SiB2

DOCUMENTATION
AND
FORTRAN CODE LISTING

VERSION 1.0
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1. INTRODUCTION

This document summarizes and accompanies a FORTRAN implementation of the latest version of the Simple Biosphere model (SiB2). SiB2 contains a significant number of modifications over the original version of SiB written up in Sellers *et al*.(1986). A series of journal papers to be released in 1994 will describe the revised formulation in detail. The changes to the original SiB include:

(i) Reduction of the two-layer vegetation canopy to a single layer,

(ii) Modification of the hydrology to give better descriptions of baseflows and more reliable calculation of inter-layer exchanges within the soil profile,

(iii) Incorporation of a "patchy' snowmelt description, which prevents rapid thermal transi tions when the area-averaged snow cover is low and decreasing,

(iv) Incorporation of a realistic stomatal conductance-photosynthesis model to describe the simultaneous transfers of CO2 and water vapor into and out of the leaf, respectively. This model is based on ecophysiological principles, see Collatz *et al* (1991) *Agric. For. Meteorol*. **54**, 107-136, and has been integrated to provide canopy-scale estimates of conductance and photosynthesis, see Sellers *et al*.(1992).

(v) Use of satellite-derived estimates of FPAR (the fraction of PAR absorbed by the green canopy) and leaf area index. GCM versions of SIB2 use monthly vegetation index fields of FPAR. In this stand-alone version, the user must specify the FPAR and/or LAI values.

Although SiB2 is designed to operate within a GCM, a "stand alone" version is provided here. In practice SiB2 is driven by incident radiation, temperature, humidity, windspeed and CO2 concentration which may be supplied by the lowest layer of a GCM, by measurements or by other simulated driver data. In addition to meteorological driver data SiB2 requires values for parameters that characterize the surface. These include absorbed fraction of incident shortwave radiation or leaf area index, canopy height, soil reflectance and hydrology, and physiology. From all this SiB2 predicts the net fluxes of heat, water vapor, radiation and momentum from the surface as well as the net CO2 flux from the leaves of the canopy.

The following files are required inorder to run this release of SiB2:

(i) The file sib2.f contains all the executable code with all the subroutines appended into one file.

(ii) Two common block files named comsibc.h and pardif.h

(iii) Data1 file which contains the input parameters that characterize the surface and the start up conditions.

(iv) Data2 file which contains a sample of meteorological driver data.

We have run this version of SiB2 with several different FORTRAN compilers including Sun, Microsoft and HP. We have noted that some compilers are sensitive to the syntax of the INCLUDE statement, the file extention of common block files and un-initilized variables. The latter problem is overcome by specifying the compiling option that sets all un-initilized variables to zero. The two sample data files, Data1 and Data2, represent a site in the Amazon basin (data published in Shuttleworth *et a*l. (1984) *Quart. J. Roy. Meteor. Soc.*, **110**, 1143-1162, as reported in Sellers *et a*l. 1989). We have included about 15 days of model output (file names: ftn35,ftn38,ftn42,ftn45,ftn48) as a baseline check.

Inorder to run the model simply compile sib2.f and run in a directory that contains Data1, Data2, comsibc.h and pardif.h files. Five output files will be generated in the same directory.

2. SIB2 VARIABLE LIST

A. Input parameters

Static parameters associated with vegetation type

Variable	Definition	Units
z2	: canopy top height	m
z1	: canopy base height	m
vcover	: vegetation cover fraction	--
chil	: leaf angle distribution factor	--
tran(iw,il)	: leaf transmittance	--
ref (iw,il)	: leaf reflectance	--
effcon	: intrinsic quantum efficiency	mol mol^{-1}
gradm	: stomatal conductance slope parameter	--
binter	: minimum stomatal conductance	mol m^{-2} s^{-1}
respcp	: respiration fraction of vmax	mol m^{-2} s^{-1}
atheta	: wc, we coupling parameter	--
btheta	: wc & we, ws coupling parameter	--
rootd	: rooting depth	m
phc	: 1/2 critical leaf water potential limit	m
trda	: temperature coefficient for leaf respiration	K^{-1}
trdm	: 1/2 critical temperature for leaf respiration	K
trop	: Q_{10} temperature coefficient for physiology(298.16)	K
slti	: slope of low temperature inhibition function	K^{-1}
hlti	: 1/2 point of low temperature inhibition function	K
shti	: slope of high temperature inhibition function	K^{-1}
hhti	: 1/2 point of high temperature inhibition function	K
istype	: soil type	--

