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

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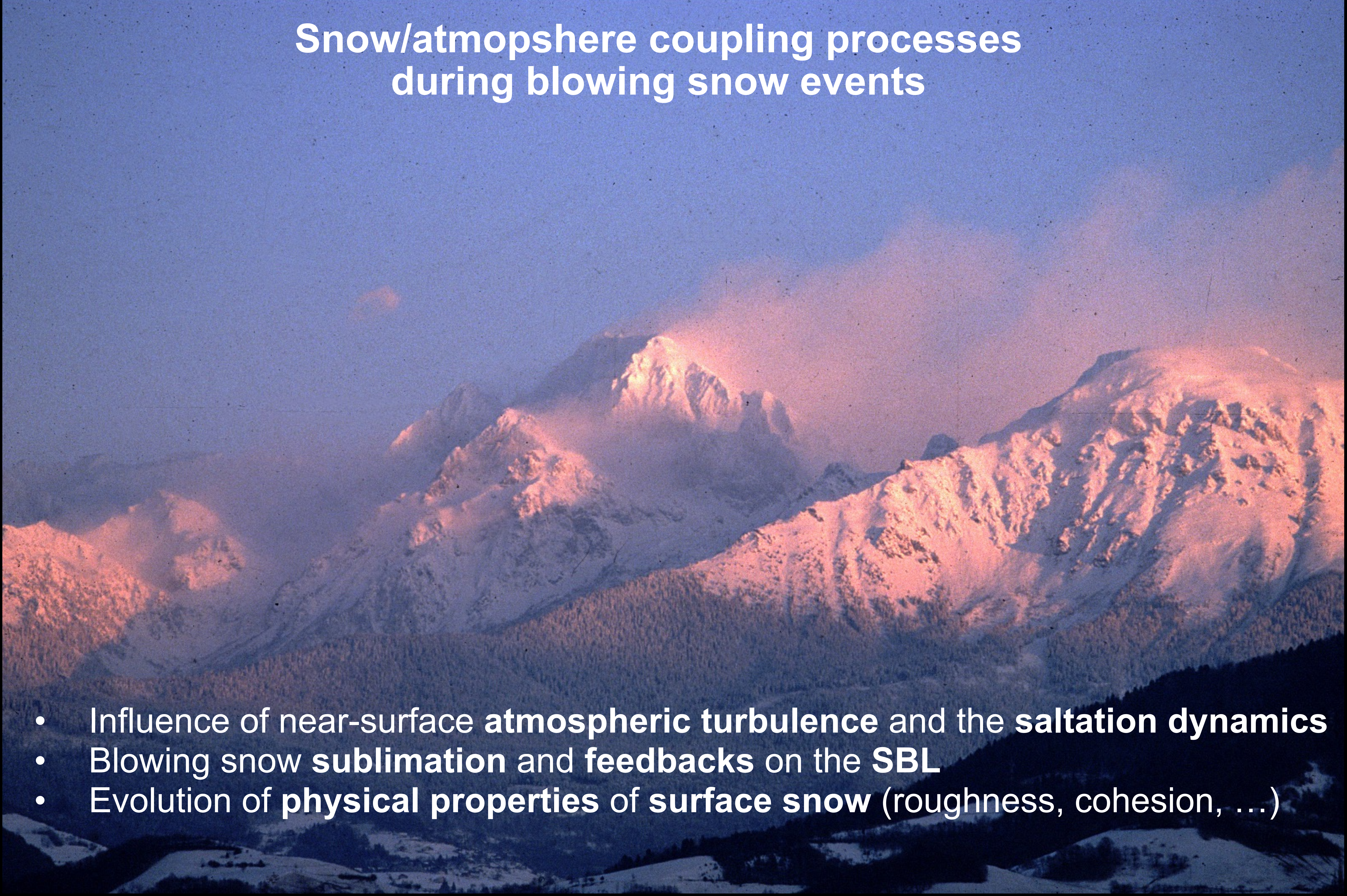
Snow/atmopshere coupling processes during blowing snow events



- 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, …)

A fully coupled snowpack/atmosphere model

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Atmospheric model: **Meso-NH**

Meso-NH
mesoscale non-hydrostatic model

- 3D Turbulence Scheme
- Cloud microphysical scheme

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

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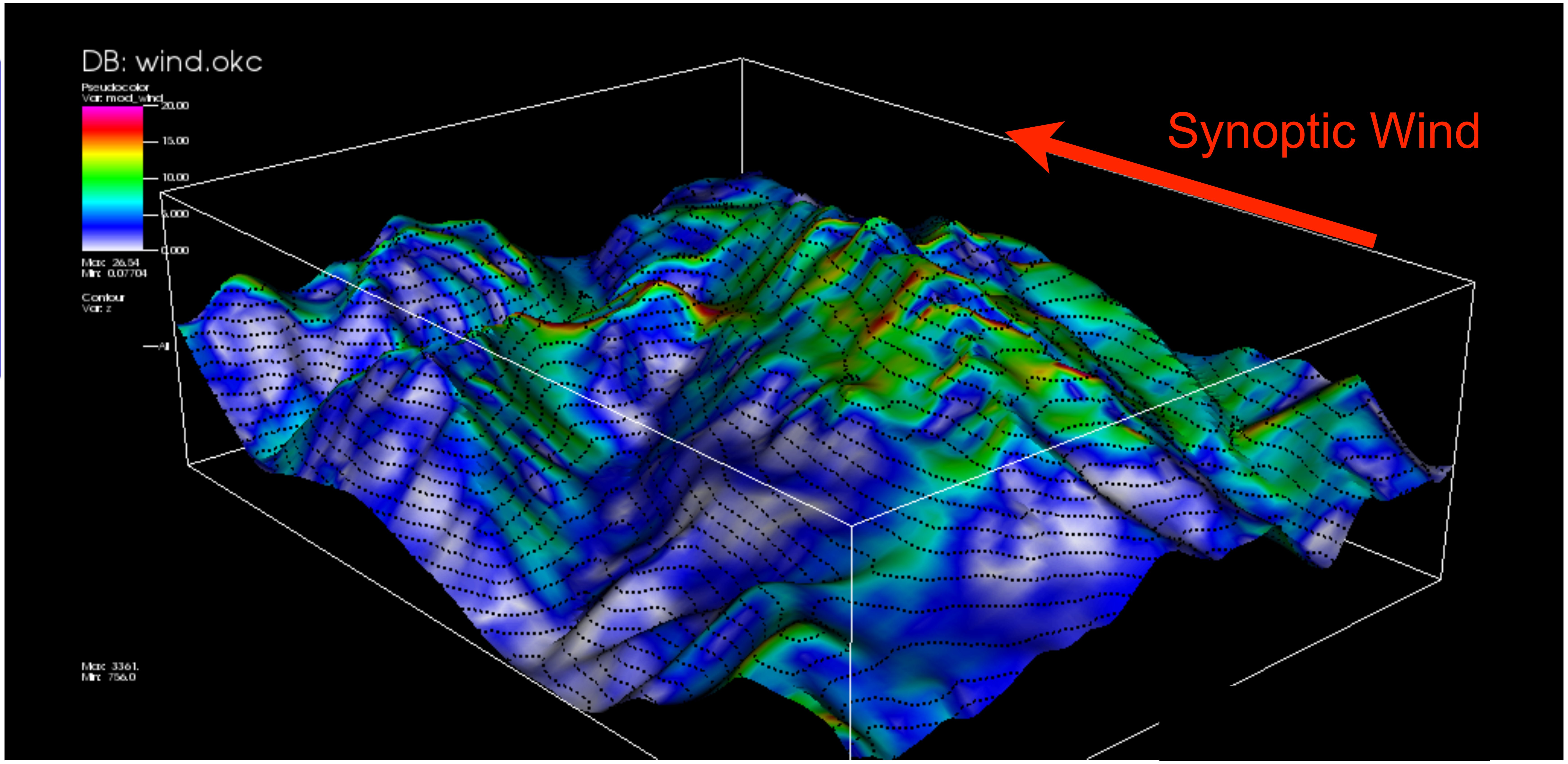

