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Digital elevation model grid size, landscape representation, and hydrologic simulations

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Abstract. High-resolution digital elevation data from two small catchments in the western United States are used to examine the effect of digital elevation model (DEM) grid size on the portrayal of the land surface and hydrologic simulations. Elevation data were gridded at 2-, 4-, 10-, 30-, and 90-m scales to generate a series of simulated landscapes. Frequency distributions of slope (tan B), drainage area per unit contour length (a), and the topographic index ($a/\tan B$) were calculated for each grid size model. Frequency distributions of $a/\tan B$ were then used in O'Loughlin's (1986) criterion for predicting zones of surface saturation and in TOPMODEL (Beven and Kirkby, 1979) for simulating hydrographs. For both catchments, DEM grid size significantly affects computed topographic parameters and hydrographs. While channel routing dominates hydrograph characteristics for large catchments, grid size effects influence physically based models of runoff generation and surface processes. A 10-m grid size provides a substantial improvement over 30- and 90-m data, but 2- or 4-m data provide only marginal additional improvement for the moderately to steep gradient topography of our study areas. Our analyses suggest that for many landscapes, a 10-m grid size presents a rational compromise between increasing resolution and data volume for simulating geomorphic and hydrological processes.

Introduction

Predicting spatial patterns and rates of runoff generation and many geomorphic processes requires both a hydrologic model and characterization of the land surface. Most physically based models of hydrologic and geomorphic processes rely on either spatially distributed or lumped characterizations of local slope and the drainage area per unit contour length [e.g., *Beven and Kirkby*, 1979; *O'Loughlin*, 1986; *Vertessy et al.*, 1990; *Dietrich et al.*, 1993], and digital elevation models (DEMs) commonly are used for such characterization in a wide variety of scientific, engineering, and planning applications. Although the increasing availability of DEMs allows rapid analysis of topographic attributes over even large drainage basins, the degree to which DEM grid size affects the representation of the land surface and hydrological modeling has not been examined systematically.

Digital elevation data are stored in one of the following formats: as point elevation data on either a regular grid or triangular integrated network, or as vectorized contours stored in a digital line graph. Each of these formats offers advantages for certain applications, but the grid format is used most widely. Several recent studies explored the effect of DEM grid size on landscape representation [*Hutchinson and Dowling*, 1991; *Jenson*, 1991; *Panuska et al.*, 1991; *Quinn et al.*, 1991]. These studies showed that distributions of topographic attributes derived from a DEM depend to some degree on grid size. None of these studies, however, systematically analyzed the effect of grid size on either the statistical characterization of the land surface, or simulated hydrologic response using topographically driven models. In this paper, we assess how grid size affects topographic representation, derived topographic attributes, and hydrological simulations for two small catchments using high-resolution digital elevation data. In contrast to previous studies, we grid the same elevation data at several different scales to isolate the effect of grid size on landscape representation. Issues associated with vertical sampling resolution are not addressed in this work.

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Study Areas

The study catchments are located at Mettman Ridge near Coos Bay, Oregon, and Tennessee Valley in Marin County, California (Figure 1). Previous field investigations determined the nature and distribution of geomorphic and hydrologic processes in each catchment. High-resolution digital elevation data were generated for testing DEM-based process models in these catchments. Field mapping in each catchment reveals that the high-resolution data provide a reasonably accurate portrayal of the land surface.

Mettman Ridge

The Mettman Ridge catchment occupies 0.3 km^2 of an area in which previous field mapping documented the extent of the channel network [*Montgomery*, 1991]. Channel head locations in this area are controlled primarily by shallow debris flows from small unchanneled valleys [*Montgomery and Dietrich*, 1988]. The catchment is highly dissected with hillslope lengths on the order of 30–50 m [*Montgomery and Foufoula-Georgiou*, 1993]. Slopes of 30°–40° are common, and there are a substantial number of slopes that locally exceed 45°.

A 1:4800 scale topographic basemap derived from low-altitude aerial photographs taken prior to timber clearing was

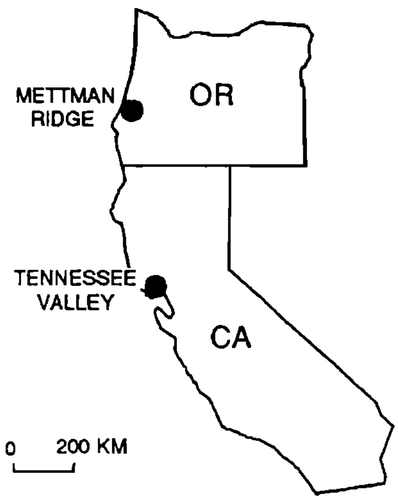


Figure 1. Location map of the study catchments.

used as the source of digital elevation data. The basemap was scanned and vectorized using an automated routine to reproduce contours identical to those on the original topographic map. Although several discrepancies were noted between this map and the ground surface, here we assume that this data provides an accurate portrayal of the land surface (Figure 2a).

