COURSE OF DOCTORAL STUDIES

Course title	Field of science (branch) code	University / Faculty	Institute / Department
Remote sensing and data-driven modelling applications for hydrogeological studies	Natural Sciences (Geology) N 005	Vilnius University / Faculty of Chemistry and Geosciences	Institute of Geosciences / Department of Hydrogeology and Engineering Geology

Study methods	Number of credits allocated	Study methods	Number of credits allocated
Lectures	—	Seminars	—
Individual work	11	Consultations	As needed

Course annotation

Advanced research-oriented course integrating Earth observation, hydrogeological monitoring and reproducible data-driven modelling.

Part I — Principles and applications of Earth observation in hydrogeological and hydrological studies, including optical, thermal, radar and satellite gravimetry techniques. Acquisition and interpretation of satellite-derived environmental variables, including precipitation, evapotranspiration, soil moisture, land cover, terrain and lithology. Fundamentals of geographic information systems (GIS), spatial data structures, coordinate reference systems, raster and vector processing, spatial interpolation and geostatistics. Spatial and temporal resolution, measurement uncertainty, data quality and limitations of remote sensing observations. Integration of satellite observations, field measurements, geological information and climate reanalysis datasets. Data preprocessing, harmonization and analysis across different spatial and temporal scales. Applications to groundwater monitoring, water balance assessment, environmental change detection and regional hydrogeological characterization.

Part II — Fundamentals of statistical analysis, artificial intelligence and machine learning in hydrogeological research. Python-based data collection, preprocessing, exploratory data analysis, missing-value imputation, feature engineering and development of spatial and temporal predictors. Supervised regression and classification methods, including regularized models, random forests, gradient boosting and artificial neural networks. Introduction to unsupervised learning, clustering, dimensionality reduction, pattern recognition data augmentation and synthetic scenarios testing. Time-series analysis, decomposition, wavelet methods and forecasting of hydrogeological variables. Spatial prediction, mapping, satellite-data downscaling and integration of remote sensing with data-driven models. Model training, hyperparameter optimization, cross-validation, performance assessment, explainable artificial intelligence and uncertainty quantification. Spatial and temporal generalization, cross-regional transferability, data limitations and potential biases. Reproducible computational workflows and critical evaluation of machine-learning applications to groundwater dynamics, storage, quality and hydrogeological hazards.

Study methods and individual assignments

Guided independent study and hands-on Python/Google Colab notebooks from the open GRANDE-U Machine Learning in Hydrogeology course. Students prepare a reproducible notebook applying a suitable remote-sensing and ML workflow to hydrogeological data, documenting assumptions, validation, limitations and uncertainty.

Assessment

Examination: five open-ended questions followed by an academic discussion covering prepared study (in reproducible notebook).

Main study literature

1. Samalavičius, V., & Zaslavsky, I. (2026). Artificial intelligence in hydrogeology: applications and an open, reproducible machine learning course. Baltica, 39(1), 37–40. (Link) (Link 2) (Link 3)
2. Kilpys, J., Jukna, L., Stonevičius, E., Šimanauskienė, R., & Bevainis, L. (2020). *Žemės stebėjimai iš kosmoso.* Vilniaus universitetas. ISBN 978-609-07-0574-2.
3. Cardille, J. A., Crowley, M. A., Saah, D., & Clinton, N. E. (Eds.). (2023). *Cloud-Based Remote Sensing with Google Earth Engine: Fundamentals and Applications.* Springer. (Link)

Additional literature

1. scikit-learn developers. User Guide — supervised learning, cross-validation and evaluation. (Link)
2. Samalavičius, V., Solovey, T., Śliwińska-Bronowicz, J., Stradczuk, A., & Zaslavsky, I. (2026). Bias-aware machine learning spatial downscaling of GRACE signals: application to the Bug River Basin. Remote Sensing, 18(17), 2909. (Link)
3. Samalavičius, V. et al. (2026). Sinkhole risk forecasting in the Lithuania–Latvia Karst region using artificial intelligence. Journal of Hydrology: Regional Studies, 65, 103372. (Link)
4. Eslamifar, G. et al. (2026). Forecasting change in groundwater storage: a multilayer perceptron model leveraging system dynamics simulation data. Journal of Hydrology: Regional Studies, 65, 103398. (Link)

5. Samalavičius, V. et al. (2025). Oxygen-18 prediction using machine learning in the Baltic Artesian Basin groundwater. Stochastic Environmental Research and Risk Assessment, 39, 765–787. (Link)
Coordinating lecturer
Vytautas Samalavičius, Associate Professor, Vilnius University (coordinating lecturer).
Approval
Approved by the doctoral committee of Geology (N 005) on 19 October 2026 (5.2.2 E-15600-KT-3953)
Committee Chairman prof. dr. Sigitas Radzevičius