JOINT INVERSION OF SYNTHETIC MONITORING DATA FOR A REALISTIC MODEL FROM CAMI FIELD RESEARCH STATION (FRS), CANADA

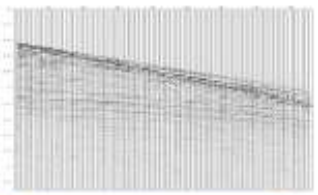
Michael Jordan, Dennis Rippe, Anouar Romdhane, Cornelia-Schmidt-Hattenberger, Marie Macquet and Don Lawton

TCCS 10, Trondheim, 18.06.2019

Motivation

- Requirements for underground CO_2 storage
  - Ensure containment and conformance
- Reliable information about the subsurface behavior and long-term fate of the injected CO_2
  - Quantitative monitoring of reservoir parameters
    - Stress, pressure, saturation, or strain in the overburden

Quantitative monitoring of reservoir parameters



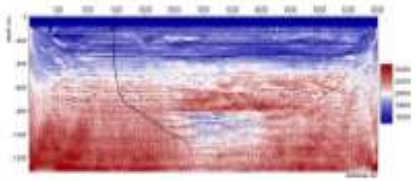
Geophysical data

- Seismic
- EM

Time-lapse imaging

FWI, CSEM

Acoustic FWI on Sleipner data (Romdhane and Querendez, 2014, Energy Procedia)



Geophysical images

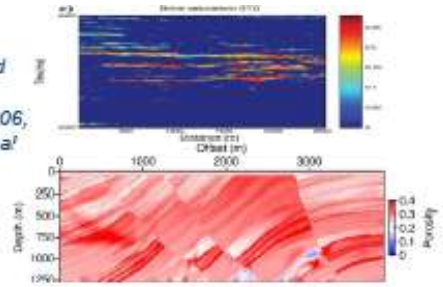
Geophysical attributes:

- Velocities
- Attenuations
- Resistivities

Rock physics inversion

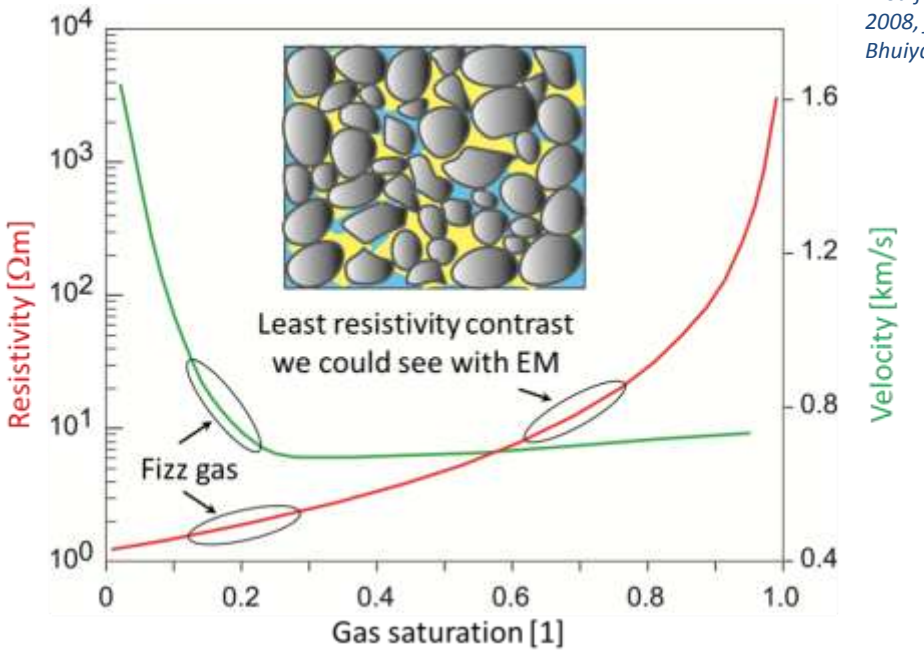
Dupuy et al, 2015, Geophysics

Saturation and porosity maps (Bachrach, 2006, and Dupuy et al 2015)

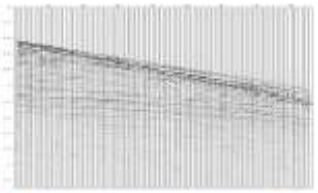


Rock physics properties

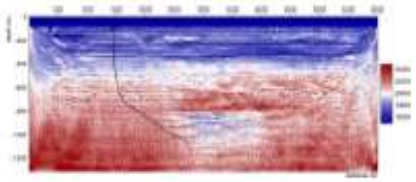
- Porosity, bulk and shear moduli
- Pressure, saturation



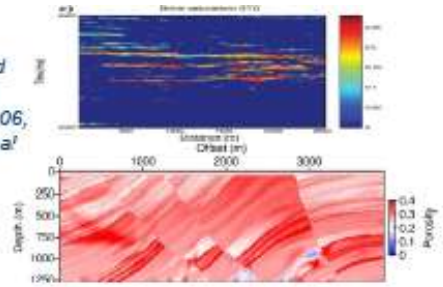
Modified after Constable, 2008, from presentation by Bhuiyan et al., 2011



Acoustic FWI on Sleipner data (Romdhane and Querendez, 2014, Energy Procedia)



Saturation and porosity maps (Bachrach, 2006, and Dupuy et al 2015)



Geophysical data

- Seismic
- EM

Time-lapse imaging

FWI, CSEM

Geophysical images

Geophysical attributes:

