

**Experimental observations and statistical modelling of crack propagation dynamics in limestone by acoustic emission analysis during freezing and thawing**

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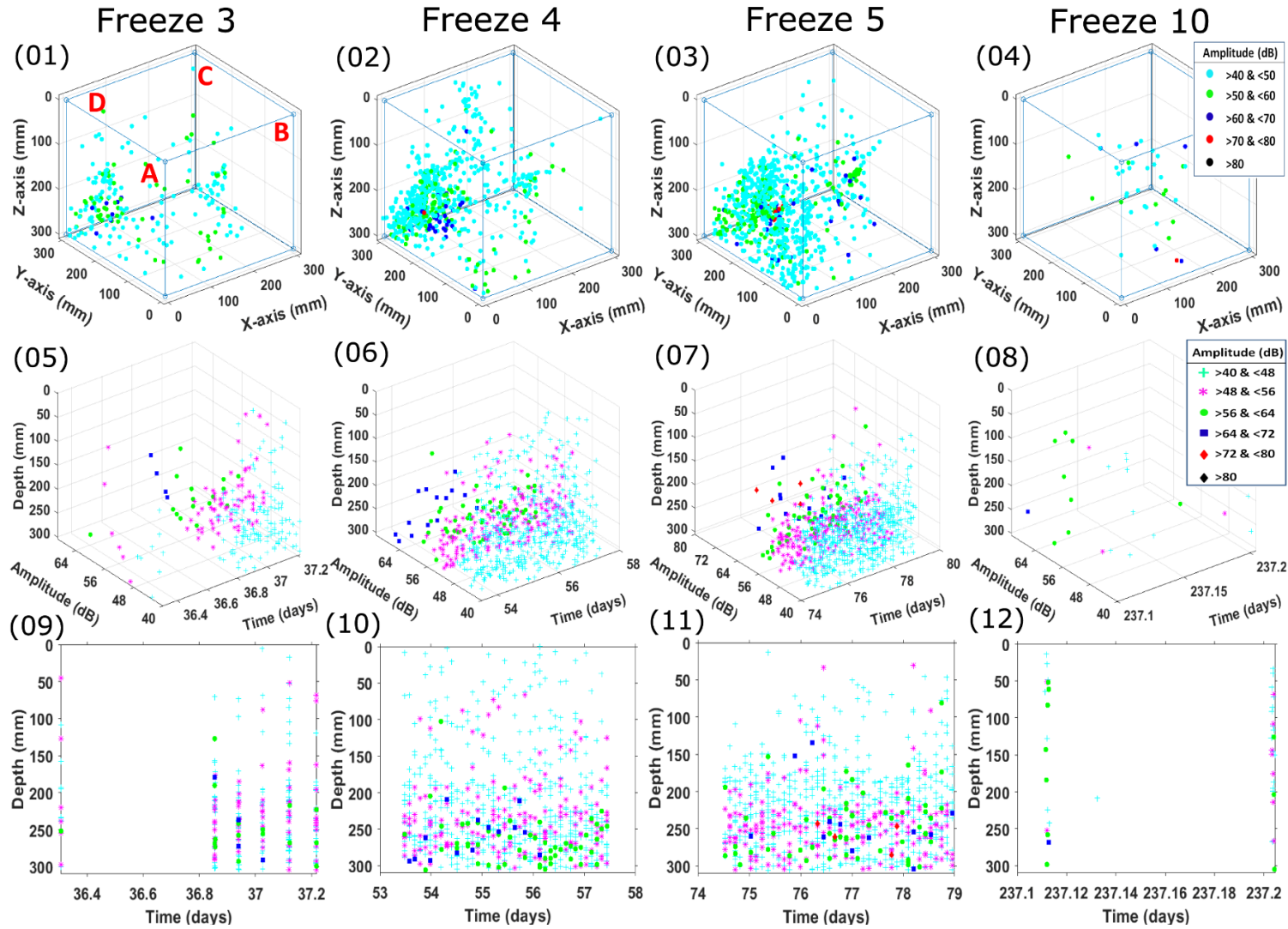
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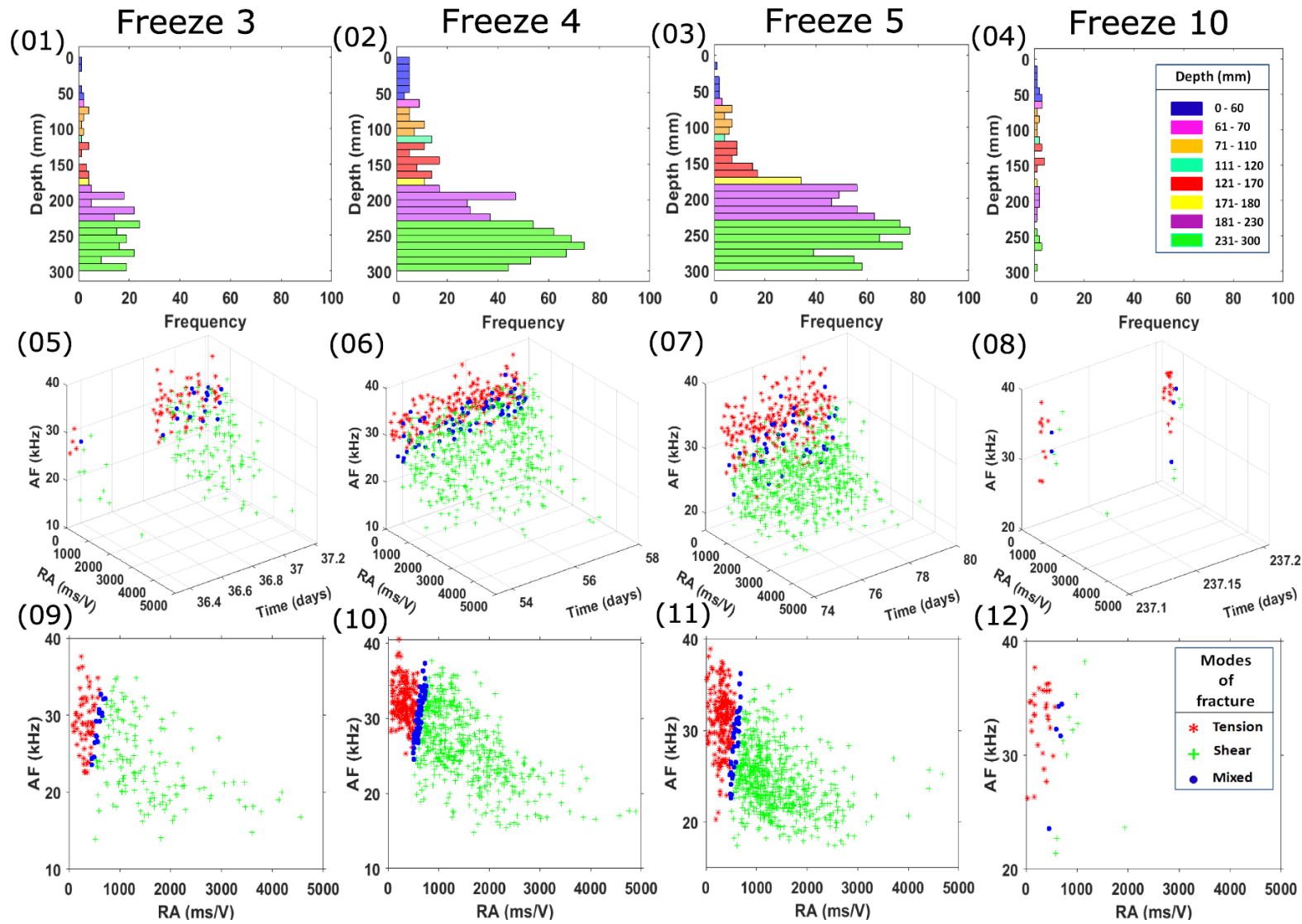
Figures S1 to S20

**Introduction**

The supporting information provides 20 figures showing the full dataset for the acoustic emission (AE) results from the 16 cycles of freeze-thaw during a laboratory experiment lasting 470 days (Figures S1–S20). Each cycle has four parts: (1) a thaw-to-freeze transition, (2) a freezing period, (3) a freeze-to-thaw transition, and (4) a thawing period, as described in section 2.1 of the main paper. The data were collected by eight AE sensors installed on a 300-mm cubic block of chalk. An AE event was identified if at least four of the eight sensors captured the pulses of energy released (hits). Only AE events whose magnitude exceeds 40dB are shown, to exclude noise in the laboratory from signals of microcracking events. The three-dimensional location, depth magnitude, AF and RA values of >40dB AE events are shown in Figures S1–S20.

