Conference

NovCare

Novel Methods for Subsurface Characterization and Monitoring: From Theory to Practice

International Conference

NovCare 2017

TU Dresden, Germany

June 06 – 09, 2017

TECHNISCHE UNIVERSITÄT DRESDEN

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

NovCare - Novel Methods for Subsurface Characterization and Monitoring: From Theory to Practice


NovCare 2011 – Cape Cod

After four successful conferences in 2009, 2011, 2013 and 2015 with over 130 participants, the **5th NovCare** Conference in 2017 will bring together environmental researchers and practitioners to discuss the latest developments in subsurface characterization and monitoring. Various topics on exploration and monitoring technologies, data assessment of natural and anthropogenic environmental impacts as well as data integration into numerical models to improve process understanding will be presented to this broad audience of scientists, consultants and decision makers.

Organizing Committee:

- **Technische Universität Dresden**: Rudolf Liedl, Falk Händel
- **UFZ-Helmholtz Centre for Environmental Research**: Peter Dietrich, Thomas Vienken
- **University of Tübingen**: Carsten Leven-Pfister
- **Kansas Geological Survey, University of Kansas:** James J. Butler, Jr., Geoffrey Bohling
- **Michigan State University:** David Hyndman
- **Centro Federal de Educação Tecnológica de Minas Gerais, Brazil:** Remke van Dam
- **Colorado School of Mines**: Kamini Singha
- **University of Waterloo:** Dave Rudolph

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Prof. Dr. Peter Dietrich (UFZ Leipzig),
Dr. James J. Butler Jr. (KGS – University of Kansas)
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HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ
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Welcome and Greetings

Rudolf Liedl

Professor and Head of the Institute for Groundwater Management, TU Dresden

Peter Dietrich

Professor for Environmental and Engineering Geophysics at the Eberhard-Karls-University of Tübingen and Head of the UFZ-Department Monitoring and Exploration Technologies

Falk Händel

Institute for Groundwater Management, TU Dresden

Uta Sauer

Department Monitoring and Exploration Technologies, UFZ-Helmholtz Centre for Environmental Research

It is a great honour for us to welcome you to the International Conference NovCare 2017. The NovCare 2017 takes place at the Technische Universität Dresden in Germany. Dresden is a beautiful city on the river Elbe with buildings from the Renaissance, the Baroque and the 19th century and a must-visit city in Germany. We are pleased to organize this NovCare Conference for the fifth time by trying to make every new conference better than the previous one.

NovCare 2017 again provides a rare opportunity and an outstanding platform for researchers and practitioners from all over the world to exchange their ideas and experiences on dealing with challenges of subsurface characterization and monitoring. Various topics on exploration and monitoring technologies, data assessment of natural and anthropogenic environmental impacts as well as data integration into numerical models to improve process understanding will be presented to a broad audience of scientists, consultants and decision makers. The conference participants will also enjoy eight Keynote Lectures delivered by well-known scientists in this field worldwide, namely Kamini Singha (Colorado School of Mines) - 2017 Darcy Lecturer, Albert Valocchi (University of Illinois), Johann Fank (JR-AquaConSol), Lee Slater (Rutgers University), James Butler (Kansas Geological Survey), Henning Prommer (CSIRO / University of Western Australia), Uwe Meinberg (Brandenburgische Technische Universität Cottbus-Senftenberg) and Gudrun Massmann (Carl von Ossietzky University of Oldenburg).

We wish all participants of NovCare 2017 stimulating conference days in Dresden, interesting discussions and new inspirations.

James J. Butler, Jr.

Senior Scientist and Section Chief, Geohydrology Section, Kansas Geological Survey, The University of Kansas

David W. Hyndman

Professor and Chair Michigan State University, Dept. of Geological Sciences

Thomas Vienken

Head Working Group Direct Push and hydrogeological measurement methods at UFZ-Department Monitoring and Exploration Technologies

David L. Rudolph

University of Waterloo, Groundwater Research, 2013 Henry Darcy Distinguished Lecturer

Remke van Dam

Centro Federal de Educação Tecnológica de Minas Gerais, Brazil

Geoffrey Bohling

Kansas Geological Survey, University of Kansas

Carsten Leven-Pfister

University of Tübingen Center for Applied Geoscience, Hydrogeology

Kamini Singha

Colorado School of Mines, 2017 Henry Darcy Distinguished Lecturer

The organizing committee would like to welcome you to Dresden and the NovCare 2017 Conference. This conference series, which began in Leipzig in 2009, then moved to Cape Cod in the United States in 2011, came back to Leipzig in 2013, and was held in Kansas in 2015 has proven to be an excellent forum for exchanging ideas and experiences regarding the challenges of subsurface characterization and monitoring.
NovCare 2017 will build on the successes of the previous conferences and provide attendees an opportunity to learn about novel approaches including a glimpse of topics still in development. We encourage you to use the discussion time and social activities to interact with your fellow attendees and our exhibitors to get the most out of the experience.

Once again, welcome to Dresden and NovCare 2017!

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

TECHNISCHE UNIVERSITÄT DRESDEN

KU KANSAS GEOLOGICAL SURVEY The University of Kansas

Agenda / June 6, 2017

6:00 pm - 9:00 pm	*Welcome Reception and Icebreaker Event*

June 7, 2017

9:00 am - 9:30 am	***Welcome address***	
	Liedl, Rudolf (TU Dresden) & Dietrich, Peter (UFZ-Helmholtz Centre for Environmental Research)	
	Butler, James J. Jr. (Kansas Geological Survey)	
9:30 am - 10:00 am	**Exhibitor Presentations**	
10:00 am - 10:40 am ***Keynote***	**K1) Combining Physically-Based and Data-Driven Models to Improve Forecasts of Groundwater Flow** *(Valocchi, Albert; Xu, Tianfang)*	
10:40 am - 11:00 am	*Coffee break, Company Exhibition, Poster presentation*	
11:00 am - 12:20 pm	***Session 1: Flow and transport in the saturated and unsaturated zone***	***Session 2: Geotechnical site characterization***
11:00 am - 11:20 am	Spatial-temporal dynamics of perched aquifer systems in Barrier Island: Application of geophysical methods *(Alam, A T M Jahangir; Hofmann, Harald; Gross, Lutz; Bore, Thierry)*	Multi-source geo-spatial information framework for subsur-face stratification using geophysical tomography, borehole and geological map *(Kim, Han-Saem; Sun, Chang-Guk)*
11:20 am - 11:40 am	Integrated passive flux measurements in groundwater: introduction of the iFLUX sampler *(Verreydt, Goedele; Meesters, Filip; Op't Eyndt, Tim; Van Keer, Ilse; Bronders, Jan; Meire, Patrick)*	Geotechnical characterization of seismic monitoring stations according to site response parameters determined from combined in-situ investigations in Korea *(Sun, Chang-Guk; Cho, Hyung-Ik; Kim, Han-Saem)*
11:40 am - 12:00 noon	Characterizing an unsaturated hydraulics of infiltrated water in unsaturated zone based on moving-windows cross-correlation analysis *(Jeong, Jina; Park, Eungyu)*	The full-automatic recognition of structure plane parameters in borehole image from deep-hole engineering *(Wang, Chuanying; Zou, Xianjian; Han, Zengqiang)*
12:00 noon - 12:20 pm	Statistical analysis of long term groundwater monitoring data and its relation to flow path and aquifer response time, Brighton Block, SE England *(Al-Jaf, Peshawa; Smith, Martin; Gunzel, Friederike)*	Monitoring of resistivity and moisture dynamics in an opera-tional railway cutting *(Uhlemann, Sebastian; Chambers, Jonathan; Meldrum, Philip; Wilkinson, Paul; Swift, Russell; Gunn, David; Dijkstra, Tom; Hutchinson, David)*
12:20 pm - 1:00 pm ***Keynote***	**K2) Monitoring by Drones – Expectations and Limitations** *(Meinberg, Uwe)*	
1:00 pm - 1:50 pm	*Lunch break, Company Exhibition, Poster Presentation*	
1:50 pm - 2:30 pm ***Keynote***	**K3) Challenges and Opportunities of Urban Water Cycles – An example from Berlin** *(Massmann, Gudrun)*	
2:35 pm - 3:55 pm	***Session 3: Flow and transport in the saturated and unsaturated zone/New tools for watershed characterization***	***Session 4: Thermal use of the shallow subsurface***
2:35 pm - 2:55 pm	Transfer of parameter determination from the laboratory to the field *(Dost, Philipp; Hellmann, Kerstin; Nitsche, Claus)*	Thermal Process Understanding: Requirements for Monitoring Systems *(Epting, Jannis; Müller, Matthias H.; Huggenberger, Peter)*
2:55 pm - 3:15 pm	Prediction of Solute Transport and Heat Transfer Processes in Groundwater for adequate Knowledge Levels and Data Inventory *(Beyer, Matthias; Albert, Theresa; Sieland, Madeleine; Dost, Philipp)*	Soil thermal behavior in different moisture condition: an overview of ITER Project from laboratory to field test monitoring *(Di Sipio, Eloisa; Bertermann, David)*
3:15 pm - 3:35 pm	Visualizing and analyzing large hydrological datasets with correlation matrices *(Haas, Johannes Christoph; Birk, Steffen)*	Visual measurement and model reconstruction for the shallow structure of underwater topography and rock mass by using B-mode ultrasonic imaging device *(Zou, Xianjian; Wang, Chuanying; Han, Zengqiang)*
3:35 pm - 3:55 pm	Water induced soil erosion assessment and monitoring in the South High Atlas of Marrakech using remote sensing and GIS *(Ourzif, Zouhair; Algouti, Ahmed; Algouti, Abdellah)*	European Project "Cheap-GSHPs" – Installation and monitoring of new designed helicoil ground source heat exchanger on the German test site *(Bertermann, David; Bernardi, Adriana; Pockelé, Luc; Galgaro, Antonio; Cultrera, Matteo; de Carli, Michele; Müller, Johannes)*
3:55 pm - 4:15 pm	*Coffee break, Company Exhibition, Poster Presentations*	
4:15 pm - 5:00 pm ***Open Lecture***	**Darcy Lecture 2017: A Tale of Two Porosities: Exploring Why Contaminant Transport Doesn't Always Behave the Way It Should** *(Singha, Kamini)*	
5:00 pm - 6:00 pm	*Company Exhibition, Poster presentations*	
8:00 pm	***Conference Dinner***	

June 8, 2017

8:30 am - 9:10 am ***Keynote***	**K4) Modelling of groundwater flow and solute transport at the groundwater body scale – concepts and solutions to shallow valley aquifers** *(Fank, Johann)*	
9:15 am - 10:35 am	***Session 5: Long Term Monitoring***	***Session 6: Hydrological, hydrochemical and hydrogeological investigation techniques and Characterization at the interface***
9:15 am - 9:35 am	New tool for authentic groundwater sampling and monitoring and a VOC case study *(Berthold, Susann; Seifert, Eckhardt)*	The application of geoelectrical methods for understanding the Punata aquifer (Bolivia) *(Gonzales Amaya, Andres)*
9:35 am - 9:55 am	A novel approach to online-biotoxicity monitoring of groundwater (*Hoffmann, Anna)*	Solute Tracer Tomography: Field Proof-of-Concept for Aquifer Characterization *(Sánchez-León, Emilio; Leven, Carsten; Cirpka, Olaf)*
9:55 am - 10:15 am	A practical, robust method for sampling design using groundwater models with large computational requirements *(Siade, Adam J.)*	Depth dependent groundwater sampling during regular well operation for RBF flow model calibration (*Paufler, Sebastian; Grischek, Thomas; Fischer, T.*)
10:15 am - 10:35 am	Standardization of groundwater sampling for microbiological investigations *(Gasch, Carina; Kurzius, Florian; Hildebrandt, Ina; Nitsche, Claus)*	Combining geophysical and tracer methods on multiple scales to assess the hydraulic connection between lake and aquifer *(Sebok, Eva; Karan, Sachin; Engesgaard, Peter; Nielsen, Ole Frits)*
10:35 am - 11:15 am	*Coffee break, Company Exhibition, Poster presentation*	
11:15 am - 11:55 am ***Keynote***	**K5) Advancing geophysical characterization of contaminated fractured rock aquifers: sensing flow and transport properties beyond the borehole wall** *(Slater, Lee; Robinson, Judy)*	
11:55 am - 12:35 pm	***Session 7: Near-surface and borehole geophysics***	***Session 8: Characterization at the Interface***
11:55 am - 12:15 pm	Geotechnical properties from geophysical data: Estimating uncertainties related to data inversion and petrophysical relations *(Tronicke, Jens; Paasche, Hendrik)*	Validation of a New Device to Quantify Groundwater-Surface Water Exchange *(Cremeans, Mackenzie M.; Devlin, John F.)*
12:15 pm - 12:35 pm	Advancement of field exploration methods for non-liquid pollutant phases: Impulse-Neutron-Neutron-Method (INN) and Radon Method *(Kurzius, Florian; Buckup, Philipp; Hüsers, Norbert; Nitsche, Claus*)	An Assessment of Alluvium Aquifer Characterization and Subsurface Mapping to Detect Fresh and saline water aquifers in Karak Valley, Khyber Pakhtunkhwa, Pakistan *(Khalid, Perveiz.; Ullah, Saif; Farid, Asam)*
12:35 pm - 1:25 pm	*Lunch break, Company Exhibition, Poster presentation*	
1:30 pm - 4:30 pm	**Field demonstration**	
7:00 pm - 10:00 pm	*Social Event - Elbe river cruise (Fee: 40 €. Registration is required.)*	

June 9, 2017

9:00 pm - 9:40 pm ***Keynote***	**K6) New Approaches for Assessment of Aquifers Supporting Irrigated Agriculture over a Range of Temporal and Spatial Scales** *(Butler, James J. Jr.; Whittemore, Donald O.; Wilson, Blake B.)*	
9:45 pm - 10:45 pm	***Session 9: DP Applications***	***Session 10: High resolution characterization I***
9:45 pm - 10:05 pm	Evaluating Hydrostratigraphy and Water Quality with the HPT-GWS System *(McCall,Wesley; Christy, Thomas M.; Knabach Evald, Mateus)*	Utilization of discrete conduit-continuum models to screen controlling parameters on hydrodynamic behavior of karst aquifers *(Kavousi, Alireza; Reimann, Thomas; Birk, Steffen; Liedl, Rudolf; Raeisi, Ezzat)*
10:05 pm - 10:25 pm	Direct push injection logging for high resolution characterization of low permeability zones *(Liu, Gaisheng; Knobbe, Steven; Butler, James J. Jr.; Reboulet, Edward C.; Borden, Robert; Bohling, Geoffrey)*	From high-resolution field data to robust model parameterization *(Guthke, Anneli)*
10:25 pm - 10:45 pm	Application of the Optical Image Profiler (OIP) to Characterize the Grimm Oil Site: Kalona, Iowa (USA) *(Christy, Thomas M.; McCall, Wesley; Goodrich, James; White, Jeffrey)*	Delineation of contamination zone using geophysical and hydrogeochemical methods around El Moheet Drain, El Minia District, Upper Egypt *(Abou Heleika, Mohamed M; Ismail, E.)*
10:45 am - 11:15 am	*Coffee break, Company Exhibition, Poster presentation*	
11:15 am - 11:55 am ***Keynote***	**K7) Groundwater replenishment in Perth, Western Australia: Modelling framework and supporting site characterisation efforts** *(Prommer, Henning; Seibert, Simone; Siade, Adam; Descourvieres, Carlos; Atteia, Olivier; Higginson, Simon)*	
12:00 noon - 1:00 pm	***Session 11: Special Investigation Techniques***	***Session 12: High resolution characterization II***
12:00 noon - 12:20 pm	Radiation anomalies mapping using UAV mini-airborne gamma-ray spectrometry *(Salek, Ondrej; Matolin, Milan)*	InSAR ground motion studies in water management *(Velasco,Violeta; Couso ,Carles)*
12:20 pm - 12:40 pm	High-Resolution Investigation Using Laser-Induced Fluorescence (LIF): Examples of Hydrocarbon-Contaminated Sites in Brazil *(Chang, Hung K.; Isler, Elias; Pede, Marco A.Z.; Teramoto, Elias H.; Oliva, Andresa; Baessa, Marcus P.M.)*	Development of a direct-push technique for localisation of iron-rich groundwater entering small streams in Lusatia *(Musche, Fabian; Paufler, Sebastian; Grischek, Thomas)*
12:40 pm - 1:00 pm	High resolution characterization of pore space, fluids and connectivity by innovative (Cryo-/LMI) BIB-SEM imaging methods *(Klaver, Jop; Schmatz, Joyce; Jiang, Mingze; Süß, Moritz; Urai, Janos L.)*	Development of an In-well Point Velocity Probe for the Rapid Characterization of Groundwater Velocity at the Centimeter-scale *(Osorno, Trevor C.; Devlin, John F.)*
1:00 pm - 1:40 pm	*Lunch break, Company Exhibition, Poster presentation*	
1:40 pm - 2:40 pm	***Session 13: High resolution characterization III***	***Session 14: Discussion Session in German***
1:40 pm - 2:00 pm	Recent achievements in high resolution characterization of aquifers using crosshole GPR full-waveform inversion *(Klotzsche, Anja; Gueting, Nils; Vienken, Thomas; Vanderborght, Jan; Englert, Andreas; Vereecken, Harry; van der Kruk, Jan)*	Initiating talks about the interplay between decision makers and consultants by Dr.-Ing. Peter Börke (Head of division "Urban Water Management, Groundwater" at Saxon State Office for Environment, Agriculture and Geology) and Dr. Claus Nitsche (Exec. Director of BGD ECOSAX company)
2:00 pm - 2:20 pm	An integrated methodology for hydrogeological assessment of nuclear plant aquifers *(Blouin, Martin; Gloaguen, Erwan; Paradis, Daniel; Krimissa, Mohamed; Couegnas, Cécile; Ballard, Jean-Marc; Lefebvre, René)*	Discussion rounds with interest groups
2:20 pm - 2:40 pm	The development of a new measuring tool for an efficient planning of very shallow geothermal systems *(Bertermann, David; Kübert, Markus; Walker-Hertkorn, Simone; Schmidt, David; Schwarz, Hans)*	Discussion rounds with interest groups
2:40 pm - 3:00 pm	**Closing remarks Liedl & Dietrich & Butler**	

Poster Presentations

No.	Poster title
P1	Development of a CPT-based seismic tomographic system for geotechnical subsurface investigation and site assessment. *(Sauer, U.; Mackens,S.; Dietrich, P.; Fechner,T.)*
P2	Direct push sensing in wetland (geo)archaeology *(Völlmer, J.; Hausmann, J.; Werban, U.; Dietrich, P.; Berg-Hobohm, S.; Werther, L.; Zielhofer, C.)*
P3	A shallow water table fluctuation model in response to precipitation with consideration of unsaturated gravitational flow *(Park, E.; Jeong, J.)*
P4	Innovative site characterization of an active sinkhole area using Direct Push technology *(Tippelt, T.; Vienken,T.; Kirsch, R.; Dietrich, P.; Werban, U.)*
P5	Assessment of aquifer connectivity using oscillatory hydraulic aquifer tests *(Zschornack, L.; Kalbacher, T.; Dietrich, P.)*
P6	Assessing the functionality of groundwater observation wells on regular water quality measurements *(Jäkel, L.; Händel, F.; Krieg, R.; Börke, P.)*
P7	Integration of geophysical tomograms and direct-push logging data for probabilistic prediction of spatially continuous hydrologic parameter distributions *(Paasche, H.; Asadi, A.; Dietrich, P.)*
P8	Temperature observation within the grouting of Borehole-Heat-Exchangers (BHE) by Raman-spectre based distributed temperature sensing (DTS) *(Seibertz, K.S.O.; Kreck, M.; Bucher, A.; Görke, U.; Dietrich, P.; Vienken, T.)*
P9	Data acquisition system for horizontal filter wells *(Lay, M.; Berthold, S.; Reimann, P.; Daffner, T.; Huber, M.; Börner, F.)*
P10	Development of methods for monitoring and prediction of transient seepage flow in levees and dams *(Lewis, R.; Hoffmann, U.; Engel, J.; Kammel, E.; Weller; Möller, M.)*
P11	Realization of a single borehole tracer test with both deuterium (2H) and oxygen-18 (18O) by direct injection of melted snow into an aquifer in Pirna, Saxony, Germany *(Binder, M.; Tritschler, F.; Händel, F.; Burghardt, D.)*
P12	Quantitative groundwater monitoring: A novel membrane extraction probe for the application with direct push technologies *(Mayer, T.; Sauer, U.; Würpel, W.; Kotas, H.; Schoßland, A.; Borsdorf, H.)*
P13	Demonstrating the advantages of innovative subsurface exploration strategies for sustainable managed aquifer recharge operation *(Vienken,T.; Kreck, M.; Pohle, M.; Tippelt,T.; Cisotto, A.; Ferri, M.; Dietrich, P.; Werban, U.)*
P14	Assessment of denitrification and mixing patterns in an alluvial aquifer by chemical and isotope data *(Utom, A.U.; Werban, U.; Dietrich, P.)*
P15	Development of a mobile measurement device for the in-situ determination of hydraulic conductivity of water body bed deposits using slug and bail testing – first results of laboratory testing *(Kalwa, F.; Kreck, M.; Schneidewind, U.; Dietrich, P.; Vienken, T.)*
P16	Computation of thermodynamic properties of the earth's lower mantle using selected earth models *(Popoola, O.I.; Awe, O.E.; Ogunseye, T.T.)*
P17	"GST-SimuTool" - simulation software for "GST" gradiometry technology. *(Lytkin, I.)*

Detailed Program

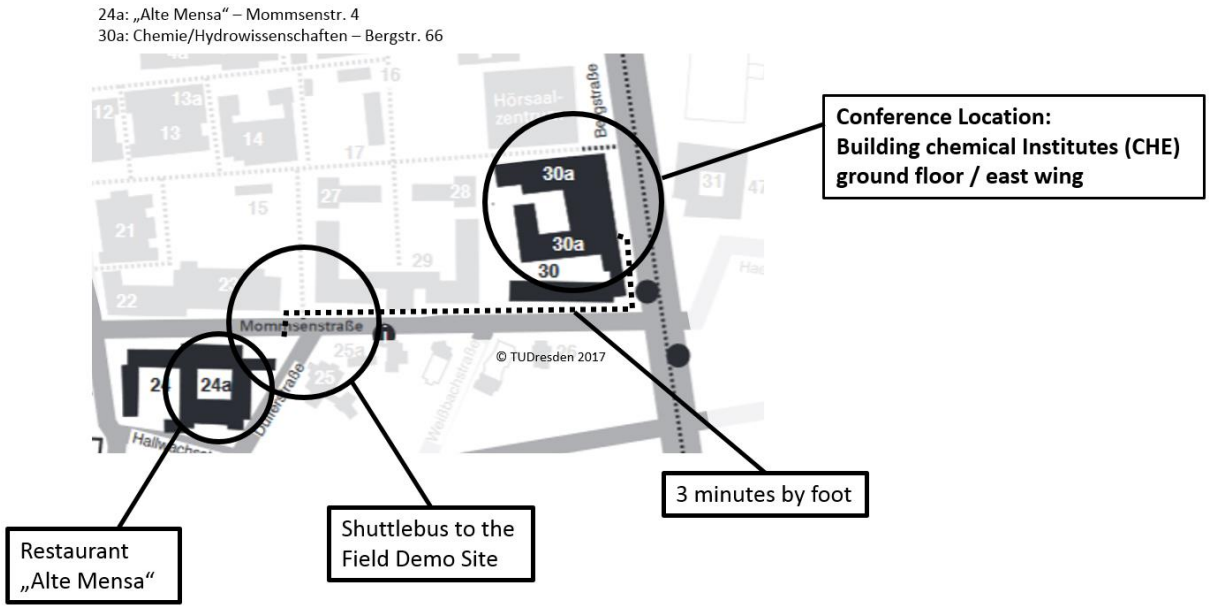
Company Exhibition

June 7	9:30 am - 8:00 pm	(Foyer)
June 8	9:00 am - 6:30 pm	(Foyer)
June 9	9:00 am - 12:00 noon	(Foyer)

Technology Demonstration and Exhibition of larger machinery

June 8 1:30 pm - 4:30 pm

A Shuttle bus to the field site is departing in front of the Restaurant "Alte Mensa" at 1:30 pm and 2:45 pm and is heading back to the inner city and conference venue no later than 4:30 pm.



