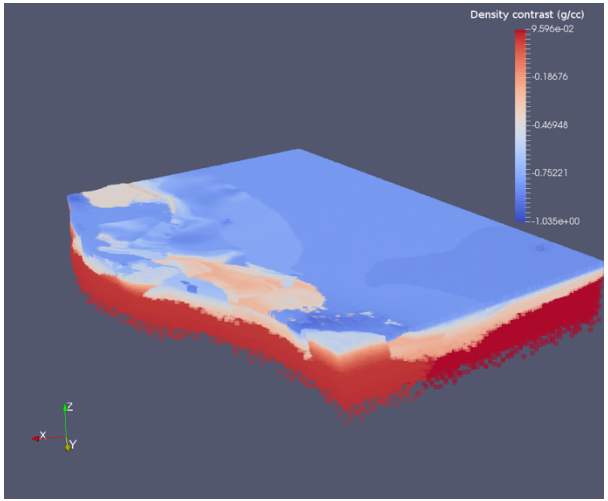
GMS: High-performance modeling for 3D geologic maps

GMS

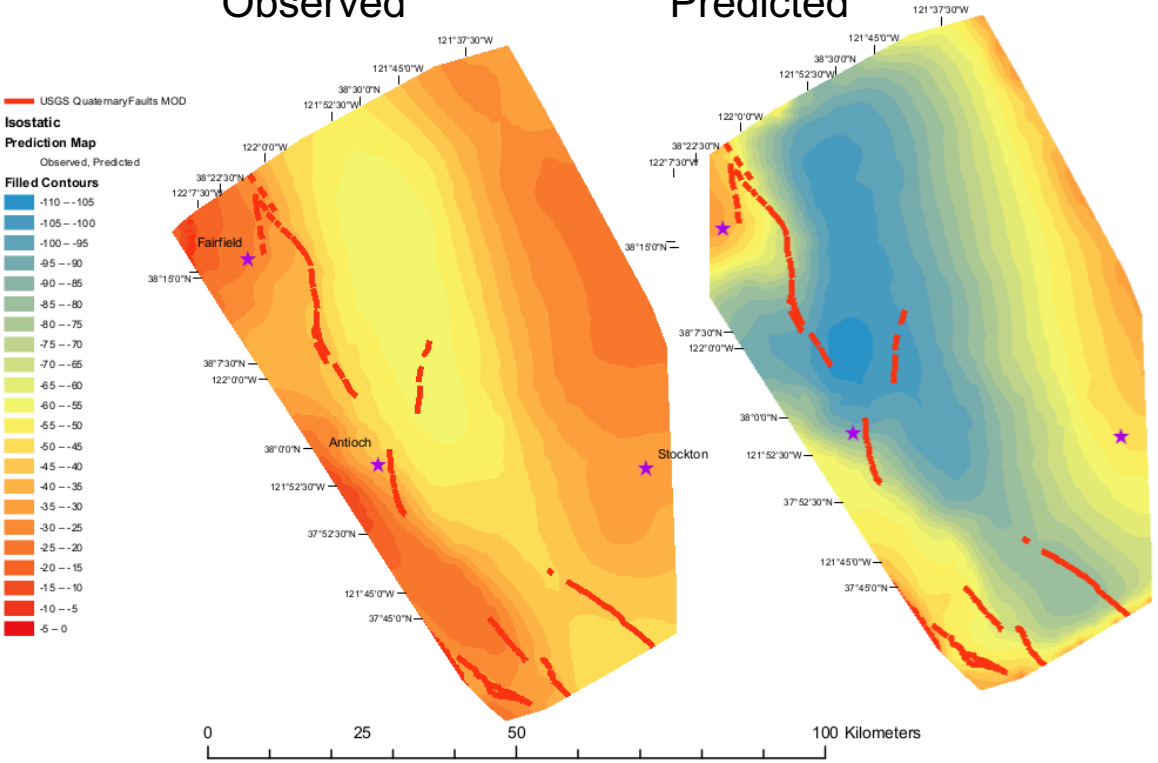
3D density model (from EarthVision)



Gravity anomaly

Observed

Predicted



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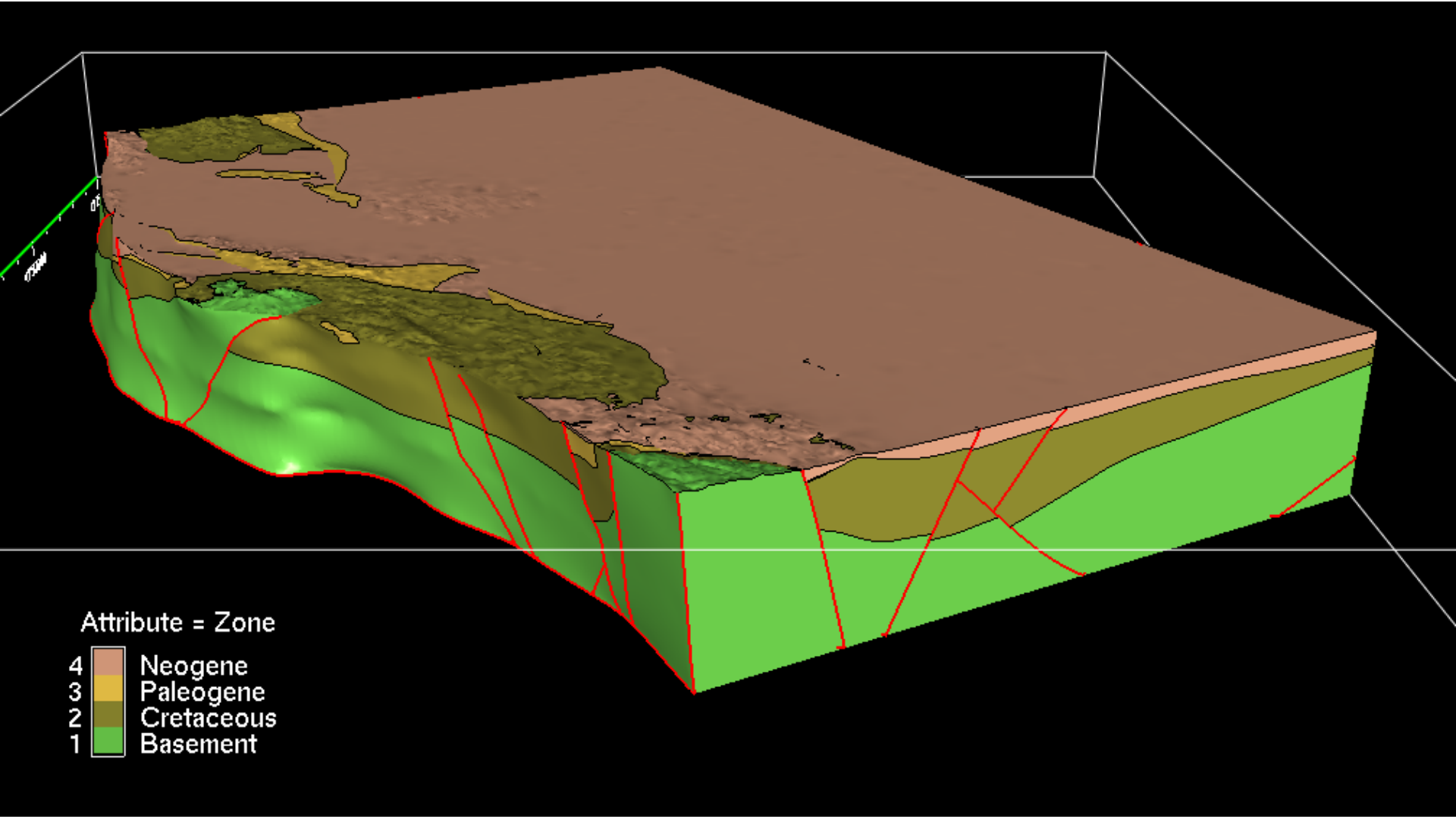
GMEG Science Center, USGS, Menlo Park

