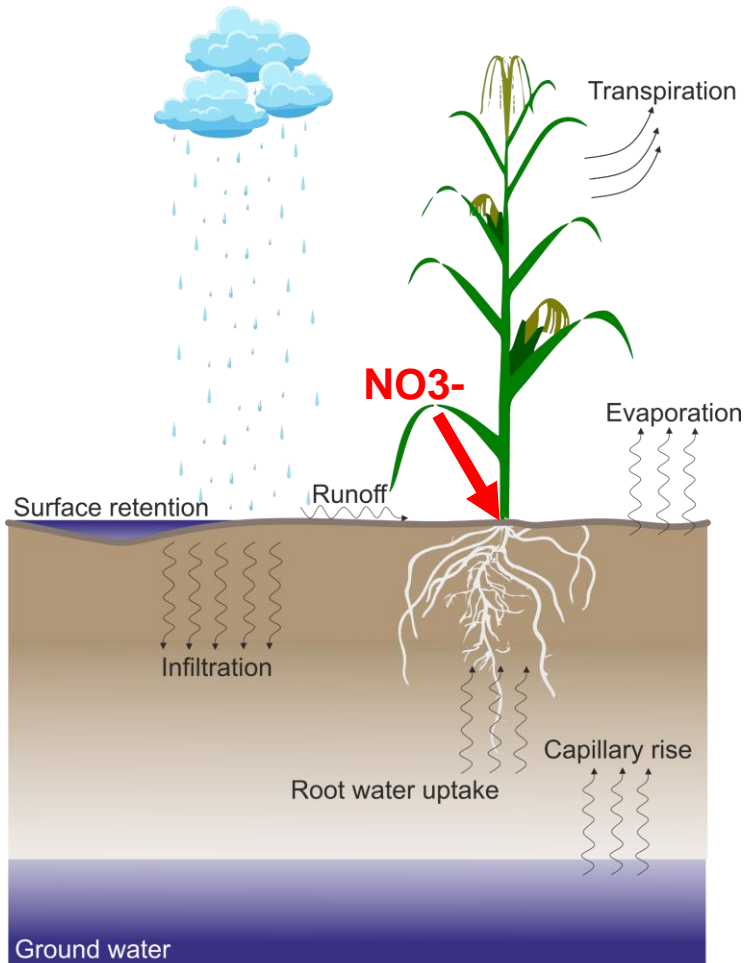


USING CROSSHOLE GPR TO MONITOR THE IMPACT OF MAIZE ROOTS AND NITRATE FERTILIZER ON THE SOIL-PLANT CONTINUUM

22.02.2025 | SCHIEBEL SOPHIA, LENA LÄRM, FELIX BAUER, ANDREA SCHNEPF, HARRY VEREECKEN, ANJA KLOTZSCHE

GEOPHYSICAL IMAGING FOR AN OPTIMIZED USE OF RESOURCES IN AGRICULTURAL PRACTICES

Soil-plant continuum



Modified after Lärm, 2024 & Slawinski & Sobzuk, 2011

Optimized use of resources



Nitrate fertilization process requires precise water supply

- Too much water → washing out of NO₃⁻
- Too less water → No dissolving of NO₃⁻
- Too much NO₃⁻ → crop damage & pollution of leakage

Ground penetrating radar (GPR)

- EM wave: 50 MHz - 3.6 GHz
- Minimal to non-invasive
- Surface & crosshole

Relative permittivity ϵ_r

Electrical conductivity σ

Soil-water-content

NO₃⁻

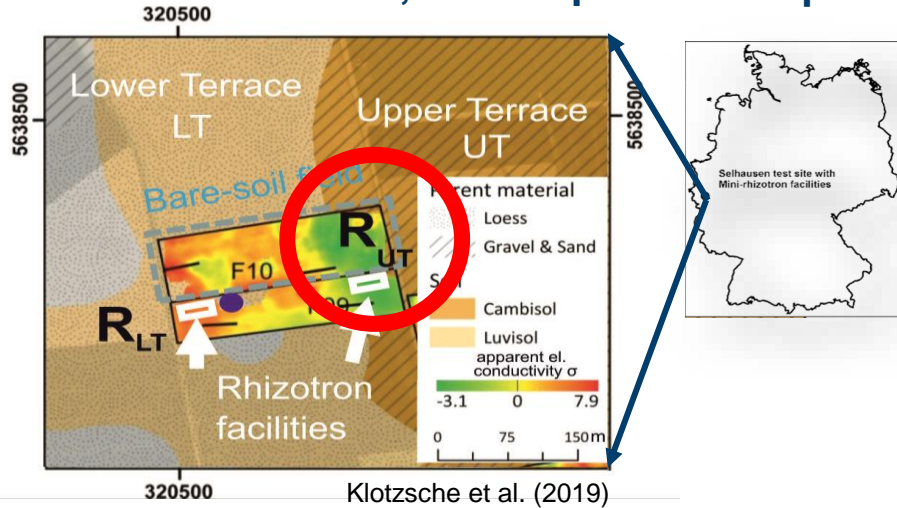
Root zone

Lärm, et. al (2024)

