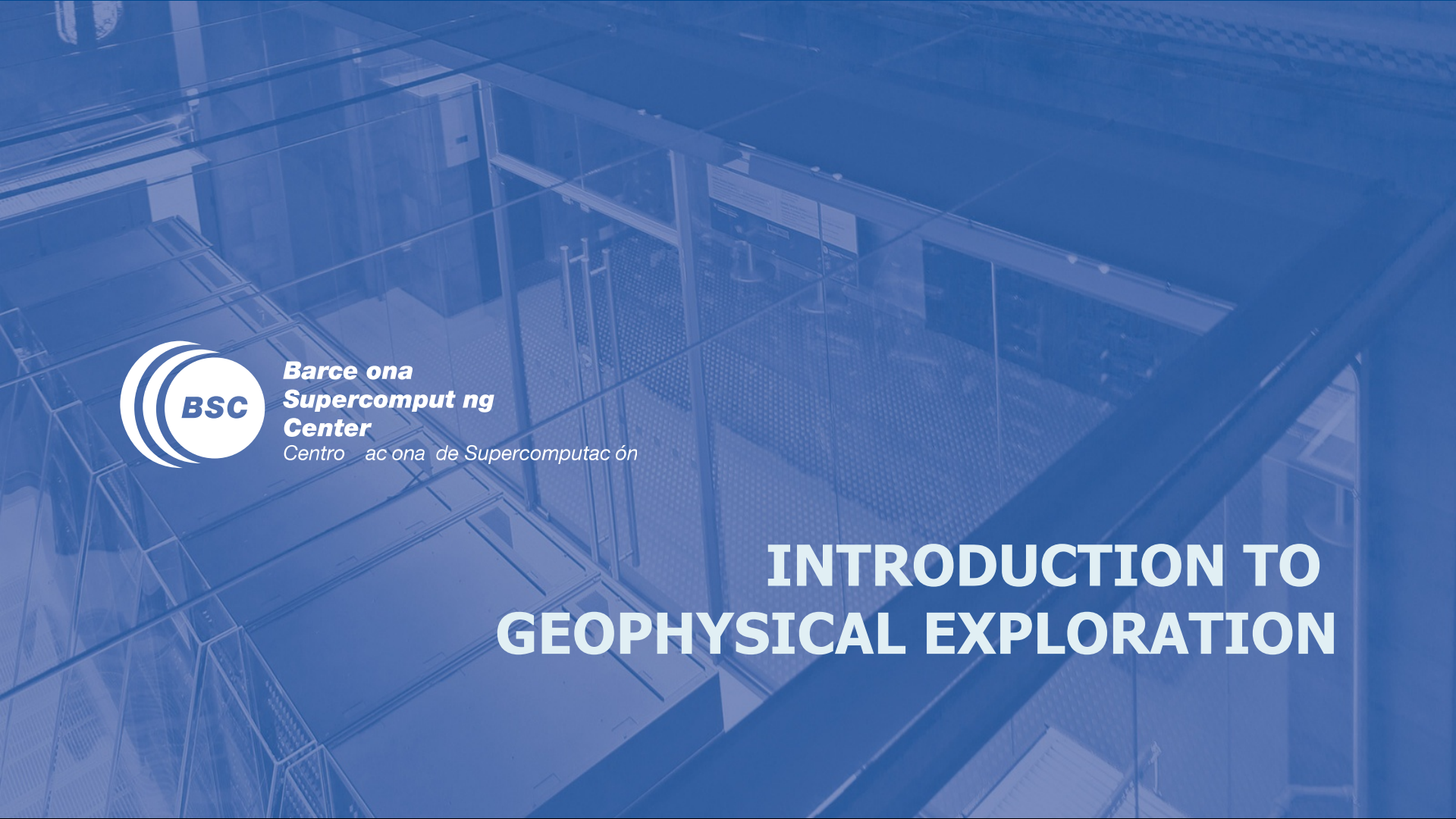
3D ELASTIC FULL WAVEFORM INVERSION : TOWARD REFLECTION BASED INVERSION

Jean Kormann, BSC-CNS CASE dpt.

CONTENT

1. Introduction to geophysical exploration
2. Full Waveform Inversion
3. Application to real dataset



INTRODUCTION TO GEOPHYSICAL EXPLORATION

Top500.org – November 2014

		SGI				
12	Exploration & Production - Eni S.p.A. Italy	**HPC2** - iDataPlex DX360M4, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband FDR, NVIDIA K20x IBM	72000	3,188.0	4,605.0	1,227
13	Government	Cray XC30, Intel Xeon E5-2697v2 12C	225984	3,143.5	4,881.3	
	United States					
20	Total Exploration Production France	**Pangea** - SGI ICE X, Xeon E5-2670 8C 2.600GHz, Infiniband FDR SGI	110400	2,098.1	2,296.3	2,118
21	LvLiang Cloud Computing Center	**Tianhe-2 LvLiang Solution** - Tianhe-2	174720	2,071.4	3,074.5	997
		Cray Inc.				
62	Saudi Aramco Saudi Arabia	**Faris** - Cluster Platform SL230s Gen8, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband QDR Hewlett-Packard	40960	816.6	917.5	
63	National Astronomical Observatory of	**Aterui** - Cray XC40, Xeon E5-2690v3 12C	25440	801.4	1,058.3	569

Top500.org – November 2015???

