SMART-CS Initiative

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Presentation to U.S. DOE Headquarters
Phase I Accomplishments Session
FWP Number: 1022462
Task 3: Imaging Pressure & Stress
January 25, 2022

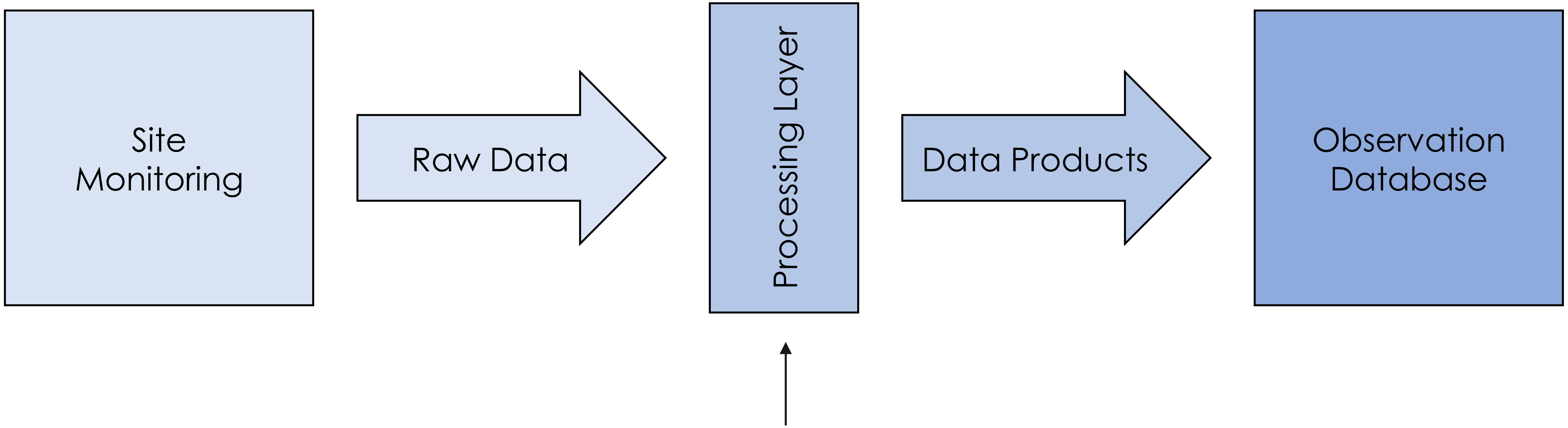
U.S. DEPARTMENT OF ENERGY

Task 3: Imaging Pressure and Stress

Radical improvement in imaging pressure and stress can be enabled with three key technologies:

1. Rapid and autonomous geophysical monitoring
   - e.g. processing monitoring datasets 100x faster with minimal human intervention
2. Real-time modeling and data assimilation tools
   - e.g. real-time seismic inversion to monitoring pressure / saturation plume migration
3. Visualization and decision-support frameworks
   - e.g. dynamic seismicity risk forecasting

