# FORGE
# Post Hydraulic Fracturing Wells 16A & 16B
# August 2024 Circulation Testing
# *With SLB PLT OVERLAYS*

Fiber Optics Monitoring of August 2024 Circulation Tests

Acquisition Date: August 2024


**Neubrex Energy Services (US), LLC**

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# Acknowledgements

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We thank the many stakeholders who are supporting this project, including Smithfield, Utah School and Institutional Trust Lands Administration, and Beaver County as well as the Utah Governor’s Office of Energy Development and Utah’s Congressional Delegation.

During field operations, Neubrex worked with many operational experts and received critical assistance from many people, including John McLennan, Joseph Moore, Kevin England, Leroy Swearingen, Alan Reynolds, Garth Larson, Monty Keown, Dr. Mukul Sharma, Ben Dyer, Dr. Peter Meir, and Neubrex Ops Chief Wayne Fishback. The frac, drilling, water management crews and HSE managers were instrumental in getting the surface and downhole work accomplished in a safe and effective manner.

# End of Technical Report and Contact Information


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# FORGE August 2024 Circulation Test Key Findings

Distributed fiber optic sensing was used in the 16B as a monitor well during Cross well circulation flow testing from16A to 16B after hydraulic fracturing had been completed on both wells.

RFS DSS and DTS were the the primary fiber measurement methods used on the Single Mode Fiber #2 and MMF #1 on 16B Shell UT Cable during all flow testing during August 2024.

Circulation tests provided useful information about the distributed temperature changes associated with fluid inflow flow at 16B producer well during the test.  The data were tied to a SLB PLT that was run after the Fiber Test data was acquired. These measurements were  not co-synchronous due to a fiber failure that occurred prior to the PLT logs being run in late August.

# Key Assessments about Post Frac Circulation Test

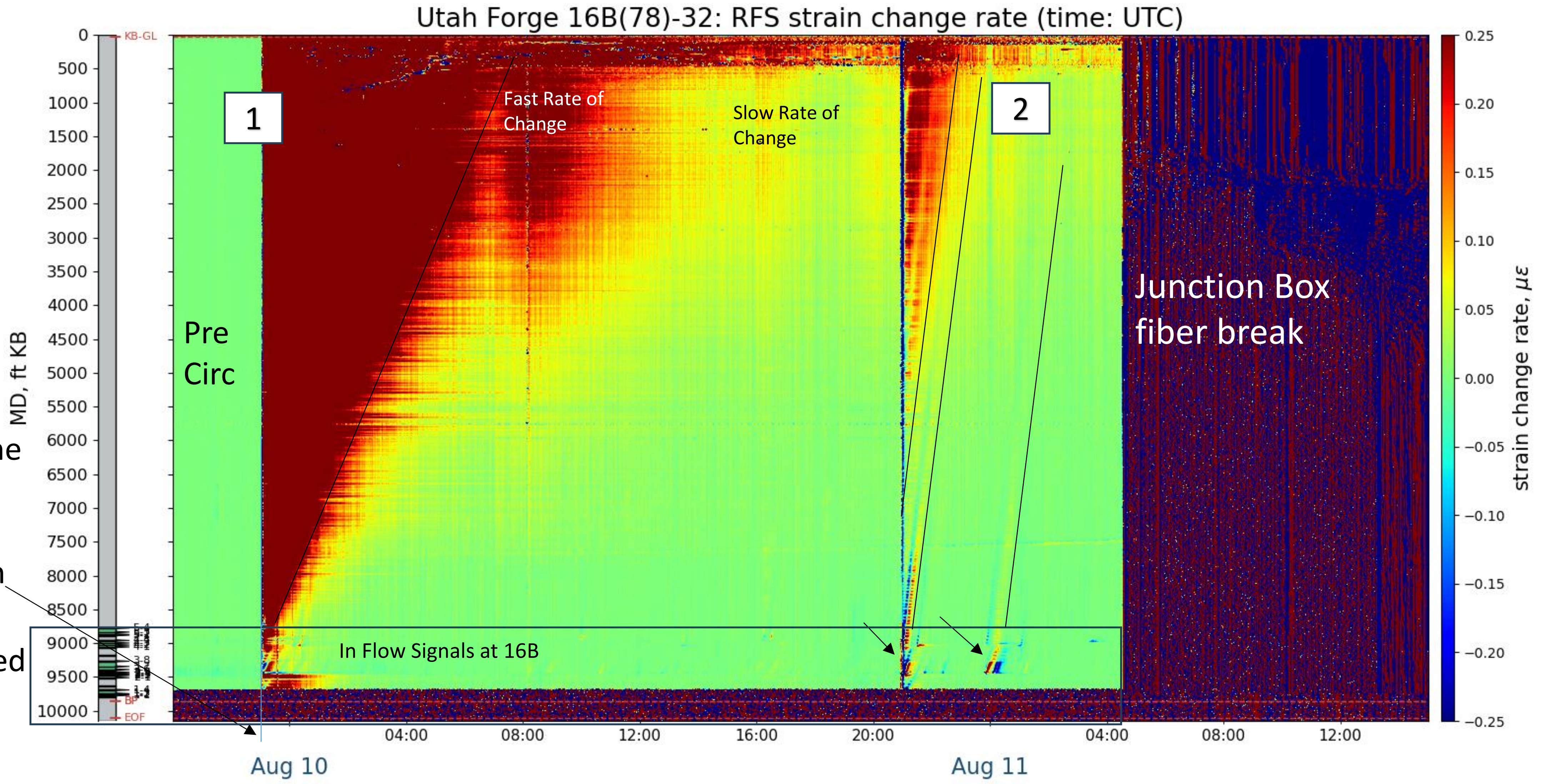
- Both RFS DSS strain change, strain change rate and DTS temperature signals are responding to thermally driven fluid in flow at the 16B well as fluid was pumped into the 16A injector well.

- Clear evidence shows association between the location of previously generated and mapped hydraulic fractures generated during the 16A and 16B frac stimulations and the location of thermally driven strain and temperature signals inferred to be associated with inflowing thermally heated fluids.
- Many of the initial thermal signatures can be "tracked" as they move up the wellbore as so called "thermal slugs" and their velocities can me calculated.

- After pumping was stopped on 16A there is a cool back period that also contains important thermal signal information about those zones which warm or cool back over time. These post pumping signatures may be indicators of which zones produced the most or hottest fluid. These discrete signatures may also be useful indicators of which fractures are most productive in terms of heat transfer.
- Fiber optic RFS DSS and DTS can be further used in combination with DAS data that was also acquired during this period in attempts to produce quantitative estimates of relative inflow contribution per clusters from all open clusters in the 16B well (20 clusters plus an open hole section below casing) during the circulation test period.

(The integration and analysis of DAS data from the circulation period to be used for "relative production allocation" is not yet completed as of November 2024.)

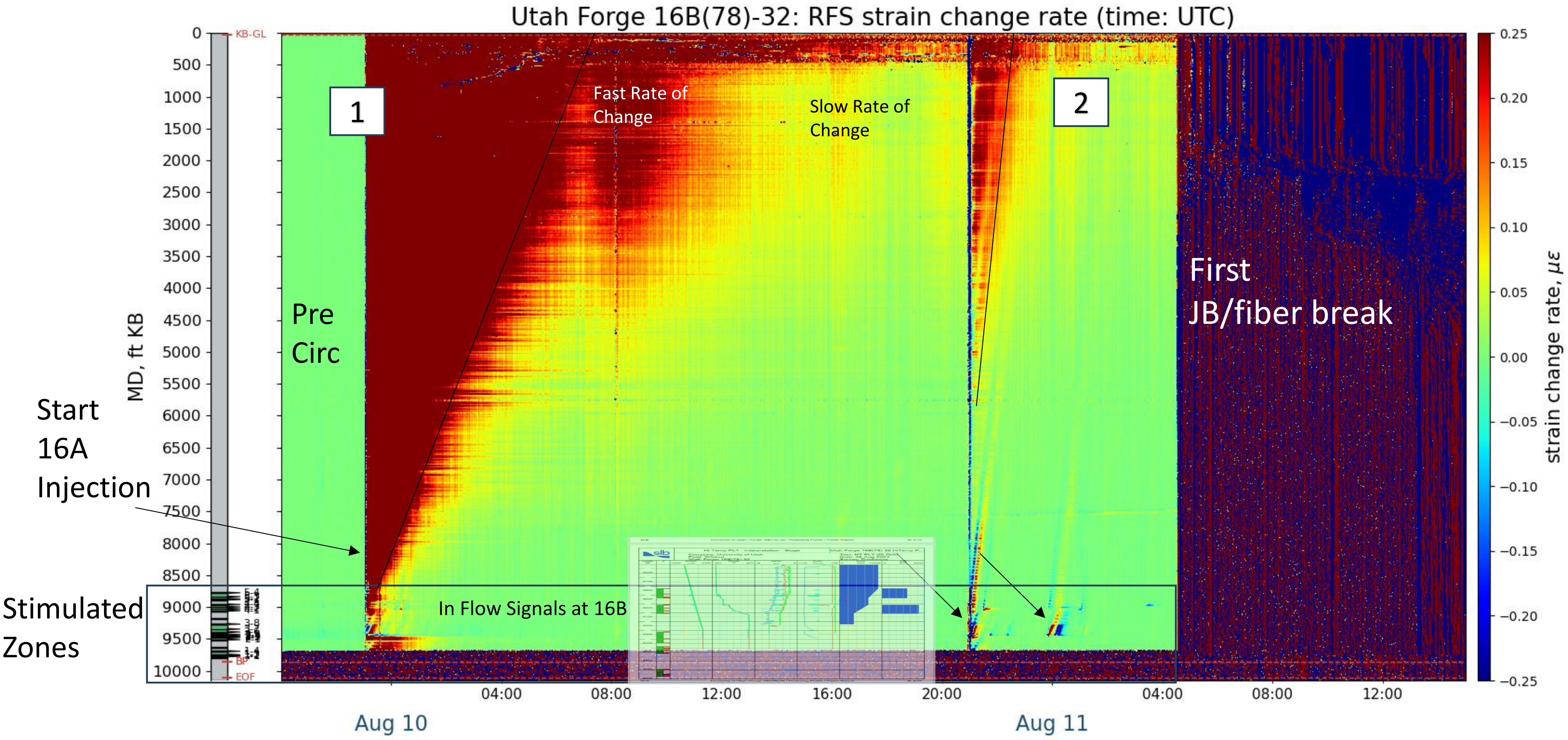
# Well 16B(78)-32 – RFS DSS strain change rate – Circulation




Start time of 16A Injection

Stimulated Zones

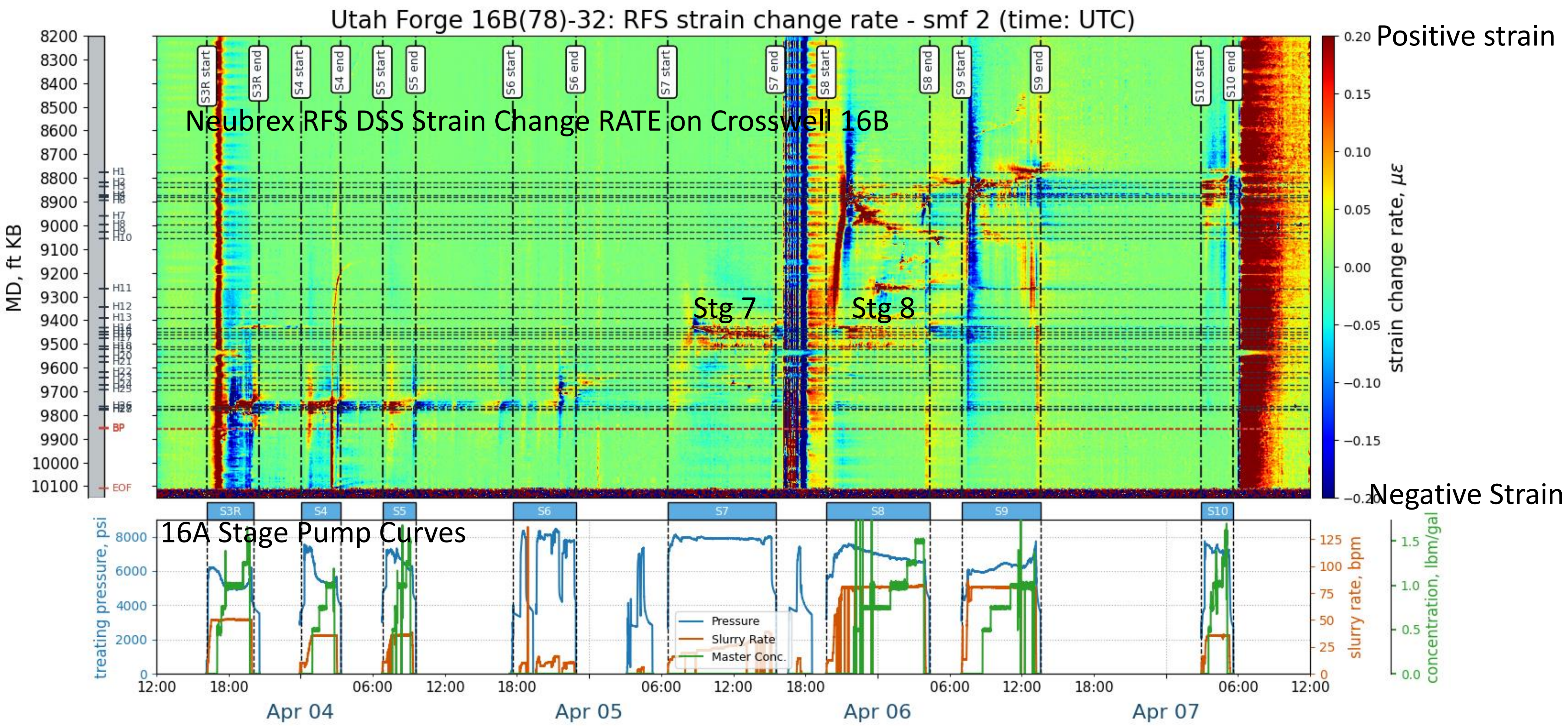
# Well 16B(78)-32 – RFS DSS strain change rate – w PLT Plot



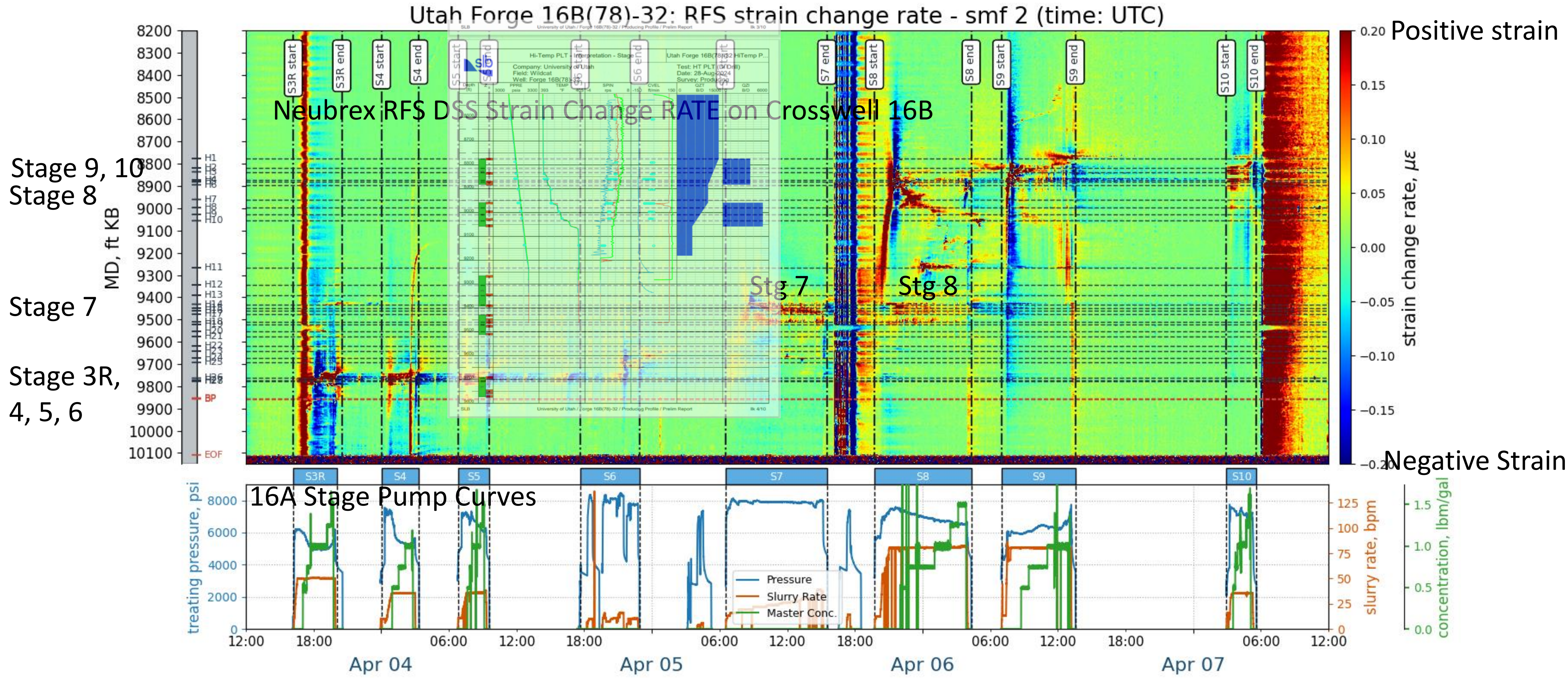
# Context: Well 16B – Review - FDI's from 16A Frac Stimulation at 16B Monitor Well

Stage 8

Stage 7



# Well 16B – Overlay – SLB PLT Data with FDI's from 16A Frac Stimulation at 16B Monitor Well

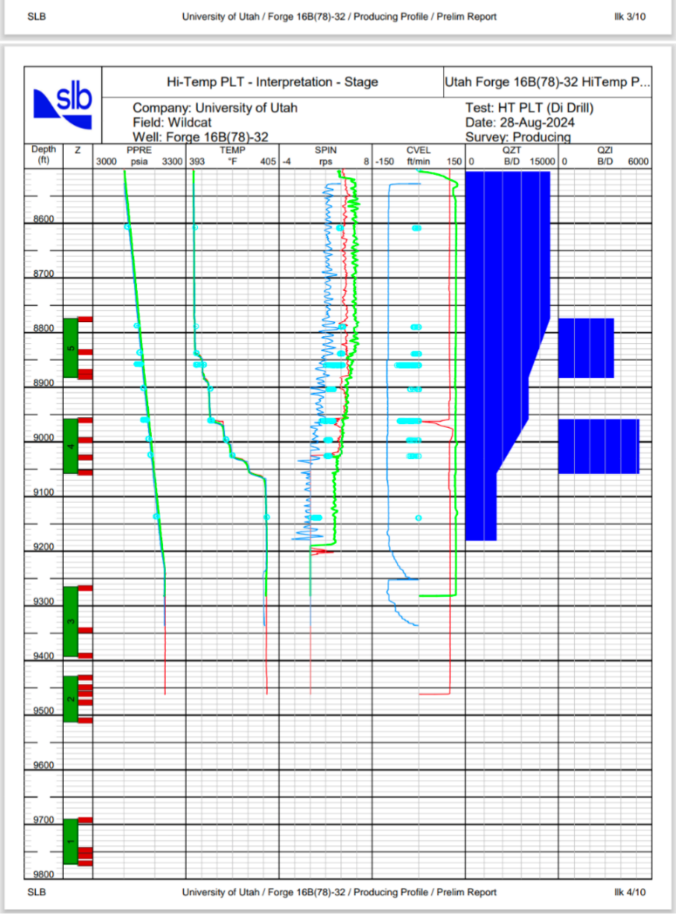


# Cross well circulation test analysis

August 2024

Extended Flow Test

# Well 16B –SLB PLT Summary Report

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**Forge 16B(78)-32**

## Interpretation Results: Surface Flowrate Resu

| Stage | Perforations | | Water (bpd) | Water (%) |
|---|---|---|---|---|
| 5 | 8774 | 8778 | trace | trace |
| | 8834 | 8838 | 1309.0 | 10.8% |
| | 8870 | 8874 | 314.2 | 2.6% |
| | 8879 | 8883 | 1489.0 | 12.3% |
| 4 | 8958 | 8962 | 1381.2 | 11.4% |
| | 8995 | 8999 | 765.9 | 6.3% |
| | 9026 | 9030 | 1439.9 | 11.9% |
| | 9054 | 9058 | 986.9 | 8.2% |
| 3 | Below 9240 | | 4388.3 | 36.3% |
| 2 | | | | |
| 1 | | | | |
| Totals | | | 12074.4 | 100.0% |

Log Analyst: Leonid Kolomytsev / Cas

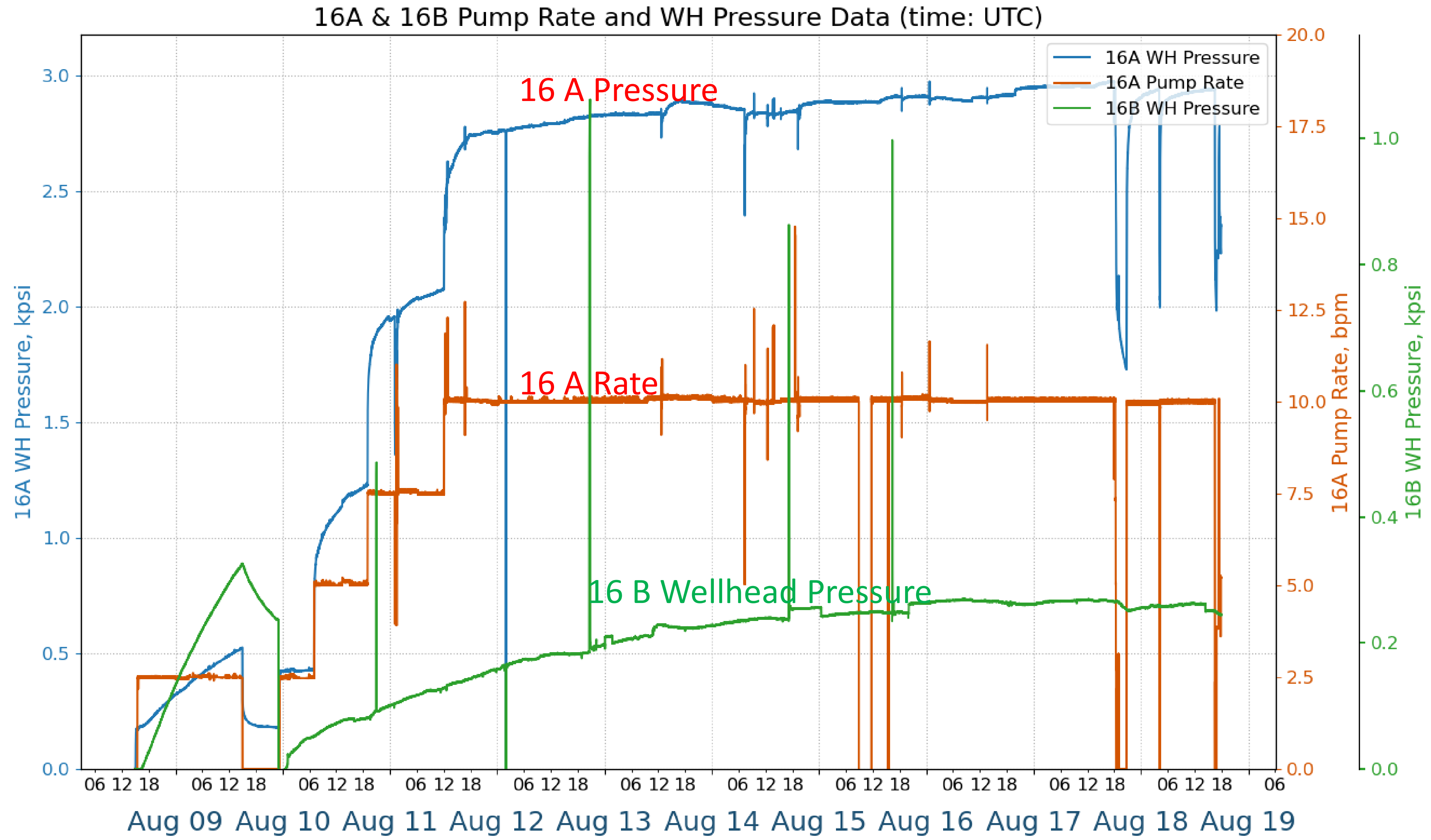
SLB University of Utah / Forge 16B(78)-32 / Pro

