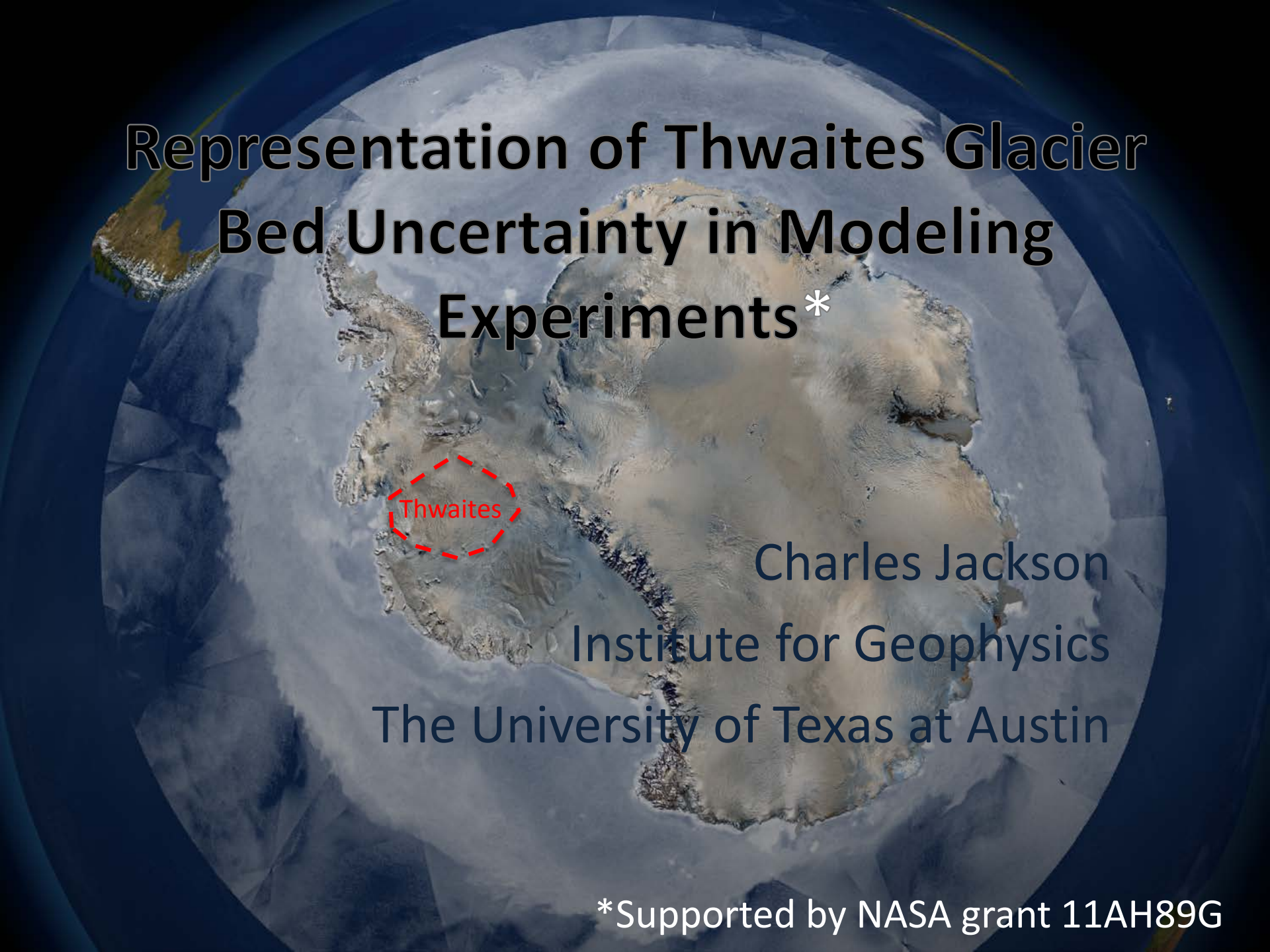
Representation of Thwaites Glacier Bed Uncertainty in Modeling Experiments*



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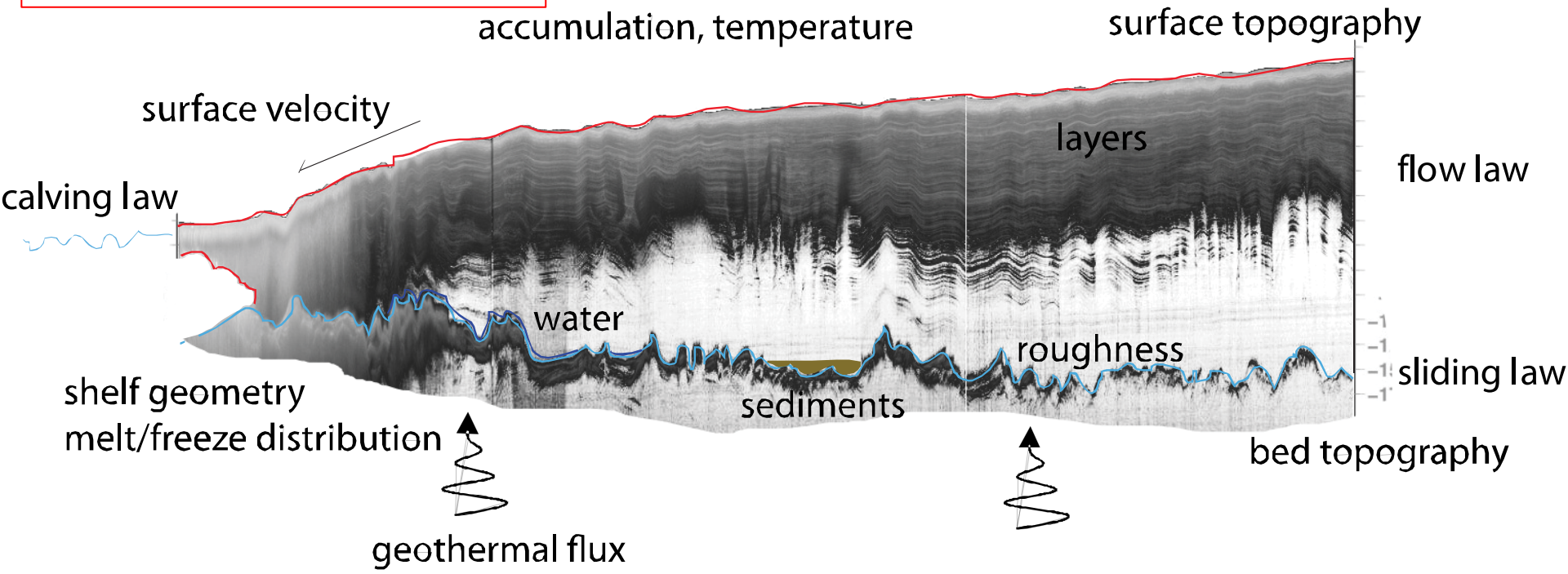
*Supported by NASA grant 11AH89G

