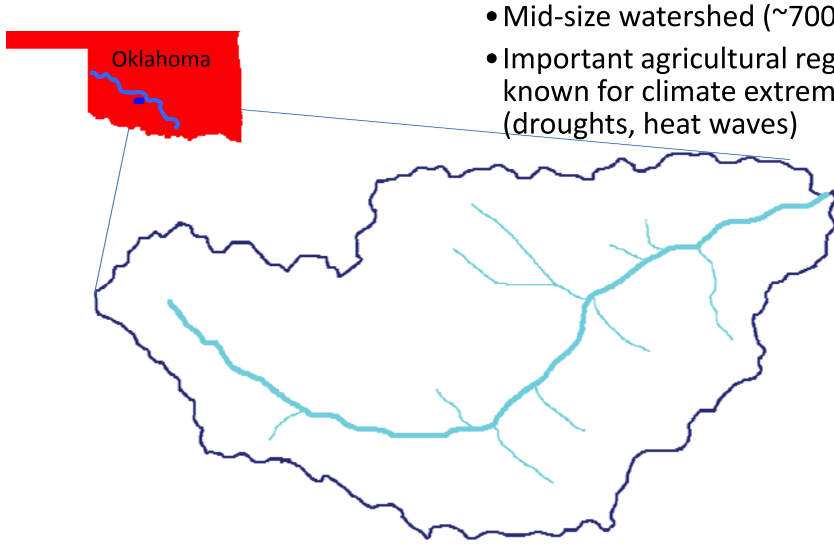
PARFLOW

Coupled Surface-Subsurface Simulation of the Little Washita River Watershed

– Detailed Example Problem –

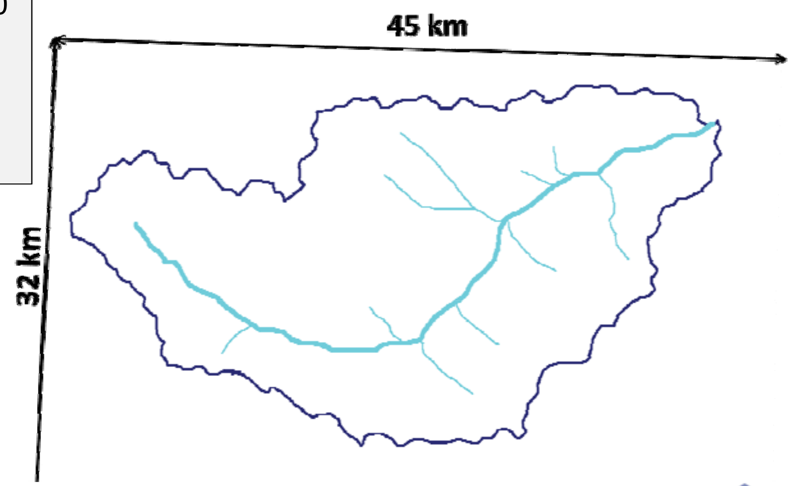
Study Site:

- Mid-size watershed (~700 km^2)
- Important agricultural region, known for climate extremes (droughts, heat waves)

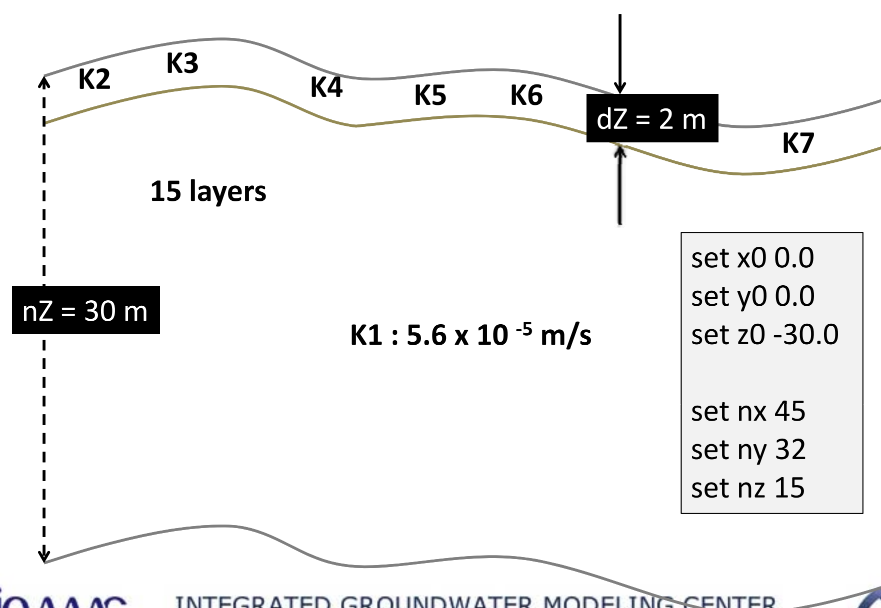


Creating the Model Domain:

```
set x0 0.0
set y0 0.0
set z0 -30.0

set nx 45
set ny 32
set nz 15
```