Simulation of complex and turbulent atmospheric flow in alpine terrain

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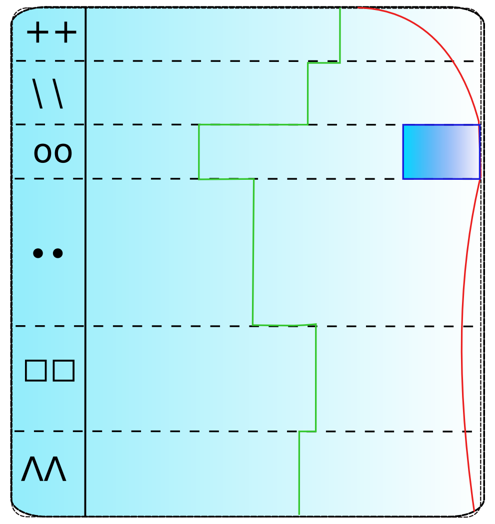
Snowpack model: **Crocus**

- Detailed layering of the snowpack
- Metamorphism laws



Brun et al. (1989, 1992), Vionnet et al. (2012)

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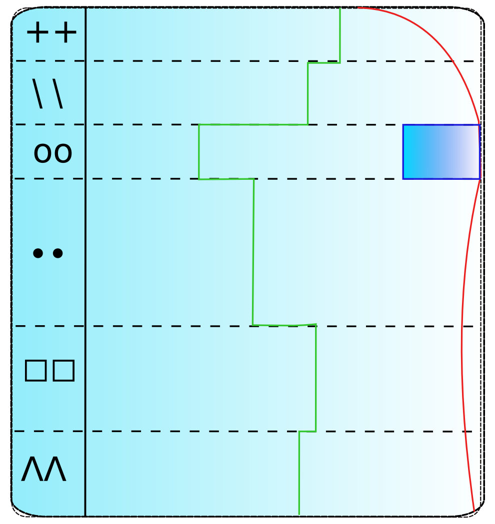

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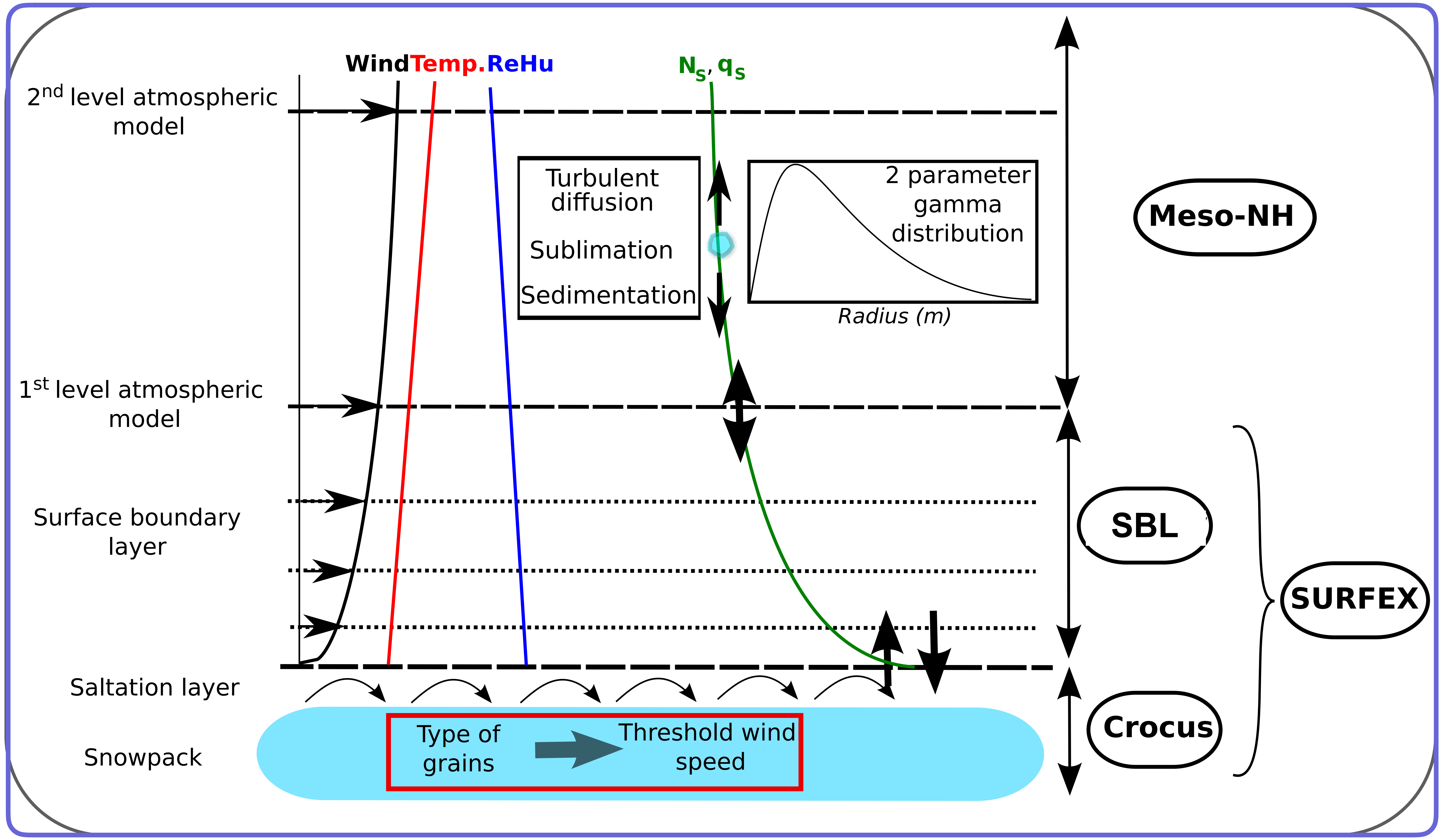
Blowing snow scheme



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)

