KMS Technologies

EM-microseismic reservoir monitoring system

S. Davydycheva, T. Hanstein, M. Smirnov, K. Strack

2018

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FOR SELF STUDY ONLY

EM-microseismic reservoir monitoring system

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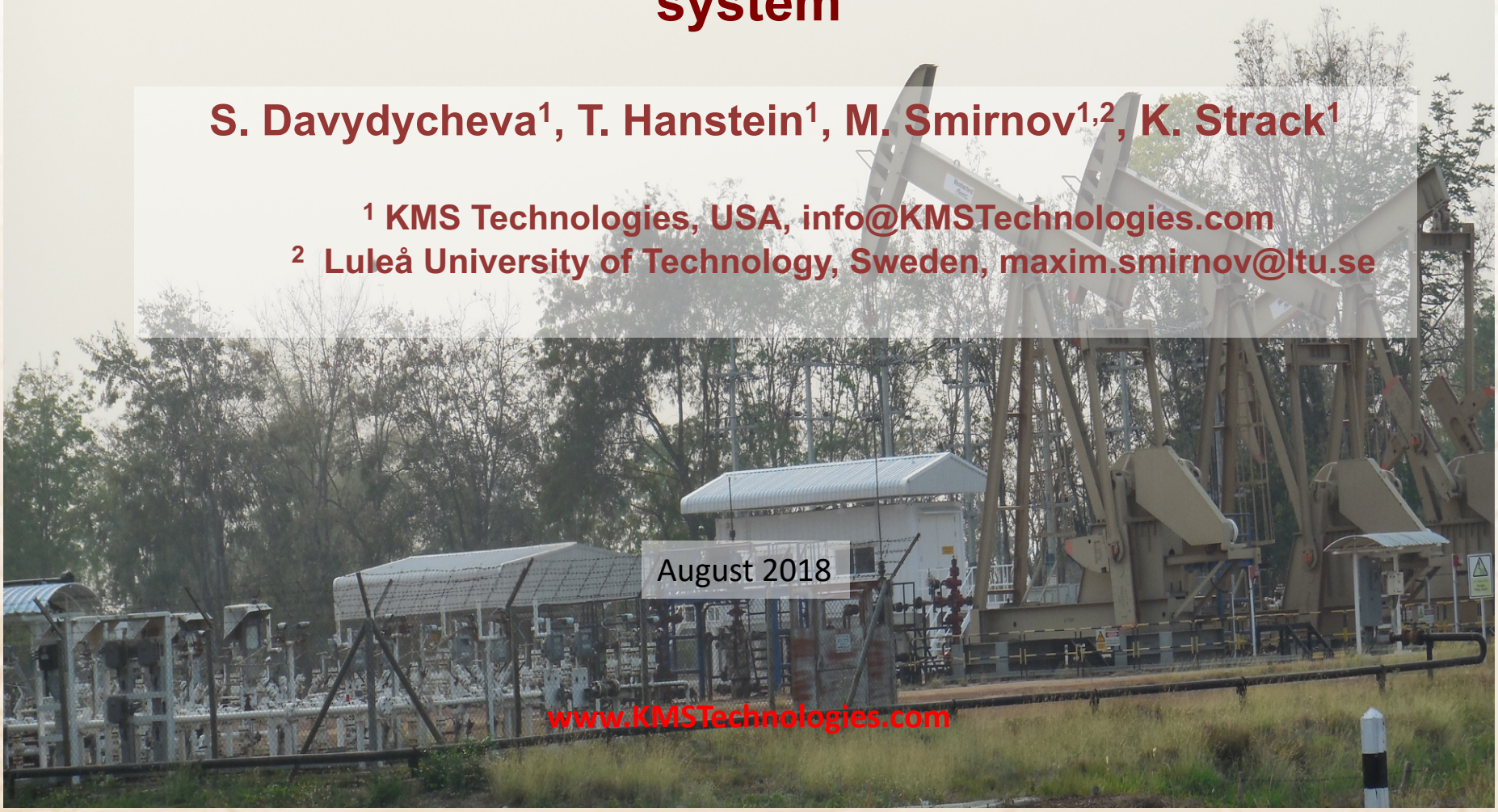
[2] Luleå University of Technology, Sweden, maxim.smirnov@ltu.se



August 2018

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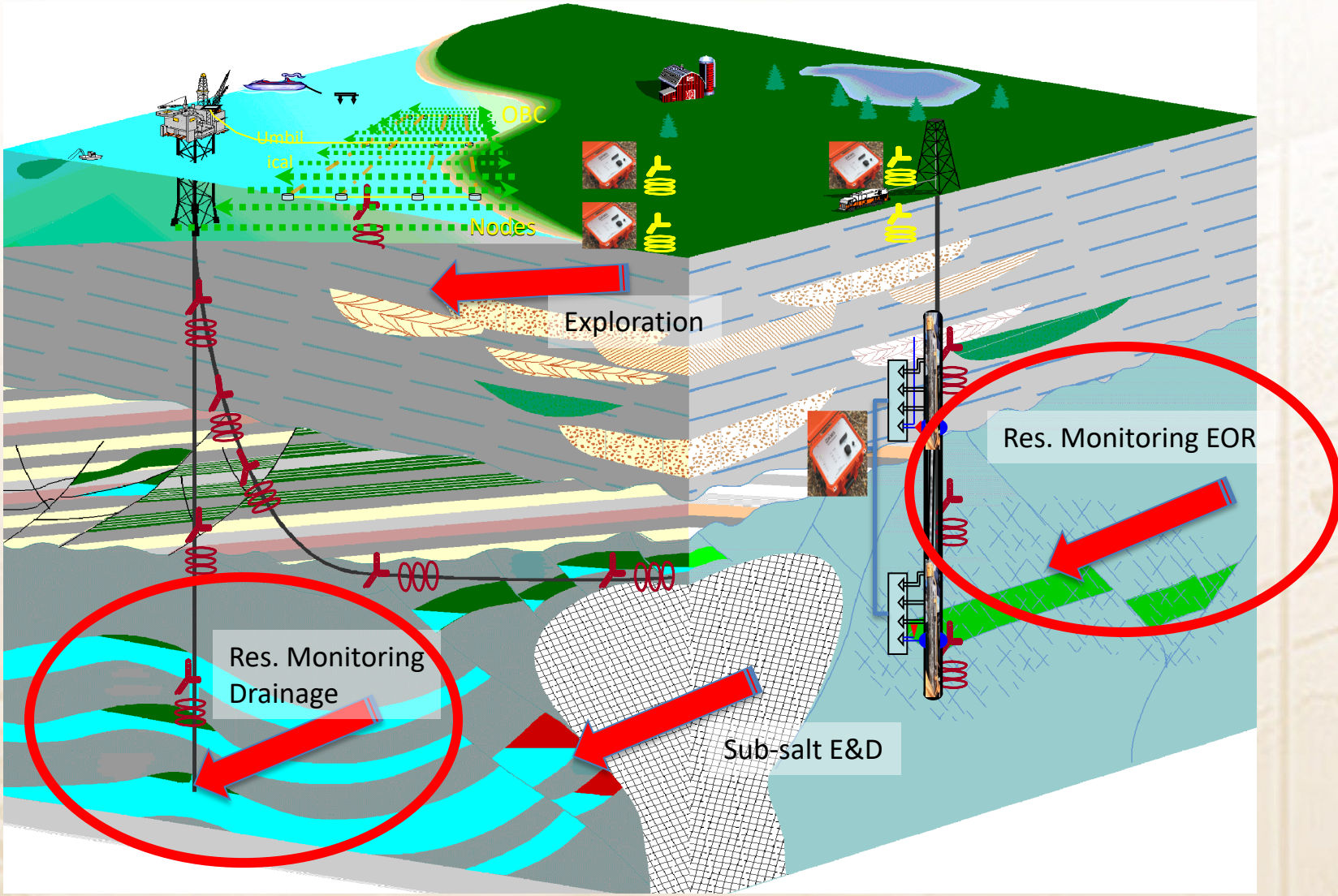
- Discuss emerging EM Imaging opportunity
- Background & issues
- System approach
- 2 Examples
- Conclusion

