Modelling Groundwater Storage in the Marmot Creek Basin

http//www.geography.ryerson.ca/wayne/thesis.htm

By:

Ken Snelgrove and Yanhzen Ou

Memorial University of Newfoundland

For:

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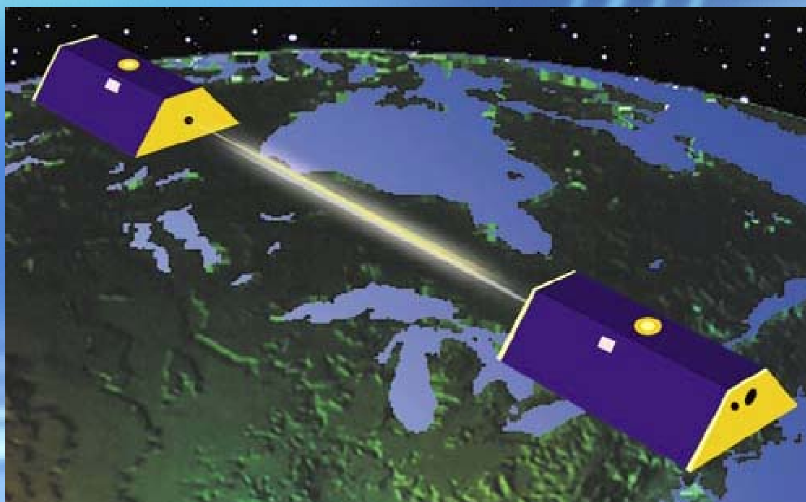
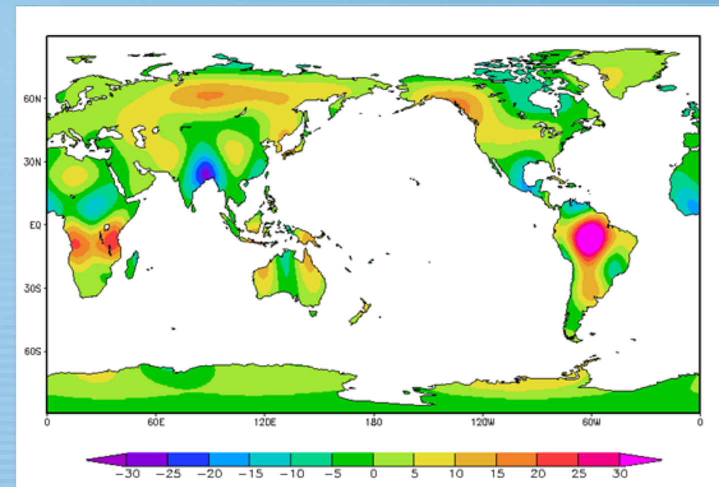
Outline

- GRACE and Gravity
- Big Grids (GRUs)
- Little Grids (Topmodel)
- ParFlow and SABAE-HW
- Conclusion

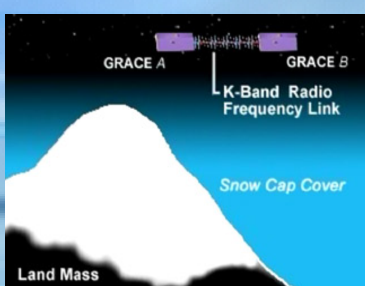
GRACE & Gravity

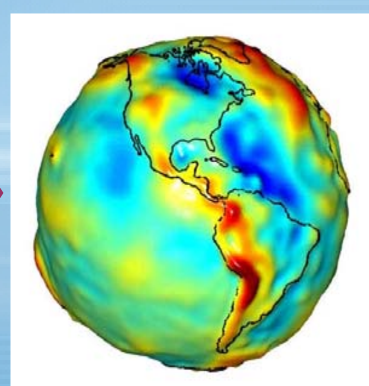


GRACE Dual Satellites



Monthly Moisture Anomalies





Geopotential Expansion

200 km Resolution

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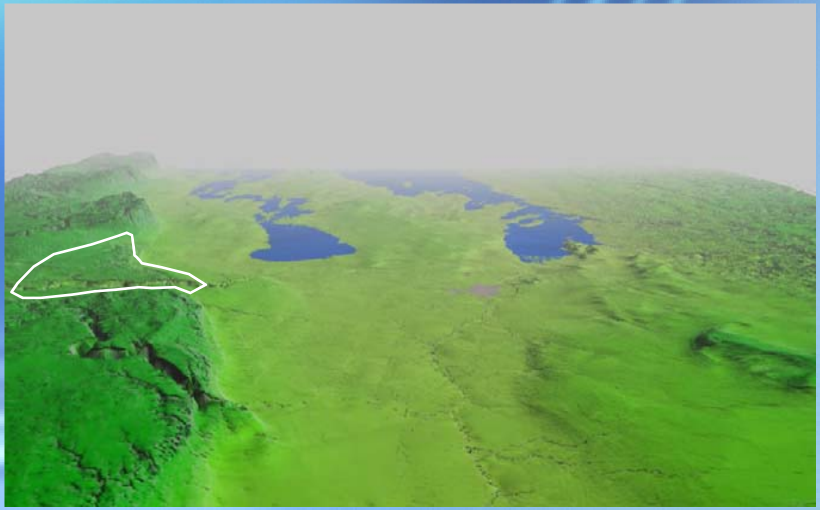
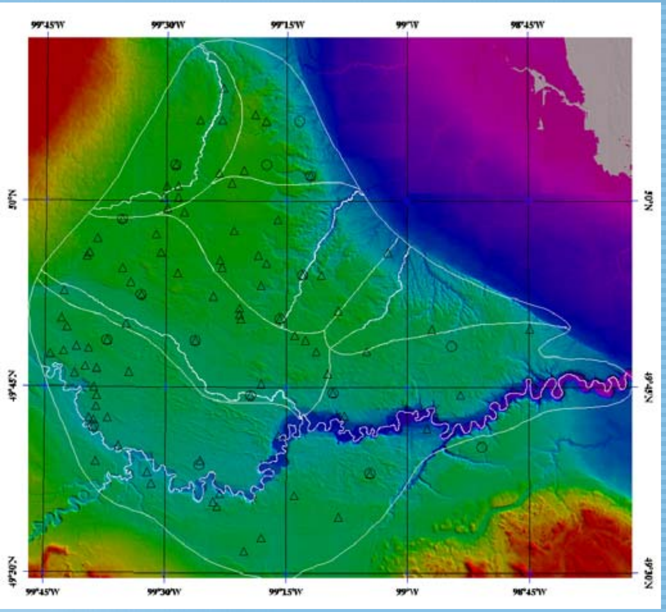
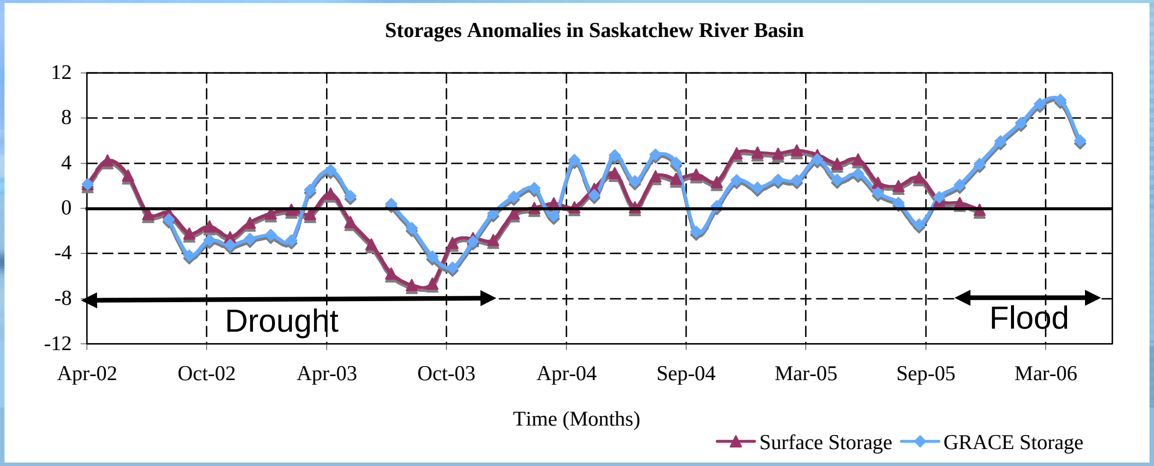
GRACE & Gravity



