A model-based analysis of the reflection response retrieval from sparse sources in the Himalaya

26th IUGG Conference, Prague, June 30, 2015.

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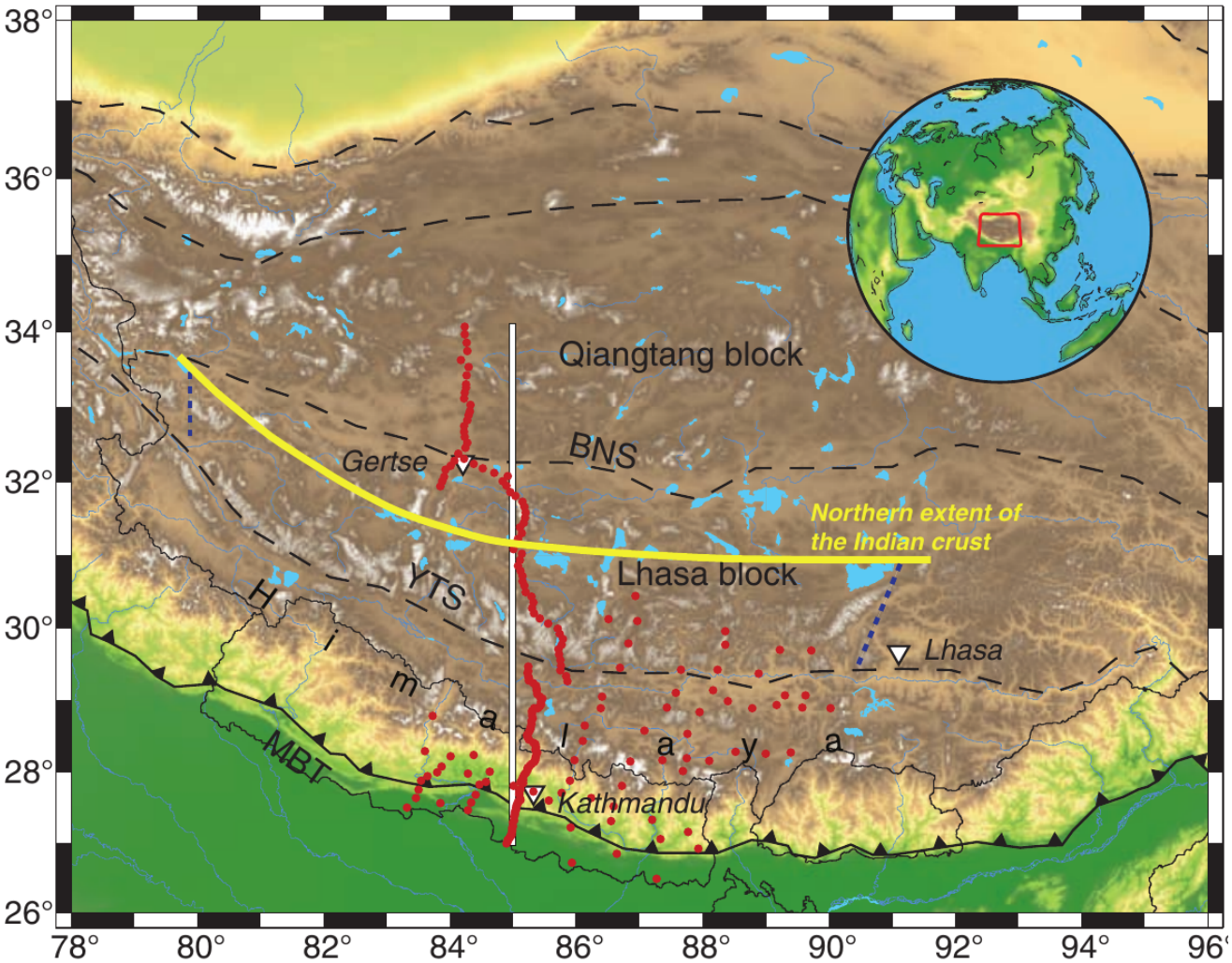
[1] Delft University of Technology

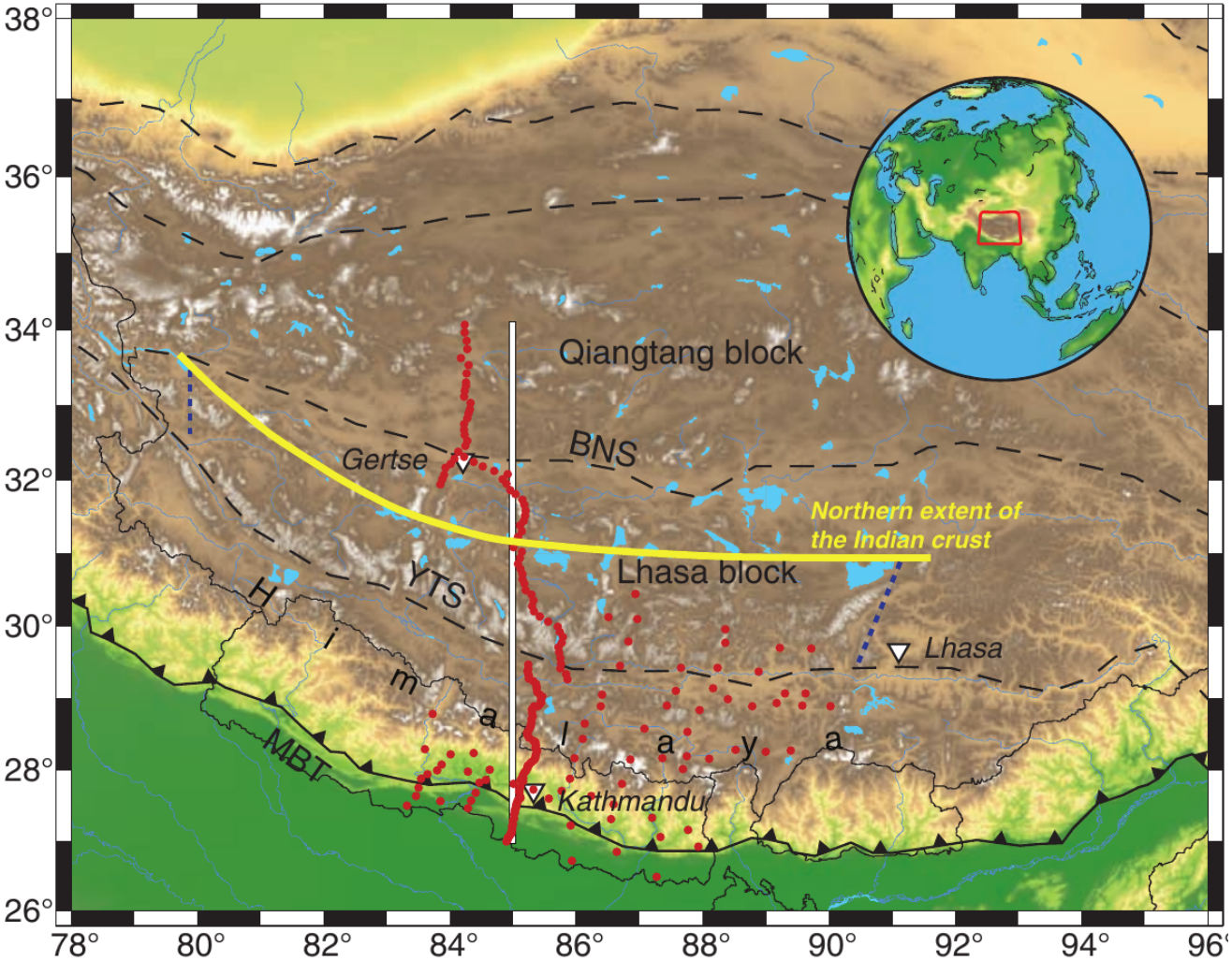
TU Delft

Contents

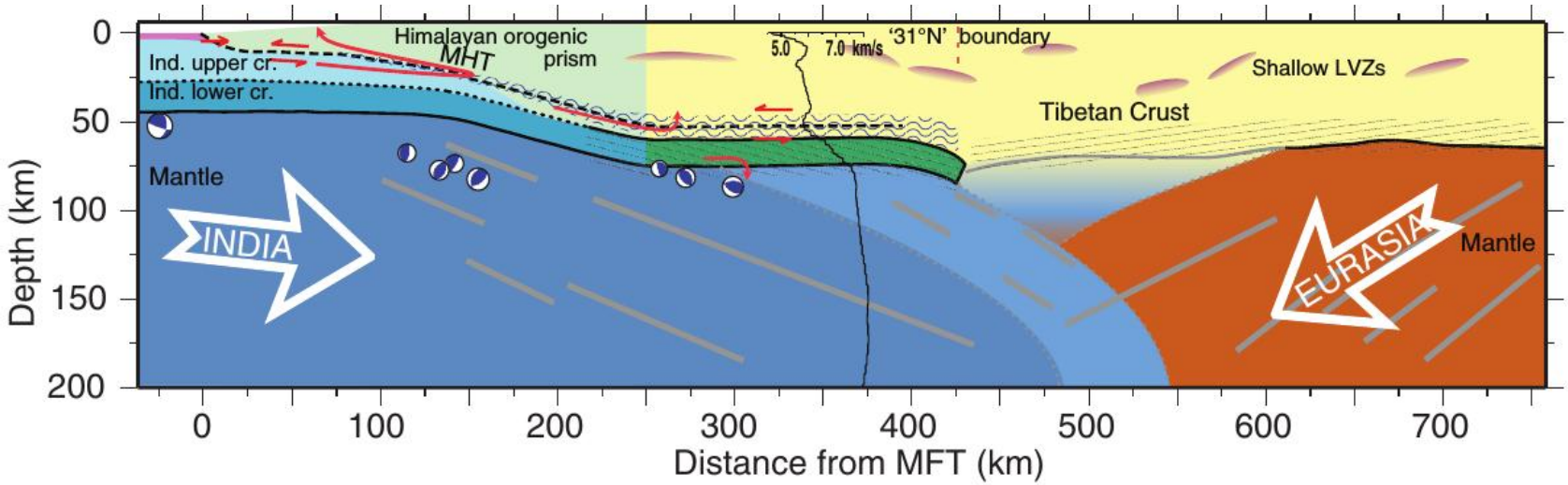
Himalaya


38°
36°
34°
32°
30°
28°
26°
78°
80°
82°
84°
86°
88°
90°
92°
94°
96°
Qiangtang block
BNS
Gertse
Northern extent of
the Indian crust
Lhasa block
YTS
Lhasa
MBT
Kathmandu

Hi-CLIMB array



Himalaya-Tibet Collision Zone



1. Collision of Indian plate and Eurasian plate
2. Resulting in complex structures
3. Active region of continental earthquakes

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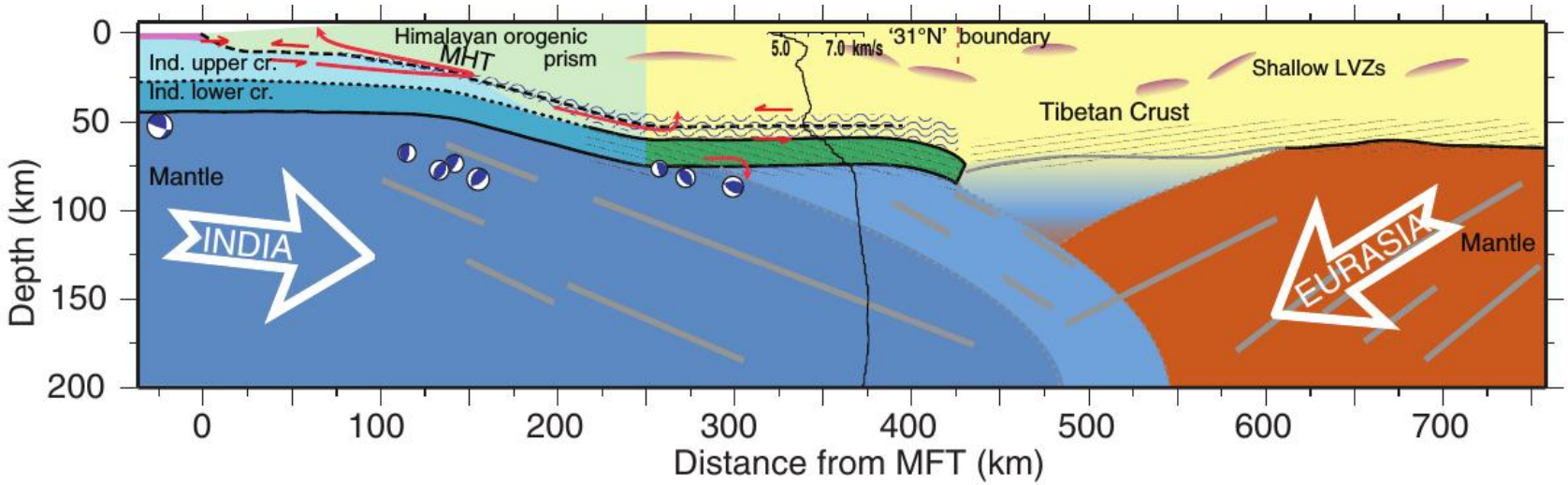

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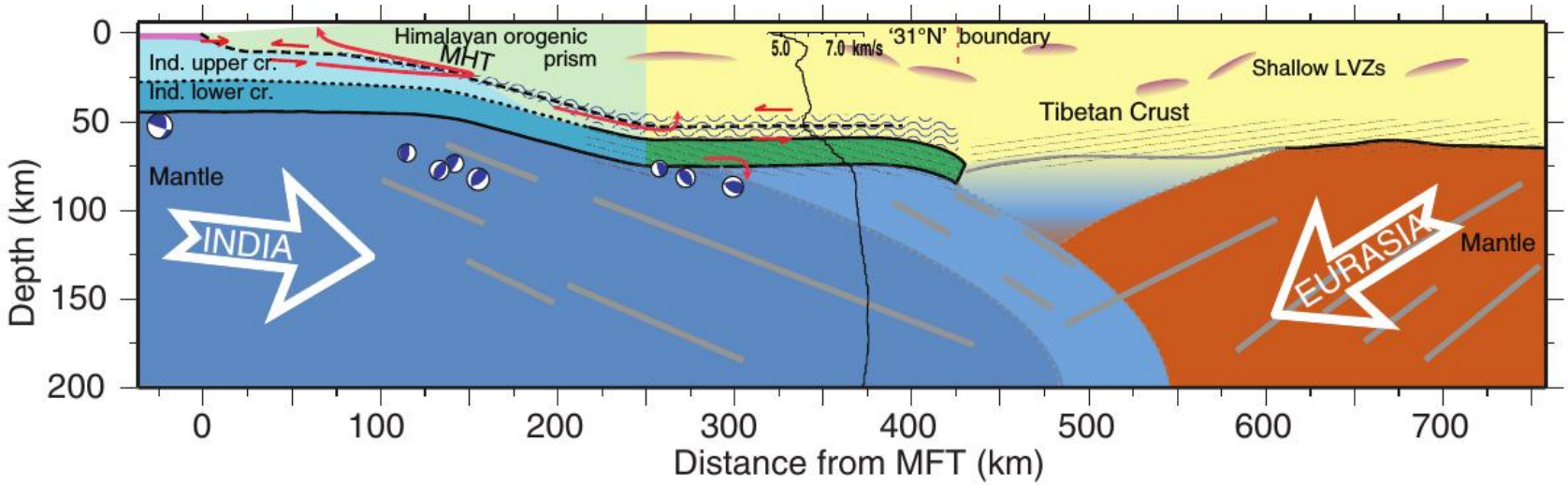

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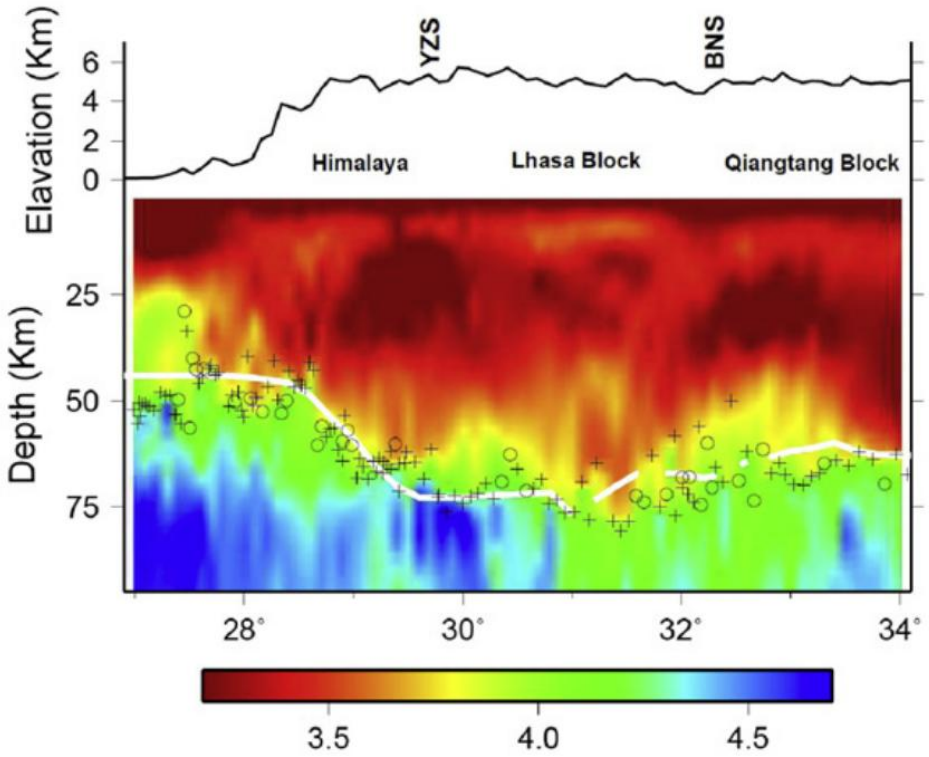
Motivation

1. This is a Hi-CLIMB S-velocity tomography by *Xu et al. 2013*
2. Objective: improve the depth resolution of S-velocity structure
3. Delineate Moho depth and low velocity zones



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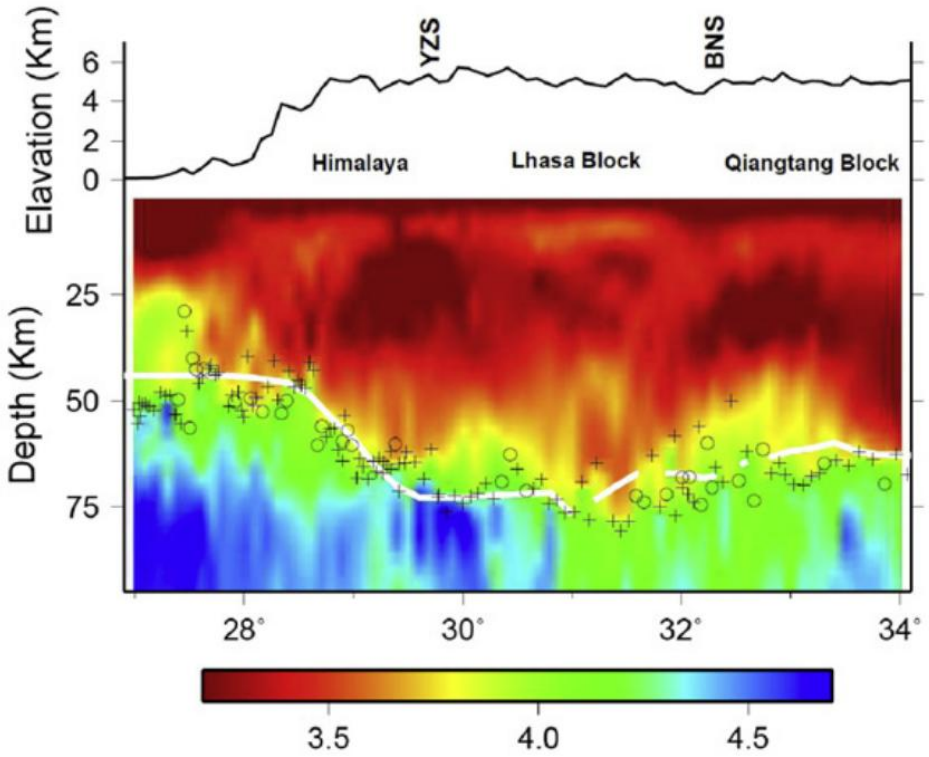