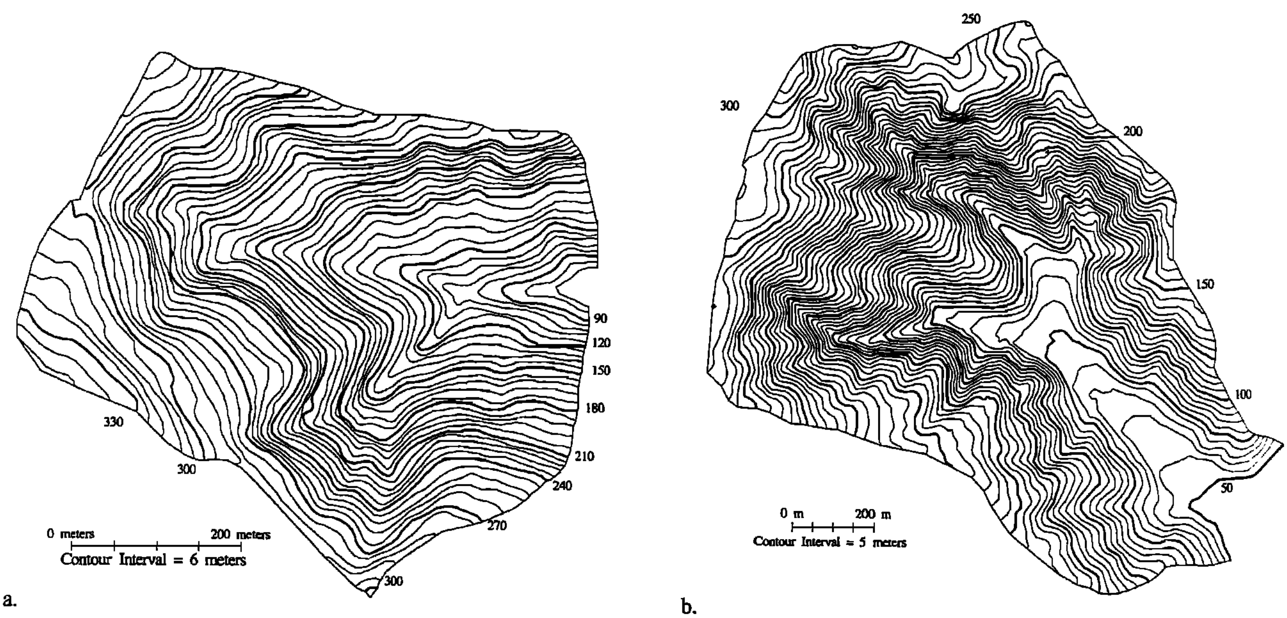
Tennessee Valley

The Tennessee Valley catchment occupies 1.2 km^2 in which previous field mapping also documented the extent of the channel network [*Montgomery and Dietrich*, 1989]. Shallow landsliding dominates sediment transport in steep hollows and side slopes, diffusive transport dominates on divergent noses, and saturation overland flow and channel processes dominate sediment transport in lower-gradient valleys. The catchment is rhythmically dissected, with hillslope lengths on the order of 30–50 m [*Montgomery and Foufoula-Georgiou*, 1993]. The topography of the Tennessee Valley catchment is less steep than that of the Mettman Ridge catchment; slopes of 20°–30° are common and slopes in excess of 40° are rare.

Digital elevation data were obtained from low-altitude aerial photographs using a stereo digitizer at a density about every 10 m [*Dietrich et al.*, 1993]. The spot elevations were gridded to generate a 5-m contour interval map of the catchment (Figure 2b). Field inspection reveals that the data provide an excellent portrayal of the land surface.

Methods

Spot elevation data for the two catchments were gridded at scales of 2, 4, 10, 30, and 90 m using the grid module of Arc/Info, with gridded elevations recorded to the nearest centimeter. Cumulative frequency distributions of three topographic attributes, local slope (tan B), drainage area per unit contour length (a), and topographic index (a/tan B), were calculated for each DEM of the two study catchments using the model of *Jenson and Domingue* [1988]. Their model defines the downslope flow direction for each cell corresponding to the orientation of the neighboring cell of lowest elevation. The tan B for the cell is then calculated based on the elevation difference between cells. Definition of the spatial distribution of flow directions allows determination of the total number of the cells that direct flow to each cell, and thus drainage areas. Here, a is the drainage area divided by the grid cell dimension calculated for the center of the cell. Although the assignment of all flow to a single downslope grid cell distorts flow paths in both divergent topography and for slopes oriented at angles other than the eight cardinal directions [*Quinn et al.*, 1991], the algorithm has been widely used in many topographic models [e.g., *Marks et al.*, 1984; *Band*, 1986; *Jenson*, 1991]. Several workers [e.g., *Quinn et al.*, 1991; *Cabral and Burges*, 1992; *Lea*, 1992] recently proposed algorithms incorporating mul-



a. b.

Figure 2. Contour map of the (a) Mettman Ridge and (b) Tennessee Valley catchments.

tiple downslope-flow directions that are more suitable for representing flow on divergent hillslopes. While we are eager to explore these newer algorithms, this study does not examine their influence on topographic representation.

Hydrologic simulations employed the steady state model TOPOG [*O'Loughlin*, 1986] to examine patterns of surface saturation and TOPMODEL [*Beven and Kirkby*, 1979] to predict runoff production to short-duration storms. Soil hydraulic parameters were estimated from field measurements [*Montgomery*, 1991]. Model simulations explored the effect of DEM grid size on simulated hydrologic response.

Landscape Representation

Cumulative frequency distributions of tan *B*, *a*, and *a*/tan *B* determined for each grid size model reflect changes in both mean and local values. Comparison of the distributions of these topographic attributes allows direct assessment of the influence of grid size on landscape representation.

Slope

Cumulative slope distributions are more sensitive to DEM grid size for the steeper Mettman Ridge catchment than for the moderate gradient Tennessee Valley catchment (Figure 3). For both study areas, the percent of the catchment steeper than a given slope systematically decreases as the DEM grid size increases, and the largest effect is for the steepest portions of the catchments. In the case of the Mettman Ridge catchment, the mean slope declines from 0.65 for the 2-m grid size model to 0.41 for the 90-m grid size model (Figure 3a). This result is consistent with, but more pronounced than those of previous studies [*Jenson*, 1991; *Panuska et al.*, 1991]. Grid size influence on slope distributions is less pronounced for the Tennessee Valley catchment (Figure 3b), where the mean slope is 0.34 for the 2-m grid model and 0.29 for the 90-m grid size model. The distributions for both catchments suggest that grid sizes smaller than 10 m yield only marginal improvement in slope representation. Since the slope of a grid cell represents an average slope for the area covered by the cell, increasing DEM grid size should result in decreasing ability to resolve the slope characteristics of steeper and more dissected topography.

The cumulative slope distribution for the Mettman Ridge catchment, especially for the 10-m and 30-m grid size models, are stepped, while distributions for both large and small grid sizes are smoother. We suspect that this reflects the small number of grid cells in large grid size models of this catchment. Fewer grid cells for the smaller Mettman Ridge catchment should result in a more discontinuous cumulative distribution than for the Tennessee Valley catchment.

Drainage Area per Unit Contour Length

Cumulative distributions of *a* also are sensitive to grid size (Figure 4). Larger grid sizes bias in favor of larger contributing areas, with comparable effects in both catchments. For the Mettman Ridge catchment, the mean value of *a* increases from 20 m for a 2-m grid size to 102 m for a 90-m grid size. In the Tennessee Valley catchment, the mean value of *a* increases from 19 m for a 2-m grid size to 120 m for a 90-m grid size.

