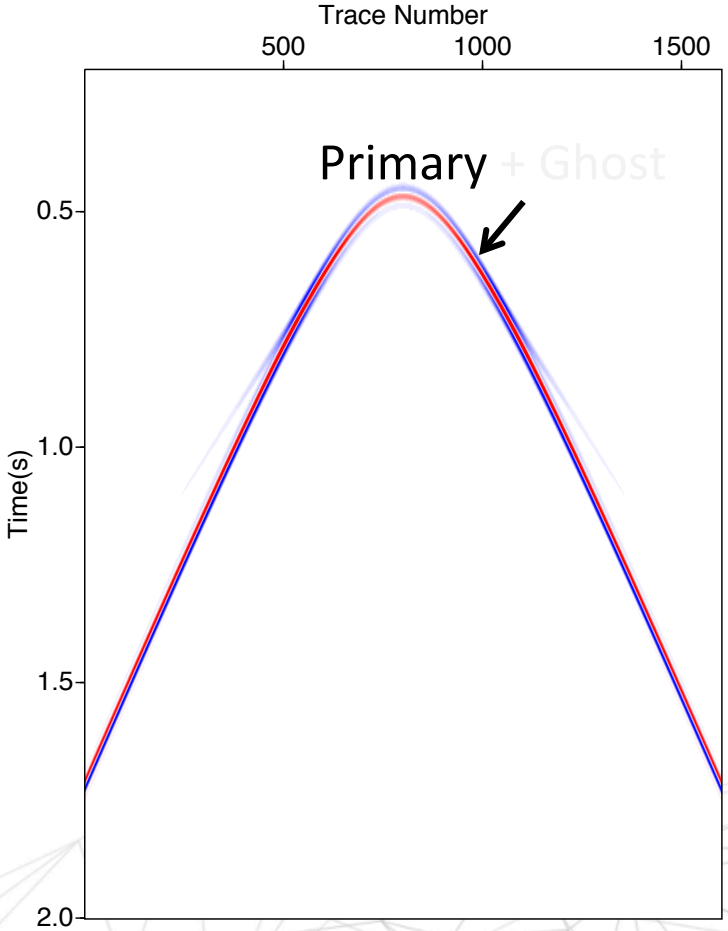
(*Jinlong Yang, 14; P. Carvalho and A. Weglein, 92; Jingfeng Zhang, 05, 06, 07*)

IMPACT OF DEGHOSTING ON ISS MULTIPLE REMOVAL

Input data without ghosts



Multiple removal result



(*Jinlong Yang, 14; P. Carvalho and A. Weglein, 92; Jingfeng Zhang, 05, 06, 07*)

DELIVERABLE OF THIS TALK

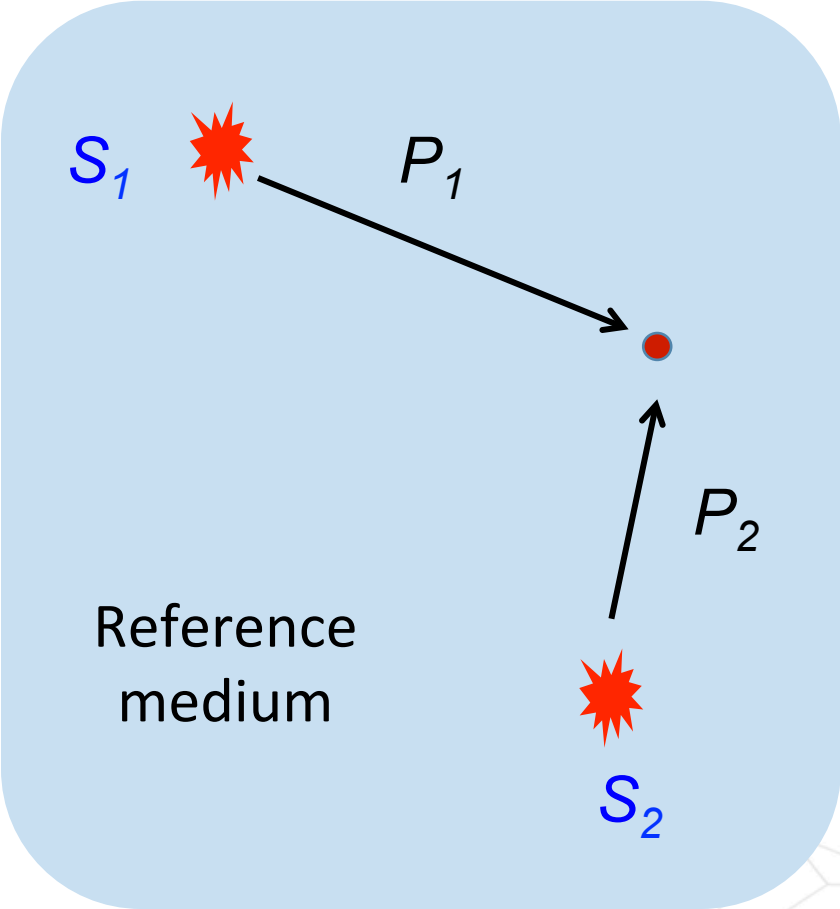
- For onshore seismic processing, with the energy source above the measurement surface, elastic Green's theorem can arrange to remove all direct waves, the receiver ghosts and the ground roll at once.

