A tunneling approach to regularized full waveform inversion

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Prior information in inversion

Seismic inversion uses both **data** and **prior information**

Prior information allows us to consider only subsurface models which are known to be reasonable

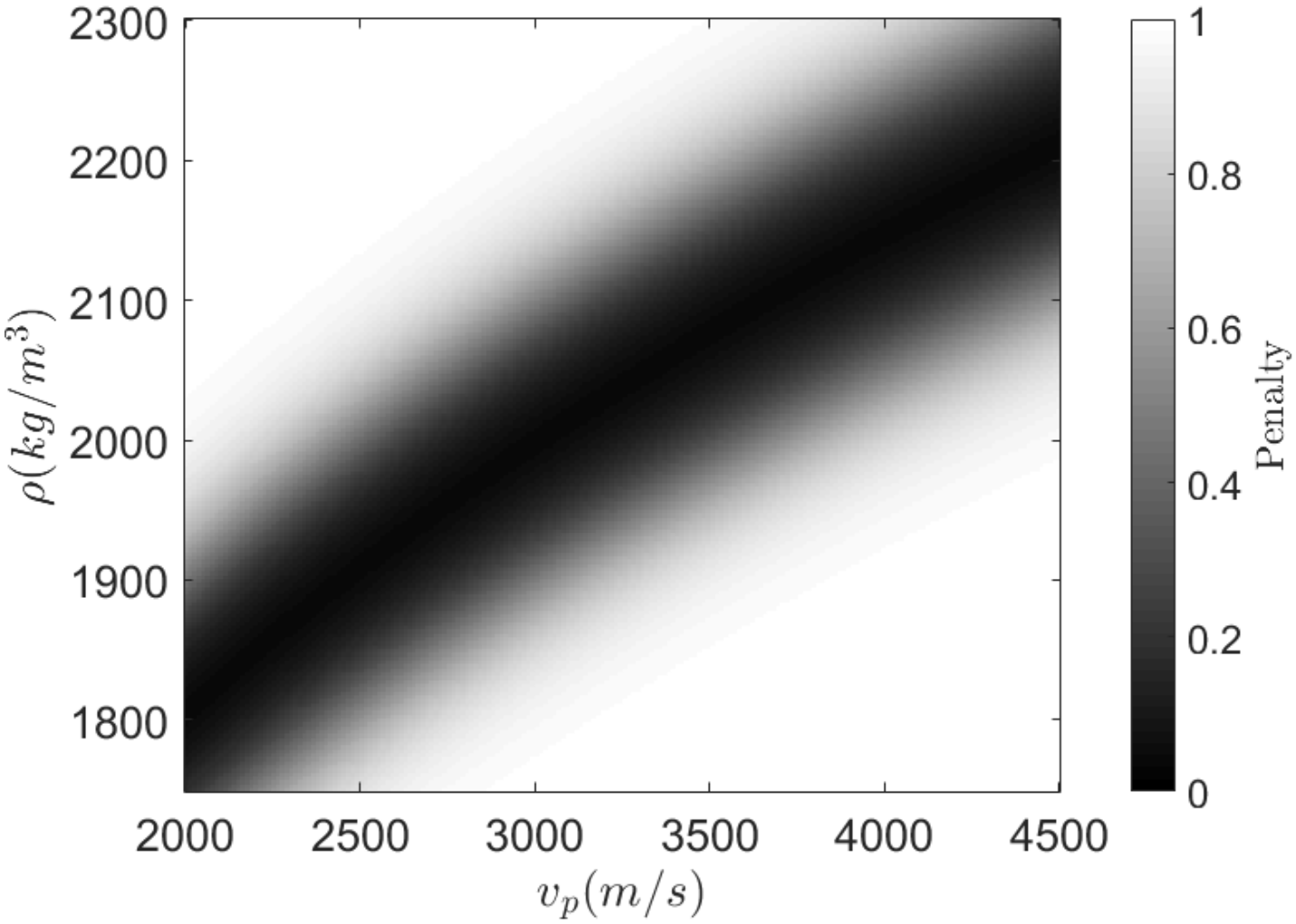
This improves accuracy by making use of more available information

It can also improve convergence, by reducing the size of model space

Regularization

Regularization terms introduce a penalty in the inversion objective function

These push the model towards the a priori likely values



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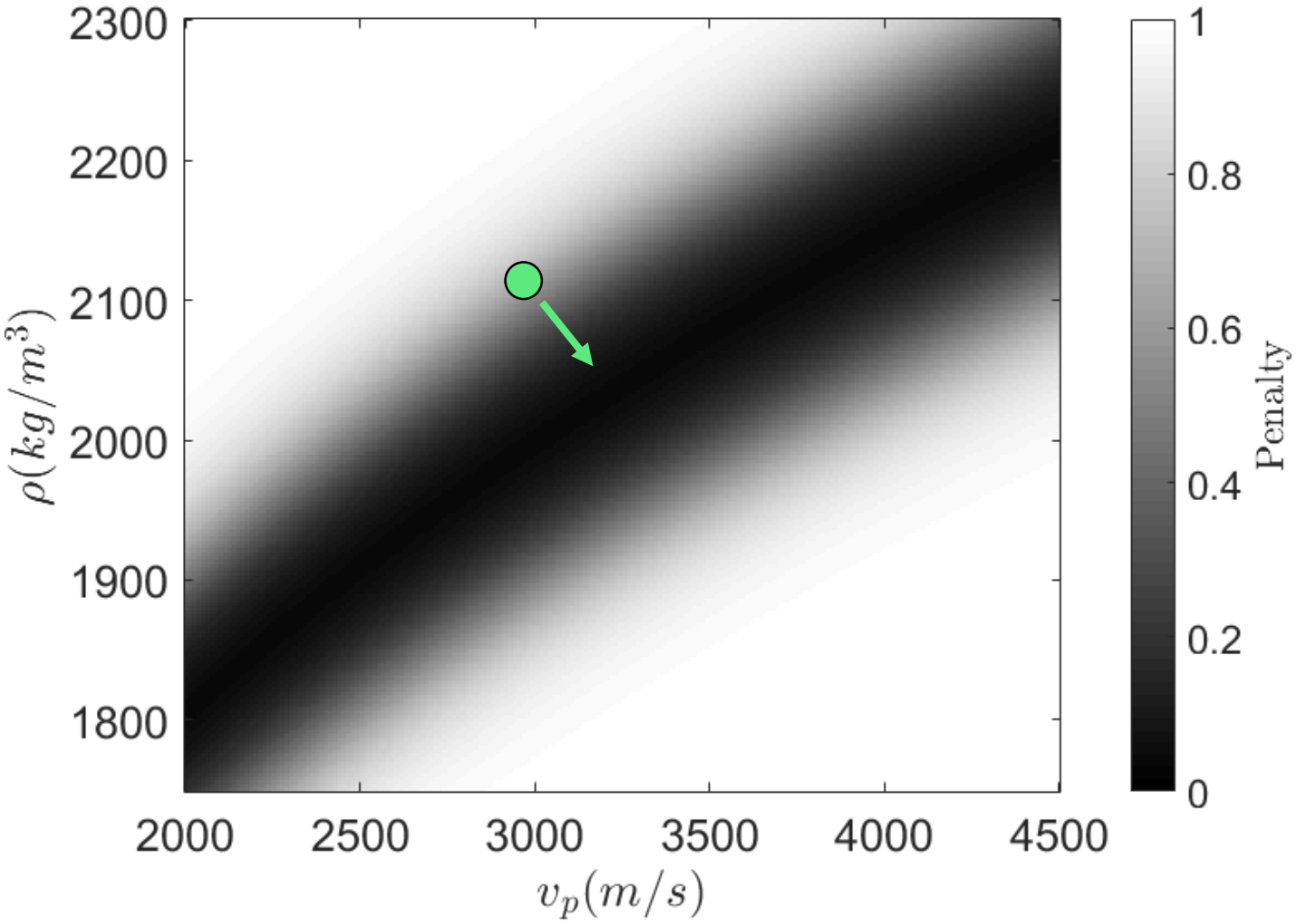


