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Université du Québec à Montréal

Estimation of Snowfall Deposition in Mountainous Terrain Using a CFD Model with a Stochastic Lagrangian Particle Tracking Model

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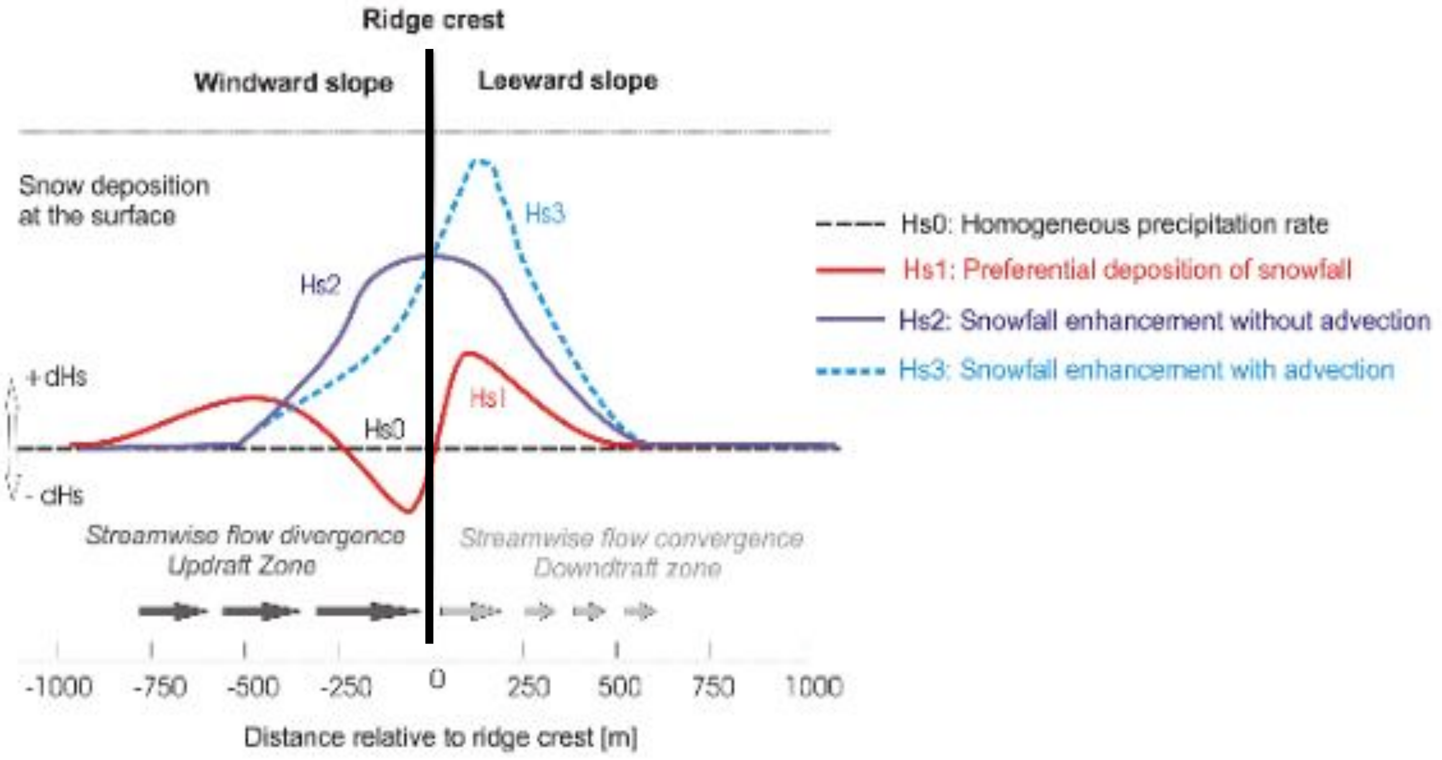
Spatial snow variability on the ground

Impacts:

- Hydrological forecasting
- Avalanche forecasting



From Mott and Vionnet (2018)

Originates from:

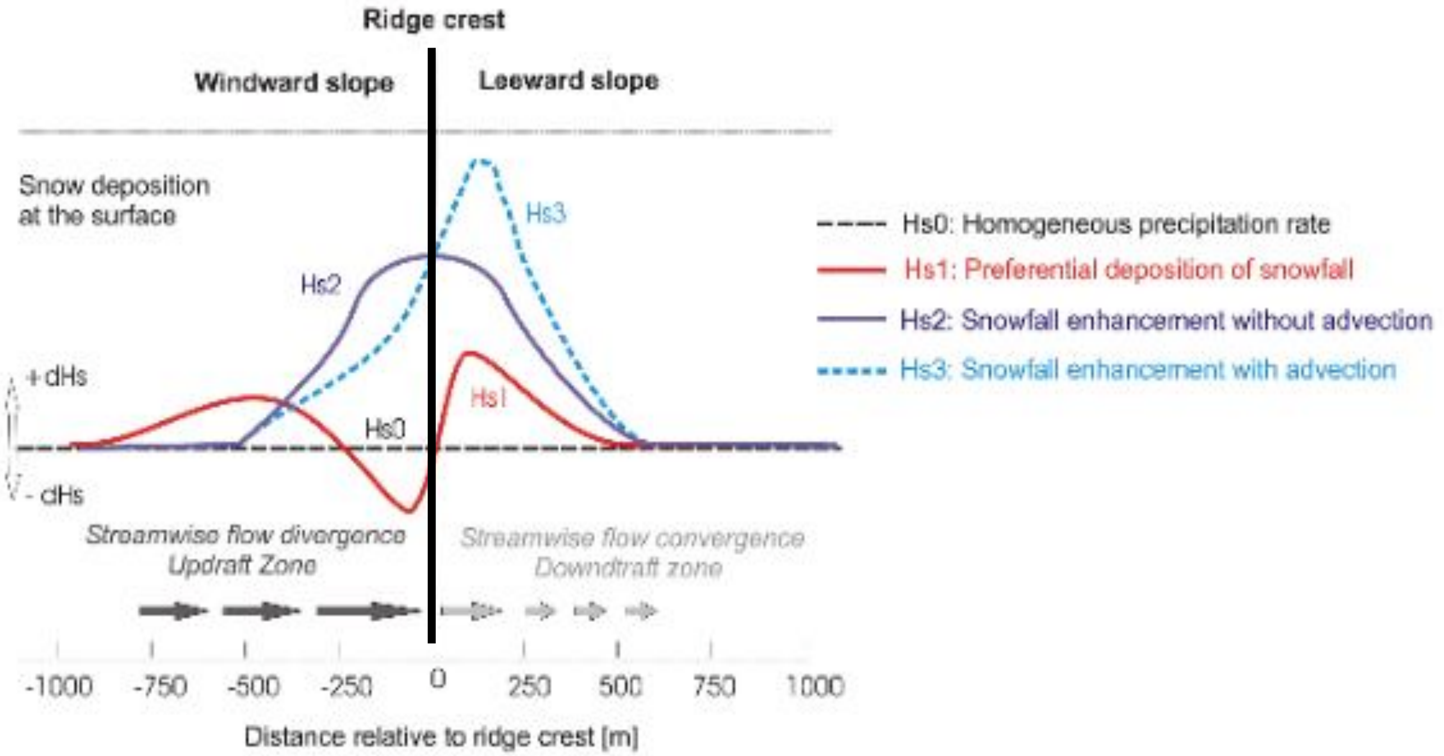
- Blowing snow
- Spatial variability of snowfall
- Heterogeneous melting

