Crocus-Resort
Manual for DEVELOPERS

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Abstract

The present manual introduces the main elements of the Crocus-Resort version of the snowpack model Crocus. The scientific development of this version of the code was described in Spandre et al. (2016). The goal of the present manual is to provide elements for both **DEVELOPERS**: the code structure is described for both the snowmaking (section 1) and grooming approaches (section 2).

- Please note that the Crocus Resort model can only be run with 'C13' formulation (Carmagnola et al., 2013) of snow metamorphism (description of snow microstructure).

- Please refer to the Manuel for USERS for additionnal details (list of main variables, example of NAMELIST OPTIONS.nam, etc.)

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Contents

References

Carmagnola, C., Morin, S., Lafaysse, M., Domine, F., Lesaffre, B., Lejeune, Y., and andLafaysse, G. P. (2013). Implementation and evaluation of prognostic representations of the optical diameter of snow in the detailed snowpack model surfex/isba-crocus. *The Cryosphere Discussions*, 7:4443–4500.

Spandre, P. (2016). *Observation et modélisation des interactions entre conditions d'enneigement et activité des stations de sports d'hiver dans les Alpes françaises*. PhD thesis, Université Grenoble Alpes.

Spandre, P., Morin, S., Lafaysse, M., George-Marcelpoil, E., François, H., and Lejeune, Y. (2016). Integration of snow management in a detailed snowpack model. *Cold Regions Science and Technology*.

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1 Snowmaking approach in Crocus Resort

Please refer to Spandre et al. (2016) and chapt. 5 of Spandre (2016) for further details on the scientific development of the model.

1.1 Decision defined in snow3L_isba.F90

IF SNOWMAK_BOOL = TRUE
Snow management conditions: suitable for production?

+ From November to March, production is allowed (PMONTH = TRUE)

+ Daily timetable

- From 1 November to 15 December: Production allowed all day (PDAY = TRUE)
- From 15 December to 30 March: Production allowed from 18:00 to 8:00 (PDAY = TRUE)

+ Production target

- IF SELF_PROD = TRUE i.e. the model produces snow based on current snow conditions
- From 1 November to 15 December
  Production allowed allowed until 150 kg m^{-2} (PRODSNOWMAK = TRUE)
- From 15 December to 28 February
  Production allowed if total snow depth < 0.6 m (PRODSNOWMAK = TRUE)

- IF SELF_PROD = FALSE i.e. you force the amounts of production.
- Set PROD_SCHEME (dimension 5): the target production.
  Expressed in seconds of prodution per day for (November, December, January, February, March)
- Every day at 18:00, production counter (PROD_COUNT) is compared to the target.
  If lower: PRODSNOWMAK = TRUE

✓ IF (PMONTH = TRUE AND PDAY = TRUE AND PRODSNOWMAK = TRUE)
TIMESNOWMAK = TRUE

Atmospheric conditions: suitable for production?
Compute ZTW (Wet-bulb temperature) and compare with threshold (PTA_SEUIL), check PVMOD (wind speed)

✓ IF (ZTW < PTA_SEUIL AND PVMOD < 4.2)
CONDSNOWMAK = TRUE

Production decision?

✓ IF (TIMESNOWMAK = TRUE AND CONDSNOWMAK = TRUE)

- Increase production counter PROD_COUNT of one time step (PTSTEP)
- Compute MM snow depth (PSNOWMAK)
- Sum with snowfall variable ZSNOWFALL = ... + PSNOWMAK
  (to be latter used by routines to decide whether to CALL SNOWCRO)
- Transfer PSNOWMAK to subroutine SNOWCRO
  Please note PSNOWMAK is systematically transfered to subroutine SNOWCRO (if called). When decision is false (either TIMESNOWMAK OR CONDSNOWMAK), PSNOWMAK is transferred with a value of 0.

1.2 Impact on snow properties defined in snowcro.F90

In **subroutine SNOWNLFALL_UPGRID**

- Compute MM snow mass flux (kg m^{-2} s^{-1}), based on PSNOWMAK
  (either 0 if no production or PSR_SNOWMAK)

- IF SNOWMAK_PROP = TRUE
  Modify newly fallen snow properties (PSNOWRHOF, PSNOWGRAN1F, PSNOWGRAN2F) by weighing properties with mass fluxes (in case of MM snow production during natural snowfall and/or blowing snow)

- Compute newly fallen snow depth SNOWFALL = (PSR + ... + PSR_SNOWMAK) x PTSTEP / PSNOWRHOF

2   Grooming approach in Crocus Resort

Please refer to Spandre et al. (2016) for further details on the scientific development of the model.

Decision and impact on snow properties defined in snowcro.F90

In subroutine SNOWCROCOMPACTN

IF SNOWCOMPACT_BOOL = TRUE
CALL subroutine SNOWGROOMING (...)

In subroutine SNOWGROOMING

Snow management conditions: suitable for grooming?

+ Grooming allowed from 1 November until SM_END (PMONTH = TRUE).
  SM_END, dimension 4 (Month, Day, Month, Day): Date to stop snow grooming for grooming only (first two dimensions) and grooming + snowmaking (two last dimensions).

+ Daily timetable

  - Grooming allowed from 20:00 to 21:00 (PDAY = TRUE)
    If snowfall during the night, grooming allowed from 6:00 to 9:00 (PDAY = TRUE)
  - Check the grooming frequency. If FREQ_GRO = 1, grooming every day (PDAY = TRUE)

✓ IF (PDAY = TRUE AND PMONTH = TRUE)
  TIMECOMPACT = TRUE

✓ Check if a minimum total snowpack water equivalent (SWE) of 20 kg m^{-2}
  TIMECOMPACT = TRUE

Impact on snow properties

- Compute ZSNOWCOMPACT (overburden weight due to the grooming machine)
  Further added to PSMASS in the computation of snow density evolution PSNOWRHO

- IF SNOWTILLER = TRUE
  Modify snow layers properties (PSNOWRHO, PSNOWGRAN1, PSNOWGRAN2)
  by weighing properties with SWE layer (within the first 35 kg m^{-2} below surface)