For each grid size, a single pixel defines the smallest possible value of *a* and thus where the cumulative frequency distributions of *a* reach 100% of the catchment area. The

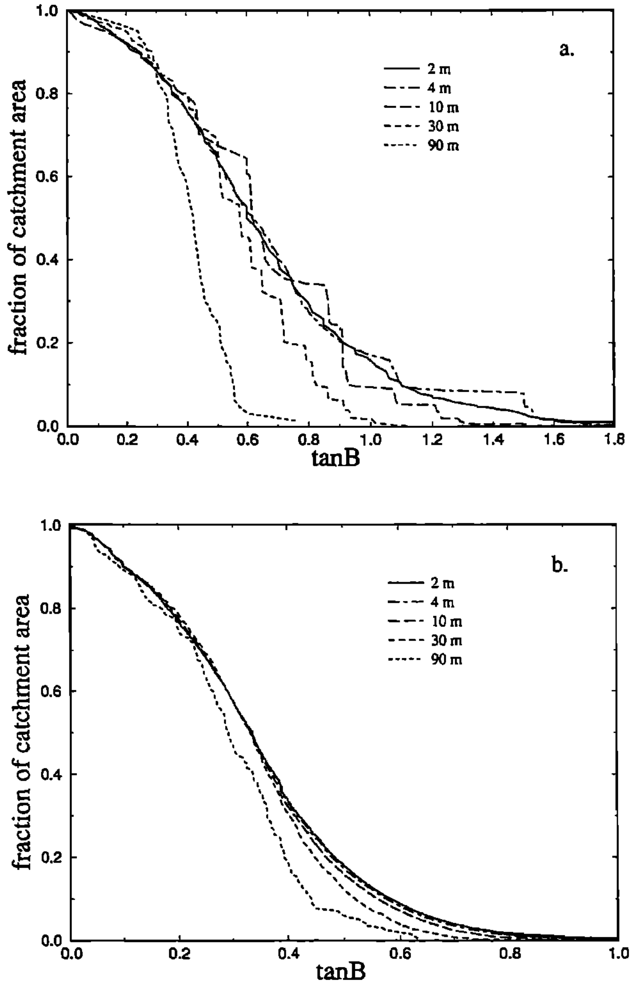


Figure 3. Cumulative frequency distributions of slope derived for different DEM grid sizes. (a) Mettman Ridge. (b) Tennessee Valley.

algorithm used to compute *a* determines this minimum value. While it is intuitive that larger grid size limits the resolution of fine-scale topographic features, the effect on both the mean and local *a* is significant for topographically driven hydrologic and surface process models.

Topographic Index

The topographic index (*a*/tan *B*) is an important component of many physically based geomorphic and hydrologic models, as it reflects the spatial distribution of soil moisture, surface saturation, and runoff generation processes [e.g., *Beven and Kirkby*, 1979; *O'Loughlin*, 1986; *Moore et al.*, 1986]. Derivation of frequency distributions of *a*/tan *B* is the first step for hydrological simulations in most topographically driven hydrologic models.

Grid size significantly affects the cumulative frequency distributions of *a*/tan *B* (Figure 5). Decreasing grid size shifts the cumulative distribution toward lower values of *a*/tan *B*, with the greatest effect on smaller values. Again, computed frequency distributions systematically converge toward that of the finest grid size. For the Mettman Ridge catchment, the mean ln (*a*/tan *B*) increases from 3.4 for a 2-m grid size to 5.6 for a 90-m grid size. In the Tennessee Valley catchment, the

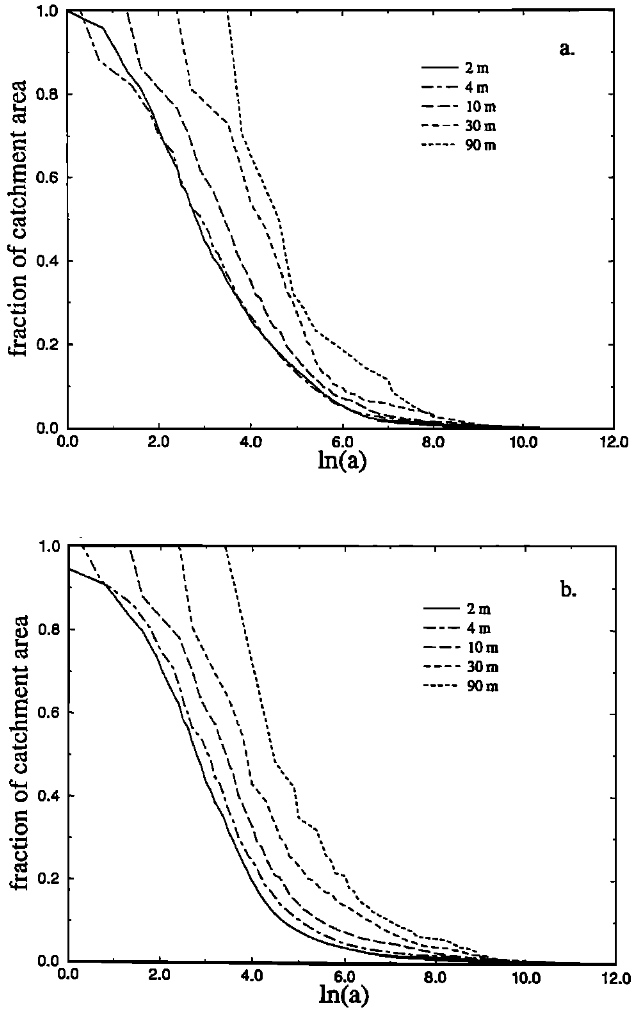


Figure 4. Cumulative frequency distributions of the drainage area per unit contour length for different DEM grid sizes. (a) Mettman Ridge. (b) Tennessee Valley.

mean ln ($a/\tan B$) increases from 4.0 for a 2-m grid size to 6.2 for a 90-m grid size. The influence of grid size on both mean and local values of $a/\tan B$ demonstrates the potential for affecting topographically based hydrologic models based on this parameter.

The effect of grid size on spatial patterns of $a/\tan B$ is even more striking (Figure 6). Detailed features that appear on finer-grid DEMs are obscured on coarser-grid DEMs, with a progressive loss of resolution for both the drainage network defined by the higher values of $a/\tan B$ and hillslopes associated with the lower values of $a/\tan B$. Degradation of these geomorphic features affects the simulation of runoff production and geomorphic processes in topographically driven models.

