

Contents

Acknowledgements	I
Abstract	III
Nomenclature	IX
List of Figures	XIII
List of Tables	XVII
List of Abbreviations	XIX
List of publications	XXIII
1 Introduction	1
1.1 Problem statement: The GeoFlow and AtmoFlow experiments	3
1.2 State of the art	9
1.2.1 Geophysical investigations	9
1.2.2 TEHD investigations	14
1.2.3 GeoFlow investigations	17
1.3 Objectives and outline	20
2 Methods	27
2.1 Origin of dielectrophoretic force and dielectric heating .	28
2.2 Equations of thermoelectric convection	37
2.3 Numerical model	38
2.3.1 Implementation of governing equations into numeric algorithm	39
2.3.2 Utilized solution algorithms	60

Contents

2.3.3	Implementation of fluid properties	62
2.3.4	Equations with applied fluid models	69
2.3.5	Geometries, numerical grids and boundary conditions	70
2.4	Numerical data post-processing	82
2.4.1	Data of interest	82
2.4.2	Dimensionless numbers	88
2.5	Validation and solver benchmark	113
2.5.1	Validation of temporal and spatial convergence	114
2.5.2	Validation of code implementation	121
2.5.3	Validation of implemented physics	125
2.6	GeoFlow and AtmoFlow post-processing	125
2.6.1	Run order and parameter space	126
2.6.2	Wollaston shearing interferometry	135
2.6.3	Averaged gradient fields	145
3	Results	149
3.1	TEHD in rectangular cavity	150
3.2	TEHD in cylindrical annuli	162
3.3	TEHD by dielectric heating in rect. cavity and cyl. annulus	173
3.4	TEHD induced by combined temperature gradient and dielectric heating	183
3.5	GeoFlow and AtmoFlow flow patterns and structures	198
3.5.1	GeoFlow experiment flow pattern classification	199
3.5.2	GeoFlow experiments linked to numerics	211
3.5.3	AtmoFlow numerical analysis	220
4	Discussion	233
4.1	Dimensionless numbers in TEHD and mantle convection	233
4.2	Mapping to other TEHD investigations	242
4.3	Mapping of TEHD with Rayleigh-Bénard convection	253
4.3.1	The impact of Gauss equation	258
4.3.2	Influence of $e\Delta T$	263
4.3.3	Boundary layers and scaling laws	269
4.4	Application to mantle dynamics investigations	273
5	Conclusion and outlook	281

A	Appendix	291
A.1	The electrostrictive force density	291
A.2	Scaling between geometries	295
A.3	OpenFOAM solver files	300
A.3.1	TEHDPimpleFoam.C	300
A.3.2	createFields.H	304
A.4	OpenFOAM case structure	309
A.4.1	electricProperties	309
A.4.2	fvSchemes	310
A.4.3	fvSolution	313
A.5	Double logarithmic plots	316
A.6	AtmoFlow numerical data	319
A.7	GeoFlow experiment and numerics flow structure	328
	References	355