Joint Bayesian spatial inversion of lithology/fluid classes, petrophysical properties and elastic attributes – A Norwegian Sea gas discovery

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Norwegian Sea case study

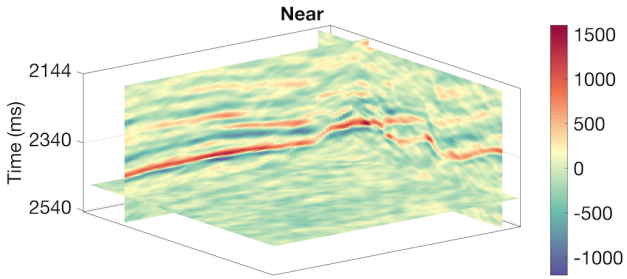
Notation:

$\boldsymbol{\kappa}$: Shale, gas sandstone or brine sandstone

r : Porosity, water saturation and clay volume

m : Log-P impedance and V_p/V_s

d : observations, seismic amplitude versus offset (AVO)



Bayesian inversion:

$$p(\boldsymbol{\kappa}, \mathbf{r}, \mathbf{m}|\,\mathbf{d}) \propto p(\mathbf{d}|\,\mathbf{m})\, p(\mathbf{m}|\,\boldsymbol{\kappa}, \mathbf{r})\, p(\mathbf{r}|\,\boldsymbol{\kappa}) \exp\left(-\sum_{c\in\mathcal{C}} \Phi_c(\boldsymbol{\kappa})\right)$$

We compare the proposed model with a model where each vertical trace is inverted independently.

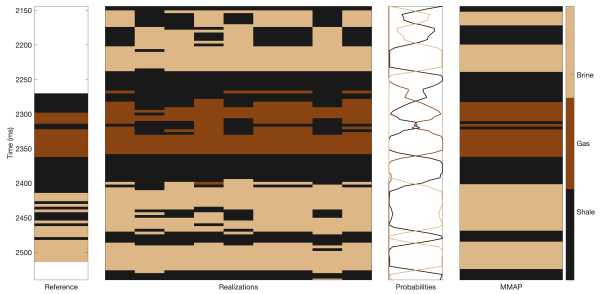
Simulation algorithm

Iterate

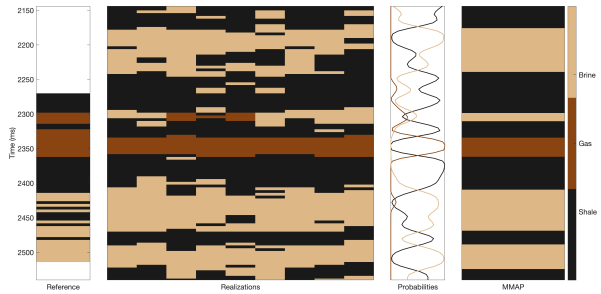
1. Choose a random vertical trace xy
2. Construct a Markov chain formulation $p(\boldsymbol{\kappa}_{xy} | \boldsymbol{\kappa}_{-xy})$ for the vertical trace given the Markov random field parametrization
3. Construct a Markov chain approximation to $p(\boldsymbol{\kappa} | \mathbf{d})$
4. Propose a realization $\boldsymbol{\kappa}$
5. Accept/reject proposed realization

Samples from $p(\mathbf{r} | \mathbf{d})$ and $p(\mathbf{m} | \mathbf{d})$ are straightforward to obtain afterwards.

