VIC Hydrology Model Training Workshop – Part III: Application of VIC Model

Ed Maurer, Civil Engineering Department, Santa Clara University

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Introduction:

In this section of the workshop, we will walk through a rudimentary implementation of the VIC model. This is only for example.

1) Opening and exploring the basic VIC model setup

From the workshop website, download the VIC model setup, and unzip it. There should be several subdirectories: code/ met/ output/ params/ route/ run/ utils/

The names and locations of these are arbitrary, and can be changed to whatever is most logical for your system.

First, go into the params/ directory.

vic_taller/vic_model$ **cd params**

And list the files.

vic_taller/vic_model/params$ **ls**

You'll see four of the essential files needed to run VIC:

- mataquito_0.25.snowbands
- mataquito_0.25.soil

- mataquito_0.25.veg
- world_veg_lib.txt

You should be familiar with what these contain, and you can open each to ensure it does contain what you expect. These are all readable text files that can be opened with Excel, gedit, notepad++. If you do use Excel, be careful if you save it again, because Windows-based programs add hidden characters to these text files that can disrupt the ability of VIC to read them correctly.

A quick check on the soil file can be done using word count:

vic_taller/vic_model/params$ **wc mataquito_0.25.soil**

  23 1242 11840 mataquito_0.25.soil

This says there are 23 rows in the file, indicating 23 VIC grid cells. There are 1242/23=54 columns. You can verify that this is correct by using the UW VIC web site soil file definition: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Documentation/SoilParam.shtml

You can also scan through some of the parameters to see if they make sense. The first column of the soil file states whether VIC is to run that cell.

Next look at the vegetation parameter file:

vic_taller/vic_model/params$ **less mataquito_0.25.veg**

```
ccg07@ccg07-desktop: ~/projects/chile/docs/vic_taller/vic_model/params
5068 4
1 0.251111 0.300000 0.300000 0.700000 0.700000
6.000000 6.000000 6.000000 6.000000 5.699999 5.565791 5.732083 6.000000 6.000000 6.000000 6.000000 6.000000
2 0.034444 0.300000 0.300000 0.700000 0.700000
6.000000 6.000000 6.000000 6.000000 5.700000 5.447369 5.747500 6.000000 6.000000 6.000000 6.000000 6.000000
6 0.202222 0.300000 0.600000 0.700000 0.400000
5.475410 5.573935 5.567847 5.452448 5.199136 5.045548 5.213412 5.475410 5.475410 5.475410 5.475410 5.475300
7 0.027778 0.300000 0.600000 0.700000 0.400000
5.475410 5.573935 5.567847 5.452448 5.199136 5.045548 5.213412 5.475410 5.475410 5.475410 5.475410 5.475300
5069 5
1 0.084444 0.300000 0.300000 0.700000 0.700000
5.897680 5.906667 5.903360 5.891440 5.635257 5.488247 5.653148 5.934427 5.940106 5.948400 5.932987 5.916106
2 0.020000 0.300000 0.300000 0.700000 0.700000
6.000000 6.000000 6.000000 6.000000 5.699999 5.407895 5.686251 6.000000 6.000000 6.000000 6.000000 6.000000
6 0.740000 0.300000 0.600000 0.700000 0.400000
5.122737 5.167052 5.124737 5.054842 5.008736 4.909253 5.122105 5.413474 5.417894 5.454421 5.355263 5.178737
7 0.116667 0.300000 0.600000 0.700000 0.400000
5.262667 4.844667 4.734000 4.898000 4.692000 4.750877 4.895333 5.067333 5.111333 5.276000 5.043334 5.070667
10 0.014444 0.300000 0.800000 0.700000 0.200000
5.368617 5.347821 5.315614 5.270926 5.071049 4.953595 5.123367 5.394828 5.405867 5.447764 5.378316 5.344995
5070 5
6 0.455556 0.300000 0.600000 0.700000 0.400000
5.267720 5.239160 5.227400 5.207800 5.125719 5.019243 5.207919 5.483240 5.526640 5.611119 5.577520 5.374440
:
```

How many root zones have been specified? Typically how many different vegetation types are there in each grid cell? Is global LAI specified? You will need some of this information later. As above, you can find details of the file contents at: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Documentation/VegParam.shtml

