Long wave dynamics in the nearshore

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Background

Long (infragravity) waves

Periods 20 s to 3 minutes.

Associated with short-wave groups.

Why?

Energetic in the nearshore.

Role in inundation and erosion.

Background

Types of long waves:

- Bound to the group -> propagating at C_g, in antiphase with the group envelope. There is a solution (Longuet-Higgins and Stewart, 1962), for constant depth and valid in deep enough water.
- Free -> detached from the groups.

Two recognised mechanisms for generation of free long waves, associated with group breaking

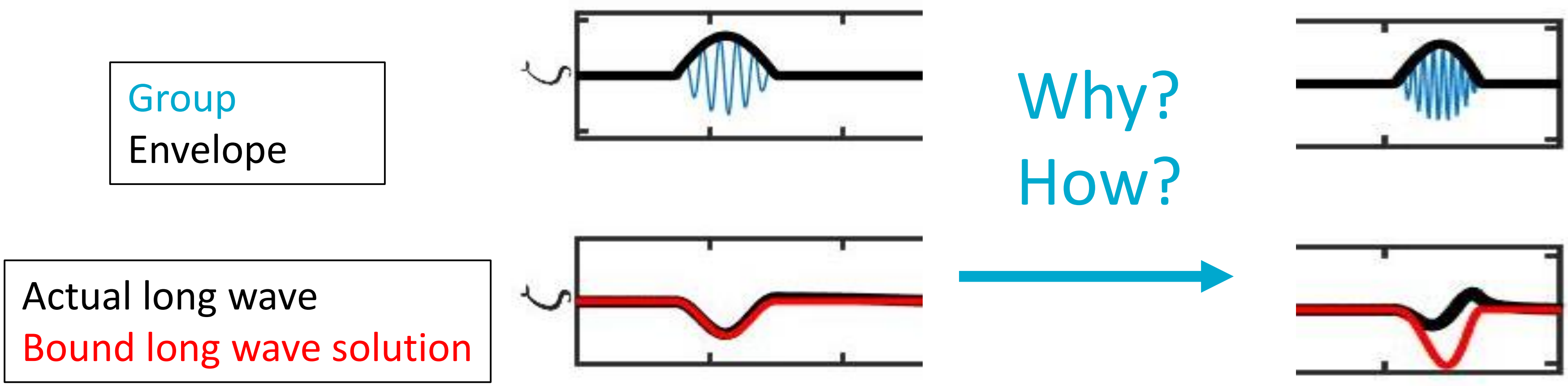
- ➢ Breakpoint forcing (Symonds et al., 1982) -> steep slopes
- ➢ Bound long wave release (Masselink, 1995 ; Inch et al., 2017) -> mild slopes

Free waves generated over depths variations (Mei and Benmoussa, 1984; Janssen et al., 2003).

Background

What we know (and what we don't know):

As wave groups propagate into shallow water,
- the phase, between the group envelope and the long shifts from 180° offshore to 90° approaching the shoreline (measured and modelled numerically).
- the bound wave solution (constant depth) overestimates the amplitude of the long waves.



What this talk is about

- Understand the generation mechanisms
- Estimate phase lags and elevation amplitudes

We run a (simple) linear 1D numerical model

- isolate the mechanisms

Some structure

- Simplest case, wave groups undisturbed (constant depth, no breaking)
- Most complicated case, depth varying and short-wave groups breaking

Simplifications:

Effect of depth variation

- Depth varying but no breaking
- One depth variation

Effect of group breaking

- \- Constant depth, breaking

The important equations

Conservation of mass and momentum
Linearized, mild slope
Group scale

$$\frac{\partial \zeta}{\partial t} + h\frac{\partial U}{\partial x} = 0$$

$$\frac{\partial U}{\partial t} + g\frac{\partial \zeta}{\partial x} = -\frac{1}{\rho h}\frac{\partial S_{xx}}{\partial x}$$

Radiation stress gradient -> forcing for the model

Radiation stress

$$S_{xx} = \frac{1}{2}\rho g {A_g}^2\left(\frac{2c_g}{c} - \frac{1}{2}\right),$$

Short-wave group envelope

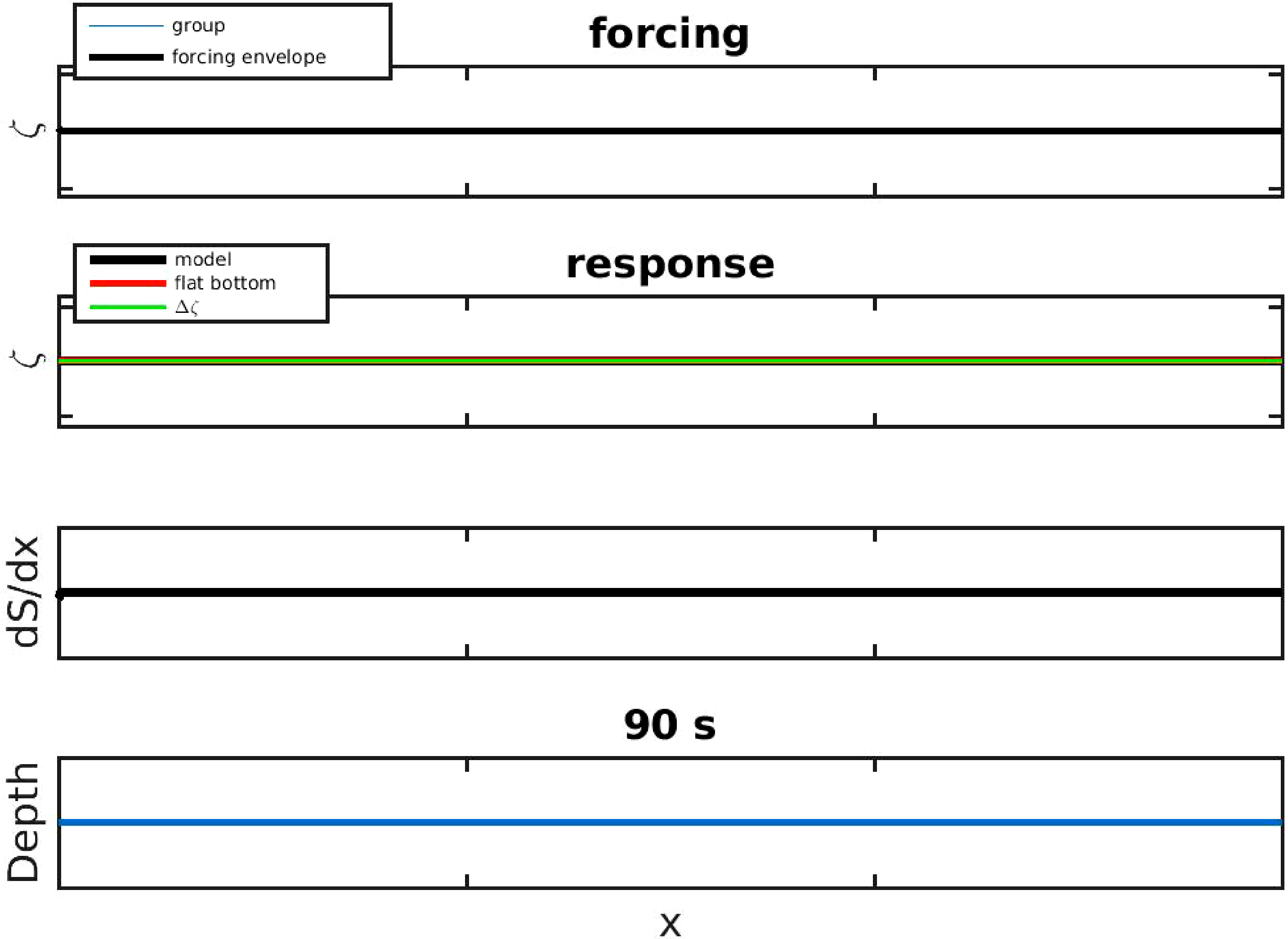
Depth

Flat bed solution (Longuet-Higgins and Stewart, 1962)

