Finding Caves Using Relative Gravimetry

State of the Earth: Shifts and Cycles | Fall 2017

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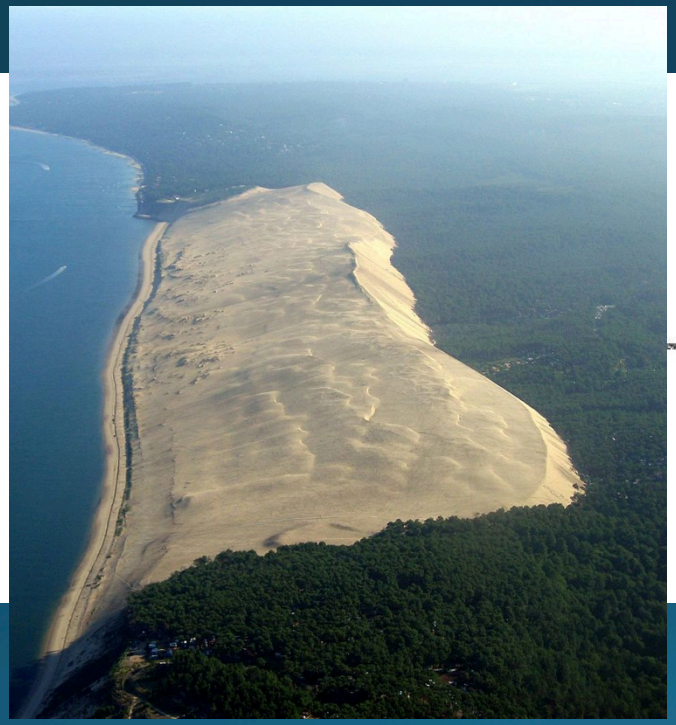
MOTIVATIONS and HYPOTHESES

1. Control environment

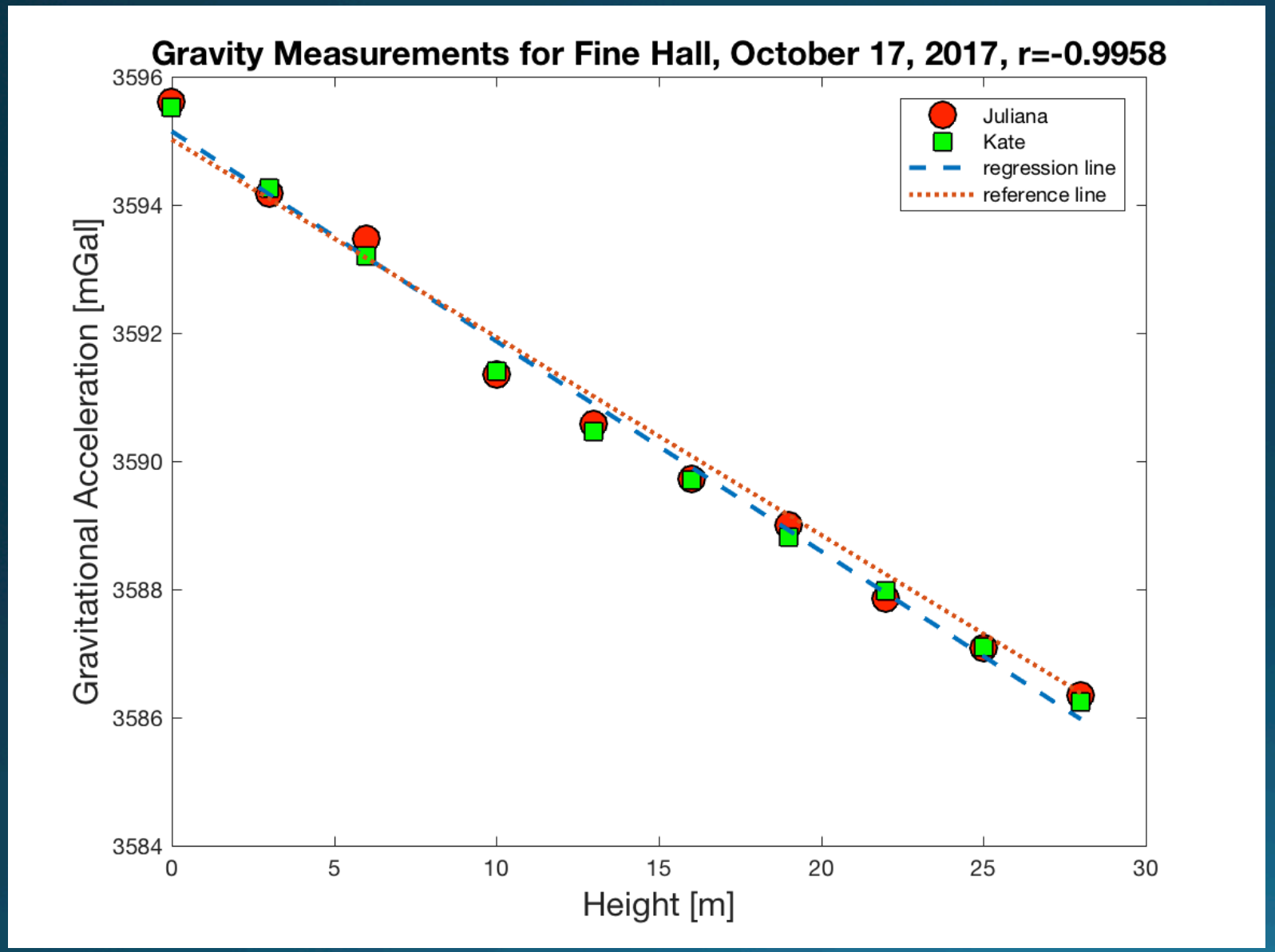
http://web.math.princeton.edu/conference/frggeometry2011/shuttle.html

