Book of abstracts

International conference on Terrestrial Systems Research: Monitoring, Prediction and High Performance Computing

April 4th-6th, 2018

University of Bonn, Bonn, Germany

Supported by

Wednesday (Modelling)

9:00 Registration + coffee

9:30 Opening

9:45 Geoverbund ABC/J - The Geoscientific Network of RWTH Aachen, University of Bonn, University of Cologne, and Forschungszentrum Jülich
Daniel Felten

10:00 Lagrangian Predictability of Coupled Water Processes (invited)
Ana P. Barros

10:30 High-resolution climate modeling on emerging supercomputing platforms: Opportunities and challenges (invited)
Christoph Schär

11:00 Understanding the connection between root zone soil moisture and surface energy flux partitioning using modeling, observations and data assimilation for a temperate grassland site in Germany
Prabhakar Shrestha, Wolfgang Kurtz, Gerd Vogel, Jan-Peter Schulz, Mauro Sulis, Harrie-Jan Hendricks Franssen, Stefan Kollet and Clemens Simmer

11:15 Propagation of patterns from soil, vegetation and weather to soil moisture and surface fluxes
Tim G. Reichenau, Wolfgang Korres, Sabrina Esch and Karl Schneider

11:30 Break

12:00 Characterizing heat and mass flux patterns in agricultural crops using landsurface and crop modelling approaches
Matthias Langensiepen, Moritz Kupisch, Mauro Sulis, Anke Schickling, Hubert Hüging, Thuy Huu Nguyen, Anja Stadler and Frank Ewert

12:15 Comparison of water balance and root water uptake models in simulating CO2 and H2O fluxes and growth of wheat
Thuy Huu Nguyen, Matthias Langensiepen, Jan Vanderborght, Hubert Hueging, Cho Miltin Mboh and Frank Ewert

12:30 Aerodynamic Roughness Length over Heterogeneous Surface
Yaping Shao and Sascha Runge

12:45 Lunch

14:00 Advancing continental scale hydrology from bedrock to atmosphere and from summit to sea (invited)
Reed Maxwell, Lauren Foster, Caitlin Collins, Mary Forrester, Danielle Tijerina and Laura Condon

14:30 Increasing the depth of a Land Surface Model: implications for the subsurface thermal and hydrological regimes
Norman Steinert, Jesus Fidel González-Rouco, Stefan Hagemann, Philipp De-Vrese, Elena García-Bustamante, Johann Jungclaus and Stephan Lorenz

14:45 How human water use induced atmospheric feedbacks may contribute to continental drying
Jessica Keune, Mauro Sulis, Stefan Kollet, Stephan Henne, Anita Drumond, Stefan Siebert, Yoshihide Wada and Diego Miralles

15:00 Multi-model assessment of hydrologic impacts of climate change in a semi-arid Mediterranean catchment
Enrica Perra, Monica Piras, Roberto Deidda, Claudio Paniconi, Giuseppe Mascaro, Enrique R. Vivoni, Pierluigi Cau, Pier Andrea Marras, Swen Meyer and Ralf Ludwig

15:15 When Does Uncertainty Matter While Modeling Climate Change in Mountain Headwaters? Contrasting model resolution and complexity under a changing climate in an alpine catchment
Lauren M. Foster, Kenneth Williams and Reed M. Maxwell

15:30 Regional climate modelling at the convection permitting scale: Climate response to increasing greenhouse gasses and land use change (invited)
Nicole van Lipzig, Sam Vanden Broucke, Hendrik Wouters and Matthias Demuzere

16:00 Poster session

18:00 Ice breaker

Thursday (Modelling, assimilation, HPC)

9:00 The Community Terrestrial Systems Model (CTSM): Unifying land modeling efforts to advance research and prediction in climate, weather, water and ecology (invited)
Martyn Clark, Dave Lawrence, Bill Sacks, Mike Barlage, Sean Swenson and Mariana Vertenstein

9:30 OLAM-SOIL: A global soil and Earth system modeling platform (invited)
Robert Walko, Dani Or, Simone Fatichi, Harry Vereecken, Stefan Kollet, Tom Hengl and Roni Avissar

10:00 Coupling reactive transport processes with root system architecture and functions: principles and application examples
Frédéric Gérard, Hannah Gatz-Miller, Sergio Bea, Renato K. Braghiere, Philippe Hinsinger, Loïc Pagès and Klaus U. Mayer

10:15 Hydrological networks as optimal transport structures
Enrico Facca, Mario Putti and Franco Cardin

10:30 Break

11:00 Selected Comparisons between Machine Learning and Deep Learning in Earth Science Applications (invited)
Morris Riedel

11:30 Improved hydrology over peatlands in a global land modeling system
Michel Bechtold, Gabrielle J M De Lannoy, Rolf H Reichle, Randal D Koster, Sarith P Mahanama and Dirk Roose

11:45 3-D physically-based modeling of the Panola hillslope
Matteo Camporese, Claudio Paniconi and Mario Putti

12:00 Representing winter wheat in the Community Land Model (version 4.5) (invited)
Yaqiong Lu, Ian N. Williams, Justin E. Bagley, Margaret S. Torn and Lara M. Kueppers

12:30 Lunch

13:30 Workflows in Geosystems Analysis (invited)
Olaf Kolditz, Hua Shao, Uwe-Jens Görke, Haibing Shao, Thomas Nagel, Lars Bilke, Thomas Fischer, Karsten Rink and Thomas Kalbacher

14:00 Coupled Systems, Numerical Libraries, and High Performance Computing: How Do We Bring These Together? (invited)
Carol Woodward

14:30 Incorporating ICON into TerrSysMP
Slavko Brdar, Cunbo Han, Stefan Kollet and Wendy Sharples

14:45 Linking coupled water-energy engineered system simulation models to HPC resources via a generalised web-interface
Stephen Knox, James Tomlinson and Julien Harou

15:00 High Performance Computing in Basin Modeling: Stratigraphic Layer tracking with the Level Set Method
Sean McGovern, Stefan Kollet, Wolfgang Bangerth, Claudius Buerger, Ronnie Schwede and Olaf Podlaha

15:15 Break

15:45 Using Data Assimilation Diagnostics to Assess the SMAP Level-4 Soil Moisture Product (invited)
Rolf H. Reichle, Qing Liu, Gabrielle J.M. De Lannoy, Wade T. Crow, John S. Kimball, Randal D. Koster and Joseph V. Ardizzone

16:15 Global Soil Moisture Estimation from L-Band Satellite Data: the Impact of Radiative Transfer Modeling in Assimilation and Retrieval Systems (invited)
Gabrielle De Lannoy, Rolf Reichle, Alexander Gruber, Michel Bechtold, Jan Quets, Jasper Vrugt and Jean-Pierre Wigneron

16:45 TerrSysMP-DART Interface: An Integrated data assimilation platform for coupled atmosphere, land surface and groundwater model
Prabhakar Shrestha, Timothy Hoar, Jeffrey Anderson, Wolfgang Kurtz, Harrie-Jan Hendricks Franssen, Fabian Gasper, Bernd Schalge, Mauro Sulis, Stefan Kollet and Clemens Simmer

17:00 The data assimilation framework TERRSYSMP-PDAF
Harrie-Jan Hendricks Franssen, Wolfgang Kurtz, Hongjuan Zhang, Dorina Baatz, Sebastian Gebler, Stefan Kollet and Harry Vereecken

17:15 Bayesian Inverse Problems for radar observation of drop-size distributions
Christian Rieger

17:30 Use and challenges of geophysics to study processes in agro-ecosystems (invited)
Sarah Garré, Mathieu Javaux, Gael Dumont, Nolwenn Lesparre, Thomas Hermans and Frederic Nguyen

19:00 Conference diner (Landesmuseum)

Friday (Monitoring, patterns)

9:00 Validation of spring wheat responses to elevated CO2, irrigation, and nitrogen fertilization in the Community Land Model 4.5 (invited)
Yaqiong Lu and Bruce A. Kimball

9:30 Quantification of root length density at the field scale with electrical impedance tomography: a numerical study
Shari van Treeck, Andreas Kemna, Maximilian Weigand and Johan Alexander Huisman

9:45 Ground-based quantitative electromagnetic induction measurements and inversions show that patterns in airborne hyperspectral data are caused by subsoil structures
Christian von Hebel, Maria Matveeva, Elizabeth Verweij, Uwe Rascher, Patrick Rademske, Cosimo Brogi, Manuela Sarah Kaufmann, Achim Mester, Harry Vereecken and Jan van der Kruk

10:00 Large-scale subsurface characterization using Multi-Configuration EMI and image classification
Cosimo Brogi, Johan Alexander Huisman, Lutz Weihermüller, Stefan Pätzold, Christian von Hebel, Jan van der Kruk and Harry Vereecken

10:15 Simultaneous non-invasive measurement of soil moisture and biomass dynamics using the cosmic-ray neutron probe
Heye R. Bogena, Jannis Jakobi, Johan A. Huisman and Harry Vereecken

10:30 Break

11:15 The temperature sensitivity (Q10) of soil respiration: controlling factors and spatial prediction at regional scale based on environmental soil classes
Nele Meyer, Gerhard Welp and Wulf Amelung

11:30 Linking spatial and temporal sun-induced fluorescence patterns to soil and atmospheric properties in a heterogeneous agriculture landscape
Maria Matveeva, Christian von Hebel, Vera Krieger, Tobias Marke, Patrick Rademske, Alexander Damm, Sergio Cogliati, Cosimo Brogi, Guido Waldhoff, Jan van der Kruk, Susanne Crewell and Uwe Rascher

11:45 Empirical Derivation of Soil Moisture and Vegetation Parameters from Sentinel-1 SAR in the Rur catchment
Sabrina Esch, Wolfgang Korres, Tim G. Reichenau and Karl Schneider

12:00 Severe Hail Detection: Hydrometeor Classification for Polarimetric C-band Radars Using Fuzzy-Logic and T-matrix Scattering Simulations
Mari L. Schmidt, Silke Trömel, Alexander Ryzhkov and Clemens Simmer

12:15 Effects of parameterizations of the drop size distribution with variable shape parameter on polarimetric radar moments
Katharina Schinagl, Christian Rieger, Martin Schneider, Clemens Simmer, Silke Trömel and Petra Friederichs

12:30 Lunch

13:30 Assessing the Applicability of CHELSA (Climatologies at High resolution for the Earth's Land Surface Areas) data for Monthly and Seasonal Precipitation Predications
Arash Malekian and Elaheh Ghasemi

13:45 Topological pattern analysis of atmospheric boundary layer turbulence
Jose Licon, Cedrick Ansorge and Angela Kunoth

14:00 Recent Progress on Intrinsic Mode Function Representation and Its Applications to Hydrological Data
Boqiang Huang and Angela Kunoth

14:15 Exploring small-scale patterns in a forest soil-vegetation-atmosphere system
Inken Rabbel, Burkhard Neuwirth, Heye Bogena and Bernd Diekkrüger

14:30 Analysis of Soil Moisture Patterns in a Mesoscale Catchment Using Plot to Catchment Scale Datasets
Wolfgang Korres, Tim G. Reichenau, Sabrina Esch and Karl Schneider

14:45 Synthesis/closing session

15:45 End

Posters

The poster session is Wednesday from 16 to 18h in the Aula.

P01 Remote sensing and GIS-based land use and crop rotation mapping for regional soil-vegetation-atmosphere modelling
Guido Waldhoff, Ulrike Lussem, Mauro Sulis and Georg Bareth

P02 A Bayesian unsupervised clustering approach for spatial and statistical pattern extraction of subsoil using satellite derived NDVI time series and electromagnetic induction measurements
Hui Wang, J. Florian Wellmann, Maximilian Kanig, Elizabeth Verweij, Christian von Hebel and Jan van der Kruk

P03 Linking remotely sensed multispectral data to large-scale electromagnetic induction measurements for soil parameter prediction by means of multiple linear regression kriging
Maximilian Kanig, Y.P. Villa-Acuna, Christian von Hebel, Hui Wang, Florian Wellmann and J. van der Kruk

P04 Modeling and Theoretical Investigation of multi-scale Interactions between Convection and Land-Surface Heterogeneity
Zahra Parsakhoo, Cedrick Ansorge and Yaping Shao

P05 Describing the spatial pattern of a shallow cumulus cloud population in terms of size and spacing
Thirza van Laar and Roel Neggers

P06 Effects of Land Surface Heterogeneity on Simulated Boundary-Layer Structure
Stefan Poll, Prabhakar Shrestha and Clemens Simmer

P07 Impact of downscaled atmospheric forcing on surface energy flux partitioning
Tanja Zerenner, Prabhakar Shrestha, Philipp Moss, Victor Venema, Petra Friederichs and Clemens Simmer

P08 Simulating soil surface temperature of a bare soil using an energy balance model at West of Iran
Younes Khoshkhoo

P09 Validation of the MODIS land surface temperature data in West of Iran
Younes Khoshkhoo

P10 Validation and Reanalysis of ERA-Interim Dataset of European Center for Medium-Range Weather Forecasts (ECMWF) in Iran
Elaheh Ghasemi, Ebrahim Fattahi and Arash Malekian

P11 High-resolution profile measurements of wind speed and scalars within and above short canopies: Applicability to flux measurement, source partitioning and process understanding
Alexander Graf, Patrizia Ney, Anne Klosterhalfen, Normen Hermes, Marius Schmidt and Harry Vereecken

P12 Understanding the Spatiotemporal Structures in Atmosphere-Land Surface Exchange at the Jülich Observatory for Cloud Evolution
Tobias Marke, Susanne Crewell, Ulrich Löhnert and Uwe Rascher

P13 CO2 fluxes before and after partial deforestation of a spruce forest
Patrizia Ney, Alexander Graf, Marius Schmidt, Thomas Pütz, Clemens Drüe, Odilia Esser, Anne Klosterhalfen, Veronika Valler, Katharina Pick and Harry Vereecken

P14 Soil respiration and its temperature sensitivity (Q10): rapid acquisition using mid-infrared spectroscopy
Gerhard Welp, Nele Meyer, Hanna Meyer and Wulf Amelung

P15 Recolonization of root-induced macropores
Mirjam Zörner, Andrea Schnepf and Jan Vanderborght

P16 Magnetic Resonance Imaging: a tool to study preferential flow in porous media
David Caterina, Andreas Pohlmeier and Harry Vereecken

P17 Small-scale surface to borehole geoelectrics - opportunities and challenges
Johanna Ochs and Norbert Klitzsch

P18 Improving subsurface characterization by combining multiple layer inversions of fixed-boom multi-coil electromagnetic induction and ground penetrating radar data
Christian von Hebel, Jan van der Kruk, Manuela Sarah Kaufmann, M. Iwanowitsch, Johan Alexander Huisman and Harry Vereecken

P19 Water content in natural soil by low-field NMR
Xin Cai, Baoxin Guo, Markus Küppers and Bernhard Blümich

P20 MRI of Water-Content Changes in Unconsolidated Natural Porous Media with Short T2
Alexander Görges, Andreas Pohlmeier, Bernhard Blümich and Sabina Haber-Pohlmeier

P21 Comparing borehole GPR FWI images with CPT data obtained at the Krauthausen test site
Zhen Zhou, Schmäck Jessica, Anja Klotzsche, Nils Güting, Harry Vereecken and Jan van der Kruk

P22 Estimating Infiltration-Induced Soil Water Content Changes using Combined Horizontal Borehole GPR and Dispersive Surface GPR data
Yi Yu, Anja Klotzsche, Denise Schmidt, Jan Vanderborght, Harry Vereecken and Jan van der Kruk

P23 Investigating the spatial and temporal soil water content variations at Rhizotron-test site using time-lapse horizontal borehole GPR data
Lena Laerm, Anja Klotzsche, Jan van der Kruk and Jan Vanderborght

P24 Scalable Subsurface flow Simulations with ParFlow
Carsten Burstedde, Jose A. Fonseca and Stefan Kollet

P25 Calculating terrain parameters from Digital Elevation Models on multicore processors
Grethell Castillo Reyes and Dirk Roose

P26 Research data management support for the large-scale, long-term, interdisciplinary Collaborative Research Center / Transregio 32: Patterns in Soil-Vegetation-Atmosphere-Systems
Constanze Curdt, Georg Bareth and Ulrich Lang

P27 Optimizing albedo simulations of the ORCHIDEE land surface model by assimilating the MODIS satellite observation data
Vladislav Bastrikov, Philippe Peylin and Catherine Ottlé

P28 Assimilating GRACE data with different spatial resolution into a high-resolution hydrological model over Europe
Anne Springer, Jürgen Kusche, Jessica Keune, Wolfgang Kurtz and Makan A. Karegar

P29 Ensemble Data Assimilation with the Community Land Model and the US National Water Model
Timothy Hoar, Mohamad El Gharamti, James McCreight, Arezoo RafieeiNasab and Andrew Fox

P30 Ensemble experiments with a coupled atmosphere-land surface-subsurface model
Bernd Schalge, Harrie-Jan Hendricks Franssen and Stefan Kollet 2 3 and Clemens Simmer

P31 Improving continental-scale hydrologic simulations over Europe using TerrSysMP–PDAF
Bibi S. Naz, Wolfgang Kurtz, Stefan Kollet, Harrie-Jan Hendricks Franssen, Carsten Montzka, Wendy Sharples, Klaus Goergen, Jessica Keune and Anne Springer

P32 Large-eddy simulation of a stratocumulus-topped arctic boundary layer
Robert Rauterkus, Cedrick Ansorge, Yaping Shao and Ulrich Löhnert

P33 Large eddy simulation of catchment scale circulations
Cunbo Han, Slavko Brdar and Stefan Kollet

P34 European extreme events simulations with the fully coupled TerrSysMP
Carina Furusho, Stefan Kollet, Klaus Görgen, Jessica Keune and Ketan Kulkarni

P35 Effects of surface properties and land-atmosphere coupling on water cycle representation in a convection permitting RCM ensemble
Klaus Goergen, Sebastian Knist and Stefan Kollet

P36 Simulation of Shallow-Water Flows on General Terrain
Elena Bachini, Ilaria Fent and Mario Putti

P37 Incorporating a root water uptake model based on the hydraulic architecture approach in terrestrial systems simulations
Mauro Sulis, Valentin Couvreur, Jan Vanderborght, Ivonne Trebs, Jessica Keune, Prabhakar Shrestha, Harry Vereecken, Clemens Simmer and Stefan J. Kollet

P38 Effect of biopores on simulated root growth and leaf area index in a field scale crop model
Cho Miltin Mboh, Thuy Huu Nguyen, Matthias Langensiepen and Frank Ewert

P39 Parameter sensitivity analysis of a root architecture model: field scale simulation of root systems and virtual field sampling
Shehan Morandage, Andrea Schnepf, Jan Vanderborght, Daniel Leitner, Mathieu Javaux and Harry Vereecken

P40 Investigation of anisotropy in induced polarization signatures of maize root-soil continuum: a virtual rhizotron study
Sathyanarayan Rao, Solomon Ehosioke, Andreas Kemna, Frédéric Nguyen, Sarah Garré and Mathieu Javaux

P41 Accounting for seasonal isotopic patterns of forest canopy intercepted precipitation in streamflow modeling
Michael Stockinger, Andreas Lücke, Harry Vereecken and Heye Bogena

P42 Understanding how interception and transpiration of trees influence water resources using modeling, observations and data assimilation for an open woodland in China
Mengna Li

P43 Water-Energy-Plant Interactions in Cold Regions
Yijian Zeng

Talks

Abstract: T01

Geoverbund ABC/J - The Geoscientific Network of RWTH Aachen, University of Bonn, University of Cologne, and Forschungszentrum Jülich

Daniel Felten

Geoverbund ABC/J is the geoscientific network in the research region of Aachen–Bonn–Cologne/Jülich. The geoscientific institutes of RWTH Aachen University, the University of Bonn, the University of Cologne, and Forschungszentrum Jülich collaborate under its umbrella. Established in 2009, the cooperation efficiently pools and interconnects the expertise in geoscientific research and education gained at these institutions over several decades.