Regularization and local optimization

Full-waveform inversion is driven by **local** optimization

Only derivatives are considered when updating the inversion model

Regularization works well if any given pair of viable models is connected by a chain of other viable models

This is usually not the case if there is clustering

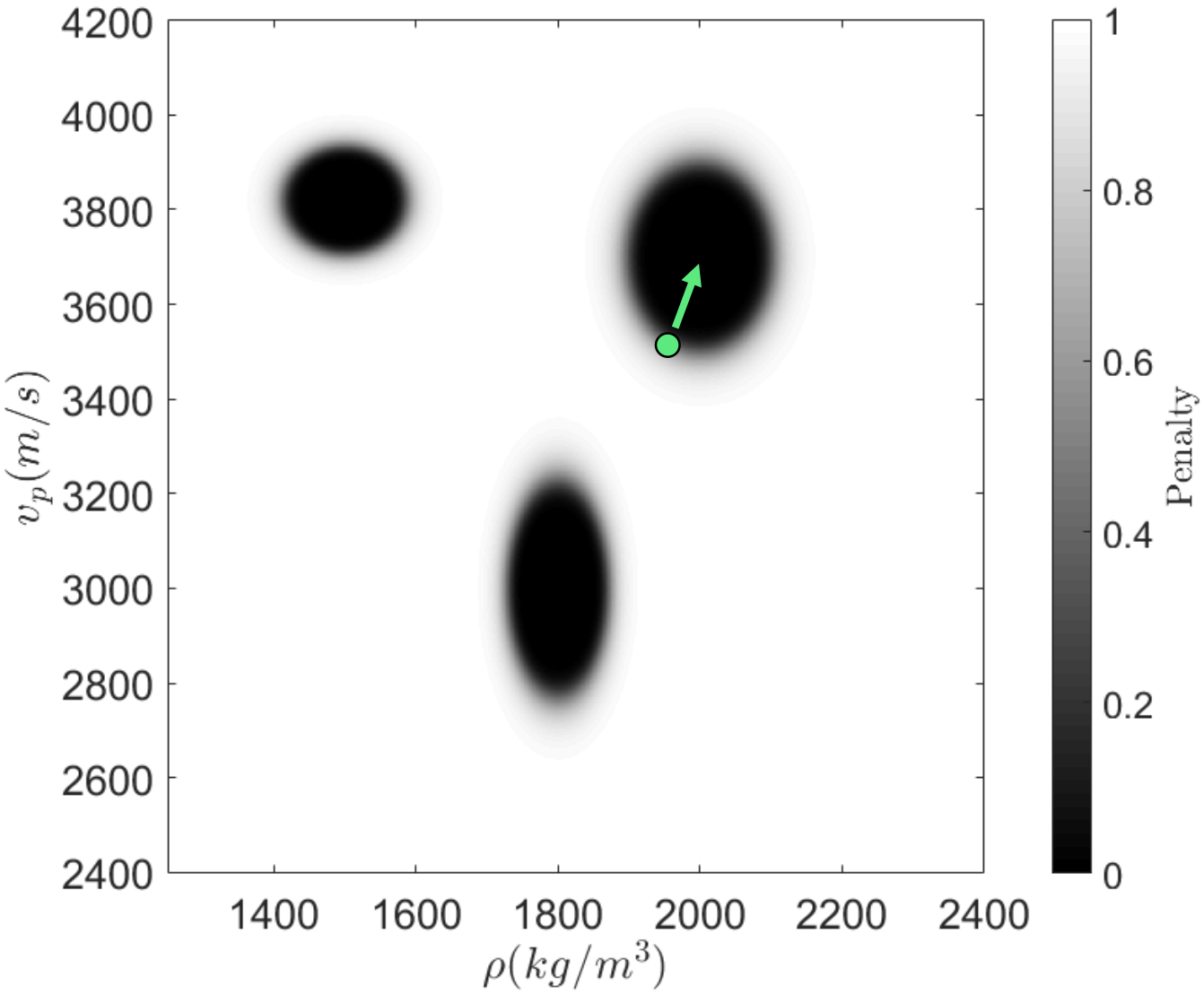
Clustering is natural in geophysics due to the very different rock types investigated

Clustering

Clustering a priori information is difficult to use in FWI

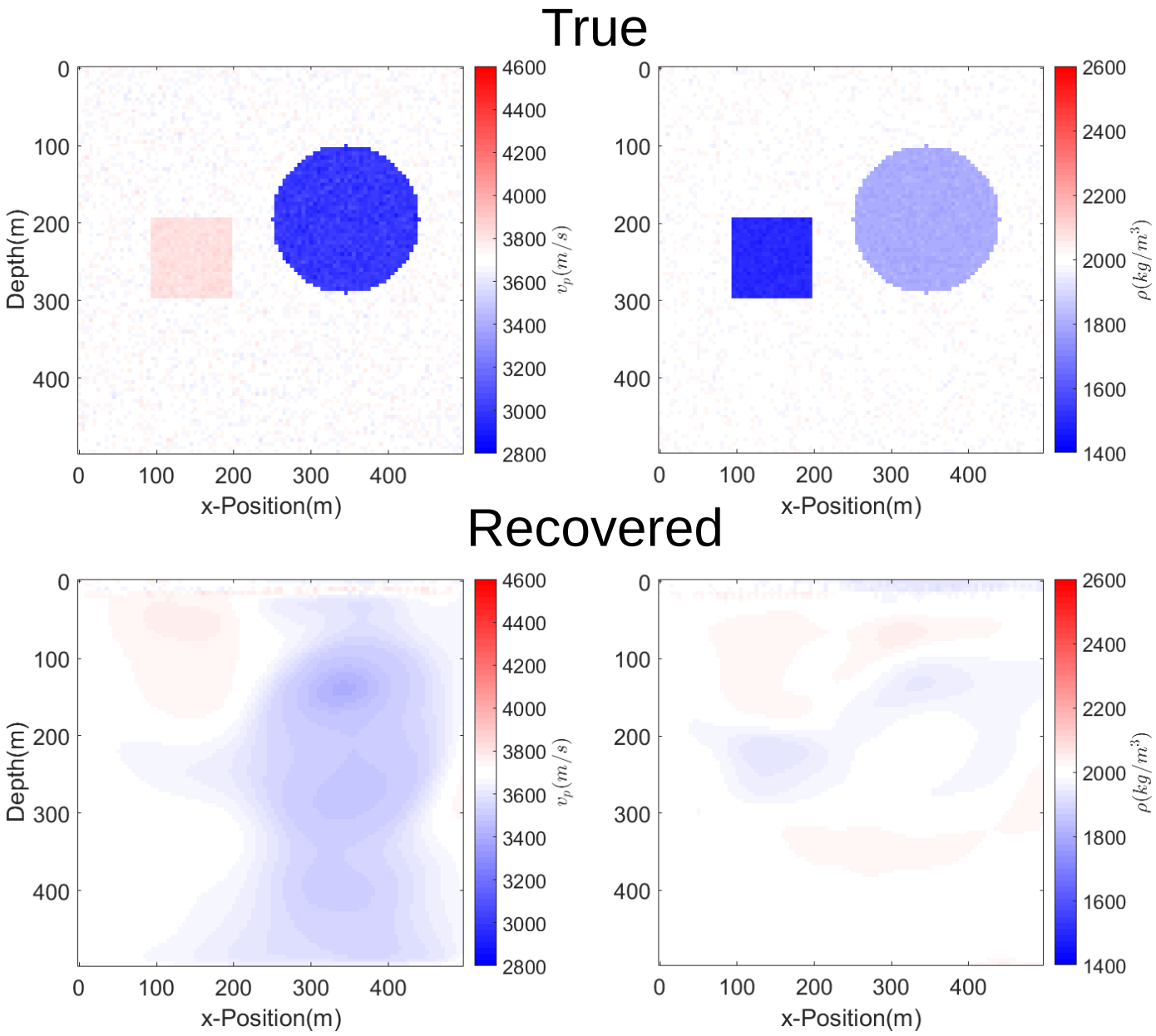
Local optimization will strongly discourage leaving a cluster