6.7

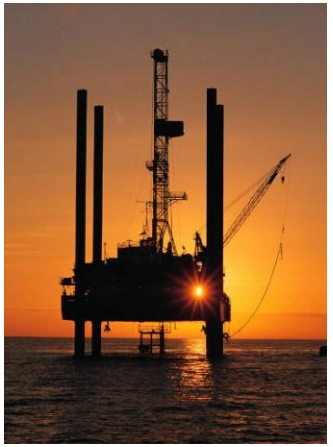
6.0

5.0

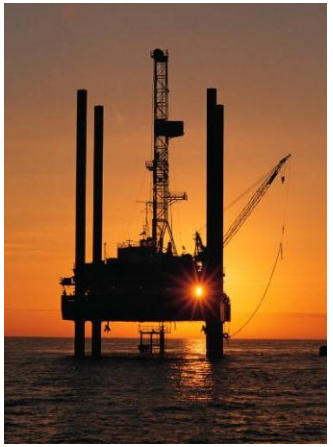
3.0

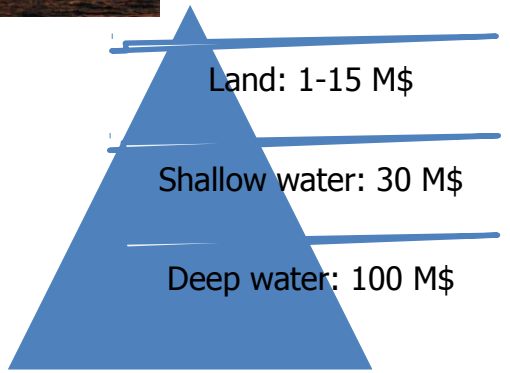
2.2

Oil and Gas Exploration



Oil and Gas Exploration



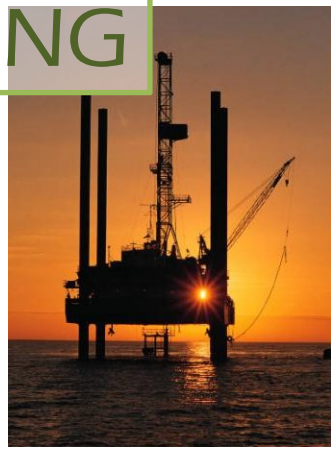


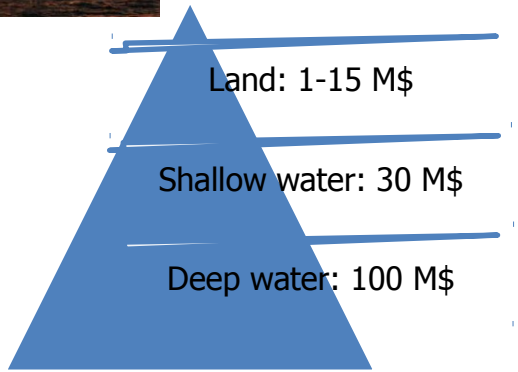
Oil and Gas Exploration

SUPERCOMPUTING

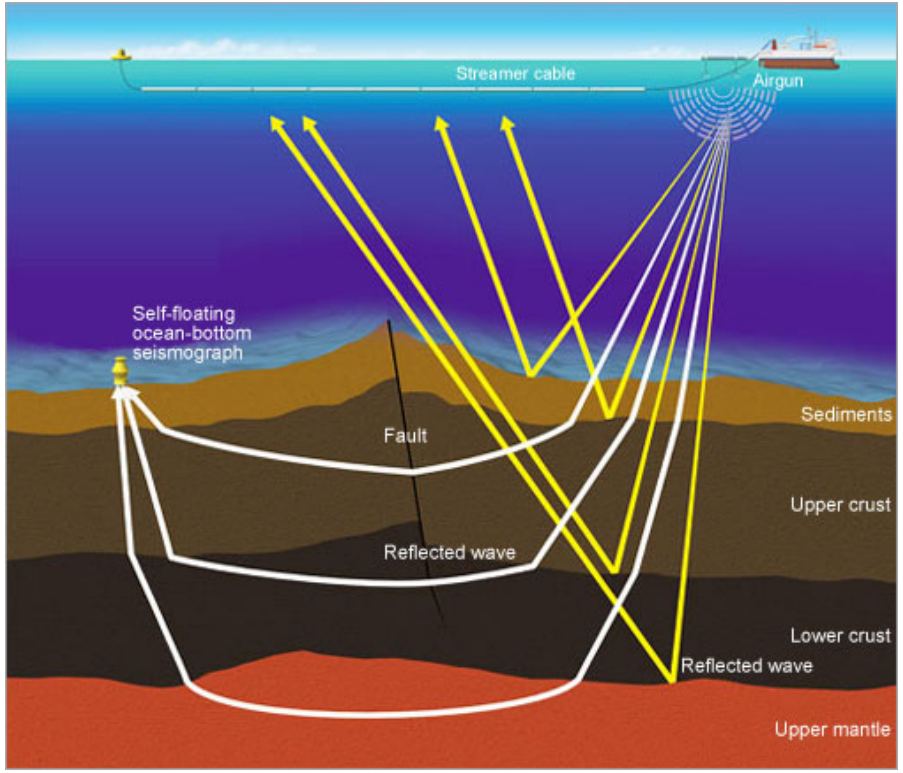
Processing

Interpretation





Transforming data into images



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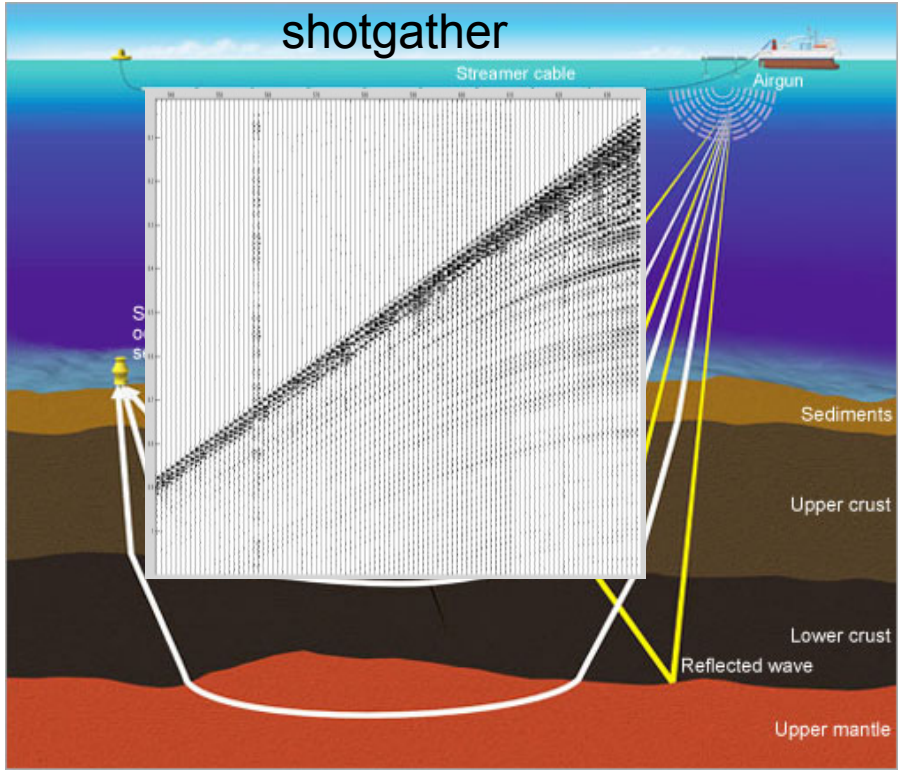
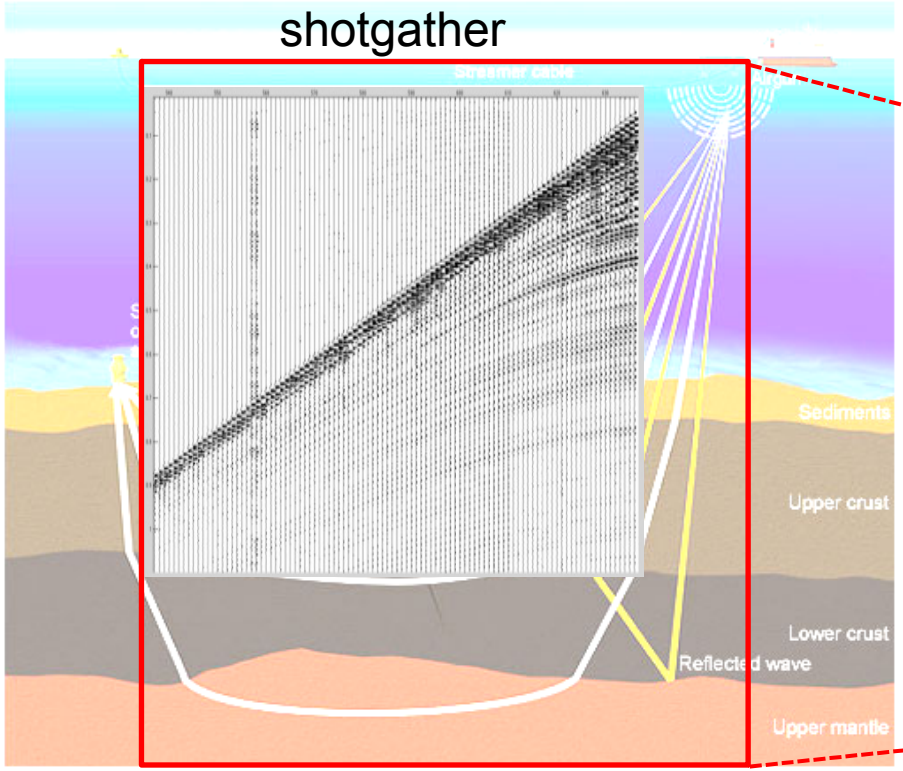
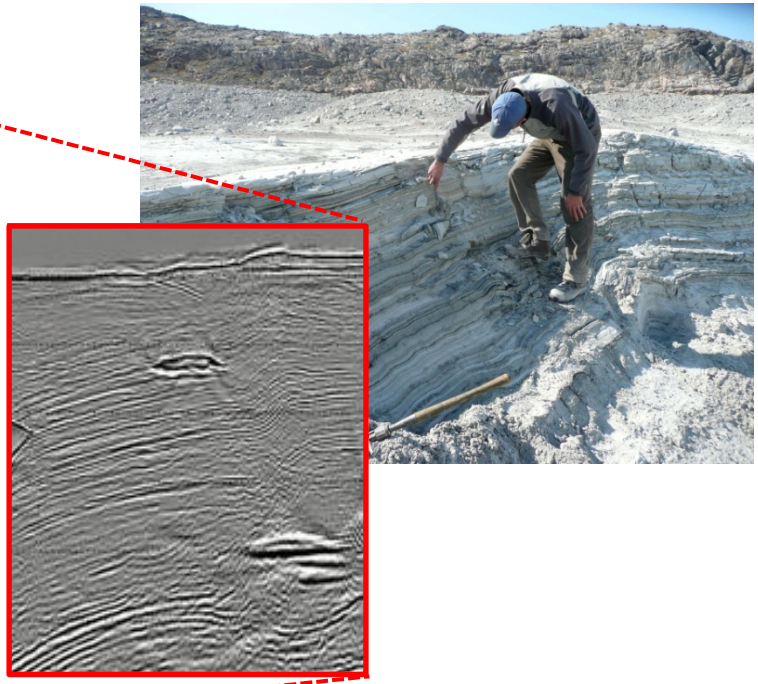


