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Applications of the Common-Reflection-Surface Stack

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Overview

- Summary and history
- Comparison of different stacking operators
- Eigenwave based CRS stacking operator
- Synthetic example: data-derived vs. forward modelled attributes
- Real data example: imaging a salt dome
- Conclusions and outlook

History and recent developments

The history as well as the recent developments of various macro-model independent imaging methods were discussed during the

Workshop on Macro-model Independent Imaging

in Karlsruhe, Germany, February 1999.

The proceedings of this workshop will be published in a special issue of the

Journal of Applied Geophysics

in spring 2000.

Similar approaches: Polystack

de Bazelaire (1986)

In the CMP gather:

$$\left(t(h) - t_0 + t_p^b\right)^2 = t_p^{b2} + 4\frac{h^2}{v_0^2} \quad \text{with} \quad t_p^b = \frac{2}{v_0}\frac{R_{NIP}}{\cos^2\alpha}$$

In the ZO section:

$$\left(t(x_m) - t_v + t_p^a\right)^2 = t_p^{a2} + \frac{(x_m - x_v)^2}{v_0^2} \quad \text{with}$$

$$x_v = x_0 - R_N \sin\alpha\,, \quad t_v = t_0 + \frac{2}{v_0}R_N\left(\cos\alpha - 1\right)\,, \quad t_p^a = \frac{2}{v_0}R_N\cos\alpha$$

Similar approaches: Multifocusing

Berkovitch et al. (1994)

$$\Delta\tau = \frac{\sqrt{(R^+)^2 + 2R^+\Delta X^+ \sin\beta + (\Delta X^+)^2} - R^+}{V_0} + \frac{\sqrt{(R^-)^2 + 2R^-\Delta X^- \sin\beta + (\Delta X^-)^2} - R^-}{V_0},$$

with $R^\pm = (1 \pm \sigma)/(1/R_N \pm \sigma/R_{NIP})$,

$$\sigma = (\Delta X^+ - \Delta X^-)/\left(\Delta X^+ + \Delta X^- + \frac{2\Delta X^+ \Delta X^- \sin\beta}{R_{NIP}}\right)$$

References

Berkovitch, A., Gelchinsky, B., and Keydar, S. (1994). Basic formulae for multifocusing stack. In *Extended Abstracts*, volume 94, page Session: P140.

de Bazelaire, E. (1988). Normal moveout revisited – inhomogeneous media and curved interfaces. *Geophysics*, 53(2):143–157.

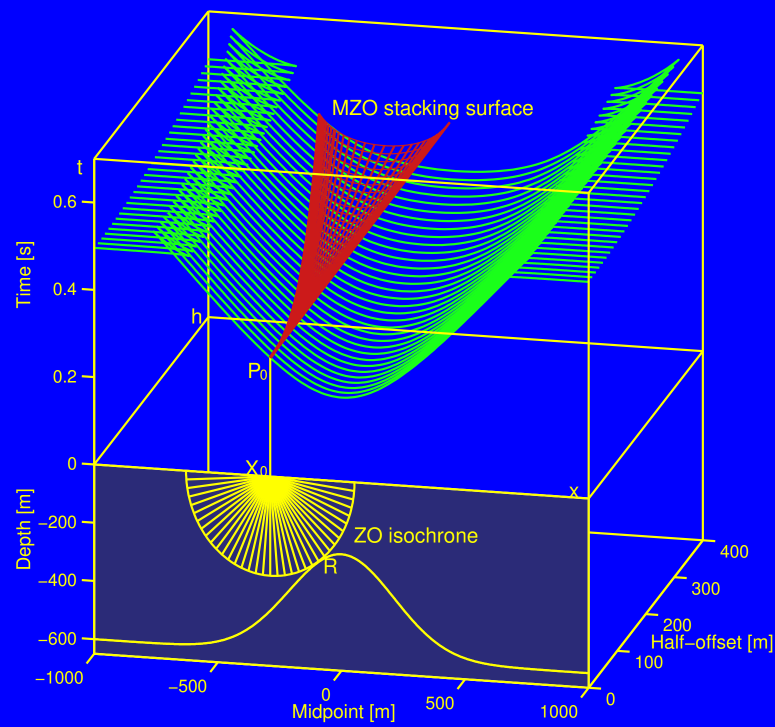
de Bazelaire, E. and Thore, P. (1987). Pattern recognition applied to time and velocity contours. In *Expanded Abstracts*, volume 87, page Session: POS2.14. Soc. Expl. Geophys.

Schleicher, J., Tygel, M., and Hubral, P. (1993). Parabolic and hyperbolic paraxial two-point traveltimes in 3D media. *Geophys. Prosp.*, 41(4):459–513.

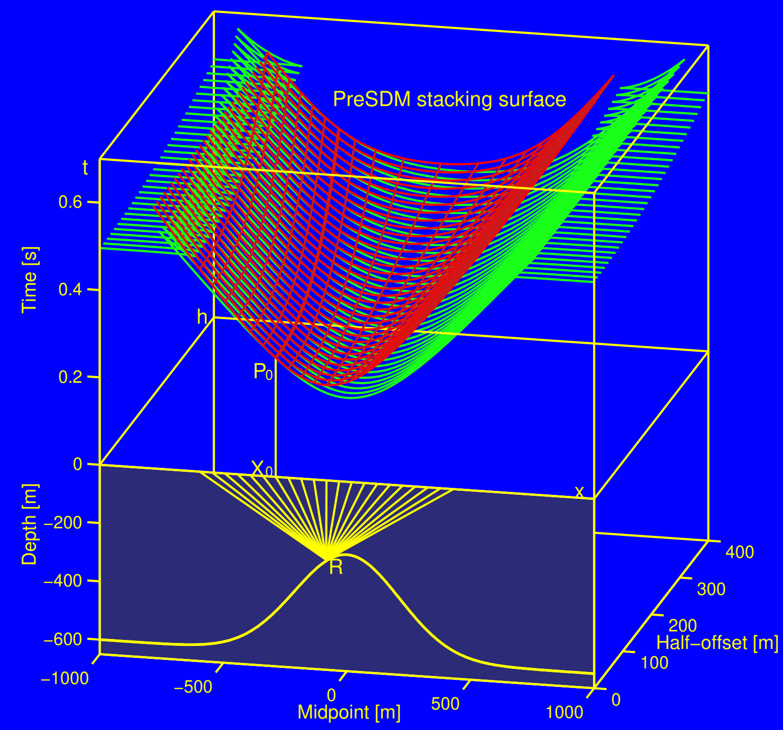
Summary

- Macro velocity model independent simulation of ZO sections from multi-coverage seismic reflection data
- CRS stacking operator depends on attributes of hypothetical wavefronts observed at the surface
- The “best” stacking operator is determined by maximizing coherence along stacking operator in multi-coverage data