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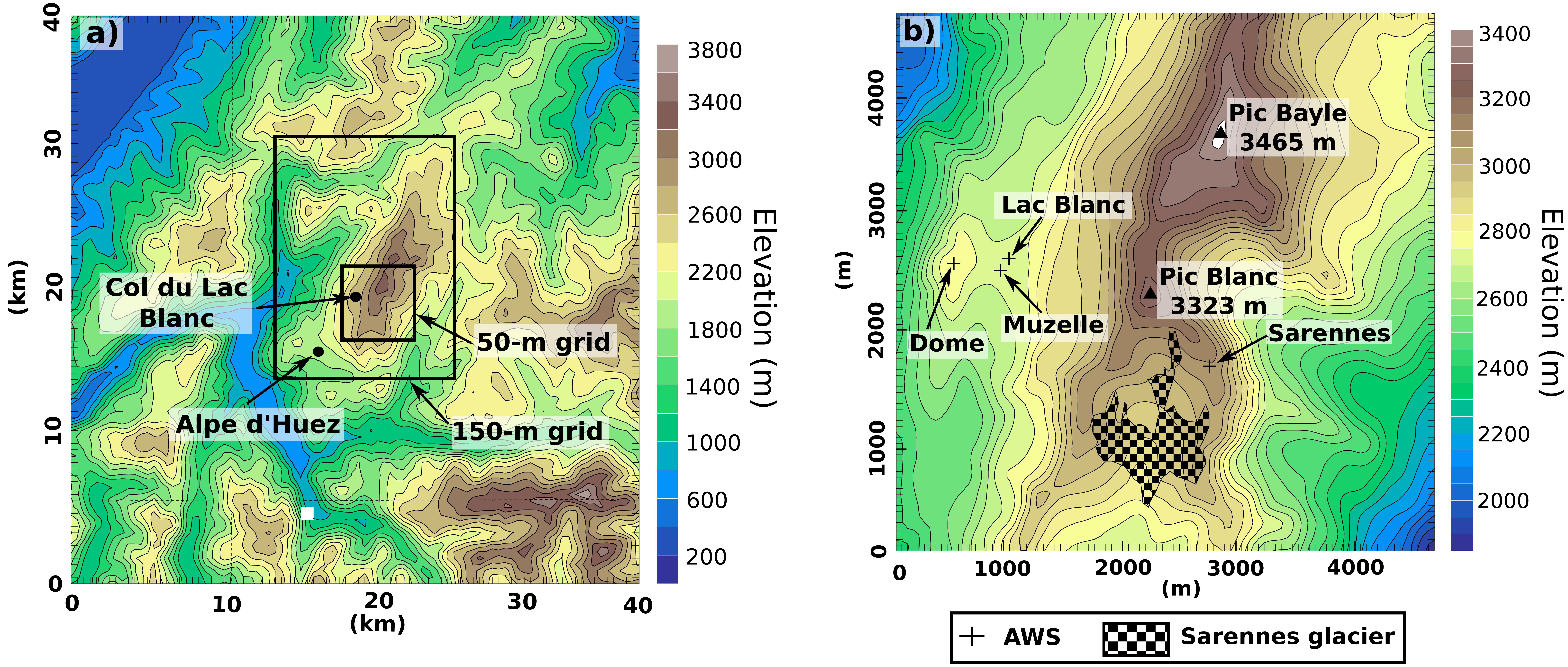
- **Case study:** 24-h blowing snow event with concurrent snowfall in Feb. 2011 around Col du Lac Blanc

