Integration of an 'Eco-hydrologic Component' to a Generic Gridding Engine for 2D Modeling of Earth-Surface Dynamics

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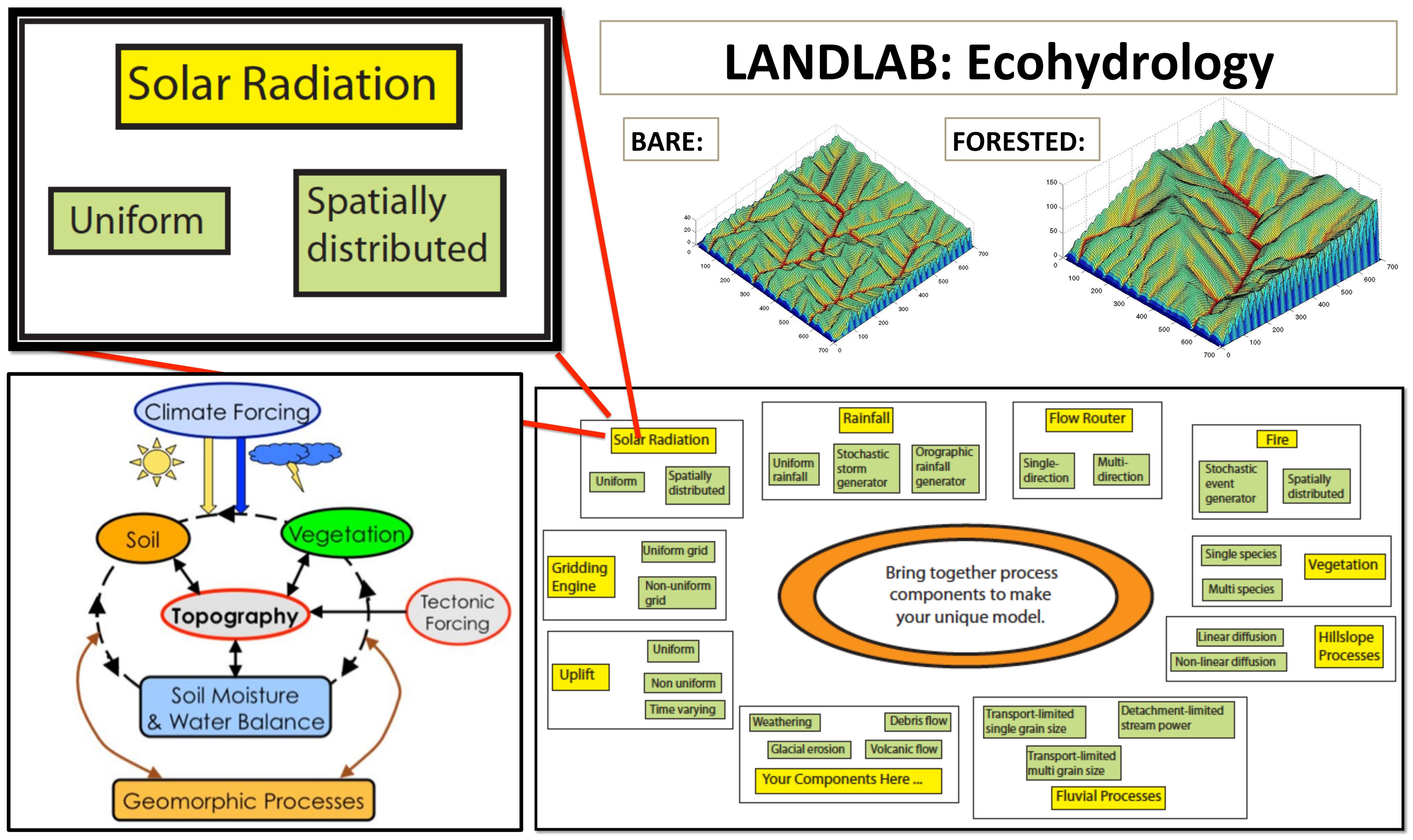
Abstract:

