Distributed Acoustic Sensing (DAS)

DAS data curation and acoustic measurements

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Introduction

1 DAS acoustic data uses

2 Data curation: ways of reducing data volume or preparing it for further analysis

3 Real-time display of curated data

In-well Use Cases

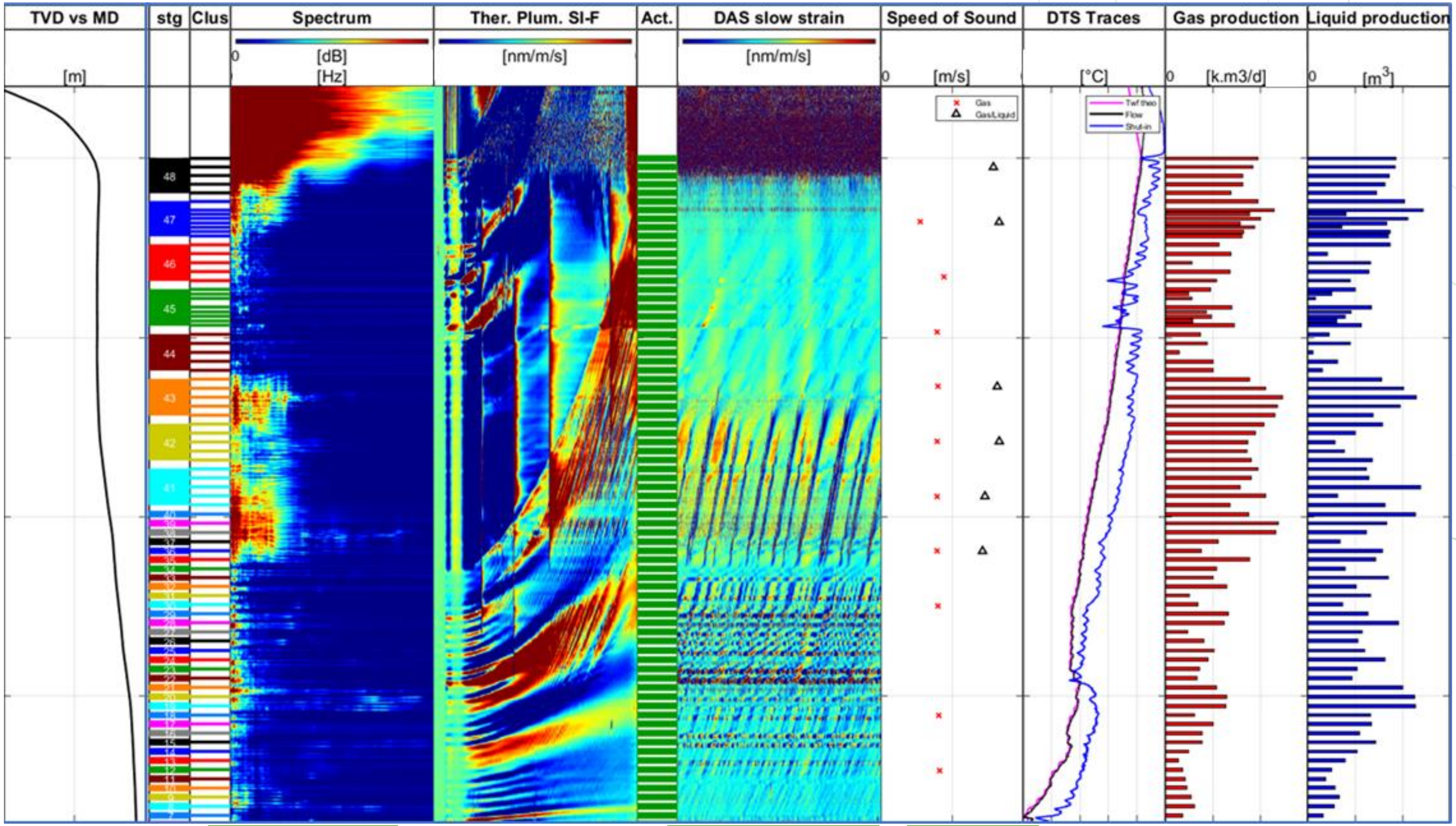
Monitoring Objective	Measurements	DFOS	Benefits
Reservoir Characterisation	Continuous Temperature Profiling Time-lapse 2D & 3D VSP (seismic)	DAS, DTS	High SNR, coverage, spatial and temporal resolution Real-time, continuous data Easy access & high repeatability
Injection Optimisation	Flow allocation Hydraulic properties Well interconnectivity	DAS, DTS	Injection performance monitoring Regulation compliance
Well Integrity	Leak detection Cementation monitoring	DAS, DTS	Operational safety Regulation compliance
Microseismic Monitoring	Microseismic event detection Fracture evolution monitoring	DAS	Operational safety Regulation compliance Public acceptance
Deformation Monitoring	Pressure development Reservoir deformation (uplift / subsidence)	DAS, DSS	Operational safety Regulation compliance Public acceptance

- Other Use Cases
- Earthquake Monitoring
- Structure monitoring
- Ground water monitoring

DAS Acoustic Data

SILIXA A LUNA company

ITINERIS



Frequency vs Distance

Low Frequency DAS

Speed of Sound

Data curation

- Units
- Filtering
  - Common Mode Noise removal
  - Basic filtering
- Basic Data reduction techniques
  - Cropping + Decimation
- Calculating metrics
  - Low Frequency DAS
  - RMS frequency bands
- Frequency domain
  - Frequency
  - Speed of Sound

Examples of ways to work with DAS data

What are the units of amplitude?

- iDAS directly measures a change in phase of the backscattered light

- For a single channel (receiver position) the native iDAS measurement gives:
  - The total phase change over a gauge length
    - Longer gauge length systems will report a higher amplitude
  - At the rate of change over one time sample
    - Higher sampling frequencies will report a lower amplitude