Enabling Technology 1: **Rapid Geophysical Monitoring**

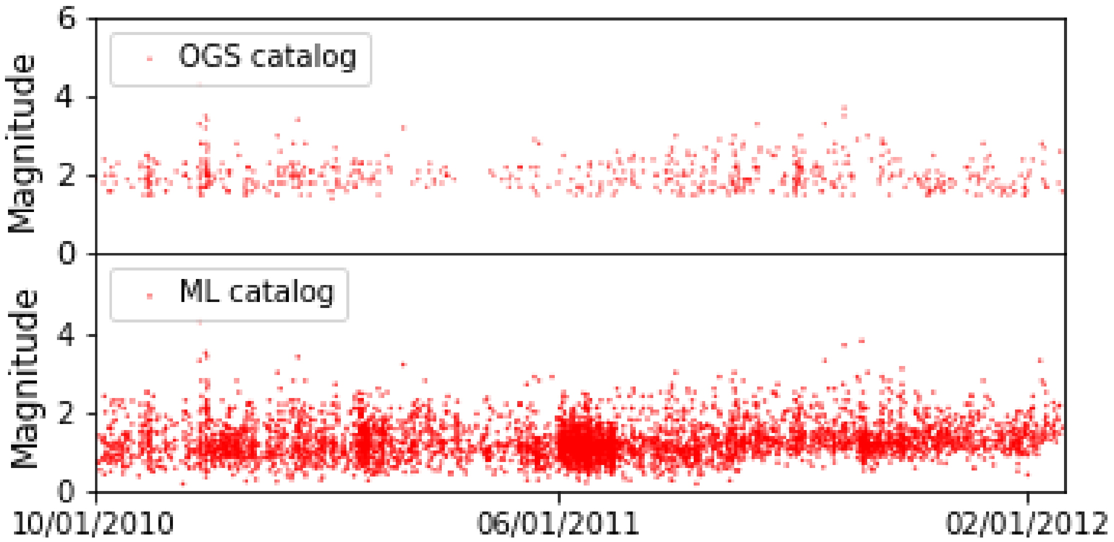


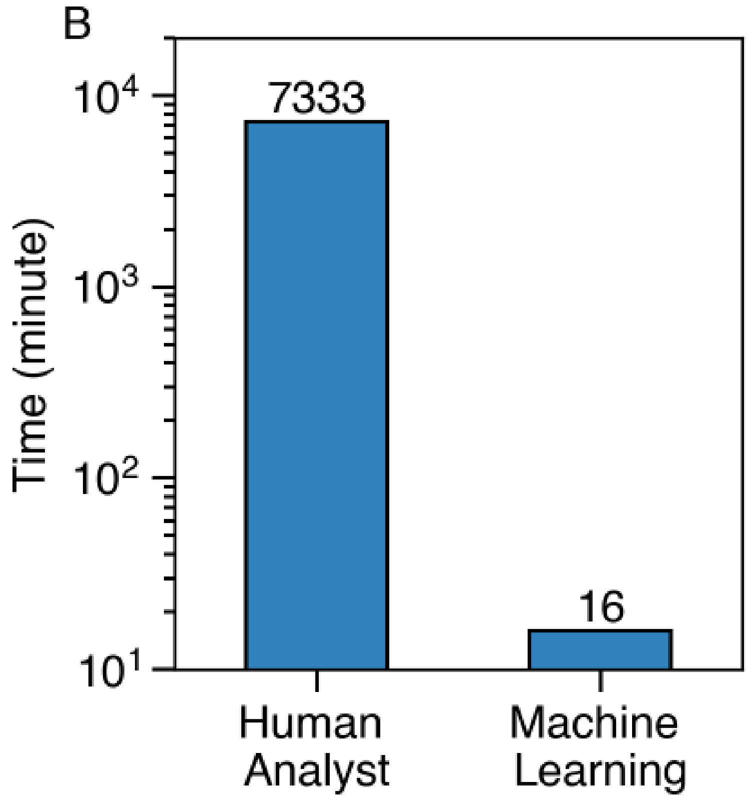
ML-Enabled Geophysical Monitoring Toolkit

Passive Seismic Imaging

POC: Chengping Chai

ML can provide better picks, locations, and tomography .... at orders of magnitude less cost.