Spatial snow variability on the ground

Impacts:

Hydrological forecasting

Avalanche forecasting



From Mott and Vionnet (2018)

Originates from:

Blowing snow

Spatial variability of snowfall → Preferential deposition along a hill

Heterogeneous melting

Previous studies of preferential snow deposition

Most numerical studies consider resolutions $\geq$ 50 m

Mainly focus on wet/heavy snow.

Measurements provide some help to better understand this process.

Comola et al. (2019), Gerber et al. (2017), Mott and Lehning (2010), Vionnet et al. (2017)

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Better understanding of preferential deposition is needed for different hydrometeor types in different terrains

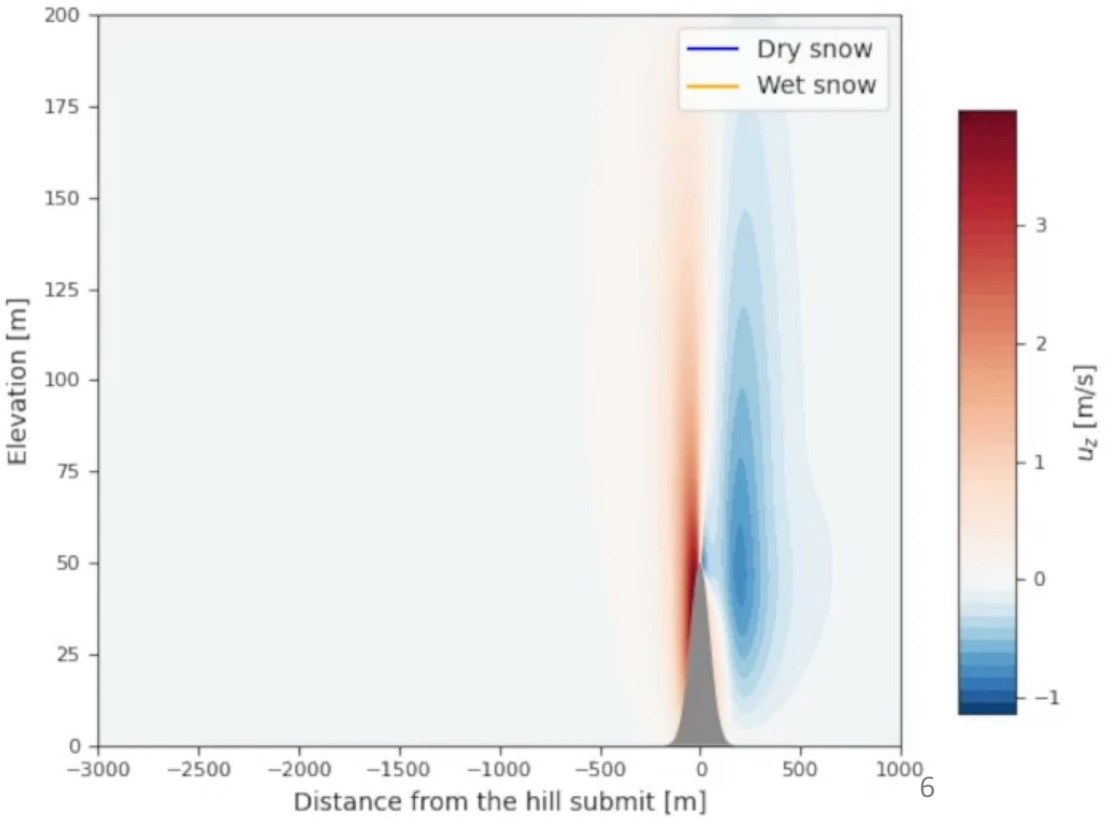
→ Through numerical modelling

Method to study fine-scale preferential deposition

Using a Computational Fluid Dynamics (CFD) model for wind simulations

Coupling the wind simulations with a Stochastic Lagrangian particle trajectory model

Quantifying snowfall deposition on the ground for different hill characteristics



Wind simulations in 2D

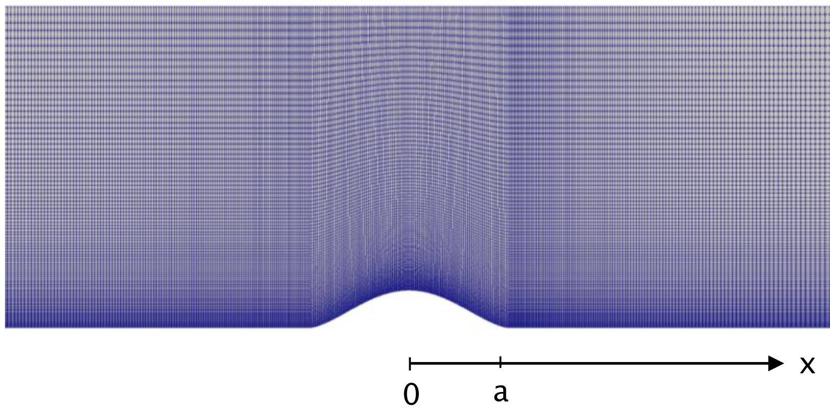
Using OpenFoam (CFD model)

