Procedure of Embedding Land Surface Schemes in CVS GSM/RSM System

– A Case Study: coupling VIC with GSM/RSM

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1. Introduction

- The Global Spectral Model (GSM)/Regional Spectral Model (RSM) system is applied to conduct researches and applications related to the earth systems of the atmosphere, the land surface and the ocean at the global and regional scales, respectively.
- The CVS GSM/RSM system is controlled by Concurrent Versions System (CVS), and is administrated by ECPC.
- The latest complete version of the CVS GSM/RSM system was carried out by Kanamitsu (ECPC/CRD/SIO/UCSD) in December, 2003.
- Currently, there are four land surface schemes embedded in the GSM/RSM system, i.e., OSU, NOAH, VIC, and CLM.

2. Installation of CVS GSM/RSM System

2.1 To ensure CVS system installed on the computer in which the GSM/RSM will be installed

2.2 To install GSM/RSM system using CVS

2.1 Ensuring CVS system installed

- Checking the availability of CVS command

  enter ‘cvs’ after the computer system prompt, e.g., $

  if shown ‘no command found’, the CVS system need install

- Installing CVS system

  download CVS package “cvs-1.11.17.tar.gz” from https://ccvs.cvshome.org/servlets/ProjectDocumentList

  $ gunzip cvs-1.11.17.tar.gz

  $ tar xf cvs-1.11.17.tar

  enter cvs-1.11.17 directory, and carefully follow the procedure described in the file “INSTALL” to complete the installation of CVS step-by-step.

  Brief summary:

  $ ./configure prefix=directory_cvs_installed

  $ make

  $ make install

- Setting up path and environmental CVSROOT

  For C shell users, in ~/.cshrc including the following lines

  set PATH=($path directory_cvs_installed/bin/)

  setenv CVSROOT :pserver:anoncvs@rokka.ucsd.edu:/rokka1/kana/cvs-server-root/cpscvs

2.2 Installation of GSM/RSM system using CVS

- To obtain the “install” of GSM/RSM using

  $ cvs co install

- To set up GSM (or RSM) system

  $ ./install

  Follow the prompts to set up the GSM (or RSM) system as desired

- To change the resolution of the system or change GSM to RSM (or RSM to GSM) manually, please follow the steps below:
  - ✓ modify the file of ./gsm/configure-model
    - ➢ change “MODEL=gsm” to “MODEL=rsm”
    - ➢ modify “MODEL_DEFINE=resolution” to the resolution available under “./gsm/def/”
  - ✓ Reconfigure ./gsm/ under ./gsm/ using
    - ➢ ./configure-model
    - ➢ make clean
    - ➢ make
  - ✓ Reconfigure ./runs/ under ./runs/ using
    - ➢ ./configure-scr script_name

    (note: script_name is an available script (without .in) under ./runs/expscr)

