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A short user guide for UBC-GIF gravity and magnetic inversions

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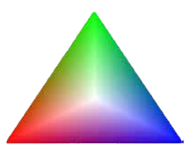
Inversion of potential field data predicts a 3D subsurface distribution of physical properties that explains measured gravity or magnetic data. The non-uniqueness of inversion solutions mandates careful and consistent parameterisation and appropriate geological constraints to ensure realistic solutions.

Since there are more unknowns (model values) than knowns (observations), inversions require trade-offs. The best model requires parameters that strike a balance between reproducing the geophysical data, the broad geological trends, and detailed geological observations.

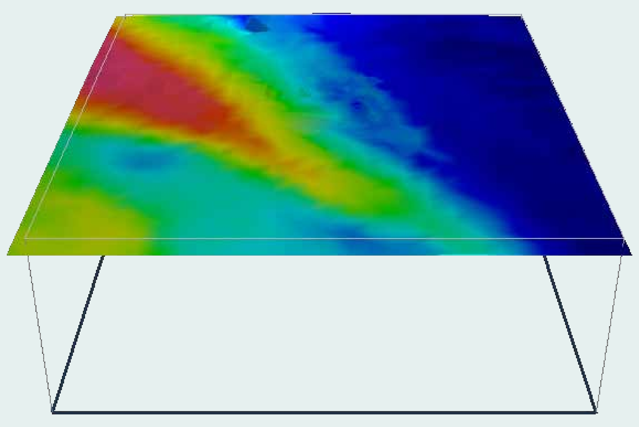
Closely reproduces geophysical data (data misfit)



Reproduces geological continuity/strike (smoothness)

Satisfies detailed geological observations (smallness)

UBC-GIF Inversion Approach



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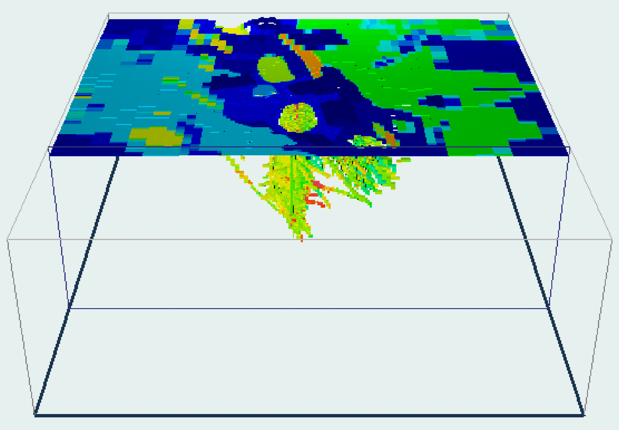

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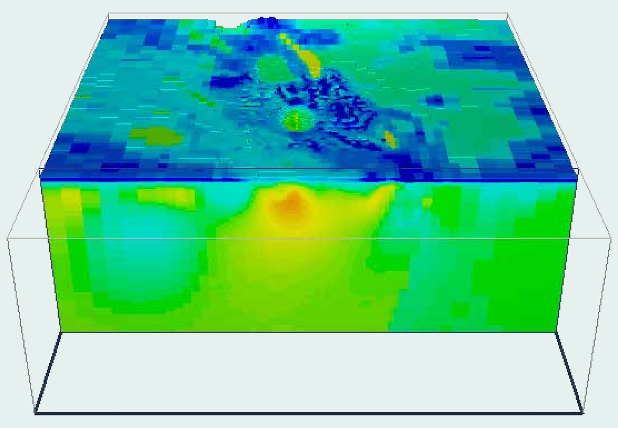


Geophysical data - either gridded or irregularly-spaced

- Remove regional data trends caused by features outside the model volume
- Upward continue data to half a cell width to remove high frequency features that cannot be reproduced with coarse cells.

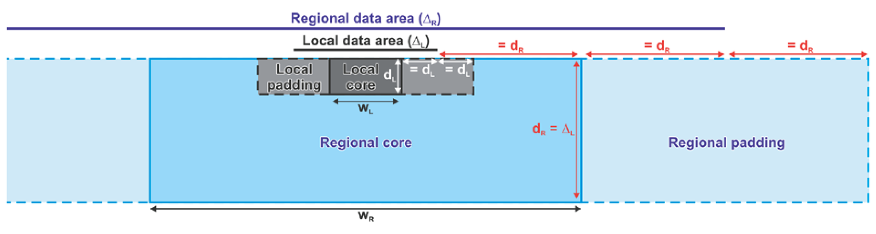
Geological observations - as important as geophysical observations

- Based on actual mapping and drilling observations
- Geological observations must be translated into physical property estimates.

