International Symposium on Snow
IGS 2022, Davos

Parameterizing snow saltation:

The exponential decay of the mass flux profile and its relation to the saltation dynamics

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28/09/2022

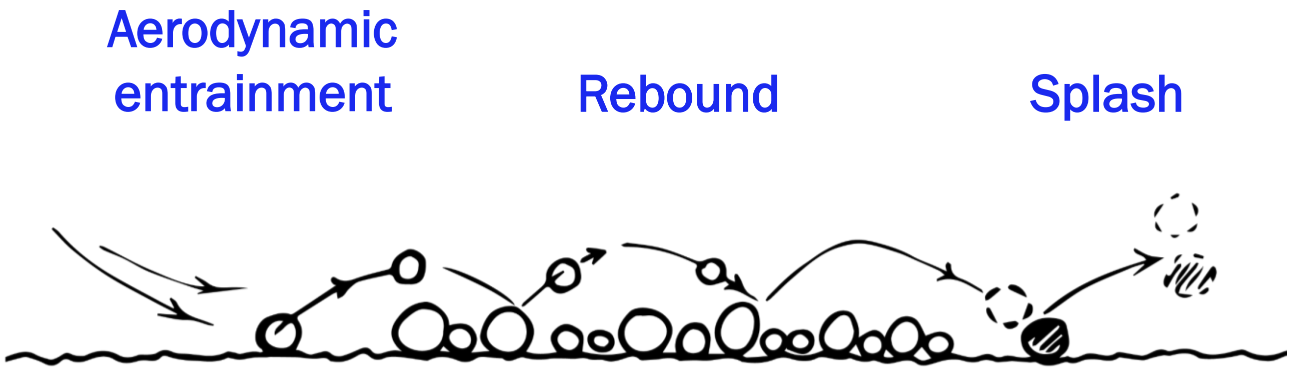
Snow saltation

When the wind blows over a snow cover with sufficient intensity,

... the most exposed grains are lifted by the air flow,

... they follow short ballistic trajectories,

... when impacting the surface, they bounce off and eject other grains.



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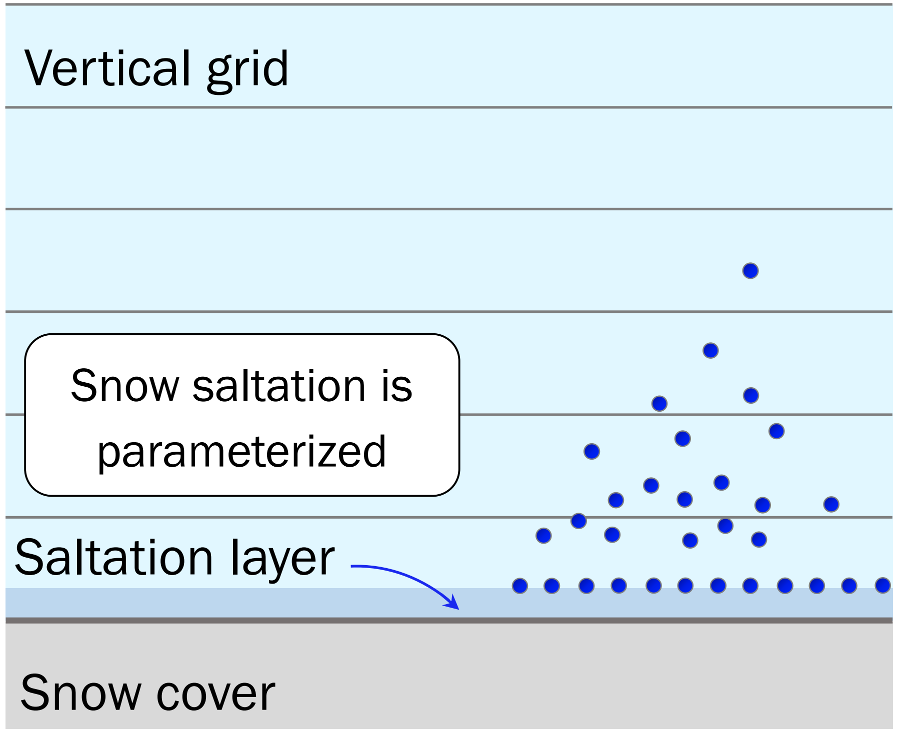
by Hendrik Huwald, PE (Antarctica)

Drifting snow plays a role in the snowpack mass and energy balances.

