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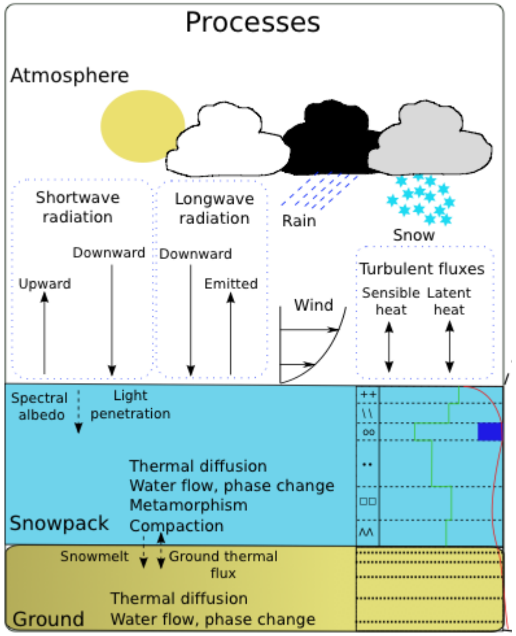
Recent developments in Crocus

M. Lafaysse, M. Dumont, V. Vionnet, S. Morin and many many others ….

SURFEX/ISBA-Crocus

- Embedded in SURFEX (surface scheme) and permanently coupled with soil model ISBA-DIF (Vionnet et al., 2012)

- Open source code, available via git repository



- Support and informations through opensource.u creating an account)

- crocus@meteo.fr

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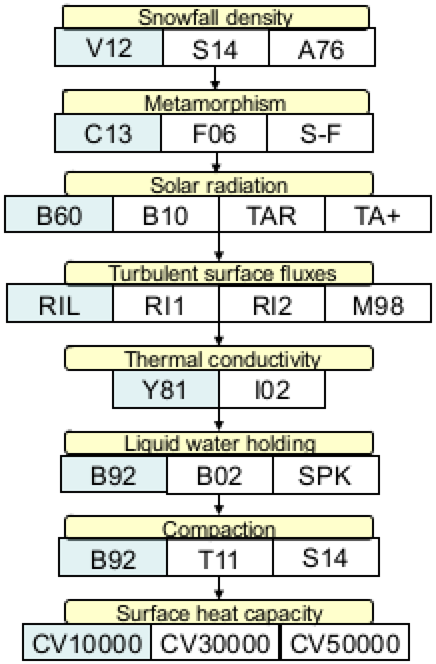
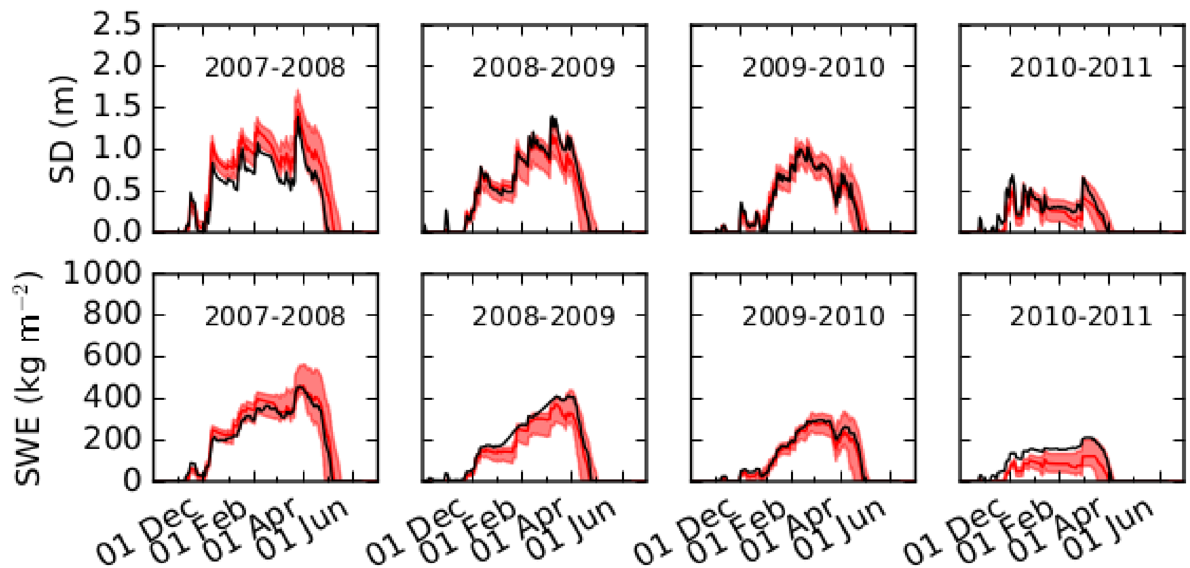
Multiphysics ensemble ESCROC (Lafaysse et al., TC, 2017)



Several parameterizations and parameters values for each process



35 «optimal » members
Underdispersive

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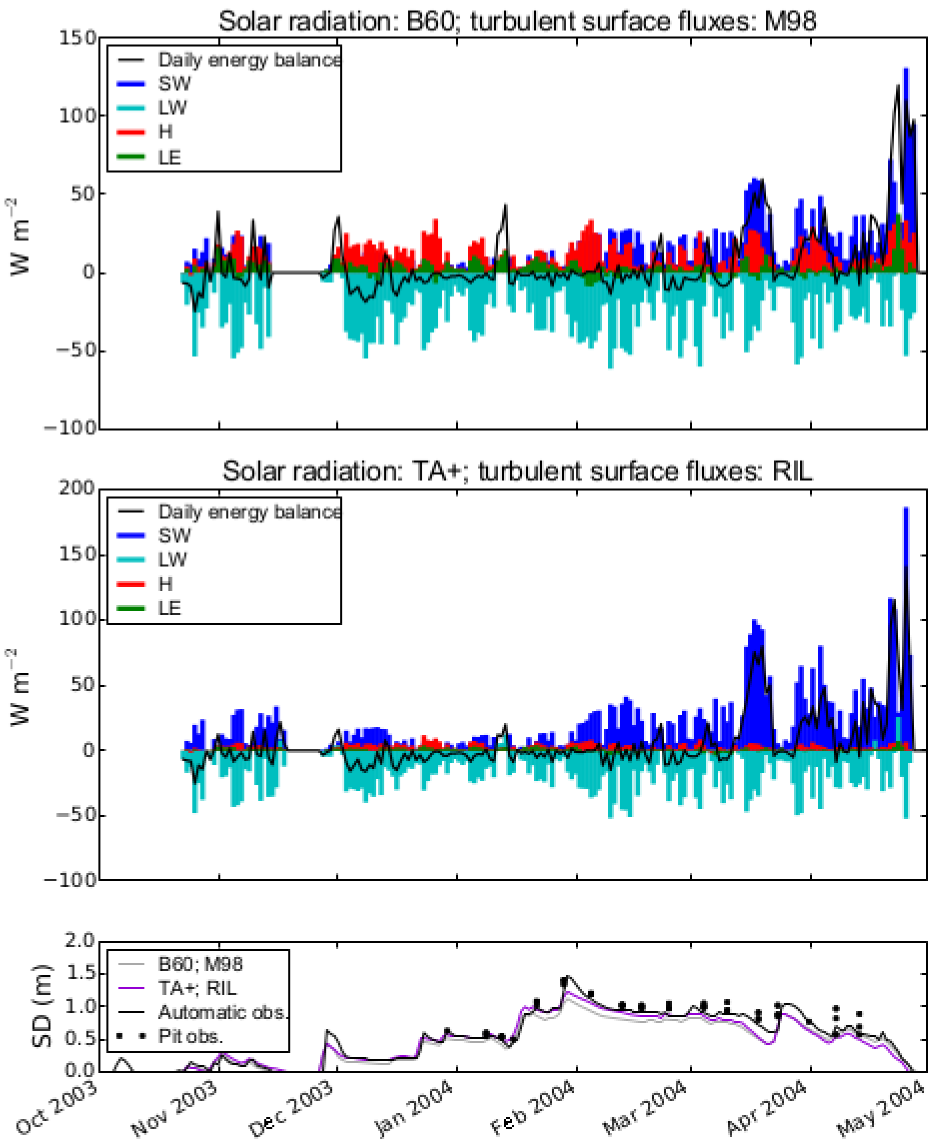
Multiphysics ensemble ESCROC (Lafaysse et al., TC, 2017)