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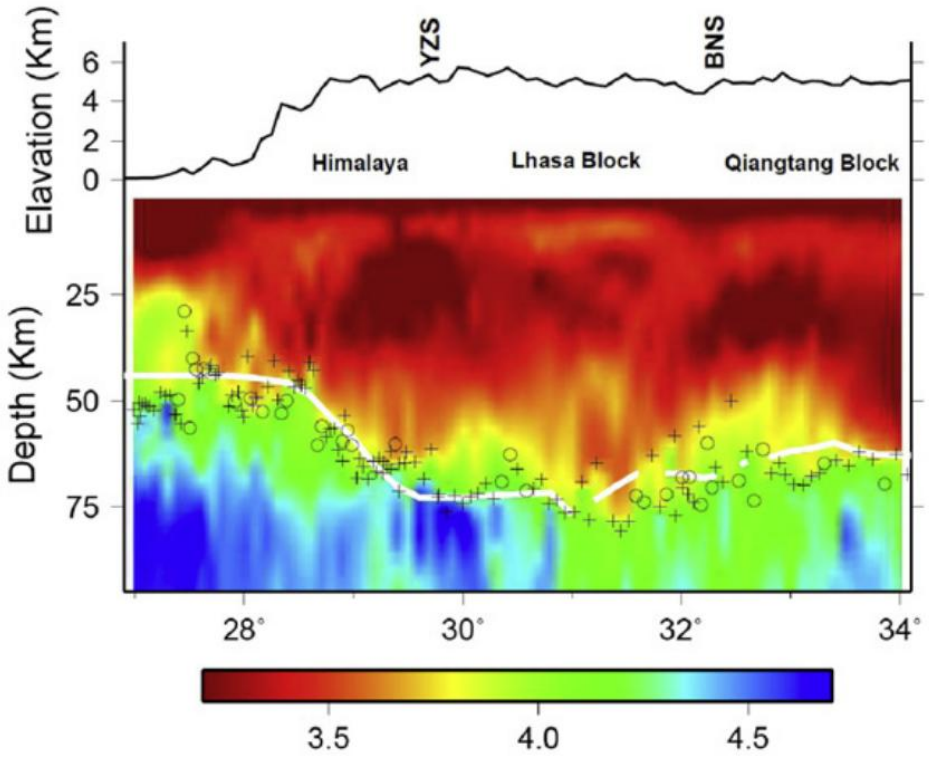

From high to low wavenumbers

1. Local crustal earthquakes provide high frequencies and illuminate structure with high wavenumbers
2. Scattered coda wave field provides broader spectrum of wavenumbers
3. Coda are generally too complex for tomographic inversion
4. Cross-correlation interferometry can transform these complex coda into virtual shot gather
5. Location and timing of a virtual source is exact

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Simulation

1. 2D scalar finite difference simulation with S-wave velocities
2. Model based on S-wave tomography (*Xu et al. 2009*)
3. Test retrievability of Moho reflection with sparse crustal source distribution
4. **Do crustal heterogeneities improve the retrieval of the Moho reflection?**

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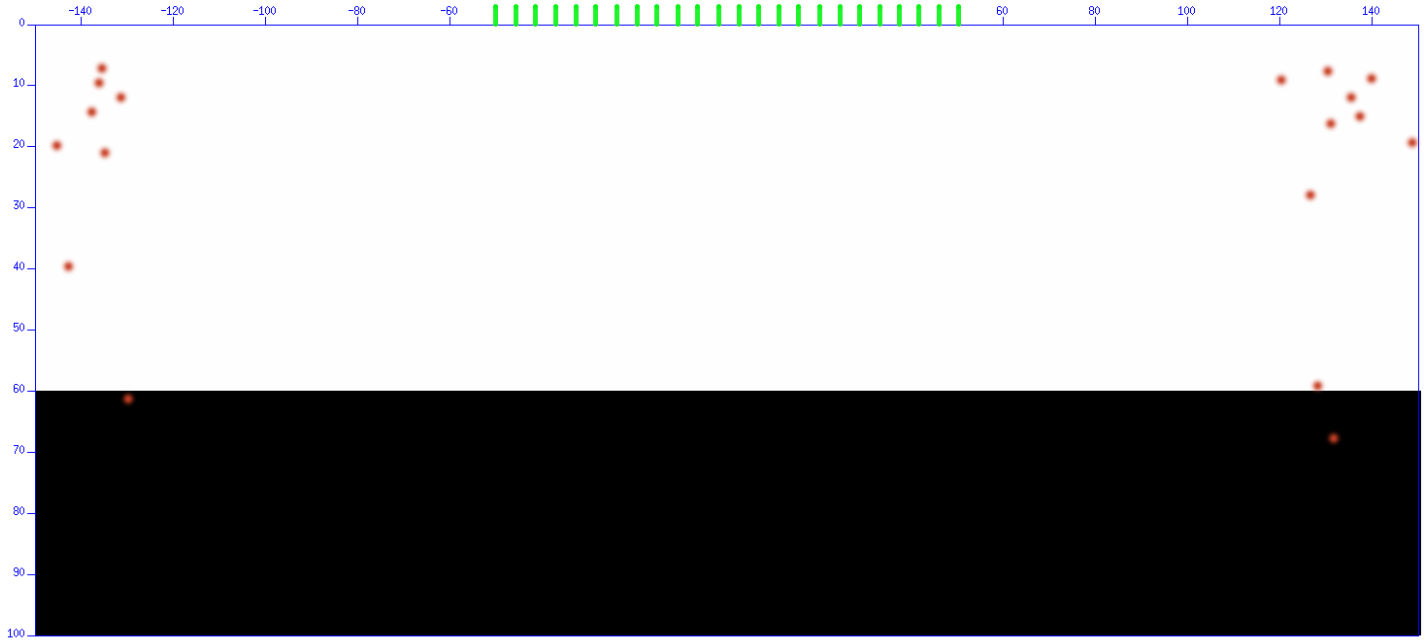
Processing flow

- Input: particle velocity recordings of 20 monopole simulations
- Remove the direct wave of each dataset
- Apply exponential gain function to the coda
- Cross-correlate traces of all possible receiver pairs
- Sum the 20 correlation gathers
- Exponential gain applied to final result

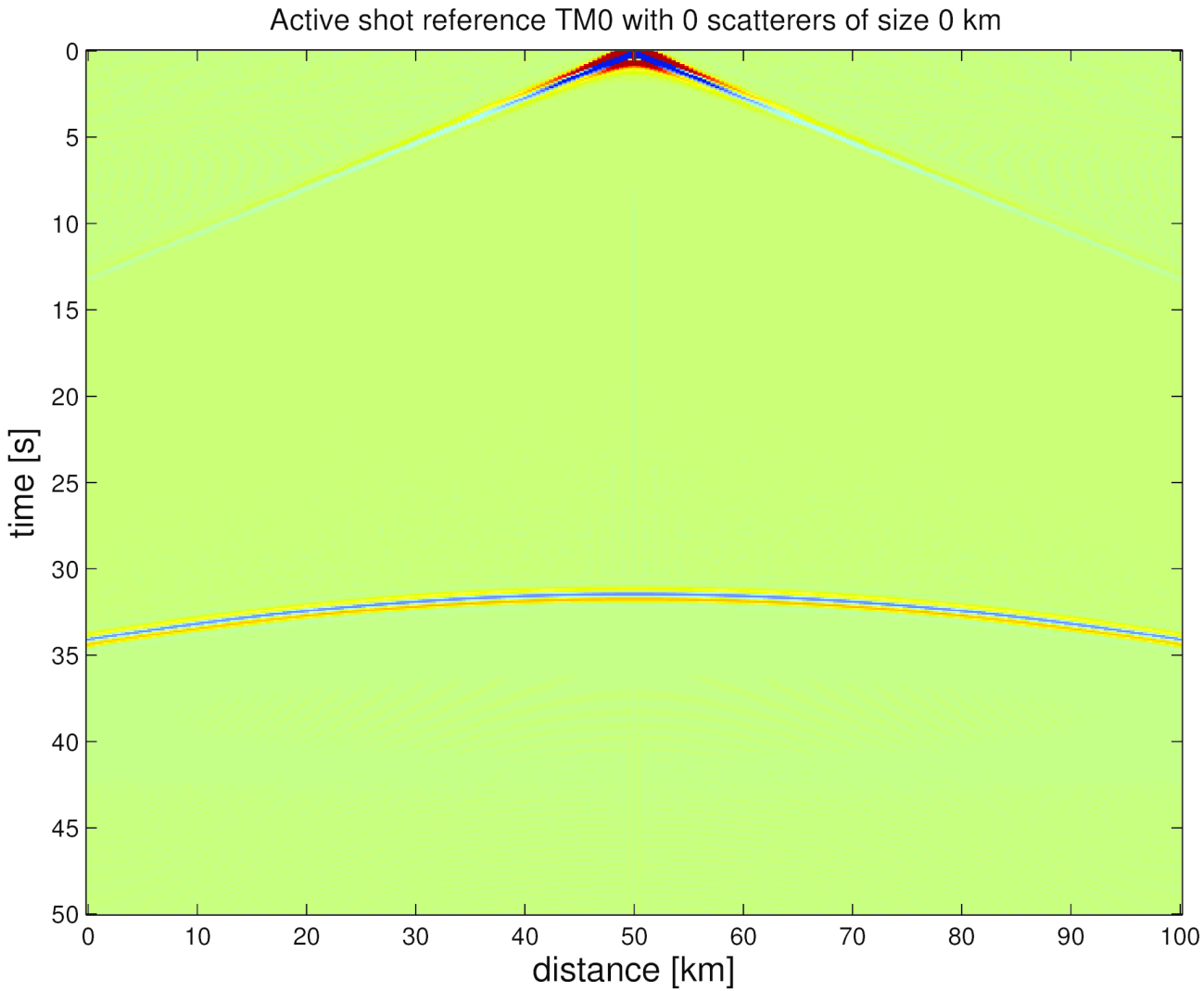
Moho model



- Moho depth and S-wave velocities from Tibetan Plateau (*Xu et al. 2009*)
- 100 km long array with 0.4 km spacing (green)
- 20 crustal sources far offset from middle (red)
- Ricker wavelet with bandwidth 0.5-3 Hz

