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Assessment of a multi-receiver low-frequency electromagnetic-induction for estimating soil moisture content in field experiments with winter wheat (*Triticum aestivum*)

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Content

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- Introduction to crop phenotyping
- Methods
- Inversion modelling of electromagnetic induction data
- Discussion
- Conclusions

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Project: BB/J01950X/1

Soil moisture profiles

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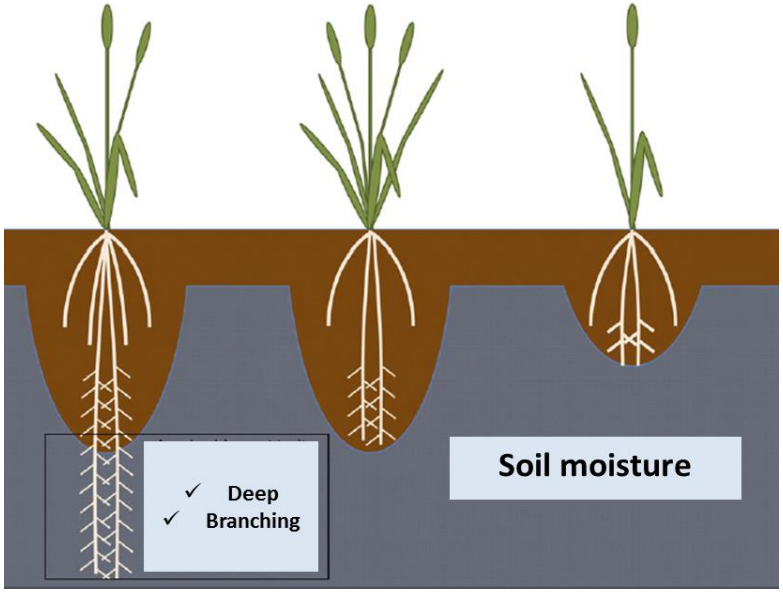
- Drought tolerance in winter wheat (*Triticum aestivum*) is crucial for global food security
- Crop roots have different effects on soil
- Traditional measurement methods are invasive, spatially limited and labour intensive



Wasson et al. (2012), J. Exp. Botany

Aim

- Can electromagnetic induction (EMI) geophysics provide rapid estimation of soil moisture profiles influenced by crop roots?

Field sites

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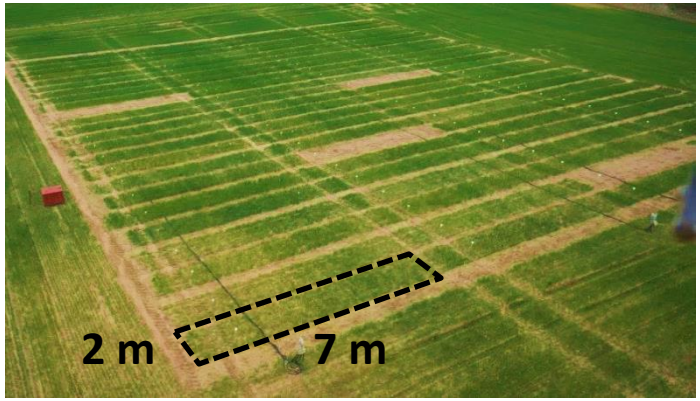
- Woburn Experimental Farm
- Two sites:
  - Butt Close = sandy loam
  - Warren Field = silt-clay loam
- 24 treatments:
  - 23 winter wheat varieties
  - Control, ‘fallow’
  - **4 replicates in 96 plots**
  - 7 x 2 m plots
- Conventional measurements:
  - Water content
  - Temperature
  - Penetration resistance



Field measurements of σ_a - Electromagnetic induction (EMI)

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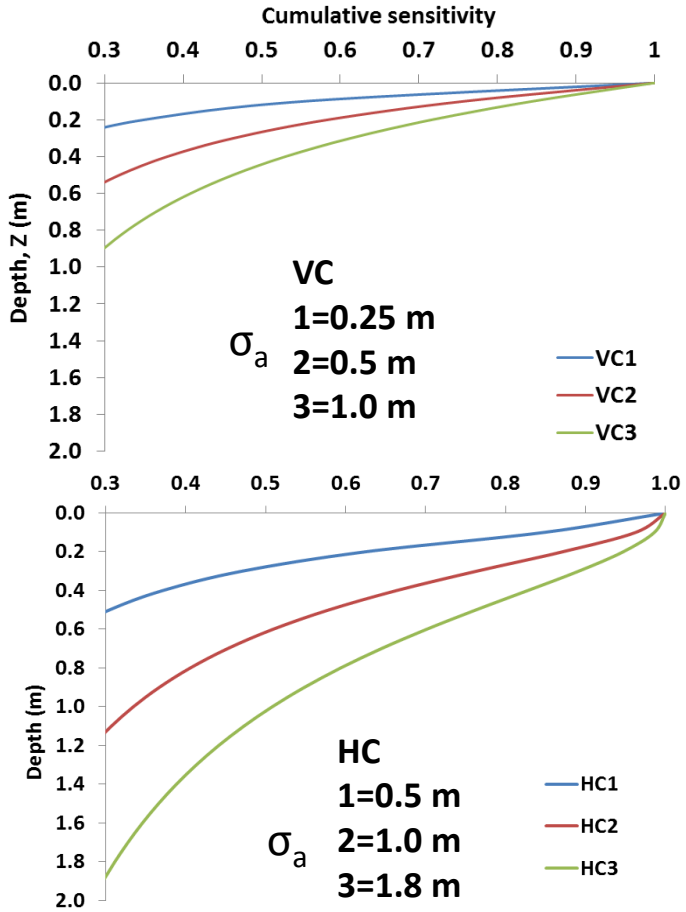
- Mini-Explorer (GF Instruments, CZ)
- 3 coil separations:
  1. 0.32 m
  2. 0.71 m
  3. 1.2 m
- 2 modes:
  - Vertical coplanar (VC, 'low')
  - Horizontal coplanar (HC, 'high')
- Drift bases
- Apparent electrical conductivity ($\sigma_{a,EM}$)
  - Formation factor (Archie, 1942)
  - σ_{water}
  - $\sigma_{surface}$
  - Texture



