Illuminating the Meteorological Modulation of Eruptions of Strokkur Geyser, Iceland

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Eibl et al. 2024, Volcanica

Eibl, E. P. S., Hamzaliyev, S., Petersen, G. N., Hersir, G. P., (in review with Scientific Reports)
Winds of Change: Meteorological Influences on Strokkur's Geyser Eruptions, Iceland

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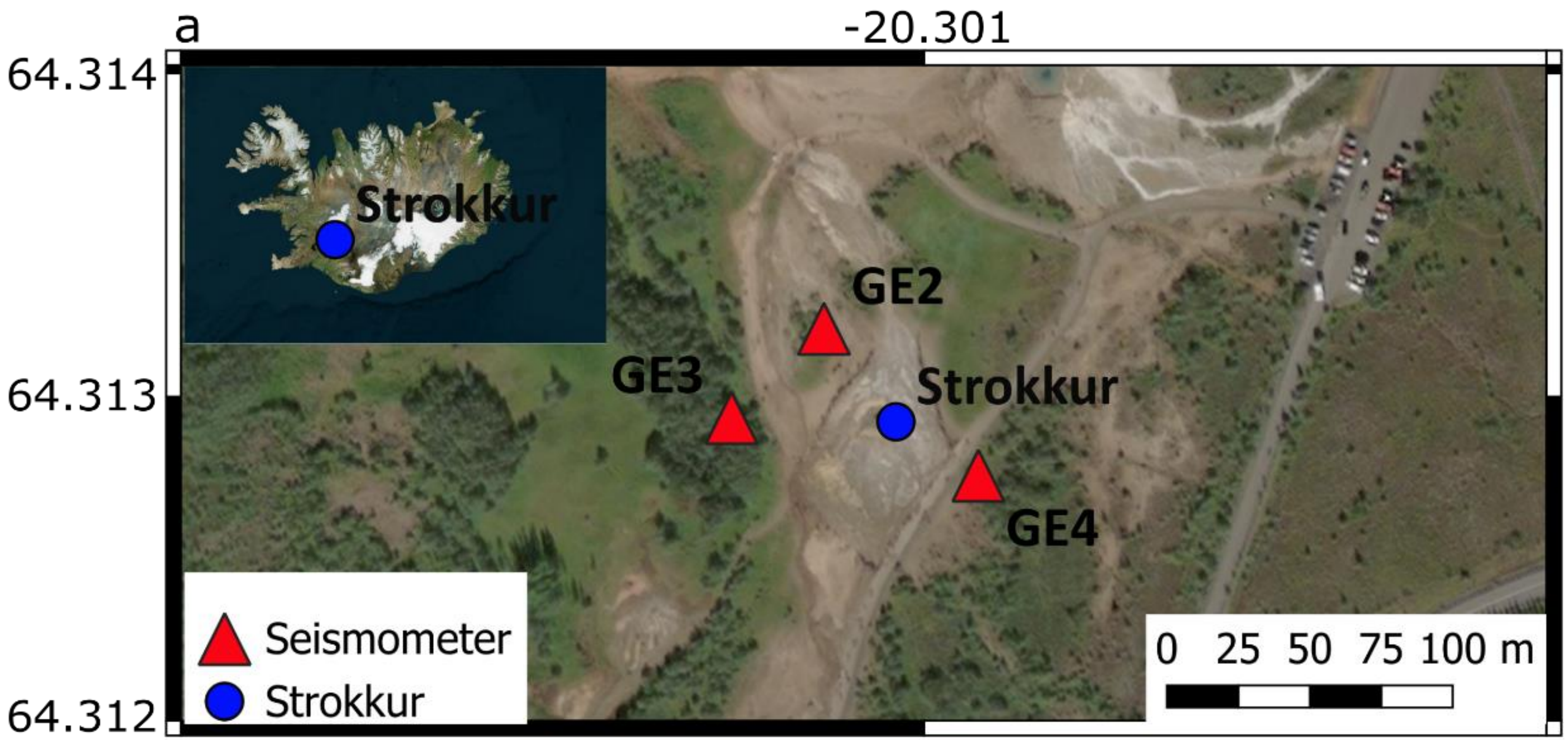
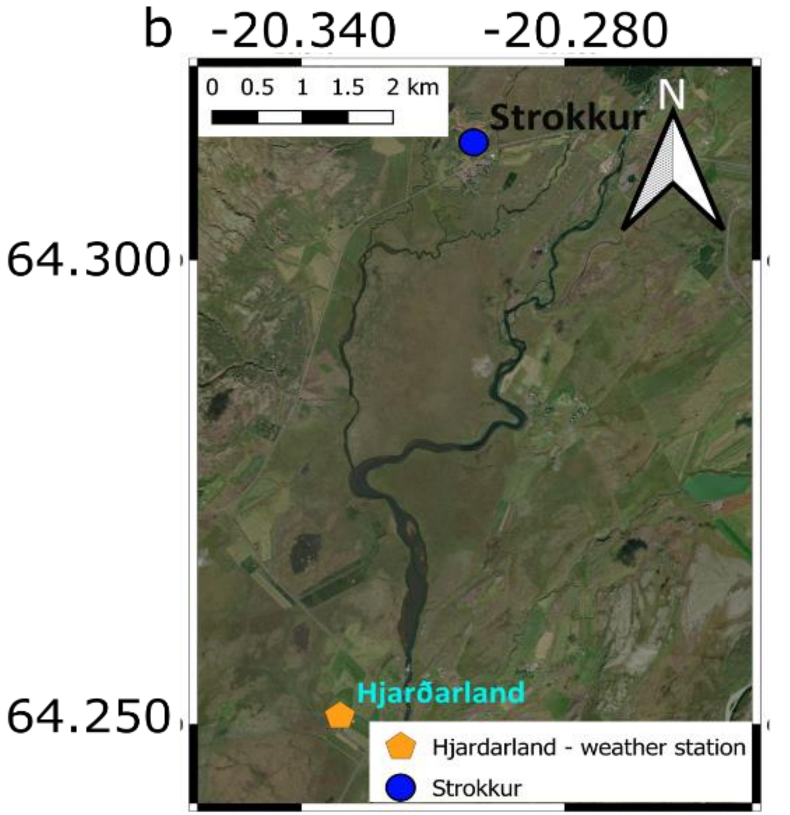
Monitoring Strokkur using seismometers and a weather station

<u>Recorded Data:</u> 6/2017 – 6/2018
3/2020 – 9/2023





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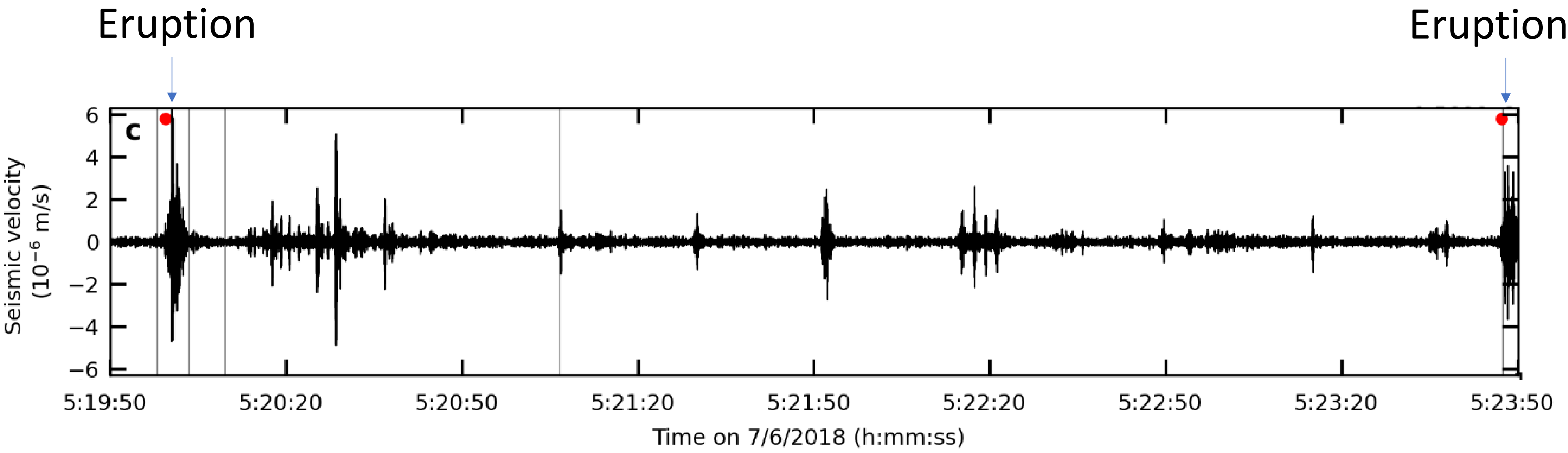
Eruptions create seismic ground motion