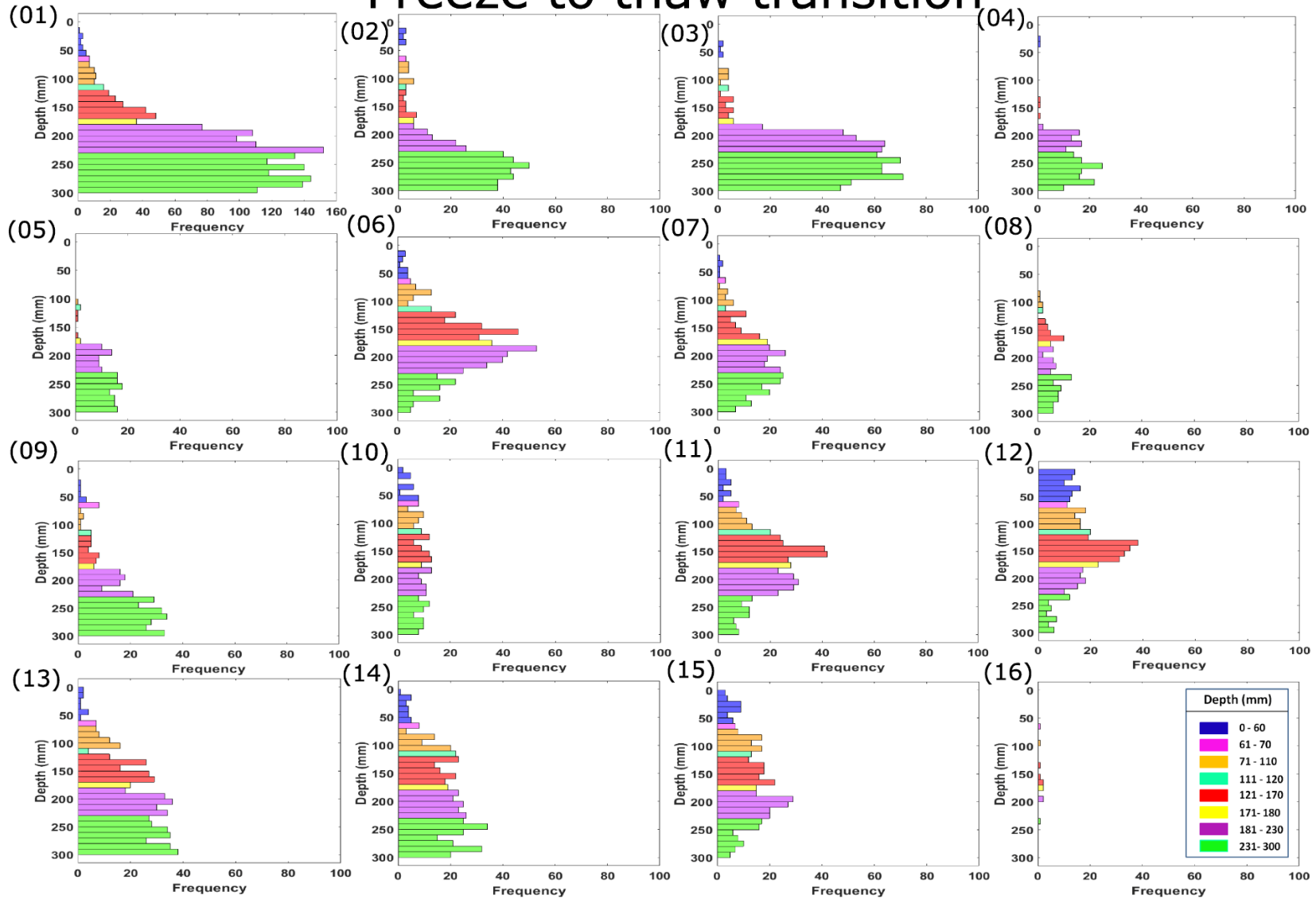


**Figure S1.** AE data for freezing periods. (01–04) 3D locations of AE events with their respective amplitude. Vertical faces A–D of the block are labelled in (01). (05–08) Visualization of AE events in terms of depth, amplitude and time. (09–12) Simplified version of plots 05–08 with depth vs time, and amplitude ranges marked with different shapes and colours.



**Figure S2.** AE data for freezing periods. (01–04) Frequency distribution of AE events along various depth intervals within the block. (05–08) Visualization of AE events in terms of AF values, RA values and time, labelled according to modes of fracture. (09–12) Simplified version of plots 05–08 with AF vs RA values and fracture modes.

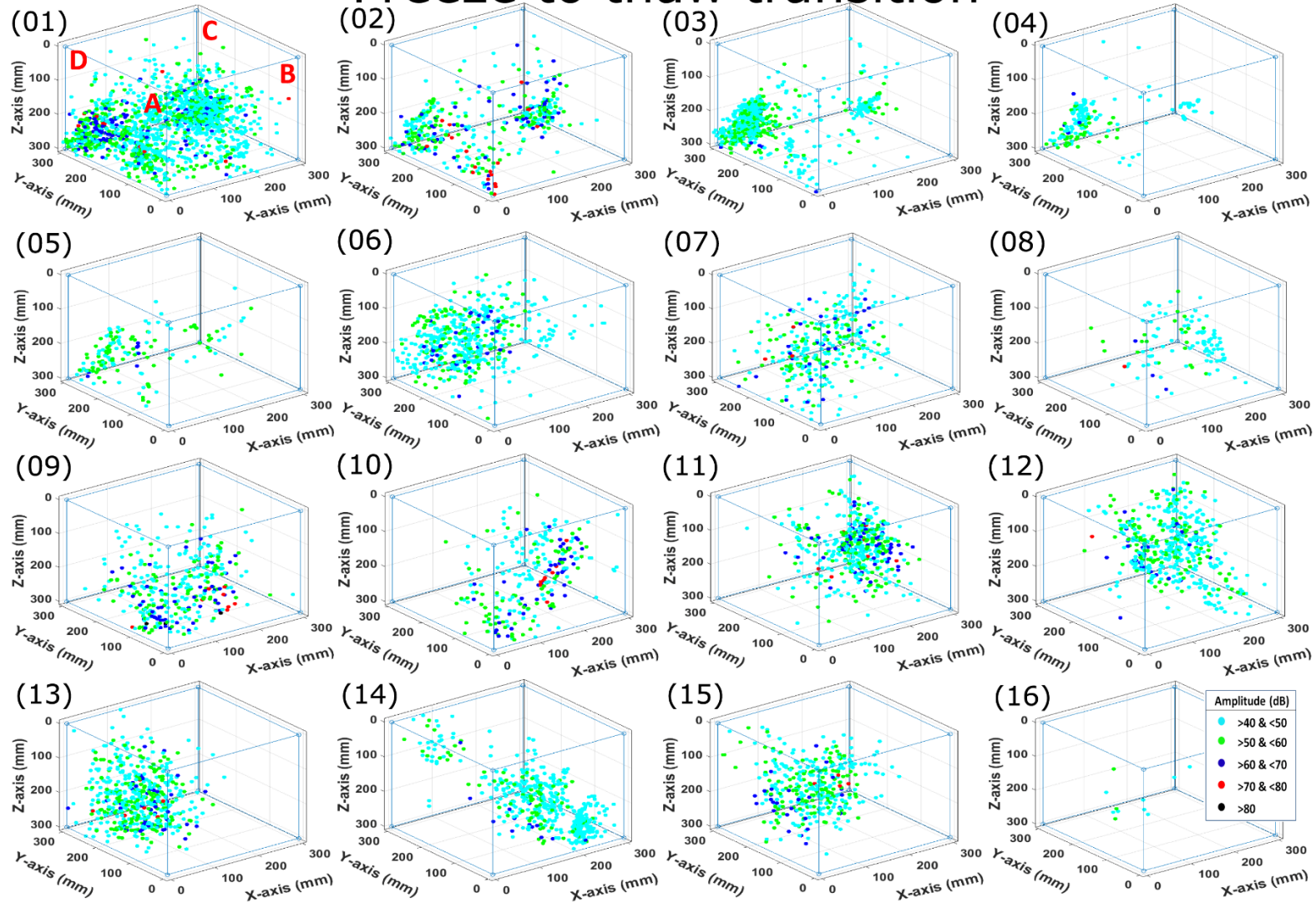
# Freeze to thaw transition



**Figure S3.** Frequency distribution of AE events along various depth intervals within the block recorded during freeze-to-thaw transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

