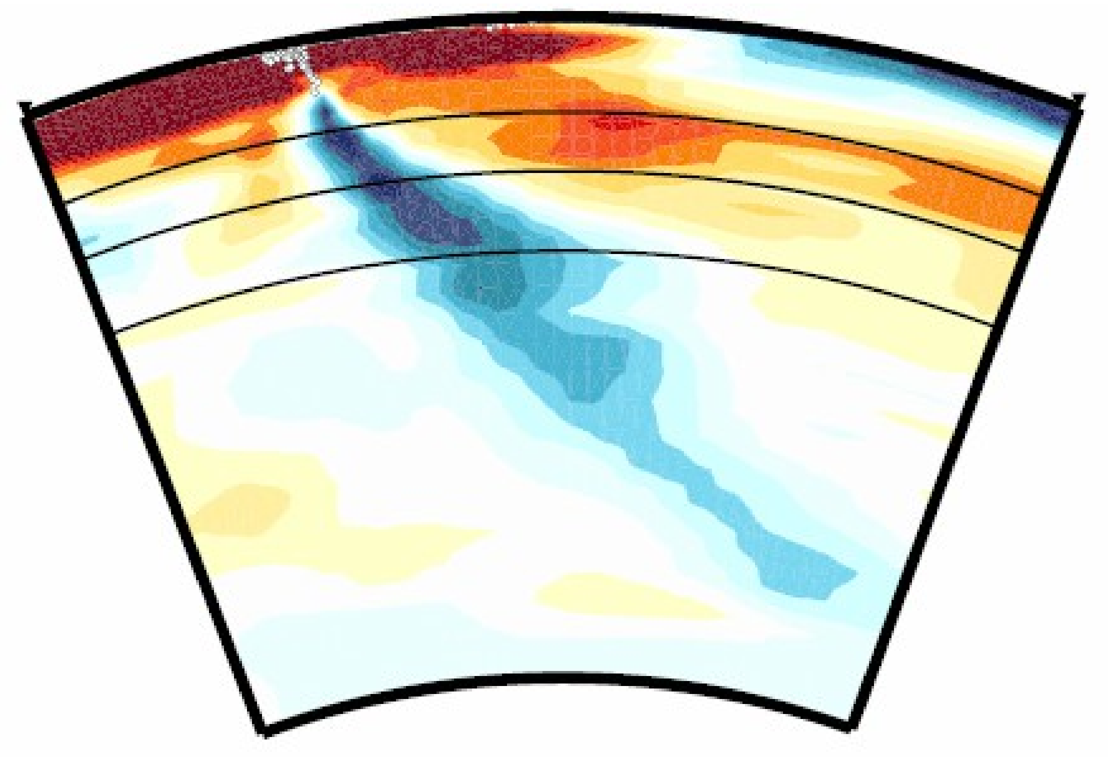
Dealing with Uncertainties in Geophysical Imaging