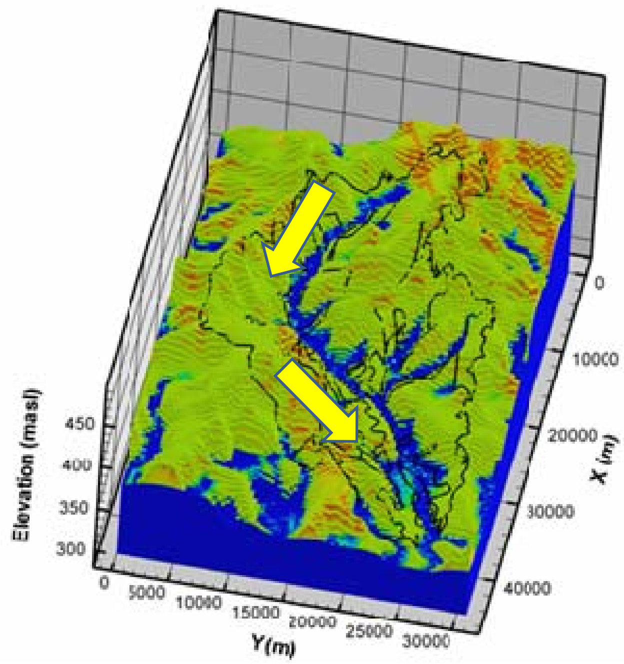


Creating the Model Domain:



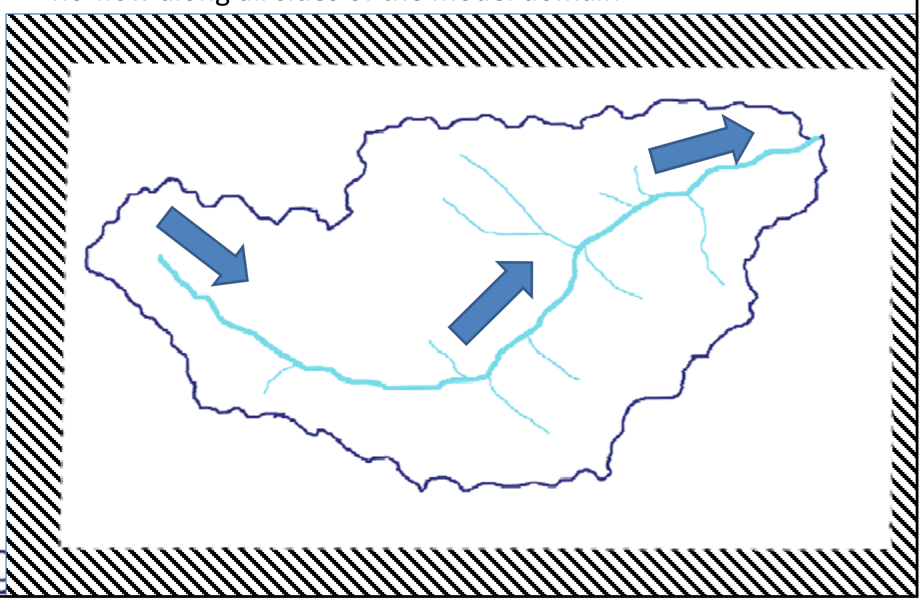

```
set x0 0.0
set y0 0.0
set z0 -30.0

set nx 45
set ny 32
set nz 15
```

https://computation.llnl.gov/casc/parflow/simulations.html



Creating the Model Domain:

- no-flow along all sides of the model domain



What we need:

1. ParFlow Inputs
   - Topographical slopes: assigned to the upper boundary of the domain
   - Soil Indicator: specify multiple soil types
2. CLM Inputs
   - drv_vegp.dat: vegetation parameter data file
   - drv_clmin.startup.dat: CLM parameters
   - drv_vegm.alluv.dat: specify vegetation type
   - Meteorological Forcings (narr_1hr.txt)

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Steps for processing the DEM:

Aditi Bhaskar, 2010 Getting Started with ParFlow: Dead Run, Baltimore, Maryland Example, CUERE Technical Report 2010/002

1. Download DEM file from USGS server
   http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/Elevation_Products
2. Re-project DEM to a projected coordinate system

   a. Open a blank map document in ArcMap.

   b. Click on "add data" button and add the DEM grid that was downloaded from the seamless server.

   c. Click on the ArcToolbox icon in ArcMap.
   d. In the ArcToolbox window, navigate to the project raster tool under Data Management Tools > Projections and Transformations > Raster > Project Raster.
   d. In the input raster field select the DEM file.
   e. Supply a name for output projected DEM file in the Output raster text input box.

   f. Click on the select output coordinate system button
   g. Click select and navigate to Projected Coordinate Systems click OK.
   The DEM should now be available as a raster in ArcMap.

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Steps for processing the DEM:

3. Resample the DEM

a. Add the spatial analyst toolbar by going to the Tools menu and selecting customize. Click on the Spatial Analyst check box.
b. In the Spatial Analyst toolbar make sure that the projected DEM file is selected in the dropdown box.
c. Click on Spatial Analyst > Options
d. Under the General Tab set the working directory to the folder where to the output files are to be saved.
e. Click on the extent tab and manually enter extent parameters
f. Click on the cell size tab and enter the desired cell size (choose as specified below) for the resampled grid.
i. In the Spatial Analyst toolbar, select the raster calculator tool.

The syntax for resampling is: <output grid> = resample([<input grid>], <cell size>, {NEAREST | BILINEAR | CUBIC | SEARCH})

j. Click "Evaluate".

