TNO SEISMIC ACQUISITION FIELD TRIALS IN THE NETHERLANDS

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TNO innovation for life

OVERVIEW

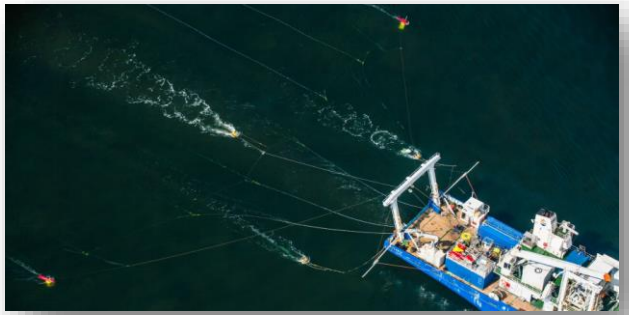
- Seismics @TNO
- P18, 3D HRS
  - Goal & Setup
  - Results & Application
- De Peel, Ambient Noise Seismic Interferometry
  - Goal & Setup
  - Results & Application
- Acknowledgements

SEISMICS @TNO

- Innovative acquisition methods
  - Off- and onshore
- Innovative processing methods / algorithms
  - Pre-stack & post-stack
  - On active & passive seismic recordings
  - Imaging/visualisation purposes and event detection and location
- Seismic inversion (time lapse) and QI
  - Monitoring of EOR and CO_2 injection

- P18, 3D HRS
- De Peel, ANSI

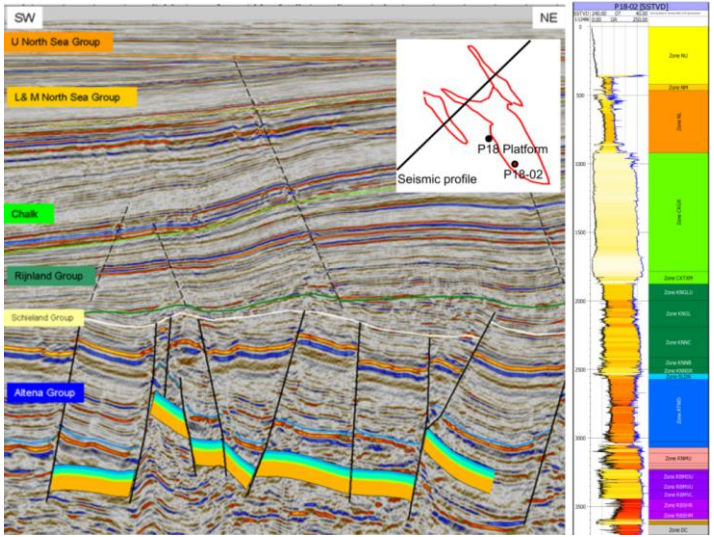
P18 3D HRS - GOAL & SETUP



- Within the CATO-2 TNO and partners performed a pilot for baseline monitoring of the overburden of P18-4
- Focus on characterization of the shallow subsurface, with emphasis on bright spots, potential migration pathways, faults & seabed features
- Assess possible gas seepage or migration pathways close to the envisioned CO_2 storage site
- Perform a 3D High-Res seismic survey:
  - Test a concept for baseline assessment close to the envisioned CO_2 storage site
  - Test a concept for containment monitoring at the envisioned CO_2 storage site
  - Low cost compared to a conventional 3D seismic

P18 3D HRS – LOCATION & GEOLOGY

- Gas reservoir in Triassic rocks at over 3 km depth
- Faults of different generations, and shallow gas accumulations in the overburden



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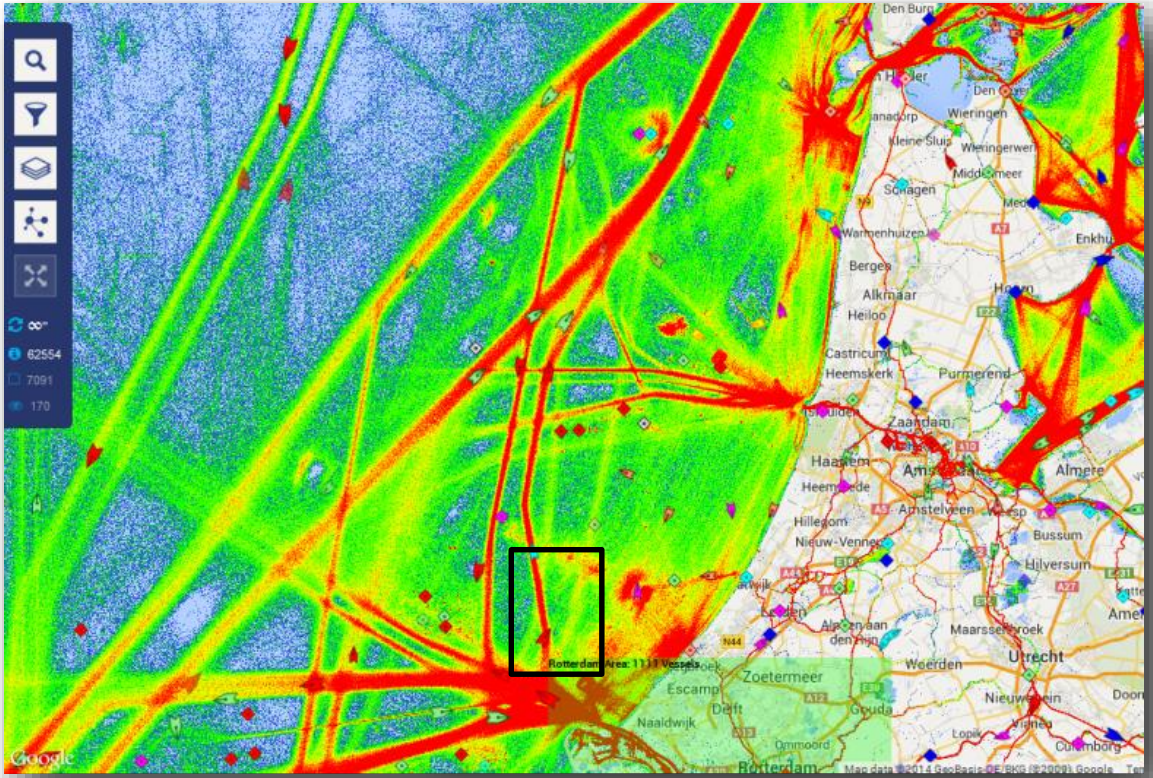
P18 3D HRS – AREA & CHALLENGES

- 2 by 3 km survey area
- 1s TWT imaging (minimal)
- shallowest events 30 msec
- Fold ~10 (6-15)

- Challenges:
  - Close to shipping lanes
  - Potentially adverse weather conditions
  - Not done before



