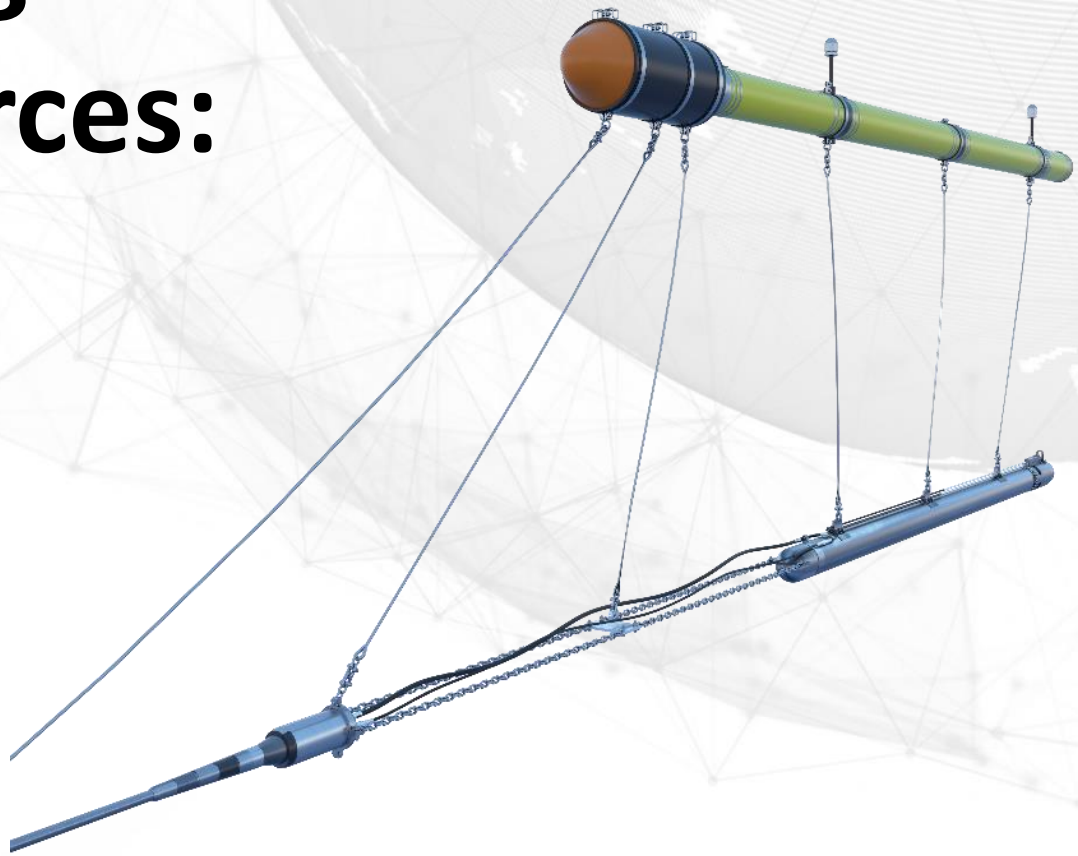
Ultra Low Frequency Signal from Pneumatic Seismic Sources: How low can we go?



Steve Chelminski and Shuki Ronen

With help from many people (to be acknowledged)

Sercel

2021 EAGE ANNUAL 82ND CONFERENCE & EXHIBITION AMSTERDAM | THE NETHERLANDS

Session Details:
Low Frequency Seismic Data Acquisition and its impact on Imaging and Inversion—Hardware (Dedicated Session)

2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Session Details:

Low Frequency Seismic Data **Acquisition** and its impact on **Imaging and Inversion**— **Hardware** (Dedicated Session)

→ Equipment manufacturing

→ Acquisition (operations)

→ Data Processing, Imaging, and Inversion

→ No interpretation in this session*

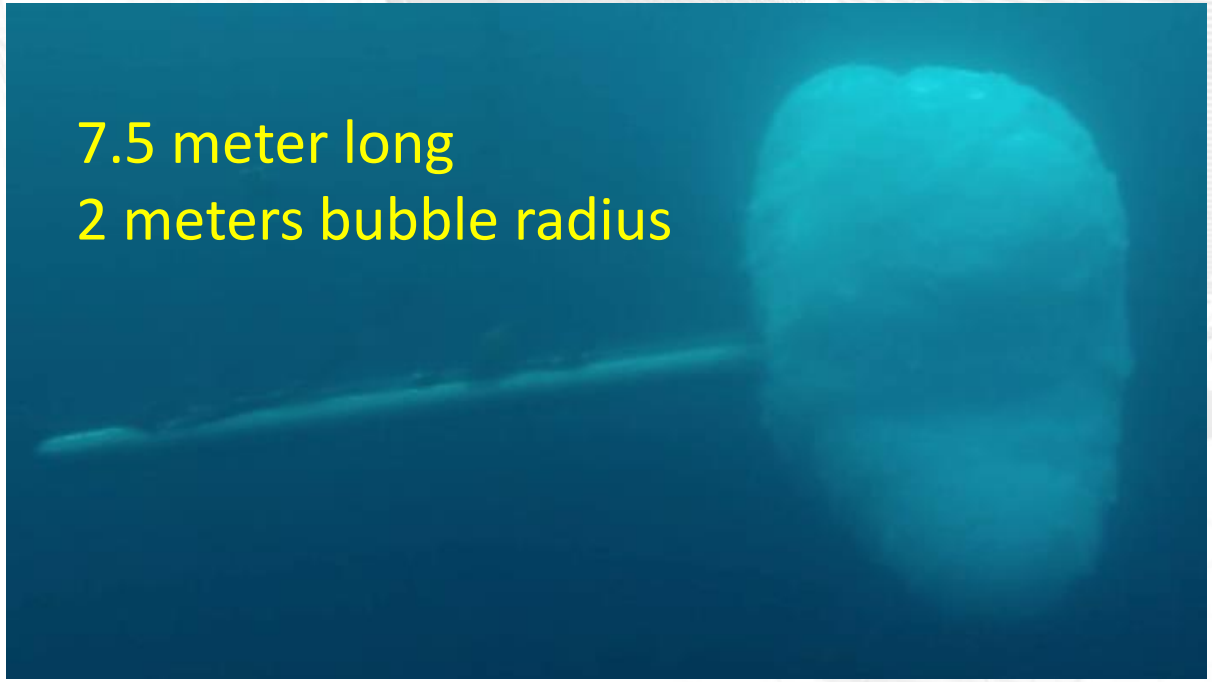
* maybe one slide

2021 EAGE ANNUAL 82ND CONFERENCE & EXHIBITION AMSTERDAM | THE NETHERLANDS

Tuned Pulse Source (TPS)

The TPS is a pneumatic source

- ✷ Impulsive
1. Low Pressure
2. Large Volumes
3. New design features
   - ❑ Cup-shaped flange
   - ❑ No acceleration distance
   - ❑ Closed mid chamber
   - ❑ Safer air supply/drain
- ➢ More low frequency signal
- ➢ Less High frequency waves



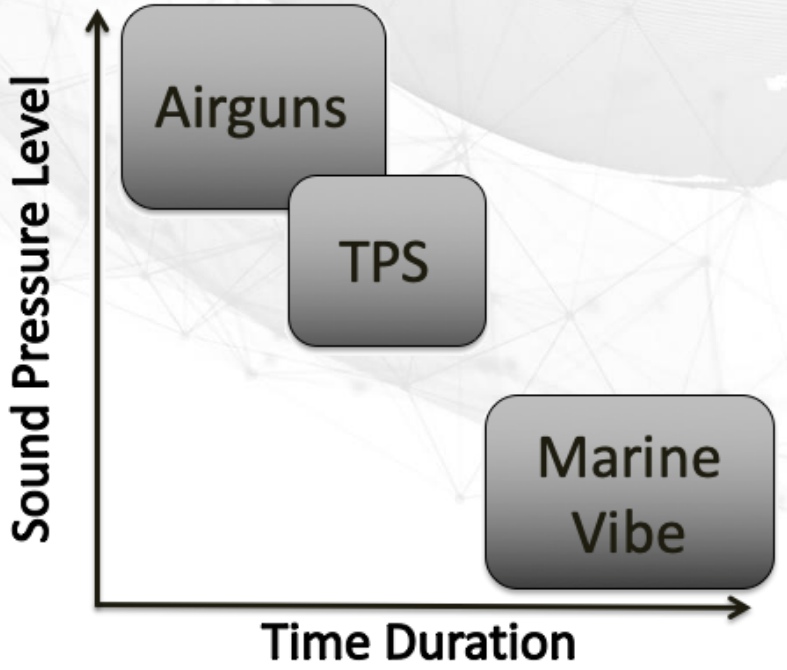
Tuned Pulse Source (TPS)

The TPS is a pneumatic source

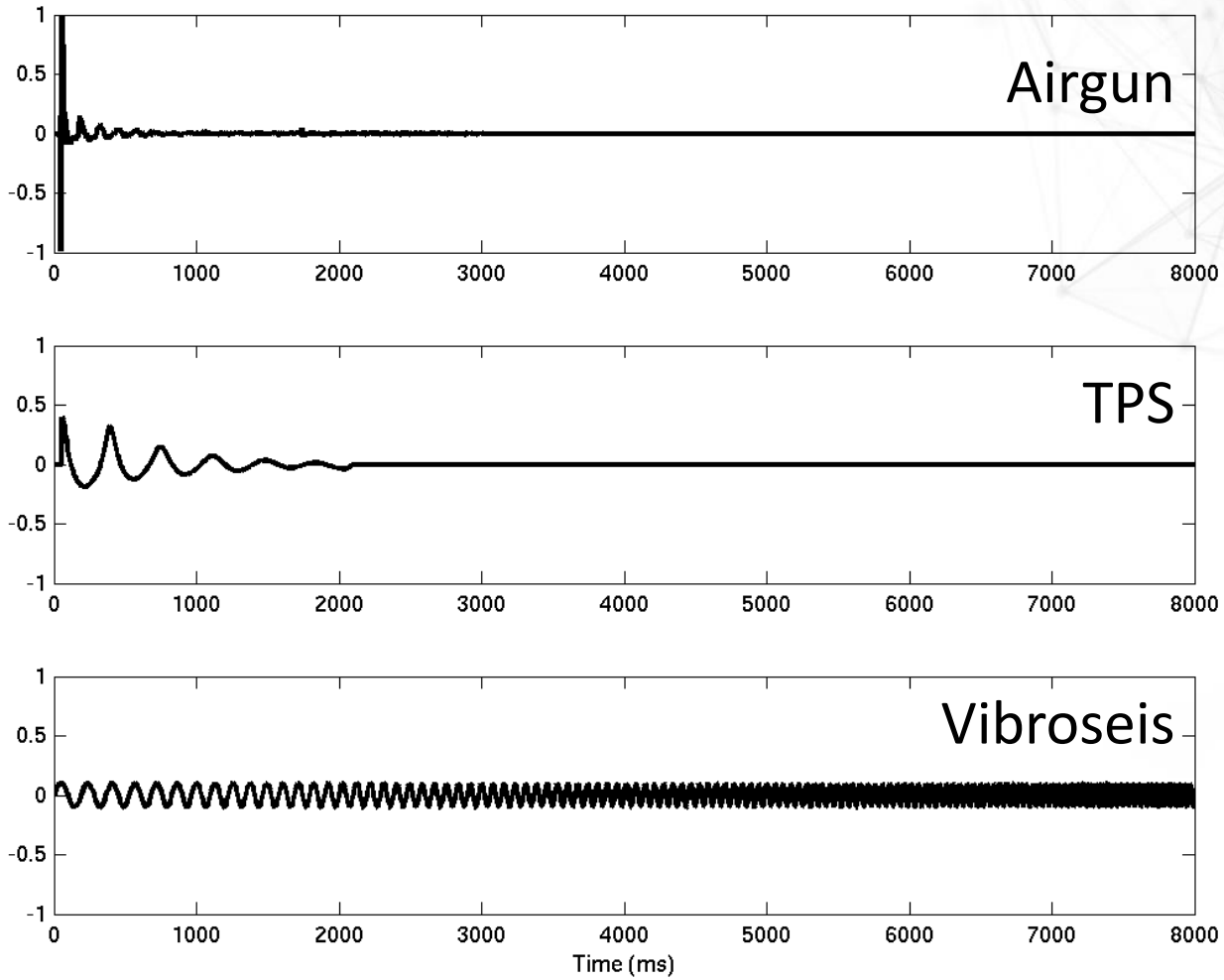
- **Impulsive**

1. Low Pressure
2. Large Volumes
3. New design features
   - ❑ Cup-shaped flange
   - ❑ No acceleration distance
   - ❑ Closed mid chamber
   - ❑ Safer air supply/drain

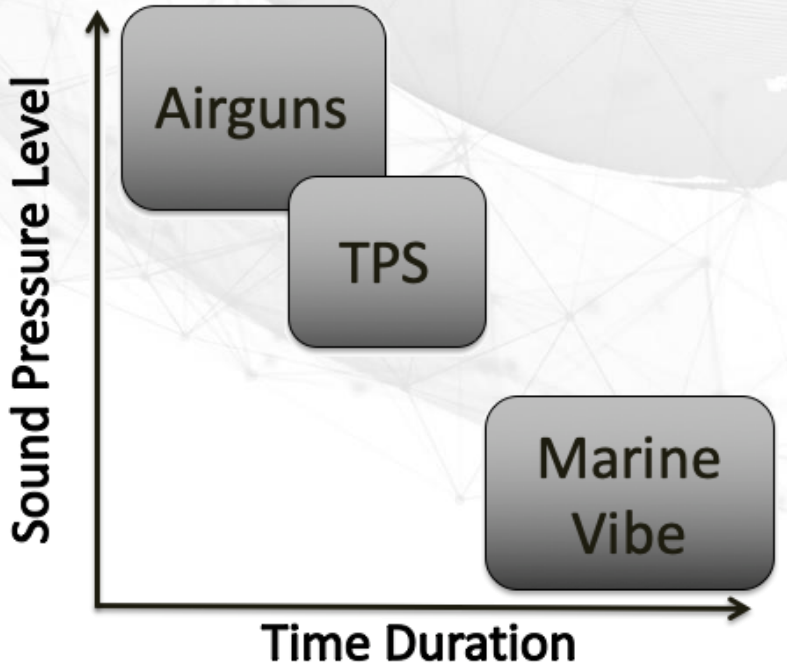
- ➢ More low frequency signal
- ➢ Less High frequency waves



Impulsive and non impulsive sources



It’s a gray area



2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

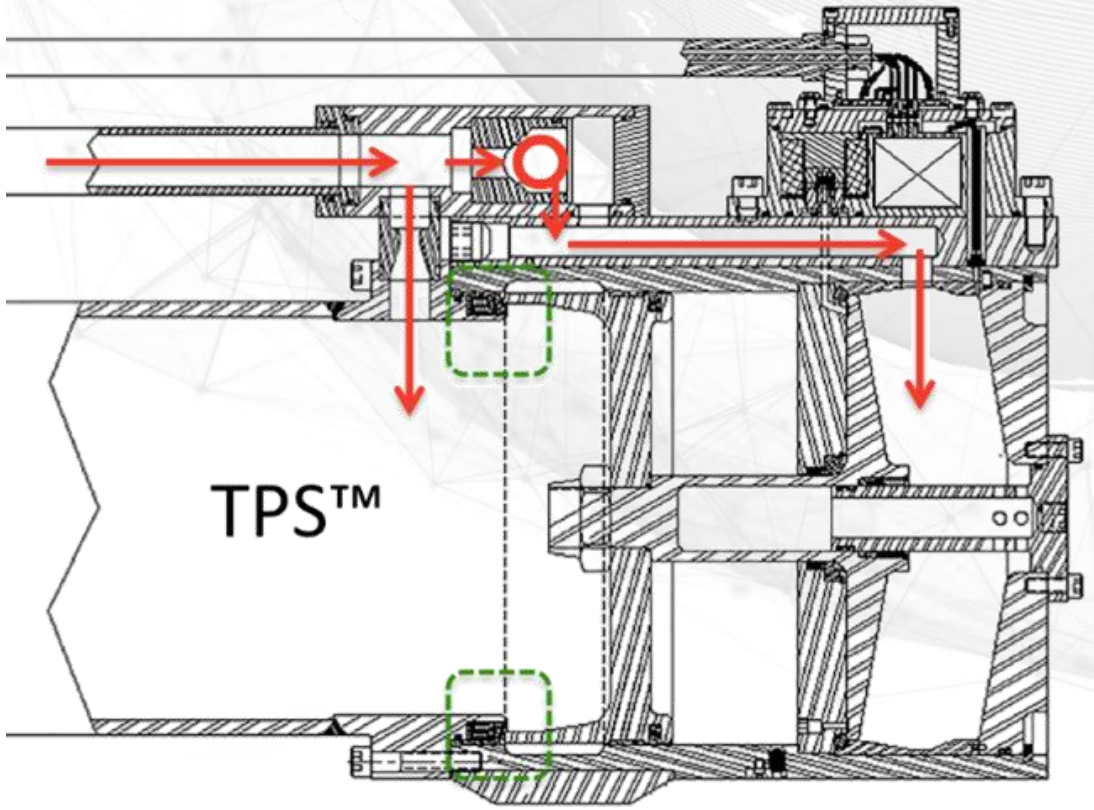
Tuned Pulse Source (TPS)

The TPS is a pneumatic source

- Impulsive

1. Low Pressure
2. Large Volumes
3. **New design features**
   - ❑ **Cup-shaped flange**
   - ❑ **No acceleration distance**
   - ❑ **Closed mid chamber**
   - ❑ **Safer air supply/drain**