OUTLINE

- THEORY
- NUMERICAL TESTS
- DISCUSSION AND SUMMARY

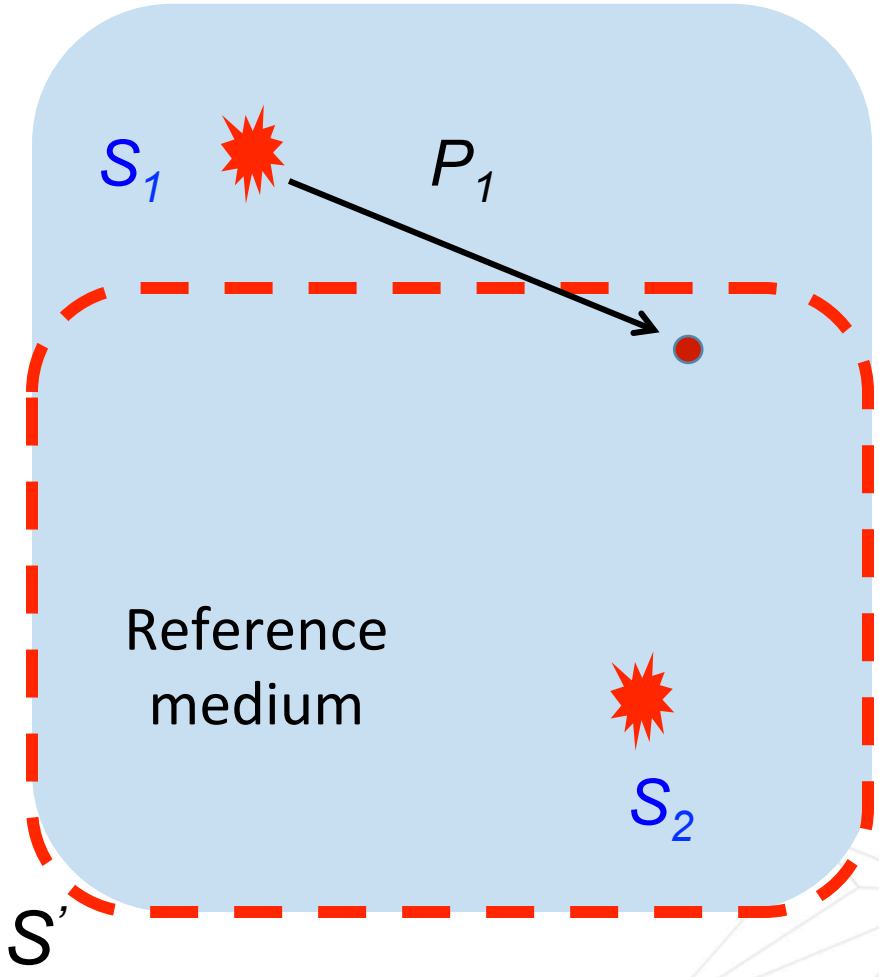
THEORY

GREEN'S THEOREM WAVE SEPARATION



$$P = P_1 + P_2$$

GREEN'S THEOREM WAVE SEPARATION

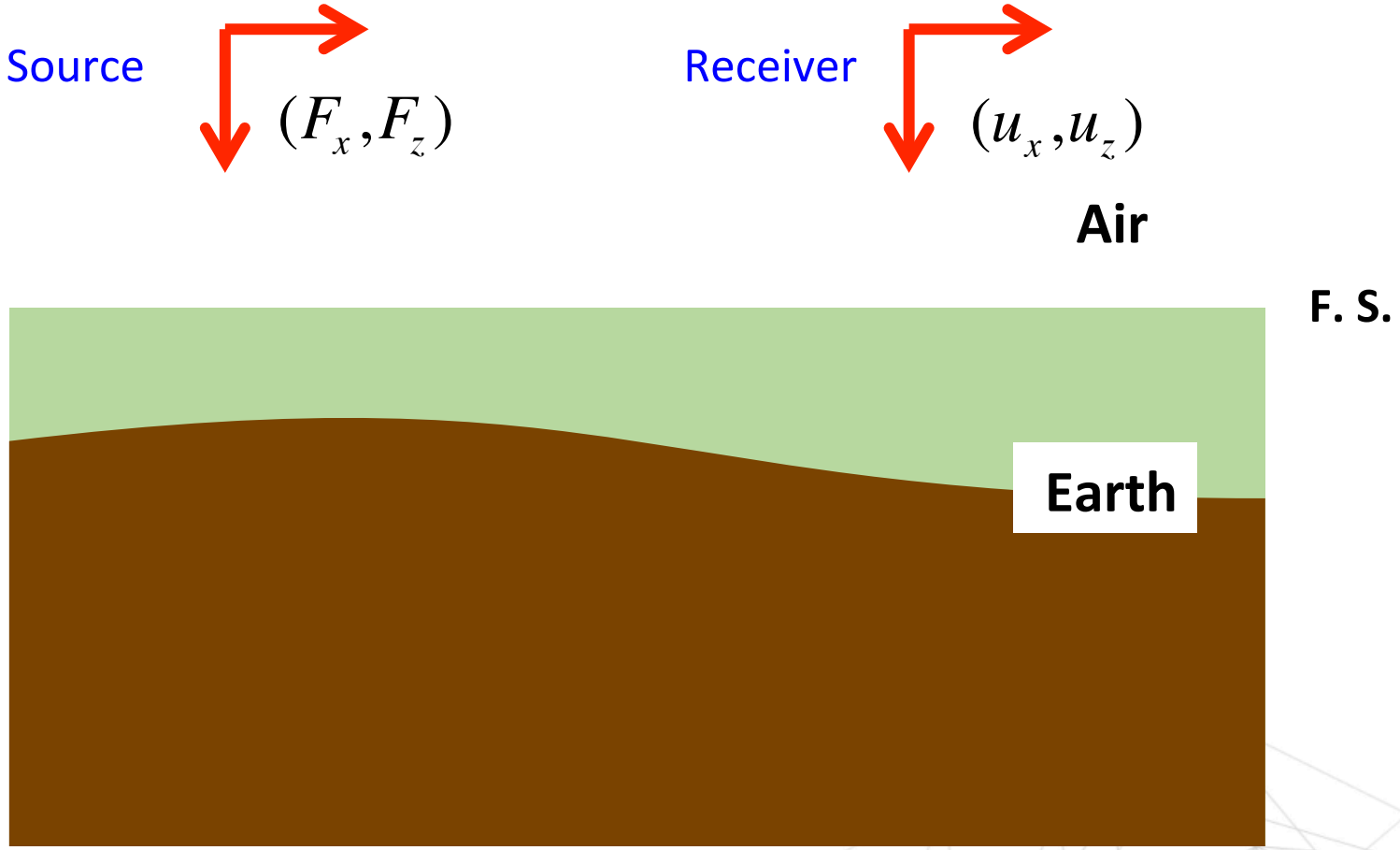


$$P = P_1 + P_2$$

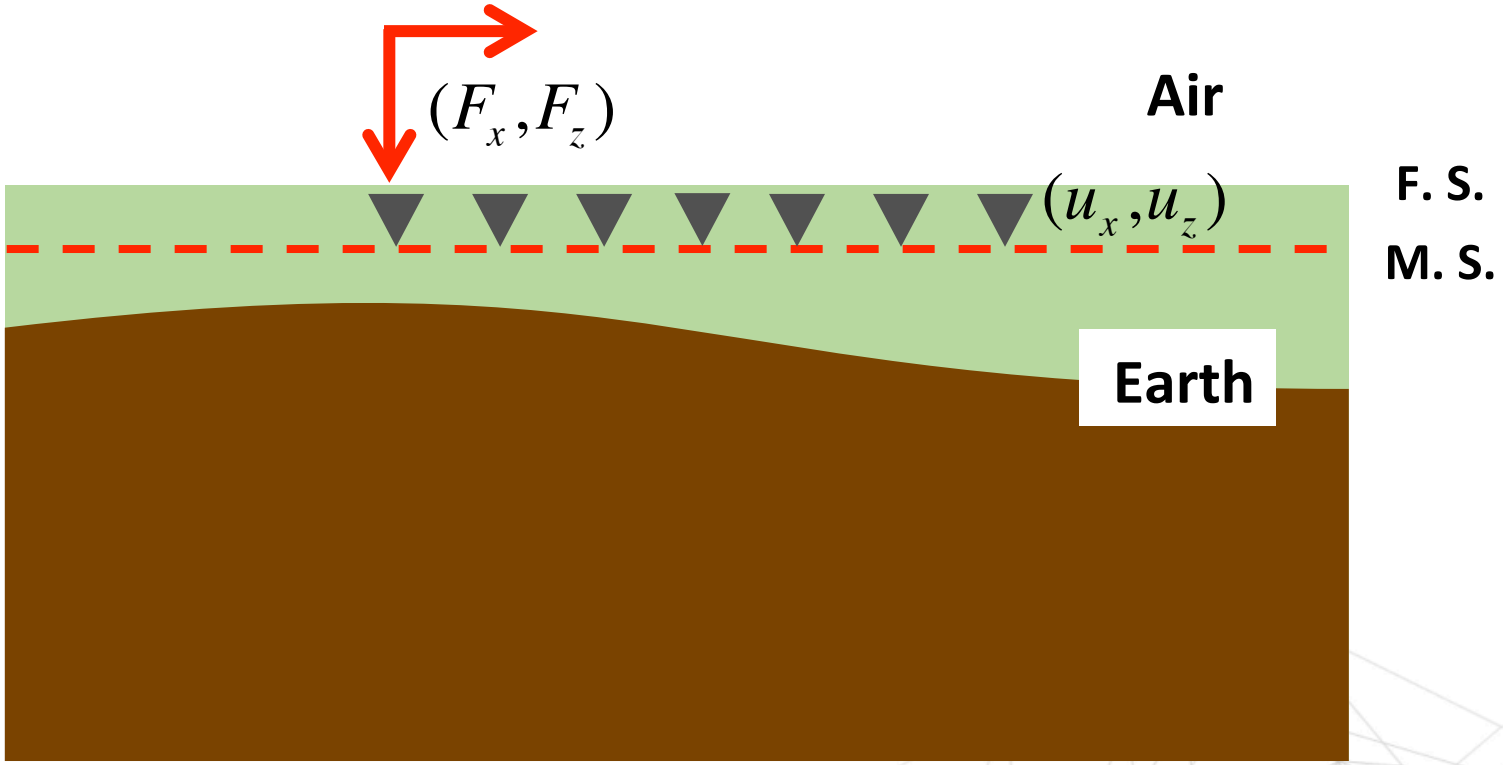
$$P_1 = \int (P\nabla' G_0 - G_0 \nabla' P) \cdot \hat{n}\, dS'$$

(*A. Weglein and B. Secrest, 90; A. Weglein, 02; J. Zhang, 05, 06, 07; J. Mayhan, 12, 13; L. Tang, 13*)