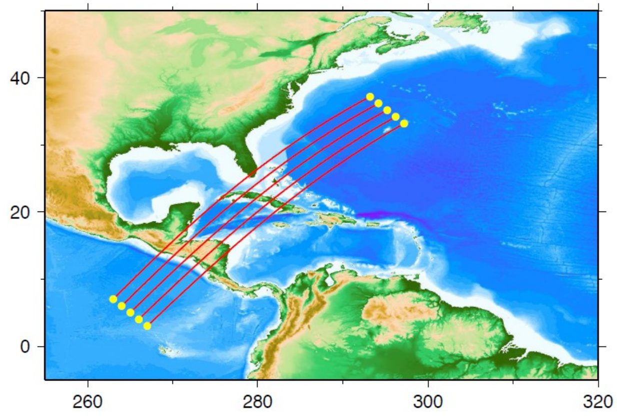
Thomas Bodin, CIDER 2012

3D Seismic tomography

P wave velocity from travel times of body waves

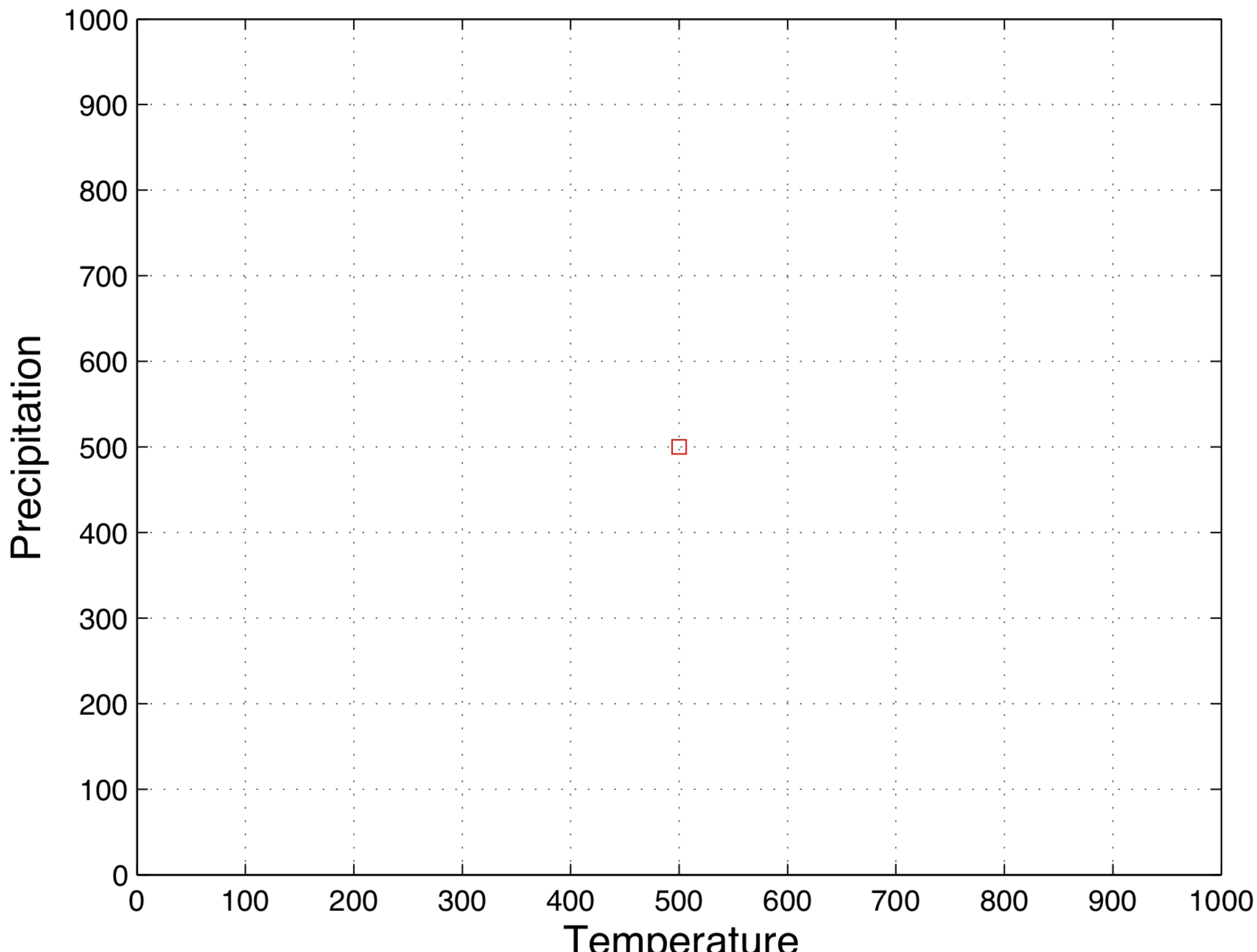


±1.2%

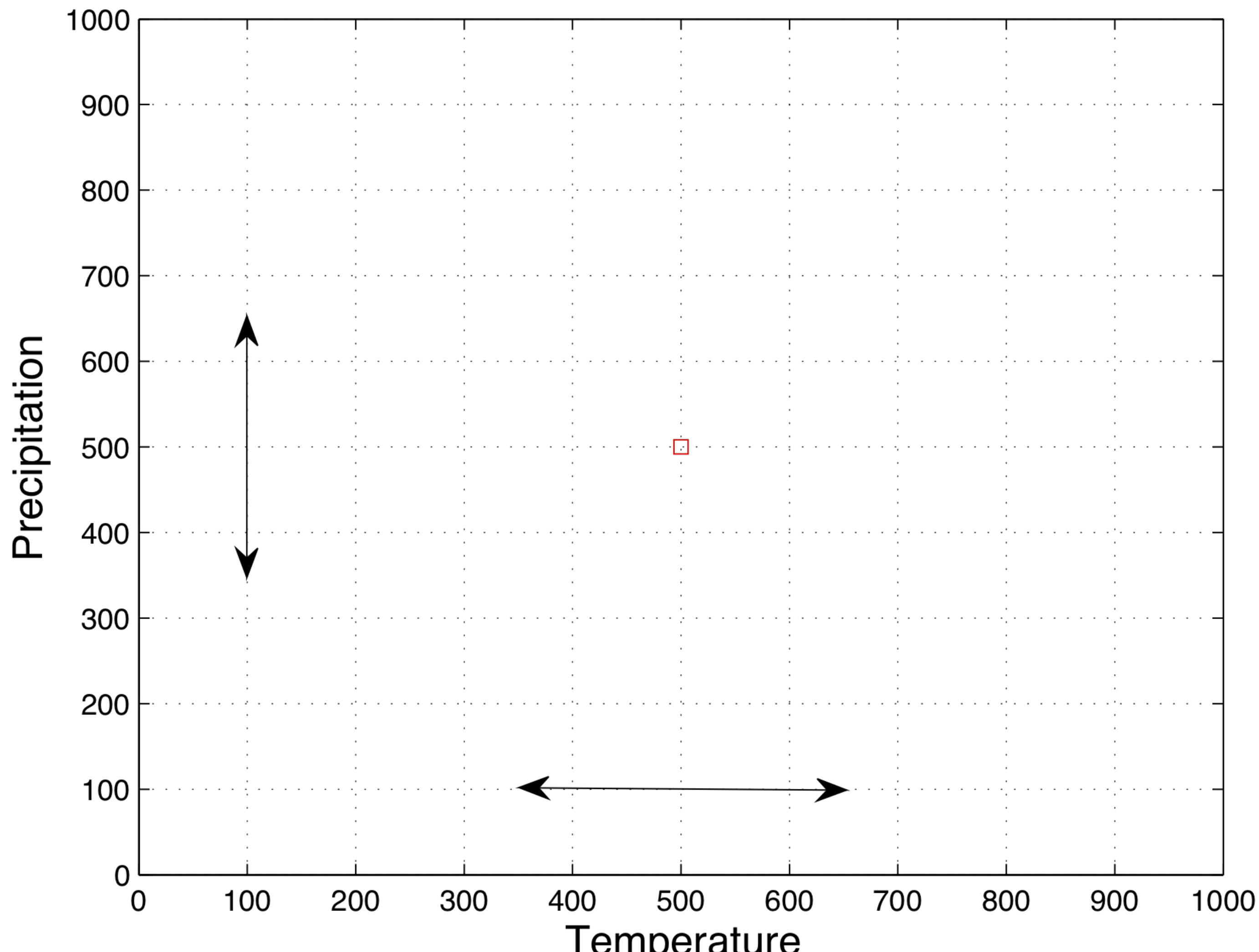


Fukao and Obayashi,2011

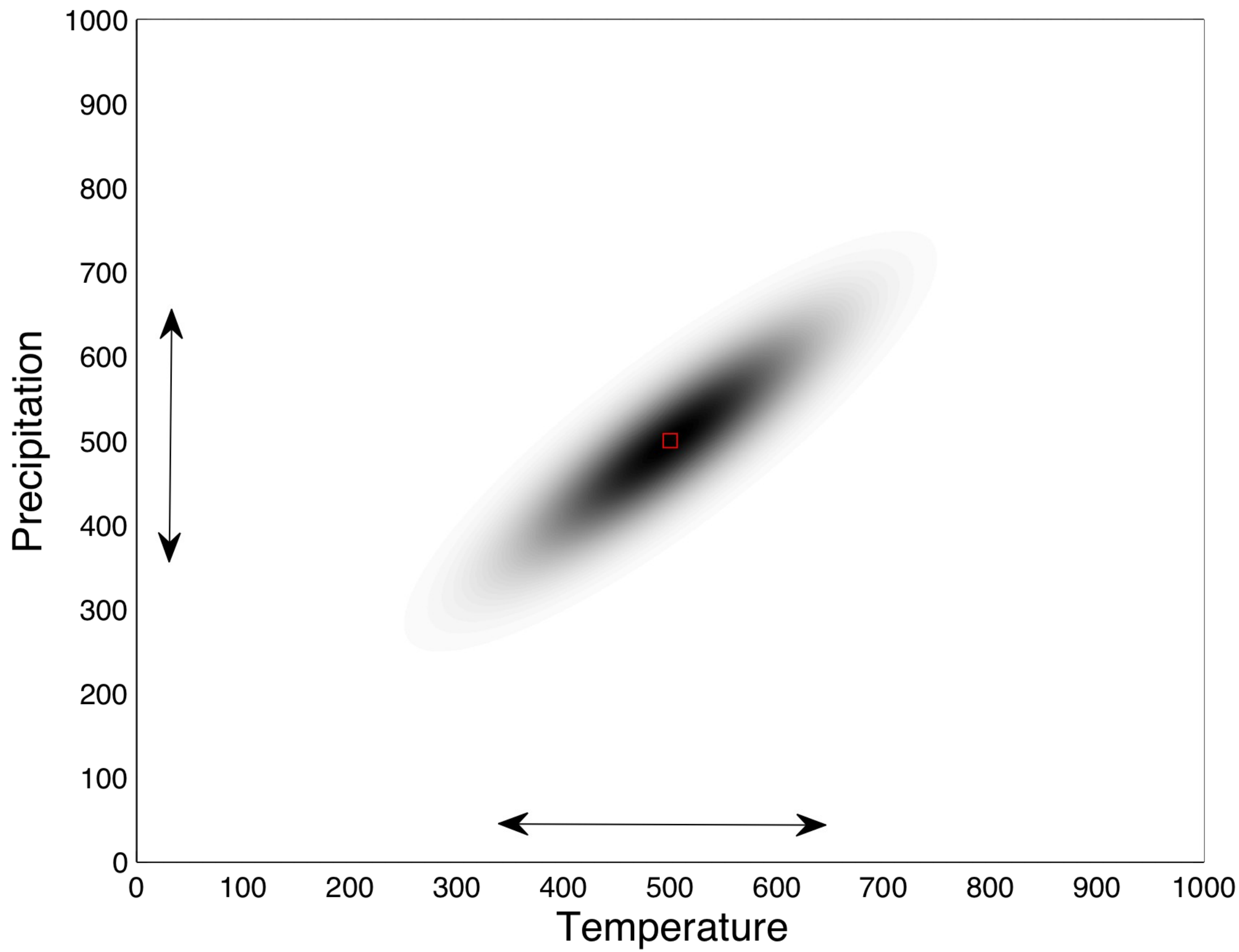
Weather forecast
1 point



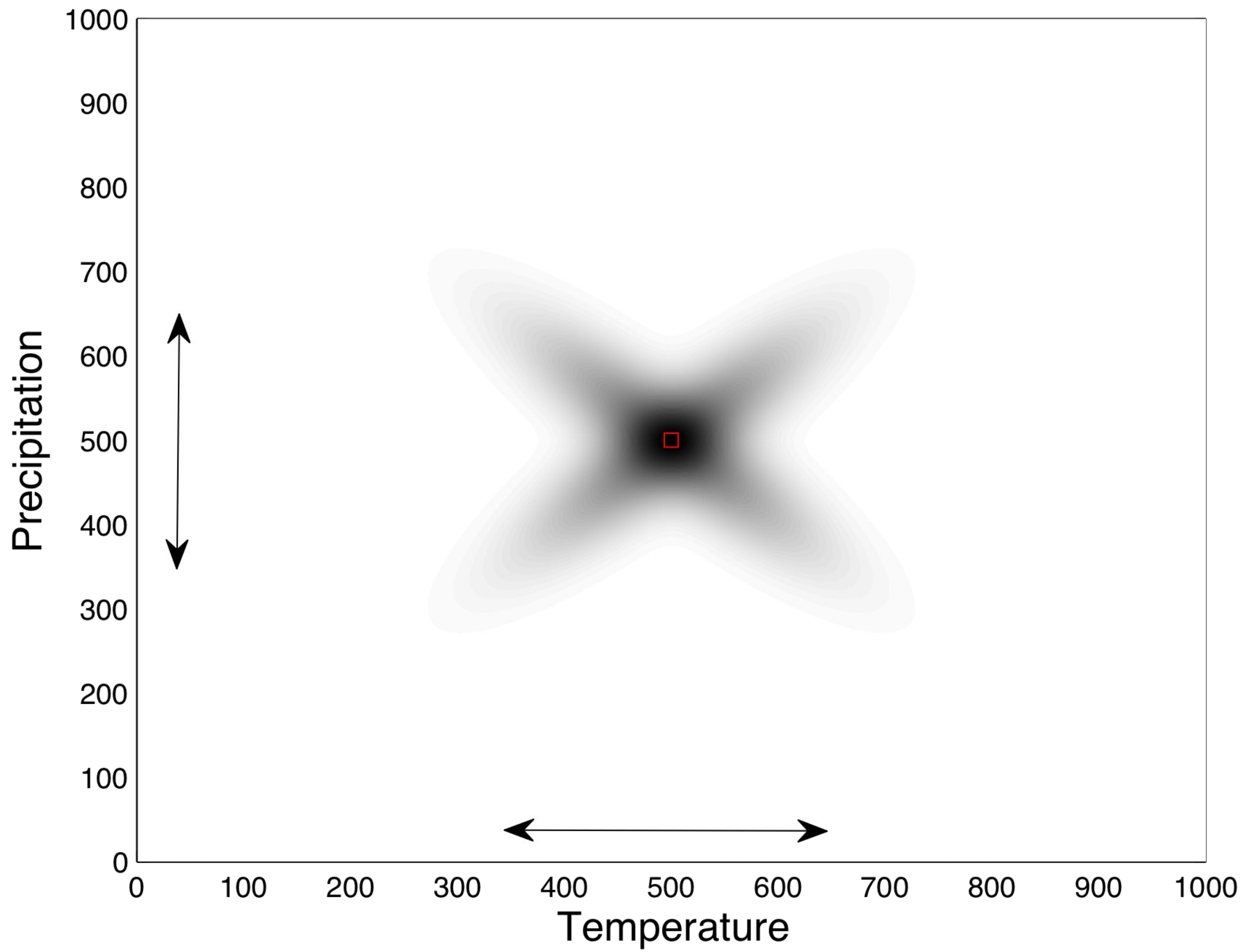
Weather forecast
1 point + error bars



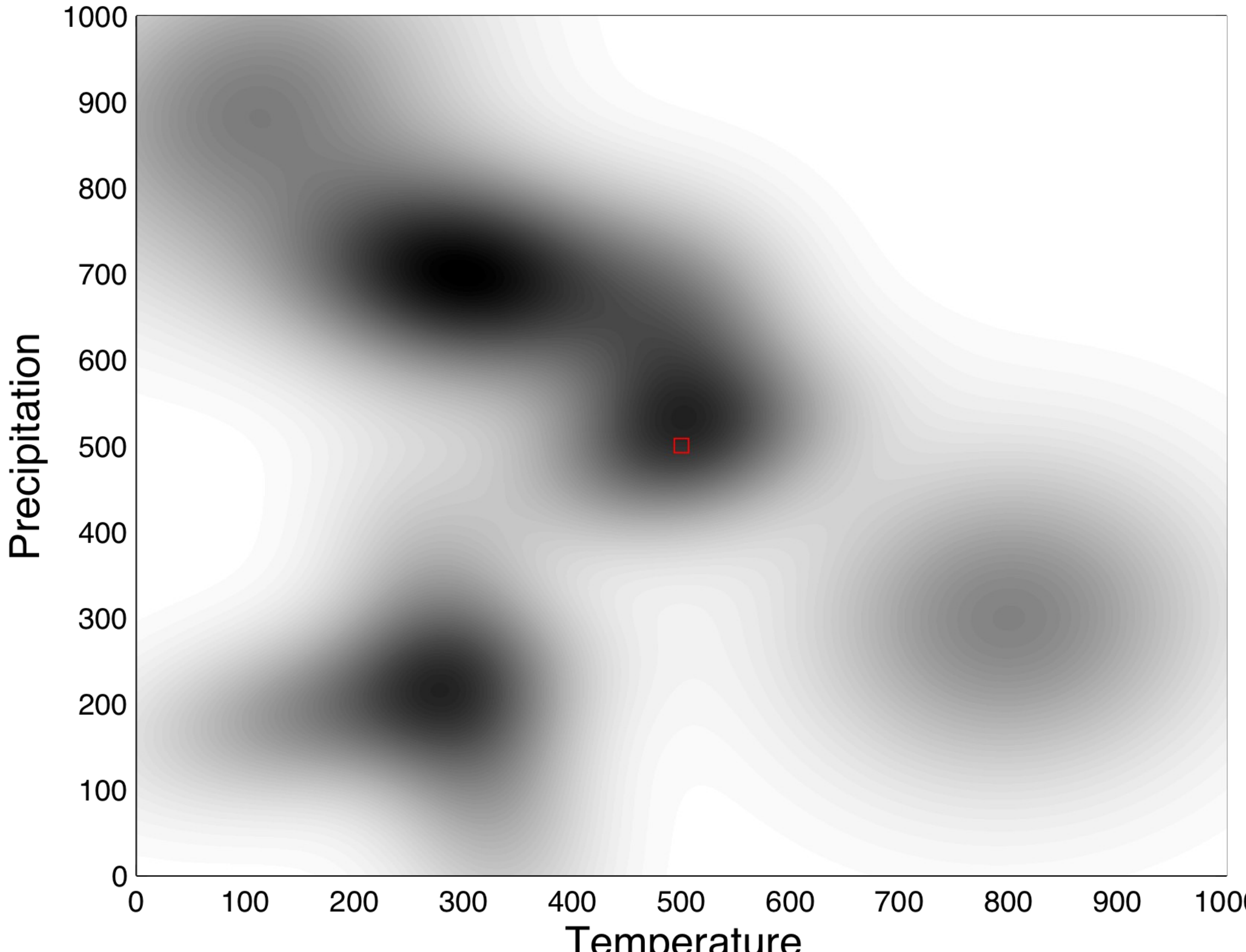
Weather forecast
Gaussian distribution



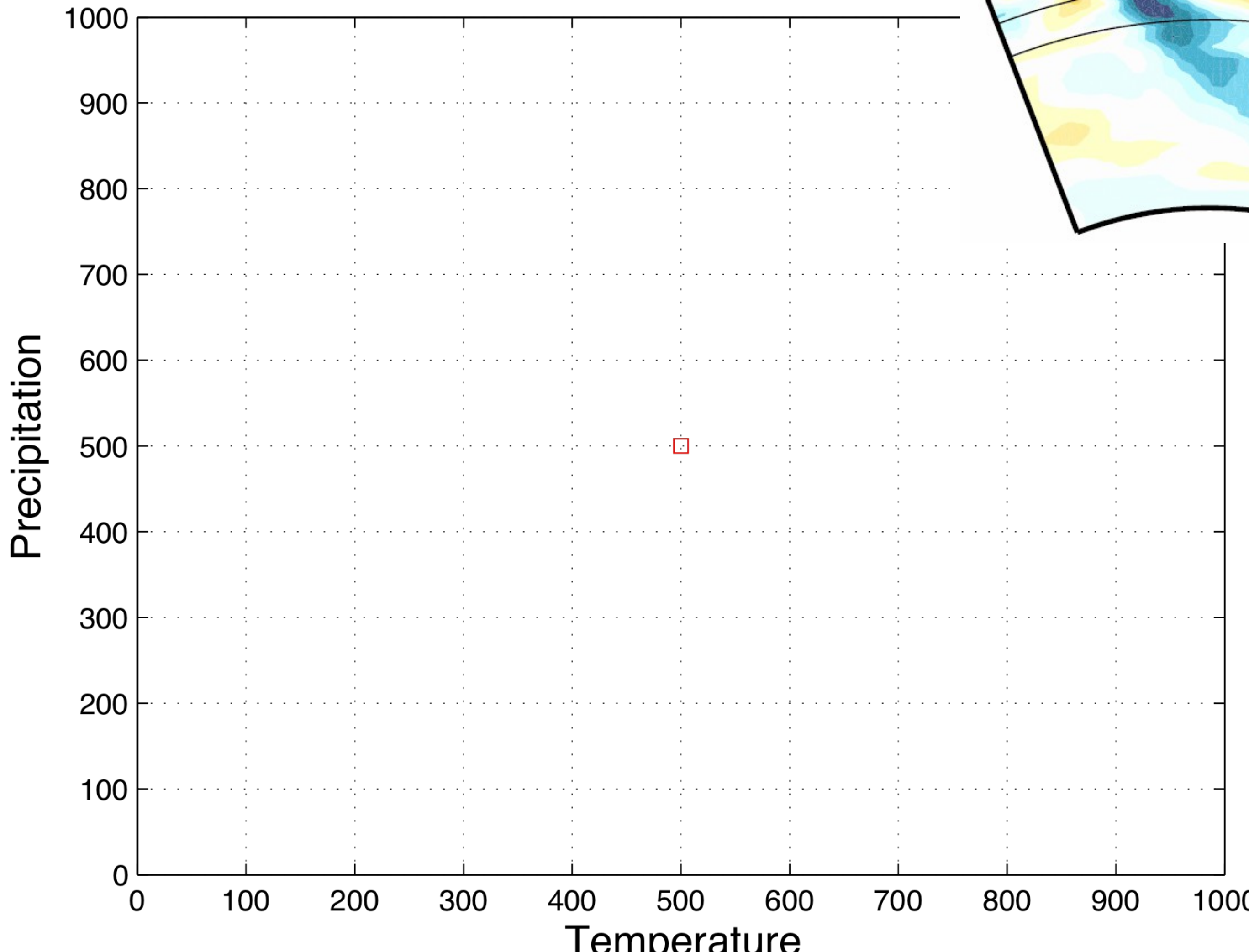
Weather forecast
2 Gaussian distributions

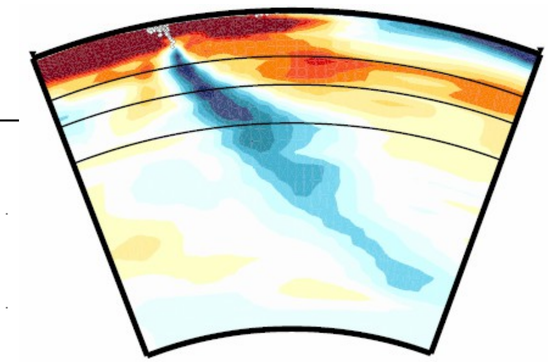


Weather forecast
Full distribution

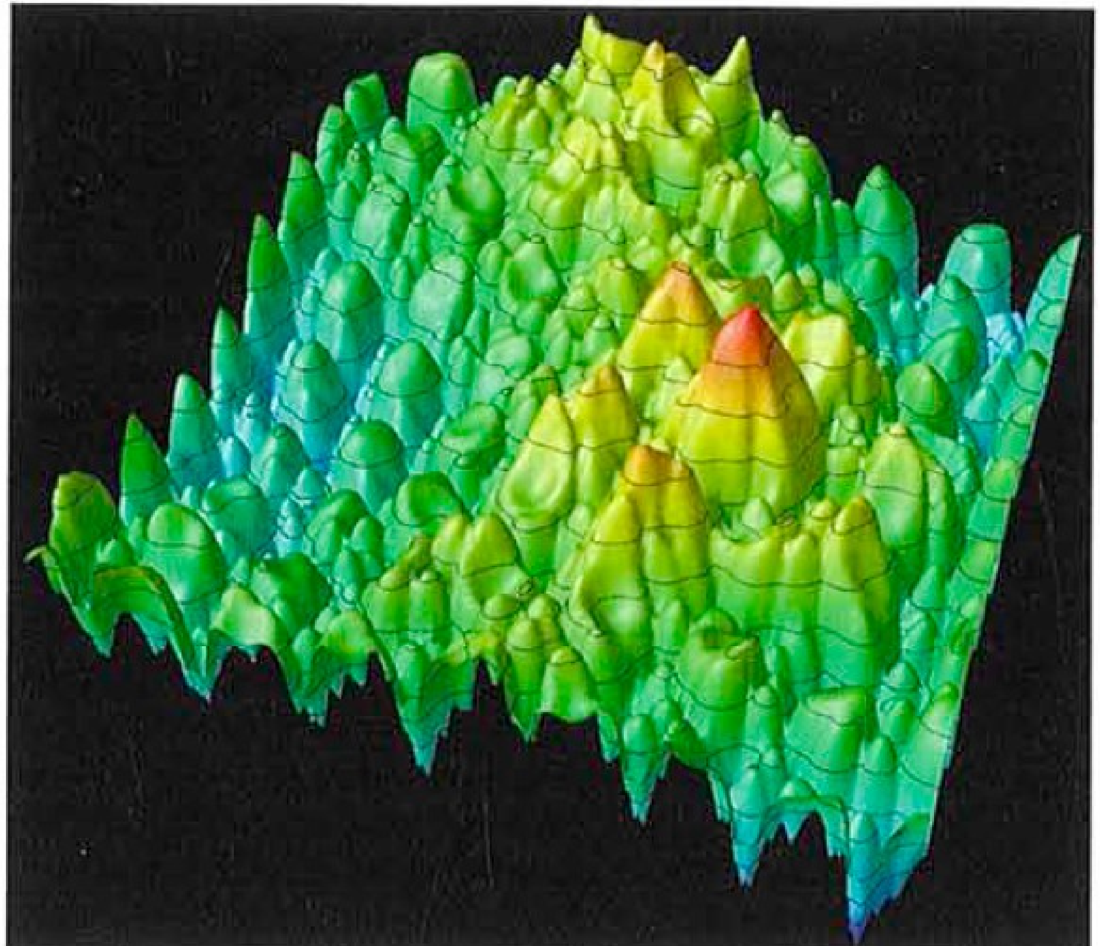


Seismic Tomography
1 point





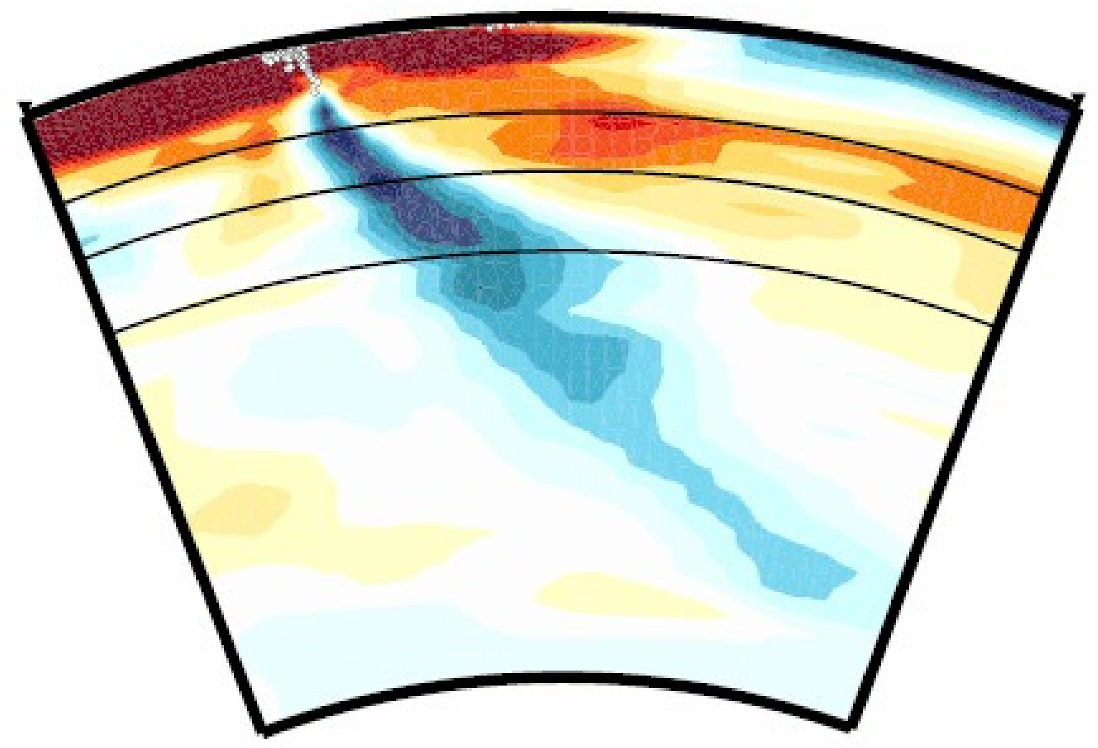
Data fit in the infrasound inverse problem



Inverse Theory, Monte Carlo Method, Figure 1 A multimodal data fit surface arising from the mismatch between two oscillatory fields in the infrasound inversion problem (Kennett et al., 2003).