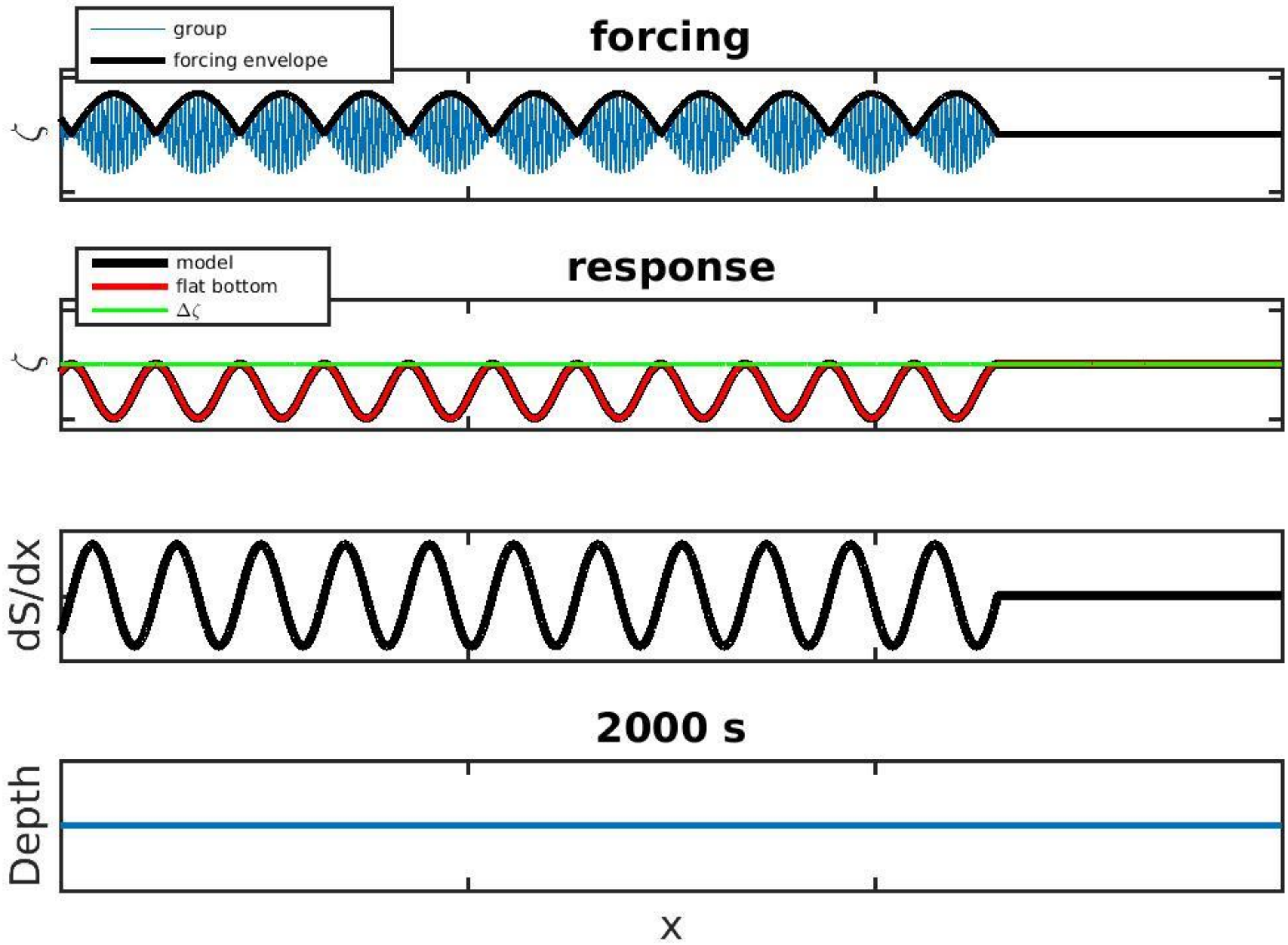
$$\zeta_{BLW} = -\frac{1}{\rho}\frac{S_{xx}}{gh - {c_g}^2} + constant$$

Model run

Flat



Model run



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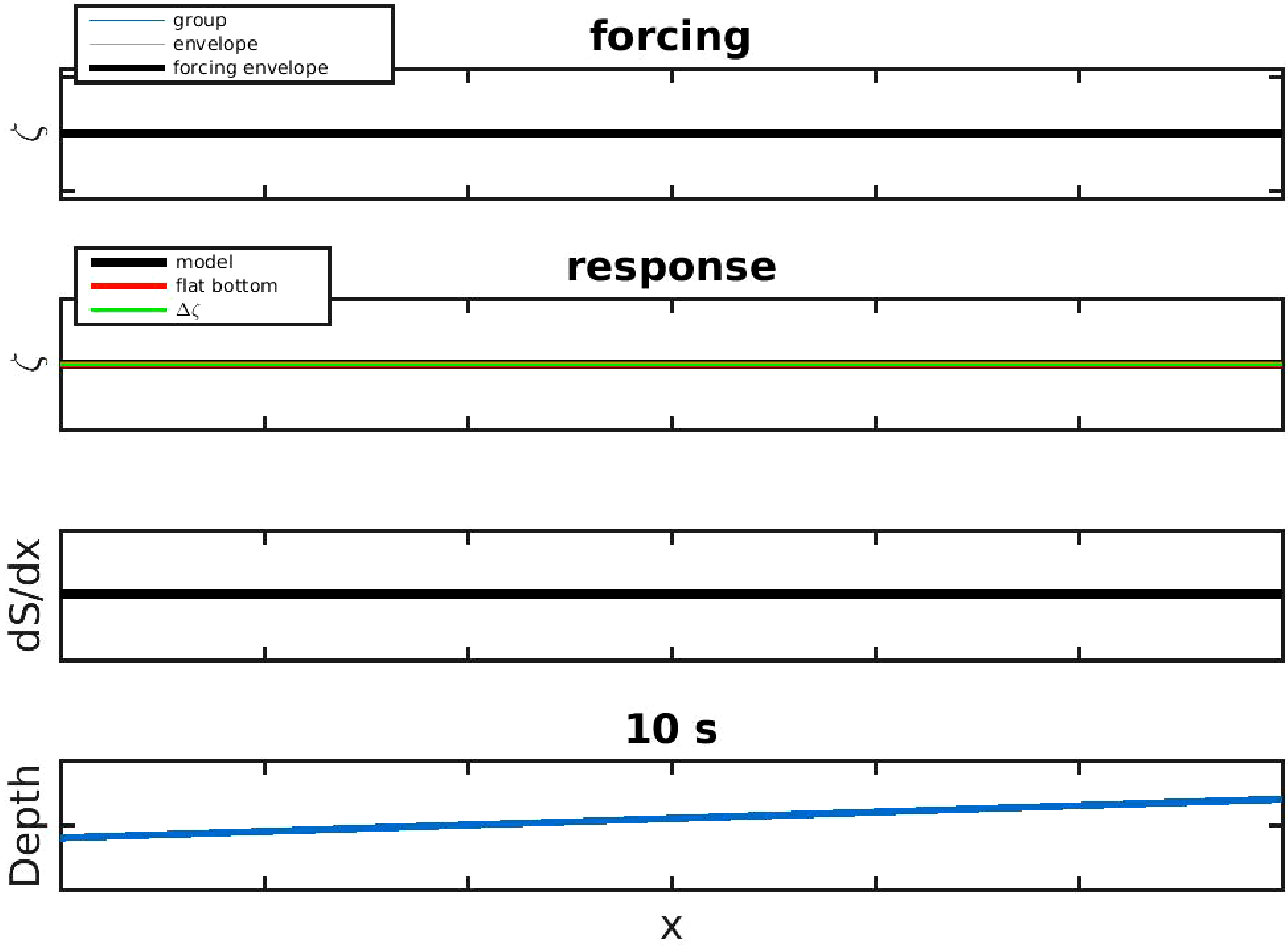
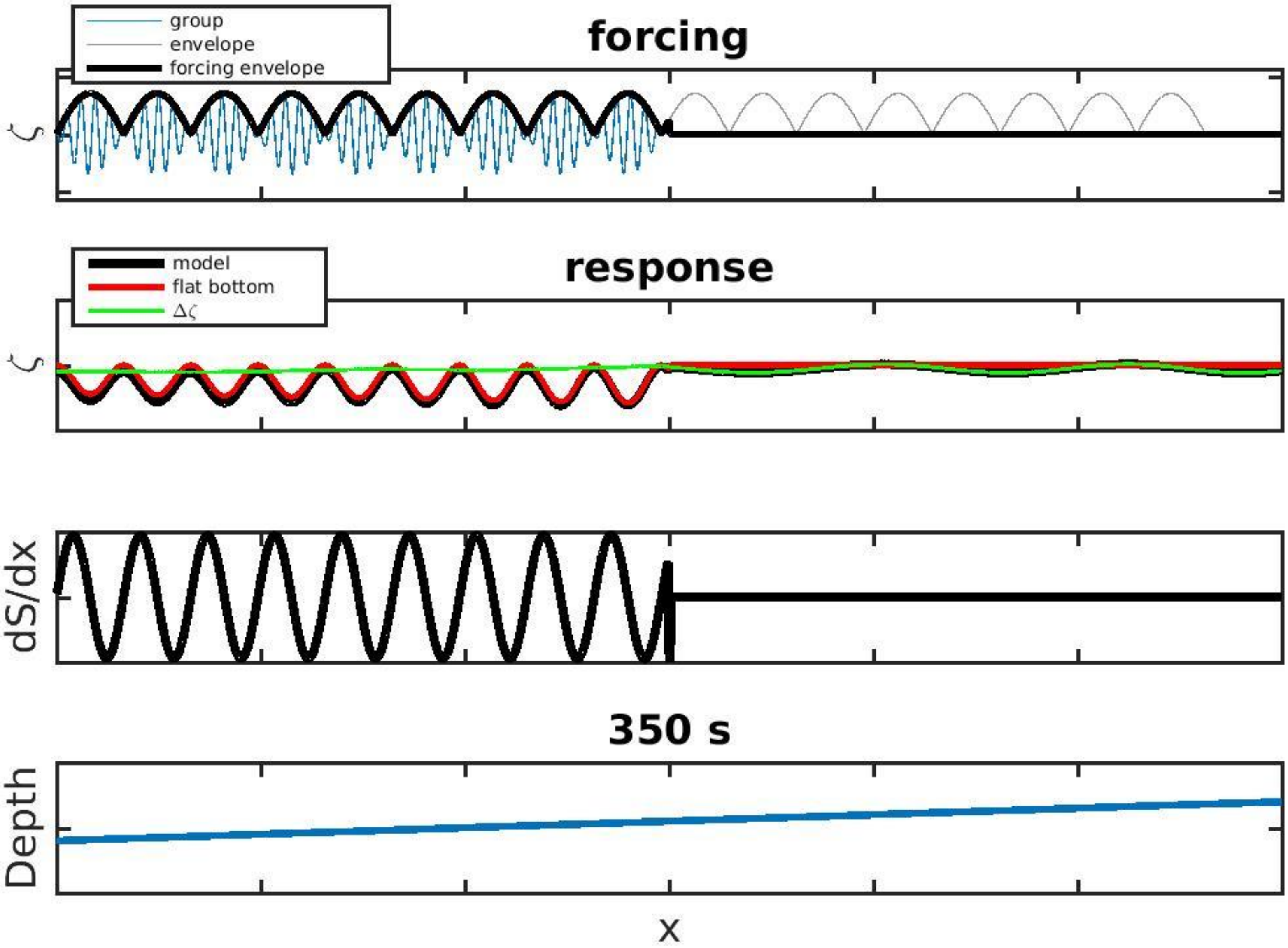
Model run


forcing
group
envelope
forcing envelope
ζ
response
model
flat bottom
Δζ
ζ
dS/dx
10 s
Depth
x