Geoverbund ABC/J initiates and promotes research projects spanning different locations, supports early-career scientists, and encourages easy access to scientific infrastructures.

The focus of our research is the dynamic Earth–human system. Together, the scientists of the ABC/J region identify current and future issues in the fields of evolution of Earth and life, environmental dynamics and atmosphere in global change, terrestrial systems and georesource management, and risks and risk regulation, as well as developing possible solutions.

Supporting early-career scientists is another fundamental concern of Geoverbund ABC/J. Since 2011, outstanding, innovative, and interdisciplinary research activities in the field of geosciences have been honoured with the ABC/J research prize for early-career scientists. Students of partner universities also benefit from an expanded range of studies since they can attend lectures and courses at the cooperating establishments. Our involvement also includes summer schools on changing topics in the field of geosciences, offering students' excursions for which the participants receive a grant, and funding for structured training programmes for doctoral researchers.

Geoverbund ABC/J also offers direct access to the high-performance supercomputers of Forschungszentrum Jülich through the centre of excellence High-Performance Scientific Computing in Terrestrial Systems (HPSC TerrSys). This centre was founded by Geoverbund ABC/J in 2011. Together with the associated Simulation Laboratory (SimLab TerrSys) and in close cooperation with the Jülich Supercomputing Centre (JSC), HPSC TerrSys provides the geoscientists of the ABC/J region with scientific and technical support for their research activities by means of its supercomputers.

Geoverbund ABC/J is committed to the continuous development of the ABC/J region, supporting attractive conditions for excellent research and students' education and keeping a close eye on early-career scientists. As a mediator between science, politics, and society, Geoverbund ABC/J's declared aim is to increase the visibility of the ABC/J region as a nationally and internationally renowned research region in the field of geosciences.

Abstract: T02

Lagrangian Predictability of Coupled Water Processes

Ana P. Barros

Seamless prediction has gained much traction in the last decade due to faster computers and novel computational architectures that enable the implementation of coupled models at very high spatial and temporal resolution. Concurrently, dramatic increases in observations from remote sensing platforms drive the widespread push for the integration of models and data through the use of data-assimilation. There is however recognition of the complexity and challenges of modeling coupled processes, including the consistency in the representation of processes across scales, and across interfaces (e.g. land-atmosphere, land-margins, and ocean-atmosphere). In the case of coupled land-atmosphere models, these challenges and complexity are manifest in a closed loop of predictability: systematic space-time errors in the diurnal cycle of clouds and precipitation impact eco-hydrologic processes at sub-daily time-scales, which in turn affect surface fluxes and PBL thermodynamics, and feedback into atmospheric moist processes, cloud formation and precipitation. Here, we explore the notion of Lagrangian predictability as a framework to track the joint space-time evolution of moist processes in the atmosphere and water fluxes and states across the land-atmosphere interface. This is demonstrated by examining the predictability of clouds and precipitation vis-à-vis landform, land-cover and evapotranspiration through coupled model simulations. Next, we examine the implications of Lagrangian predictability for model parameter estimation using data assimilation and, or classical model calibration approaches. Finally, we discuss the complexity inherent to coupled multi-scale multi-physics models, and the need to formulate alternative metrics of model predictive skill that capture the relevant dynamics.

Abstract: T03

High-resolution climate modeling on emerging supercomputing platforms: Opportunities and challenges

Christoph Schär

Until recently, most global and regional climate models were operating at horizontal resolutions around 10-100 km, and employed parameterization schemes for the representation of moist convective processes. The value of such models for integrated hydrometeorological considerations is somewhat dubious, as heavy precipitation events are misrepresented, and as the spatial resolution is insufficient for consideration of many catchment-based applications.

With the advent of km-scale regional climate models, there are now promising prospects in this area, but also staggering challenges. In this presentation an overview will be provided on the emerging use of km-resolution regional climate models. Consideration will be given to aspects related to (i) convergence of simulations, (ii) challenges in model validation, (iii) emerging needs regarding land-surface models, as well as (iv) attractive applications in climate change studies. Examples will benefit from a recently developed modeling strategy using a GPU-based version of the COSMO model, for applications over European, Alpine and Atlantic regions.

It will be argued that soon convection-resolving resolution will become a key target of global climate simulations. This development raises a number of technical issues, covering a wide range of areas including hardware and software design, as well as the optimal choice of numerical and analysis methodologies.

Abstract: T04

Understanding the connection between root zone soil moisture and surface energy flux partitioning using modeling, observations and data assimilation for a temperate grassland site in Germany

Prabhakar Shrestha[1], Wolfgang Kurtz[2,5], Gerd Vogel[3], Jan-Peter Schulz[3], Mauro Sulis[4], Harrie-Jan Hendricks Franssen[2,5], Stefan Kollet[2,5] and Clemens Simmer[1,5]

[1] Meteorological Institute, Bonn University, Bonn, Germany;

[2] Forschungszentrum Jülich, Germany;

[3] DWD, Germany;

[4] Luxembourg Institute of Science and Technology, Environmental Research and Innovation, Luxembourg;

[5] High-Performance Scientific Computing in Terrestrial Systems, Jülich, Germany

Land surface models (LSMs) acting as lower boundary for atmospheric models have evolved considerably in representing key biogeophysical processes. Nevertheless, LSMs with different degrees of complexity are in use with still the simpler LSMs preferentially used in numerical weather forecasting. This study aims to evaluate the second generation TERRA Multi-Layer (TERRA-ML) and the third generation Community Land Model version3.5 (CLM3.5) to better understand the connection between root zone soil moisture and surface energy fluxes, which are important for predictions. Additionally, this study demonstrates, how observations and data assimilation with joint state-parameter updating with third-generation LSMs can be used to improve the realism and thus our understanding of the connection between root zone soil moisture and surface energy flux partitioning.

Abstract: T05

Propagation of patterns from soil, vegetation and weather to soil moisture and surface fluxes

Tim G. Reichenau, Wolfgang Korres, Sabrina Esch and Karl Schneider

Institute of Geography, University of Cologne, Albertus-Magnus-Platz, 50923 Köln

Soil properties, vegetation dynamics and weather events are the main influences on soil moisture and surface fluxes of water and energy. Patterns of the former (causes) are connected to patterns of the latter (effects) via nonlinear processes in the soil-vegetation-atmosphere system. Input data used to drive simulations of the soil-vegetation-atmosphere system differ in terms of spatial resolution and spatial distribution as well as in terms of temporal repetition. Due to the nonlinearities, the emerging patterns of fluxes and state variables are rather complex as are cause and effect relationships leading to these patterns. To investigate these relationships, the community land model (CLM) is run with input data of different source and accuracy. Soil data from global and regional soil maps and leaf area index data derived from local measurements, remote sensing and regional plant growth simulations were used as input to CLM model runs. Based on the comparison of the simulation results, we analyze the effects of utilizing theses different input data sets upon the simulated fluxes, states, and patterns on the catchment scale.

Abstract: T06

Characterizing heat and mass flux patterns in agricultural crops using landsurface and crop modelling approaches

Matthias Langensiepen[1], Moritz Kupisch[1], Mauro Sulis[2], Anke Schickling[3], Hubert Hüging[1], Thuy Huu Nguyen[1], Anja Stadler[1] and Frank Ewert[4]

[1] University of Bonn;

[2] Luxembourg Institute of Science and Technology;

[3] Jülich Reseach Centre;

[4] Centre for Agricultural Landscape Research Müncheberg

Developing landsurface models for calculating and scaling heat and mass fluxes from agricultural landsurfaces must be based on a conscious choice of model theory and parameterization. Three problems have to be solved to achieve this goal: An appropriate solution must be found for approximating the biological response of plants to given environmental conditions. Characterizing the effects of environmental heterogeneity on flux regulation requires sensible choices of model theory and scaling approach. Realistic simulation of the spatio-temporal evolution of flux patterns must take into account physiological aging and adaptation to suboptimal growing conditions through differential gene activity. The hypothesis of this work was that introducing crop modelling approaches into landsurface schemes improves their simulation of heat and mass flux patterns. A series of field measurement campaigns was conducted between 2011 and 2013 to analyse the heterogeneity of physical soil properties and their effects on flux responses at leaf, plant and canopy scales. A closed-canopy flux chamber and an improved method for measuring sap-flow in plants were developed and tested for this purpose. State of the art leaf gas-exchange equipment was used for measuring leaf fluxes. All measurements confirmed that an accurate characterization of flux pattern evolution in agricultural field must account for the effect of soil heterogeneity on physiological regulation of heat and mass fluxes. Using the aforementioned information, we contributed to the further development of the landsurface model CLM 3.5 by validating that a crop-type specific parameterization improves the calculation of latent and sensible heat fluxes. Aiming at improving the calculation of leaf area index in CLM 3.5, the flux analyses were accompanied by a study on soil heterogeneity effects on crop growth and resulting leaf area development. Carbon-source driven crop models were calibrated and different parameter aggregations tested for characterizing the effect of growth on flux patterns in field crops. It became apparent during this study, that any source driven approach for calculating crop growth has limitations, particularly under stress conditions. Further developing crop models towards an inclusion of physiological-based characterisations of carbon metabolism will likely improve the simulation of leaf area index under heterogeneous environmental conditions. Based on analyses of sap-flow, growth, and fluxes at different levels of crop system organisation we propose the consideration of anisohydric and isohydric regulation of plant-water balance in land-surface models.

Abstract: T07

Comparison of water balance and root water uptake models in simulating CO2 and H2O fluxes and growth of wheat

Thuy Huu Nguyen[1], Matthias Langensiepen[1], Jan Vanderborght[2,3], Hubert Hueging[1], Cho Miltin Mboh[1] and Frank Ewert[1,4]

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Accurate modelling of how soil water stress affects canopy exchange processes is crucial for reliable predictions in heterogenous fields and landscapes from crop models and land surface models (LSMs). Current crop models and LSMs that use a coupled photosynthesis-stomatal conductance model (A – gs) for simulating canopy CO2 and H2O exchange account for water stress which is simply calculated either from soil water content (SWC) or soil water potential without consideration of the hydraulic and/or chemical signaling, thus, those models are unable to represent the specific stomatal behaviors. We modified the original LINTULCC2 crop model which has the coupled (A – gs) model and linked it with Couvreur's root water uptake model (RWU) and HILLFLOW 1D water balance model in order to explicitly represent stomata regulation while involving the whole plant hydraulic signal. We carried out a comprehensive comparision of three simulation scenarios: (i) HILLFLOW 1D-Couvreur's RWU-modified LintulCC2, (ii) HILLFLOW 1D-Feddes-modified LintulCC2, (iii) and the original LintulCC2 which considers a tipping-bucket (TB) water balance approach in prediction of gas fluxes and crop growth using a data collected from a wheat field grown in 2016 under three water supply regimes (sheltered, rain-fed and irrigated) and two soil types (stony and loamy) in Western Germany. Scenario (i) considers the whole plant hydraulic conductance while scenarios (ii) and (iii) do not. Under all studied water regimes, the scenarios (i) and (ii) out-performs scenario (iii) in predicting gross primary product (Pn) with R2 (0.56, 0.53 and 0.42) and RMSE (7.45, 7.92 and 10.29 micromole m-2 s-1), respectively. Under optimum water conditions, all scenarios had a similar performace for Pn prediction (R2 = 0.65 for all models), while the R2 of scenarios (i), (ii) and (iii) under severe drought (stony soil with the shelter) were 0.42, 0.40 and 0.25, respectively. These indicated that model performance declined in the order of scenario (i) >= (ii) > (iii) for both CO2. A similar performance order was observed for the predicted seasonal SWC profiles and above ground biomass. The better performance by using Couvreur approach (scenario (i)) as compared to the conventional approaches (scenarios (ii) and iii)) could be attributed to the consideration of the hydraulic conductance from root to shoot in the coupled A-gs model. Consideration of stomatal control thus improved the prediction of canopy gas exchange and other outputs under a wide range of water and soil conditions that may occur in heteronenous fields and landscapes. The newly coupled model (modified LINTULCC2 with Couvreur method) requires futher testing for other crop types.

Abstract: T08

Aerodynamic Roughness Length over Heterogeneous Surface

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Aerodynamic roughness, z0, a descriptor of the capacity of a surface for momentum absorption, is a widely used parameter. It is for instance used in land-surface parameterization scheme, embedded in the estimates of eddy diffusivity/viscosity, which are then used for computing surface fluxes. All models (e.g. global climate, numerical weather prediction and surface hydrologic models) with a surface component require the specification of z0. Although z0 is basic, it is not well understood in the case of surface heterogeneity. In this study, we investigate the spatial variation of z0 over an urban surface using large eddy simulation and tower data. We first show from the observations that z0 at a given location is dependent of the upstream configurations of roughness elements. Using a large-eddy simulation model, a series of numerical experiments has been carried out, such that the spatial variation and scale dependency of z0 can be explicitly analyzed. It is shown that tall roughness elements (60 m tall buildings) exert large influences on the surface aerodynamic properties downstream (1000 m). This shows that point-based z0 measurements over heterogeneous surfaces are very difficult to use. Estimates of z0 using morphometric methods are also problematic because how to quantify the geometric features of a heterogeneous surface is difficult and scale dependent.

Abstract: T09

Advancing continental scale hydrology from bedrock to atmosphere and from summit to sea

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Advances in hyper-resolution, integrated hydrologic modeling at large spatial scales have the potential to improve global simulation of water quantity and quality. However, as these tools progress in parallel with input datasets, a process of continuous critical assessment is needed to drive further improvement and understand the unique strengths and weaknesses of large-scale approaches. Our team has developed a hyper-resolution (1km2) integrated hydrologic model of the continental US (CONUS). We use the hydrologic model ParFlow-CLM which simulates three-dimensional groundwater flow with fully integrated overland flow and coupled land surface processes. ParFlow is designed for efficient parallel simulation, and previous work has demonstrated good scaling performance across thousands of processors. Still, simulating variably saturated flow and nonlinear groundwater surface water interactions in complex, heterogeneous domains remains a computational challenge. The CONUS model has roughly 32 million grid cells, topography ranging from sea level to thousands of meters, semi-arid to humid climates and subsurface hydrologic properties that cover multiple orders of magnitude. We build upon intensively-studied, smaller catchments to understand the parameter sensitivity and process interaction to better inform the larger-scale simulations. We have intercompared our ParFlow-CONUS model to the WRF-Hydro model running as the US National Water Model configuration. Model validation, demonstrates strengths and weaknesses of currently available tools and datasets, highlighting the need for improved high-resolution inputs to facilitate local prediction. We also, combine our integrated hydrologic simulation with Lagrangian particle tracking to connect hydrologic patterns in watershed characteristics (i.e. geology, topography, and climate) to residence time distributions. Additionally, we highlight ongoing developments as we expand our simulation domain, increase spatial resolution and couple with additional simulation platforms.

Abstract: T10

Increasing the depth of a Land Surface Model: implications for the subsurface thermal and hydrological regimes

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The representation of the thermal and hydrological state in Land Surface Models (LSM) is crucial to have a realistic simulation of subsurface processes and the coupling between the atmo-, lito- and biosphere. There is evidence suggesting an inaccurate simulation of subsurface thermodynamics in current generation Earth System Models (ESM), which have LSM components that are too shallow. In simulations with a zero flux Bottom Boundary Condition Placement (BBCP) too close to the surface, the amplitude and phase of the energy propagation with depth and the spatial (vertical) and temporal variability of subsurface temperatures are distorted. This impedes the simulation of land-air interaction and subsurface phenomena, e.g. energy/moisture balance and storage capacity, freeze/thaw cycles and permafrost evolution. Yet, the full potential of increasing the depth of the soil in ESMs has to be explored. Our concept of “soil depth” is twofold. The “thermal depth” describes the location of the BBCP with respect to the thermal regime. The depth of the BBCP has implications for the hydrology regime, in which the moisture in the root zone and in the space above the bedrock limit (“water depth”) is sensitive to depth changes in the thermal scheme. We introduce modifications for a deeper BBCP into the Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (JSBACH). Four subsurface layers were added progressively to increase the soil depth from 10m (5 layers) to 275m (9layers) in simulations with historical, pre-industrial and RCP8.5-scenario radiative forcing conditions. We use two different datasets of hydrologic parameters to initialize JSBACH, with major implications for vertical soil moisture distribution and its exchange with the land surface. In line with advances that recently have been made in the representation of permafrost and the coupling between the soil thermal and hydrology regimes, we explore the sensitivity of our results to an extended soil scheme from 1) the evaluation of the soil thermodynamic aspects and 2) the simulation of permafrost in reference to its potential importance, considering the vulnerable carbon stock in the Northern Hemisphere high latitudes, the area in which the largest warming is expected to occur in future climate.

Abstract: T11

How human water use induced atmospheric feedbacks may contribute to continental drying

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In the global hydrologic cycle, continental land masses constitute a sink for atmospheric moisture as annual terrestrial precipitation commonly exceeds evapotranspiration. Simultaneously, humans intervene in the natural hydrologic cycle and pump groundwater to sustain, for example, drinking water and food production through irrigation. However, studies usually focus on either the impact of irrigation on land-atmosphere feedbacks, or combined water abstraction-irrigation impacts on subsurface-land surface feedbacks neglecting the interactions with the atmosphere. In this study we combine both approaches using the coupled groundwater-to-atmosphere modeling platform TerrSysMP. We use a setup of TerrSysMP over the European continent, to study the influence of human water use on atmospheric water vapor transport and its contribution to continental drying. Four water use scenarios, based on two data sets and two water use schedules, are constructed to account for the uncertainties in human water use related atmospheric feedbacks. We perform simulations over the heatwave year 2003 and analyze how human water use alters the continental sink at regional to continental scales. Our results indicate that human water use has impacts beyond the watershed scale and that the associated atmospheric feedbacks are a key contributor to potential continental drying in Southern Europe. Furthermore, the application of the Lagrangian particle dispersion model FLEXPART allows us to trace human water use induced changes of atmospheric water vapor transport. This helps us to unravel atmospheric feedback pathways and establish a process-based understanding of the remote impacts of human water use on continental drying.

Abstract: T12

Multi-model assessment of hydrologic impacts of climate change in a semi-arid Mediterranean catchment

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Assessing the hydrologic impacts of climate change is of great importance in the Mediterranean region, which is particularly sensitive to climate variability, with significant impacts on water resources and hydrologic extremes. In this work we focus on a scenario-driven investigation of the hydrologic response of the Rio Mannu catchment, a small basin located in southern Sardinia (Italy) and characterized by a semi-arid climate, in terms of catchment-scale water fluxes from five different conceptualizations of the hydrologic water balance. Specifically, we investigate inter-model variability by comparing the results of five distributed hydrologic models, namely CATchment HYdrology (CATHY), Soil and Water Assessment Tool (SWAT), TOPographic Kinematic APproximation and Integration eXtended (TOPKAPI-X), TIN-based Real time Integrated Basin Simulator (tRIBS), and WAter flow and balance SIMulation (WASIM), that differ greatly in their representation of terrain features, physical processes, and numerical complexity. The hydrologic models were independently calibrated and validated on observed meteorological and hydrological time series, and then forced by the output of four combinations of global and regional climate models (properly bias-corrected and downscaled) in order to evaluate the effects of climate change for a reference (1971-2000) and a future (2041-2070) period. The focus is on a set of variables characterizing and affecting the water balance at the catchment scale, including precipitation, air temperature, discharge, soil water content in the first meter, and actual evapotranspiration. The results are discussed in the context of the process representations for each model and within a rigorous analysis of agreement framework. Notwithstanding their differences, the five hydrologic models responded similarly to the reduced precipitation and increased temperatures predicted by the climate models, and lend strong support to a future scenario of increased water shortages.