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Steps for processing the DEM:

4. Convert DEM to ASCII

a. In the ArcToolBox window navigate to Conversion Tools > From Raster > Raster to ASCII.
b. In the input raster select the resampled raster.
c. Supply an output name for the ASCII file.
d. Click OK.

i	j	X	Y	Easting	Northing	Elevation
1	1	-950.00	-950.00	558450.00	3840550.00	363.569519
2	1	-850.00	-950.00	558550.00	3840550.00	363.770355
3	1	-750.00	-950.00	558650.00	3840550.00	364.596161
4	1	-650.00	-950.00	558750.00	3840550.00	364.286682
5	1	-550.00	-950.00	558850.00	3840550.00	363.293610
6	1	-450.00	-950.00	558950.00	3840550.00	367.486359
7	1	-350.00	-950.00	559050.00	3840550.00	372.024841
8	1	-250.00	-950.00	559150.00	3840550.00	375.873077
9	1	-150.00	-950.00	559250.00	3840550.00	376.186707
10	1	-50.00	-950.00	559350.00	3840550.00	371.107422
11	1	50.00	-950.00	559450.00	3840550.00	367.798615

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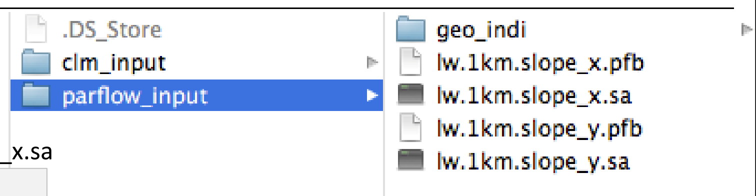
Topographical slopes:

1. Process DEM for ParFlow inputs
   - Read raw DEM, set grid info
     pfsetgrid {nx ny nz} {x0 y0 z0} {dx dy dz} $dem
   - Process flat areas (if any)
     set flatfill [pffillflats $dem]
   - Pit-fill to remove local minima/pits
     set pitfill [pfpitfilldem $dem 0.01 50]
   - Compute slopes
   - Save to txt, silo, and pfb
2. Example tcl script - CONUS.process_dem1000.tcl

Slope Files:

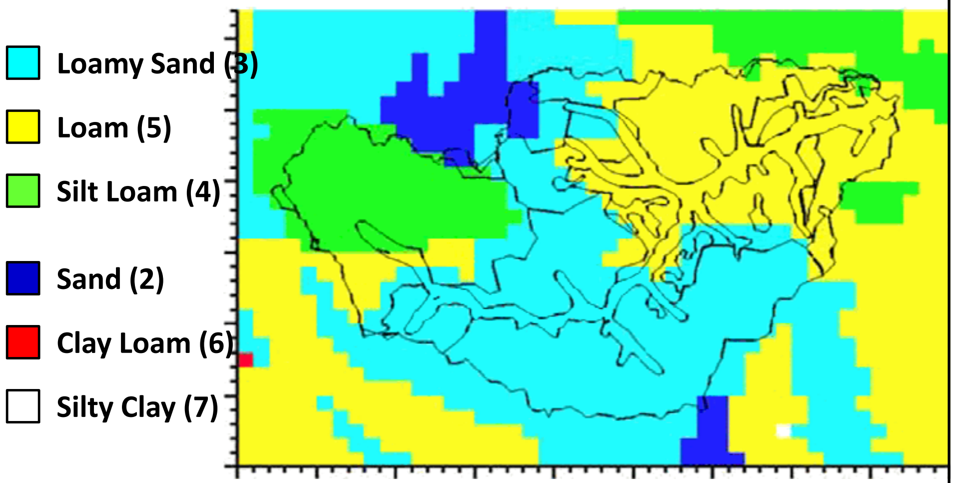


lw.1km.slope_x.sa

```
45  32  1
   -0.00548
   -0.00464
    0.00000
    0.00766
    0.00980
    0.00346
   -0.00378
   -0.00755
   -0.00809
    0.00000
    0.00288
    0.00160
   -0.00386
```

- The x and y slope in each cell is needed for the overland flow component of the model.
- negative slopes point ‘downhill’ and positive slopes ‘uphill’.

Soil Indicator File:



Kollet, S. J., and R. M. Maxwell (2008), Capturing the influence of groundwater dynamics on land surface processes using an integrated, distributed watershed model, Water Resour. Res., 44, W02402, doi:10.1029/2007WR006004

Soil Indicator File:

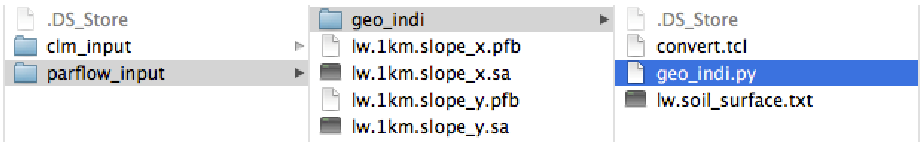
lw.soil_surface.txt

45	32	15
1	1	5
2	1	5
3	1	5
4	1	5
5	1	5
6	1	5
7	1	5
8	1	5
9	1	3
10	1	3
11	1	3

Assigned for 1440 cells

- Each indicator value is associated with a different set of hydrologic properties (e.g., porosity, permeability, and van Genuchten parameters)
- Indicator files must be in PFB format.

Soil Indicator File:



geo_indi.py (python script)

- Quick script to generate a 3D indicator field for Little Washita domain
- Use soil indicator values at land surface
- Assign uniform subsurface (below top layer)
- Create lw.geo_indi.sa

```
hseo@gc297-12:~$ cp -r ../pf_shortcourse/LW
hseo@gc297-12:~/LW/parflow_input$ cd geo_indi/
hseo@gc297-12:~/LW/parflow_input/geo_indi.py$ python geo_indi.py
```


Soil Indicator File:

- *lw.geo_indi.sa* has soil info for 21600 cells.
- Use convert.tcl (convert ascii file to silo & pfb)

```
lappend auto_path $env(PARFLOW_DIR)/bin
package require parflow
namespace import Parflow::*

set fname    "lw.geo_indi.sa"
set indi     [pfload $fname]

pfsetgrid {45 32 15} {0.0 0.0 -30} {1000.0 1000.0 2} $indi
pfsave $indi -silo "lw.geo_indi.silo"
pfsave $indi -pfb  "lw.geo_indi.pfb"
```