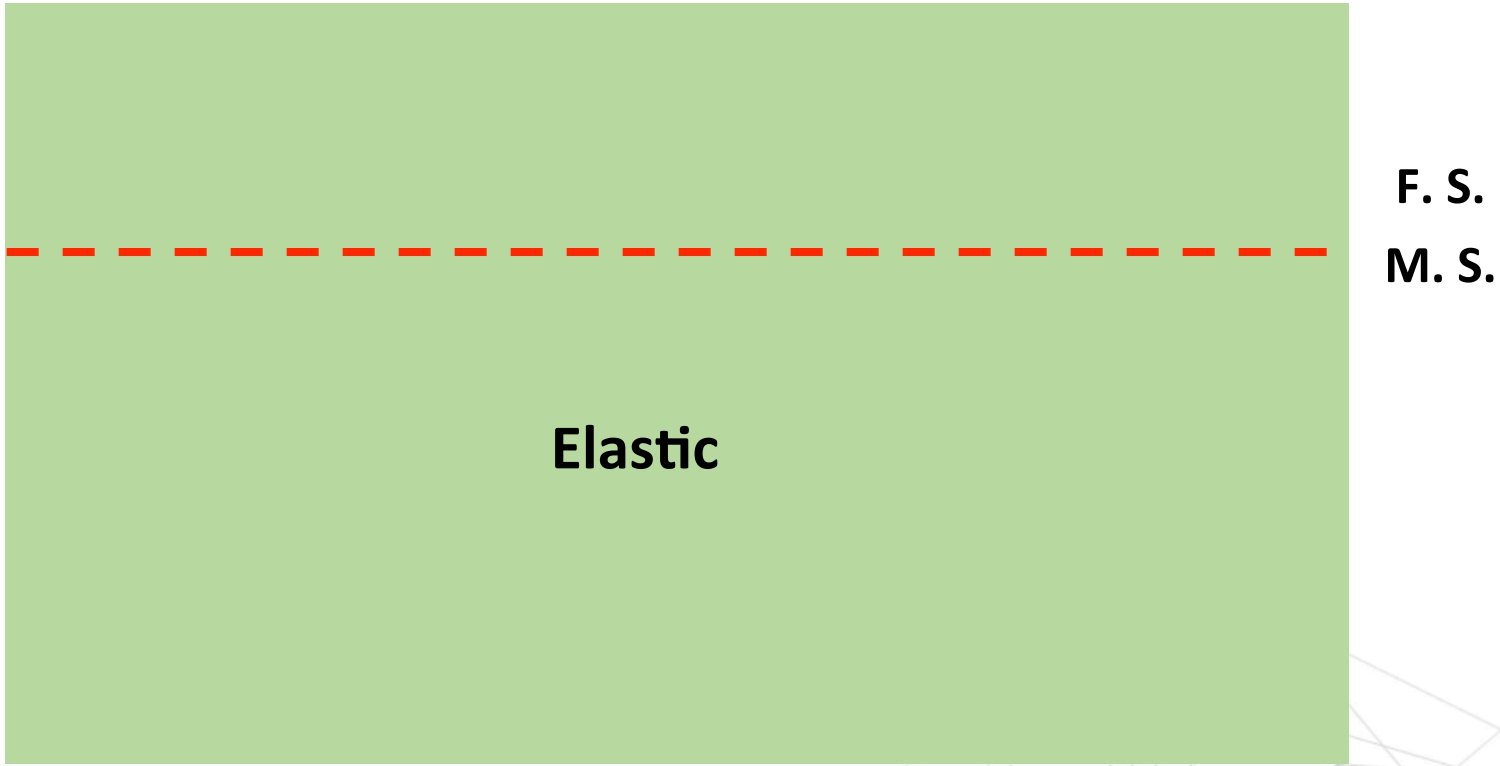
ONSHORE: 2D EXPERIMENT



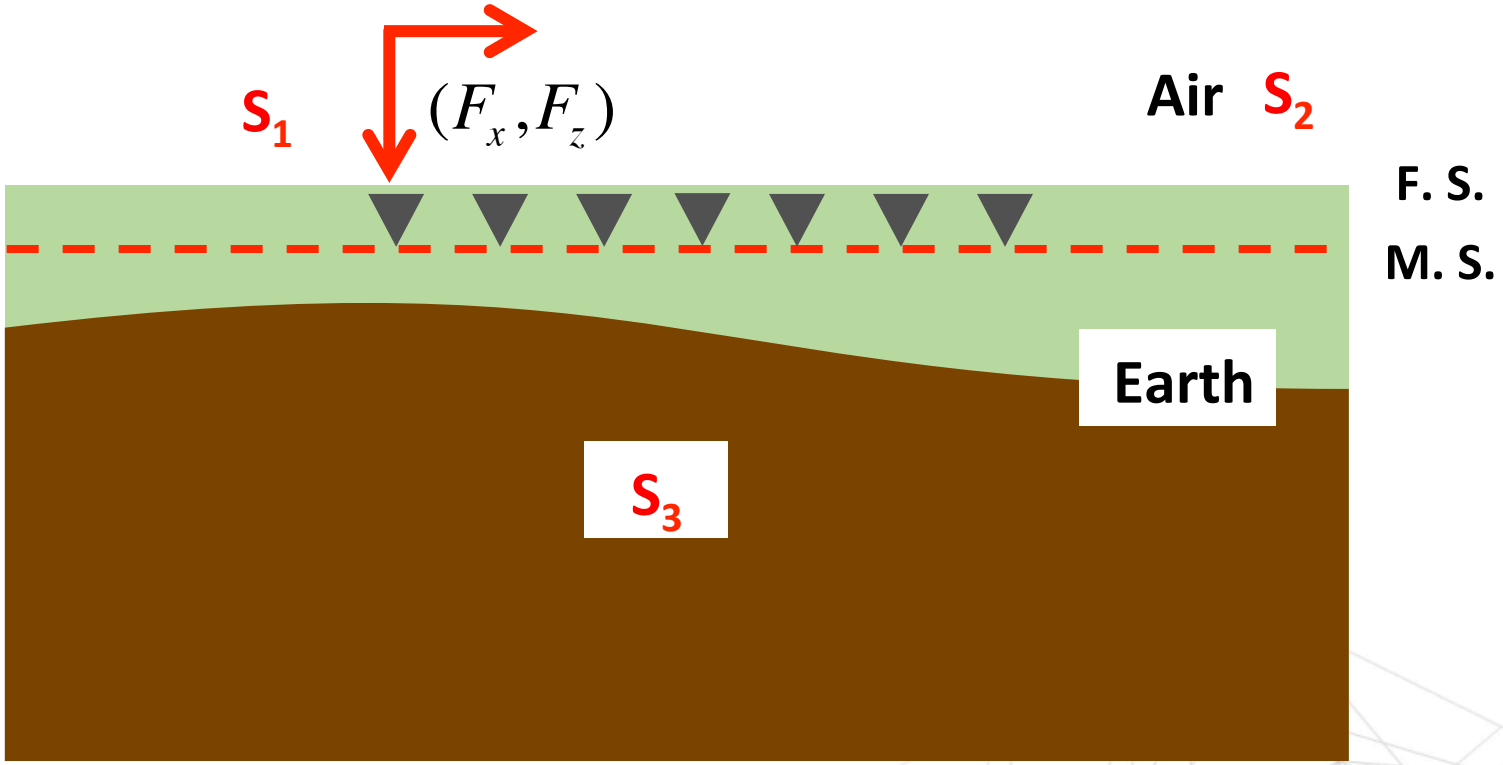
ONSHORE: 2D EXPERIMENT



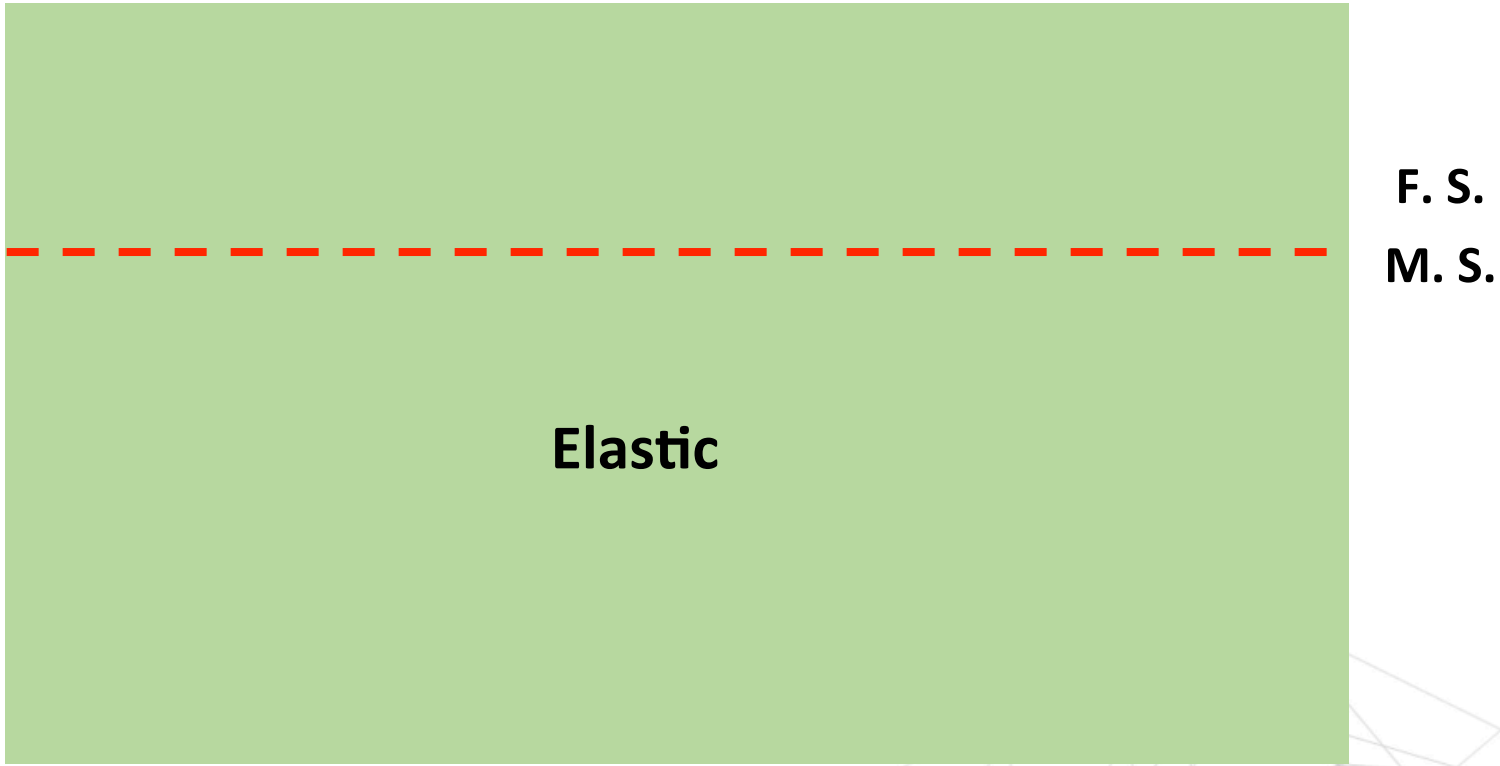
ONSHORE: REFERENCE MEDIUM



ONSHORE: REFERENCE MEDIUM + 3 SOURCES + RECEIVERS

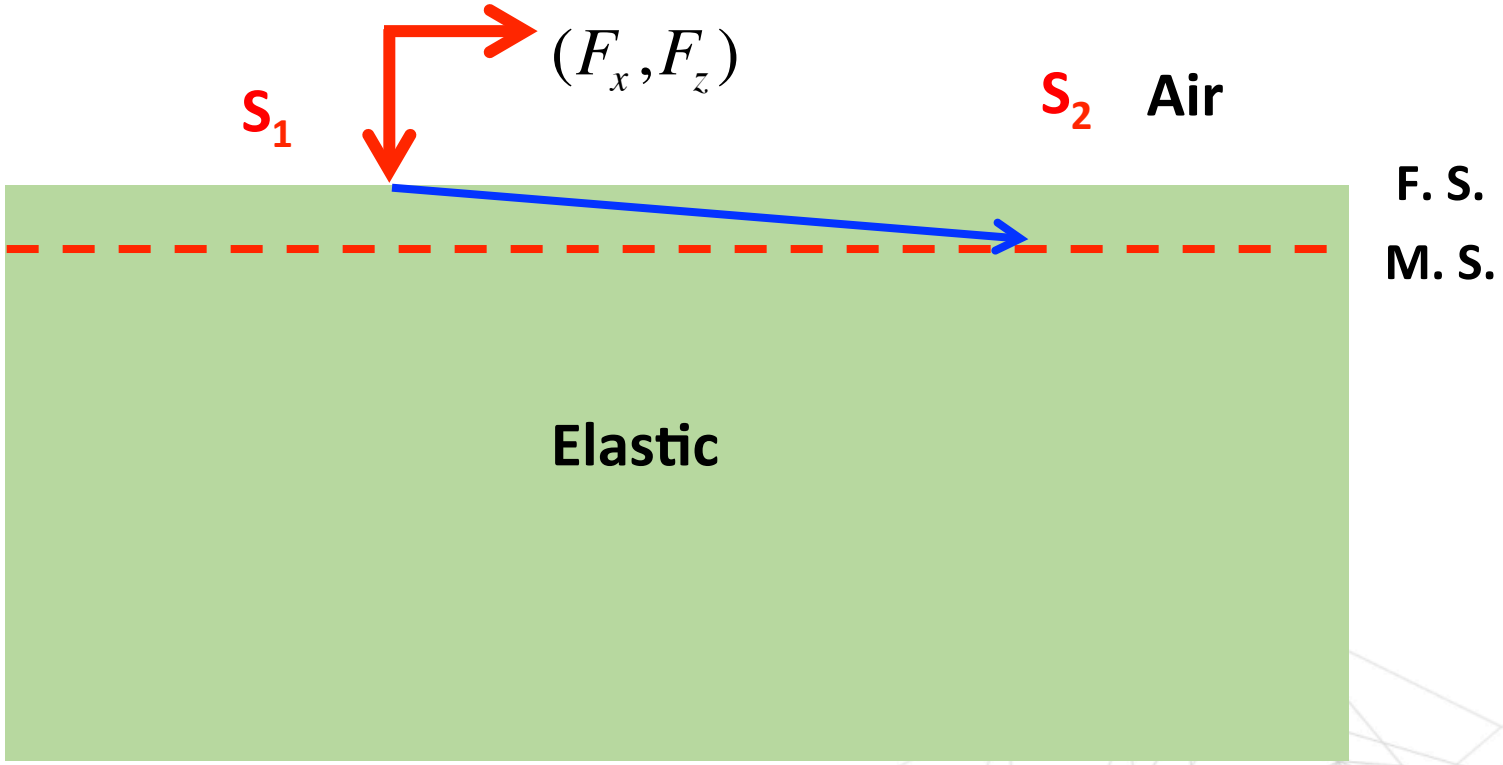


ONSHORE: REFERENCE MEDIUM



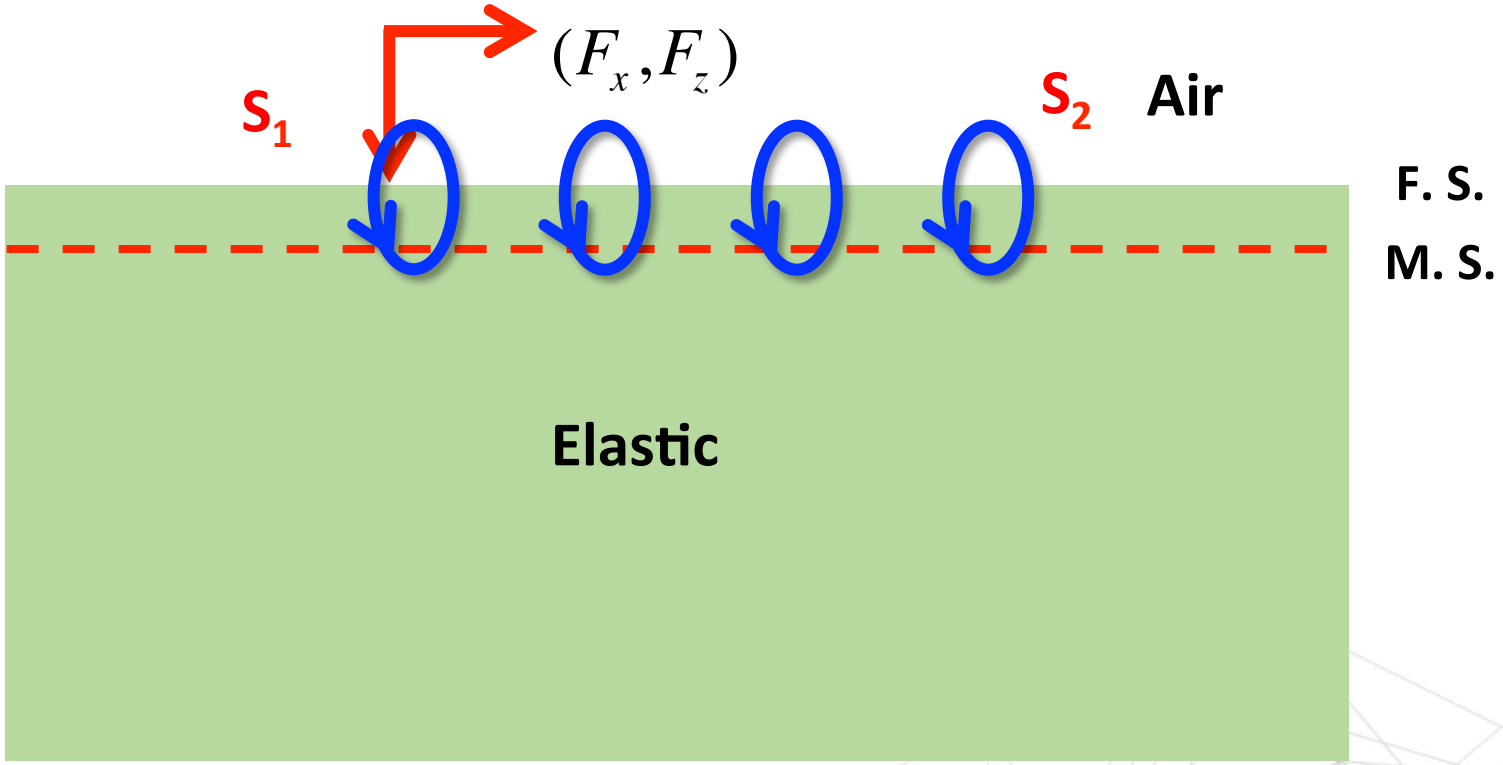
ONSHORE: REFERENCE MEDIUM + SOURCES

✓ $S_1 + S_2$ generate **direct wave**



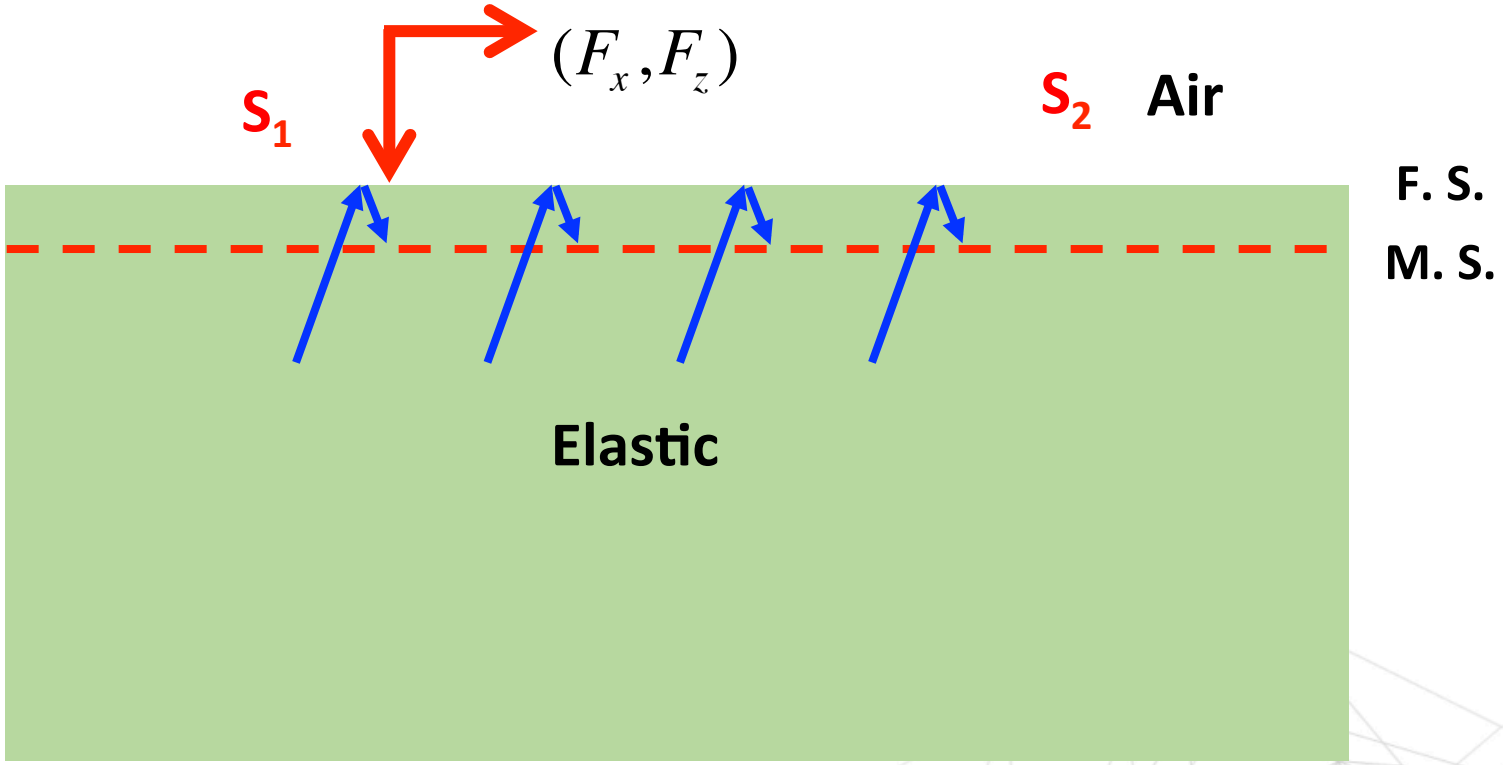
ONSHORE: REFERENCE MEDIUM + SOURCES

✓ $S_1 + S_2$ generate **ground roll**



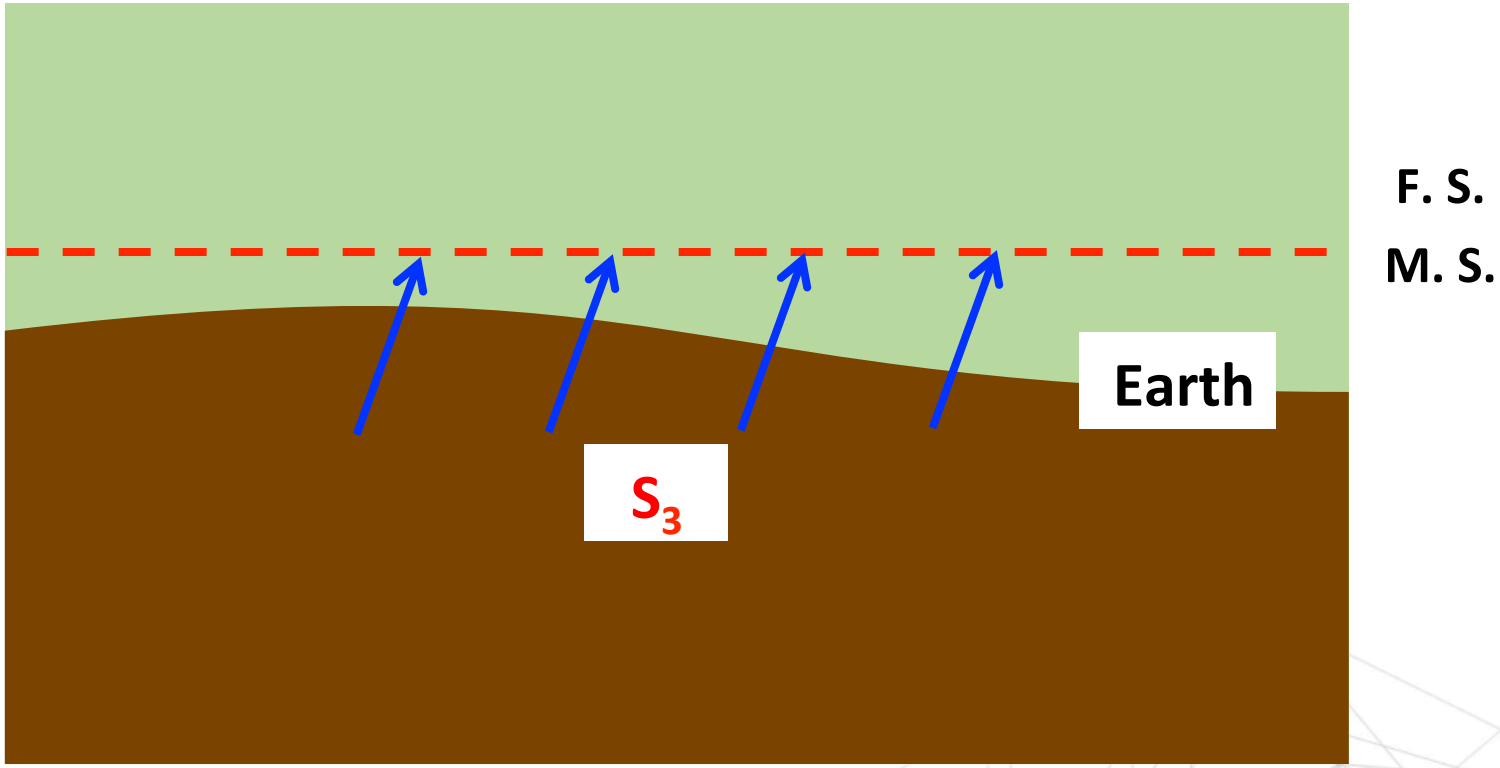
ONSHORE: REFERENCE MEDIUM + SOURCES

✓ $S_1 + S_2$ generate **ghosts**