Acknowledgements

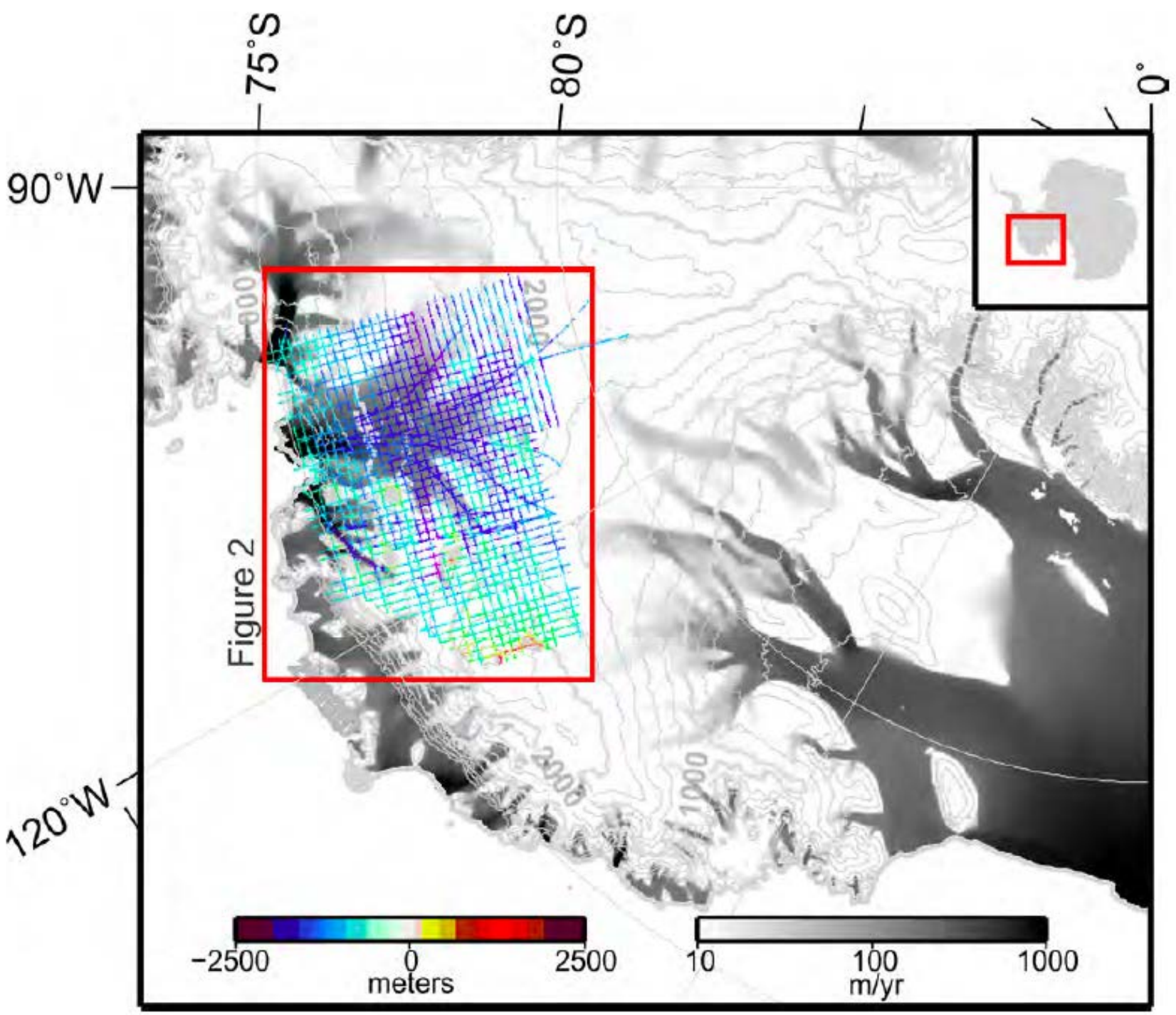
- John Goff
  - Senior Research Scientist, UTIG
- Scott Waibel
  - graduate student, Portland State University, Oregon
- Christina Hulbe
  - Dean, Otago University, New Zealand

