

Rapid-repeat time lapse seismic sensing of CO₂ injection

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**NSERC
CRSNG**



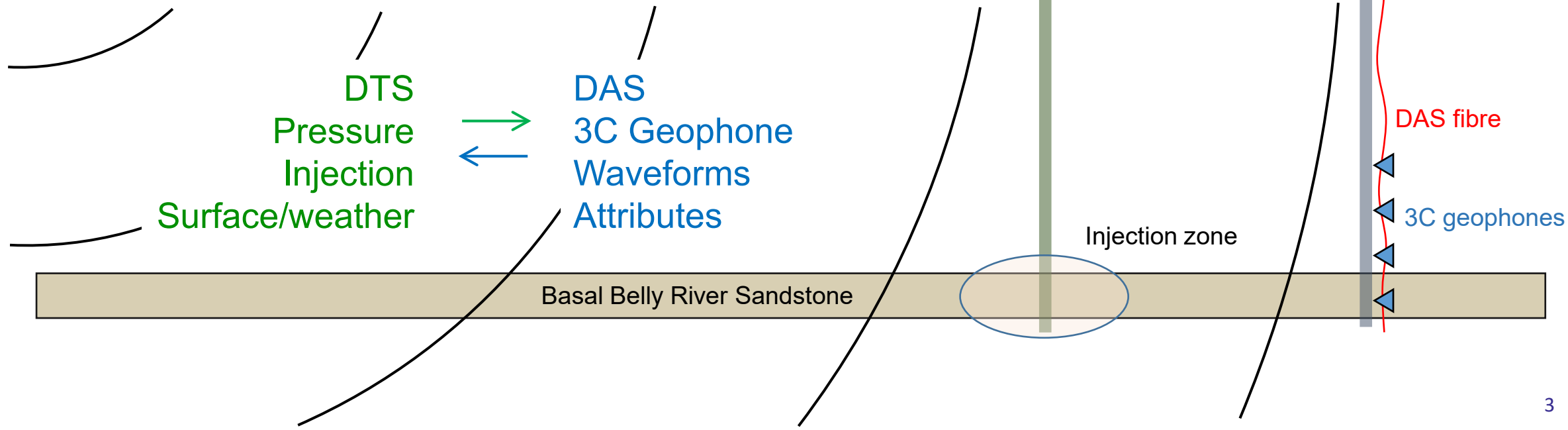
UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Department of Geoscience



- The case for rapid-repeat monitoring
 - JOGMEC microbubble data (Kamei et al., EAGE 2017)
 - Apache DAS experiment (Byerley et al., TLE 2018)
 - “Elastic bracing” (Innanen et al., SEG 2018)
- “Tiny bubbles” experiments @ CREWES and CaMI 2019
 - Repeatability
 - Spectral transients
- Imaging rapid-repeat data (2021-2022)
 - Incorporate DAS and imaging strategies
 - Corroborate/correlate with CaMI injection data

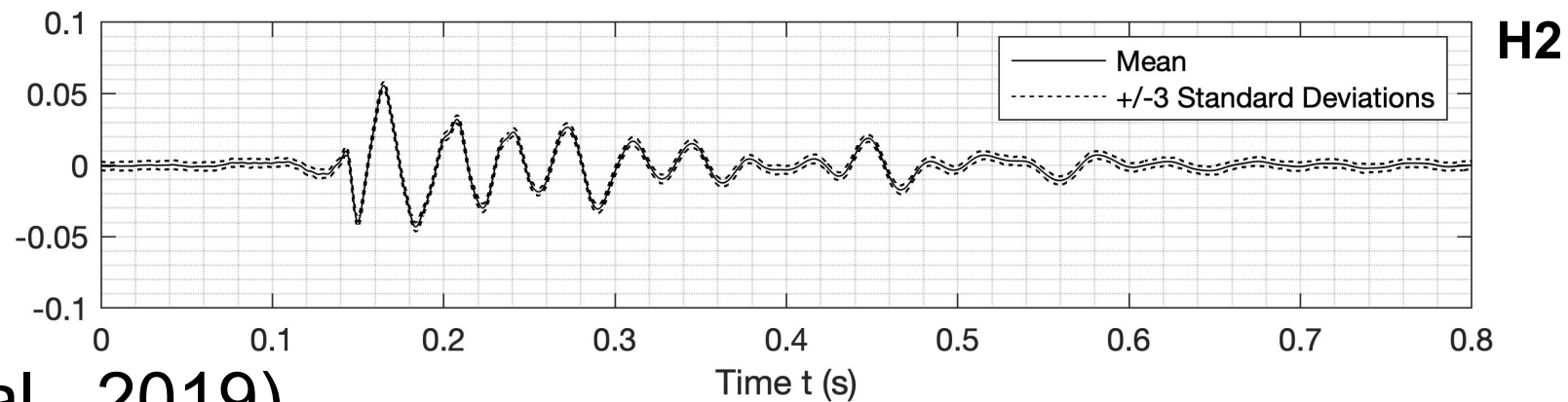
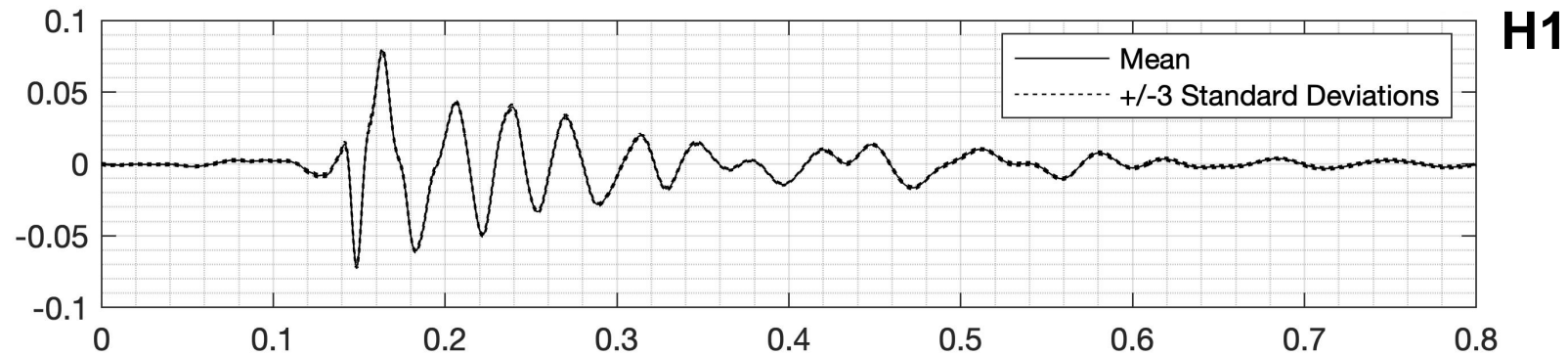
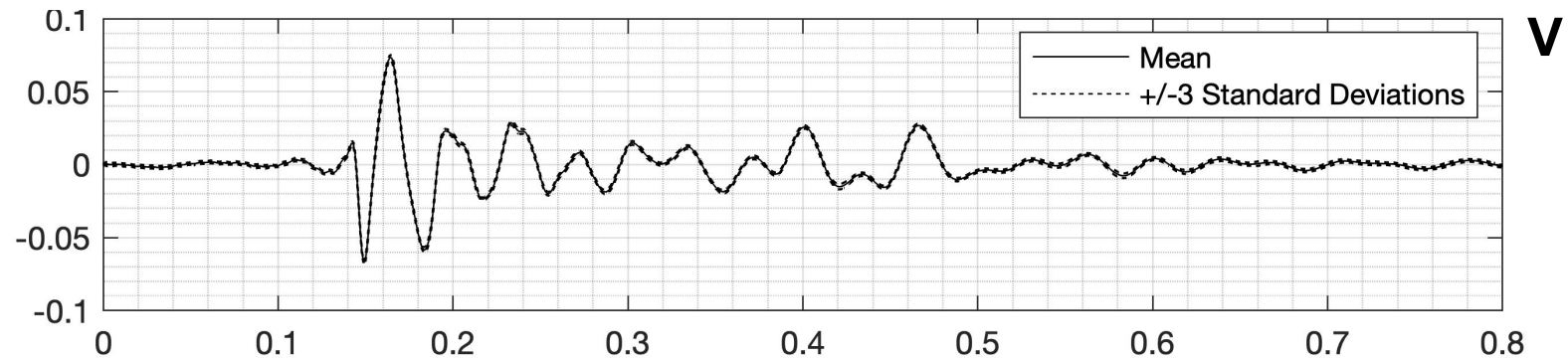


Rapid-repeat fixed source experiment (2021-2022)





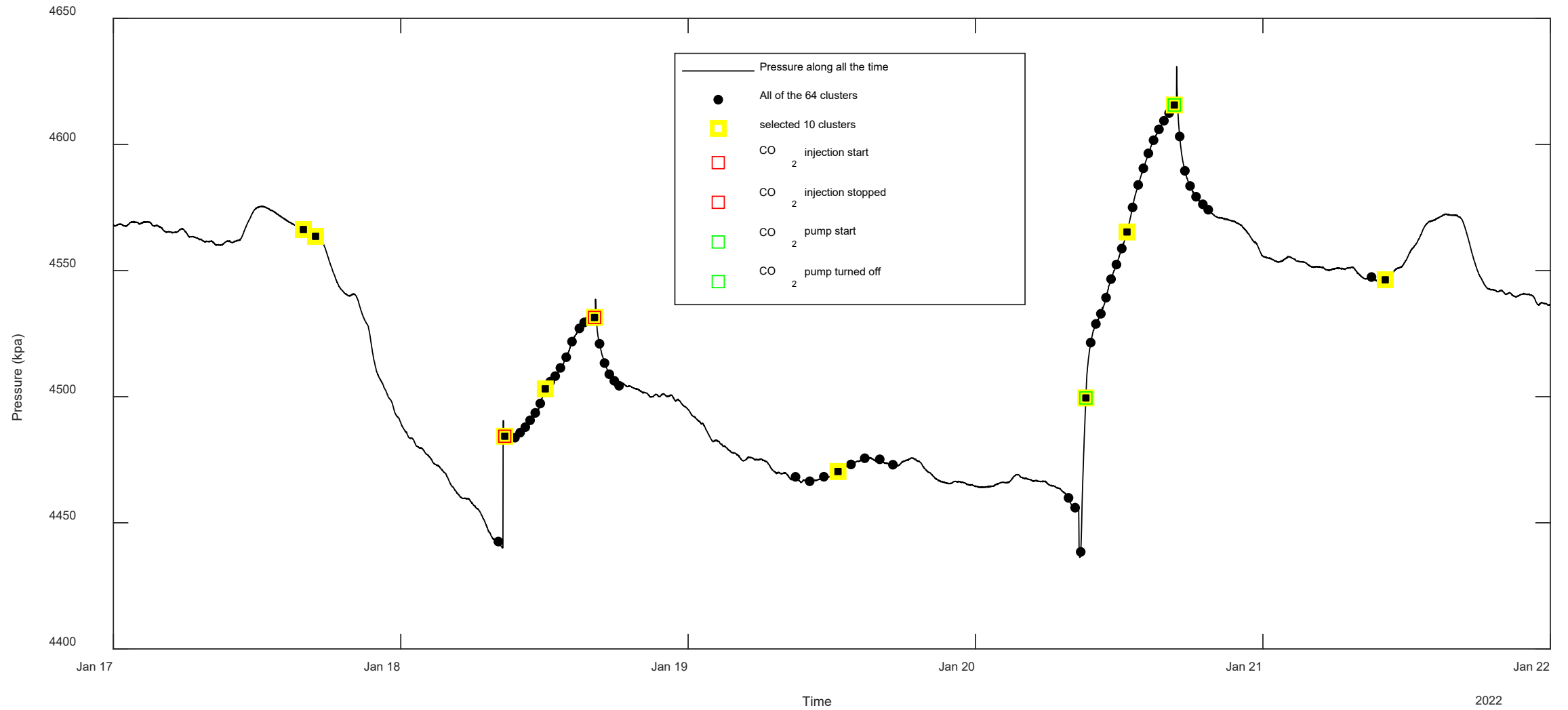
Repeatability tests 2019 (packed ground, time domain)



(Innanen et al., 2019)