Run wasita01.tcl (without CLM part) – takes about 20min

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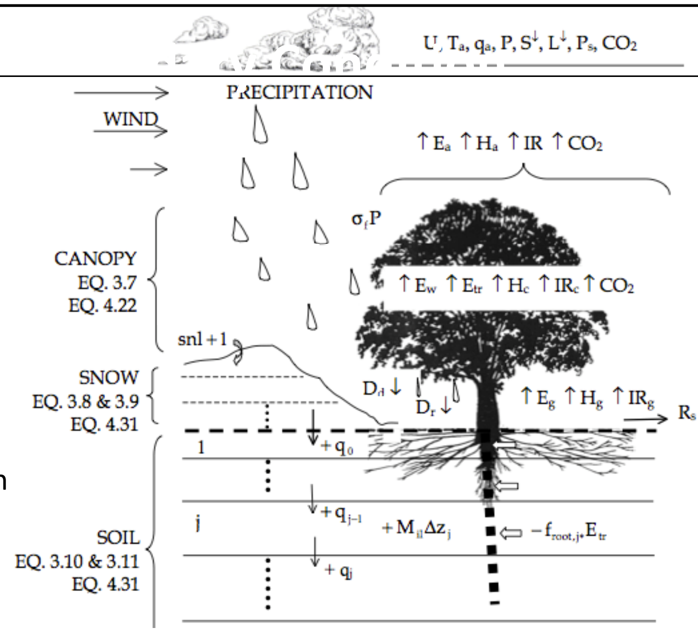
CLM

- Structure of the CLM model. CLM has one vegetation layer, ten soil layers and up to 5 snow layers depending on the snow depth.



Technical Documentation and User's Guide

http://igwmc.mines.edu/short-course/ParFlow/clm_user_guide.pdf

CLM Inputs: drv_clmin.dat

- Define CLM parameters

```
nc              45   Number of Columns in Grid
nr              32   Number of Rows in Grid
nt              18   Number of Vegetation Types (18 for IGBP)
maxt            1    Maximum tiles per grid (originally 3;
                     changed it, becasue we have one type per cell)
mina            0.05    Min grid area for tile (%)
udef            -9999.  Undefined value
vclass          2       Vegetation Classification Scheme
                      (1=UMD,2=IGBP,etc.) NOT the index
vegtf      drv_vegm.alluv.dat Vegetation Tile Specification File
vegpf      drv_vegp.dat       Vegetation Type Parameter
metf1d     narr_1hr.dat       Meterologic input file- valdai 3 hr
outf1d     clm_out.txt        CLM output file
poutf1d    clm_para_out.dat   CLM 1D Parameter Output File
rstf       clm.rst.           CLM active restart file
```

CLM Inputs: drv_vegp.dat

Vegetation parameter data file for IGBP Land Cover Types

- Water type
- Max/Min leaf area index
- Stem area index
- Aerodynamic roughness length
- Displacement height
- Leaf dimension
- etc

! 1 evergreen needleleaf forests
! 2 evergreen broadleaf forests
! 3 deciduous needleleaf forests
! 4 deciduous broadleaf forests
! 5 mixed forests
! 6 closed shrublands
! 7 open shrublands
! 8 woody savannas
! 9 svannas
! 10 grasslands
! 11 permanent wetlands
! 12 croplands
! 13 urban and built-up lands
! 14 cropland / natural vegetation mosaics
! 15 snow and ice
! 16 barren or sparsely vegetated
! 17 water bodies
! 18 bare soil

CLM Inputs: drv_vegm.alluv.dat

IGBP land cover classes

x	y	lat	lon	sand	clay	color	fractional coverage of grid by vegetation class (Must/Should Add to 1.0)																	
		(Deg)	(Deg)	(%/100)		index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1	34.750	-98.138	.16	.26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	0	0	40	0	0	313	0	0	900	0	183	0	0	0	0	0	0
0.28%			3%			21.74%			62.50%		12.71%						

* 10 - grasslands, 7- open shrublands, 12 - croplands

CLM Inputs: Meteorological Forcings

- narr_1hr.txt (from North American Regional Reanalysis data set) - Single text file with eight columns (one per variable)
- Columns must be ordered as shown below

DSWR	DLWR	APCP	Temp	UGRD	VGRD	Press	SPFH
202.1561737	377.2239075	0.0000013	299.5496521	-0.4811662	1.9399214	96823.0000000	0.0107270
404.3123474	390.3383484	0.0000006	302.3895874	-0.1488854	1.2980552	96797.3984375	0.0107364
606.4685059	403.4527588	0.0000000	305.2294922	0.1833954	0.6561890	96771.7968750	0.0107457
724.0780029	417.3330994	0.0000000	306.9219971	-0.5513973	0.4200338	96785.6953125	0.0101042
841.6875000	431.2134094	0.0000000	308.6145020	-1.2861899	0.1838786	96799.6015625	0.0094627
959.2969971	445.0937500	0.0000000	310.3070068	-2.0209825	-0.0522766	96813.5000000	0.0088212
897.8647461	445.3592529	0.0000026	310.8130188	-2.4682891	-0.1502635	96726.8359375	0.0086115
836.4324951	445.6247559	0.0000052	311.3190002	-2.9155958	-0.2482504	96640.1640625	0.0084018
775.0002441	445.8902588	0.0000078	311.8250122	-3.3629024	-0.3462372	96553.5000000	0.0081921
559.6094971	439.3017578	0.0000055	311.2347717	-3.1434541	-0.3865510	96567.5000000	0.0081576
344.2187500	432.7132568	0.0000033	310.6445007	-2.9240057	-0.4268647	96581.5000000	0.0081231
128.8280029	426.1247559	0.0000011	310.0542603	-2.7045574	-0.4671785	96595.5000000	0.0080886

