Convolutional Long Short-Term Memory (convLSTM) for Spatio-Temporal Forecastings of Saturations and Pressure in the SACROC Field

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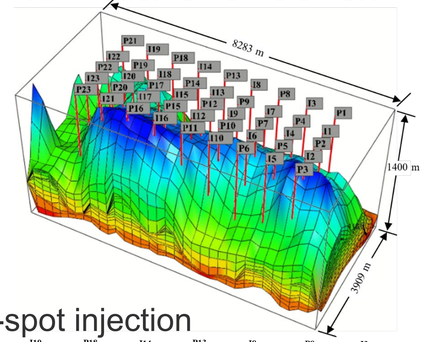
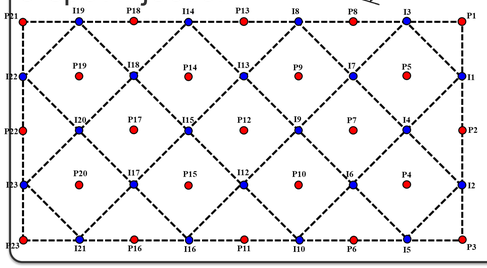
A machine learning architecture composed of convolutional long short-term memory (convLSTM) is developed to predict spatial-temporal parameters in the SACROC field, Texas, USA.

Reservoir Model, Completion and Operation

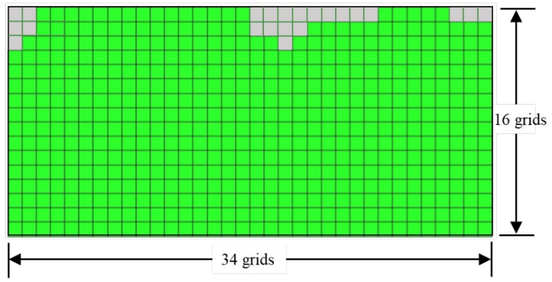
3D model: SACROC field



5-spot injection



Layer 21 : active (green) and inactive (gray)

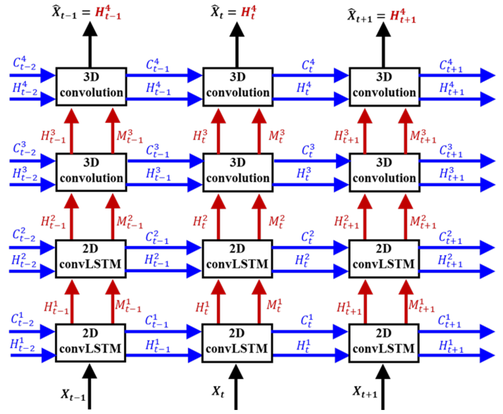


(Layer of interest in this study)

- Grid size: 13,600 (34 X 16 X 25)
- Wells: 45 (23 producers + 22 injectors)
- Perforations: 19, 20, 21, 22 layers
- Compositional simulation, CMG-GEM
- Annual alternation of CO_2 and Water injections
- Duration : 30 years or 360 months

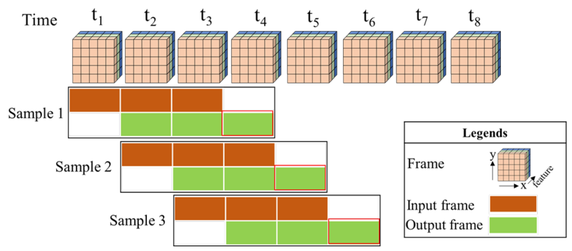
Sample Preparation and Machine Learning Network

- Total end of Month Data : 360
  - 300 frames for **training** ~83%
  - 60 frames for **testing** (blind) ~17%
- Historical pressure and saturations as inputs.
- Future pressure and saturations as outputs.
- One sample consists of 10 frames



Brown : transition paths of the spatial memory
Blue : update directions of the temporal memory

Sample preparation
(e.g. 1 sample = 3 frames)



Number of ML parameters

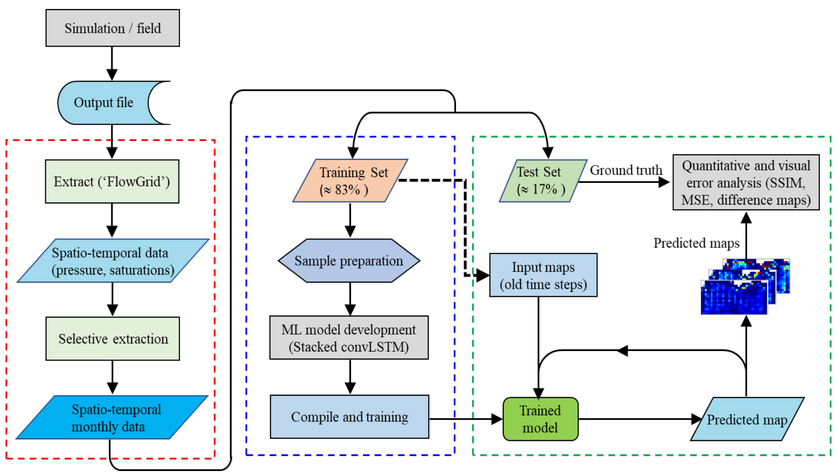
ML layer	No. of parameters
convLSTM 1	9856
convLSTM 2	6944
3D convolution 1	868
3D convolution 2	5
All batch normalizations	100
Total	17773

Workflow

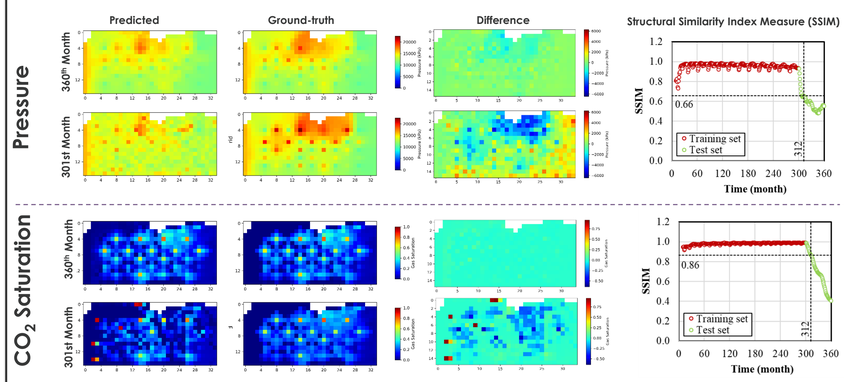
Data extraction, preprocessing

Sample preparation and training

Testing and error analysis



Results and Discussions



- Lower and higher intensity zones are rightly captured by the ML models.
- Higher accuracy during training: SSIM ≈ 1.0, NRMSE < 5%.
- Acceptable accuracy during test : SSIM > 0.4, NRMSE < 20%.
- During testing, early predicted frames are better than the frames predicted in the later.
- Sharp contrasts in pressure and saturations are observed in the near well-bore regions.

Conclusions

- ConvLSTM has potential for flow characterization in subsurface due to spatial and temporal relationships.
- The workflow is useful for preparing samples and training model for flow systems regardless of complexity.
- Pressure and saturations predictions (blind) of first 12 months can be accepted with higher accuracy.
- Precursor of the development of an integrated workflow for data-driven model using real field data.