Electrical resistivity tomography (ERT)

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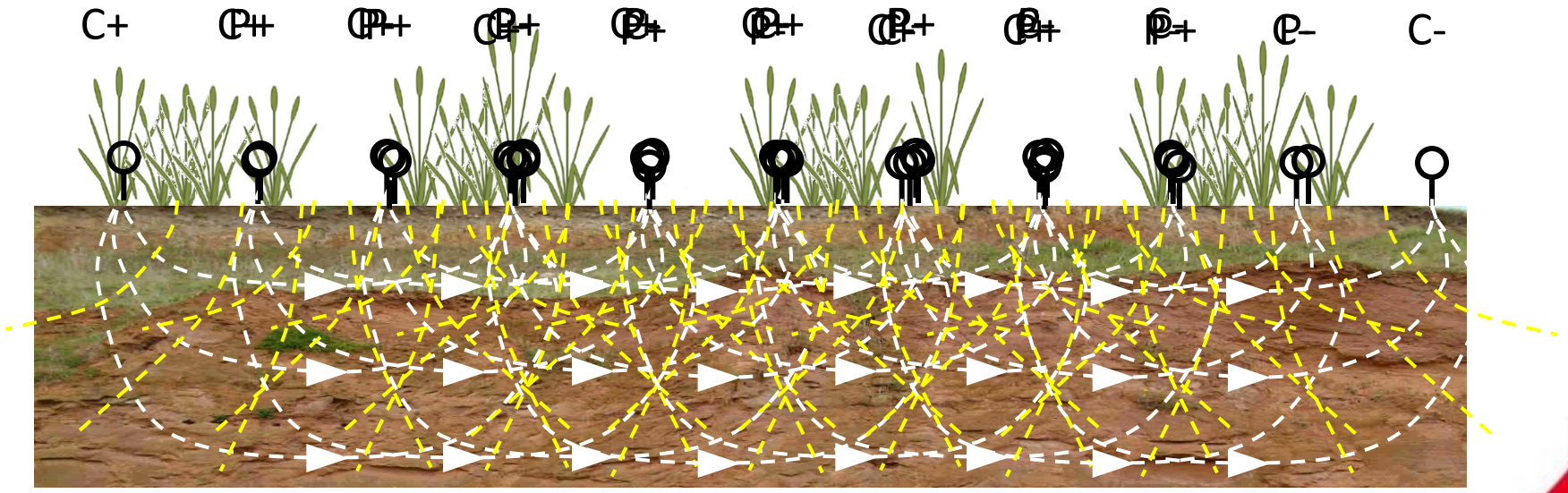
- Imaging soil electrical conductivity (σ)
- Calibration of EMI (Lavoué et al., 2010, *Near Sur. Geophys*.)
- Comparison against EMI data
- 4 x 31 m long arrays at each site (each span 12 plots)

C = current (I) P = potential (Volts)



Ratio inversion ERT - Butt Close

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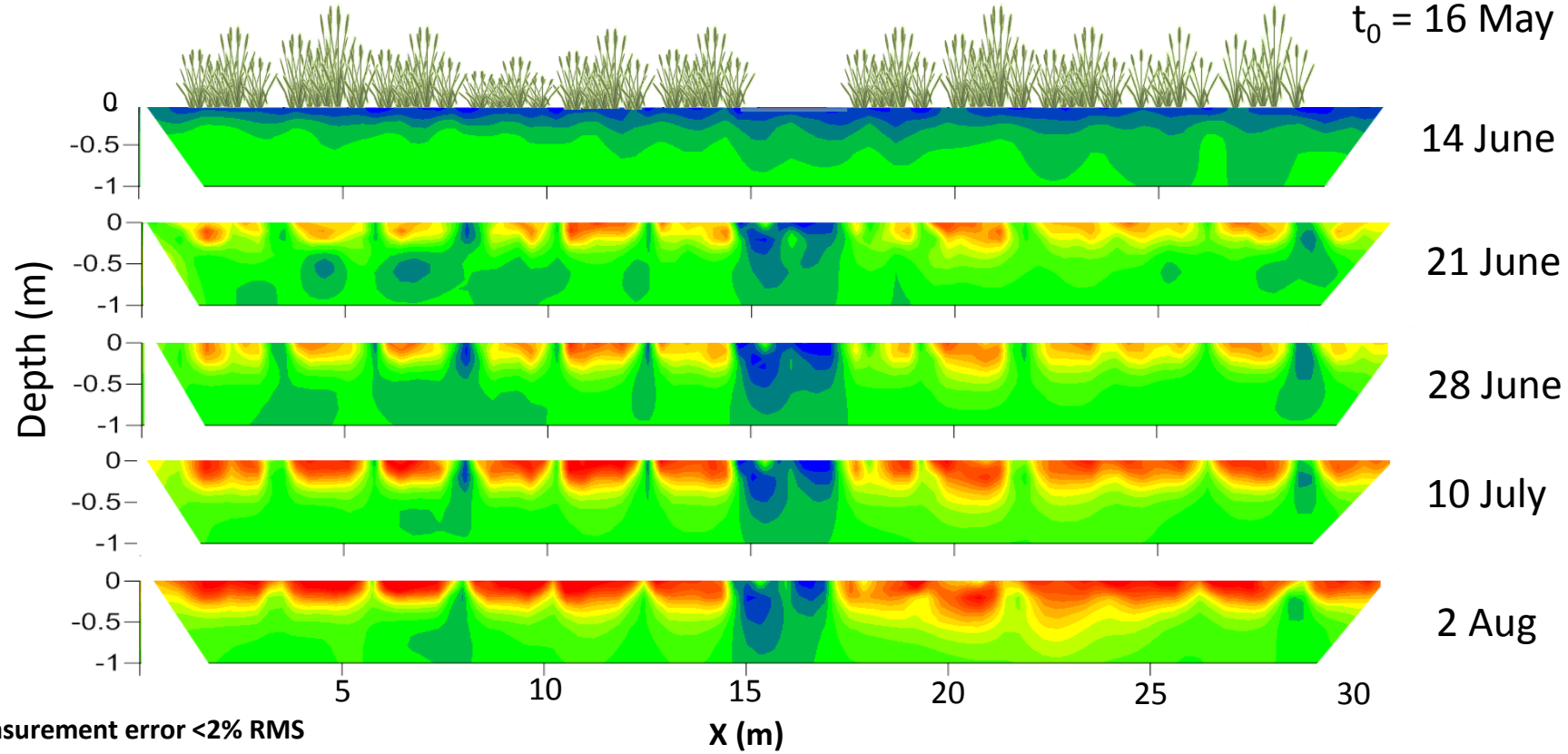

