Integrated Climate and Hydrology Modelling – Coupling of the HIRHAM Regional Climate Model and the MIKE SHE Hydrological Model - DTU Orbit (13/12/2018)

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To ensure optimal management and sustainable strategies for water resources, infrastructures, food production and ecosystems there is a need for an improved understanding of feedback and interaction mechanisms between the atmosphere and the land surface. This is especially true in light of expected global warming and increased frequency of extreme events. The skill in developing projections of both the present and future climate depends essentially on the ability to numerically simulate the processes of atmospheric circulation, hydrology, energy and ecology. Previous modelling efforts of climate and hydrology have used each model component in an offline mode where the models are run in sequential steps and one model serves as a boundary condition or data input source to the other. Within recent years a new field of research has emerged where efforts have been made to dynamically couple existing climate and hydrology models to more directly include the interaction between the atmosphere and the land surface.

The present PhD study is motivated by an ambition of developing and applying a modelling tool capable of including the interaction and feedback mechanisms between the atmosphere and the land surface. The modelling tool consists of a fully dynamic two-way coupling of the HIRHAM regional climate model and the MIKE SHE hydrological model. The expected gain is twofold. Firstly, HIRHAM utilizes the land surface component of the combined MIKE SHE/SWET hydrology and land surface model (LSM), which is superior to the LSM in HIRHAM. A wider range of processes are included at the land surface, subsurface flow is distributed in three dimensions and the temporal and spatial resolution is higher. Secondly, the feedback mechanisms of e.g. soil moisture and precipitation between the two models are included. The preparation of the HIRHAM and MIKE SHE models for the coupled study revealed several findings. The performance of HIRHAM was highly affected by the domain size, domain location and resolution and of these the domain size was found to be the key parameter. For the inverse calibration of MIKE SHE the measured latent, sensible and soil heat fluxes lacked energy balance closure, requiring modifications based on different scenarios on the origin of the erroneous component. Also, the differing modelling platforms of Windows and Linux posed a great challenge in the development and testing of the coupling code.

A primary task in the study was to assess the computational interaction between the two models in terms of scaling and simulation performance. Of six HIRHAM climatic output variables four showed an improvement with an increase in the data transfer frequency between the models alongside an increase in the computation time. In general however, the coupled runs were poorer than the uncoupled runs. This is not surprising and is attributed to each of the models having undergone substantial refinement and calibration in uncoupled modes to reproduce observations. By imposing a new LSM to HIRHAM and new driving data to MIKE SHE the coupled results are likely to be poorer. The feasibility and prospects of the coupled setup of HIRHAM and MIKE SHE are however clearly suggested by the simulations in the present PhD study. Further research is required to improve the simulations through coupled model calibration and other refinements are needed with respect to spatial and temporal scales, model processes and evaluation.

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