"Blowing snow experimental test site Col du Lac Blanc (French Alps) : past and on-going researches"

L. Arnaud, H. Bellot, Y. Deliot, F. Fontaine, H. Gallée, C. Genthon, I. Gouttevin, G. Guyomarc'h, K. Nishimura, F. Naaim-Bouvet, G. Picard, A. Prokop, P. Schon, A. Trouvilliez, V. Vionnet

Col du Lac Blanc (2720 m) :

An natural wind-tunnel for studying drifting snow at 2700ma.s.l

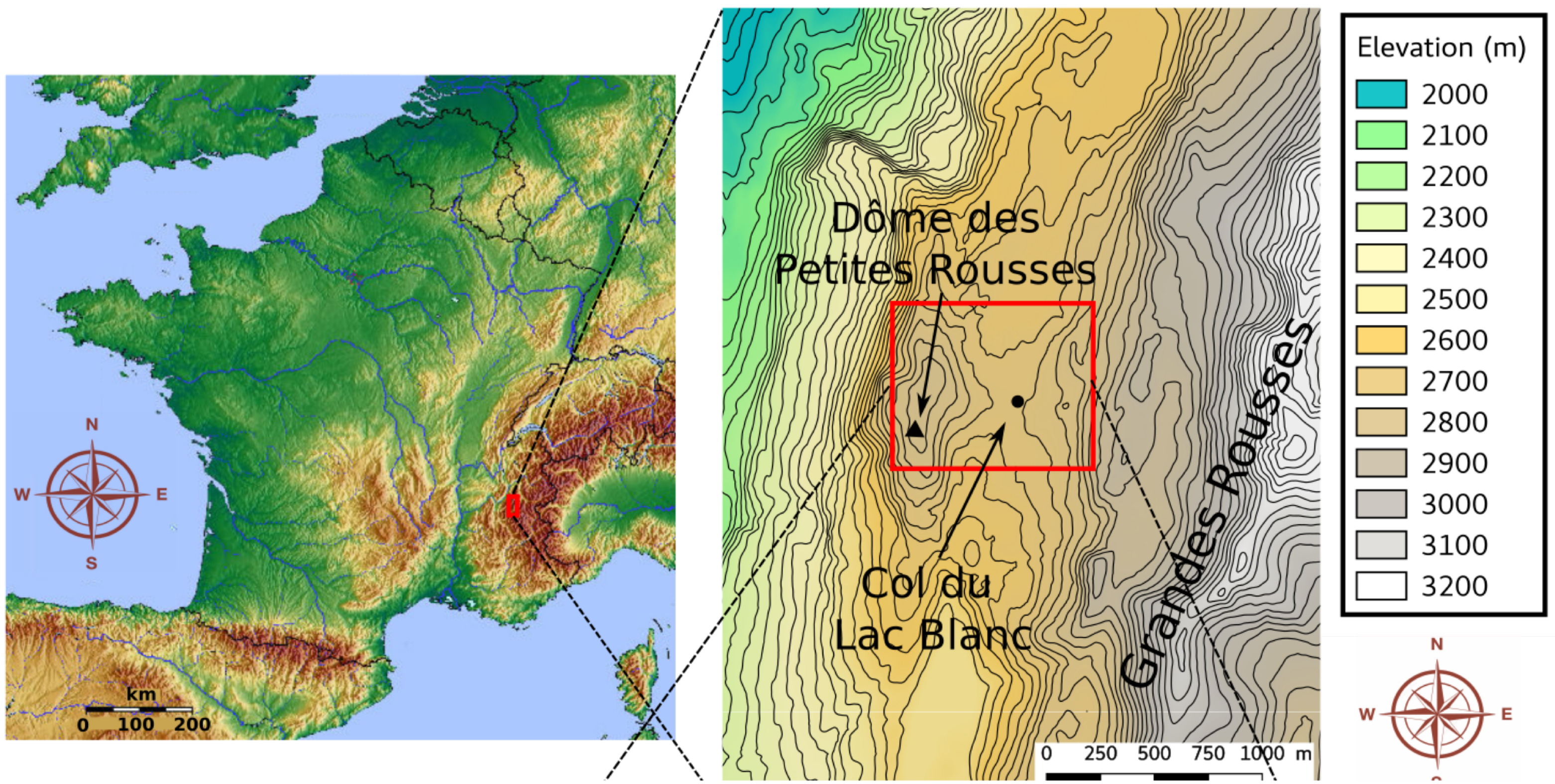
Interests

1. To have **climatological reference**
2. To **test** and compare specific **sensors**
3. To study involved **physical processes in** an Alpine context
4. To create **database for numerical models** (input/output)

Lac Blanc Pass : Description

A "natural" wind tunnel

- **located near the Alpe d'Huez ski resort (French Alps) at 2700 a.s.l**



Lac Blanc Pass : Description

A “natural” wind tunnel

- located near the Alpe d’Huez ski resort (French Alps) at 2700 a.s.l
- relatively flat terrain on a length of about 300 meters. Then the slope becomes steeper both in the northern and southern parts of the place.

Lac Blanc Pass : Climatological reference

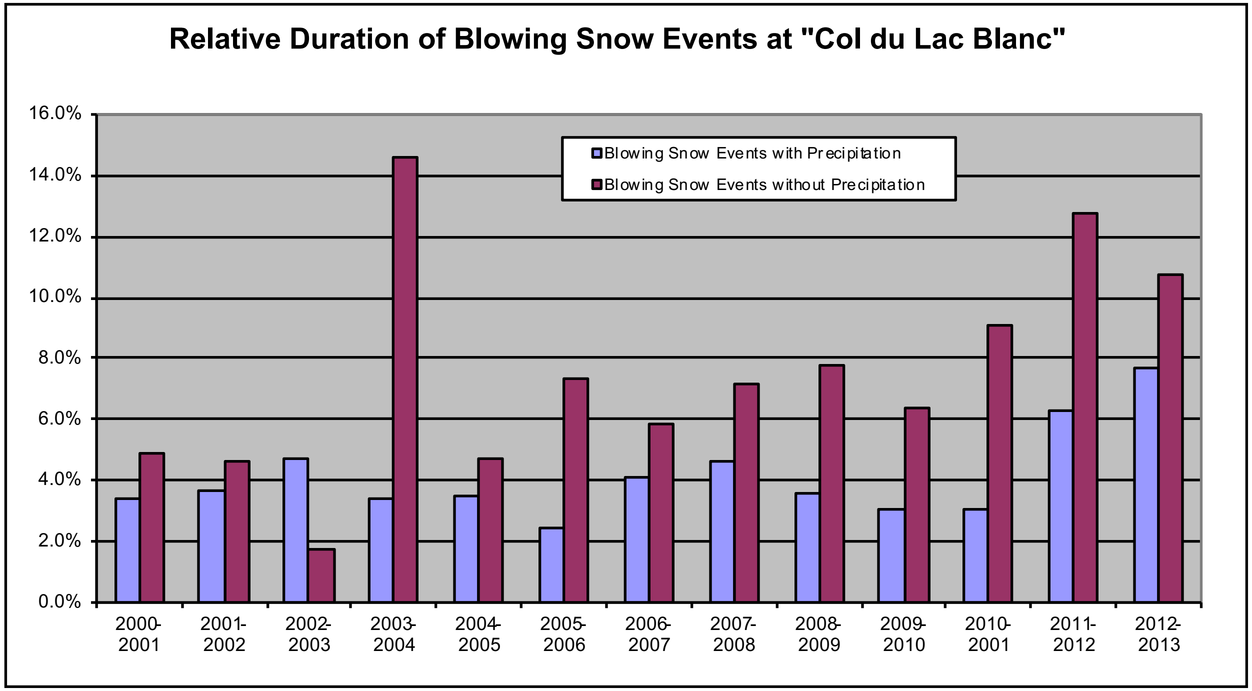
4 Automatic weather stations

1993-2016

+ SAFRAN analysis

Lac Blanc Pass : Climatological reference

Blowing snow events empirical data base
Combination of several datasets(wind, precipitation and snow depth) and their detailed analysis by an expert



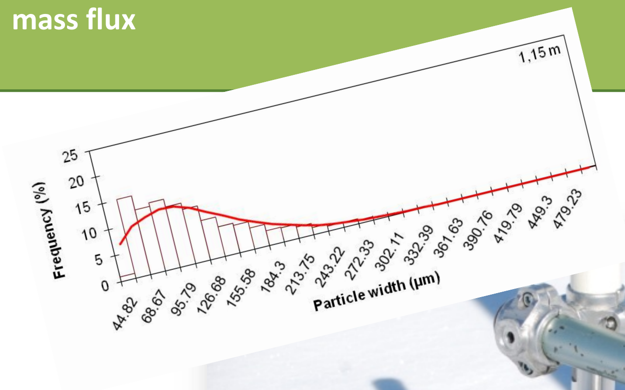
2000-2016

Vionnet, V., Guyomarc'h, G., Naaim Bouvet, F., Martin, E., Durand, Y., Bel, C., Bellot, H., Puglièse, P. 2013. Occurrence of blowing snow events at an alpine site over a 10-year period: observations and modeling, Adv. Water Res., 55, 53-63.