High equifinality

No single « best » model

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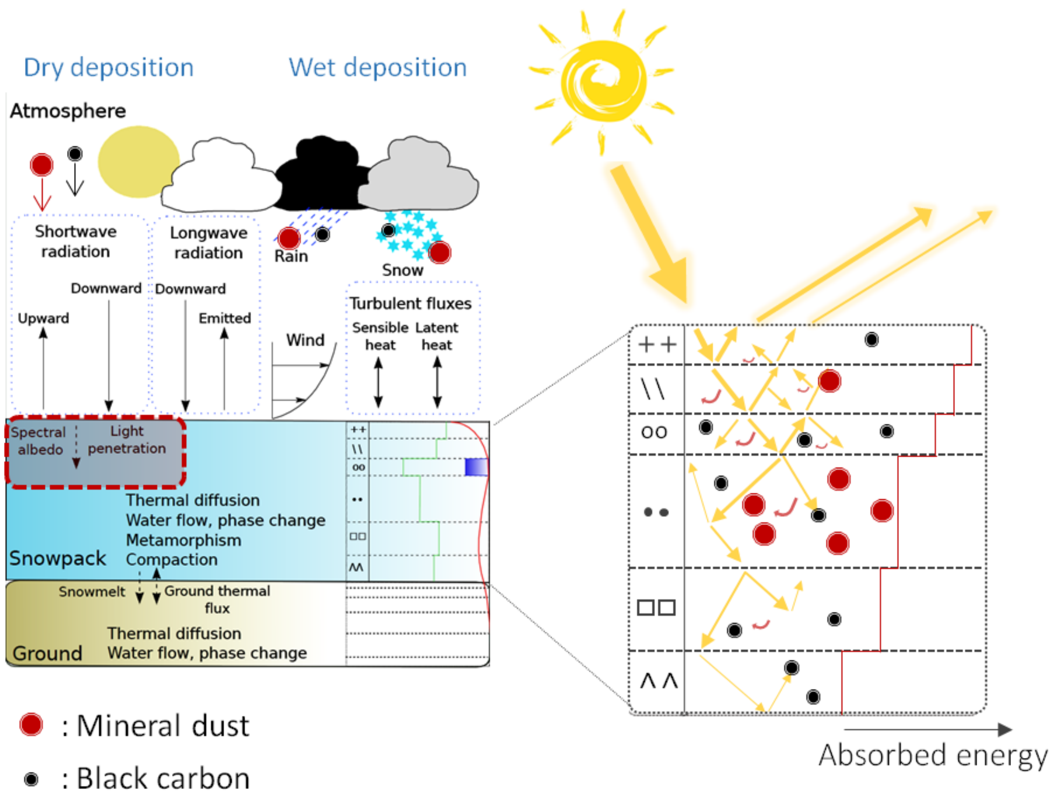
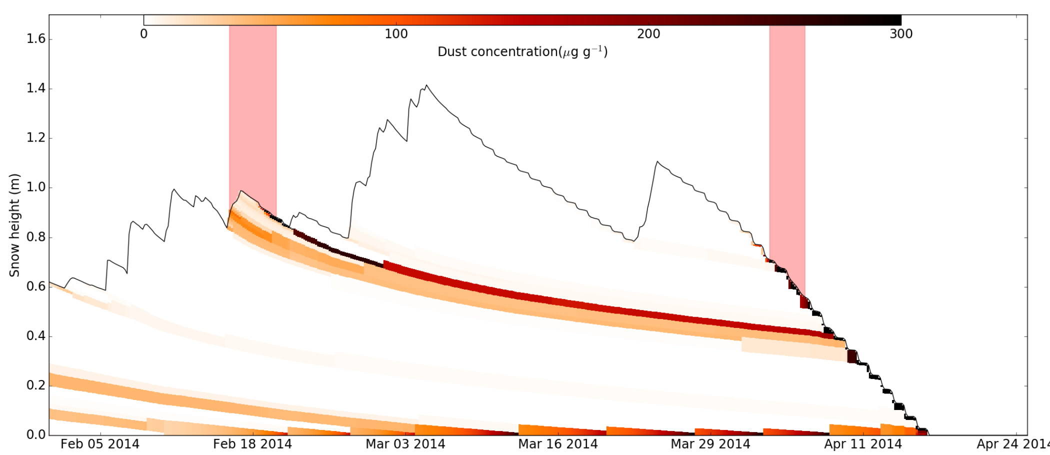
Light absorbing impurities in snow (Tuzet et al., TC, 2017)





Impurity content as a prognostic variables

Number and type defined by users (need density and refraction index for each impurity type) → rayleight scatterers

Forcing via wet and dry deposition fluxes (MOCAGE, ALADIN ...)

Handles deposition, fate (concentration enhancement through compaction, liquid water entrainment etc.), impact (using the TARTES radiative transfer code)

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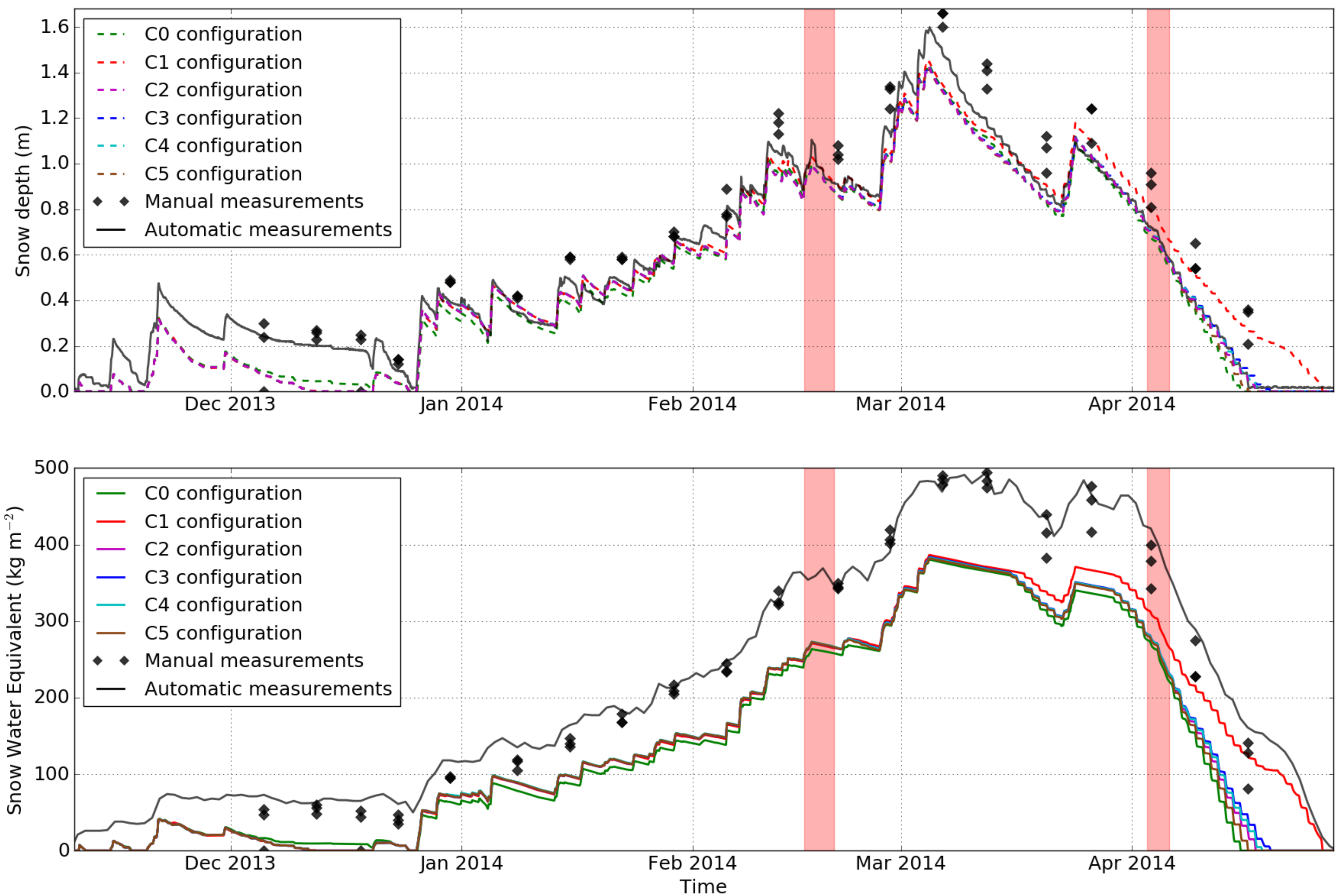
Light absorbing impurities in snow (Tuzet et al., TC, 2017)