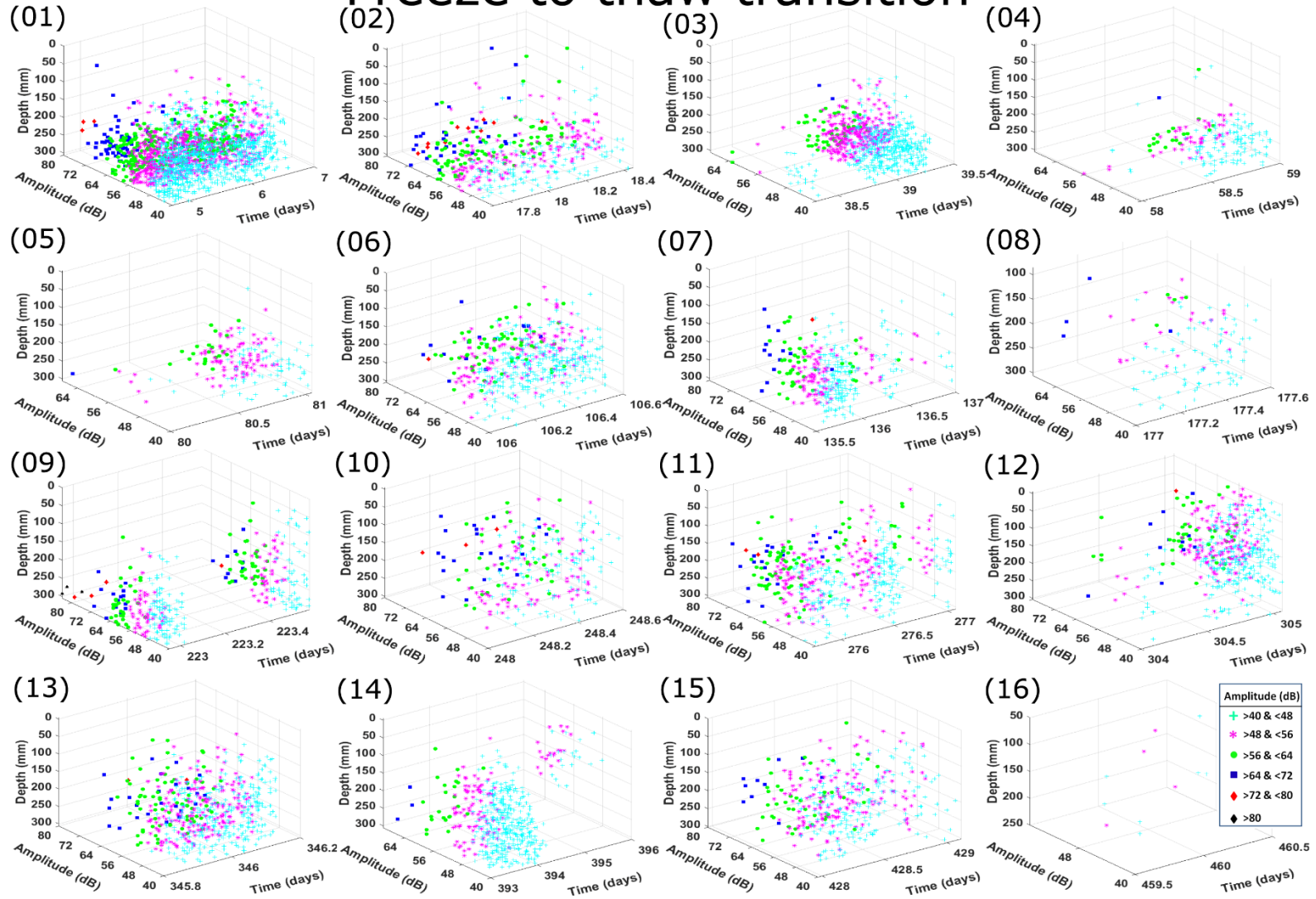


## Freeze to thaw transition



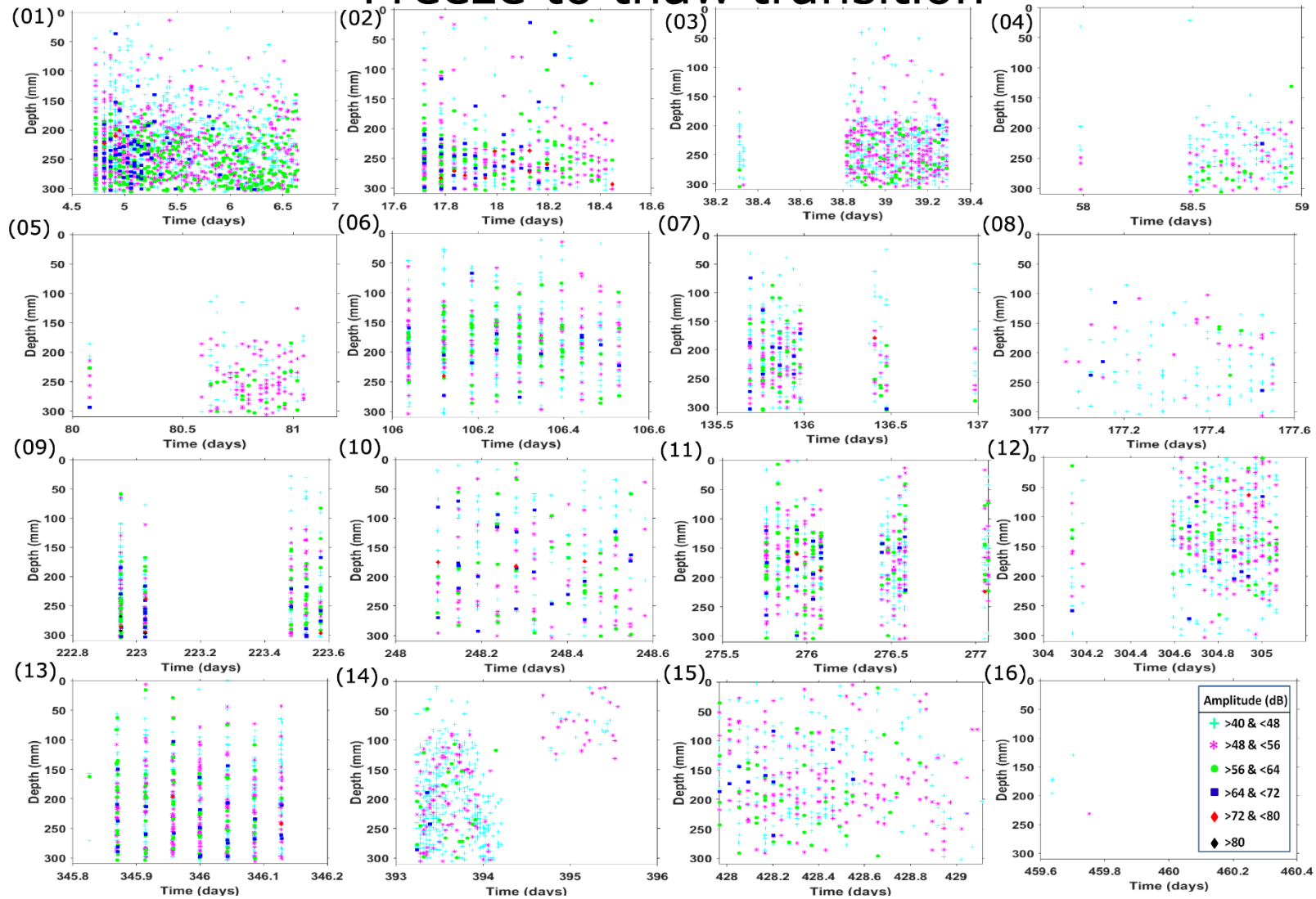
**Figure S4.** 3D locations of AE events with their respective amplitude recorded during freeze-to-thaw transitions over the course of 16 freeze-thaw cycles. Vertical faces A–D of the block are labelled in (01). The number beside each subpanel indicates the number of the respective cycle.

## Freeze to thaw transition



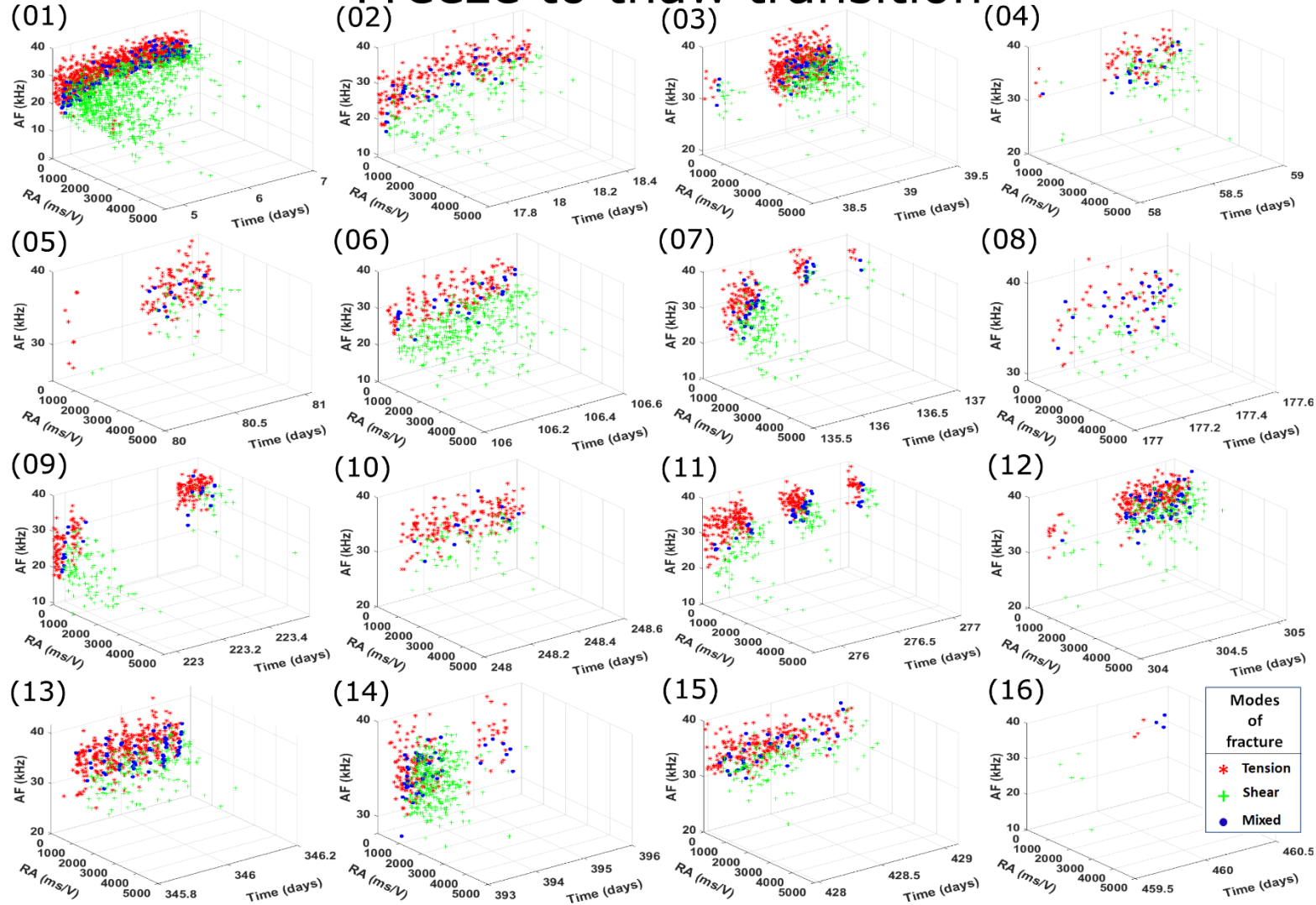
**Figure S5.** Visualization of AE events in terms of depth, amplitude and time recorded during freeze-to-thaw transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

# Freeze to thaw transition



**Figure S6.** Simplified version of **Figure S5** with depth vs time, and amplitude ranges marked with different shapes and colours. The number beside each subpanel indicates the number of the respective cycle.