Lac Blanc Pass : Climatological reference

3 Snow particles counter

Diameter and the number of blowing snow particles are detected by their shadows on photosensitive semi-conductors → horizontal snow mass flux

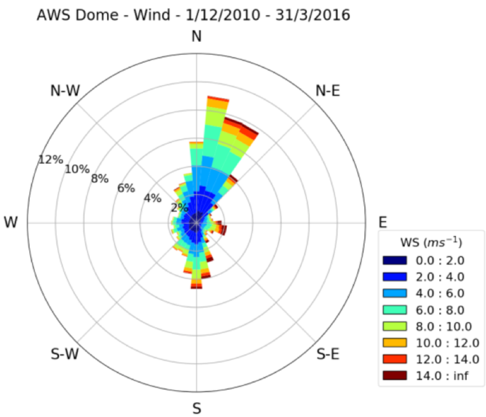


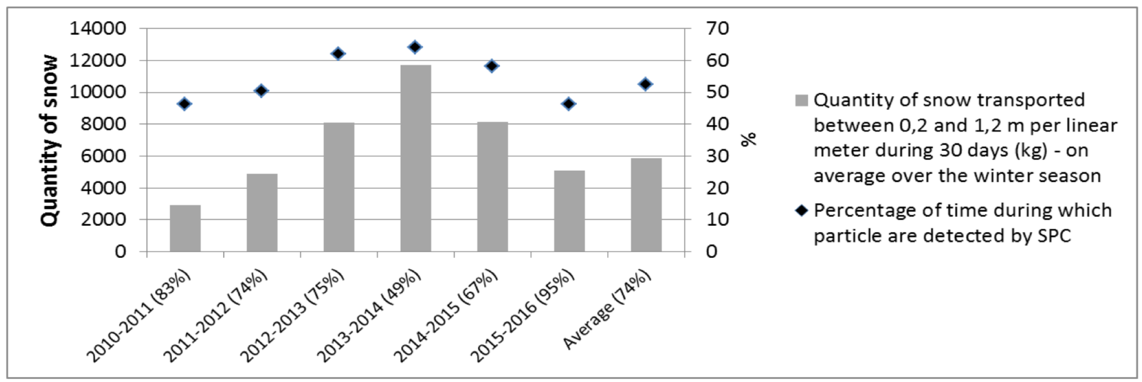
2009-2016

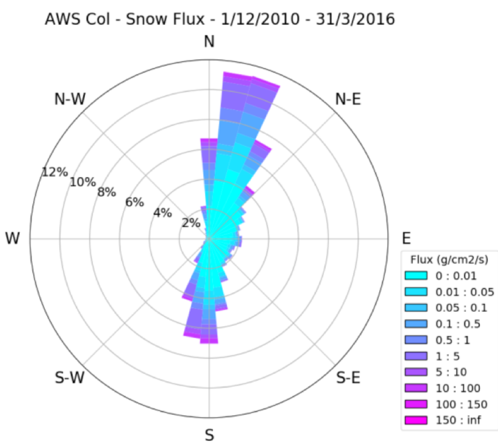
Lac Blanc Pass : Description

Prevailing direction : S / NE

Drifting and blowing snow transport :
- 30% of the time in winter
- quantity of snow transported between 0.2 and 1.2 m per linear meter of 28100 kg during the winter season over the period 2010-2016

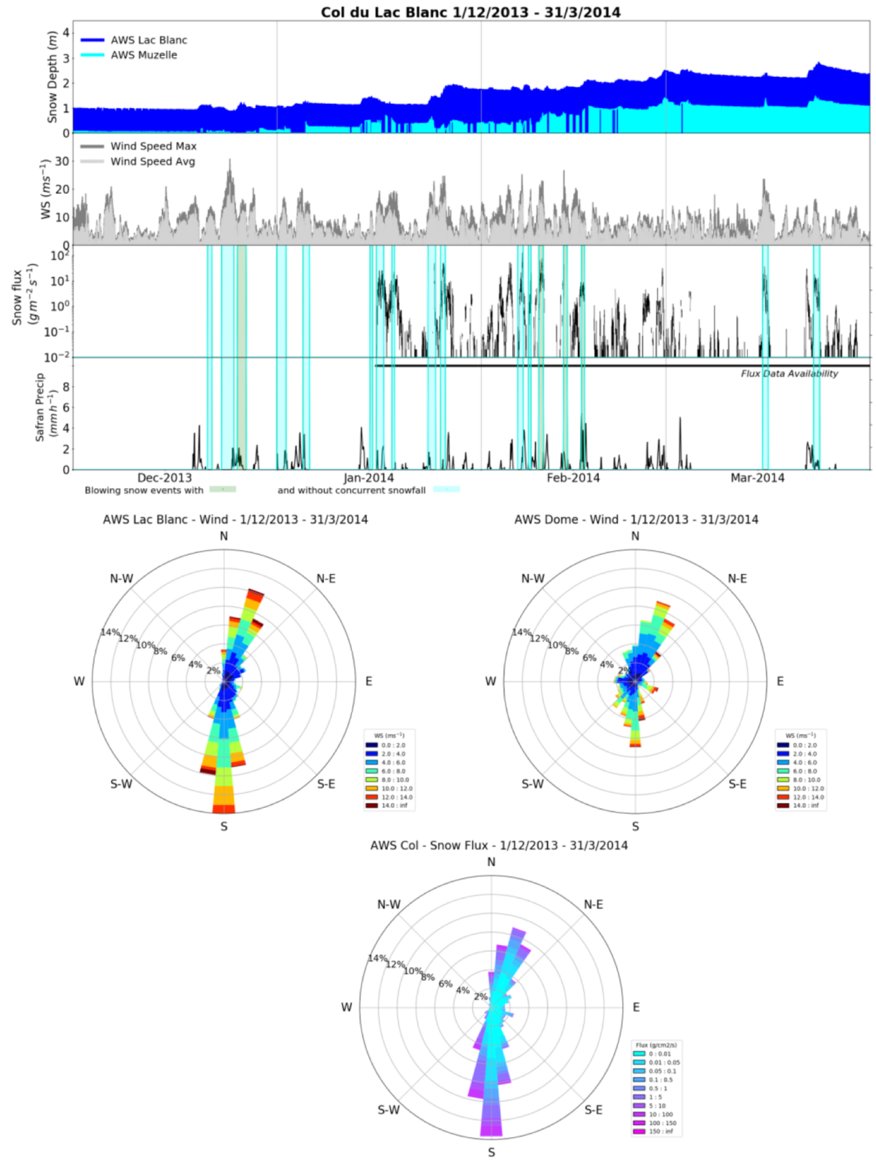






Guyomarc'h, G., Bellot, H., Naaim Bouvet, F., Vionnet, V., Deliot, Y., Fontaine, F., Pugliese, P., Naaim, M., Nishimura, K., 2018. A meteorological and blowing snow dataset (2000-2016) from a high-altitude alpine site (Col du Lac Blanc, France, 2 720 m a.s.l.), ESSD, submitted.

Lac Blanc Pass : Description



Data availabilty

Data base

- http://data.cryobsclim.fr
- doi:10.17178/CRYOBSCLIM.CLB.all

Real time data

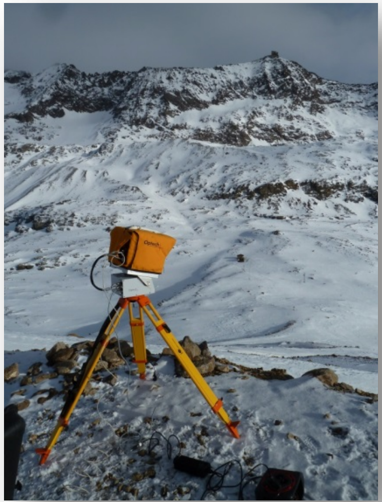
http://www.cnrm-game.fr/cen/huez/PageWebCLB.htm

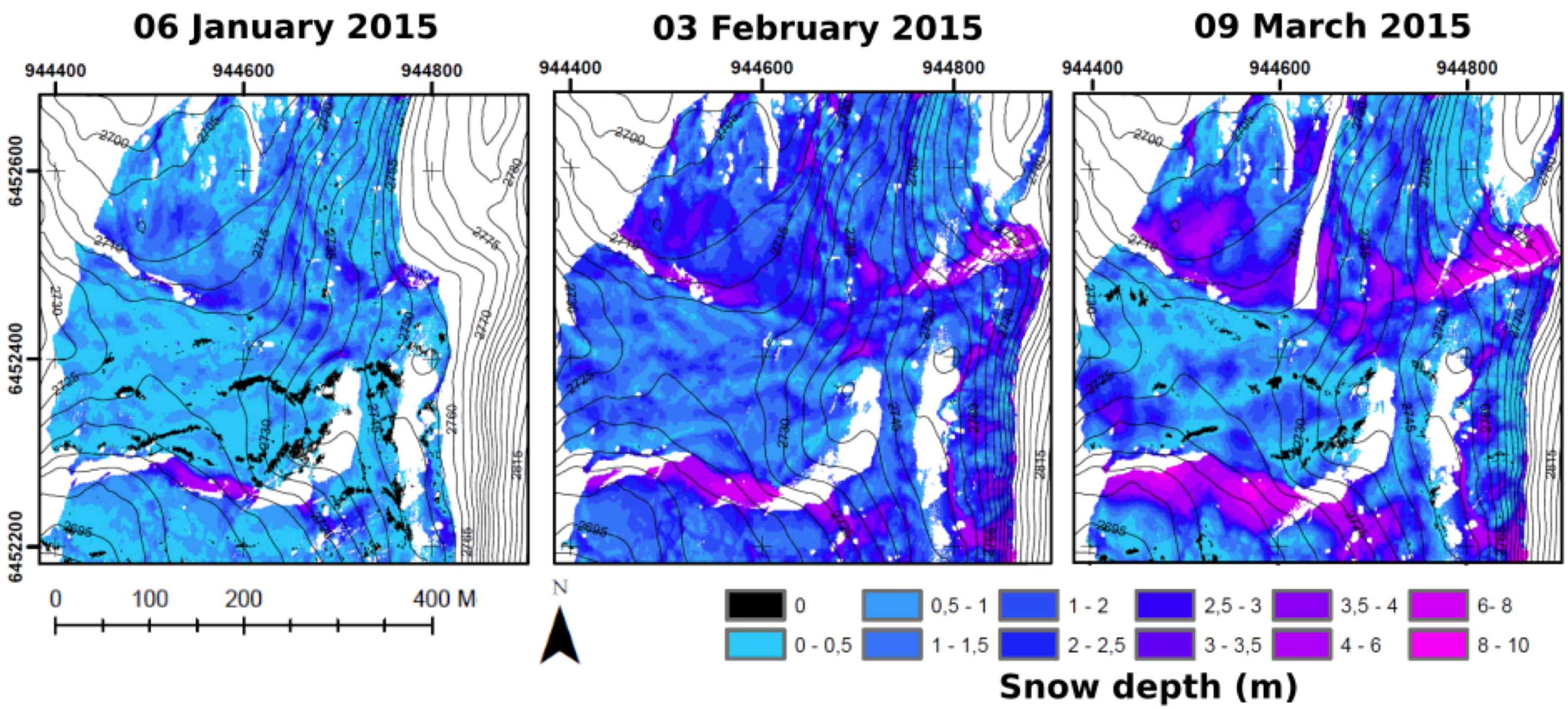
Guyomarc'h, G., Bellot, H., Naaim Bouvet, F., Vionnet, V., Deliot, Y., Fontaine, F., Pugliese, P., Naaim, M., Nishimura, K., 2018. A meteorological and blowing snow dataset (2000-2016) from a high-altitude alpine site (Col du Lac Blanc, France, 2 720 m a.s.l.), ESSD, submitted.

