



Development of Electromagnetic Induction Measurement and Inversion Methods for Soil Electrical Conductivity Investigations

Xihe Tan

Information

Band / Volume 62

ISBN 978-3-95806-490-4

Forschungszentrum Jülich GmbH
Zentralinstitut für Engineering, Elektronik und Analytik (ZEA)
Systeme der Elektronik (ZEA-2)

Development of Electromagnetic Induction Measurement and Inversion Methods for Soil Electrical Conductivity Investigations

Xihe Tan

Schriften des Forschungszentrums Jülich
Reihe Information / Information

Band / Volume 62

ISSN 1866-1777

ISBN 978-3-95806-490-4

Contents

1	Introduction	1
1.1	Background	1
1.2	Electromagnetic Induction	2
1.3	Quantitative EMI Data	3
1.3.1	Temperature or Time Dependent Drifts	4
1.3.2	Constant Shifts	4
1.4	Objectives and Outline	5
2	Temperature Drift Correction	9
2.1	Electromagnetic Induction System	9
2.2	Circuit Design of the EMI System	12
2.3	Transfer Function Analyzer (TFA)	14
2.4	Temperature Drift Correction	17
2.5	Experimental Investigations	18
2.5.1	System Noise Measurement	18
2.5.2	Measurement Timeline	19
2.5.3	Experimental Verifications	20
2.5.4	Case Studies	22
2.6	Results and Discussion	23
2.6.1	Optimization of the System Noise	23
2.6.2	Initial Value for Calibration	24
2.6.3	Temperature Controlled Measurement	24
2.6.4	Temperature Drift Correction	26
2.6.5	Case Studies	27
2.7	Conclusions	30
3	Multi-elevation Calibration and Inversion Method (MECI)	33
3.1	Electromagnetic Induction Forward Modeling	33
3.2	Local Sensitivity for Different Tx-Rx Configurations and Elevations	36
3.3	Simultaneous Calibration and Inversion Algorithm	38
3.3.1	Shuffled Complex Evolution Method	39
3.3.2	Gauss-Newton Method	40
3.4	Determination of the Minimum Number of Elevations	40
3.5	Synthetic Data Simulation	43
3.5.1	Noise Free Model	43

3.5.2	Noisy Model	44
3.6	Experimental Data Verification	46
3.6.1	EMI Data Acquisition and Processing	46
3.6.2	Vertical Electrical Sounding (VES)	48
3.7	Results and Discussion	48
3.7.1	EMI Data Calibration	49
3.7.2	Two-layer Inversion of Uncalibrated and Calibrated EMI Data	54
3.8	Conclusion	56
4	Field Applications of MECI and Comparisons with Electrode-based Calibration Methods	59
4.1	EMI Instruments	59
4.2	Study Field	61
4.3	EMI Measurement Setup	62
4.4	Verification Data	63
4.4.1	Electrical Resistivity Tomography (ERT)	64
4.4.2	Vertical Electrical Sounding (VES) Measurements	67
4.5	MECI Data	68
4.6	Inverted Soil Model Comparisons between MECI and the Three Verification Methods at Two CPs	70
4.7	Calibration Results of the Three Verification Methods	72
4.8	Calibrated Data Comparisons between MECI and the Three Verification Methods	75
4.9	Inversion Results of the Transect	82
4.9.1	2-layer Inversion	82
4.10	3-layer Inversion	86
4.11	Conclusion	88
5	Conclusions and Outlook	91
5.1	Obtaining Temperature Independent Measurement Data	91
5.1.1	Temperature Drift Correction Method	92
5.1.2	Verifications	92
5.1.3	Highlights	93
5.2	Obtaining Quantitative EC _a Values without Using Additional Instruments	93
5.2.1	Multi-elevation Calibration and Inversion (MECI) Method	94
5.2.2	Synthetic and Experimental Verifications for a Hand-held EMI Instrument	94
5.2.3	MECI for Sled-based EMI Field Applications	95
5.2.4	Highlights	96
5.3	Outlook	97
Appendix A	Temperature Drifts of the Amplifier	99
Appendix B	Gauss-Newton Method	101
B.1	Methodology	101
B.2	Noise-free Model Simulation	103
B.3	Noisy Model Simulation	104
B.4	Experimental Investigations	105

Appendix C 3D Forward Modeling	107
List of Figures	115
List of Tables	118
Bibliography	

Information
Band / Volume 62
ISBN 978-3-95806-490-4

Mitglied der Helmholtz-Gemeinschaft