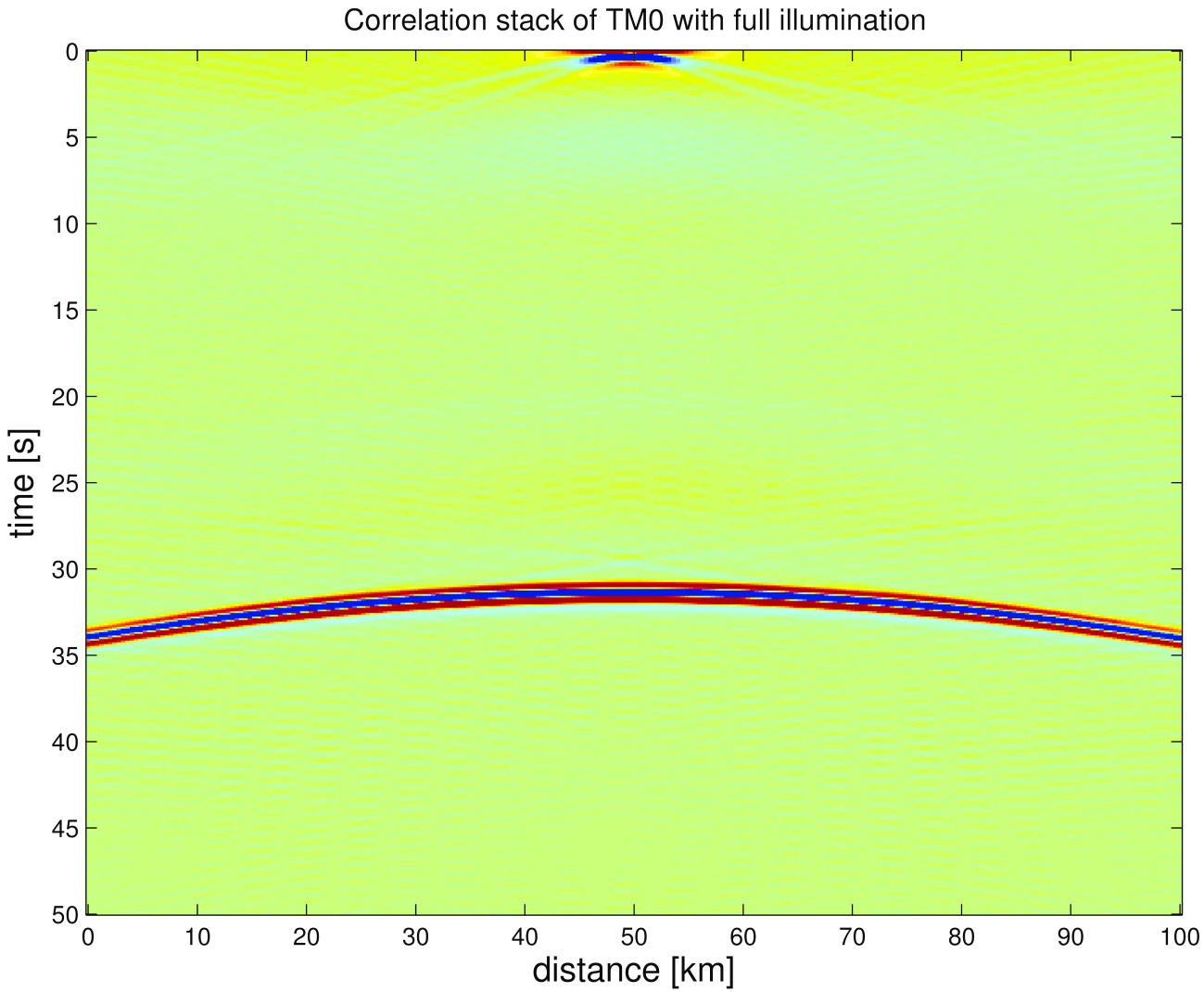
Moho model

- Active source at the center



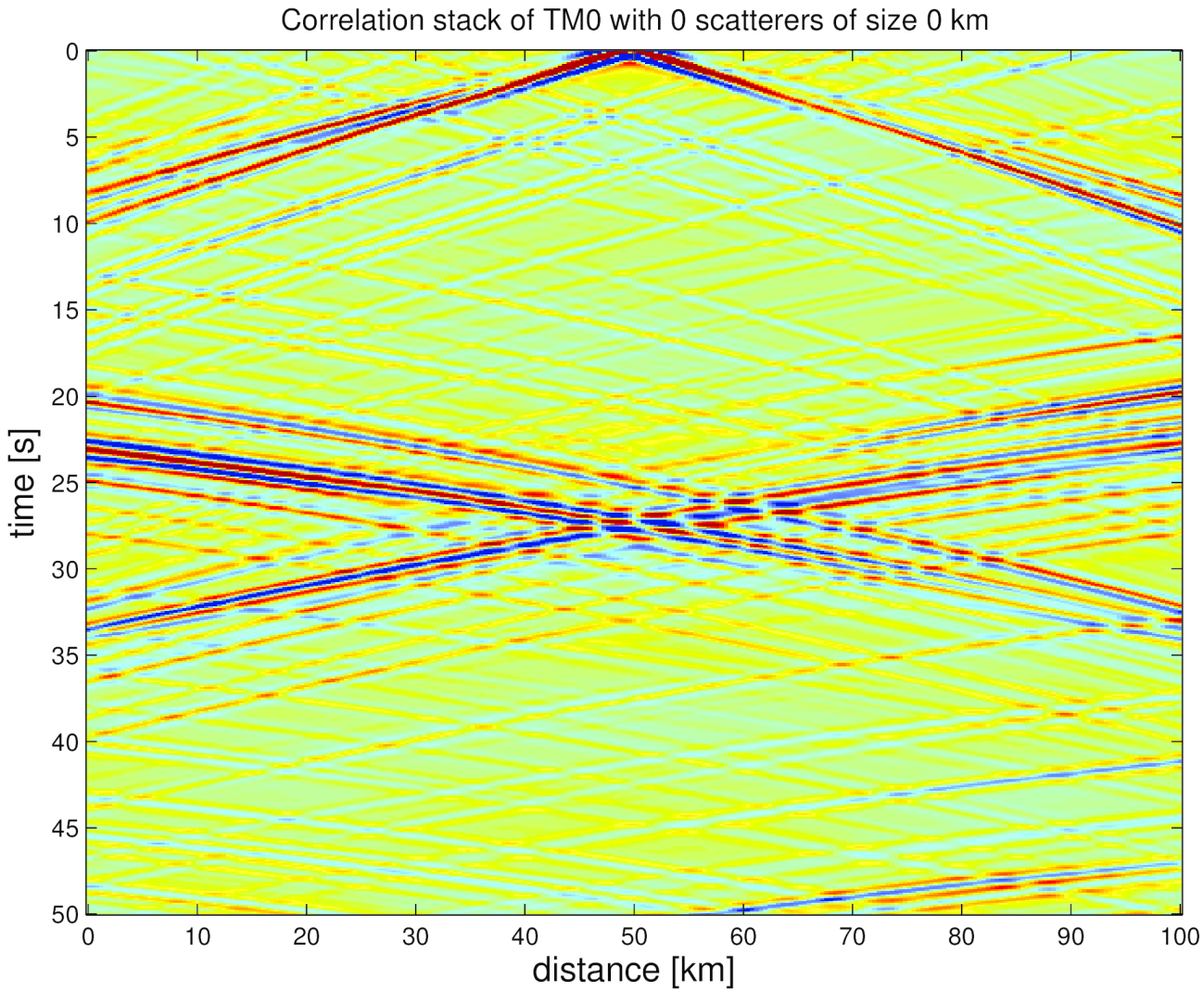
Moho model

- Cross-correlation retrieval for optimal illumination conditions

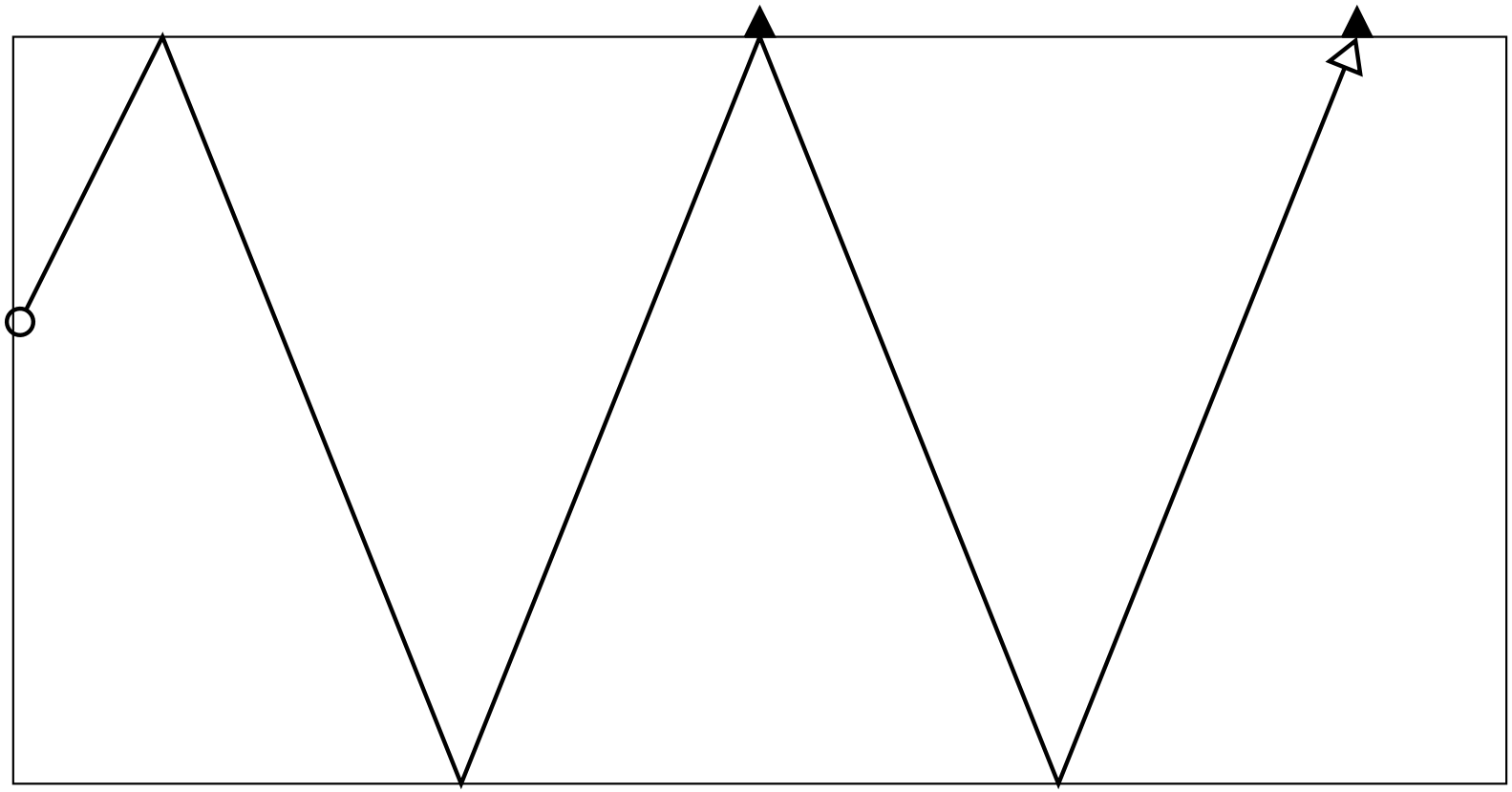


Moho model

- Cross-correlogram with virtual source at the center

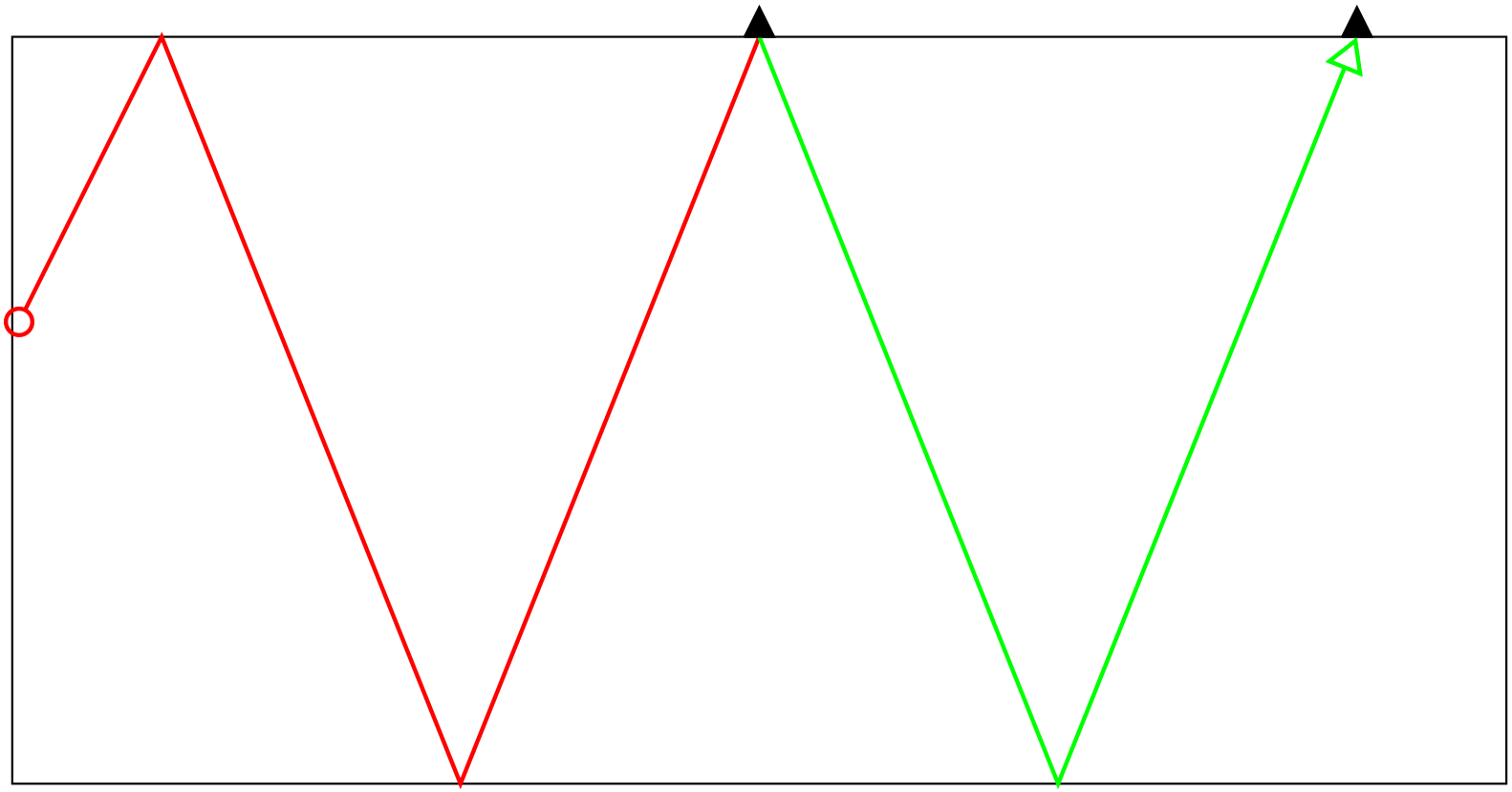


Ray diagram



1. Long aperture
2. Reflection is retrieved by cross-correlation
3. Limited aperture
4. Reflection is not retrieved

Ray diagram



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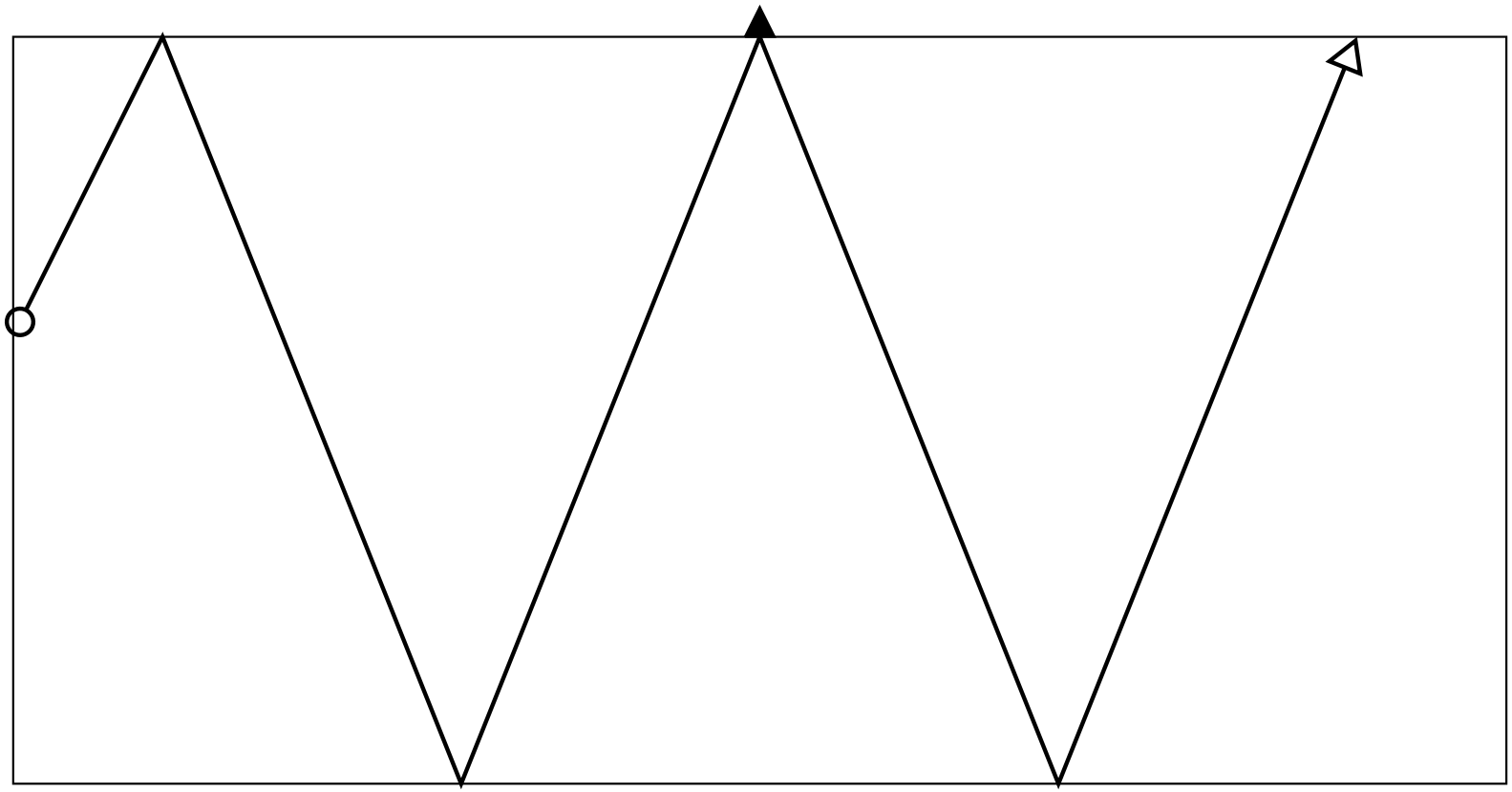

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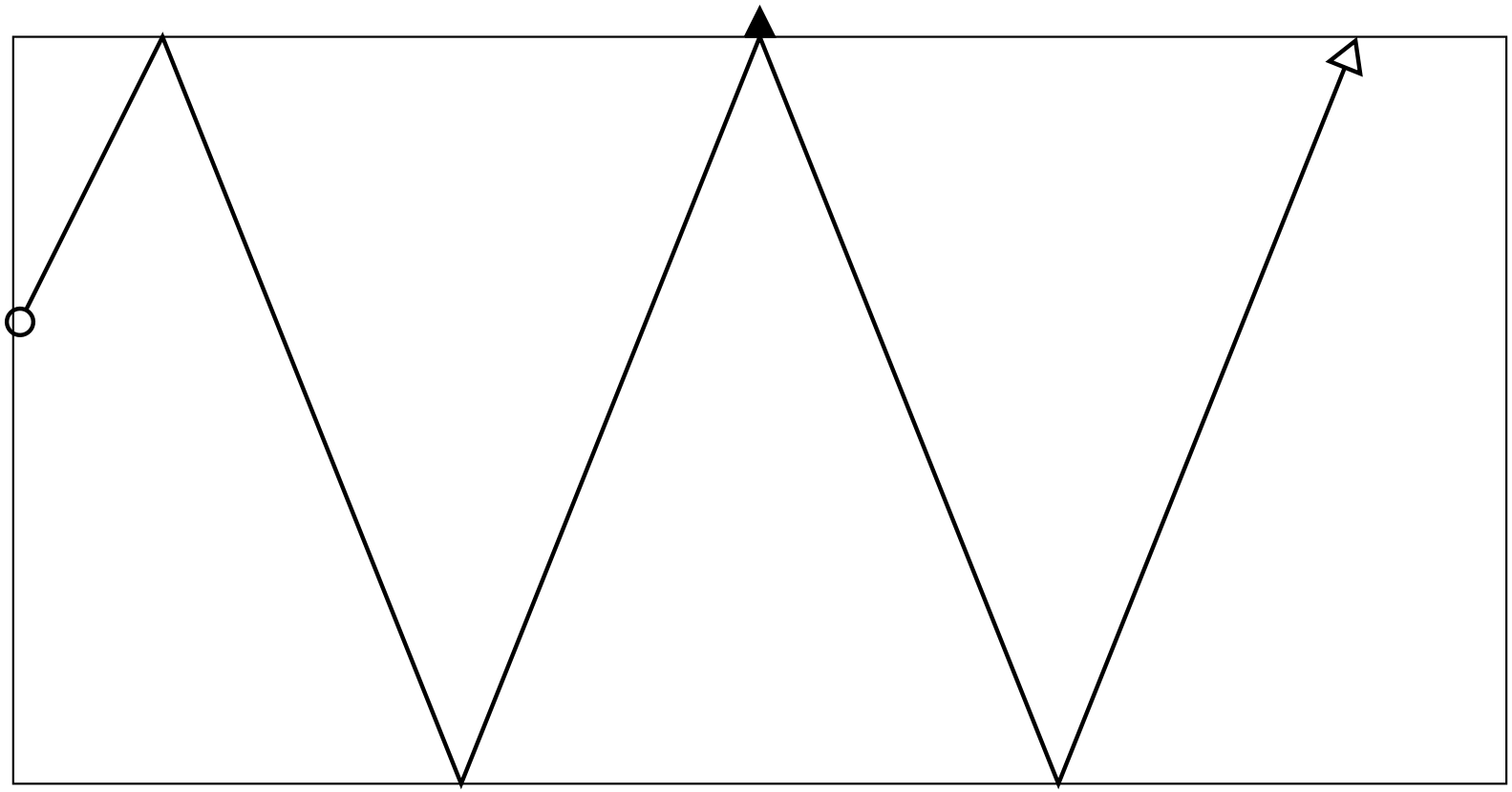

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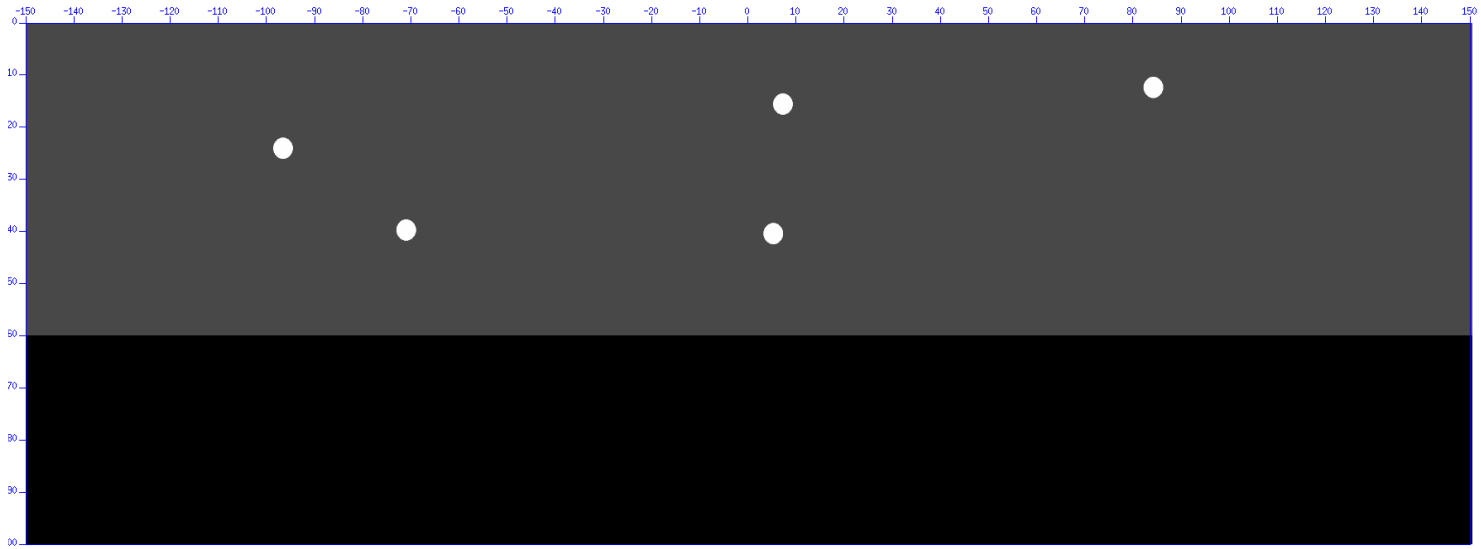
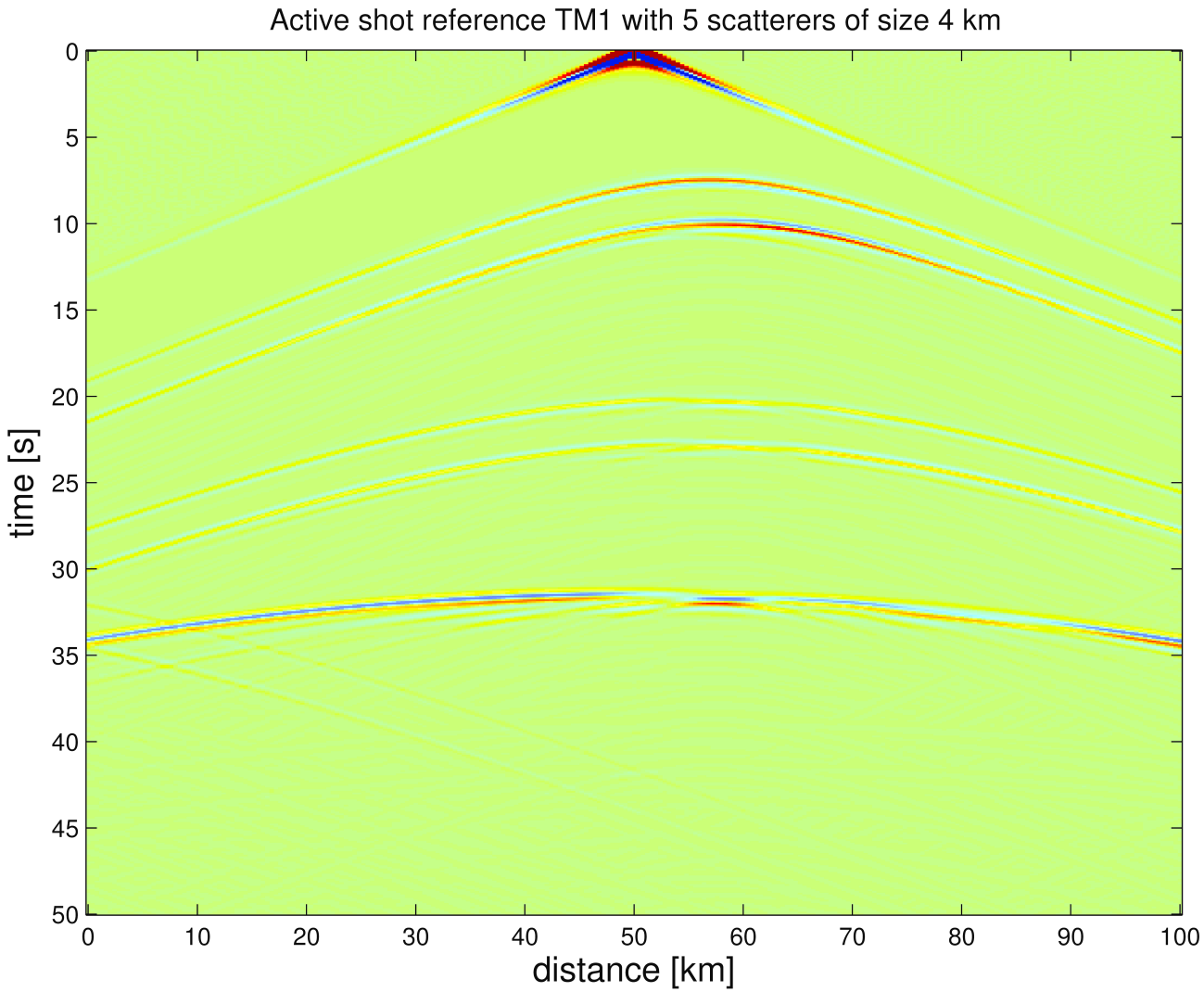
Moho model with 5 scatterers