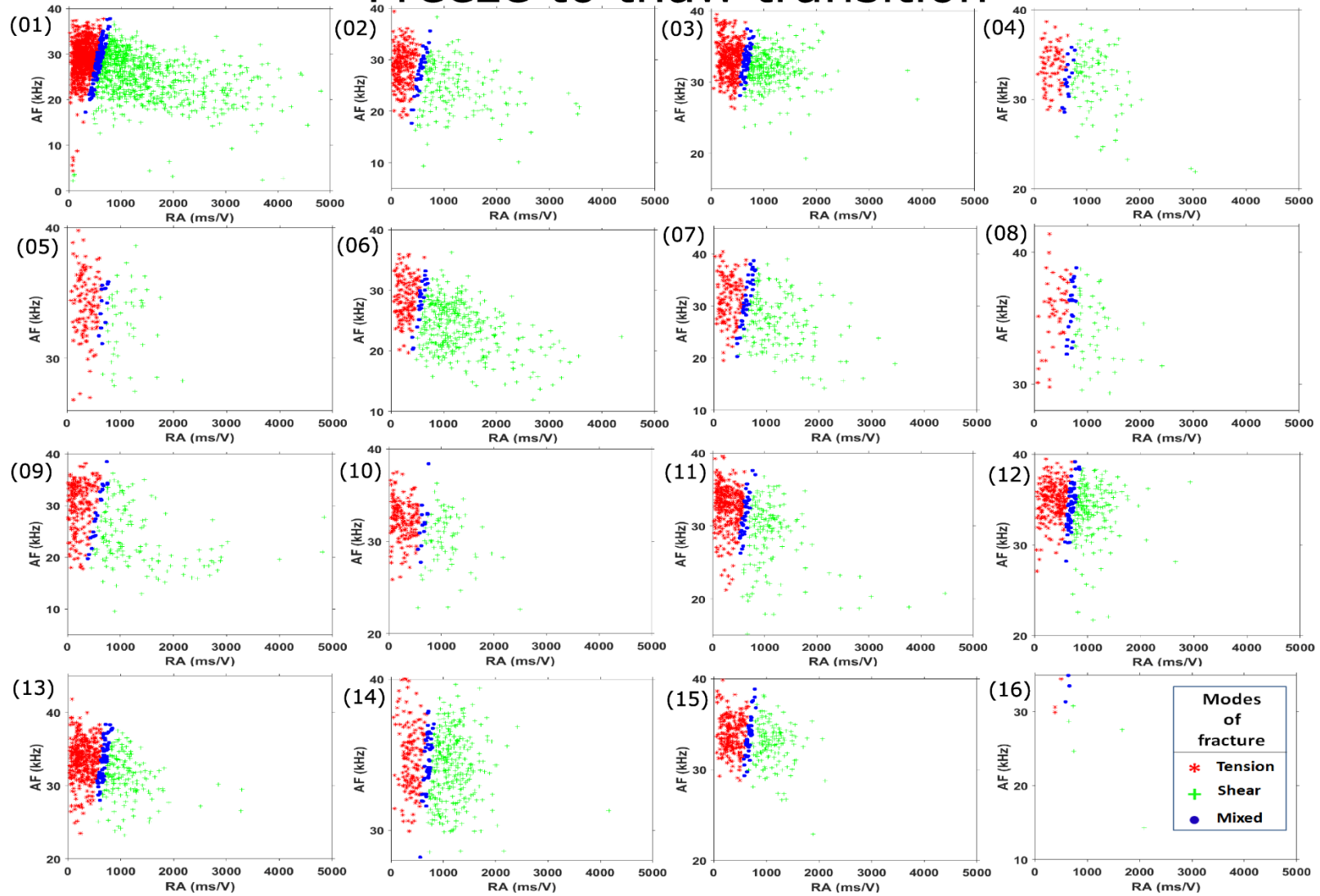
# Freeze to thaw transition



**Figure S7.** Visualization of AE events in terms of AF values, RA values and time, labelled according to modes of fracture and recorded during freeze-to-thaw transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

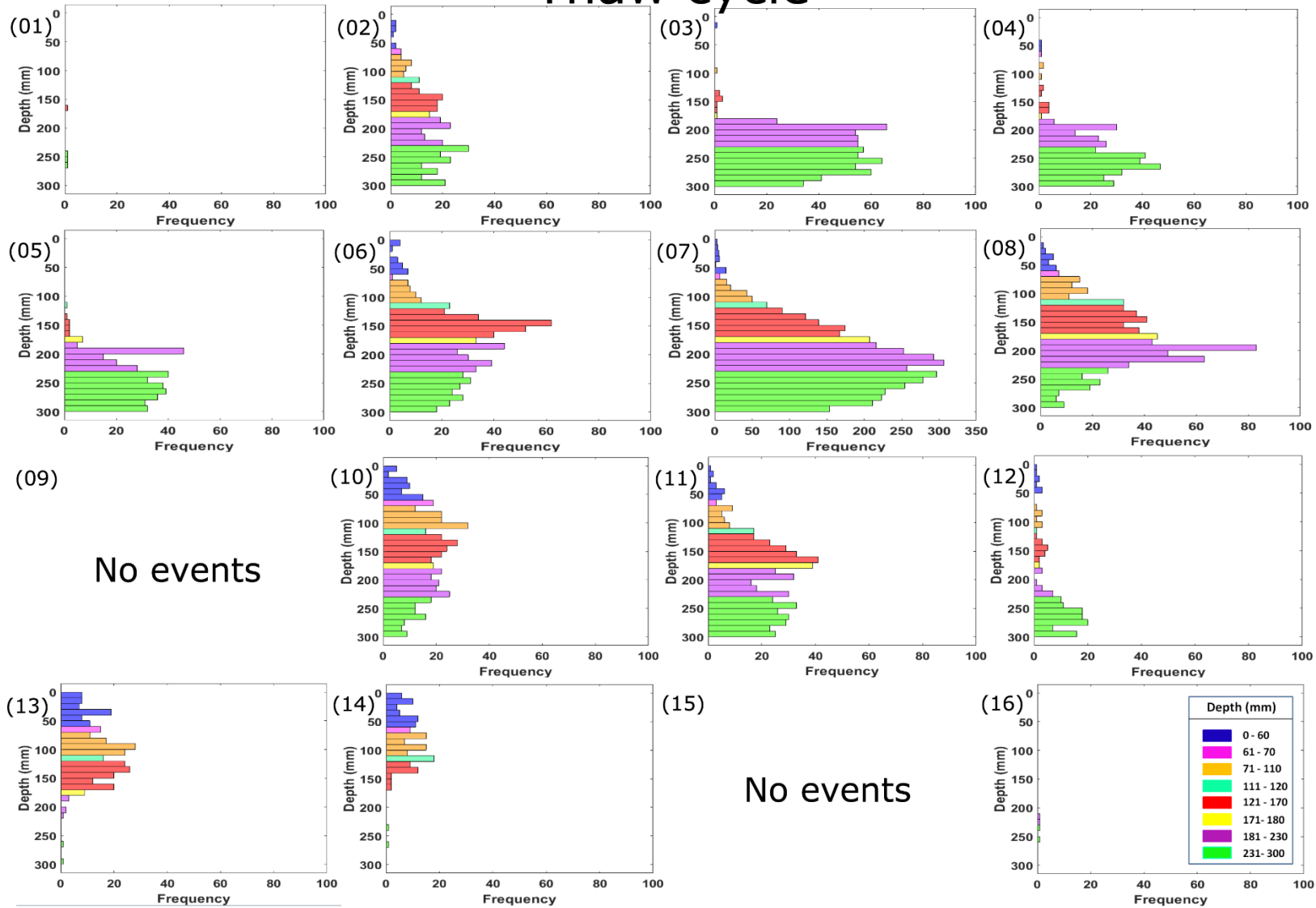


## Freeze to thaw transition



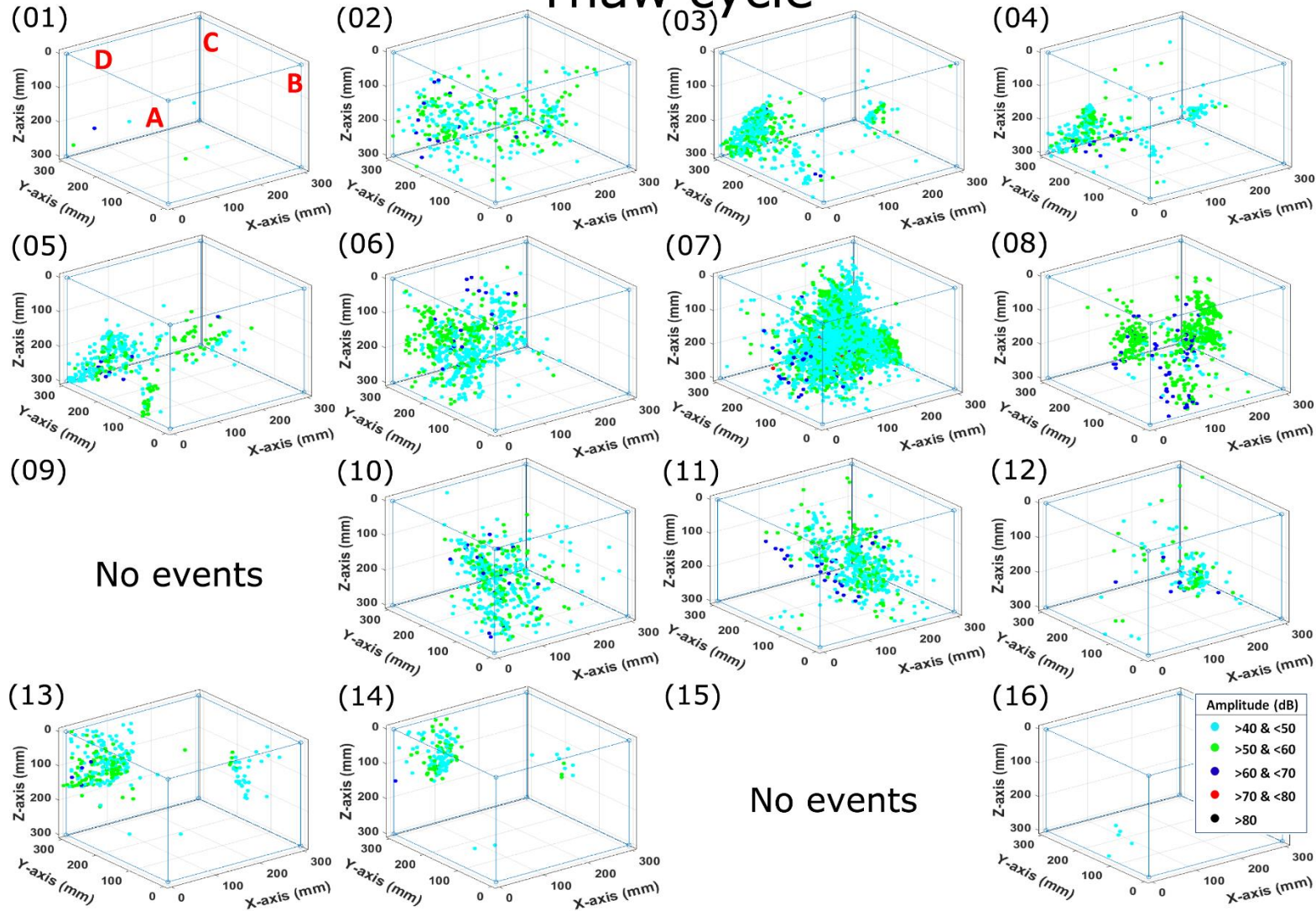
**Figure S8.** Simplified version of **Figure S7** with AF vs RA values and fracture modes. The number beside each subpanel indicates the number of the respective cycle.