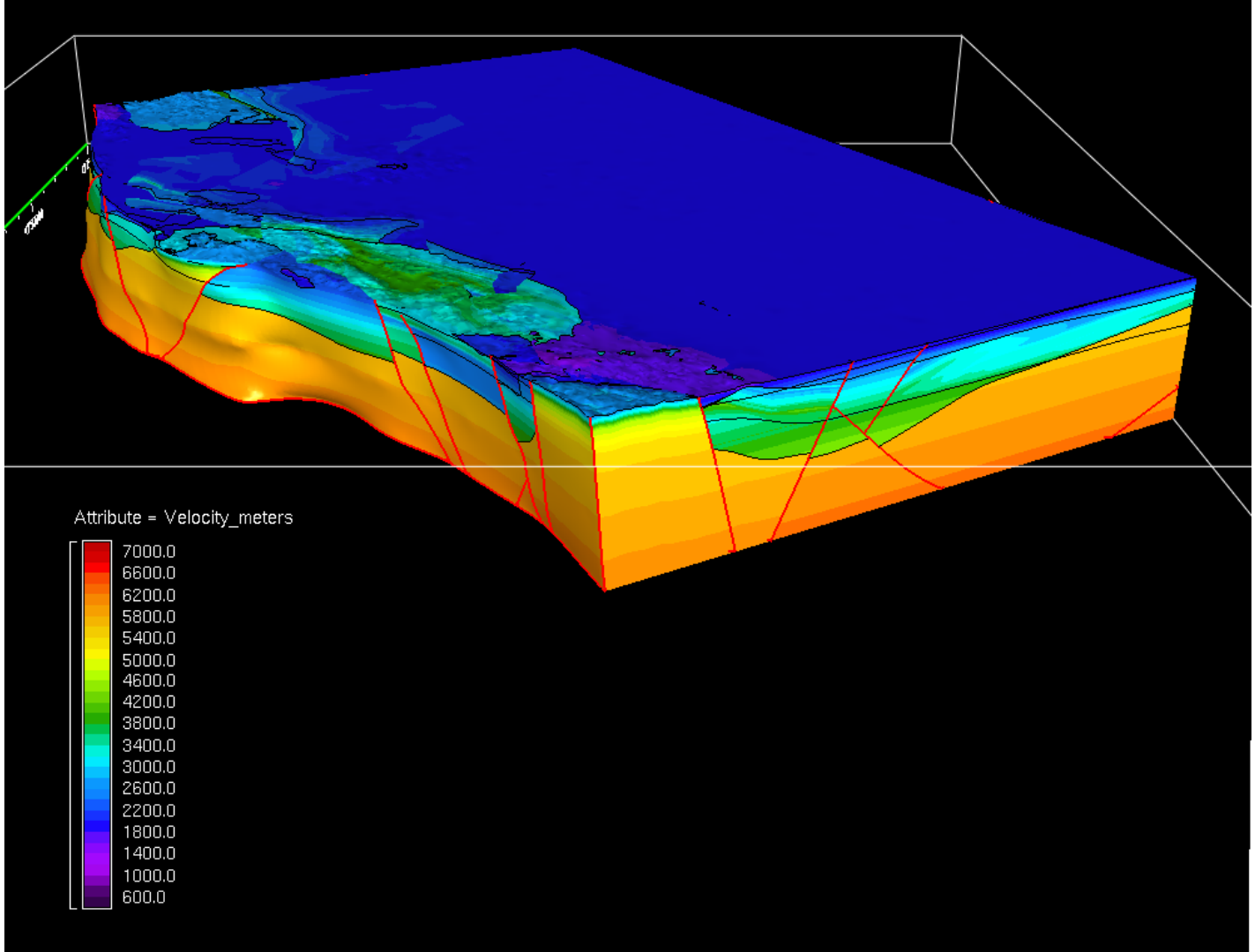
Forward modeling expected gravity for Delta Velocity Model

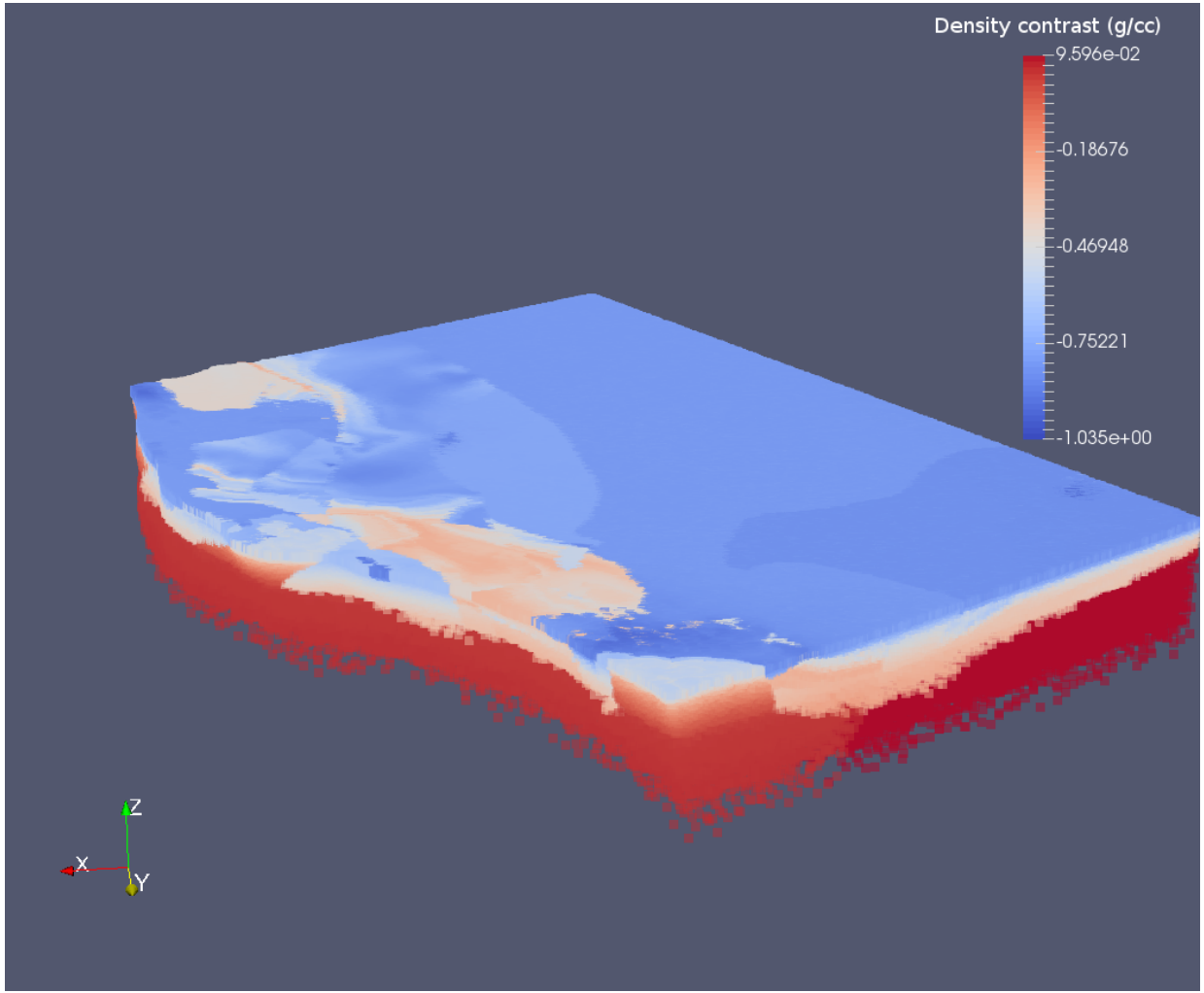
- Goals:
  - Improve model consistency
  - where is change needed?
    - Geology
    - Velocity (velocity-geology relation)
    - Velocity-density relation
  - Develop change strategies
    - Avoid change via Ad Hoc modifications
  - Change that impacts seismic shaking

