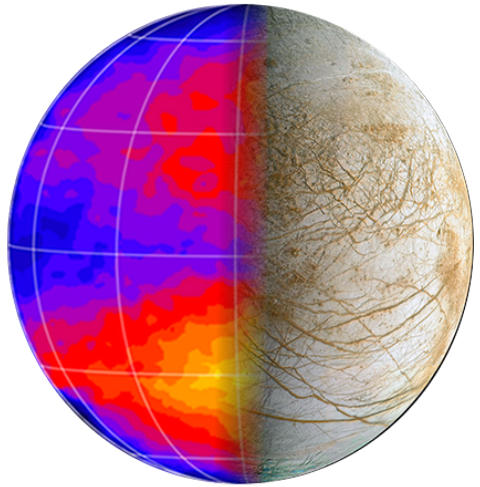

Occurrence and Detectability of Thermal Anomalies on Europa

Predictions based on Resurfacing Rates and Thermal Models

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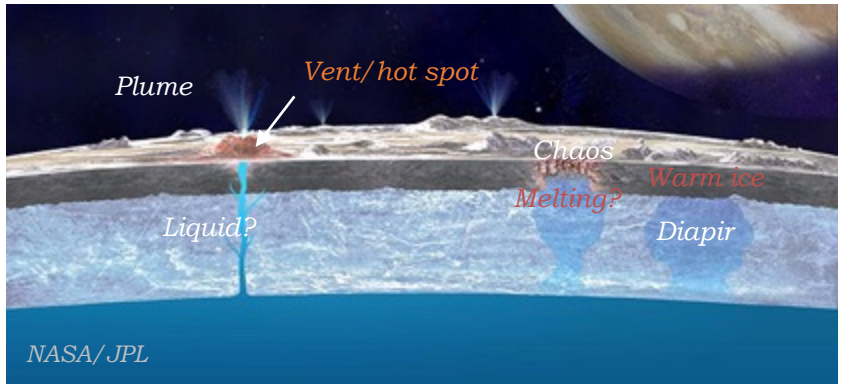
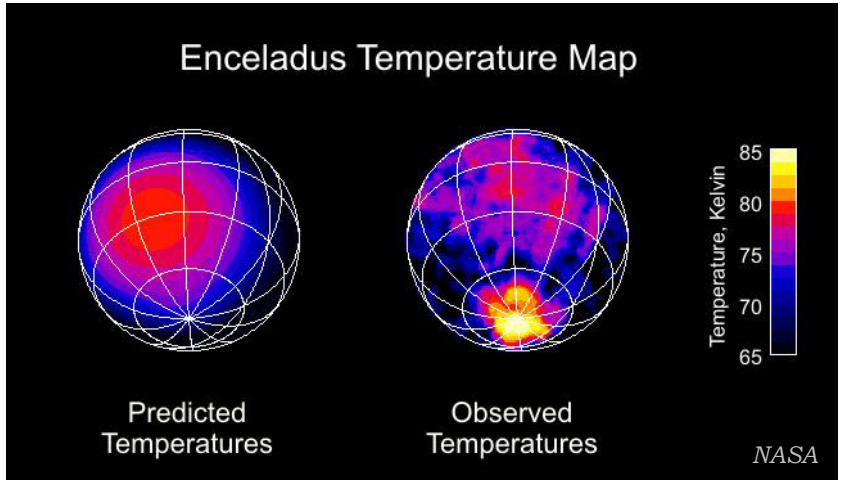
[3]Southwest Research Institute
[4]Planetary Science Institute
[5]Applied Physics Laboratory, Johns Hopkins University

Motivation

- Recent endogenic activity is likely [1] given Europa's young surface age of < 100 Myr [2], and tidal heating [3, 4].
- Enceladus: case in point
- Temperature is a fundamental indicator of activity [5].
- Possible thermal anomalies [6, 7] on Europa could be associated with geologic features such as **lenticulae, chaos, ridges and bands**.