High value APPLICATIONS – LOW to HIGH – TECHNICAL driven



Market overview – business driven

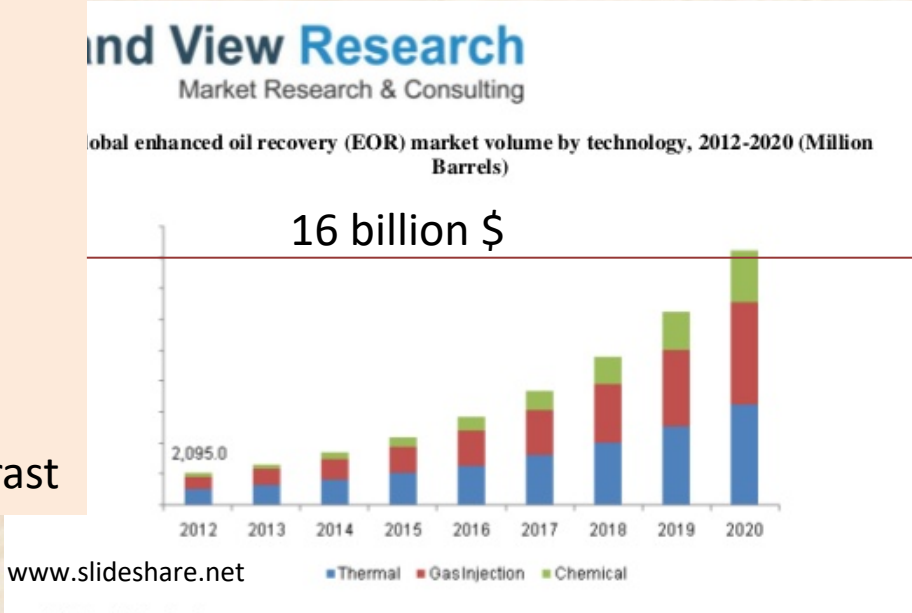
- Improve reservoir production with knowledge from only wells
- EOR market 2015: 20.4 Billion US $
  - Geophysical data: temperature & pressure
- EOR market predictions:
  - https://globenewswire.com/ - 283 billion US $ by 2020
  - https://grandviewresearch.com/ Conservative 89.3 billion US $ by 2025