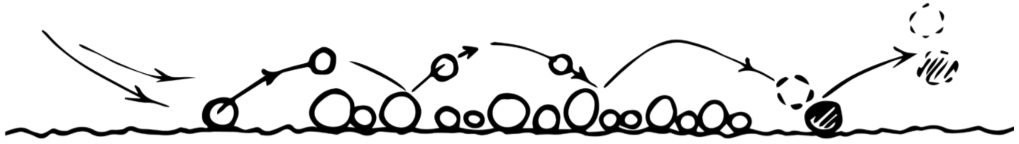
Modeling snow saltation

In regional and mesoscale models:



VS

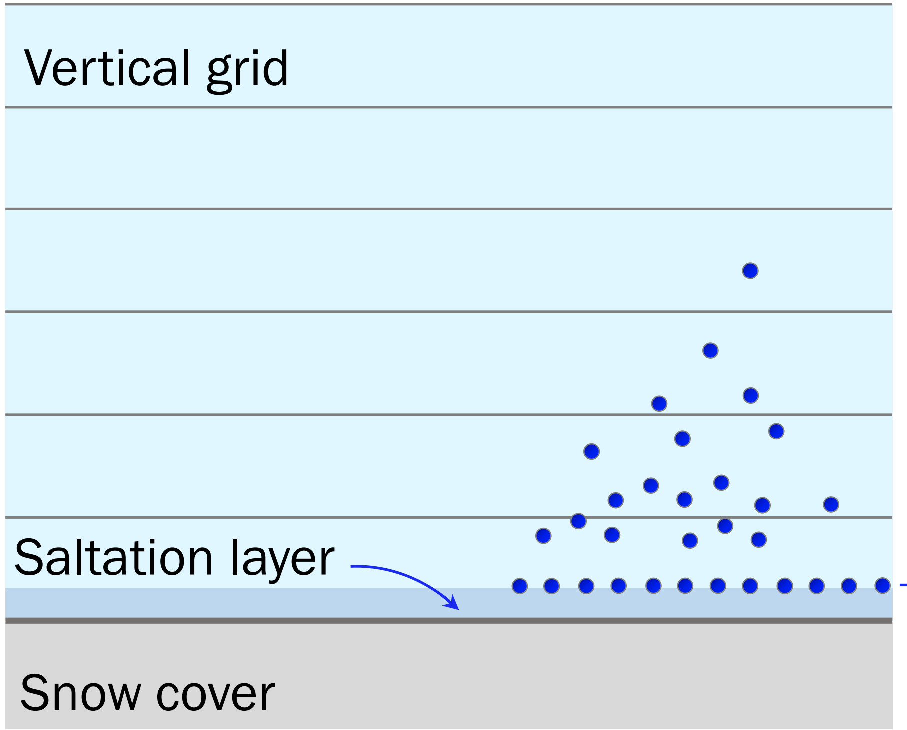
With small scale numerical models:



Detailed description of the particle trajectories

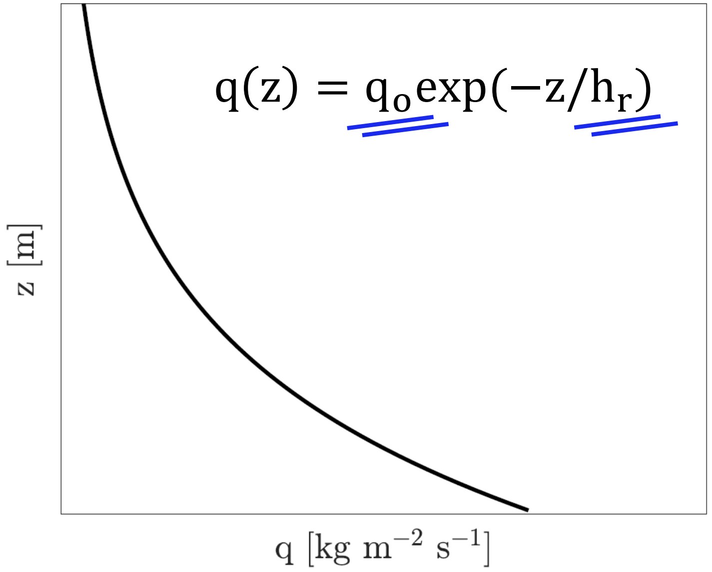
Modeling snow saltation

In regional and mesoscale models



$$\text{Concentration [kg m}^{-3}\text{]} = \frac{\text{Mass flux [kg m}^{-2}\text{ s}^{-1}\text{]}}{\text{Horizontal velocity [m s}^{-1}\text{]}}$$

- Mass flux:



e.g., Sugiura et al., 1998
Nishimura and Nemoto, 2005

Meso-NH (Vionnet et al., 2014)

CRYOWRF (Sharma et al., in rev.)