Likewise, look at the snowbands (elevation bands) file:

vic_taller/vic_model/params$ **less mataquito_0.25.snowbands**

```
ccg07@ccg07-desktop: ~/projects/chile/docs/vic_taller/vic_model/params
5068 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
5069 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
5070 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
5071 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
5072 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
5073 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
5074 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
5075 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4929 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
4930 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
4931 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
4932 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
4933 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
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4935 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4936 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4798 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
4799 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
4800 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4801 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4676 0.000 0.000 0.000 0.000 0.000 0.000 0.880 0.000 0.000 0.120 0.00 0.00 0.00 0.00 0.00 0.00 124.65 0.00 0.00 188.01 0.000 0.000 0.000 0.000 0.000 0.000 0.829 0.000 0.000 0.171
4677 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
4678 0.000 0.040 0.200 0.120 0.200 0.080 0.200 0.080 0.040 0.040 0.00 977.47 1274.26 1529.93 1695.31 1909.22 2135.04 2404.04 2531.94 2863.43 0.000 0.022 0.141 0.102 0.188 0.085 0.237 0.107 0.056 0.063
(END)
```

There is a lot of information in this file, but you should be able to determine quickly 1) how many cells are represented in the file; 2) how many elevation bands are included, and 3) whether precipitation is expected to vary with elevation. Item 2 is important at this point, as it needs to be input to the global control file when running VIC.

The final input parameter file is the vegetation library world_veg_lib.txt, the format of which is also described on the UW website.

Now navigate to the met file directory

vic_taller/vic_model/params$ **cd ../met**

and look at one file:

```
1990 1 1   0.000  20.622   6.778   3.573
1990 1 2   0.000  23.165   8.272   4.038
1990 1 3   0.000  21.058   7.887   4.139
1990 1 4   0.000  21.251   7.314   4.712
1990 1 5   0.000  22.803   7.112   4.002
1990 1 6   0.000  21.590   8.151   3.894
1990 1 7   0.000  24.401  10.243   3.932
1990 1 8   0.000  22.234  10.311   4.078
1990 1 9   0.000  19.154   5.332   3.608
```

This is an inefficient way to store data, but it is useful in that each day is fully defined, and in ascii format it can be quickly viewed. Note there are 7 columns, with the last 4 providing the meaningful data of precipitation (mm/d), Tmax (C) Tmin (C), and wind speed (m/s). There should be a file in this directory for each VIC grid cell to be run.

<u>2) Build the global control file for VIC</u>

in the run/ directory there is only one file, which is the global control file. It is always easiest to start with an existing global control file than to try to create one from scratch. Open this in an editor like gedit

vic_taller/vic_model/run$ **gedit chile_vic_taller_global_4.1.1**

The top portion of this file is shown below. For details on any entry, again refer to the UW VIC web site:

http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Documentation/GlobalParam.shtml

chile_vic_taller_global_4.1.1 (~/projects/chile/docs/vic_taller/vic_model/run) - gedit

```
#######################################################################
# This text file contains information used by the vicNl model to define
# needed global variables, and model parameters, as well as allowing the
# user to control the features of the model to be used in the current
# model run.
#
# Modified:     Apr 2011 for VIC ver.4.1.1
# Comments:     1/4 degree global file, daily input data
#
#######################################################################
#
# Define Global Parameters
#######################################################################
NLAYER          3     # number of soil layers
TIME_STEP       24    # model time step in hours (= 24 for water balance)
STARTYEAR       1990  # year model simulation starts
STARTMONTH      1     # month model simulation starts
STARTDAY        1     # day model simulation starts
STARTHOUR       0     # hour model simulation starts
ENDYEAR         1999  # year model simulation ends
ENDMONTH        12    # month model simulation ends
ENDDAY          31    # day model simulation ends
SKIPYEAR        0     # years to skip in model output
WIND_H          10.0  # height of wind speed measurement
MEASURE_H       2.0   # height of humidity measurement
NODES           5     # number of soil thermal nodes
MAX_SNOW_TEMP   0.5   # maximum temperature at which snow can fall
MIN_RAIN_TEMP  -0.5   # minimum temperature at which rain can fall

#######################################################################
# Define Global Options
#######################################################################
FULL_ENERGY     FALSE # calculate full energy balance
FROZEN_SOIL     FALSE # calculate frozen soils
DIST_PRCP       TRUE  # use distributed precipitation
COMPRESS        FALSE # compress input and output files when done
CORRPREC        FALSE # correct precipitation for gauge undercatch
GRID_DECIMAL    3     # number of decimals to use in gridded file names
PRT_SNOW_BAND   FALSE # whether to print indiv. snow band data
ARC_SOIL        FALSE # read soil parameters from ARC/INFO ASCII grids
SNOW_STEP       1     # time step in hour for which to solve the snow model
ROOT_ZONES      2     # Number of root zones defined in VEGPARAM file
BINARY_OUTPUT   FALSE # output files in binary format
MIN_WIND_SPEED  0.1   # minimum observable wind speed
PREC_EXPT       0.6   # exponential for distributed precipitation (0.6)
GRND_FLUX       FALSE # true for full energy, false for water balance
QUICK_FLUX      FALSE # true uses Liang (1999), false uses finite diff.
NOFLUX          FALSE # false uses const. T at damping depth
COMPUTE_TREELINE 10   # sets areas w/July Tavg <10C to this veg class
BASEFLOW        ARNO  # switches from using Ds Ws c bi to d1 d2 d3 d4
JULY_TAVG_SUPPLIED TRUE
#######################################################################
```