Model run



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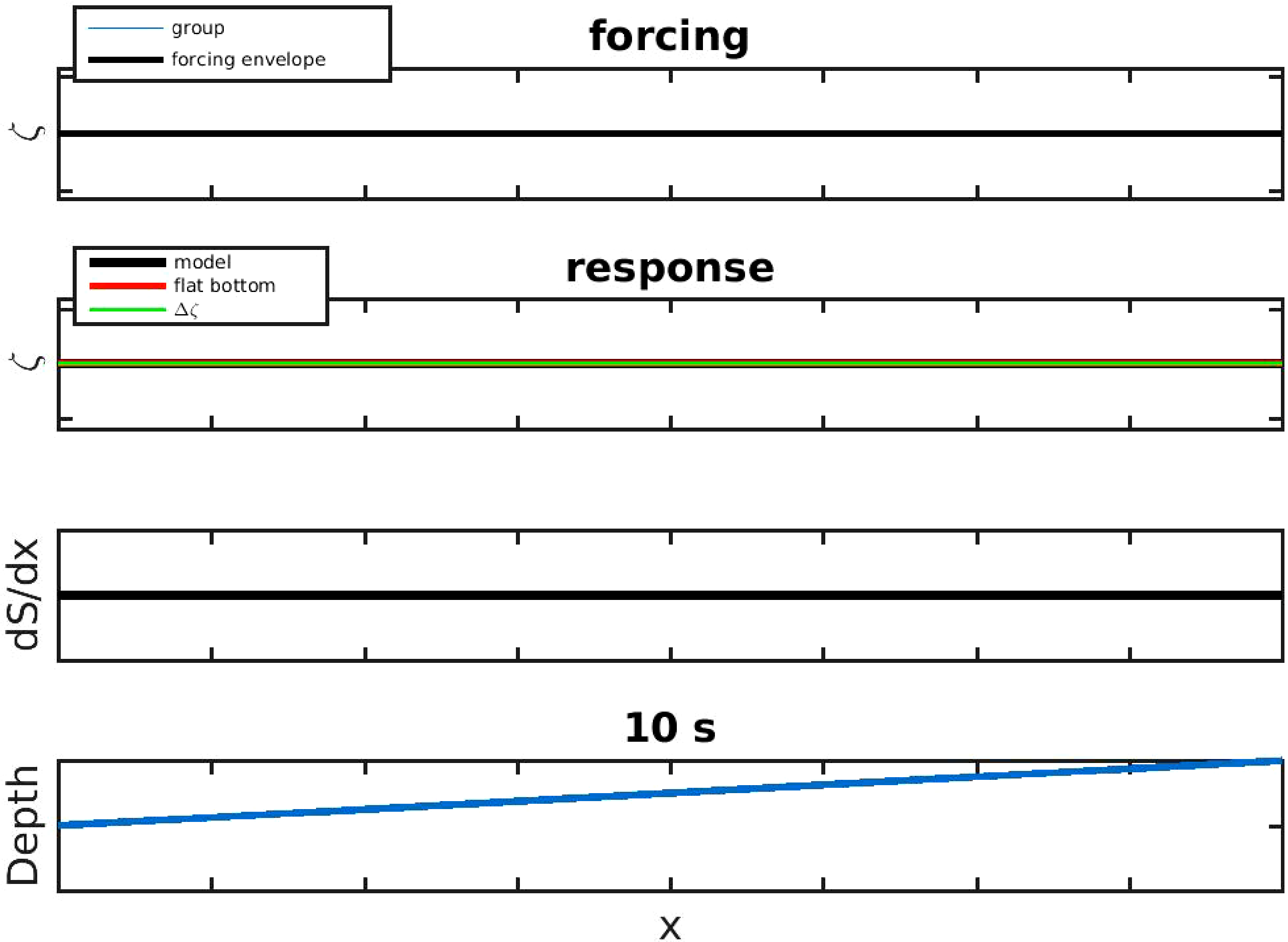
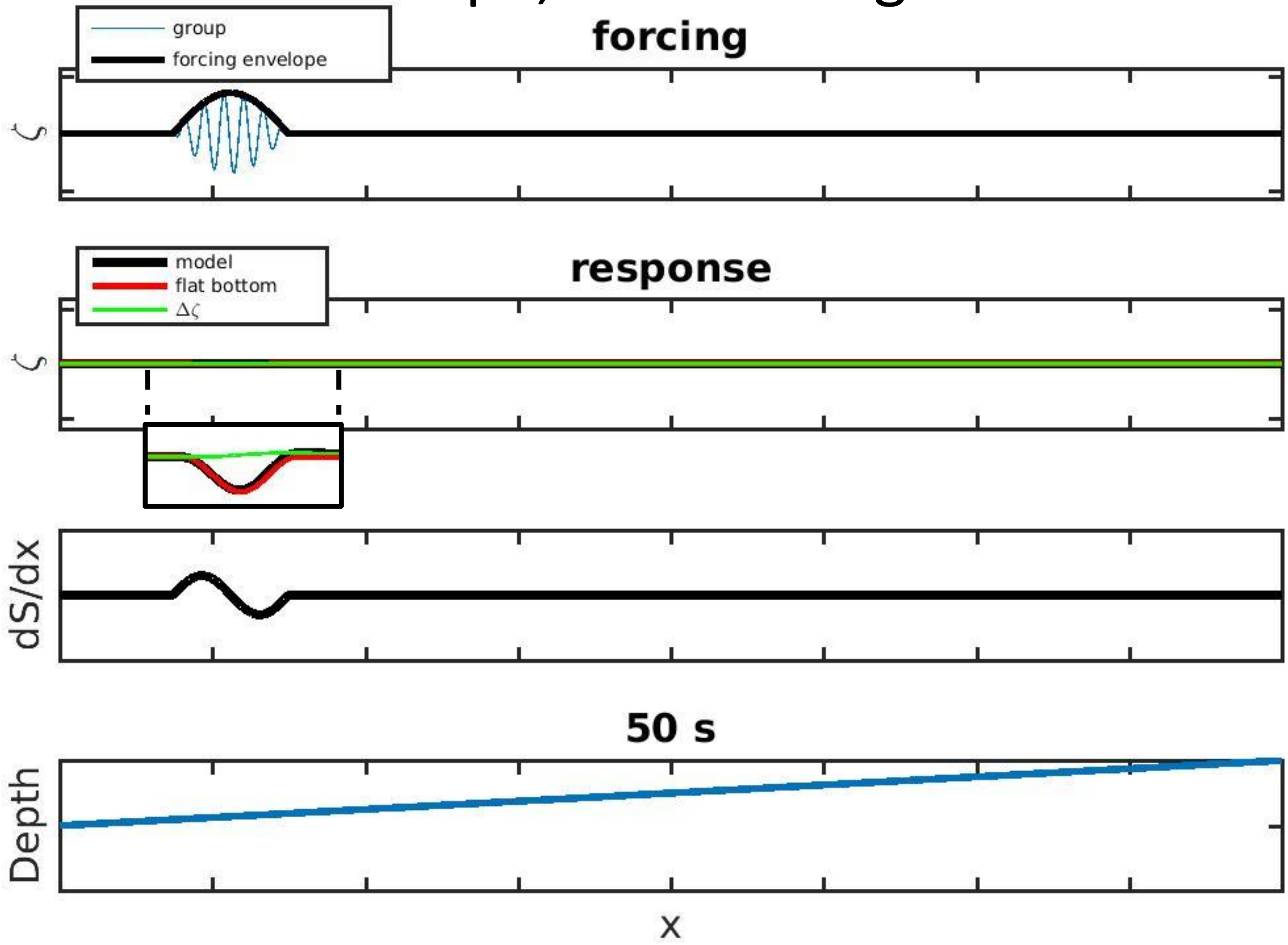
Model run