3D Seismic tomography

P wave velocity from travel times of body waves



Issues :

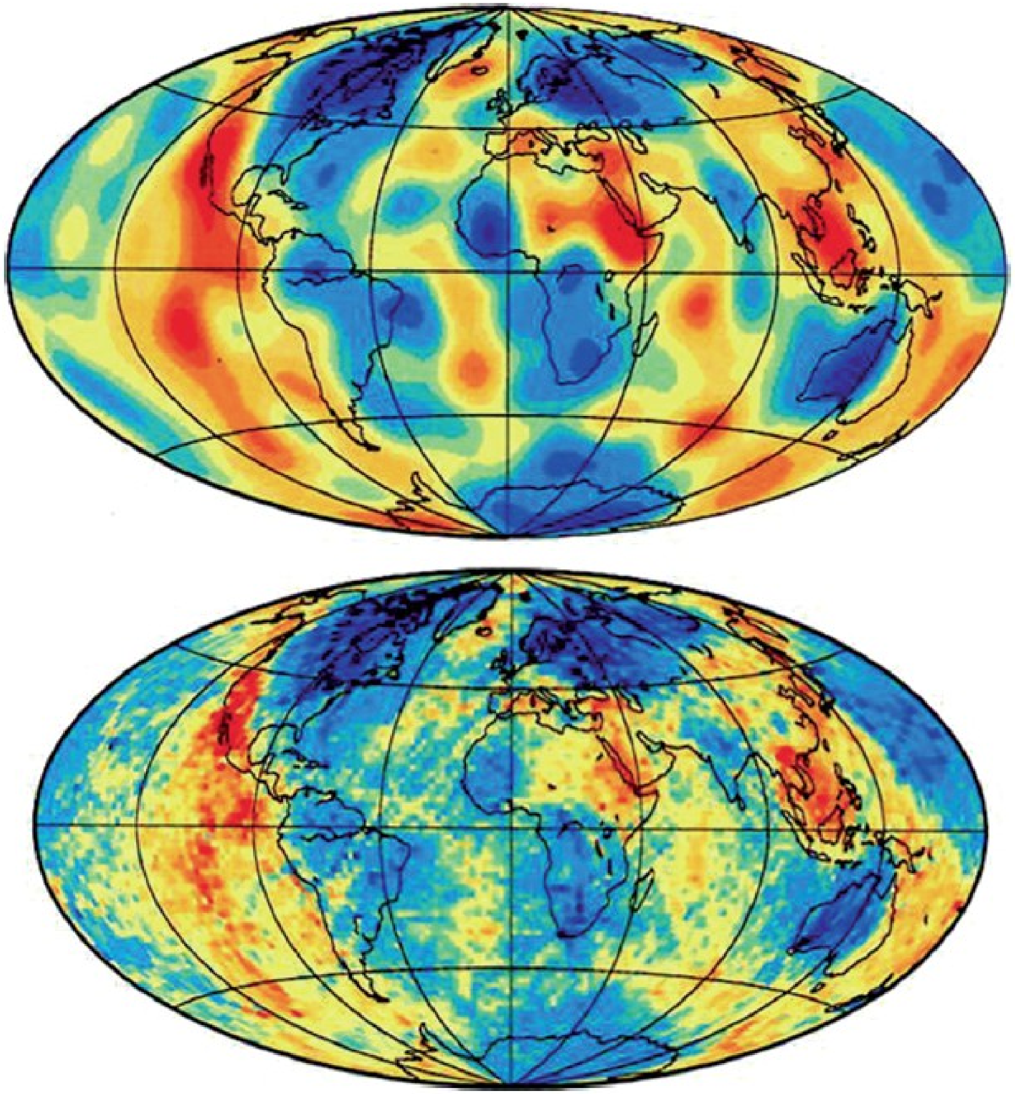
* Non linearity

* Il-posedness

* Parameterization

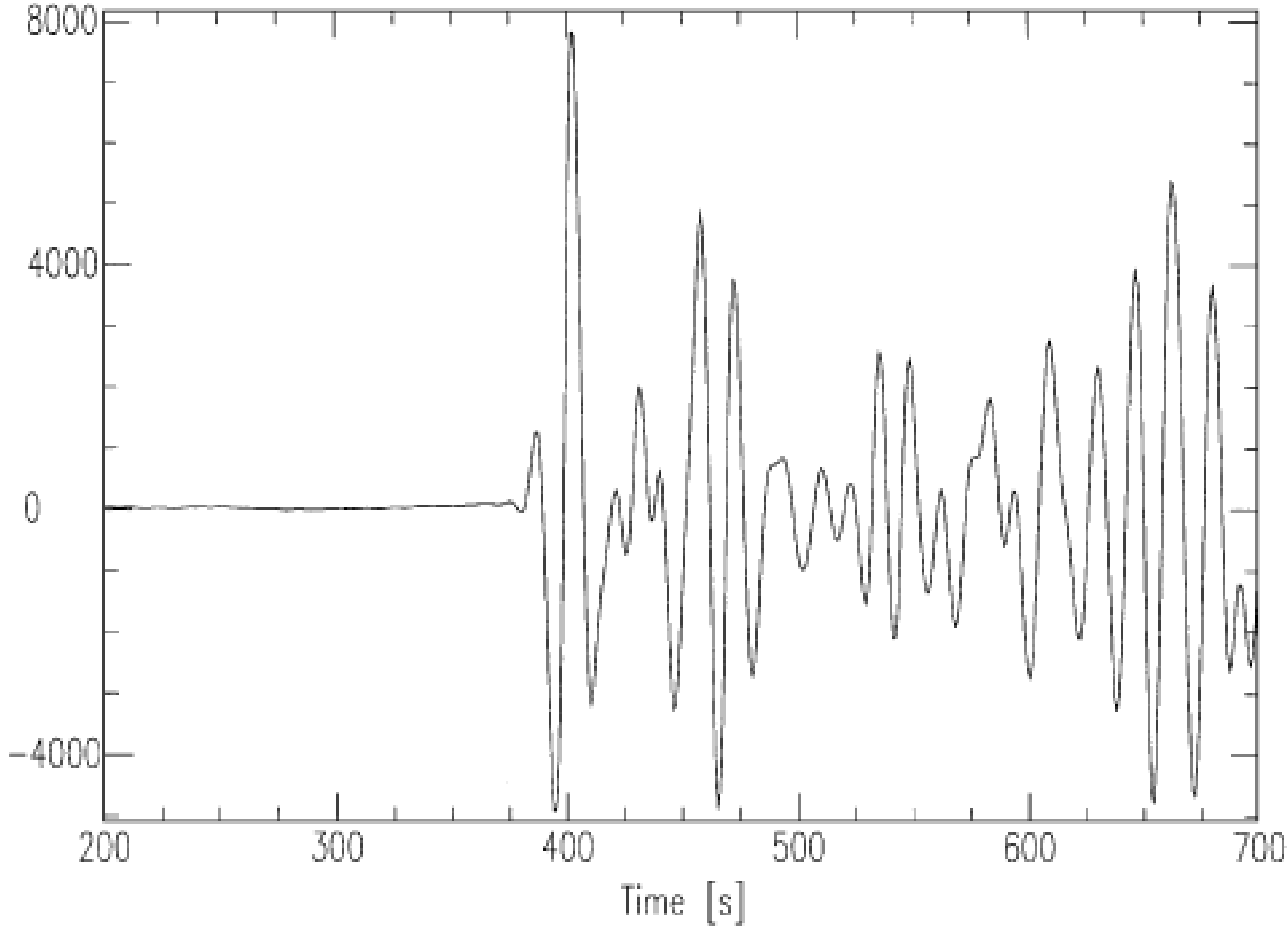
Fukao and Obayashi,2011

Parameterization



Dziewonski, A. M. and B. Romanowicz (2007)