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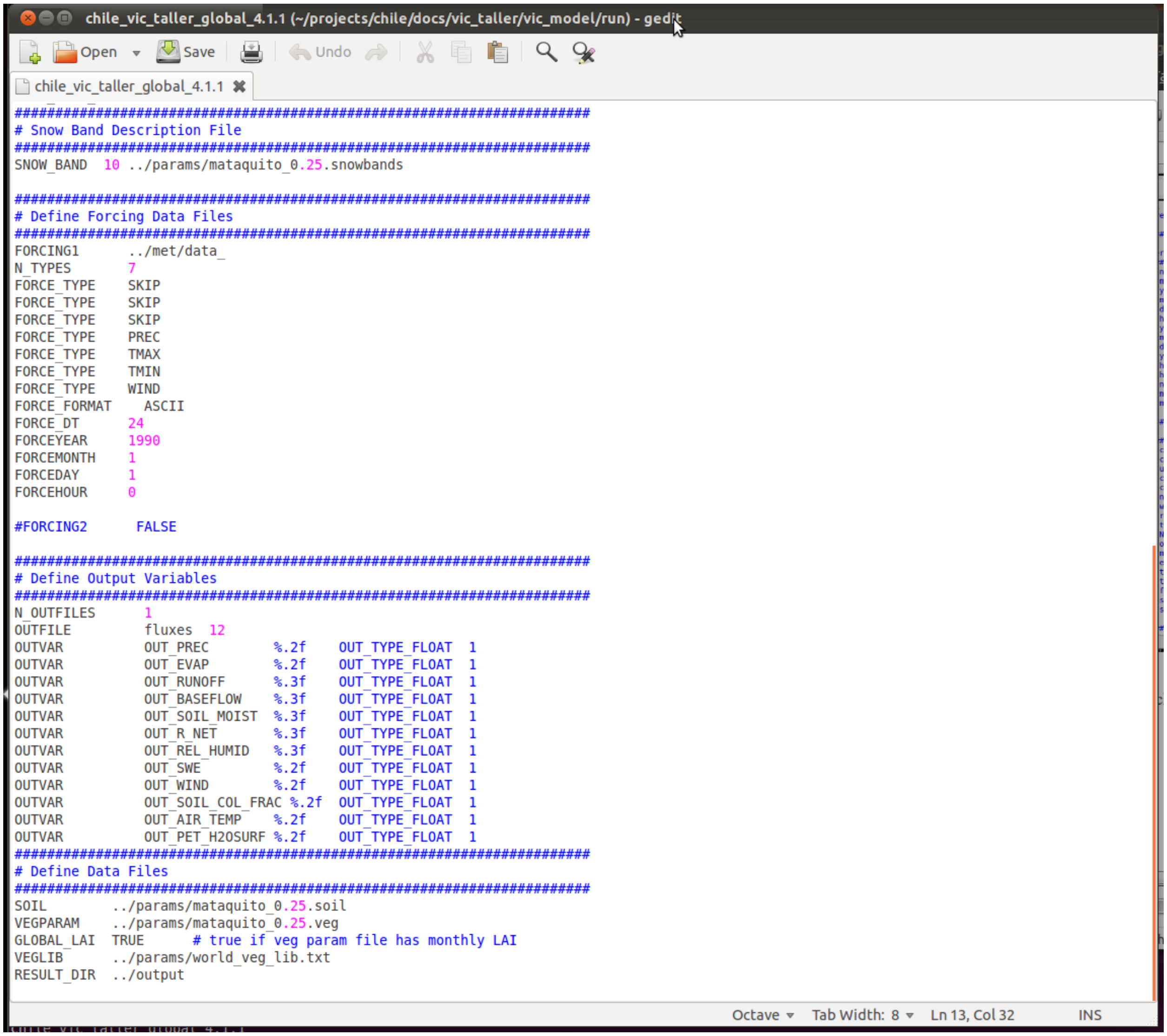
Walk through each of the items and ensure that it is set correctly for your run. The second half of this file describes the location and contents of the input and output files.