Assiniboine Delta Aquifer



Observation Wells



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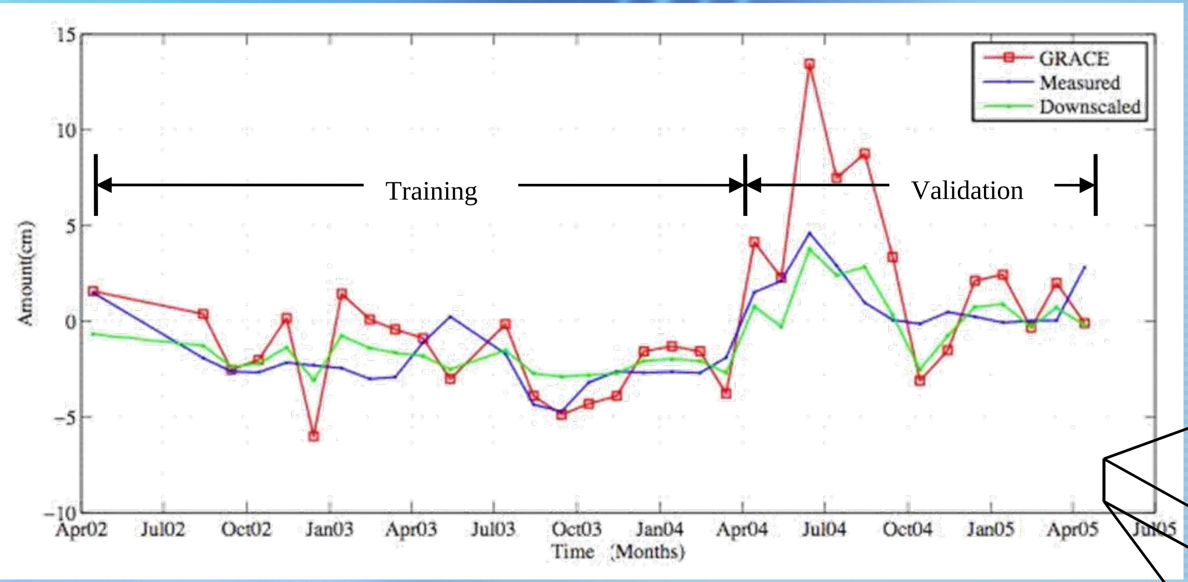
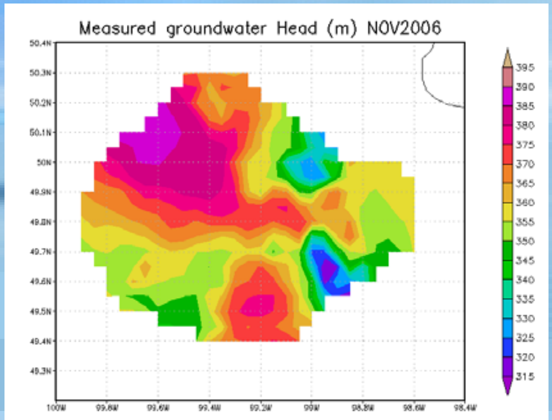
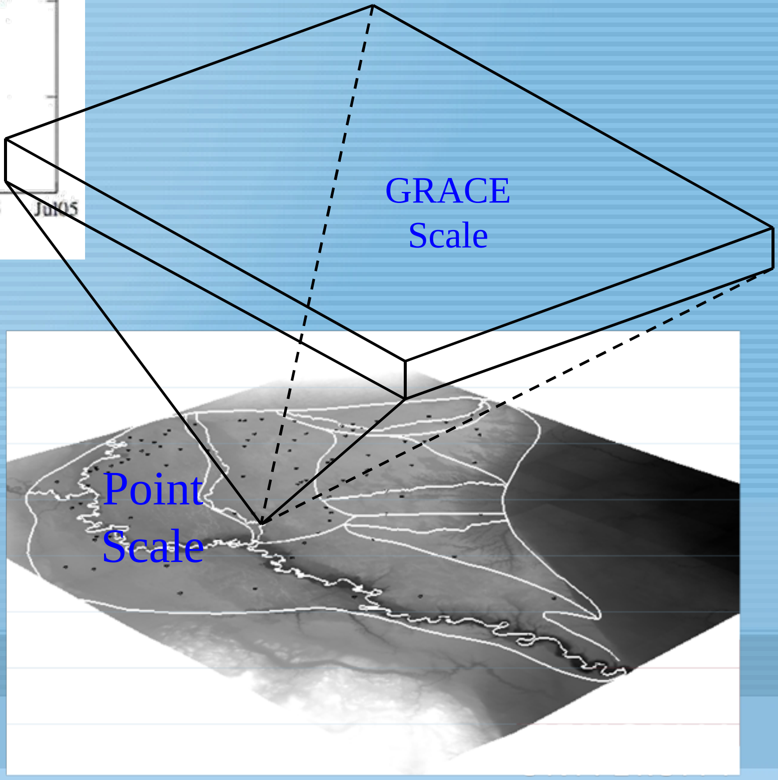
GRACE & Gravity