Defining data noise

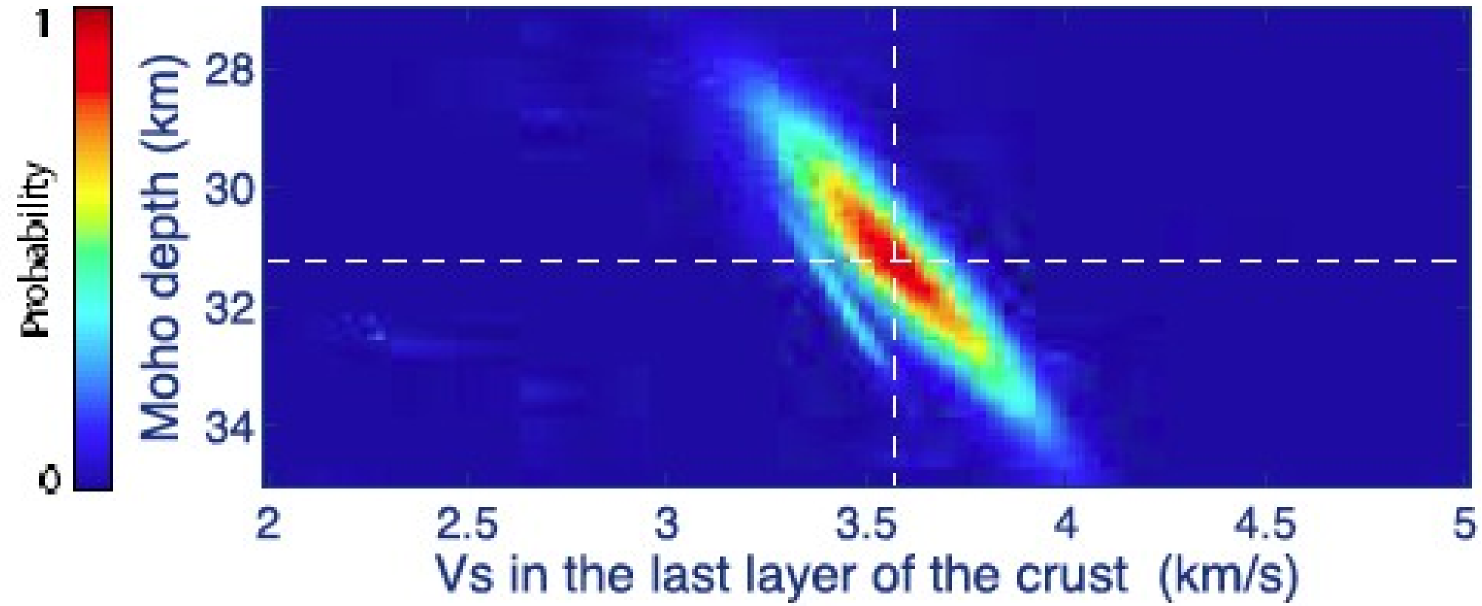


Data noise = measurement uncertainty + modeling uncertainty

Scales & Snieder, 1998

Trade offs between parameters

Inversion of a receiver function



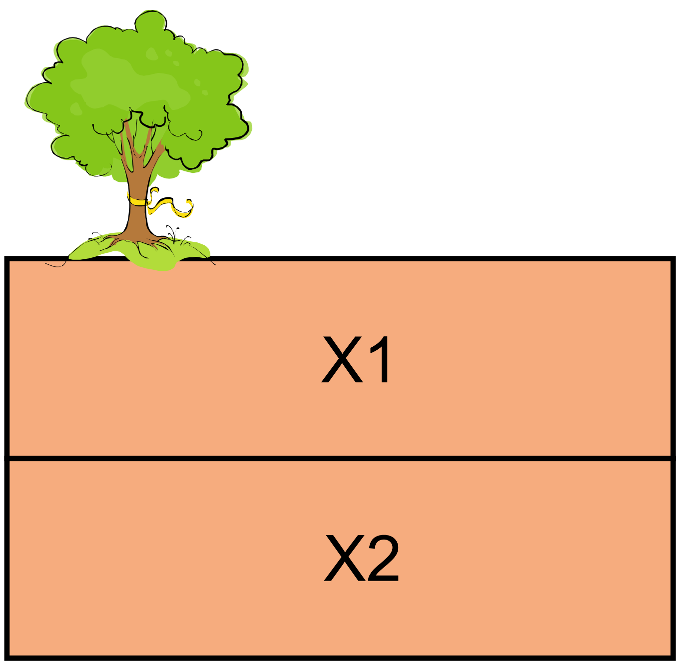
Bayesian Inference

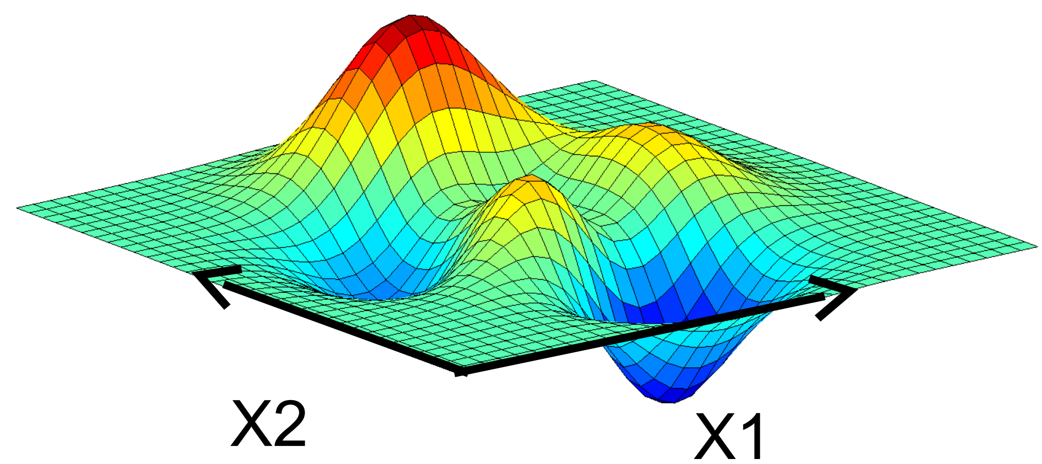
$$p(m|d) = p(d|m) * p(m)$$

Posterior = likelihood * prior

Bayesian Sampling

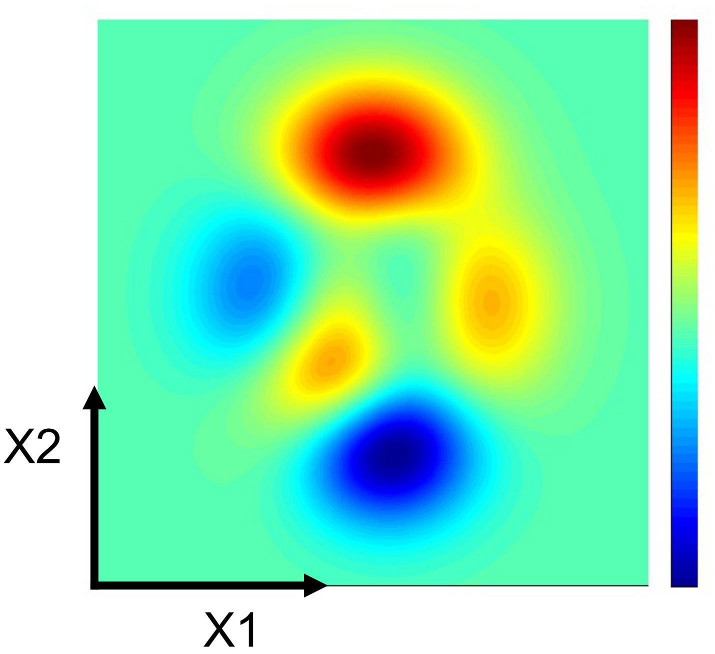
Sampling a multi-dimensional function

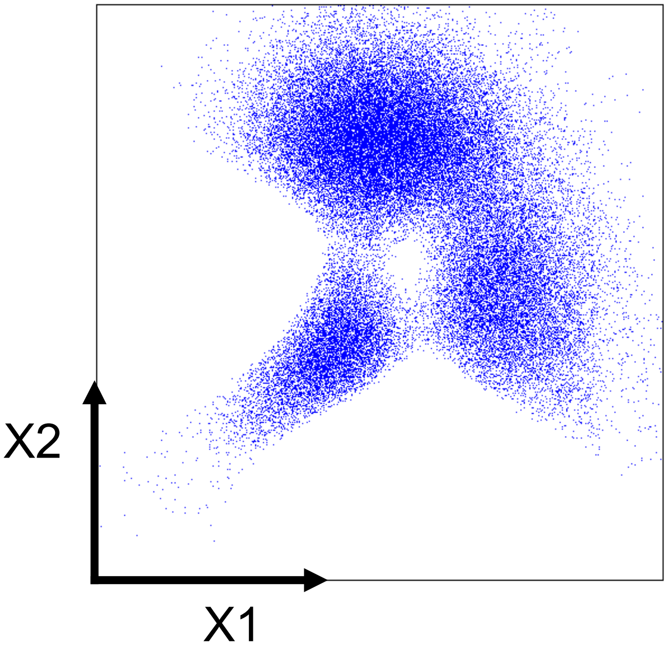




Bayesian Sampling Algorithm

Solution : statistical distribution





Monte Carlo Markov chains

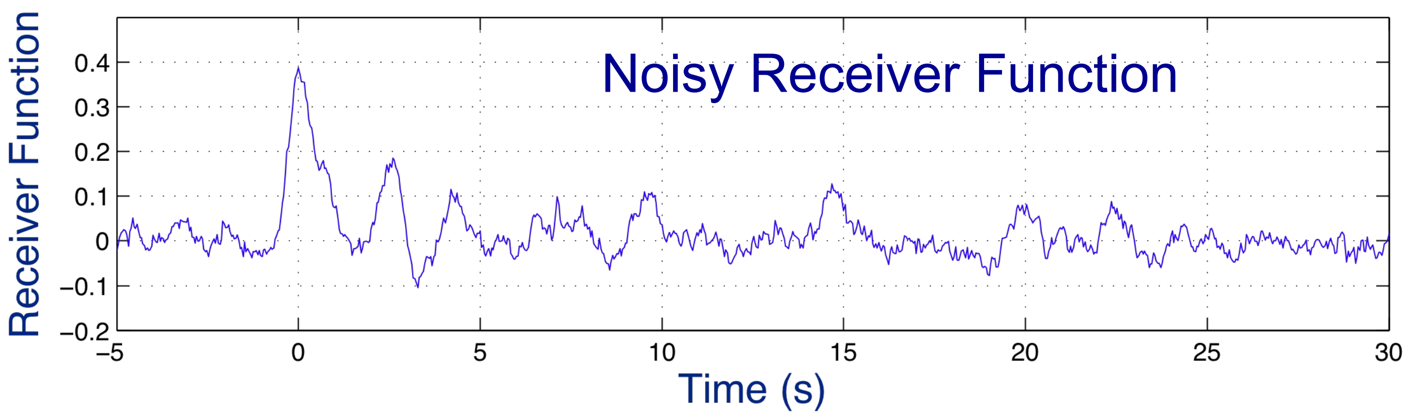
Expanded Bayesian Inference

Transdimensional Markov Chains

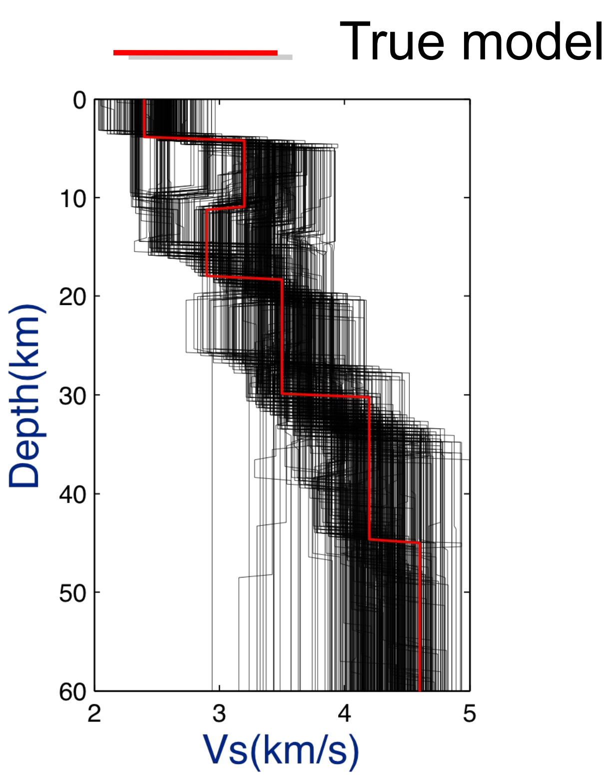
Let the number of model parameters being an unknown

The dimension of the model is variable

Synthetic experiment

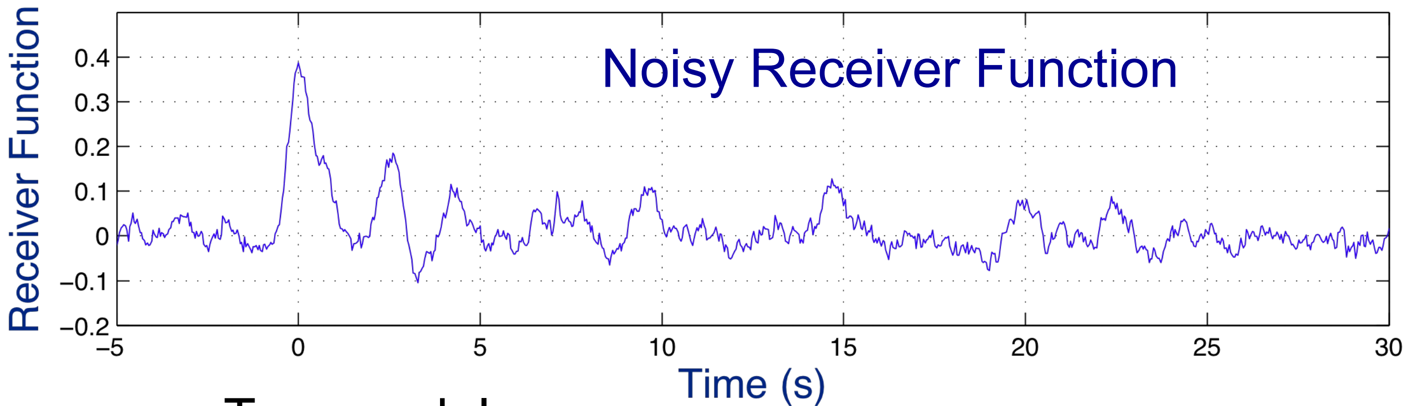


Magnitude and correlation of noise are unknown

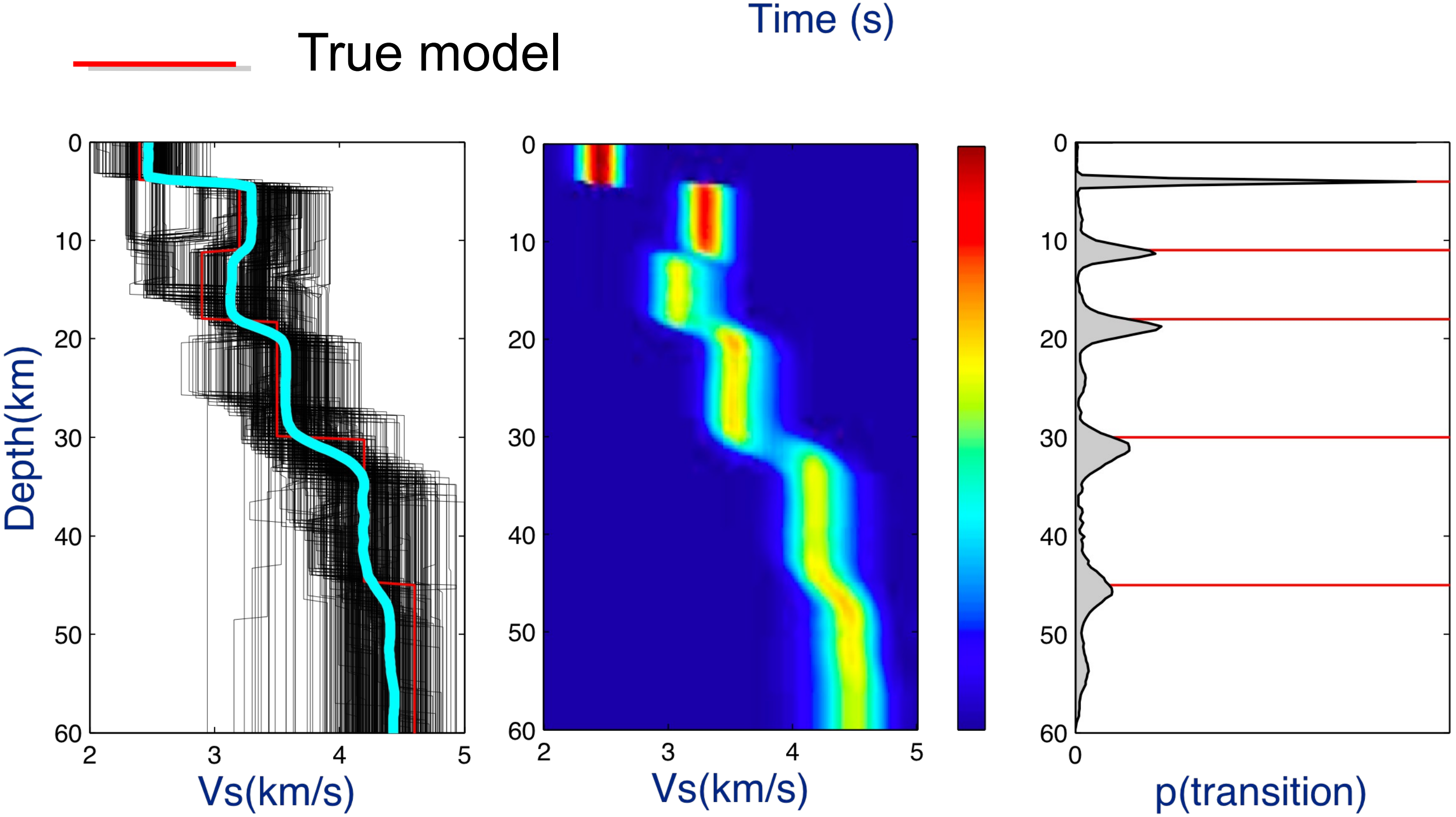


Solution is a large ensemble of models distributed according to the target distribution

