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Subsurface Temperature Measurement Using Electromagnetic Waves and Machine Learning for Enhanced Oil Recovery

Kees van den Doel, Colin Stove, Michael Robinson and Gordon Stove

Adrok Ltd

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Outline

- Background and motivation
- EM and borehole field measurements
- Machine learning approach
- Results
- Discussion

Background and motivation

Enhanced Oil Recovery (EOR)

- Allows more (~60%) oil to be extracted from reservoir
  - Viscosity
  - Mobility ratio
- Various methods in use
  - Gas injection
  - Thermal methods ← this application
- Steam injection
  - Need to monitor subsurface temperature profile
  - Use temperature observation wells (TOW)
  - Measure 3-4 times a year, expensive
    - Cost of drilling
    - $5000,- typical cost per well for measurement
    - No production during measurement

Virtual TOW wish list

- No drilling
- Using surface data
- Measure without well downtime
- Faster acquisition
- More frequent monitoring
- Low cost per measurement
- Easy data processing

EM and borehole field measurements

EM data/TOW data

- Pulsed radar subsurface imaging
  - Low frequency (1-3MHz) for deeper penetration
  - Bistatic data acquisition
  - Stacking 100,000 shots
  - Measurement takes a few minutes per well
- Data acquired on large producing oil field
  - 21 wells measured from relatively homogeneous field
  - 3 wells measured from a different oil field
  - TOW data used a ground truth
  - TOW data down to 1400ft

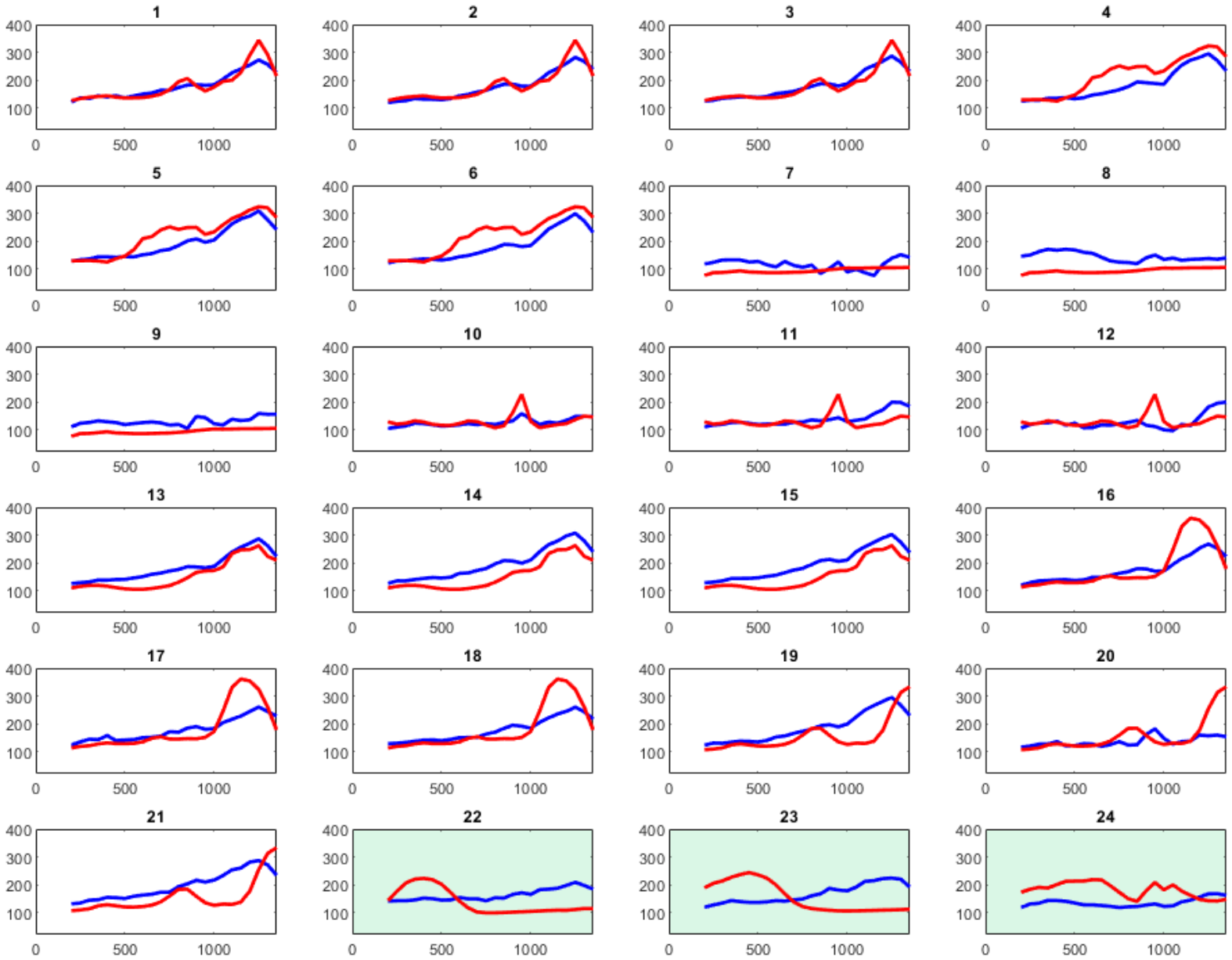
Machine learning

EM data → temperature using ML

- Both data are time series
- Using ML to predict temperature (T) from EM data (M)
- Exclude 1 well from data set and train on rest (blind tests)
- 5 layer feedforward neural network used
  - Trained on 20 (M,T) pairs
  - Then predict well not trained on
- 3 sites from different field not used in training
  - Used to evaluate effect of ground conditions