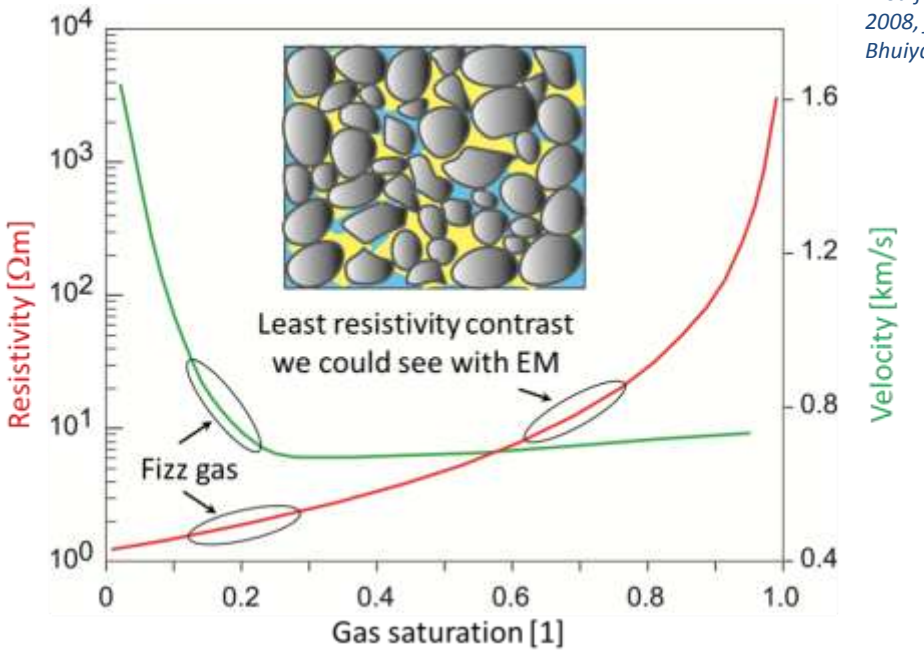
- Velocities
- Attenuations
- Resistivities

Rock physics inversion

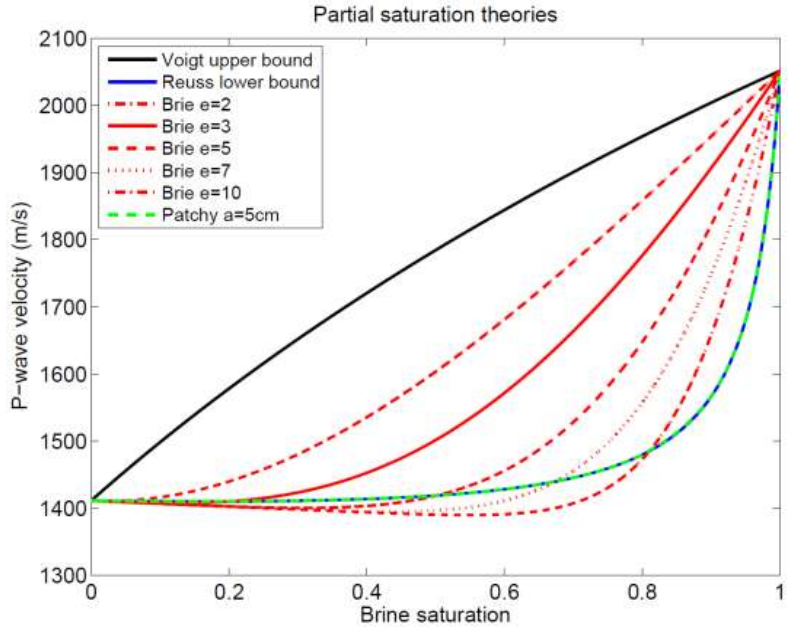
Dupuy et al, 2015, Geophysics

Rock physics properties

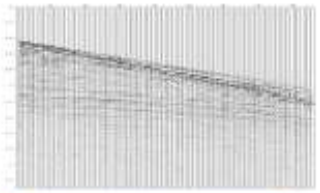
- Porosity, bulk and shear moduli
- Pressure, saturation



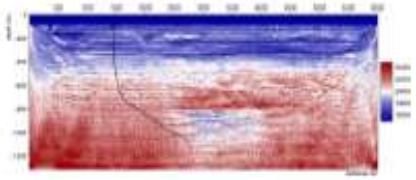
Modified after Constable, 2008, from presentation by Bhuiyan et al., 2011



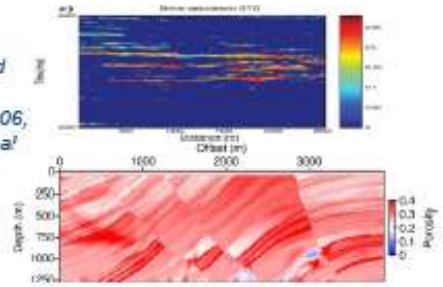
Dupuy, 2018



Acoustic FWI on Sleipner data (Romdhane and Querendez, 2014, Energy Procedia)



Saturation and porosity maps (Bachrach, 2006, and Dupuy et al 2015)



Geophysical data

- Seismic
- EM

Time-lapse imaging

FWI, CSEM

Geophysical images

Geophysical attributes:

- Velocities
- Attenuations
- Resistivities

Rock physics inversion

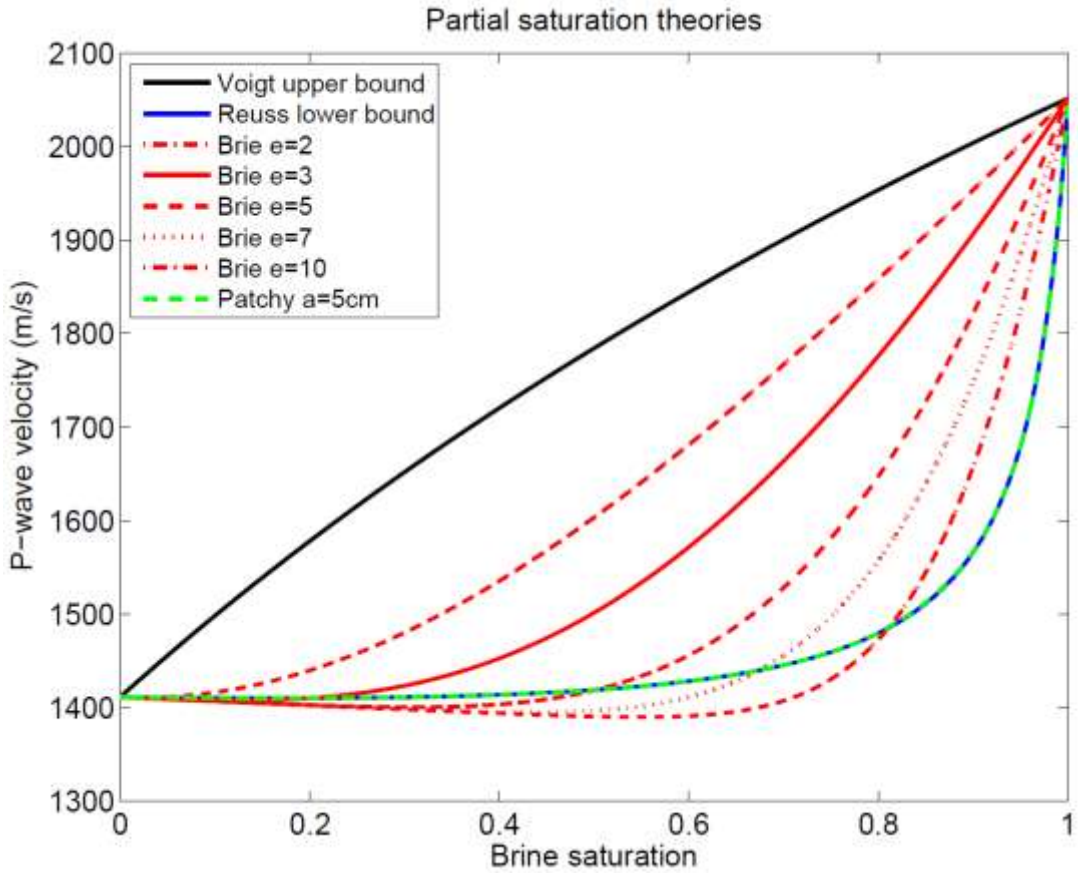
Dupuy et al, 2015, Geophysics

Rock physics properties

- Porosity, bulk and shear moduli
- Pressure, saturation

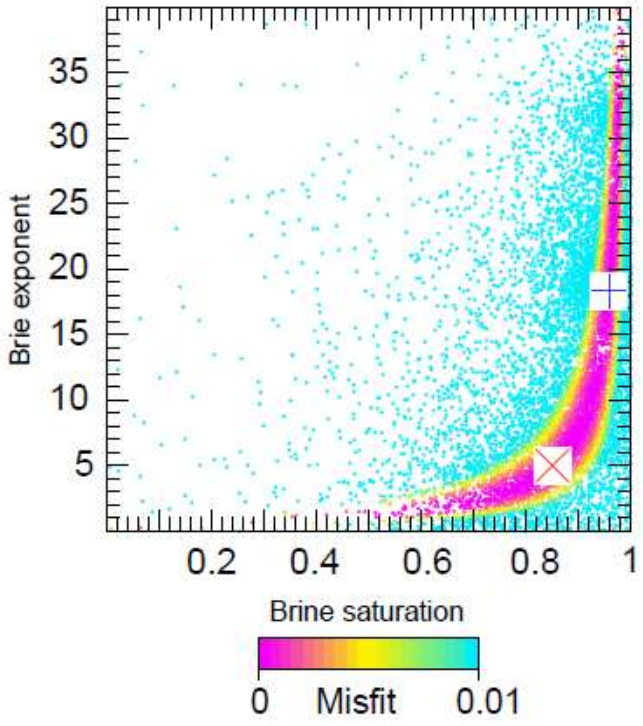
SINTEF

Quantitative inversion and rock physics models

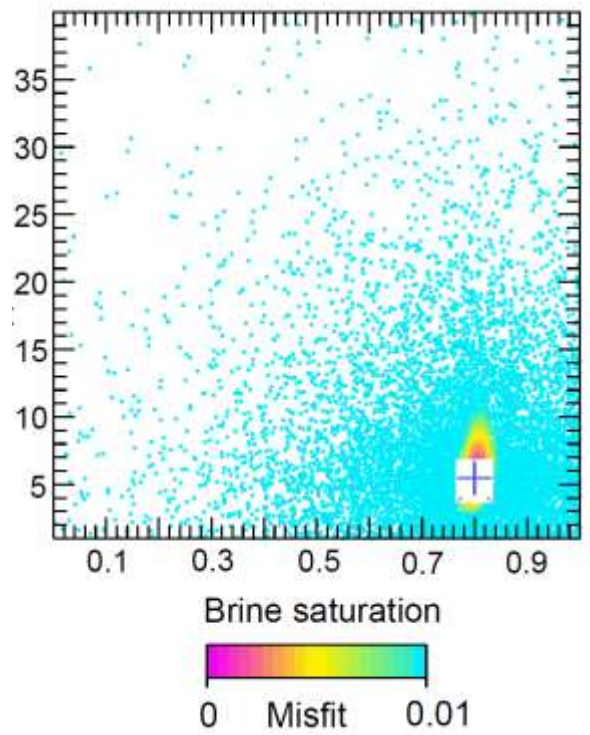


Dupuy, 2018

SEISMIC



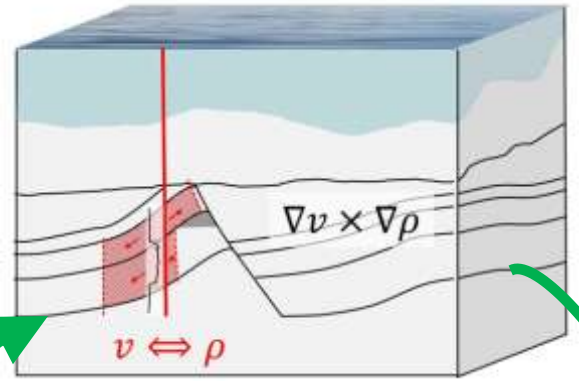
SEISMIC + CSEM

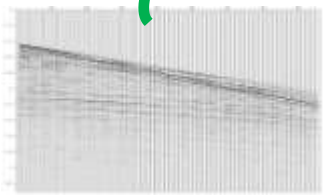


Dupuy, 2018

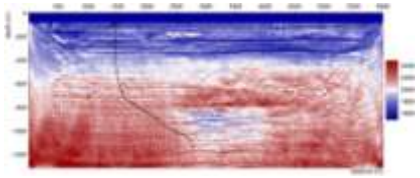
SINTEF

Data integration through joint inversion

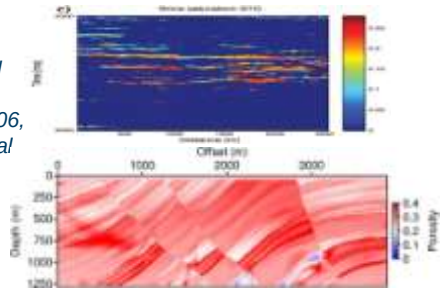




Acoustic FWI on Sleipner data (Romdhane and Querendez, 2014, Energy Procedia)



Saturation and porosity maps (Bachrach, 2006, and Dupuy et al 2015)



Geophysical data

- *Seismic*
- *EM*
- *gavity*

Time-lapse imaging

FWI, CSEM, ERT, gravity

Geophysical images

- *Geophysical attributes:*
- *Velocity*
- *Attenuation*
- *Resistivities*
- *Density*