9 days delay in melt out date due to impurities

No significance change in performance compared to the original version

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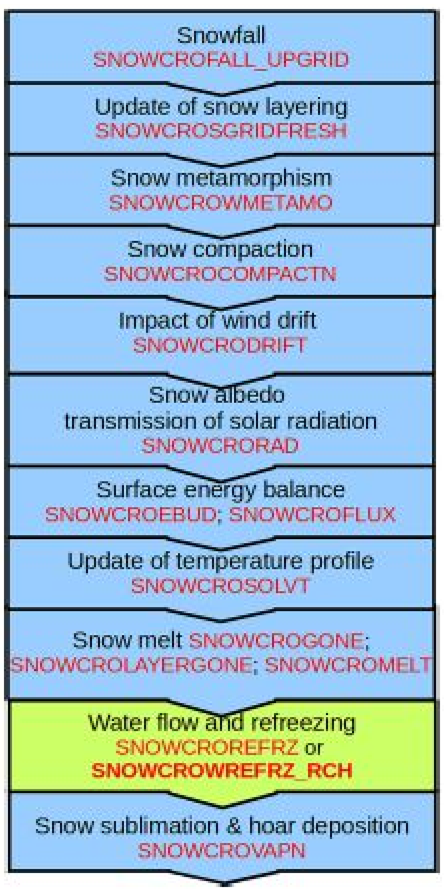
Water percolation (D'Amboise et al., GMD, 2017)

Richards equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K(\theta) \cdot \frac{\partial H}{\partial z}\right) \quad (1)$$

$K(\theta)$ is the hydraulic conductivity which is a function of the volumetric water content (θ), and t and z denote time and depth (positive downward). H is the hydraulic head, which is the sum of the pressure head (h) and the elevation (z), which is negative because z is positive downward (Eq. 2).

$$H = h - z \quad (2)$$



Numerical stability issues

Quite a tricky problem to solve within Crocus/SNOWPACK framework (see Wever et al.)

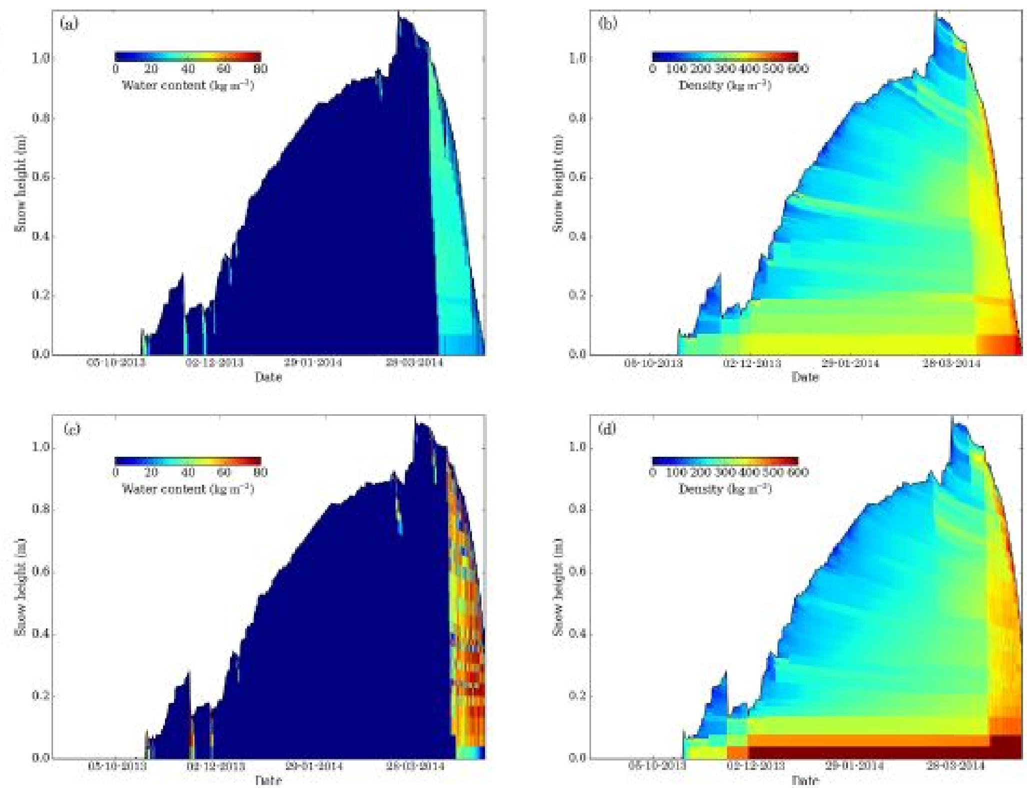


Figure 6. Crocus output from Filefjell, Norway, in which the top plots use the bucket routine and the bottom plots use the Richards routine. Panels (**a, c**) show distribution of liquid water, and (**b, d**) show the density distribution. $T_{\mathrm{crocus}} = 900$ s (15 min) was the time step duration.