Climatological reference

Seasonal evolution of snow cover

- Terrestrial Laser Scanner (precision of the order of 5 cm at 400 m and 10 cm at 800 m)
- Regular scanning during the winter since 2011





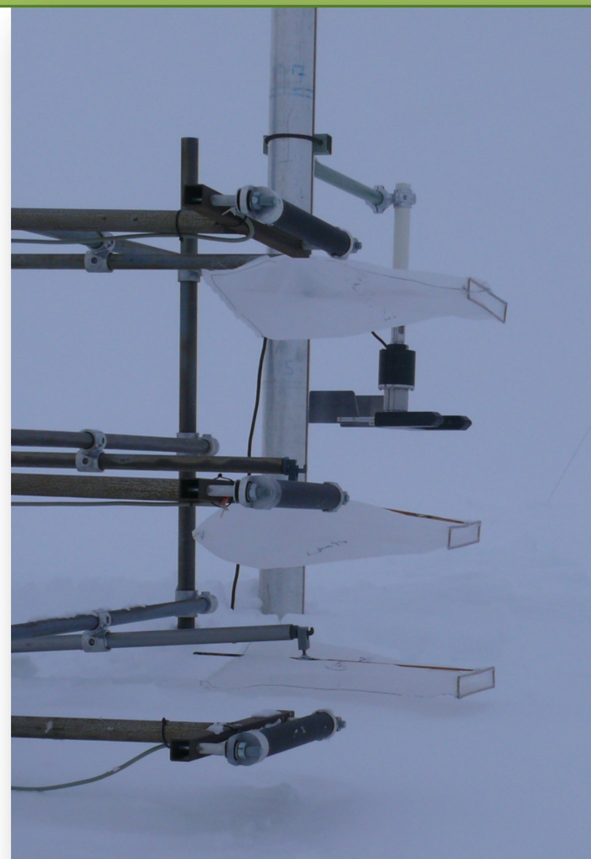
2011-2016

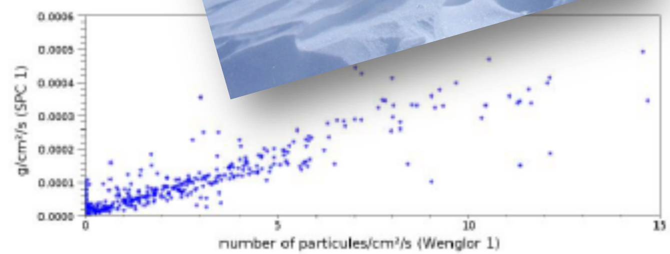
Lac Blanc Pass : Benchmark for drifting snow sensors

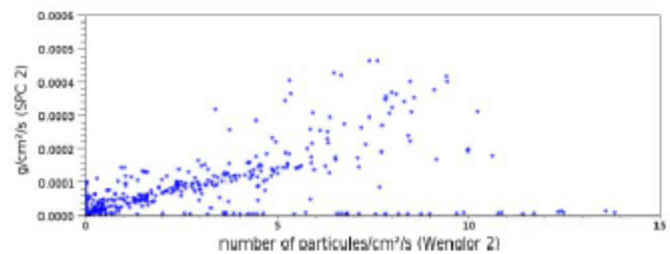
Drifting snow measurements : intercomparison between sensors

Lac Blanc Pass : Benchmark for drifting snow sensors

Optical sensors (SPC, Wenglor, ABS, Disdrometer), acoustic sensors (Flowcapt), mechanical traps







Bellot, H., Trouvilliez, A., Naaim-Bouvet, F., Genthon, C., Gallée, H. - 2011. Present weather sensor tests for measuring drifting snow. Annals of Glaciology, vol. 52, n° 58, p. 176-184.

Bellot, H., Naaim-Bouvet, F., Piard L., Palerme C., Genthon, C. - 2013. Drifting and blowing snow measurements: comparison between snow particle counter and a simple photoelectronic fork sensor (Wenglor).Proceedings of the International Snow Science Workshop – Grenoble-Chamonix Mont-Blanc, 1009-1013.

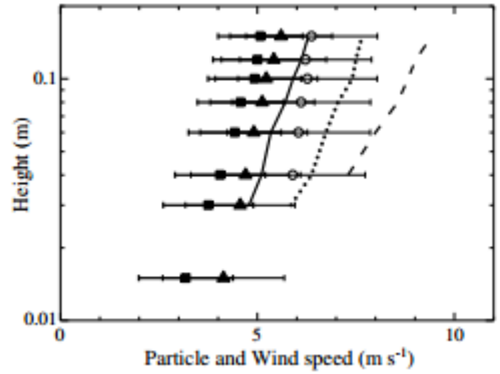
Trouvilliez, A., Naaim-Bouvet, F., Bellot, H., Genthon, C. and H. Gallée (2015) – "Evaluation of the FlowCapt acoustic sensor for the aeolian transport of snow, Journal of Atmospheric and Oceanic Technology", 32, 1630-1641. doi: http://dx.doi.org/10.1175/JTECH-D-14-00104.1 .

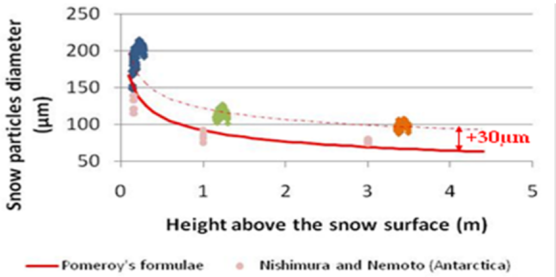
Lac Blanc Pass : Physical processes

Vertical profile of 3 Snow particles Counters

- Schmidt number, fall velocity, diameter, particle distribution
- Snow particles velocity
- Drifting snow concentration profiles

$$\frac{C(z)}{C_{ref}(z_{ref})} = \left(\frac{z}{z_{ref}}\right)^{-\frac{\sigma_s U_F}{k u_*}}$$





Naaim-Bouvet, F., Bellot, H., Naaim, M., Nishimura, K., - 2013. Size distribution, Schmidt number and termiinal velocity of blowing snow particles in the French Alps : comparison with previous studies, Proceedings of the International Snow Science Workshop – Grenoble-Chamonix Mont-Blanc, 140-146.

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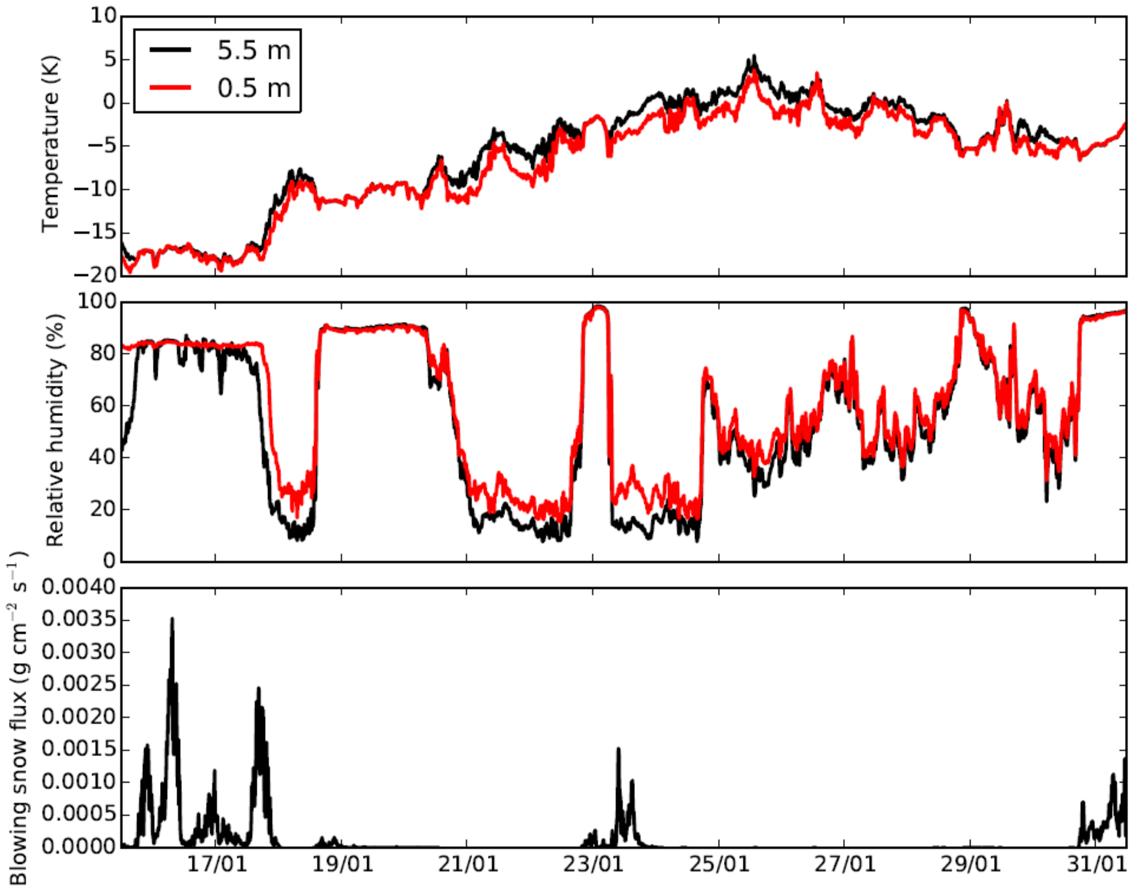
Nishimura, K., Yokoyama, C., Ito, Y., Nemoto, M., Naaim-Bouvet, F., Bellot, H. and K. Fujita (2014) - Snow particle speeds in drifting snow, Journal of Geophysical Research - Atmosphere Volume 119, Issue 16, pages 9901–9913, 27 August 2014 doi:10.1002/2014JD021686..

