DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/141

Drainage in MIKE SHE, a sensitivity study for model domain grid size

Explored for a sub basin of the DK-model Area 3 (Funen)

Peter van der Keur, Jens Christian Refsgaard & Anker L. Højberg

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Introduction

Background

Recently it has become clear that there is a need to inquire into how the way drainage, from primarily agricultural areas, is represented in the MIKE SHE-MIKE11 (hereafter: MIKE SHE) model code and how simulated drainage as well as water balance in general is affected by the selected computational grid size. Thus, the way drainage is represented in the model and the grid size resolution is expected to have an impact on the overall regional water balance and also on temporal stream flow dynamics. Representation of drainage can occur at different spatial scales, both as artificial drainage pipe systems and as natural small streams and ditches, all presumably related to the selected grid size. To explore this is important as MIKE SHE is the underlying model in the national water resources model (DK-model) for assessments of available drinking water resources, including temporal and spatial variation. For large parts of Denmark detailed information on location and extension of drainage systems is not available in digital form and a lumped approach is applied in the DK-model. Usually, within the DK-model setup the applied grid size in MIKE SHE is 500 m by 500 m and therefore small scale drain systems and their hydraulic contact to the surface water system cannot spatially be resolved in the model. To try to compensate for this effect, drainage is implemented in the model to represent both artificial and natural drainage channels by defining a draining level (depth) and a time constant (leakage factor) for the entire model domain as well as a grid code map that spatially assigns drainage to recipients in the basin.

Purpose of this study

The purpose of this study is to investigate how grid size affects the water balance of a selected small catchment especially with respect to simulated drainage flow reflecting the model representation of both artificial (pipes) and natural drainage (ditches) systems. It is explored how grid size affects the models ability to capture draining related components of the overall water balance.

The Funen basin

DK-model region 3 (Funen)

The Fyn model area is one of the best instrumented and described in Denmark. The area is well described in Troldborg et al. (2010) and within the context of groundwater resources mapping in Fyns Amt (2005), VMP3 (Nielsen et al., 2004) and as Pilot River Basin (Fyns Amt, 2003). The Funen basin is part of the National Water Resources Model (DK-model). The Funen basin consists primarily of a weakly undulating moraine landscape and post glacial melting water induced features. The most important groundwater resources are found in limestone formations between 30 and 80 meter below surface. Details on the geological features relevant for the hydrological model can be found in Troldborg et al. (2010).
Instead of the entire Funen model area 3 release for the present simulation study it has been assessed that especially the upstream part of the Odense River in this basin is useful due to an appropriate topography and size that enables scaling of grid size. Also, small model domain grid sizes for a smaller sub catchment would not impose extreme long simulation times. Thus, simulation computation time is reduced by considering the sub basin only.

Methods

To explore how computational grid size for the selected sub catchment within the Funen catchment affects the water balance related to drainage, the model is setup for gradually smaller grid sizes for the selected catchment domain and run for the period 1990 to 2007. The sub-catchment simulation with 500 m by 500 m grid, the usual grid size for the DK-model, is referred to as 'reference run' and subsequent simulations with lesser grid sizes are compared to the reference run. Since the spatial data layers that represent climate, UZ, land use and drainage within the sub catchment also often are derived at the 500 m by 500 m scale, some of these also need to be resampled to a finer grid size in order to support simulations at smaller computational grid sizes. Thus, a sub-catchment model is setup using the original data layers and grid size for the Funen catchment and subsequent model runs with finer computational grid sizes are compared to the reference run with respect to changed water balance. Also, it is investigated how time series statistics of selected discharge stations within the sub catchment change when computational grid size is decreased. In this section the setup of the sub-catchment is presented and subsequently the modification of data layers needed to support a model representation of the sub-catchment at a finer computational grid scale.

Drainage options in MIKE SHE

In MIKE SHE, the Saturated Zone (SZ), Unsaturated Zone (UZ) and river sub model are fully coupled, which means that interaction exists between the groundwater domain (SZ), unsaturated zone and the river network. External boundary conditions are climate, interacting with the unsaturated zone, whereas surrounding waters (sea and fjords) constitute a boundary to the groundwater and river domain. Several drainage options exist in MIKE SHE. Saturated zone (groundwater) drainage, that cannot be resolved by the MIKE11 river model, as mentioned previously, can be captured in a lumped fashion by drainage pipes and then routed to a river node, surface streams, local topographic depressions or removed from the model. In the latter case water is removed immediately to a recipient which can be a MIKE11 river node, a SZ grid cell or model boundary. Drainage to pipes and from there to streams occurs when groundwater level exceeds the depth at which drainage is defined (in the DK-model usually at 0.5 m below surface). Atmospheric potential in drainage pipes is assumed, and thus when groundwater potential (level) reaches a level higher than this, the positive potential generates drainage flow. Dependent on hydraulic properties in the unsaturated zone, the upper boundary condition, rainfall (intensity) can either generate surface runoff or infiltration to drain level or further down to groundwater. In case the soil matrix is bypassed and preferential flow is generated, this can directly add to groundwater recharge. If infiltration capacity is exceeded by rainfall intensity, surface runoff or ponded water can also temporarily be stored in local depressions.
MIKE SHE has 4 drainage options (DHI, 2009):1. Drainage routed downhill based on adjacent drain levels: a reference system is created by the pre-processor using the slope of the drains calculated from the drainage levels in each cell. This may generate drainage to local depressions in cases of a flat topography and lead to generation of lakes that are not present in reality; 2. Drainage routing based on grid codes if topography is flat or when the drainage system is very well defined, such as in agricultural applications this method is often used. As in the previous method drainage

levels and the time constants are defined and the amount of drainage is calculated based on the drain level, the time constant (leakage factor) and computed as a linear reservoir. If the drainage routing is specified by Drain Codes, a grid code map is required that is used to locate drain recipients, typically river streams. In this case, all drainage generated within one zone is routed to recipient nodes with the same drain code value; 3. Distributed drainage options: choosing this method, an integer grid code distribution can be specified to indicate different drainage options in different areas of the model; 4. Drain flow not routed, but removed from the model: in this option, groundwater level exceeding the depth of drain pipes is not routed to the surface water system but simply removed from the system. For the present sensitivity study option 2 is selected.

Sub-catchment model

The sub catchment model (Fig. 1) is selected from within the DK-Model for the entire Funen basin, described in detail by Troldborg et al. (2010). This model from which the sub-catchment model is derived is referred to as 'release model' in this document. The selected sub-catchment model is used for all grid size simulations and not calibrated. The numerical model consists of a fully distributed and physically based MIKE SHE / MIKE11 code (Release 2009, servicepack 5) for simulating all processes in the hydrologic cycle. The model includes a coupled fully distributed 3-D saturated zone description, a 2-D surface water module, water balance in the unsaturated zone, 2-D drain discharge and 1-D river flow description (MIKE11).

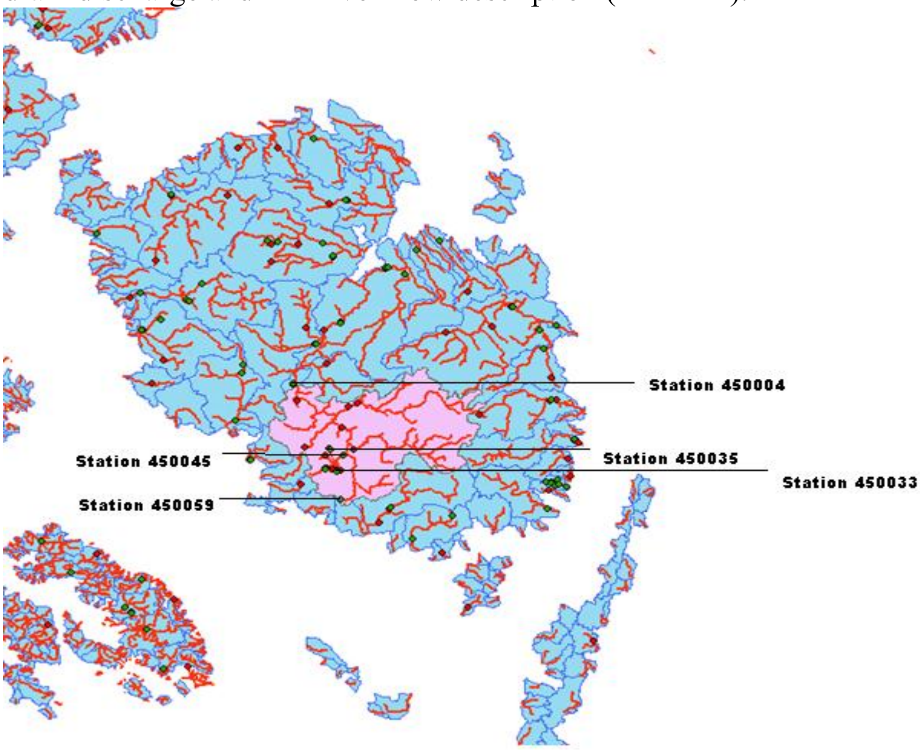

Figure 1. Sub-catchment is upstream of discharge station 450004 and included as model domain in MIKE SHE. Discharge stations 450004 (draining 302 km^2), 450045 (draining 30.2 km^2, 450033 (3.51 km^2), 450035 (2.56 km^2) and 450059 (0.38 km^2) are also indicated

