

Project overview

Sleipner CO₂ plume

TNO | Knowledge for business



Filip Neele, Rob Arts

E filip.neele@tno.nl, rob.arts@tno.nl

T +31 30 256 4859

Jan 14, 2010



Sleipner CO₂ injection

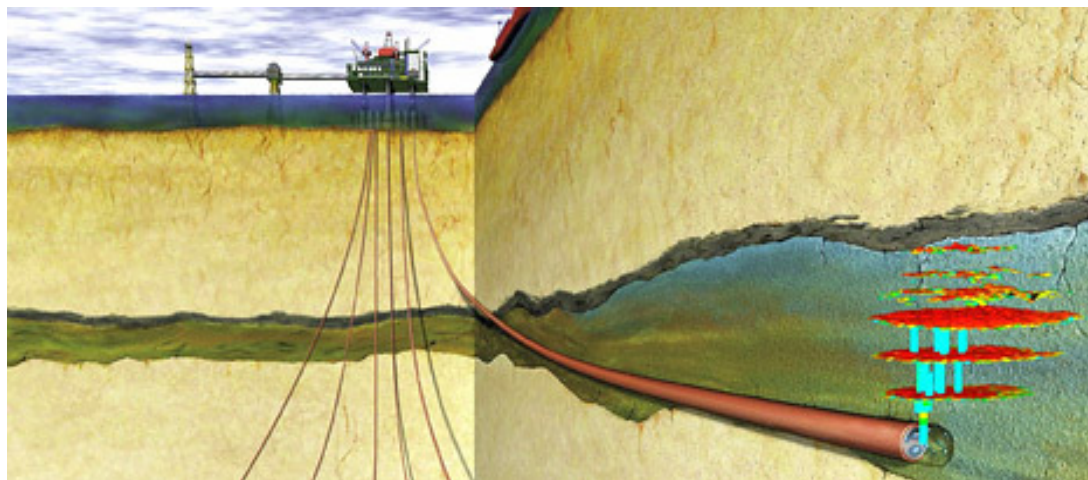


CO₂ injection commenced 1996
~ 1 Mt CO₂ injected per annum
> 11 Mt currently *in situ*

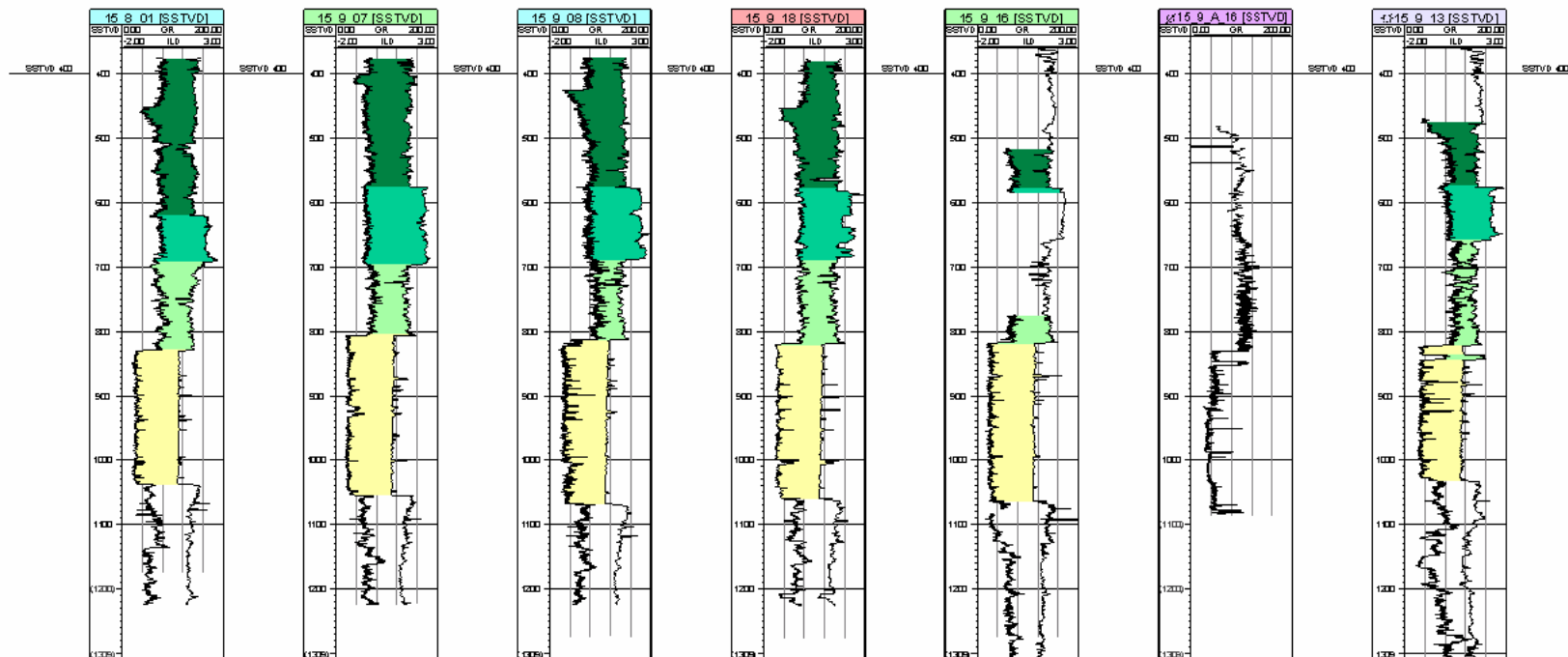


Time-lapse monitoring

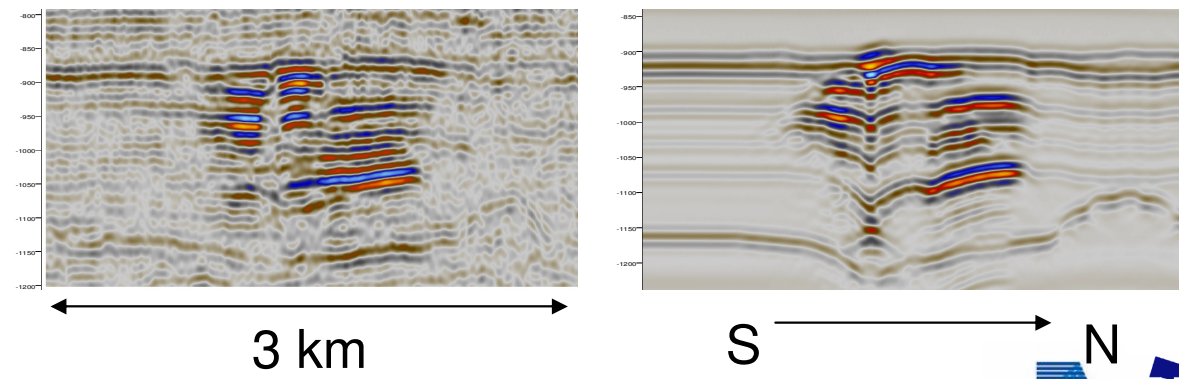
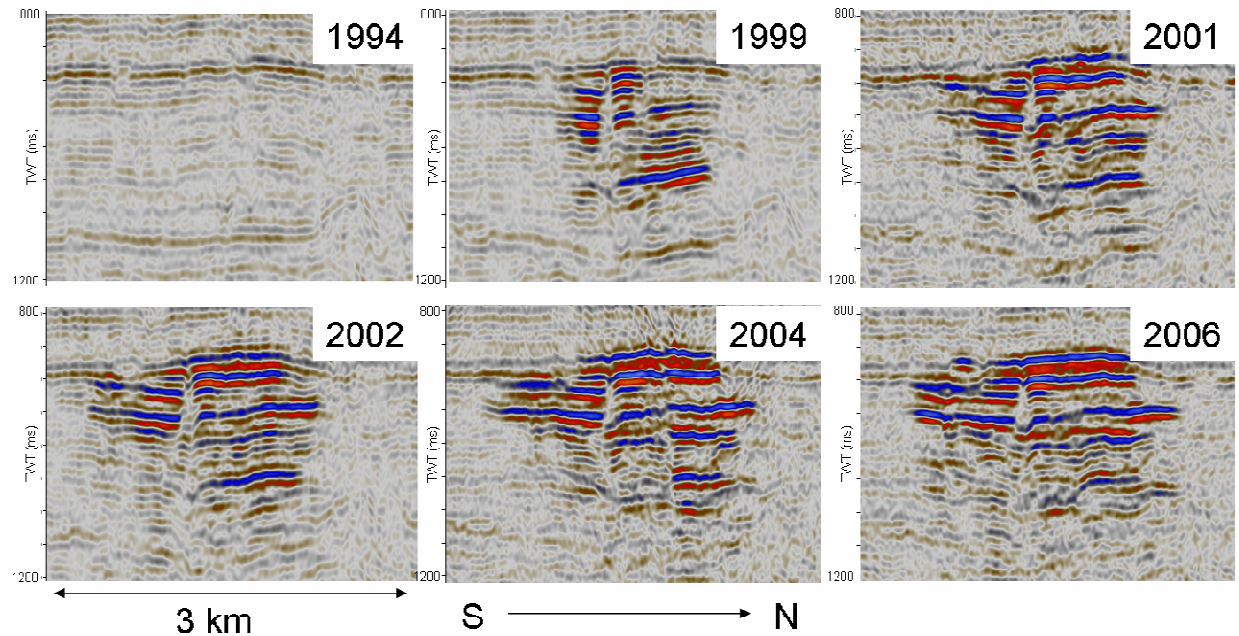
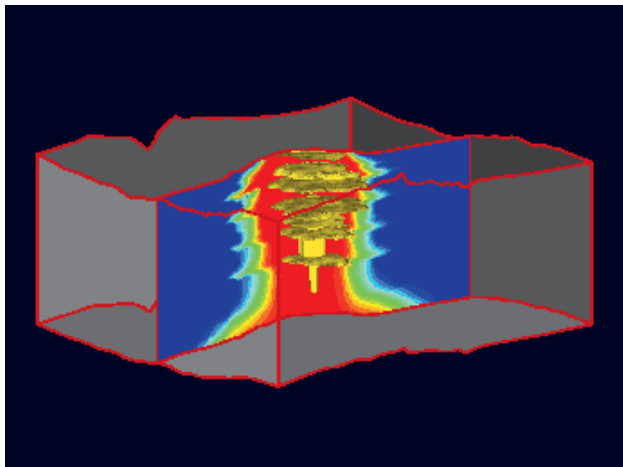
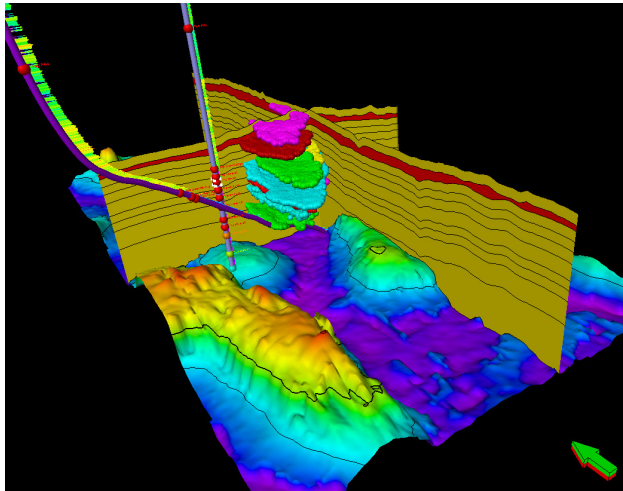
1994	3D seismic baseline
1999	3D seismic
2001	3D seismic
2002	3D seismic
2004	3D seismic
2006	3D seismic
2008	3D seismic
	[2D hi-res]
	[Seabed gravity]
	[CSEM]
	[Seabed imaging]