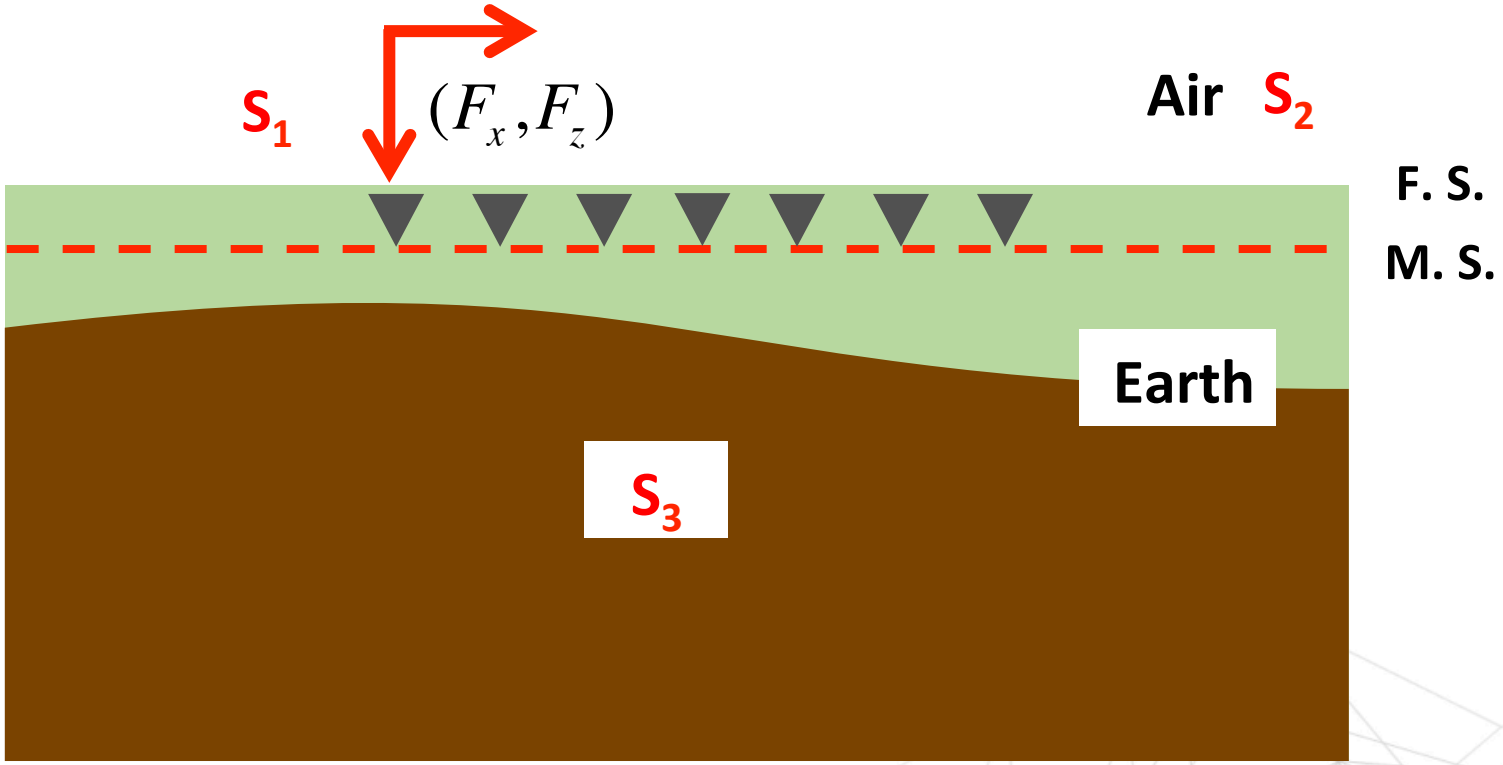


ONSHORE: REFERENCE MEDIUM + SOURCES

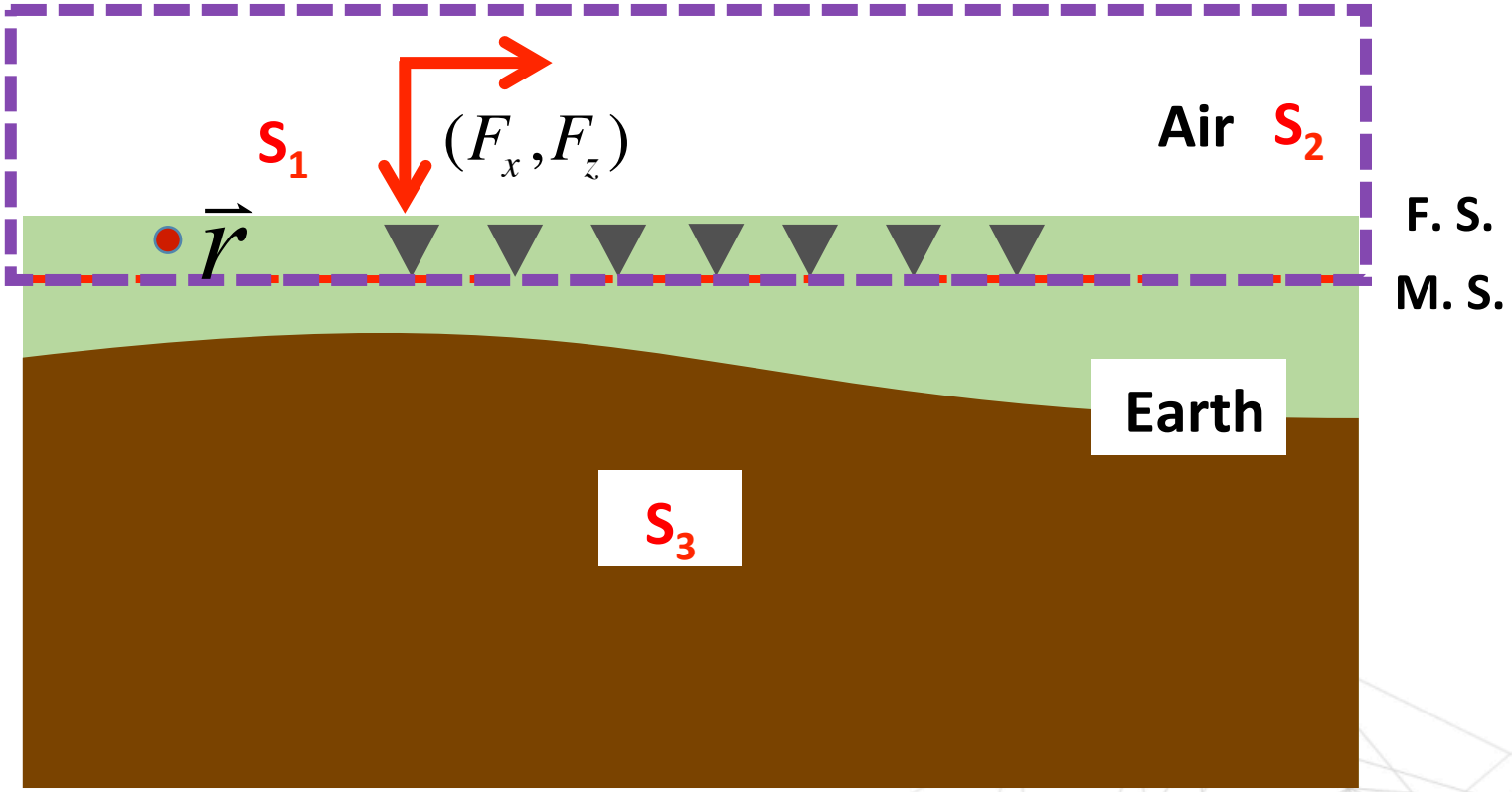
✓ S_3 generates **up reflections**



ONSHORE: REFERENCE MEDIUM + 3 SOURCES + RECEIVERS



ONSHORE: OBTAIN UP WAVE WHEN $\vec{r}$ IS ABOVE M.S.



ONSHORE: UP WAVE PREDICTION

2D:

$$\vec{u}^{up}(\vec{r},\vec{r}_s,\omega) = -\int_{m.s.} \left(\vec{t}(\vec{r}\,',\vec{r}_s,\omega)\cdot G_0(\vec{r}\,',\vec{r},\omega) - \vec{u}(\vec{r}\,',\vec{r}_s,\omega)\cdot\left(\hat{n}'\cdot\Sigma_0(\vec{r}\,',\vec{r},\omega)\right)\right)\cdot dS$$

(*Weglein and Secrest, 1990*)

$\vec{u} = (\ u_x \quad u_z\ )$ Total wave

$\vec{t} = (\ t_x \quad t_z\ )$ Traction along the m.s.