In the following, the sub-catchment model is described and later only changes to the sub-catchment model when applied for other grid sizes are explained. The sub-catchment is selected by delineating and joining the areas draining to discharge station 450004 in the upstream part of the release model. Thus, the area draining into discharge station 450004 is selected in ArcGIS and defined as the MIKE SHE model domain (Fig. 1). In the release model four discharge stations are included within the selected sub-catchment for calibration / validation purposes. The 4 stations are kept in the sub-catchment and the station draining the entire sub-catchment (station 450004) is added. The discharge stations used for comparing changes in discharge as a result of changed grid size are DMU stations 450004 (draining 302 km^2), 450045 (draining 30.2 km^2), 450033 (draining 3.51 km^2), 450035 (draining 2.56 km^2) and 450059 (draining 0.38 km^2) all indicated in Fig. 1. The recently released 1.6 m DEM aggregated to 10 m resolution (Fig. 2) replaced the original 100 m resolution, as improved spatial resolution is a prerequisite and of specific interest when exploring sensitivity of model domain spatial resolution towards water balance, including drain and stream discharge.

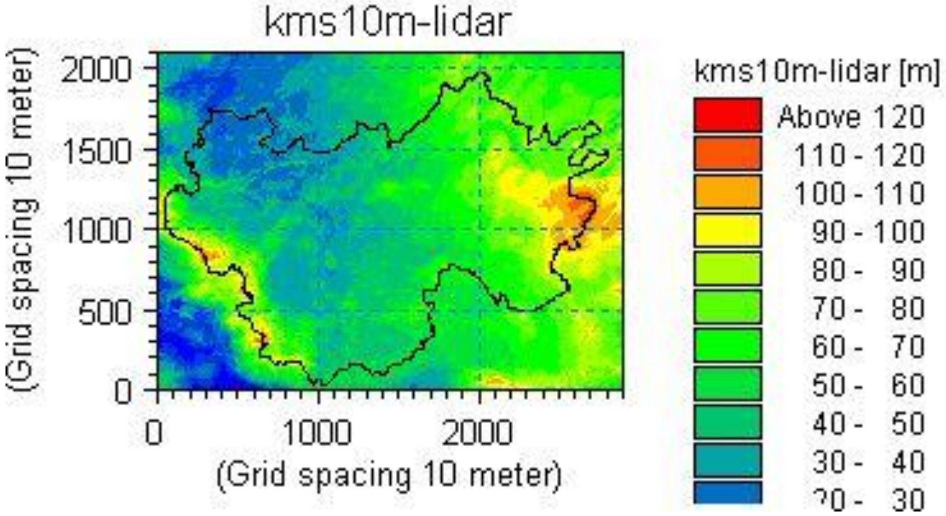

Figure 2. Sub-catchment DEM with 10 m spatial resolution.

The River Network file (nwk11) is adjusted by removing all river branches outside the sub-catchment domain. This is required as the MIKE11 river model does not automatically ignore branches outside the sub-catchment model, embedded in the original model domain. For the same reason the Boundary Conditions file (bnd11) is modified to exclude river boundaries that are not located in the reference model domain. The Land use map including vegetation and soil classification map is adjusted in ArcGIS from a 500 m resolution to a 10 m spatial resolution map (but still based on 500 m grid resolution) for MIKE SHE model technical reasons. The obtained land use map is shown in Fig. 3.

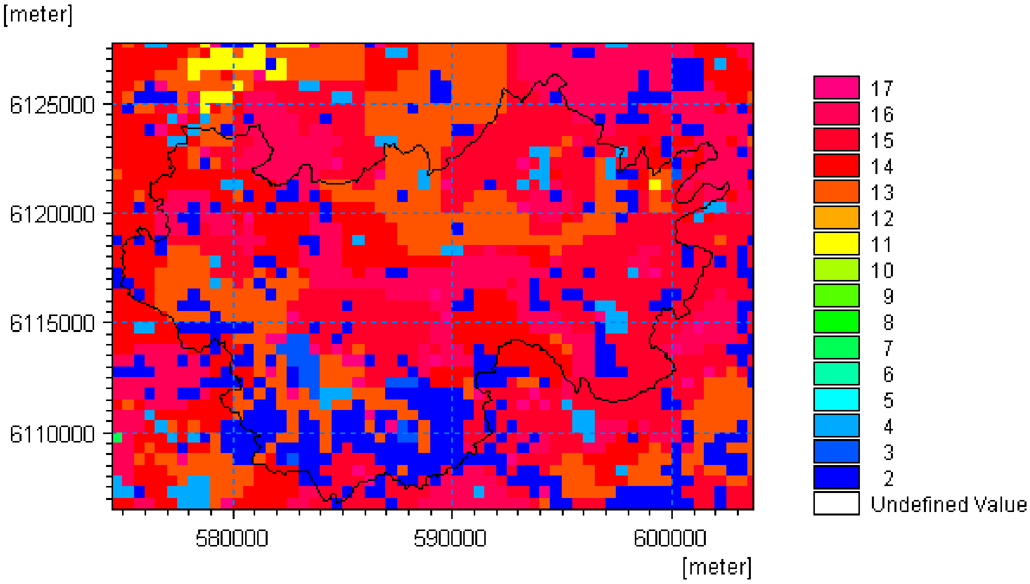

Figure 3. Land use map in 10 m grid size resolution (derived from actual 500 m grid resolution). Sub-catchment indicated by black line, legend refers to land use codes (2-17), of which some do not occur in the sub-catchment. The codes are explained in the text..

The grid codes in Fig. 3 refer to the following land use and crop rotation (CR) belonging to a soil type (grid code value in parenthesis): forest (2), lakes (3), urban areas (4), JB1-CR (coarse sand, 11), JB3-CR (clayey sand, 13), JB4-CR (clayey sand, 14), JB5-CR (sandy clay, 15), JB6-10-CR (sandy clay to heavy clay, 16) and JB11-CR (organic soils, 17). Remaining grid codes in Fig. 3 do not exist within the sub-catchment model domain (but do outside). A very minor part of the sub-catchment is classified as paved areas. The Manning number for overland flow is spatially distributed in the original model setup for Fyn, but within the sub-catchment the value does not vary spatially and is therefore set to a spatially uniform value of 2, rather than resampling the map to a finer resolution. The soil map that provides the hydraulic properties for the unsaturated zone within the two-layer UZ model is resampled from 500 m grid size to 10 m grid size in ArcGIS (Fig. 4)

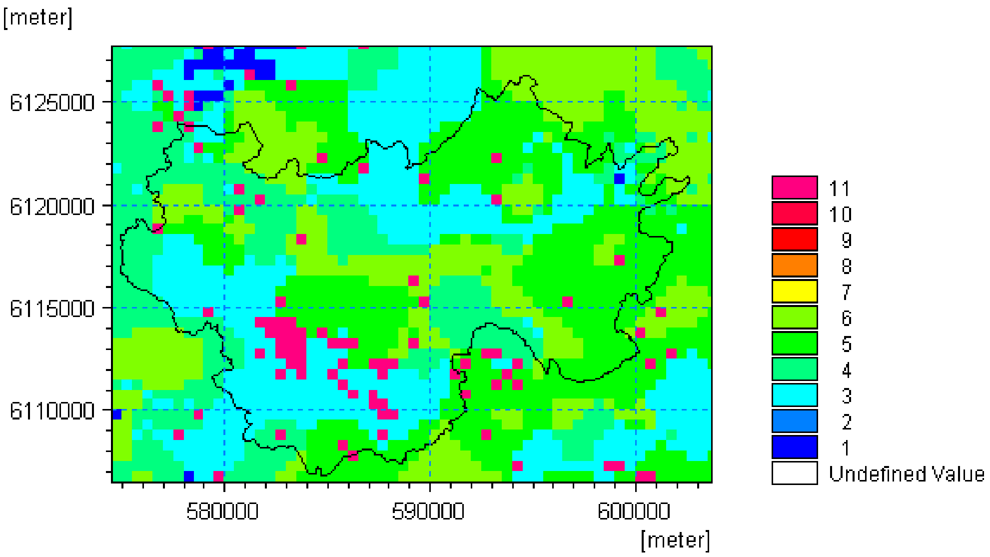

Figure 4. Spatial distribution of soil classification and associated hydraulic properties in the unsaturated zone. Refer to Table 1 for grid codes and assigned soil hydraulic properties. Some codes in the legend (2,7,8,9,10) do not occur in the sub-catchment