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CLM Inputs: Meteorological Forcings

- Variable Names

DSWR: Short wave radiation [W/m^2]
DLWR: Long wave radiation [W/m^2]
APCP: Precipitation rate [mm/s]
Temp: Air temperature [K]
UGRD: East-west wind speed [m/s]
VGRD: North-south wind speed [m/s]
Press: Air pressure [Pa]
SPFH: Specific humidity [kg/kg]

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Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Processor topology(P=x-direction,Q=y-direction,R=z-direction)
#-----------------------------------------------------------------
pfset Process.Topology.P                    1
pfset Process.Topology.Q                    1
pfset Process.Topology.R                    1
#-----------------------------------------------------------------
# Computational Grid
#-----------------------------------------------------------------
pfset ComputationalGrid.Lower.X             0.0
pfset ComputationalGrid.Lower.Y             0.0
pfset ComputationalGrid.Lower.Z            -30.0

pfset ComputationalGrid.NX                  45
pfset ComputationalGrid.NY                  32
pfset ComputationalGrid.NZ                  15

pfset ComputationalGrid.DX                  1000.0
pfset ComputationalGrid.DY                  1000.0
pfset ComputationalGrid.DZ                  2.0
```

Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Domain
#-----------------------------------------------------------------
pfset Domain.GeomName                  "domain"
```

→Define Domain Geometry

```
#-----------------------------------------------------------------
# Names of the GeomInputs
#-----------------------------------------------------------------
pfset GeomInput.Names                  "box_input indi_input"
```

InputType - Box

InputType - IndicatorField

- Geometries types
  - Box
  - SolidFile
  - IndicatorField

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Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Indicator Geometry Input
#-----------------------------------------------------------------
pfset GeomInput.indi_input.InputType      IndicatorField
pfset GeomInput.indi_input.GeomNames      "F1 F2 F3 F4 F5 F6 F7"
pfset Geom.indi_input.FileName            "lw.geo_indi.pfb"
```

Soil Indicator File

```
pfset GeomInput.F1.Value          1
pfset GeomInput.F2.Value          2
pfset GeomInput.F3.Value          3
pfset GeomInput.F4.Value          4
pfset GeomInput.F5.Value          5
pfset GeomInput.F6.Value          6
pfset GeomInput.F7.Value          7
```

1 → Uniform subsurface

2–7 → Soil categories at land surface (top cell) (six surface soil types in domain)

Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Permeability (values in m/hr)
#-----------------------------------------------------------------
pfset Geom.Perm.Names                 "domain F1 F2 F3 F4 F5 F6 F7"

pfset Geom.domain.Perm.Type           Constant
pfset Geom.domain.Perm.Value          0.2
pfset Geom.F1.Perm.Type               Constant
pfset Geom.F1.Perm.Value              0.2
pfset Geom.F2.Perm.Type               Constant
pfset Geom.F2.Perm.Value              0.21
pfset Geom.F3.Perm.Type               Constant
pfset Geom.F3.Perm.Value              0.0141
pfset Geom.F4.Perm.Type               Constant
pfset Geom.F4.Perm.Value              0.00457
pfset Geom.F5.Perm.Type               Constant
pfset Geom.F5.Perm.Value              0.0041
pfset Geom.F6.Perm.Type               Constant
pfset Geom.F6.Perm.Value              0.00195
pfset Geom.F7.Perm.Type               Constant
pfset Geom.F7.Perm.Value              0.0141
```

Set parameters individually for each geometry

Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Boundary Conditions
#-----------------------------------------------------------------
pfset BCPressure.PatchNames          [pfget Geom.domain.Patches]

pfset Patch.x-lower.BCPressure.Type            FluxConst
pfset Patch.x-lower.BCPressure.Cycle           "constant"
pfset Patch.x-lower.BCPressure.alltime.Value          0.0

y-lower
Z-lower
X-upper
Y-upper

pfset Patch.z-upper.BCPressure.Type            OverlandFlow
pfset Patch.z-upper.BCPressure.Cycle           "constant"
pfset Patch.z-upper.BCPressure.Cycle           "rainrec"
pfset Patch.z-upper.BCPressure.rain.Value         -0.005
pfset Patch.z-upper.BCPressure.rec.Value       0.00000
```

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Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------------
# Timing (time units is set by units of permeability)
#-----------------------------------------------------------------
pfset TimingInfo.BaseUnit                  1.0
pfset TimingInfo.StartCount                0.0
pfset TimingInfo.StartTime                 0.0
pfset TimingInfo.StopTime                  500
pfset TimingInfo.DumpInterval              -1
pfset TimeStep.Type                        Constant
pfset TimeStep.Value                       1.0
#-----------------------------------------------------------------
# Time Cycles
#-----------------------------------------------------------------
pfset Cycle.Names                          "constant rainrec"
pfset Cycle.constant.Names                 "alltime"
pfset Cycle.constant.alltime.Length         1
pfset Cycle.constant.Repeat                -1
pfset Cycle.rainrec.Names                  "rain rec"
pfset Cycle.rainrec.rain.Length            10
pfset Cycle.rainrec.rec.Length             10
pfset Cycle.rainrec.Repeat                 -1
```

