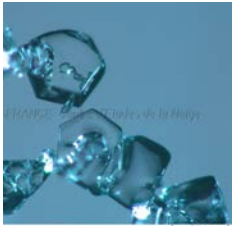


# Grain size in snow avalanches



[thierry.faug@inrae.fr](mailto:thierry.faug@inrae.fr)



Atelier neige de l'OSUG : "qu'est-ce qu'un grain de neige ?" – jeudi 27 mars 2025

# INTRO : snow avalanche triggering

$t = \epsilon$

Slab failure



Dry case in the  
avalanche  
starting zone

# INTRO : snow avalanche triggering

$$t = \epsilon + 2s$$

Slab  
fragmentation



# INTRO : avalanche propagation

$t = \epsilon + 6s$

Transition  
to a flow



# INTRO : avalanche propagation

$t = \epsilon + 14 s$

Flow of  
snow  
aggregates



# Grains in snow avalanche deposits



Granular deposit with slab fragments  
(very weak propagation)



Granular deposit with more rounded grains  
(dry, fully developed flow)



Granular (bigger grains) and pasty  
(wet snow avalanches)

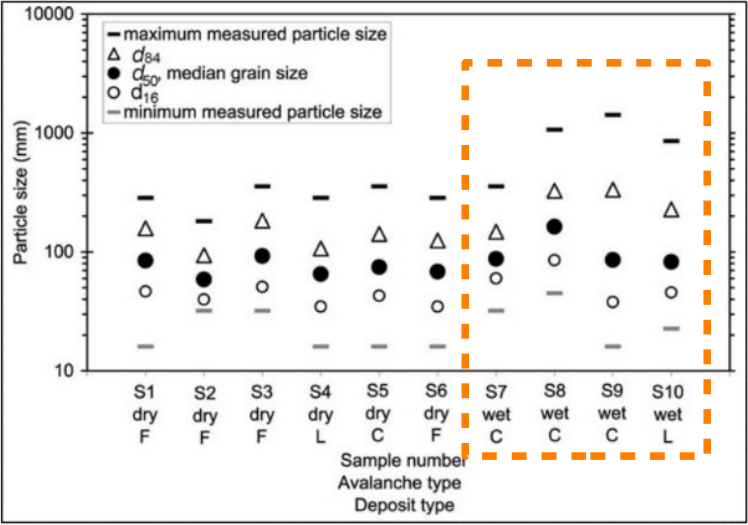
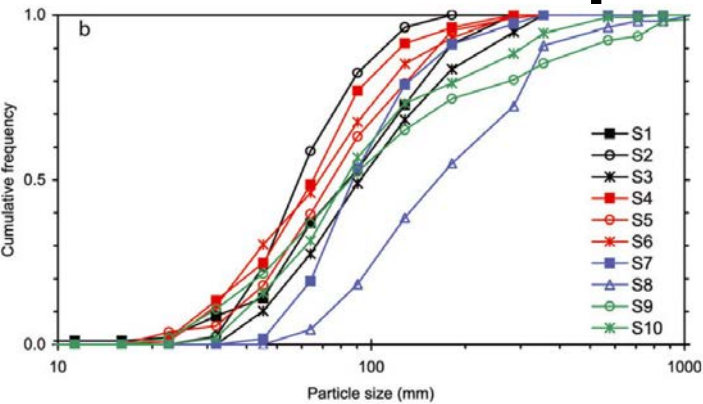
*Big snow grains* in dense avalanches  
= **aggregates of hundred thousands of snow crystals**

# Grains in snow avalanche deposits



Snow aggregates can be (nearly perfect) snow balls!  
(large traveled distance, role of water ?, ...)

