Flash Flood Modeling on HPC Systems

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Introduction

What is a Flash Flood?
• Flood of short duration with a relatively high peak discharge (IHPOH, 1998).

Why are Flash Floods so dangerous?
• occurrence within minutes to hours and not necessarily bound to watercourses;
• cascade effects: landslides, mudflow, sediment transport, etc.
• Excessive hydrodynamic forces with high destructive potential for buildings and other assets.
• heavy rain events are small-scale and highly variable
• conventional measuring systems can not measure flash floods efficiently
• prediction and warning of flash floods is difficult.
• flash floods are still little understood and documented.

The Cooperation Project HiOS

• Project HiFrequenzkarte Oberflächenabfluss und Sturzflut (Indicator Map for Surface Runoff and Flash Floods) abbreviated HiOS.
• Funded by the Bavarian State Ministry of the Environment and Consumer Protection (StMWiU).
•Supervised by the Bavarian Environment Agency.
• 3 years (August 2017 until August 2020).

Project Goal
• Development of a method to evaluate and classify the risk due to surface runoff and flash floods using a GIS application.
• The GIS application will be used to query, link and evaluate the factors promoting and triggering the generation of surface runoff and flash floods.
• Detailed study on 80 towns and municipalities in Bavaria using coupled hydrological and hydrodynamic simulation.
• Generation of a flash flood indicator map for Bavaria indicating different hazard zones for each of the more than 2000 Bavarian municipalities.

Applied Models

Three different kinds of models are used in the HiOS project:
• GIS-Tools (GIS)
• Hydrological Models
• Hydrodynamic Models

<table>
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<th>GIS</th>
<th>Hydrology</th>
<th>Hydrodynamics</th>
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<td>ArcGIS Pro</td>
<td>WaSiM</td>
<td>TELEMAC</td>
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<tr>
<td>AmMap</td>
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<td>GGS</td>
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The models WaSiM and TELEMAC are parallelized and scaled on HPC cluster systems. All other models can be used on cloud systems.

Model Coupleing

Two types of offline, one-way coupling of hydrological and hydrodynamic models:

<table>
<thead>
<tr>
<th>Type</th>
<th>Model Coupling</th>
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<tr>
<td>1. Off</td>
<td>WaSiM and TELEMAC</td>
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<tr>
<td>2. On</td>
<td>TELEMAC and TELEMAC</td>
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Advantages
• Better representation of hydrological processes (e.g. infiltration and runoff)
• Smaller domain (city area) for the high-resolution hydrodynamic model saves computational time and resources.
• Possibility to compare inflows from the two models and evaluate runoff from the hydrodynamic model against SCS-CN method (NRCS, 2010).

HPC Topology

All models simulate processes in a spatially 2-dimensional and time-dependent space. Output: n x m-datasets for the catchment/town region for each time level.

Models suited for HPC-cluster split the computational problem in several parts:
• Hydrology: WaSiM, catchment split.
• Hydrodynamics: TELEMAC, town region split.
• Input: One catchment/town with n-parameter sets and m-load cases.

Models suited for cloud calculate the domain en bloc:
• GIS-Template: Parallelism using virtual machines VM (embarrassingly parallel use).
• Hydrological models: Parallelism using VMs.
• Input: One catchment with n-parameter sets and m-load cases.

Summary and Outlook

High performance computing is an essential part of the HiOS project. The benefit results from the combined use of cloud and cluster systems. The need for HPC is caused by:
• Great amount of measured and observed data.
• Discretization of catchment areas covering all of Bavaria.
• High discretization of 80 town regions.
• Long time series (2 days) to be calculated at a low time resolution (dt = 1 sec).
• Need for analysis of hundreds of variations.

The compute cloud is already used for GIS-analysis (ArcGIS-server) and hydrodynamic calculations. The parallelized programs WaSiM and TELEMAC are carried out on the cluster CoolMUC. It is planned to expand to the more powerful SuperMUC-cluster. First runs proved the performance gain on this system.

The benefits of HPC for the time consuming simulations of the 80 Bavarian towns and municipalities will be analyzed and optimized in the next work package.

Literature