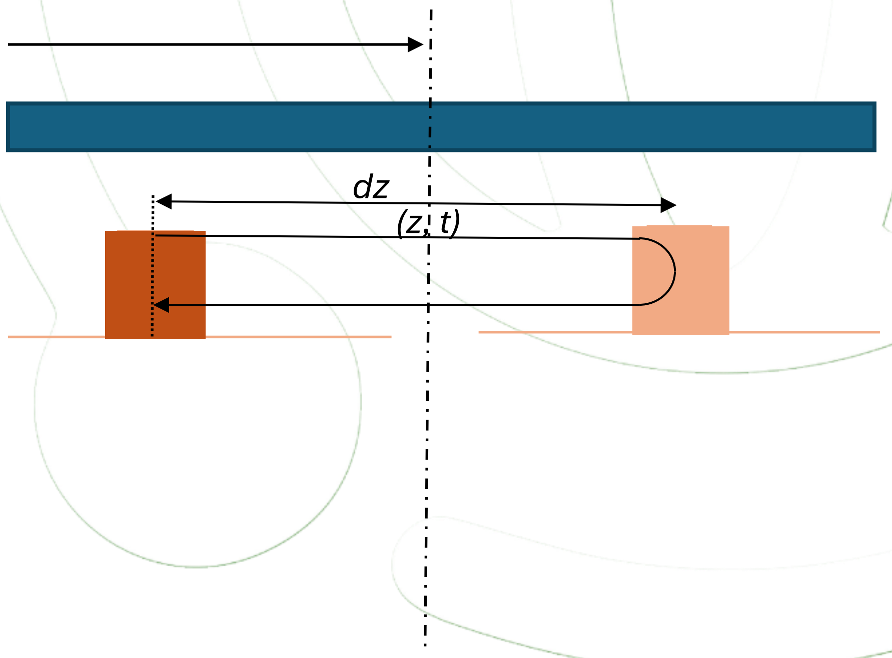
- The optical to acoustic conversion must be very fast so is done in a hardware FPGA module on-board the iDAS. These work best on integer arithmetic

- Also, integers are much smaller to store in a file than floating point (decimal) numbers

- To work in integers without losing precision the iDAS values are scaled up by a factor

- These scaled values are the values that are saved in TDMS and PRODML files

- Engineers want to the amplitude of iDAS data to tell them what the physical extension of the fibre is and express that extension in standard units



What are the units of amplitude?

- For accurate comparison of data, or in order to provide data in engineering units, the data must be scaled

- There are two steps to this process

1. Remove the scale factor applied to turn the data to integers. This converts the values to a strainrate value that is phase change per gauge length, per time sample

    - Scale factor = $\frac{1}{8192}$

  - The scale factor is a multiplier. The data should be multiplied by this factor after loading to convert to the required units

What are the units of amplitude?

- For accurate comparison of data, or in order to provide data in engineering units, the data must be scaled

- There are two steps to this process

2. Convert to engineering units. The standard units are nm/m/s. nm/m is sometimes called nanostrain.

   - Instead of total strainrate over a gauge length, we want to normalise this to total strainrate per metre
     - To do this, divide by the gauge length

   - Instead of total strainrate in a time sample, we want to normalise this to total strainrate per second
     - To do this, multiply by the sampling frequency

   - Instead of a phase change in the backscattered light, we want the elongation of the fibre
     - The standard value that relates 1 radians of phase change to 1nm of fibre elongation = 116

   - Therefore, the overall equation for iDAS values that have had the previous scale factor applied

   - $strainrate\left(\frac{\frac{nm}{m}}{s}\right) = 116\ x\ iDAS\ values\ x\ \frac{sampling\ freq\ (Hz)}{gauge\ length\ (m)}$

Data Reduction Techniques: Cropping and Decimation

Original Data

Lots of DAS data is oversampled, especially in distance e.g. 1m sampling with 10m gauge length

It is common to record parts of the fibre that are not interesting

d

t

Cropping (distance)

Cut off the unnecessary parts of the fibre

Decimation (time)

Decimation (distance)

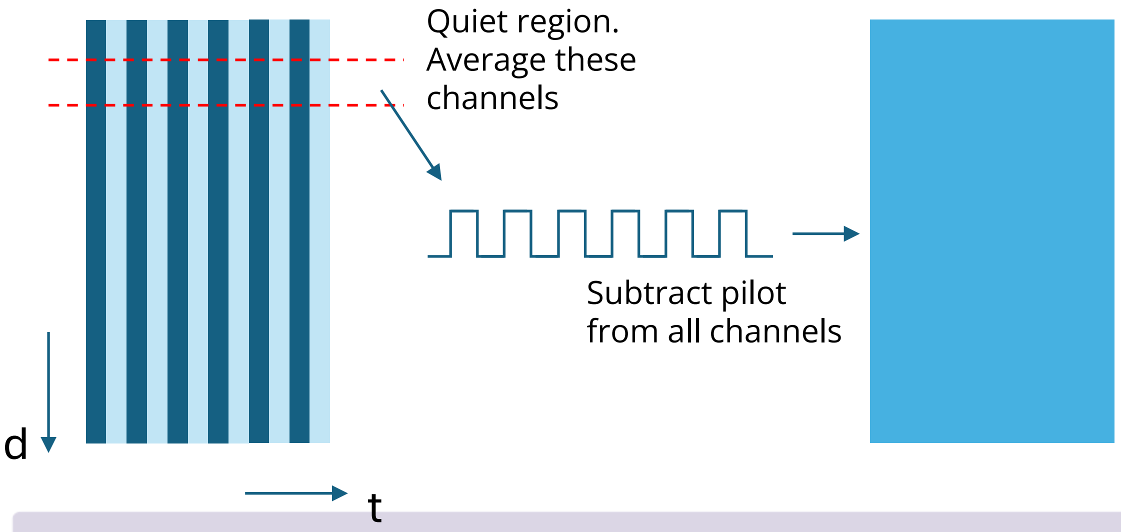
Final smaller data

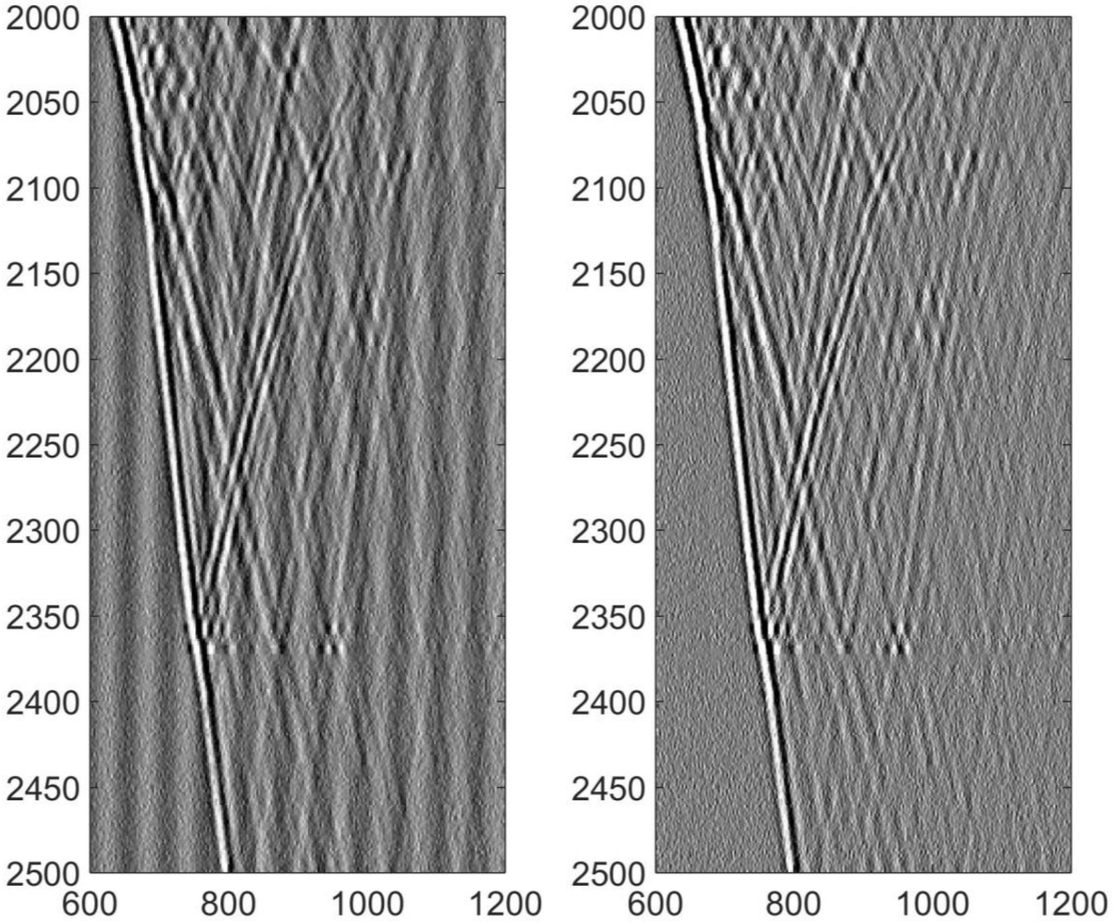
If oversampled, decimation (with or without averaging) can be used to reduce data size

