A velocity method for global river routing scheme

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1. Introduction

Total Runoff Integrating Pathways (TRIP) is a global river routing model which can help to collect and route runoff to the river mouths for the major rivers. In the previous version of TRIP, a simple approach of constant flow velocity is used. In general, that approach is sufficient to model mean long-term discharges. However to model flood events for example, more sophisticated approach is required. In this study, we implement a variable velocity approach to TRIP.

2. Methodology

The water balance within a grid cell of TRIP [Oki and Sud, 1998], $S$, [m$^3$], is given by:

$$\frac{dS}{dt} = D_{wp} + D_{LSM} - Q$$ (1)

where $D_{wp}$ [m$^3$/s], $D_{LSM}$ [m$^3$/s], and $Q$ [m$^3$/s] are total inflow from upstream grid boxes, input runoff from LSMs, and outflow from the grid box, respectively.

Dingman and Sharma [1997] developed the following relation from objective statistical analysis of over 500 in-bank flows:

$$Q = 1.564 A^{1.173} R^{0.400} S^{-0.0543 \log_{10} S}$$ (2)

where $A$ [m$^2$] is cross-sectional area, $R$ [m] is hydraulic radius, and $S$ [m/m] is the river slope.

Assuming the river channel is shaped as a rectangle of width $W$ [m] and depth $h$ [m], we have:

$$R = \frac{hW}{2h + W}$$ (3)

The volume of water in the river channel is:

$$S_s = hWl_{r_M}$$ (4)

where $l$ is the straight length of the river channel within the grid box calculated geometrically and $r_M$ (equal to 1.4 globally) is the meandering ratio adjusting the river length to be realistic.

Substituting Eq.2, Eq.3, Eq.4 into the continuity equation Eq.1 yields:

$$\frac{dh}{dt} = \frac{1}{Wl_{r_M}} \left( D_{wp} + D_{LSM} - 1.564 A^{-0.0543 \log_{10} S} h^{1.573} W^{1.573} \right)$$ (5)

$l$ and $S$ can be obtained from global elevation and routing direction maps. In this study, $W$ is obtained using a geomorphological relationship with annual mean discharge $Q_m$ [m$^3$/s] proposed by Arora and Boer [1999]:

$$W = \max(10, (6.0 + 10^{-4} Q_{m,mouth}) \times Q_m^{0.5})$$ (6)

where $Q_{m,mouth}$ [m$^3$/s] is the annual mean discharge at the river mouth. $Q_m$ is initially calculated from the constant velocity version of TRIP and adjusted after each year of simulation.

At this step, only $h$ is the unknown variable in Eq.5. An explicit forward step finite difference
approximation is used to determine the flow depth:

\[
h_{i+1} = h_i + \frac{\Delta t}{Wl_m} \left( D_{dp} + D_{OUT_g} + D_{LSM} - 1.564S^{-0.0543\log_{10} S} h_i^{1.573}W^{1.573} \frac{h_i}{(2h_i+W)^{0.400}} \right)
\]

(7)

3. Results

Two simulations are performed. The first one, called CVR (Constant Velocity Run) is obtained with the previous version of TRIP which used the constant velocity approach. The second one, called VVR (Variable Velocity Run) is obtained using the new approach. Both simulations use the multi-model runoff product provided by GSWP2 [Dirmeyer et al., 2006].

![Figure 1: The Mekong river sequence map designed by Oki et al. [1998]. River information from the World Data Bank II is superimposed.](image)

![Figure 2: River discharge at the Pakse station for 1989: red curve: observation data obtained from Global Runoff Data Center; black curve: simulation with the constant velocity approach; blue curve: simulation with the new approach](image)

Simulation results are compared to the observations over the Mekong (Figure 1). The simulated river discharges are significantly improved with the new approach of TRIP (Figure 2). The correlations between simulated and observed discharges are 0.94 and 0.83 for the new and the previous approach of TRIP, respectively.

4. References


Keyword: global river routing model, river velocity, flood simulation