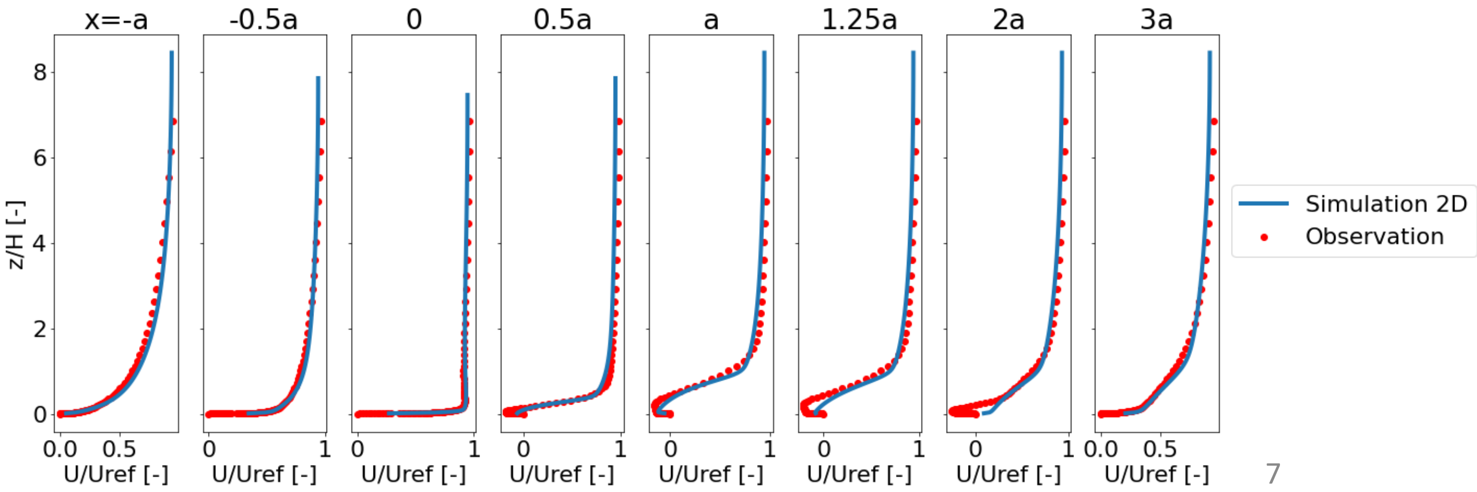
Solving for RANS k-ϵ: $\overline{\boldsymbol{u}}$

Boundary conditions:

- Log profile at the inlet
- Slip condition at the top
- Rough surface wall-functions at the bottom

Model evaluation using wind tunnel data (Khurshudyan et al. 1981)





Particle trajectory model

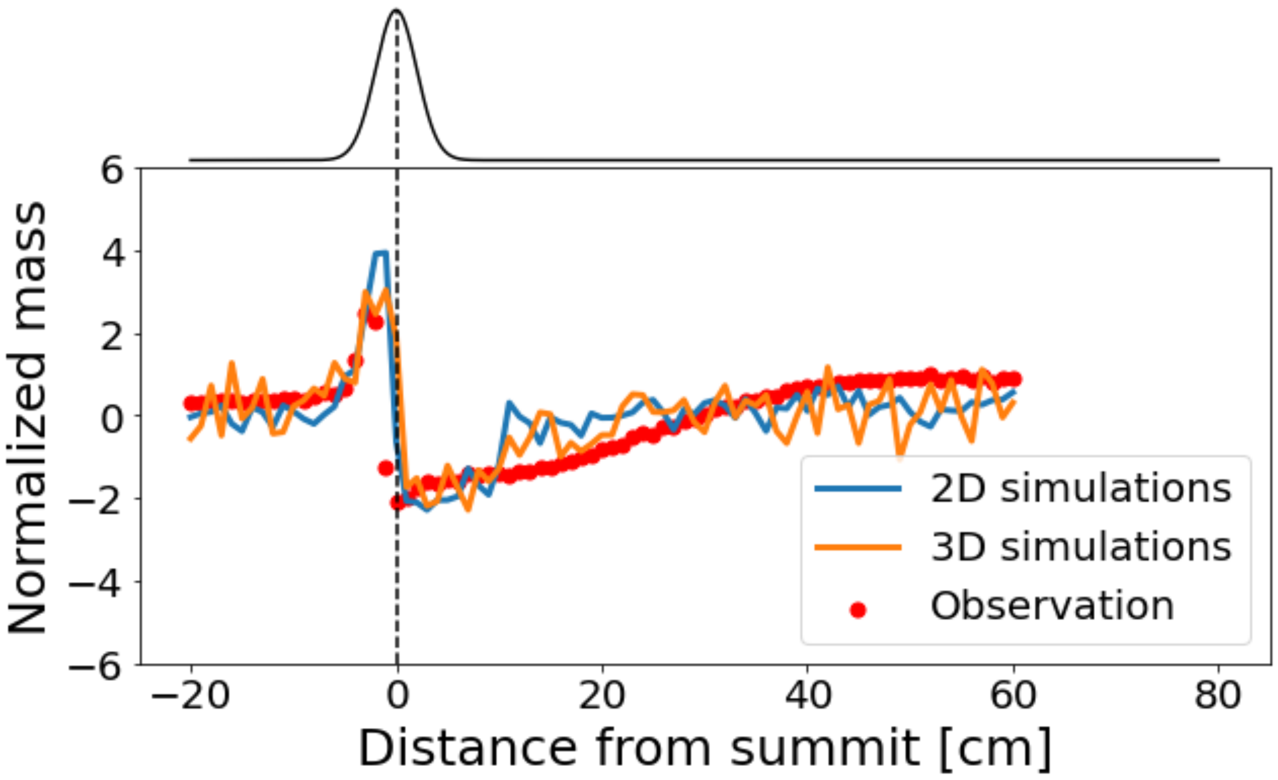
$$m_p \frac{\partial \boldsymbol{v_p}}{\partial t} = -\frac{1}{2} C_{\mathrm{d}} A_p \left(\boldsymbol{v_p} - \boldsymbol{u}\right)^2 + m_p \boldsymbol{g}$$

Stochastic model to estimate $\boldsymbol{u}'$

$$\boldsymbol{u} = \overline{\boldsymbol{u}} + \boldsymbol{u}'$$

Drag coefficient from Khvorostyanov and Curry (2005) for snow crystals

Model evaluation against wind tunnel dust deposition data (Goossens 1996)



Hill characteristics

Gaussian distribution with two parameters

Height (H)