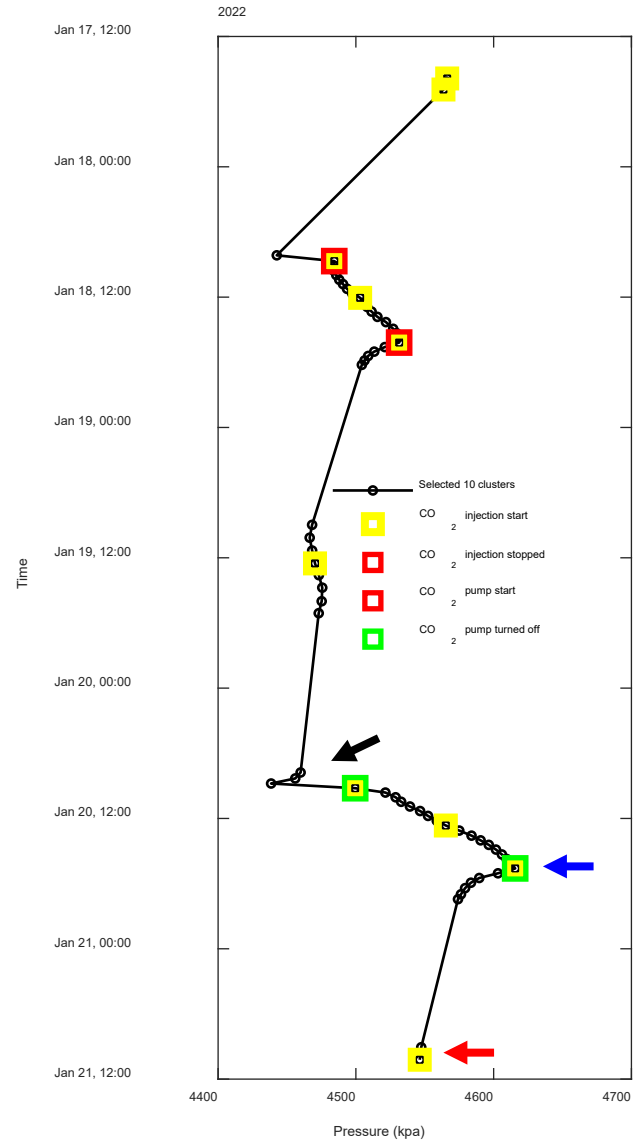


2022 experiment

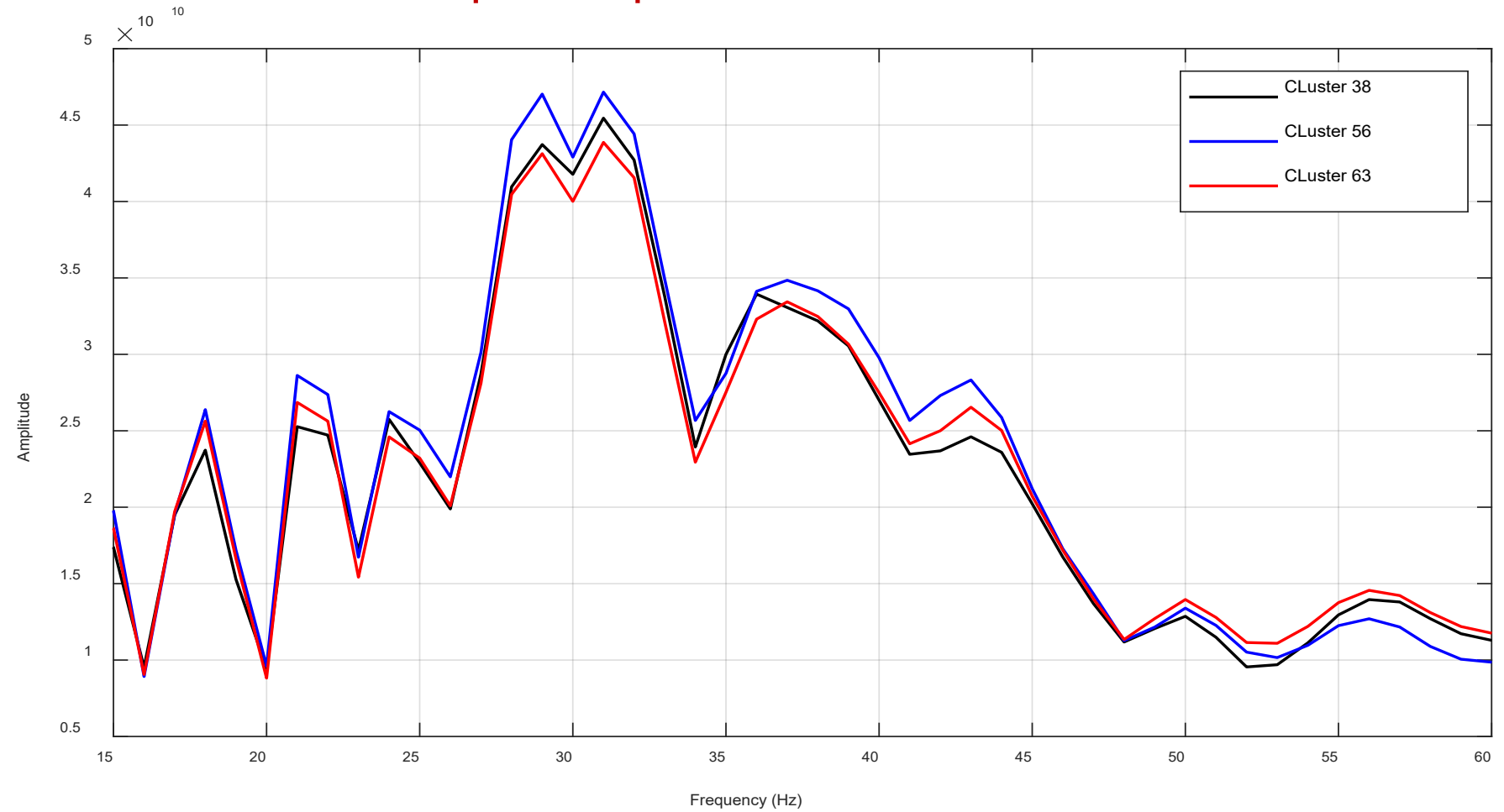




2022 experiment

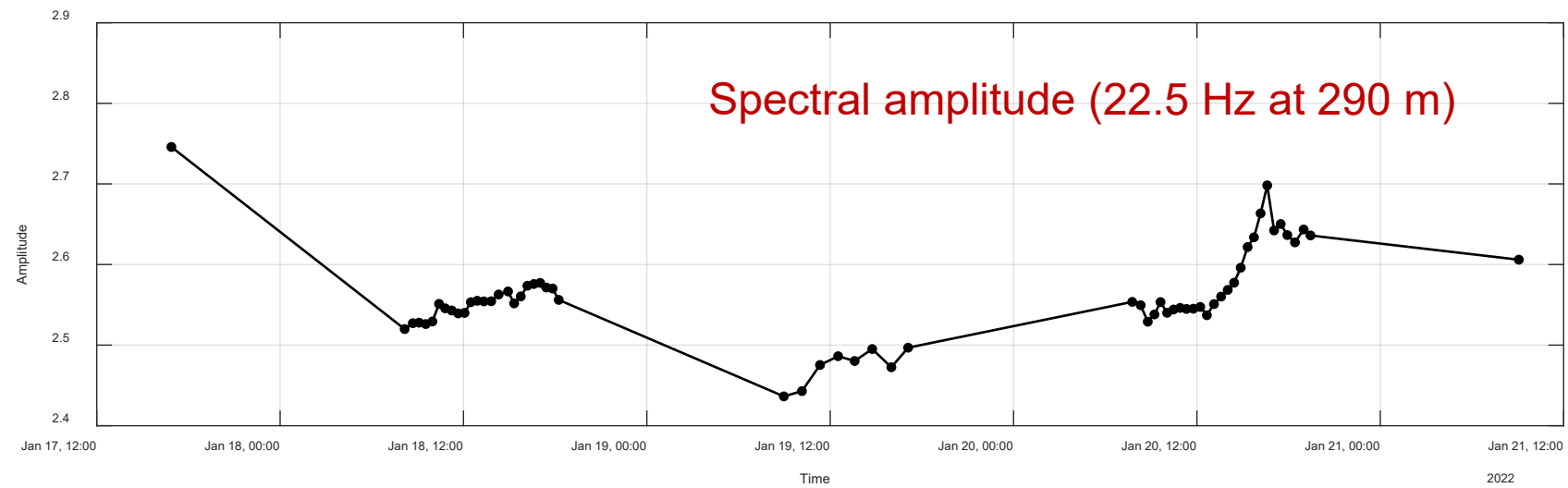
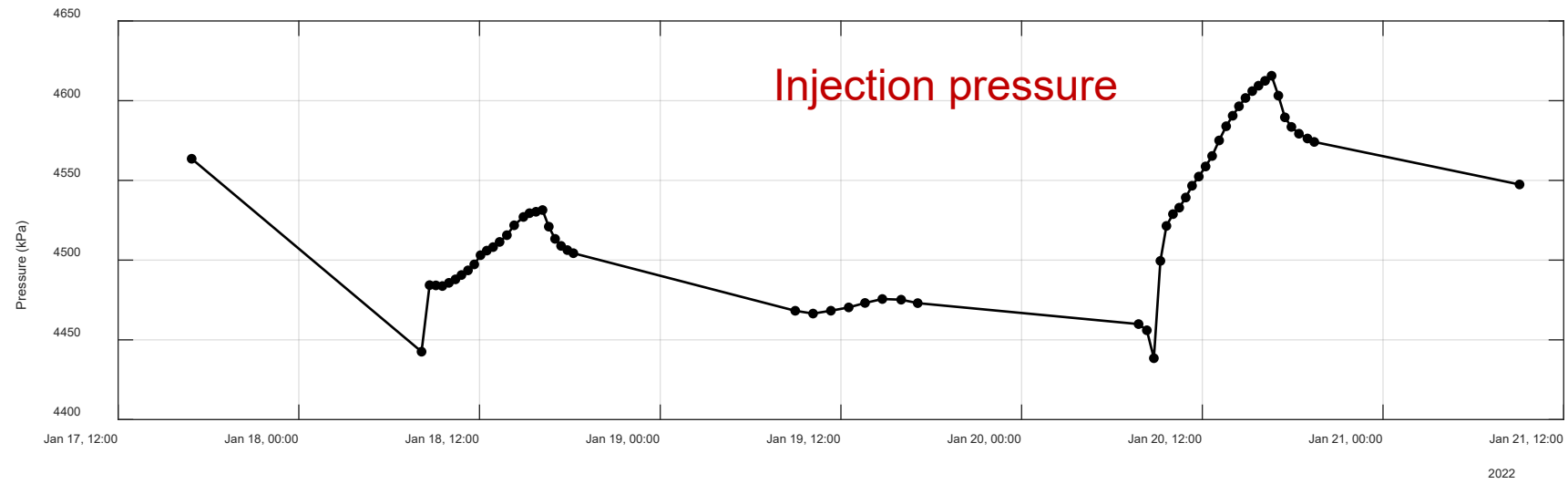


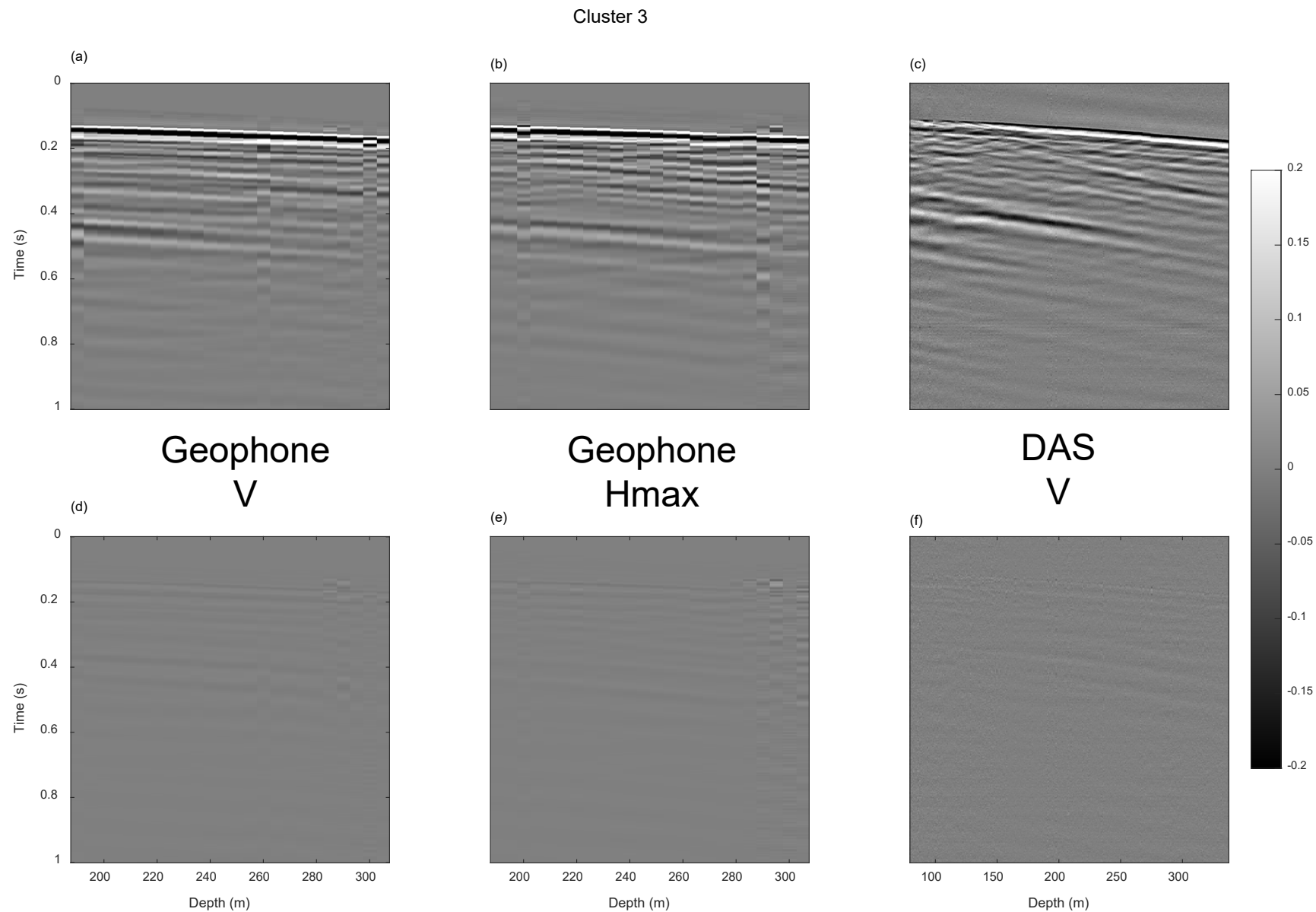
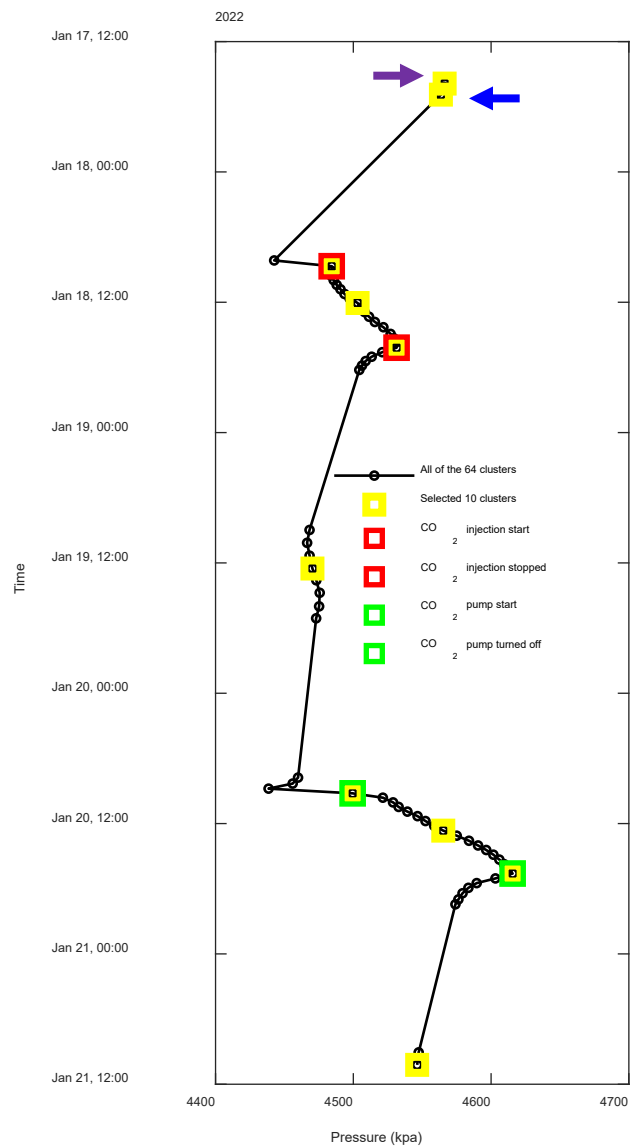
spectral peaks

