# Investigating the effect of maize roots under different nitrate applications using crosshole GPR

**S. Schiebel***, L. Lärm, H. Vereecken, A. Schnepf, F. Bauer, A. Klotzsche
Institute of Bio- and Geosciences: Agrosphere (IBG-3), Forschungszentrum Jülich GmbH, Jülich, Germany *s.schiebel@fz-juelich.de

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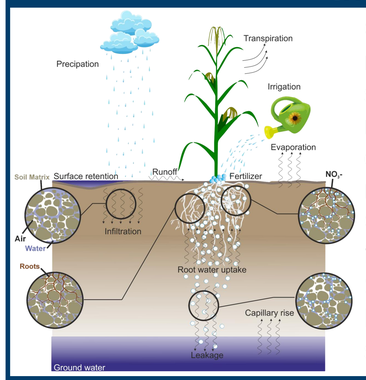
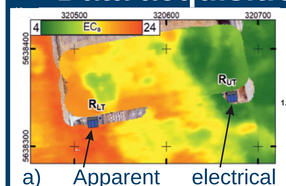
## Introduction

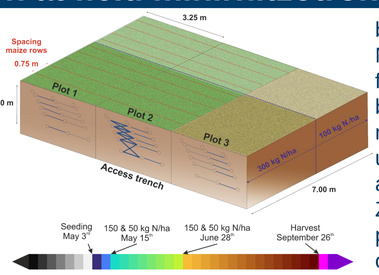



Ground Penetrating Radar **(GPR)** monitors small-scale variations in the soil-plant continuum by retrieving **relative dielectric permittivity $\varepsilon_r$** and **electrical conductivity $\sigma$** of the medium. In 2023, we conducted weekly GPR crosshole measurements at the field minirhizotrone (MR) facilities in Selhausen using 200 MHz and 500 MHz antennas to better characterize such small-scale processes.

## Data acquisition at field minirhitzotrone facility



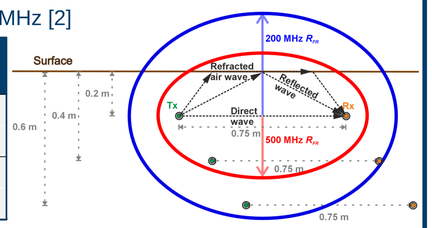

a) Apparent electrical conductivity map based on Electromagnetic Induction data & location of the MR facilities. [1]




b) 2023 – R$_{UT}$: Maize sowing & fertilization & belowground GPR measurements using 200 MHz and 500 MHz for Zero-offset profiling and Multi-offset gather.

c) Fresnelradius $R_{FR}$ for 200 MHz and 500 MHz [2]

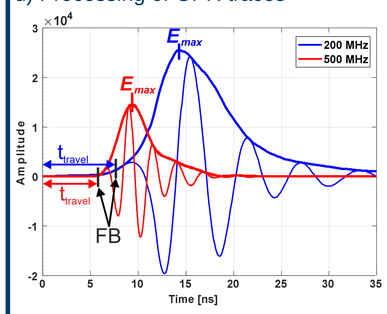
| Frequency [MHz] | Soil condition | $\varepsilon_r$ [-] | $R_{FR}$ [m] |
|---|---|---|---|
| 200 | Dry | 4 | **0.46** |
| | Saturated | 10 | 0.35 |
| 500 | Dry | 4 | 0.28 |
| | Saturated | 10 | 0.22 |