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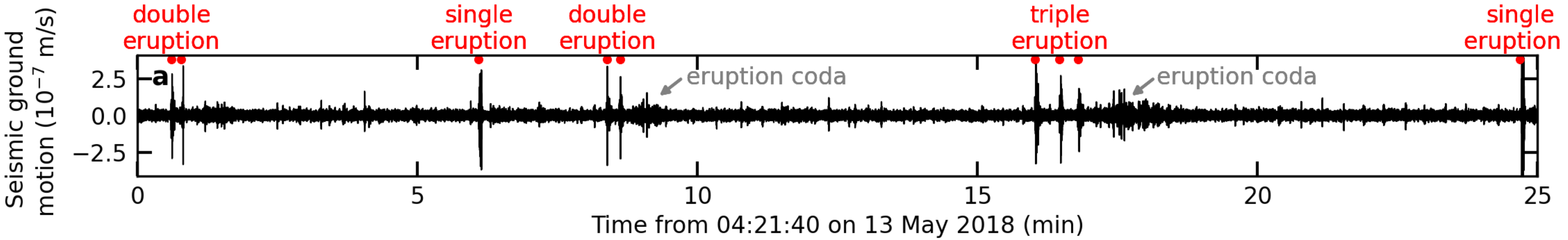
Eruptions are regular …



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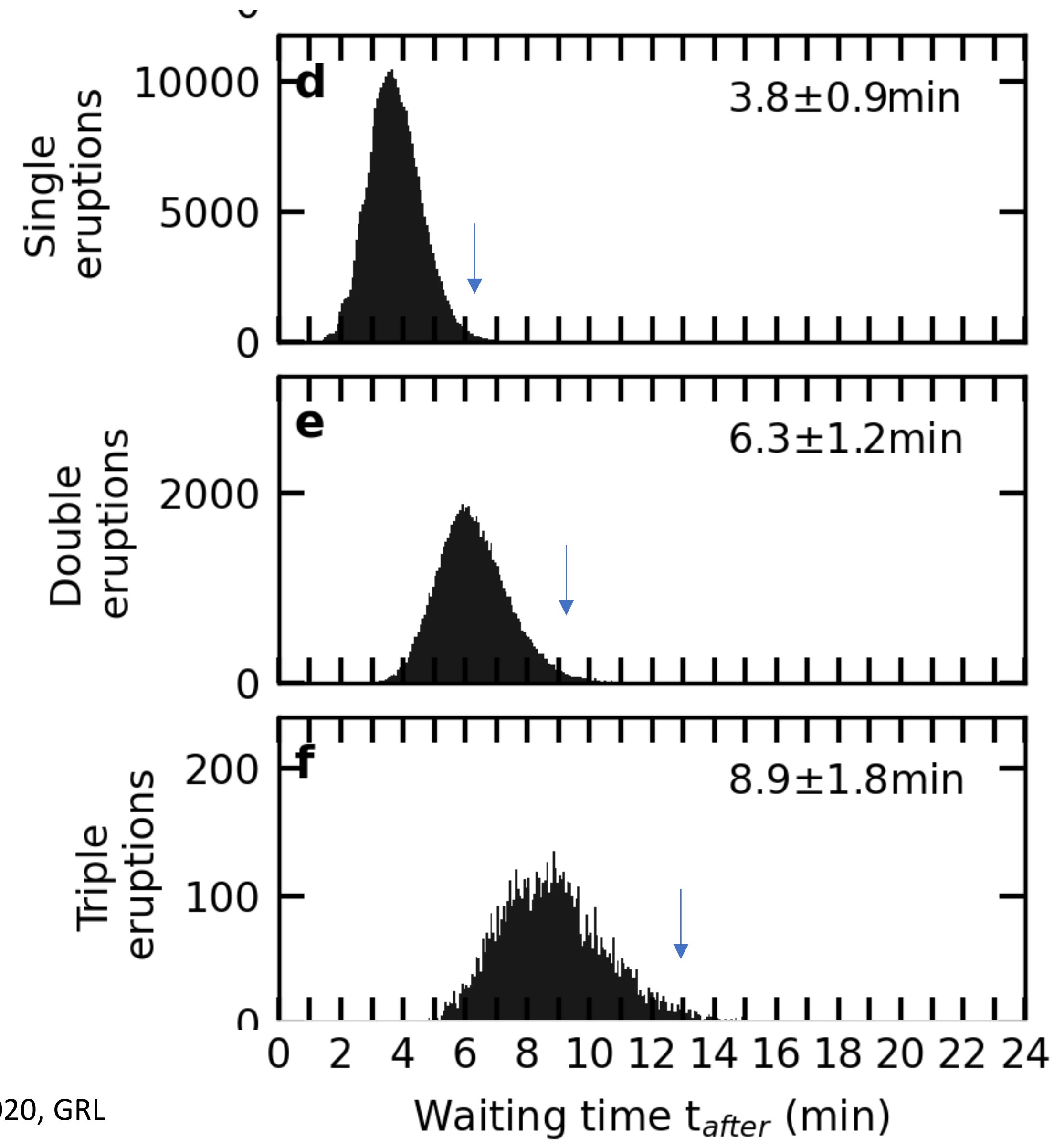
… but sometimes 'late'



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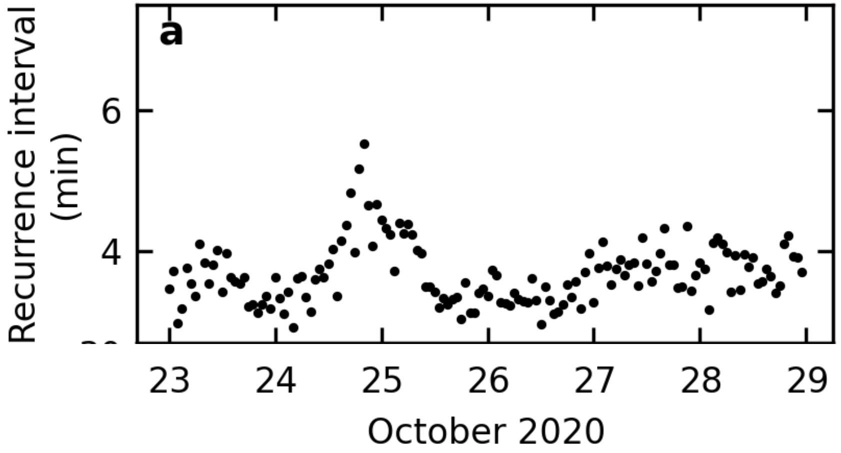
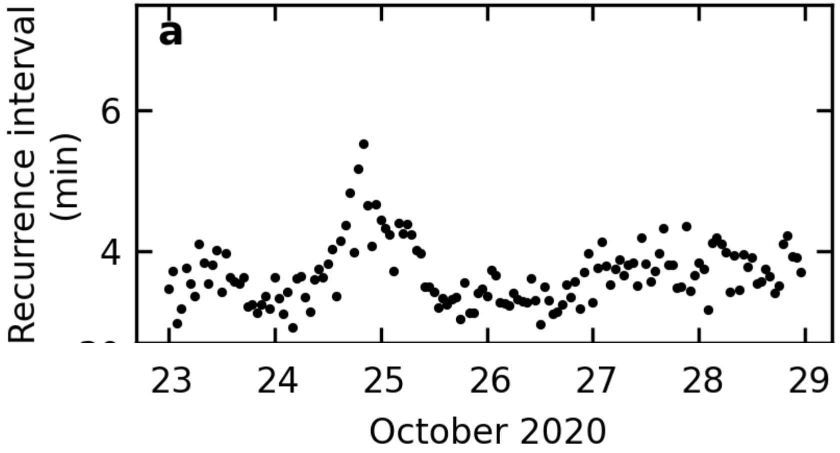
The recurrence interval correlates with the wind speed





