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Supplement of

Modulation of polar mesospheric summer echoes (PMSEs) with high-frequency heating during low solar illumination

Tinna L. Gunnarsdottir et al.

Correspondence to: Tinna L. Gunnarsdottir (tinna.gunnarsdottir@uit.no)

Supplementary Material

1 Overview of the measurements

1.1 Night of Aug 11/12, 2018

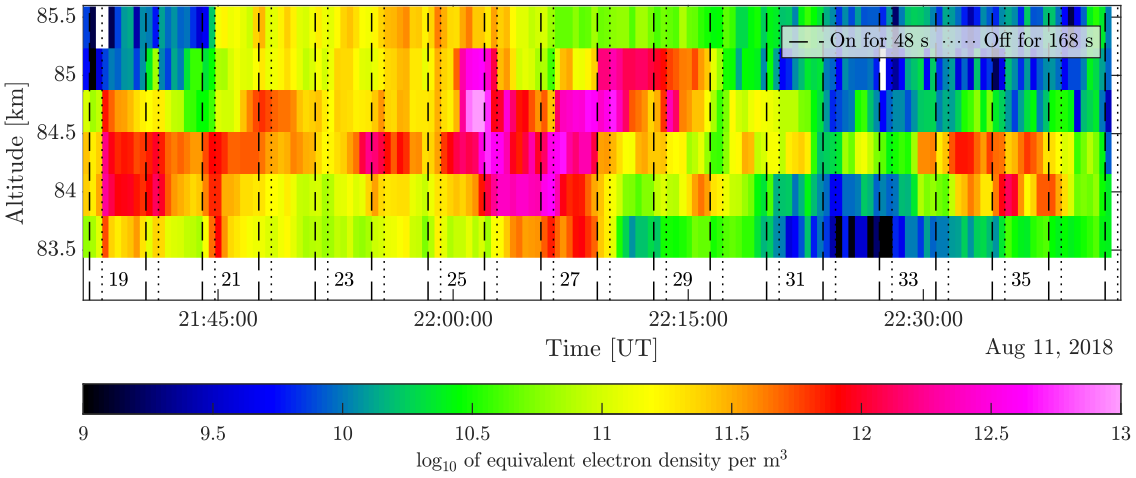

Figure S1. Back scattered power as function of altitude and heating intervals observed during the night of August 11/12, 2018 in Area 1.

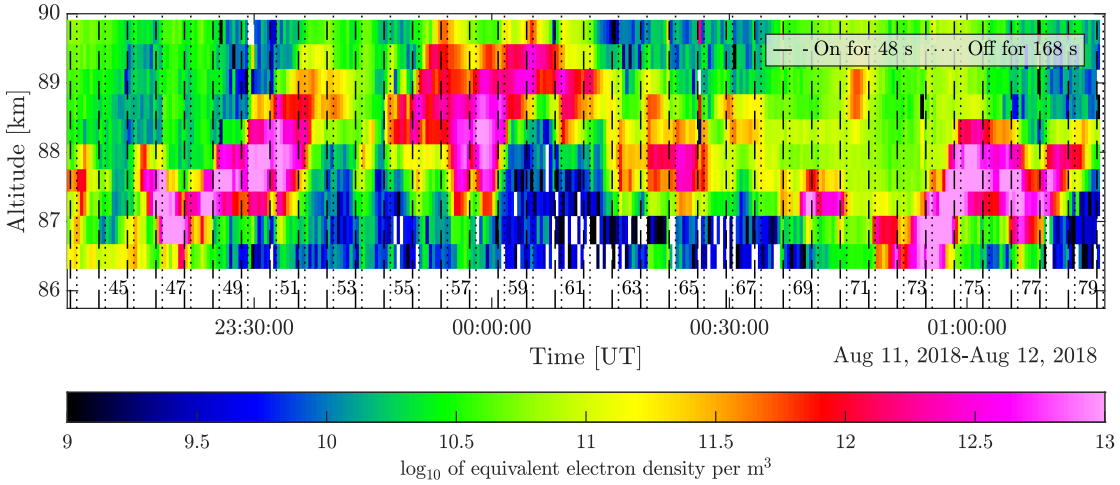

Figure S2. Back scattered power as function of altitude and heating intervals observed during the night of August 11/12, 2018 in Area 2.

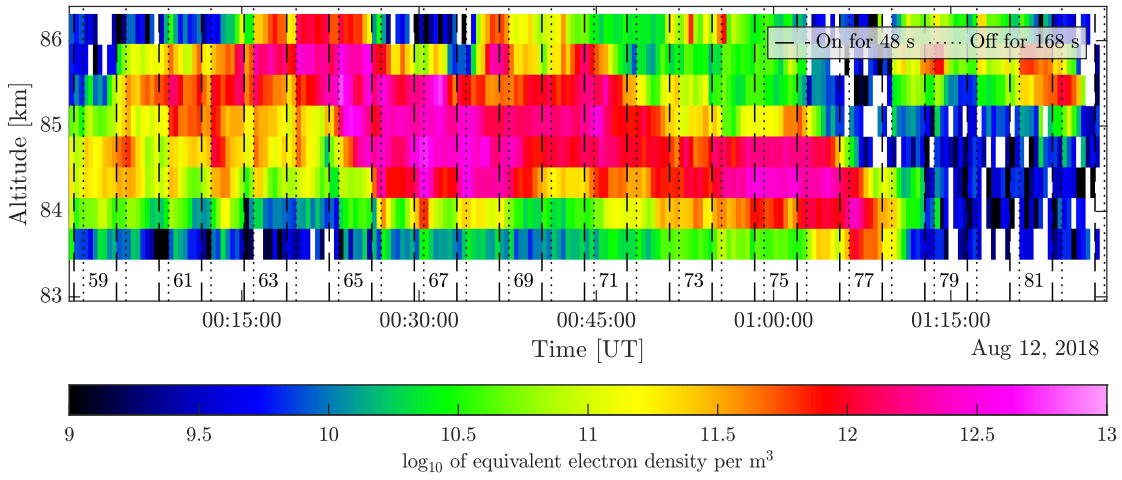

Figure S3. Back scattered power as function of altitude and heating intervals observed during the night of August 11/12, 2018 in Area 3.

1.2 Night of Aug 15/16, 2018

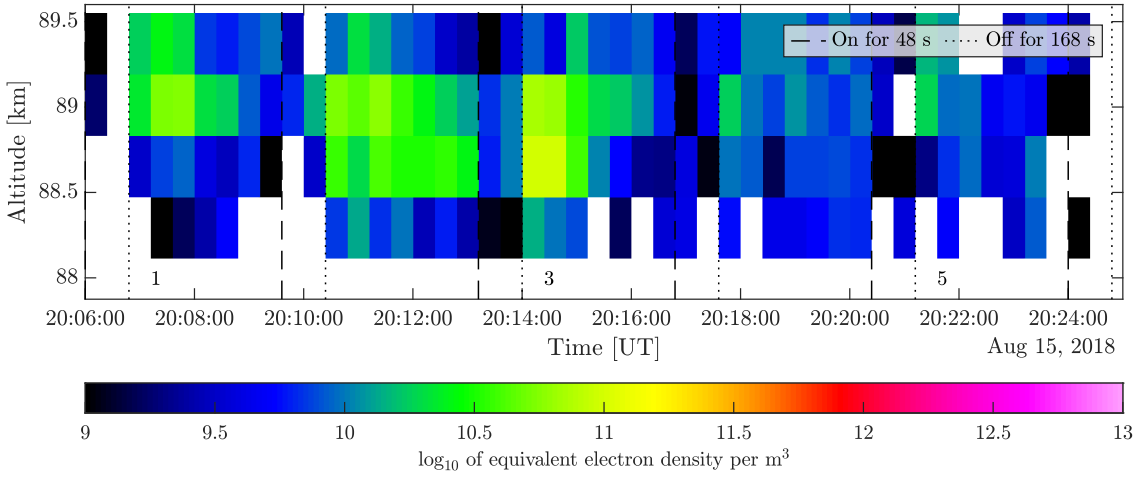

Figure S4. Back scattered power as function of altitude and heating intervals observed during the night of August 15/16, 2018 in Area 1.

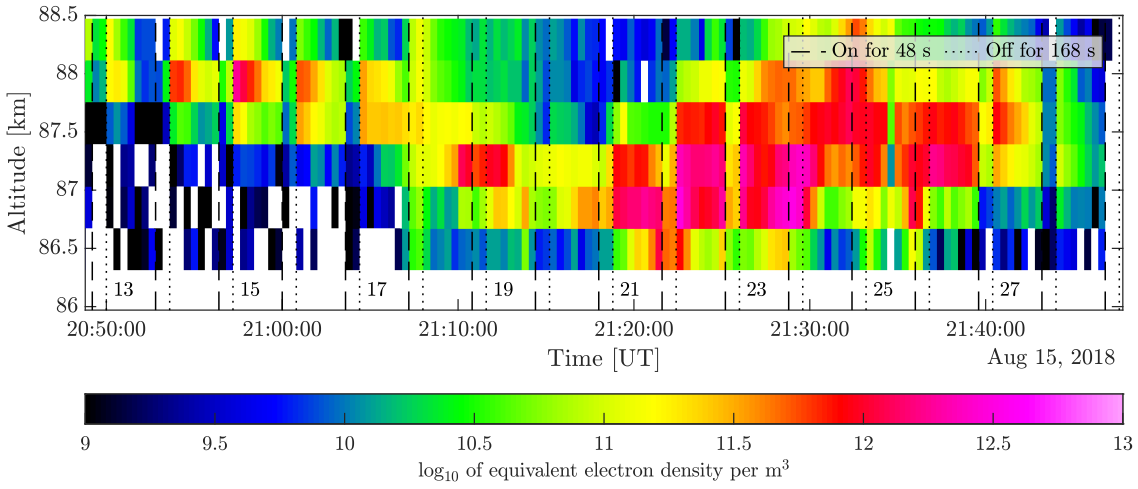

Figure S5. Back scattered power as function of altitude and heating intervals observed during the night of August 15/16, 2018 in Area 2.

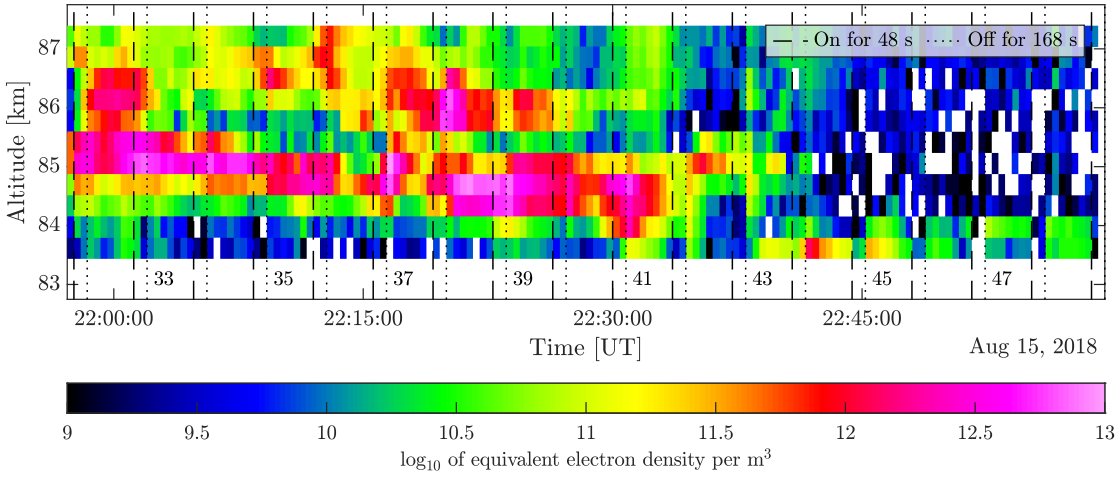

Figure S6. Back scattered power as function of altitude and heating intervals observed during the night of August 15/16, 2018 in Area 3.

1.3 Night of Aug 05/06, 2020

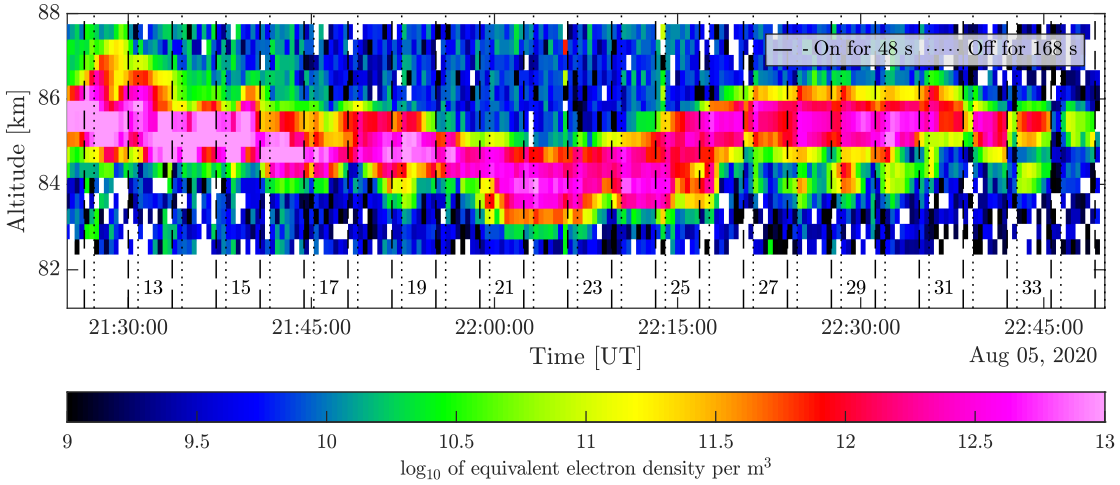

Figure S7. Back scattered power as function of altitude and heating intervals observed during the night of August 05/06, 2020 in Area 1.

