USM – Unified Simulation Module

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

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FECM/NETL Carbon Management Research Project Review Meeting
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U.S. DEPARTMENT OF ENERGY

Outline of the talk

- Overview: The Role of USM in SMART
- USM tool – Features and Workflow
  - Data Management
  - Forward ML Models Execution
- Example Usage - Illinois Basin Decatur Projects (IBDP)
- Next Steps
- Impact – How will the USM help the CCS industry?

Key Participants

Developers and contributors from PNNL, LLNL , SNL, UTBEG, BATTELLE, and NETL

Lead developers

- Wenjing Wang (PNNL)
- Jeff Burghardt (PNNL)
- Chris Sherman (LLNL)

ML model developers

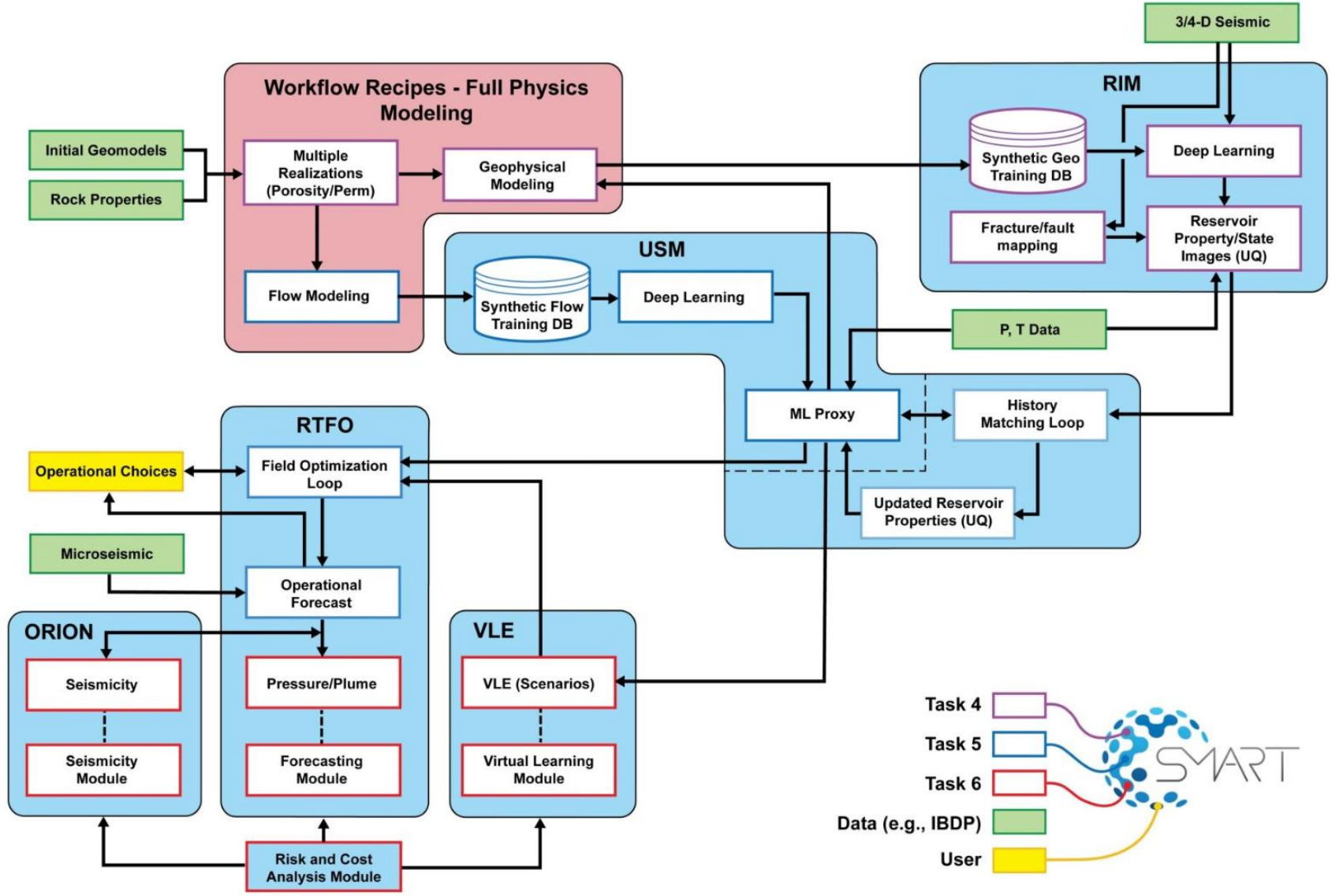
- Seyyed Hosseini (UTBEG)
- Hongsheng Wang (UTBEG)
- Hongkyu Yoon (SNL)
- Joe Hogge (SNL)

Contributors

- Josh White (LLNL)
- Veronika Vasylkivska (NETL)
- Jared Schuetter (BATTELLE)
- Eusebius Kutsienyo (PNNL)
- Maruti Mudunuru (PNNL)

USM's Role in SMART

USM is a common framework for sharing data & ML models across SMART tools.