Synthetic experiment

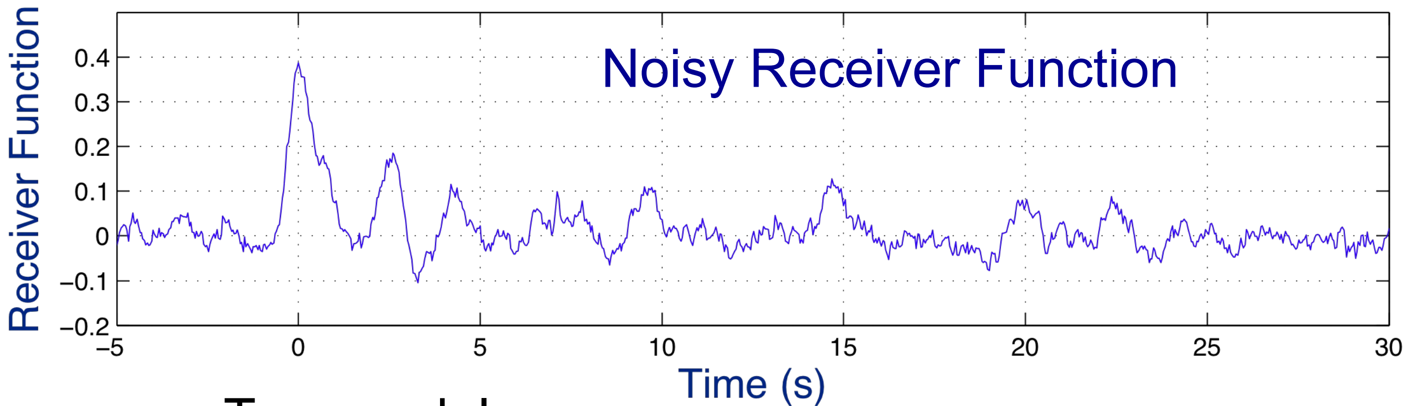


Magnitude and correlation of noise are unknown

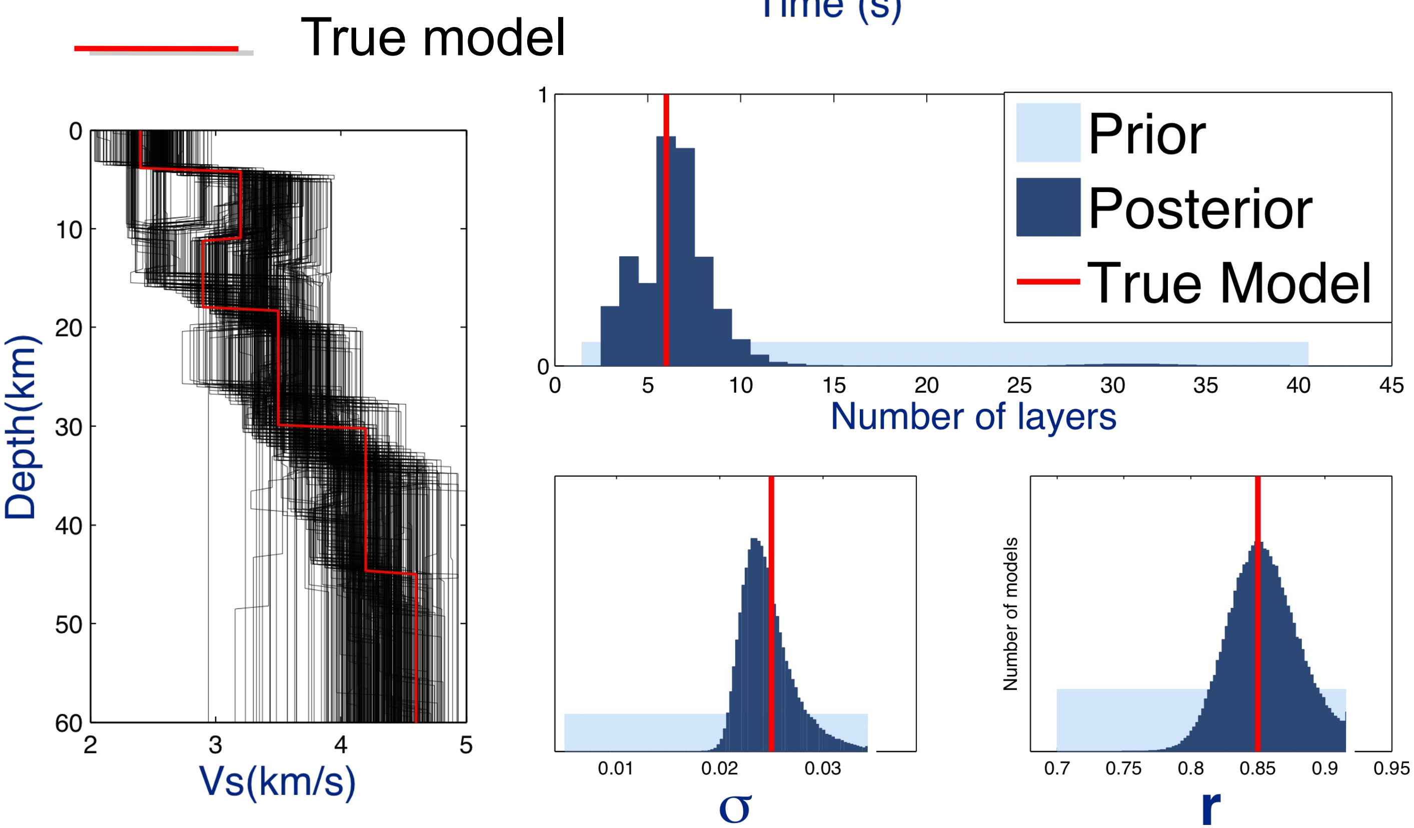


Different ways to look at the solution

Synthetic experiment

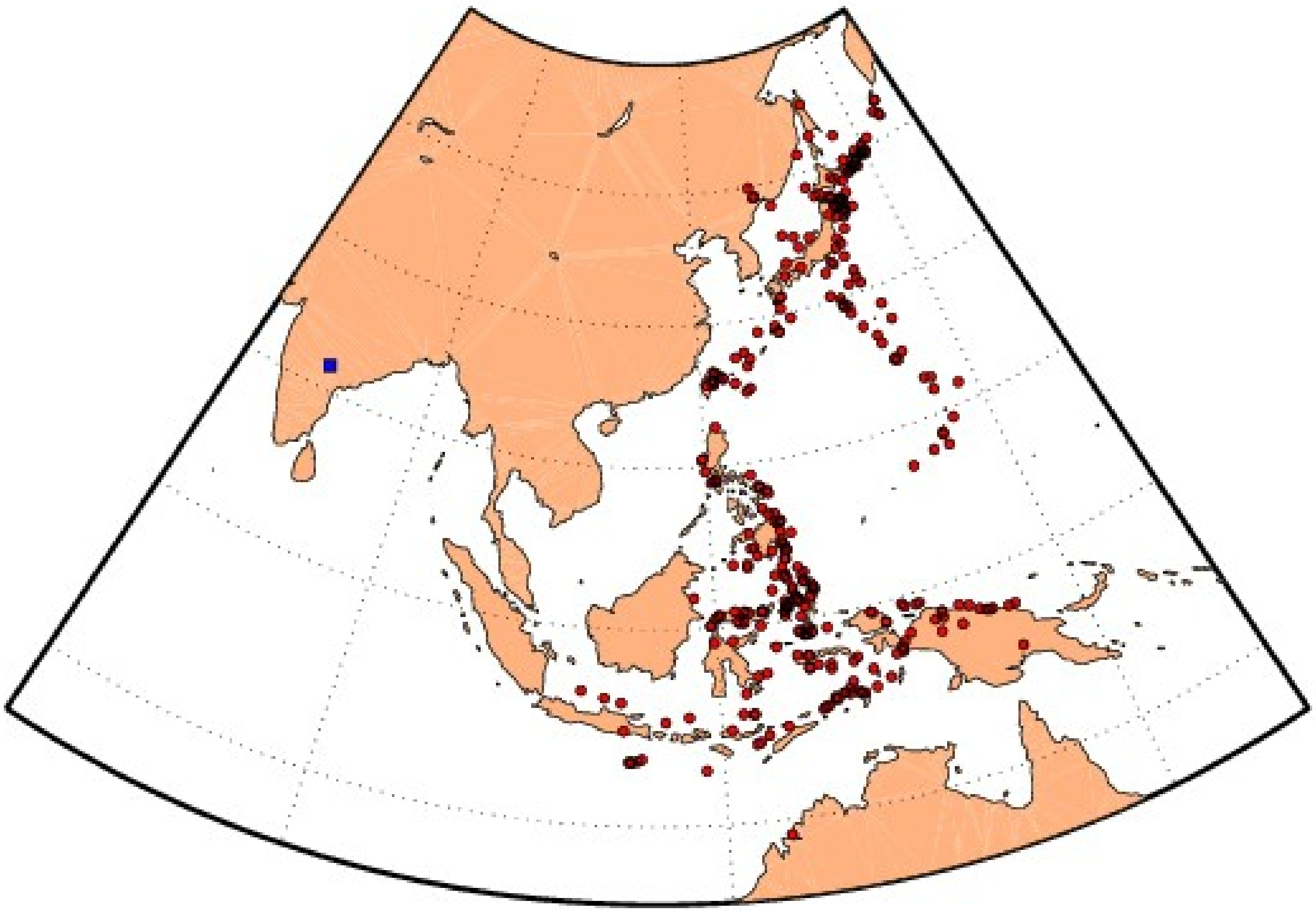


Magnitude and correlation of noise are unknown

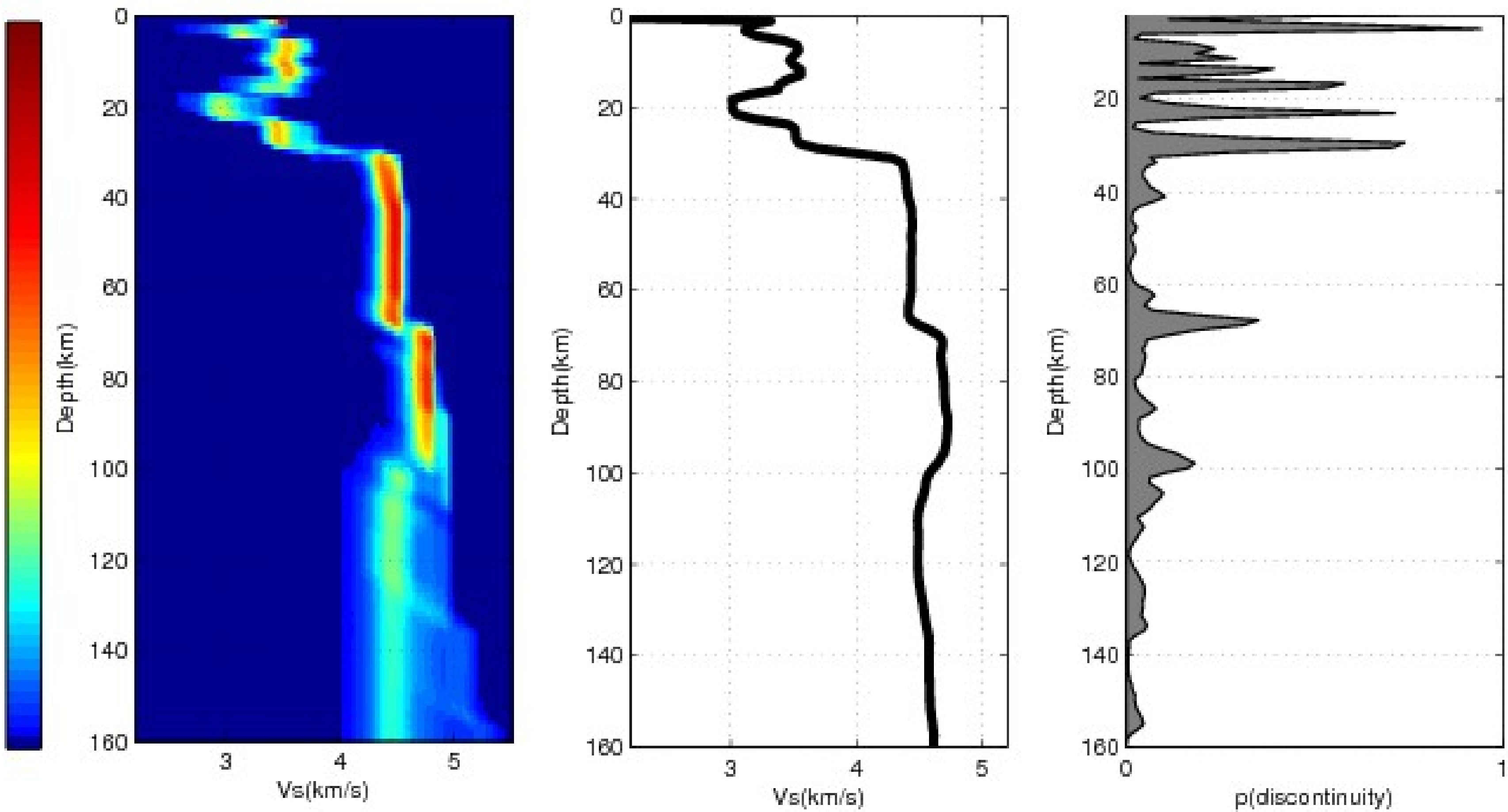


Algorithm is able to recover the complexity of the model and the level of data noise

Application to Hyderabad station, India



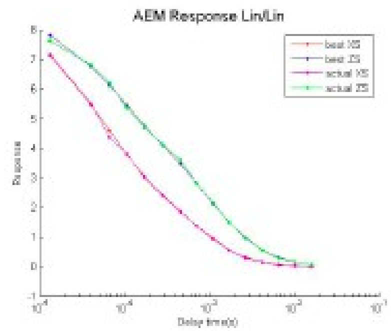
Application to Hyderabad station, India

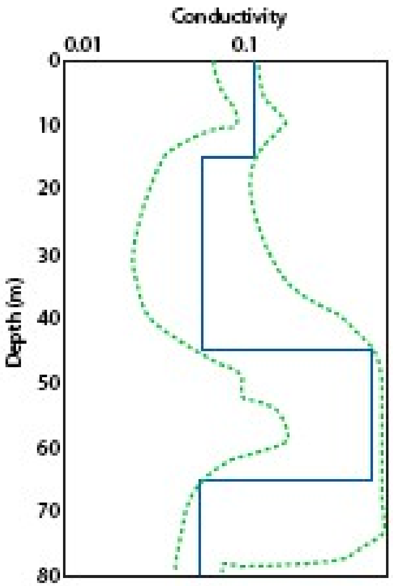


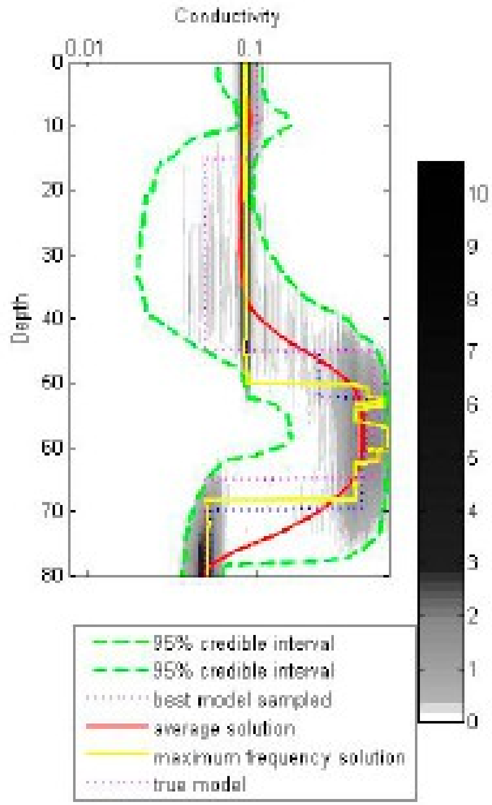
Inversion for 1D Earth Models

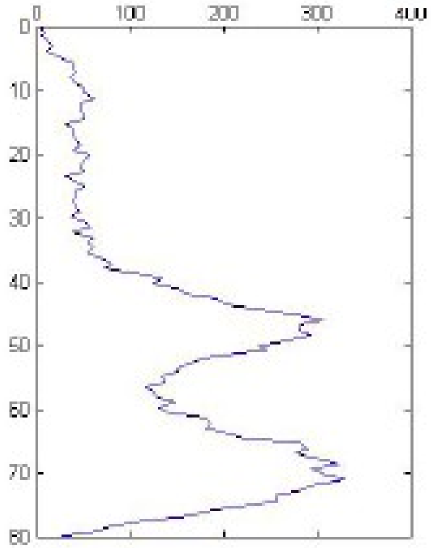
Using Airborne EM to constrain subsurface conductivity.