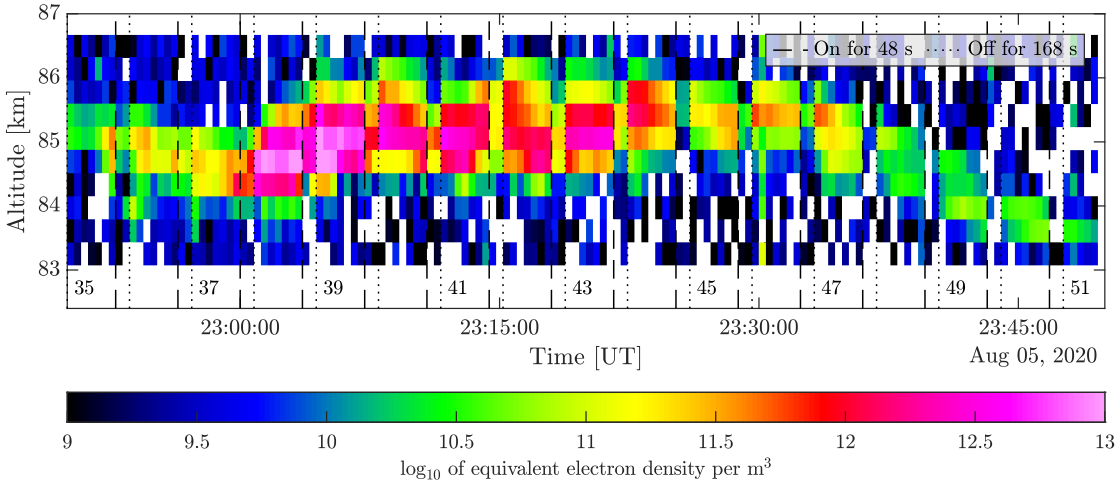

Figure S8. Back scattered power as function of altitude and heating intervals observed during the night of August 05/06, 2020 in Area 2.

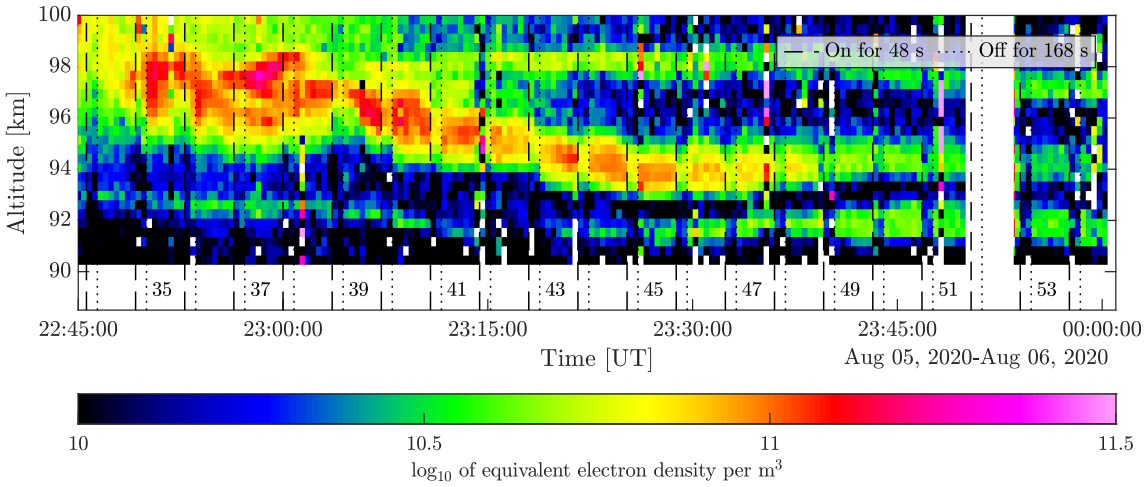

Figure S9. Back scattered power as function of altitude and heating intervals observed during the night of August 05/06, 2020 in Area 3. It should be noted that other limits of the colour scale have been chosen for this plot.

1.4 Night of Aug 06/07, 2020

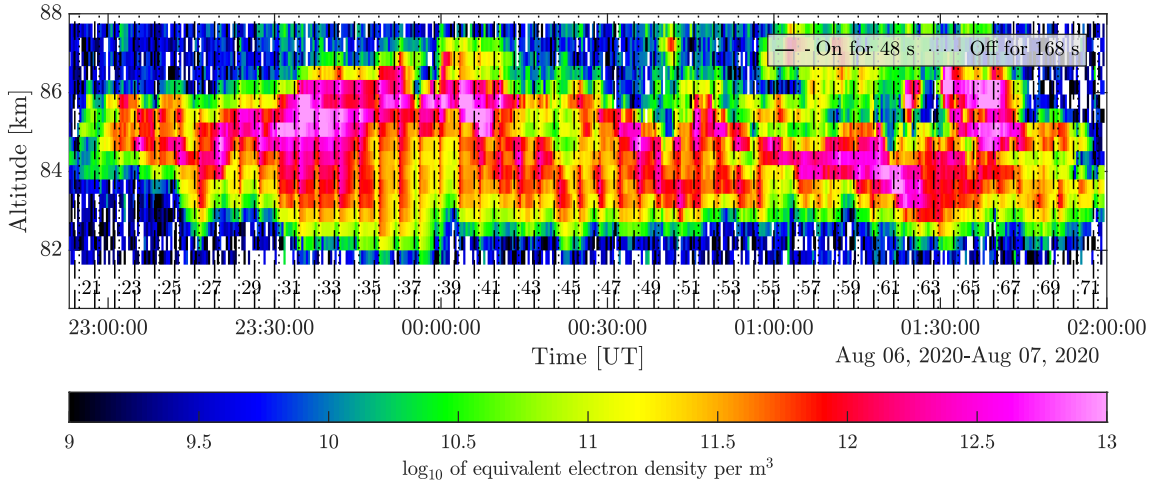

Figure S10. Back scattered power as function of altitude and heating intervals observed during the night of August 06/07, 2020 in Area 1.

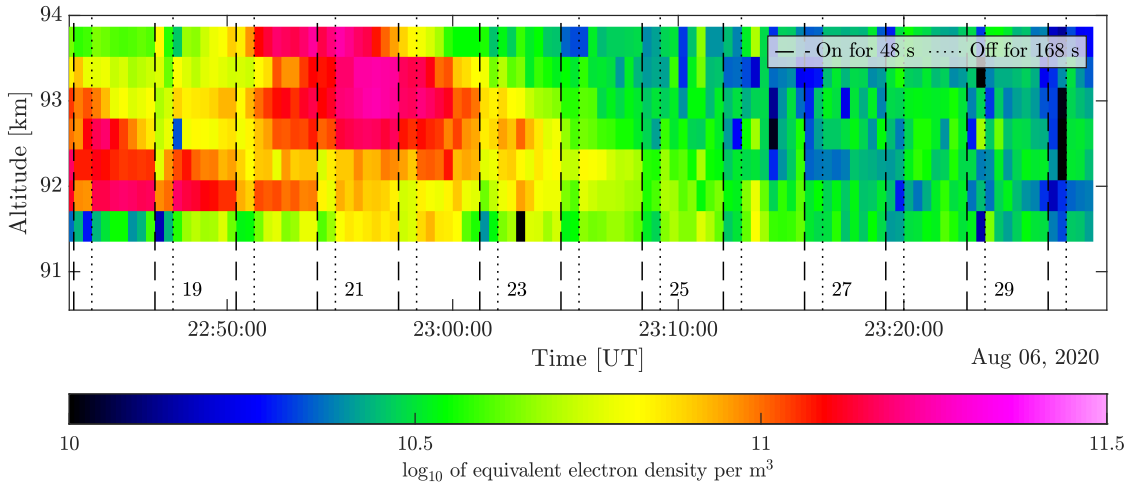

Figure S11. Back scattered power as function of altitude and heating intervals observed during the night of August 06/07, 2020 in Area 2. It should be noted that other limits of the colour scale have been chosen for this plot.

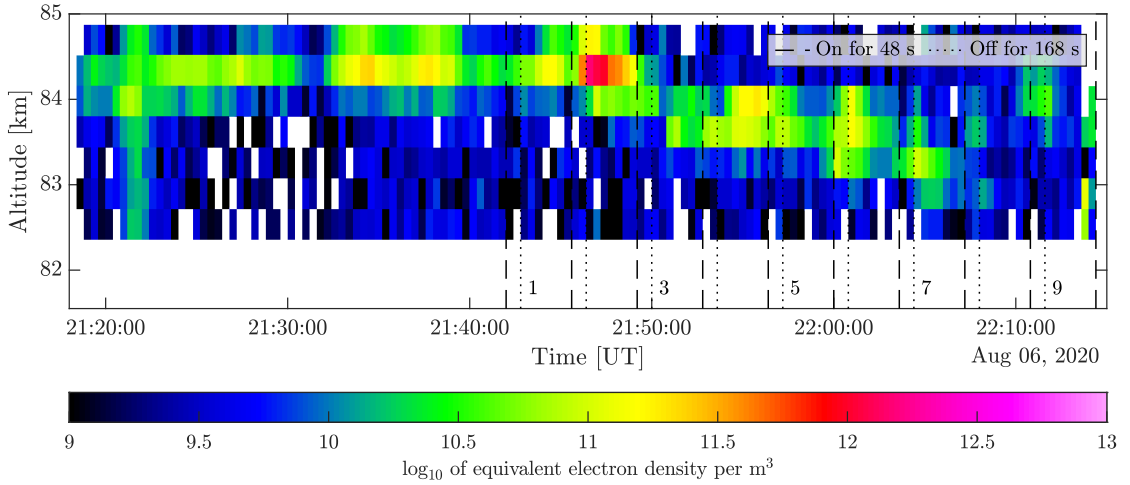

Figure S12. Back scattered power as function of altitude and heating intervals observed during the night of August 06/07, 2020 in Area 3.

2 Selected detailed PMSE signal

2.1 Night of Aug 15/16, 2018

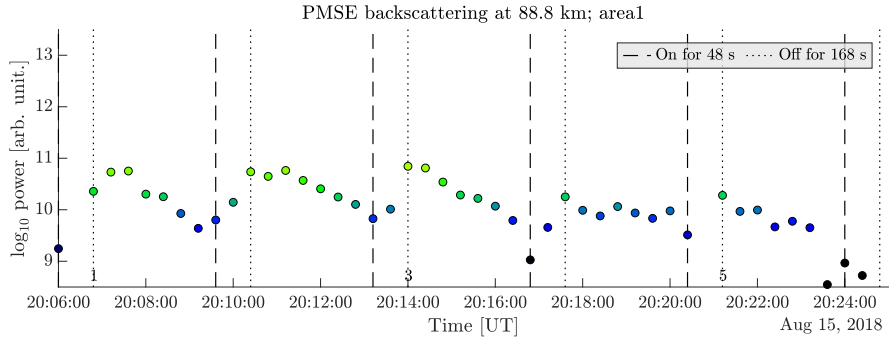

Figure S13. Back scattered power at altitude 88.8 km and heating intervals observed during the night of August 15/16, 2018 in area 1. The colour of the dots follow the colour scale of Fig. S4.

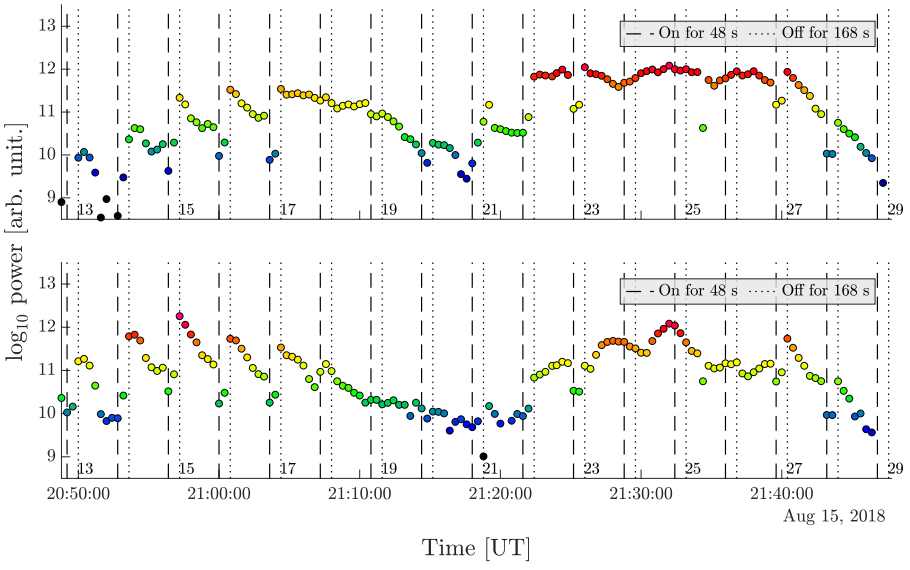

Figure S14. Back scattered power at altitude 87.4 and 87.8 km and heating intervals observed during the night of August 15/16, 2018 in area 2. The colour of the dots follow the colour scale of Fig. S5.