Forward modeling gravity for Delta Velocity Model

- Delta velocity model: 100 x 60 x 12 km (86,000 km^3)
- Density estimated using velocity-density relations:
  - Nafe-Drake curve (Ludwig et al 1970)
  - Zelt (1989)
  - Gardner et al (1974)
  - Brocher (2005)


Attribute = Zone
4 Neogene
3 Paleogene
2 Cretaceous
1 Basement

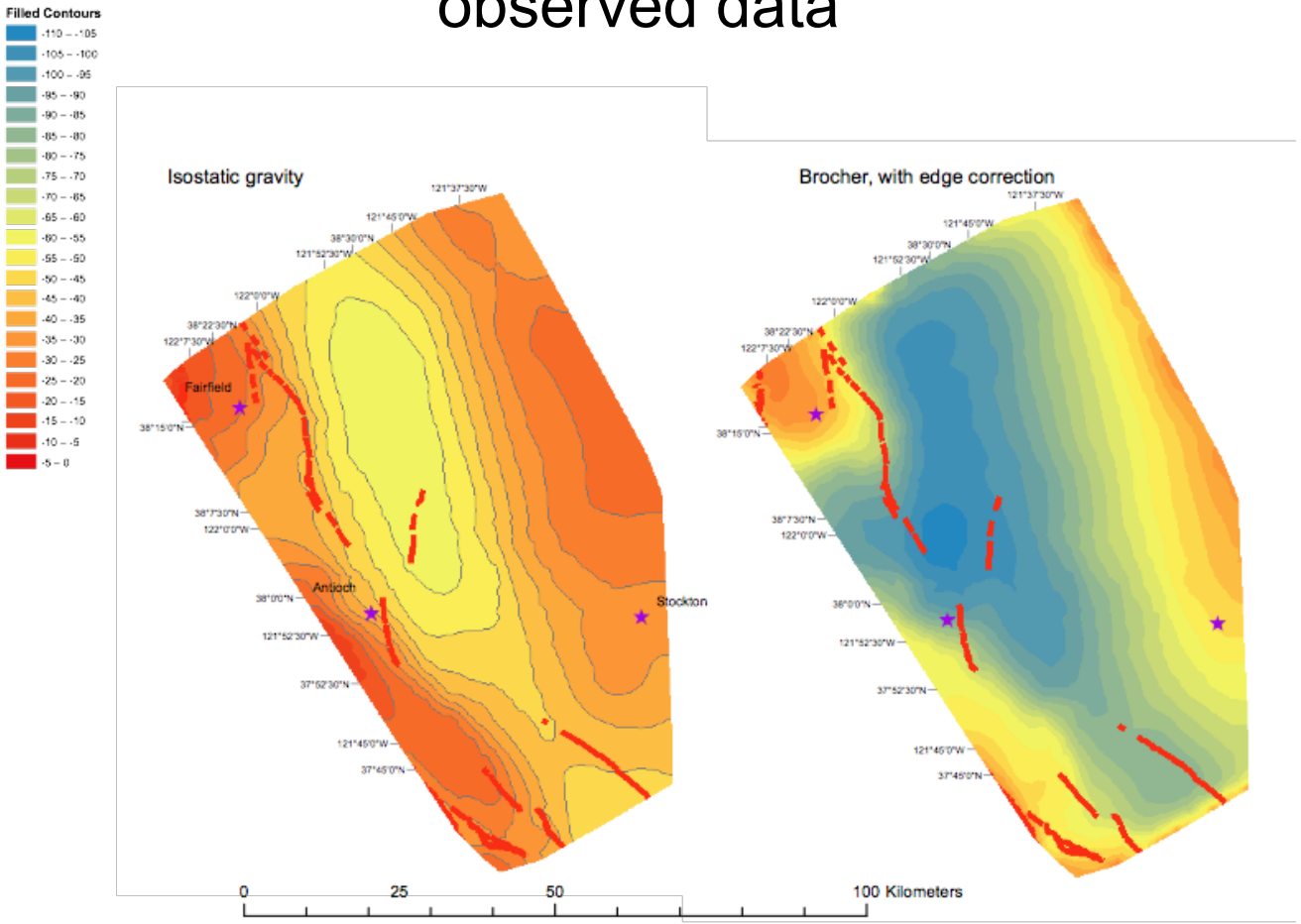

Attribute = Velocity_meters
7000.0
6600.0
6200.0
5800.0
5400.0
5000.0
4600.0
4200.0
3800.0
3400.0
3000.0
2600.0
2200.0
1800.0
1400.0
1000.0
600.0