**University of Utah**
**Forge 16B(78)-32**

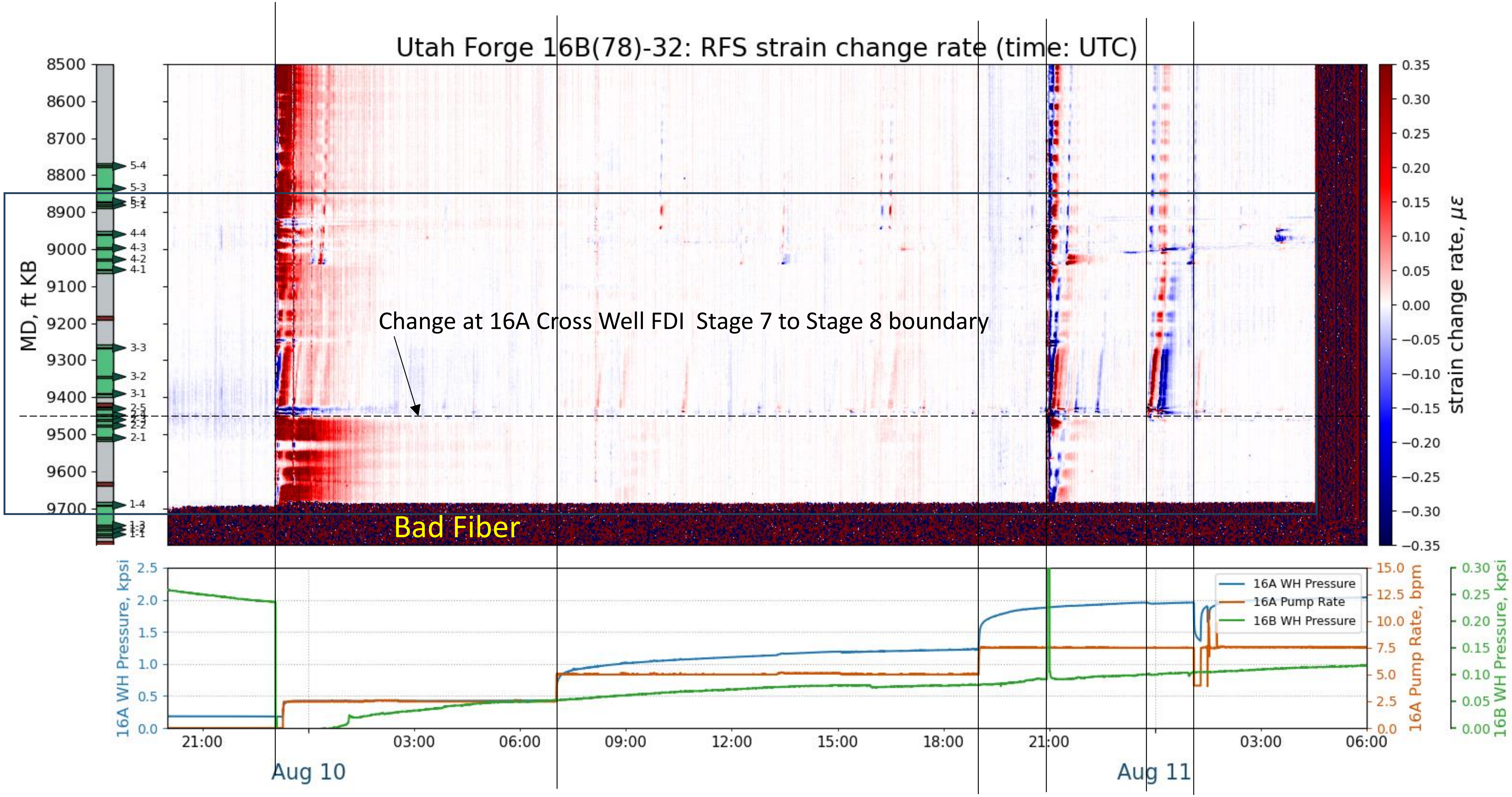
## Interpretation Results: Surface Flowrate Res

| Stage | Perforations | | Water (bpd) | Water (%) |
|---|---|---|---|---|
| 5 | 9270 | 9276 | 3112.2 | 25.8% |
| 4 | 9320 | 9493 | 4573.9 | 37.9% |
| 3 | Below 9240 | | 4388.3 | 36.3% |
| 2 | | | | |
| 1 | | | | |
| Totals | | | 12074.4 | 100.0% |

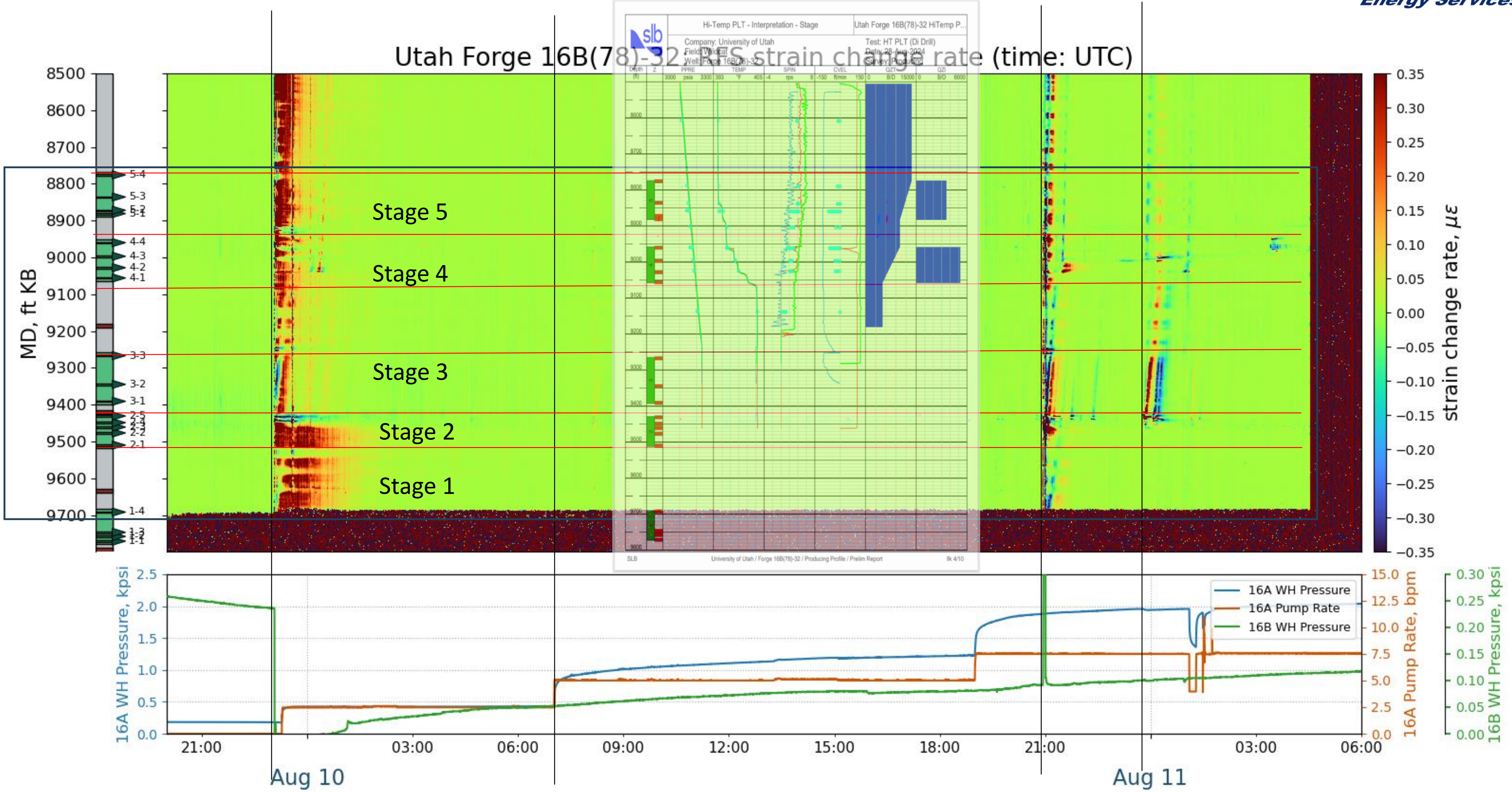
# Circulation test – 16A pumping Pressure and Rate and 16B Pressure



# RFS DSS Strain Rate during Initial Circulation between Wells



# Rate Changes on 16A Pump - 0 to 2.5 bbl/min to 5.0 bbl/min to 7.5 bbl/min – 16B RFS DSS Thermal Driven Strain



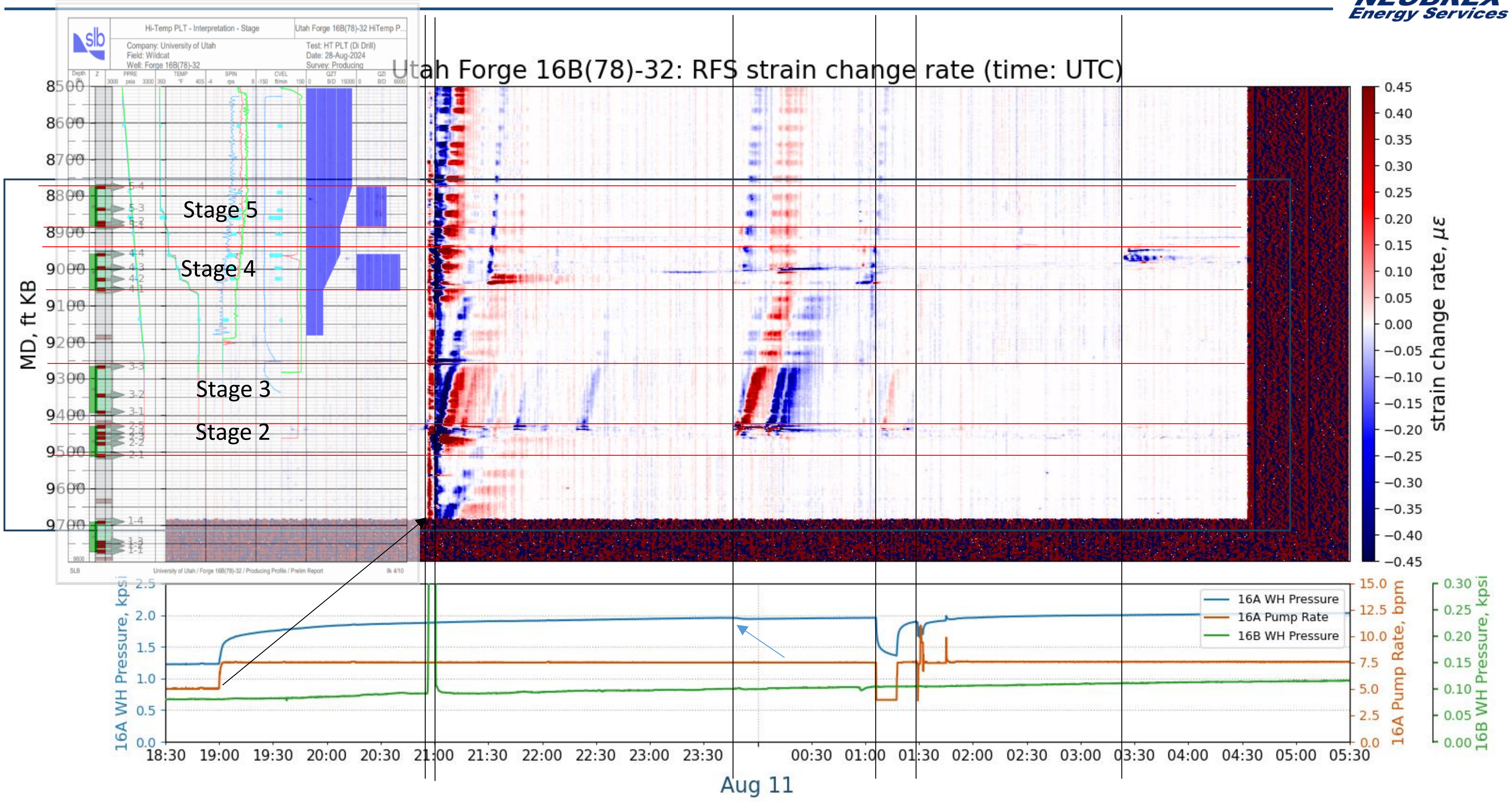
# Delay Time Analysis – all times UTC

- Events:
  - 1st increase of rate and pressure on 16A: 2024-08-09 23:16:59
  - 2nd increase of rate and pressure on 16A: 2024-08-10 19:00:4

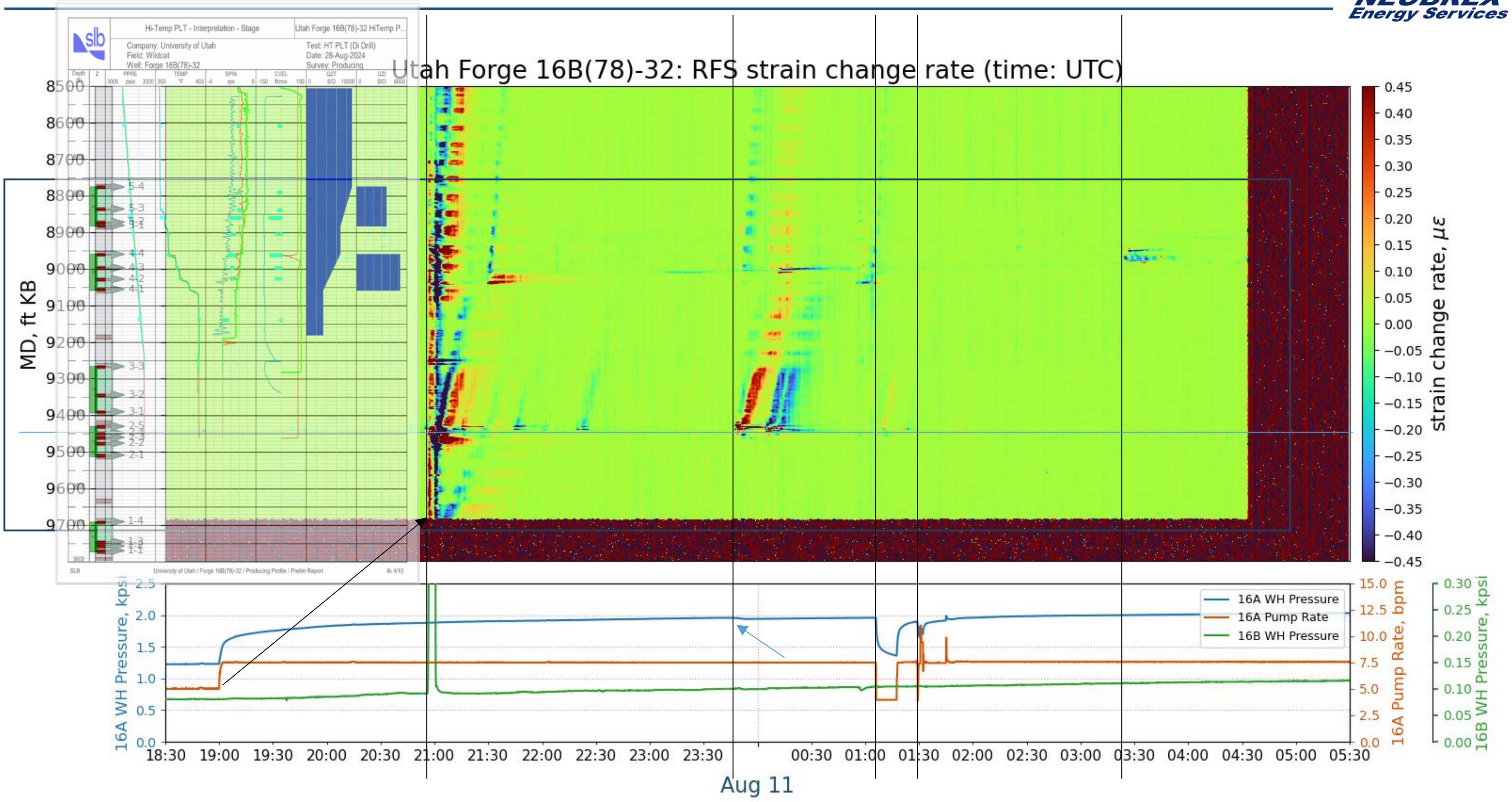
- Strain response: 2024-08-10 20:54:52

- **Delay from 16A to 16B is approx. 1 h 54 min**

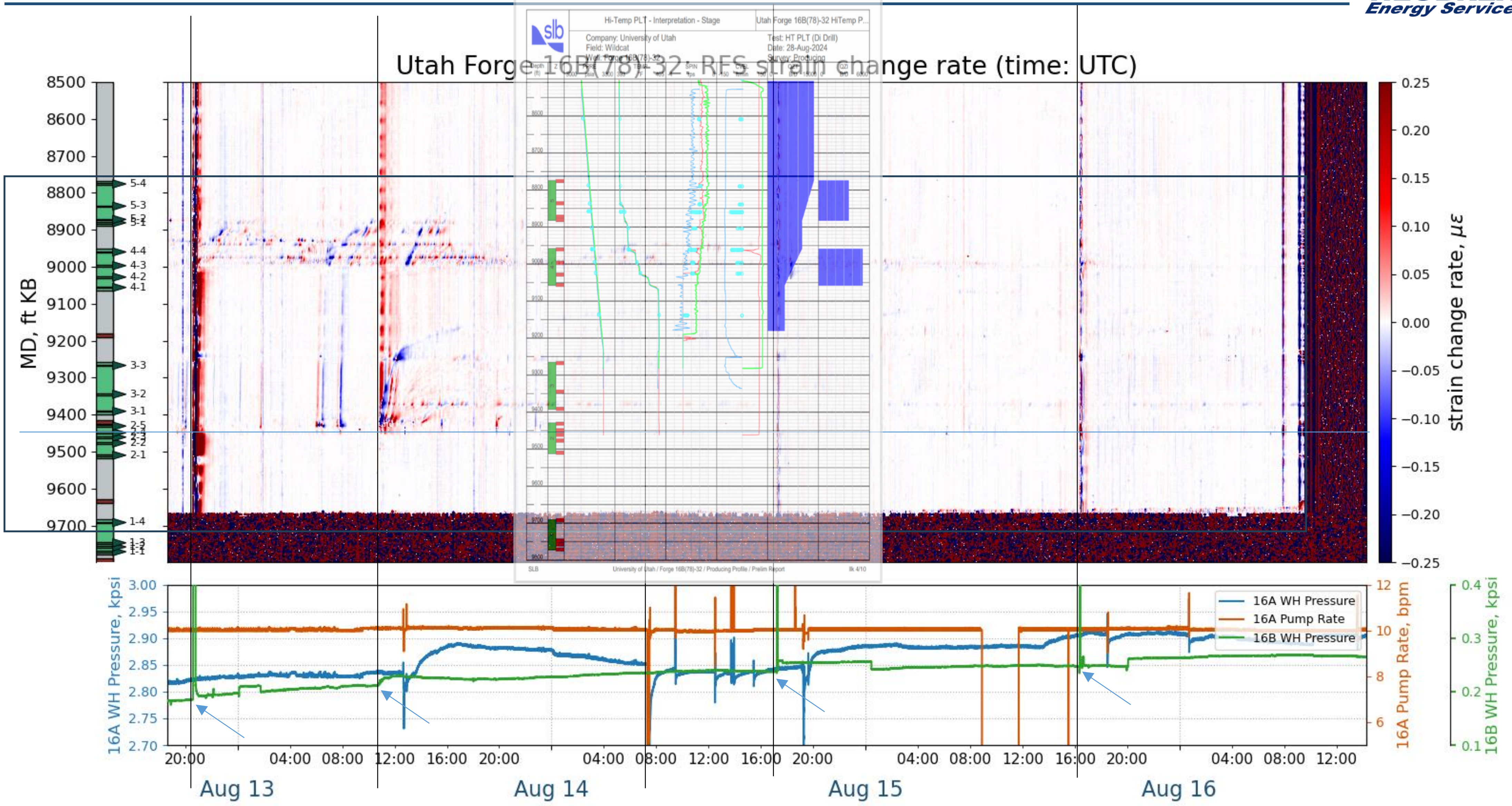
# Input Rate Change: 5 bbl/min to 7.5 bbl/min pump rate increase



