

# Mass Balance Threshold Matching of Geoelectric and Seismic Data - A case study from Ketzin

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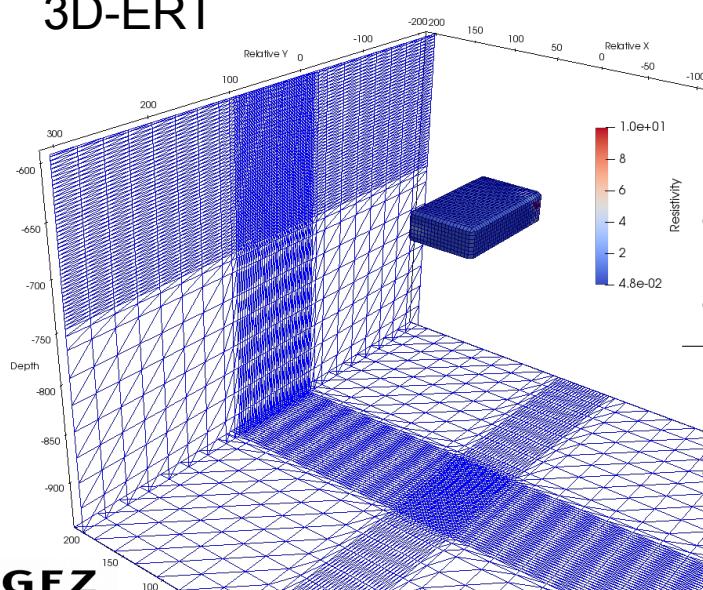
# Summary – Match Seismic and ERT derived Masses



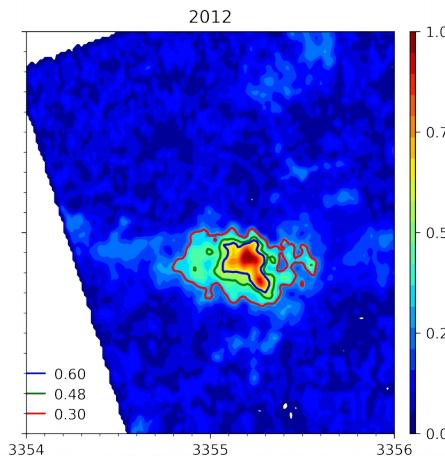
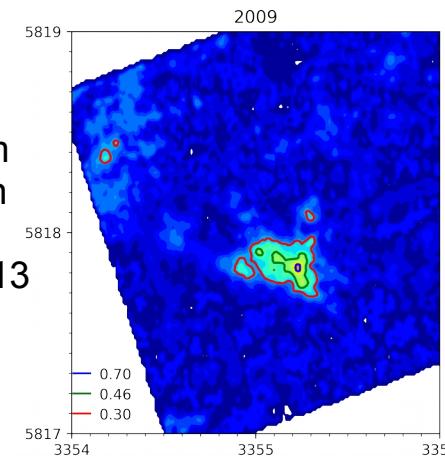
## Introduction

- 20 km NW Potsdam
- Injection depth 635-650m
- Upper Stuttgart formation
- Porosities: 20-25%
- Injection during 2008-2013
  - Total: ~67 kT
  - 2009: 22-25 kT
  - 2012: ~61 kT