Figures: Comparisons of ML picking vs. standard catalog generation methods in terms of numbers of events detected and processing time.

15x as many events detect. 460x faster analysis.

Passive Seismic Imaging

POC: Richard Alfaro-Diaz

Passive seismic data also offers new, unexploited data streams to constrain state-of-stress.

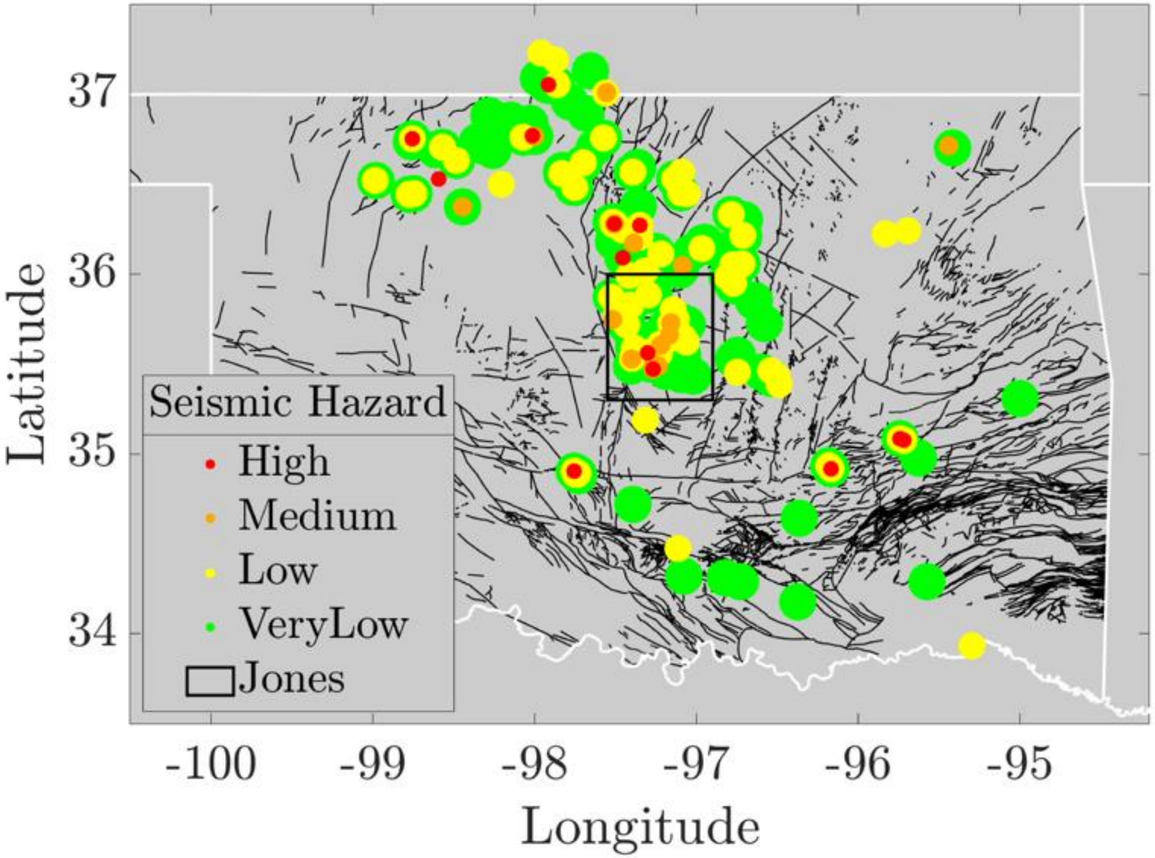
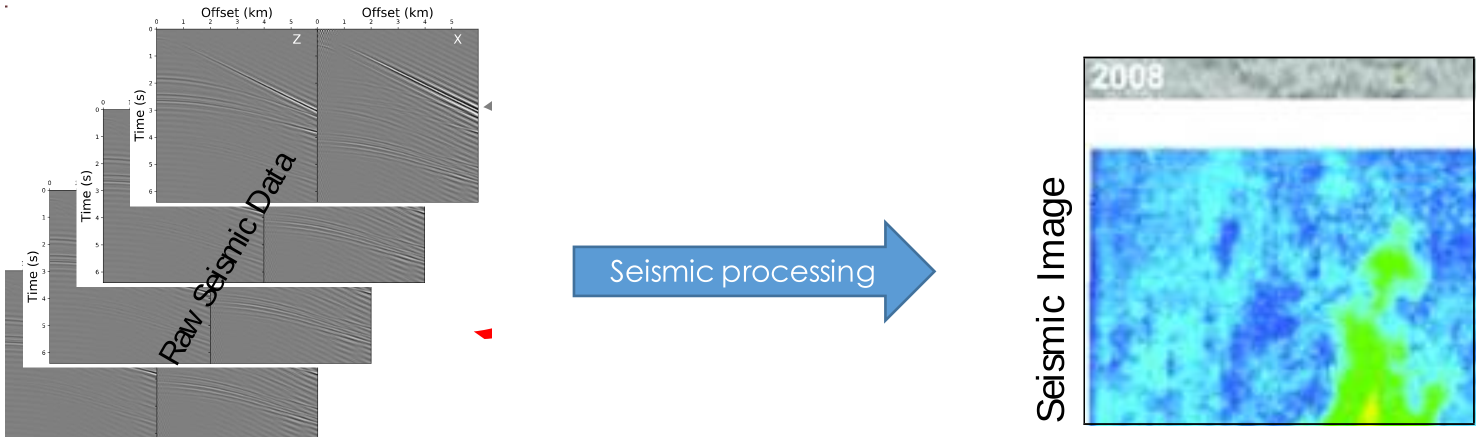