- $h_r \propto h_{salt} \propto u_*^2$

RACMO (Lenaerts et al. 2012)
MAR (Amory et al. 2021)

Modeling snow saltation

With a small-scale numerical model

LES-LSM: (Sharma et al., 2018; Melo et al., 2022)

- Large Eddy Simulations flow solver.
- Lagrangian model for particle trajectories.
- Statistical models for aerodynamic entrainment, rebound and splash.

Wind tunnel experiments: (Sugiura et al., 1998)

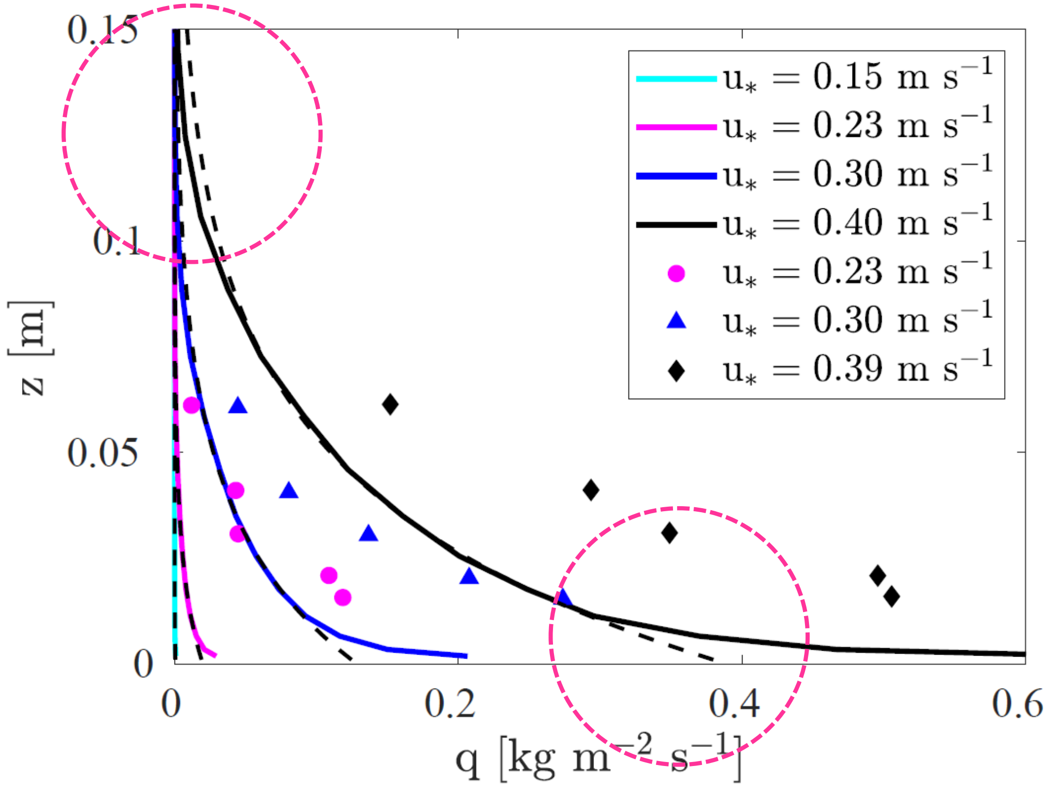
- **Wind tunnel:** $0.5 \times 0.5\ \mathrm{m}^2$, $8\ \mathrm{m}$ length
- **Mass flux:** Snow Particle Counter (SPC)
  $\mathrm{z} = [0.016\ 0.021, 0.031, 0.041, 0.061]\ \mathrm{m}$
- **Friction velocity:** Ultrasonic anemometer
  $\mathrm{u}_* = [0.15, 0.23, 0.3, 0.39]\ \mathrm{m\ s^{-1}}$

Numerical settings: (half-channel flow)

- **Domain:** $6.4 \times 6.4 \times 6.4\ \mathrm{m}^3$
- **Roughness length:** $\mathrm{z_o} = 10^{-5}\ \mathrm{m}$
- **Particle size distribution:** Lognormal
  $\langle \mathrm{d} \rangle = 360\ \mu\mathrm{m}$, $\sigma_\mathrm{d} = 140\ \mu\mathrm{m}$
- **Particle density:** $917\ \mathrm{kg\ m^{-3}}$