Can result in deadlock, or regularization too weak to work effectively



Inversion with cluster-based regularization

Regularization terms that prevent highly unlikely models also prevent cluster changing



Regularization tunneling

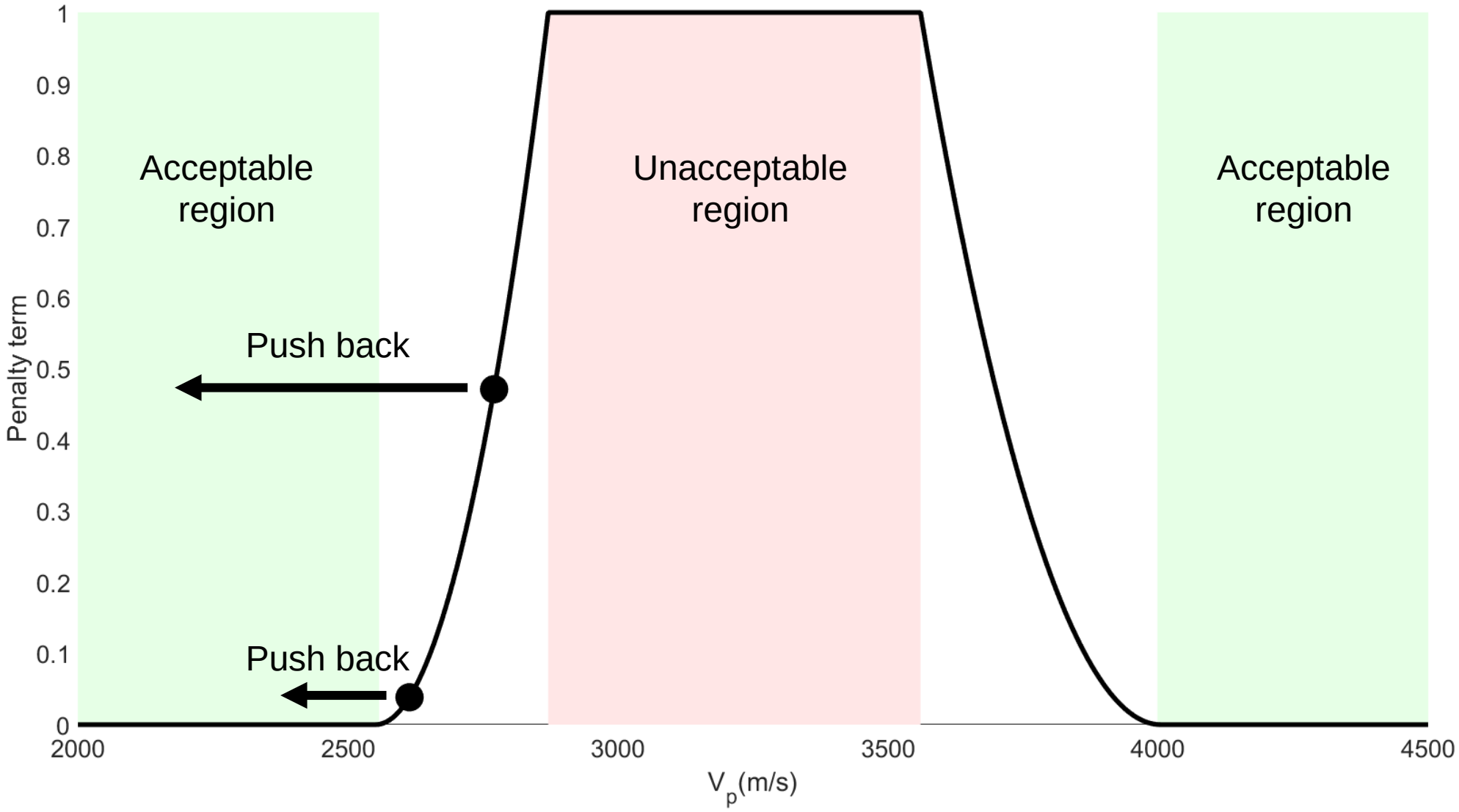
Computational cost makes global optimization impractical in FWI

The regularization term is generally known throughout model space at negligible computational cost

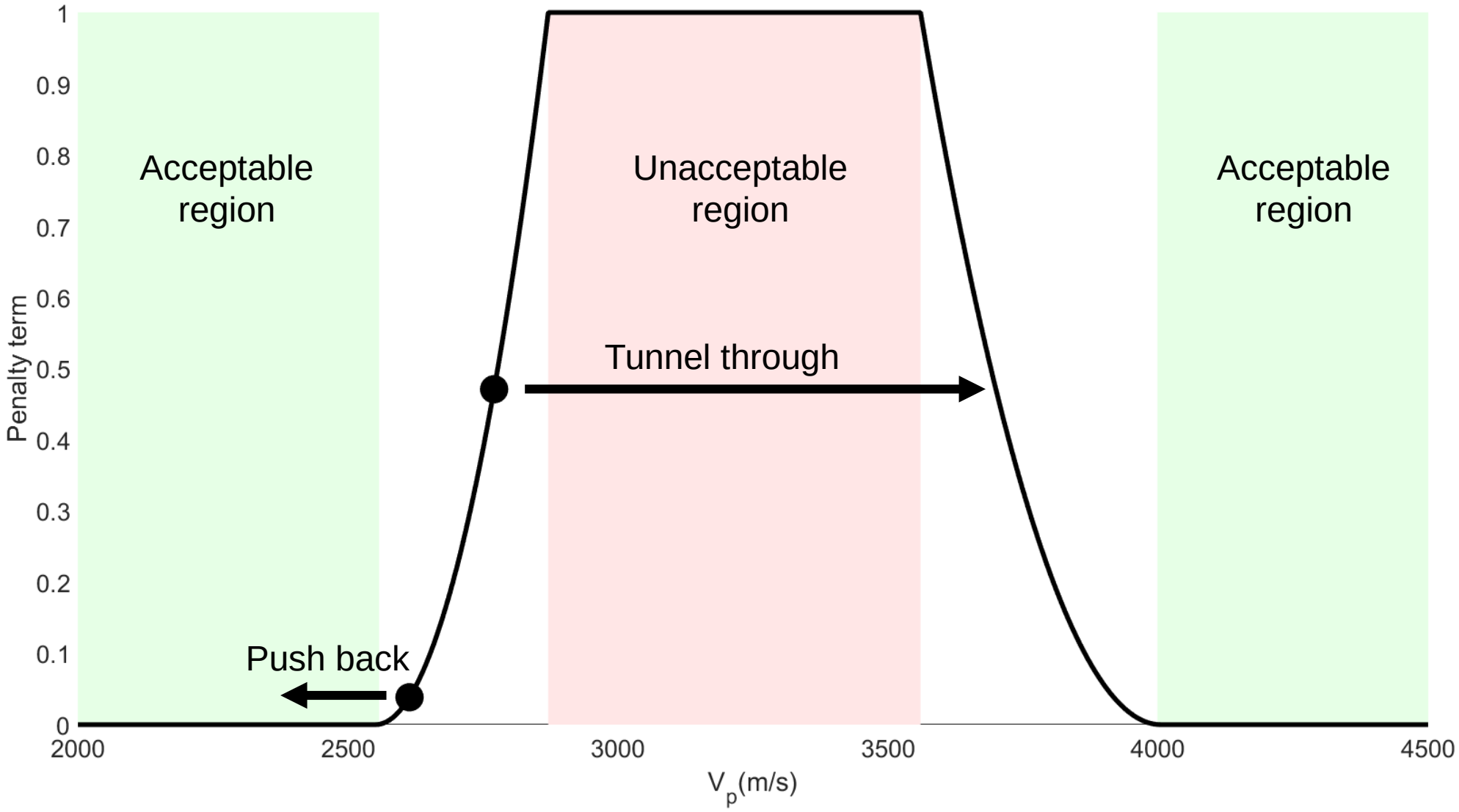
Non-local information may motivate a decision to let a model element change clusters