Here you can see that the number of snowbands is defined, and this must match what is in the file you created (or were given).

The meteological forcing files are described column by column, as is their format (ascii or binary). Note that the dates are often not included in met files, so the start year, month, day and hour must also be defined, as well as the time step.




```
#######################################################################
# Snow Band Description File
#######################################################################
SNOW_BAND  10 ../params/mataquito_0.25.snowbands

#######################################################################
# Define Forcing Data Files
#######################################################################
FORCING1      ../met/data_
N_TYPES       7
FORCE_TYPE    SKIP
FORCE_TYPE    SKIP
FORCE_TYPE    SKIP
FORCE_TYPE    PREC
FORCE_TYPE    TMAX
FORCE_TYPE    TMIN
FORCE_TYPE    WIND
FORCE_FORMAT    ASCII
FORCE_DT      24
FORCEYEAR     1990
FORCEMONTH    1
FORCEDAY      1
FORCEHOUR     0

#FORCING2      FALSE

#######################################################################
# Define Output Variables
#######################################################################
N_OUTFILES      1
OUTFILE         fluxes  12
OUTVAR          OUT_PREC        %.2f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_EVAP        %.2f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_RUNOFF      %.3f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_BASEFLOW    %.3f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_SOIL_MOIST  %.3f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_R_NET       %.3f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_REL_HUMID   %.3f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_SWE         %.2f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_WIND        %.2f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_SOIL_COL_FRAC %.2f  OUT_TYPE_FLOAT  1
OUTVAR          OUT_AIR_TEMP    %.2f    OUT_TYPE_FLOAT  1
OUTVAR          OUT_PET_H2OSURF %.2f    OUT_TYPE_FLOAT  1
#######################################################################
# Define Data Files
#######################################################################
SOIL        ../params/mataquito_0.25.soil
VEGPARAM    ../params/mataquito_0.25.veg
GLOBAL_LAI  TRUE      # true if veg param file has monthly LAI
VEGLIB      ../params/world_veg_lib.txt
RESULT_DIR  ../output
```

With the newer (circa v 4.1) VIC versions, it is now completely flexible as to what the output files contain, and how many output files are created for each grid cell. **It is highly recommended that the first four OUTVAR always be those shown above.**

3) Compile and run VIC

In the code/ directory, the VIC code can be compiled by typing the command 'make model'

vic_taller/vic_model/code$ **make model**

Using the default VIC setup is probably fine, but if you later run into issues, it may be that some default settings need to be changed. If so, the most likely location of the needed setting would be the file user_def.h. If you open this you will see many things defined, such as:

```
#define MAX_VEG       12     /* maximum number of vegetation types per  cell */
#define MAX_LAYERS     3      /* maximum number of soil moisture layers */
#define MAX_NODES     18     /* maximum number of soil thermal nodes */
#define MAX_BANDS     13     /* maximum number of snow bands */
```

If you do change any of these, you should type 'make clean' prior to recompiling the program.

Compilation produces the executable file **vicNl**. You can copy or move this to the run/ directory for simplicity.

vic_taller/vic_model/code$ **mv vicNl ../run/.**

Now return to the /run directory, and you should have the executable VIC code you just created and the global control file. Now you can run the VIC model:

vic_taller/vic_model/run$ **vicNl -g chile_vic_taller_global_4.1.1**

You can watch the output that is dumped to the screen as the model runs each grid cell. This can be useful for diagnosing problems with the model later. Note that this example VIC model setup is not refined, and produces some warnings. We won't concern ourselves with that now, however.

After VIC completes its run, ensure that the output/ directory contains one file for each grid cell that was run, and that the files have the expected number of rows and columns, and content that seems reasonable.

4) Examining Spatial Output from VIC

There are several ways to look at VIC output. The simplest is to just open an output file (provided you have specified ascii output) and plot the values. This way you can see a few things:

- whether spinup is significant
- whether glaciers are being formed
- if the annual cycle of water storage and flux seems reasonable

For a daily simulation, output will also be daily. Often it is desirable to aggregate to a coarser time step. In the utils/ directory you will find a utility agg_time.pl that is very useful. You can type:

vic_taller/vic_model/utils$ agg_time.pl -h to see all the details of how to use it.

There are also tools for spatial aggregation of output in the same directory, and tools are available to build GIS-compatible files for viewing the spatial output.

5) Generating streamflow

While spatial hydrology is interesting, typically the only way to validate a hydrology simulation is to route the runoff to a streamflow point. This is dealt with in a followup document.