**TerraE Scheme for Interception of Precipitation by Vegetation Canopies**

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**Canopy Interception Reservoir**

The scheme for precipitation interception by a canopy is based on a water-balance equation applied to a canopy reservoir



where *wc* is the canopy water storage [m], *t* is time [s], *Ic,net* is the canopy interception rate not including evaporation losses [m/s], *fc,wet* is the wet fraction of the canopy [-], *fsn* is the fraction of the grid cell that is covered by snow [m2 snow/m2 ground], *fsn,c* is the fraction of the canopy that is covered by snow [m2 snow/m2 canopy], and *Ev,w* is the evaporation rate from the canopy reservoir (wet canopy) [m3/m2 ground/s]. *Ic,net* is expressed as



where *Ptot,tot* is the total (convection and large-scale) precipitation in the grid cell [m/s] and *Dr,tot* is the total drip (rain and snow) from the canopy [m/s]. The equation is solved using the Euler’s method (explicit in time) as



w(0,2) = w(0,2) + ( fc(1) - fc(0) )\*dts

ht(0,2)=ht(0,2) + ( fch(1) - fch(0) )\*dts

fc(0) = -pr+evapvw\*fw\*(1.d0-fm\*fr\_snow(2))

! snow masking of pr is ignored since

! it is not included into drip

fc(1) = -dripw(2) - drips(2)

where Δ*t* is the time-step size [s]. The constitutive equations for the canopy water balance are based on empirical relationships for *Dr,tot*, *fc,wet*, *fsn*, *fm*, and *Ev,w*..

**Interception Reservoir Capacity and Wet Canopy Fraction**

The expression for wet fraction of the canopy is written as



where *wc,max* is the maximum storage capacity of the canopy reservoir [m]. This variable is currently computed in the Ent DGTEM as 0.0001*Lt* (or 0.1 *Lt* for units of kg/m2).

**Fraction of Grid Cell Covered by Snow**

The fraction of the grid cell that is cover by snow, *fsn*, is computed from the three-layer snow model, while the fraction of vegetation covered by snow is given as



where *S* is the water-equivalent snow depth [m] assuming the snow is distributed uniformly in space over the snow cover fraction of the cell, *Vh* is the height of the vegetation [m], and *Gs* is the specific gravity of snow [-] assumed to be equal to 0.1.

**Precipitation Types**

The precipitation currently passed to GHY.f is the total (convection and large-scale) precipitation in the grid cell, *Ptot,tot*. The large-scale precipitation, *PLS*, passed to GHY.f is currently set to zero.

The convective rainfall, *Prain,c*, in GHY.f is computed as



ptmps=prs-snowfs

ptmps=ptmps-evapvw\*fw

ptmp=pr-prs-(snowf-snowfs)

where *PLS,tot* is the large-scale precipitation rate [m/s], *Ptot,sn* is the total (convective and large-scale) snowfall rate [m/s], and *PLS,sn* is the large-scale snowfall rate [m/s].

**Precipitation Throughfall from Canopy**

The total throughfall is the sum of drip due to rain and snow. It is assumed that the canopy does not intercept snow, such that the drip due to snow, *Dr,sn*, is



where *Psn* is the total (convective and large-scale) snowfall rate using equivalent water depth [m s-1].

The drip from rainfall, *Dr,rain*, is then computed based on whether *Prain,c* is greater than zero and based on the value of the factor *Pfac*. *Pfac* is computed as



pfac=(pmax-ptmps)\*prfr/ptmp

where *μ* is the fraction of the grid cell over which rainfall is occurring. *P*max is the maximum precipitation rate for which there is no throughfall. *P*max is taken to be a fixed precipitation rate times the dry canopy fraction, which is given as



pm=1d-6

pmax=fd0\*pm

where *Pm* is a constant equal to 1×10-6 m/s. The expression for *Dr,rain* is then for positive *Pc* as



if(ptmp.gt.0.d0)then

pfac=(pmax-ptmps)\*prfr/ptmp

if(pfac.ge.0.d0)then

if(pfac.lt.30.d0) dr=ptmp\*exp(-pfac)

