Fully coupled snowpack/atmosphere simulations of snowfall and blowing snow in alpine terrain

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Snow/Atmosphere coupling processes during blowing snow events

- Influence of near-surface atmospheric turbulence and the saltation dynamics
- Blowing snow sublimation and feedbacks on the SBL
- Evolution of physical properties of surface snow (roughness, cohesion, ...)

[Image of snowy mountains with text overlay]
A fully coupled snowpack/atmosphere model
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Atmospheric model: **Meso-NH**

- 3D Turbulence Scheme
- Cloud microphysical scheme

*Lafore et al. (1998), Lac et al. (2018)*
A fully coupled snowpack/atmosphere model

Atmospheric model: Meso-NH

- 3D Turbulence Scheme
- Cloud microphysical scheme

Lafore et al. (1998), Lac et al. (2018)

Simulation of complex and turbulent atmospheric flow in alpine terrain
A fully coupled snowpack/atmosphere model

Atmospheric model: **Meso-NH**

- 3D Turbulence Scheme
- Cloud microphysical scheme

*Lafont et al. (1998), Lac et al. (2018)*
A fully coupled snowpack/atmosphere model

**Atmospheric model: Meso-NH**

- 3D Turbulence Scheme
- Cloud microphysical scheme

*Lafore et al. (1998), Lac et al. (2018)*

**Snowpack model: Crocus**

- Detailed layering of the snowpack
- Metamorphism laws

*Brun et al. (1989, 1992), Vionnet et al. (2012)*
A fully coupled snowpack/atmosphere model

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- 3D Turbulence Scheme
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Blowing snow scheme

2nd level atmospheric model

1st level atmospheric model

Surface boundary layer

Salination layer

Snowpack

Type of grains → Threshold wind speed

Wind Temp, ReHu

Turbulent diffusion

Sublimation

Sedimentation

Radius (m)

2 parameter gamma distribution

Meso-NH

SBL

SURFEX

Crocus

Vionnet et al. (2014)
Spatial variability of snow accumulation during snowfall

- Orographic snowfall
- Preferential deposition of falling snow
- Wind-induced transport of deposited snow (salation/suspension)
Spatial variability of snow accumulation during snowfall

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- What is the relative importance of these processes?
- Can atmospheric models provide useful informations?
Spatial variability of snow accumulation during snowfall

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**Case study:** 24-h blowing snow event with concurrent snowfall in Feb. 2011 around Col du Lac Blanc

Study: *High resolution Large Eddy Simulation of Snow Accumulation in Alpine Terrain* (Vionnet et al., JGR-A, 2017)
Downscaling the meteorology to the local scale:

➢ 3 nested grids from operational analysis at 2.5 km down to 50-m grid spacing
Main structures of atmospheric flow in alpine terrain

Good agreement around CLB

Strong overestimation of wind speed at Sarennes AWS
Spatial variability of total solid precipitation

- Different contributions of snowflakes and graupel (rimed particles)
- **Graupel:** higher terminal fall velocity, reduced downwind transport
Detailed cloud processes

➢ Strong updrafts producing supercooled cloud droplets
➢ Growth of snowflakes by riming of cloud droplets
➢ Local maximal production of graupel

➢ Local microphysical processes can potentially affect the spatial distribution of snowfall in alpine terrain (similar results as Mott et al. 2014)
Overestimation of near-surface fluxes for intermediate wind speeds
Influence of falling snow flakes on the vertical profile of flux

Blowing snow fluxes at Col du Lac Blanc

Observations
Simulated fluxes:
- Blown snow particles only
- With falling snow flakes

Snow Particles Counters (SPC)

Particle Flux (kg m$^{-2}$ s$^{-1}$)
Wind-induced snow redistribution

➢ Strong spatial variability when including snow transport
➢ Main source of variability of snow accumulation
Model limitations

➢ **Spatial resolution (50 m)** is not sufficient to capture fine-scale patterns of snow accumulation

➢ **Parameterizations** in the blowing snow scheme: saltation layer, representation of non-steady processes, ...

➢ Uncertainties in the representation of **cloud processes** at high-resolution

Vionnet et al (2014)
Conclusion and perspectives

- **Meso-NH/Crocus**: a numerical lab. to investigate coupling processes between the atmosphere and the snow surface in alpine terrain (available in Meso-NH 5.4 mesonh.aero.obs-mip.fr).
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Future challenges for blowing snow models in alpine terrain (in general)

- **Representation of physical processes:**
  - **Interactions** between local and non-local atmospheric turbulence and blowing snow dynamics (ejections, splash, …) (Paterna et al., 2016; Comola and Lehning, 2017; Askamit and Pomeroy, 2018)
  - Evolution of **snow surface properties** during blowing snow events: surface roughness (Amory et al. 2015), fragmentation (Comola et el. 2017) and hardening (Sommer et al., 2017)
- Models at temporal and spatial scales relevant for avalanche hazard and hydrological forecasting
- Model evaluation with multiple sensors (TLS, ALS, Radar, Wind Lidar, SPC, …)
Thanks for your attention!
Case study: 14-15 February 2011

Synoptic conditions

➢ **Cold front** crossing France
➢ **Southern flow** ahead of the front
➢ **Snowfall** over the Alps (limit rain/snow 1200 m)

Wind field and specific humidity at 700 hPa on 14 February 2011 12:00
Case study: 14-15 February 2011

**Synoptic conditions**

➢ Cold front crossing France
➢ Southern flow ahead of the front
➢ Snowfall over the Alps (limit rain/snow 1200 m)

**Local conditions at CLB (2700 m)**

➢ Non-erodable initial snow cover
➢ Snowfall (around 15 cm)
➢ Wind-induced redistribution of falling snow

Wind field and specific humidity at 700 hPa on 14 February 2011 12:00

Southern Winds