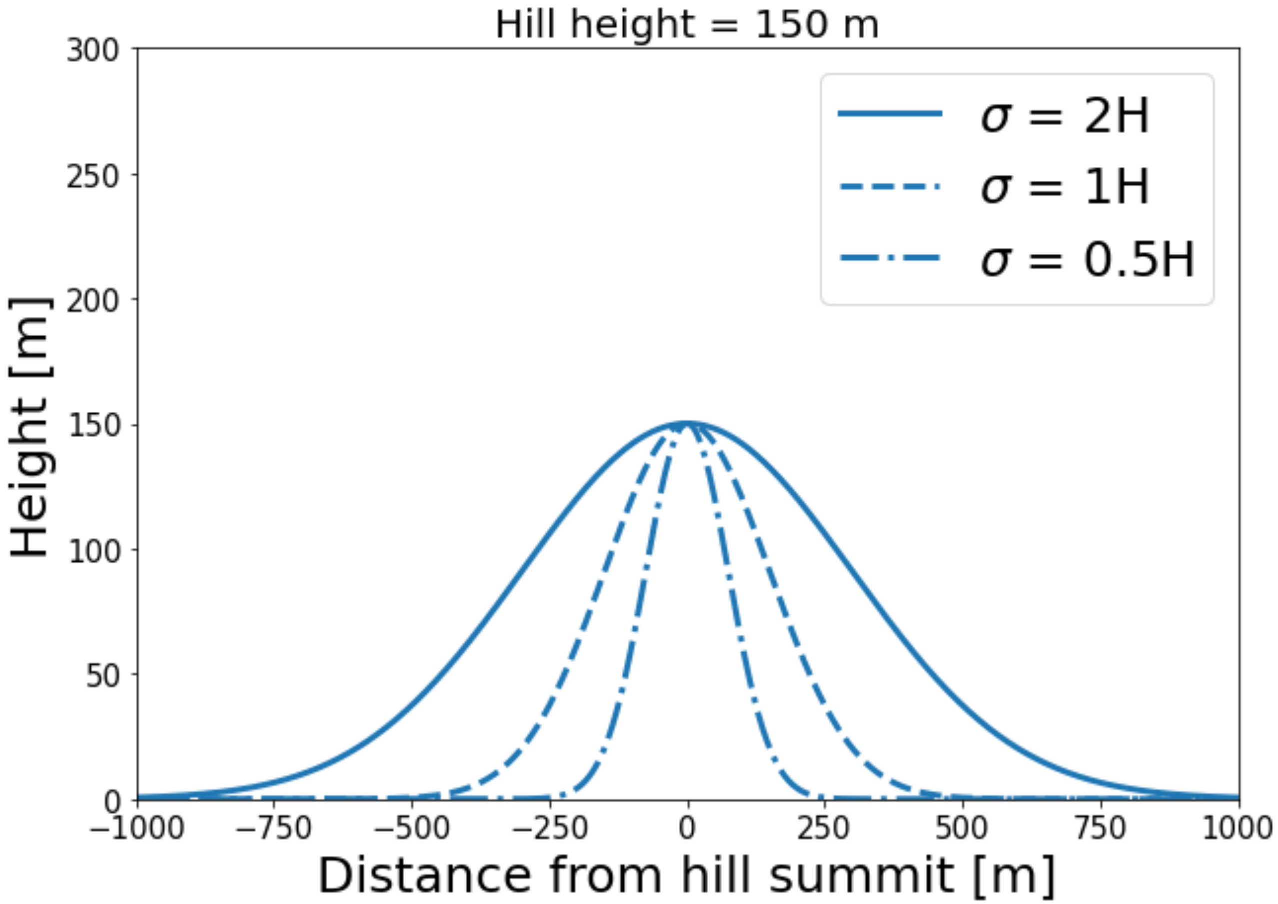
Standard deviation (σ)

3 different heights:

10 m, 50 m, and 150 m

3 different widths:

σ = 2 H, σ = 1 H, σ = 0.5 H



Model setup for snow particle trajectory and snowfall deposition

Wind model:

$5\ m\ s^{-1}$ at 2 m above the ground

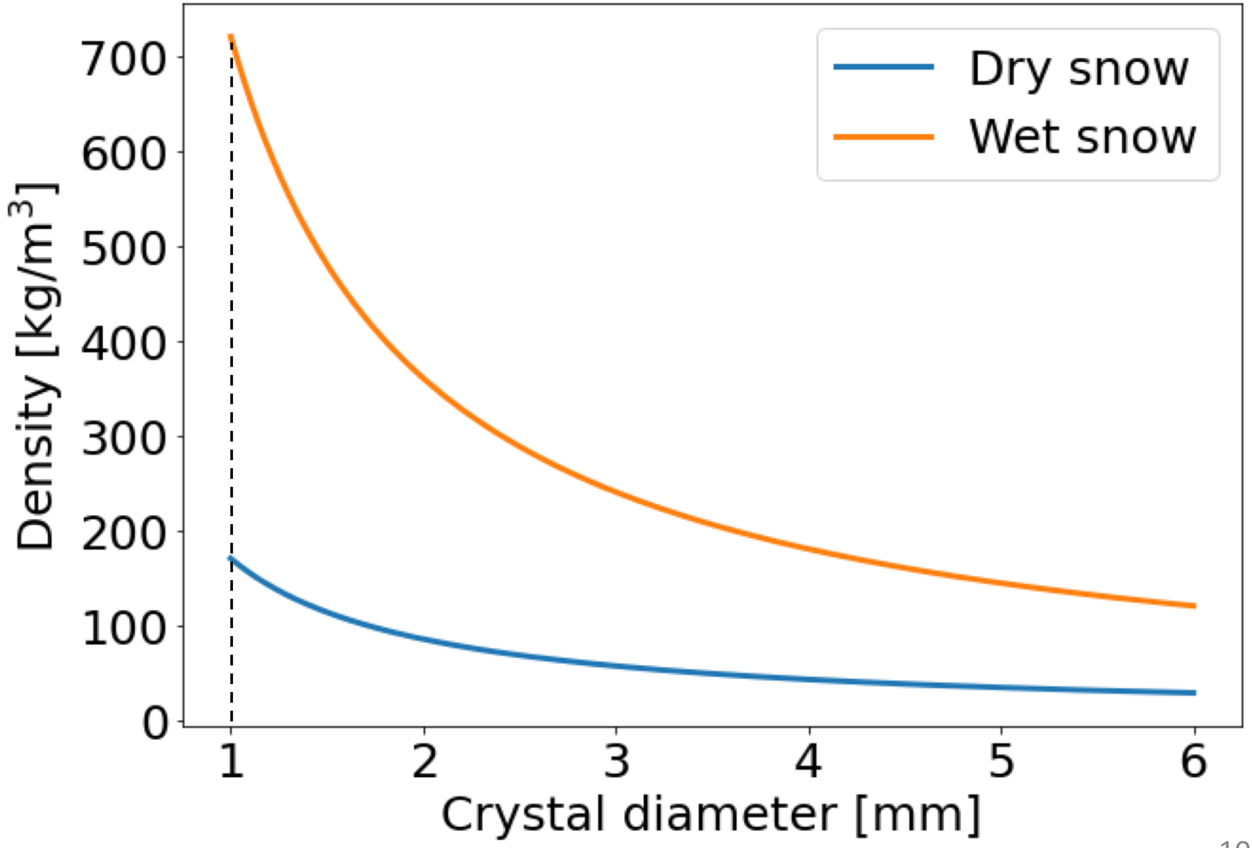
$z_0 = 0.01$ m

Two particle types:

Dry/unrimed snow

Wet/rimed snow

Snow deposition of 20,000 particles

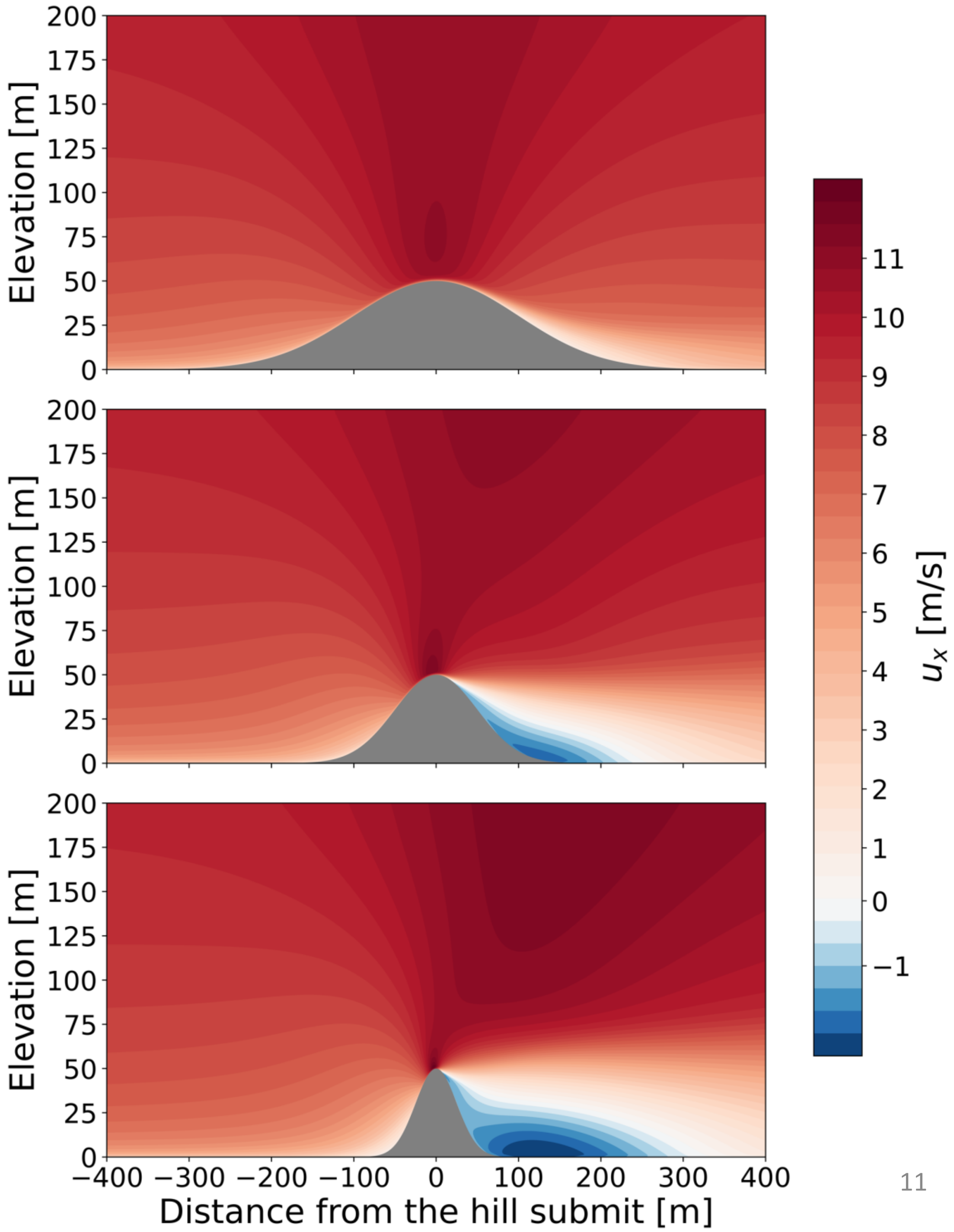


Horizontal wind speed u_x

Hill height = 50 m

Separation flow downhill of the hill

Maximum u_x at the summit

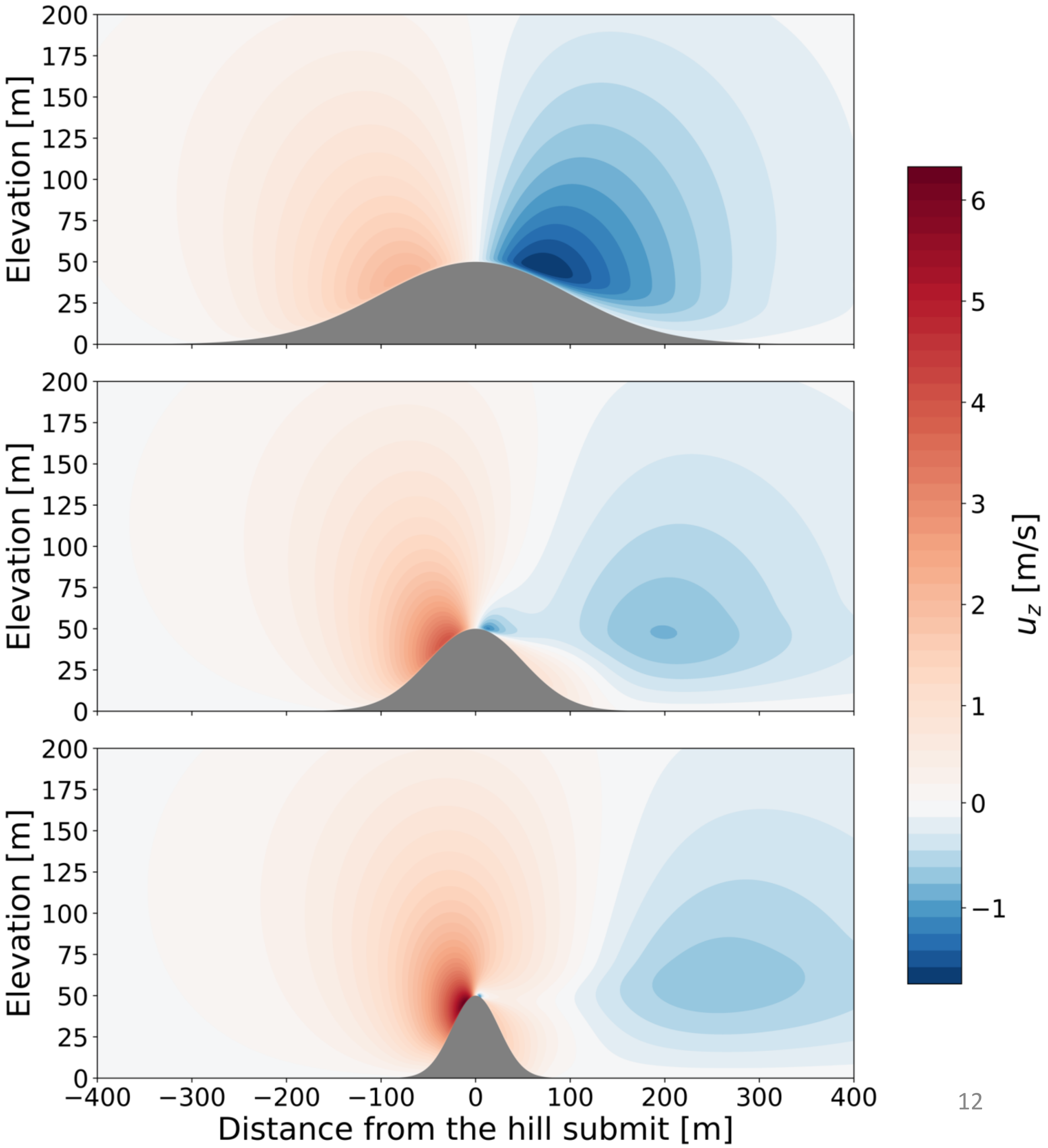


Vertical wind speed u_z

Hill height = 50 m

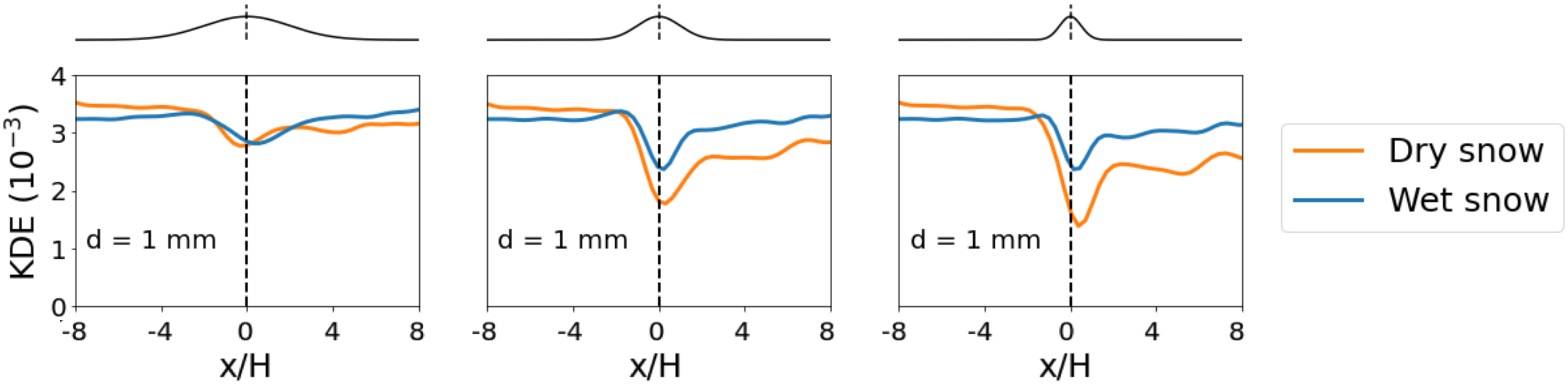