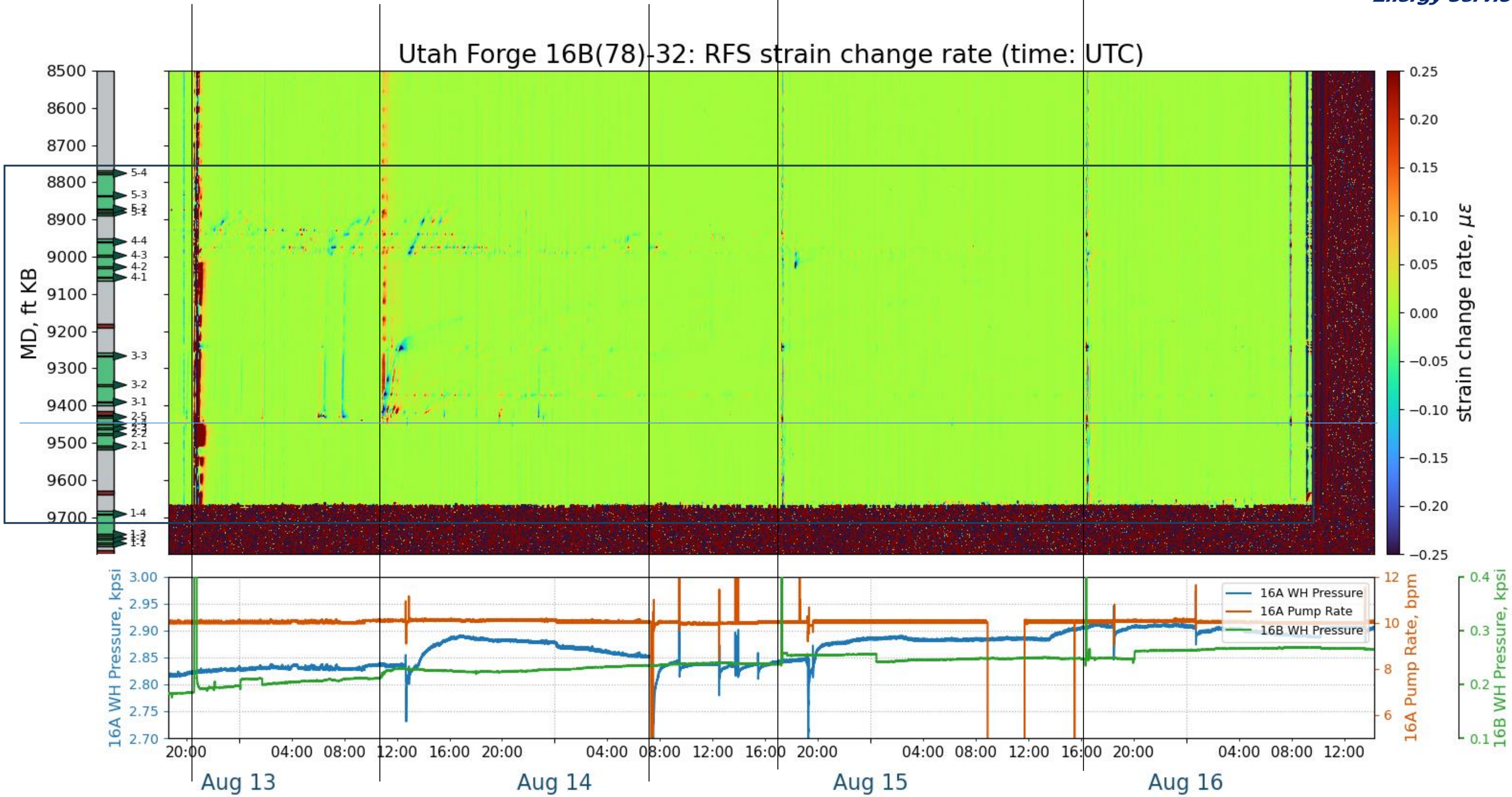
# Input Rate Change: 5 bbl/min to 7.5 bbl/min pump rate increase



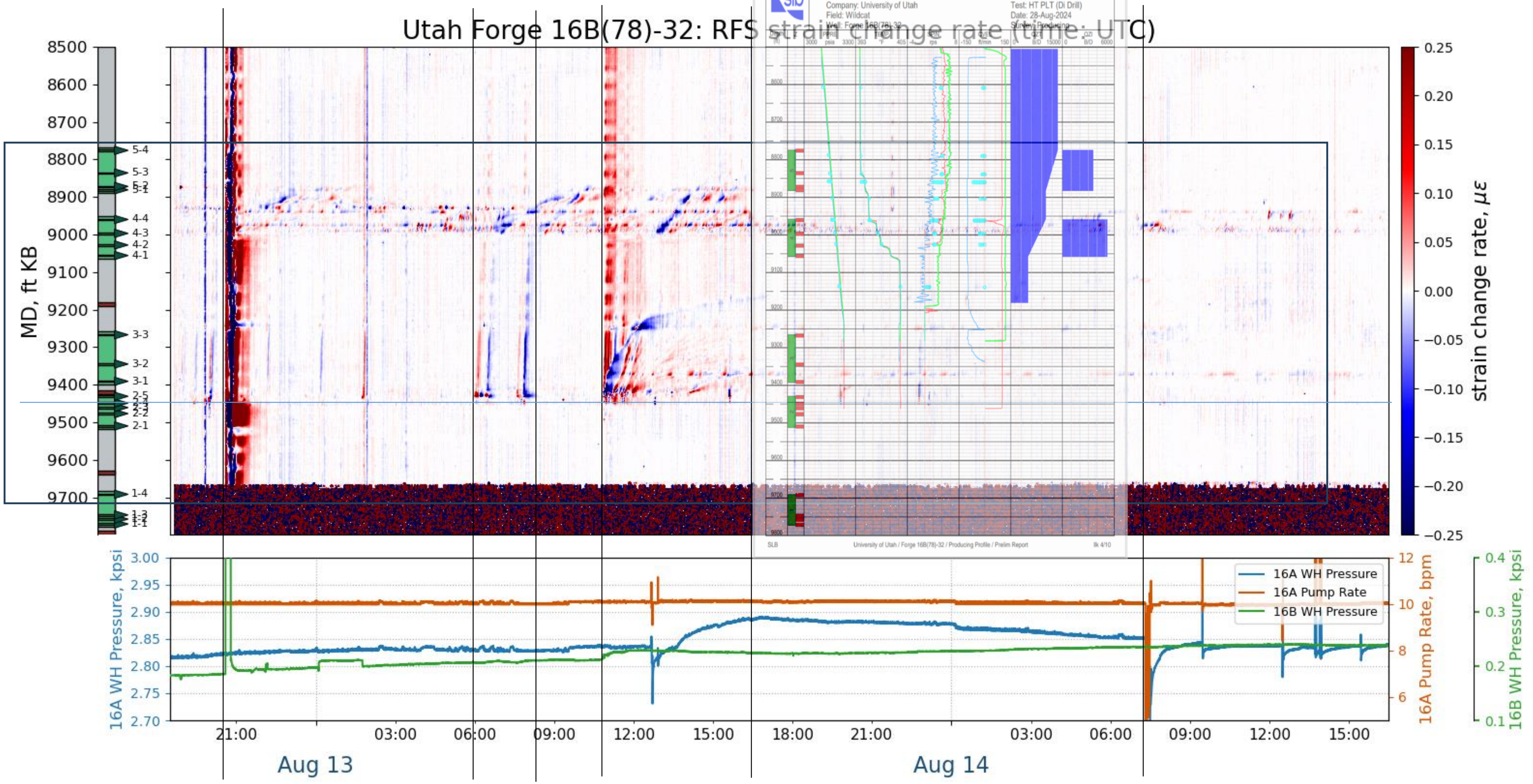
# Injection Rate: 10 bbl/min pump rate Steady



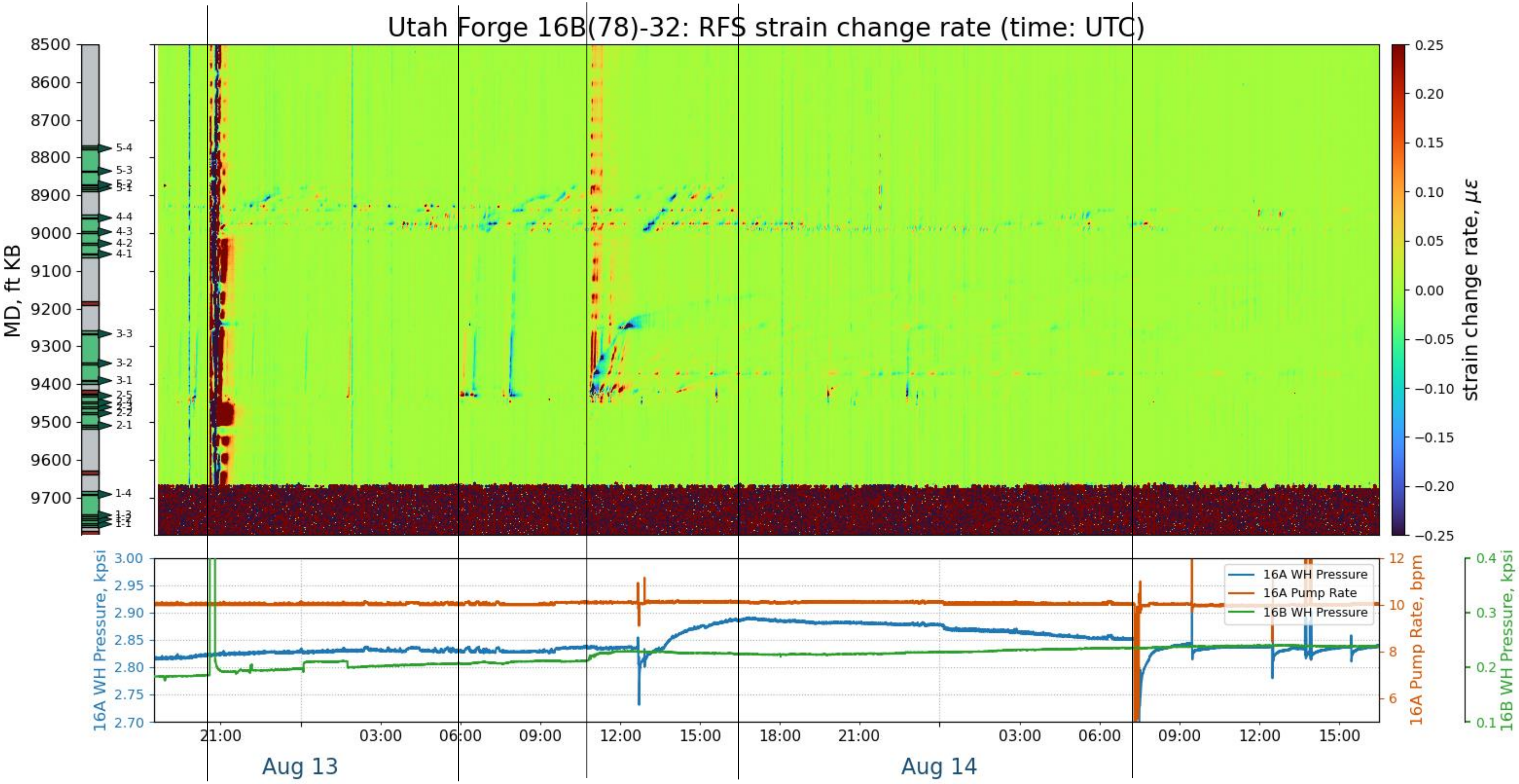
# Injection Rate: 10 bbl/min pump rate Steady



# Injection Rate: 10 bbl/min pump rate Steady



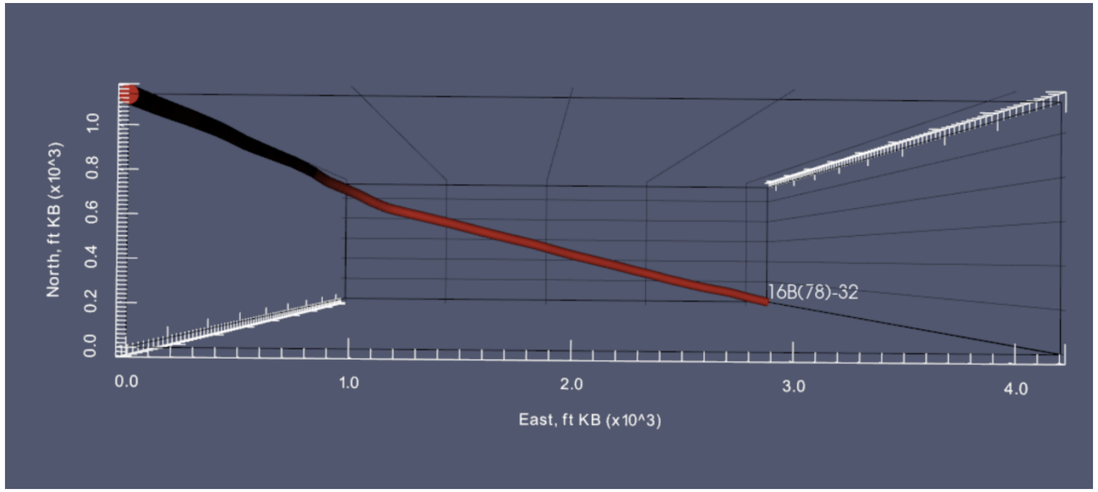
# 10 bbl/min pump rate Steady

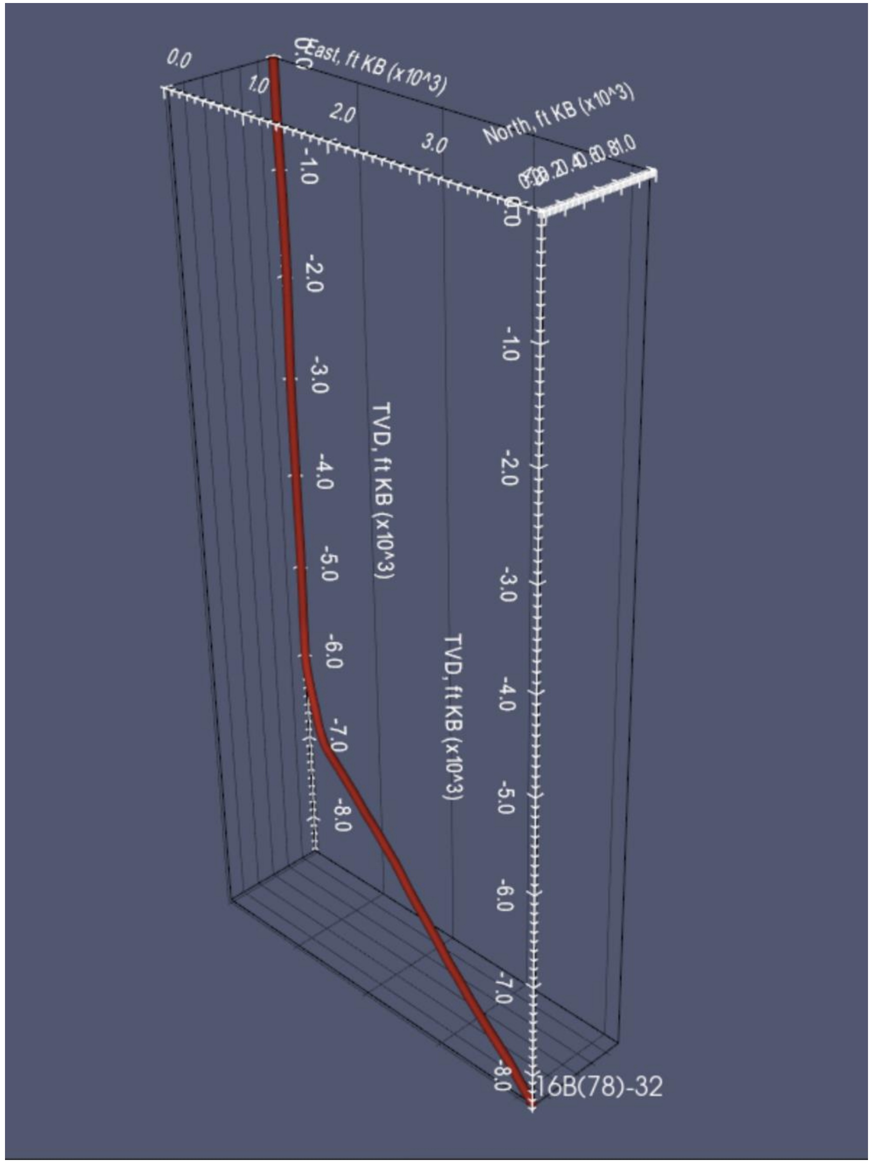


# Well Survey Renderings

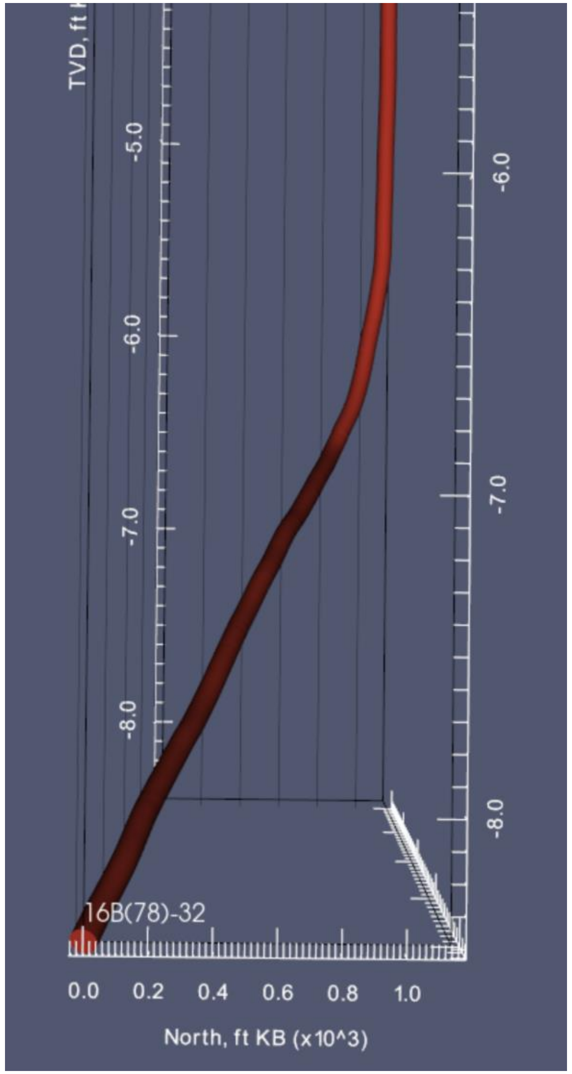
Based on schematics and  deviation survey data provided by Operator