Results & Discussion

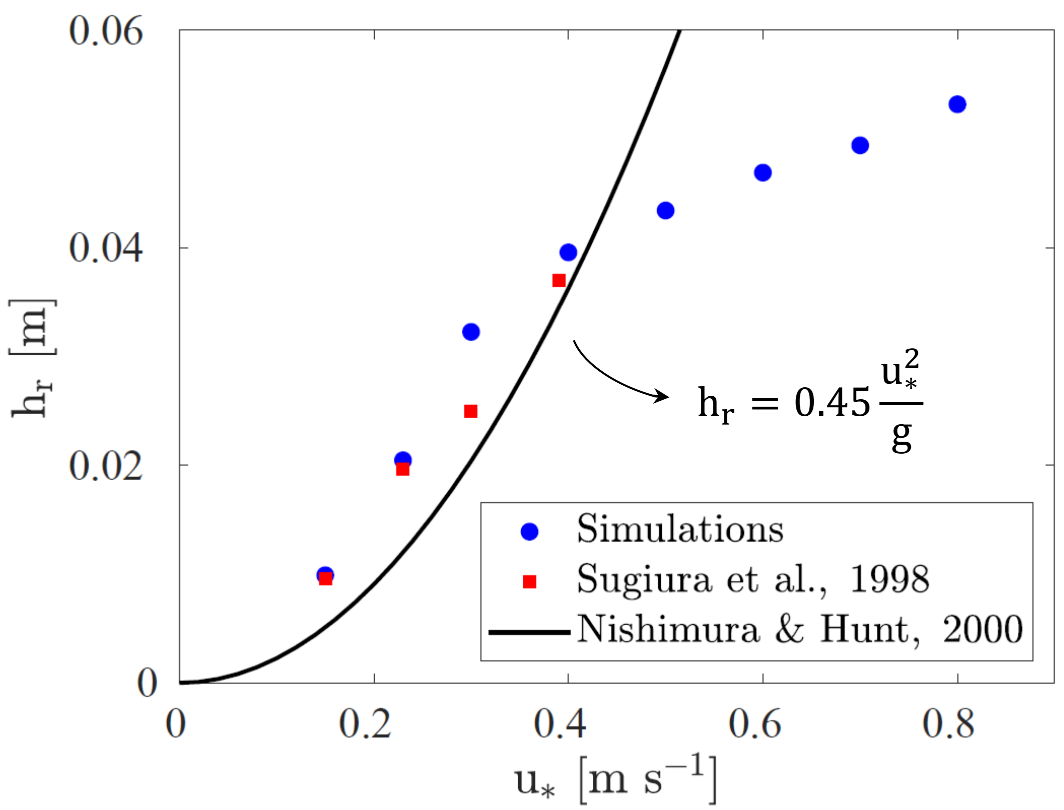
The exponential fit



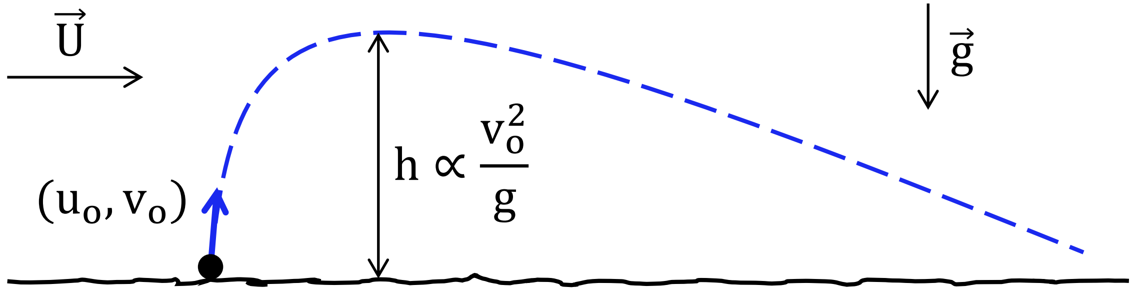
- The model underestimates the mass flux in comparison with the wind tunnel experiments of Sugiura et al. (1998).
- The fit with an exponential equation is seen at intermediate heights of the saltation layer.
- The exponential decay underestimates the mass flux close to the surface. (Bauer and Davidson-Arnott, 2014)
- Deviations are also seen away from the surface due to the saltation-suspension transition. (e.g. Nishimura and Nemoto, 2005; Gordon et al., 2009)

Results & Discussion

The decay parameter



- The decay parameter, h_r, follows a similar trend as the measurements and the model proposed by Nishimura and Hunt (2000).
- **For high values of u_*, the simulation results significantly deviate from the scaling with u_*^2.**