Blind-well comparison (50,000 realizations)

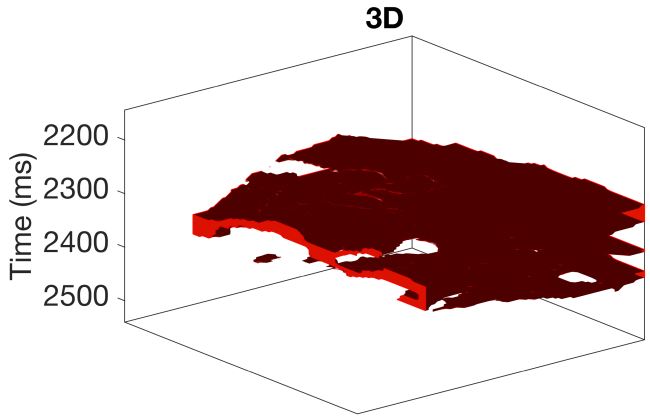


Dependent traces

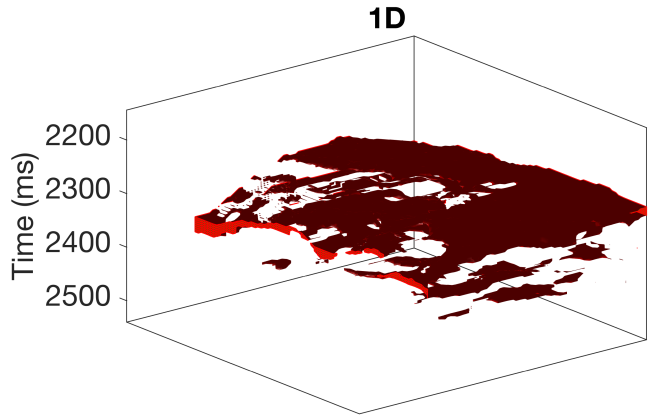


Independent traces

Iso-50 probability gas



Dependent traces

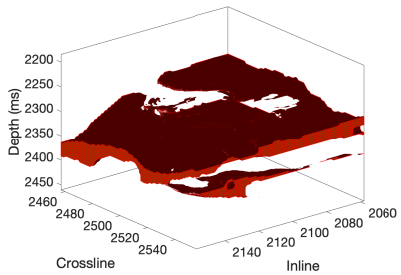


Independent traces

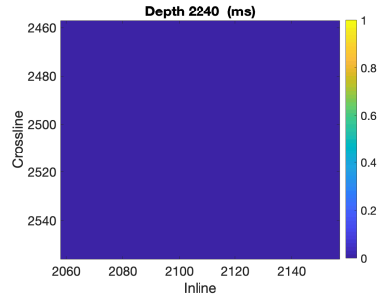
Prediction error (blind well)

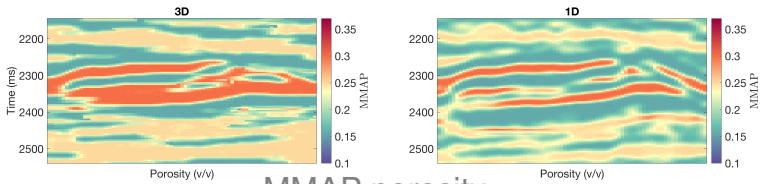
	Mean absolute error		Root mean square error	
	Dependent	Independent	Dependent	Independent
Porosity	**0.0326**	0.0376	**0.0402**	0.0484
Water saturation	**0.0667**	0.1629	**0.1124**	0.2986
Clay volume	0.1014	**0.0819**	0.1353	**0.1130**
Log ρV_P	**0.0498**	0.0822	**0.0636**	0.0822
Log V_P/V_S	**0.0244**	0.0325	**0.0351**	0.0438

Results

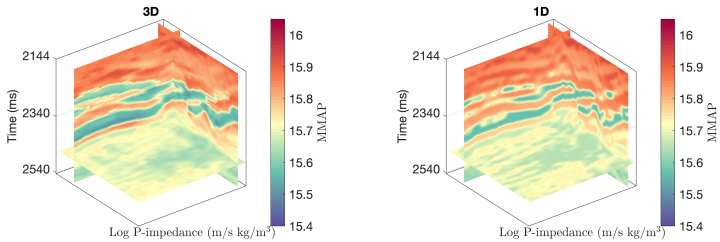


Iso-50 probability gas
[click for animation]





MMAP porosity



MMAP log-acoustic impedance

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