The top layer of the MIKE SHE model is handled by the Two-Layer model (Yan & Smith, 1994) that on a daily basis computes water percolation from the surface layer to the groundwater aquifers from precipitation and actual evapotranspiration and changes in rootzone water content. Percolation from the rootzone occurs when water content exceeds the soils field water capacity (at 100 hPa water suction). However, it is possible to specify an amount of water percolation through preferential flow, even at water potential below 10 kPa (pF2). The hydraulic parameters required by the Two-Layer model are indicated in Table 1.

Table 1. Soil hydraulic properties in unsaturated zone in Two-Layer model; JB refers to Danish soil classification system, θ_{sat}, θ_{FC} and θ_{WP} are water content at saturation, field capacity and wilting point respectively; K_{sat} is unsaturated hydraulic conductivity.

Gridcode/JB class	θ_{sat} [$cm^3.cm^{-3}$]	θ_{FC} [$cm^3.cm^{-3}$]	θ_{WP} [$cm^3.cm^{-3}$]	K_{sat} [$m\ s^{-1}$]
1/JB1	0.48	0.24	0.039	6E-06
3/JB3	0.46	0.27	0.058	6E-06
4/JB4	0.45	0.3	0.067	6E-06
5/JB5	0.44	0.31	0.087	6E-07
6/JB6-10	0.44	0.32	0.091	6E-07
11/JB11	0.48	0.34	0.091	6E-07

The saturated zone is parameterized following the geological layers. Pumping wells and subsurface drainage are selected in the release model and kept unchanged. The number of geological layers in the model is three, fractured clay in the top layer, clay in the layer below top layer, and finally the prequartary layer at the bottom. All layers are spatially distributed input to the model. In addition, geological lenses are defined. To reduce the computational time, the number of computational layers is reduced from 9 to 5: 1. Topo-Fyn-blag1 (LST), 2. Fyn-blag1-ks1top (KL1), 3. ks1top-ks1bund (KS1), 4.ks1bund-ks2top (KL2) and ks2top-bund (remaining of geological profile downwards). Refer to Troldborg et al. (2010) for the details on model geological stratification. The lower levels of all geological layers 1-5 are spatially distributed and specified in the MIKE SHE dfs2 map format. The initial potential head for each layer is calculated by first running the model for the entire 1990-2007 time period and extracting average potential head for the period 2002-2007 for each computational layer. The thus obtained spatially distributed initial potential heads for each grid size are then input to MIKE SHE. The outer boundary condition for the saturated zone is set to zero flux, meaning that no interaction is allowed between the saturated zone in the sub-catchment and the surrounding Funen catchment in which it is embedded. This is to ensure a closed water balance within the sub-catchment, independent of saturated water flux interaction between main and sub-catchment. Drainage routing is based on the Level of drainage pipes set to -0.5 m (drain level); a Drain Time Constant (leakage factor) regulating how fast water drains to a drainage system whenever drainage occurs, i.e. when water from the saturated zone rises above drain level. Spatially distributed drain codes are defined to identify recipients for drainage water. The reference model setup description is summarised below in Table 2

Table 2. Sub-catchment model setup description

Description	Derived from original setup novomr3_release_inc_klimadata.zip and novomr3_release.she, described in Troldborg et al. (2010)
Discharge stations	5 discharge stations in reference sub catchment are selected for comparing effects of grid size. 450004 (302 km^2), 450045(draining area 30.2 km^2), 450033 (draining area 3.51 km^2), 450035 (draining area 2.56 km^2) , 450059 (draining area 0.38 km^2)

Changes in derived sub-catchment setup compared to release model	1. new model domain: opland450004_dissolved.shp, generated in ArcGIS by selecting all sub catchments draining into discharge station 2. Edited nwk file by removing all branches outside the new domain 3. Edited bnd file by removing all boundaries outside the new model domain 4. Replacing original DEM from 100 m resolution by new 10 m DEM, aggregated from 1.6 m DEM 5. Original 'Landuse_DK_500m_7JBtyper.dfs2' in Land Use/Vegetation/ changed to 10 m grid file (see appendix for proc.) 6. Overland flow/Manning Number from 500 m dfs2 grid to uniform, value=2, as there is no spatial variation within the new domain 7. Changed original 2-layer UZ property file (500 m grid) to 10 m grid file 8. Reduced number of computational layers to 5: 1: Topo-Fyn-blag1 (LST), 2: Fyn-blag1-ks1t (KL1), 3: ks1t-ks1b (KS1), 4: ks1b-ks2t (KL2) and ks2t-bund (Rest of geological profile downwards) 9. Replaced 'fynnova_drain2river_opl.dfs2 with 'drain_codes_dk.dfs2' and changed the latter file to 10 m grid file
Setup specs	
Simulation specification	Overland Flow (OL), Rivers and Lakes (OC), Unsaturated Zone (UZ, Two Layer), Evapotranspiration (ET) and Saturated Zone (SZ)
Simulation Period	1990/01/02 – 2007/12/31, Time step=12 hrs, water balance considered for 2002/1/1 to 2007/12/31
Model domain	Opland450004_dissolve.shp NX=58, NY=42, Cell Size=500 m, X0=574500 m, Y0=6106500, NON-UTM Model grid size: 100, 200, 300, 400 and 500 m
Topography	450004_10m.dfs2 (10 m spatial resolution derived from 1.6 m resolution LIDAR data at: \\geusnt1\geuskort\gisdata\geocenterGDB\)
Climate	PREC: Standard_korrigeret_Prec_DK__hav0_10km_1990-2008.dfs2 EREF: Novana_DK_EPmak_40km_1990-1998_20km_1999-2008_ed.dfs2 TAIR: Novana_DK_Ta_40km_1990-1998_20km_1999-2008_ed.dfs2
Landuse/vegetation	10m spatial resolution at: \2-layer-filer\landuse_10m.dfs2
Rivers and lakes	Odense450004.sim11 Network: \DK2010Drain\Mike11\Odense450004_v06b.nwk11 (edited) Cross-sections: \DK2010Drain\Mike11\Omr3_novana_new.xns11 (unchanged) Boundary data: \DK2010Drain\Mike11\Odense450004_v02.bnd11 (edited) HD Par: \DK2010Drain\Mike11\Omr3_novana_new.HD11 (unchanged) Simulation/Time Step: 12 hrs
Overland flow/Manning number	Uniform: 2
UZ/2-layer UZ Soil	\2-layer-filer\7_JB_typer_a_opland450004_10m_UZ_soil.dfs2
SZ **SZ/Geological Layers** **SZ/Geological lenses** **SZ/Computational Layer**s	Include pumping wells, include subsurface draining 1: opspr. Ler, 2: ler, 3: preq 1: jordart, 2: ks1, 3: ks2, 4: ks4, 5: Lense_Hav 1: Fyn-blag1, 2: kst1, 3: ks1b, 4: ks2t, 5: bund Initial potential for each computational layer is calculated as average for 2002-2007 (from 1990-207 run) for each grid size
SZ/Drainage	'Drainage routing based on grid codes'

SZ/Drainage/Level	Uniform at 0.5 m below topography
SZ/Drainage/Time Constant	Uniform: 5.35524e-008 s-1
SZ/Drainage/Drain Codes	\maps\drncodes4501_10m.dfs2
SZ/Pumping Wells	\time\novomr3_171109.wel

Drainage generation for changed computational grid sizes

Data layer description

Horizontal grid discretization for the model domain is varied from the 500 m x 500 m grid size used in the reference run to smaller discretisations: 500-400-300-200-100 m. The grid resolution for the geological model layers is 100 m x 100 m and is not changed. The vertical resolution is reduced from nine to five geological computational layers, see previous section on sub-catchment model.