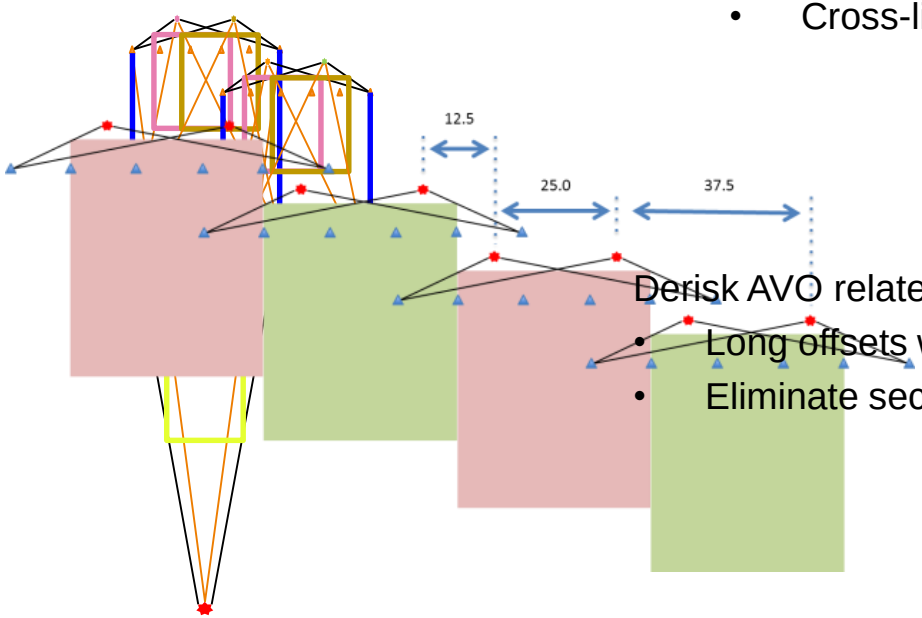
P18 3D HRS - ACQUISITION

- Initially inspired by the practical simplicity of the P-Cable concept, but extended to full offset 3D

Our system concept:

- Positioning monitoring by multiple GPS nodes
- Rudimentary depth control through initial trimming (no birds)
- Use of standard sources (Sleeve/GI guns)
- Long offset data; shot by dedicated long offset gun array*
- Deployment to take max 3 to 5 hours

P18 3D HRS - GEOMETRY



Adjacent Sail Line Fold Overlap Pattern

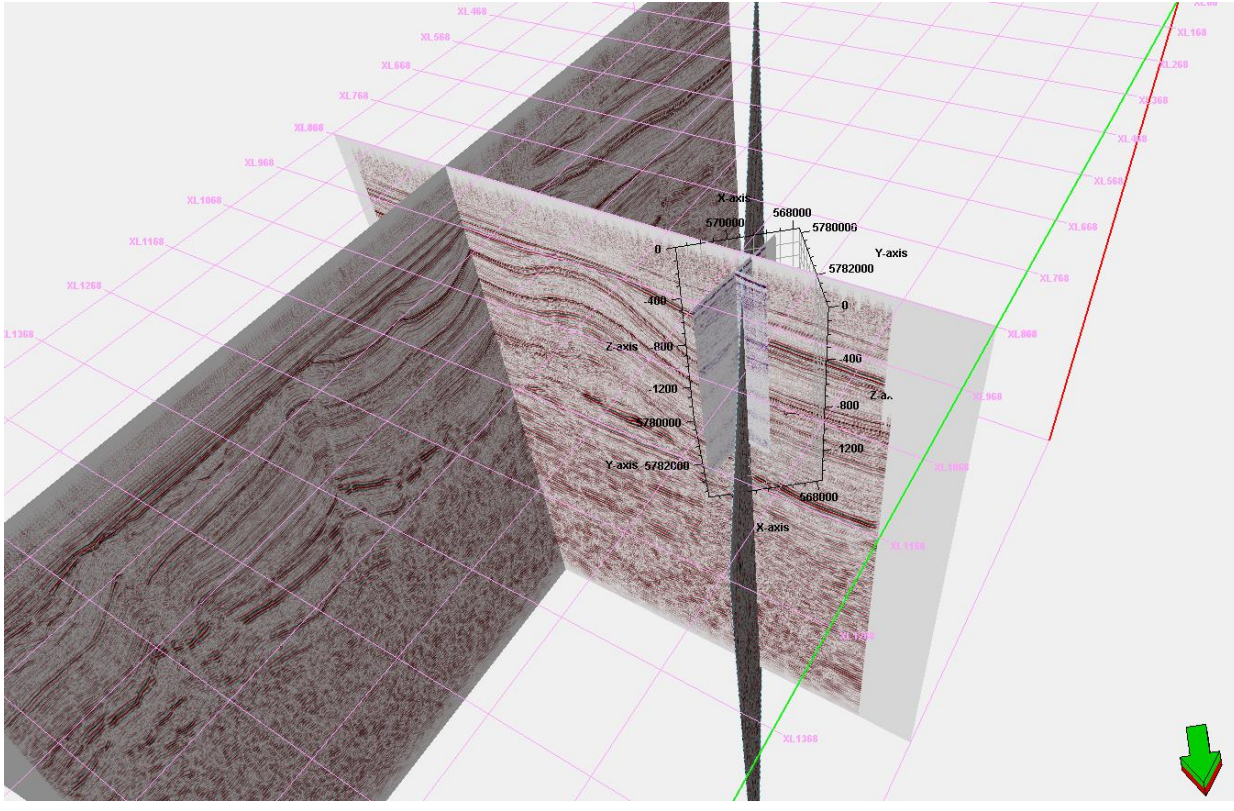
- In-line fold halved
- Cross-line fold doubled

Derisk AVO related operations:

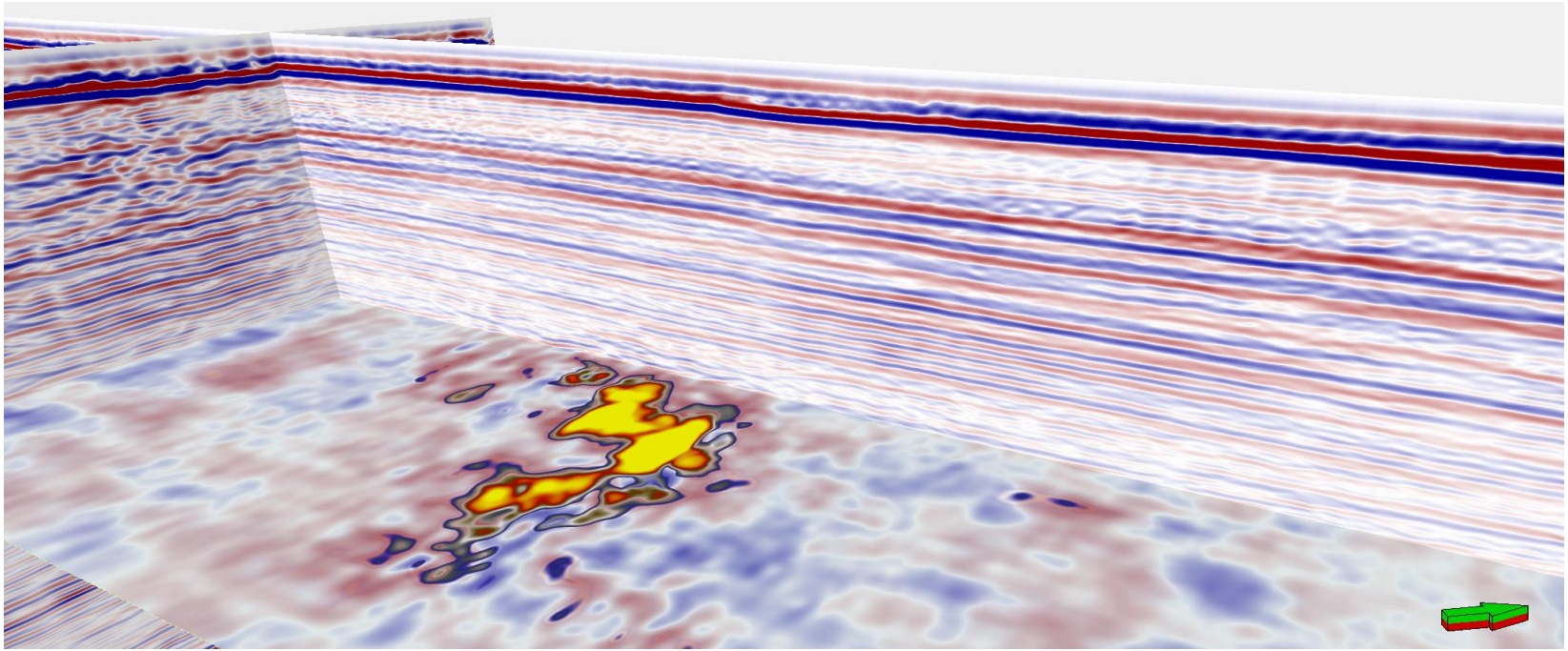
- Long offsets will be shot by a dedicated long offset gun array
- Eliminate second source vessel or long cables

P18 3D HRS - RESULTS

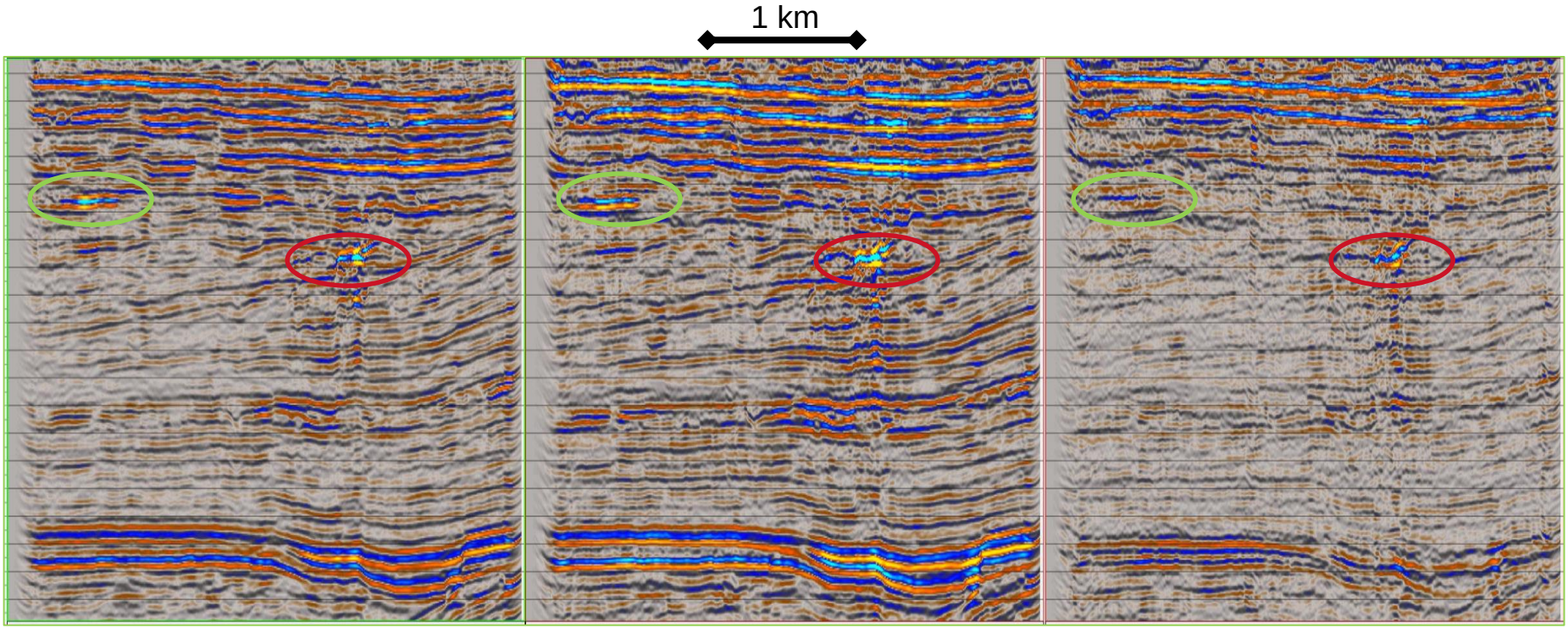
- Four processed data cubes:
  - near-far offset stacks,
  - various migration apertures
- Additional data:
  - cross-line reconstruction,
  - far off-set gun data,
  - 2-D tie line to P18-4,
  - …remain to be processed