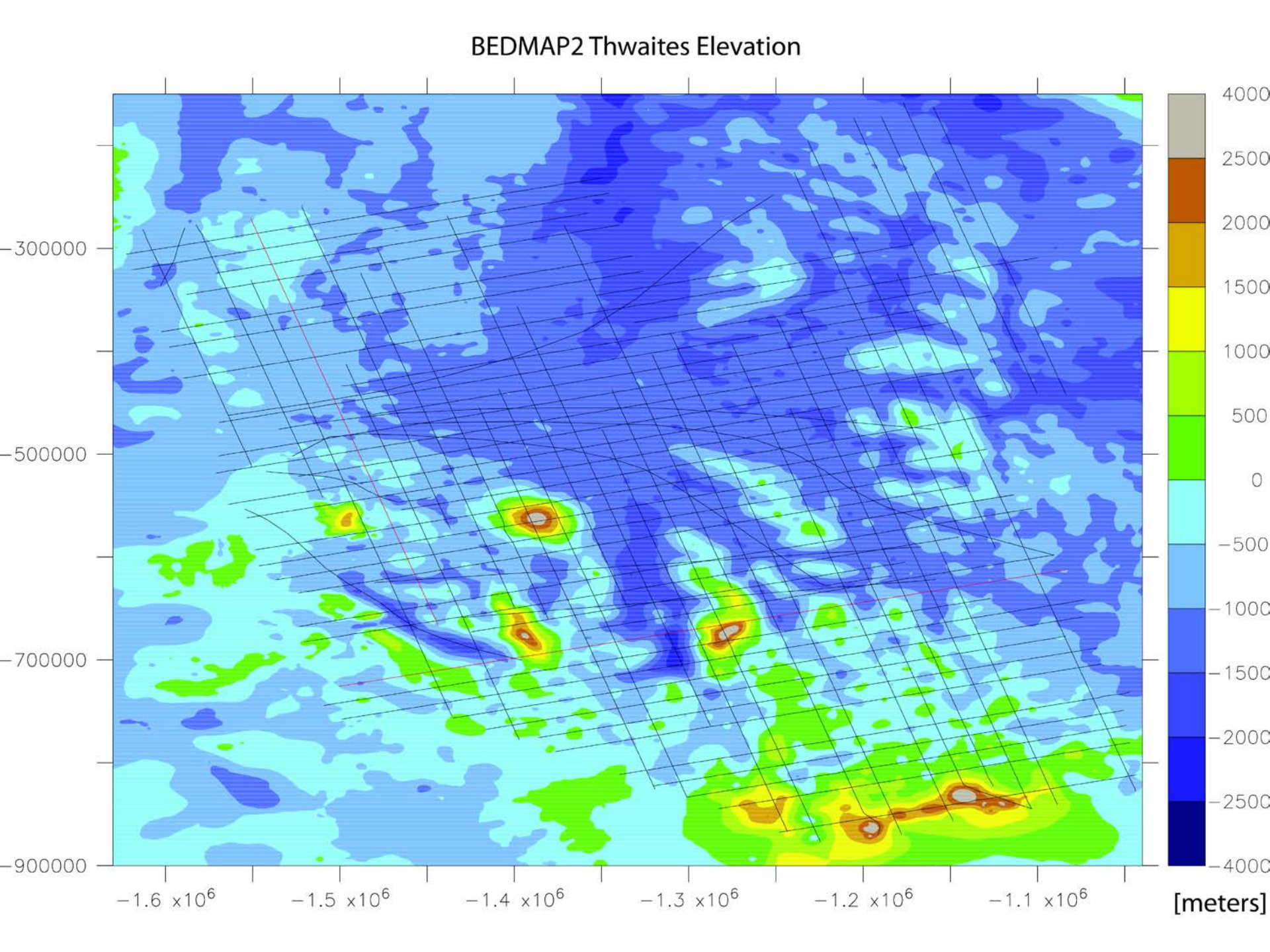
Scientific aspects of problem

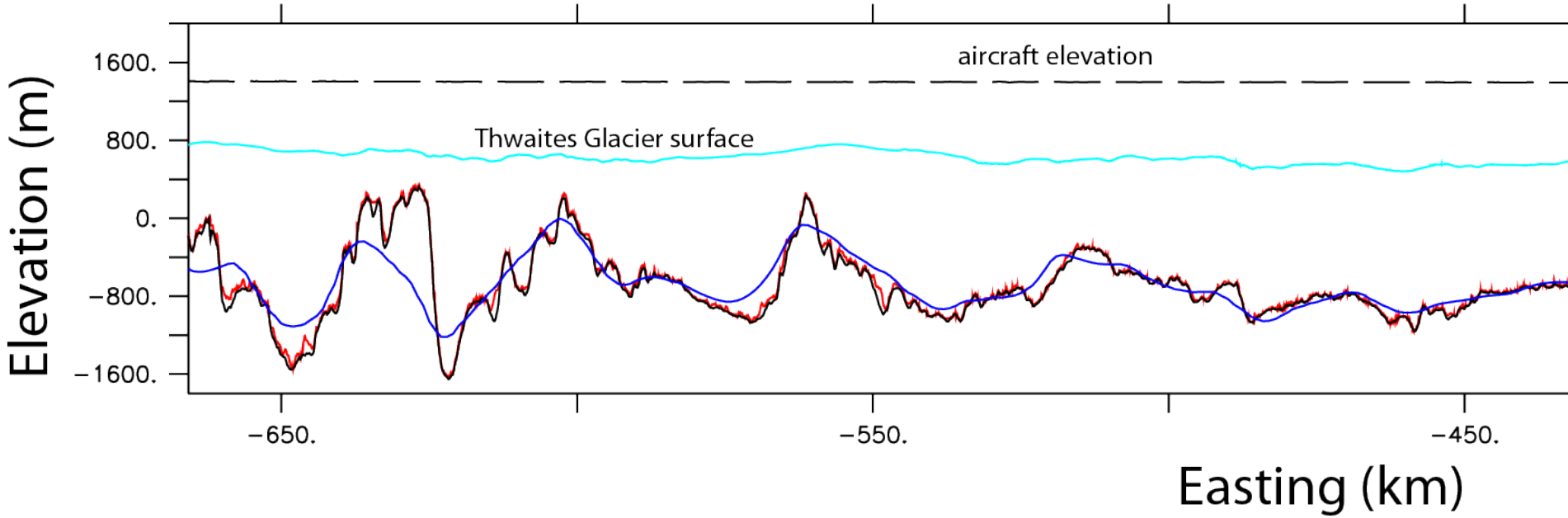
Profile of Thwaites from radar



- Marine ice sheet instability is a 2D theory. Needs to be tested with 3D models.
- Bed Topography data sets miss small-scale roughness and valleys important to modeling ice flow retreat rates

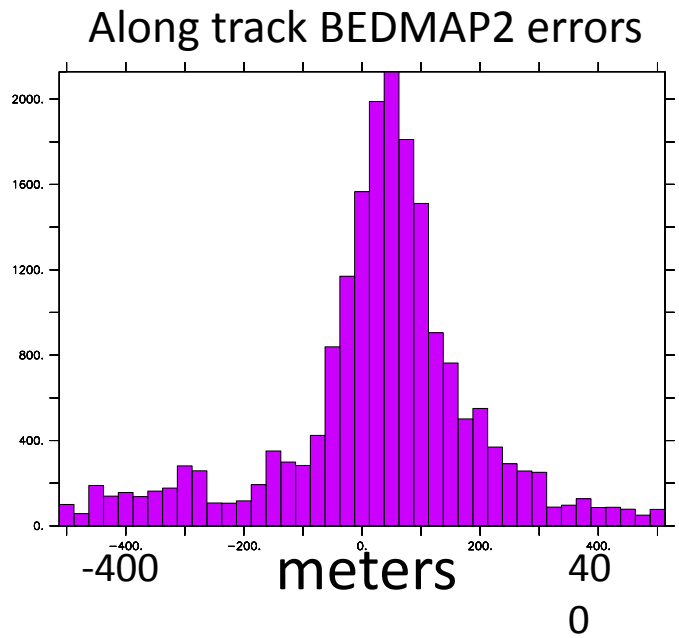

75°S
80°S
0°
90°W
120°W
Figure 2
2000
1000
2000
1000
−2500
0
2500
meters
10
100
1000
m/yr