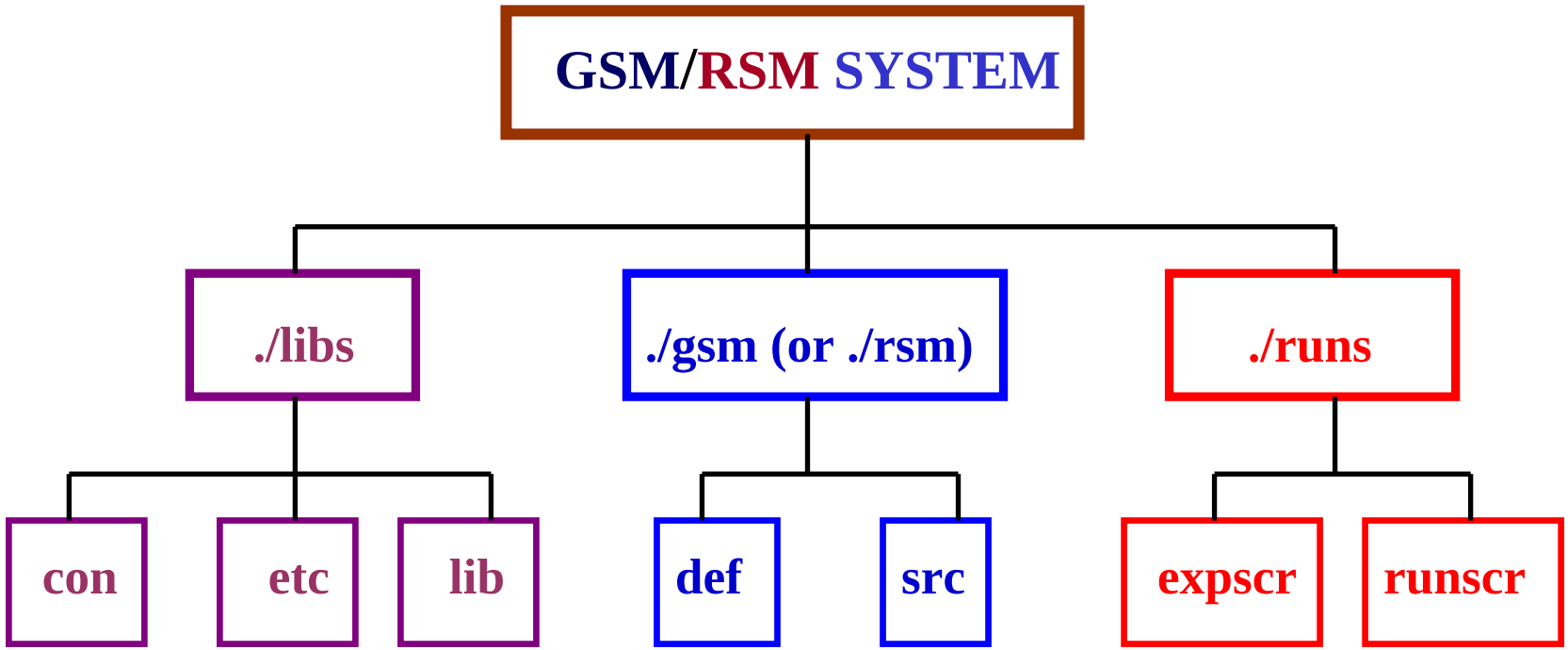
3. GSM/RSM System and Land Surface Schemes

3.1 Basic structure of GSM/RSM

3.2 Parts of system related to land surface schemes

3.3 Available land surface schemes in CVS GSM/RSM

3.1 Basic Structure of GSM/RSM System (1)



3.1 Basic Structure of GSM/RSM System (2)

- **./libs/**
  - ./libs/con/ contains globally shared constants and climatologic files
  - ./libs/etc/ contains miscellaneous utility files, e.g., for dealing with grib files
  - ./libs/lib/ contains forecast model library sources
- **./gsm/ (or ./rsm/)**
  - ./gsm/def/ contains options for the system and for its various resolutions
  - ./gsm/src/ contains the GSM/RSM model source code
- **./runs/**
  - ./runs/expscr/ contains running script templates for different scenarios
  - ./runs/runscr/ contains scripts and their templates for driving GSM/RSM system

3.2 Parts of GSM/RSM Related to Land Surface Schemes

The files under the following directories relate to embedding the land surface schemes in the GSM/RSM system.

- ./libs/lib/modelib/
  - sfcfld.F
- ./gsm/def/
  - physics.h, depend.h, cvar.F
- ./gsm/src/include/
  - comsfc.h, sfcfld.h, vargrb.h, varsfc.h
- ./gsm/src/sfc0/
  - sfc0.F, sfcfcnv.F
- ./gsm/src/sfcl/
  - sfc.F, inds2g.F
- ./gsm/fcst/
  - gbphys.F, sfcdrv.F