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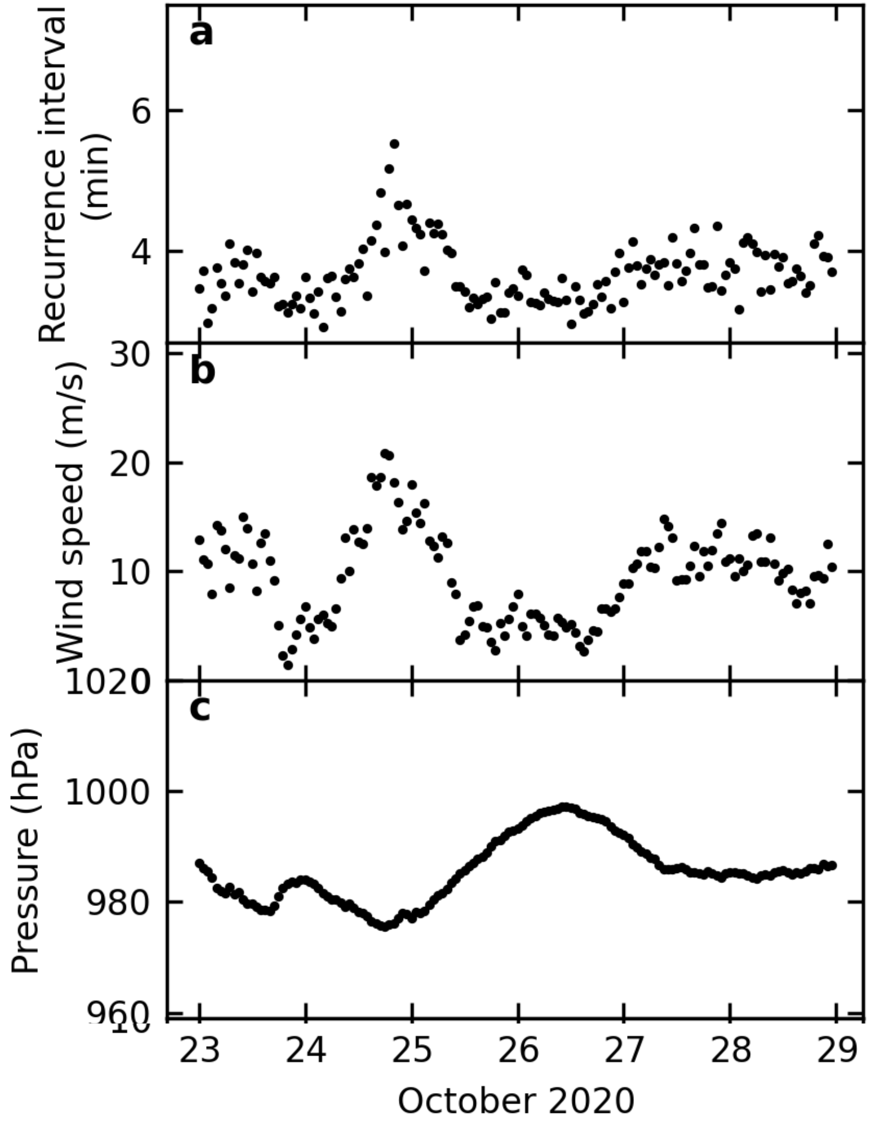