With M. Harltey and
R. Brodie



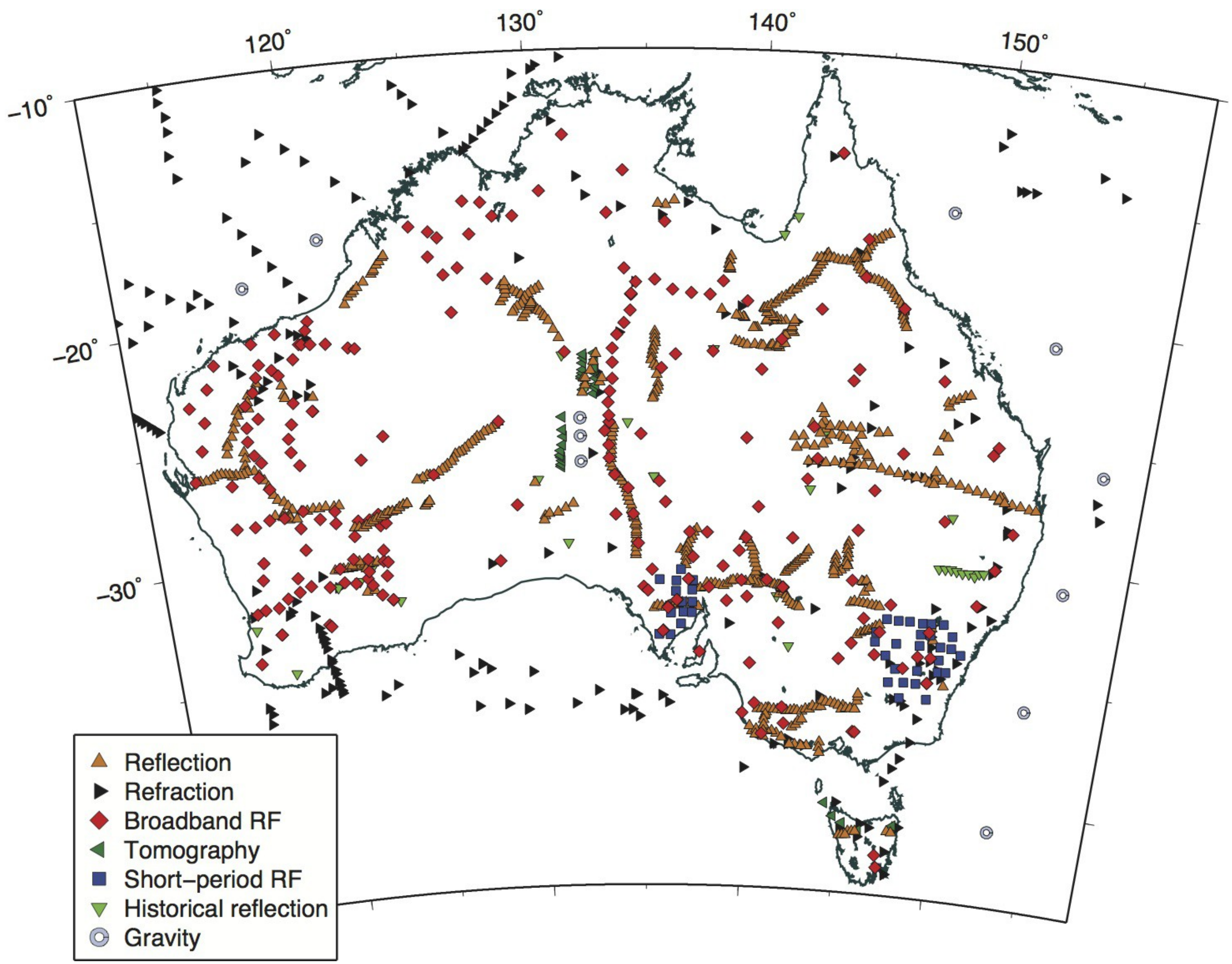






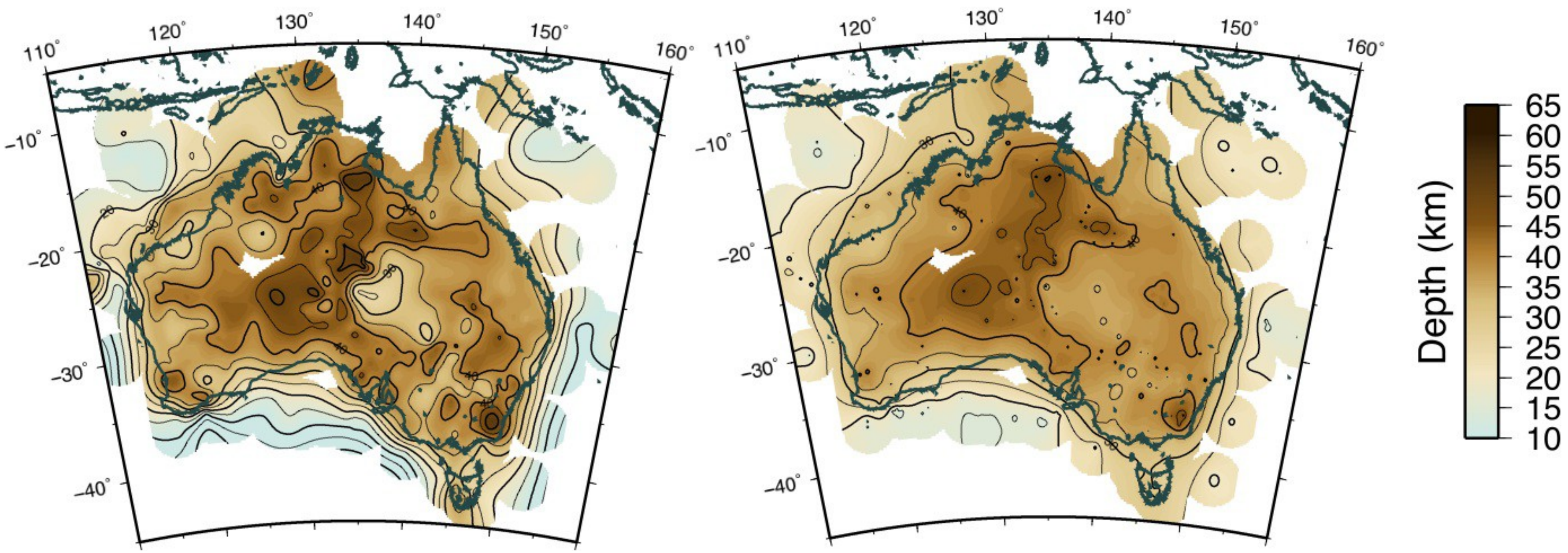
Marginals in interface position

Constructing Moho Topography for Australia



With Brian Kennett and Michelle Salmon

Standard Cubic B-spline Interpolation



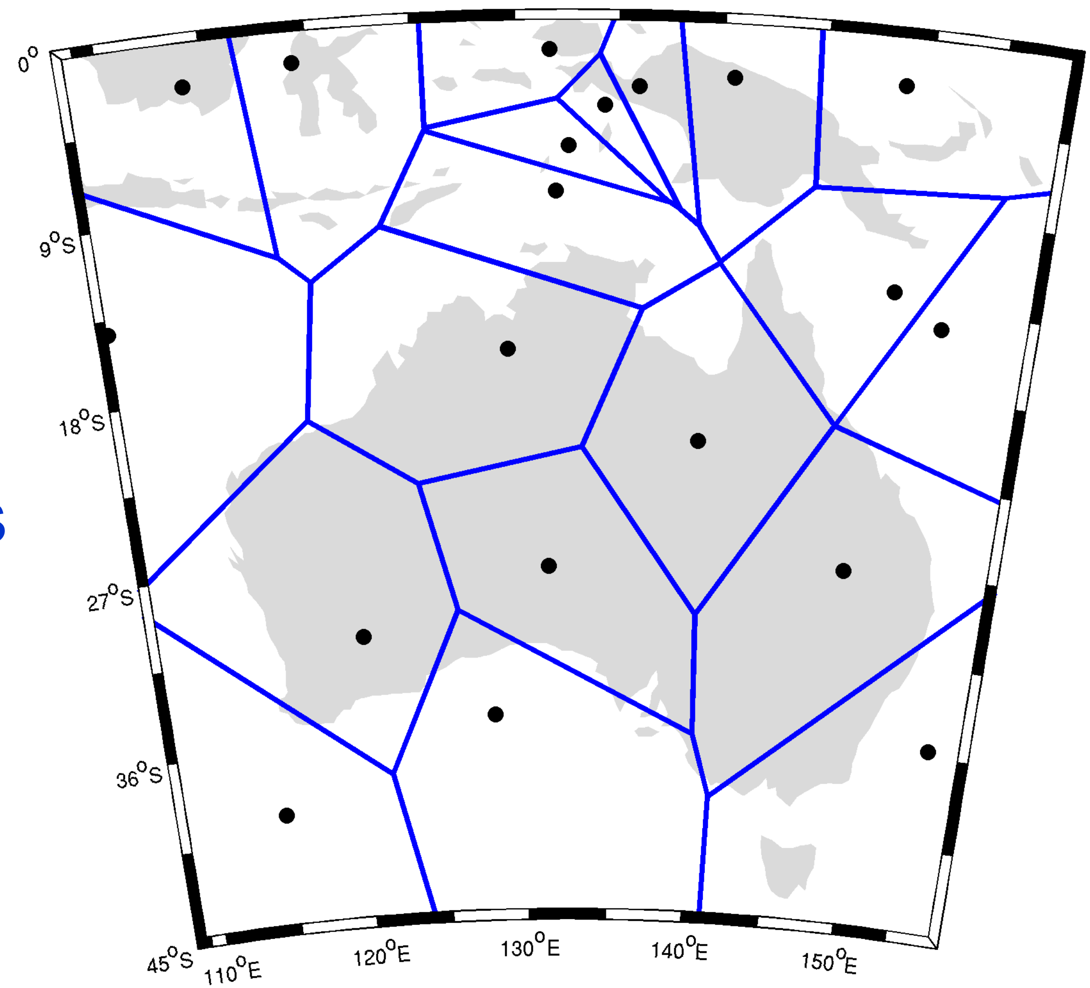
Voronoi cells

Cells are only defined by their centres

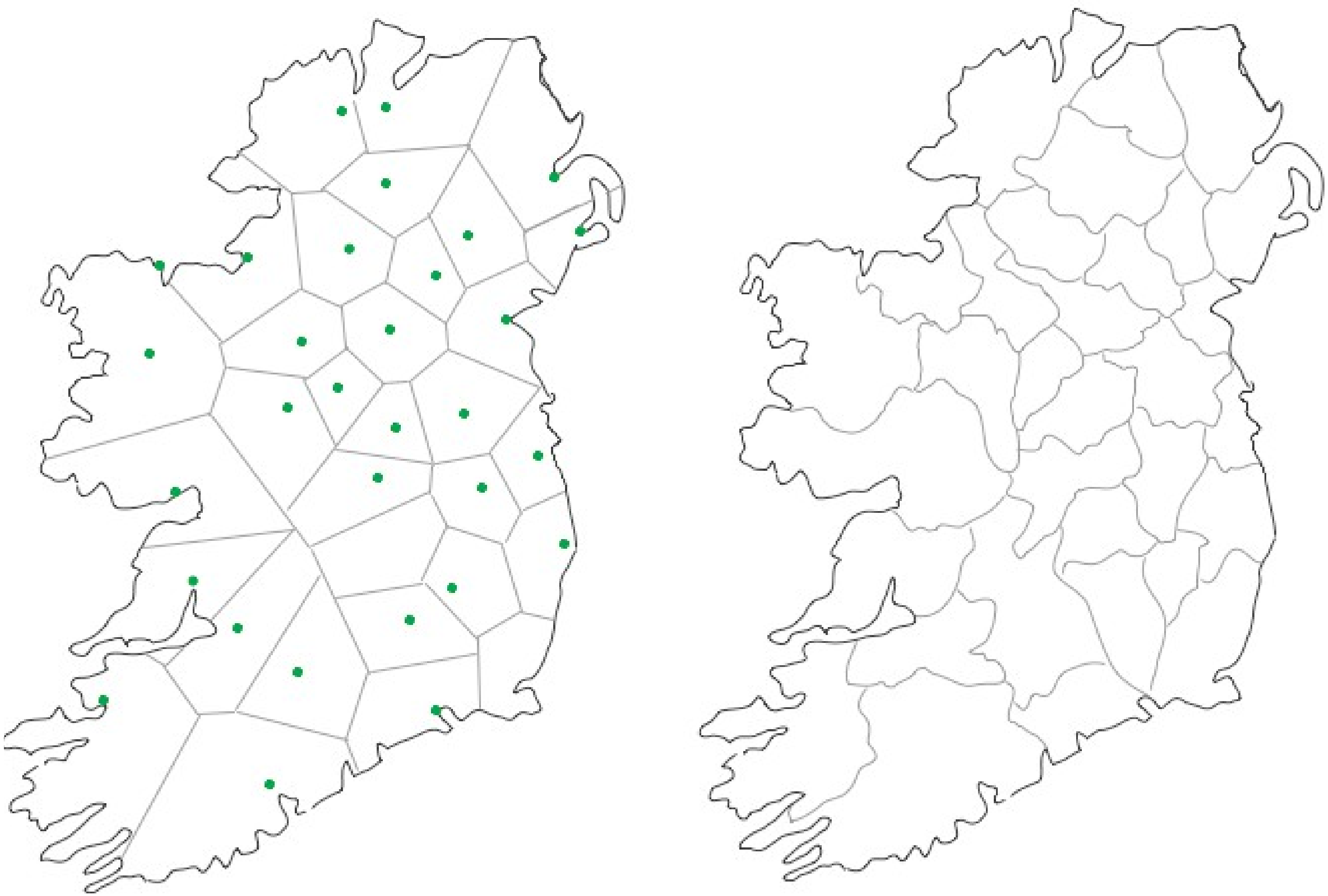
Variable number of cells

Model is defined by:

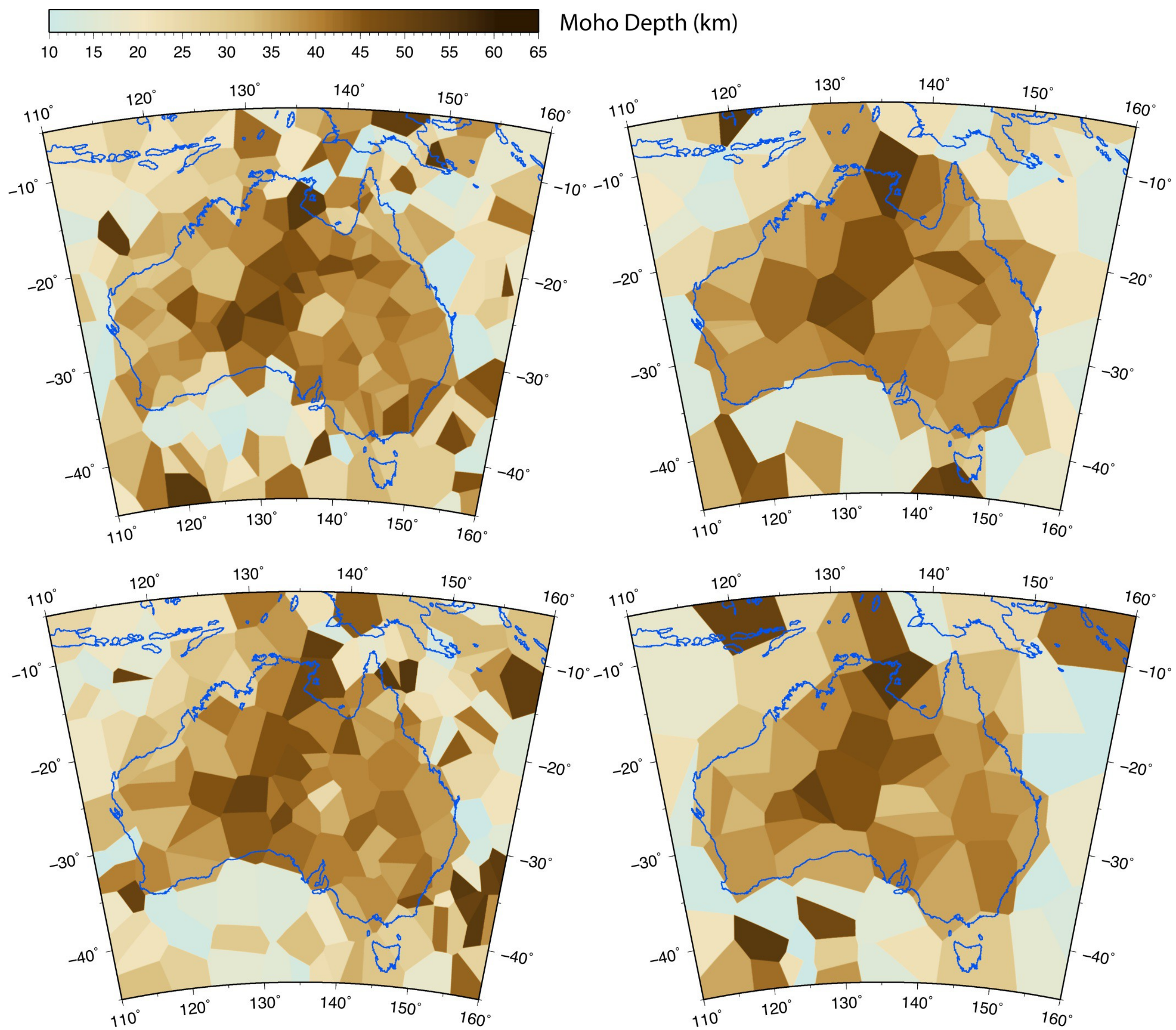
* Velocity in each cell
* Position of each cell



