Uncertainty quantification in imaging and automatic horizon tracking—a Bayesian deep-prior based approach

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1{a

Abstract

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

1 Introduction

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 [**? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [pSGLD, **? ?**] cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc
1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**? ? ? ? ? ? ? ? ? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**? ? ? ? ? ? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 **?**] cc 1[**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1[**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**? ? ? ? ? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [SGLD, **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1[see e.g. **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 Parihaka-3D cc 1 [**? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

2 Bayesian Seismic Imaging

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\delta\mathbf{m}$ cc 1 cc 1 cc 1 cc 1 $\delta\mathbf{d}_i$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathbf{m}_0$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathbf{q}_i$ cc 1$i = 1, 2, \cdots, N$ cc 1N cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1p_{like} [**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\{\delta\mathbf{d}_i\}_{i=1}^{N}$ cc 1 cc 1 cc 1 cc 1 cc 1

$$
\begin{aligned}
-\log p_{\text{like}}\left(\{\delta\mathbf{d}_i\}_{i=1}^N|\delta\mathbf{m}\right) &= -\sum_{i=1}^N \log p_{\text{like}}\left(\delta\mathbf{d}_i|\delta\mathbf{m}\right) \\
&= \frac{1}{2\sigma^2}\sum_{i=1}^N \|\delta\mathbf{d}_i - \mathbf{J}(\mathbf{m}_0,\mathbf{q}_i)\delta\mathbf{m}\|_2^2 \quad + \underbrace{\text{const}}_{\text{Ind. of } \delta\mathbf{m}}.
\end{aligned}
\tag{1}
$$

cc 1 cc 1 cc 1σ^2 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathbf{J}$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\mathbf{m}_0$ cc 1 cc 1 cc 1 cc 1

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**? ? ? ? ? ? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\delta\mathbf{m} = g(\mathbf{z},\mathbf{w})$ cc 1 cc 1 cc 1 $\mathbf{z} \sim \mathrm{N}(\mathbf{0},\mathbf{I})$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\mathbf{w}$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathbf{w} \sim \mathrm{N}(\mathbf{0}, \frac{1}{\lambda^2}\mathbf{I})$ cc 1 cc 1λ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

$$
\begin{aligned}
&-\log p_{\text{post}}\left(\mathbf{w}|\{\delta\mathbf{d}_i\}_{i=1}^N\right) \\
&= -\left[\sum_{i=1}^N \log p_{\text{like}}\left(\delta\mathbf{d}_i|\mathbf{w}\right)\right] - \log p_{\text{prior}}\left(\mathbf{w}\right) + \underbrace{\text{const}}_{\text{Ind. of } \mathbf{w}} \\
&= \frac{1}{2\sigma^2}\sum_{i=1}^N \|\delta\mathbf{d}_i - \mathbf{J}(\mathbf{m}_0,\mathbf{q}_i)g(\mathbf{z},\mathbf{w})\|_2^2 + \frac{\lambda^2}{2}\|\mathbf{w}\|_2^2 + \text{const},
\end{aligned}
\tag{2}
$$

cc 1p_{post} cc 1p_{prior} cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

3 UQ for Seismic Imaging

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 12 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**? ? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\mathbf{M}_k$ cc 1k^{th} cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

$$
\mathbf{w}_{k+1} = \mathbf{w}_k - \frac{\epsilon}{2}\mathbf{M}_k\nabla_{\mathbf{w}}L^{(i)}(\mathbf{w}_k) + \boldsymbol{\eta}_k, \quad \boldsymbol{\eta}_k \sim \mathrm{N}(\mathbf{0}, \epsilon\mathbf{M}_k),
\tag{3}
$$

cc 1 $L^{(i)}(\mathbf{w}) = \frac{N}{2\sigma^2}\|\delta\mathbf{d}_i - \mathbf{J}(\mathbf{m}_0,\mathbf{q}_i)g(\mathbf{z},\mathbf{w})\|_2^2 + \frac{\lambda^2}{2}\|\mathbf{w}\|_2^2$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 12 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 i^{th} cc 1 cc 1 cc 1 cc 1 cc 1 cc 1ϵ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 [**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 T cc 1 cc 1 cc 1 cc 1 cc 1

