MAP3

alcotra

Healing of snow interfaces by sintering

Podolskiy Evgeny, Barbero, M., Barpi, F., Borri-Brunetto, M., Pallara, O., Frigo, B., Chiaia, B., Chambon, G. , and M. Naaim

LabEx OSUG@2020

Observatoire des Sciences de l'Univers de Grenoble

Dry snow slab avalanches

Podolskiy et al., 2010

Schweizer et al., 2003

Sub-critical weak layer fractures & slab avalanche release

McClung, 1979, 2011; Fyffe and Zaiser, 2004; Birkeland et al., 2006

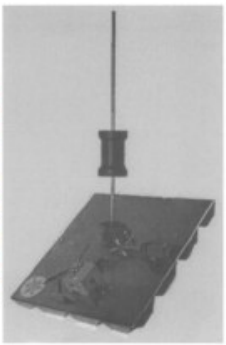
Objectives of this work:

1) develop and test a new instrument

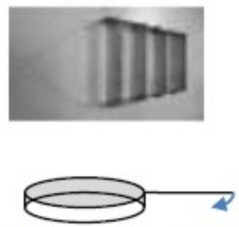
2) study strength dynamics of snow interfaces

Existing in-situ instruments

Schweizer *etal*, 1995

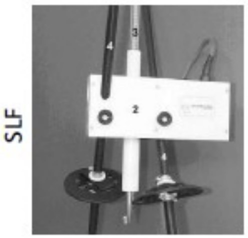


SLF



Watanabe, 1977
(Hybrid)

SLF



Problems of existing vanes/frames:

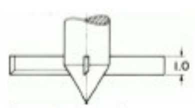
- Manual loading rate
- Manual normal load
- Manual loading angle
- Operator - variability