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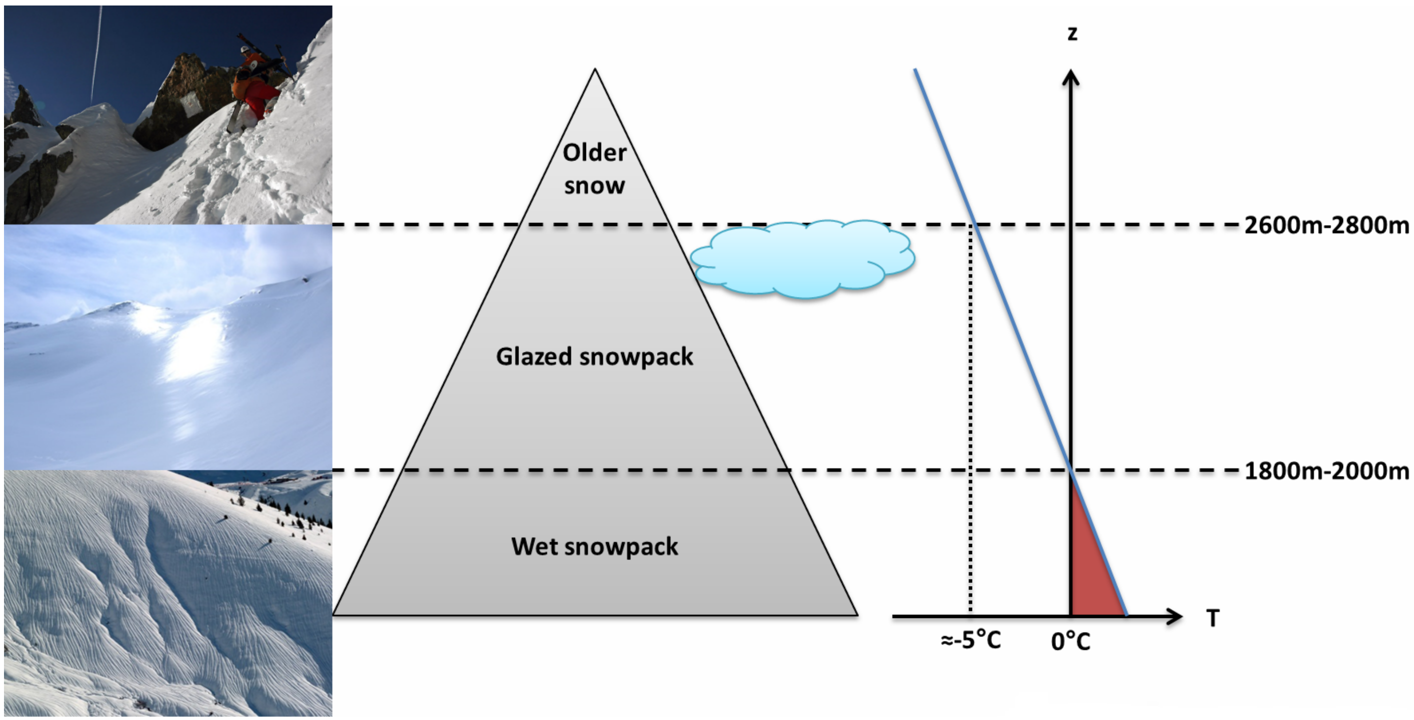
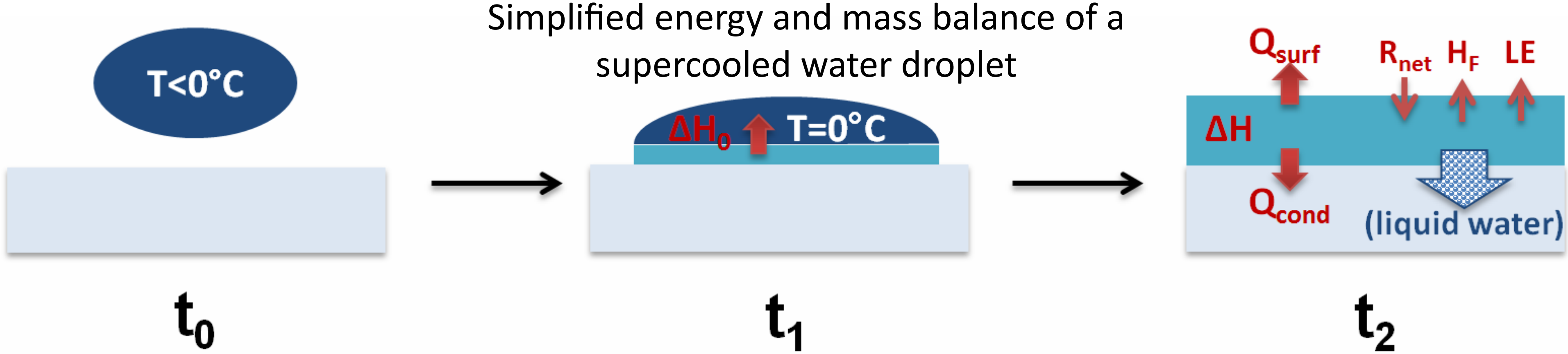
Ice layer formation due to freezing precipitation (Quéno et al., CRST, 2017, in revision)



