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Geophysics Revolution

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There's Been a Revolution in Offshore Geophysics

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With engineering improvements now expanding the scope of offshore exploration, can offshore seismic keep pace?

So far, so good.

Offshore geophysics has taken a step forward in the past decade. Not surprisingly, that development came from new data-processing capabilities, better algorithms and high-quality seismic interpretation. It came from broader bandwidth and improved low-frequency seismic sources.

Maybe a little surprisingly, it also came from a combination of supercomputers and satellites.

Wadii El Karkouri is executive vice president for geophysical and energy data company TGS in Houston. He cited four areas responsible for the biggest recent advances in offshore seismic capability:

- Broader bandwidth, especially with low-frequency sources
- Common use of elastic full-waveform inversion (eFWI)
- Extensive high-performance computing power
- Networks of low Earth orbit satellites

"The key advances that are driving improvements in both quality and efficiency in offshore geophysical work are acquiring broader bandwidth data especially with low-frequency sources, the ability to access large amounts of high-performance computing power, either via large on-premises data centers or increasingly via the cloud, and the advent of large networks of low earth orbit satellites," he said.

Broader Bandwidth

In geophysical exploration, "bandwidth" refers to the range of frequencies recorded in a signal or within a given band. Broadening the bandwidth increases the ability to detect and record seismic waves across multiple frequencies.

That includes both high-frequency and low-frequency waves. But the detection of low-frequency seismic is especially important in imaging deep objectives. LFS waves have weaker attenuation and scattering than high-frequency waves.

"In areas of complex geology and where the exploration interest is now at greater depths than before, it is imperative that we sample the subsurface with as wide a bandwidth of seismic energy as possible," El Karkouri noted.

"The low frequencies are most critical, as in deep, complex areas the Earth tends to naturally filter out the high frequencies," he said.

"This has led to the development and

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deployment of novel low-frequency sources – such as the TGS Gemini source – which have shown significant uplifts in derived Earth-model quality when used in the presence of complex, rugose salt bodies," he added.

Gemini, an extended frequency-source technology, was initially deployed by ION Geophysical and later acquired by TGS. It produces a broader spectrum of frequencies, from 2-to-80 hertz or higher, than most other conventional sources, emitting very low frequencies helpful in imaging complex geologies.

"The low frequencies are critical to deriving an accurate velocity model, especially at depth. The eFWI-based inversion and imaging more accurately represents the Earth, properly handles amplitude and phase variation in the data and thus improves resolutions at reservoir depths," El Karkouri said.

"In particular, the methods more accurately simulate the wavefield at high-contrast media boundaries, leading to sharper sediment-salt interfaces (and) reduced salt 'halos,' and helps handle converted modes for improved illumination," he added.

Use of eFWI

Elastic waveform inversion considers elastic geophysical properties in seismic evaluation, including P- and S-wave velocities. It is widely used to characterize reservoir properties. And it has been a real challenge for the geophysical industry to apply as a practical tool.

"At greater depths – and thus commonly higher temperatures and pressures – in complex geology, we can now routinely use elastic full-waveform inversion to accurately characterize the elastic properties of the Earth," El Karkouri said.

"Whilst the theoretical basis for these approaches has been known for decades, it is only now that we have access to enough computing power to make their application tractable," he added.

Using broader bandwidth and improved algorithms, geophysics has unraveled some of the trickiest problems in offshore reservoir imaging involving complex geology. In many ways it's just as impressive an advance, if not as celebrated, as the industry's earlier breakthroughs in offshore imaging.

"The offshore seismic industry now is able to deliver more accurate seismic images in areas that have been previously considered difficult, especially at depth," El Karkouri said.

"It has been shown in such areas as the Messinian salt provinces of the Eastern Mediterranean and in the notoriously complex areas of the Gulf of Mexico such as the Garden Banks, that a combination of broader bandwidth seismic data – particularly if rich in low-frequencies – and eFWI algorithms for both model-building and imaging can lead to a step-change in structural image quality," he explained.

High-Performance Computing

High-performance computing has enabled many of the current advances in offshore geophysics. Through cloud services, TGS has expanded its total computing usage to more than three times on-premises capacity for some individual projects. The resulting efficiencies reduced large-dataset seismic processing from a matter of months to weeks, then to days.

In one example, a TGS Insights report noted, "the CPU utilization on a number of recent pre-stack time migration (PSTM), land-based projects has exceeded 200 percent of the total on-premises capacity for a single job. This led to a shortening of turnaround times for the project from weeks to days."