The address of the field site is: Radeburger Strasse 30, Dresden

Poster Session

June 7	5:00 pm - 6:00 pm and during breaks	(Foyer)
June 8	during breaks	(Foyer)
June 9	during breaks	(Foyer)

Keynote Talks

K1	June 7 10:00 am - 10:40 am	Albert J Valocchi	**Combining Physically-Based and Data-Driven Models to Improve Forecasts of Groundwater Flow**
K2	June 7 12:20 pm - 1:00 pm	Uwe Meinberg	**Monitoring by Drones – Expectations and Limitations**
K3	June 7 1:50 pm - 2:30 pm	Gudrun Massmann	**Challenges and Opportunities of Urban Water Cycles – An example from Berlin**
K4	June 8 8:30 am - 9:10 am	Johann Fank	**Modelling of groundwater flow and solute transport at the groundwater body scale – concepts and solutions to shallow valley aquifers**
K5	June 8 11:15 am – 11:55 am	Lee Slater	**Advancing geophysical characterization of contaminated fractured rock aquifers: sensing flow and transport properties beyond the borehole wall.**
K6	June 9 9:00 am – 9:40 am	James J. Butler Jr.	**New Approaches for Assessment of Aquifers Supporting Irrigated Agriculture over a Range of Temporal and Spatial Scales**
K7	June 9 11:15 am – 11:55 am	Henning Prommer	**Groundwater replenishment in Perth, Western Australia: Modelling framework and supporting site characterisation efforts**
Darcy Lecturer 2017	June 7 4:15 pm – 5:00 pm	Kamini Singha	**A Tale of Two Porosities: Exploring Why Contaminant Transport Doesn't Always Behave the Way It Should**

Keynote Speakers – 7th June

K1) Albert J Valocchi
University of Illinois; Department of Civil and Environmental Engineering

Combining Physically-Based and Data-Driven Models to Improve Forecasts of Groundwater Flow

(Albert J. Valocchi; Tianfang Xu)

Date: June 7
Time: 10:00 am - 10:40 am

Physically-based numerical groundwater models (PBMs) are powerful quantitative tools to manage scarce groundwater resources and assess risk of subsurface contamination. As these models are being used to inform decisions and policies with major social, political and economic impact, it is critically important to improve the accuracy of these model and quantify their intrinsic uncertainties. Groundwater models suffer from uncertainty associated with errors in model structure, parameter values, input data and measurements. However, current state-of-the-art does not properly treat model structural error, which is ubiquitous in groundwater models, for example due to improper interpretation of geological structure and simplified conceptualizations of flow and contaminant transport processes. Current practice is to develop a single groundwater model, and use field data as targets for calibrating parameter values. However, when calibrating an imperfect model, parameters may be over-adjusted to compensate for model structural error. This can lead to biased model forecasts for scenarios different from historical conditions reflected by calibration data.

We present two data-driven frameworks to reduce the detrimental effects of model structural error on model forecasts. The post-processor (also called the "complementary modeling") framework constructs error models using machine learning techniques to correct for bias of an existing calibrated model. The error-explicit Bayesian framework jointly estimates model structural error (described using nonparametric kernel methods) with the physically-based model parameters. We demonstrate the performance of these frameworks for several real-world large-scale regional flow models. The data-driven framework brings together the strength of physically-based groundwater models and inductive data-driven statistical learning techniques, and is in harmony with new trends toward increased data availability and promotion of hydrologic observatories.

Albert J. Valocchi is the Abel Bliss Professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign. He has been on the faculty at Illinois since 1981. Dr. Valocchi teaches undergraduate and graduate courses in water resources engineering, groundwater hydrology and contaminant transport, groundwater modeling, and computational methods. His research focuses on computational modeling of pollutant fate and transport in porous media, with applications to groundwater resources sustainability, groundwater contamination, geological sequestration of carbon dioxide, and impacts of model uncertainty on groundwater resources management. He received his B.S. in Environmental Systems Engineering from Cornell University in 1975 and did his graduate studies at Stanford University in the Department of Civil Engineering, receiving his M.S. in 1976 and Ph.D. in 1981. In 2009 he was recognized as Fellow of the American Geophysical Union.

K2) Uwe Meinberg

BTU Cottbus-Senftenberg

Monitoring by Drones – Expectations and Limitations

(Meinberg, Uwe)

Date: June 7
Time: 12:20 pm - 1:00 pm

The civil use of drones is one of nowadays hype-topics. Unmanned Aerial Systems are being expected to revolutionise a lot of business cases in respect to efficiency or even in respect to solve problems, never solved before. Monitoring is one of the most popular use cases, propagated by service providers as well professionalised. After having a closer look at the current abilities of drones and moreover at the business processes, these platforms will be used in, disillusion is a pretty often result.
The presentation opposes expectations to limitations showing present developments for drones and subsystems.

Prof. Dr.-Ing. Uwe Meinberg, Head of Chair "Industrial Information Systems" at the Brandenburg University of Technology and managing partner of a consulting company, is active more than 30 years in the range of "logistics and IT" and can experience from about 400 dedicated projects, including 2014 Winter Olympic Games. Out of one of these projects, which dealt with the security in critical infrastructures (airports), the intensive study of unmanned aerial systems has evolved in the context of logistics and other application scenarios since of 2009. Currently, the topics "Mission Planning", "Mission Evaluation (Big Data)" and thus - directly connected "Exact/Precise Flights and Landings" are subject of industrial and research-oriented projects. Recently the competence centre "CURPAS (Civil Use of Remotely Piloted Aircraft Systems)" under the direction of Prof. Meinberg was established in the capital region. CURPAS is co-financed by the state of Brandenburg.

K3) Gudrun Massmann

Universität Oldenburg, Hydrology and landscape hydrology

Challenges and Opportunities of Urban Water Cycles – An example from Berlin

(Massmann, Gudrun)

Date: June 7
Time: 1:50 pm - 2:30 pm

Urban aquifers are often under pressure, as they may be subject to groundwater contamination or excessive use, either for drinking water or, for example, for geothermal purposes. Hence, urban areas are in the focus of the conflict between water use and protection. The water budget including groundwater recharge above all, can be strongly affected by human activities such as underground infrastructure or surface sealing. Human activities also directly or indirectly cause pollution of urban water resources, for example with organic trace contaminants such as pharmaceuticals or personal care products originating from wastewater. Leaking pipes can be point sources for treated or raw sewage. If drinking water is abstracted via managed aquifer recharge (MAR) such as induced bank filtration while wastewater is discharged into the surface water, a semi-closed water cycle exists. In such cases persistent trace pollutants originating from wastewater are merely diluted within this cycle by mixing with surface water or ambient groundwater. Under worst case conditions, some compounds may even reach abstraction wells. MAR, however, also holds the potential to satisfy the drinking water needs of urban populations and, if managed properly, has many benefits even in urban areas. It can act as an efficient pre-treatment for drinking water production. The talk aims at highlighting some of the current challenges and likewise opportunities related to urban groundwater, in particular with regard to the fate of organic trace pollutants, using the city of Berlin as an example.

Prof. Dr. Gudrun Massmann is professor at the Institute for Biology and Environmental Sciences at the Carl von Ossietzky University Oldenburg. She is head of the research group on Hydrogeology & Landscape Hydrology, which was founded in 2010. The research interests of the group include the fate of emerging organic contaminants in groundwater, managed aquifer recharge, surface water- groundwater interaction, coastal hydrogeology and geoecology. The research group aims at getting a comprehensive and better understanding on pollutant behavior in groundwater, taking into account hydrogeological, hydraulic and hydrochemical aquifer conditions. The group follows and integrative approach, conducting field work, hydrochemical analysis and laboratory experiments accompanied by modeling. Gudrun Massmann has started working on urban groundwater in the years she spent as a research assistant at the Free University of Berlin and has since been involved in several projects related to the urban water cycle of Berlin. Presently, the group is participating in a BMBF funded project named TrinkWave, which aims at developing operation strategies and technologies for water reuse to support drinking water supply in urban areas.

Keynote Speakers – 8th June

K4) Johann Fank
JR-AquaConSol GmbH

Modelling of groundwater flow and solute transport at the groundwater body scale – concepts and solutions to shallow valley aquifers.

(Fank, Johann)

Date: June 8
Time: 8:30 am – 9:10 am

The Water Framework Directive states that water has to be managed at the scale of a "groundwater body" as the basic unit for groundwater management. Modelling tools simulating groundwater processes at the groundwater body scale can be used to improve the understanding of the functioning of groundwater systems and for predictions about the state of the system under defined pressures. Groundwater models are used (1) as interpretative tools for investigating groundwater system dynamics; (2) as simulation tools for analyzing responses of the groundwater system to stresses; (3) as assessment tools for evaluating recharge, discharge and aquifer storage processes, and for quantifying sustainable yield; (4) as predictive tools for predicting future conditions or impacts of human activities; (5) as supporting tools for planning field data collection and designing practical solutions; (6) as screening tools for evaluating groundwater development scenarios; (7) as management tools for assessing alternative polices; and (8) as visualization tools for communicating key messages to public and decision-makers.

At the groundwater body scale, simulation models provide present state-of-the-art methods for quantifying the impact of different land-use practices on groundwater. Sequential coupling of a 1-D unsaturated water flux and nitrate transport model with a 2-D horizontal representation of groundwater flow and nitrate transport is found to be an appropriate method for modeling the changes of the quantitative and ecological status of a typical shallow phreatic aquifer. The results for saturated water flow confirm that there is no need for an iterative coupling or a fully 3-D approach given a groundwater depth deep below the root zone and predominantly sandy soil conditions.

The sequential coupling between PEARL and FEFLOW models allows to describe the subsurface fate of pesticides and their metabolites including groundwater transport at the aquifer scale. The parametrization of PEARL was supported by an experimental application of the pesticide s-Metolachlor (SMOC) on a well-established lysimeter and the lab analysis of soil samples to delineate location specific fate parameters of SMOC and the relevant metabolite metolachlor ethane sulfonic acid (MESA). The fate parameter set was used to simulate the leaching of MESA into the groundwater body and subsequent groundwater transport considering distribution of soil types and of maize cultivation percentages.

Johann Fank graduated with a PhD from the University of Graz and obtained in 2000 the permission to teach (habilitation) physical geography at the university. His research is focused on flow- and transport processes in soil and in the unsaturated and saturated zone of shallow phreatic aquifer systems. Main aspects involve the interdisciplinary approach using methods in the fields of tracer hydrology, isotope hydrology, hydraulics, soil physics, numerical modeling, mathematics, and statistics. He wrote more than 50 publications and presented various papers at international and national congresses. He managed various national and international research projects in applied hydrology and hydrogeology. 2012 he took over the management of "RESOURCES – Institute for Water, Energy and Sustainability"of JOANNEUM RESEARCH. Since 2016 Dr. Fank acts as CEO at the JR-AquaConSol GmbH.

K5) Lee Slater

Department of Earth & Environmental Sciences, Newark College of Arts and Sciences (NCAS)

Advancing geophysical characterization of contaminated fractured rock aquifers: sensing flow and transport properties beyond the borehole wall.

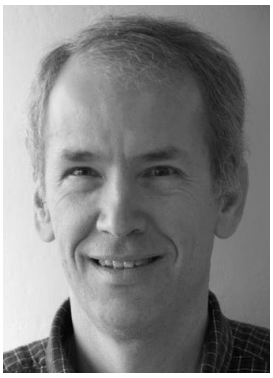
(Slater, Lee; Robinson, Judy)

Date: June 8
Time: 11:15 am - 11:55 am

Conventional technologies for investigating rock properties controlling flow and contaminant transport in the subsurface remain limited to primarily providing information local to a borehole. Geophysical imaging technologies offer opportunities to improve the characterization of flow and transport beyond the borehole wall in contaminated fractured rock systems. Understanding the fate of amendment injections delivered to remediate contamination requires spatially extensive information that is impractical and cost prohibitive from direct sampling methods. This problem is exacerbated in fractured rock aquifers due to the heterogeneity in flow and transport caused by the network of fracture zones. Furthermore, long term storage of contaminant mass occurs due to diffusion of contaminants into the primary porosity of the rock matrix adjacent to fractures, making conventional treatment methods that pull water from the hydraulically active fractures ineffective.We report selected results from six years of research funded by the US Department of Defense to advance the use of multi-scale geophysical technologies to improve understanding of contaminated fractured rock aquifers. We first address one of the major challenges in remediation of fractured rock systems: understanding the fate of contaminants injected into the aquifer and design of amendment injection strategies that effectively target the contamination in the rock mass adjacent to fracture zones. We demonstrate a strategy for using high-resolution, time-lapse cross-borehole electrical geophysical imaging, constrained by local geophysical observations at boreholes, to characterize the rock mass and design effective amendment delivery strategies for remediating a TCE contaminated mudstone aquifer. Although successful, the demonstration required the development of first of its kind in-borehole infrastructure, data acquisition strategies and dedicated infrastructure deployed with geophysical imaging requirements in mind. We also describe laboratory scale petrophysical research directed at advancing the use of the complex resistivity (CR) geophysical method for quantification of matrix permeability in fractured rock aquifers, highlighting results from two predominantly sandstone systems and one mudstone system. These results demonstrate that measurable geophysical length scales can be used in place of conventional hydraulic length scales to predict permeability. A recently developed CR logging tool provides new opportunities to use these petrophysical relations to estimate vertical profiles of permeability from a borehole log. However, the petrophysical research demonstrates that rock mass permeability prediction is critically dependent upon a reliable estimation of the electrical formation factor, a property that remains inherently challenging to estimate in situ.

Dr. Lee Slater, Distinguished Professor and Henry Rutgers Professor in Geophysics at Rutgers University Newark, is an internationally recognized expert in hydrogeophysics. He has published extensively, including 145 papers in peer reviewed international journals of hydrogeology and geophysics. Dr. Slater has served as principal investigator on multiple research and technology demonstration projects funded by the US Department of Defense, US Department of Energy, US Department of Agriculture, US National Parks Service and National Science Foundation. He has also served in prominent leadership roles in the academic geophysical community, including Chair of the Near Surface Geophysics Focus Group of the American Geophysical Union (AGU), Chair of the AGU Hydrogeophysics Technical Committee and President of the Environmental and Engineering Geophysical Society (EEGS). Dr. Slater currently serves as Associate Editor of Water Resources Research (WRR) and he recently edited a new volume on Near Surface Geophysics published in the 2nd Edition of the Treatise on Geophysics, part of the Elsevier Major International Reference series. Dr. Slater has served on multiple advisory boards for large interdisciplinary hydrogeological research projects in Europe. His numerous PhD graduates have mostly gone onto academic positions and are now making their own contributions to advancing research in hydrogeophysics.

Keynote Speakers – 9th June



K6) James J. Butler Jr.
Kansas Geological Survey

New Approaches for Assessment of Aquifers Supporting Irrigated Agriculture over a Range of Temporal and Spatial Scales

(Butler Jr., James J.; Whittemore, Donald O.; Wilson, Blake B.)

Date: June 9
Time: 9:00 am – 9:40 am

Aquifers are under stress worldwide as a result of large imbalances between inflows and outflows. These imbalances are particularly severe in aquifers in semi-arid regions that are heavily pumped for irrigation, such as much of the High Plains aquifer (HPA) in the central United States, resulting in an alarming rate of depletion for those systems. Food security, whether it is viewed from a local, regional, or global perspective, will be affected if this depletion continues unabated. The most effective means of moderating the rate of depletion is to reduce the pumping of groundwater. The key questions are what level of pumping reductions are needed to bring these heavily stressed aquifers into a more sustainable condition and are those reductions practically achievable. Information about the components of an aquifer's water budget is essential to address such questions and to formulate more sustainable management plans for these systems. This information, however, is rarely available beyond coarse approximations. We have recently developed a new approach for characterization of the net inflow (capture) term of the aquifer water balance over scales of hundreds to tens of thousands of square kilometers using only water-level and water-use data. This net inflow term can then be used to estimate the annual pumping volume that would produce stable areally averaged water levels over an area. We demonstrate the power of this approach for rapid assessment of the prospects for sustainability in the data-rich portion of the HPA in Kansas. Although the projected aquifer response to pumping reductions varies across the Kansas HPA, we find that practically achievable reductions in annual pumping (15-25%) would have a large impact on the rate of depletion throughout the aquifer. Large-scale assessments such as these critically depend on the quality and quantity of available data. We therefore must place a high priority on the collection of annual water-level and water-use data. When smaller-scale assessments are needed, we can couple the information about an aquifer's response to development activities embedded in hydrographs from continuously monitoring wells with the high-resolution information from direct-push technology to obtain important insights into an aquifer's future.

Jim Butler is a Senior Scientist and Chief of the Geohydrology Section of the Kansas Geological Survey at the University of Kansas, where he has worked since 1986. He holds a B.S. in Geology from the College of William and Mary, and a M.S. and Ph.D. in Applied Hydrogeology from Stanford University. His current research interests include development of field methodology for site characterization, interpretation of water-level fluctuations in monitoring wells, and development of approaches for assessing the sustainability of aquifers supporting irrigated agriculture. Jim was the 2007 Darcy Distinguished Lecturer of the National Ground Water Association and the 2009 recipient of the Pioneers in Groundwater Award of the Environmental and Water Resources Institute of the American Society of Civil Engineers. He has held visiting researcher positions at the Polytechnical University of Valencia, Sandia National Laboratory, and the University of Tuebingen. He is currently a visiting professor at Stanford.

K7) Henning Prommer

CSIRO; University of Western Australia

Groundwater replenishment in Perth, Western Australia: Modelling framework and supporting site characterisation efforts

(Prommer, Henning; Seibert, Simone; Siade, Adam; Descourvieres, Carlos; Atteia, Olivier; Higginson, Simon)

Date: June 9
Time: 11:15 am - 11:55 am

Climate-induced decreasing availability of ground and surface water resources in conjunction with increasing water demands has motivated the exploration of unconventional new water sources in Perth, Western Australia. Among a range of possible solutions, recycling municipal wastewater through advanced tertiary treatment techniques and its subsequent reinjection into deeper aquifers has evolved over the last 15 years as a key strategy to augment the currently existing drinking water supplies. During the treatment process reverse osmosis (RO) plays a critical role in the removal of undesired solutes, but results in low ionic strength product water. As the recycled low ionic strength water is typically in chemical disequilibrium with the native aquifer conditions, its injection into aquifers can trigger a range of complex coupled physical and geochemical processes that can strongly affect the quality of the groundwater in the recharged aquifer.

In this study, we revisit the major stages of this managed aquifer recharge project from the initial ideas in 2002 to the completion of the full-scale replenishment scheme in 2017 with a focus on the iterations that have occurred between site characterisation and modelling efforts. One of the most important steps in this procedure was a trial injection that was performed between November 2010 and December 2012. This 'groundwater replenishemnt trial' (GWRT) clarified the principal technical feasibility as well as the societal acceptance of large-scale wastewater reuse. Initial modelling tasks related to the GWRT were dedicated to obtaining an accurate understanding and description of the injectant and temperature propagation within the highly heterogeneous sedimentary aquifer (Seibert et al., 2014).

Incorporating the reactive transport processes that were identified from both, well-controled laboratory-scale experiments such as respirometer tests (e.g., Descourvieres et al., 2010a, 2010b) and collected field data, the calibrated solute and heat transport model was further extended to a multi-component reactive transport model (Seibert et al., 2016). The model results showed that pyrite oxidation acts as the major driver for reaction-induced concentration changes within the aquifer. Therefore, understanding the nature and longevity of the buffering mechanisms that maintain circum-neutral conditions in the aquifer was cruicial for the design of the large-scale implementation of groundwater replenishment and for minimising the risk of metal(oid) mobilisation.

(Descourvieres *et al. (*2010a) *Appl. Geochem* 25, 261–275.; Descourvieres *et al.* (2010b) *Env. Sci. Technol.,* 44, 6698-6705.; Seibert et al. (2014) *Water Resour. Res.* 50, 9463-9483.; Seibert et al. (2016) *Water Resour. Res.* 52, 4003-4025)

Dr. Henning Prommer is a Winthrop Research Professor at the University of Western Australia and a Principal Research Scientist and Team Leader in the Environmental Contaminant Mitigation and Technologies Program at CSIRO Land and Water. His main expertise and research interests are (i) the development and application of reactive transport models to water quality issues in porous media, in particular the quantification of redox processes and the associated fate of organic and inorganic pollutants such as arsenic at both the laboratory- and field-scale (ii) understanding and quantifying coupled transport and (bio)geochemical processes induced by managed aquifer recharge techniques such as aquifer storage and recovery and (iii) numerical modelling of spatial and temporal variations of isotope signatures and environmental tracers in natural and contaminated aquifers.

Open Lecture
2017 Darcy Distinguished Lecturer

Kamini Singha
Colorado School of Mines

A Tale of Two Porosities: Exploring Why Contaminant Transport Doesn't Always Behave the Way It Should

(Singha, Kamini)

Date: June 7
Time: 4:15 pm - 5:00 pm

Transport through preferential flowpaths is important in a broad range of scientific disciplines. In hydrology, the ability to quantify subsurface transport is an issue of paramount importance due to problems associated with groundwater contamination. Observational challenges and complexity of hydrogeological systems lead to severe prediction challenges with standard measurement techniques. One important example of a prediction challenge is "anomalous" solute-transport behavior, defined by characteristics such as concentration rebound, long breakthrough tailing, and poor pump-and-treat efficiency.

These phenomena have been observed at research and aquifer-remediation sites in diverse geologic settings, and are not predicted by classical theory. Numerous conceptual models have been developed to explain anomalous transport, such as the presence of two distinct populations of pores — one where solutes are highly mobile and another where they are not — but verification and inference of controlling parameters in these models in situ remains problematic, and often estimated based on data fitting alone. Recent tests using simple electric geophysical methods directly measure the process of mobile-immobile mass transfer and allow estimation of parameters controlling anomalous transport.

This lecture presents a rock-physics framework, an experimental methodology, and analytical expressions that can be used to determine parameters controlling anomalous solute transport behavior from colocated hydrologic and electrical geophysical measurements in a series of settings, including groundwater and surface water/groundwater systems. The long-term goals of this work are to contribute toward improving the predictive capabilities of numerical models and enhancing the fidelity of long-term groundwater monitoring frameworks.

Kamini Singha is a professor in the Department of Geology and Geological Engineering and the Associate Director of the Hydrologic Science and Engineering Program at the Colorado School of Mines. She worked at the USGS Branch of Geophysics from 1997 to 2000, and served on the faculty of The Pennsylvania State University from 2005 to 2012. Her research interests are focused on the physical process controlling solute and contaminant mass transport including "long-tailed" distributions of solute arrival times in groundwater systems and during groundwater-surface water exchange, integration of geophysical imaging with flow and transport modeling, and establishing field-scale rock physics relations between geophysical and hydrogeologic parameters. Dr. Singha is the recipient of an NSF CAREER award, and the Early Career Award from the Society of Environmental and Engineering Geophysics in 2009. She earned her B.S. in geophysics from the University of Connecticut and her Ph.D. in hydrogeology, from Stanford University.