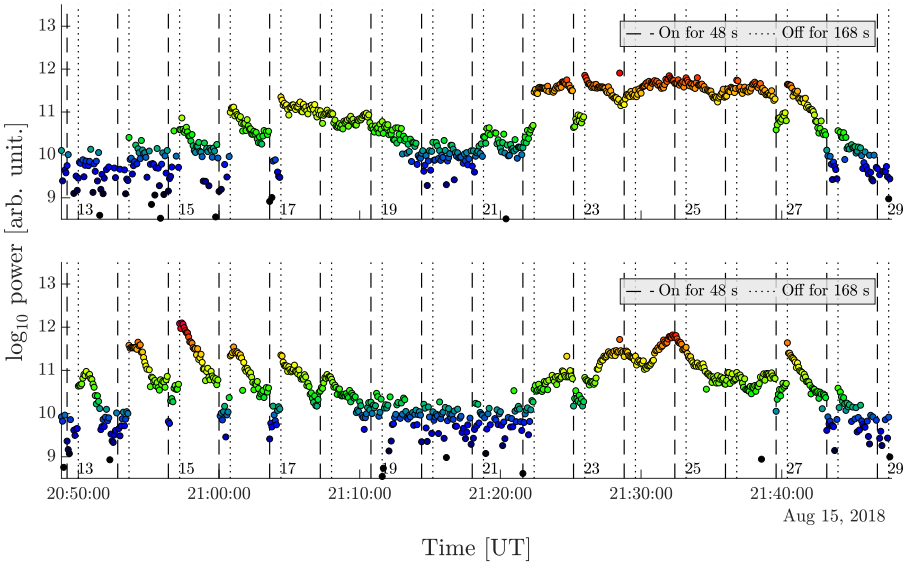

Figure S15. Back scattered power at altitude 87.4 and 87.8 km and heating intervals observed during the night of August 15/16, 2018 in area 2. Each 4.8 seconds there is a data point, usually the interval is 24 seconds. The colour of the dots follow the colour scale of Fig. S5.

2.2 Night of Aug 05/06, 2020

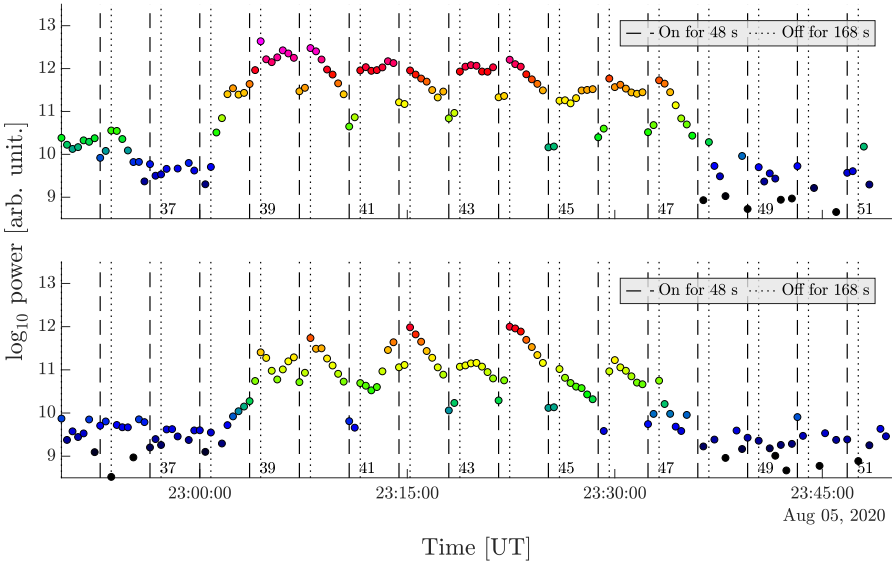

Figure S16. Back scattered power at altitude 85.2 and 85.6 km and heating intervals observed during the night of August 05/06, 2020 in area 2. The colour of the dots follow the colour scale of Fig. S8.

10 **3 Comparison of power amplitudes**

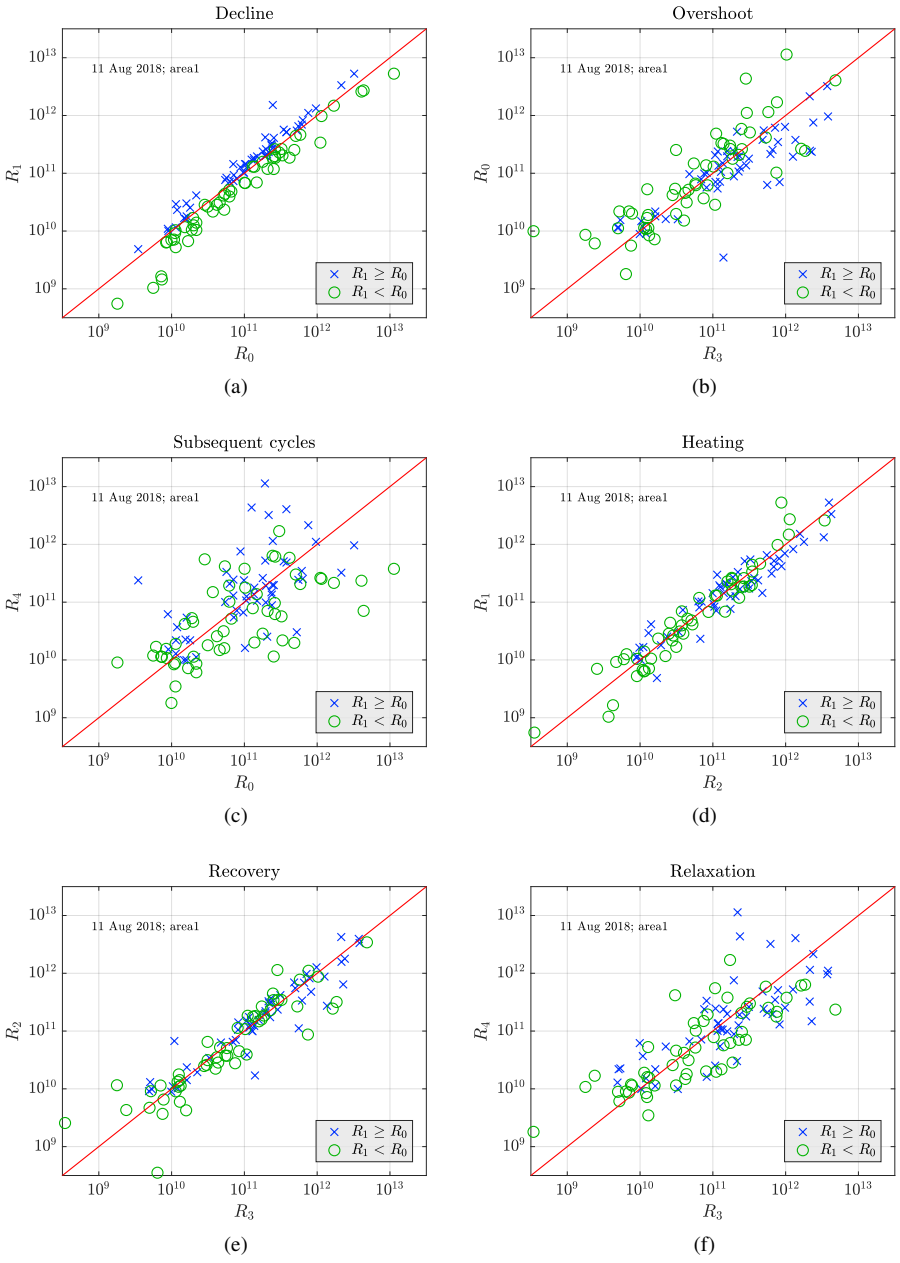

Figure S17. Comparison of the power amplitudes observed on the 11 August 2018 in Area 1.

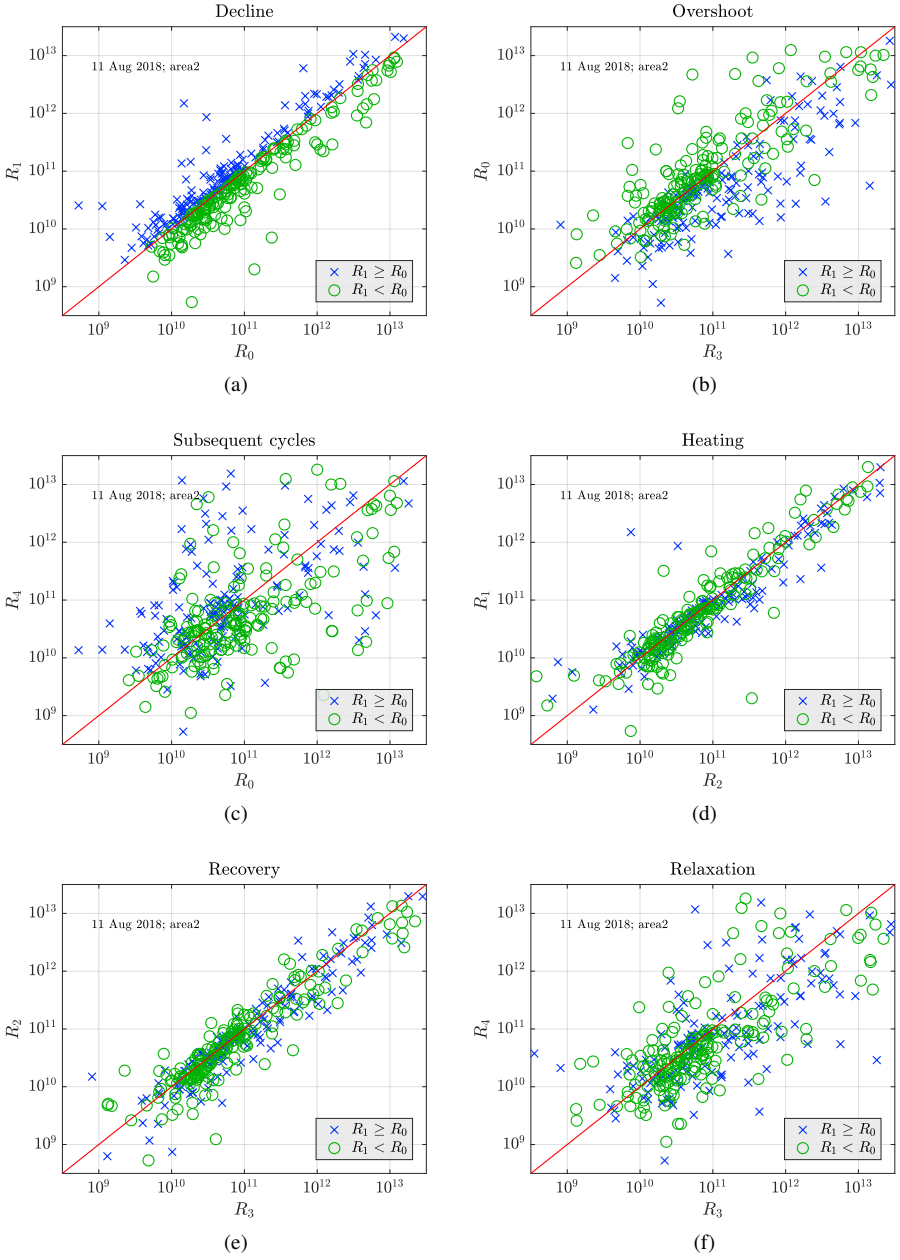

Figure S18. Comparison of the power amplitudes observed on the 11 August 2018 in Area 2.