# Monitored well

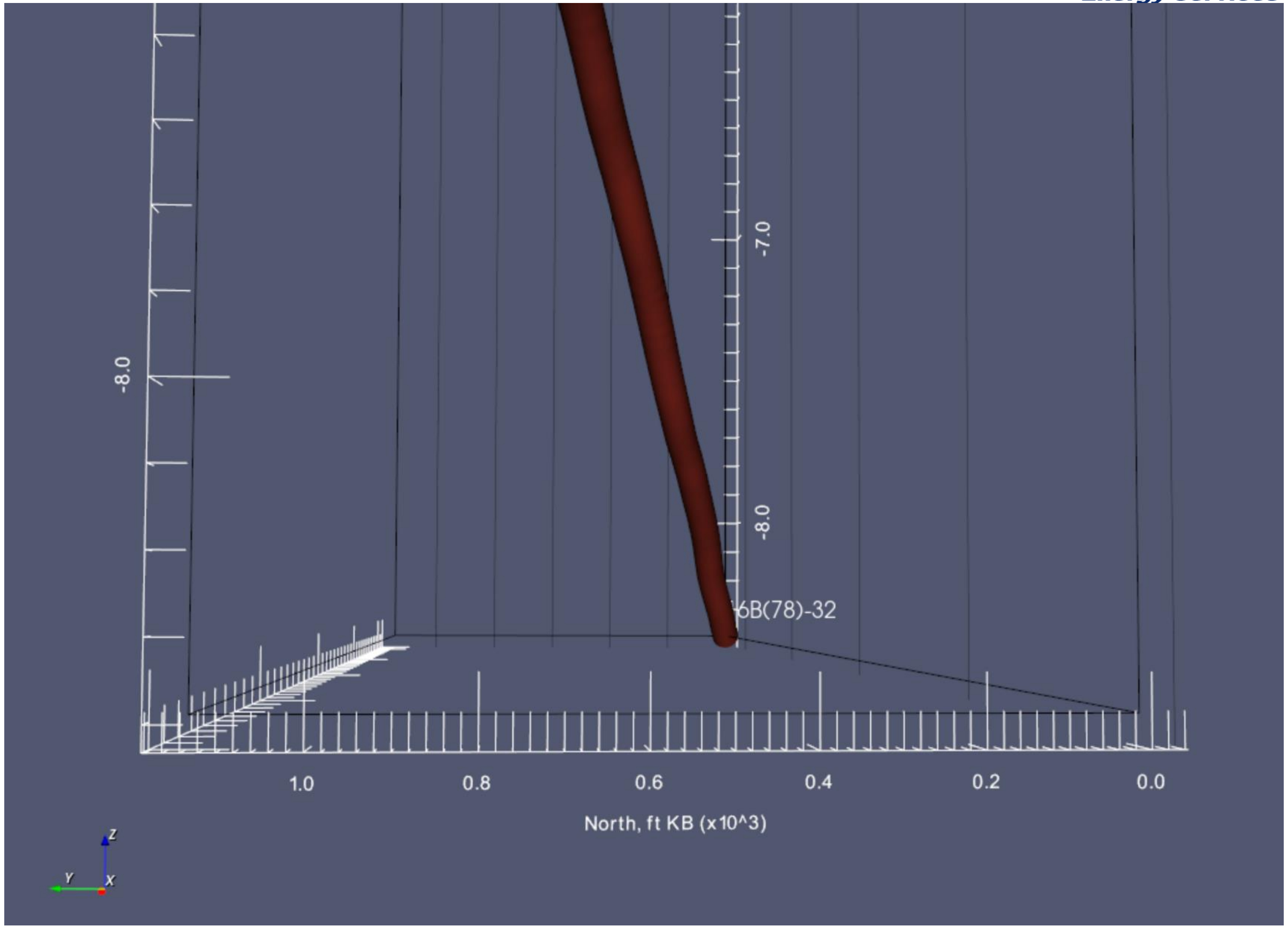


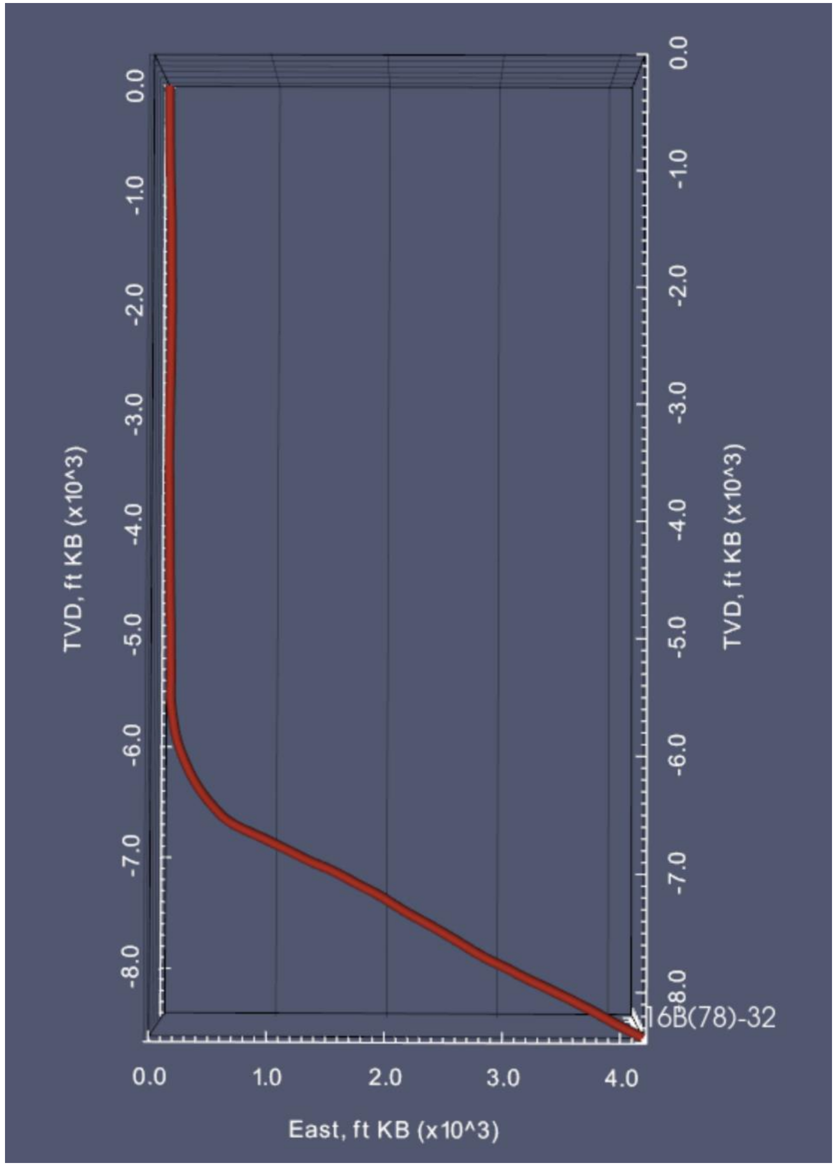
# Monitored well

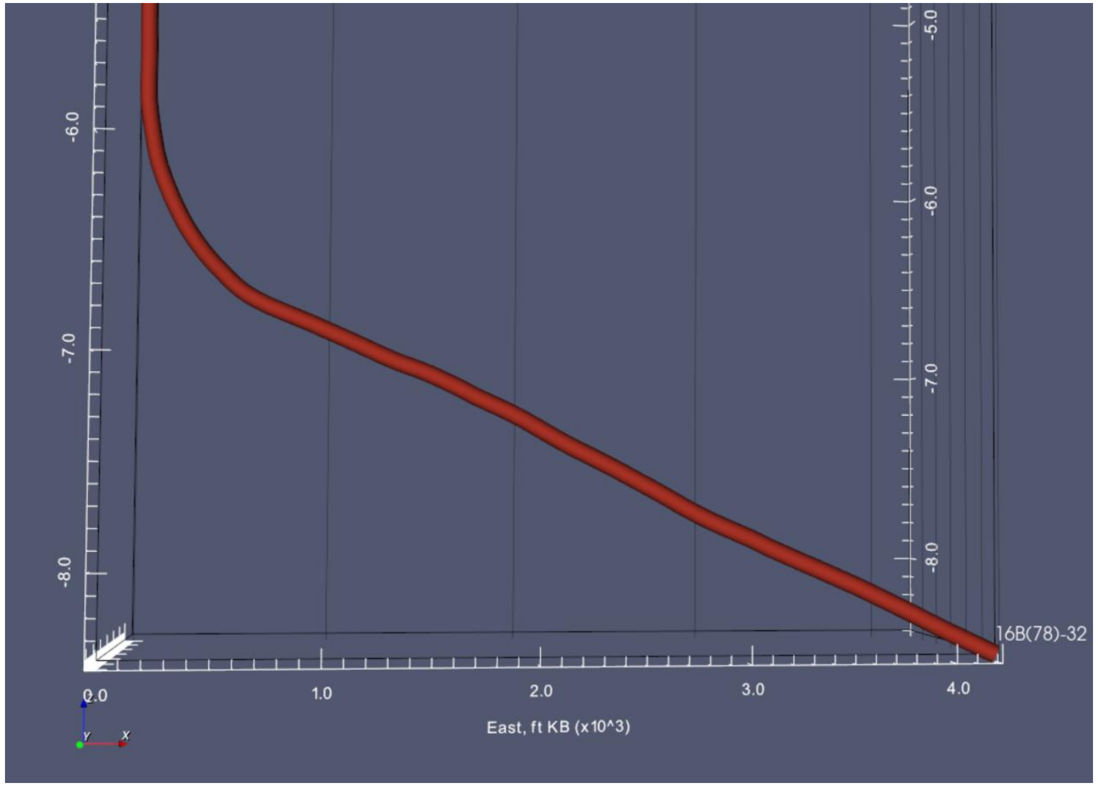



Gun barrel view



# Monitored well



# Measurements

Summary of measurements using RFS, DTS, and BCF

RFS = Rayleigh Frequency Shift fiber optic measurement

DTS = Distributed Temperature Sensing fiber optic measurement

BCF = Brillouin Center Frequency fiber optic measurement

# Distributed Temperature Sensing

-- first trace: Aug 12, 2024, 19:24:32

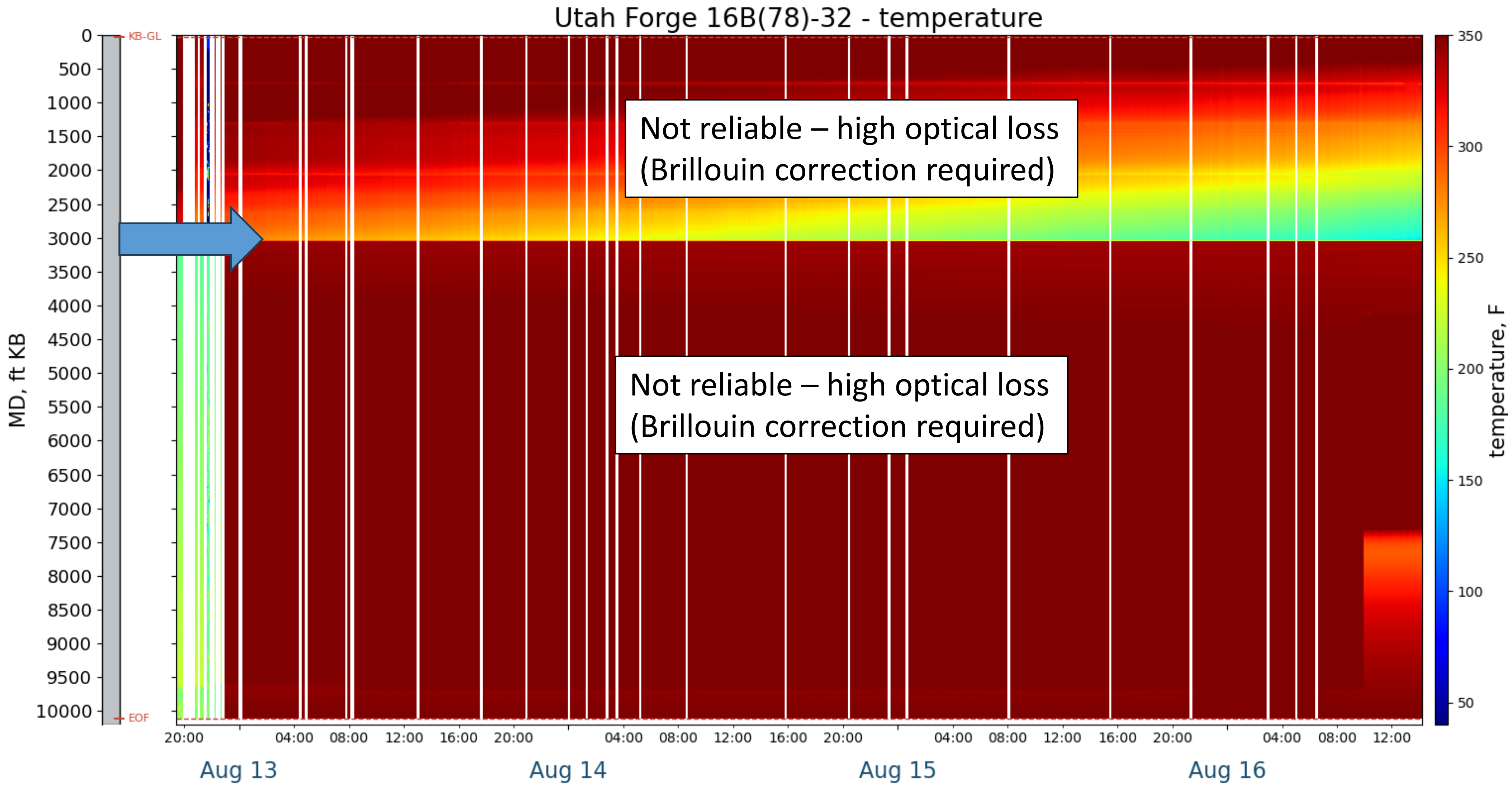
-- last trace: Aug 16, 2024, 14:12:27

-- number of traces: 2269

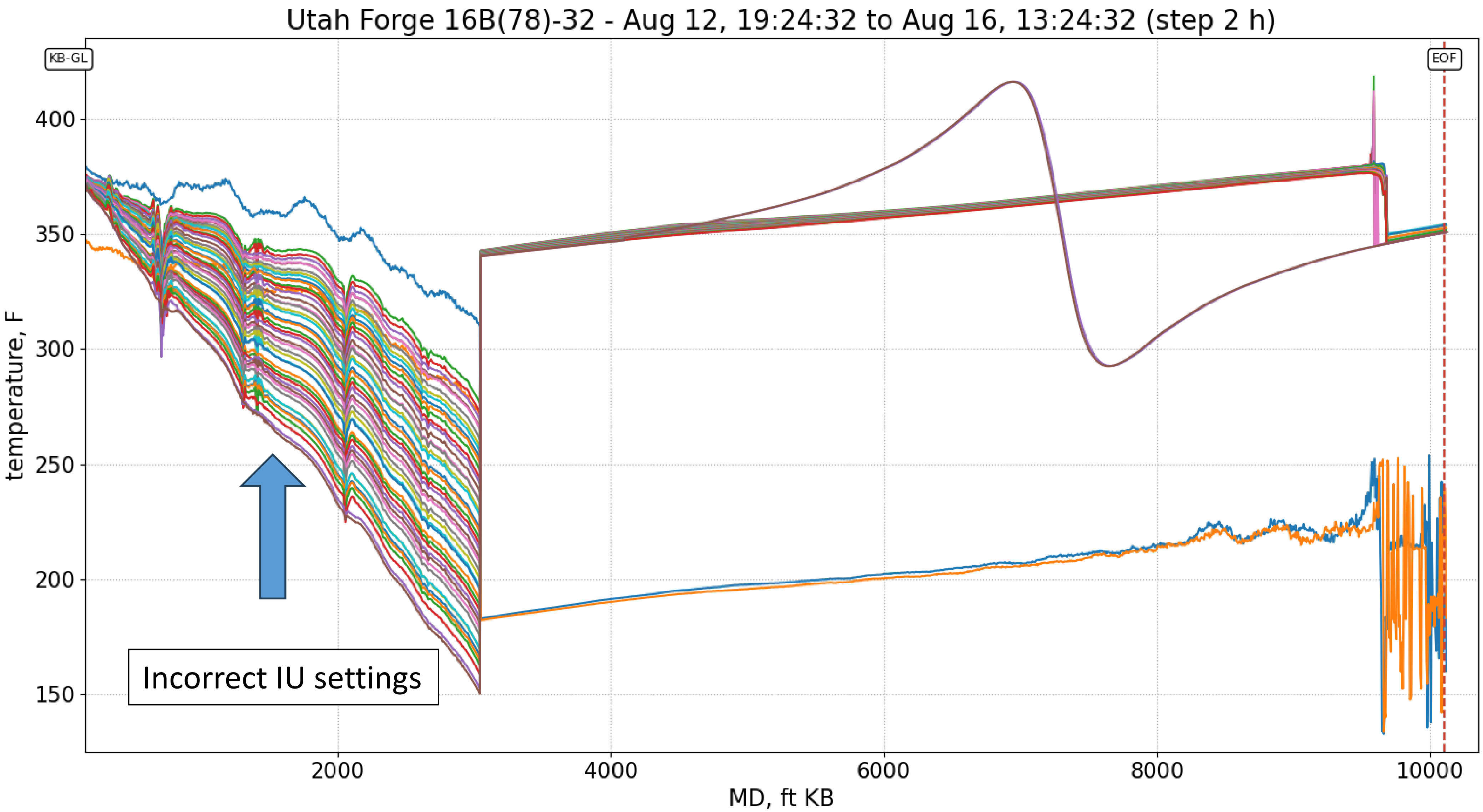
-- number of samples per trace: 1582

-- average temporal interval (sec): 144

# Well 16B(78)-32 – DTS – waterfall – temperature overview



# Well 16B(78)-32 – DTS – selected traces



# Brillouin absolute total strain

-- first trace: Aug 12, 2024, 20:04:49

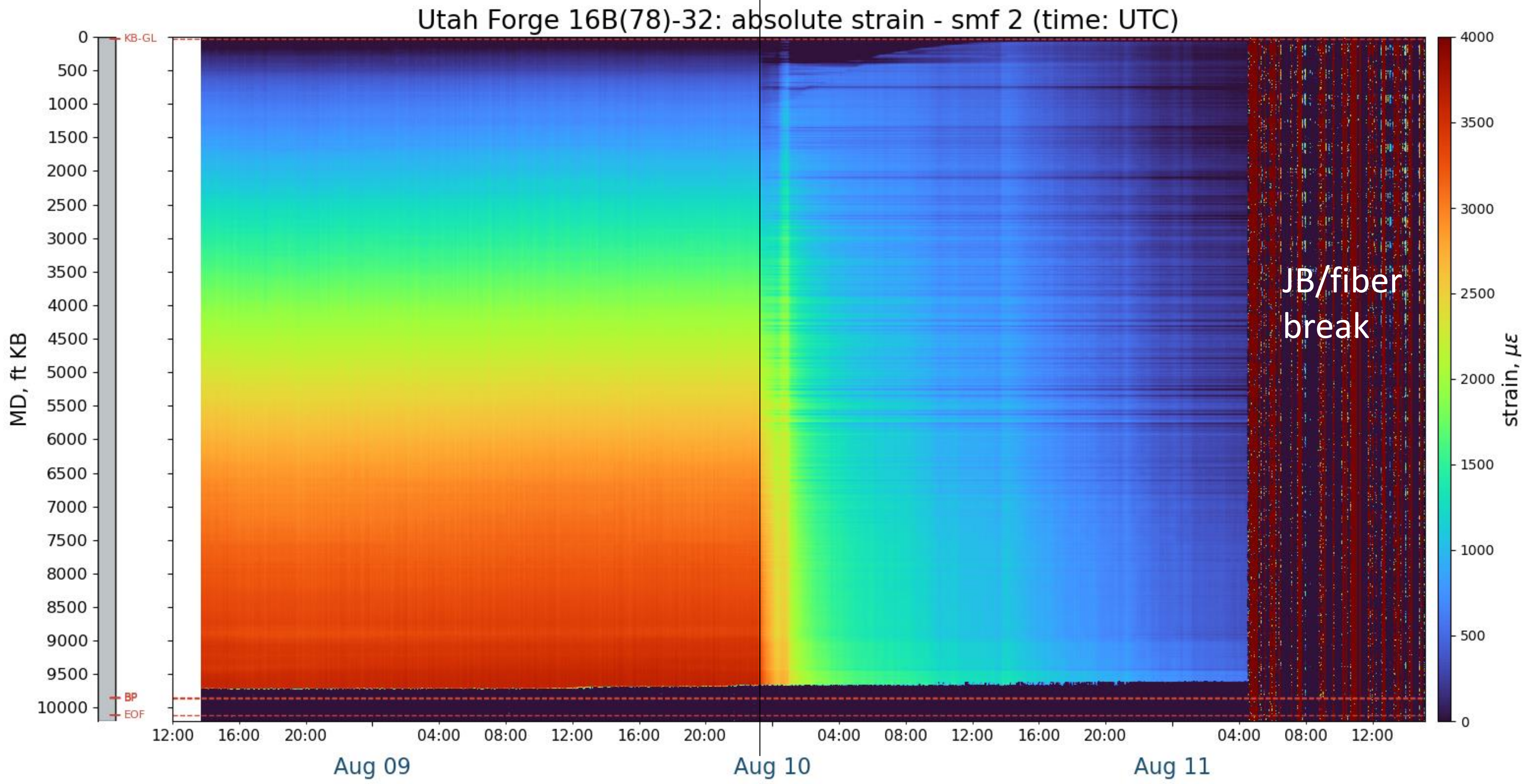
-- last trace: Aug 16, 2024, 14:05:54

-- number of traces: 3232

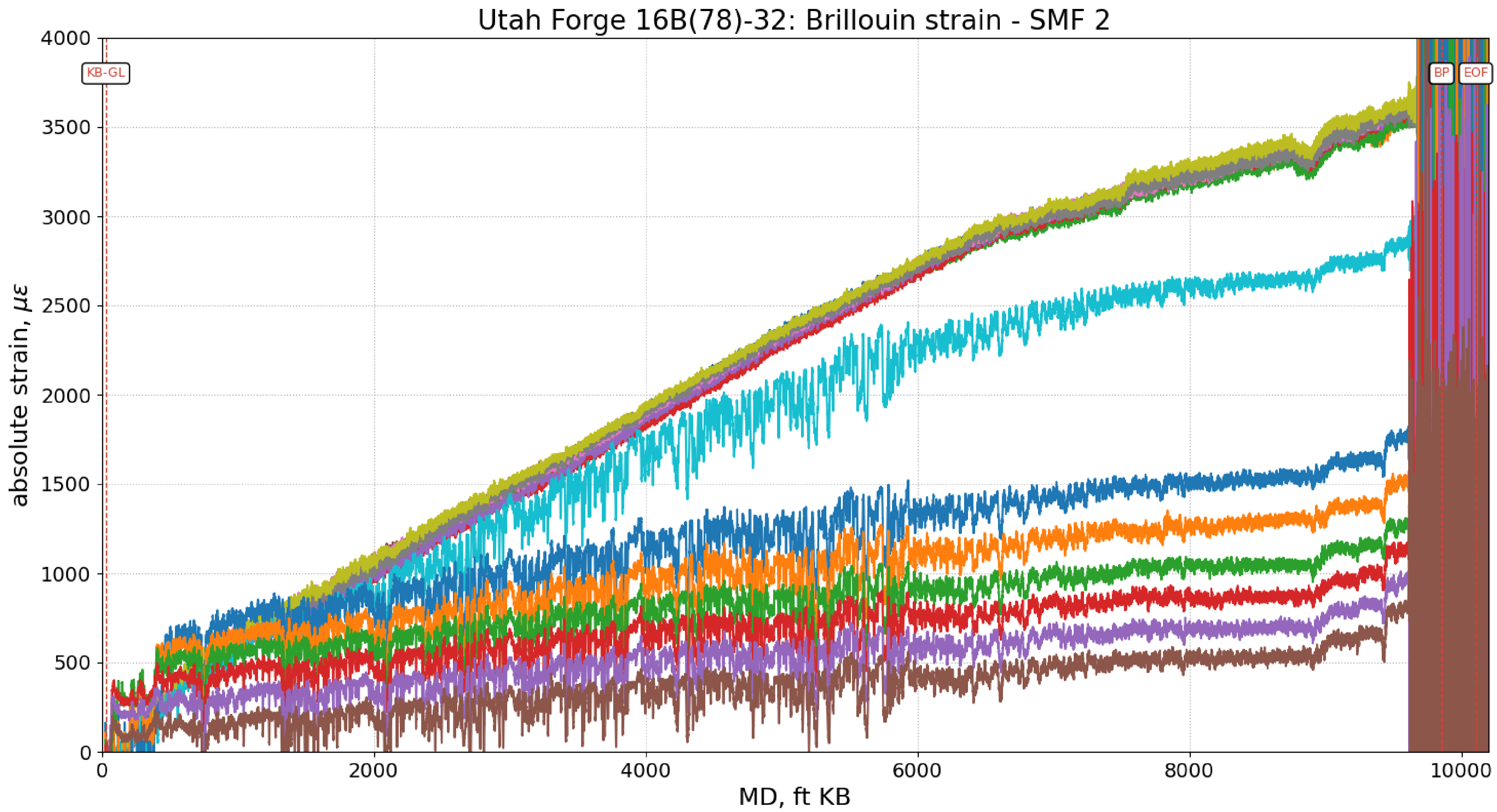
-- number of samples per trace: 78349

-- average temporal interval (sec): 100

# Well 16B(78)-32 – Total Absolute Strain – overview



# Well 16B(78)-32 – Total Absolute Strain – selected traces



# Well 16B(78)-32 – after JB/fiber repair

- Fiber break detected on Aug 11, 2024 at 4:34:15 UTC
- Occurred in surface JB north of the wellhead
- JB leaking fluid