TODAY: only pressure & temperature

Geophysical data →
ONLY feed forward methods

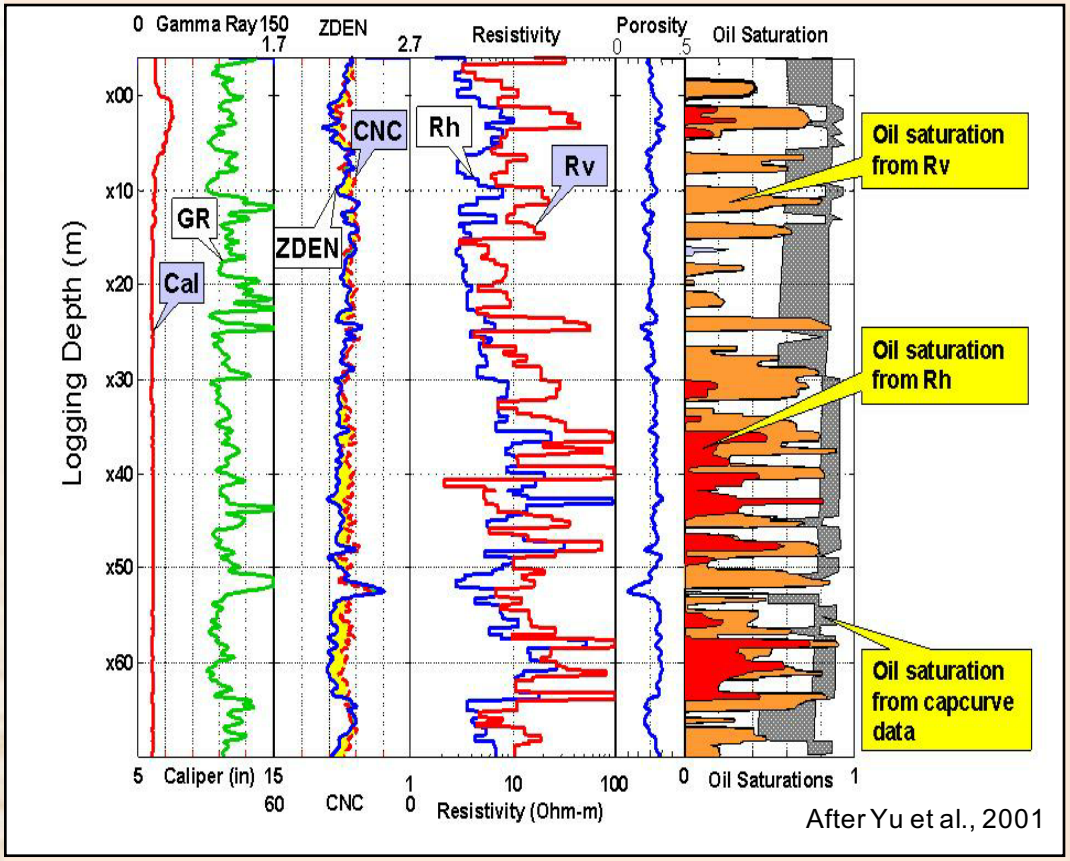
→ GREAT opportunity

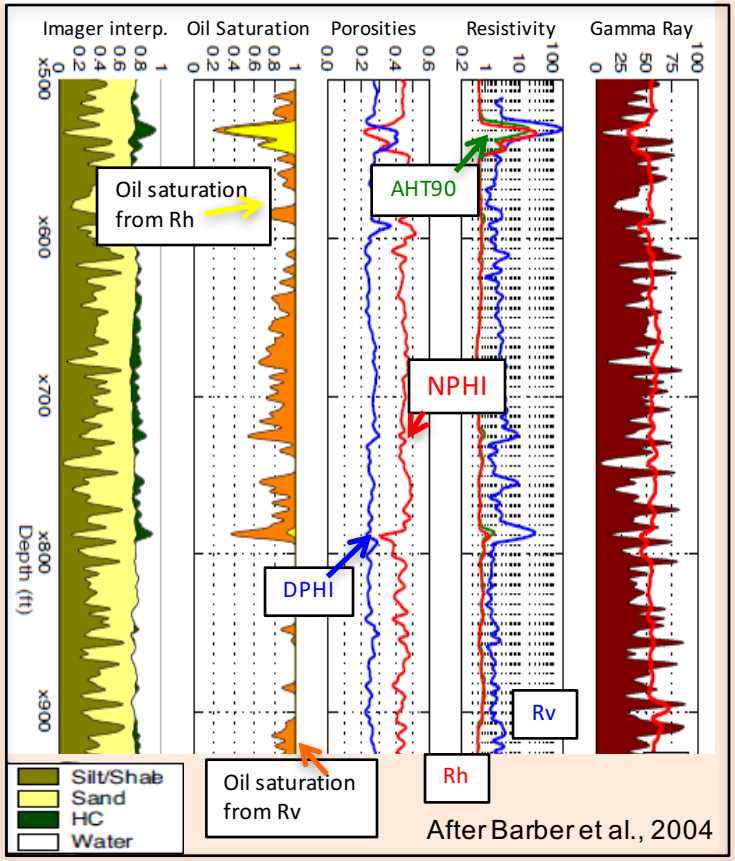
→ ALL changes cause resistivity contrast



Key issues limiting success I – how much error can we see

Anisotropy - > 40% improved Oil-in-place (OIP)



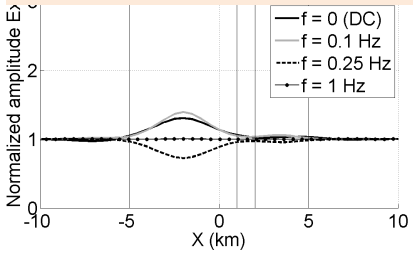


Courtesy Baker Atlas

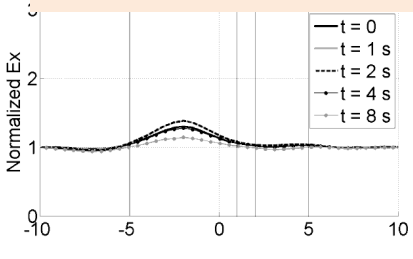
Key issues limiting success II – where is the information from

CSEM versus Focused Source

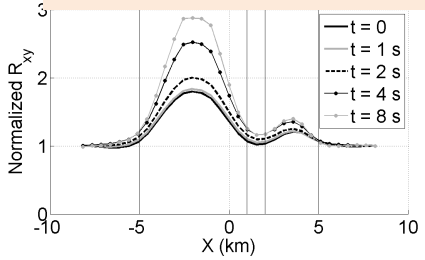
Frequency domain CSEM

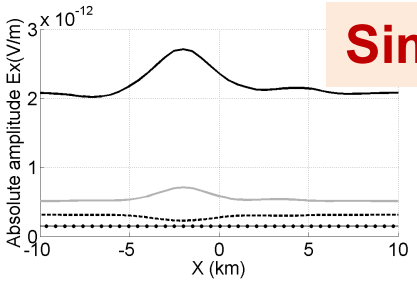


Time domain CSEM

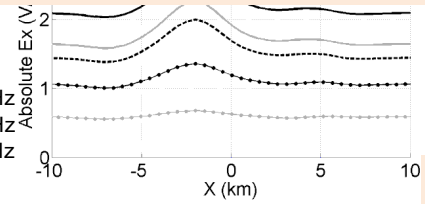


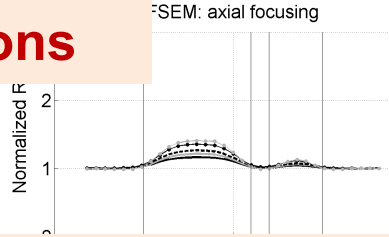
Focused Source EM

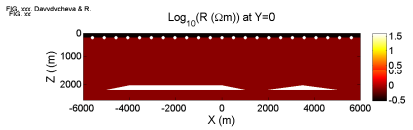


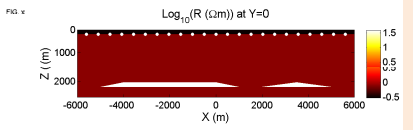


Similar to our observations









- Smaller reservoir can be detected
- Higher spatial resolution
- Shallow structure removable
- Shallow structure removable

fCSEM & tCSEM: Anomaly: 40% - 10%

FSEM: Anomaly: 200% - 40%

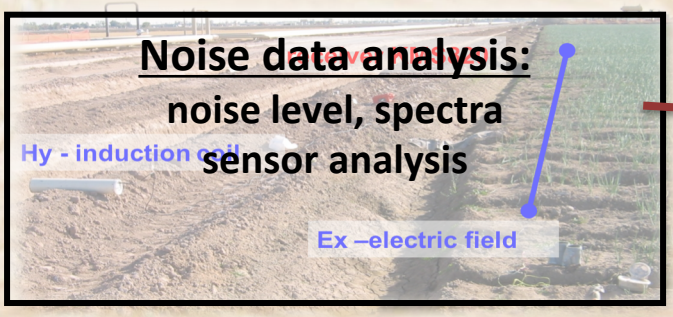
Rykhlinskaya, E., & Davydycheva, S., 2014, U.S. Patent 8,762,062 B2.
Davydycheva, S., 2016, U.S. Patent Application US 2016/0084980 A1.

Overall Workflow leading to design of specific reservoir

Deliverables & objectives

Input data:
well log data
geologic information
seismic horizons
noise measurements

Noise data analysis:
noise level, spectra
sensor analysis



3D Feasibility & noise test

Verification 3D modeling benchmarks

Define target variations

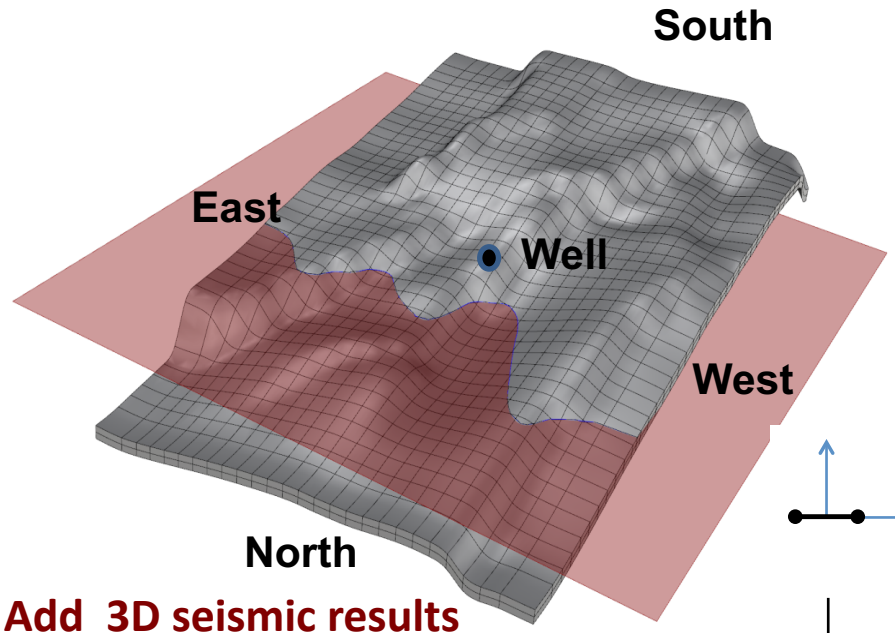
Resolution study

Pilot design:

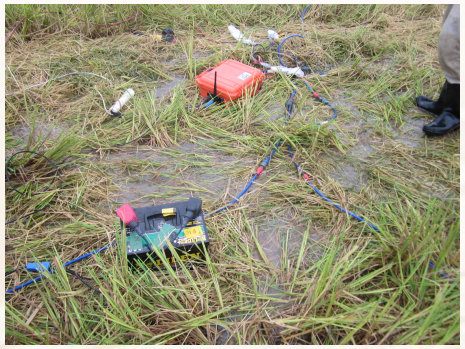
Sensors & methods

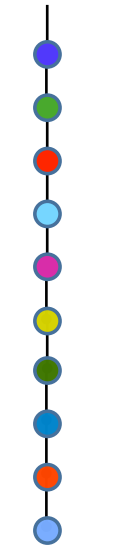
SYSTEM DESIGN

Example Asian oil field: 3D reservoir Feasibility

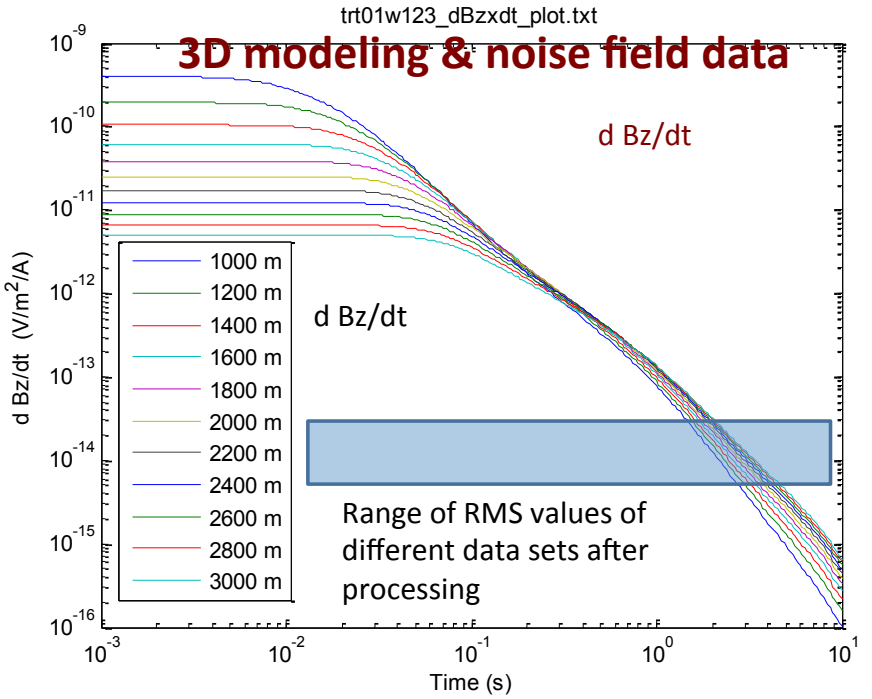


Add 3D seismic results

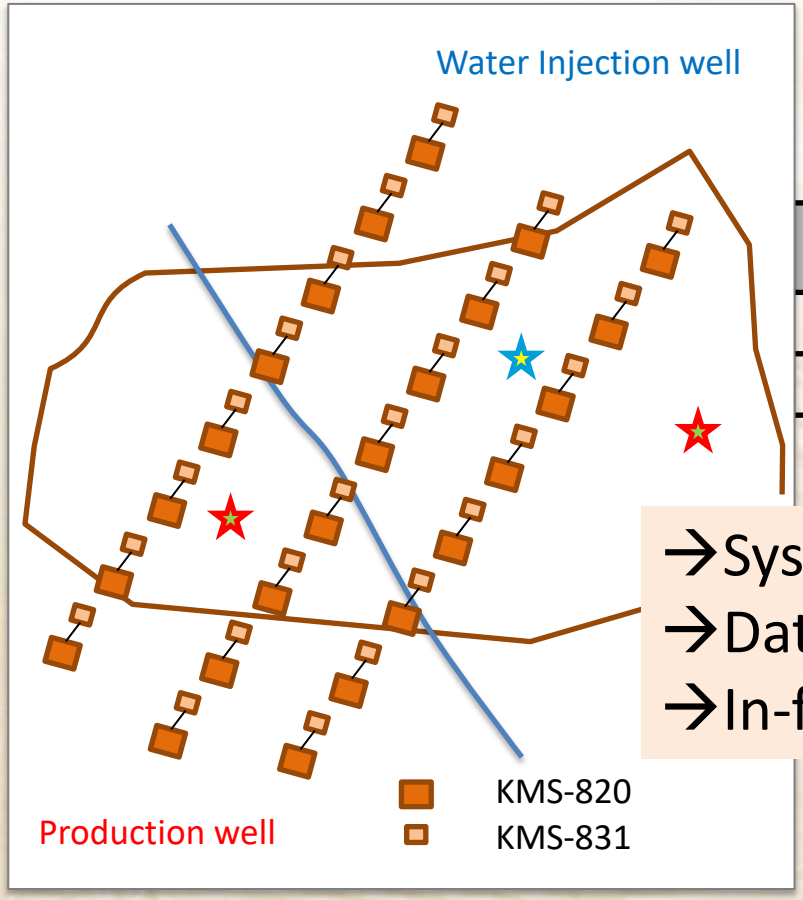




3D modeling & noise field data



Example layout



Microseismic sensors

Site	KMS instrument	Ex & Ey	Hz	3C fluxgate H	3C geophone	SH borehole
■	820	x	x	x	x	X
▪	831	x			x	

→System hardware
→Data storage/telemetry
→In-field processing design (QA)

