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Interactive comment on "The sensitivity of landscape evolution models to spatial and temporal rainfall resolution" *by* T. J. Coulthard and C. J. Skinner

Anonymous Referee #2

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Review of "The sensitivity of land scape evolution models to spatial and temporal rainfall resolution" Coulthard and Skinner

This paper examines the effect of temporal and spatial resolution has the erosion and landform evolution predictions of a LEM. The broad conclusions of the paper are a worthwhile contribution but the discussion misses some important points and previous work, and misrepresents previous work by other authors.

First looking at the question of spatial resolution. It's rather hard to judge the results without some idea of what the spatial pattern of rainfall is in the 10 year record and how persistent this pattern is over the 10 year period. A couple of thought experiments will clarify my concerns. 1. Imagine now that the pattern remains exactly the same

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Discussion paper

over the 10 year period (i.e. the amount of rainfall over the catchment changes from year to year, but the pattern of this rainfall is exactly the same form year to year). Then the random redistribution of rainfall in space will be completely invalid since what is required a random resampling of the rainfall in each year. This is an extreme case of orographic rainfall. 2. Imagine now that the pattern is completely uncorrelated from year to year and from 5km pixel to 5km pixel. In this case the random redistribution will be OK and any changes will simply result in random noise in the erosion and landform results. The authors have failed to justify that the differences they observe are anything other than random effects.

The way the question about time resolution is posed shows a misunderstanding of some of the solutions that other workers have used to address the problems highlighted of differences in mean erosion rate observed by the authors. There is no question that high time resolution runoff series results in significantly increased in erosion rates. The reviewer has also seen this in his our erosion computations and the 100% increase from daily to 0.25 hour accords with our own, unpublished, experience. This is because of the nonlinear dependence of the erosion time series on the runoff time series. A simple first order second moment analysis of the erosion time series shows this. Consider an erosion equation that is dependent on the square of discharge (approximately the dependency of Einstein-Brown sediment transport equation) E=bQˆ2 (1)

If Q is now a random value with mean Q* and variance SQ. A second order first moment analysis of this equation yields

E=b(Q*ˆ2+SQ) (2)

So that the erosion is higher than that where there is no variation in Q by a factor

(1+SQ/Q*ˆ2) (3)

This analysis shows that the erosion rate when you allow for randomness versus where you average out the variability will always be higher and the percentage increase is a function of the coefficient if variation of the runoff series. My own observation is that this factor can easily by a factor 2 going from a daily runoff series to a 15 minute runoff series for a small catchment (i.e. the erosion will increase by 100%). The appearance of variance in equation (2) comes solely from the square dependence in equation (1). If equation (1) were a power of 1 (i.e. linear) then the variance term does not appear and the sub-daily variability would have no impact on the mean erosion rate.

Finally, the authors quote Hancock papers (2000,2002,2010) as examples where the long time resolution of the timesteps in the landform evolution model will yield significant underestimates of the erosion. This assertion is categorically incorrect and reflects a lack of understanding of how the model parameters were developed for these papers. I'm surprised at this because the first author has been collaborating for some time with Hancock. The parameters used in the Hancock papers are based on a calibration procedure described in Willgoose and Riley (1993,1998)

Willgoose, G. R., and S. J. Riley (1993), Application of a catchment evolution model to the prediction of long-term erosion on the spoil heap at Ranger Uranium MineRep. Open File Report 107, The Office of the Supervising Scientist, Jabiru.

Willgoose, G. R., and S. J. Riley (1998), An assessment of the long-term erosional stability of a proposed mine rehabilitation, Earth Surface Processes and Landforms, 23, 237-259.

In brief this process was 1. A conceptual rainfall-runoff model (with much the same capability as LISFLOOD) was calibrated to rainfall-runoff-erosion plot studies at the time and space resolution of the data (minutes and 100 sq metres) 2. A multiple regression was developed between sediment load, discharge and slope from the plot studies. 3. The rainfall-runoff model was then scaled up to the landform using a low resolution DEM of the site (about 1000 nodes) and 30 years of pluviograph data at 15 minute resolution was used to generate a 30 year runoff time series. 4. This 15 minute resolution time series was then used to generate a 15 minute sediment transport series using the regression. 5. This 15 minute erosion series was then lumped up to the annual level and "effective" parameters where developed that gave the same average and area and slope dependence at the yearly time step as the 15 minutes erosion time series. These are the parameters that are used in the annual time steps.

Now there is no doubt this was an extremely compute intensive task. In 1992 when this work was done it took about 4 weeks of CPU time on a high end workstation to generate the time series in step 3. This calibration has been used as the basis for other sites studied by Hancock.

The key difference between what was done by Willgoose and Riley (1998) (hereafter W&R) and in this paper is that the authors have explicitly included the randomness of the hydrology timeseries within the LEM, while in W&R this has been averaged out in the derivation of the effective parameters.

Finally on bottom of p10 and top of p11 the author contemplates whether there is a "compensatory factor or exponent". Indeed this is what the "effective parameters" in the approach of W&R do.

So in conclusion if we go to the plots of changes when using different averaging periods, the lower erosion rate observed by the author for low resolution rainfall is to be expected. But this can be adjusted by the use of "effective parameters" as done in W&R. The more interesting question, but unfortunately not addressed by the authors, is if the average erosion rate for all the different time resolutions were adjusted to give the same annual erosion are the landforms generated significantly different (i.e. does the higher rainfall resolution and explicit modelling of runoff events lead to fundamental differences beyond a general change in the calculated mean erosion rate).

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