Figure: Geo-spatial visualization of seismic hazard in critically-stressed regions of Oklahoma inferred from dynamically triggered seismicity .

Additional constraint on seismic hazard provided through data streams never used before in traditional reservoir monitoring workflows

Active Seismic Imaging

POC: Jyoti Behura



Challenge:

4D seismic processing is time-consuming and very expensive

Opportunity:

Use trained CNNs as a rapid seismic processor to have imaging results in hours, not months

Active Seismic Imaging

POC: Jyoti Behura

Methodology

- CNN trained using 400 shot-gathers from year 0 and year 1 seismic surveys
- Years 2 to 5 predicted

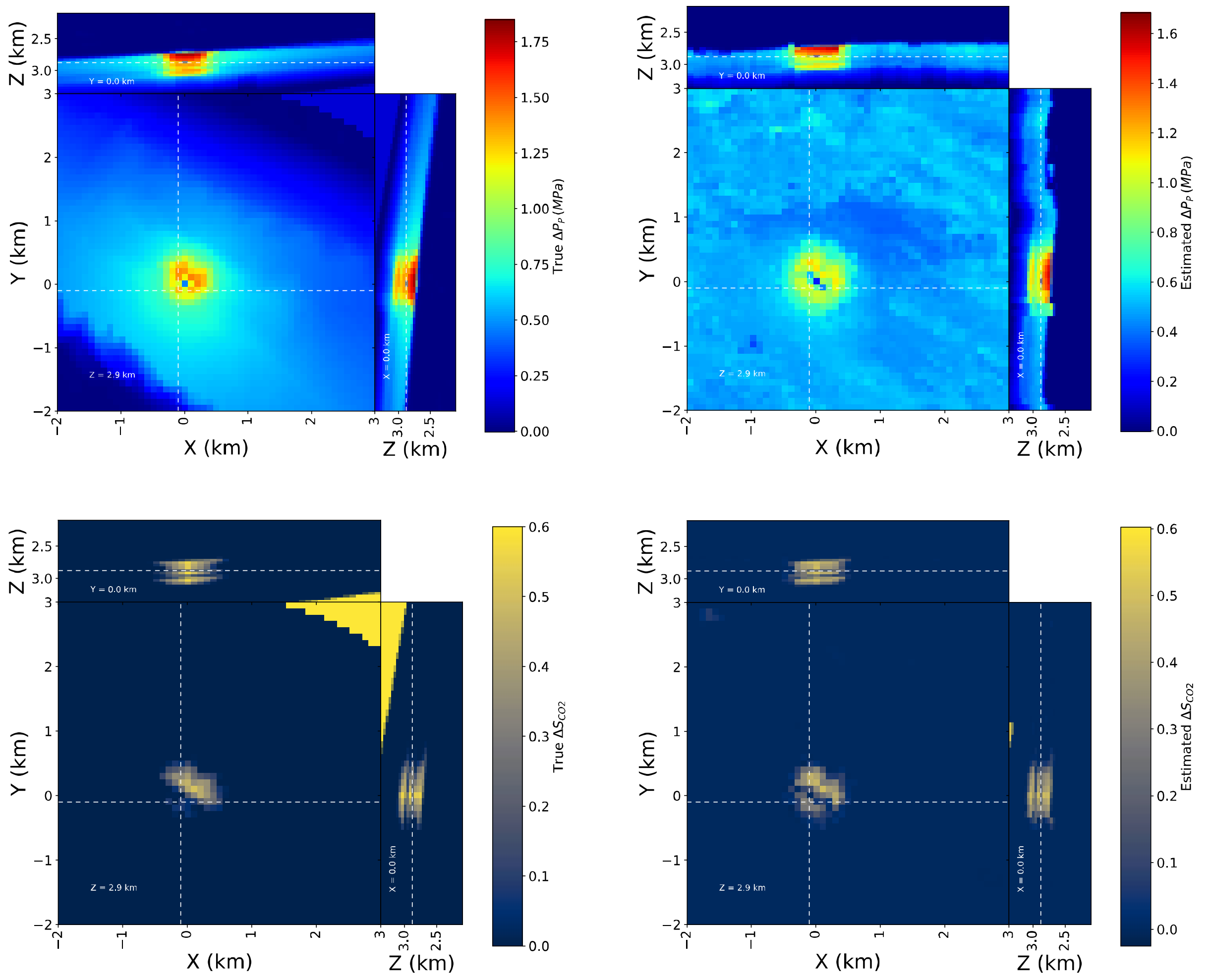
Implication

- Could use rapid NN for real-time monitoring while awaiting more time-intensive processing

