# GeoΣim

2nd Annual GeoSim Workshop
November 18th & 19th 2013
at

GFZ
Helmholtz Centre
POTSDAM

HELMHOLTZ
ASSOCIATION

# Program

## November 18th

| Time | Event |
| --- | --- |
| 10:30 - 10:45 | Welcome Speach by Prof. Oncken |
| 10:45 - 11:00 | The GeoSim-Beginners introduce themselves |
| 11:00 - 11:20 | Olga Zakharova:<br>*Where to expect more aftershocks after a large event and what kind of factors can influence on their occurrence?* |
| 11:20 - 11:40 | Nico Becker:<br>*Secondary Circulations in a Regional Climate Model* |
| 11:40 - 12:00 | **Coffee Break** |
| 12:00 - 12:20 | Øystein Thordén Haug:<br>*Dynamics of Rock Slides: From Sliding Block to Granular Flow* |
| 12:20 - 12:40 | Ariane Papke:<br>*Multi-scale Models and Asymptotics of Atmospheric Flows* |
| 12:40 - 13:00 | Ulrich Wilbrandt:<br>*The coupling of (Navier-)Stokes and Darcy equations* |
| 13:00 - 14:00 | **Lunch Break** |
| 14:00 - 15:00 | Guided Tour around the GFZ |
| 15:00 - 15:30 | Poster Indroduction Round for RA I and RA II |
| 15:30 - 17:30 | Poster Session 1 (RA I + II) - Coffee and Cake available |
| 17:30 - ??:?? | **Dinner** at 'Alter Stadtwächter' Potsdam |

## November 19th

| Time | Event |
|---|---|
| 10:30 - 11:00 | Poster Indroduction Round for RA III |
| 11:00 - 13:00 | Poster Session 2 (RA III) - Coffee and Fruits available |
| 13:00 - 14:00 | **Lunch Break** |
| 14:00 - 14:20 | Elvira Mulyukova:<br>*Defying Gravity: How Mantle Plumes Lift Heavy Material from the Earths Deep* |
| 14:20 - 14:40 | Sanjay Bora:<br>*A Bridge between the Requirement of an 'Engineer' and Understanding of a 'Seismologist'* |
| 14:40 - 15:00 | Catherine Abon:<br>*Evaluating the potential of Radar Rainfall Data for Hydrological Simulations in the Philippines* |
| 15:00 - 15:15 | **Coffee Break** |
| 15:15 - 17:00 | Information round on general GeoSim issues |

## Abstracts
## Talks on November 18th

# Where to expect more aftershocks after a large event and what kind of factors can influence on their occurrence?

**Olga Zakharova, Sebastian Hainzl**
Section 2.1, GFZ Potsdam

After the mainshock occurrence a sequence of events with a smaller magnitude is expected to occur. Where higher aftershocks activity will take place after a large event and what kind of factors can influence on this activity occurrence? To answer this question we analyze different kind of data related to the megathrust Maule event (Chile, 2010, Mw=8.8). In particular, we test the correlation between spatial aftershock activity represented by the aftershock parameters of the ETAS model * and such physical properties of the crust like seismic coupling and slip. We find out that spatial distribution of aftershocks, related to the Maule earthquake, depends on seismic coupling on the subduction interface and coseismic slip, caused by the mainshock.

∗ETAS model – Epidemic Type Aftershock Sequence model

# Secondary Circulations in a Regional Climate Model

**Nico Becker, Uwe Ulbrich, Rupert Klein**
Institut für Meteorologie, Freie Universität Berlin

Regional Climate Models (RCMs) solve the Navier-Stokes-Equations on a three-dimensional grid, to simulate the atmosphere and its interactions with the surface. RCMs use high resolutions ( 20 km) to add details to Global Climate Model (GCM) simulations with lower resolution ( 200 km). The RCM simulations are limited to a region of interest and they are driven by the GCM data at the lateral boundaries of the model domains. Due to the different properties of the global and regional models, the RCM simulations deviate from the GCM simulations on different spatial scales. That may lead to problems at the RCM boundaries, because of interactions between the two different atmospheric states.

By analysing the differences between the atmospheric flows in a simulation with the regional model COSMO-CLM and the global model ECHAM5, we found that a Secondary Circulation (SC) develops within the domain of the RCM. The SC is induced by changes of momentum within the RCM relative to the GCM, e.g. due to the differences in the topography. These changes of momentum cannot exit the RCM domain, because the atmospheric state is prescribed at the lateral boundaries. Therefore, a balancing circulating flow must develop within the RCM domain.

A non-hierarchical method for cluster analysis is used to classify distinctive patterns of the atmospheric circulation. The SC is then calculated for the time steps, which are related to the individual circulation patterns. It is shown, that the SC forms anticyclonic vortices related to the topography and cyclonic vortices related to troughs of the geopotential height. Furthermore it is evident, that the SC vortices are modified by the RCM boundaries and form balancing flows parallel to the boundaries.

# Dynamics of Rock Slides: From Sliding Block to Granular Flow

**Øystein Thordén Haug**[†] **Matthias Rosenau, Karen Leever, Onno Oncken**

GFZ German Research Center for Geosciences, Telegrafenberg, Potsdam 14473, Germany

[†]Email address for correspondence: thorden@gfz-potsdam.de

Consider a piece of rock traveling down a slope. The movement may be described as bouncing, rolling, sliding, flowing, fracturing and/or combination of these depending on the topography of the slope and the material properties of the rock. In analogue models we have the advantage of controlling these variables, however, even in such idealized systems the prediction of the dynamics is far from trivial. Nevertheless, what can we learn about the physics of rock slides from these analogue models?

In an attempt to answer this question we use dimensional analysis and derive physically meaningful parameters that allow us to predict the behavior of laboratory rock slides given a set of controlled parameters.

Results from the analogue models suggests material cohesion to be a key parameter for the dynamics of rock slides.

# Multi-scale Models and Asymptotics of Atmospheric Flows

**A. Papke, R. Klein**
Fachbereich Mathematik & Informatik, Freie Universität Berlin, 14195 Berlin, Germany

The dynamics of atmospheric vortices play a great role in many environmental flow phenomena. We utilize matched asymptotic analysis to describe vortex motion and structure. In some events moisture is an important factor, i.e. for hurricanes and tropical storms, and to account for these we specifically include diabatic heating in our model. We find that the theory is consistent with established models as regards precession frequencies of tilted vortices. The theory also provides new insight into tilt-induced mechanisms of vortex amplification/attenuation.