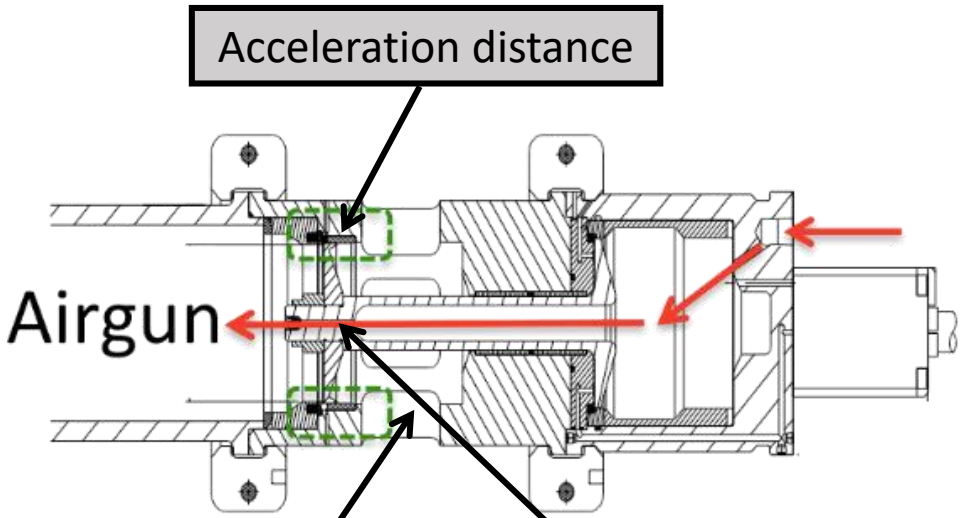
- ➢ More low frequency signal
- ➢ Less High frequency waves

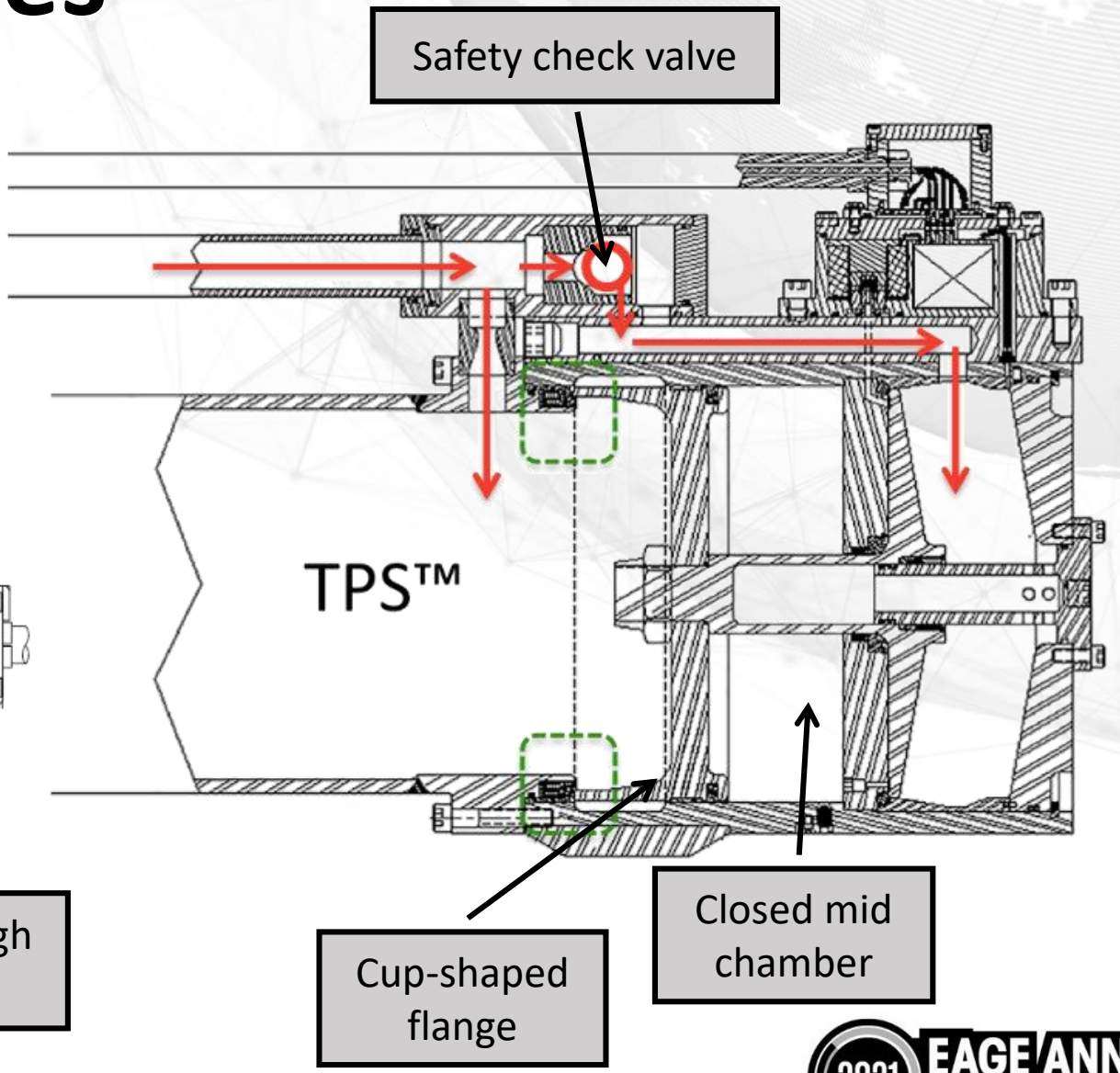


New design features

Safer air flow method

Zero acceleration distance





2021 EAGE ANNUAL 82ND CONFERENCE & EXHIBITION AMSTERDAM | THE NETHERLANDS

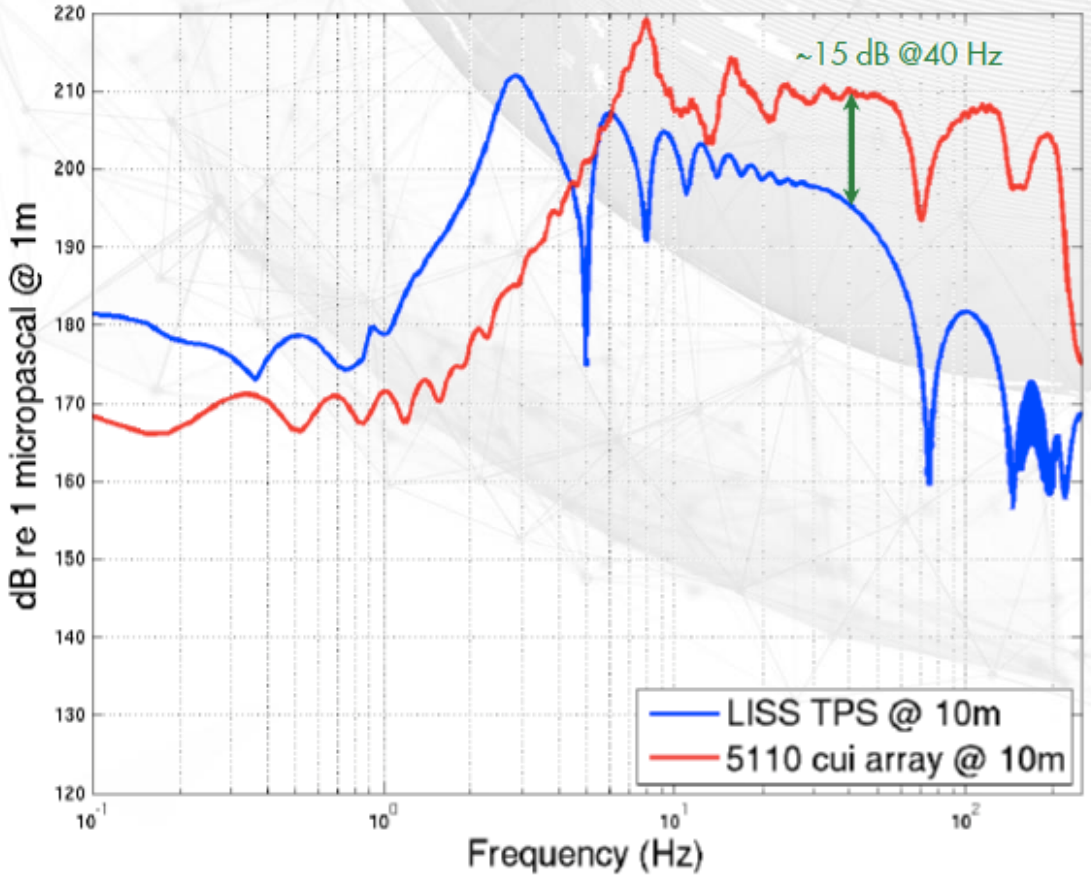
Tuned Pulse Source (TPS)

The TPS is a pneumatic source

- Impulsive

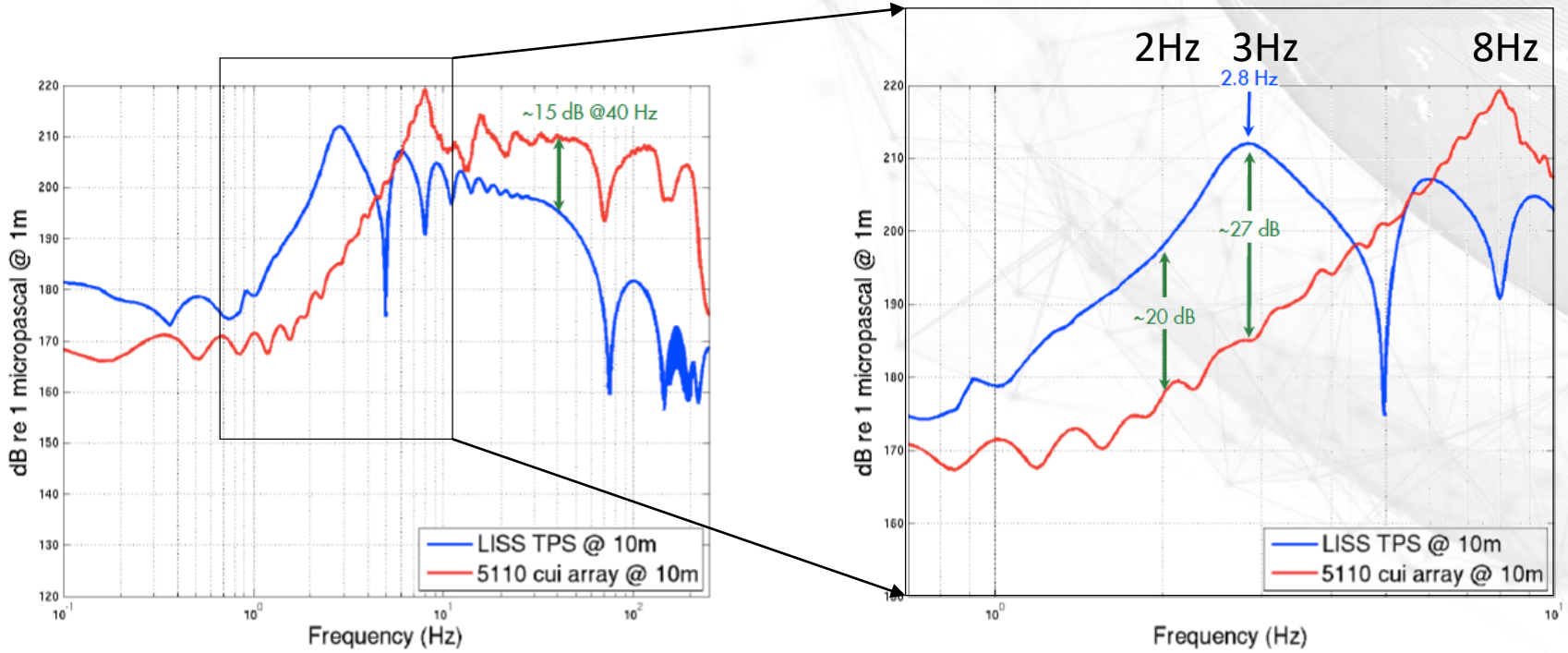
1. Low Pressure
2. Large Volumes
3. New design features
   - ❑ Cup-shaped flange
   - ❑ No acceleration distance
   - ❑ Closed mid chamber
   - ❑ Safer air supply/drain