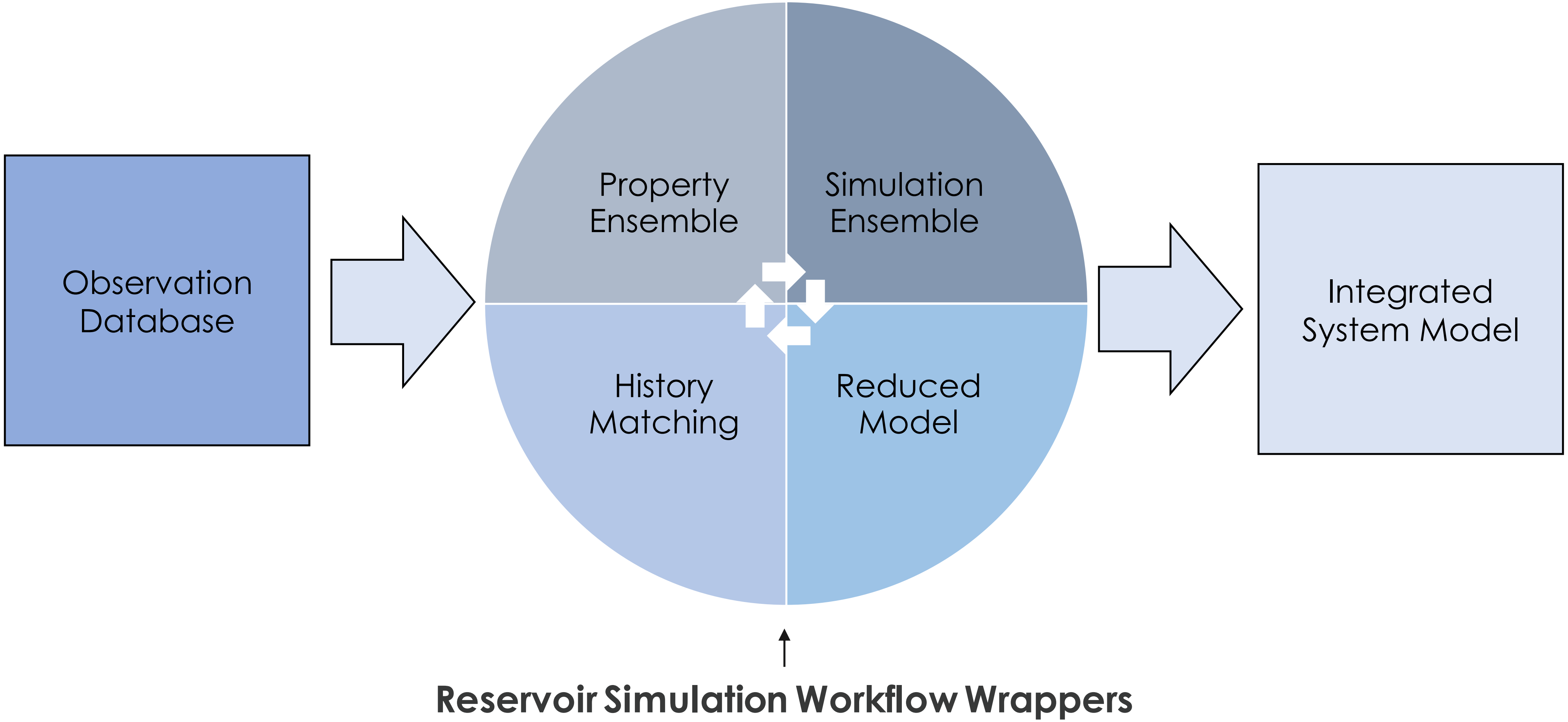
Ground Truth | ML Result

Year 2 - Year 0 Perturbation in Pore - pressure

Year 2 - Year 0 Perturbation in CO_2 Saturation



Enabling Technology 2: **Real-Time Modeling & Data Assimilation**



Autonomous Inversion of Deformation Data

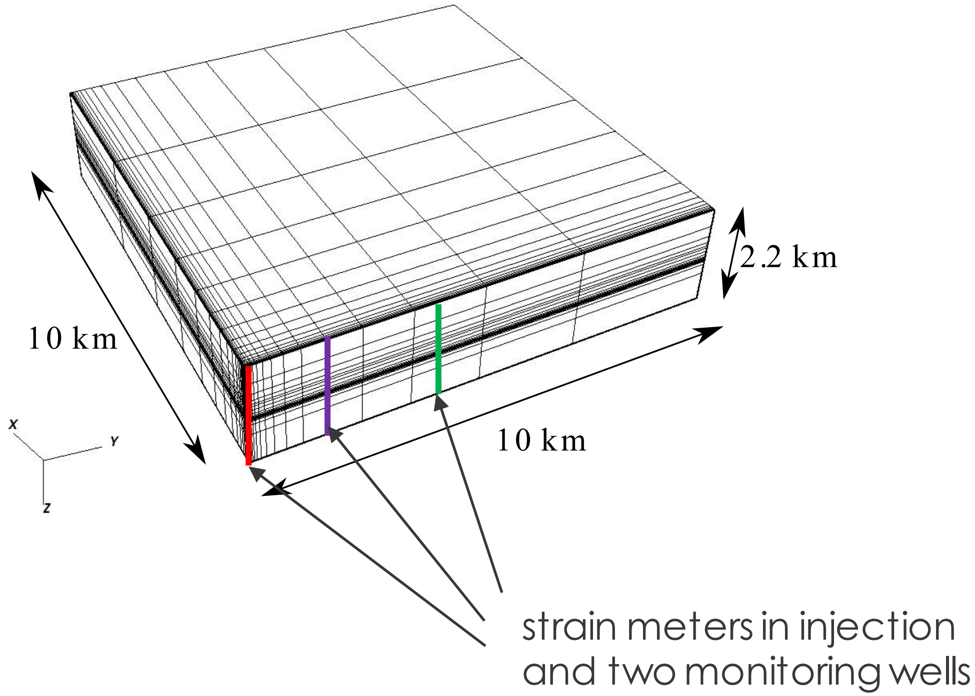
POC: Jeff Burghardt

Challenge:

Workflows for determining rock properties and state-of-stress are often slow and clunky.

Proposed Approach:

Combine NNs, a physics-based finite element model, and a gradient-based inversion algorithm to rapidly estimate elastic properties from sparse strain measurements.



Battelle

POC: Jeff Burghardt

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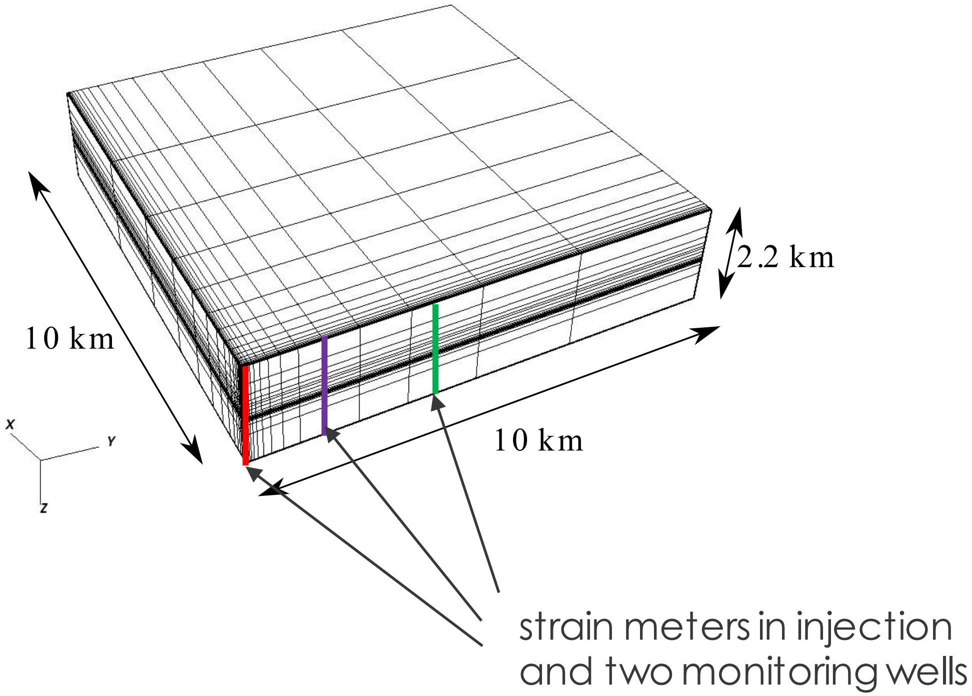