We use a cluster changing approach we call tunneling

Conventional FWI



Tunneling

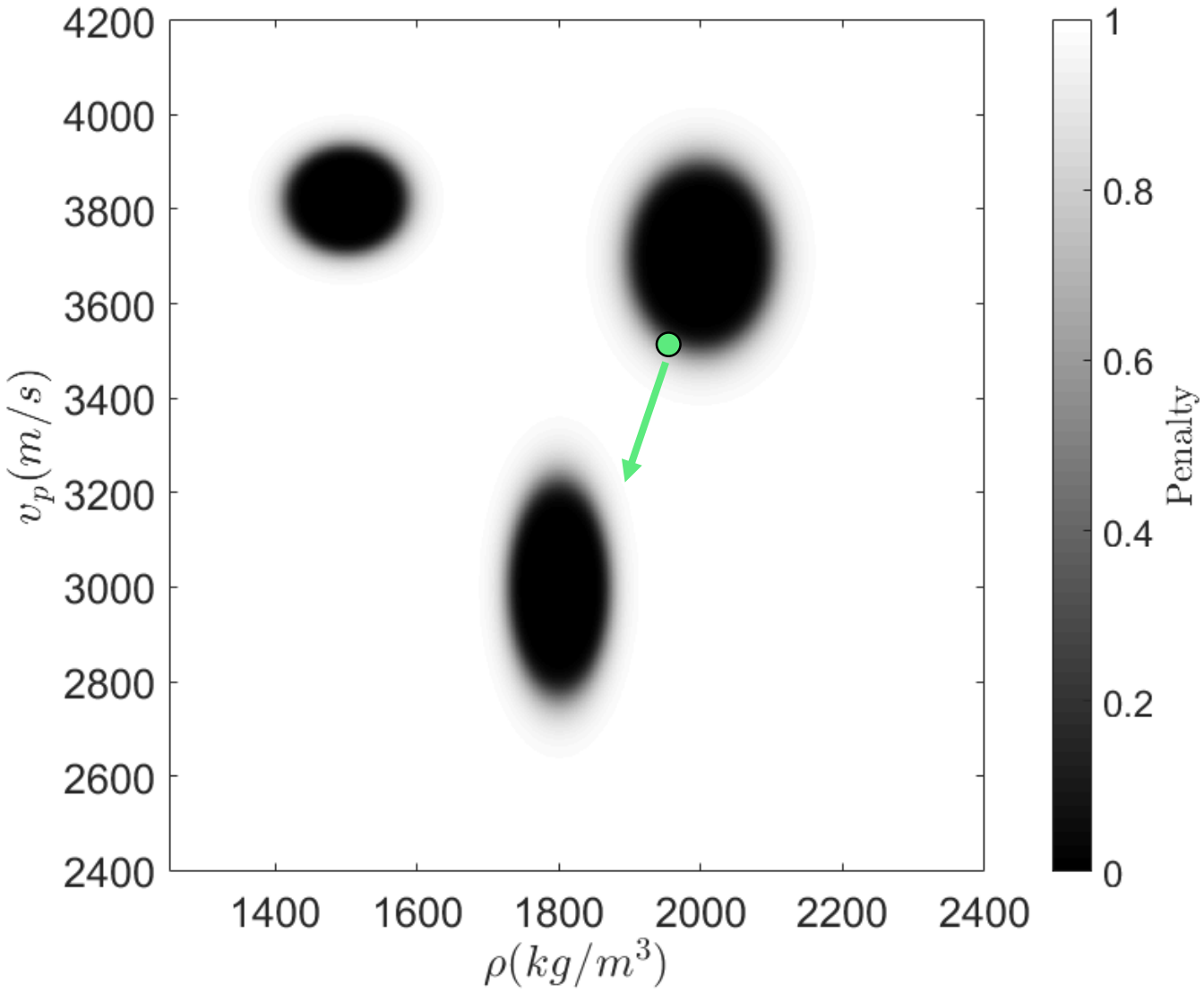

Acceptable region
Unacceptable region
Acceptable region
Tunnel through
Push back
Penalty term
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2000
2500
3000
3500
4000
4500
V_p(m/s)

When to tunnel?