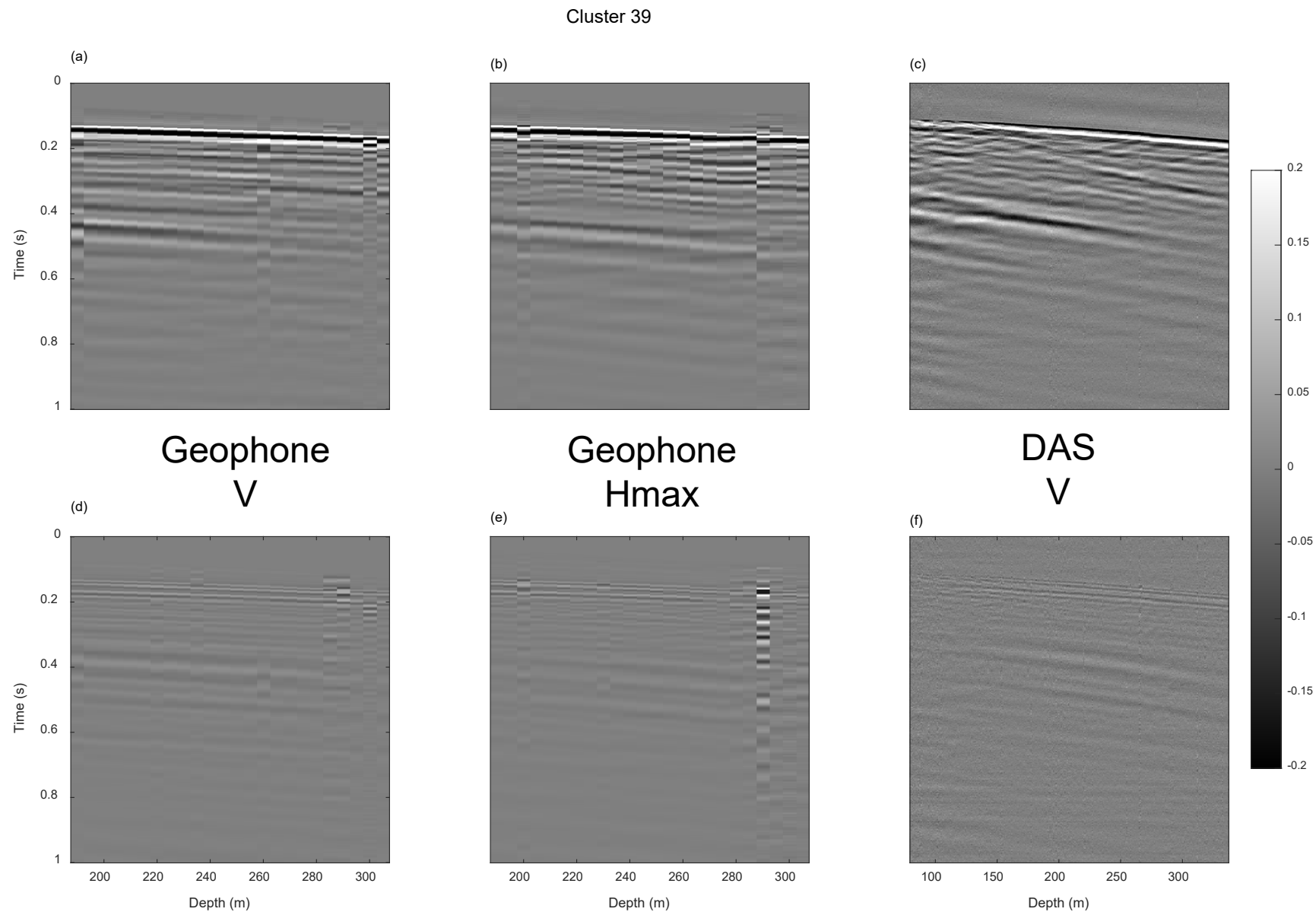
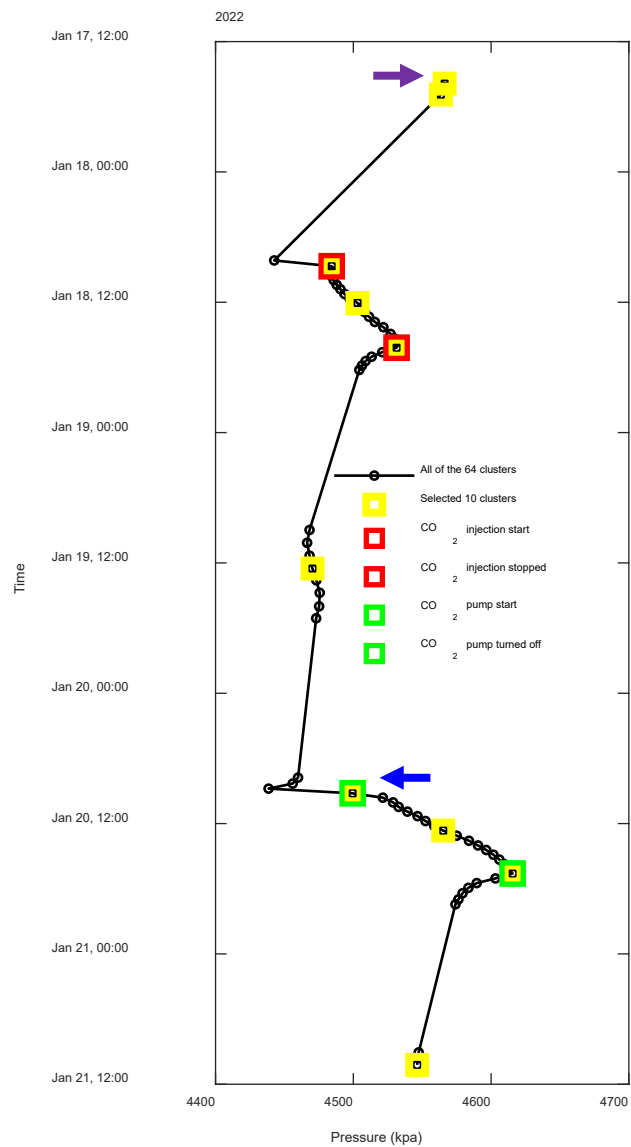




2022 experiment







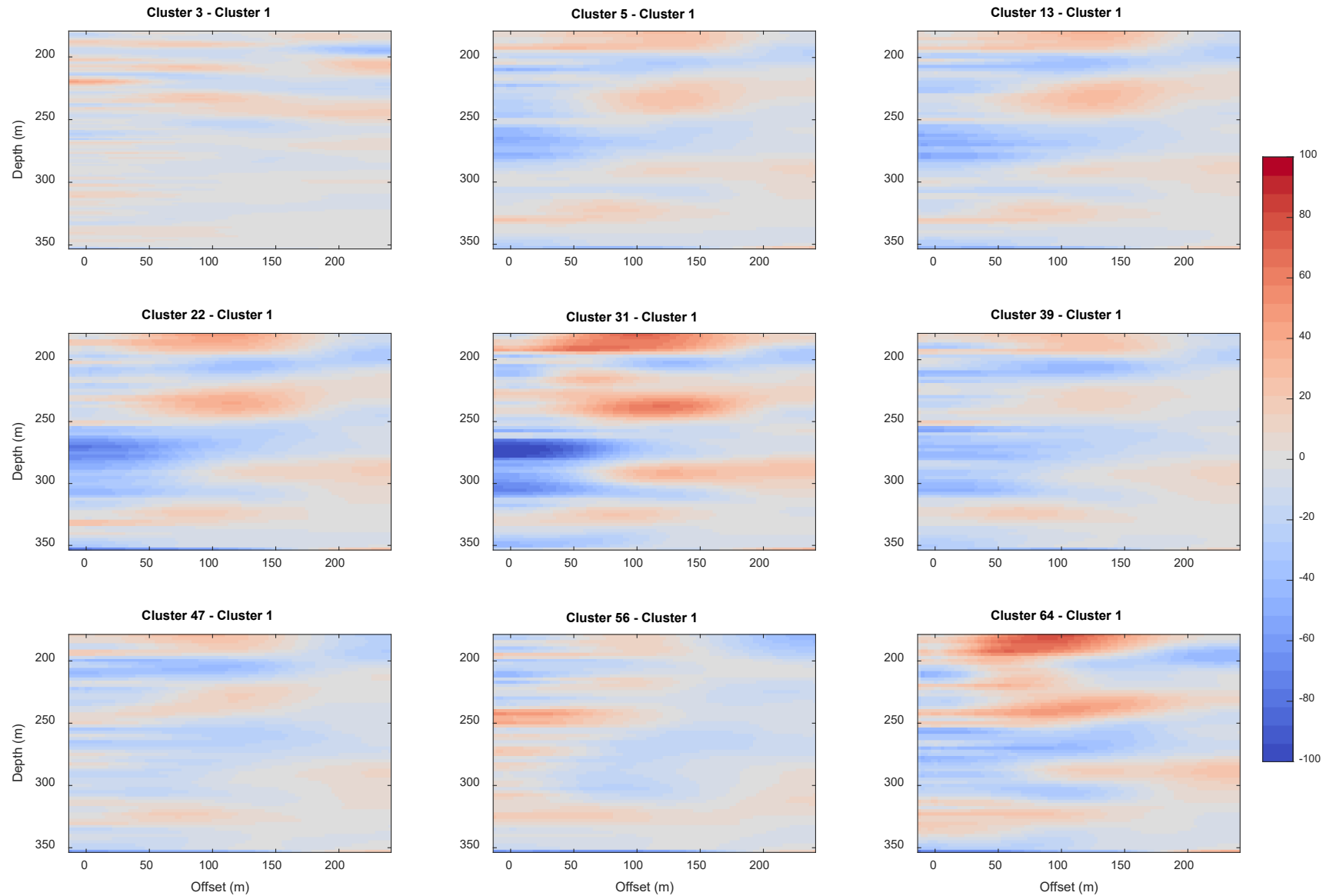


- Full waveform inversion
 - Frequency domain elastic (Keating et al., 2020)
 - **Single source! Large lateral uncertainty, good vertical**
- Practical features
 - Near surface elimination (Keating, 2021)
 - DAS accommodation (Eaid 2020)
 - Well log-derived relationship (Hu, 2021; Eaid 2021)
 - **Vp parameterized FWI**
 - **Multiparameter FWI**
- Time lapse mode:
 - Parallel strategy