# Grains size distribution in deposits

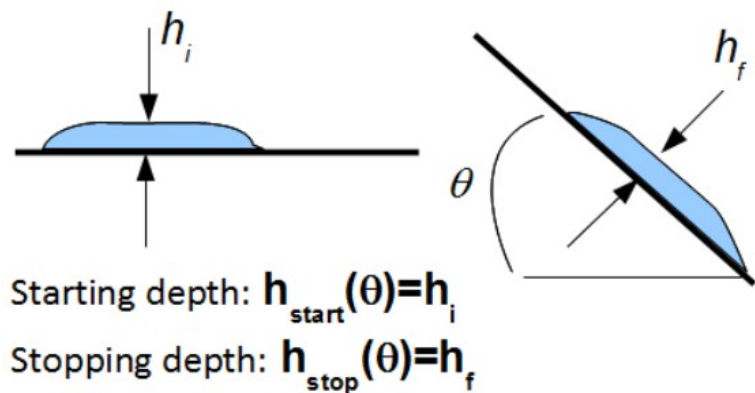


Maximum sizes are greater in wet snow avalanches

$$d = 65 - 152 \text{ mm}$$

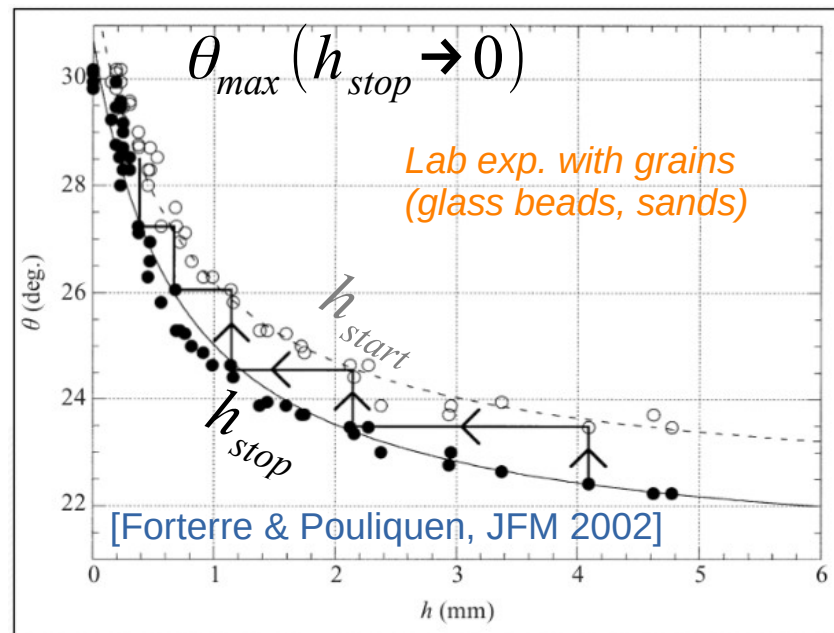
# Grain size : $h_{\text{stop}}$ in the lab

- Pioneering experiments of physicists in the field of granular flows  
[PhD thesis A. Daerr] [Pouliquen, Phys Fluids 1999]