Inversion property model - physical properties that satisfy the geophysical data, geological observations, and mathematical constraints

- UBC-GIF inversions use two mathematical constraints where geological information is missing:
  - › Smoothness: properties shall vary smoothly between cells
  - › Smallness: difference between reference model and recovered model should be small.
- Solutions are non-unique. A geophysical dataset may be explained by many models but only a few models will explain both geological and geophysical observations.

Mesh Design



Design mesh and data areas to prevent edge effects. May require use of additional padding zones.

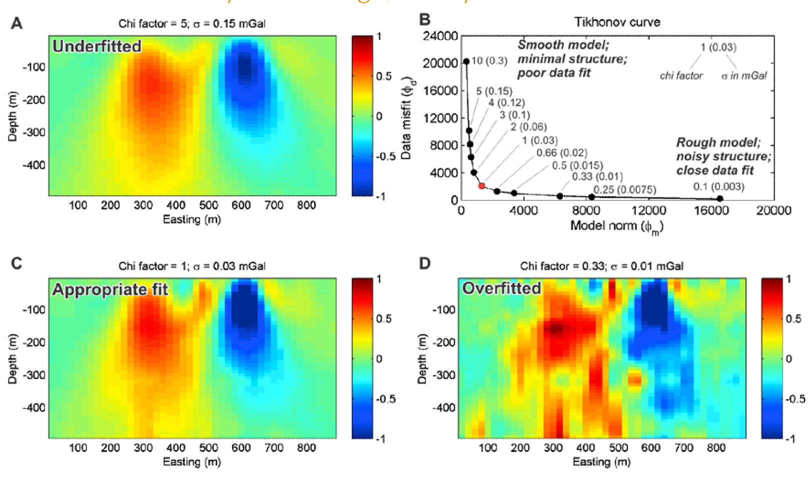
- Use a cell size smaller than the geological features you wish to model and equivalent to the minimum geophysical data spacing
- A large, coarse inversion model can be used to compute a model-based regional trend to remove from the detailed local data.

Smoothness depends on the size of cells, squared, so using different sized cells across the model causes large changes in the importance of smoothness versus smallness.

- Using a uniform cell size throughout a mesh is recommended; however, the inversion will run faster with larger cells in less critical areas.

Data Preparation

Data uncertainty set too high, overly smooth model



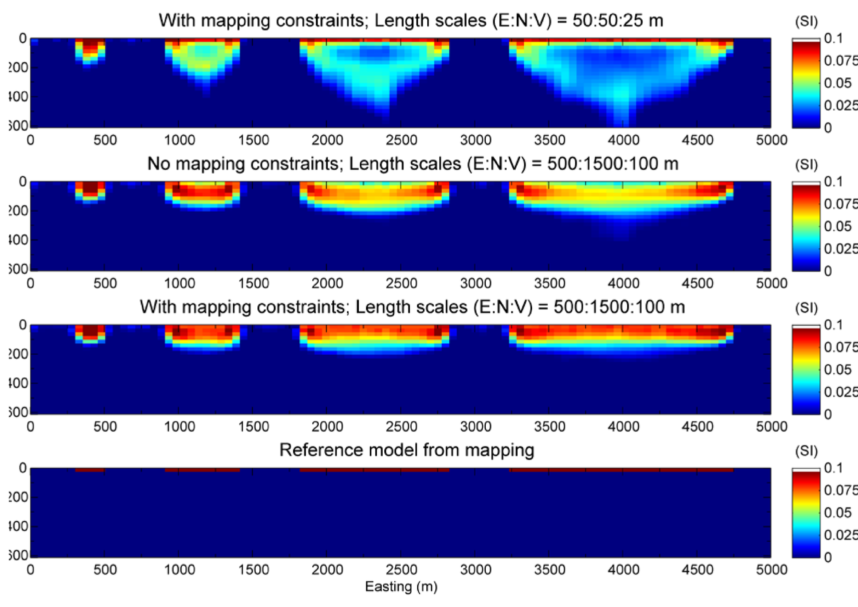
Correct data uncertainty

Data uncertainty set too low, overly noisy model

Geophysical data must be assigned an uncertainty, expressed as a standard deviation. This includes uncertainty in measurements and approximations due to using discrete cells and model volume.

- Uncertainty set too low produces a rough, noisy model, uncertainty set too high produces a smooth, featureless model
- Ground gravity data: Use best Bouguer and terrain corrected data (in mGal) with uncertainty ~ 0.03 to 0.07 mGal
- Aeromagnetic data: Advisable to subtract the mean TMI value (in nT) and use uncertainty ~ 5 % TMI + 5 nT.