# The coupling of (Navier-)Stokes and Darcy equations

**Ulrich Wilbrandt[1], Volker John[1,2], Alfonso Caiazzo[2]**
[1]Department of Mathematics and Computer Science, Freie Universität Berlin
[2]Weierstrass Institute for Applied Analysis and Stochastics

There are a number of options in the numerical simulation of the (Navier-)Stokes-Darcy problem. This talk will focus on an example modeling a riverbed in two space dimensions taken from Cardenas and Wilson, 2007. The impact of different possible discretizations will be discussed and compared to the mentioned paper.

# Data assimilation of tree-ring-width-like observations using ensemble Kalman filtering techniques

**Walter Acevedo**
Institute of Meteorology, Frei Universität Berlin

In recent years the assimilation of proxy data into climate models has appeared as a very promising procedure for reconstructing paleoclimate, as the states obtained in this way are in principle consistent both with historic records and the physics of the climate system as represented by the model equations. In practice, however, the development of this process- based climate reconstructions has been considerably hindered by several stumbling blocks, notably (i) the necessity of realistic yet affordable observation forward models able to simulate the multivariate and non-linear character of proxy response to climate forcing and (ii) the time-averaged nature of proxy information. Regarding tree-ring proxies, in particular, a new process-based forward model named VS-Lite has been shown to skilfully simulate tree-ring width chronologies coming from very different climate regimes, based solely on 3 external factors - temperature, soil moisture and solar radiation - and 5 tunable parameters.

In order to investigate the applicability of VS-Lite forward model as an observation operator for tree-ring-width data within an ensemble Kalman filtering framework, we perform a set of identical twin experiments on the 2-scale Lorenz 96 model using a VS-Lite-like observation operator, which exhibits 3 special features: (i) alternating recording of two variables, (ii) saturation beyond upper and lower variable thresholds and (iii) time-averaging. As a consequence of the non-linearities of this forward model, the parameter space area where the filter has skill is substantially reduced as compared to the performance when a completely linear operator is used. We considerably counteract this undesired effect via a modification of the forward model which smooths the shifting of recorded variable.

# Metastability in Time Series Analysis

**Stefan Rüdrich**
Department of Mathematics and Computer Science, Freie Universität Berlin

In Geophysics the application of Time Series Analysis usually aims at forecasting future behavior of a dynamical system from limited, incomplete and imprecise observation of the past. This is the case specifically for seismology, where scientifically reliable data was not available until a global system of modern seismographs was build up in the early 20th century.

The simulation of dynamical systems is often hampered by the problem, that the dynamics are unknown in detail and need to be estimated from a finite sequence of observations. In the simplest case, the underlying process is memoryless in the sense of Markovian Theory.

Then, it is easily possible to construct a Markov process on an arbitrarily chosen finite subdivision of the state space by estimating transition probabilities through simple statistical evaluation of the observed trajectory. Unfortunately, long-term observation indicates that seismic events do not follow such a simple scheme.

In general we must assume that the original process has a memory of unknown length m. This is: we need to consider the last m events of the given Time Series to provide a good-as-possible estimation of the next step.

Applying Takens' embedding theorem, we may construct an m-dimensional embedding of the original process, such that the embedded process is memoryless, allowing for easy estimation of the relevant transition probabilities at the cost of considerably increased computational effort. This is why it is important to find an m as low as possible such that a corresponding embedding approximates the original process sufficiently well.

Now that we can assure memorylessness, the behavior of the system shall be investigated further with a recurrence network derived from the embedded Time Series. As the embedding of the process into a higher-dimensional space might cause a considerable blow-up of computational effort needed to simulate future behavior, Markov State Modeling allows to simplify the network and reduce computational complexity to a reasonable level.

# A Clustering Algorithm for Earthquake Networks based on Variational Bayesian methods

**Tobias Willenbockel and Christof Schütte**
Fachbereich für Mathematik und Informatik, Freie Universität Berlin

To analyze seismic data, S. Abe and N. Suzuki introduced the concept of Earthquake Networks. When analyzing Earthquake Networks, the problem lies with the complexity of these networks. As a solution, we calculate a clustering of the network, thus enabling the application of more complex mathematical models to those networks.

The result of our clustering is a Metanetwork. This Metanetwork is a compression of the Earthquake Network and captures at the same time the most important properties of the original network.

We present a new algorithm for the clustering of directed Earthquake Networks. Our approach is based on Variational Bayesian Expectation Maximization Algorithm (VBEM) of a Stochastic Blockmodel.

To demonstrate our method, we applied it to the Southern California Area (32s; 37n; 122w; 114w), for a time span of thirty years (01 - 01 - 1982 to 31 - 12 - 2011) with a total of 527797 earthquakes. With this example, we show that reliable, consistent and fast clustering of Earthquake Networks with VBEM based methods is possible.

# Tsunami threat posed by near-field seismic sources offshore southern Middle America Trench, Costa Rica

**Natalia Zamora and Andrey Babeyko**
Geodynamic Modelling, GeoForschungsZentrum GFZ

The Middle America megathrust fault is capable of generating tsunamigenic earthquakes as portrayed through historical data. Despite that most of the destructive earthquakes in last decades occurred inland along this subduction zone, tsunami catalogs reveal this is a tsunami prone area.

We hereby present the results of tsunami simulations to assess tsunami threat along southern Nicaragua and the Nicoya Peninsula. This region lies in the southern tip of Nicaragua 1992 Mw 7.6 ‘tsunami earthquake’ that generated water heights up to 10 m. Nicoya Peninsula location relatively close to the trench and above the seismogenic zone provide a suitable place to conduct geodetic and geophysical data providing better understanding of the seismogenic zone below the peninsula, the structural characteristics of the subduction zone and the slip deficit; thus providing fundamental data to determine tsunamigenic sources.

In this study, our aim is to assess tsunami threat along Costa Rican Pacific coast posed by the Nicoya and south Nicaragua seismic sources. These fault scenarios used as input data were determined based on geodetic and historical data. We used the Rupture Generator (RuptGen) modeling tool to obtain surface deformation and EasyWave tsunami code to simulate water propagation. Numerical simulations have shown that southern Nicaragua and the coast along the Nicoya Peninsula are under threat of tsunamis generated by near-field shallow ruptures. We have assessed several earthquake sources in a deterministic study to set the basis to compare with future work based on stochastic slip distribution.

**Key words:** slip distribution, coseismic deformation, tsunamigenic sources, tsunami threat, Nicoya Peninsula, Costa Rica.