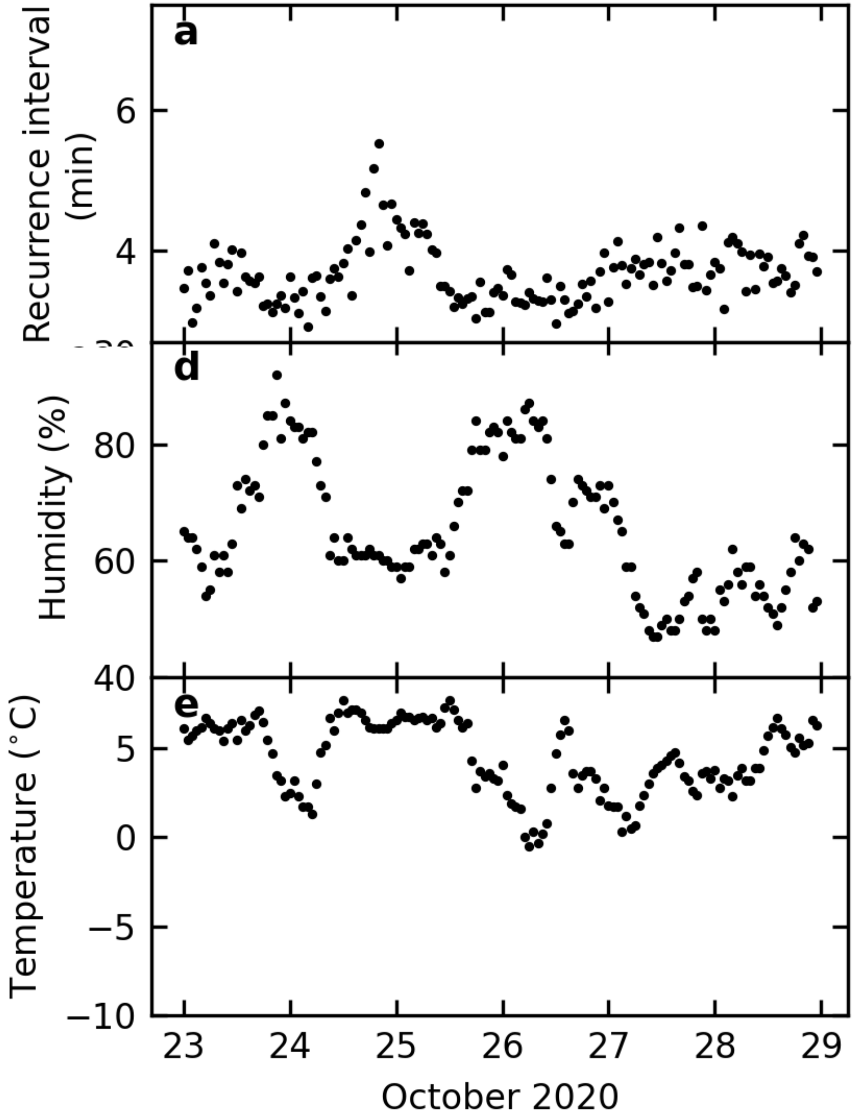

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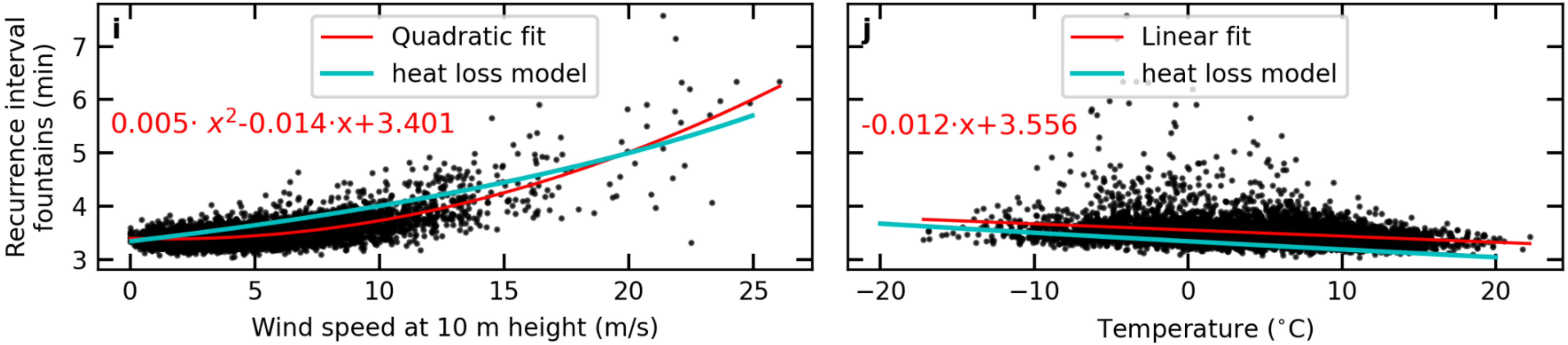
High wind speeds and low air temperatures cause fewer eruptions



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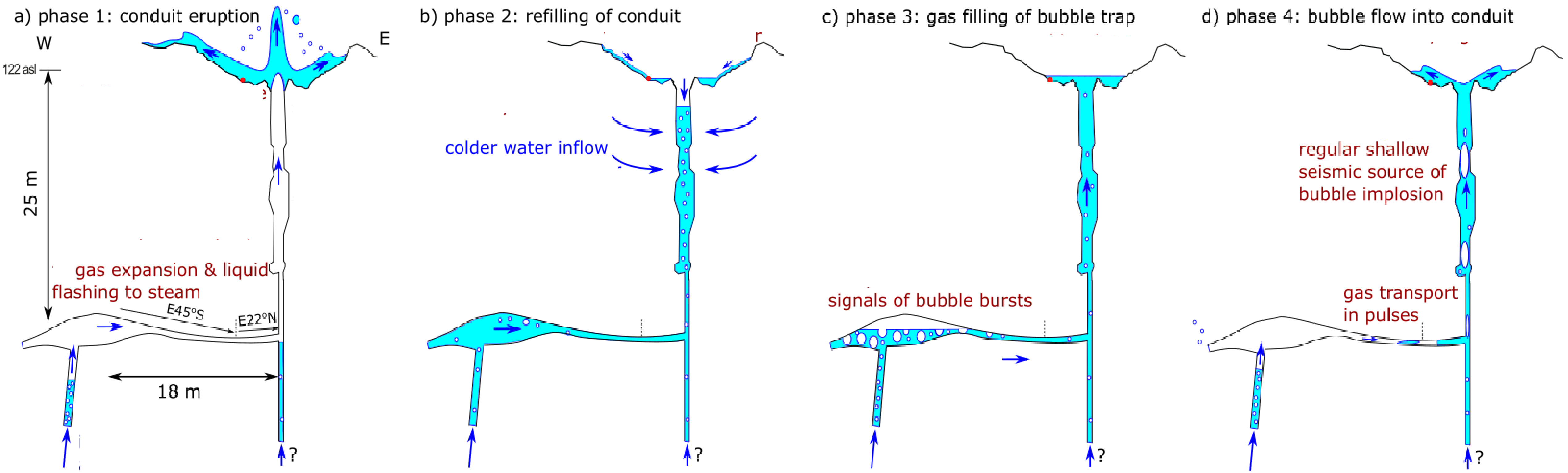
Four phases of the eruptive cycle of Strokkur



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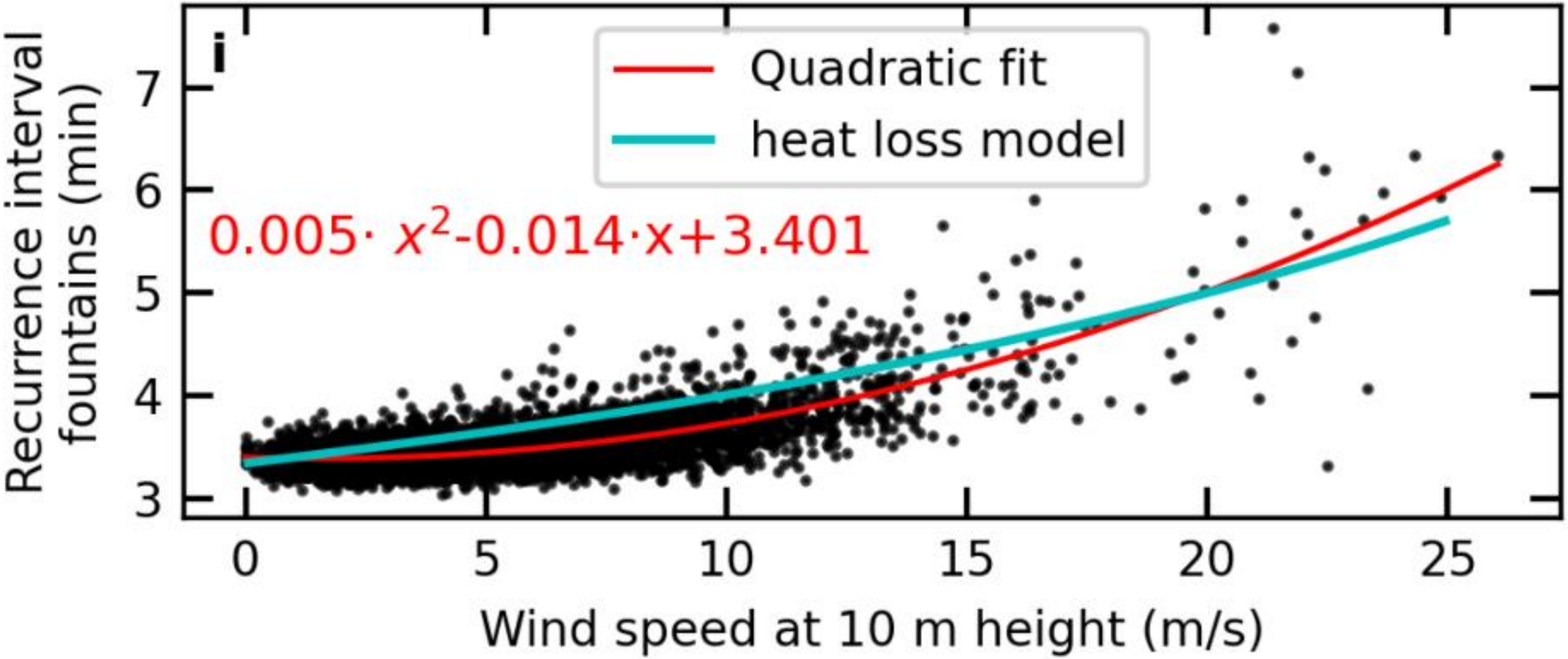
In which of the four phases do we see this trend?