- ➢ **More low frequency signal**
- ➢ **Less High frequency waves**



2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Low frequency Source

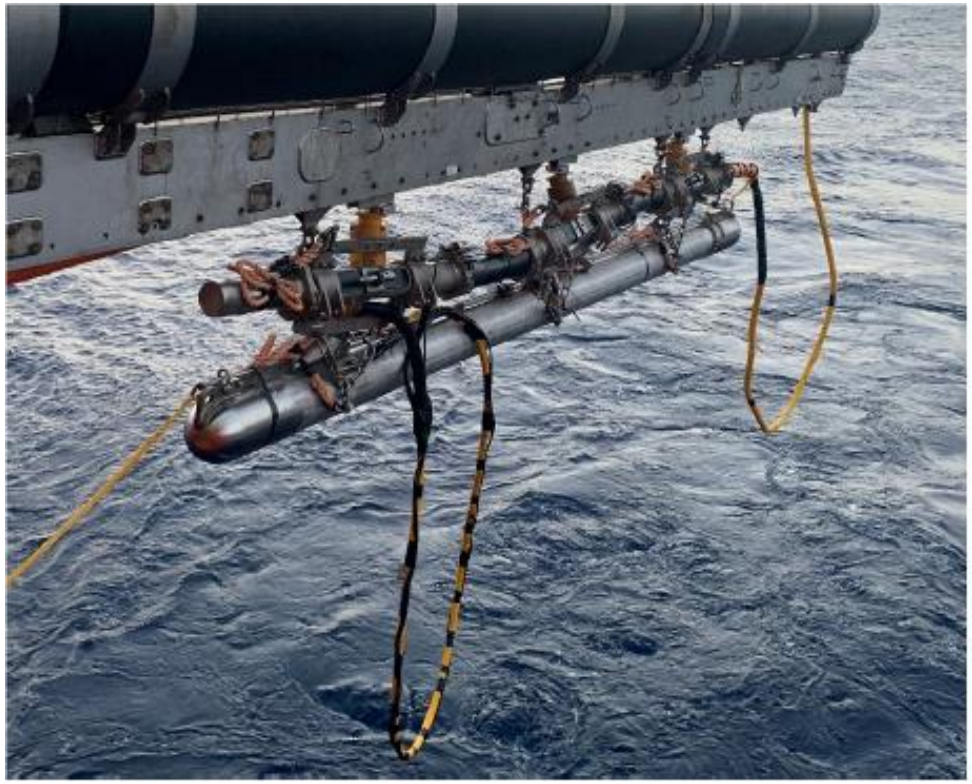


Over 20 dB stronger at 1-3 Hz (infra-sound) → Geophysical advantage

Over 15 dB weaker above 40 Hz (sound) → Environmental advantage

One Acquisition slide: Plug-and-play

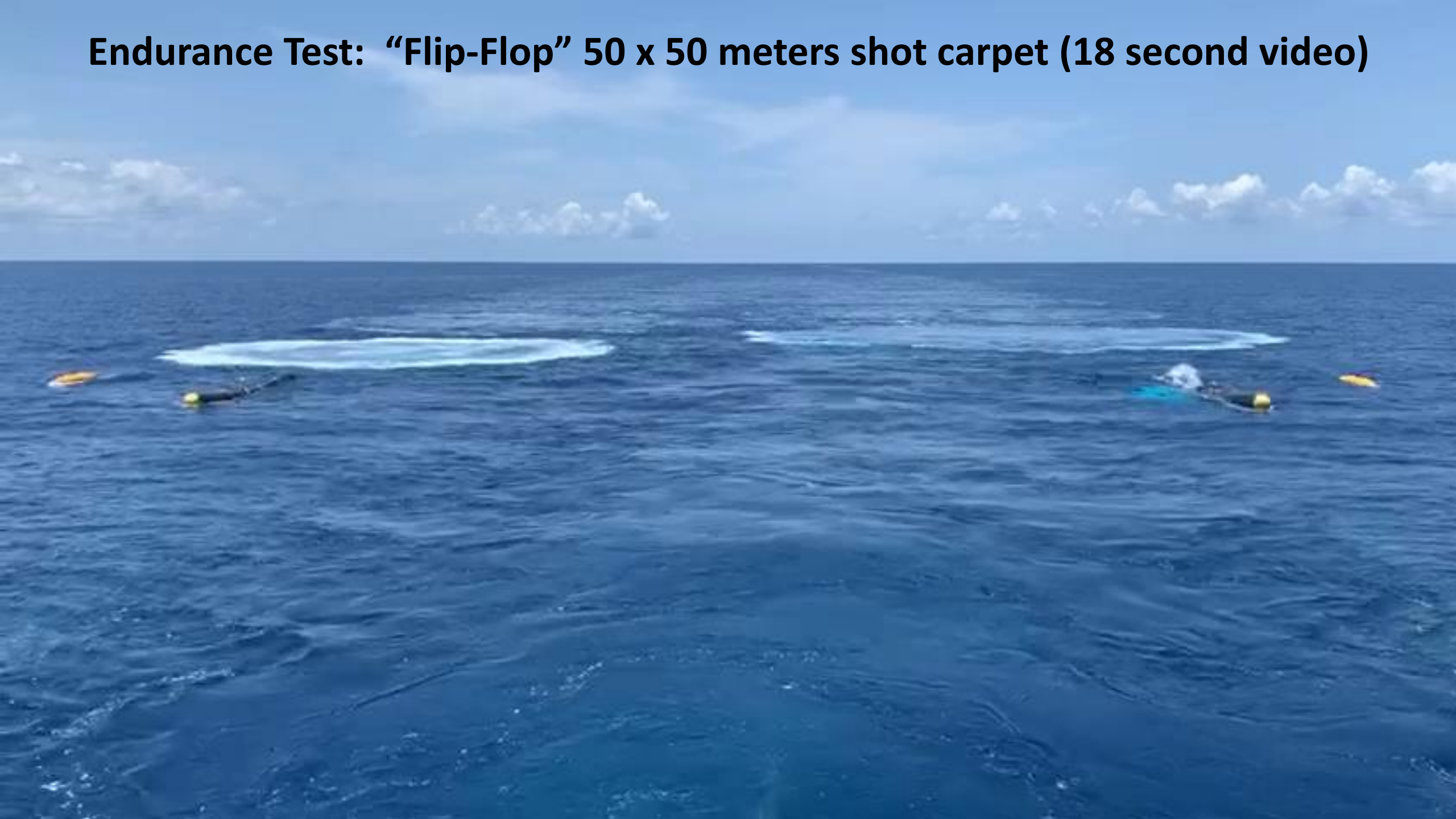
2020 “Sea Trial”
booms and rigid floats



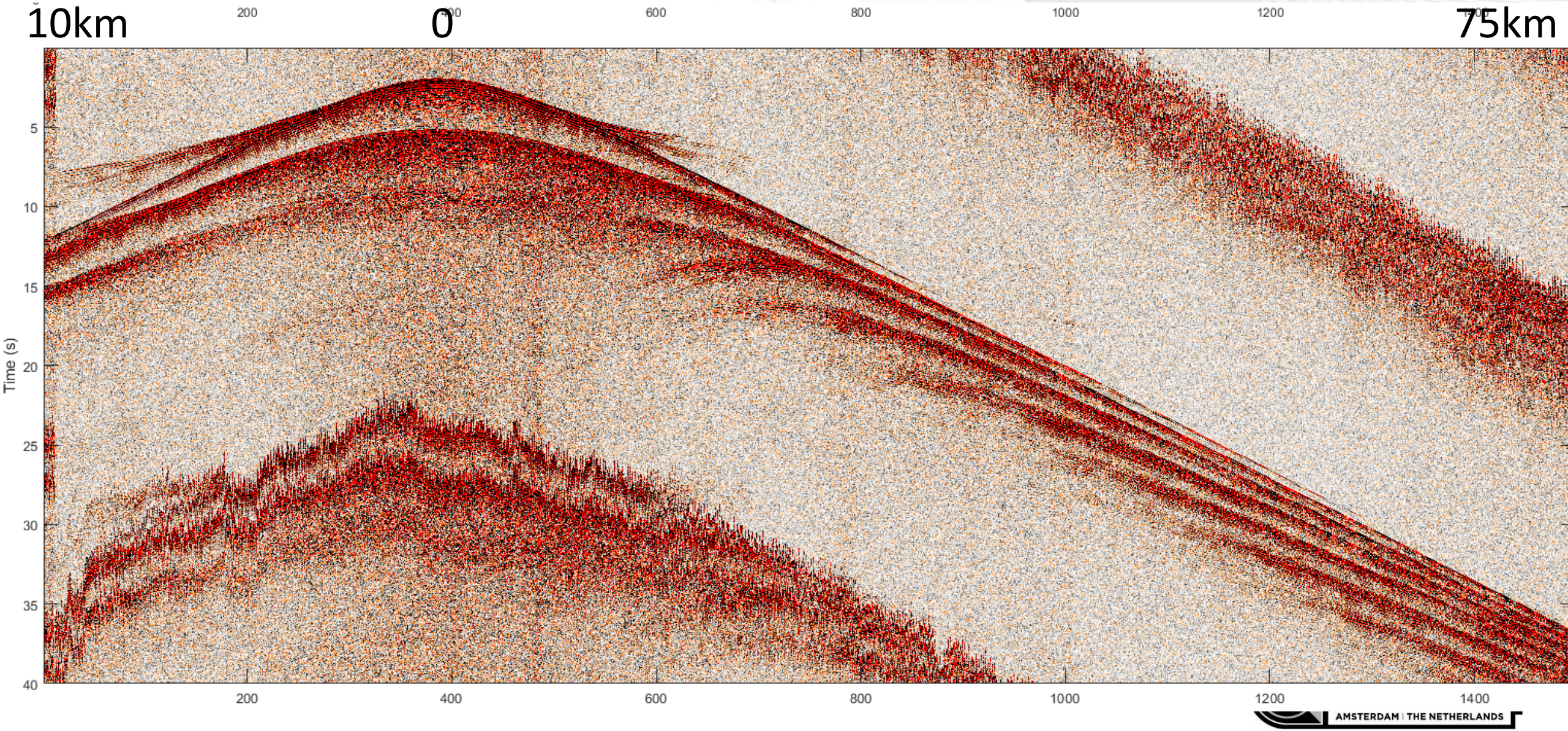
2021 “Endurance Test”
Slipway with flexible floats



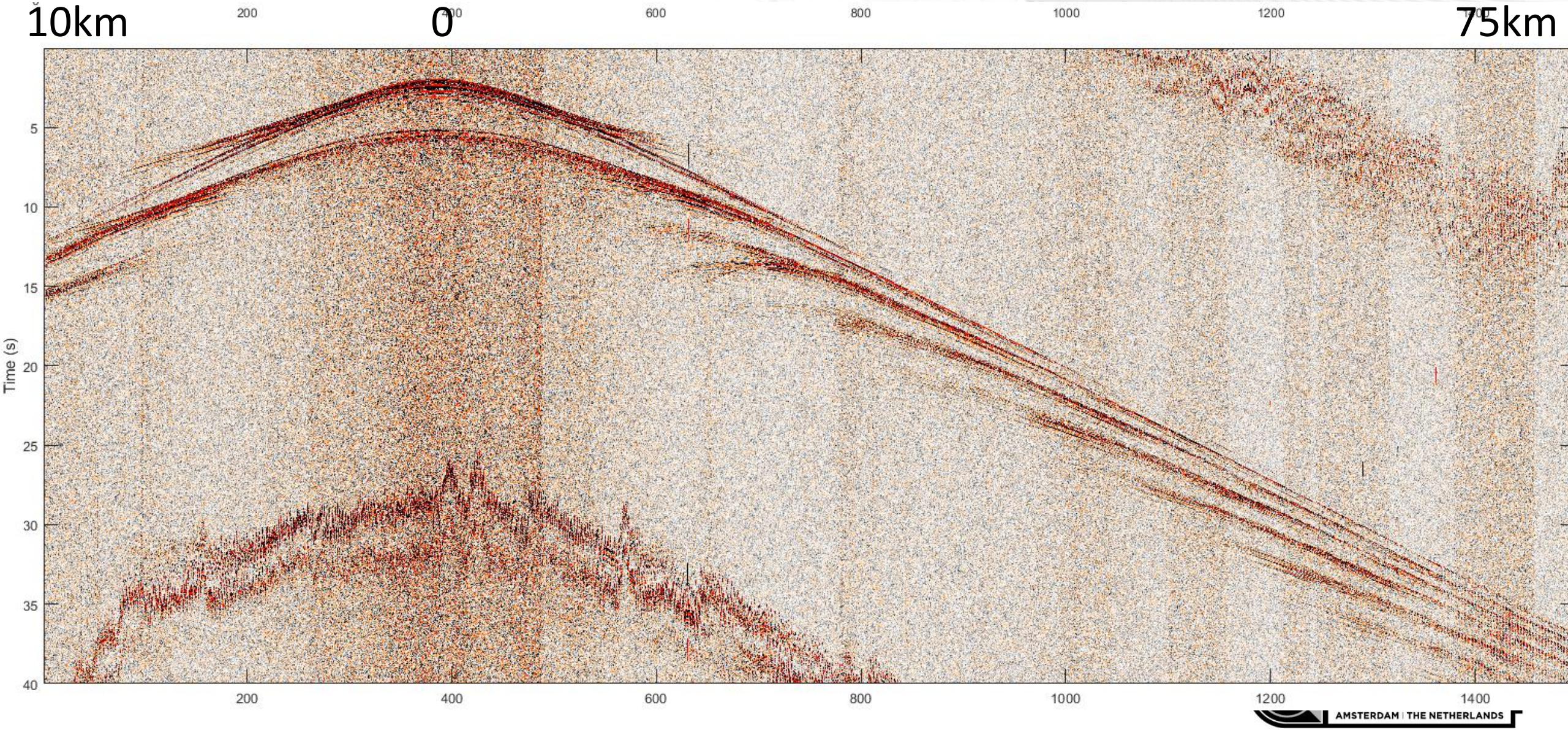
Endurance Test: “Flip-Flop” 50 x 50 meters shot carpet (18 second video)



Common Receiver Gather—Airgun array



Common Receiver Gather—TPS



Next few slides

Limited Time and space

0 to 40 km offset (one side)

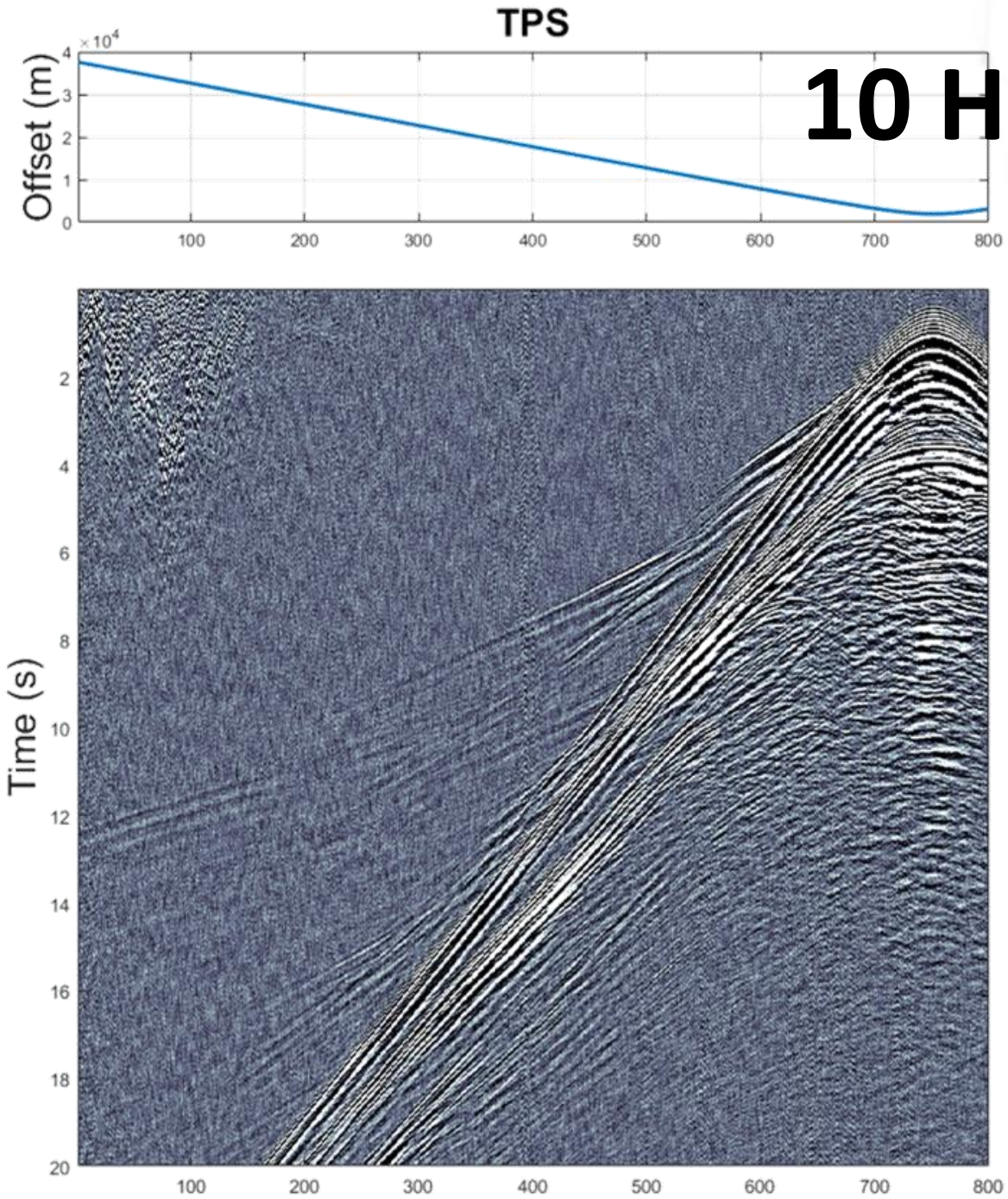
20 seconds time window

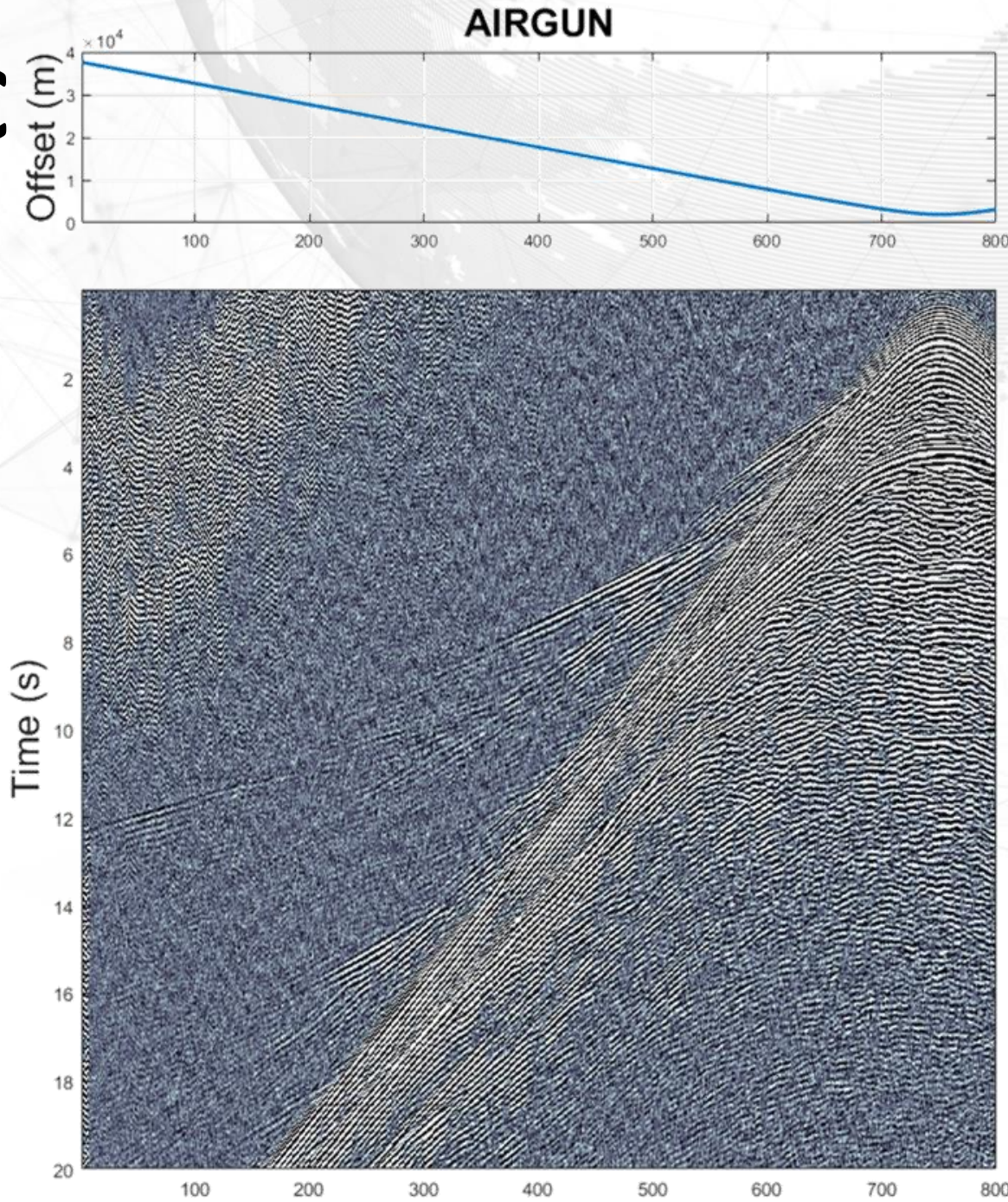
Limited Frequency Displays (in time space domain)