Artificial Neural Network Downscaling





GRACE & GOCE

- Gravity and Ocean Circulation Explorer (GOCE)
- 10x Increase in Spatial Resolution
- 250 km Orbit
- Only 20 month Mission ☹
- Launch Spring, 2008

Marmot Creek Basin

- Location
  - --Longitude 115°09’15’’W
  - --Latitude 50°56’57’’N
  - -- Southwest of Calgary
  - --9.1 km^2
- Land cover
  - --Forest — 60%
  - --Alpine meadow, rock— 40%
- Precipitation
  - --Mean annual 1080mm
  - --Snowfall 70 to 75%

http//wwwg8legacy.ca/public_html/cgi-bin/facilities.php

- Stream flow
  - --Most derived from groundwater
  - --Mean Annual Runoff 425 mm

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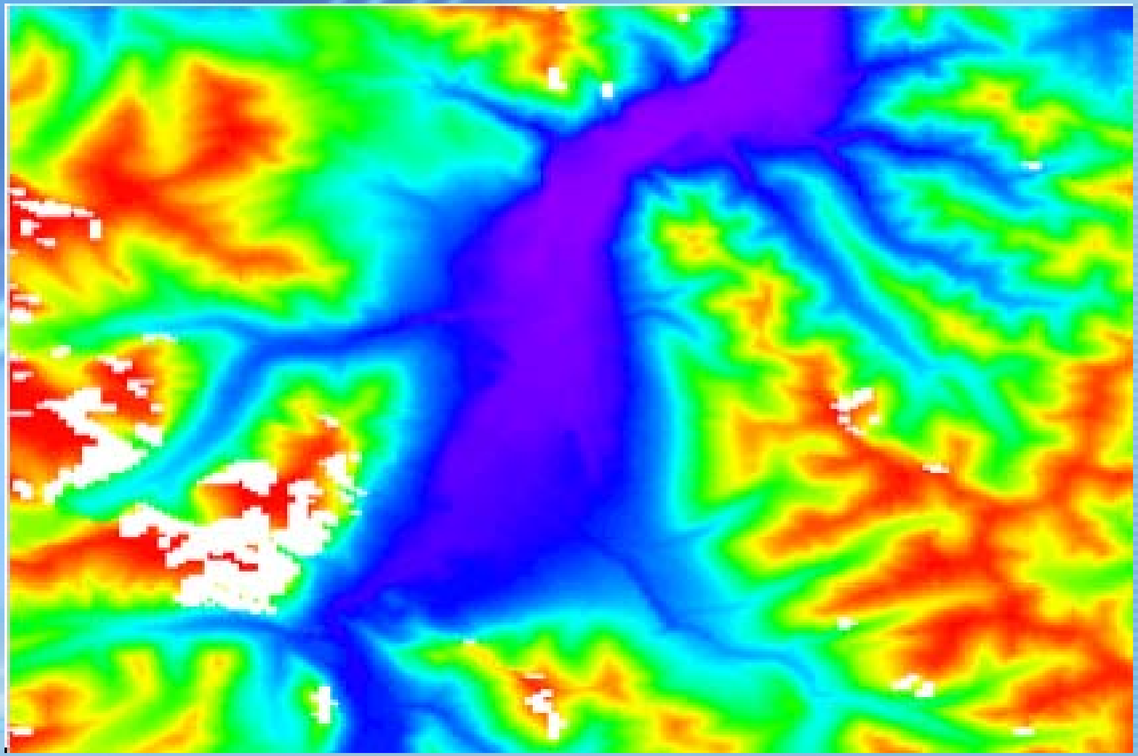
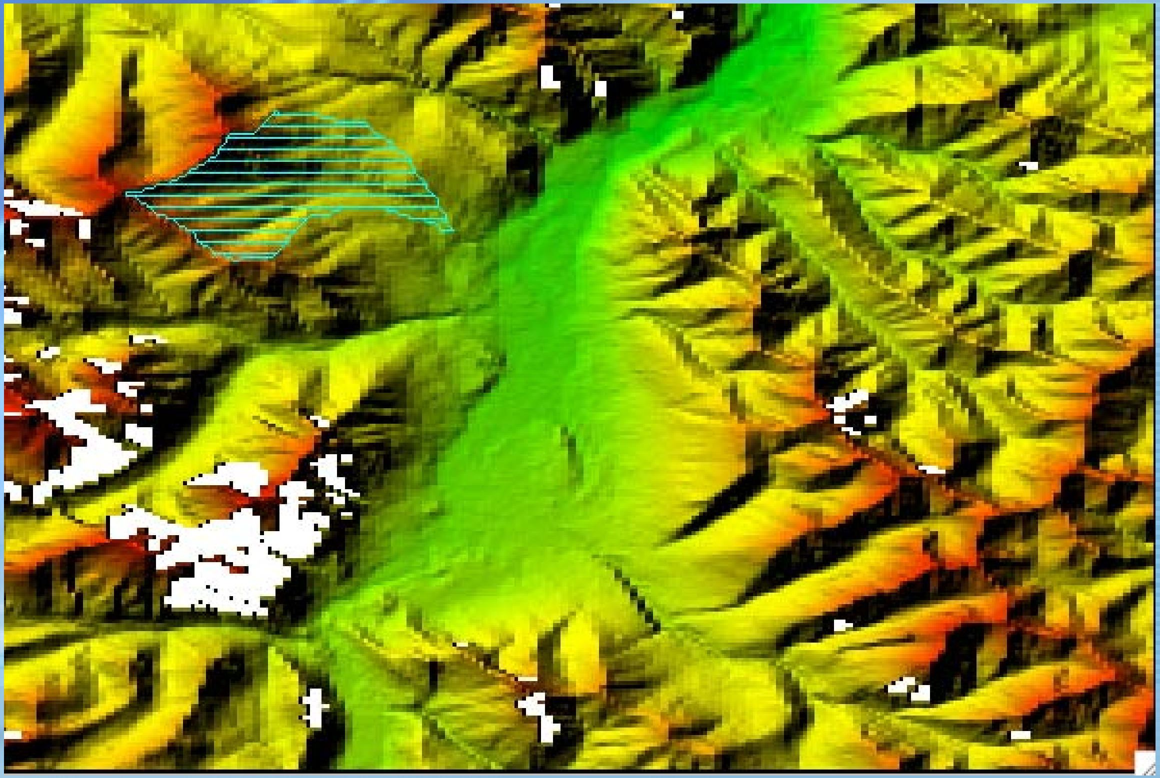
Basin Information