This presentation discusses the implementation of component-based software design in Eco-hydrologic modeling. As a first step, we present development and integration of a radiation component that uses the local topographic variables to compute shortwave and longwave radiation data over a complex terrain for modeling Eco-hydrologic dynamics. This component is integrated to a central element that develops and maintains a grid, which represents the landscape under consideration. This component communicates with various other components such as 'vegetation component' and 'soil moisture component'. This component is adapted from the Channel-Hillslope Integrated Landscape Development (CHILD) Model code and has been enhanced. This study demonstrate the advantages of adopting component-based software design such as improved flexibility, interchangeability and adaptability.



Physics:

$$\delta = [0.006918 - 0.399912\times\cos(\Gamma) - 0.070257\times\sin(\Gamma) - 0.006758\times\cos(2\times\Gamma) - 0.000907\times\sin(2\times\Gamma) - 0.002697\times\cos(3\times\Gamma) - 0.00148\times\cos(3\times\Gamma)]$$

$$\cos(\theta) = \sin(\delta)\sin(\Lambda)\cos(S) - \sin(\delta)\cos(\Lambda)\sin(S)\cos(\gamma) + \cos(\delta)\cos(\Lambda)\cos(S)\cos(\omega) + \cos(\delta)\sin(\Lambda)\sin(S)\cos(\gamma)\cos(\omega) + \cos(\delta)\sin(\gamma)\sin(S)\sin(\omega)$$

$$k_{ET} = I_{sc} E_0 \cos(\theta) \qquad E_0 = \frac{1}{1+0.033\cos\left(\frac{2\pi\times DOY}{365}\right)} \qquad K_{ET-S} = \int_{\omega_{sr}}^{\omega_{ss}} k_{ET}$$

$$\omega_{sr} = \sin^{-1}\left(\frac{ac-b\sqrt{b^2+c^2-a^2}}{b^2+c^2}\right) \qquad \omega_{ss} = \sin^{-1}\left(\frac{ac+b\sqrt{b^2+c^2-a^2}}{b^2+c^2}\right)$$

$$a = \sin(\delta)\cos(\Lambda)\sin(S)\cos(\gamma) - \sin(\delta)\sin(\Lambda)\cos(S)$$
$$b = \cos(\delta)\cos(\Lambda)\cos(S) - \cos(\delta)\sin(\Lambda)\sin(S)\cos(\gamma)$$
$$c = \cos(\delta)\sin(\gamma)\sin(S)$$

δ: is the declination of the earth
Λ: latitude of the location
S: local slope
γ: surface aspect angle
ω: hour angle
Γ : Day angle
I_{sc} is solar constant
E_0 is eccentricity correction
θ is solar zenith angle

Clear day direct solar radiation K_{dir} at the surface:

$$K_{dir} = K_{ET} \times f_{di} \qquad f_{di} = \exp(-nm(0.128 - 0.054\log_{10} m))$$

$$f_{df} = \begin{cases} 0.35 - 0.36 f_{di} & f_{di} \geq 0.15 \\ 0.18 + 0.82 f_{di} & 0.065 < f_{di} < 0.15 \\ 0.10 + 2.08 f_{di} & f_{di} < 0.065 \end{cases}$$

n is turbidity factor
m is the optical air mass
α is the solar altitude

Total Incoming Shortwave Radiation: Horizontal Surface

$$K_{diff-h} = K_{ET-h} \times f_{df}$$
$$K_{total-h} = K_{dir-h} + K_{diff-h}$$

$$f_{df} = \begin{cases} 0.35 - 0.36 f_{di} & f_{di} \geq 0.15 \\ 0.18 + 0.82 f_{di} & 0.065 < f_{di} < 0.15 \\ 0.10 + 2.08 f_{di} & f_{di} < 0.065 \end{cases}$$