NovCare 2009 - MET, UFZ

Company Exhibition

The field demonstration will take place on June 8. There will be several information booths in the foyer. Transport will be provided to the technology demonstration and exhibition of larger machinery at the field site near Dresden.

Information booths

June 7	9:30 am - 8:00 pm
June 8	9:00 am - 6:30 pm
June 9	9:00 am - 12:00 noon

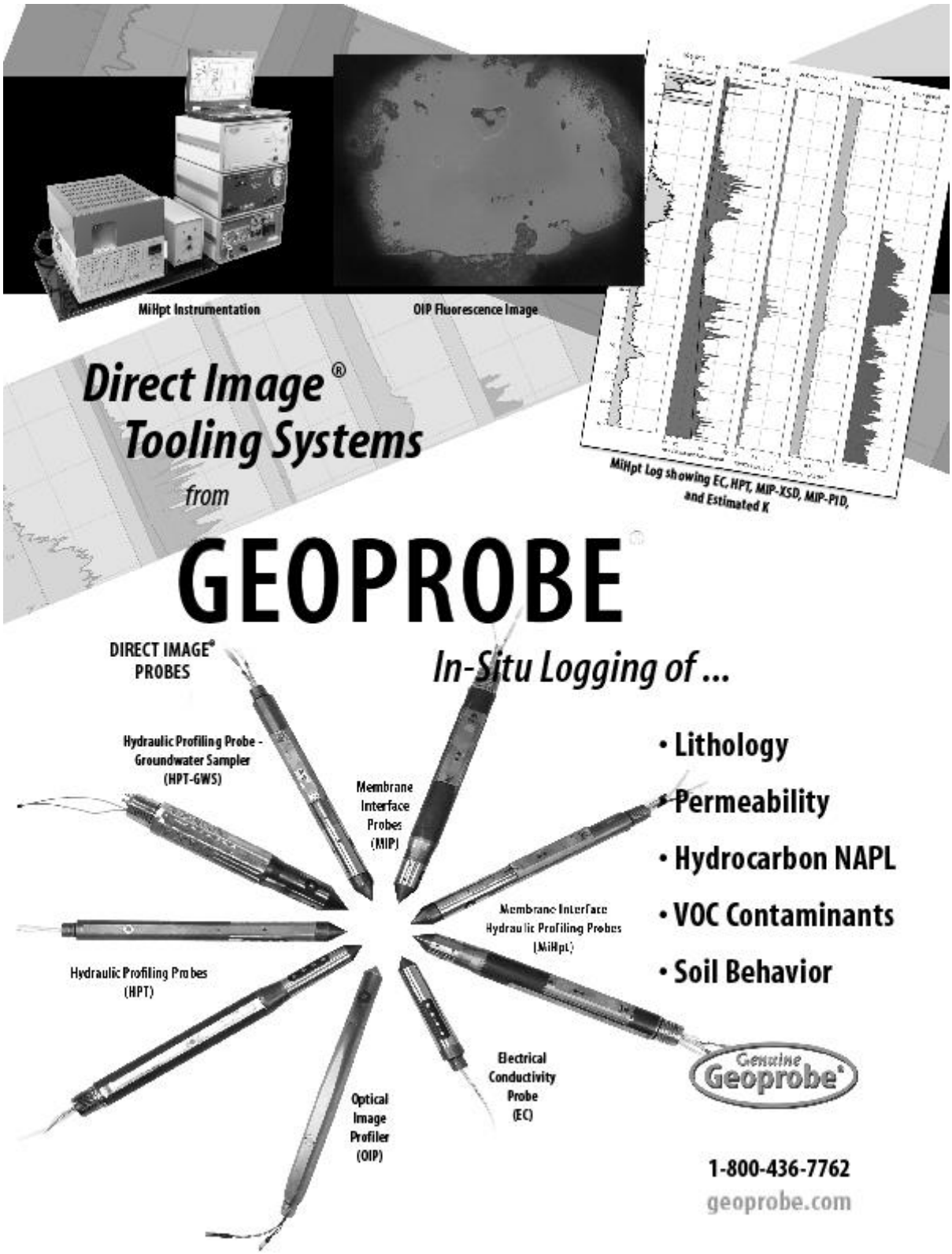
1. *Geoprobe*
2. *Fugro Consult GmbH*
3. *Eijkelkamp SonicSampDrill*
4. *Sensatec GmbH, NL Berlin*
5. *Nordmeyer GEOTOOL GmbH*
6. *BDG Ecosax*
7. *a.p. van den berg*

Exhibition of larger machinery/Technology demonstrations

June 8 1:30 pm - 4:30 pm

1. *Geoprobe*
2. *Fugro Consult GmbH*
3. *Eijkelkamp SonicSampDrill*
4. *Nordmeyer GEOTOOL GmbH*

No.	Company	Contact	Website	Phone
1	**Geoprobe**	*Thomas M. Christy*	www.geoprobe.com	+1 789 404 1146
2	**Fugro Consult GmbH**	*Eugen Martac*	www.fugro.de	+49 7473 95 138 02
3	**Eijkelkamp SonicSampDrill**	*Harm Nolte*	www.sonicsampdrill.com	+31 313800936
4	**Sensatec GmbH, NL Berlin**	*Mark Zittwitz*	www.sensatec-berlin.de	+49 30 80941576
5	**Nordmeyer GEOTOOL GmbH**	*Philip Weichbrodt*	www.nordmeyer-geotool.de	+49 30 934 905 212
6	**BGD Ecosax**	*Philipp Dost*	www.bgd-ecosax.de	+49 351 478789810
7	**a.p. van den berg**	*Mirjam Delea*	www.apvandenberg.com	+31 513 631355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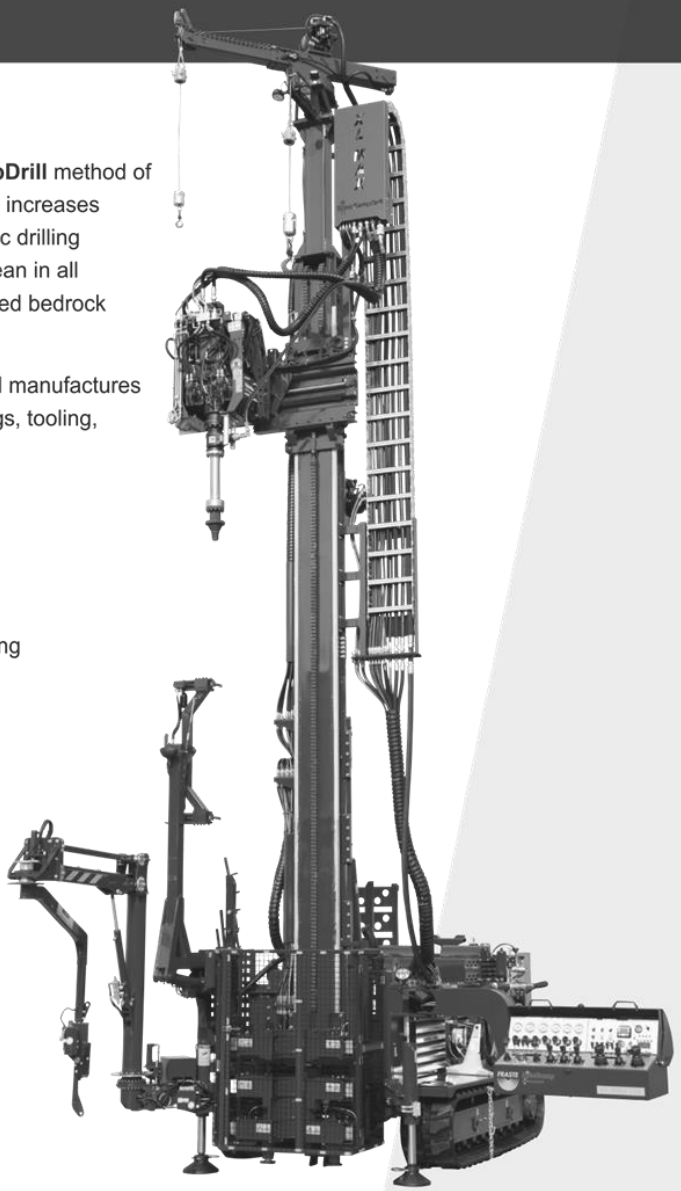

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- Bodenluftsondierungen
- Monitoringmessstellen
- Injektionslanzen
- Infiltrationsbrunnen
- Wirkstoff-Direkt-Injektionen
- Bohrungen mit Hohlbohrschnecke (HBS 200/110)

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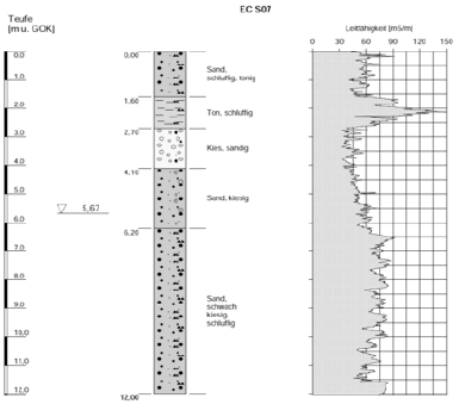

Direct-Push

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Darüber hinaus ist es möglich, direkt über das Sondiergestänge mittels speziellen Injektionsspitzen zielgenaue Injektionen von Hilfsstoffen (basierend auf vorlaufender MIP-Sondierung) für die in-situ-Sanierung durchzuführen, so dass eine Vielzahl an Injektionspunkten und –niveaus in kürzester Zeit realisiert werden können.

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Participants

This list only shows those participants, who agreed to the publication of their personal details.
(registered by May 12, 2017)

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Bertermann	*David*	Universität Erlangen - Nürnberg	Germany
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Binder	*Martin*	Technische Universität Dresden	Germany
Britt	*Reto*	Eawag	Switzerland
Butler	*James*	University of Kansas	United States
Christensen	*Anders G.*	NIRAS	Denmark
Credoz	*Anthony*	TOTAL S.A.	France
Cremeans	*Mackenzie*	University of Kansas	United States
de Weirdt	*Fabian*	Geoprobe Environmental Technologies	Belgium
Devlin	*Rick*	University of Kansas	United States
Di Sipio	*Eloisa*	FAU University Erlangen	Germany
Dietrich	*Peter*	Helmholtz-Zentrum für Umweltforschung GmbH - UFZ	Germany
Dunkerley	*Owen*	EMA Universität Greifswald	Germany
Epting	*Jannis*	Angewandte und Umweltgeologie - Universität Basel	Switzerland
Fank	*Johann*	JR-AquaConSol GmbH	Austria
Gasch	*Carina*	BGD ECOSAX GmbH	Germany
Gonzales Amaya	*Andres*	Lund University	Sweden
Haas	*Johannes*	University of Graz	Austria
Händel	*Falk*	Technische Universität Dresden	Germany
Hoffmann	*Anna*	Sensatec GmbH	Germany
Hyndman	*David*	Michigan State University	United States
Khalid	*Perveiz*	University of the Punjab	Pakistan
Kim	*Han-Saem*	Korea Institute of Geoscience and Mineral Resources	Korea, Republic of
Klaver	*Jop*	MaP Microstructure and Pores GmbH	Germany
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Musche	*Fabian*	University of Applied Sciences Dresden	Germany
Osorno	*Trevor*	University of Kansas	United States
Ourhzif	*Zouhair*	Laboratoiry Earth Science, Geotourism, Natural Hazard and Remote Sensing	Morocco
Paradis	*Daniel*	Natural Resources Canada	Canada
Prommer	*Henning*	CSIRO / UWA	Australia
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Salek	*Ondrej*	Charles University in Prague	Czech Republic
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Seibertz	*Klodwig*	Helmholtz-Centre for Environmental Research UFZ	Germany
Siade	*Adam*	University of Western Australia	Australia
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Sun	*Chang-Guk*	Korea Institute of Geoscience and Mineral Resources	Korea, Republic of
Tritschler	*Felix*	TU Dresden	Germany
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Uhlemann	*Sebastian*	British Geological Survey	United Kingdom
Valocchi	*Albert J.*	Univerity Illinois	United States
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Name		Institution	Country
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The Center for Advanced Water Research (CAWR) brings together the water competences of the Helmholtz Centre for Environmental Research - UFZ and the Technische Universität Dresden (TUD). The highly qualified scientists are jointly tackling some of the key challenges in the water sector in a breadth of research topics that is outstanding and at the same time with a profound disciplinary expertise.
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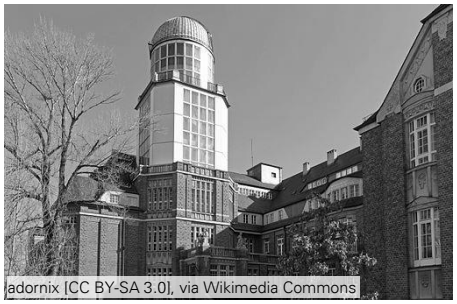
Sebastian Wiedling, UFZ

The **Helmholtz Centre for Environmental Research - UFZ** was established in 1991 as the first and only centre in the Helmholtz Association of National Research Centres (Helmholtz Association) to be exclusively devoted to environmental research in a great variety of fields. It currently employs around 1000 people studying the complex interrelationships between humans and the environment and develops tools and strategic concepts for policy makers, the economy and society. They aim to contribute to creating a balance between economical and societal development and long-term protection of our natural resources. The UFZ has a strong focus on interdisciplinary research involving ecologists, social and legal scientists, and economists.

The **Department Monitoring and Exploration Technologies** (MET) brings together expertise from several different areas, such as hydrogeology, direct-push technology, geophysics, on-site analysis, sensor development and the analysis and optimization of multivariate data. The department MET develops and tests application-oriented methods, technologies and strategies for the observation and investigation of the natural and anthropogenic environment as well as the processes of interaction between soil, water and air. Therefore, a wide variety of methods from geophysics, such as hydrogeology, chemical analytics, remote sensing, sensor technology and data analysis, are combined allowing an efficient and target-oriented investigation and evaluation of environmentally relevant issues and sites.

The Technische Universität Dresden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The **Technische Universität Dresden** (TUD) is one of the largest "Technische Universitäten" in Germany and one of the leading and most dynamic universities in Germany. As a full-curriculum university with 14 faculties in five schools it offers a broad variety of 133 disciplines and covers a wide research spectrum. Its focuses of Biomedicine, Bioengineering, Materials sciences, Information technology, Microelectronics as well as Energy and Environment are considered exemplary in Germany and throughout Europe. Since 2012 TUD is officially one of the "Universities of Excellence". About 36.000 students are enrolled at TUD – more than three times as many as in 1990 (11.220 students). Internationally, the TUD has earned a good reputation, about one eighths of its students come from abroad. Today, about 5.000 scientists from 70 countries are working at the Technische Universität Dresden *(from Website TUD).*

The **Institute for Groundwater Management** covers the main topics of groundwater management and contaminant hydrology in terms of research and teaching. In 1946 it was formed from the Institute for Soil and Water Management of the former Technische Hochschule Dresden and is now located at the main TUD-Campus.
Student teaching includes lectures, tutorials, training courses and field trips for the bachelor study course of Hydrosciences and also for 5 master courses (Water Management, Hydrology, Waste Management and Contaminant Hydrology, Hydrobiology and Hydro Science and Engineering).
Research activities include both basic research and applied science. Mine drainage water treatment, stable isotope analyses, tracer techniques, karst hydraulics, coastal aquifers and managed aquifer recharge are some of the various research topics of the institute often combining laboratory, field and modelling techniques.

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Kansas Geological Survey, University of Kansas


Kansas Geological Survey, KU

The **Kansas Geological Survey** is a research and service division of The University of Kansas. Created in 1889, the Survey studies the geology of Kansas, develops new techniques for exploring and analyzing geologic data, and produces maps, reports, and scientific papers. The Survey currently employs more than 80 researchers and technicians engaged in a variety of geosciences-related activities. The Geohydrology Section of the Survey conducts both fundamental and applied research on hydrologic and hydrogeochemical systems ranging in scale from site-specific to the river basin and regional aquifer level. Present areas of research include: physical, stratigraphic, and geochemical characterization of sedimentary aquifer systems; surface-water/ground-water interactions; ecohydrology of riparian corridors; spatial data analysis/geostatistics; assessment of recharge and sustainable yields in complex hydrologic systems; simulation of aquifer dynamics; technology for subsurface characterization; and contaminant transport and source identification.

Social Program


IGW, 2012

Welcome Reception

Date: June 6
Time: starting at 6:00 pm
Place: Foyer of Building CHE – TU Dresden – Bergstr. 66

The Welcome Reception is open to all conference participants. You have the opportunity to meet the other conference participants at the Foyer of the TU Dresden building CHE where the conference takes place. At the reception you will receive your conference materials, drinks and some fingerfood. The reception is an informal and highly interactive environment that gives participants the opportunity to engage with one another in discussions about relevant, ongoing work and critical issues in key areas. The welcome reception is included in the conference registration fee.


Kay Körner, [CC BY 2.5], via Wikimedia Commons

Conference Dinner

Date: June 7
Time: starting at 8:00 pm
Place: Restaurant "Alte Mensa" – Mommsenstr. 13

The Conference Dinner takes place at the Restaurant "Alte Mensa" on campus of the TU Dresden. Enjoy a nice evening with colleagues and friends in the historic University Restaurant, which was restored and partially modernized in 2007.


Felix Tritschler, 2017

Social Event – Steamboat Cruise

Date: June 8
Time: 7:00 pm – 10:00 pm
Place: Wharf at Brühl's Terrace

Fee: € 40 Euros. Registration is required.

Starting from Dresden's Wharf at the foot of Brühl's Terrace the steamboat will go upstream in the direction of the castle Pillnitz, passing the picturesque slopes of the Elbe valley in Dresden. A light evening meal will be served. At around 22:00 the boat arrives back at its starting point right in the center of Dresden.

Welcome to Dresden

Dresden is the capital city of the Free State of Saxony (Freistaat Sachsen) in eastern Germany. Today, with a population of just over half a million, it is a thriving city as part of a reunited Germany. But it is perhaps best known for the massive firebombing that destroyed most of the city during the last months of World War II.

Noteworthy sights:

- **Frauenkirche** - Dresden's Church of Our Lady collapsed days after being damaged in Allied bombing raids in 1945. The ruins were a moving anti-war monument until the early 1990s, when reconstruction using the original stones in their original locations began. The church reopened in 2005.

By Dampftrain [CC BY-SA 4.0], via Wikimedia Commons

- **The Zwinger** a courtyard complex which is today home to the Semper Art Gallery, the Porcelain Collection, and several other museums.

Pedro Krtička [CC BY 3.0], via Wikimedia Commons

- The **"Procession of Princes"** in Dresden is a remarkable panorama made up of 25,000 Meissen porcelain tiles**.**

- **Brühl Terrace** above the Elbe River is somewhat called "Europe's Balcony." Originally designed as a private garden for the Saxon Count Brühl, this promenade is now the best place to enjoy a river vista, good views of the Neustadt section of Dresden across the river and the *Terrassenufer* boat landing below, where the Elbe tour boats dock.

By Ingersoll [Public domain], via Wikimedia Commons

- **Semper Opera House** built between 1871 and 1878

Important information for your stay

Public Transport information

Felix Tritschler, 2017

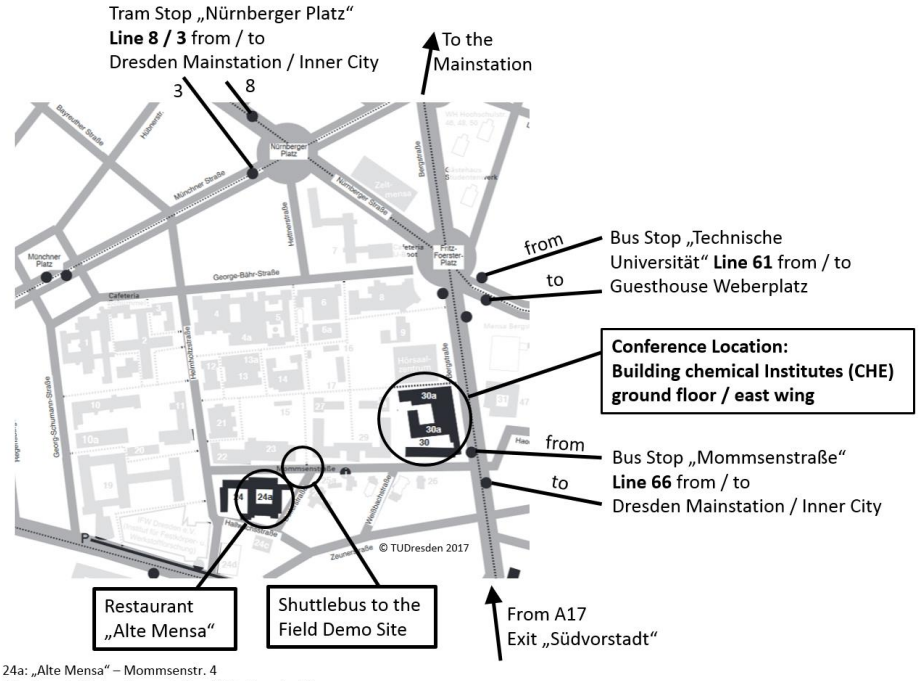
L.E.rewi-sor [GFDL, CC-BY-SA-3.0], via Wikimedia Commons

A single ticket valid on trams, buses and S-Bahn for the Dresden fare zone costs € 2,30.
Your registration fee includes a DVB pass for the public transport. The pass is valid June 7-9, 2017 for all DVB-lines (mostly yellow buses and trams) in the Dresden fare zone; "S-Bahn" - trains are not included.

Buying tickets:

1. from a ticket vending machine at the bus/tram stops. Tickets need to be stamped.
2. from a machine on any Dresden tram. The tickets can be used straight away and do not need to be stamped. Please note that the machines only accept coins.