Use anti-aliasing filters if possible, to avoid aliasing effects

Filtering: Common mode noise removal

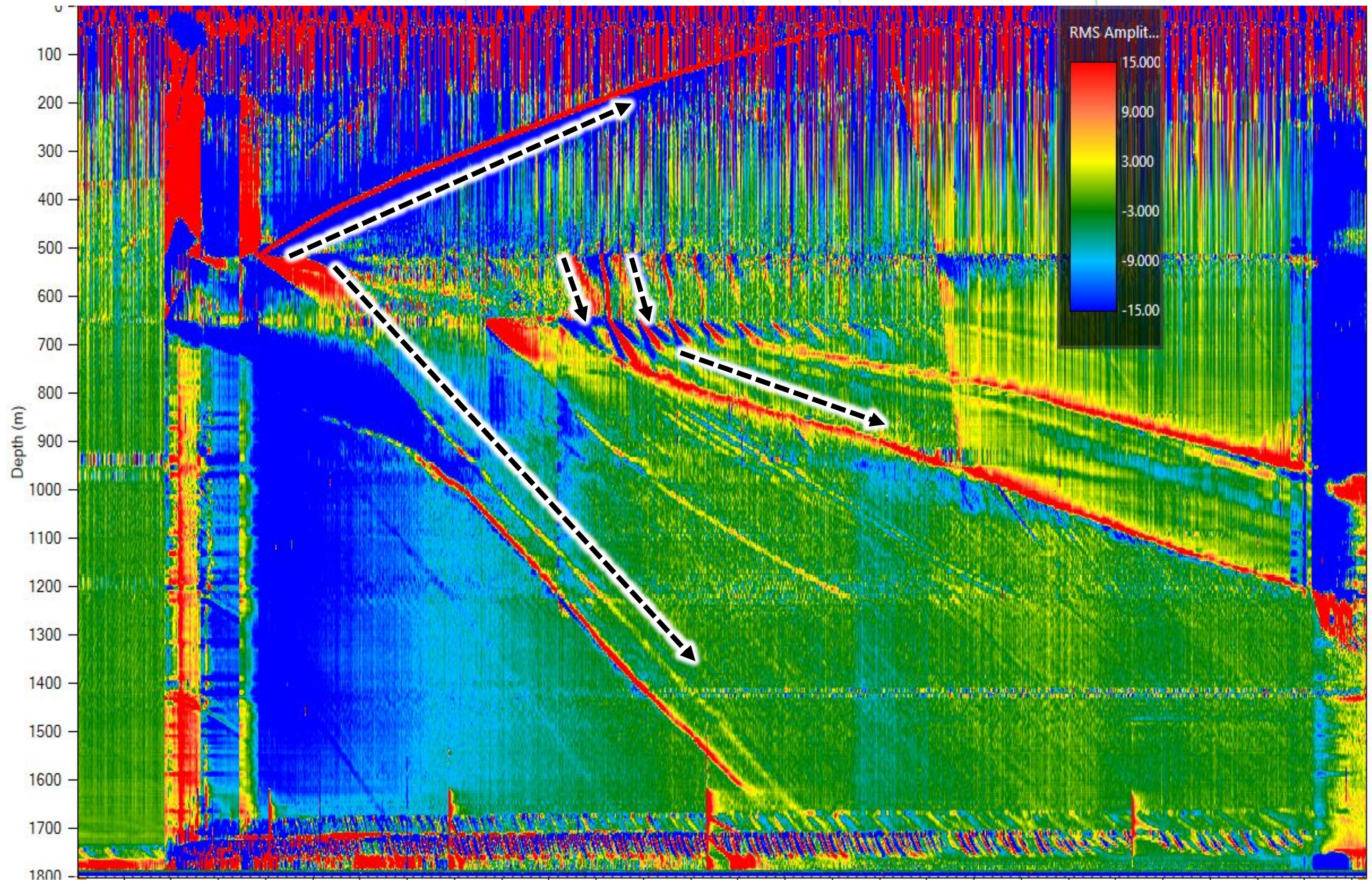
- Common mode noise is caused by vibration of the interrogator box
- The effect is a pattern of stripes in the data where the vibration signal is seen at the same time on all other fibre receiver channels
- Can be easily removed by creating an estimate of the vibration signal (normally by averaging a few channels in a quiet region of the fibre), and then subtracting that signal from every channel