Results

Blind test results



Red = TOW data (Kelvin)
Blue = EM prediction
Depth in feet

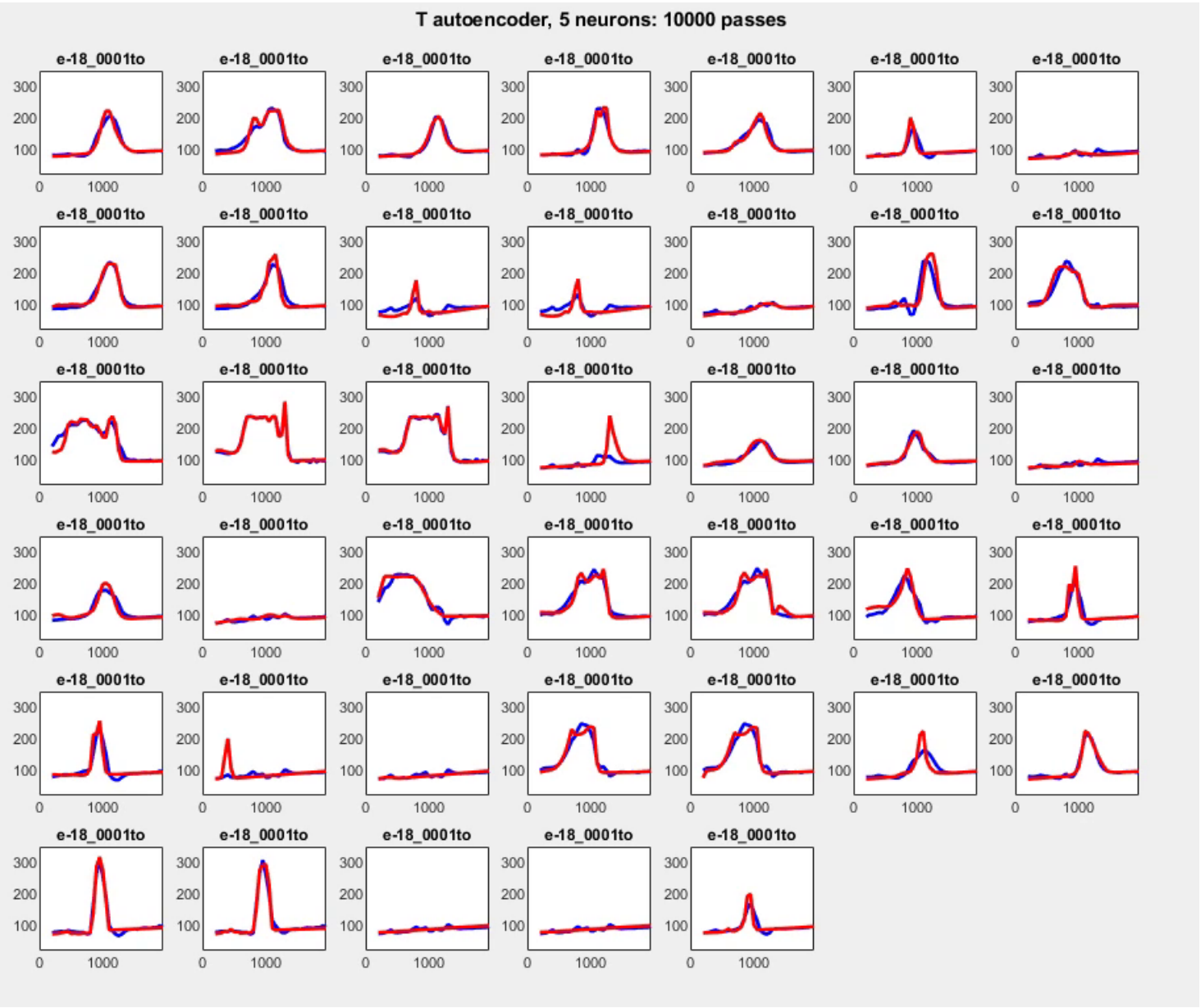
Last 3 are from a different field (not used in training)

Discussion

Discussion

- Results are encouraging
- 3 “foreign” wells failed
  - Training site specific
  - Local variations in ground conditions “spoil” results
- How can we improve accuracy/reliability?
  - Assumed ground conditions homogeneous
  - Use also geological data for training to address this
  - Use autoencoder based training (as used for virtual NMR)
- Why does it work?
  - EM waves penetrate sufficiently deep
  - Similar to apparent seabed imaging using conventional radar

Autoencode T data to 5 activations



Preliminary data. 40 TOW profiles (red) encoded to 5 activations using an autoencoder network (Blue).

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More results in 2021

Thanks for your attention!

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