Incurring large penalty term

Data pushing model toward another cluster

Assign high tunneling probability

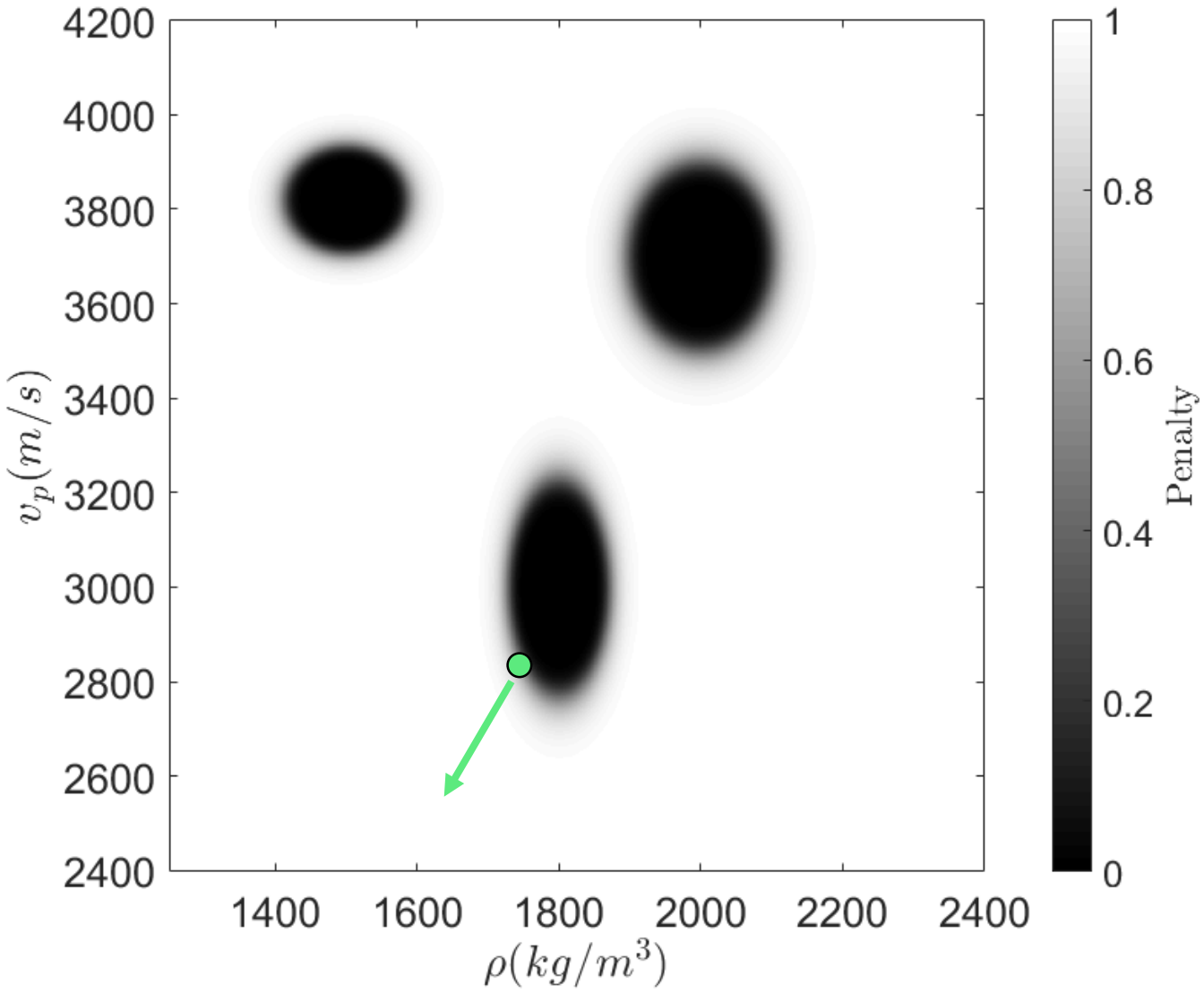


When to tunnel?

Incurring large penalty term

Data not pushing model toward another cluster

Assign low tunneling probability

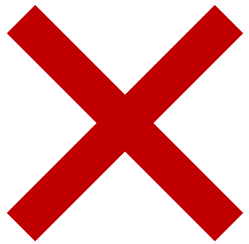


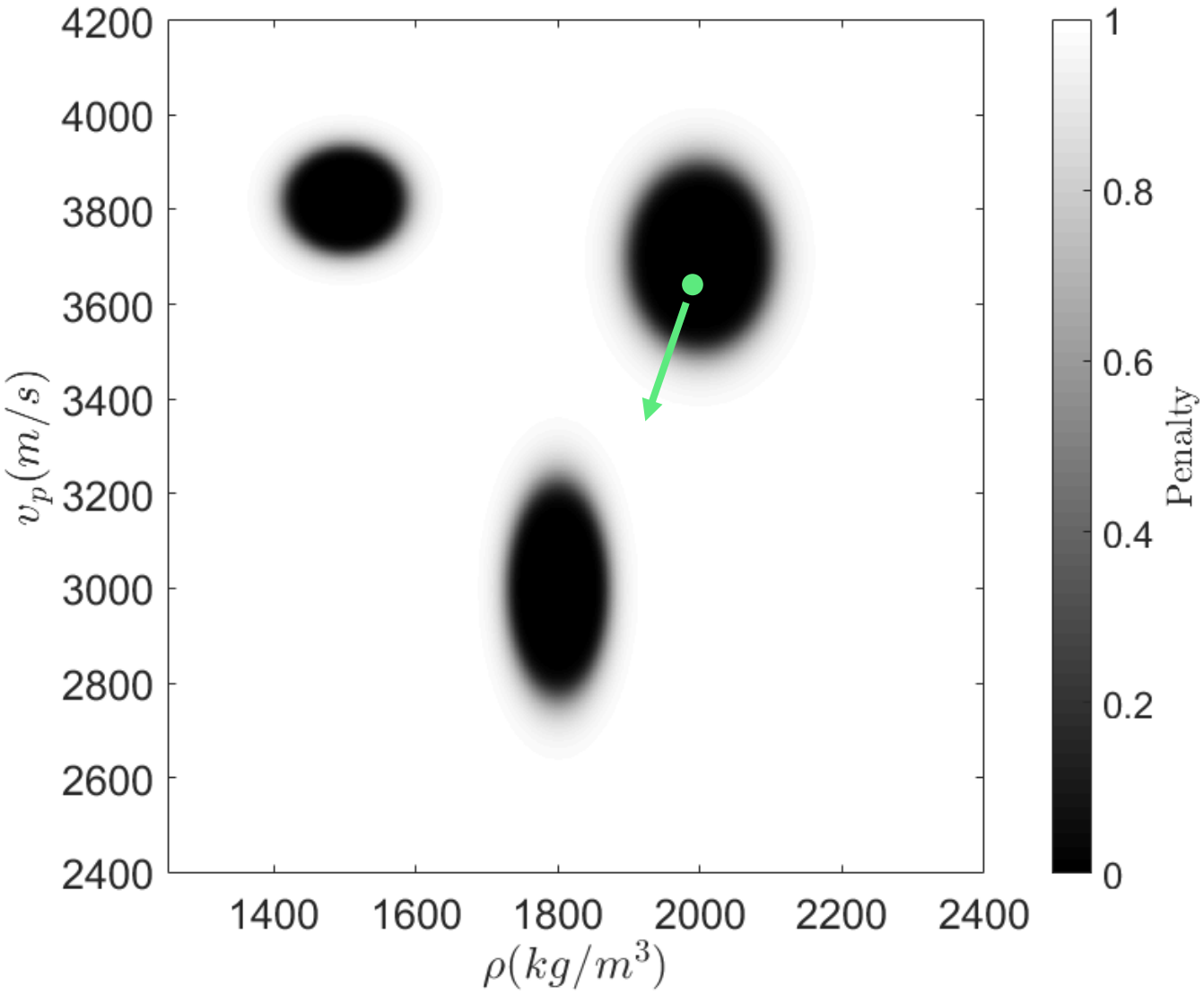
When to tunnel?