Suchkov, 2012; Samoilov & Ushakov, 1984

Examples of previous instruments

Kusaka et al, 2010

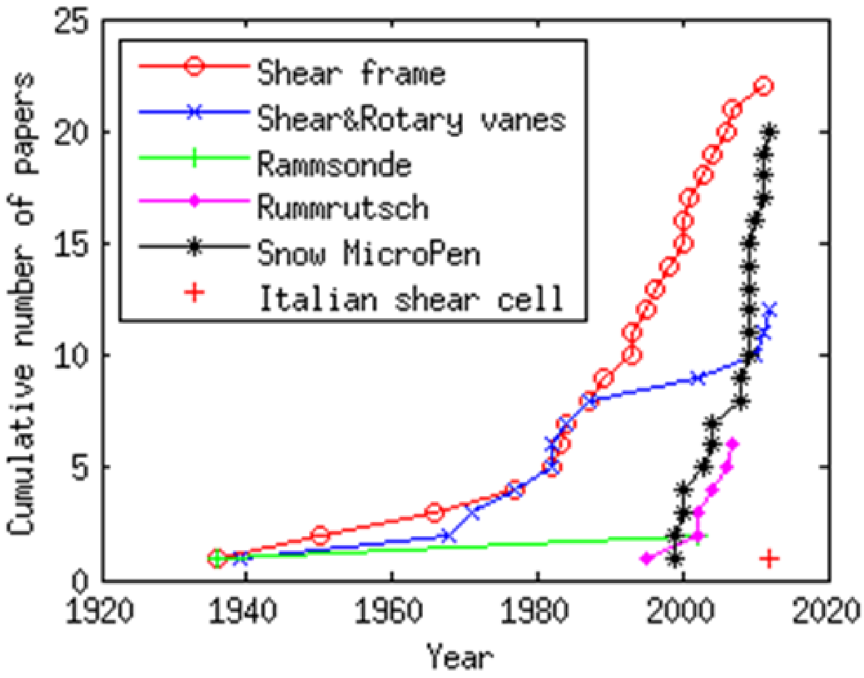
with or without a ring



Keeler & Weeks, 1968

Montmollin, 1982

Evolution of instruments

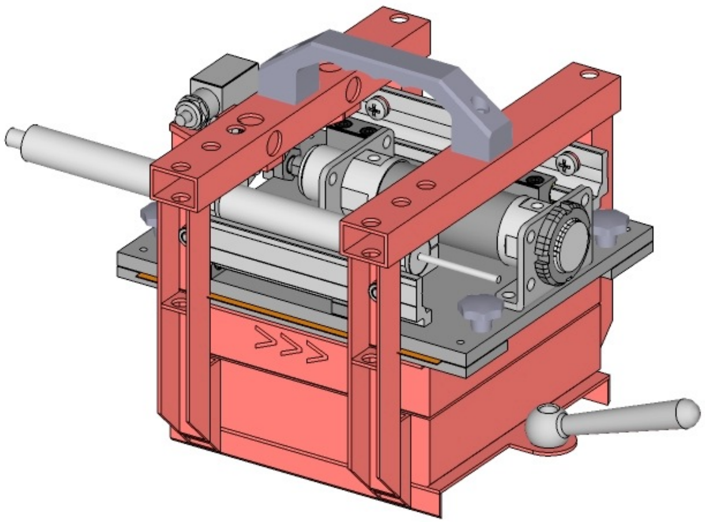


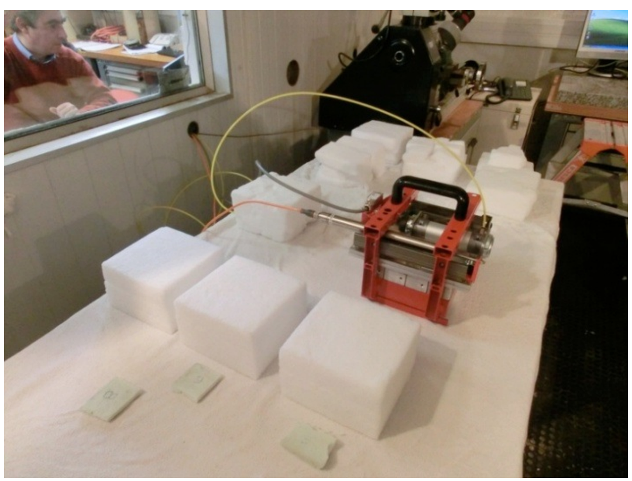
Brown and Jamieson, 2006

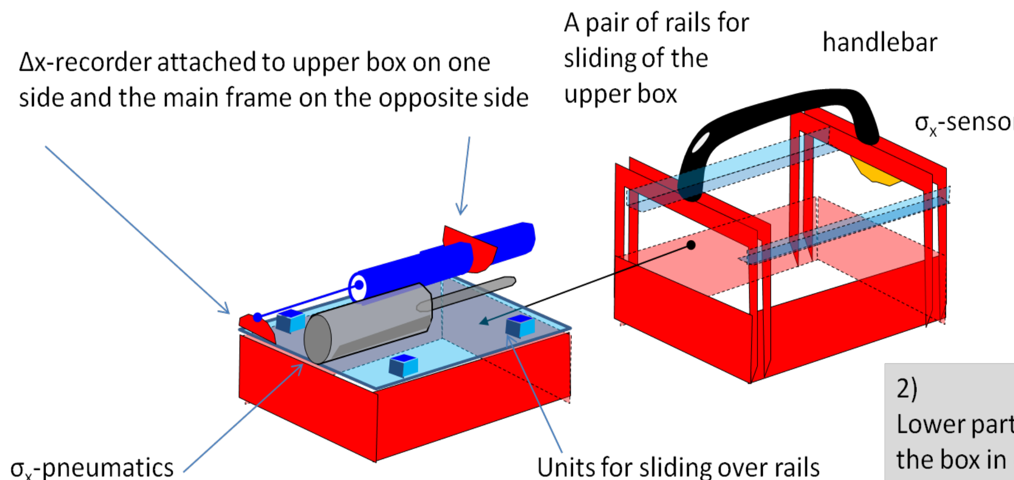
Shear frame – *"a useful tool for gathering statistical data on strength distributions … until a more fundamental technique is developed"* [*Perla and Beck*, 1983]

