

Comparison of 2-D and 3-D finite-difference simulations for infrasound propagation in heterogeneous atmospheres

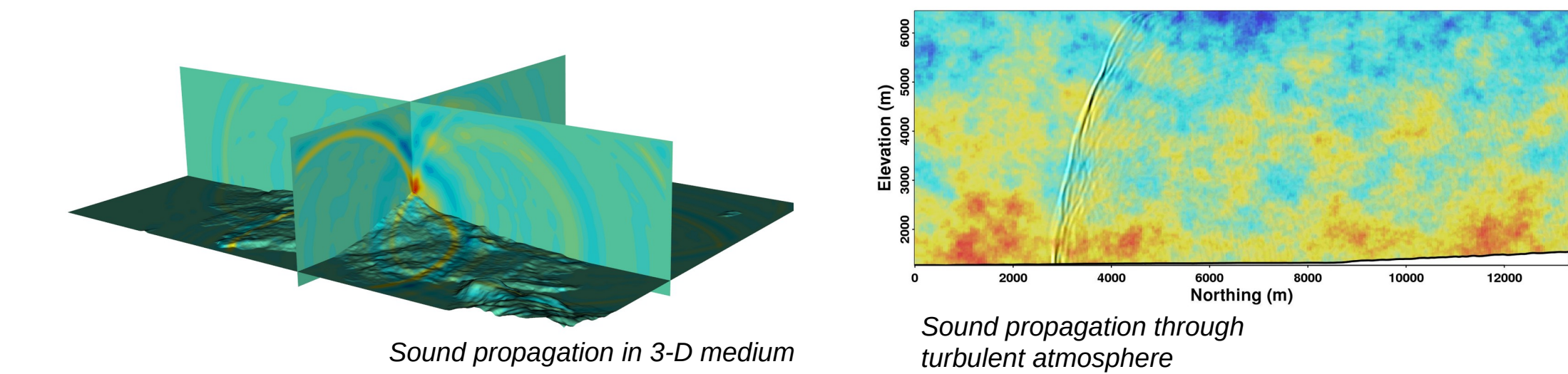
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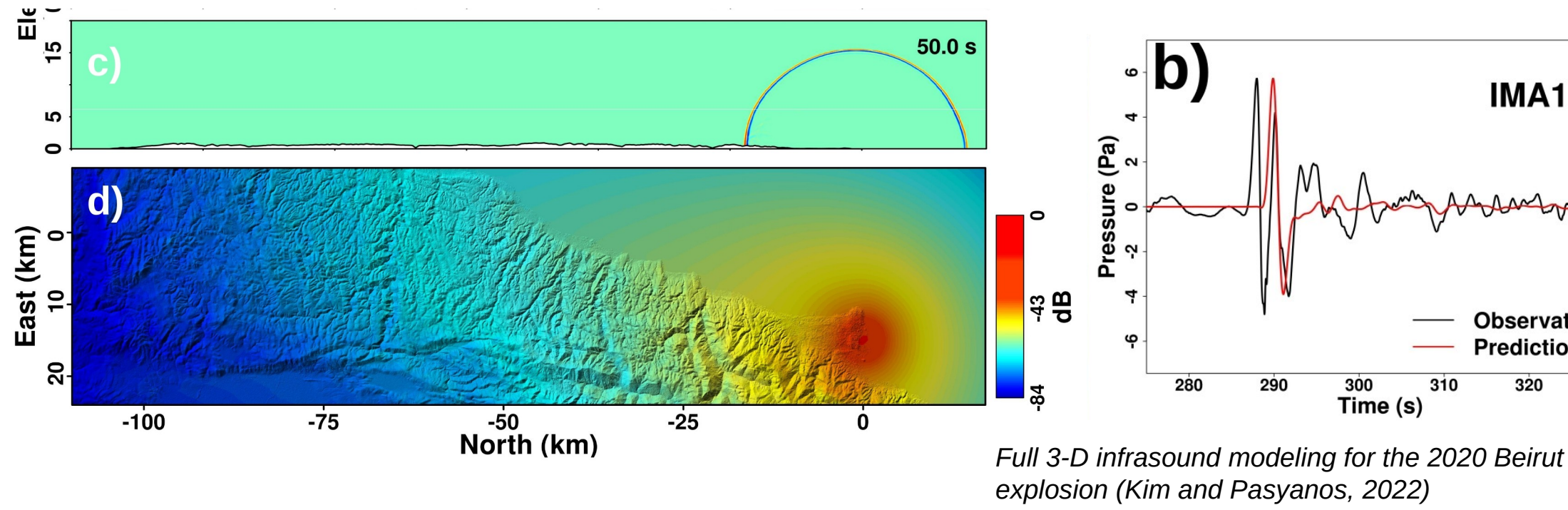


Motivation

- Full 3-D finite-difference modeling is widely used for infrasound propagation simulations including complex topography and atmospheric conditions