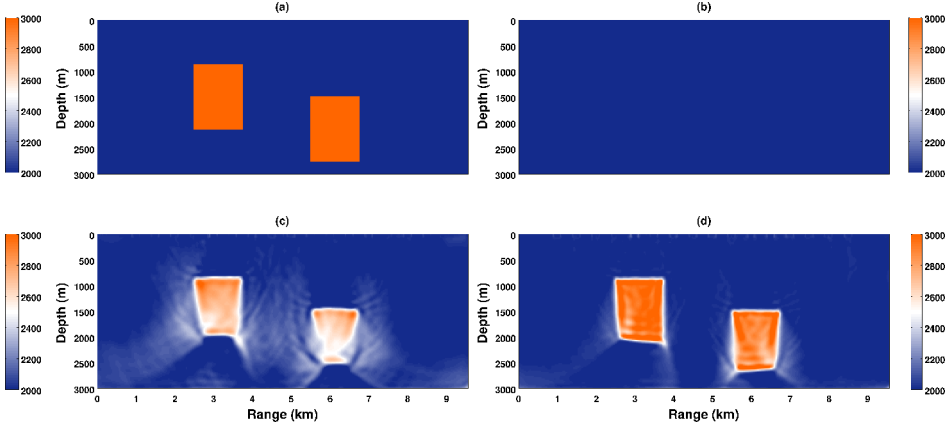
Transforming data into images

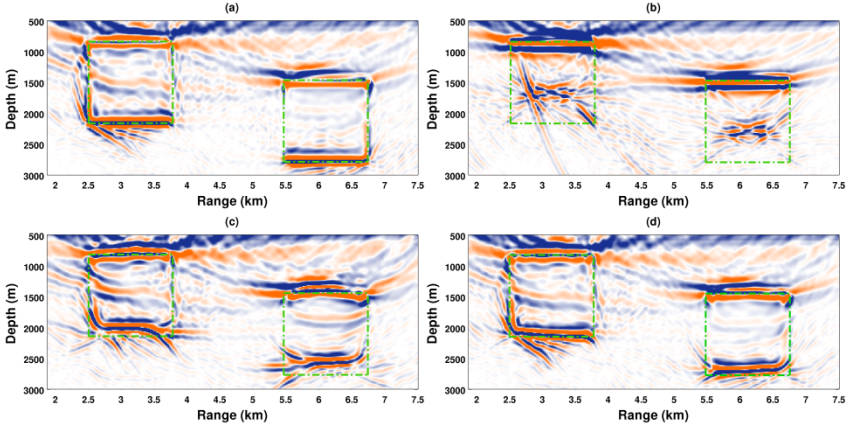


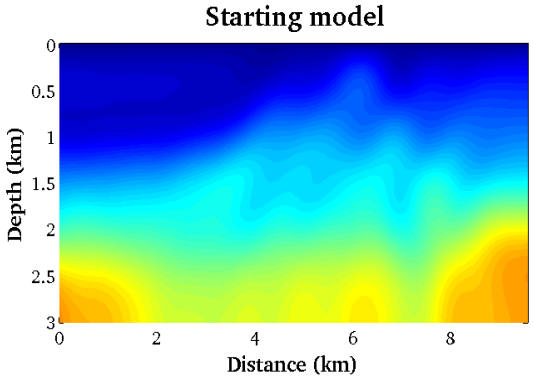


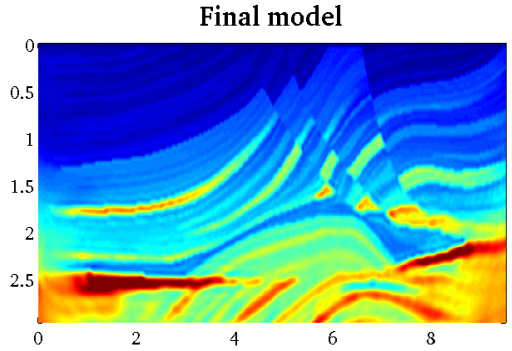
Time-domain image

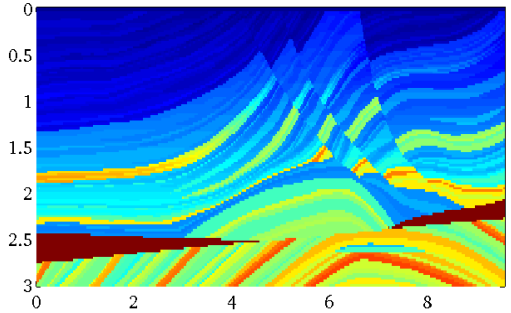
BSIT FWI: Model impact on RTM imaging

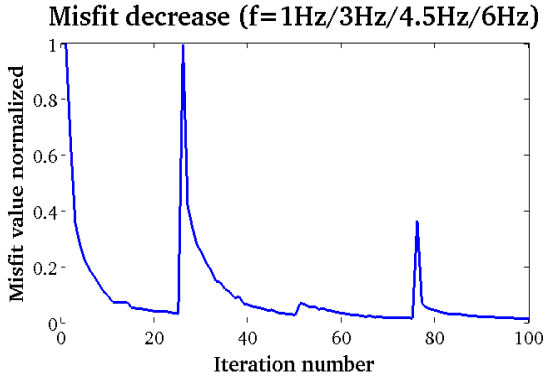





Starting model
Depth (km)
Distance (km)
0
0.5
1
1.5
2
2.5
3
0
2
4
6
8

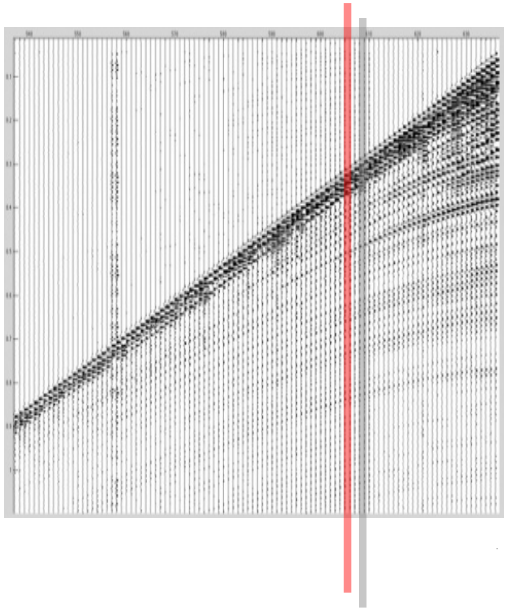

Final model
0
0.5
1
1.5
2
2.5
0
2
4
6
8

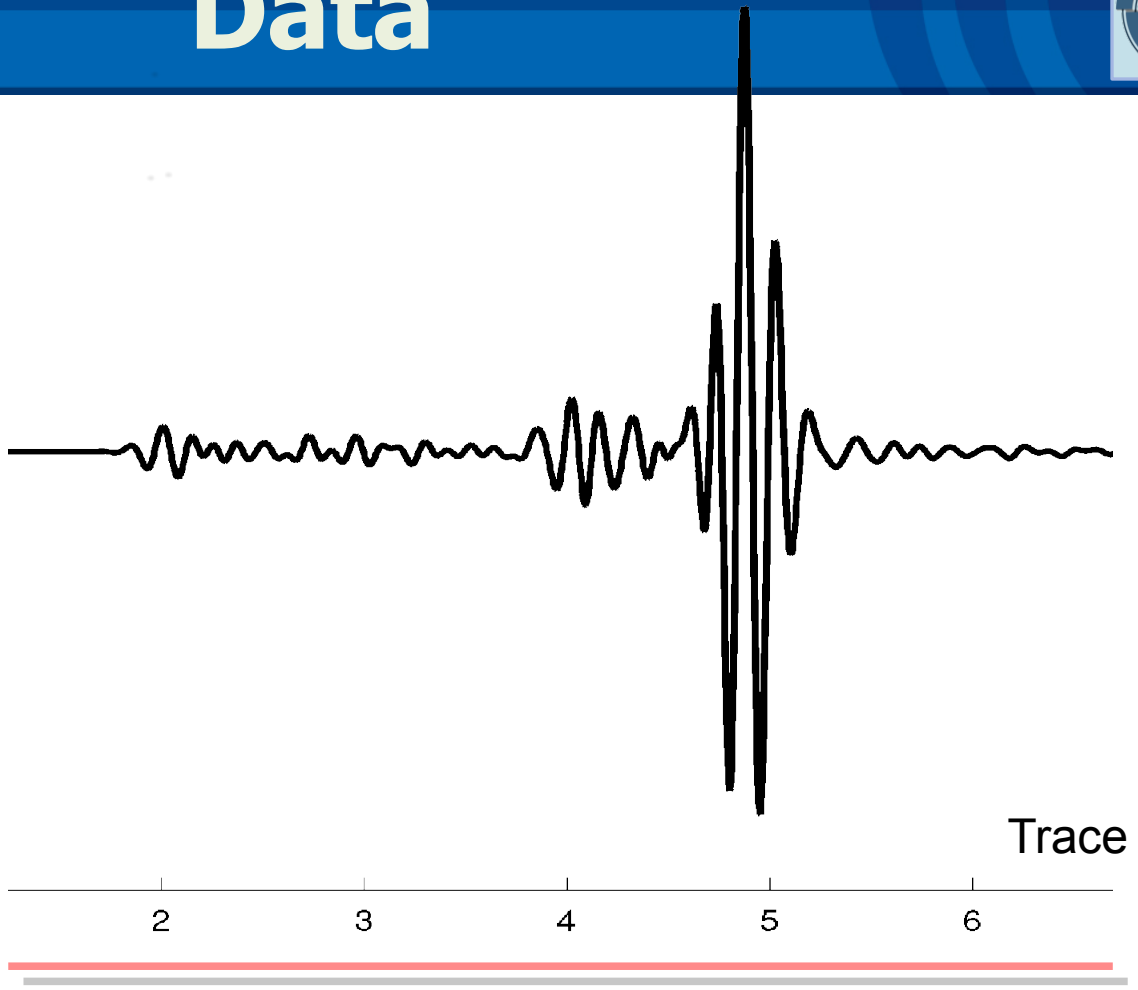

True model
0
0.5
1
1.5
2
2.5
3
0
2
4
6
8


Misfit decrease (f=1Hz/3Hz/4.5Hz/6Hz)
Misfit value normalized
Iteration number
0
0.2
0.4
0.6
0.8
1
0
20
40
60
80
100