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

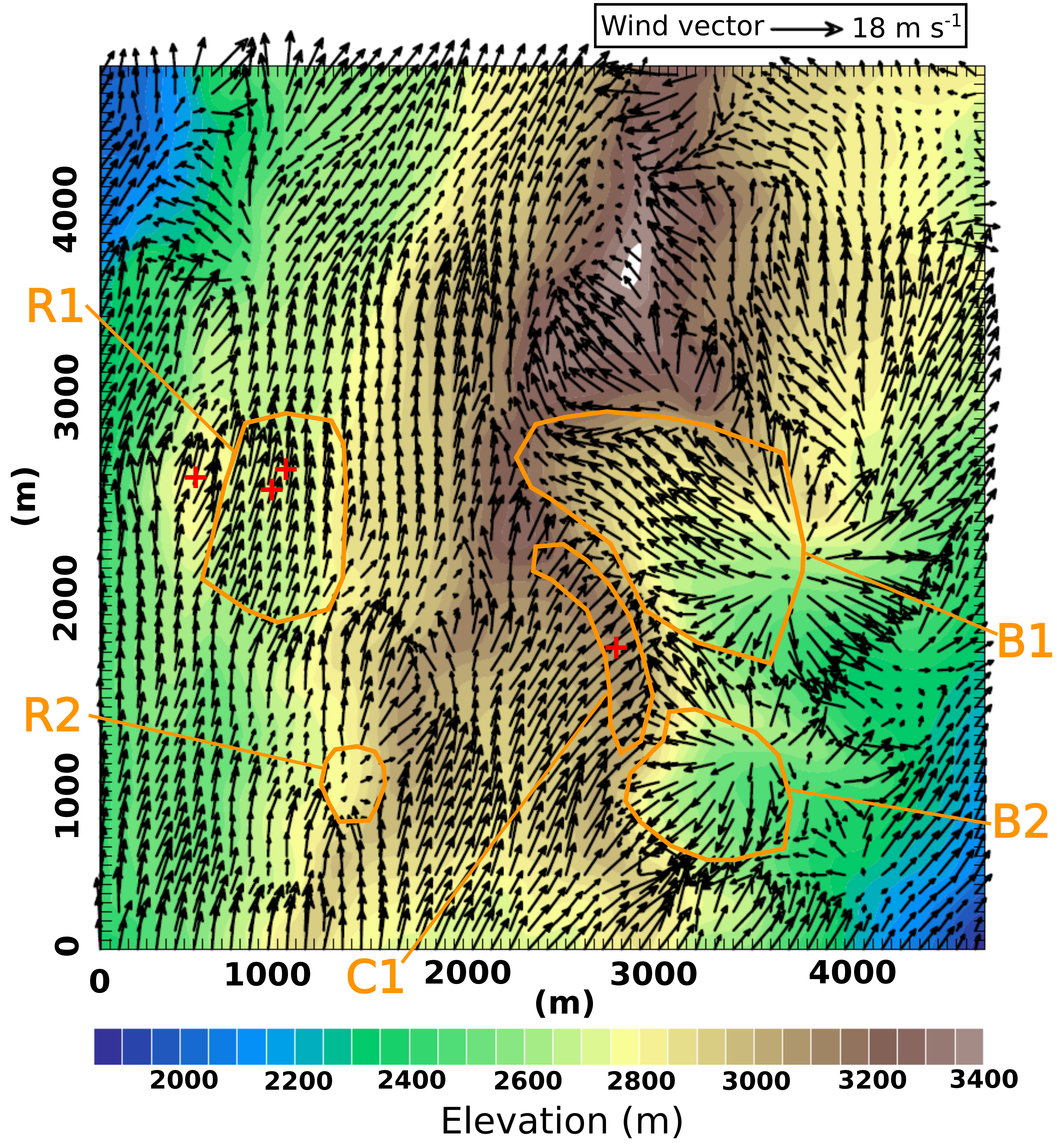
Model configuration



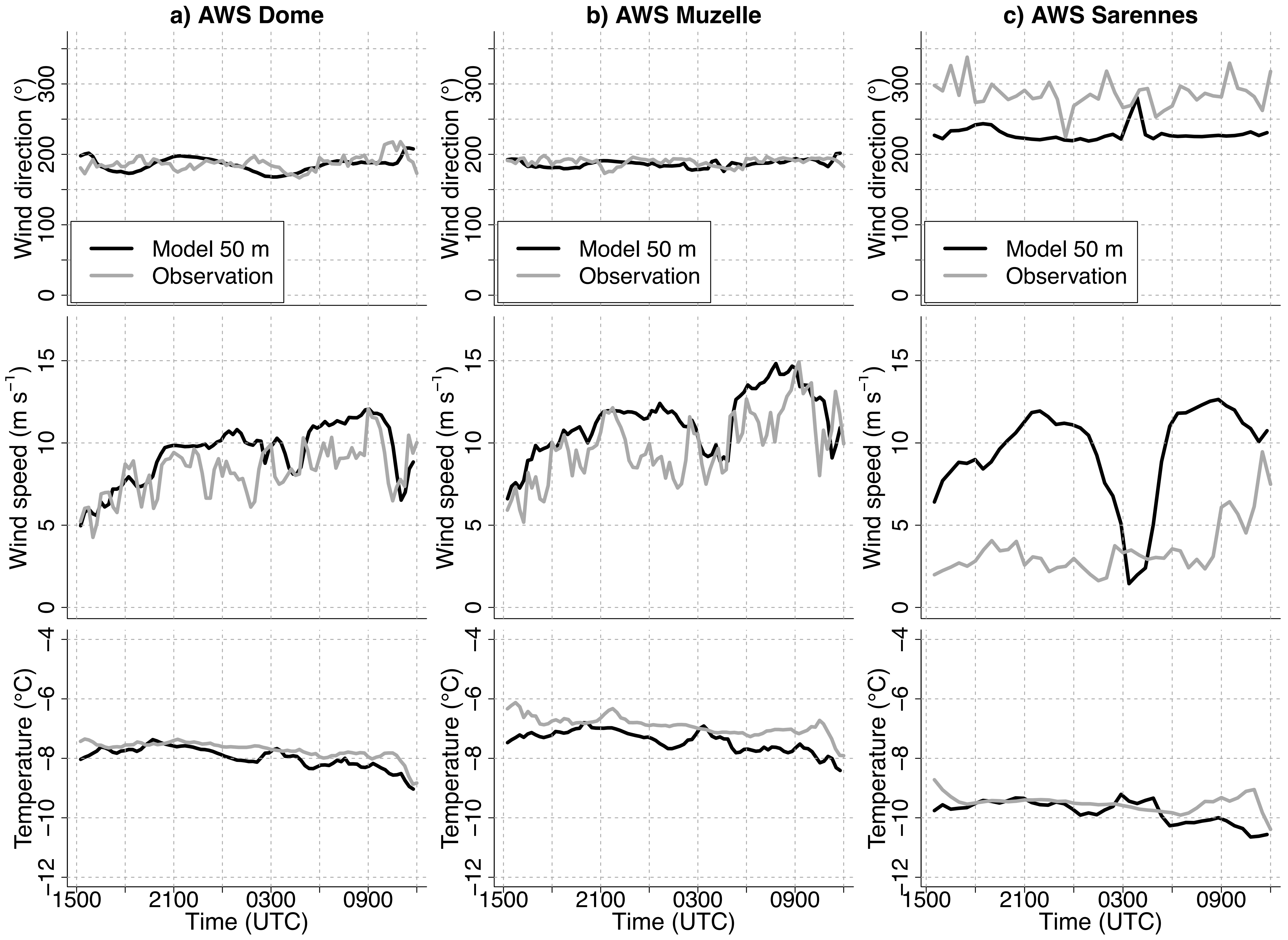
Downscaling the meteorology to the local scale:

➢ 3 **nested grids** from operational analysis at 2.5 km down to 50-m grid spacing