High cuts: 10Hz, 5, 4, 3,2 ,1 Hz

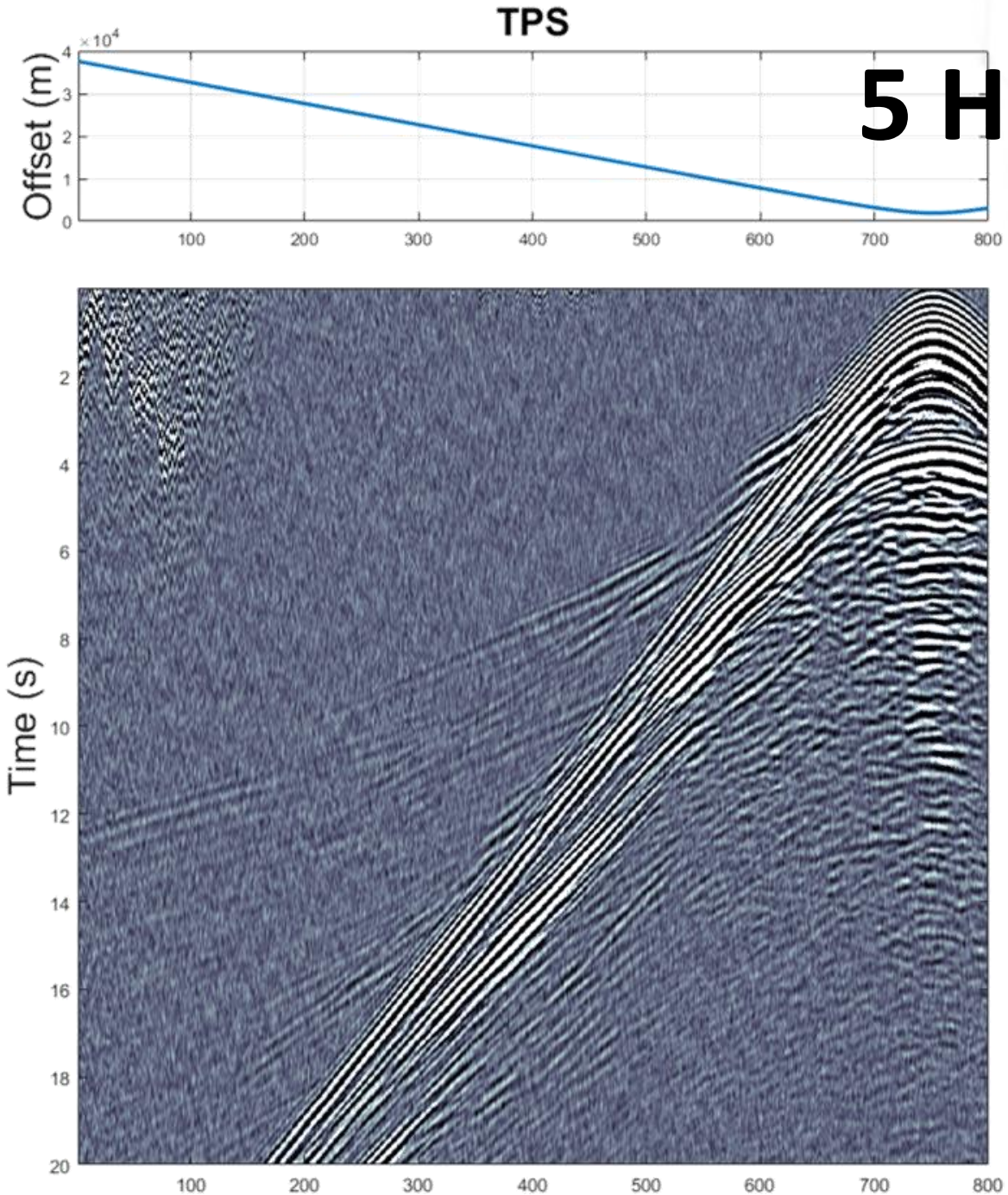
2021 EAGE ANNUAL 82ND CONFERENCE & EXHIBITION AMSTERDAM | THE NETHERLANDS

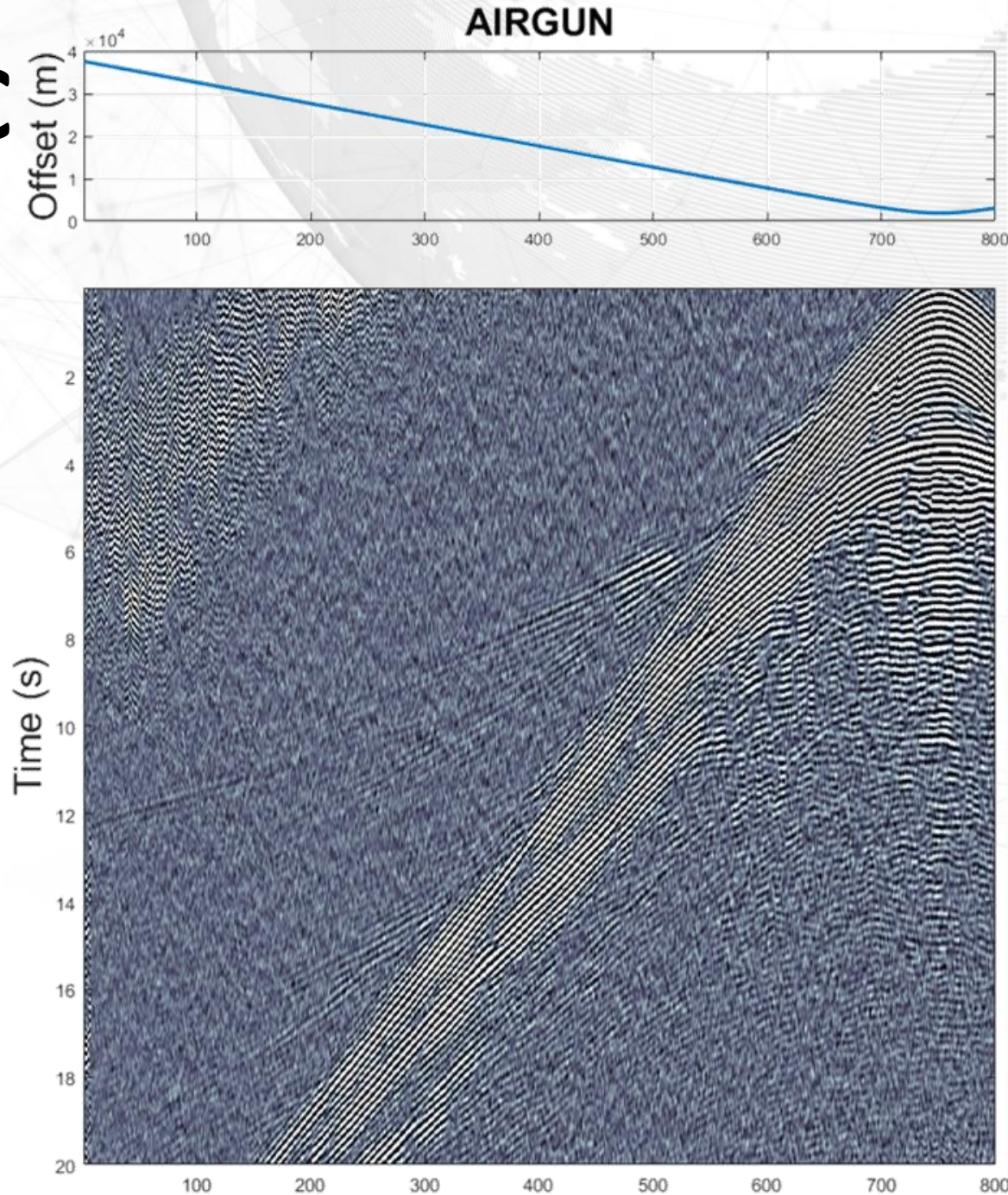
10 Hz HC



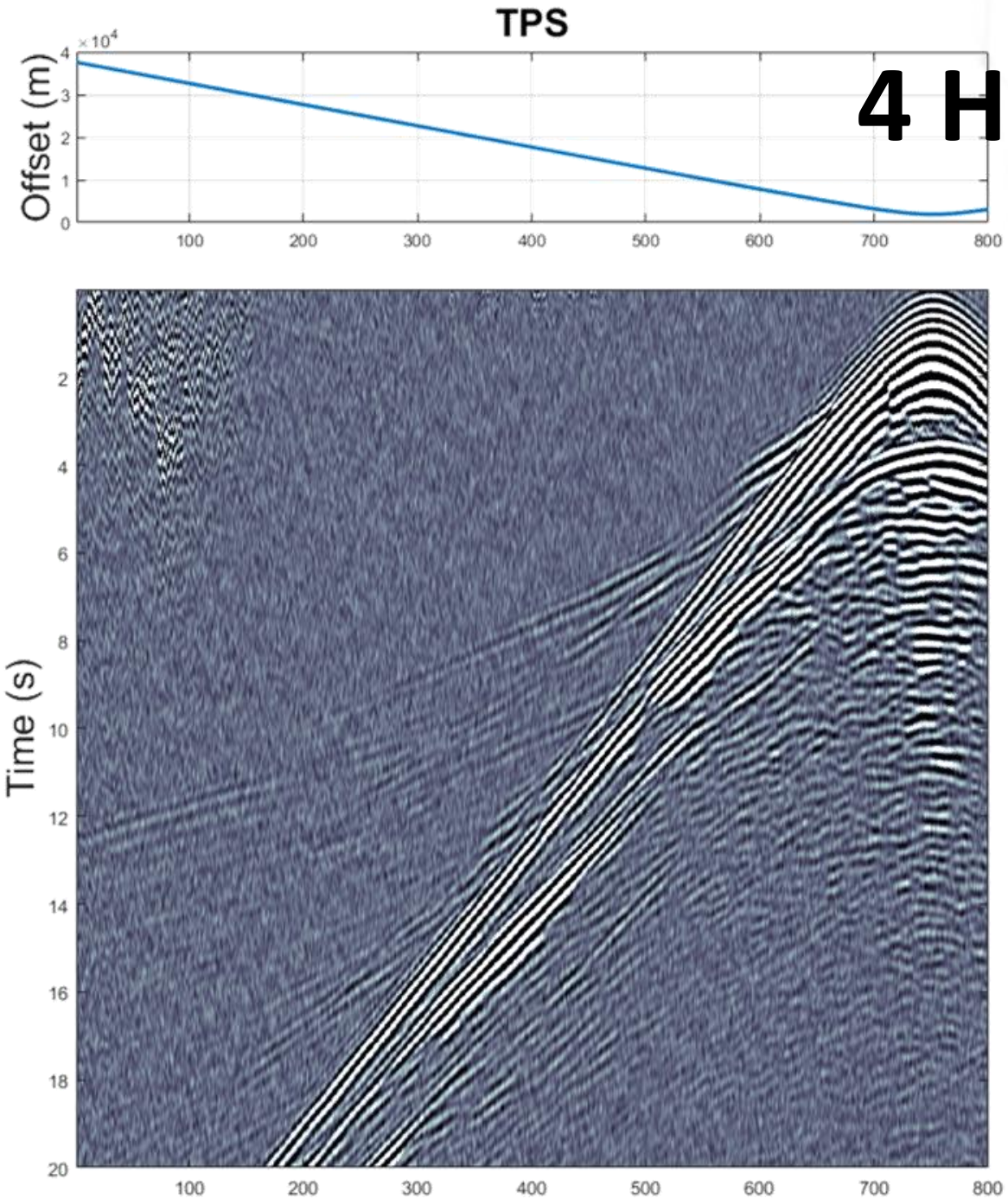


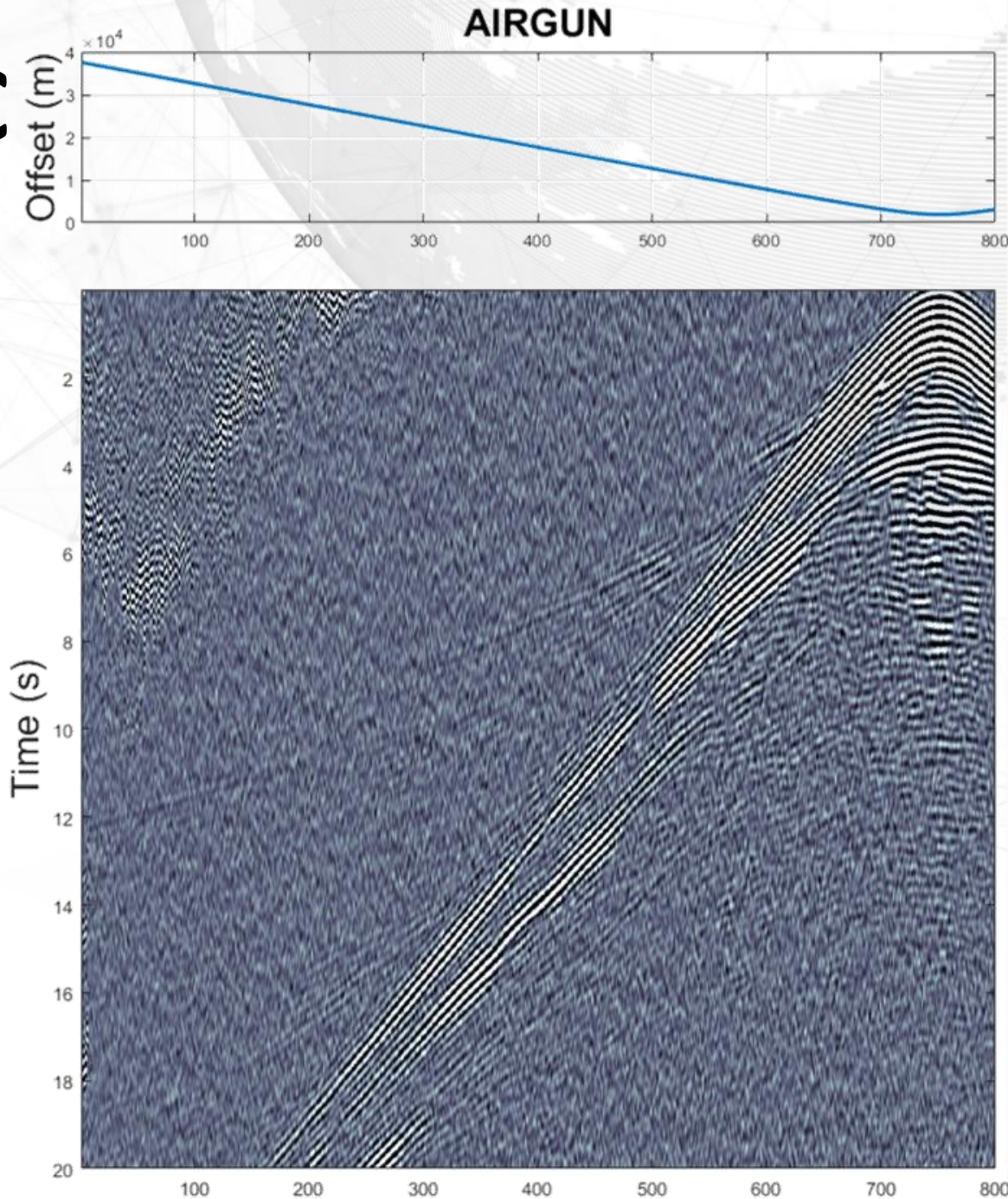
5 Hz HC



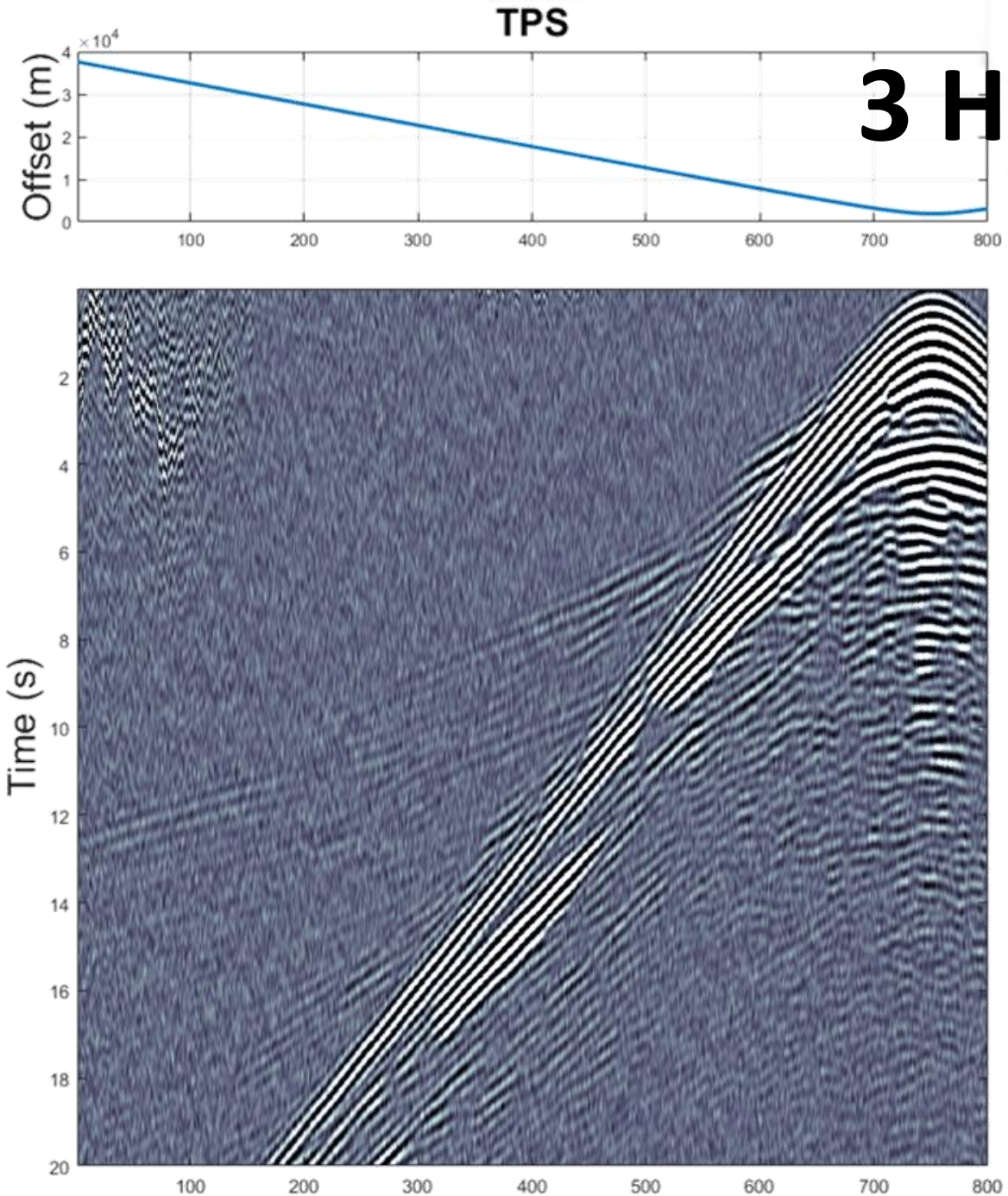


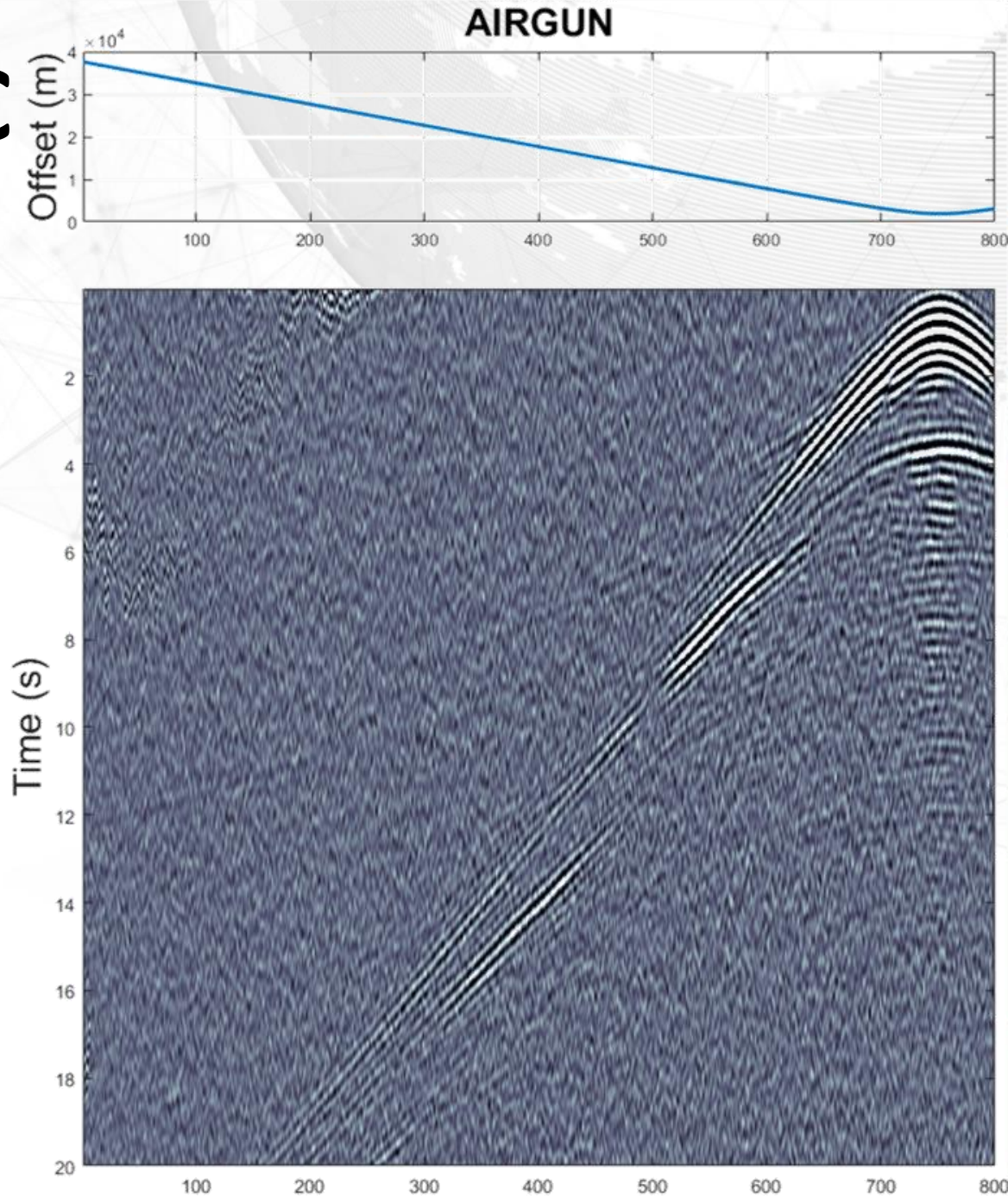
4 Hz HC



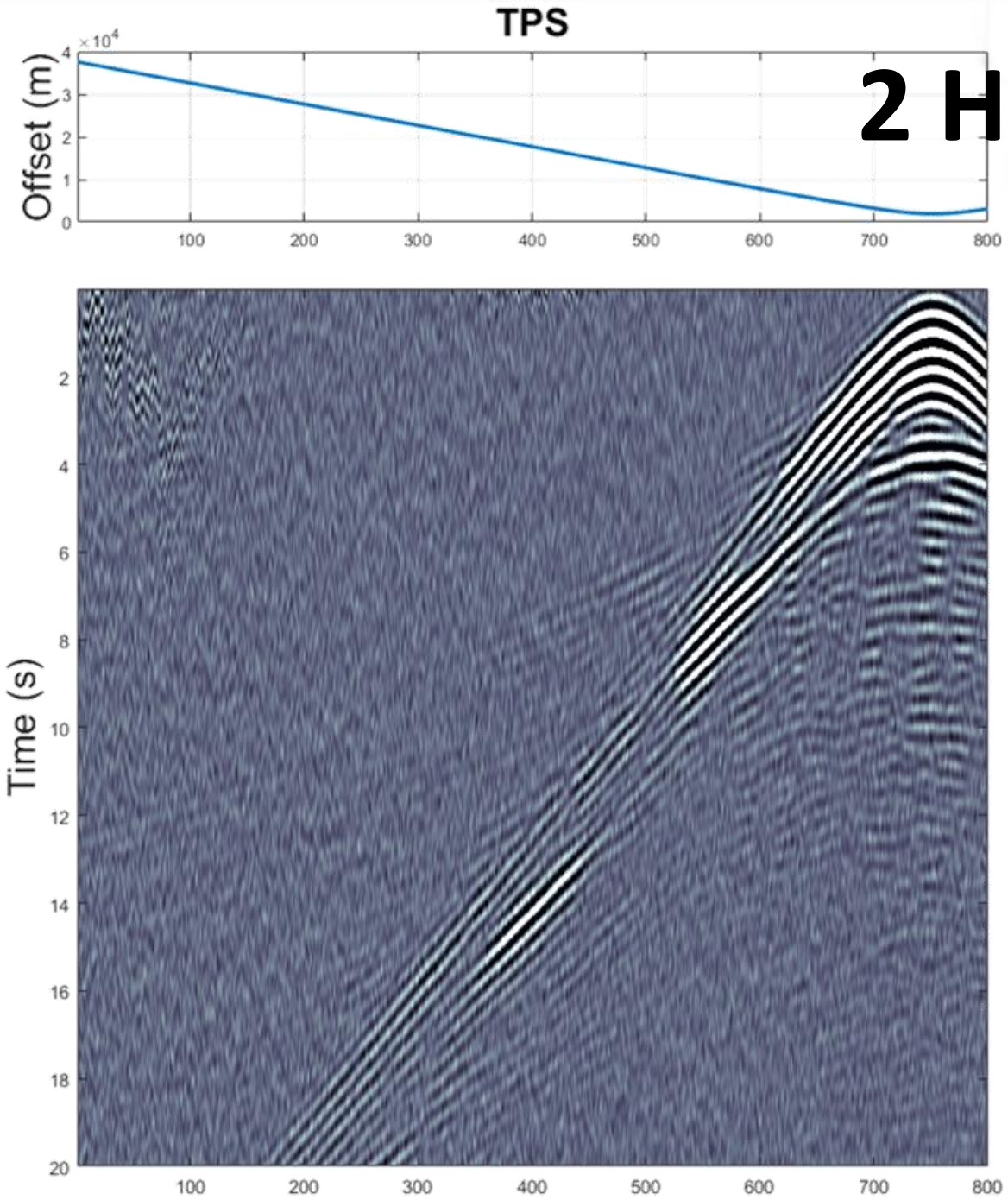