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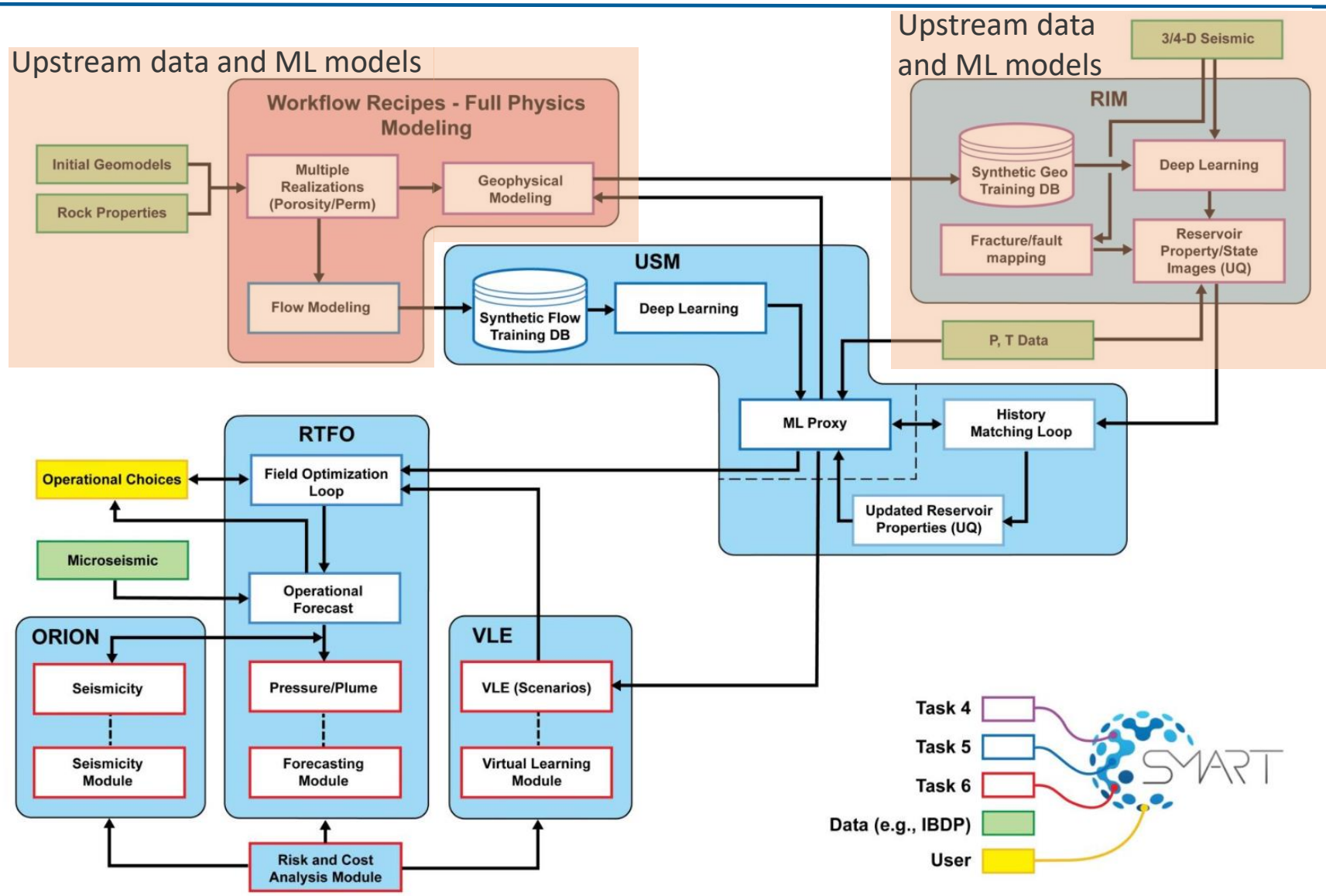

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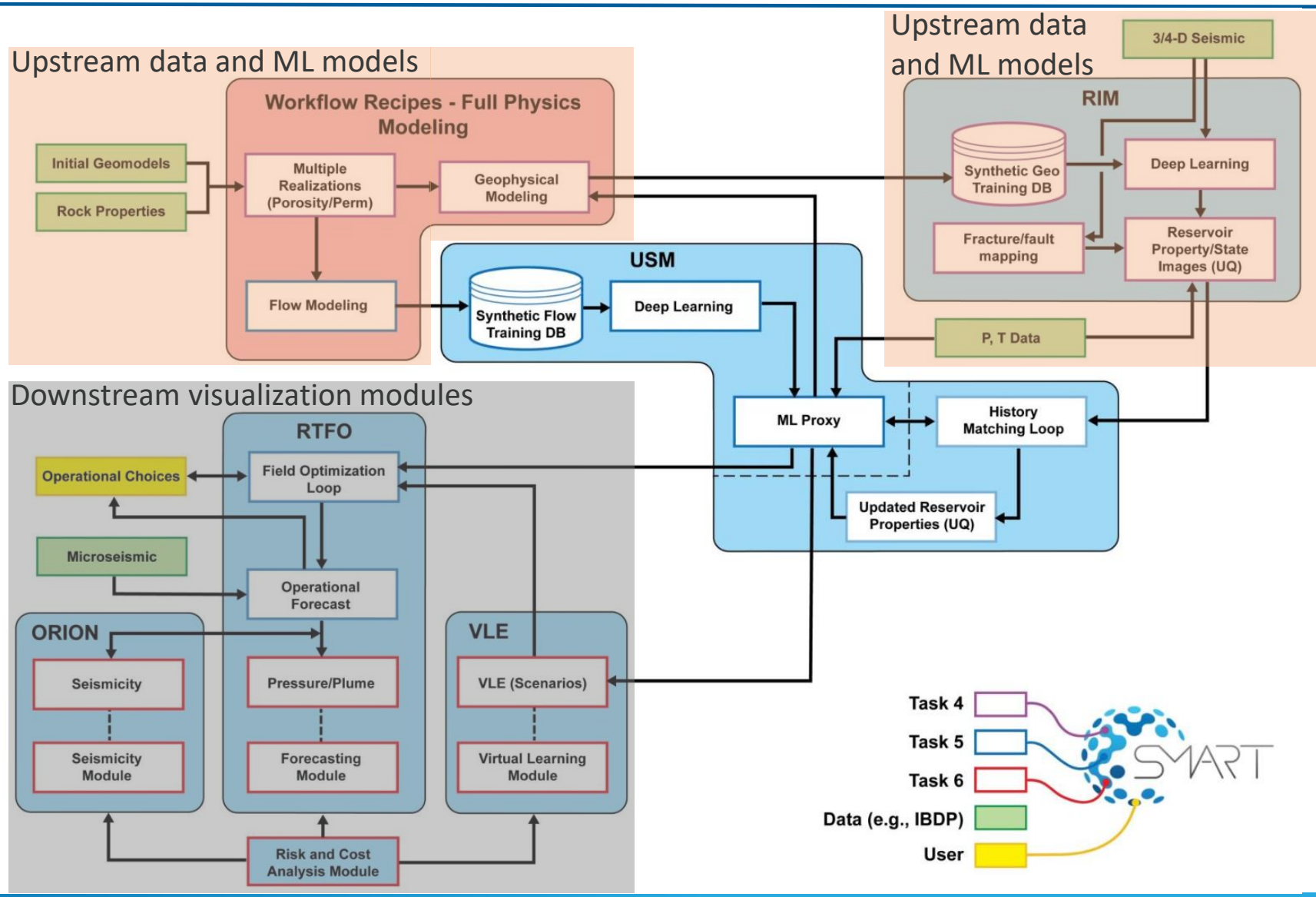


Tool Features

Status

- **Data Managers – data extraction and management from industry-standard geologic and reservoir model data formats**