Vp parameterized time-lapse inversion

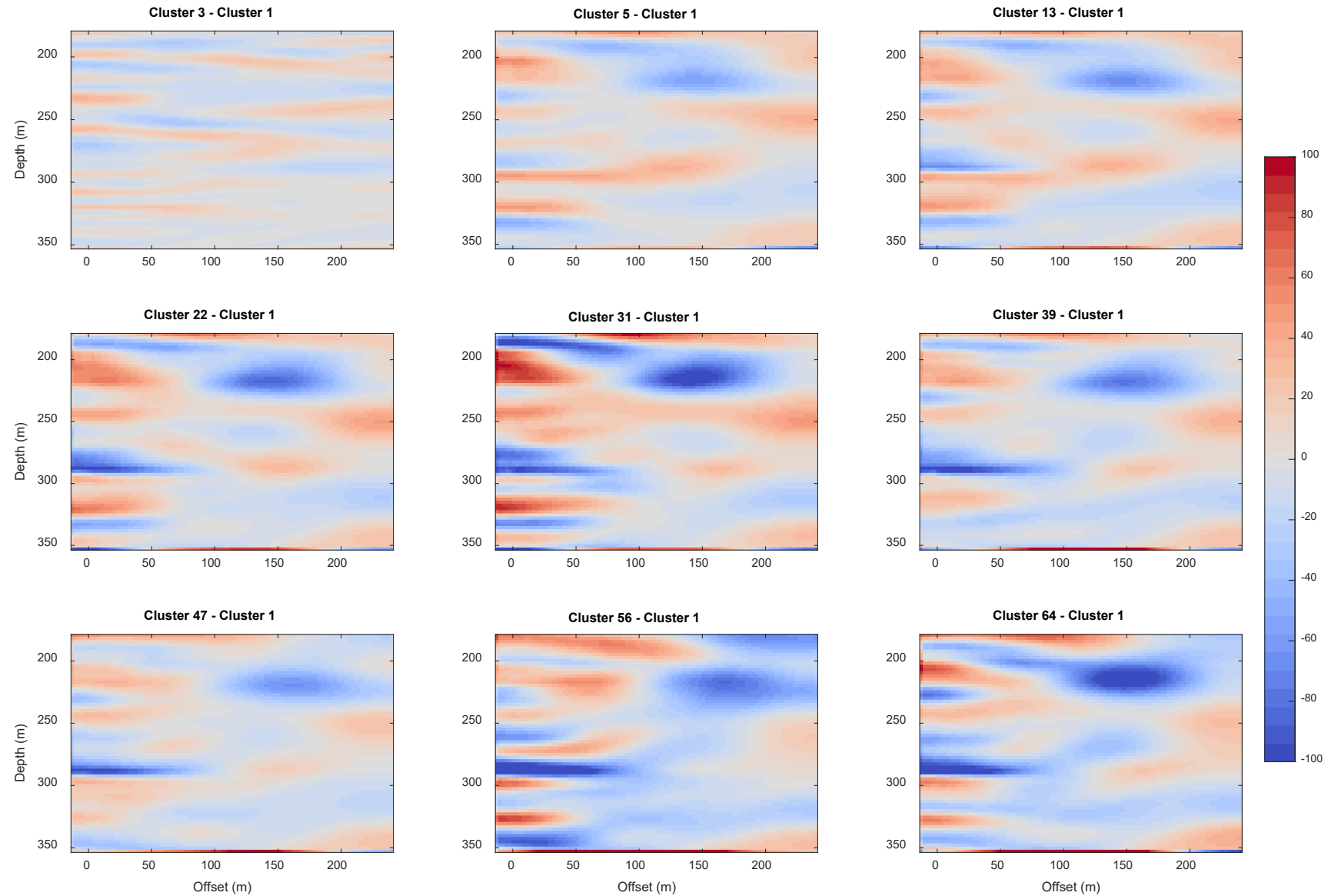
Only DAS data





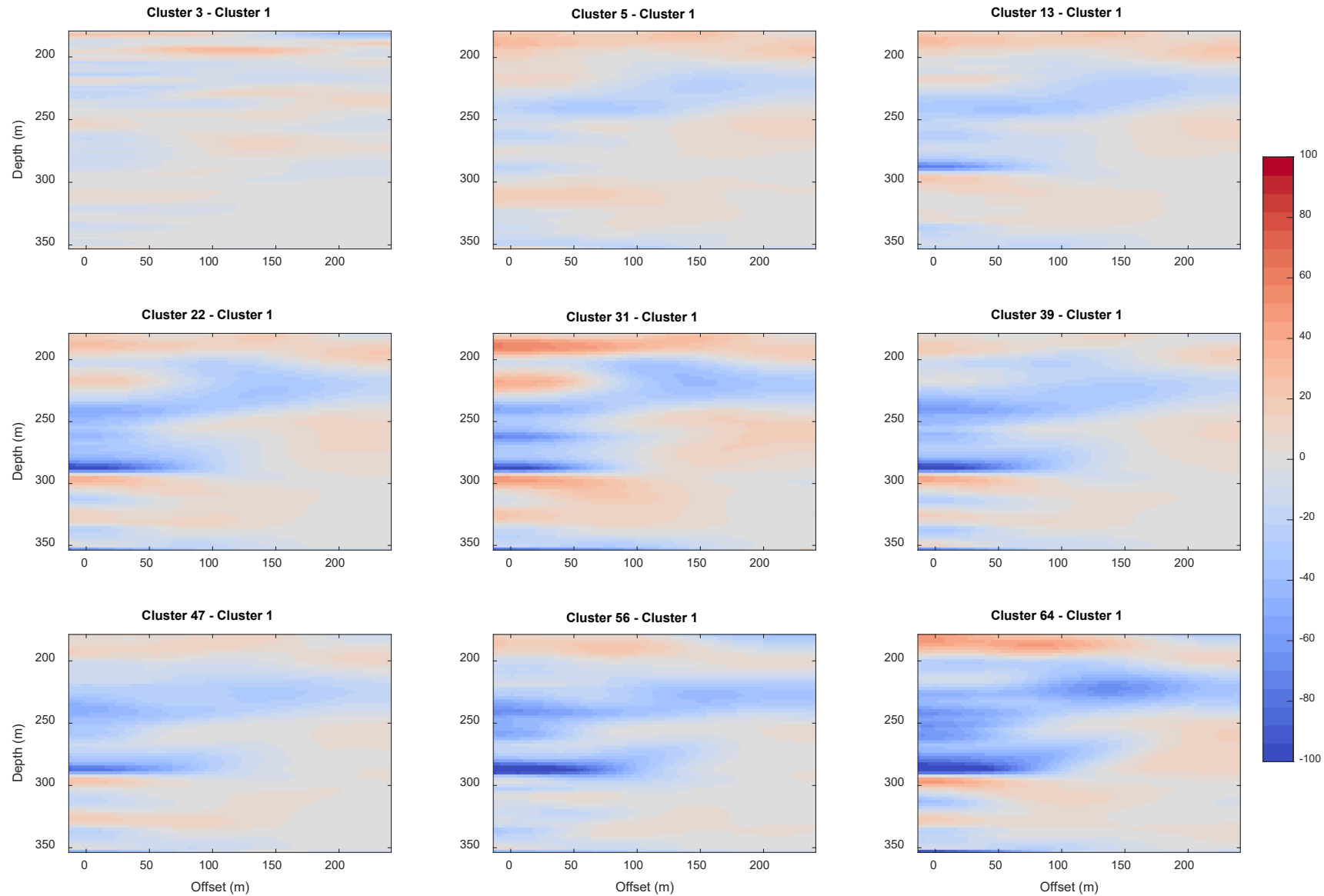
Vp parameterized time-lapse inversion

Only Geophone data





Combined geophone and DAS data



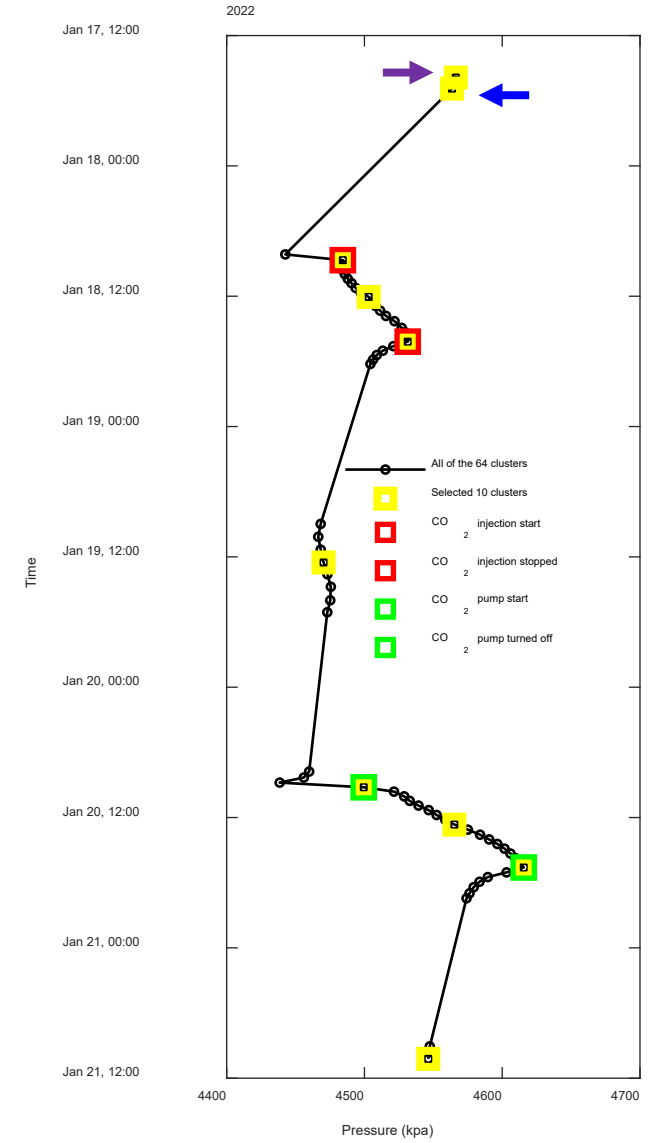
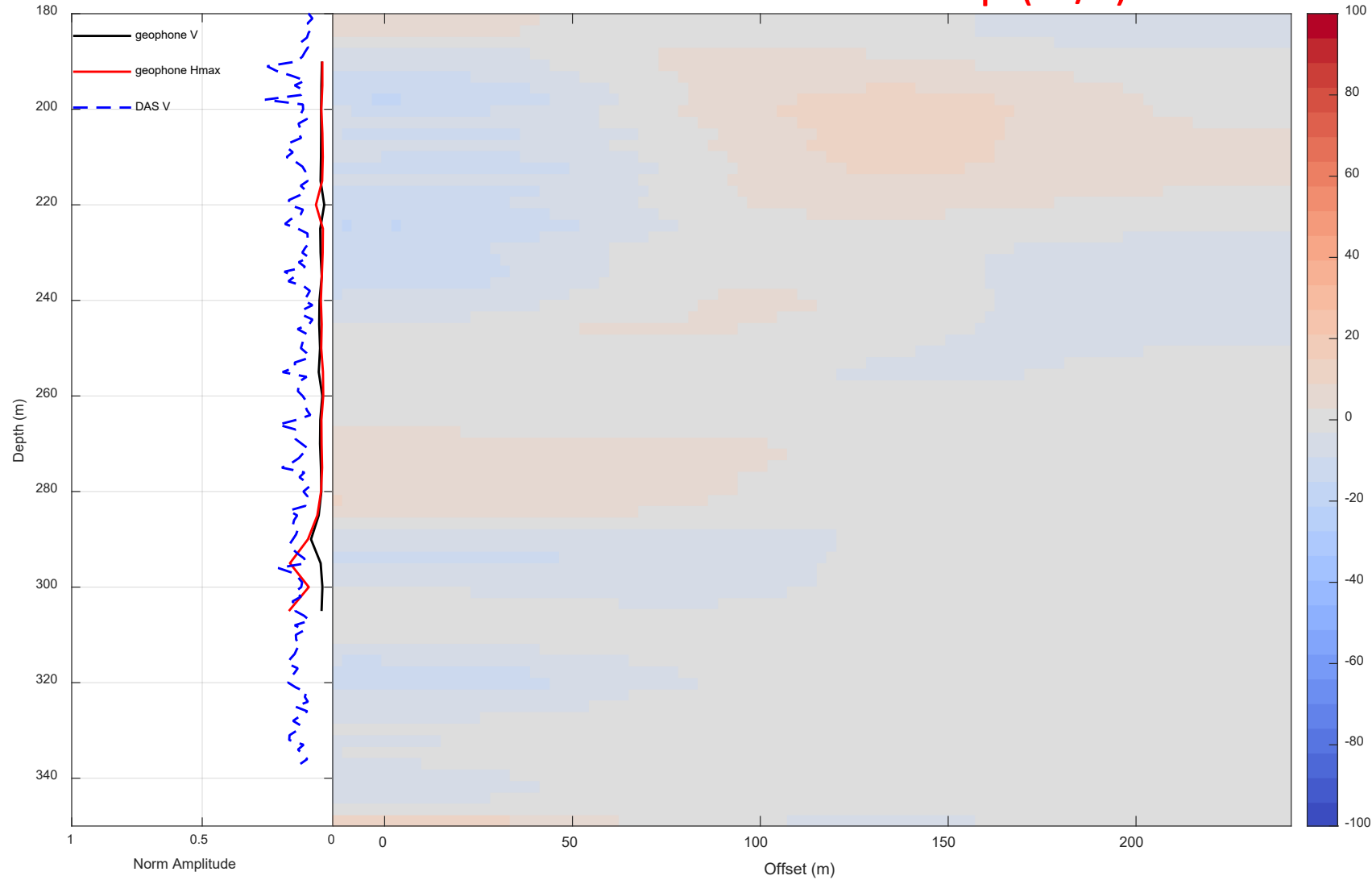


Vp parameterized time-lapse inversion

Field data difference

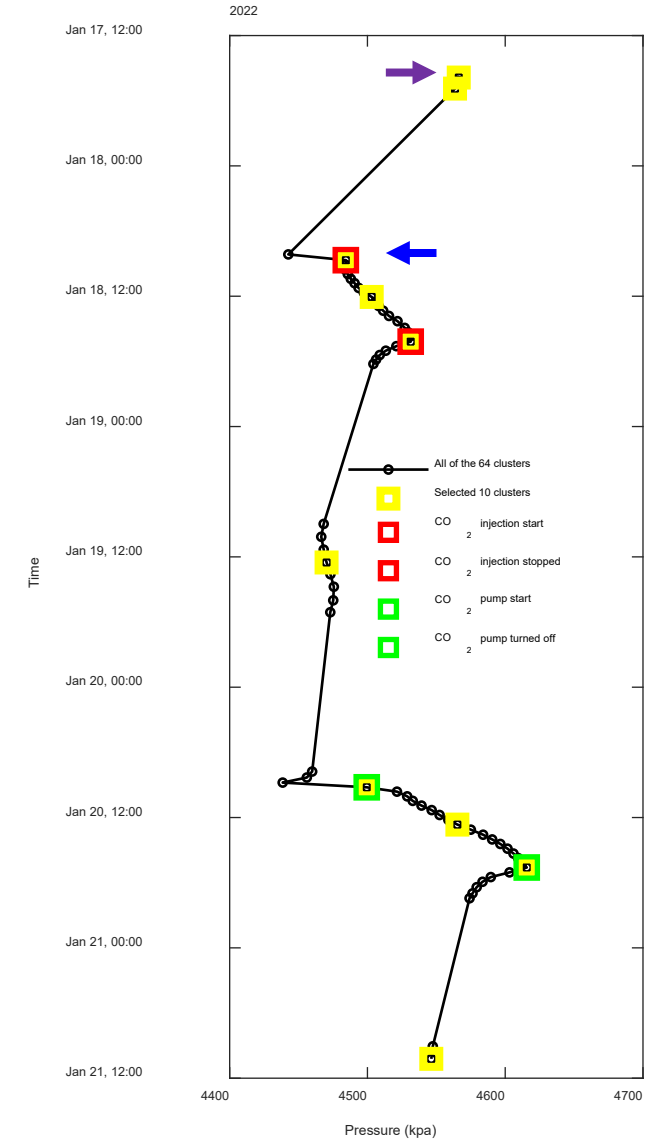
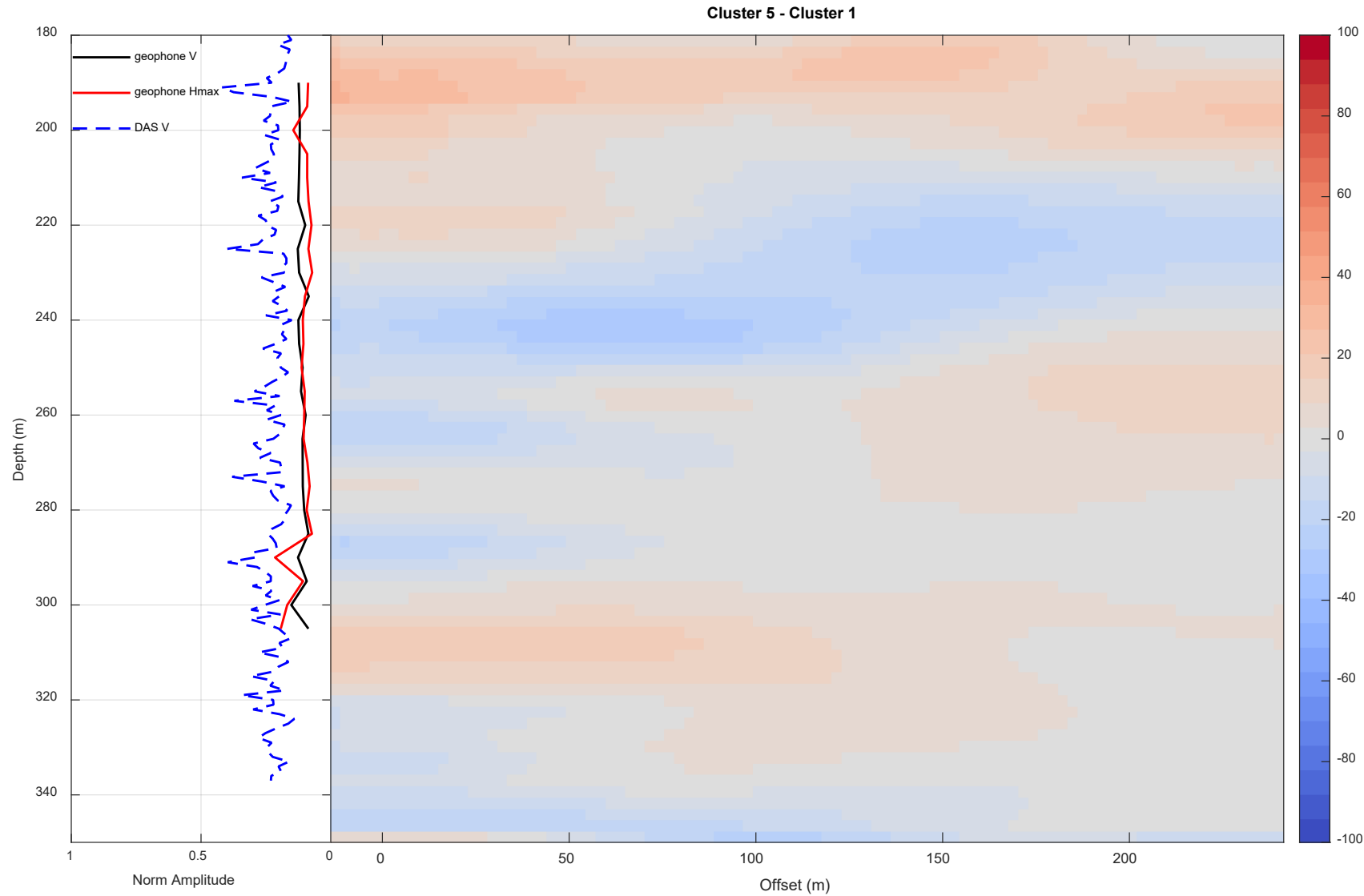
Cluster 3 - Cluster 1

Vp (m/s)