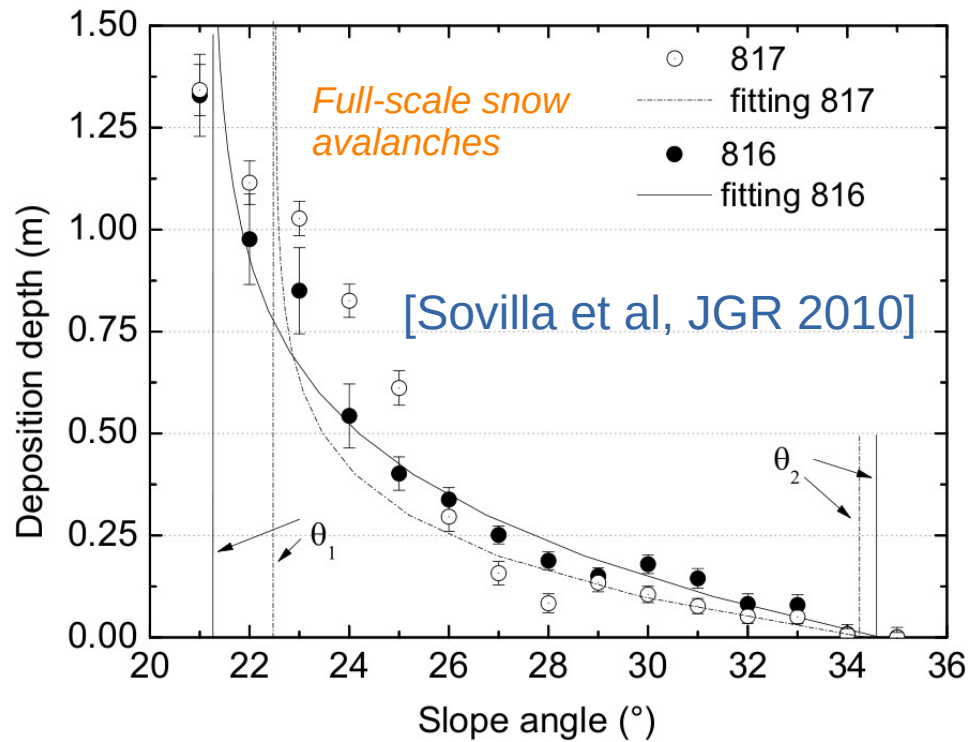
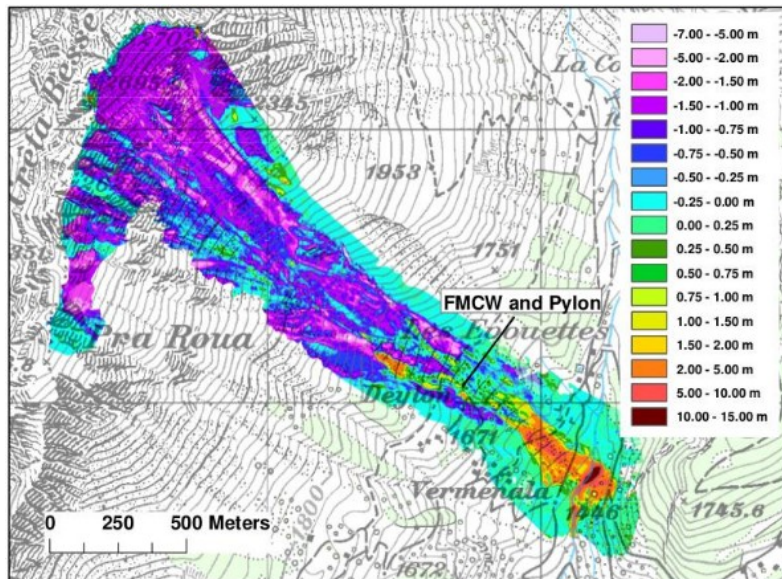


$$h_{\text{stop}}(\theta) = A d \left[ \frac{\tan \theta_{\text{max}} - \tan \theta}{\tan \theta - \tan \theta_{\text{min}}} \right]$$