Slope, no breaking



Model run

Slope, no breaking



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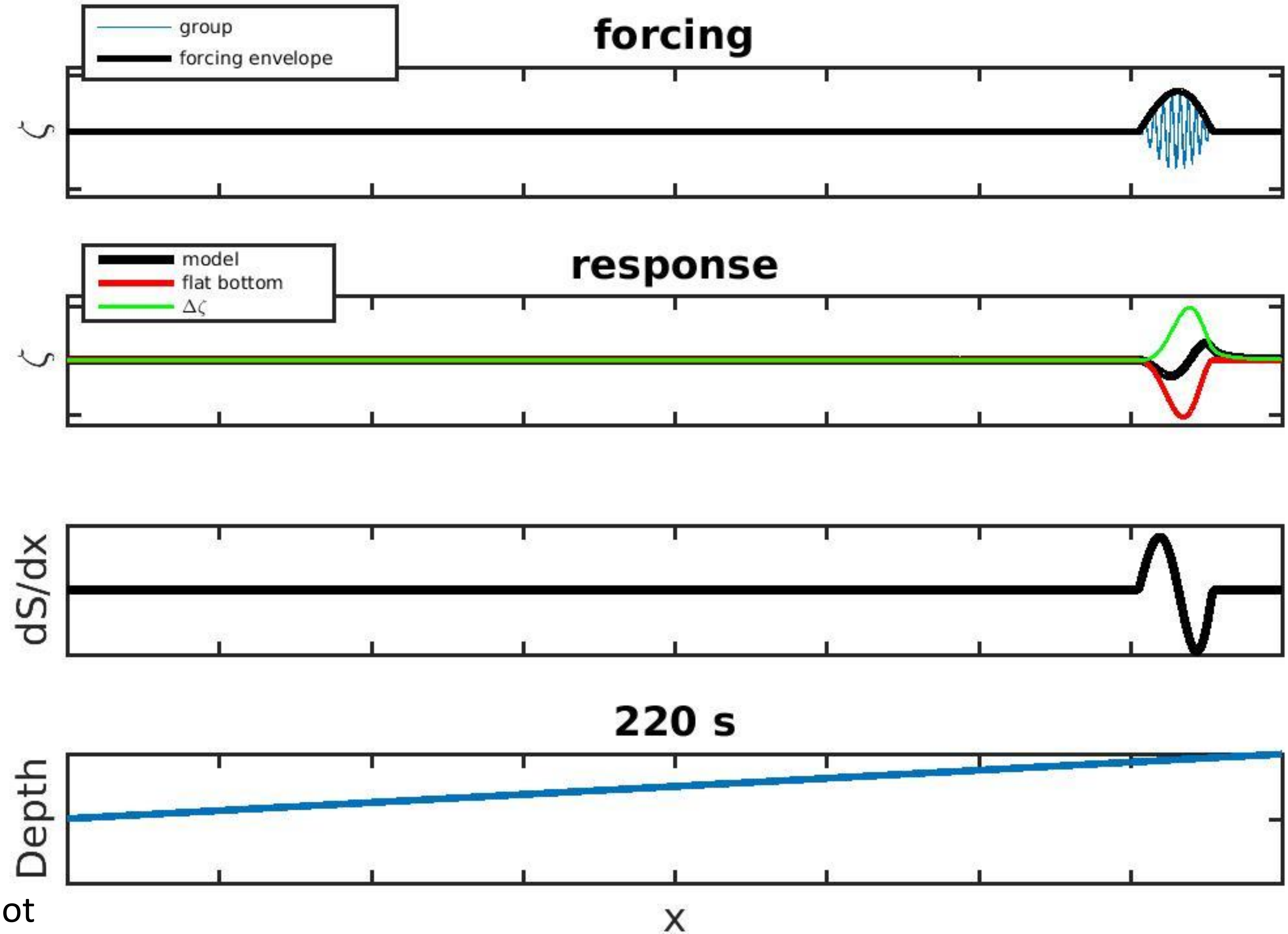
Model run

