Solidification of Impact Melts and Lavas

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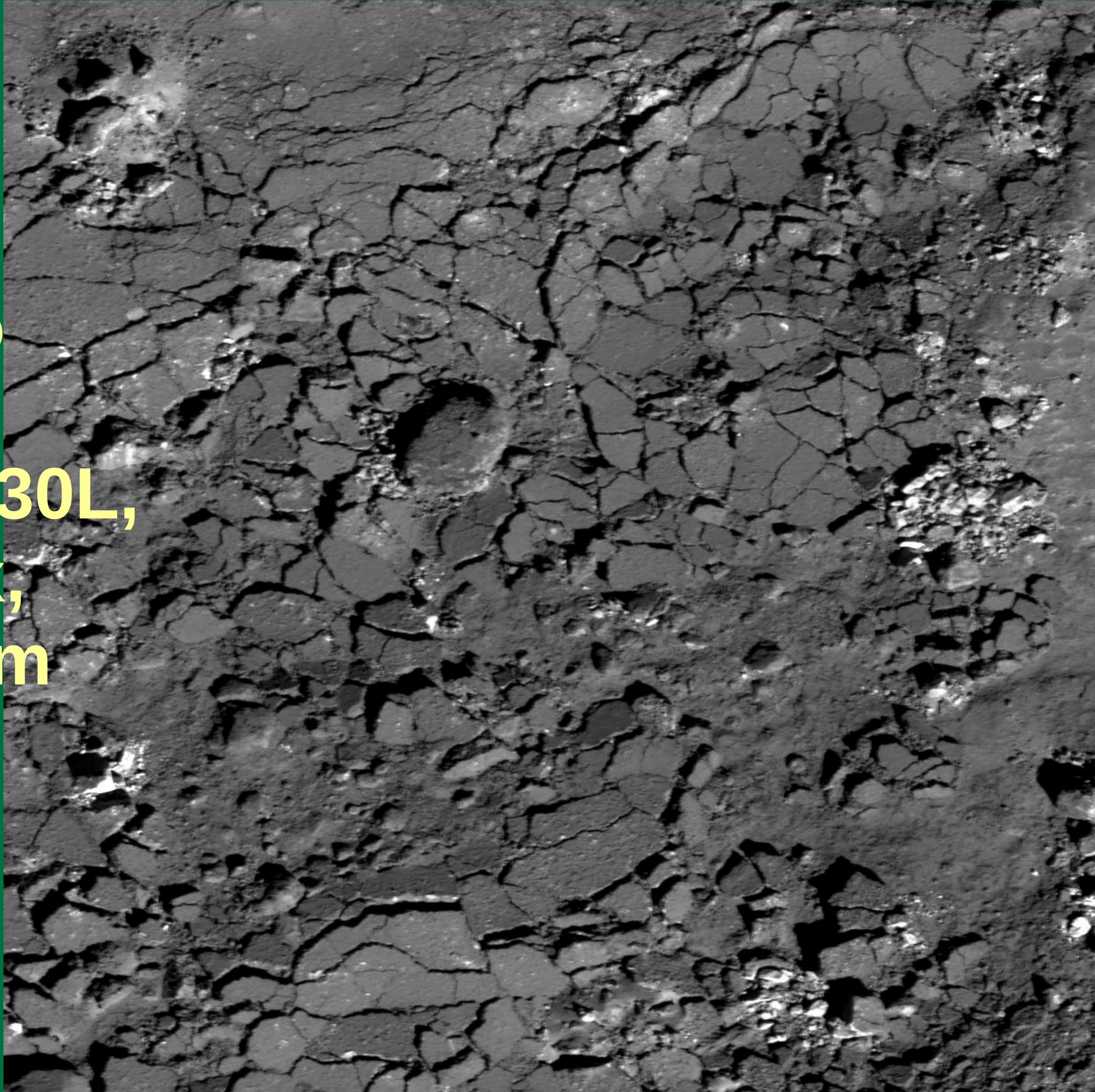
Outline