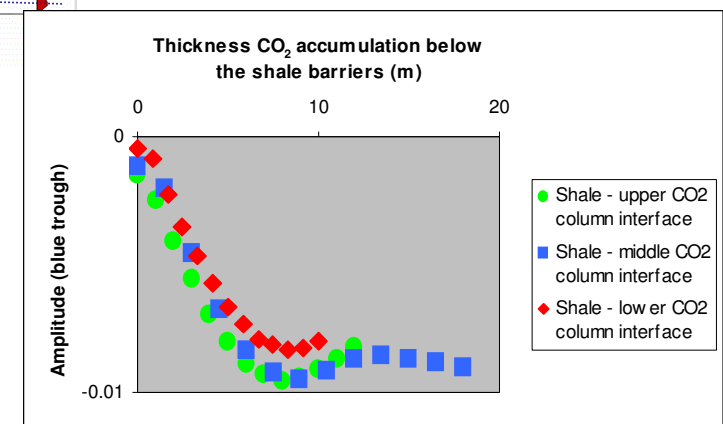
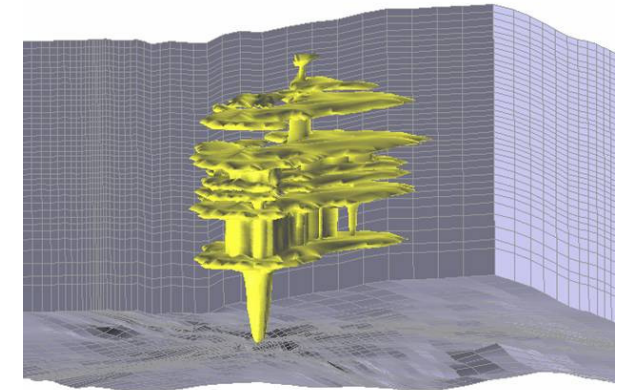
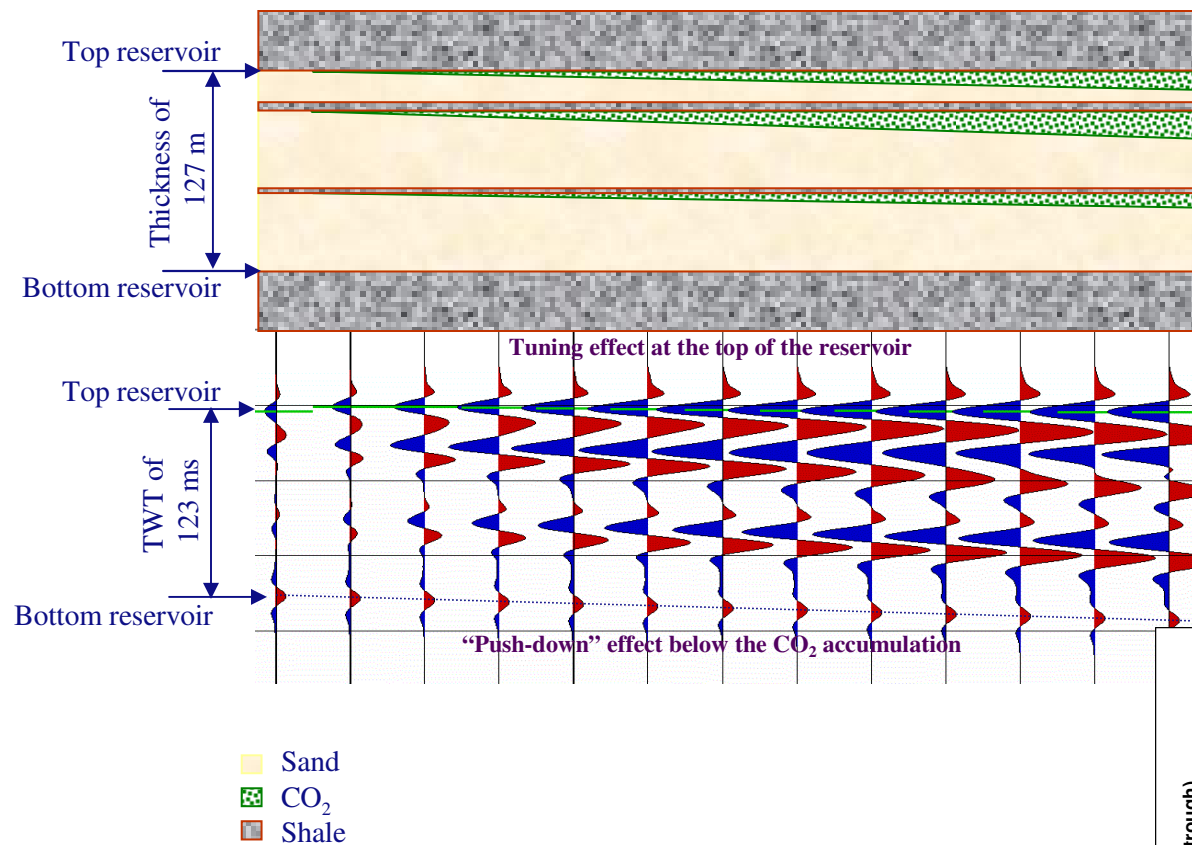
Sleipner: the reservoir