P18 3D HRS – BRIGHT SPOT



P18 3D HRS – AVO EFFECTS



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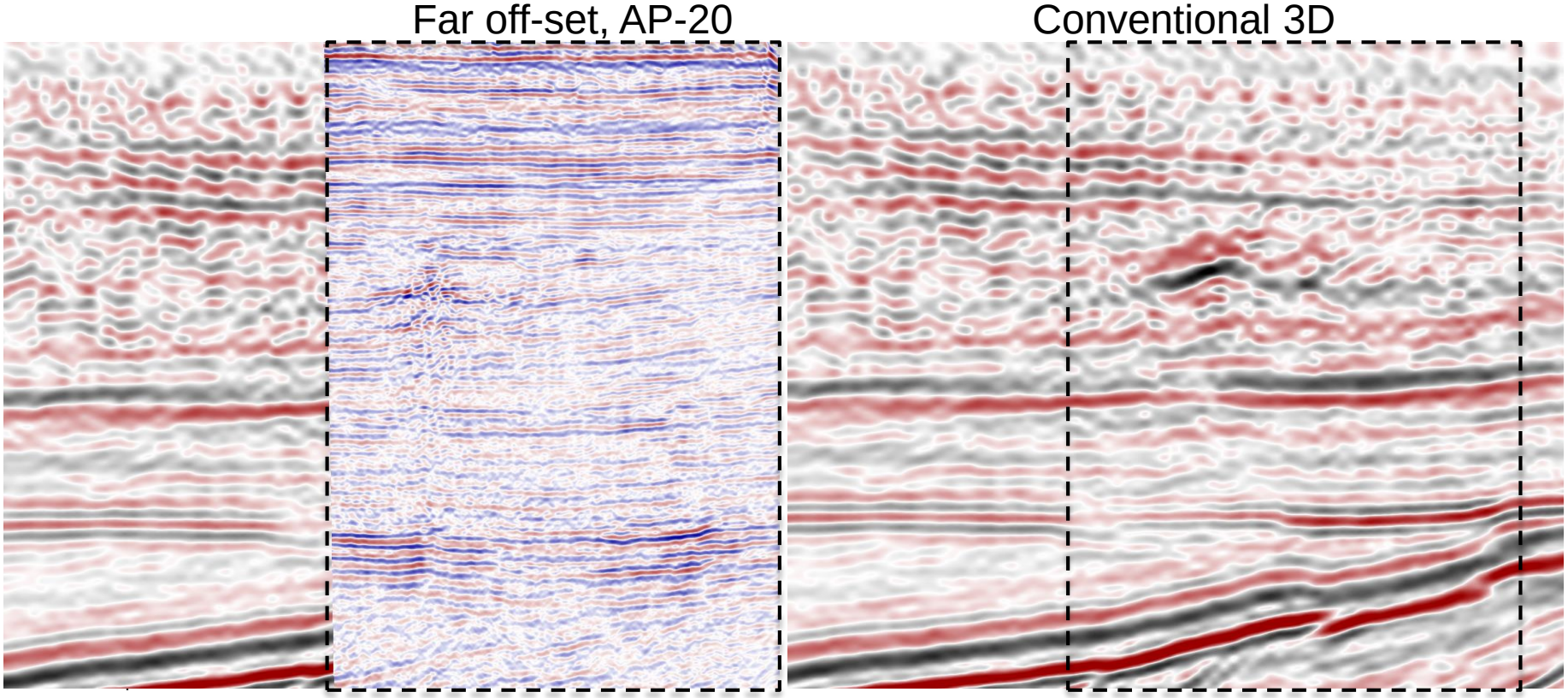
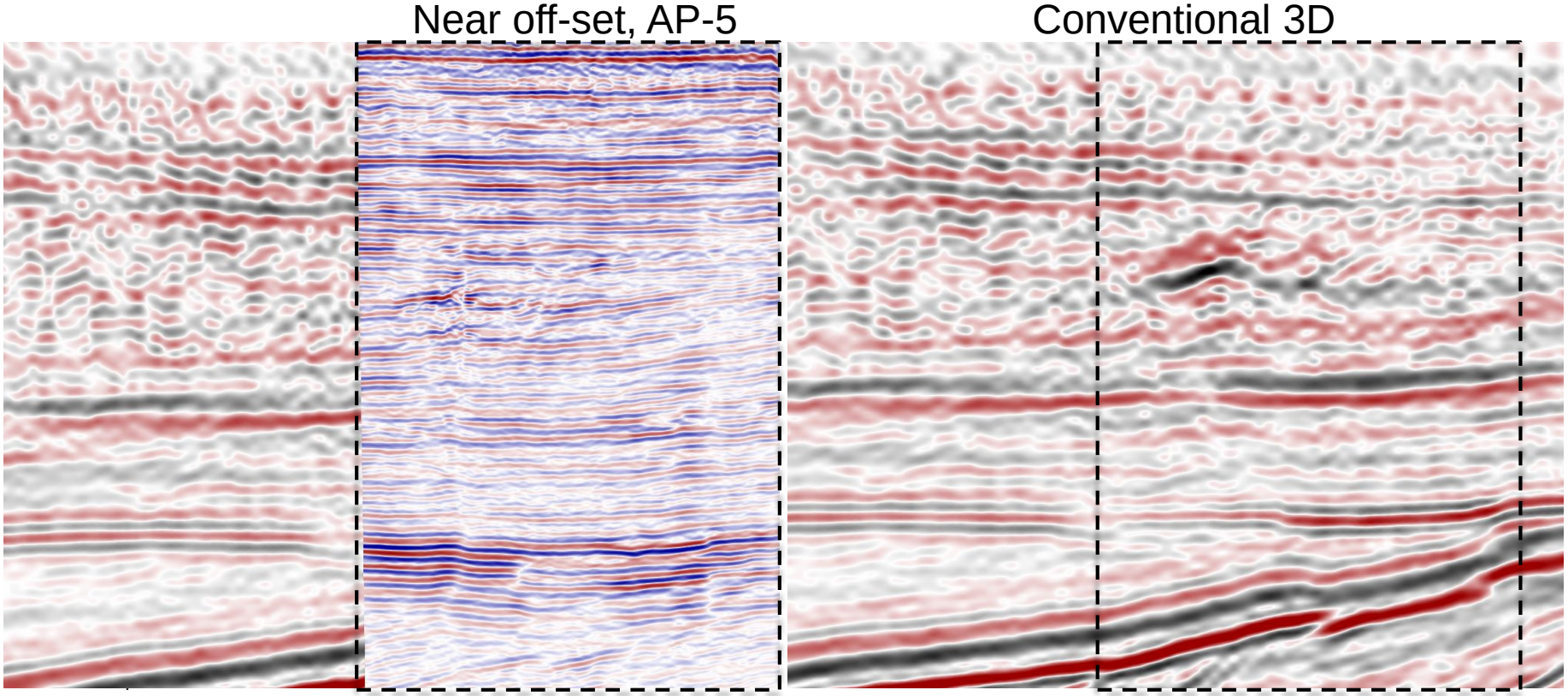
P18 3D HRS



P18 3D HRS



DE PEEL AMBIENT NOISE SEISMIC INTERFEROMETRY (ANSI)

- Part of the work presented took place under IMAGE (Integrated Methods for Advanced Geothermal Exploration, grant agreement no. 608553) a EU-funded project.

Within the IMAGE project:

- TNO was tasked to **build and test methods to obtain an improved image of the subsurface from ambient noise** recorded over long time intervals

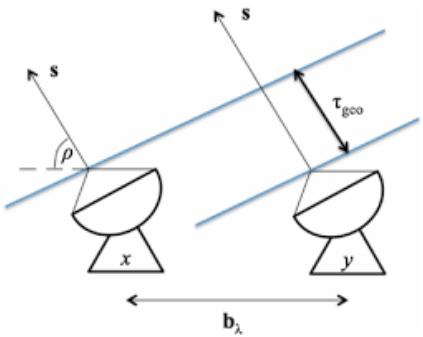
- TNO performed **acquisition** and is still **processing passively recorded seismic data**

- TNO tested and **validated the capability of ANSI to contribute to image resolution** by exploiting passive sources in conjunction with existing active seismic.
  TNO also assessed its capability for **increasing resolution of seismic monitoring**

DE PEEL ANSI – WHAT IS ANSI?