- 5 scatterers: diameter of 4 km and contrast $= -15\%$
- 100 km long array with 0.4 km spacing
- 20 crustal sources far offset from middle
- Ricker wavelet with bandwidth 0.5-3 Hz

Moho model with 5 scatterers

- Active source at the center



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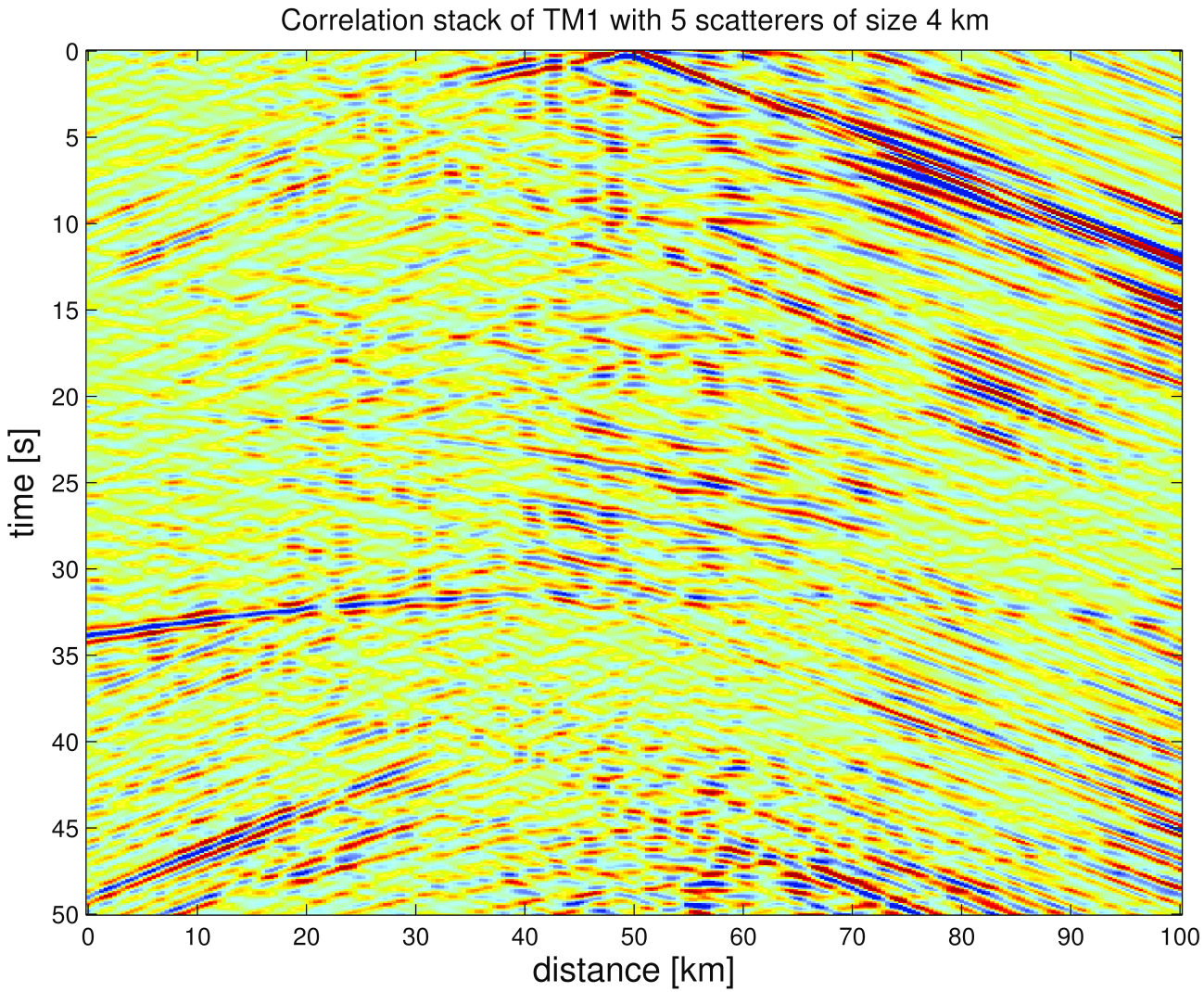
- Cross-correlogram with virtual source at the center



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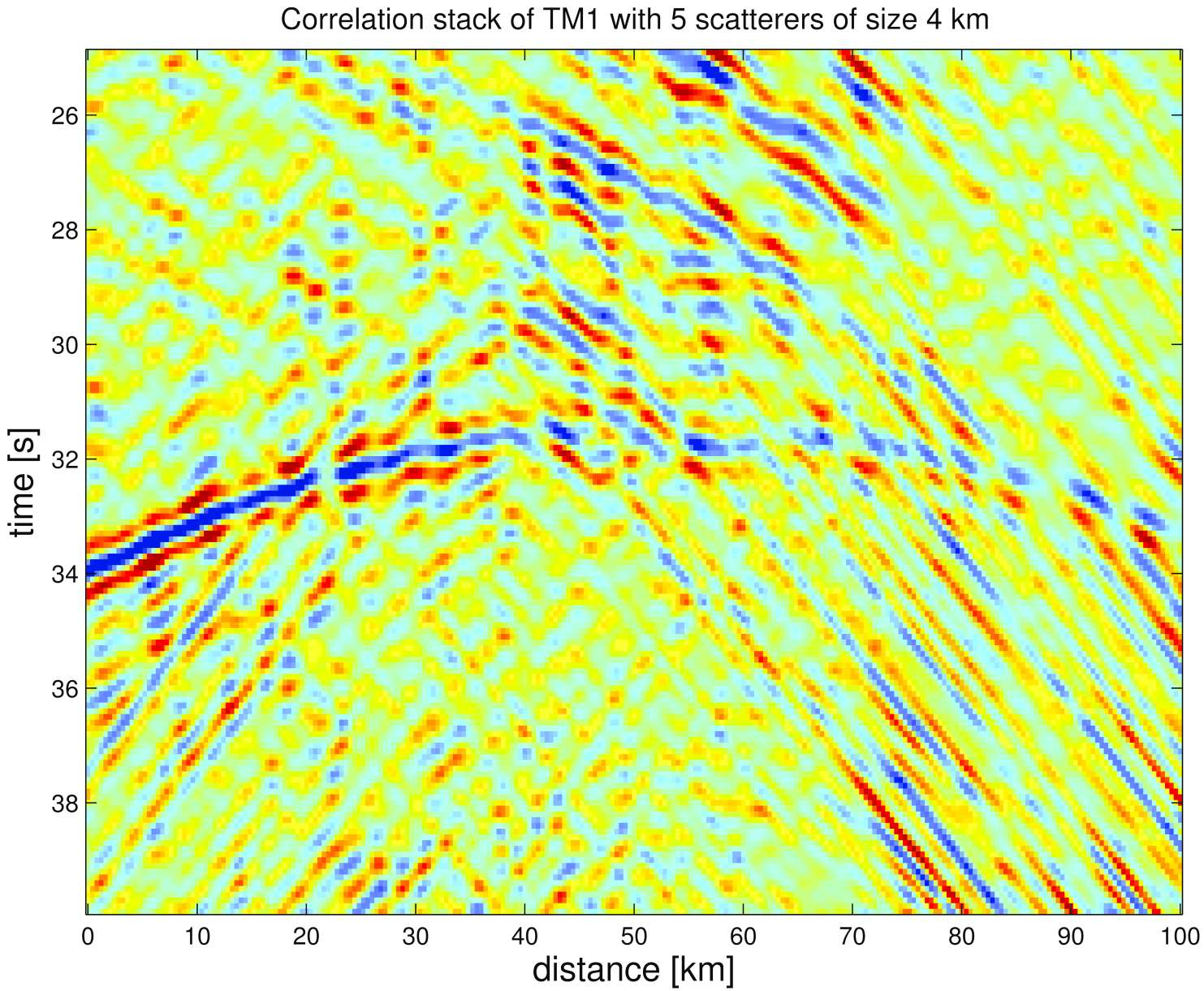

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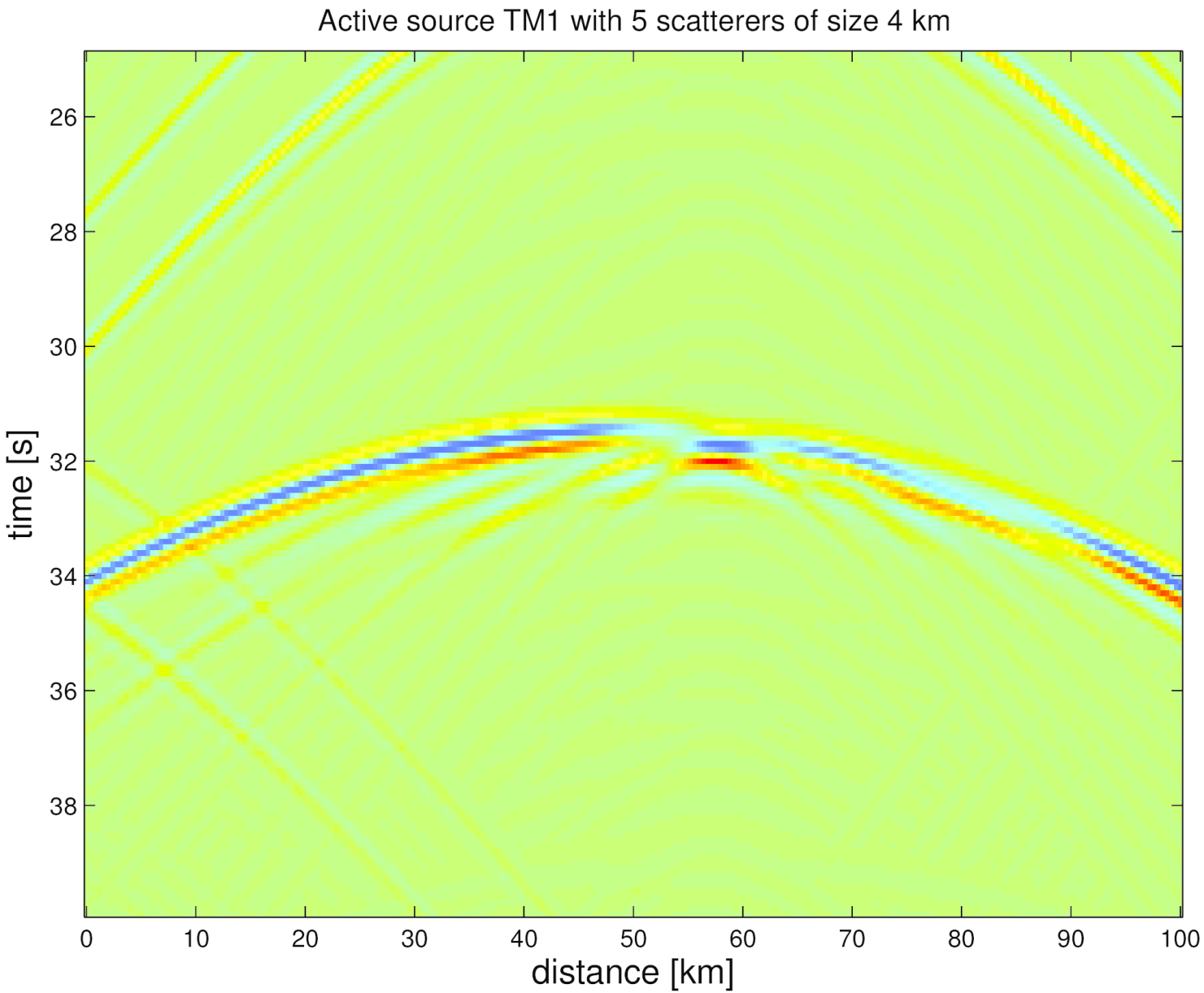

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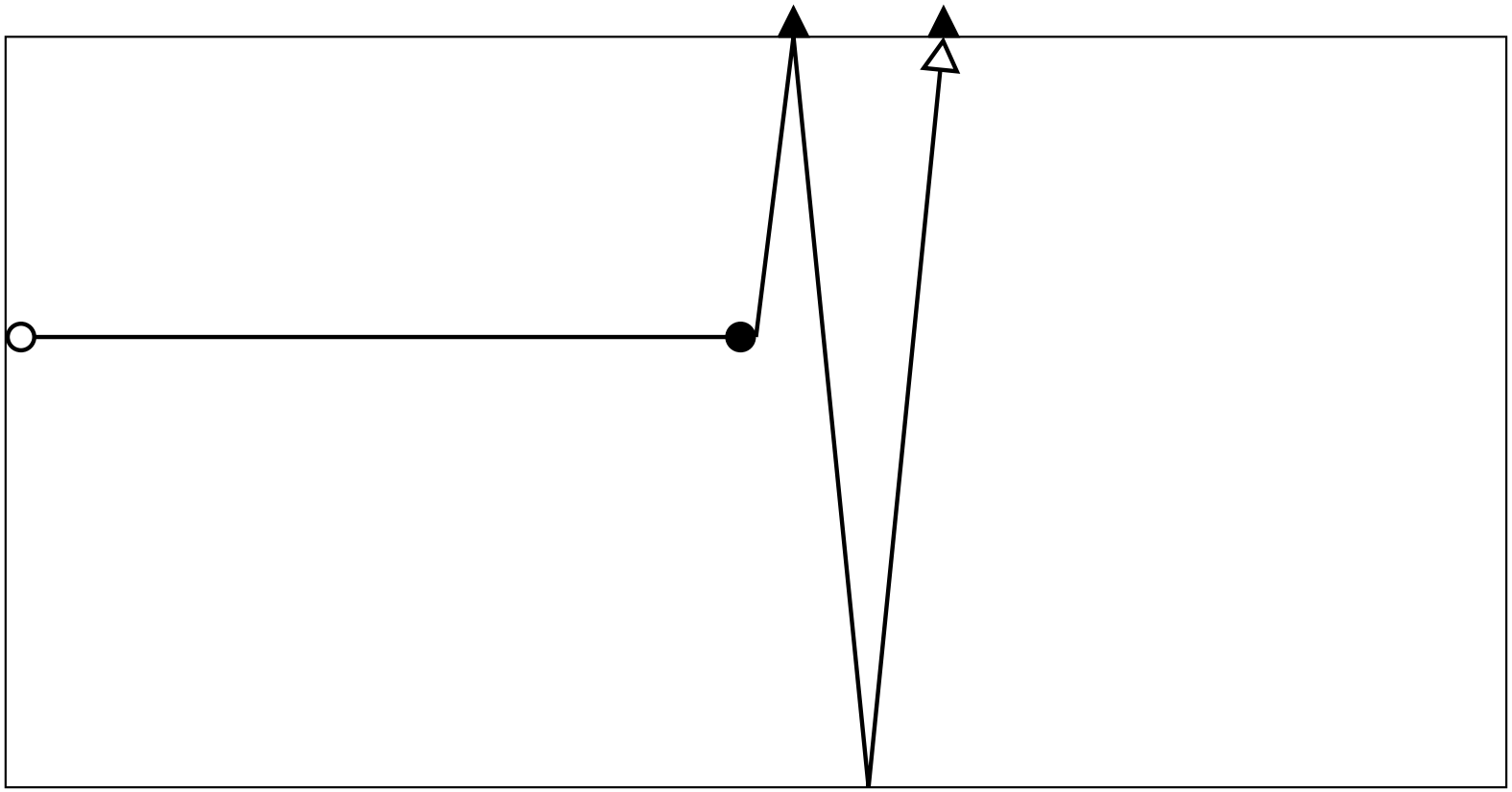
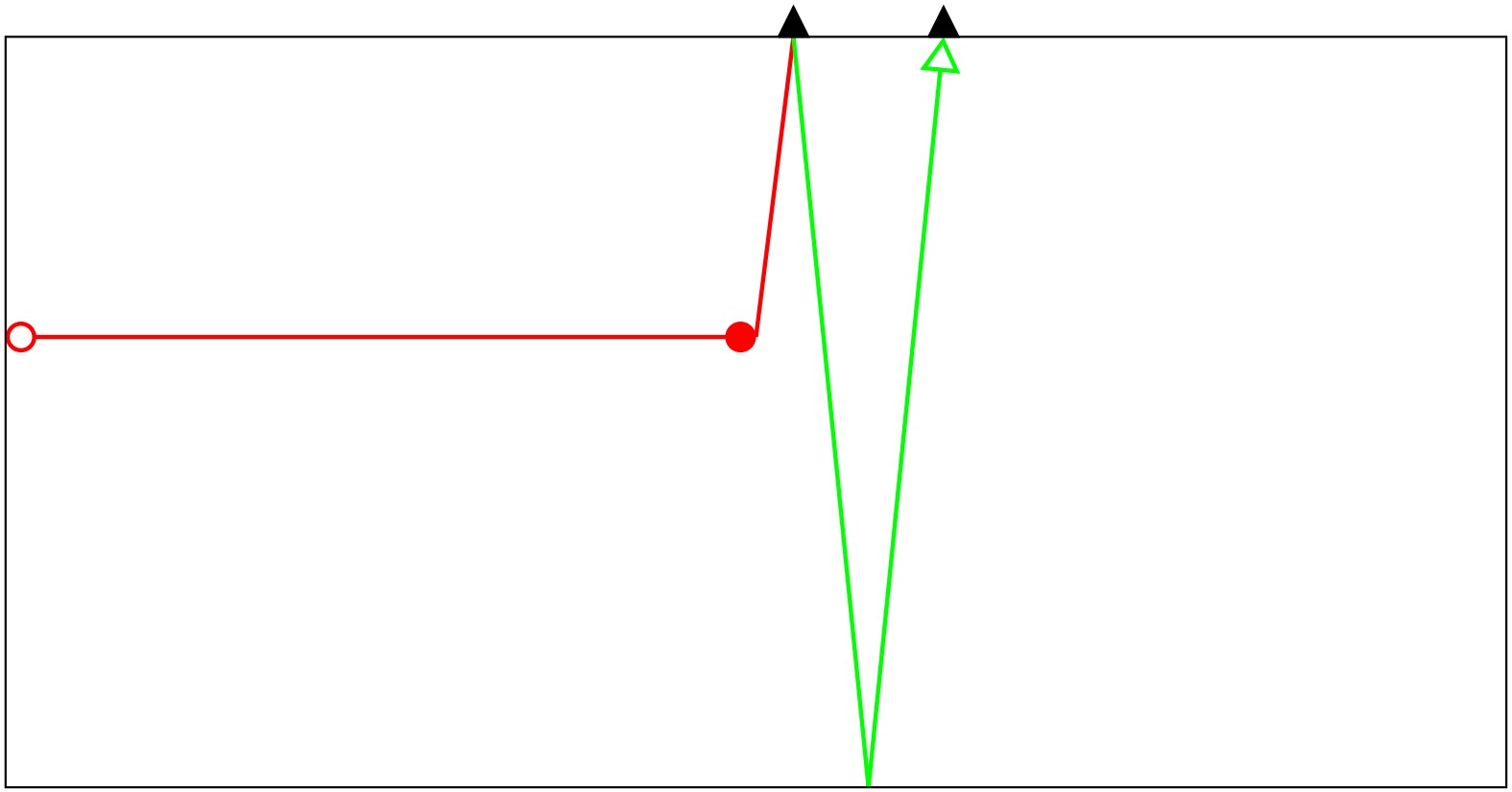


