Snowpappus - user guide

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In this document, we present SnowPappus-specific SURFEX options. For more details about SURFEX use, refer to SURFEX user guide (https://www.umr-cnrm.fr/surfex/spip.php?rubrique10). The mathematics-style notations used in this user guide are the same as in the SnowPappus description paper.

1 Recommendations of general namelist options

SnowPappus is not designed to work with some other options of SURFEX, in the other snow transport modules (SYTRON, Crocus-Meso-NH), and some options of Crocus. To avoid problems, here is a list of namelist parameters which should be fixed to these values :

&NAM_ISBA_SNOWn
CSNOWDRIFT='NONE'
LSNOWDRIFT_SUBLIM= .FALSE.
LSNOWSYTRON=.FALSE. (défault)

More justification about some of these requirements will be given in the following sections. More generally, SnowPappus has currently be tested with the "default" Crocus options. They are given in the provided namelists. The consistent behaviour of SnowPappus with other physical options (metamorphism, compaction, properties of falling snow) should be carefully evaluated before any large scale application.

2 Snowpappus specific namelist parameters

2.1 Options

Snowpappus options (to activate or disactivate SnowPappus and different subprocesses, choose the parameterizations ...). They are all gathered in the group &NAM_ISBA_SNOWn .

activating or disactivating SnowPappus: LSNOWPAPPUS (logical) : Activates SnowPappus if set to .TRUE. . If .FALSE. (default) , the program does not run SnowPappus code.

Snowfall, blowing snow occurence and wind-induced snow metamorphism: Blowing snow occurrence detection depends mainly on (i) The parameterization linking surface properties to threshold friction velocity $u_{*,t}$ (ii) The properties of snowfall (in terms on microstructure and possibly density). An important thing to know is that (i) wind-induced snow metamorphism can be computed by the SNOWCRO routine (Crocus main routine) (ii) several options are available for fresh snow properties (iii) Activating or disactivating wind-induced snow metamorphism interacts with the snowfall properties option. First of all, we will explain how it works in Crocus without SnowPappus. Second, we will explain the modifications and additional SnowPappus option. In Crocus without SnowPappus :

- 'CSNOWFALL' controls falling snow density (see SURFEX documentation for more details)
- 'CSNOWDRIFT' controls wind-induced snow metamorphism and falling snow microstructure.'NONE': falling snow microstructure as described in Vionnet et al. 2012 and Guyomar'ch et al. 1998, no wind-induced snow metamorphism; 'VI13': falling snow microstructure as described in Vionnet et al. 2013, wind-induced snow metamorphism as described in Vionnet et al. 2012; 'DFLT'(default) : not described here; 'GA01' : not described here.
- 'CSNOWMOB': gives the option for threshold wind speed. Threshold wind speed is computed in the SNOWCRO routine.

For SnowPappus use, we have to set CSNOWDRIFT='NONE' so that all snow transport-related computations are done by SnowPappus. In order to keep control on falling snow properties, we enabled independent selection of wind-induced snow metamorphism option and snowfall properties

- CSNOWFPAPPUS overcomes 'CSNOWDRIFT' to select falling snow microstructure.'GM98' (Guyomar'ch & merindol 1998, Vionnet 2012) ; 'VI13' Vionnet 2013, 'NONE'(default) : no effect, CSNOWDRIFT prevails.
- CSNOWMOB : Chooses the way threshold wind speed is computed in SnowPappus when surface snow age is superior to the threshold value XAGELIMPAPPUS (and in snowcro if HSNOWDRIFT=.TRUE.). 'GM98' (default) historical version, Guyomarc'h et Mérindol (1998), see SnowPappus description article ,'CONS' threshold wind speed is constant equalling 9 m/s (at 5m height), see SnowPappus description article, 'VI12' parameterization described in Vionnet et al 2012, 'LI07' parameterization as a function of density as described in Liston et al. 2007, 'COGM' constant at 9 m/s if snow is non-dendritic, given by GM98 parameterization for dendritic snow (beware: this option is also used for Crocus alone or Sytron. Only 'GM98' and 'VI12' work in these cases)
- CDRIFTPAPPUS : 'NON' (default): no wind-induced snow metamorphism (WISM) in snowpappus, 'CRO' : WISM with its own threshold

wind speed computed with the same code as in SNOWCRO routine. This threshold wind speed does not apply to the computation of fluxes, 'CRM': WISM. with it's own thr wind speed applying to all snowpappus (overpassing HSNOWMOB');'PAP' : "" using pappus threshold wind speed to compute the mobility index (see Vionnet et al. 2012 for more details).

other options

- OPAPPUDEBUG : Boolean. If True triggers snowpappus debug mode. This option displays additional information on the computation. It displays warnings, swe conservation verification results, time and date during computation for easier debugging. And proof of SnowPappus mass conservation. (default .False.)
- CSALTPAPPUS : 'P90' (default) : Saltation transport given by Pomeroy 1990 formulation, 'S04' : Sorensen 2004 - Vionnet 2012 formulation. More details about it in Baron et al. 2023 Snowpappus description paper
- CLIMVFALL : 'DEND' fall speed v_f^* of suspended snow particles is computed as old snow if snow is non-dendritic,'PREC' old snow = non-dendritic OR age ¡ XAGELIMPAPPUS2, 'MIXT' (default) old snow for non-dendritic, new snow for dendritic and age¡XAGELIMPAPPUS2 , weighted average if dendritic more aged snow, the option is described in SnowPappus description paper
- CPAPPUSSUBLI : 'NONE' : no sublimation in pappus transport scheme, 'SBSM': SBSM sublimation parametrisation, 'B9810': Bintanja 1998 with 10m wind , 'B9803' : Bintanja 1998 with 3m wind, 'GR06' : Gordon 2006 sublimation parameterization.
- OPAPPULIMTFLUX : Boolean. If True = snow transport flux limitation activated. It limits the flux on a pixel if there is not enough snow on it to avoid removing more snow than there is on it. There is limitations on Q_t and q_{subl}. The condition is the following :