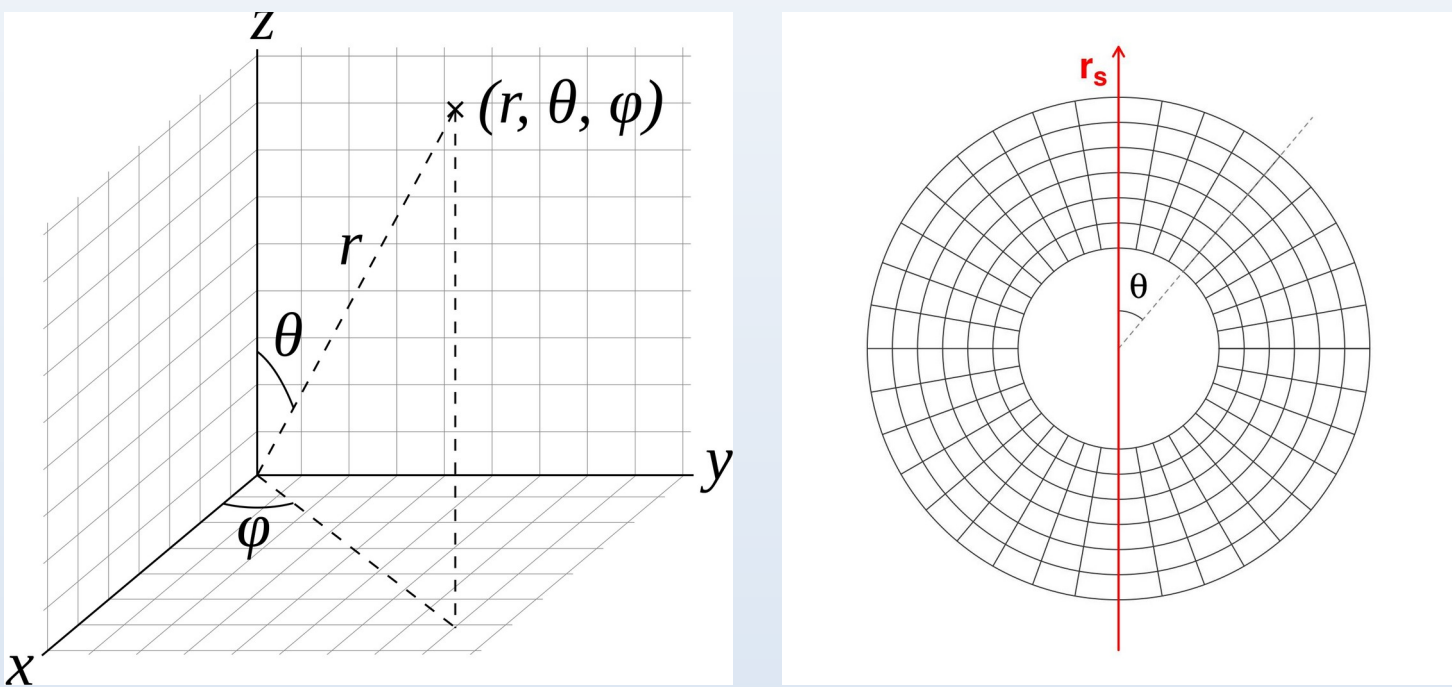
- With appropriate weather models, 3-D simulations can provide accurate amplitude prediction for atmospheric infrasound, allowing for accurate source inversion (e.g. explosion yield estimation, Kim and Pasyanos, GRL 2022)



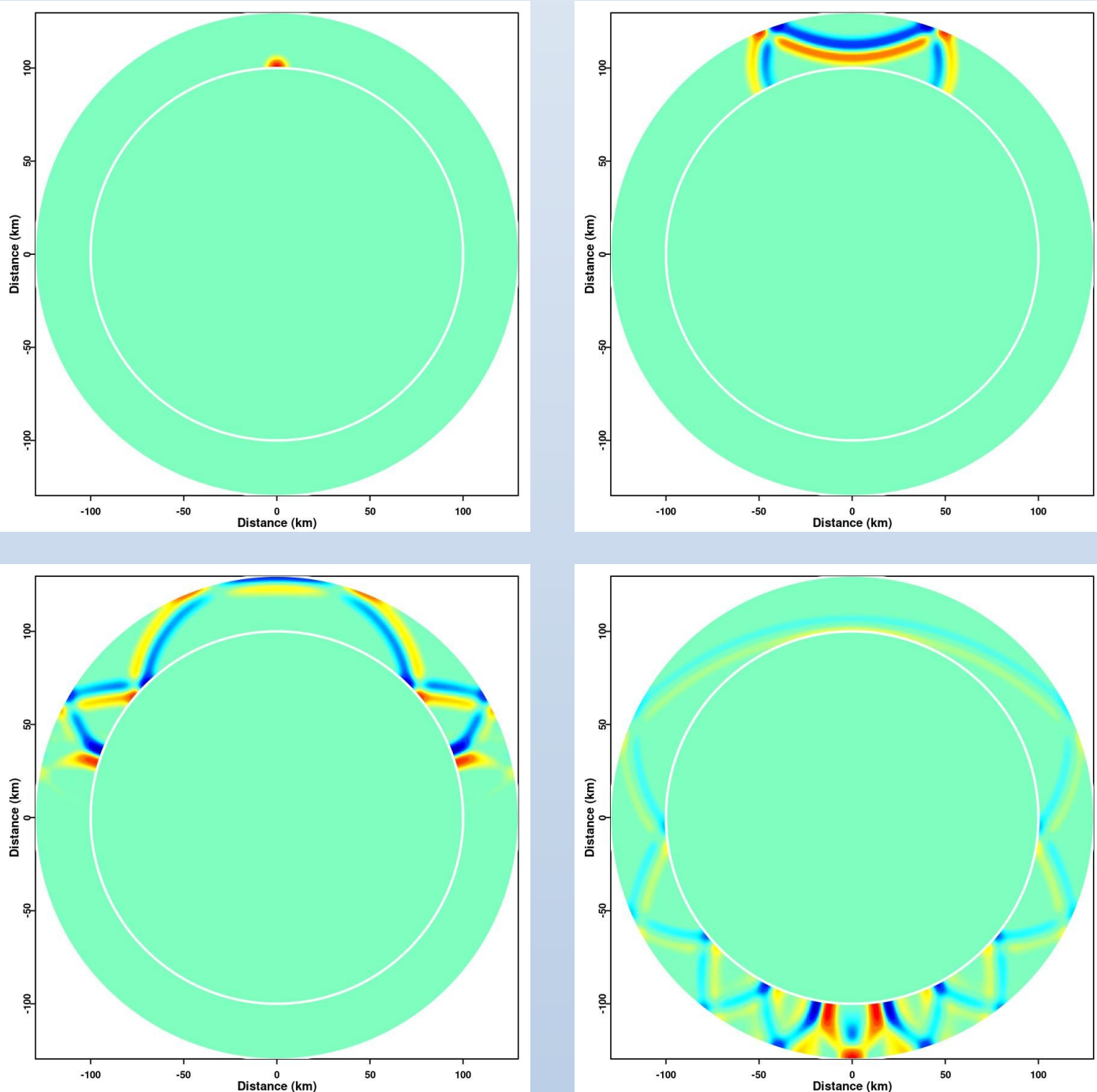
- However, 3-D modelings require large computational resources and computation time which limits its application to long-range infrasound propagation.