Rock physics inversion

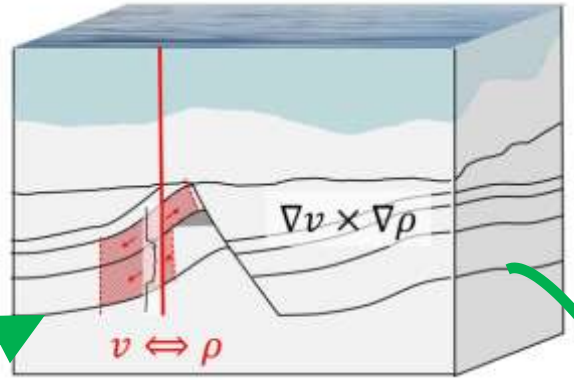
Dupuy et al, 2015, Geophysics

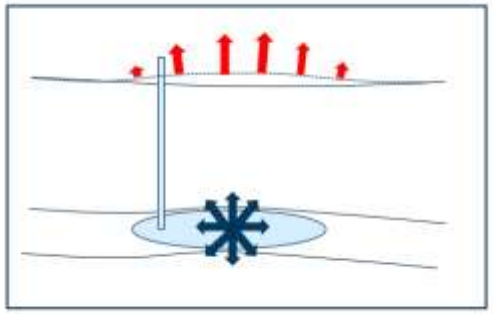
Rock physics properties

- *Porosity, bulk and shear moduli*
- ***Pressure, saturation***

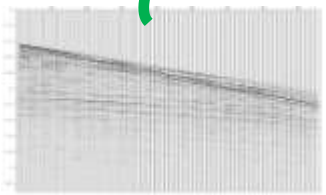
SINTEF

Data integration through joint inversion

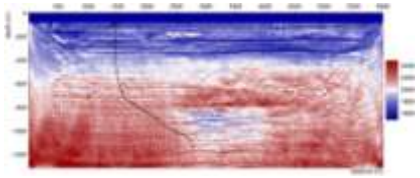




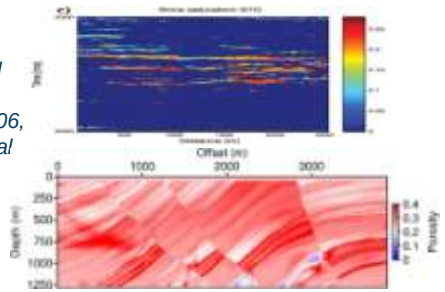
uplift / tilt
&
geomechanical
modelling



Acoustic FWI on Sleipner data (Romdhane and Querendez, 2014, Energy Procedia)



Saturation and porosity maps (Bachrach, 2006, and Dupuy et al 2015)



Geophysical data

- *Seismic*
- *EM*
- *gavity*

Time-lapse imaging

FWI, CSEM, ERT, gravity

Geophysical images

- *Geophysical attributes:*
- *Velocity*
- *Attenuation*
- *Resistivities*
- *Density*

Rock physics inversion

Dupuy et al, 2015, Geophysics

Rock physics properties

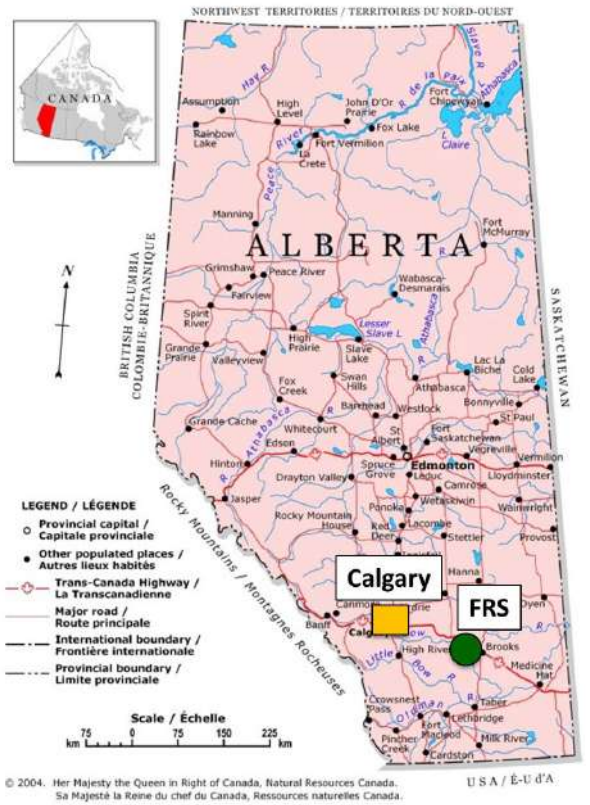
- *Porosity, bulk and shear moduli*
- ***Pressure, saturation***