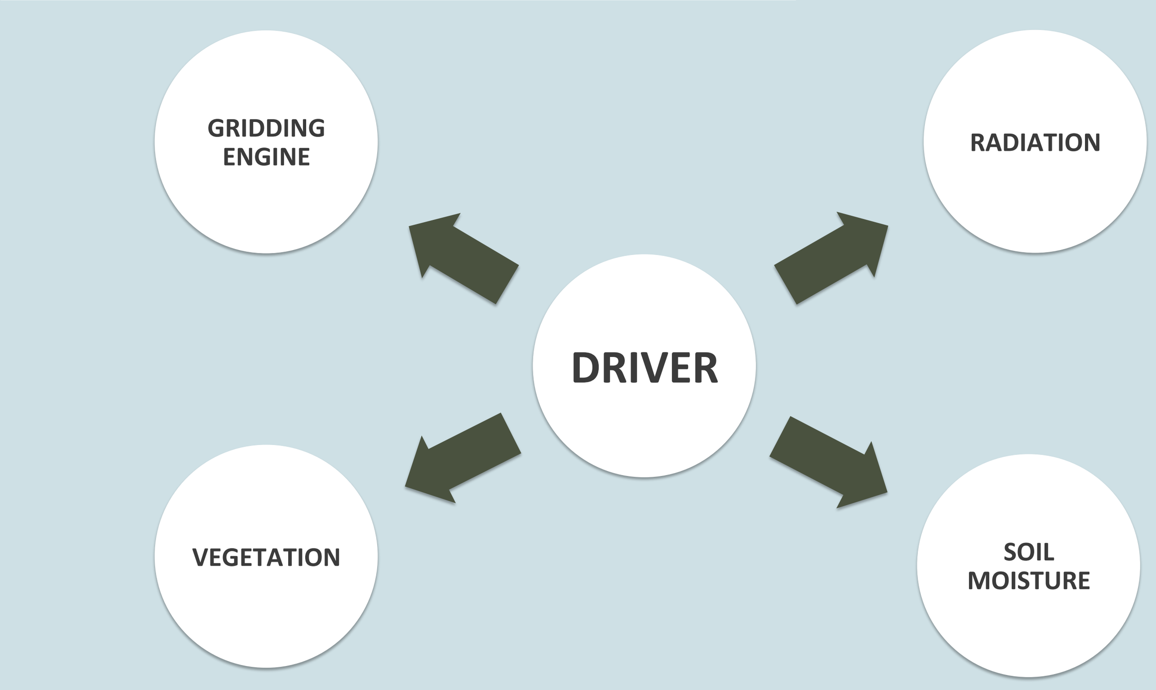
Total Incoming Shortwave Radiation: Sloping Surface

$$K_{diff-S} = K_{diff-h} \times f_{ia} \qquad f_{ia} = 0.75 + 0.25\cos(s) - \frac{0.5s}{\pi}$$