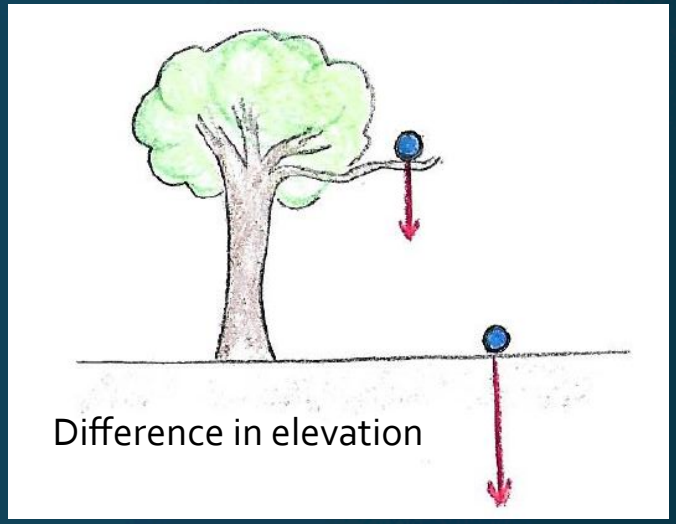


https://en.wikipedia.org/wiki/Dune_of_Pilat

2. Looking for caves

Photo: Frederik SImons

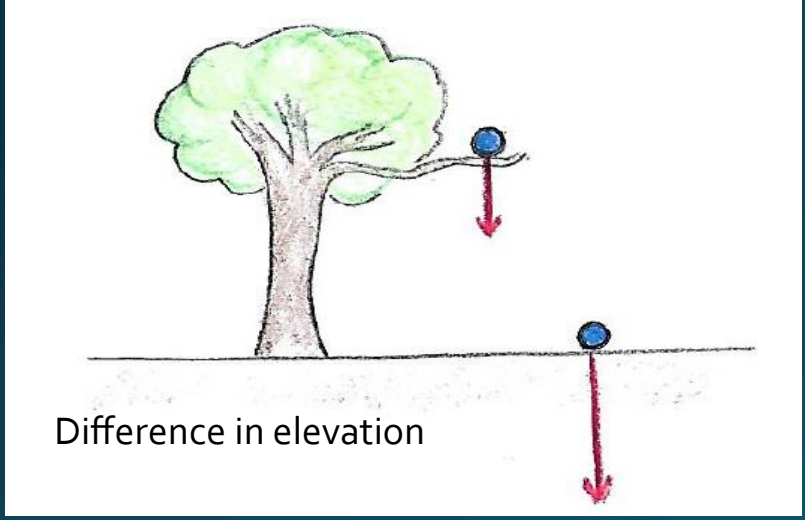




https://www.princeton.edu/news/2016/01/07/princetons-mathematicians-explore-science-patterns