## 3D-ERT



Thickness threshold on seismic and ERT comparison using range of parameters

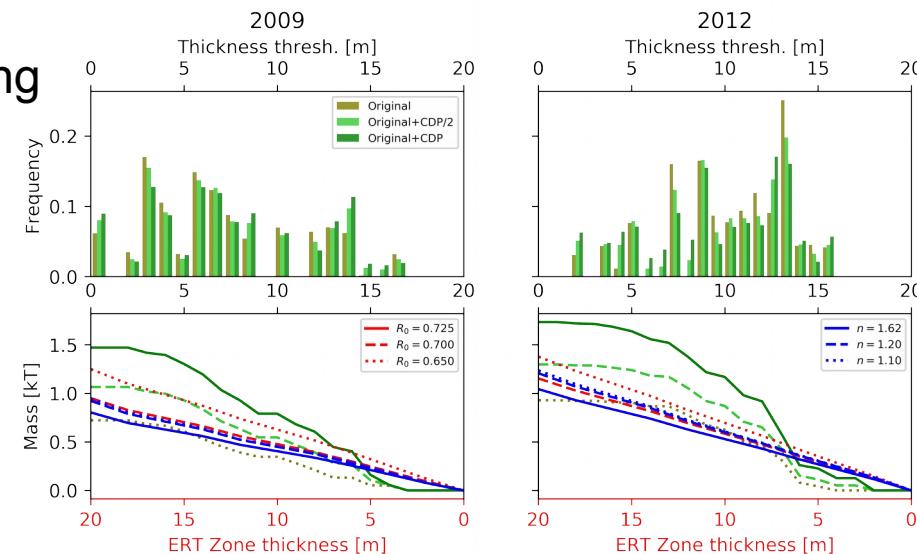


## Seismic

- Amp. Diff. between baseline and repeat  