Measurement error <2% RMS

More conductive — More resistive

Ratio inversion ERT - Warren Field

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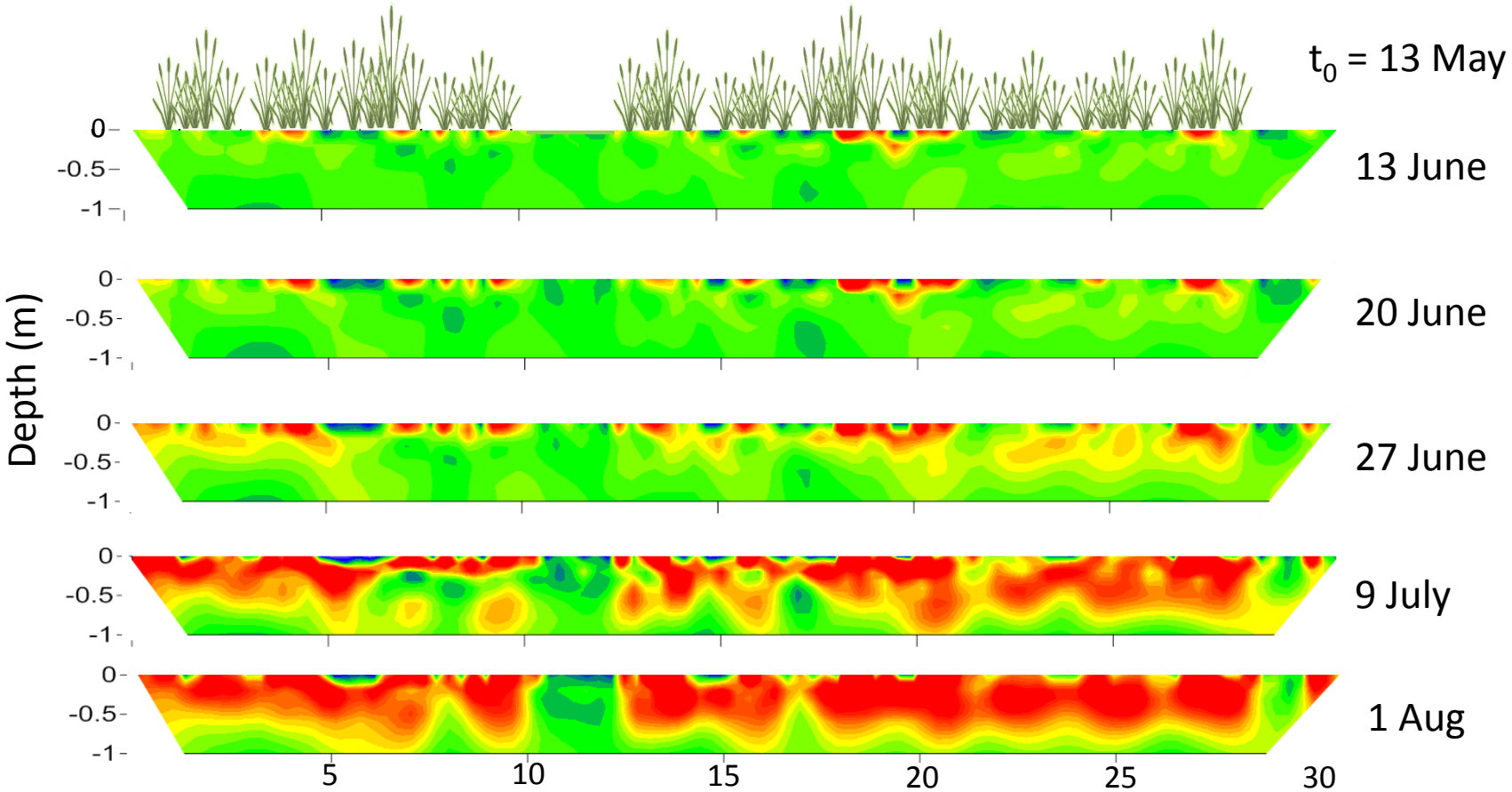

EMI σ_a calibrations from ERT

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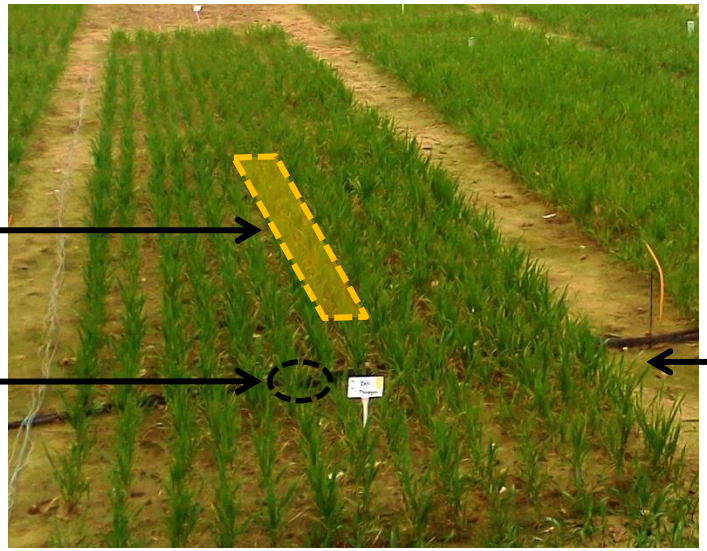
- Method based on Lavoué et al. 2010 and von Hebel et al., in press.
- EMI σ_a ($\sigma_{a,EM}$) compared to calculated σ_a from ERT data ($\sigma_{a,ERT}$) for 12 plots per ERT array (48 per site)
- $\sigma_{a,ERT}$ calculated from McNeill (1980):

$$\boldsymbol{\sigma_a = \sum_{i=1}^{n} \sigma_i \left[\mathbf{CS}(z_{i-1}) - \mathbf{CS}(z_i)\right], z_0 = 0}$$