Conference venue at Bergstrasse 66



24a: „Alte Mensa“ – Mommsenstr. 4
30a: Chemie/Hydrowissenschaften CHE – Bergstr. 66

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Your way to the conference venue at Bergstrasse 66 in Dresden

Attendees should plan on being responsible for their own transportation to and from the airport. From the airport you can get to Dresden city centre quickly and easily by rail (S-Bahn), bus or tram

From / To the airport (DRS):


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- Double-decker trains run every 30 minutes between the airport and the city centre --> ***S-Bahn S2*** - (Journey time about 20 minutes)
- The underground station is located in the terminal building.
- Taxi - about 15-30 minutes (depending on traffic)

From / To Dresden Main Station:


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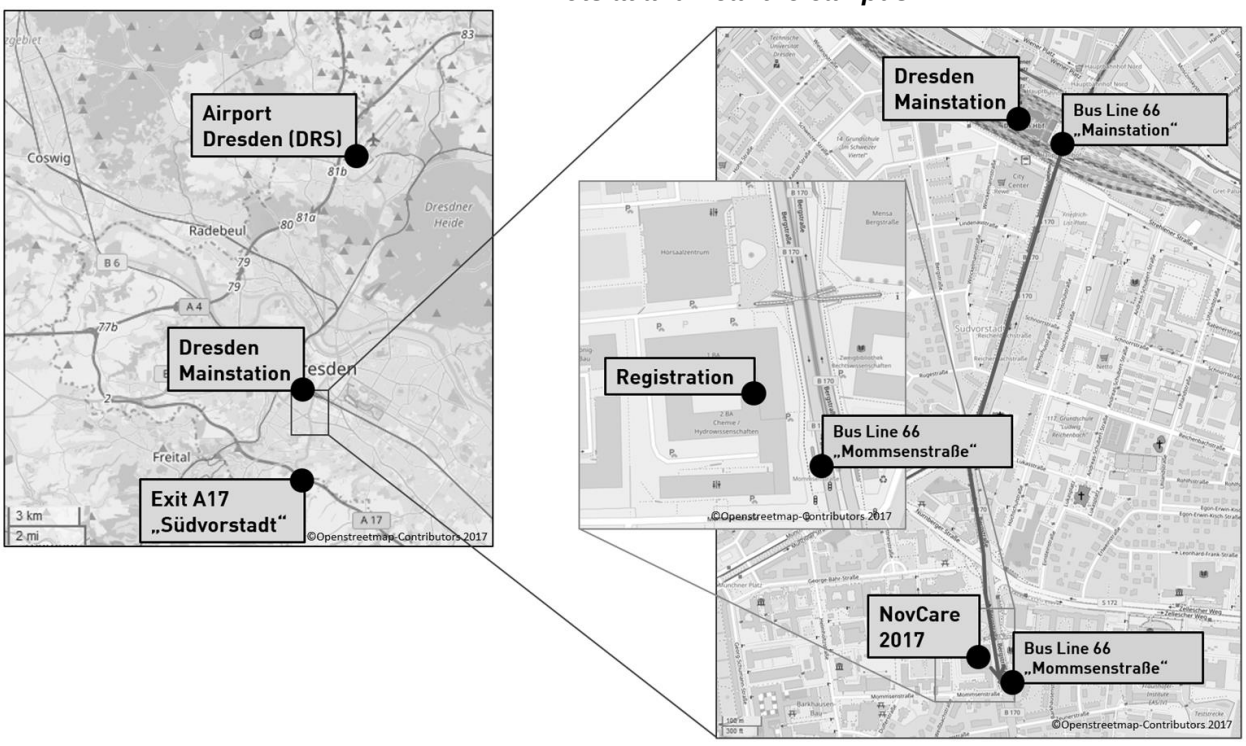
- 1.6 km walk - 25 minutes
- Bus Line 66 to " Freital / Coschütz / Südhöhe / Mockritz"
- Approx. 5 minutes to Bus Stop " Mommsenstrasse" (Third Stop)

By car:

- Autobahn A17 take exit " Südvorstadt"
- follow B170 3km towards City Center

--> Please notify that there are very limited parking lots at and near the campus!



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Abstracts - Oral Presentations

Session 1: Flow and transport in the saturated and unsaturated zone
(CHE-89 / June 7, 11:00 am - 12:20 pm)

1.1 Spatial-temporal dynamics of perched aquifer systems in Barrier Island: Application of geophysical methods

A T M Jahangir Alam[1]; Harald Hofmann[1]; Lutz Gross[1]; Thierry Bore[2]

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Keywords: Electrical resistivity tomography, Ground penetrating radar, perched aquifer systems, Barrier Island

Barrier islands are acting as barriers in the land/sea interface and they have significant ecological and environmental importance. One of the important characteristics of the barrier islands in Australia is the presence of perched aquifer systems above the regional aquifers, which in many cases host fragile ecosystems. While the concept of perched aquifer systems is widely known, there is still a gap in the knowledge of the hydrological dynamics of these systems. This study presents a multiple method framework of two geophysical methods, namely Electrical resistivity tomography (ERT) and Ground penetrating radar (GPR) in addition to hydrometric point observation of groundwater level and unsaturated zone moisture content to obtain information about the water balance dynamics and spatio-temporal extent of the perched aquifers at Brown Lake on North Stradbroke Island, Southeast Queensland.
The electrical resistivity in the subsurface is directly related to water content and the resistivity value is lower when the water content is higher. Other parameters to solve Archie's law, such as grain size, organic matter content and clay content were determined in laboratory experiment on samples from the Brown Lake catchment.
We found a low resistive zone of 5-6m thickness below 2-3m depth from the ground surface. The high resistivity in the near surface was related to very dry sands while the low resistivity at depth could be associated with saturated conditions and hence the perched water table. Reflection of GPR signal from the top of that low resistive zone supports the findings. These observations have also been validated with groundwater levels measured in groundwater bores in the middle of the ERT survey. Conversion of 2D ERT profile into 2D volumetric water allows us to monitor the temporal changes in moisture content in the unsaturated zone above perched aquifer which have been validated by point measurement of water content by time domain reflectometry (TDR) and soil moisture probes at different depth.

1.2 Integrated passive flux measurements in groundwater: introduction of the iFLUX sampler

Goedele Verreydt[1,3]; Filip Meesters[1,3]; Tim Op 't Eyndt[2,3]; Ilse Van Keer[2]; Jan Bronders[2]; Patrick Meire[1]

[1]*University of Antwerp, Antwerp, Belgium*
[2]*VITO, Land and Water Management, Mol, Belgium*
[3]*iFLUX, Science Park Antwerp, Niel, Belgium*

Keywords: passive sampler, groundwater flow, contaminant mass flux

The monitoring and management of soil and groundwater is a challenge. Current methods for the determination of movement or flux of pollution in groundwater use no direct measurements but only simulations based on concentration measurements and Darcy velocity estimations. This entails large uncertainties which cause remediation failures and higher costs for contaminated site owners. On top of that, the lack of useful data makes it difficult to get approval for a risk-based management approach which completely avoids costly remedial actions.

The iFLUX technology is a key development of Dr. Goedele Verreydt at the University of Antwerp and VITO. It is supported by the passive flux measurement technology as invented by Prof. Mike Annable and his team at the University of Florida. The iFLUX technology includes an in situ measurement device for capturing dynamic groundwater quality and quantity, the iFLUX sampler, and an associated interpretation and visualization method.

The iFLUX sampler is a modular passive sampler that provides simultaneous in situ point determinations of a time-averaged target compound mass flux and water flux. The sampler is typically installed in a monitoring well where it intercepts the groundwater flow and captures the compounds of interest. The sampler consists of permeable cartridges which are each packed with a specific sorbent matrix. The sorbent matrix of the water flux cartridge is impregnated with known amounts of water soluble resident tracers. These tracers are leached from the matrix at rates proportional to the groundwater flux. The measurements of the contaminants and the remaining resident tracer are used to determine groundwater and target compound fluxes. Exposure times range from 1 week to 6 months, depending on the expected concentration and groundwater flow velocity.

The iFLUX sampler technology has been validated and tested at several field projects. Currently, 4 cartridges are tested and available: 1 waterflux cartridge to monitor speed and direction of flow and 3 cartridges to monitor different sources of pollution – VOC's, heavy metals and nutrients. The modular design enables to sample several types of pollution at the same time.

The principles and the design of the iFLUX technology will be presented, together with the results from performance and sensitivity analysis for different field scenarios and several field cases.

1.3 Characterizing an unsaturated hydraulics of infiltrated water in unsaturated zone based on moving-windows cross-correlation analysis

Jina Jeong; Eungyu Park

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Keywords: unsaturated zone, residence time, cross-correlation analysis, delayed drainage water table fluctuation model, unsaturated zone hydraulic

The residence time of water within an unsaturated zone from the infiltration to recharge may provide useful information on the characterization of unsaturated hydraulics. In this study, a method to estimate residence time in a sequential manner with high temporal resolution is developed. The developed method is on the basis of the previous methods using a cross-correlogram analysis of precipitation and water table level time series whereas the estimation errors are significantly reduced by the proposed scheme compared to the conventional methods. In addition, a closed-form analytical relationship between the estimated residence time and the corresponding model parameter of a physically-based water table fluctuation model that considers variably saturated flow is developed. In the validation of the developed method, the applications to actual water table level fluctuation and precipitation data from two locations in South Korea with contrasting unsaturated hydraulic characteristics are conducted to delineate the impact of the unsaturated zone media and the climatic condition on the estimated residence time. From the applications, the proposed method is found to derive distinct characteristics in the estimated residence time reflecting the hydraulic properties of the unsaturated zone. In the area composed of low permeable media, the mean residence time is large and the standard deviation is also large with showing high sensitivity to the climatic condition. In contrast, both the mean and standard deviation of the estimated residence time are small for the area composed of high permeable media. This aspect is closely related to the unsaturated moisture profiles of the respective area which are considerably affected by unsaturated hydraulics due to the composing media (e.g., intrinsic permeability and clay contents). From the analyses, it is concluded that the proposed methods can be effectively adopted in the hydraulic characterizations of unsaturated zones complementarily with the other existing methods.

1.4 Statistical analysis of long term groundwater monitoring data and its relation to flow path and aquifer response time, Brighton Block, SE England

Peshawa Al-Jaf; Martin Smith; Friederike Gunzel

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Keywords: Chalk aquifer; unsaturated zone; correlation analysis; bypass flow; matrix hydraulic conductivity

This study has examined the correlation between rainfall events and rises in the groundwater level at three sites (North Heath Barn, Pyecombe East and Preston Park) on the Chalk of the Brighton block, South East England. North Heath Barn is rural site, on interfluves and relativly undisturbed site; Pyecombe East is also a rural site, on interfluves but used as an effluent artificial discharge; Preston Park is an urban site, vally floor and surrounded by impermable developments.

Daily time series of groundwater level, electrical conductivity, and rainfall were correlated (autocorrelated and cross-correlated) to analyze seasonal changes (3-month intervals) in groundwater level response times and the influence of geological setting and anthropogenic disturbance. The time periods showing a faster response were then correlated on an hourly base to examine the possibility of preferential flow occurring through fractures and karst within the Chalk unsaturated zone. The time lags (in both daily and hourly time series) show significant correlations between the effective rainfall and thickness of the unsaturated zone during each season. The correlation results were then used to the calculate flow rate through the unsaturated zone and compared to the matrix unsaturated hydraulic conductivity calculated using the centrifuge technique. The result were also analyzed in relation to tensiometer data from ternsiometers installed throughout the unsaturated zone profile of the North Heath Barn site.

In general, a slower response occurs during dry seasons when the amount of effective rainfall is less than 4mm/day, the unsaturated zone is thick (> 40 m at NHB and Pyecombe east and > 6 m in Preston park), and the unsaturated zone has a minimum storage (matric potential < - 1 kPa). However, the autocorrelation results shows that water was continuously added to the groundwater until late summer through flow from matrix storage, but groundwater level declined as the discharge was greater than recharge. Rapid response occurs during wet seasons when these conditions are reversed.

The observed time lag for each site has been used to calculate the flow rate through the Chalk unsaturated zone and compare these results with the matrix hydraulic conductivity calculated using the centrifuge technique; the matrix hydraulic conductivity varies from 1.4 to 4.2 mm/day using a Chalk sample from the study area. The flow rate throuhg the Chalk unsaturated zone varies considerably according to the location and seasons, which are varies from 769 mm/day during winter 2014 at Pyecombe East to 0.4 mm/day during autumn 2013 at Preston Park. A fast response in a couple of hours was observed in the interfluves sites, this may be to do with bypass flow, whereas a slower response is observed at the urban site as the area is covered by impermeable development.

Session 2: Geotechnical site characterization
(CHE-91 / June 7, 11:00 am - 12:20 pm)

2.1 Multisource geospatial information framework for subsurface stratification using geophysical tomography, borehole and geological map

Han-Saem Kim[1]; Chang-Guk Sun[2]

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[2]*Geological Research Division, Korea Institute of Geoscience and Mineral Resources, 124 Gwahak-ro, Yuseong-gu, Daejeon 34132, Korea*

Keywords: site-specific site characterization, geostatistical integration, geophysical tomography, borehole, geological map

Development of geo-spatial database is essential to characterize the local geotechnical information in multi-scale areas and optimized geotechnical survey results having high-potential spatial variability based on geostatistical assessment. To estimate the two- or three-dimensional sub-surface, such database should be previously reviewed based on reliability validation and applied the advanced integration technique with multi-source information; borehole, geophysical investigation, and geological map. Recently, the advanced integration methodologies using boring and prove investigation are generally conducted at construction sites, to identify local geotechnical characteristics with respect to engineering judgements. Moreover, geometrical models with geomorphological and geological map provide continuous geo-knowledge-based subsurface information for large-scale filed characterization. In this study, a multi-source geo-spatial information framework, composed outlier analysis, geostatistical integration, and geometrical construction, was proposed for subsurface stratification and applied at pilot testbed.

The engineering geological units and boundary were locally defined in order to investigate their relationship to geotechnical data. First, the borehole datasets were optimized to modify a boring-log-based geological boundary using the cross-validation-based outlier detection method. Outliers indicate data that appear to be inconsistent with the remainder of the data. This method is a blind test using kriging for determining whether the target point shares a trend with the surrounding base values. Especially, the outliers are detected for each cluster of borehole having similar effective range based on variogram. Thus, the possible outliers among the collected borehole datasets are regarded as re-examinable reference for reconstruction geological strata and should be preferentially replaced by new borehole.

Then, site-specific classification criteria of the geological boundary were determined using appropriate statistical comparisons to transform 3D geophysical datasets into 3D strata, and applied as reference values to determine the indicator thresholds. Indicator kriging, a simple non-linear method of interpolation, was the geostatistical integration method used in this study. Indicator kriging is used primarily to evaluate the probability of exceeding some predefined threshold value. Indicator kriging requires an indicator transform, which transforms each hard value by incorporating borehole datasets into indicator values or local information that is a direct or indirect proxy for the variable of interest. After development of three-dimensional stratification geo-database, surface layer is re-built by overlaying the geological map and digital elevation model (DEM). Thus top-down overlaying of geo-layer grid was applied at pilot testbed in Seoul to confirm the geotechnical characteristic value (stratum, *SPT-N*, etc.) and validate the proposed framework.

2.2 Geotechnical characterization of seismic monitoring stations according to site response parameters determined from combined in-situ investigations in Korea

Chang-Guk Sun[1]; Hyung-Ik Cho[2]; Han-Saem Kim[2]

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Keywords: seismic site response, shear wave velocity, site characterization, seismic monitoring station

Earthquake ground motions inducing catastrophic losses are strongly influenced by the local site characteristics. To observe the ground motions during an earthquake, seismic monitoring stations have been installed at a number of locations, not only in strong seismicity regions but also in moderate seismicity regions, including the Korean Peninsula, where most sites have shallow bedrock depths of less than 30 m. As part of the evaluation of seismic responses of regional seismic stations, this study carried out a series of site investigations involving borehole drilling and in-situ seismic tests. Two kinds of seismic tests composed of downhole and MASW methods, were performed to obtain shear wave velocity (V_S) profiles of the seismic station sites. Some representative V_S profiles were drawn based on the combination of in-situ seismic tests taking into account their reliability and testing depth.

The site conditions at the seismic stations were characterized based on seismic site response parameters, which have been widely applied in the field of earthquake engineering practices. The site response parameters consist of the depth to bedrock (H), the mean V_S to 30 m depth (V_{S30}), and the fundamental site period (T_G). Especially, the site periods at several seismic stations were compared with the resonance periods from the acceleration response spectra of the M_L 5.8 earthquake occurred in Gyeongju, South Korea, on 12 September 2016.

Most of the stations in Korea were site class C meaning soil condition to be amplified, based on the V_{S30} for earthquake-resistant design, rather than site class B indicating rock condition. In terms of site response parameters and their correlations, the site characteristics of the seismic stations in Korea were compared with those in other strong seismicity regions such as Japan, western US, and Turkey. The regional comparisons showed that the Korean seismic stations have region-specific geotechnical characteristics differing from those of regions with strong seismicity. In particular, the depth to bedrock in Korea is shallower and soils are stiffer than those in Japan and western US. Owing to these differences in site conditions, the site periods in the seismic stations are significantly lower than those in Japan and western US.

2.3 The full-automatic recognition of structure plane parameters in borehole image from deep-hole engineering

Chuanying Wang[1]; Xianjian Zou[1,2]; Zengqiang Han[1]

[1]*State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China; E-mail: chywang@whrsm.ac.cn*

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Keywords: borehole image; structure plane; regional division; automatic recognition; sine curve

Digital panoramic borehole camera technology has been widely employed in actual projects, and a large number of high-accuracy borehole images have been obtained. The borehole images have accurately recorded the geological information and the structure characteristics of rock mass, especially the key feature parameters of borehole structure planes. However, since the acquisition of these structure plane parameters is usually finished by manual operation, the workload is large and the results can be affected by human factors. To solve this problem, this paper presents a full-automatic recognition method of structure plane parameters in the obtained borehole image from borehole camera or imaging system. In this method, image gray, gradient values and projection method are employed to distinguish the occurrence region of borehole structural planes. Then, standard sine function matching method is employed to search the structure plane in the region. Lastly, the optimal sine curve is screened out among the kinds of conditions and it is adopted as the feature curve of the structure plane in the region. And the related parameters of these feature curves are analyzed and converted into the parameters of structure planes, such as the central position, orientation, dip angle and fracture width of discontinuity, which are required in engineering projects. This method can automatically identify the structure planes in the borehole image continuously and quickly, and obtain the corresponding structural parameters. It is stable and reliable, and greatly improves the working efficiency. This method can realize the full-automatic recognition of structure planes and the analysis of their geometric parameters in the borehole image. This paper can provide an effective and reliable solution for the improvement of drilling information acquisition technique and borehole image signal processing technique.

2.4 Monitoring of resistivity and moisture dynamics in an operational railway cutting

Sebastian Uhlemann[1,2]; Jonathan Chambers[1]; Philip Meldrum[1]; Paul Wilkinson[1]; Russell Swift[1]; David Gunn[1]; Tom Dijkstra[1]; David Hutchinson[3]

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[2]ETH Zurich, Institute of Geophysics, Zurich, Switzerland
[3]*Network Rail Infrastructure Ltd, York, UK*

Keywords: Long-term monitoring, slope stability, moisture dynamics, Resistivity monitoring

The British railway network is one of the busiest in the world. A major part was constructed more than a century ago, prior the advent of modern soil mechanics understanding. Today about 50% of the earthworks are in poor or marginal condition. There is a need for cost-effective, remote condition monitoring technology to evaluate their state. A novel Proactive Infrastructure Monitoring and Evaluation (PRIME) system has been developed, which employs electrical resistivity tomography monitoring linked with wireless data telemetry, web-portal access, and acquisition of auxiliary data. We present data obtained from an operational railway cutting over a period of about two years, employing a network of monitoring lines to study the spatial variability of resistivity and related moisture dynamics, which were linked using laboratory studies. The monitoring site comprises a combination of heavily wooded and grass covered sections. This offers the opportunity to use resistivity data to study the effects of vegetation on the shallow moisture dynamics in infrastructure earthworks and assess their impact on the slope stability. Our results show that evapotranspiration and canopy led to strongly increasing resistivities in summer, indicative of significant losses of moisture in the vegetated part of the slope, while the grassland only showed minor variability. In winter, rainfall and groundwater dynamics led to a fast saturation of the entire slope, during times when biological activities were at their minimum and no canopy was present. Resistivity, and thus moisture dynamics show significantly higher amplitudes in the vegetated than in the grass-covered part. This may lead to faster weathering of the surficial materials in the vegetated part, as the material cycles between states of very low saturation, where desiccation cracks are likely to occur, and full saturation. These insights into the moisture dynamics will aid engineers in designing infrastructure slopes and intervention strategies for unstable slopes.

Session 3: Flow and transport in the saturated and unsaturated zone / New tools for watershed characterization

(CHE-89 / June 7, 2:35 pm - 3:55 pm)

3.1 Transfer of parameter determination from the laboratory to the field

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Keywords: Monitored natural attenuation, parameter determination, remediation planning, laboratory experiment, scale factor

During the planning of MNA and ENA concepts as well as remediation planning, the representative determination of source and transport term parameters is essential as a basis. For a long time, it was assumed that the required parameters (elution rates or microbial degradation rate, for example) including the soil-physical parameters are to be determined exclusively in the field.

Through long-term experience and research in the area of migration parameter determination, reliable source and transport term parameters can be determined and verified by using laboratory tests.

The duration required for test execution and number of experimental approaches depends primarily on the scale factors that exist between the laboratory and the field. These are independent of the laboratory test procedure and form the basis for the transfer of the laboratory test results into the field. The scale factor for the trial time is equal to one. It follows that the experiments to be carried out in the laboratory cannot be shortened in comparison with the field. For example, test durations of 24 hours per experimental stage are used for investigations of adsorption and desorption processes. For microbiological investigations, the required test duration under anaerobic conditions can be up to 6 months. In principle, the collected solid samples must allow consideration for transferring the laboratory test results into the field. The prerequisite for this is the representativeness of the samples used. The number of samples is not essential, but rather the distribution of the process-determining specific value contained therein. These arise from the correlation relationships of these specific values with the source and transport term parameters. For example, it may be sufficient to consider three samples from the test area for the laboratory tests: 1) without or with low proportion, 2) medium proportion, and 3) with the highest proportion of the process-determining specific value (total organic carbon, silt or clay percentage). The corresponding conditions of the site can be plausibly transferred by means of an undisturbed sampling of the soil (preservation of the storage density, avoidance of losses of easily volatile pollutants) and the creation of natural conditions (aerobic or anaerobic conditions, temperature 10 ° C). Sustainable results form the basis for reactive mass transfer models and the resulting remediation methods.

Through selected examples, transferability of the determined parameters from the laboratory to the field has been demonstrated. For this, experiments in the field were carried out and compared to the laboratory tests. Accordingly, cost-intensive and time-consuming field trials, which are often incomplete, can be avoided.