- Observational motivation
- Model and baseline (Kilauea) case
- Planetary runs
- Results
- Caveats and future work

Bray et al. 2010 GRL Giordarno Bruno M110919730L, 0.61 m/pix, plates ~8 m thick



Lava Cooling Model (1 of 2)

- Evolution of Keszthelyi (1995), Keszthelyi and Denlinger (1996), Keszthelyi and McEwen (1997).
- Surface cooling by radiation and wind.
- Internal heat transfer by conduction with temperature dependent thermophysical parameters with corrections for bubbles and crystallization.
- Simple model for cooling by rain.

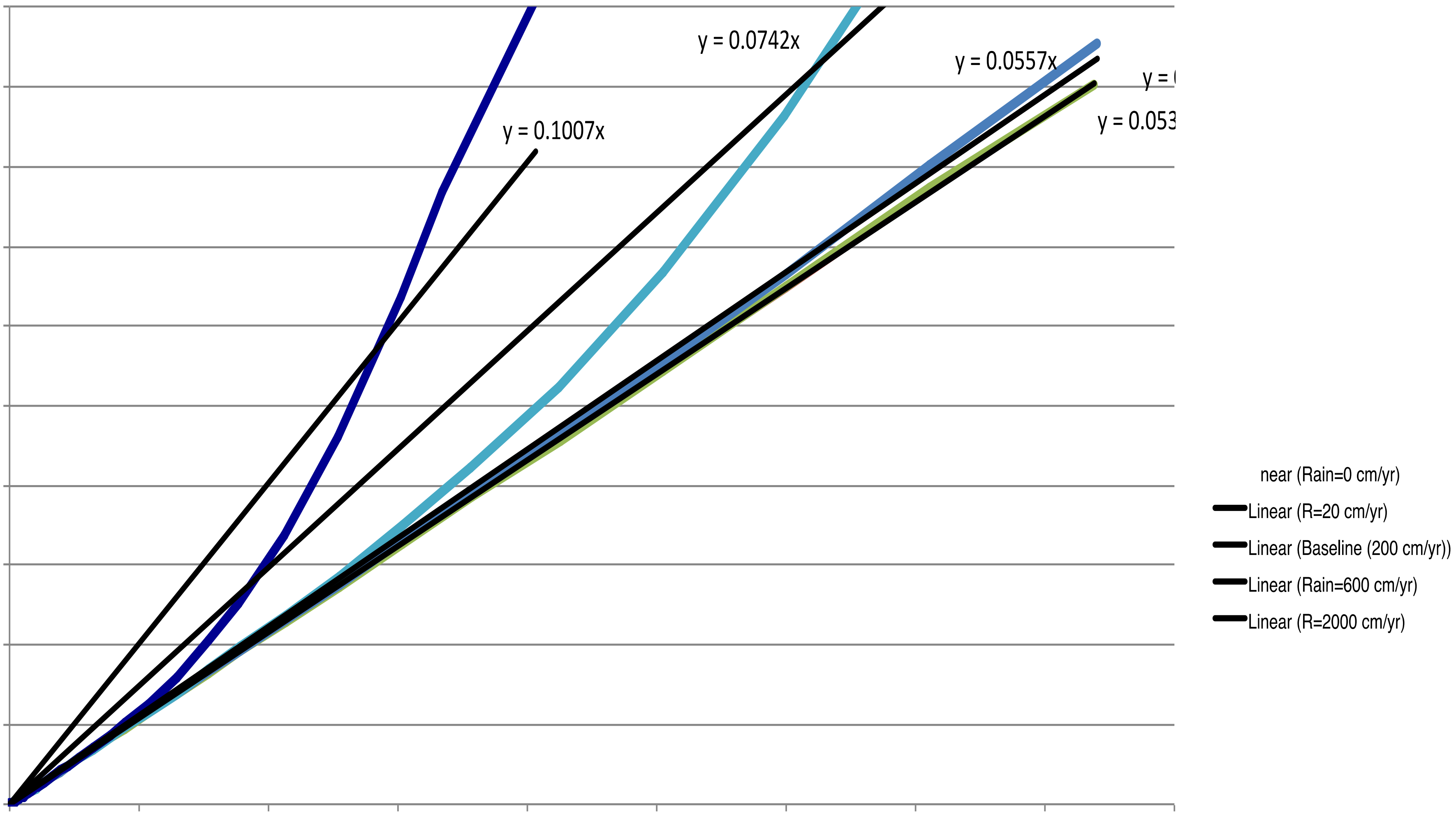
Lava Cooling Model (2 of 2)