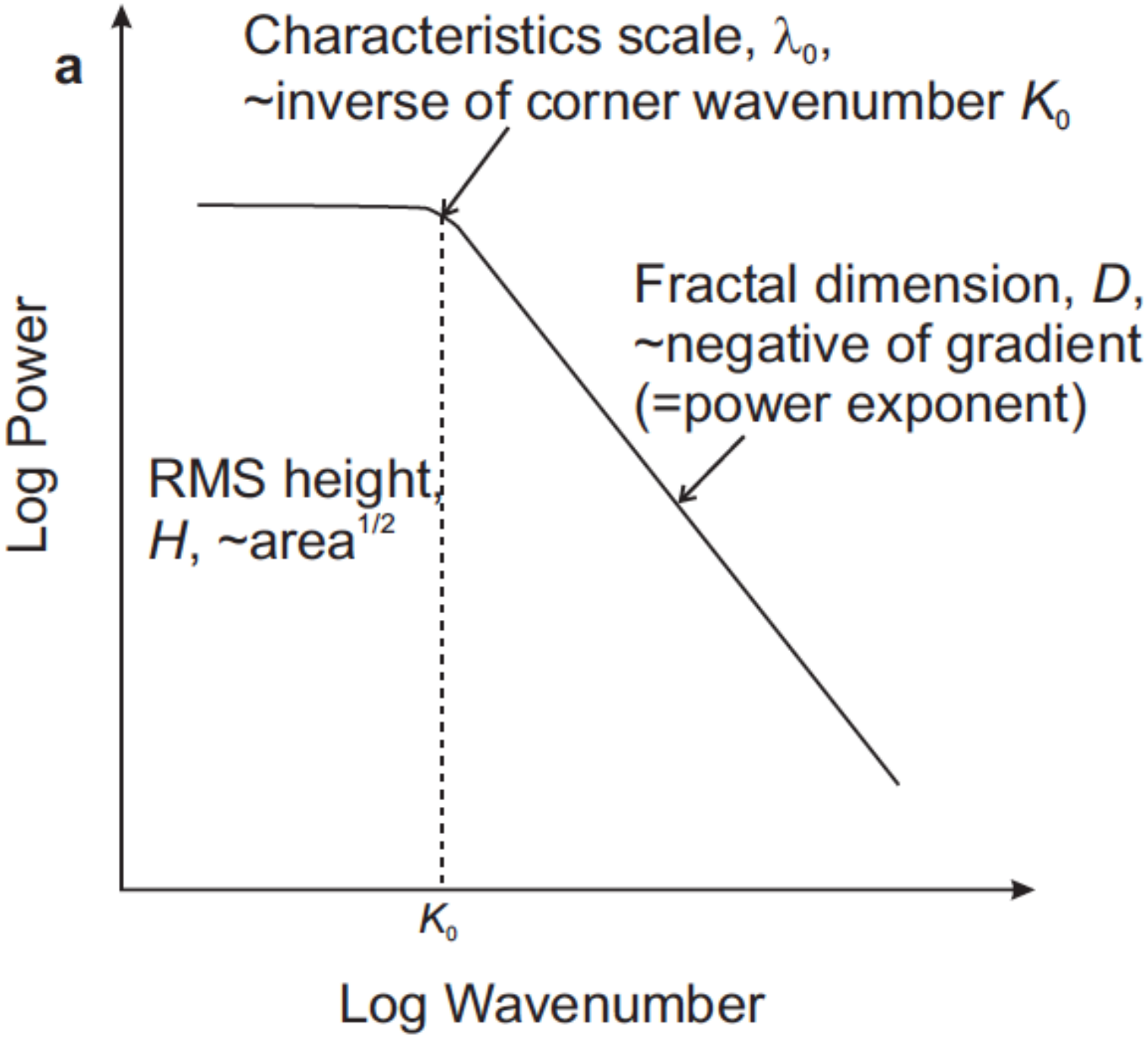

BEDMAP2 Thwaites Elevation
−300000
−500000
−700000
−900000
−1.6 x10^6
−1.5 x10^6
−1.4 x10^6
−1.3 x10^6
−1.2 x10^6
−1.1 x10^6
4000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
−4000
[meters]

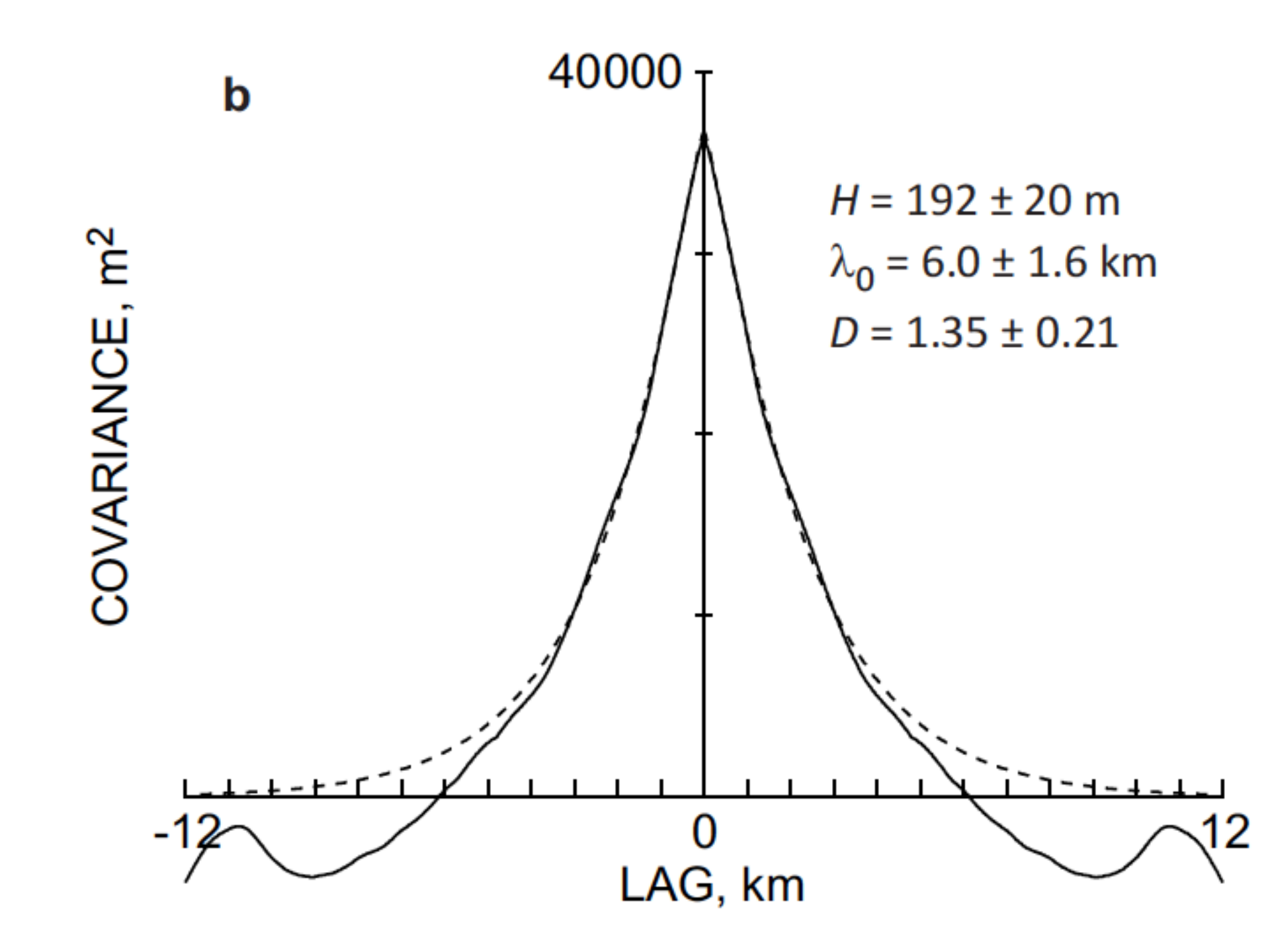


- Data along flight tracks shows detail not included in BEDMAP2, based on the same data.