3.2. Prediction of Solute Transport and Heat Transfer Processes in Groundwater for adequate Knowledge Levels and Data Inventory

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Keywords: parameter estimation, MNA, solute transport and heat transfer, dual porosity

Within the scope of the detailed investigation of sites containing contaminated soil and groundwater and the development of MNA-concepts (Monitored Natural Attenuation) as well as the resulting demand and extent of remediation measures, reliable prediction of contamination propagation is required. The available stage of investigation is often not sufficient to enable reliable prediction of the propagation of contaminants in the soil and groundwater area. This often results in considerable uncertainties in their assessment. In order to avoid these issues, two practice-orientated and closely linked research & development projects were undertaken. The **groundwater prediction system** (**GWSimPro**)[a)] enables the application of reactive solute transport and heat transfer simulation models in groundwater with the current state of knowledge using the model approach of dual porosity. The development of a **process-based laboratory system**[b)] is applied to automatically determine soil and groundwater migration parameters. Based on both research & development projects, a tool was developed which enables decisions as to whether remediation activities for soil or groundwater cleanup are necessary (based on risk assessment) and which remediation costs are to be expected, resulting in high standards of prediction quality, a high degree of cost certainty and acceptance by the authorities. In order to predict the spread of contaminants in soil and groundwater, a tool is used to select models which are adapted to the specific issue, status of investigation and data inventory (from simple analytical to complex numerical model solutions). In groundwater with simple hydrogeological conditions, simplified analytical model solutions are applied. For more complicated hydrogeological conditions (aquifer heterogeneity, fractured rock aquifer, necessity for 3-dimensional groundwater flow and solute transport modeling) numerical modeling is required. For parameterizing such complex models, a broad data collection is made available to the prediction system to provide any needed data.The interface between GWSimPro and the laboratory system forms a parameter tool, which provides the necessary input parameters from a database for usage in GWSimPro. The database contains more than 2,600 parameters for describing contaminant source and transport. It is thereby already possible at an early stage of investigation to be able to achieve a project-specific, reliable max./min. prediction with respect to propagation of the pollutants. In contrast to target values, it is not only possible to estimate acute risks, it is also possible to determine whether the achieved preciseness of the prediction results is adequate, or whether additional project-specific investigations/ parameters inquiries are appropriate and proportionate.

a) AiF-F&E-project in cooperation of GICON GmbH (KF2158814JA3), TU Dresden – Institute of groundwater management (KF3067301RH2) and Jungk Consult (KF3250201JA3)
b) AiF-F&E-project in cooperation of BGD GmbH (KF3294101SA4), IUP Ingenieure GmbH (KF3067102SA4) and TU Dresden – Institute of groundwater management (KF3253802SA4)

3.3 Visualizing and analyzing large hydrological datasets with correlation matrices

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Keywords: long-term monitoring; visualization; standardization; stream-aquifer interaction; catchment characterization

With the advancement of hydrological monitoring tools as well as appropriate information technologies, comprehensive hydrological data is becoming increasingly available. Thus, adequate approaches are needed to compile and analyze the data. Using the official data from the Austrian ehyd.gv.at site[a)] and standardizing it with the SPI[b)], SGI[c)] and SRSI[d)], we show an innovative, python based correlation matrix approach to visualize and compare correlations between hydrological time series of catchments and their subregions[d),e)].
We show that in the regions we analyzed, the river stages are highly correlated with groundwater levels when assessing long term (35 years and 12 years) time series. For the short term (1 year), extreme events, such as flood, drought and snow rich or poor years appear to show a distinct influence on groundwater, namely an increase in correlations under drought and snow rich conditions and a decrease in correlations under flood and snow poor conditions. Besides the analysis of the effects of extreme events, the matrix tool can also be used for evaluating the data more generally, e.g. for identifying outliers or wells that belong to different aquifer systems. For our specific regions, we conclude that human induced changes – especially when changing the stream-aquifer interaction through means such as the construction of run-of-river powerplants – are among the most important factors for the development of the aquifer dynamics over time and that in general, wells or aquifers under natural conditions are not found among the shallow aquifers within the study area.
We suggest to test this method for other regions and other resolutions – such as for example a very fine direct push based well grid at a small site or a very large scale watershed – to see if our findings and assumptions hold true in more general terms and whether this method will be an interesting addition to the hydrologists toolbox.

a) BMLFUW, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Abteilung IV/4 - Wasserhaushalt (HZB) eHYD - Der Zugang zu hydrografischen Daten Österreichs, http://ehyd.gv.at
b) McKee, T. B.; Doesken, N. J. & Kleist, J. The relationship of drought frequency and duration to time scales Proceedings of the 8th Conference on Applied Climatology, 1993, 179-183
c) Bloomfield, J. P. & Marchant, B. P. Analysis of groundwater drought building on the standardised precipitation index approach Hydrology and Earth System Sciences, 2013, 17, 4769-4787
d) Haas, J.C. & Birk, S., Characterizing the spatiotemporal variability of groundwater levels of alluvial aquifers in different settings using drought indices, Hydrology and Earth System Sciences Discussions, 2016, 1-30
e) Haas, J.C., https://climatefootnotes.com/2016/12/12/visualizing-complex-hydrological-systems-with-correlation-matrices/

3.4 Water induced soil erosion assessment and monitoring in the South High Atlas of Marrakech using remote sensing and GIS

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Keywords: Water Erosion, vulnerability, GIS, semiarid climate

The average and high mountain country semi-arid such as it appears in the High Atlas, seems a original domain very different from the wet mountain and temperate:The precipitations and the mediocrity of the vegetable cover are brutal and powerful there: it is a mountain dissected by the streaming at all elevation, even if in High Mountain the mark of the gelifraction which starts the mass movement of material, such as rock, earth or debris, down the slope of a hill or cliff.
The Imini plateau is a capable area for occurrence various kinds of erosion because of its mountainous feature, geological and climatologic variety.The main objective of this research is to produce adetailed water erosion susceptibility map for the Imini and Ounilla basin in the south front of the high Atlas of Marrakech. Erosion susceptibility zoning involves a degree of interpretationand spatial distribution rate of the terrain unitsaccording to their propensity to produce erosion which is that dependent on topography, geology, geotechnical properties, climate, vegetation andanthropogenic factors such as development and clearing of vegetation.

This study was conducted using a Geographic Information System (GIS), in order to prioritize the different areas of the sub-watershed, producing a synthetic map for the distribution of degrees of sensitivity to erosion.
In effect, three classes of multifactorial vulnerability to water erosion have been distinguished areas with low vulnerability 40.18%; the areas to medium vulnerability 24.93% and areas highly vulnerable 34.88%. As well, in the sub-basin, the classes at medium and high multifactor vulnerability represent 60% of the area.

Session 4: Thermal use of the shallow subsurface
(CHE-91 / June 7, 12:35 pm - 3:55 pm)

4.1 Thermal Process Understanding: Requirements for Monitoring Systems

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Keywords: temperature monitoring; urbanization; geothermal energy use; climate change; heat-transport models

Several anthropogenic impacts such as urbanization, geothermal energy use and climate change have changed natural thermal regimes of subsurface environments. Particularly shallow groundwater resources in urban areas often are over-heated, resulting in the so-called Subsurface Urban Heat Island (SUHI) effect.

In order to qualitatively and quantitatively protect subsurface resources and to find solutions for use conflicts, which come along with increasing urbanization and subsurface development, it is important to document the "present state" of subsurface resources. The "present state" is governed by the interaction of the various natural and anthropogenic thermal boundary conditions and impacts. The aim of our contribution is to discuss results of a combined monitoring and modeling approach to characterize thermal subsurface regimes.

Commonly groundwater temperature is measured as secondary parameter to groundwater head and usually only a few times a year, while comprehensive temperature monitoring rather is an exception than the rule. We introduced seven multilevel observation wells in the city of Basel, Switzerland, which provide undisturbed continuous temperature measurements at discrete points vertically within the coarse fluvial deposits as well as within the saturated and unsaturated zone of the aquifer. Several factors affecting the magnitude and timing of temperature increases and decreases were examined, which focus on: (1) thermal groundwater use for cooling purposes; (2) the effect of heated buildings reaching into the unsaturated and saturated aquifer, with emphasis on building density and the urban heat island effect; and (3) the role of river-groundwater interaction.

Our concept allows considering the high dynamics of hydraulic and thermal subsurface regimes and the interaction of the different natural and anthropogenic boundary conditions. The results demonstrate that the setup of multilevel monitoring systems for subsurface temperature measurements is suitable to gain an understanding on local heat-transport processes and time-rates of temperatures changes due to urban subsurface development. We show how existing conventional monitoring systems can be supplemented by multilevel groundwater temperature measurements which provide a useful data basis to improve the parameterization of local and regional scale 2D and 3D numerical heat-transport models.

4.2 Soil thermal behavior in different moisture condition: an overview of ITER Project from laboratory to field test monitoring

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Keywords: soil, thermal conductivity, very shallow geothermal energy, helix, heat exchangers

The thermal properties of soils can be considered one of the most important parameters for many engineering projects designing. In detail, the thermal conductivity plays a fundamental role when dimensioning ground heat exchangers, especially very shallow geothermal (VGS) systems, interesting the first 2 m of depth from the ground level. However, the determination of heat transfer in soils is difficult to estimate, because depends on several factors, including, among others, particle size, density, water content, mineralogy composition, ground temperature, organic matter.

The performance of a VSG system, as horizontal collectors or special forms, is strongly correlated to the kind of sediment at disposal and suddenly decreases in case of dry-unsaturated conditions in the surrounding soil. Therefore, a better knowledge of the relationship between thermal conductivity and water content is required for understanding the VSG systems behavior in saturated and unsaturated conditions.

Key challenge of ITER Project, funded by European Union, is to understand how to enhance the heat transfer of the sediments surrounding the pipes, taking into account the interactions between the soil, the horizontal heat exchangers and the surrounding environment.

In order to obtain reliable data for modelling, an interdisciplinary approach is used. In laboratory the physical-thermal properties of more than 15 soil mixtures, consisting in (i) natural soil, (ii) pure sand and (iii) mixtures of pure sand and clay additives, have been tested under different water content percentages and different consolidation degree. Then the same parameters are monitored in the project case study, in Eltersdorf, (Germany), where five helix collectors are installed in horizontal trenches filled in with five different mixtures already tested in laboratory. In addition, a monitoring system allows to record every 15 minutes, by means of devoted sensors, values related to ground temperature (undisturbed, inside and outside each helix), fluid temperature and flow running in the collectors, volumetric water content at 20 and 60 cm depth. Moreover, a meteorological station provides climatic data acquisition as rainfall, wind speed, relative humidity and air temperature.

The main results achieved until now are useful for future modeling because shed new light (i) on the differences between data collected in laboratory and in the field and (ii) on the influence of the technical solution adopted in situ to fill in the trenches, able to create a non-homogeneous distribution of the soil bodies around the helix.

4.3 Visual measurement and model reconstruction for the shallow structure of underwater topography and rock mass by using B-mode ultrasonic imaging device

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Keywords: Ultrasonic imaging; underwater topography; rock mass shallow structure; visual measurement; model reconstruction

The shallow structure of rock mass and topography under muddy water or in sediment-laden flow is often clouded by suspended or moving particles, which is hard to be detected for the visual analysis and real-time measurement in engineering application. The real-time observation and model reconstruction of shallow structure for underwater rock mass and sedimentary topography is vital for many geotechnical engineering projects. In this paper, a novel visual measurement and 3D model reconstruction method is described for the shallow structures of topography and rock mass under muddy water based on the real-time ultrasonic video images, which is obtained by using B-mode ultrasonic imaging device. This method is based on the similarity and gradual change of sedimentary topography and the imaging of rock mass in the consecutive multi-frame images to automatically identify underwater boundary lines and shallow structures. And then the change of topographic lines and rock mass shallow structure is real-time measured and the true 3D model topography is reconstructed by these measured lines according to the ultrasonic imaging features of underwater topography and rock mass. Experimental results show the shallow structure of rock mass and sedimentary topography can be clearly showed and the visual measurement and 3D model reconstruction error of underwater topographic bed surface can be less than 1 mm when used in inner model testing. This method can effectively neglect the imaging interference of moving or suspended particles on the analysis of topography and rock mass under muddy water or in sediment-laden flow. Underwater invisible topography and rock mass surface can be easily re-appeared with the advantages of fast speed, high accuracy and real time. Geology shallow structure reconstruction and measuring analysis has clearly shown the morphology characteristics of underwater geographic and geomorphic conditions and their inner distributions. Ultrasonic imaging method is an effective approach for the research of surface water-sediment movement for riverbed erosion and deposition under muddy water and flow conditions. It is also an effective approach of visual measurement and model reconstruction for the shallow structure of underwater topography and rock mass.

4.4 European Project "Cheap-GSHPs" – Installation and monitoring of new designed helicoil ground source heat exchanger on the German test site

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Keywords: very shallow geothermal, backfilling material, monitoring, renewable technologies

Nowadays the energy price fluctuations and the economic crisis are jeopardizing the development and diffusion of renewable technologies and sources. With the aim of both reduce the overall costs of shallow geothermal systems and improve their installation safety, an European project has took place recently, under the Horizon 2020 EU Framework Programme for Research and Innovation. The acronym of this project is Cheap-GSHPs, meaning "Cheap and efficient application of reliable Ground Source Heat exchangers and Pumps"; the Cheap-GSHPs project involves 17 partners among 9 European countries such Belgium, France, Germany, Greece, Ireland, Italy, Romania, Spain, Switzerland. In order to achieve the planned targets, a holistic approach is adopted, where all involved elements that take part of shallow geothermal activities are here integrated.

In order to reduce the specific costs of geothermal installations some new designed geometries of heat basket type ground source heat exchanger (GSHE) is modified drastically to receive a better performance of the geothermal installation. Within the sector of very shallow geothermal systems these new developments are being tested on six representative demonstration sites around Europe. At the German test site in Northern Bavaria four heat basket type GSHE are installed and equipped with certain monitoring systems (moisture, two different temperature sensors) and various backfilling materials of different grain size classes. The different installations will we tested for 12 months to evaluate the best combination of the new designed heat basket type GSHE and corresponding backfilling mixture.

Session 5: Long Term Monitoring
(CHE-89 / June 8, 9:15 am - 10:35 am)

5.1 New tool for authentic groundwater sampling and monitoring and a VOC case study

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Keywords: groundwater monitoring, sampling, adulteration, VOC, mass balance

Long-term monitoring results of groundwater quality are influenced by time-dependent variations that are of interest (e.g., contaminant degradation, temporarily occurring pollutants, recharge effects) and by interfering time-independent variations or bias. The latter are created, e.g., by the sole presence of the monitoring well or in combination with sampling methods and sample handling. This effects can by large enough to mask actual changes in the aquifer. The innovative monitoring and sampling system consisting of GW-Shuttle (Groundwater-Shuttle) and GWMon-Station (Groundwater-Monitoring-Station) tackles this problems. The system is applicable for retrofitting existing intact monitoring wells and can be removed non-destructively and quickly, if necessary. It protects the aquifer from contact with the chemically altered casing water of the well and enables depth-oriented continuous monitoring plus repeated depth-oriented, isobar retrieval of unadulterated groundwater samples at the same time.

Current research results show that vertical mass transport between atmosphere and aquifer or within the aquifer often exists in the water column of groundwater monitoring wells, even if they are constructed conforming to standards[a)]. Mass transport is caused by unavoidable vertical gradients in pressure, temperature and/or mass concentration. Infiltration and propagation of the altered water in the aquifer can lead to an adulteration of the geochemical setting in the probed aquifer region around the monitoring well. Hence, unprotected in-situ measurements by stationary data loggers or passive samplers and conventional pump or scoop sampling methods can be considerably biased by these unwanted effects[b)].

The patented system of GW-Shuttle and GWMon-Station tackles a further problem of groundwater sampling. With the GW-Shuttle water samples are retrieved and transported isobaric and under in-situ pressure. Degassing effects and thus changes in pressure-dependent parameters, such as oxygen and carbon dioxide content, redox potential and pH value, content of volatile organic compounds (VOC), but also chemical precipitation reactions, are prevented thereby. In combination with the lately developed Lab-Transfer-Module, this water samples under in-situ pressure can be depressurized under control while preserving mass balance.

To show the advantages of the new system, a case study of a halogenated volatile hydrocarbon monitoring was conducted in a drinking water catchment area. The variability of the contaminant concentrations was captured by 17 water samples retrieved by the GW-Shuttle over a duration of nine month. In all probes at least 1,2-Dichloroethane (12DCA) and Tribromomethane (TBrM) were found. The concentrations of 12DCA were all above the limit of German Ordinance on Potable Water from 2001 (3,0 µg/L). Only the water sample obtained with a groundwater sampling pump immediately before installing the new system, showed a concentration below the official limit. The TBrM concentrations showed similar results.

a) Boerner & Berthold 2009, Groundwater Geophysics – A Tool for Hydrogeology, p. 367-389
b) Berthold et al. 2010, wwt 4/2010, p.14-17

5.2 A novel approach to online-biotoxicity monitoring of groundwater

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Keywords: biotoxicity, groundwater, online, monitoring, sensor-technology

Traditionally, groundwater monitoring is performed by the analysis of chemical and physical parameters. These do not allow any conclusions on the effect of toxic substances. Therefore, additional biological tests for the monitoring of groundwater are creating increasing interest. This work focusses on the application of an online biotoxicity measurement system for use in groundwater monitoring.
The objective in the first part of this work was to measure the change in motion of the test organism *Gammarus pulex* with different groundwater constituents. The experiments were carried out with the biomonitoring system SensaGuard under laboratory conditions. The typical groundwater constituents chloride, nitrate, sulfate, potassium, magnesium and calcium were tested. Salts with the sodium cation and the chloride anion were used for testing the groundwater constituents. For each substance, experimental series were performed with 6 concentrations.
Experimental series were tested with the environmental pollutants arsenic and lead in the second part of this study. The experimental series were conducted in soft water and hard water. The tests proof if the water hardness will affect the response of the gammarids to the pollutants.
Three methods was used for the analysis of the results. The changes in movement of *Gammarus pulex* between the phase of adaption and the experimental phase were compared. The qualitative analysis was performed in two variants. The direction of the movement is the difference in the two variants. The first version distinguishes between the direction, the second version considers the reaction in itself. The quantitative analysis was carried out with the Wilcoxon Signed-Rank test. Here, a significance level of 5% was chosen.
The results for the first part of the study show that Gammarus Pulex reacts to the substances chloride, nitrate, potassium, magnesium and calcium. No reaction was recorded for the series of experiments with sulfate. The comparison of the results of the three analysis methods has generally shown a good correlation for the reaction of *Gammarus pulex*. Differences were seen in the concentration, which leads to a reaction. In the analysis method of the qualitative variant two and the quantitative method, the gammarids react at a lower concentration than in the qualitative analysis variant one.
The experiments with arsenic showed that the gammarids reacted to the addition. For the trend-dependent qualitative method a reaction-causing concentration was observed at 50 µg/l arsenic. The other two methods showed a reaction-causing concentration at 10 µg/l arsenic. Reactions in the experiments with lead were detected only up to a concentration at 25 µg/l. Then the tests were carried out in hard water. The results showed that the reaction of *Gammarus pulex* is affected by the water hardness.The tests provided evidence that it is generally feasible to use online biotoxicity measurement systems for groundwater monitoring. However, natural occurring groundwater characteristics, e.g. water hardness, may have an effect on the biotoxicity observed.

5.3 A practical, robust method for sampling design using groundwater models with large computational requirements

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Keywords: Experimental Design, Uncertainty Quantification, Regional Groundwater Modeling

Groundwater models play an important role in the management of water resources; however, the uncertainty associated with model parameters and model assumptions can significantly hinder the reliability of model predictions. One way to reduce this uncertainty is to collect new observation data from the field; however, knowing where and when to obtain such data is not straightforward. Methodologies known as data-worth and experimental design are developed for this purpose. However, these current methods often ignore issues related to real-world groundwater models such as, computational expense, existing observation data, high parameter dimension, etc. In this study, we propose a methodology, comprised of existing methods and software, to efficiently conduct such analyses for large-scale, complex regional groundwater flow systems for which there is a significant amount of available observation data. The proposed method employs the well-established d-optimality criterion, and the minimax criterion for robust design. The so-called Null-Space Monte Carlo method is used to reduce the computational requirements associated with uncertainty quantification. Additionally, a heuristic methodology, based on the concept of the greedy algorithm, is proposed for obtaining robust designs using a subset of the posterior parameter samples. The proposed methodology is applied to an existing, complex, regional groundwater system in the Perth region of Western Australia. The Perth Regional Aquifer Model (PRAMS) framework has been used for over a decade now to evaluate the potential anthropogenic impacts associated with groundwater management decisions. PRAMS is quite complex in that it contains over 1,000 parameters, and has a computer run-time of about three hours. A primary prediction commonly addressed using PRAMS will be the environmental effects of various deep-aquifer groundwater management scenarios. A particular model-structure component that greatly affects these predictions is the characterization of the local fault structure. Therefore, the objective of the sampling design was to obtain new water-level data to maximize information about fault parameters. The proposed methodology successfully evaluated an optimal, robust design that is immune from the adverse effects associated with potential design artefacts that arise from parameter uncertainty. The results have provided a valuable tool for governmental decision-making regarding the completion of new monitoring bores.

5.4 Standardization of groundwater sampling for microbiological investigations

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Keywords: microbiology, standardization, groundwater sampling, gas-tight sampling system, pump flow

Groundwater is Germany's most important drinking water resource. However, several sources have influenced its quality at many locations. Currently, there are no standardized indicators and methods for evaluating the ecological functioning and stress tolerance of groundwater ecosystems. Rather, even standardized sampling procedures struggle to obtain representative samples for biological analyses.
Based on current legislation for conventional groundwater monitoring (with the purpose of chemical characterization), and taking into account previous knowledge, the planning and implementation of groundwater sampling for the detection of microbiological parameters was critically scrutinized. The increased sensitivity of microbiological parameters with regard to sampling procedures (e.g. pump flow and well construction) could be demonstrated by means of comparative studies. A low variability of the standard physicochemical parameters (temperature, pH, electrical conductivity, dissolved oxygen and redox potential) does not allow any conclusions to be drawn regarding the variability of microbiological parameters (e.g. total cell count, microbial activity, abundance of heterotrophic bacteria and coliforms). In contrast to physicochemical parameters, these microbiological parameters exhibit pronounced, temporary rise upon increased pump flow rates, indicating a removal of biofilms from the filter area of the well. In the case of missing seals, the volume to be pumped must be increased by an order of magnitude in order to remove water influenced by the measuring point and to detect the mobile biocenosis located outside the well. Thus, both the volume to be pumped and the flow rate are to be adapted to the specific microbiological question, where appropriate.
Furthermore, comparative studies were carried out among different sampling techniques to examine the influence of the sampling equipment on microbiology. A gas-tight, sterilizable sampling system, which enables in-situ sampling and maintains the existing environmental conditions in the sampling vessel until the sample can be analyzed, was tested. This system minimizes contaminating the groundwater sample with ambient microorganisms. Such interference became apparent due to increased abundance of coliforms when collecting common bailed samples and by means of conventional sampling.
The newly acquired and validated findings are used to standardize sampling procedures for biological investigations and to prepare a guideline for the implementation of groundwater sampling for the detection of microbiological parameters, which is made available to the environmental authorities and the water management industry. The standardization of groundwater sampling for biological analyses is the first and most important step in obtaining representative samples for an informative monitoring of the groundwater ecosystem.

Session 6: Hydrological, hydrochemical and hydrogeological investigation techniques and Characterization at the interface

(CHE-91 / June 8, 9:15 am - 10:35 am)

6.1 The application of geoelectrical methods for understanding the Punata aquifer (Bolivia)

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Keywords: Time Domain Electromagnetic, Electrical Resistivity Tomography, Punata alluvial fan

In many parts of the world, agriculture is the main social and economic activity. Consequently, agriculture becomes one of the principal uses of water, and the most common of get it is from surface water, e.g. rainfall, rivers, and lakes. However, climate change has affected the water budget in many regions of the world leading to severe shortages. Therefore, groundwater can be an important water source, and this importance becomes more evident in arid and semiarid areas, where there is a deficit in the surface water supply. In Bolivia, a semiarid region is the Punata alluvial fan, which is an agricultural zone. In the study area, the deficit in water supply led to the local people to drill boreholes, increasing considerably in the recent years. However, the real geometry of the aquifer system is partially unknown. In order to fill in the gaps and demonstrate the applicability of indirect data retrieved from geoelectrical methods several surveys were performed. Electrical Resistivity Tomography (ERT), Normalized Chargeability and Time Domain Electromagnetic (TDEM) surveys were performed in the Punata alluvial fan. The ERT measurements proved to be a good tool for mapping the subsurface in alluvial fan, especially when used in combination with Induced Polarization parameters (i.e., Normalized Chargeability); the interpretation of the results showed an unconfined aquifer close to the apex fan, and a confined aquifer in the distal part of the fan, The TDEM sounding were performed in a grid of 150 m separation, which provided significant information for proposing 2-D and 3-D models where it is possible to analyze the lateral and vertical extent of the different layers. Moreover, TDEM measurements reached greater depths than ERT. TDEM method is sensitive to low resistivity features, and this sensibility assisted in identifying a thin layer with brackish water in the aquifer bottom. With the integration of the results and lithological information, a refined conceptual model is proposed; this model gives a more detailed description of the local aquifer system. It can be concluded that geoelectrical methods are useful for mapping aquifer systems in alluvial fans, and with the gathered information, further planning and policies can be proposed for a sustainable and appropriate groundwater exploitation.