Data Reduction Techniques: Low Frequency DAS

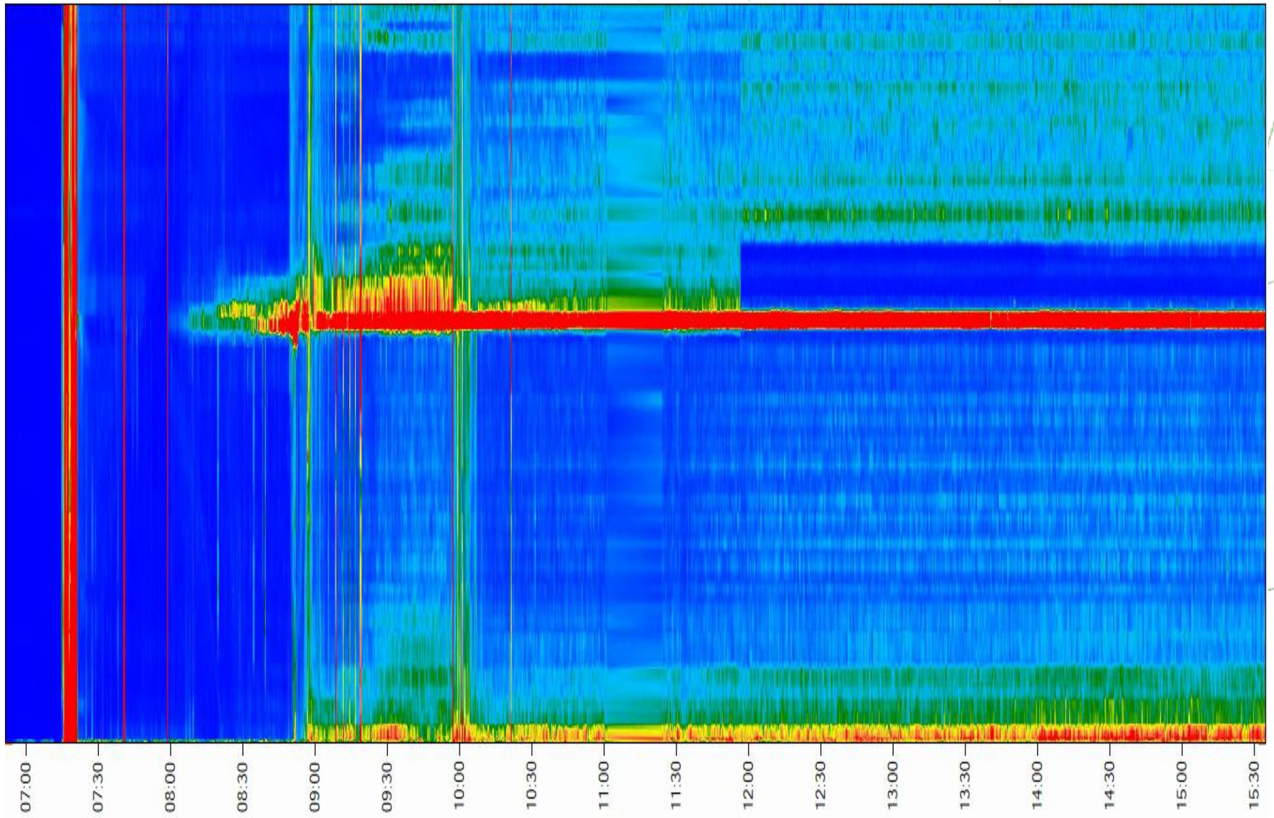
- Low pass filter and average
- Sub-Hz frequencies are visible
- Can track very low frequency strain changes caused by thermal or pressure effects
- Others have used the sea tides as a seismic source



RMS Frequency Bands

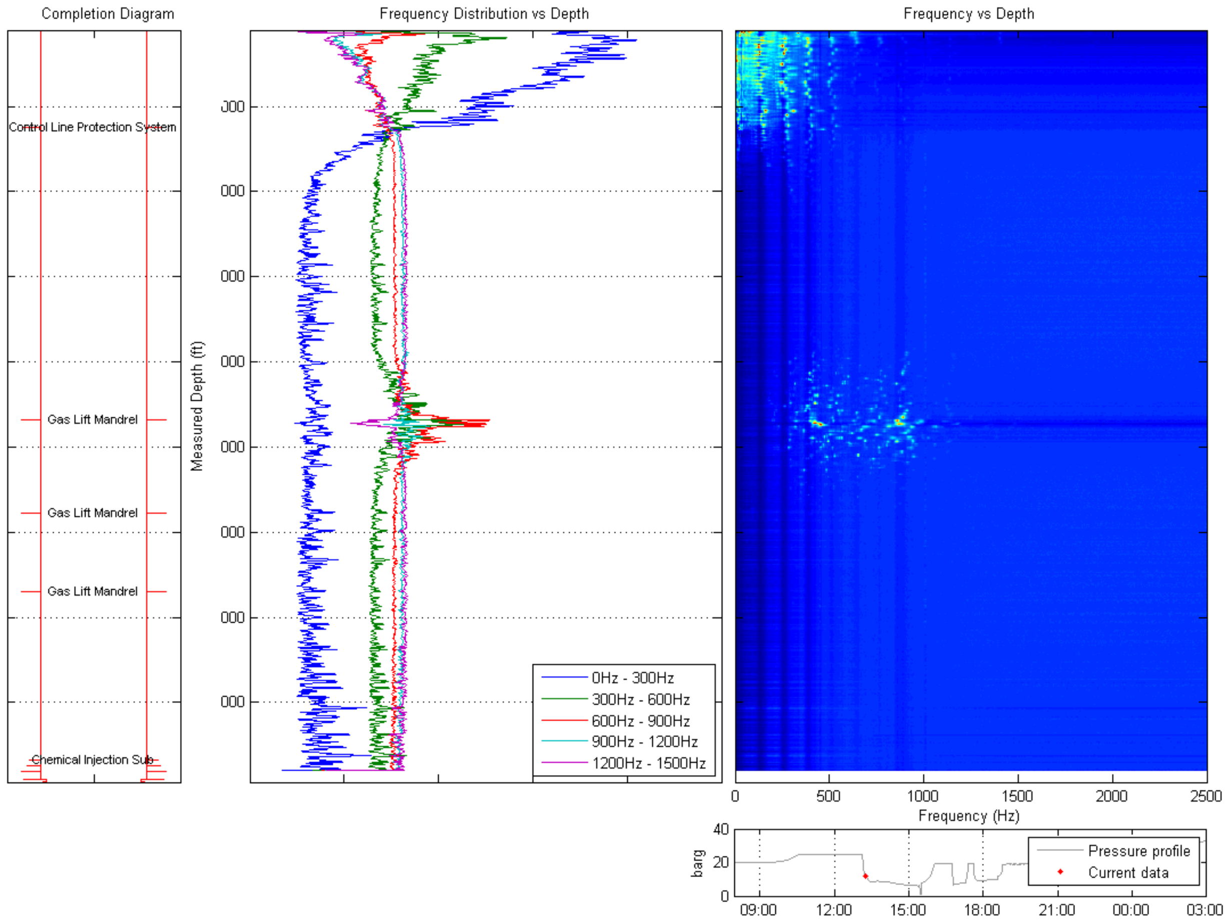
- Take the FFT of the data over a chosen time window (e.g. 1 sec) for every channel
- Do this for every 1 second window in the acquisition
- Divide the FFT into frequency bands e.g.
    - 0-1Hz
    - 1-10Hz
    - 10-100Hz
    - 100-1000Hz
- Within each frequency band calculate the RMS value
- Much smaller data that still contains frequency content information
- Caution! RMS saves the amplitude only, phase information is lost
- Be careful with amplitude units