Force-controlled shear box

Barbero et al. [2013]







Pneumatic piston pushes against the stress sensor on the opposite side of the main frame

1) Upper, movable (x-direction) part of the box

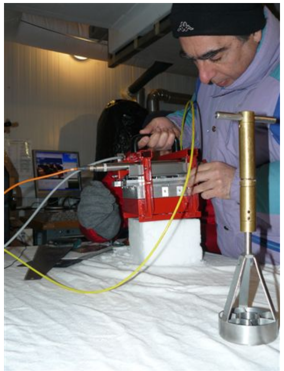
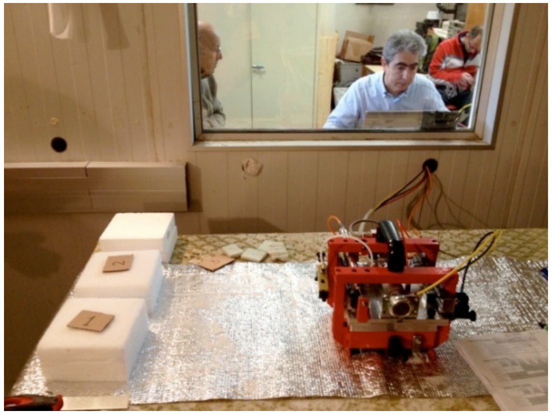
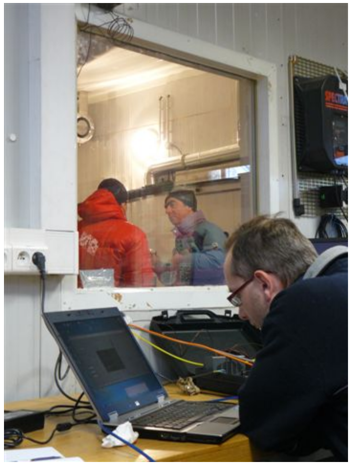
2) Lower part of the box in one solid piece with a frame

Measurements

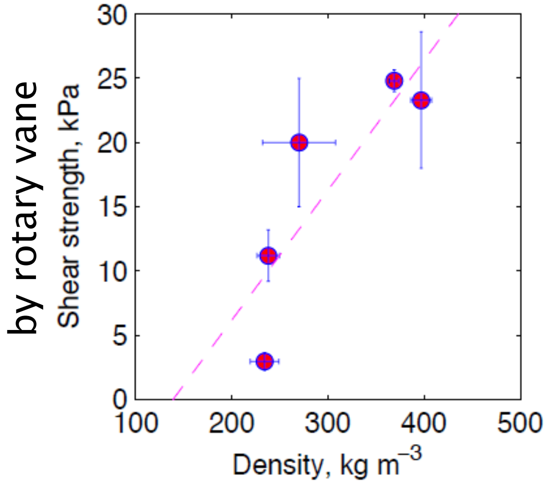
Tested in cold laboratory
of CEN (Meteo-France)
air temperature = −9°C, RH = 70%

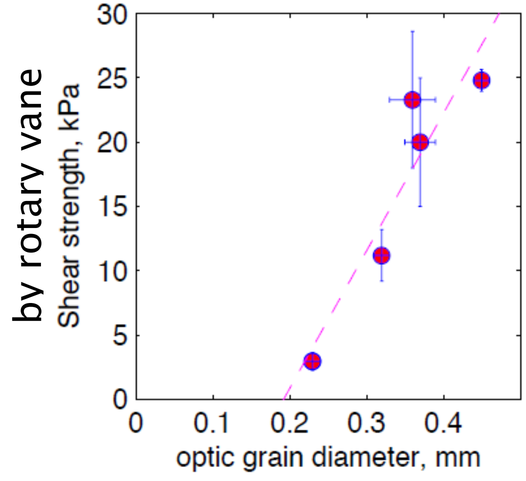
- **Instrument signals** (input/output pressures, force, normal pressure, x-displacement), at ~200 Hz with accuracy 0.1-0.2 %.