6.2 Solute Tracer Tomography: Field Proof-of-Concept for Aquifer Characterization

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Keywords: aquifer characterization, hydraulic tomography, tracer tomography, ensemble kalman filter

Aquifer heterogeneity is a key characteristic controlling to a large extent groundwater flow and solute transport. To enhance the performance of hydrogeological models, this heterogeneity needs, very often, to be described at a high resolution. Recent numerical studies on parameter estimation and inverse modeling show the advantages of using not only large datasets, but also of different type (e.g. from hydraulic and tracer tests) for describing small-scale features of aquifer properties. Field applications, however, lag behind mainly due to technical limitations. This work presents a method for subsurface characterization, using measurements from a field hydraulic and solute-tracer tomography test to constrain the estimation of parameters with the Ensemble Kalman Filter. While hydraulic tomography has been repeatedly applied at a field scale, field applications of tracer tomography experiments were so far mostly limited to heat tracer testing. A strong limitation of heat as a tracer - among others - is its high diffusivity, reflected in highly dampened temperature signals within short distances from an injection point. We design an experimental setup to implement a tracer tomography using a conservative solute (Uranine) as tracer, rather than heat. To estimate the spatially distributed hydraulic conductivity of the aquifer, the collected dataset was analyzed with the Ensemble Kalman Filter, coupled to a three dimensional groundwater flow and solute transport model. This filter is a Monte Carlo-based approach that avoids an explicit calculation of sensitivities, and the uncertainty is propagated via the statistics of the ensemble. The efficiency of the filter allows the description of aquifer heterogeneity at a high resolution while keeping reasonable computational costs. To proof the applicability of the method, a hydraulic and solute-tracer tomography experiment was performed in the shallow alluvial aquifer at the Research Site Lauswiesen, Tübingen, Germany. Results show the benefits of combining data from both hydraulic and tracer tomographic experiments, expressed in the estimated hydraulic conductivity fields, and better model predictions. This study pursues to narrow the gap between numerical studies and field applications, showing the potential of hydraulic and solute tracer tomography for high-resolution aquifer characterization.

6.3 Depth dependent groundwater sampling during regular well operation for RBF flow model calibration

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Keywords: Riverbank filtration, iron, manganese, depth dependent sampling, Elbe River

Water quality at most riverbank filtration (RBF) sites is monitored by regularly taken samples from the standpipe above the surface. Thus, each water sample represents a composite of bank filtrate and possibly groundwater entering the entire screen. Depth dependent sampling allows determining, if discrete zones along the filter screen show varying water qualities. Common depth dependent sampling approaches do first remove the pump and afterwards lower a smaller pump combined with a packer system. In this study, a depth dependent sampling procedure was applied during the regular well operation at eight pumping wells from two RBF sites in Dresden (Germany) and Cairo (Egypt). A peristaltic pump with an attached PTFE hose and a sinter filter fitted to the hose end was used. The hose was lowered into the pumping wells through the inner observation well, which was open below the pump. In Dresden, results indicate that groundwater flow from the opposite riverbank below the riverbed of the Elbe River, causes elevated manganese concentrations in the raw water. Depth dependent water quality in Cairo suggests that the thick organic-, Fe- and Mn-rich riverbed of the Nile River is a source for iron, manganese and ammonium in the riverbank filtrate. Results helped to calibrate groundwater flow models for travel time estimation. The applied methodology avoids time-consuming pump removal and does not require expensive equipment. Furthermore, steady-state flow conditions to the well are not disturbed by changing the pump.

6.4 Combining geophysical and tracer methods on multiple scales to assess the hydraulic connection between lake and aquifer

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Keywords: groundwater-surface water exchange, temperature as a tracer, water stable isotopes

Lake bank filtration can be a successful method for extracting water from surface water bodies provided that there are shallow aquifers near the lake with a good hydraulic connection to the surface water body. The aim of this study was to establish if lake bank filtration is a feasible method for water extraction from Tissoe, the fourth largest lake in Denmark, where the present water extraction of 5 million m³/year surface water could be increased by an additional 5 million m³/year.

Several geophysical and thermal methods and chemical tracers were used at various spatial scales to obtain detailed information in the area of the selected site of investigations. On the large scale, the shallow subsurface sediments were mapped by Electrical Resistivity Tomography and Ground Penetrating Radar measurements both offshore and on-land over a 5 km long shoreline. Based on these surveys, the hydraulic connection at the sediment-water interface was characterized at a selected site by the aid of thermal and chemical tracer methods. On the medium scale, aerial thermal imagery was used to identify temperature patterns at the air-water interface, followed by the qualitative mapping of potential groundwater discharge locations at the lakebed by Distributed Temperature Sensing (DTS). Groundwater flow and mixing was also traced by sampling for water stable isotopes both in piezometers on-land and vertical profiles off-shore. On the point-scale, exchange fluxes across the sediment-water interface were calculated based on vertical temperature profiles from the upper 0.5 m of the lakebed.

The offshore geophysical surveys efficiently identified several areas of interest with disconnected lenses of coarser material. The spatial extent of these areas was suitable for the medium scale thermal mapping with aerial thermal imagery and DTS which indicated groundwater discharge to the lake at 80-100 m distance from the shore at a selected site. Finally, point-scale flux estimates gave a more detailed image of the spatial and temporal variability in groundwater discharge.

Session 7: Near-surface and borehole geophysics
(CHE-89 / June 8, 11:55 am - 12:35 pm)

7.1 Geotechnical properties from geophysical data: Estimating uncertainties related to data inversion and petrophysical relations

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Keywords: site characterization, parameter estimation, global inversion, Monte-Carlo methods

Near-surface geophysical imaging techniques such as seismic, electrical, and ground-penetrating radar (GPR) tomography are extensively used in a variety of engineering, environmental, geologic, and hydrologic applications. Often, they represent the only means to explore subsurface environments in two or three dimensions. Traditionally, the first step in a geophysical interpretation is to infer structural models representing geological units and interfaces. In addition, because many of todays applications ask for detailed, quantitative models of selected material properties, geophysical data are increasingly used to estimate such target properties. Such a more quantitative interpretation is usually performed using petrophysical models relating the imaged geophysical parameters to the actual material properties of interest. For example, this includes the translation of electrical resistivity and GPR velocity into models of water content and porosity or the translation of seismic P- and S-wave velocity into sets of elastic and geotechnical properties. The workflow associated with this parameter estimation problem is a two-step procedure comprising (i) the inversion of geophysical data and (ii) the petrophysical translation of the inverted parameter models into the target properties. Standard deterministic implementations of this workflow result in a single best-estimate model, in which the uncertainties related to (i) and (ii) are often not considered and propagated, respectively.
Here, we address the problem of estimating uncertainties related to geophysical data inversion and petrophysical translation by using stochastic and Monte Carlo procedures, respectively. We present a workflow relying on a global approach to jointly invert different geophysical data sets and a Monte Carlo procedure to estimate target properties from the inverted geophysical parameter models. This allows for propagating the identified uncertainties in the geophysical model domain and concurrently considering uncertainties in the used petrophysical relations. We apply our workflow to crosshole GPR and seismic data sets (P- and S-wave) collected at a well-constrained test site for a detailed characterization of sand and gravel deposits. The global joint inversion of GPR and seismic traveltimes results in ensembles of acceptable velocity models, which are analyzed to appraise inversion-related uncertainties. Then, the entire ensembles of inverted velocity models are considered to estimate selected petrophysical properties including porosity, bulk density, and elastic moduli using well-established petrophysical relations. Our results demonstrate the potential benefit of such an advanced interpretation strategy; i.e., the proposed workflow allows to study how uncertainties propagate into the finally estimated property models, while concurrently we are able to study the impact of uncertainties in the used petrophysical relations. We conclude that such statistical approaches for the quantitative interpretation of geophysical data can be easily extended and adapted to other applications and geophysical methods and might be an important step toward increasing the popularity and acceptance of geophysical tools in engineering practice.

7.2 Advancement of field exploration methods for non-liquid pollutant phases: Impulse-Neutron-Neutron-Method (INN) and Radon Method

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Keywords: INN, Radon, NAPL

Organic non-liquid pollutant phases are the major source-term for contamination located in the vadose and groundwater zones. Furthermore, the qualitative and quantitative field explorations of these phases are challenging. The determination of the actual distribution of pollutant phases by means of phase-measurement or sampling in groundwater observation wells is unquantifiable and sampling of soil is expensive and time-consuming. Based on these facts, the development of a screening method for the near-surface vadose zone and a quantifying, space-filling measurement system for the groundwater zone was encouraged.
The Radon Method is a screening method, for which the measurement system is based on the accumulation of radon in organic, non-liquid pollutant phases. Radon is produced from radium, which is a natural soil component, and transported in the gas phase. Measured values can be processed rapidly, due to a combination of soil-gas-measurements, specially-adjusted measurement technology, process software and geological data based on a graphical user interface.
The INN Method (impulse-neutron-neutron) has been established as an exploration technique. As part of a "EuroNorm" government-funded research project, the method was developed for a quantitative exploration of DNAPL and LNAPL within a measurement radius of approximately 5 meters by distinguishing aqueous substances.

Key advantages of this method are:

- flexible and efficient exploration of non-liquid pollutant phases and plumes with graphic supported evaluation software
- utilization of groundwater observation wells with diameters from 50 mm
- transportable measurement system fitting inside a vehicle (no fixed installation required)

The model-based combination of petrographic parameters (hydrogeological structure-model) and measured values allows the interpretation, three dimensional visualisation and quantification of non-liquid pollutant phases. The developed INN-method has been verified through wide-ranging praxis tests for chlorite and aromatic hydrocarbons. In addition to a short introduction of the respective measurement system, concrete results of selected projects will be presented.

Session 8: Characterization at the Interface
(CHE-91 / June 8, 11:55 am - 12:35 pm)

8.1 Validation of a New Device to Quantify Groundwater-Surface Water Exchange

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Keywords: groundwater-surface water, exchange, technology, Point Velocity Probe, tracer tests

Flow patterns at the groundwater-surface water interface should be expected to be as complex as the associated geologic deposits making up the stream or lake beds, and the underlying aquifers. With such complexity in mind, conventional Darcy-based methods of characterizing flow systems have significant limitations, including reliance on parameters with high uncertainties (e.g., hydraulic conductivity), the need for drilled wells, and potentially lengthy measurement times for aquifer characterization and water level measurements. Recently, alternative methods of characterizing these flow patterns, such as temperature profiling, have gained popularity. However, at the GWSWI
Vertical temperature gradient measurements can be affected by horizontal hyporheic flow, which can vary in magnitude and depth on a site-specific basis, limiting the usefulness of measurements near the GWSWI. The Streambed Point Velocity Probe (SBPVP), a newly developed tool designed to quantify groundwater-surface water interactions (GWSWI) at the interface, can effectively, rapidly, and, with high density sampling, accurately complement conventional methods. The SBPVP is a direct push device that measures *in situ* water velocities at the GWSWI on the basis of a small-scale tracer test on the probe surface. Tracer tests do not have the same limitations as Darcian approaches because they do not rely on hydraulic conductivity or gradient information, nor do they require long equilibration times. Additionally, the SBPVP is designed to take measurements unaffected by hyporheic flow, and therefore, can function directly at the interface. Laboratory testing indicated that the SBPVP has an average accuracy of ± 3% and an average precision of ± 2%. Preliminary field testing, conducted in the *Grindsted Å* in Jutland, Denmark, yielded results with promising agreement between groundwater fluxes, determined by conventional methods, and those estimated from the SBPVP tests executed at similar scales. These results suggest the SBPVP is a viable tool to quantify groundwater-surface water interactions in high definition in sandy streambeds.

8.2 An Assessment of Alluvium Aquifer Characterization and Subsurface Mapping to Detect Fresh and saline water aquifers in Karak Valley, Khyber Pakhtunkhwa, Pakistan

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Keywords: Hydrogeology, groundwater modeling, Karak valley, Resistivity inversion, salinity

Karak valley lies in a semi-arid area of Pakistan where the fresh water supply is one of the main issues as the presence of high amount of total dissolved solids salt content makes the subsurface water highly saline. The over exploitation of ground water due to increase in population and decrease in rainfall is also a major agents in increase in groundwater salinity. To overcome these problems, delineation of fresh and saline water interfaces in subsurface is fundamental for urbanization and agricultural purpose. This study utilizes the inversion of 1D electrical resistivity data acquired as a part of ground water investigation in Karak Valley, Khyber Pakhtunkhwa, Pakistan. The inverted results were converted into 2D and 3D resistivity surfaces maps to achieve the objectives. The available borehole data at different locations in the area were useful to map the near surface lithology and to calibrate the modeled resistivity curves. The formation resistivity value was calculated at each resistivity point and calibrated with drilled boreholes lithologies. The electrical resistivity data indicates that a thick cover of Quaternary sediments is present in the valley. The re-inversion of 1D electrical resistivity data with modern analysis techniques was highly effective to map the boundary between fresh and saline water aquifers in the Karak Valley. The zone of brackish water is clearly seen in the resistivity inverse model. The generated 2D resistivity surface maps at different depth levels above and below the water table and formation resistivity map were very useful to map the boundary between fresh and saline water zones. The presence of saline water aquifer with clay rich sediments was identified by very low resistivity values on the northern part whereas relatively high resistivity values with sand and gravel sediments on the south eastern part indicate the presence of fresh water aquifer. The results of this study are very useful for groundwater monitoring and tubewells installation in the study area.

Session 9: DP Applications
(CHE-89 / June 9, 9:45 am - 10:45 am)

9.1 Evaluating Hydrostratigraphy and Water Quality with the HPT-GWS System

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Keywords: DP logging, Groundwater profiling, Archies Law

Over the past few years the hydraulic profiling tool (HPT) with its injection pressure logs and tandem electrical conductivity (EC) logs has proven to be a valuable technology for detailed characterization of site hydrostratigraphy in unconsolidated formations. A modified HPT probe has been designed with multiple injection ports that also may function as sampling ports. This probe is called the Hydraulic Profiling Tool-Ground Water Sampler. Field testing of the HPT-GWS was conducted in an alluvial aquifer system in central Kansas, USA at depths approaching 30m to evaluate performance of the tool.

The injection pressure logs were monitored to define the hydrostratigraphy and determine permeable zones in the formation where groundwater could be successfully sampled. At selected depths probe advancement was halted and a small down-hole pump was operated to purge groundwater from the aquifer. Water quality parameters were monitored to stability prior to sampling. Changes in water quality parameters versus depth were observed and used to guide selection of depth intervals for sampling major element cations/anions as well as arsenic, barium and uranium.

During field work, subtle variations in the EC log across the coarse-grained aquifer were observed where the corrected HPT pressure log (Pc) was flat. A strong relation also was observed between groundwater specific conductance and bulk formation EC in the coarse-grained aquifer facies. Modeling of field data found that the DP EC logs follow Archie's Law in the aquifer facies even at the relatively low dissolved ion concentrations observed. Additionally, both positive and negative EC anomalies were identifiable by contrasting the background EC log with other EC logs across the site. Negative EC anomalies were observed where fresh water recharge was occurring below local storm water retention basins. Conversely, positive EC anomalies were observed where brine from the underlying shale bedrock was impacting the water at the base of the aquifer. Results for arsenic and uranium were all below action levels indicating that neither the fresh water recharge nor the brine impact were mobilizing these naturally occurring, hazardous elements. However, the elevated levels of sodium, chloride and sulfate due to the brine impact in the lower zone of the aquifer limit its use for a municipal water supply in this area.

The results demonstrate that the HPT-GWS can be used to define formation hydrostratigraphy at the centimeter-scale and sample for contaminants at multiple depths (profiling) in permeable formations. The system also could be used to effectively assess seawater/brine impact and evaluate sites for placement of aquifer recharge basins or wells.

9.2 Direct push injection logging for high resolution characterization of low permeability zones

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Keywords: Direct push, high resolution, site characterization, low permeability

One of the grand challenges for groundwater protection and contaminated site remediation efforts is dealing with the slow, yet persistent, release of contaminants from low permeability zones. In zones of higher permeability, groundwater flow is relatively fast and contaminant transport can be more effectively affected by treatment activities. In the low permeability zones, however, groundwater flow and contaminant transport are slow and thus become largely insensitive to many in-situ treatment efforts. Clearly, for sites with low permeability zones, accurate depiction of the mass exchange between the low and higher permeability zones is critical for designing successful groundwater protection and remediation systems, which requires certain information such as the hydraulic conductivity (K) and porosity of the subsurface. The current generation of field methods is primarily developed for relatively permeable zones, and little work has been undertaken for characterizing zones of low permeability. For example, the direct push injection logging (DPIL) approach (e.g., Hydraulic Profiling Tool by Geoprobe) is commonly used for high resolution estimation of K over a range of 0.03 to 23 m/d. When K is below 0.03 m/d, the pressure responses from the current DPIL are generally too high for both the formation (potential formation alteration at high pressure) and measuring device (pressure exceeding the upper sensor limit). In this work, we modified the current DPIL tool by adding a low-flow pump and flowmeter so that injection logging can be performed with much reduced flow rates when K is low. Numerical simulations showed that the reduction in injection rates (reduced from 250 to 1 ml/min) allowed pressures to be measurable even when K was as low as 0.001 m/d. They also indicated that as the K decreased, the pore water pressure increase induced by probe advancement had a more significant impact on DPIL results. A new field DPIL profiling procedure was developed for reducing that impact. Our preliminary test results in both the lab and at a field site have demonstrated the promise of the modified DPIL approach as a practical method for characterizing low permeability zones.

9.3 Application of the Optical Image Profiler (OIP) to Characterize the Grimm Oil Site: Kalona, Iowa (USA)

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Keywords: Fluorescence, LNAPL, UV LED, EC log, CMOS camera

The Optical Image Profiler (OIP) has been developed by Geoprobe Systems for the delineation of petroleum light nonaqueous phase liquids (LNAPL) in the subsurface. The probe uses an ultra-violet light-emitting diode (UV LED) to induce fluorescence in multi-ring aromatic hydrocarbons in unconsolidated formations. The LED is positioned behind a sapphire window in the probe and UV induced fluorescence from the formation passes back through the window to be captured by a small CMOS camera mounted behind the window. Images of the fluorescence are captured by the camera at a rate of 30 frames per second and analyzed by the system software to determine the percent of image area exhibiting fluorescence. The images are viewed real-time on-screen as logging is conducted. One image is saved for every 0.05 ft (~15 mm) of log depth and may be reviewed later with the DI Viewer software. The percent area of fluorescence is plotted on the OIP log versus depth. A visible light LED is included in the probe and allows the operator to capture images of the formation color and texture at selected depths. In addition, the OIP probe includes an electrical conductivity (EC) array to measure and log the bulk formation EC. At many sites higher EC readings indicate increased clay content while lower EC suggests coarser-grained materials.

The Iowa Department of Natural Resources (IDNR) invited Geoprobe to demonstrate the OIP logging system at the Grimm Oil Site in Kalona, Iowa, USA. Kalona is a small farming community in eastern Iowa; it is located on the alluvial deposits of the English River. The facility had at least three underground storage tanks (USTs) and two pump islands to dispense gasoline and diesel fuels. Geoprobe coordinated with Jeff White at IDNR and James Goodrich at VJ Engineering to run 18 OIP logs, mostly along two transects, across the site. Log depths ranged from approximately 7 m to 9 m and 17 of the logs were completed in two days.

The OIP logs revealed fluorescence from LNAPL occurred primarily between 3.5m to 5.5m depth in the upper silty-sandy unit. Significant fluorescence also was observed between 6m to 7m depth near the north pump island in a lower sandy unit. Log #7 revealed that significant LNAPL was present across the street from the facility while log #14 indicated some LNAPL was present near the closest residence, elevating the risk level. Cross sections based on EC logs and targeted soil cores indicated an upper fine-grained unit across the site underlain by two silty-sandy units divided by a second, thin, fine-grained unit. Most LNAPL fluorescence was observed in the upper silty-sandy unit extending south and west of the pump islands; none was observed in the area where the USTs had been removed. The responsible party is working with IDNR to determine how to address LNAPL and site closure.

Session 10: High resolution characterization I
(CHE-91 / June 9, 9:45 am - 10:45 am)

10.1 Utilization of discrete conduit-continuum models to screen controlling parameters on hydrodynamic behavior of karst aquifers

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Keywords: karst, spring observation, fissured / fractured rock matrix, Modflow, inverse simulation

Karst aquifers are highly anisotropic, heterogeneous groundwater systems where recharge, storage, flow, and discharge processes may take place throughout a wide range of opening sizes. Due to this peculiar hydrogeological setting, exploration and characterization of karst aquifers is a demanding and costly task. Although some karst aquifers are well studied, utilizing long-term observations of hydrodynamic and physicochemical signatures, controlling aquifer parameters are usually indefinite and less quantitatively inspected.
Distributed numerical hybrid models, coupling discrete conduits with a matrix continuum, directly incorporate the observed aquifer geometry and measured hydraulic parameters; thus permit evaluation of different aquifer realizations. Inverse applications of such models allows to characterize parameter sensitivities and uncertainties for complex real-world karst systems, for example to define future exploration demand.
In this research, effects of different aquifer controlling parameters on hydraulic and transport behavior are investigated by Modflow-2005 Conduit Flow Process v2, a numerical discrete conduit-continuum flow and transport model, in the framework of global sensitivity analysis (GSA). Parameters involved described the conduit system, the saturated matrix system, the epikarst diffuse system as well as the vadose zone, and direct recharge components. Three idealized model settings with different conduit geometries (i.e. single, branched and networked), but similar distributed and direct recharge components were investigated. Model input parameters are selected according to the properties of Sheshpeer catchment in Iran or feasible ranges from literature, generated by Sobol's quasi-random sequence. Among available GSA methods, Sobol' variance-based indices, Spearman Rank Correlation Coefficient, and scatter-plots were utilized to investigate the importance of controlling parameters on hydrodynamic and physicochemical signatures of idealized aquifer settings. Inverse model application is based on long-term measured data within the relatively well know Sheshpeer catchment. Results show that the conduit diameter is by far the main controlling parameter on spring hydro-chemo-thermo-graphs. Conduit storage, conduit tortuosity, conduit roughness, and saturated water content of epikarst/vadose zone are the next key parameters on spring signatures; while the matrix parameters are insensitive (i.e. unidentifiable).
Finally, these model results are used to screen the effective parameters and set up less uncertain model of the Sheshpeer catchment that can be inversely solved, based on measured long-term hydrographs together with chemo- and thermographs, at reasonable computational effort. In conclusion, future exploration demand can be defined.

10.2 From high-resolution field data to robust model parameterization

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Keywords: Subsurface characterization, hydraulic conductivity, hydraulic tomography, numerical inversion, model complexity

Recent advances in high-resolution techniques for subsurface characterization have the potential to greatly improve our understanding of subsurface flow and transport processes. However, the appropriate interpretation of field data of varying resolution and scale still poses a major challenge to hydrogeologists and modellers. Both conceptual issues and computational burden need to be considered when choosing a method for translating field data into useful model parameterizations.

On a conceptual level, we need to select a specific parameterization scheme for extracting information about spatial heterogeneity from field data. For example, when evaluating hydraulic tomography data to infer the spatial distribution of hydraulic conductivity in the subsurface, we need to select an appropriate parameterization for spatial heterogeneity. Possible parameterizations could be zonation models with fixed boundaries, interpolation schemes that allow for arbitrary geometries, highly flexible geostatistical approaches, or any combination thereof. These possible parameterizations vary significantly in their complexity (i.e., the number of degrees of freedom). Which level of complexity in the parameterization scheme is most appropriate in a specific case depends on the type, amount and quality of the field data and on the overall goal of the data collection and subsequent modelling exercise.

Further, each parameterization calls for individual numerical inversion schemes that vary significantly in run times. Limited computational budgets typically constrain the choice of an appropriate numerical scheme and hence also the choice of parameterization.

It is the aim of this contribution to discuss approaches to and consequences of choosing a specific parameterization for interpreting spatially distributed field data and extracting the relevant information for use in numerical models. It needs to be acknowledged that the assumptions made about the spatial structure of the heterogeneous distribution of subsurface parameters influence the resulting parameter fields that are used as inputs for numerical modelling. Hence, the interpretation of field data has a direct impact on all subsequent modelling steps and results such as flow fields and contaminant plumes. It is therefore critical to address the choice of parameterization scheme in an objective and transparent way in order to make the best use of data toward reliable model predictions.

