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Abu Dhabi International Petroleum Exhibition & Conference
15-18 November 2021

Technical Conference
organised by

SPE International
Society of Petroleum Engineers

ADIPEC 2021

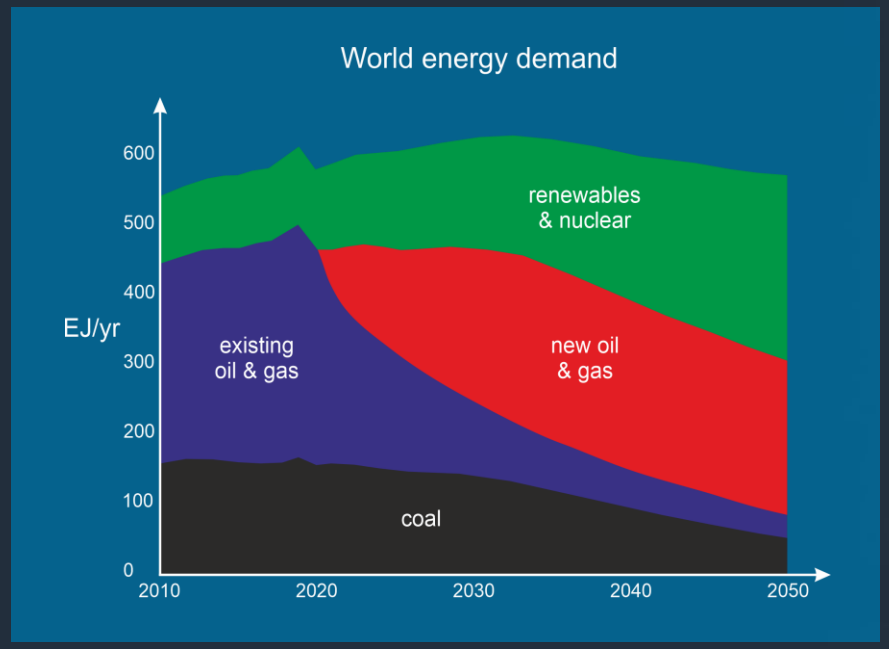
Seeing the low-carbon energy

The role of cloud-native Full Waveform Inversion in the Energy Transition

The Context

Advanced seismic imaging is required to:

- replace reserves efficiently
- reduce emissions generated through safe CO2 storage



S-CUBE

Who am I?

Nikhil Shah

- Mathematics: Cambridge University
- Geophysics: Imperial College London
- R&D Geophysics: Chevron, Houston
- CEO: S-Cube, London

Recent Publications: S-Cube & AWS

2021

Adaptive reflection waveform inversion: faster, tighter, deeper, smarter (SEG 2021)

Mike Warner, Tenice Nangoo, Adrian Umpleby, Nikhil Shah (S-Cube)
Dan Kahn, Mik Isernia (Amazon Web Services)

https://library.seg.org/doi/abs/10.1190/segam2021-3594686.1

2021

Accelerating Subsurface Data Processing and Interpretation with Cloud-based Full Waveform Inversion Systems (ADIPEC 2021)

Sirivan Chaleunxay (Amazon Web Services)
Nikhil Shah (S-Cube)

The Problem

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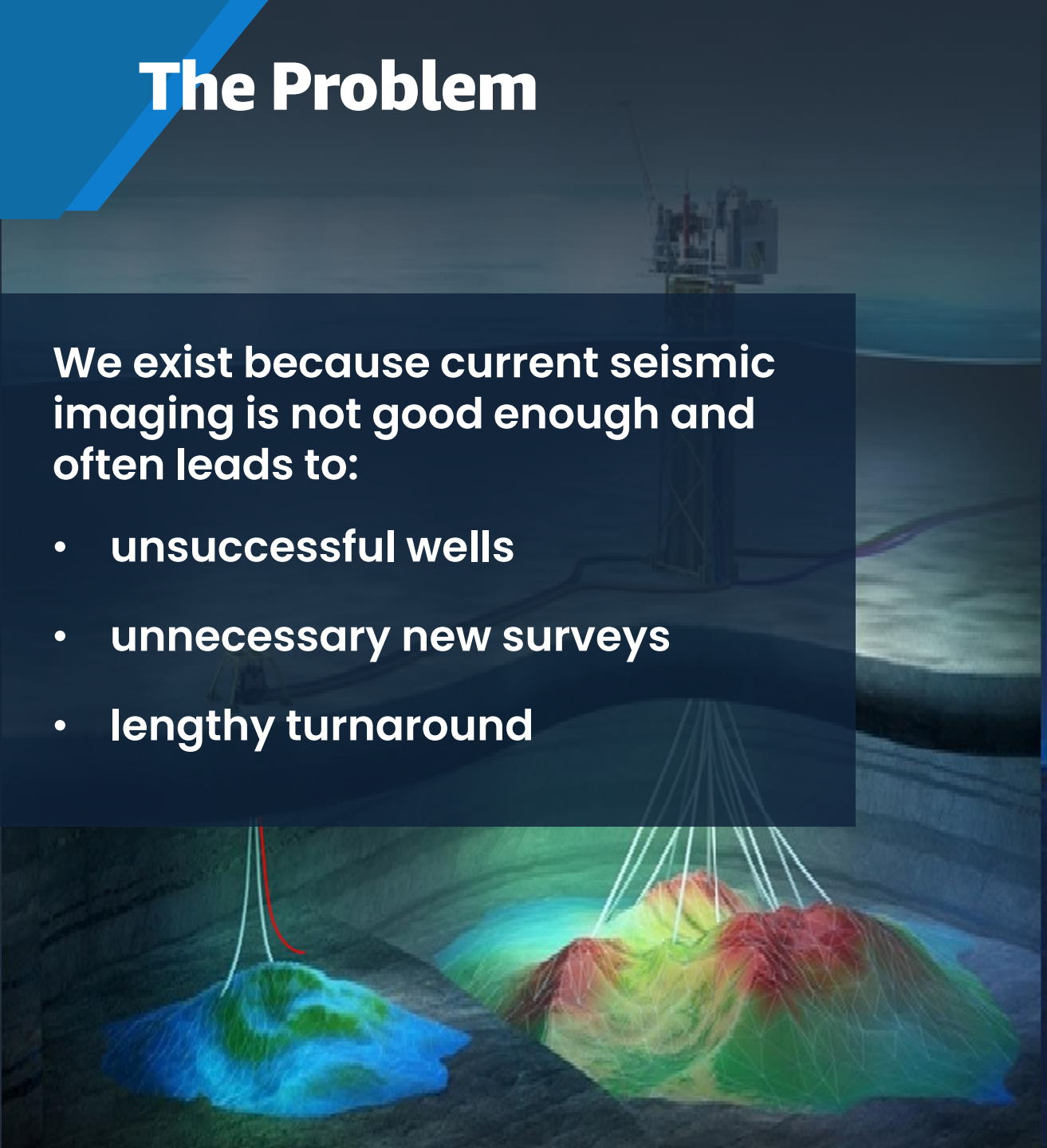
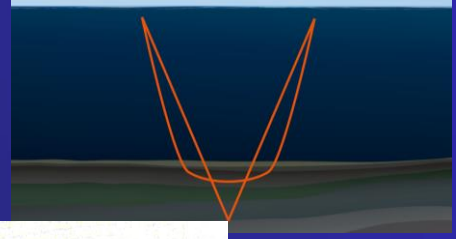
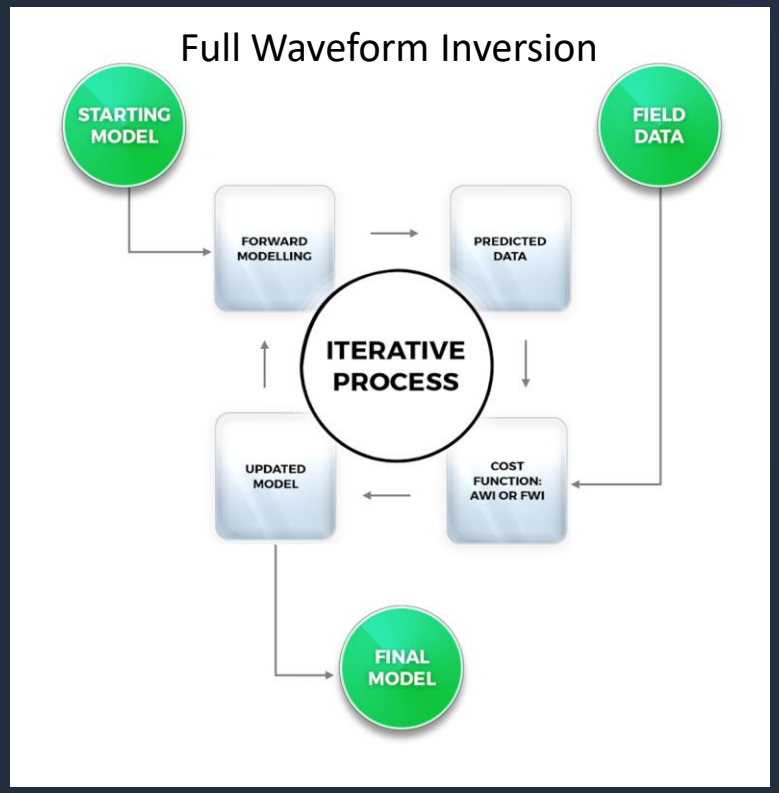
We exist because current seismic imaging is not good enough and often leads to:

- unsuccessful wells
- unnecessary new surveys
- lengthy turnaround

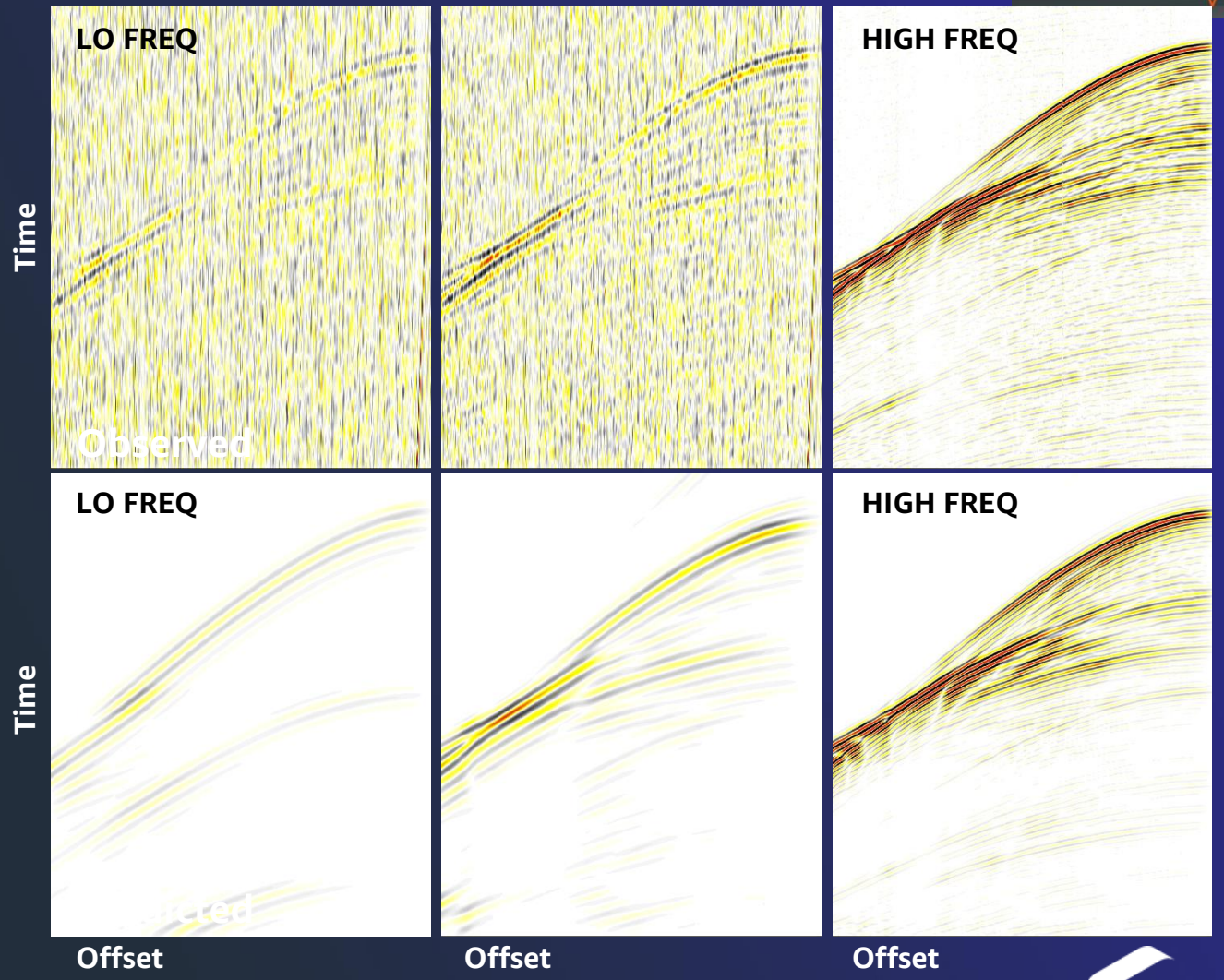


Automated seismic imaging





- iterative feedback loop
- repeated simulations
- minimising prediction errors



matching predictions (p) to observations (d)

Full Waveform Inversion

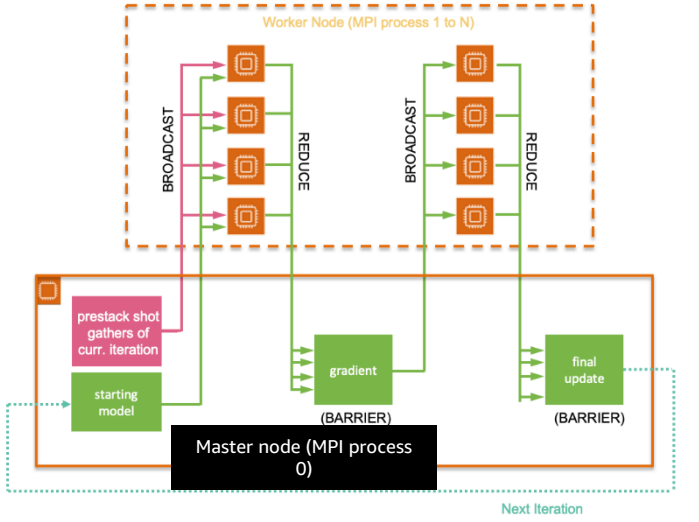
FWI can make seismic imaging:

- Faster – works from raw data
- More automated – works without human intervention
- More accurate with greater resolution – works with the full recorded wavefield
- Scalable – works on the cloud

A Cloud-Native Architecture for FWI

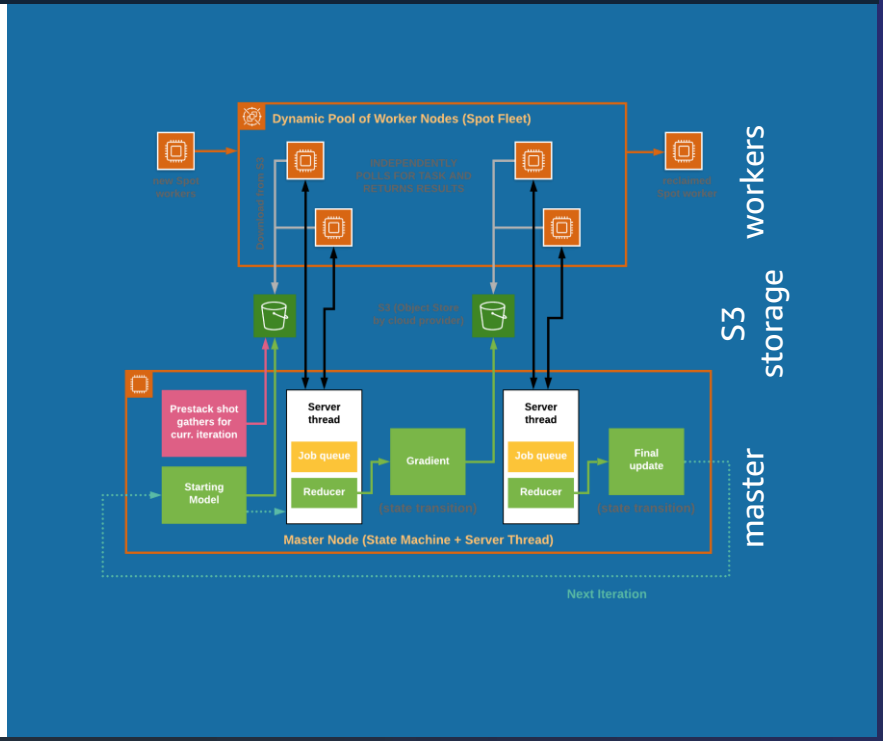
Lift and Shift

- Static pool of workers
- Full price “reserved” instances
- Heavily constrained by MPI



Cloud-native

- Dynamic pool of workers coming in and out
- Discounted “Spot” interruptible hardware
- AWS services for communication to workers



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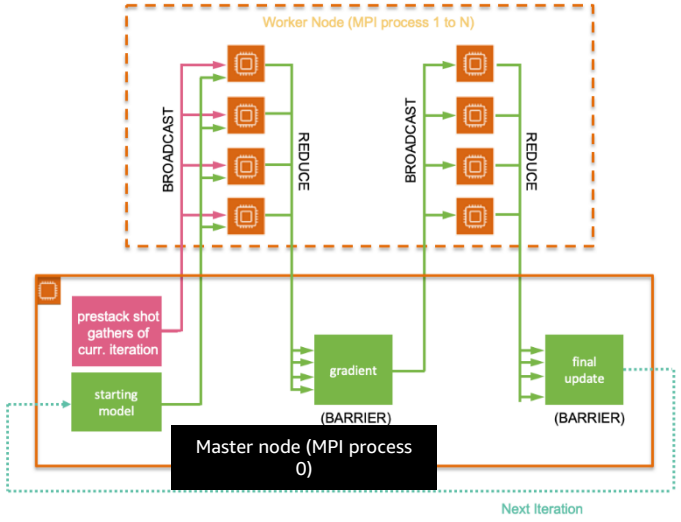

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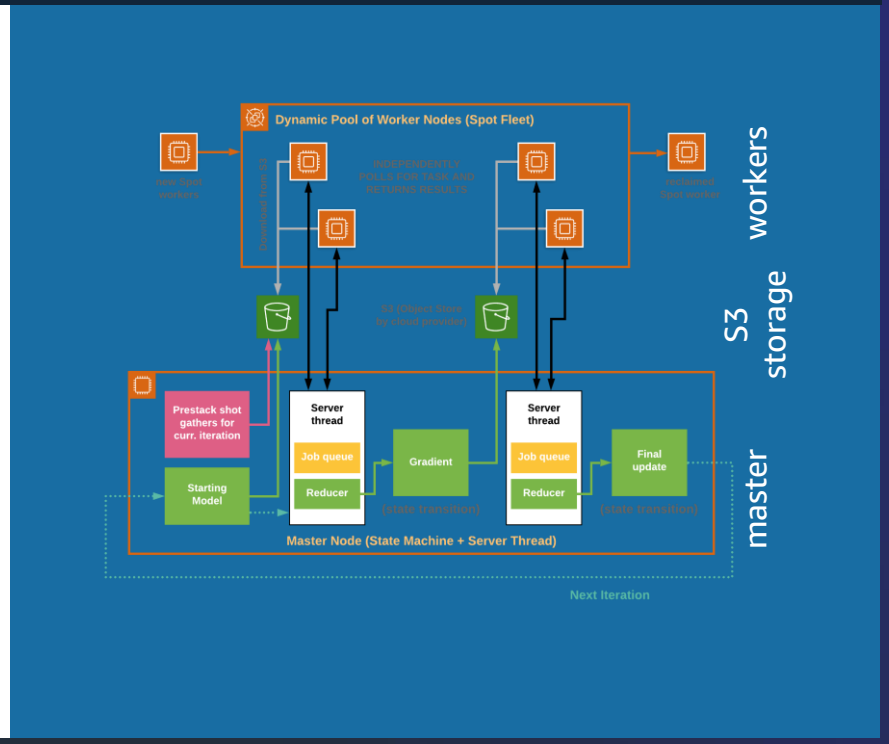
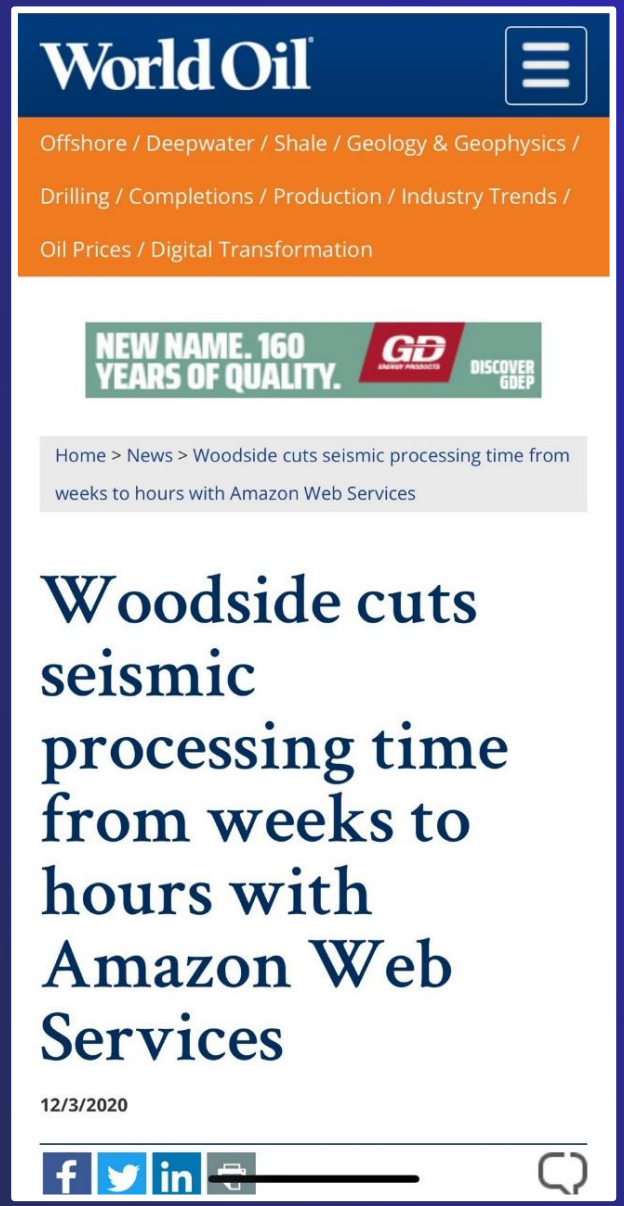


Industry’s first 1m vCPU workload

Slashed run times by 150x wrt on prem cluster


World Oil

Offshore / Deepwater / Shale / Geology & Geophysics / Drilling / Completions / Production / Industry Trends / Oil Prices / Digital Transformation

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12/3/2020

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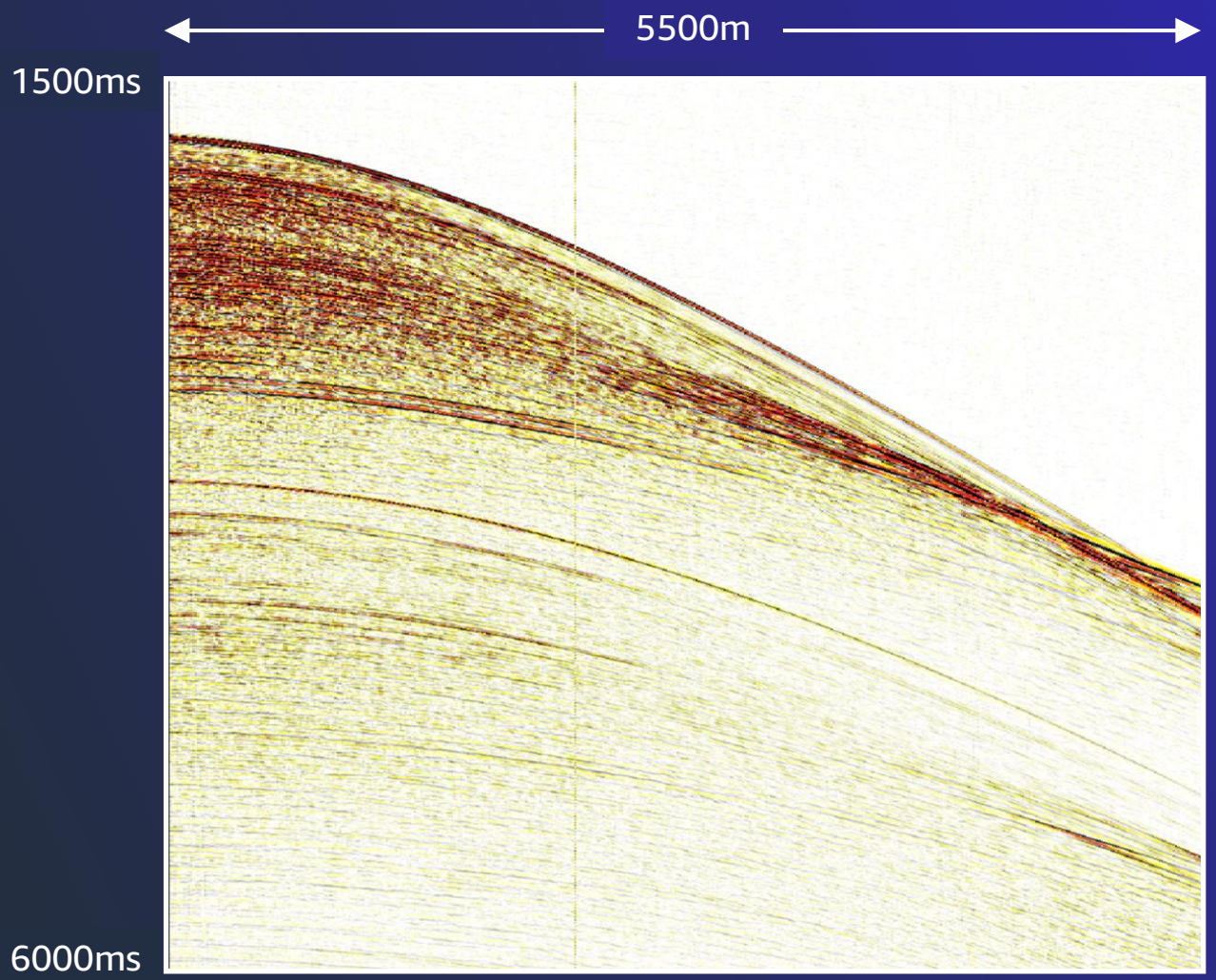
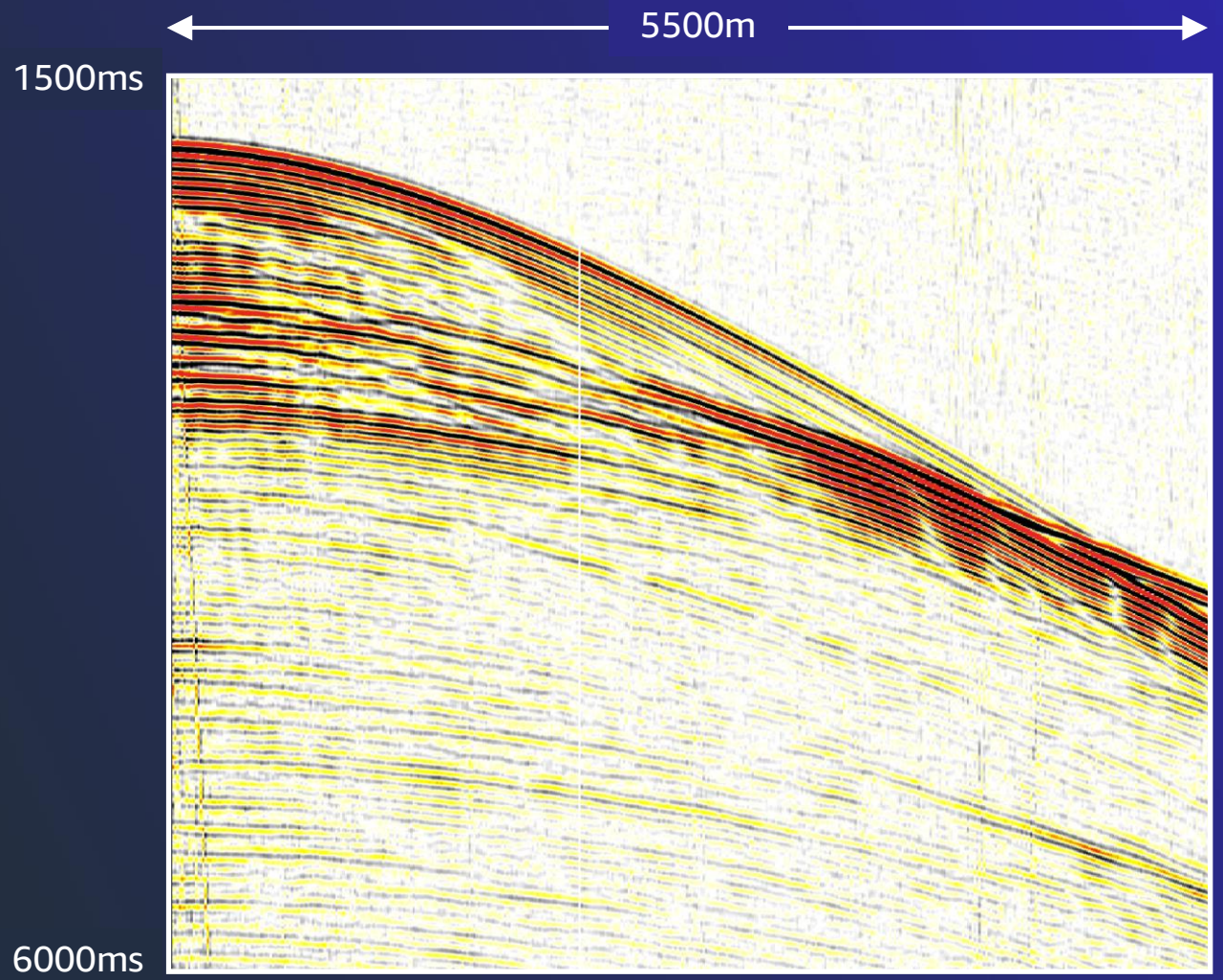
Case study - raw field data