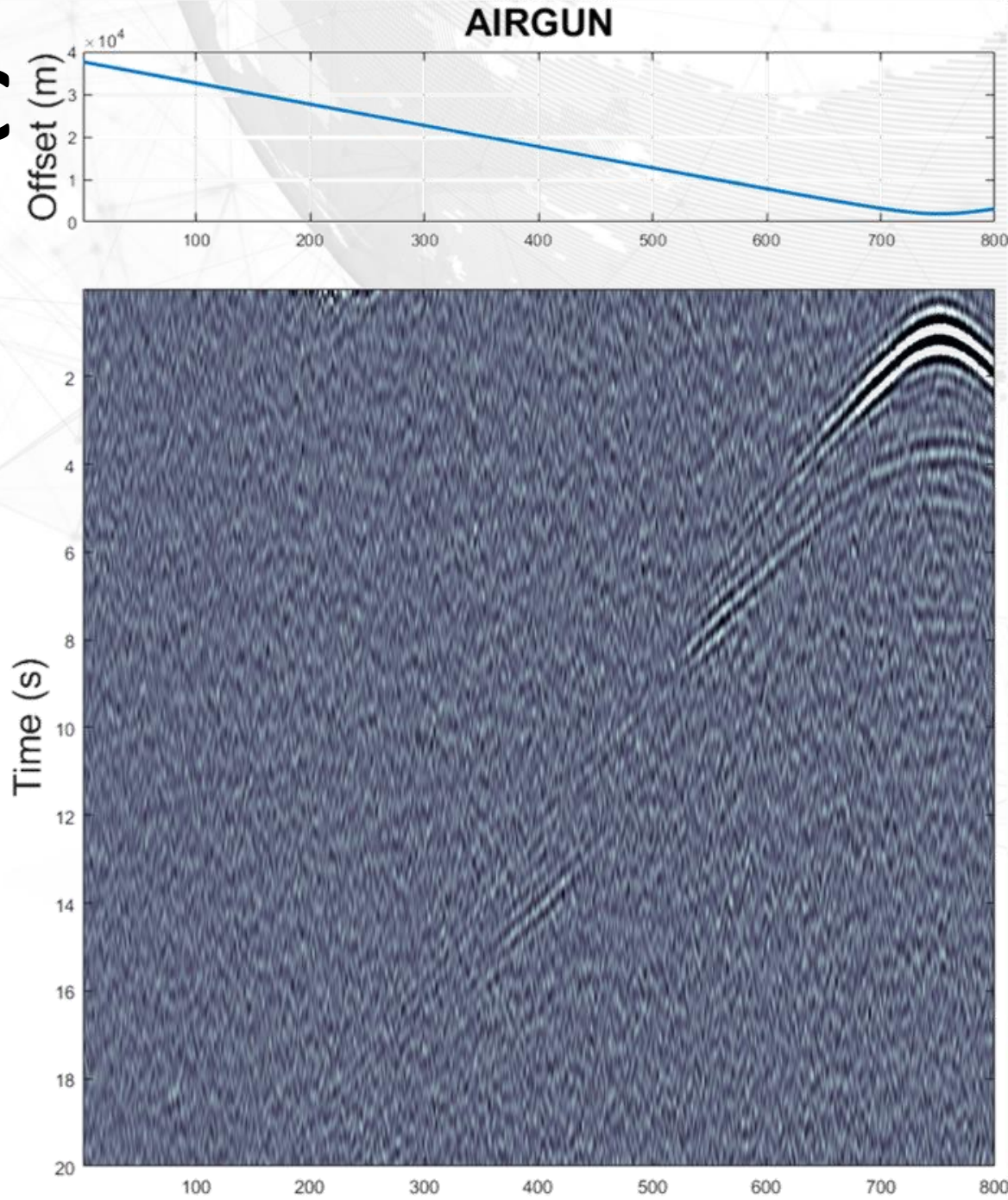
3 Hz HC



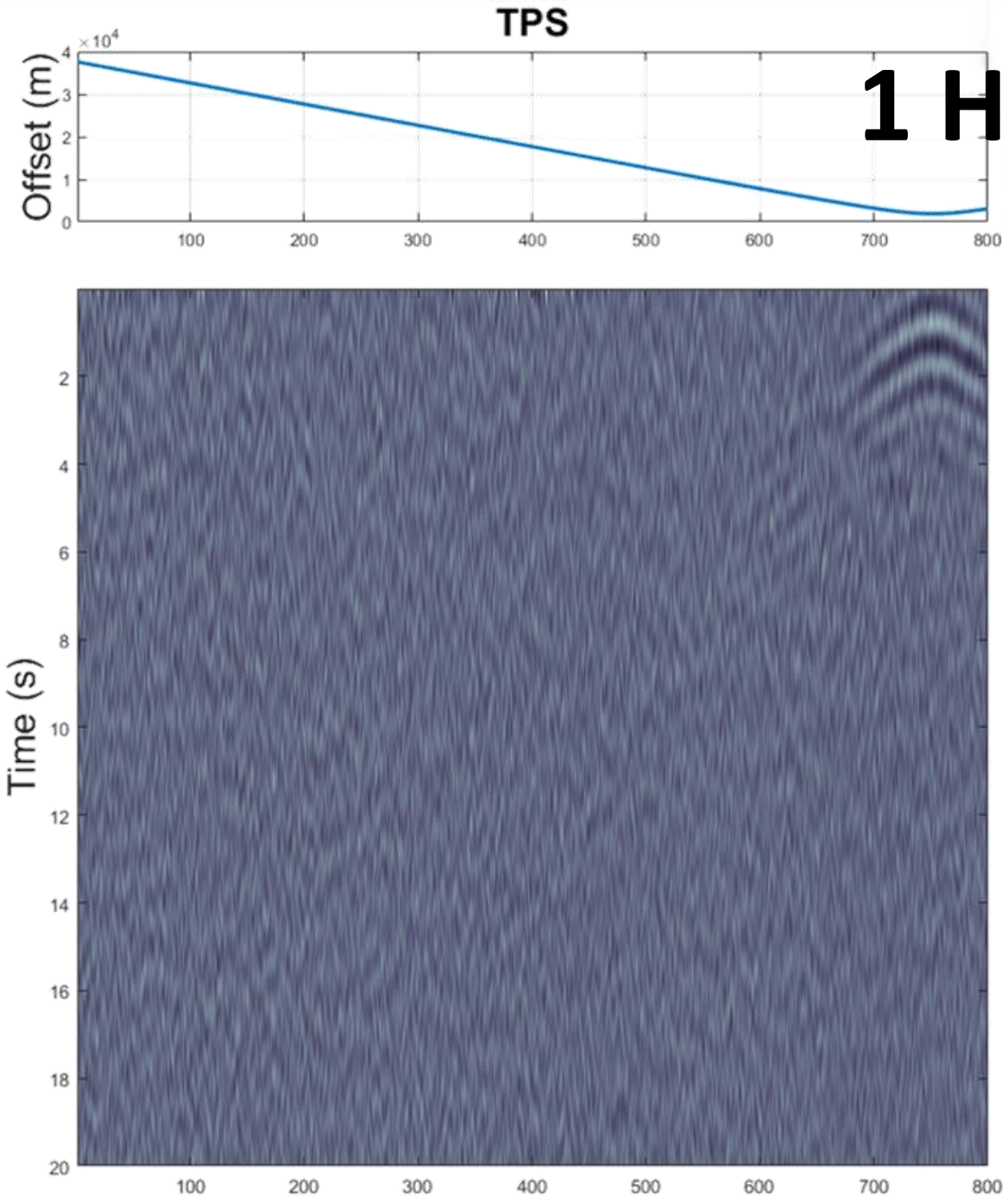


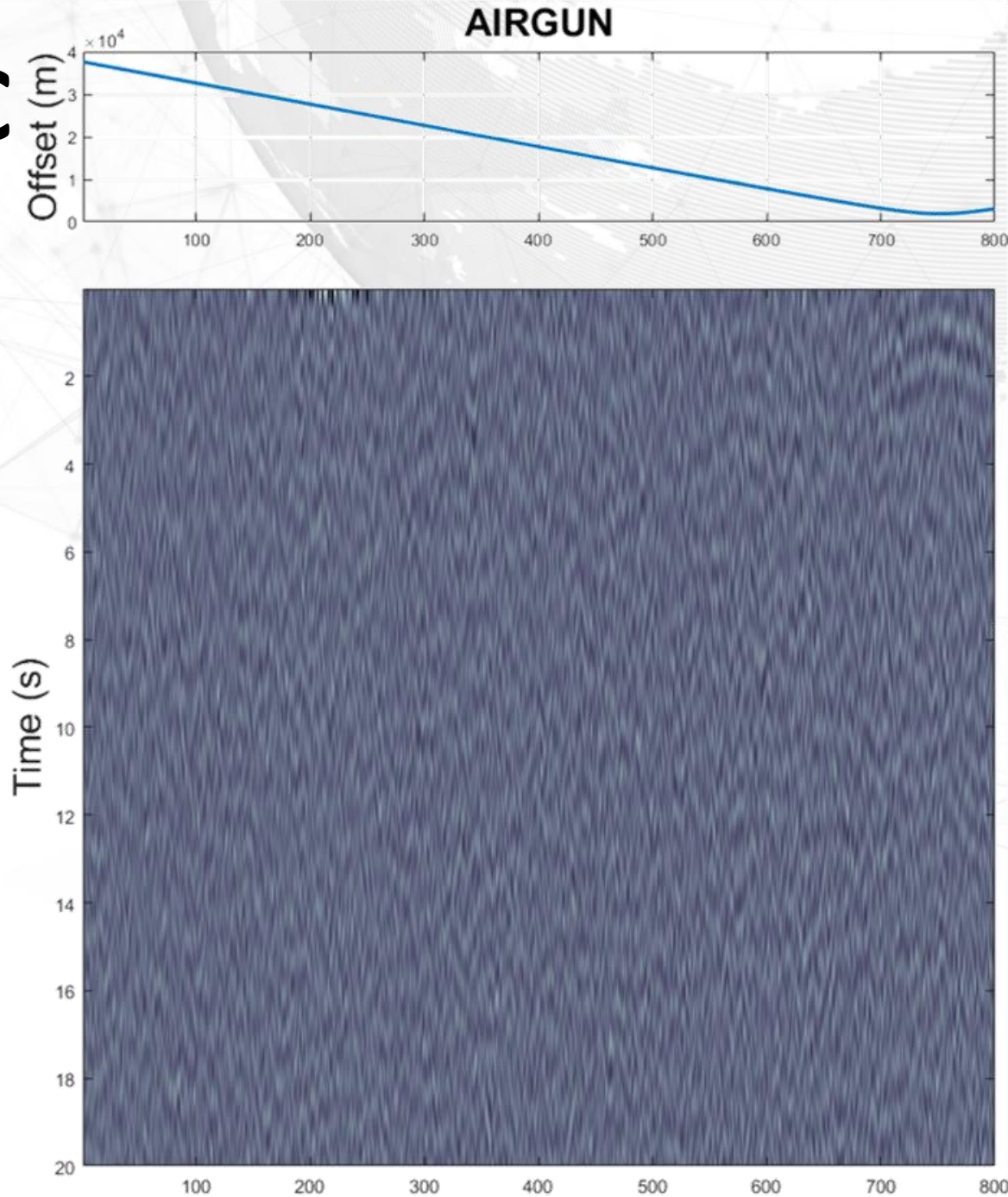
2 Hz HC

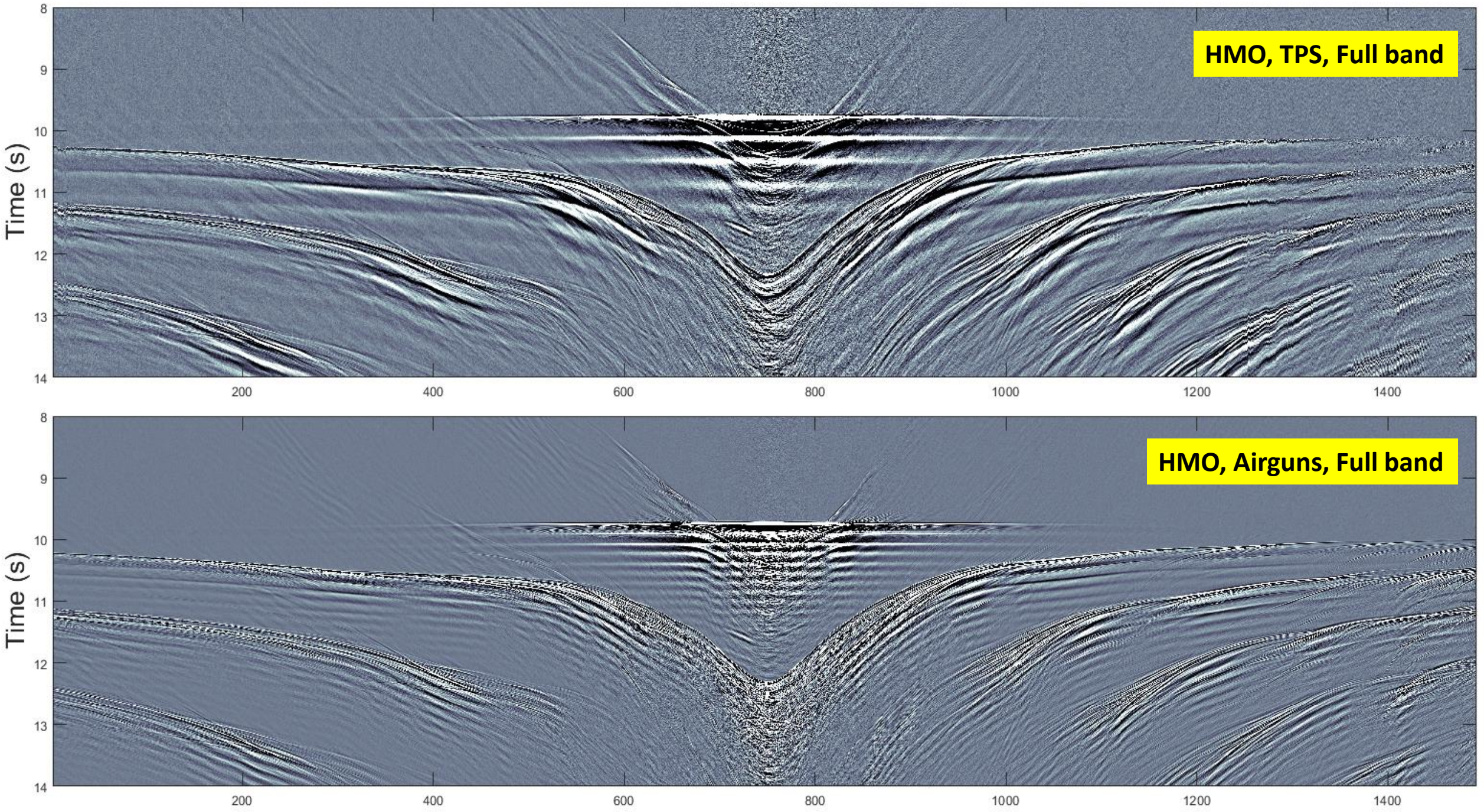




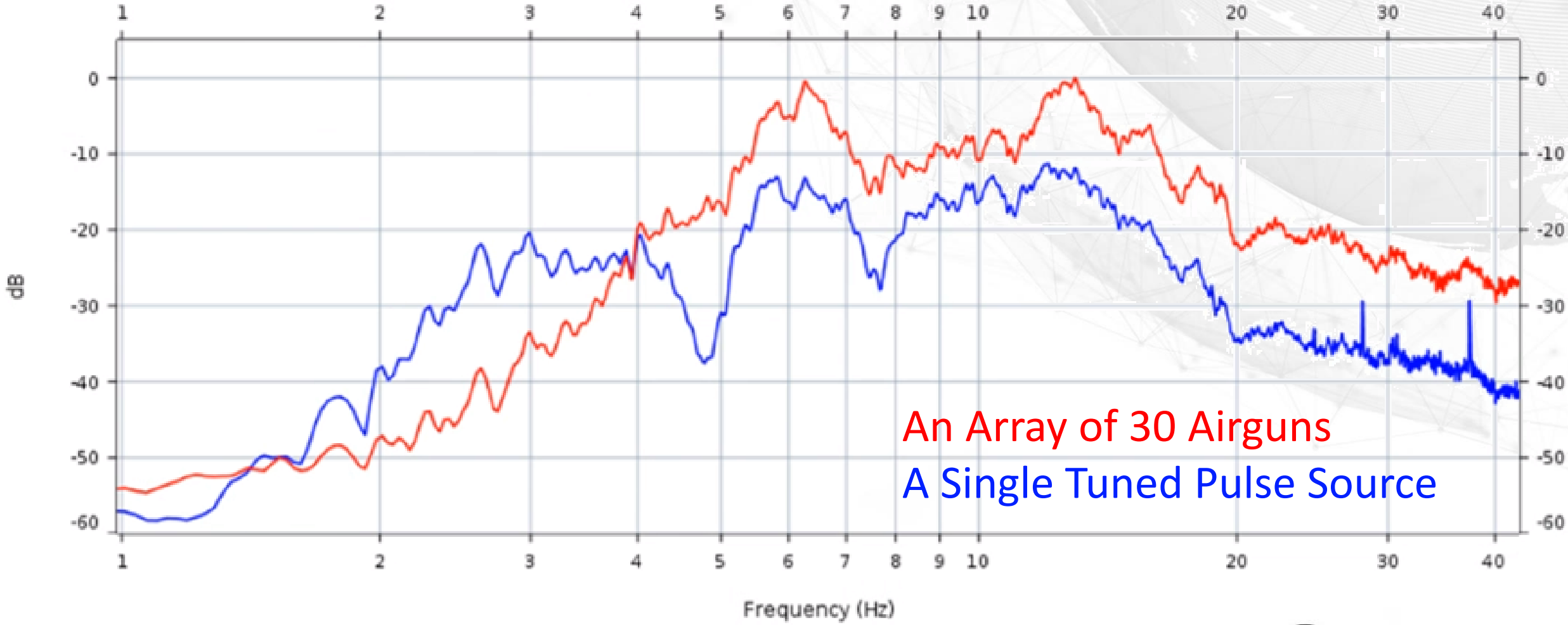
1 Hz HC






HMO, TPS, Full band
HMO, Airguns, Full band
Time (s)
8
9
10
11
12
13
14
200
400
600
800
1000
1200
1400

Spectral overlay (average OBN data)