Field measurements of σ_a - Butt Close σ_a calibration

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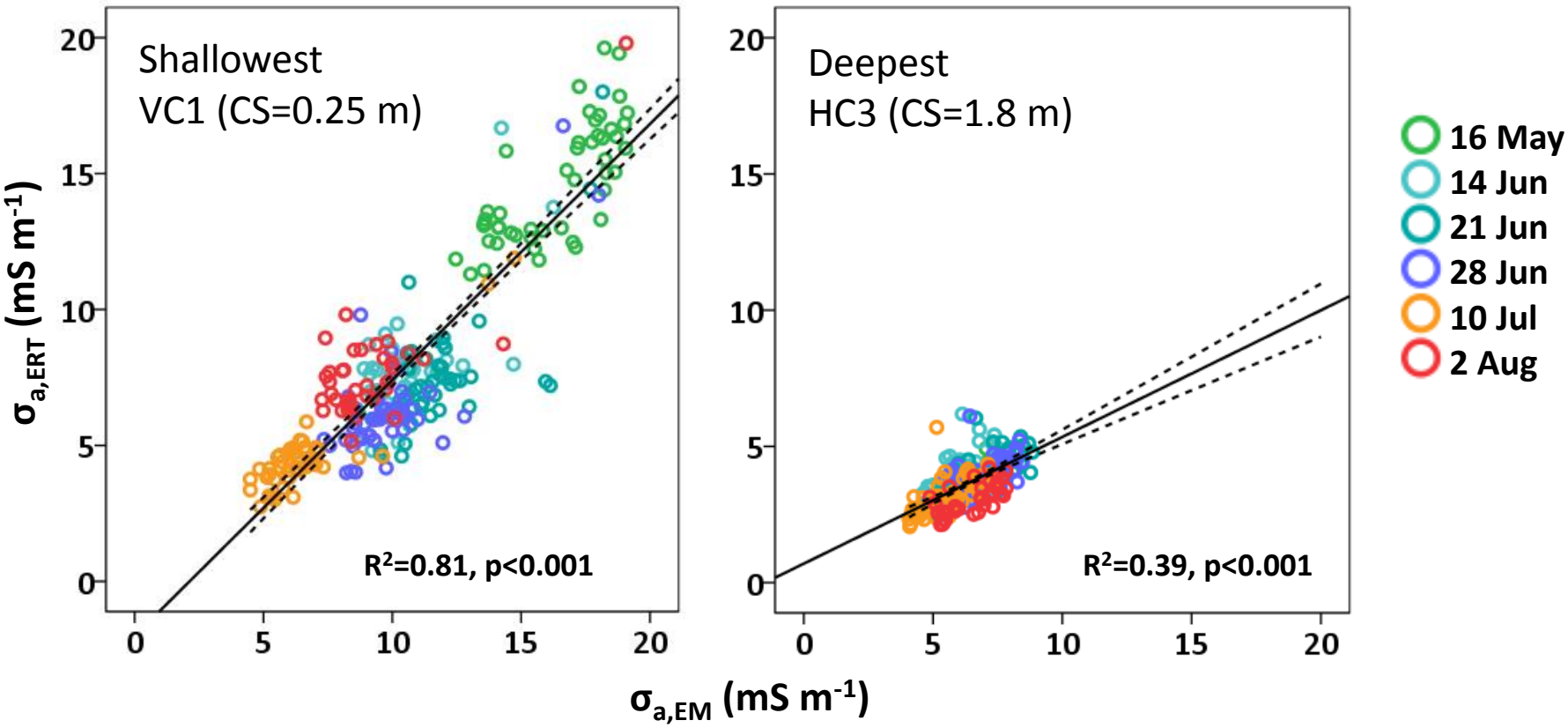
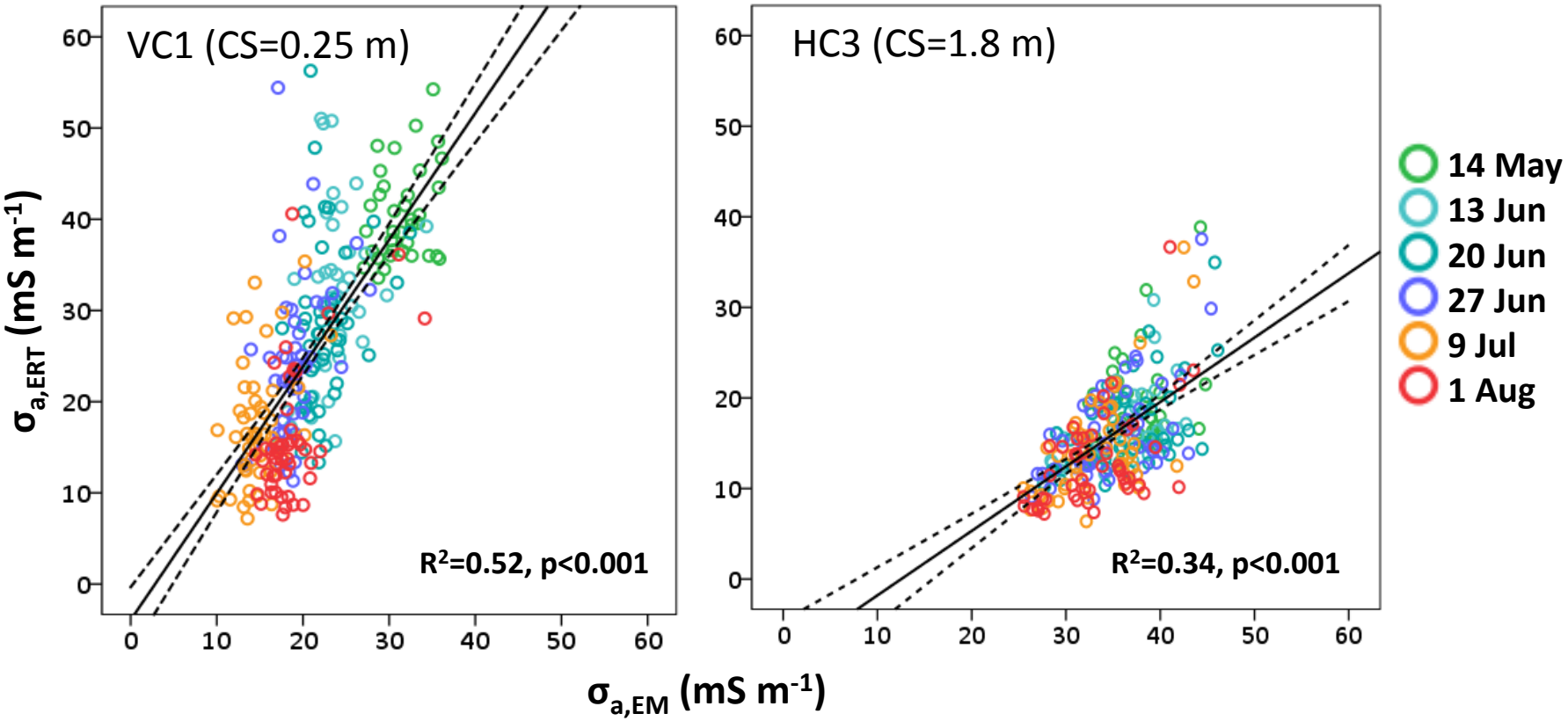