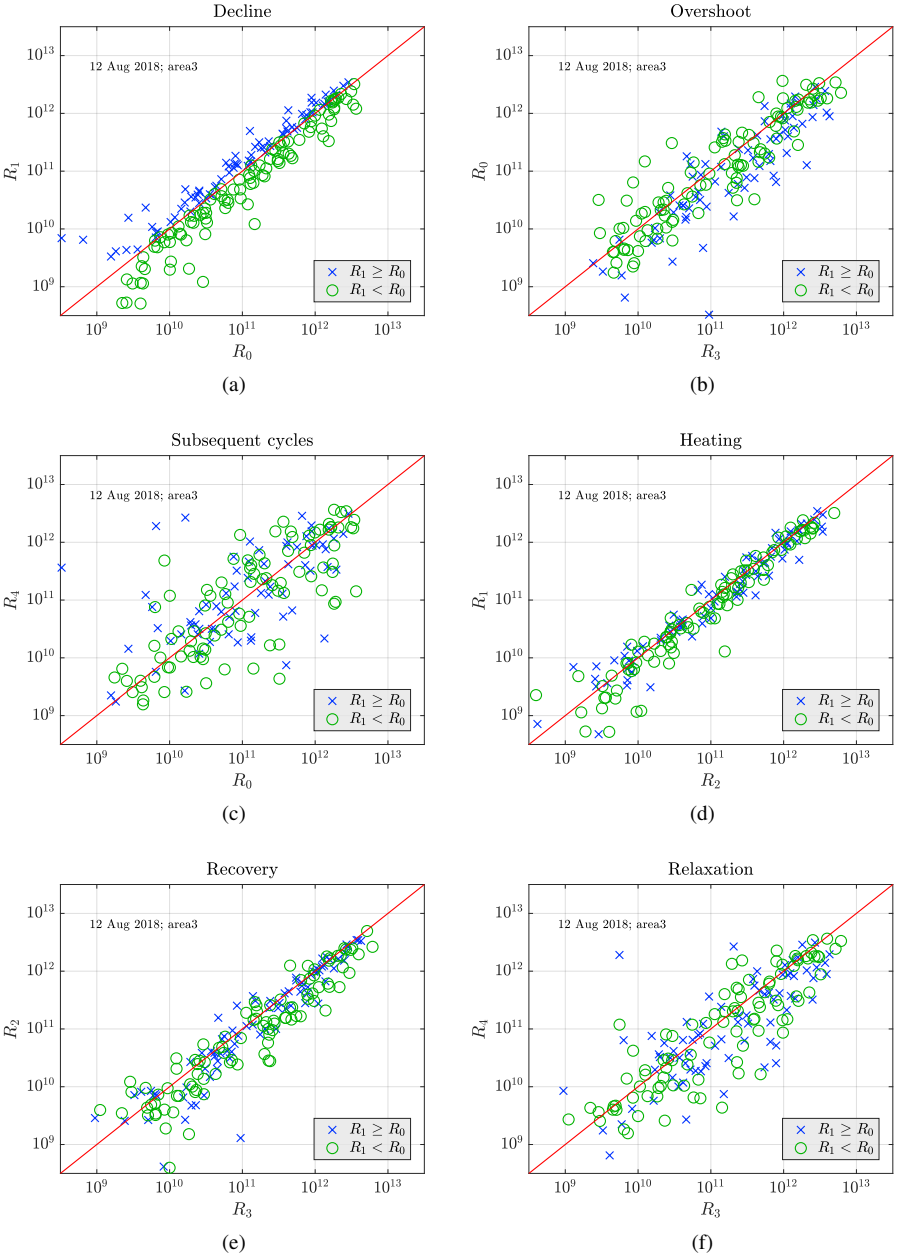

Figure S19. Comparison of the power amplitudes observed on the 11 August 2018 in Area 3.

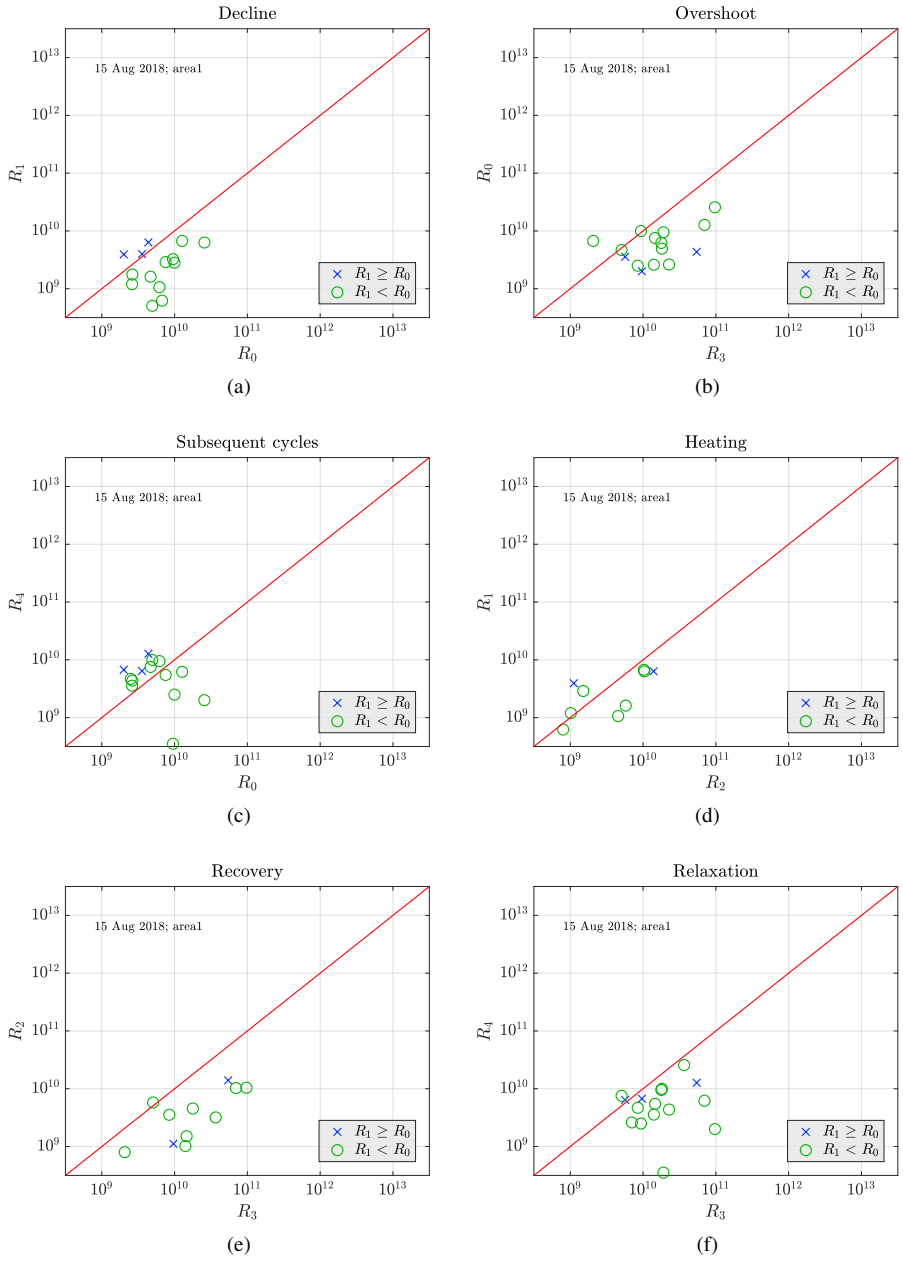

Figure S20. Comparison of the power amplitudes observed on the 15 August 2018 in Area 1.

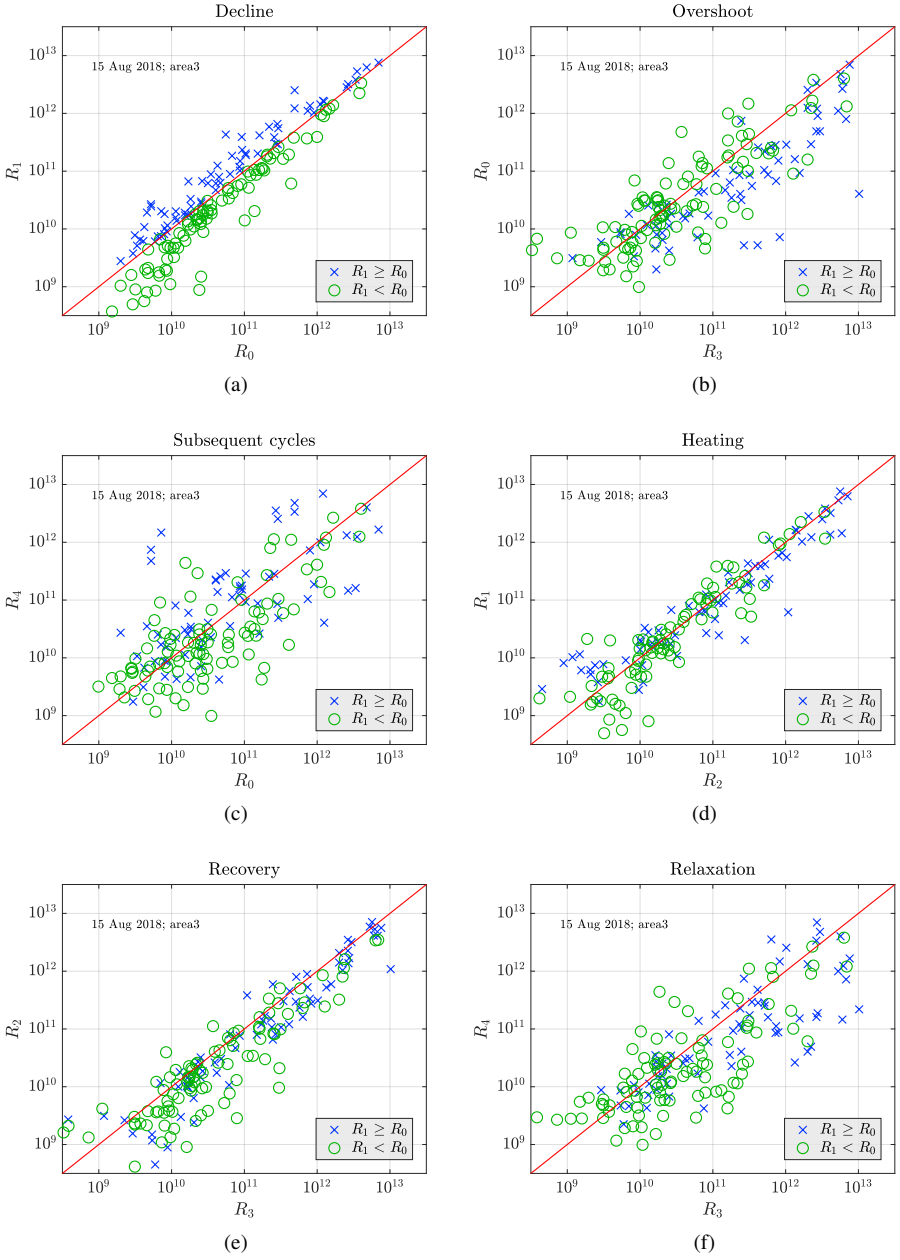

Figure S21. Comparison of the power amplitudes observed on the 15 August 2018 in Area 3.

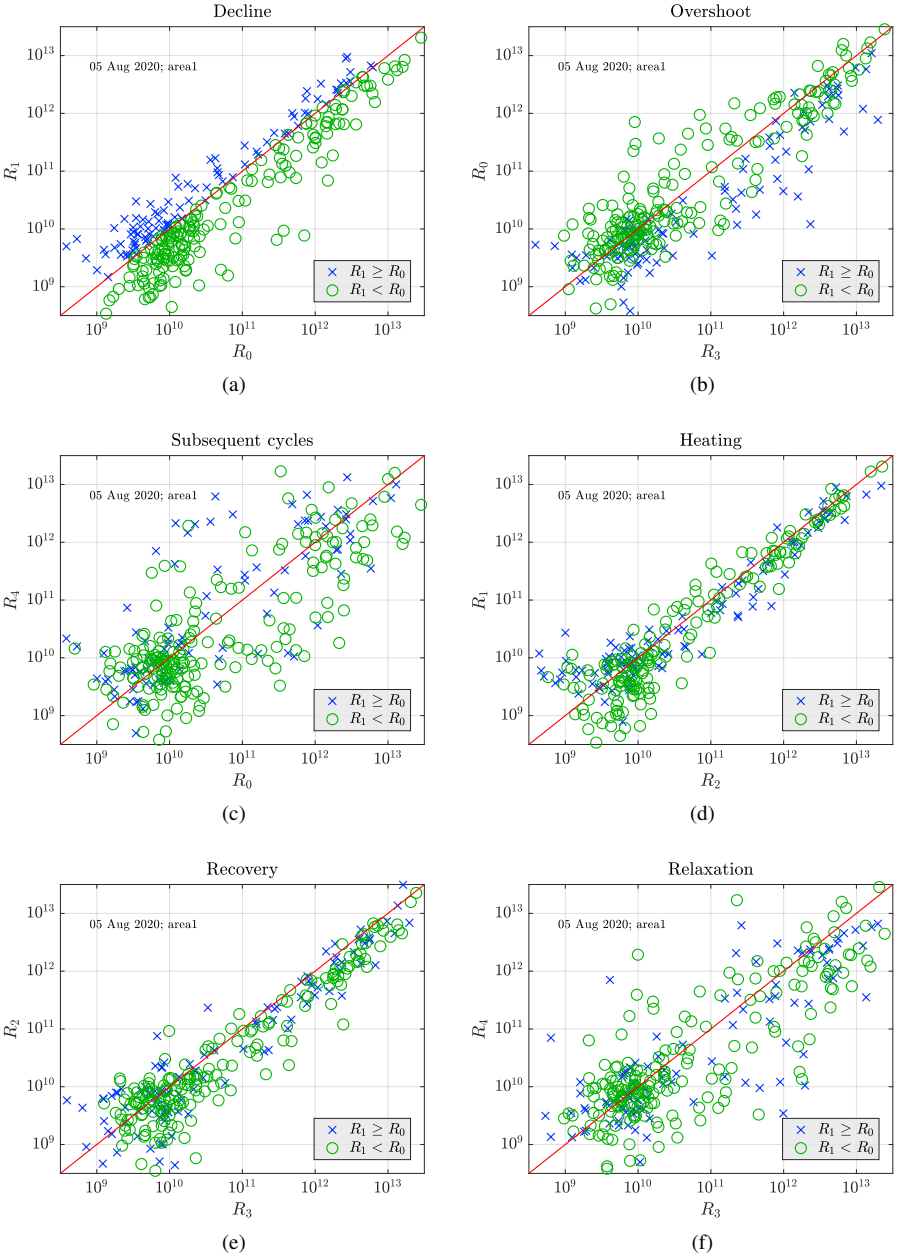

Figure S22. Comparison of the power amplitudes observed on the 5 August 2020 in Area 1.