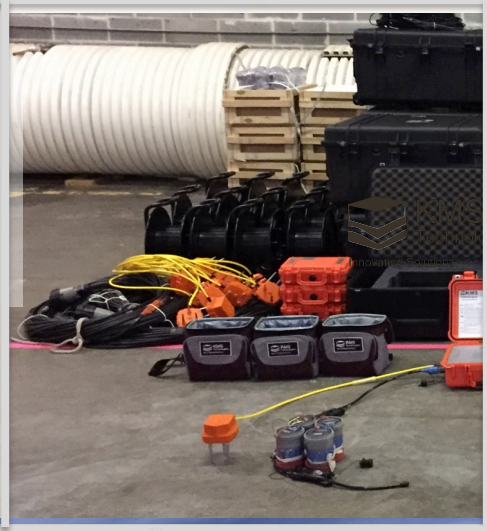
ensors

195 channel monitoring system

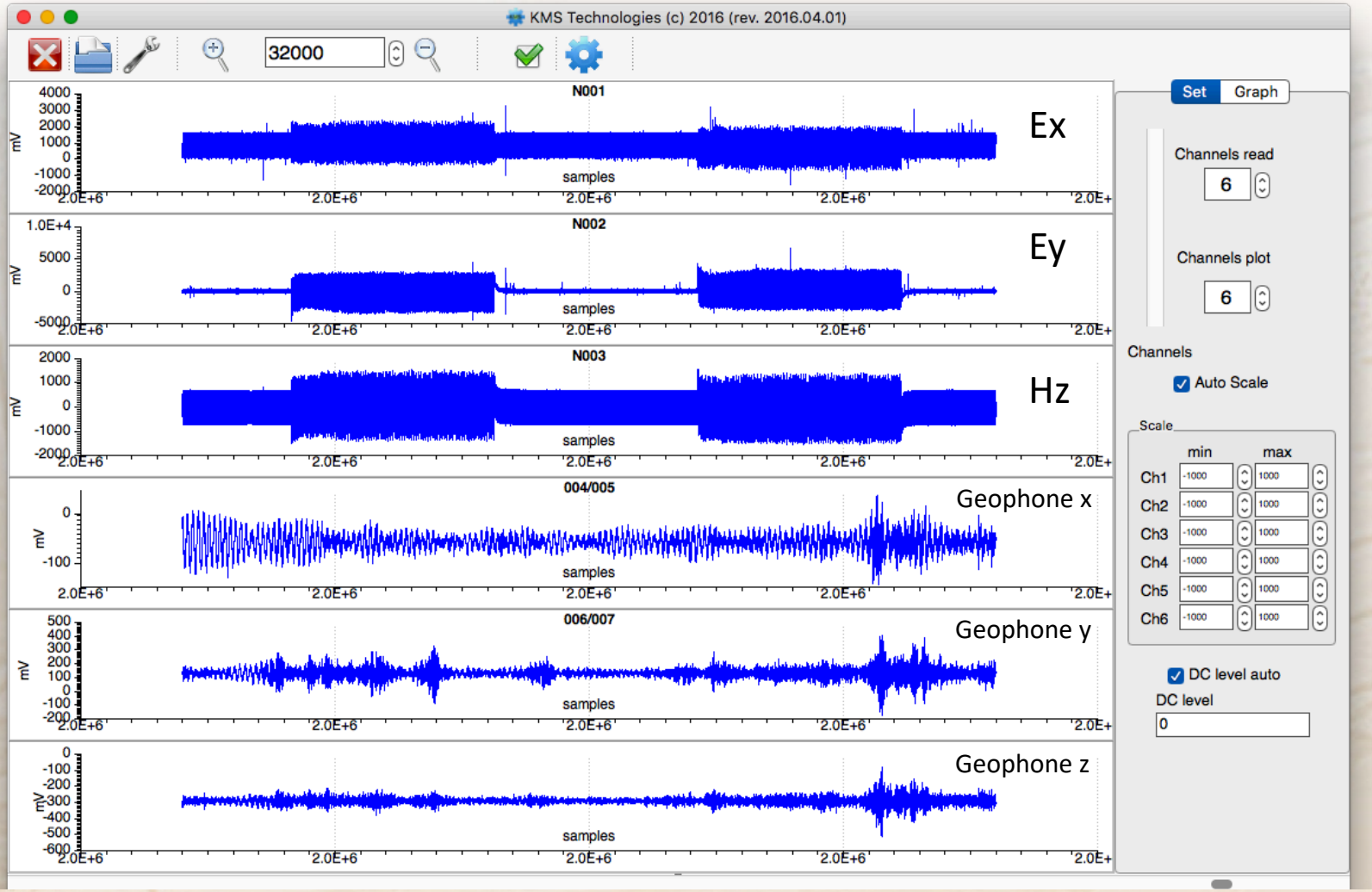
RESERVOIR MONITORING

ARRAY Electromagnetics

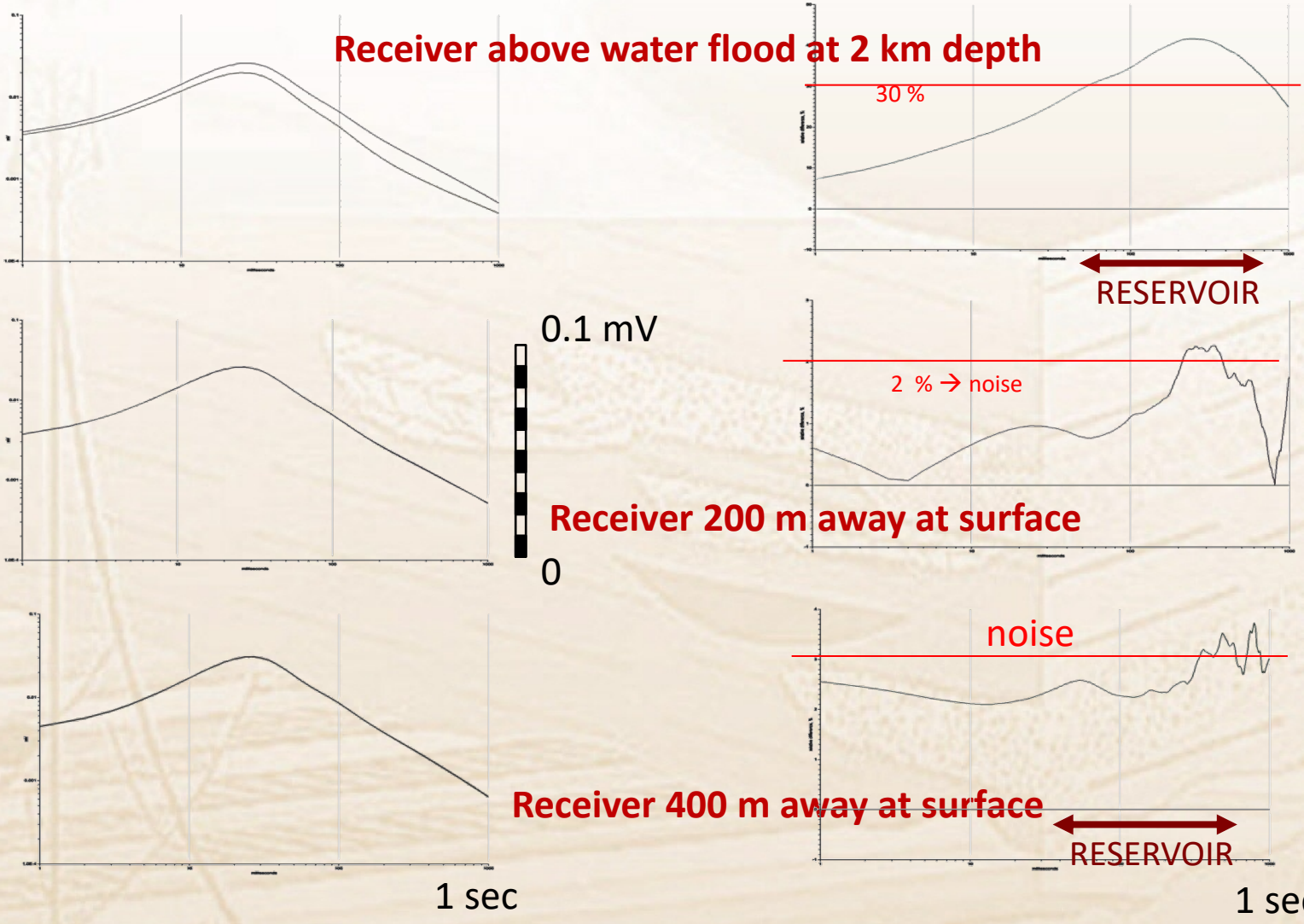
- 195 channels, wifi, wireless or LAN
- 3C magnetic field (DC to 40 kHz)
- 3C microseismic
- 2C electric fields
- Shallow borehole (microseismic/EM)