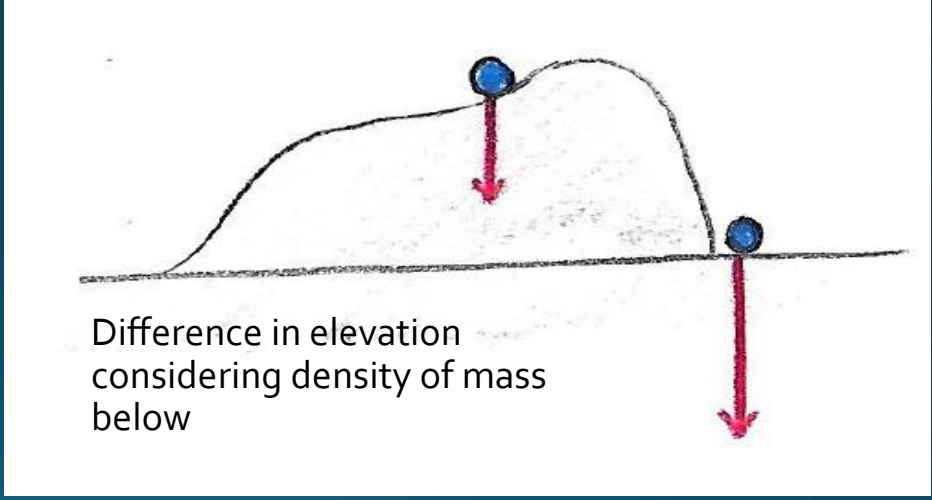
Gravity Corrections

Free air



$+0.3085$ mgal/meter

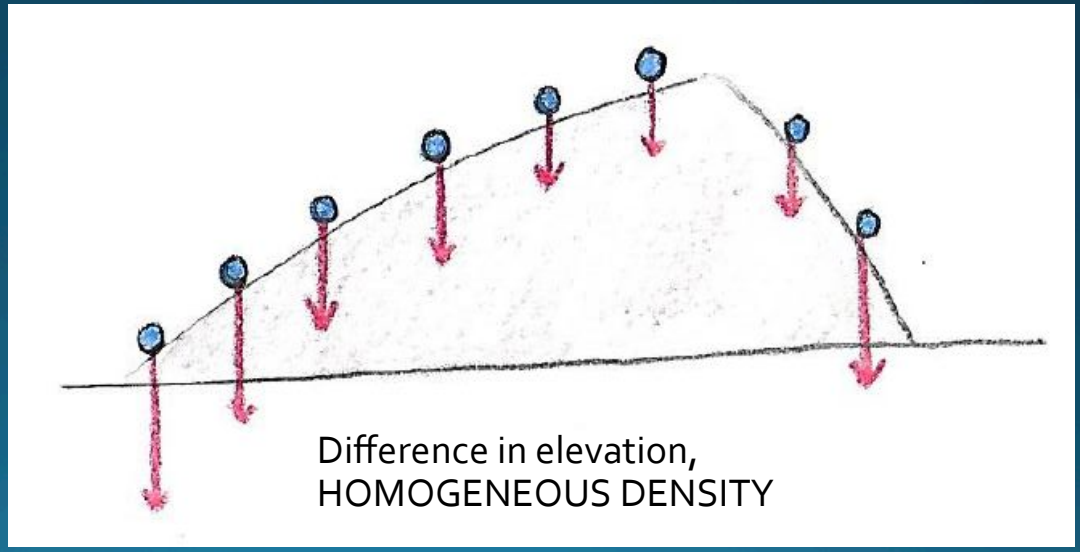
Bouguer