# Thaw cycle



**Figure S9.** Frequency distribution of AE events along various depth intervals within the block recorded during thawing periods over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

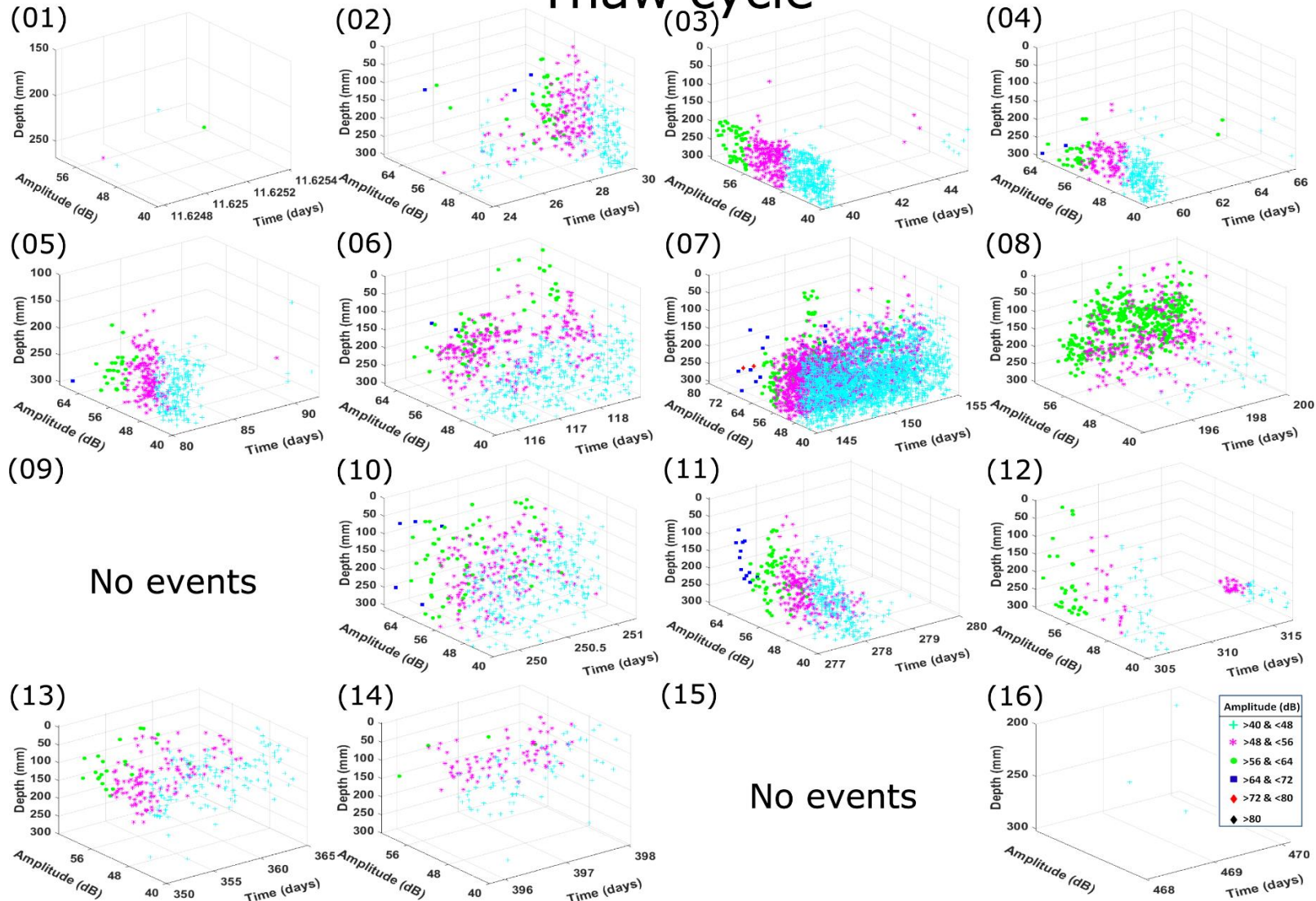
## Thaw cycle



**Figure S10.** 3D locations of AE events with their respective amplitude recorded during thawing periods over the course of 16 freeze-thaw cycles. Vertical faces A–D of the block are labelled in (01). The number beside each subpanel indicates the number of the respective cycle.

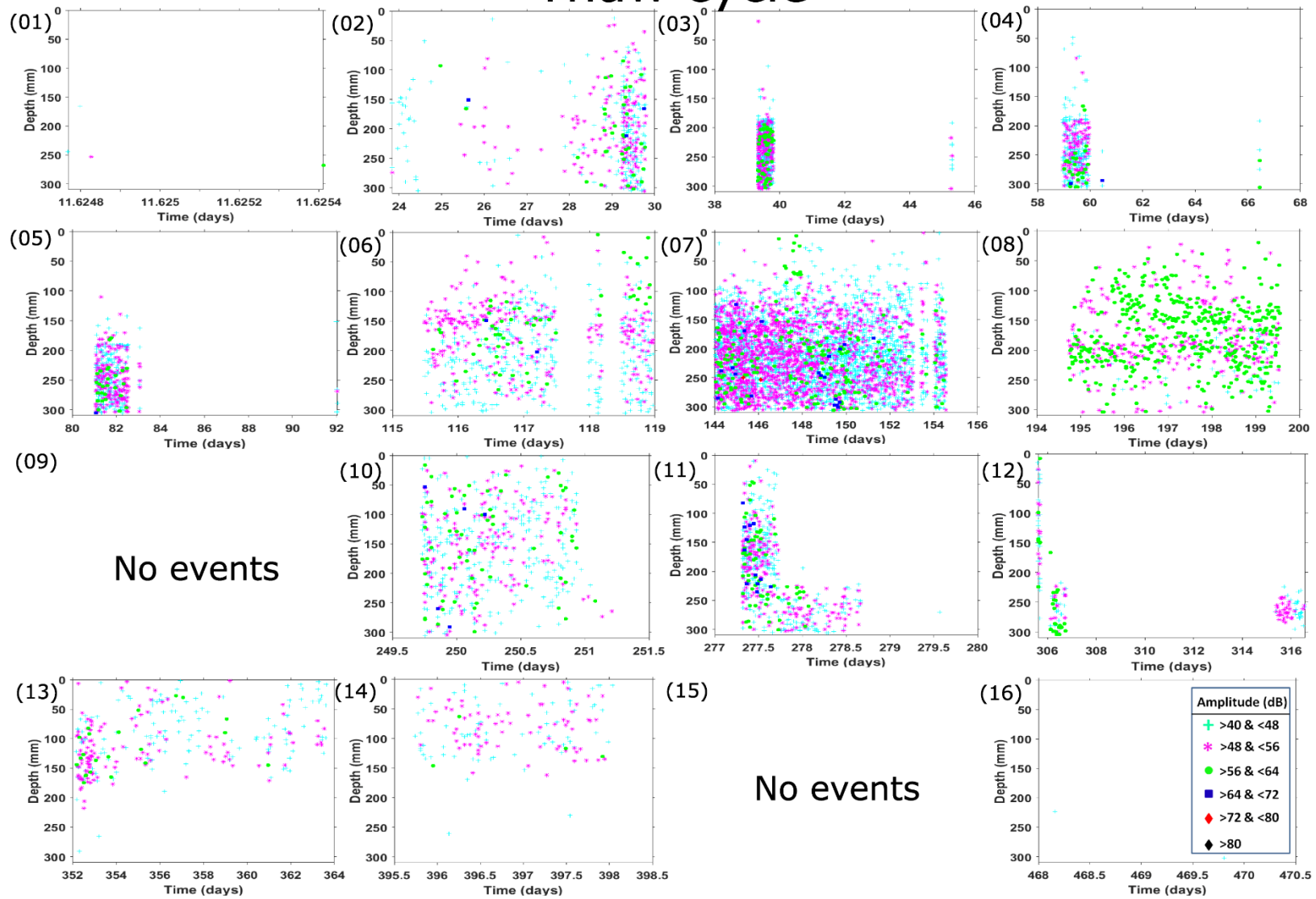


# Thaw cycle



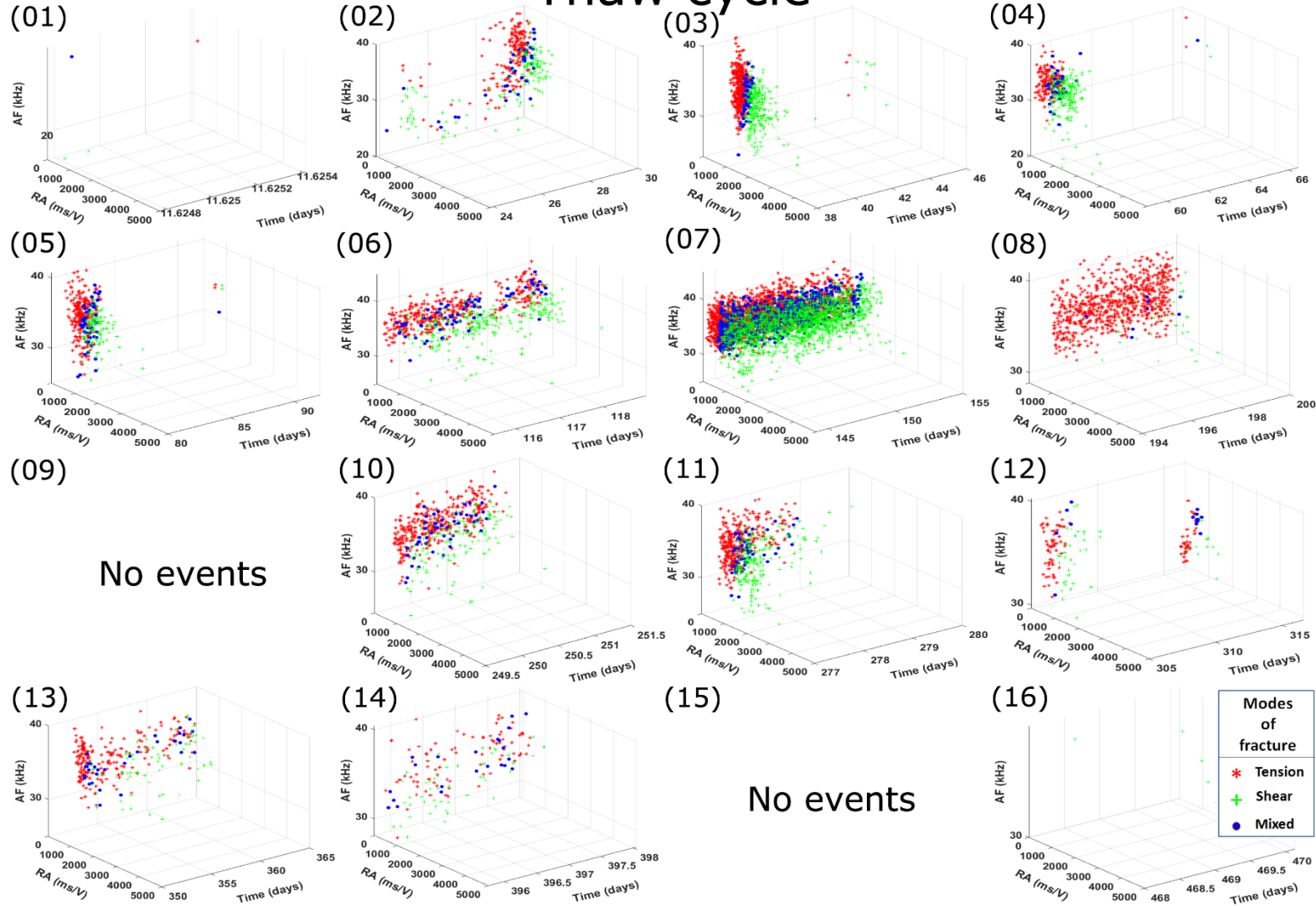
**Figure S11.** Visualization of AE events in terms of depth, amplitude and time recorded during thawing periods over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