2-D Finite-Difference Simulations

- 2-D finite-difference code development for infrasound propagation in the atmosphere
- Linearized Euler Equation for the governing equation
- A spherical coordinate with an axial symmetry: 3-d geometric spreading simulated by 2-D



- Includes the Earth's curvature for long-range propagation



Comparison of 2-D and 3-D Simulations

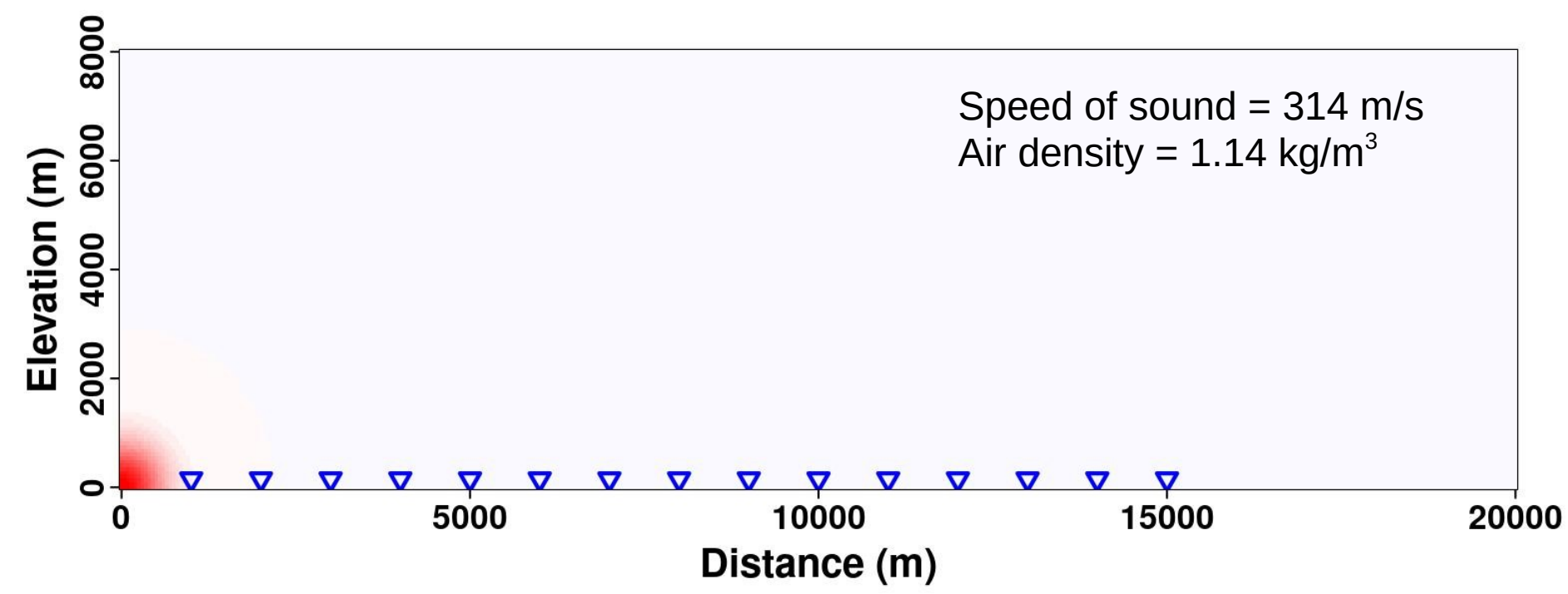
- The capability and limitation of 2-D modeling needs to be quantitatively evaluated by the comparison with a 3-D method (Petersson and Sjogreen, 2018).