# RFS strain change

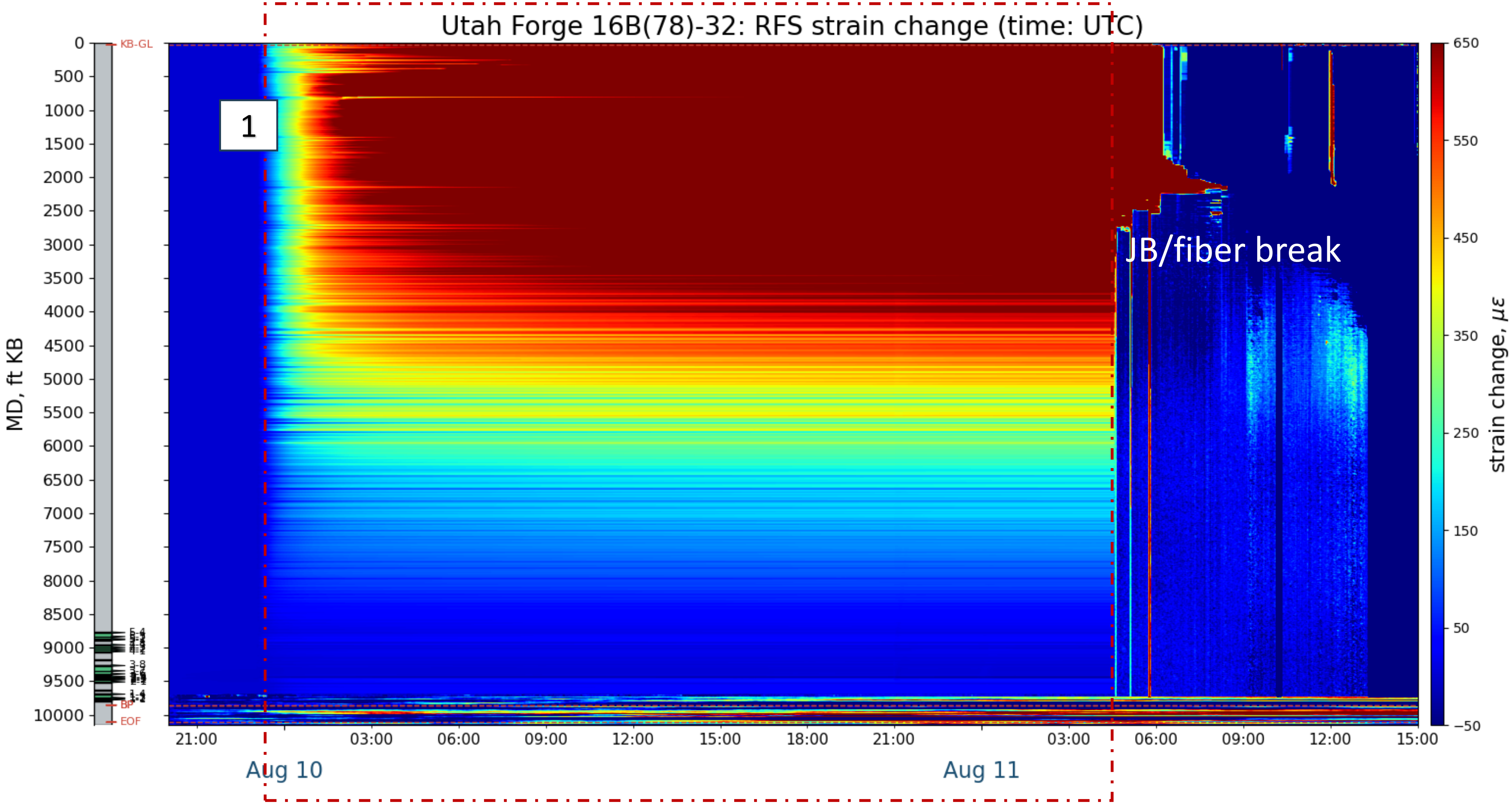
-- first trace: Aug 09, 2024, 20:00:24

-- last trace: Aug 16, 2024, 14:17:18

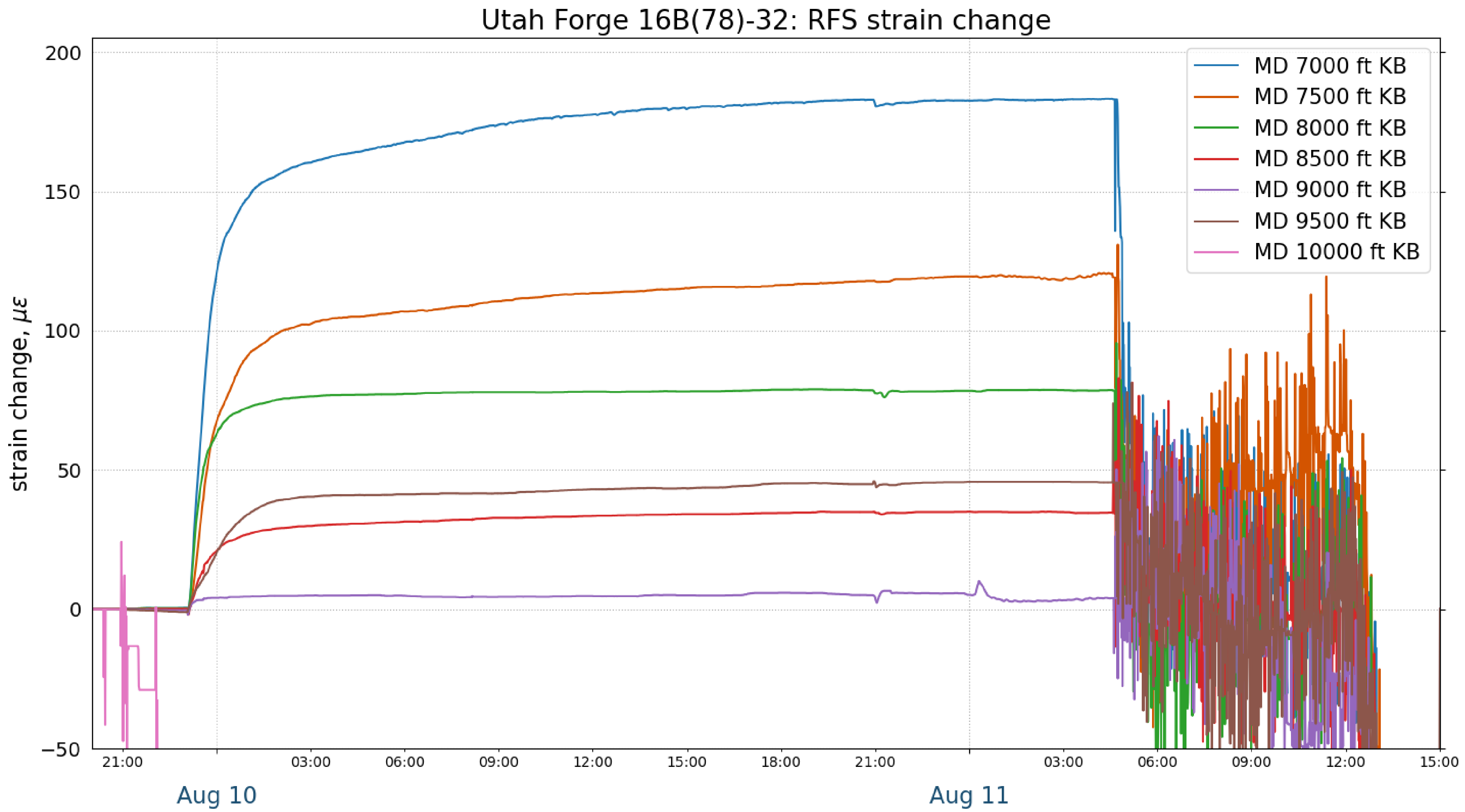
-- number of traces: 14,164

-- number of samples per trace: 39,175

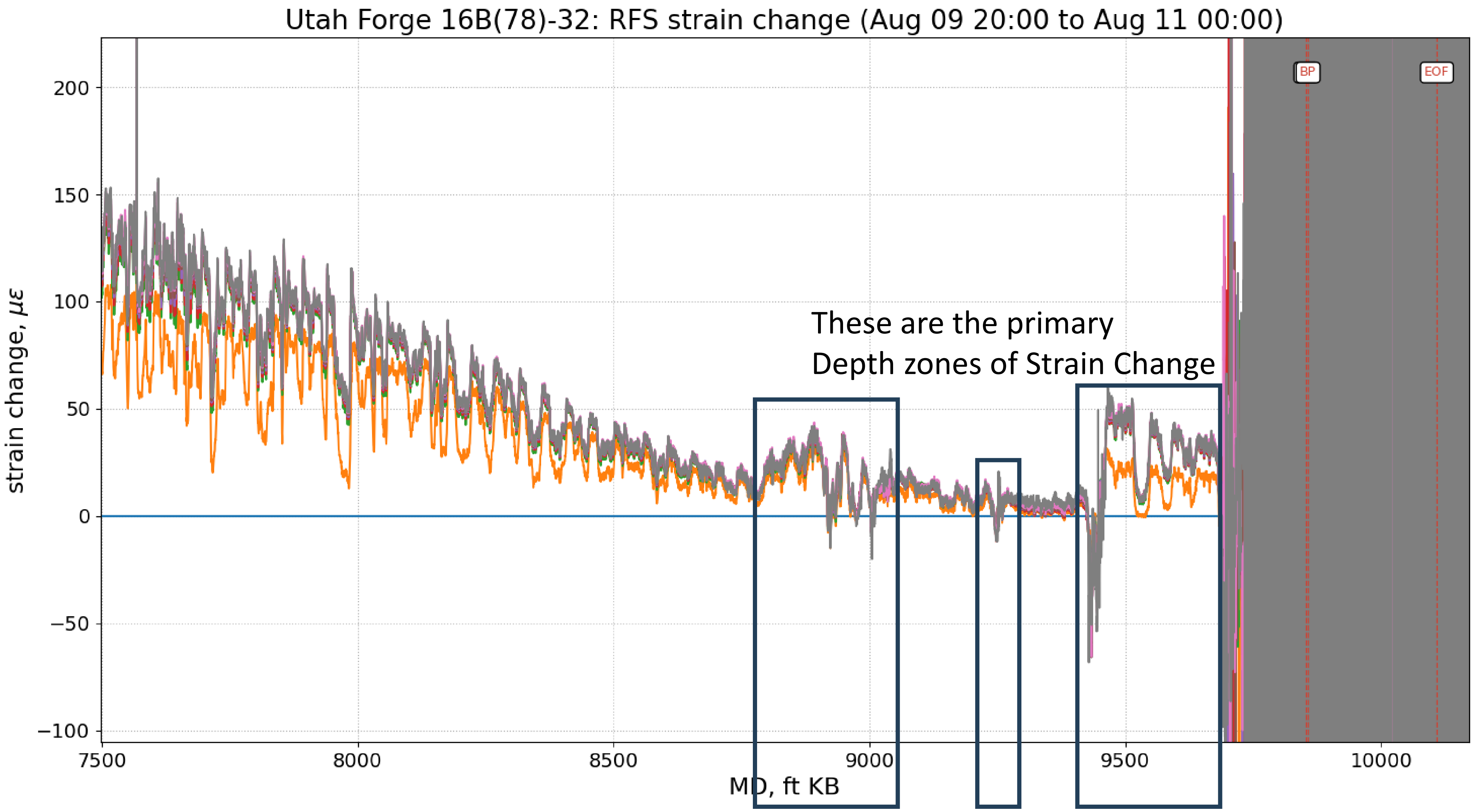
# Well 16B(78)-32 – RFS strain change – overview



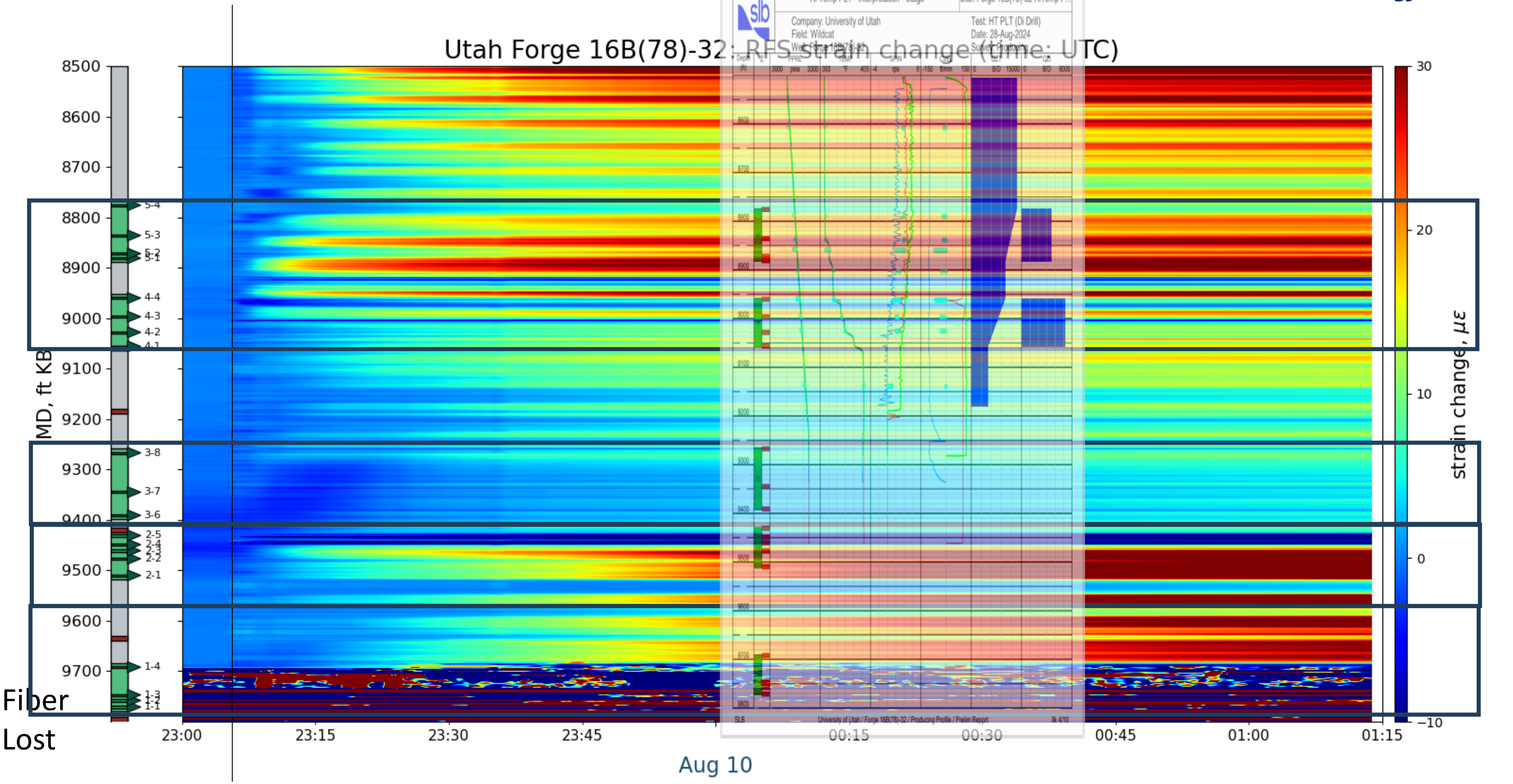
# Well 16B(78)-32 – RFS strain change – selected depths



# Well 16B(78)-32 – RFS strain change – selected traces



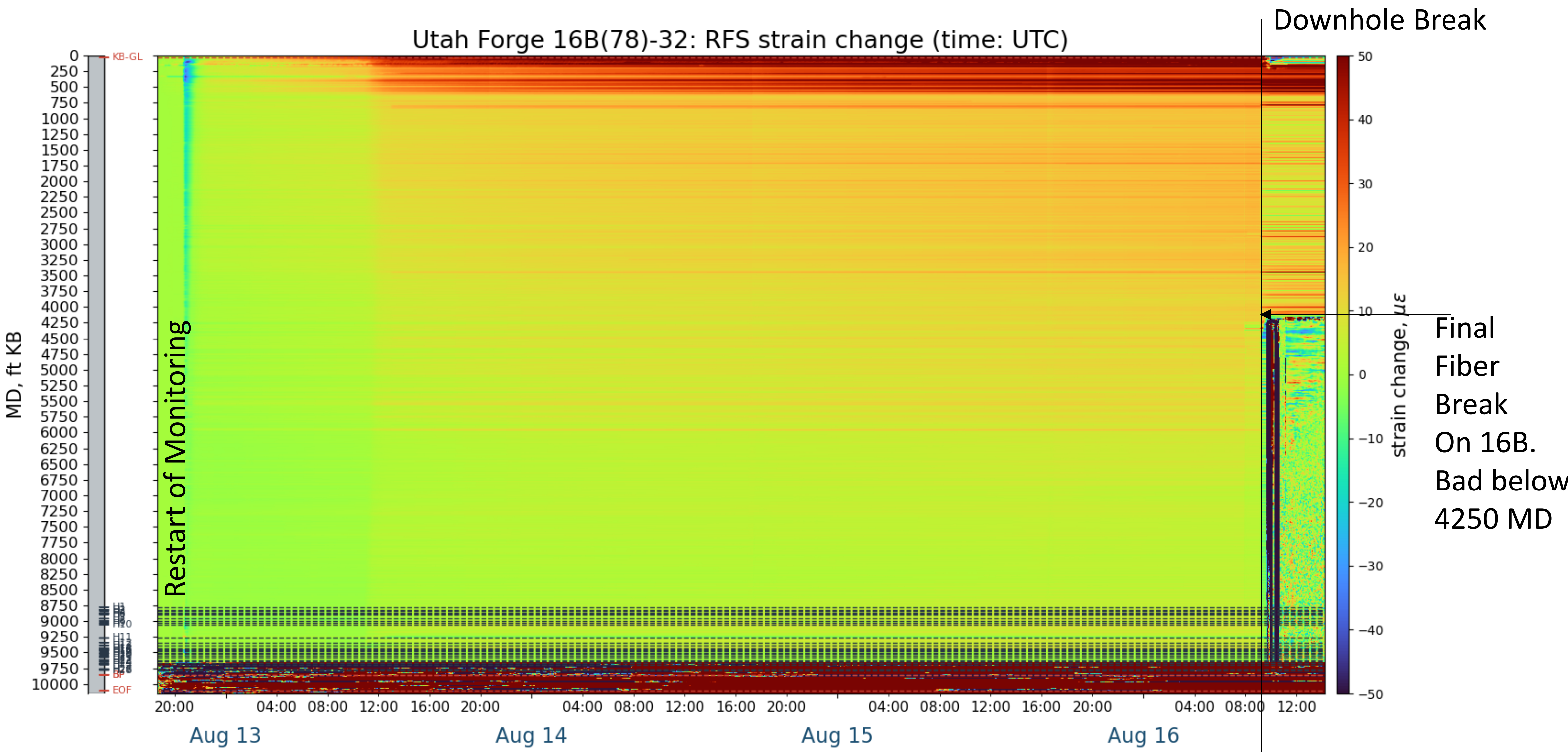
# Well 16B(78)-32 – RFS strain change – period 1 – zoomed in



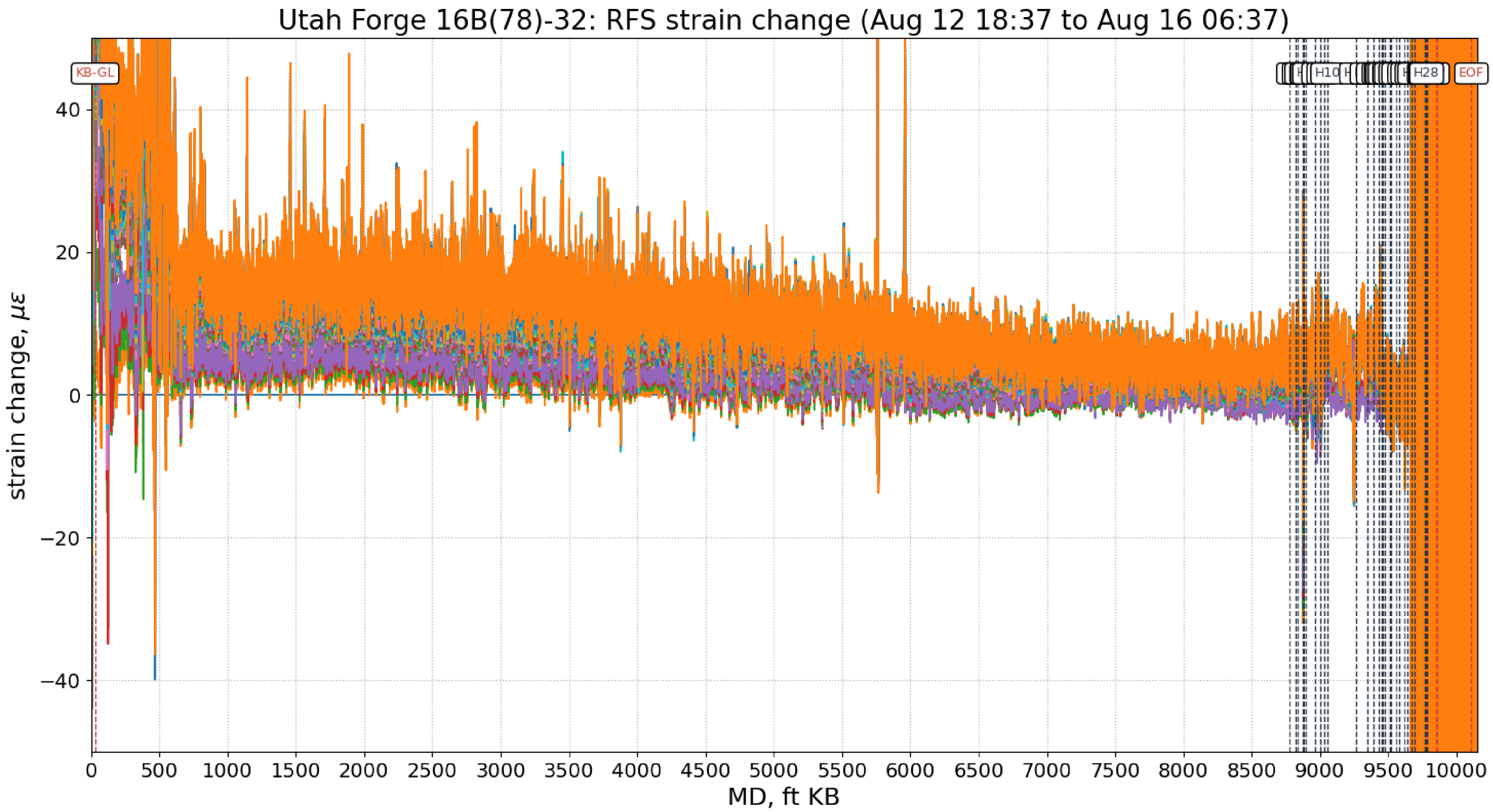
# Well 16B(78)-32 – after JB/fiber repair

- Fiber break detected on Aug 11, 2024 at 4:34:15 UTC
- Occurred in surface JB north of the wellhead
- JB leaking fluid
- Neubrex repair inside junction box
- Splice all fibers back together
- Resume monitoring on 1447pm(local) August 12, 2024
- Gauges also resumed working

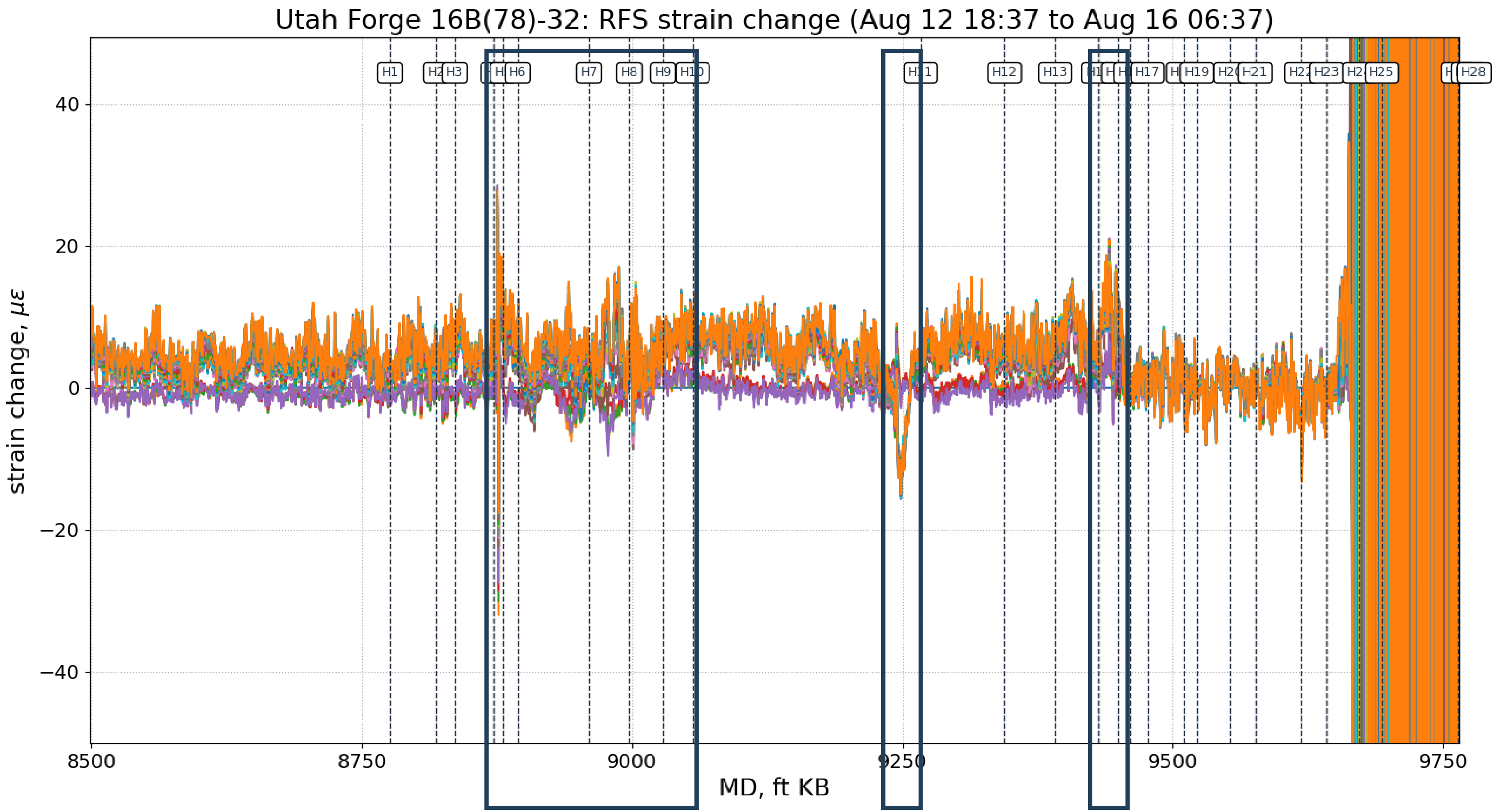
# Well 16B(78)-32 – RFS strain change after REPAIR By Neubrex