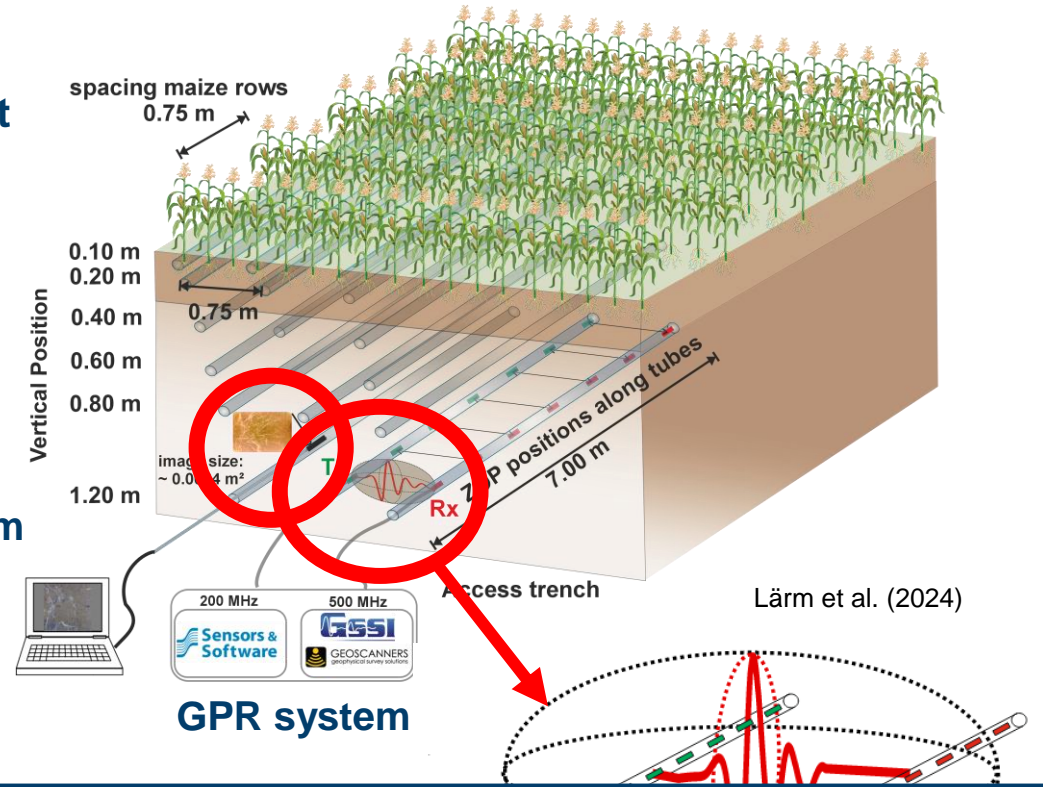
DATA AQUISION

Field Minirhizotrone Facility in Selhausen

Rhizotron locations, soil map & EMI map



Exemplary plot



Root image camera system

Previous years:

- Different treatments & crop types
- 200 MHz (Sensors & Software) for ZOP-monitoring
- Only $\epsilon_r \rightarrow$ SWC