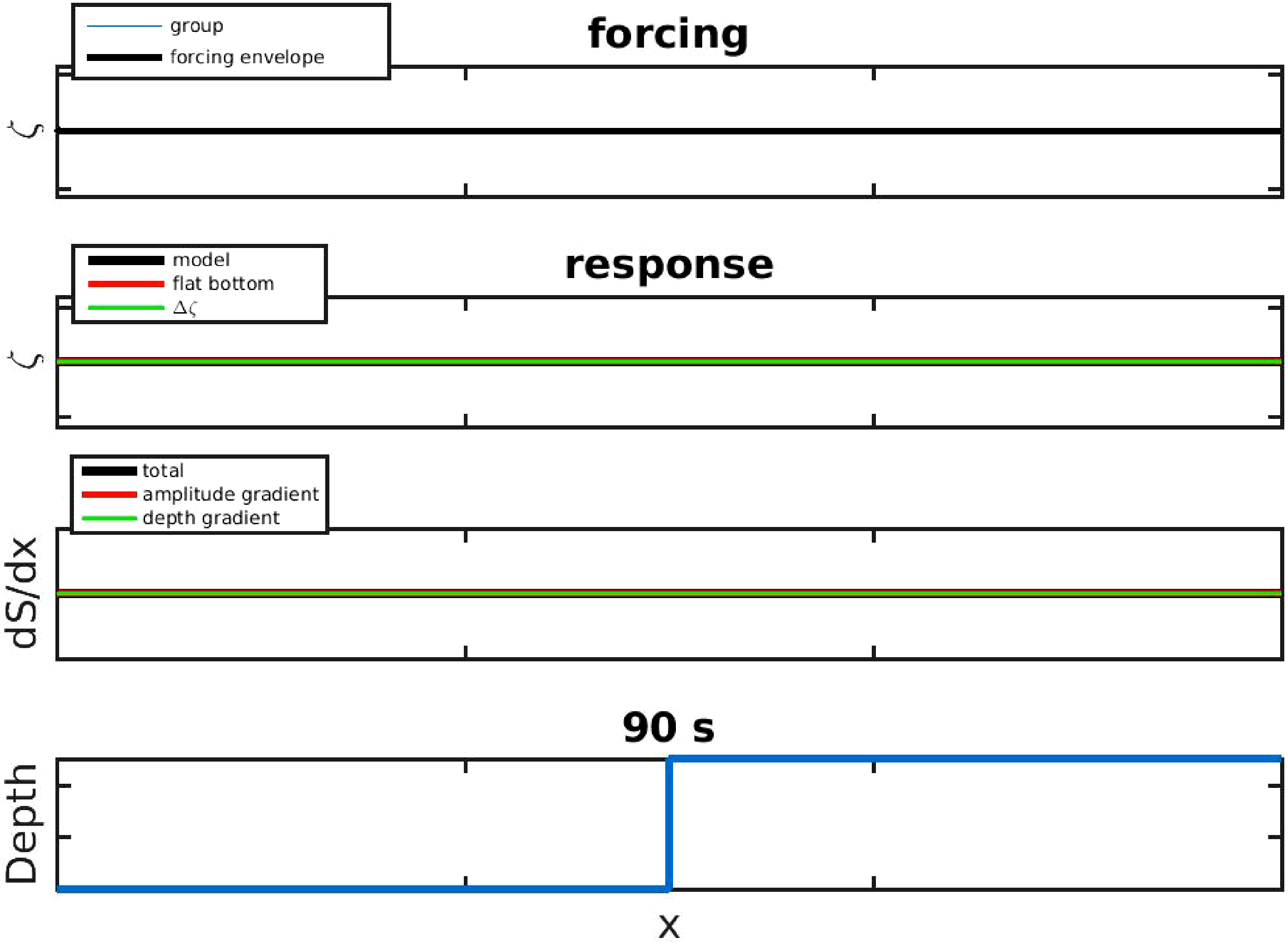
Slope, no breaking



snapshot

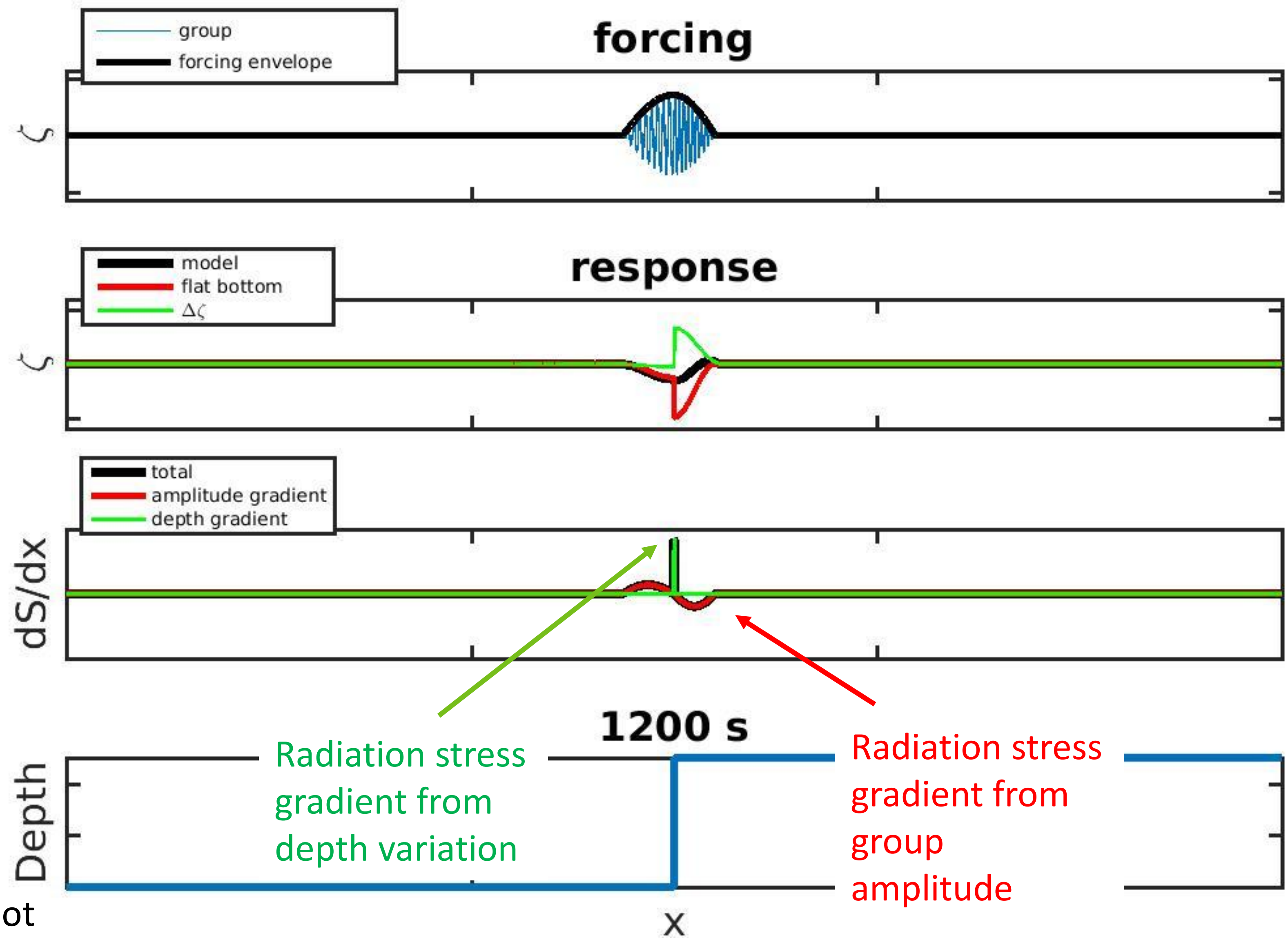
Model run

Single step



Model run

Single step



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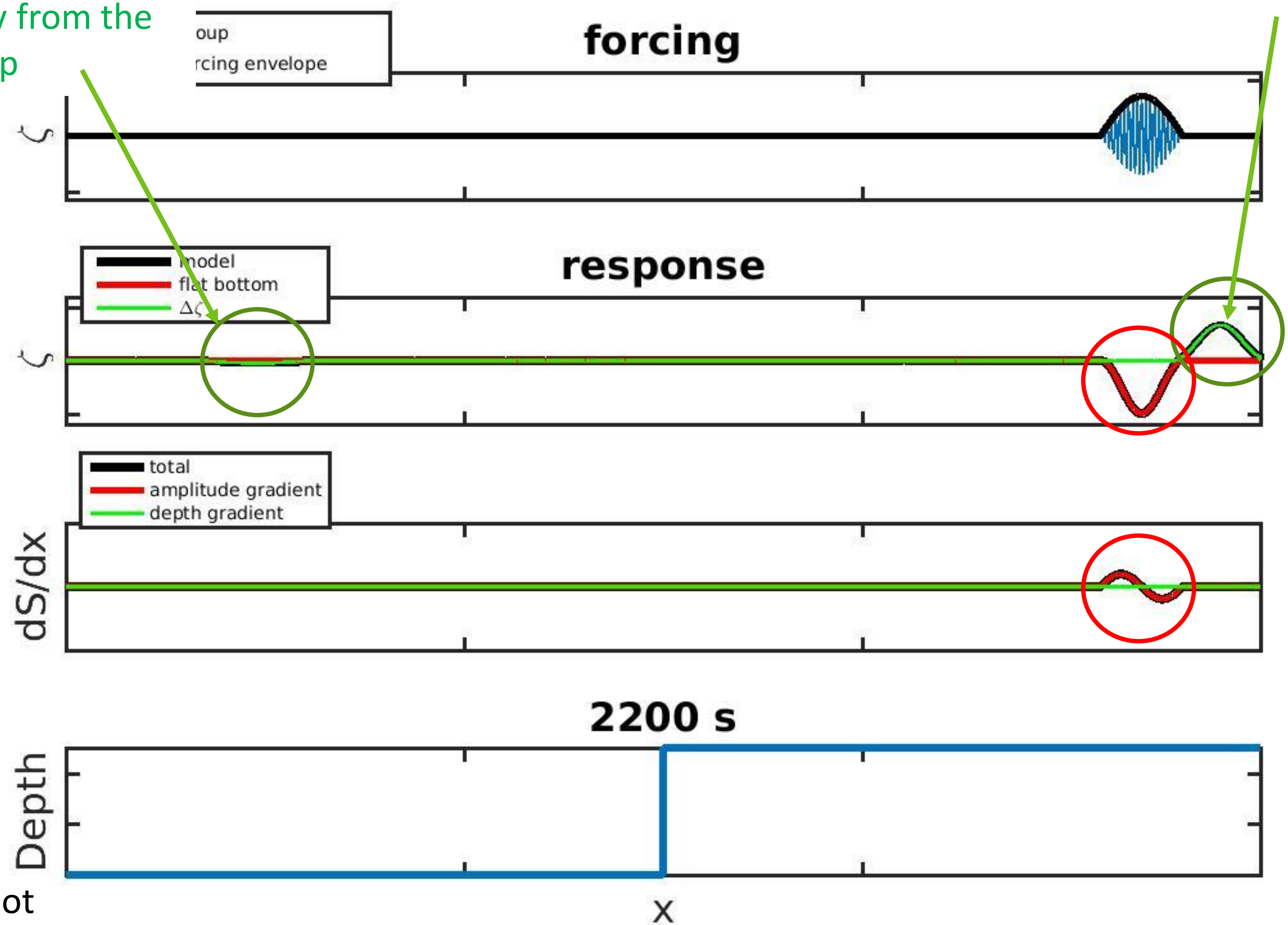
Model run

Single step

Outgoing Free Long Wave Small and propagating away from the group

Incoming Free Long Wave



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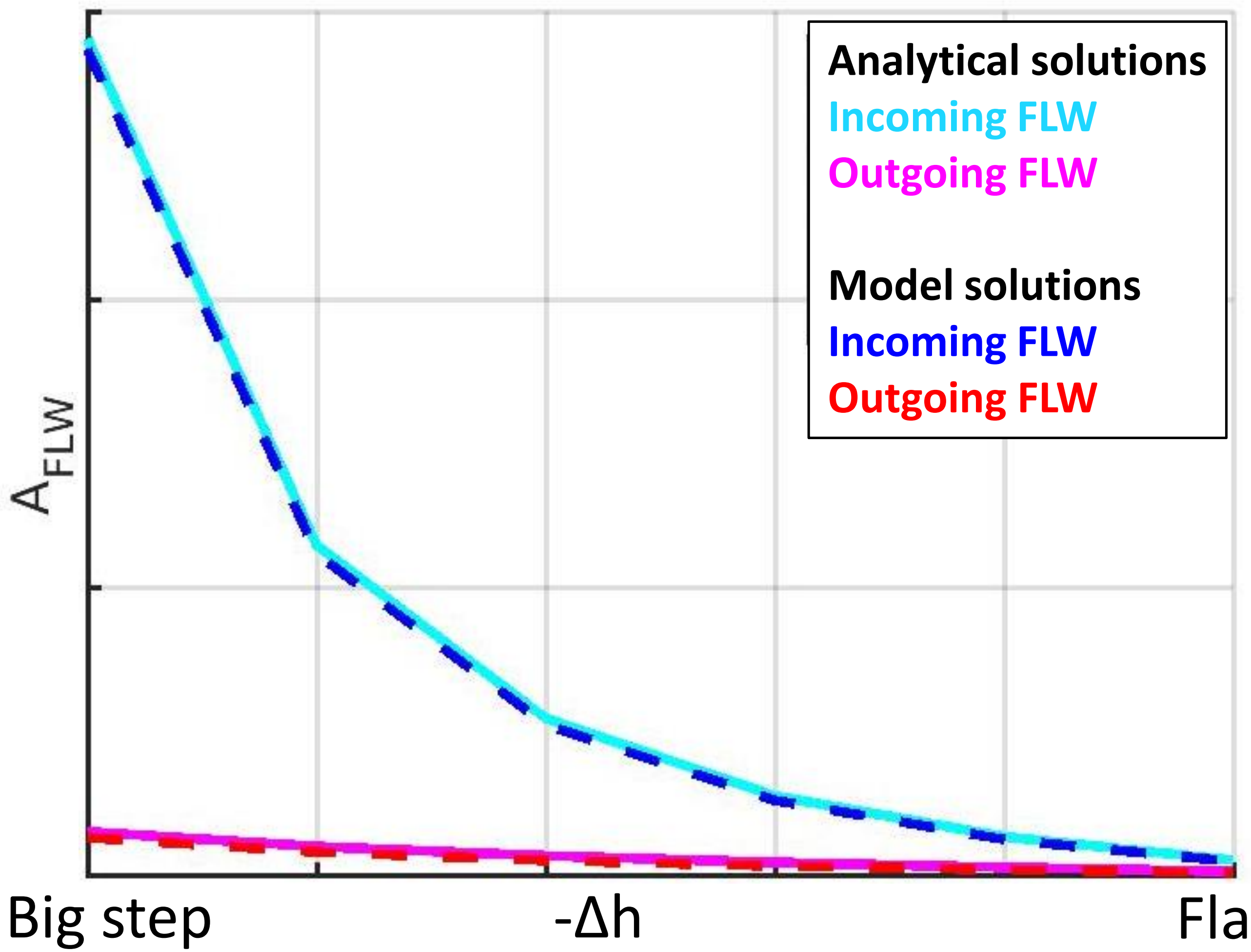
Analytical solution

Single step

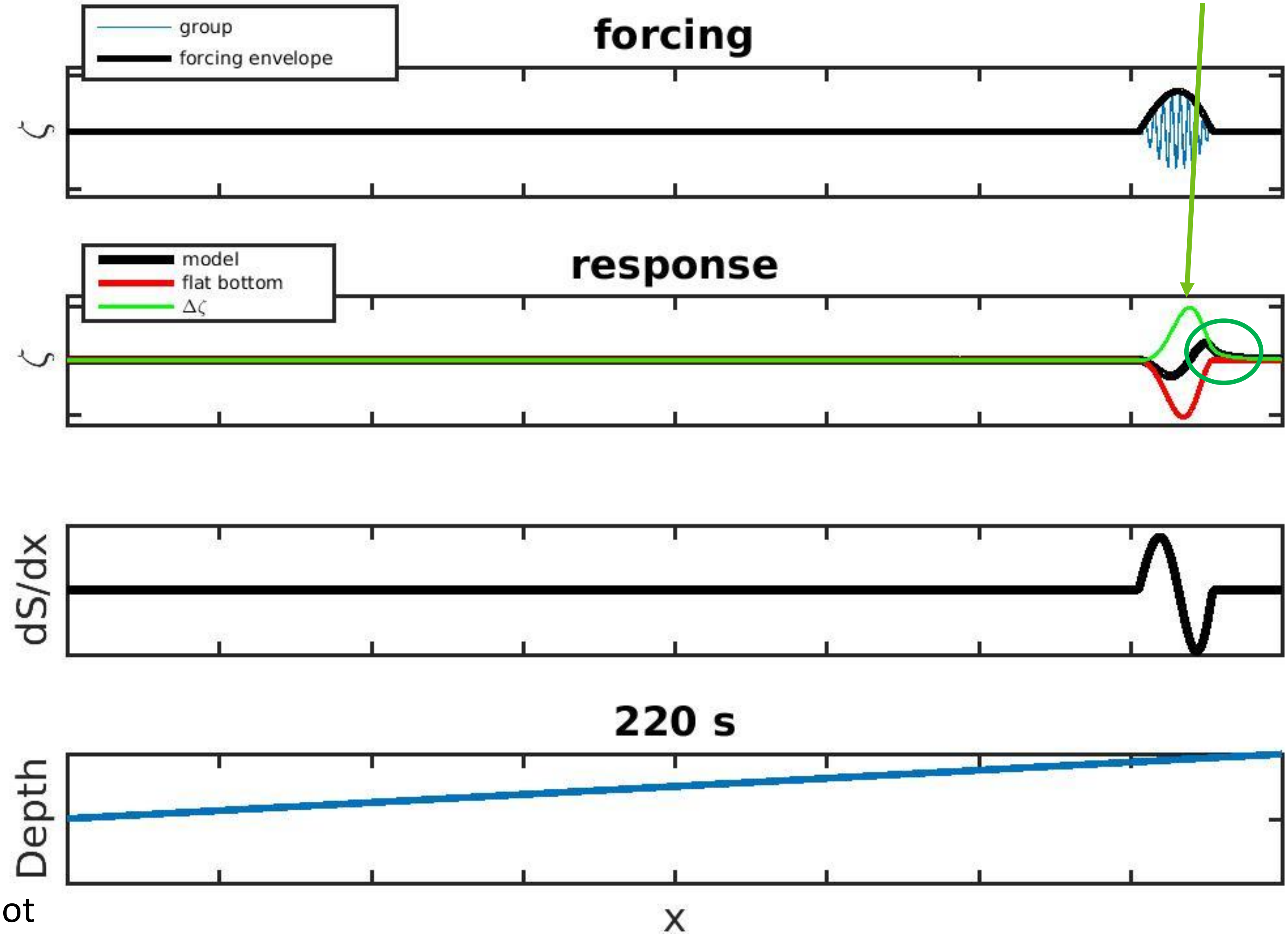
Amplitude of free long waves (FLW): incoming and outgoing