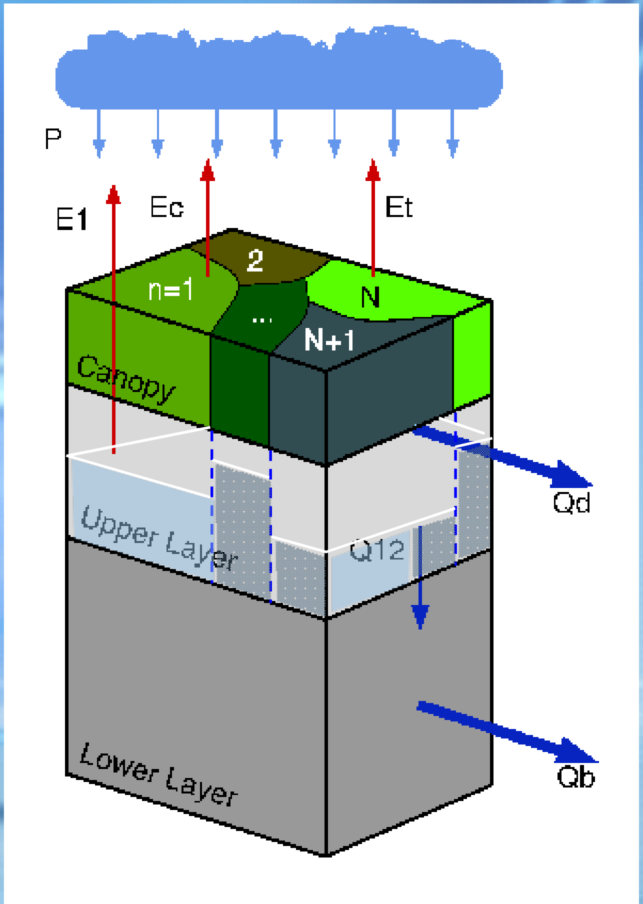
SRTM DEM for the Marmot Creek basin

Basin Information

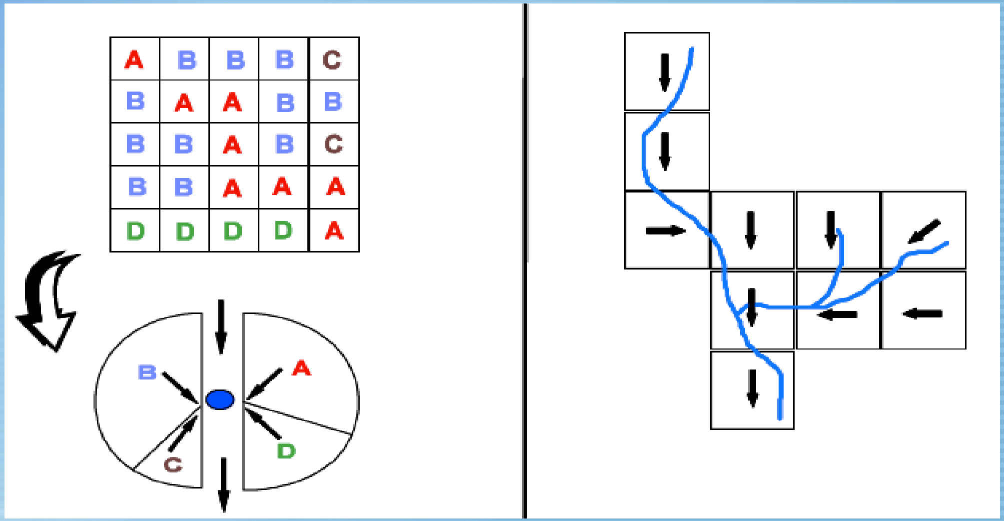


The watershed for the Marmot Creek basin

Big Grids



Lateral Connections through Streams



GRU Hydrology (1 → 50 km)
Hydrologic similarity by non-area specific land cover

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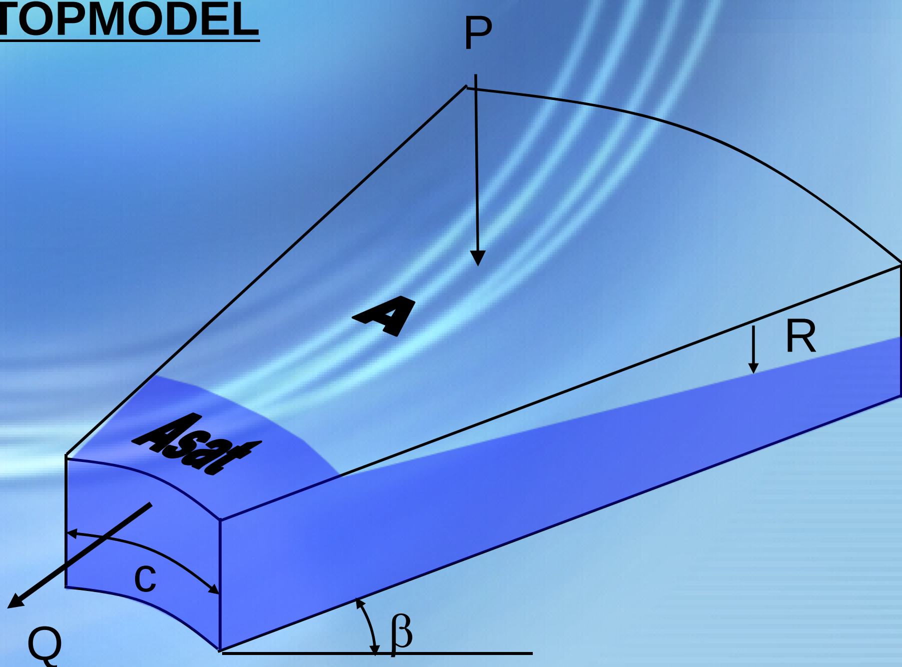
Little Grids

TOPMODEL



Continuity:

$$I - O = \frac{dS}{dt} = 0 \quad \text{(Steady Assumption)}$$

$$AR - Q = 0$$

$$Q = AR$$

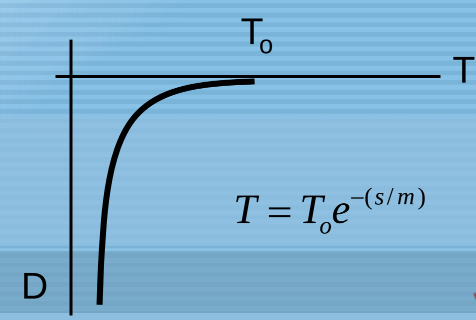
Darcy's Law:

$$q = K\frac{dh}{dx}$$

$$q(Dc) = K(Dc)\tan(\beta)$$

$$Q = Tc\tan(\beta)$$

Transmissivity vs Depth



s - soil moisture deficit

Problems:

Precipitation Uniform

Instantaneous Redistribution

Little Grids

$$AR = Q = Tc\tan(\beta)$$

$$\frac{AR}{c\tan(\beta)} = T_o e^{-(s/m)}$$

$$a = \frac{A}{c}$$ flow accumulation

$$\frac{Ra}{T_o\tan(\beta)} = e^{-(s/m)}$$

$$s = -m\left[\ln\left(\frac{R}{T_o}\right) + \ln\left(\frac{a}{\tan(\beta)}\right)\right]$$

$$\ln\left(\frac{a}{\tan(\beta)}\right)$$ - Topographic Index

$$\bar{s} = -m\left[\ln\left(\frac{R}{T_o}\right) + \lambda\right]$$

λ - Average Topographic Index

Simple Algebra

$$s_i - \bar{s} = -m\left[\ln\left(\frac{a}{\tan(\beta)}\right)_i - \lambda\right]$$

known from DEM

TOPMODEL
Linear Redistribution Equation ☺

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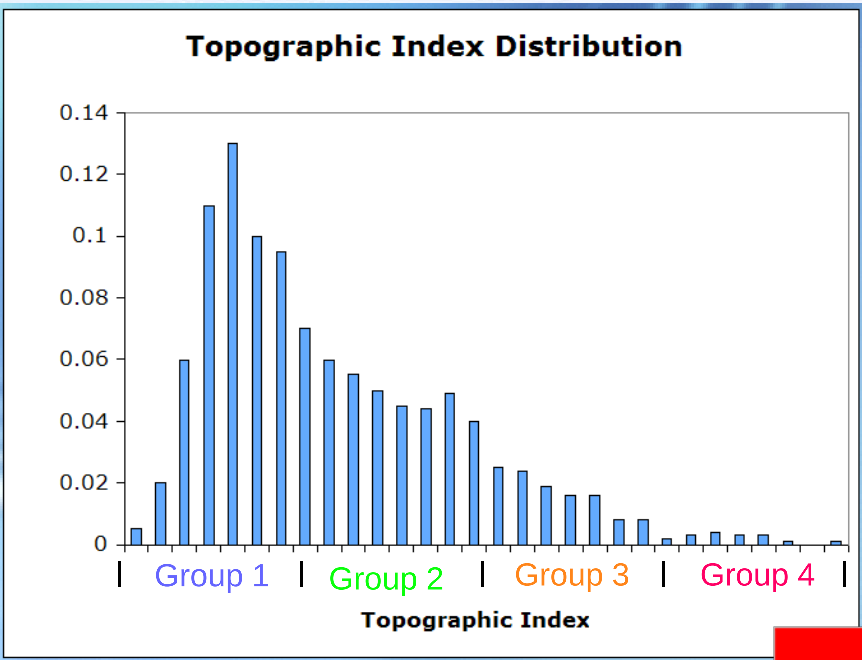
Little Grids

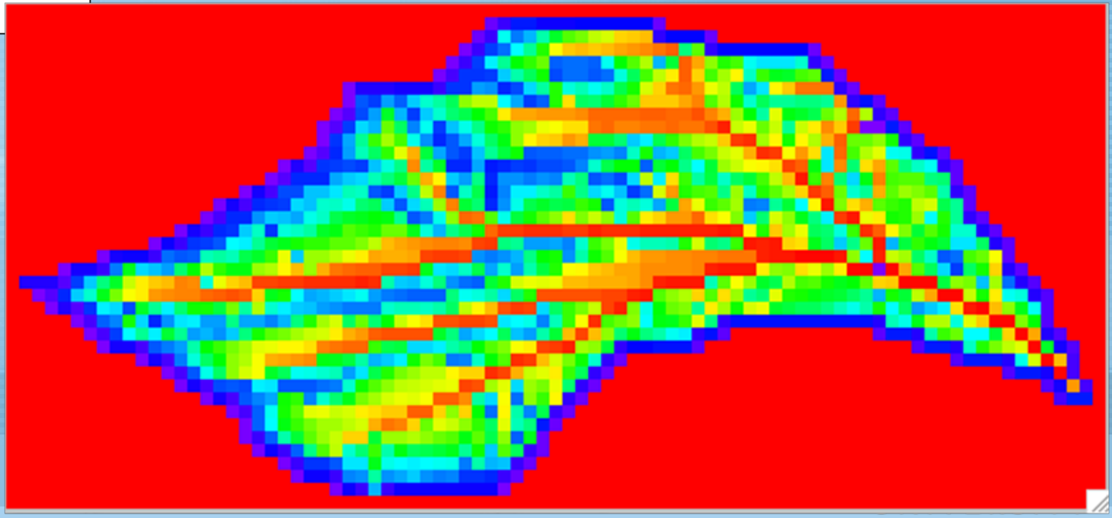


Hydrologic Similarity via Slope Position

Moisture Distribution via Average Storage

Measurable Parameters $[T_o, m, \ln(a/\tan(\beta))]$

Topographic Index
Marmot Creek



TOPMODEL

$$q_{total} = q_{Subsurface} + q_{overland}$$

Surface Flow Calculation (Saturated Area):

$$q_{overland} = \frac{A_{sat}}{A} p + q_{return}$$

where: Asat/A = the fraction of the hillslope area that is saturated [L]

p = throughfall or snowmelt rate $[LT^{-1}]$

q_{retur} = return flow $[LT^{-1}]$

Sub-surface Flow Calculation (Integrated Darcy's Law) :