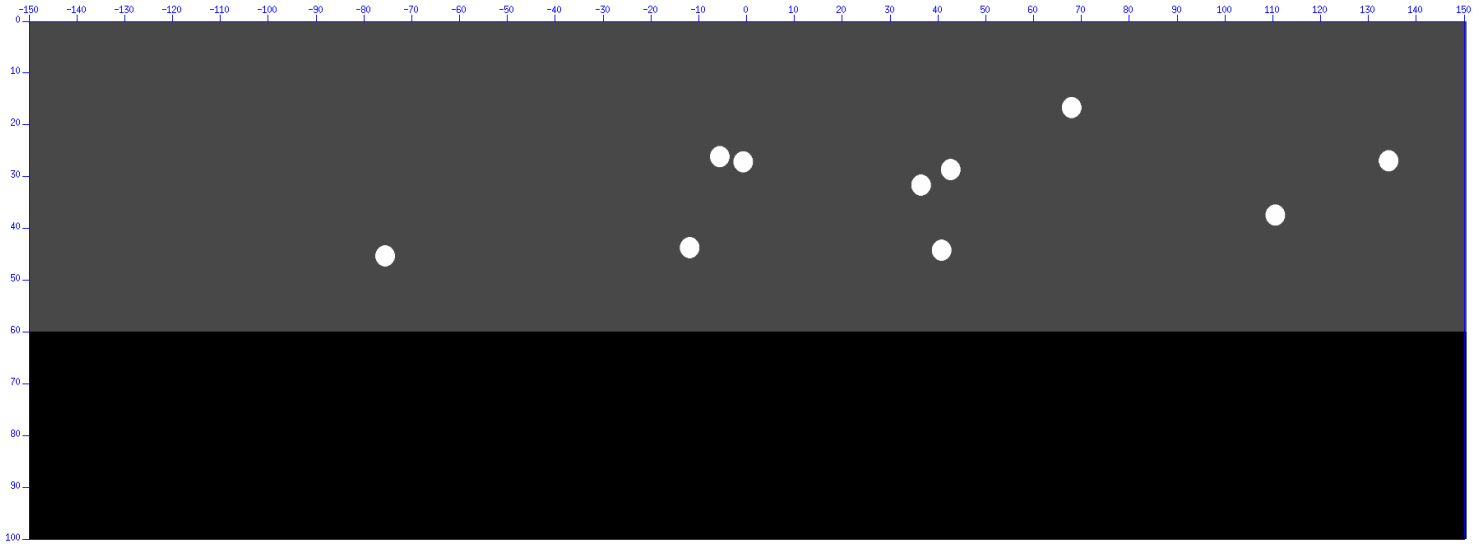
1. Scatterers generate strong low wavenumber reflections

Ray diagram



1. Cross-correlation yields the correct reflection retrieval in green

Moho model with 10 scatterers



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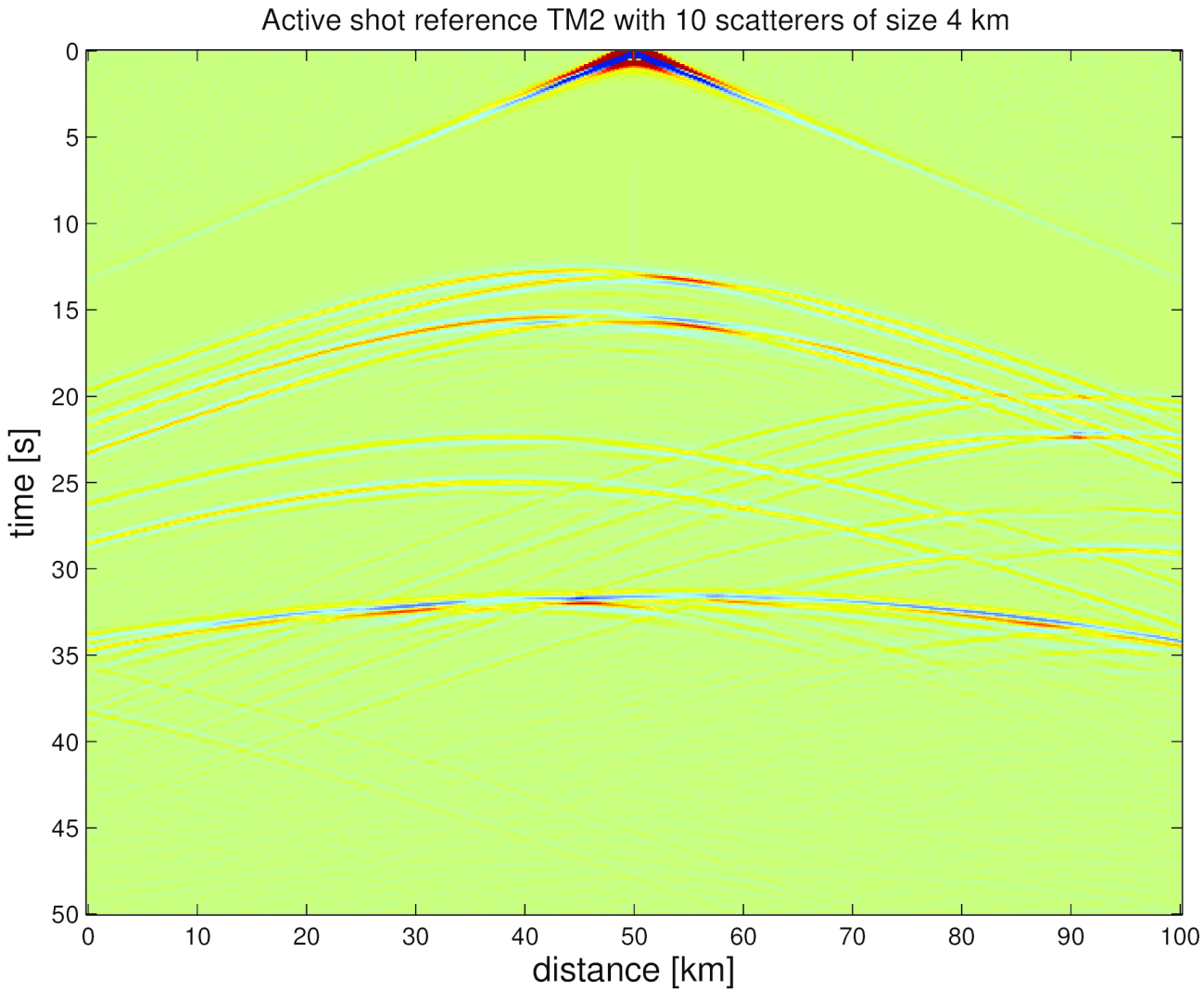
- 100 km long array with 0.4 km spacing
- 20 crustal sources far offset from middle
- Ricker wavelet with bandwidth 0.5-3 Hz

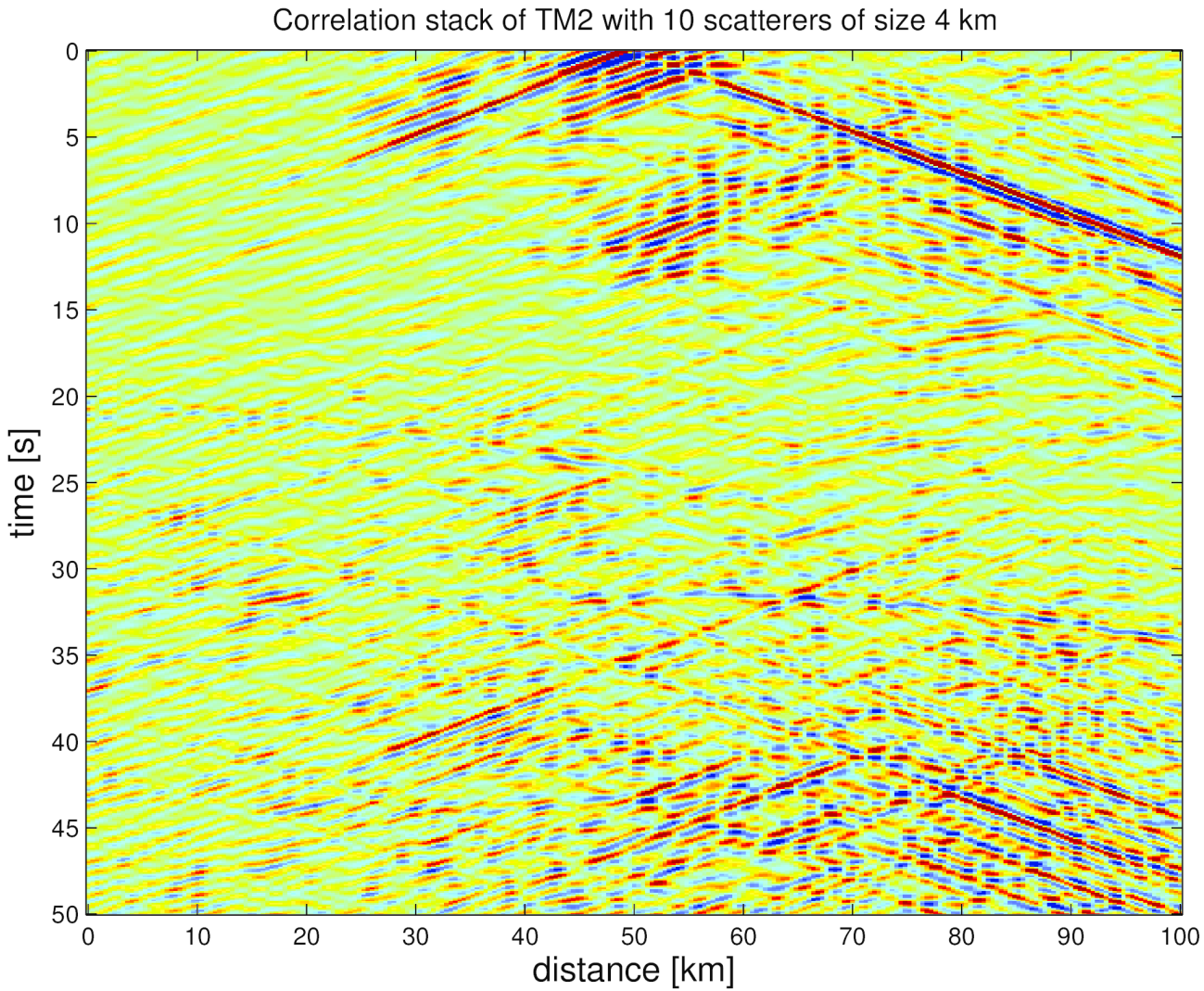
Moho model with 10 scatterers

- Active source at the center



Moho model with 10 scatterers

- Cross-correlogram with virtual source at the center



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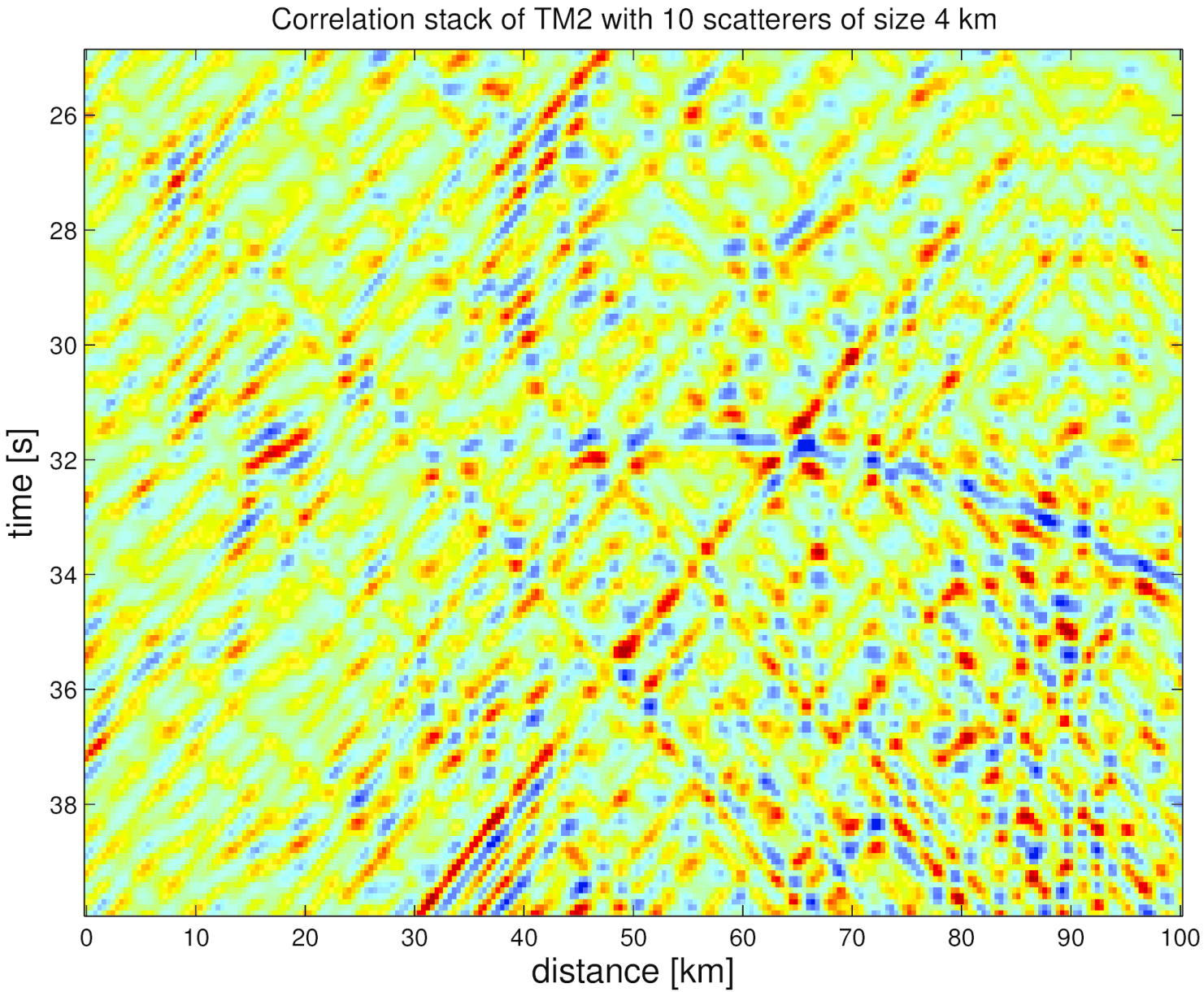

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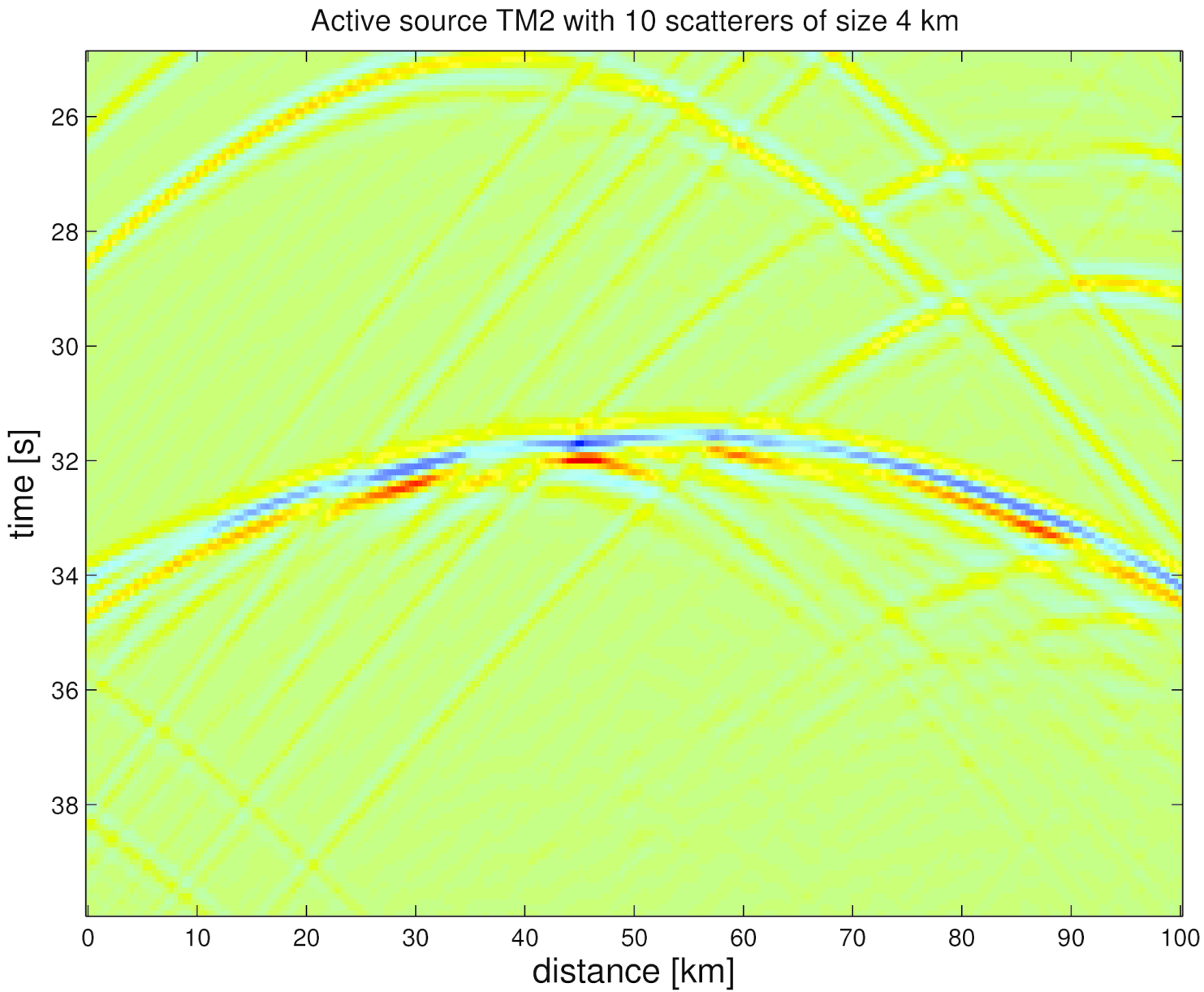
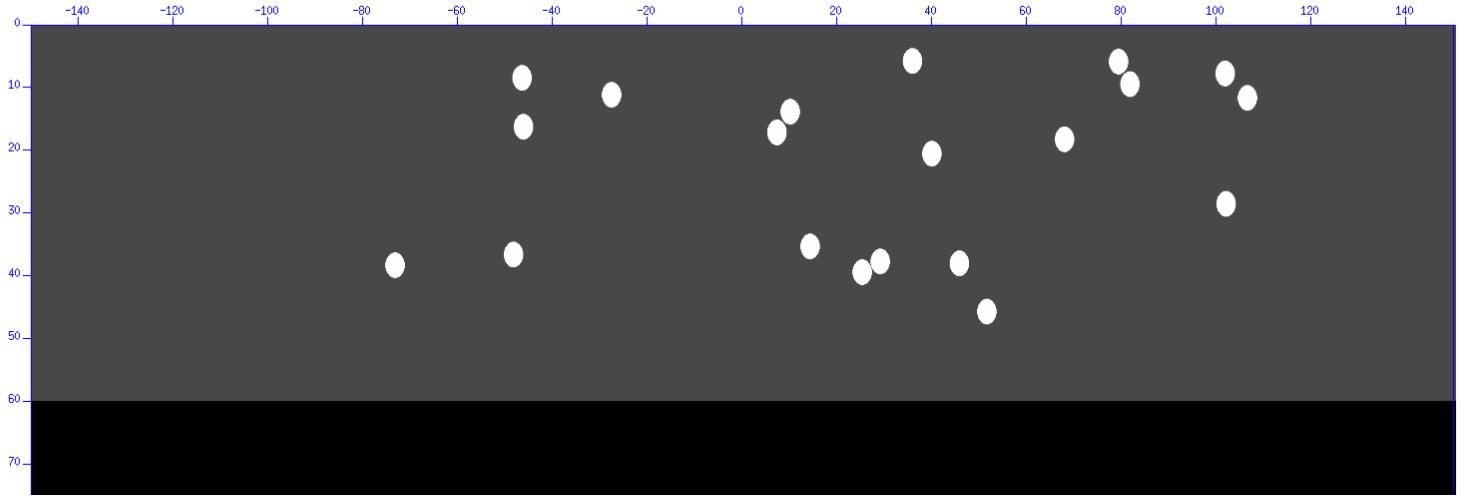