Atmospheric conditions

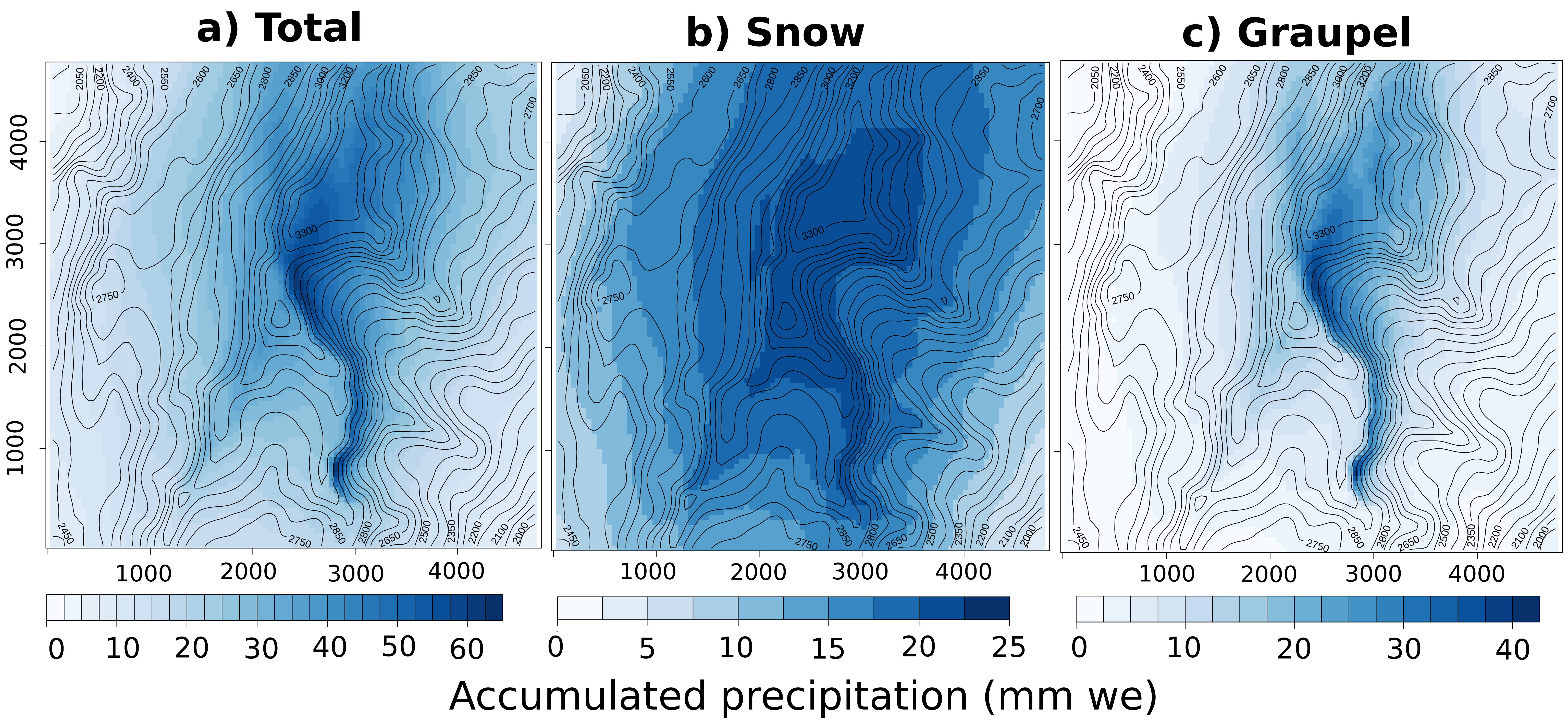


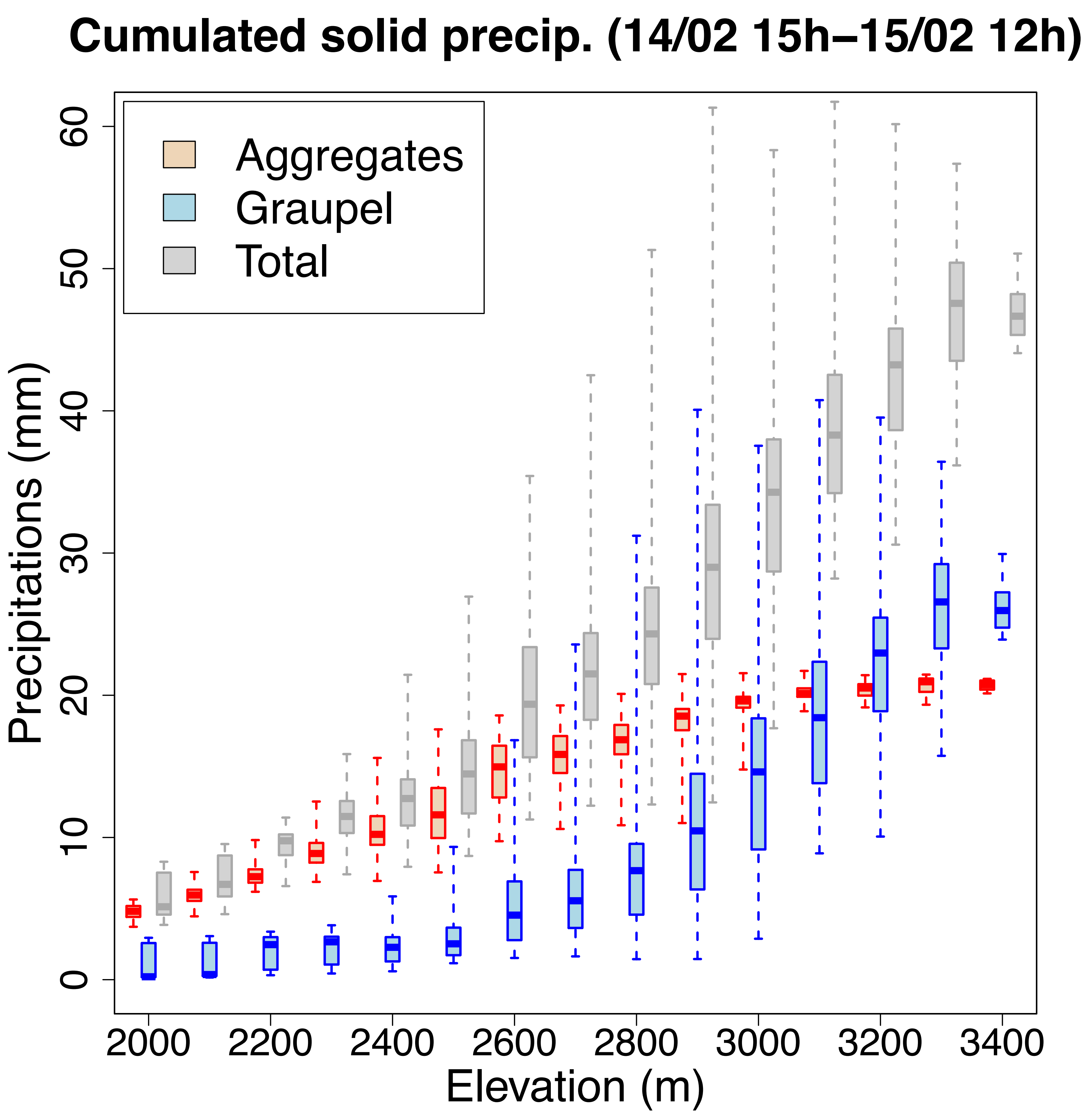
Wind field at 1st atmos. level at 09:00 15 Feb.



- ➢ Main **structures of atmospheric flow in alpine terrain**
- ➢ Good agreement around CLB
- ➢ Strong **overestimation** of wind speed at **Sarennes** AWS