SINTEF

The aCQurate project

- Quantitative monitoring of reservoir parameters
  - pressure, saturation, stress, or strain in the overburden
- Integrate methods relevant for CO_2 storage through advanced hybrid structural-petrophysical joint inversion
  - Large-scale and high resolution
  - On-shore / off-shore
  - Quantitative
- FRS data for development and performance validation

The CaMI.FRS site

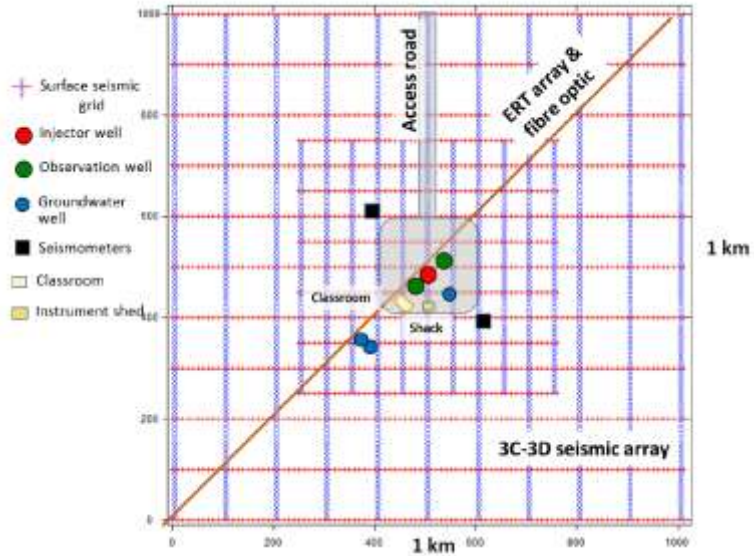


Field Research Station (FRS) provides data sets ideal for project

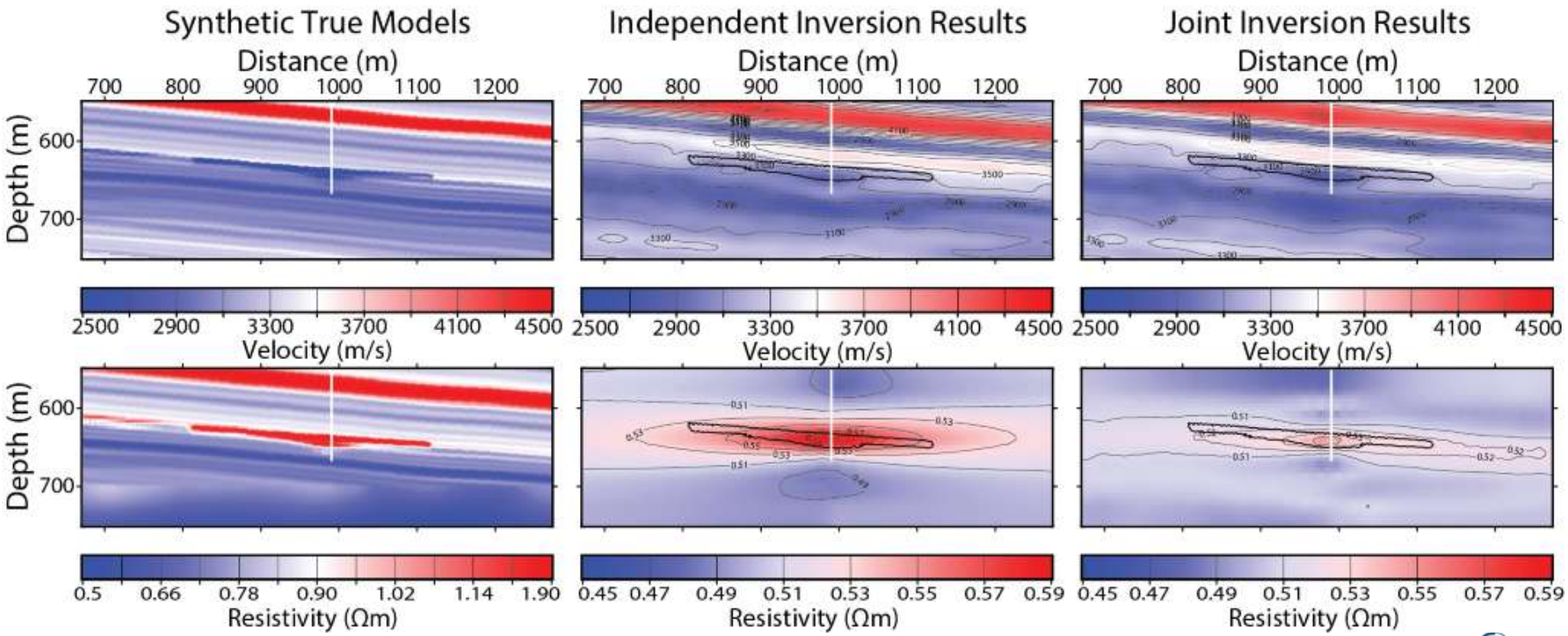
- Designed for advancing and testing CO_2 monitoring technology
- Variety of specific monitoring challenges
- Provides both on- and off-shore data types for development and testing of joint inversion/data integration methods
  - Collocated
  - Surface, VSP-type, Cross-well

geophysical parameter	from brine to supercritical CO_2	from brine to gaseous CO_2	from brine to dissolved CO2	references
compressional wave velocity	↓↓	↓↓	↓	Myer (2001), Ghaderi and Landrø (2009), Mavko et al. (2009), Pride et al. (2004), Carcione et al. (2006), Lepore and Ghose (2015)
resistivity	↑	↑	↓	Hoversten and Gasperikova (2005), Kummerow and Spangenberg (2011), Szecsody et al., (2014),Myer (2001)
density	↓	↓	↑	Ghaderi and Landrø (2009)