$$q_{subsurface} = T_{max} e^{-\lambda} e^{-\frac{\bar{s}}{m}}$$

where: T_{max} = the transmissivity when soil is just saturated $[L^2T^{-1}]$

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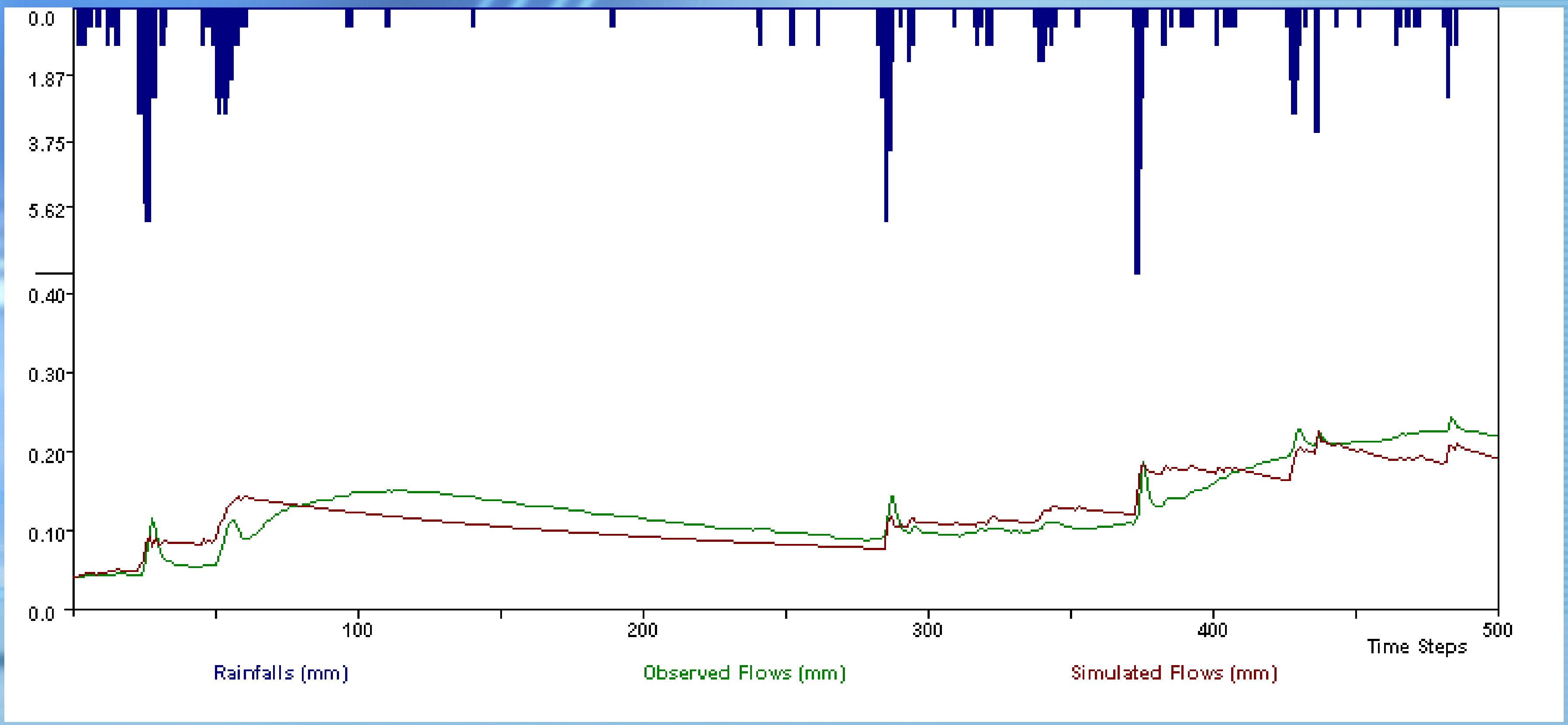
Result

Hydrograph Prediction by TOPMODEL (not Marmot Creek!):



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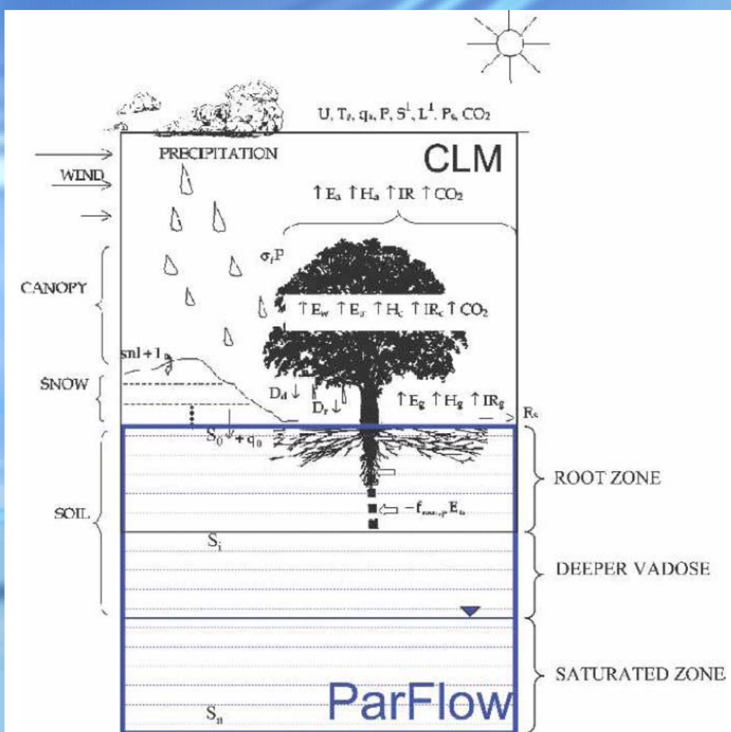
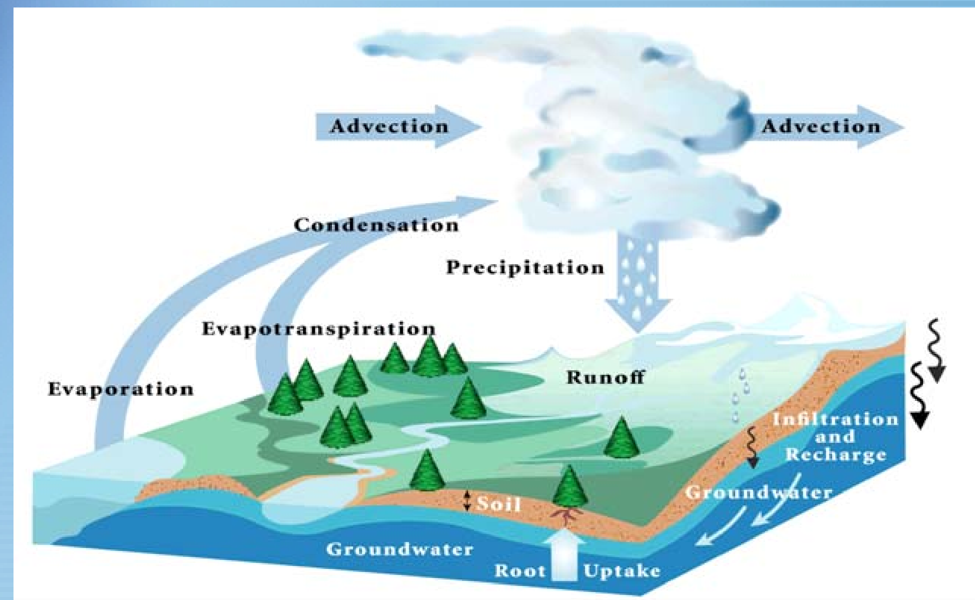
ParFlow





From:
Chow F.T., Kollet, S.J., Maxwell, R.M., and Duan, Q. (2006), Effects of soil moisture heterogeneity on boundary layer flow with coupled groundwater, land-surface, and mesoscale atmospheric modeling, AMS 17th Symposium on Boundary Layers and Turbulence, San Diego.