$$A \sim 1.23 - 2.90 \quad [\text{Pouliquen, PoF 1999}]$$



# Grain size : $h_{\text{stop}}$ in nature

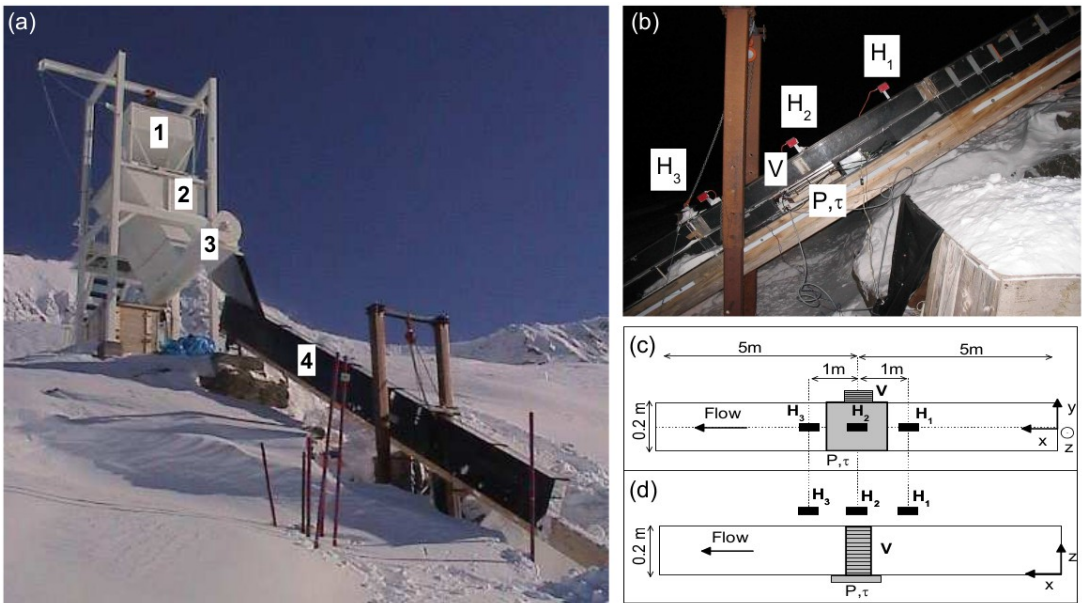


$$h_{\text{stop}}(\theta) = A d \left[ \frac{\tan \theta_{\text{max}} - \tan \theta}{\tan \theta - \tan \theta_{\text{min}}} \right]$$

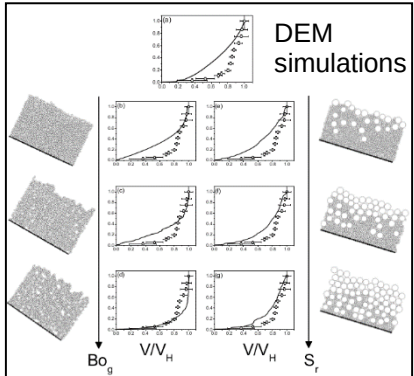
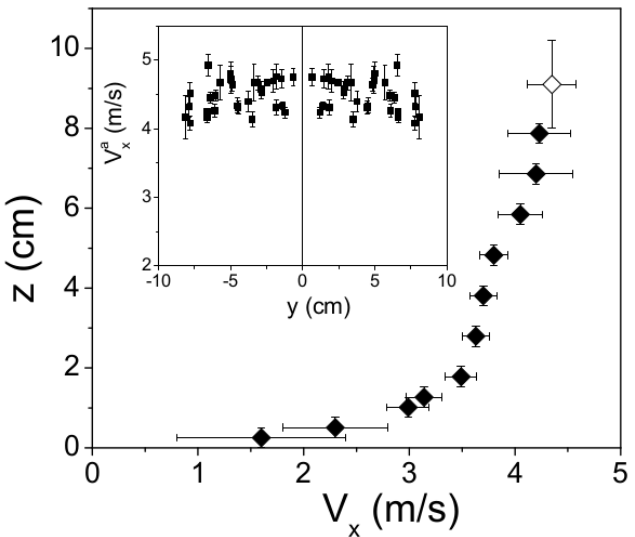
$$l = A d = 0.19 - 0.31 \text{ m} \quad \xrightarrow{A \sim 1.23 - 2.90}$$

$$d = 65 - 252 \text{ mm}$$

# Grain size segregation over depth



[PhD thesis, A Bouchet, P. Rognon]



$$\dot{\gamma} \sim \frac{\sqrt{(gd)}}{d} = \sqrt{\frac{g}{d}}$$

$$d \sim 0.5 \text{ mm} \rightarrow \dot{\gamma} = 140 \text{ s}^{-1}$$

$$d \sim 100 \text{ mm} \rightarrow \dot{\gamma} = 10 \text{ s}^{-1}$$

Cohesive Bidisperse

# When water comes into play...

- Critical issues in past and different snow experiments when **water**, beyond a sufficient amount (close to water triple point) **comes into play**