# Ensemble-based Data Assimilation Method using Gaussian Mixture

**Nawinda Chutsagulprom**
Institute of Mathematics, Potsdam University

Ensemble-based filters for global numerical weather prediction applications com- bines observations into model prediction. These techniques rely on the Monte Carlo approach in order to approximate the state probability distribution by a finite num- ber of realizations, also called ensembles. The ensemble Kalman filter (EnKF) and sequential importance resampling (particle filter) are two Monte Carlo-based se- quential data assimilation methods that have been widely tested in many nonlinear systems. However, both methods have their drawbacks: EnKF cannot give optimal results under non-Gaussian distribution, while particle filter requires a large number of realizations in order to obtain the accurate estimates.

A new approximation scheme based on Gaussian mixture, initially motivated by the rank histogram filter (Anderson, 2010), is presented. In the rank histogram filter, each scalar observation with its error distribution is assimilated sequentially and other un-observed variables are then corrected by linear regression which might be questioned in terms of statistical sense among these variables. Instead of applying linear regression in the assimilation step, this proposed technique relies closely on the optimal Bayesian ap-proach which ultimately leads to the transform mapping. It provides well-approximated results under the non-Gaussian distribution and a large number of ensembles is not needed. Some experiments will be presented.

# Towards ODTLES Simulations of Turbulent and Buoyant Phenomena

**Christoph Glawe**
Juniorprofessur Strömungsmodellierung, BTU Cottbus, Germany

Most computational models for turbulent, atmospheric flows approximate small scales using parameterizations (e.g. large eddy simulations (LES)). These approaches can lead to order one numerical effects in areas of unstable stratification on small scales for example occurring in cloud-top mixing layers (investigated by [1]).

Stochastic turbulent models like the one-dimensional turbulence model (ODT, see e.g. [2]) are a promis- ing tool to reduce the numerical effect, because they are able to resolve turbulent small-scale flows down to the Kolmogorov scale (like direct numerical simulations, DNS) with reduced degrees of freedom due to a one-dimensional computational domain. ODT uses a stochastic process compatible with conservation laws to describe three-dimensional turbulent flow behavior on the one-dimensional domain. A buoyant elaboration of the ODT model can capture turbulent and buoyant small-scale effects in sufficiently symmetric problems for example cloud-top analogs (see [3]).

ODTLES, a three dimensional multi-scale elaboration of the ODT model, can capture additional non-turbulent three-dimensional effects within wall-bounded flows (see [4]), also including passive scalars (see [5]). The abil- ity to resolve molecular transport distinguishes ODT and ODTLES from techniques such as LES and Reynolds- averaged Navier-Stokes (RANS) models.

I will introduce an ODTLES model including a buoyant scalar using the Boussinesq approximation. This approach will allow simulations of turbulent stratified flows not affordably using DNS and will accomplish this without parameterizing small scales. Rayleigh-Bénard results by ODT and ODTLES, compared to DNS and experiments, will be presented.

## REFERENCES

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# Asymptotic Modelling of Storm Fronts

**Verena Molina, Rupert Klein**
Department of Mathematics and Computer Sciences, Freie Universität Berlin

Extreme weather events represent a special challenge to humanity in general, and to the scientific community in particular. High windspeeds and heavy precipitation can have devastating impact, so a thorough understanding of severe weather events is desirable. Science is therefore making considerable efforts to investigate, measure and simulate such phenomena as hurricanes, supercell thunderstorms, squall lines, or similar organized convective storms. This work is to be seen as an attempt to contribute to that goal. We try to untangle the physical and dynamical processes relevant for the origination and preservation of a squall line.

As usual for meteorological problems, large storm events as the mentioned above involve a great number of temporal and spatial scales. The techniques of asymptotic analysis, as presented e.g. in [Klein 2008], constitute a suitable way of meeting this scale variety and of deriving a plausible mathematical modell (i.e. a system of equations) able to describe the dynamics and the scale interactions of a squall line.

Using multiple-scales and matched asymptotics as well as simulations, we hope to get an insight into all relevant mechanisms responsible for the development and evolution of a squall line, such as conversion processes, energy budget etc.

We expect to be able to apply or extend some of our results also to other storm events like e.g. hurricanes, linking our work to the results of [Paeschke et al. 2012].

## REFERENCES

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# Towards a unified Concept of two and three dimensional Vortex Dynamics

**Annette Müller**
Institut für Meteorologie, FU Berlin

In meteorology, scale analysis conceptually leads to two different descriptions of vortex motion. For example, high and low pressure areas are synoptic scale events that can be described by two dimensional vortex theory. More precisely, contracting these pressure areas, their dynamics can be characterized by point vortex theory. Blocking situations as examples of 2D point vortex theory will be shown. On the other hand, a tornado is an example of a meteorological event appearing in the three-dimensional convective scale. On this scale a challenging aspect is the understanding of storm splitting.

Both vortex motions can be described by the energy-vorticity theory (EVT) that focuses on two conserved quantities. These quantities are equally important for the nonlinear evolution of fluids. The first conserved quantity in two and three-dimensional turbulence theory is the kinetic energy. The second one depends on the spatial dimension and is given by the positive definite enstrophy in two dimensions and the indefinite helicity in three dimensions. These different vorticity conserved quantities lead to diverging topological properties. Group theoretical description will be considered to describe a unified structure for two and three dimensional vortex motion.

# Modelling spatial and temporal variability of surface water-groundwater fluxes and heat exchange along a lowland river reach

**Matthias Munz[1], Christian Schmidt, Sascha Oswald[1]**
Institute of Earth and Environmental Sciences, University of Potsdam

In this study we used the deterministic, fully-integrated surface-subsurface flow and heat transport model (HydroGeoSphere) to investigate the spatial and temporal variability of surface water-groundwater (SFW-GW) interaction along a lowland river reach. The model incorporates the hydrological as well as the heat transport processes including (1) radiative fluxes warming and cooling the surface water; (2) seasonal groundwater temperature changes; (3) occasionally occurring heat inputs due to precipitation and (4) highly variable SFW-GW water advective heat exchange driven by the general relation between SFW and GW hydraulic heads and geomorphological structure of the riverbed. The study area is a 100 m long lowland river reach of the Selke river, at the boundary of the Harz mountains characterized by distinctive gravel bars. Continuous time series of hydraulic heads and temperatures at different depth in the river bank, the hyporheic zone and within the river are used to define the boundary conditions, to calibrate and to validate the numerical model.

