Diffuse Flank Degassing Controls the Edifice-Scale Thermal Anomaly Preceding the 2006 Augustine Eruption

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1 Thermal Anomaly Signals at Augustine

How early before eruption does a detectable thermal anomaly emerge ?

Fig 1(a): Conduit Temperature (monthly average) vs MODIS-Based Edifice-Scale Thermal Anomaly (Girona et al.)

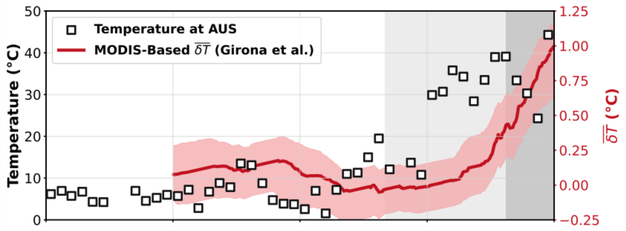
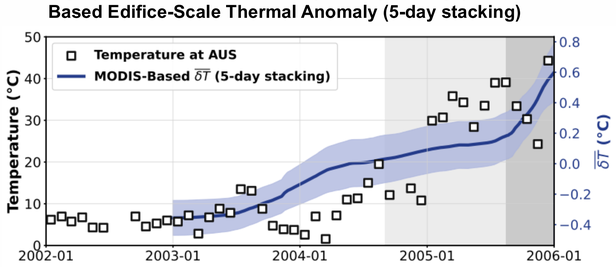
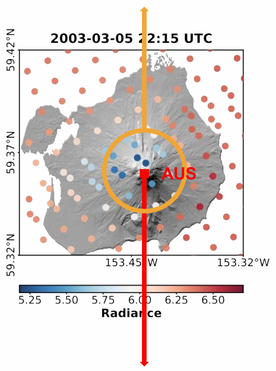


Fig 1(b): Conduit Temperature (monthly average) vs MODIS-Based Edifice-Scale Thermal Anomaly (5-day stacking)



Edifice-scale

Integrated thermal behavior of the volcanic edifice. Represents the temperature pattern over a broader area. Spatial scale: kilometers.

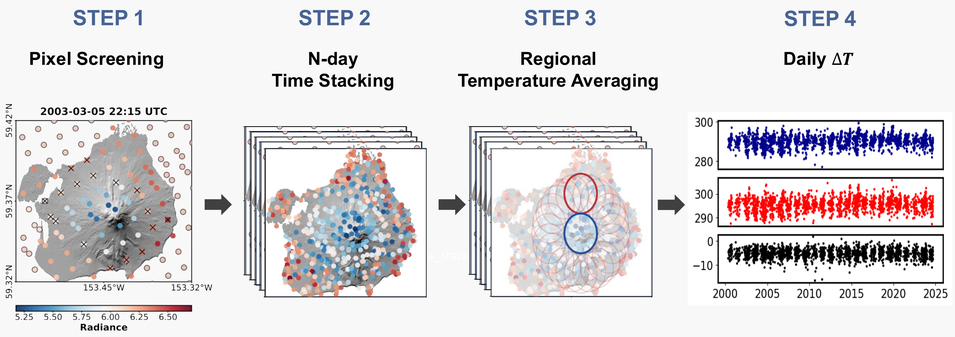


Conduit-scale

Localized conduit thermal signal. Measured by field instruments or high-resolution satellites. Spatial scale: meters to tens of meters

Time-Stack MODIS-Based Thermal Anomaly Calculation

From raw MODIS TIR images to edifice-scale thermal anomaly



- Remove cloudy and water pixels. Only valid land pixels are retained for further analysis
- **Dataset:** MOD021KM / MYD021KM, **Band 31** $(10.78–11.28\ \mu m)$
- **Spatial resolution:** ~ 1km

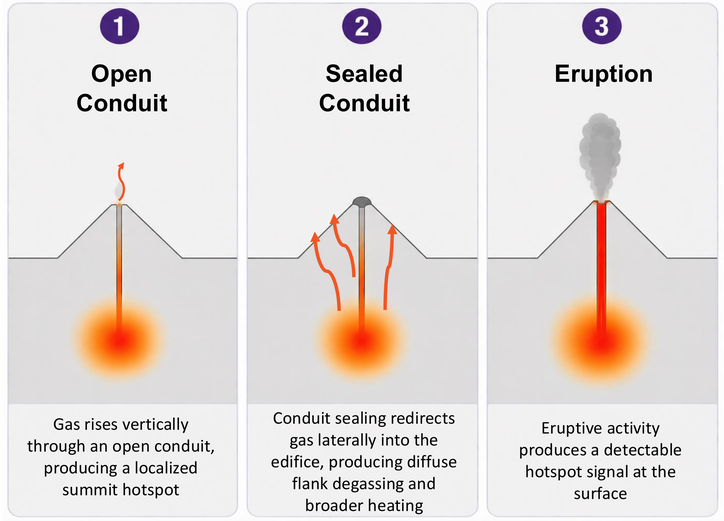
- Combine all valid pixels within a **n-day window** into one image