static parameters associated with soil type

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sodep	: total depth of 3 soil moisture layers	m
soref(iw)	: soil reflectance	--
bee	: soil wetness exponent	--
phsat	: soil tension at saturation	m

satco	: hydraulic conductivity at saturation	m s^{-1}
poros	: soil porosity	--
slope	: cosine of mean slope	--

time-space varying vegetation parameters, from spectral vegetation indice (SVI).
----

zlt	: leaf area index	$m^2\ m^{-2}$
green	: green leaf fraction	--
fparc	: canopy absorbed fraction of photosynthetically active radiation (par) derived from SVI	--
fparkk	: leaf to canopy integration factor	--

derived parameters
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gmudmu	: time-mean leaf projection (g(μ)/ μ)	--
z0d	: roughness length	m
dd	: zero plane displacement	m
cc1	: rb coefficient (c1)	$(s\ m^{-1})^{1/2}$
cc2	: rd coefficient (c2)	--
zdepth(3)	: individual depths of 3 soil moisture layers	--

other variables
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vmax0	: max rubisco capacity of sun-leaf	mol $m^{-2}\ s^{-1}$
g1	: ratio of K_m(actual) to K_m(log-linear) at z = z2	--
g2	: ratio of ra(actual) to ra(log-linear) for momentum between: z = z2 and z = zx, where zx = min(zl,zwind)	-- --
g3	: ratio of ra(actual) to ra(log-linear) for heat between: z = z2 and z = zx, where z_x = min(zl,zmet)	-- --
ztz0	: parameter to determine depth of transition layer above canopy, zl. zl = z2 + ztz0 * z0	--
corb1	: non-neutral correction for calculation of aerodynamic resistance between ha and z2. when multiplied by h*rbb/tm gives bulk estimate of local Richardson number	--
corb2	: neutral value of rbb*u2 (squared), equivalent to rdc^2 for upper canopy (rbb = ra for heat between ha and z_2. corb2 = 9*g/(rhoair*cpair* $(du/dz)^2$)	--
ha	: canopy source height for heat	m
zwind	: reference height for wind measurement	m

zmet	: reference height for temperature, humidity measurement	m

the above are generated from sibx + momopt subroutine output

B. Prognostic variables

tc	: canopy temperature	K
tg	: ground surface temperature	K
td	: deep soil temperature	K
thm	: mixed layer potential temperature	K
qm	: mixed layer mixing ratio	kg kg^{-1}
www(3)	: ground wetness fraction	--
capac(2)	: canopy/ground liquid interception store	m
snoww(2)	: canopy/ground snow interception store	m

C. Prognostic variable increments

dtc	: canopy temperature increment	K
dtg	: ground surface temperature increment	K
dth	: mixed layer potential temperature increment	K
dqm	: mixed layer mixing ratio increment	kg kg-1
dtd	: deep soil temperature increment	K

D. Forcings

tm	: surface air temperature	K
em	: mixed layer vapor pressure	mb
um	: mixed layer wind speed	m s^{-1}
radn	: incident radiation fluxes	W m^{-2}
ppl	: large scale precipitation	mm
ppc	: convective precipitation	mm
psurf	: surface pressure	mb
sunang	: cosine of solar zenith angle	--
po2m	: partial pressure of O_2	Pa
pco2m	: partial pressure of CO_2	Pa

E. SIB2 output for GCM

etmass (fws)	: evapotranspiration	mm
hflux (fss)	: sensible heat flux	W m^{-2}

roff	: runoff	mm
drag	: shear stress	Pa
salb	: surface albedos	--
tgeff	: effective surface radiative temperature	K
assimn	: canopy assimilation flux	mol m^{-2} s^{-1}

