Assembling a multi-PVT model in PATH, using MC2 output

Dave Conklin, Common Futures, 5/15/13 rev. 5/26, 6/3, 6/16, 9/24, 1/24/14

There is an R package called MC2toPath which has the R scripts referenced below. The MC2toPath routines will be used once for each set of MC2 output (i.e. each future climate scenario), and then may be used one final time after all the output sets have been processed and their results collated.

The desired end product of this process is a PATH model consisting of multiple strata and transitions between them. Each stratum originates as an ILAP VDDT model. Transitions are added between the early seral states of the strata to represent climate-change-induced changes in vegetation type. Mean probabilities of transition between strata are derived from MC2 output and prescribed as the transition probabilities for the transition types representing the vegetation type changes. The prescribed transition probabilities are then modified year by year using tables of transition probability multipliers.

Console output from the initial processing of an MC2 output file is useful in selecting the MC2 vegetation types (VTYPEs) and USFS potential vegetation types (PVTs) to be represented in the PATH model. Console output in step 11 below includes the mean fraction of the study area occupied by each VTYPE. Typically, VTYPEs occupying less than 1% of the area are ignored in the PATH model. The remaining VTYPEs are associated one-to-one with representative USFS PVTs. The ILAP VDDT models for those PVTs form the strata in the PATH megamodel

Initial processing of an MC2 output set

1. Obtain an MC2 output data file in netCDF format containing yearly data for the VTYPE output variable. The appropriate files for the two future climate data sets used in the Washington Coast Range (WCR) project are named:
    WCR_RegCM3_Echam5_A2_year.nc
    WCR_HadleyCM3_A2_year.nc
Set the R variable *ncdf.path* to the path and file name of the MC2 output data file to be processed, e.g.
    ncdf.path = “C:\\Users\\Dave\\WCRproject\\WCR_HadleyCM3_A2_year.nc”

2. Find out the name of the base calibration used in the MC2 simulations. For the WCR project, the name is “WCR”. For the Willamette Water 2100 (WW2100) project and the Blue Mountains projects, the name is “CONUS”. Set the R variable *base.calibration* to the name of the base calibration set, e.g.
    base.calibration = “WCR”

3. Execute

vegChanges = VegTypeChanges(ncdf.path, base.calibration)

The resulting object, vegchanges, is a list consisting of 5 named items:

tgtfile is *ncdf.path*

years is a vector of the calendar years represented in the change data, e.g. 2011, 2012, ..., 2100

vts2keep is a vector of the VTYPEs occurring in the data, (VTYPEs which never occur, such as tropical vegetation types in the WCR study area, are omitted from vts2keep)

vtFracsReduced is a 2-dimensional matrix containing for each vegetation type for each year the fraction of the total number of cells which has the given vegetation type in the given year

changeFracsReduced is a 3-dimensional matrix containing the vegetation change data

Executing the *VegTypeChanges()* function in this instance also has the result of printing a list of the average fractions of all grid cells occupied by each vegetation type. Vegetation types which do not appear at all in the output data are omitted from the list. Fig. 1 is the printed output from executing *VegTypeChanges()* on WCR_HadleyCM3_A2_year.nc.

```
Mean values over  89  years:
frac of all cells, VTYPE
4.6882325363338e-06 2 tundra aka alpine
2.53164556962025e-05 3 taiga-tundra
0.0020253164556962 4 boreal needleleaf forest
0.00127801218940459 5 boreal woodland
0.339178152836381 8 temperate needleleaf forest
0.0524491326769808 10 cool mixed forest
0.000488513830285982 11 temperate warm mixed forest
0.0313553680262541 12 temperate needleleaf woodland
0.00124097515236756 14 temperate cool mixed woodland
1.50023441162682e-05 15 temperate warm mixed woodland
0.00961134552273793 16 C3 shrubland
0.000822315986872949 17 C3 grassland
1.87529301453352e-06 18 temperate desert and semidesert
0.000476324425691514 36 cool needleleaf forest
0.219342709798406 43 Sitka spruce zone
0.237355836849508 44 western hemlock zone
0.0750646976090014 45 Pacific silver fir zone
0.0125743084857009 46 mountain hemlock zone
0.0033792780121894 47 subalpine fir zone
0.0133108298171589 48 subalpine parkland zone
>
```

Fig. 1. Example of console output from VegTypeChanges().