10.3 Delineation of contamination zone using geophysical and hydro-geochemical methods around El Moheet Drain, El Minia District, Upper Egypt

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Keywords: El Moheet drain**,** Self-potential, electrical resistivity, trace and major elements

El-Moheet drain of El Minia district receives high amounts of wasteful water (e.g. agricultural, domestic, and sewage) from different lateral minor drains. These wastes may represent the sources of contamination for surface and groundwater aquifers through the seepage process. For the detection and delineation of this contamination zone, some geochemical analyses, electrical resistivity and self potential (SP) measurements were carried out. Chemical analyses have been performed for the water samples which collected from the drain and drilled wells. These analyses revealed that, the water samples of El Moheet drain and groundwater exhibit substantial concentrations of major and trace elements. The electrical data were processed and interpreted through iteration process using IX1D V3 software. High bulk electrical conductivity and SP anomaly were detected perpendicular to the drain of nearly E-W direction, associated with increase of salt concentrations. Management of waste water in El-Moheet drain is intensively recommended for further protection of the groundwater aquifer, to be suitable for various purposes.

Session 11: Special Investigation Techniques
(CHE-89 / June 9, 12:00 noon - 1:00 pm)

11.1 Radiation anomalies mapping using UAV mini-airborne gamma-ray spectrometry

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Keywords: Size-limited uranium anomaly, Mini-airborne measurement, Gamma-ray spectrometry, unmanned aerial vehicle (UAV), Detection of radiation anomaly

Localization of size-limited gamma-ray anomalies plays a fundamental role in uranium prospecting and environmental studies. Possibilities of newly developed mini-airborne gamma-ray spectrometric technique were tested on uranium anomaly near the city Pribram, Czech Republic. The measurement technique was based on a scintillation gamma-ray spectrometer specially developed for unmanned aerial vehicles (UAV) loaded on powerful hexacopter. The gamma-ray spectrometer has two 103 cm^3 BGO scintillation detectors of relatively high sensitivity. Tested anomaly was assessed by ground gamma-ray spectrometric measurement in a detail rectangular measurement grid. The extension of the anomaly is approximately 80 by 40 m and concentration of uranium attains up to 700 ppm eU. The mini-airborne measurement was carried out on three 100 m long parallel profiles at eight flying altitudes from 5 to 40 m above the ground. Resulting one second 1024 channel gamma-ray spectra, recorded in counts per second (cps), were processed to concentration units of K, U and Th, while total count (TC) was reported in cps. Increased gamma ray intensity of the anomaly was recognized by mini-airborne measurement at all profiles and altitudes including the highest altitude of 40 m, at which the recorded intensity is close to the natural background. Reported experiment brings new experience with using unmanned semi-autonomous aerial vehicles and latest mini-airborne radiometric technique. The experiment has demonstrated instrument ability to localize size-limited gamma ray sources.

11.2 High-Resolution Investigation Using Laser-Induced Fluorescence (LIF): Examples of Hydrocarbon-Contaminated Sites in Brazil

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Keywords: Direct-push technology, laser-induced fluorescence, crude oil, diesel, jet fuel

High-resolution investigation using laser-induced fluorescence (LIF) tool has been tested in three hydrocarbon-contaminated sites – crude oil, diesel and jet fuel. The crude oil site is located in a waste landfill of an onshore producing oil field. The diesel contamination was originated from fuel tank leakage and that of jet fuel was associated with a subsurface pipe rupture in an oil-refinery. LIF spectral patterns obtained from direct-push investigation of crude oil site indicated strong weathering of the hydrocarbon with pronounced depletion of light chains of PAHs, particularly naphthalene. In the diesel site, a ten-year-old spill in a relatively clean quartz-rich sand, LIF spectral patterns formed well-defined intensity curves, which are very similar to LNAPL saturation profiles, making possible evaluating the non-aqueous phase distribution in the pores. Similar results were observed in a jet fuel-contaminated site, despite of the strong water table fluctuation, which is responsible for trapping and release of jet fuel in the subsurface. The results obtained from these hydrocarbon-contaminated sites clearly demonstrate the usefulness of LIF to map the extent of hydrocarbon contamination and to evaluate residual saturation of LNAPL in shallow subsurface, as well as offering a qualitative information of the degree of hydrocarbon degradation in both saturated and unsaturated zones.

11.3 High resolution characterization of pore space, fluids and connectivity by innovative (Cryo-/LMI) BIB-SEM imaging methods

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Keywords: Multiscale imaging, microstructural characterization, pore geometry, pore size distributions, elemental analysis

Understanding storage capacity and transport properties in the subsurface at the pore level is challenging due to poor accessibility. Recent advances over the past decade in Broad Ion Beam (BIB) milling followed by Scanning Electron Microscopy (SEM) imaging, however, paved the way for new insights into the pore space morphology of fine-grained sediments like shales and clays. Large area mapping at high resolution together with advanced image processing algorithms enable quantification of pore space from centimeter down to nanometer scale in representative areas. The visible porosity can be obtained and pore size distributions can be drawn. Moreover, pore-mineral associations can be deduced by combining SE/BSE and EDS image maps. Implementing cryogenic BIB-SEM supports preparation and imaging of both unsaturated and saturated as well as sensitive samples, facilitating the finding and analyses of pore fluids and its relation to mineral interfaces. Additionally, sublimation of the water phase enables characterization of drying damage due to shrinkage of for example clay minerals or organic matter. To gain insight into pore connectivity complementary Liquid Metal Injection (LMI) followed by BIB-SEM is applied. By forcing the non-wetting alloy into the pore space at incremental pressure steps pore throats of specific diameters can be filled according to the Washburn equation. Further BIB-SEM analyses shows the connected porosity indicating preferred transport pathways. In this contribution, we present application of these (Cryo-/LMI) BIB-SEM imaging methods on a variety of sandstones, shales and clay(stones) core samples and cuttings for the characterization of pore space, pore fluids and pore connectivity. These insights can be of value for benchmarking existing models.

Session 12: High resolution characterization II
(CHE-91 / June 9, 12:00 noon - 1:00 pm)

12.1 InSAR ground motion studies in water management

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Keywords: water management, InSAR technology, ground deformation measurements

The application of advance remote sensing techniques based on InSAR (Interferometric Synthetic Aperture Radar) has proved to be an effective tool in water management practices. In recent years, satellite InSAR technology has an improved performance due to the availability of high resolution images. Additionally, the most evolved algorithms have the capability of providing millimetric precision of ground movement measurements with high spatial density over very large areas (e.g. 50 x 50 km).
This technology strongly improves the capability to map, monitor the effect of the groundwater injections/extractions on surface deformation and characterizing boundaries (e.g. faults) of aquifer systems.
Further InSAR techniques have successfully been applied to assess flood risks. Identification of areas experiencing subsidence contributes to a better establishment of safety measurements.
The use of InSAR techniques has the following benefits: (1) no installation of instrumentation on the ground is required, making this technology very suitable for the monitoring of remote, inaccessible or restricted access sites; (2) it allows past ground deformation to be analyzed and the ground displacements to be understood over time; (3) it provides distinct spatial and temporal patterns of ground surface displacement; (4) it assists reservoir management because the boundaries of the system are better characterized and (5) it can feed hydrogeological models improving their prediction capabilities and the management of groundwater resources.
In order to illustrate the applicability of this technology, several study cases located worldwide will be presented.

12.2 Development of a direct-push technique for localisation of iron-rich groundwater entering small streams in Lusatia

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Keywords: river, groundwater, iron, acid mine drainage, direct-push technology

In the German Lusatian Lignite Mining Region, high iron concentrations occur in the groundwater, which discharges to natural streams and brings about unfavourable conditions. It was suspected that the iron load to streams varies greatly in space, and that the contamination originates from discrete point sources (hot spots). Remedial measures such as subterranean barriers, injection of oxidizing agents or pump-and-treat are costly and must be restricted only to areas of high priority.

To explore the hot spots a direct push method for water sampling was developed, in which an abstraction element is rammed into the stream bed or bank to the desired depth and the water abstracted using a hand vacuum pump. This technique requires only two people and results can be gained fast and flexibly while on site. Challenges included the thick sludge deposit of iron hydroxide in the stream and fine soil material in the aquifer, which can clog the filter of the abstraction element and lead to turbid water samples and falsified lab results. Furthermore, the sampling technique was adapted to determine high dissolved iron concentrations up to 500 mg/l by avoiding any aeration of the water while pumping, filtering and bottling. Temperature measurements were conducted to qualitatively characterize the groundwater influxes along the studied section of the stream.

The developed method was tested at an 800-m-long section of the stream "Kleine Spree", where the presence of hot spots was suspected. Along that section several samples have been taken and a large spatial variation of iron concentrations was found. While the highest detected dissolved iron concentration in the groundwater beneath the stream bank was about 450 mg/l, 50 m downstream the concentration was only about 240 mg/l and 100 m further it decreased to 50 mg/l. Additional experiments were conducted at a section of the stream "Greifenhainer Fließ" to evaluate and ensure the reliability of the results gained by the developed technique.

12.3 Development of an In-well Point Velocity Probe for the Rapid Characterization of Groundwater Velocity at the Centimeter-scale

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Keywords: PVP, velocity, in-well measurement, groundwater

The In-well Point Velocity Probe (IWPVP) is a low-cost reusable device designed for the rapid measurement of groundwater velocity at the centimeter-scale in open boreholes and wells. IWPVP measurements of groundwater speed are determined on the basis of a small-scale tracer test conducted as the ambient groundwater passes through the well bore and the body of the probe. The horizontal flow direction can be estimated from the tracer mass differential passing detectors placed in four channels arranged in a '+' pattern in the probe. The design viability of the IWPVP was confirmed using a two-dimensional numerical model in Comsol Multiphysics, that accounted for laminar flow in the porous media outside the well and turbulent flow within the well and probe. Numerical validation was followed by a series of laboratory tank experiments in which IWPVP measurements were calibrated to quantify seepage velocities in medium sand. Both the model simulations and laboratory tank experiments were conducted with the probe oriented parallel to the primary flow direction as well as with the probe rotated at known angles from the primary flow direction. This combination tested both the practical range of groundwater velocities the IWPVP can measure and its ability to accurately determine the horizontal flow direction in the vicinity of the borehole. Overall, the magnitude of the groundwater velocity was determined with a precision of ± 7%, and an accuracy of ± 14%, on average, compared to the expected linear calibration line, when tank velocities ranged from 0.5 to 4.0 m/d. The horizontal flow direction was determined with a precision of ± 3°, and an accuracy of about ± 15°, on average. All tests were completed in under 20 minutes from the time of injection. Based on these promising results, the IWPVP appears to be a viable tool for the verification of groundwater velocity variations at the centimeter-scale.

Session 13: High resolution characterization III
(CHE-89 / June 9, 1:40 pm - 2:40 pm)

13.1 An integrated methodology for hydrogeological assessment of nuclear plant aquifers

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Keywords: hydrogeology, 3D, GIS, groundwater modeling

Nuclear plants entering their decommissioning stage around the world are in increasing number. Following the evaluation of the International Atomic Energy Agency, 300 nuclear reactors will be shut down in the next 20 to 30 years, all over the world. Decommissioning a nuclear plant arises major technical, economical and social challenges. In this context, particular attention must be paid to environmental aspects. Consequently, there is a need for efficient environmental assessment of the sub-surface for nuclear plant installations in order to implement the best remediation practices limiting radio-nuclides emissions in the environment while optimizing the radioactive waste generated during decommissioning. In this paper, we present a nested hydrogeological characterization methodology that permits to optimize the existing data and the number of new data acquisition. First, historical data coming from hydrogeological tests and civil engineering operations before and during the construction of the nuclear plant are used to build the frame of the hydrogeological model in a 3D GIS. This frame includes building, reactors and chimneys foundations, so as the geotechnical enclosures left in place after the construction, but also, the different geological and geotechnical information. Particularly, the model also integrates historical geotechnical CPT (Cone Penetration Test) and well information within and outside the plant (>several tens of kilometers upstream the site). Based on all these information, geophysical data acquisition was decided to refine the interfaces between geological units at some more uncertain places. After analysis of the geological model 17 wells were chosen for the measurement of slug tests and geophysical logs in order to build hydro-physical relations. These statistical relationships are used to simulate the hydrogeological properties within the geological units of the 3D geological model. Groundwater flow and transport was run and calibrated using groundwater levels. This methodology has proven to be efficient and permitted to optimize the new data acquisition while maximizing the level of information required for the model to be accurate for the environmental management of the site.

13.2 The development of a new measuring tool for an efficient planning of very shallow geothermal systems

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Keywords: electrical resistivity tomography, thermal conductivity, very shallow geothermal energy, soil properties

Due to the prospective shortage of resources and the decentralisation of power plants renewable energy sources will play a crucial role within all energy supplying systems. Shallow geothermal systems are used as efficient energy storage and supplier of thermal energy. These near-surface systems are split in two groups of vertical and horizontal forms. Double-U probes and coaxial probes reflect the most common vertical forms of shallow ground source heat exchangers (GSHE). The most frequently installed horizontal form is the collector system. A special form of horizontal GSHE is the heat basket. A horizontal collector system has significant advantages compared to other vertical types of GSHE in terms of financial and planning aspects. There are also less legal requirements that have to be considered within a very shallow geothermal installation. The key parameter for the performance of a horizontal system is the thermal conductivity of the surrounding soil. This parameter has huge impact on the economic as well as on the ecologic efficiency of such an installation. Within the uppermost meters of the ground thermal conductivity is mainly driven by soil texture. Therefor, the main parameters are bulk density, soil moisture and grain size distribution. All these parameters are analysed within this study in terms of how much they affect the thermal conductivity. Additionally these effects are also compared to their influence on the electric conductivity. Due to these findings, a new tool, measuring the electric conductivity to make reliable statements about the existing soil properties and the thermal conductivity, is been developed. Finally this measurement tool allows the provision of information to planners and property owners if their ground is feasible for a near-surface horizontal installation.
Until these days, there is a large uncertainty about the area which is required to achieve a certain heat extraction rate. Because of uncertainties regarding soil type and safety requirements these areas are often overdimensioned. The main research focus within this study is the reduction of this uncertainty factor. The new measurement tool is developed to analyse soil properties influencing the performance of horizontal systems. With the result of these measurements the heat extraction rate can be defined more precisely. This provides the opportunity in order to make clear recommendations about the size of the required area for installing a shallow geothermal horizontal system.

13.3 Recent achievements in high resolution characterization of aquifers using crosshole GPR full-waveform inversion

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Keywords: Hydrogeophysics, Full-waveform inversion, porosity

Ground penetrating radar (GPR) measurements can be performed quickly and effectively to map and characterize aquifers within the unsaturated and saturated zone. GPR can provide permittivity and electrical conductivity of the subsurface environment. Permittivity is highly correlated with soil water content and porosity, whereas the electrical conductivity depends also on soil properties such as soil texture and clay content and on the electrical conductivity of the pore water. Over the last years, crosshole GPR full-waveform inversion has been proved to be a powerful tool to map, characterize and monitor aquifers at a decimeter-scale resolution but also in improving our understanding of dynamic processes that are taking place in the critical zone. The method especially demonstrated the potential to detect small-scale high contrast layers that can be related to zones of high porosity, zones of preferential flow or clay lenses. Furthermore, we introduced an amplitude analysis of GPR data that can directly be applied to the observed data, and, is able to identify and detect the boundaries of such small scale layers at the borehole location. The full-waveform inversion and amplitude analysis was successfully applied to several different aquifers and comparison to independently measured e.g. logging data proved the reliability of the method.

Here, we give an overview of the theoretical developments and achievements of full-waveform inversion of the recent years. Further, we investigate in detail the application of full-waveform inversion to a dataset from the Krauthausen test site. Thereby, the saturated aquifer in a domain of 25m by 45m and a depth of 10m was characterized within a decimeter scale resolution by stitching several 2D crosshole planes together. The full-waveform inversion results showed a higher resolution than standard ray-based methods. Instead of a positive correlation between permittivity/porosity and hydraulic conductivity that was found at other test sites in Widen and Boise, we found at the Krauthausen site a negative correlation due to textural sorting and the structural features of the pore network. Comparison to porosity and hydraulic conductivity measurements from direct-push, flowmeter and grain size data indicated that the GPR predicted facies classification is hydrogeologically meaningful. Furthermore, the facies that were mapped based on full-waveform inversion allowed explaining the heterogeneity of transport processes in the aquifer that was detected by ERT time lapse measurements.

Abstracts - Poster Presentation

P1 Development of a CPT-based seismic tomographic system for geotechnical subsurface investigation and site assessment

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Keywords: Cone Penetration test, seismic tomography, geotechnical parameters, seismic wave attenuation wave dispersion

Geotechnical methods serve as standard methods for investigation, metrological acquisition and the monitoring of abundant old mining sites. These methods provide point information of several soil parameters. The Cone penetration test (CPT) representing one of the most versatile direct push methods for subsurface investigation in unconsolidated rocks determines the geotechnical engineering properties of soils and delineating soil stratigraphy. The CPT device produces in-situ records of resistance at the cone tip, the sleeve friction, penetration speed of the probe and the deviation of the tip from the perpendicular. In the last few years additional seismic measuring methods have already been used for various geotechnical applications and risk assessment. The seismic velocity, in particular the S-wave velocity is directly linked to geotechnical parameters such as shear modulus. Crosshole seismic tomography for structural subsurface investigation has been widely used for high-resolution exploration between existing wells.

In the recently launched German R&D project (CPTTOMO - ZF4318901LT6 & ZF4315801LT6), a CPT-based tomography system is to be integrated in a small-bore Direct-Push CPT rod. Several three-component geophones will be installed at a distance of 1 m in this CPT rod. In addition, a seismic source that emits P and S waves will be integrated in a different rod. By directly linking the seismic velocity with soil dynamic parameters, the high-resolution tomographic method is ideally suited to transfer the 1D point information from CPT measurements into the 2D measuring plane and the 3D space. New theoretical approaches allow the assessment of the seismic wave attenuation by analyzing the dispersion of body waves. The attenuation is a major factor in controlling the impact of vibrations to e.g. soil liquefaction processes. Thus, seismic tomographic measurements provide additional geotechnical parameters as an important contribution to the stability assessment.

The poster presentation presents the project idea of combining CPT and seismic tomography, summarizes the expected measurement data and the derived geotechnical parameters, displays first examples for the evaluation of amplitudes and discusses new approaches for assessing the attenuation.

P2 Direct push sensing in wetland (geo)archaeology

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Keywords: color log, geoarchaeology, wetland, direct push

Trenching is an important method in (geo)archaeological investigations. However, in wetlands unstable trench edges caused by invasive groundwater let this method become more expansive. An alternative method is the classical driving core with inexact depth accuracy caused by compressed or stretched layers and expansive laboratory analysis for a large number of samples.
The aim of this study is to present an application of direct push technology for a high-resolution and minimal invasive investigation in a groundwater affected site as alternative solution for the detection of archaeological structures. The field site is located at the Charlemagne's summit canal (Fossa Carolina); an Early Medieval building to bridge the Central European Watershed between Danube and Rhine catchment.
During the field work especially the flexibility and the real-time data preview offer additional advantages compared to classical methods. For generating the data set less time and high cost effectiveness was required.
Two direct push probes were used to measure the electrical conductivity and colorimetric proxies to investigate a buried canal structure in SW Germany.
The results provide information about the structure and the texture of the canal fillings with high depth accuracy. The cross-section was investigated in 2014[in press][a)] and 2016 to detect the structure in a high resolution in vertical and lateral direction. Multiple organic canal fillings and different sediment units in the ground and on the edges are visible. Furthermore, at the edges colluvial layers were detected.
The statistical coupling of direct push logs with robust geochemical and grain size data strengthen the interpretation of organic fills and sedimentary properties. As a result the two-dimensional modelling of the buried canal cross-section is possible.
The results provide a new multiproxy approach for the reconstruction of (geo)archaeological sites within wetlands. The reconstruction of the buried canal with a detailed color image and the structural information derived from electrical conductivity over the full cross section shows fillings and canal edges with a geometry of 6 m depth and 3 to 4 m width. Furthermore, grainsize and geochemical analysis of the organic trench fillings feature semi-terrestrial stillwater deposition indicating Carolingian and post-Carolingian ponds. Finally the results show that the use of the Carolingian scows seems possible.

a) Hausmann, J., Zielhofer, C., Werther, L., Berg-Hobohm, S., Dietrich, P., Heymann, R., Werban, U., 2017 [in press]. Direct push sensing in wetland (geo)archaeology: High-resolution reconstruction of buried canal structures (Fossa Carolina, Germany). Quaternary International.

P3 A shallow water table fluctuation model in response to precipitation with consideration of unsaturated gravitational flow

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Keywords: shallow unsaturated zone, groundwater fluctuation, delayed recharge flux, unsaturated zone drainage, water table fluctuation model

Water table fluctuations reveal important hydrogeological aspects of an aquifer, such as the recharge rate and hydraulic conductivity. In addition, information on the temporal and spatial distribution of groundwater level is important in many fields of hydrogeology, including free phase nonaqueous phase migration and solute transport, groundwater vulnerability, and groundwater induced inundation. In this study, a precise estimation of groundwater fluctuation is studied by considering delayed recharge flux and unsaturated zone drainage. Both delayed recharge flux and unsaturated zone drainage are due to gravitational flow impeded in the unsaturated zone, which may no negligibly affect groundwater level changes. In the validation, a previously developed model without the consideration of unsaturated flow is benchmarked where both the previous and new models are separately calibrated for three different climatic periods (i.e., pre-storm (P1), storm (P2), and post-storm (P3)) using multi-year groundwater data from a monitoring station in South Korea. Consistent model parameter statistics of both models are obtained from a model calibration to 11 years of water table data and the statistics are validated based on a Monte Carlo simulation. In the comparisons of the model fitness measures (i.e., Root Mean Squared Error (RMSE) and Akaike Information Criterion (AIC)), the new model has superior performance compared to the previous model, especially since the previous model is unable to represent the rounded and delayed water table responses in P1 and the slowed water table recession P3. It is also found that the calibrated parameters of the new model for each period agree well with the hypothesized mechanisms of the delayed recharge flux and unsaturated zone drainage. From the overall analysis, it is concluded that the new model reasonably represents the groundwater level changes in response to precipitation by incorporating important unsaturated features regarding the detailed processes in the vadose zone. In this sense, the new water table fluctuation model has higher adaptability to various climate and unsaturated zone conditions.

P4 Innovative site characterization of an active sinkhole area using Direct Push technology

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Keywords: sinkholes, Direct Push, site model, geotechnical characterization

Sinkholes pose a natural geologic hazard in areas where soluble layers are present in the subsurface. A detailed knowledge of subsurface properties of those areas is essential for the understanding of sinkhole formation and propagation. It enables to distinguish between three types of sinkholes, which are different in terms of origin, development and hazardousness: dissolution, cover-subsidence and cover-collapse type. This serves as base for risk evaluation and the development of an early warning system. However, in many cases data from drillings and surface geophysical surveys cannot resolve the spatial distribution of relevant geotechnical and hydrogeological parameters sufficiently. To enhance the resolution of the site model, an active sinkhole area in Münsterdorf, Northern Germany, was investigated in detail using Direct Push technology, a minimally invasive sounding method. In situ measurements of electrical conductivity combined with Cone Penetration Tests were performed to analyze the lithology of the sinkhole site. As additional approach, the Hydraulic Profiling Tool was applied in order to determine preferential flow paths. It further successfully identified the position of the upper chalk horizon, which could not be detected by the other methods sufficiently.