Model Domain and Grid

From the entire Funen catchment the sub-catchment, is delineated, as described earlier, by joining draining areas from tributaries to the Odense River that drain to discharge station 450004 (Fig. 1). The sub-catchment model domain grid file (dfs2) is saved as ESRI shape file and grid size changed to 400 m and 300 m for consecutive simulations at these computational grid sizes. For MIKE SHE model specific reasons, this procedure is changed for 200 m and 100 m grid resolutions by extracting data from 500 m x 500 m resolution shape file and saving as 200 m and 100 m resolution shape file respectively. The shape files are then saved as ASCII format files and converted to dfs2 format in Mike ZeroTool (MZT/GIS/GRD2 MIKE) and subsequently imported to MIKE SHE setup.

Results and interpretation

Results of MIKE SHE runs for grid sizes 400 m, 300 m, 200 m and 100 m are evaluated for sensitivity towards shift of simulated water balance components relative to the reference run with grid size 500 m. In addition, sensitivity towards simulated discharge for the five selected discharge stations (Fig. 1) is included in the evaluation as it is expected that different grid sizes will have an impact related to a shift in other water balance components. Overall water balance results are extracted in chart format by applying the MIKE SHE Water Balance Tool. Statistics on results for discharge time series are obtained by using the dedicated CompQstat software. All simulations are run for the period 1990 to 2007, but results for water balance and discharge are extracted for the sub period 2002 to 2007, allowing a warming up period of 12 years. Initial potential for each computational layer is calculated as described in the previous section and specified in the model setup for each grid size resolution.

Water balance changes

Table 3 summarizes the major water balance component results for the period 2002-2007 (six years), where the entire simulation period is from 1990 to 2007. For clarity, minor components of the water balance that are not affected by changes in grid size are omitted in Table 3. These include e.g. change in snow storage, change in overland flow storage and pumping. From this table it can be observed that infiltration, from UZ to SZ and exfiltration, from SZ to UZ increase with 19 % and 81 % respectively when changing the model domain gridsize from 500 m to 100 m. In addition, drain to river and overland flow to river increase with 15 % and 34 % respectively. Base flow, from SZ to river, however increases by changing grid size from 500 m to 400 m, 300 m and 200 m by 41 %, 16 % and 11 % respectively, but decreases with 33 % when changing to 100 m grid size. Overall, total inflow to river increases 8-9 % with decreasing grid size.

Tabel 3. Major water balance components for sub-catchment model runs using different grid sizes.

	500 m	*400 m*	*300 m*	*200 m*	*100 m*
	[mm.yr^{-1}]	[mm.yr^{-1}]	[mm.yr^{-1}]	[mm.yr^{-1}]	[mm.yr^{-1}]
Precipitation	906.2	906.3	906.5	906.3	906.7
Evapotranspiration	650.3	636.8	634.8	629.7	635.8
Infiltration UZ-SZ	281.3	300.7	309.0	328.5	334.2
Exfiltration SZ-UZ	62.5	67.5	78.2	96.0	113.3
Base flow	56.5	79.8	65.5	62.7	37.7
Drain to river	165.2	157.0	168.8	174.2	190.5
OL to river	36.8	36.3	41.2	44.2	49.5
Total inflow to river	258.5	273.1	275.5	281.1	277.7

Although the overall drainage to river for the period 2002-2007 does not show large differences for different grid sizes, refer to Table 3, the temporal dynamics as shown in Fig. 5 indicates that drainage to the river for the 500 m grid size simulations is higher during winter periods and lower in summer than for lower grid size resolutions. Thus drainage contributes to a higher degree to river discharge during summer and to a lower degree during winter time with decreasing grid size resolution.

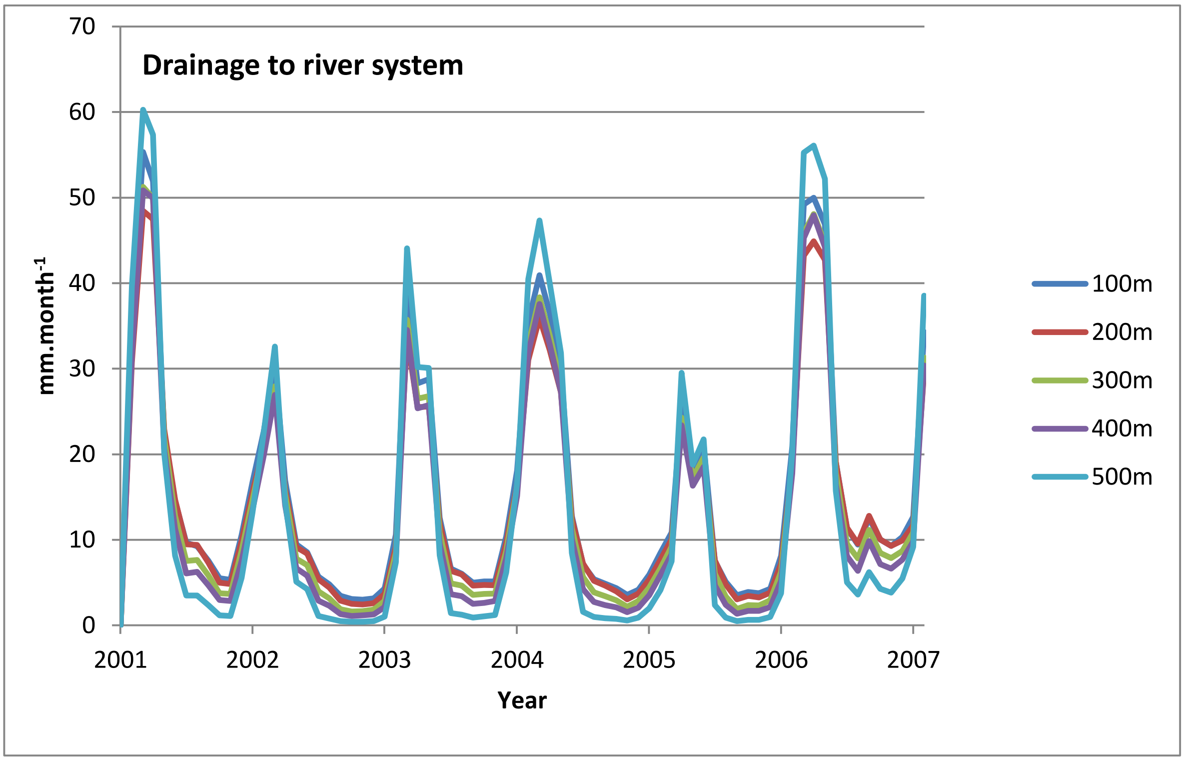

Figure 5. Seasonal variation in drainage to the river system for the sub catchment.

Table 3 and Fig. 6 and 7 show an increased overland flow with decreasing grid size resolution. From the temporal dynamics in Fig. 6 it is seen that a lesser grid size not always leads to increased overland flow to the river system during the spring period, it does in winter/spring 2003 and 2005 (Fig. 7), but not in 2001 and 2006. During summer, simulated overland flow using the grid size resolution of 500 m results in close to zero discharge while somewhat larger discharge is sustained with lower resolution grid size (Fig. 8). This seems plausible as decreased grid size results in better resolving the topographic features and thus leading to increased topographic induced overland runoff.