Hydrologic Simulations

We used the models TOPOG [*O'Loughlin*, 1986] and TOPMODEL [*Beven and Kirkby*, 1979] to investigate the effect of grid size on hydrologic simulations. We examined both representation of saturated areas within a catchment using TOPOG and the influence on hydrographs calculated using TOPMODEL for a range of rainfall intensities and baseflows for the study catchments.

Surface Saturation

Many hydrological, geomorphological, and ecological phenomena are closely related to the behavior of the variable saturation area within a catchment. By assuming a steady state drainage condition, *O'Loughlin* [1986] expressed the condition for surface saturation at any location in a catchment as

$$a/\tan B \geq \bar{T}A_t/Q_0 \qquad (1)$$

where $\bar{T}$ is the mean soil transmissivity of the catchment, A_t is the total catchment area, and Q_0 is the runoff rate from the catchment. The term on the right-hand side of the equation is defined as the average wetness state of a catchment (W). The total saturated area for a given catchment wetness is simply the sum of all the local areas which have values of $a/\tan B \geq W$.

The effect of DEM grid size on the computed saturation area can be directly examined using (1) and the cumulative distribution of $a/\tan B$. For a given wetness condition, predicted saturation areas for both catchments increase with

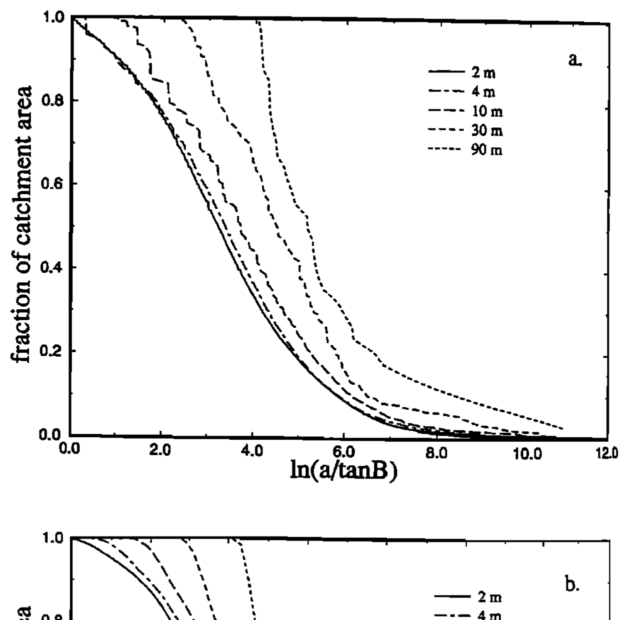


Figure 5. Cumulative frequency distributions of the topographic index, ln ($a/\tan B$), for different DEM grid sizes. (a) Mettman Ridge. (b) Tennessee Valley.

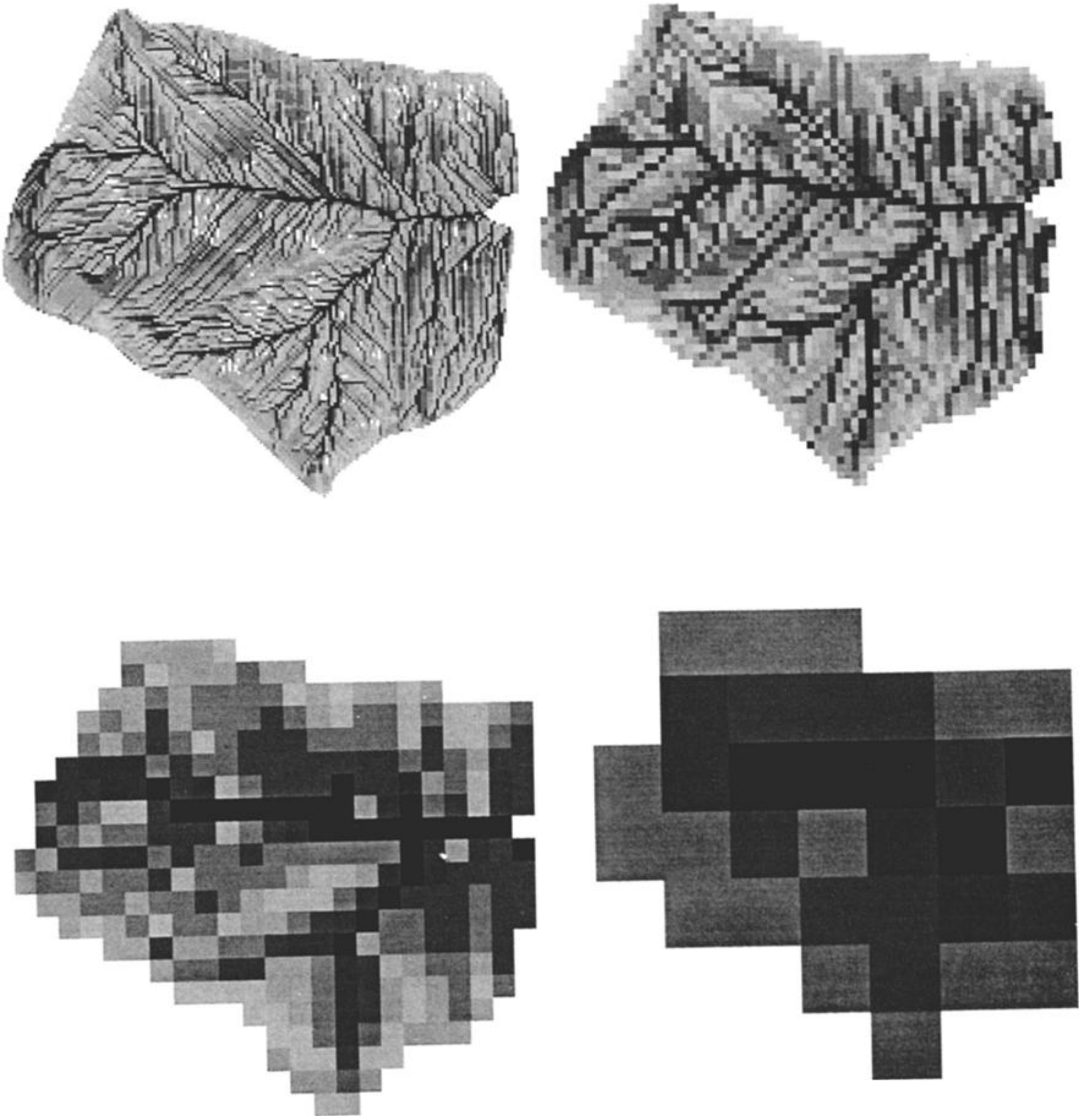


Figure 6a. Maps of Mettman Ridge showing the spatial distribution of the topographic index ln (a/tan B) for four different DEM grid sizes: 4, 10, 30, and 90 m. Darker shades represent larger ln (a/tan B).