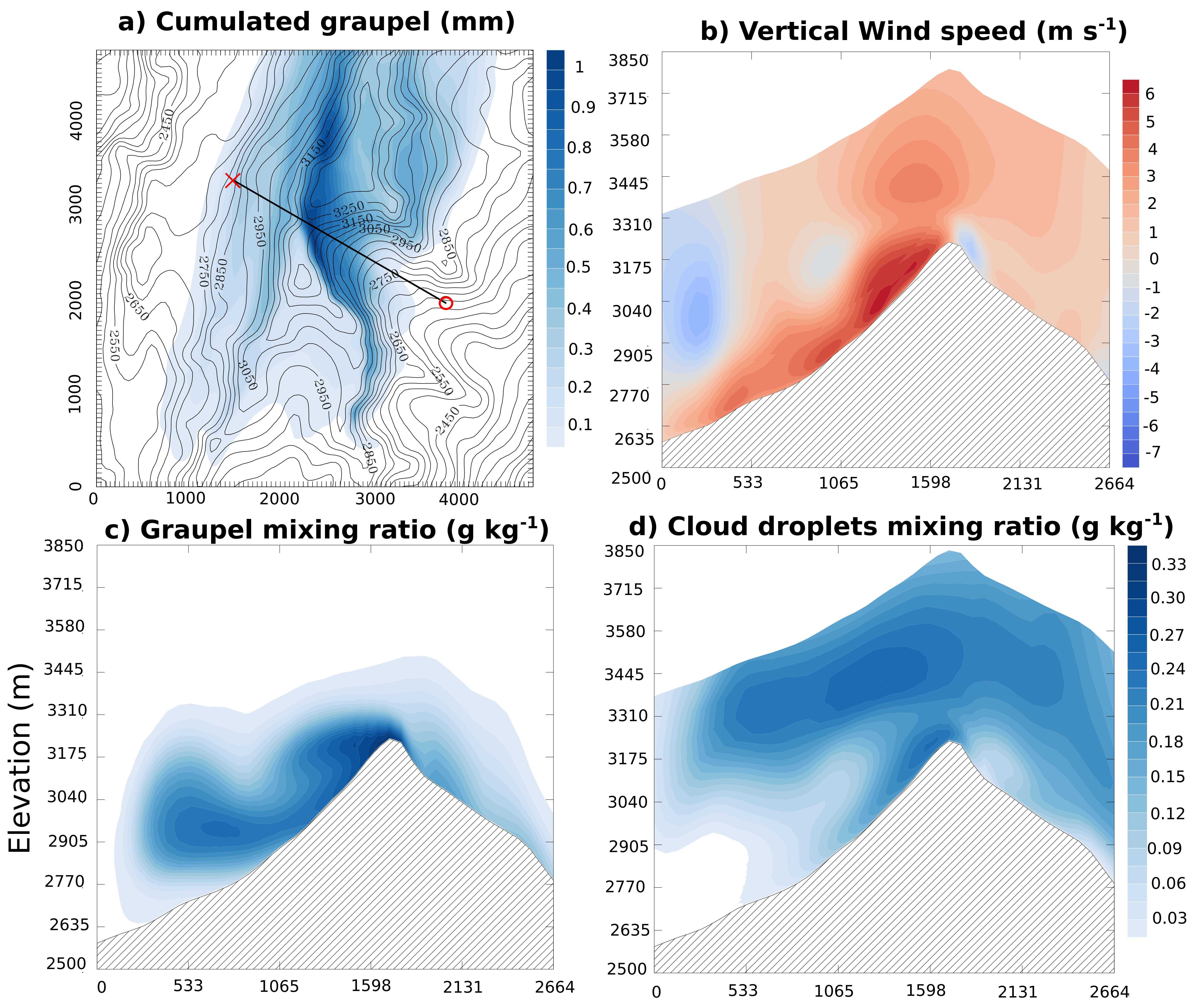
Total solid precipitation





- ➢ **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**

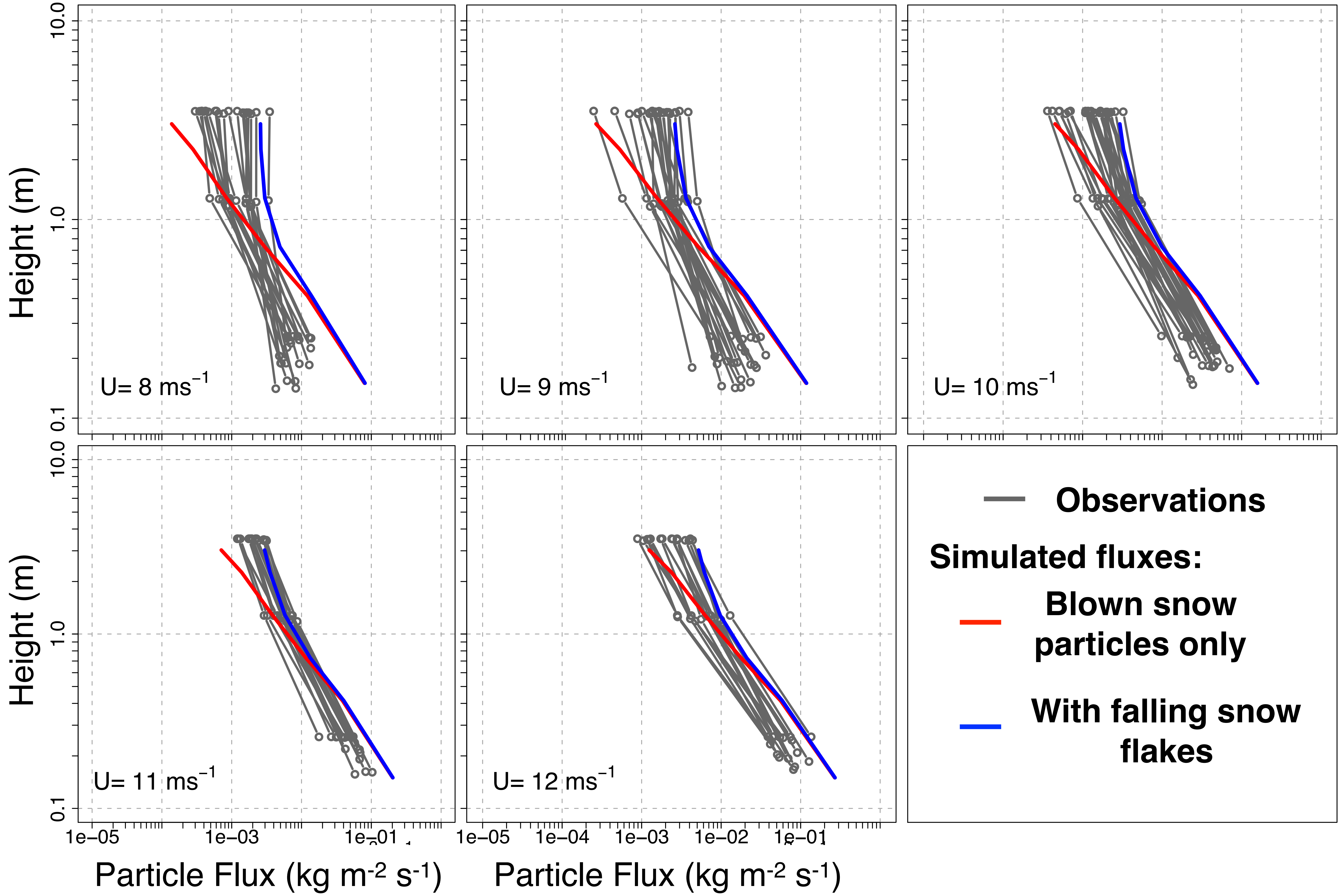
➢ Growth of snowflakes by **riming of cloud droplets**

➢ 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)