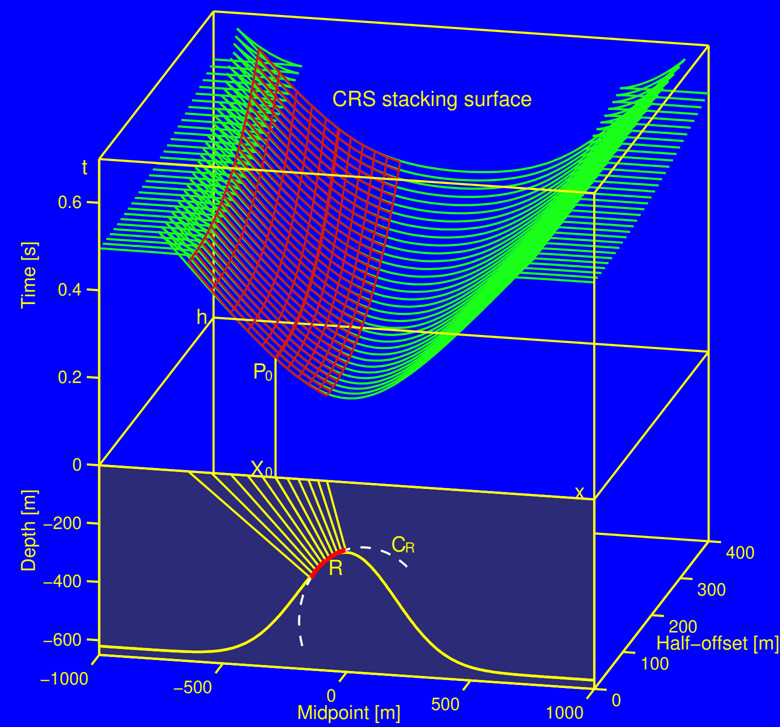
Stacking operator
of
NMO/DMO/stack



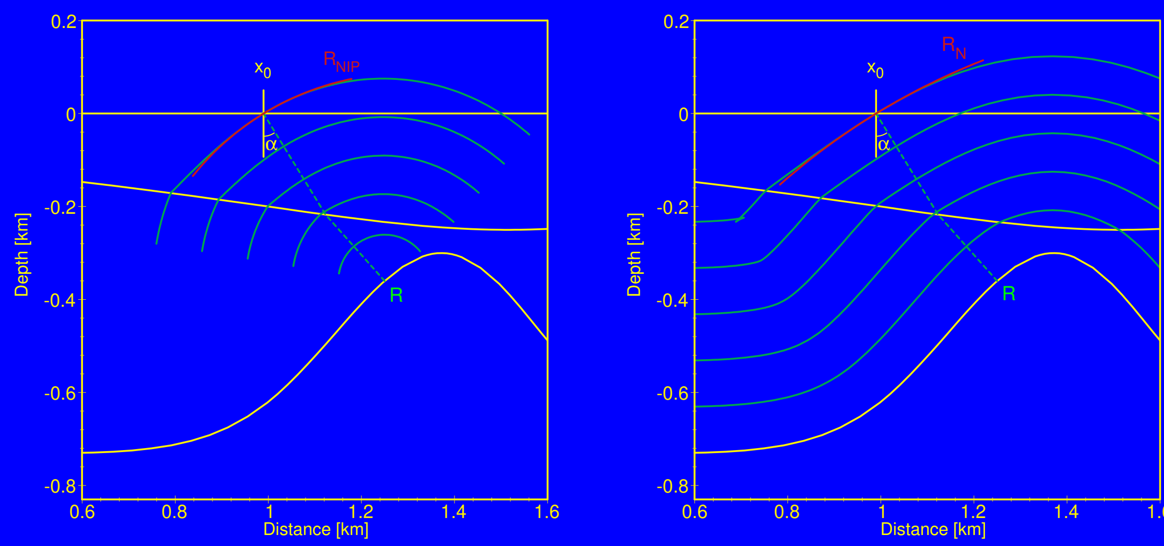
Stacking operator
of pre-stack
depth migration



CRS stacking operator



Hypothetical eigenwave experiments



CRS stacking operator

$$t^2(\Delta x, h) = \left(t_0 + \frac{2\sin\alpha\,\Delta x}{v_0}\right)^2 + \frac{2\,t_0\cos^2\alpha}{v_0}\left(\frac{\Delta x^2}{R_N} + \frac{h^2}{R_{NIP}}\right)$$

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h: half offset between shot and receiver
Δx: midpoint distance relative to the normal ray
α: emergence angle of the normal ray
R_{NIP}: radius of curvature of the NIP wave
R_N: radius of curvature of the normal wave

