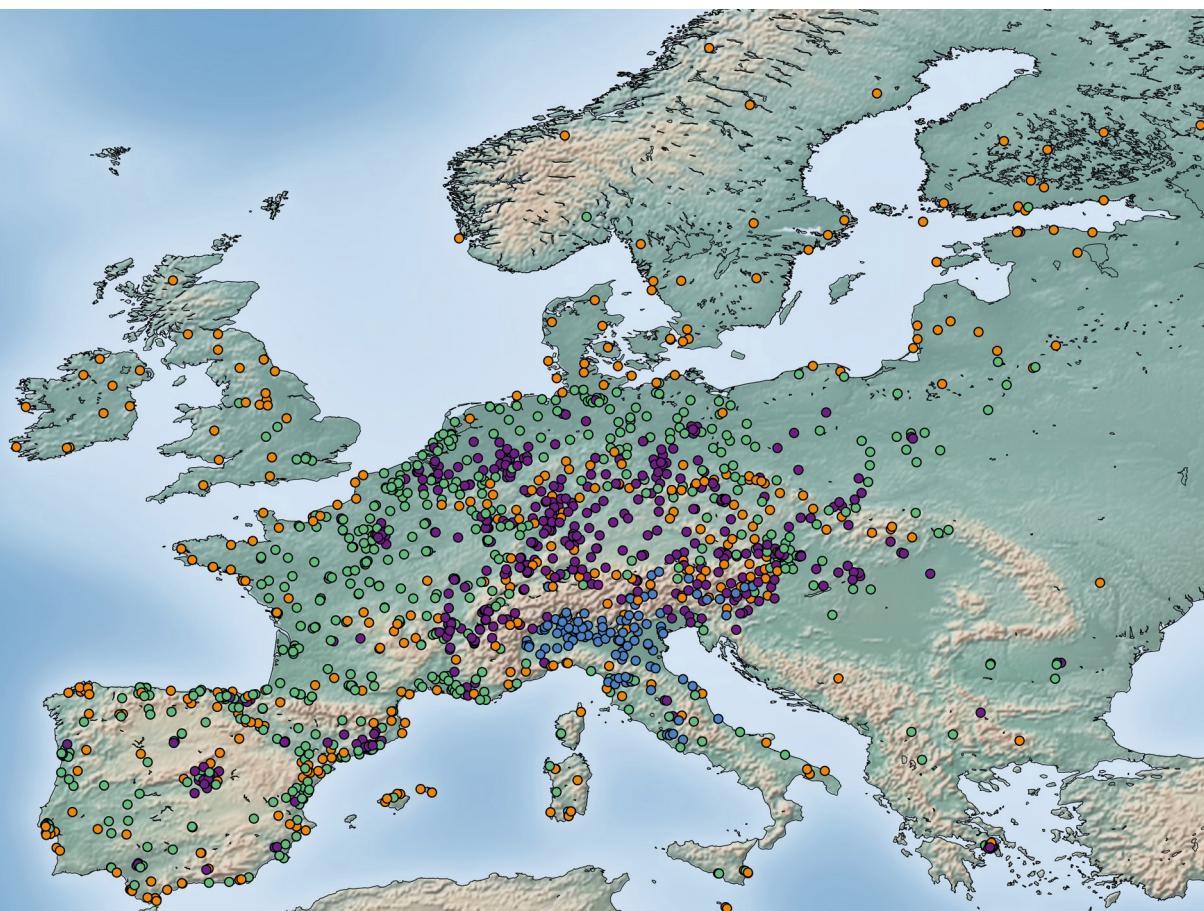


Cluster analysis of European surface ozone observations for evaluation of MACC reanalysis data

Olga Lyapina



Energie & Umwelt /
Energy & Environment
Band / Volume 265
ISBN 978-3-95806-060-9

 JÜLICH
FORSCHUNGSZENTRUM

Forschungszentrum Jülich GmbH
Institute of Energy and Climate Research
Troposphere (IEK-8)

Cluster analysis of European surface ozone observations for evaluation of MACC reanalysis data

Olga Lyapina

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 265

ISSN 1866-1793

ISBN 978-3-95806-060-9

Contents

1	Introduction	1
1.1	Tropospheric ozone.....	1
1.2	Historical ozone evolution and current situation	2
1.3	Motivation.....	5
1.3.1	Representativeness and stations categorization	5
1.3.2	Model evaluation	7
1.4	Objectives of present work	10
2	Theory	13
2.1	Air pollution control: policies	13
2.2	Tropospheric ozone budget.....	15
2.2.1	Ozone photo-chemistry	17
2.2.2	Stratosphere-troposphere exchange	25
2.2.3	Ozone dry deposition	26
2.3	Ozone measurement methods and instruments.....	27
2.3.1	Historical measurements.....	27
2.3.2	Recent measurement techniques	28
3	Data	33
3.1	Data for trend analysis	33
3.2	Data for cluster analysis.....	34
3.2.1	Data filtering	34
3.2.2	Properties for cluster analyses	37
3.3	MACC model data.....	40
3.4	Initial model-data comparison	40
4	Methodology	45
4.1	Trend statistics	45
4.1.1	Normal distribution.....	45
4.1.2	T-statistics	46
4.1.3	Linear regression statistics.....	46
4.2	Cluster Analysis.....	48
4.2.1	K-means	49
4.3	Earth Mover's Distance	52
4.4	Bootstrapping.....	53

5 Results and discussion.....	55
5.1 Trend analysis.....	55
5.1.1 Alpine stations (1990-2011)	55
5.1.2 German stations (1990-2011)	61
5.1.3 Selected European stations (1998-2011)	65
5.2 Cluster analysis.....	74
5.2.1 Geographical distribution and cluster allocation of stations.....	75
5.2.2 Comparison with the Airbase station classification scheme.....	80
5.2.3 Cluster representatives.....	82
5.2.4 Comparison of Airbase ozone data with MACC model results.....	89
5.2.5 Frequency distributions of ozone in clusters	92
5.2.6 Analysis of annual, diurnal, and weekly variations.....	97
5.2.7 Cluster Analysis with 7 clusters	107
5.2.8 Quality of cluster separation.....	112
5.2.9 Robustness of the cluster analyses.....	117
6 Summary and outlook.....	125
References	133
Appendix A	143
Appendix B.....	144
Appendix C.....	145
Appendix D	146
List of figures	183
List of tables	185
Abbreviations	186
Acknowledgements	187

**Energie & Umwelt /
Energy & Environment
Band / Volume 265
ISBN 978-3-95806-060-9**