Sleipner: Forward modelling

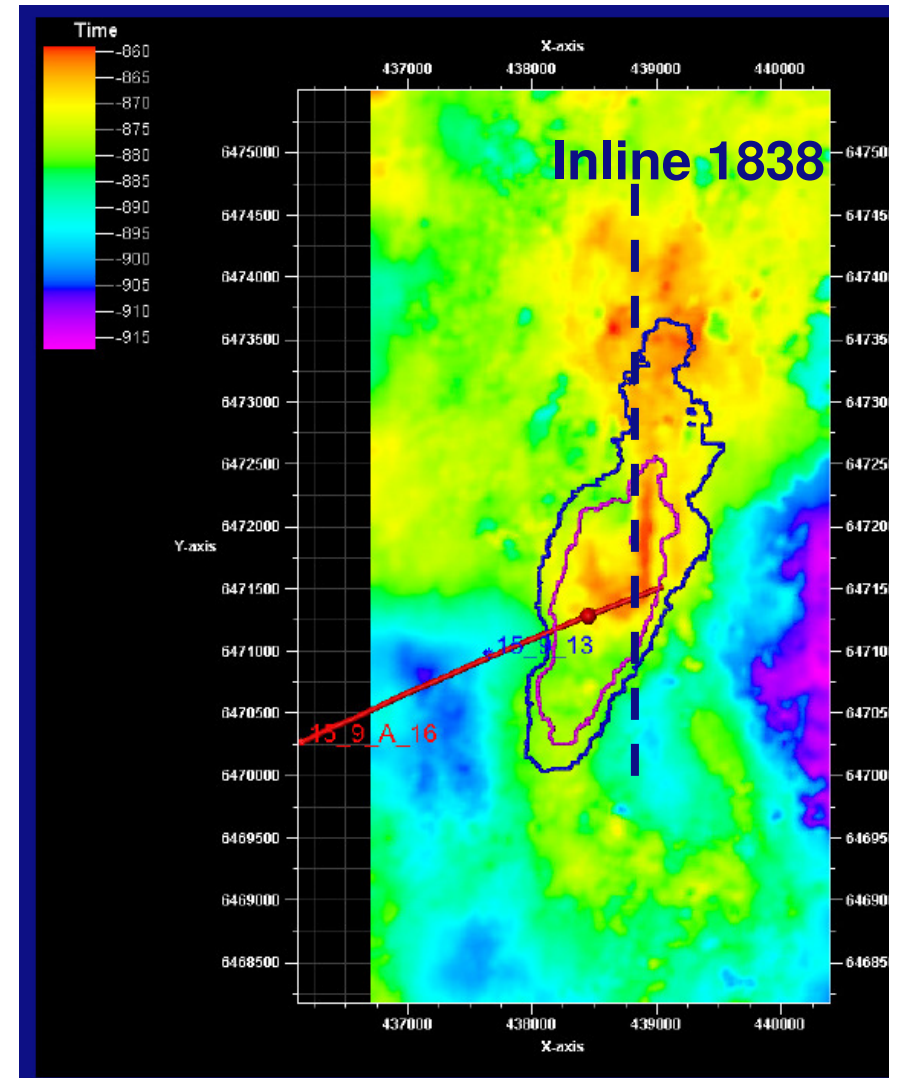


Detailed synthetic modeling of the seismic response

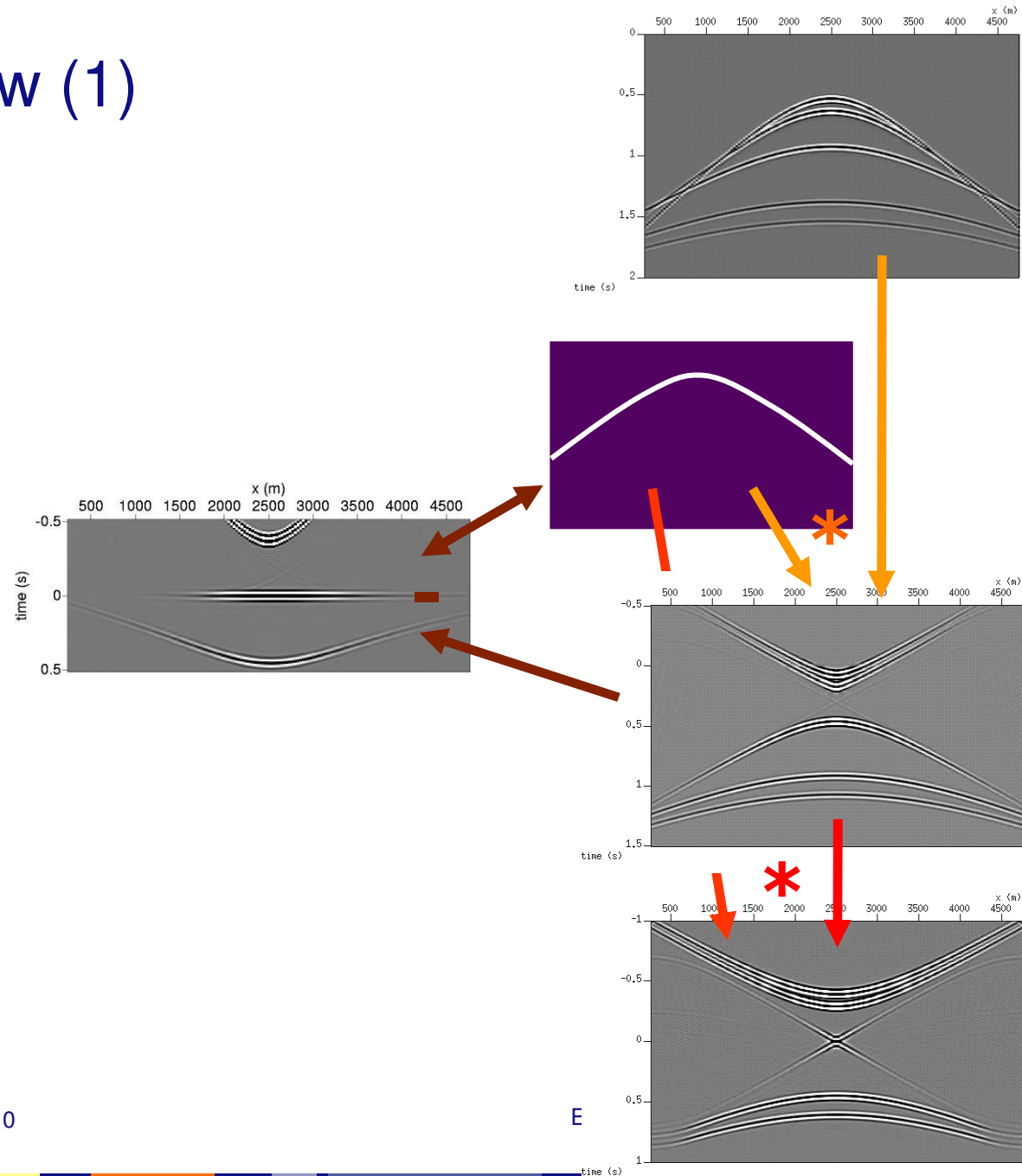
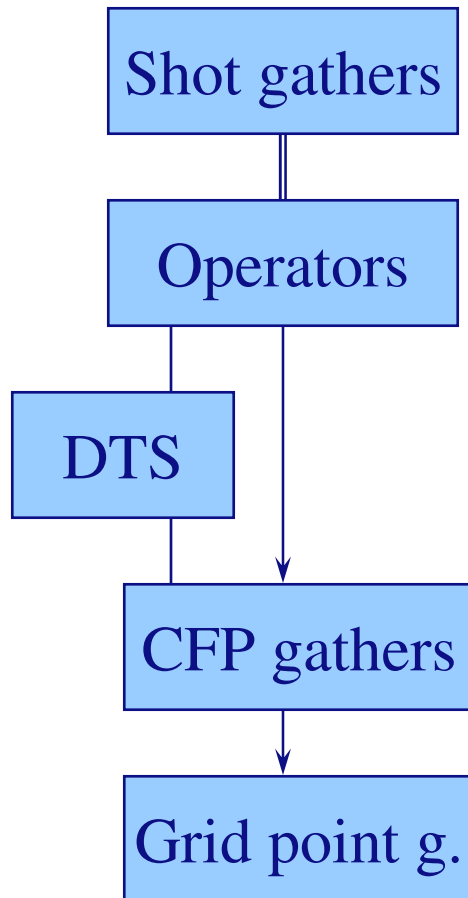


Aim (EU CO₂ReMoVe)

- Study Sleipner CO₂ plume
 - Development through time
 - Focus on “undisturbed” top layer
 - Confirm properties of CO₂ filled Utsira reservoir
- Method
 - Shot gathers from Inline data (2D)
 - Common Focus Point (CFP)
 - AVP data
 - AVP data → rock physics

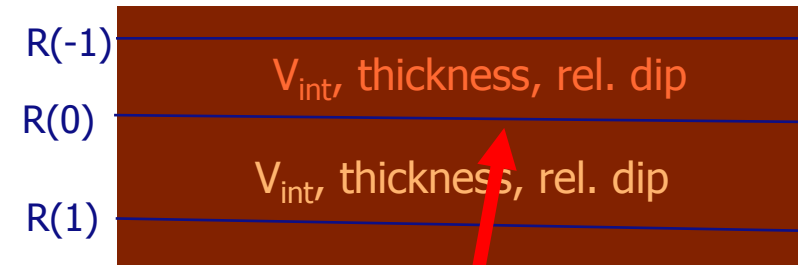
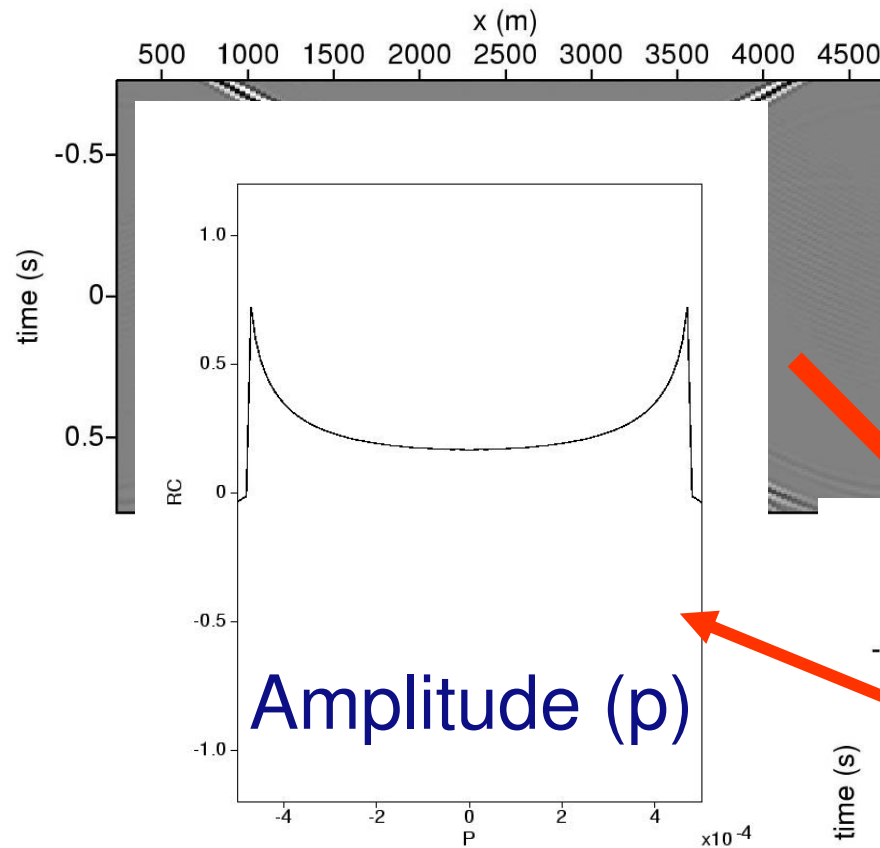


CFP work flow (1)