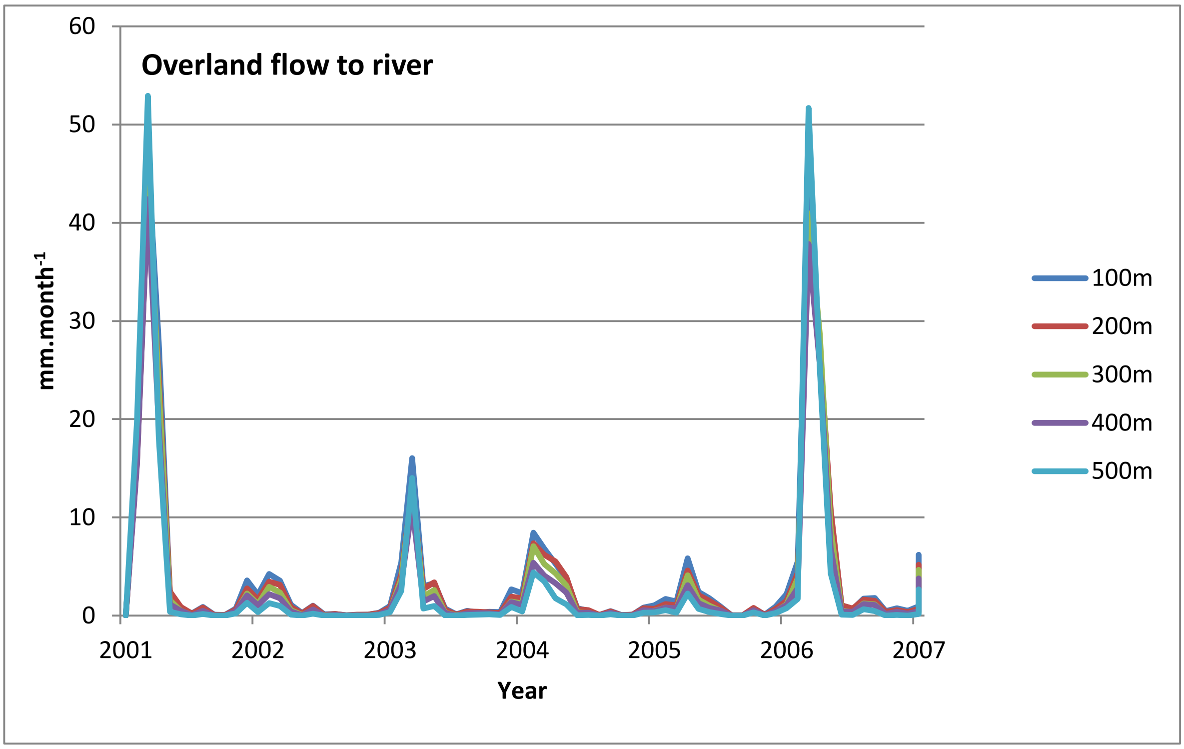

Figure 6. Simulated overland flow to river for the sub catchment

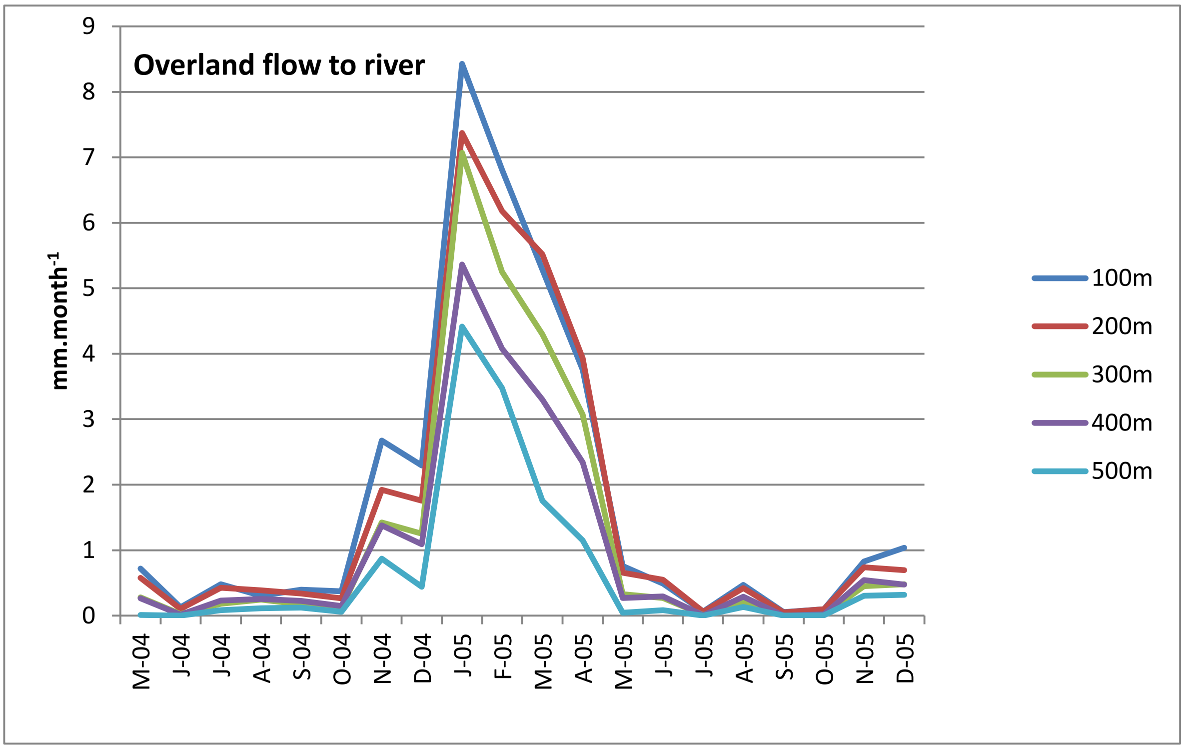

Figure 7. Simulated overland flow winter/spring period

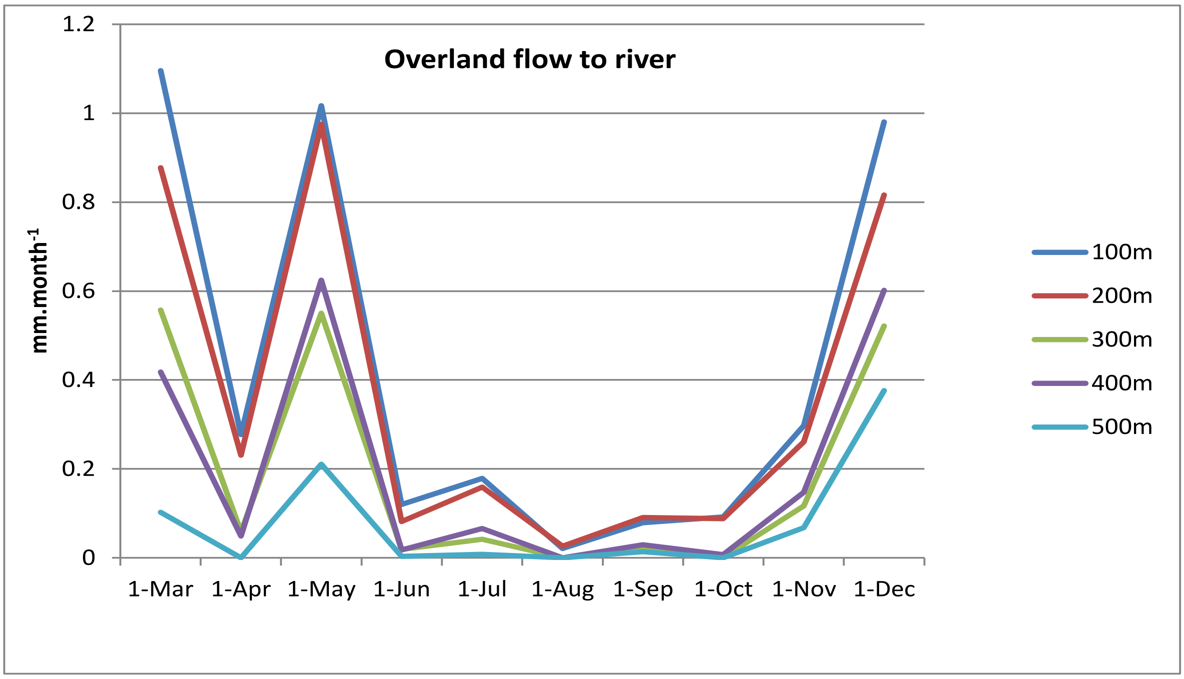

Figure 8. Simulated overland flow summer 2003. Lower grid size sustains higher overland flow.

A finer grid size resolution results in an overall lower contribution to base flow from the saturated zone (SZ) to the river system. This is indicated in Fig. 9. Highest contribution is from simulations with 400 m grid size, followed by 300 m, 200 m, 500 m and 100m. The remarkable position of the 500 m grid size is caused by higher drainage to the river and evapotranspiration associated with 500 m grid size as compared to 400 m (Table 3).