Datapaper: Lärm & Bauer et al., 2023



My research

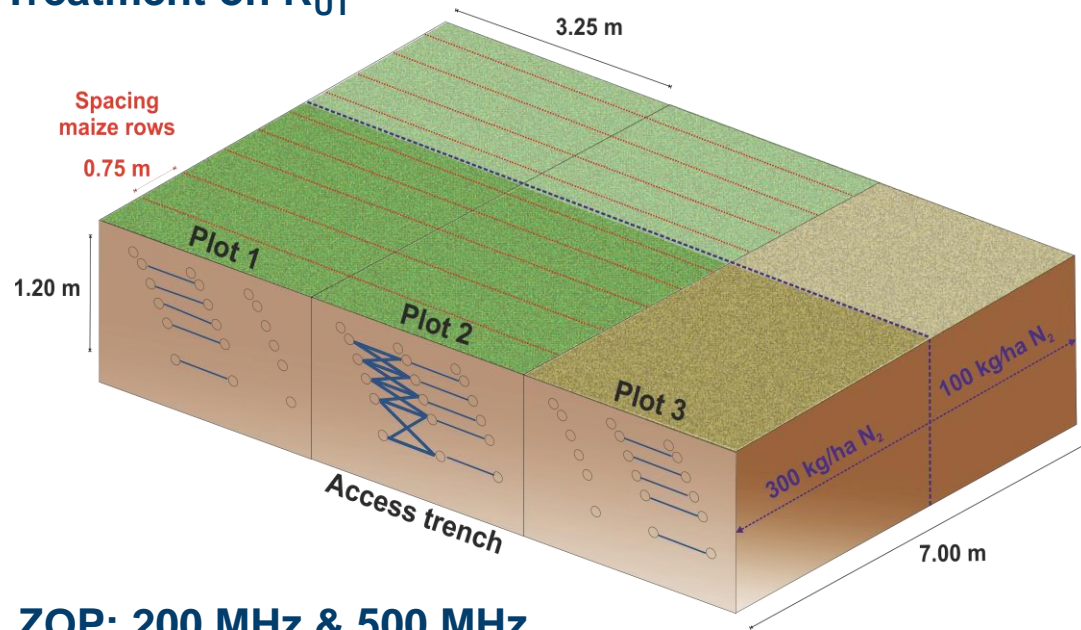
- **500 MHz** (Geonics BA-Scanner & SIR-30 GSSI)
- better resolution of root zone
- Comparison of antennae
- Fertilizers not visible in $\epsilon_r \rightarrow \sigma$