Incurring negligible penalty

Data pushing model toward another cluster

Assign low tunneling probability





Regularization tunneling in FWI

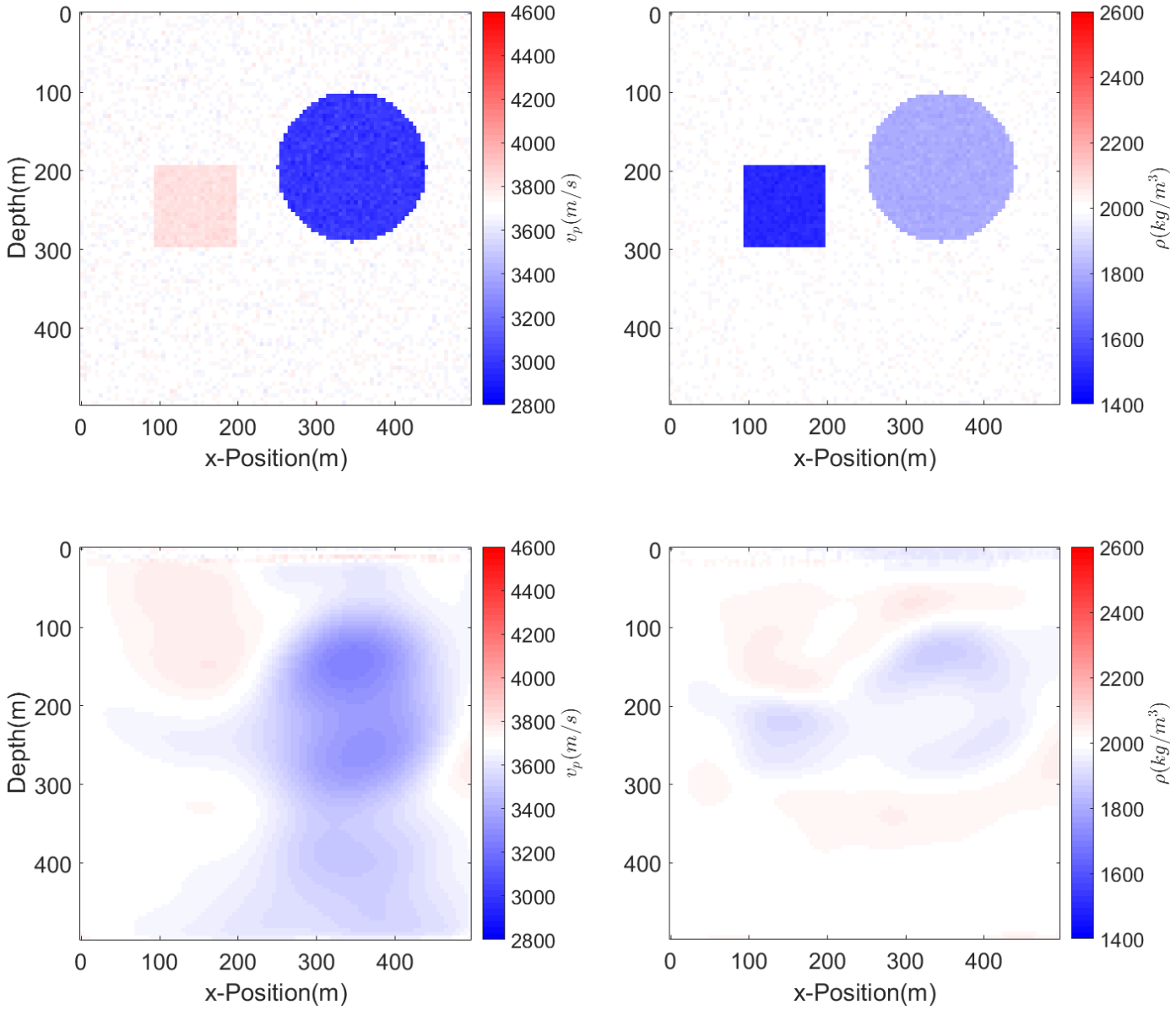
At each stage of the inversion we

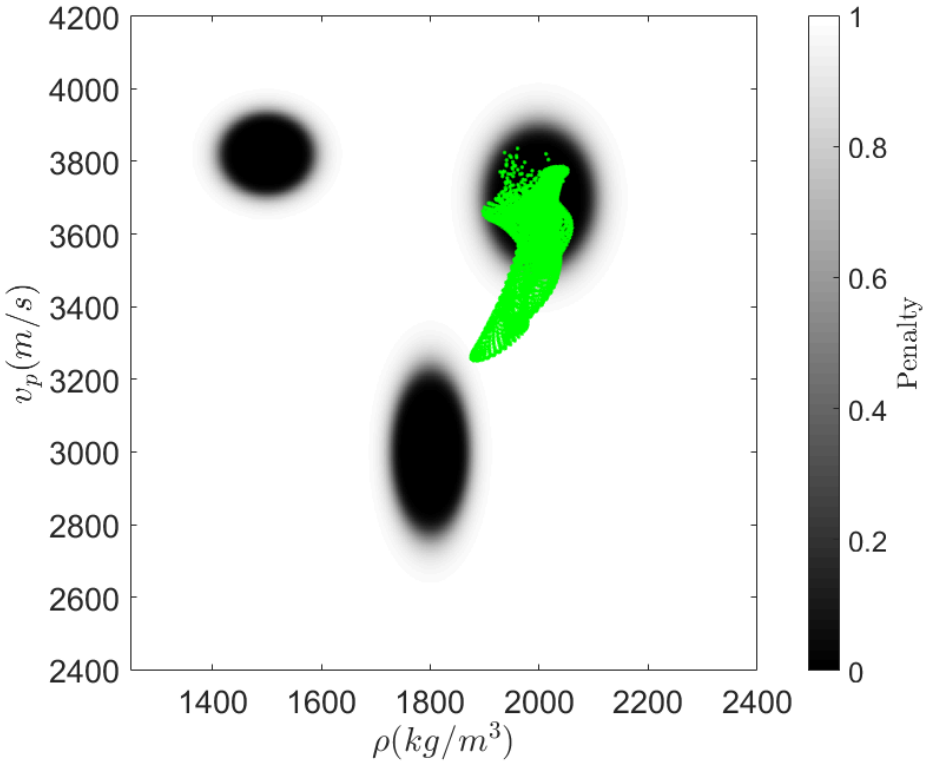
1) Apply normal FWI update

2) Assess tunneling probability for each model element