Vertical gradient of wind speed on the windward side

Negative vertical wind speed on leeward side



Snow deposition for hill height of **10 m**

Particle diameter = 1 mm



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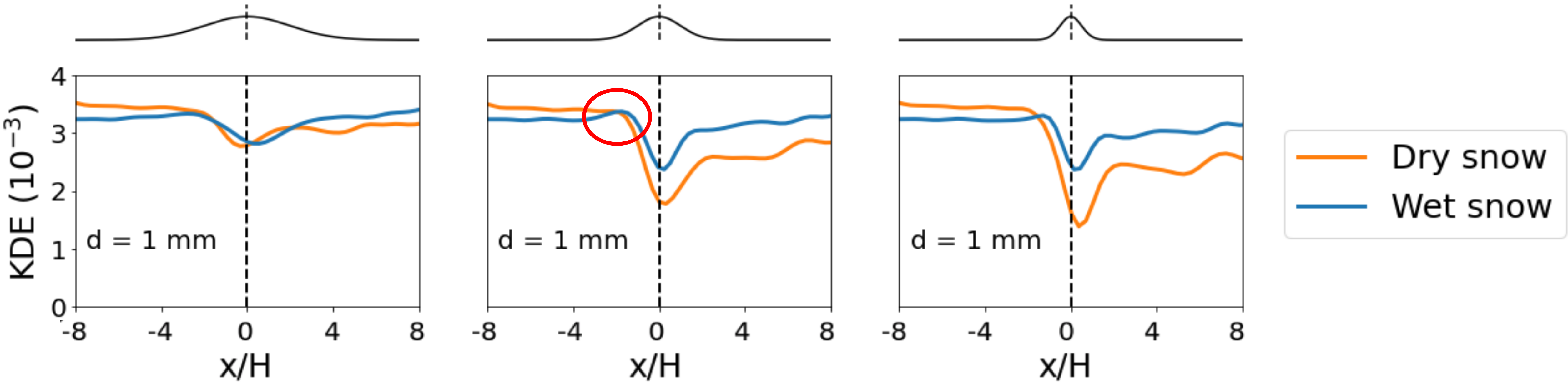
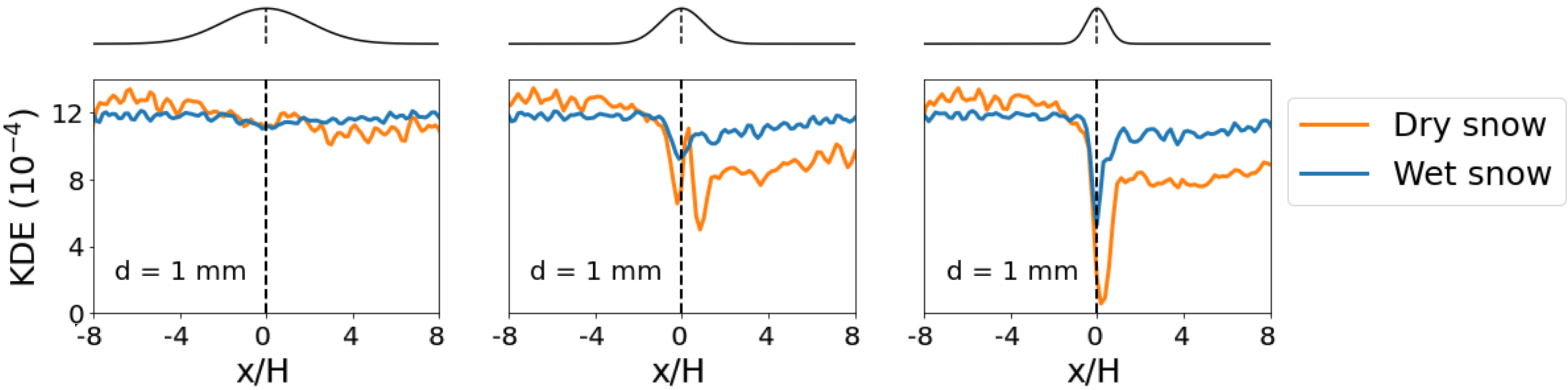


Maximum deposition of wet snow on the leeward slope (not for dry snow)