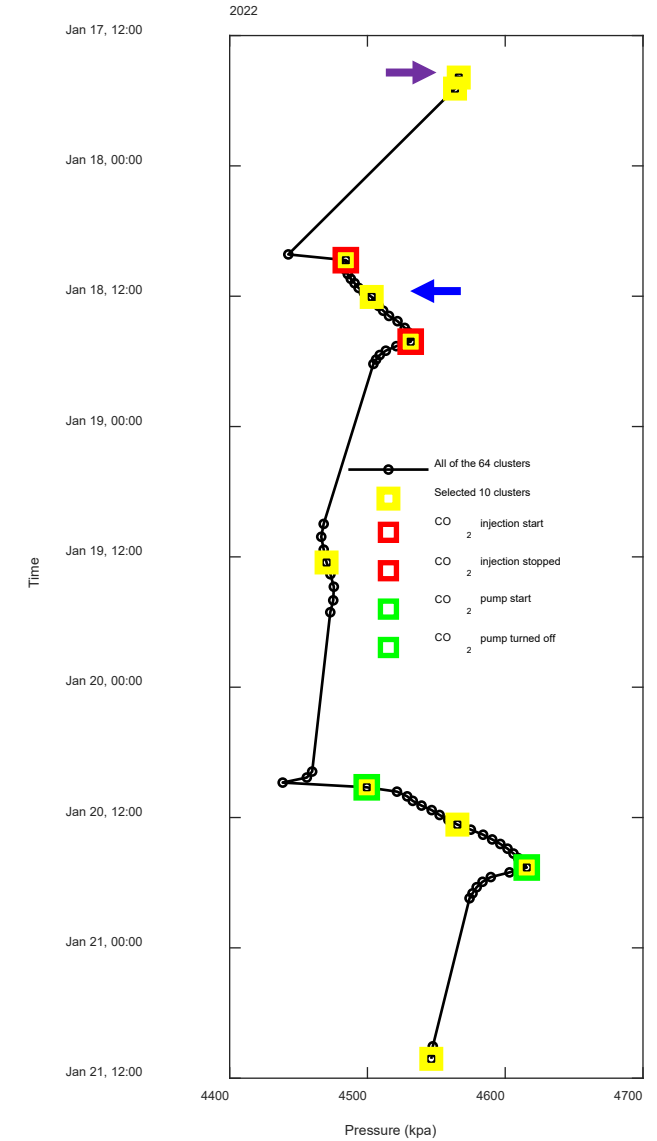
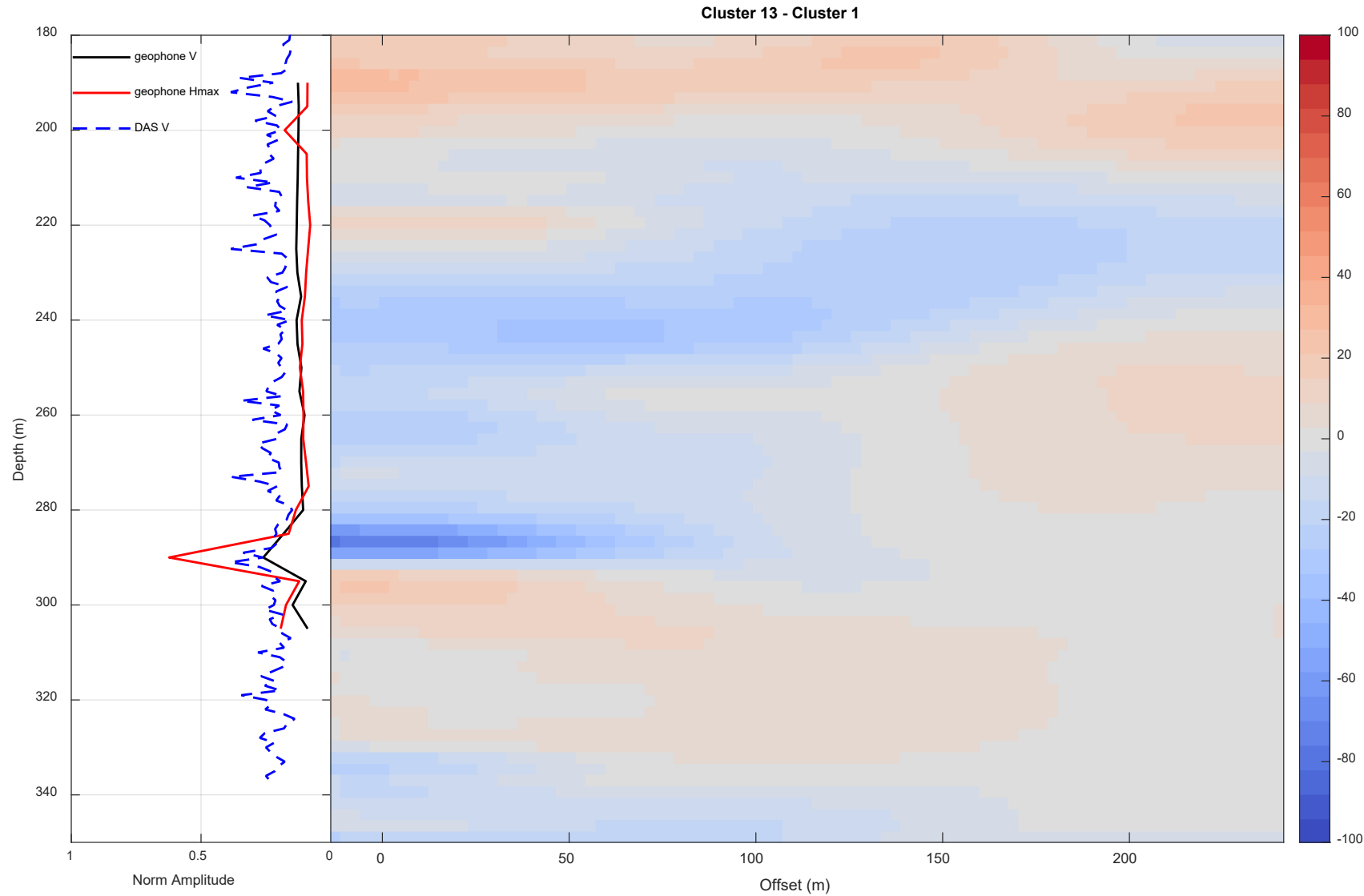


Vp parameterized time-lapse inversion



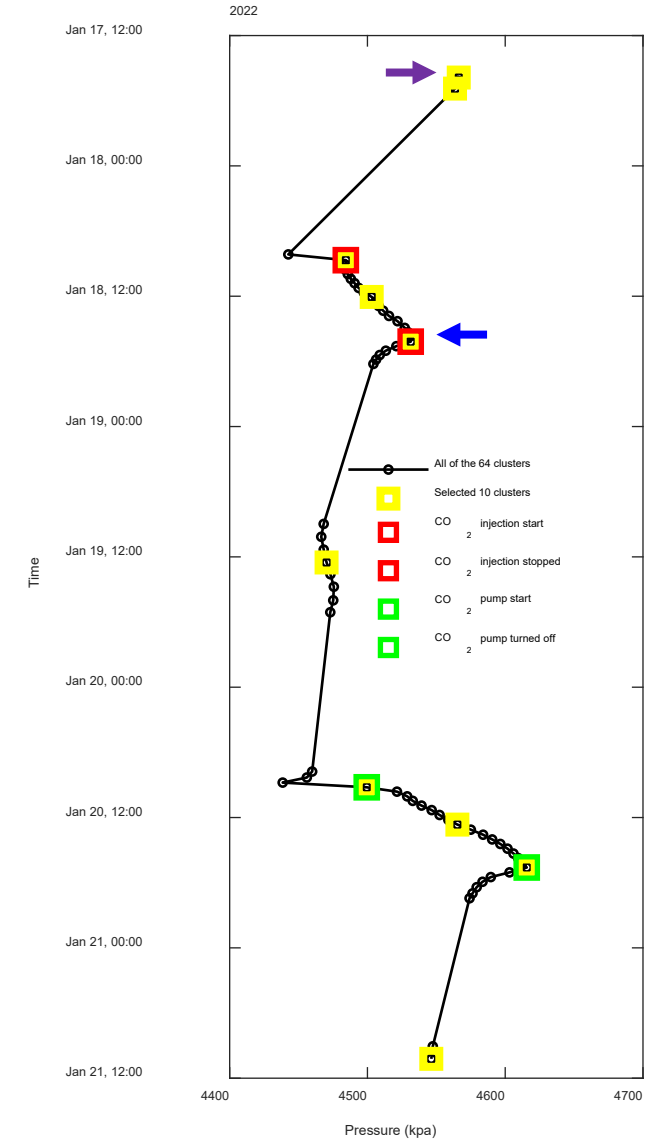
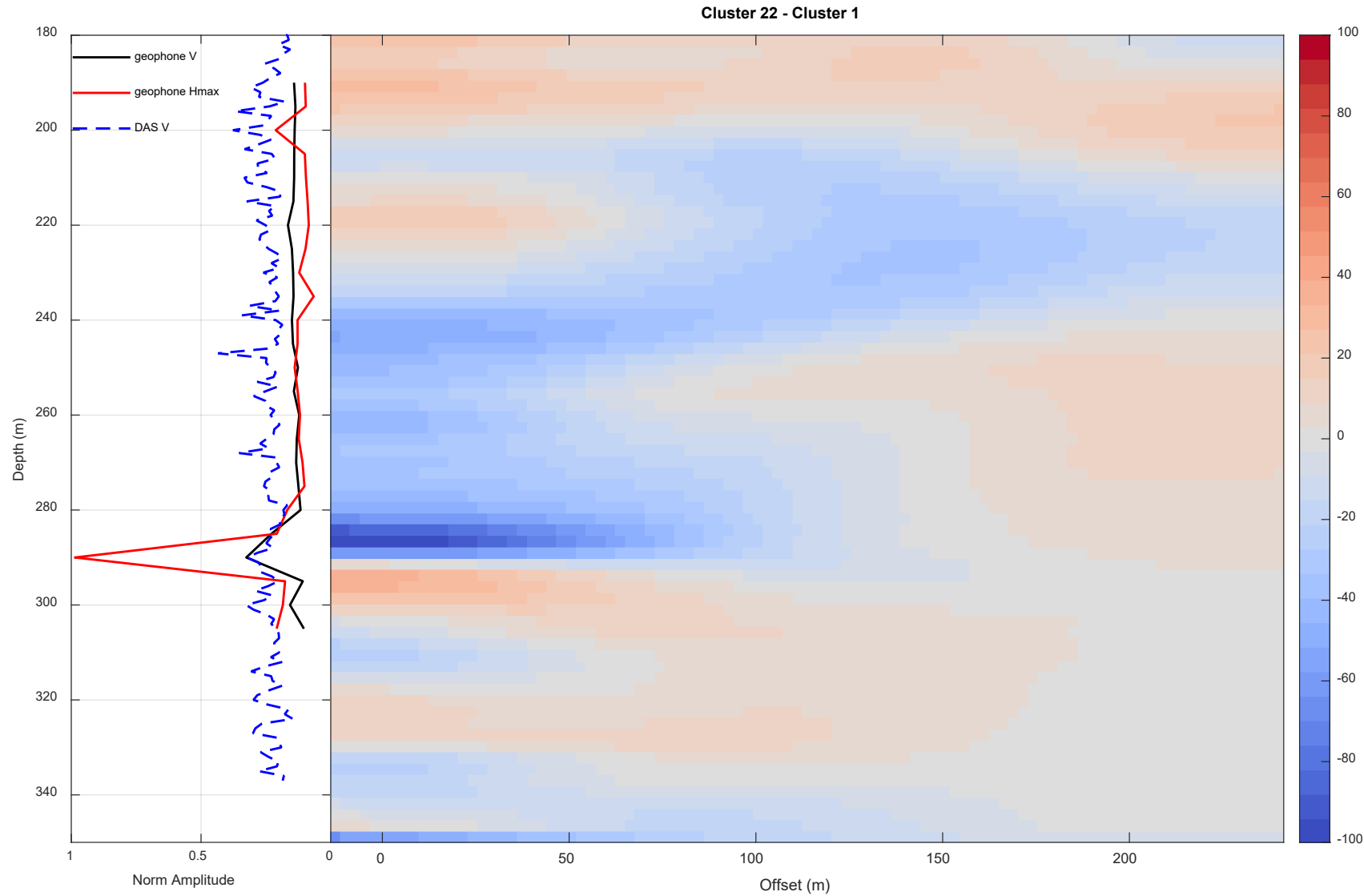


Vp parameterized time-lapse inversion



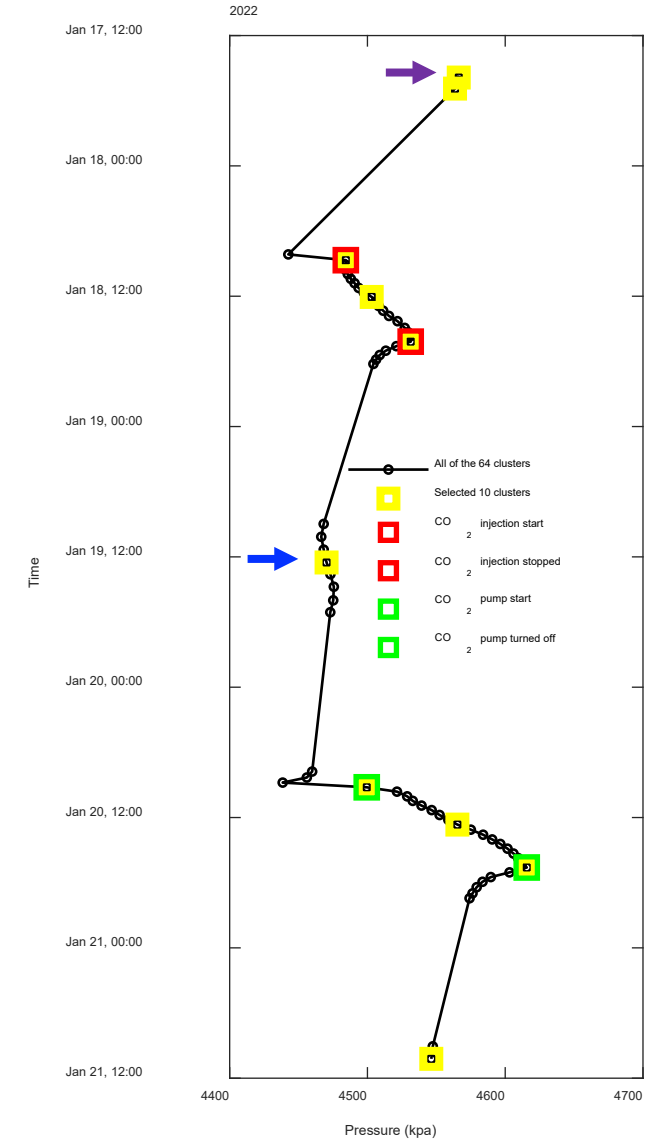
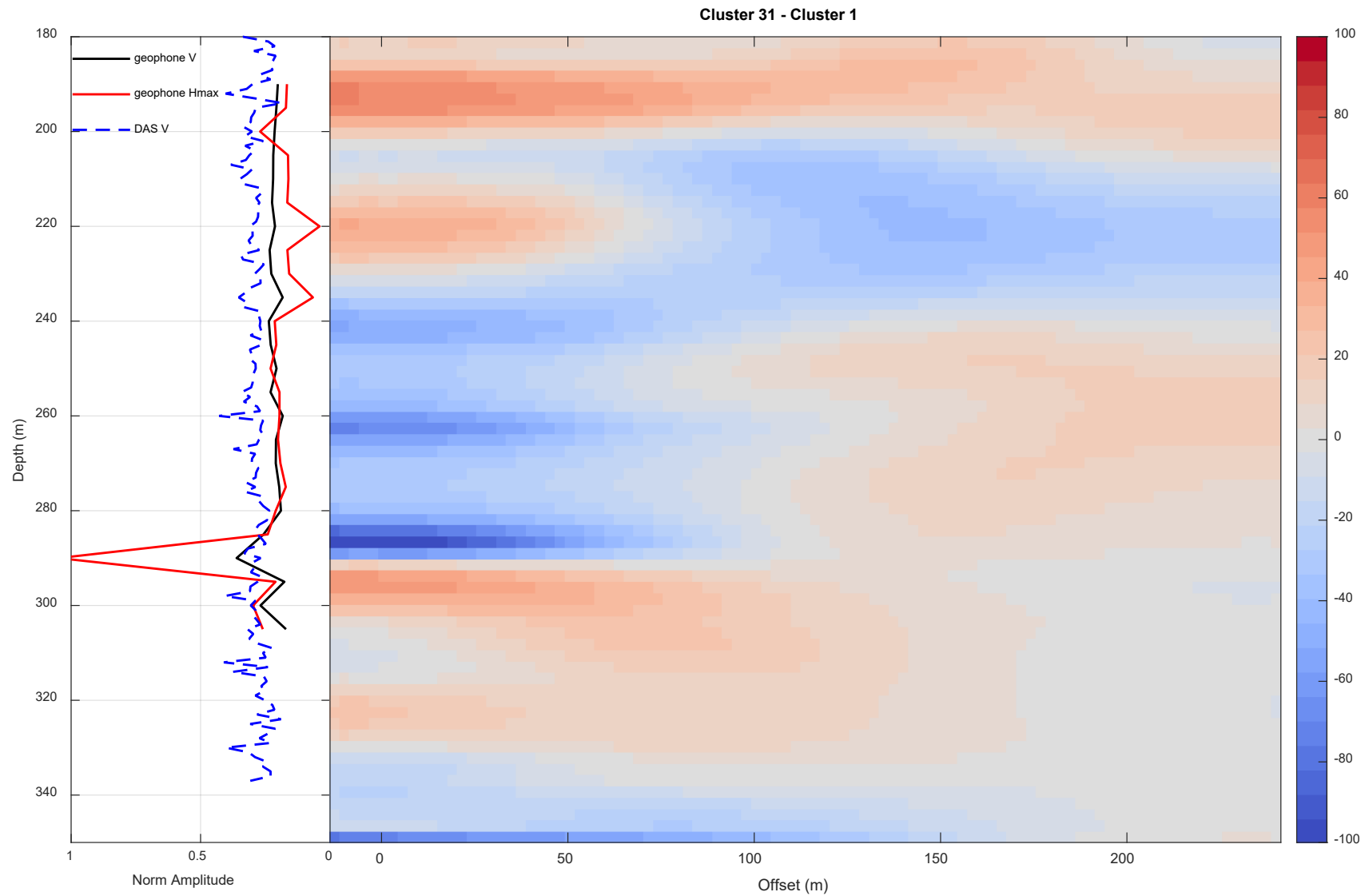