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Wind speed affects the bubble trap

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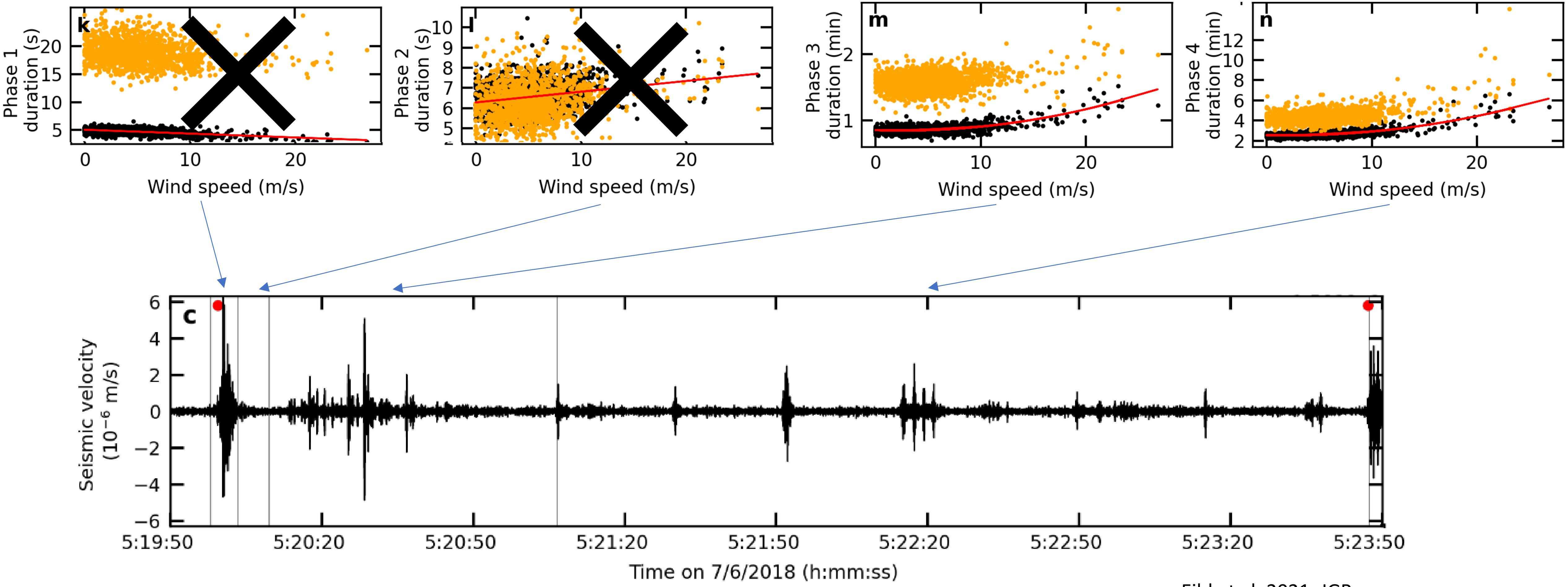

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Take home key points

- Catalog with >650 000 water fountains published from a 4.5-year dataset
- High wind speeds strongly decrease the eruption frequency of pool geyser Strokkur, Iceland.
- At high wind speed more heat and water is lost from the catchment.
- Wind affects the system down to the bubble reservoir at 24 m depth.

Take home key points & References

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Eibl, E. P. S., Hersir, G. P., Petersen, G. N. (2025) Catalogues of weather parameters, water fountains and eruptive cycle phases at the Strokkur Geyser, Iceland from 2017-2018 and 2020-2023. GFZ Data Services. DOI: 10.5880/fidgeo.2025.015

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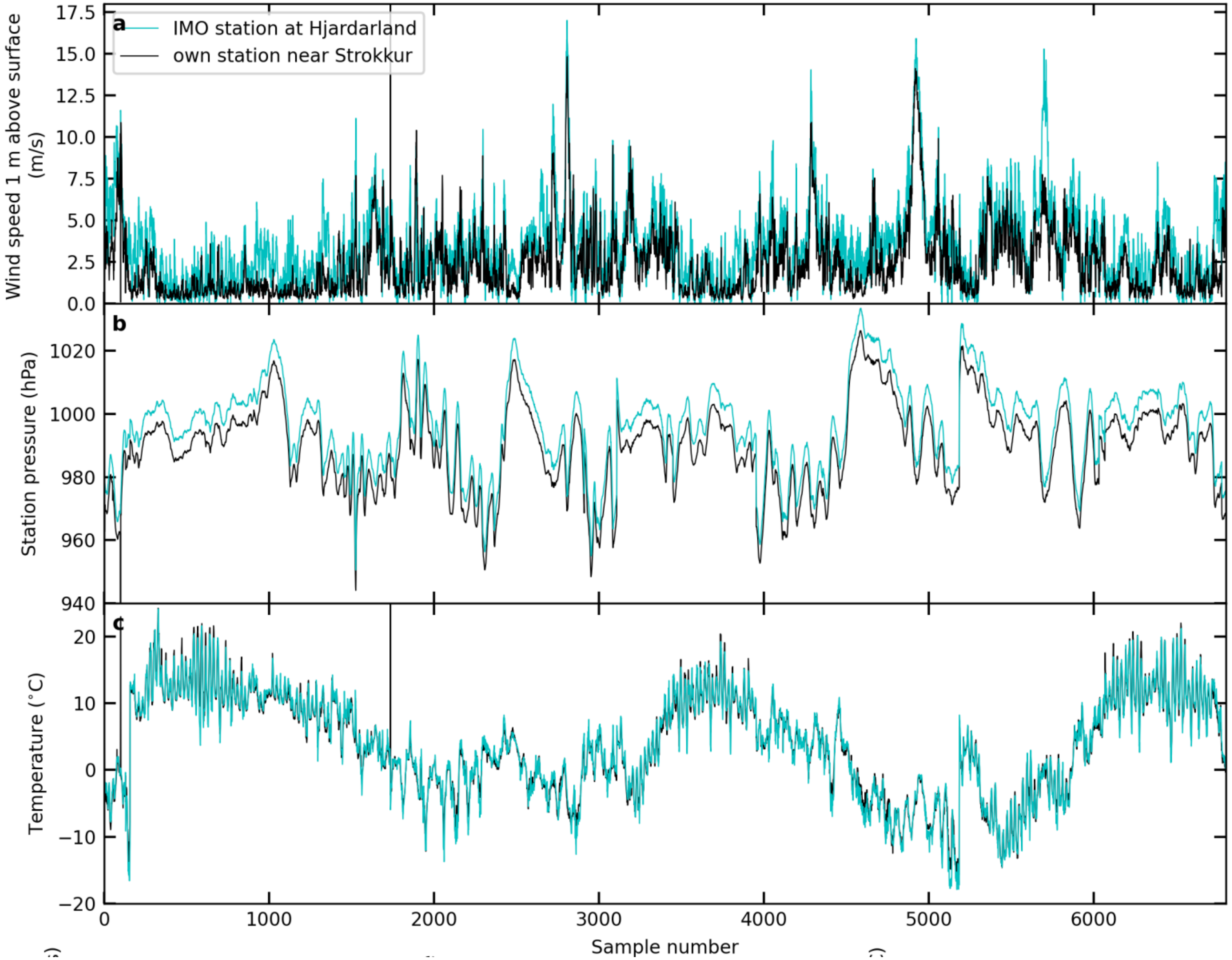
Our vs. IMO weather sensor



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Eruption distribution 2017-2018

- 144 095 water fountains
- 97 219 single eruptions
- 19 841 double eruptions
- 2 006 triple eruptions
- 238 quadruple eruptions
- 39 quintuple eruptions
- 4 sextuple eruptions