Minimum deposition close to the hill summit

Snow deposition for hill height of **50 m**

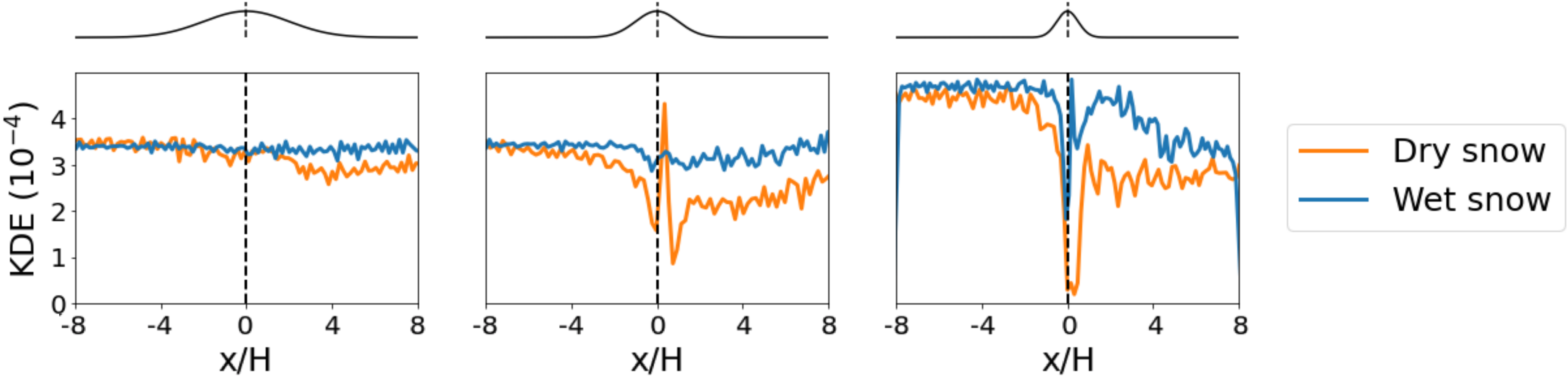
Particle diameter = 1 mm



Oscillating deposition around hill summit for dry snow

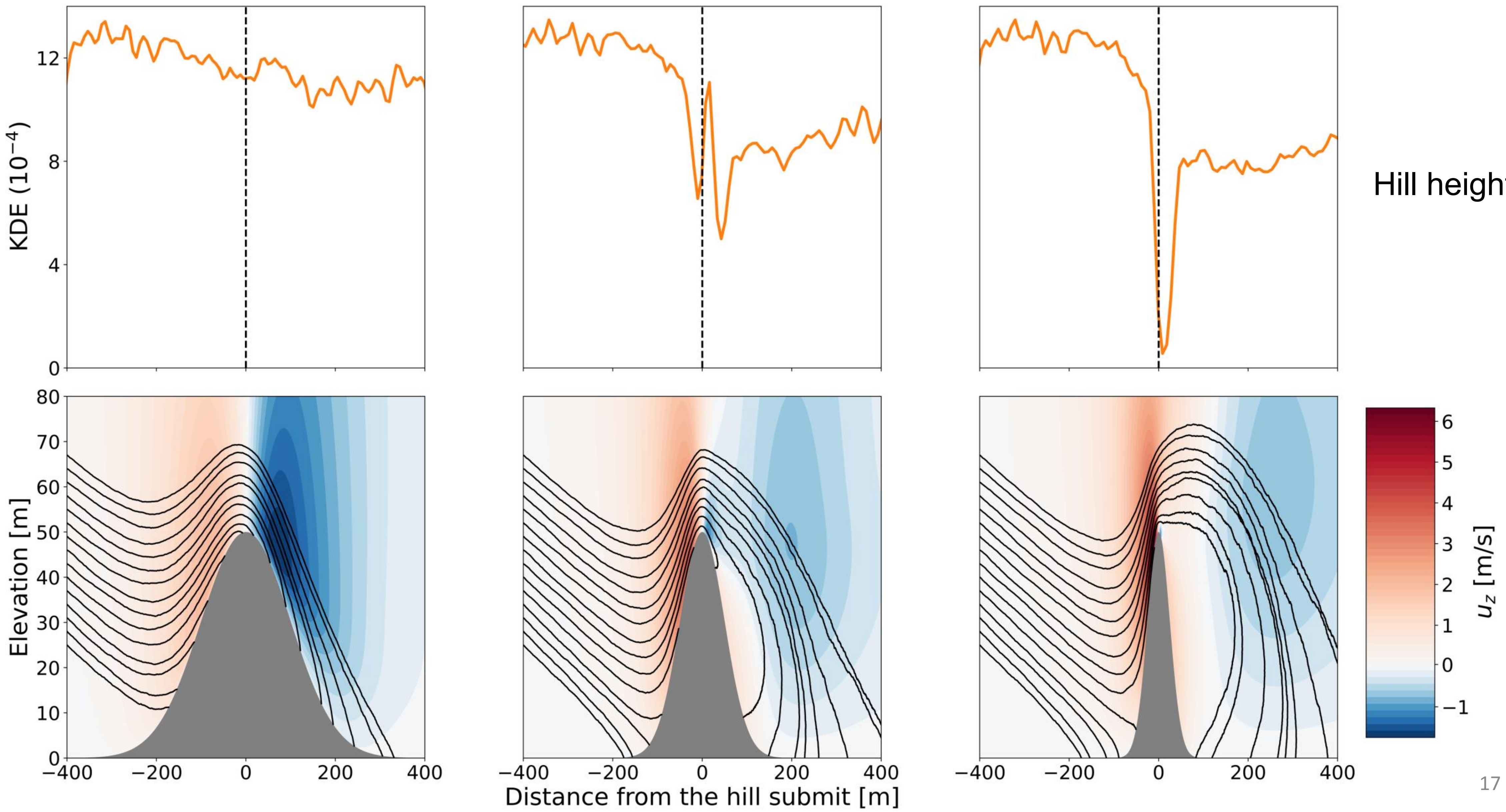
Snow deposition for hill height of **150 m**