# Thaw cycle



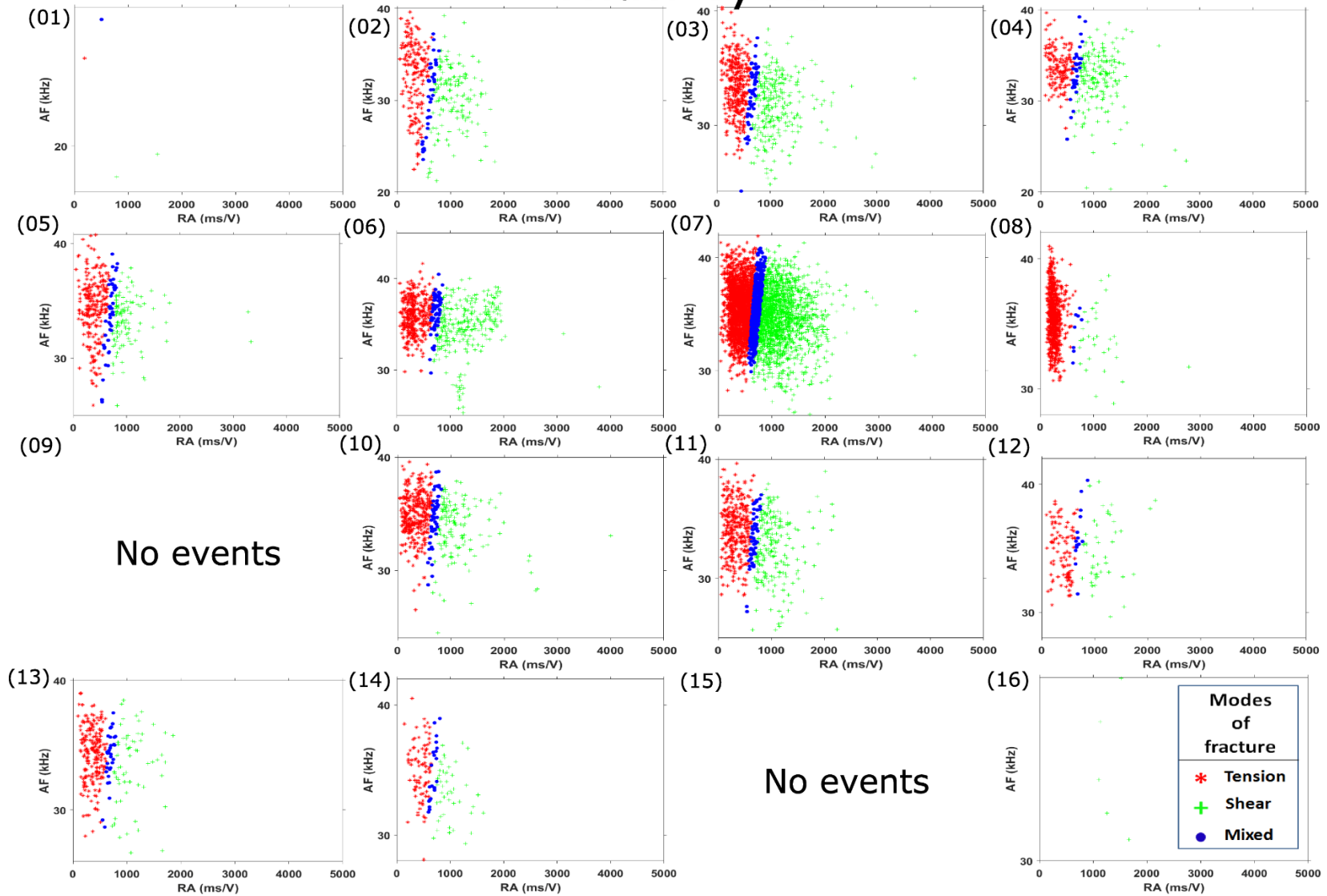
**Figure S12.** Simplified version of **Figure S11** with depth vs time, and amplitude ranges marked with different shapes and colours. The number beside each subpanel indicates the number of the respective cycle.

## Thaw cycle



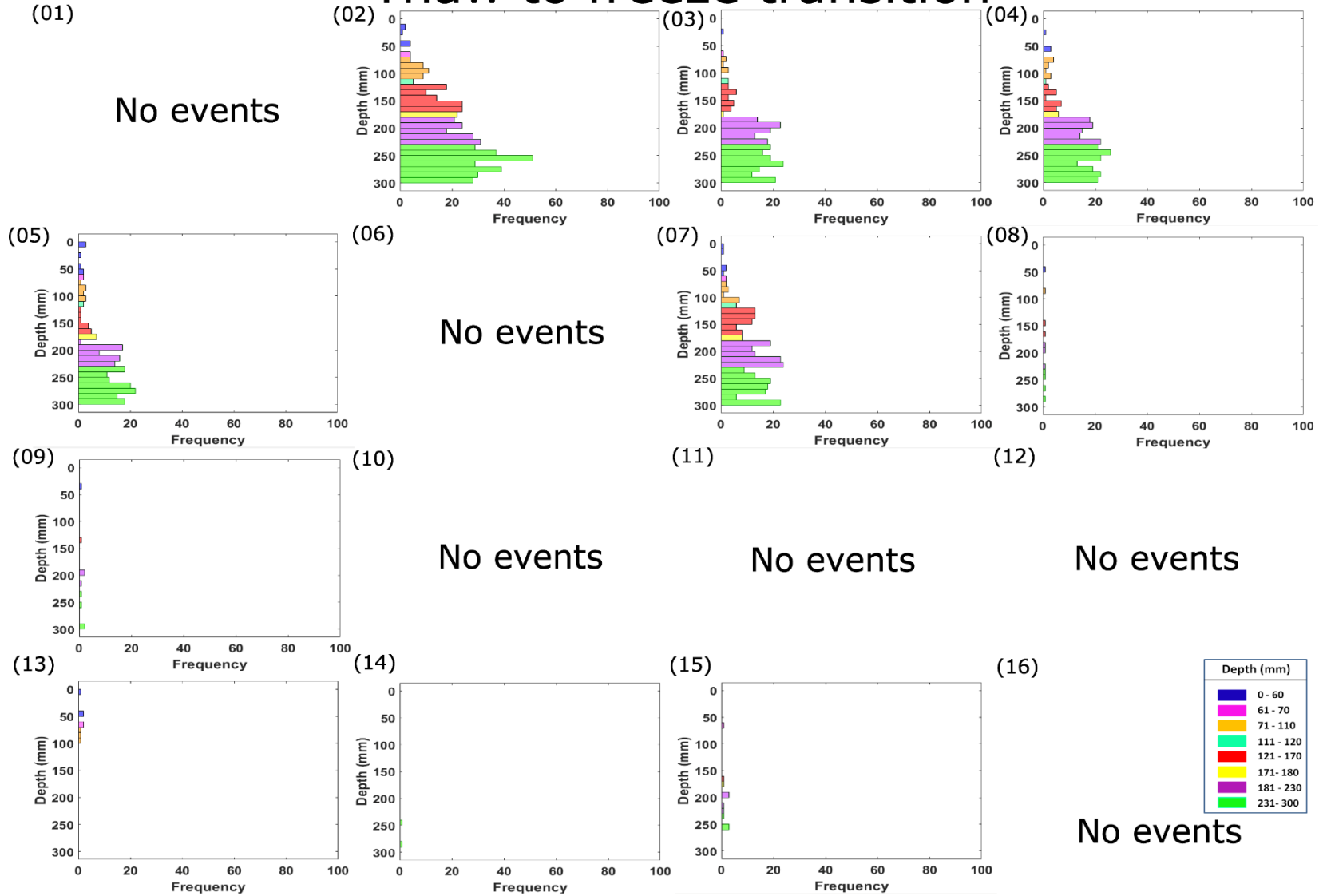
**Figure S13.** Visualization of AE events in terms of AF values, RA values and time, labelled according to modes of fracture and recorded during thawing periods over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

# Thaw cycle



**Figure S14.** Simplified version of **Figure S13** with AF vs RA values and fracture modes. The number beside each subpanel indicates the number of the respective cycle.