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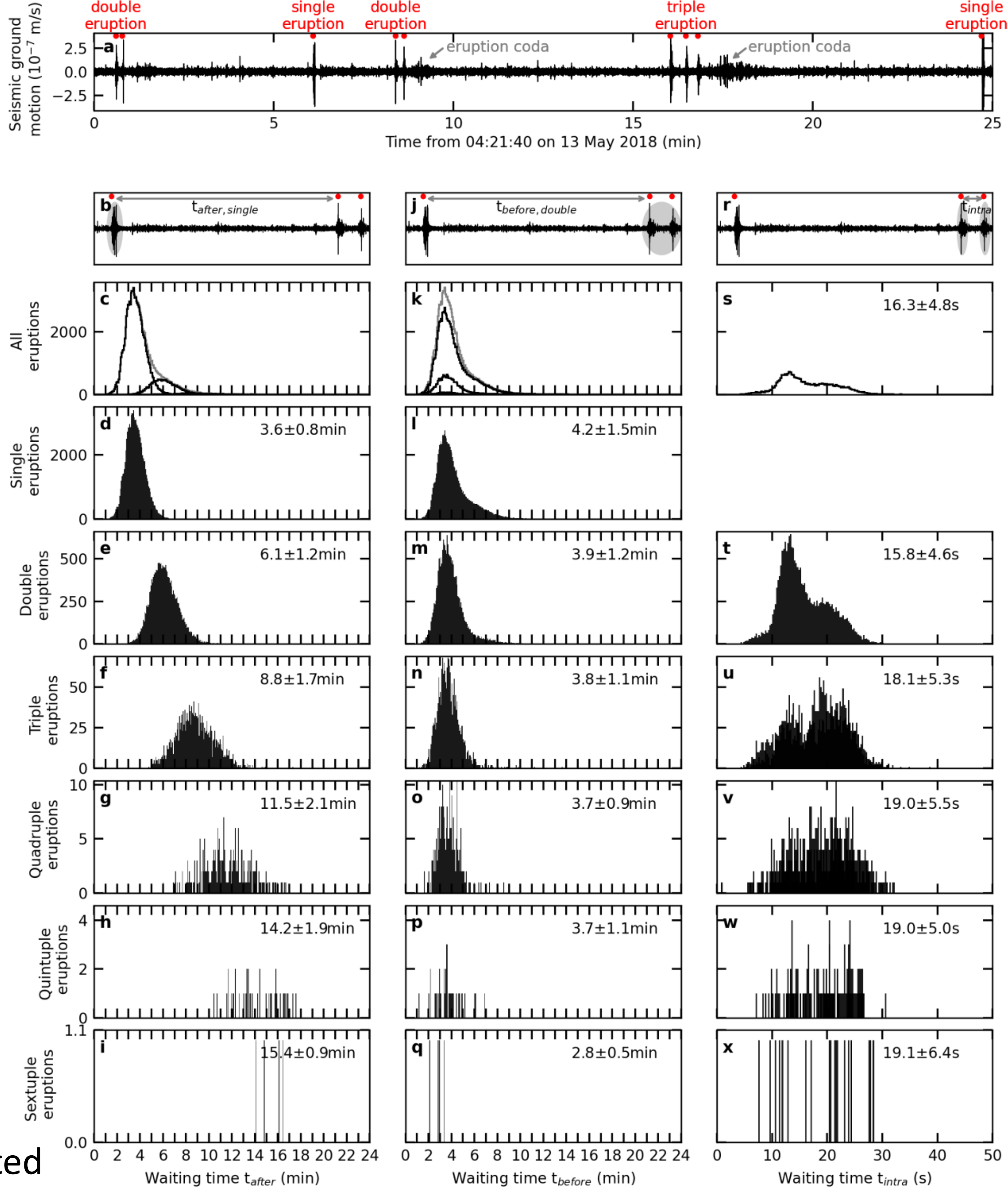

Eibl et al. 2020 updated

Eruption distribution 2020-2023

- 482 029 water fountains
- 315 129 single eruptions
- 72 038 double eruptions
- 6 644 triple eruptions
- 634 quadruple eruptions
- 61 quintuple eruptions
- 7 sextuple eruptions

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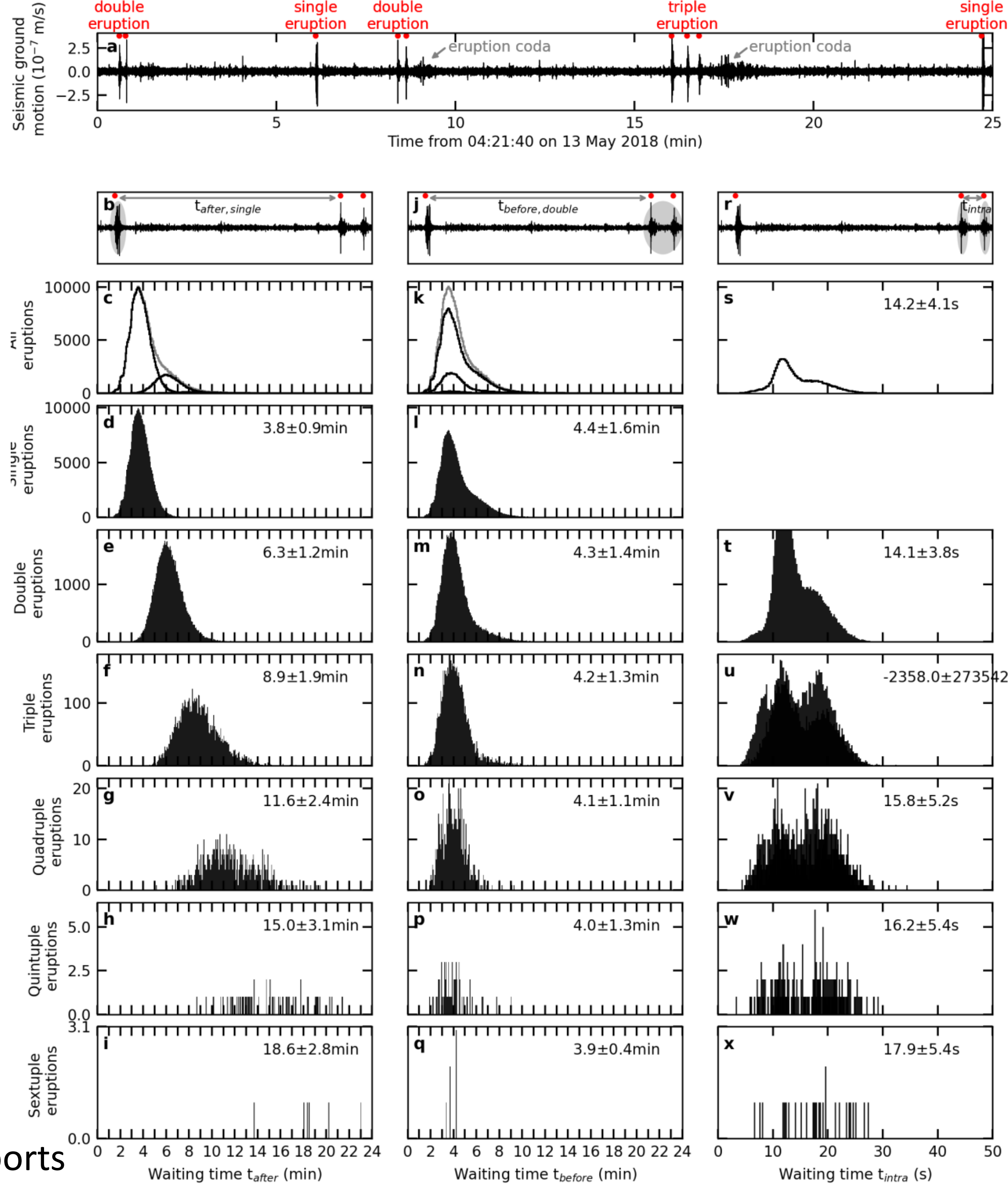