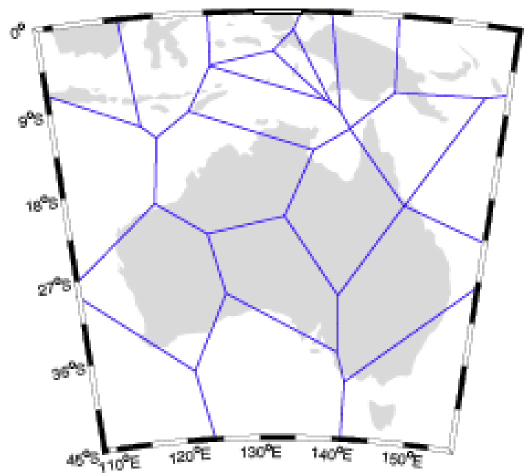
Voronoi cells are everywhere



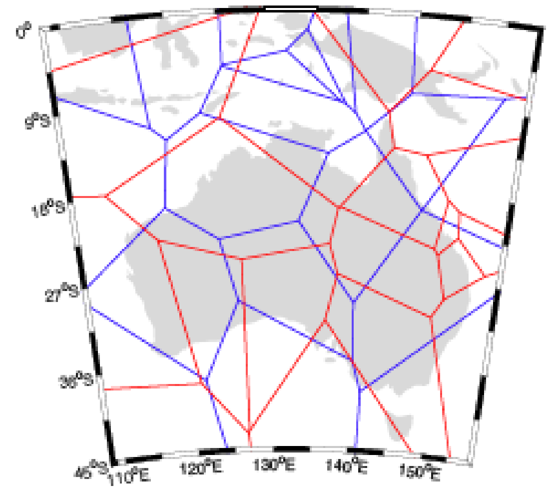
Solution = Large number of models



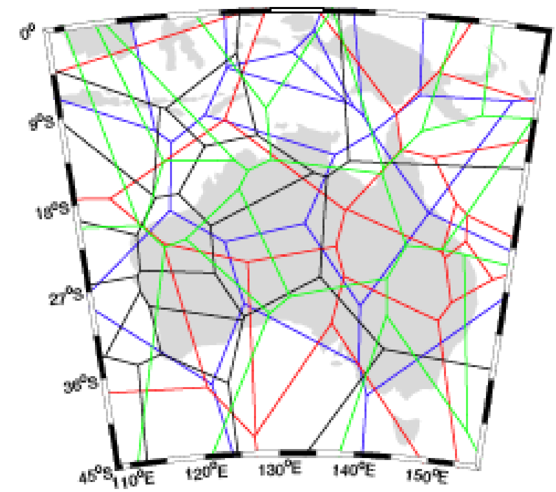
Self- Adaptive Smoothing



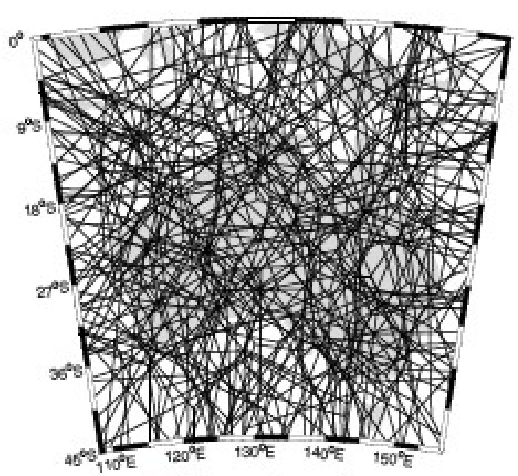
20 uniformly random Voronoi cells



2 overlapping Voronoi meshes

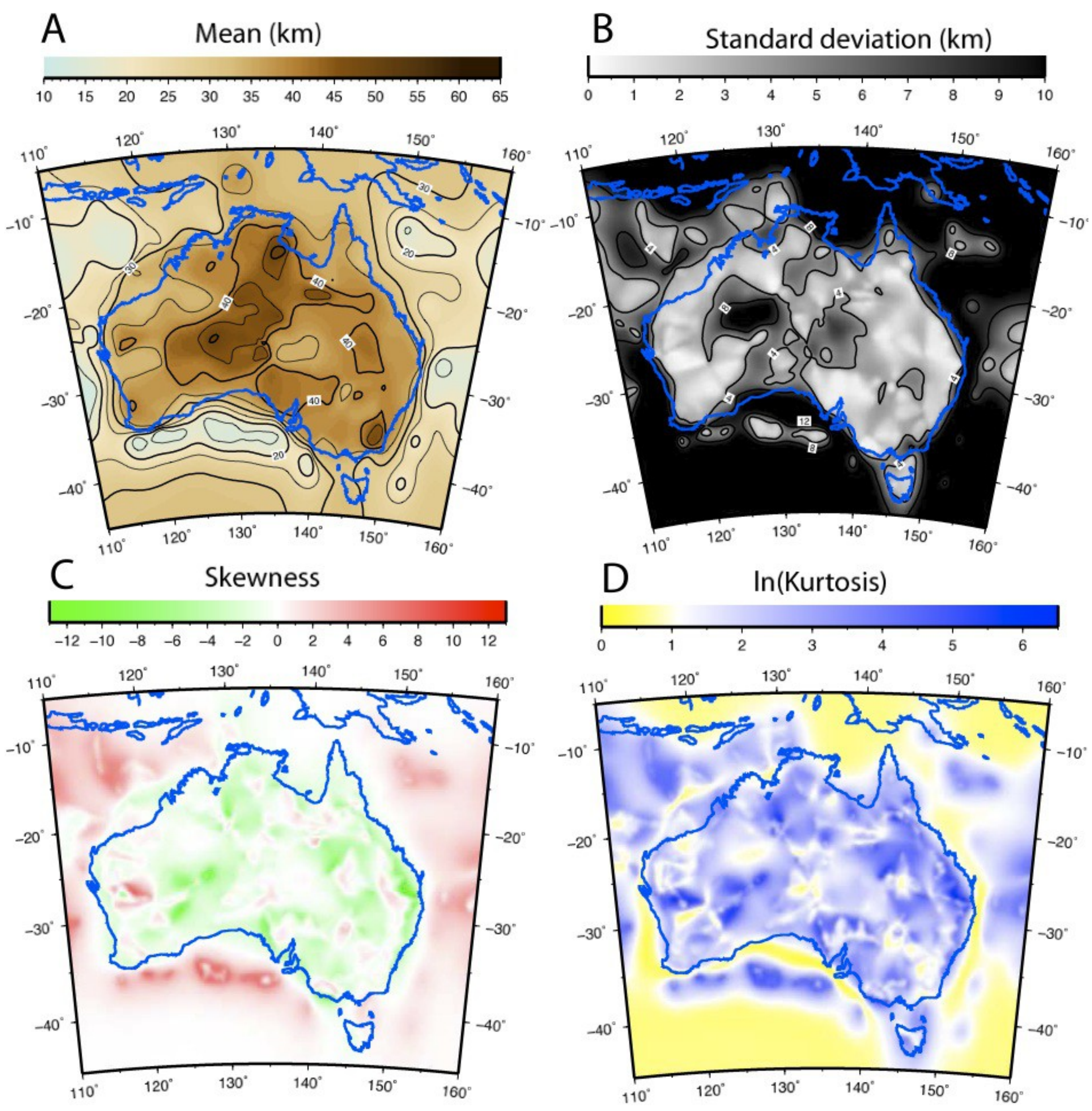


4 overlapping Voronoi meshes

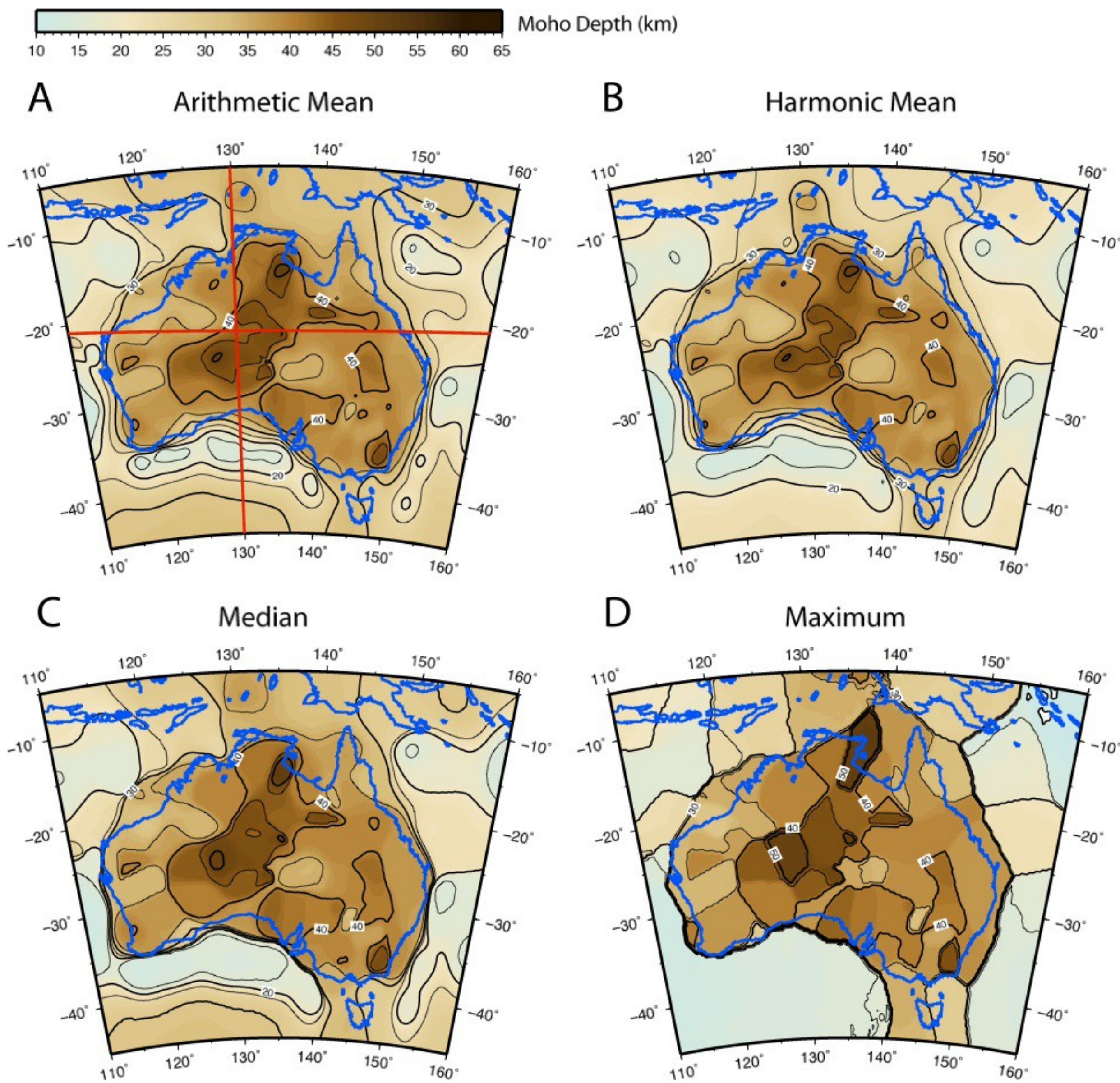


20 Voronoi meshes

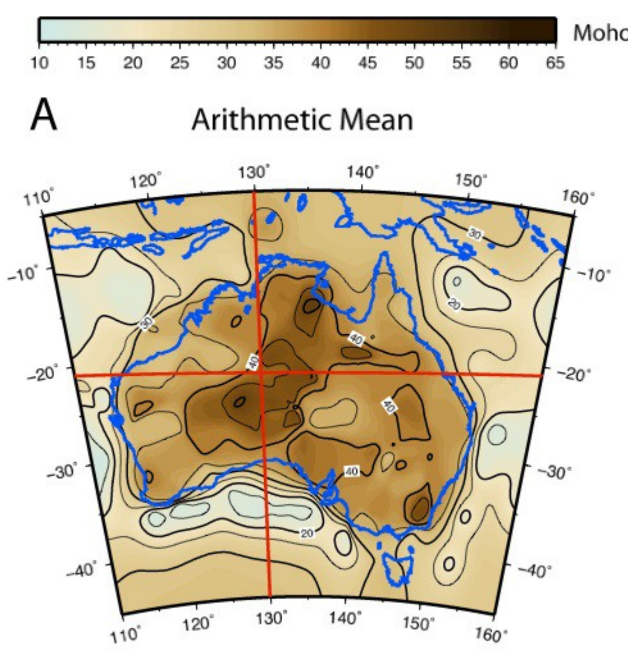
Statistical Moments of the ensemble solution