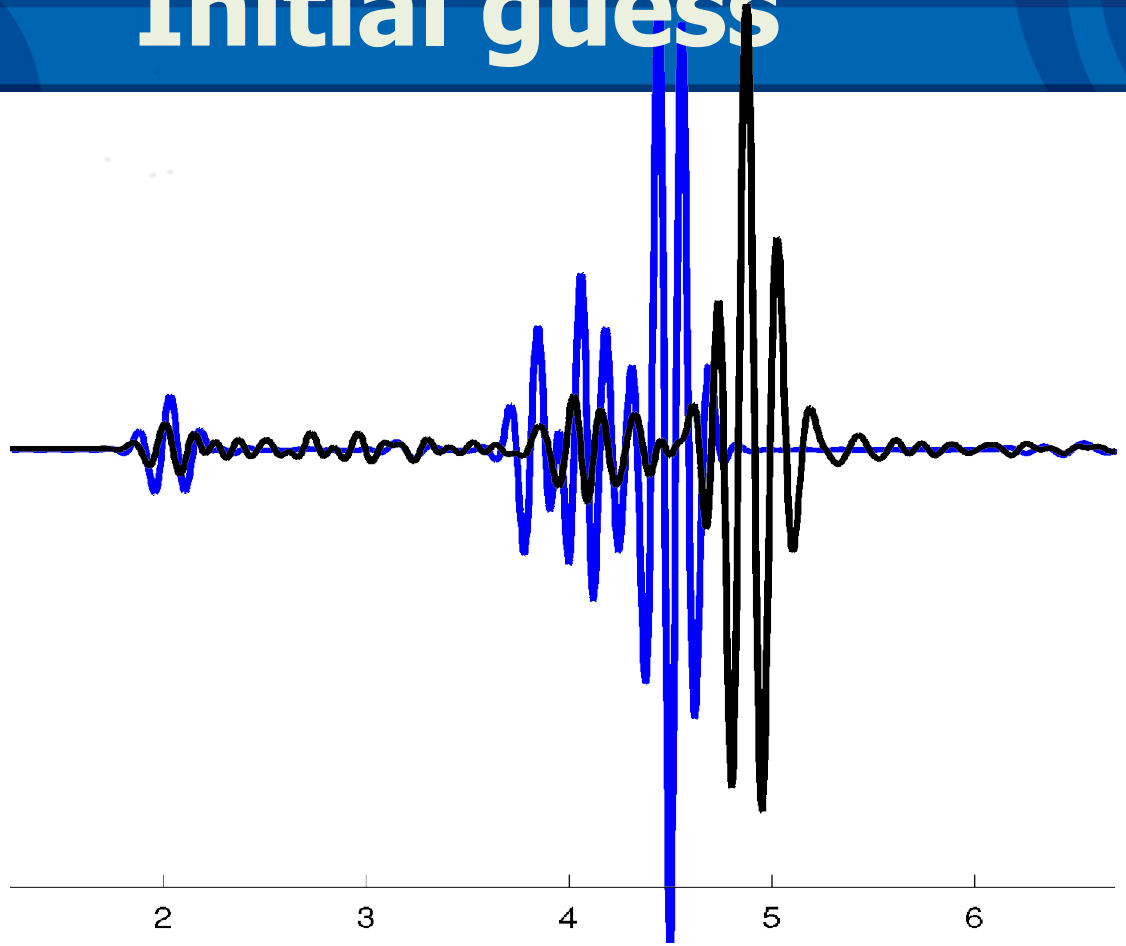
FULL WAVEFORM INVERSION

Data

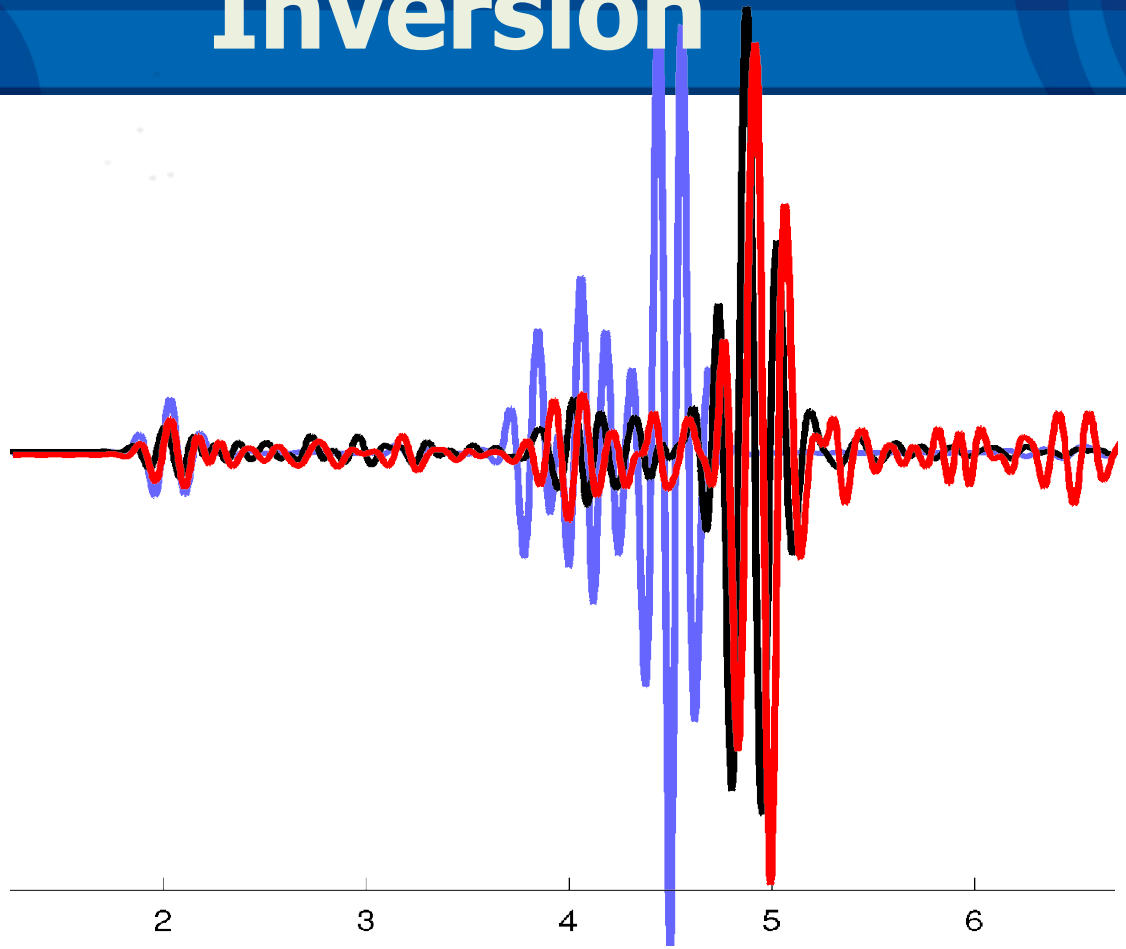




Initial guess



Inversion



BSIT FWI: 3D Acoustic model builder

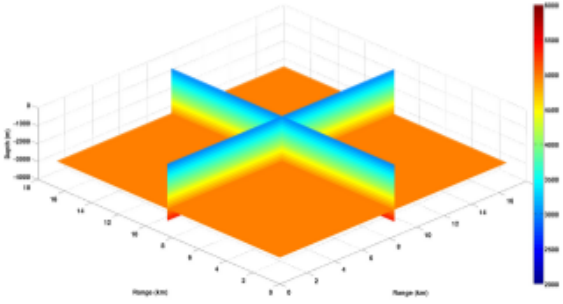
SEG/EAGE Overthrust Model

3249 sources, 3249 receivers
Staggered geometry
Receivers and sources are at depth 50 m
8 s of simulation (250 GB of data)
Ricker with central frequency 10 Hz
Constant density
Δd is 20 m (3.2 x 16 x 16 km3) and Δt is 0.0013 s.
8th order FDTD in space and 2nd in time

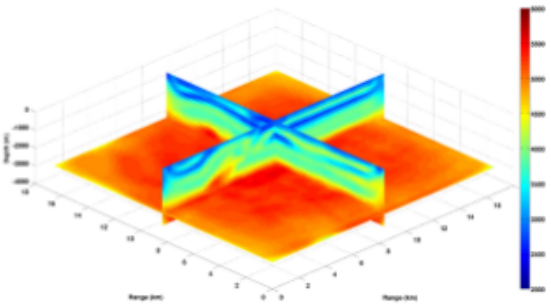
BSIT FWI: 3D Acoustic model builder

Multi-Scale strategy: 4 low-pass filters to linearize problem
Mesh adapted to frequency
Multi-shooting for data reduction: 3249 shots → 56 supershots
Novel in-house preconditioner
Non-linear Conjugate Gradient method
No fixed part of the model
Neither sources nor receivers are coincident with the mesh grid
Noise free dataset
8 hours and 57 nodes for 80 iterations