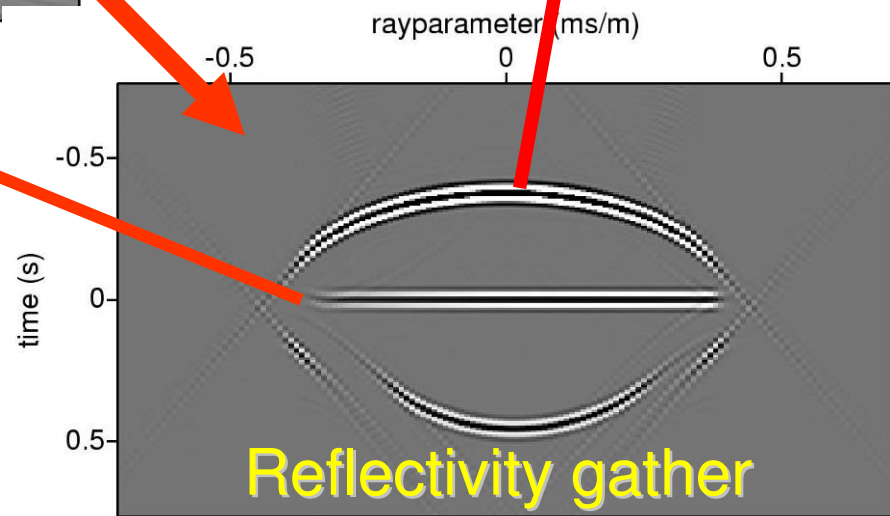


After Berkhout

Local characterization



τ - p transform

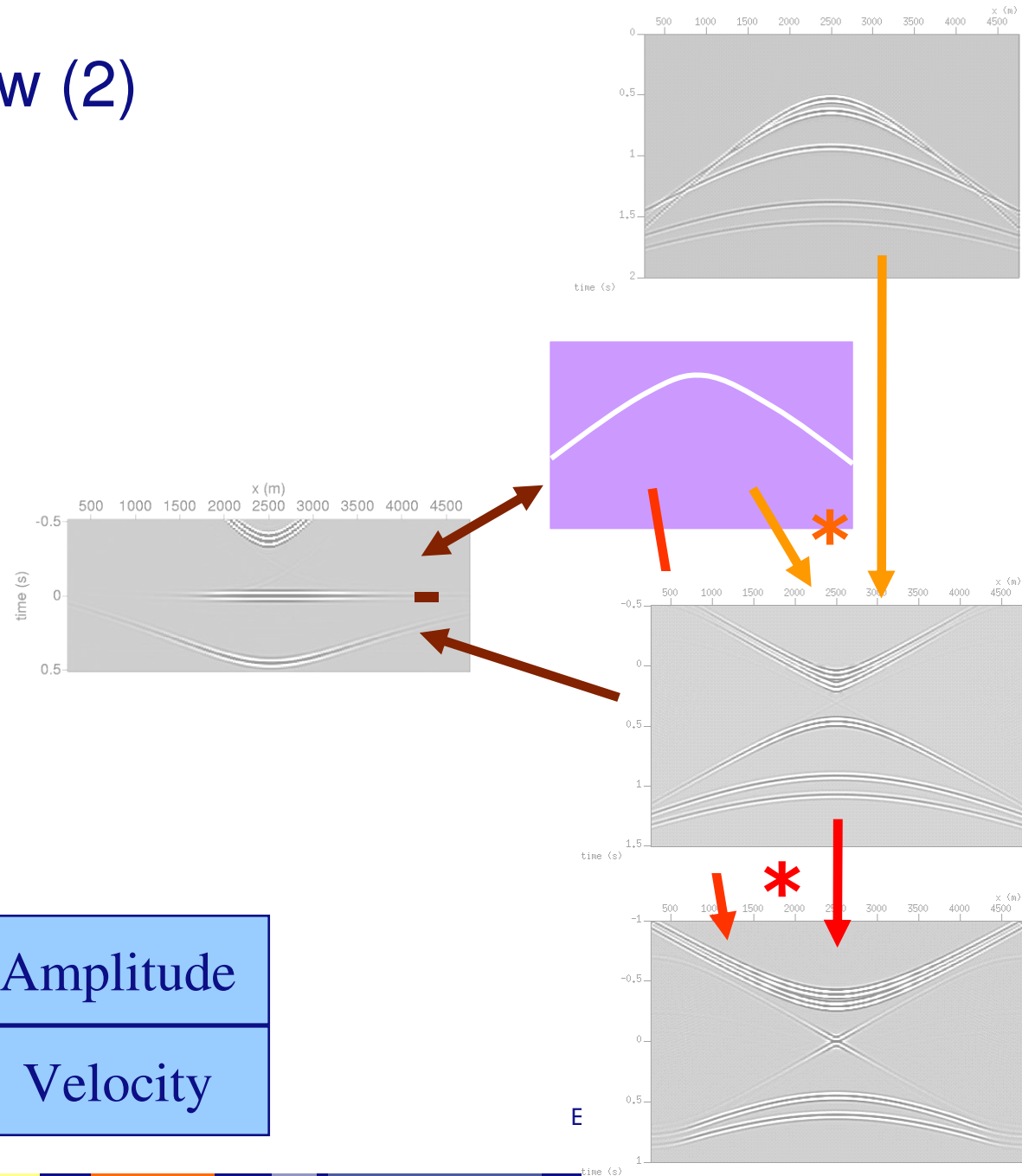
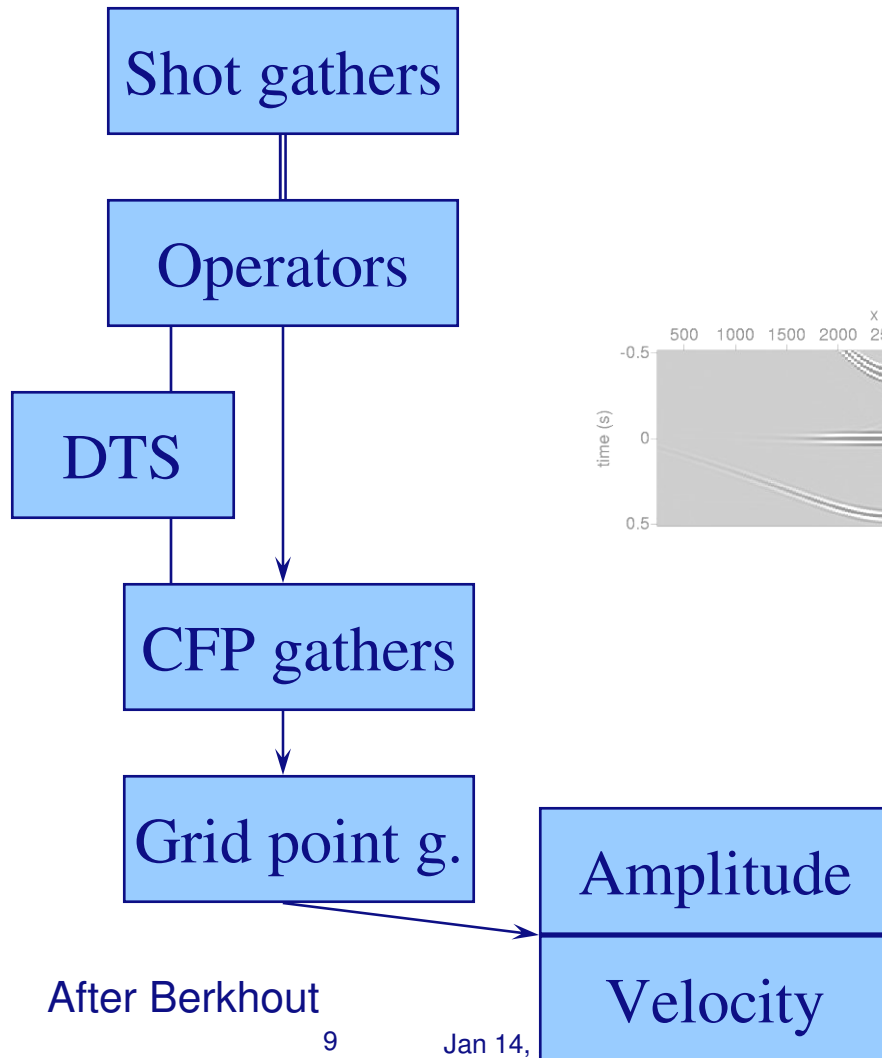


After Berkhout; Winthagen

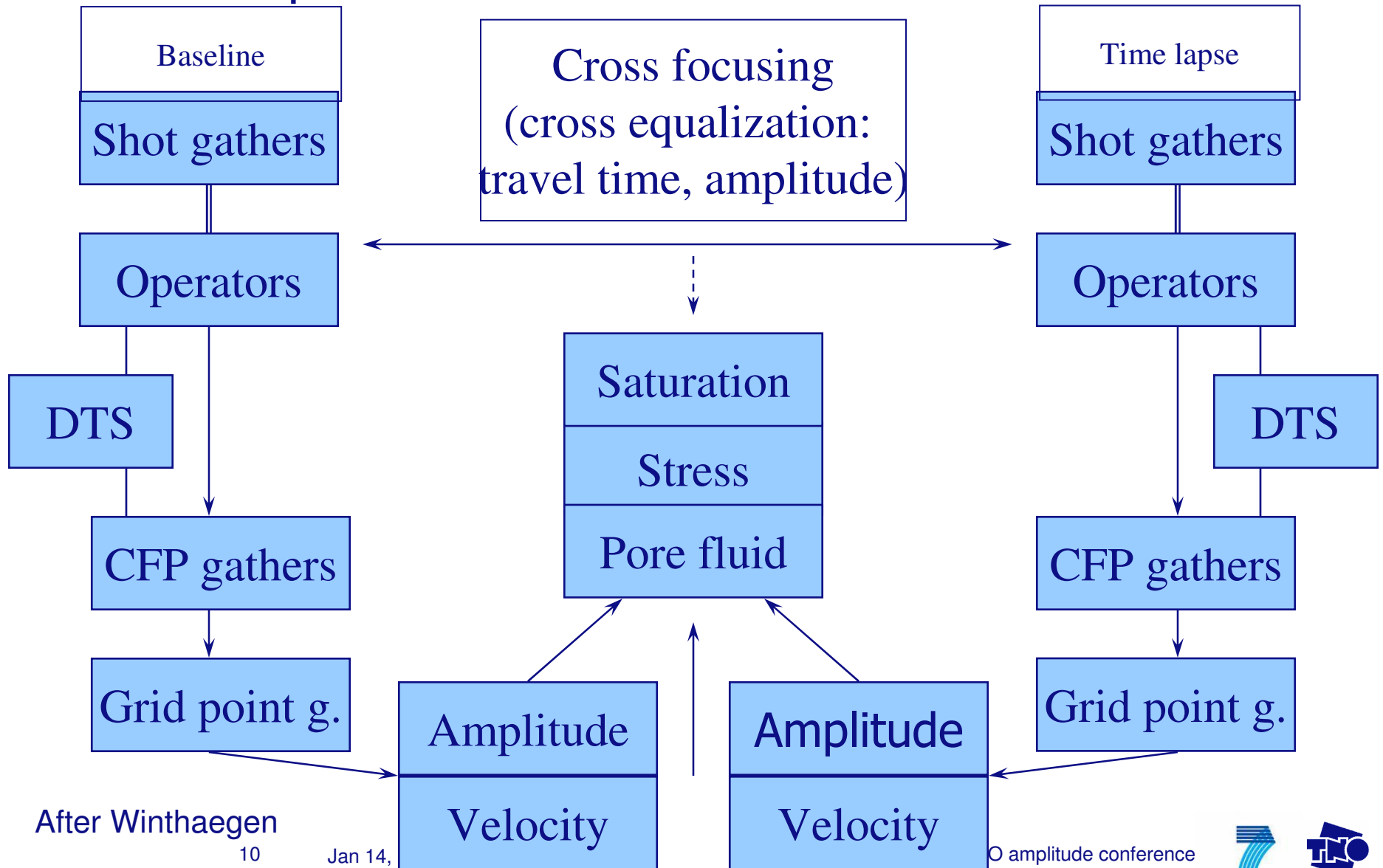
8

Jan 14, 2010

CFP work flow (2)