→ **Saturations**
- Time-shifts  
→ **Thickness**
- Mass estimation

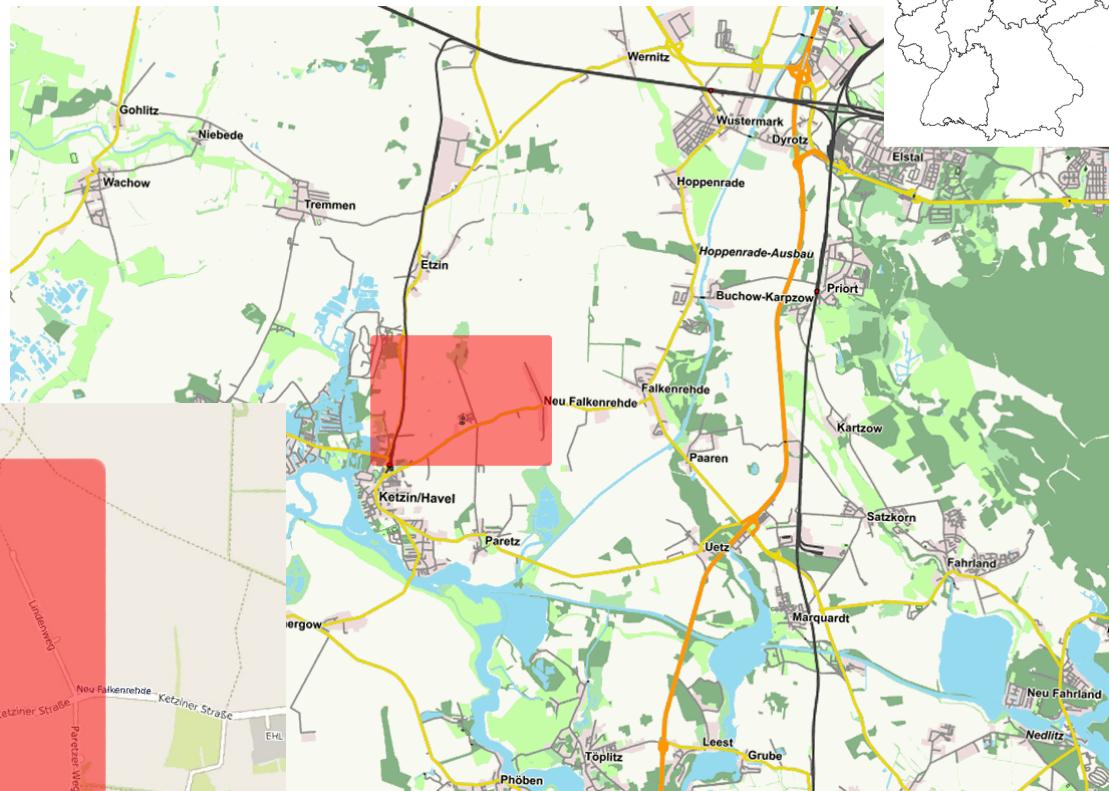
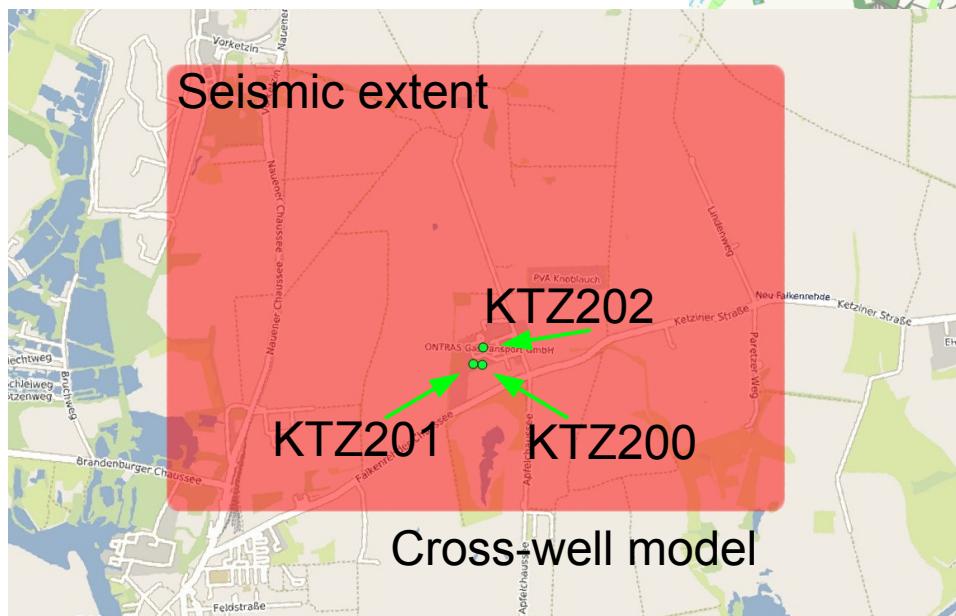
## Mass matching