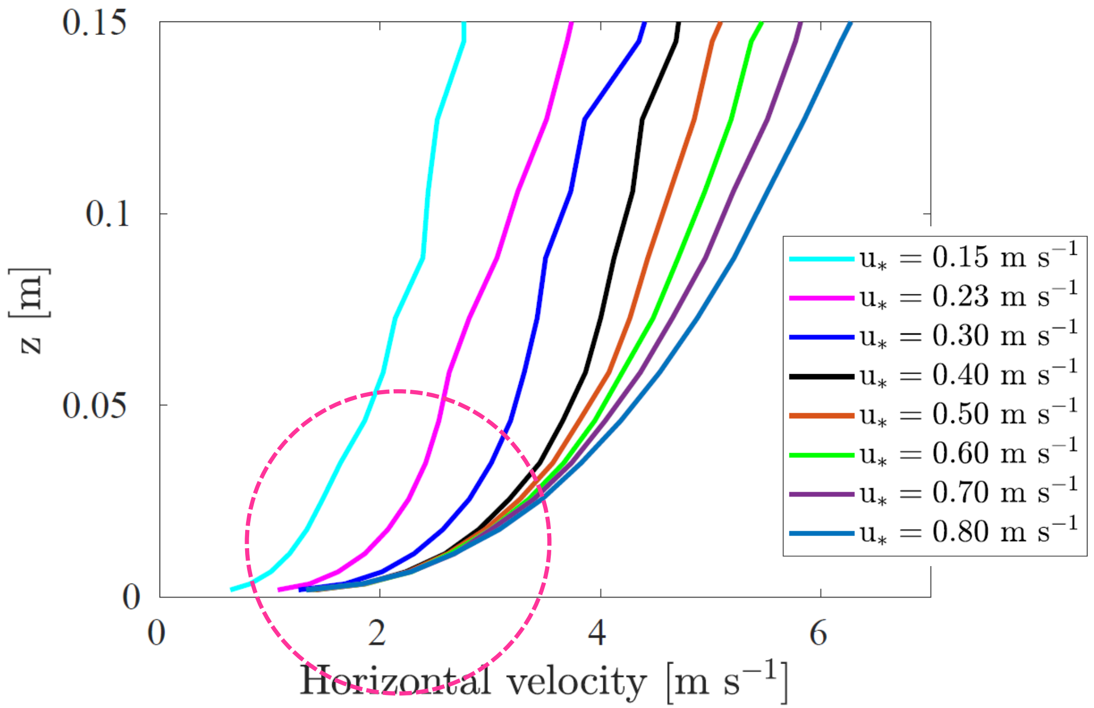
- $v_o \propto u_* \rightarrow h \propto u_*^2 \rightarrow h_r \propto u_*^2$ (Bagnold, 1941; Owen, 1964; Nishimura and Hunt, 2000)

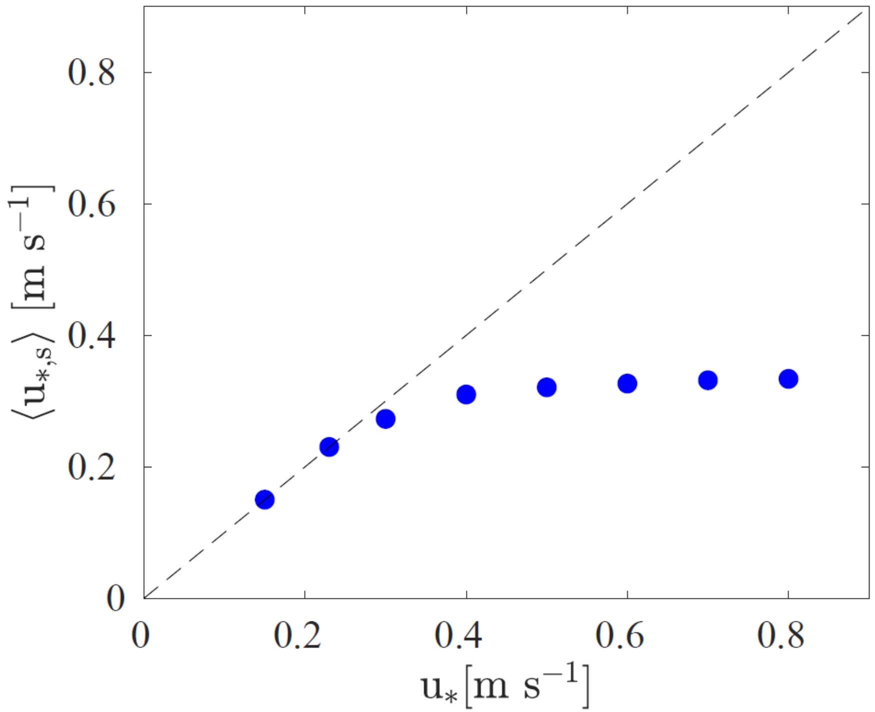
Results & Discussion

The particle velocity close to the surface

- The particle velocity close to the surface does not scale with the friction velocity. (e.g., Pomeroy and Gray, 1990; Vionnet et al., 2014; Kok et al., 2012)