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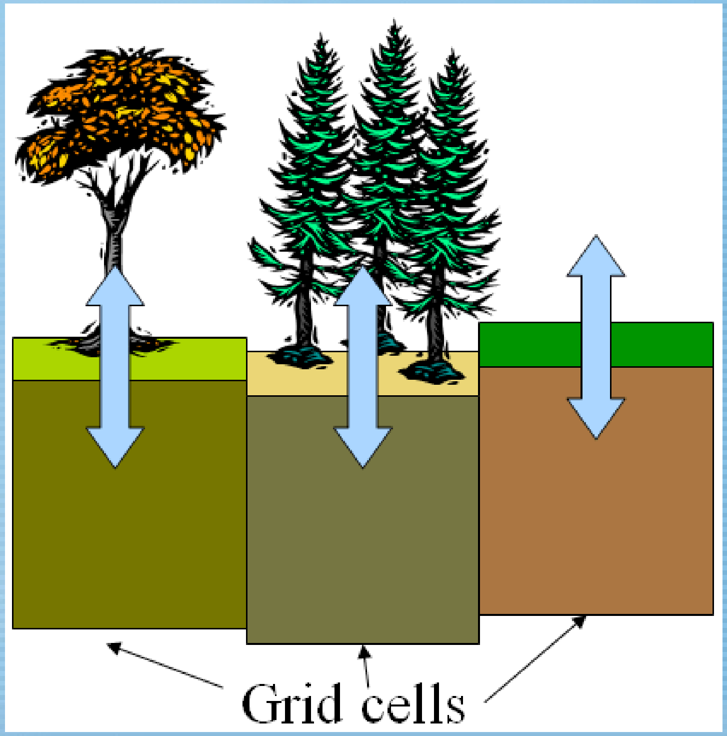
ParFlow

- Provides surface flux to atmosphere
- Vertical transport only
- No lateral subsurface communication
- No surface topography effect



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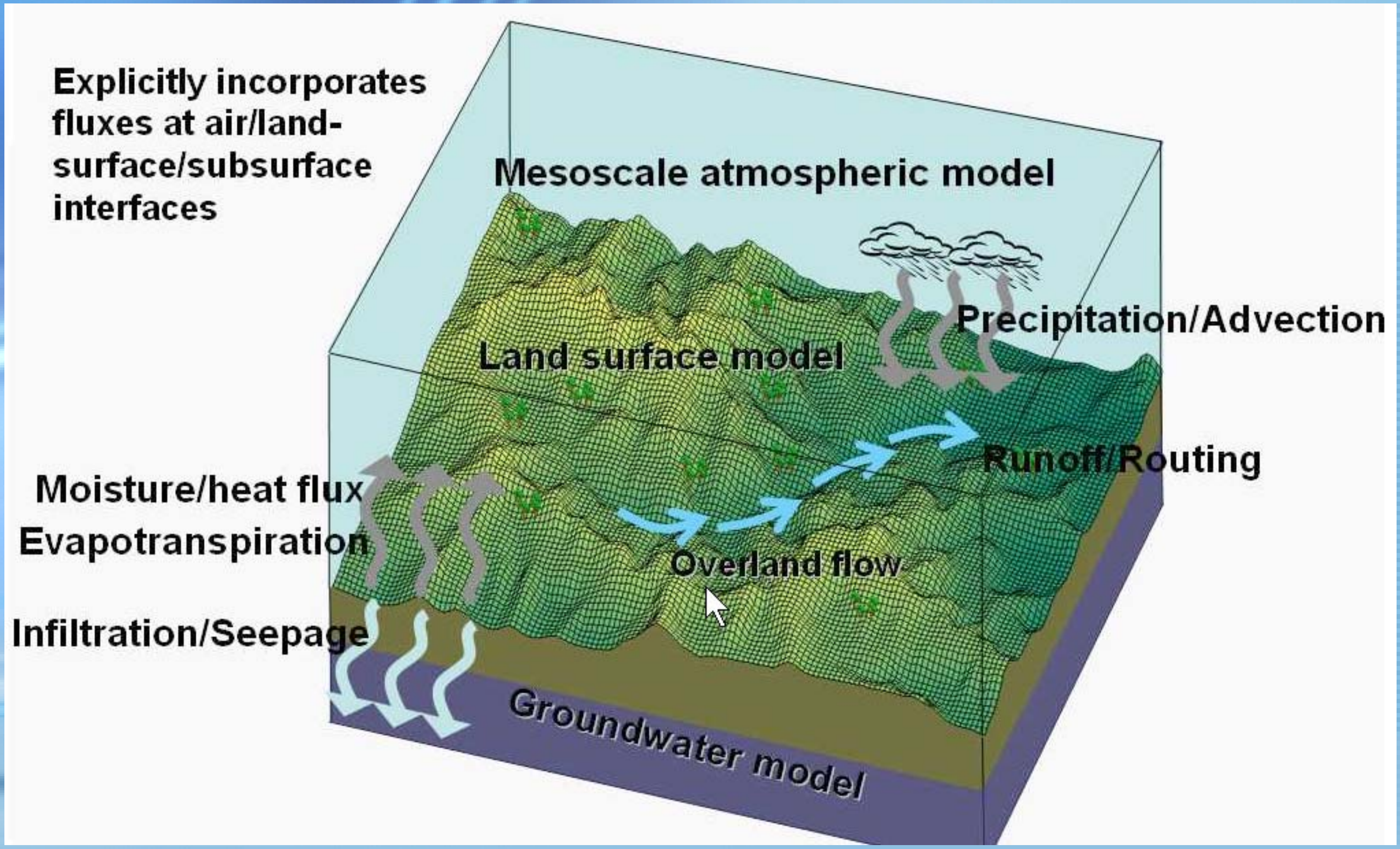
ParFlow Coupled Model