- Narrow azimuth towed-streamer
- Reflection dominated
- 5550-m cables
- 5-m source depth
- 6-m receiver depth
- No useable signal below 4 Hz

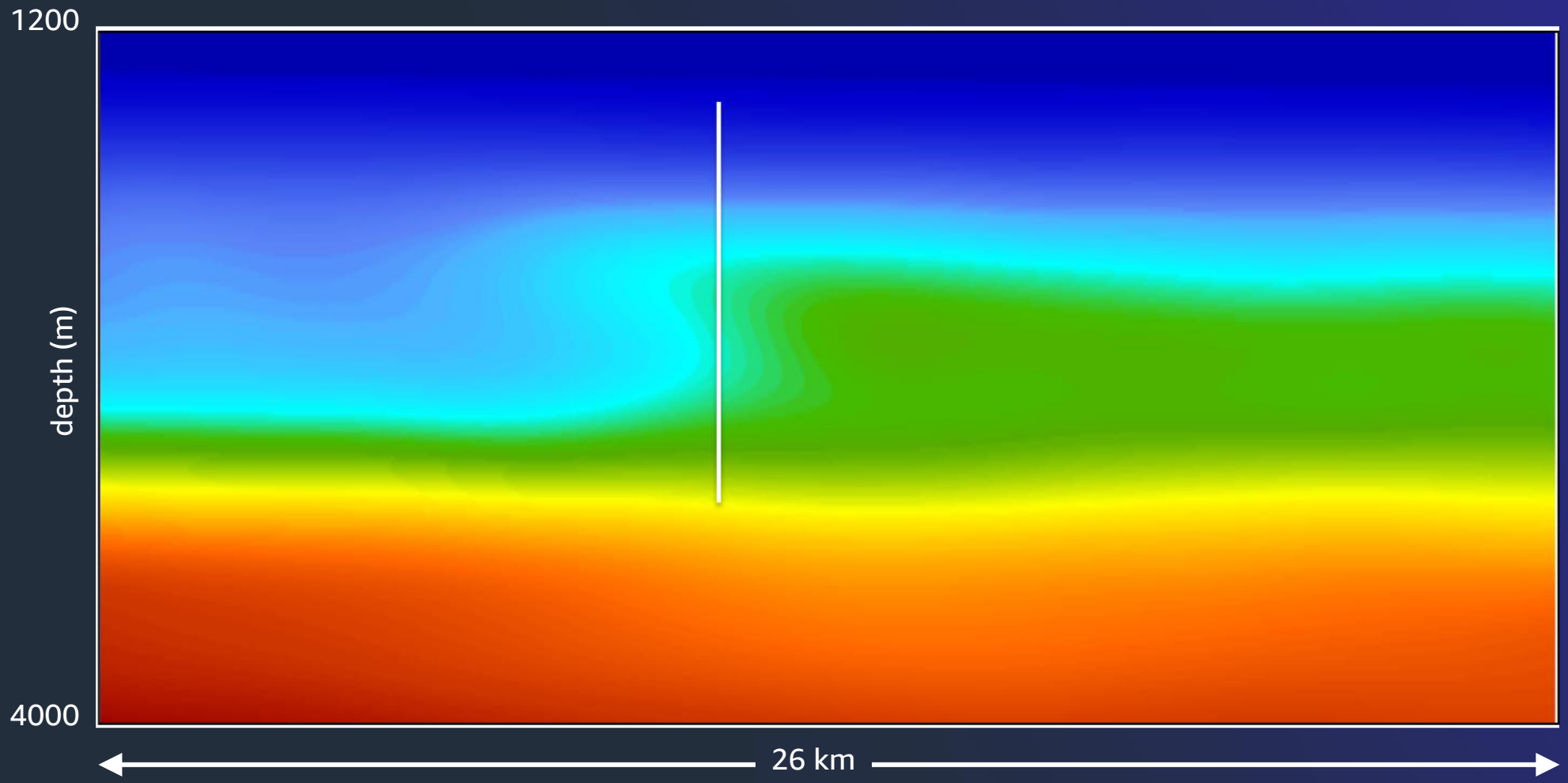


Case study - raw field data

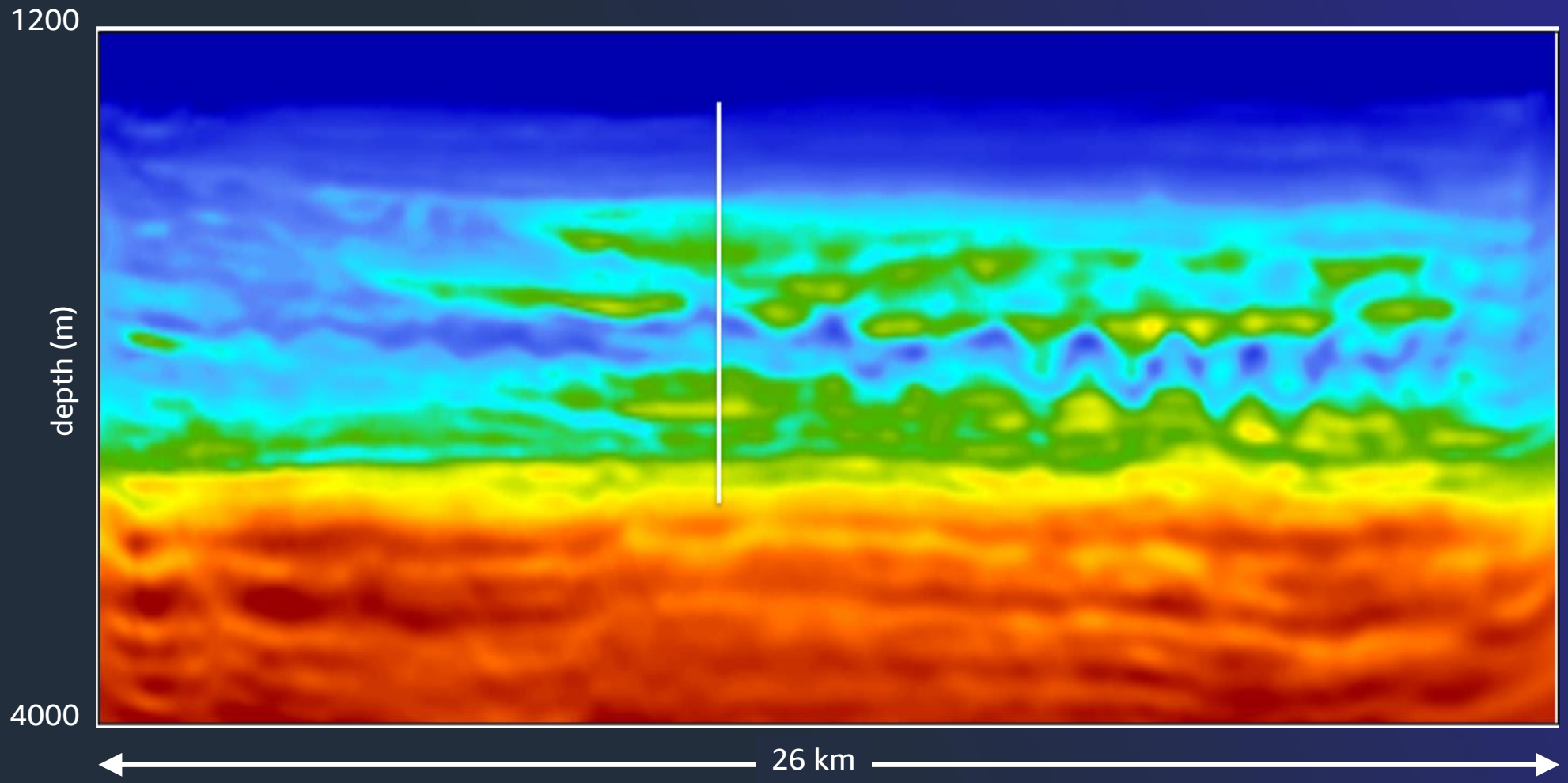
- Minimal preprocessing
- Bandpass filtering 4 to 23 Hz
- Include multiples
- Include ghosts
- 1000 shots per iteration



Start Model



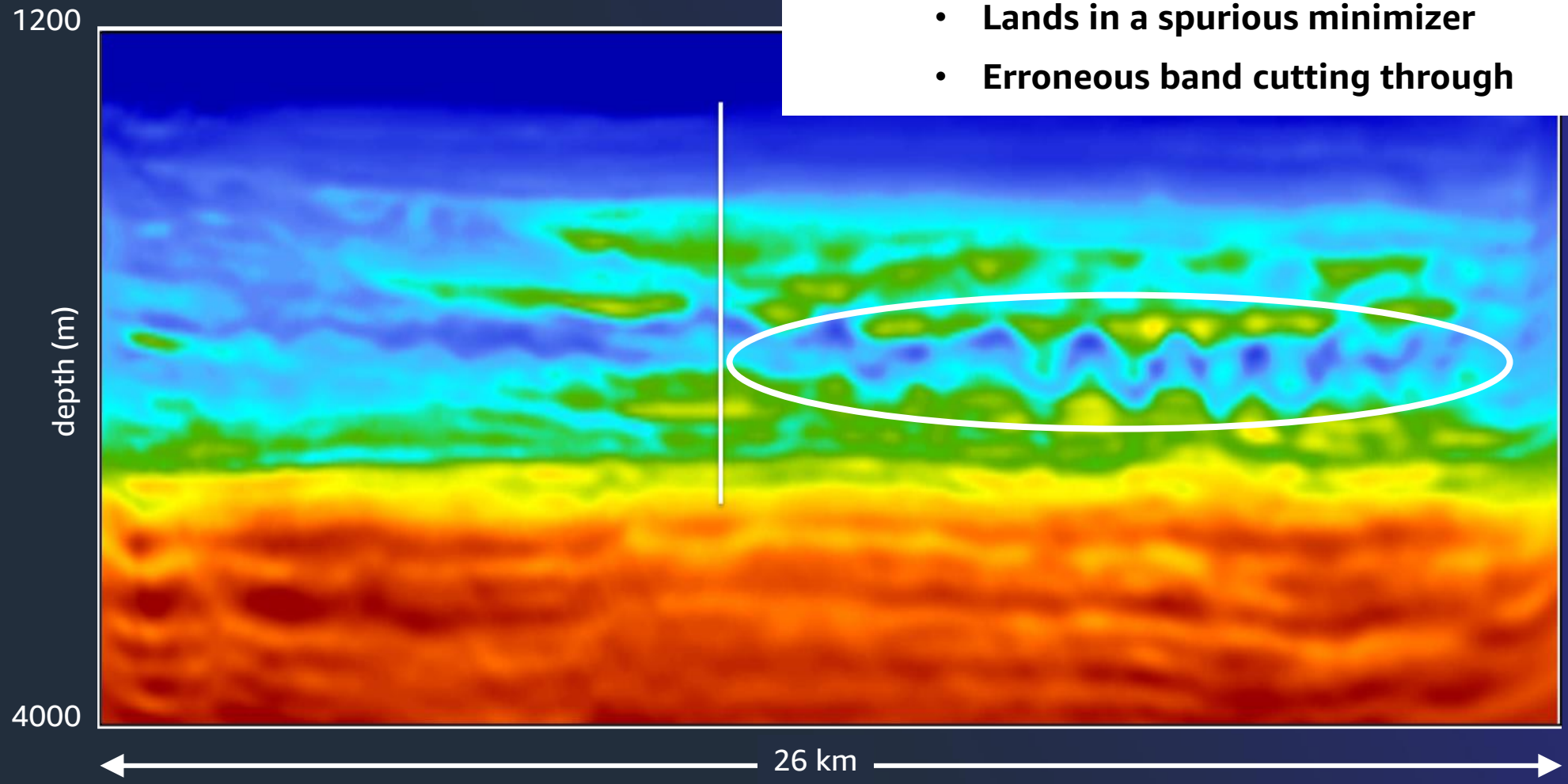
Conventional FWI



Conventional FWI

Fundamental challenge of FWI – it's possible to get a high-resolution model but a completely wrong one

