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Challenges in physically-based distributed catchment modelling for inter-disciplinary work

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Three-dimensional gridding is simultaneously the strength and weakness of physically-based distributed catchment modelling (PBDM). The strength comes from being able to represent the catchment geometry and the spatial distribution of physical properties and processes in some detail. A suitable grid geometry is chosen and each grid cell is allocated a suitable set of parameter values that are based directly on physical property data for soils, river channels, etc. This gives enormous scope for a wide variety of inter-disciplinary work where the hydrological states and flows on the grid are used as states and vectors for variables related to vegetation, sediment, solute, and temperature, to name but a few. PBDM has two well-known and widely-debated weakness: (a) it can be difficult to create a suitable grid and assemble and allocate suitable sets of data for physical properties and processes; and (b) unless the grid cells are very small it is usually impractical to solve accurately the underlying sets of governing physically-based partial differential equations (GPBPDEs) such as the Darcy-Richards equation for subsurface flow.

Arguably, however, the real challenges that must be faced in creating PBD models suitable for inter-disciplinary work don't relate to these weaknesses. They relate instead to the wider problems associated with assessing fitness for purpose, where answers must be found to questions such as: is a given PBD model useful for the proposed inter-disciplinary work or not? There is very little information available on the link between fitness for purpose and the strengths and weaknesses of PBDM, and this whole area needs to be researched. For example, it may sometimes be advantageous to exacerbate some of the weaknesses, to benefit from the strengths of PBDM, such as when representing 'hot spots' where cows congregate in a field and affect local infiltration, sediment generation, and pollution. Adapting the grid geometry to accommodate hot spots may well exacerbate problems with solving GPBPDEs, but there is much to be gained by explicitly representing hot spots directly on the grid, rather than having to somehow represent them as sub-grid features.

The strengths and weaknesses of PBDM, and methods for testing fitness for purpose, will be discussed using examples for the SHETRAN PBD model, a free-format grid that accommodates hot spots, and hypothesis testing of fitness for purpose.