# Thaw to freeze transition



**Figure S15.** Frequency distribution of AE events along various depth intervals within the block recorded during thaw-to-freeze transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

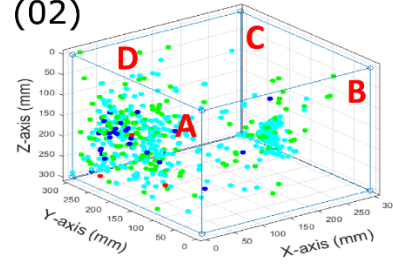


# Thaw to freeze transition

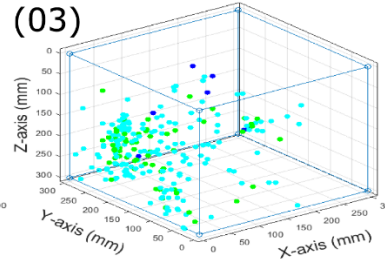
(01)

No events

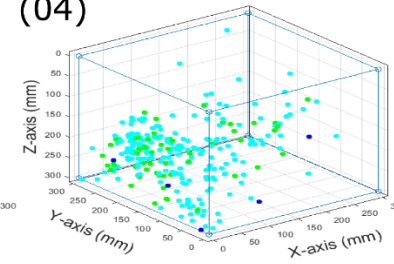
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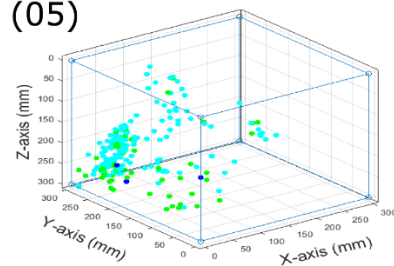
(03)



(04)



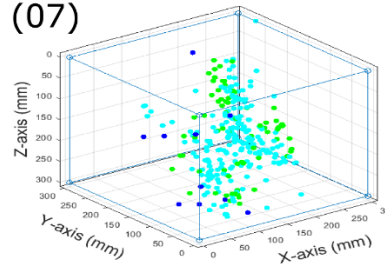
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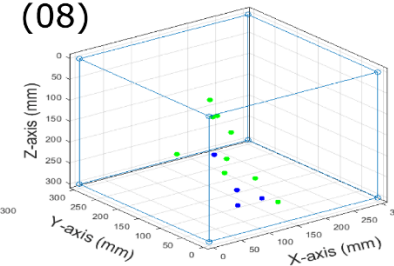
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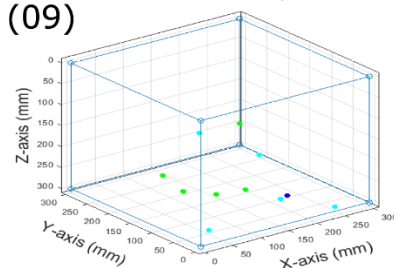
(07)



(08)



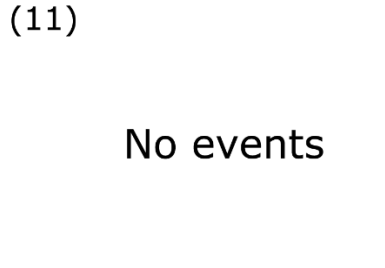
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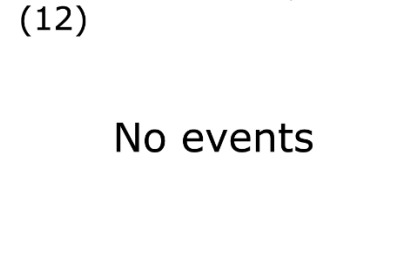
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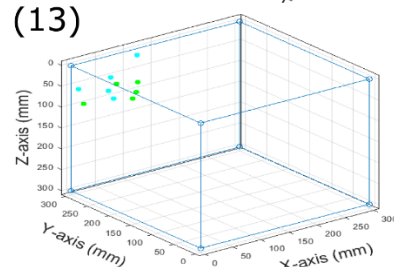
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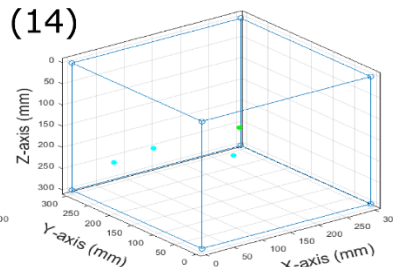
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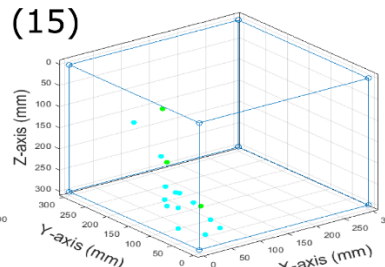
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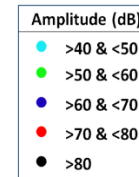
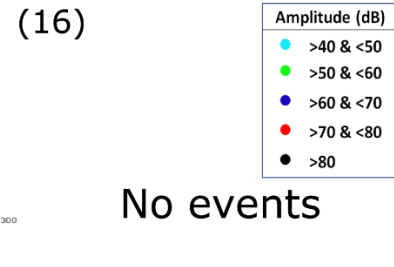
(14)



(15)



(16)



No events

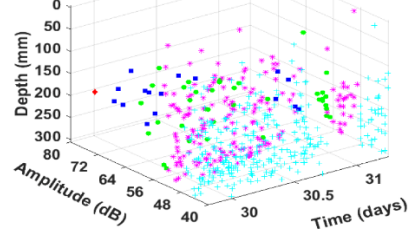
**Figure S16.** 3D locations of AE events with their respective amplitude recorded during thaw-to-freeze transitions over the course of 16 freeze-thaw cycles. Vertical faces A–D of the block are labelled in (01). The number beside each subpanel indicates the number of the respective cycle.

# Thaw to freeze transition

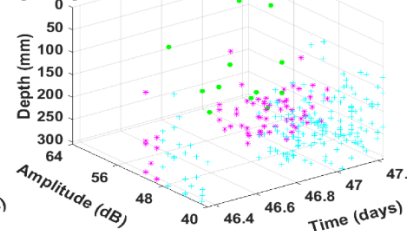
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No events

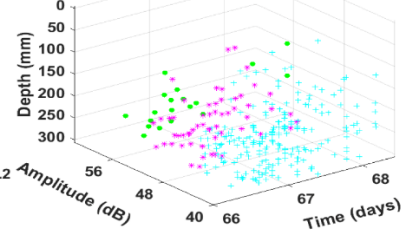
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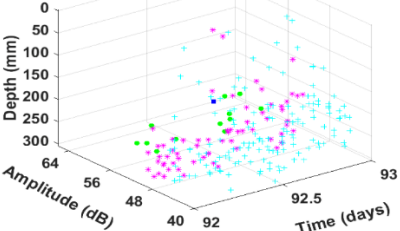
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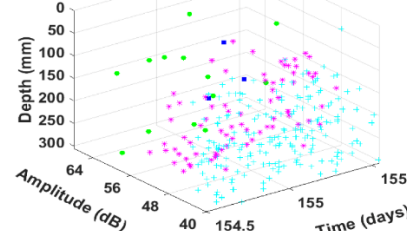
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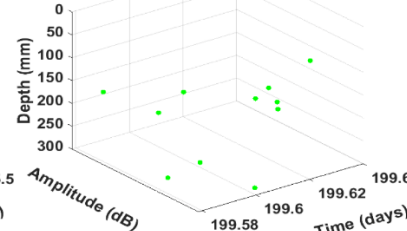
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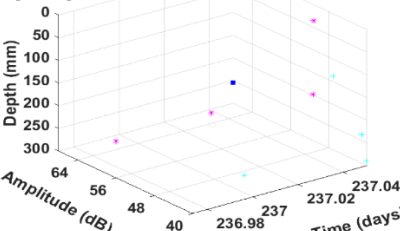
(07)



(08)



(09)



(10)

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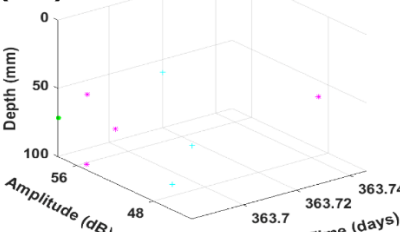
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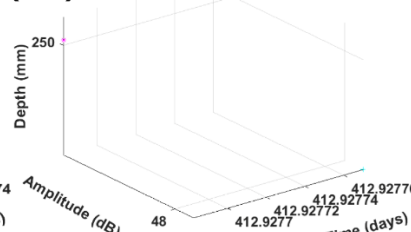
(12)

No events

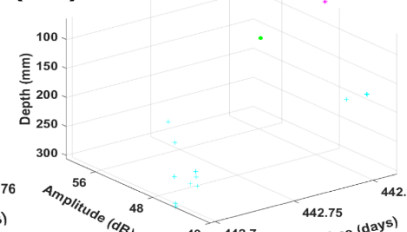
(13)



(14)



(15)



(16)