CRS operator in specific gathers

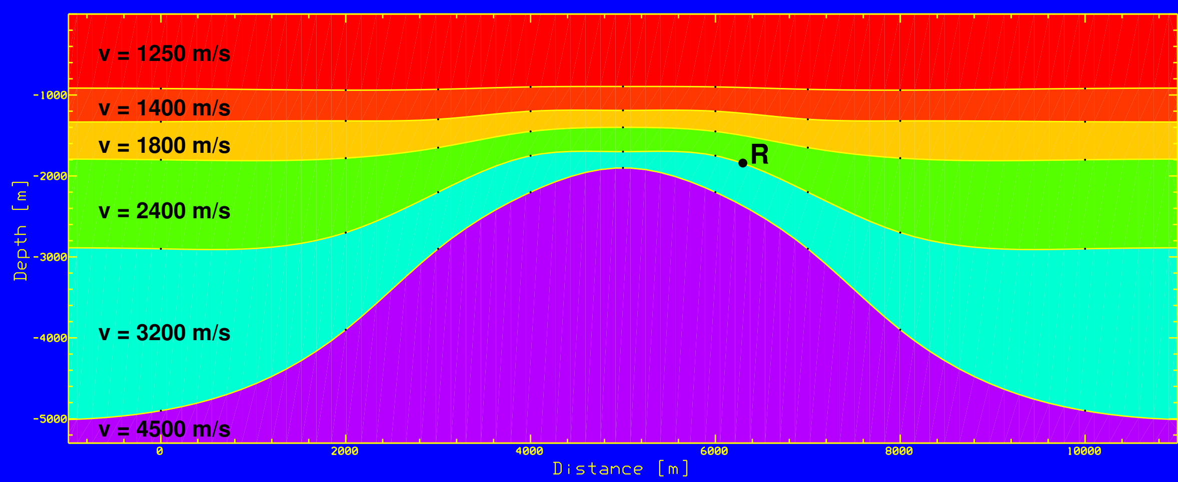
In the CMP gather in terms of the stacking velocity v_{NMO}:

$$t^2(h) = t_0^2 + \frac{4\,h^2}{v_{NMO}^2} \quad \text{with} \quad v_{NMO}^2 = 2\,v_0\,R_{NIP}/(t_0\cos^2\alpha)$$

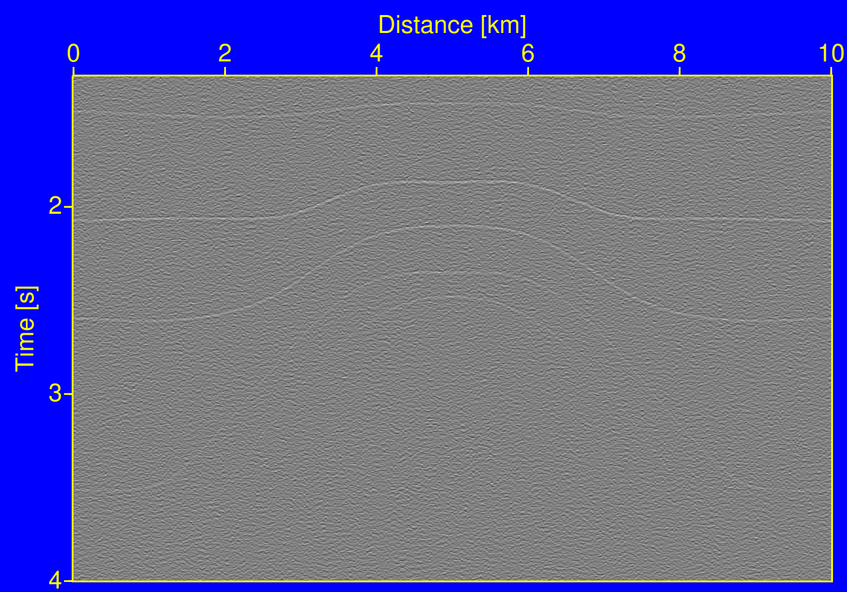
In the ZO section $(h=0)$:

$$t^2(\Delta x) = \left(t_0 + \frac{2\,\sin\alpha\,\Delta x}{v_0}\right)^2 + \frac{2\,t_0\,\cos^2\alpha}{v_0}\,\frac{\Delta x^2}{R_N}$$

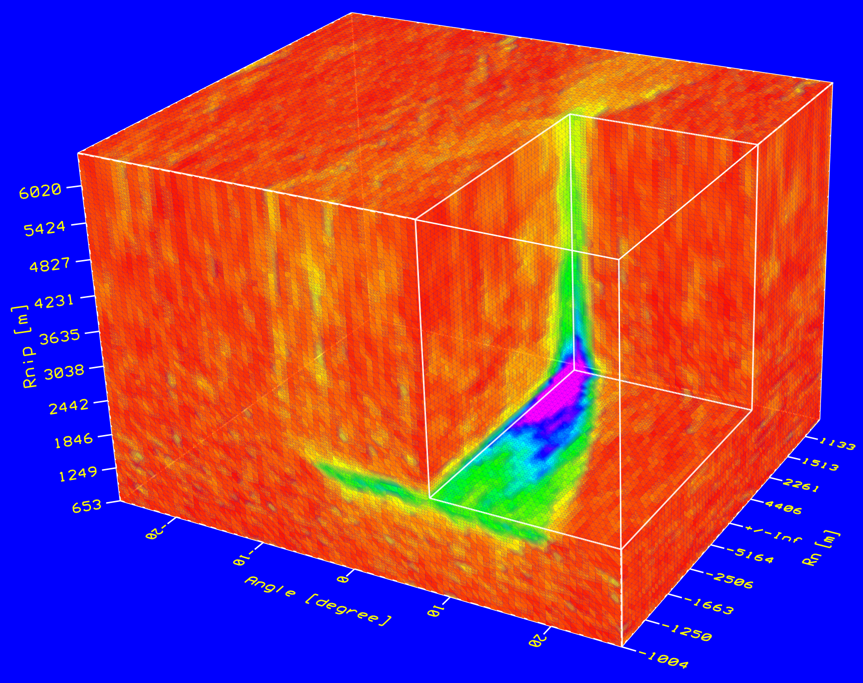
Synthetic example: model with homogeneous layers



