AdHydro model

- Water Management
- Snowmelt
- Rainfall
- Groundwater
- Infiltration
- Channel Network
- Surface water
- Evapo-Transpiration

State Variables:
- mesh geometry
- groundwater head
- surface water depth
- vadose zone state
AdHydro model mesh structure
1D channel routing

Dynamic wave equations:

\[
\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = S
\]

\[
\frac{\partial Q}{\partial t} + \frac{\partial Q^2 / A}{\partial x} = -gA \frac{\partial Z}{\partial x} - gAS_f
\]

Diffusive wave equation:

\[
\frac{\partial A}{\partial t} - \frac{\partial}{\partial x} \left( \frac{R^{2/3} A}{n} \frac{\partial Z / \partial x}{\sqrt{\partial Z / \partial x}} \right) = S
\]

- \( A \) = cross-section area;
- \( Z \) = water surface elevation;
- \( Q \) = flow rate;
- \( S \) = source term;
Overland 2D shallow water flow

Dynamic wave equations:

\[
\frac{\partial h}{\partial t} + \frac{\partial hu}{\partial x} + \frac{\partial hv}{\partial y} = q_r
\]

\[
\frac{\partial hu}{\partial t} + \frac{\partial huu}{\partial x} + \frac{\partial huv}{\partial y} = -gh \frac{\partial z}{\partial x} - \frac{gn_x^2 u \sqrt{u^2+v^2}}{h^{1/3}}
\]

\[
\frac{\partial hv}{\partial t} + \frac{\partial huv}{\partial x} + \frac{\partial hvv}{\partial y} = -gh \frac{\partial z}{\partial y} - \frac{gn_y^2 v \sqrt{u^2+v^2}}{h^{1/3}}
\]

Diffusive wave equation:

\[
\frac{\partial h}{\partial t} + \frac{\partial}{\partial x} \left( hk_x \frac{\partial Z}{\partial x} \right) + \frac{\partial}{\partial y} \left( hk_y \frac{\partial Z}{\partial y} \right) = q_r
\]

- \( h \) = water depth;
- \( Z \) = water surface elevation;
- \( u, v \) = velocities;
- \( q_r \) = rainfall;
- \( k_x, k_y \) = diffusion coefficients;
Saturated 2D groundwater flow in unconfined aquifer

Boussinesq Eq: \[ S_y \frac{\partial H}{\partial t} = \frac{\partial}{\partial x} \left( K_x (H - z_b) \frac{\partial H}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y (H - z_b) \frac{\partial H}{\partial y} \right) + R = \frac{\Delta S}{\Delta t} \]

\( H = \) water head;  
\( S_y = \) specific yield;  
\( R = \) recharge rate;  
\( S = \) storage;  
\( K_x, K_y = \) conductivity;
Numerical scheme

Explicit time-stepping cell-centered finite volume method.

Advantage: Mass conservation; Parallelizable computing;

\[
\frac{\partial U}{\partial t} + \nabla \cdot F = S
\]

\[
\int_{\Omega_i} \frac{\partial U}{\partial t} d\Omega + \int_{\Omega_i} \nabla \cdot F \, d\Omega = \int_{\Omega_i} S \, d\Omega
\]

\[
\int_{\Omega_i} \frac{\partial U}{\partial t} d\Omega + \oint_{\Gamma_i} \tilde{F} \cdot n \, d\Gamma = \int_{\Omega_i} S \, d\Omega
\]

\[
\frac{U^{n+1}_i - U^n_i}{\Delta t} + \frac{1}{\Omega_i} \sum_{j=1}^{3} \tilde{F}_{ij} \cdot n_{ij} \, \Delta \Gamma_{ij} = S_i
\]
Improvement of T-O infiltration model

Introduce slugs;

Better capturing ponding time;

\[
\frac{dZ_k}{dt} = \frac{K(\theta_d) - K(\theta_i)}{(\theta_d - \theta_i)} \left( \frac{\left| \Psi(\theta_d) \right|}{Z_k} + 1 \right)
\]
Time = 1 hr
Time = 2 hr
Time = 3 hr
Time = 4 hr
Time = 5 hr
## Ponding time error

<table>
<thead>
<tr>
<th></th>
<th>First pulse (hr)</th>
<th>Second pulse (hr)</th>
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<tbody>
<tr>
<td></td>
<td>$t_{p_RE}$</td>
<td>$t_{p_TO} - t_{p_RE}$</td>
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<tr>
<td>Sand</td>
<td>0.0620</td>
<td>0.0296</td>
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<tr>
<td>Loamy sand</td>
<td>0.1762</td>
<td>0.0161</td>
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<td>0.4092</td>
<td>0.0505</td>
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<tr>
<td>Loam</td>
<td>0.6229</td>
<td>0.0791</td>
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<tr>
<td>Silt loam</td>
<td>0.5604</td>
<td>0.0541</td>
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<tr>
<td>Sandy clay loam</td>
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<td>0.0416</td>
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<tr>
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<td>0.6375</td>
<td>0.0513</td>
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<tr>
<td>Sandy clay</td>
<td>0.4861</td>
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<tr>
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<td>0.2569</td>
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<tr>
<td>Clay</td>
<td>0.4277</td>
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## Error analysis

<table>
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<tr>
<th></th>
<th>Original T-O method</th>
<th></th>
<th>Improved T-O method</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>NSE</td>
<td>PBIAS (%)</td>
<td>RMSE (cm)</td>
<td>NSE</td>
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<tr>
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<td>0.98439</td>
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<td>1.76080</td>
<td>0.99123</td>
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<td>0.98785</td>
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<tr>
<td>Sandy clay loam</td>
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<td>0.13350</td>
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</tbody>
</table>
Overland and channel flows interaction

Weir type equations:

\[ Q = C_d \cdot L \left( Z_s - Z_{\text{bank}} \right) \sqrt{2 \cdot g \left( Z_s - Z_{\text{bank}} \right)} \]

- \( Q \) = flow rate;
- \( L \) = weir length;
- \( C_d \) = discharge coefficient;
- \( Z_s \) = surface water elevation;
- \( Z_{\text{bank}} \) = bank elevation.

\[ \text{Datum} \]
Groundwater and channel flows interaction

Conductance concept type equation:

\[ V = \begin{cases} 
K_r \frac{H_{gw} - (Z_{bed} + h)}{\Delta Z_b}, & H_{gw} > Z_{bed} - \Delta Z_b \\
-K_r \frac{h + \Delta Z_b}{\Delta Z_b}, & H_{gw} \leq Z_{bed} - \Delta Z_b 
\end{cases} \]

- \( V \) = flow velocity;
- \( h \) = channel water depth;
- \( K_r \) = river bed conductivity;
- \( Z_{bed} \) = river bed elevation
- \( H_{gw} \) = groundwater elevation;
- \( \Delta Z_b \) = river bed thickness;
Future works

Geometry data for channel, lake, reservoir;

Land use / land cover and soil data;

Snowmelt model;

Water management model;