3.3 Available Land Surface Schemes in CVS GSM/RSM

- OSU (Oregon State University land surface scheme)
  - ✓ OSU1: the old version of OSU and used in NCAR/NCEP Reanalysis study
  - ✓ OSU2: the new version of OSU and the land surface vegetation and soil type properties obtained from grib files
- NOAH (NOAH land surface model)
  - ✓ Developed in **N**CEP, **O**SU, **A**ir force, **H**ydrologic Research Lab
  - ✓ NOA1: maximum one-vegetation type considered in each cell
- VIC (Variable Infiltration Capacity)
  - ✓ Developed in the University of Washington, Seattle, and Princeton University
  - ✓ VIC1: maximum one-vegetation type considered in each cell
- CLM (Common Land Model)
  - ✓ Developed in NCAR, NASA, GIT, and Beijing Normal University
  - ✓ Combined the best features, as possible, of NCAR LSM (Bonan 1996), BATS (Dickinson 1993), and IAP94 (Dai and Zeng 1997)

4. Case Study: Embedding VIC1 in GSM/RSM

4.1 Modify ./libs/lib/modelib/sfcfld.F

4.2 Modify head files under ./gsm(or rsm)/src/include/

4.3 Modify files under ./gsm(or rsm)/src/sfc0/

4.4 Modify files under ./gsm(or rsm)/src/sfcl/

4.5 Modify files under ./gsm(or rsm)/src/fcst/

4.6 New files added to system for embedding VIC1

4.7 Flowchart of the embedded VIC1

4.1 Modify: ./libs/lib/modelib/sfcfld.F (1)

- sfcfld.F contains the lists of all the parameters and variables used in each land surface scheme which is embedded in GSM/RSM
- inputs:
  - sfcftyp: land surface type which is embedded in the system
  - iflag: output flag (=0: return array size; =1: return arrays)
- outputs:
  - nrecs: the number of total parameters and variables used in a land surface “sfcftyp”
  - ksoil: the number of soil layers used in “sfcftyp”
  - maxlev: the maximum layers used in the land surface scheme
  - lev(nrecs): integer array for containing the number of levels of the parameters and variables
  - svar(nrecs): character array for for containing the names of the parameters and variables

4.1 Modify: ./libs/lib/modelib/sfcfld.F (2)

- local variables for VIC1 in sfcfld.F
  - kalbd: the number of albedo type
  - nsoil: the number of soil nodes for computing soil temperature profile
- When introducing any new land surface scheme which will be embedded in the GSM/RSM system, we need add the lists of lev(nrecs) and svar(nrecs) in sfcfld.F for the new land surface scheme.
- Parameters and variables, lev(nrecs) and svar(nrecs), used for VIC1
  - 56 parameters and variables used

4.2 Modify head files under ./gsm(or rsm)/src/include/

- vargrb.h: containing grib surface variables and their properties. If there are new land surface parameters introduced into the model through grib files, we need add these new grib files into the vargrb.h
  - ✓ after adding related grib surface variables, we also need to revise the following vargrb.h-related head files: vargrb1.h, vargrb2.h, vargrb3.h, vargrb4.h, vargrb5.h, vargrb6.h, vargrb7.h, vargrb8.h, vargrb9.h
- sfcfld.h: including the new land surface type, e.g., for VIC1

```
#ifdef VICLSM1
        data sfcftyp/'vic1'/
#endif
```

- comsfc.h: including the new land surface parameters and variables in the common block /comsfc/
- varsfc.h: defining numsfcs (the sum of total variables times their dimension) and numsfcv (the number of total variables) for the new land surface scheme
  - ✓ varsfc_nlay.h: defining the dimension of each land surface variables
  - ✓ varsfc_qcty.h: setting-up the maximum and minimum of related variables

4.3 Modify files under ./gsm(or rsm)/src/sfc0/

- sfc0.F: the main program for generating the initial surface files.
  - ✓ When the new land surface scheme introduces some new variables needing initialization, we should modify sfc0.F.
  - ✓ For embedding VIC1, we have added “call vic1ini()” into the program.
- sfcfcnv.F: a subroutine of sfc0.F.
  - ✓ When introducing a new land surface scheme, we need add a program as a subroutine of sfcfcnv.F for converting the GSM/RSM original land surface initial conditions (e.g., using NCEP/NCAR reanalysis 2) to ones for the new land surface scheme.