# Well 16B(78)-32 – RFS strain change – selected traces



# Well 16B(78)-32 – RFS strain change – selected traces



# RFS DSS strain change rate calculated every 49 seconds

-- first trace: Aug 12, 2024, 18:37:58

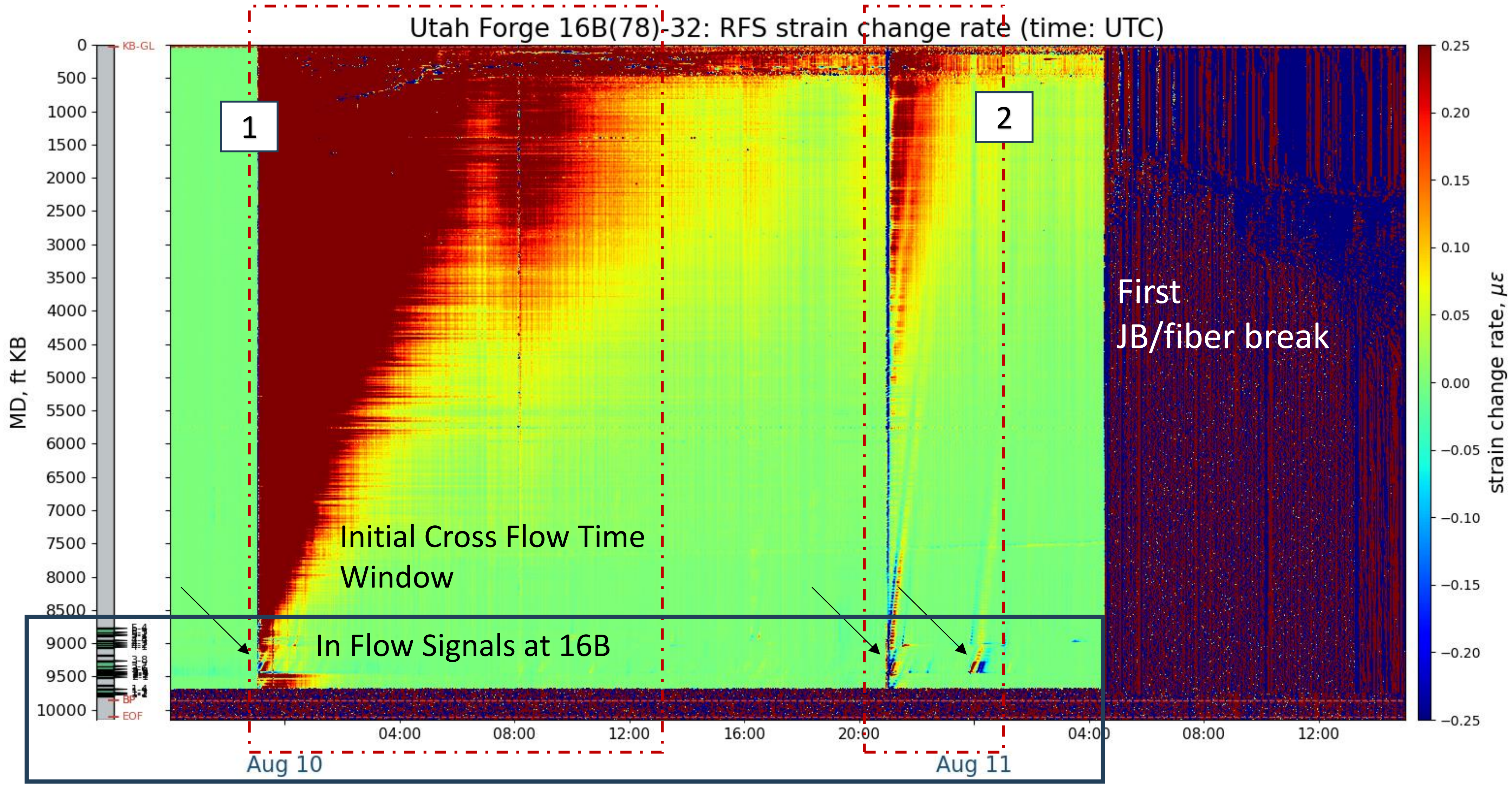
-- last trace: Aug 16, 2024, 14:17:18

-- number of traces: 6749

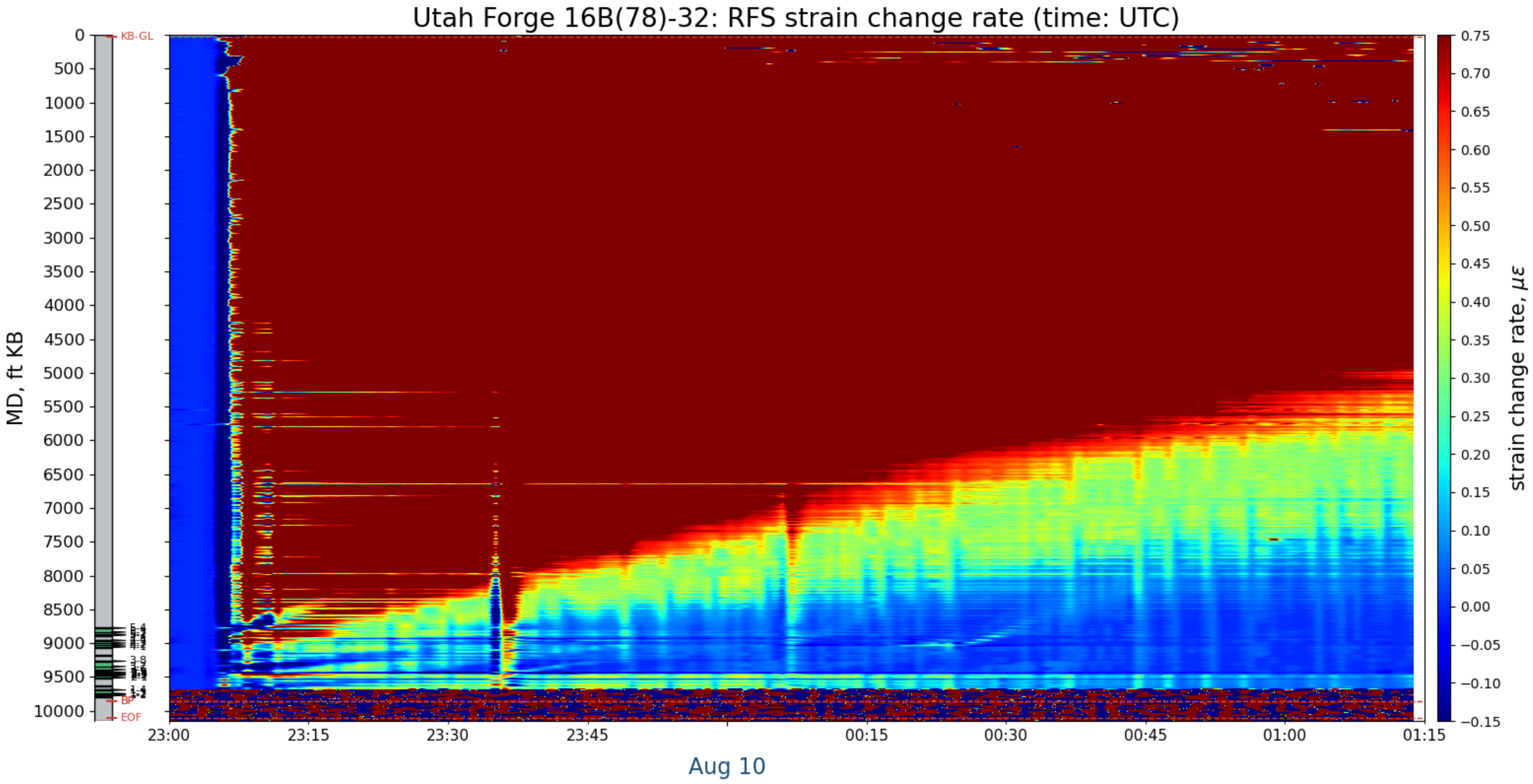
-- number of samples per trace: 39,175

-- average temporal interval (sec): 49

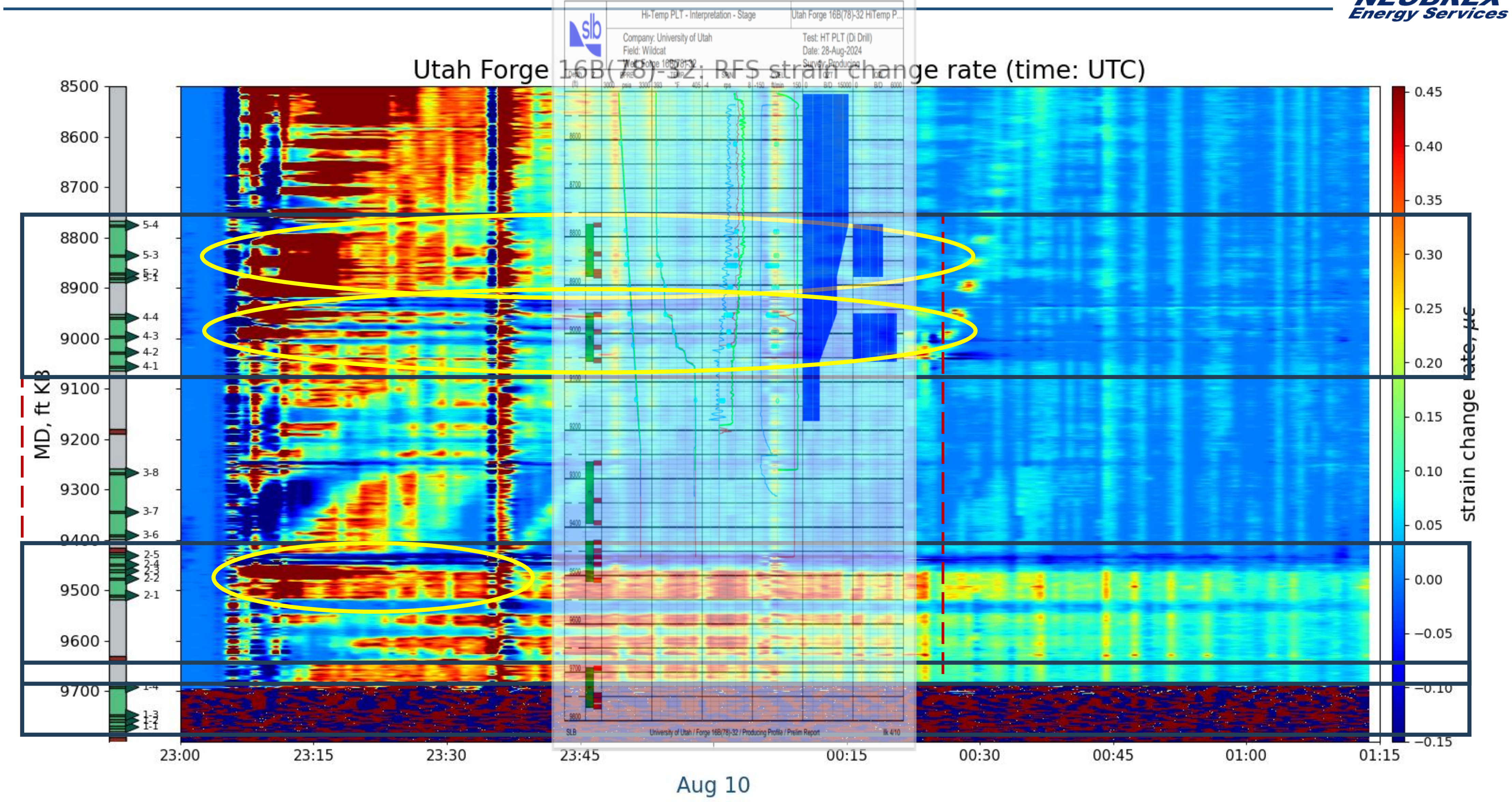
# Well 16B(78)-32 – RFS strain change rate – overview



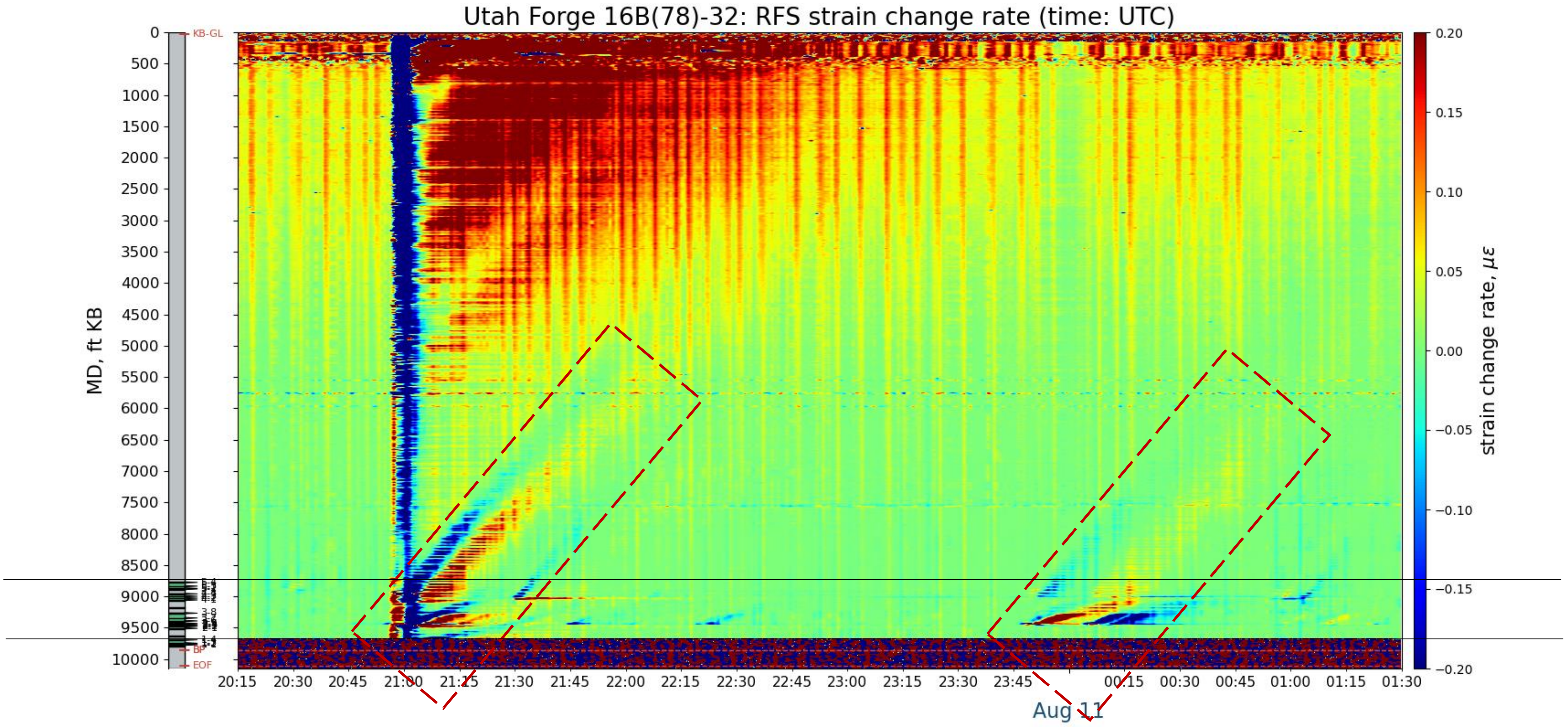
# Well 16B(78)-32 – RFS strain change rate – period 1



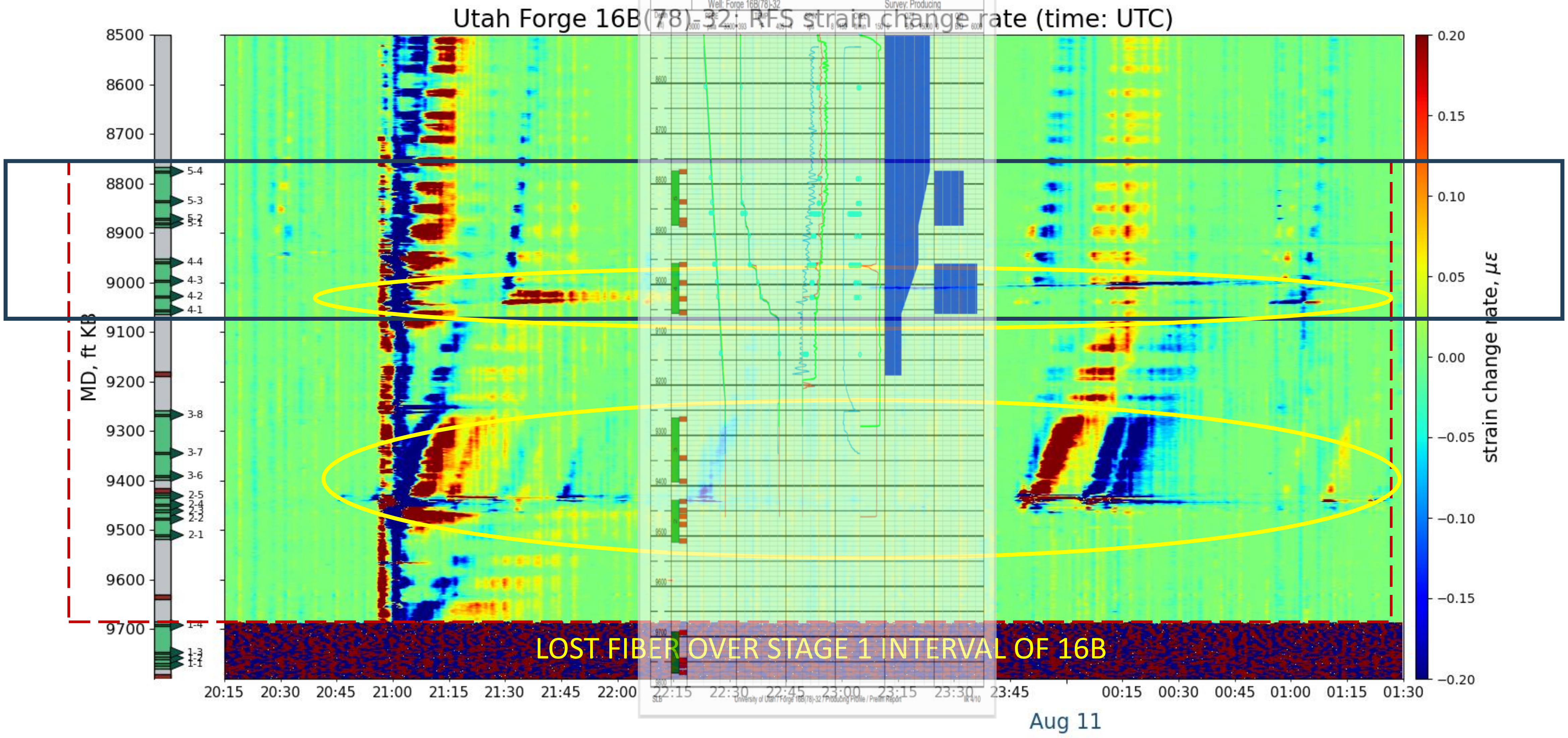
# Well 16B(78)-32 – RFS strain change rate – period 1 (zoomed)