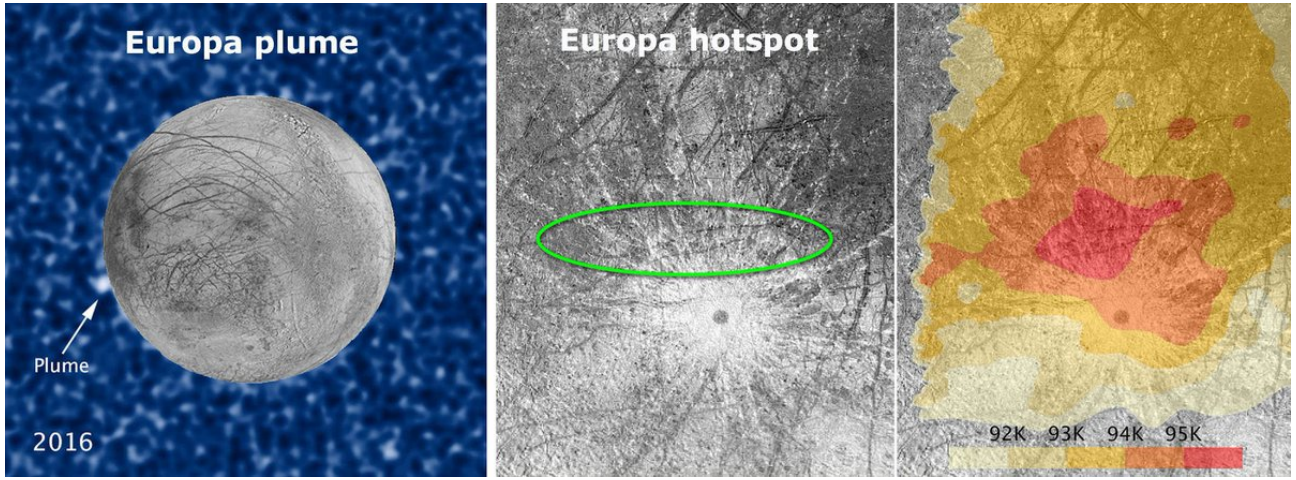




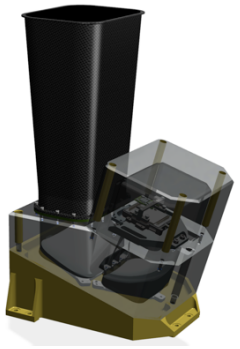
Spencer et al. (2006)

E-THEMIS: Measuring Endogenic Heat

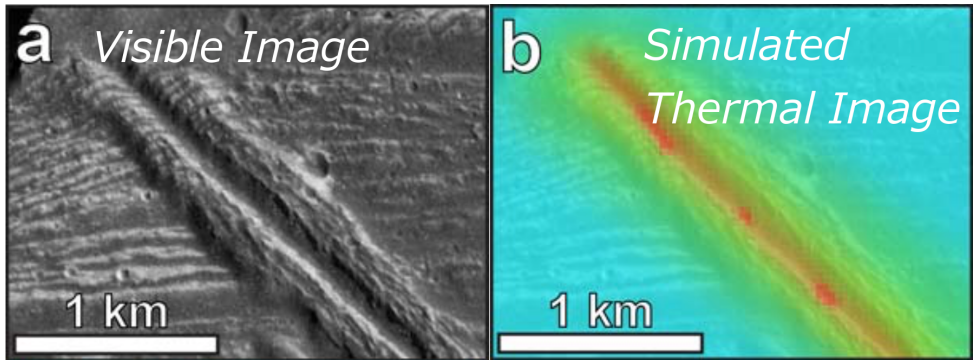
- Surface temperatures indicate:
  - Thermophysical properties (thermal inertia, block abundance, roughness, albedo)
  - Heat flow
    - Background (~10 – 100 mW m^{-2})
    - Anomalies (e.g., Enceladus, > 1,000 mW m^{-2})



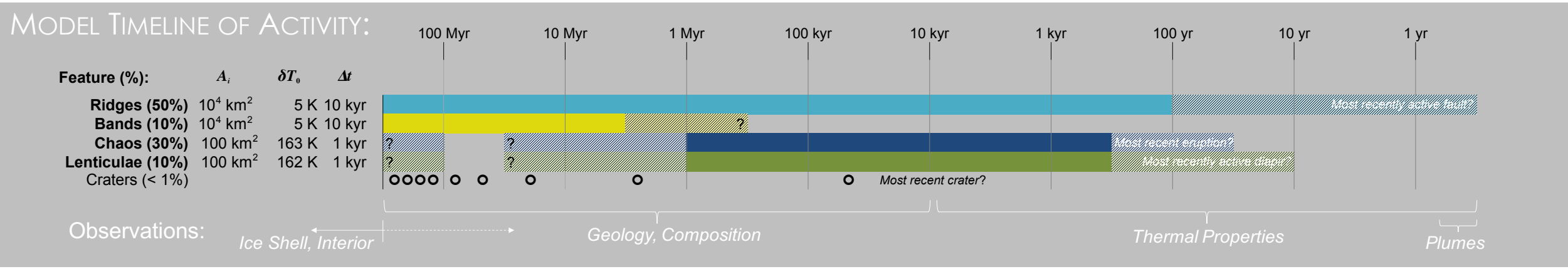
Sparks et al. (2017)



E-THEMIS



Approach: Model Timeline of Activity



Methods: Probability of Resurfacing Events

- Probability of *N* events during interval Δ*t*, assuming events are independent:

$$P(\Delta t, N) = \left(\frac{\Delta t}{\tilde{t}_i}\right)^N \frac{e^{-\Delta t/\tilde{t}_i}}{N!}$$