Setting up the ParFlow Run Script:

```
#-----------------------------------------------------------
# Initial conditions (example file - washita01.tcl)
#-----------------------------------------------------------
pfset ICPressure.Type                              HydroStaticPatch
pfset ICPressure.GeomNames                               domain
pfset Geom.domain.ICPressure.Value                        -5.0
pfset Geom.domain.ICPressure.RefGeom                     domain
pfset Geom.domain.ICPressure.RefPatch                    z-upper


#-----------------------------------------------------------
# Initial conditions (example file - washita02.tcl)
#-----------------------------------------------------------
pfset ICPressure.Type                                    PFBFile
pfset ICPressure.GeomNames                               domain
pfset Geom.domain.ICPressure.FileName  fname.out.press.00400.pfb
```


Setting up the ParFlow Run Script:

Overland Flow Parameters – Slopes, Mannings

```
#-----------------------------------------------------------------
# Topo slopes in y-direction
#-----------------------------------------------------------------
set    sy    [pfload lw.1km.slope_y.sa]

pfset TopoSlopesY.Type                                   "PFBFile"
pfset TopoSlopesY.GeomNames                              "domain"
pfset TopoSlopesY.FileName                    "lw.1km.slope_y.pfb"


#-----------------------------------------------------------------
# Mannings coefficient
#-----------------------------------------------------------------
pfset Mannings.Type                                      "Constant"
pfset Mannings.GeomNames                                 "domain"
pfset Mannings.Geom.domain.Value                         5.52e-6
```

Slopes specified from PFB files generated before

Mannings coef. Specified as constant over domain

Setting up the ParFlow Run Script:

Solver Settings for Subsurface & Overland Flow

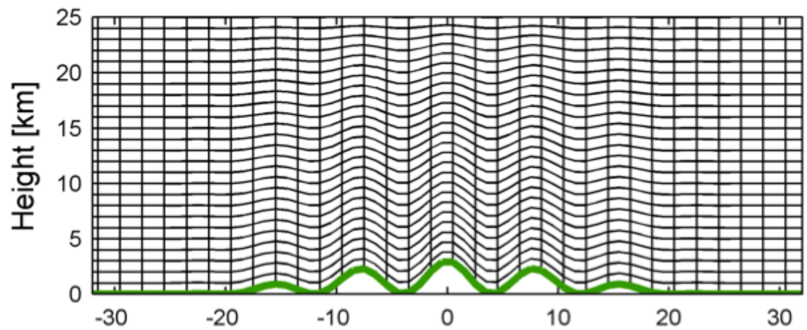
```
pfset Solver                                              Richards
pfset Solver.TerrainFollowingGrid                         True
pfset Solver.Nonlinear.VariableDz                         False
pfset Solver.MaxIter                                      25000
pfset Solver.Drop                                         1E-20
pfset Solver.AbsTol                                       1E-8
pfset Solver.MaxConvergenceFailures                       8

# new solver settings for Terrain Following Grid
pfset Solver.Nonlinear.EtaChoice                         EtaConstant
pfset Solver.Nonlinear.EtaValue                              0.001
pfset Solver.Nonlinear.UseJacobian                           True
pfset Solver.Nonlinear.DerivativeEpsilon                     1e-16
pfset Solver.Nonlinear.StepTol                            1e-30
pfset Solver.Nonlinear.Globalization                      LineSearch
pfset Solver.Linear.KrylovDimension                          70
pfset Solver.Linear.MaxRestarts                               2
pfset Solver.Linear.Preconditioner                           PFMG
pfset Solver.Linear.Preconditioner.PCMatrixType         FullJacobian
```

Terrain-following Grid:

The four lateral boundaries of each finite volume are perpendicular to *x* and *y* axes, and the two vertical boundaries are not purely horizontal.

The coordinate system defines the vertical position of a point in the atmosphere as a ratio of the pressure difference between that point and the top of the domain to that of the pressure difference between a fundamental base below the point and the top of the domain.



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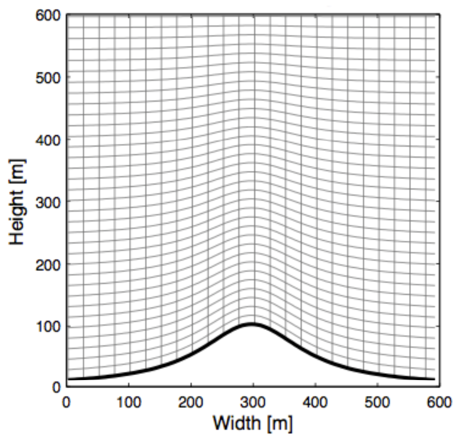
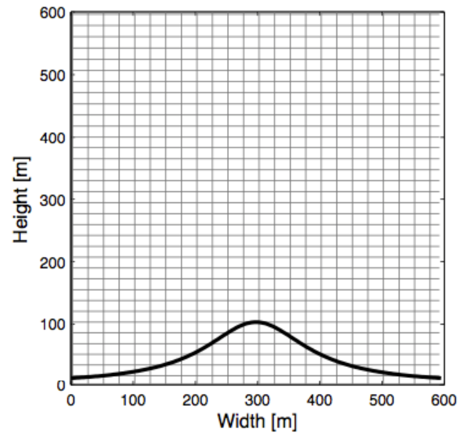
Setting up the ParFlow Run Script:



Terrain-following grid



General grid

Katherine Ann Lundquist (2010) Immersed Boundary Methods for High-Resolution Simulation of Atmospheric Boundary-Layer Flow Over Complex Terrain