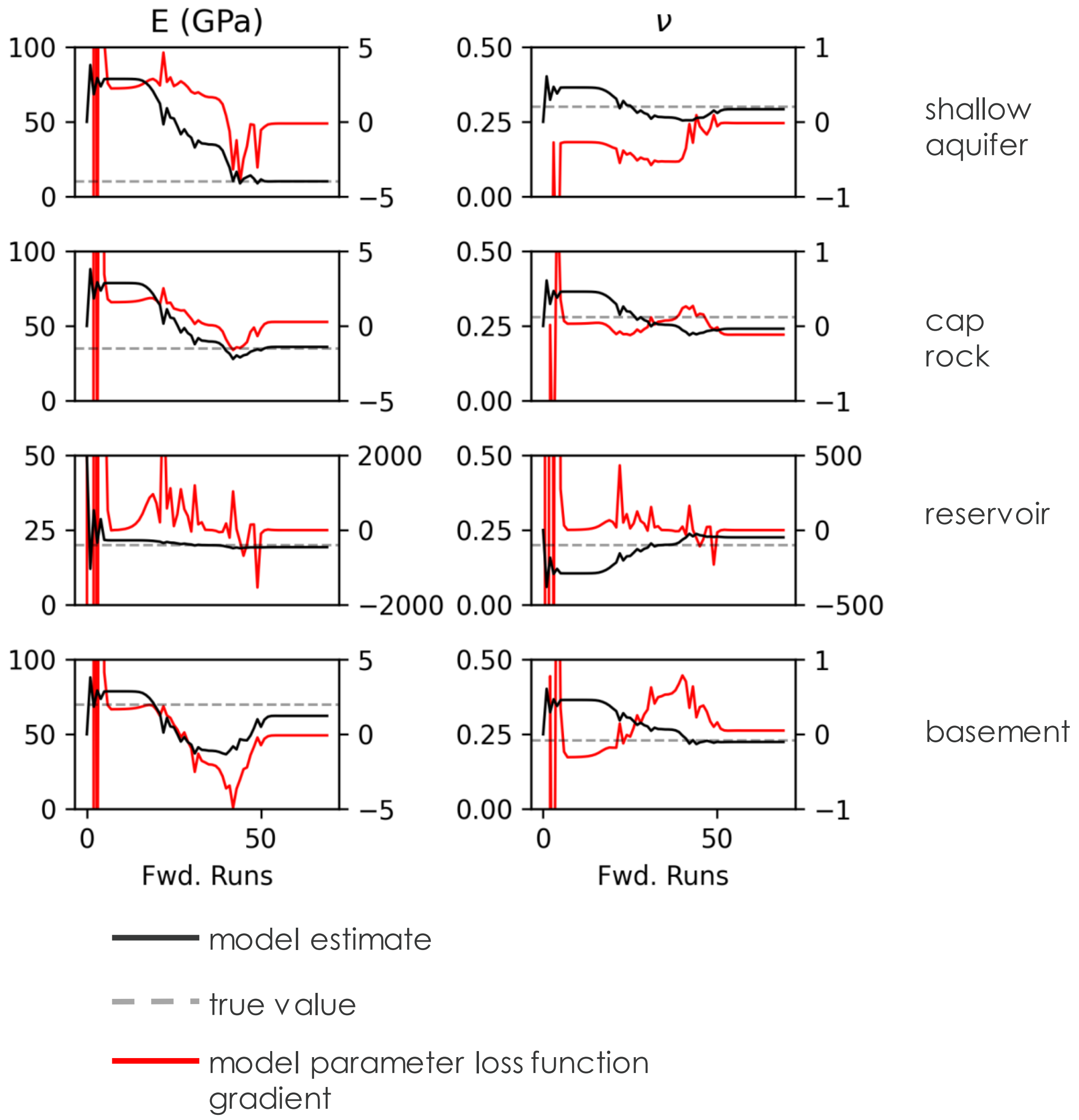


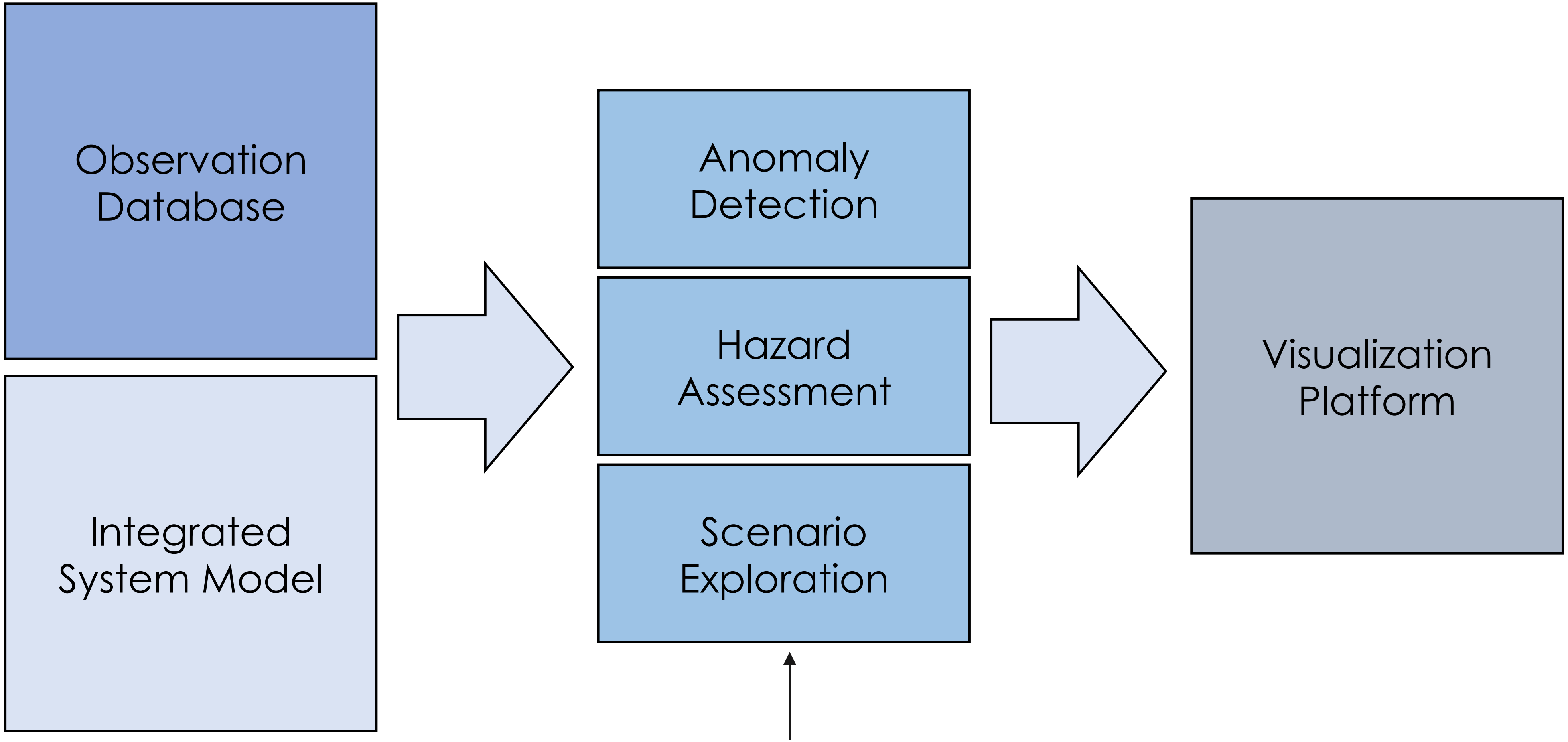
Figure: Convergence of inversion model to true estimate

Implication

Rapid processing adds significant value to novel monitoring techniques:

- fiber optic strain sensing
- InSAR (onshore)
- ocean bottom pressure sensors (offshore)

Enabling Technology 3: **Visualization & Decision Support**



Decision-Support Tools (see Demos!)

Phase I Accomplishments

Automated Monitoring & Characterization

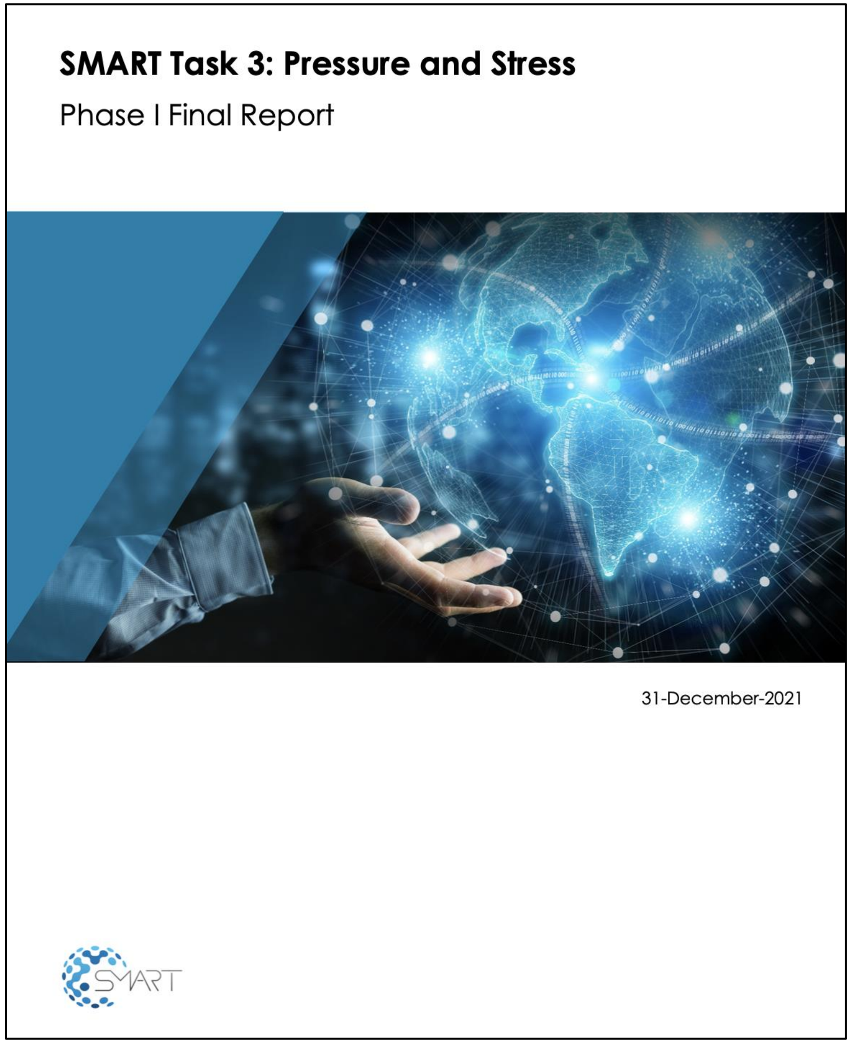
- *Study 1A:* Seismic event detection and source properties with machine learning
- *Study 1B:* Artificial intelligence enhanced body and surface wave tomography
- *Study 1C:* Using ambient noise to estimate stress orientation
- *Study 1D:* State of stress from triggered earthquakes
- *Study 1E:* Deep learning and anomaly detection applied to distributed acoustic sensing (DAS)
- *Study 1F:* Pre-injection characterization by transfer learning to identify features below active seismic resolution from induced events.
- *Study 1G:* Time-lapse quantitative monitoring of CO_2 plume using supervised deep learning