Abstract: T13

When Does Uncertainty Matter While Modeling Climate Change in Mountain Headwaters? Contrasting model resolution and complexity under a changing climate in an alpine catchment

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Alpine, snowmelt-dominated catchments are the source of water for more than 1/6th of the world's population. These catchments are topographically complex, leading to steep temperature gradients and nonlinear relationships between water and energy fluxes. Recent evidence suggests that alpine systems are more sensitive to climate warming, but these regions are vastly simplified in climate models and operational water management tools due to computational limitations. Simultaneously, point-scale observations are often extrapolated to larger regions where feedbacks can both exacerbate or mitigate locally observed changes. It is critical to determine whether projected climate impacts are robust to different methodologies, including model resolution and complexity. Using high performance computing and a representative headwater catchment modeled in Parflow-CLM we determined the spread of uncertainty in hydrologic fluxes across 30 projected changes for the Rocky Mountains. These projections were run on multiple model configurations of varying complexity, including 100m and 1km resolution, a traditional land surface modeling single column vertical flow, and subsurface 3D lateral flow.

We find that model complexity alters nonlinear relationships between water and energy fluxes; for example, higher-resolution models predicted larger reductions to snowpack, surface water, and groundwater stores per degree of temperature increase, suggesting that warming signals may be underestimated in simple models. Hydrologic impacts from increases in temperature are robust to variation in model complexity, but impacts from changes in precipitation are within uncertainty bounds of model configurations. This result corroborates previous research showing that mountain systems are significantly more sensitive to temperature changes than to precipitation changes and that increases in winter precipitation are unlikely to compensate for increased evapotranspiration in a higher energy environment. These experiments help to (1) bracket the range of uncertainty in published literature of climate change impacts on headwater hydrology; (2) characterize the role of precipitation and temperature changes on water supply for snowmelt-dominated downstream basins; and (3) identify changes to climate impacts at different scales of simulation.

Abstract: T14

Regional climate modelling at the convection permitting scale: Climate response to increasing greenhouse gasses and land use change

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Regional climate models have been frequently used to study the climate impact of different forcings. Generally, these models have been operating at a grid spacing (x) of 12 km or coarser at which a parameterization of deep convective processes is necessary. Recently, a resolution of 4 km or smaller has been applied where convection is partly resolved, referred to as the Convection Permitting Scale (CPS). Several studies have pointed out that this has brought substantial improvement in the representation of precipitation and clouds, in especially the daily cycle and extreme precipitation. However in order to identify the relevance of CPS models for future climate change projections, it is much needed to identify how the climate change signal is affected. Here, we address both land use change and greenhouse gas-induced climate change. The FLUXNET twin-sites, where meteorological observations are performed over a forest site and a nearby grassland site, provide an excellent observational framework to study land use change. Here, we compared these observations with climate model integrations both at the CPS (x=2.8 km) and non-CPS (x=25 km). It was found that during the daytime, the non-CPS model shows a significant decrease in cloudiness over grassland. In the CPS, the response is much smaller and much better in agreement with the observations. During night, forests are observed to receive more downwelling longwave radiation compared to the grassland, which is not represented by both model versions. Next, in order to study the climate response to increasing greenhouse gasses, the EC-Earth model was dynamically downscaled to non-CPS (x=25 km) and subsequently to the CPS (x=2.8 km). By comparing a 30-year future climate projection with an integration for the present-day, it was found that the increase in extreme precipitation is more pronounced over the flatland regions in CPS compared to the non-CPS model. In contrast, over the hilly regions in the Ardennes, the difference between CPS and non-CPS vanished, suggesting the forcing of the systems (surface heating, fronts, orography) play an important role. A comparison with the ALARO model indicates that this behavior is not dependent on the model that was used. Therefore it is concluded that the climate response in CPS compared to non-CPS is influenced by the orography and not model which is used. This opens avenues for combining traditional non-CPS model projections – which give insight in the uncertainty of the climate change signal – with the CPS model projections – which are more reliable for extreme precipitation.

Abstract: T15

The Community Terrestrial Systems Model (CTSM): Unifying land modeling efforts to advance research and prediction in climate, weather, water and ecology

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NCAR's unified land modeling efforts converge on developing a general terrestrial systems model (the Community Terrestrial Systems Model, or CTSM). CTSM integrates modeling approaches across multiple labs at NCAR, and is suitable for use as the land modeling component in climate models, numerical weather prediction models, ecological models, and hydrologic prediction frameworks. CTSM follows a unified approach to land modeling has recently been developed and implemented at NCAR (the Structure for Unifying Multiple Modeling Alternatives, or SUMMA). The SUMMA approach starts with a general set of conservation equations for mass and energy, about which the land modeling community generally agrees, and provides flexibility in areas where existing models differ (e.g., spatial configurations and disaggregation, process parameterizations, and time stepping schemes).

This presentation will focus on the progress and challenges in building CTSM. We will discuss key modeling challenges to (1) define suitable model equations, (2) define adequate model parameters, and (3) cope with limitations in computing power. We will provide examples of modeling advances that address these challenges, and argue for the need to more effectively use our diversity of modeling approaches in order to increase the physical realism of terrestrial systems models.

Abstract: T16

OLAM-SOIL: A global soil and Earth system modeling platform

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The Ocean-Land-Atmosphere Model (OLAM) is an Earth system model that has been under continual development for nearly two decades and has been applied in a number of studies of weather and climate. It features a variable-resolution unstructured grid and a unique formulation of horizontal atmospheric levels and cut cells to represent the topographic surface. The OLAM-SOIL project, begun in 2017, is an initiative to transform the land surface model component of OLAM into a comprehensive vegetation-soil-groundwater model that is fully integrated within an earth system model. Chief goals of the project are to improve the representation of key soil processes in the context of the earth system, to provide a platform that can easily incorporate new process models and geospatial datasets developed within the soil science community, and to produce a comprehensive modeling system that facilitates linkage of multiple scientific disciplines and communities within the common goal of improving our understanding the complexity of our natural environment. These goals fall within the broader objectives of the recently-formed International Soil Modeling Consortium (ISMC).

Accomplishments in the first year of the OLAM-SOIL project include construction of a 3D unstructured soil grid with variable resolution that is independent of the atmosphere grid (and can be of much higher resolution), implementation of a unique and computationally simple formulation of groundwater flow that is horizontally explicit and ideally suited to large parallel computers, incorporation of recent soil composition and hydraulic parameter datasets from SoilGrids and other sources, and representation of the effect of soil structure on hydraulic conductivity. The presentation will highlight these developments and will show results from benchmark tests as well as sensitivity of modeled climate to the soil structure effect.

Abstract: T17

Coupling reactive transport processes with root system architecture and functions: principles and application examples

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We developed a novel soil-plant interaction model based on the coupling of a root system architecture model (ArchiSimple) with a reactive transport model (Min3P). The main novelty of this macro-scale model is to facilitate the simulation of soil-plant interactions by simultaneously accounting for principles of plant biology, aqueous geochemistry and the transport of water, solutes and gases in soil. This contribution is devoted to introduce the formulation of the coupled soil-plant interaction model and to present two application examples highlighting the capabilities of this tool for tackling a wide range of agronomic and environmental issues. The first application focuses on phosphorus acquisition by annual plants from alkaline soils. In this case, we performed 2D simulations to investigate the role of common root processes (i.e., nutrient uptake and related pH changes) in releasing phosphate from the mineral and adsorbed pools in soil. Results are compared with observed data collected in the field and in the laboratory published in the literature . The second application is addressing the capacity of select plant species to induce the formation of calcium carbonates (and alkalization) in tropical soils through the oxalate-carbonate pathway (OCP). We simulate OCP for Iroko trees (Milicia excelsa), because these plants were shown capable of sequestering substantial amounts of calcium carbonate over the life-span of a tree (80 years) in Ivory Coast. Our process-based modeling investigation provides insight in elemental balances, most importantly the fate of carbonate produced by the decomposition of oxalate, which is not only sequestered in the form of calcium carbonate, but can also be exported to groundwater in dissolved form or to the atmosphere as CO2 gas.

Abstract: T18

Hydrological networks as optimal transport structures

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Plant roots and river networks are two examples of complex systems presenting coherently ramified structures with distinctive patterns common to many other natural and anthropogenic transport architectures. A recently expanding area of mathematics, called Branched Transport Problem (BTP), traces back the recurrent presence of these singular formations as the solution of a problem of least-cost resource reallocation called, in all generality, Optimal Transport Problem (OTP). Unfortunately, the lack of efficient numerical approaches to BTP has so far limited its application to real-problems.

We recently introduced a PDE-based model coupling a diffusion equation with ODE imposing a transient dynamics to the diffusion coefficient, whose long-time solutions approaches stationary configurations where ramified structures appear. Based on numerical evidence and partially rigorous mathematical results we claim that these structures are solutions of a BTP problem, possibly reformulated in a non-standard setting. The relevance of our proposed model is twofold. First, it is capable of describing the time evolution of the network. But, more importantly, it reinterprets the emerging branching structures as the result of an optimal trade-off between the energy dissipated during the diffusive transport and the cost of building the transportation network, assumed to be non-linearly proportional to the transport intensity (i.e. the diffusion coefficient). The second important advantage of the proposed formulation is that its numerical solution turns out to be very efficient and well-defined using simple discretization schemes.

In this work we present two preliminary results aimed at showing applications to real-world problems. In the first, we show how the main features of the Po river network in northern Italy naturally emerge, in a qualitative and statistical sense, as a process of optimal ramified transport starting from a highly simplified geographical and hydrological setting. In the second, we introduce a plant root evolution model within a coupled Soil-Plant-Atmosphere simulator. We implement the above BTP model to simulate the plant root dynamics in response to water availability in the soil, assumed to be the only resource to be transported from the soil to the xylem. This model is coupled to the CATHY simulator, which already contains an advanced optimization-based plant functioning model tested in several applications.

Abstract: T19

Selected Comparisons between Machine Learning and Deep Learning in Earth Science Applications

Morris Riedel

Juelich Supercomputing Centre

This talk focuses on several comparisons between traditional machine learning models and a more recent machine learning approach known as deep learning that emerged as a promising disruptive approach, allowing knowledge discovery from large datasets in an unprecedented effectiveness and efficiency. It is particularly relevant in research areas, which are not accessible through modelling and simulation often performed in High Performance Computing (HPC). Traditional learning, which was introduced in the 1950s and became a data-driven paradigm in the 90s, is usually based on an iterative process of feature engineering, learning, and modelling. Although successful on many tasks, the resulting models are often hard to transfer to other datasets and research areas. The talk will introduce deep learning as a new approach in context and outlines its advantages and disadvantages.

This talk provides selected examples of earth science applications that take advantage of deep learning and its inherent ability to derive optimal and often quite generic problem representations from the data (aka 'feature learning'). Concrete architectures such as Convolutional Neural Networks (CNNs) will be applied to real datasets of applications using known deep learning frameworks such as Tensorflow and Keras. As the learning process with CNNs is extremely computational-intensive the talk will cover aspects of how parallel computing can be leveraged in order to speed-up the learning process using general purpose computing on graphics processing units (GPGPUs). In order to obtain a broader view, the talk will contrast the GPU deep learning approach with using traditional machine learning methods such as parallel and scalable support vector machines (SVMs).

In order to not loose sight of emerging computing architectures the talk will further describe how the DEEP-EST EU project concept of a Modular Supercomputing Architecture (MSA) that is implemented in the Juelich Supercomputing Centre (JSC) is bringing numerous benefits to machine learning applications. The talk will finish with short examples of using other succesful deep learning techniques such as Long-Short Term Memory (LSTM) for time series datasets. After this talk the audience will have a general understanding for which problems deep learning in general and CNN or LSTM topologies in particular are useful and how parallel and scalable computing is facilitating the learning process when facing big datasets.

Abstract: T20

Improved hydrology over peatlands in a global land modeling system

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Peatlands of the Northern Hemisphere represent an important carbon pool that mainly accumulated since the last ice age under permanently wet conditions in specific geological and climatic settings. The carbon balance of peatlands is closely coupled to water table dynamics. Consequently, the future carbon balance over peatlands is strongly dependent on how hydrology in peatlands will react to changing boundary conditions, e.g. due to climate change or regional water level drawdown of connected aquifers or streams. Global land surface modeling over organic-rich regions can provide valuable global-scale insights on where and how peatlands are in transition due to changing boundary conditions. However, the current global land surface models are not able to reproduce typical hydrological dynamics in peatlands well. We implemented specific structural and parametric changes to account for key hydrological characteristics of peatlands into NASA's GEOS-5 Catchment Land Surface Model (CLSM, Koster et al. 2000). The main modifications pertain to the modeling of partial inundation, and the definition of peatland-specific runoff and evapotranspiration schemes. We ran a set of simulations on a high performance cluster using different CLSM configurations and validated the results with a newly compiled global in-situ dataset of water table depths in peatlands. The results demonstrate that an update of soil hydraulic properties for peat soils alone does not improve the performance of CLSM over peatlands. However, structural model changes for peatlands are able to improve the skill metrics for water table depth. The validation results for the water table depth indicate a reduction of the bias from 2.5 to 0.2 m, and an improvement of the temporal correlation coefficient from 0.5 to 0.65, and from 0.4 to 0.55 for the anomalies. Our validation data set includes both bogs (rain-fed) and fens (ground and/or surface water influence) and reveals that the metrics improved less for fens. In addition, a comparison of evapotranspiration and soil moisture estimates over peatlands will be presented, albeit only with limited ground-based validation data. We will discuss strengths and weaknesses of the new model by focusing on time series of specific validation sites.

Abstract: T21

3-D physically-based modeling of the Panola hillslope

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The Panola Mountain Research Watershed experimental trenched hillslope is a well-known experimental research station located within the Panola Mountain State Conservation Park, in the Piedmont of Georgia (USA), approximately 25 km southeast of Atlanta. Over the last 25 years, experimental investigations on the Panola hillslope have contributed important knowledge about threshold rainfall-runoff response and its relation to patterns of transient water table development. However, previous modeling efforts with physics-based simulation tools led to conflicting results and assumptions, questioning the actual capability of Richards equation-based models to accurately reproduce the fill-and-spill processes occurring within the hillslope. In this work, we develop a 3-D physics-based representation of the Panola hillslope using the CATHY subsurface flow simulator and we test its ability to simulate internal transient subsurface stormflow dynamics. Our simulations show the capability of the model, with minimal calibration based on a simple sensitivity analysis of soil and bedrock properties, to successfully reproduce the integrated hydrological response and the distributed water table within the soil profile.

Abstract: T22

Representing winter wheat in the Community Land Model (version 4.5)

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Winter wheat is a staple crop for global food security, and is the dominant vegetation cover for a significant fraction of Earth's croplands. As such, it plays an important role in carbon cycling and land-atmosphere interactions in these key regions. Accurate simulation of winter wheat growth is not only crucial for future yield prediction under changing climate, but also for well predicting the energy and water cycles for winter wheat dominated regions. We modified the winter wheat model in the Community Land Model (CLM) to better simulate winter wheat leaf area index, latent heat flux, net ecosystem exchange of CO2, and grain yield. These included schemes to represent vernalization, as well as frost tolerance and damage. We calibrated three key parameters (minimum planting temperature, maximum crop growth days, and initial value of leaf carbon allocation coefficient) and modified the grain carbon allocation algorithm for simulations at the U.S. Southern Great Plains ARM site (US-ARM), and validated the model performance at eight additional sites across North America. We found that the new winter wheat model improved the prediction of monthly variation in leaf area index, reduced latent heat flux and net ecosystem exchange RMSE by 41% and 35% during the spring growing season. The model accurately simulated the interannual variation in yield at the US-ARM site, but underestimated yield at sites and in regions (Northwestern and Southeastern US) with historically greater yields by 35%.

Abstract: T23

Workflows in Geosystems Analysis

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Environmental systems are complex. For unravelling this complexity both observation and modeling concepts are being developed and applied - still and mostly in independent ways. Developing and establishing continuous workflows in environmental systems analysis shall help overcoming this disparity. Including concepts from Data Science will help to improve data workflows and therefore will support progress in domain sciences as well. In this paper we present basic concepts of workflow development in environmental sciences and show examples from different disciplines in geosciences. Benchmarking is an essential tool for proving complex workflows, e.g. the consistency between experimental work and process modeling. We briefly introduce the DECOVALEX project an international initiative for benchmarking geotechnical applications.

Abstract: T24

Coupled Systems, Numerical Libraries, and High Performance Computing: How Do We Bring These Together?

Carol Woodward

Lawrence Livermore National Laboratory

With continued advances in computing system capabilities, many scientific areas are simulating increasingly complex physical systems. One aspect of this increased complexity is a drive to coupling more physical models into a given simulation. For example, 15 years ago, we might simulate groundwater flow in a watershed system. But, 10 years ago, we started seeing the addition of overland flow, and, recently, atmospheric weather and climate systems have started to include these more complex watershed models. With this increase in model complexity comes the need to solve coupled numerical problems on high performance systems. In this talk, I will discuss advances in numerical software, high performance computing, and coupled model simulation and address how these advances connect to result in highly complex simulations. I will also address challenges that slow progress in developing these complex simulations and look toward new research in algorithms and libraries that will likely lead to further advances. Examples from the application of the SUNDIALS suite of nonlinear and differential algebraic solvers to systems from subsurface and climate modeling will be included.

Abstract: T25

Incorporating ICON into TerrSysMP

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The Terrestrial System Modeling Platform (TerrSysMP) was developed to model the interaction between ground and surface flow processes with that of the lower atmosphere up to several kilometers in height. TerrSysMP is composed of an atmospheric model (Consortium for Small-Scale Modeling - COSMO), a surface/vegetation model (the NCAR Community Land Model - CLM3.5), and the groundwater flow model (ParFlow). These three models are jointly run using an OASIS3 coupler to exchange information during run-time while taking care of different temporal-spatial scales of the atmosphere, land and subsurface flows. Following current development at the German Weather Service, we incorporate an alternative atmospheric model, ICON into TerrSysMP which unlike COSMO does not suffer from a pole problem and has a better mass-energy conservation properties. In this talk, we will report on the progress and on some technical aspects during this development.

Abstract: T26

Linking coupled water-energy engineered system simulation models to HPC resources via a generalised web-interface

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Deploying engineered-natural system models incorporating large datasets and involving potentially long run times requires an infrastructure beyond the traditional single desktops. Also, a multi-disciplinary project with geographically diverse participants requires infrastructure for sharing data, results and ideas. These challenges are being met while developing a water-energy system simulation model. We are developing a web interface where participants can access and share data and deploy model runs. This interface is general enough to satisfy the diverse needs of participants, yet specific enough to maintain a common focus and vocabulary. Model runs are started and monitored from the interface, which deploys each run on an external cluster. The underlying HPC stores the raw data which can be accessed from the interface through tools dedicated for performing large-scale data analysis.