$$
\widehat{\delta\mathbf{m}} = \mathbb{E}_{\mathbf{w}\sim p_{\text{post}}(\mathbf{w}|\{\delta\mathbf{d}_i\}_{i=1}^N)}\left[g(\mathbf{z},\mathbf{w})\right] \simeq \frac{1}{T}\sum_{j=1}^T g\left(\mathbf{z},\widehat{\mathbf{w}}_j\right),
\tag{4}
$$

cc 1 $\widehat{\mathbf{w}}_j \sim p_{\text{post}}(\mathbf{w}|\{\delta\mathbf{d}_i\}_{i=1}^N), j = 1,\ldots,T$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

4 Seismic horizon tracking with UQ

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\mathcal{H}$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 [see e.g. **?**] cc 1

5 Implementation

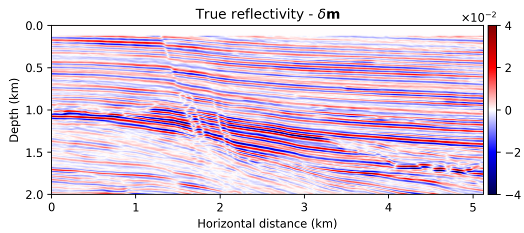
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 13 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1[**? ?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1[**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 13 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1software cc 1 cc 1 **?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 GitHub cc 1

6 Numerical experiments

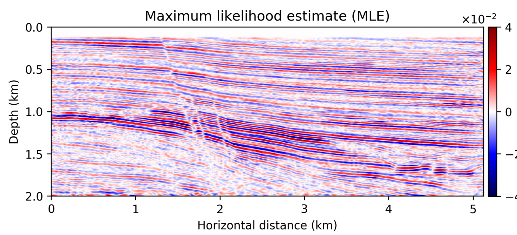
cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 Parihaka-3D cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1**?**] cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11a cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\mathbf{m}_0$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 205 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 125 m cc 1 cc 1 cc 1 cc 1 cc 1 cc 11.5 cc 1 cc 1410 cc 1 cc 1 cc 1 cc 1 cc 112.5m cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 130 Hz cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1-18.01 dB cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 13 cc 1 cc 1 cc 1 cc 1 cc 1 3k cc 1 cc 1 cc 115 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 120th cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 13 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\epsilon = 0.002$ cc 1 cc 1 cc 1 cc 1$\lambda^2 = 200$ cc 1 $\sigma^2 = 0.01$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 cc 110k cc 1 cc 1 cc 149 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$T = 351$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11b cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\widehat{\delta\mathbf{m}}$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11a cc 11c cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11d cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 99% cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathcal{H}(\widehat{\delta\mathbf{m}})$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11.225 km cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 $\mathbb{E}_{\mathbf{w}\sim p_{\text{post}}(\mathbf{w}|\{\delta\mathbf{d}_i\}_{i=1}^N)}\left[\mathcal{H}\left(g(\mathbf{z},\mathbf{w})\right)\right]$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 12b cc 12c cc 12d cc 12e cc 1

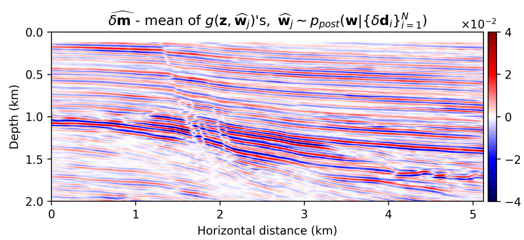


(a)

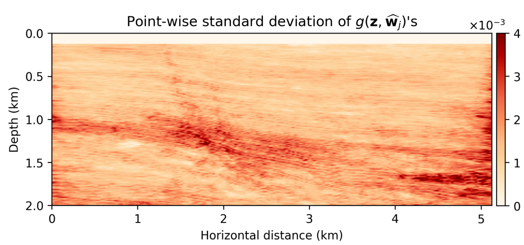


cc 1

(b)



(c)



(d)

Figure 1: cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1$\widehat{\delta\mathbf{m}}$ cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

