Doctoral Thesis

Physics based dynamic modeling of space-time data

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Physics Based Dynamic Modeling of Space-Time Data

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presented by
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Abstract

Space-time data sets are increasingly becoming larger with more and more data being generated by radars, satellites, or highly resolved numerical models. It is therefore crucial that spatio-temporal models can deal with large data sets without running into a computational bottleneck. Statistical models in general and spatio-temporal models in particular need to have interpretable parametrizations that make a compromise between simplicity and generality. A physics based statistical approach uses knowledge from other areas of Science to build probabilistic models that meet these requirements.

In the first part of this thesis, a dynamic model for short term prediction of precipitation is presented. The model is based on a physically motivated stochastic integro-difference equation (IDE) which allows for a non-separable correlation structure that is temporally non-stationary. External meteorological variables such as wind and humidity, amongst others, are combined with a non-parametric spatio-temporal process.

Next, a model for large space-time data sets that is based on a stochastic partial differential equation (SPDE) is proposed. This approach has the advantage that the (hyper-)parameters of the process can be meaningfully interpreted, for instance, as being transport vectors and diffusion parameters. We show how to design computationally efficient algorithms by solving the SPDE in the spectral space and using the fast Fourier transform (FFT). Applying the model to postprocessing of precipitation forecasts from a numerical weather prediction (NWP)
model for northern Switzerland, we find that the statistically postprocessed forecasts outperform the raw NWP forecasts. In addition, the probabilistic forecasts appropriately quantify prediction uncertainty.

Both the IDE and the SPDE based model are formulated in a Bayesian framework and fitted using Markov chain Monte Carlo (MCMC) methods.

Furthermore, in the last part of this thesis, we demonstrate how the mixed predictive distribution (MPD) can be used for graphical model checking in Bayesian analysis. This can be applied generally for Bayesian models and, in particular, it is useful in spatio-temporal statistics.
Zusammenfassung


Danach schlagen wir ein Modell für grosse Raum-Zeit Datensätze vor, welches auf einer stochastischen partiellen Differentialgleichung beruht. Dieser Ansatz hat den Vorteil, dass die (Hyper-)Parameter des Prozesses sinnvoll interpretiert werden können, zum Beispiel als Transport-Vektor oder Diffusionsparameter. Wir zeigen, wie man re-

Beide Modelle folgen einem Bayesianischem Ansatz und werden mit Markov chain Monte Carlo Methoden an die Daten angepasst.