Model run

Back to slope

Combination of
lagging
Incoming Free
Long Waves



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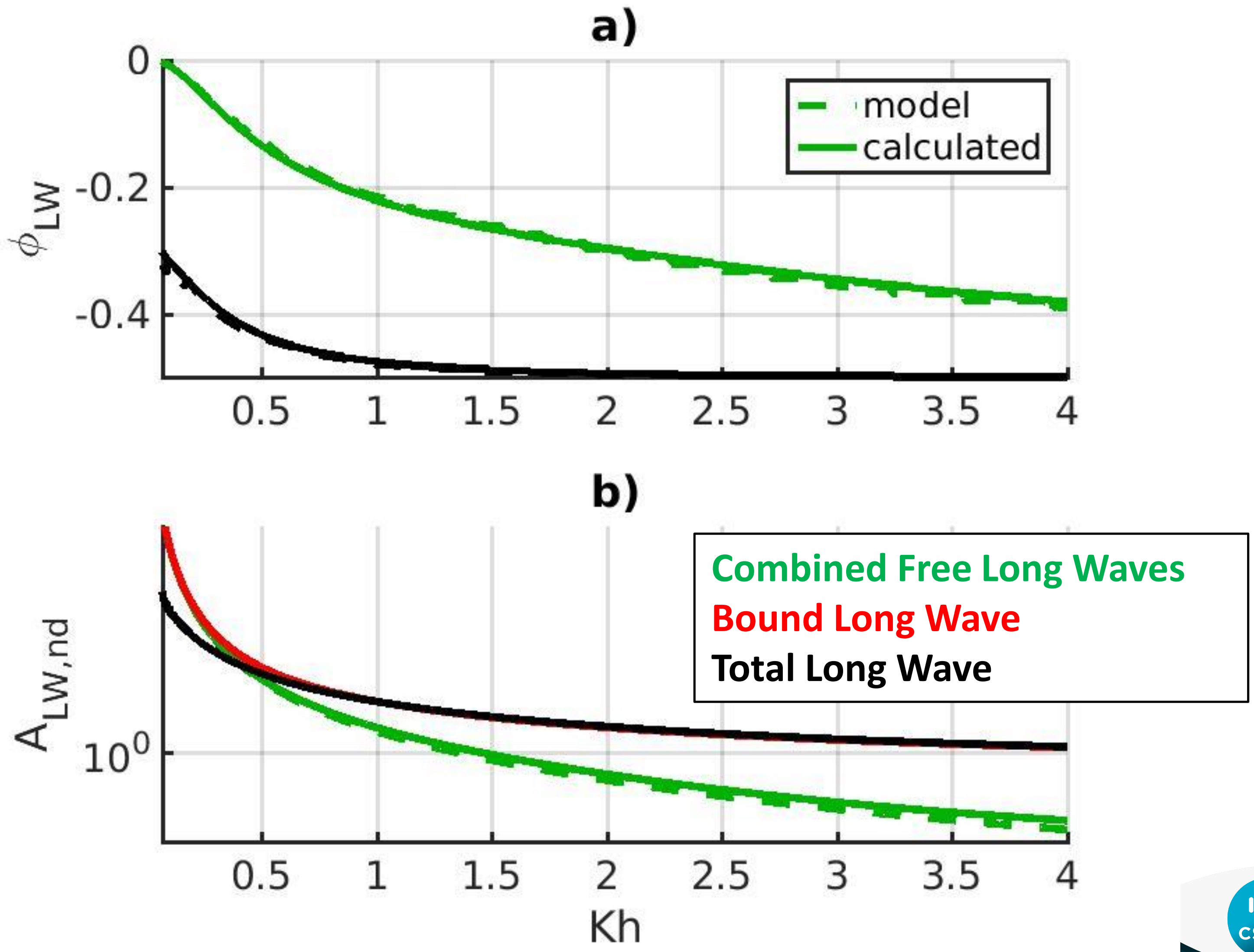
Analytical solution