Moho model with 20 scatterers



- 20 scatterers: diameter of 4 km and -15% contrast
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Moho model with 20 scatterers

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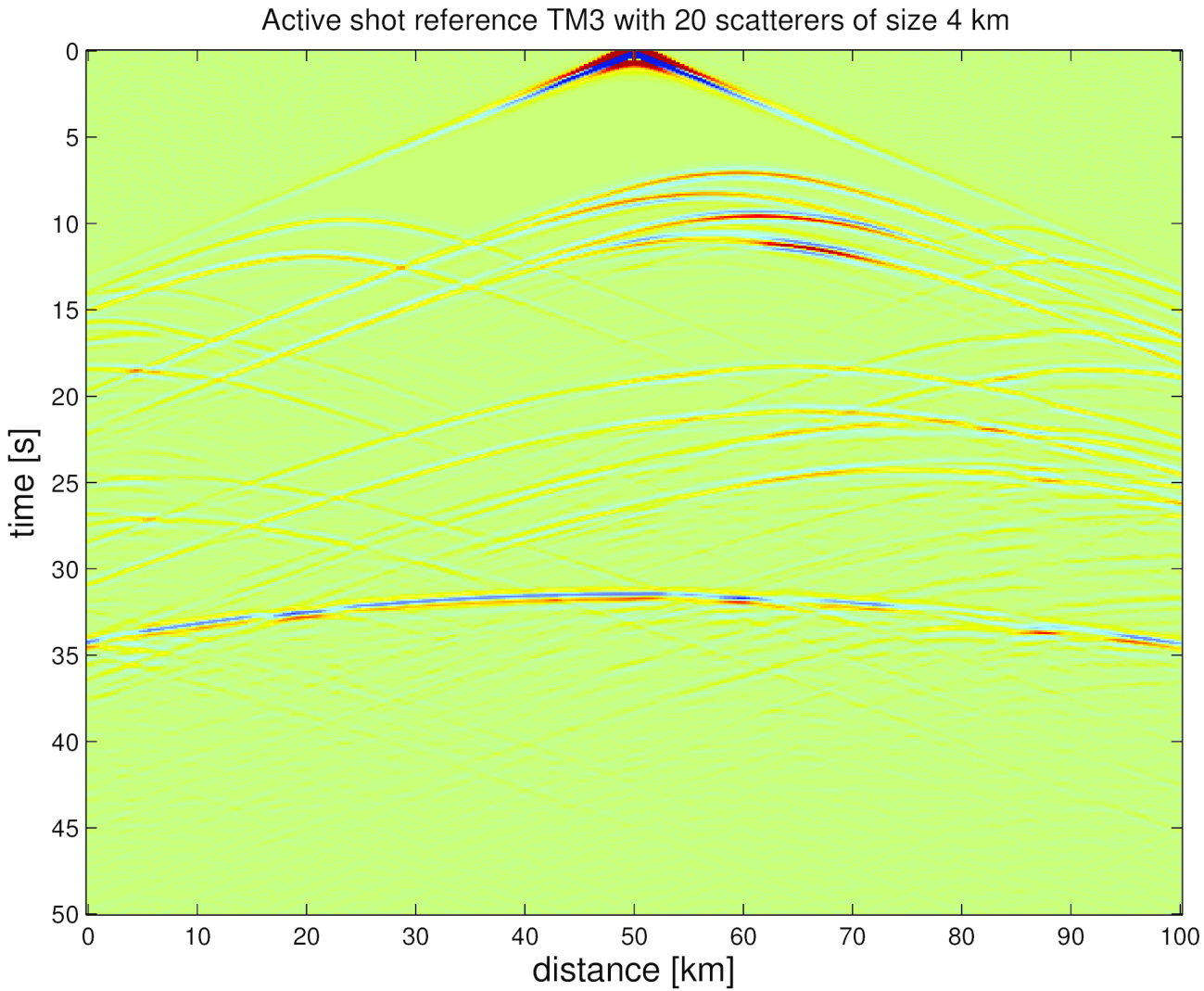

Moho model with 20 scatterers

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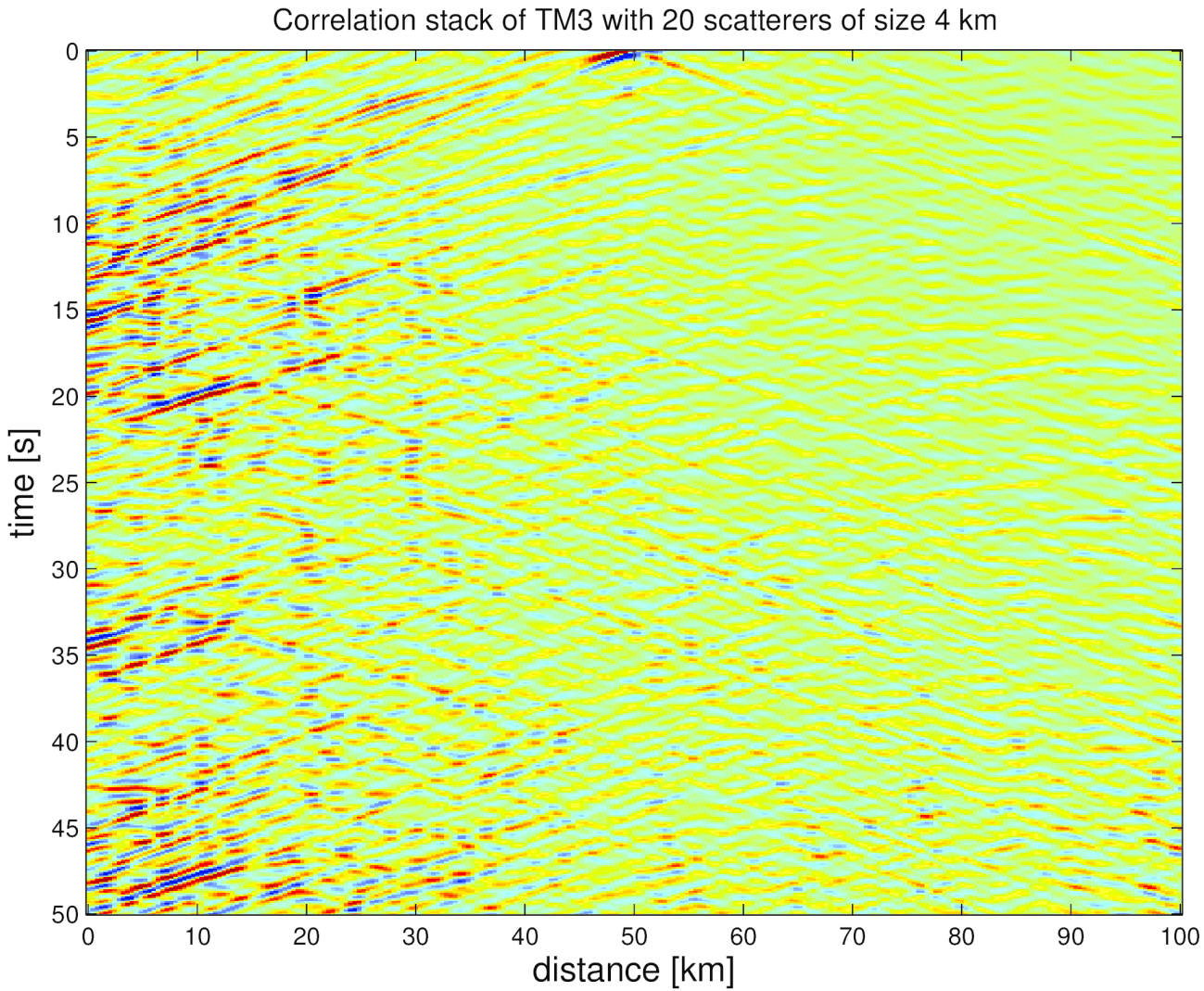

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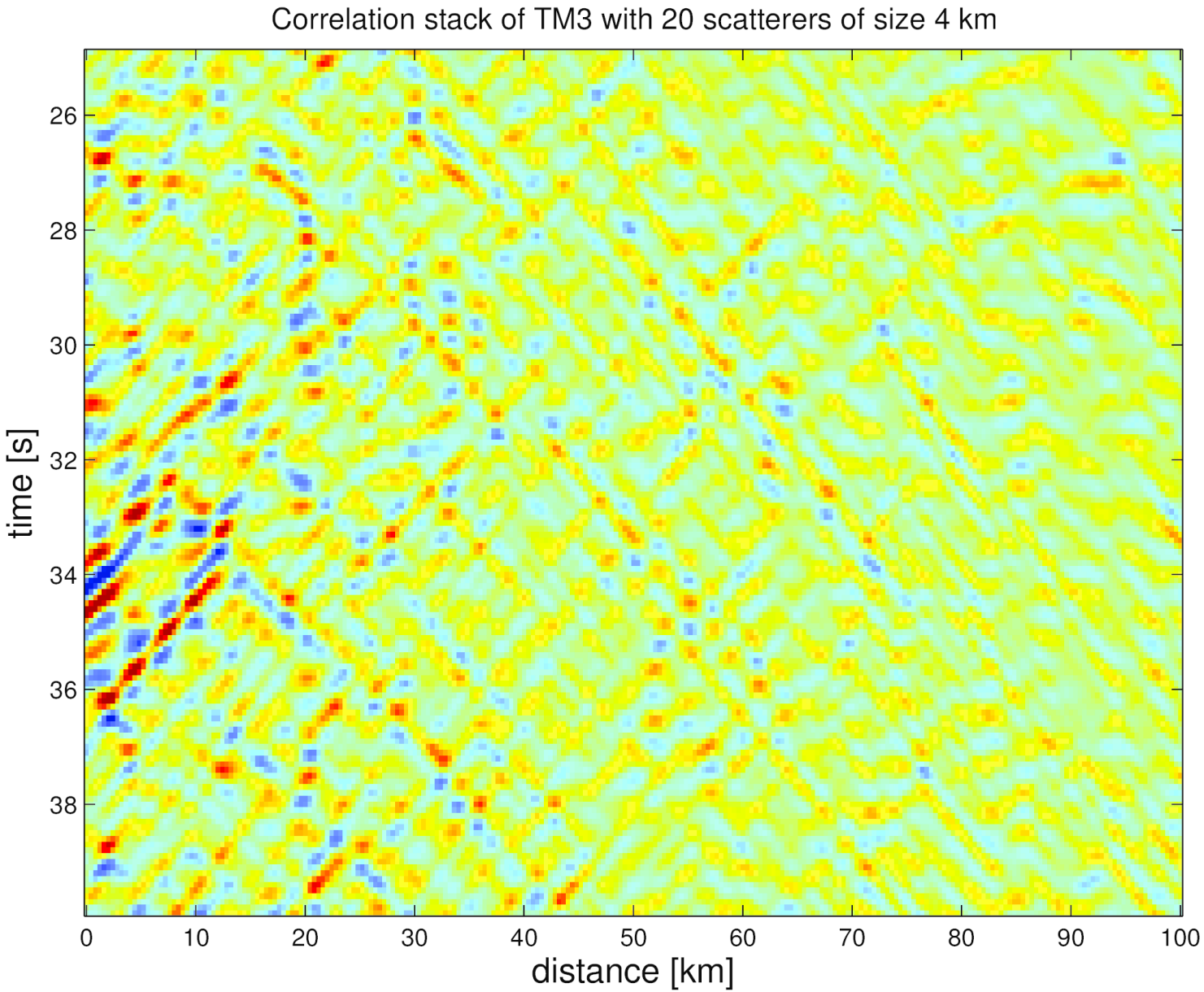

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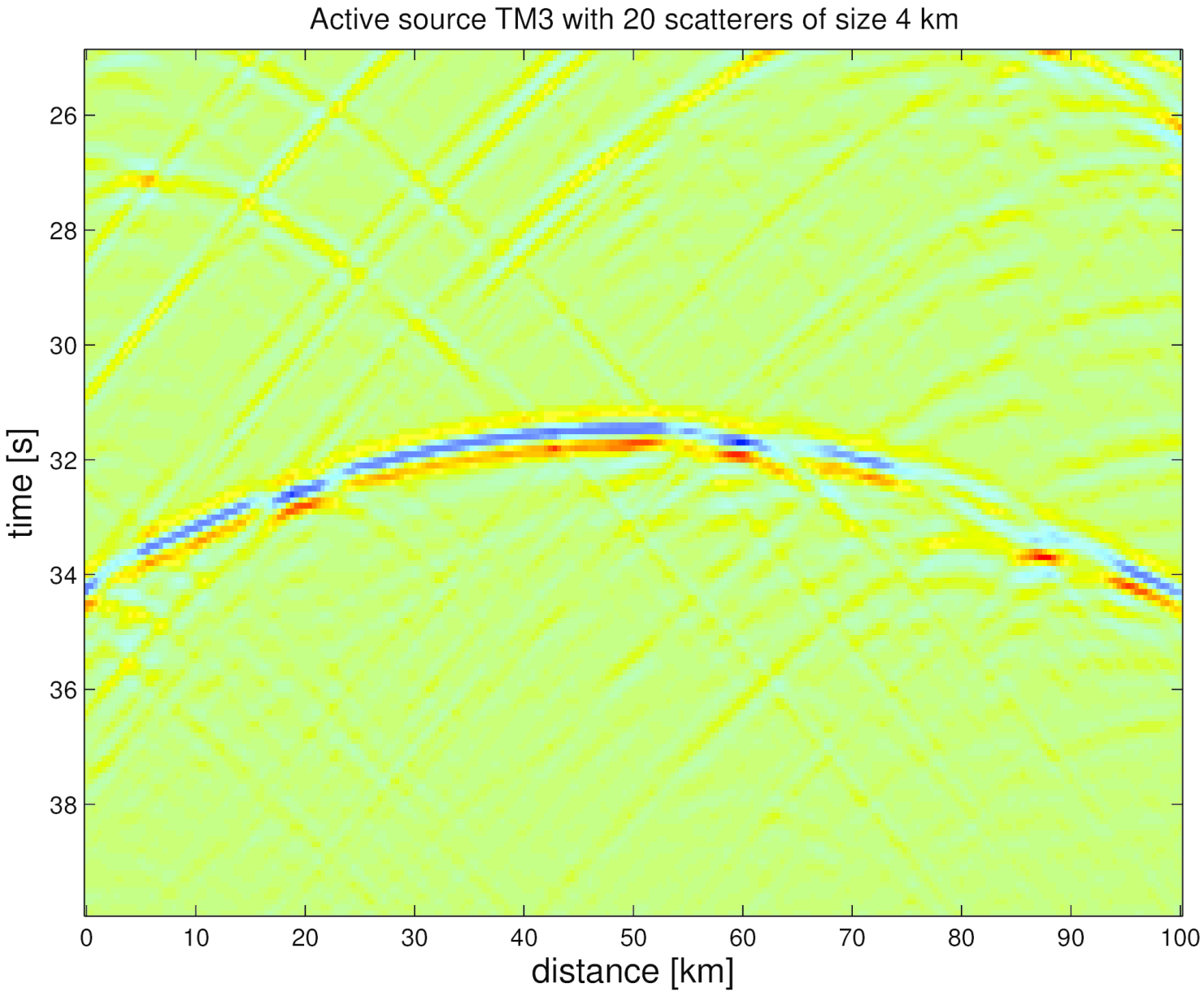
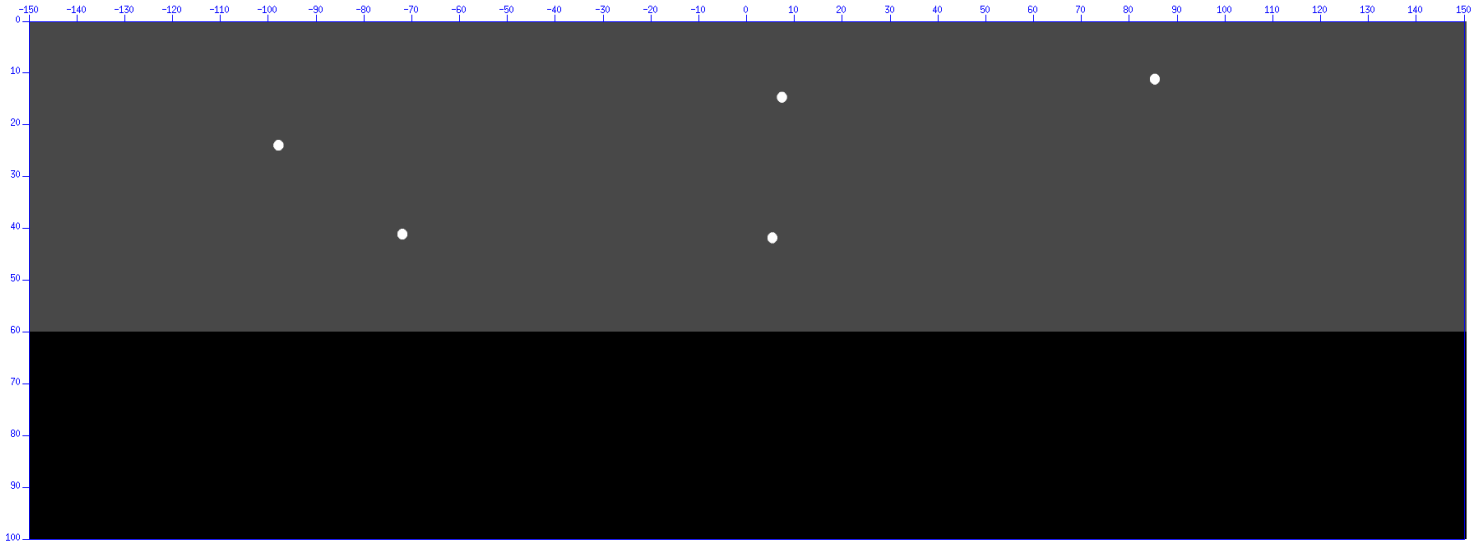