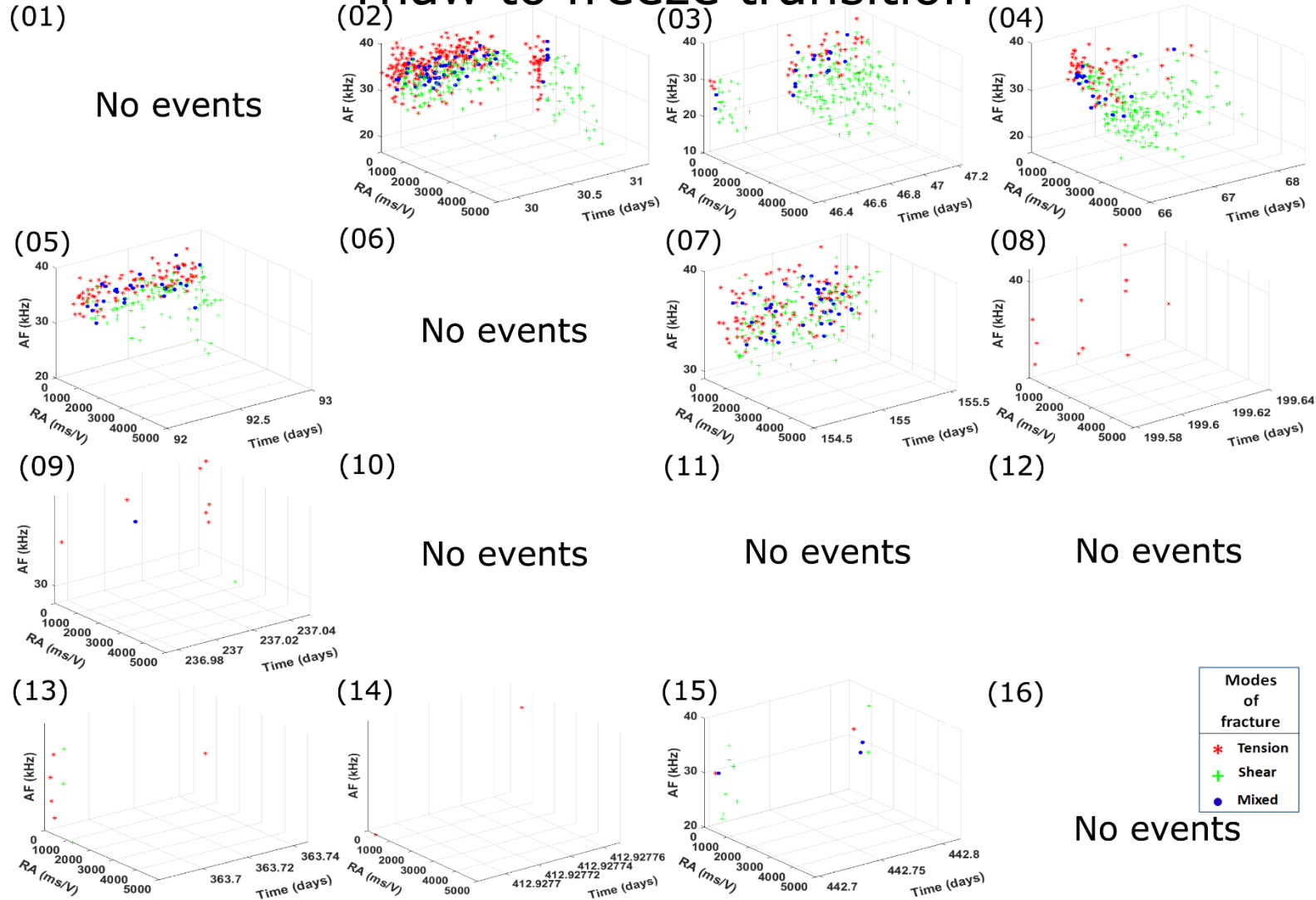
No events



**Figure S17.** Visualization of AE events in terms of depth, amplitude and time recorded during thaw-to-freeze transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

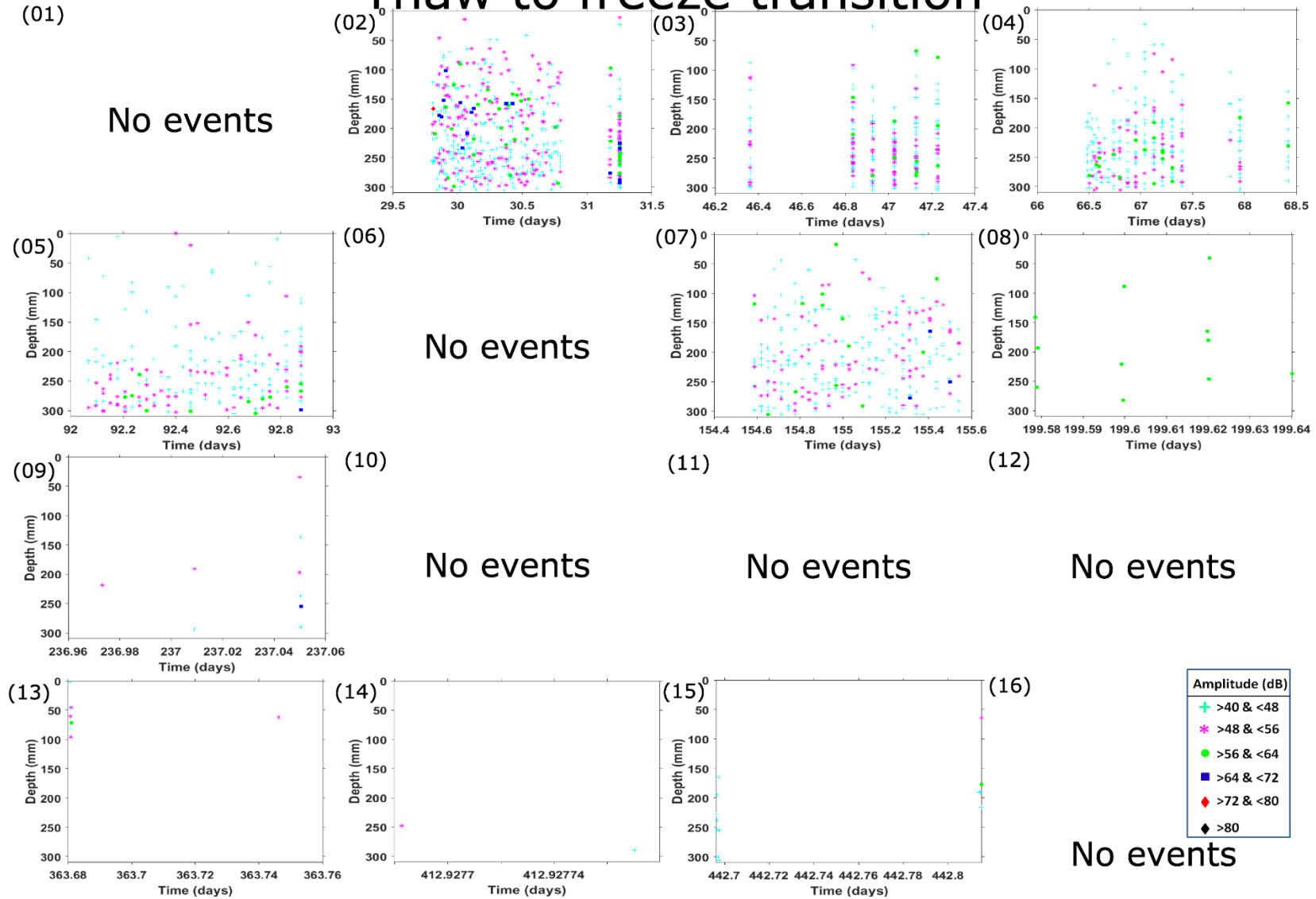


# Thaw to freeze transition



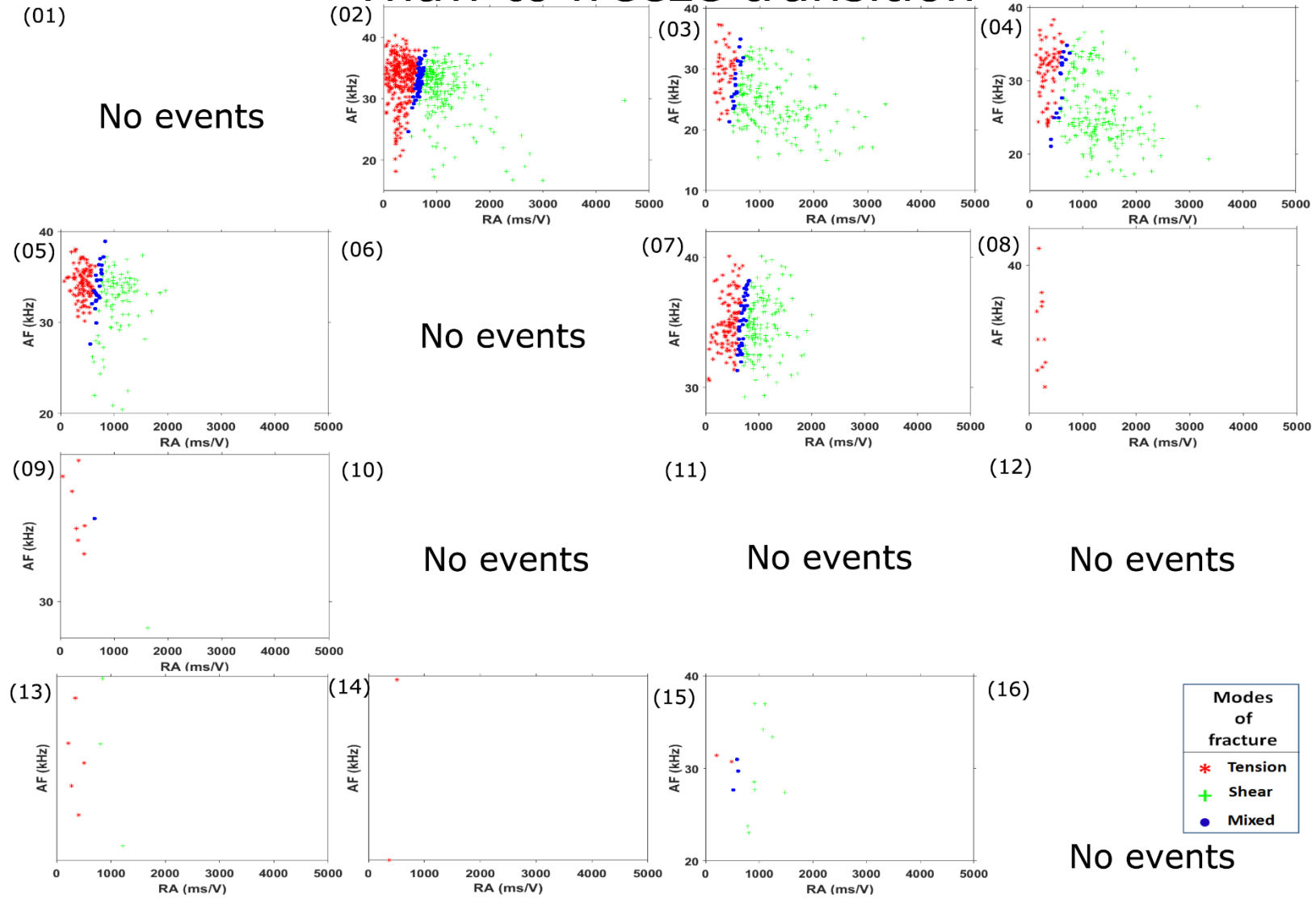
**Figure S18.** Visualization of AE events in terms of AF values, RA values and time, labelled according to modes of fracture and recorded during thaw-to-freeze transitions over the course of 16 freeze-thaw cycles. The number beside each subpanel indicates the number of the respective cycle.

# Thaw to freeze transition



**Figure S19.** Simplified version of Appendix 17 with depth vs time, and amplitude ranges marked with different shapes and colours. The number beside each subpanel indicates the number of the respective cycle.

# Thaw to freeze transition



**Figure S20.** Simplified version of **Figure S18** with AF vs RA values and fracture modes. The number beside each subpanel indicates the number of the respective cycle.