

Pro4D Time-lapse modeling and analysis

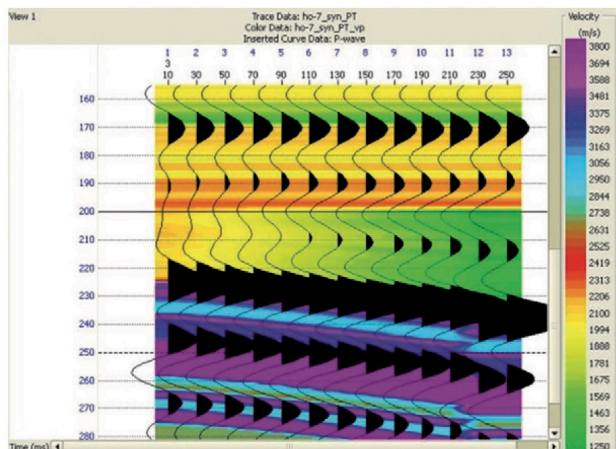
Pro4D is the module for time-lapse modeling and interpretation and for seismic data matching. A range of anticipated reservoir scenarios can be modeled to predict the seismic response to reservoir changes. Bypassed reserves or inefficient production are tracked on survey-calibrated seismic volumes. Advanced volumetric tools allow a QC of the 4D interpretation via a comparison with the production data.

Pro4D Features

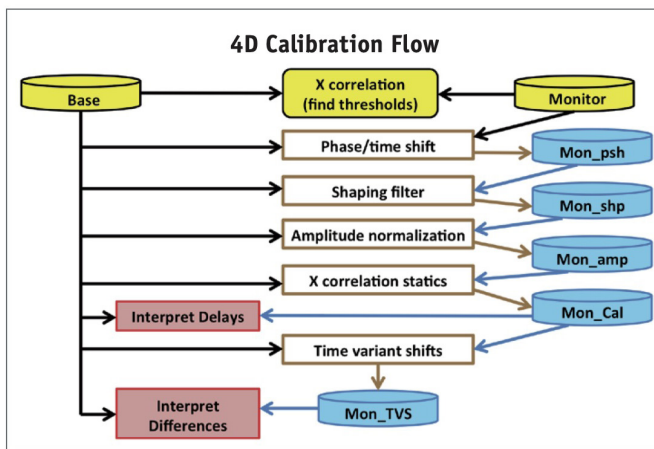
- Leading-edge survey calibration tools to match base and monitor surveys
- Prestack and poststack synthetics for many reservoir and geometry scenarios
- A wide range of time-lapse attribute maps to highlight production anomalies
- Volumetric analysis to compare time-lapse anomalies to production and injection data
- Comprehensive rock physics modeling:
 - Pressure calculation for rock framework and reservoir fluids
 - Three-phase fluids scenarios, including an option for CO₂
 - Fluid properties calculation using advanced FLAG consortium or Batzle-Wang methods
 - Bubble-point calculation using either the Standing or Butler equations
- Mixed mineralogy calculation with homogeneous pattern saturation, or with Voigt or Brie average patchy saturations
- Enhanced Biot-Gassmann implementation
- S-wave estimation using Xu-White, Gregory, Greenberg-Castagna, or Castagna methods
- Medium modeling using Reuss, Hill, or Hashin-Shtrikman averaging
- Kuster-Toksoz pore geometry effect option

Rock Physics & Synthetic Modeling

Rock physics relationships are used to form a bridge between the primary reservoir properties and the seismic response. Synthetic modeling in **Pro4D** is used to create a range of responses to predict how the seismic data will be affected by the reservoir changes in terms of temperature, pressure, fluid saturation, Gas-Oil-Ratio, and reservoir thickness. The modeling results will then be used to guide the interpretation.



Synthetic traces showing the time delay in a bitumen reservoir where the modeled increase in temperature produces a velocity decrease (velocities are represented by different colors).



The 4D calibration flow includes: cross-correlations and cross-plots of seismic volumes and comparison of volumes using a differencing tool; volume matching by time & phase matching, shaping filter, amplitude cross-normalization, and time-variant shifts.

Time-lapse Volume Calibration

Fundamental to time-lapse studies is the removal of non-production-related differences from the monitor seismic volumes. The **Pro4D** module in **HampsonRussell** has comprehensive survey calibration features that match the phase, frequency, amplitude and event times of base and monitor surveys in areas where production has not occurred. The integration of **Pro4D** into the **Geoview** interface makes complex time-lapse analysis simple, with customizable workflows, faster run-times and highly efficient sequence processing options.

Time-lapse Interpretation

Both time delays and amplitude differences between base and monitor surveys are interpreted. The extent of production effects can be interpreted in **Pro4D** from volumes of amplitude ratios, cross-correlation coefficients and time shifts. Amplitude differences between vintages in the reservoir interval highlight reflectivity changes caused by the production process; these can be related back to the synthetic responses generated during the modeling phase.

Time-laps Inversion (4D Inversion)

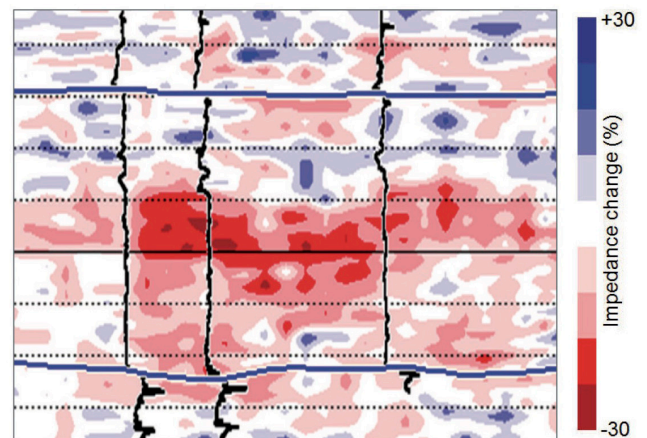
Velocity changes and time delays caused by production can be used to update the background models used for inverting the base and monitor surveys. This provides essential information that is below the seismic resolution and therefore not apparent from amplitude changes in the seismic volumes. Comparison between inversions of the base and monitor surveys can be more revealing than comparison between seismic amplitudes of the same volumes.

Benefits of Pro4D Include:

- Simple and effective data management tools for handling multiple time-lapse seismic surveys and corresponding horizons
- Easy tracking of production-related changes and of bypassed reserves or inefficient production
- Unlocking information below seismic resolution that is not apparent from amplitude changes in the seismic volumes

Volumetrics

The challenge of time-lapse interpretation is to address the non-uniqueness of the 4D response. **Pro4D** offers advanced capabilities for comparing time-lapse anomalies to production and injection data, thereby reducing the uncertainty in the interpretation.



Acoustic Impedance difference between base and monitor inversions.