increasing grid size. In the Mettman Ridge catchment, for example, W = 180 m predicts a saturated area equal to about 13% of the total catchment area for a 2-m grid spacing, 32% for a 30-m grid spacing, and 50% for a 90-m grid spacing. The Tennessee Valley catchment exhibits a similar, although less pronounced, relation between grid size and saturated area for a given wetness condition.

Catchment Response During a Storm Event

We used TOPMODEL to explore the effect of DEM grid size on the simulated hydrologic response of each catchment to a simple short-duration rainfall event. The model predicts the distribution of soil moisture and the runoff on the basis of surface topography and soil properties. A critical assumption of the model is that locations with similar topography and soil properties respond identically to the same rainfall. By assuming a spatially uniform recharge rate and a quasi-steady subsurface response, *Beven and Kirkby* [1979] derived a function relating local soil moisture storage to the topographic index of a catchment:

$$S = \bar{S} + m\{\lambda - \ln(a/\tan B) - m(\delta - \ln(T)\} \quad (2)$$

where S is the local soil moisture deficit, $\bar{S}$ is the mean soil moisture deficit of the basin, m is a parameter that characterizes the decrease in soil conductivity with soil depth, and λ and δ are the mean values of ln (a/tan B) and ln (T) for the catchment. For locations where $S > 0$, the soil moisture store is not filled and there is no surface saturation. For locations with $S \leq 0$, the soil moisture store is full, and surface saturation occurs.

The model computes both the relative amount of subsurface and saturation overland runoff, as well as the spatial distribution of these runoff processes. During a model simulation, the mean soil moisture deficit of a catchment at time t, $\bar{S}_t$, is calculated by

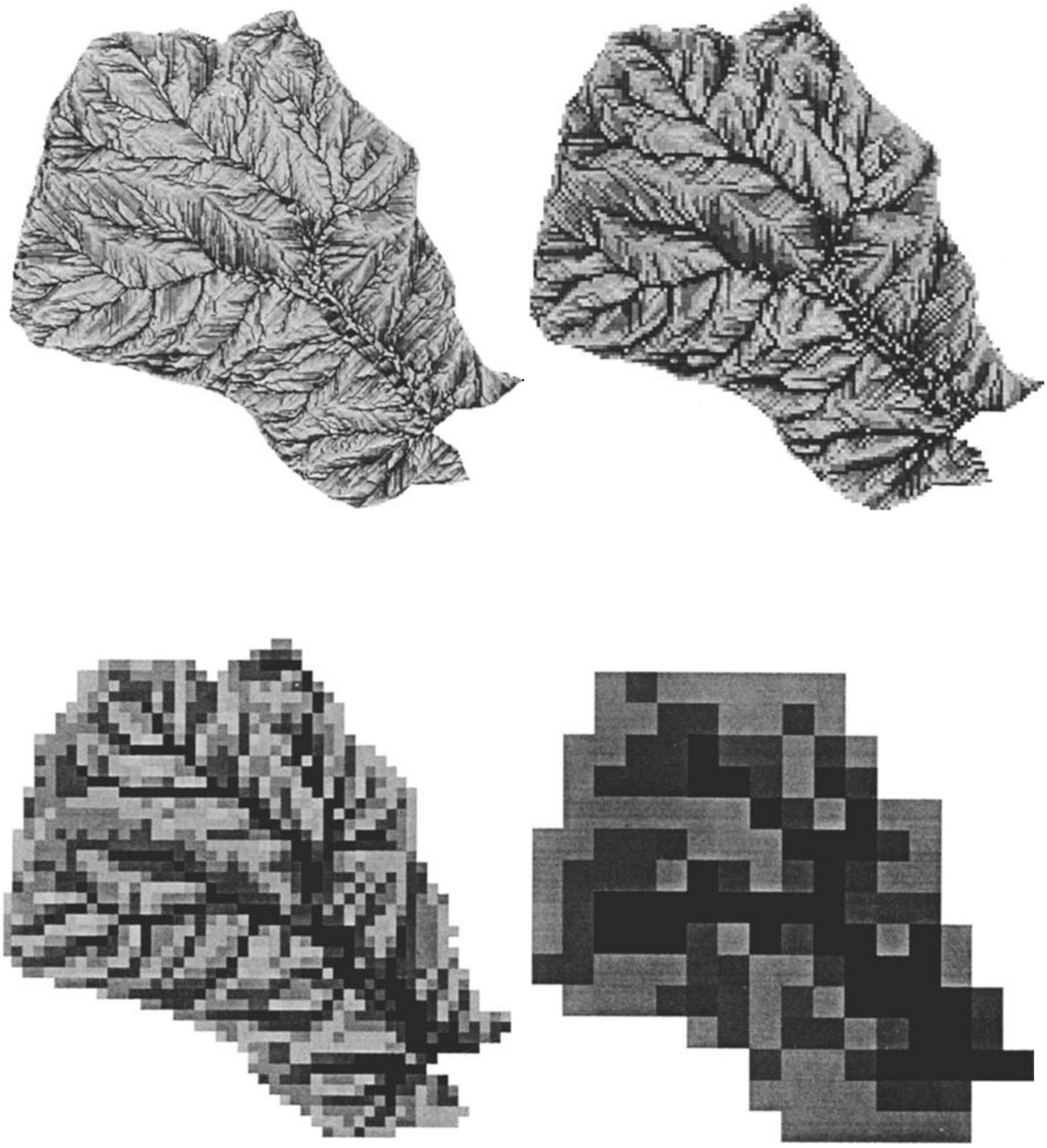


Figure 6b. Same as Figure 6a except for Tennessee Valley.