$\vec{u}^{up} = (\ u_x^{up} \quad u_z^{up}\ )$ Up wave

G_0 Green's tensor in reference medium

Σ_0 Stress tensor of Green's function

ONSHORE: UP WAVE PREDICTION

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- ✓Directional derivative of displacement is required to compute traction
- ✓Triangle relationship among wavelet, displacement and traction can be used to determine traction (*A. Weglein & L. Amundsen, 2002*)

ONSHORE: UP WAVE PREDICTION

2D:

$$\vec{u}^{up}(\vec{r},\vec{r}_s,\omega) = -\int_{m.s.} \left(\vec{t}(\vec{r}\,',\vec{r}_s,\omega)\cdot G_0(\vec{r}\,',\vec{r},\omega) - \vec{u}(\vec{r}\,',\vec{r}_s,\omega)\cdot\left(\hat{n}'\cdot\Sigma_0(\vec{r}\,',\vec{r},\omega)\right)\right)\cdot dS$$

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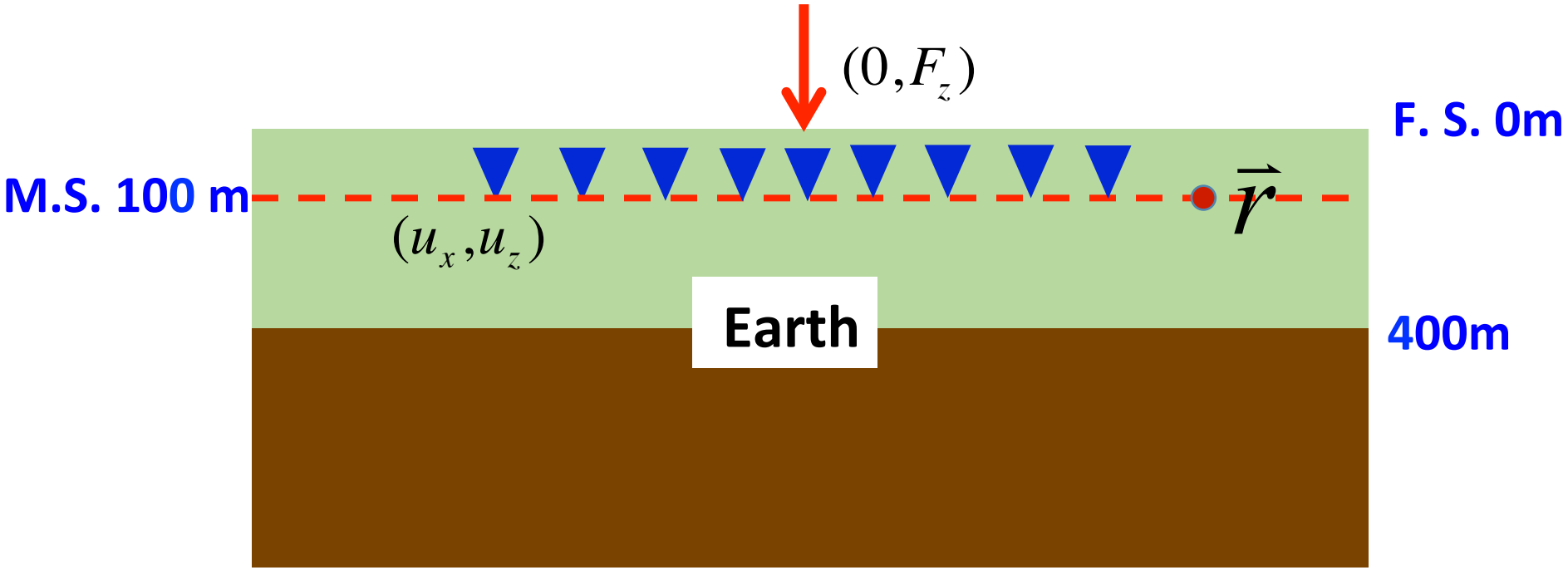
NUMERICAL TESTS

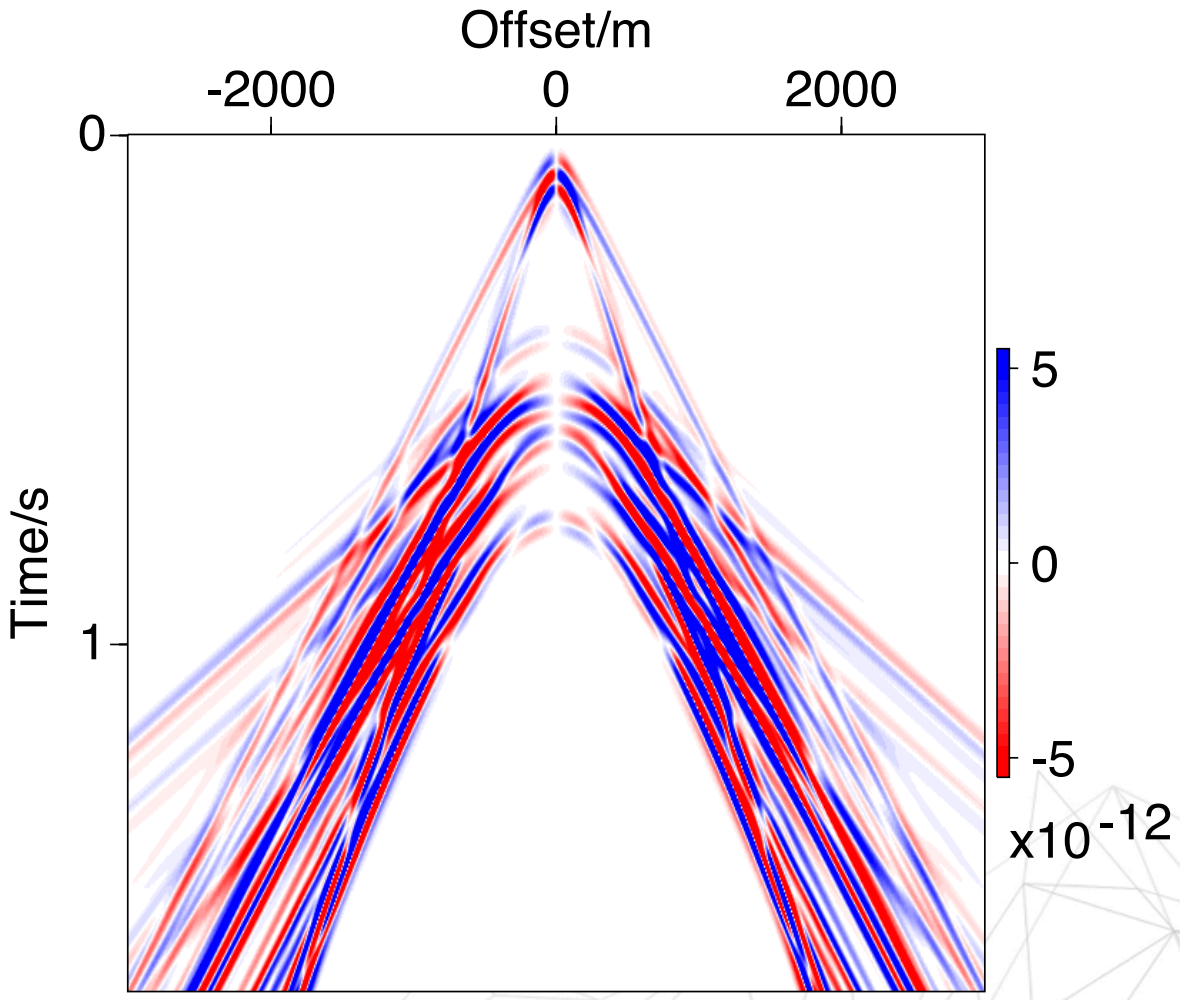
- ✓ Onshore shot record with buried receivers
- ✓ Onshore shot record with on-surface receivers

ONSHORE MODEL WITH BURIED RECEIVERS



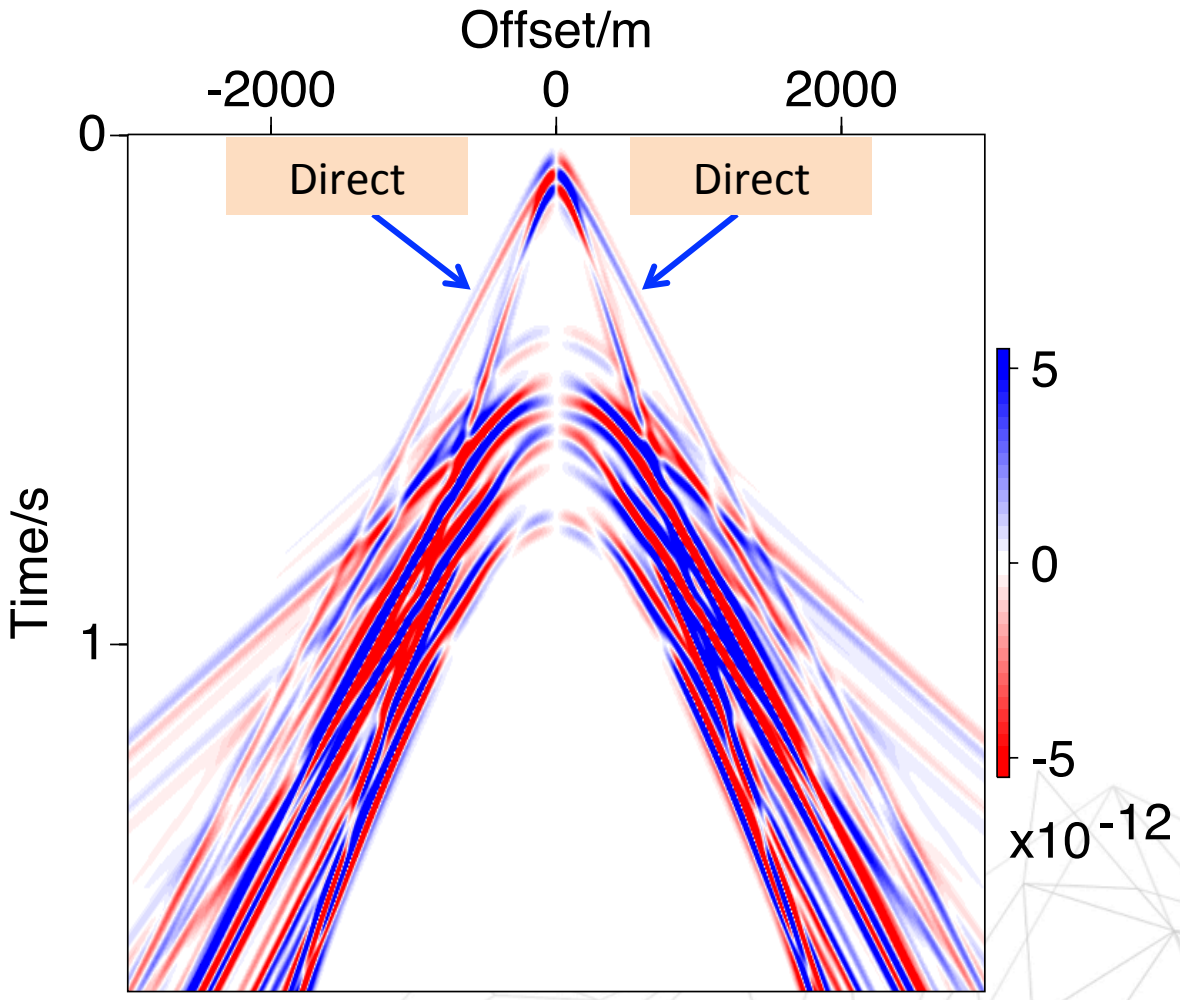
Layer	P Velocity (m/s)	S Velocity (m/s)	Density (kg/m³)
1	1800	1200	1500
2	4000	2500	1800

u_x TOTAL WAVE INPUT TO SEPARATION ALGORITHM



Depth of receivers at 100 m

u_x TOTAL WAVE INPUT TO SEPARATION ALGORITHM



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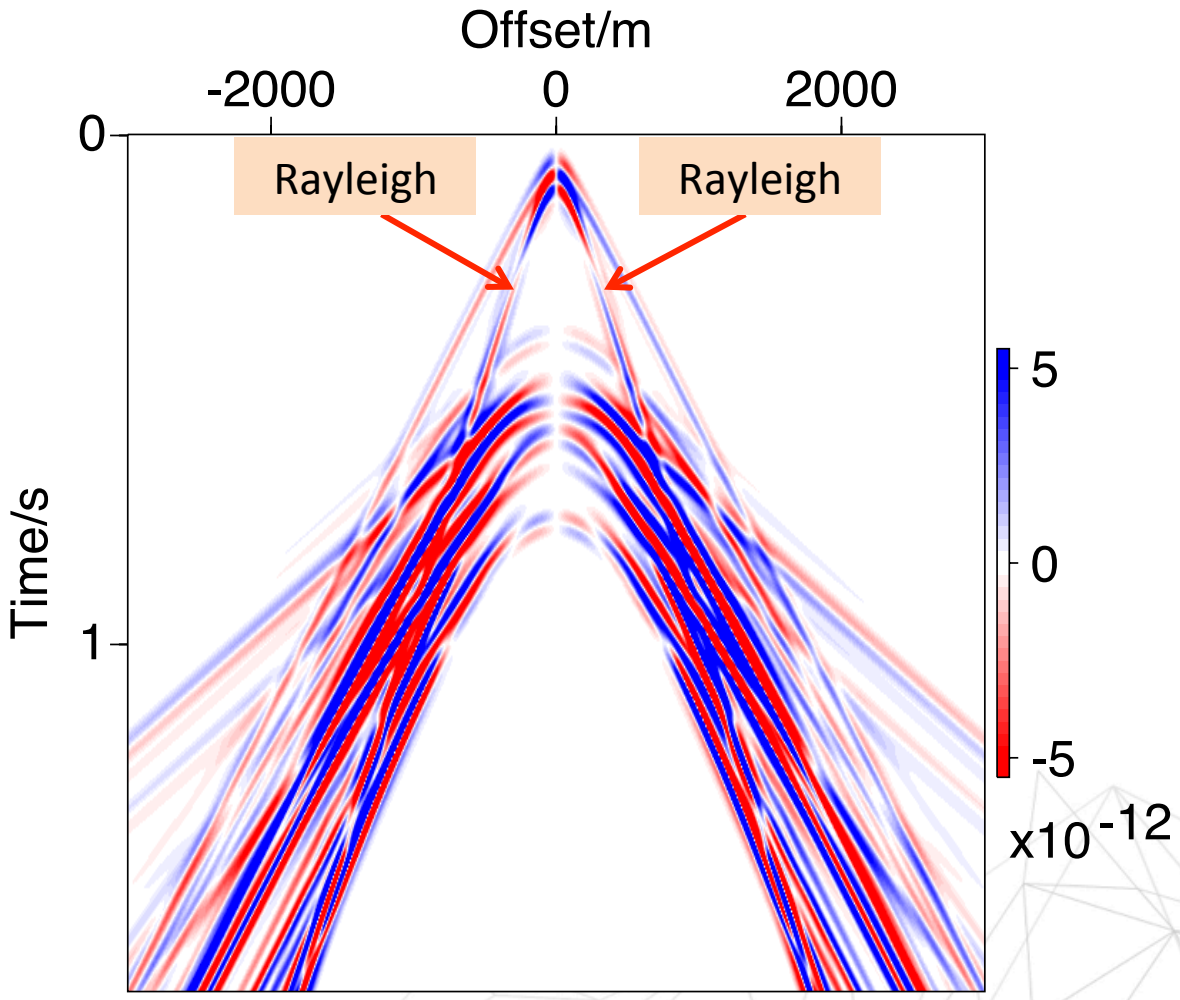