0-100Hz band energy



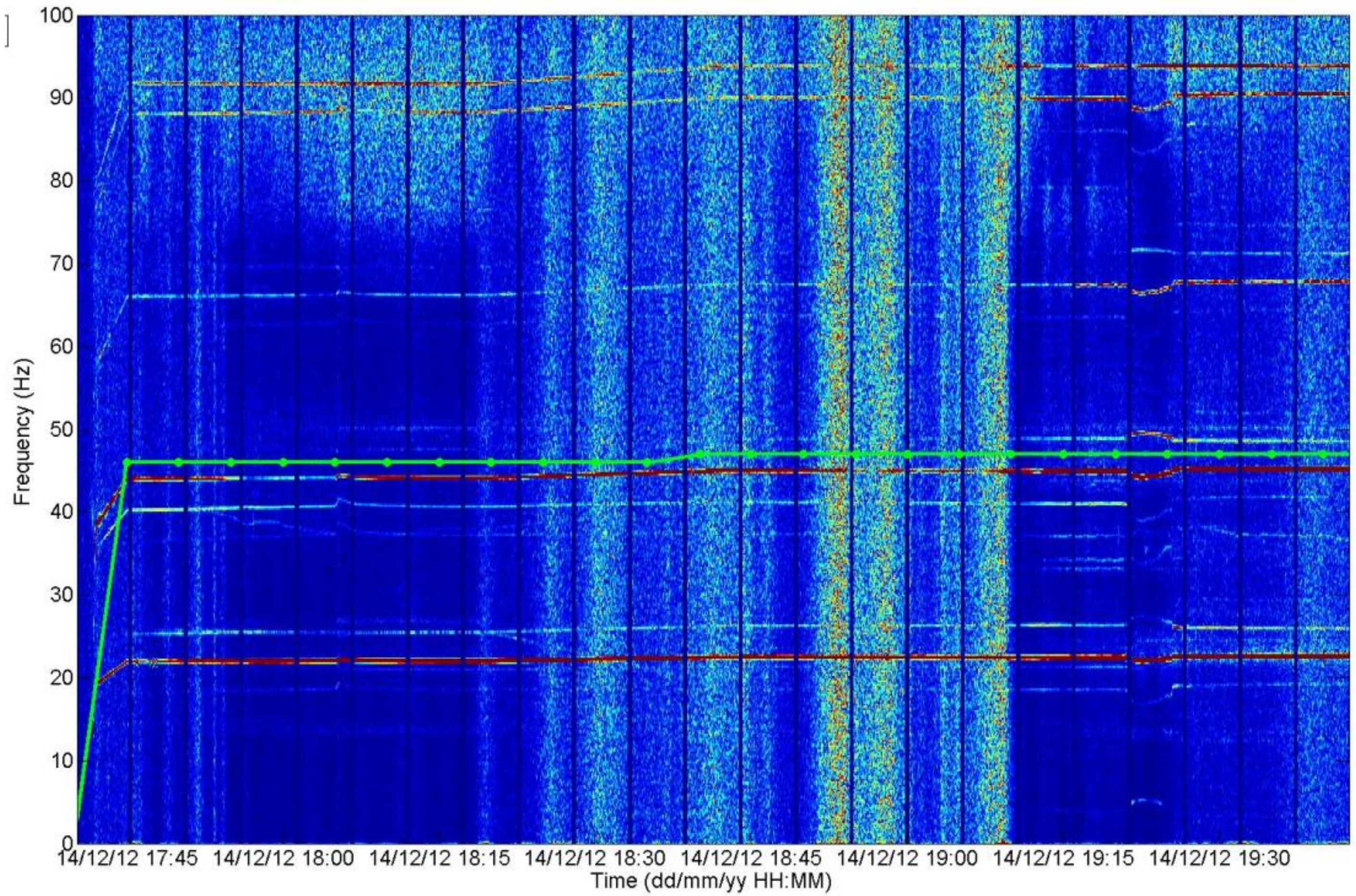
Frequency Domain: 1D-FFT vs depth

- Looking at the full frequency spectrum is very useful
- Small signals masked by higher amplitudes in other frequencies can be found
- Take the FFT vs all depth channels
- Plot as a 2D heatmap image
- Better for snapshots in time, because the 2D data is still quite large