Abstract: T27

High Performance Computing in Basin Modeling: Stratigraphic Layer tracking with the Level Set Method

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We consider the numerical modeling of processes occurring in the development of sedimentary basins. In our basin model, we concern ourselves with the flow of a saturated single phase pore fluid through a porous medium undergoing compaction due to the effect of sedimentation. We assume an effective stress principle to describe the interaction between the solid matrix and the fluid. The reduction in porosity, through Athy's law, leads to geometrical shifts in the boundaries between different rock layers. Heterogeneity in the properties of the rock strata can lead to the generation of overpressure. To properly represent material discontinuities, it is primarily the positions of stratigraphic layer interfaces that we focus on, i.e., the geometry of the basin. The challenge that this work addresses is that the interfaces between different rock layers can, in nature, be severely deformed, and this leads to challenges with the numerical techniques standardly used to model the deformation process. In contrast to the well-known approach of moving the mesh nodes to conform with moving interfaces, we use the level set method to implicitly represent the rock layer interfaces to evaluate the potential benefit in performance of maintaining a fixed grid (modified only in possible hierarchical local adaptive refinements, not arbitrary regridding). This presentation concerns primarily numerical experiments of our development code using the deal.II finite element library run on the Juelich Supercomputing Center's Jureca machine.

Abstract: T28

Using Data Assimilation Diagnostics to Assess the SMAP Level-4 Soil Moisture Product

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The Soil Moisture Active Passive (SMAP) mission Level-4 Soil Moisture (L4_SM) product provides 3-hourly, 9-km resolution, global estimates of surface (0-5 cm) and root-zone (0-100 cm) soil moisture and related land surface variables from 31 March 2015 to present with ~2.5-day latency. The ensemble-based L4_SM algorithm assimilates SMAP brightness temperature (Tb) observations into the Catchment land surface model. This study describes the spatially distributed L4_SM analysis and assesses the observation-minus-forecast (O-F) Tb residuals and the soil moisture and temperature analysis increments. Owing to the climatological rescaling of the Tb observations prior to assimilation, the analysis is essentially unbiased, with global mean values of ~0.37 K for the O-F Tb residuals and practically zero for the soil moisture and temperature increments. There are, however, modest regional (absolute) biases in the O-F residuals (under ~3 K), the soil moisture increments (under ~0.01 m3 m-3), and the surface soil temperature increments (under ~1 K). Typical instantaneous values are ~6 K for O-F residuals, ~0.01 (~0.003) m3 m-3 for surface (root-zone) soil moisture increments, and ~0.6 K for surface soil temperature increments. The O-F diagnostics indicate that the actual errors in the system are overestimated in deserts and densely vegetated regions and underestimated in agricultural regions and transition zones between dry and wet climates. The O-F auto-correlations suggest that the SMAP observations are used efficiently in western North America, the Sahel, and Australia, but not in many forested regions and the high northern latitudes. A case study in Australia demonstrates that assimilating SMAP observations successfully corrects short-term errors in the L4_SM rainfall forcing.

Abstract: T29

Global Soil Moisture Estimation from L-Band Satellite Data: the Impact of Radiative Transfer Modeling in Assimilation and Retrieval Systems

Gabrielle De Lannoy[1], Rolf Reichle[2], Alexander Gruber[1], Michel Bechtold[1], Jan Quets[1], Jasper Vrugt[3] and Jean-Pierre Wigneron[4]

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The SMOS and SMAP missions have collected a wealth of global L-band brightness temperature (Tb) observations. The retrieval of surface soil moisture estimates, and the estimation of other geophysical variables, such as root-zone soil moisture and temperature, via data assimilation into land surface models largely depends on accurate radiative transfer modeling (RTM). This presentation will focus on various configuration aspects of the RTM (i) for the inversion of SMOS Tb to surface soil moisture, and (ii) for the forward modeling as part of a SMOS Tb data assimilation system to estimate a consistent set of geophysical land surface variables, using the GEOS-5 Catchment Land Surface Model.

Abstract: T30

TerrSysMP-DART Interface: An Integrated data assimilation platform for coupled atmosphere, land surface and groundwater model

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The Terrestrial Systems Modeling Platform (TerrSysMP) has evolved as a highly modular interface, which uses an external coupler (OASIS3 coupler interfaced with MCT; OASIS3-MCT) and three component models for the atmosphere (Consortium for Small-Scale Modeling; COSMO), land surface (the NCAR Community Land Model; CLM) and groundwater (ParFlow) to improve our understanding of time-space patterns of energy, water and carbon fluxes and feedbacks in the terrestrial system.

For predictions of the terrestrial system, uncertainty estimates of states and fluxes of the atmosphere, land surface and groundwater, and the connection with commensurate observations via ensemble data assimilation with corresponding observations is also crucial. The Data Assimilation Research Testbed (DART) provides a community-based and flexible data assimilation (DA) capability across all components, which is easy to implement and to customize according to model and data needs.

In this study, we present the development of a TerrSysMP-DART interface for COSMO, CLM and ParFlow and its experimental application for weakly coupled DA for each model component in fully coupled runs. We use the synthetic observations of boundary layer temperature profile, soil temperature and soil moisture for the atmosphere, land surface and groundwater model respectively. The DA experiment examines the impact of the above observations on the behavior of the individual component models and their influence on the propagation of patterns of energy, moisture and carbon fluxes along the assimilation cycle.

Abstract: T31

The data assimilation framework TERRSYSMP-PDAF

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TerrSysMP is a fully coupled model from the groundwater via the land surface to the atmosphere which offers some main advantages like a physically consistent description of model states across compartmental boundaries and a very favorable scaling on supercomputers, which allows high resolution model calculations. However, calculations with TerrSysMP are affected by errors and uncertainties, which in part are related to the many uncertain input parameters and forcings. Therefore the data assimilation framework PDAF has been coupled to TerrSysMP, which allows a correction of model states and parameters by real-time measurements. The data assimilation framework is also parallelized in a very efficient way, allowing for high resolution models with up to 10^8 unknown states and parameters to be estimated, for each of the 10^2 ensemble members. The TerrSysMP-PDAF framework has been tested in a series of synthetic and real-world experiments ranging from the hillslope scale to the continental scale, and for the assimilation of different data types like soil moisture, groundwater levels and river water levels. Some main results obtained with the framework will be shown, and an outlook will be given highlighting current developments and planned future developments.

Abstract: T32

Bayesian Inverse Problems for radar observation of drop-size distributions

Christian Rieger

Bonn University

In this talk, we will present the general framework of Bayesian inverse problems for the reconstruction of functions from discrete radar measurements. We will consider as unknown function the "most likely" drop-size distribution function under the posterior measure given the data. Under certain mathematical conditions, the Bayesian approach allows to characterize an variational problem which has this maximum a posteriori (MAP) function as its minimizer.

Such an approach is not only interesting from a purely academic viewpoint, but in practice objects like the drop-size distribution function usually are discretized on a space-time grid. Because of the large spatial domain, the resulting number of grid points can be very large but still be only a coarse grid for numerical purposes. Those coarse grids will induce an numerical error in the reconstruction problem for the drop-size distribution function which is usually difficult to control.

Variational methods can circumvent this problems since they consider continuously given functions and only discrete data. Hence, we do not expect discretization effects due to discretization of the unknown function but only the reconstruction error which stems from the finite amount of data.

The error contribution which is due to the numerical solution of the variational problem is usually easier to control by standard numerical analysis techniques.

Moreover, such a variational approach can also guide the design of efficient algorithms for the actual numerical computations since they do not suffer the large grid size of the grid which was used to discretize the unknown function in the fist place.

Abstract: T33

Use and challenges of geophysics to study processes in agro-ecosystems

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Electrical resistivity tomography (ERT) is increasingly used in the context of agriculture since the measured resistivity distribution can be linked to soil moisture, soil structure or pore water salinity. Due to its minimally invasive character, its spatial coverage and its monitoring abilities, ERT can be used to study field heterogeneity and competition between plants, quantify water fluxes throughout a growing season or distinguish preferential flow pathways in soils. Nevertheless, a lot of challenges still remain. From a mathematical point of view, the inverse problem linked to ERT is ill-posed. To solve it, the inverse problem is often regularized with a Tikhonov-type approach resulting in a smoothed resistivity distribution. However, in reality strong contrasts can exist due to e.g. compacted soil layers due to ploughing, water infiltration fronts, etc. and in that case other operators have been proposed to regularize the inversion. Taking into account spatial heterogeneity of petrophysical characteristics and providing a realistic uncertainty estimation are additional challenges, which can be addressed using stochastic approaches. Monitoring data provides further elements to constrain the inverse problem: data can be replaced by data difference and regularization may incorporate the temporal dimension for instance. However, such constraints require their compatibility with the studied temporal process, which is not always straightforward. Several alternative strategies are being developed, such as coupled hydrogeophysical inversion, or stochastic approaches using a prior falsification/validation method following a Popper-Bayes philosophy. In this presentation, we will illustrate the mentioned challenges and some recent developments in the context of agrogeophysics.

Abstract: T34

Validation of spring wheat responses to elevated CO2, irrigation, and nitrogen fertilization in the Community Land Model 4.5

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The Community Land Model (CLM) is a state-of-the-art land surface model that simulates biogeophysical and biogeochemical processes. CLM started to incorporate crop growth models since version 4.0 in 2012, and since then the crop model in CLM has been evolved remarkably, but some of the key crop growth responses to environmental conditions (such as the elevated CO2) have not been well validated. The Maricopa spring wheat Free Air CO2 Enrichment (FACE) experiment is one of the most frequently used experiments for such validation because the experiment consisted of multi-year paired treatments to understand the growth response to elevated CO2, irrigation, nitrogen fertilization, and their interactions. We set up single point simulations with CLM (version 4.5) forcing with the observed hourly meteorology and applied the same amount of CO2, irrigation, and nitrogen fertilization as actually applied for each treatment. We focused on both spring wheat growth and energy flux responses to these land managements. Overall, CLM underestimated above ground biomass by 7% (117 g m-2) and overestimated grain yield by 13% (91 g m-2), and showed too positive growth response to elevated CO2, but insufficient growth response to irrigation. The overestimated growth response to elevated CO2 may be due to ignoring factors (e.g., leaf traits) that will limit crop growth under elevated CO2. The insufficient response to irrigation is due to CLM simulating lower latent heat flux during April and May, which resulted in higher soil moisture. Thus, spring wheat grows well even with lower amounts of irrigation in CLM. In response to nitrogen fertilization, CLM underestimated LAI increase but overestimated grain yield increase. In terms of energy fluxes, CLM showed decreased latent heat flux in response to elevated CO2 but increased latent heat flux in response to nitrogen fertilization, but the response magnitude was much smaller than the observations. The poor simulated energy fluxes was partly due to CLM underestimating vegetation controls on transpiration, and partly due the observed latent heat flux was not obtained by direct measurments where an abnormal high amount (97%) of energy partitioning into latent heat flux. Based on these validations, we summarized further model developments for CLM to better simulate crop growth process.

Abstract: T35

Quantification of root length density at the field scale with electrical impedance tomography: a numerical study

Shari van Treeck, Andreas Kemna, Maximilian Weigand and Johan Alexander Huisman

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The root system is an important component of the biosphere, linking the soil to the vegetation-atmosphere environment. To improve crop breeding, production and management, it is essential to gain a better understanding of root-soil interactions and associated processes. Here, root architecture, growth and activity play a key role. Measurement methods capable of imaging, characterizing and monitoring root structure and dynamics in a non-invasive manner are still lacking, in particular for field-scale investigations. Previous laboratory studies on crop root systems using electrical impedance tomography (EIT) provided first insights into the possible monitoring of root system extension and root physiological processes. EIT utilizes low-frequency impedance measurements to image the spatial distribution of electrical conduction and polarization properties, for example in terms of real and imaginary conductivity. The previous studies have indicated that the real conductivity is primarily sensitive to water content changes in the rhizosphere, while imaginary conductivity, originating from polarization processes around and within individual root segments, captures information on root mass, root length and root activity. We therefore hypothesize that EIT can be used to image the spatial delineation of root systems as well as to monitor root physiological processes. With a view to establishing EIT as a tool for root system characterization and monitoring at the field scale, we here present a numerical feasibility study focusing on achievable image resolution of the approach. Synthetic complex conductivity models representing a field with crop root systems were generated employing varying electrical model parameterizations. The latter were adapted from available laboratory and field data, such as root length density (RLD), soil conductivity and water content, to simulate realistic scenarios. Synthetic EIT measurements were then computed, contaminated with noise and subsequently inverted by means of finite-element based forward modelling and inversion codes. The imaging capability is assessed by comparing original and reconstructed complex conductivity models respectively root length density data and models. Our results demonstrate that the model can reconstruct the forward model quite well but underestimates the data for higher RLD values at deeper depths (>60cm).

Abstract: T36

Ground-based quantitative electromagnetic induction measurements and inversions show that patterns in airborne hyperspectral data are caused by subsoil structures

Christian von Hebel[1], Maria Matveeva[2], Elizabeth Verweij[1], Uwe Rascher[2], Patrick Rademske[2], Cosimo Brogi[1], Manuela Sarah Kaufmann[1], Achim Mester[3], Harry Vereecken[1] and Jan van der Kruk[1]

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Non-invasive geophysical fixed-boom multi-coil electromagnetic induction (EMI) instruments return apparent electrical conductivity (ECa) values that depend on subsurface soil properties. Using different transmitter-receiver coil separations and orientations, ECa values of different depths of investigation (DOI) are obtained. After calibration, the quantitative EMI data are inverted to obtain electrical conductivity (s) changes over depth assuming a layered subsurface model. Airborne hyperspectral measurements are used to estimate plant performance and growth, however, the top- and subsoil structural changes influencing plant performance and growth is often ignored. Here, we have investigated the origin of observed patterns in sun-induced fluorescence data by performing quantitative large-scale EMI measurements and quantitative inversions. The fixed-boom multi-coil EMI ECa data of nine coil configurations indicated spatial patterns due to buried paleo-river channels. After inversion, the obtained layered quasi-3D electrical conductivity model showed a relatively homogeneous ploughing layer and the presence of the paleo-river channels at > 1 m depth. Contrary to often used assumptions, s of the ploughing layer only showed minor correlation to fluorescence data ($r \sim 0.35$), while the subsoil returned a significant correlation ($r \sim 0.65$) indicating a substantial influence of the subsoil on the plant performance, especially during dry periods which is probably due to differences in soil water holding capacity. For the first time, we have related soil-depth specific 3D subsurface information obtained by quantitative multi-coil EMI data inversions with sun-induced fluorescence data and have shown that above surface plant performance is caused by subsoil structural changes. Consequently, the subsurface structures should be incorporated in plant modeling as well as in terrestrial system modeling tools to improve the understanding of soil-vegetation-atmosphere exchange processes.

Abstract: T37

Large-scale subsurface characterization using Multi-Configuration EMI and image classification

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An appropriate characterization of the spatial variability of soil properties and layering is vital when modelling the relationships between soil and vegetation. At the field scale, such subsurface structures can be investigated with a combination of soil sampling and non-invasive geophysical measurements (e.g. electromagnetic induction EMI) within a quantitative inversion framework. It is not feasible to apply such quantitative interpretation at the farm scale where heterogeneous agricultural fields with variable management are present. This because the required EMI calibration is currently not feasible and a complex and large study area cannot be measured during the same period without interfering with the agricultural activity. In this study, we used an image classification method to analyze high-resolution multi-configuration EMI measurements and characterize patterns of soil structural organization (layering and texture) and their impact on crop productivity at the km2 scale. We collected EMI data on an agricultural area of 102 ha near Selhausen (NRW, Germany). The area consists of 51 agricultural fields cropped in rotation. Measurements were collected between April and December 2016, preferably within a few days after harvest. EMI data were automatically filtered, temperature corrected, and interpolated onto a common grid of 1 m resolution. The ECa maps indicated three main sub-areas with different subsurface heterogeneity. Small-scale geomorphological structures as well as anthropogenic activities such as soil management and buried drainage networks could be also identified. To obtain areas with similar subsurface structures, we applied an image classification technique to the EMI data. For this, we fused the ECa maps obtained with different coil configurations in a multiband image and applied supervised and unsupervised classification methodologies. Both showed good results in reconstructing observed patterns in plant productivity and the subsurface structures associated with them. However, the supervised methodology proved more efficient in classifying the whole study area. In a second step, we selected hundred locations within the study area and obtained a soil profile description with type, depth, and thickness of the soil horizons. Each layer with characteristic texture was sampled and a total of 570 samples were analyzed to obtain information on grain size distribution. Using this ground truth data, it was possible to assign a typical soil profile to each of the main classes obtained from the classification. The proposed methodology was effective in producing a high resolution subsurface model in a large and complex study area that extends well beyond the field scale.

Abstract: T38

Simultaneous non-invasive measurement of soil moisture and biomass dynamics using the cosmic-ray neutron probe

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Understanding the feedback mechanisms between soil moisture and biomass production is important for sustainable resources management. Here we present a new method enabling simultaneous non-invasive measurement of soil moisture and biomass dynamics based on cosmic-ray neutron sensing. Cosmic radiation produces neutrons with kinetic energies ranging from <1 eV (thermal) to >1 MeV at ground level. In the fast neutron energy range (1 eV - 100 keV), neutrons are strongly moderated by collisions with hydrogen nuclei enabling non-invasive soil moisture measurements at the field scale. Recently, it was found that the ratio between thermal and fast neutron intensity contains information on other hydrogen pools like vegetation, canopy interception, and snow. This opens up the possibility to use the cosmic-ray neutron measurements for continuous and non-invasive monitoring of biomass development at the field scale. To test the possibility for simultaneous measurement of soil moisture and biomass dynamics, we instrumented an arable field cropped with sugar beet with cosmic-ray neutron probes and a wireless sensor network with more than 140 in-situ soil moisture sensors as reference. Below- and aboveground biomass was sampled in-situ in 3 to 4 weekly intervals. We found a close linear relationship between the thermal to fast neutron intensity ratio and the aboveground biomass. Using this relationship, we were able to continuously quantify the aboveground biomass development throughout the growing season with an RMSE of 0.173 kg/m^2. This information together with in-situ measured belowground biomass was used to correct the effect of biomass on soil moisture determination. This reduced the RMSE from 0.0435 to 0.0118 m^3/m^3. We anticipate that future research on thermal to fast neutron intensity ratios can both improve the accuracy of the soil moisture estimates and extend the application of cosmic-ray neutron sensing to include biomass, canopy interception, and snow water equivalent estimation for both stationary and roving systems.