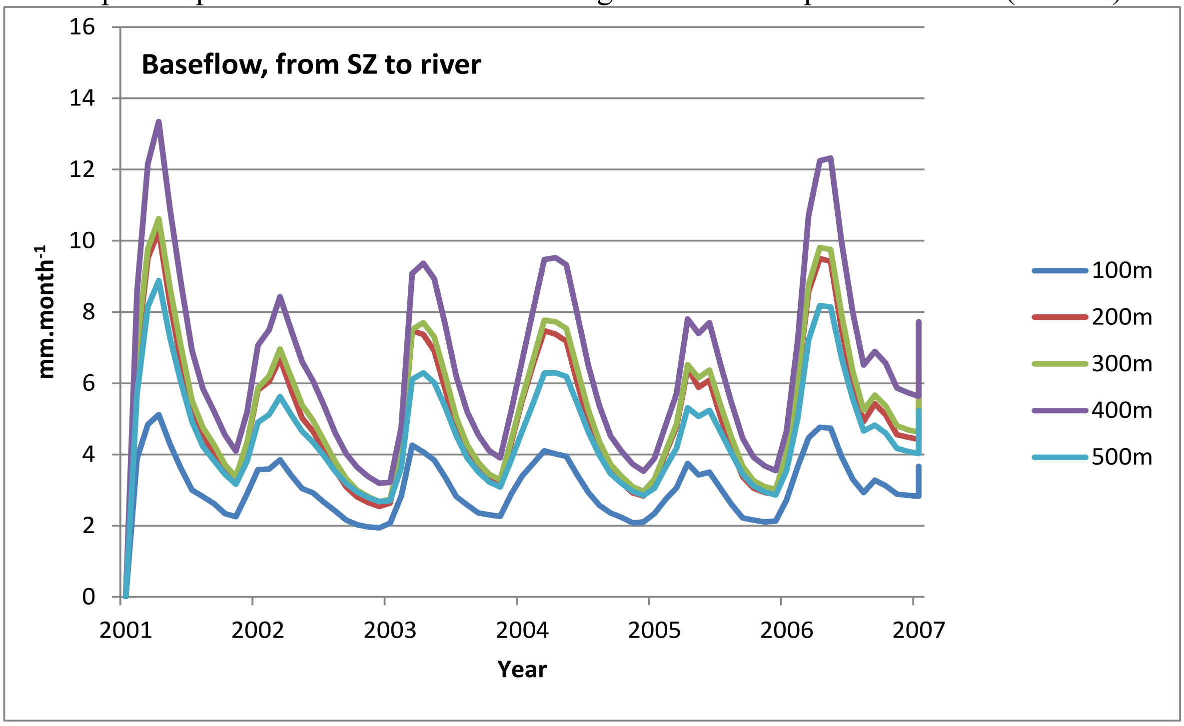

Figure 9. Simulated base flow from SZ to river for sub catchment.

Stream discharge changes

Smaller model domain grid size should improve resolving river channels and branches and increasing the number of hydraulic contact points between drainage channels (pipes and ditches, lumped) and the river network. This is explored below.

Simulated low (Q0.01), medium (Q0.50) and high (Q0.99) percentile discharge are plotted in Fig. 10 to 15 for discharge station 450004, draining 302 km^2 and 450045, draining 30.2 km^2. All graphs show the monthly, and entire period, calculated 1, 50 and 99 percentile discharge from daily simulated values for the period 2002 to 2007 (six years). Fig. 10 for discharge station 450045 indicates higher simulated 1 pct discharge (Q0.01) for decreasing grid size throughout the year, with one exception (May). For station 450004, draining the entire sub catchment it can be noted that while decreased grid size still results in higher low flow Q0.01 values as compared to 500 m, the sequence is more ambiguous (Fig. 11).

For simulated median values (Q0.50) the result of grid size is not entirely clear. While for the entire period there is a tendency that median discharge increases with decreasing grid size for both station 450045 (Fig. 12) and 450004 (Fig. 13), the monthly variation differs with a tendency that smaller grid sizes lead to higher Q0.50 discharges in summer and fall periods and, although ambiguously, the opposite for winter/spring. For high percentile Q0.99 discharge, decreasing grid sizes result in substantial decrease in discharge during January to March and for the entire period, while small differences exist during summer time for both stations (Fig. 13 and 14).

Other discharge stations, 450033 (draining area 3.51 km^2), 450035 (draining area 2.56 km^2) and 450059 (draining area 0.38 km^2) represent much smaller drained areas in the sub catchment, but indicate same tendency as 450045 and 450004, but more ambiguity between grid sizes exists, i.e. not always a clear sequence in results when moving from larger to smaller grid sizes (not shown here). Also, besides 1 pct, 50 pct and 99 pct data, 5 pct. and 95 pct discharge are computed, showing the same tendency and are therefore not shown here.

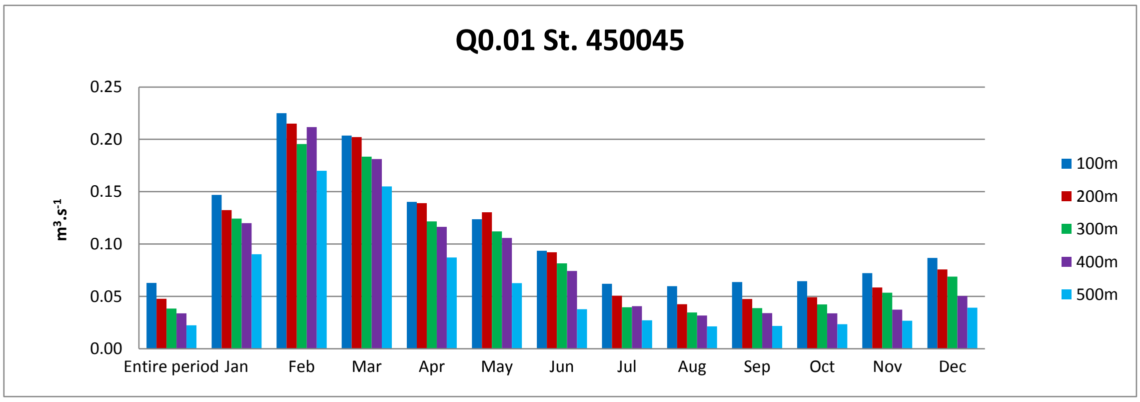

Figure 10. Monthly values for 1 pct discharge (Q0.01) calculated from daily data for period 2002-2007 for discharge station 450045 (30.2 km^2). First columns are averaged for entire period.

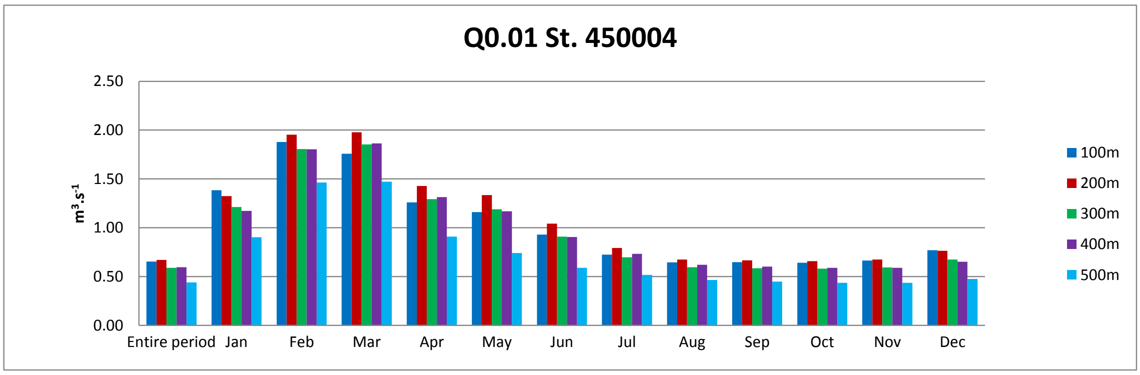

Figure 11. Monthly values for 1 pct discharge (Q0.01, median) calculated from daily data for period 2002-2007 for discharge station 450004 (302 km^2). First columns are averaged for entire period.

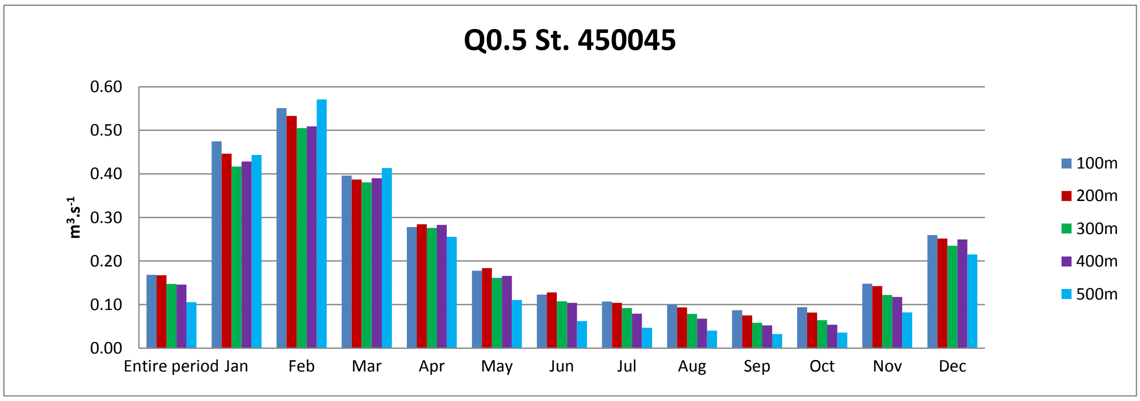

Figure 12. Monthly values for 50 pct discharge (Q0.50) calculated from daily data for period 2002-2007 for discharge station 450045. First columns are averaged for entire period.