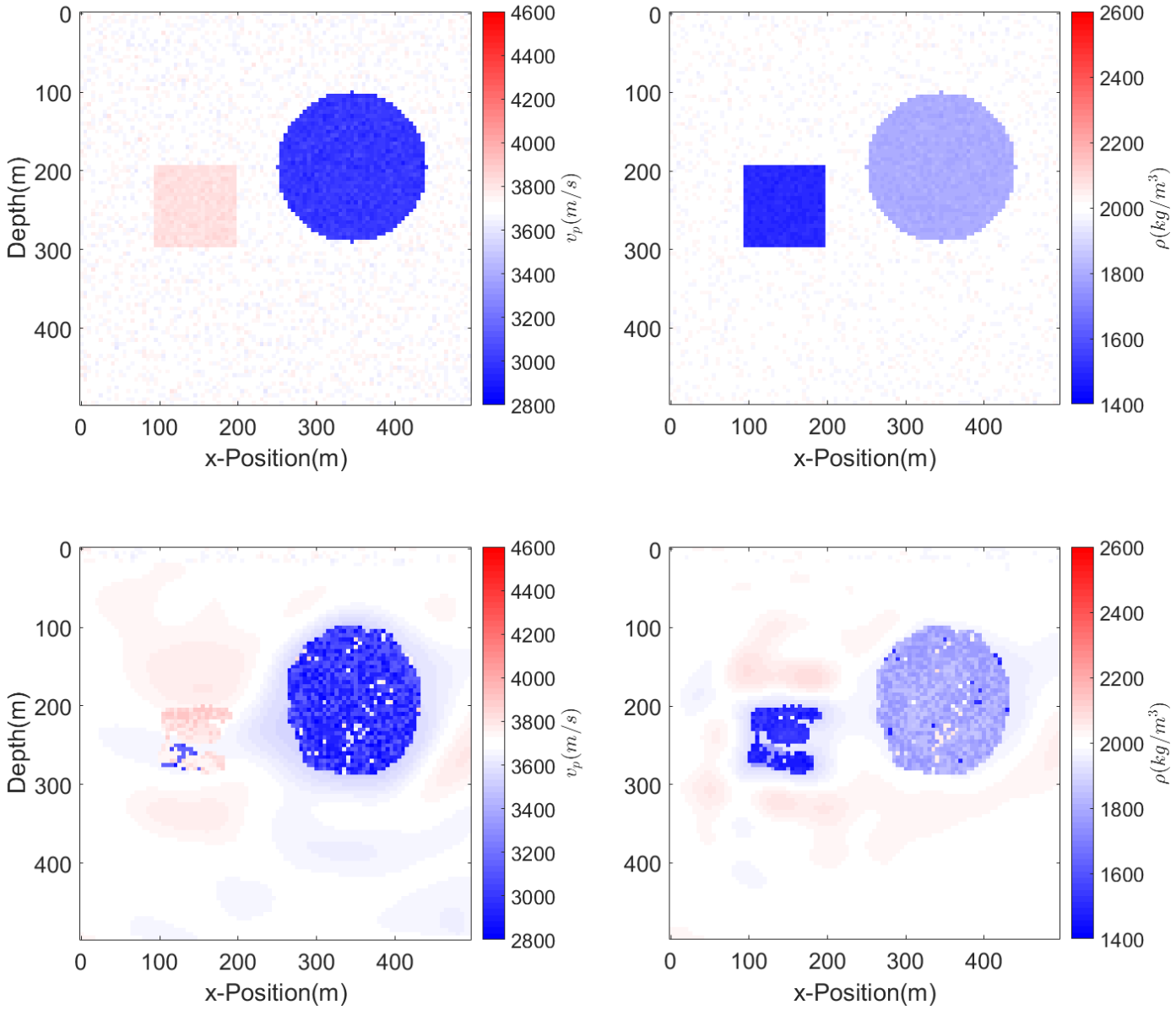
3) Tunnel appropriate model elements

FWI with no regularization

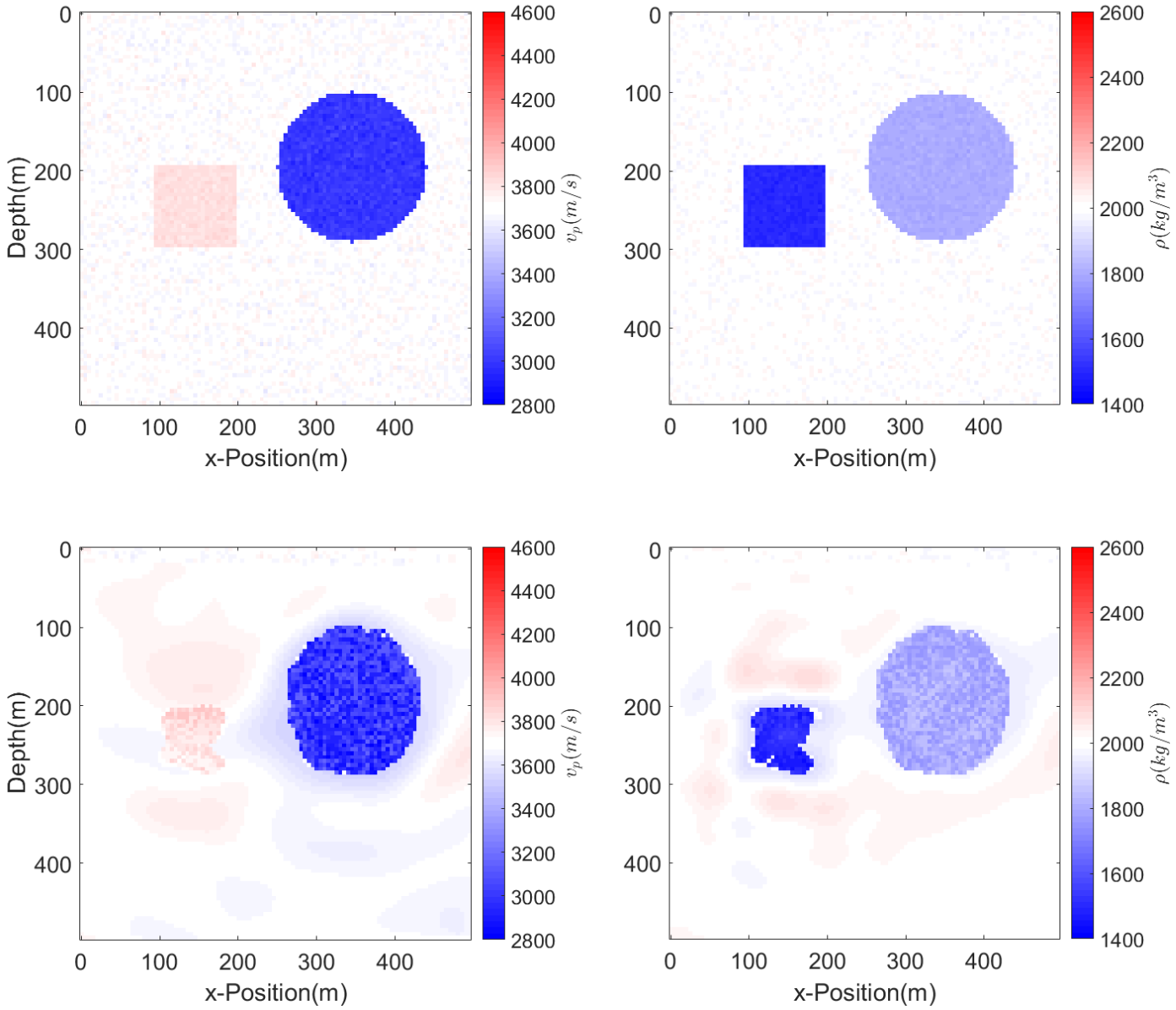


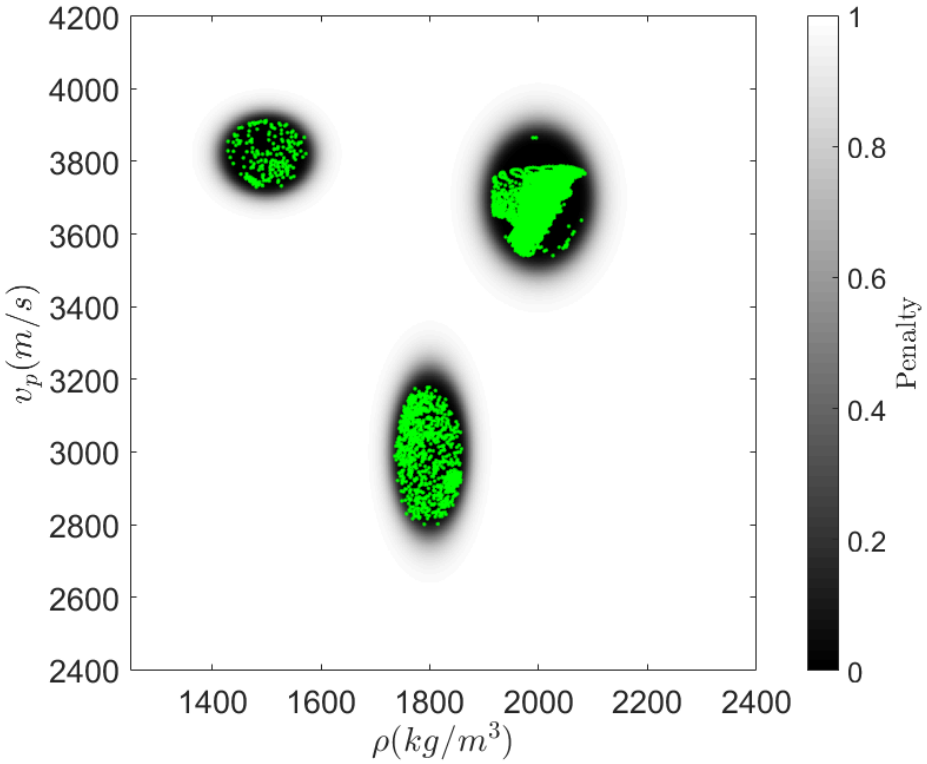


Tunneling FWI

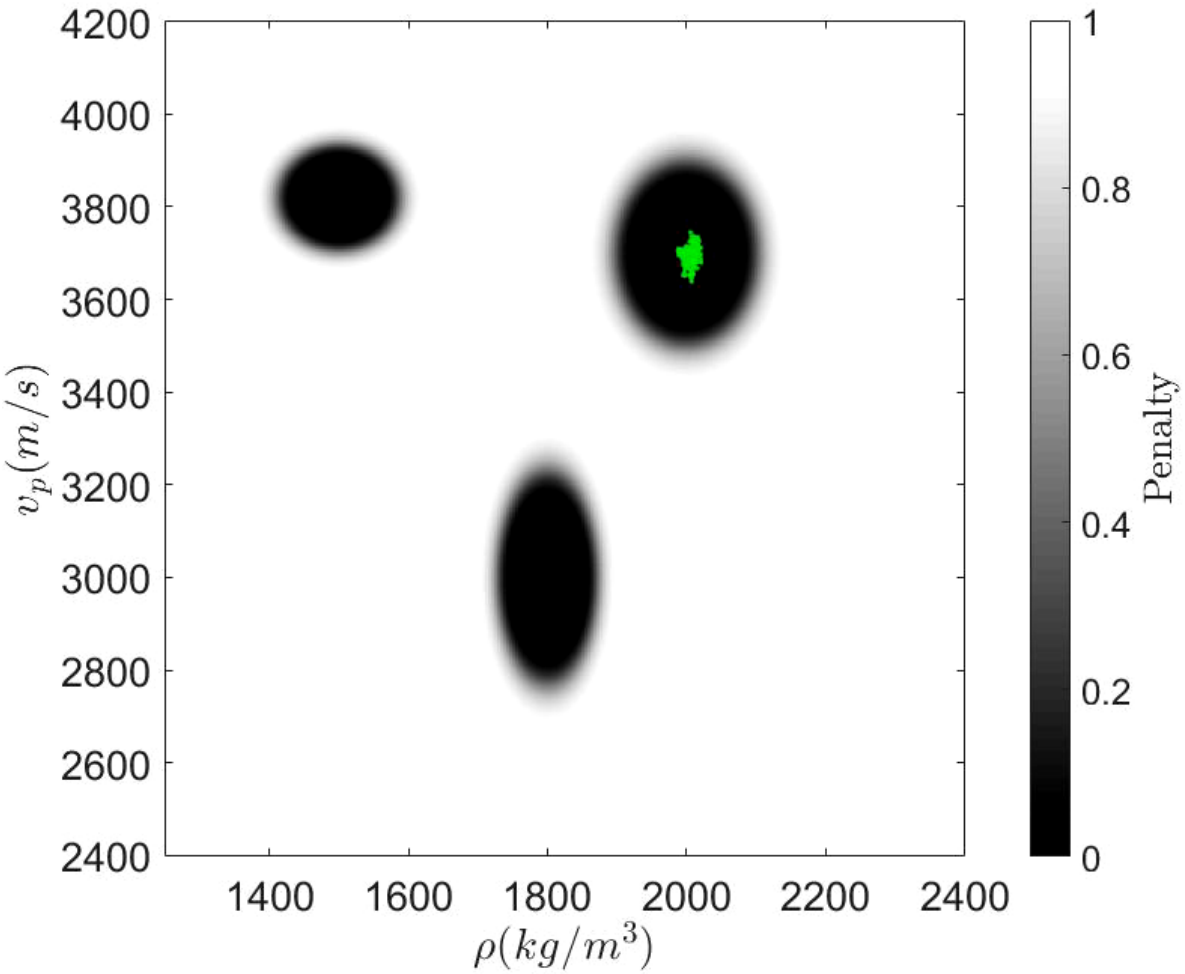


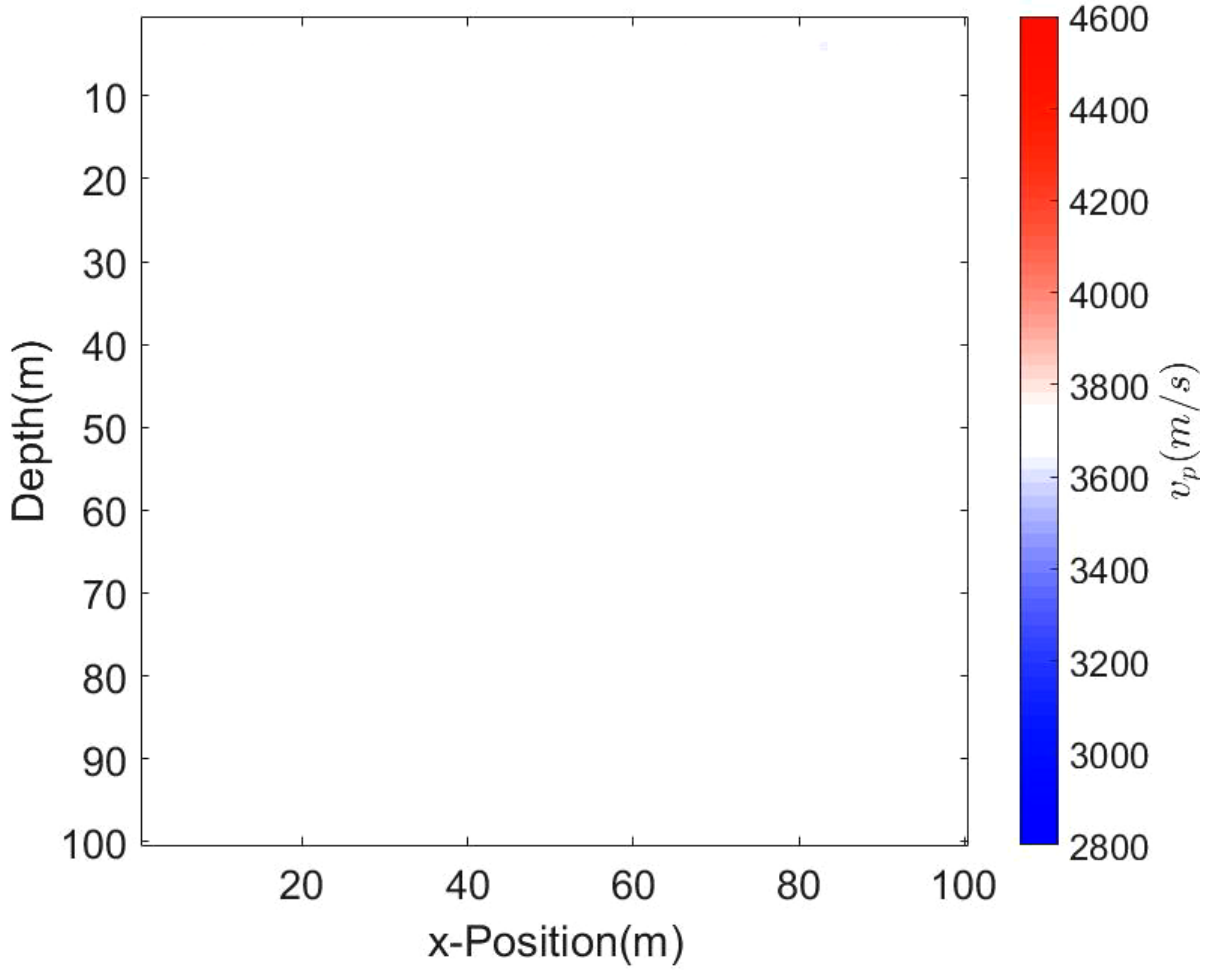
Filtered Tunneling FWI





Model progression





Conclusions

Prior information can be very useful in seismic inversion

Conventional FWI struggles to effectively incorporate regularization terms not amenable to local optimization

By making use of non-local regularization information, tunneling may allow these regularization terms to be used much more effectively

Acknowledgements

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