- Numerical method is simple (1-D first order finite difference) with dynamic adjustment of grid spacing.
- Excellent match to field data on the first few minutes of cooling.
- Long term constraint from Hon et al. 1994 based on Makaopuhi lava lake

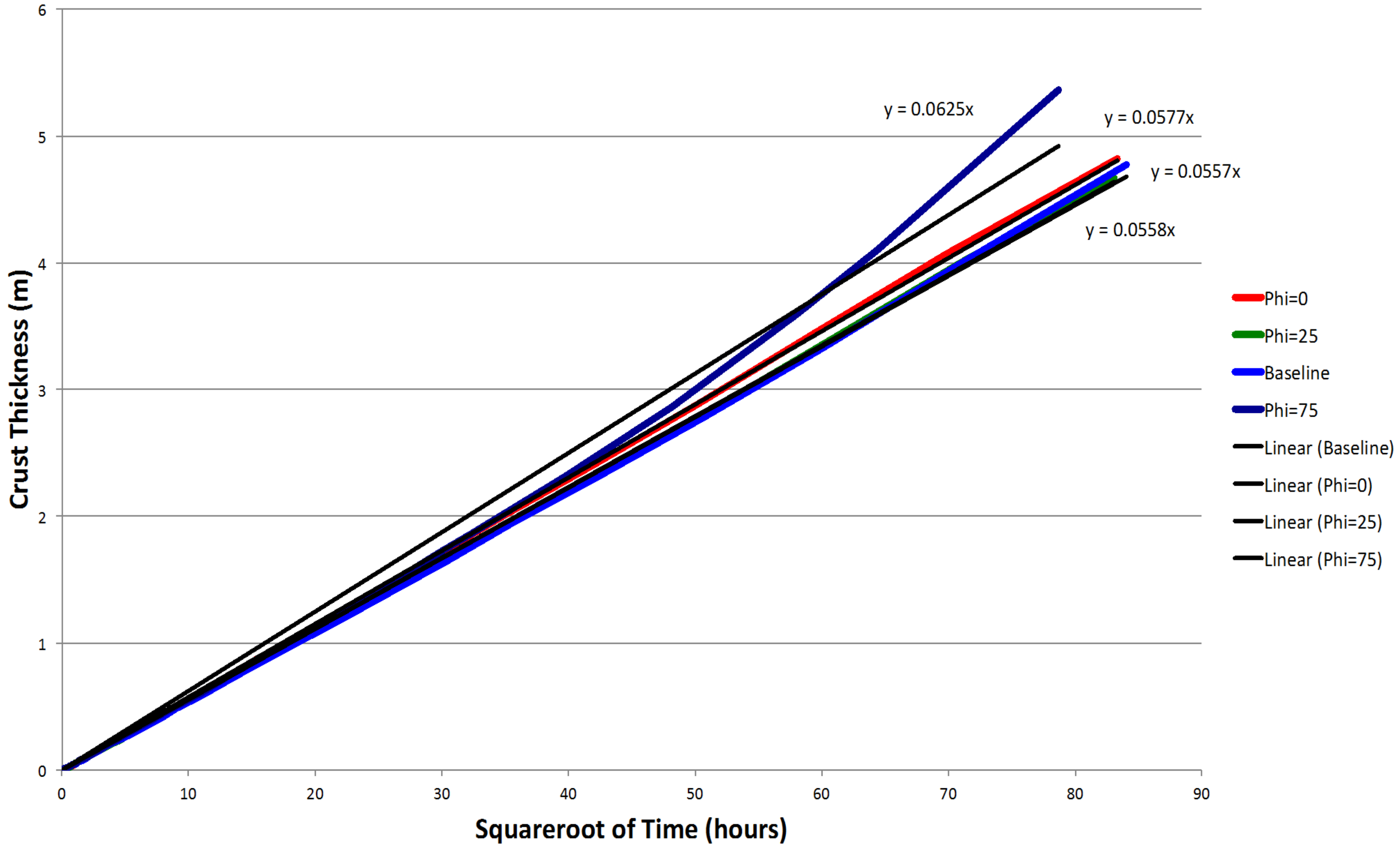
Baseline Run (Kilauea)