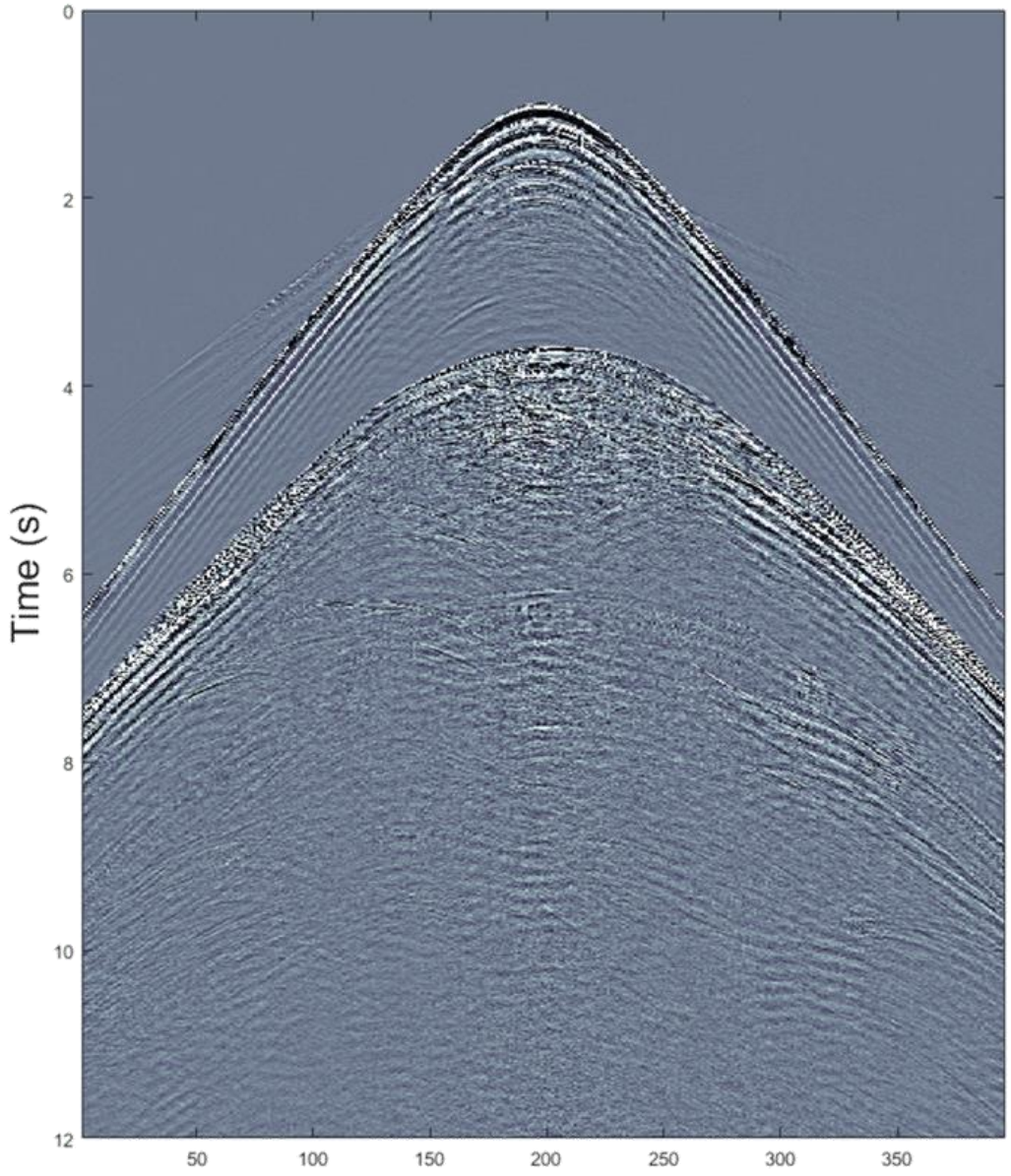


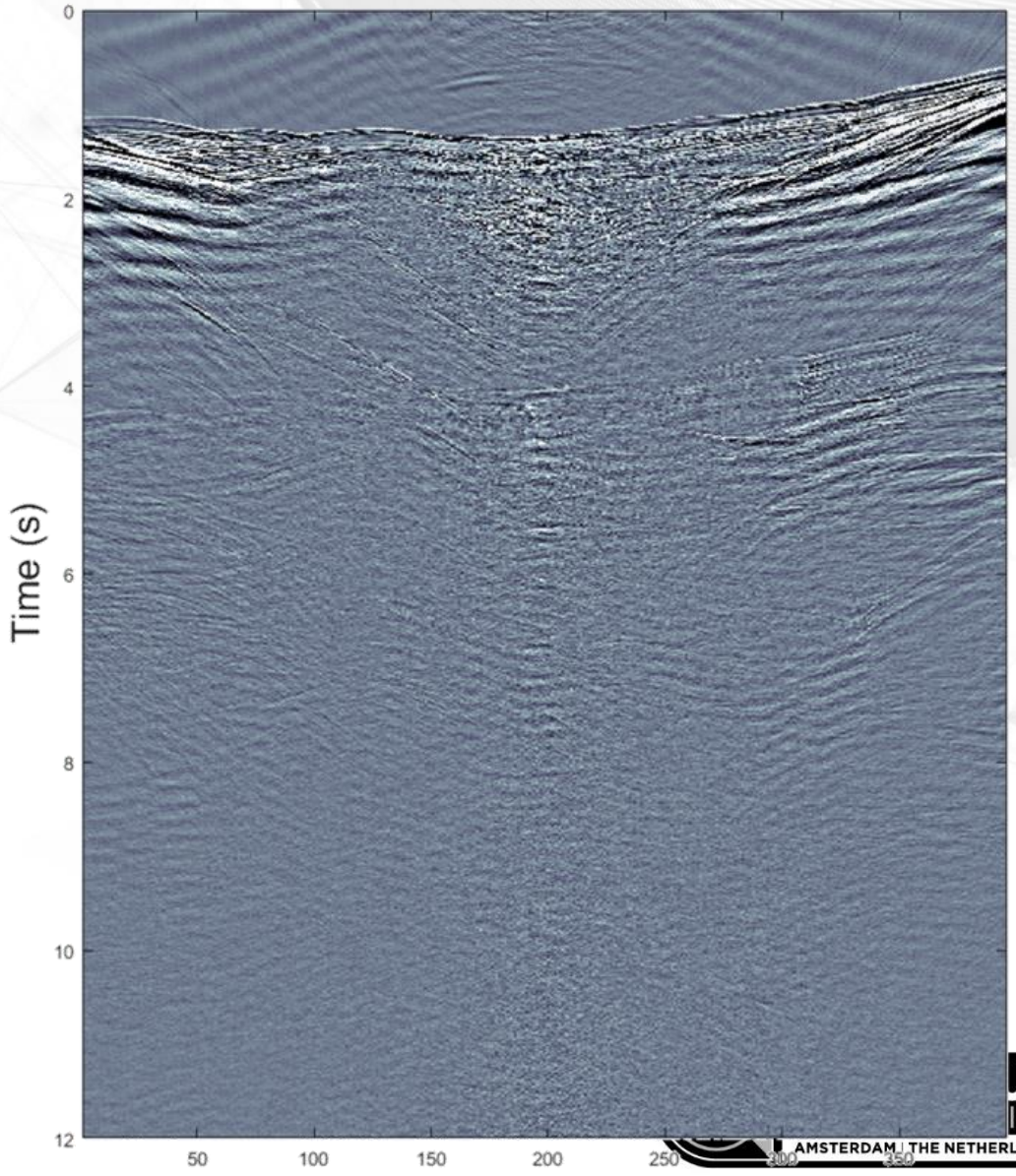
2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Next few slides

- (Poor man's) Mirror Imaging
- One node's common receiver gather
- One shot line
- Spherical spreading (tpow) gain
- Normal moveout (NMO)
- Select the first multiple which is the mirror image
- That's it, just display it
- Airgun array and TPS
- Full band and High cut