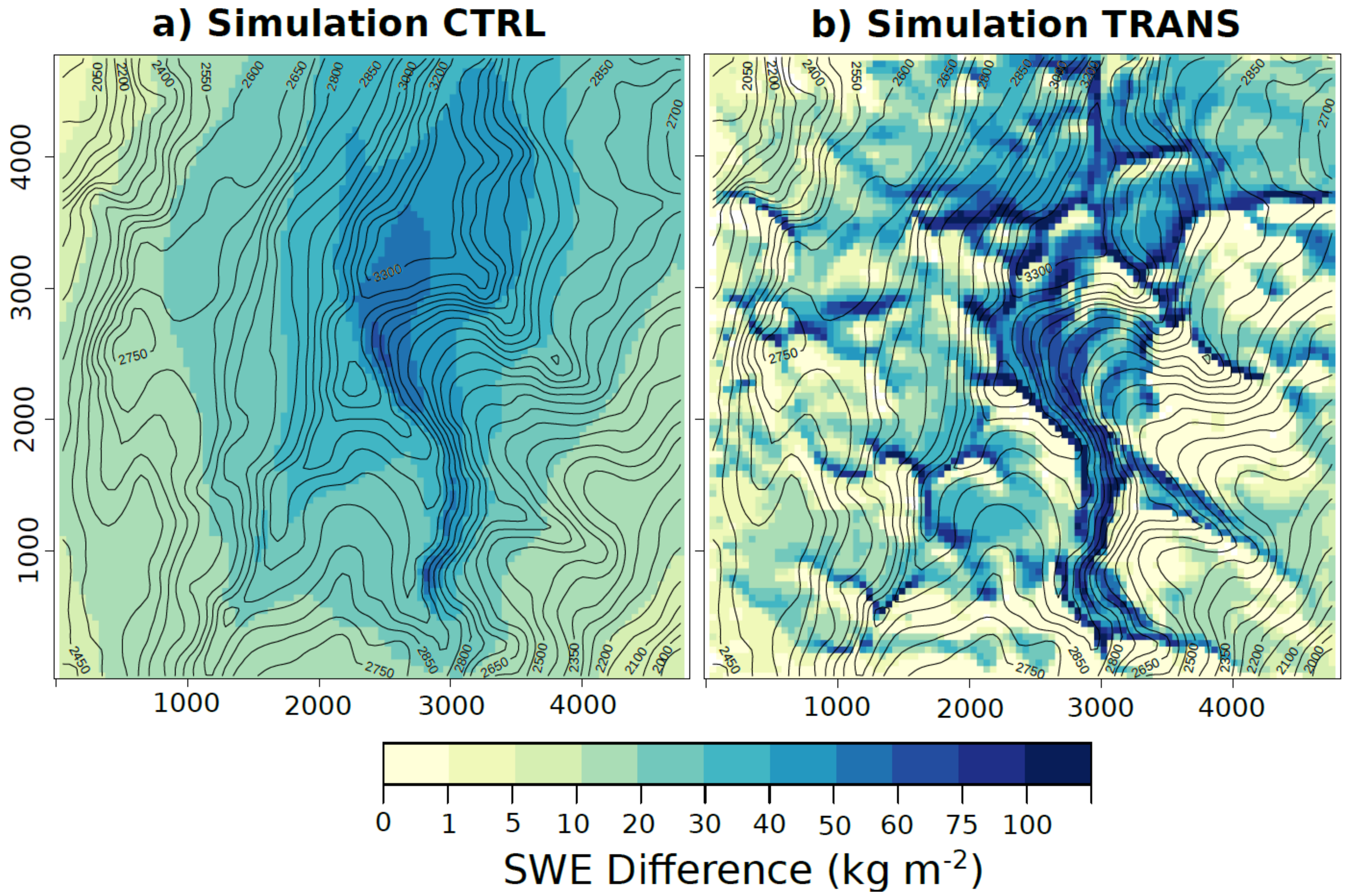
Blowing snow fluxes at Col du Lac Blanc

Snow Particles Counters (SPC)



- ➢ **Overestimation of near-surface fluxes** for intermediate wind speeds
- ➢ **Influence of falling snow flakes** on the vertical profile of flux

Wind-induced snow redistribution



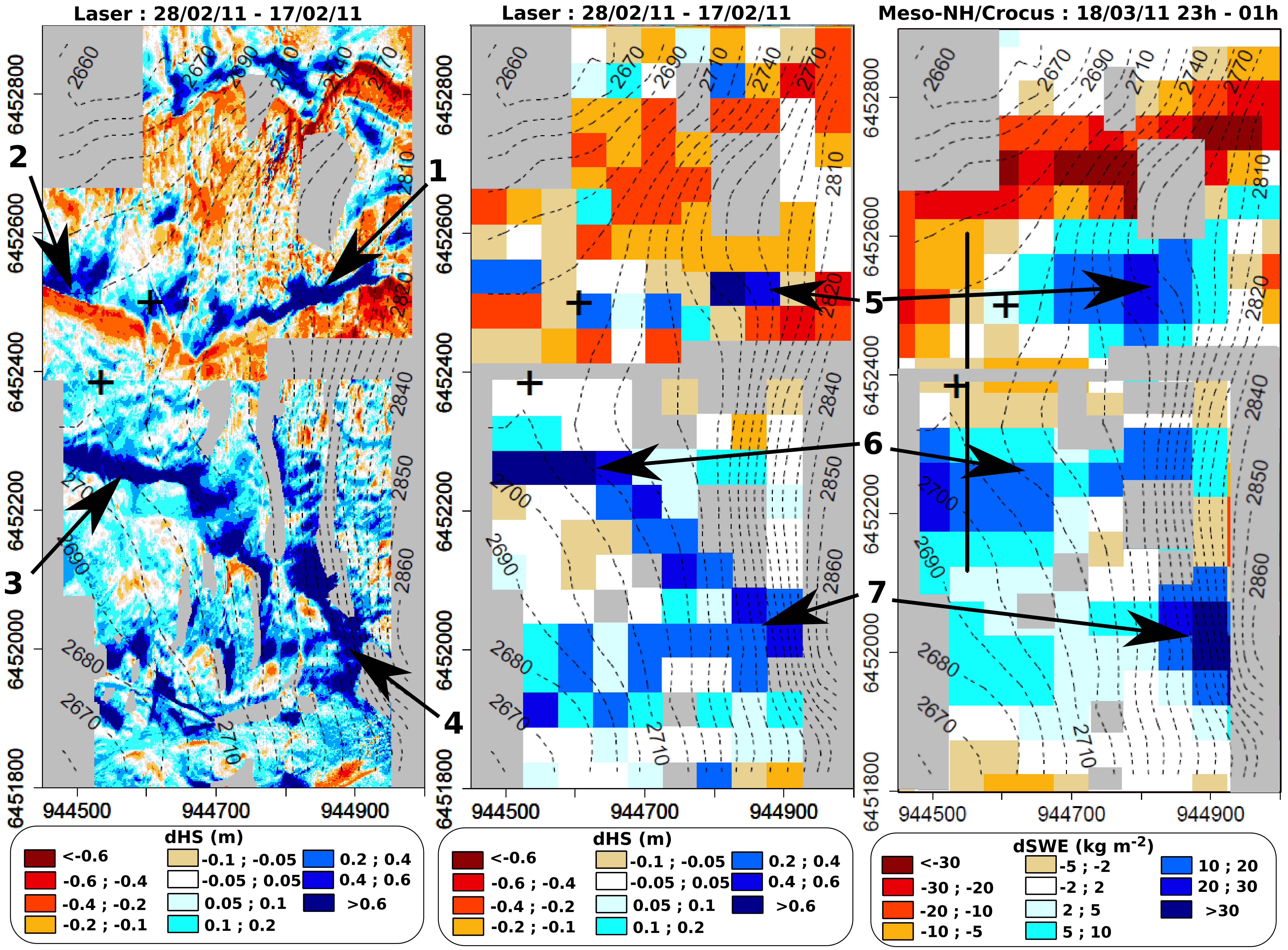
- ➢ **Strong spatial variability** when including snow transport
- ➢ **Main source of variability** of snow accumulation

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



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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)