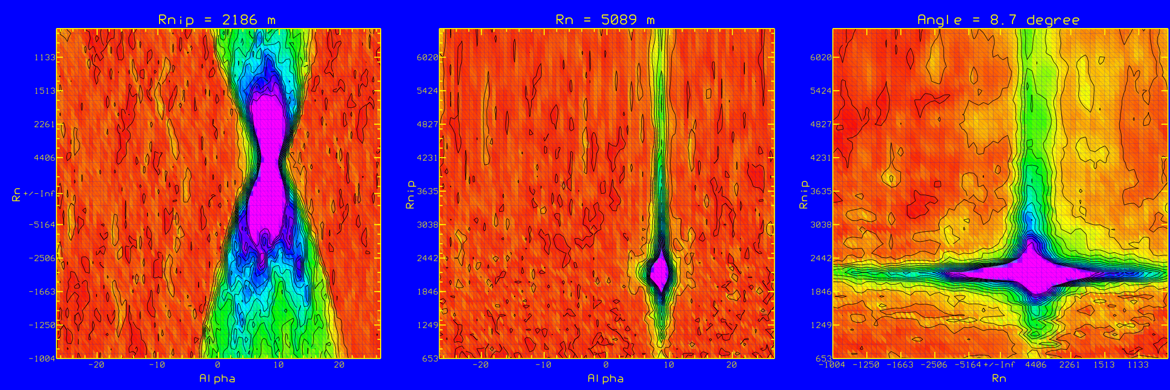
Synthetic example:
ZO section of multi-coverage data



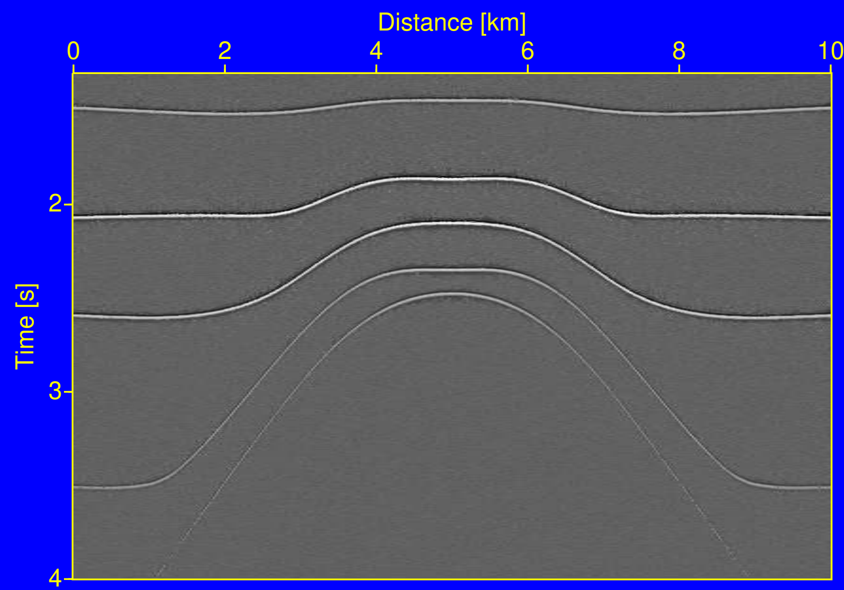
Coherence in the wavefield attribute domain



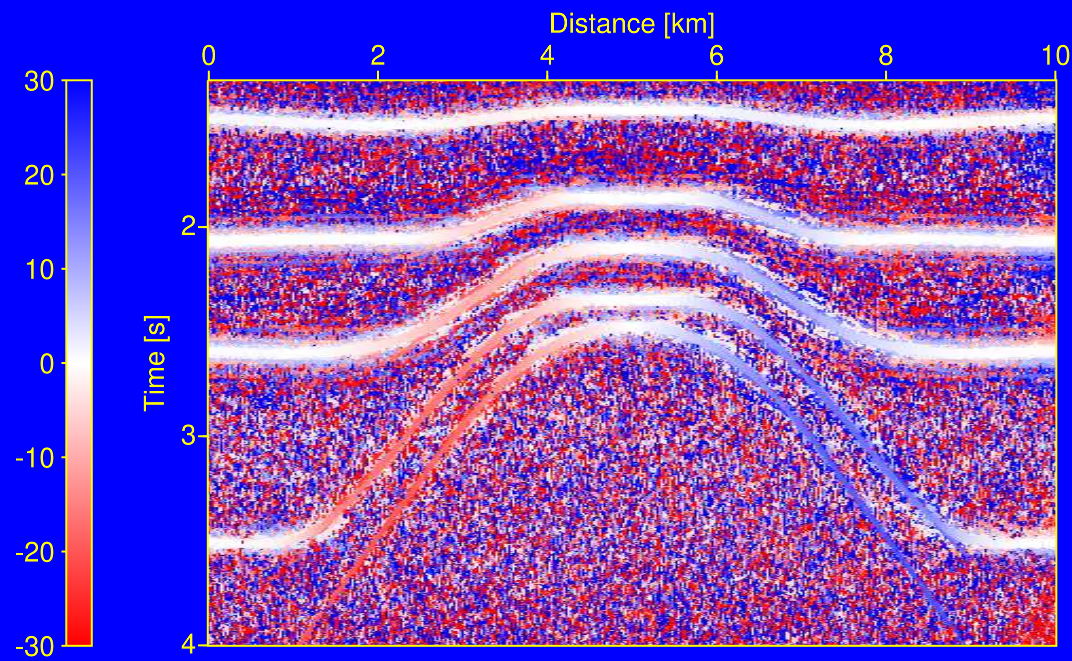
Coherence in the wavefield attribute domain: orthogonal slices through the global maximum