- It rather scales with the surface friction velocity. Hence, for splash dominated systems, the particle velocity scales with the impact threshold. (e.g. Kok et al., 2012)

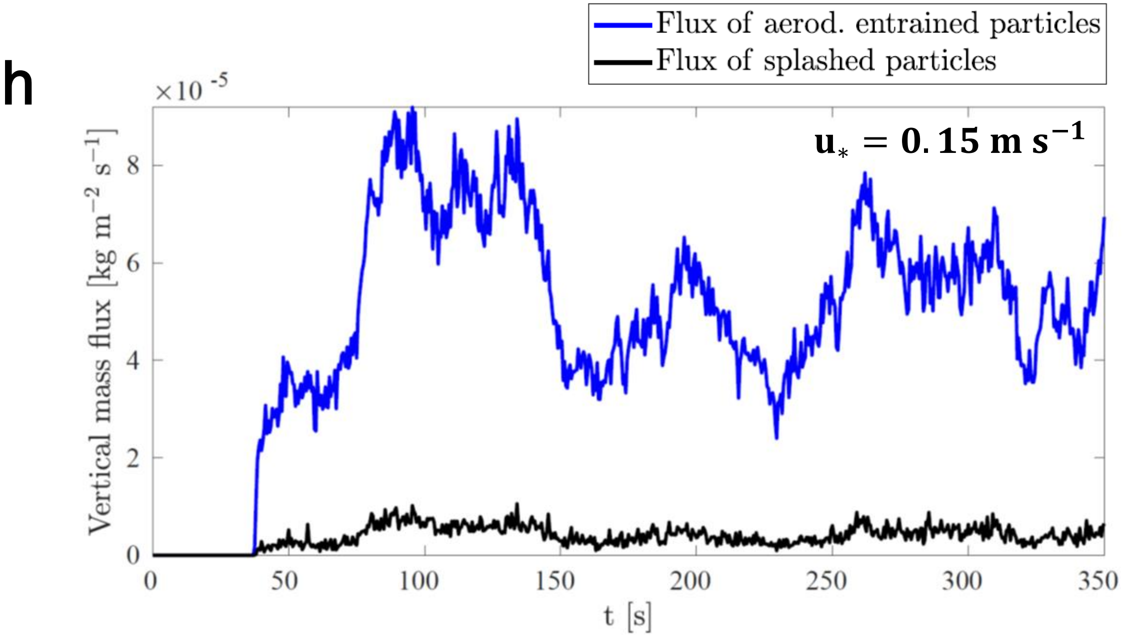


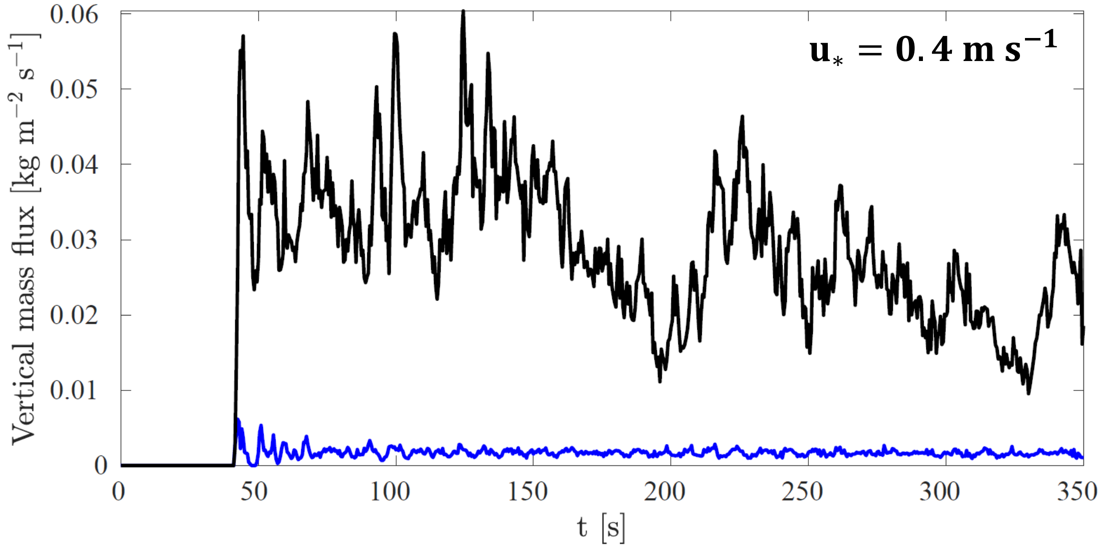


Results & Discussion

The role of aerodynamic entrainment and splash

