Col du Lac Blanc (2720 m):
An natural wind-tunnel for studying drifting snow at 2700 m a.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)
A “natural” wind tunnel
• located near the Alpe d’Huez ski resort (French Alps) at 2700 a.s.l.
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
Blowing snow events empirical data base
Combination of several datasets (wind, precipitation and snow depth) and their detailed analysis by an expert

Relative Duration of Blowing Snow Events at "Col du Lac Blanc"

2000-2016

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
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

Lac Blanc Pass : Description

Data availability
Data base
- doi:10.17178/CRYOBSCLIM.CLB.all

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

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

Vertical profile of 3 Snow particles Counters

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

\[
\frac{C(z)}{C_{\text{ref}}(z_{\text{ref}})} = \left( \frac{z}{z_{\text{ref}}} \right)^{\frac{\sigma_s U_F}{k u}}
\]


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)
Vertical profile of anemometers + automatic laserscan

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

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

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

During the drifting snow event - 22/23 01 2008 - North wind
After the drifting snow event - 24/25 01 2008 - North wind
Before the drifting snow event - 21/22 01 2008 - North wind


Sastrugi geometrical properties and morphometry

Lac Blanc Pass: Physical processes

Snowfall
18 + 12 cm

- Snow fall
- Flux de neige (dg/cm² /jour)
- Height (m)
- Day of the Year
- S/A maximal
- S/A minimal
- Drifting snow flux (dg/cm² /day)
- Av. snow height
- Av. sastrugi’s height

V=2.2 m/s

S-A frontal area / A Covered Area %

Day of the Year
Snow fall
18 + 12 cm

Flux de neige (dg/cm² /jour)

Hauteur (m)

Sastrugi geometrical properties and morphometry

Lac Blanc Pass : Physical processes

V=2.2 m/s

Drifting snow flux (dg/cm² /day)

Height (m)

Day of the Year

S/A max
S/A min
Drifting snow flux
Av. snow height
Av. sastrugi’s heigth
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

- Snowfall: 18 + 12 cm
- Flux de neige (dg/cm²/jour)
- Hauteur (m)
- Jour de l’année (2016)
- S/A maximal
- S/A minimal
- Drifting snow flux (dg/cm²/day)
- Height (m)
- V=2,2 m/s
- V=11 m/s
- 35°
- Av. snow height
- Av. sastrugi’s height
- V=11 m/s
- S/A max
- S/A min
- Drifting snow flux
- Av. snow height
- Av. sastrugi’s height
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

- Snowfall: 18 + 12 cm
- Flux de neige (dg/cm²/day)
- Hauteur (m)
- S/A maximal
- S/A minimal
- Drifting snow flux
- Av. snow height
- Av. sastrugi’s height

Graph showing the relationship between day of the year and Drifting snow flux (dg/cm²/day) with S/A (covered area %) and Height (m).
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

Day of the Year

Drifting snow flux (dg/cm²/day)

Height (m)

Flow of snow
18 + 12 cm

Snowfall
50 cm

V=11 m/s

V=2,2 m/s

V=2,7 m/s

35°

Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

Day of the Year

Drifting snow flux (dg/cm²/day)

Height (m)

Flow of snow
18 + 12 cm

Snowfall
50 cm

V=11 m/s

V=2,2 m/s

V=2,7 m/s

35°

S/A max

S/A min

Drifting snow flux

Av. snow height

Av. straurugi’s height
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

Snowfall
- 50 cm
- 18 + 12 cm

Flux de neige (dg/cm² /jour)

Hauteur (m)

Surface opposée au vent / Surface totale (%)

Day of the Year

S/A maximal

S/A minimal

Drifting snow flux (dg/cm² /day)

Flux de neige

Drifting snow flux (dg/cm² /day)

Av. snow height

Av. sastrugi’s height

V = 2.2 m/s

V = 2.7 m/s

V = 11 m/s

V = 10 m/s

V = 10 m/s

V = 2.7 m/s

V = 11 m/s

V = 20 m/s

V = 35 m/s

35°

°
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry
Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

- Snowfall: 18 + 12 cm
- Wind Speed: V=11 m/s, V=2.7 m/s, V=2.2 m/s, V=10 m/s
- Angles: 36°, 29°, 20°
- V=10 m/s, V=20 m/s
- Height: 50 cm, 60 cm
- Flux of snow: 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12
- Day of the Year: 15 to 40
- Covered Area %: 0 to 12
- Drifting snow flux: 0 to 2 g/cm²/day
- Av. snow height: 1.40 to 2.00
- Av. sastrugi’s height

V=2.2 m/s
V=2.7 m/s
V=10 m/s
V=11 m/s

°
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Lac Blanc Pass: Physical processes

Sastrugi geometrical properties and morphometry

- Snowfall values: 18 + 12 cm, 50 cm, 60 cm
- Speeds: V=11 m/s, V=10 m/s, V=2.7 m/s, V=2.2 m/s
- Angles: 35°, 20°, 11°, 10°, 20°
- Day of the year (2016): 15 to 40
- Flux of snow (dg/cm²/day)
- Height (m)
- Frontal area / Total area (%)
- S/A max, S/A min
- Drifting snow flux
- Average snow height
- Average sastrugi’s height

V=2.2 m/s
V=2.7 m/s
V=11 m/s
V=10 m/s
35°
20°
11°
20°
Lac Blanc Pass: Validation of numerical models

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

Vincent Vionnet’s talk.
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 $\Delta H$ by wind in high spatial resolution.
- We present an alternative method to complex numerical models, based on a terrain-based parameter $S_x$ (Winstral, 2002) and the estimation of drifting snow fluxes.

$\Delta H = \alpha \ast S_x$

Use of drifting snow quantities as a proxy for $\alpha$

$\alpha = C \ast Q$

Lac Blanc Pass: Validation of numerical models

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.


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°

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

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