  (1) Reservoir Property Manager

  - Static reservoir property data: e.g. porosity and permeability

  (2) Reservoir State Manager

  - Dynamic reservoir data: e.g. pressure and CO_2 saturation

  (3) Operational Scenario Manager

  - Injection & monitoring wells: e.g. injection rate and bottomhole pressure

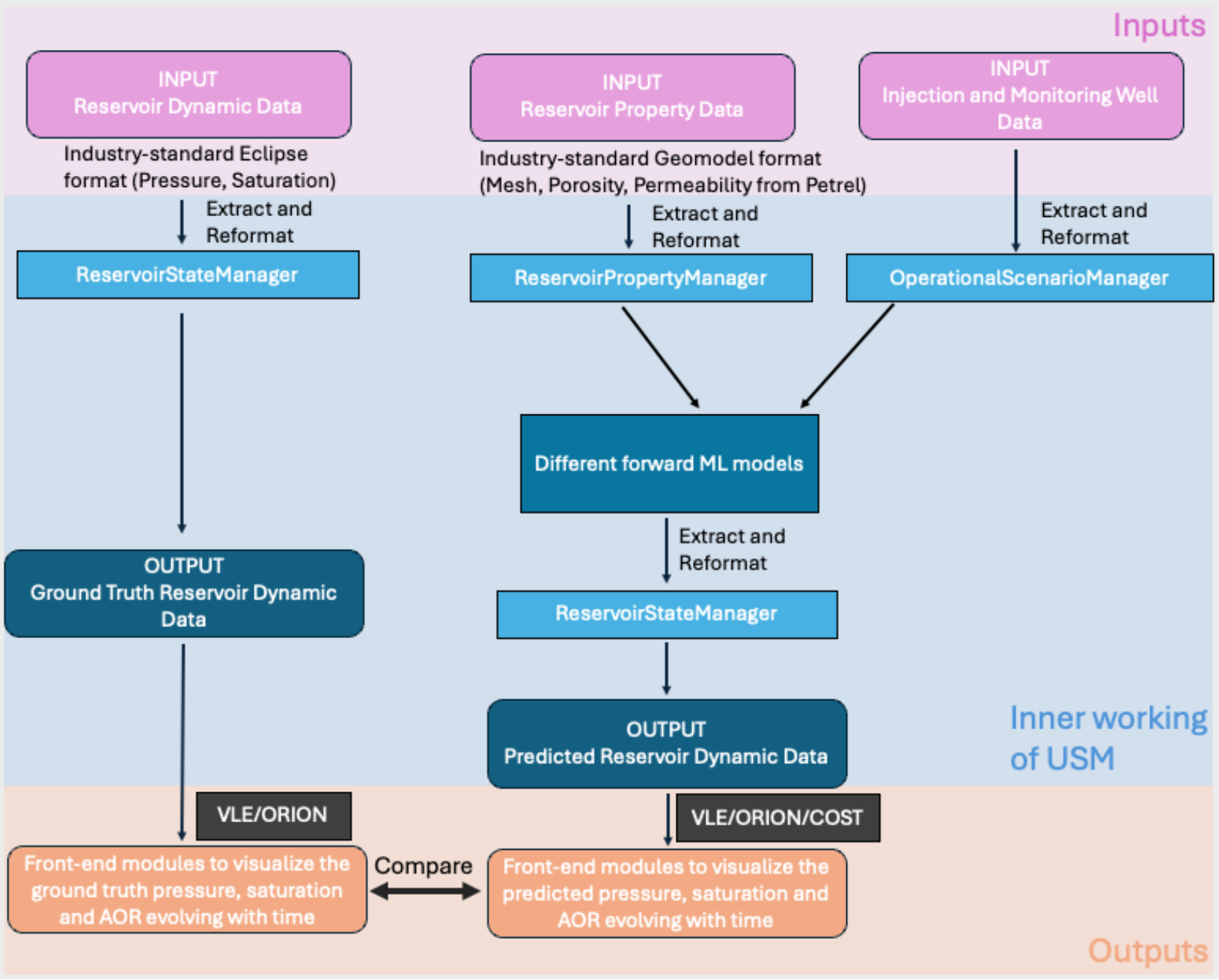
- **Organizes ML-based surrogated models into a centralized platform**

  Reservoir flow simulator for rapid prediction of reservoir responses

Tool Workflows

Status

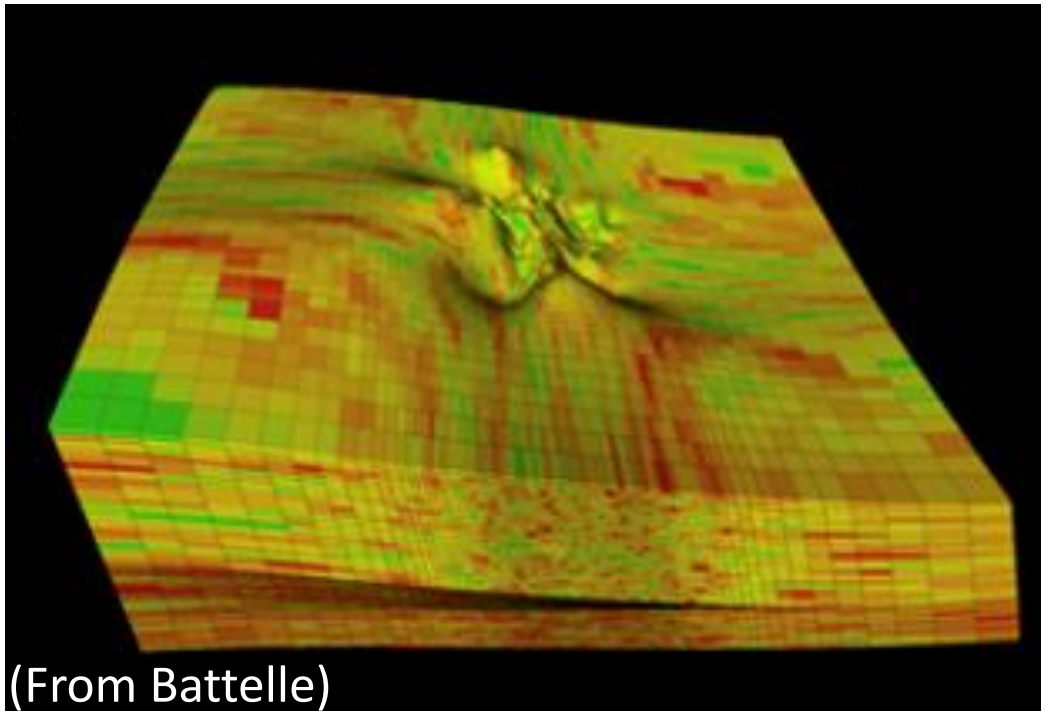
- Data extraction from industry-standard format
- Data sharing for visualization modules
- ML-based reservoir flow simulator



Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir property manager

USM reads geomodels (GRDECL file format from Petrel)

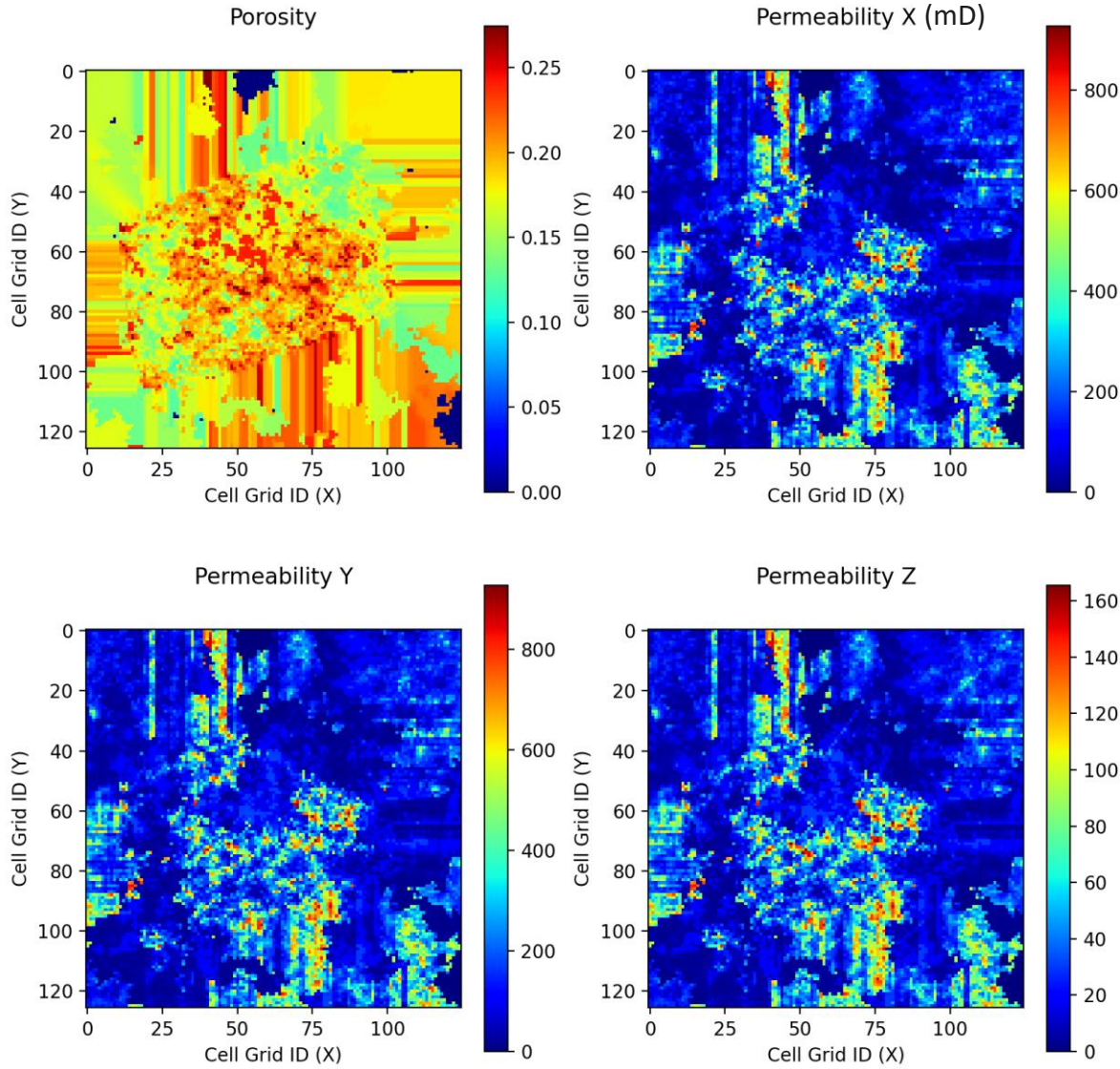


(From Battelle)

nx=126, ny=125, nz=110

(1.73 M cells)