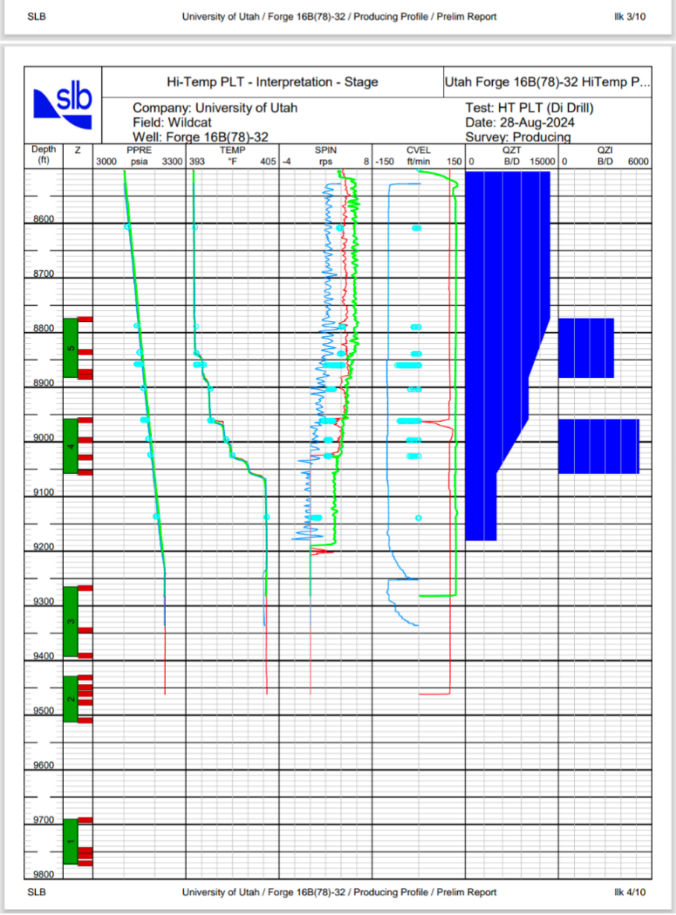


# Well 16B(78)-32 – RFS strain change rate – period 2



# Well 16B(78)-32 – RFS strain change rate – period 2 (zoomed)



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## Forge 16B(78)-32

### Interpretation Results: Surface Flowrate Resu

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## Forge 16B(78)-32

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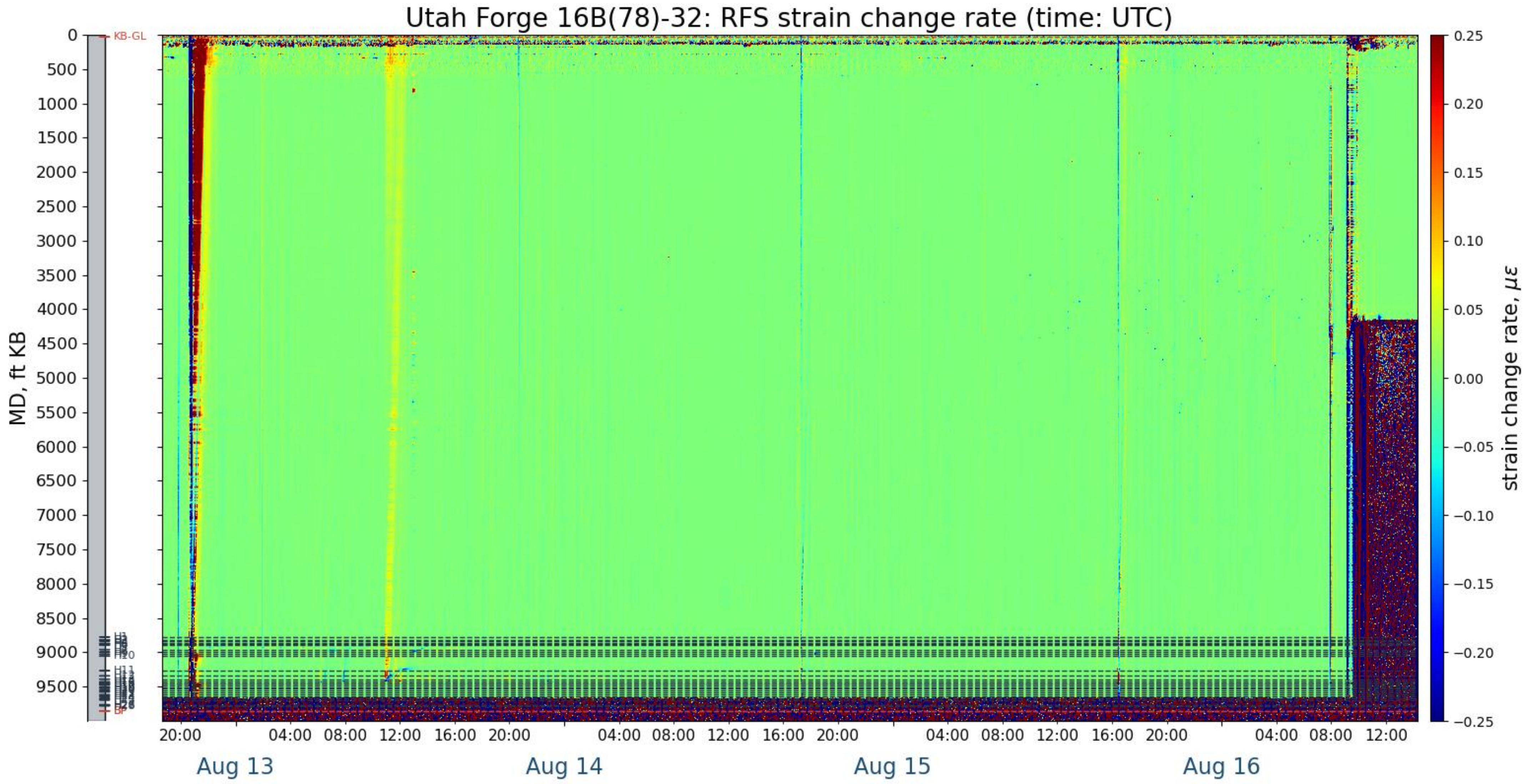
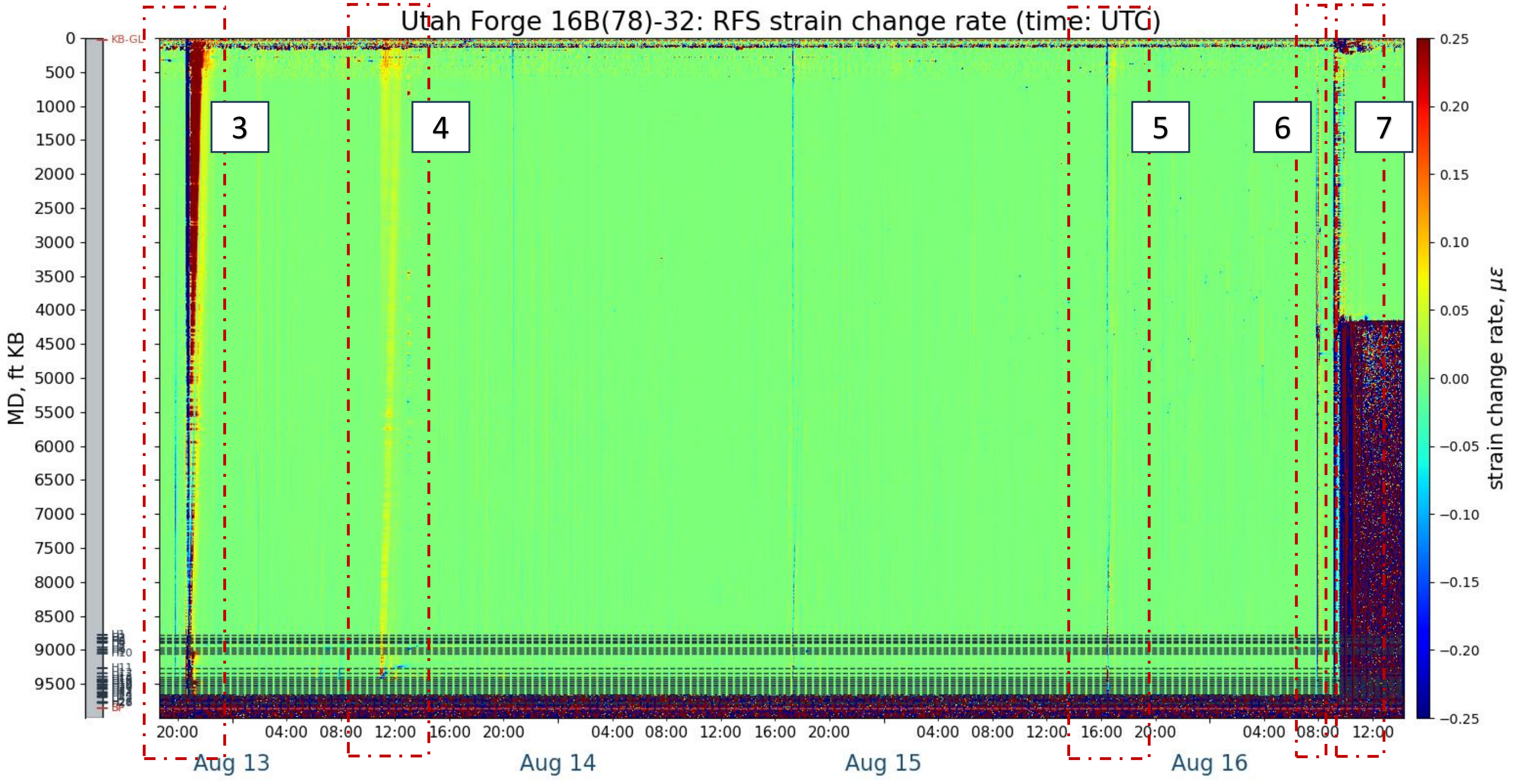
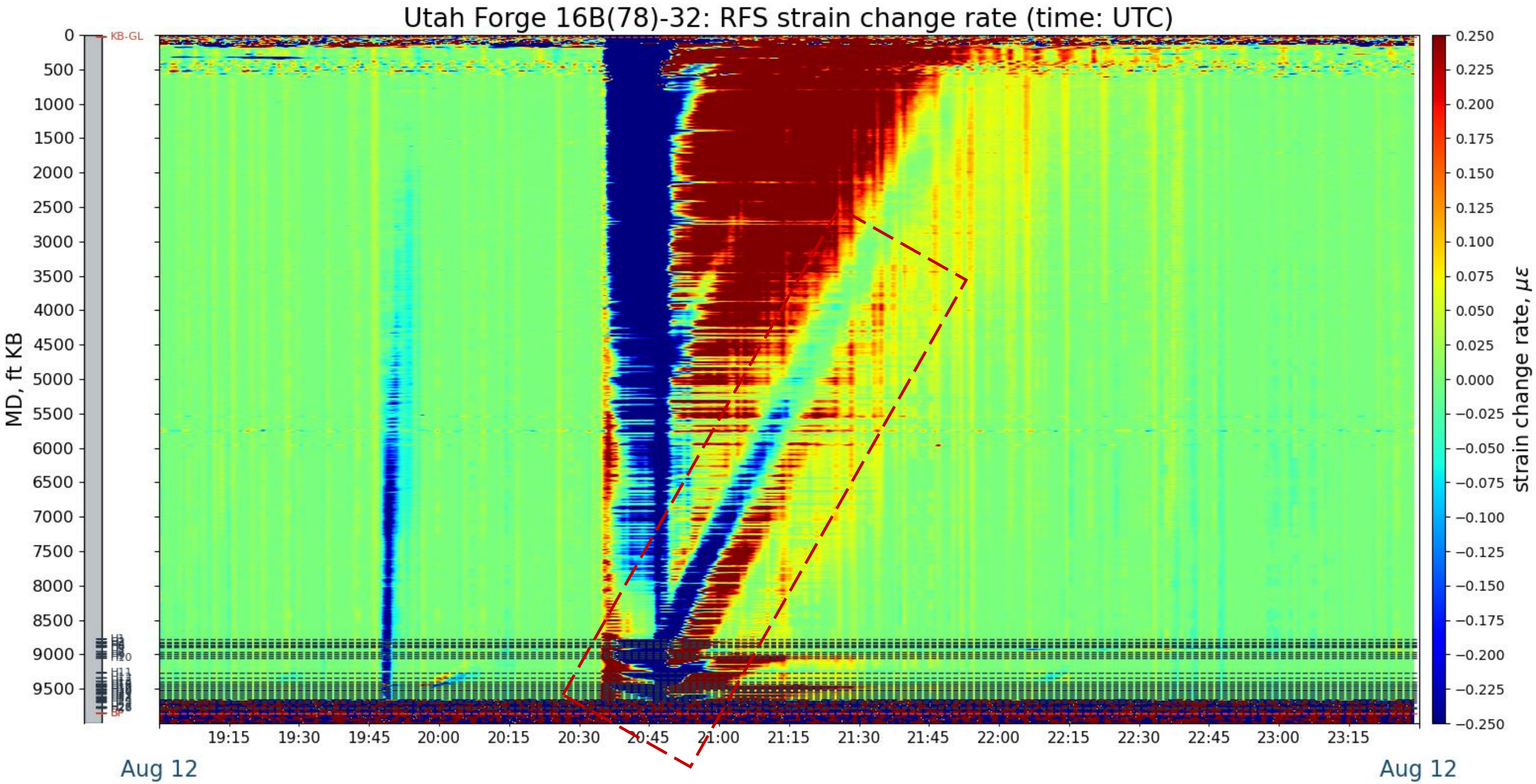
# Well 16B(78)-32 – RFS strain change rate – overview



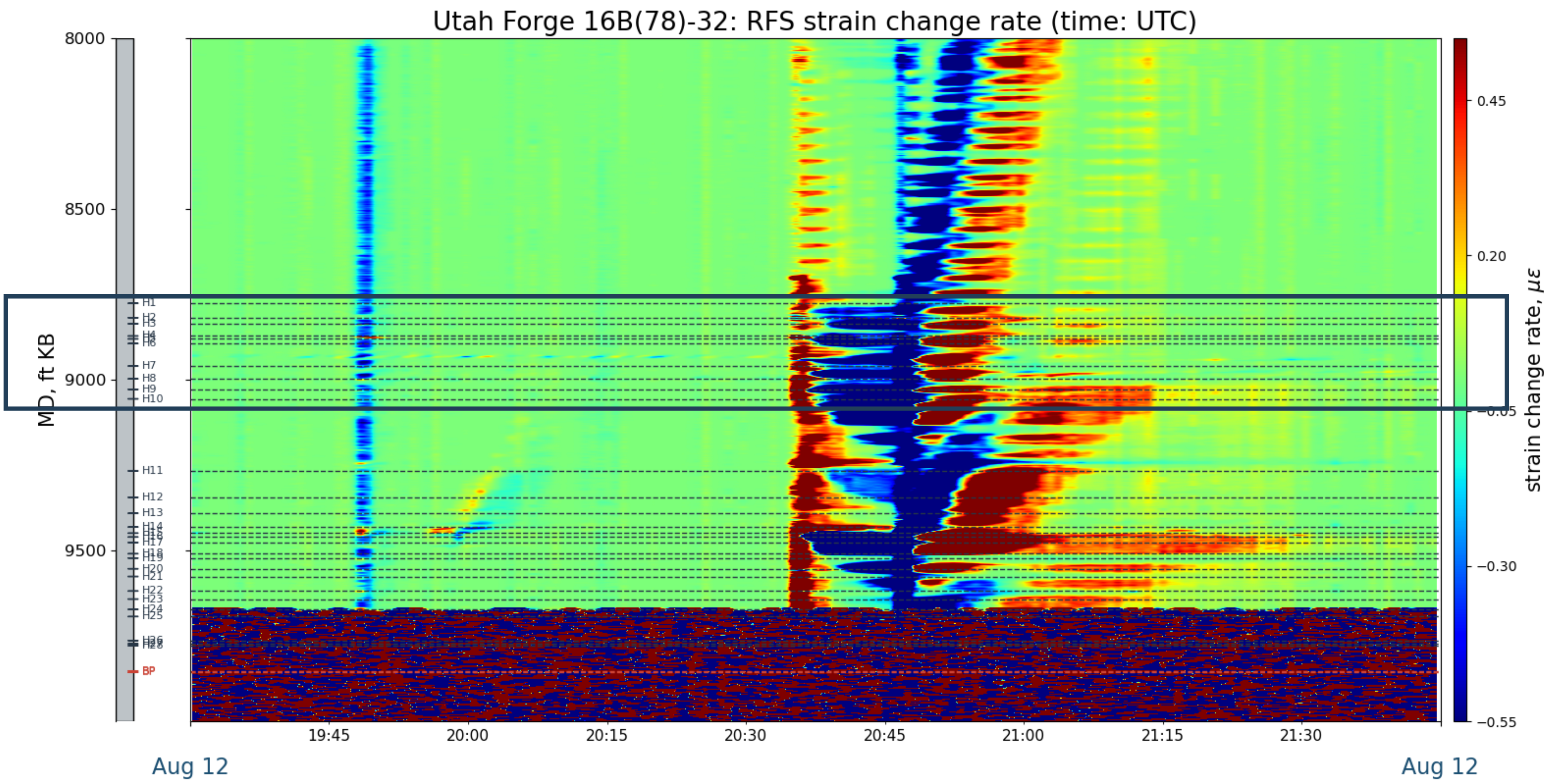
# Well 16B(78)-32 – RFS strain change rate – overview



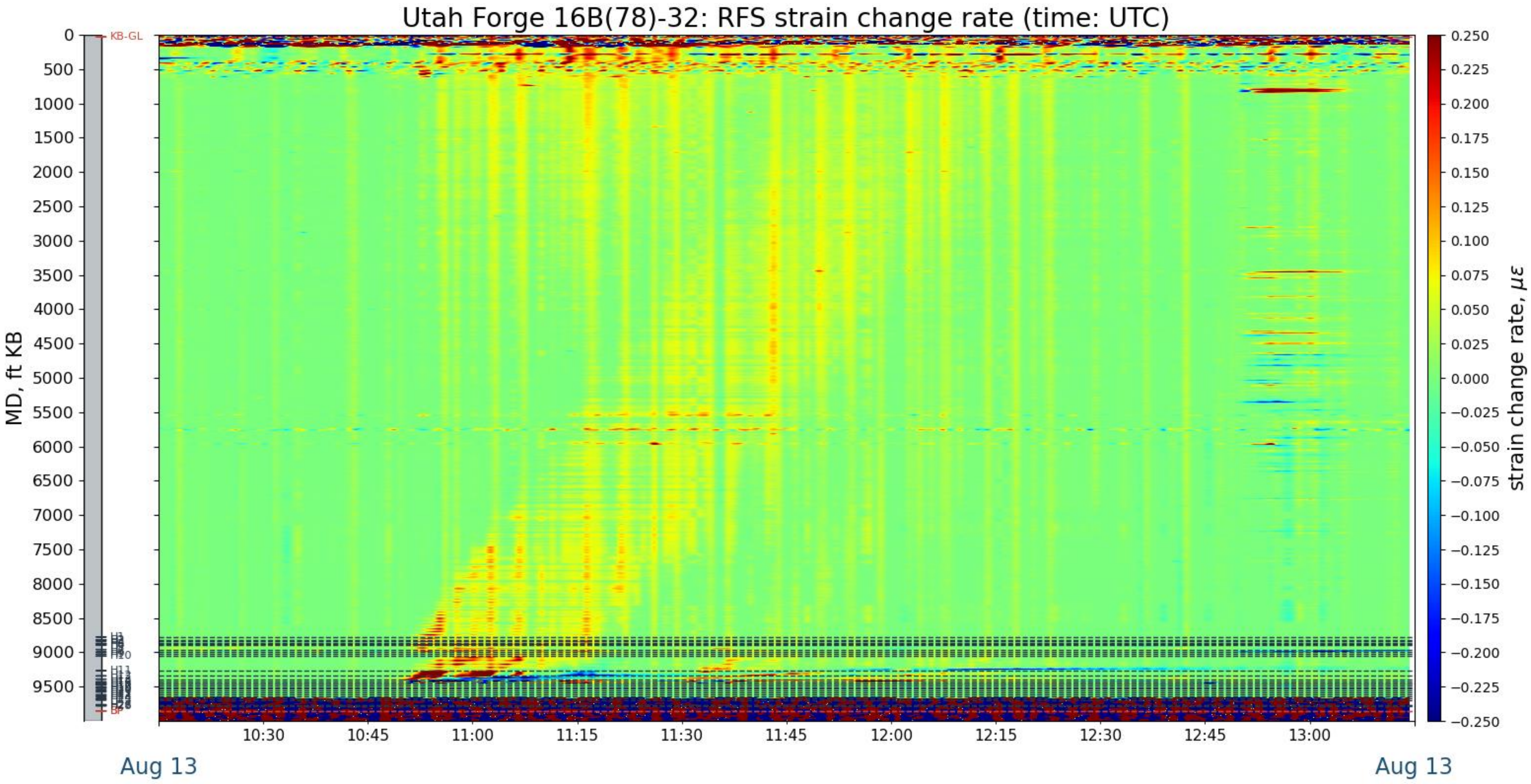
# Well 16B(78)-32 – RFS strain change rate – period 3



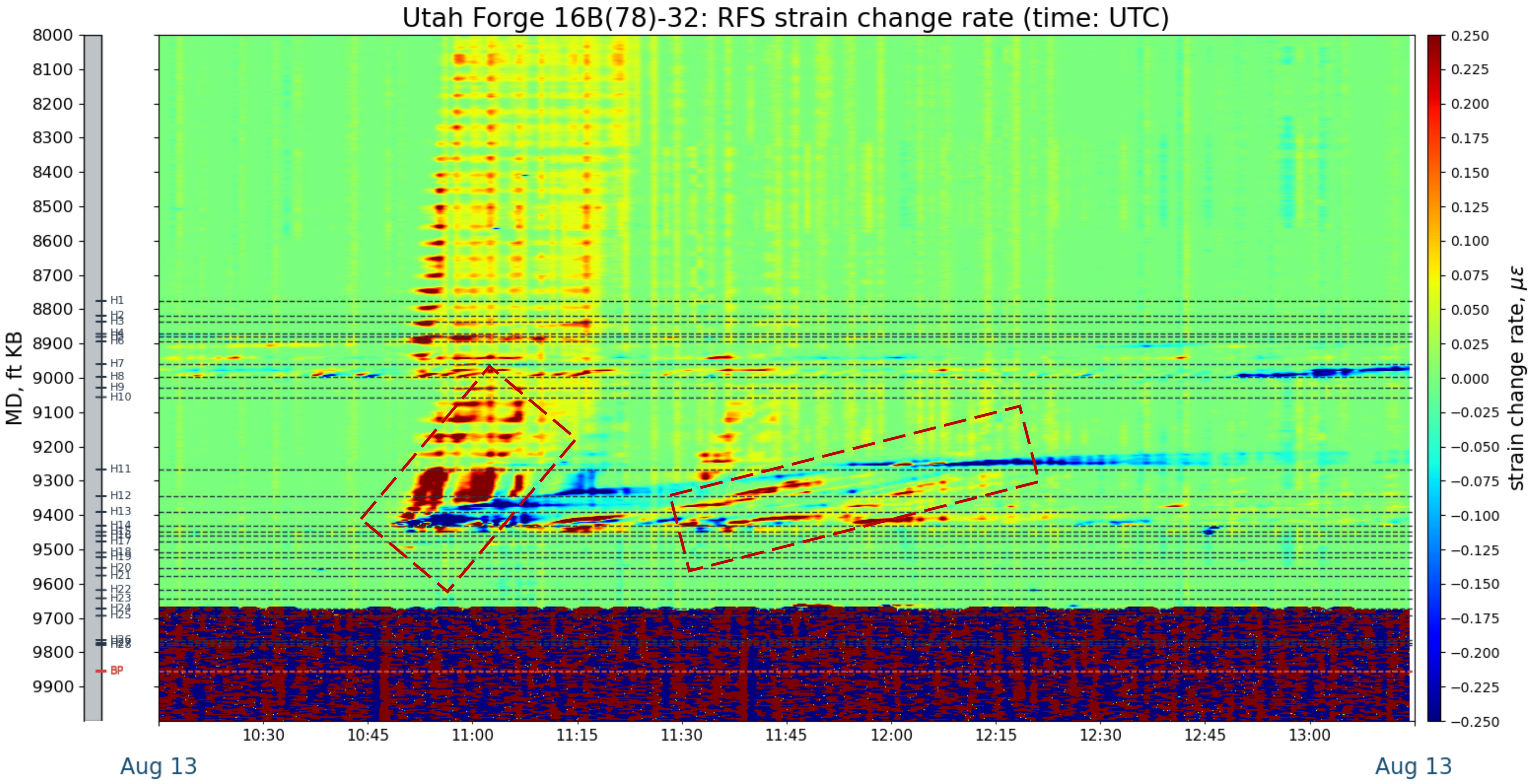
# Well 16B(78)-32 – RFS strain change rate – period 3 (zoomed)