Lac Blanc Pass : Physical processes

Physical processes

Vertical profile of humidity and temperature sensors

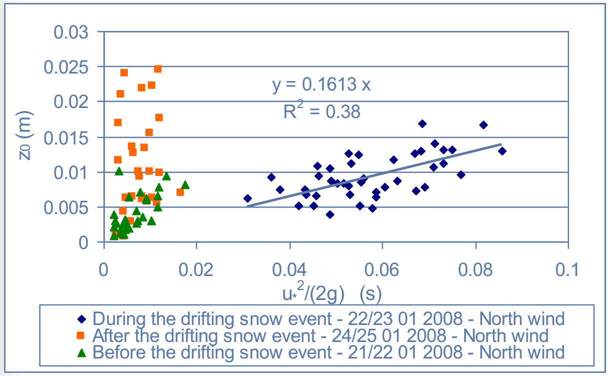
- Quantification of feedbacks of blowing snow sublimation on air temperature and humidity (work in progress)



Lac Blanc Pass : Physical processes

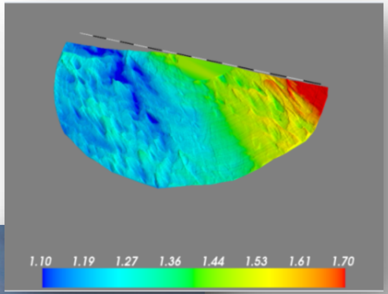
Vertical profile of anemometers + automatic laserscan

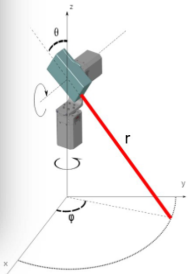
- **Aerodynamic roughness in connection with geometrical roughness (work in progress)**



$$u(z) = \frac{u_*}{k}\ln\left(\frac{z}{z_0}\right)$$

$$\tau = -\rho\overline{u'v'} = \rho u_*^2$$



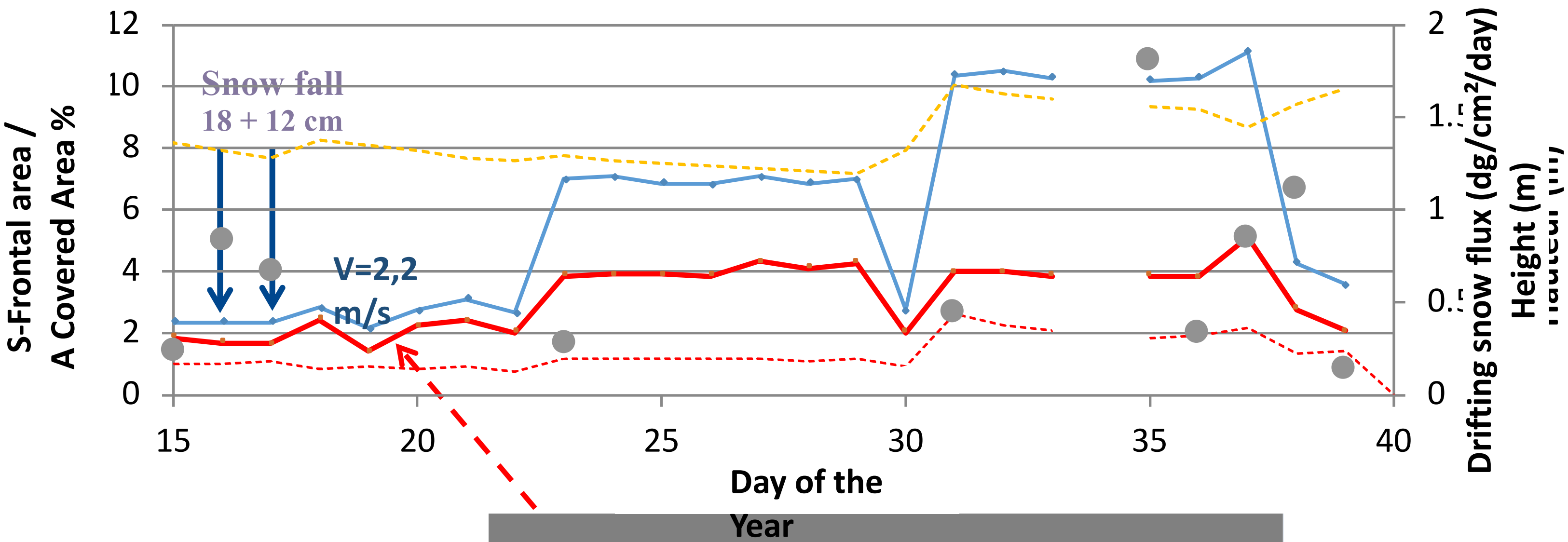


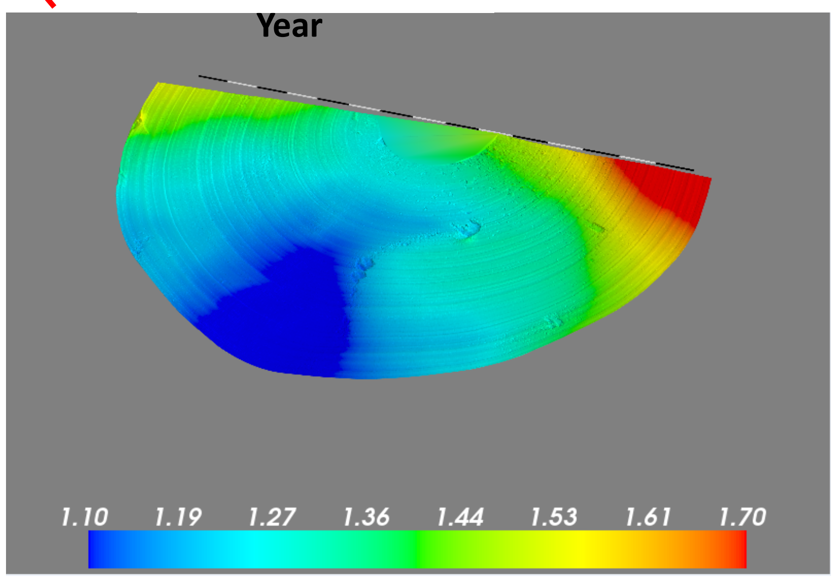
Naaim-Bouvet F., Picard G., Bellot H., Arnaud L., Vionnet V., 2016. Surface roughness monitoring using time-lapse terrestrial laserscan, International Snow Science Workshop, Breckenridge.

Naaim-Bouvet F., Bellot H., Naaim M., 2011. Back analysis of drifting snow measurements over an instrumented mountainous site, Annals of Glaciology, vol. 51, n°54, 207-217.

Lac Blanc Pass : Physical processes

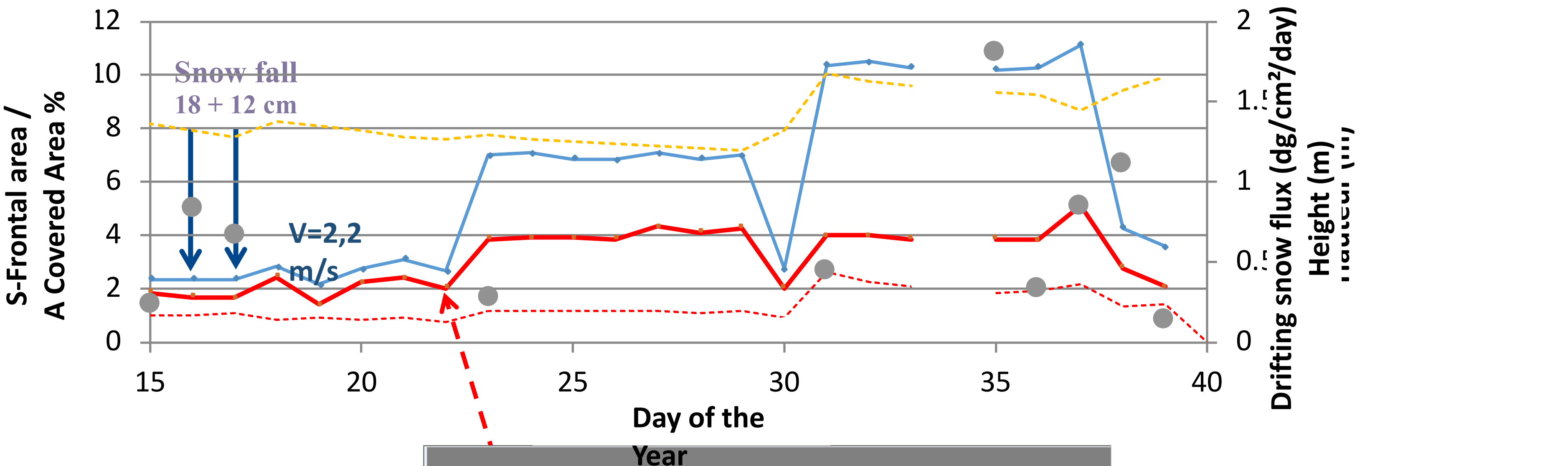
Sastrugi geometrical properties and morphometry