4. Use the list of vegetation types and fractional occurrences to choose candidate MC2 vegetation types for representation in the PATH state-and-transition model. For example, in figure 1 the vegetation types which occupy at least 1% of the gridcells are temperate needleleaf forest aka Douglas-fir zone (34%), western hemlock zone (24%),

Sitka spruce zone (22%), Pacific silver fir zone (8%), cool mixed forest (5%), temperate needleleaf woodland (3%), subalpine parkland zone (1%), and mountain hemlock zone (1%).

Collate the results from all the MC2 output sets and choose PVTs

5. Merge the lists of candidate MC2 vegetation types from all the MC2 output sets into a single list. Continuing the previous example, for the WCR study area there is a second MC2 output set in a file named “WCR_RegCM3_Echam5_A2_year.nc”. Processing this second output set and choosing vegetation types occupying at least 1% of the gridcells results in one more candidate MC2 vegetation type, temperate warm mixed forest (8% in the RegCM3 output).

Further inspection may result in choosing additional vegetation types, for example C3 shrubland and subalpine fir zone.

The complete list for the WCR example now consists of

```
8 temperate needleleaf forest (aka Douglas fir zone)
10 cool mixed forest
11 temperate warm mixed forest
12 temperate needleleaf woodland
16 C3 shrubland
43 Sitka spruce zone
44 western hemlock zone
45 Pacific silver fir zone
46 mountain hemlock zone
47 subalpine fir zone
48 subalpine parkland zone
```

6. Choose or create PVTs for use in the STM, to correspond to each of the selected MC2 vegetation types. For the WCR project, 9 existing PVTs were selected, and one new PVT was created. The correspondence between VTYPEs and PVTs is given in Table 1.

Table 1. MC2 vegetation types selected for representation in the STM, and the PVTs chosen to represent them. This example is from the WCR project.

<table>
<tr><th>VTYPE</th><th>PVT</th></tr>
<tr><td>8 temperate needleleaf forest (aka Douglas fir zone)</td><td>fdg Douglas-fir/grand fir - dry</td></tr>
<tr><td>10 cool mixed forest</td><td>fvg grand fir - valley</td></tr>
<tr><td>11 temperate warm mixed forest</td><td>fww western hemlock - wet</td></tr>
<tr><td>12 temperate needleleaf woodland</td><td rowspan="2">new PVT: fcc</td></tr>
<tr><td>16 C3 shrubland</td></tr>
<tr><td>43 Sitka spruce zone</td><td>fss Sitka spruce</td></tr>
<tr><td>44 western hemlock zone</td><td>fwi western hemlock - intermediate</td></tr>
<tr><td>45 Pacific silver fir zone</td><td>fsi Pacific silver fir - intermediate</td></tr>
<tr><td>46 mountain hemlock zone</td><td>fmt mountain hemlock - wet</td></tr>
<tr><td>47 subalpine fir zone</td><td>faf subalpine fir</td></tr>
<tr><td>48 subalpine parkland zone</td><td>fal subalpine parkland</td></tr>
</table>

Create a vegChangeProbabilityMultipliers.txt file for each MC2 output set

7. Encapsulate the correspondence between MC2 vegetation types and STM PVTs and strata in an R object named *vt2pvtlut* (“vt to pvt lookup table”). For example:

VTs = c(8, 10, 11, 12, 16, 43, 44, 45, 46, 47, 48)
PVTs = c("fdg", "fvg", "fww", "fcc", "fcc", "fss", "fwi", "fsi", "fmt", "faf", "fal")
Strata = c("WCR_fdg", "WCR_fvg", "WCR_fww", "WCR_fcc", "WCR_fcc",
"WCR_fss", "WCR_fwi", "WCR_fsi", "WCR_fmt", "WCR_faf", "WCR_fal")
vt2pvtlut = data.frame(VT=VTs, PVT=PVTs, Stratum=Strata)

8. In Path, adopt the convention that transitions from one stratum to a different stratum are given transition type names of the form <sourcePVT>2<destinationPVT>, i.e. a transition from the fdg PVT stratum to the fww PVT stratum would be of transition type “fdg2fww”. Construct a list of all possible transition types of that form:

climateChangeTransitionTypes =
paste(rep(PVTs, length(PVTs)), "2", rep(PVTs, each = length(PVTs)), sep="")

9. In Path, add the transitions between strata which correspond to the climate change transition types. These transitions typically go from the states in GF and GFp structural stages in the source stratum to the corresponding states in the destination stratum.

10. In Path, create a distinct user scenario for each MC2 output data set. These scenarios are typically identical in all respects except the probabilities assigned to the climate change and wildfire transitions, and their associated year-by-year probability multipliers.

11. Rerun the VegTypeChanges() routine with the VTYPE to PVT lookup table *vt2pvtlut* to get the default probability values for the climate change transitions. Set *ncdf.path* for the desired MC2 output set. Then execute

vegChanges =VegTypeChanges(ncdf.path, base.calibration, vt2pvtlut)

The default probability values will be reported on the R console; fig. 2 is an example for the WCR project. Use these values as the probability value for each probabilistic transition of the associated type in the given user scenario.

12. Execute

SaveVegChangeProbabilityMultipliers(vegChanges, base.calibration,
climateChangeTransitionTypes, vt2pvtlut)

This will create a file named “vegChangeProbabilityMultipliers.txt”. The file can be imported into Excel, and used as the basis for importing transition probability multipliers into the appropriate user scenario in Path. Figure 3 lists portions of the file created for the WCR project.

```
 mean transition probabilities for transitions out of fdg ...
fdg 2 fvg 0.00379438707755038
fdg 2 fww 1.93568139788561e-05
fdg 2 fcc 0.00153851265364141
fdg 2 fcc 0.0047308042357373
fdg 2 fss 0.00857645427335472
fdg 2 fwi 0.0473733368048432
fdg 2 fsi 0.0101932698857661
fdg 2 fmt 0.000203961754637439
fdg 2 faf 5.57232044310886e-05
fdg 2 fal 5.44438182534424e-05

 mean transition probabilities for transitions out of fvg ...
fvg 2 fdg 0.0112367770242172
fvg 2 fww 0.0128244692020229
fvg 2 fcc 0.00015723689560459
fvg 2 fcc 0.000461621526353358
fvg 2 fss 0.124042057439882
fvg 2 fwi 0.0636099095693809
fvg 2 fsi 0.205091551294749
fvg 2 fmt 0.0042749210225031

...

fcc 2 faf 0.000882939174233847
fcc 2 fal 0.0133097337890835

 mean transition probabilities for transitions out of fcc ...
fcc 2 fcc 0.261373736467806

 mean transition probabilities for transitions out of fss ...
fss 2 fdg 0.0229722563057056
fss 2 fvg 0.0445522697532167

...

 mean transition probabilities for transitions out of fsi ...
fsi 2 fdg 0.159931473660596
fsi 2 fvg 0.00100764756159339
fsi 2 fww 0.000362450163102573
fsi 2 fcc 0.00305928220581159
fsi 2 fcc 0.00660801770762861
fsi 2 fss 4.59574743590707e-05
fsi 2 fwi 0.0270977190219689
fsi 2 fmt 0.000703155370222486

...

Mean values over  89  years:
frac of all cells, VTYPE
0.339665436585068 8 temperate needleleaf forest
0.0525244842577725 10 cool mixed forest
0.000489215658657051 11 temperate warm mixed forest
0.0314004150351653 12 temperate needleleaf woodland
0.00962515376019982 16 C3 shrubland
0.219657830737016 43 Sitka spruce zone
0.237696836530606 44 western hemlock zone
0.0751725400715513 45 Pacific silver fir zone
0.012592373494089 46 mountain hemlock zone
0.00338413288637239 47 subalpine fir zone
0.0133299529564213 48 subalpine parkland zone
```