Methodology

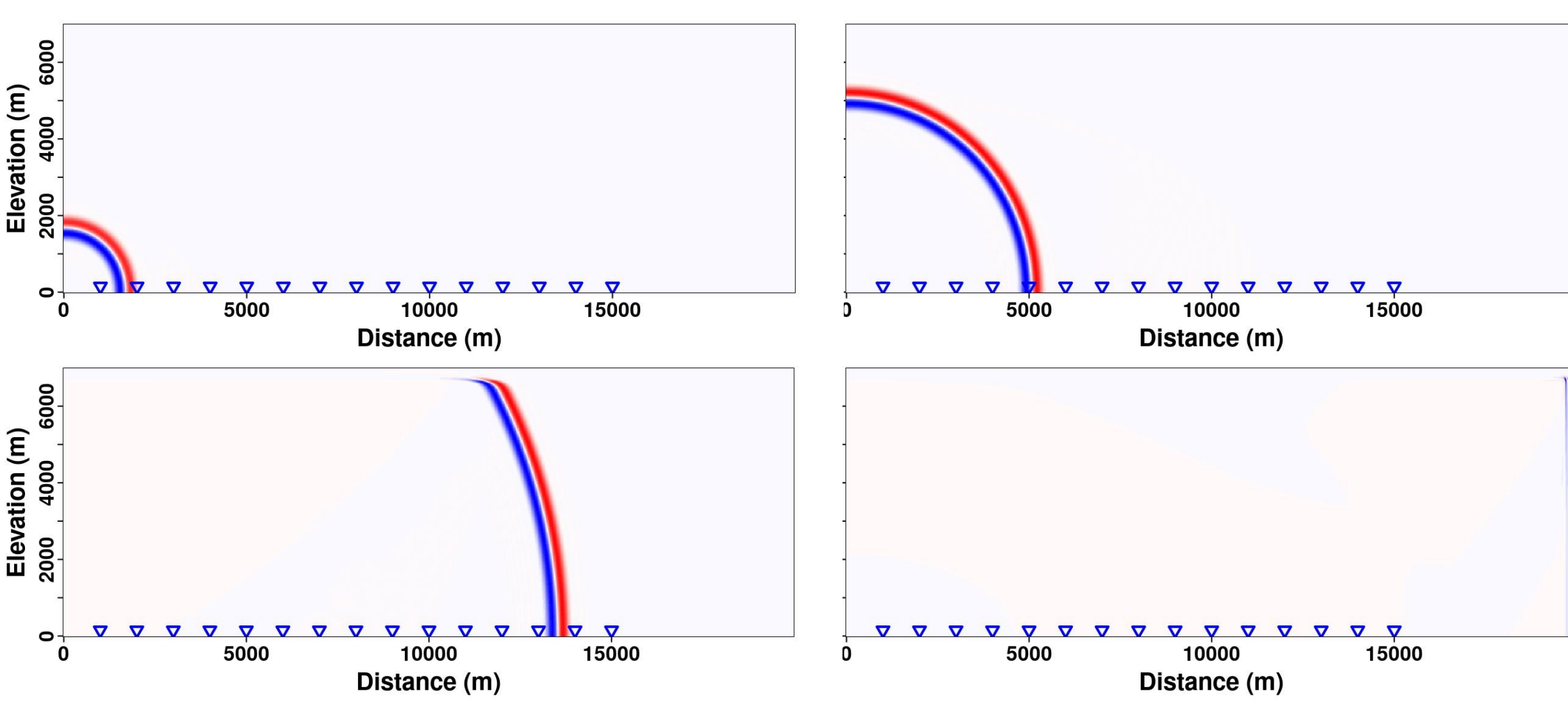
	3-D	2-D
Source Code	EIAc (Cartesian Coord.)	AC2Dr (Spherical Coord)
Spatial Discretization	6 th order finite difference	6 th order finite difference
Temporal Discretization	4 th order Runge Kutta	4 th order Runge Kutta
Absorbing Boundary	Super-grid	Super-grid