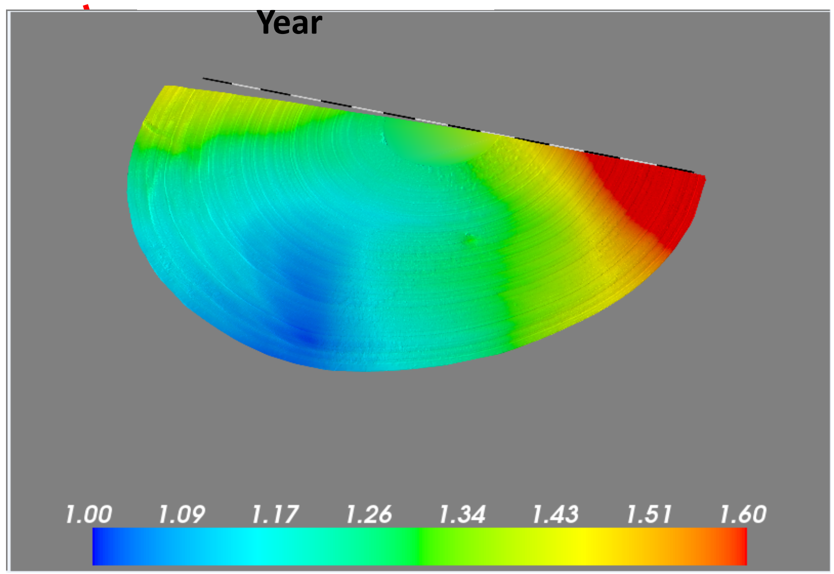




Lac Blanc Pass : Physical processes

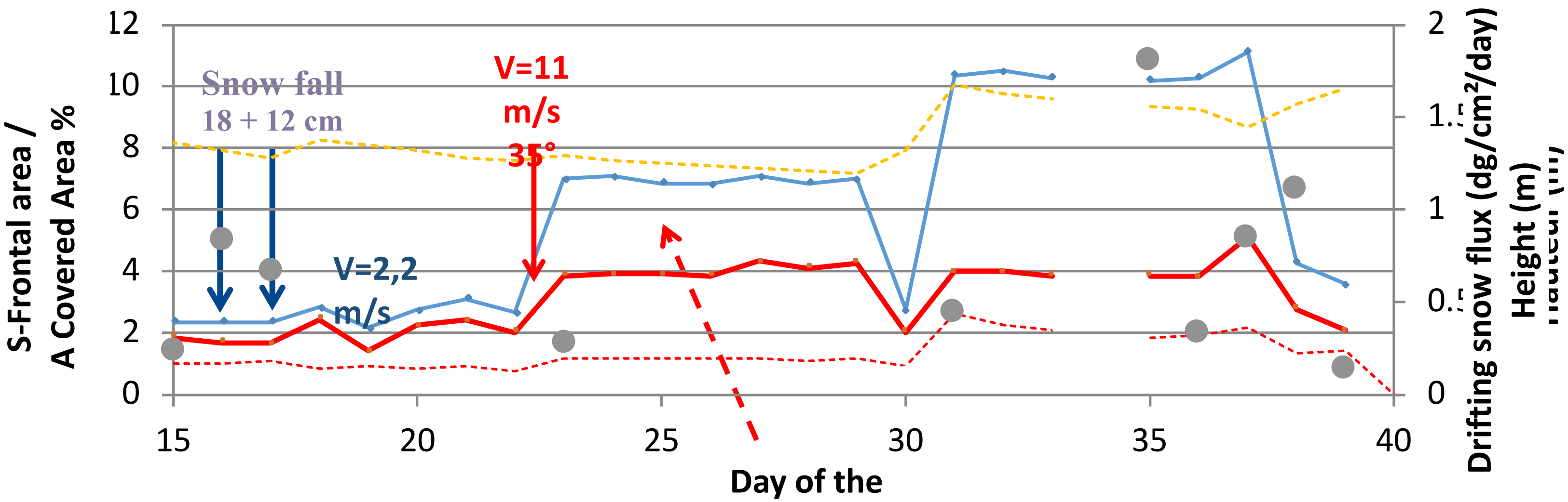
Sastrugi geometrical properties and morphometry

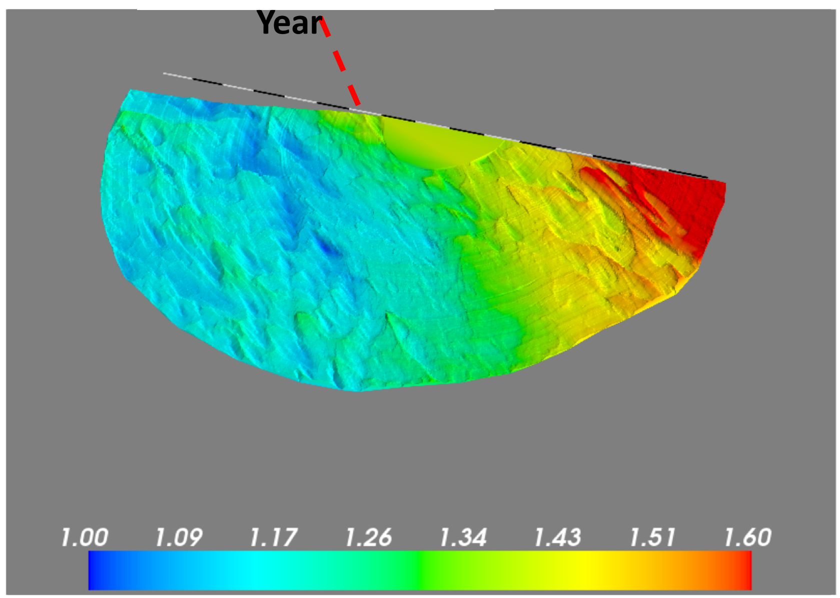




Lac Blanc Pass : Physical processes

Sastrugi geometrical properties and morphometry





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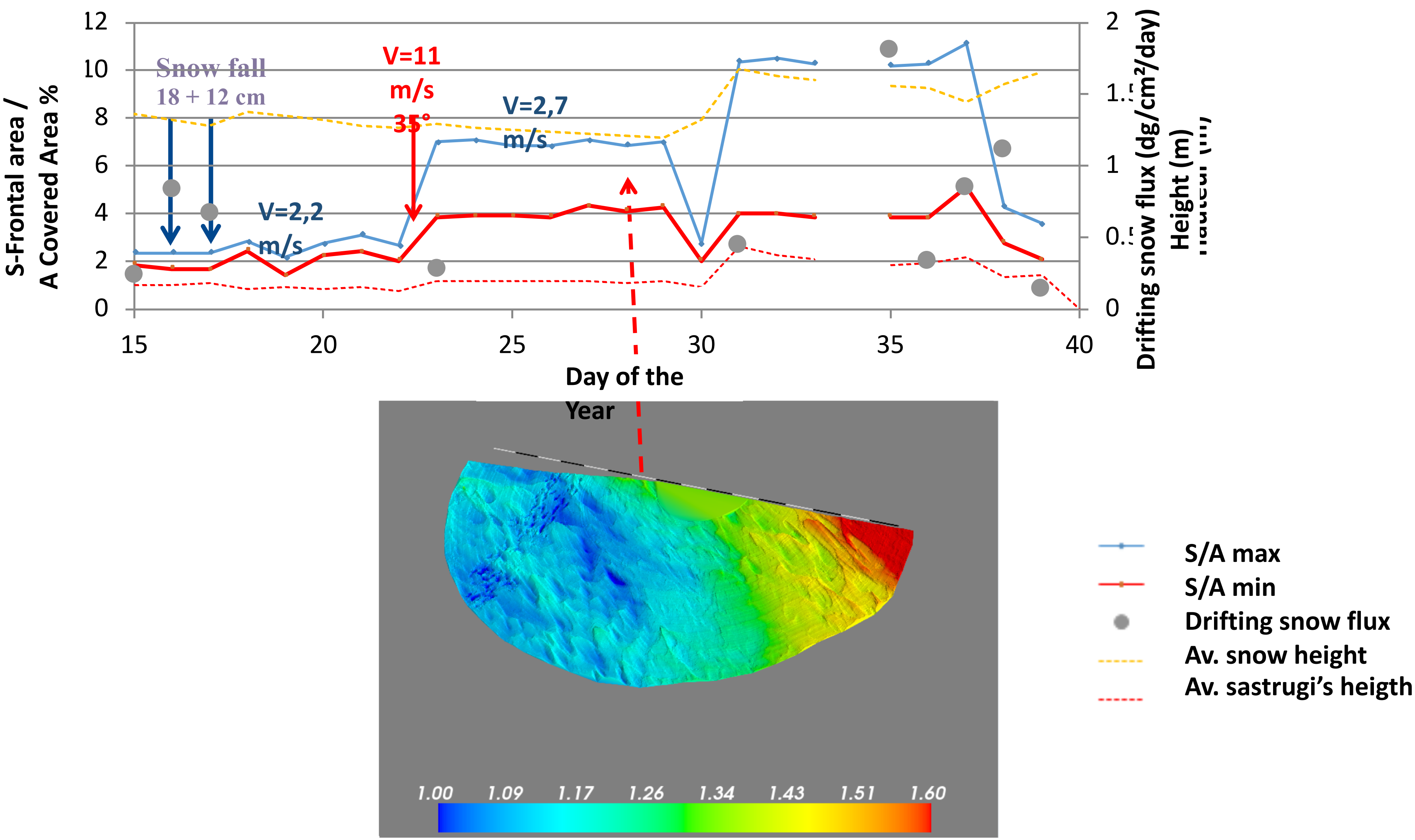
Sastrugi geometrical properties and morphometry