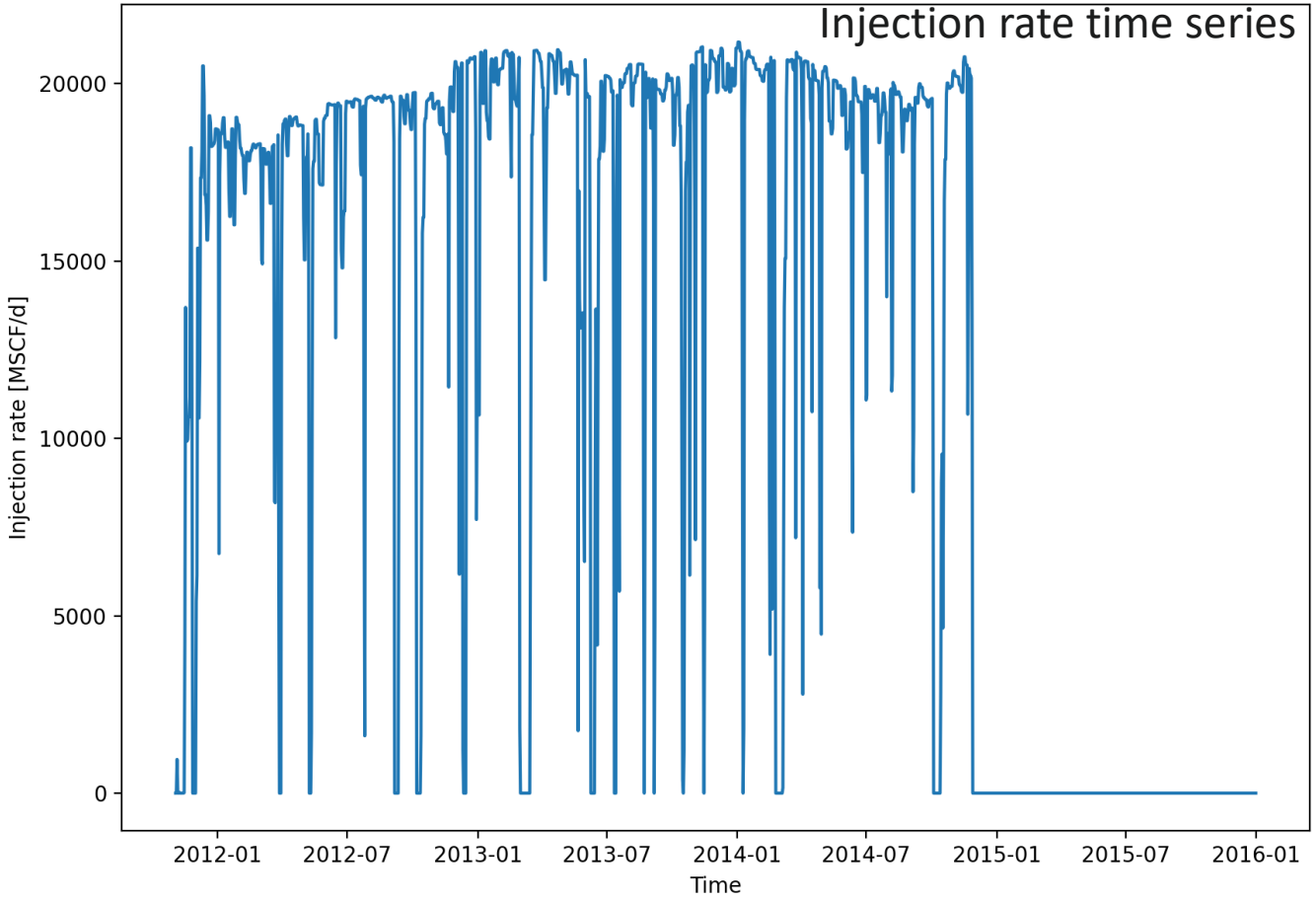
At a certain depth



Example Usage – Illinois Basin Decatur Projects (IBDP)

Operational scenario manager

USM reads injection-related files



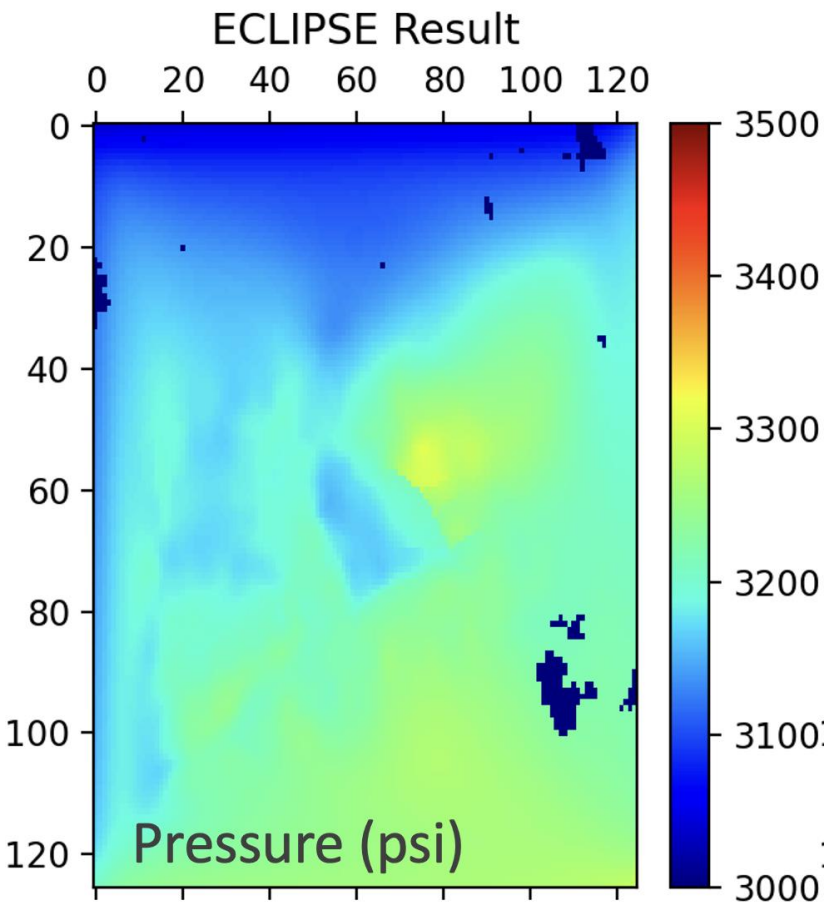
Operational injection started on Nov 17th,2011 and was completed successfully on Nov 26th , 2014 with a total volume of 999,231 tons.

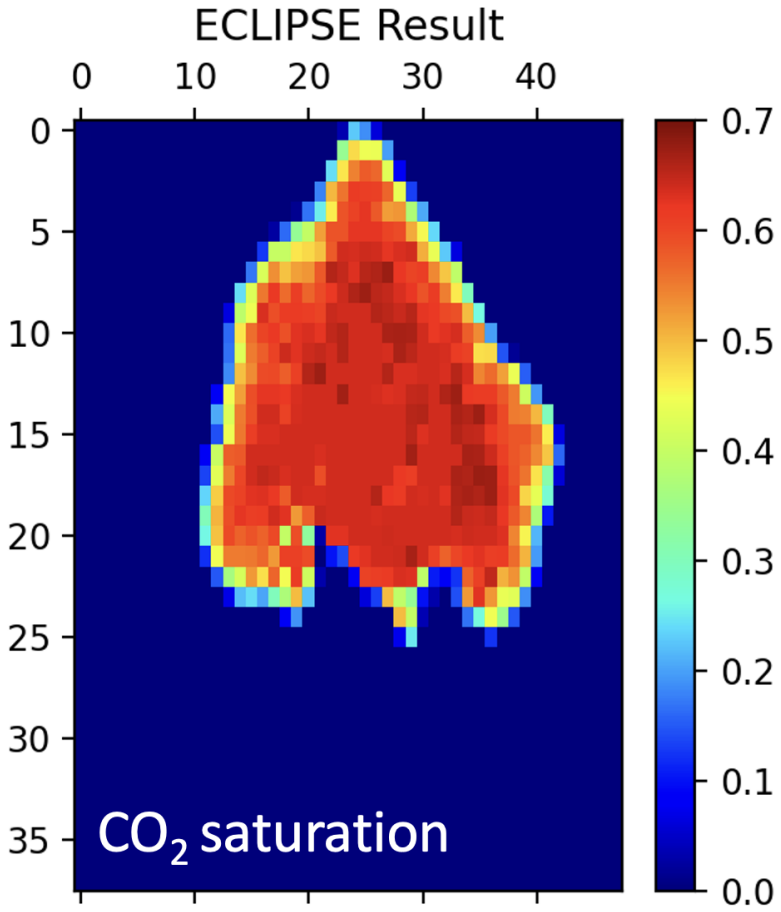
Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir state manager

USM reads dynamic models (GRDECL file format from Eclipse)