Time lapse CFP work flow



After Winthaegen

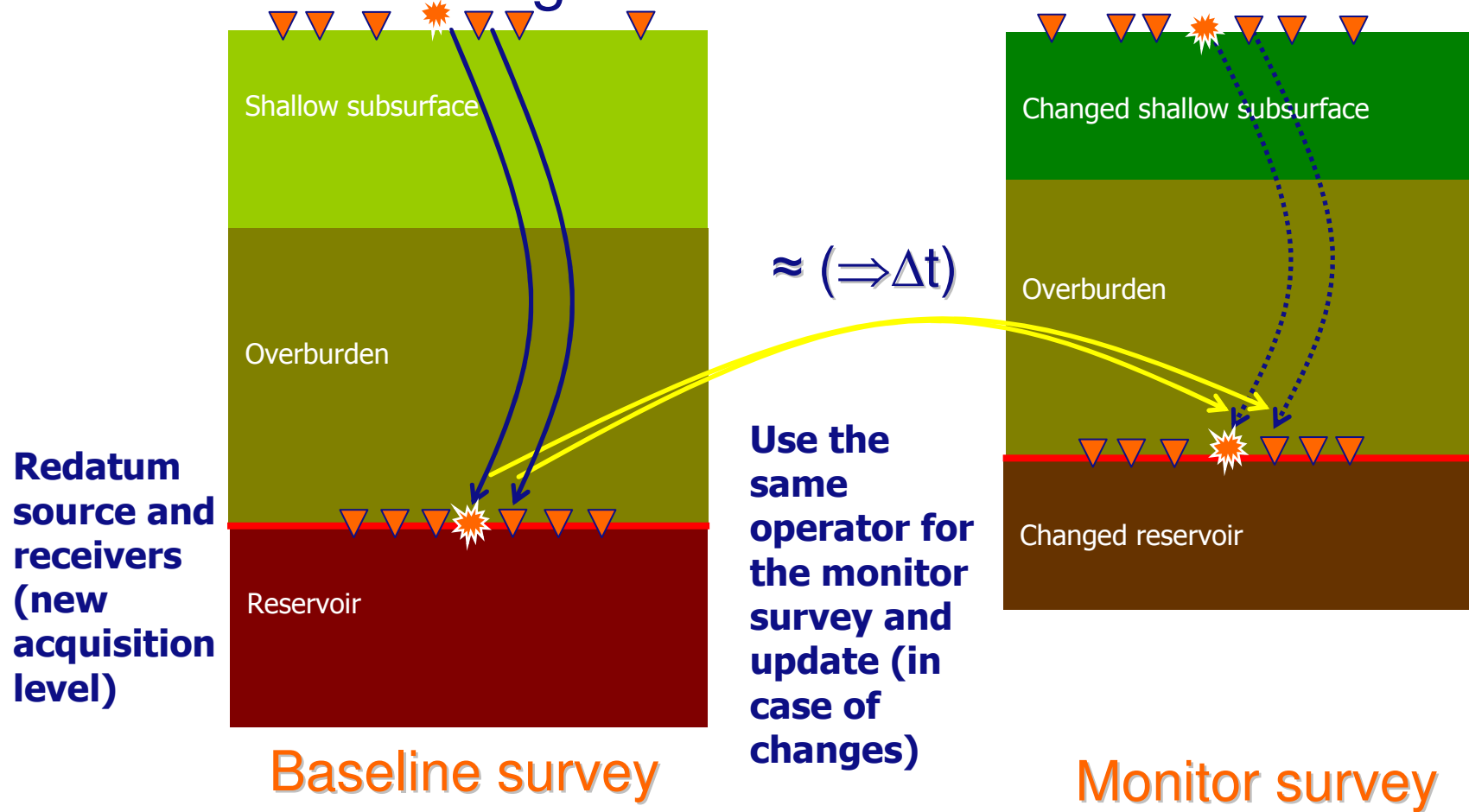
10

Jan 14,

O amplitude conference



Cross focusing: travel time



Note: focusing includes
regularization/interpolation at new datum level

After Winthagen

11

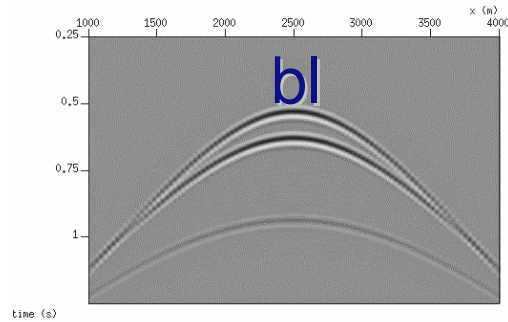
Jan 14, 2010

EBN-TNO amplitude conference

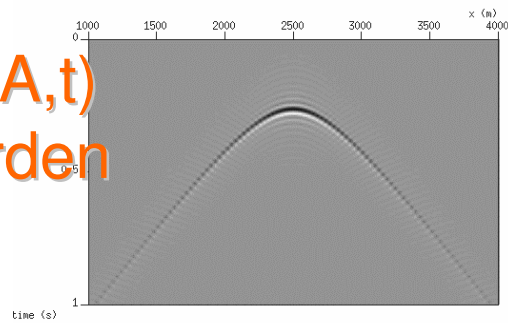


Focusing: time correction

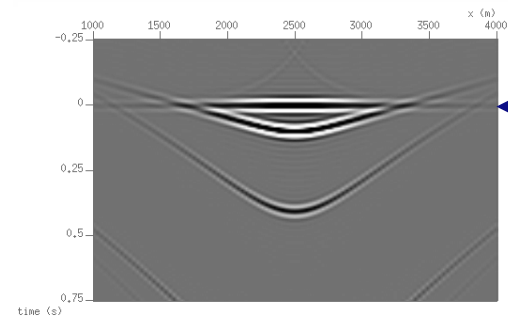
shot



Operator (A,t)
for overburden

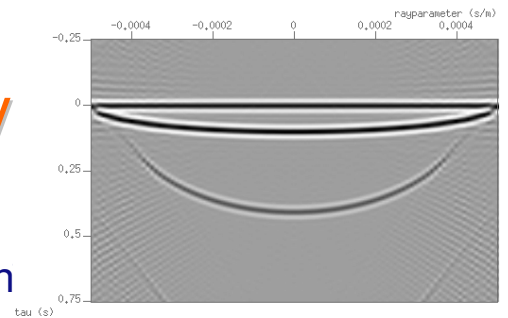


DTS



Differential time = 0

Reflectivity

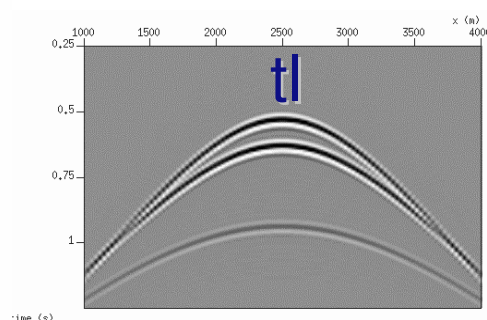
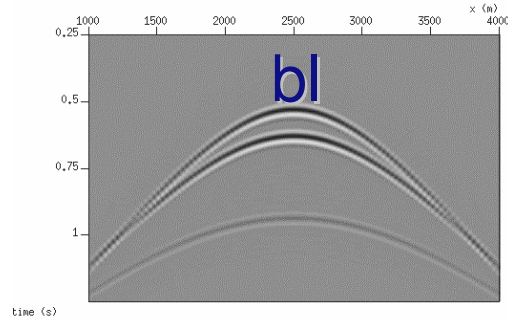


After Winthagen



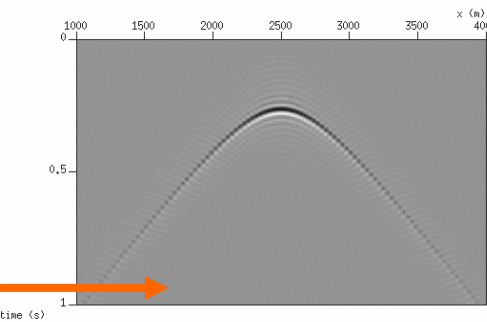
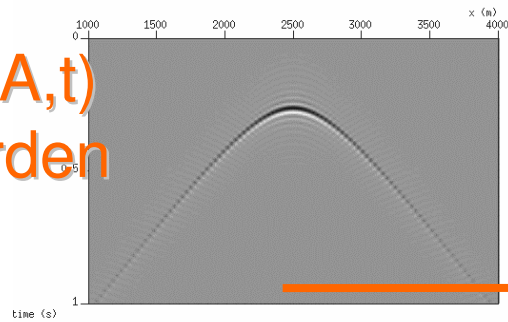
Cross equalization: time

shot



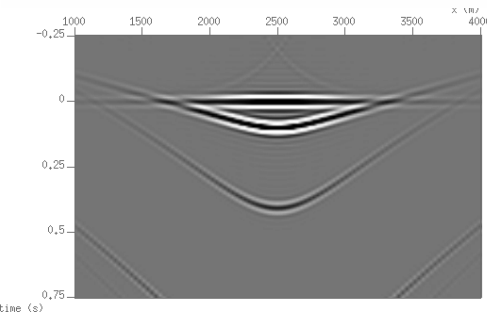
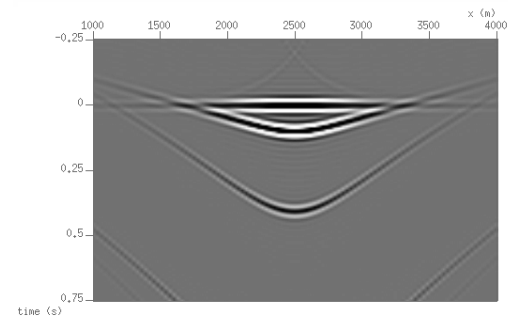
Operator (A,t)
for overburden

$$?? T_{Otl} = T_{Obl}$$

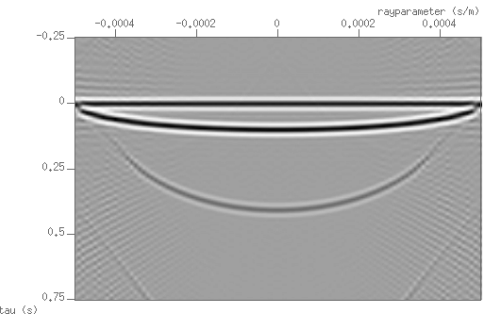
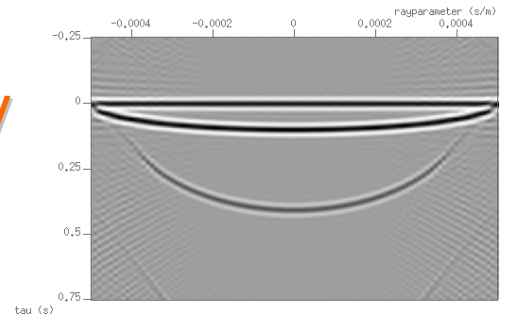


Apply kinematic
correction using
the base line
operator to the
monitor data
(and update)