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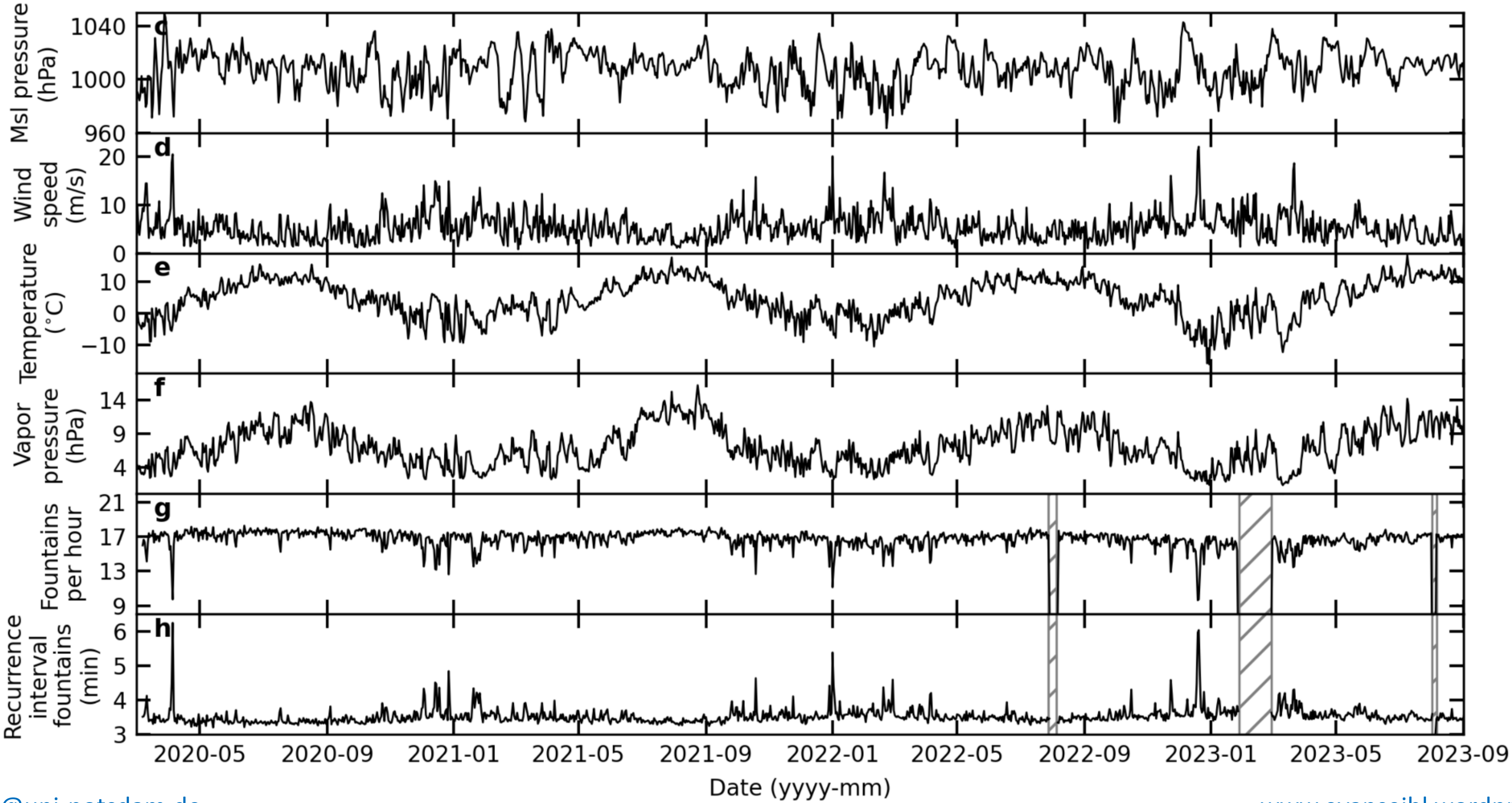
Eruptions and weather over 3.5 years



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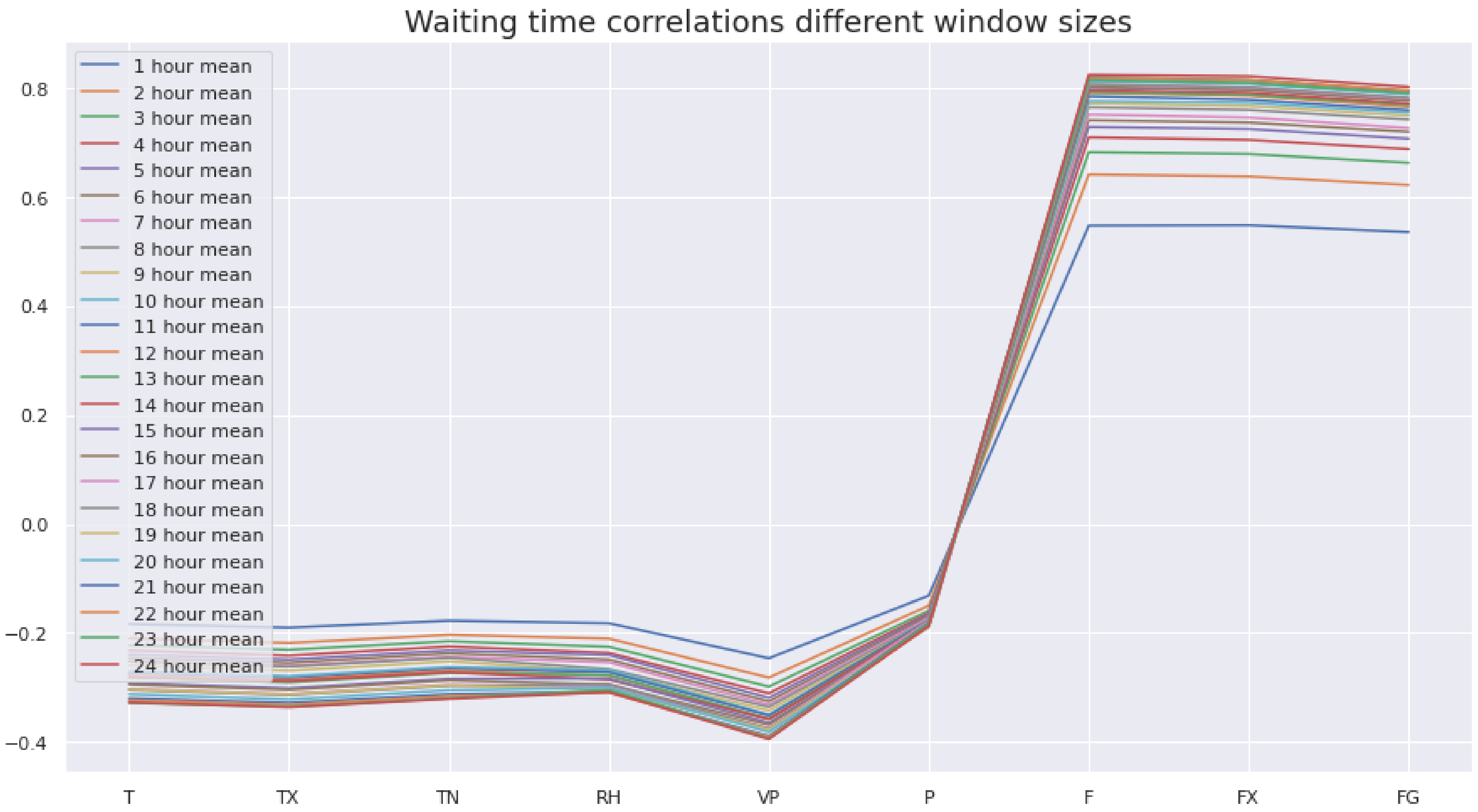
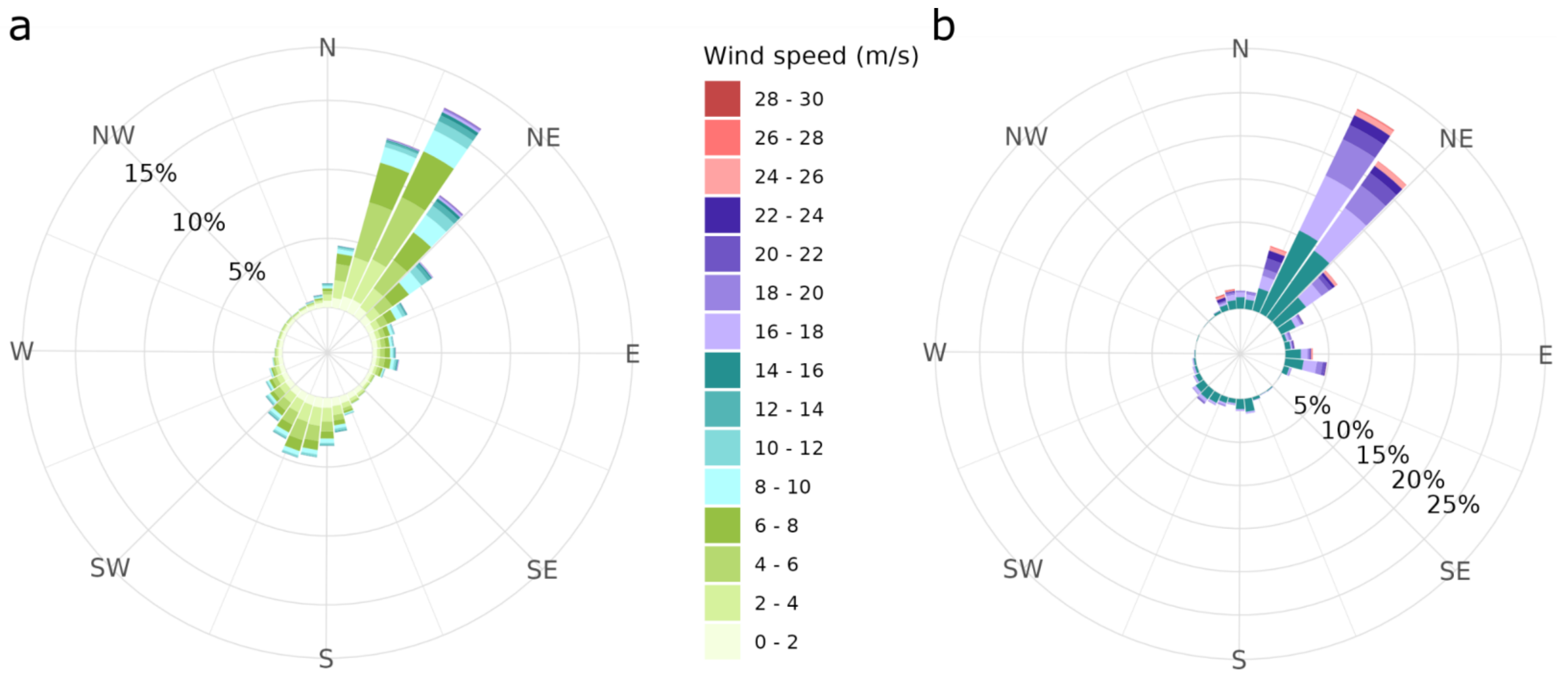
The correlation is always present, independent of the window length