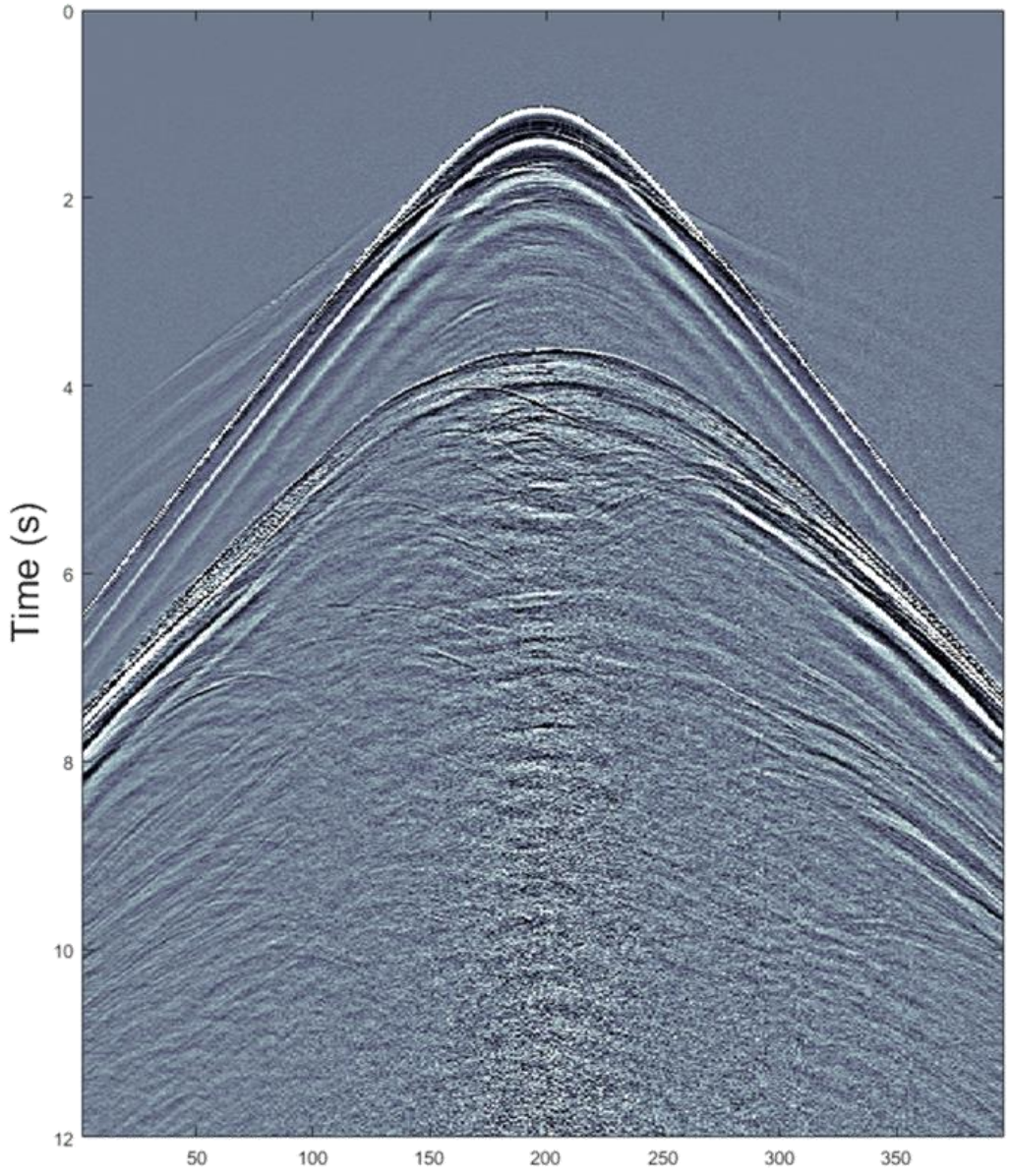
Airgun array—full band, NMO

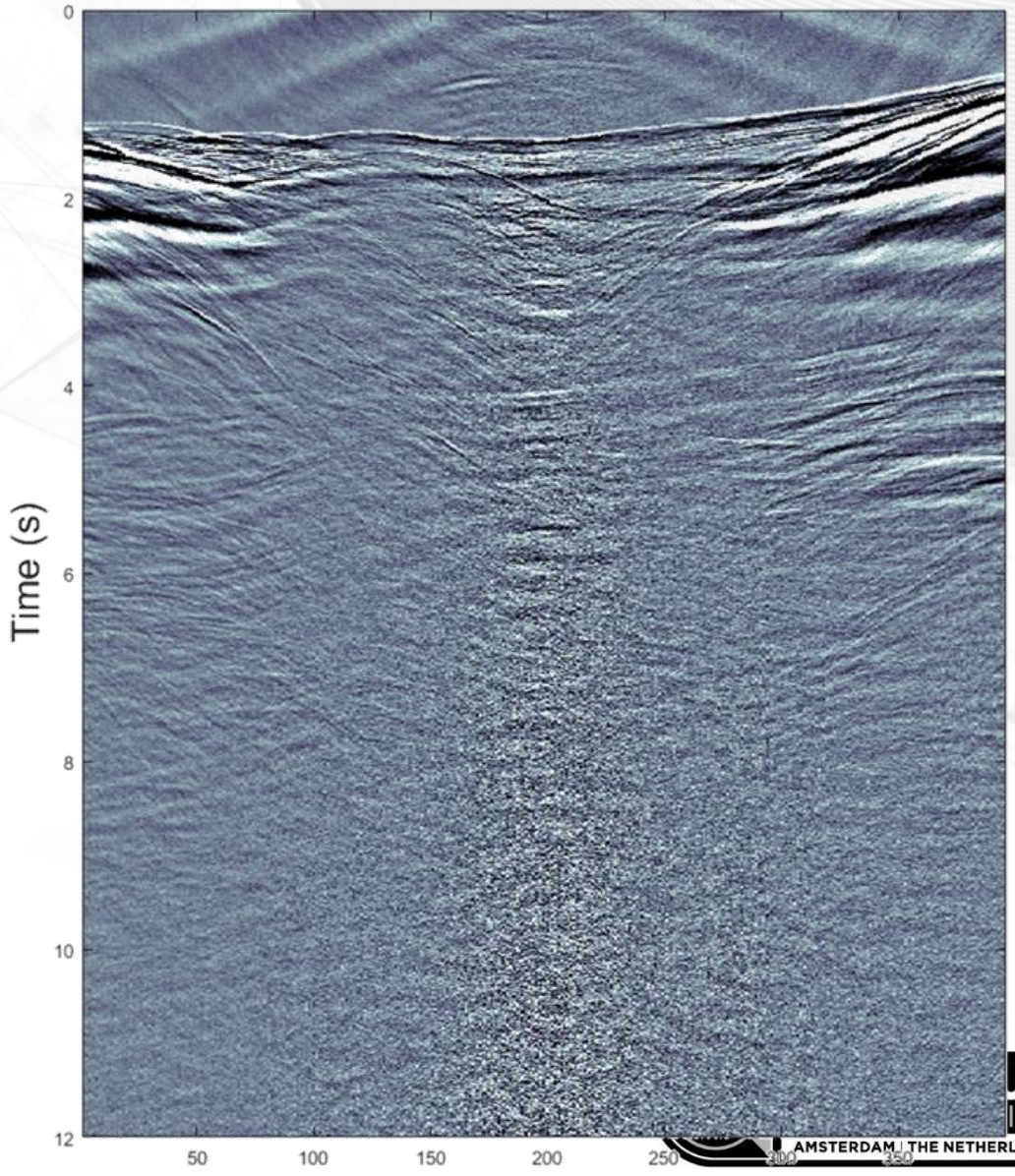




AMSTERDAM | THE NETHERLANDS

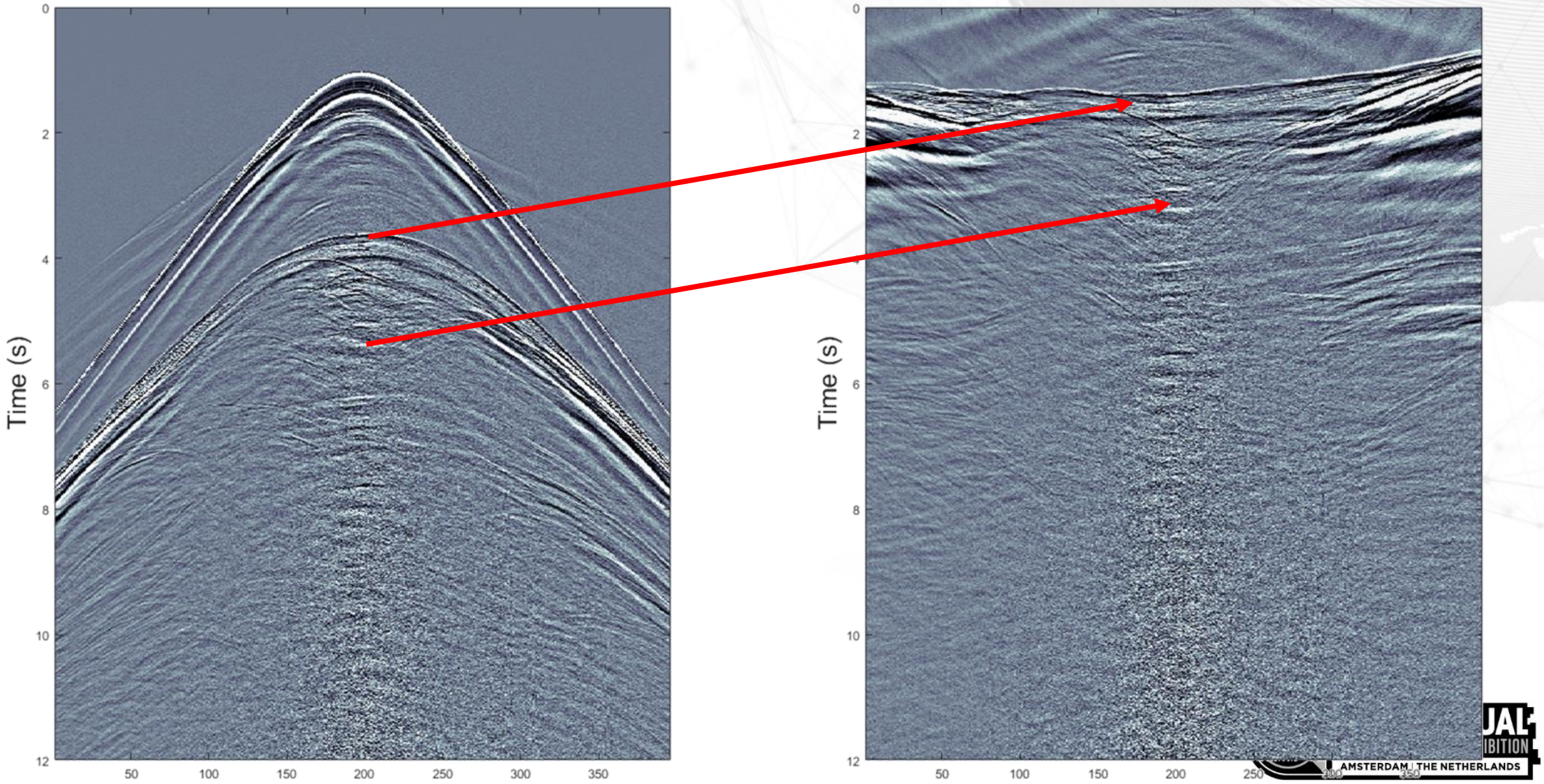
TPS—full band, NMO



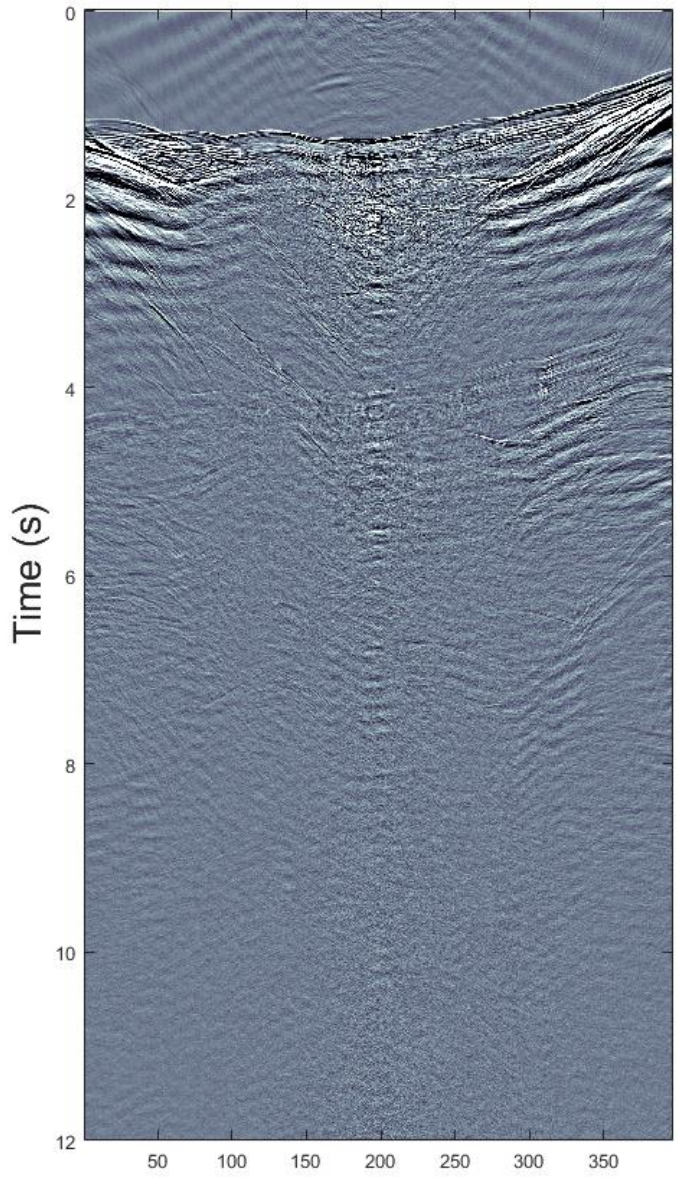


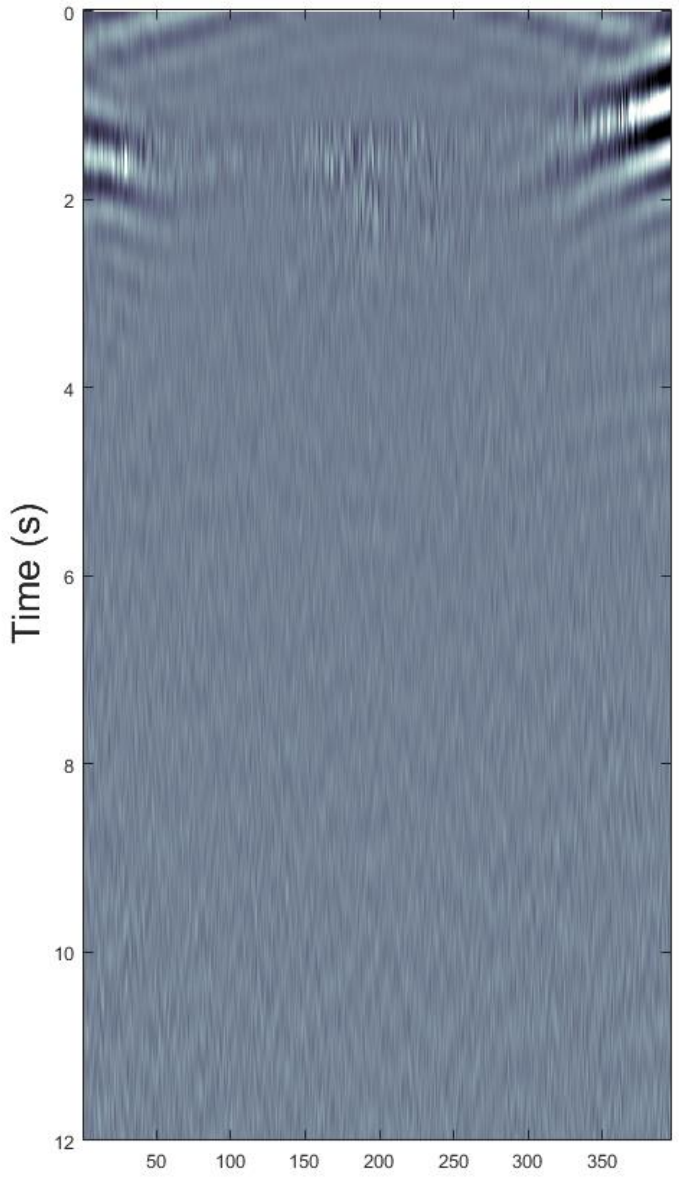
AMSTERDAM | THE NETHERLANDS

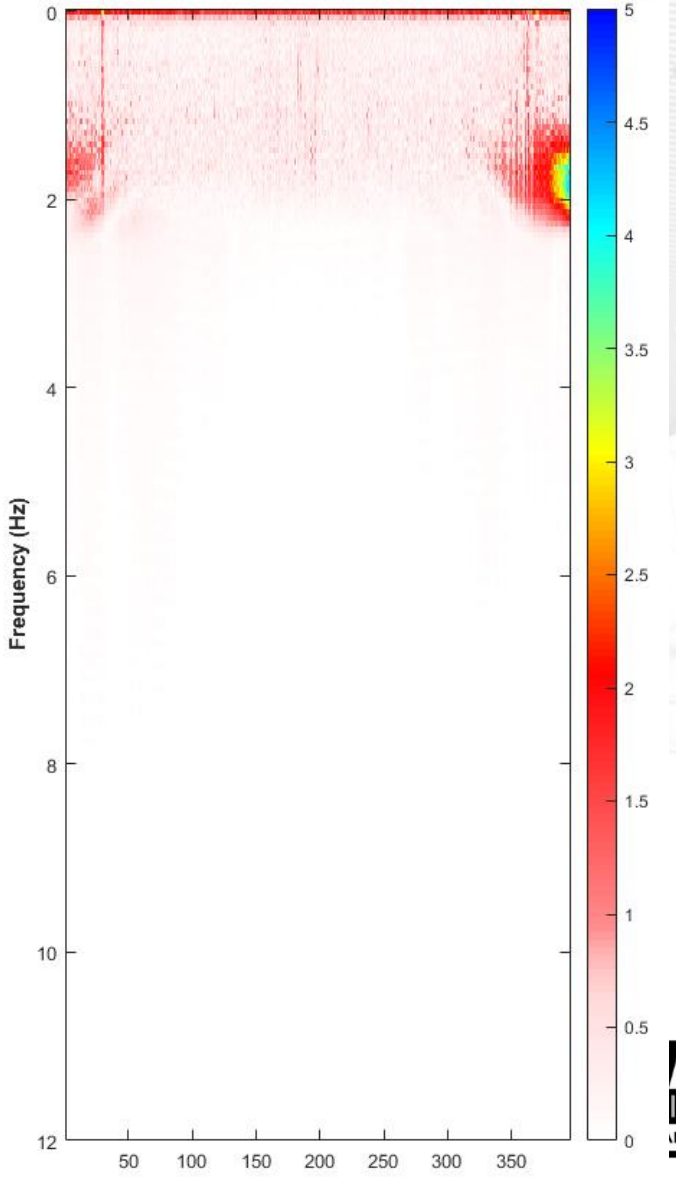
TPS—full band, NMO



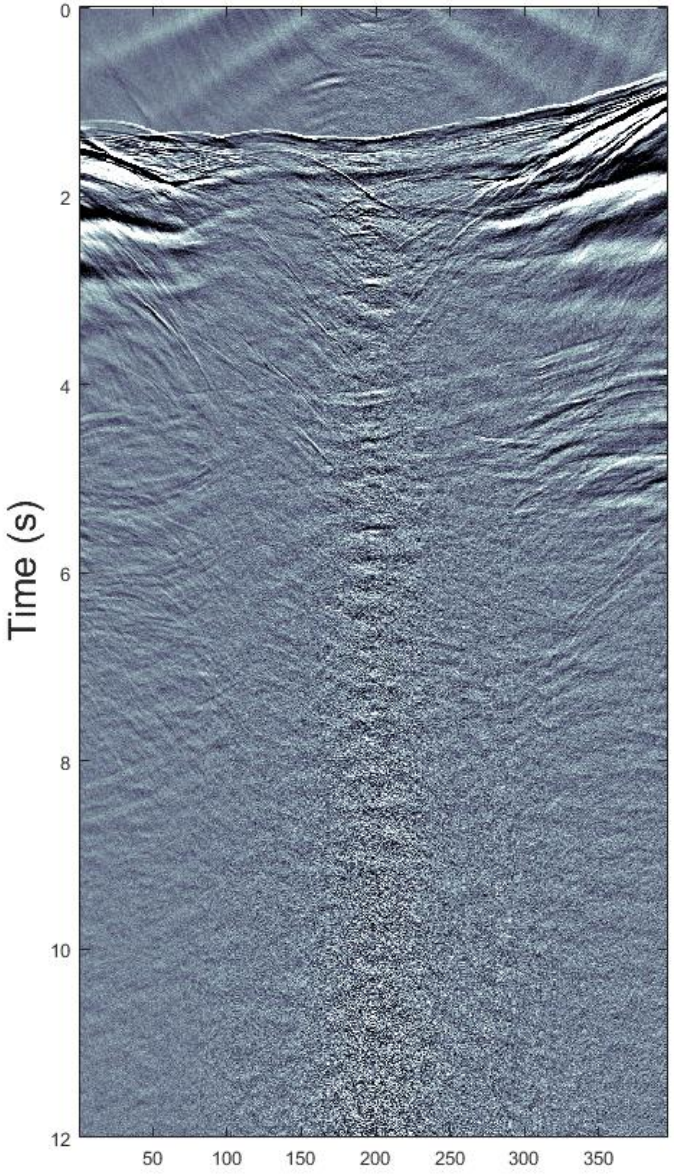
Airgun array—2 Hz High Cut

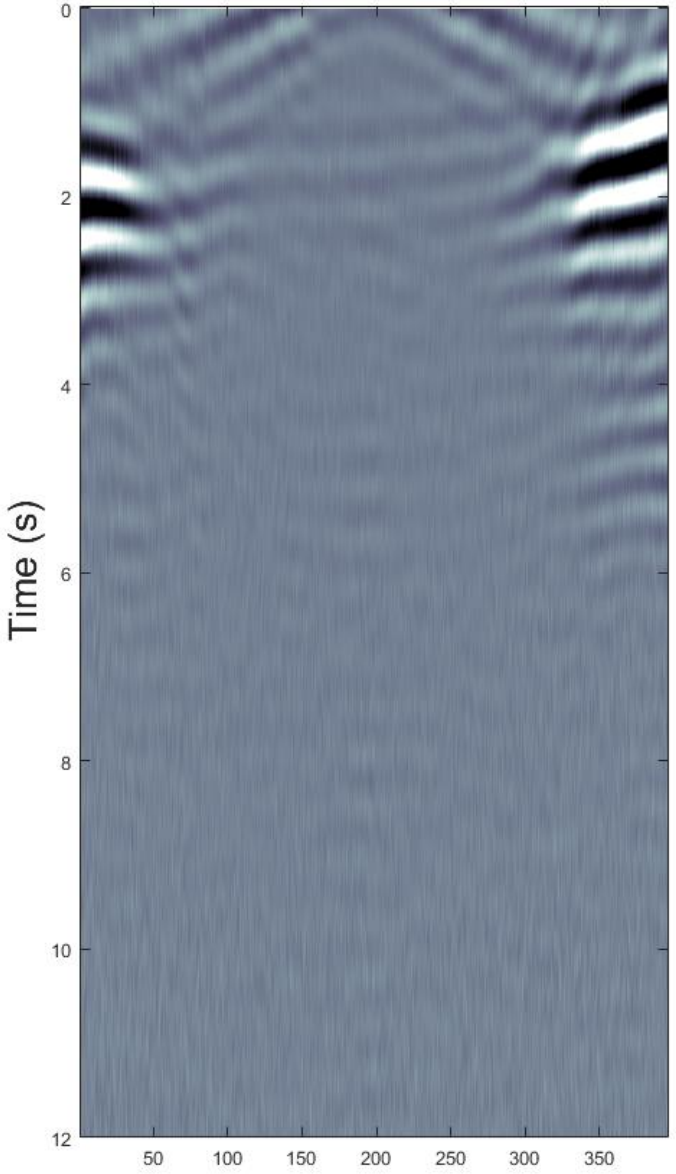


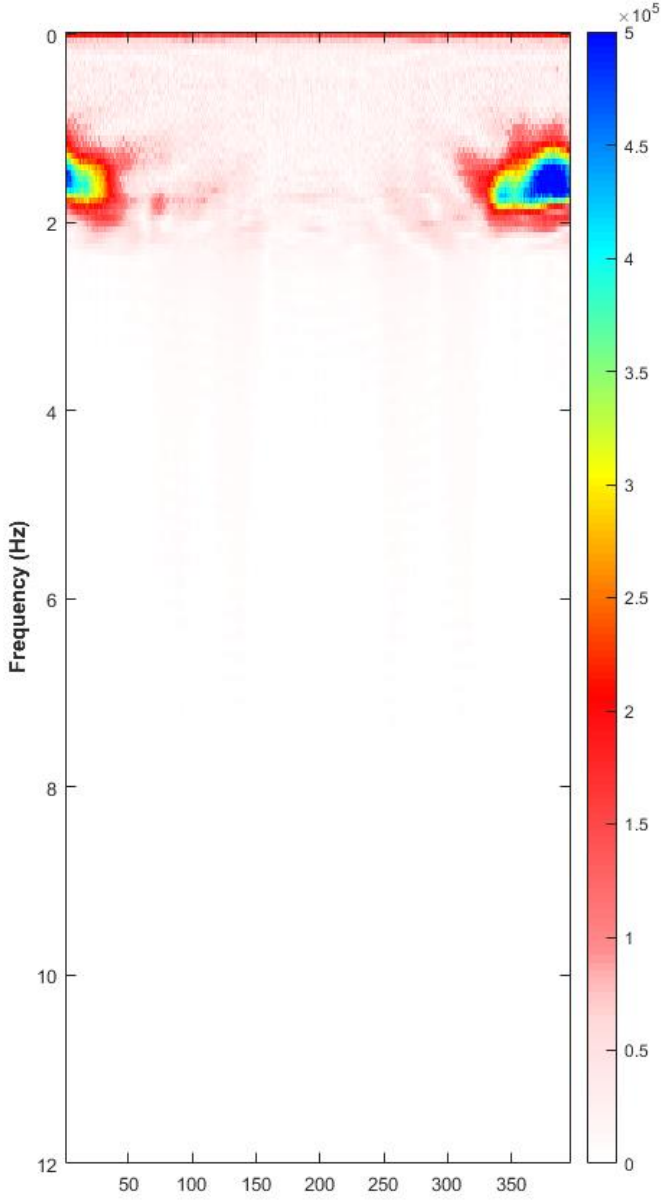




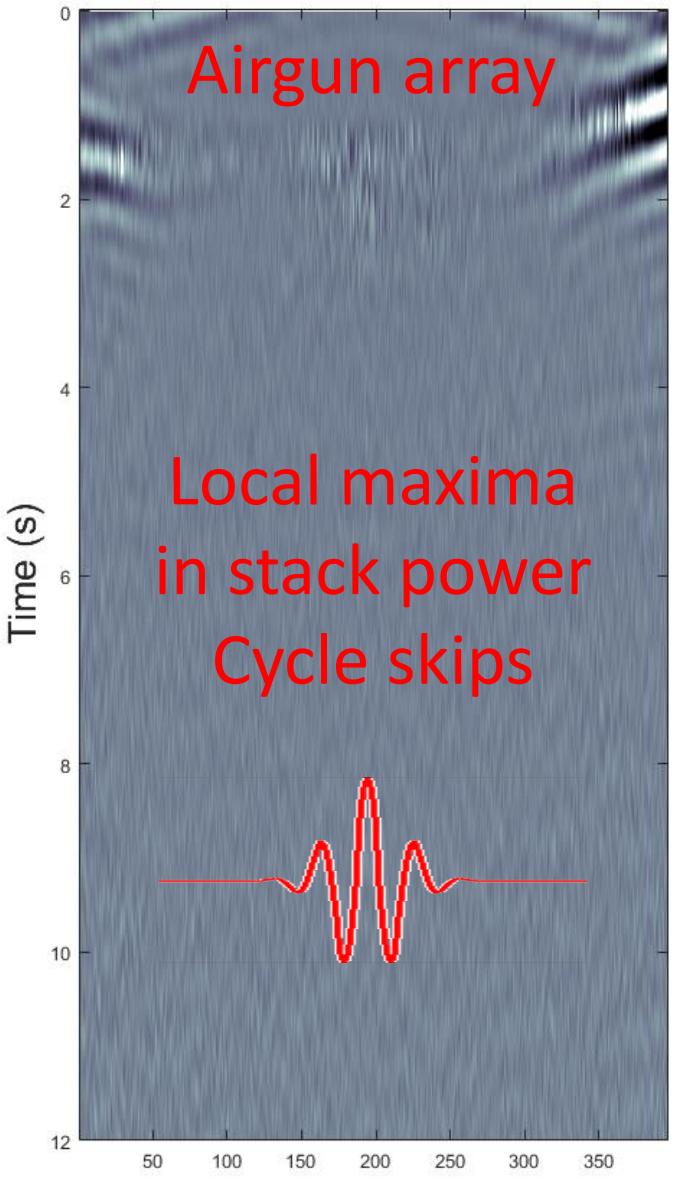
TPS—2 Hz High Cut

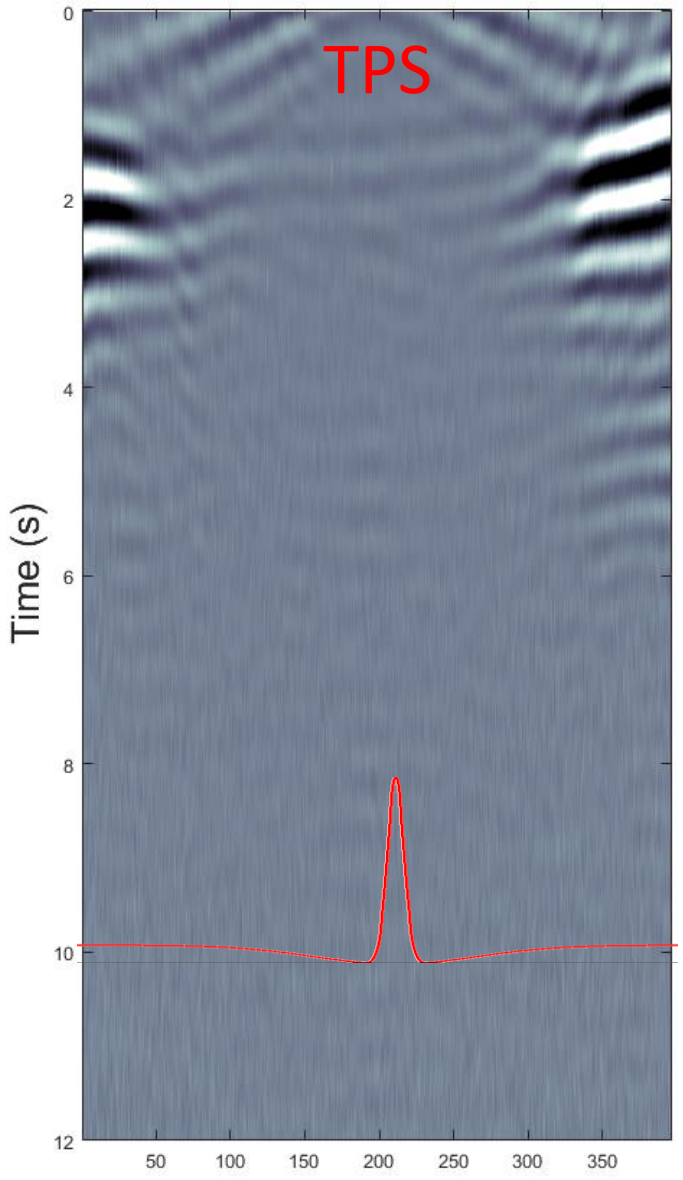






TPS Vs AG—2 Hz High Cut





This is single fold, single shot line, trace by trace NMO and tpow gain. No migration, no demultiple, no stacking

Full CRG: 50x50 meters shot carpet, 3D migration → Fresnel zone stacking, improved S/N

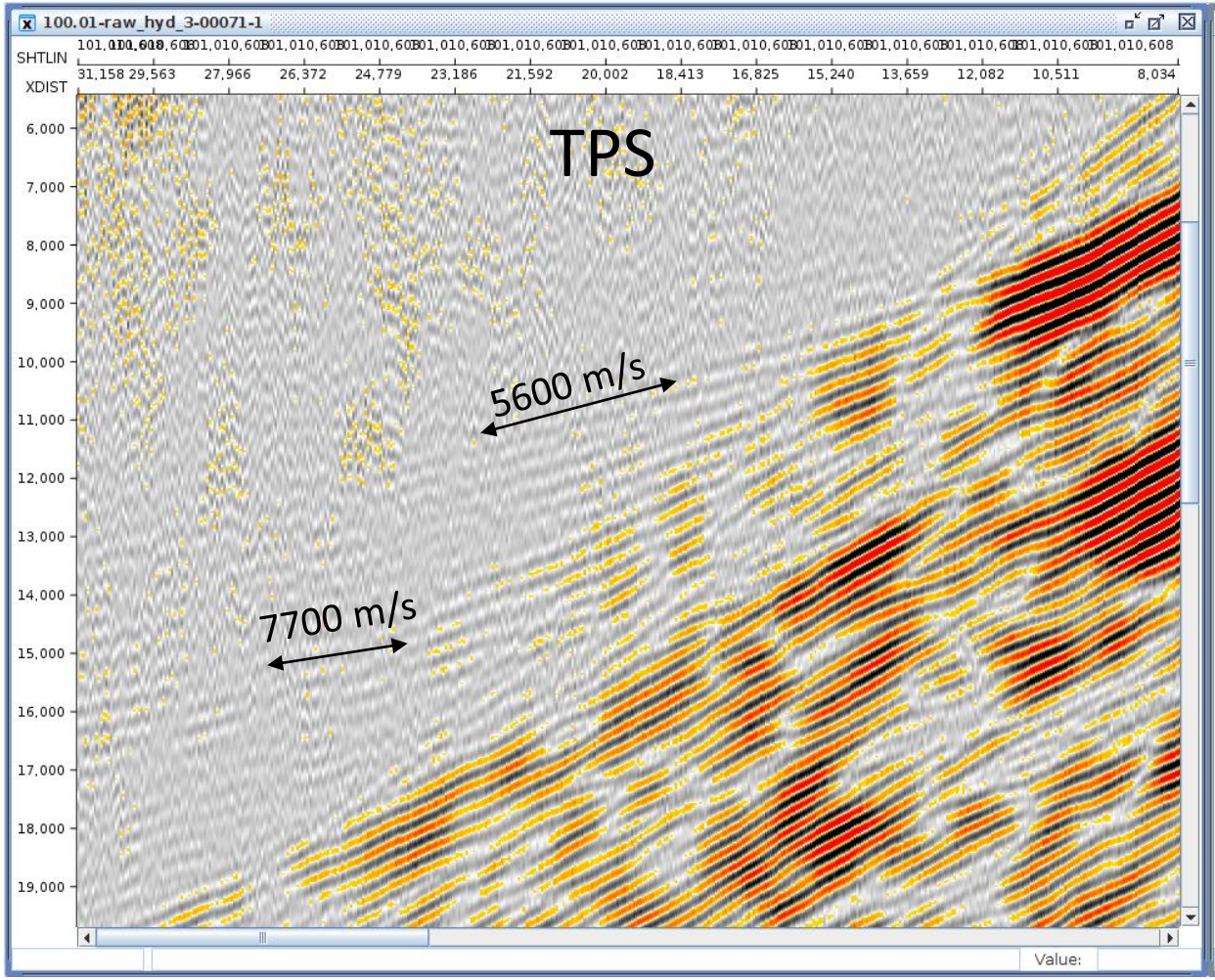
Stacking OBNS:

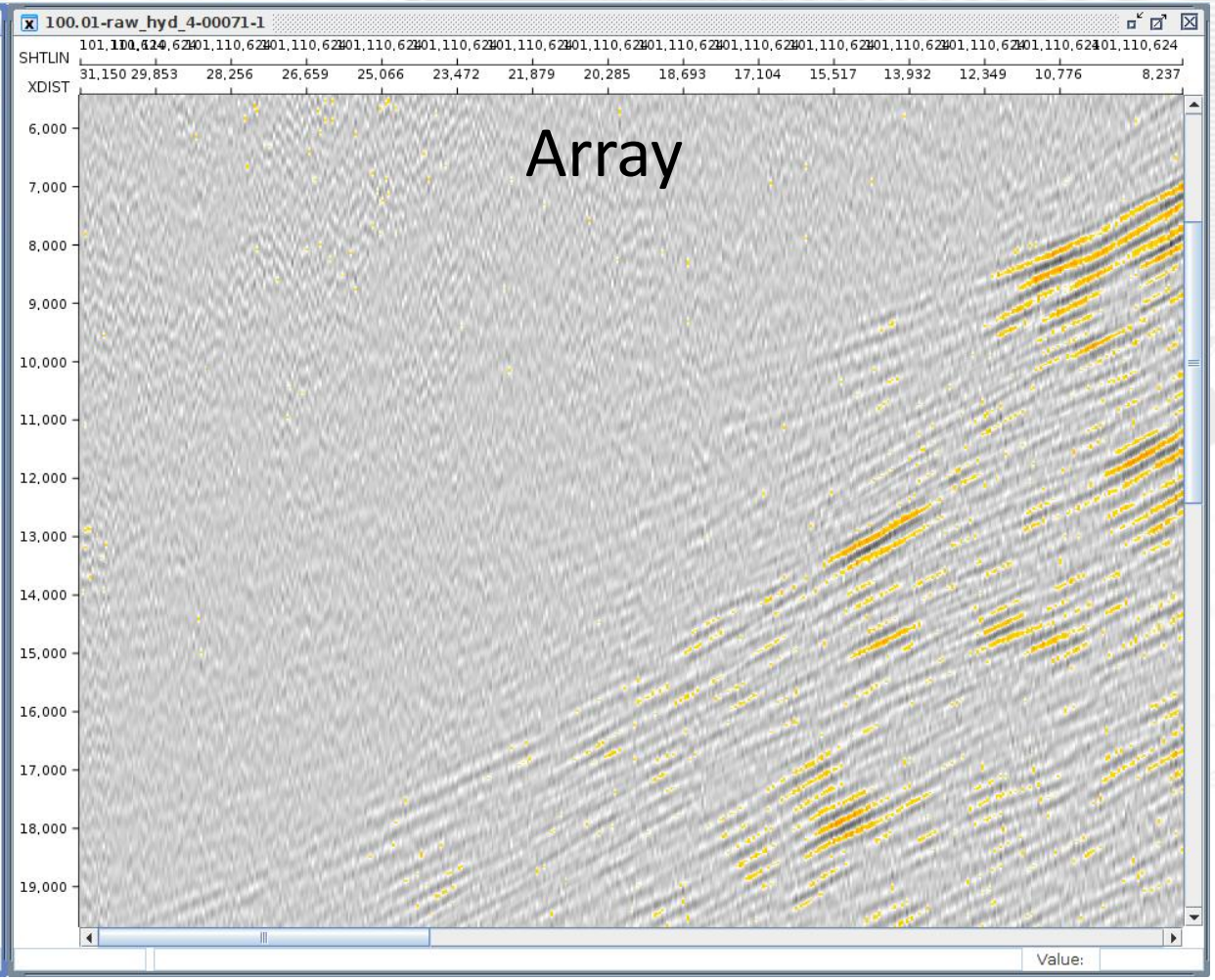
→ Improved S/N

→ FWI = find the optimal velocity model to maximize the tack power

2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Maybe one interpretation slide





2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Summary: How low can we go?

- Hard number: the bubble frequency was 2.6-2.8 Hz
  - The difference was the source depth (8 meters, 10 meters)
  - Same volume (26,500 cubic inch) and same pressure (1,000 PSI)
- Soft number: what is the lower limit of useful signal? (26Kcui)