DTS



Reflectivity



Cross equalization: amplitude

shot

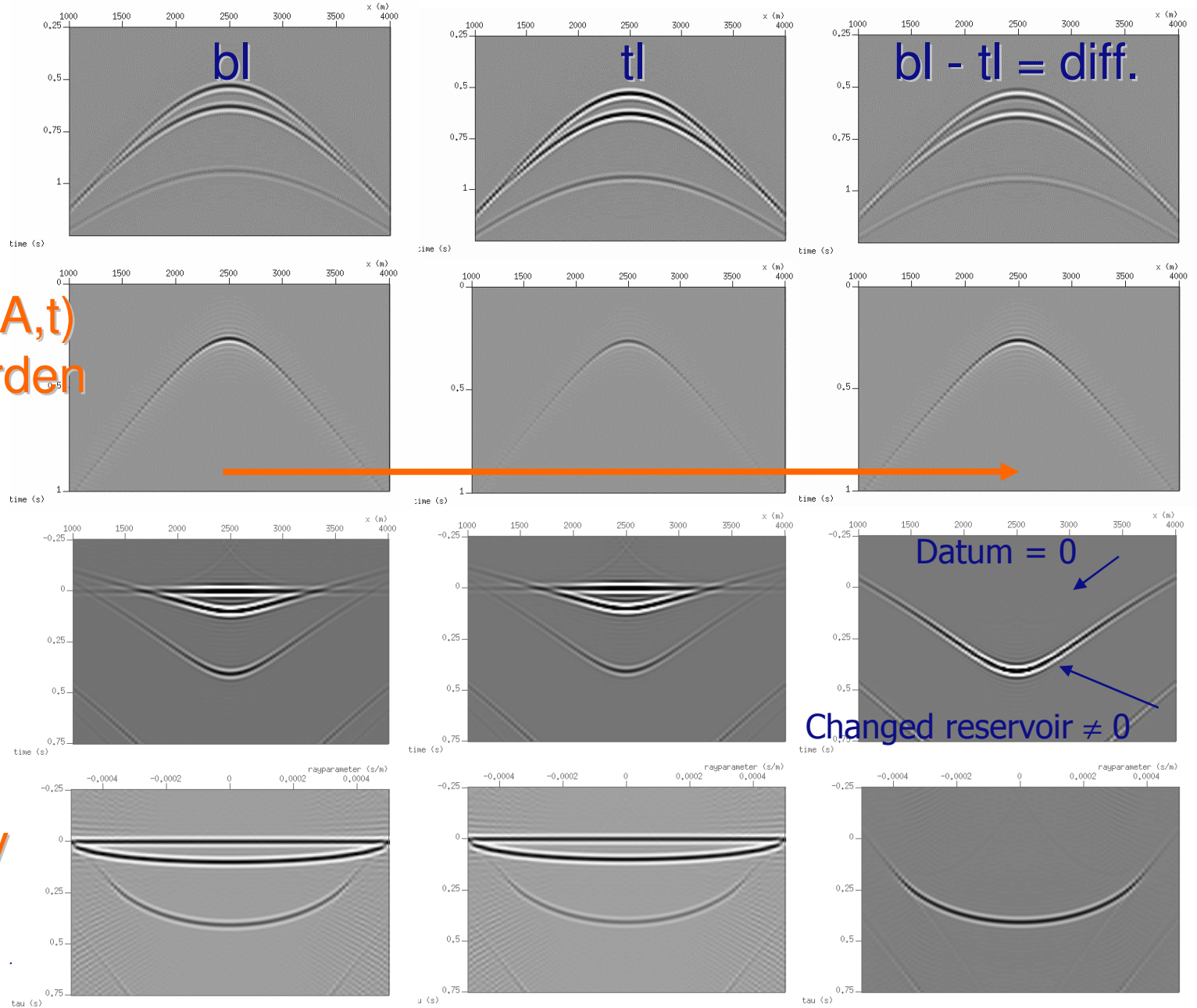
$$A_{Stl} = 4A_{Sbl}$$

Operator (A,t)
for overburden

$$A_{Otl} = 0.5 A_{Obl}$$

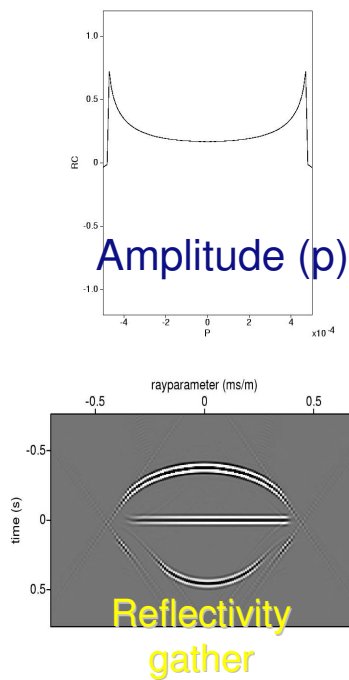
DTS

Reflectivity
(AVP)



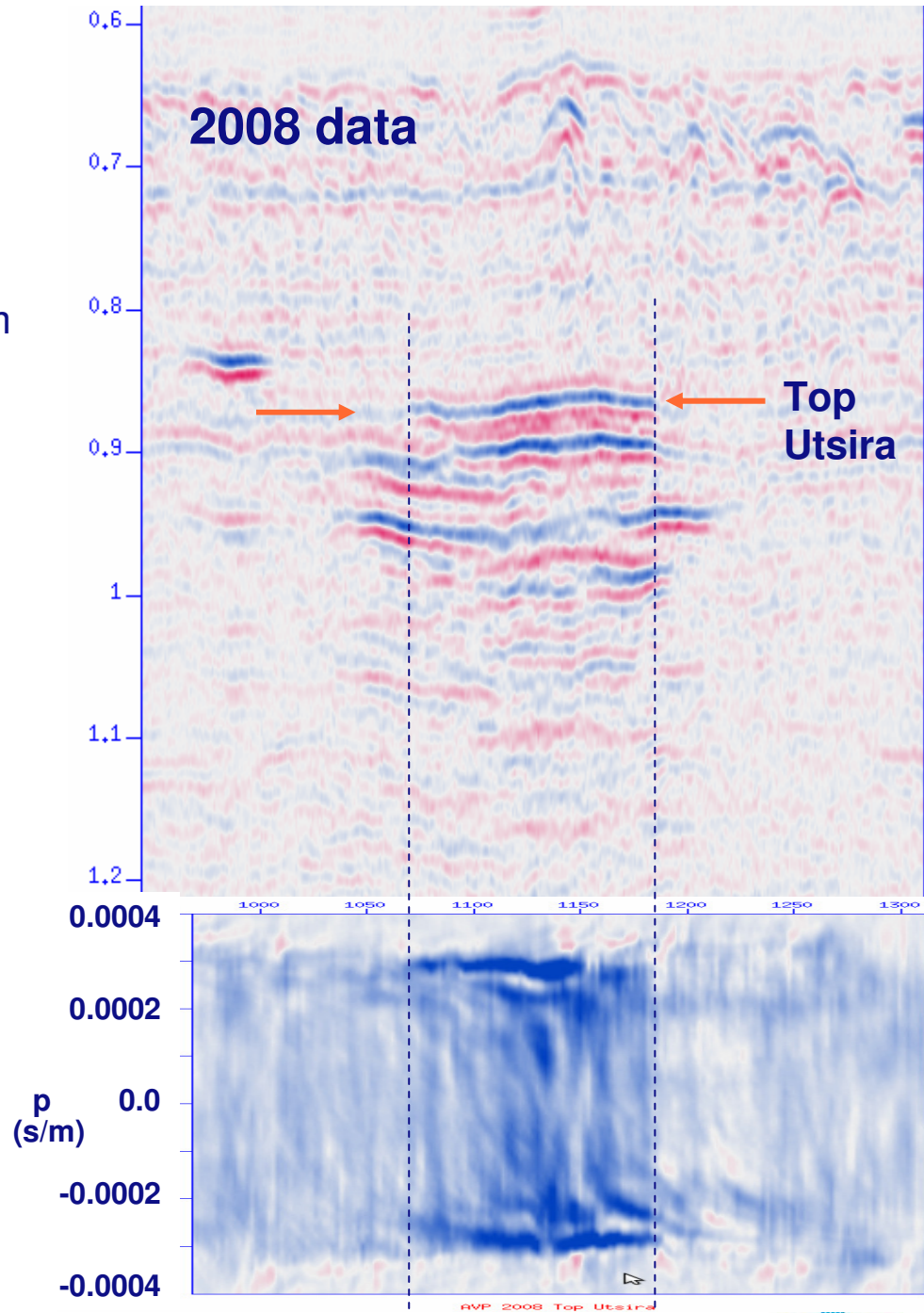
2008 data set

- CFP processing on top Utsira Fm
 - Clear reflection in plume, weak reflection elsewhere