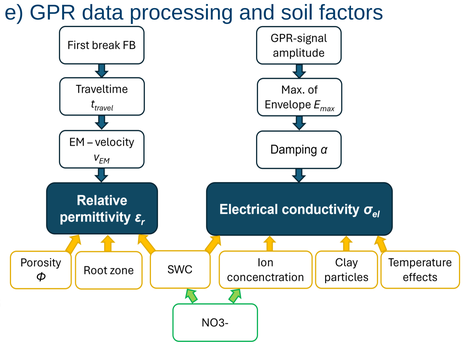

→200 MHz: Influence of **refracted airwave** expected until 0.4 m

## GPR data processing

d) Processing of GPR traces



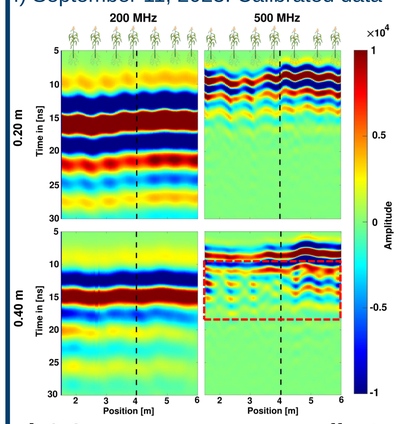

e) GPR data processing and soil factors



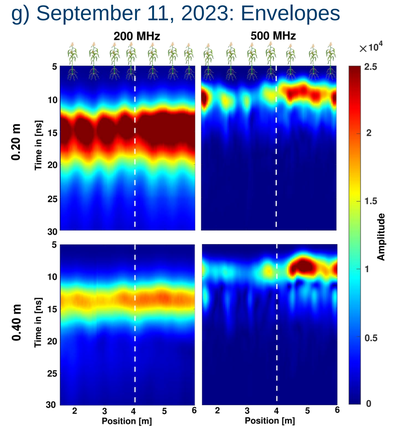

→Time-lapse analysis: **Trendcorrection** [3]: $\varepsilon_r$ , $E_{max}$ → $\Delta\varepsilon_r'$ , $\Delta E'_{max}$

## Comparison: 200 MHz & 500 MHz GPR data

f) September 11, 2023: Calibrated data

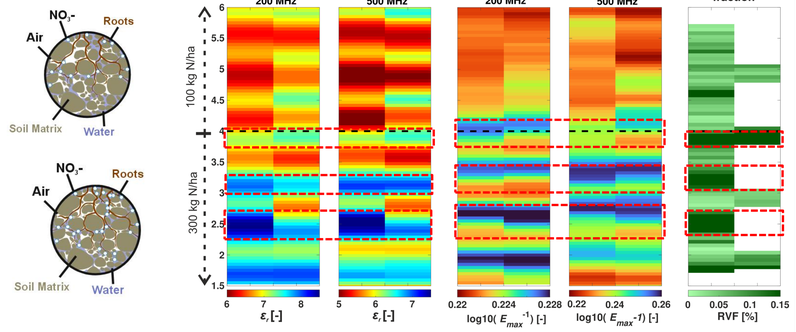



g) September 11, 2023: Envelopes



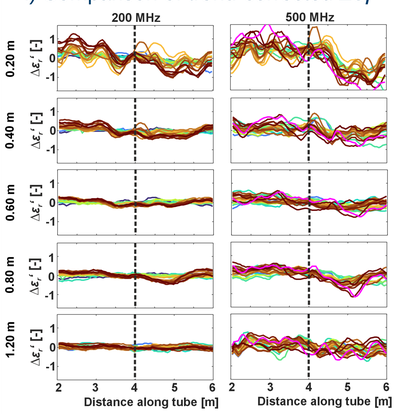

→0.2 m: **root presence** affect $t_{1^{st}arrival}$ & **envelopes** at 0.2 m
→0.4 m: **Reflection** observed only in 500 MHz

h) Comparison of $\varepsilon_r$ & inverse $E_{max}$ & root volume fraction (RVF) along rhizotube at 0.2 m depth

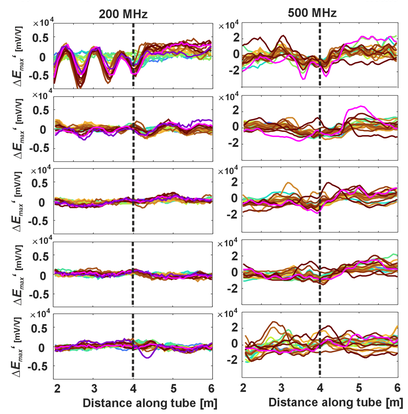



→Large **RVF** at location of large $\varepsilon_r$ and increasing **inverse** $E_{max}$

