**Frequentist and Bayesian Approaches to State-Space Modelling of Ice Dynamics in Antarctic Ice Basins**

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**Abstract**

The melting of the Antarctic ice sheet is anticipated to play a significant role in sea level rise over the upcoming decades. Long-term mass and volume changes of the Antarctic ice sheet are predominantly caused by changes in the movement of the ice layer, referred to as ice dynamics. Mass and volume changes of the Antarctic ice sheet are monitored by gravimetry and altimetry satellites. Their data are corrected for glacial isostatic adjustment and changes in the surface climate, namely cumulated surface mass balance anomalies and firn thickness changes, to obtain ice-dynamical mass and volume time series. These time series are modelled using dynamic state-space models in this thesis.

State-space models decompose the data into several components. These components consist of parameters that are constant with time and states that vary with time. This thesis considers two modelling approaches to estimate the parameters and states, referred to as the the Frequentist and Bayesian approaches. The Frequentist approach entails estimating model parameters using maximum likelihood estimation and subsequently determining the states at each epoch using the Kalman Filter and Smoother. The Frequentist parameter estimates are deterministic. As a result, potential stochasticity of parameters is not accounted for when determining the states. This may lead to overconfident small uncertainties in Frequentist models. The Bayesian approach remedies this by considering model parameters to be stochastic. Following the Bayesian approach, the marginal posterior distributions of the parameters are estimated using Markov Chain Monte Carlo methods. Samples from these distributions are used to estimate the conditional distributions of the states at each epoch using the simulation smoother. Because parameter samples are used to estimate the states, stochasticity of the parameters is accounted for when sampling the states following the Bayesian approach.

Three distinct Antarctic ice drainage basins are investigated in this thesis. For their ice-dynamical ice mass data, significant differences between the uncertainties of Frequentist and Bayesian models are found. The Bayesian uncertainties are consistently larger than the Frequentist uncertainties. The largest differences between Frequentist and Bayesian uncertainties are found for the slope components of state-space models. Depending on the complexity of the data that are being modelled, the Bayesian uncertainty of a slope component can be up to 4 times larger than its Frequentist uncertainty.

Frequentist and Bayesian methods to combine the trends of gravimetry-based and altimetry-based state-space models of ice-dynamical ice mass in Antarctic ice basins are also investigated in this thesis. Epoch-wise weighted averaging, with weights based on the uncertainties in the gravimetry-based and altimetry-based models, is done to combine the trends. It is found that the gravimetry data is of significantly higher quality than the altimetry data, having much smaller uncertainties. As a result, the weighted average of the trends aligns closely to the gravimetry-based trend. Finally, several choices that have to be made when working with Bayesian Markov Chain Monte Carlo methods for state-space modelling and their impact on the results are discussed.