4.4 Modify files under ./gsm(or rsm)/src/sfcl/

- sfc.F: this is called by sfc0.F and inside the forecast model.
  - ✓ to read climatology and analysis from grib files, and to merge the forecast land surface with these climatology and/or analysis land surface.
  - ✓ embedding a new land surface scheme, we need add the grib file names for the new land surface parameters and variables, *i.e.*, fnt0(), fnfc(), into sfc.F.
- inds2g.F: assigning flags for reading land surface grib files. For the new land surface scheme, we need assign these flags for the new grib files in inds2g.F.
- sfcmrg.F: when a new land surface type definition is used in the new land surface scheme, we need modify sfcmrg.F for matching the new land surface type definition with the original definition used.

4.4 Modify files under ./gsm(or rsm)/src/fcst/ (1)

- gbphys.F: this program contains the simulation of the GSM/RSM physical processes in the atmosphere, the land and the ocean.
  - ✓ before calling the land surface scheme, we need convert the parameters and variables for the new land surface scheme to the latitude-fixed parameters and variables
  - ✓ after calling the land surface scheme, restore these variables to the their original dimensions
  - ✓ Compared with the previous GSM/RSM version for coupling land surface schemes, the new version includes a new option, “MRGLSM”, in gbphys.F for merging sfcdif, sfcdrv and sfcdiag.
  - ✓ In the pervious version, the sfcdif, sfcdrv and sfcdiag are compacted together in progtm (for OSU1) and in progtm99 (for OSU2).
  - ✓ sfcdif.F: calculating the coefficients used for computing earth surface fluxes
  - ✓ sfcdiag.F: updating the surface layer properties

4.4 Modify files under ./gsm(or rsm)/src/fcst/ (2)

- sfcdrv.F: processing the earth surface scheme.
  - In the old version of GSM/RSM, there are no apparent separations among simulating physical processes over sea, land, and sea-ice
  - Currently, in the sfcdrv.F, we have
    - ✓ sfc_ocean (for ocean surface),
    - ✓ sfc_seaice (for sea ice surface),
    - ✓ On the land surface
      - sfc_osu (for OSU land surface scheme)
      - sfc_noah (for NOAH land surface scheme)
      - sfc_vic1 (for VIC1 land surface scheme).

4.5 Modify files under ./gsm(or rsm)/def/

- physics.h: adding the new land surface definition, e.g., for VIC1

```
#define VICLMS1
#ifdef VICLSM1
#define RUNSMDIF
#define _lsoil_  3
#define _nsoil_  5
#define _lsoilin_  2
#define _sfcftyp_ vic1
#endif
```

- depend.h: declaring the dependence of definitions, e.g., for VIC1

```
#ifdef VICLSM1
#define MRGLSM
#undef OSULSM1
#undef OSULSM2
#undef NOALSM1
#undef USGS_SFC
#endif
```

- cvar.F: including the new land surface type, e.g., for VIC1

```
#ifdef VICLSM1
        viclsm1=yes
#endif
```

4.6 New Files Added to System for embedding VIC1 (1)

- ./libs/con_vic/ grib files for VIC1 soil and vegetation parameters
  - glob.soil.BBLE.grib, glob.soil.BLKD.grib, glob.soil.Ds.grib, glob.soil.Dsmax.grib, glob.soil.SDEN.grib, glob.soil.Ws.grib, glob.soil.binf.grib, glob.soil.cef.grib, glob.soil.dph.grib, glob.soil.expt.grib, glob.soil.ksat,grib, glob.soil.qurtz.grib, glob.soil.silz,grib, glob.soil.smr.grib, glob.soil.snwz.grib, glob.soil.wcr.grib, glob.soil.wpwp.grib, glob.veg1typ.vegcov.grib, glob.veg1typ.vegrt.grib, glob.veg1typ.vegtyp.grib
- ./gsm(or rsm)/src/include/
  - vartyp.h: includes “implicit none” for VIC land surface scheme, and defines “DBGVIC” for debugging VIC specifically.
  - vic_veglib.h: contains the VIC vegetation library
  - vic_surfeb.h: contains common blocks used in computing surface energy balance
  - vic_soileb.h: contains a common block used in computing soil temperature profile
  - vic_snoweb.h: contains common blocks used in computing snow energy balance