$$\bar{S}_t = \bar{S}_{t-1} + (q_{t-1} - r)\Delta t \quad (3)$$

where q is the total catchment runoff at time $t - 1$ divided by the catchment area, r is the net recharge rate into the soil column, and Δt is the computation time step. The updated S at all points in the catchment are then computed using (2). Any area with a soil moisture deficit larger than the incremental precipitation in a unit time step will only produce subsurface runoff, while those areas with either a soil moisture deficit smaller than the incremental precipitation in a unit time step, or that were saturated during the previous time step will produce both subsurface and saturation excess runoff. The subsurface flow rate q_b of the catchment is calculated by

$$q_b = e^{-(\lambda - \delta)} e^{-\bar{S}/m} \quad (4)$$

The saturation excess runoff q_0 is the sum of excess soil moisture and direct precipitation that falls on the saturated areas. This is expressed as

$$q_0 = \frac{1}{A_t} \int_{A_s} \left\{ \frac{-S}{\Delta t} + r \right\} dA \quad (5)$$

where A_s is the area of the catchment with surface saturation (i.e., $S \leq 0$). Total runoff q at any time step is the sum of subsurface and surface runoff. While the equation for subsurface flow is only related to the mean value of $a/\tan B$, λ, the equation for saturation excess flow is also related to the distribution form. Thus the influence of DEM grid size on predicted response differs for (4) and (5).

We first examine the simulated subsurface hydrologic response using (4) without considering either surface flow, or

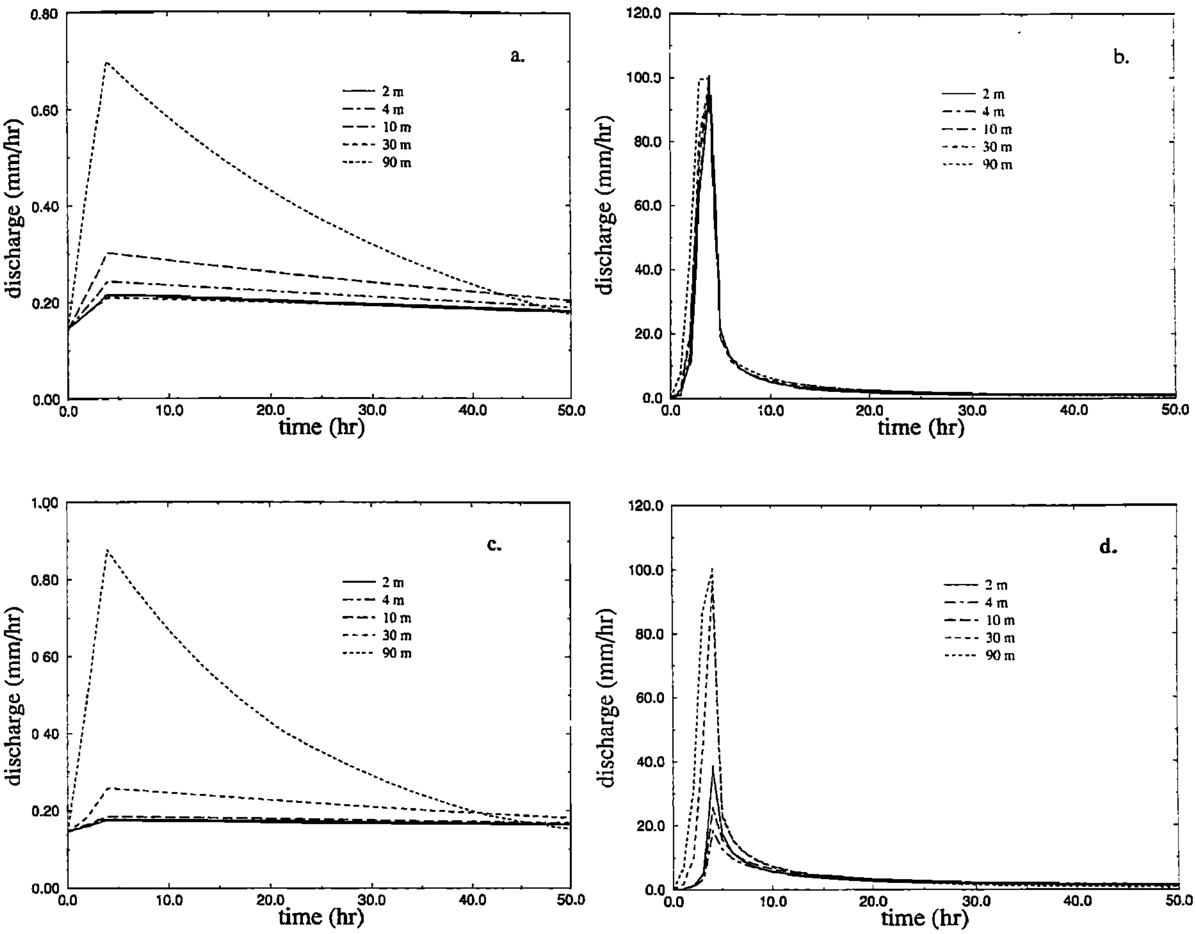


Figure 7. Runoff hydrographs for different DEM grid sizes under different rainfall and initial base flow conditions. (a) Mettman Ridge catchment under 5 mm/h rainfall and 3.5 mm/day initial base flow. (b) Mettman Ridge catchment under 100 mm/h rainfall and 3.5 mm/day initial base flow. (c) Tennessee Valley catchment under 5 mm/h rainfall and 3.5 mm/day initial base flow. (d) Tennessee Valley catchment under 100 mm/h rainfall and 3.5 mm/day initial base flow.

interactions between surface and subsurface flow paths. This example approximates conditions of small initial base flow and rainfall in steep catchments. For this case, it is shown that by adjusting the initial values of the mean soil deficit $\bar{S}$, the model will produce the same runoff hydrographs, independent of the form of $a/\tan B$ distribution.