- Environment:
  - T = 25 ° C,
  - Rain = 600 cm/yr,
  - $h = 50\ W/m^2K$
- Hawaiian Basalt
  - T = 1135 ° C
  - 50 vol.% bubbles, 1 mm diameter
  - $\partial T/\partial t$ for glass = 10 ° C/s down to 900 ° C
  - @ 1135 ° C, $\rho = 2600\ kg/m^3$, Cp = 1130 J/kg ° C
  - $L = 4.7\text{x}10^5$ J/kg

Model Output (Rain)



Model Output (Vesicularity)



Planetary Cases

- Rain = 0
- Ta = 240 K for Moon, Mars; 120 K for Io; 440 K for Mercury; 750 K for Venus
- h = 0 for Io, Moon, Mars, Mercury; 1000 for Venus
- Low-Ti Basalt: To = 1300 ° C, Tg = 1100 ° C
- Anorthosite: To = 1300 ° C, Tg = 1000 ° C

Planetary Cases

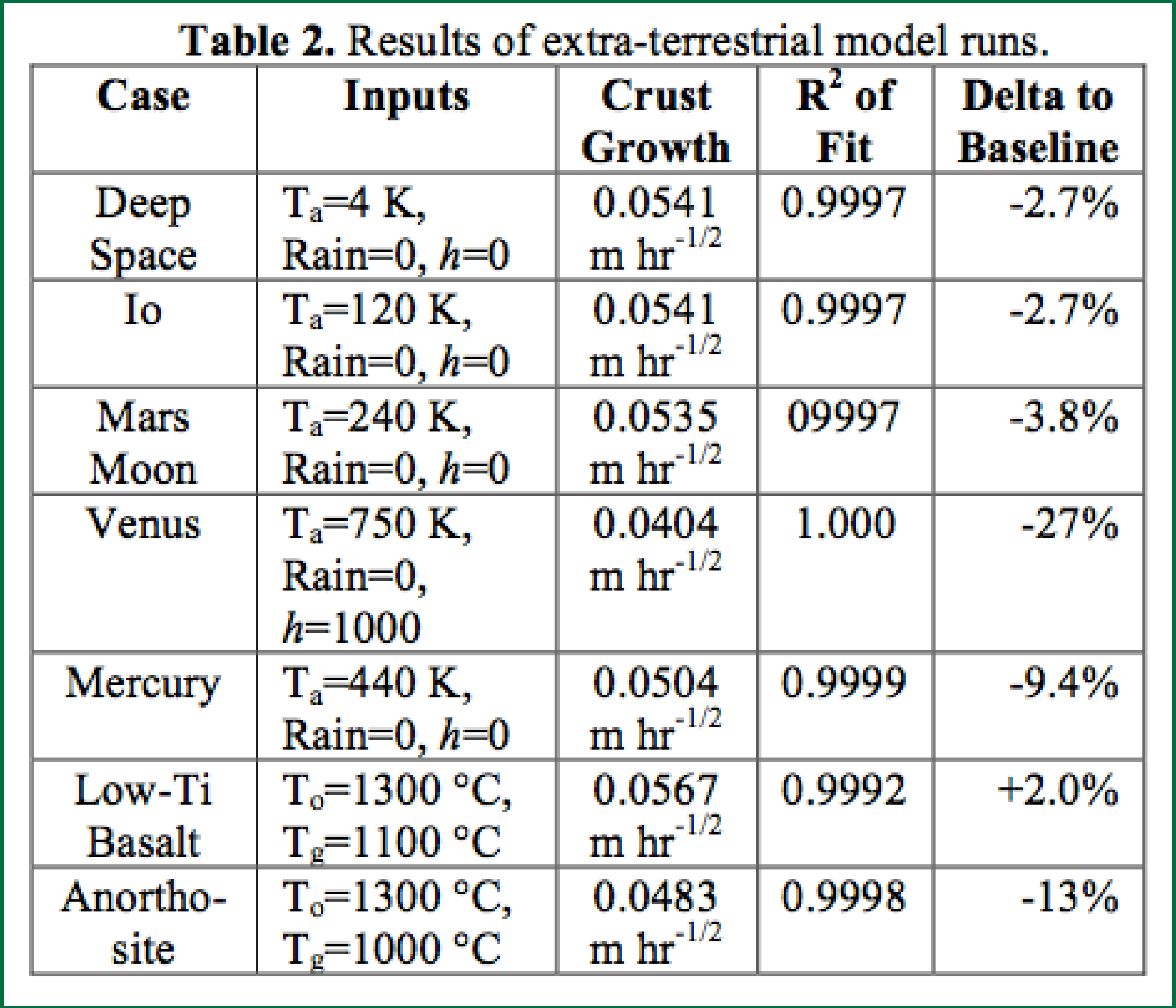


Table 2. Results of extra-terrestrial model runs.

Case	**Inputs**	**Crust Growth**	**R^2 of Fit**	**Delta to Baseline**
Deep Space	T_a=4 K, Rain=0, h=0	0.0541 m $hr^{-1/2}$	0.9997	-2.7%
Io	T_a=120 K, Rain=0, h=0	0.0541 m $hr^{-1/2}$	0.9997	-2.7%
Mars Moon	T_a=240 K, Rain=0, h=0	0.0535 m $hr^{-1/2}$	09997	-3.8%
Venus	T_a=750 K, Rain=0, h=1000	0.0404 m $hr^{-1/2}$	1.000	-27%
Mercury	T_a=440 K, Rain=0, h=0	0.0504 m $hr^{-1/2}$	0.9999	-9.4%
Low-Ti Basalt	T_o=1300 °C, T_g=1100 °C	0.0567 m $hr^{-1/2}$	0.9992	+2.0%
Anortho-site	T_o=1300 °C, T_g=1000 °C	0.0483 m $hr^{-1/2}$	0.9998	-13%

Conclusion

- Crust thickness versus time relationship is very robust and should give reliable results for the Moon – EXCEPT –
  - Entrained blocks are not modeled
  - Impact melts can be superheated

- Flow morphology can help constrain rheology which is affected by entrained clasts and melt temperature

Rheology constraints?