4.6 New Files Added to System for embedding VIC1 (2)

- ./gsm(or rsm)/src/sfc0/
  - osu1tovic1.F: converting the initial conditions for the OSU1 variable format to ones for the VIC1 variable format
  - osu2tovic1.F: converting the initial conditions for the OSU2 variable format to ones for the VIC1 variable format
  - noa1tovic1.F: converting the initial conditions for the NOA1 variable format to ones for the VIC1 variable format
  - vic1ini.F: initializing the some specific new variables for VIC1
  - nodepara.F: initializes the soil node thermal characteristics
- ./gsm(or rsm)/src/sfcl/
  - viclandck.F: checking the land surface with VIC land surface parameters
- ./gsm(or rsm)/src/fcst/
  - sfc_vic1.F: a subroutine of sfcdrv.F for driving VIC1 land surface scheme
  - sfuwvic.F: a subroutine of sfc_vic1.F for driving VIC1 at one grid cell

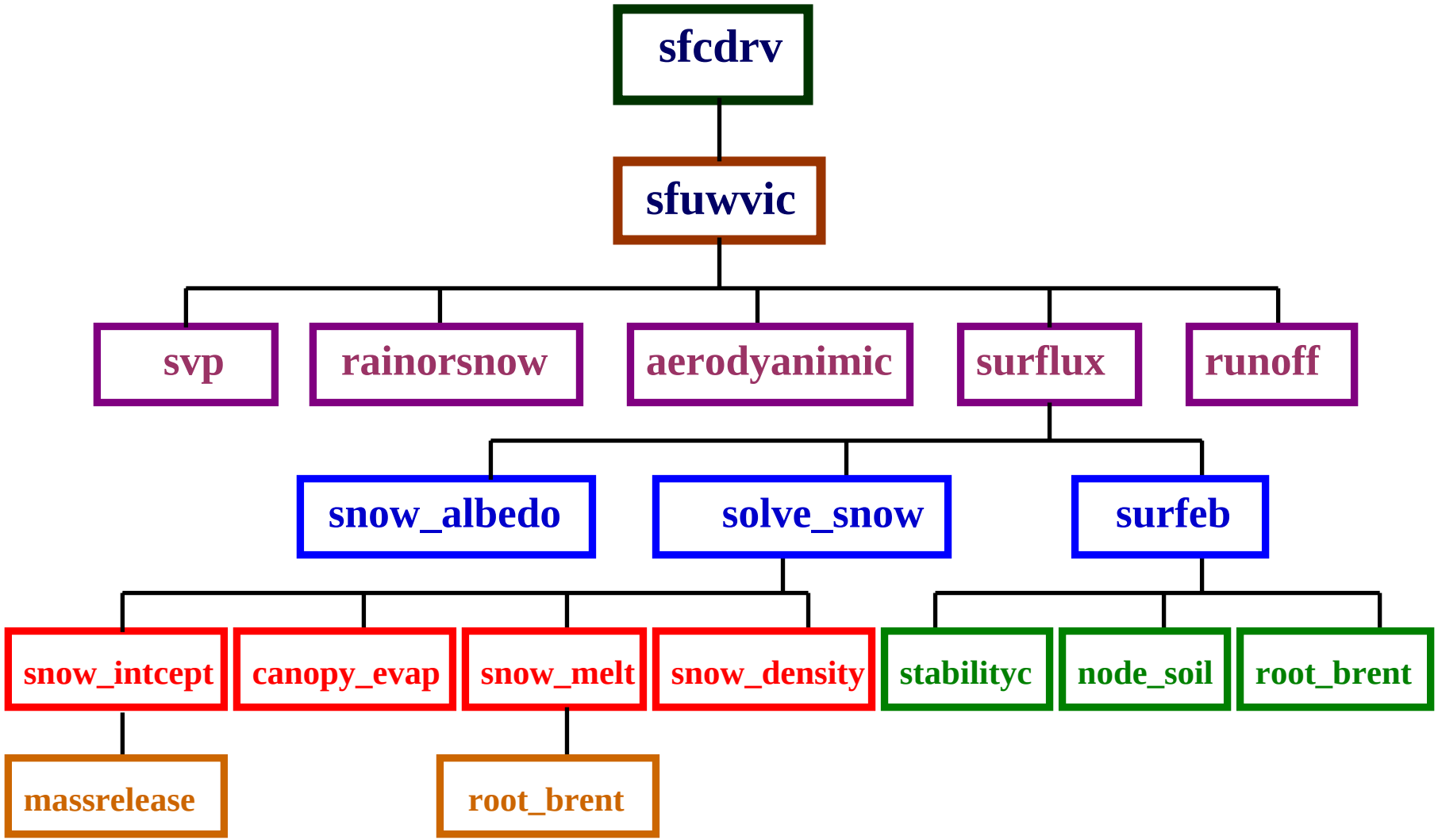
4.6 New Files Added to System for embedding VIC1 (3)