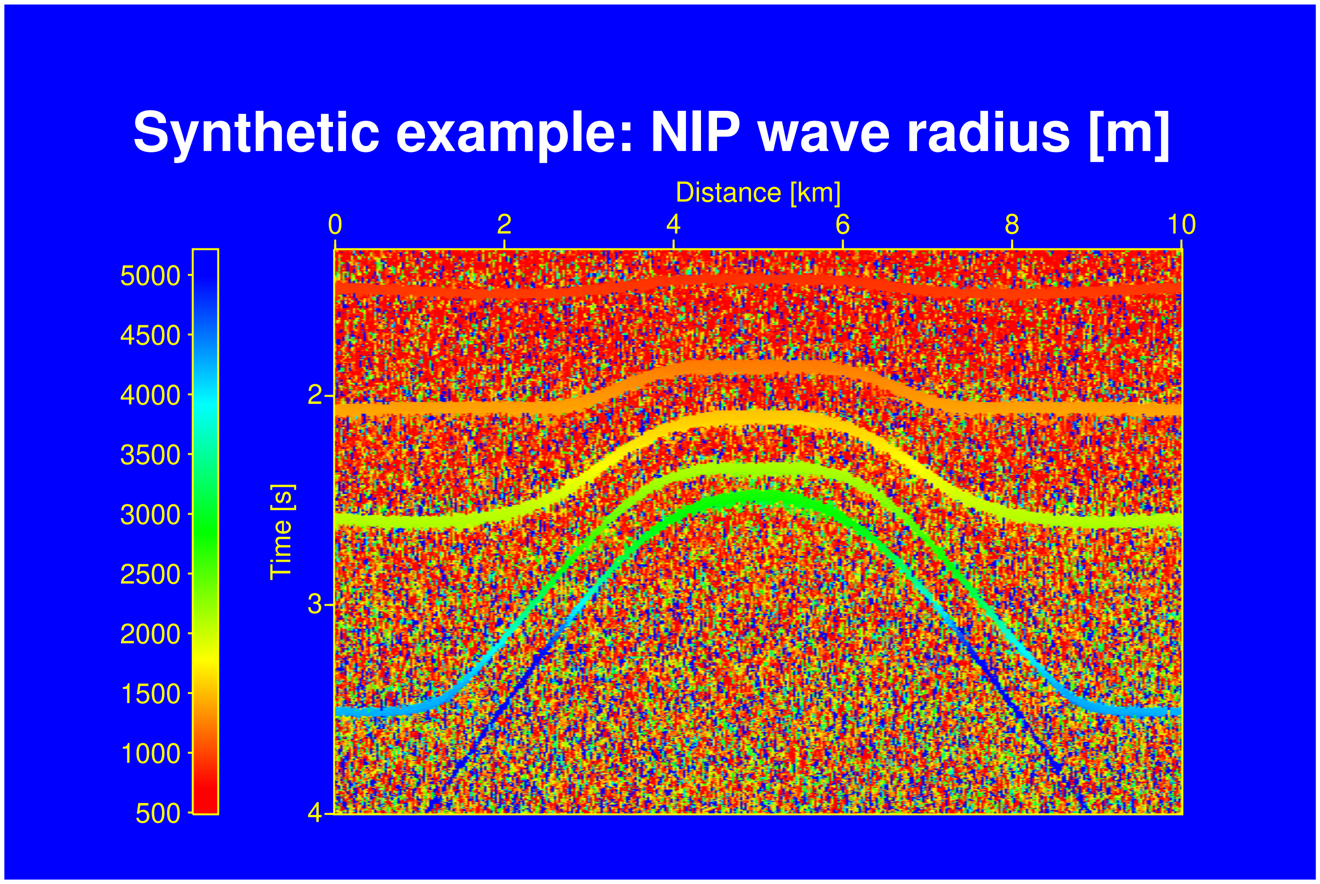


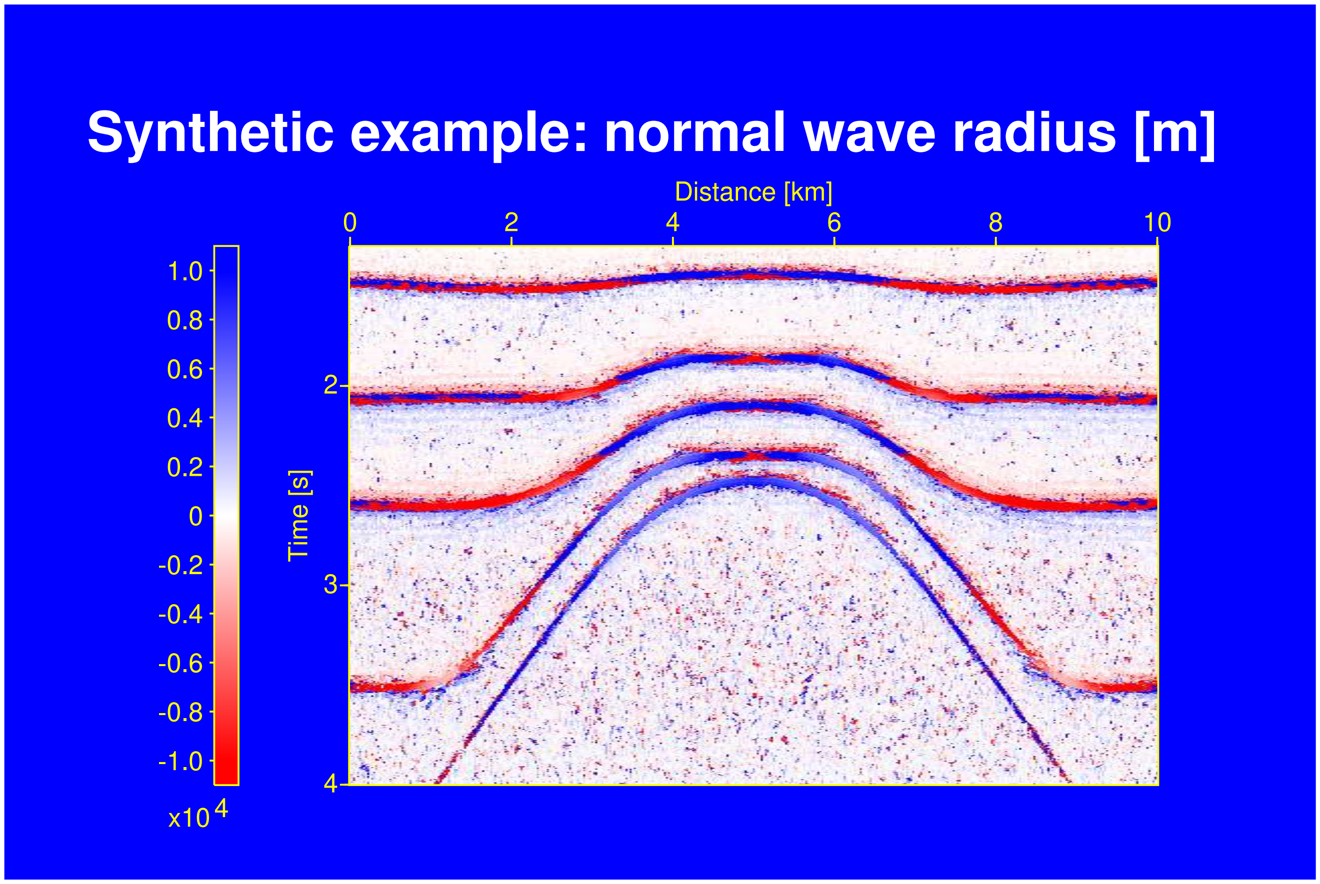
Synthetic example:
result of the optimized CRS stack