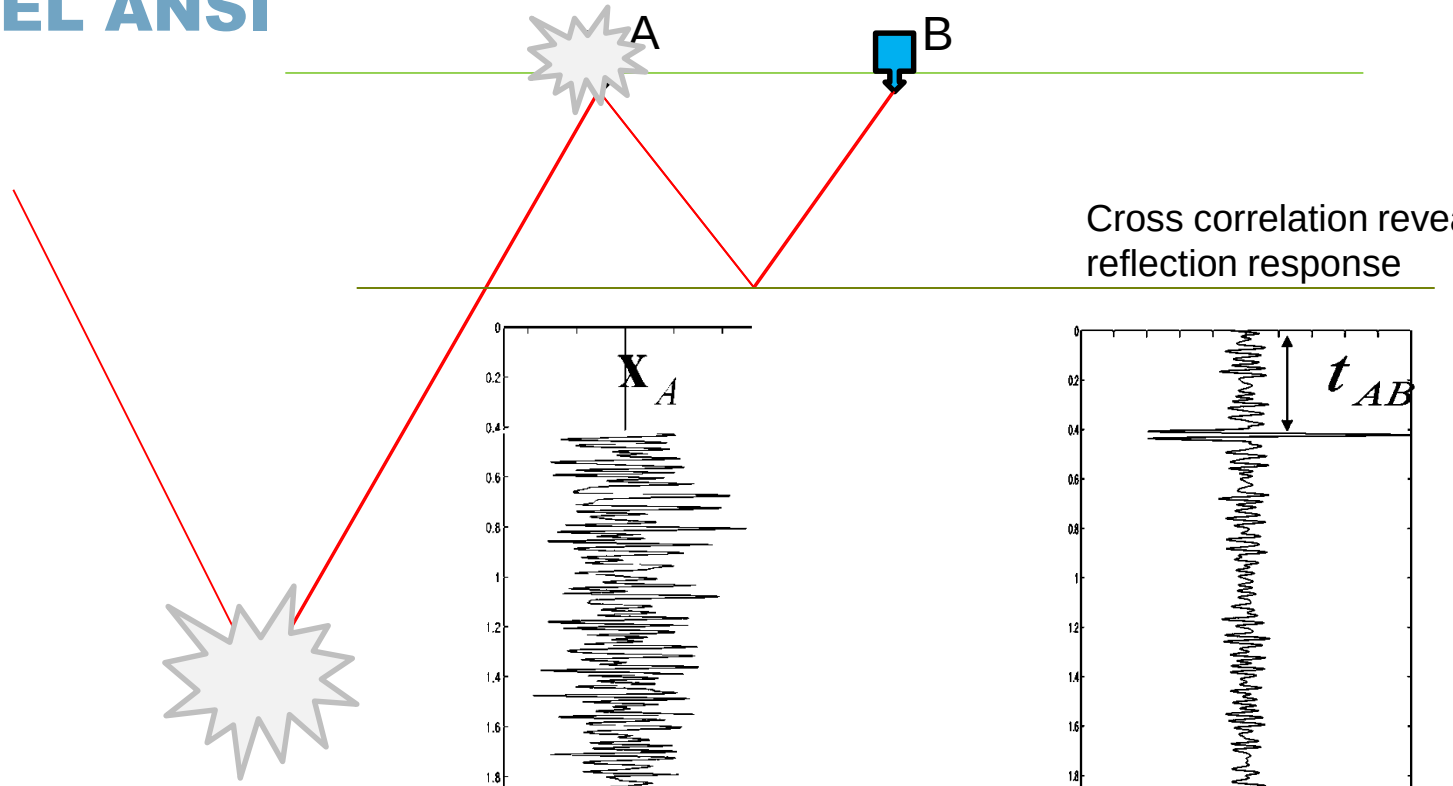
- The technique of Interferometry is widely applied over many metrological fields like: astronomy, oceanography, seismology, etc.

- @TNO we have learned to use Ambient Noise Interferometry to gain useful information about the subsurface



The Very Large Array near Socorro, New Mexico, United States

DE PEEL ANSI



Cross correlation reveals reflection response

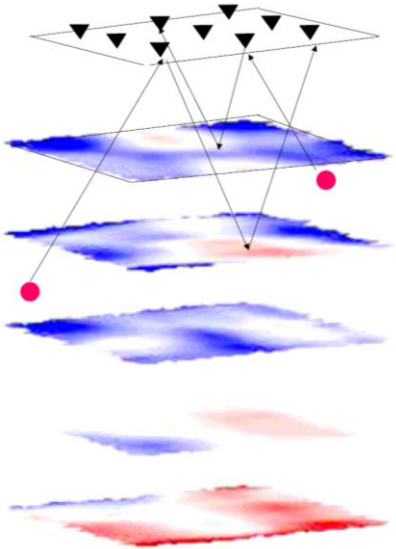
Wapenaar, 2004

DE PEEL ANSI – WHAT SETS ANSI APART

In current seismic practice the active-source effort often exceeds the receiver effort

ANSI offers the possibility for regular and true 3D sampling of the wave field since each receiver acts as virtual source as well

- Exploration
  - relatively cheap and
  - easy and environmentally friendly
- Monitoring
  - like above and
  - accurate (in time-lapse applications)
- Goal is to reduce risk and cost and increase the pace of exploration, in particular when terrain access is difficult or restricted

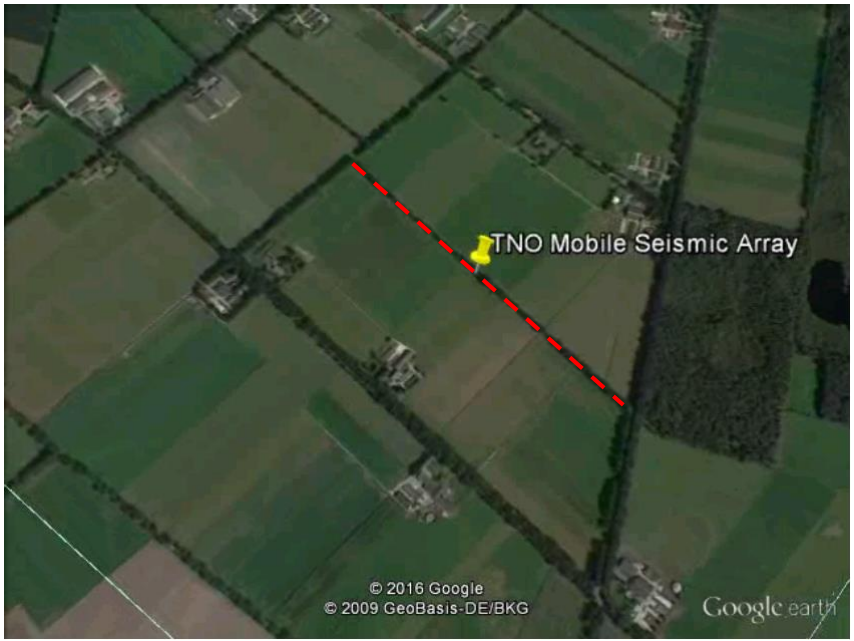


Verdel, 2009

DE PEEL ANSI – WHERE?