- As the friction velocity increases, the saltation system changes from an aerodynamic entrainment dominated mechanism to a splash dominated system.





Conclusions

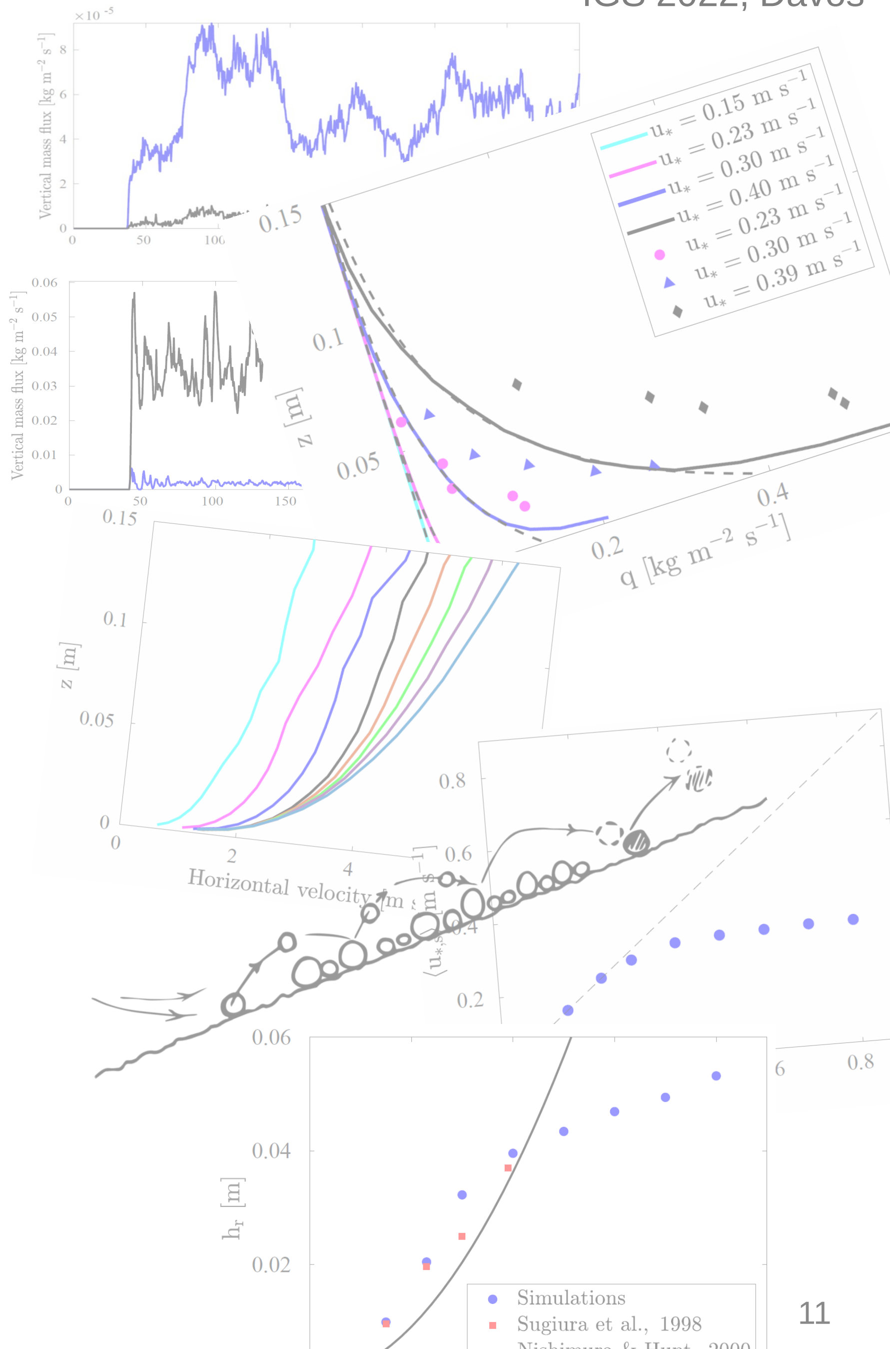
- Drifting snow is still an unknown contributor to the snowpack mass and energy balances.