Particle diameter = 1 mm



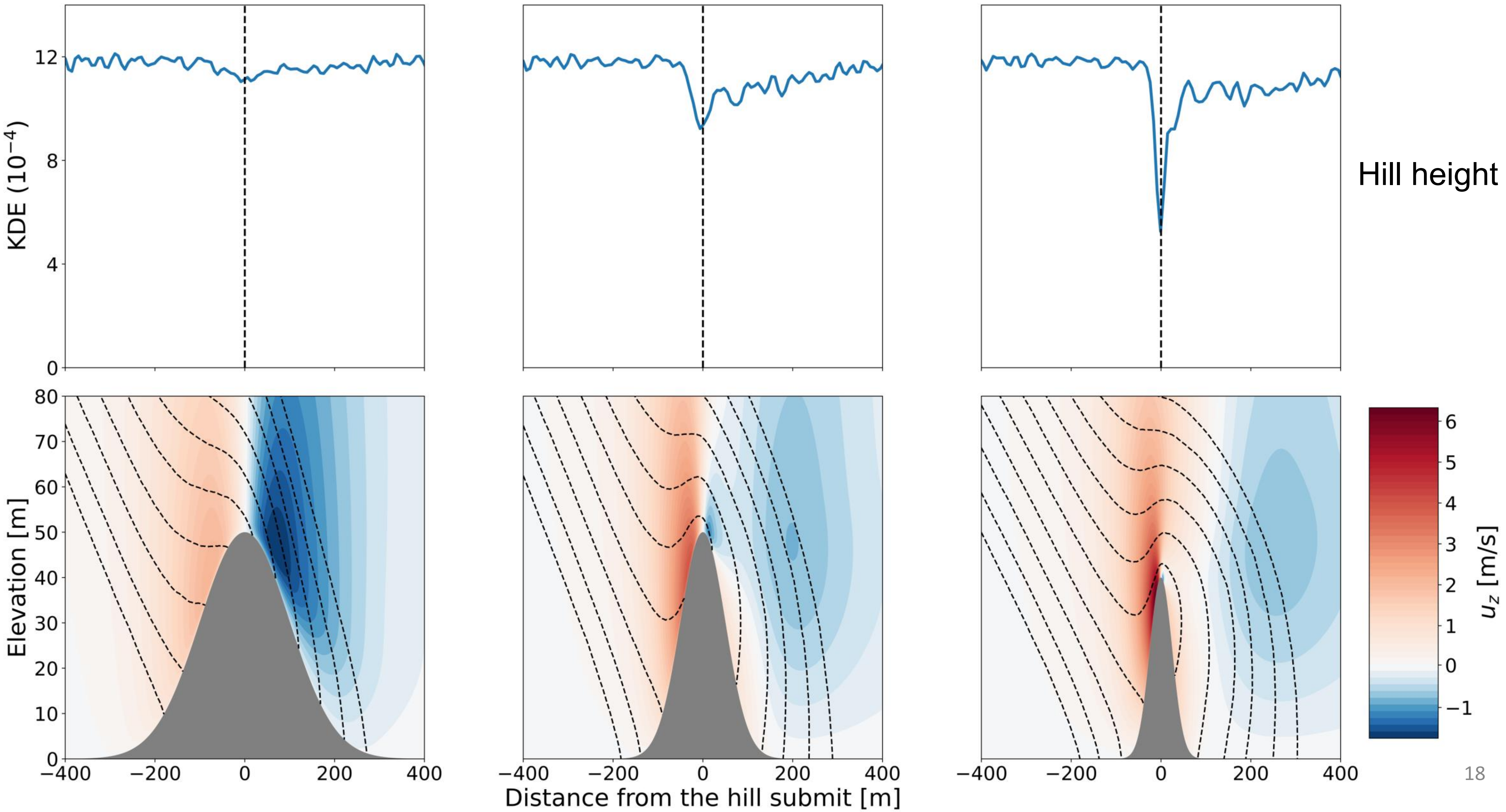
Additional oscillating deposition around hill summit for both wet and dry snow

Particle trajectory and snow deposition for **dry snow**



Hill height of 50 m

Particle trajectory and snow deposition for **wet snow**



Hill height of 50 m

Conclusions

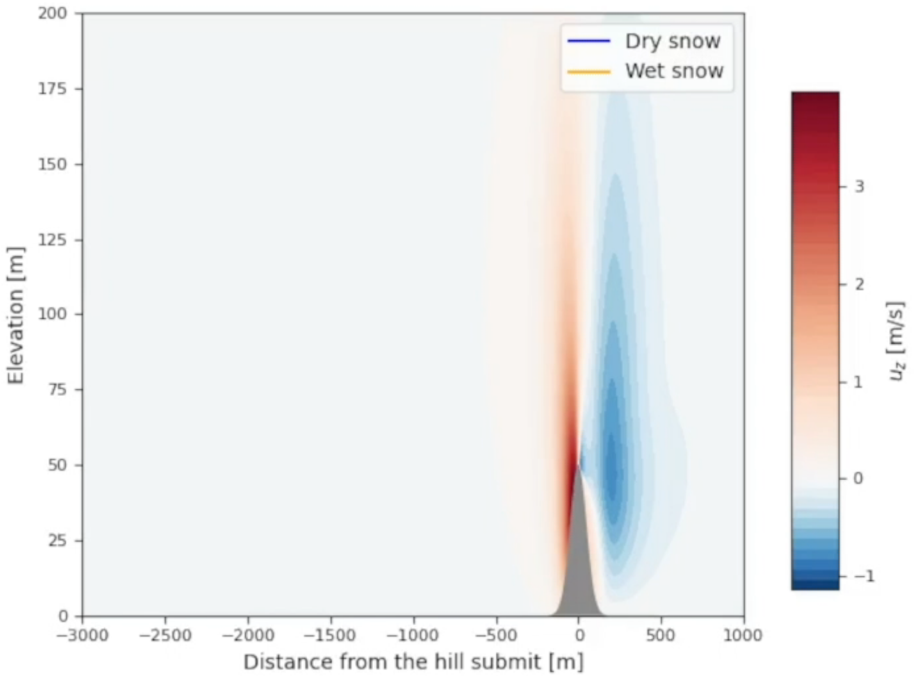
Preferential deposition is mainly affected by the vertical component of the wind speed.

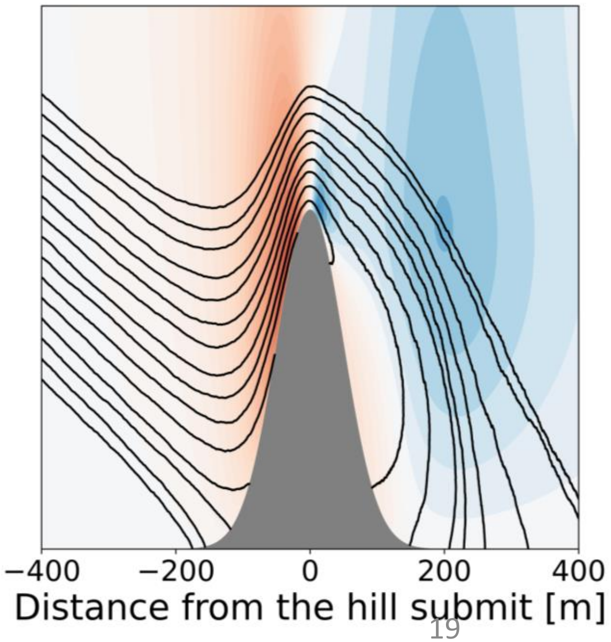
Wet snow deposition:

- Little perturbed by small hills
- Minimum deposition at the hill summit
- Maximum deposition on the windward side of the hills

Dry snow:

- No maximum deposition on windward side
- Minimum deposition around hill summit
  - Moves downwind with steepness
  - More important than in wet snow case





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