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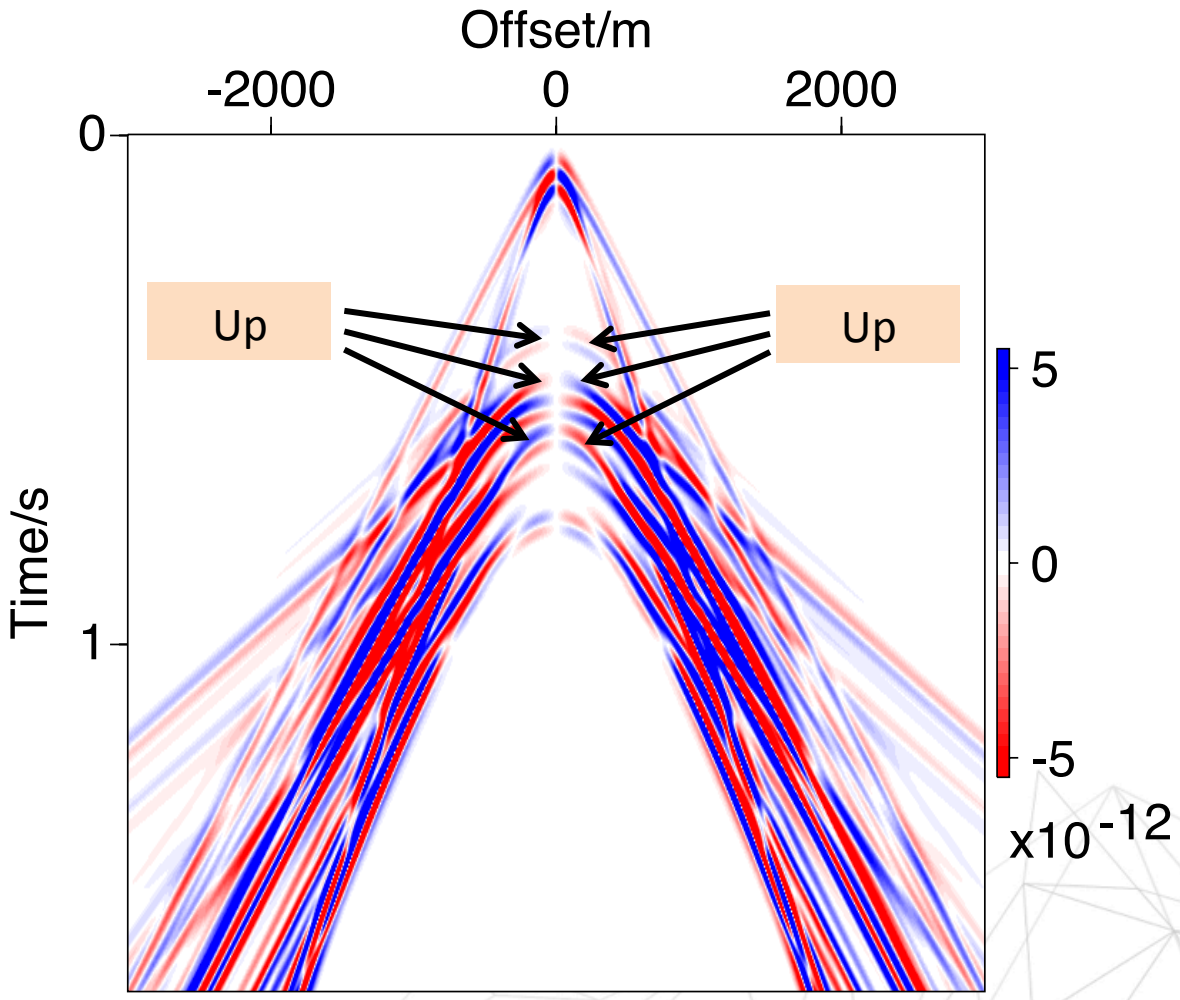

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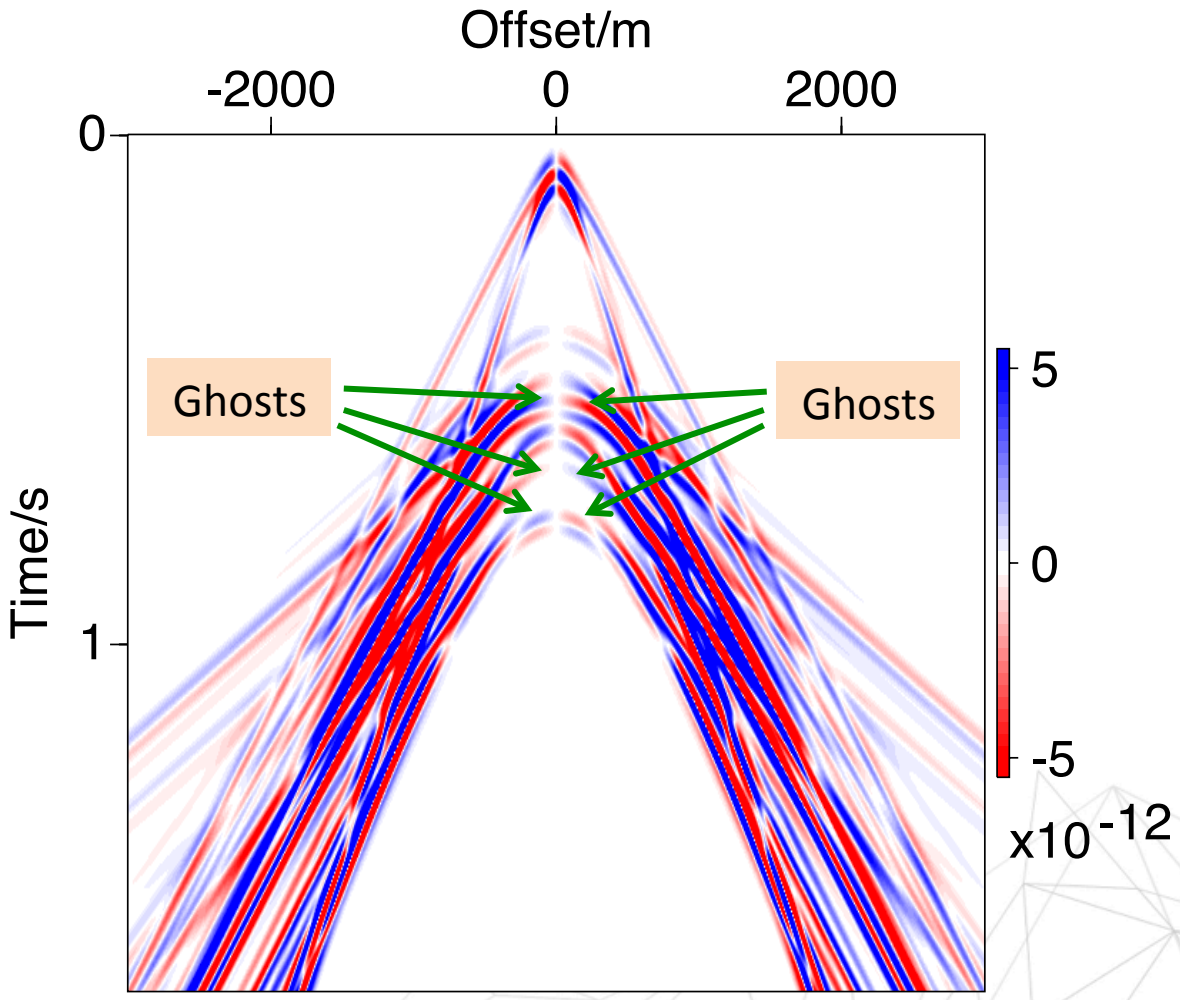

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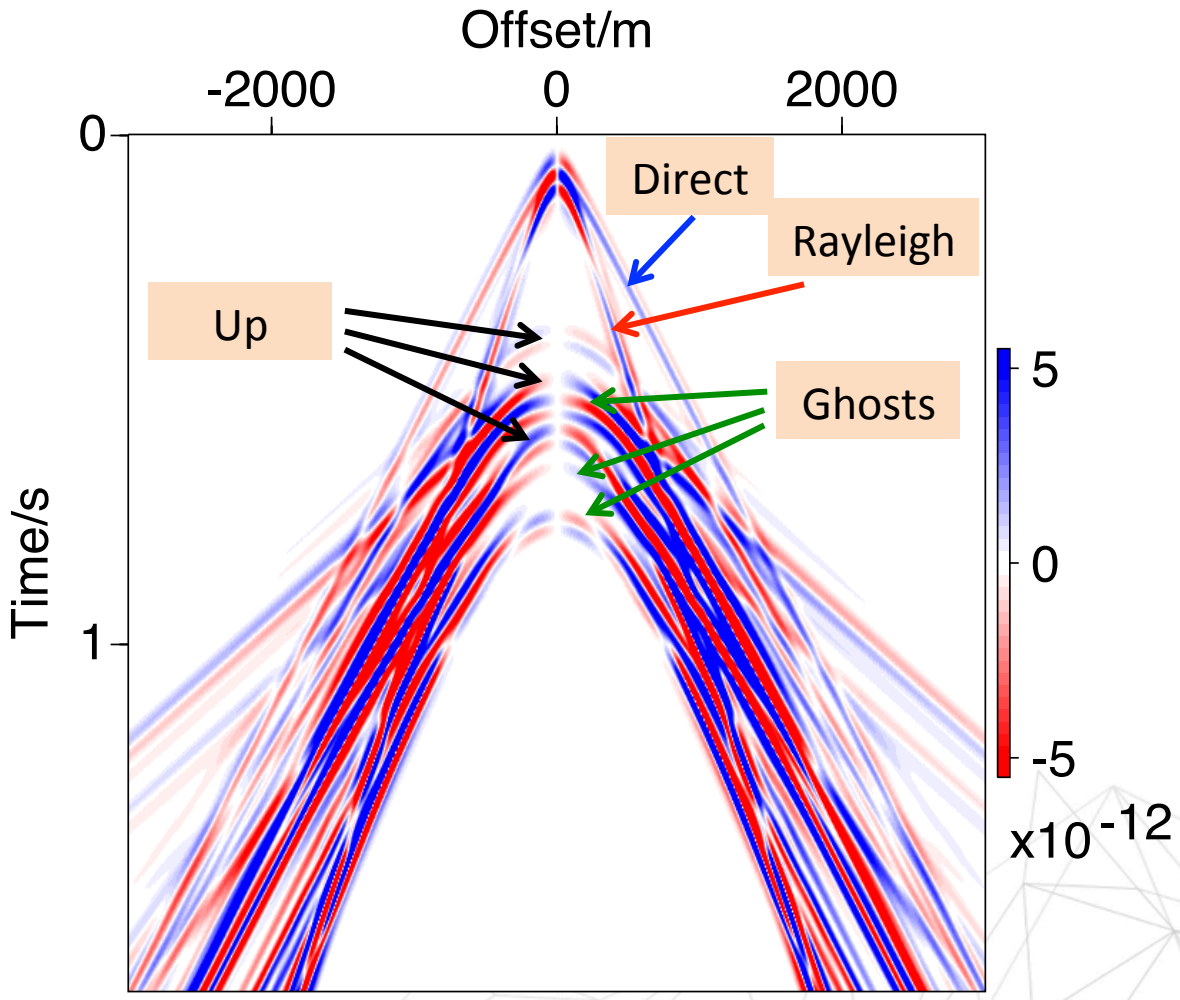
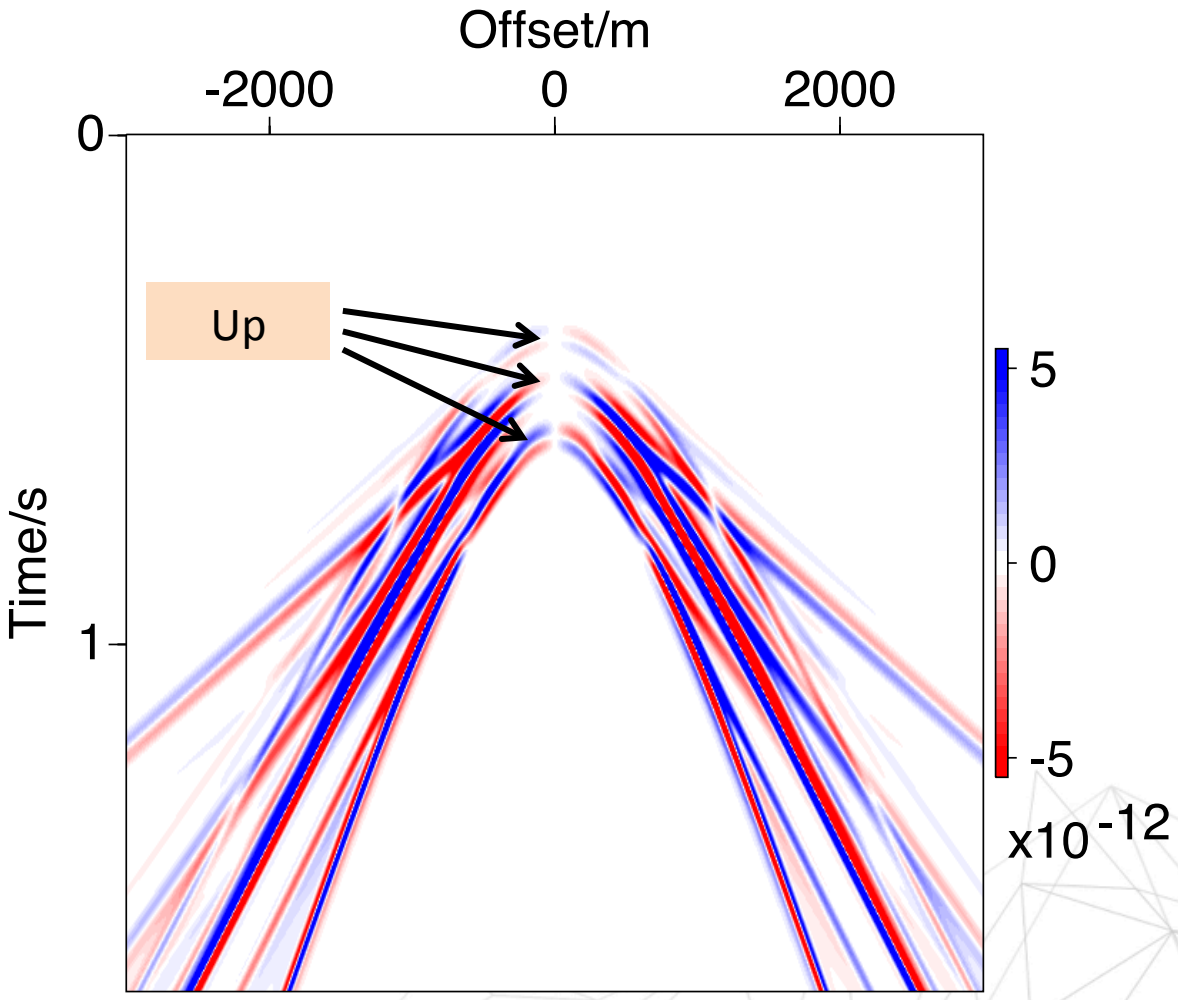