Fig. 2. Sample console output from running VegTypeChanges() in step 11 for the WCR project.

```
C:/Users/Dave/WCRproject/WCR_HadleyCM3_A2_year.nc
1  Temporal   fdg2fvg      0
2  Temporal   fdg2fvg      0
3  Temporal   fdg2fvg      0
4  Temporal   fdg2fvg      0
5  Temporal   fdg2fvg      0
6  Temporal   fdg2fvg      0
7  Temporal   fdg2fvg      0
8  Temporal   fdg2fvg      0
9  Temporal   fdg2fvg      0
10 Temporal   fdg2fvg      0
11 Temporal   fdg2fvg      0
12 Temporal   fdg2fvg      0
13 Temporal   fdg2fvg      0
14 Temporal   fdg2fvg      0
15 Temporal   fdg2fvg      0.05973417
16 Temporal   fdg2fvg      0
17 Temporal   fdg2fvg      0
...
78 Temporal   fdg2fvg      0
79 Temporal   fdg2fvg      0
80 Temporal   fdg2fvg      1.387981
81 Temporal   fdg2fvg      11.65113
82 Temporal   fdg2fvg      0
83 Temporal   fdg2fvg      2.913171
84 Temporal   fdg2fvg      3.573226
85 Temporal   fdg2fvg      3.335579
86 Temporal   fdg2fvg      0
87 Temporal   fdg2fvg      2.769855
88 Temporal   fdg2fvg      14.18438
89 Temporal   fdg2fvg      2.670016
1  Temporal   fdg2fww      0
2  Temporal   fdg2fww      0
...
81 Temporal   fdg2fww      0
82 Temporal   fdg2fww      3.489692
83 Temporal   fdg2fww      16.89496
84 Temporal   fdg2fww      0
85 Temporal   fdg2fww      0
86 Temporal   fdg2fww      0
87 Temporal   fdg2fww      68.61535
88 Temporal   fdg2fww      0
89 Temporal   fdg2fww      0
1  Temporal   fdg2fcc      0
2  Temporal   fdg2fcc      0
3  Temporal   fdg2fcc      0
4  Temporal   fdg2fcc      0
5  Temporal   fdg2fcc      0
6  Temporal   fdg2fcc      1.036648
7  Temporal   fdg2fcc      0
8  Temporal   fdg2fcc      15.6522
9  Temporal   fdg2fcc      1.449227
10 Temporal   fdg2fcc      0
```

Fig. 3. Excerpts from the vegChangeProbabilityMultipliers.txt file for the WCR project.

Create the fireProbabilityMultipliers.txt file for each MC2 output set

13. Use R-scripts to post-process the MC2 output to get year-by-year fire probabilities for each VTYPE/PVT. Execute:

SaveFireProbabilityMultipliers(ncdf.path, base.calibration, vt2pvtlut)

This command produces both console output and 2 text files, named "fireProbabilityMultipliers.txt" and "fireFracs.txt". fireProbabilityMultipliers.txt can be imported into Excel, and used as the basis for importing transition probability multipliers into Path.

14. Load the probability multipliers for PVT-to-PVT transitions and for wildfire transitions into the PATH model.

Replace other placeholder transition probabilites

15. In the PATH model, replace the "0.1" placeholder probabilities for anthropogenic transitions from the ILAP VDDT models with values appropriate for the study assumptions.