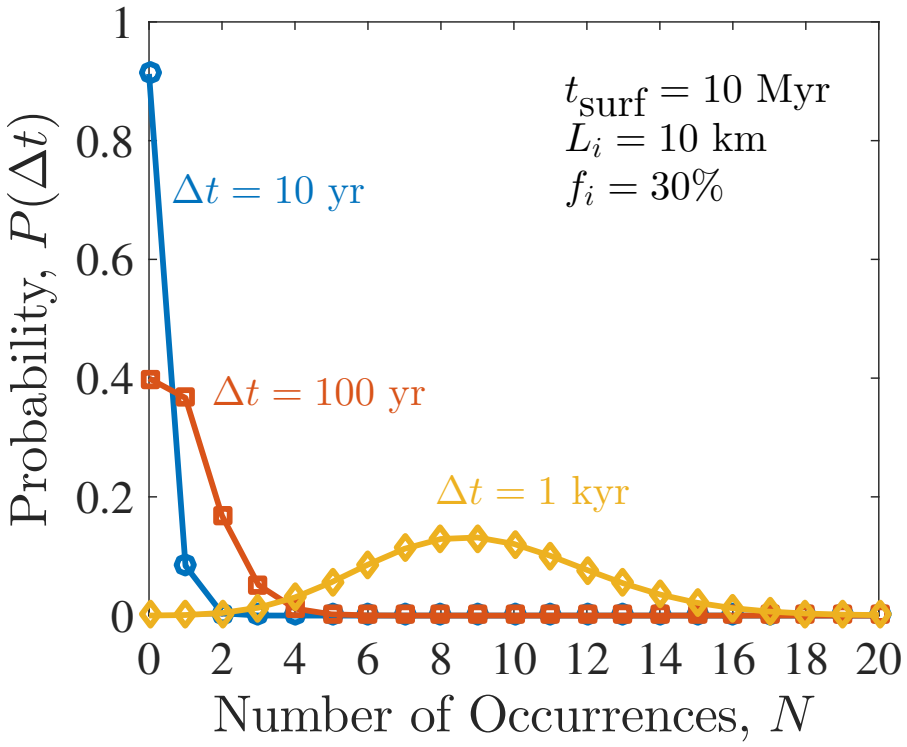


Figure: *Probability of* N *events occurring during the specified time interval* Δt*, representing the detectable lifetime for a given thermal anomaly with dimension 10 km.*

Methods: Resurfacing Rates

- Global average resurfacing rate:

$$\langle \dot{A} \rangle = A / t_{\text{surf}} \sim 1 \text{ km}^2 \text{ yr}^{-1}$$

- Average occurrence rate for feature *i* with area A_i (= L_i^2) whose total population occupies a fraction of Europa's surface f_i:

$$\langle R_i \rangle = f_i \langle \dot{A} \rangle / A_i$$

- Average time between events *i*:

$$\tilde{t}_i = \langle R_i \rangle^{-1} = \frac{A_i}{f_i \langle \dot{A} \rangle}$$

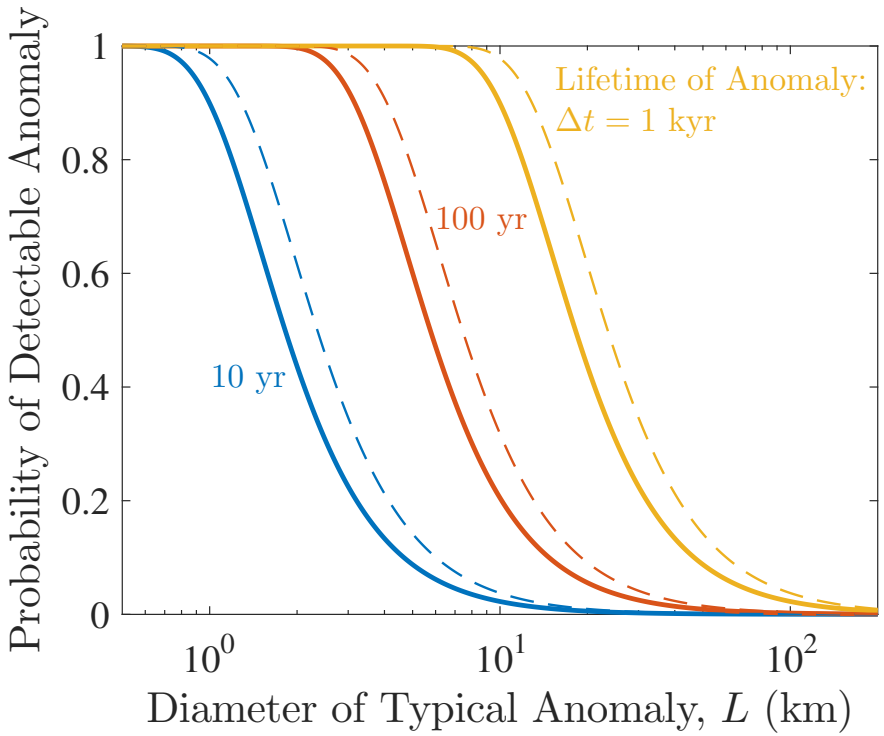


Figure: *Probability of* at least one event *occurring during the specified time interval* Δt, *representing the detectable lifetime for a given thermal anomaly size. Solid lines indicate* f_i = 0.3; *dashed lines indicate* f_i = 0.5.