F. SIB2 variables (by group)

Aerodynamic (CAS = canopy air space)
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ra	: CAS to lowest layer aerodynamic resistance	s m^{-1}
rb	: canopy to CAS aerodynamic resistance	s m^{-1}
rd	: ground to CAS aerodynamic resistance	s m^{-1}
ta	: CAS temperature	K
ea	: CAS vapor pressure	mb
u2	: windspeed at z2	m s^{-1}

Radiative transfer (TIR = thermal infrared)
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salb(2,2)	: surface albedos	--
tgeff	: effective surface radiative temperature	K
radfac(2,2,2)	: radiation absorption factors	--
radt(2)	: net radiation	W m^{-2}
thermk	: canopy gap fraction for TIR radiation	--
albedo(2,2,2)	: component reflectances	--
closs	: TIR emission from the canopy	W m^{-2}
gloss	: TIR emission from the ground	W m^{-2}

Surface resistance characteristics
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rst	: canopy resistance	s m^{-1}
rstfac(4)	: canopy resistance stress factors	--
rsoil	: soil surface resistance	s m^{-1}
hr	: soil surface relative humidity	--
fc	: canopy dew indicator	--
fg	: ground dew indicator	--

Hydrology and snow
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satcap(2)	: interception capacities	m
canex	: fraction of exposed canopy (snow-free)	--
areas	: ground snow cover fraction	--
wc	: canopy wetness fraction	--
wg	: ground wetness fraction	--
tgs	: bulk ground/snow temperature	K
tsnow	: snow temperature	K

Physiology
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respc	: canopy respiration	mol m^{-2} s^{-1}
respg	: ground respiration	mol m^{-2} s^{-1}
pco2i	: bulk leaf internal CO_2 concentration	mol mol^{-1}
gsh2o	: canopy conductance	mol m^{-2} s^{-1}
h2os	: canopy surface H_2O concentration	mol mol^{-1}
assimn	: canopy assimilation flux	mol m^{-2} s^{-1}

Heat flux components
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ect	: canopy transpiration increment	J m^{-2}
eci	: canopy interception loss increment	J m^{-2}
egs	: ground evaporation increment	J m^{-2}
egi	: ground interception loss increment	J m^{-2}
ec	: ect + eci	J m^{-2}
eg	: egs + eg	J m^{-2}
hc	: canopy sensible heat increment	J m^{-2}
hg	: ground sensible heat increment	J m^{-2}
chf	: canopy heat storage increment	J m^{-2}
shf	: soil heat storage increment	J m^{-2}
heaten	: heat loss increment to snow melt process	J m^{-2}

Heat storage components
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ccx	: canopy heat capacity	J m^{-2} K^{-1}

cg	: ground heat capacity	J m^{-2} K^{-1}

Partial derivatives of fluxes
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hc	: canopy sensible heat increment	J m^{-2}
hg	: ground sensible heat increment	J m^{-2}
hcdtc	: $\partial H_c/\partial T_c$	J m^{-2} K^{-1}
hcdtg	: $\partial H_c/\partial T_{gs}$	J m^{-2} K^{-1}
hcdth	: $\partial H_c/\partial \theta$	J m^{-2} K^{-1}
hgdtc	: $\partial H_g/\partial T_c$	J m^{-2} K^{-1}
hgdtg	: $\partial H_g/\partial T_{gs}$	J m^{-2} K^{-1}
hgdth	: $\partial H_g/\partial \theta$	J m^{-2} K^{-1}
aac	: $\partial H/\partial T_c$	J m^{-2} K^{-1}
aag	: $\partial H/\partial T_{gs}$	J m^{-2} K^{-1}
aam	: $\partial H/\partial \theta$	J m^{-2} K^{-1}
ecdtc	: $\partial E_c/\partial T_c$	J m^{-2} K^{-1}
ecdtg	: $\partial E_c/\partial T_{gs}$	J m^{-2} K^{-1}
ecdqm	: $\partial E_c/\partial q_m$	J kg kg^{-1} m^{-2}
egdtc	: $\partial E_g/\partial T_c$	J m^{-2} K^{-1}
egdtg	: $\partial E_g/\partial T_{gs}$	J m^{-2} K^{-1}
egdqm	: $\partial E_g/\partial q_m$	J kg kg^{-1} m^{-2}
bbc	: $\partial E/\partial T_c$	kg m^{-2} K^{-1}
bbg	: $\partial E/\partial T_{gs}$	kg m^{-2} K^{-1}
bbm	: $\partial E/\partial q_m$	J kg kg^{-1} m^{-2}