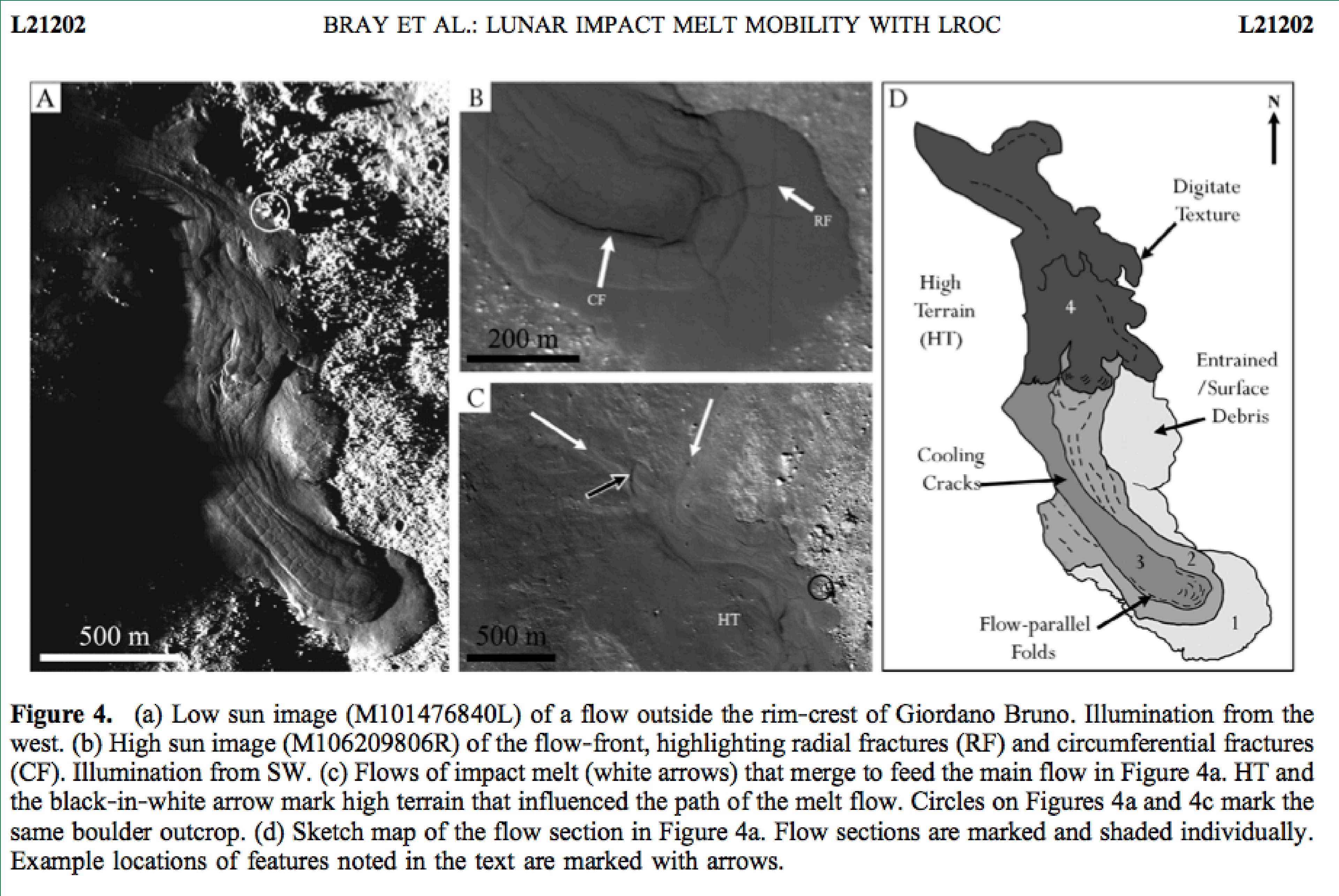


Figure 4. (a) Low sun image (M101476840L) of a flow outside the rim-crest of Giordano Bruno. Illumination from the west. (b) High sun image (M106209806R) of the flow-front, highlighting radial fractures (RF) and circumferential fractures (CF). Illumination from SW. (c) Flows of impact melt (white arrows) that merge to feed the main flow in Figure 4a. HT and the black-in-white arrow mark high terrain that influenced the path of the melt flow. Circles on Figures 4a and 4c mark the same boulder outcrop. (d) Sketch map of the flow section in Figure 4a. Flow sections are marked and shaded individually. Example locations of features noted in the text are marked with arrows.