Given any two mean values of $\ln(a/\tan B)$, λ_1, and λ_2, we have the following base flow equations:

$$q_{b1} = e^{-(\lambda_1 - \delta)} e^{-\bar{S}_1/m} \tag{6}$$

$$q_{b2} = e^{-(\lambda_2 - \delta)} e^{-\bar{S}_2/m} \tag{7}$$

The necessary condition for $q_{b1} = q_{b2}$ is

$$(\overline{S_2} - \overline{S_1}) = m(\lambda_2 - \lambda_1) \tag{8}$$

Once initial values of the mean soil moisture deficit are set according to this functional relation, the relation will hold for all time steps during a storm, leading to an identical hydrograph. In other words, DEM grid size does not affect the computed hydrographs using only the subsurface flow equation.

We also examined the effect of DEM grid size on simulated hydrologic response considering both subsurface and saturation excess flow. We assumed that soil parameters were spatially uniform in our simulation to isolate the effect of topographic representation. We used values of 70 mm and 360 mm/h for the parameter m and surface hydraulic conductivity, respectively. For simplicity, we only calculated runoff production and ignored flow routing in channels. Simulations were conducted with four rainfall intensities (5, 10, 50, and 100 mm/h) sustained for 4 hours and five initial base flow conditions (1, 2.5, 3.5, 4.5, and 9.5 mm/day). The lowest simulated rainfall intensity (5 mm/h) occurs frequently in these areas, and the highest simulated rainfall intensity (100 mm/h) represents an extreme event. At most times, the antecedent base flow rates for the study areas are less than 4 mm/day.

The effect of grid size on computed hydrographs depends on both rainfall intensity and initial base flow (Figure 7). To quantitatively examine these results, we normalized peak discharges computed with different grid size models by the corresponding peak discharges computed from the 90-m DEM.

A plot of normalized peak discharge versus grid size for a

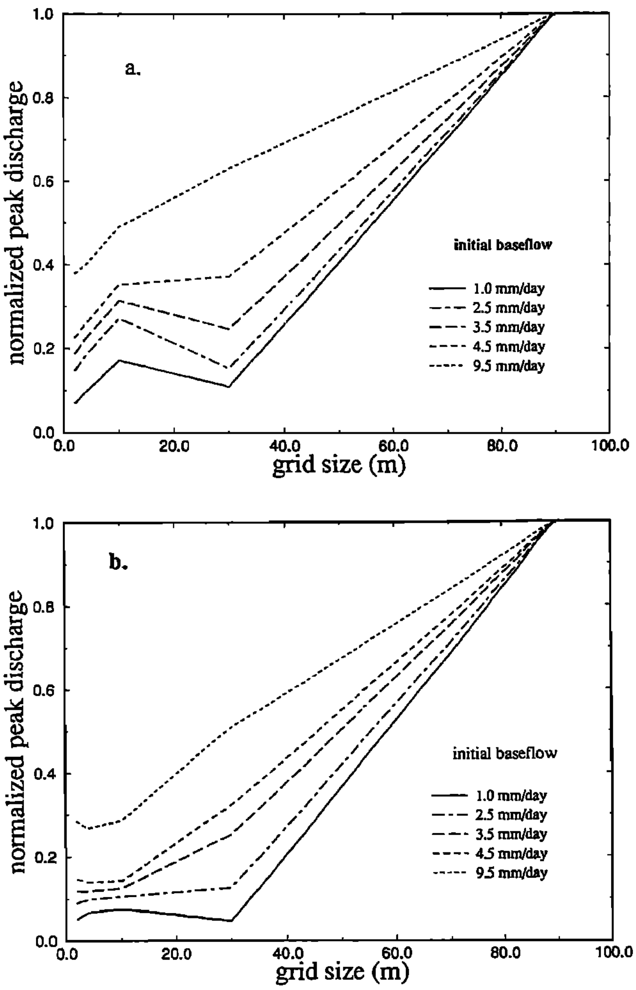


Figure 8. Computed peak discharge versus DEM grid size for a rainfall intensity of 10 mm/h and different initial base flows. Peak discharges are normalized to those of the 90-m grid size. (a) Mettman Ridge. (b) Tennessee Valley.

10 mm/h rainfall at various antecedent base flow rates is shown in Figure 8. In general, the computed peak discharge increases with increasing grid size. However, as the initial base flow increases, the effect of grid size on the computed discharge decreases. There are also some deviations from the positive correlation between the computed discharge and the grid size, especially for the Mettman Ridge catchment. Further examination reveals that the deviations in Figure 8a reflect variations in the back-calculated mean initial soil moisture deficit. For a given initial base flow, the mean soil moisture deficit generally decreases as the grid size increases, but there is a deviation from this trend at a 30-m grid size, where the initial mean soil moisture deficit is larger than that of 10-m grid size. With a larger moisture deficit and therefore a smaller saturated area, the runoff production rate will be smaller. For the Tennessee Valley catchment, both the computed initial mean soil moisture deficit and peak discharge vary more systematically with grid size.

The effect of rainfall intensity on the relation between computed discharge and the grid size is more complex (Figure 9). Within a rainfall intensity range of 5- to 10 mm/h for the Mettman Ridge catchment and 5- to 50-mm/h for the Tennessee Valley catchment, the difference between the peak discharge from grid sizes smaller than 90 m and that from a 90-m grid increases with the rainfall intensity. As rainfall intensity further increases, however, these differences decrease. This result is expected considering that peak discharge would be the same for all grid size models for the extreme cases of (1) no surface saturation under a very small rainfall intensity and (2) complete surface saturation under a very large rainfall intensity.

Within a range of reasonable rainfall intensities (e.g., less than 50 mm/h), peak discharge differences are less than 5% for grid sizes smaller than 30 m for the Tennessee Valley catchment, and less than 8% for grid sizes smaller than 10 m for the Mettman Ridge catchment. This suggests that there is a DEM grid size beyond which computed hydrologic response is less sensitive to grid size, and that this grid size is approximately 10 m for Tennessee Valley catchment and 4 m for the Mettman Ridge catchment.

Discussion

The analyses presented above are based on the single-direction flow-partitioning algorithm. This algorithm does not resolve hillslope divergence, introducing artifacts that influence cumulative frequency distributions of a and tan B. *Quinn et al.* [1991] showed that for the same grid size the single-direction algorithm yields higher tan B values, and therefore lower a/tan B, than a multiple-direction algorithm. They also illustrated that DEM grid size influences the distribution of a/tan B for multiple-direction algorithms, with the percent of area having larger a/tan B increasing with grid size. Thus the flow-partitioning algorithm also affects topographic representation, in addition to the grid size dependence documented in this paper.