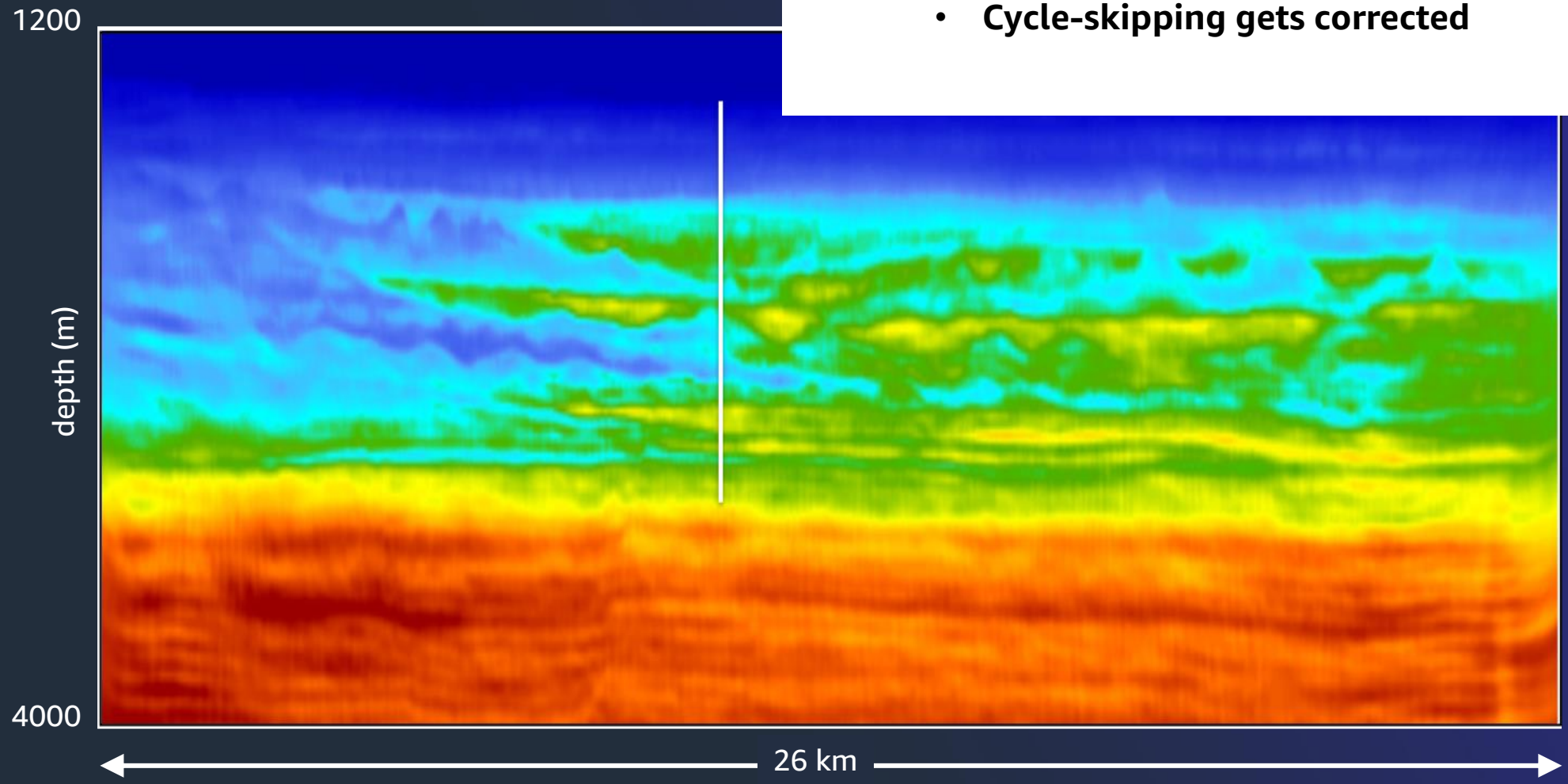
- **Lands in a spurious minimizer**
- **Erroneous band cutting through**



Conventional AWI

That was with the least-square norm which FWI was originally formulated with … which we now switch to AWI

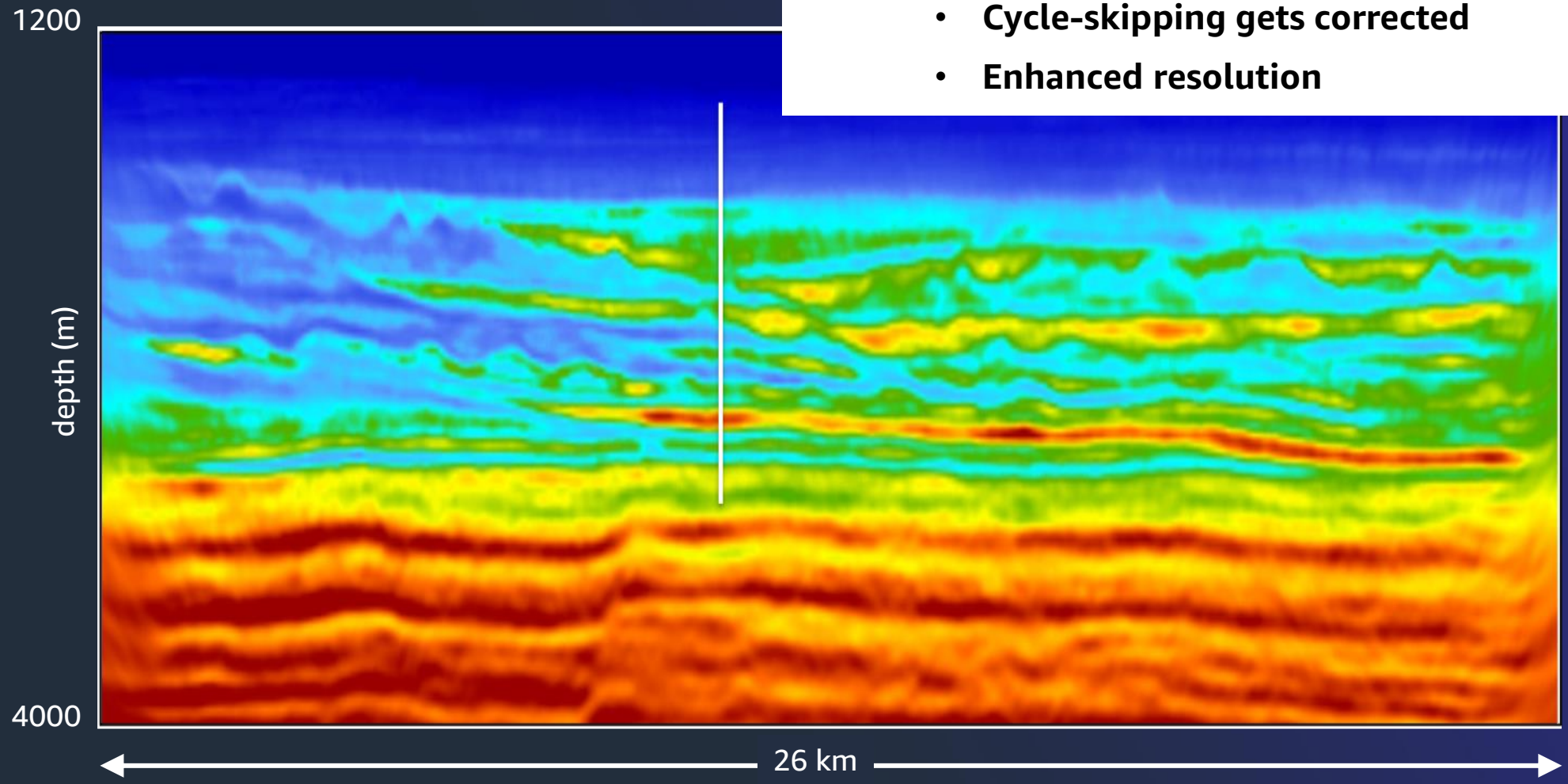
- **Cycle-skipping gets corrected**



Reflection AWI

That was with the least-square norm which FWI was originally formulated with … which we now switch to AWI

- **Cycle-skipping gets corrected**
- **Enhanced resolution**



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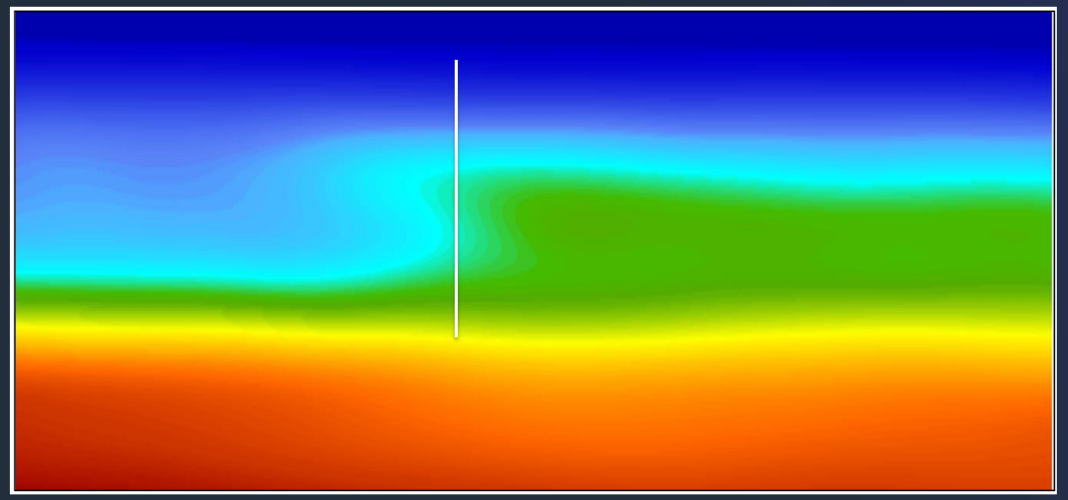
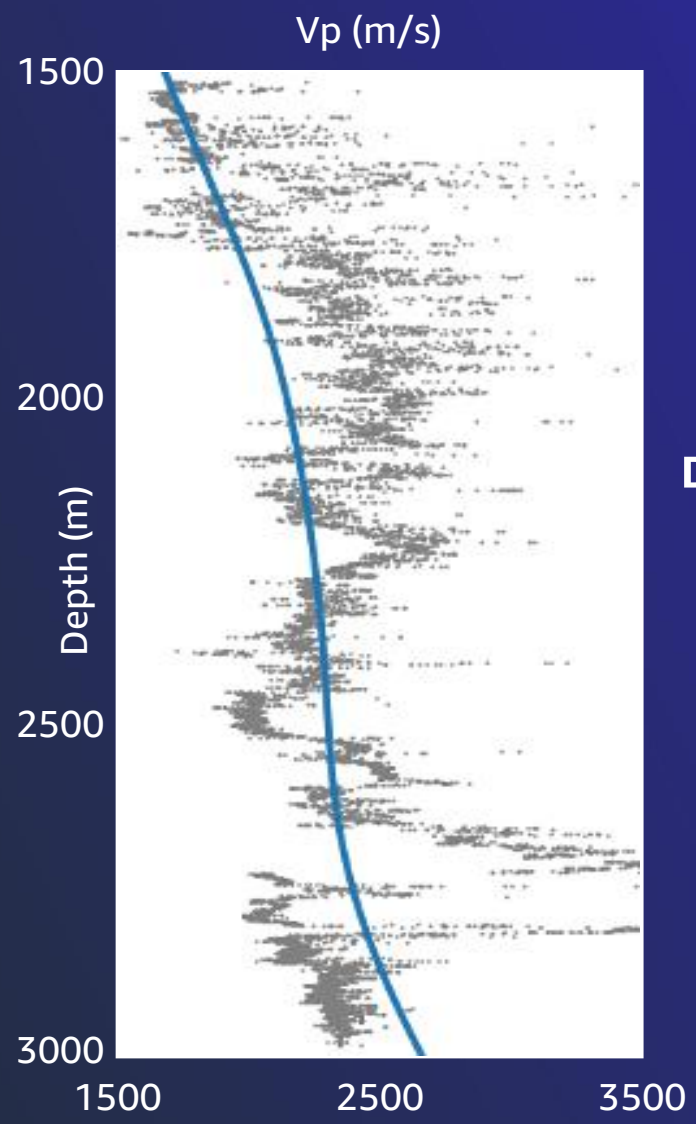
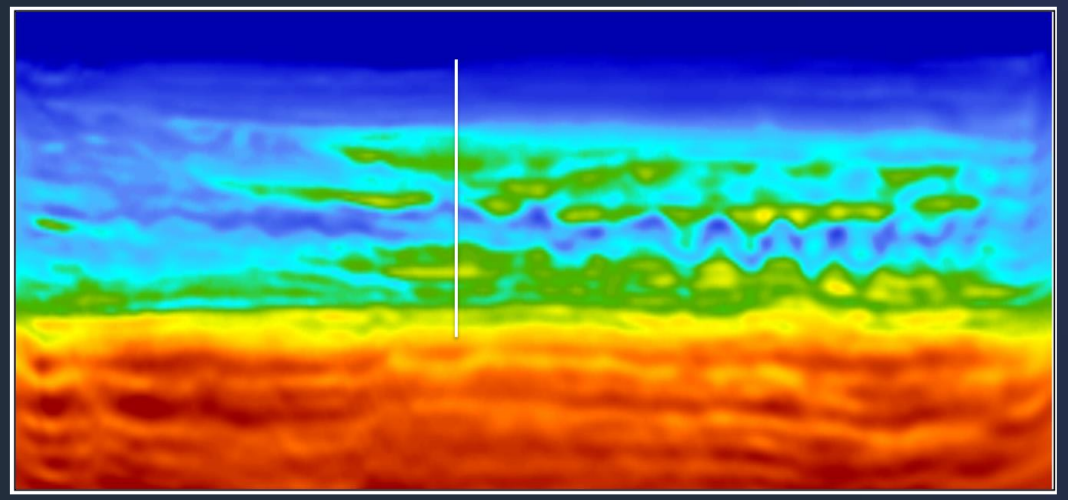