Abstract: T39

The temperature sensitivity (Q10) of soil respiration: controlling factors and spatial prediction at regional scale based on environmental soil classes

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The temperature sensitivity of heterotrophic soil respiration is crucial for modeling carbon dynamics. Most models employ a fixed value of 1.5 or 2.0 for the increase of soil respiration per 10°C increase in temperature (Q10). However, it is well known that the Q10 value is variable but spatial patterns and regulating factors of Q10 variability at regional scale remain speculative so far. Hence, we aimed at (1) identifying the controlling factors of Q10 variability at regional scale (Rur catchment, Germany/Belgium/Netherlands) and at (2) developing an approach for the spatial estimate of Q10 based on widely available proxies. Therefore, we divided the catchment into environmental soil classes (ESC), which we define as unique combinations of land use, aggregated soil groups, and soil texture. We took nine soil samples from each of the 12 most common ESCs and incubated them at four soil moisture levels and five temperatures (5-25°C). We hypothesized that Q10 variability is controlled by soil organic carbon (SOC) degradability and by soil moisture. We further assumed that ESCs can be used as widely available proxies for Q10, owing to differences in SOC degradability across ESCs. Measured Q10 values ranged from 1.2 to 2.8 and were correlated with indicators of SOC degradability (e.g., pH and C/N, r=-0.52 and 0.32, respectively). As SOC degradability varied across ESCs, they were also indicative for the spatial patterns of Q10. Here, ESCs captured 44% and 36% of Q10 variability at dry and intermediate soil moisture conditions, respectively, where Q10 increased in the order cropland<grassland<forest. The effect of soil moisture on Q10 was significant but also ESC-specific: the Q10 value increased with moisture in croplands but decreased in forests. Hence, we suggest that scaling Q10 on the basis of both ESC and soil moisture might be a promising concept for spatially continuous estimates of carbon turnover at regional scales.

Abstract: T40

Linking spatial and temporal sun-induced fluorescence patterns to soil and atmospheric properties in a heterogeneous agriculture landscape

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There are strong interactions between soil properties, plant growth and atmosphere. We use sun-induced fluorescence (F) to obtain information about plant physiological status that can be linked to soil and atmospheric properties, improving our understanding of energy and matter flows. F is a remote sensing signal closely related to the actual rate of photosynthesis and vegetation stress. It reflects functional limitations of the photosynthetic carbon gain and can be measured in solar and atmospheric absorption lines using high performance spectrometers. We have collected data for spatial analyses using the high performance imaging spectrometer HyPlant, measuring in wavelength ranges 400 – 2500 nm and 670 – 780 nm with a spectral resolution of 0.26 nm. Data were recorded with a spatial resolution of 3 m per pixel for the entire region (ca. 14×14 km2) and with a 1 m resolution for the Selhausen area (ca. 1.5×5 km2) that was better characterized, in particular in terms of the land use classification, soil properties and had an Eddy Covariance (EC) tower. The data was processed using iFLD (Improved Fraunhofer Line Discrimination) and SFM (Spectral Fitting Method). We investigated the within- and between-species variability of red and far-red fluorescence and vegetation indices. We have chosen fields with the same crop type and found the distributions of F for the main most active regional crops at the measurement time such as sugar beet, potato and corn. We have found that the variability of the red and far-red fluorescence, PRI and Simple Ratio vegetation indexes is normally distributed. Broader distributions are caused by structural effects (growing canopies) or canopy senescence. For the first time we have shown that the within-field inhomogeneity of F caused by differences in plant performance is related to specific subsurface structures obtained by multi-coil EMI data inversions. The electrical conductivity of the ploughing layer showed minor correlation to fluorescence data, while the correlation between the subsoil conductivity and far-red fluorescence indicate a significant influence of the subsoil on the plant performance, especially during dry periods. In addition to spatially resolved airborne data measured once per year, temporally-resolved passive measurements of F for the chosen crop (sugar beet) were performed in 2017 from the middle of June to the end of October using the hyperspectral field instrument FloxBox. The FloxBox was installed on the same location as the EC tower to allow linking the plant functioning and atmospheric changes. A huge dataset collected and processed during the last years allows us performing deep analyses of interactions within the system soil-plant-atmosphere.

Abstract: T41

Empirical Derivation of Soil Moisture and Vegetation Parameters from Sentinel-1 SAR in the Rur catchment

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In-situ measurements of soil moisture are time consuming and give only point-wise information. Due to the large spatial heterogeneity of soil moisture, interpolation from ground measurements results in large uncertainties. In that context, microwave remote sensing provides an opportunity to derive spatially-distributed soil moisture information. While passive microwave remote sensing of soil moisture is well established, it provides spatial resolutions only on the kilometer scale. In contrast to that, Synthetic Aperture Radar (SAR) remote sensing provides data with a spatial resolution in the meter range, but so far there are no operational retrieval algorithms. The problem of soil moisture retrieval from vegetated areas with SAR is that the backscatter intensity is not only influenced by the amount of soil moisture but also by the vegetation layer and the surface roughness. Consequently, retrieval algorithms must be developed that correct for the influence of vegetation and roughness on the backscatter intensity. This can be done for example by using empirical relationships that exploit the observation space of multi-polarimetric SAR systems. Sentinel-1A and –B are ESA C-band satellites that provide dual-polarimetric VV-VH images with a spatial resolution of 15 m and a 6-day repeat cycle.

This study uses 21 Sentinel-1A acquisitions with corresponding ground truth measurements from 2015 and 2016 in the Rur catchment, to develop empirical retrieval algorithms for soil moisture and vegetation parameters (green and brown Leaf Area Index (LAI), canopy height, wet and dry biomass and vegetation water content). After state-of-the-art processing of the SAR images, correlations of SAR observables to soil moisture and different vegetation parameters are assessed and retrieval algorithms are developed. The results show that soil moisture retrieval on bare soil and maize is possible for our measurement configuration by using a simple linear regression approach resulting in an RMSE of 7 Vol. %. For other vegetation types, vegetation proved to be the dominating factor affecting the radar signal provided by the used satellite configuration (15 m resolution, high incidence angle, C-band). Vegetation parameters were derived with a median error of 25 % of the respective value range. Different SAR observables are sensitive to different vegetation parameters. Our study underlines the importance of using dual-polarimetric observations in SAR remote sensing.

Abstract: T42

Severe Hail Detection: Hydrometeor Classification for Polarimetric C-band Radars Using Fuzzy-Logic and T-matrix Scattering Simulations

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Large hail is a frequently occurring and sometimes devastating phenomenon, especially during summertime convective events. Many occasions of hail stones with diameters above 5 cm up to 14 cm have been reported and confirmed in the last years in central Europe. Concepts and algorithms to detect and distinguish large hail from small hail or rain with polarimetric radars at S band exist. However, most weather radars in Europe operate at C band. Here we present the usability of operational hydrometeor classification algorithms, like the fuzzy-logic based algorithm in Park et al. (2009), at C band and the necessity of wavelength-specific, simulated parameters for these algorithms. We emphasize that specific attenuation Ah is a major factor in identifying and discriminating hail at C band. Simulating value ranges of polarimetric variables at C band and including Ah are vital key factors for hydrometeor classification at C band. Additionally, we provide an approach to obtain parameters to distinguish between rain and small, large and giant hail at C band with fuzzy-logic.

Abstract: T43

Effects of parameterizations of the drop size distribution with variable shape parameter on polarimetric radar moments

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The drop size distribution (DSD) plays a central role in quantitative precipitation estimation. It is related to both the polarimetric radar variables and the rain rate. Recently, the assimilation of polarimetric information emerged as a new and promising research field to achieve a better representation of cloud and precipitation processes in numerical weather prediction (NWP). In this context the capability of DSD parameterizations to produce physically reliable polarimetric moments is mandatory.

The standard formalization of the DSD is the gamma model, which satisfies the high natural variability of the DSD. In NWP, it has recently become popular to assume diagnostic relations between the mean-mass hydrometeor diameter Dm' and the DSD shape parameter, derived from idealized simulations.

While this is appropriate to mitigate the effects of size sorting which are overly strong in two-moment schemes, further implications of such DSD parameterizations are not thoroughly understood yet. We study how – in the case of pure rain – these DSD parameterizations impact synthetic polarimetric radar variables and discuss whether the resulting behavior is physically reasonable. Further, we examine the agreement of such Dm'-based-relations with disdrometer observations.

Abstract: T44

Assessing the Applicability of CHELSA (Climatologies at High resolution for the Earth's Land Surface Areas) data for Monthly and Seasonal Precipitation Predications

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In recent years gridded global databases with high spatially accuracy has been developed by climatologists from many institutes for solving lack in climate observational data. Iran is an extensive country and its observational network is not sufficient, especially throughout the middle of this country and studies in the field of hydrology and climatology usually need high punctual data. In this study CHELSA (Climatologies at high resolution for the earth's land surface areas) precipitation database is validated as one of the ECMWF products. This database is based on a quasi-mechanistical statistical downscaling of the ERA interim global circulation model in High resolution grid cells (30 arcsec, ~1 km) of temperature and precipitation patterns for every month for the time period 1979-2013. Totally, precipitation data of 48 weather stations and CHELSA gridded precipitation databases are compared to each other in 1979 -2013-time period. The Nash- Sutcliffe efficiency (NSE)(52%-99%), Mean Absolute Error (MAE) (0.07-2.62), Mean Absolute Deviation (MAD) (0.02-31) and Root Mean Square Error) RMSE) (1.3-44.3). The results suggested a significant correspondence between monthly scale observation data and CHELSA reanalysis dataset. The bias of CHELSA are calculated on specific (48) grid cells for all months and seasons and the results showed that there was not a considerable difference between the observation data and CHELSA dataset. Findings showed that estimation of the rainfall in October and November is not as accurate as in other months. And there is an overestimation by CHELSA. The amount of this overestimation is between 84-105 mm in October and November and in annual timescale is 10-105 mm. It seems that this database has a fault in the estimation of precipitation that originates from the factor of lowlands near the sea specially Caspian Sea and some parts of mountains but in the most cases has high performance and accuracy.
Keywords: CHELSA database, Analysis, Precipitation, Bias

Abstract: T45

Topological pattern analysis of atmospheric boundary layer turbulence

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The modeling of atmospheric boundary layer turbulence results in complex four-dimensional datasets, for which summaries or visualizations are not easily obtained without projecting to lower dimensional subspaces, or mapping the data to the spectral domain. In our case, a convective flow driven by buoyancy from the surface, land surface patterns add to the complexity. Here we introduce computational techniques that allow the detection of coherent structures in the turbulent flow, and their representation in a tree-like hierarchical pattern, based on their geometric and topological properties in the physical domain. This allows us to trace large-scale convective structures in the outer layer to individual links with the surface.

Abstract: T46

Recent Progress on Intrinsic Mode Function Representation and Its Applications to Hydrological Data

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Abstract: Time-frequency distribution/spectrum of a signal, in general, can provide more distinct periodic/aperiodic information to us in comparison to observe the signal itself. However, many natural signals monitored from precise sensors contain nonstationary processes which cannot be accurately illustrated in the time-frequency domain by using standard existing methods, e.g. short-time Fourier transform, wavelet transform (with reassignment or synchrosqueezing techniques). The reason is that a convolution between the signal and cosine/wavelet basis significantly smears the time-frequency pattern within the nonstationary process, which is the well-known uncertainty principle. To avoid such perplexing contradiction between the time and frequency resolutions, adaptive signal decomposition methods, like empirical mode decomposition (EMD), separate the signal into cascading components without any predefined basis. Each component is mathematically defined as an intrinsic mode function (IMF) a(t) cos(theta(t)) to be contained in a narrow time-frequency band. Unfortunately, such methods are heuristic and, to this end, lack a solid mathematical foundation. A differential equation based operator is introduced to characterize the desired IMF, by which the instantaneous amplitude a(t) and the instantaneous frequency theta'(t) can be accurately retrieved from the IMF (without any constraint from the theory of Hilbert transforms). By taking into account properties, e.g. orthogonality, cascading and sparsity, excavated from our additive signal model, a promising optimization framework is designed to accurately extract all IMFs from the given signal. After all a(t) and theta'(t) are retrieved, an unambiguous time-frequency-amplitude spectrum of the signal can be generated. Finally, some numeral studies together with applications of hydrological data analysis illustrate the advantages of the proposed method comparing to other existing ones.

Abstract: T47

Exploring small-scale patterns in a forest soil-vegetation-atmosphere system

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Forests play an important role in regional and trans-regional cycles of water, energy and matter exchange. The magnitude of fluxes that can be observed in forest eco-systems depends e.g. on atmospheric conditions, soil properties, soil water availability and stand structure. One current challenge in the assessment of prevailing processes and fluxes is the scaling of measurements often available only at the point-scale to the forest stand and catchment scale. To improve the regional and trans-regional assessment of water, energy and matter fluxes, a better understanding of existing small-scale patterns and their relevance for the upscaling procedure is needed. We apply an interdisciplinary research approach to address the following research questions in a 38 ha forested headwater catchment in western Germany: (1) Which kind of small-scale patterns can we observe in the forest soil-vegetation-atmosphere system? (2) How are existing patterns inter-related? (3) How important are the observed patterns and feedbacks for the upscaling of processes and fluxes? Our investigations are based on short- and long-term measurements of soil and atmospheric conditions, soil water availability, sap flow and stand structure. The test-site is an even-aged Norway spruce plantation, which has the advantage that observed patterns can be interpreted independent from tree-age and as a pure result of ambient conditions.

Abstract: T48

Analysis of Soil Moisture Patterns in a Mesoscale Catchment Using Plot to Catchment Scale Datasets

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Soil moisture and its spatio-temporal pattern is a key variable in hydrology, meteorology and agriculture. The aim of our subproject within the SFB/TR32 is to analyze spatio-temporal patterns of soil moisture using datasets from the Rur catchment (Western Germany, total area 2364 km2) which consists of a low mountain range (forest and grassland) and a loess plain dominated by arable land. Data was acquired across a variety of land use types, on different spatial scales (plot to mesoscale catchment) and with different methods (field measurements, remote sensing, and simulation). Patterns are analyzed using principal component analysis, autocorrelation analysis, geostatistical analysis, and fractal analysis.

Different parameters, for example soil properties, topography or land use structure, could be identified to be the driver of the spatial soil moisture patterns on different scales. The joint analysis of the different datasets also showed that small differences in soil moisture dynamics, especially at maximum porosity and wilting point in the soils, can have a large influence on the soil moisture patterns and their autocorrelation structure. In addition, the influence of the spatial structure of model inputs (e.g. precipitation, soil properties) on modelled soil moisture patterns was investigated.

Posters

Abstract: P01

Remote sensing and GIS-based land use and crop rotation mapping for regional soil-vegetation-atmosphere modelling

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For the assessment of the different matter and energy fluxes in the soil-vegetation-atmosphere (SVA) system on a regional scale, high quality land use data is of key importance. This means that for arable land parcel-related crop type and crop rotation information has to be provided to model the associated fluxes accurately. Besides this, sophisticated (agro-)ecosystem modelling for large regions is usually done at grid resolutions, which are coarser than the spatial resolution of modern land use maps. Maintaining the original land use information as much as possible for such cases, is therefore crucial for the model outcomes. In this contribution we present the results of our Multi-Data Approach for the Rur catchment, which was developed to address these requirements. Its methodological basis is the integration of remote sensing, geographic information systems (GIS) and ancillary data to generate annual land use/crop maps with enhanced information content. A key aspect is the consideration of crop phenology for the data selection and for the classification of multi temporal optical and/or radar remote sensing data. In the GIS, the annul crop maps were integrated to a crop sequence dataset from which the major crop rotations were derived. To retain the detailed land use and crop type information as well as the change from year to year even at coarser grid resolutions, cell-based land use fractions were calculated for each year and for various co-aligned target cell sizes (1-32 arc seconds). Our results for the years 2008-2017 show that with our approach the major crop types can be differentiated with a high accuracy for individual parcels and on an annual basis. The analysis of the crop sequence data revealed that a very large number of different crop rotations exists, but relatively few crop rotations cover larger areas. This strong diversity emphasizes the importance of information on crop rotations to reduce uncertainties in agro-ecosystem modelling. Through the combination of the multi annual land use fractions, detailed information about cell composition and land use change at each cell size is available to be used in platforms like the Community Land Model (CLM).

Abstract: P02

A Bayesian unsupervised clustering approach for spatial and statistical pattern extraction of subsoil using satellite derived NDVI time series and electromagnetic induction measurements

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We address the question of linking remotely sensed surface vegetation performance with heterogeneity of subsoil physical properties by means of a Bayesian unsupervised clustering approach used for spatial and statistical pattern extraction. This question has considerable relevance and practical meaning for precision agriculture as visible spatial differences in crop development and yield are often directly related to horizontal and vertical variations in soil texture caused by complex deposition/erosion processes. Besides, active and relict geomorphological settings, such as floodplain, buried paleo-channels, and glacial terrace can cast significant complexity into surface hydrology and crop modeling, this also requires a better approach to detect, quantify, and simulate subsoil heterogeneity. In this work, we introduce a novel spatial and statistical pattern recognition and uncertainty quantification framework based on hidden Markov random field and finite mixture model. The approach is validated using synthetic data. By combining satellite derived NDVI time series with proximal soil sensor data acquired by a multi-receiver electromagnetic induction (EMI) survey system, and clustering the multiple dimensional information into clusters, we show, for the first time, how the similarity in geometry structures between amplitude images from harmonic analysis of NDVI time series and soil apparent electrical conductivity (ECa) for nine depths of exploration (DOE) can be extracted and the associated epistemic uncertainty can be quantified in a statistical manner. In addition, we also detect, estimate, and visualize the statistical similarity intra-cluster and the separability inter-cluster. The correlation coefficients between different amplitude terms and soil apparent electrical conductivity at multiple DOE are calculated for a quantitative measure. The spatial and statistical patterns are interpreted by incorporating additional knowledge from geological map and soil samples.

Abstract: P03

Linking remotely sensed multispectral data to large-scale electromagnetic induction measurements for soil parameter prediction by means of multiple linear regression kriging

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Soils provide vital resources and different techniques have been proposed to characterize soil inherent processes. We use non-invasive high-resolution multi-configuration electromagnetic induction (EMI) that senses multiple depths of investigation (DOI), sparse soil sampling, and satellite derived normalized difference vegetation index (NDVI) data to predict top- and subsoil properties by means of multiple linear step-wise regression-kriging (RK). The study determines the most descriptive covariates as well as the optimal number and soil sampling calibration locations at a 4 ha field located in the Rur River valley (Germany) with a distinct underlying fluvial geomorphology. The EMI data were acquired for nine DOIs using simultaneously two fixed-boom multi-coil EMI instruments. A three- and a six-coil EMI instrument respectively used vertical coplanar and horizontal coplanar coils to provide shallow and deep DOIs between 0.25 m and up to 2.70 m depth. Differential GPS systems delivered coordinates for each instrument. Two multispectral satellite images showed NDVI patterns similar to those observed with ground-based EMI and soil sampling data of 45 probing locations. The relationships between EMI, NDVI, texture, and water content were explored by RK and used to upscale the soil properties. To discern the explanatory variables and to obtain the best prediction accuracy iteratively, the correlation coefficient (r) and root mean square error were computed. We found that RK outperformed ordinary kriging due to the fairly linear covariate and soil property correlation. Stepwise reducing the 45 soil samples resulted in 12 minimum samples that can be used together with different EMI DOI data to fully describe soil heterogeneity with a 1×1 m resolution for five depth ranges down to 1 m. The EMI data were the most explanatory covariates and best predictions were obtained using DOIs similar to the soil sampling depth for silt (r= 0.5-0.7) and clay (r= 0.4-0.6). However, adding NDVI improved predictions only in 4 out of 25 cases. The low correlation between NDVI and the deepest sensing HCP coils (DOI ~ 1.5 to 2.7 m) showed that the deeper subsoil had lower impact on plant performance at this test site probably due to the shallow buried fluvial system depth and/or shallow grass rooting depth. Consequently, EMI data combined with sparse soil samples provide high-resolution soil property maps. Improvements are expected when using non-linear (3D) regression models that consider spatial correlation and system metrics such as data entropy.