- Files under ./gsm(or rsm)/src/vic_land/
  - Subroutines of sfuwvic.F
    - rainorsnow.F: determining precipitation as rainfall or snowfall
    - aerodynamic.F: computing aerodynamic resistance for each vegetation layer
    - surflux.F: computing mass and energy fluxes from land surface
    - runoff.F: computing surface and subsurface flow from land surface
  - Subroutines of surflux.F
    - snow_albedo.F: computing snow surface albedo
    - solve_snow.F: simulating snow accumulating and melting processes
    - surfeb.F: computing heat fluxes for snow free surface and soil temperature
  - Subroutines and related programs of solve_snow.F
    - snow_intcept.F: simulating snow intercepted by vegetation canopy
    - canopy_evap.F: computing evapotranspiration from canopy surface
    - snow_melt.F: simulating snow accumulating and melting process
    - massrelease.F: calculating mass released from canopy intercepted snow
    - transprt.F: calculating vegetation transpiration
    - func_snoweb.F: computing snow pack energy balance
    - stabilityc.F: calculating the stability correction for computing heat fluxes
    - snow_density.F: computing snow density

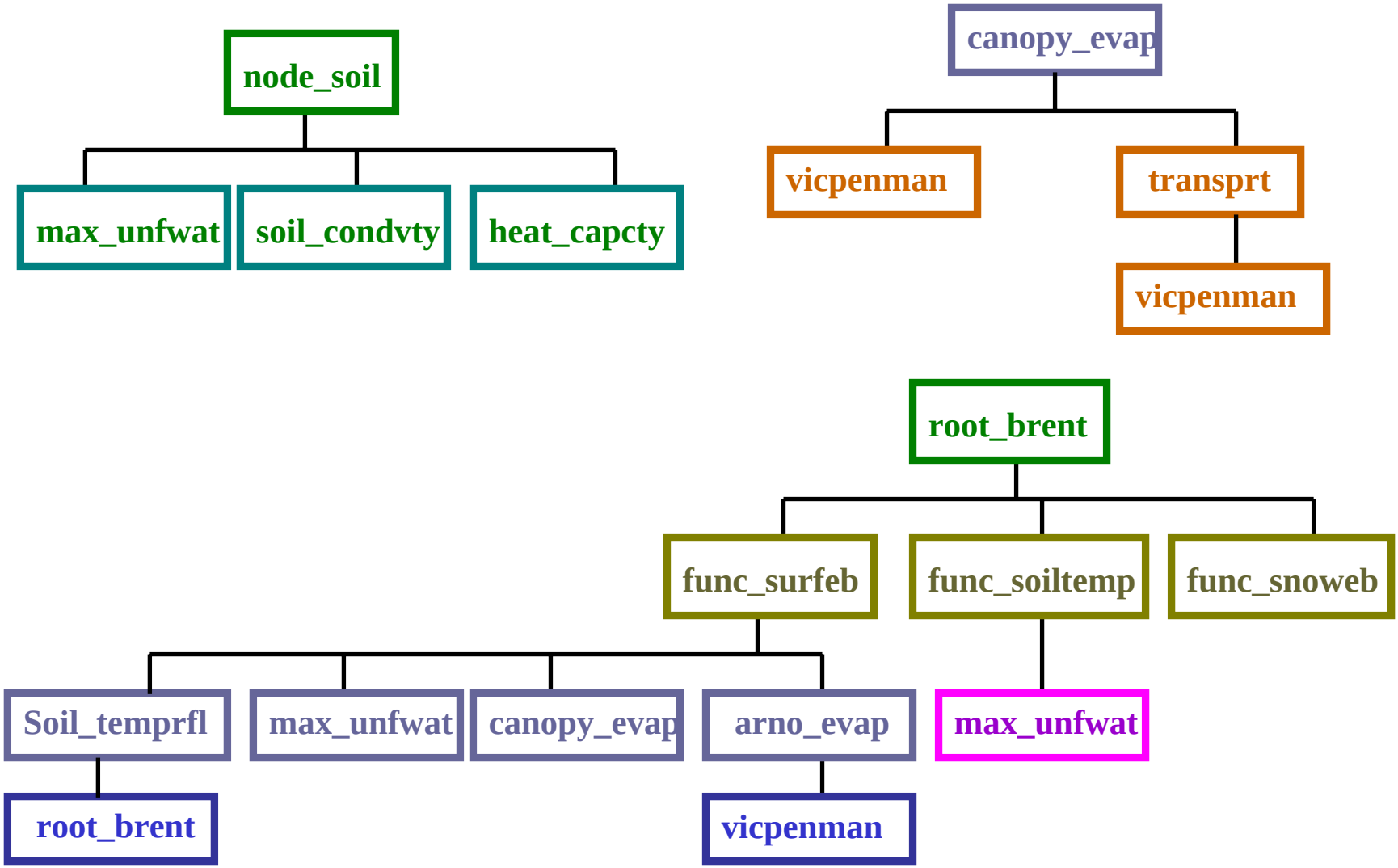
4.6 New Files Added to System for embedding VIC1 (4)

- Files under ./gsm(or rsm)/src/vic_land/
  - Subroutines and related programs of surfeb.F
    - node_soil.F: calculating soil node thermal variables
    - max_unfwat.F: computing the maximum amount of unfrozen water