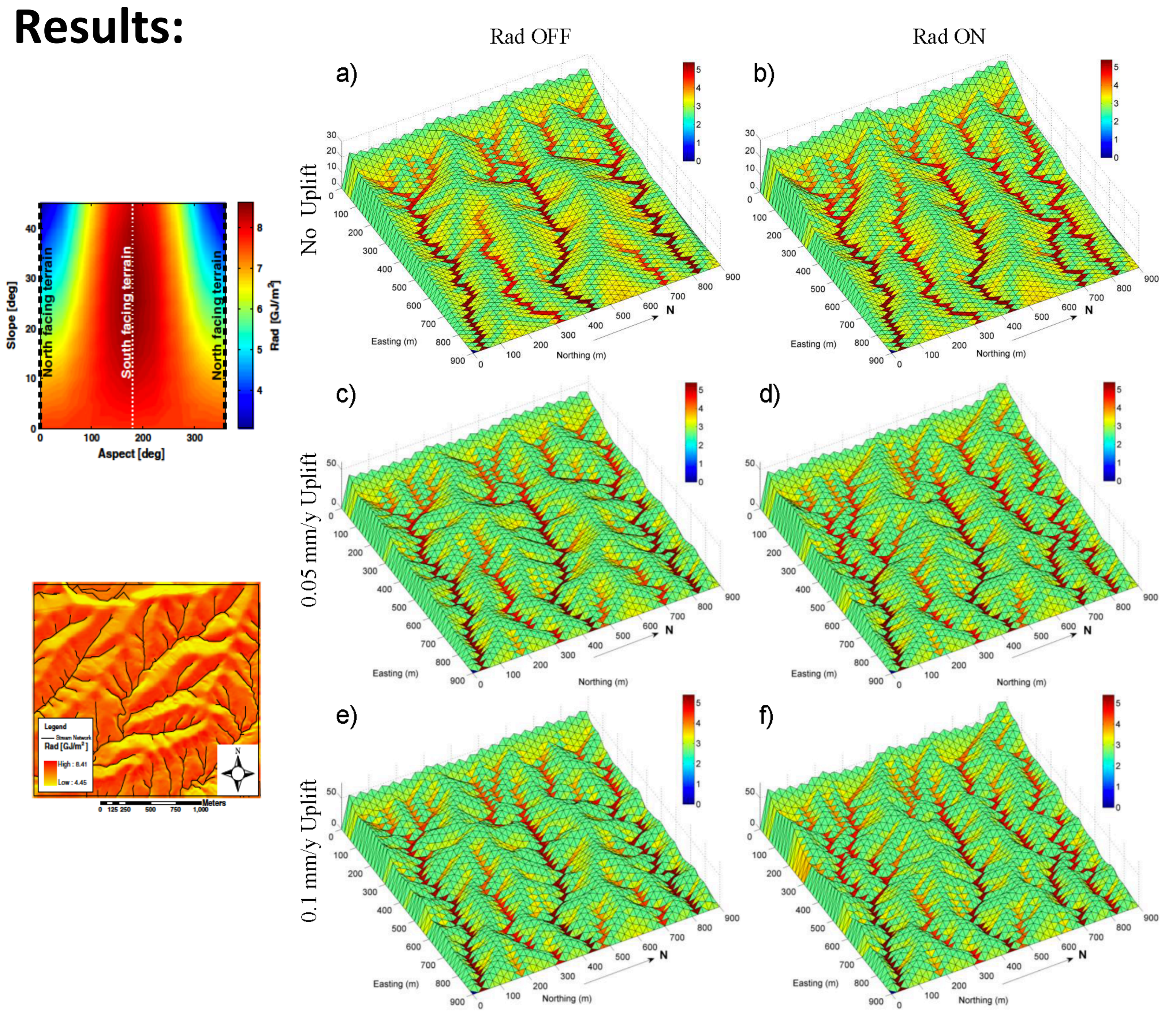
$$K_{total-S} = K_{dir-S} + K_{diff-S} + K_{ref-S} \qquad K_{ref-S} = K_{total-h} \times \alpha \times (1 - f_{ia})$$

$$R_{solar} = K_{total-S} / K_{total-h}$$

C++/CSDMS Framework:



Results:



Figures: [LEFT] Annual solar radiation for 32°N (SE Arizona Site)[2] [RIGHT] Simulated landscapes for uniform (Rad OFF) & spatially distributed (Rad ON) solar radiation for different uplift rates

Code Structure:

Radiation_driver
- read input
- configure model
- initialize ( )
- update_until ( )
- finalize

initialize ( )
- initialize mesh
- set up variables
- read inputs
- compute flat surface radiation factor
- initialize output files

update_until ( )
- loop time
- call update ( )
- update time

update ( )
- call flow routing component
- compute slopes along edges
- compute local aspect
- compute radiance factor
- compute net shortwave radiation
- compute net longwave radiation

finalize ( )
- check mesh owner
- finalize mesh
- delete mesh
- close output files

References:

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