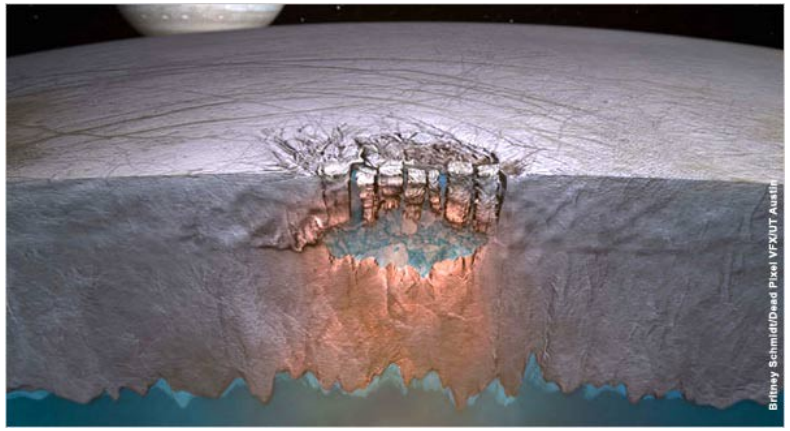
Methods: Temperature Anomalies

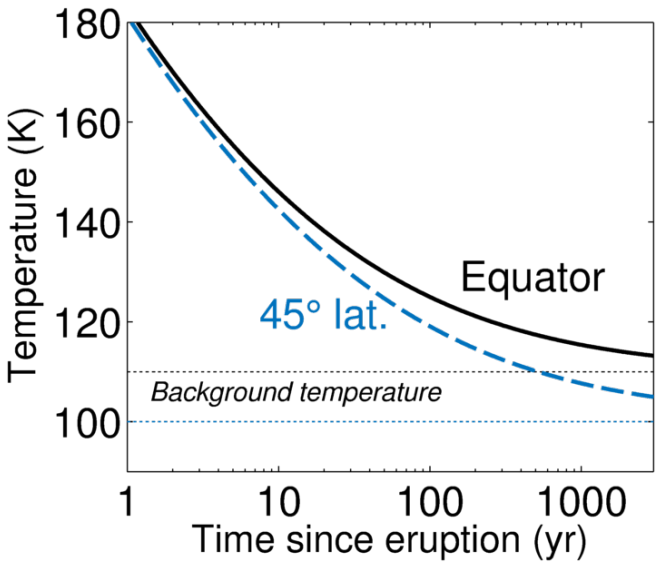
- Numerical thermal models for four feature types: Ridges, Bands, Chaos, Lenticulae
- Buried **liquid layer** with temperature T_l produces surface anomaly:

$$\delta T \sim k \frac{T_l - T_s}{4\sigma T_s^3 z}$$

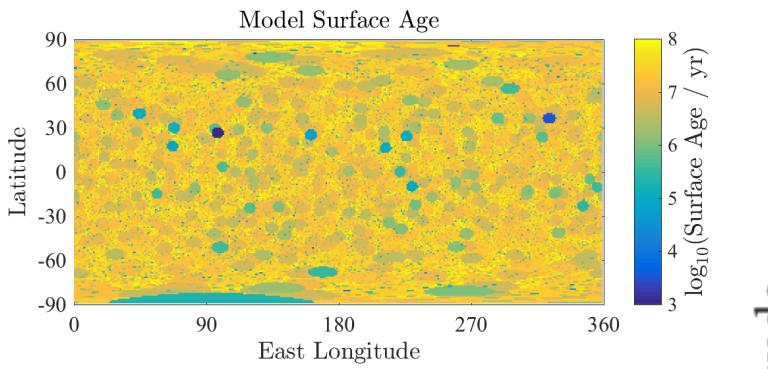
  - **Maximum detectable depth: ~0.1 – 1 km**