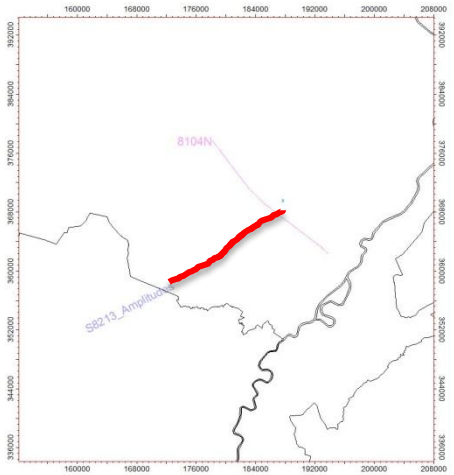
- press play

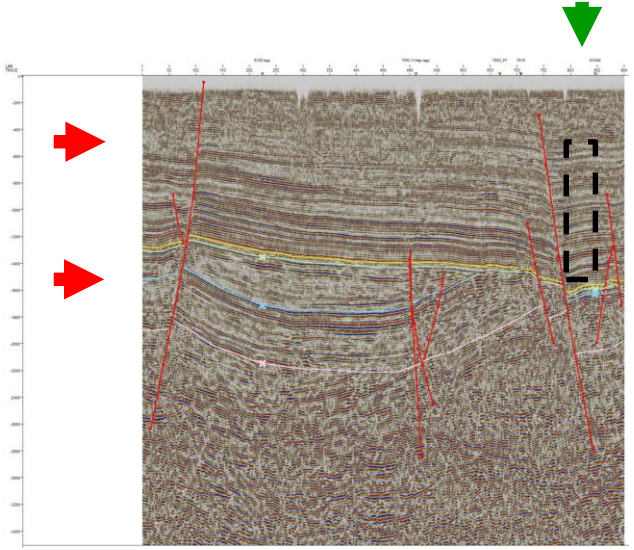
DE PEEL ANSI – WHERE?



DE PEEL ANSI – WHY THE PEEL?

- Vintage seismic data available, indicated relatively simple geology
- Location not very seismically active and far away from any subsurface activities (e.g. geothermal, gas production/storage, etc.)
- Close to possible future geothermal activities





DE PEEL ANSI – EQUIPMENT @TNO

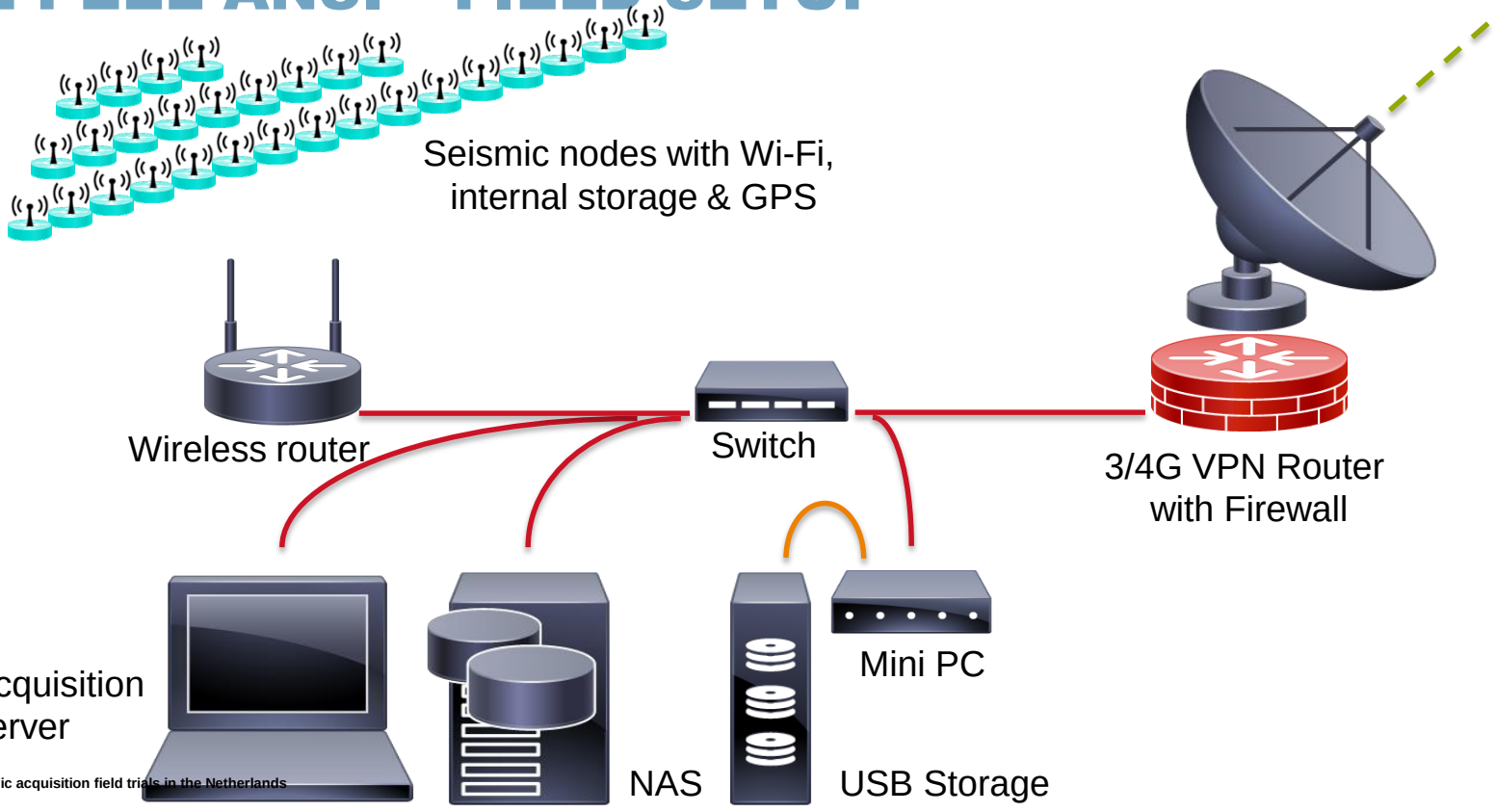
- Fully digital remote acquisition units (seismic nodes), each unit has:
- its own internal battery and can be powered externally
- its own internal data storage
- a GPS receiver for positioning and time synchronization
- a Wi-Fi transmitter/receiver for communication