Setting up the ParFlow Run Script:

```
pfset Solver.Nonlinear.VariableDz            True

pfset dzScale.GeomNames                      domain
pfset dzScale.Type                           nzList
pfset dzScale.nzListNumber                   15

pfset Cell.0.dzScale.Value 1.0
pfset Cell.1.dzScale.Value 1.0
pfset Cell.2.dzScale.Value 1.0
pfset Cell.3.dzScale.Value 1.0
pfset Cell.4.dzScale.Value 1.0
pfset Cell.5.dzScale.Value 1.0
pfset Cell.6.dzScale.Value 1.0
pfset Cell.7.dzScale.Value 1.0
pfset Cell.8.dzScale.Value 1.0
pfset Cell.9.dzScale.Value 1.0
pfset Cell.10.dzScale.Value 1.0
pfset Cell.11.dzScale.Value 1.0
pfset Cell.12.dzScale.Value 1.0
pfset Cell.13.dzScale.Value 1.0
pfset Cell.14.dzScale.Value 0.2
```

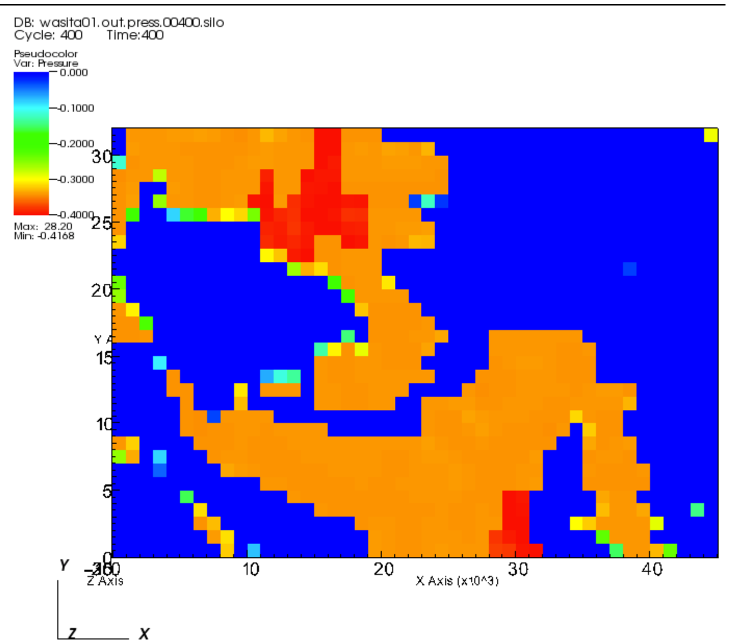
Thickness of top layer 0.2*2=0.4m

Setting up the ParFlow Run Script:

Solver Settings for CLM Land Surface Model

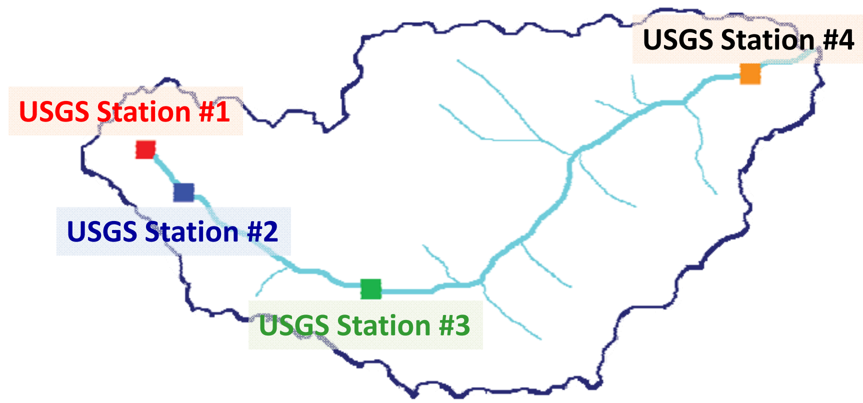
```
pfset Solver.LSM                                CLM
pfset Solver.CLM.CLMFileDir                   "clm_output/"
pfset Solver.CLM.Print1dOut                     False
pfset Solver.BinaryOutDir                       False
pfset Solver.CLM.CLMDumpInterval                24

# Evap and veg stress functions/parameters
pfset Solver.CLM.EvapBeta                       Linear
pfset Solver.CLM.VegWaterStress                 Pressure
pfset Solver.CLM.ResSat                         0.1
pfset Solver.CLM.WiltingPoint                   0.12
pfset Solver.CLM.FieldCapacity                  0.98
pfset Solver.CLM.IrrigationType                 none

# Met forcing
pfset Solver.CLM.MetForcing                     1D
pfset Solver.CLM.MetFileName                  narr_1hr.txt
pfset Solver.CLM.MetFilePath                    ./
pfset Solver.CLM.IstepStart                      1
```

In VisIt:



Use Observations: (wasita02.tcl)