The 3D modelling results show that the water and heat exchange at the SFW-GW interface is highly variable in space with zones of daily temperature oscillations penetrating deep into the sediment and spots of daily constant temperature following the average GW temperature. To increase the understanding of evolving pattern, the observed temperature variations in space and time will be linked to dominant stream flow conditions, streambed morphology, advective and conductive heat exchange between SFW and GW and subsurface solute residence times.

This study allows to analyse and quantify water and heat fluxes at the SFW-GW interface, traces subsurface flow paths within the streambed sediments and thus improves the understanding of hyporheic zone exchange mechanisms. It is a sound basis for investigating quantitatively variations of sediment properties, boundary conditions and streambed morphology and also for subsequent generalization of SFW-GW exchange on reach scale river stretches and beyond.

# Variational Methods for Problems of Rate- and State-dependent Friction

**Ralf Kornhuber[1], Onno Oncken[2], Elias Pipping[1], and Oliver Sander[3]**
[1]Mathematical Institute, Free University of Berlin
[2]GFZ German Research Centre for Geosciences, Potsdam,
[3]Institute for Geometry and Practical Mathematics, RWTH Aachen University

The model of rate- and state-dependent friction is introduced and briefly motivated; an elastic problem incorporating this friction model is then formulated and analysed.
The aforementioned formulation is also the basis of numerical simulations, for which illustrative results are presented and convergence properties are pointed out.

# Estimating the vertical structure of an extra-tropical vortex

**Lisa Schielicke**
Institute of Meteorology, FU Berlin

Extra-tropical cyclones play an important role in the heat and moisture transport between the (sub)tropics and the poles. The effectiveness of this process depends on the circulation, the system's speed as well as the size of the cyclones. Although extra-tropical cyclones can clearly be seen on satellite images, it is a challenge to extract them from the 4-dimensional flow field. Unfortunately, a uniform method does not exist. The various methods for the estimation of cyclone properties that have been published give different results in a given flow. This work applies mathematical definitions of vortex sizes to meteorological flow fields.

Properties of the flow field can be described by the velocity gradient tensor. This tensor can be decomposed into the sum of a symmetric tensor, called strain-rate tensor, and an antisymmetric tensor called vorticity tensor. The kinematic vorticity number is defined by the ratio of the norm of the vorticity tensor and the norm of the strain-rate tensor and therefore relates rotation and deformation of the flow field. A vortex is then defined as a region in the flow field where the rotation prevails over the deformation.

In the presented work, the size and circulation of an extra-tropical winter storm system was analyzed over its lifetime. Therefore, the 4-dimensional geopotential height field was investigated with help of the kinematic vorticity number. Well-known cyclone characteristics can be reproduced.

# Poster Session on November 19th - RA III

## Towards more realistic physics based aftershock models: the effect of afterslip and secondary triggering

**Camilla Cattania, Sebastian Hainzl, Frank Roth, and Lifeng Wang**
Section 2.1, GFZ Potsdam

Most seismicity models based on Coulomb stress consider only the mainshock and the few largest events as a source of stress, and assume a constant stress field. However, mainshocks also trigger aseismic phenomena which modify the stress field, such as afterslip, viscoelastic and poroelastic response of the crust; moreover, aftershocks themselves contribute to the a relocalization of stresses. These processes have the potential to trigger seismicity, and several lines of evidence suggest that they play a role in triggering earthquakes. The cumulative moment of afterslip can be a significant fraction of the mainshock moment; and while stress changes induced by individual aftershocks are orders of magnitude smaller than those due to the mainshocks, they can still be large in the near field: the clustering of aftershocks, and the success of statistical models with cascade triggering, suggest that secondary triggering may be an important aspect.
Our goal is to study the impact of afterslip and secondary triggering in models based on Coulomb stresses. We model the seismic response to stress changes following the Dieterich constitutive law. We study the first 250 days from the mainshock, for two cases: the Parkfield, Mw=6.0 and the Tohoku, Mw=9.0 earthquakes. For each case, we consider a starting model with only coseismic stresses; a model with afterslip; a model with secondary triggering; and a model with both processes. Model parameters (ta and A$\sigma$) are inverted separately for each model.
We find that in both cases, thereating aftershocks as stress sources leads to a significant improvement in model performance (LogLikelihood): both the spatial and temporal distribution improve. For Parkfield, we find that including afterslip leads to a higher LogLikelihood: reloading by afterslip explains seismicity on the rupture area of the mainshock, where coseismic stresses alone would produce quiescence. The inclusion of afterslip and secondary triggering has a significant impact on the constitutive parameter A$\sigma$: the value obtained from the inversion is significantly higher, and physically more realistic, when postseismic processes are modeled. Our results indicate that the postseismic stresses can play an important role in aftershock triggering, and modeling them has the potential to improve forecasts.

# Dynamics and Structure of thermo-chemical Mantle Plumes: Are numerical Models consistent with Observations?

**Juliane Dannberg[1] and Stephan V. Sobolev**
[1]Geodynamic Modelling, GFZ German Research Centre for Geosciences

According to widely accepted models, plumes are hot thermal anomalies ascending from the core-mantle boundary, which cause massive melting when they reach the base of the lithosphere. Most of these models consider plumes as purely thermal and predict flattening of the plume head to a disk-like structure, thin plume tails with a radius on the scale of 100 km and kilometer-scale topographic uplift before and during the accompanying volcanic eruptions.

However, several field studies indicate significantly smaller surface uplift, and seismic imaging reveals thicker plume tails as well as a more complex plume structure in the upper mantle including broad low-velocity anomalies up to 400 km depth and elongated low-velocity fingers. Moreover, geochemical data indicate a plume composition that differs from that of the average mantle and recent geodynamic models of plumes in the upper mantle show that plumes containing a large fraction of eclogite and therefore having very low buoyancy can explain the observations much better. Nevertheless, the question remains how such a low-buoyancy plume can rise through the whole mantle and how this ascent affects its dynamics.

We perform numerical experiments in 2D and 3D spherical shell geometry with prescribed velocity at the upper boundary to investigate the interaction between plume- and plate-driven flow. For that purpose, we use modified versions of the finite-element codes Citcom and Aspect. Our models employ complex material properties incorporating phase transitions with the accompanying density changes, Clapeyron slopes and latent heat effects for the peridotite and eclogite phase, mantle compressibility and a highly temperature- and depth-dependent viscosity.