Simplified energy and mass balance of a supercooled water droplet



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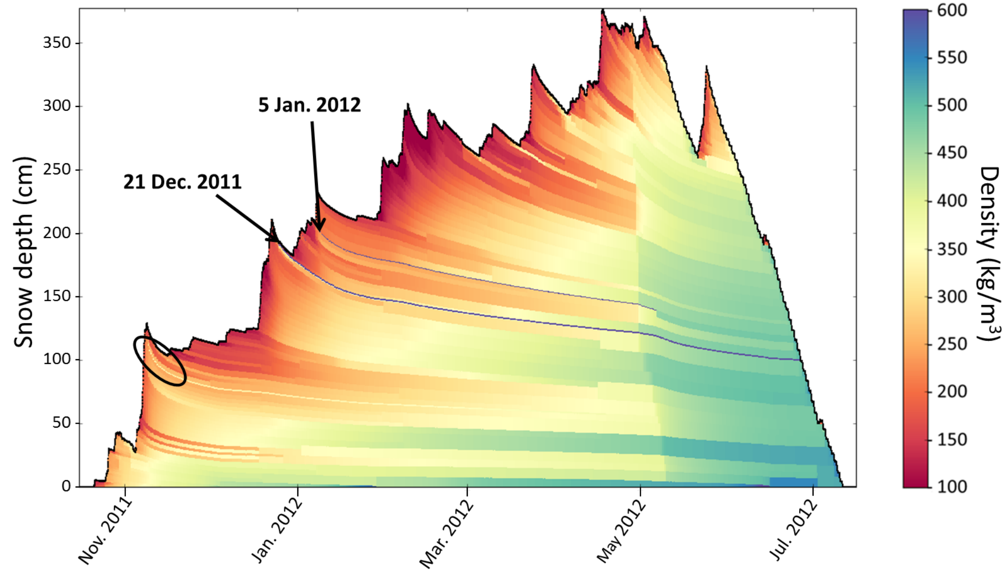
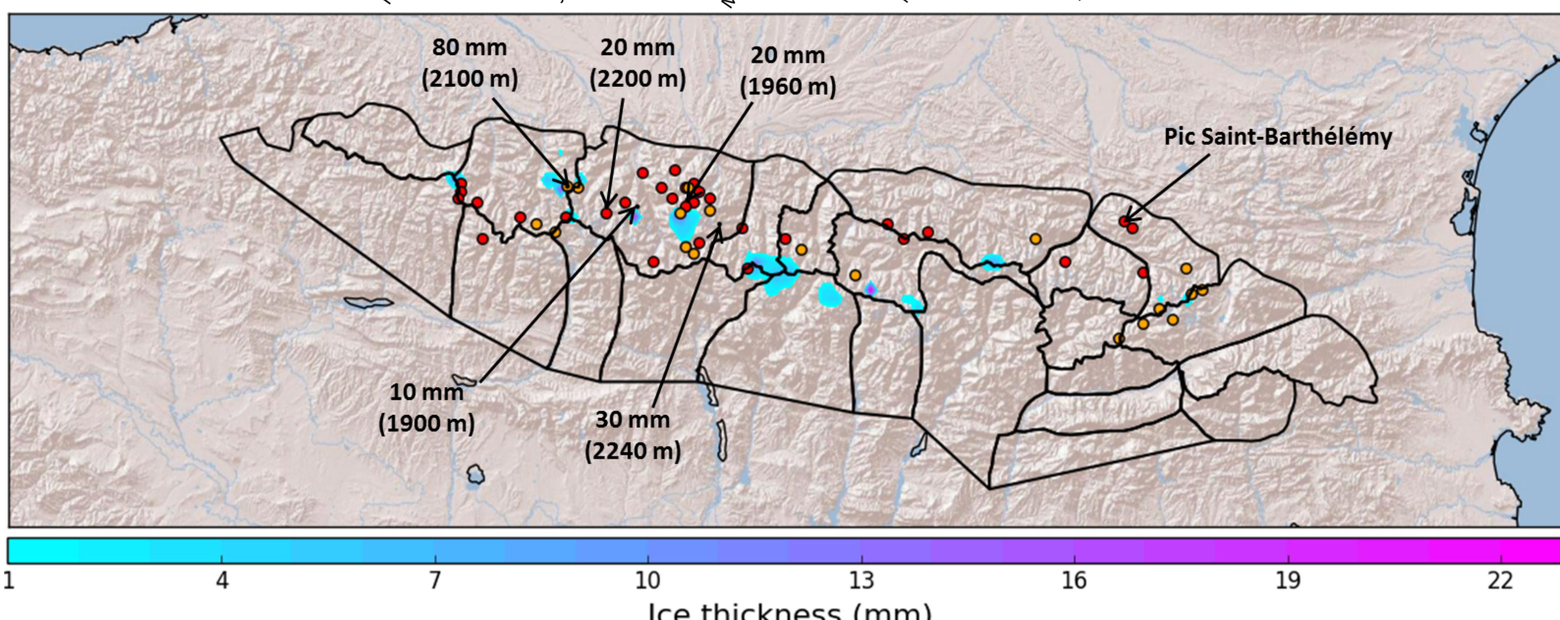
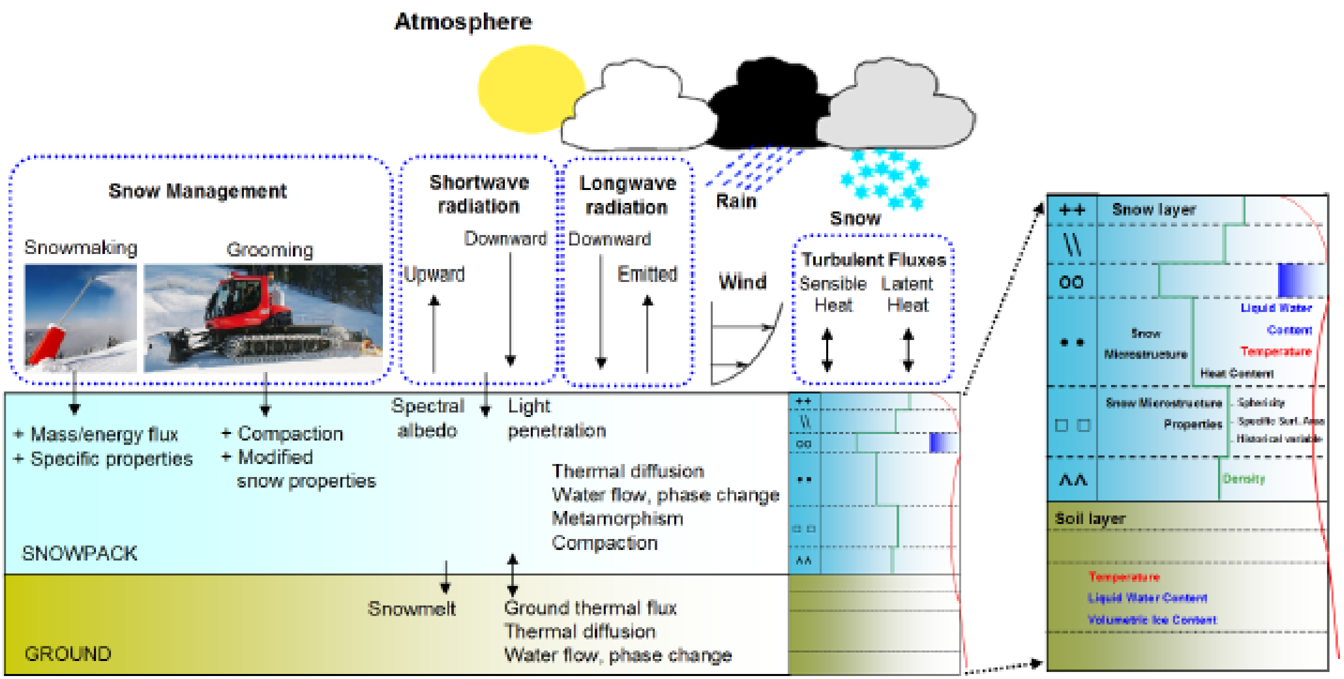
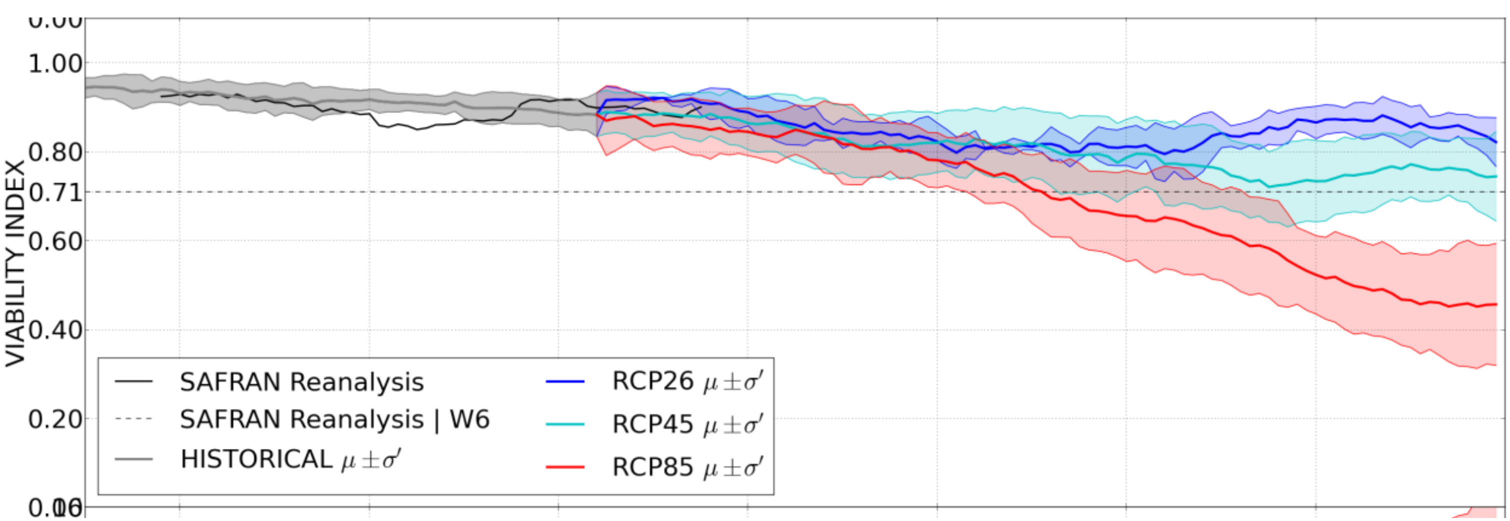




Ice thickness in the first 5 cm of the snowpack (AROME), in red accidents, orange moutaineers observations, arrows (ice layer thickness measurements)

Crocus RESORT (Spandre et al., CRST, 2016)





Resort-level viability using adjusted climate scenarios, Spandre et al., in prep

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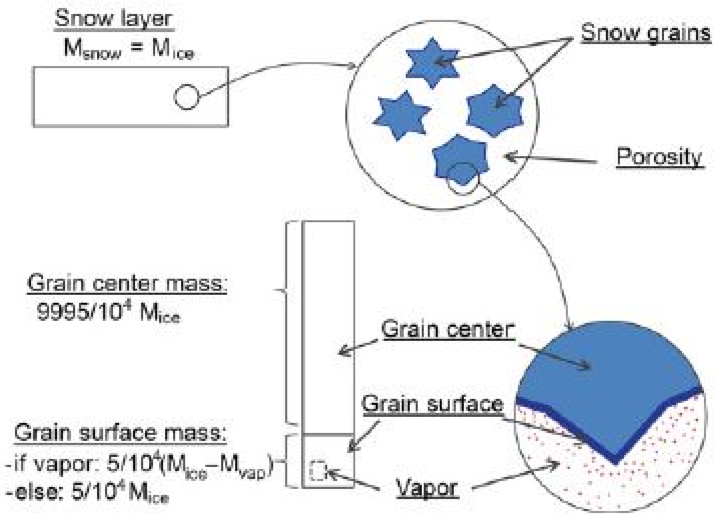
Water isotopes (Touzeau et al., submitted to GMDD)



Preliminary investigations on isotopic variations along with water vapor exchange between snow layers + at ice/air interface