Moho model with 5 smaller scatterers



- 5 scatterers: diameter of 2 km and -15% contrast
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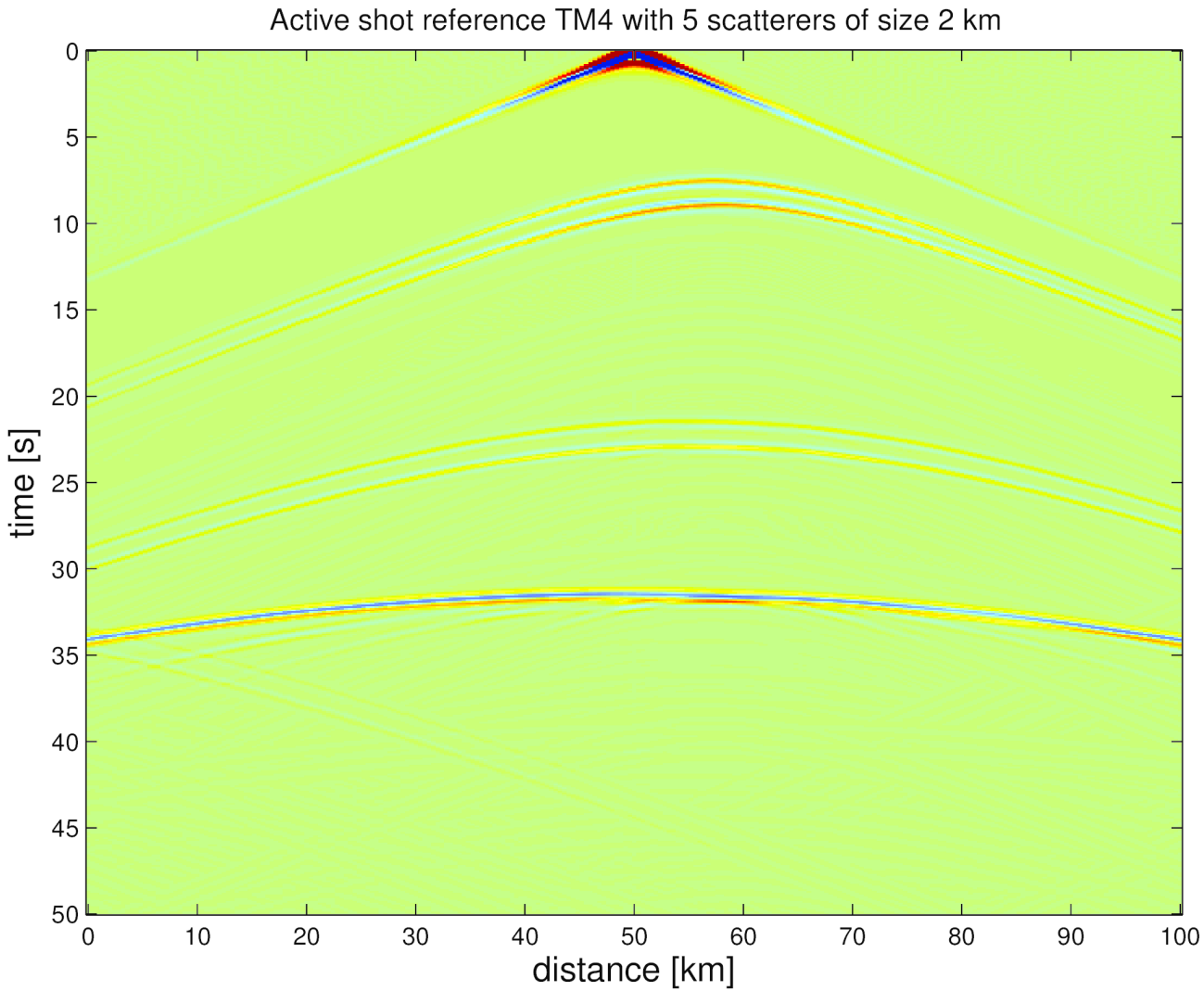
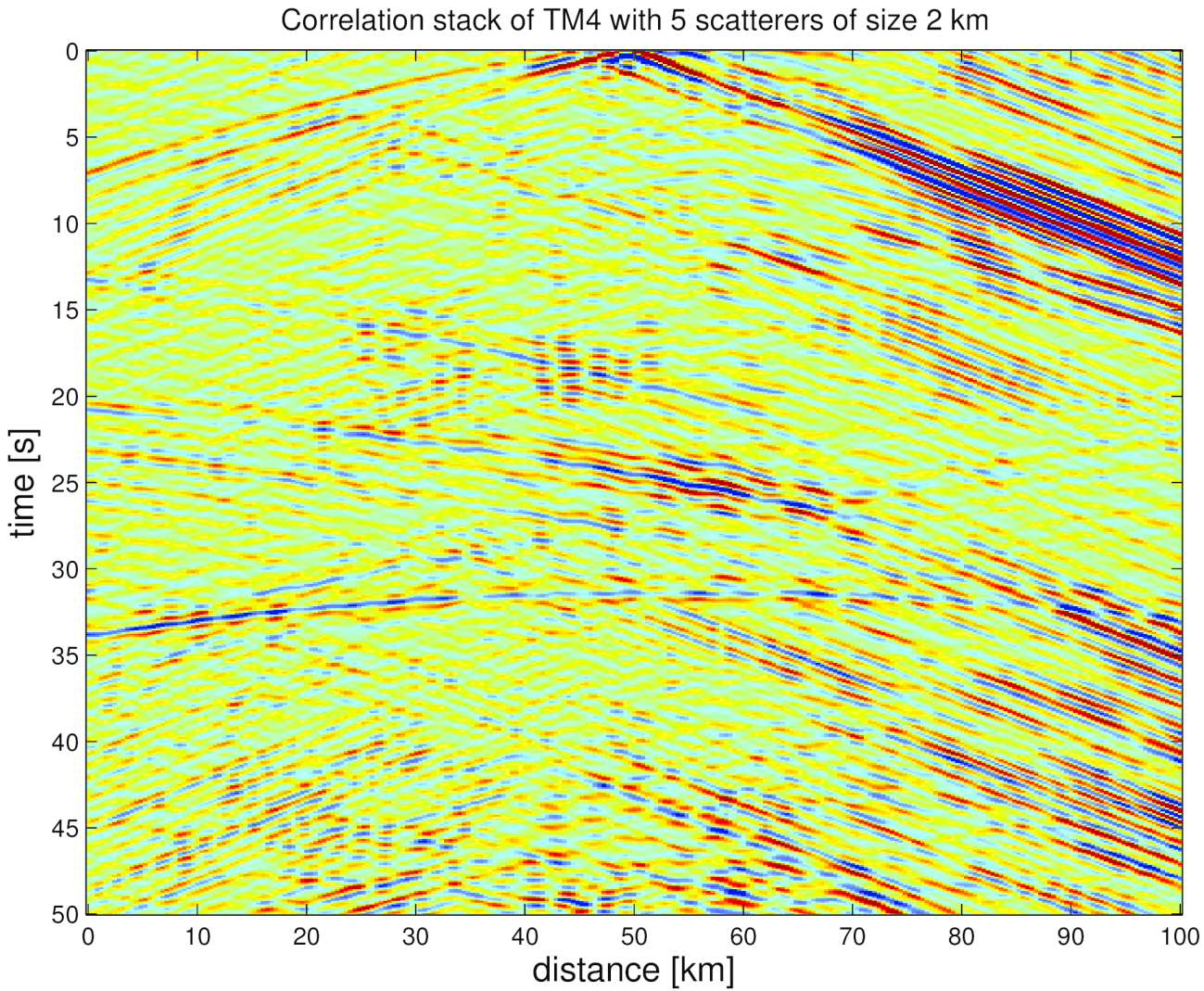


Moho model with 5 smaller scatterers

- Cross-correlogram with virtual source at the center



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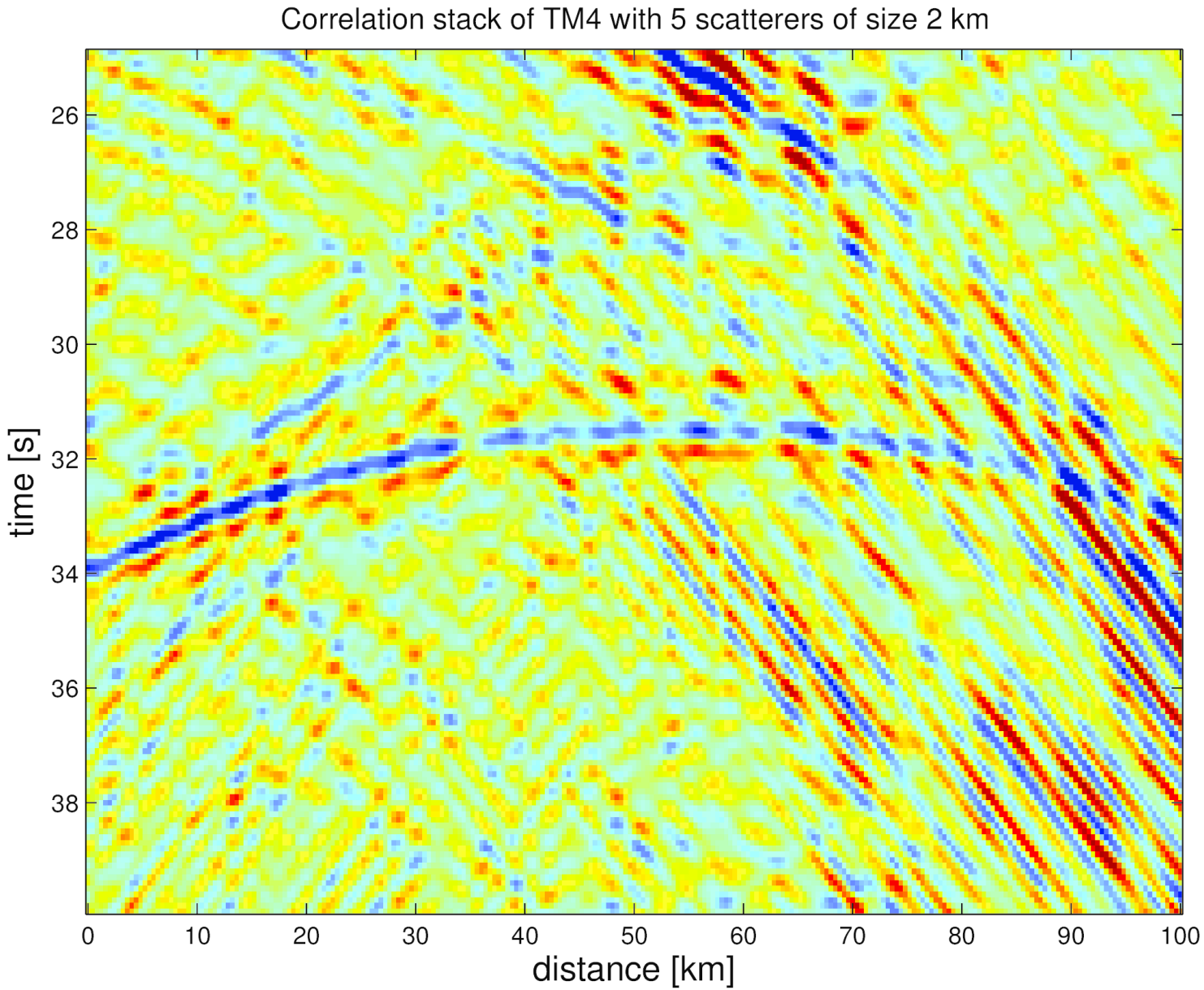

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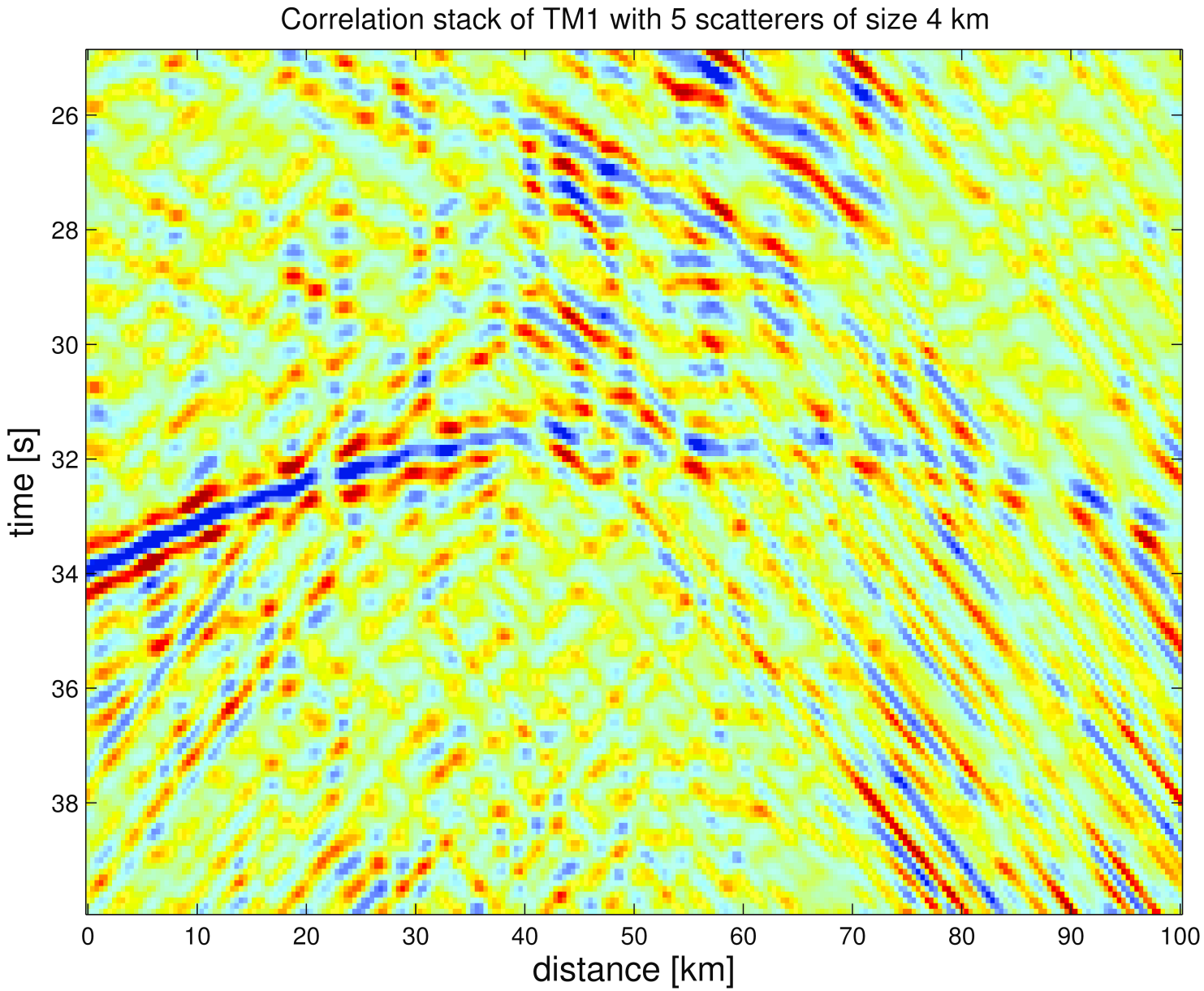

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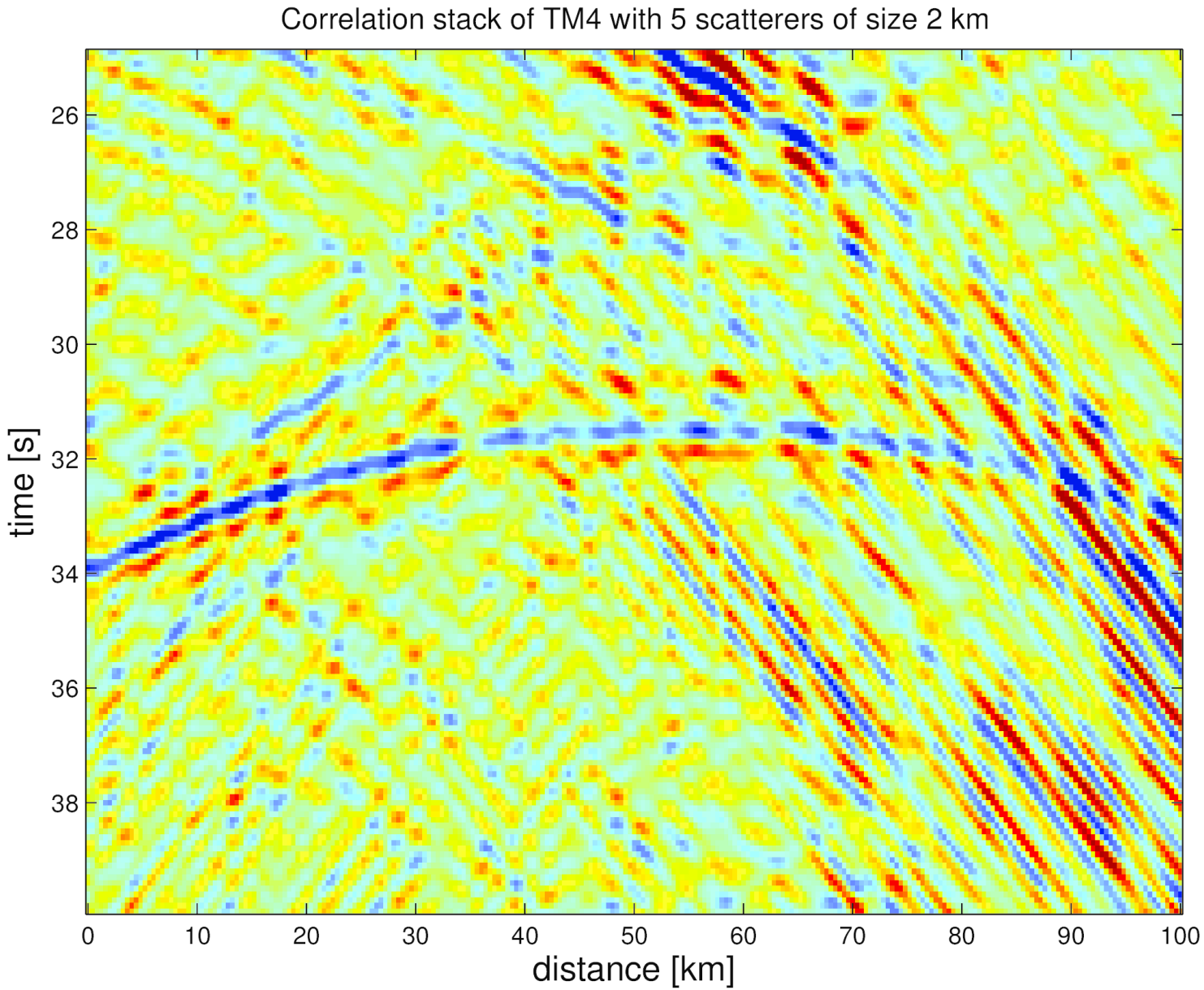