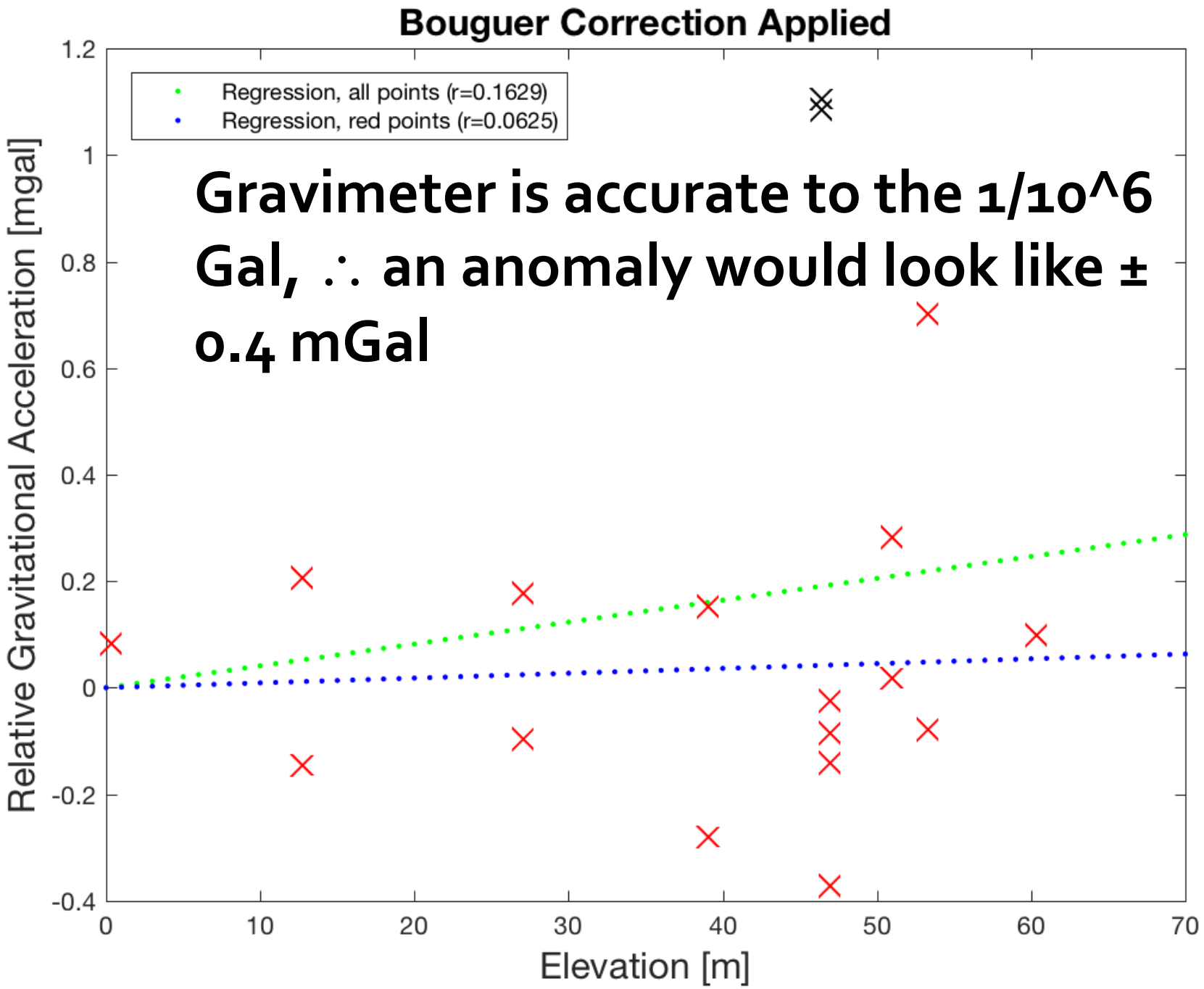


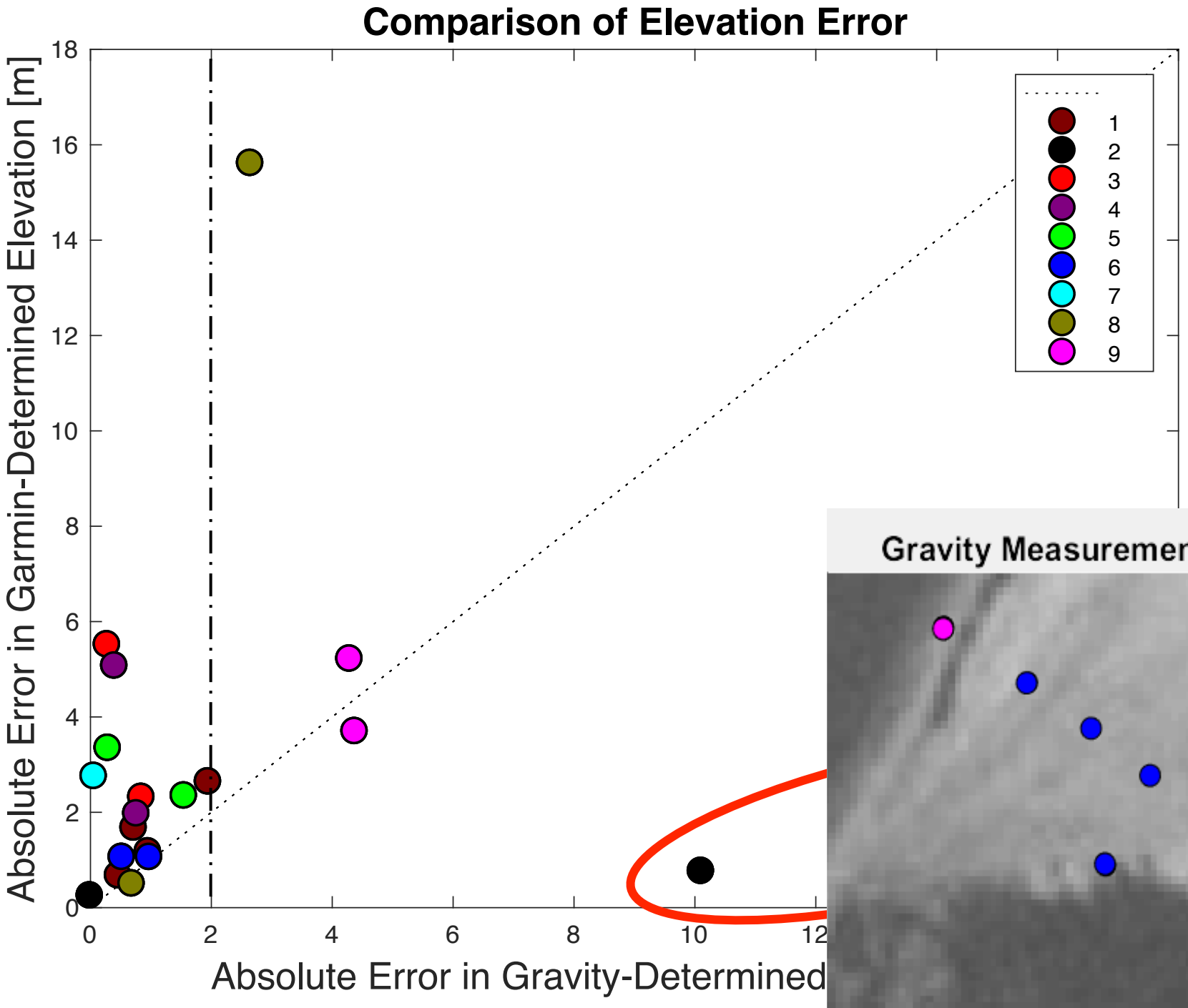
-0.04188σ mgal/meter, where σ represents slab density