Reservoir Monitoring: Raw data example: microseismic/EM monitoring



Magnetic field sees water flood - 2 DAYS time lapse

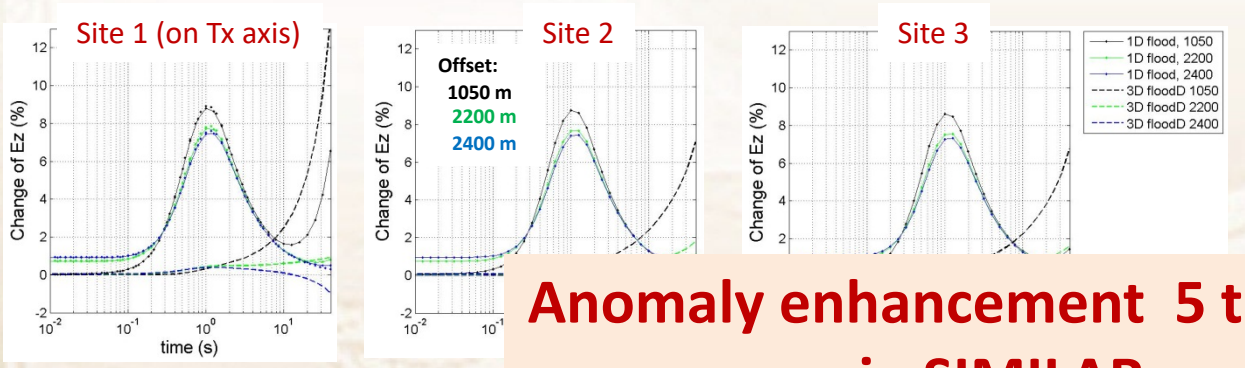


Reasons for discrepancy

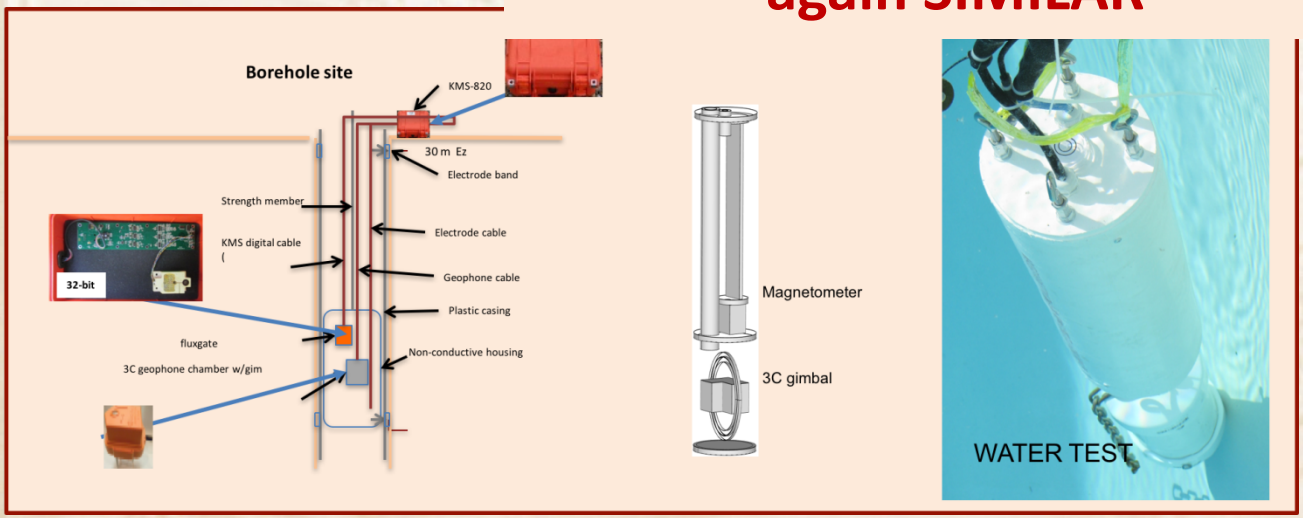
- MANY underground well (highly deviated)
  - 3D modeling → casing effect unlikely (?)
- Image focus
  - Remedy 1: FSEM
  - Remedy 2: Ez in shallow borehole

Alternative: Shallow borehole tool – Ez 3D response

Ez at z = 10 m



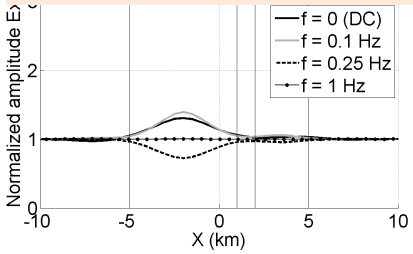
Anomaly enhancement 5 times again SIMILAR



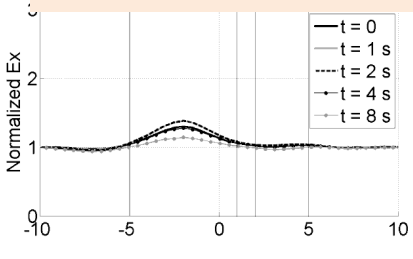
FSEM: Focused source solution to volume imaging

CSEM versus Focused Source

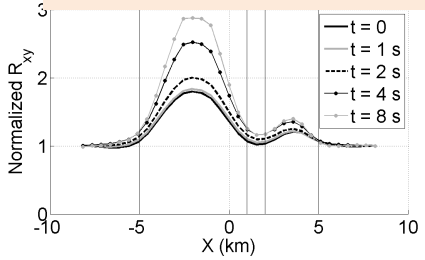
Frequency domain CSEM



Time domain CSEM



Focused Source EM



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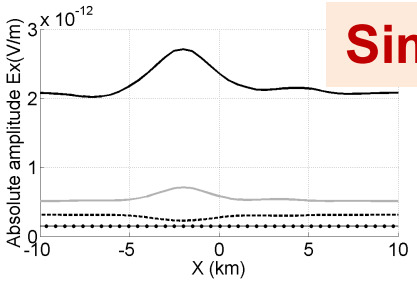