i) Comparison of trend-corrected $\Delta\varepsilon_r'$



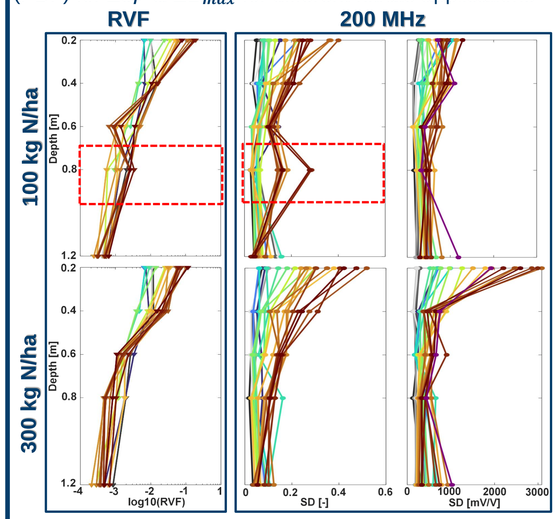

j) Comparison of trend-corrected $\Delta E'_{max}$




→Decreasing influence of **root presence** on $\Delta\varepsilon_r'$ and $\Delta E'_{max}$

## Linking 200 MHz GPR data & root images

k) Depth profiles of the RVF vs. standard deviation (SD) of the probability density function (PDF) for $\Delta\varepsilon_r'$ & $\Delta E'_{max}$ for different nitrate applications

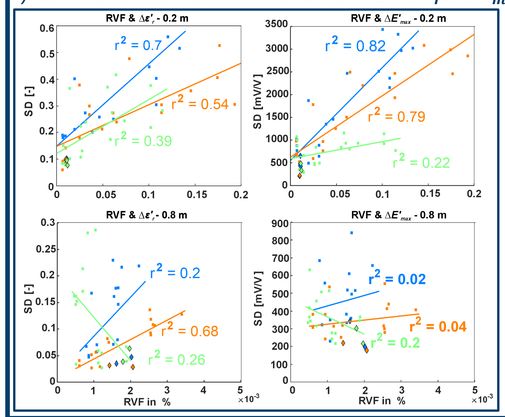



**RVF:**
→ **High root formation** observed at 0.2 m

**$\Delta\varepsilon_r'$ & $\Delta E'_{max}$:**
→ Highest SD at 0.2 m
→ SD decreases with increasing depth

**100 kg N/ha:**
→ Increasing RVF and variability of $\Delta\varepsilon_r'$ at 0.8m

l) Correlation between RVF & SD of PDF $\Delta\varepsilon_r'$ & $\Delta E'_{max}$ for different amount of fertilizer




**Combined & 300 kg N/ha**
→$r^2 > 0.5$ for $\Delta\varepsilon_r'$ at 0.2 m
→$r^2 > 0.5$ for $\Delta E'_{max}$ at 0.2 m

**100 kg N/ha:**
→$r^2 > 0.5$ for $\Delta\varepsilon_r'$ at 0.8 m
→$r^2 > 0.5$ for $\Delta E'_{max}$ at 0.2 m

→Clear effects of **old root systems** observable.

## Conclusion

- **500 MHz: Reflection** at 0.4 m
- Variations in **root presence** significantly influence $\varepsilon_r$ along tube and over time at 0.2 m & 0.8 m depth
- $E_{max}$ : New processes revealed
  → 0.2 m depth: Significant **root presence** affecting $E_{max}$
  → Depth > 0.4 m: other processes become more dominant

## References

[1] Lärm, L., Bauer, F. M., Hermes, N., van der Kruk, J., Vereecken, H., Vanderborght, J., ... & Klotzsche, A. (2023). Multi-year belowground data of minirhizotron facilities in Selhausen. *Scientific data*, *10*(1), 672.
[2] Klotzsche, A., Lärm, L., Vanderborght, J., Cai, G., Morandage, S., Zörner, M., ... & van der Kruk, J. (2019). Monitoring soil water content using time-lapse horizontal borehole GPR data at the field-plot scale. Vadose zone journal, 18(1), 190044.
[3] Lärm, L., Bauer, F. M., van der Kruk, J., Vanderborght, J., Morandage, S., Vereecken, H., ... & Klotzsche, A. (2024). Linking horizontal crosshole GPR variability with root image information for maize crops. *Vadose Zone Journal*, *23*(1), e20293.

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