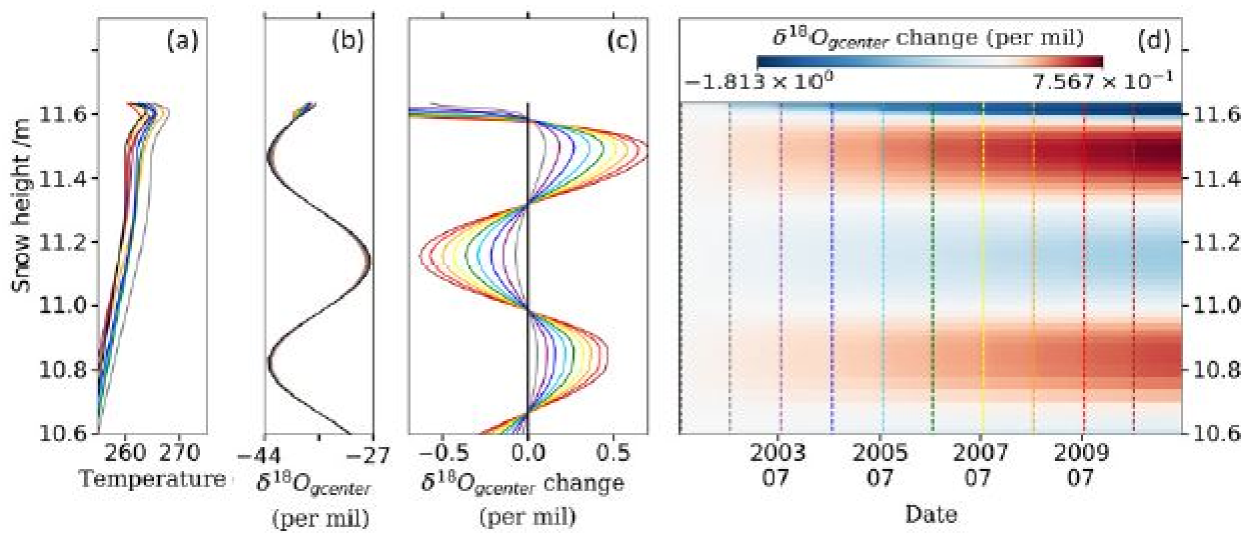


Figure 3. Simulation of the attenuation of the seasonal $\delta^{18}O_{gcenter}$ variation caused by diffusion in vapor phase over 10 years (with temperature evolution, original signal with mean value of -35.5 ‰ and amplitude of 16 ‰). (a) Vertical temperature profile for each summer; (b) $\delta^{18}O_{gcenter}$ profile for each summer; (c) Deviation of the $\delta^{18}O$ relative to the original profile, for each summer; (d) Evolution of the deviation to the original profile of $\delta^{18}O_{gcenter}$.

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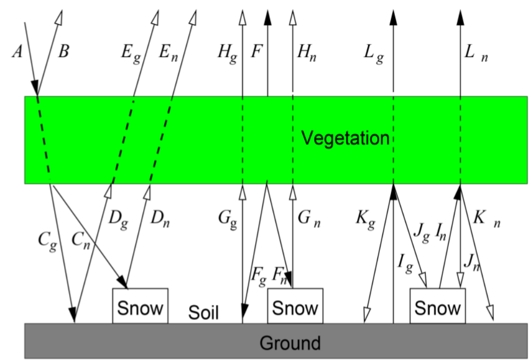
Multi-energy balance

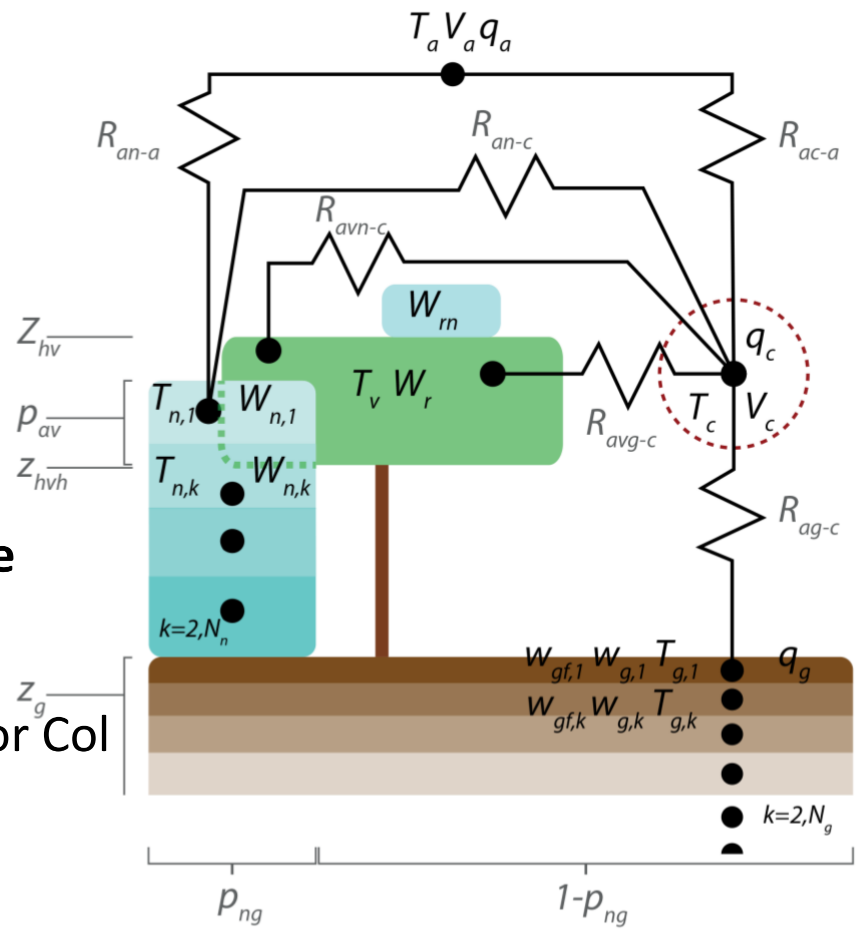
- MEB (Boone et al, 2017): Implicitely solve equations for Tsnow, Tveg and Tsoil

$$\mathcal{C}_{\mathrm{v}} \frac{\partial T_{\mathrm{v}}}{\partial t} = R_{\mathrm{n\,v}} - H_{\mathrm{v}} - L E_{\mathrm{v}} + L_{\mathrm{f}} \Phi_{\mathrm{v}}, \tag{4}$$

$$\begin{aligned} \mathcal{C}_{\mathrm{g},1} \frac{\partial T_{\mathrm{g},1}}{\partial t} = & \left(1 - p_{\mathrm{ng}}\right) \left(R_{\mathrm{n\,g}} - H_{\mathrm{g}} - \mathrm{LE}_{\mathrm{g}}\right) \\ & + p_{\mathrm{ng}} \left(G_{\mathrm{gn}} + \tau_{\mathrm{n},N_{\mathrm{n}}} \mathrm{SW}_{\mathrm{net},\mathrm{n}}\right) \\ & - G_{\mathrm{g},1} + L_{\mathrm{f}} \Phi_{\mathrm{g},1}, \end{aligned} \tag{5}$$

$$\begin{aligned} \mathcal{C}_{\mathrm{n},1} \frac{\partial T_{\mathrm{n},1}}{\partial t} = & R_{\mathrm{n\,n}} - H_{\mathrm{n}} - \mathrm{LE}_{\mathrm{n}} - \tau_{\mathrm{n},1} \mathrm{SW}_{\mathrm{net},\mathrm{n}} + \xi_{\mathrm{n},1} \\ & - G_{\mathrm{n},1} + L_{\mathrm{f}} \Phi_{\mathrm{n},1}, \end{aligned} \tag{6}$$





Energy fluxes and Ts constrain the snow scheme

Possibility to add a litter layer (might be useful for Col de Porte meadow)