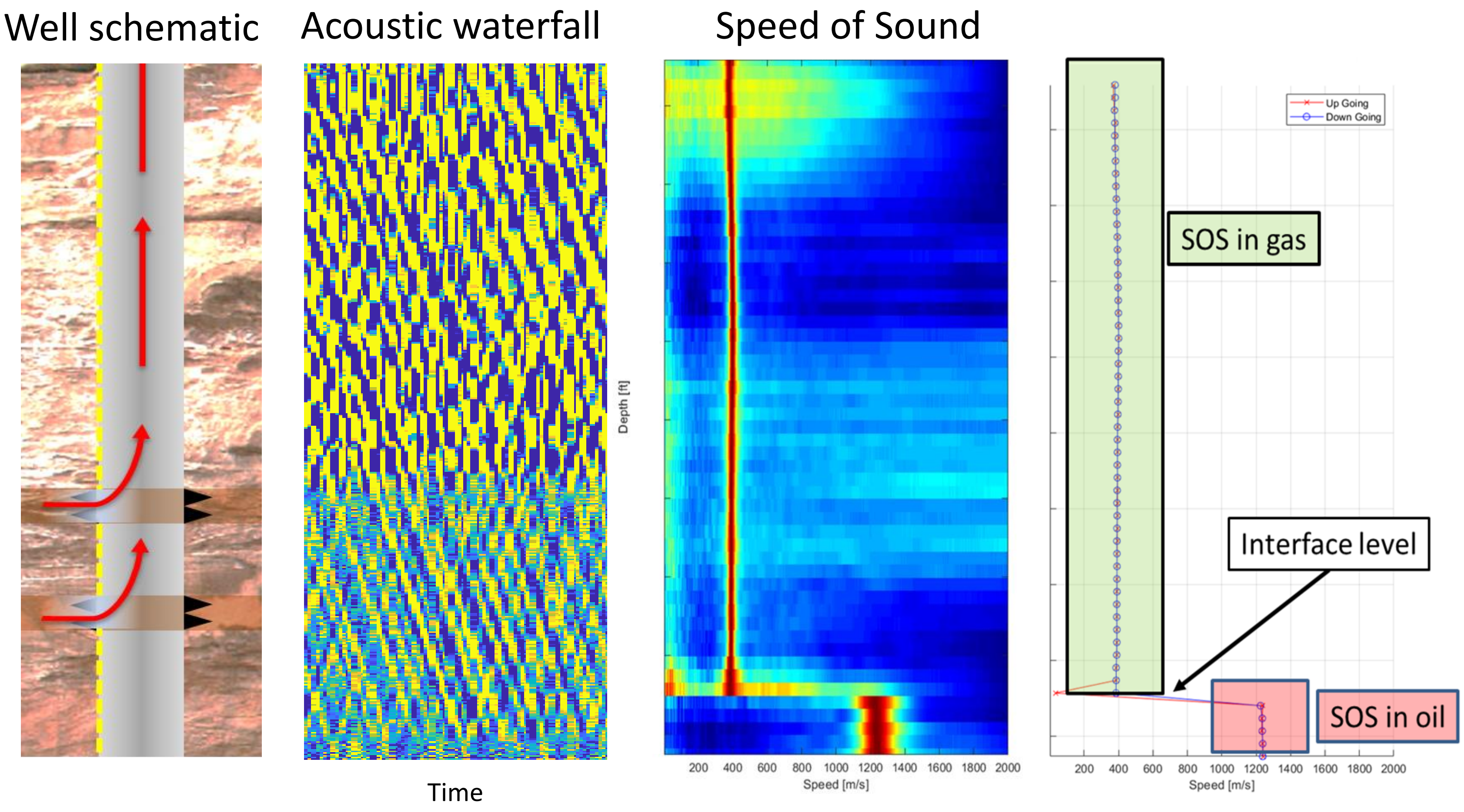


Frequency Domain: Spectrogram

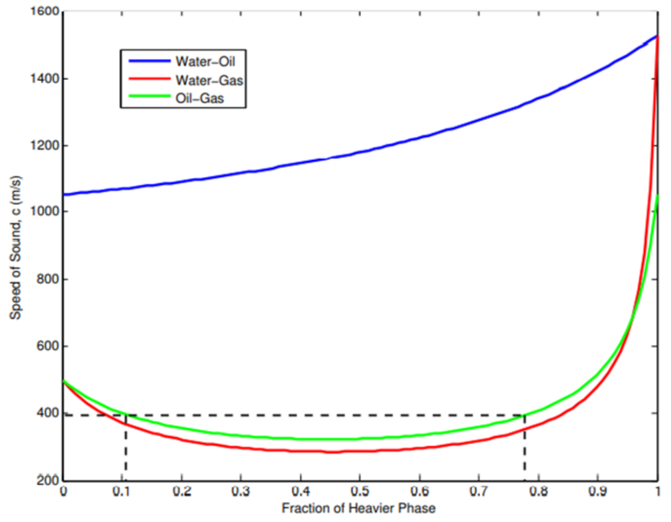
- Frequency vs time
- Take a single receiver channel divide into small time windows
- Calculate the short time FFT
- Plot these next to each other to create a time history of the frequency content at that location
- Useful for monitoring changes over time in a single location
- E.g. downhole gauges, valves or pumps