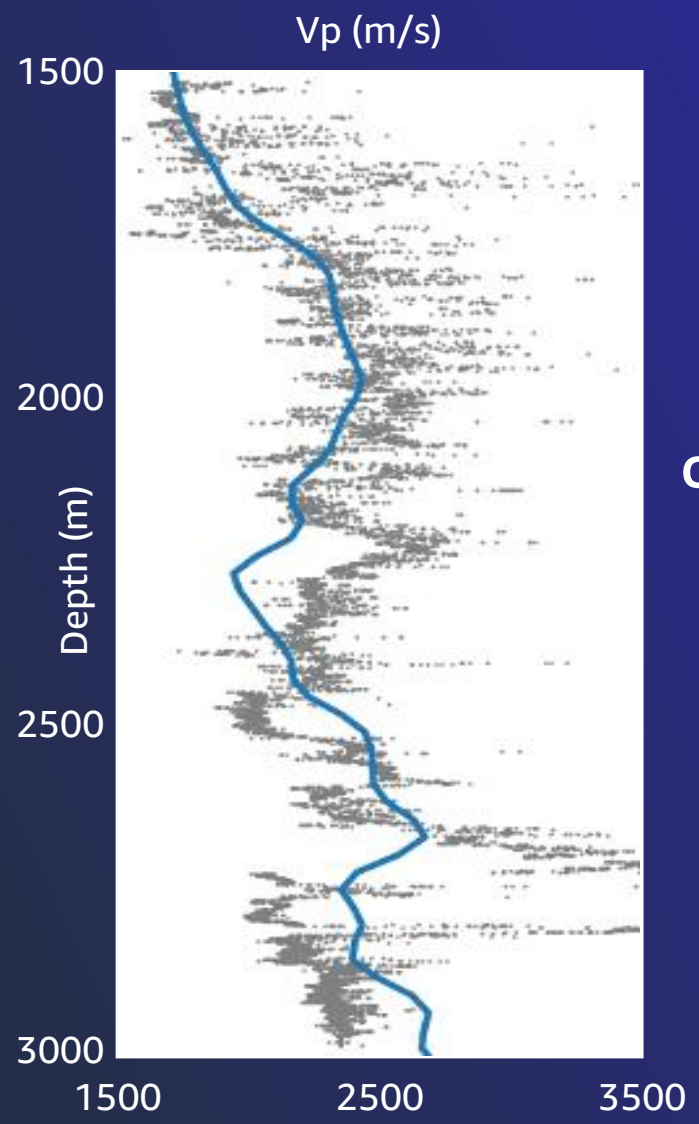


Distant start model

Conventional FWI

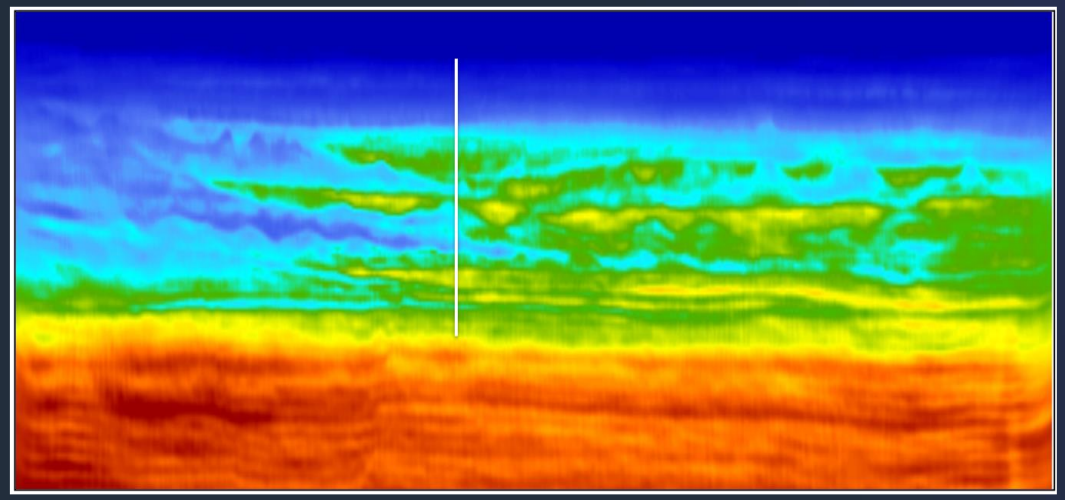


FWI forces **p – d** towards zero
AWI forces **p / d** towards one
Provides immunity to cycle skipping



Cycle-skipping

Conventional AWI



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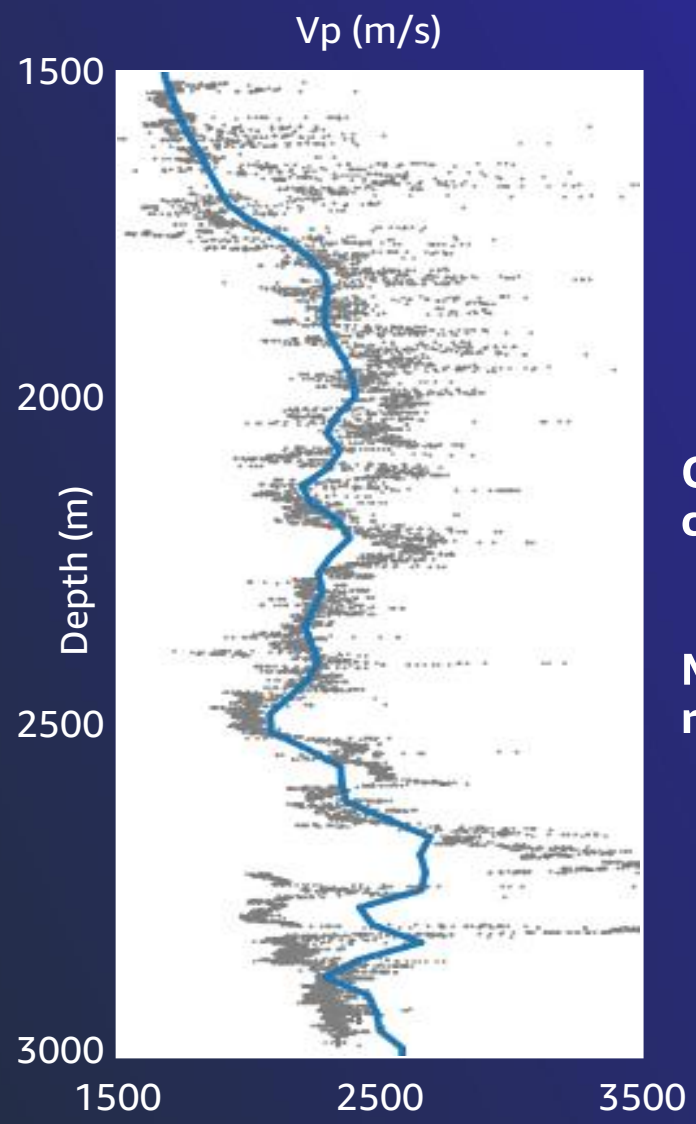
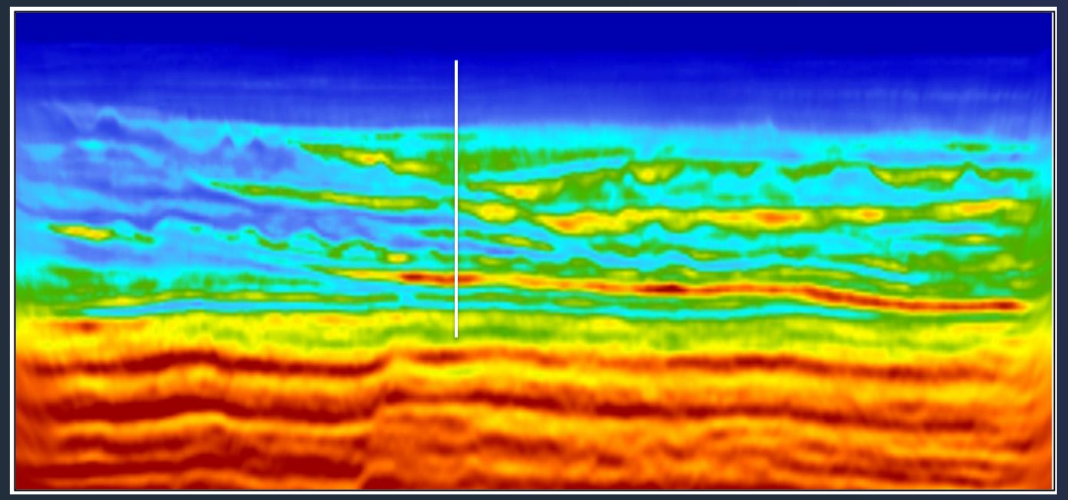


Cycle-skipping corrected

Macro trend recovered

Reflection AWI



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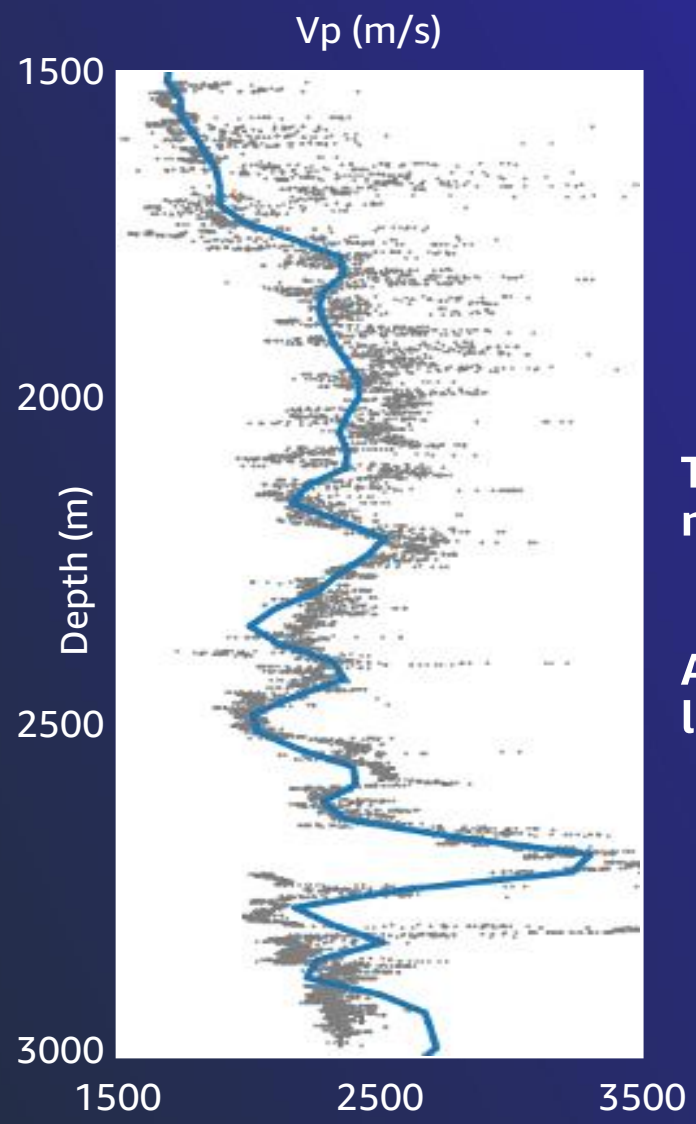
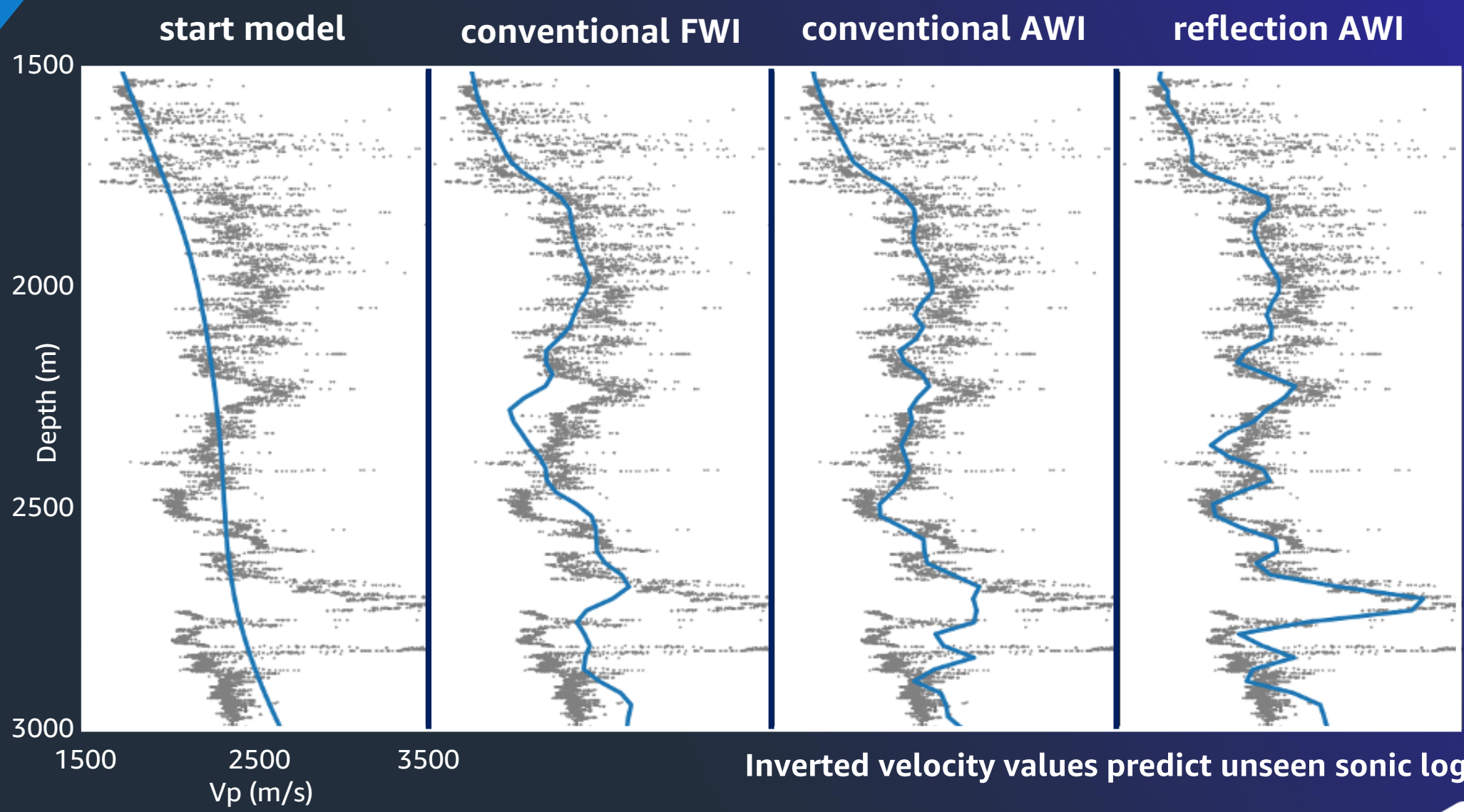