Field measurements of σ_a - Warren Field σ_a calibration



EMI inversion

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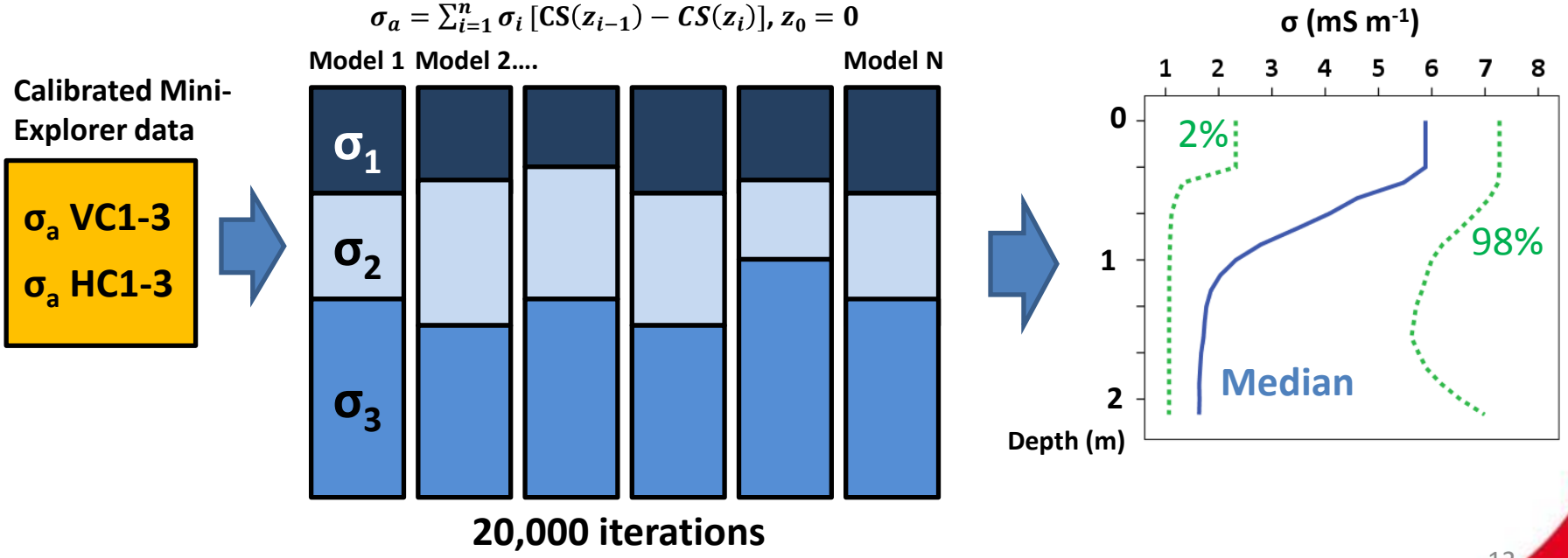
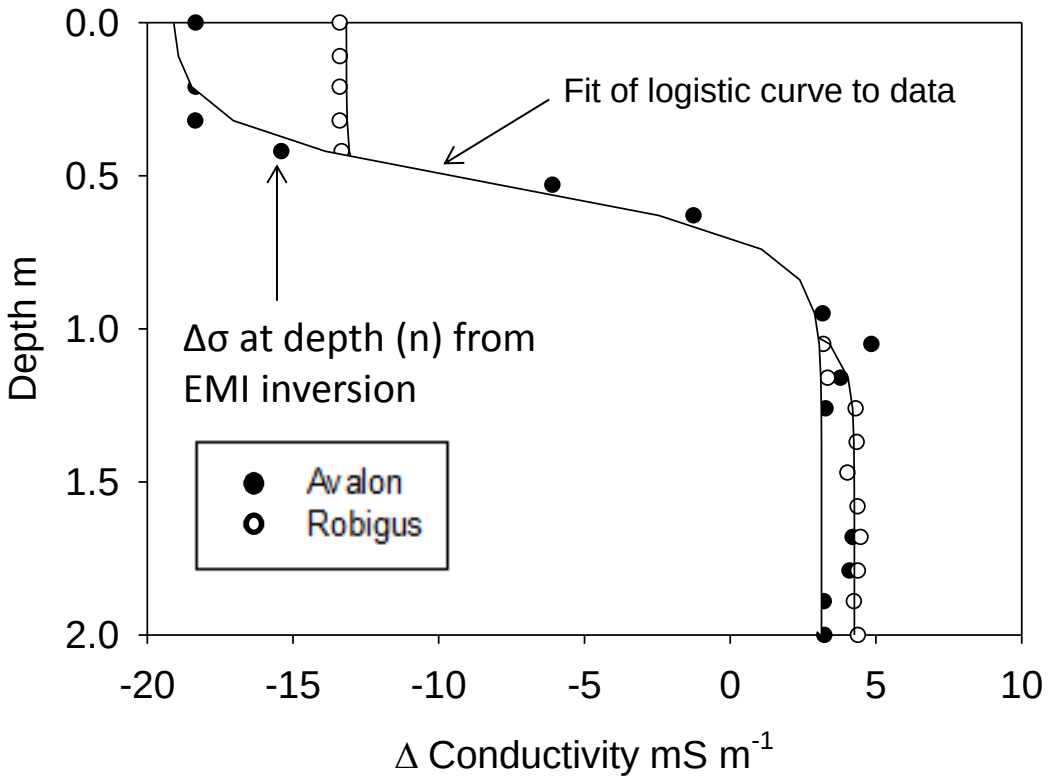
- Multiple models of soil σ
- Markov chain Monte Carlo search-based inversion algorithm (JafarGandomi and Binley, 2013, *J. App. Geophys*.)
- Simple approach with cumulative sensitivity (McNeill, 1980)
- Uncertainty from model