- **Properties of snow samples**
  Snow density
  Weights
  Microphotographs
  Specific Surface Area [Gallet et al., 2009]
  Shear vane resistance [Domine et al., 2011]

Snow material

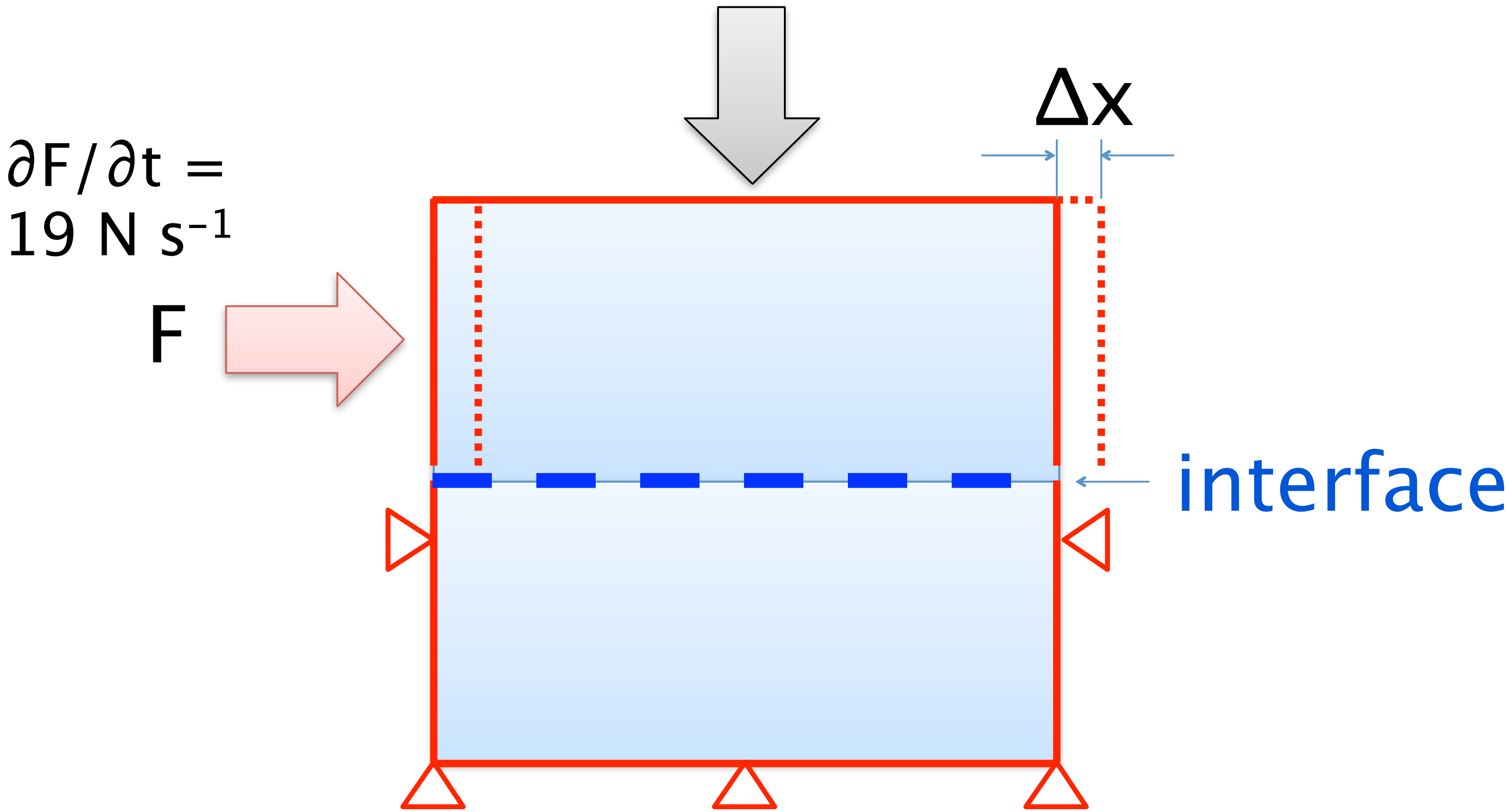




f(SSA) – by DIFUSSS

- Snow was harvested at **Col du Lautaret** (2,000 m a.s.l.), **Massif du Connex** (1,200 m a.s.l.) and **St.-Martin-d'Heres**
- Stored in cold storage room (−20°C; 10–100 days)