Comparison of relative effect of presence CO_2 on physical parameters (increase, decrease)



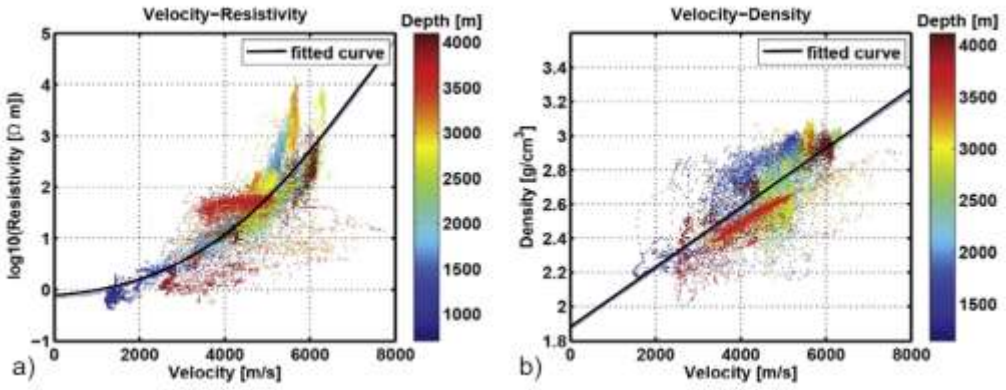
Joint inversion examples (Ketzin)