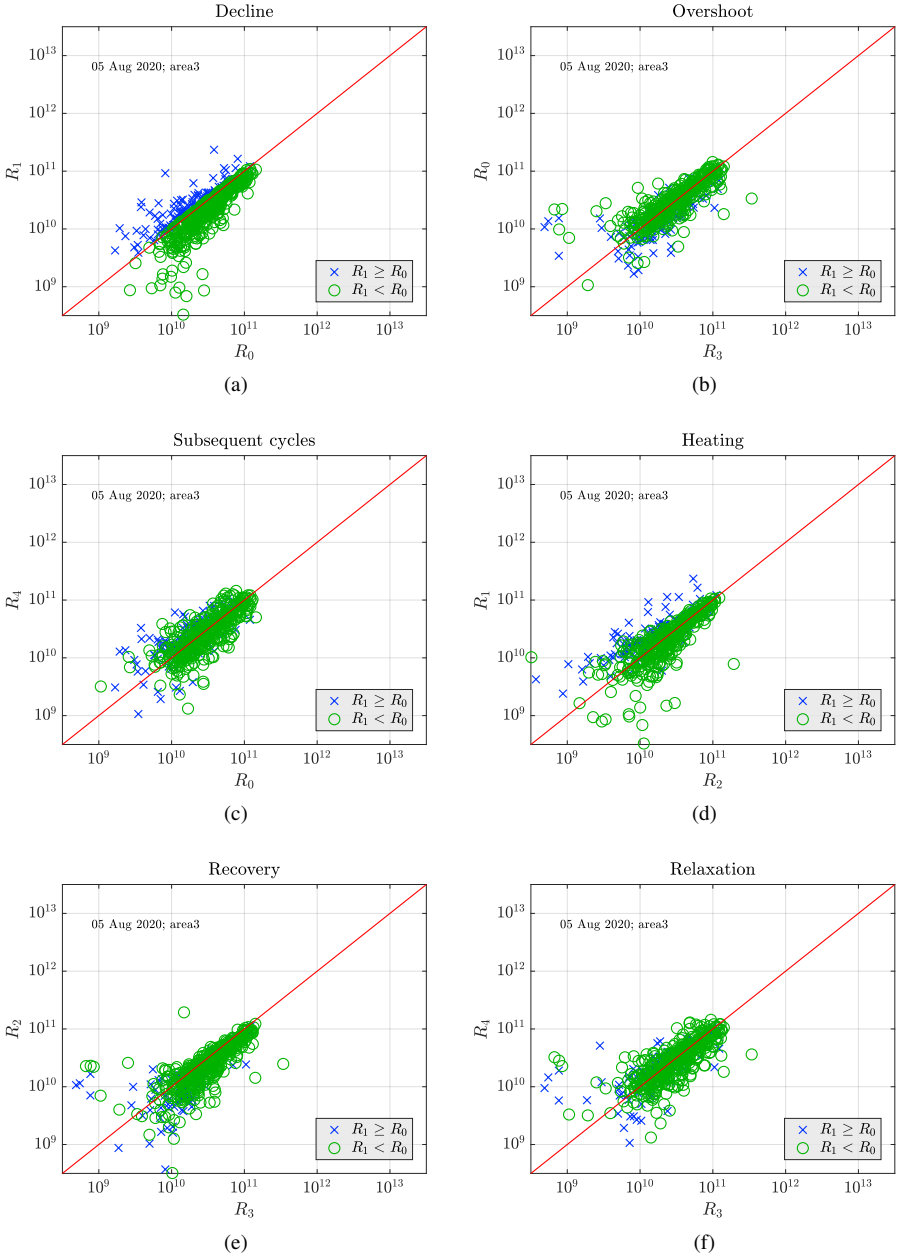

Figure S23. Comparison of the power amplitudes observed on the 5 August 2020 in Area 3.

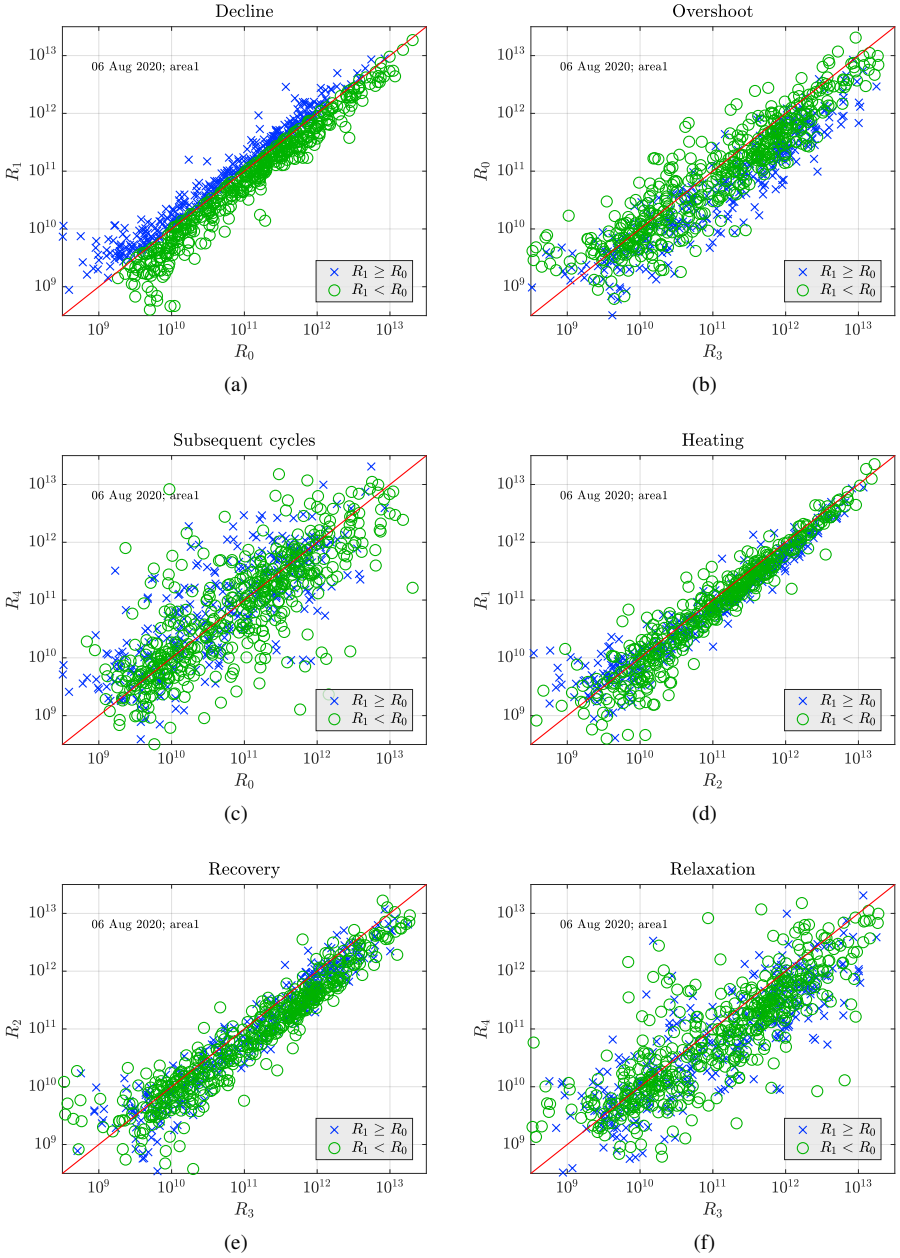

Figure S24. Comparison of the power amplitudes observed on the 6 August 2020 in Area 1.

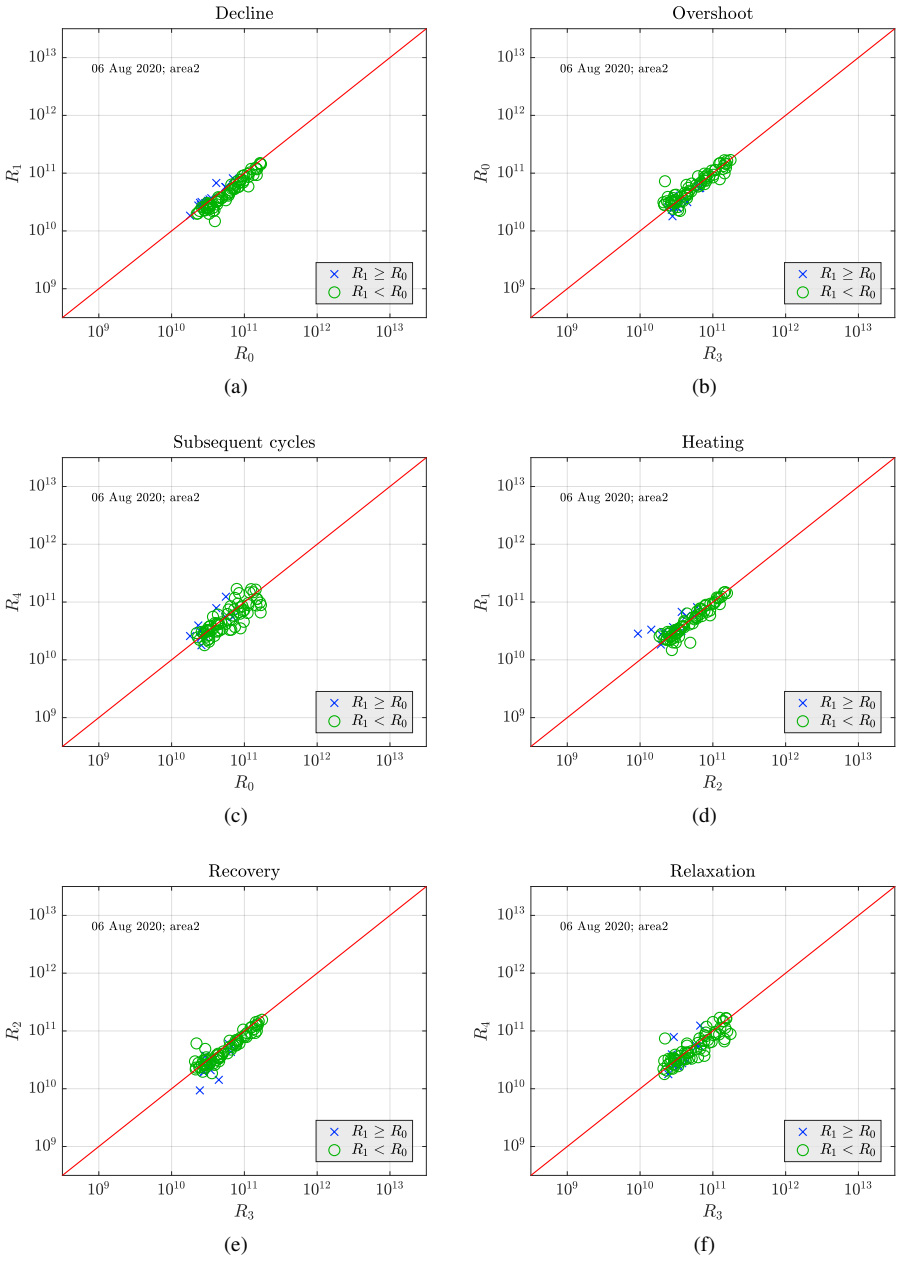

Figure S25. Comparison of the power amplitudes observed on the 6 August 2020 in Area 2.