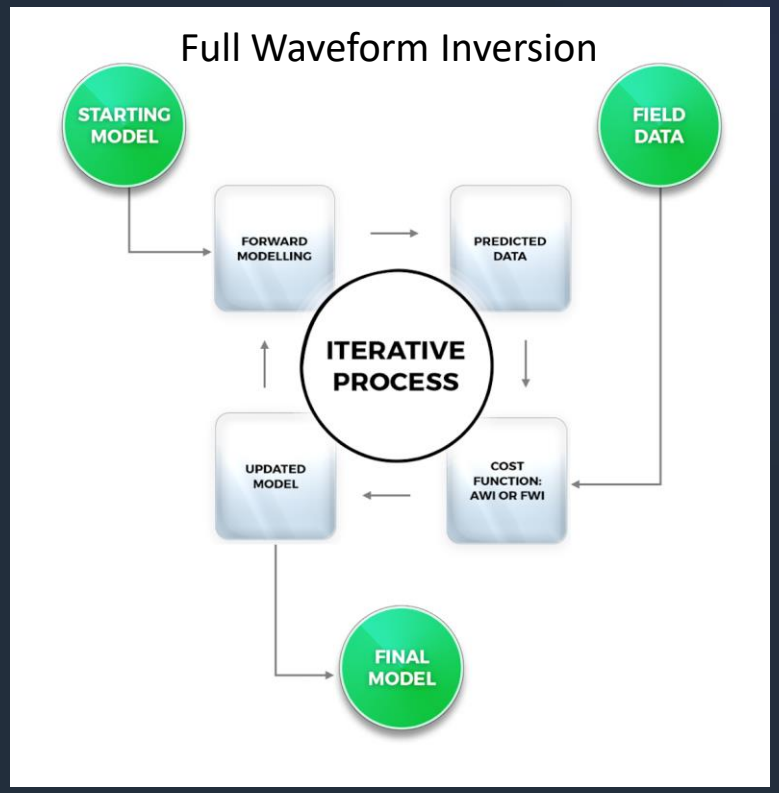
True amplitude match onto wells

All driven by p locking onto d



Inverted velocity values predict unseen sonic logs

Reflection AWI



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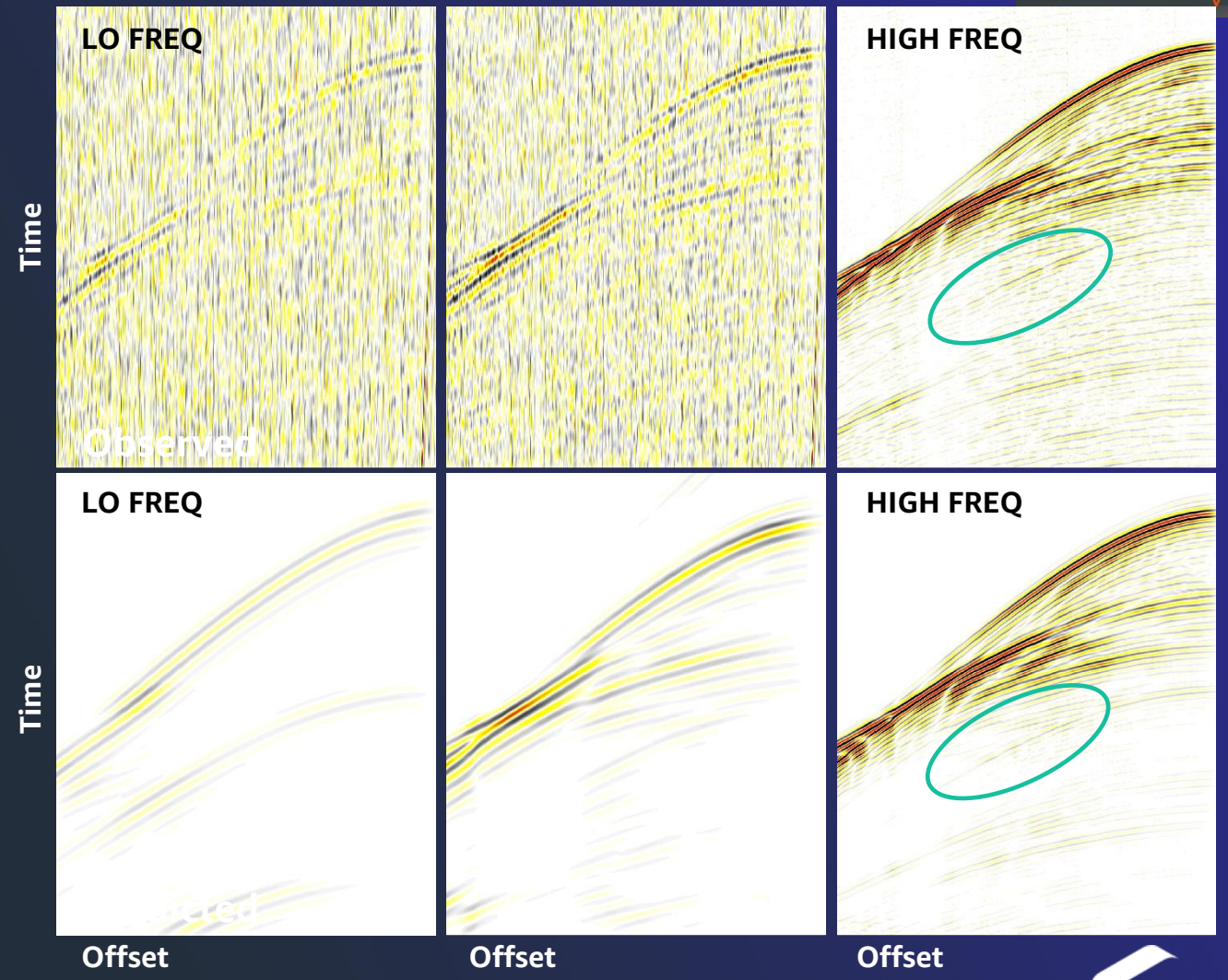
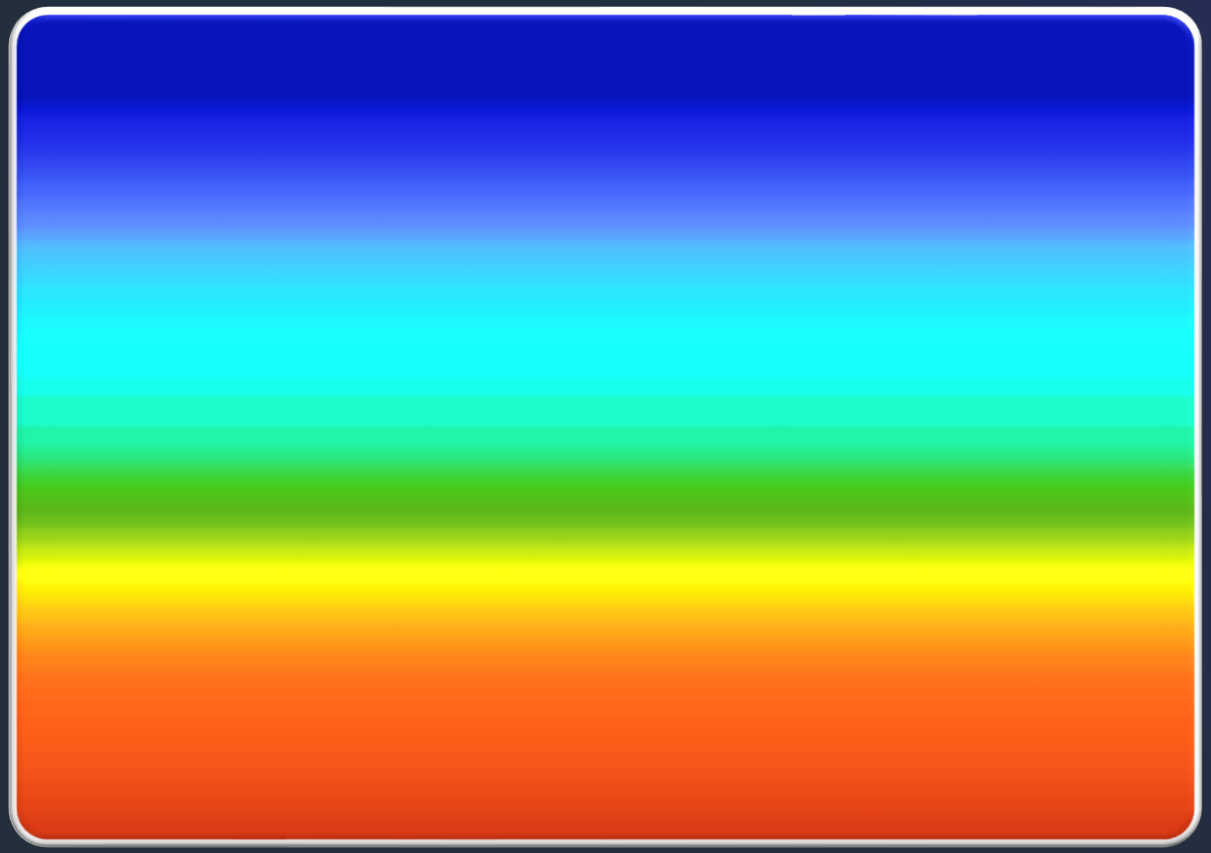


matching predictions (p) to observations (d)