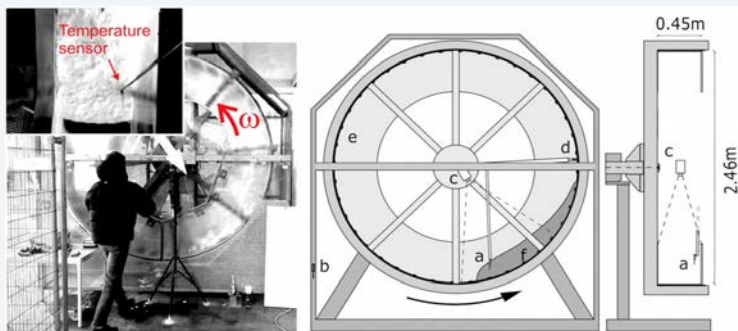
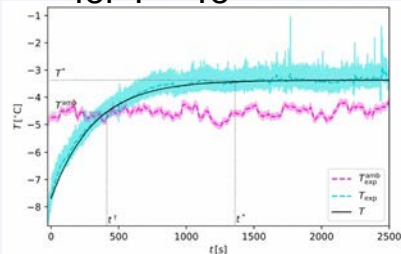
1

Lac Blanc pass snow flow chute : experiments made with dry snow during night, clogging otherwise [PhD thesis A Bouchet, P. Rognon ; Rognon et al, JoR 2008]

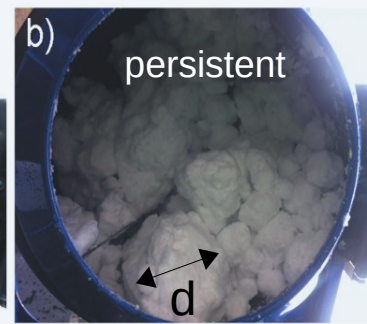
Rotating drum snow experiments in a cold room [Fischer et al, GRL 2018]

3

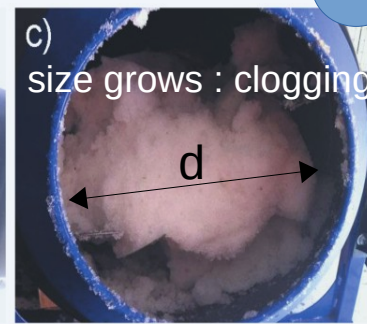
Thermal equilibrium for  $T < T_0$



$T_{\text{neige}} < -1^{\circ}\text{C}$



$T_{\text{neige}} > -1^{\circ}\text{C}$



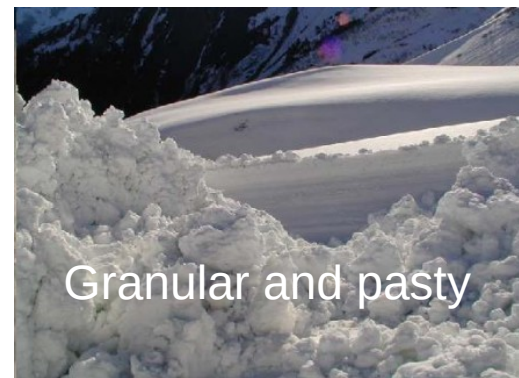
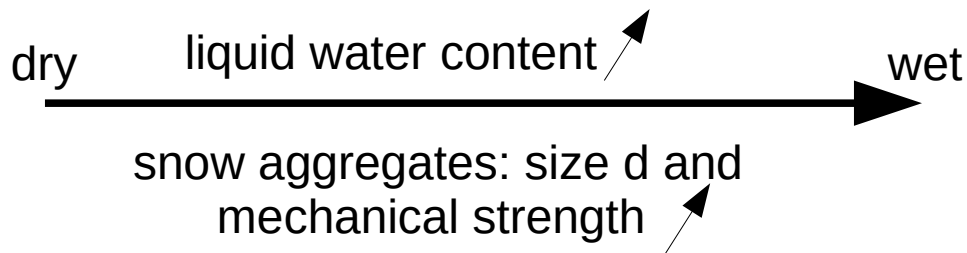
$T_{\text{neige}} = 0^{\circ}\text{C}$