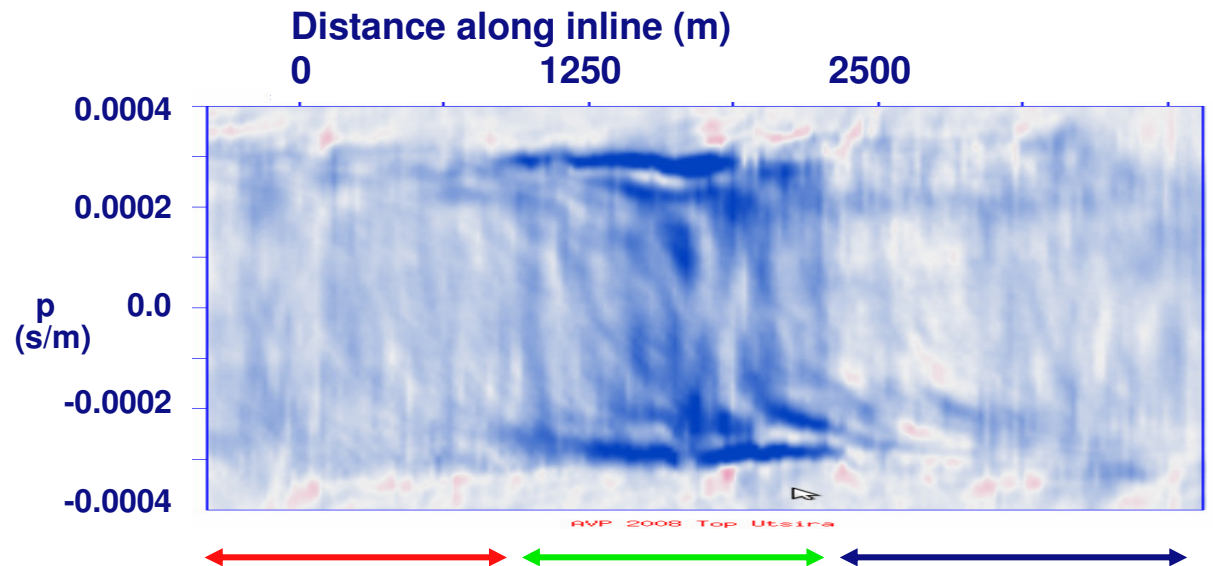
15

Jan 14, 2010

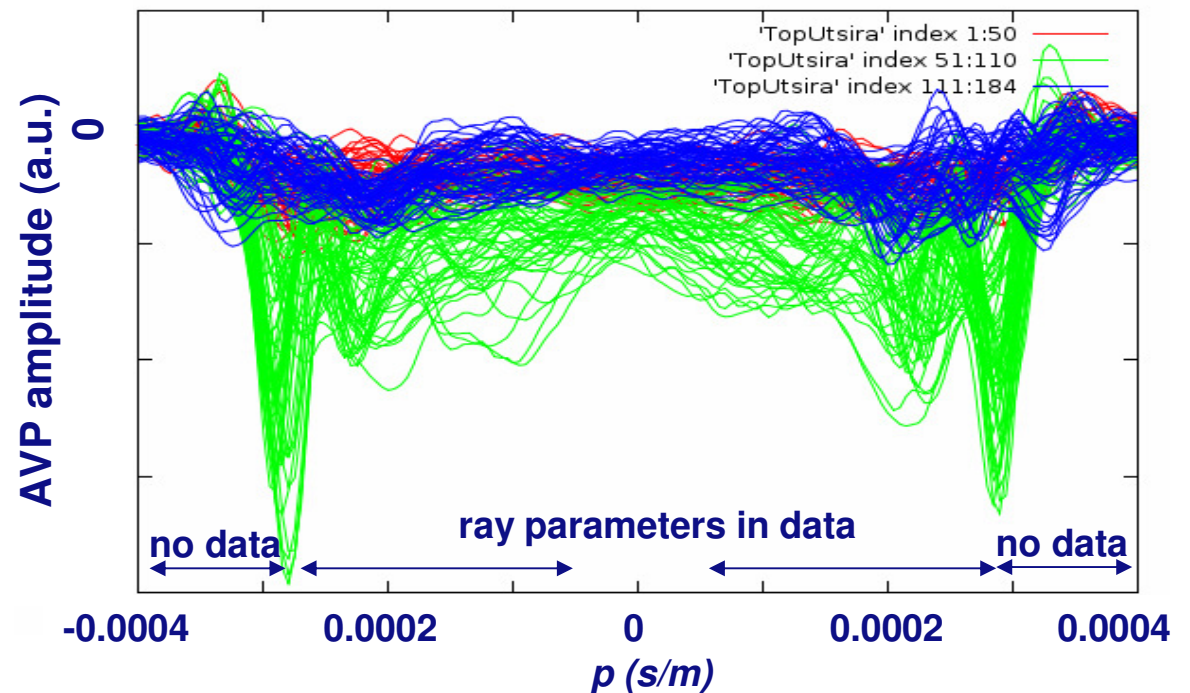


2008 data set AVP Top Utsira

- AVP panel

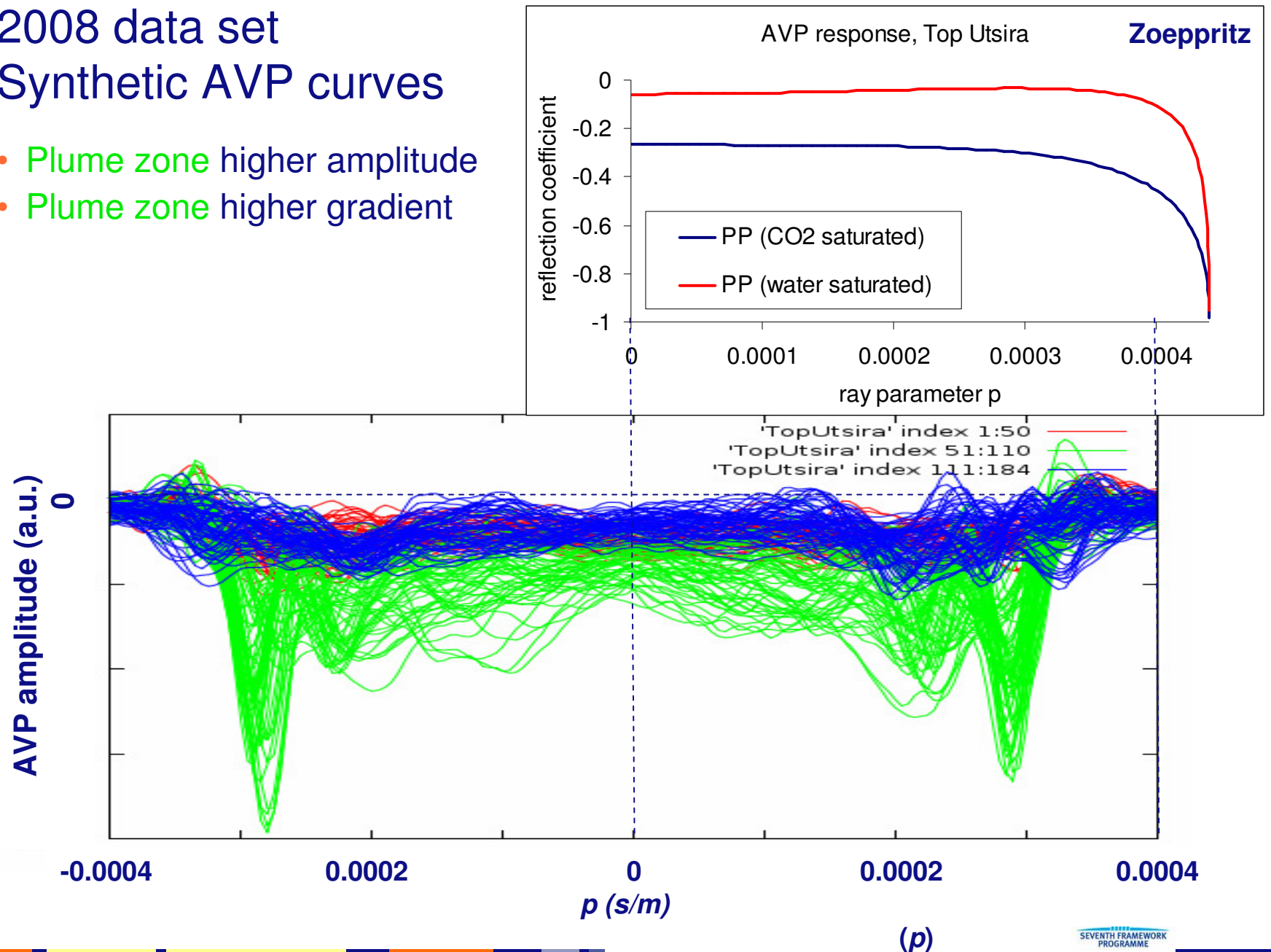


- AVP curves
 - red: 'left' of plume
 - green: 'in' plume
 - blue: 'right' of plume
- Data contain interval (approx.)
 $4e-5 < p < 0.0003$