- Define **edifice** and **background** regions.
- Compute the mean temperature of valid pixels within each region

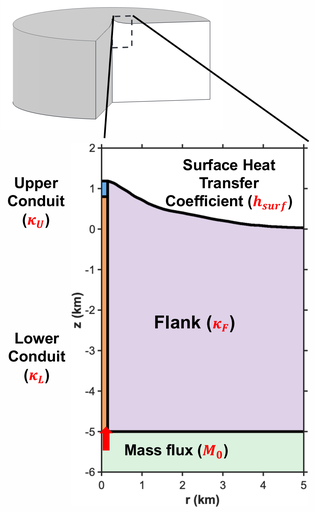
- $\Delta T = T_{edifice} - T_{background}$
- Build the daily thermal anomaly time series

2 What Drives the Thermal Anomaly

Can diffuse flank degassing drive the edifice-scale thermal anomaly?



3 Testing the Mechanism with Numerical Modeling



Open conduit

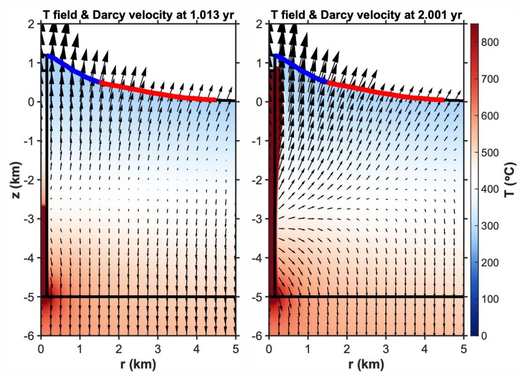
$\kappa_U = \kappa_L = 10^{-10} m^2$

$M_0 = 1.7\ kt/d$

Sealed conduit

$\kappa_U = 10^{-13} m^2$

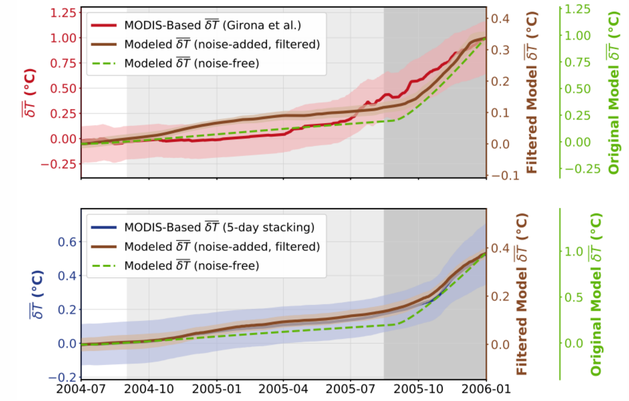
$M_0 = 15.3\ kt/d$



The model follows Zhan et al. (2022) and further incorporates permeability in the volcanic flanks, allowing laterally redirected gas and heat transport through the edifice.

4 Model vs Observations

How well does the model reproduce the observations ?



Observations

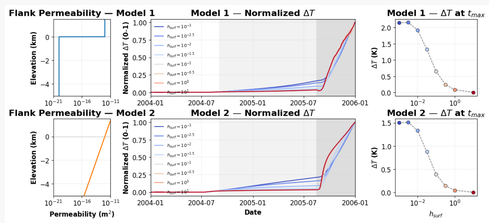
- Red: MODIS (Girona et al.)
- Blue: MODIS, 5-day stacking, this work (shading = 95 % CI)

Modeled

- Green dashed: raw model.
- Brown: model + noise from 24 reference regions, filtered identically to observations.

5. Main Takeaways

- ✓ At Augustine, vent warming began >1 year before eruption, while the edifice-scale MODIS anomaly emerged ~6 months later, consistent with sealing-driven diffuse flank degassing.
- ✓ Broad satellite thermal anomalies can track edifice-wide changes in heat and degassing during unrest.
- ✓ Heat transfer and flank permeability mainly control anomaly amplitude, while timing and overall shape remain robust.



References

[1] Girona, T., Realmuto, V. and Lundgren, P., 2021. Large-scale thermal unrest of volcanoes for years prior to eruption. Nature Geoscience, 14(4), pp.238-241.

[2] Zhan, Y., Le Mével, H., Roman, D.C., Girona, T. and Gregg, P.M., 2022. Modeling deformation, seismicity, and thermal anomalies driven by degassing during the 2005-2006 pre-eruptive unrest of Augustine Volcano, Alaska. Earth and Planetary Science Letters, 585, p.117524.

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