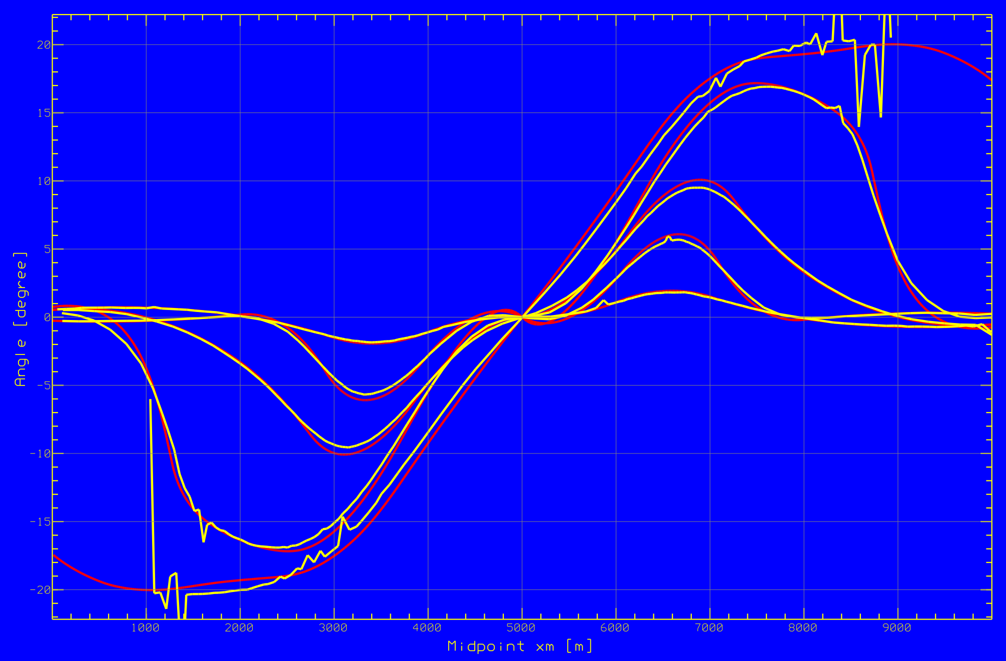
Synthetic example: angle of emergence [°]

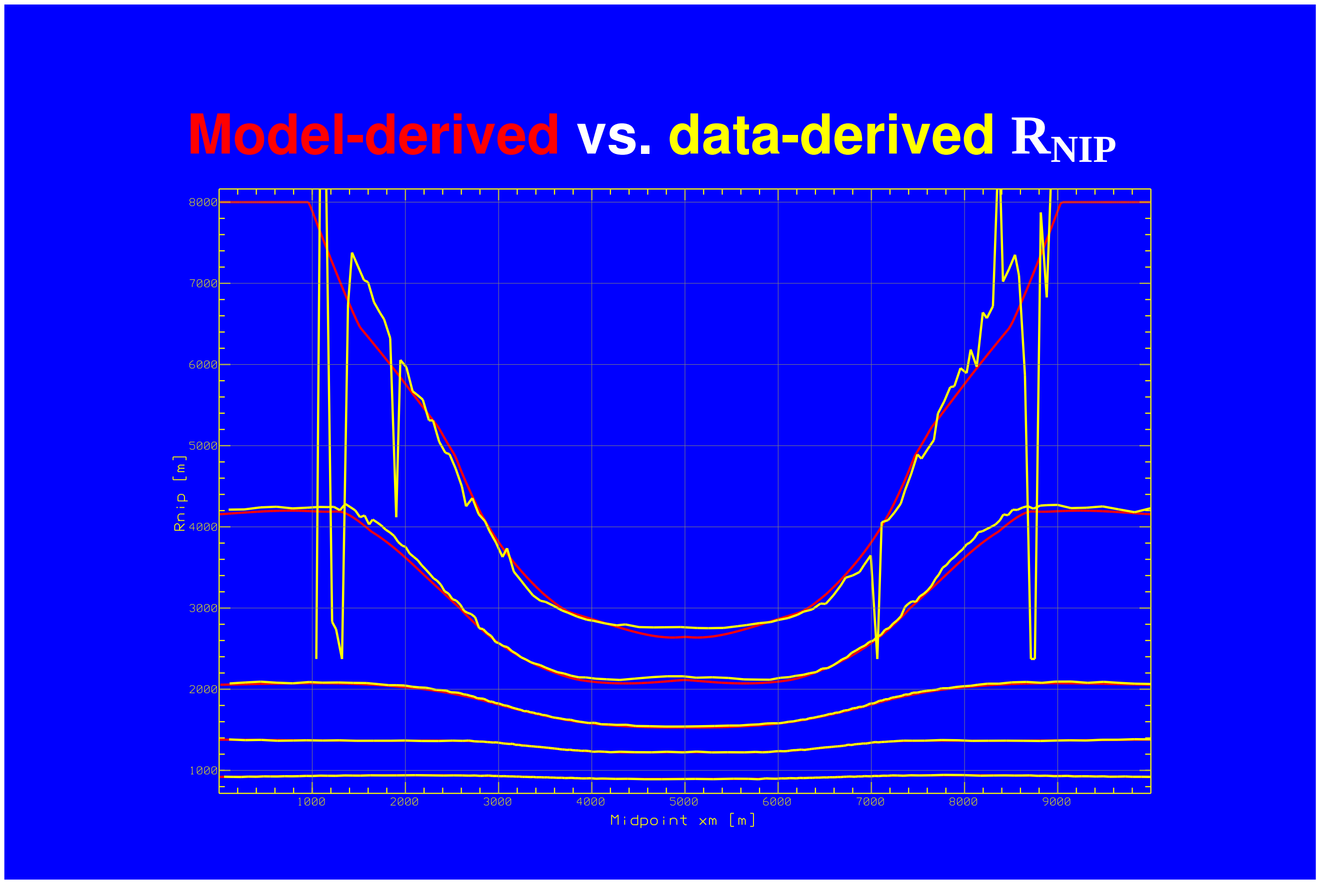



Synthetic example: NIP wave radius [m]
Distance [km]
0
2
4
6
8
10
Time [s]
2
3
4
5000
4500
4000
3500
3000
2500
2000
1500
1000
500