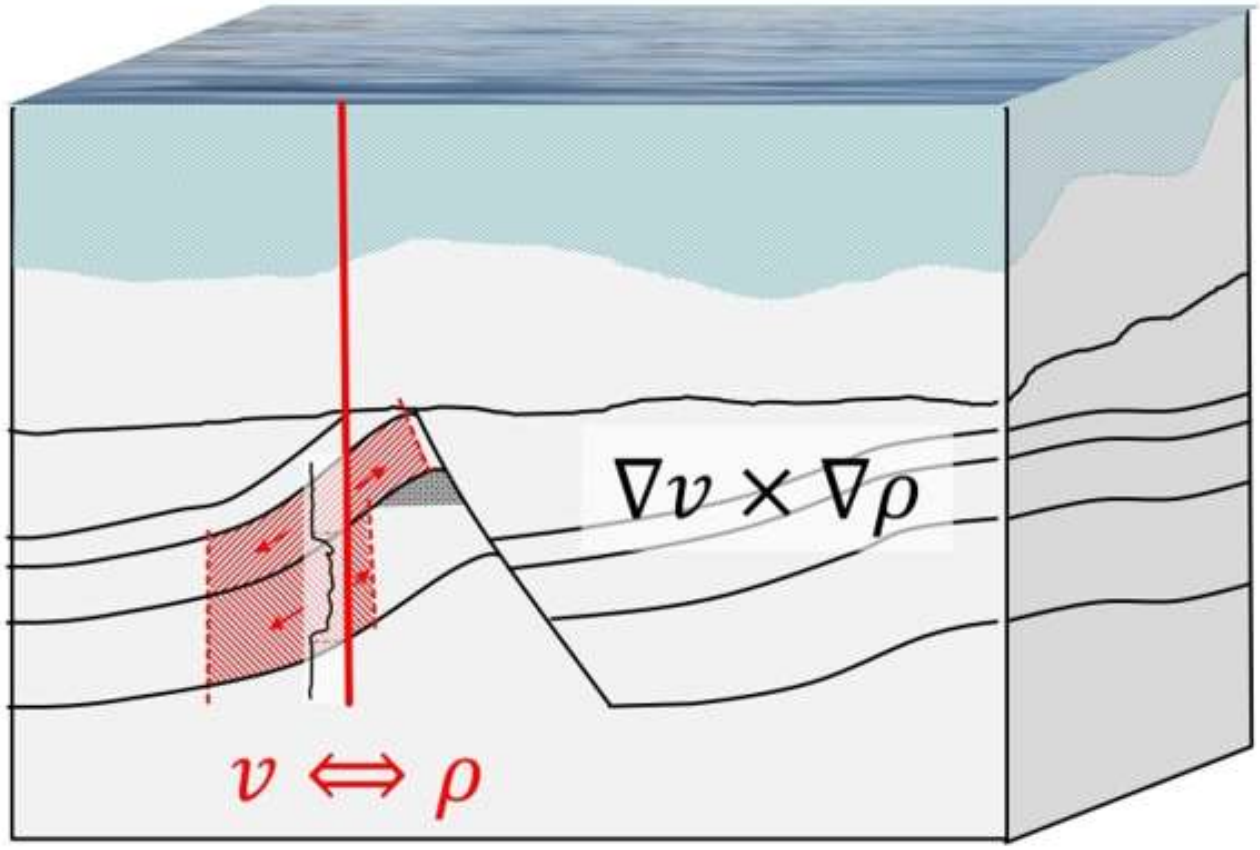


SINTEF

Joint inversion in aCQurate

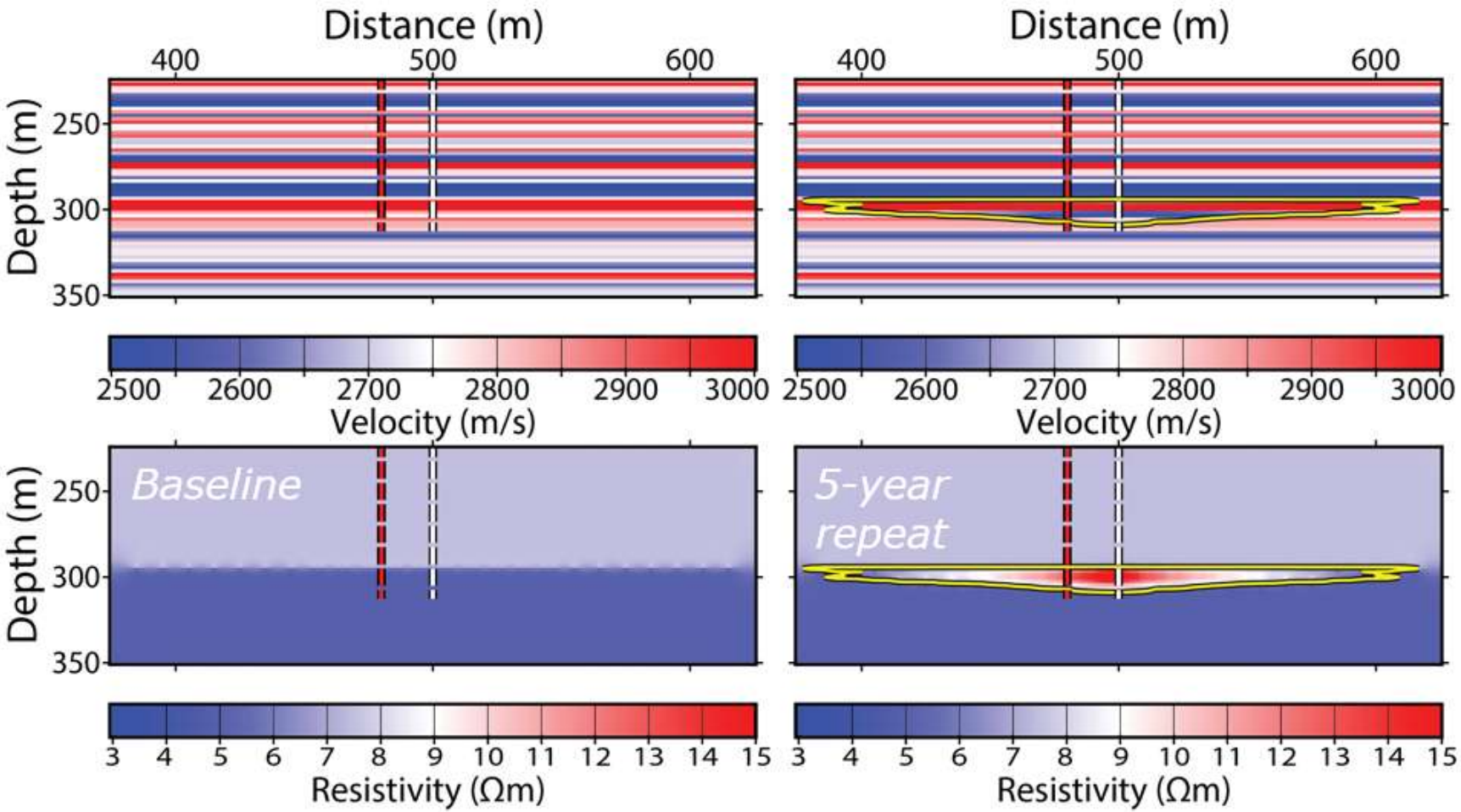
- Hybrid joint inversion (JI)
  - Structural JI
  - Petrophysical JI