- Cross-well resistivity model
- Inverted Resistivities  
→ **Saturations**
- Thickness threshold
- Mass estimation



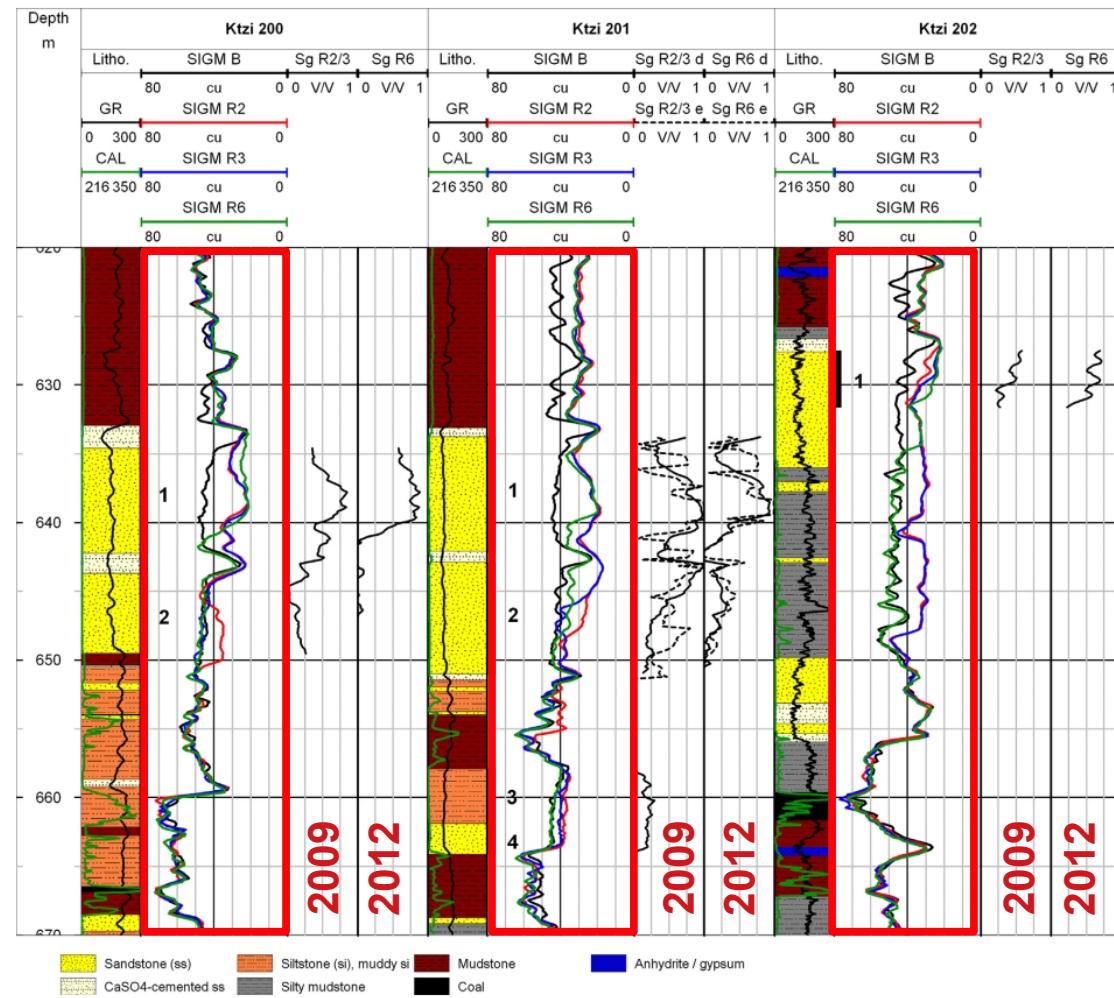
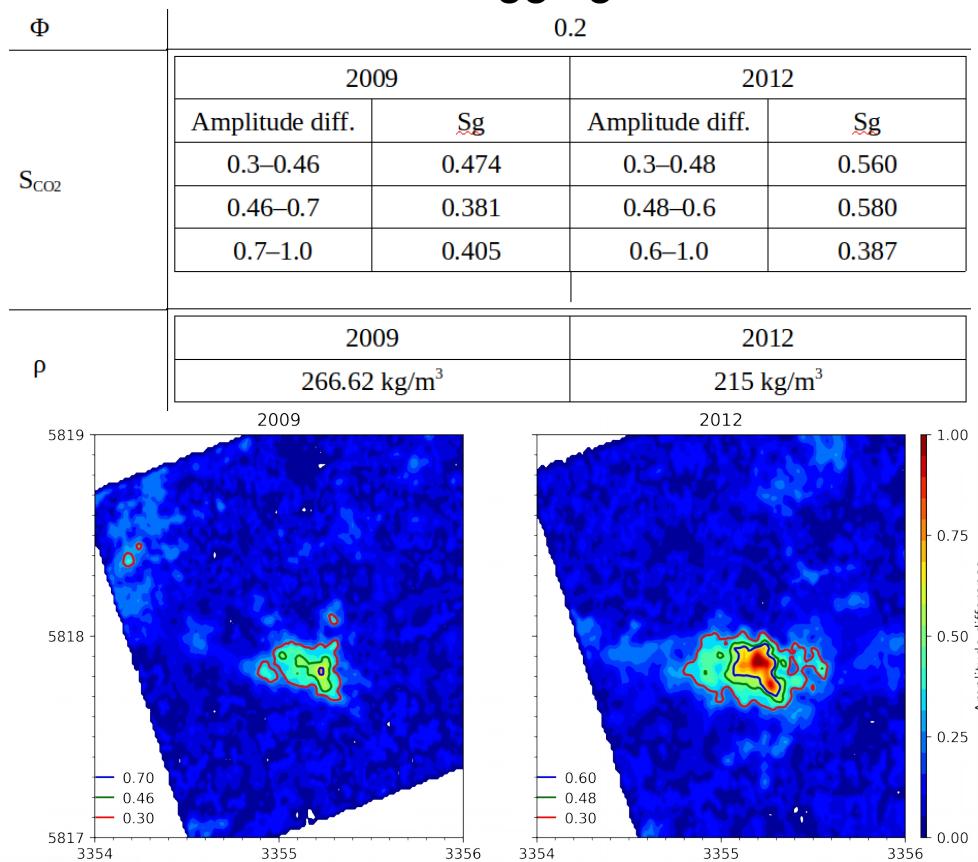
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# Seismic mass