1-D case

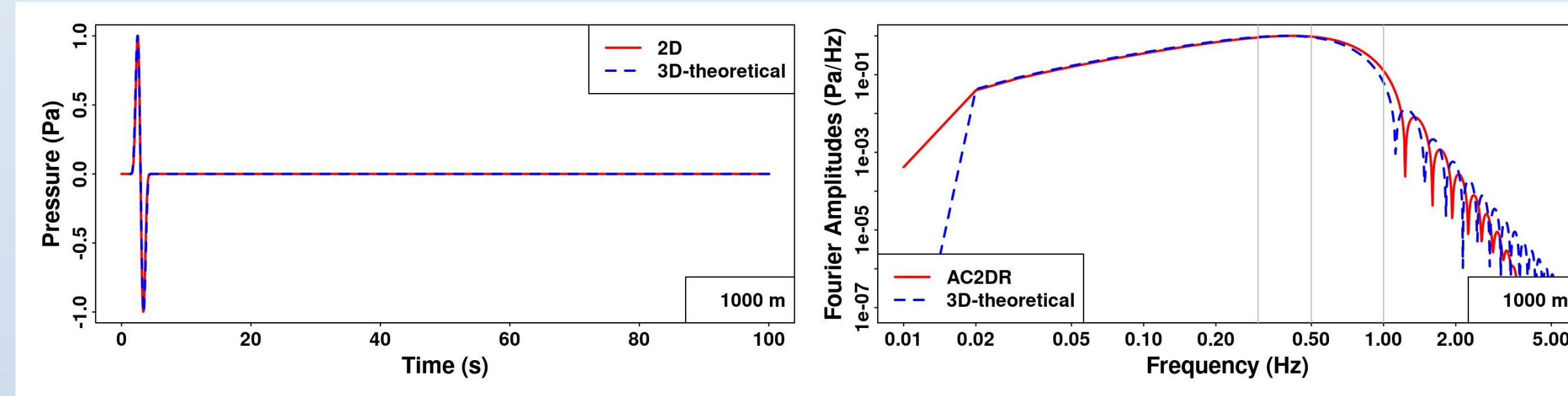
Homogeneous Medium without Wind



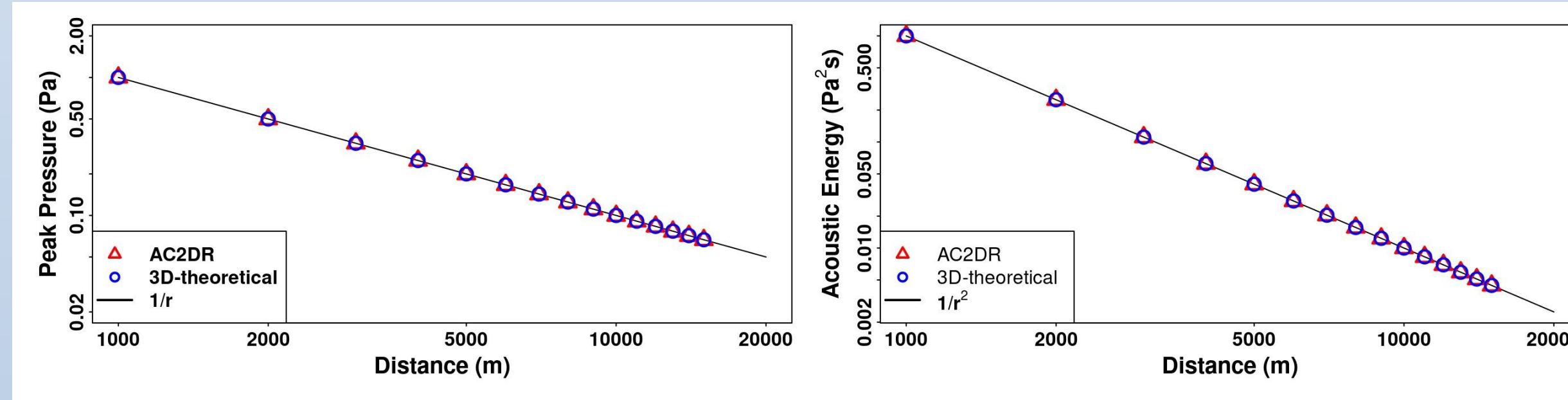
Source Characteristics	Shape	Peak Frequency	Corner Frequency
3-D (EIAc)	Gaussian (point)	0.5 Hz	1.0 Hz
2-D (AC2Dr)	Gaussian (initial field)	0.5 Hz	1.0 Hz