- is connected to a 3C accelerometer

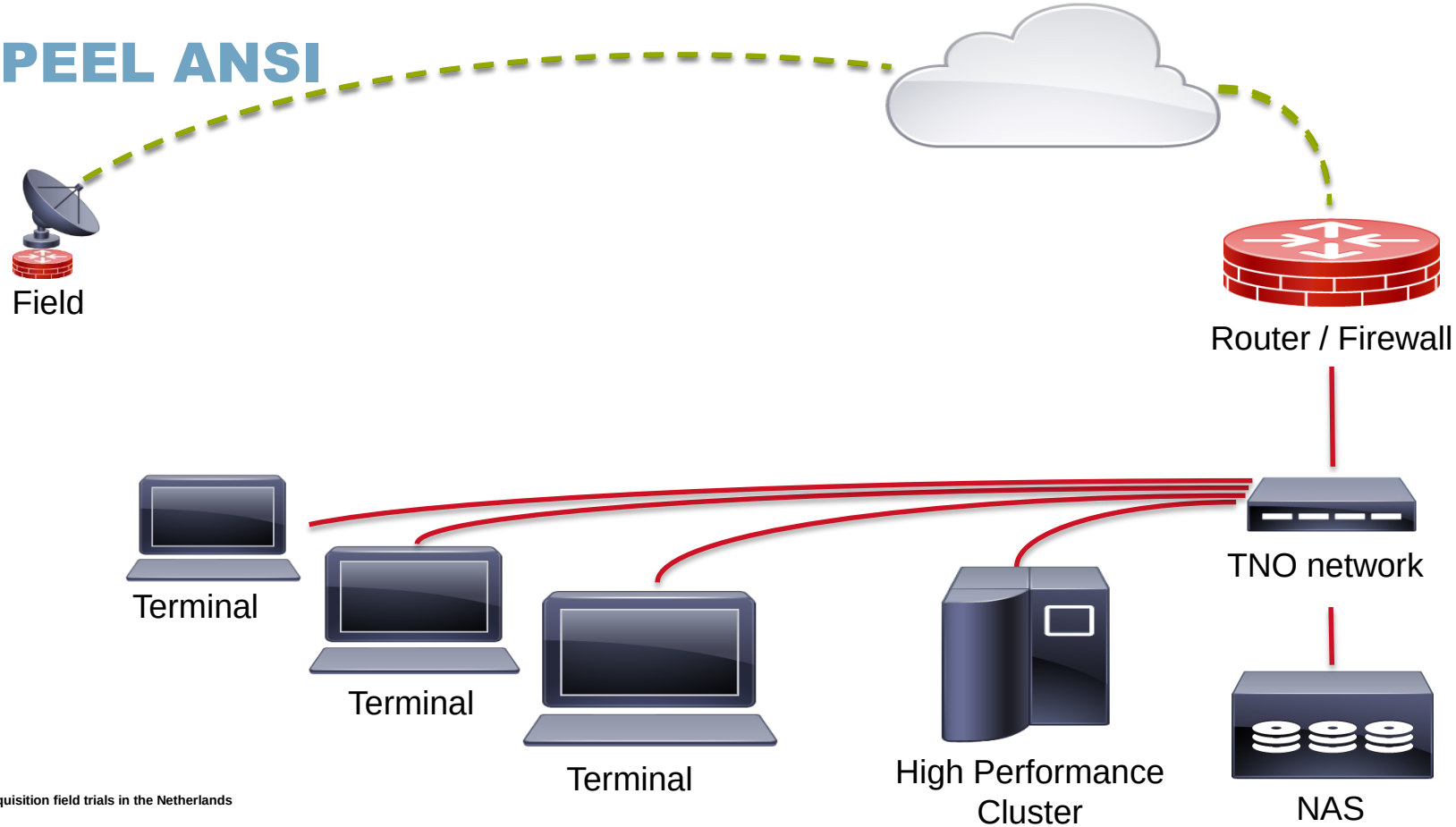
- The units are controlled by a Central Acquisition Unit (PC/Laptop)

Fully digital remote acquisition units at TNO's workshop

DE PEEL ANSI – FIELD SETUP



DE PEEL ANSI


Field
Router / Firewall
Terminal
Terminal
Terminal
TNO network
High Performance Cluster
NAS

DE PEEL ANSI - ACQUISITION

- Acquisition server installed at a nearby farm
- Barn closest to the seismic nodes proved a good place to mount the a powerful Wi-Fi transmitter

- View of the farm from the South-East end of the receiver line.

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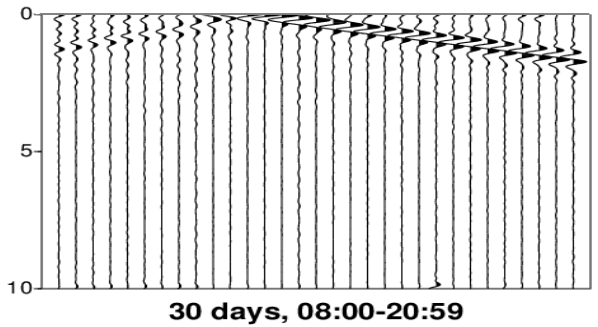
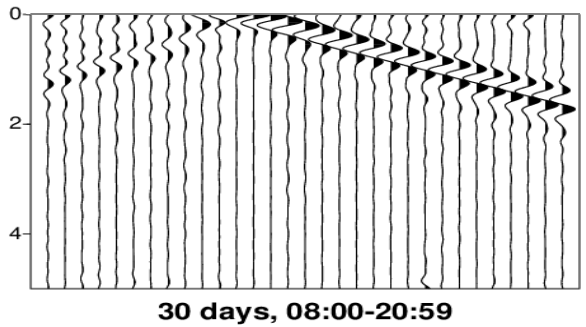
DE PEEL ANSI - ACQUISITION