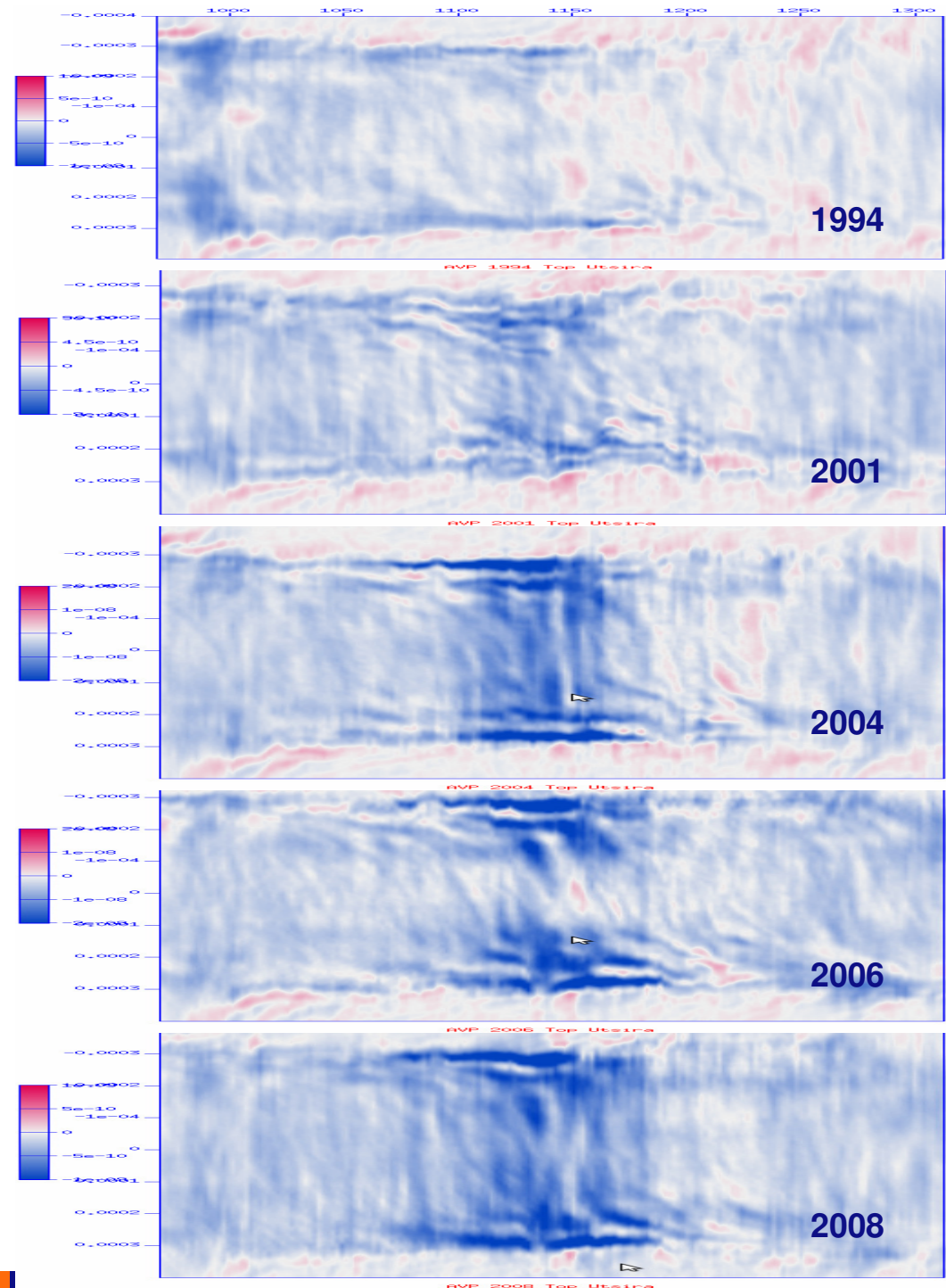


2008 data set Synthetic AVP curves

- Plume zone higher amplitude
- Plume zone higher gradient

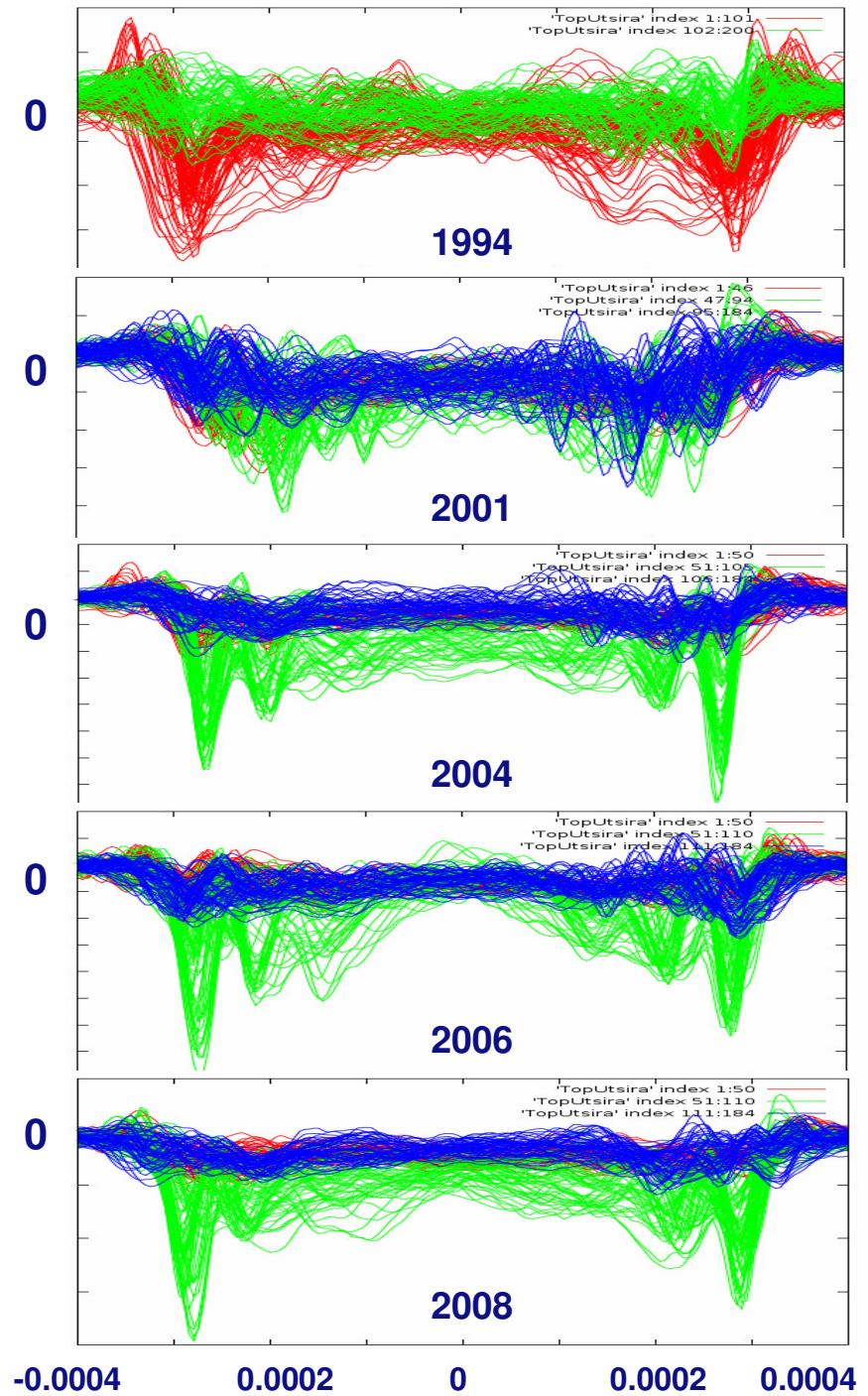


- Plume imprint on data increases
- Consistent results for time lapse surveys



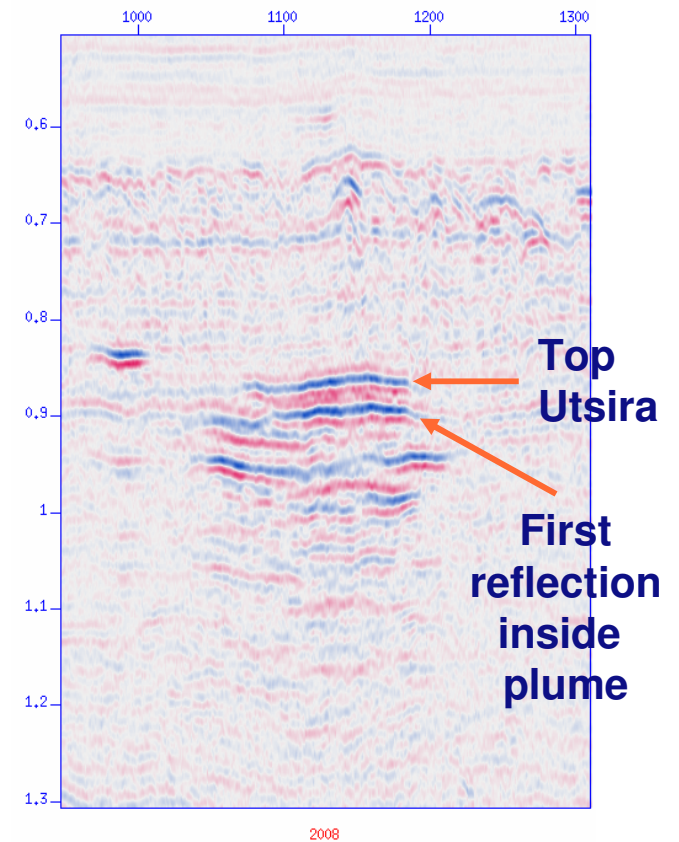
AVP curves

- Red: 'left' of plume
- Green: 'in' plume
- Blue: 'right' of plume
- Data contain interval (approx.)
 $4e-5 < p < 0.0003$
- Interference from shallower reflections
 - Restricts validity of results to interval
 $0 < p < 0.0002$ (approx.)
- More far offsets in more recent data sets

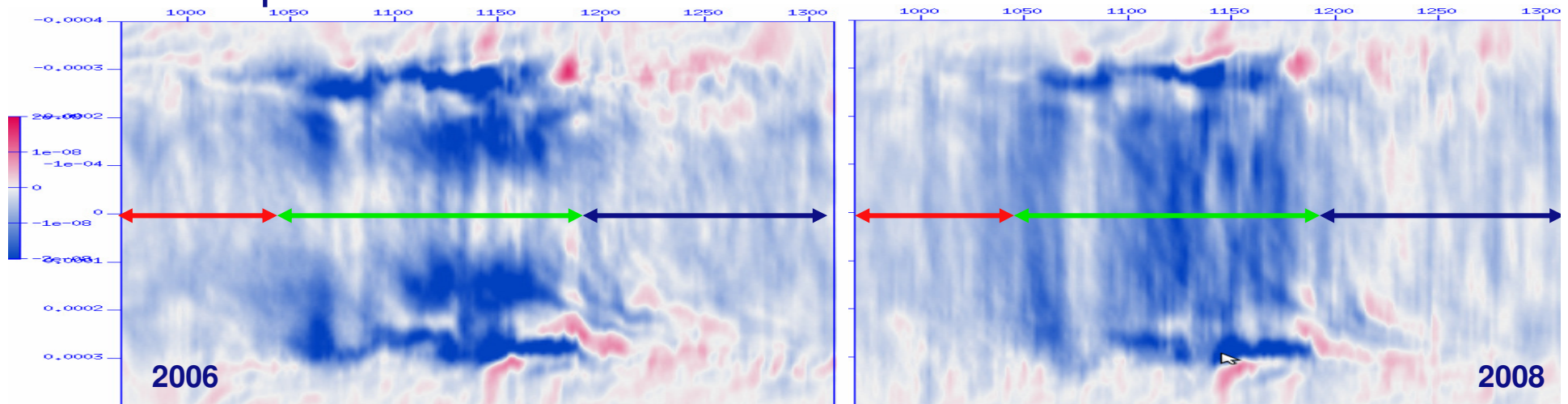


Future work

- Interpretation in terms of rock physics
- Image and analyse deeper parts of the plume (next slide)

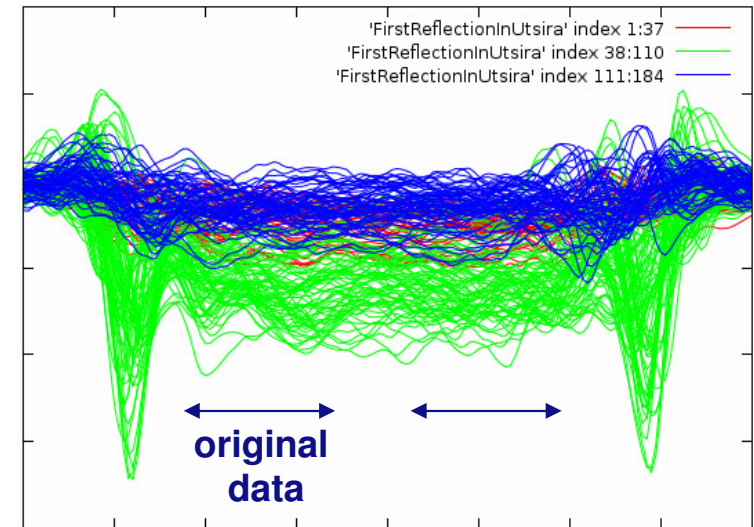
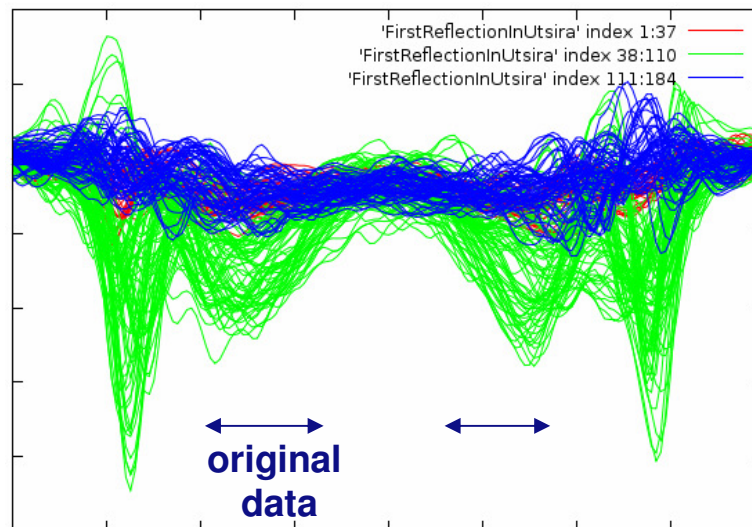


First reflections inside plume AVP panels and curves



AVP 2006 First refl in Utsira

AVP 2008 First refl in Utsira



Sleipner surveys

Inline through plume