$$\sigma_a = \sum_{i=1}^{n} \sigma_i \, [CS(z_{i-1}) - CS(z_i)], \; z_0 = 0$$



Comparing Δσ between winter wheat varieties



(Warren Field: 14 May – 1 August)

Genstat (V. 16) S-shape logistic curve:

$$\Delta_{Conductivity} = A + \frac{C}{1 + e^{-b(depth - M)}}$$

Where:

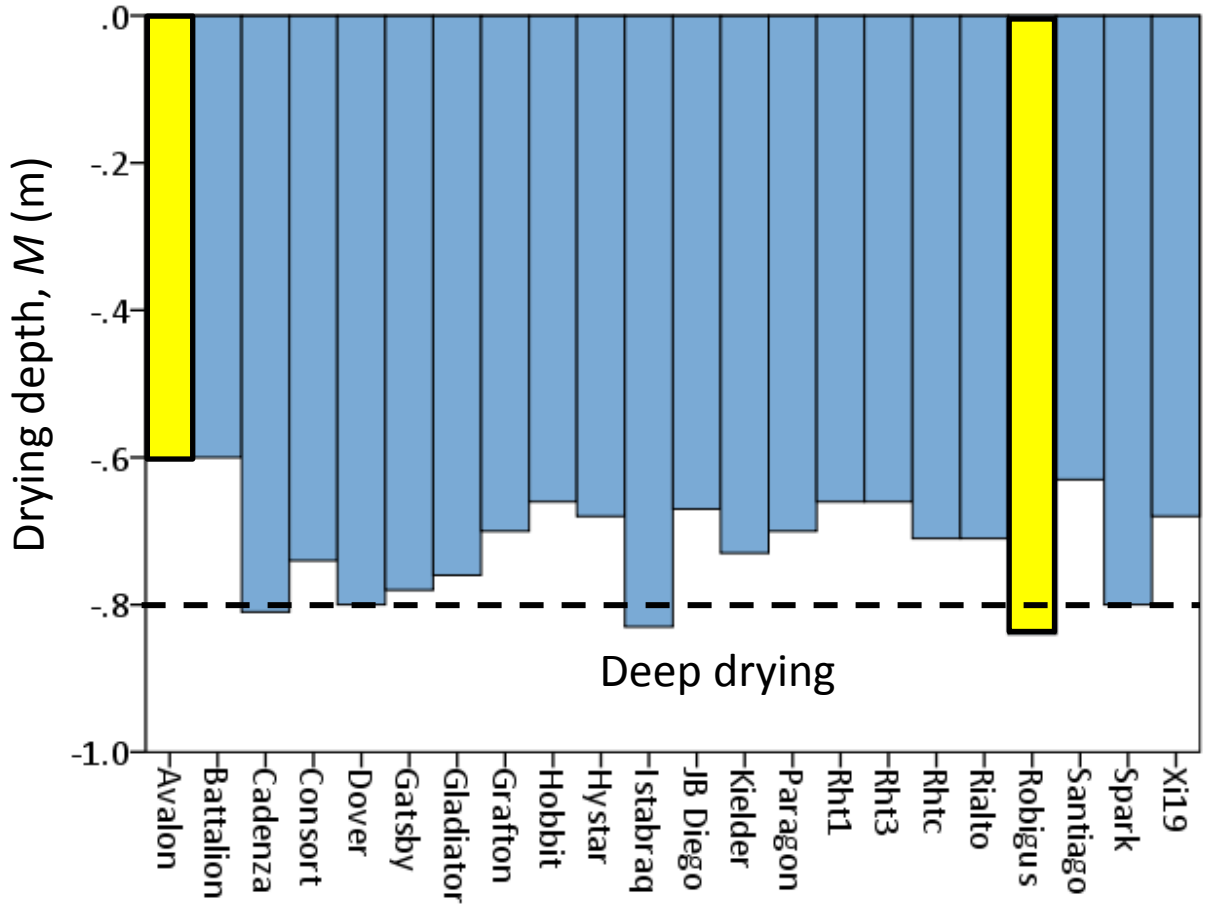
A = Δσ at surface

C = Δσ at depth

b = constant

M = inflection depth (m)

Quantitative comparison between winter wheat drying depth (Warren Field)