We study under which conditions (excess temperature, plume volume and eclogite content) thermo-chemical plumes can ascend through the whole mantle and what structures they form in the upper mantle. Modelling shows that high plume temperature and/or volume together with low content of eclogite (i.e. high bouyancy) result in plumes directly advancing to the base of the lithosphere. Due to the high eclogite density in a region between 300 and 400 km depth, plumes with slightly lower buoyancy accumulate there and form pools or a second layer of hot material. Further reduction of buoyancy leads to plumes ponding in this depth and never approaching the base of the lithosphere. All these structures become asymmetric when the plume interacts with the quickly moving overlying plate. Our models also suggest that thermo-chemical plumes ascend in the mantle much slower compared to thermal plumes, have thicker plume tails and cause a much smaller (hundred meters scale) surface uplift.

# Statistical modeling of the arctic sea ice coverage

**Jana de Wiljes[1], Illia Horenko[2]**

[1]Institute of Mathematics, Free University Berlin, Arnimallee 6, 14195 Berlin, Germany, jana.dewiljes@math.fu-berlin.de

[2]Institute of Computational Science, Università della Svizzera Italiana, Via Giuseppe Buffi 13, 6900 Lugano, Switzerland, illia.horenko@usi.ch

In pursuance of addressing existing issues of time series analysis techniques we developed a method for model parameter identification of discrete dynamical processes on the basis of spatio-temporal data. The technique is designed to take all influences on the system of interest into account, even, if they are not available in data form. This is achieved by a non-stationary non-homogenous model formulation. The aim is to identify a set of model parameters describing the dynamics of the arctic sea ice extent in order to study phase transitions. Specifically, the key idea is to use the determined model parameters to examine the tipping point of the arctic sea ice by employing a percolation model. Tuning of the external factors will then allow to analyze which quantities cause a phase transition.

# Extracting Subsurface Information from Seismic Noise – C3 Correlations

**Annabel Händel**[1], **Matthias Ohrnberger**[1], **Frank Scherbaum**[1], **Volker John**[2]

[1]Institute of Earth and Environmental Science, University of Potsdam

[2]Department of Mathematics and Computer Science, Free University of Berlin

In order to assess the seismic hazard at a site of interest it is essential to know how seismic waves are attenuated in the ground directly below a site (described by a parameter kappa). In most of the applications seismic waves generated by earthquake- or man-made sources are used to infer subsurface information. Diffuse waves on the other hand such as multiply scattered coda waves from earthquakes or background noise (like cultural noise from traffic or oceanic microseism) are usually unwanted. In recent years however it has emerged that diffuse waves also carry information about the medium through which they propagate. In many studies it has been shown that simple cross-correlation of random wavefields recorded at different locations at Earth's surface gives the response of the medium between these stations (Greens function). The obtained response equals the signal that would be recorded at one of the receivers if an impulsive source was placed at the location of the other receiver. From these signals travel time information and subsequently the shear wave velocity structure of the ground can be obtained. Amplitude and attenuation retrieval on the other hand remains very challenging.

In our study we want to employ the correlation of the coda of correlation of noise (C3 correlation). The method combines the strenght of normal noise correlations and earthquake coda correlations resulting in Greens functions which show a better time symmetry and are less dependent on the original noise source distribution. C3 correlations have been shown to give more reliable amplitude and attenuation estimates than single cross-correlations. We investigate whether this new approach allows the determination of kappa for seismic hazard studies.

# What controls the triggering of splay faults during great subduction earthquakes?

**Shaoyang Li**[1,†] **Marcos Moreno**[1], **Matthias Rosenau**[1], **Daniel Melnick**[2] **and Onno Oncken**[1]

[1]Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Telegrafenberg, Potsdam 14473, Germany

[2]Institut für Erd- und Umweltwissenschaften, DFG Leibniz Center for Surface Process and Climate Studies, Universität Potsdam, Potsdam 14415, Germany

[†] Email address for correspondence: shaoyang.li@gfz-potsdam.de

Great subduction earthquakes can trigger slip on steeply-dipping splay faults in the overriding plate, which are capable of producing large seafloor deformation adding complexity to tsunamigenesis. However, because these faults are located offshore, direct measurements of splay fault rupture are rare and it remains unknown what controls their activation during great subduction events.

Here, we present results from a comprehensive 2D Finite Element Method (FEM) analysis that investigates the influence of the amplitude and distribution of megathrust slip on the behavior of splay faults. The effect of gravity and variable frictional strength properties are analyzed. We simulated both landward and seaward dipping splay fault geometries, and imposed different depth-varying slip distributions of characteristics large subduction events.

Our results indicate that the two typical splay faults have similar faulting behaviors despite of different dipping angles and branching depths. Nevertheless, the variation of splay fault strength only results in different seismic magnitude on it. Splay faulting may account for ∼2% of the seismic moment released in the interface, equivalent to a Mw=6.5 event during a megathrust earthquake of Mw>8.5. We find that a critical distance defined by the depth of peak megathrust slip to the branching point controls the triggering process. Megathrust slip concentrated shallower than the critical distance will favor normal displacement along splay faults, whereas reverse splay fault motion may result from megathrust slip located deeper than the critical distance.

Our study provides a useful tool for predicting the activation of secondary faults usually not included in slip inversion models, which may have direct implications on tsunami hazard research.

# Extending a Scheme for solving the Linear Advection Equation: the Second Order Moments Method

**Linda Michalk**
Department of Mathematics and Computer Science, Freie Universität Berlin

"Advection is a fundamental physical process associated with many fluid applications, such as mass, energy, and tracer transportation in atmospheric and oceanic flows" [Li, 2008]. Furthermore, the quality of advection schemes has a strong influence on ocean general circulation models [Hofmann & Maqueda, 2006]. Hence, it is not surprising that many mathematicians and meteorologists put a lot of effort in finding adequate advection schemes, see Li, [2008] and references therein. It can be a challenging task to solve the linear advection equation even with constant velocity flow in one space dimension [Leonard, 1991], if the solution needs to be highly accurate, positive, non-oscillatory and and nevertheless computationally cheap. However, some successful numerical schemes already exist. The Second Order Moments (SOM) method [Prather, 1986] with convincing results is among these methods.

On my poster I will focus on an extension of the existing SOM method. I will describe its basic idea and show the performance of the method. I will demonstrate which properties are eligible to be extended. Specifically, the velocity field for the SOM method is limited to constant velocity. The extended version can handle a more general velocity field, namely piecewise linear velocities given in each grid cell. As a consequence the computational cost grows significantly, if I hold on to the idea of using the analytical solution during the time step as the original SOM method does. Furthermore, I loosened the time step restriction of formerly permitting a Courant number up to one to theoretically no limitation on the time step at all. This is achieved using a Semi-Lagrangian ansatz [Staniforth & Côté, 1991]. I finally will show a small test case and give an example for an application where the extended SOM method could be employed.