Vp parameterized time-lapse inversion



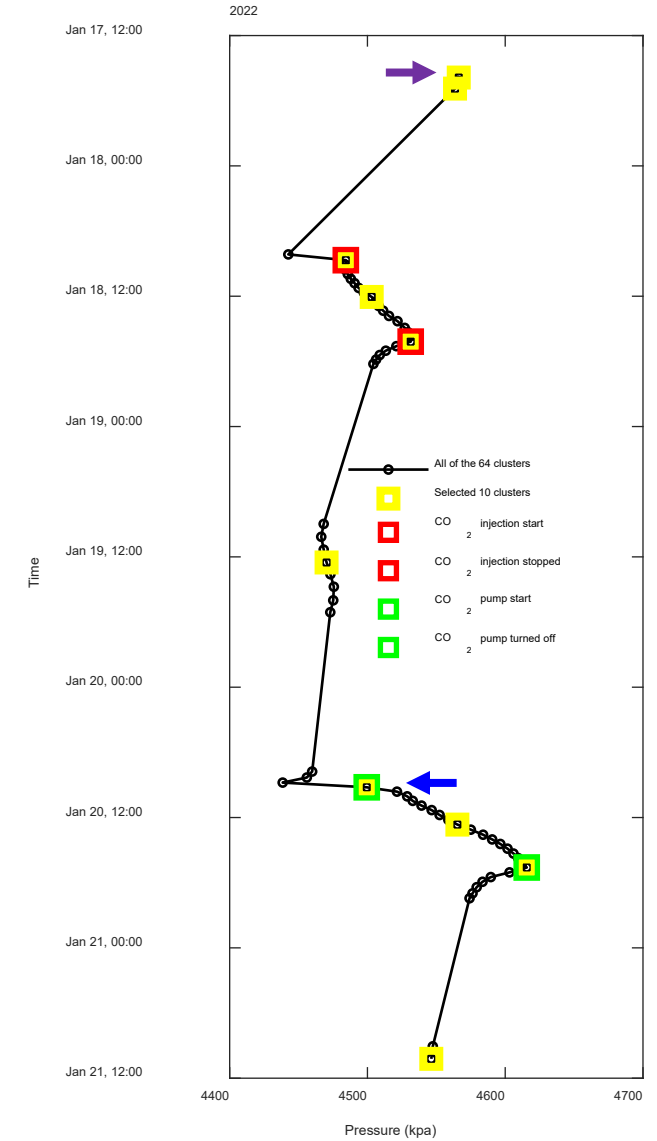
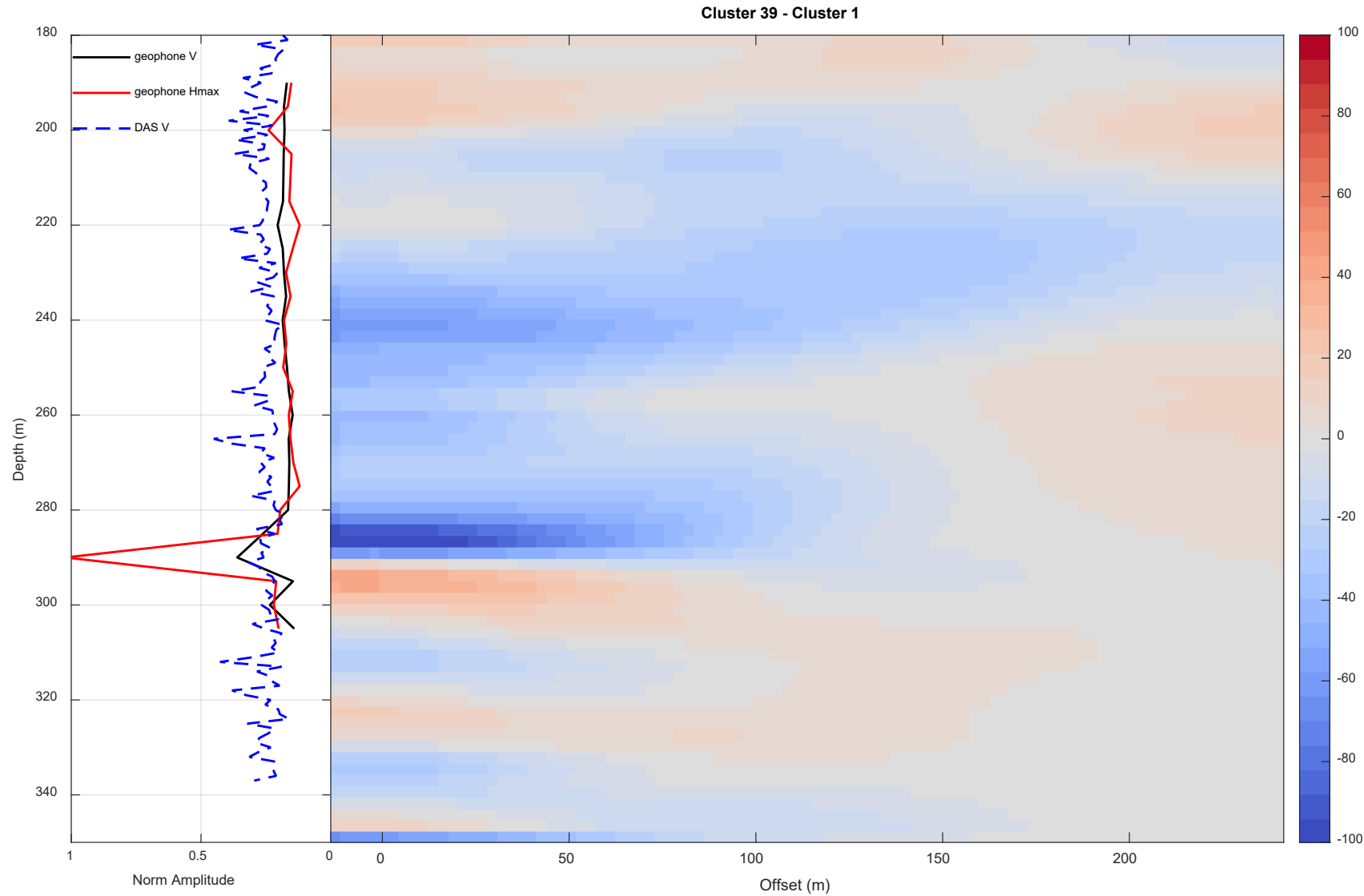


Vp parameterized time-lapse inversion



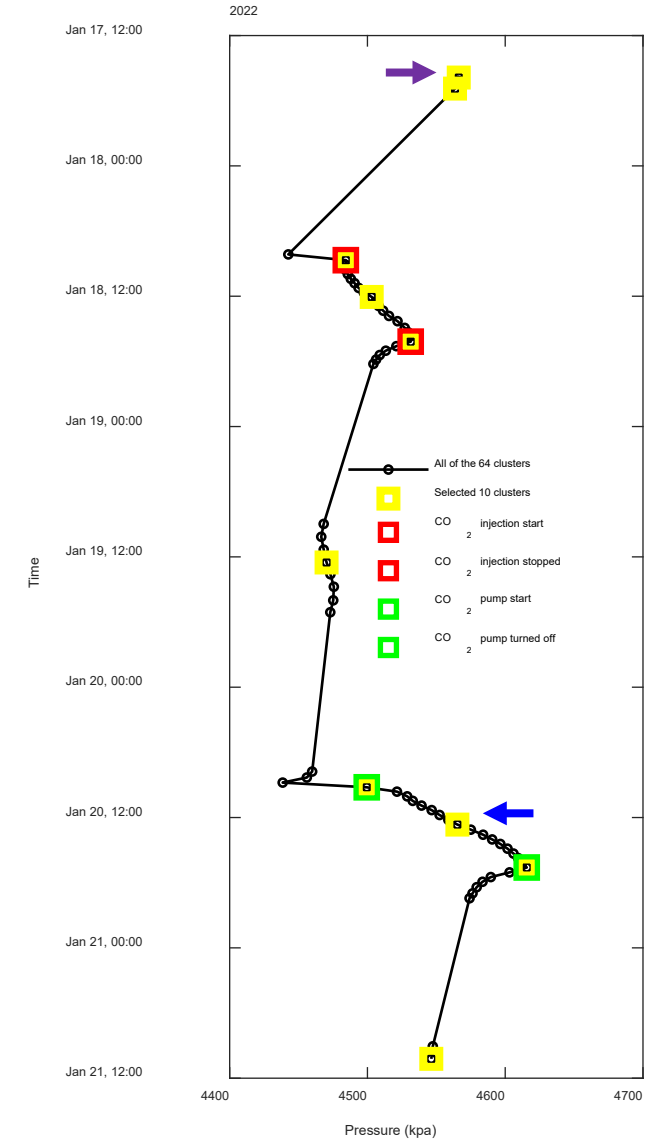
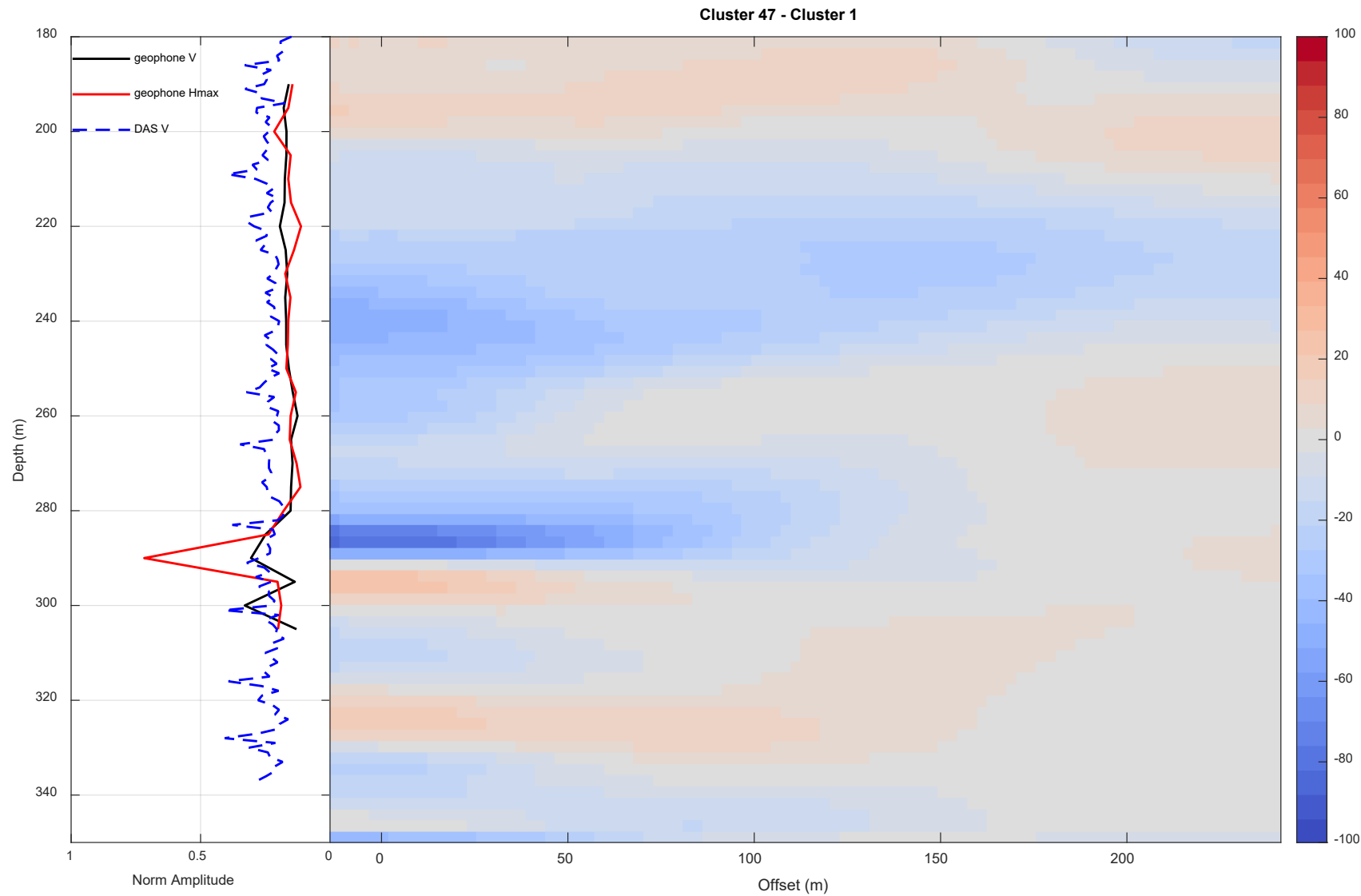