  - Waves in the water (not very useful)—under 1 Hz
  - Refractions and reflections (useful signal)—under 2 Hz
- 26Kcui is not the upper limit. We will go much higher in volume (and cubic root of much lower in frequency)
- Expecting significant improvement in sub-salt, sub-basalt, FWI (Full Waveform Inversion), blocky model building, and resolution

Acknowledgements

- Shell for funding LISS and providing support in physics and geophysics
- George Steel who took LISS to a successful delivery
- TGS and WesternGeco and the crew of the Sanco Atlantic
- Sercel who bought LISS and quickly got on top of the technology
- MagseisFairfield and the crew of the Artemis Atlantic

- Special thanks to data analysis by Zijian Tang and Stephane Laroche

2021 EAGE ANNUAL
82ND CONFERENCE & EXHIBITION
AMSTERDAM | THE NETHERLANDS

Acknowledgements—fine print

Steve Chelminski, Claire Zopf, Gareth Williams, Stuart Denny, Shuki Ronen, Tim Wells, George Steel, Paul Chelminski, Robert Hobbs, Joe Dellinger, Jay Huang, Guido Baeten, Boris Kuvshinov, Dhwajal Chavan, Fons ten Kroode, Wim Walk, Jan Chelminski, Stephen Hallows, Fred Chelminski, Jon Claerbout, Eric Dunham, Leighton Watson, Joe Jennings, Fred Lam, Matt McDonald, the crew of the Sanco Atlantic, Gaetan Mellier, Daniel Boucard, Julien Large, Rich Kelley, Andrew Lawrence, the crew of the Artemis Arctic, Zijian Tang, Stephane Laroche, Philippe Hermann, Stephane Baris, Philippe Feugere, …