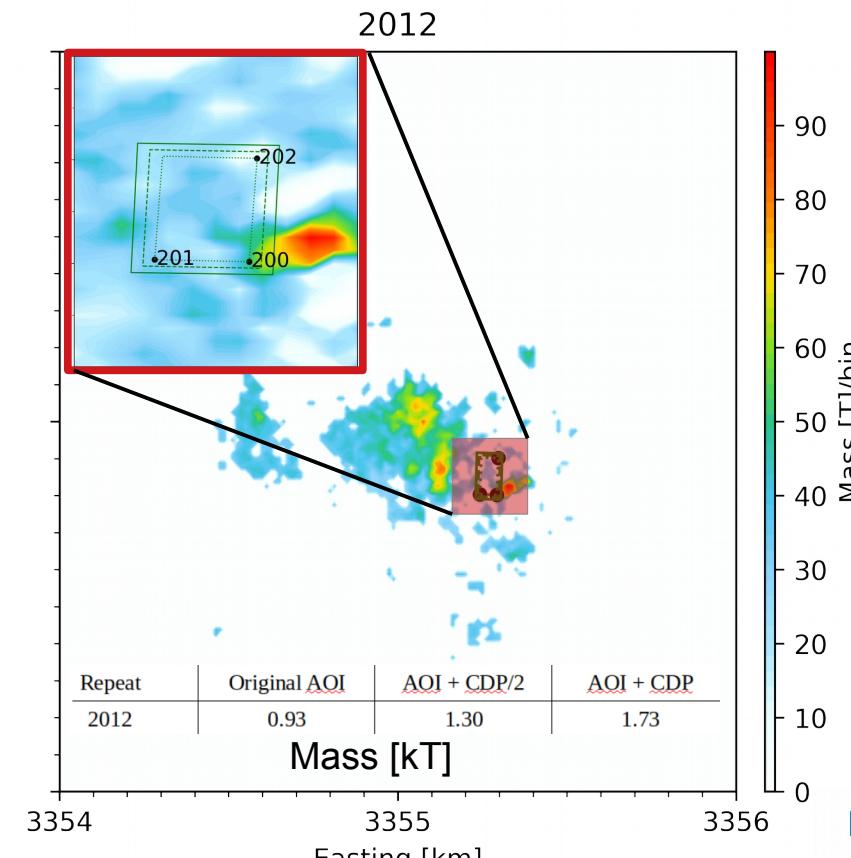
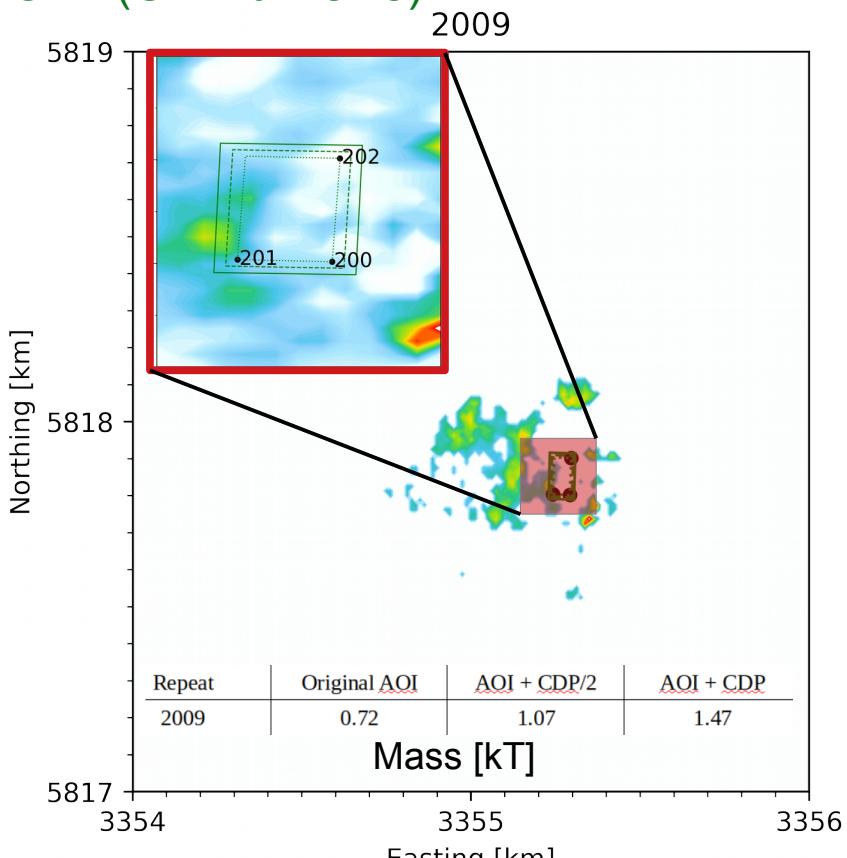
- Analysis 42ms below anhydrite (K2)
- Amp. Diff. between baseline and repeat
- Matched to PNG logging