The obtained vertical high-resolution profiles of geotechnical and hydrogeological characteristics lead to a strong improvement of the geologic site model. The conceptual site model regarding sinkhole formation and propagation will then be tested based on the gathered data and, if necessary, adapted accordingly. Within the framework of the joint project SIMULTAN, funded by the German Ministry of Education and Research (BMBF), the findings of the study will contribute to the development of monitoring strategies for areas at risk of sinkhole development.

P5 Assessment of aquifer connectivity using oscillatory hydraulic aquifer tests

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Keywords: Oscillatory Pumping Test, Aquifer Characterization, Hydraulic Connectivity

Connectivity is often referred to a rather intuitive concept which lacks a unique mathematical expression which is especially true for continuous fields of porous aquifers. However in aquifer hydraulics the connectivity concept is related to the existence of spatially connected features which concentrate groundwater flow and reduce travel times of solutes. To assess these connected aquifer features for a reliable integration in predictions of groundwater and solute transport we utilized multi-frequency hydraulic aquifer tests (also referred as oscillatory pumping test or oscillatory hydraulic tomography) to characterize connectivity in porous aquifers. Recently, such multi-frequency hydraulic aquifer tests have been successfully used to characterize and image hydraulic conductivity fields on a detailed level.

With the ambition to come up with a connectivity concept we modeled multi-frequency oscillatory hydraulic aquifer tests in various connectivity scenarios in 2D as wells as in 3D. Each scenario contains at least 3 hydraulic conductivity fields which are characterized by similar (geo)-statistical parameters but apparently differ in the degree of spatially connection of the aquifer features. Furthermore the connectivity within these scenarios was characterized with other already published connectivity metrics to e.g., ensure that the modeled fields are different in their connectivity.

The aim of the simulations was to infer (e.g., equivalent hydraulic) parameters from the results of multi-frequency oscillatory hydraulic tests which can be related to the various ranges of aquifer connectivity of the simulated scenarios. These derived parameter(s) might contribute to improve prediction of groundwater flow and solute transport especially in heterogeneous aquifers. The exhibited poster will present preliminary simulation results as well as their relation to already existing connectivity metrics and may come up with a new preliminary concept of connectivity for porous aquifers based on multi-frequency hydraulic aquifer tests.

P6 Assessing the functionality of groundwater observation wells on regular water quality measurements

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Keywords: groundwater observation wells, water quality, well functionality

As comparable to regular water production wells, groundwater monitoring wells can be subject to well aging processes, such as physical clogging, corrosion, chemical precipitation or biological growth at the filter screen. These processes have the potential to negatively influence water quality measurements by using such wells and may lead to misjudgment in terms of water management decisions. Therefore, these wells are regularly tested by using borehole geophysical measurements, such as borehole cameras or passive gamma-logs. However, these investigations cannot be easily applied to a large number of observation wells. At this point, it is important to support the selection of wells to be tested by additional analyses based on available data.

The aim of this work was to develop robust indicators to identify non-representative observation wells. Based on regular water quality measurements, the functionality of groundwater observation wells was to be investigated. Hence, it is possible to delineate optimal measures for an advanced examination of respective wells using borehole geophysical measurements. For this, a large amount of mostly annual measurements of the main quality parameters pH-value, electric conductivity, temperature, oxygen concentration and redox potential in unconsolidated aquifers of Saxony had been reviewed. Different statistical methods were applied to analyse the time series (ranging from 10 to 27 years) of each parameter of the 289 wells to detect divergences which might result from a reduced validity of data gained from these wells. Statistical analyses included detection of abrupt offsets, outliers and trends. A special challenge was to delineate thresholds for parameter variabilities, as these have on the one hand a high influence on the observation wells detected by the analyses but on the other hand also a high potential for natural variation.

Based on already carried out borehole geophysical measurements which provide insights into the functionality of selected wells, possible indicators could be delineated which can then be applied to untested wells. The results could indicate that, using the analyses mentioned above, it was possible to derive a set of wells which have a higher potential of having a reduced functionality than a random selection of wells. In a next step, it would be very important to apply the statistical analyses to other data sets to show their broader applicability.

P7 Integration of geophysical tomograms and direct-push logging data for probabilistic prediction of spatially continuous hydrologic parameter distributions

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Keywords: logging data, tomography, prediction, fuzzy sets, artificial neural networks, uncertainty

Geophysical tomograms can guide the interpolation between direct-push logs. This can be done by using the geophysical tomograms as soft information guiding the qualitative outline of subsurface units linked to some hydrologic target parameter information. Alternatively, and more challenging, quantitative parameter inference techniques can be used to link multiple geophysical tomograms and direct-push logging data providing laterally sparse information about the hydrologic target parameter, which requires accounting for uncertainty in the relations between geophysically imaged and measured hydrologic parameters. Data-driven approaches learning optimal relations between the considered tomographic and direct-push data appear appealing integration and prediction approaches. Recently, Asadi et al., (2016)[a)] and Paasche (accepted)[b)] presented powerful probabilistic integration approaches building on artificial neural networks (ANN) and fuzzy sets (FS), respectively. Geophysical Radar, P-wave and S-wave tomographic data sets have been inverted searching the solution space of the inverse problems globally. This resulted in ensembles of radar-, P- and S-wave velocity tomograms whose members fit the underlying data sets equally well. These tomogram ensembles discretely illustrate tomographic reconstruction ambiguity. Different combinations of selected radar, P-, and S-wave velocity tomograms are considered learning optimal petrophysical prediction models to infer hydrological parameters where no direct-push logging data have been measured. This allows for transducing tomographic ambiguity quantitatively into the inference of spatially continuous scenarios of hydrologic parameter distribution. Additionally, scale differences between tomogram discretization and logging data sample interval are fully considered. Both approaches result in highly similar predictions when ignoring logging data errors and tomographic imaging errors, which results in overfitted prediction models learned. Predicted ranges are very broad and the posterior density distributions of the predicted hydrological parameter are poorly focused. However, results start to differ if overfitting the prediction models shall be avoided. Both approaches follow Gaussian error theory but in two different considerations. While the FS approach uses least-squares averaging principles, the ANN-based approach considers accumulated relative errors in a weighted rms-error objective function when learning the prediction models. Both approaches result generally in similar effects, e.g., reduced prediction ranges and focused posterior density distributions. However, differences between both approaches increase when striving to avoid overfitting leaving doubts on the general suitability of error handling based on Gaussian assumptions.

a) Asadi. A., Dietrich, P., Paasche, H., 2016, 2D probabilistic prediction of sparsely measured earth properties constrained by geophysical imaging fully accounting for tomographic reconstruction ambiguity. Environmental Earth Sciences, 75, 1487.

b) Paasche, H., accepted, Translating tomographic ambiguity into the probabilistic inference of hydrologic and engineering target parameters. Geophysics.

P8 Temperature observation within the grouting of Borehole Heat Exchangers (BHE) by Raman-spectre based distributed temperature sensing (DTS)

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Keywords: fibre-optic distributed temperature sensing; borehole ground heat-exchanger; subsurface temperature observation

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During the last decades, with the advent of Raman-spectre based distributed temperature sensing (DTS), the amount of scientific work on the thermal characterisation of BHE has grown. Common methods like the Thermal-Response-Test (TRT) were improved by the possibility to measure continuous temperature profiles along multiple points of the fibre simultaneously provided by the DTS technology. Besides using DTS for enhanced Thermal-Response-Test applications (eTRT), additional insight into the interaction of pipes, grouting, and geological environment was gained.

The presented work follows these studies and focuses on experimentally derived temperature evolutions along BHEs during hydration of the grouting and during eTRT application at the interface between heat-transfer medium pipes and grouting. The results presented originate from a laboratory scale experiment and a double-U-tube field installation, covering thermo-cement hydration, and TRT temperature measurements as well as the temperature dissipation after the respective TRT.

Hereby, the laboratory experiment is a simplified, scaled coaxial-BHE design for observation of hydration heat related temperature change in the context of artificial installation failures.

The field-experiment data originates from BHEs with a length of about 21 m, with the upper 50% of the BHEs being within the vadose zone and the lower 50% reaching into the groundwater. The optical-fibre for the DTS measurements was mounted onto all of the pipes allowing measurements at the interface of grouting and pipes.

Our results show that the temperature evolution within the grouting of a BHE during hydration, eTRT-operation, and cooling may provide deeper insight into sensor and therefore pipe positioning; and to a limited extent, allows the detection of possible installation failures.

P9 Data acquisition system for horizontal filter wells

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Keywords: horizontal well logging

Horizontal filter wells produce huge amounts of water over long periods of time. They are used for drinking water supply or the limitation of rising groundwater levels. The determination of the optimum hydraulic excitation of the horizontal filter strings and their monitoring during the production phase are valuable possibilities to increase the efficiency of filter wells.
To obtain a continuous record of the hydraulic and geochemical conditions inside of the horizontal wells the data acquisition system "HoriWell Inspector" was developed at the Dresden Groundwater Research Center as part of a cooperative project.
By adapting methods from the wireline logging in vertical wells and the additional development of a lock and drive unit a technically feasible solution has been implemented that complies with complex requirements of horizontal well logging.
The measured quantities along the horizontal strings are flow rate, pH value, oxidation and reduction potential, temperature, oxygen saturation and electrical conductivity of the water. The acquisition system has a modular design and offers capacities for additional sensors and additional modules. The performance of the measuring system was confirmed by extensive preliminary tests inside the pilot plant for horizontal well investigations at our project partner UBV. The pilot plant consists of four sections with filter tubes that are commonly used for horizontal filter wells. Based on different rock material fillings at each section the plant allows a realistic experimental simulation of different hydraulic and geochemical conditions along the horizontal filter string. After the successful completion of component tests at the pilot plant and inside a real horizontal filter well during operation it is planned to apply the HoriWell Inspector within development and regeneration procedures inside of horizontal well sections.

P10 Development of methods for monitoring and prediction of transient seepage flow in levees and dams

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Keywords: dike monitoring, geoelectrics, geotechnical investigation

Methods for monitoring and prediction of transient seepage flow by numerical calculations have to be developed for the risk assessment of slopes in unsaturated soils. Such approaches can be useful for the assessment of the stability of levee embankments.

Extensive field and laboratory tests and in situ measurements were performed at a reference test site at a levee of Elbe River. The long-term monitoring system consists of a permanent electrode array for resistivity imaging and geotechnical tools including tensiometers, frequency-domain reflectometry sensors and an automatic logging system to measure the groundwater level in an observation well. Additionally, a meteorological unit measures air temperature, humidity, and precipitation The monitoring systems records time series of volumetric water content, pore water pressure, soil temperature, and electrical conductivity at different locations and depths along a profile crossing the levee.

The components of the levee monitoring system have been working for more than one year without any failure. If adequate forecast models are available the comprehensive data sets recorded by the monitoring systems can be used to recognize critical states of seepage flow and levee stability.

The fundamental studies for the development of forecasting models for transient seepage flow have been done by field measurements and laboratory investigations of soil parameters that are necessary for the calculation of stability considering the variability of the relevant parameters in the unsaturated soil zone. Model tests for different soil types and levels of saturation have been performed and evaluated. The results of the model calculation have to be verified by comparison with the available field data.

P11 Realization of a single borehole tracer test with both deuterium (^{2}H) and oxygen-18 (^{18}O) by direct injection of melted snow into an aquifer in Pirna, Saxony, Germany

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Keywords: push-pull tracer test, deuterium, oxygen-18, column experiments

Tracer tests are the state-of-the-art method for the detection of flow paths, the determination of residence times and specific transport parameters as well as the identification of subsurface structures. For most scientific works and practical applications, conservative behavior of the traceable substance (the 'tracer') is strictly needed. In this context, a tracer method for the combined and active use of deuterium (^{2}H) and oxygen-18 (^{18}O) as groundwater tracers was developed. By directly using precipitation water as naturally labeled injection water, this "rain tracer" approach takes advantage of the natural inherent differences between typical groundwater and precipitation, especially regarding the stable isotope signature and electrical conductivity (EC). In contrast to the conventional application of stable isotopes as environmental tracers, the approach used here includes advanced information about the tracer input function.

To test the "ideal" transport behavior, laboratory experiments as well as a small-scale field test at a field site in Pirna, Saxony, Germany were conducted.

First, approx. 10 m^3 of fresh snow were collected in January 2017 and subsequently melted avoiding direct contact to the atmosphere resulting in a total water volume of more than 1m³. The isotopic signature of this tracer water and the groundwater at the field site Pirna were analyzed using the isotope ratio mass spectroscopy method. Here, significant isotopic signature differences of approx. 60‰ for δ^2H and approx. 8‰ for δ^{18}O between tracer and background were determined. Besides this, the EC value of melted snow is comparable to demineralized water leading to a difference of almost 0.5 mS/cm when compared to the groundwater at field site Pirna.

In a next step, a comparative laboratory-scale tracer test with the collected, melted snow was conducted in a 1D-column experiment and the breakthrough of δ^2H, δ^{18}O and EC were analyzed and compared to the breakthrough of sodium fluorescein (uranine), potassium bromide and sodium chloride.

Finally, a push-pull tracer test with approx. 1 m³ melted snow, additionally marked with uranine, was realized by direct injection into the aquifer using a groundwater observation point. Here, breakthrough curves of the stable isotopes ratios (δ^2H and δ^{18}O), EC and uranine were obtained.

In the mentioned 1D column experiments and the small-scale push-pull tracer test, a very good consistency of the breakthrough behavior of both δ^2H and δ^{18}O was observed, whereby the applicability of this new tracer method could be shown.

P12 Quantitative groundwater monitoring: A novel membrane extraction probe for the application with direct push technologies

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Keywords: groundwater monitoring, membrane extraction probe, direct push technologies

A novel membrane extraction probe for the application with direct push technologies has been developed. Our approach permits the *in-situ* determination of the three-dimensional distribution of volatile and semi-volatile organic compounds in groundwater and soil gas. In contrast to well-established techniques such as MIP (membrane interface probe) or UVOST (ultra violet optical screening tool), our extraction tool allows the quantitative analysis of separate substances instead of a rough assessment. The ground water is guided using a micro annular gear pump via a sequential filter stage and a miniaturized heating block to a membrane extraction cell. Within this cell, the organic compounds permeate through the PDMS (polydimethylsiloxane) membrane into a gas flow, transporting the compounds to a mobile gas chromatograph (GC) via a transfer line. The whole system is integrated into a stainless steel rod with an outer diameter of 3.6 cm and an inner diameter of 3.0 cm. The rod length is 70 cm. Therefore, the whole system can be integrated into standard rods of direct push equipment. In the first step, standard rods (1.5 inch inner diameter) with a lost tip are driven into the subsurface. The depth of investigations is currently limited to 10 m due to limited differential pressure range of the micro annular gear pump up to 5 bar. The extraction probe is then inserted into the standard rod system. Using a suitable linkage and a weak pullback, the lost tip will be removed and the lower hole of standard rods is closed by a conic filter (porous aluminum, 40-60 µm) which is the first part of our sequential filter stage.
The advantage of our development is the defined conditions at the membrane. The transport gas flows at one side of the membrane while on the other side a controlled water flow at a defined temperature can be adjusted. Therefore, a defined equilibration state can be reached and our system therefore enables the quantitative analysis of the most frequent groundwater pollutions. The equilibration varies between 5 and 25 min depending on the physiochemical properties of contaminants and the length of transfer line to the GC.
The poster presents the detailed set-up, the optimization of operational parameters and the first results of field tests.

P13 Demonstrating the advantages of innovative subsurface exploration strategies for sustainable managed aquifer recharge operation

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Keywords: direct push technology, surface geophysics, managed aquifer recharge, exploration strategies

Water scarcity and drought led to a strong decline of water availability in many semiarid regions with resulting ecological and economic impacts. Managed aquifer recharge (MAR) represents a promising technique to replenish water resources, and in combination with awareness raising, is an important step towards sustainable water management. The choice of type and positioning of large scale MAR infrastructure, e.g. water infiltration basins and trenches, requires a detailed understanding of subsurface sediment composition and structures to ensure high MAR functionality. Economic sustainability with high functionality and low maintenance is a key factor for MAR application in practice.
Often, traditional sample based site characterization strategies are pursued prior to large scale MAR infrastructure installation that fail to reliably resolve the complexity of sedimentological structures in heterogeneous deposits. Innovative and, in many cases, advantageous techniques are already available on the market today. However, their uptake is yet beyond their capabilities. Against this background, we present results of a successful field application of the combined use of surface geophysics and minimum invasive direct push probing technology for enhanced MAR site characterization. The obtained information lead to a better understanding of subsurface structures and determination of representative sampling points for environmental and economically sound MAR system design and operation.

P14 Assessment of denitrification and mixing patterns in an alluvial aquifer by chemical and isotope data

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Keywords: nitrogen biogeochemical processes, denitrification, admixture

From within and outside the detected channelized zone of an alluvial aquifer, groundwater was collected using the direct push multilevel sampling technology for chemical and nitrogen and oxygen isotope values of residual nitrate ($\delta^{15}N_{NO_3^-}$ and $\delta^{18}O_{NO_3}$) assays. On account of the nitrate to chloride ratios, we identified potential partitioning of the local shallow groundwater flow system into shallow and deep compartments. Whereas the deeper parts of the aquifer show the existence of dilution/mixing processes (higher nitrate to chloride ratios), the shallower parts comparatively appear defined by denitrification processes (lower nitrate to chloride ratios). Although denitrification is illustrated by progressive increase of the $\delta^{15}N_{NO_3^-}$ and $\delta^{18}O_{NO_3}$ values as depicted in this study, the $\delta^{18}O_{NO_3^-}$ vs. $\delta^{15}N_{NO_3^-}$ trajectories of 0.35 and 1.11 corroborate denitrification (trajectories ≤ 1) and mixing (trajectories > 1) potentials in the shallower and deeper parts, respectively. It is however apparent that the response of the groundwater nitrogen cycle to oxygen depletion in the deeper parts of the aquifer indicate complex biogeochemical processes and do not follow basic assumptions of nitrate removal processes, as high nitrate correlated low dissolved oxygen. Particularly, the shifts in the ratio of $\delta^{18}O_{NO_3^-}$: $\delta^{15}N_{NO_3^-}$ above the 1:1 trajectory reflects the influence of nitrate reproduction in direction towards the deeper parts. The inverse relationship between the nitrate and bicarbonate (which functions as both chemical intermediate for oxygen evolution and nitrifying bacteria's structural growth and reproduction source) further substantiate the occurrence of nitrification in the deeper parts of the aquifer. The lack of $\delta^{15}N_{NO_3^-}$ isotopic evidence or the under expression of the nitrogen isotope effect in the stable isotope values of nitrate associated with denitrification in the deeper parts of the aquifer could be explained by diffusion-controlled mechanisms driven by the channelized subsurface structure that probably created differential hydrologic processes. This conceptualization offers opportunities to provide useful insights into the coupling of processes using reaction-diffusion kinetic model.

P15 Development of a mobile measurement device for the in-situ determination of vertical hydraulic conductivity of surface water bed deposits using slug and bail testing – first experimental results

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Keywords: Mobile measurement device, slug and bail testing, ground water surface water interaction, artificial recharge

Information about lake and river-bed hydraulic conductivity and its variation in space and over time is essential for various applications, including: Understanding surface water and ground water interaction; maintenance of artificial water bodies; or assessment of clogging behavior during aquifer recharge. In many cases, piezometer tests are used for bed hydraulic conductivity in-situ measurements. If tests are performed within screened sections, results reflect measured hydraulic conductivity in horizontal instead of vertical direction. In these cases, effects of small diameter layers of low hydraulic conductivity that may highly impact water exchange processes, cannot be sufficiently resolved. If classical falling head tests are conducted in unscreened standpipes that are open at the bottom, vertical hydraulic conductivity of river- or lakebed deposits can be determined. However, results strongly depend on the quality of installation of the standpipe into the sediments and piezometer installation can be intricate.
Hence, a new tool was developed (Patent 10 2014 220 212) to allow for a more reliable and easy in-situ assessment of bed hydraulic conductivity of surface water bodies, based on traditional pneumatic slug testing. Thereby, the tool is tailored for mobile application in sandy bed deposits. To test basic functionality and to investigate reproducibility of the measured head recovery, real scale tests under controlled conditions were performed in a sediment- and water-filled pool. In our contribution, the tool as well as first test results are explained and discussed.

P16 Computation of thermodynamic properties of the earth's lower mantle using selected earth models

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Keywords: Debye temperature, Gruneisen parameter, Earth interior, Selected earth model

Adequate understanding of the earth's interior within the Lower mantle requires the determination of thermodynamic properties of constituent minerals at very high temperatures and pressures that they experience in the earth's interior. These properties are Gruneisen parameter (γ_a), Debye temperature (θ),Coefficients of thermal expansion (α) and Thermal pressure gradient (αK_T).The Parametric Earth Model commonly used for determining thermodynamic properties could handle only two of these properties (α and θ).This work was designed to determine all the four thermodynamic properties(γ_a, θ, α and αK_T) in the Lower mantle (depth 670 – 2891 km) by using Selected Earth Models namely: Preliminary Reference Earth Model, Anderson Temperature Distribution Model and Birch-Murnaghan Model. The values of γ_a and θ obtained ranged from 0.41 to 3.30 and 986.6 to 1309.0 K while the values of α and αK_T ranged from 8.22 to 21.6 $\times$ 10^{-6} K^{-1} and 5.019 to 5.648 $\times$ 10^{-3} $GPaK^{-1}$ respectively. The values of α and θ obtained compared favourably with those of Parametric Earth Model. These results suggest that Corundum with Debye temperature 1040 K and other un-identified minerals are present in the lower mantle.

P17 "GST-SimuTool" - simulation software for "GST" gradiometry technology

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Keywords: simulation, gradiometry, gravitation, software, modeling

The GST-SimuTool is a multi-platform software and is used to simulate gravimetry processes and to create high-accuracy field models. This SimuTool software consists of visual and scripting instruments based on Python Programming Language to create a virtual environment with defined sets of massive physical bodies, and gravimeters (with specified, customizable measuring modules) by considering parameters such as system time function, motion function, outer environment effects, vibrations and temperature gradient inside measuring block. This software includes also a customizable mathematical processor providing anti-noise, smoothing and analytical libs for real data, tools for 3d-visualisation of gravity field in a various representation (potential, tensor, satellite), and a program module for the "GST-Navigator" project providing some navigation / route correction functionality.
This program is intended to create high-accuracy gravity maps (as imposition of real satellite data and tensor components), to ensure virtual experiments (measuring with various conditions, as a part of real experiments planning) as well as high-level processing of field data received from "GST" devices. "GST" - is a gravimetric technology developed by the Synest company is based on a gradiometry method includes hardware and software solutions for a gravity field complex research. Gravity gradiometry measures the variations in the acceleration caused by gravity. The gravity gradiometry is able to measure spatially independent gravity components. Therefore it has significant advantages over conventional gravity measurements, which records only the vertical component. Technical implementation of "GST" gradiometry based on a four 3-axis high-accuracy accelerometers, placed inside thermostatically controlled measuring module. Depending on the purpose of the each device version, the distance between the sensors changed as well as the physical form of the measuring module. Various implementations of "GST" can be used in navigation, geo exploration and scientific research.
The "GST-Navigator" project is a hardware complex providing GPS and radio signal independent navigation for air and water units as well as landing groups (including subsurface and arctic conditions). This project based on a three step algorithm:
1) scanning the area with the main "GST" gradiometry scanner to create a gravity map includes tensor and topography data
2) scanning the sub-area with the field “GST” scanner
3) calculating the sub-area topography coordinates as a result of mathematically imposition of tensor data from step 1 and step 2.
The "GST-Navigator" can also use low-resolution satellite gravity data to check or correct position received from GPS or radio signals.