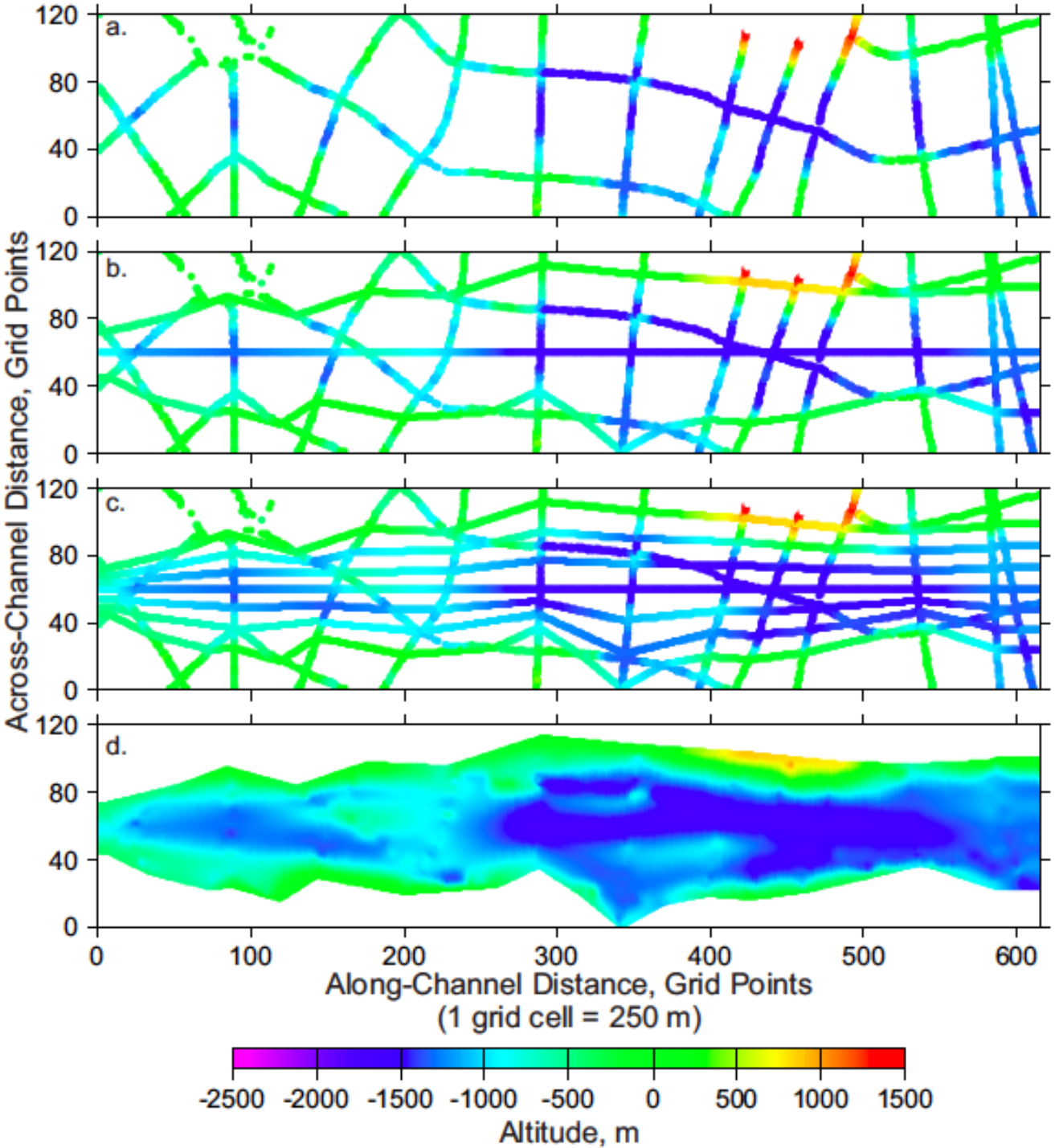
- John Goff created a statistical model of bed morphology to represent the type of features that could exist between flight lines. (Goff et al., J. Glaciology, submitted)

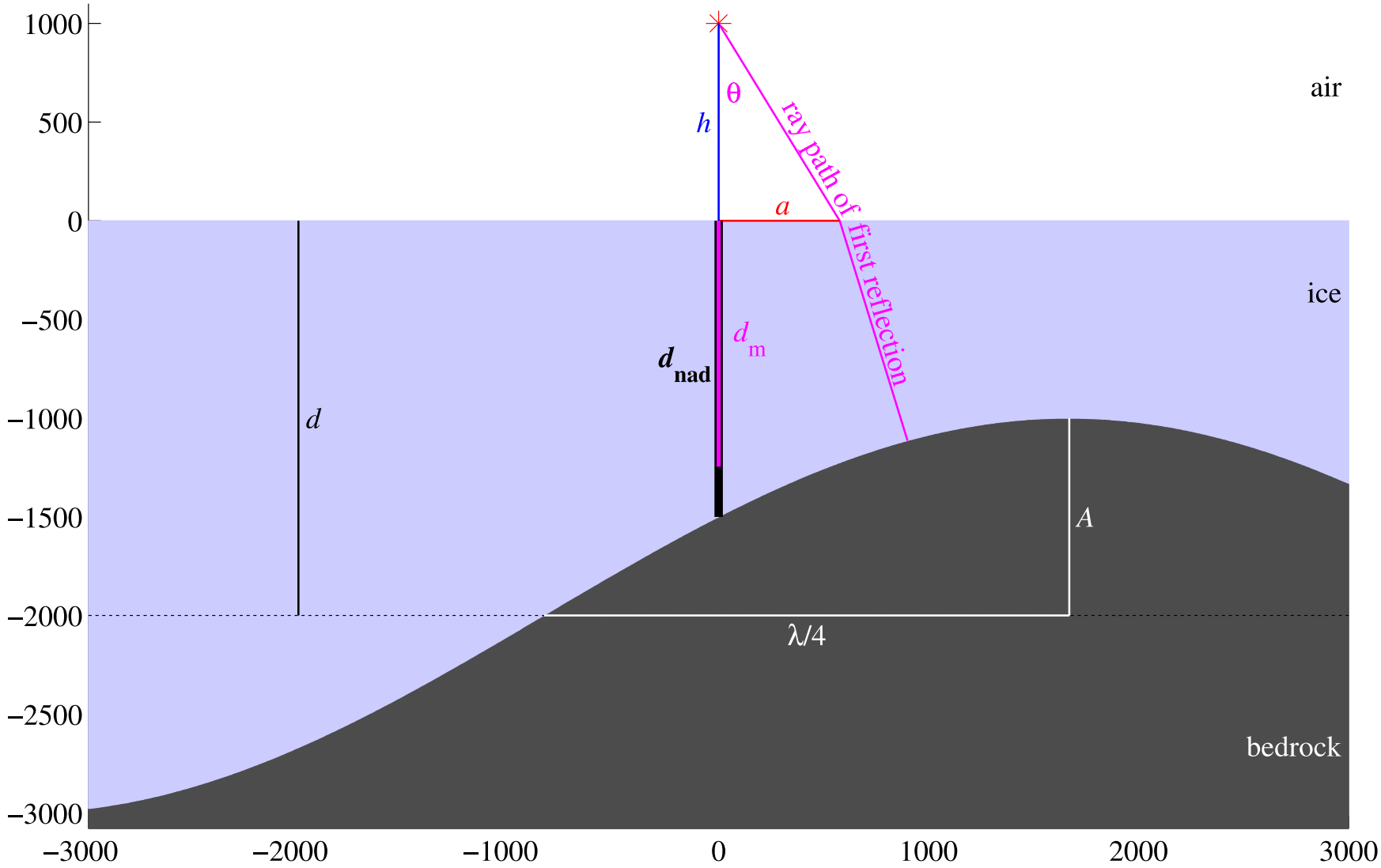



a
Characteristics scale, λ_0,
~inverse of corner wavenumber K_0
Fractal dimension, D,
~negative of gradient
(=power exponent)
RMS height,
H, ~area$^{1/2}$
Log Power
K_0
Log Wavenumber


b
40000
COVARIANCE, m²
H = 192 ± 20 m
λ0 = 6.0 ± 1.6 km
D = 1.35 ± 0.21
-12
0
12
LAG, km