Dominant wind directions



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How is heat lost from the pool?

energy U: needs to be added to pool water volume to raise temperature to boiling point
energy is provided at a rate H from deeper source
A: pool area
E: heat loss to atmosphere per unit area from the exposed pool surface (by free and forced convection at rate AE)
t=0: time eruption ends
τ : beginning of the next eruption

$$U = \int_0^\tau H \, dt - \int_0^\tau AE \, dt,$$

energy loss from heated pool calculated from semiempirical model (Adams et al. 1990, modified Fournier et al. 2009):

$$E = \left[\left(2.7 \Delta \theta_v^{\frac{1}{3}} \right)^2 + \left(8.1 A^{-0.05} W_s \right)^2 \right]^{\frac{1}{2}} (e_s - e_a),$$

Δθv : temperature difference between surface water in pool at Tp and ambient air Ta (K)
W_s : wind speed (m/s)
e_s-e_a: difference between the near-surface and ambient vapor pressures (in mbar)

Simplifying the equations

$$E = \left[\left(2.7\Delta\theta_{\mathrm{v}}^{\frac{1}{3}}\right)^2 + \left(8.1A^{-0.05}W_{\mathrm{s}}\right)^2\right]^{\frac{1}{2}}(e_{\mathrm{s}} - e_{\mathrm{a}}),$$

the pool is always close to the boiling temperature so that $e_s - e_a \approx e_s$

Assumptions: A, H, and E remain constant as the pool refills on timescales shorter than τ

weather phenomena affecting Ta and W_s vary on timescales longer than τ

initial temperature in pool is not much below the temperature at which it erupts

$$U = (H - AE)\tau.$$

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To predict how air temperature Ta and wind speed Ws influence the IBE

$$E = \left[\left(2.7\Delta\theta_{\mathrm{v}}^{\frac{1}{3}}\right)^2 + \left(8.1A^{-0.05}W_{\mathrm{s}}\right)^2\right]^{\frac{1}{2}}(e_{\mathrm{s}} - e_{\mathrm{a}}),$$

$$U = (H - AE)\tau.$$

- estimate U and H from sensitivity of the IBE to wind speed
- use the IBEs at two representative wind speeds, 135 and 180 min at 2 m/s and 8 m/s

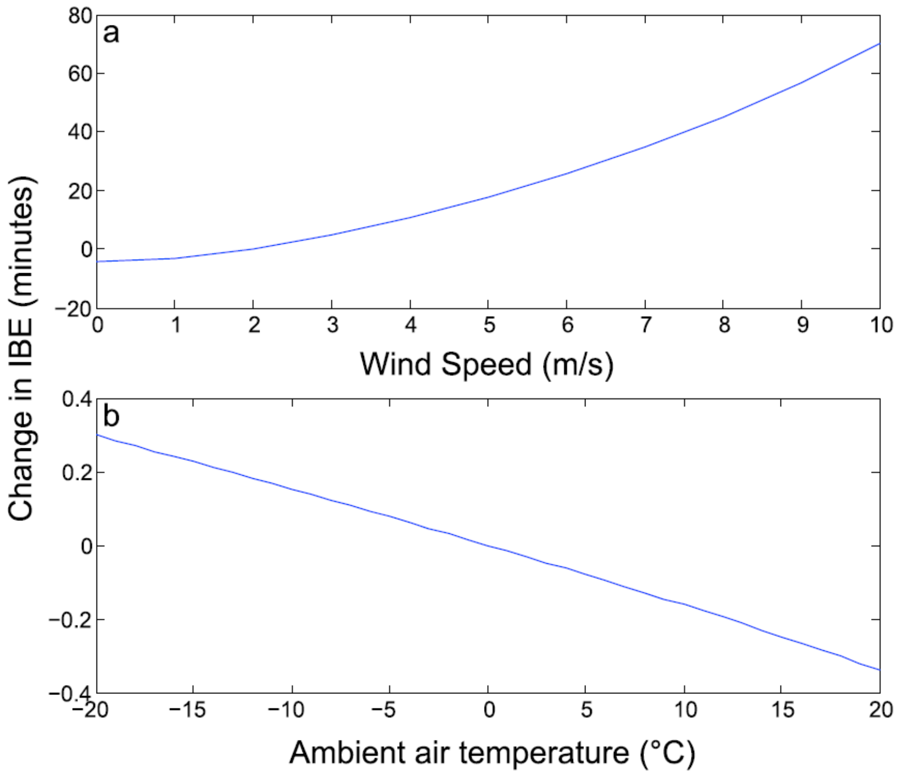

Figure 10. (a) Effect of wind speed on interval between eruption (IBE) changes, assuming a pool temperature of 90°C, air temperature of 0°C, and pool surface area of 10 m^2. (b) Effect of changes in air temperature on changes in IBE assuming a wind speed of 2 m/s and all other parameters the same as in Figure 10a.

Hurwitz et al. 2014

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