Synthetic example: normal wave radius [m]
Distance [km]
0
2
4
6
8
10
Time [s]
2
3
4
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
x10 4

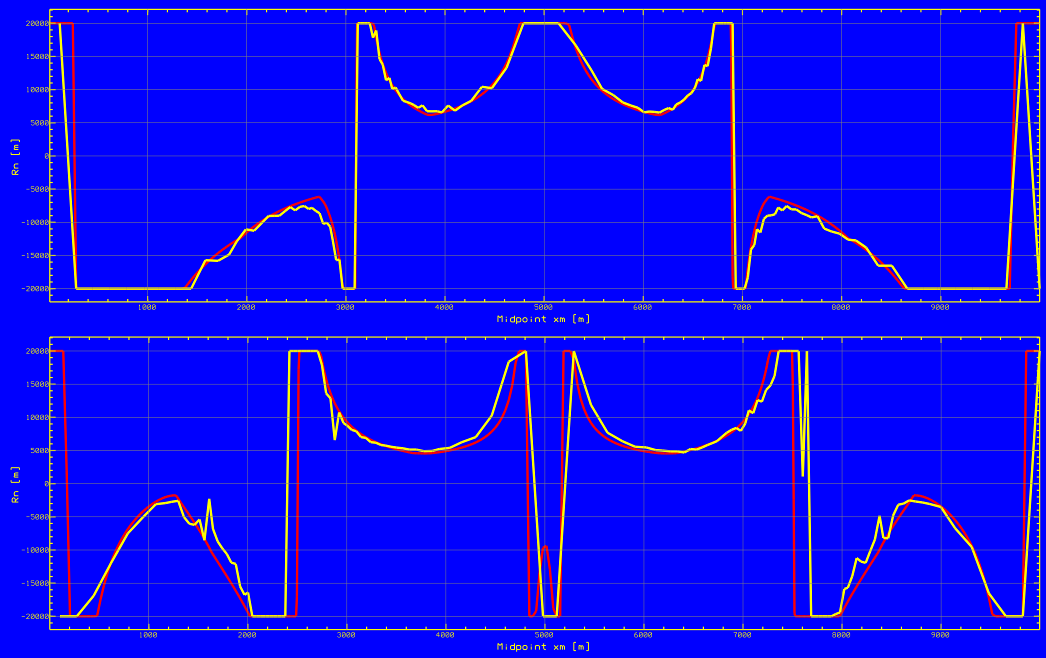
Model-derived vs. data-derived angle



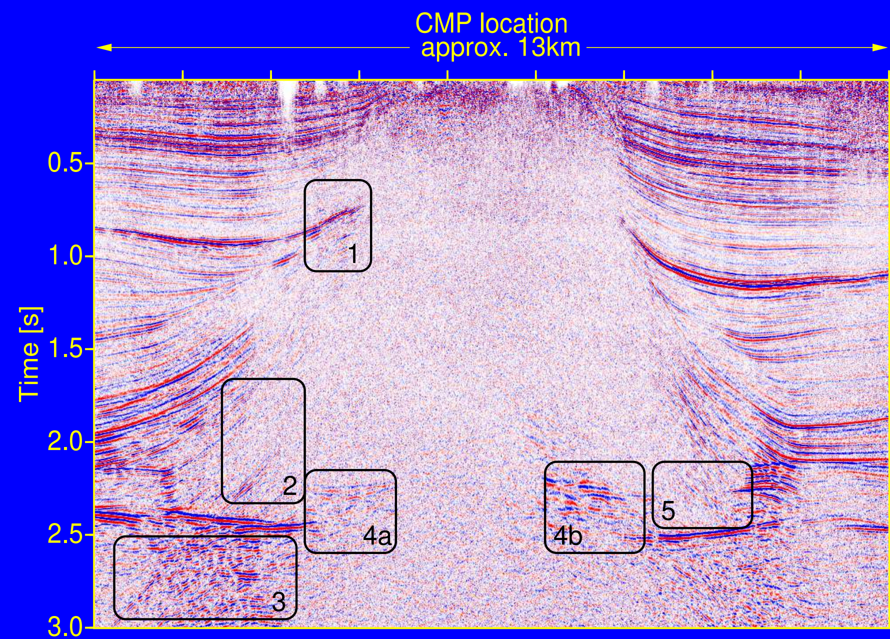


Model-derived vs. data-derived R_{NIP}
Rnip [m]
8000
7000
6000
5000
4000
3000
2000
1000
1000
2000
3000
4000
5000
6000
7000
8000
9000
Midpoint xm [m]