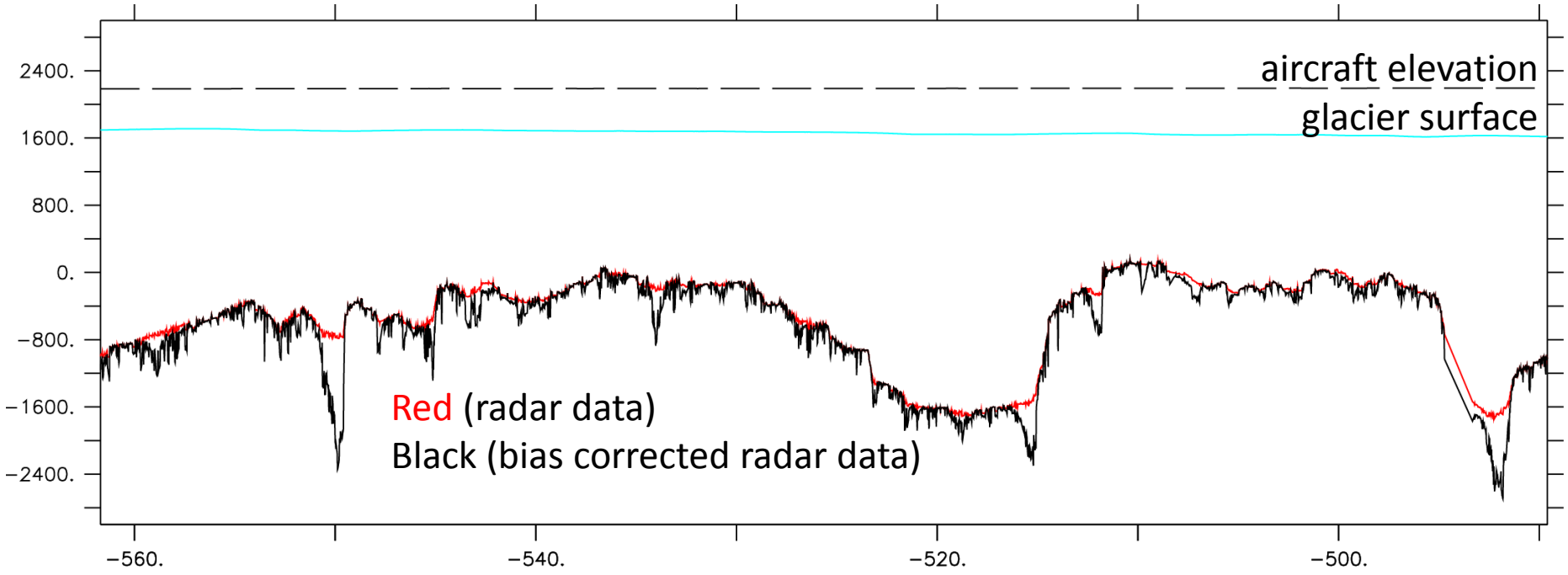
In addition, glacier carved U shaped valleys were identified by undergraduate students. The same valleys were connected across flight lines. Interpolation of topographic features within valleys only occurred along the direction of the valley floor.