Visualized at a certain time and a certain depth



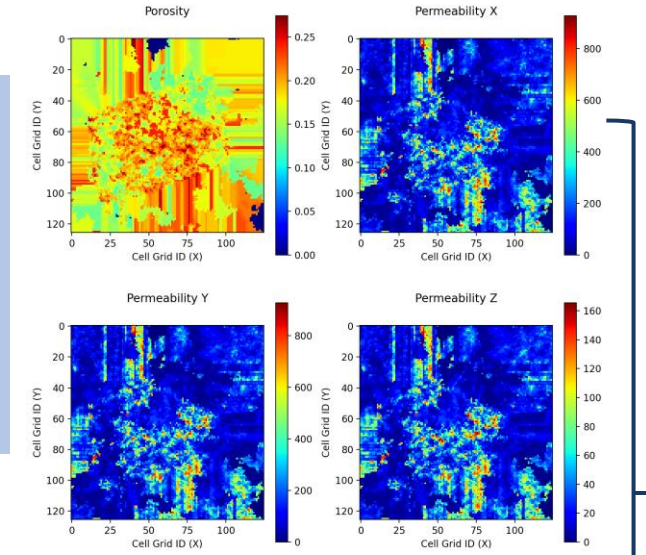


Example Usage – Illinois Basin Decatur Projects (IBDP)

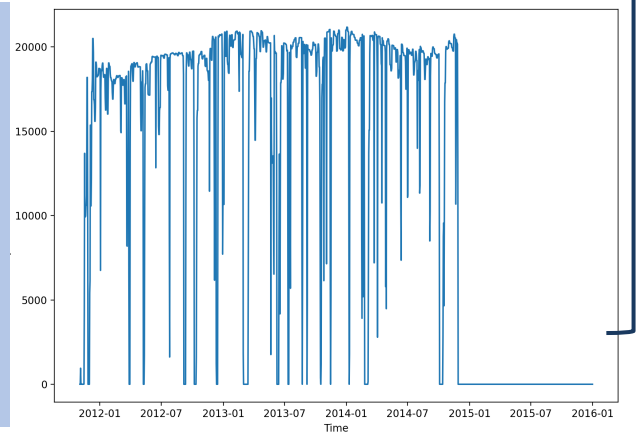
Reservoir flow simulator

USM executes ML-based reservoir simulators

Reservoir Property



Operational Scenario



ML models in USM:
(1) UNet-MLP (developed by UTBEG)
(2) DeepONet, CNN-LSTM (developed by SNL)

Predicted Reservoir State Manager (stores pressure, saturation) in USM

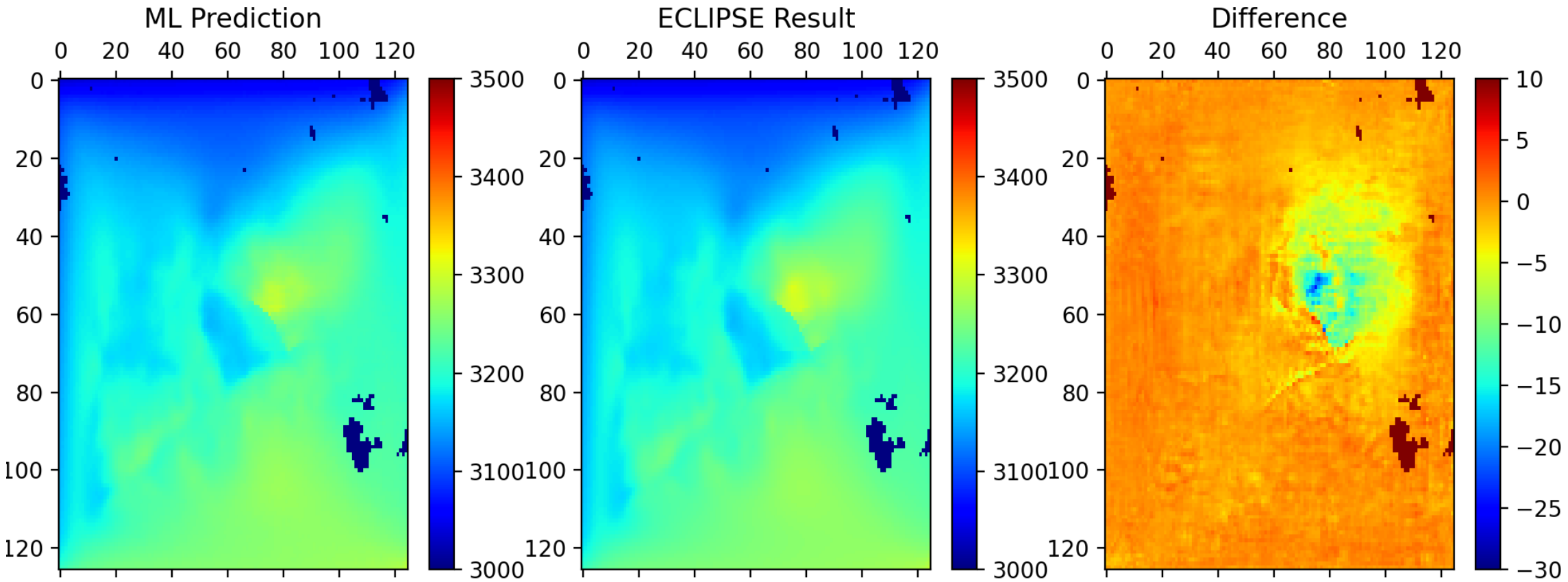
Compare

Ground Truth Reservoir State Manager in USM extracted from Eclipse exports

Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir flow simulator

Comparisons between reservoir responses (Pressure in psi)