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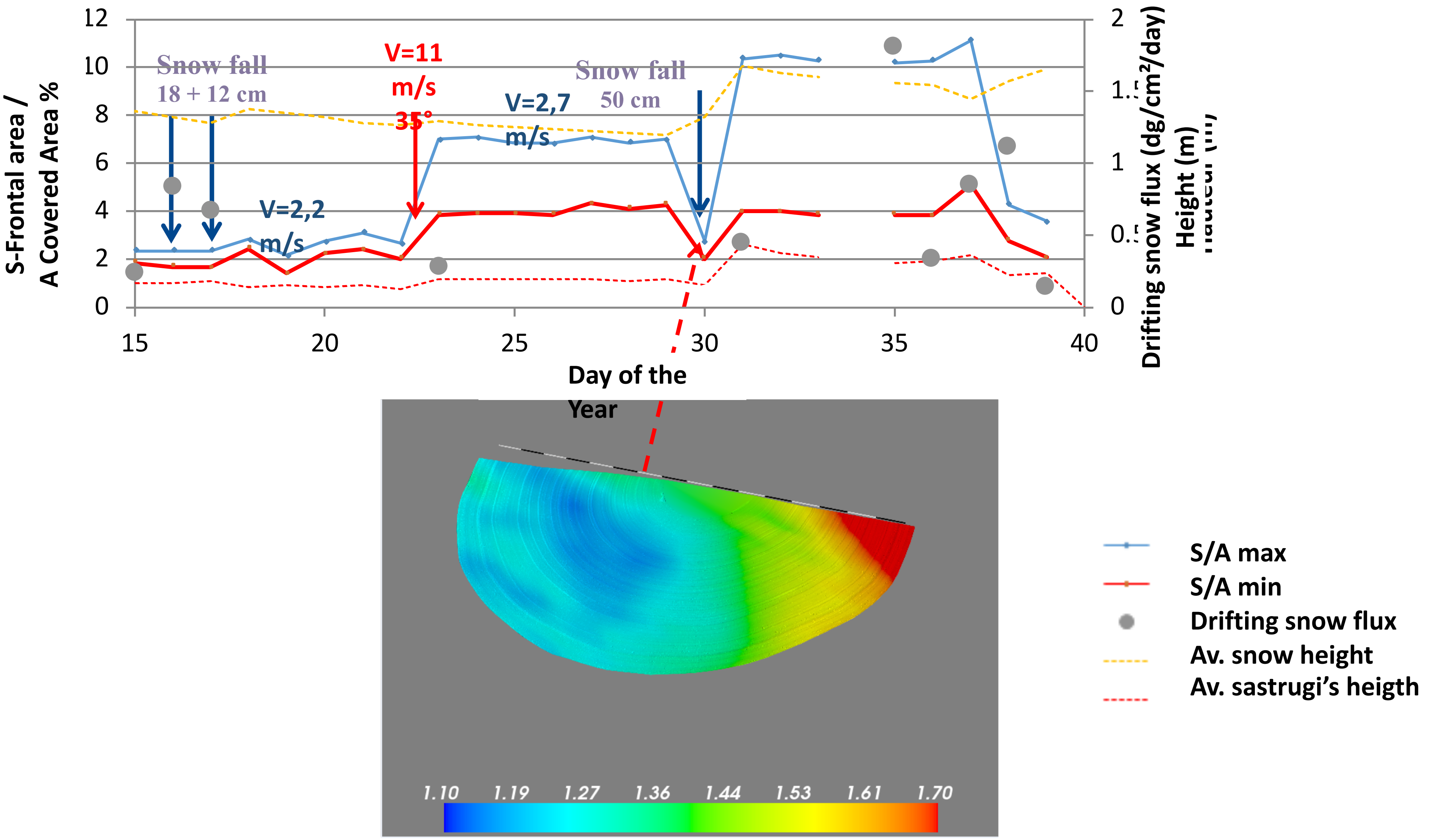

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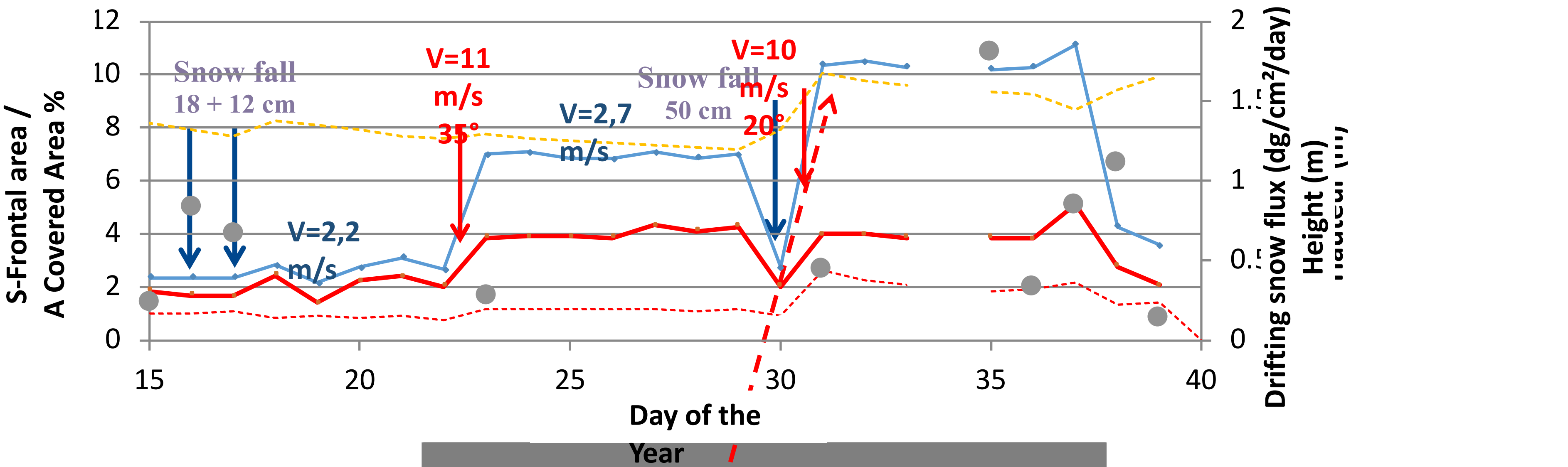