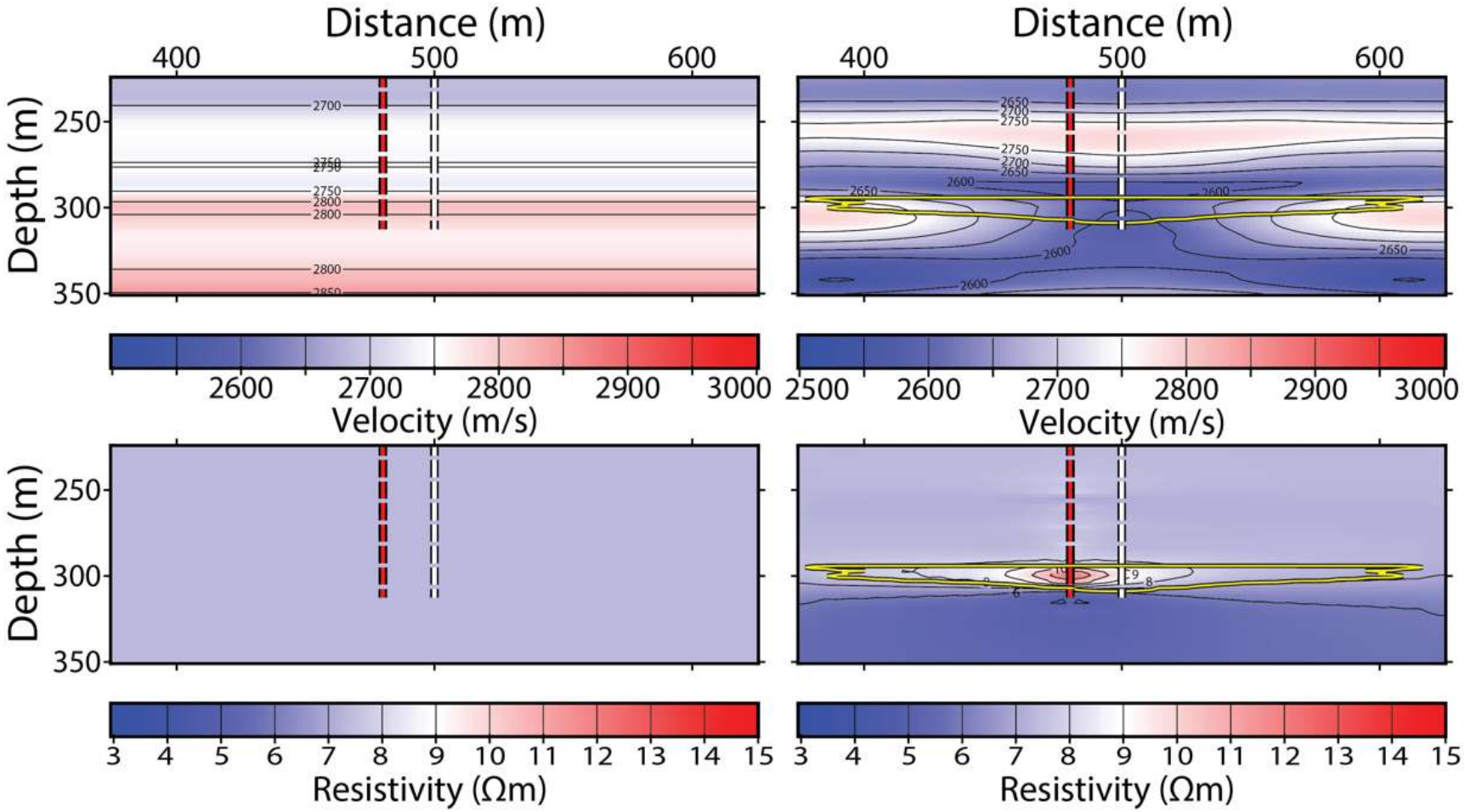
SINTEF

True (synthetic) CaMI.FRS models



SINTEF

Independent FWI and ERT inversions

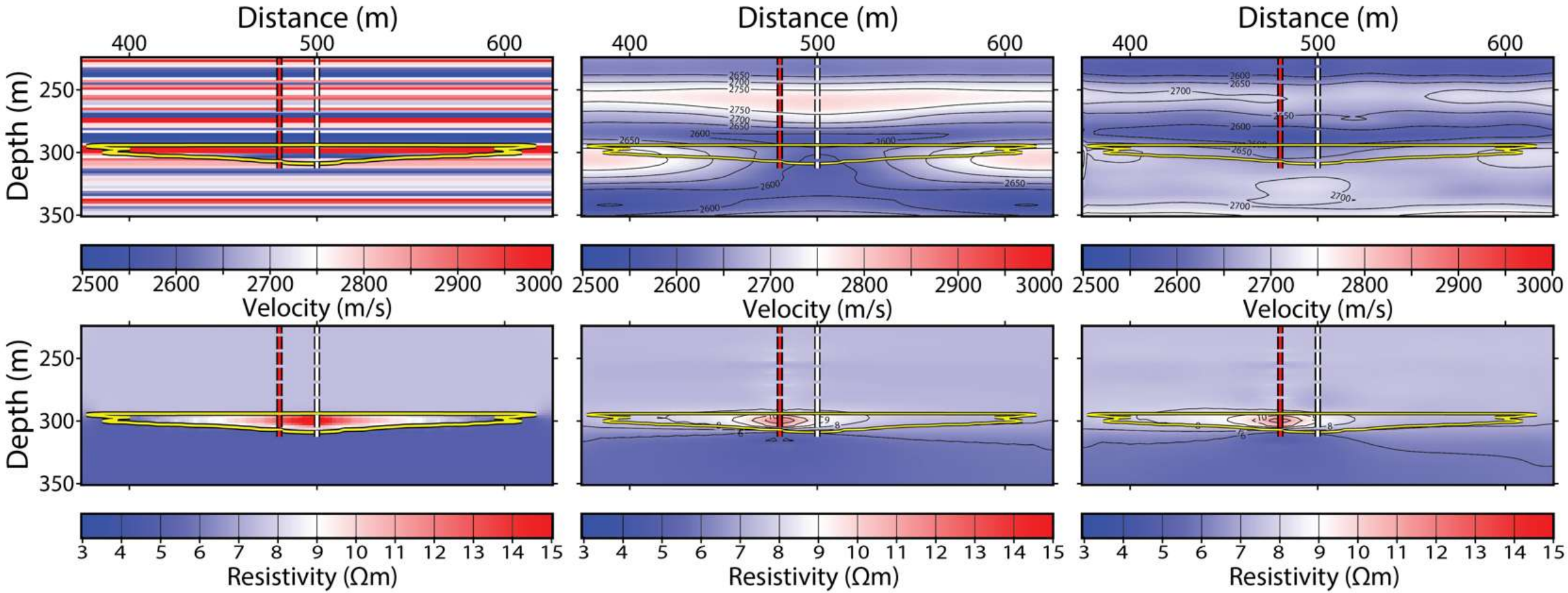


Starting models

Independent results

SINTEF

Joint Inversion Results



True models

Independent results

Joint results

Summary and conclusion

- Joint inversion for quantitative monitoring of reservoir parameters
- First tests of the structural part show good improvements over the independent inversions
- CaMI.FRS provides relevant collocated data types for development and testing
- Development ongoing
  - Focus on large scale feasibility and proper balancing of methods and constraints
  - Petrophysical joint inversion implementation ongoing
  - 3D/4D

Acknowledgements

Funding is provided by the Norwegian CLIMIT program (project number 616067), Equinor ASA, CMC Research Institutes Inc., University of Calgary, Lawrence Berkeley National Laboratory (LBNL), Institut national de la recherche scientifique (INRS), Quad Geometrics Norway AS and GFZ German Research Centre For Geosciences (GFZ).

SINTEF

Teknologi for et bedre samfunn