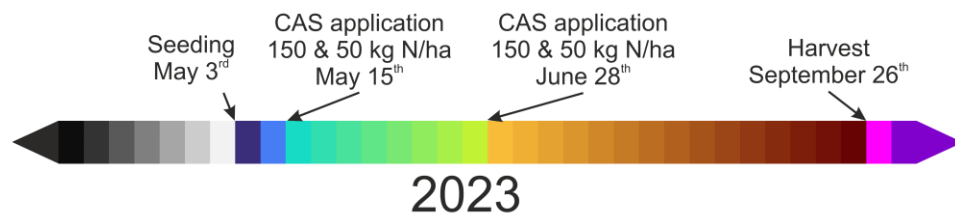
DATA ACQUISITION

Experimental setup at R_{UT} for 2023

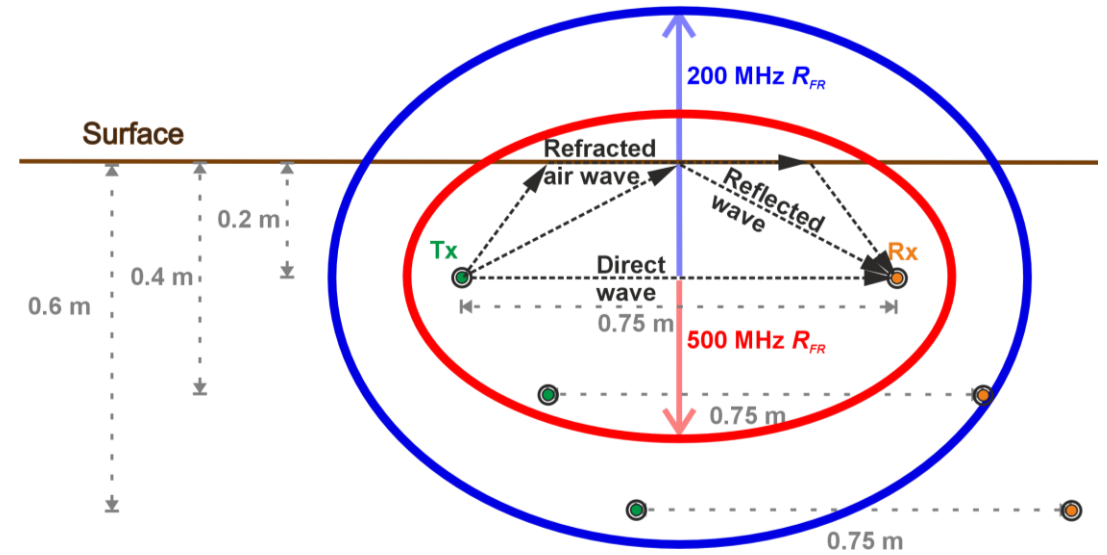
Treatment on R_{UT}



ZOP: 200 MHz & 500 MHz



Fresnelzone radius R_{FR}



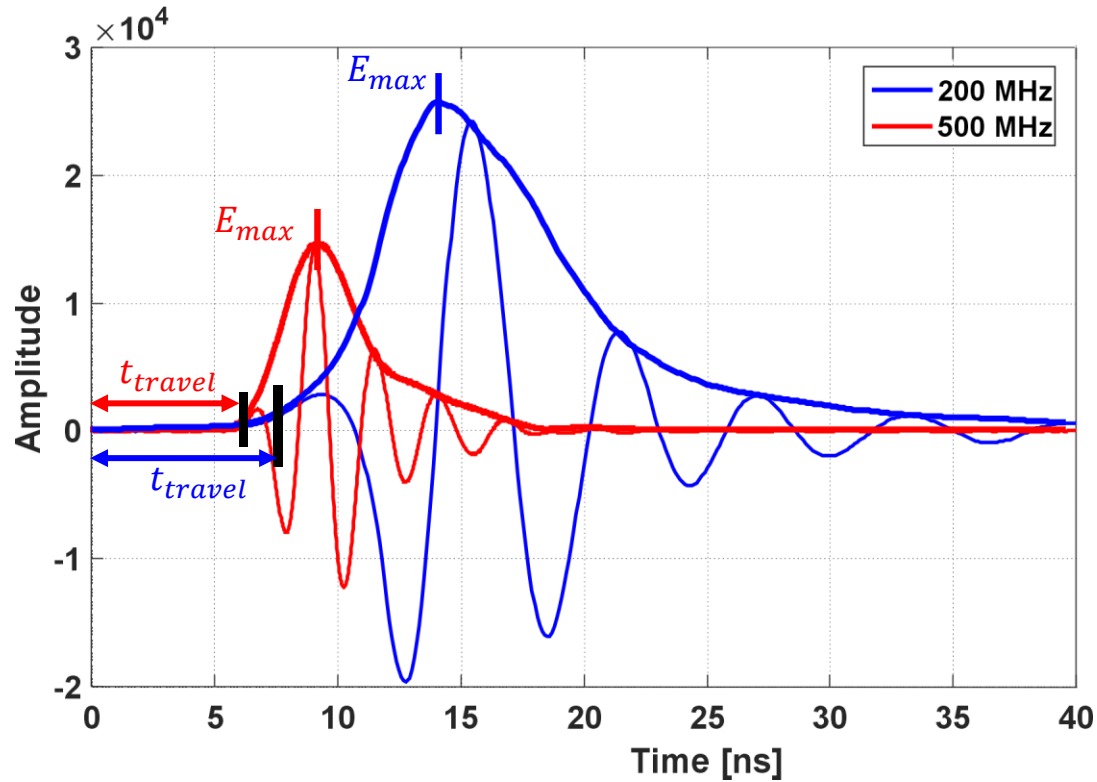
Antennae	Soil condition	ϵ_r [-]	λ_c [m]	R_{FR} [m]
200 MHz	Dry	4	0.88	0.46
	Wet	10	0.56	0.35
500 MHz	Dry	4	0.37	0.28
	Wet	10	0.23	0.22

Modified from Klotzsche et al. (2016)

Influence of **refracted air wave** is expected at **0.2 m** and **0.4 m**.

PROCESSING OF GPR DATA

T_0 -corrected GPR traces



ϵ_r - estimation



t_{travel}



$$v_{EM} = \frac{d_{rhizotube}}{t_{travel}}$$



$$\epsilon_r = \left(\frac{c}{v_{EM}} \right)^2$$

Amplitude analysis

$\sigma \uparrow \rightarrow$ damping $\uparrow \rightarrow$ signal amplitude \downarrow

$\sigma \downarrow \rightarrow$ damping $\downarrow \rightarrow$ signal amplitude \uparrow