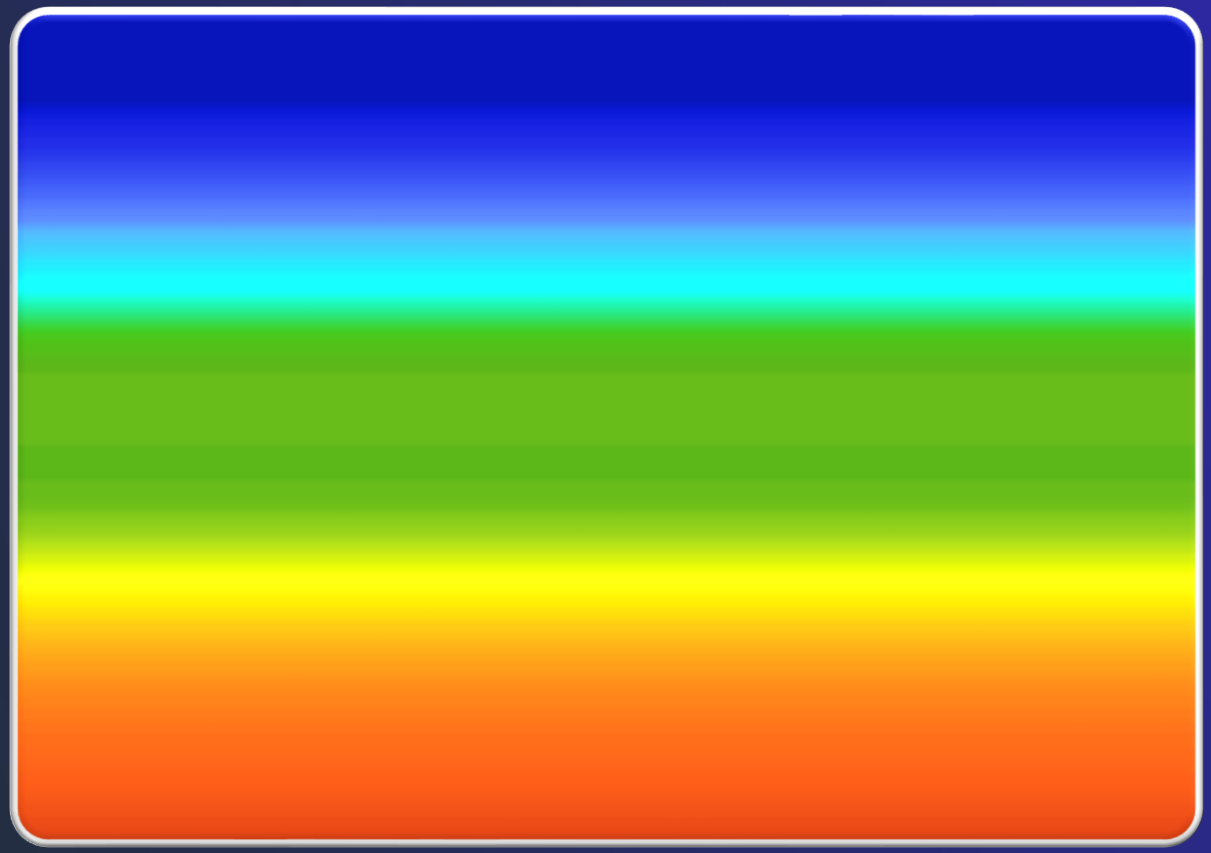
Different start models

- Results independent of start model
- Begin from any reasonable model

slow start



fast start



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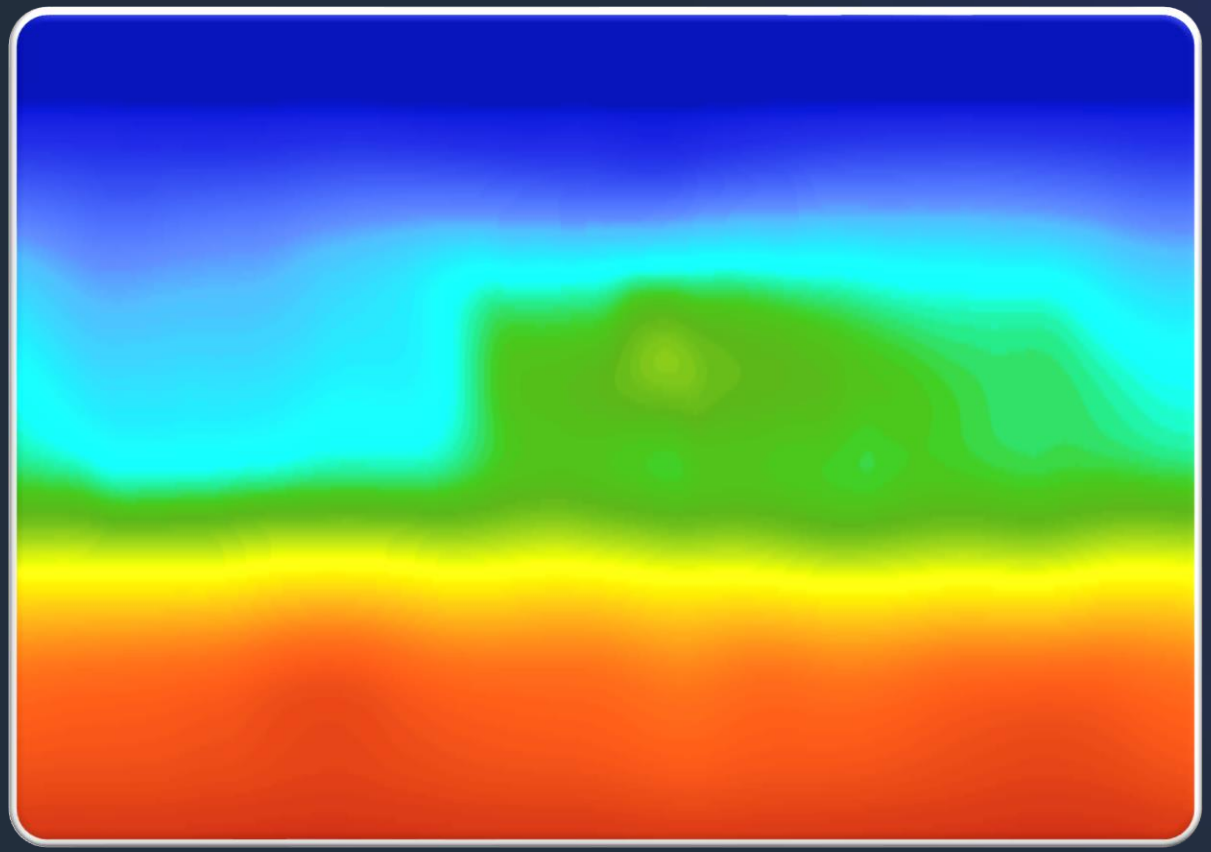

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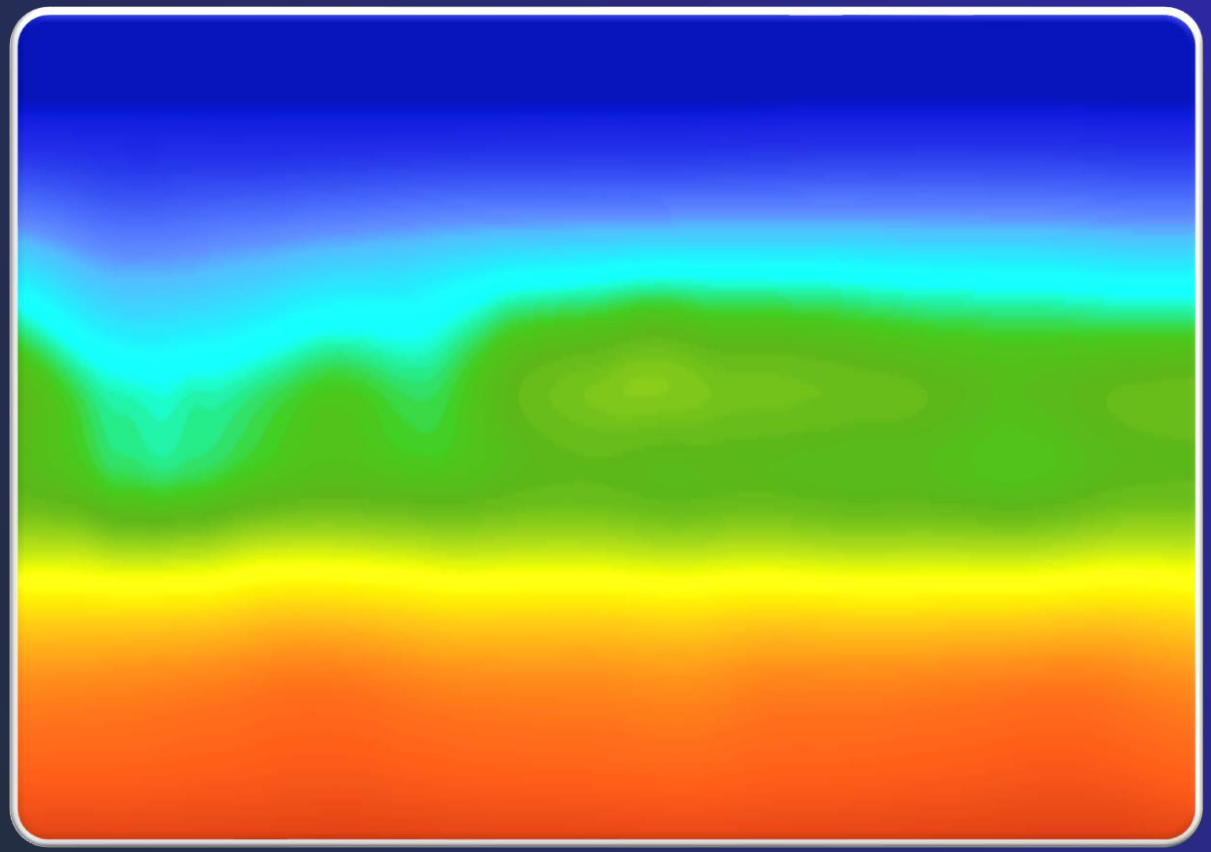

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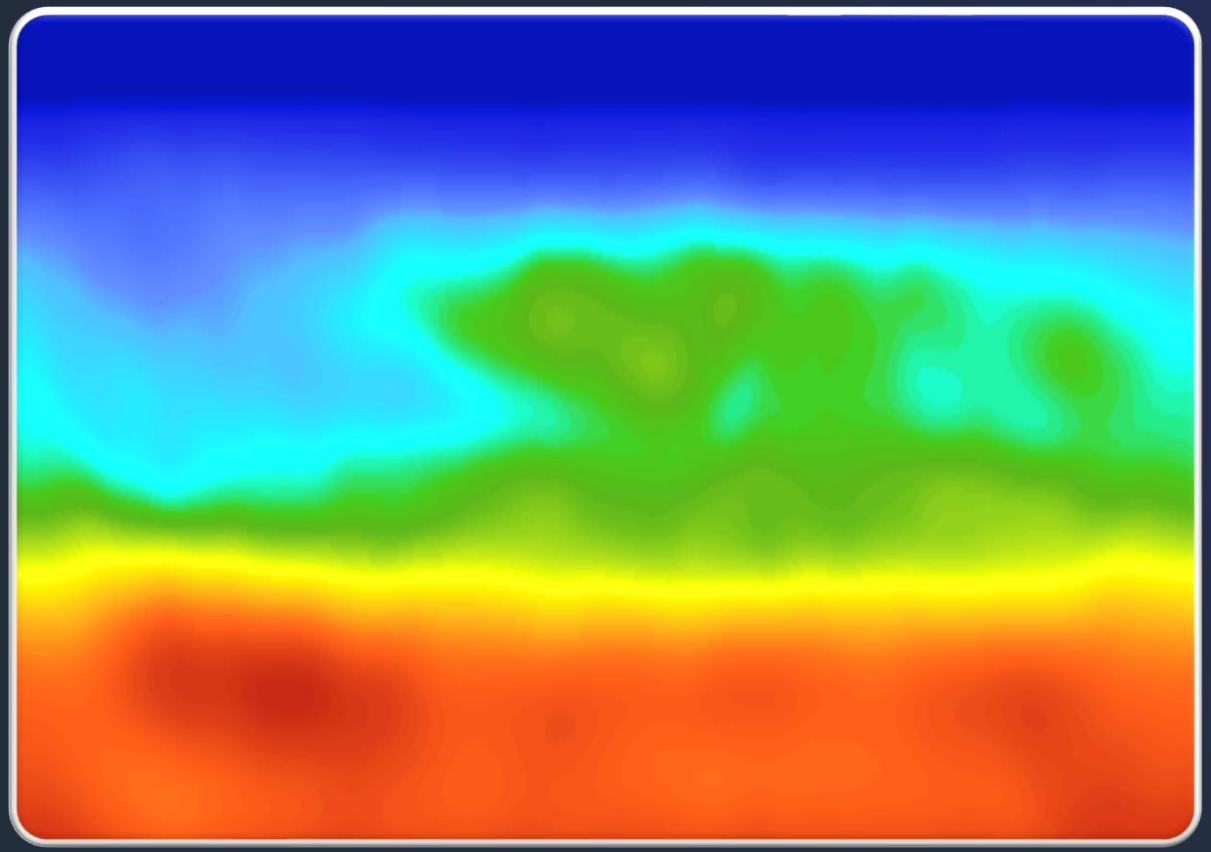

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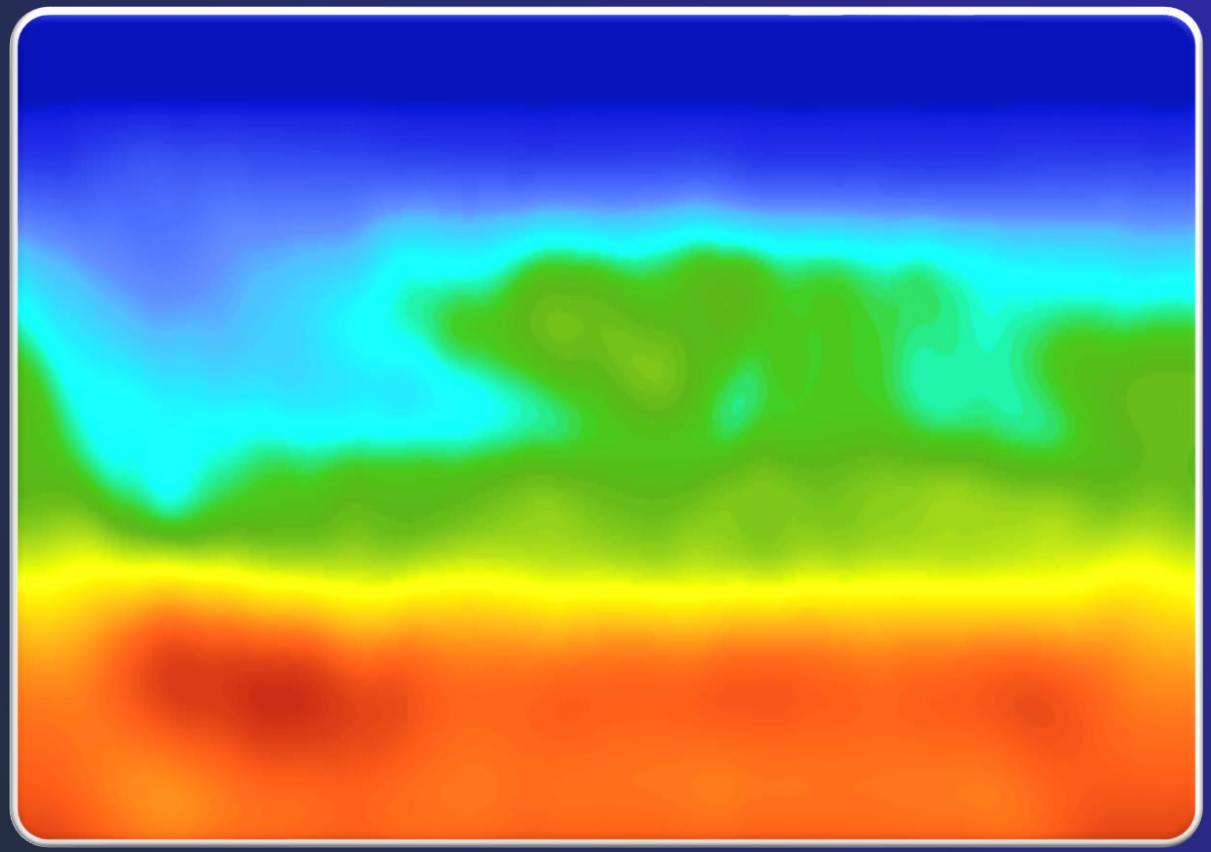