$$\sigma_n = \begin{bmatrix} 0.0 \\ 0.5 \\ 1.0 \end{bmatrix} \text{ kPa}$$

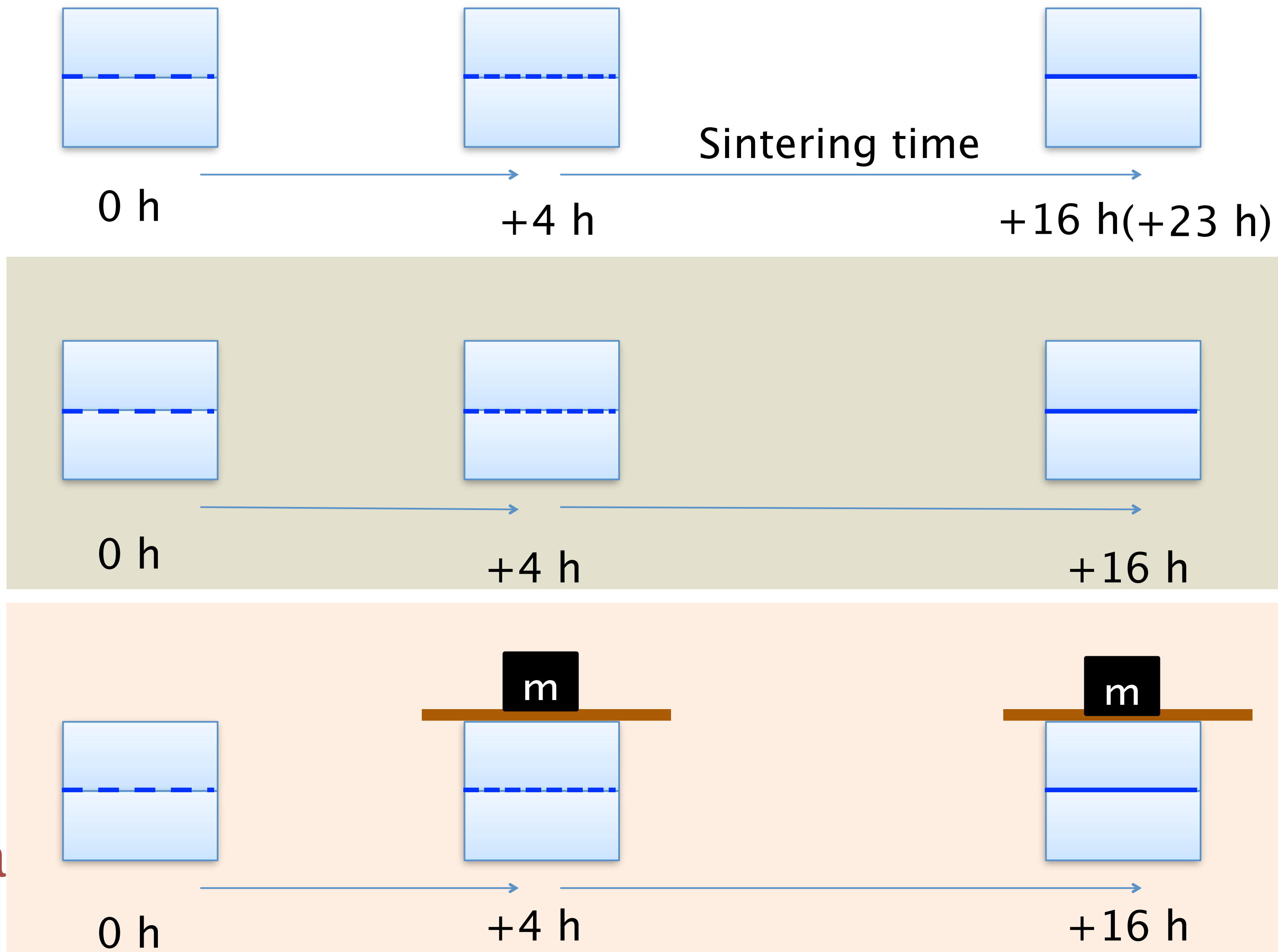


Testing procedure