Methodology – Speed of Sound analysis

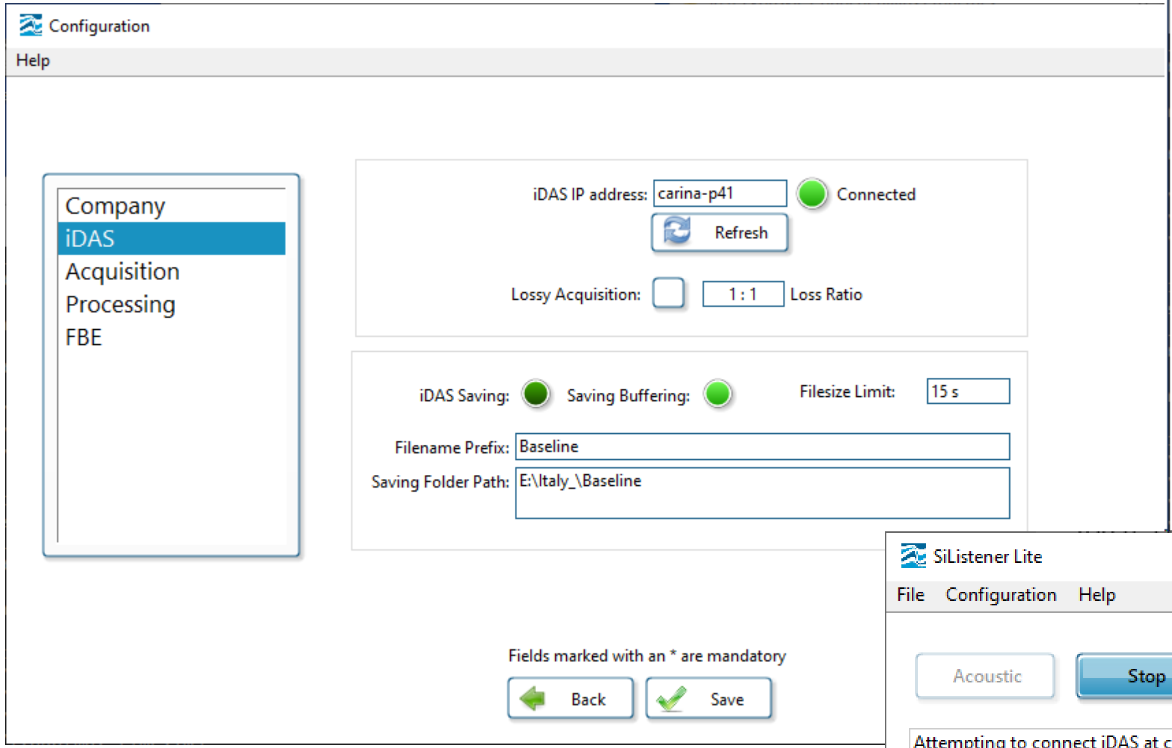


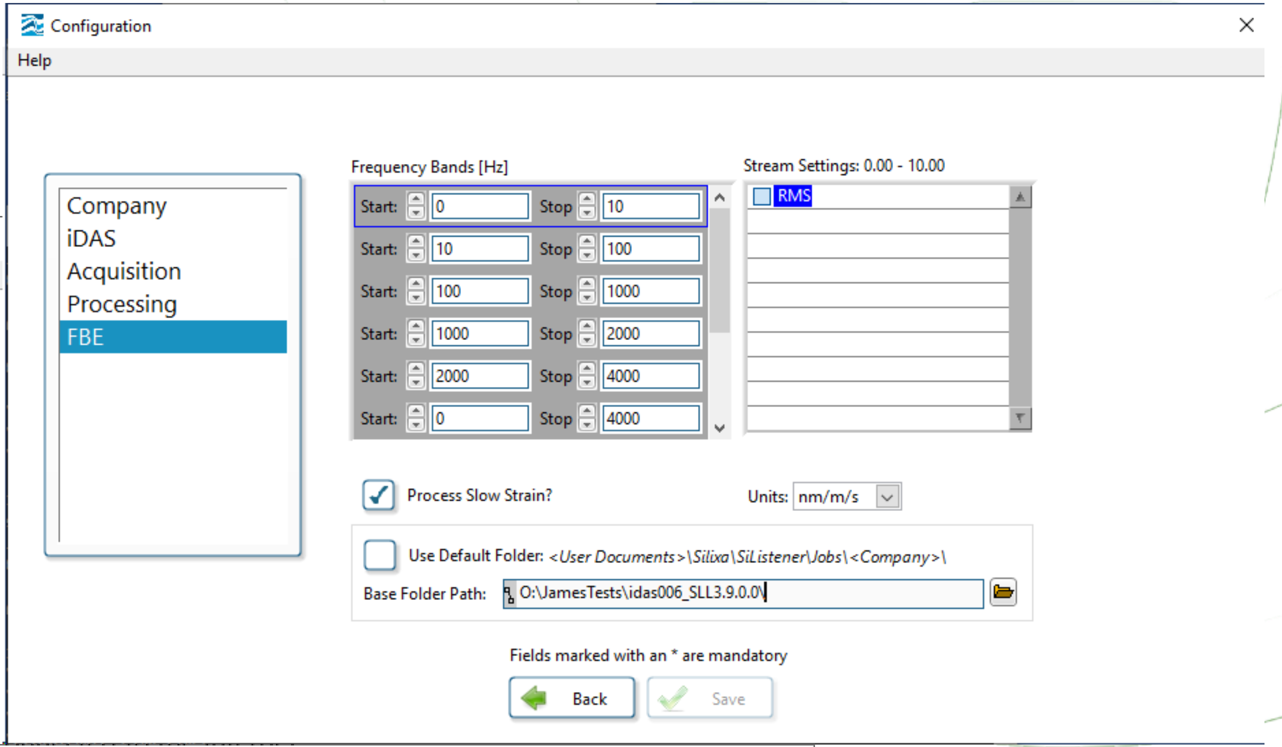
- Fluid composition and profiling
- Interface level detection