- Seismic nodes placed in the field

TNO seismic acquisition field trials in the Netherlands

DE PEEL ANSI – VIRTUAL SOURCE PANELS

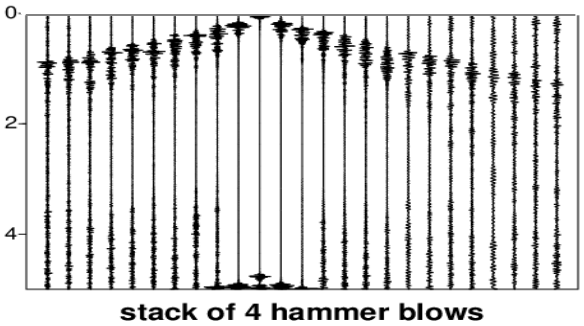


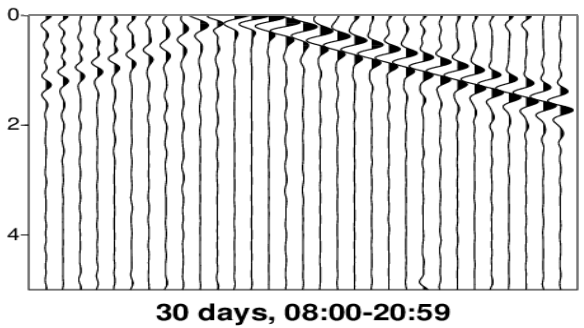


DE PEEL ANSI – VIRTUAL SOURCE PANELS

Results: Conventional source panel versus Virtual source panel

- Stack of 4 hammer blows

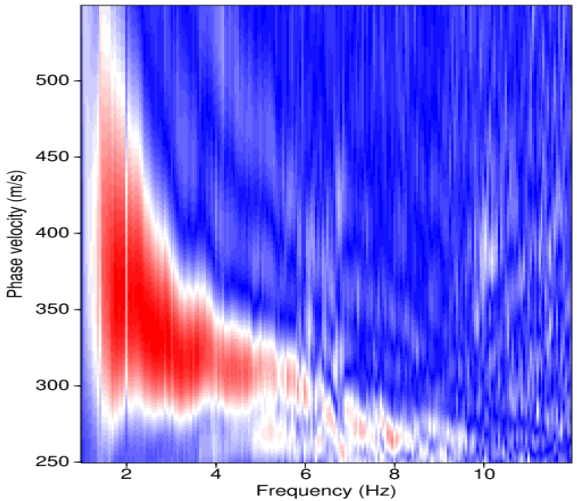


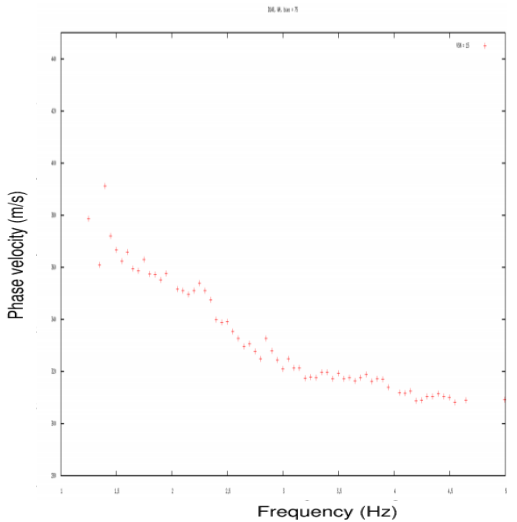


DE PEEL ANSI - DISPERSION

Results: Dispersion curves, inversion for shallow subsurface

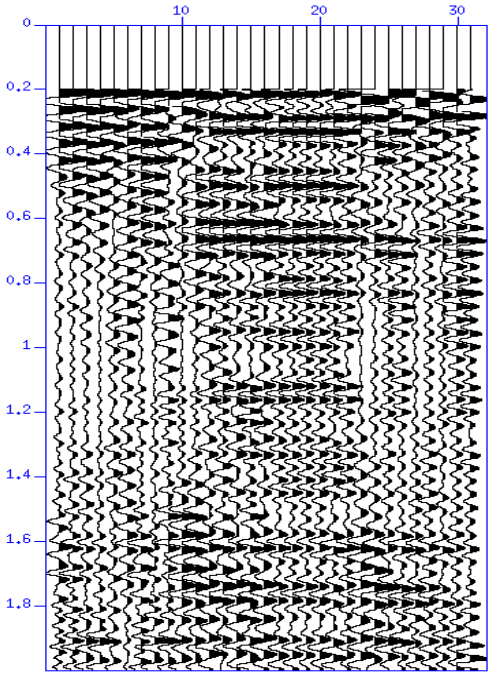
- Of use for shallow imaging and monitoring
- Subsurface stiffness mapping
- Improve deep target imaging



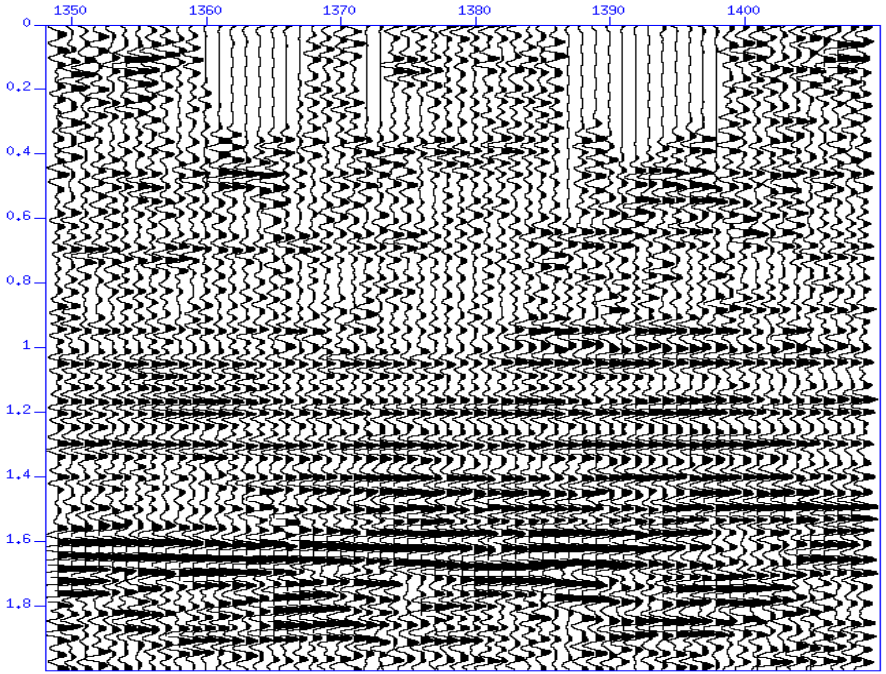


DE PEEL ANSI - REFLECTION PANELS

ANSI 2D



Vintage 2D



DE PEEL ANSI - POTENTIAL

Imaging of deeper subsurface

- ANSI can reveal the structure of the deeper subsurface
- Additionally the array can also be used for more classic techniques like
  - Combine acquisition with conventional active seismic
  - Extending bandwidth of conventional active seismic
  - Classic event detection

Monitoring of deeper subsurface

- ANSI can be used to monitor the subsurface

Geotechnical engineering

- Less ground truthing (wells) needed to (3D) map the shallow subsurface for parameters like stiffness, groundwater level variations, etc.

TEAM & ACKNOWLEDGEMENTS

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seismic data processing

THANK YOU FOR YOUR ATTENTION

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