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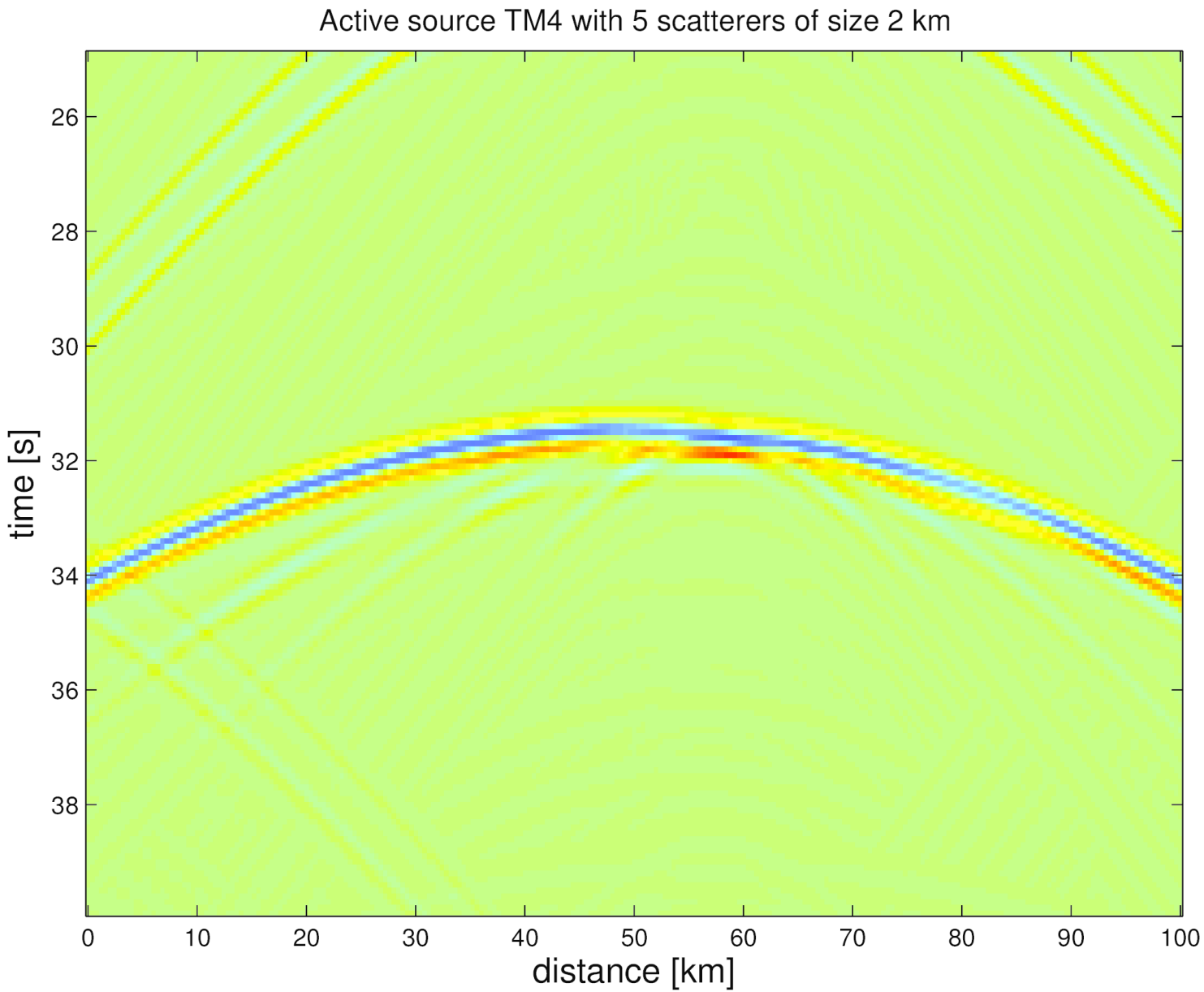
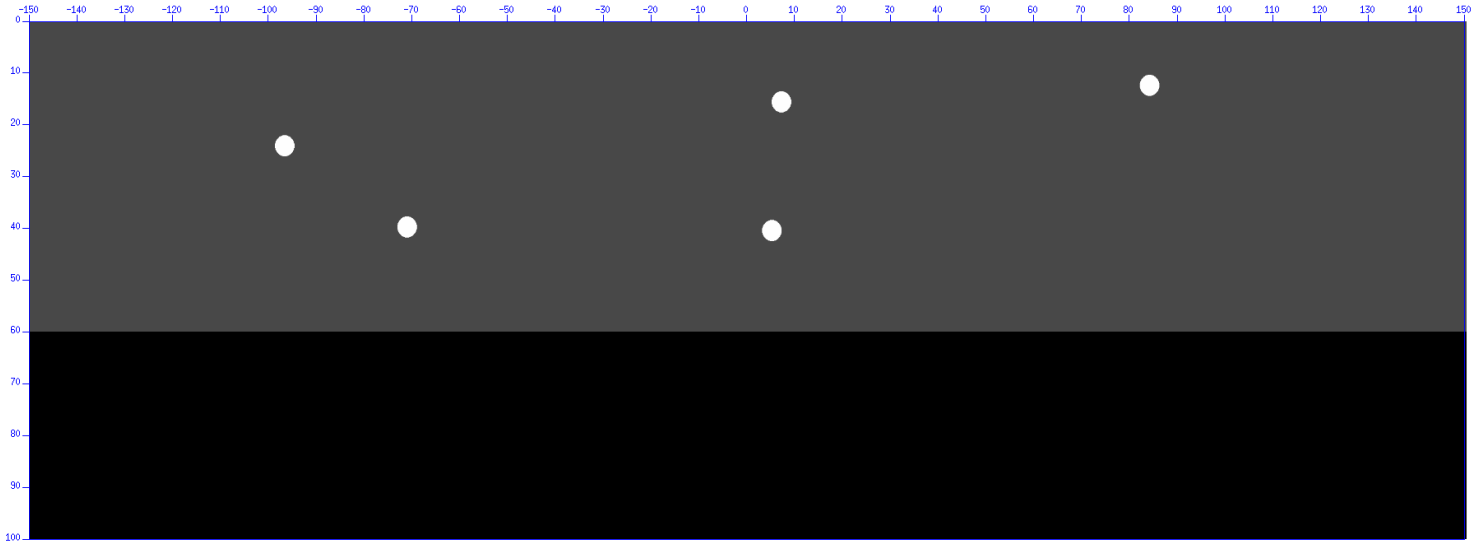


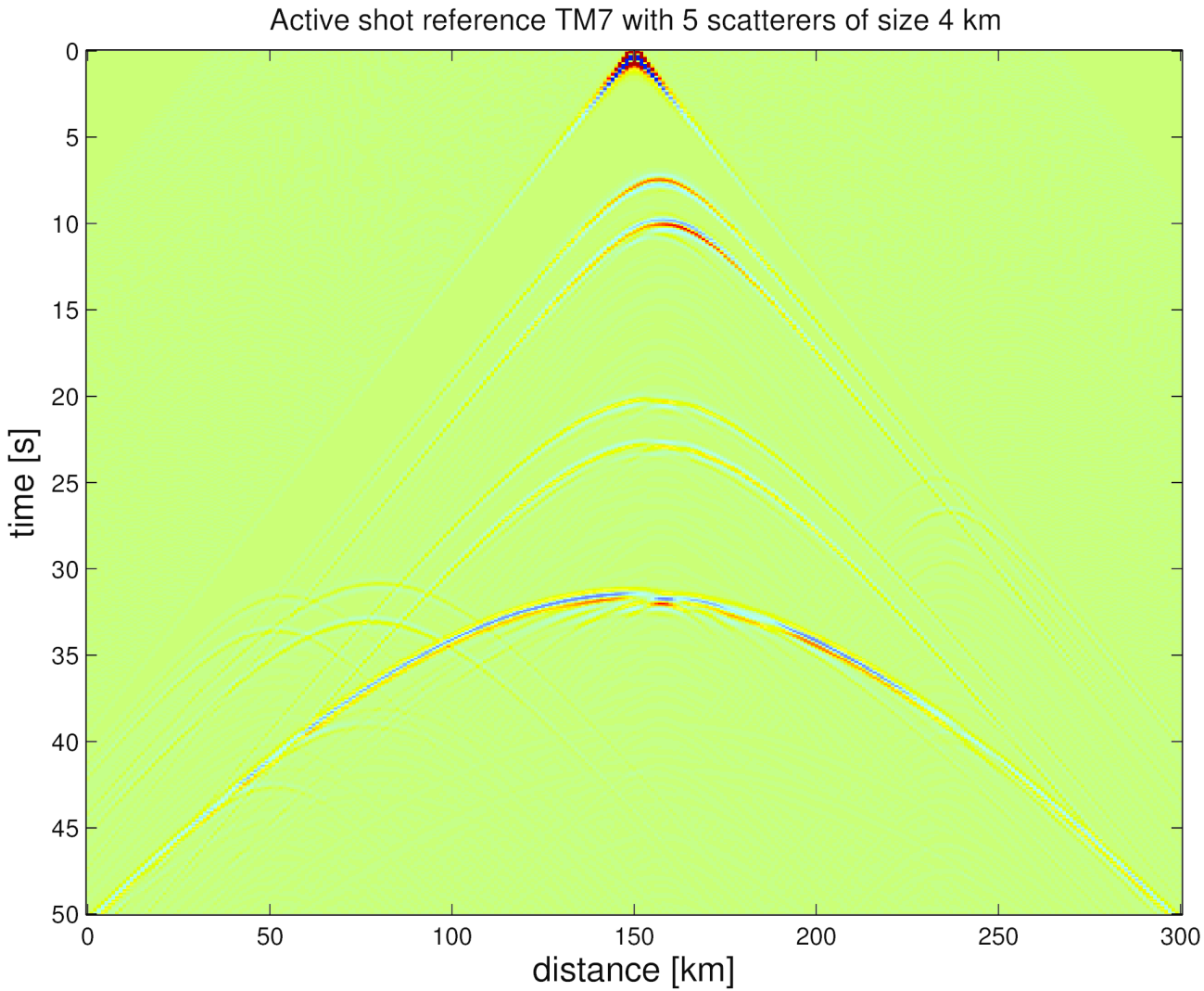
Moho model with 5 scatterers and 300 km array



- 5 scatterers: diameter of 4 km and -15% contrast
- 300 km long array with 1 km spacing
- 20 crustal sources far offset from middle
- Ricker wavelet with bandwidth 0.5-3 Hz

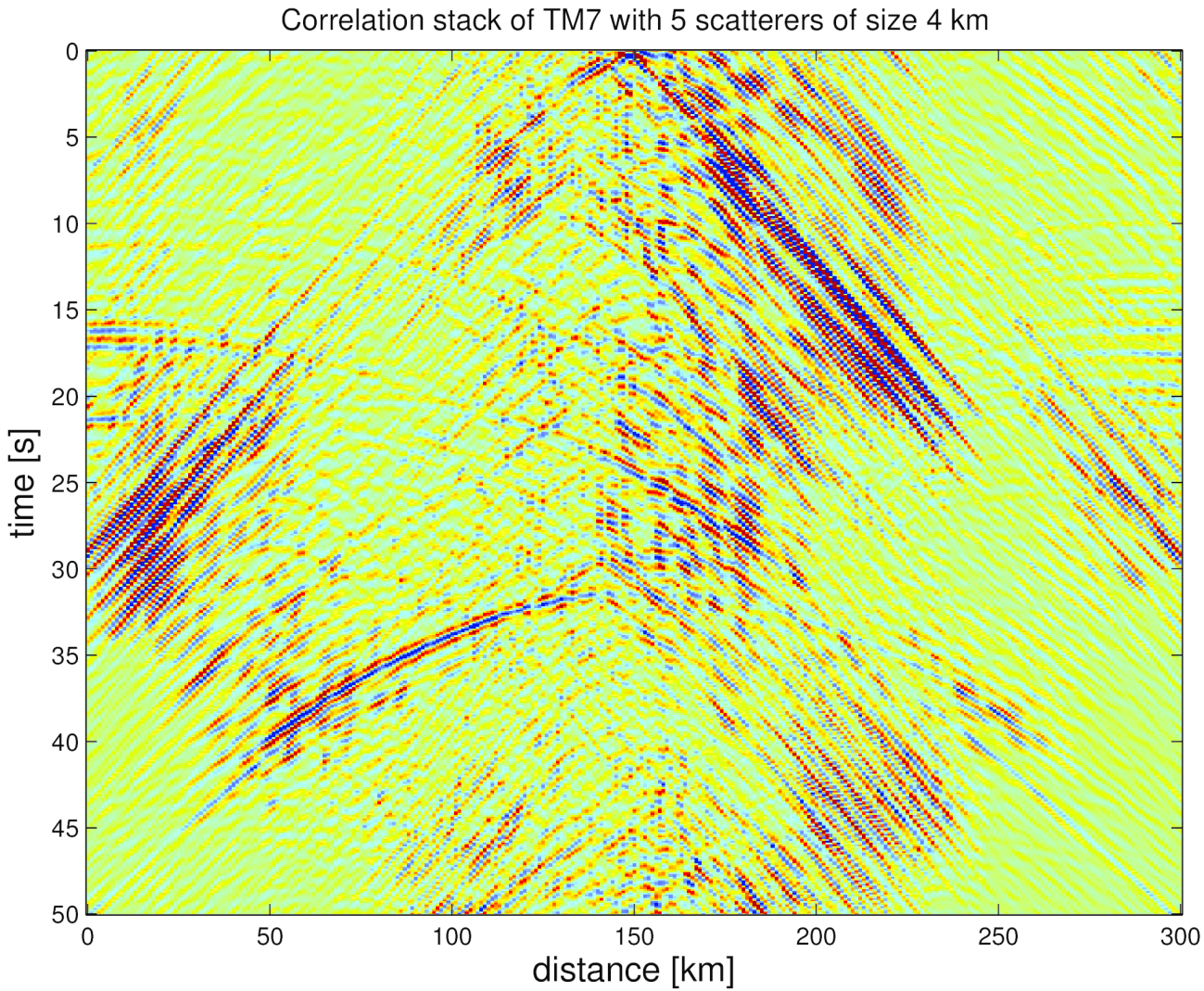
Moho model with 5 scatterers and 300 km array

- Active source at the center



Moho model with 5 scatterers and 300 km array

- Cross-correlogram with virtual source at the center



Hi-CLIMB equivalent array

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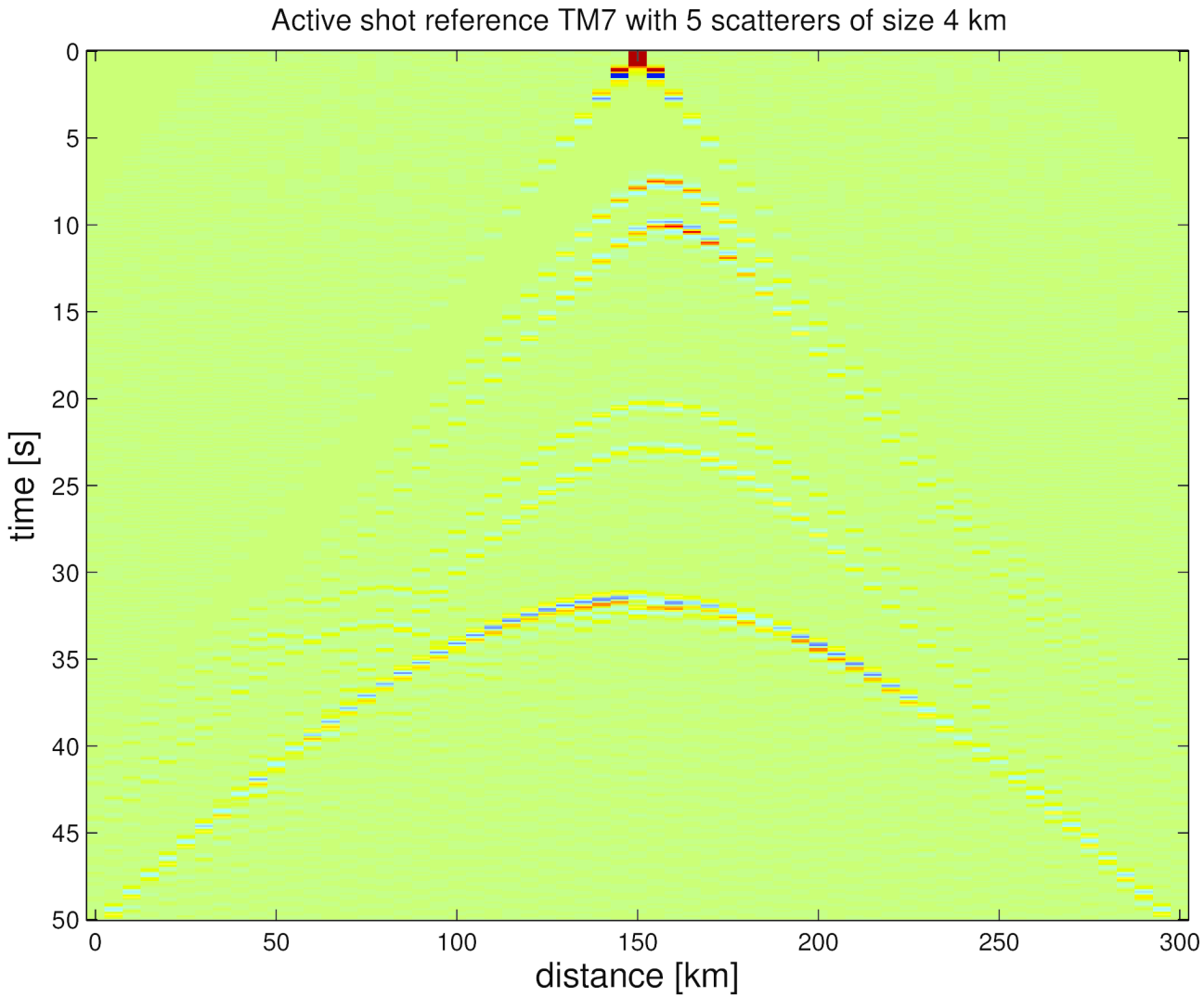

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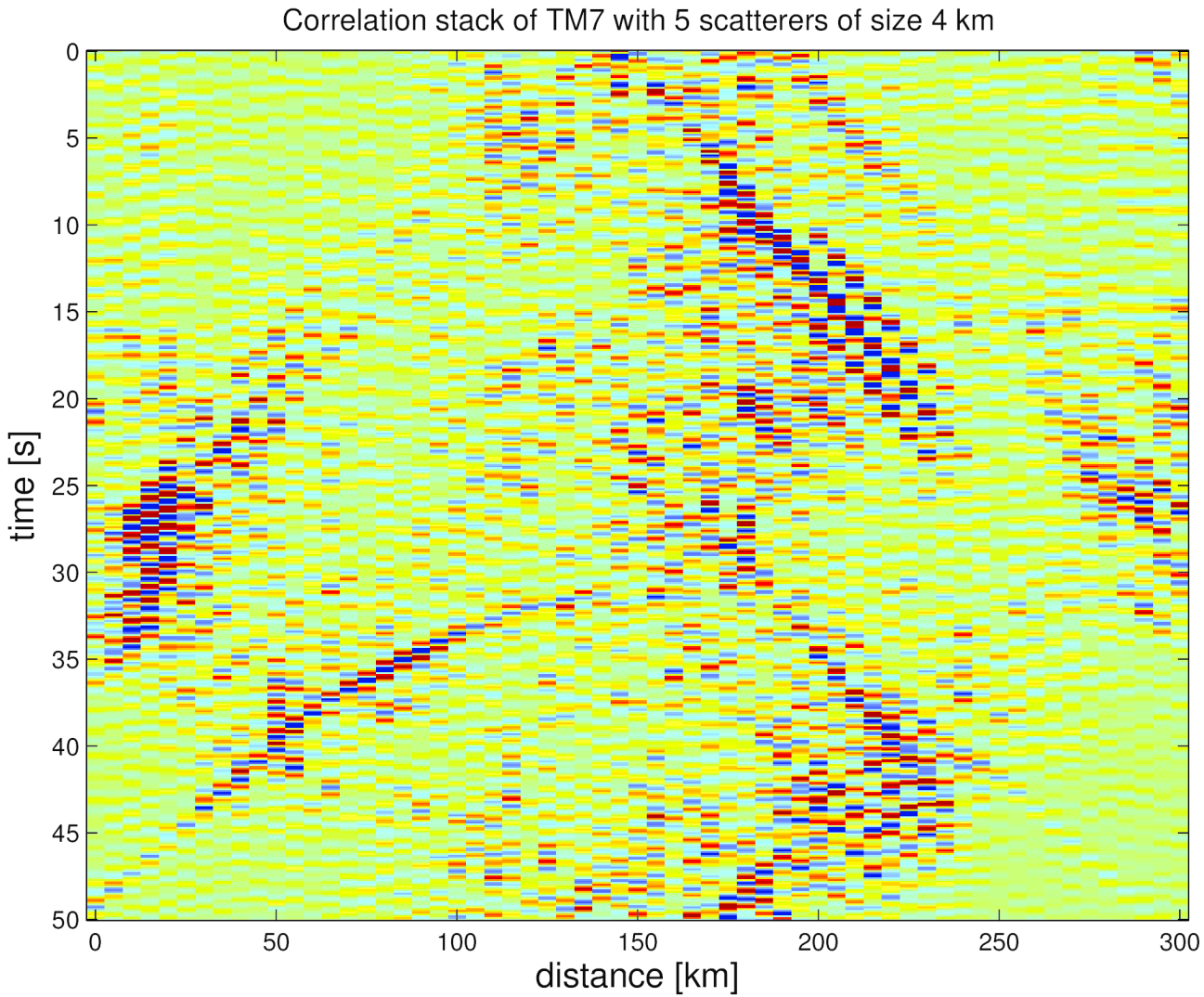

Conclusions

1. Scatterers generate low wavenumbers and thus increase illumination of the image target
2. Scatterers can introduce additional artifacts
3. Size and location of scatterers influences the retrieval of the reflection
4. Too high density of effective scatterers adversely affects the retrieval

Outlook to reality

- Heterogeneity in the crust prevails over a wide range of scales and is region dependent
- The optimal effective heterogeneity of the crust can be set by applying a bandpass filter to the recorded wavefield