Module Name
Inverse Modelling (IM)

Type of Module	**Module Code**
Advanced Module	AM-IM

Identification Number	**Workload**	**Credit Points**	**Term**	**Offered Every**	**Start**	**Duration**
MN-GM-IM	180 Hours	6 CP	1. – 3. Semester	SuSe	Summer semester	1 Semester

1	**Course Types**	**Contact Time**	**Self-study times**	**Intended Group Size**
	a) Lecture	30 h	60 h	15 Students
	b) Exercise	30 h	60 h	

2 Aims of the module and acquired skills

Understanding inverse modelling methods for the determination of meteorological and geophysical parameters from measurements, gaining knowledge in major spatial-temporal data assimilation methods.

Acquired skills are the mathematical foundation of linear and non-linear inverse problems, formulation of inverse problems, assessment of statistical prerequisites and numerical complexity, assessment of inverse solutions, practical limitation of current assimilation methods, critical judgment of model simulations and capacity of model development.

3 Contents of the Module

- Basics: Inverse problems in geophysics and data assimilation in meteorology, overview of methods and definitions
- Deterministic approaches: linear problems, general formulation, least-squares method, normal equations, Jacobian matrix, generalised matrix inverse, adjoint and tangent-linear models, SVD decomposition, data and model gain matrices, data and model covariance matrices (data error and model assessment), nonlinear problems, Jacobian matrix, iterative conjugate gradient and Gauss- Newton methods, regularisation (Occam, Levenberg-Marquardt)
- Stochastic approaches, general formulation, Bayes theorem, optimal estimation, information content, error assessment
- data assimilation, optimum interpolation, 3d-var, Kalman filtering and 4d-var
- Applications: geoelectric and electromagnetic methods, gravity, magnetics, remote sensing of the atmosphere (humidity and temperature), weather forecasting

4 Teaching/Learning Methods

Lectures and tutorials (compulsory attendance in the tutorials)

5 Prerequisites for participation

Formal: None

Regarding content: Basics of mathematics and physics

6 Type of Examination

Written examination (graded)

7 Requisites for the allocation of credits

Successful participation in the tutorials (50 % of the possible points have to be obtained) and passing a final examination.

8	**Compatibility with other Curricula** N/A
9	**Proportion of Final Grade** 6/114
10	**Module Coordinator** B. Tezkan and H. Elbern
11	**Further Information** **Recommended Literature:** Aster, R.C., B. Borchers, C.H. Thurber, Parameter estimation and inverse problems, Elsevier, 2005. Benner, A. F., 2005. Inverse Modeling of the Ocean and Atmosphere. Cambridge University Press, ISBN: 9780521021579. Evensen, G., 2009. Data Assimilation: the Ensemble Kalman Filter. Springer, SBN 978-3-642-03711-5 Kalnay, E., 2003. Atmospheric Modelling, data assimilation and predictability, Cambridge Univ. Press, 342 pp. Meju, M.A., 1994. Geophysical data analysis: Understanding inverse problems, Theory and practice, Society of Exploration Geophysicists. Rodgers, C. D., 2000. Inverse methods for atmospheric sounding: Theory and practice. World Scientific, 238 pp. Menke, W., 2012. Geophysical Data Analysis: Discrete Inverse Theory – 3rd Ed., Elsevier. Oliver et al., 2008, Inverse Theory for Petroleum Reservoir Characterization and History Matching, Cambridge Univ. Press. Tarantola, A., 2005. Inverse Problem Theory and Methods for Model Parameter Estimation. SIAM. ISBN 978-0-89871-572-9.