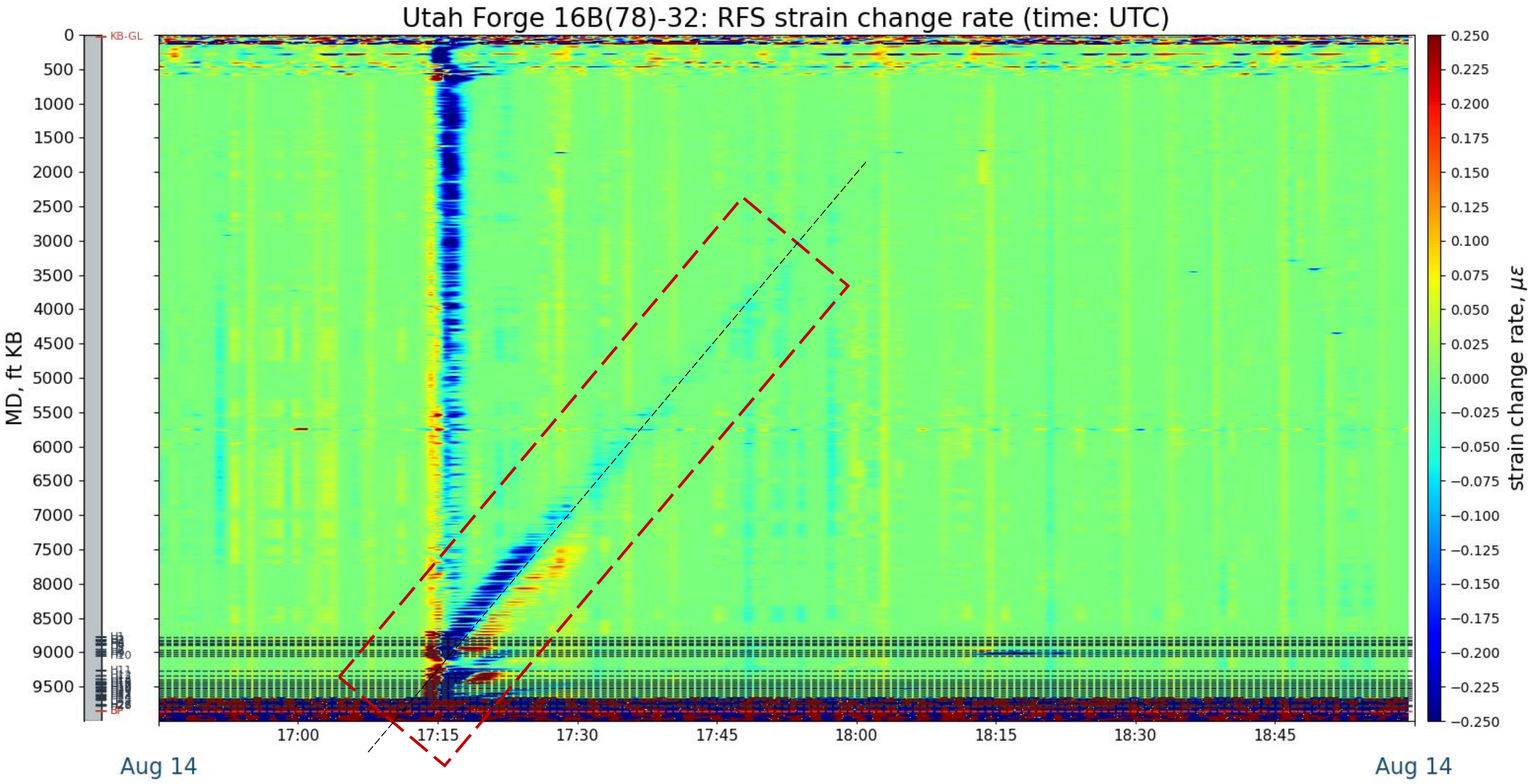
# Well 16B(78)-32 – RFS strain change rate – period 4



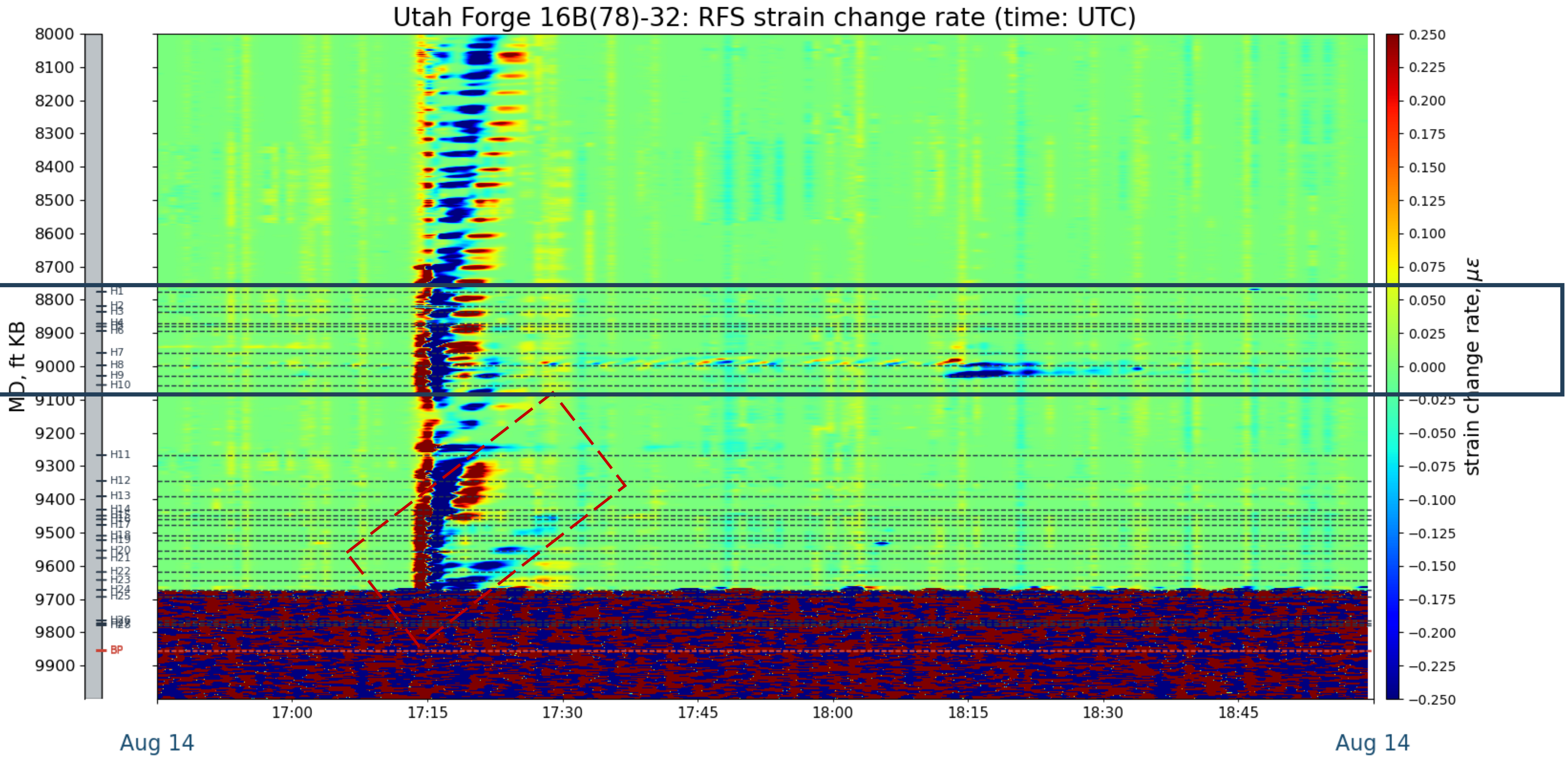
# Well 16B(78)-32 – RFS strain change rate – period 4 (zoomed)



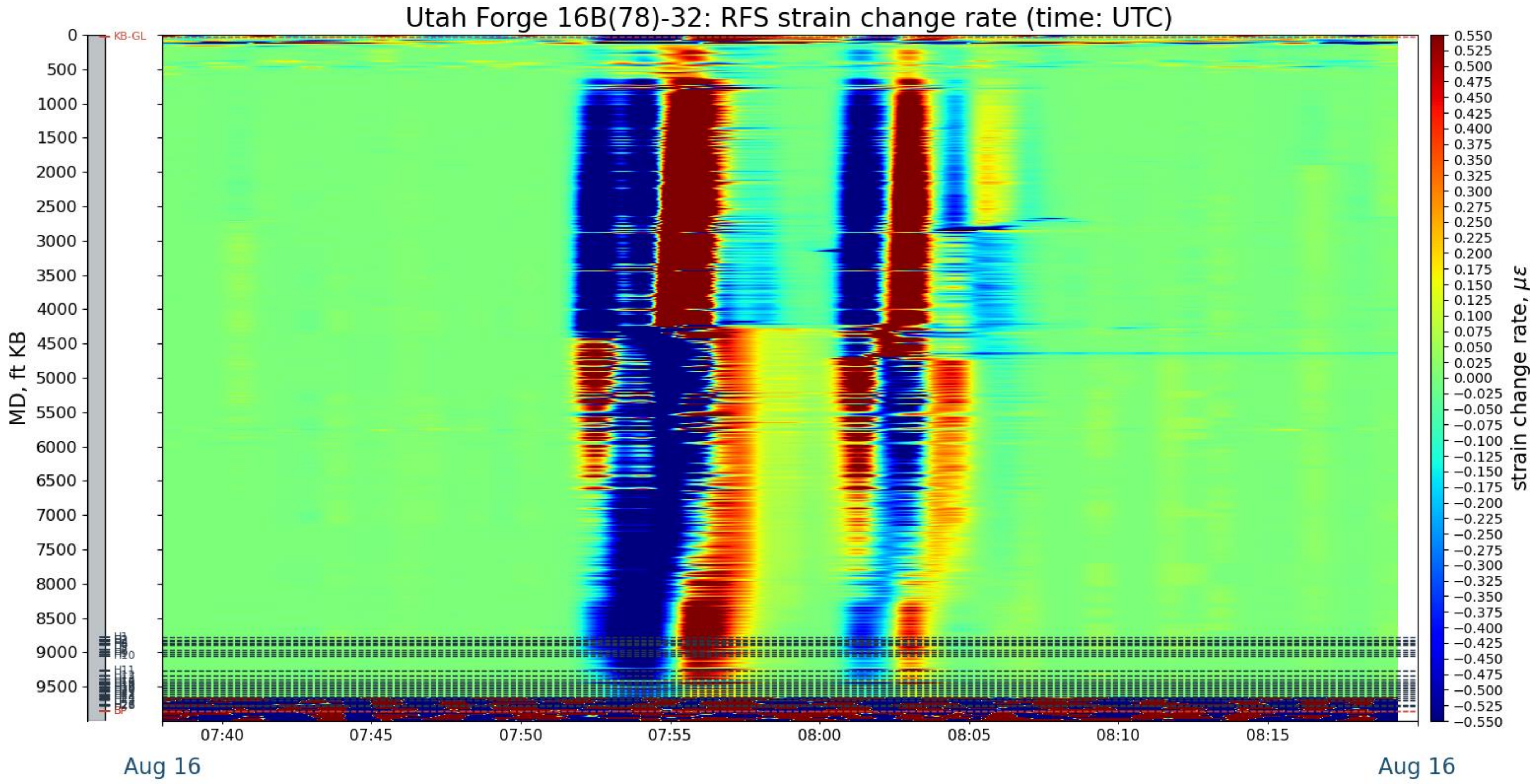
# Well 16B(78)-32 – RFS strain change rate – period 5



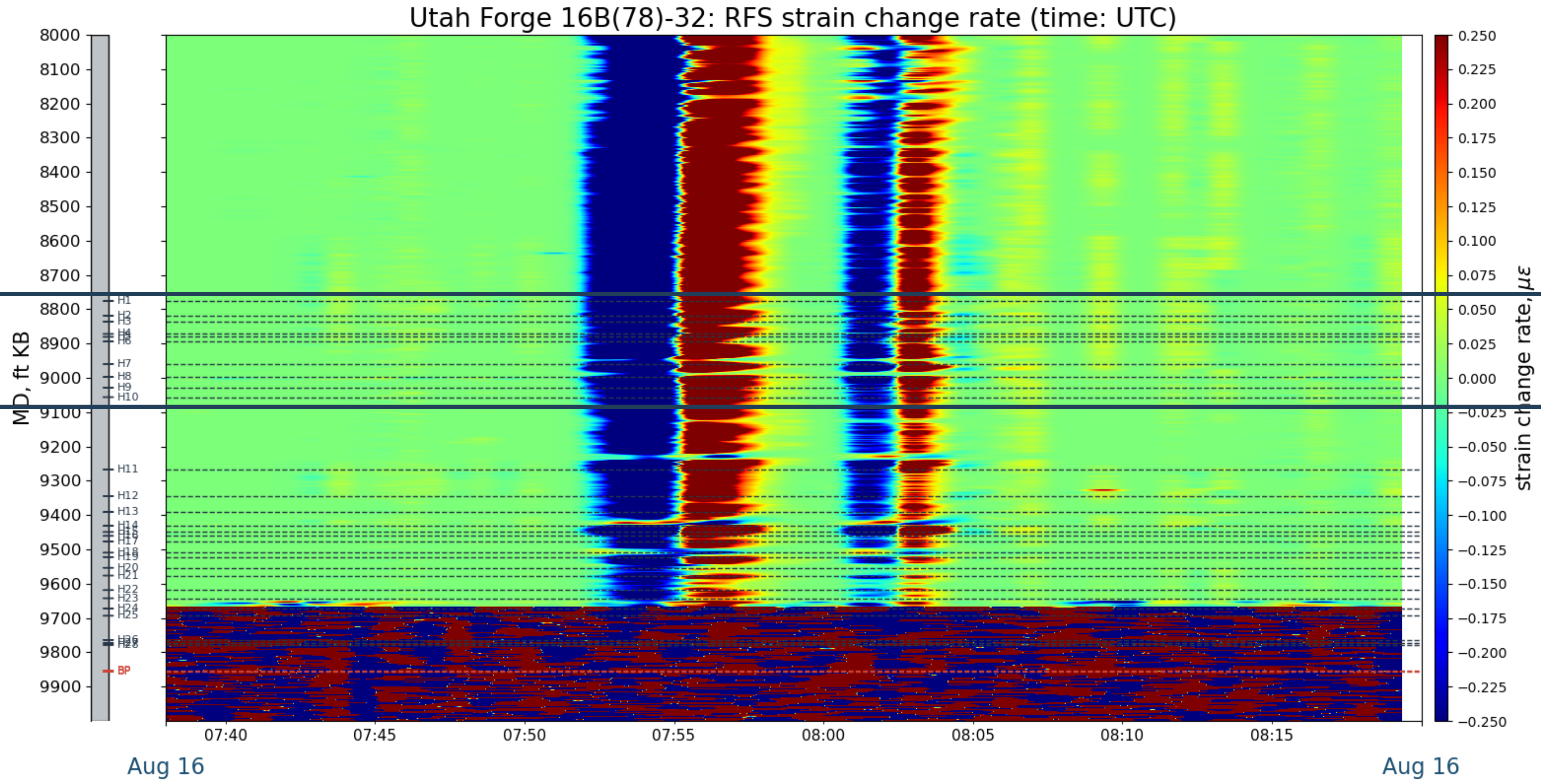
# Well 16B(78)-32 – RFS strain change rate – period 5 (zoomed)



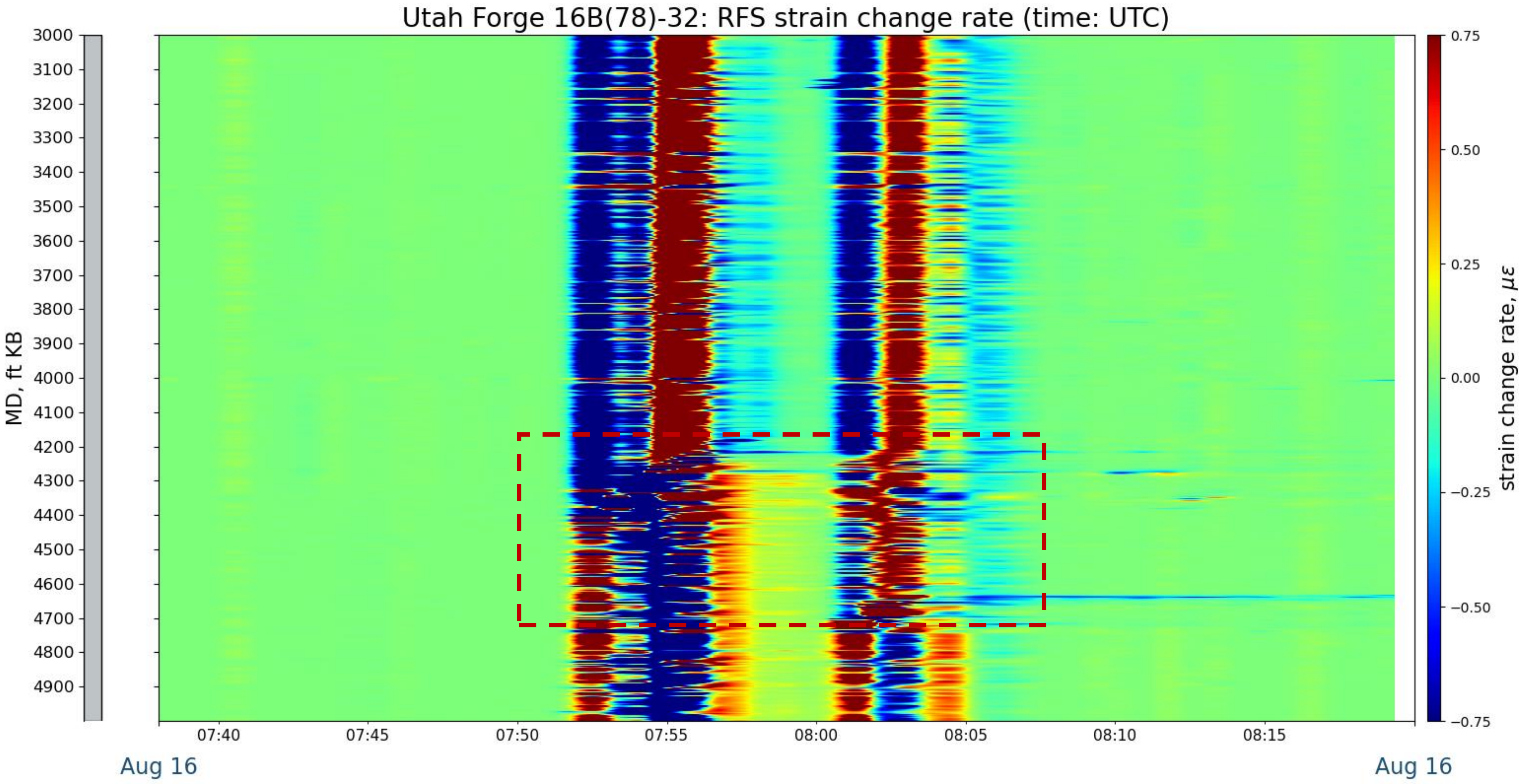
# Well 16B(78)-32 – RFS strain change rate – period 6



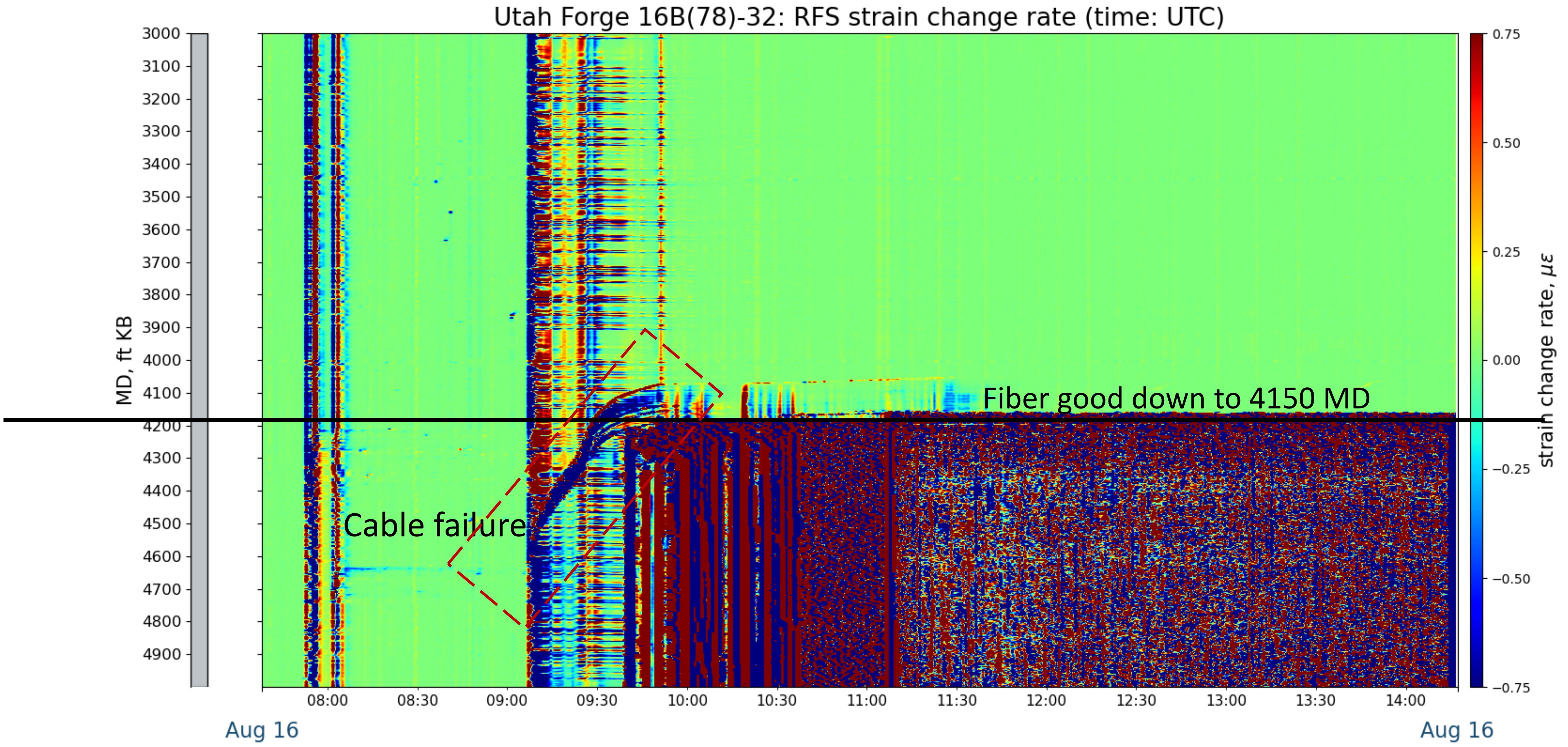
# Well 16B(78)-32 – RFS strain change rate – period 6 (zoomed)



# Well 16B(78)-32 – RFS strain change rate – period 6 (zoomed)



# Well 16B(78)-32 – RFS strain change rate – period 6- failure



# End of Technical Report and Contact Information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