Calculation of envelopes



Finding maximum envelopes
 E_{max}

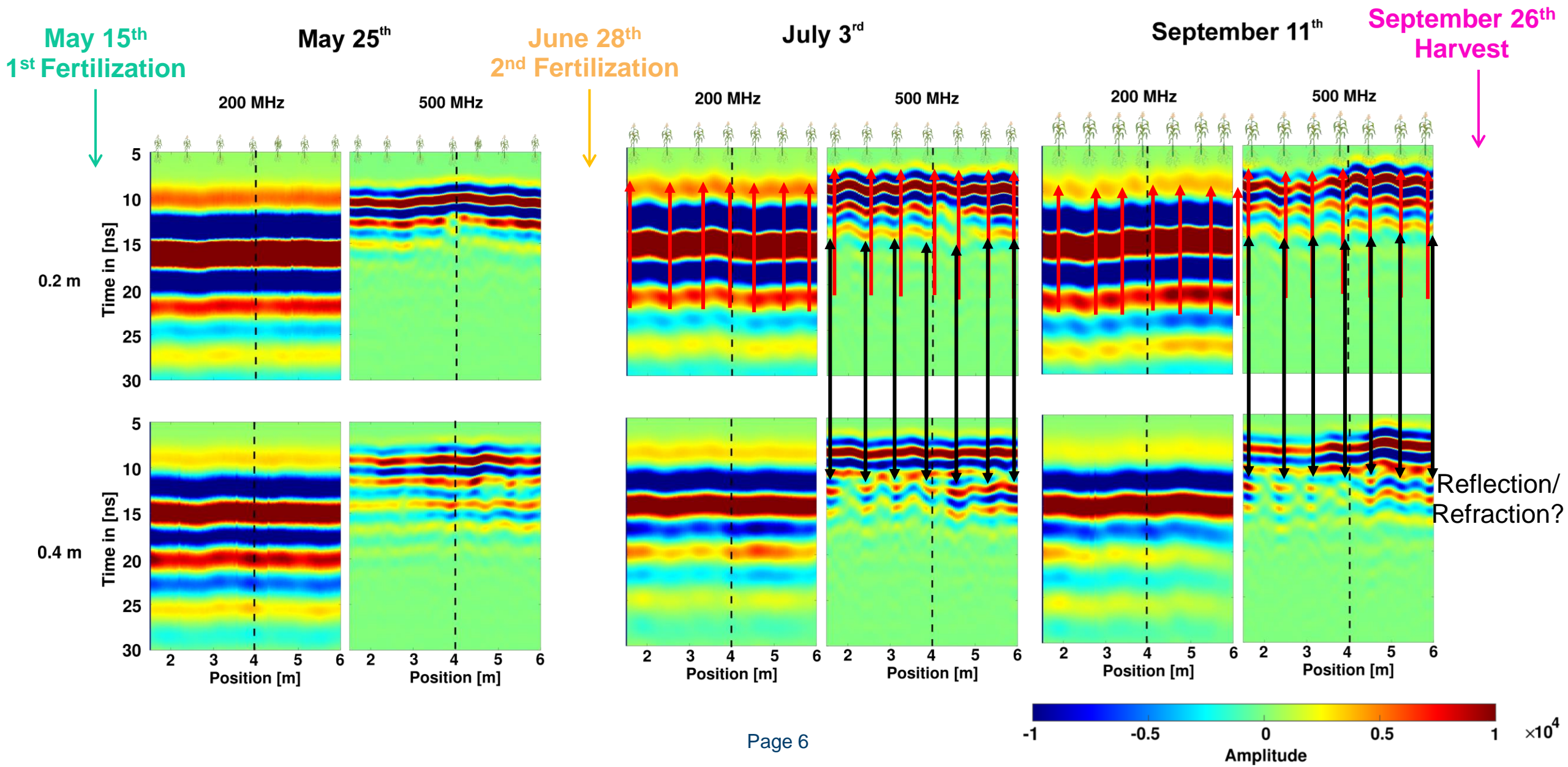
Trend-correction*



$\Delta\epsilon'_r$ & $\Delta E'_{max}$

*Lärm, et. al 2024

DATA COMPARISON: T_0 -CORRECTED DATA



DATA COMPARISON: ENVELOPES

May 15th
1st Fertilization

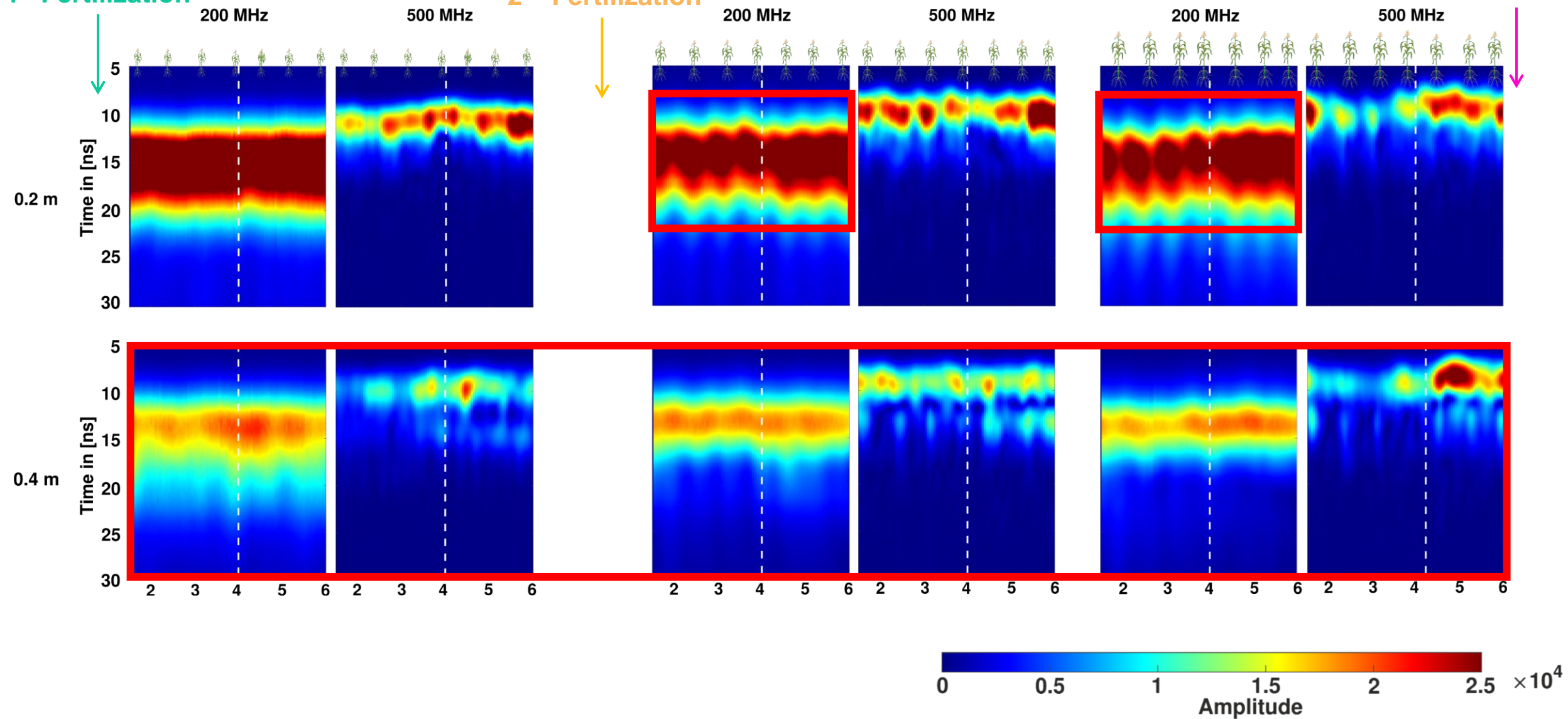
May 25th

June 28th
2nd Fertilization

July 3rd

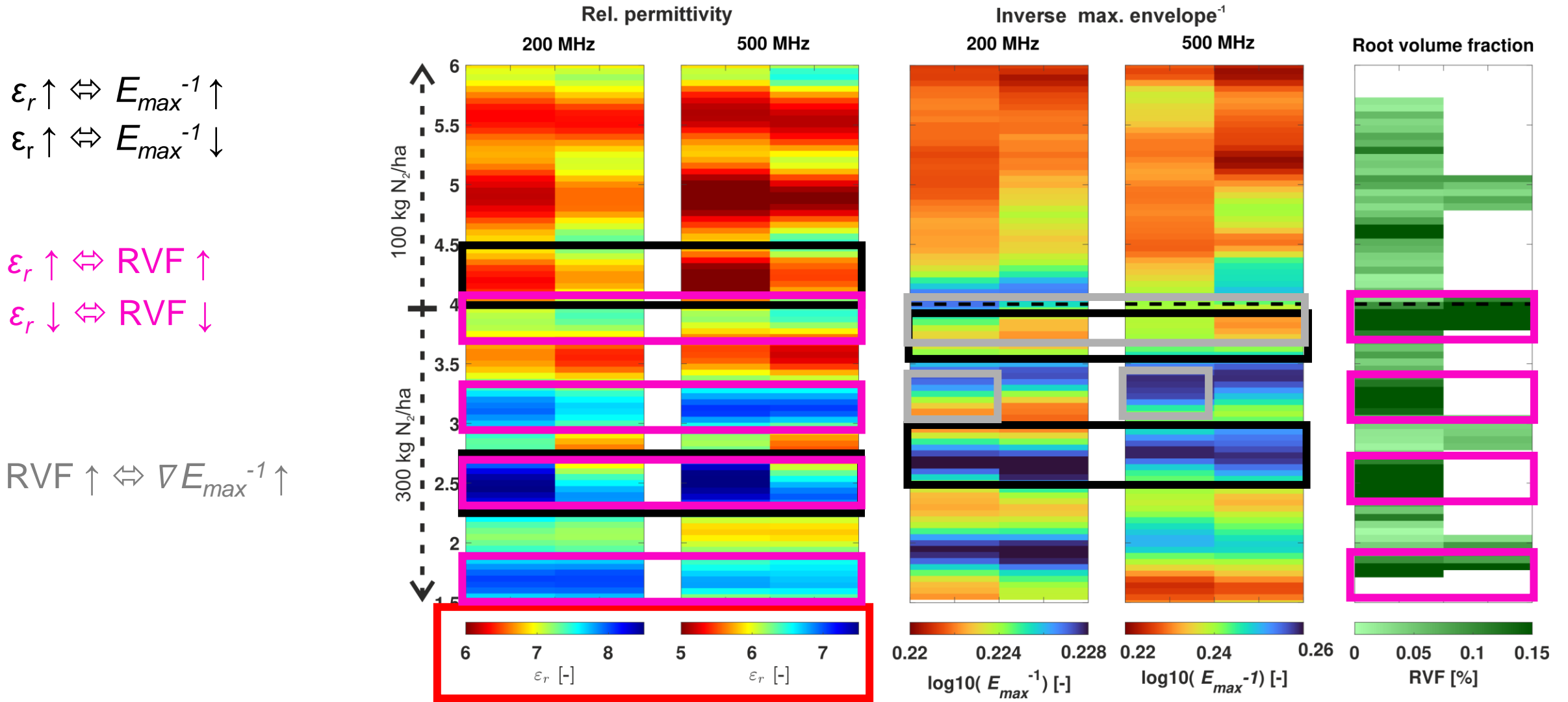
September 11th

September 26th
Harvest