Approach is under test in 2014 by:

i. comparison with neutron-probe data, and

ii. the use of a mapping population to search for known rooting QTLs

EMI and soil water: Butt close

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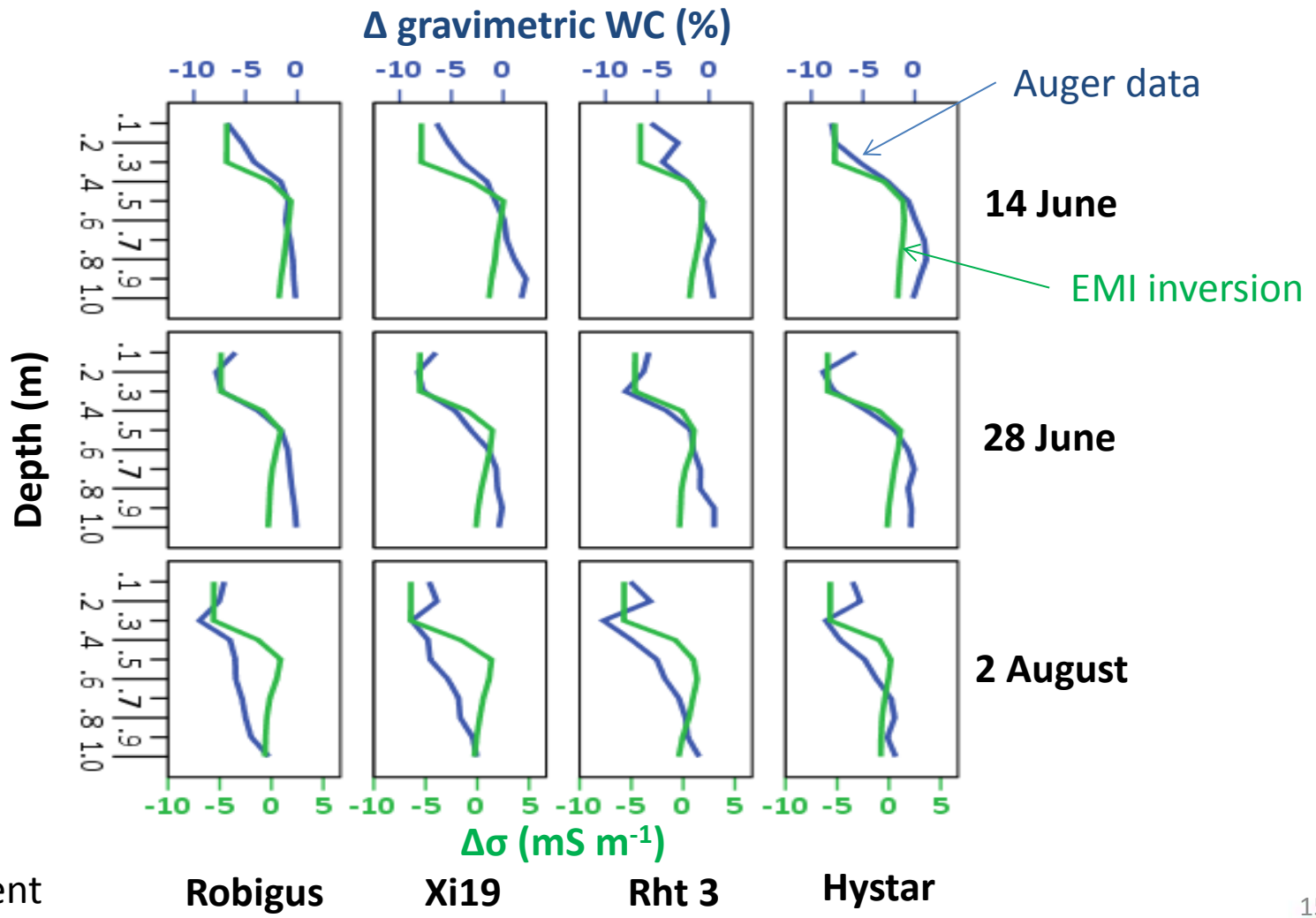

EMI and soil water: Warren Field

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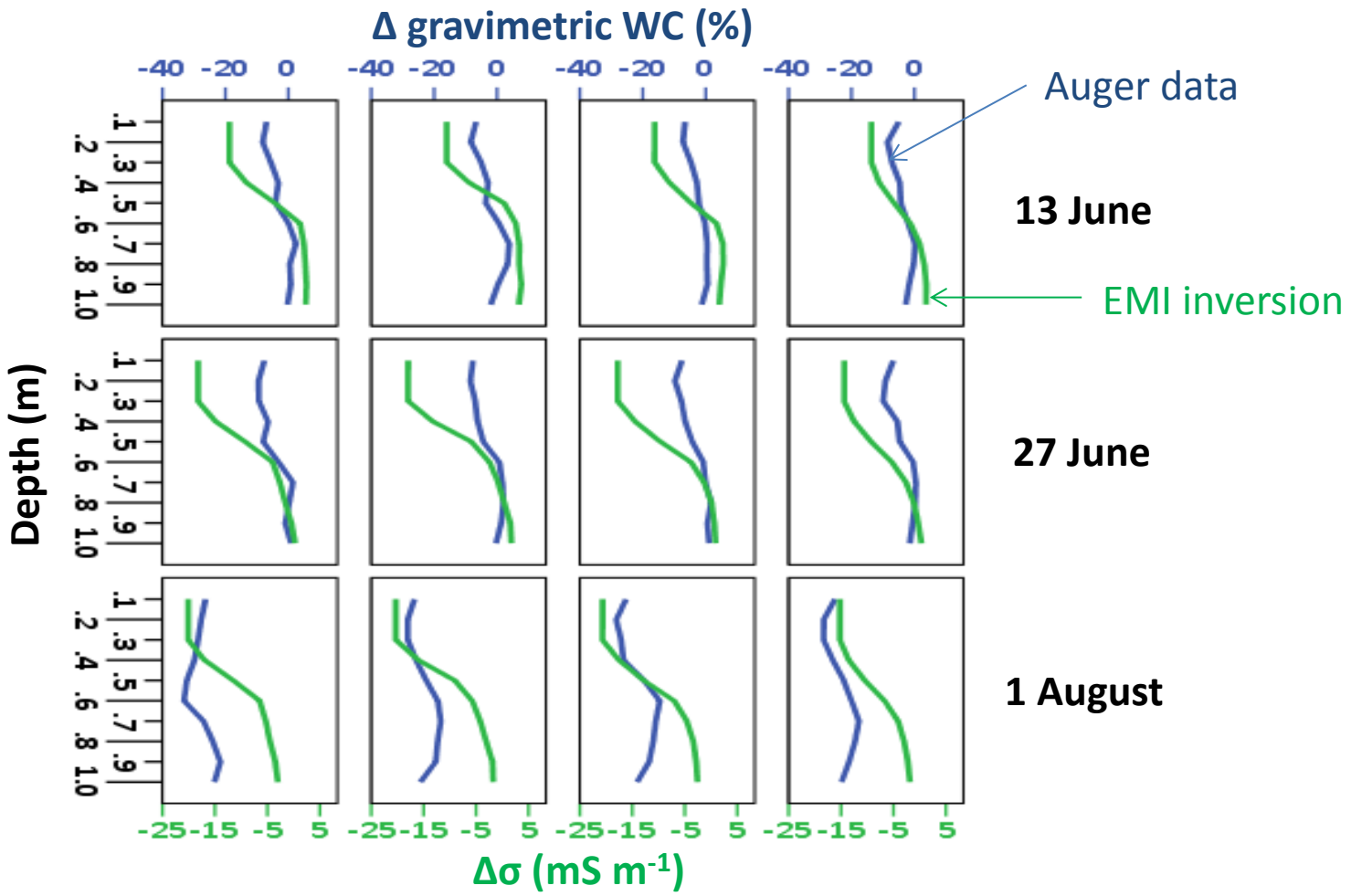