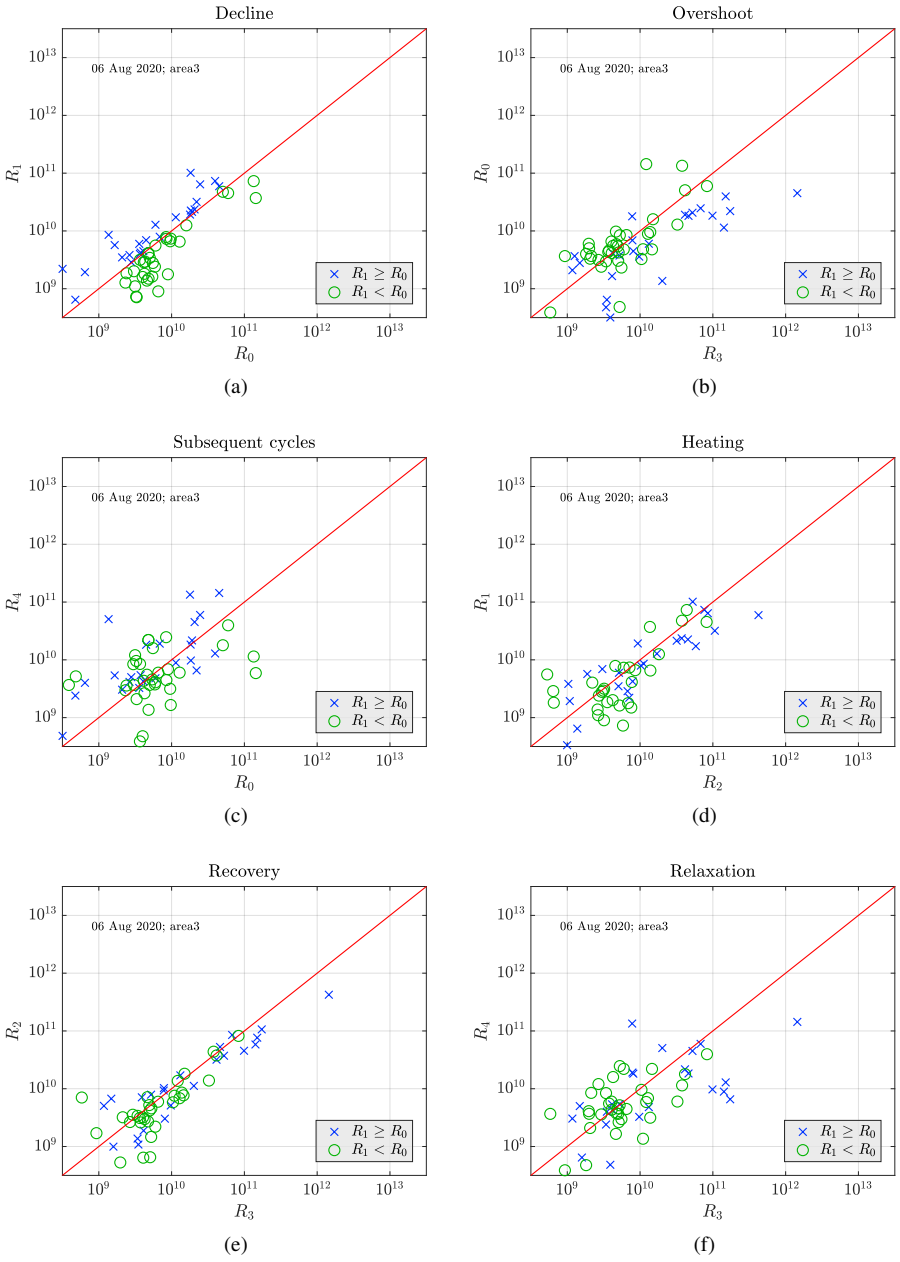

Figure S26. Comparison of the power amplitudes observed on the 6 August 2020 in Area 3.

4 Histograms of heating cycle ratios with averages

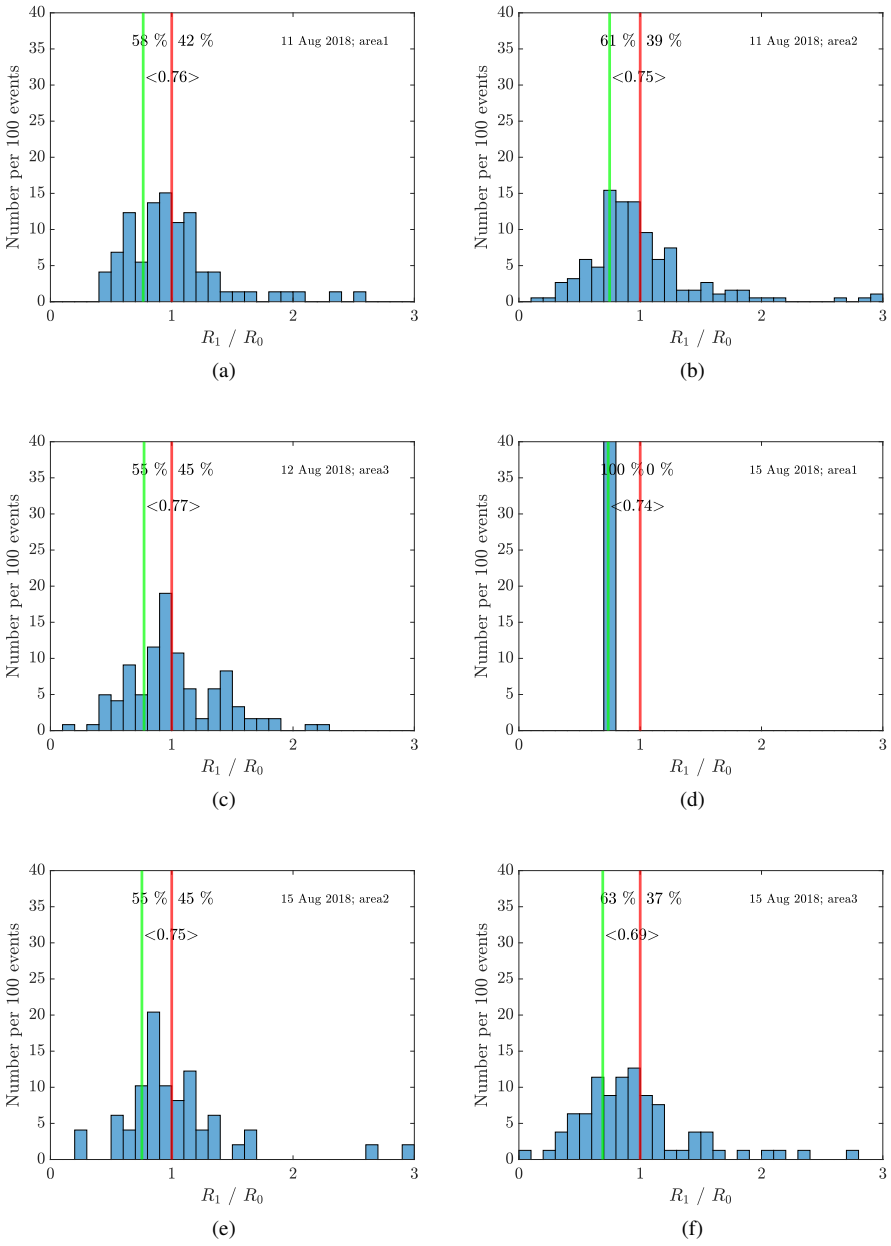

Figure S27. Average of the decline for the observed data on the 11 and 15 August 2018. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

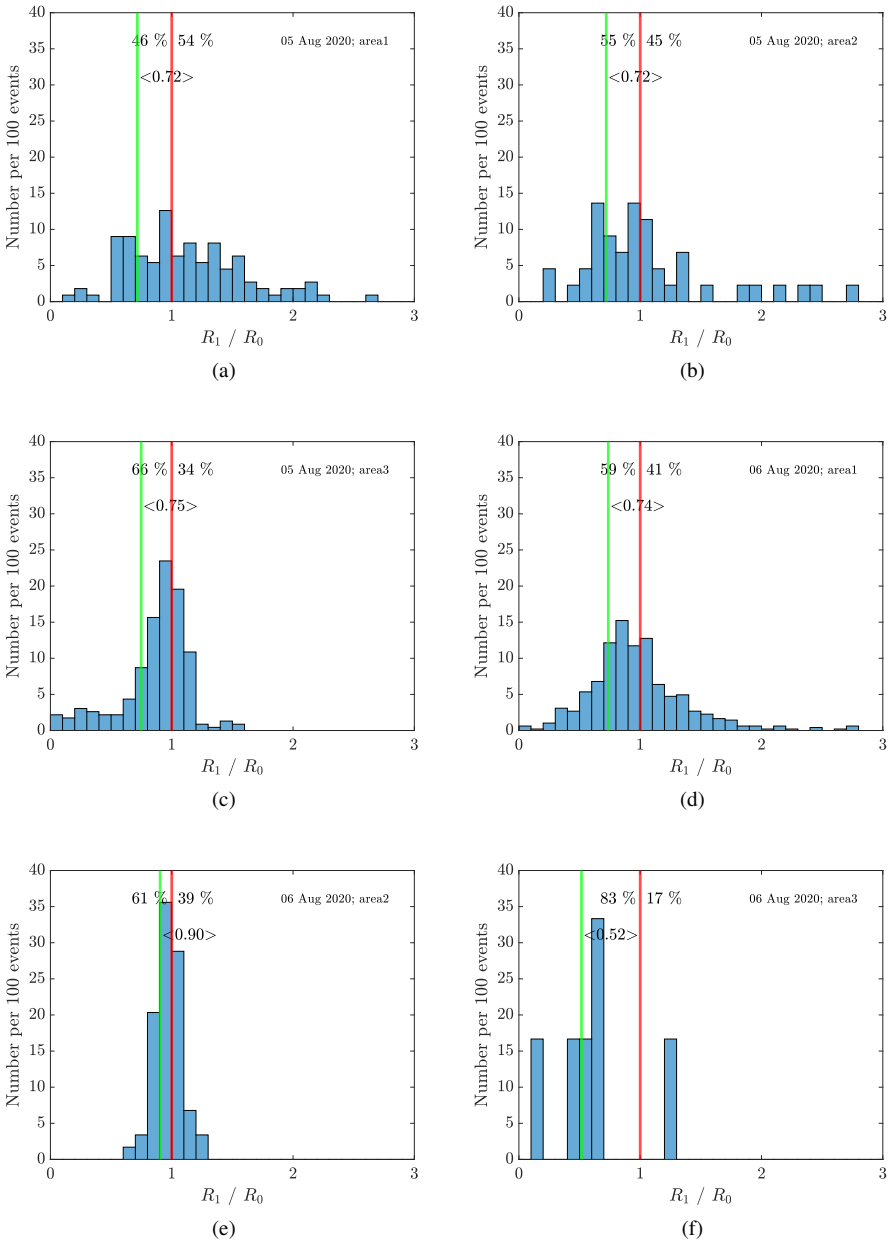

Figure S28. Average of the decline for the observed data on the 5 and 6 August 2020. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

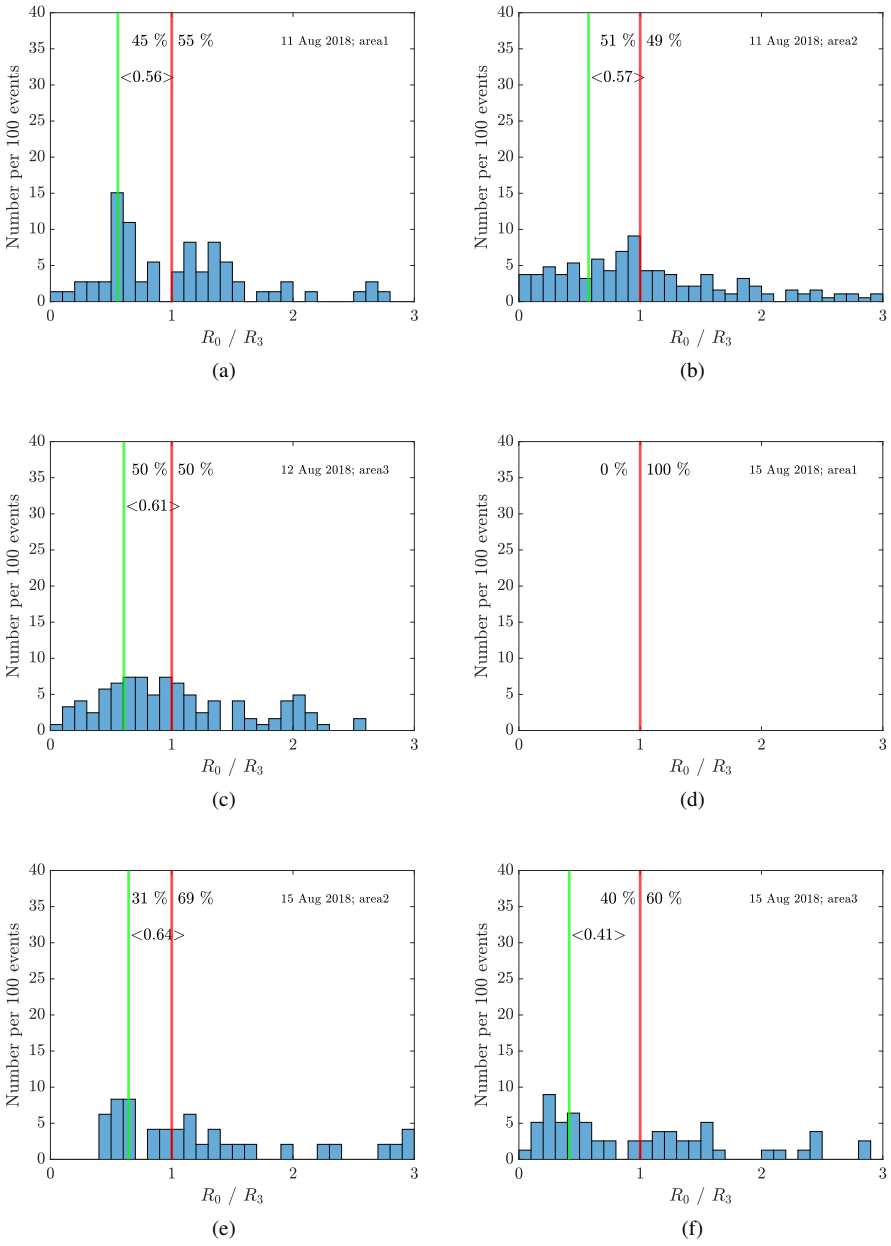

Figure S29. Average of the overshoot for the observed data on the 11 and 15 August 2018. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