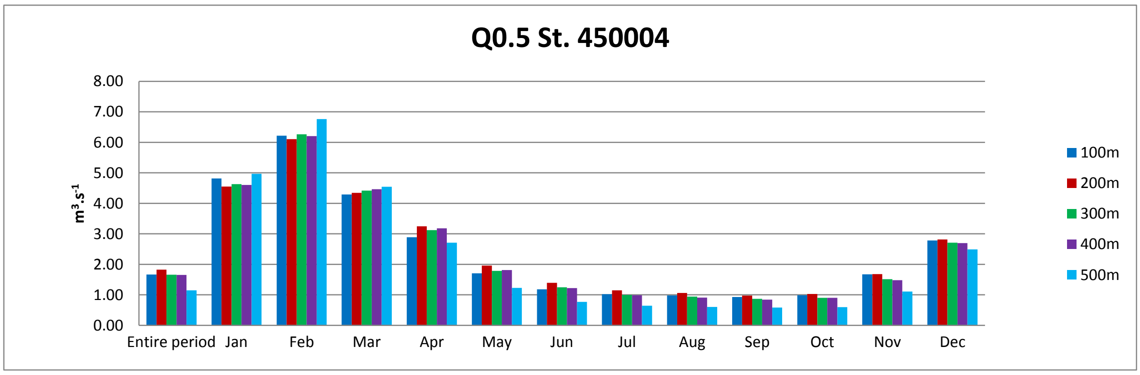

Figure 13. Monthly values for 50 pct discharge (Q0.50) calculated from daily data for period 2002-2007 for discharge station 450004. First columns are averaged for entire period.

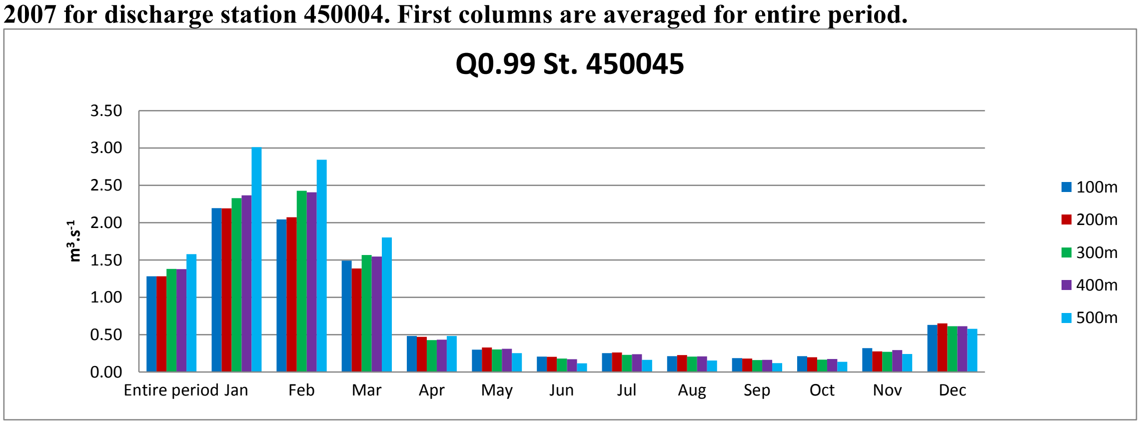

Figure 14. Monthly values for 99 pct discharge (Q0.99) calculated from daily data for period 2002-2007 for discharge station 450045. First columns are averaged for entire period.

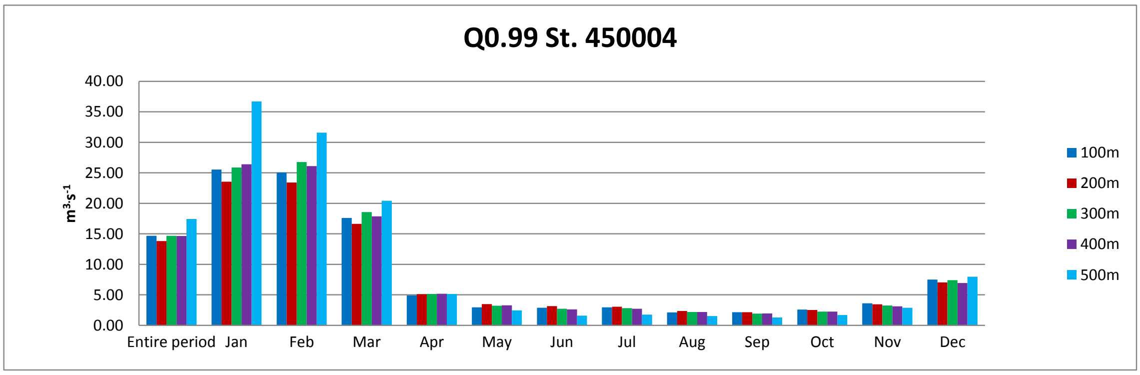

Figure 15. Monthly values for 99 pct discharge (Q0.99) calculated from daily data for period 2002-2007 for discharge station 450004. First columns are averaged for entire period.

Discharge timeseries for station 450004 and 450045 for January and July 2007 are plotted in Fig. 16 to 19. In accordance with Fig. 10-15 they show higher and lower discharge for 500 m grid size during winter and summer time respectively. Thus a finer grid discretization results in increased discharge level during summer and vice versa during winter time.

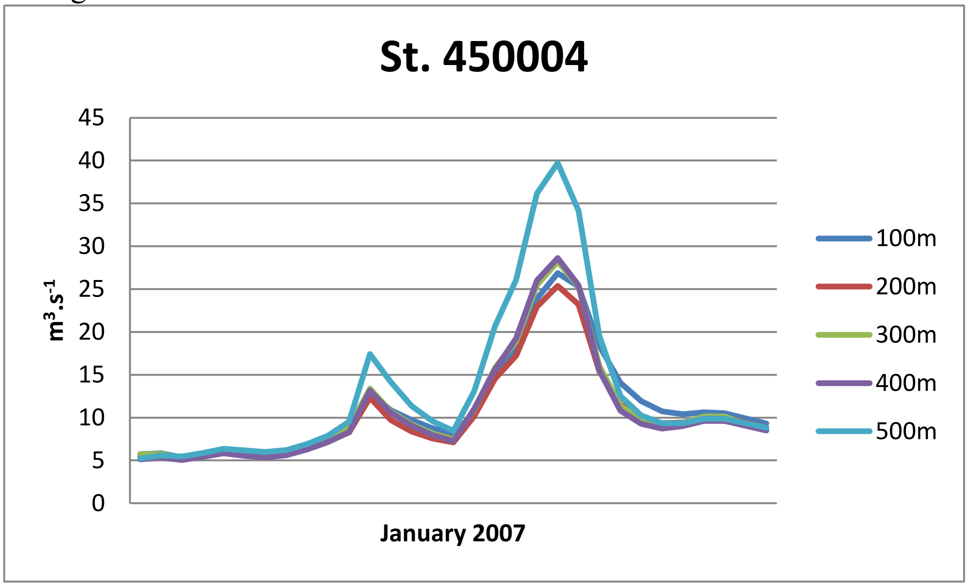

Figure 16. Discharge for January 2007 at station 450004 for grid sizes 100-500. Increasing discharge with increasing grid size.