Wave propagation simulated by AC2Dr



Waveform simulated by AC2Dr at 1000 m

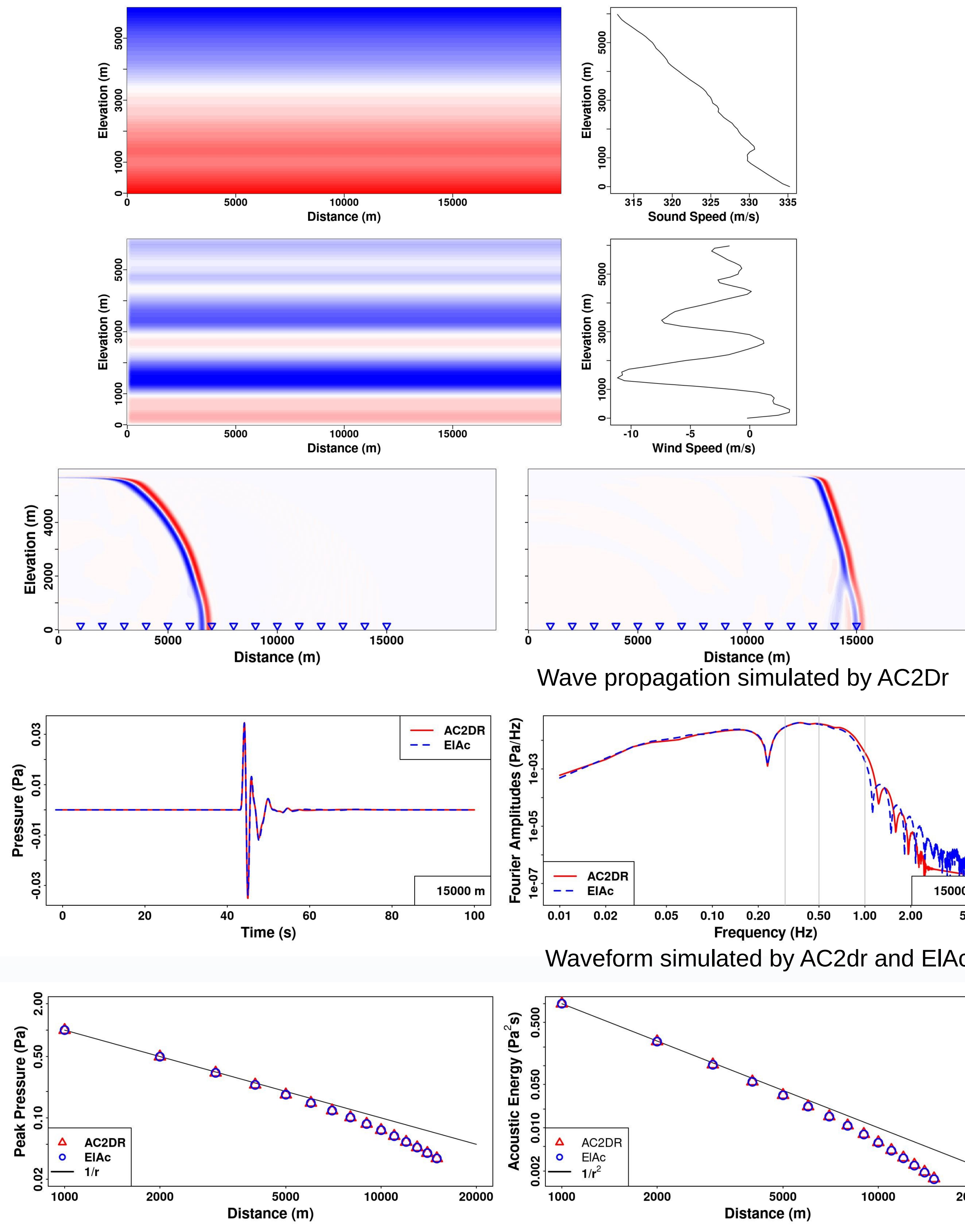


Peak amplitude and acoustic energy attenuation simulated by AC2Dr

1-D Case (contd.)

Range Independent

- Define range-independent sound speeds and horizontal winds for EIAc (3D) and AC2Dr (2D)