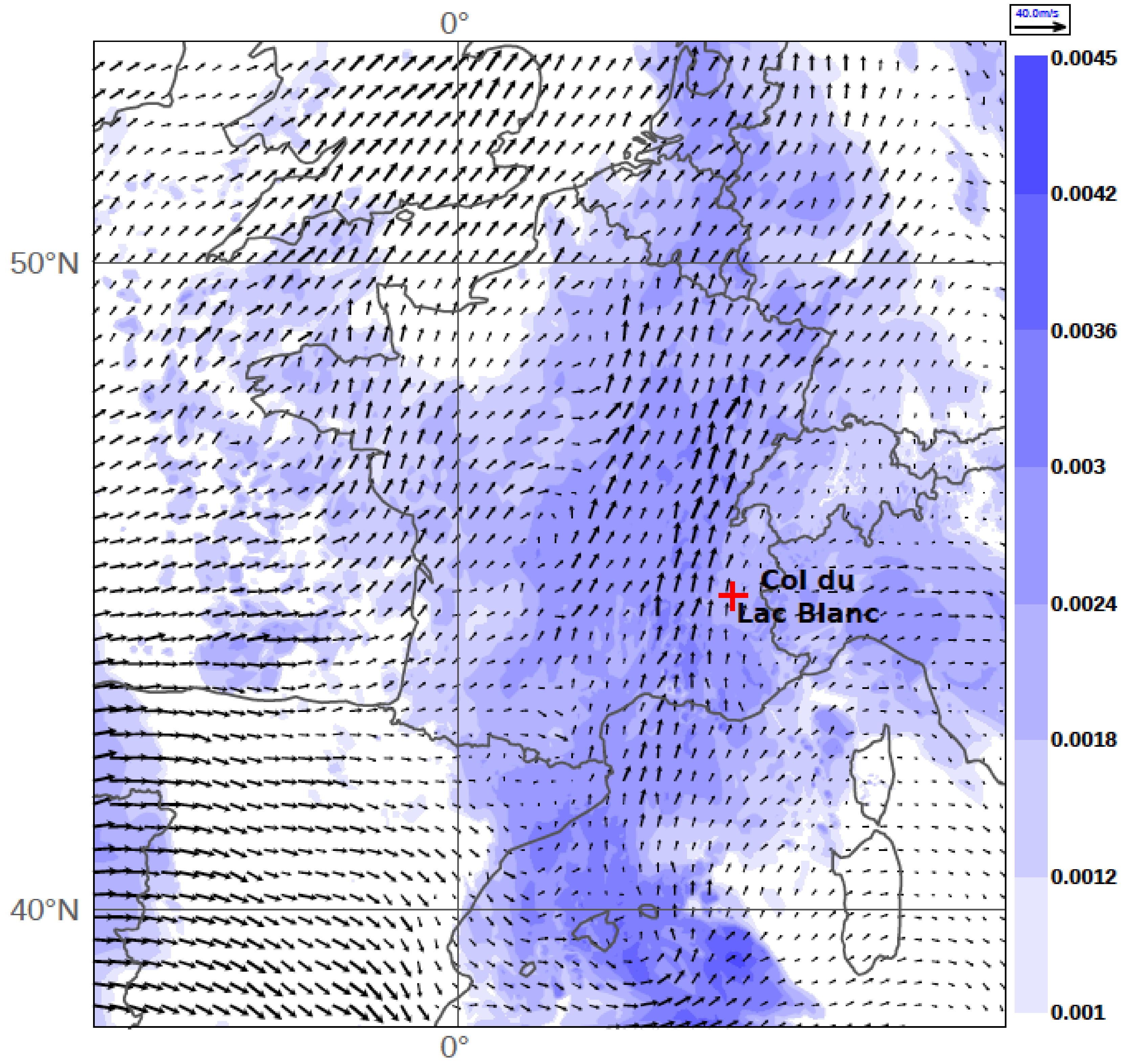
- Representation of **physical processes:**
  - **Interactions** between local and non-local **atmospheric turbulence** and **blowing snow dynamics** (ejections, splash, …) (Paterna et al., 2016; Comola and Lehning, 2017; Askamit and Pomeroy, 2018)
  - Evolution of **snow surface properties** during 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

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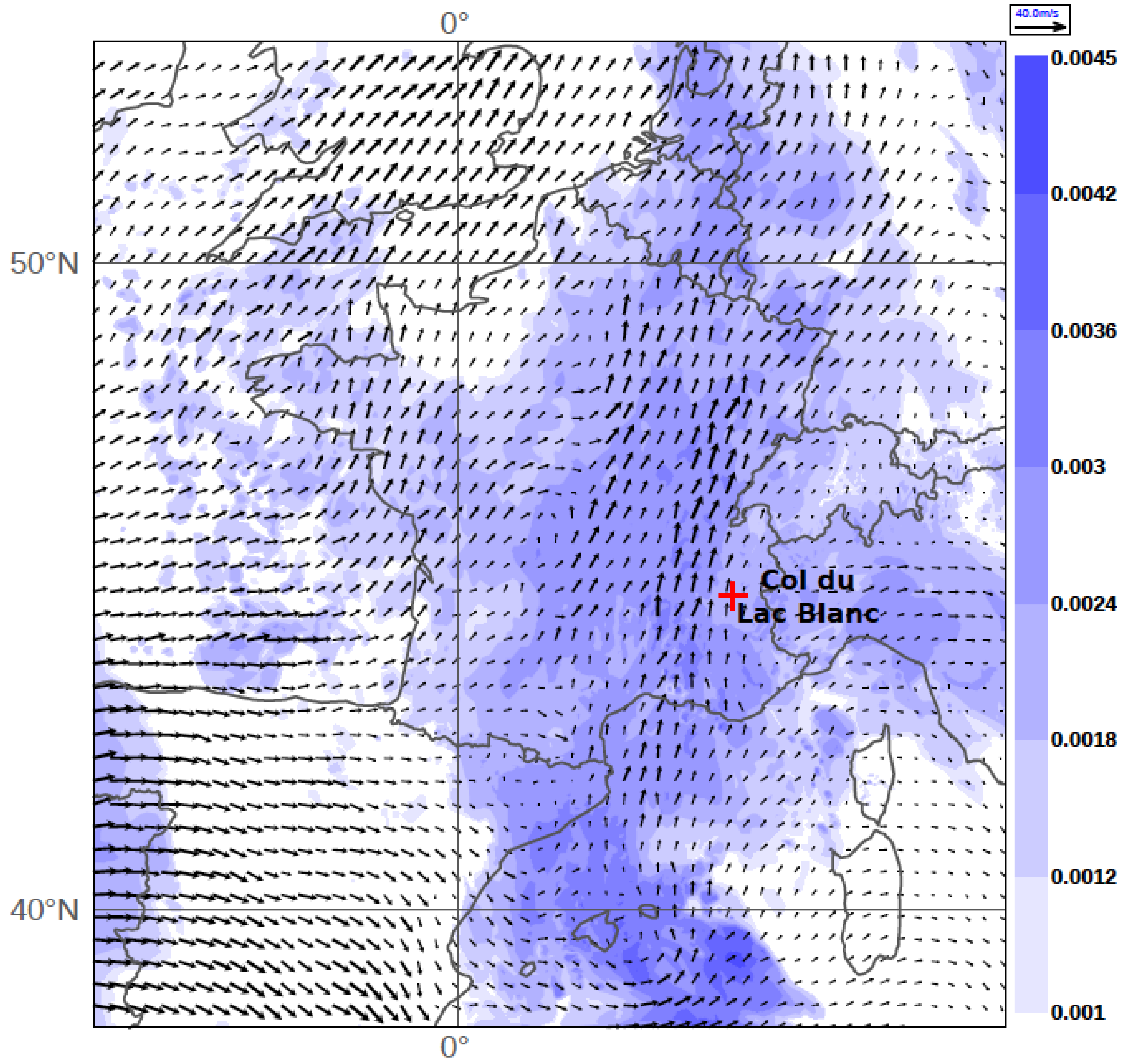

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Local conditions at CLB (2700 m)

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