HITS
Heidelberg Institute for Theoretical Studies

Emulator Day

27 January 2020

Studio Villa Bosch/
Heidelberg Institute for Theoretical Studies (HITS)

11:00-12:00	HITS Colloquium Studio Villa Bosch
	Corinna Hoose, Karlsruhe Institute of Technology (KIT) *Simulation of deep convective clouds under various meteorological and microphysical impacts*
12:00-13:30	Lunch and coffee Cafeteria, HITS
	Emulator Day Alan Turing room, HITS
13:30-14:00	Tilmann Gneiting, Karlsruhe Institute of Technology (KIT)/ Heidelberg Institute for Theoretical Studies (HITS) *Emulators - a statistical perspective*
14:00-14:30	Constanze Wellmann, Heidelberg University *Using statistical emulation for sensitivity studies of deep convective clouds*
14:30-15:00	Coffee break
15:00-16:00	Takahiro Nishimichi, University of Tokyo *Emulating halo statistics for large scale structure cosmology*

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Abstracts

Corinna Hoose, Karlsruhe Institute of Technology (KIT)

Simulation of deep convective clouds under various meteorological and microphysical impacts

Deep convective clouds and the resulting heavy precipitation, hail, lightning and wind gusts can cause severe damage. Their forecasting with current numerical weather prediction models is a challenge, both because of limitations on spatial resolution and because of the low predictability of timing, location and properties of the storms. In numerical simulations, the impact of changes in meteorological (e.g. temperature, wind) and in microphysical conditions (e.g. aerosol particles acting as cloud condensation nuclei, strength of ice formation) can be investigated in sensitivity experiments, and I will show results for different cases and different variables of interest. However, for realistic cases, such sensitivity experiments become very costly or not feasible at all. For some applications, statistical emulation can be used as an approach to address this problem.

Tilmann Gneiting, Karlsruhe Institute of Technology (KIT)/ Heidelberg Institute for Theoretical Studies (HITS)

Emulators - a statistical perspective

I will provide a basic introduction to the use and design of emulators, with emphasis on Gaussian process solutions.

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Constanze Wellmann, Heidelberg University

Using statistical emulation for sensitivity studies of deep convective clouds

Severe hailstorms have a large damage potential and cause harm to buildings and crops, for instance. However, important processes for the prediction of hailstorms are insufficiently represented in operational weather forecast models. This project aims to identify environmental conditions and microphysical parameters such as wind shear and strength of ice multiplication which lead to large uncertainties in the prediction of deep convective clouds. In an idealized setup of a cloud resolving model including a double-moment microphysics scheme we use the approach of statistical emulation to allow for a Monte Carlo sampling of the parameter space which enables a comprehensive sensitivity analysis. Furthermore, we investigate whether the sensitivities are robust for different trigger mechanisms of convection. The uncertainties of most cloud and precipitation outputs are dominated by the potential temperature profile if the environment is changed. If microphysical parameters are modified, the fall velocities of graupel and hail are the main contributors to the output uncertainty. Comparing the impact of both environmental conditions and the microphysics shows that there are prevailing contributors for the uncertainty of the considered outputs. For example, the uncertainty of the precipitation output is mainly caused by microphysical parameters. Moreover, our results show that depending on the choice of the trigger mechanism the contribution of the input parameters to the uncertainty varies which means that studies with different trigger mechanisms might not be comparable.

Takahiro Nishimichi, University of Tokyo

Emulating halo statistics for large scale structure cosmology

There is a growing interest in large scale structures of the Universe for the understanding of the fundamental framework of cosmology. Especially, the nature of two mysterious components that govern the dynamics of the Universe, dark matter and dark energy, are the main targets of future gigantic observational projects. We need a reliable mathematical model for the observables of these projects with sufficient accuracy to give them a theoretical interpretation. The system of interest is mainly driven by gravitational interactions, and the N-body simulation has long been employed as a powerful tool to solve such problems. While its ability to predict the dynamics has dramatically been improved with the increasing computational resources, it is still infeasible to explore and fill the cosmological parameter space with sufficiently accurate simulations for statistical inference problems given the typically large dimensionality of the input parameter space. We have developed a software dubbed “Dark Emulator” to fit in with, for instance, a Markov-chain Monte Carlo sampler to extract cosmological information out of various set of cosmological observations. The emulator is composed of four main steps: i) a carefully chosen experimental design that fulfills desirable projection and space-filling properties, ii) a huge dimensionality reduction of the data vector obtained from each simulation based on the weighted principal component analysis, iii) nonparametric regression based on the Gaussian process, and, iv) rigorous cross-validation studies based on the split of training/validation sets, again optimized a priori in the process i). The high accuracy (typically 2 to 3% precision) and the high evaluation speed (about a few seconds per evaluation per target galaxy sample on a modern laptop computer; this compares to about 2 days on a supercomputer using about 600 CPU cores) together with the flexibility in relating the simulated halos to the observed galaxies allow Dark Emulator to be implemented efficiently into the actual parameter inference pipeline to analyze observed galaxy data for the first time.