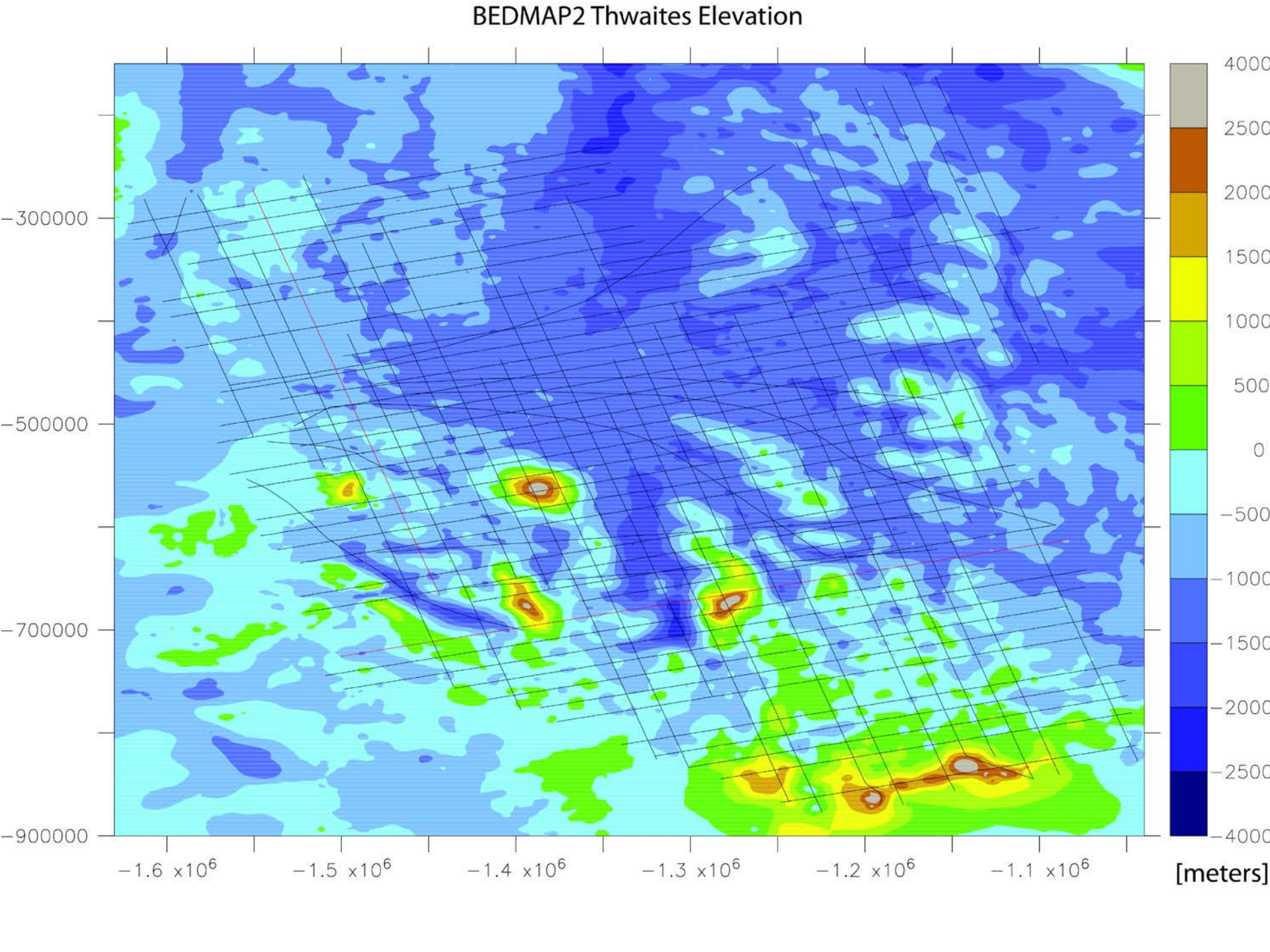


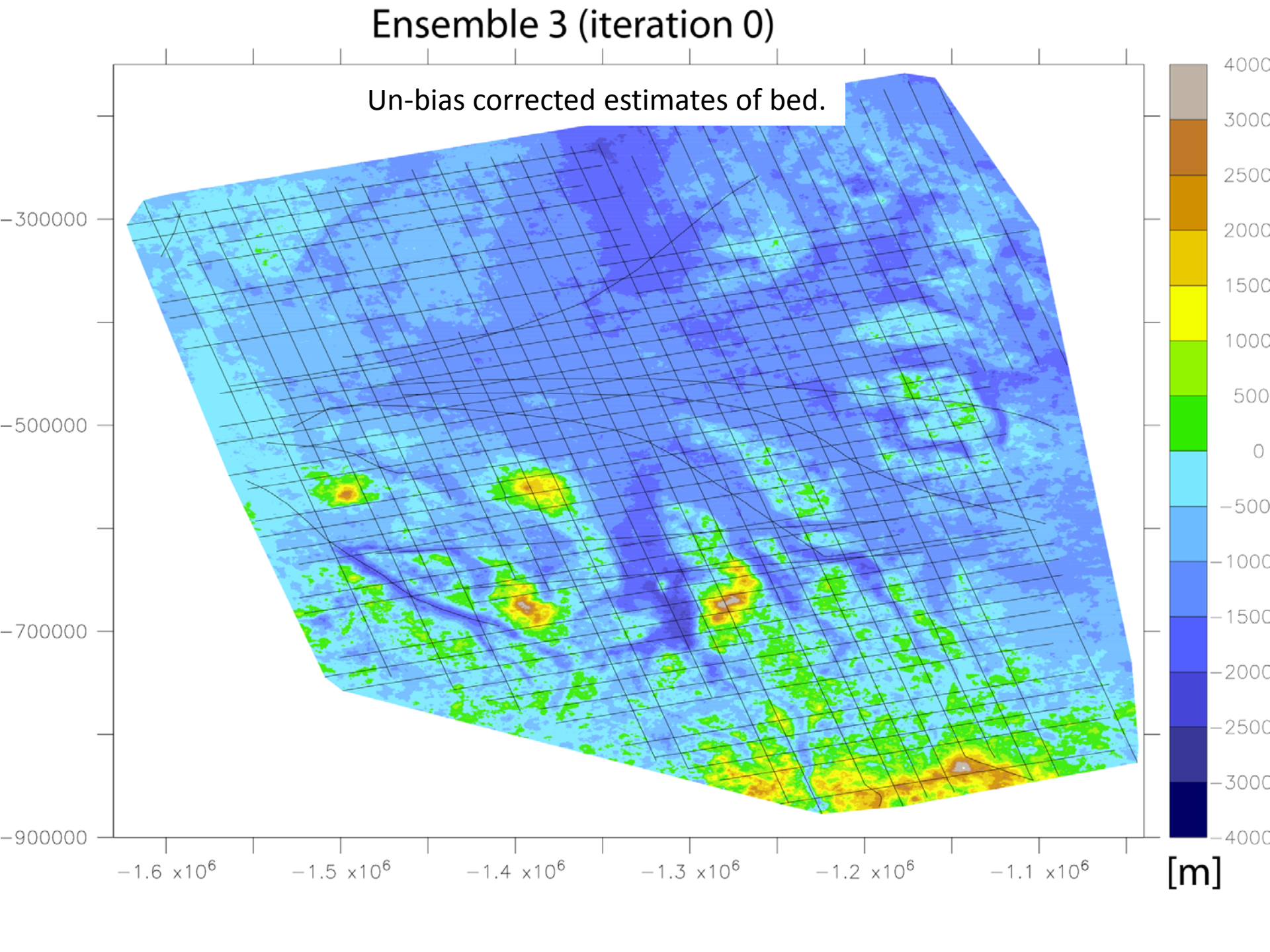
a model output.

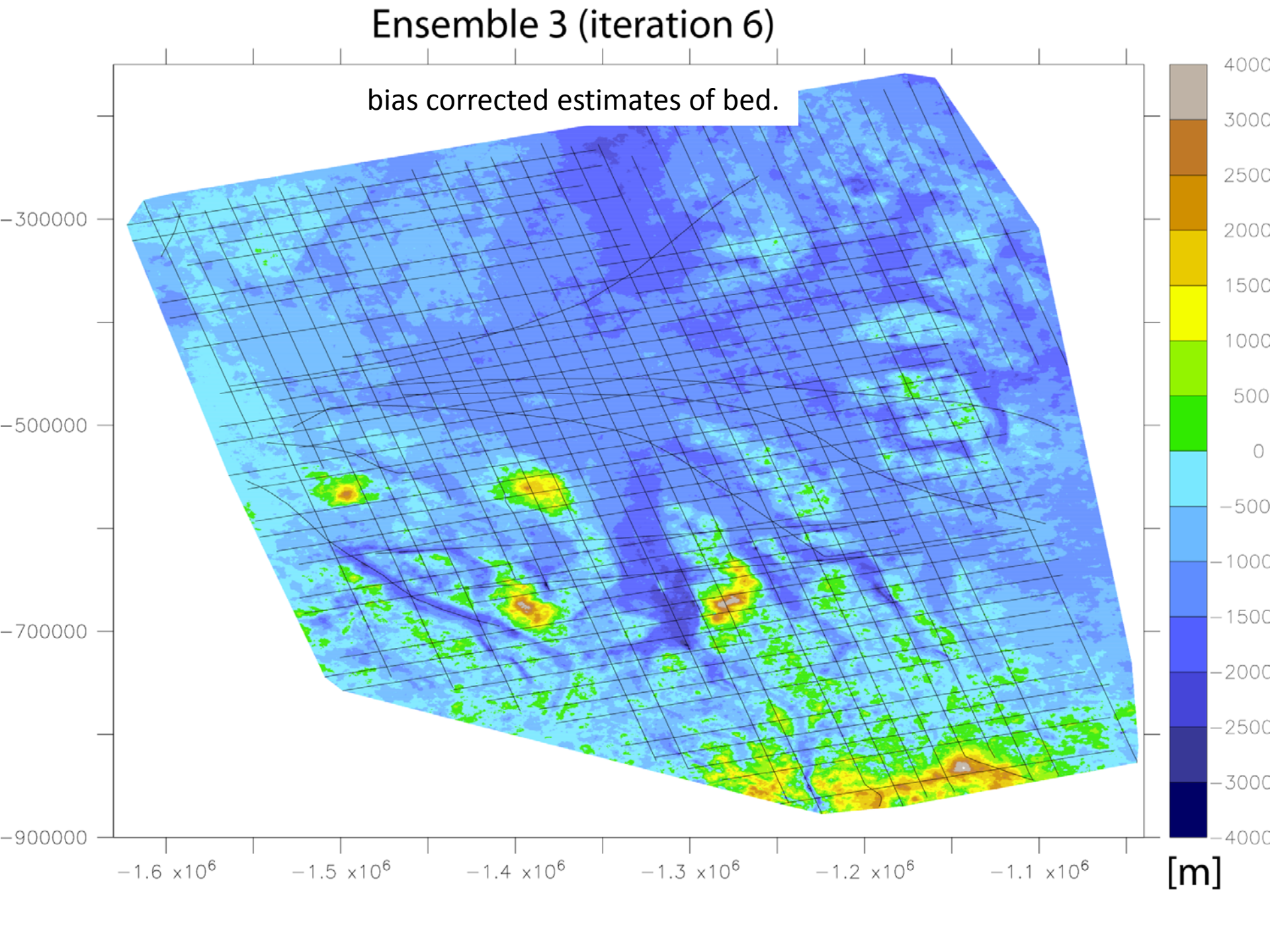
Radar sensor model is used to correct biases in original radar data.