Modified after Ivandic et al. 2015 and Förster et al. 2010

# Seismic mass

- Timeshifts used for thickness estimation: H
- Three areal envelopes
  - Well span (Original AOI)
  - AOI + (CDP bin size)/2
  - AOI + (CDP bin size)



$$V_2 = -0.46 \cdot S_{CO_2} V_1$$

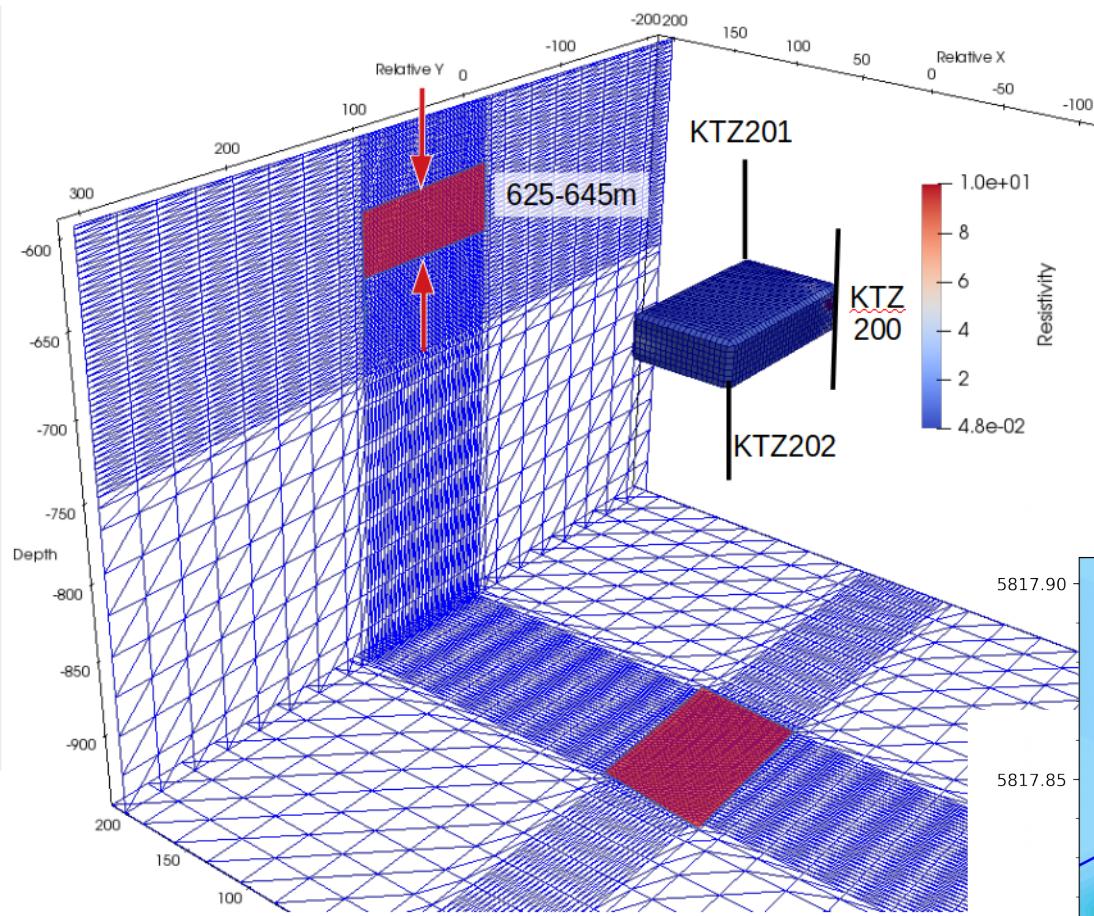
$$H = \Delta T / 2 (1/V_2 - 1/V_1)$$

$$M_{CO_2} = \sum_N \varphi S_{CO_2} \rho dx dy H$$

with  $V_1 = 3135$  m/s from

Lab measurements

# ERT mass



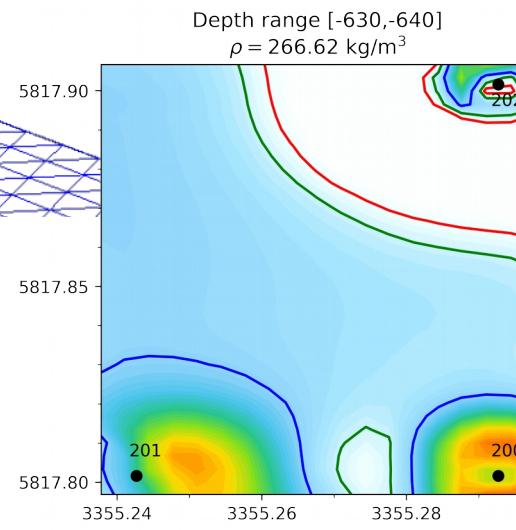
- Unstructured cross-well model
- Central:  $dx/dy/dz: 3.3/3.3/1\text{m}$
- Boundary increasing increments
- Sensitive in the injection zone: 625-645m
- Inverted resistivity used for saturation estimation