    - soil_condvty.F: computing soil thermal conductivity
    - heat_capcty.F: computing soil heat capacity
    - func_surfeb.F: computing soil surface temperature based on energy balance
    - root_brent.F: searching a root of a function using Brent method
    - soil_temprfl.F: computing soil temperature profile
    - func_soiltemp.F: computing soil temperature
    - vicpenman.F: calculating evaporation using Penman method
    - arno_evap.F: computing evaporation from bare soil surface
    - svp.F: computing the saturated vapor pressure
    - svp_slop.F: computing the gradient of saturated vapor pressure

4.7 Flowchart of the Embedding VIC1 (1)



4.7 Flowchart of the Embedding VIC1 (2)



5. Setting up experiments using coupled system

- Modifying “Makefile.in” under ./gsm(rsm)/src/sfc0/, ./gsm(rsm)/src/sfcl/, ./gsm(rsm)/src/fcst/, and ./gsm(rsm)/src/vic_land/, and adding the new program names for embedding VIC1 in GSM/RSM
- Reconfigure ./libs/
- Modifying ./gsm(or rsm)/def/physics.h using “#define VICLSM1”
- Reconfigure ./gsm(or rsm)/ and remake the model
- Reconfigure ./runs/

6. References: web sites and some documents

- ECPC Web: http://ecpc.ucsd.edu/
- GSM: http://ecpc.ucsd.edu/projects/GSM_model.html
- RSM: http://ecpc.ucsd.edu/projects/RSM/
- RSM document: http://ecpc.ucsd.edu/projects/RSM/manual/rsm_cvs_system.pdf
- VIC: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/VIChome.html