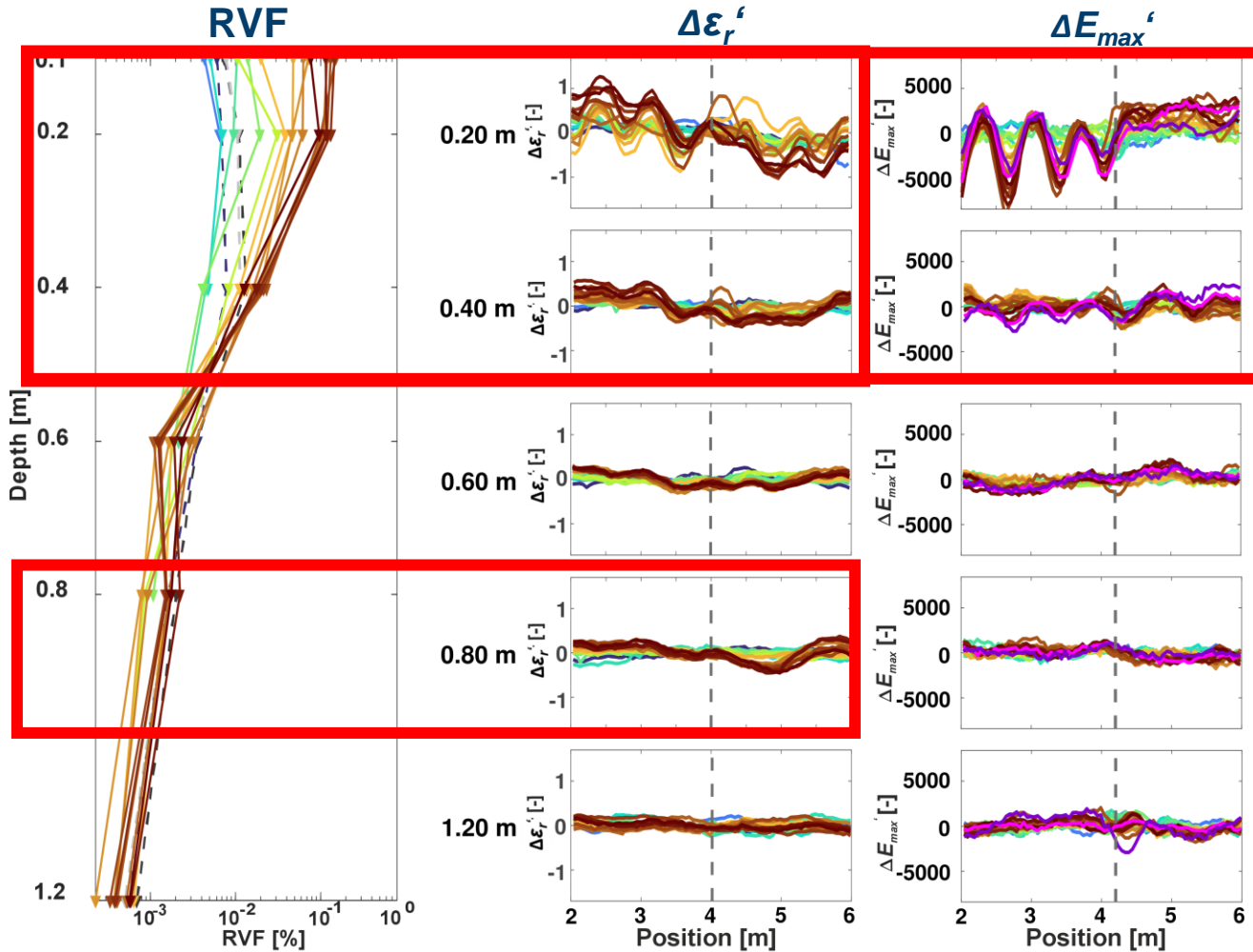


DATA COMPARISON

September 11th – Comparison of ϵ_r & inverse E_{max}^{-1} & root data along rhizotube at 0.2 m



LINKING 200 MHZ GPR DATA & ROOT INFORMATION

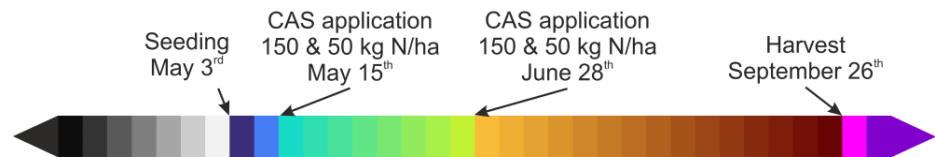


Correlation: RVF & $\Delta\epsilon_r'$

Depth	All positions	300 kg N/ha	100 kg N/ha
0.2 m	0.73	0.64	0.54
0.4 m	0.59	0.55	0.73
0.6 m	0.22	0.11	0.03
0.8 m	0.61	0	0.77

Correlation: RVF & $\Delta E_{max}'$

Depth	All positions	300 kg N/ha	100 kg N/ha