$$S_{\text{CO}_2} = 1 - (R_0/\text{Resistivity})^{1/n}$$

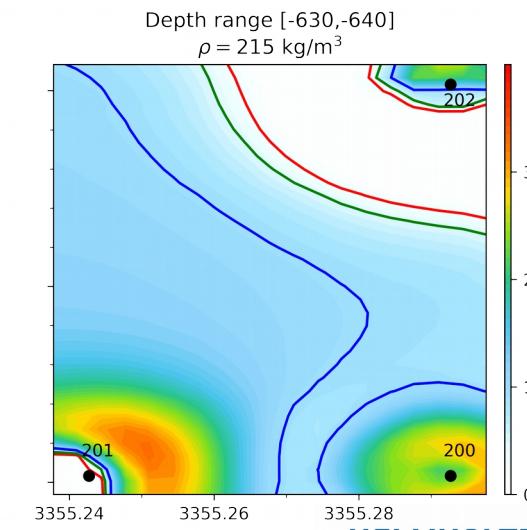
$$n = 1.62$$

with Defaults Parameters       $R_0 = 0.725$

$$\Phi = 0.2$$



2009

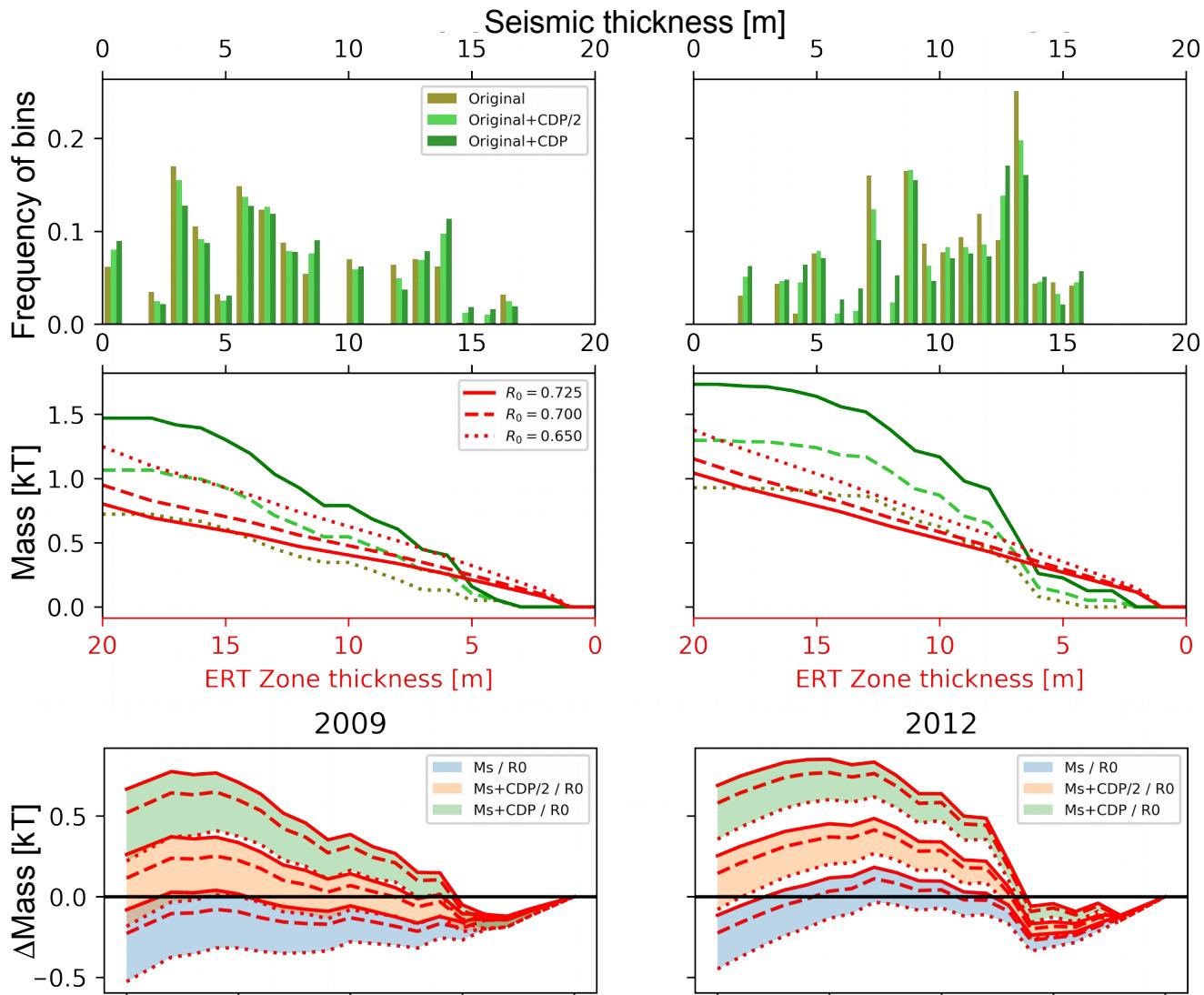


2012

HELMHOLTZ

# Mass matching

- Compare Mass estimates of seismic and ERT measurements
  - ERT: Parameter uncertainty  $R_0$  and saturation exponent  $n$
  - Seismic: Variable AOI derived estimates
- Default values show largest similarity for the estimated mass for the original AOI
- Increasing the thickness threshold shows increasing deviation between estimated masses



## References

- [1] Ivandic, M., Juhlin, C., Lueth, S., Bergmann, P., Kashubin, A., Sopher, D., Ivanova, A., Baumann, G. and Henninges, J., 2015. Geophysical monitoring at the Ketzin pilot site for CO<sub>2</sub> storage: New insights into the plume evolution. International Journal of Greenhouse Gas Control, 32, pp.90-105.
- [2] Förster, A., Schöner, R., Förster, H.J., Norden, B., Blaschke, A.W., Luckert, J., Beutler, G., Gaupp, R. and Rhede, D., 2010. Reservoir characterization of a CO<sub>2</sub> storage aquifer: the Upper Triassic Stuttgart Formation in the Northeast German Basin. Marine and Petroleum Geology, 27(10), pp.2156-2172.