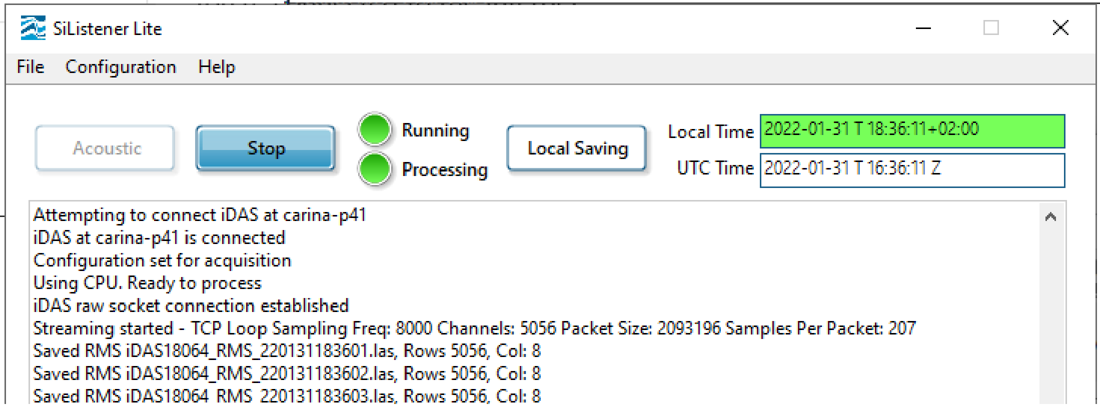


Real-time calculation of data derivatives

- Tool that can accept data streams and calculate

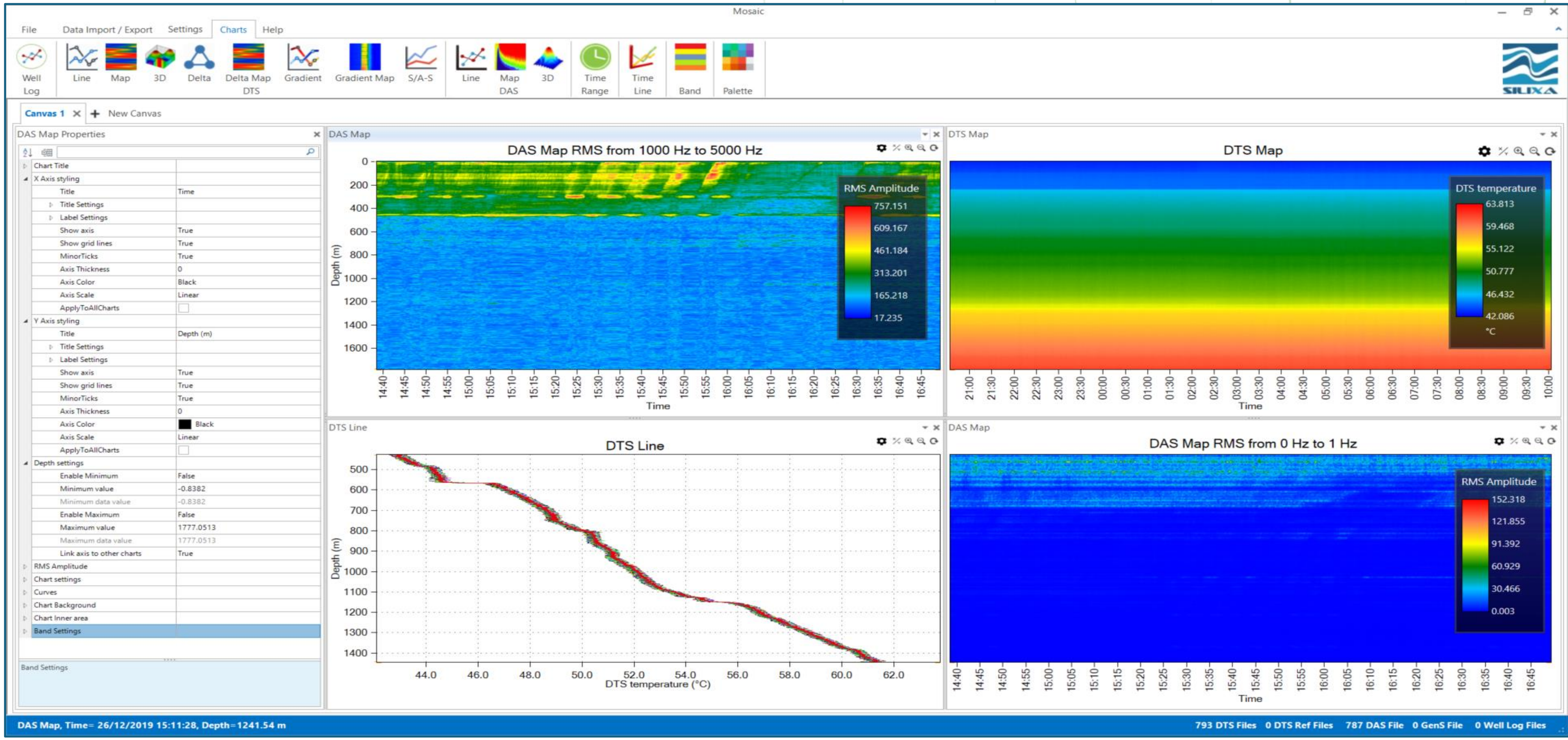






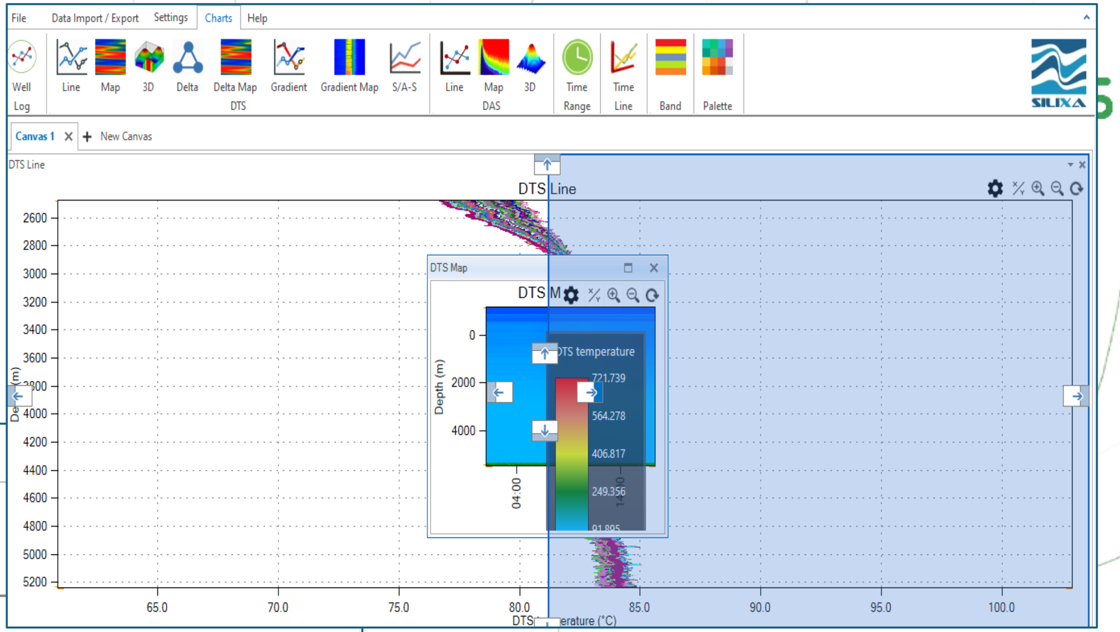
Real-time display of multiple datasets

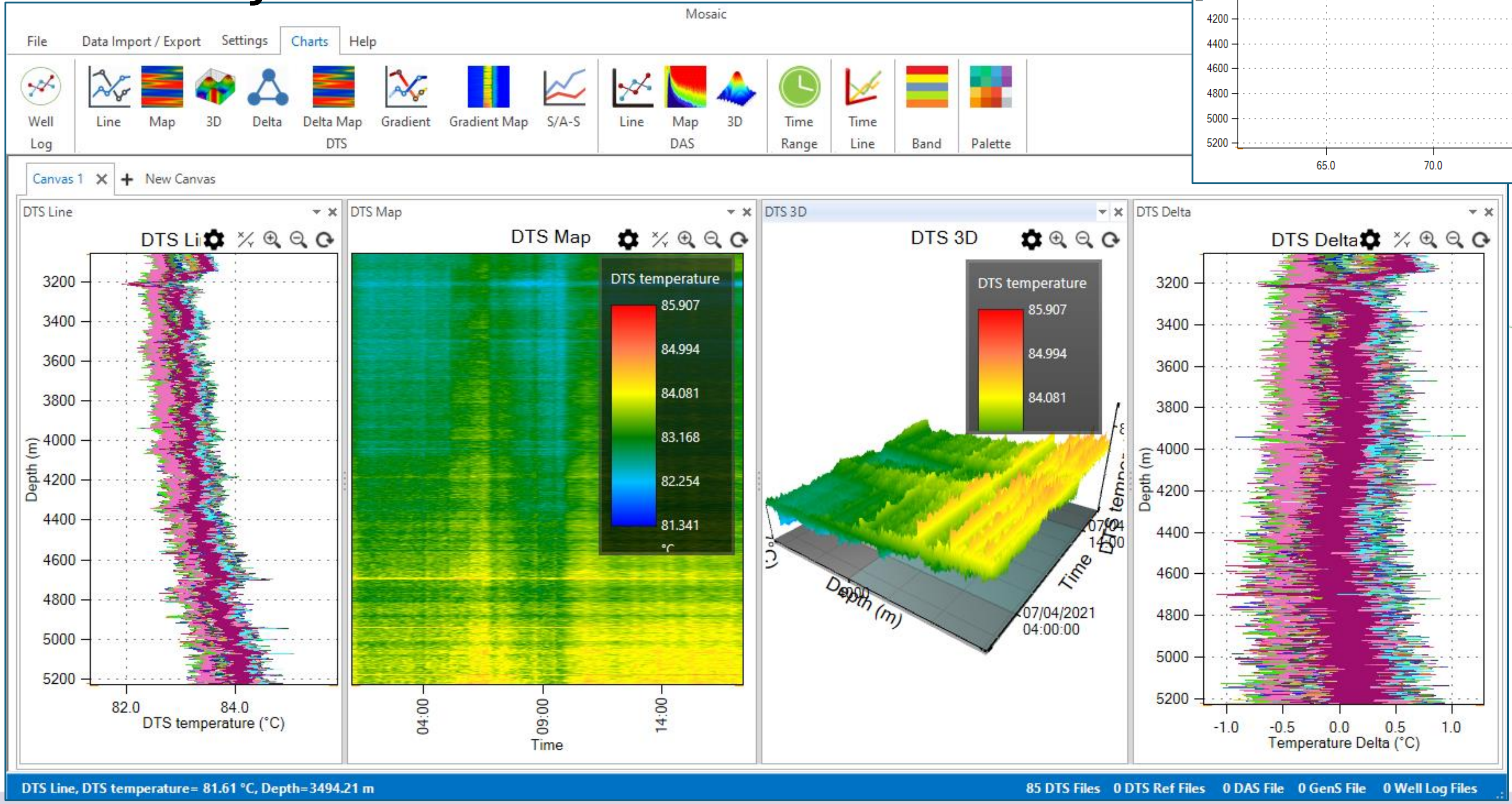
- Mosaic
- Real-time or offline visualisation
- DAS, DTS and DSS data
- Customisable displays



Real-time display of multiple datasets

- <u>Mosaic</u>
- Place different plot types where you want them





THANKS!

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