USGS Streamflow Stations



Total 1460 Observations

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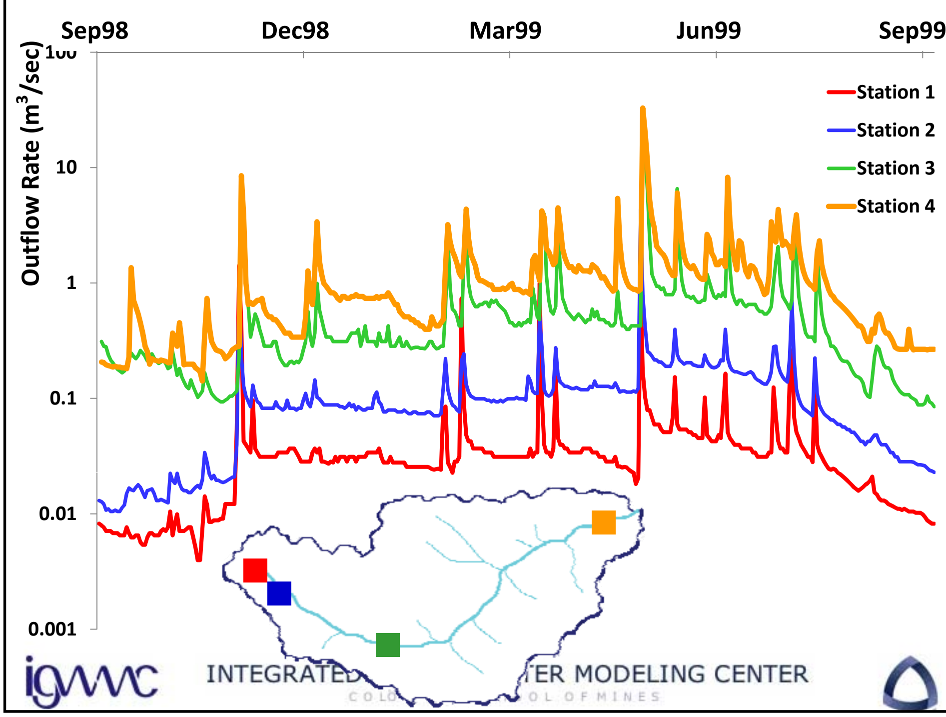

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Calculate Flow:

$$Q = vA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S}$$

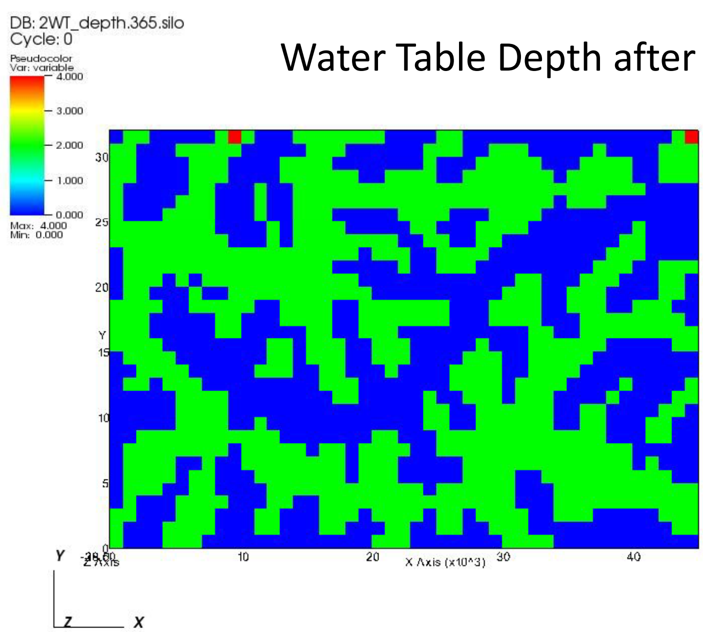
Q = Flow Rate (m^3/hr)
v=Velocity (m/hr)
A = m^2
n=Manning's Roughness Coefficient
R=Hydraulic Radius (m)
S=Channel Slope (m/m)

Flow Observation File:

fobs_location.txt

```
4 ← # of observation points
4  19 ← location of station 1
6  17
16 10
36 25
```


Water Table Depth after Spin-up



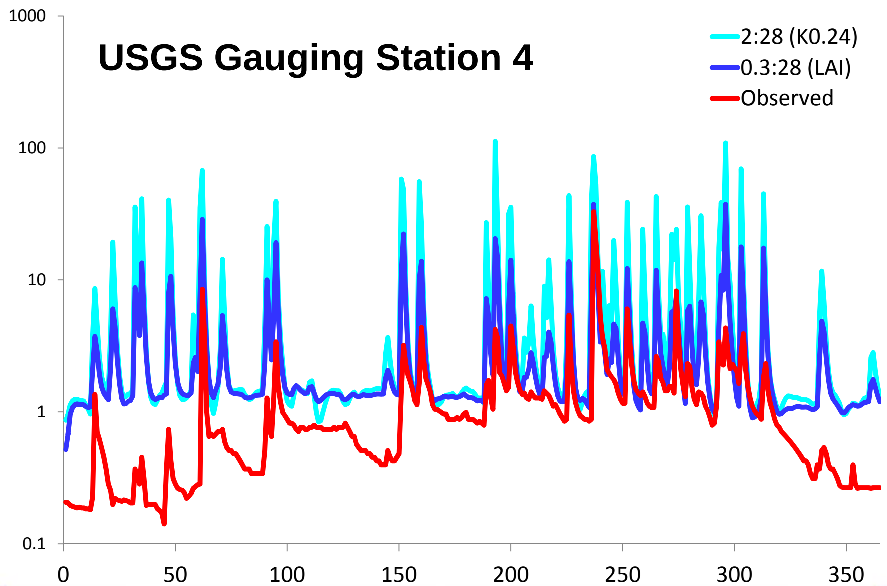
user: hseo
Sat Mar 17 23:35:31 2012

After ParFlow Run :

- Look at the output files
  lw_obs_out.txt – flow rate at oberservations

```
calculated flow at USGS station 1 = 0.0
calculated flow at USGS station 1 = 0.004114160528892156
calculated flow at USGS station 1 = 0.005859932115971816
calculated flow at USGS station 1 = 0.00592805737780334
calculated flow at USGS station 1 = 0.006153406214090841
calculated flow at USGS station 1 = 0.006118666773569936
calculated flow at USGS station 1 = 0.006320227377556771
calculated flow at USGS station 1 = 0.0064684472828943455
calculated flow at USGS station 1 = 0.006249467187500599
calculated flow at USGS station 1 = 0.005655035141241339
calculated flow at USGS station 2 = 0.0044867083536024996
```


Comparison:



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