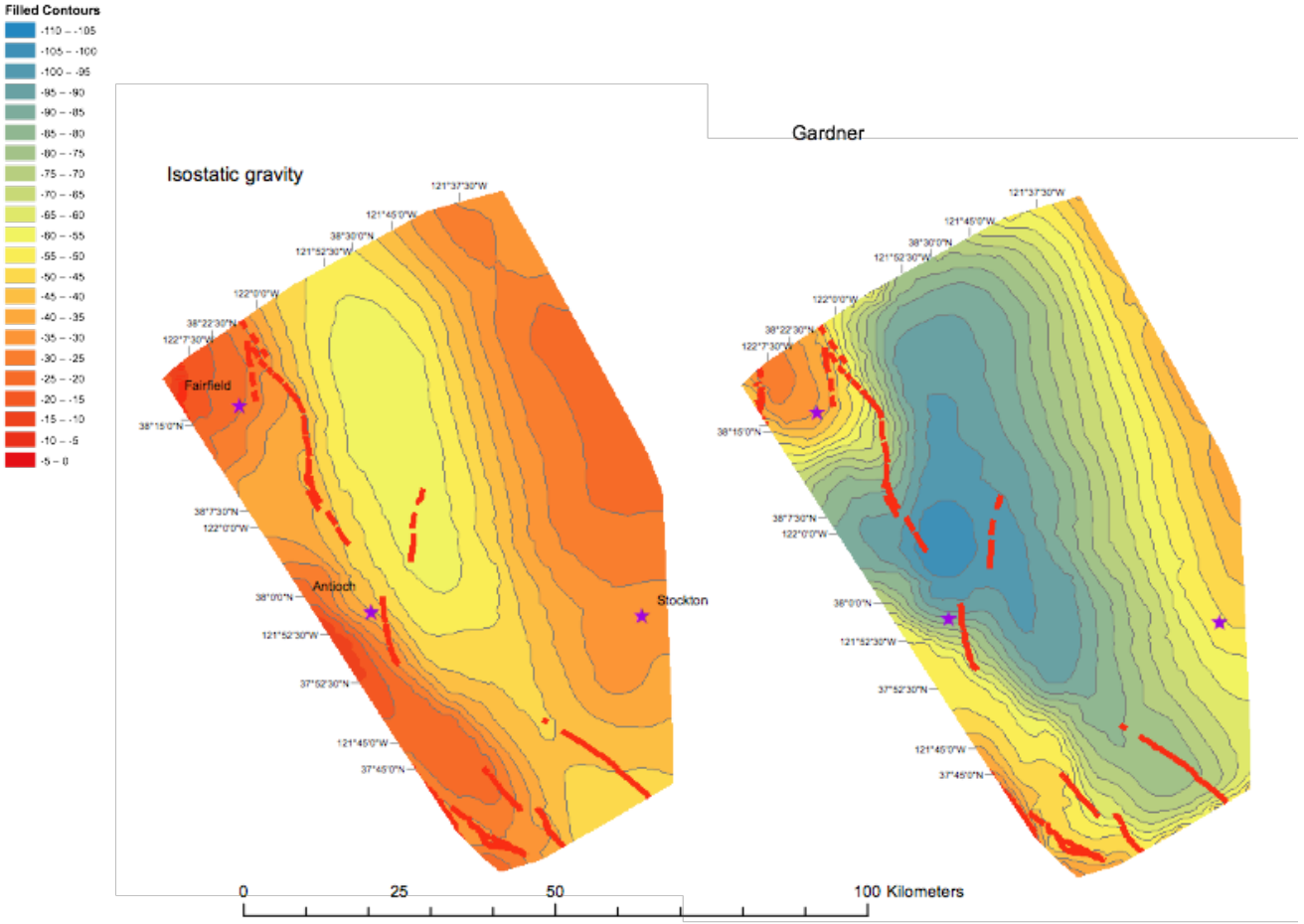
Exploring the model

- Delta velocity model converted to density via Brocher
- Density contrast vs 2.67 g/cc

Edge-corrected Brocher model showing significant misfit with observed data



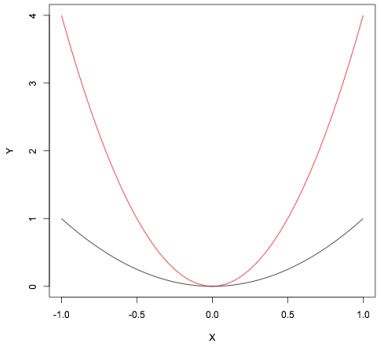
Gardner model has similar misfit to Brocher model

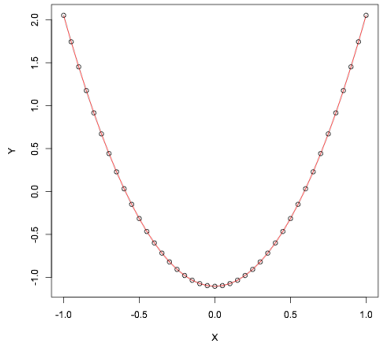


Separating differences in shape from differences in scale: Z-score transform [(x - mean) / stddev]

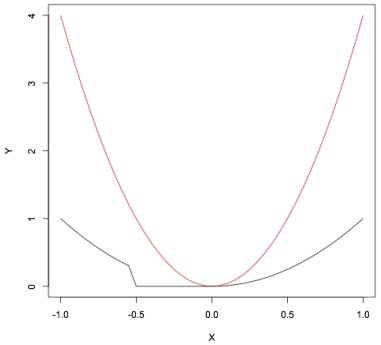
Original data

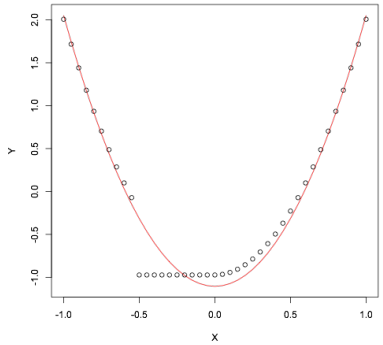
z-score transform





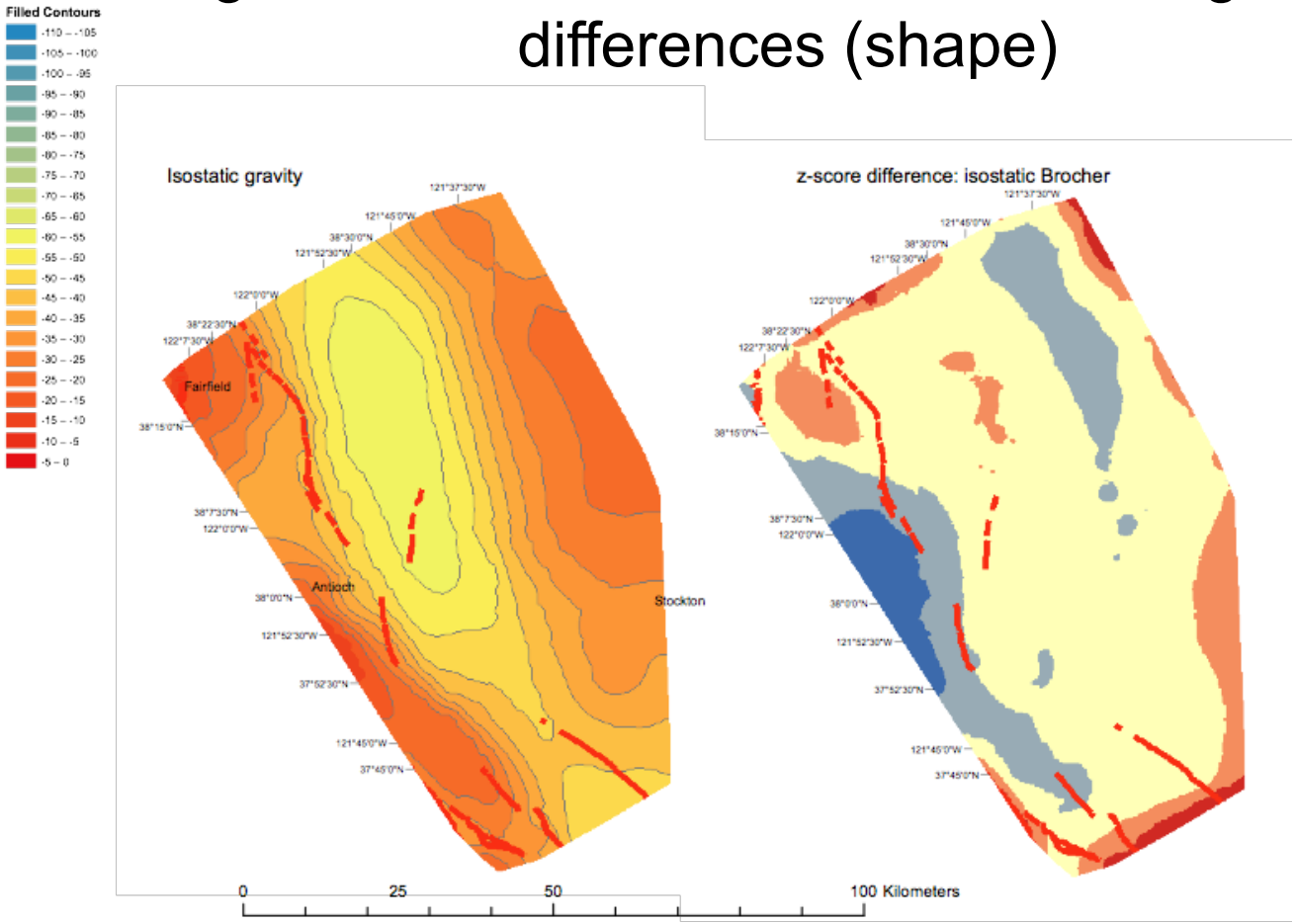
Cross-section of two surfaces with different scaling but same shape. The z-score transform shows the similarity between the two.