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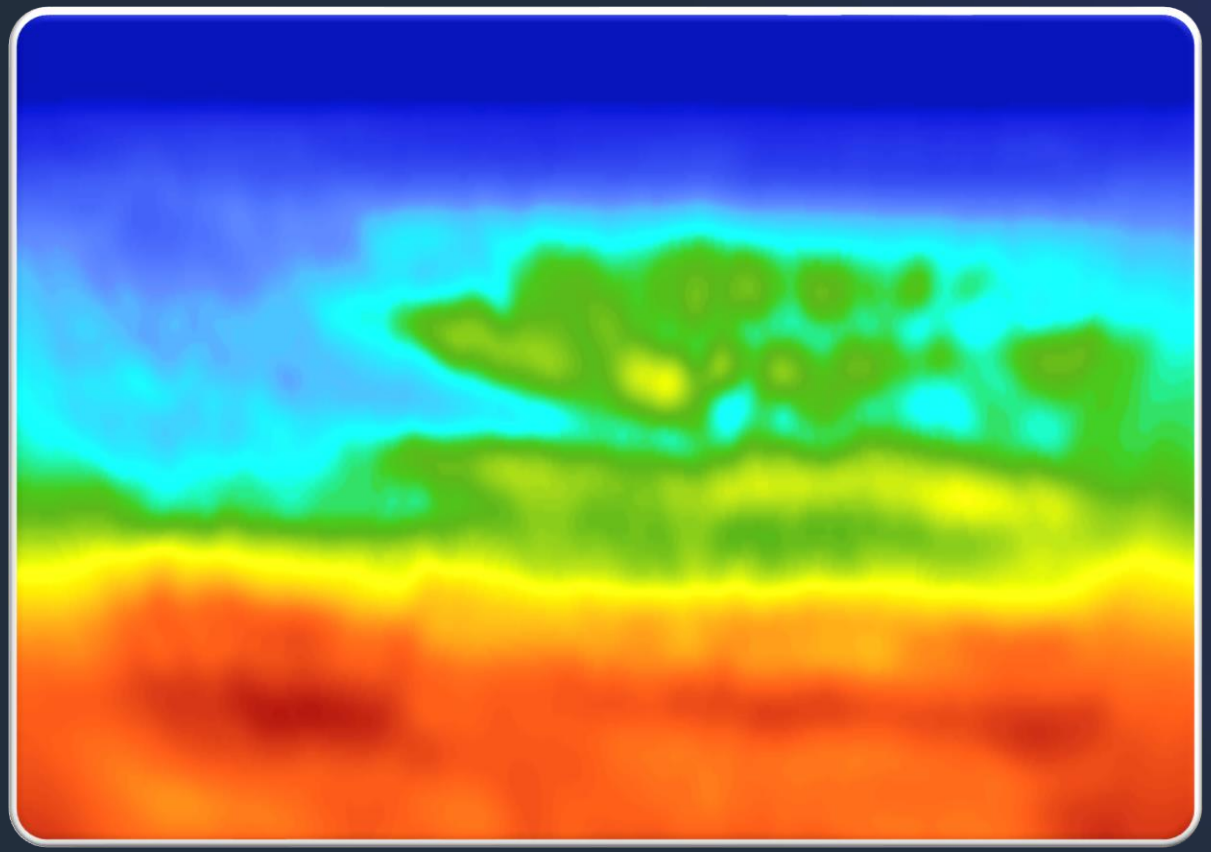

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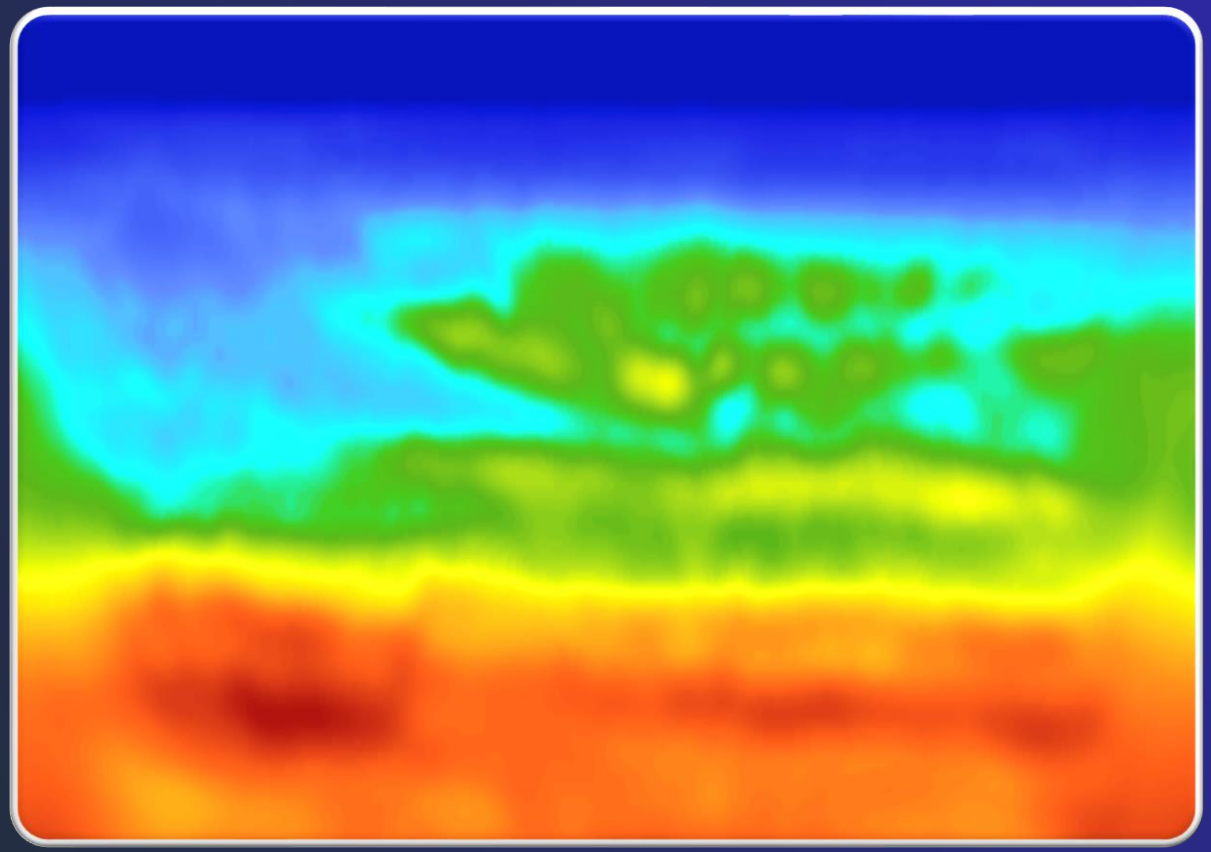
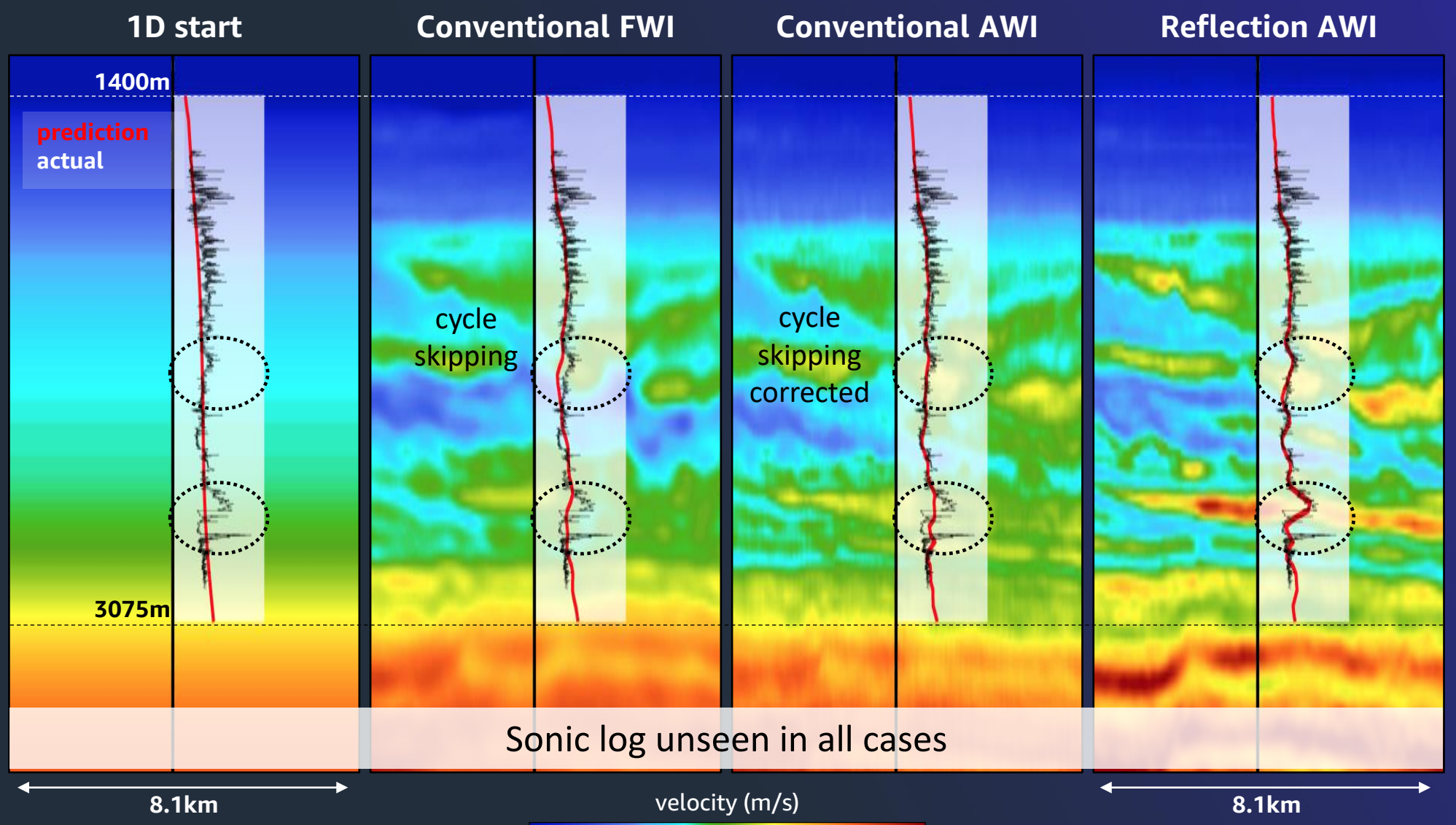


Automated Predictive Power



Predicts unseen logs

Optimizes new well locations

Conclusions

Reflection AWI:

- Applied unique formulations of FWI
- To data with no frequencies lower than 4 Hz

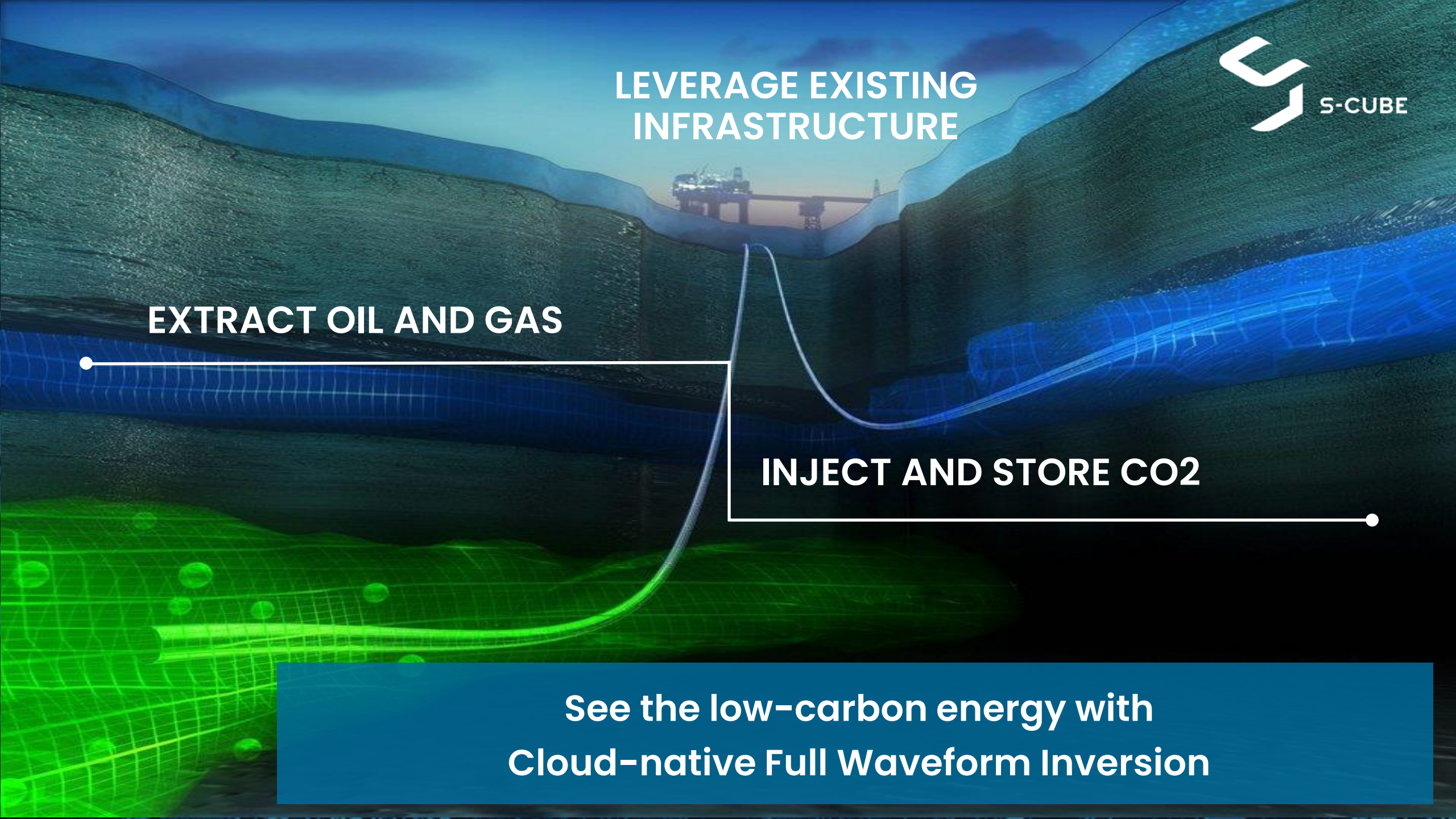
Conclusions

Reflection AWI:

- Applied unique formulations of FWI
- To data with no frequencies lower than 4 Hz

Saving for customer:

- No new survey
- Replaces conventional processing workflow
- Use proceeds and technology for CO2 storage


LEVERAGE EXISTING
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See the low-carbon energy with
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Thank you!

Nikhil Shah

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