$$q_{subl} \leq \frac{P_{SWE}}{Pt_{step}} \tag{1}$$

$$and \quad Q_t \leq (\frac{P_{SWE}}{Pt_{step}} - q_{subl})\frac{P_{mesh}}{cos(\theta)} \tag{2}$$

with P_{SWE} being the snow mass for each pixel in kg/m^2, Pt_{step} the computation time step in s, P_{mesh} the pixel size in m and θ the slope angle. (default: False) It also limits the mass bilan of snowcro.F90 to XUEPSI. It also corrects the water mass flux balance to a precision of XUEPSI. The condition is the following:

```
WHERE (ZQDEP_TOT(:)<XUEPSI .AND. ZQDEP_TOT(:)>-XUEPSI)
      ZQDEP_TOT(:) = 0.
ENDWHERE
```

The drawback of this condition is that it reduces the mass balance of snowpappus (error of xuepsi possible if there is more than 2 pixels contributing to the mass balance of one pixel) but improves the snowcro one by satisfying the snownlfall condition of snowfall ¿xuepsi all the time.

- CSNOWPAPPUSERODEPO : Determines how the deposition flux q_{dep} is computed from Q_t 'ERO' : fictive "pure erosion" case $q_{dep} = -\frac{Q_t}{l}$ with $l = 250m$, 'DEPO' : fictive "pure deposition" case $q_{dep} = +\frac{Q_t}{l}$, 'DIV' (default): q_{dep} computed with a mass balance (needs 2D grids, described in SnowPappus article), 'NON' : $q_{dep} = 0$ =¿ SnowPappus diagnostics are computed but it does not adds or removes any snow. 'ERO', 'DEPO' and 'NON' options can be used in point-scale simulations.

2.2 Physical constants

Constant parameters can be specified in the namelist. They all are in the group &NAM_SURF_SNOW_CSTS

- XAGELIMPAPPUS : maximum age of snow layer for which wind speed threshold is set to fresh threshold wind speed !(default: 0.05 days)
- XAGELIMPAPPUS2 : maximum age of snow for using Naaim96 formulation of terminall fall speed in snowpappus (default: 0.05 days)
- XWINDTHRFRESH : 5 m wind speed threshold for transport of freshly fallen (or deposited) snow (default: 6 m.s^1)·
- XRHODEPPAPPUS, XDIAMDEPPAPPUS, XSPHDEPPAPPUS :density (kg.m^{-3}), optical diameter (m) and sphericity of wind blown deposited snow (default :$\rho = 250$ kg.m^{-3}, D_{opt} =3.10^{-4} m, $s = 1$)
- XLFETCHPAPPUS : constant fetch distance l_{fetch} applied to all points for snowpappus blowing snow flux calculation (m)· (default : $l_{fetch} = 250m$)
- XDEMAXVFALL : when option MIXT is chosen for terminal fall speed calculation, maximum dendricity $d_{\max}$ to have pure young snow fall speed. (default : $d_{max} = 0.3$)

3 Snowpappus diagnostic variables

In general in SURFEX, the list of diagnostic variables names which are to be written in the output file has to be specified in the namelist option CSELECT, in group &NAM_WRITE_DIAG_SURFn.

Here we give the exhaustive list of SnowPappus - related diagnostics.in SURFEX, time step at which diagnostic variables are given (namelist option XTSTEP_OUTPUT in &NAM_IO_OFFLINE) is not the same as model time step. Thus, the output value is either "instantaneous" (i.e. the given value is the one at the model time step which equals the output time) or "cumulated" (i.e. the given value is the averaged value on the whole output time step)

"cumulated" diagnostic variables

- XQDEP_TOT : total wind-blown snow net deposition rate $q_{\rm dep}$(kg.m^{-2}.s^{-1})
- XQ_OUT_SUBL : sublimation rate $q_{\rm subl}$(kg.m^{-2}.s^{-1})
- XQT_TOT : total wind-blown horizontal vertically integrated snow transport rate Q_t(kg.m^{-1}.s^{-1})
- XSNOWDEBTC : cumulated amount of snow which should have been removed on the oint but was not because it became snowfree (kg.m^{-2}) (see the paragraph "mass balance" in the article)

"instantaneous" diagnostic variables

- XBLOWSNWFLUX_1M : horizontal blowing snow flux 1 m above snow surface (kg.m^{-2}.s^{-1})
- XBLOWSNWFLUXINT : average horizontal blowing snow flux between 0.2 and 1.2 m $Q_{t,int}$(kg.m^{-1}.s^{-1})
- XQ_OUT_SALT : total horizontal transport rate in the saltation layer $Q_{\rm salt}$(kg.m^{-1}.s^{-1})
- XQ_OUT_SUSP : total horizontal transport rate in the suspension layer $Q_{\rm susp}$(kg.m^{-1}.s^{-1})
- XVFRIC_PAPPUS : wind friction velocity computed by Snowpappus u_*(m.s^{-1})
- XVFRIC_T_PAPPUS : threshold friction velocity (at ground level) for snow transport $u_{*,t}$(m.s^{-1})
- XPZ0_PAPPUS : roughness length for momentum z_0 (m) used by Snowpappus
- XVFALL_PAPPUS : mass averaged terminal fall velocity of snow particles at the bottom of the suspension layer v_f(m.s^{-1})