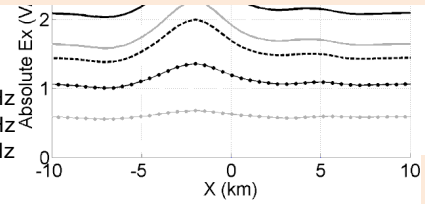

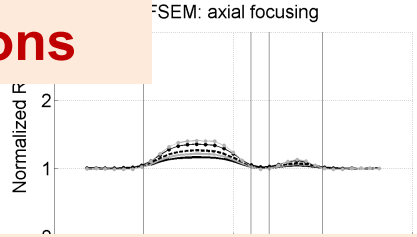

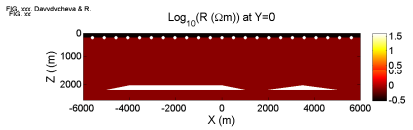

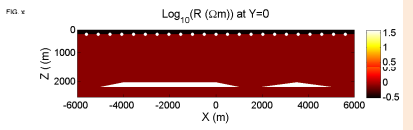

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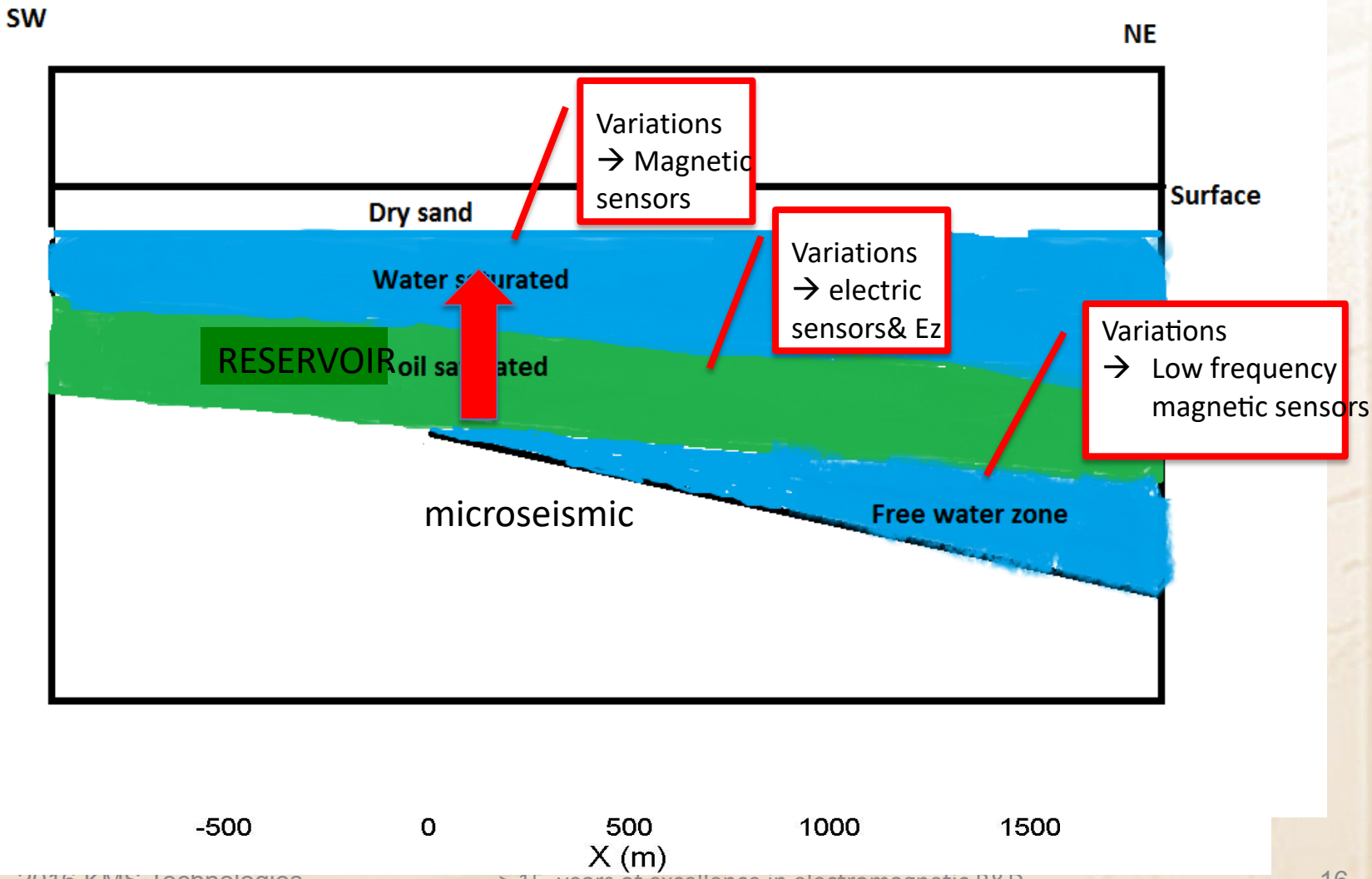
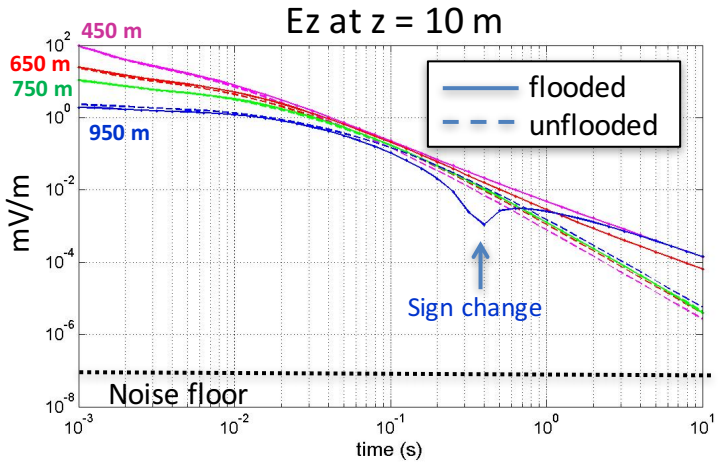
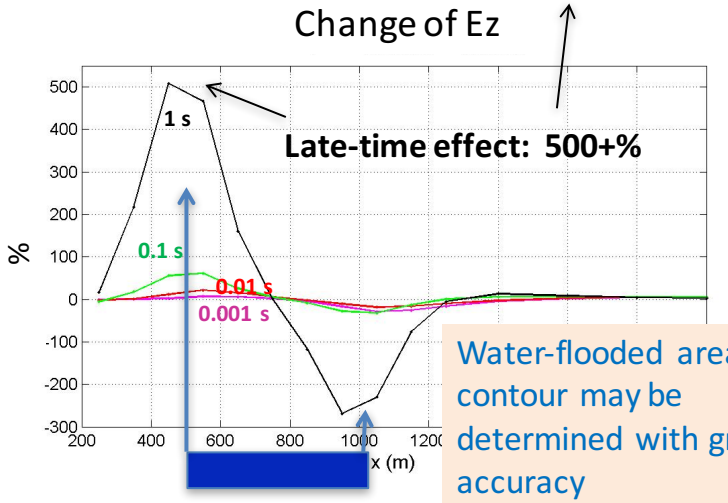
FSEM: Anomaly: 200% - 40%