"Final Reverse Time Migration (RTM) processing has been reduced to between three and five days in the cloud, for an operation that might previously have taken 25-30 days on-premises."

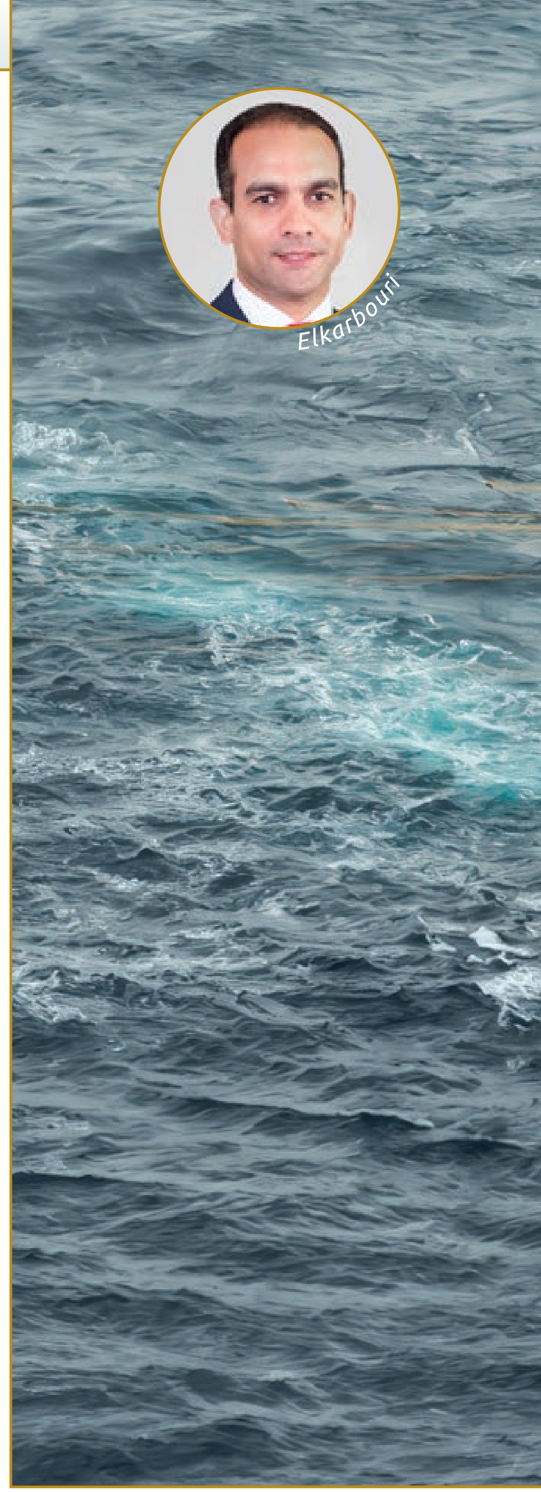
"Economic and large-scale HPC enables us to apply significantly more complex geophysical algorithms to the acquired data, which represent more accurately the physical state of the Earth's subsurface and thus lead to step change in the derived attributes used in exploration," El Karkouri said.

LEO Satellites

At one time, geophysical companies had to wait until seismic acquisition vessels returned to shore to begin processing offshore data sets. Data transmission using low Earth orbit satellites proved to be a game-changer.

"The advent of large networks of LEO satellites is heralding a step change in our ability to move geophysical data from offshore to onshore and thus provide almost real-time access to the data as it is collected," El Karkouri noted.

LEO satellites orbit much closer to the Earth's surface than traditional geosynchronous satellites, around 1,000 kilometers (roughly 620 miles) compared to about 36,000 kilometers. At the greater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height, a satellite's orbital period can equal the Earth's rotational period.

By contrast, LEOs completely circle the planet in about 90 minutes to two hours. And there are more orbital paths available for low-orbit satellites because their plane can be tilted.

Low-earth satellites aren't super-low. The International Space Station orbits at an average altitude of 400 kilometers, or about 250 miles. But because of their low orbits their individual coverage area is limited, so a network of LEO satellites is typically used for telecommunications.

El Karkouri called the combination of satellite network transmission and supercomputing a "revolution" in offshore geophysics.

"The HPC and LEO advances allow these improved representations of the Earth to be delivered in a fast and economically efficient manner," he observed. "This change is then driving a revolution in the way the offshore seismic industry delivers both QC products and data to the customer."

TGS Ramform Titan-class vessels were designed to fully utilize the potential of GeoStreamer technology. These ultra-high-capacity seismic vessels are the most powerful design yet, enabling greater flexibility and safer operations than any other 3-D seismic vessels.