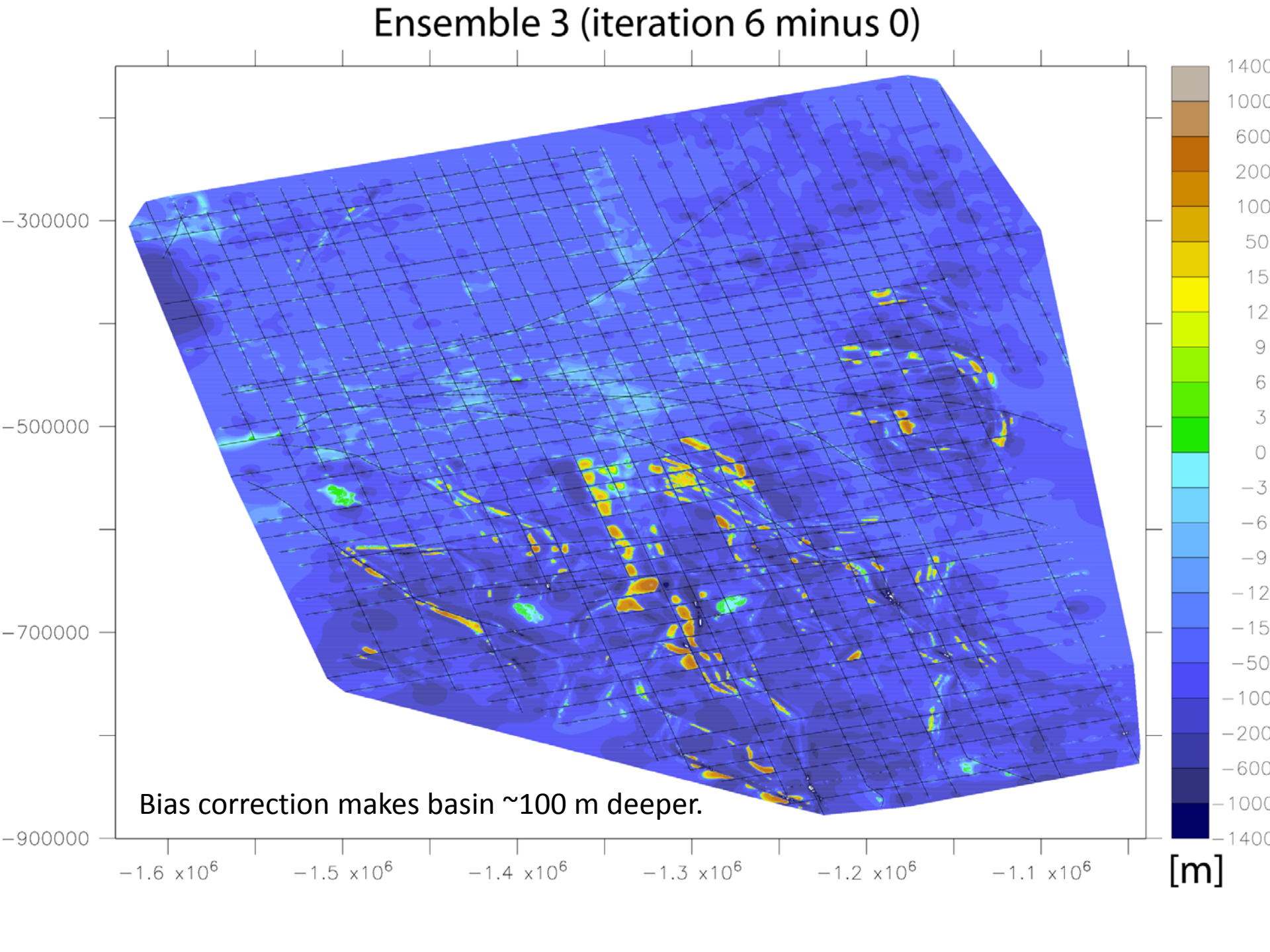


Flying radar model over bias corrected topography returns original data.


BEDMAP2 Thwaites Elevation
−300000
−500000
−700000
−900000
−1.6 x10^6
−1.5 x10^6
−1.4 x10^6
−1.3 x10^6
−1.2 x10^6
−1.1 x10^6
4000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
−4000
[meters]


Ensemble 3 (iteration 0)
Un-bias corrected estimates of bed.
−300000
−500000
−700000
−900000
−1.6 x10^6
−1.5 x10^6
−1.4 x10^6
−1.3 x10^6
−1.2 x10^6
−1.1 x10^6
4000
3000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
−3000
−4000
[m]


Ensemble 3 (iteration 6)
bias corrected estimates of bed.
−300000
−500000
−700000
−900000
−1.6 x10^6
−1.5 x10^6
−1.4 x10^6
−1.3 x10^6
−1.2 x10^6
−1.1 x10^6
4000
3000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
−3000
−4000
[m]


Ensemble 3 (iteration 6 minus 0)
−300000
−500000
−700000
−900000
−1.6 x10^6
−1.5 x10^6
−1.4 x10^6
−1.3 x10^6
−1.2 x10^6
−1.1 x10^6
1400
1000
600
200
100
50
15
12
9
6
3
0
−3
−6
−9
−12
−15
−50
−100
−200
−600
−1000
−1400
[m]
Bias correction makes basin ~100 m deeper.

Representation of Uncertainties

- In inverse model calculations for bed traction, a generic “prior” exists for defining variations in quantities that are not well constrained by data.
- We can use ensemble of beds from our calculation here to improve estimates of this “prior” covariance matrix. (I’m very excited about this possibility)

Another approach to represent bed uncertainties (geared toward observational strategies)

$$Top_{new} = \sum_{\lambda} Top(\text{spacing, channel, Hurst})\, ROI_{\lambda} +$$

$$Top(\text{spacing}_{\text{base}}, \text{channel}_{\text{base}}, \text{Hurst}_{\text{base}})\left(1 - \sum_{\lambda} ROI_{\lambda}\right)$$

- Spacing refers to the density of flight lines
- Channel refers to whether a given U-shaped valley receives special along-valley interpolation
- Hurst refers to roughness at fine scales
- ROI is region of interest, i.e. the topography that matters to predictions of mass loss.

To estimate “Regions of Influence”

- Run large ensemble of ice flow modeling experiments in which ice is forced to retreat.
- Within each experiment collect information about which topographic features cause increase/decrease in retreat rates.
- Take principle components of this variable retreat rate map to represent “regions of influence” relevant to sea level rise.

Summary

- Uncertain ice sheet bed geometries are thought to be very important to governing rate of sea level rise.
- The approach to problem benefits from science perspectives concerning ice flow physics and observational data.
- Most challenging part of problem is translating the high dimensional uncertainties to a few concepts that would guide observational design into what details need to be observed.