EXAMPLE: Geologic schematic – Heavy Oil Middle East

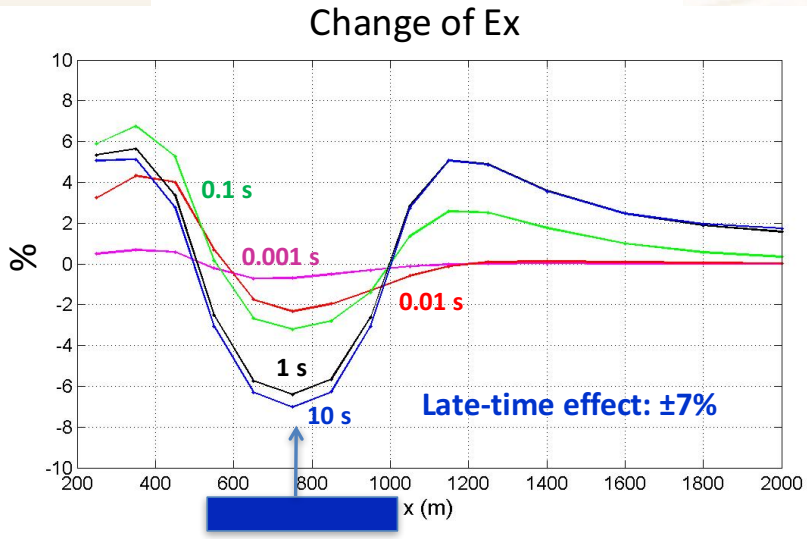


EXAMPLE: Heavy Oil Kuwait – Ez and Ex

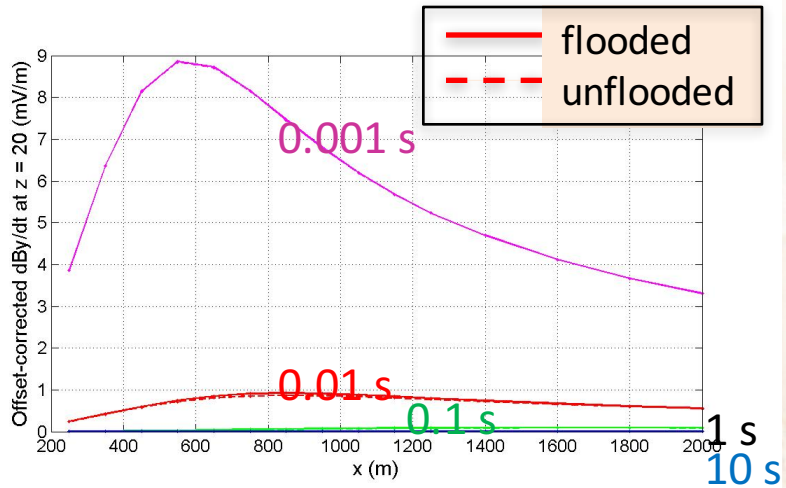


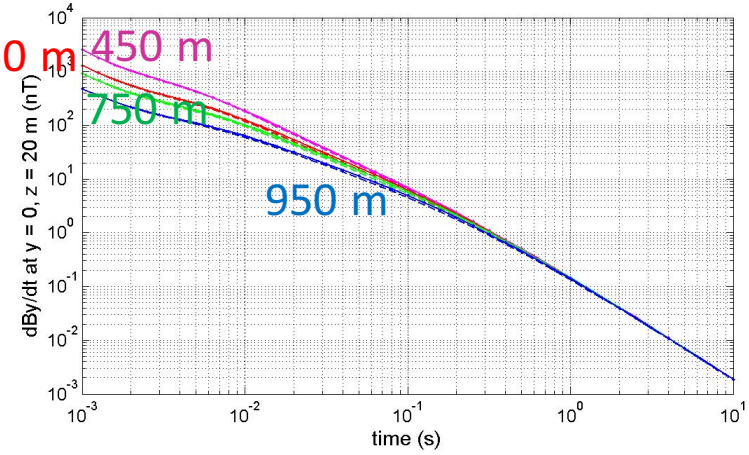


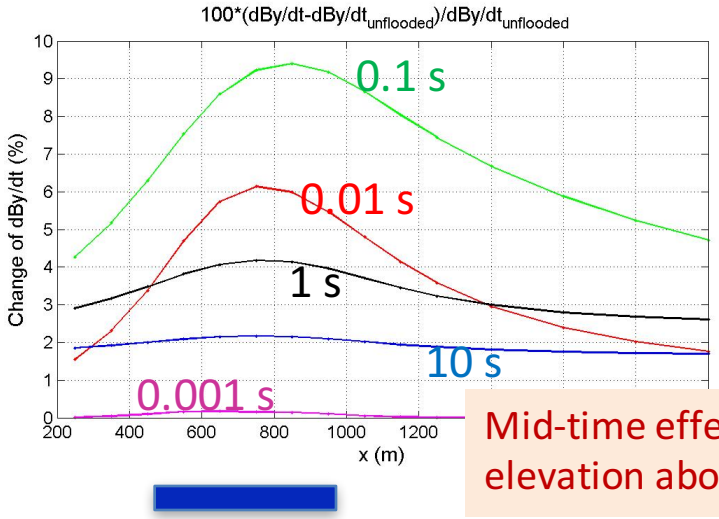
Water-flooded area contour may be determined with great accuracy

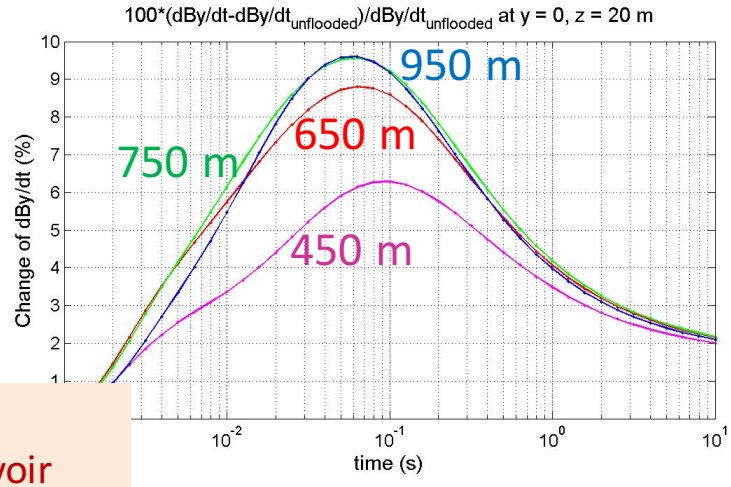


EXAMPLE: Heavy Oil Kuwait – dBy/dyt









Mid-time effect: ~10% elevation above reservoir

EXAMPLE: Heavy Oil Kuwait – suggested equipment

Conclusion

- We have finished part of a full field monitoring system
- Integration of borehole is MUST
- What limits us in success in reservoir monitoring?
  - Check against production & well data
  - → need high accuracy, log integration
  - Fast turn-around → hardware & acquisition

THANK YOU

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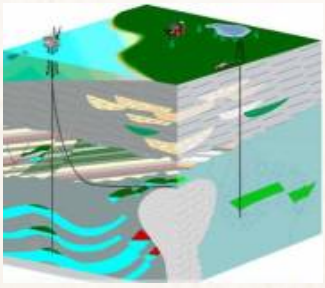

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