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# Sensitivity Studies in Probabilistic Seismic Hazard Analysis

**Christian Molkenthin[1], Frank Scherbaum[1], Sebastian Reich[2], Peter Stafford[3]**

[1]Institute of Earth and Environmental Science, University of Potsdam

[2]Department of Mathematics, University of Potsdam

[3]Department of Civil and Environmental Engineering, Imperial College London

The quantification of the ground shaking hazard at a site of interest is an important step for the evaluation of the impact of future earthquakes on humans and structures. This is a prerequisite for the development of mitigation strategies for seismic risk.

The present state of the practice is to use a probabilistic description of the ground motion that can occur at a particular site and to estimate the annual rate of exceedance (or its reciprocal: return period) for certain levels of shaking, expressed in terms of a ground-motion hazard curve. This is achieved by a commonly used approach which is termed Probabilistic Seismic Hazard Analysis (PSHA). Sensitivity studies in PSHA play an important role to identify critical parameters to the results or even those parameters which have no influence on the ground-motion hazard. Derived sensitivities provide also an understanding which factors contribute to the uncertainty of the hazard.

The aim of this study is to develop a tool that provides results in terms of sensitivities of the PSHA with respect to its inputs. This is done by calculating the absolute parameter sensitivities (sensitivity coefficients) defined as the partial derivatives of the model output with respect to its input parameters. However, deriving exact partial derivatives of complex models for a differential sensitivity analysis can be very challenging. We propose in this study to apply Algorithmic Differentiation (AD). Given a computer implementation of a model, AD makes it possible to obtain exact quantitative estimates of first order sensitivities. This makes AD both theoretically as well as practically an invaluable tool. Preliminary results of the implementation of AD for simple cases of PSHA will be presented.

# 3-D Modeling of Reflection Coefficients at Thin Fluid Layers Representing a Hydraulic Fracture

**A. Oelke, O.S. Krüger and S.A. Shapiro**
Department of Geophysics, Freie Universität Berlin

In this work we investigate the wave propagation in an elastic and fractured rock by modelling the wavefield using a Finite Difference algorithm that is based on a rotated staggered grid. Angle-dependent reflection coeffients at thin fluid layers are derived from 3-D synthetic data, deploying an explosion and a double couple mechanism, and are compared to the analytical solution. The thin fluid layer is embedded in an elastic isotropic rock. The fluid filler water represents the simplest model of a hydraulic fracture. The results are in a good agreement and support the idea that microseismic events can be reflected at hydraulic fractures with a high reflection coefficient. Examples from data recording microseimic events that will serve for further investigation with respect to reflection coefficients are shown.

# Strain Localisation and the Development of Fault Networks: quantitative Assessment of the Role of Strain Weakeining Mechanisms through Analogue Modelling

**Malte Ritter**
Section 3.1, GFZ

Deformation in the brittle domain is characterised by the localisation of strain into distinct faults. Fault behaviour is controlled by several well-known external and internal forcing factors, such as the mode of deformation (compression vs. extension) and material properties that prescribe e. g. the taper angle of a compressional wedge. But what drives the localisation of strain into faults? Strain softening is commonly assumed to be the responsible material property, but how it relates to strain localisation remains yet unknown.

Physical models using granular analogue materials have been widely used to describe fault evolution and clearly show the localisation of strain. Strain softening in granular materials, on the other hand, is known from force measurements using devices such as uniaxial testers, which do not allow for the direct, optical observation of the sample. In order to link strain softening to, and quantify its influence on strain localisation, two new experimental setups have been developed that both link the characteristics of one method with the advantages of the other. These setups are presented here together with preliminary results.

The first setup is a rectangular, quasi-2D shear cell for uniaxial testing. Its transparent front allows observation using digital image correlation methods (DIC) at a very high spatial resolution, and the similarity of the system to common shear cells ensures comparability to previous measurments. The second setup is a common strike-slip setup for analogue experiments using DIC, but with the possibility to measure boundary forces. In this setup boundary conditions are less strictly confined and therfore allow the formation of more complex, realistic fault systems. In order to evaluate the data from both se- tups and to compare them to each other statistical modelling and time-series analysis will be needed.

# Solar Cycle Effects on Climate and their Modulation by decreasing Solar Activity and Climate Change (SOMOSA)

**Tobias Spiegl**
Institute for Meteorology, FU-Berlin

Since the completion of solar cycle 23 (1996-2008), with its low and ongoing minimum, a public debate was started whether the heating effect of rising human induced greenhouse gas concentrations (GHGC) could be compensated by a decrease in solar activity. These kind of discussion clearly shows the necessity, of a better understanding of natural and anthropogenic climate forcings and to distinguish between their typical imprints and effects in Earth's past, recent and future climate.

The primary aim of this study is to quantify the effects of the long term variability of the 11-year solar cycle, with respect to a changing environment where greenhouse gases were increased rapidly. Beside short observational stratospheric times series, neither the chemical reactions that proceed within the stratosphere, nor the connection between the UV effect and the ocean-atmosphere system are satisfactory understood yet. To quantify the feedback reactions of varying solar intensities on both the UV effect ("top down") and the ocean-atmosphere response ("bottom up"), a state-of-the-art CCMs (chemistry climate model) will me used. These model uses parametrizations of all necessary processes concerning the middle atmosphere and the atmosphere-ocean reactions, what makes it possible to assess both effects separately. The 11-year solar cycle represents one of the most prominent examples for solar variability. Model results and observations show, that decadal changes in solar activity are highly correlated i.e. to variabilities of the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), as well as cyclone activity over the Northern Atlantic. On that account a better understanding of the 11-year solar cycle could lead to an enhanced interannual and seasonal climate prediction on global and regional scales.

To assess the effect of the solar cycle in a world with increasing GHG, sensitivity experiments with a prescribed solar cycle but varying CO 2 scenarios will be run. Analysis of time series of cosmogenic $^{10}$Be in the Greenlandic GRIP ice core suggest a further decline of solar activity within 3 decades. To that account, simulations with a weak solar cycle (comparable to the Maunder Minimum) and changes in TSI and different short wavelengths bands will be implemented.