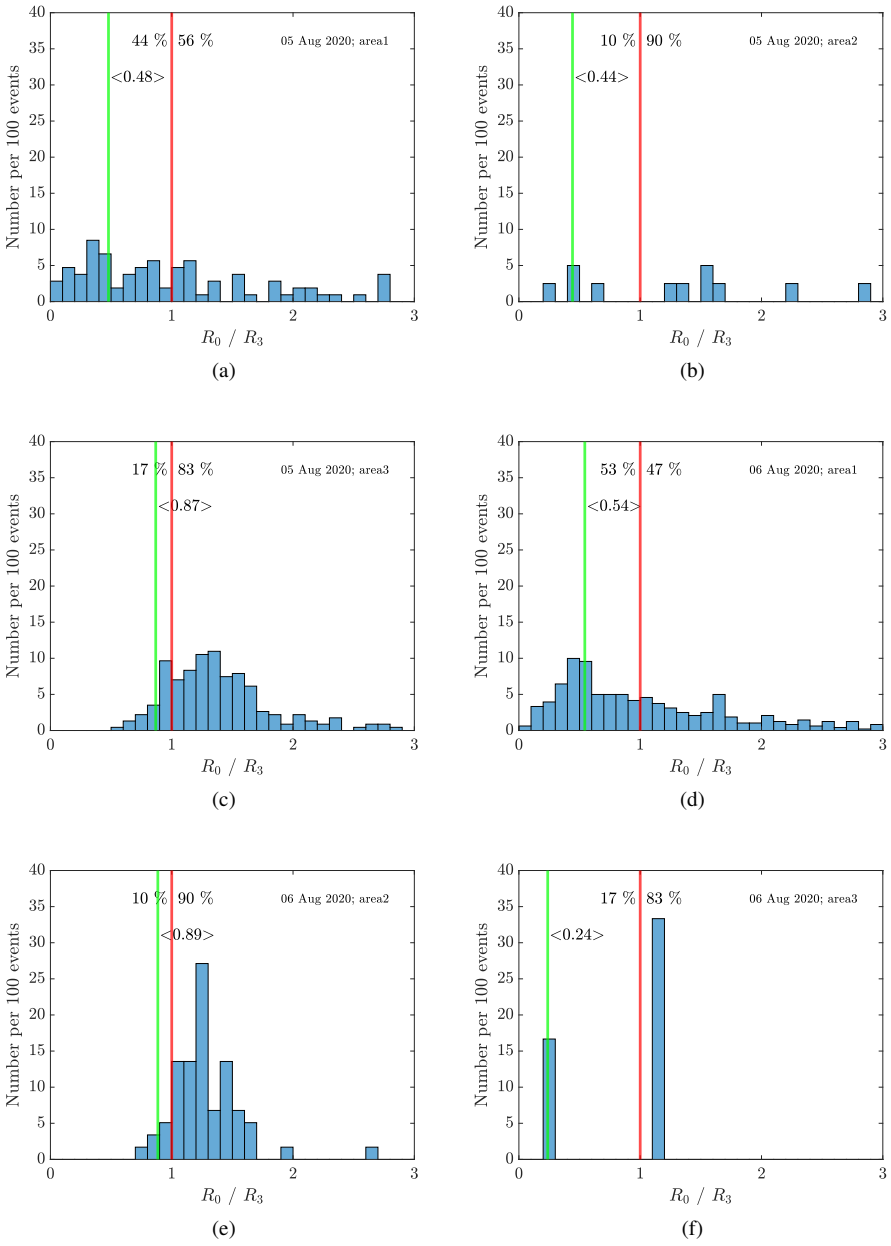

Figure S30. Average of the overshoot for the observed data on the 5 and 6 August 2020. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

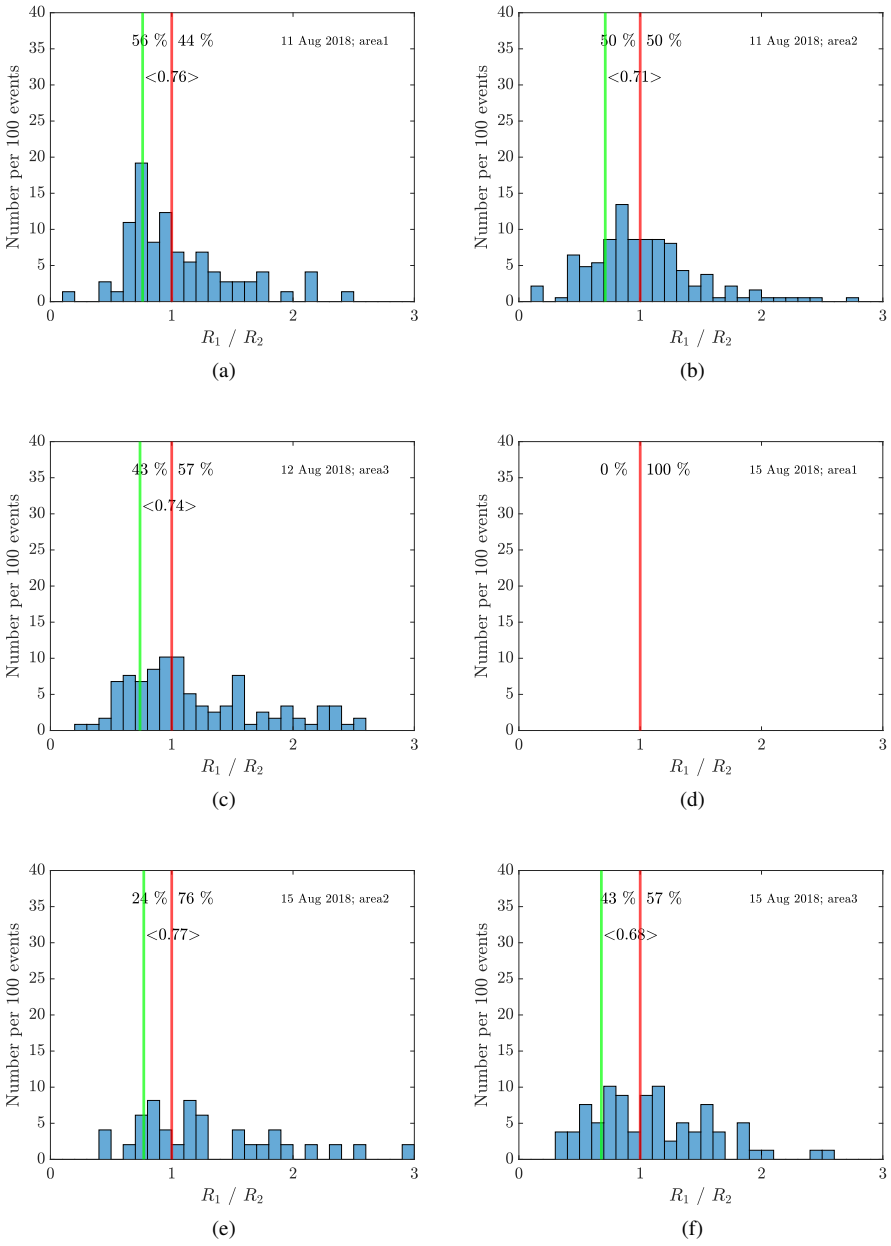

Figure S31. Average of the heating for the observed data on the 11 and 15 August 2018. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

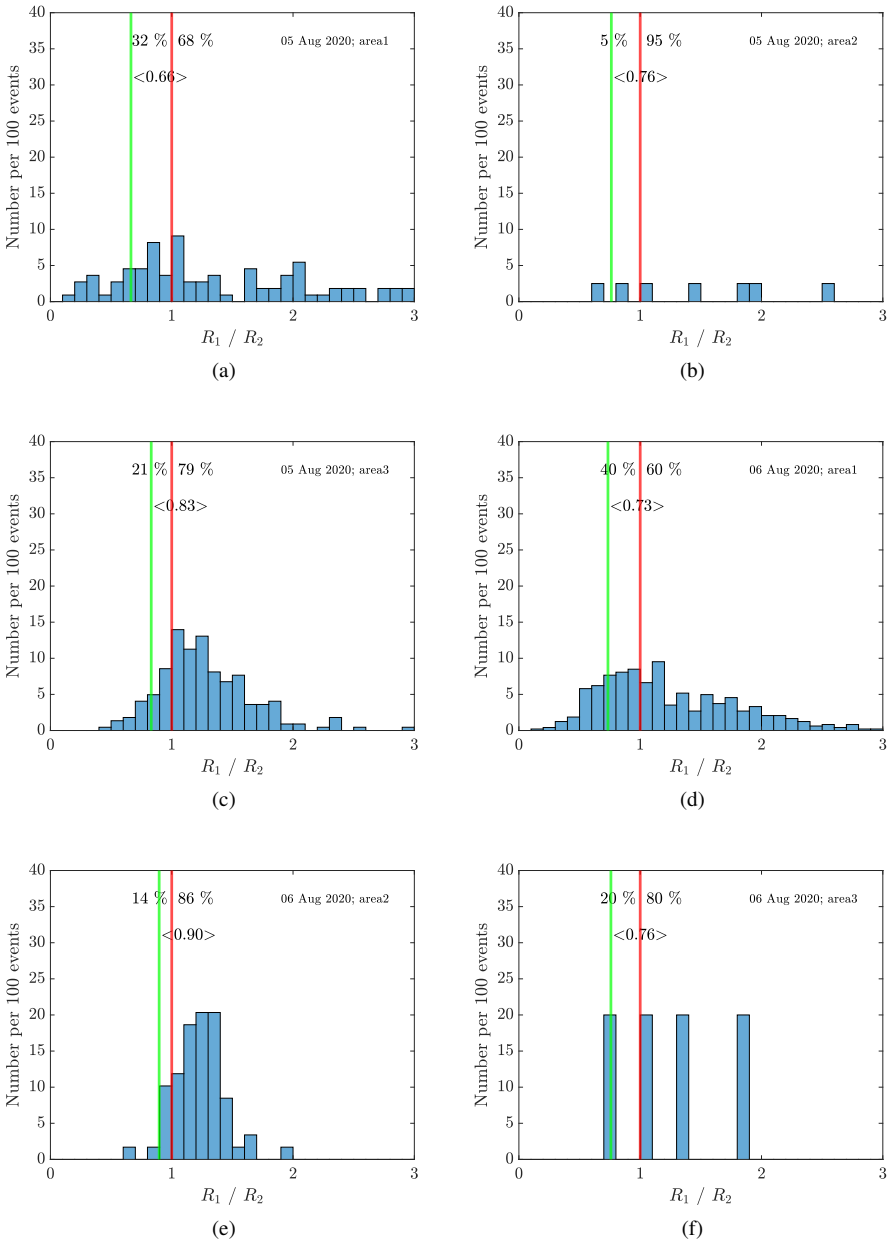

Figure S32. Average of the heating for the observed data on the 5 and 6 August 2020. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