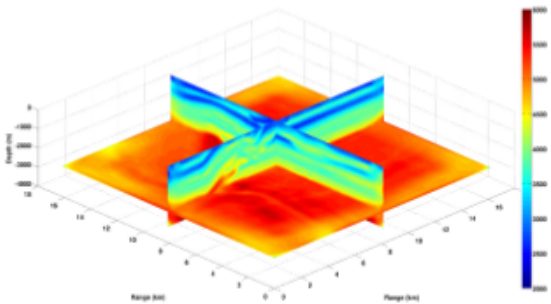
BSIT FWI: multi-scale/multi-grid



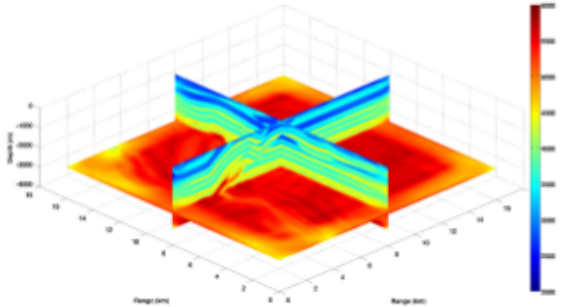
START



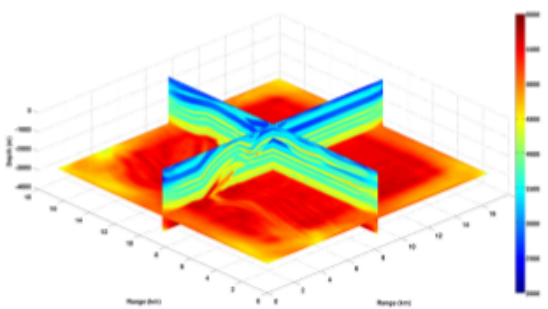
1 Hz



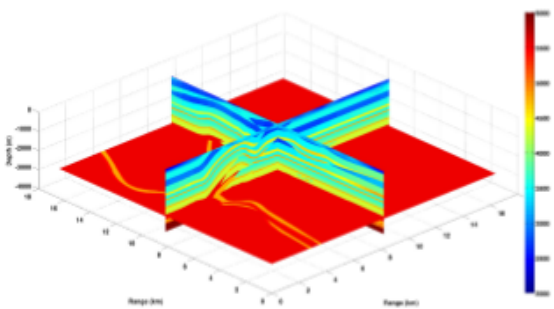
2 Hz



4 Hz

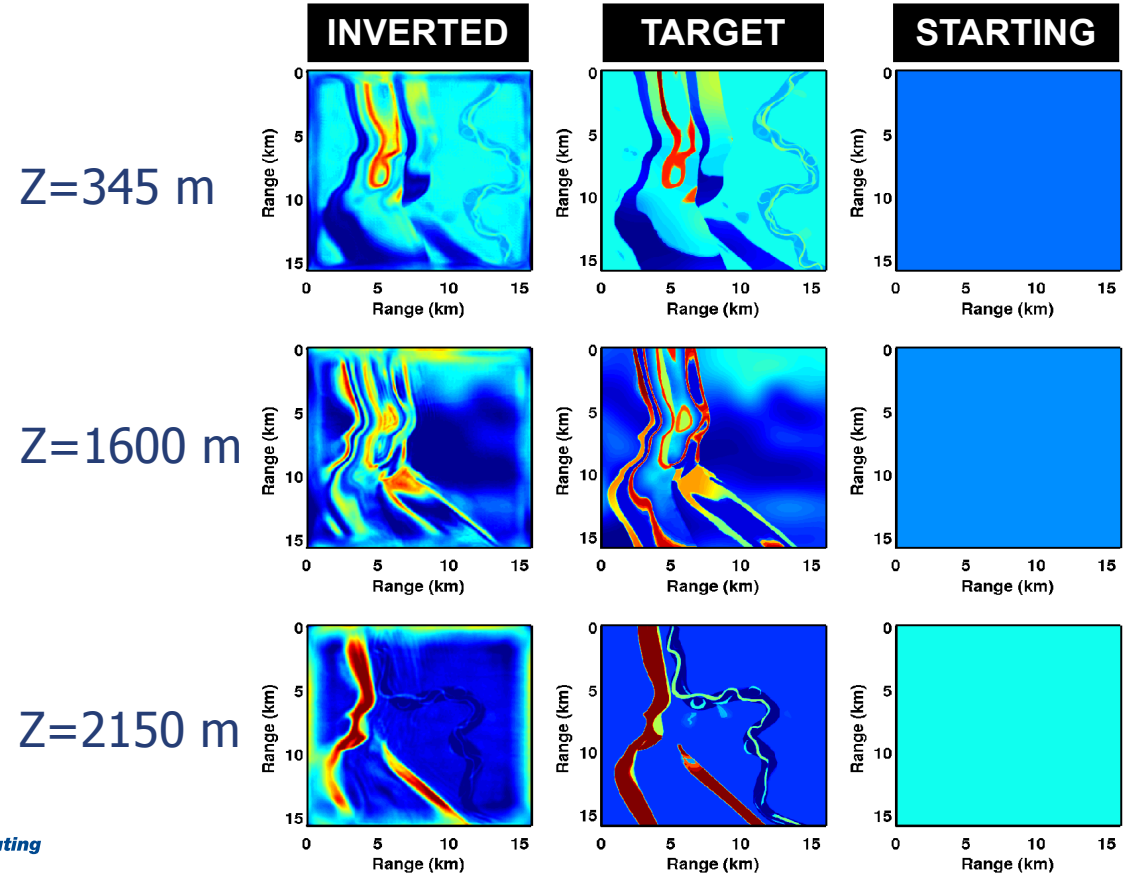


8 Hz



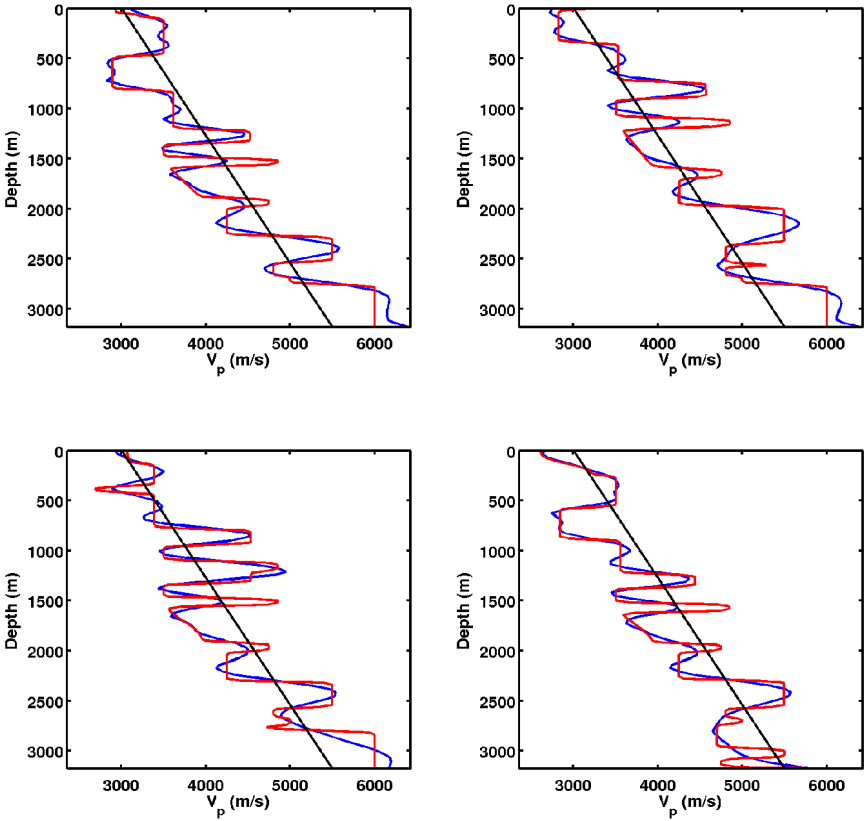
TARGET

BSIT FWI: inverted depth slices

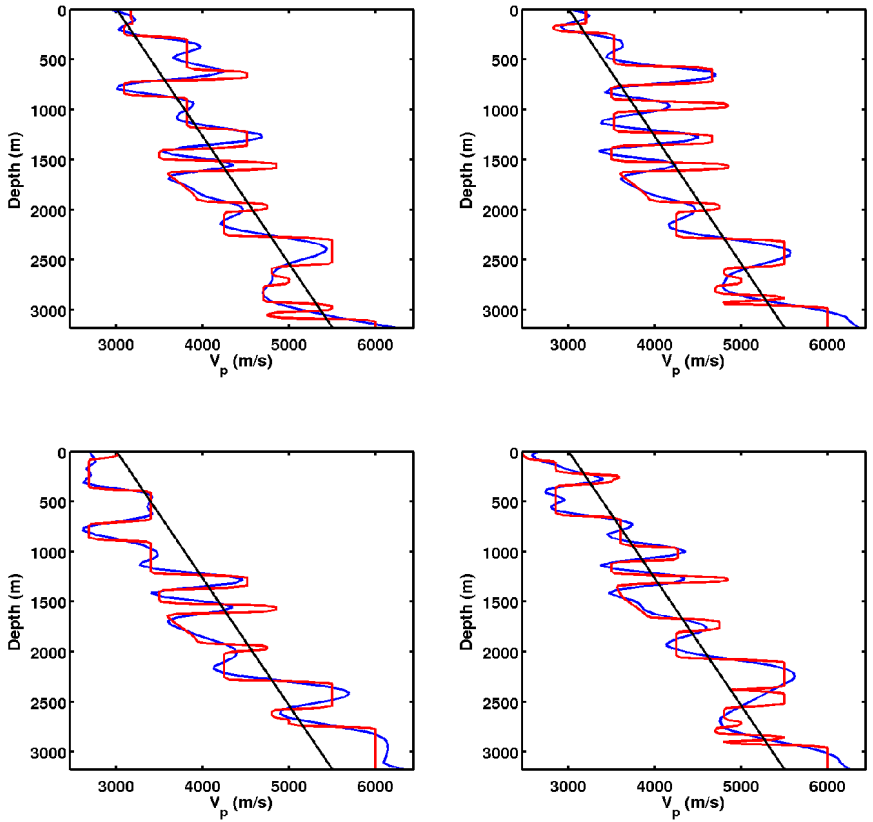


BSIT FWI: inverted velocity profiles

X-Line



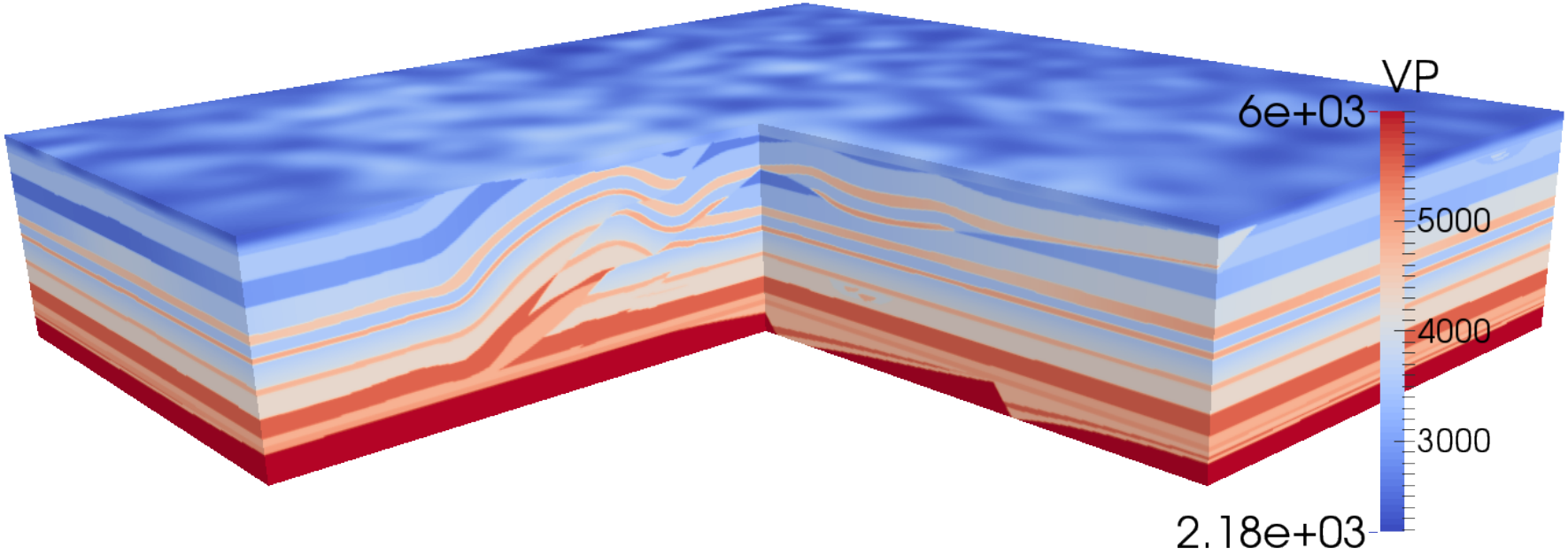
Y-Line



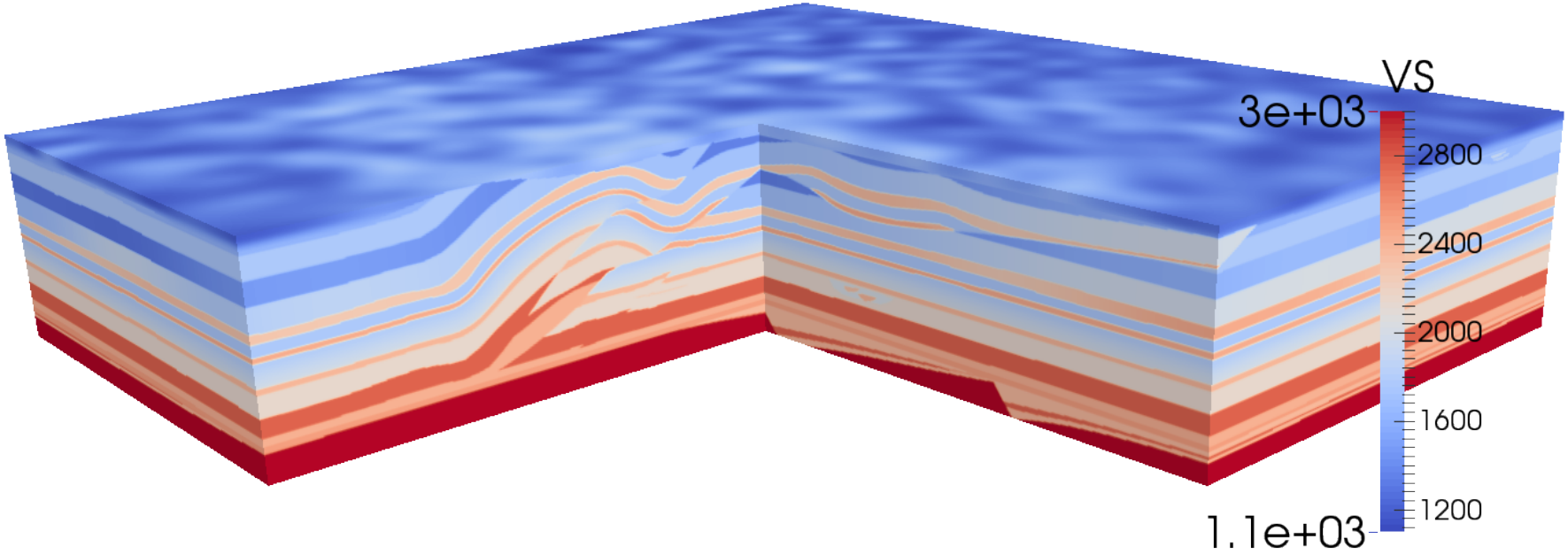
BSIT FWI: 3D Multi-Parameters Inversion

- **Modelling:**
- 6 s simulation with 10 Hz source frequency peak, 5041 shots, 3x16x16 Km3 (Vp and Vs models), fixed density
- SSG grid with mimetic operator for free-surface modelization
- ~48000 cpus during 3 days (~ 3000 nodes)
- Run on BSC-CNS *Mare Nostrum III* supercomputer