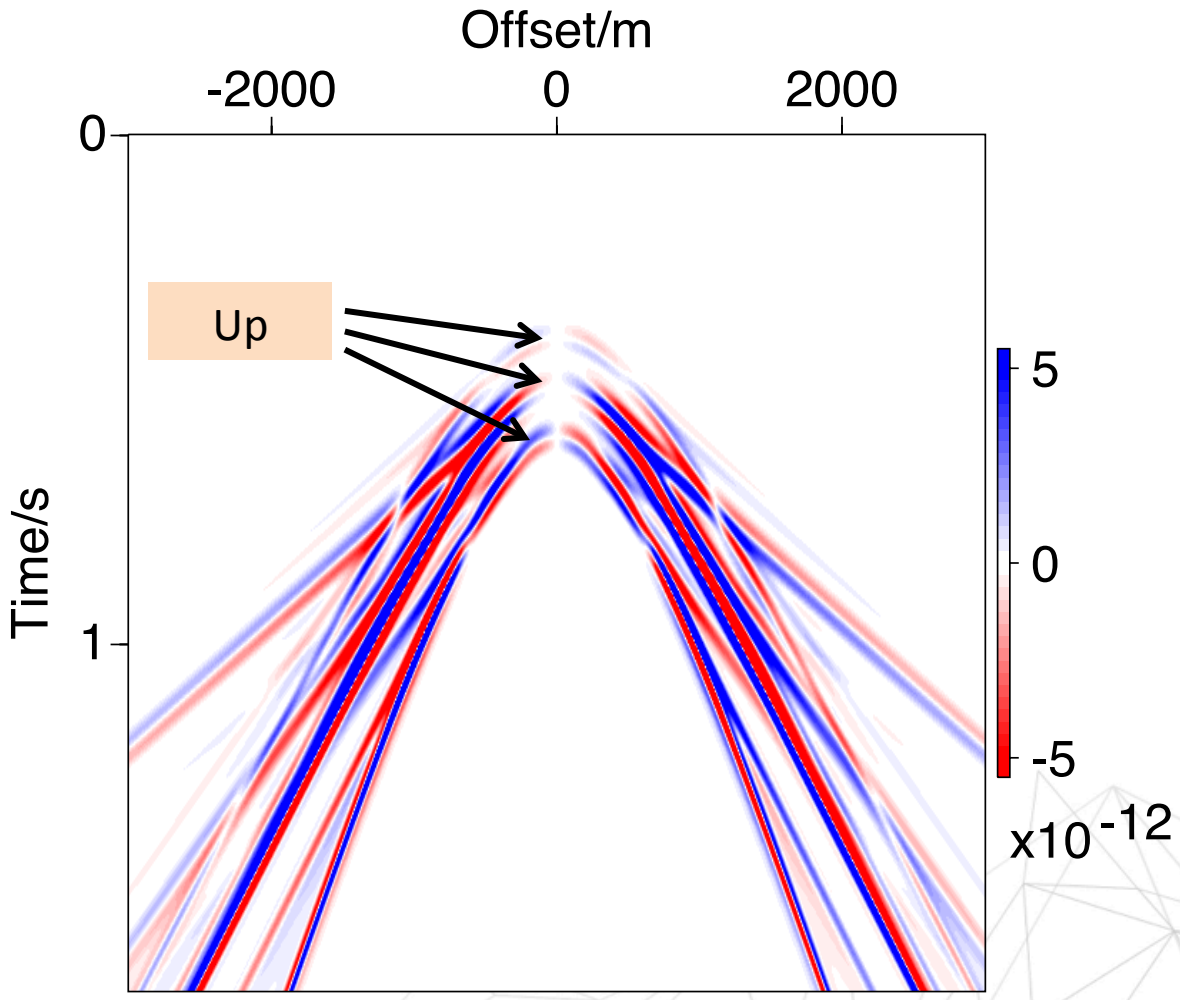
Depth of receivers at 100 m

SEPARATED X COMPONENT OF UP WAVE



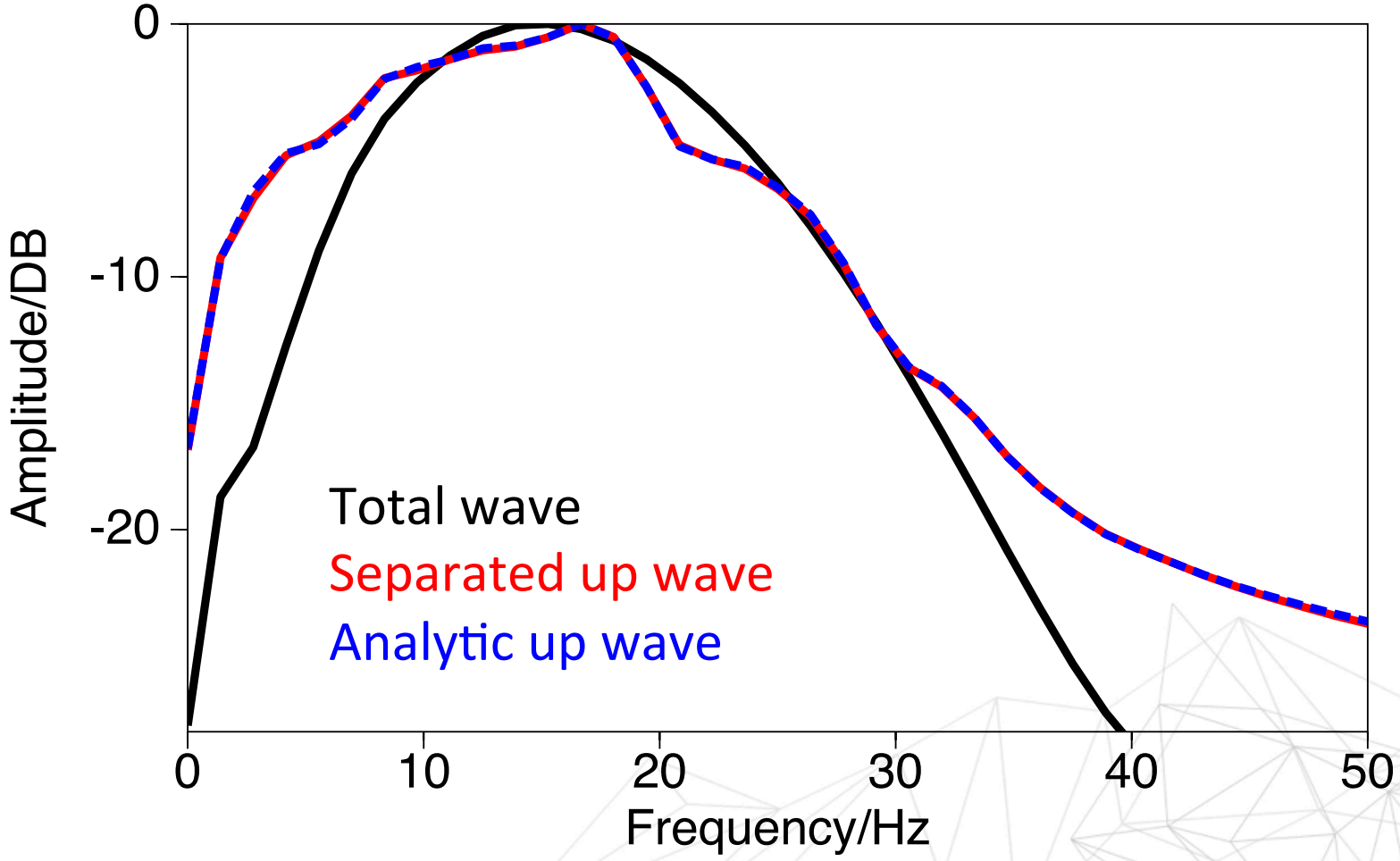
Depth of receivers at 100 m

ANALYTIC X COMPONENT OF UP WAVE

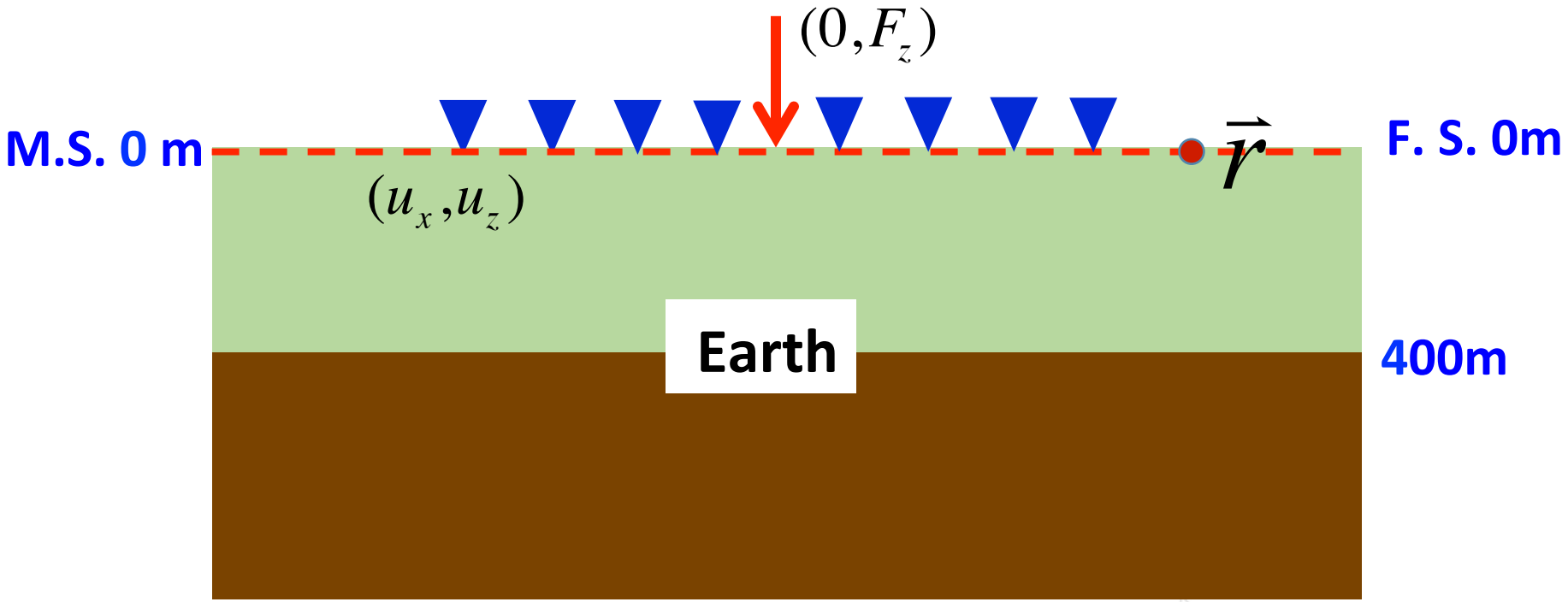


Depth of receivers at 100 m

SPECTRUM COMPARISON



ONSHORE MODEL WITH ON-SURFACE RECEIVERS



Layer	P Velocity (m/s)	S Velocity (m/s)	Density (kg/m³)
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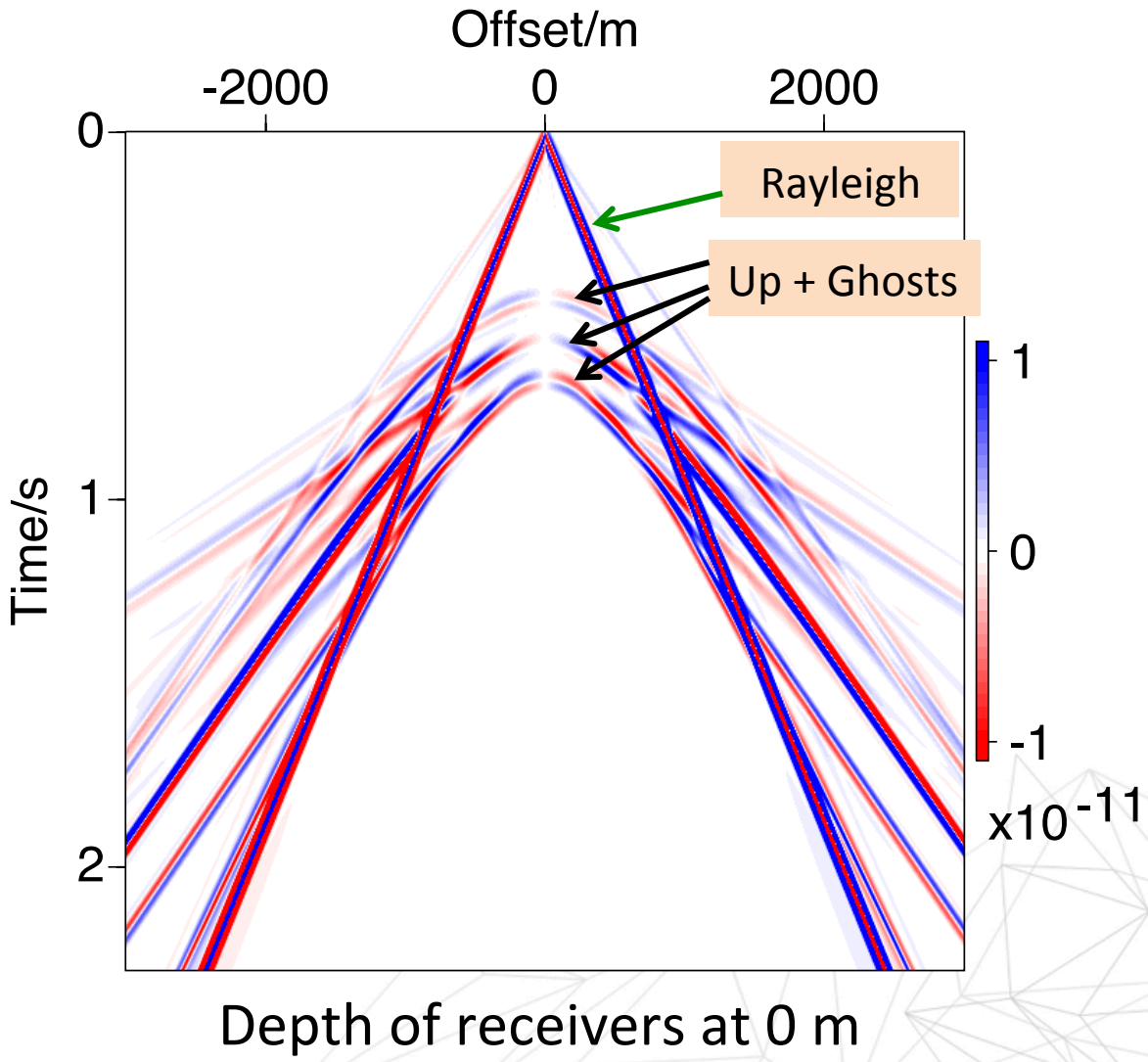
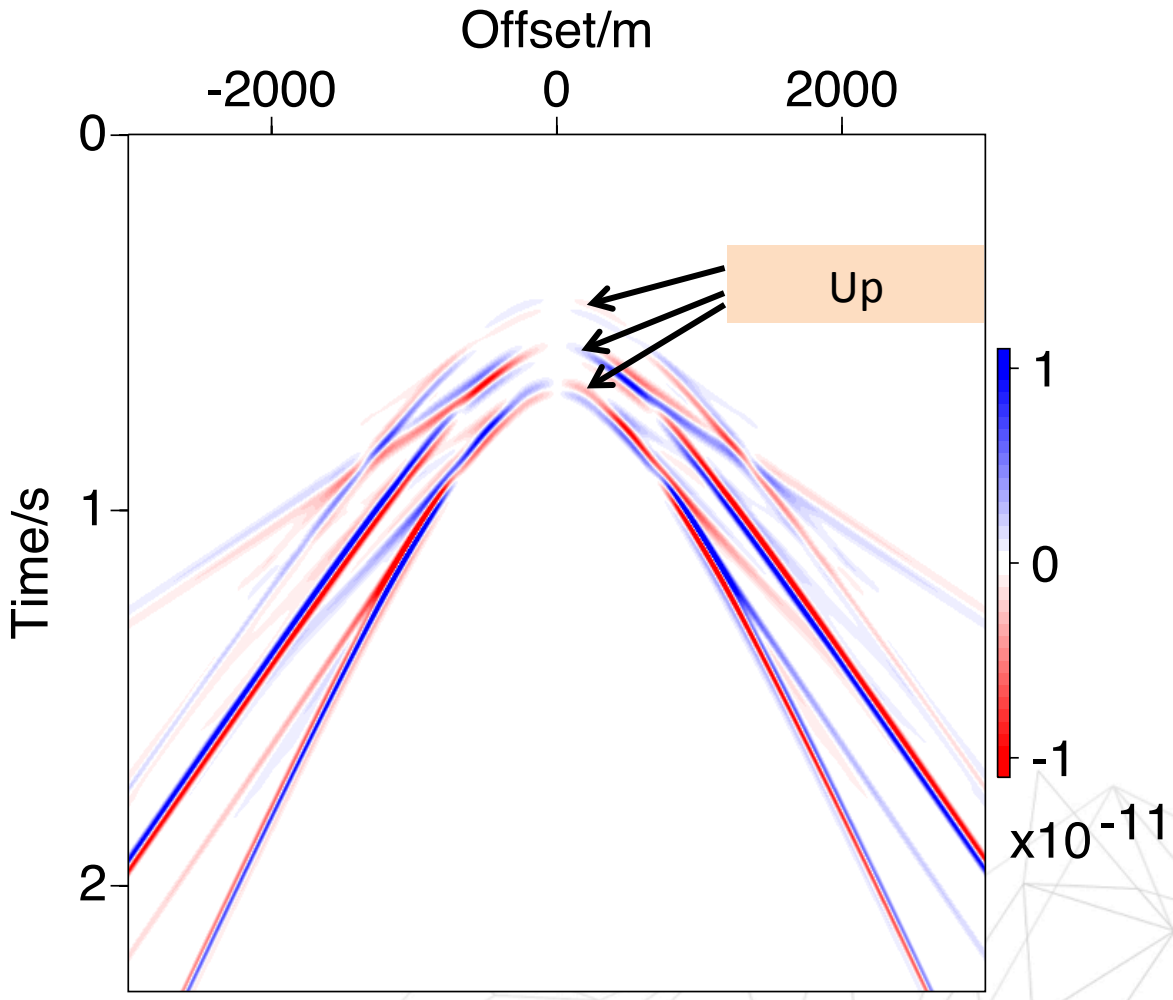
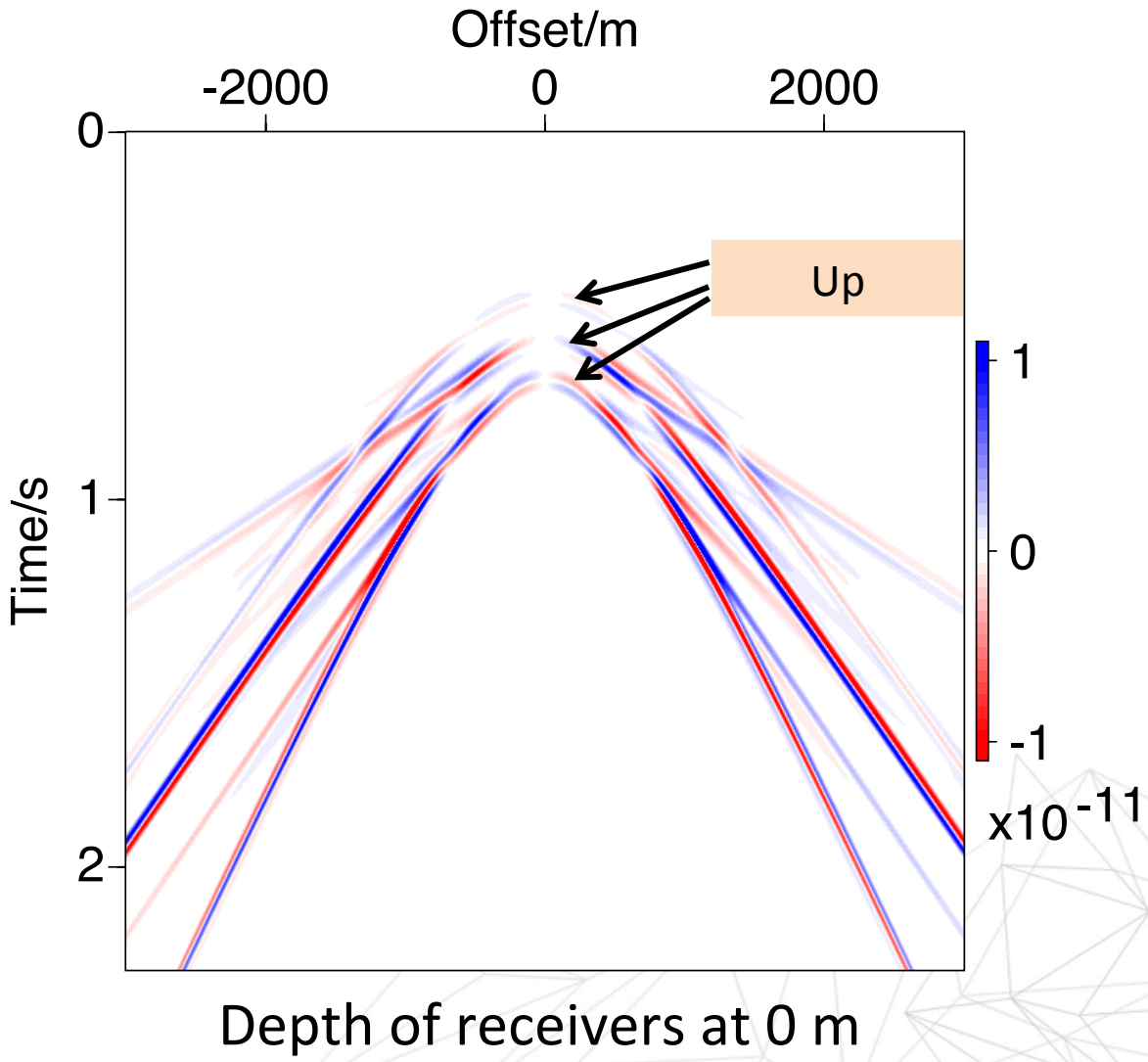


SEPARATED X COMPONENT OF UP WAVE



Depth of receivers at 0 m

ANALYTIC X COMPONENT OF UP WAVE



DISCUSSION AND SUMMARY

FOR DIFFERENT ONSHORE WAVE SEPARATION OBJECTIVES

- ✓ If obtaining the upgoing reflection is the only interest,

  elastic Green's theorem can remove both ground roll and ghosts at once;

- ✓ If separated ground roll / ghosts are useful for other applications, elastic Green's theorem can provide them separately.
  - *A companion talk in SPNA-EP: Coherent Noise Removal, room229, Wednesday, 10/21/2015 10:00 AM*

SUMMARY

- Elastic Green's theorem in the displacement space can
  - ✓ remove ground roll, without damaging reflection data;
  - ✓ remove ghosts from reflection data;
  - ✓ provide effective preparation for all onshore seismic processing;
  - ✓ provide a necessary prerequisite for onshore ISS multiple elimination.

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Thank you