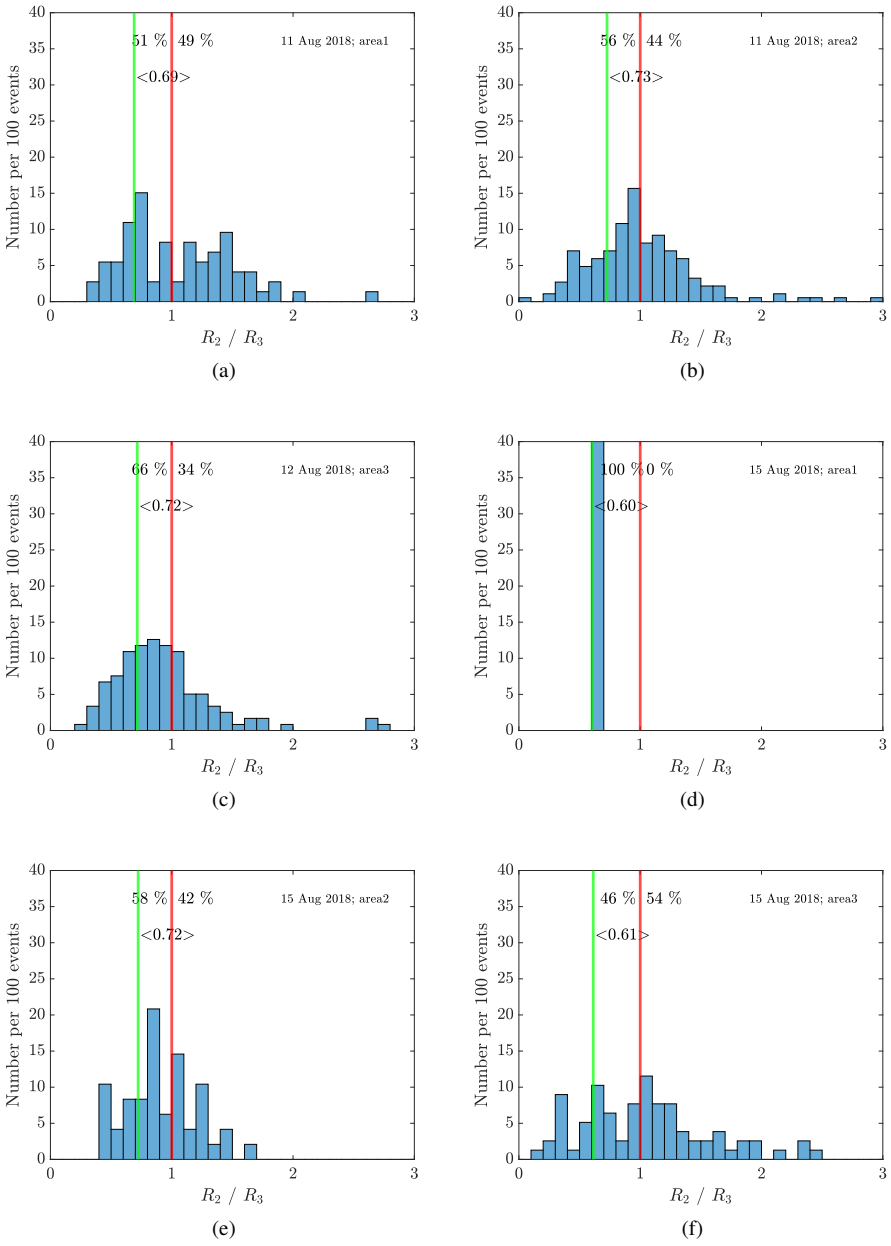

Figure S33. Average of the recovery for the observed data on the 11 and 15 August 2018. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

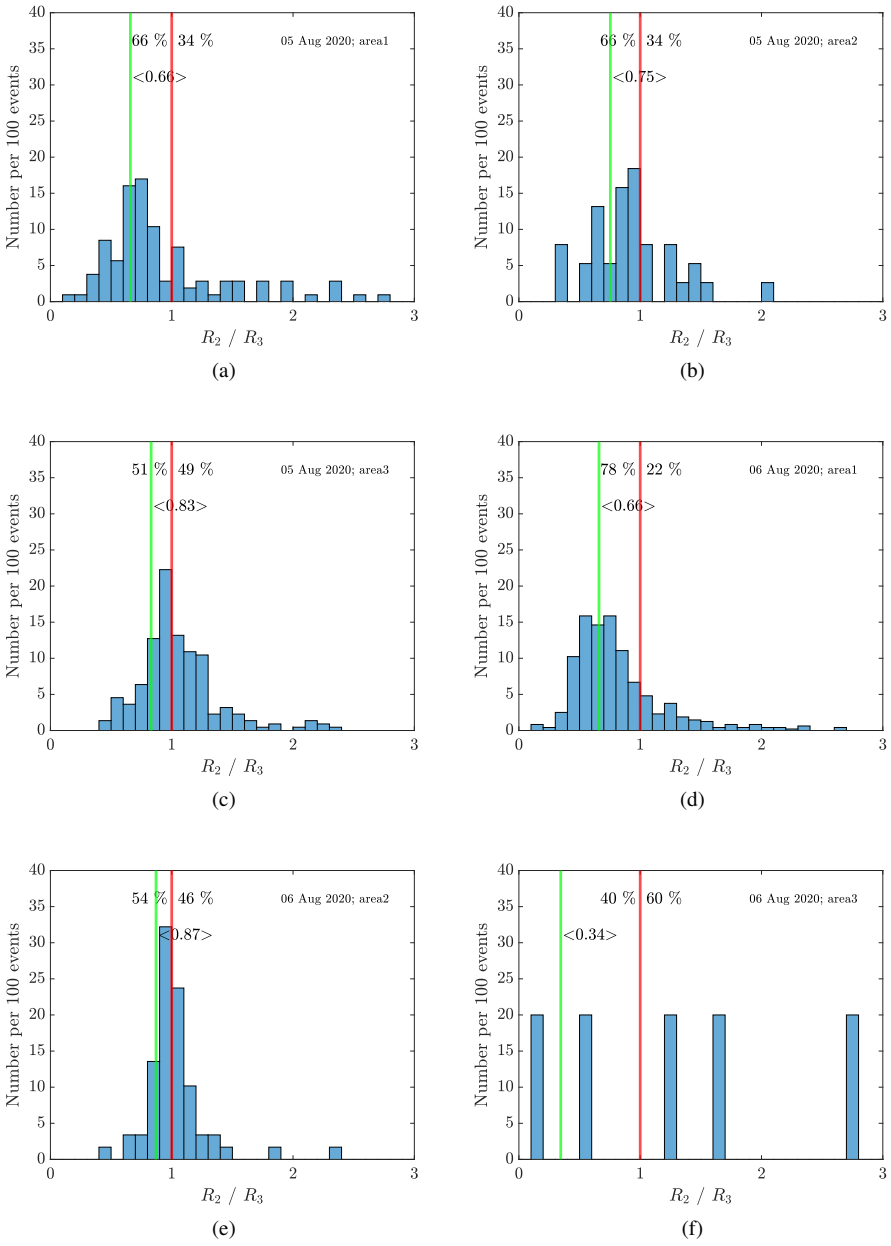

Figure S34. Average of the recovery for the observed data on the 5 and 6 August 2020. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

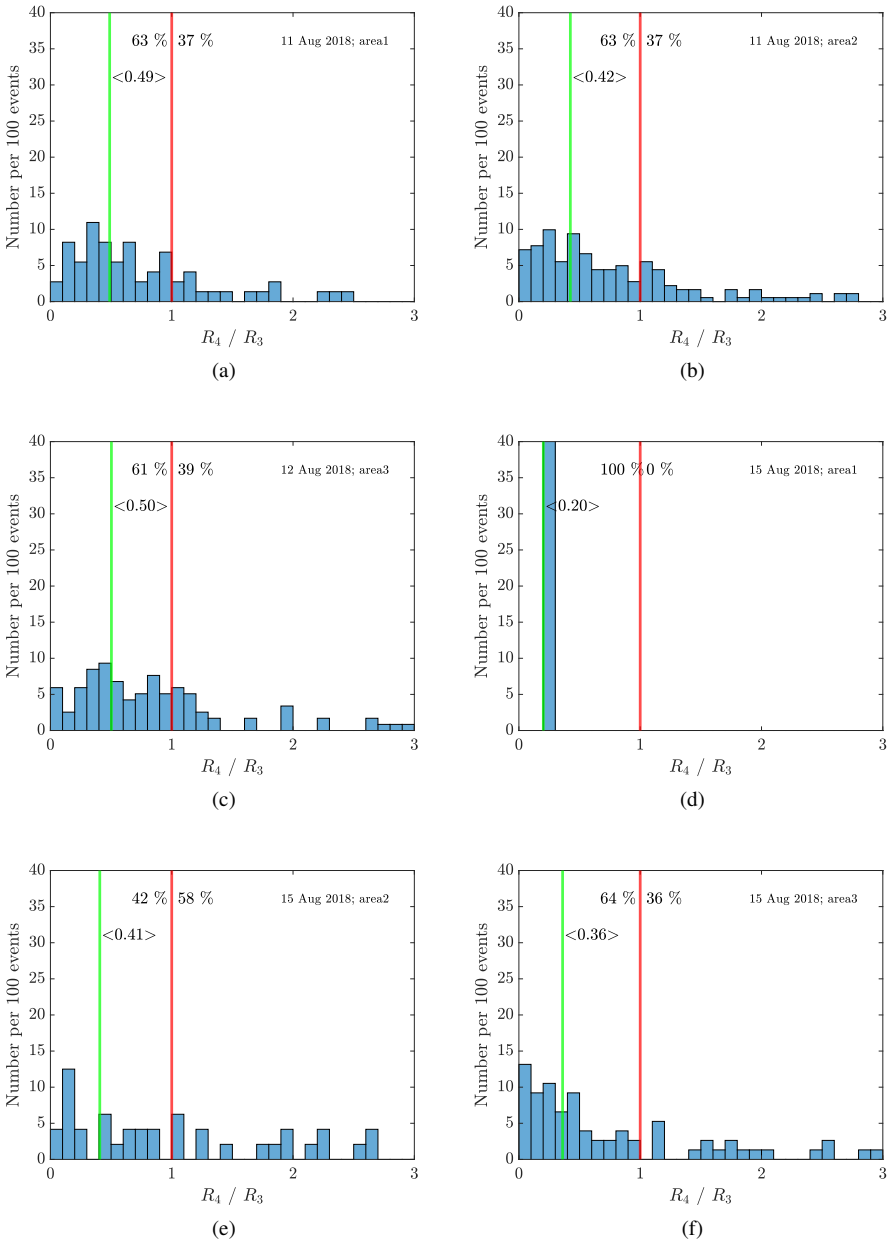

Figure S35. Average of the relaxation for the observed data on the 11 and 15 August 2018. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.

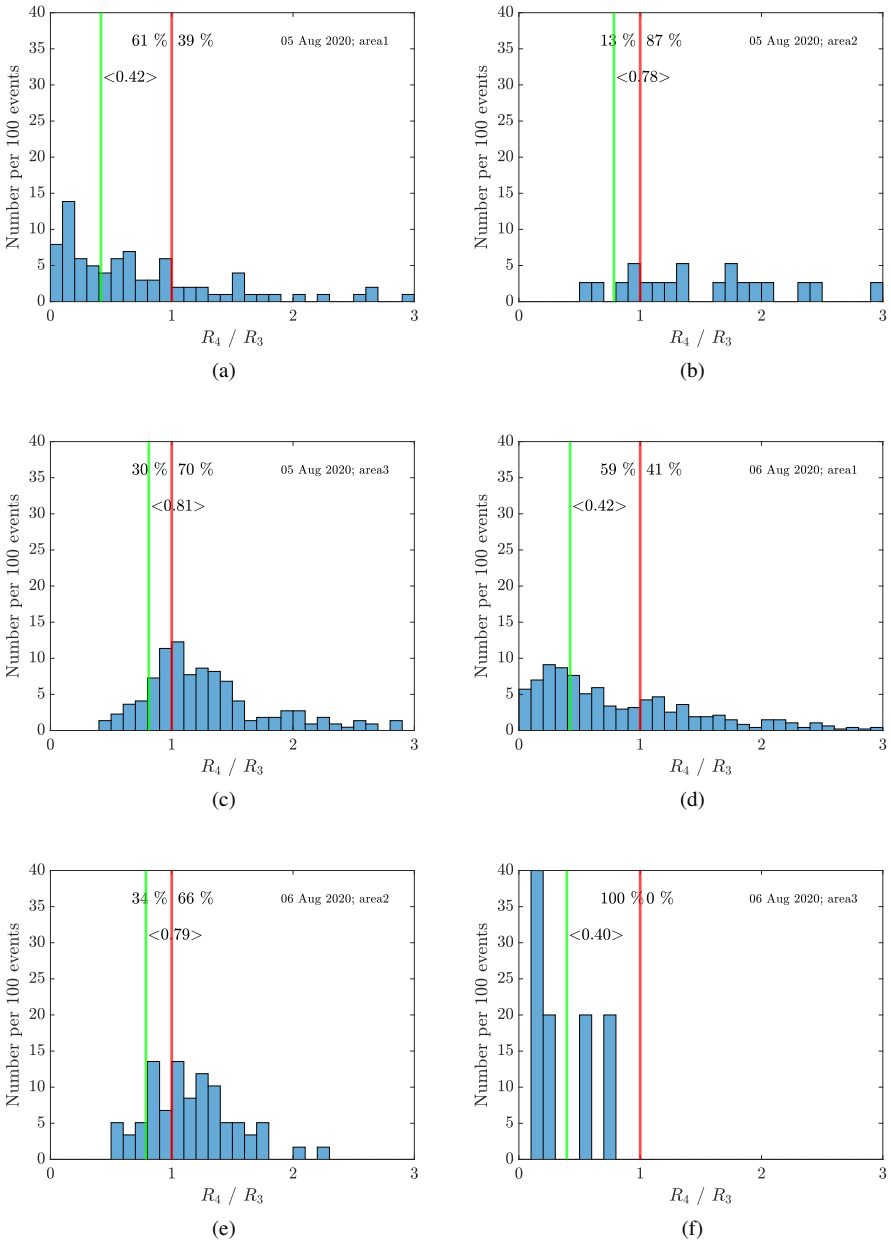

Figure S36. Average of the relaxation for the observed data on the 5 and 6 August 2020. Only overshoot curves with a minimal background amplitude of $R_0 > 10^{10.5}$ are considered. The ratios are chosen in such a way, that, if we observe an overshoot curve like shown in Fig. **??**, all ratios are smaller than 1. Thus, the histograms are clipped at a maximum ratio of 3. The green line and the corresponding number displays the mean for all ratios smaller than 1.