BSIT FWI: 3D Multi-Parameters Inversion



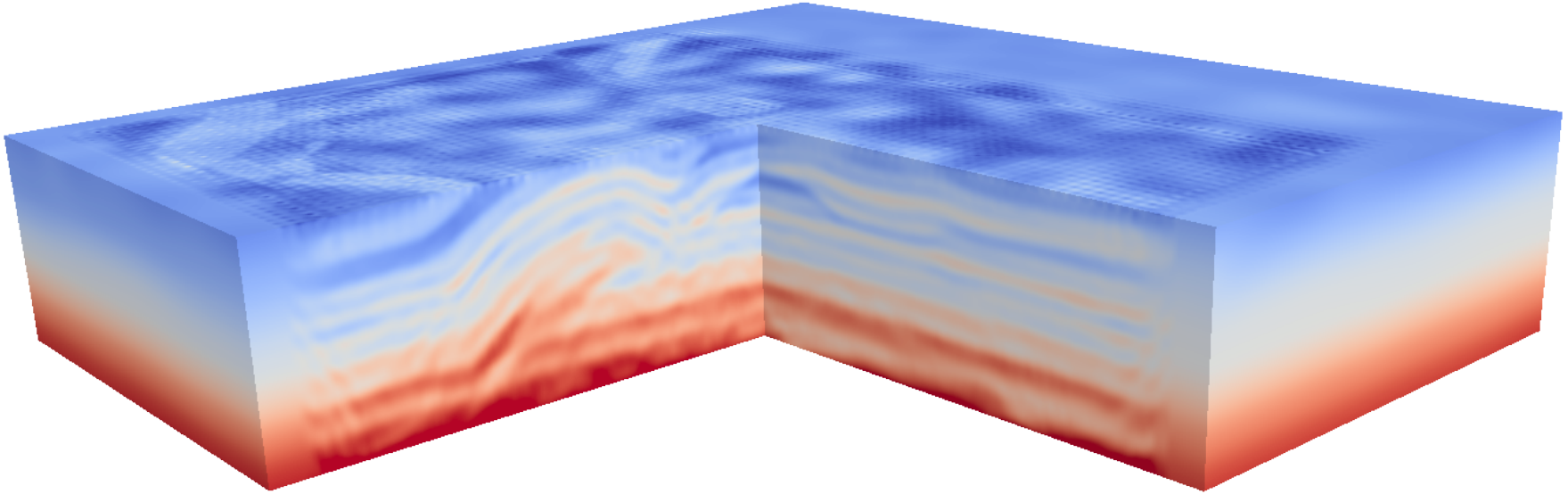
BSIT FWI: 3D Multi-Parameters Inversion



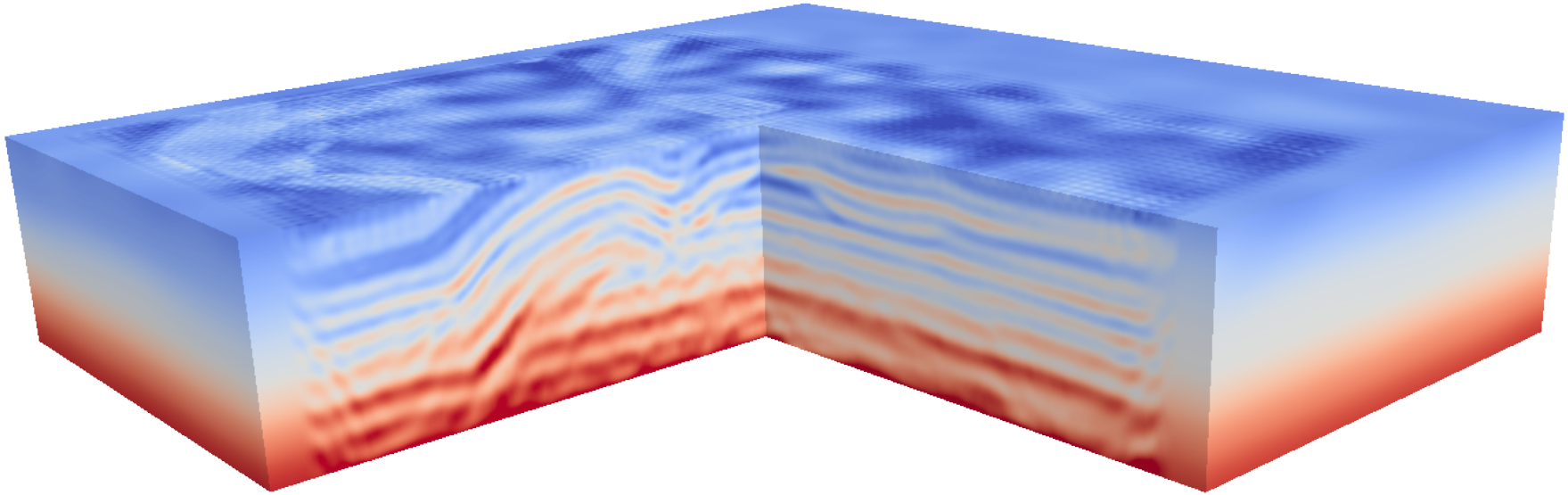
BSIT FWI: 3D Multi-Parameters Inversion

- **Inversion:**
- Simultaneous inversion of Lame's paramters, fixed density
- 4 frequencies: 2.6, 3.4, 5.2, and 6.8 Hz; 10 Iterations/freq
- Efficient Multi-Scale, Multi-grid implementation for mesh size reduction
- Free-surface included, no phase selection, no fixed parts of the models
- 3296 shots used for inversion
- *Dynamic Offset Control* for domain reduction
- 72 hours using 1408 cpus (88 nodes) on BSC-CNS *Mare Nostrum III* supercomputer for 40 iterations