Abstract: P04

Modeling and Theoretical Investigation of multi-scale Interactions between Convection and Land-Surface Heterogeneity

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To study the interaction between land-surface and atmosphere, we run the WRF model in its meso-scale mode forced by ERA-INTERIM reanalyses for a time period covered by the HOPE campaign. The analysis period covers three consecutive days with different synoptic situations: 24th was clear sky, 25th was cloudy and 26th was rainy in April 2013 according to the HOPE experiment. In our simulations, we replace the surface boundary condition by surface patterns generated by a multi-fractal spectral approach varying the dominant pattern scale (in terms of a wave number) and pattern persistence (in terms of a slope in spectral space). Many different surface patterns varying these two parameters but keeping the probability distribution of land surface types are used as surface boundary condition. It is planned to generate an ensemble of a size of the order of 10^3 varying the surface pattern parameters. In this ensemble, we will analyze the sensitivity of bulk parameters of the atmosphere to the parameters describing the surface pattern.

Abstract: P05

Describing the spatial pattern of a shallow cumulus cloud population in terms of size and spacing

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In a previously performed study a strong correlation was found between the maximum horizontal size of a shallow cumulus cloud and the cloud fraction of the field it is living in. Also the degree of clustering of the cumuli was found to correlate with cloud fraction. Research like this on the spatial patterns in cumulus cloud formation are of key importance since this regime still is a significant source of uncertainty in global climate models. We need to better understand the underlying processes of the formation of these clouds to be able to accurately represent them in large scale models. The earlier found correlations were based on a large library of cases of shallow cumulus over land. For every day a LES was performed, thereby providing enough data for reliable statistics. However, a downside of the study was the relatively small domain size, preventing bigger clouds to form. Therefore as a next step high-resolution ICON data on a large domain is used to tackle this shortcoming. The simulations are performed over the Atlantic ocean with a resolution fine enough to resolve typical cumulus clouds. This allows us to take a next step in describing a cumulus cloud population, namely the way clouds interact in terms of the spacing in between them. To this end, an algorithm designed to determine cloud size densities is expanded in order to also calculate the nearest neighbour spacing between clouds of similar size. Within this framework we will study the relation between the size of a cloud and the mean distance to it’s neighbour. With the combination of information on the nearest neighbour spacing and the cloud size distribution we can describe the spatial patterns in a shallow cumulus cloud population. The results can be used to improve cumulus parametrization schemes, especially the ones that are based on cloud size densities.

Abstract: P06

Effects of Land Surface Heterogeneity on Simulated Boundary-Layer Structure

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Land surface heterogeneity exerts a strong control on atmospheric boundary layer (ABL) structure via spatio-temporal variability in turbulent fluxes and convectively induced secondary circulations, however, its effects cannot be incorporated explicitly in regional and climate models, due to their coarse horizontal grid resolutions. While tile/mosaic approach improves the mean surface fluxes due to subgrid-scale land surface heterogeneity, they do not include its dynamical effects on boundary layer mixing. These model structural errors in the representing of these key physical processes, could be however compensated by grid scale turbulent mixing length scale parameter used in the ABL schemes, which can impact the stability of the ABL, convection initiation and precipitation.

In this study, we make use of the German wide high resolution ICON-LES runs at 156 m resolution available from $HD(CP)^2$ as a reference to first investigate the impact of different horizontal grid resolutions (312 m, 625 m, 2.8 km, 7 km and 20 km) on the simulated boundary layer structure in terms of ABL stability, height and convectively induced secondary circulations. We perform heterogeneity analysis using probability density functions, entropy spectrum and patchiness at four different locations encompassing measurement sites and relate these indices to boundary layer quantities and explore methods to develop its empirical relationship to turbulent mixing length scale parameter.

Abstract: P07

Impact of downscaled atmospheric forcing on surface energy flux partitioning

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Dynamical processes in the atmosphere, at the land surface and within the subsurface act at their intrinsic spatial and temporal scales. With increasing computational power, integrated modeling platforms such as the Terrestrial Systems Modeling Platform (TerrSysMP) coupling atmospheric component model COSMO, land surface model CLM and hydrological subsurface model ParFlow are increasingly used to account for interactions and feedback processes between the components in a scale consistent manner. TerrSysMP exploits the mosaic approach for the land surface and groundwater model to improve flux estimates, but typically neglects subscale variability of the near surface atmosphere. An appropriate atmospheric downscaling which recovers subscale variability of the near-surface atmospheric variables (temperature, wind speed, etc.) might further improve flux estimates as well as the simulation of threshold dependent processes such as snow melt or soil freezing.

Different downscaling techniques using spline-interpolation, linear regression, simple noise generators and genetic programming have been developed during the past years and implemented in the OASIS3 coupling interface of the TerrSysMP. In this study, we report on the different downscaling techniques, along with their application in a sensitivity study using both offline runs with CLM and coupled runs with COSMO-CLM over the western part of Germany. The results from the sensitivity study are used to address the following specific questions: 1) How strong is the influence of atmospheric downscaling on the simulated fluxes?, and 2) Is the influence systematic, e.g., does downscaling increase spatial and/or temporal variability of latent and sensible heat flux?

Abstract: P08

Simulating soil surface temperature of a bare soil using an energy balance model at West of Iran

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In this research, a physically-based soil surface energy balance model was adopted to estimating daily soil surface temperature of a bare soil. For this purpose, daily meteorological data including mean air temperature, precipitation, wind speed, relative humidity and sunshine along with the maximum and minimum soil surface temperature data of an Agro-meteorological station located at West of Iran were considered in the 1996-2010 period. The agreement between the simulated and measured daily mean soil surface temperatures was evaluated using Mean Absolute Error (MAE) and Nash-Sutcliffe Efficiency (NSE) indices. The results showed an acceptable agreement between the simulated and measured data with the 2.3 °C and 0.92 values for the MAE and NSE indices, respectively. By considering the NSE index, the lowest and highest model performance was obtained at the winter and autumn seasons, respectively. With respect to having some extra uncertainty sources regarding to the snow modeling during winter and its effect on the soil surface temperature, a more complicated simulating of the soil surface temperature under the snow pack could be considered as the reason of the lower model performance during the winter. To obtain the better results from the model, a calibration process is suggested to adjust the main and effective model parameter values by measuring more data regarding to the different energy balance components.

Abstract: P09

Validation of the MODIS land surface temperature data in West of Iran

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The land surface temperature (LST) products of the MODIS were validated in this research based on the measured daily mean soil surface temperature extracted by averaging the minimum and maximum soil surface temperature data during 2013-2014 time period for Sararoud station located in the West of Iran. The agreement between MODIS and measured LST data was validated by considering the coefficient of determination (R2). With respect to that there are four products from Aqua and Terra satellites including LST_day-aqua, LST_night-aqua , LST_day-terra and LST_night-terra, different combinations of these products were considered as the possible candidates of the daily mean of LST and the best case with the higher value of R2 was recognized and considered as the daily mean of LST. The results showed that by averaging of the LST_night-aqua, LST_day-terra and LST_night-terra and considering it as the mean daily of LST, the higher agreement between measured and MODIS LST data is occurred with a R2 value of 0.93.

Abstract: P10

Validation and Reanalysis of ERA-Interim Dataset of European Center for Medium-Range Weather Forecasts (ECMWF) in Iran

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Availability of reliable data with dense and long-term spatial coverage is important in climate change studies, water resource management and drought monitoring. However, observational data are often short-lived, with inappropriate spatial distribution, inadequate data and low density relative to the area under study. Due to the importance of understanding the spatial distribution of precipitation in Iran's plateau and the need for correction of observation data and awareness of rainfall in areas without a measuring station, the monthly ERA-Interim rainfall data as an advanced generation of The European Center for Medium-Range Weather Forecasts (ECMWF) was compared with observational data of 119 stations in the 1991-2010 period. These stations account for 33% of the synoptic stations of Iran and the monthly precipitation data of ERA-Interim with a spatial resolution of 0.75 * 0.75 degrees were considered which cover 35% of the stations studied in the grid cells of ERA-Interim data. The R2, RMSE, ME and Bias statistics were used to evaluate the accuracy of precipitation estimates at each station and the results showed that despite the correlation of 99.9%, 95%, 98%, 99%, and the coefficient of 0.87-0.99% of the RMSE and MAE statistics for 8-12% of the studied stations were more than 35. The spatial distribution of these stations is in the Caspian Sea, Zagros, Azarbaijan and Ardebil highlands. The minimum and maximum bias of the measured values of observations between the stations studied is between -185 and 41 mm. The interactions of sea and land, complex topography of some regions and the presence of convection conditions and precipitation occurrences can influence the performance of the ERA-Interim model in predicting rainfall.

Keywords: Weather Forecasts, Spatial distribution, Validation, Precipitation reanalysis

Abstract: P11

High-resolution profile measurements of wind speed and scalars within and above short canopies: Applicability to flux measurement, source partitioning and process understanding

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Vertical profiles of CO_2, water vapour, temperature and wind speed from the soil surface to ~ 2 m a.g.l. at centimetre-scale resolution were measured repeatedly at an agricultural eddy-covariance site between 2015 and 2017, covering various crops, weather conditions and times of day. The poster briefly describes the profile measurement system based on a continuously moving elevator and required data processing steps. We demonstrate, by comparison to eddy-covariance data, that net fluxes of momentum, sensible and latent heat and CO_2 over horizontally homogeneous bare soil and short plant canopies can be robustly derived using Monin-Obukhov Similarity Theory (MOST) based profile analysis. As a result, the more complex profiles measured within and immediately above higher canopies, are expected to be a reliable data source and testbed for other analysis frameworks adapted to such non-MOST situations. These profiles include effects of aboveground plant CO_2 exchange vs. soil respiration, transpiration, evaporation and height-dependent dew formation, sensible heat source levels changing during the day, and resulting opposite local thermal stability between the deep and upper canopy. Various existing non-MOST frameworks are tested on the data, and their methodological uncertainties and requirements for improvement are identified from differences between their predictions.

Abstract: P12

Understanding the Spatiotemporal Structures in Atmosphere-Land Surface Exchange at the Jülich Observatory for Cloud Evolution

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In this study the spatial and temporal patterns of surface-atmosphere exchange parameters from temporal and spatial highly-resolved measurements as well as long-term observations are identified.

For this objective the Jülich ObservatorY for Cloud Evolution (JOYCE) provides a combination of state-of-the-art ground-based remote sensing techniques. The constantly growing multi-year data set at JOYCE offers detailed insight into boundary layer development concerning turbulence, clouds and winds. Studying the mixing processes and their evolution in the lower atmosphere is essential in order to understand the coupling between near surface turbulence and cloud formation.

A classification of the boundary-layer into specific types based on Doppler wind lidar measurements provides information on the strength and origin of the turbulence with a high temporal resolution. In this method, the backscatter coefficient and higher moments (variance, skewness) of Doppler lidar measured vertical velocity are used together with horizontal winds derived from azimuth scans. In this way, a discrimination between surface and cloud driven turbulence can be made.

The first statistical analysis of the classification showed the potential of characterizing processes like the diurnal cycle of atmospheric mixing, cloud coupling and turbulence related to low-level jets. Due to the emerging Doppler wind lidar network in Europe, the classification can also be applied at other sites in different climatic regimes, including maritime and high latitude sites.

Furthermore, the classification can be used to select specific conditions favoring the evaluation of coupling processes between near surface turbulence and cloud evolution to surface and vegetation properties. In these predominantly convective cases, the land surface heterogeneity is assessed by exploiting the time series of a eddy-covariance station at the ground level and a land use classification. Following this, the spatial variability of the surface fluxes is connected to horizontal gradients in water vapor and liquid water path measurements of a scanning microwave radiometer. Depending on the mean wind flow, to exclude advection related phenomena, the orographic and vegetation based influences can be identified.

In addition, the boundary layer classification can also be used for evaluating parameterizations of mixing processes and in terms of coupled boundary layer clouds in the ICOsahedral Nonhydrostatic unified modeling system (ICON), that performs as a large eddy simulation.

Abstract: P13

CO2 fluxes before and after partial deforestation of a spruce forest

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Disturbances in forest ecosystem lead to changes in the functional characteristics of the ecosystem. Deforestation has a major impact on the carbon dioxide (CO2) exchange between the forested ecosystem and the atmosphere. We present seven years of eddy covariance (EC) measurements (October 2013 to October 2017) over a 70 year old spruce stock, including three years prior to and four years after partial deforestation. We analyzed the changes of carbon fluxes as affected mainly by the forest transition. The measurements were carried out in a small headwater catchment (38.5 ha) within the TERENO (TERrestrial Environmental Observatories) network in the Eifel National Park Germany (50°30'N, 06°19'E, 595-629 m a.s.l.). An EC system, mounted on the top of a 38 m high tower, continuously samples fluxes of momentum, sensible heat, latent heat and CO2. In August 2013, more than 20% of the catchment was deforested and planned for regeneration towards natural deciduous vegetation, and a second EC station (up to 3 m height) was installed in the middle of this clearcut. Full time series and annual carbon budgets of the net ecosystem exchange (NEE) and its components gross primary production (GPP) and total ecosystem respiration (Reco) were calculated by using gap filling and flux partitioning methods. After the partial deforestation, soil respiration was measured with manual chambers on average every month at 25 transect points in the forest (12 points) and deforested area (13 points). In contrast to the deforested area, annual sums of NEE measured above the forest showed -a carbon sink with small inter-annual variability. In the first year after partial deforestation, regrowth on the deforested area consisted mainly of grasses and red foxglove (Digitalis purpurea L.), while since the second year also growth of mountain ash (Sorbus aucuparia L.) and broom (Cytisus scoparius L.) increased. The regrowth of biomass is reflected in the annual sums of NEE, which decreased from a carbon source of + 500 g C m-2 y-1 towards neutral over the past four years, due to an increase in the magnitude of GPP.

Abstract: P14

Soil respiration and its temperature sensitivity (Q10): rapid acquisition using mid-infrared spectroscopy

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Spatial patterns of soil respiration (SR) and its sensitivity to temperature (Q10) are one of the key uncertainties in climate change research but since their assessment is very time-consuming, large data sets can still not be provided. Here, we investigated the potential of mid-infrared spectroscopy (MIRS) to predict SR and Q10 values for 124 soil samples of diverse land use types taken from a 2868 km^2 catchment (Rur catchment, Germany/Belgium/Netherlands). Soil respiration at standardized temperature (25°C) and soil moisture (45% of maximum water holding capacity, WHC) was successfully predicted by MIRS coupled with partial least square regression (PLSR, R^2 = 0.83). Also the Q10 value was predictable by MIRS-PLSR for a grassland submodel (R^2 = 0.75) and a cropland submodel (R^2 = 0.72) but not for forested sites (R^2 = 0.03). In order to provide soil respiration estimates for arbitrary conditions of temperature and soil moisture, more flexible models are required that can handle nonlinear and interacting relations. Therefore, we applied a random forest model, which includes the MIRS spectra, temperature, soil moisture, and land use as predictor variables. We could show that SR can be simultaneously predicted for any temperature (5-25°C) and soil moisture level (30-75% of WHC), indicated by a high R^2 of 0.73. We conclude that the combination of MIRS with sophisticated statistical prediction tools allows for a novel, rapid acquisition of SR and Q10 values across landscapes and thus to fill an important data gap in the validation of large scale carbon modeling.

Abstract: P15

Recolonization of root-induced macropores

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Roots are able to shape their direct environment by creating stable channels, so-called root-induced macropores. Those pores can become recolonized by roots of the subsequent growing season, what can enhance the root growth into deeper soil layer and also may have influence on the nutrient and water uptake. We studied for wheat and maize roots in two different soils the growth over time, the vertical distribution, and the recolonization of root-induced macropores. The experiments were conducted in the two rhizotron facilities, where one has a sandy soil with high gravel content and the other one has a silty soil. The root growth over time and depth was observed with a minirhizotron camera via in different soil layers horizontally installed acrylic glass tubes. The crop rotation was as follows: winter wheat (2013/2014) followed by summer wheat (2015), winter wheat (2015/2016), and maize (2017). To quantify the recolonization of root-induced macropores we analyzed the root count density of all observed roots at the end of every growing season and the density of those roots that growth in the predefined channels from previous roots. We evaluated for each season the fraction of macropores recolonized by successive roots as well as the proportion of roots that recolonize the pores created from the previous growing crops. The results show higher root biomass and more frequent recolonization in the silty soil; the sandy soil has shallow and sparse rooting and to a lesser extent stable channels. Higher numbers of recolonization could also be found when maize was following wheat compared to wheat following wheat; one reason could be the presence of crop specific pathogens in the pores. That leads to the assumption that the recolonization of root-induced macropores is a function of soil type, soil depth, and crop rotation.

Abstract: P16

Magnetic Resonance Imaging: a tool to study preferential flow in porous media

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In soil, the presence of macropores may create preferential flow paths for the transport of gas, liquids and particles. Despite their importance to understand many environmental problematics, the characterization of such structures and how they impact flow patterns still remain very complex. Magnetic Resonance Imaging (MRI), a scanning method offering high performances in terms of achieved spatial and temporal resolution, holds the potential to answer some issues related to the topic. We present here two applications of the method to study preferential flows in porous media. We first evaluate the benefits of using MRI to quantitatively infer soil hydraulic properties of a phantom soil column designed to contain preferential flow pathways. To assess how these pathways affect flow patterns, we conducted a tracer infiltration test using a MRI contrast agent. Solute transport through the system was dynamically monitored with MRI using an Ultrashort Time-to-Echo (UTE) pulse sequence which permits to obtain high resolution 3D images in a relatively short time frame. From the variations of the signal intensity induced by the replacement of pore water by the tracer solution, flow patterns in the system could be evidenced. To quantitatively use data, we determined the relation between image intensity and tracer concentration. Then we built a hydrological model describing the setup and tried to simulate MRI data by automatically adjusting solute transport properties. At the end of calibration, we achieved a good fitting of experimental data (R^2 = 0.9) with estimated properties consistent with literature values. MRI appears particularly attractive for the estimation of transverse dispersivity, a parameter generally difficult to measure. MRI was also used to study macropore flow in natural soil. Thanks to convenient acquisition sequence (Zero echo-time - ZTE), we successfully imaged the different steps of the activation of macropore flow under increasing infiltration flow rates. At low rates, no macropore flow was detected. When the infiltration rate increased, film flow first developed at the interface between the macropores and the soil matrix. Then, at higher flow rates, macropores progressively became saturated and contributed significantly to the overall flow. When using a contrast agent, exchange between the macropore and the soil matrix domains could be investigated. The successful use of MRI to study flow in natural soil is a great outcome of our research. Up to now, the very fast decay of the MRI signal in textural pore space hindered the application of the method to that scope. The study opens perspectives for a quantitative use of MRI to explore properties of complex porous media.

Abstract: P17

Small-scale surface to borehole geoelectrics - opportunities and challenges

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We developed a geoelectrical borehole tool for near-surface measurements, allowing for highly resolved tomographic resistivity distributions in soils. They can be used as an indicator for the water distribution on a small scale and help identifying thin hydraulic barriers. The tool consists of 20 ring electrodes distributed over one meter on a plastic rod and is pushed into the ground ensuring good electrical contact. It is operated in combination with surface electrodes whenever possible for recovering 2D structures, while the whole setup is characterized by its small electrode distances. This feature, allowing for a high resolution, also poses a challenge in terms of data processing and modeling, as the spatial extent of the electrodes is no longer negligible. We verify that the ring electrodes (and even the surface electrodes) can not be represented by dimensionless point electrodes as they are usually assumed in standard ERT inversion codes. We utilize another way of representing electrodes with a finite spatial extent, the conductive cell model, in a 3D inversion. This allows for an exact replication of the actual data acquisition conditions, as the whole electrode surface is involved in the measurement. The accuracy of the approach is evaluated for a couple of artificial model cases using a crossed-bipoles configuration. Moreover, we apply the approach to laboratory data from a well-defined layered box model, using only the borehole tool. The developed inversion procedure reconstructs the artificial model cases accurately and recovers the laboratory model realistically.