Slope

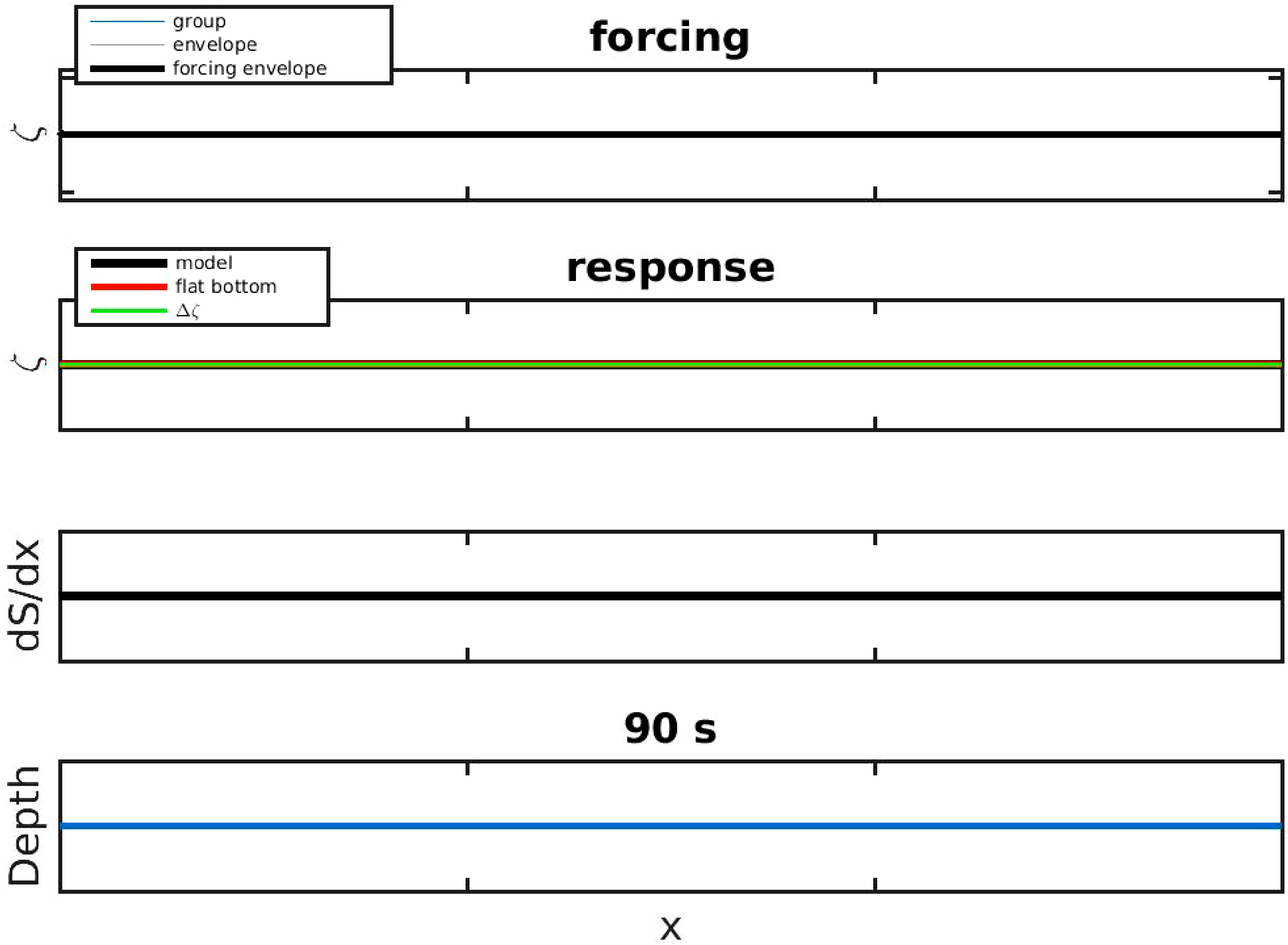
Phase

Amplitude



Model run

Flat, breaking



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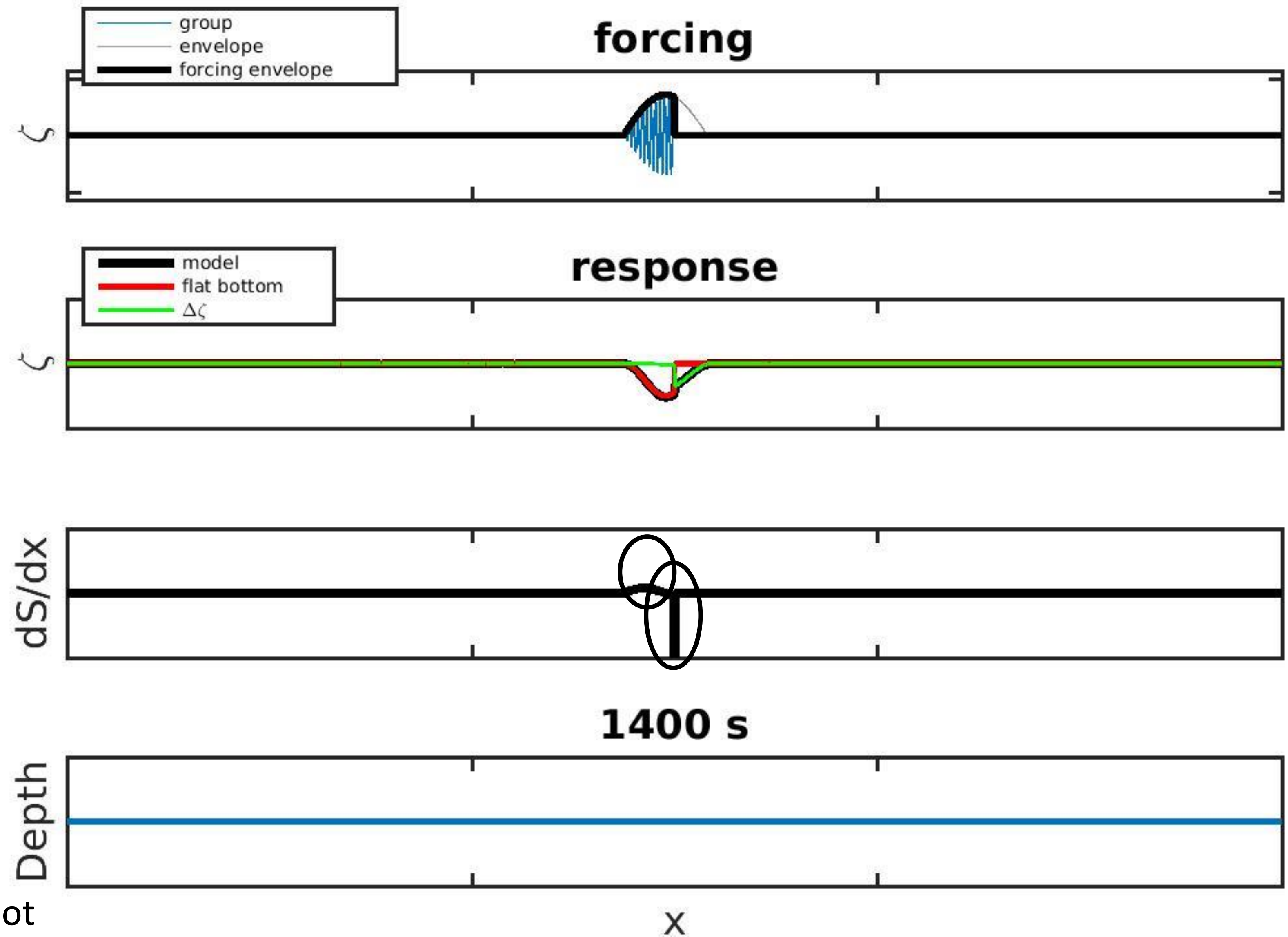

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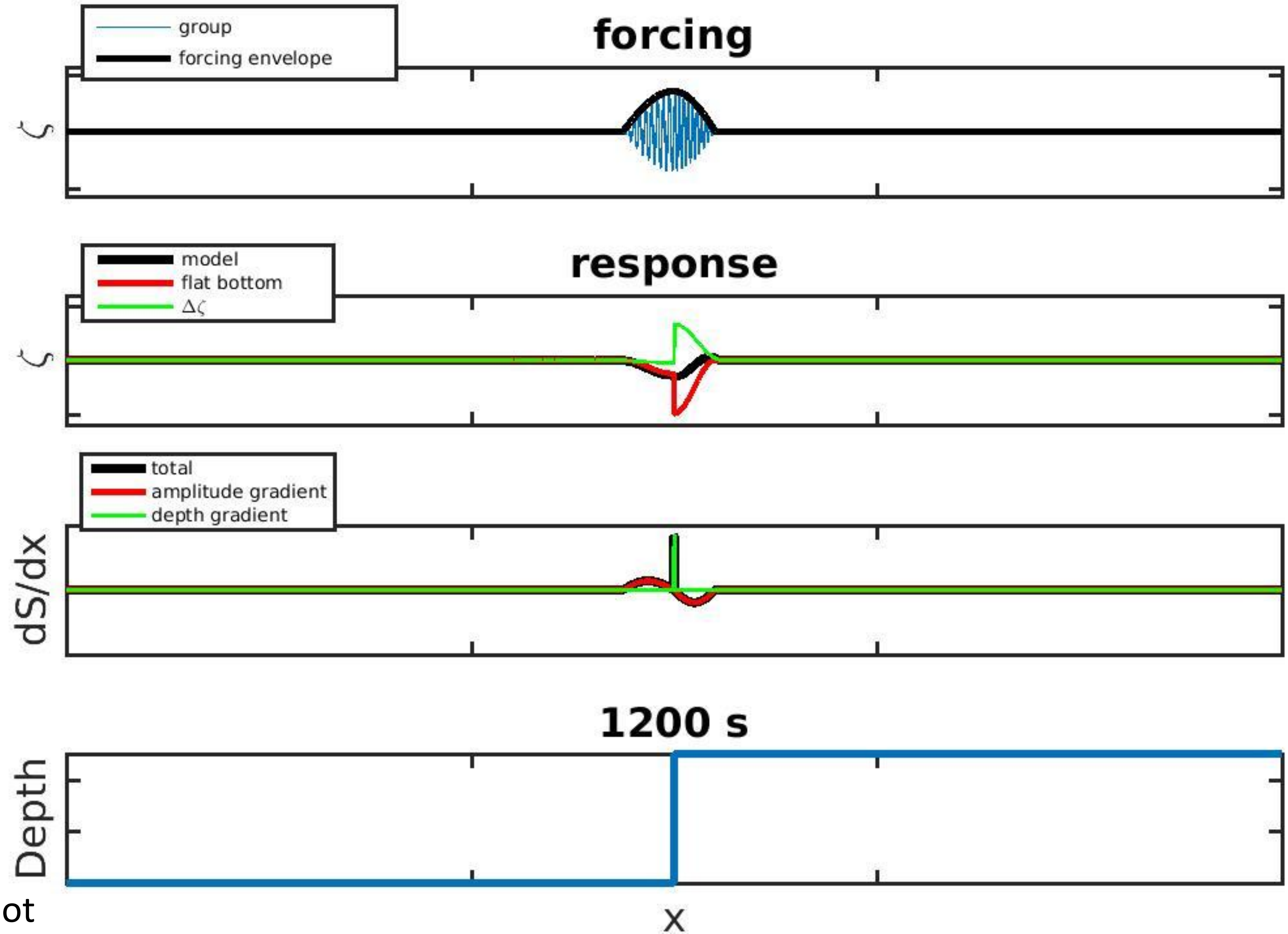
Model run

Back to single step



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Conclusions

Simple model

- Visualise the processes.
- Base to develop solutions.
- Can be forced with measured short-wave amplitude.
- Any bathymetry profile.

Solutions which explain observations.

Conclusions

Understanding

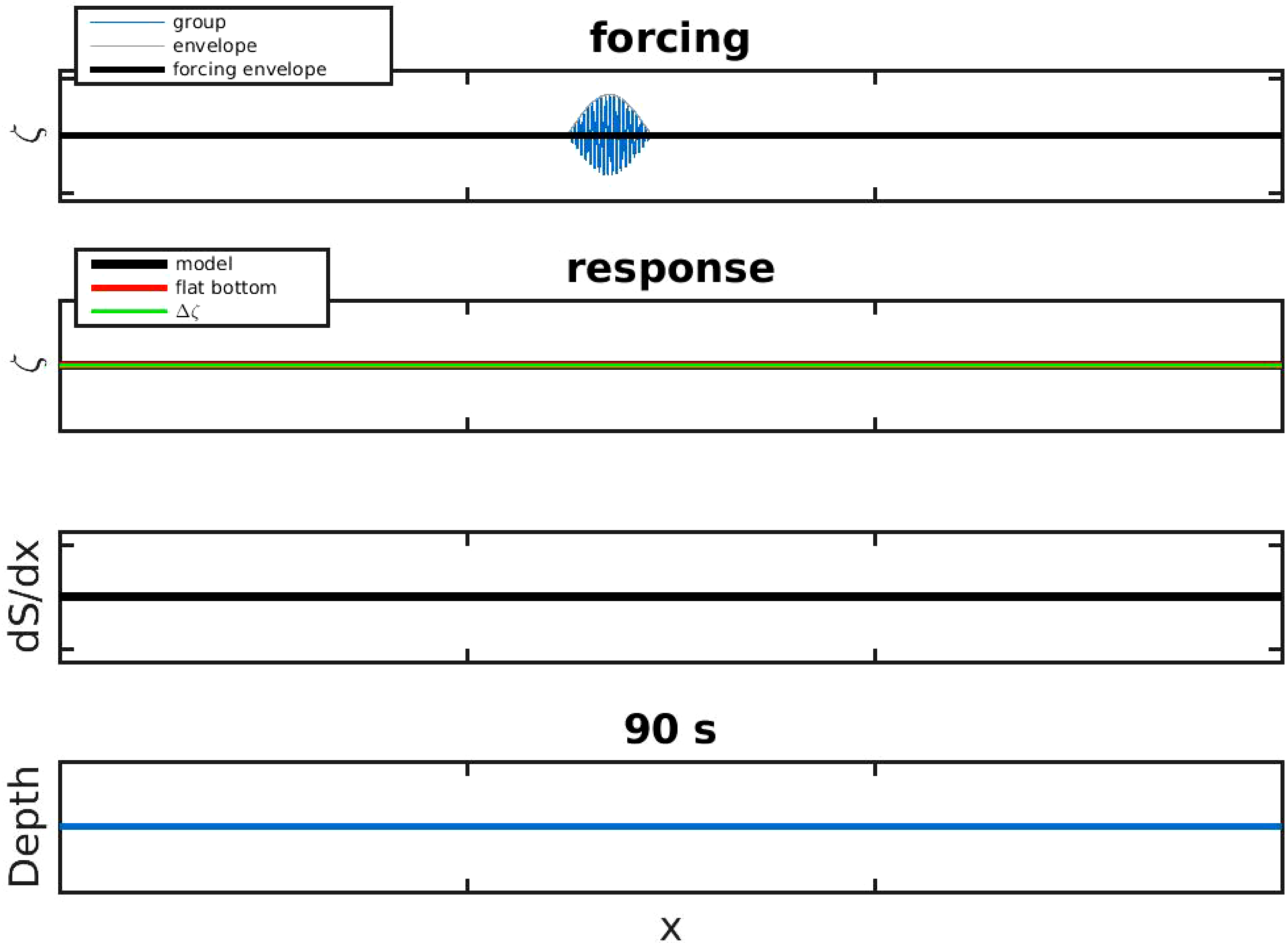
- Role of the radiation stress gradients.
- Radiation stress gradients caused by short-wave group amplitude gradients or depth gradients.
- Similarity between free wave generation via breakpoint forcing and depth variation.
- Co-dependence between breakpoint forcing and bound wave release