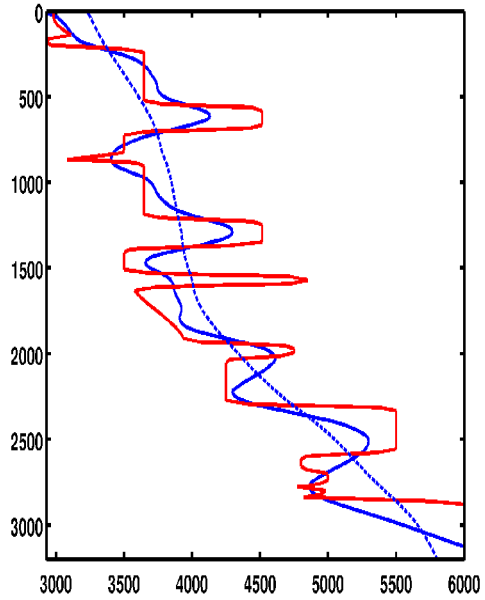
BSIT FWI: 3D Multi-Parameters Inversion

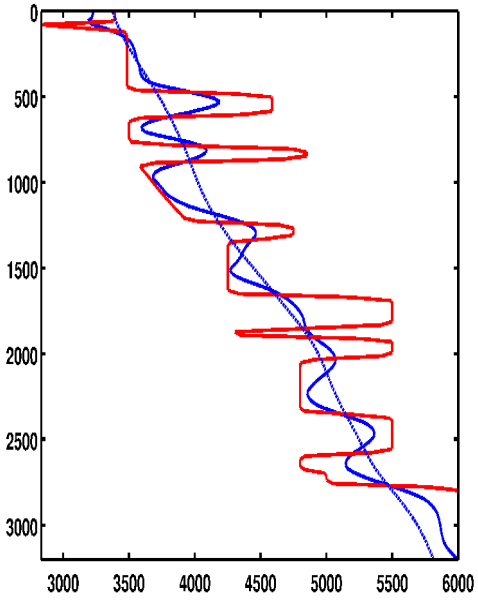


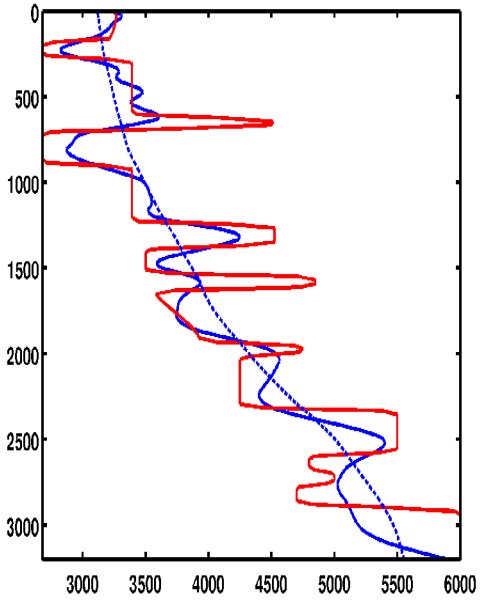
BSIT FWI: 3D Multi-Parameters Inversion



BSIT FWI: 3D Multi-Parameters Inversion







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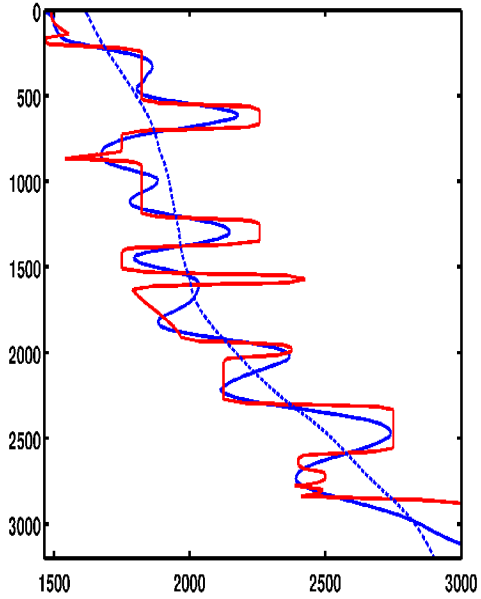
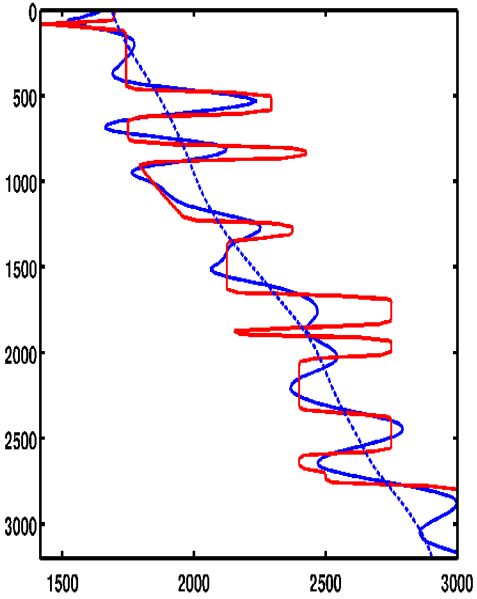
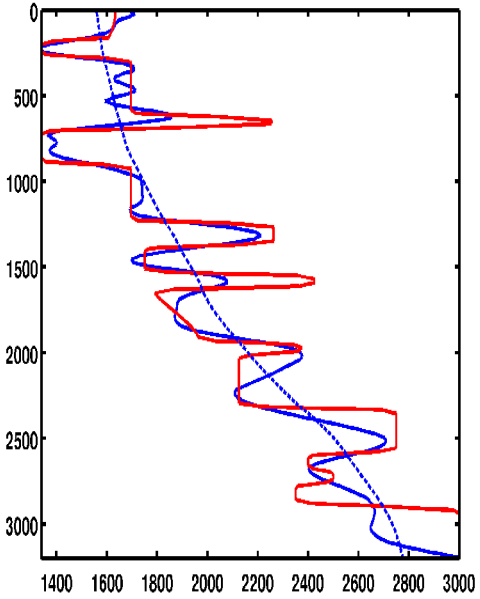
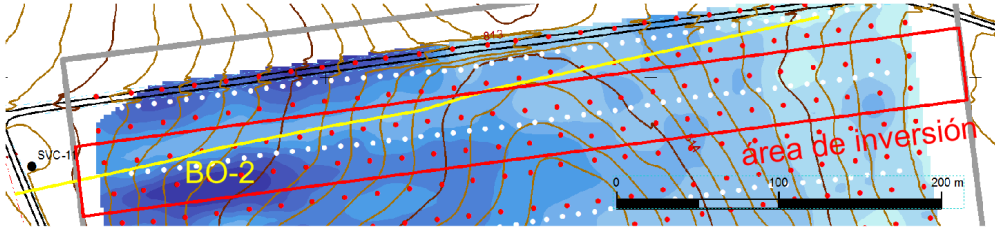


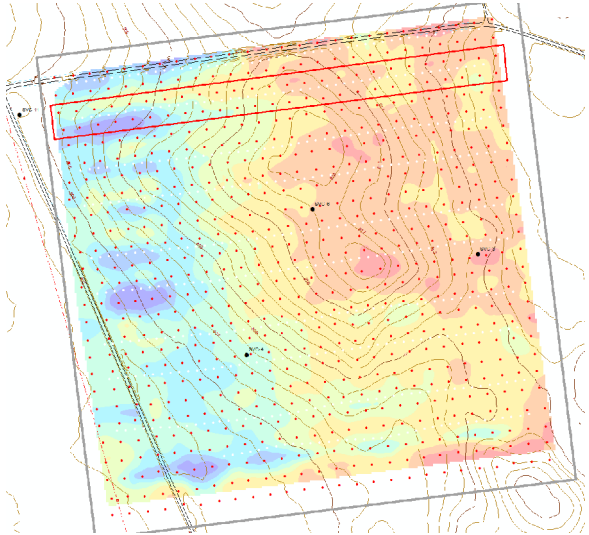





BSC
Barce ona
Supercomput ng
Center
Centro ac ona de Supercomputac ón
DOES IT
REALLY WORK ?

BSIT FWI: Real Dataset Application





DATASET:

- 52 shots of 2 s (red dot)
- 48 receivers a_z component only (white dot)
- Vibroseis source

INVERSION

- 0.4 s
- Topography
- Source extract from dataset
- V_p starting model obtained from TTT

BSIT FWI: Real Dataset Application

DATASET:

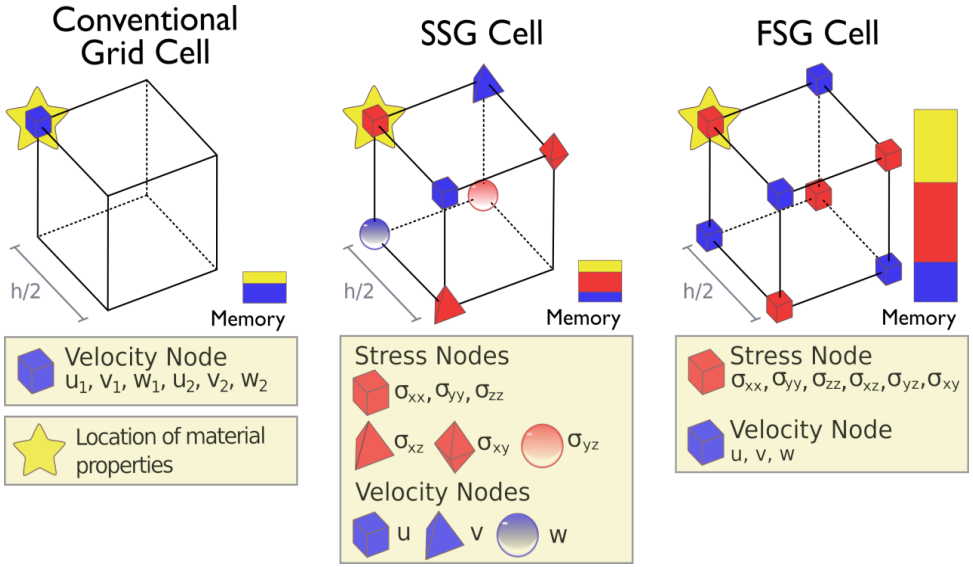
- 52 shots of 2 s (red dot)
- 48 receivers a_z component only (white dot)
- Vibroseis source
- Utile bandwitdth : 10-40 Hz

INVERSION

- 0.4 s
- Topography
- Source extract from dataset
- V_p starting model obtained from TTT
- 2 frequencies : 15 and 20 Hz
- 27 nodes, 24 hours ; 2 nodes per shots