G. Constants

pie	: 3.1415926	--
timcon	: pie/86400.	s^{-1}
cpair	: specific heat of air	J kg^{-1} K^{-1}
psy	: psychrometric constant	mb
hlat (hlatm)	: latent heat of vaporisation (2520000)	J kg^{-1}
g (grav)	: acceleration of gravity (9.81)	m s^{-2}
vkc	: von karman’s constant (0.41)	--
snomel	: latent heat of fusion	J kg^{-1}
stefan	: stefan-boltzman constant	W m^{-2} K^{-4}
tf	: freezing temperature (273.16)	K
asnow	: fractional snow covered area/snow mass (13.2)	--

3. REFERENCE LIST

The SiB2 subroutines are internally documented with references to equations in published papers. These papers are listed with the abbreviations used in the code (e.g. SE-92 refers to Sellers et al. ; 1992)

CO-92 : Collatz G.J, M.Ribas-Carbo and J.A.Berry (1992) ’Coupled Photosynthesis-stomatal conductance model for leaves of C4 plants’, Aust. J. Plant Phys., 19, 519-538.

CS-81 : Camillo P.J. and T.J. Schmugge (1981) ’ Heat and moisture flow in soils’, NASA Tech. Memo., NASA/GSFC 974, Greenbelt, MD 20771, pp87.

ME-82 : Milly P.C. and P.S. Eagleson (1982) ’Parameterization of moisture and heat fluxes across the land surface for use in atmospheric General Circulation Models. Rep. 279, Dept. of Engineering, Massachusetts Institute of Technology, pp159.

SA-89A : Sato N., P.J.Sellers, D.A.Randall, E.K.Schneider, J.Shukla, J.L.Kinter III, Y-T Hou and E.Albertazzi (1989a) ’ Effects of implementing the simple biosphere model in a general circulation model’, J. Atmos. Sci., 46, (18), 2757-2782.

SA-89B : Sato N., P.J.Sellers, D.A.Randall, E.K.Schneider, J.Shukla, J.L.Kinter III, Y-T Hou and E.Albertazzi (1989b) ’Implementing the simple biosphere model (SiB) in a general circulation model: Methodologies and results’, NASA Contractor Report 185509, NASA HQ, Washington DC 20546, pp76.

SE-85 : Sellers P.J.(1985) ’ Canopy reflectance, photosynthesis and transpiration’, Int. J. Remote Sens., 6,(8), 1335-1372.