7 Conclusions

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc

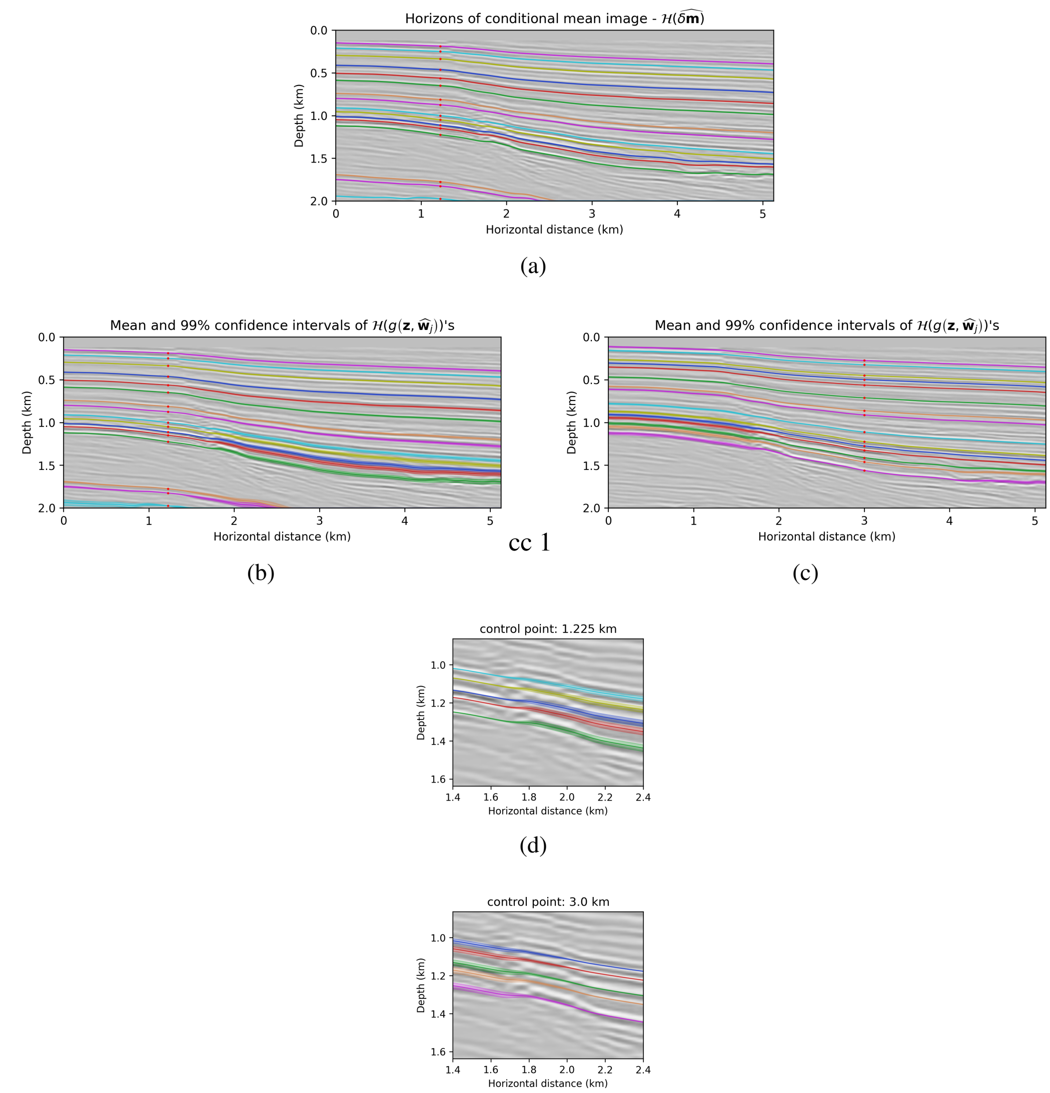


Figure 2: cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 11.225 km cc 13 km cc 1 cc 1 cc 1 cc 1 cc 12b cc 12c cc 1 cc 1 cc 1 cc 1 cc 1 cc 1

1 cc 1

8 Acknowledgments

cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1 cc 1