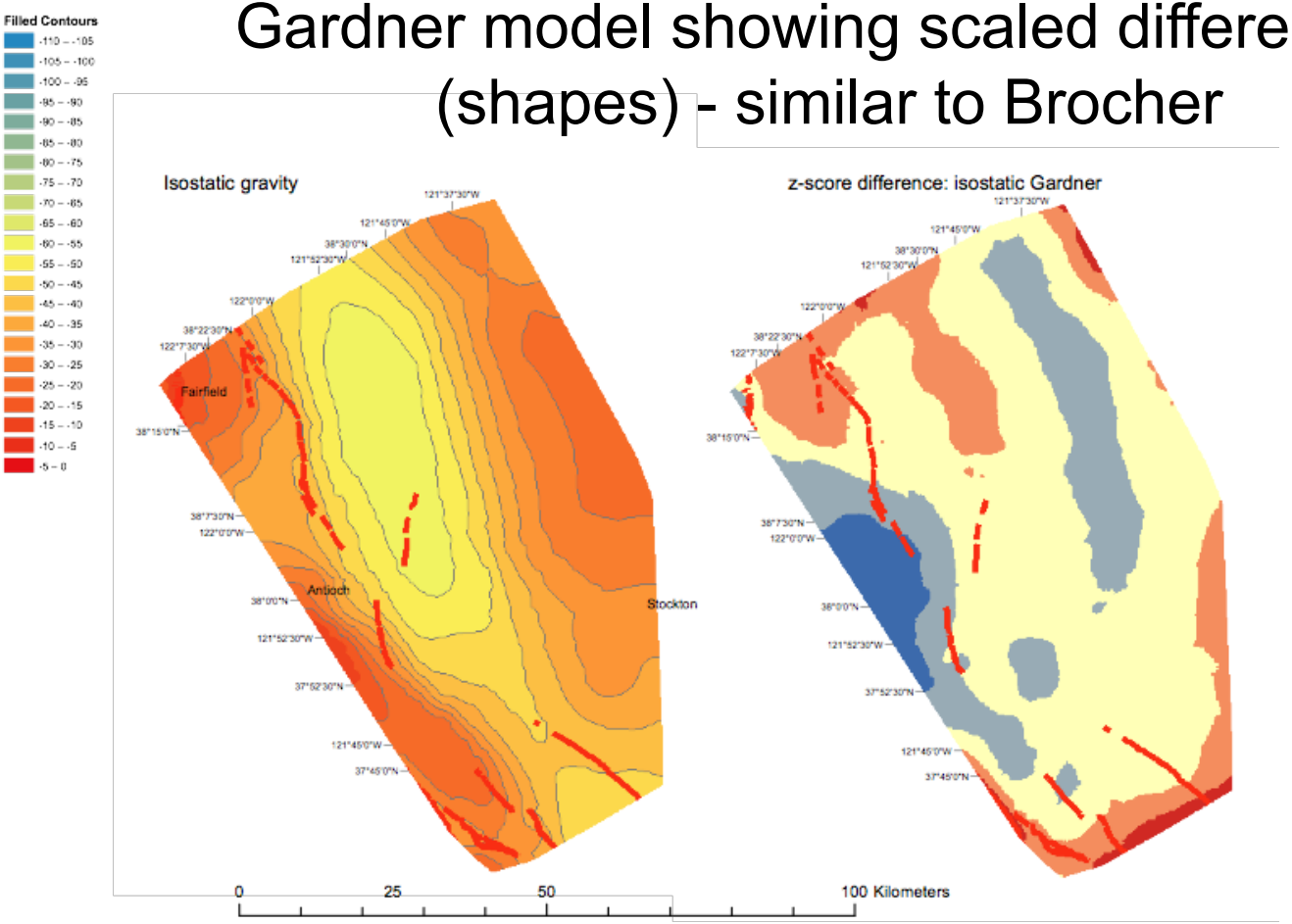


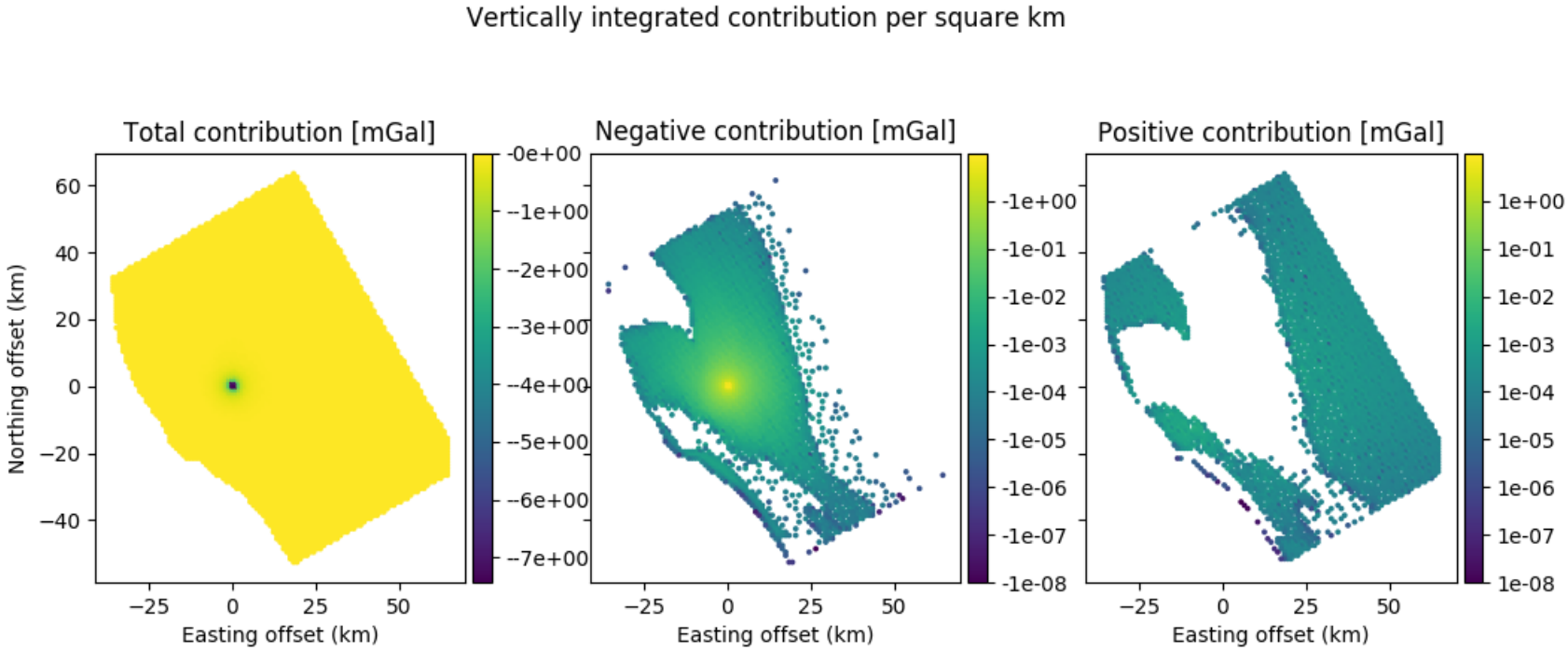
Cross-section of two surfaces with different scaling and shape. The z-score transform highlights the areas that are of similar and different shape.