Important in the context when forecast is needed and numerical models are efficient but time consuming.

Thanks

Model run

Flat, breaking, breakpoint forcing only



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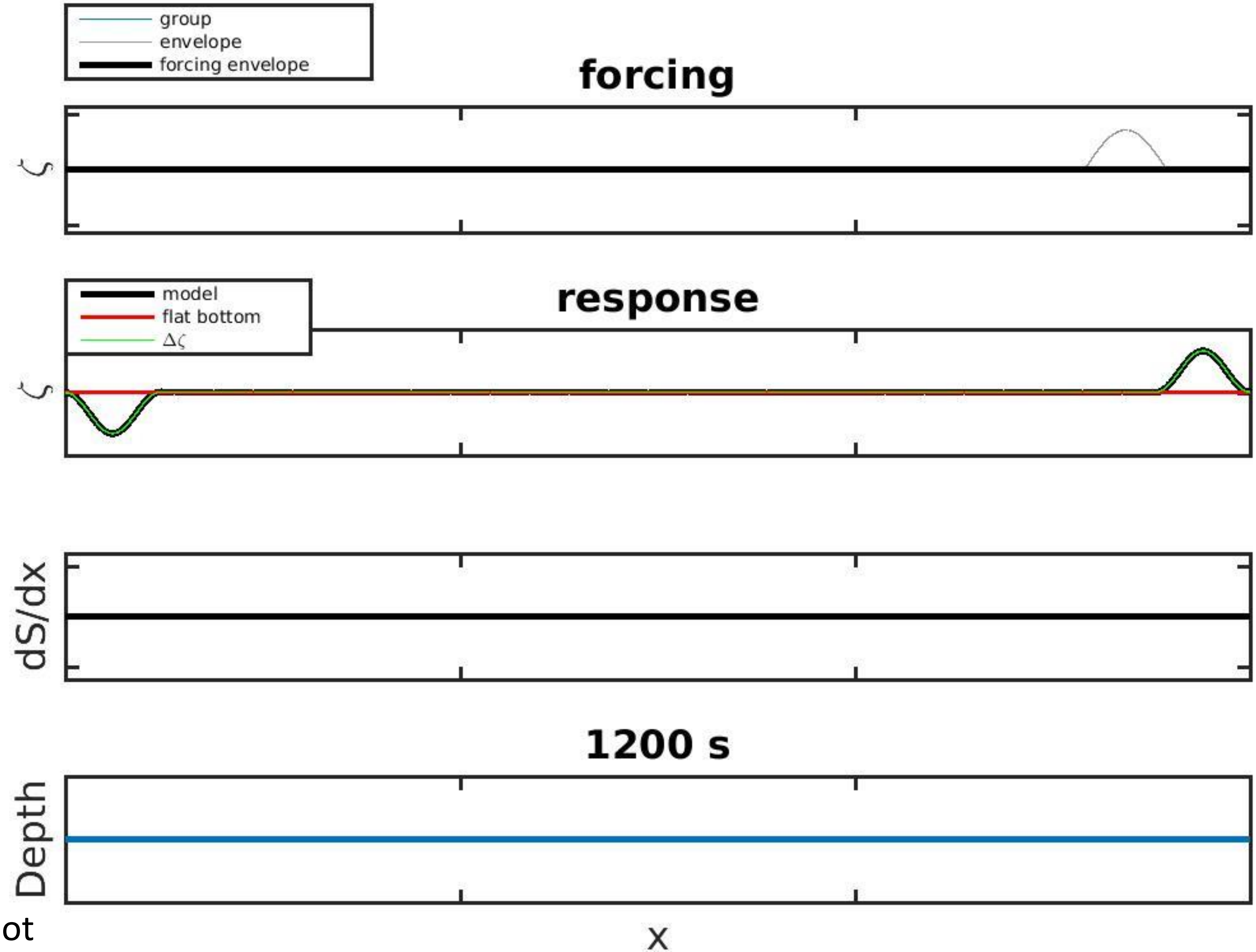
Flat, breaking, breakpoint forcing only



snapshot

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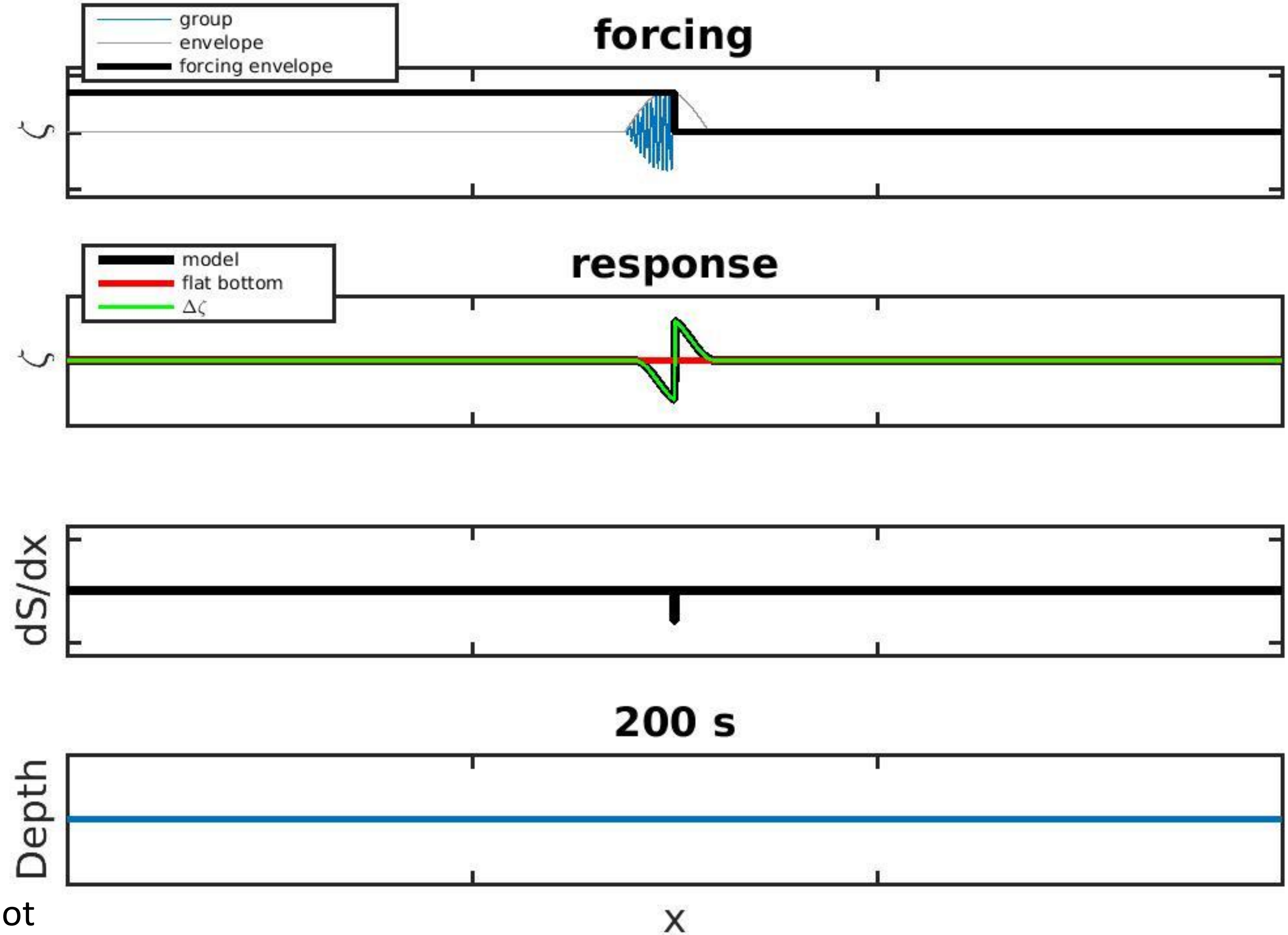
Flat, breaking, breakpoint forcing only



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