Dune: $\sigma = 1.8$ g/cm^3 Grottes: $\sigma = 3.15$ g/cm^3


N
Approx. 500 m

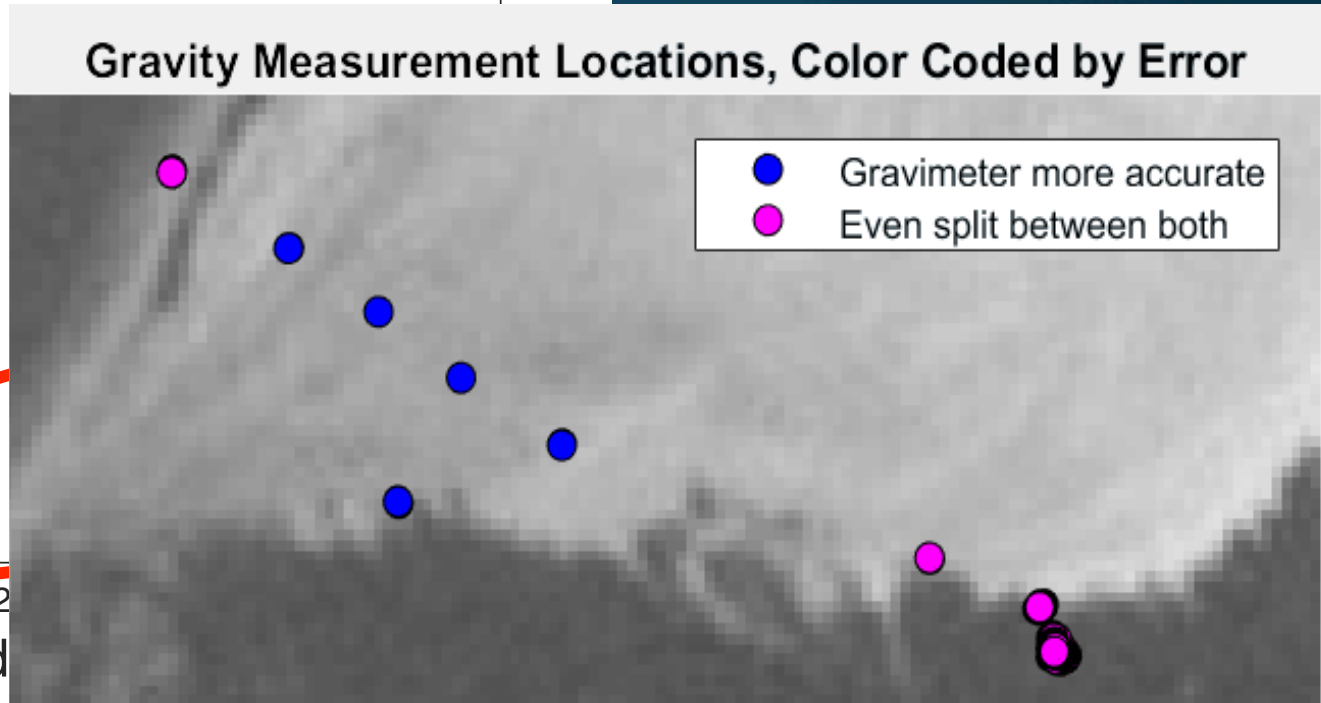

Difference in elevation,
HOMOGENEOUS DENSITY

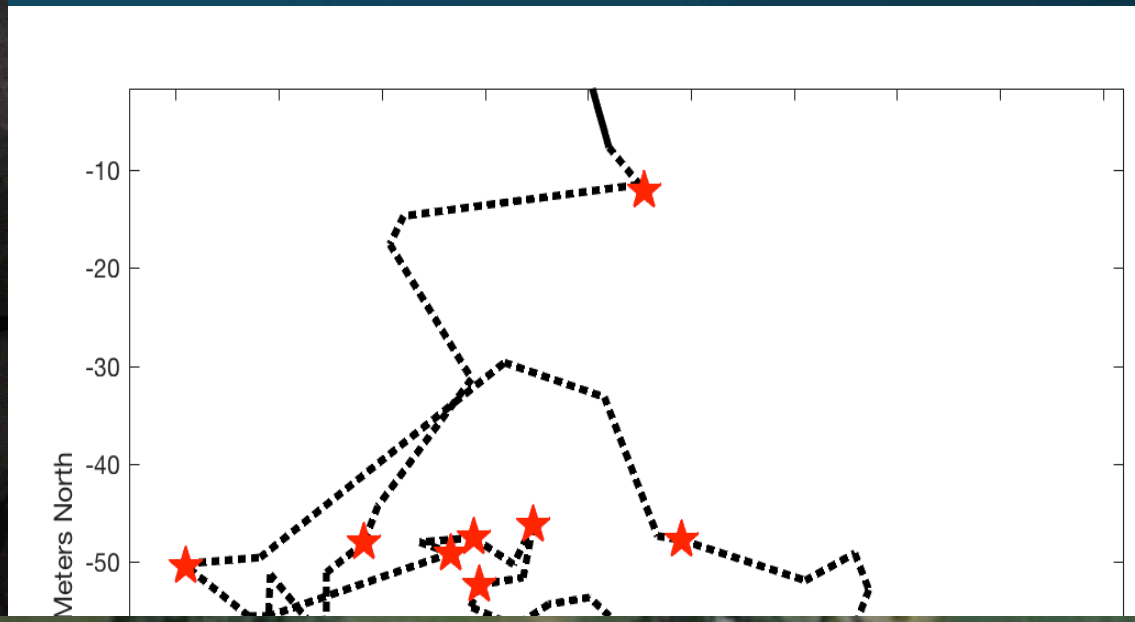

Bouguer Correction Applied
Regression, all points (r=0.1629)
Regression, red points (r=0.0625)
Gravimeter is accurate to the 1/10^6 Gal, ∴ an anomaly would look like ± 0.4 mGal
Relative Gravitational Acceleration [mgal]
Elevation [m]
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
10
20
30
40
50
60
70

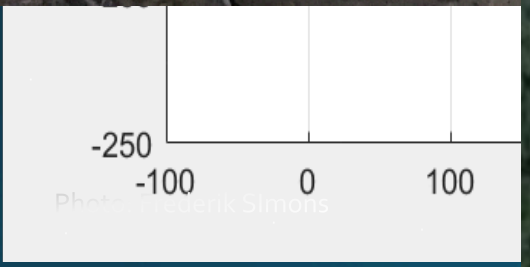


Gravity measured and Garmin point taken twice at each locations, 9 locations total (4 measurements at base camp)