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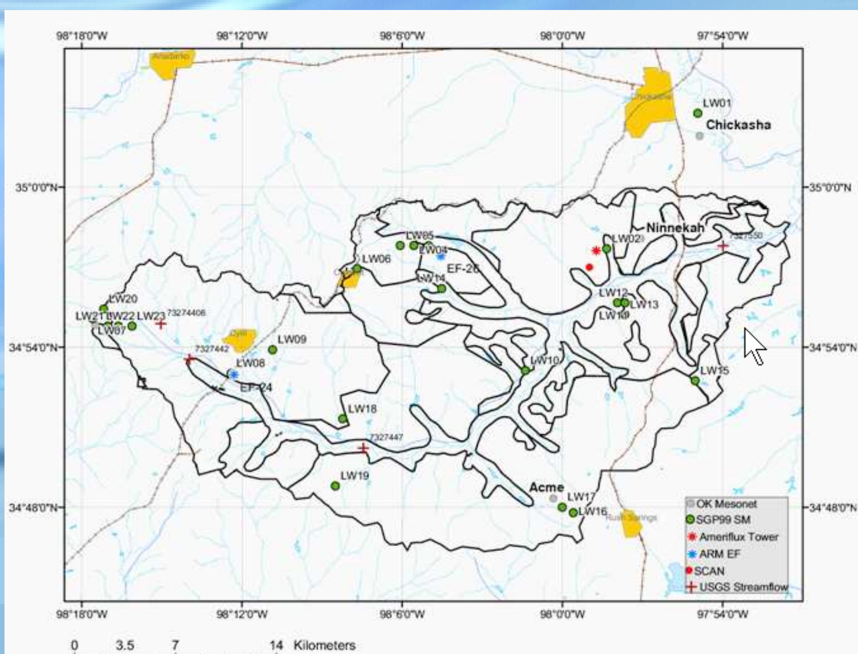
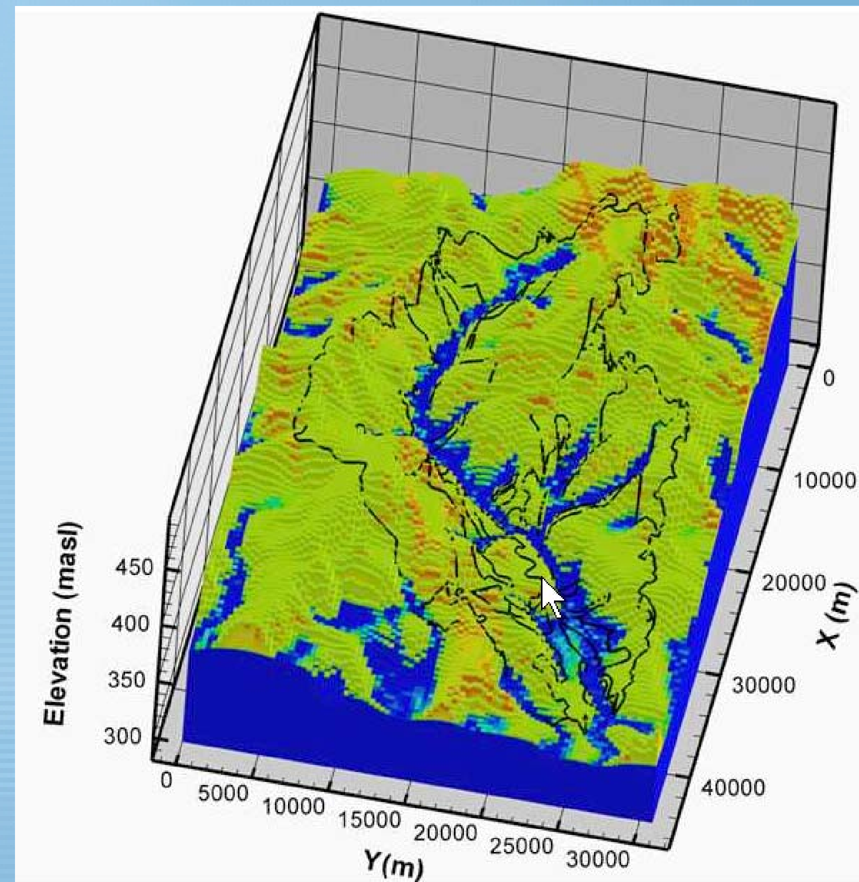
Little Washita Watershed Result





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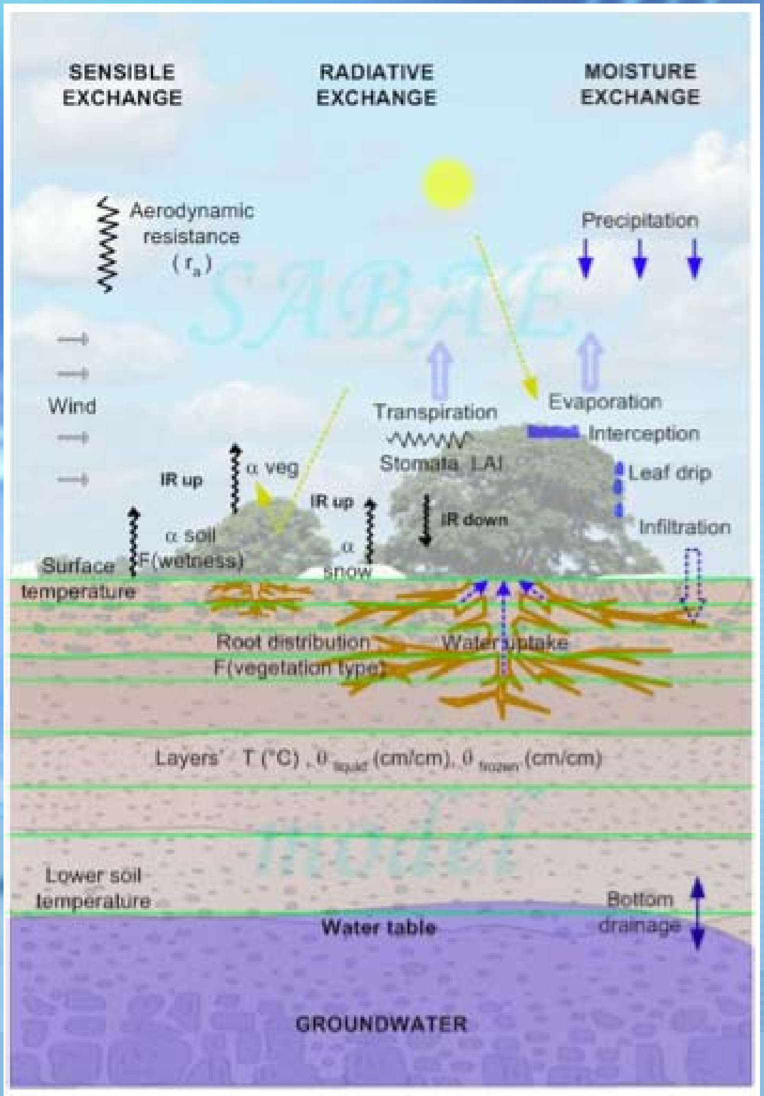
SABEA HW & GW



HW - Heat and Water

Built on CLASS
Extra Soil Layers to Impervious Surface
Efficient Implicit Energy Solution
Tests Against HYDRUS-1D and SHAW

GW - Groundwater

Quasi-3D Groundwater Solution
Less Costly than ParFlow
Development on-going
Testing on Assiniboine Delta Aquifier
Marmot Testing 🛠☺

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Conclusion

- Storage is key to hydrologic modeling - FEW MEASUREMENTS
- Topographic Index based hydrologic similarity - TILE CONNECTOR
- ParFlow explicitly models GW and SW - COMPUTATIONALLY EXPENSIVE
- SABEA enhancement for CLASS will add GW connection - NOW IN THE SHOP

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