Urban Flood Modelling Using Cloud Computing

Vassilis Glenis[1], Vedrana Kutija[1], Chris Kilsby[1], Andrew Stephen McGough[2], Simon Woodman[2]
[1]School of Civil Engineering , [2]School of Computing Science, Newcastle University, Newcastle upon Tyne, UK.

Abstract

Assessment of pluvial flood risk is particularly difficult because it is sensitive to the spatial-temporal characteristics of rainfall, topography of the terrain and surface flow processes influenced by buildings and other man-made features. A Cloud Computing compatible version of the urban flood modelling, analysis and visualisation software "CityCat" was developed and deployed on the Cloud to estimate spatial and temporal flood risk at a city-scale. The use of Cloud Computing enabled modelling of flooding over larger domains with much higher resolution than has been done previously. It has been demonstrated that the use of Cloud Computing can enable efficient and detailed assessment of flood risk at a high resolution for city or even regional scales.

CITYCAT

CityCat is an urban flood modelling, analysis and visualisation tool with very accurate and computationally efficient numerical solutions in a user-friendly visual environment, Glenis, et al (in preparation). The object-oriented architecture of CityCat provides great development flexibility and enables easy extension of functionality due to its fully modular structure. Additionally, the object-oriented architecture of the model increases the computational efficiency because all the required decisions are made only once during the setup of the model and as a result many conditional statements ("If-then-else" type statements) are removed from the run time. The model can be run under the Windows or Linux operating systems and a 64bit version can be used to model large domains with high resolution grids where the size of the model is limited only by the available memory of the computer.

CityCAT uses standard datasets: a Digital Terrain Model (DTM) for the topography and the OS MasterMap data to delineate the urban features such as: buildings, roads and permeable surfaces. Simulations of different flood events can be driven by rainfall, flow and/or water depth time series.

The computational grid is generated automatically using the DTM. In order to exclude the buildings' footprint from the grid the buildings layer from the OS- MasterMap is used. This improves the ability of the model to capture realistically the flow paths in urban areas and reduces the simulation time due to the reduction in the number of computational cells. The cells which are removed from the computational domain form the "buildings" layer used in the roof drainage algorithms. Additionally, green surfaces polygons from OS- MasterMap are used to define areas of the computational domain where infiltration algorithms are applied.

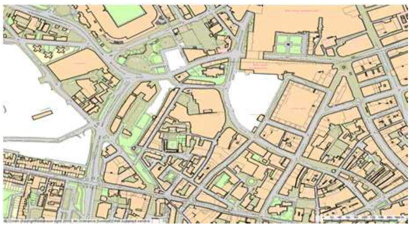

Figure 1. MasterMap coverage

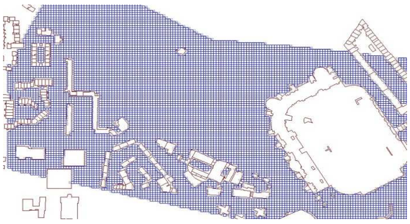

Figure 2. CityCat grid without buildings

DEPLOYMENT OF CITYCAT ON THE CLOUD

A Cloud Computing version of CityCat was developed and a high throughput model of computation on the Cloud was adopted in which a Condor (http://research.cs.wisc.edu/condor/) cluster of nodes were deployed as a set of virtual machines instances on the Amazon Cloud. Each instance was a standard Ubuntu Linux image with the addition of the Condor deployment configured to use the large scratch space provided with these images. A set of parameter sweep jobs were deployed by modifying the original source code such that each job could be instantiated by passing a single integer number as part of the command line arguments to the program. This caused the correct configuration files to be selected. A simple script was used to wrap each job and would first decompress the files needed for each run before executing the main program and then compressing the results back up before returning the results to a central Condor computer on the Cloud. A detailed explanation of the Cloud computing deployment of CityCat can be found in Glenis et. al. (2013).

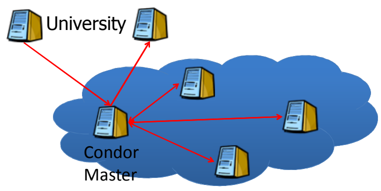

Figure 3. CityCat cloud deployment

SIMULATION RESULTS

CityCat has been applied to large areas and for extensive number of rainfall events on the Cloud. Three different domains, ranging in size from 4km2 to 1100km2 were used. Additionally, for one of the domains, four different grid sizes were used which resulted in very different model sizes (between 1,000,000 and 16,000,000 cells). Most of the models were then run in parallel using a set of 36 rainfall events, containing a combination of 6 different return periods and 6 different storm durations. All these simulations required different memory, CPU effort and total run time and benefitted in different ways from the Cloud (Glenis et al, 2013). The whole area of Newcastle City Council which covers approximately 120km2 was one of the largest domains modelled with CityCat. This area was used to demonstrate that development of Surface Water Management Plans - required by local authorities - can be improved when using such big domains and a large ensemble of simulations addressing the uncertainty and variability in the characteristics of present and future extreme rain storms.

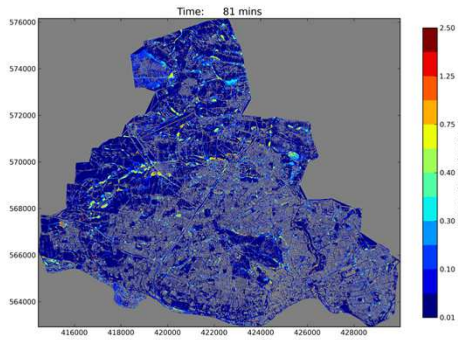

Figure 4. Water depth map of Newcastle City Council area. Storm event of 120min and 100 years return period.

CONCLUSIONS

The use of Cloud enabled high resolution large scale modelling of pluvial flooding for different rainfall events required in studies of flood risk. It also kept the total simulation time reasonable by processing 21 months of simulation within 30 days and demonstrated that flood risk studies at a city-scale can be performed efficiently by using a high-throughput system on the Cloud.

The city-wide application demonstrated here can be easily replicated for other cities in the United Kingdom using readily available data sets (Ordnance Survey MasterMap and airborne lidar data). This approach can also be used outside the United Kingdom where similar data are available as there is considerable demand for such detailed urban flood risk assessments from the insurance industry, government authorities and other hazard management and civil protection agencies around the world.

References

- Glenis, V., McGough, A.S., Kutija, V., Kilsby, C.G. and Woodman, S (2013). Flood modelling for cities using Cloud computing. Journal of Cloud Computing: Advances, Systems and Applications 2013, 2:7.
- Glenis V., Kutija V., Kilsby C.G. City Catchment Analysis Tool – CityCAT (in preparation)

JISC
EPSRC Pioneering research and skills