Team 2: Final Report

Uncertainty Quantification in Geophysical Inverse Problems
Statement of the Tomography Problem

- Observe the arrival time, given the first order physics
- Invert for the slowness, or density
Creating Synthetic Data

- Our ‘unknown’ earth model is a layered mode
- Vertical/Horizontal observations are important!
- The observations are calculated as line integrals through the synthetic model.
Choose A Model

- There are many choices for model!
- Each choice leads to a different solution
- Each solution can be evaluated for goodness of fit.
- Haar wavelets provide an easy way to describe a region.
Our Model Has Errors!

• The travel times do not allow us to reconstruct all the details of the layers.

• We use covariance matrices are used to measure the uncertainty of the model.
  – Prior covariance matrix is used to account for the model uncertainty without considering the observed travel times.
  – Posterior covariance is accounts for the observed travel times.
Solving the Inverse Problem for a single choice of model
Partial Data Set

synthetic example data set
Full Data Set
The Prior Distribution

“The natural choice for a prior pdf is the distribution that allows for the greatest uncertainty while obeying the constraints imposed by the prior information, and it can be shown that this least informative pdf is the pdf that has maximum entropy” (Jaynes 1968, 1995, Papoulis 1984)

From Malinverno, 2000
Prior Uncertainty
Colormap To Code Mean and Uncertainty
Prior Composite Image

prior PDF
The Data Prediction Matrix

• For each observation, we calculate the same line integral through our wavelet model. These are the columns.

• The better the model is, the closer these integrals match up with our observations.
Data Prediction Matrix
Posterior Surfaces - Full Data
Posterior Mean – Full Data
Posterior Uncertainty – Full Data
Posterior Composite – Full Data
Posterior Surfaces – Limited Data
Posterior Mean – Limited Data
Posterior Uncertainty – Limited Data
Posterior Composite – Limited Data
Solving the Inverse Problem for many choices of model
Partial Data Set

synthetic example data set
Posterior Surfaces
Posterior Mean Surface

posterior PDF sampled mean image

[Color bar with values ranging from 0 to 4]
Posterior Uncertainty
Posterior Composite Image
Decimation Histogram
MCMC Statistics