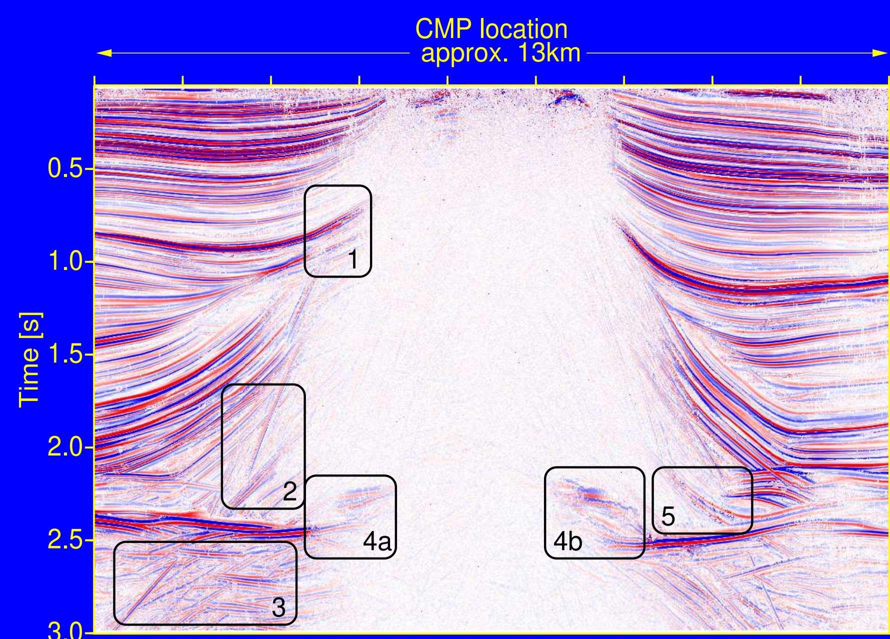
Model-derived vs. data-derived R_N



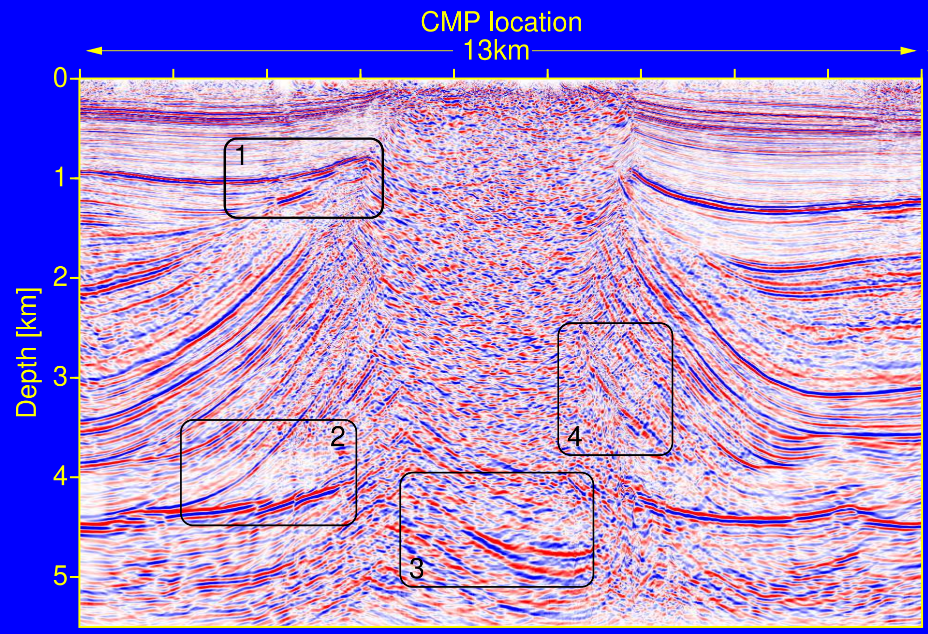
Real data example: NMO/DMO/stack



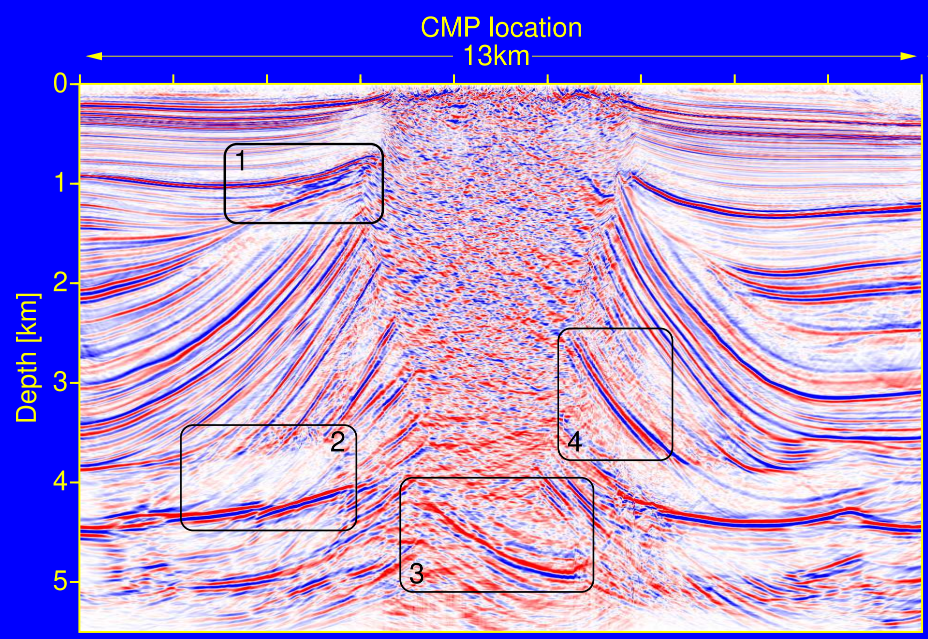
Real data example: optimized CRS stack



Post-stack depth migration NMO/DMO/stack



Post-stack depth migration of CRS stack



Conclusions & outlook (I)

The CRS stack is a model independent seismic imaging method and thereby can be performed without any ray tracing and macro velocity model estimation. Only the knowledge of the near surface velocity is required.

As a result of a CRS stack one obtains in addition to each simulated ZO reflection time important wavefield attributes: the angle of emergence and the radii of curvature of the *NIP* and the *normal* wave.

Conclusions & outlook (II)

The application to real and synthetic datasets showed noteworthy results with respect to the stack section and the determined attributes. In view of the authors, the proposed strategies offer an exciting approach to improve the stack section and to allow for a subsequent inversion.

Future research aims:

- Accounting for the conflicting dip problem
- Derivation of the size of the Fresnel zone from the wavefield attributes
- Inversion of the wavefield attributes to a depth model

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For more information about the
Common-Reflection-Surface Stack and our
other activities, please visit the

Wave Inversion Technology Consortium

in the consortium showcase.