BSIT FWI: Real Dataset Application

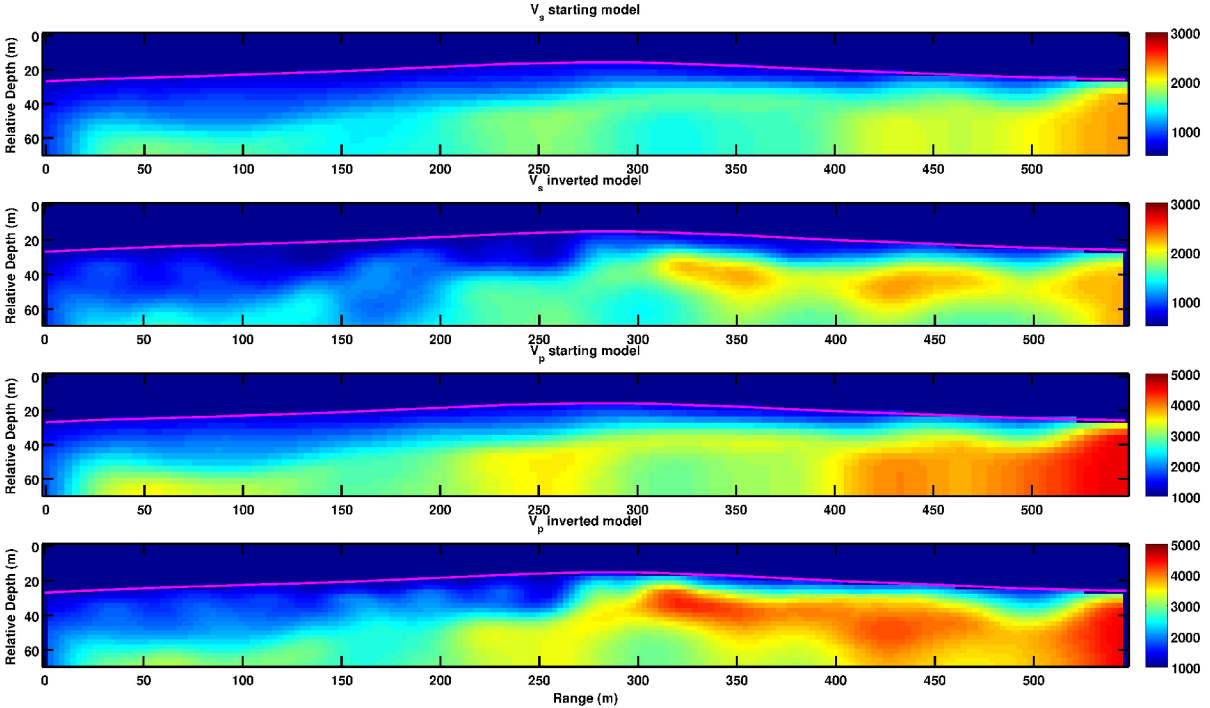
Acoustic



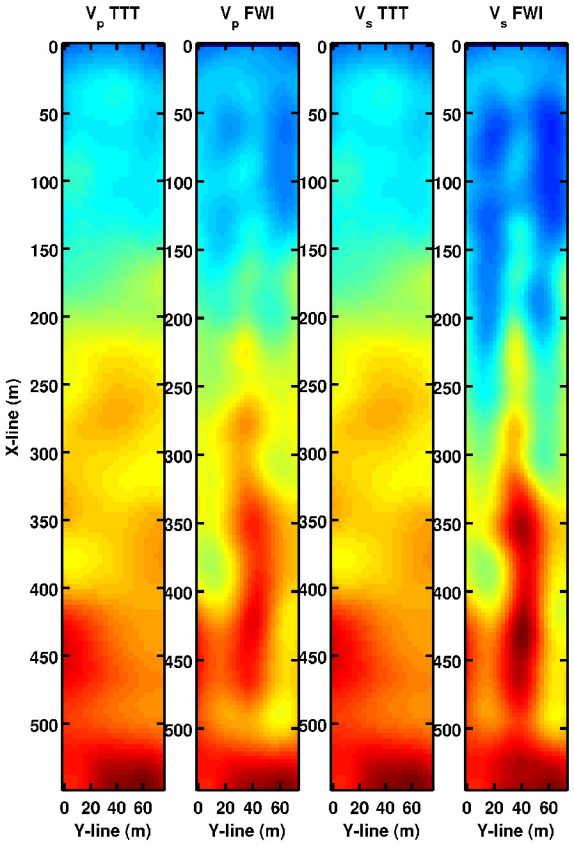
Elastic Triclinic

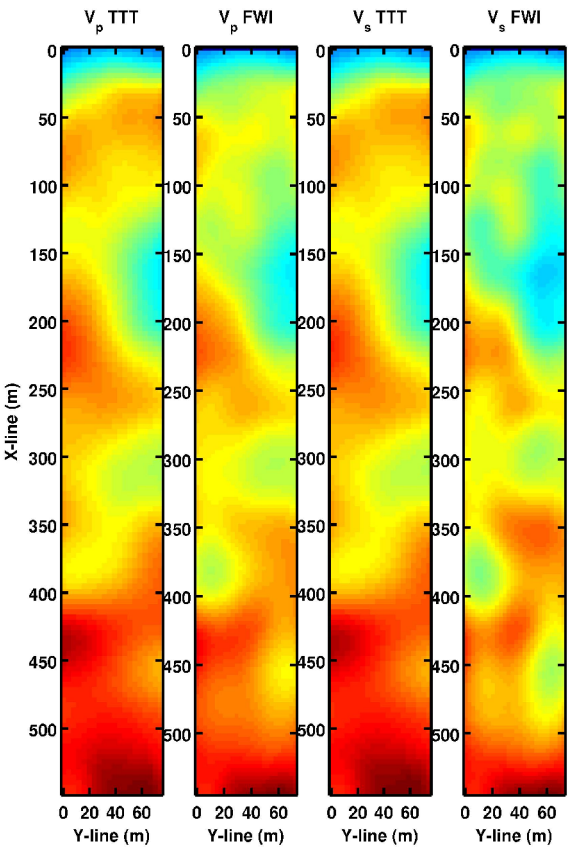
Elastic ISO/VTI/HTI/...

BSIT FWI: Real Dataset Application



BSIT FWI: Real Dataset Application





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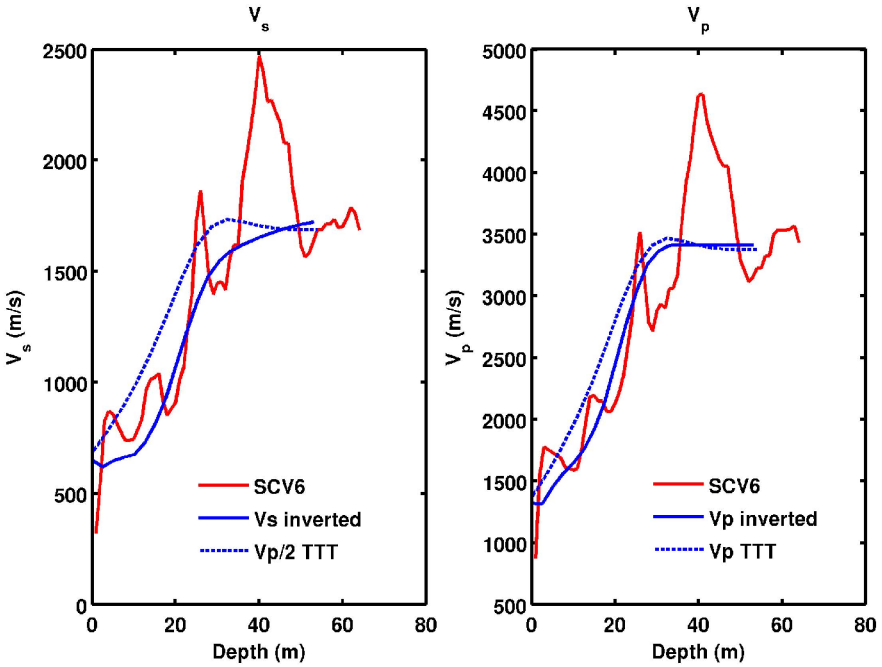
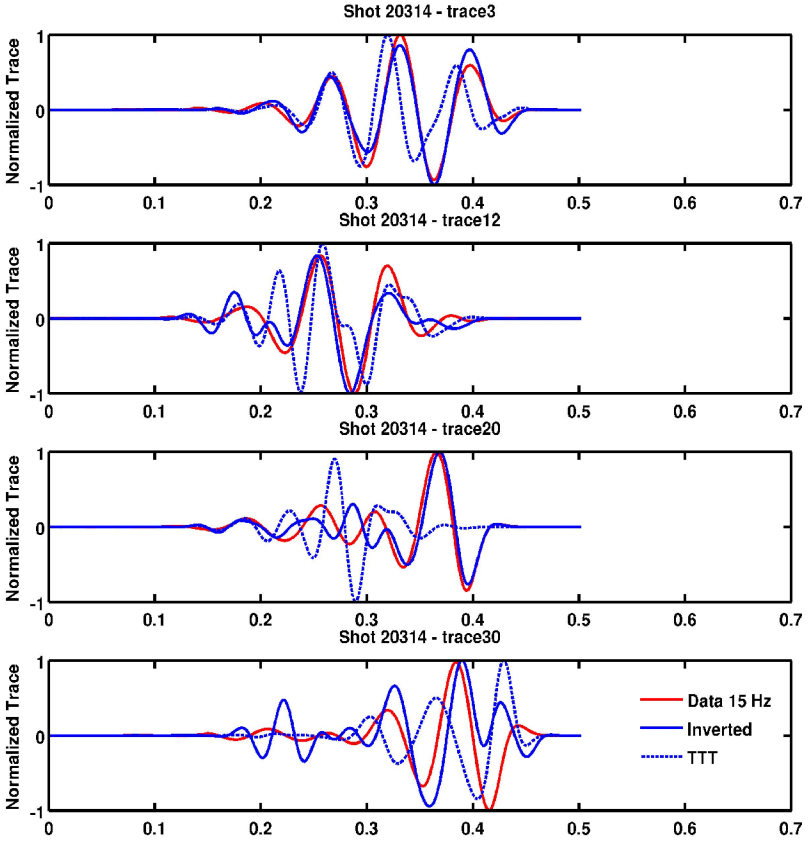
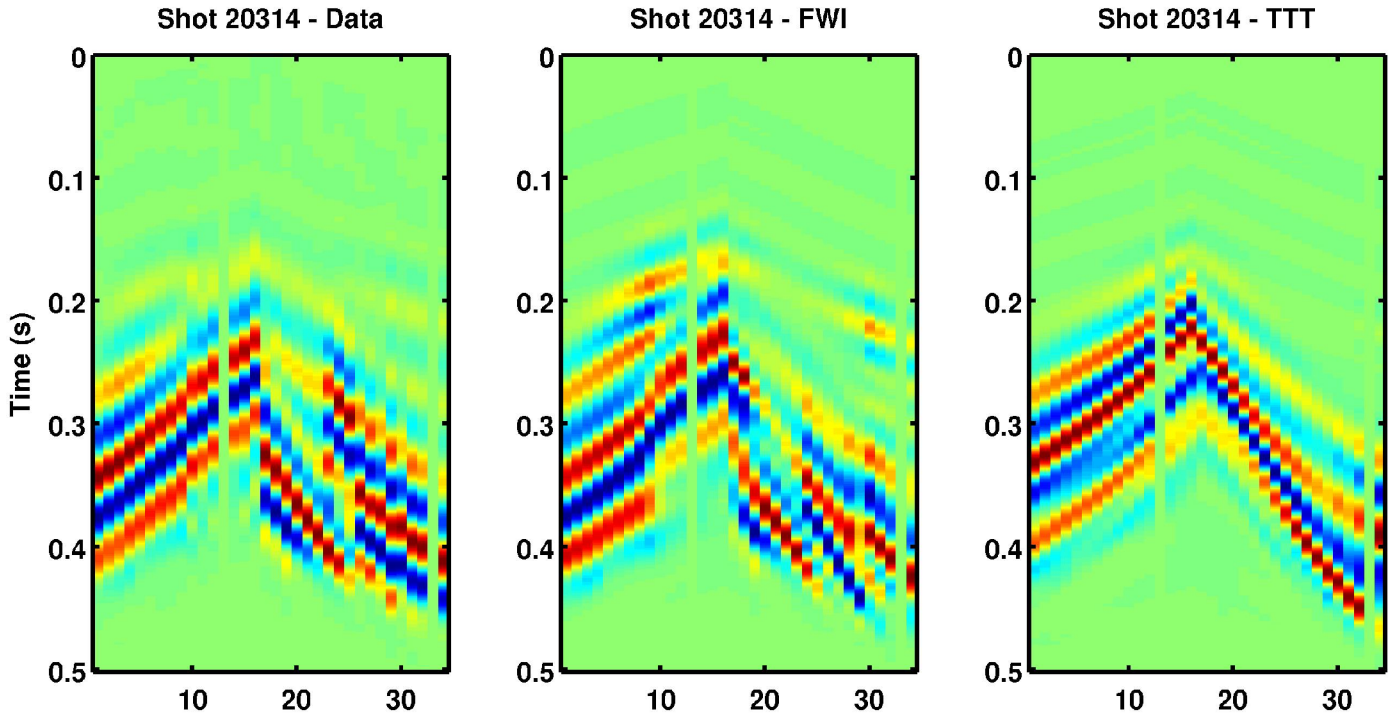




BSIT FWI: Real Dataset Application



BSIT FWI: Real Dataset Application