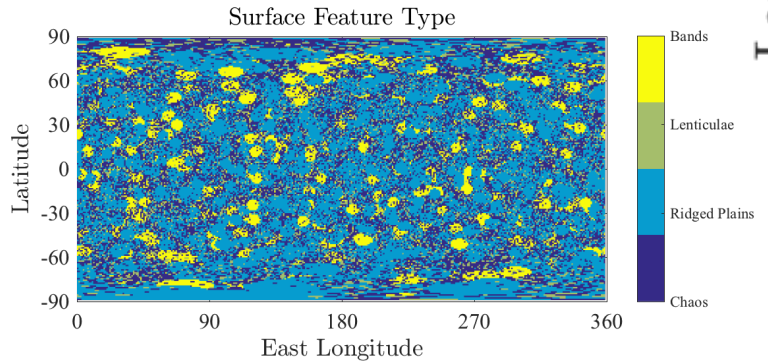
- Shear heating [13]: Δt ~ **10 kyr**, δT ~ 5 K
- Freezing and cooling of liquid water ~10 – 100 m thick: detectable lifetime Δt ~ **0.01 – 1 kyr** [6]
- Chaos model: Δt ~ **1 – 10 kyr**, δT ~ 163 K (melting) [6]

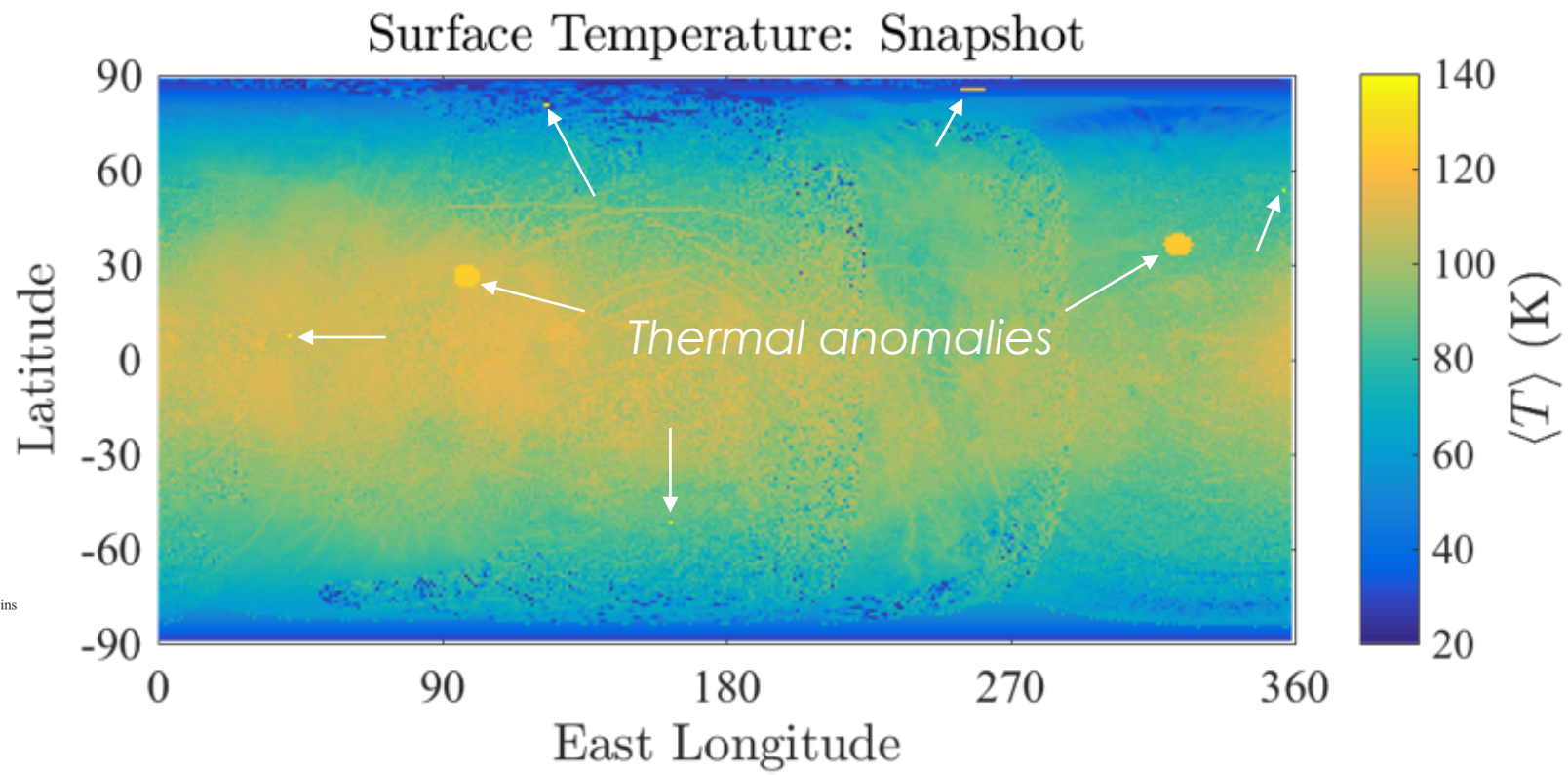




Results

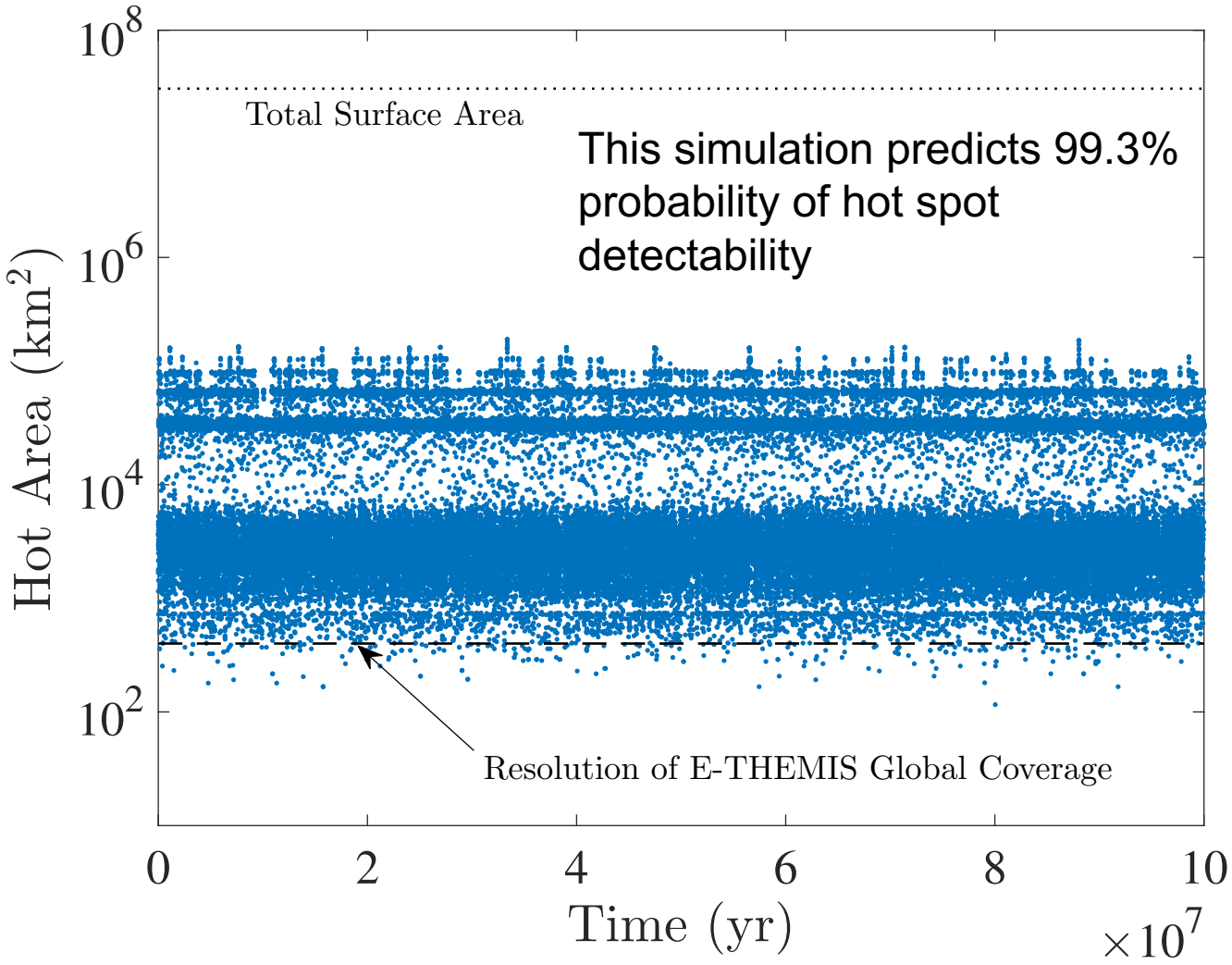


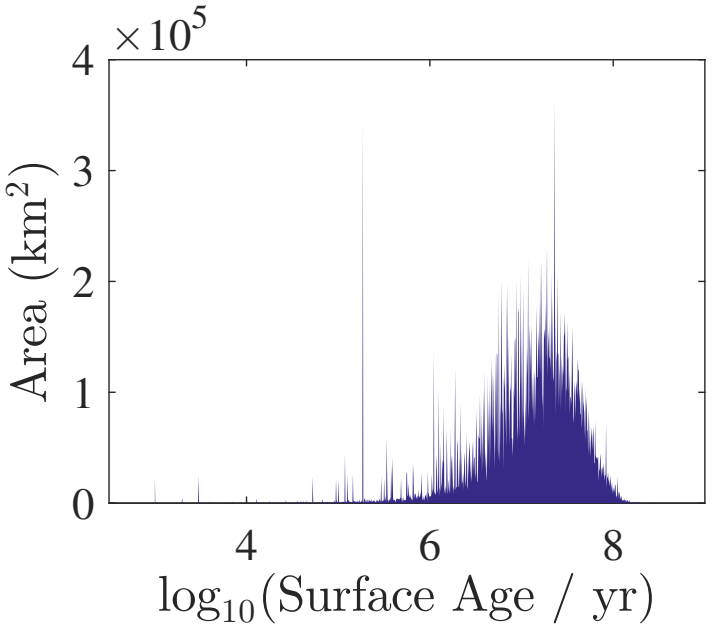




- Example simulations, total duration 200 Myr.
- Surface temperature “snapshot” is diurnal mean temperature, arbitrary instant in time.