Smoothness Length Scales



Smoothness provides geological continuity where geophysical data are sparse or provide limited information.

- Length scales are defined along east-west (E), north-south (N) and vertical (V) axes
- Define length scales in each direction to match the size (in meters) of the expected geological bodies. The direction of maximum smoothness should correlate with the main geological strike direction.

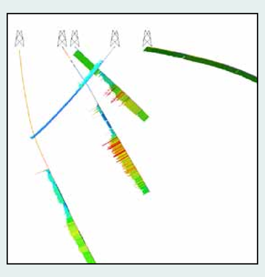
Defining Geological Constraints

Constraints defined using:

- Reference model: best estimate property value → expected arithmetic mean property in each cell
- Property bounds: maximum and minimum allowed property → use a confidence interval (95 %) on the mean
- Smallness weights: confidence in the reference model → higher values indicate higher confidence
- Directional weights: smoothness of property variations between cells in each direction → values < 1 promote breaks and values > 1 promote geological continuity.

Geological observations: based on mapping or drilling.

Mapping

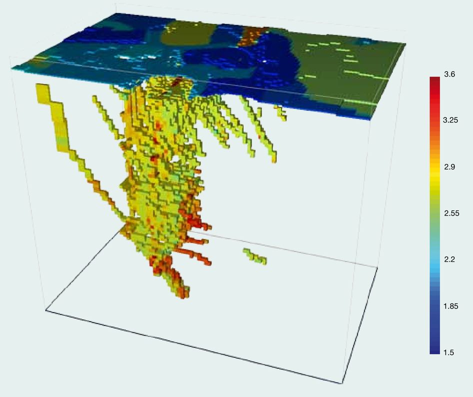


Drilling

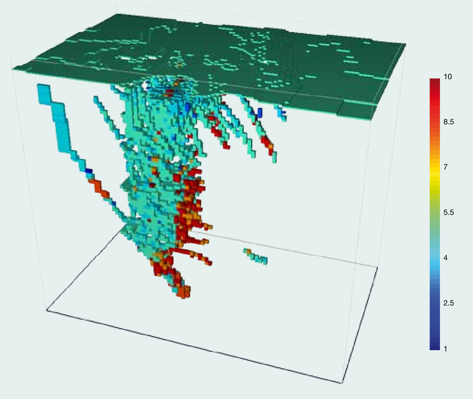
Physical property database translates geology observations into physical property estimates.

Populate reference model with all available physical property measurements and estimates.

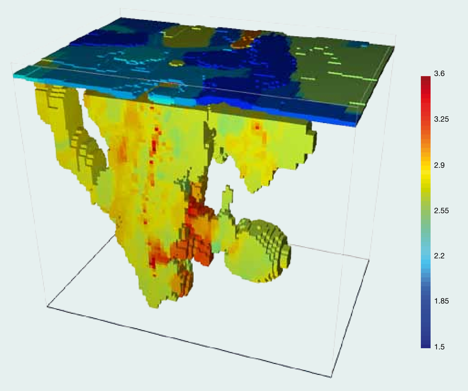
Reference model: best estimate physical properties based on available geological knowledge.



Smallness weights: reliability weights based on quality of geological observations.

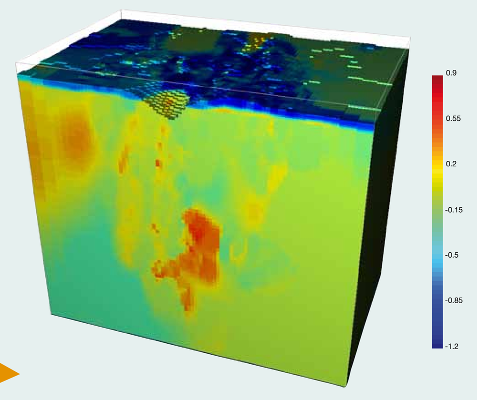


Non-located constraints: use structural information or known 3D geometries to fill out the model, if desired.



Inversion

Inversion result: best prediction of the subsurface properties given the supplied geophysical and geological data.



Constraints are considered as either "located" or "non-located"

- Located constraints are those associated with distinct spatial coordinates and are used to create the basic reference model
- Non-located constraints may include information about stratigraphic relationships, structural trends, and the size and shape of bodies
- Information from non-located constraints can be used to modify and extend the values of located constraints to surrounding cells where located constraints are missing.

Reference

Williams, N.C., 2008, Geologically-constrained UBC–GIF gravity and magnetic inversions with examples from the Agnew-Wiluna greenstone belt, Western Australia: unpublished Ph.D. thesis, University of British Columbia (http://hdl.handle.net/2429/2744)

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