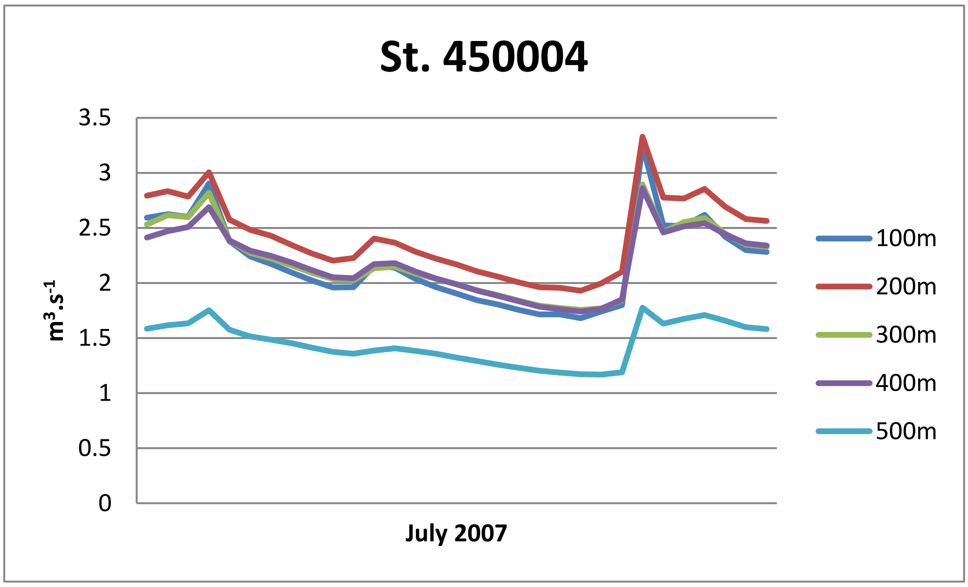

Figure 17. Discharge for July 2007 at station 450004 for grid sizes 100-500. Increasing discharge with decreasing grid size.

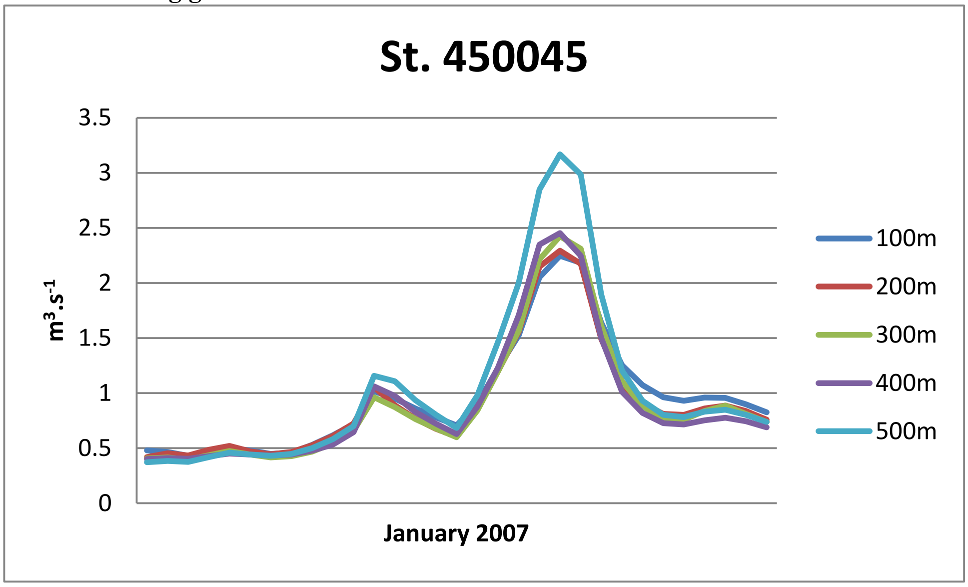

Figure 18. Discharge for January 2007 at station 450045 for grid sizes 100-500. Increasing discharge with increasing grid size.

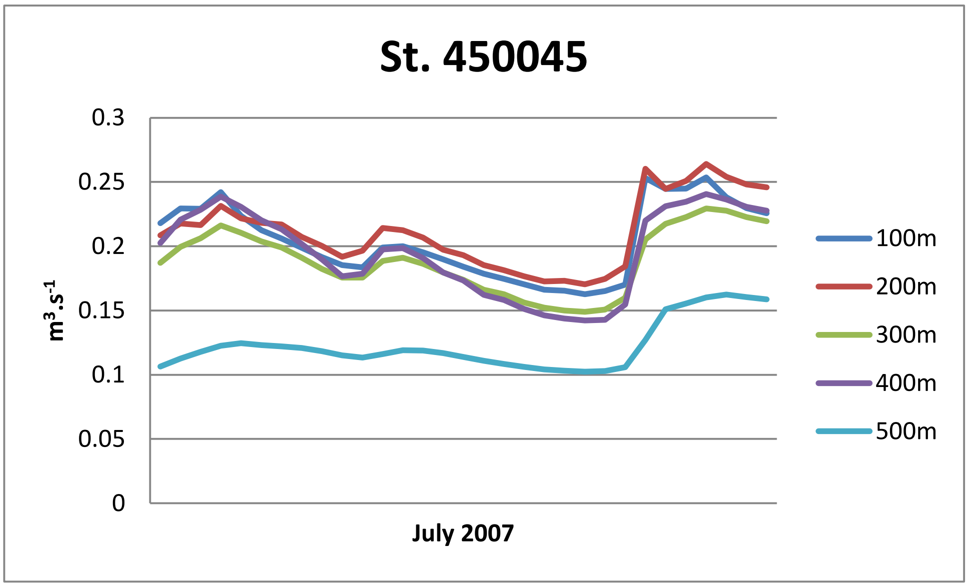

Figure 19. Discharge for July 2007 at station 450045 for grid sizes 100-500. Increasing discharge with decreasing grid size.

Conclusions

A case study addressing how model domain grid size affects the water balance related to drainage in an upstream area of the Funen basin leads to the following observations for simulations for a period 1990-2007 and results extracted for a six year period 2002 to 2007.

- Drainage to the river system is moderately sensitive to model grid size. However, the temporal dynamics indicate a decreased drainage during winter and increased drainage during summer months with decreasing grid size

- Overland flow to river system is increasing with decreasing grid size, probably due to improved resolving topographic features

- Discharge is higher during summer and lower during winter with decreasing grid size.

- The low 1 pct. discharge increases with decreasing grid size. This is especially pronounced during summer and fall months (month 5-11)

- The high 99 pct. discharge decreases with decreasing grid size for the months January to March and is rather insensitive to grid size for the remaining months.

Overall conclusion

Decreasing model domain grid size from 500 m to lower resolution was expected to alter the simulated groundwater-stream interactions with respect to dynamics of and partitioning between the various flow components, i.e. drainage-, overland and baseflow. The results presented here support this, as simulations show that for finer grid sizes temporal stream discharge dynamics is changed, resulting in higher low-flow 1 pct discharge, especially in summer (and to a lesser degree fall) and lower high-flow 99 pct discharge during winter months. However, recalibration of the model against observed data is required to correctly interpret the changed simulated discharge dynamics as a result of drainage, natural and artificial, representation for different model domain grid sizes. Clearly, the selected model domain grid size will depend on the purpose and requirements of a modeling study. In case a high temporal resolution of stream discharge is important consideration should be given to select an appropriate grid size.

It must be noted that, while applying a finer resolution model domain grid size than 500 m may improve model performance with regard to observed discharge, it happens at the cost of (much) longer computation time

Recommendations

DK model application

From the study it becomes clear that when applying the DK-model one must be aware of the effect of selected computational grid size on water balance and stream discharge, as demonstrated in the present report. In practice this means that the selection of computational grid size depends on whether relevant processes such as drainage and overland flow need to be resolved at such a selected scale. However, a changed grid size would likely require recalibration at that scale.
Selecting an appropriate model domain grid size should be considered when monthly or weekly discharge dynamics is in focus influenced by how much of streams, ditches, and drainage pipes can be spatially resolved. Likewise, to obtain improved dynamics in low flow stream discharge a finer grid resolution must be considered. This is important when low flow model output is focused on, e.g. assessment of sustaining ecological functions.
When, on the other hand, emphasize is on the overall water balance, selection of grid size is not equally important.

Further study

The change in water balance components as a result of grid size, i.e. drainage to river (Fig.5), overland flow to the river (Fig. 6, 7 and 8) as well as baseflow to the river (Fig.9), described in this study should be explored in depth to improve process understanding on hydrological pathways, especially the impact of drain depth and distribution on stream discharge level (Fig.10-19). Increased process understanding should then ultimately lead to improved conceptual models.
Further research is needed on the effect of introducing both areas with and without drainage as opposed to drainage in the entire catchment. This includes differentiating draining, in which the model, by disabling the drainage option, indicates areas where pipe drainage is needed.
Further study is needed on to which extend recalibration is required when changing grid size in a selected sub catchment that is calibrated at another grid size.
Does a model performance improve for smaller model domain grid sizes when tested against observed data.

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