Vp parameterized time-lapse inversion



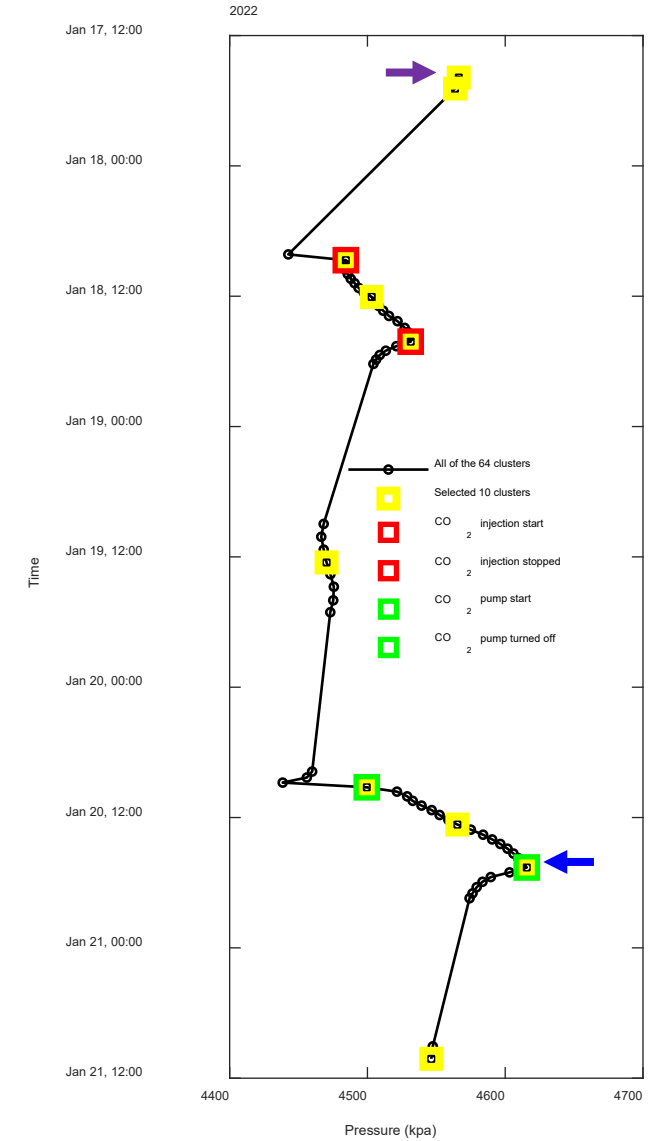
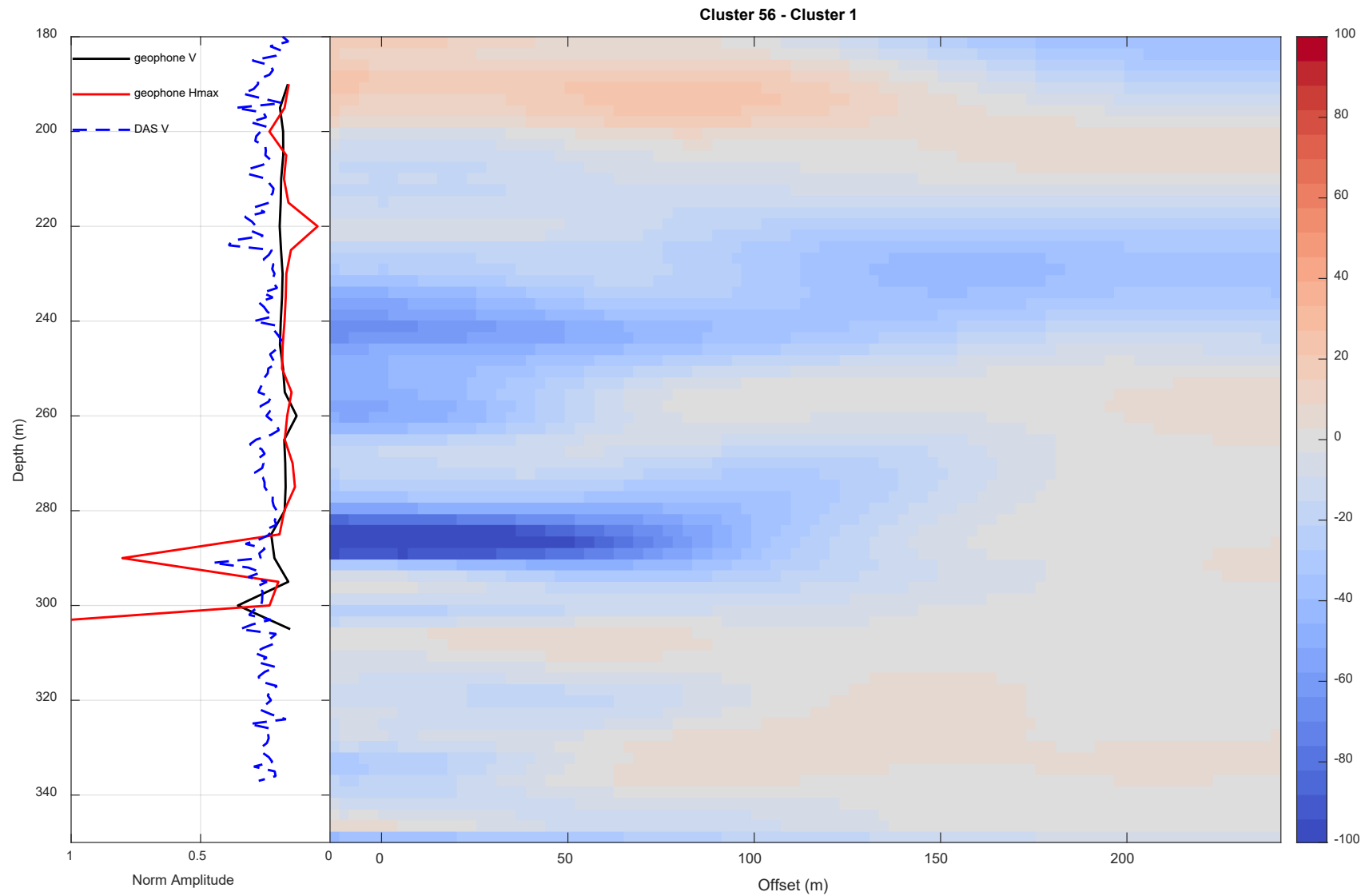


Vp parameterized time-lapse inversion



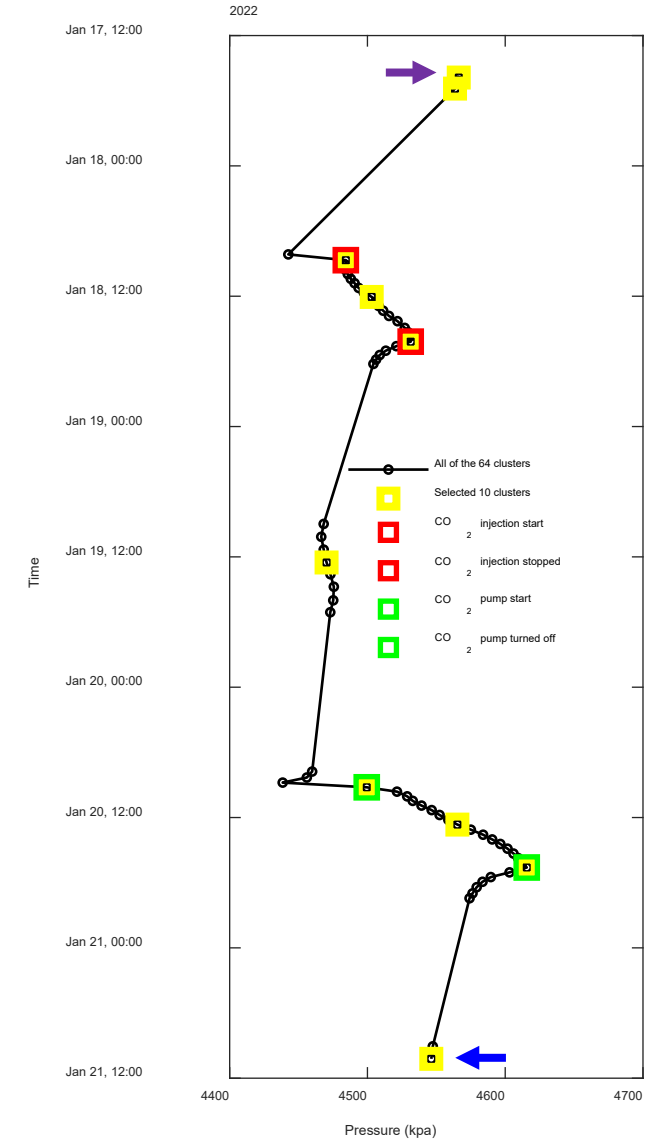
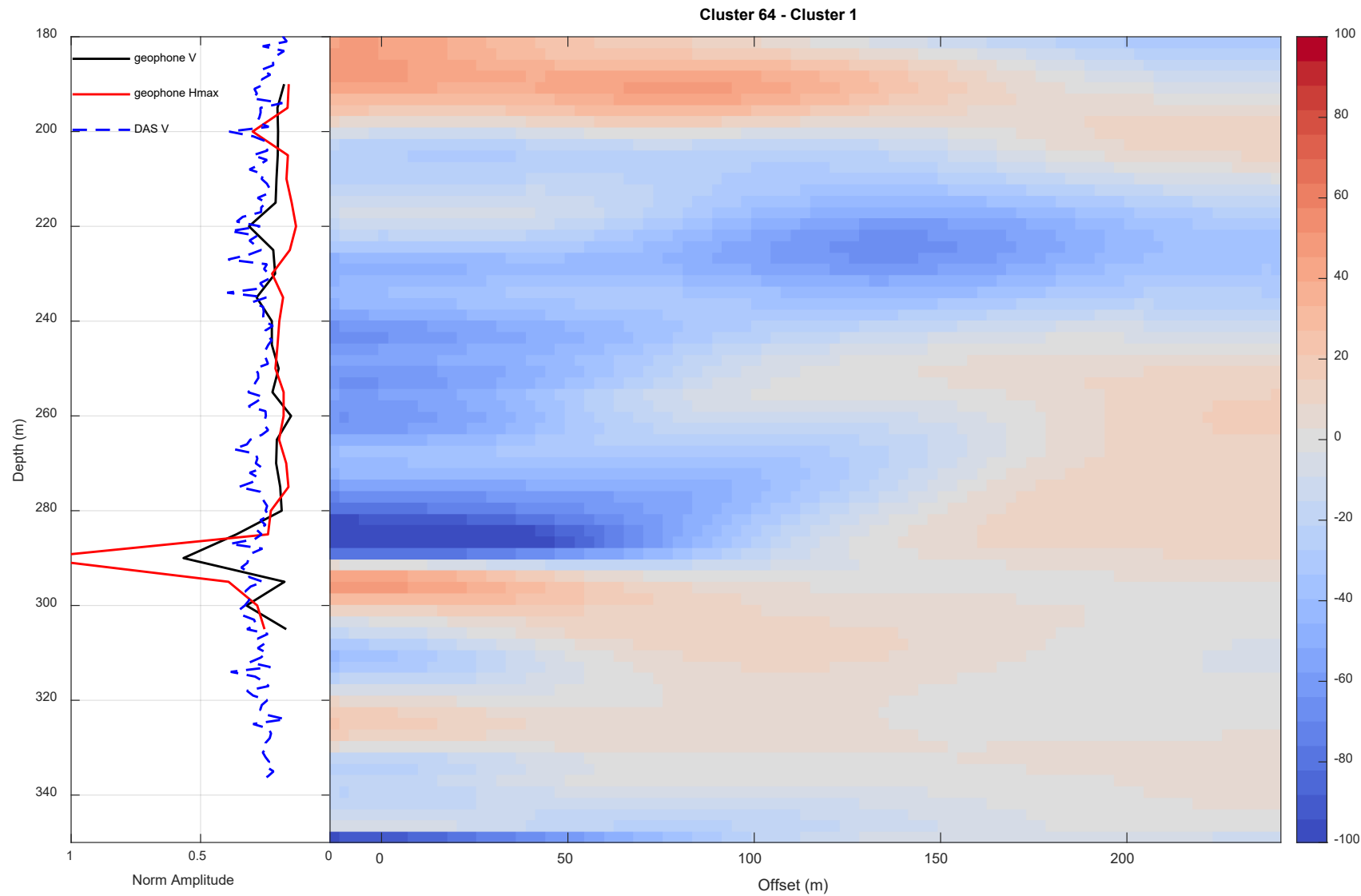


Vp parameterized time-lapse inversion



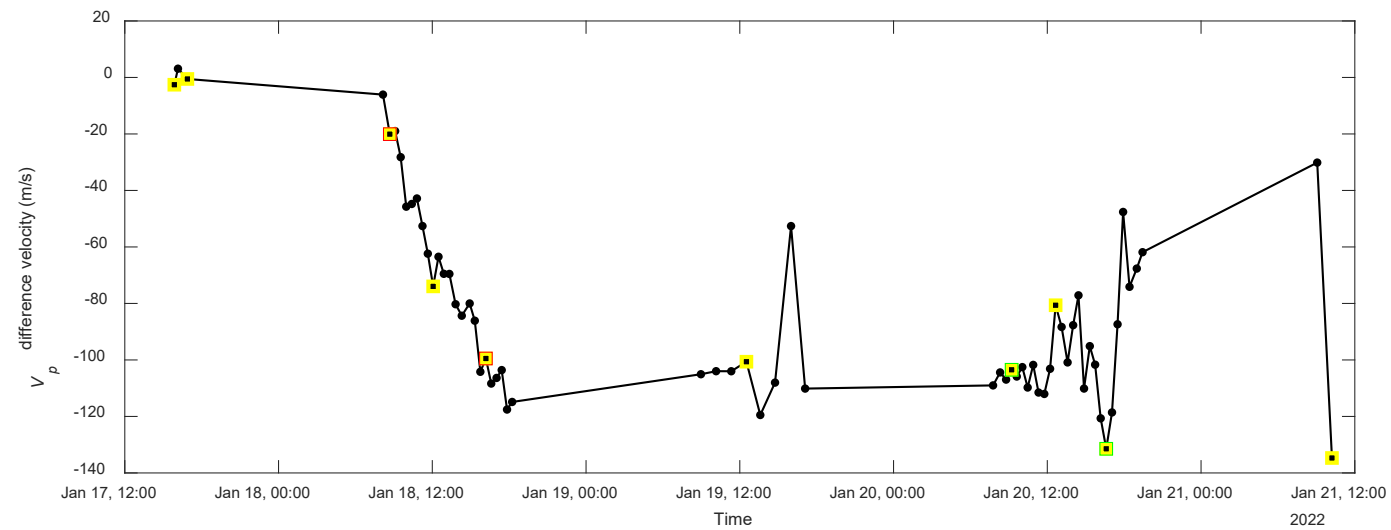
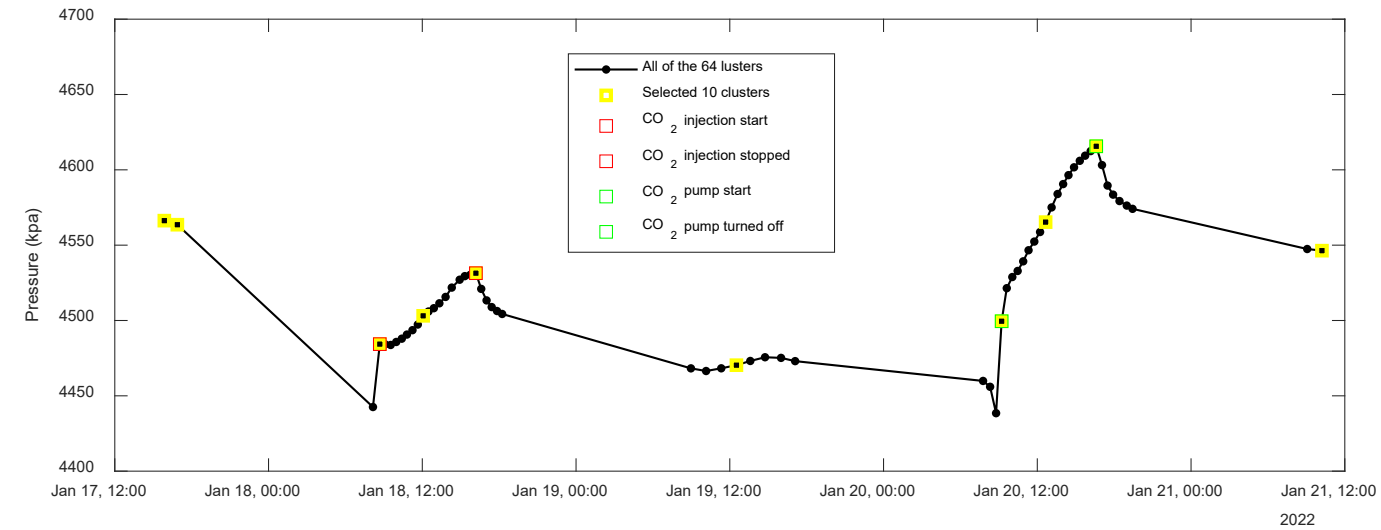