- [3] Ivanova, A., Kashubin, A., Juhojuntti, N., Kummerow, J., Henninges, J., Juhlin, C., Lüth, S. and Ivandic, M., 2012. Monitoring and volumetric estimation of injected CO<sub>2</sub> using 4D seismic, petrophysical data, core measurements and well logging: a case study at Ketzin, Germany. Geophysical Prospecting, 60(5), pp.957-973.
- [4] Bergmann, P., Schmidt-Hattenberger, C., Kiessling, D., Rücker, C., Labitzke, T., Henninges, J., Baumann, G. and Schütt, H., 2012. Surface-downhole electrical resistivity tomography applied to monitoring of CO<sub>2</sub> storage at Ketzin, Germany. Geophysics, 77(6), pp.B253-B267.
- [5] Schmidt-Hattenberger, C., Bergmann, P., Bösing, D., Labitzke, T., Möller, M., Schröder, S., Wagner, F. and Schütt, H., 2013. Electrical resistivity tomography (ERT) for monitoring of CO<sub>2</sub> migration-from tool development to reservoir surveillance at the Ketzin pilot site. Energy Procedia, 37, pp.4268-4275.
- [6] Bergmann, P., Diersch, M., Goetz, J., Ivandic, M., Ivanova, A., Juhlin, C., Kummerow, J., Liebscher, A., Lueth, S., Meekes, S. and Norden, B., 2016. Review on geophysical monitoring of CO<sub>2</sub> injection at Ketzin, Germany. Journal of Petroleum Science and Engineering, 139, pp.112-136.
- [7] Lüth, S., Ivanova, A. and Kempka, T., 2015. Conformity assessment of monitoring and simulation of CO<sub>2</sub> storage: A case study from the Ketzin pilot site. International Journal of Greenhouse Gas Control, 42, pp.329-339.

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