Conclusions

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- Inverted EMI field data reveals patterns of deceasing soil electrical conductivity with time similar to soil moisture profiles.
- EMI inversion results have uncertainty, but data are consistent for two sites and over 24 treatments.
- We can infer significant differences in soil drying depth between winter wheat varieties based on preliminary analysis.

Thank you

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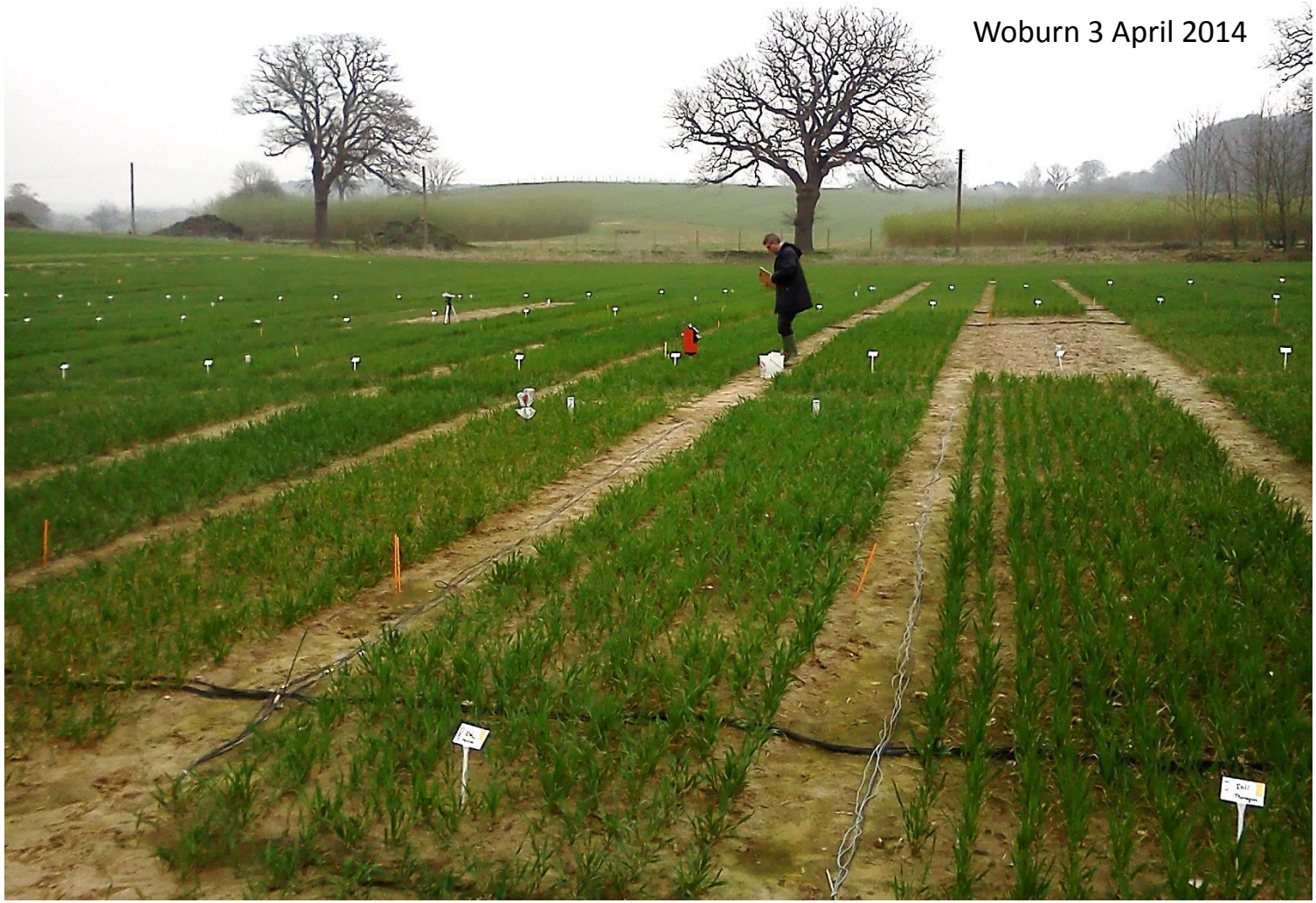

Woburn 3 April 2014