Results





***Left**: Each point represents one instant in time; points above the dashed line are detectable.*

Conclusions

- Thermal anomalies are expected for several modeled styles of resurfacing: emplacement of warm ice or liquid water, or shear heating on faults with sufficient dissipation [13]

- Subsurface heat sources (e.g., liquid water) detectable within ~100 m to 1 km

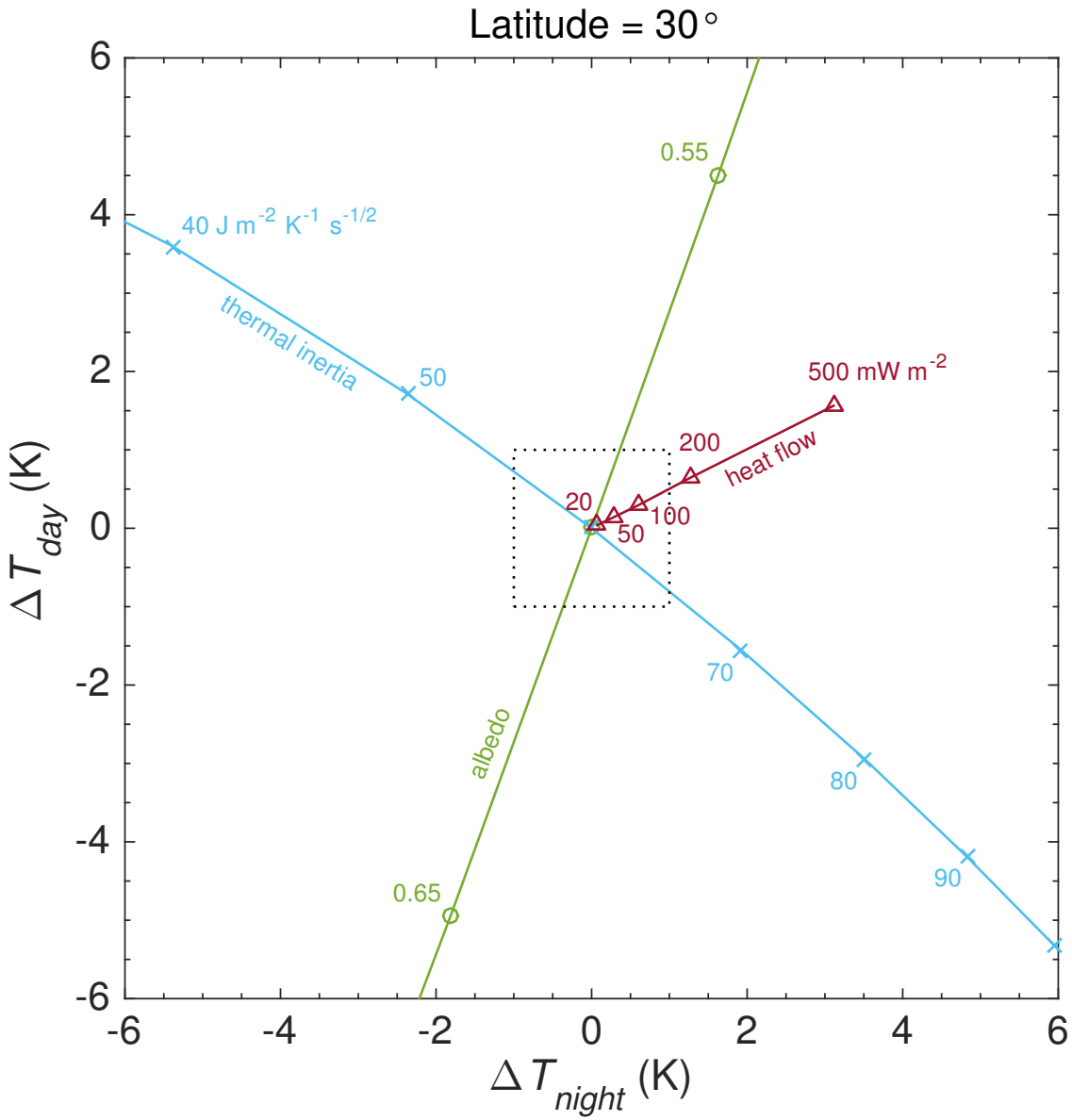
- Daytime and nighttime E-THEMIS measurements needed; also solar albedo from EIS (+ MISE?)