Real-Time Modeling & Data Assimilation

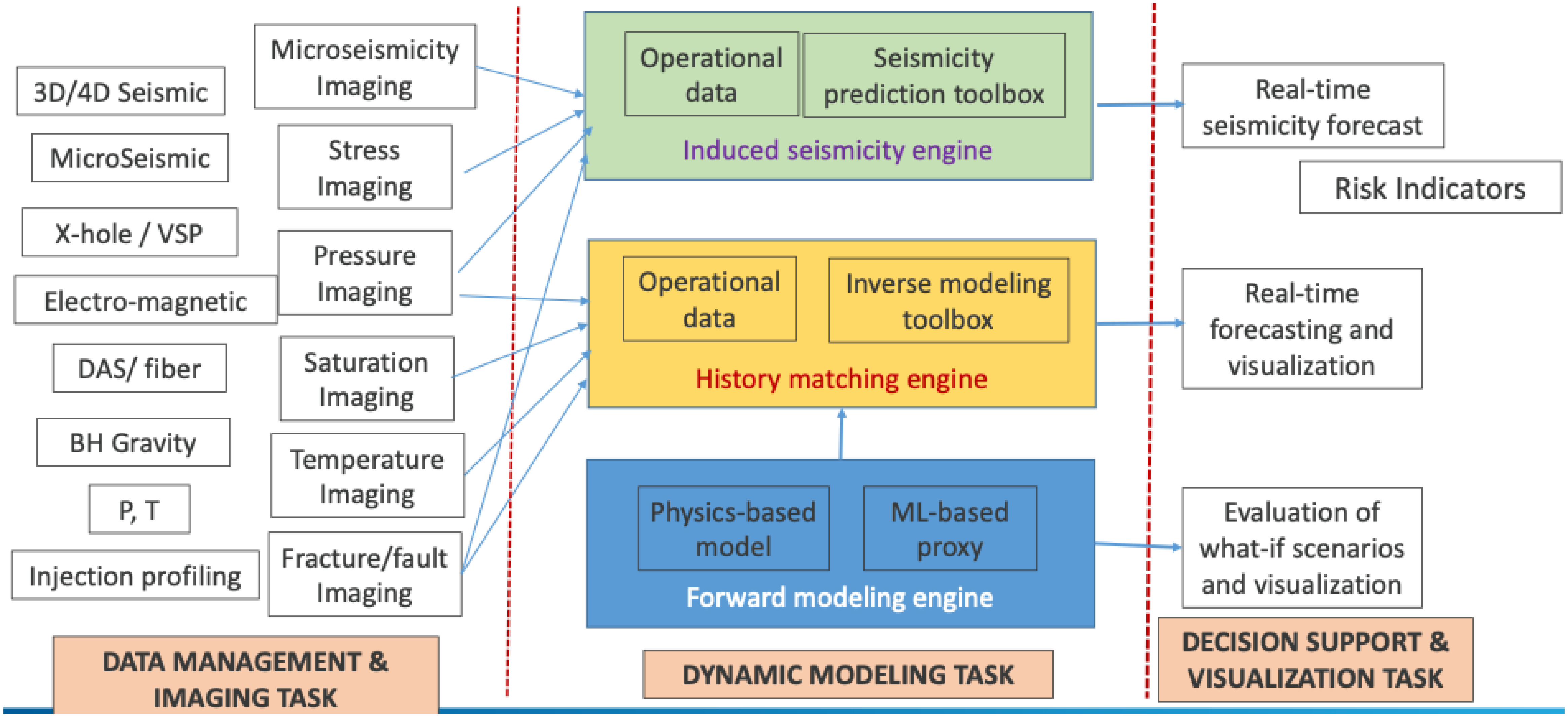
- *Study 2A:* Predictive analysis of pressure and temperature in carbonate reservoirs
- *Study 2B:* State of stress modeling from geophysical joint inversion
- *Study 2C:* Autonomous inversion of in situ deformation data for CO_2 storage decision support

Visualization & Decision Support

- *Study 3A:* Operational Forecasting of Induced Seismicity



Phase II Goals



Questions?

Thank you!

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