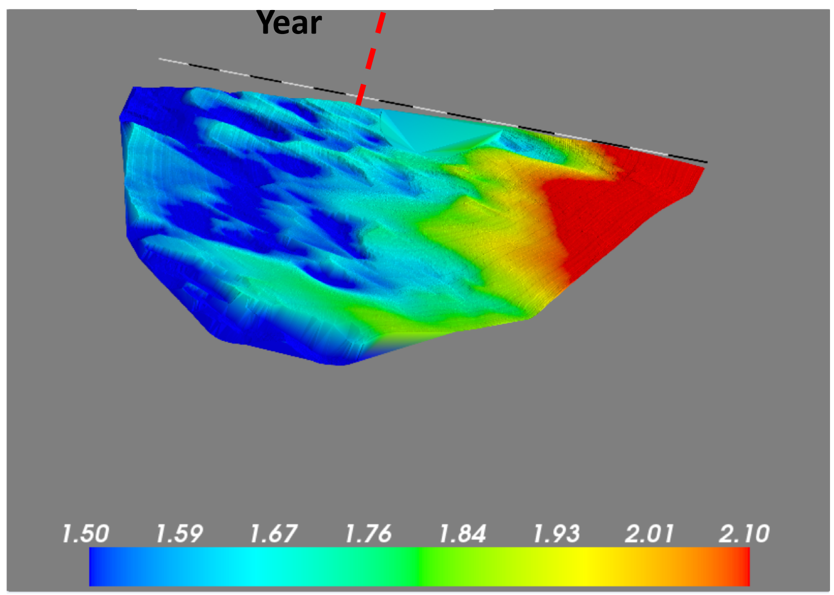

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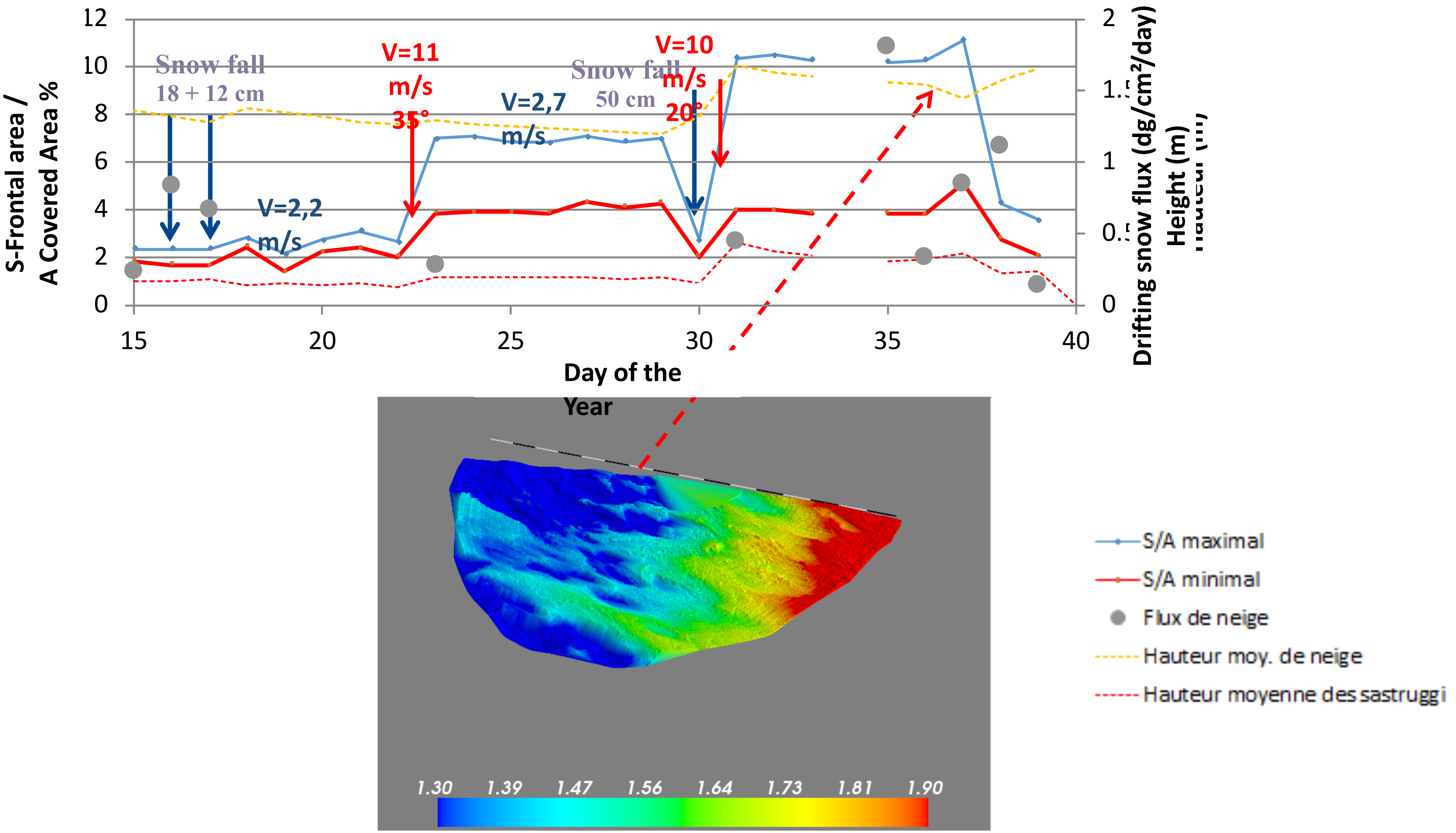
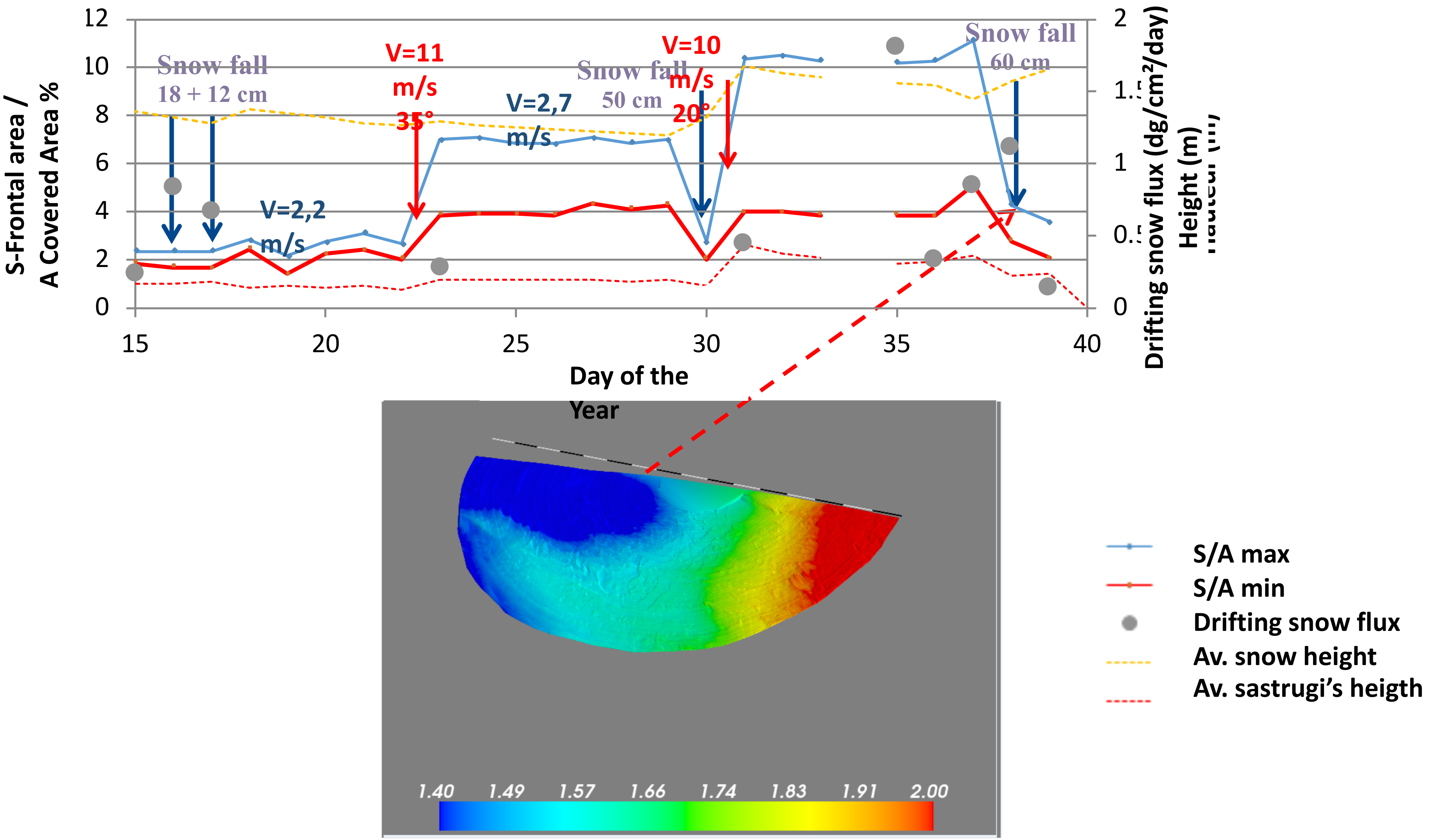
Sastrugi geometrical properties and morphometry