The effect of DEM size on the distribution of derived slopes has important implications for geomorphic and hydrologic modeling and land management decisions based on such models. While a coarse-grid DEM may be most practical for modeling large-scale geomorphic processes, the coefficients incorporated in process models and transport laws at such scales are not analogous to those measured in field studies.

The effect of DEM size on the derived a/tan B will affect prediction of the spatial distribution of runoff processes, and the associated material transport processes over a land surface. Runoff processes are governed by neither the finest, nor the coarsest scale topography within a landscape. Rather, they are governed by processes acting over intermediate scales. If the DEM grid size is too large, then many topographic features such as hollows, low-order channels, and hillslopes will not be resolved. We suggest that the most appropriate DEM grid size for topographically driven hydrologic models is somewhat finer than the hillslope scale identifiable in the field.

Another implication is for flood forecasting in a drainage basin. Our results indicate that with the same values for soil parameters but different DEM grid sizes, the magnitude of the peak runoff rate, and therefore the runoff volume, predicted in response to a given storm may differ significantly. These results, however, are only for runoff production; hydrographs at the basin mouth also reflect routing of flow through the channel network. Grid size effects should be smaller for a large drainage basin where runoff hydro-

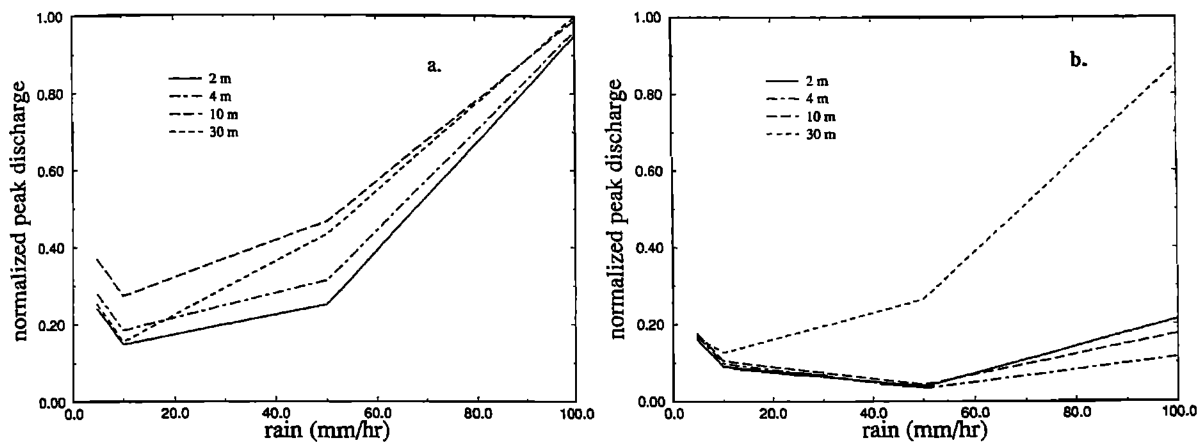


Figure 9. Computed peak discharge versus DEM grid size for an initial base flow of 2.5 mm/day and different rainfall intensities. Peak discharges are normalized to those of the 90-m grid size. (a) Mettman Ridge. (b) Tennessee Valley.

graphs are dominated by channel routing. Even so, the influence of DEM grid size on predicted runoff production is an important consideration for interpreting hydrological simulations using a topographically driven model.

A particularly intriguing implication is for calibration and validation of dynamic physically based hydrologic models. All hydrological models make simplifying assumptions and only approximate real hydrologic systems. In practice, calibration is required to obtain acceptable correspondence between field results and model simulations. Calibrated parameters for a particular catchment are then used for hydrological forecasting either for the same catchment, or for a different catchment with similar physical properties. However, our results show that DEM grid size, rainfall, and initial base flow all affect simulated hydrographs computed with the same set of parameter values. Consequently, model calibrations are grid size specific.

Appropriate Grid Size

The results of our study invite the question of what defines an appropriate grid size for simulations of geomorphic and hydrologic processes using topographically driven models. This question is best examined in two parts; the relation between land surface and the spot elevation data used to create a DEM and that between grid size and the original spot elevation data.

The data used to create a DEM are a filtered representation of landscape sampled at some regular or irregular interval to build a collection of elevation data. The spacing of the original data used to construct a DEM effectively limits the resolution of the DEM. Decreasing the grid size beyond the resolution of the original survey data does not increase the accuracy of the land surface representation of the DEM and potentially introduces interpolation errors. The relation of the original elevation data to the land surface is a crucial, but often neglected, characteristic of a DEM. This is a problem with many commercially available DEMs. While there are data collection strategies that could optimize landscape representation (e.g., dense topographic sampling in areas of complex topography and sparse sampling in areas with simple topography), the average spacing of the data used to derive a DEM provides a guide to the grid size that would take full advantage of the original spot elevation data, and thus provide the most faithful landscape representation.

We suggest that the length scale of the primary landscape features of interest provides a natural guide to an appropriate grid size. The most basic attribute of many landscapes is the division into topographically divergent hillslopes and convergent valleys. A grid size smaller than the hillslope length is necessary to adequately simulate processes controlled by land form. For other processes, the most appropriate grid size for simulation models is best scaled in reference to the process being modeled. For example, a coarse (e.g., 90 m) grid size may be most appropriate for modeling orogenic processes over large areas and long time scales.

Our results imply that it is unreasonable to use a 30- or 90-m grid size to model hillslope or runoff generation processes in moderately to steep gradient topography without some calibration of the process model. While a 10-m grid is a significant improvement over 30 m or coarser grid sizes, finer grid sizes provide relatively little additional resolution. Thus a 10-m grid size presents a reasonable compromise between increasing spatial resolution and data handling requirements for modeling surface processes in many landscapes.

Conclusions

The grid size of a DEM significantly affects both the representation of the land surface and hydrologic simulations based on this representation. As grid size decreases, landscape features are more accurately resolved, but faithful representation of a land surface by a DEM depends on both grid size and the accuracy and distribution of the original survey data from which the DEM was constructed. These results have important implications for simulations of hydrologic and geomorphic processes in natural landscapes. Our ability to model surface processes soon will be limited primarily by data quality and other issues directly related to processes under consideration. We suggest that a grid size of 10 m would suffice for many DEM-based applications of geomorphic and hydrologic modeling.

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