Vp parameterized time-lapse inversion



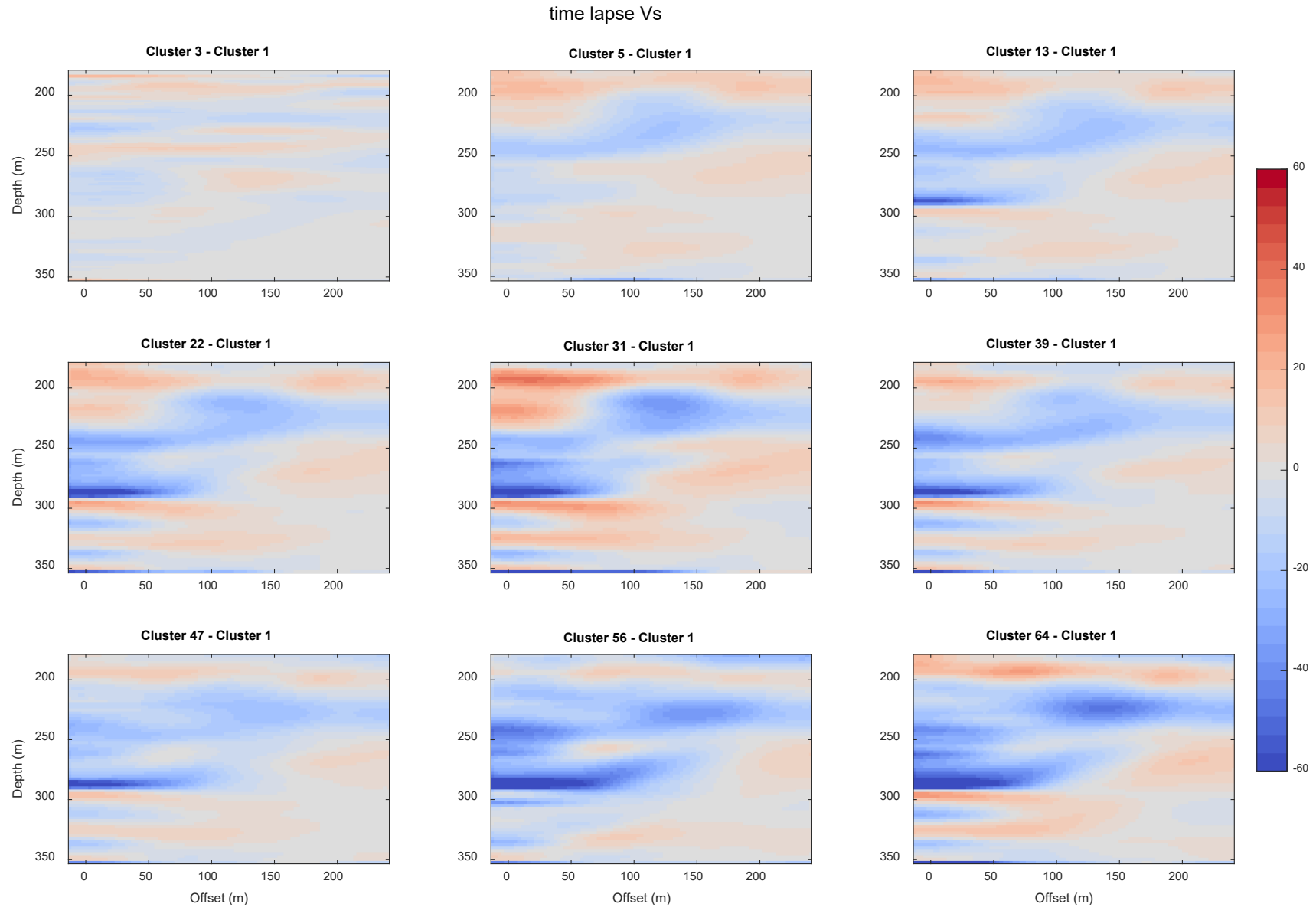


Vp parameterized time-lapse inversion



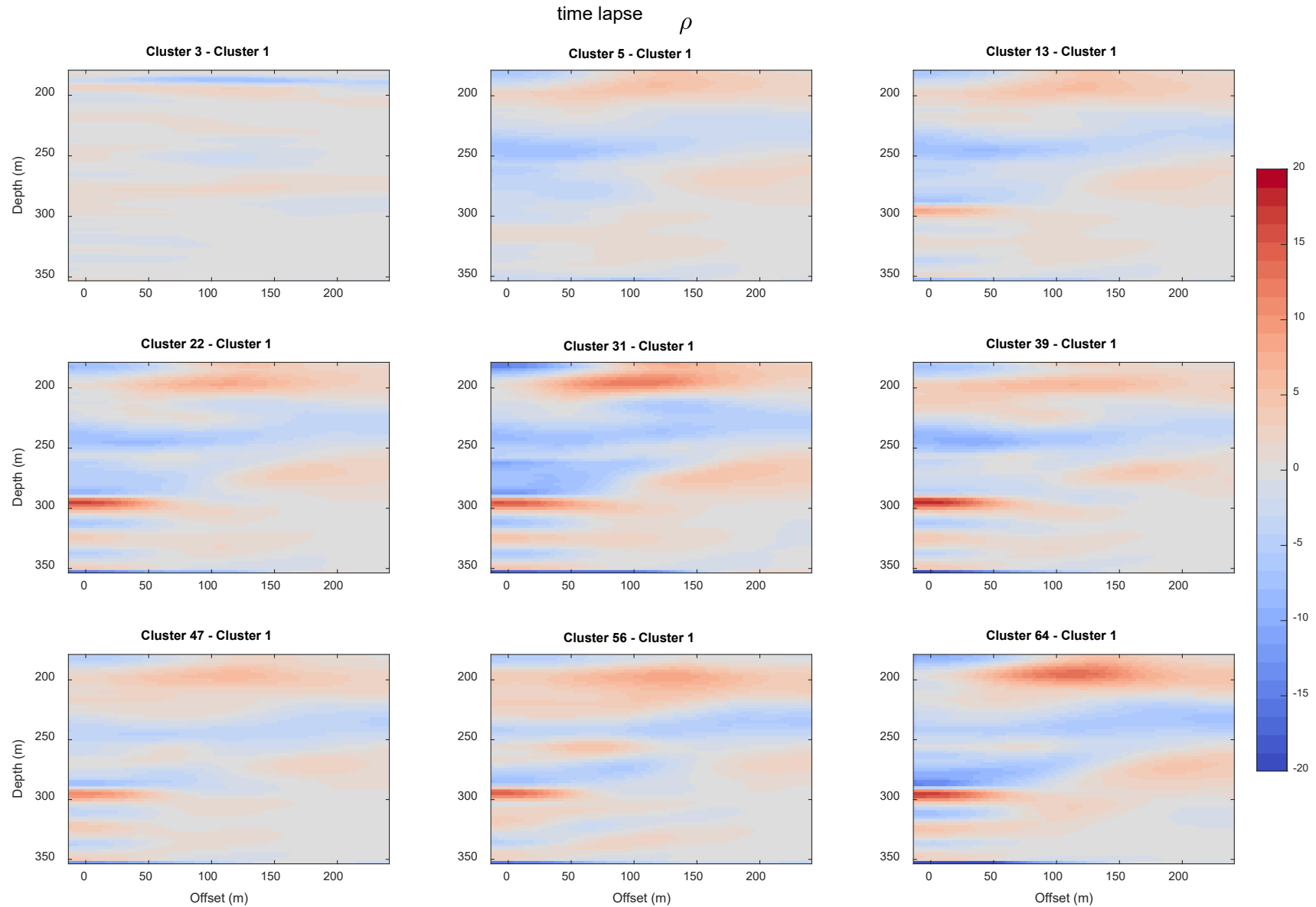


Multiparameter FWI time-lapse inversion



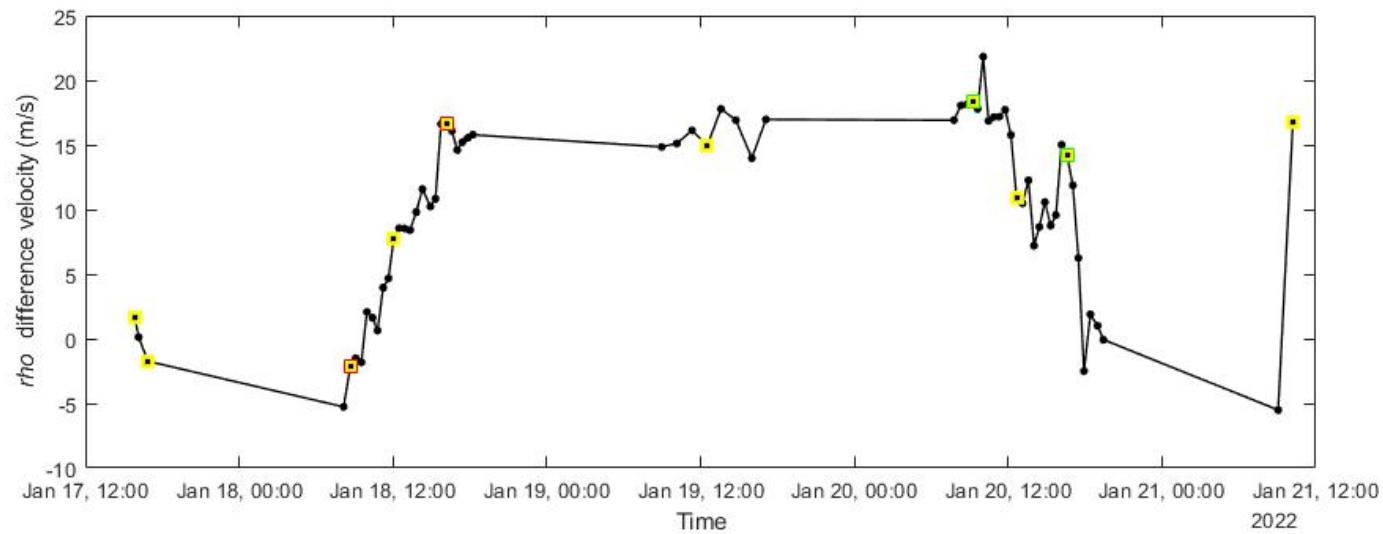
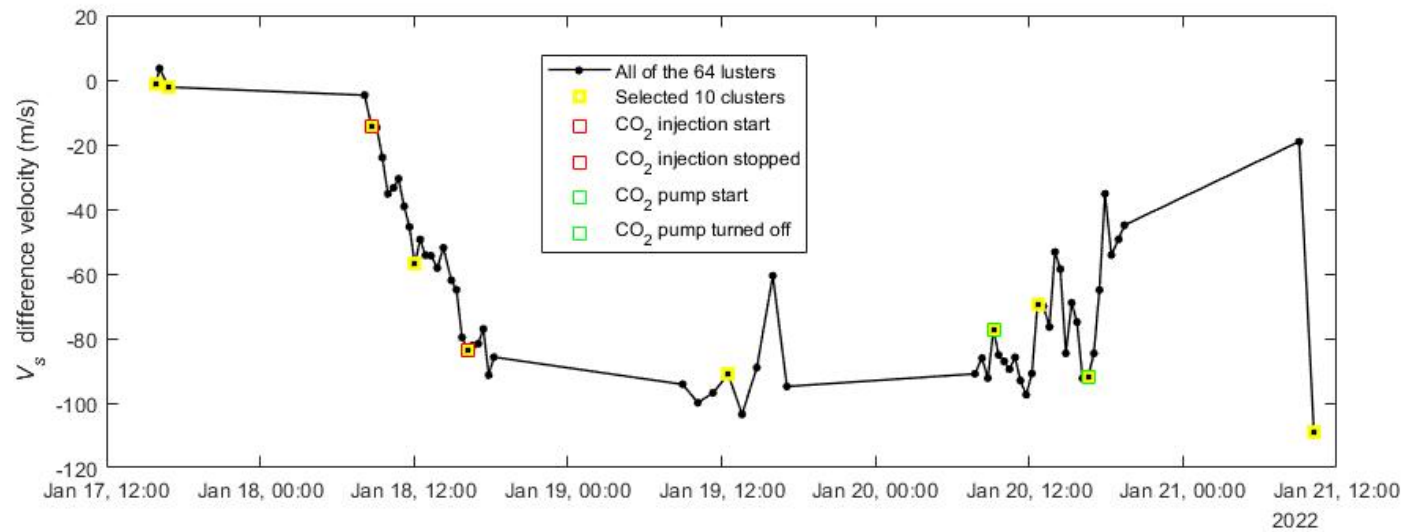


Multiparameter FWI time-lapse inversion



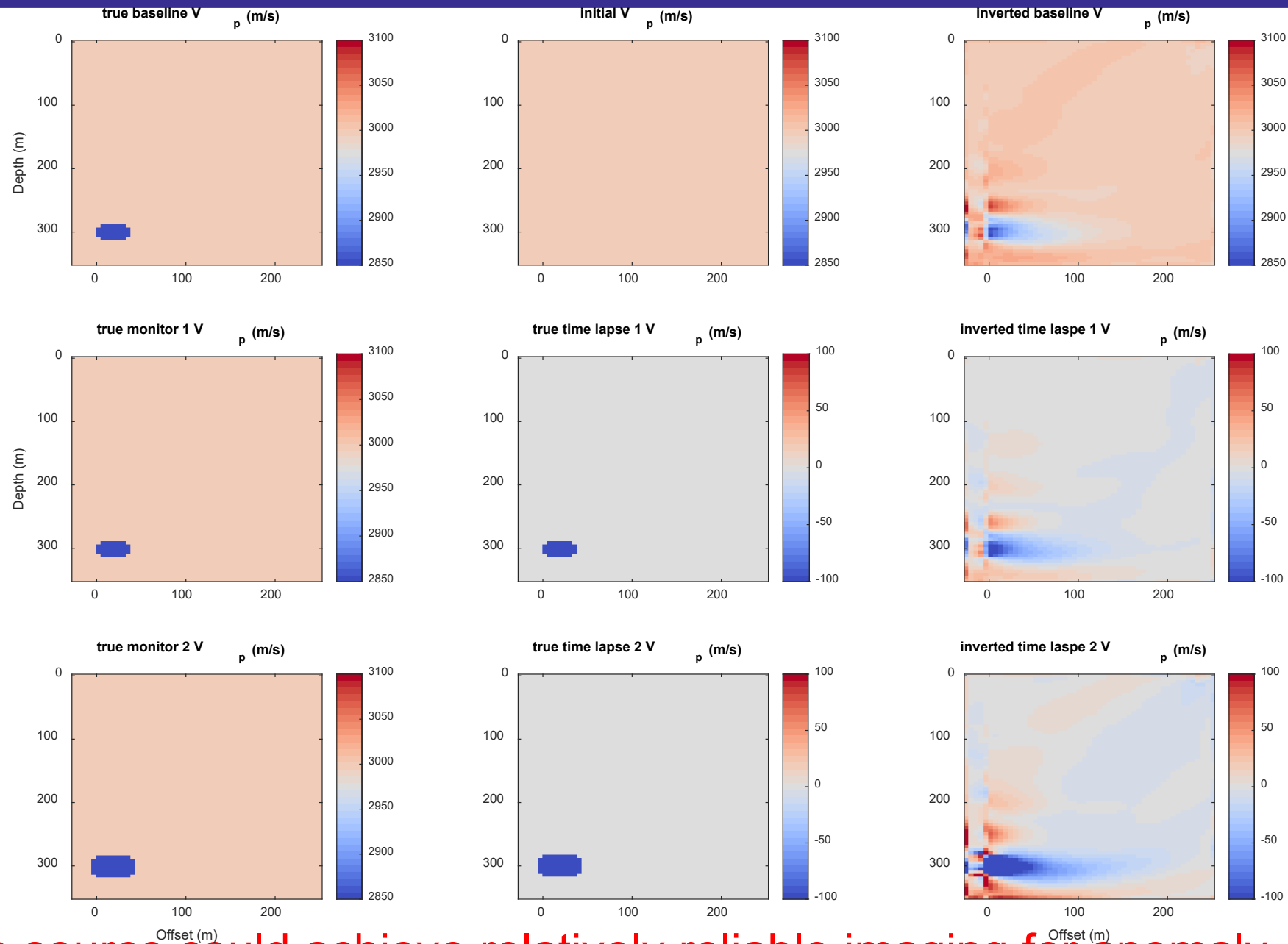


Multiparameter FWI time-lapse inversion





Synthetic data test



Single source could achieve relatively reliable imaging for anomaly

- Opportunities
 - Plausible sensing mode for leak detection, injectivity
 - Leverage low-cost monitoring: fixed source, DAS, VSP
 - New science: mechanisms?
- Challenges
 - Plausible models with sparse sources?
- Next steps
 - Moderate increase in source numbers
 - Standard imaging / FWI / RTM comparisons
 - FWI given plausible rock physics models



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Marie Macquet

Joanna K. Cooper