Abstract: P18

Improving subsurface characterization by combining multiple layer inversions of fixed-boom multi-coil electromagnetic induction and ground penetrating radar data

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Non-invasive geophysical methods such as electromagnetic induction (EMI) and ground penetrating radar (GPR) can reveal subsurface soil structures that can impact soil-vegetation-atmosphere exchange processes. EMI measures an average electrical conductivity value in the kHz range over a specific depth range that depends on the transmitter-receiver coil separation and orientation, whereas GPR uses electromagnetic waves in the MHz range to obtain estimates of dielectric permittivity and layer depths. Both methods are complementary such that information of both EMI and GPR can be used to improve subsurface imaging. We performed EMI and GPR measurements along transects at an agricultural test site that is characterized by buried paleo-river channels that were filled with fine textured clay-rich material being present in a gravelly soil. Three fixed-boom multi-coil EMI instruments with up to 24 coil configurations sensed up to six meter depth and the data were inverted with up to five layers. The EMI inversion results indicated paleo-river channel structures below about 1 m depth with an increased electrical conductivity compared to the upper and lower layers. The GPR radargrams showed increased damping of the reflected signals at the position of the paleo-river channels due to the increased clay content, indicating that the EMI inversions performed well. Future work consist of combining the interpretation of GPR and EMI data in a single joint inversion scheme to achieve an improved characterization of subsurface structure to support terrestrial system modeling.

Abstract: P19

Water content in natural soil by low-field NMR

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At present, Low-field NMR is quite popular in geological application. The amplitude obtained from NMR reflect the soil water content due to it is directly sensitive to protons in water. Transverse relaxation time T2 indicate the different types of water in different pore spaces which give the pore size distribution of soil (porosity). In this talk we investigated the relationship of NMR acquired amplitude and soil water content for our specialized Slim-line logging tool and commercialized NMR-MOUSE. The T2 distribution map also studied in this work to find out the water dynamics during the soil drying process. In conclusion, the detailed calibration curves were obtained for SLL tool and NMR-MOUSE and it is critical to applied these two tools to achieve the accurate soil water content. T2 distribution map also give the pore size distribution and illustrate the water dynamics during the soil drying process. Typically, three T2 peaks were marked which stands for free water in macropores, capillary bounded water and clay bounded water. What’s more, the free mobile water peak gradually disappear during the drying procedure.

Abstract: P20

MRI of Water-Content Changes in Unconsolidated Natural Porous Media with Short T2

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One important methodology in need for understanding water flow processes in the vadose zone, the unsaturated upper zone of the earth crust, is quantitative imaging by non-destructive methods. MRI is a suitable technique, since it visualizes water directly and permits non-destructive investigations of time-dependent sample properties like drying. However, most natural soils exhibit very short relaxation times. In order to overcome this obstacle and to be able to obtain well resolved images from these samples, special pulse sequences have to be utilized. Established imaging pulse sequences like UTE [1], ZTE [2], and SPRITE [3] have been successfully applied in the past on rocks or biological samples with comparable, short T2 relaxation. However, natural soil samples are even more complex due to heterogeneous composition and partial water saturation. They are, in fact three-phase systems. This causes susceptibility artefacts, as well as image blurring due to short T2* and T2 values.
We are testing MRI pulse sequences suitable for imaging of objects with short T2* and T2. First we show images measured with UTE and ZTE for soil samples like a sand, a silt loam, a soil conditioner and two natural soils under saturated conditions indicating that these methods are applicable in principle. After optimizing the MRI parameters we continue with imaging unsaturated states at different water saturation levels. A plot of NMR signal intensity versus the absolute gravimetric water content allows to calibrate the images with respect to the total water content. It is possible to differentiate in 3D between different water fractions like mobile and bound water. In subsequent multi-step outflow experiments different pressure steps are applied to the soil systems while matrix potentials and the spatial distribution of the water fractions are simultaneously monitored as a function of time. These data sets are employed for numerical modelling to derive water retention properties as well as unsaturated hydraulic conductivities.

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Abstract: P21

Comparing borehole GPR FWI images with CPT data obtained at the Krauthausen test site

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Ground penetrating radar (GPR) is a useful electromagnetic tool, which can be used for a wide range of application to non- or minimal-invasively image the subsurface. It can provide two electromagnetic parameters simultaneously, relative dielectric permittivity e_r and electrical conductivity s, which influence the velocity and attenuation of electromagnetic waves, respectively. Crosshole GPR has often been used for hydrogeological investigations to obtain cross-sectional information of property distribution and connectivity of structures. Conventional crosshole GPR tomographic inversions are generally based on geometrical ray theory that employs first-arrival travel times and maximum first-cycle amplitude to obtain the velocity and attenuation images. In recent years, full waveform inversion (FWI) has been developed and is able to provide higher resolution images due to the use of the entire waveform information. Several crosshole GPR measurements acquired at the Krauthausen test site were inverted using the FWI approach and returned higher resolution images for permittivity and conductivity in comparison with ray-based approaches. To investigate the obtained images, results obtained from CPT measurements performed at a certain location in between the boreholes were compared with the FWI results. CPT data is inherently one-dimensional and returns high resolution data at one location for the vertical distribution of porosity. Selecting within the obtained FWI images the relative permittivity and conductivity data that are co-located with the CPT data enables a comparison of the obtained resolution of the Ray-based and FWI results. The Complex Refractive Index Model (CRIM) is used to convert the ray-based and FWI dielectric permittivity into porosity. The ray-based, FWI, and CPT data were transformed into the spatial frequency domain using a spatial FFT to investigate the spatial bandwidth of the different data sets. A broader spectrum indicates a higher resolution. As expected, the ray-based data showed the smallest bandwidth whereas the FWI data showed a larger bandwidth. The CPT data showed the largest bandwidth. The obtained ray-based and FWI bandwidths also depend on the distance between the two boreholes.

Abstract: P22

Estimating Infiltration-Induced Soil Water Content Changes using Combined Horizontal Borehole GPR and Dispersive Surface GPR data

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Surface and borehole ground penetrating radar (GPR) are useful non- or minimal-invasive electromagnetic techniques to investigate the shallow subsurface of the earth. Using horizontal borehole GPR antennas at specific depths, dielectric permittivity and electrical conductivity at these depths can be obtained by analyzing the direct wave traveling from source to receiver. However, horizontal borehole GPR results for very shallow depth (0.1 - 0.2m) cannot be analyzed by ray-based techniques due to the ground surface reflection and the critical refracted air wave interference. To obtain high resolution information for shallow depths high frequency surface GPR can be used.

We carried out a 5-day infiltration experiment at the rhizotron facility RI at the Selhausen testsite (50°52´ N, 6°27´E), Germany. The measurement plot was sheltered before the experiment to obtain a dry soil. Borehole GPR and surface GPR were measured before, during and after infiltration. By combining the borehole and surface GPR data analysis, the dynamic infiltration process was investigated in detail. The start and end time of the irrigation, volume of the water (L/m2), temperature and the electric conductivity of the water were recorded. The Zero-offset-profiling (ZOP) horizontal borehole data were measured at 0.1, 0.2, 0.4, 0.6, 0.8, 1.2m depth by 200 MHz horizontal borehole antennas. After time correction of the borehole data, an automatic picking routine for ZOP data was applied to pick the first breaks for each trace and averaged permittivities were obtained and converted to soil water content by using the CRIM model. Surface GPR WARR measurement using 500MHz antennas of the PulseEKKO system showed pronounced waveguide dispersion, due to a thin saturated layer that is generated by infiltration and precipitation events, acting as a waveguide. Single layer waveguide dispersion inversion was used to invert the dispersive surface GPR data and obtain the thickness and average permittivity of the saturated layer. Soil water content profiles during the infiltration experiments were obtained by combining the horizontal borehole and surface GPR results. For the upper 0.2m depth, the surface GPR results are used whereas the horizontal borehole GPR returns soil water contents between 0.2-1.2m depth. The inverted permittivity from surface GPR data shows a good consistency with the borehole GPR results and the combination of surface and horizontal cross-hole data clearly shows the depth depending soil water content changes during the five days repeated infiltration experiment.

Abstract: P23

Investigating the spatial and temporal soil water content variations at Rhizotron-test site using time-lapse horizontal borehole GPR data

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In order to understand near surface changes in soil water content (SWC) originating from meteorological conditions (e.g. infiltration and evaporation) and vegetational influences (e.g. root water uptake), measurements in a convenient spatial scale and time-interval are necessary. Those requirements are realized at the Selhausen rhizotron test site which is part of the TERENO Eifel-Lower Rhine observatory located close to Selhausen (North Rhine-Westphalia, Germany). The two rhizotrons are situated within different geological units with different hydraulic properties and enable the collection of horizontal borehole Ground Penetrating Radar (GPR) data from various depths and under different treatments (natural, sheltered and irrigated conditions at the surface) to monitor SWC data.

Ground Penetrating Radar measurements with a 200 MHz-antennae were weekly carried out during two different crop seasons. In 2016 and 2017 the measurements were carried out for winter wheat and corn, respectively. Additional bare soil measurements prior to sowing and after harvest were recorded as a reference. Because for every depth GPR crosshole measurements over 6m length could be carried out every 5 cm not only temporal and vertical information about SWC variations were obtained but also lateral information.

The obtained data was investigated by analyzing the overall SWC mean at every depth to show the temporal changes in comparison with the meteorological and atmospheric conditions (temperature, precipitation and evapotranspiration) and to see the principal changes with increasing depth. Since the lower rhizotron site is situated in a more fine-grained material, the observed SWC is higher compared to the more coarse-grained upper rhizotron site. To obtain information about the small scale spatial SWC changes the standard deviation, mean, minimum, maximum and range over the year were derived for every trace position along the horizontal borehole dimension. Preliminary results indicate that SWC variations in the shallowest depths seem to be originating from the vegetation and the root water uptake.

Abstract: P24

Scalable Subsurface flow Simulations with ParFlow

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Accurate simulation of variably saturated flow in a porous media is a valuable component in understanding physical processes taking place in many water resources problems. Such simulations require expensive and extensive computations and efficient usage of the latest high performance parallel computing systems becomes a necessity.

The simulation software ParFlow has been shown to have excellent solver scalability for up to 16,384 processes (MPI ranks). To scale to the full size of current petascale systems, we propose a reorganization of ParFlow's mesh subsystem: we modify it to use state of the art mesh refinement and partition algorithms provided by the parallel software library p4est.

We evaluate the scalability and performance of the modified version of ParFlow demonstrating weak and strong scaling to over 458.000 processes of the Juqueen supercomputer at the Research Center Jülich.

Abstract: P25

Calculating terrain parameters from Digital Elevation Models on multicore processors

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The calculation of terrain parameters from Digital Elevation Models (DEMs) is an important task in Geographic Information Systems and Digital Terrain Analysis. In many of these algorithms, the computational cost is dominated by a stencil computation, in which each cell of the DEM is updated using the values of cells in a 2D neighborhood of the cell. Hence, the efficient parallel implementation of these stencil kernels is crucial. Stencil calculations perform global sweeps through data structures that are typically much larger than the capacity of the available data caches. As a result, these computations generally achieve a low fraction of the theoretical peak performance, since data from main memory cannot be transferred fast enough to avoid stalling the computational units. This performance problem increases with the increasing number of cores on modern processors. We compare two parallel programs, designed for multicore processors, to calculate the slope of the terrain in a DEM. The first one is a straightforward implementation in C using OpenMP and the second one uses PATUS, a framework for generating auto-tuned code to perform stencil operations [1]. In the latter case, a decomposition (or partitioning) of the DEM over the threads can be imposed. In all cases, the optimal block decomposition corresponds to a row-wise partitioning of the DEM matrix and the block size should be set such that hypertreading can be exploited. We used multicore processors with up to 12 cores and DEMs of size 4000 x 4000 up to 16000 x 16000. The parallel software generated by PATUS, using the Basic Threading option, results in 5 to 19 times faster execution than the program parallelized using OpenMP. The larger the number of cores, the larger the gain obtained by using PATUS. Hypertreading results in a performance gain of 15 – 50 %, when compared with a single thread per core. An extra gain in performance is obtained by using the autotuning option, especially for DEMs of medium size when using 8 – 10 cores.

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Abstract: P26

Research data management support for the large-scale, long-term, interdisciplinary Collaborative Research Center / Transregio 32: Patterns in Soil-Vegetation-Atmosphere-Systems

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In particular research that is conducted in cross-institutional, collaborative research projects requires an active sharing not only of research ideas, but also of project data, documents and further information. At best this should be done in a well-managed, controlled and structured manner. Thus, it is important to establish corresponding infrastructures and services for the scientists. An exchange of research ideas is supported by regular project meetings and joint field campaigns, while an effective sharing of research output, such as data and publications, requires a well-elaborated technical infrastructure. This infrastructure should enable storage, documentation and exchange for all kind of data generated by the project members such as research data, publications, PhD reports, conference contribution, presentations, posters, pictures etc.. For the creation of synergies both sharing of knowledge and data is essential. This poster contribution presents research data management services (RDM) that have been established for the Collaborate Research Centre / Transregio 32 (CRC/TR32) 'Patterns in Soil-Vegetation-Atmosphere-Systems: Monitoring, Modelling and Data Assimilation' (www.tr32.de). Since 2007, a RDM support infrastructure and associated services have been set up according to the needs of the project scientists. Scientists covering several disciplines, e.g. soil & plant science, geography, meteorology or geophysics, collect data during field campaigns or by applying various modelling approaches. To manage the heterogeneous scientific output, the TR32DB data repository (www.tr32db.de) was designed and implemented for the CRC/TR32 project data in 2007. Since this implementation, the system has been continuously developed. The TR32DB supports features, such as secure and sustainable data storage and backup, documentation with interoperable metadata, data publication with DOIs, data search, data download associated with a rights management, data statistics (e.g. upload, access and download), as well as web mapping features. Moreover, RDM consulting and support services, as well as training sessions for project members are carried out on an irregular basis.

Abstract: P27

Optimizing albedo simulations of the ORCHIDEE land surface model by assimilating the MODIS satellite observation data

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Modern land surface models (LSMs) provide a powerful tool to explore the global climate change and analyze biosphere responses to various environmental impacts. However, uncertainties in model simulations, arising from inaccurate model parametrization as well as from unreliable representation of biogeochemical processes, limit their ability to represent the ecosytems development under the current or future climate conditions. The recent increase in different kinds of remote sensing observations provides the potential for significant improvements of crucial process formulations (structure and parameter values) and for refinement of the model predictions. In this study, we focus on the albedo parametrization of the ORCHIDEE global land surface model, a key process controling the energy balance at the surface. We present a two-step assimilation technique that integrates the Moderate Resolution Imaging Spectroradiometer (MODIS) albedo observations to optimize the parameters controlling the albedo in ORCHIDEE. Without changing the model albedo equations, but only optimizing the snow, vegetation and background albedo coefficients within the current model physics, we significantly improved the spatial and temporal dynamic of the albedo with respect to MODIS observations. The too small initial temporal dynamic was successfully corrected at all latitudinal bands. A detailed description of the assimilation technique together with the model albedo simulations improvement will be presented.

Abstract: P28

Assimilating GRACE data with different spatial resolution into a high-resolution hydrological model over Europe

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Hydrological models are indispensable for water resources management, disaster prevention, and for the assessment of long-term climate variability. However, models are built on a simplified representation of reality, and therefore are subject to large uncertainties leading to limited predicting skills. One approach for reducing these errors is the assimilation of observational data. Since 2002, the Gravity Recovery and Climate Experiment (GRACE) mission enables the direct observation of total water storage (TWS) variations from space, and thus, provides valuable data for improving modeled water storage of soils, groundwater, and surface water bodies.

In this study, we assimilate GRACE TWS observations into the Community Land Model version 3.5 (CLM3.5) over the European CORDEX domain, utilizing the Parallel Data Assimilation Framework (PDAF), in order to create a high-resolution regional reanalysis of the terrestrial water cycle. CLM3.5 represents a component of the Terrestrial Systems Modeling Platform, TerrSysMP, which also includes coupling with the groundwater model ParFlow and the numerical weather prediction model COSMO.

First, we discuss the challenges arising from the resolution mismatch of CLM and GRACE. While our CLM implementation simulates the evolution of water storage and flux for up to 27 compartments at hourly time steps, on a 12.5 km grid, GRACE monitors vertically aggregated TWS at spatial scales of a few hundred kilometers and at monthly time scales. Furthermore, GRACE-derived TWS estimates are contaminated with correlated noise, which cannot be neglected in the context of data assimilation. Here, we (i) investigate the effects from assimilating GRACE data into CLM on different spatial scales, and (ii) evaluate the experiments with several independent data sets including soil moisture, runoff, and vertical deformation from continuously-operating GPS sites.

The final scope of the project is the assimilation of GRACE data into the fully coupled TerrSysMP for generating a consistent reanalysis of the entire terrestrial and atmospheric water cycle.

Abstract: P29

Ensemble Data Assimilation with the Community Land Model and the US National Water Model

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The Data Assimilation Research Testbed (DART) is a community tool for ensemble data assimilation that has been coupled to several models of interest for water resource management. These include (but are not limited to) the Community Land Model (CLM) and the (United States) National Water Model; which is an operational implementation of the community WRF-Hydro modeling system.

Many types of hydrological observations and data products, such as in-situ soil moistures, neutron intensities, satellite estimates of moisture, brightness temperatures, etc., have been successfully assimilated into land surface models. This produces model-based estimates of quantities that are more consistent with the information content of the observations and yet have the desirable spatio-temporal attributes of the gridded model output. Due to the nature of ensemble data assimilation, other non-hydrological observations may also impact variables influencing model hydrology through the covariances specified in the ensemble of model states. Uncertainties in the resulting model states can be quantified. DART offers a number of tools to improve upon naive implementations of Ensemble Kalman Filters and several of these, such as spatially- and temporally-adaptive inflation and localization, will be discussed.

The utility of DART is illustrated with examples of research of its use with CLM4.5 and CLM5.0, as well as the recently developed HydroDART (a coupling of the offline WRF-Hydro model and DART). The work with CLM has mostly focused on soil moisture. We have developed observation operators and tested assimilation methodologies for observations from a variety of sensors that have widely varying temporal and spatial coverage. In this complex land surface model, we assess the impact of the assimilation on both observed and unobserved portions of the model state, and quantify the resulting indirect effects on modeled fluxes and coupled biogeochemical cycles. In addition, we also investigate the impact of assimilation of observations that may indirectly provide information about soil moisture status (such as leaf area index). The emphasis of the work with HydroDART has been on improving estimates of stream discharge.