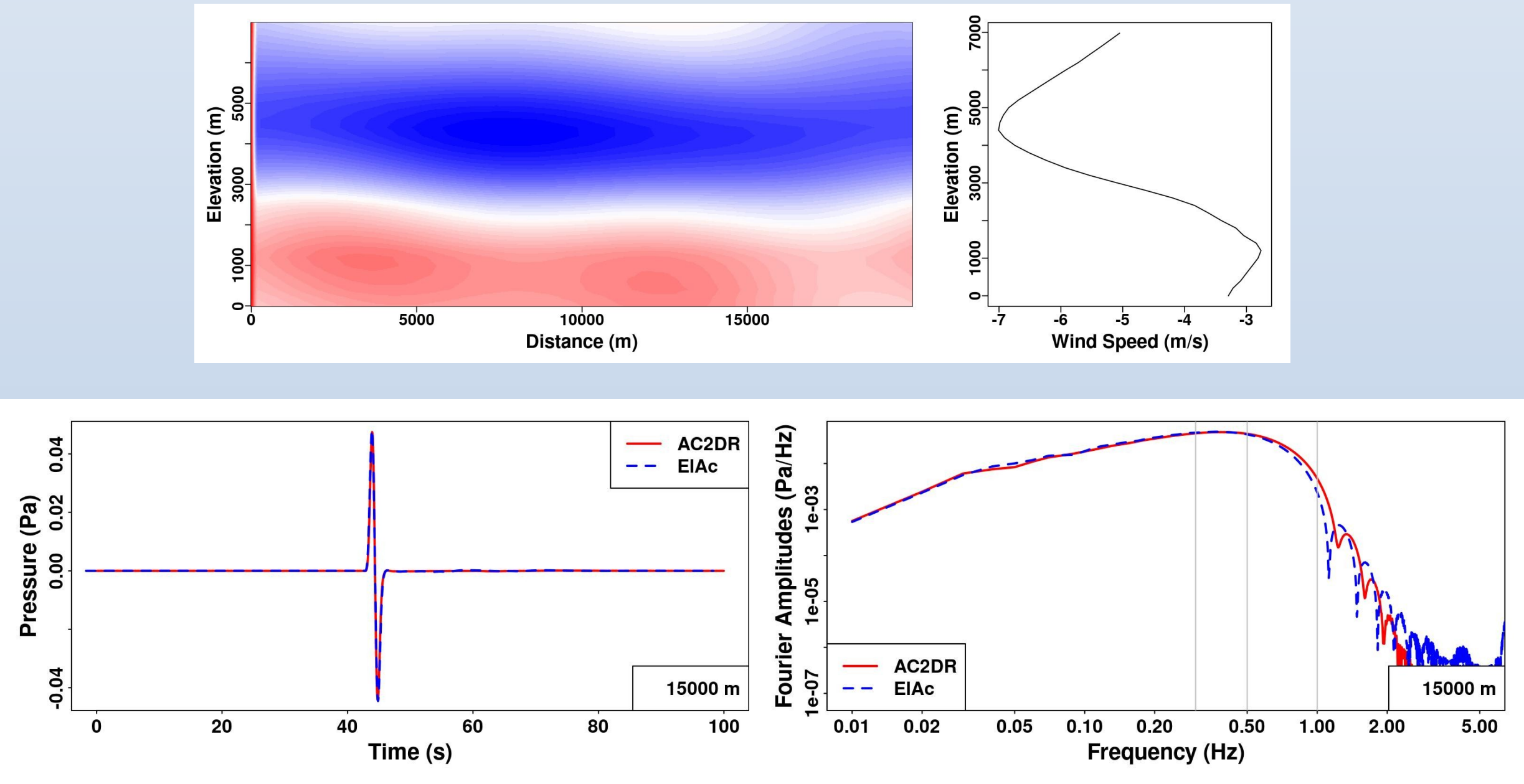


Amplitude and energy attenuation simulated by AC2dr and EIAc

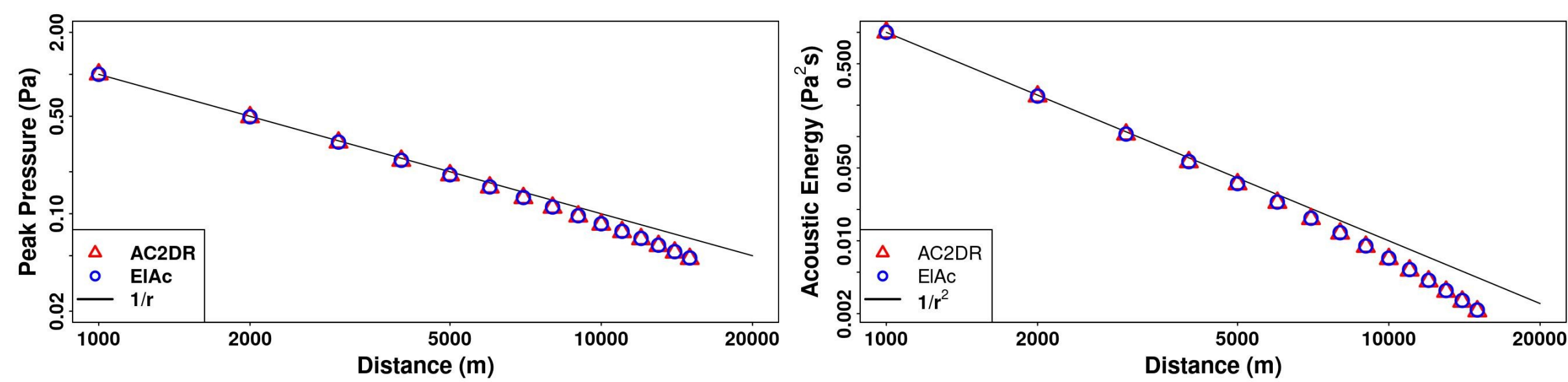
2-D Case: Range Dependent

Slowly Varying Field

- Use 1-D sound speed profile and 2-D range-dependent wind field for simulations
- The wind field is randomly perturbed with the characteristic length scale of 10 km

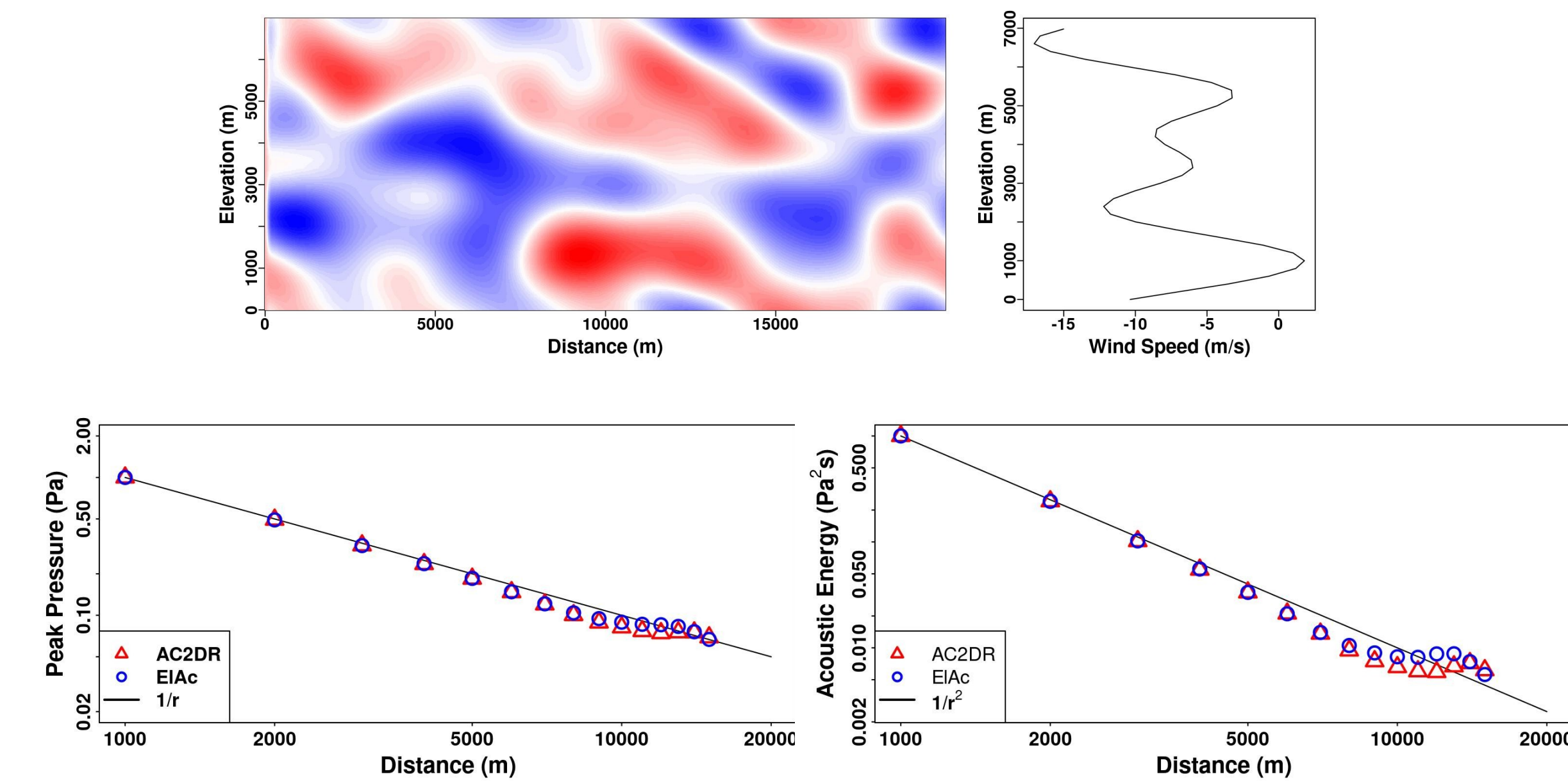


2-D Case (contd.)

