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Scale-independent large-scale runoff routing: A new approach

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The accuracy of runoff routing for global water-balance models and land-surface schemes is limited by the low spatial resolution of flow networks. Many such networks have been developed for specific models at specific spatial resolutions. Although low-resolution networks can be derived by up-scaling algorithms from high-resolution datasets, such low-resolution networks are inherently incoherent, and slight differences in their spatial resolution can cause significant deviations in routing dynamics. By neglecting convective delay, storage-based routing algorithms produce artificially early arriving peaks on large scales. A theoretical comparison between a diffusion-wave-routing algorithm and linear-reservoir-routing (LRR) algorithm on a 30-km cell demonstrated that the commonly used LRR method consistently underestimates the travel time through the cells. A new aggregated network-response-function (NRF) routing algorithm was proposed in this study and evaluated against a conventional flow-net-based cell-to-cell LRR algorithm. The evaluation was done firstly for the 25 325 km2 Dongjiang (East River) basin, a tributary to the Pearl River in southern China well equipped with hydrological and meteorological stations, and then extended to the continental scale. The NRF method transfers high-resolution delay dynamics, instead of networks, to any lower spatial resolution where runoff is generated. It preserves, over all scales, the spatially distributed time-delay information in the 1-km HYDRO1k flow network in the form of simple cell-response functions for any low-resolution grid. The NRF routing was shown to be scale independent for latitude-longitude resolutions ranging from 5' to 1°. This scale independency allowed a study of input heterogeneity on modelled discharge modelled with a daily version of the WASMOD-M water-balance model. The model efficiency of WASMOD-M-generated daily discharge at the Boluo gauging station in the Dongjiang basin in south China was constantly high (0.89) within the whole range of resolutions when routed by the NRF algorithm. The performance dropped sharply for decreasing resolution when runoff was routed with the LRR method. The three WASMOD-M parameters were scale independent in combination with NRF, but not with LRR, and the same parameter values gave equally good results at all spatial resolutions. The effect of spatial resolution on the routing delay was much more important than the spatial variability of the climate-input field for scales ranging from 5' to 1°. The extra information in a distributed versus a uniform climate input could only be used when the NRF method was used to route the runoff. NRF requires more labour than LRR to set up but the model performance is very much higher than the LRR's once this is done. The NRF method, therefore, provides a significant potential to improve global-scale discharge predictions.