Edge-corrected Brocher model showing scaled differences (shape)



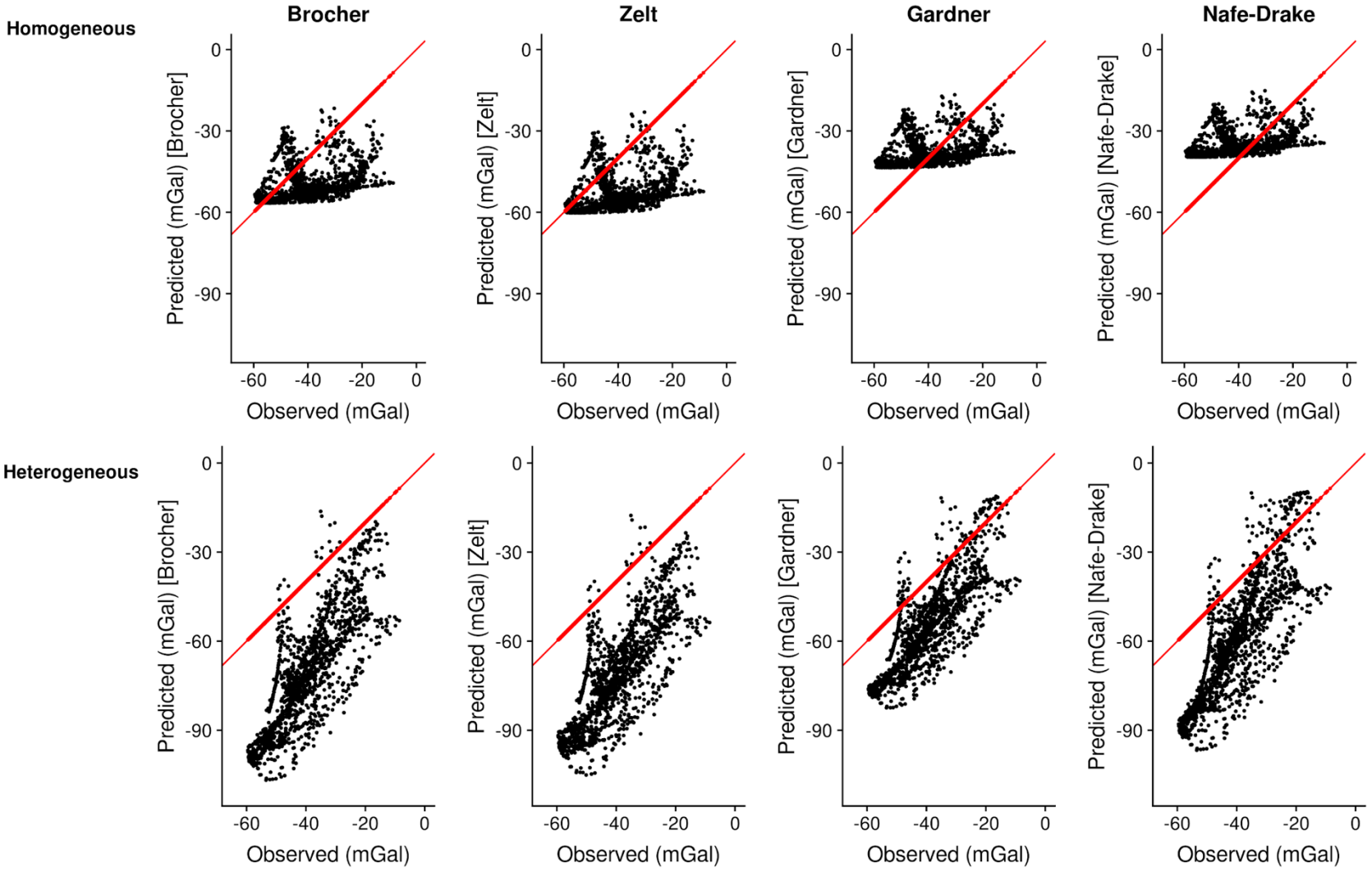
Gardner model showing scaled differences (shapes) - similar to Brocher

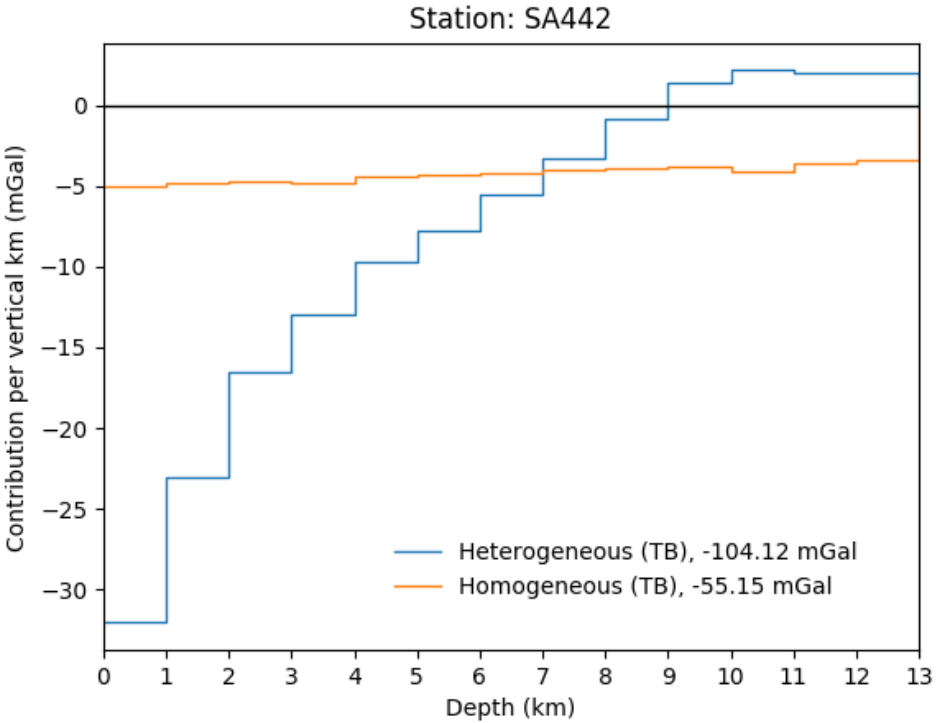



Vertically integrated contribution per square km
Total contribution [mGal]
Negative contribution [mGal]
Positive contribution [mGal]
Northing offset (km)
Easting offset (km)
Easting offset (km)
Easting offset (km)
60
40
20
0
−20
−40
−25
0
25
50
-0e+00
−1e+00
−2e+00
−3e+00
−4e+00
−5e+00
−6e+00
−7e+00
-1e+00
-1e-01
-1e-02
-1e-03
-1e-04
-1e-05
-1e-06
-1e-07
-1e-08
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08

Next steps: working together!