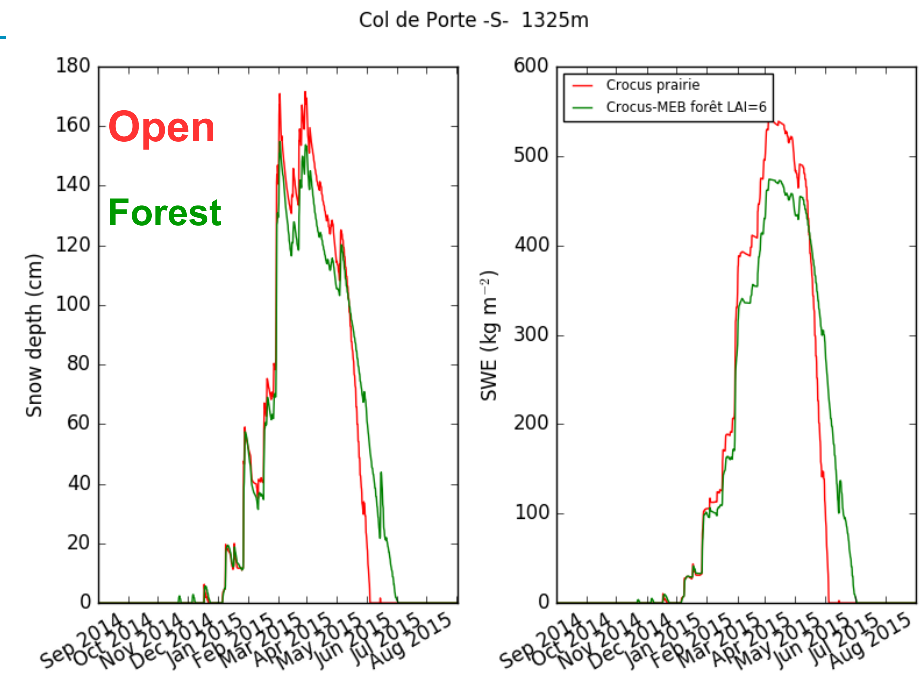
Multi-energy balance

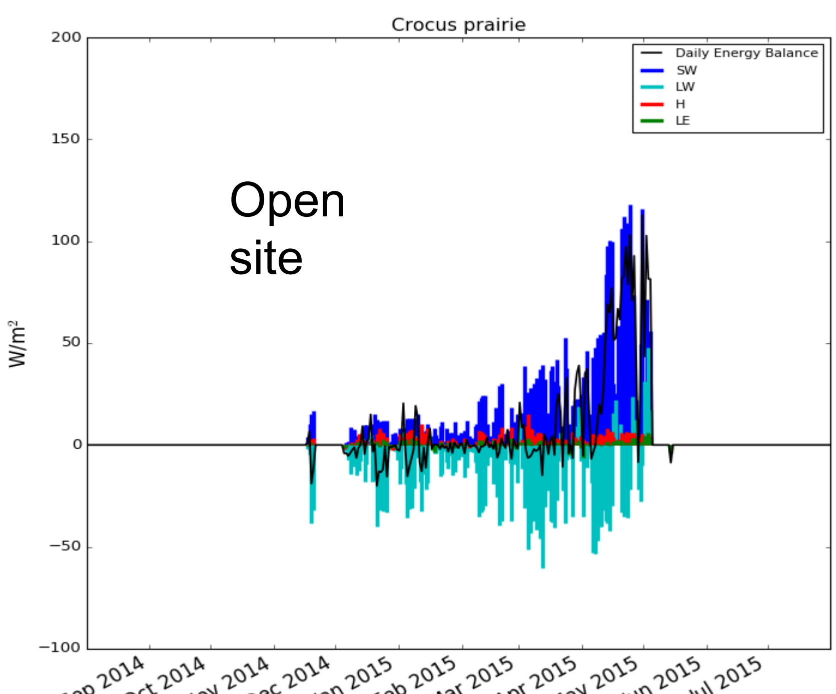
- MEB-Crocus coupling done

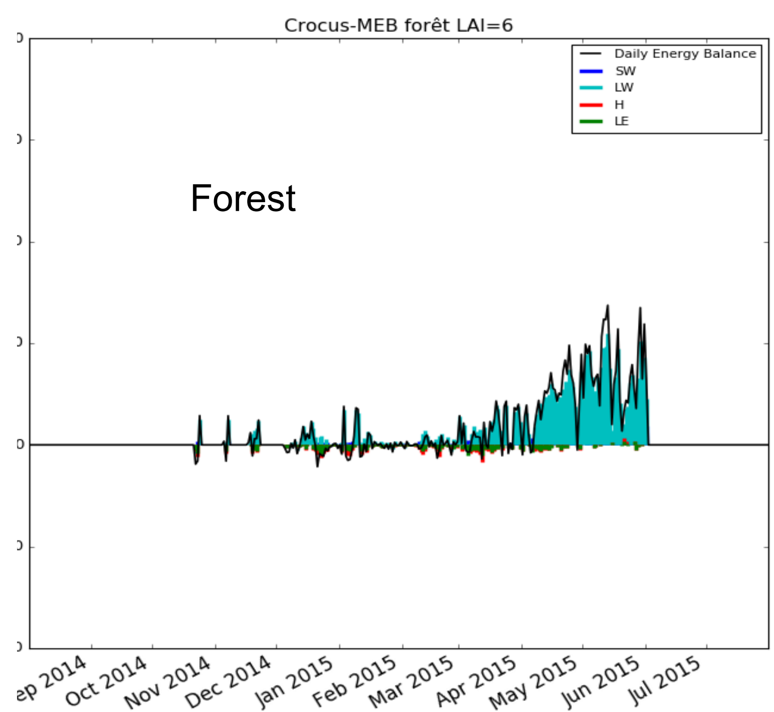
Test on Col de Porte forest

  - Strong modification of the EB
  - Possible underestimation of interception

  - In progress (SNOUF project)







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Wind-drift (Vionnet et al., submitted to CRST)