# Process-based Detection of Changes in Flood Seasonality under Climate Change

**Klaus Vormoor**
Institute for Earth- and Environmental Science, Section for Hydrology and Climatology, University of Potsdam

Based on a multi-model-multi-parameter ensemble, hydrological projections for a future period (2071-2100) and a reference period (1961-1990) are simulated using eight combinations of Global and Regional Climate Models (GCM/RCM combinations) driven by the A1B emission scenario. The scale gap between the climate model domain and the hydrological catchment scale is bridged by applying two different local adjustment methods: Expanded Downscaling and Empirical Quantile Mapping. Hydrological simulations for ten Norwegian catchments are generated by the conceptual HBV model using 25 best-fit parameter sets derived from a model calibration with a special emphasis on flood peaks.

Comparing the future with the reference period, it shows that regional changes in flood seasonality are likely to occur. Regions in central and northernmost Norway which are currently dominated by high flows during spring and summer will increasingly be influenced by high flows in autumn and winter. Pluvial autumn and winter floods which are dominant in western Norway are likely to become even more prominent in the future. Changes in the flood generating processes are the reason for these regional patterns. Therefore, in each of the ten catchments an event-based analysis of the simulated hydrographs is performed to classify flood events according to their generation processes (rain vs. snowmelt vs. rain-and-snowmelt). The results allow for drawing conclusions about the impact of climate change on the flood generating processes in Norway. The range of the projections by the multi-model-multi-parameter ensemble delineates the uncertainties which are associated by these kinds of impact studies.

# Modeling Garnet geochemistry: from first principles to growth models

**Johannes Wagner**
GFZ Potsdam Section 3.3: Chemistry and Physics of Earth Materials

Garnet is one of the most important phases in the Earth's mantle, particularly in subduction zones. Its ability to preserve geochemical signatures over geological timescales makes garnet an ideal proxy for processes in the deeper earth, for precise dating of metamorphic processes or for modelling rates of subduction. The mechanisms that control element incorporation into garnet on its way down a subduction zone are qualitatively understood, their interplay however is not very well constraint. In order to understand the controlling factors of garnet growth we need to understand the distribution behavior of major- and trace elements between garnet and fluid/melt at changing pressure and temperature conditions. In this study, we investigate garnet-melt partitioning behavior by combining insights from atomistic simulations with macroscopic garnet-growth models.

As a first step on an atomic scale, we aim to study properties such as surface-, grain-boundary- and defect energies as well as the energetics of trace element incorporation into the garnet lattice. Since a single garnet unit cell is already quite large (160 atoms) it is computationally to expensive to model these systems with a quantum mechanical approach. Instead, we construct classical interaction potentials that enable us to model systems of up to several thousand atoms on reasonable timescales. Classical potentials are obtained by fitting modelled system properties (e.g. ionic forces, dipole moments, stress tensor) to those obtained from first-principles calculations. The fit is done by adjusting a set of more than 10 parameters per ion-type and as such, is a complex procedure in multi-component systems such as minerals or melts. We use a combination of simplex and conjugate-gradient search algorithms for minimisation.

Here we present the construction of classical potentials for Y, La, Sr and other trace elements important for the interpretation of garnet geochemistry. The goal is to use these potentials in the coming months to calculate garnet-melt partition coefficients for changing conditions and study the incorporation of those elements into a growing garnet crystal.

## Talks on November 19th

# Defying Gravity: How Mantle Plumes Lift Heavy Material from the Earths Deep.

**Elvira Mulyukova[1], Bernhard Steinberger, Marcin Dabrowski, Stephan Sobolev**
[1]GFZ – Potsdam, Section 2.5 – Geodynamic Modelling

Earth's deep interior, namely the mantle, is heterogeneous: both thermally and chemically. The thermal anomaly arises due to heating from the underlying outer core, as well as from the radioactive elements intrinsic in the mantles composition. This heating gives rise to vigorous convection in the mantle, with the hot low-density material (mantle plumes) rising through the cold high-density ambient mantle material.

The chemical anomaly consists mainly of two large dense piles residing at the bottom of the mantle. These are called LLSVPs, Large Low Shear Velocity Provinces, a term derived from tomography studies. The origin of the LLSVPs, as well their chemically anomalous composition are still debated. The destabilising upwelling flow, or mantle plumes that rise from the bottom of the mantle, entrain some of the anomalously dense LLSVP-material and carry it all the way up to the surface of the Earth. Once they reach the surface, the mantle plumes cause eruptions, similar to volcanoes, and form magmatic structures such as Ocean Islands (e.g. Hawaii) and Large Igneous Provinces (e.g. Siberian Traps). The geochemical data of these magmatic structures provides some constraints on the composition of the deep mantle, including the LLSVPs, as well as the amount of the LLSVP-material that gets entrained into the rising plume.

If it wasn't for the destabilizing flow, or entrainment, by the hot rising plumes, the anomalously dense material in the Earth's deep mantle may have never made its way to the surface. In order for the entrainment to take place, the destabilizing viscous stresses acting on a volume of anomalously dense material must exceed the gravitationally stabilizing stresses associated with buoyancy. At what conditions are these criteria met in a dynamically active deep mantle?

To investigate this question, we perform numerical simulations of thermal convection with presence of a chemically dense basal layer in a 2D Cartesian box. In agreement with other studies, we find that the governing parameters are the buoyancy ratio between the thermal and the chemical density anomalies, as well as the viscosity variations.

# A Bridge between the Requirement of an 'Engineer' and Understanding of a 'Seismologist'

**Sanjay Bora[1], Frank Scherbaum[1], Nicolas Kuehn[2], Peter Stafford[3], Benjamin Edwards[4]**

[1]Institute of Earth and Environmental Science, University of Potsdam
[2]Department of Civil and Environmental Engineering University of California, Berkeley
[3]Department of Civil and Environmental Engineering, Imperial College London
[4]Swiss Seismological Service, ETH Zürich, Switzerland

With the increasing population and inhabitation on our planet, it is being observed that the shaking of ground because of earthquakes poses an increased threat to human life. Seismic hazard analysis is a term which refers to the quantification of the seismic threat at a particular site of interest caused by earthquakes from a specified region or zone.