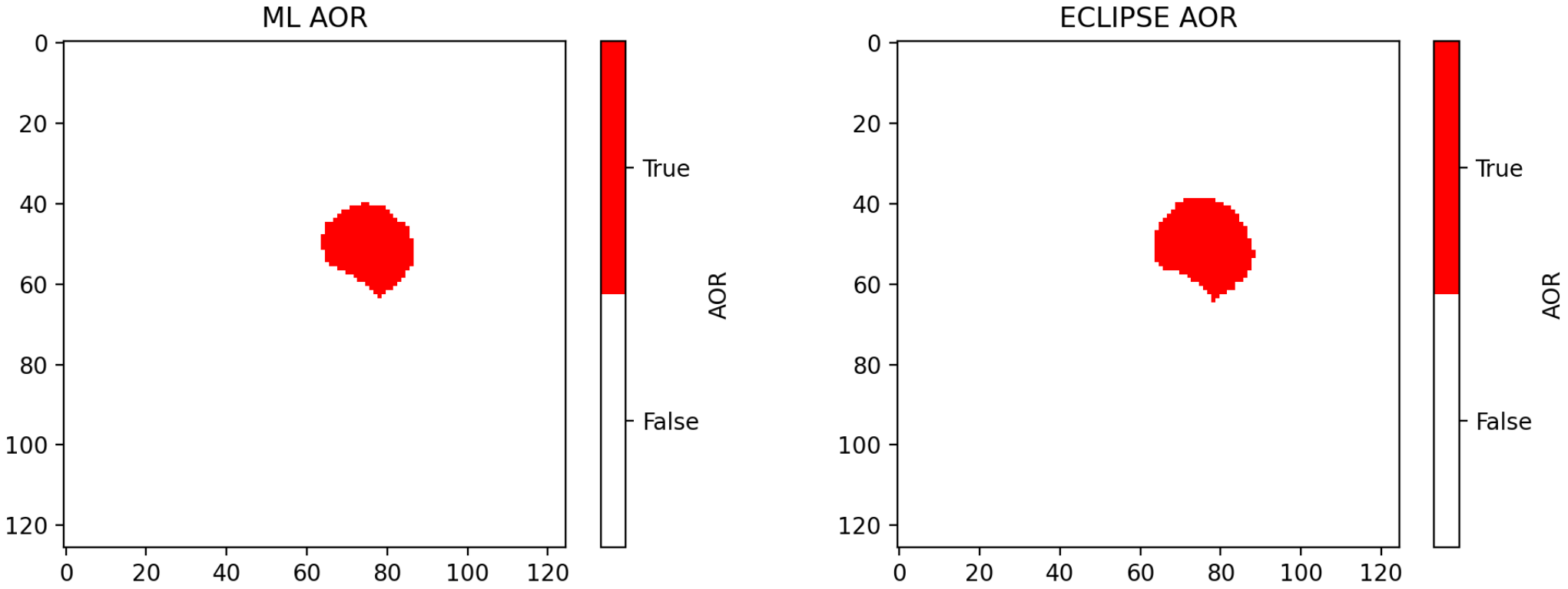
Visualized at a certain time and a certain depth

Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir flow simulator

Comparisons between reservoir responses (Pressure in psi)

Pressure Front (> 96 psi)

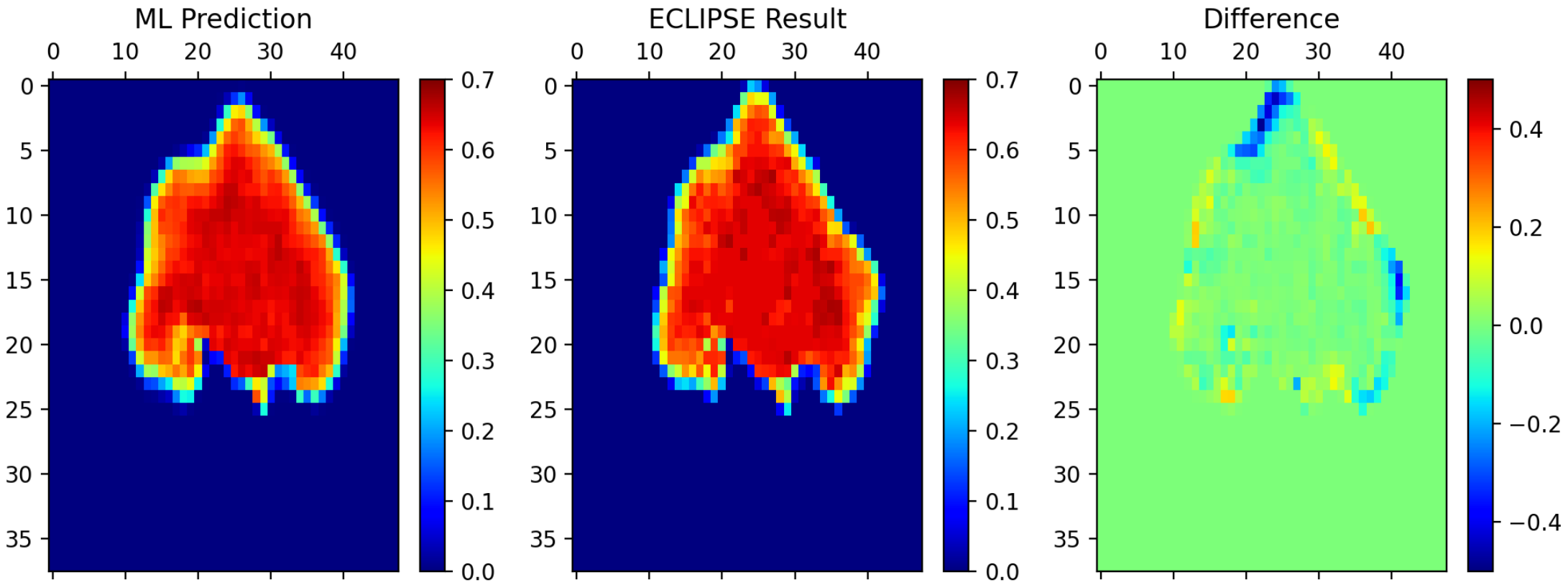


Visualized at a certain time

Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir flow simulator

Comparisons between reservoir responses (Saturation)