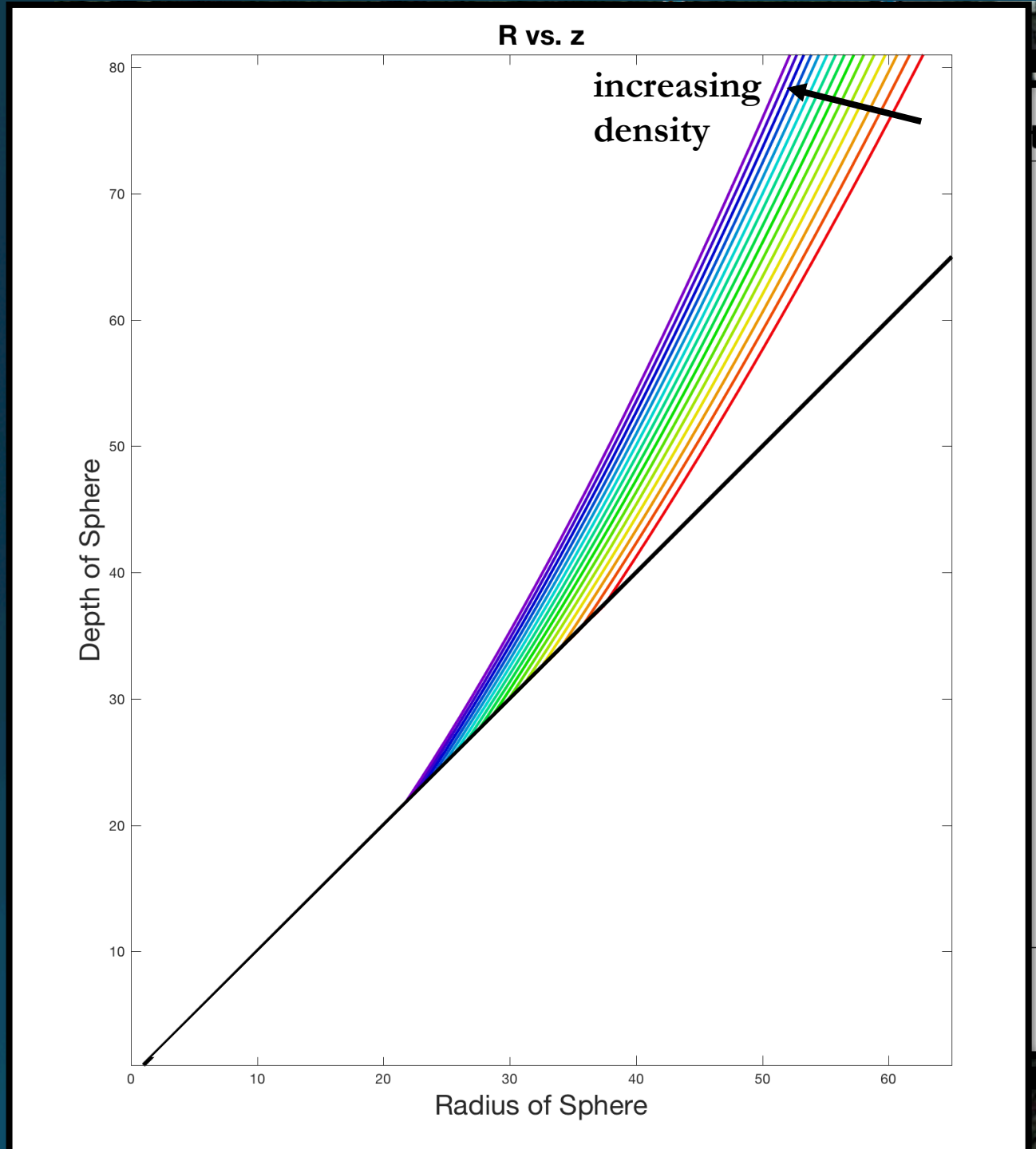
16/20 Gravimeter did a better job

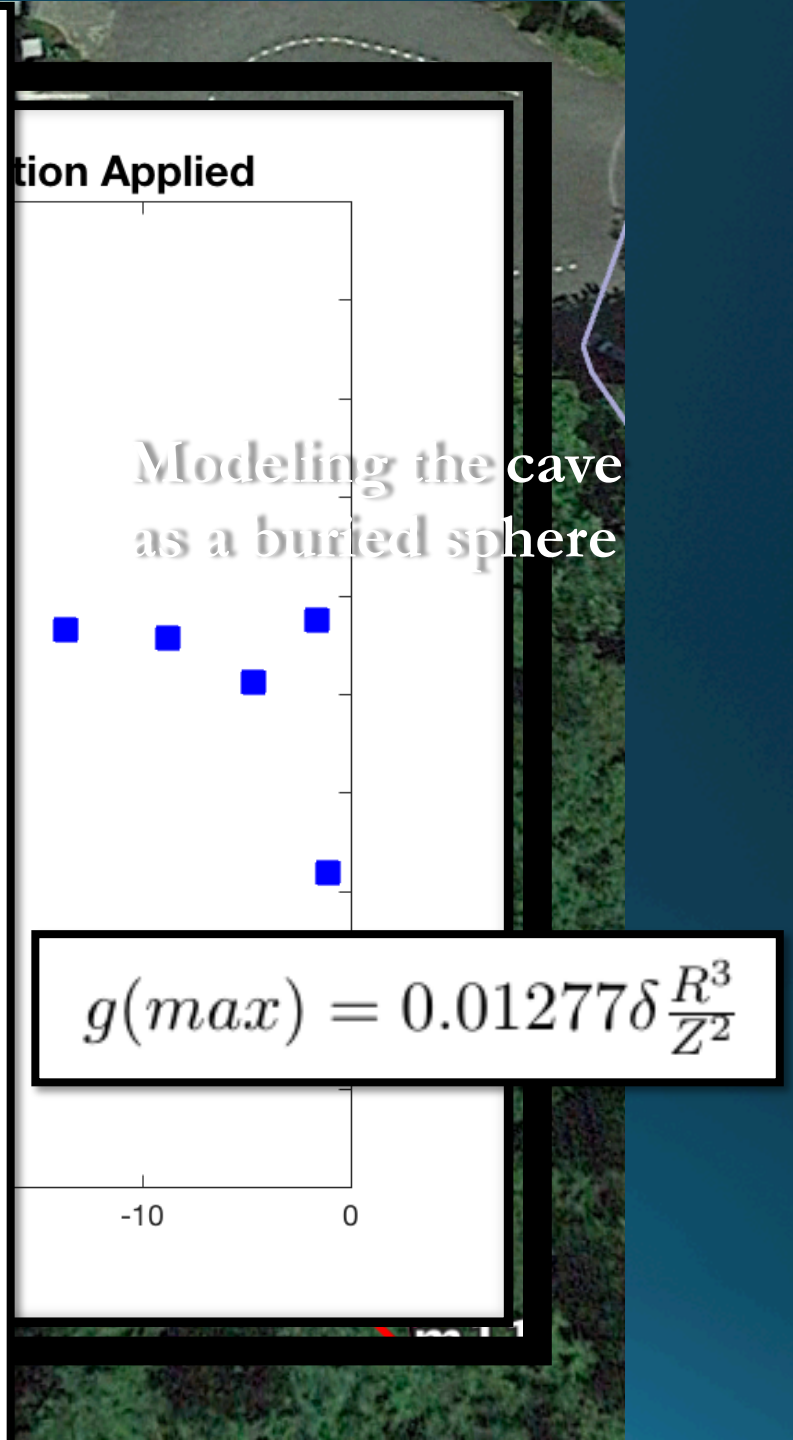



-10
-20
-30
-40
-50
Meters North


-250
-100
0
100


1
2
Approx. 1km in length

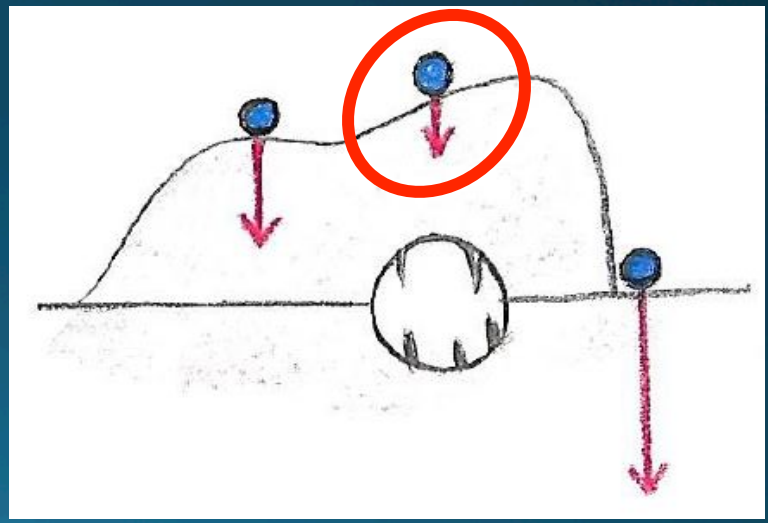


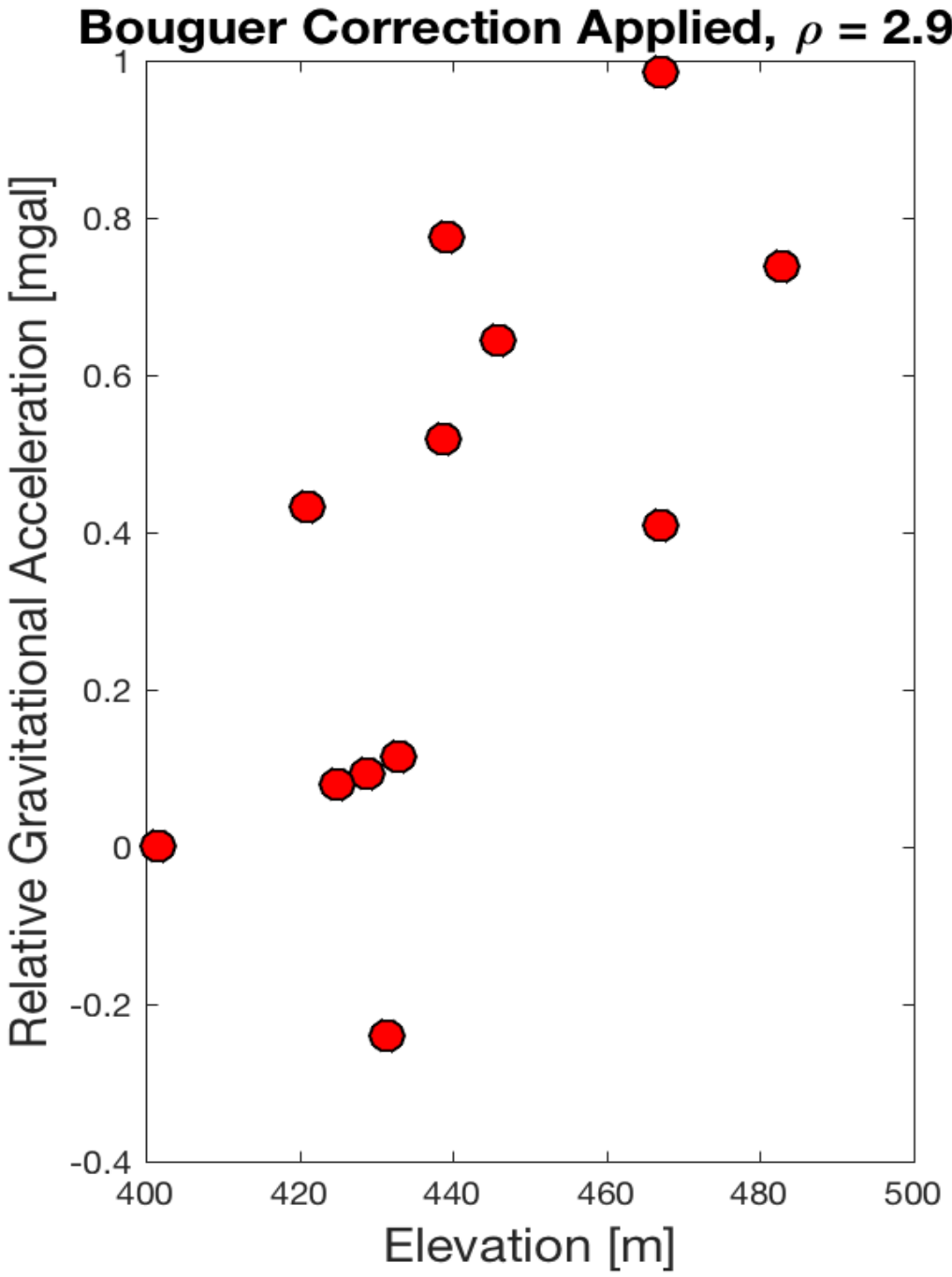


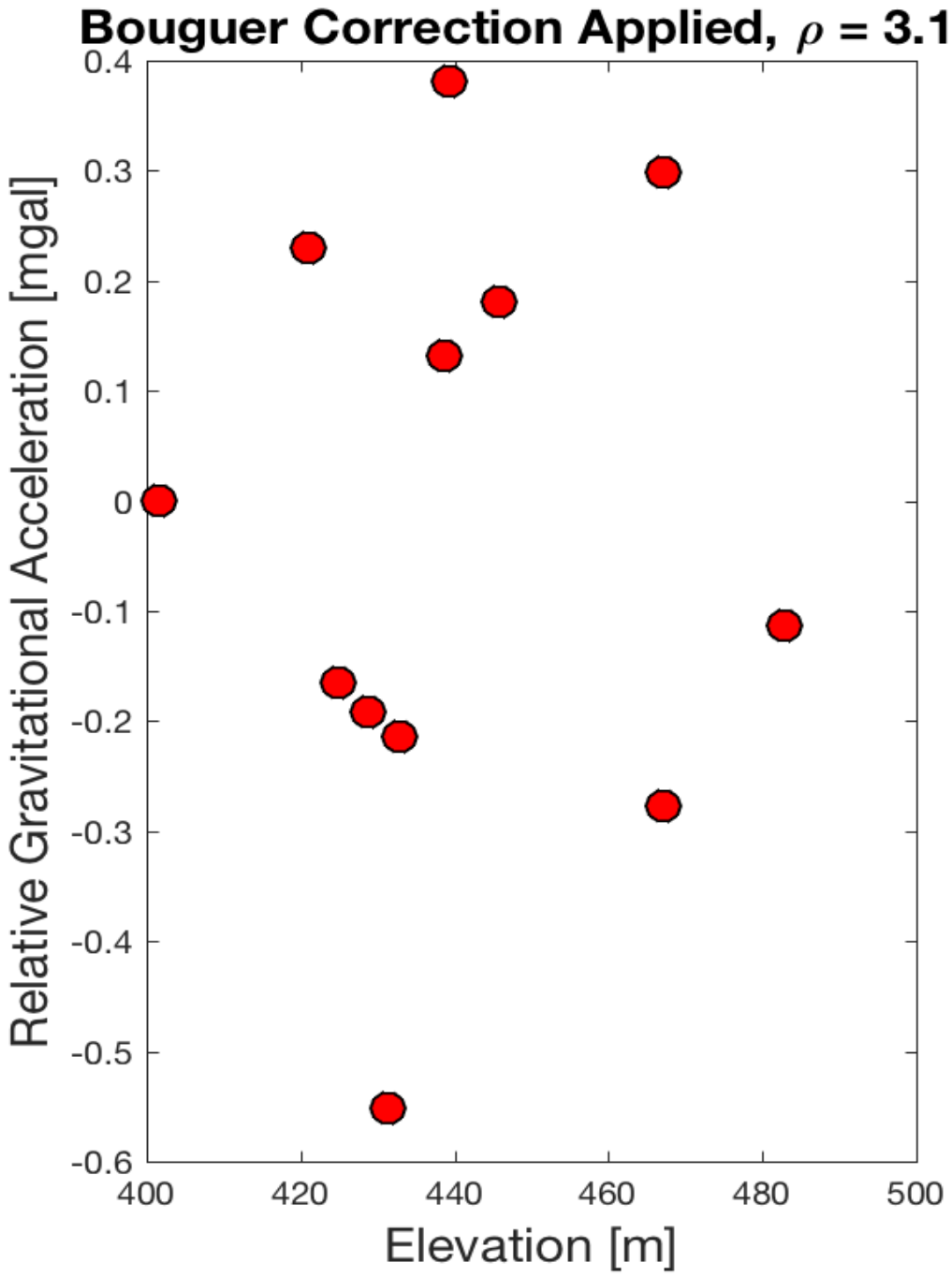
Modeling the cave as a buried sphere

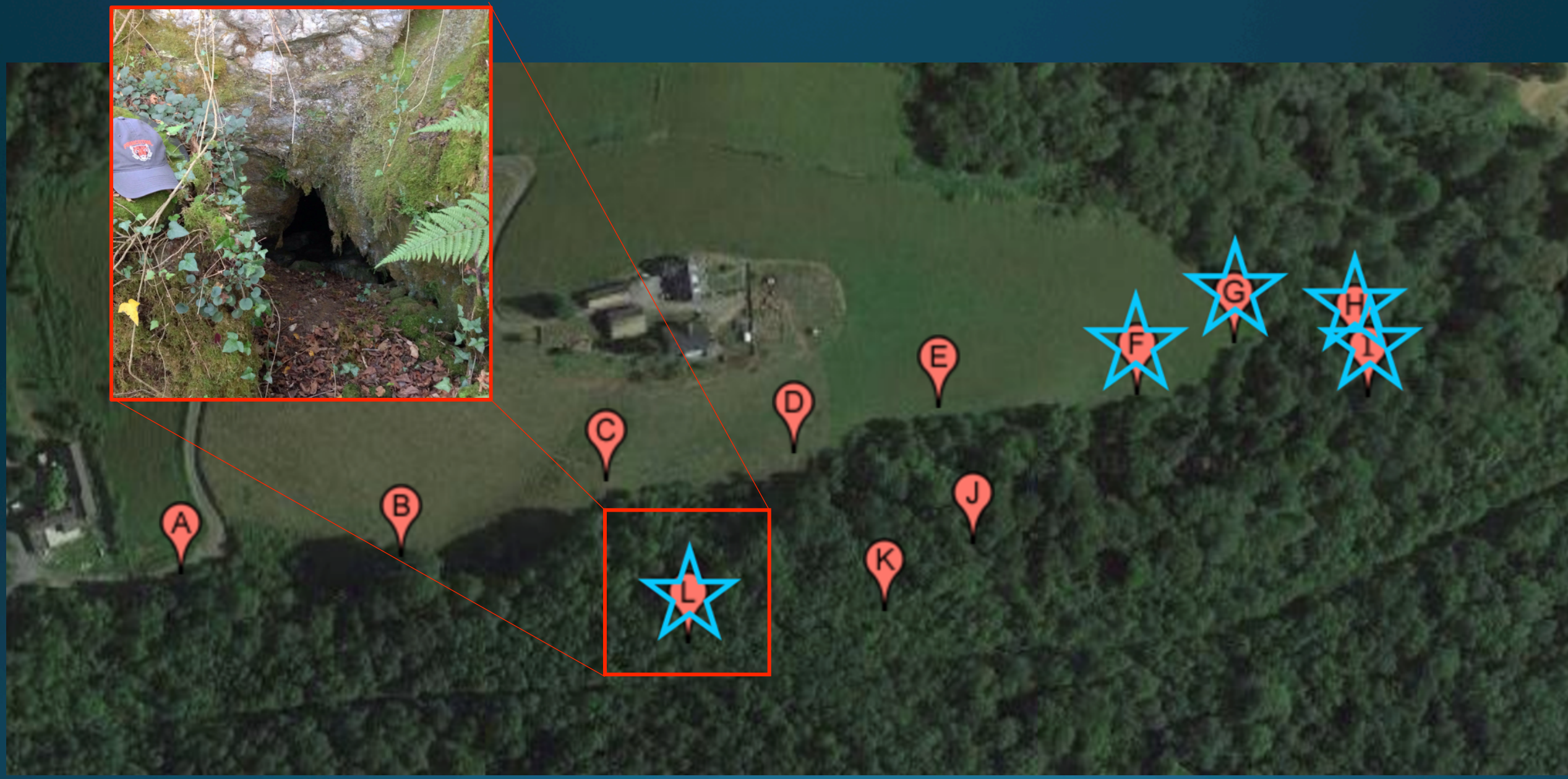
$$g(max) = 0.01277\delta\frac{R^3}{Z^2}$$

Photo: Frederik Simons




Bouguer Correction Applied, ρ = 2.90
Relative Gravitational Acceleration [mgal]
Elevation [m]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
400
420
440
460
480
500


Bouguer Correction Applied, ρ = 3.15
Relative Gravitational Acceleration [mgal]
Elevation [m]
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
400
420
440
460
480
500


A
B
C
D
E
F
G
H
I
J
K
L

Conclusions

[1] LaCoste and Romberg gravimeter can measure variations in gravity with a precision of 0.4 milligals

[2] Gravimeter maps surface elevation more accurately than a handheld Garmin GPS

[3] Gravimetry surveying in the Grottes de Betharram indicate mass deficiencies and show the possibility of caves underneath the developed pathway

[4] Anomalies in Bouguer corrected gravity measurements from the hill above the Grottes indicate mass deficiencies at several locations

Acknowledgments

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References

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Questions?