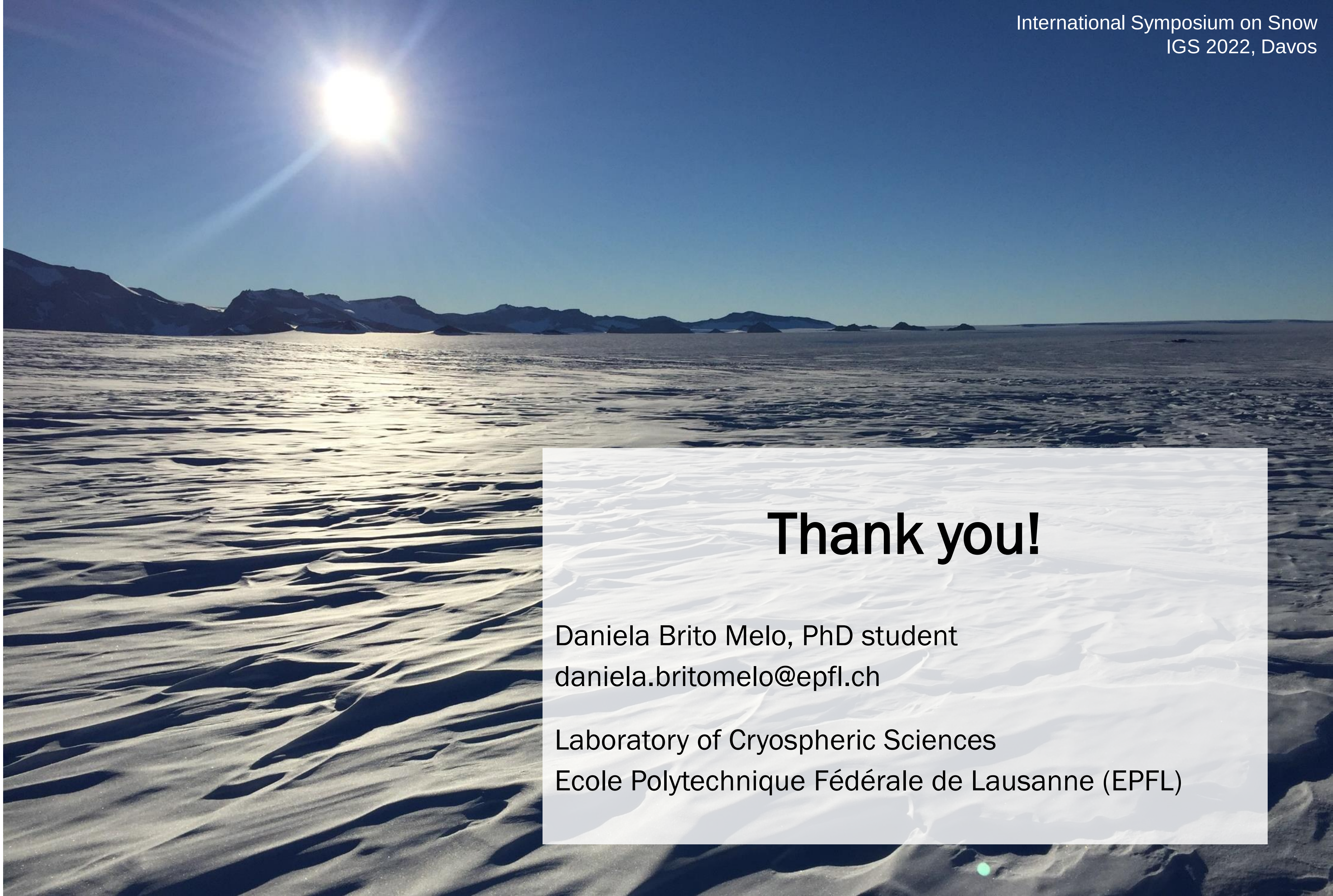
- The snow saltation model employed sets the lower boundary condition for drifting snow and influences snow sublimation estimates.

- An exponential decay of the particle mass flux profile in the saltation layer is obtained both from measurements and simulations.

- At high wind speeds, splash becomes the dominant mechanism. Therefore, the decay parameter is not expected to scale with the square of the friction velocity outside of the saltation layer.

- The experimental study of snow saltation faces several challenges. Analytical and numerical models can significantly contribute to improve our understanding of snow saltation.





Thank you!

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