0.2 m	0.73	0.72	0.04
0.4 m	0.15	0.16	0.39
0.6 m	0	0.01	0.01
0.8 m	0.03	0	0



2023

CONCLUSION

Data comparison

- 200 MHz & 500 MHz: similar structures
- 500 MHz
 - is refining structures of 200 MHz
 - Reveals reflection/refraction at 0.4 m
- Envelopes shows new anomalies

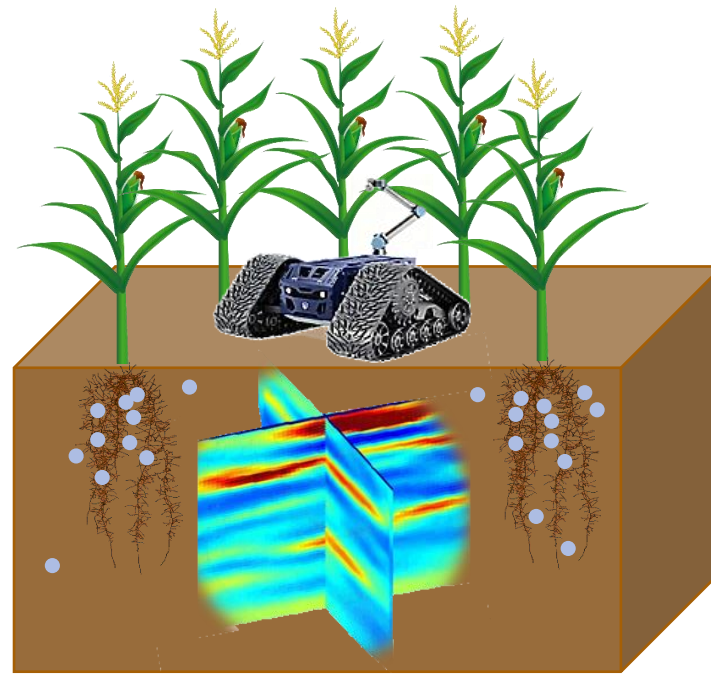
Links

- Data paper (Lärm, Bauer, et. al 2023)
- Video: Phenorob – Rhizotronen facility



Link to root images

- Root images: Nitrate causes strong root formation at 0.2 m & 0.4 m 0.8 m
- 200 MHz
 - Link between $\Delta\epsilon_r'$ and RVF at 0.2 m & 0.4 m & 0.8 m
 - Link between $\Delta E_{max}'$ and RVF at 0.2 m



THANK YOU

CREDITS: Tim Spieker, Tilman Hiller, Neil Sommer, Maximilian Gregorius, Normen Hermes, Annika Sommer, Moritz Harings, Felix Bauer, Andrea Schnepf, Lena Lärm, Dominik Hoven, Anja Klotzsche, Harry Vereecken

This work was partially funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC 2070 – 390732324