Two-step geophysical inversion

Seismic data

CSEM data

Seismic inversion (FWI)

CSEM inversion

P-wave velocity map

Resistivity map

Saturation and fluid mixing maps

Figures from Romdhane and Querendez (2014), Park et al. (2013), Bae et al. (2017), Dupuy et al. (2017), Yan et al. (2018)

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CO₂ injection at Sleipner

- CO₂ separated from the produced gas in the Sleipner Vest gas field.
- CO₂ injection site since 1996.
- Approximately 1 Million tonnes per year of injected CO₂.
- Injection into Utsira saline reservoir between 800 -1000 m depth.
- Injection point is about 1010 m below sea level.
- Near critical state at reservoir conditions.
- Storage reservoir: Utsira formation (Upper Miocene to Lower Pliocene).

Location of the Sleipner East field and sketch of injection in Utsira formation (IPCC, 2005).
Time-lapse strategy at Sleipner

Well logs and core measurements:
- Specific rock frame properties (permeability, tortuosity...)
- Fluid phase properties (pressure, temperature, salinity)
- Mineralogy, solid grains parameters (clay content)

Acoustic FWI
Bayesian RPI

Uncertainty quantification

BASELINE DATA

Seismic data
- Acoustic FWI
- P-wave velocity $V_p$
- Porosity $\phi$
- Dry rock bulk modulus $K_D$
- Dry rock shear modulus $G_D$

Seismic data
- Acoustic FWI
- P-wave velocity $V_p$
- CO2 saturation $S_{CO2}$

MONITOR DATA

Uncertainty quantification

$K_D$, $G_D$, $\phi$ baseline maps (+ uncertainties)

Methods
Input data
Estimated properties

Full seismogram

$V_p$ map + uncertainty

Well logs and core measurements:
- Specific rock frame properties (permeability, tortuosity...)
- Fluid phase properties (pressure, temperature, salinity)
- Mineralogy, solid grains parameters (clay content)

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Figure from Dupuy et al. (2020)
Sleipner Inline 1836: seismic inversion (FWI) results, reservoir close-up

Figures from Yan et al. (2018)
Saturation maps (2008) by rock physics inversion

Patchiness exponent $e=1$

$\text{CO}_2$ saturation

$\text{CO}_2$ saturation uncertainty

Patchiness exponent $e=5$
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https://www.sintef.no/nccs

References:

• Dupuy B., Romdhane A., Eliasson P. and Yan H., Quantitative monitoring workflow for CO2 storage, submitted to IJGGC.
Teknologi for et bedre samfunn