Tumbler granulation [Steinkögler et al, JGR 2015]

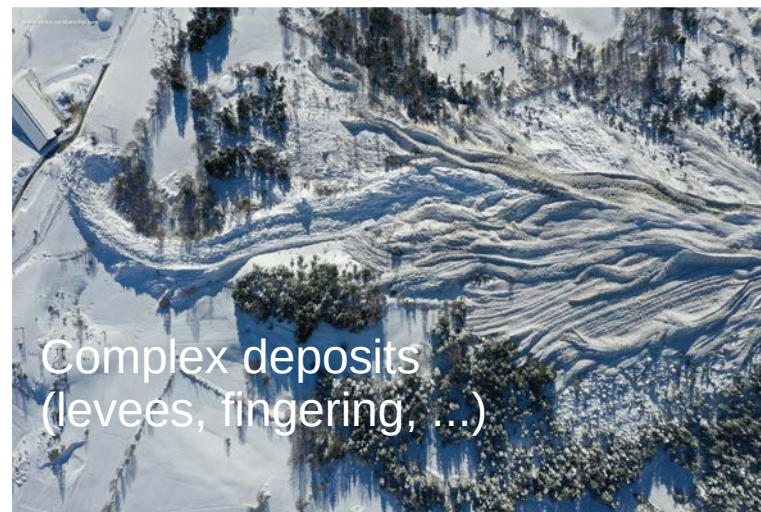
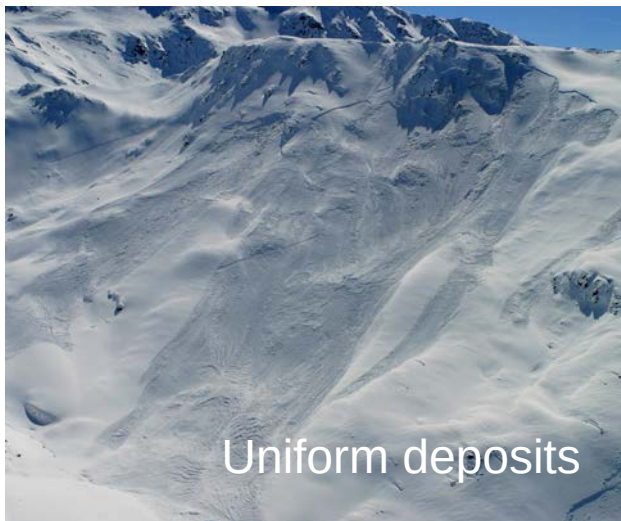
→ there exists a threshold beyond which the things change with the size of the system : lab (small-scale) versus nature (large scale)

2

# When water comes into play



- steady-state in terms of GSD
- aggregation is balanced by crushing
- the ambient air acts as a thermostat



- no steady-state in terms of GSD
- aggregation is dominant

# Conclusion

- *Big snow grains* in dense avalanches (= **aggregates of hundred thousands of snow crystals**) : different types of granular deposits, measured grain size distribution in avalanche deposits (65 – 152 mm),  $h_{\text{stop}}$  left at the tail of avalanche give consistent typical sizes (65 – 252 mm)
- Avalanche flow dynamics : grain size segregation over depth (relation between shear rate and grain size) → **dry/cold snow, not too wet avalanches : granular flow models are pertinent**  
BUT at real-scale : this remains challenging (not to say impossible) to simulate each grain as well as all granular processes involved → need of depth-averaged models that encapsulate minimum some ingredients : constitutive law, grain size, grain size distribution, shape, ... ? (enrichement from advances in granular physics)
- The saltation layer between the dense part and the aerosol ? (*link to the presentation of Hervé Bellot*)
- **Wet snow avalanches beyond a critical threshold** do not behave as pure granular flows : a pasty behavior coexists with the granular behavior → **very challenging in terms of rheology, of avalanche modeling and prediction**

MERCI !