else

dr=ptmp+ptmps-pmax

endif

endif

and *Pc* equal to 0 as



drs=max(ptmps-pmax,zero)

dr=drs

The following limits are also imposed sequentially:







dr = min( dr, pr-snowf-evapvw\*fw )

dr = max( dr, pr-snowf-evapvw\*fw - (ws(0,2)-w(0,2))/dts )

dr = max( dr, 0.d0 ) ! just in case (probably don''t need it)

dripw(2) = dr

**Revisions to Precipitation Throughfall & Wet Canopy Fraction**

The determination of precipitation interception is challenging in a global-scale land surface model, because precipitation is rarely uniform over the model’s grid cell (Koster and Suarez, 1996). The amount of precipitation intercepted (precipitation loading) is affected by the fraction of the grid cell, *μ*, covered by precipitation. The mass of precipitation that needs to reach the land surface is the same, such that the effective precipitation rate increases as *μ* decreases. As a result, less precipitation is intercepted as *μ* decreases. Some models (SiB) use an exponential function to describe the subgrid distribution of precipitation, but a steeper exponential function is analogous to smaller *μ* values and will result in less intercepted water. For ecosystem-scale simulations, the fraction of the grid cell, *μ*, covered by precipitation is set to 1. That is, the size of a storm is much greater than the ecosystem size.

The precipitation rate for the dry fraction of the canopy is



and the rate for the wet fraction of the canopy, which fall through directly to the ground, is



where *P*dry and *P*wet are the precipitation rates occurring on the dry and wet leaves, respectively. The maximum amount of precipitation that can be added in the region with a dry canopy and covered by convective rainfall is



The total intercepted precipitation is updated with



where *Ic* is the canopy interception [m]. The precipitation throughfall or drip is computed as



The temporal correlation in storm position is a problem that most LSMs do not address, which stems from the fact that a simulated storm can span several timesteps (Koster and Suarez, 1996). On one timestep, a storm will fill a fraction of the interception reservoir. In the next timestep, the model produces precipitation over the same fraction *μ* (Koster and Suarez, 1996). The amount of intercepted water on the subsequent timestep depends on how and if the model redistributes water from the previous timestep. If a model does redistribute water and has no memory (that is, does not account for temporal correlation in storm position), then it will intercept more water than if the model had memory. The time step size of the GISS LSM ranges from 5 sec to 30 minutes, and, because storms typically last much longer than this, accounting for temporal correlation in storm position is arguably more realistic (Koster and Suarez, 1996).

The fraction of precipitation that falls on leaves previously wetted is



Water added to the dry canopy, covered by convective rainfall, and not previously wetted by a storm is



where *τ*storm is an arbitrary time scale for storm length that is greater than or equal to Δ*t* (Koster and Suarez, 1996).

**Evaporation from the Wet Canopy**

The evaporation from the wet canopy, *Ev,w*, is compute based on potential evaporation, *Ep*. *Ep* is expressed as



epv = rho3\*ch\*( vs\*(qv-qs) -v\_qprime )

where *ρa* is the density of surface air [kg/m3], *qs* is the humidity of surface air [-], *qsat* is the saturated humidity at the temperature of the canopy *Tcan*, *Vs* is wind speed, and *Cq* is the humidity transfer coefficient [-]. The following limits are then used to constrain *Ev,w*:





ibv = 2; evap\_max\_wet(ibv) = w(0,2)/dt !+ pr ! pr doesn''t work for snow

evapvw = min( epv, evap\_max\_wet(2) )

c\*\*\*\* qm1 has mass of water vapor in first atmosphere layer, kg m-2

qm1dt=.001d0\*qm1/dt

evapvw = max( evapvw,-qm1dt )

where *qm,1* is the mass of water vapor in the first atmospheric layer [kg/m3].

References:

Koster, R.D. and Suarez, M.J., 1996. Energy and water balance calculations in the Mosaic LSM, NASA Goddard Space Flight Center, Greenbelt, Maryland.