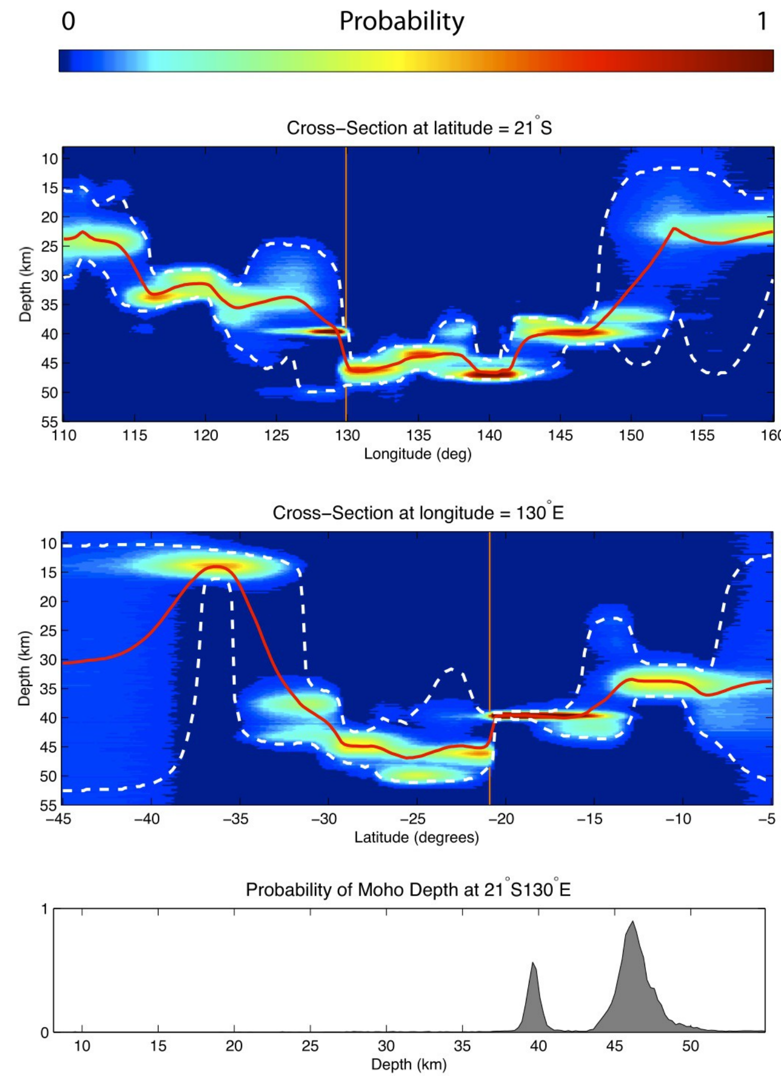


Different ways to look at the solution

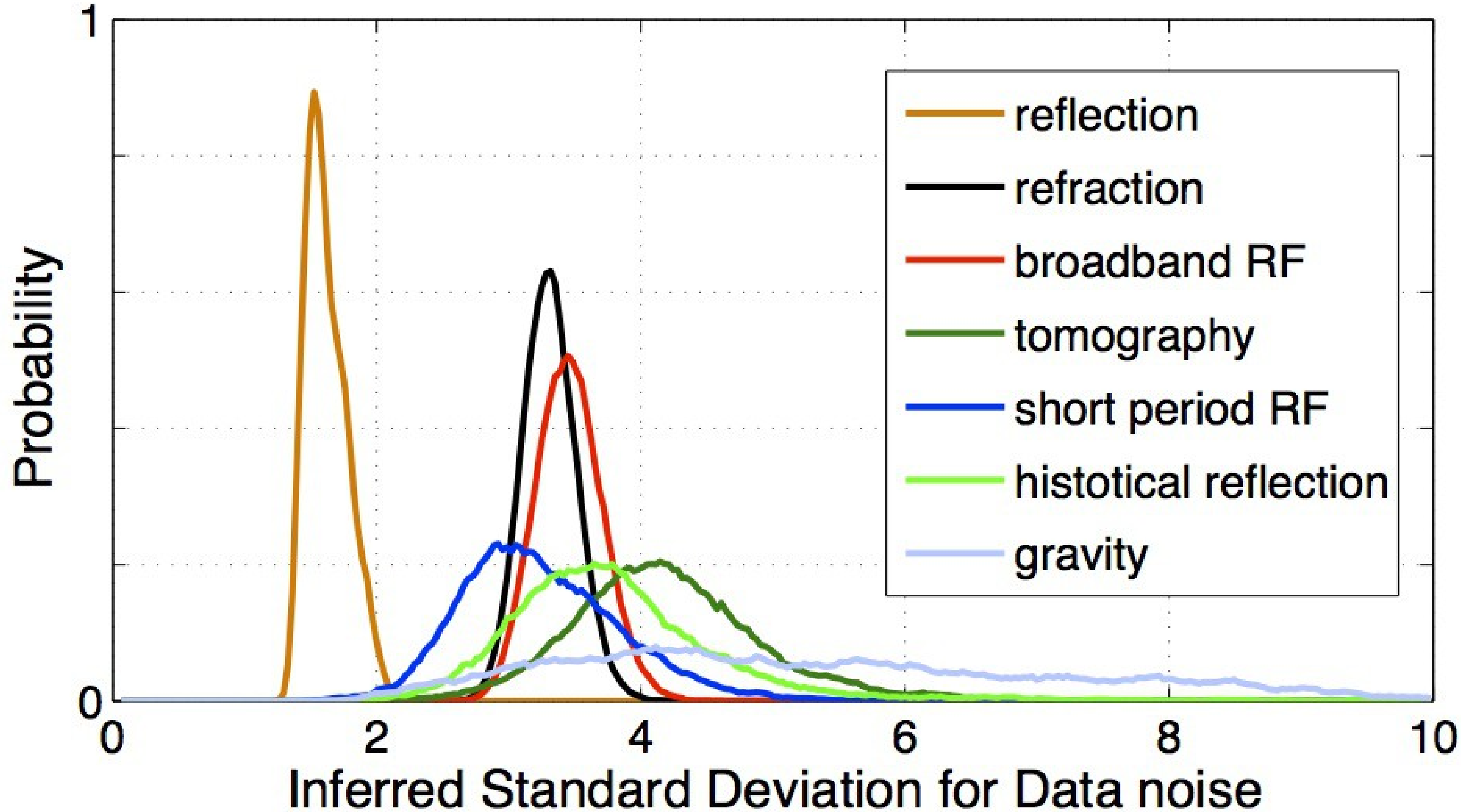


Full probability distribution along two cross sections

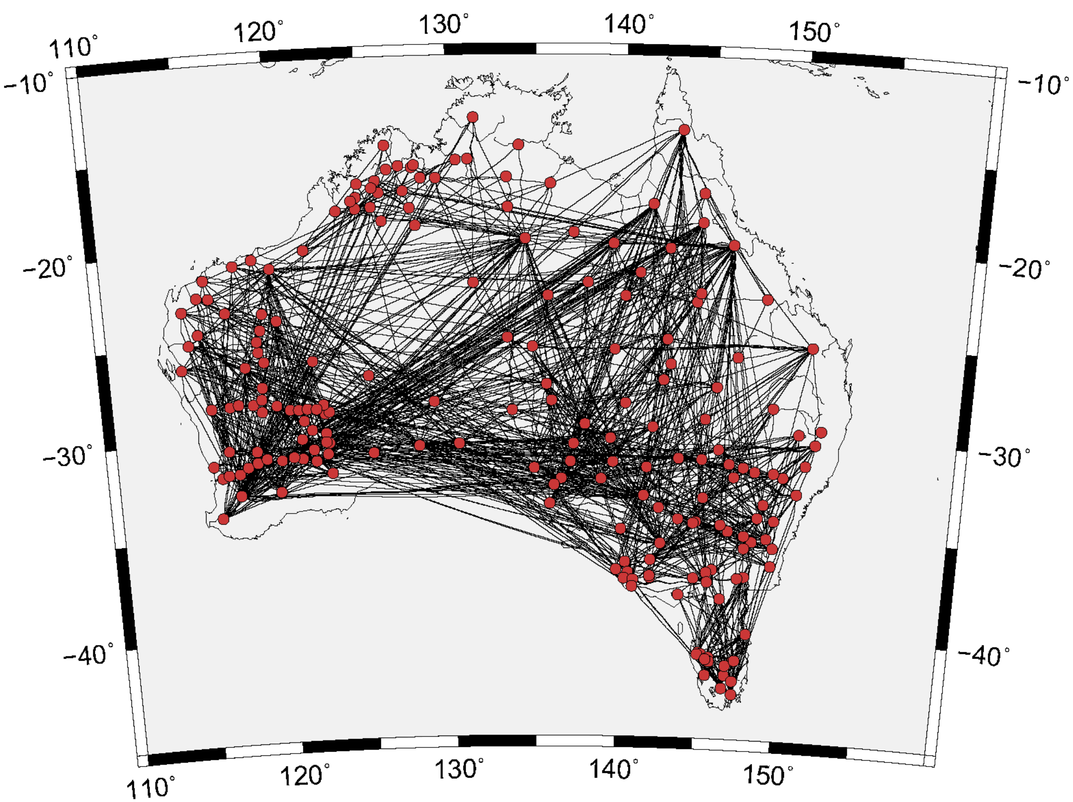


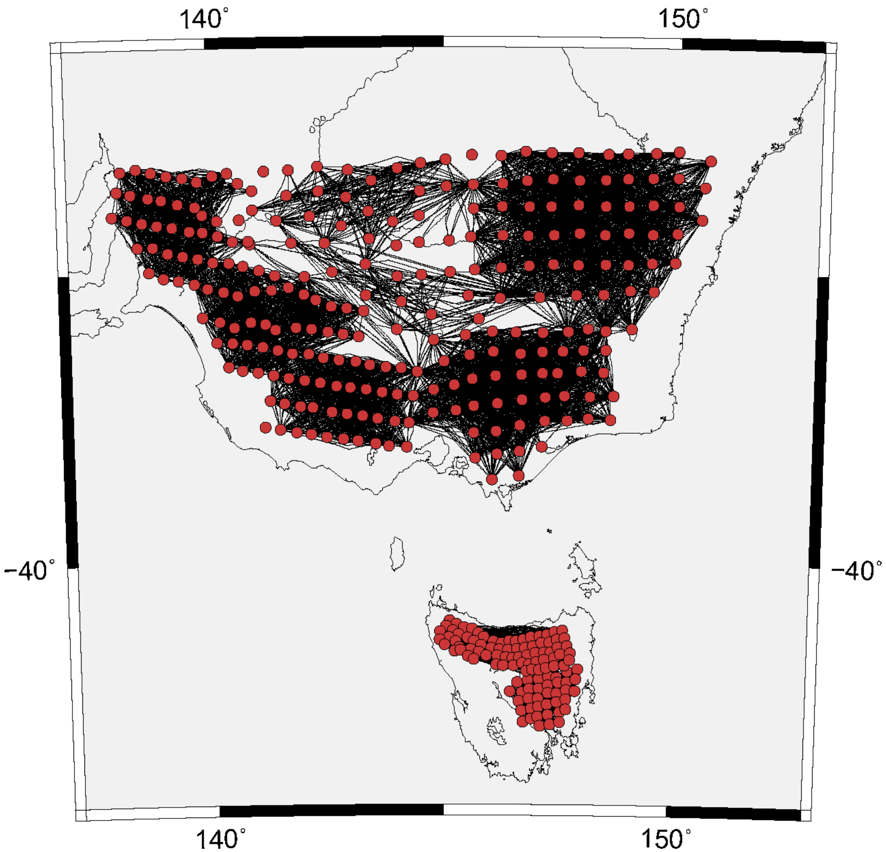


Posterior Inference on Data noise

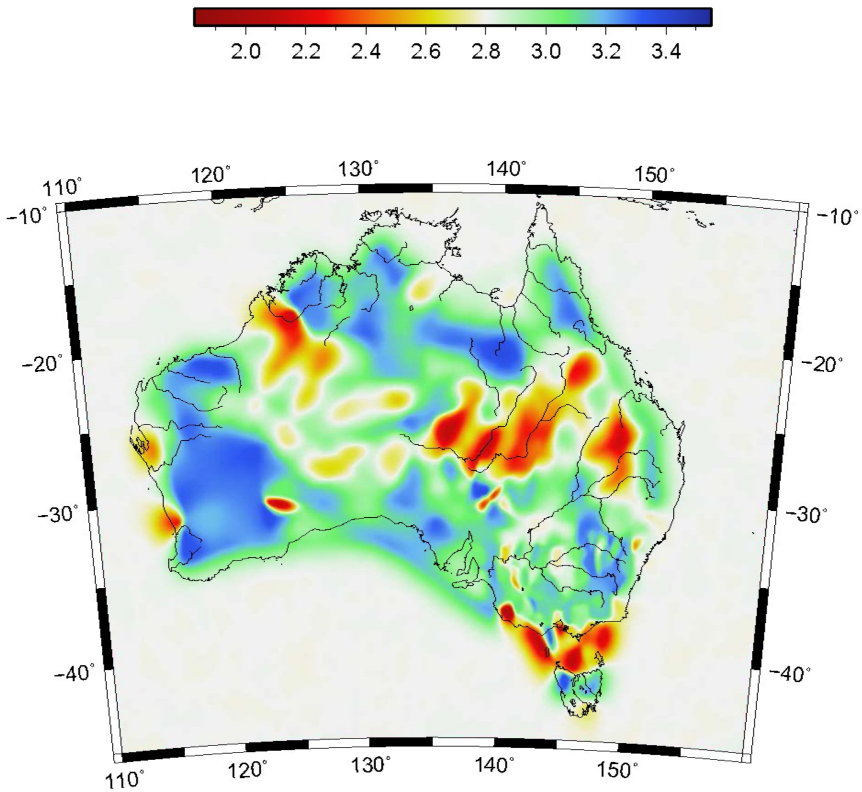


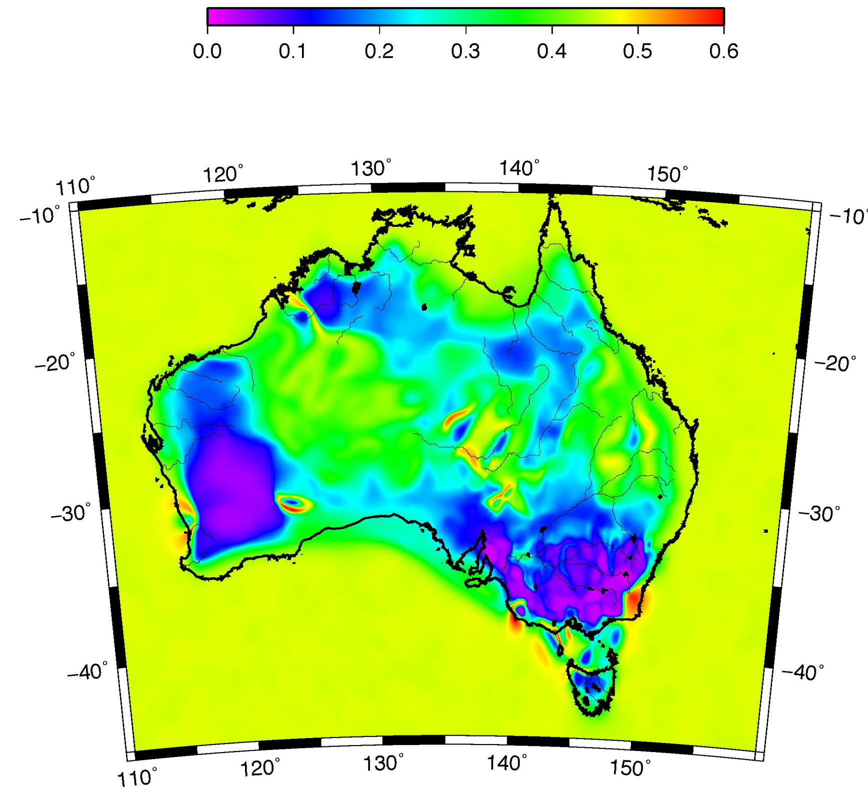
Cross correlation of seismic ambient noise for Rayleigh wave group velocity at 5s





Real Data

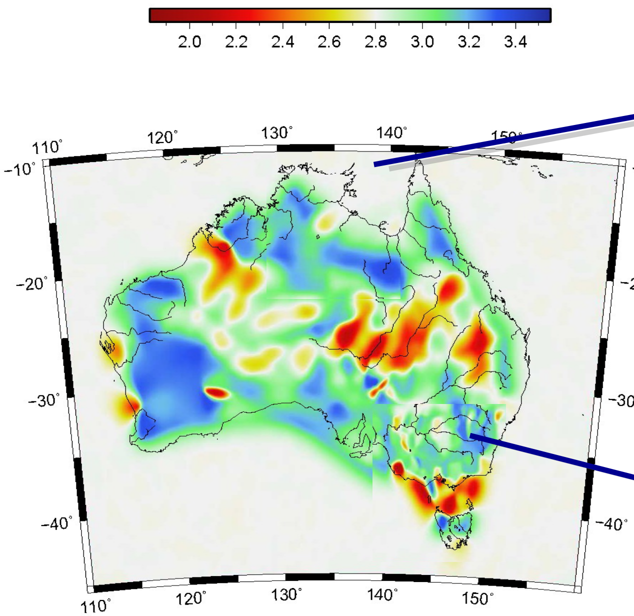




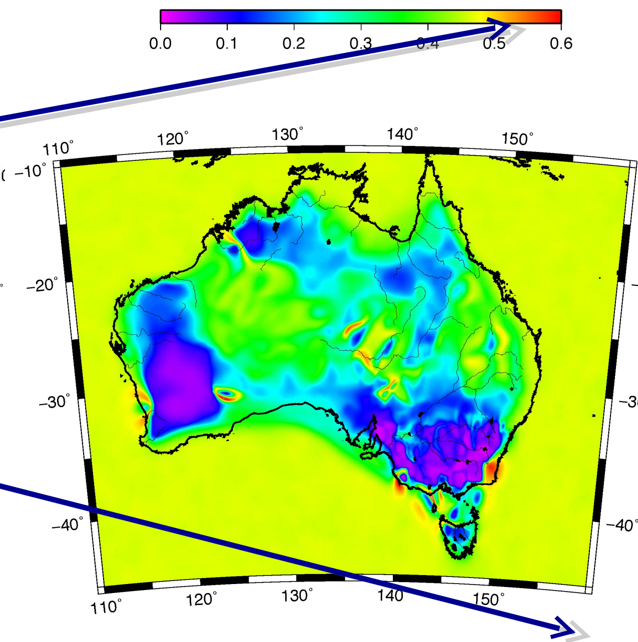
Average model (Km/s)

Error estimation (Km/s)

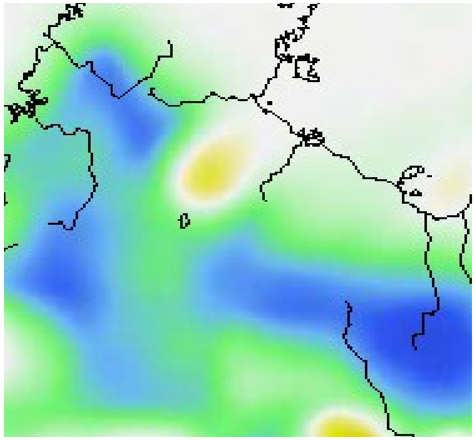
Transdimensional Tomography

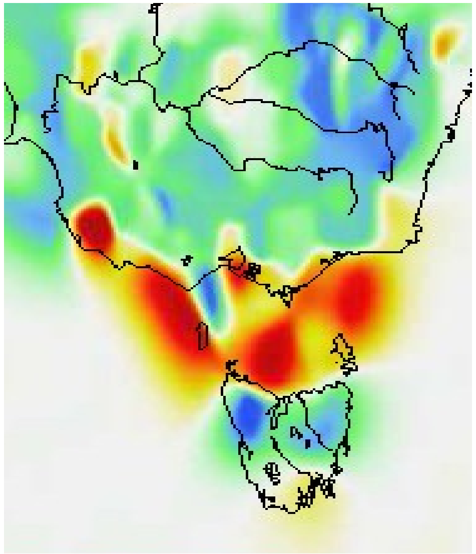


Average model (Km/s)



Error estimation (Km/s)





Conclusion

"We use fantastic telescopes, the best physical models, and the best computers. The weak link in this chain is interpreting our data using 100 year old mathematics"

Mc Kenzie, 2004