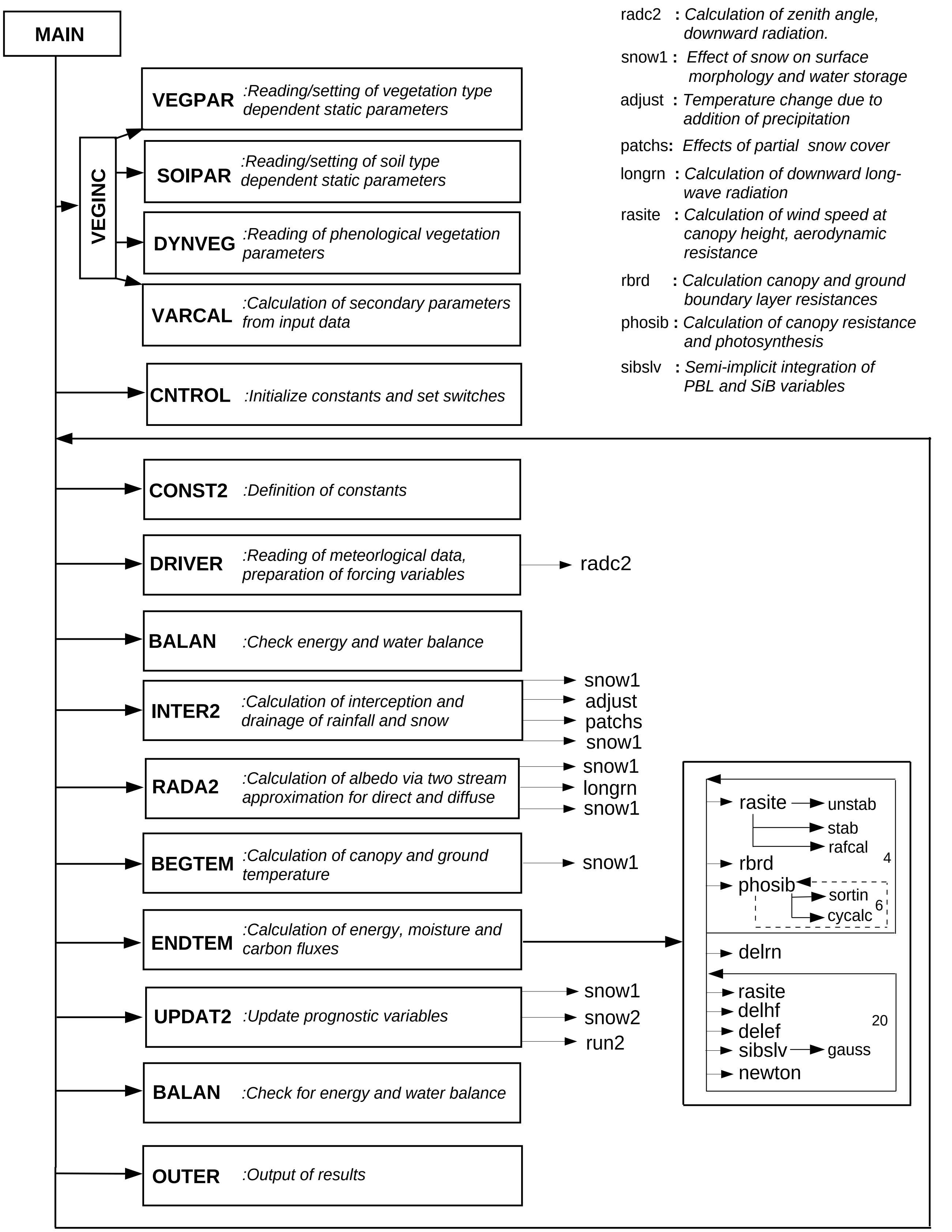
SE-86 : Sellers P.J, Y. Mintz, Y.S.Sud and A.Dalcher (1986) ’A simple biosphere model (SiB) for use within general circulation models’, J. Atmos. Sci., 43, 6, 505-531.

SE-87 : Sellers P.J.(1987) ’ Canopy reflectance, photosynthesis and transpiration, II. The role of biophysics in the linearity of their interdependence’, Remote Sens. Env., 21, 143-183.

SE-89 : Sellers P.J., W.J.Shuttleworth, J.L.Dorman, A.Dalcher, and J.M. Roberts (1989) ’ Calibrating the simple biosphere model (SiB) for Amazonian tropical forest using field and remote sensing data. Part I: Average calibration with field data ’, J. Appl. Met., 28, (8), 727-759.

SE-92 : Sellers P.J., J.A.Berry, G.J.Collatz, C.B.Field and F.G.Hall (1992) ’ Canopy reflectance, photosynthesis and transpiration III. A reanalysis using improved leaf models and a new canopy integration scheme’, Remote Sens. Env., 42, 1-20.

SIB2 FLOWCHART



5. SIB2 FORTRAN CODE, COMMON BLOCKS, INPUT DATA