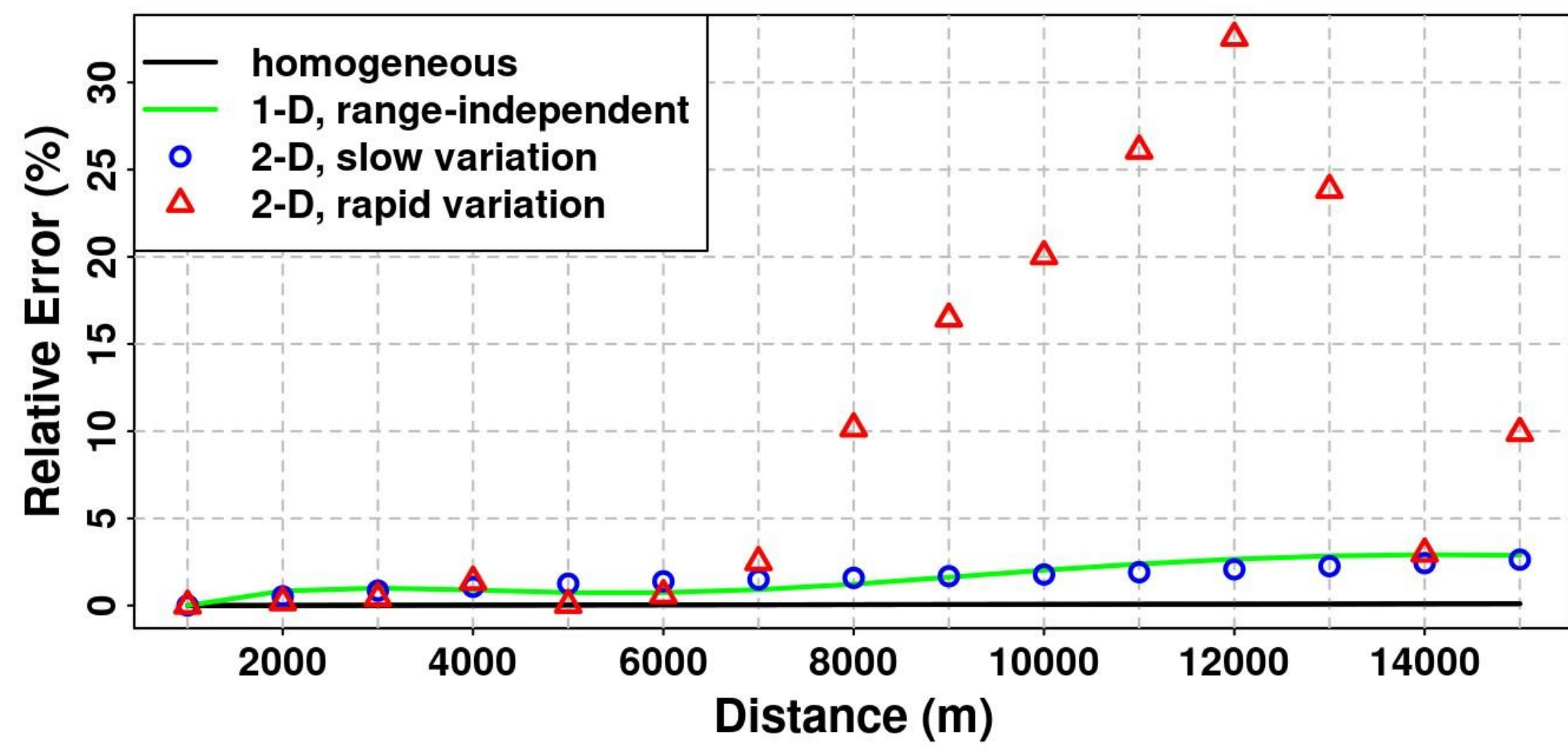


Rapidly Varying Field

- The wind field is randomly perturbed with the characteristic length scale of 2 km



Summary



- Relative errors between the acoustic energies calculated by EIAc and AC2dr are calculated with respect to the EIAc's results (3-D).
- 2-D simulation results show good agreement with the 3-D simulation (errors less than 5%) for the homogeneous, 1-D, and slowly varying 2-D materials.
- For the rapidly varying 2-D material, the 2-D simulation had an error up to 40% of the 3-D results. In this case, caution must be taken for quantitative approximation by 2-D.

References

Kim, K., & Pasyanos, M. E. Yield Estimation of the August 2020 Beirut Explosion by Using Physics-Based Propagation Simulations of Regional Infrasound. Geophysical Research Letters, e2022GL101118.

Petersson, N. A., & Sjögren, B. (2018). High order accurate finite difference modeling of seismic-acoustic wave propagation in a moving atmosphere and a heterogeneous earth model coupled across a realistic topography. Journal of Scientific Computing, 74(1), 290-323.

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