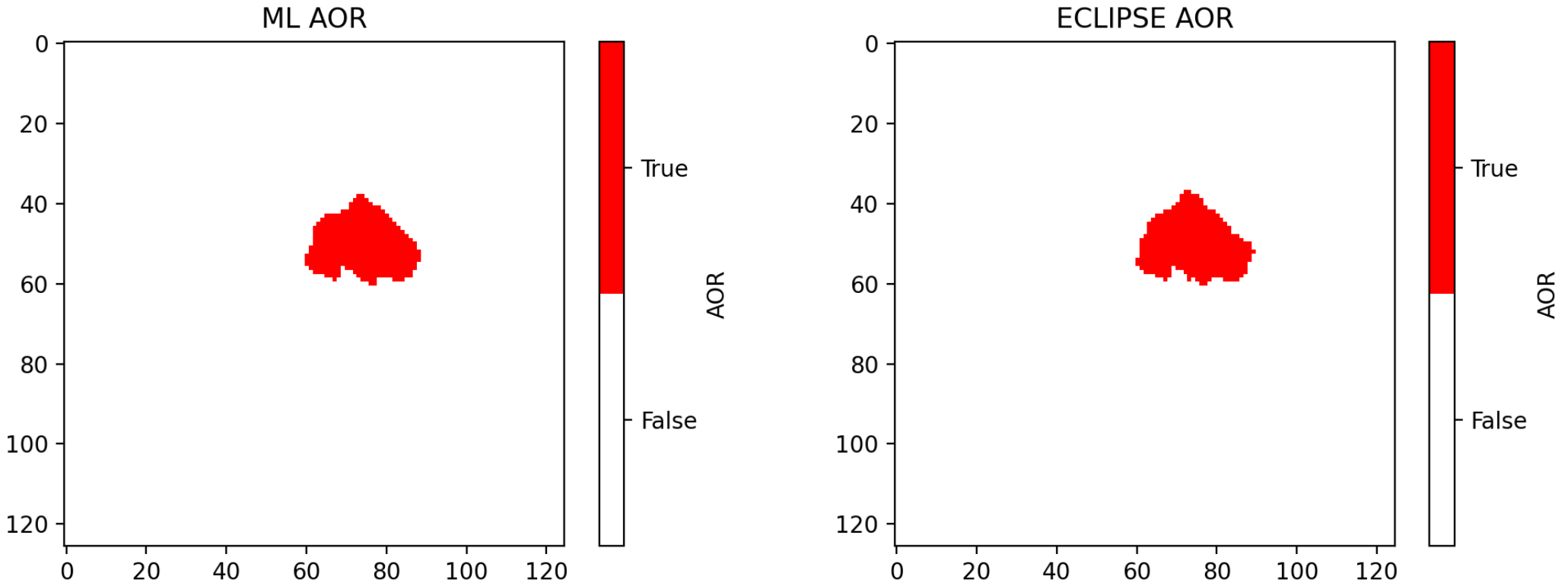
Visualized at a certain time and a certain depth

Example Usage – Illinois Basin Decatur Projects (IBDP)

Reservoir flow simulator

Comparisons between reservoir responses (Saturation)

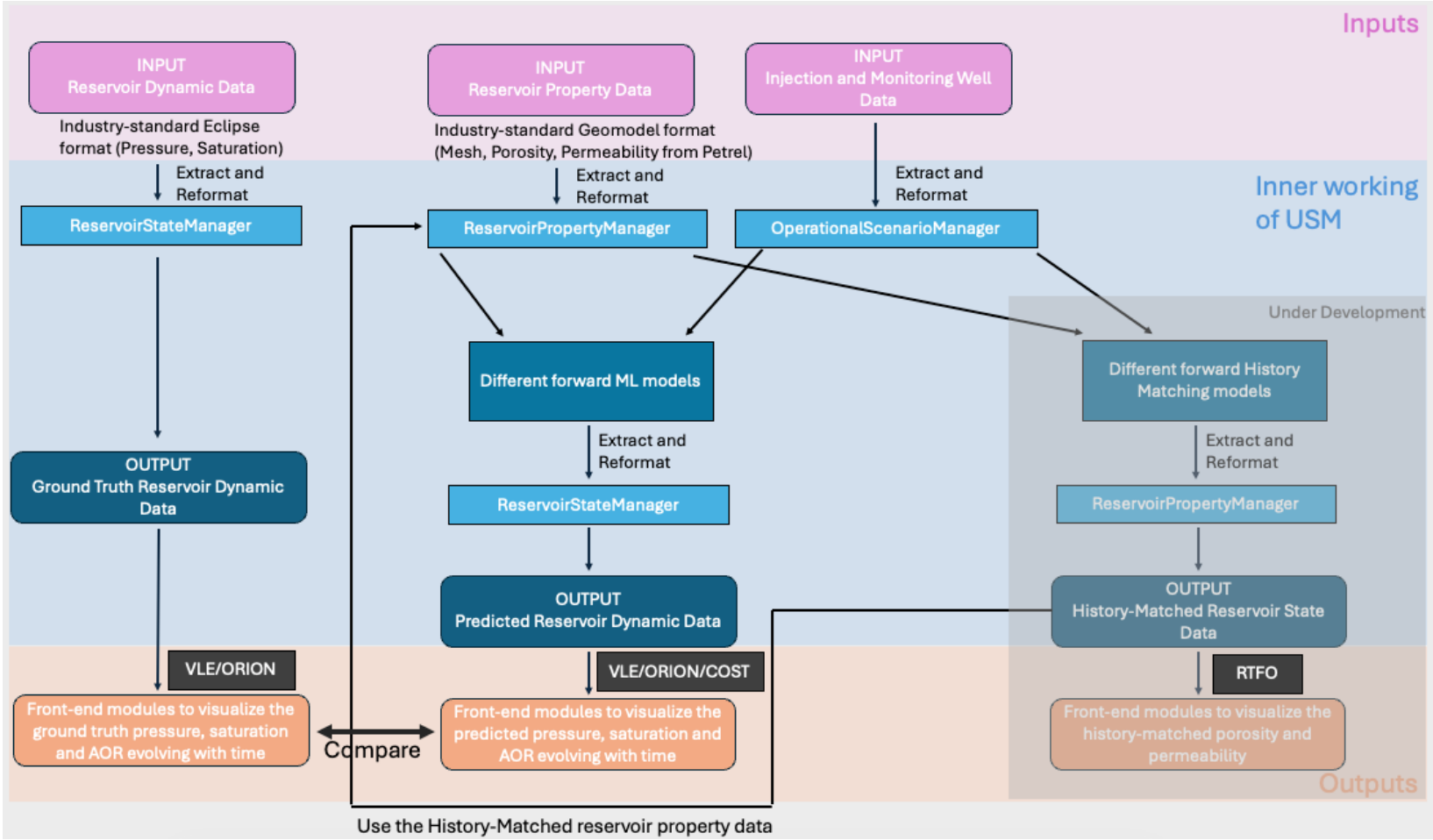
Saturation Front (> 0.2)



Visualized at a certain time

Data and model infrastructure – Next Steps/Scale-up Potential

- Update data managers to extract data from RESQML file formats that exported from popular industry software
- Improve ML-based reservoir flow simulators
- Design and incorporate efficient history matching workflows to update geomodels



Conclusions – SMART-USM

Contributions to commercial-scale CCS deployment

- Enhancing a capability to consolidate site-specific characterization information and manage data for exported industrial geomodel files to ensure seamless integration with other SMART visualization tools
- Establishing an ability for “real-time” forecasting of carbon storage reservoir behavior
- Facilitating a “real-time” tracking of pressure and CO_2 saturation fronts
- Improving the class VI well process and accelerating the deployment of field-scale carbon storage

@ Poster/Tool Demo Session
5:45 – 7:45 PM

Thank you!

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Acknowledgement

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