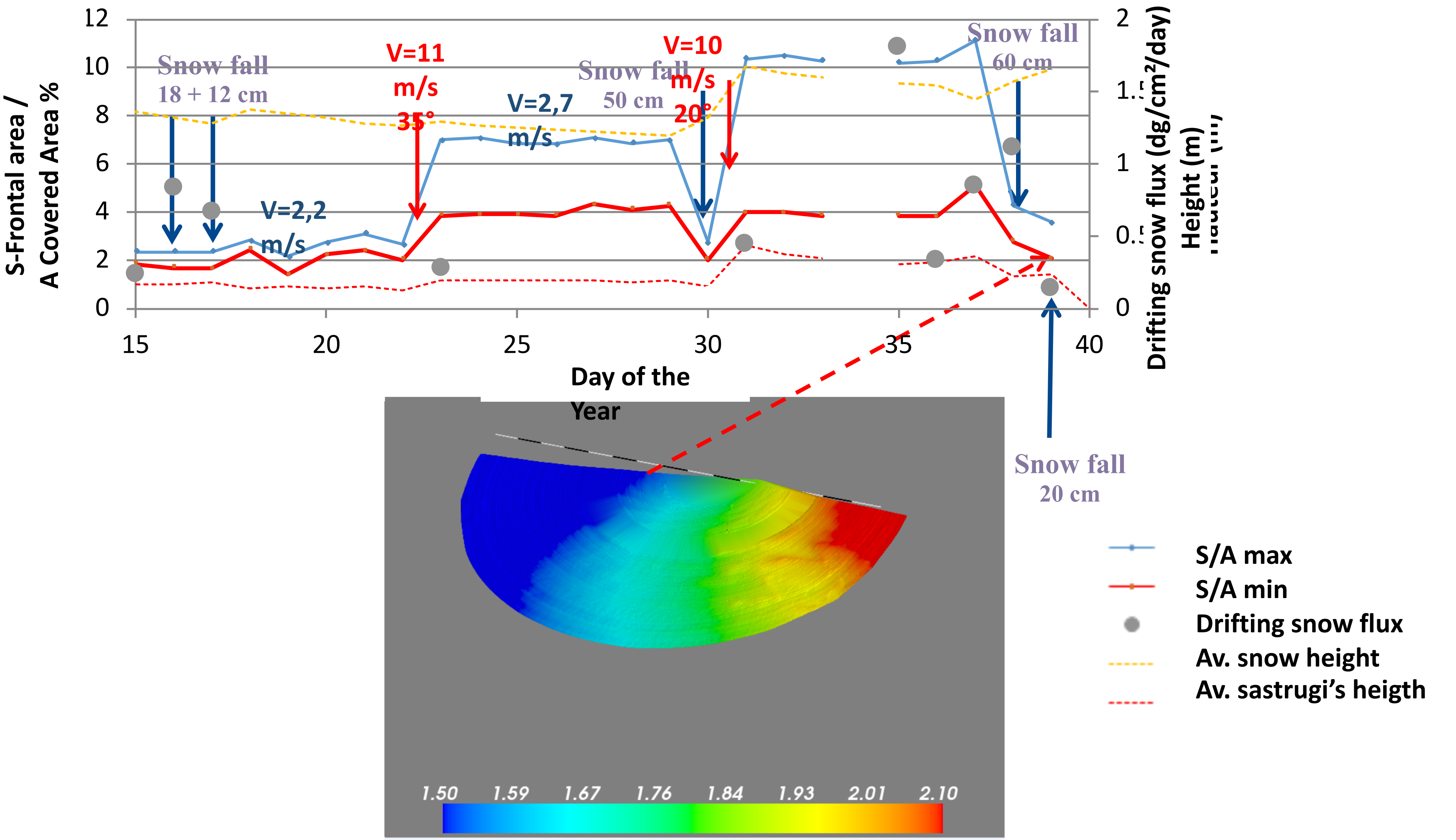
Lac Blanc Pass : Physical processes

Sastrugi geometrical properties and morphometry



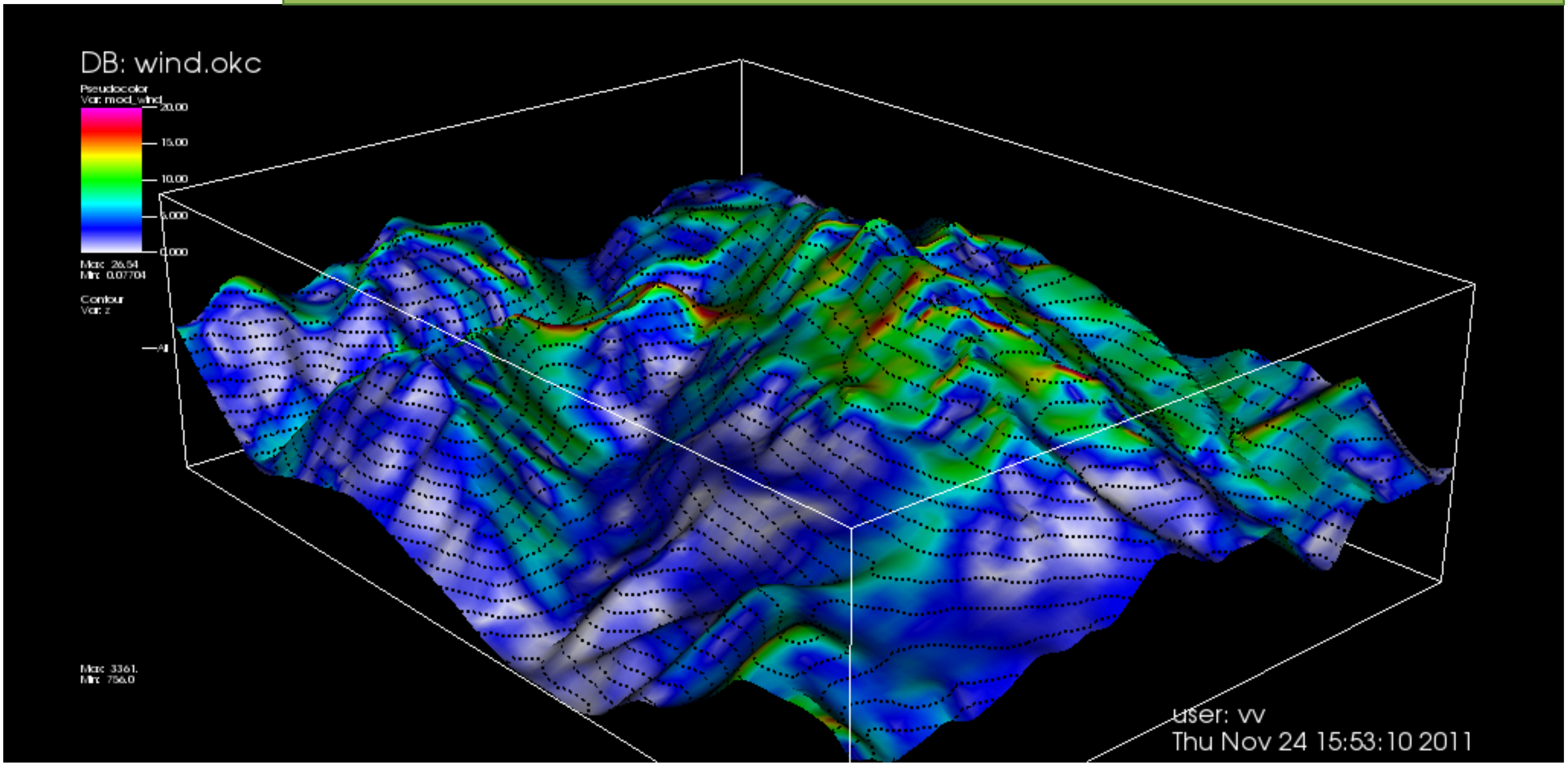
Lac Blanc Pass : Physical processes

Sastrugi geometrical properties and morphometry



Lac Blanc Pass : Validation of numerical models

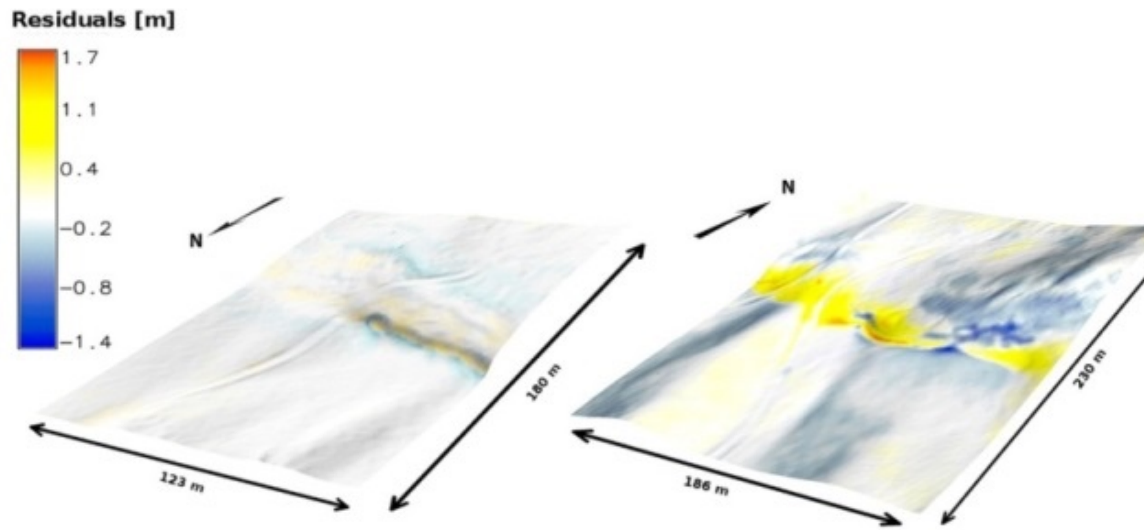
Meso-NH/Crocus : Wind field simulation over complex terrain



Vincent Vionnet's talk.

Lac Blanc Pass : Validation of numerical models

Case study → **Case study II**



3D view of the digital snow surface on a) 11 February 2010, CS I; b) 17 February 2010, CS II. The overlay shows residuals between estimated and measured changes in snow heights

Merging a Terrain-Based Parameter with Drifting Snow Fluxes for Assessing Snow Redistribution in Mountainous Areas

- There is a need for a method that can represent the redistribution of snow **ΔH** by wind in high spatial resolution.
- We present an alternative method to complex numerical models, based on a terrain-based parameter **Sx** (Winstral, 2002) and the estimation of drifting snow fluxes.

$\Delta HS = \alpha * Sx$

Use of drifting snow quantities as a proxy for α

$\alpha = C_* Q$

Schon, P., Prokop A., Vionnet, V., Guyomarc'h, G., Naaim-Bouvet, F. and Heiser, M., "Improving a terrain-based parameter for the assessment of snow depths with TLS data in the Col du Lac Blanc area". Cold Regions Science and Technology. 2015, vol 114, p. 15-26..

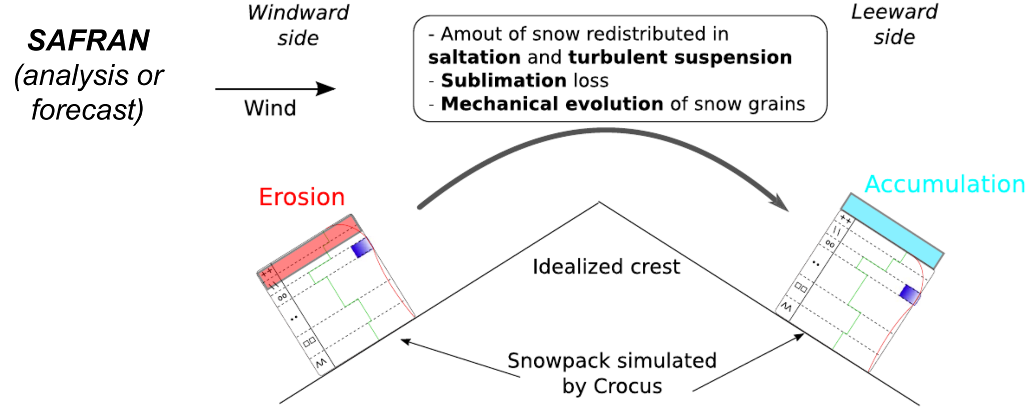
Schon, P., Prokop A., Naaim-Bouvet, F., Vionnet, V., Guyomarc'h, G., and Heiser, M., "Merging a terrain-based parameter with blowing snow fluxes for assessing snow redistribution in alpine terrain,". Cold Regions Science and Technology. 2018, submitted.

Lac Blanc Pass : Validation of numerical models

Perspective :

towards a new blowing snow estimation for avalanche warning based on fine-grid NWP model

Current wind redistribution for avalanche warning :
conceptual representation of massifs with altitude/orientation discretization, slope = 40°



Source : Vionnet et al., 2017.

Model validated at Lac Blanc Pass

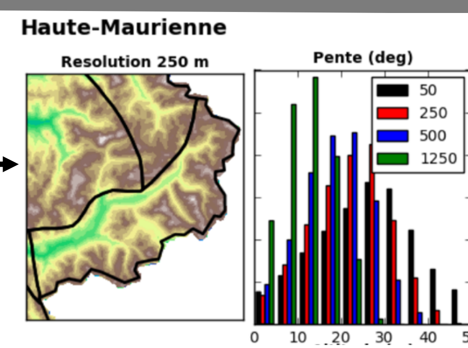
Perspective : use fields from the gridded NWP model AROME+ downscaling (~ 250 m)

Better captures intra-massif variability and slopes

AROME (oper) @ 1.3 km

AROME (ens) @ 2.5 km

→ downscaling →



Source : Dumont, Lafaysse, Vionnet and Morin, technical note

Pre-requisite : Detailed evaluation of AROME fields incl. wind at Lac Blanc Pass