- How do we improve the Delta model's internal consistency?
  - Propose alternatives to current geologic model
    - Indications from shape mismatch
    - Evidence for basement / basin density variations
  - Modify velocities
    - Revisit interpolation / extrapolation
- Delta model update strategy as a blueprint for future 3D maps / models

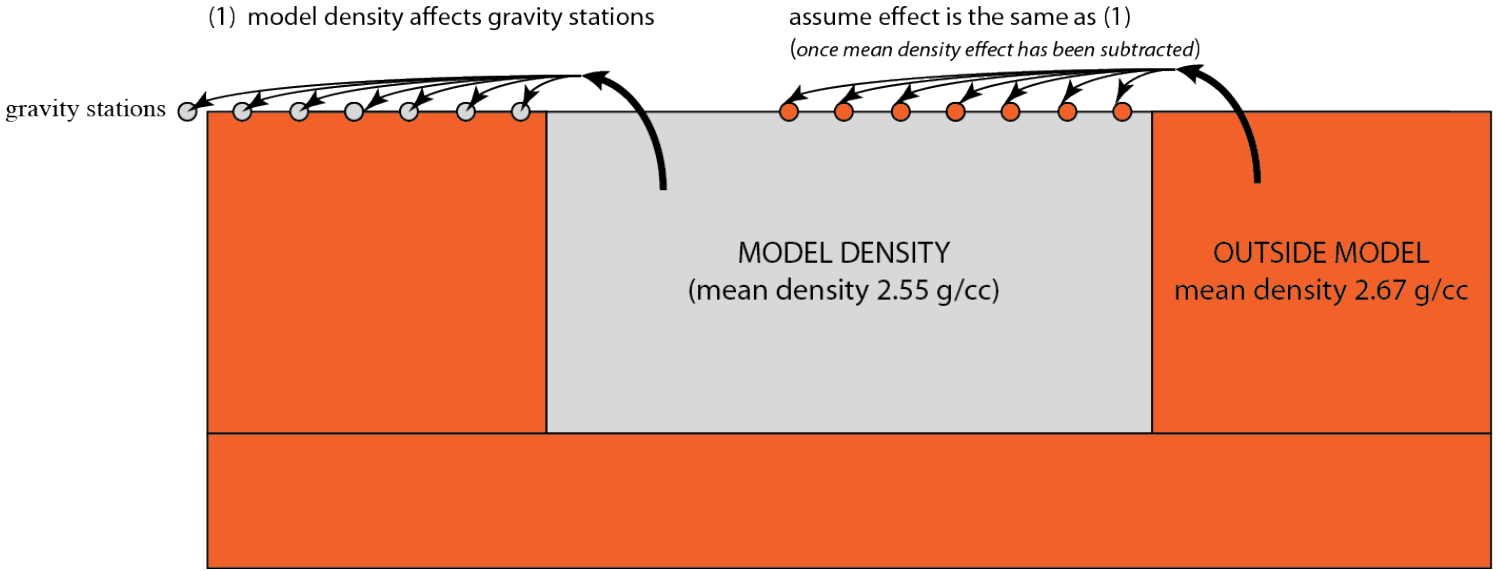

Homogeneous
Heterogeneous
Brocher
Zelt
Gardner
Nafe-Drake
Predicted (mGal) [Brocher]
Predicted (mGal) [Zelt]
Predicted (mGal) [Gardner]
Predicted (mGal) [Nafe-Drake]
Observed (mGal)
0
-30
-60
-90
-60
-40
-20
0


Station: SA442
Contribution per vertical km (mGal)
0
−5
−10
−15
−20
−25
−30
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Depth (km)
Heterogeneous (TB), -104.12 mGal
Homogeneous (TB), -55.15 mGal