Abstract: P30

Ensemble experiments with a coupled atmosphere-land surface-subsurface model

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It has become apparent that fully coupled atmosphere, land-surface and subsurface models can benefit from data assimilation which goes beyond the classical weakly coupled approach. As the usage of fully coupled models that incorporate the atmosphere, land-surface and subsurface in a physically consistent way increases, the need for strongly coupled data assimilation systems becomes apparent. In order to set up a working ensemble based data assimilation system it is necessary to investigate the sensitivity of fluxes and states of different compartments with respect to states and parameters of (other) compartments. In addition to the direct insights that help setting up the Ensemble this also provides additional insights in the potential of weakly or fully coupled data assimilation to further improve characterization of states in the atmosphere-land surface-subsurface system. In this study we present preliminary results from 16 members of a 32-member ensemble where 8 members each either had different vegetation or soil properties. For the analysis of this subset of Ensemble members we concentrated on the impact of the different setups with respect to a reference simulation. The Terrestrial Systems Modeling Platform (TerrSysMP) is used to realize the simulation which is based on the region surrounding the Neckar river catchment located in SW-Germany. The spatial resolution of the atmospheric compartment of TerrSysMP is 2.8km while the land-surface and subsurface run at 800m resolution. Even at this relatively low resolution substantial computing recourses are needed to realize the one year timeseries we aimed for. We found that without having different atmospheric forcings to consider the differences between the members was relatively small in many respects, unless directly related properties (evapotranspiration for the different land surface setups etc.) are considered. Nevertheless, feedbacks are still strong enough to warrant developing a coupled data assimilation system. It is found that the role of uncertain vegetation states is larger than the role of uncertain soil properties, while in summer the role of uncertain soil and vegetation properties is larger than in winter, for this particular case. Furthermore, feedbacks from the surface and subsurface may be more impactful if larger domains, such as continental scales are considered.

Abstract: P31

Improving continental-scale hydrologic simulations over Europe using TerrSysMP–PDAF

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We used Parallel Data Assimilation Framework (PDAF) integrated with the Community Land Model, version 3.5 (CLM3.5) in the Terrestrial System Modeling Platform (TerrSysMP-PDAF) to improve continental-scale hydrologic estimates of soil moisture, surface runoff, discharge and total water storage. The model was forced with the high-resolution reanalysis COSMO-REA6 from Hans-Ertel Centre for Weather Research (HErZ) and implemented at a spatial resolution of approximately 3km over Europe for a time period of 2000 – 2014. Using this modeling framework, remotely sensed ESA CCI soil moisture (CCI-SM) daily data were assimilated into TerrSysMP-PDAF. The impact of remotely sensed soil moisture data on improving continental-scale hydrologic estimates was analyzed through comparisons with independent observations including ESA CCI-SM, E-RUN runoff, GRDC river discharge and total water storage from GRACE satellite. Cross-validation with independent CCI-SM observations show that estimates of soil moisture improved, particularly in the summer and autumn seasons. The assimilation experiment also showed overall improvements in runoff particularly during peak runoff. The results demonstrate the potential of assimilating satellite soil moisture observations to improve high-resolution hydrologic model simulations at the continental scale, which is useful for water resources assessment and monitoring.

Abstract: P32

Large-eddy simulation of a stratocumulus-topped arctic boundary layer

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Arctic low-level stratocumulus is the main contributor to inter-seasonal variability of the surface radiation balance. Vice versa, latent and sensible heat fluxes originating from the surface determine its existence and evolution. While stratocumuli may extend over hundreds of meters vertically, phenomena on scales below few tens of meters, like the cloud-top entrainment or vigorous mixing within the atmospheric boundary layer, drive their development. The interactions of radiation, microphysics, and turbulence not only challenge climate and weather models but also large-eddy simulation approaches. Using highly-resolved large-eddy and direct numerical simulation, recent studies (e.g. Matheou and Chung, 2014; Kopec et al., 2016; de Lozar and Mellado, 2017) for the first time yield a detailed view of the cloud-driving processes. While these studies focus on steady and homogeneous regimes, transitional ones and heterogeneous surfaces remain elusive. Studies with comparable resolutions are non-existent in the Arctic where observational data is lacking, most clouds are mixed-phase, and the characteristic eddies are even smaller than for other regions.

To analyze non- or under-resolved microphysical, radiative, and turbulent processes along with their interaction, we performed a resolution-convergence study of a well-investigated low-level stratocumulus case (DYCOMS-II RF01) using a modified version of WRF-LES. We find that the first-moments of e. g. liquid potential temperature, total water mixing ratio, and boundary layer height are independent of the horizontal resolution only below 10m - less than what many other studies of low-level stratocumulus employ. Based on observational data from ACLOUD and PASCAL (Wendisch et al., 2017), two recent measurement campaigns focusing on the Arctic boundary layer, we define an Arctic case with a low-level mixed-phase stratocumulus during Arctic summer over ice surface. With our modified version of WRF-LES, we perform a resolution-convergence study. Benchmarking the simulations against observational data allows process-level insight to the cloud-driving processes beyond what can be learned from observational data or large-eddy simulation alone.

De Lozar and Mellado (2017), J. Atmos. Sci., vol74(3), 751-765. Kopec et al. (2016), Q.J.R. Meteorol. Soc., vol142(701), 3222-3233. Matheou and Chung (2014), J. Atmos. Sci., vol71(12), 4439-4460. Wendisch et al. (2017), EOS, vol98(8), 22-26.

Abstract: P33

Large eddy simulation of catchment scale circulations

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The influence of soil moisture heterogeneity and induced circulations on surface heat fluxes and boundary-layer characteristics are investigated using a coupled large-eddy simulation (LES) atmosphere and land surface model framework. “River-like” soil moisture pattern was used as initial condition and was shown to dramatically alter the structure of convective boundary-layer by inducing significant organized circulations which modify turbulent statistics. And also, intensities of organized circulations are found sensitive to the magnitudes of soil moisture heterogeneity, even though the domain mean values of soil moisture are same.

Abstract: P34

European extreme events simulations with the fully coupled TerrSysMP

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For the first time 20 years (1989-2008) of the fully-coupled TerrSysMP simulations in the EURO-CORDEX domain at 12km resolution will be presented, focusing on the added value of 3D groundwater dynamics on land-surface and atmosphere feedback processes to reproduce extreme events as heat waves and intense precipitation.

The Terrestrial Systems Modeling Platform, TerrSysMP (Gasper et al., 2014; Shrestha et al., 2014), comprises the numerical weather prediction COSMO model in a convection permitting configuration (Baldauf et al., 2011), the land surface model CLM3.5. (Oleson et al., 2008) and the surface-subsurface hydrologic model ParFlow (Ashby & Falgout, 1996; Jones & Woodward, 2001; Kollet & Maxwell, 2006). The models are coupled via the external Ocean Atmosphere Sea Ice Soil coupling tool OASIS-MCT (Valcke, 2013).

The EURO-CORDEX regional climate models (RCMs) capacity of reproducing heat waves in the past two decades has been examined and compared to observational reference data (Vautard et al., 2013). It has been pointed out that current EURO-CORDEX model ensemble show an overestimation of summertime temperature in Mediterranean region and an underestimation in Scandinavia (Vautard et al. 2013). Moreover, In the transition zone from strong to weak coupling covering large parts of central Europe many of the RCMs tend to overestimate the coupling strength in comparison to observations (Knist et al., 2016). The 3D representation of groundwater dynamics can improve simulated spatial variation of soil moisture and therefore it can better capture the feedbacks between land-surface and atmosphere. Keune et al. (2016) showed how groundwater dynamics representation indeed impacts land-surface-atmosphere processes during the 2003 heat wave. The present long-term simulations allow further investigation on the capacity of the model to represent extremes and climatological annual and seasonal mean values (as in the evaluation by Kotlarski et al. 2014).

Furthermore, TerrSysMP simulations are compared to observations (ECA&D data set, Klein Tank et al., 2002) but also to the outputs of other EURO-CORDEX model outputs, focusing particularly in climate indices to evaluate the added value of including groundwater dynamics to the simulation of extreme events.

Abstract: P35

Effects of surface properties and land-atmosphere coupling on water cycle representation in a convection permitting RCM ensemble

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Novel convection permitting regional climate model (RCMs) simulations at spatial resolutions of 4km and below without error-prone convection parametrisations have shown a number of improvements compared to coarser-resolution simulations, e.g., in the representation of small-scale surface and sub-surface heterogeneities and orographic features; the representation of dynamical processes, like local wind systems; the reproduction of Clausius-Clapeyron temperature-extreme precipitation scaling; or the reproduction of the spatial distribution, timing and intensity of precipitation. Owing to this, an increasing number of studies have evolved around convection permitting climate modelling, towards improved regional climate projections. This study explores some of the sensitivities of a RCM ensemble to more realistic land surface properties, i.e., land cover and soil texture, and the added value of a convection permitting resolution with regard to water cycle processes. Work is part of the Coordinated Regional Downscaling Experiment (CORDEX) project's Flagship Pilot Study on "Convective phenomena at high resolution over Europe and the Mediterranean". In a coordinated ensemble, the Weather Research and Forecasting (WRF) model system is used in a one-way double nesting setup, driven by ERA-Interim reanalysis, over pan-European (15km) and central European / Alpine (3km) model domains for short extreme precipitation event simulations with strong and weak synoptic background forcing as well as selected seasons. Simulations using different land surface models with a varying level of sophistication (Noah, Noah-MP, and CLM) and land cover (Moderate Resolution Imaging Spectroradiometer satellite data, MODIS, vs Coordination of Information on the Environment land cover data, CORINE) and soil texture (Food and Agriculture Organisation, FAO, vs Harmonized World Soil Database, HWSD) fields are analysed. Topics addressed are: The reproduction of observed states and fluxes in the atmospheric boundary layer, at the land surface, and in the upper soil compared to observations; flux partitioning and coupling strength and associated soil moisture-(extreme) precipitation feedbacks as well as precipitation recycling rates, which all comprise important components of the water cycle.

Abstract: P36

Simulation of Shallow-Water Flows on General Terrain

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Shallow Water Equations are classically used as models of environmental fluid dynamics when the horizontal (longitudinal and lateral) components of the flow field are predominant with respect to the vertical components. This is the so called Shallow Water (SW) hypothesis. Application of SW equations for surface water flow are considered, where general topographic features are encountered. The presence of a general terrain plays an important role, increasing the geometrical complexity of the fluid streamlines. It is then difficult to accurately identify the negligible velocity component under the SW hypothesis. We propose a derivation of the SW model obtained by integrating the Navier-Stokes (NS) equations along a direction locally normal to the bed topography. This direction is used as an approximation of the “cross-flow” integration path, defined by the condition of being at each point orthogonal to the NS velocities. Along these paths it is possible to precisely state the hydrostatic pressure condition, thus enabling the actual reduction of the 3D NS equations to the 2D SW model. This yields a set of equations in intrinsic coordinates, characterized by non-autonomous fluxes and sources containing the metric induced by the bottom. The resulting SW equations are closely related to the model developed by Bouchout-Westdickemberg (2004), and shares similar approximations and limitations in terms of the bottom geometry. For our model, we show second order of approximation of the NS equations with respect to an appropriate “geometric” aspect ratio parameter that includes information on local curvatures. Moreover, we prove that the system admits a conservative energy equation, in case of no dissipation, and it is well balanced (preserves the “lake-at-rest” condition).

We then derive a first-order Godunov type Finite Volume scheme defined intrinsically on the bed surface, and address difficulties and limitations of the proposed scheme, discussing possible future developments. We test our numerical approach on a number of realistic examples over general bottom topography. The results show the effectiveness of the numerical approach ad its accuracy and robustness. Finally, we use these simulations to verify the importance of considering the effects of the geometric features of the bed topography in the equations. This is obtained by comparing differences with respect to the case in which standard non-geometry-aware models are used. The numerical results show differences up to 30% in the time-to-peak and maximum discharge of selected streamflows, even for relatively mild and slowly varying curvatures.

Abstract: P37

Incorporating a root water uptake model based on the hydraulic architecture approach in terrestrial systems simulations

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This work presents the integration of a macroscopic root water uptake (RWU) model based on the hydraulic architecture approach in the land surface component of the Terrestrial Systems Modeling Platform, TerrSysMP. As compared to the standard RWU model used in many land surface models, the new approach is based on three parameters derived from first principles describing the root system equivalent conductance (Kres), the compensatory RWU conductance (Kcomp), and the leaf matric potential at stomatal closure (lmpsc) that identifies the water stress condition for the plants. The developed RWU model intrinsically accounts for changes in the roots density as well as for the simulation of the hydraulic redistribution. The standard and the new RWU approaches are compared by performing point-scale simulations for crop land use over a sheltered rhizotron facility in Selhausen (Germany) and validated against transpiration fluxes estimated from sap flow measurements. In order to evaluate the interplay between soil hydrodynamics and plant characteristics, sensitivity numerical experiments are carried out using different soil characterizations (e.g., soil saturated conductivity) and plant physiological properties (e.g., roots distributions). Results show a good agreement between simulated and observed transpiration fluxes, with a more distinct response between the two RWU formulations under water stress conditions. The two RWU models show also a different degree of sensitivity to the roots distributions when simulating the onset of the water stress period. Finally, a one-way ANOVA indicates that for both models, and especially under water stress conditions, a larger proportion of the response variable (i.e., transpiration fluxes) variance is induced by the soil characterization.

Abstract: P38

Effect of biopores on simulated root growth and leaf area index in a field scale crop model

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Accurate estimates of the leaf area index and root water uptake are necessary for simulating canopy CO2 and H2O exchange. While aspects of soil structure such as biopores are expected to influence root growth and root water uptake, their effect is seldom considered in crop and land surface models. In this study we coupled a 3-Dimensional root system architecture model to a field scale crop model and investigated the effect of biopores on the simulated root growth and leaf area index using two scenarios. In the first scenario, a biopore network is considered while in the second scenario no biopore network is considered in the soil. We assumed that biopores are relics of a pre-crop root system and we generated biopore networks that match with measured biopore densities. Our results show a remarkable improvement of the simulated leaf area indices of drought-stressed spring wheat and soil water content in the scenario where a biopore network is considered (R2=0.76 for scenario 1 against R2=52 for scenario 2). Therefore it is concluded that appropriate root growth physics and soil structure is necessary for reliable estimates of the leaf area index and root water uptake which influence canopy exchange processes.

Abstract: P39

Parameter sensitivity analysis of a root architecture model: field scale simulation of root systems and virtual field sampling

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Traits of the plant root architecture play a key role in crop performances, especially under non-optimal environmental and climatic conditions. Therefore, plant phenotyping methods based on architectural root traits are becoming increasingly important to develop new genotypes. However, the main challenge in root phenotyping programs is the limited accessibility to the root system because it is hidden in the soil. Classical field root sampling methods such as coring, trenching, and minirzhizotrons provide only aggregated data about the root system architectures. Architectural root traits can be represented by parameters of root architecture models. When describing the root architecture using a model, methods like sensitivity analysis and inverse modelling can be deployed to investigate which parameters are sensitive to and can be derived from aggregated data. We investigate which parameters are highly sensitive to data obtained from different types of field root sampling schemes.

The root growth model "CRootBox" was used to simulate virtual 3-D root systems of wheat and maize plants in field plots. The ground truth of the virtual experiment was established for coring, trench profile and minirhizotron methods. From these data, root length density, root intersection density profiles and arrival curves for rhizotubes were computed and considered to be the observed data. We then performed a sensitivity analysis to find out which RSA parameters have the significant influence to the virtual field sampling results. Finally, we analyzed the spatial/temporal correlation of the field sampling data to find out the influence on the likelihood function used for optimization.

We found that the numbers of branches, maximum length, internodal distance, elongation rate, insertion angles of main roots are the most sensitive and the parameters of branching roots are less sensitive to the model. Moreover, different sampling schemes and respective error function show different degrees of sensitivities of root architecture parameters. Most sensitive parameters could be retrievable using suitable optimization algorithm. This is an important step in the characterization of root traits from field observations. These root architectures can be used in models that simulate water and nutrient uptake so as to evaluating the performance of root systems with certain traits.

Abstract: P40

Investigation of anisotropy in induced polarization signatures of maize root-soil continuum: a virtual rhizotron study

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A numerical electrical conductivity model was coupled with a plant-soil water flow model to investigate the impact of plant root architecture and water uptake pattern in a rhizotron on the frequency dependent induced polarization (IP) signature. The roots were explicitly represented with their frequency dependent electrical properties in the finite element mesh, including the properties of cortex and stele. Our experiments on maize root segments indicate that roots are strongly polarizing in terms of frequency dependent complex conductivity spectra and is a function of root properties such as root surface area, root type and root age. The effective electrical conductivity (bulk property) of the soil root medium computed using simulated plate electrodes at boundaries reveal that anisotropy factor induced by root system architecture can be used to identify or quantify root system structural properties. In our model, different Maize root architectures are considered and their effective IP properties are investigated.

Abstract: P41

Accounting for seasonal isotopic patterns of forest canopy intercepted precipitation in streamflow modeling

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Forest canopy interception alters the isotopic tracer signal of precipitation leading to significant isotopic differences between open precipitation (OP) and throughfall (TF). This has important consequences for the tracer-based modeling of streamwater transit times. Some studies suggested a simple static correction of OP by uniformly increasing it as TF is rarely available in hydrological modeling. Here, we used data from a 38.5 ha spruce forested headwater catchment where three years of OP and TF were available to develop a data driven method that accounts for canopy effects on OP. Changes in isotopic composition, defined as the difference TF-OP, varied seasonally with higher values during winter and lower values during summer. We used this pattern to derive a corrected OP time series and analyzed the impact of using (1) OP, (2) reference throughfall data (TFref) and (3) the corrected OP time series (OPSine) in estimating the fraction of young water (Fyw), i.e., the percentage of streamflow younger than two to three months. We found that Fyw derived from OPSine came closer to TFref in comparison to OP. Thus, a seasonally-varying correction for OP can be successfully used to infer TF where it is not available and is superior to the method of using a fixed correction factor. Seasonal isotopic enrichment patterns should be accounted for when estimating Fyw and more generally in catchment hydrology studies using other tracer methods to reduce uncertainty.

Abstract: P42

Understanding how interception and transpiration of trees influence water resources using modeling, observations and data assimilation for an open woodland in China

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Accurately quantifying the tree rainfall interception and transpiration is critical for rainfall-runoff modeling and flood forecasting, and is also essential for understanding its impact on local, regional, and even global water cycle dynamics. To understand the effect of tree interception and transpiration on water resources, an integrated model for groundwater and unsaturated zone will be established. Since precipitation is an essential driving force in model, efforts will first focused on the comparison and validation of satellite precipitation products before and after assimilation by using a Kalman filter with independent rain gauge networks located within the study area. Then measurement of tree interception and transpiration will be conducted in the field and upscaling techniques will be used to the collected data. Finally, the integrated model will be established and used to identify how tree interception and transpiration influence water resources.

Abstract: P43

Water-Energy-Plant Interactions in Cold Regions

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The permafrost carbon climate response (PCCR) projection from the recent IPCC report remains highly uncertain. I propose to quantify the PCCR by fully coupling hydro-permafrost-carbon processes. Such an approach can only be successful if implemented in an area currently undergoing an accelerated permafrost thawing. The Tibetan Plateau is such a case and selected as the pilot region, considering: a) the increasing availability of in-situ observations; and b) its widespread discontinuous permafrost zones, which are excluded from the current PCCR estimates. As such, this project will complement the current understanding of the PCCR over the discontinuous permafrost regions. I intend to test the following hypothesis: the soil moisture and heat coupling and its interactions with groundwater control the permafrost thermal state and the associated PCCR. Besides, this hydro-permafrost-carbon coupling will influence the spatial pattern of the regional water and energy dynamics. To test this hypothesis, the coupling of different processes will be implemented by exchanging relevant information among a suite of models of hydrology, groundwater, and biogeochemical dynamics.