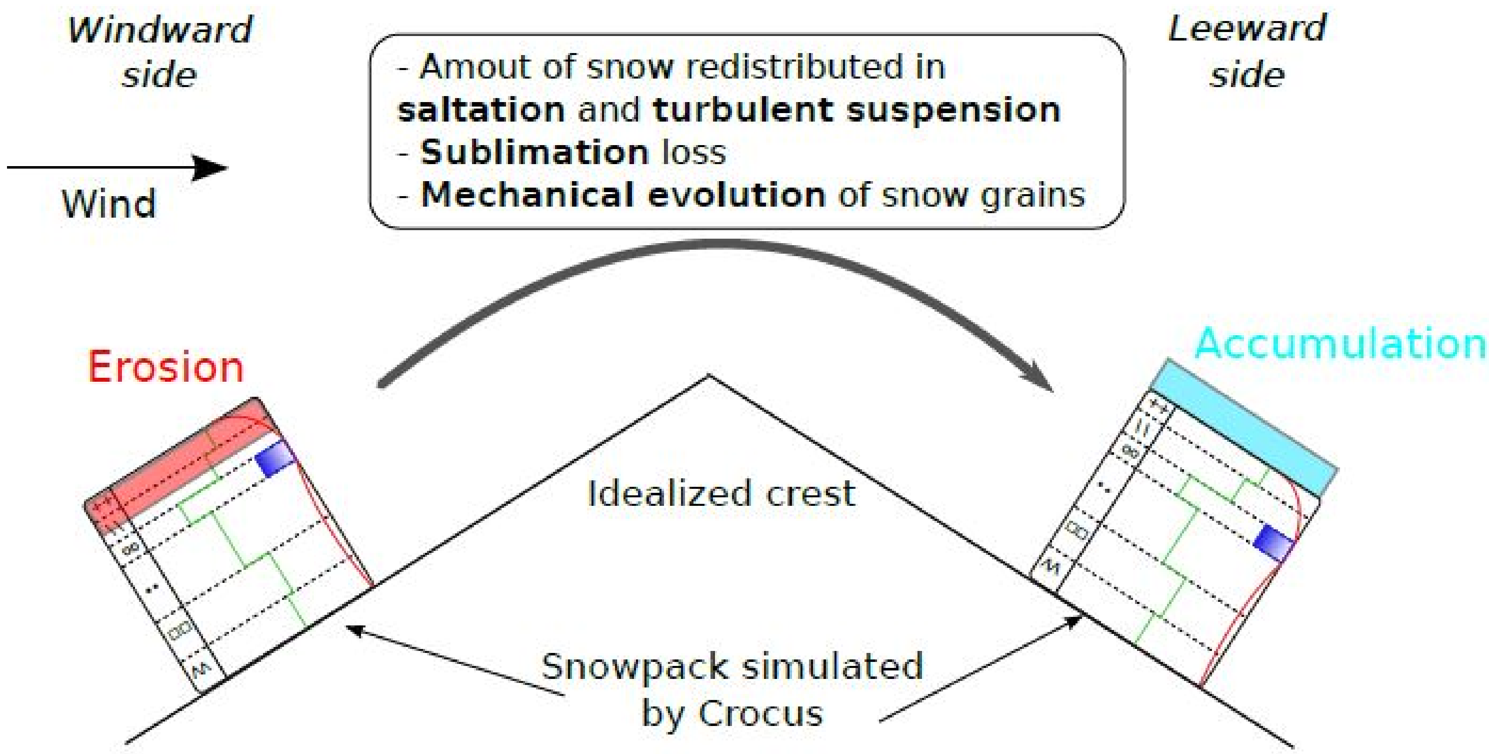

Figure 1: Sytron conceptual scheme

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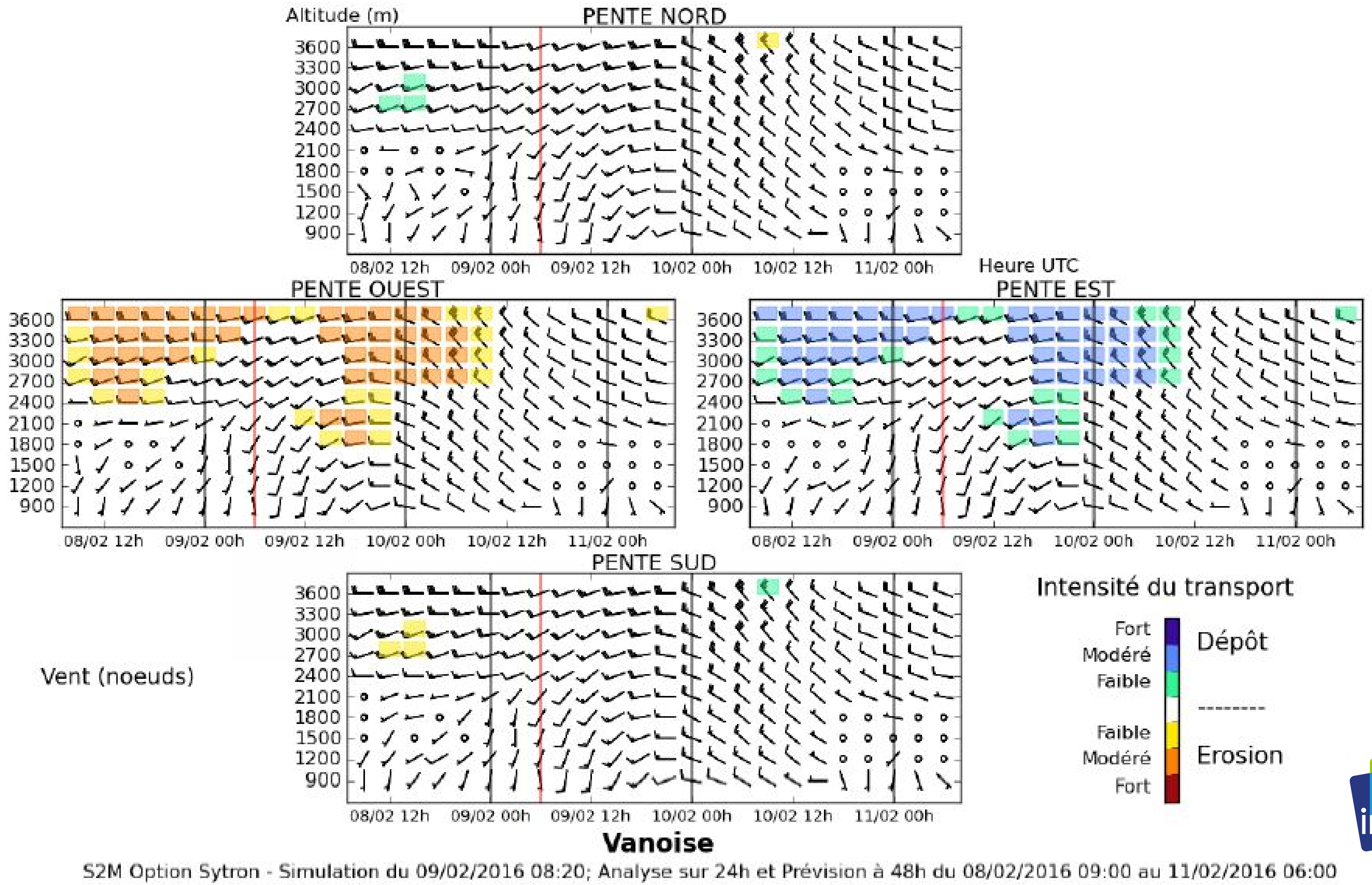

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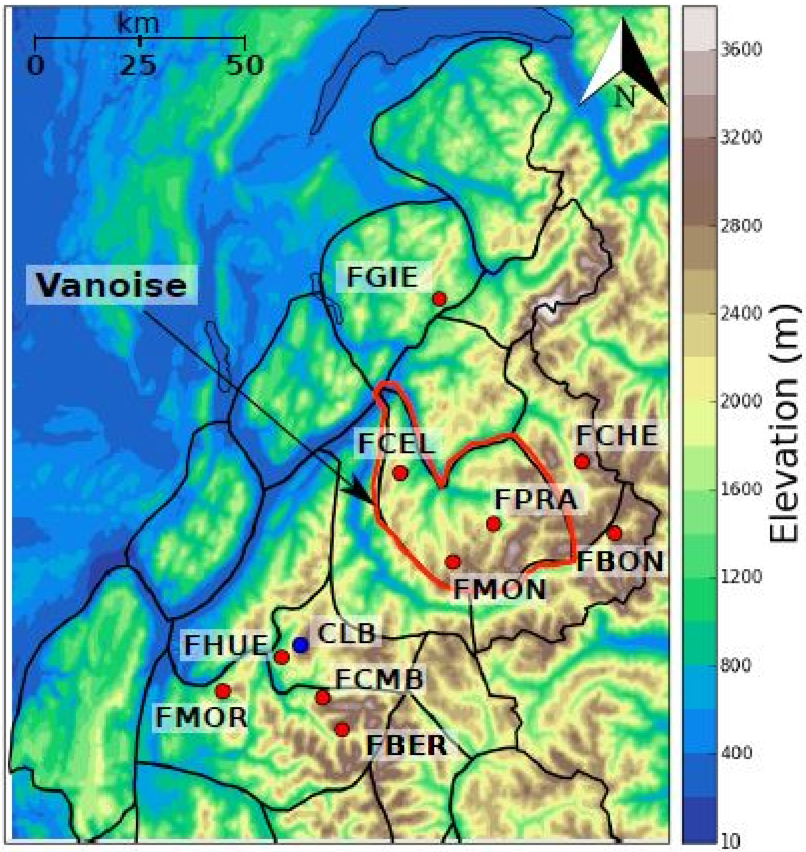
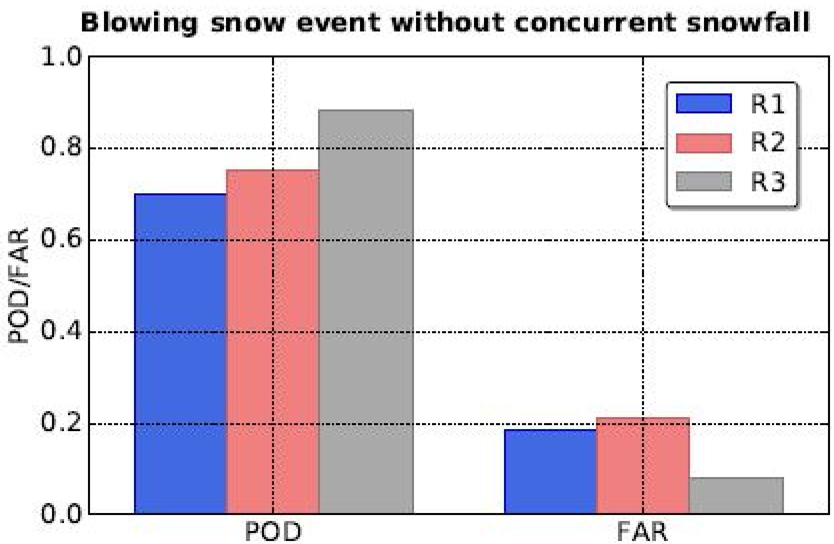


Evaluation using 10 FlowCapt and 1 SnowParticleCounter (CLB)

Testing of various model configs for wind effects on snow microstructure



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