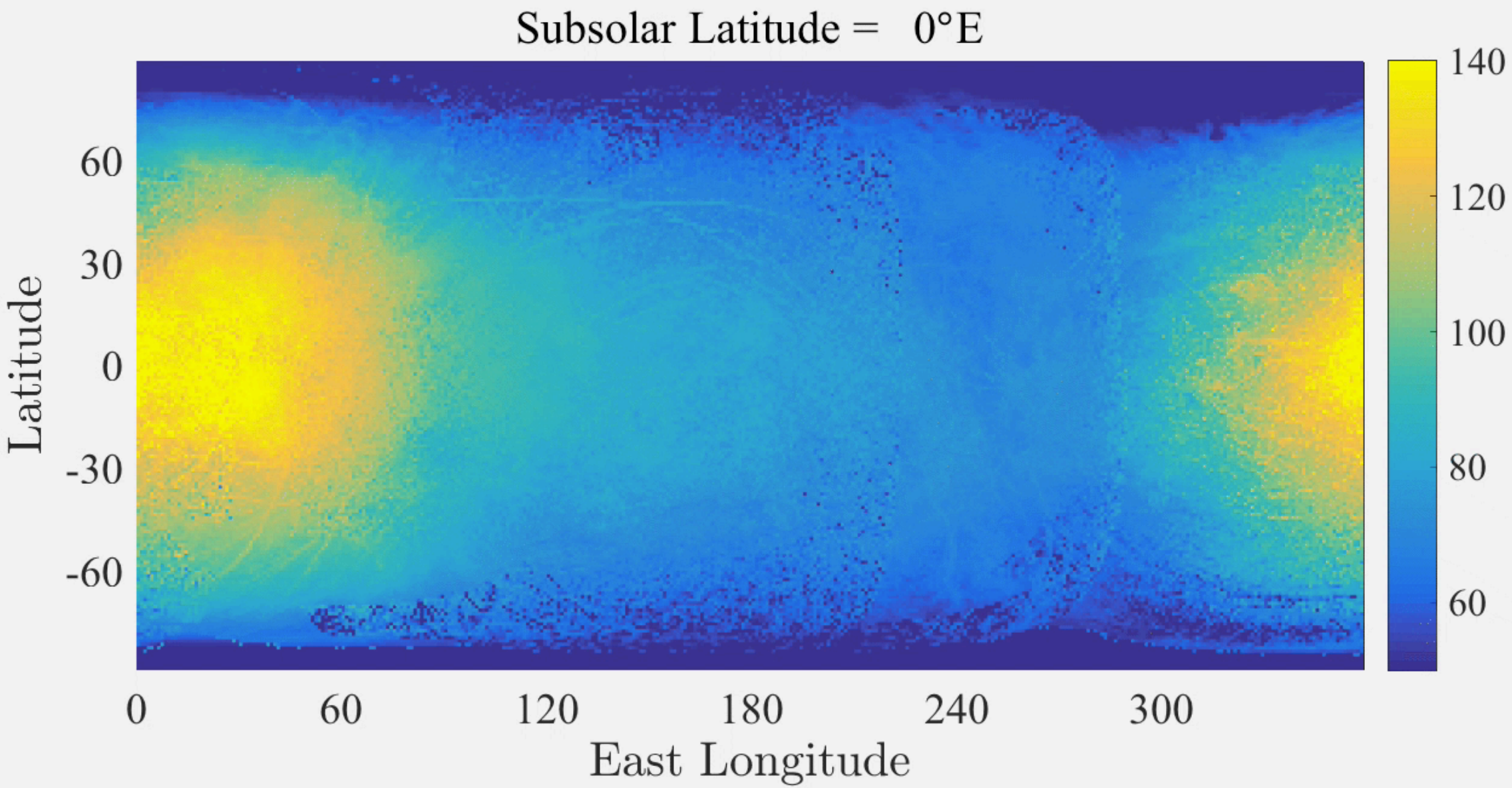
- Background heat flow could be measured if >200 mW m^{-2} at the equator, or >100 mW m^{-2} at the pole

Future Work

- More realistic geometries for thermal anomalies (e.g., lineae, or “patchy” chaos)
- More realistic proportions of surface features
- 2-d or 3-d thermal models for hot spots
- Assessment of number of observations and local times needed from E-THEMIS to distinguish hot spots from other features

Extras


Latitude = 30°
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6
Δ T_day (K)
Δ T_night (K)
40 J m^-2 K^-1 s^-1/2
thermal inertia
50
70
80
90
0.55
0.65
albedo
500 mW m^-2
200
heat flow
20
50
100


Subsolar Latitude = 0°E
Latitude
60
30
0
-30
-60
0
60
120
180
240
300
East Longitude
140
120
100
80
60