Usually, in engineering practices ground-shaking is quantified in terms of acceleration/velocity/displacement of the ground. Current state-of-the-practice in engineering-seismology/seismic-hazard utilizes peak values of these parameters and/or corresponding response spectrum of a SDOF (Single Degree of Freedom) system. Often, estimation of these ground motion parameters is performed using empirical Ground Motion Prediction Equations (GMPEs). GMPEs are derived through a regression algorithm over a selected set of data comprising ground-motion parameter against a chosen set of predictor variables like magnitude, source-to-site distance, site condition information, etc. Essentially, a GMPE describes the conditional distribution of a selected ground-motion parameter in terms of a median value and a logarithmic standard deviation which is a measure of the spread of the observed data around the median. However, there are many regions, particularly the intra-plate regions across the globe which are seismically active, but have a paucity of recorded data which is insufficient to generate endemic empirical GMPEs. For performing seismic hazard studies in such regions the usual approach is to consider GMPEs from some other regions. Therefore, one of the major challenges associated with the current practice of seismic hazard studies is the adjustment of GMPEs in different seismological environments. The ongoing study presents a hybrid empirical approach to address this issue. Typically Fourier Amplitude Spectrum (FAS) of ground motion is modeled in terms of commonly used seismological parameters such as stress drop, seismic moment, quality factor and kappa.

The presented approach of developing a GMPE consists of empirical equations for FAS and duration of ground motion. Estimates from both the empirical equations are combined within the framework of random vibration theory (RVT) to obtain the corresponding response spectrum. The presented analysis is performed on the recently compiled RESORCE strong motion database across Europe, the Mediterranean, and the Middle East.

# Evaluating the potential of Radar Rainfall Data for Hydrological Simulations in the Philippines

**C.C. Abon**[1], **M. Heistermann, D. Kneis, A. Bronstert**

[1]University of Potsdam, Institute of Earth and Environmental Sciences, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

An accurate representation of the spatial and temporal distribution of rainfall input is a prerequisite for hydrological models that aim to generate accurate hydrographs. Traditionally, precipitation data from networks of rain gauges are used in hydrologic models. There are instances however that the rain gages fail to capture the spatio-temporal spread of rainfall events due to technical flaws and/or sparse positioning. Over the past decade the potential of radar rainfall estimates as an input for a hydrological model has been increasingly applied and evaluated. The advantages of radar rainfall observations are their real-time nature with high spatial and temporal resolution and large areal coverage over ground based raingauges.

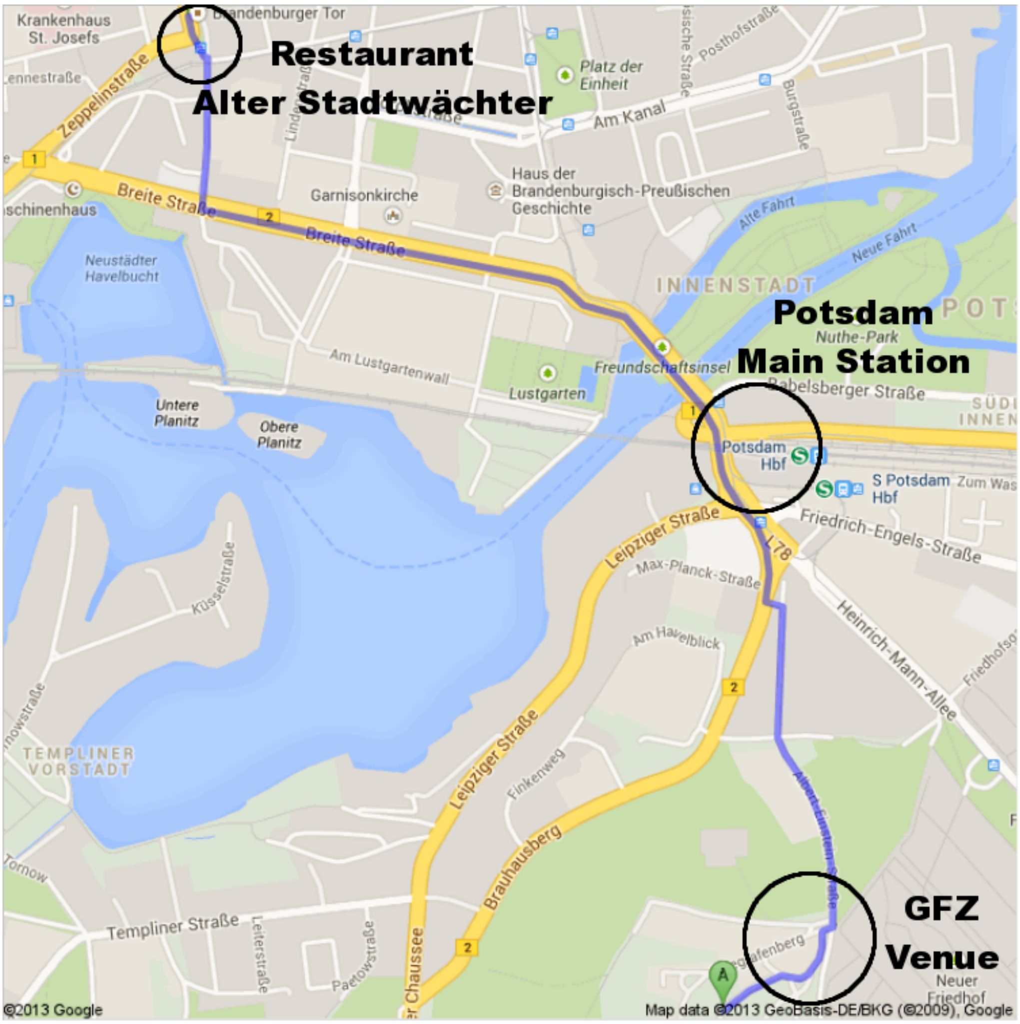
This study presents a very first evaluation of the performance of radar rainfall data retrieved from the S-band radar as input to the hydrological model in the Marikina River basin (MRB), Philippines. In particular, the processing tools from wradlib –an open-source radar processing library are used, and the result of hydrological simulations using (1) interpolated rain gauge data, (2) radar rainfall data alone, and (3) different corrected radar rainfall data are presented. The study seeks to answer which radar data product can generate the most accurate hydrographs and whether radar data can perform even better than the rain gauges.

# Maps and Directions

## Map of the Telegrafenberg - GFZ Potsdam including Venue House H

**Wissenschaftspark Albert-Einstein, Telegrafenberg Potsdam**

# Walkway from GFZ to Potsdam Main Station and the Restaurant "Alter Stadtwächter"




Just walk down to Postdam Main Station. From there you might take

- Bus 606 in direction to Potsdam, Alt-Golm.
  After 3 stations leave the bus at Luisenplatz-Süd/Park Sanssouci,
- or every bus which is passing Luisenplatz-Süd/Park Sanssouci
  (i. e. Bus 605, 606, and 631),

then walk to Schopenhauerstraße 31, 14467 Potsdam.