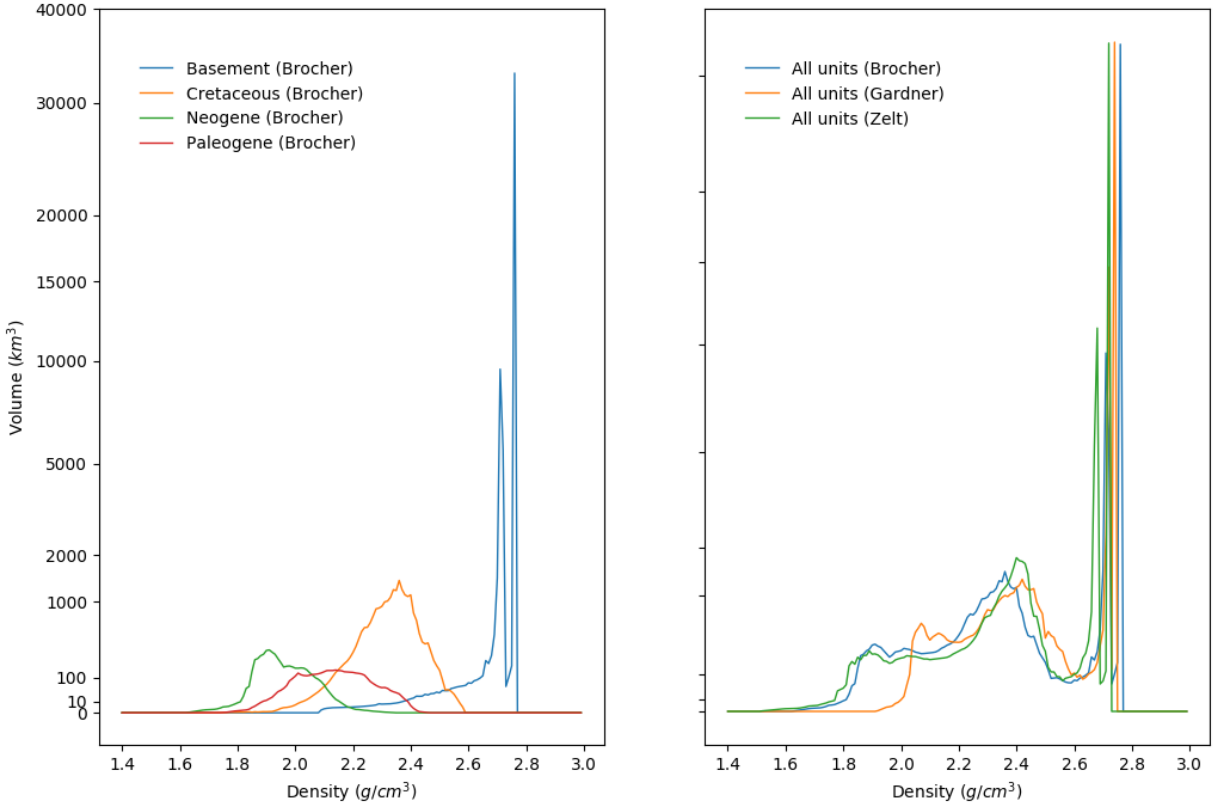
Estimation of the edge correction

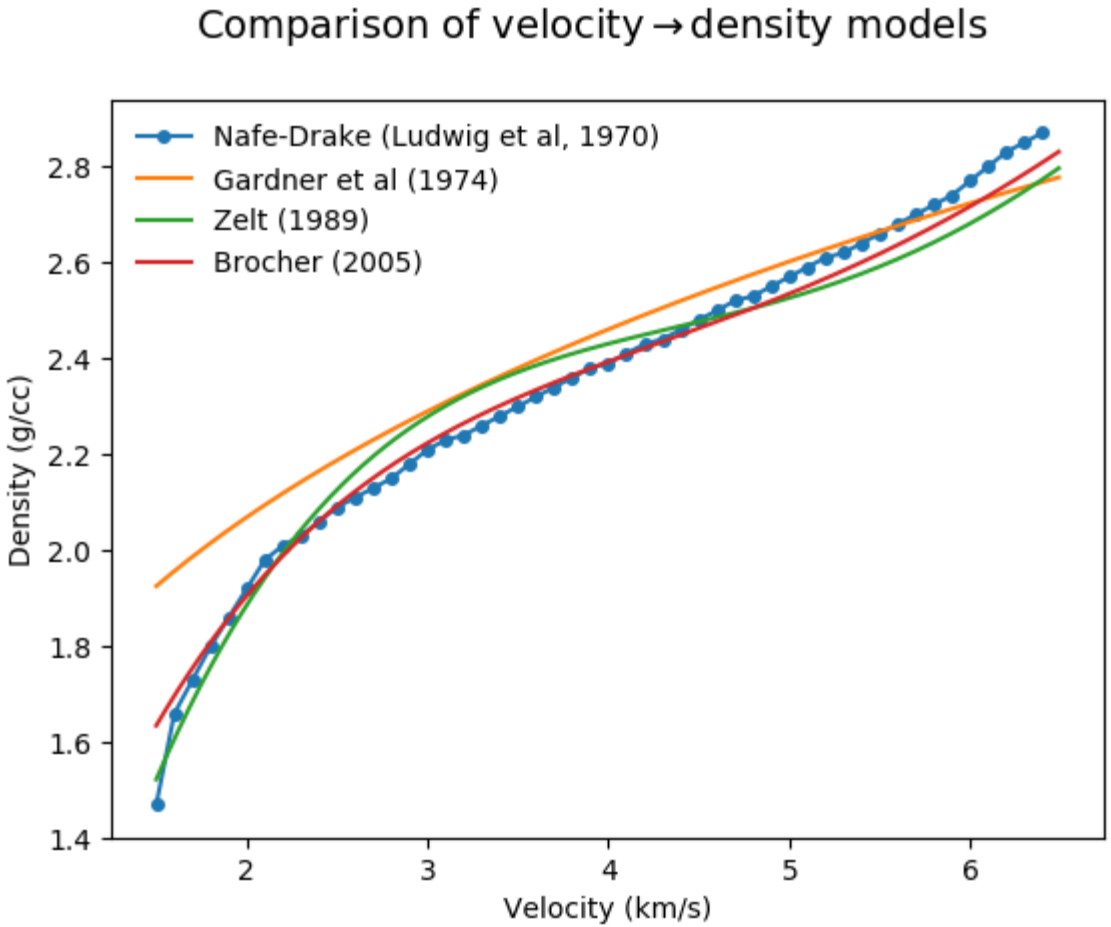
- Assume effect of variable density within model, on gravity stations outside of model,
  ~= effect of variable density outside model on gravity stations within model

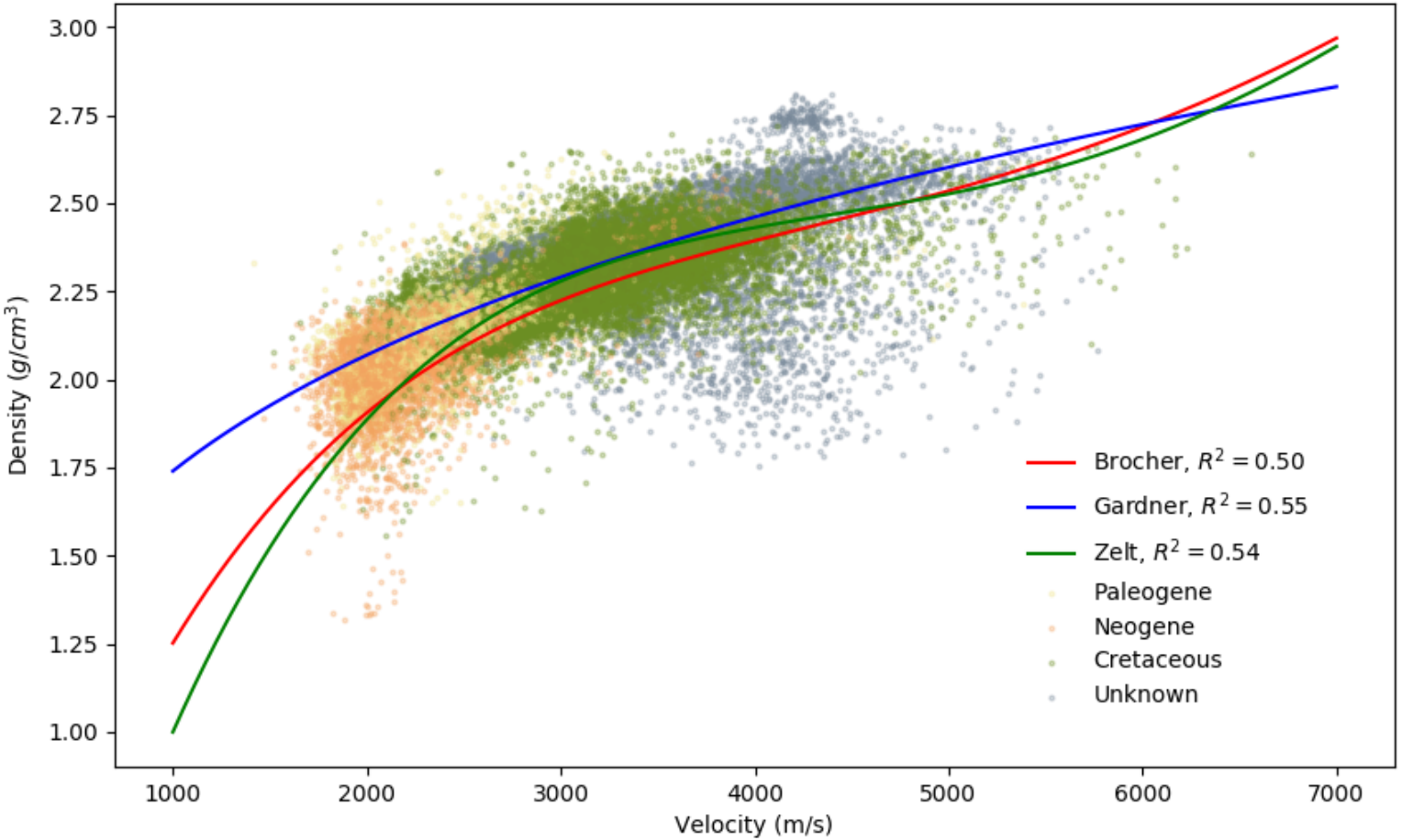
- Calculate effect of model density with distance away from model edge (1)
- Calculate effect of equivalent homogeneous model density with distance away from model edge
- ***Subtract homogeneous from total*** to estimate effect of variability with distance away from model edge
- Add effect of variability back to gravity stations within model as a function of distance from model edge



>60% of model volume in the Basement




Comparison of velocity→density models
Nafe-Drake (Ludwig et al, 1970)
Gardner et al (1974)
Zelt (1989)
Brocher (2005)
Density (g/cc)
Velocity (km/s)
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
2
3
4
5
6


3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
Density (g/cm^3)
1000
2000
3000
4000
5000
6000
7000
Velocity (m/s)
Brocher, $R^2 = 0.50$
Gardner, $R^2 = 0.55$
Zelt, $R^2 = 0.54$
Paleogene
Neogene
Cretaceous
Unknown