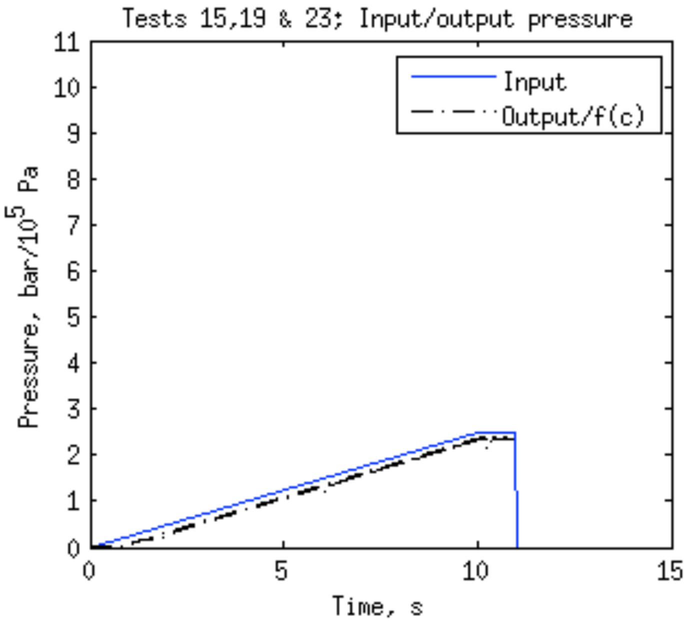
σ_n = 0.0 kPa

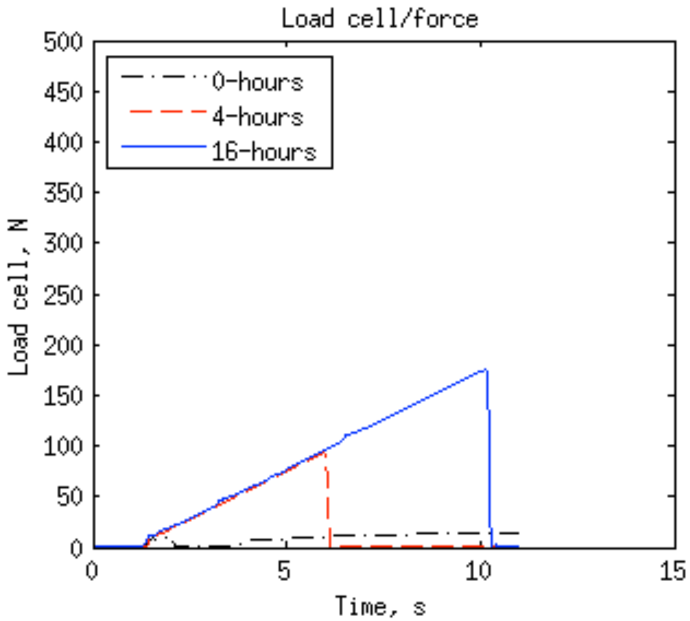
σ_n = 0.5 and 1.0 kPa

+ weights equiv. to σ_c=0.5 kPa

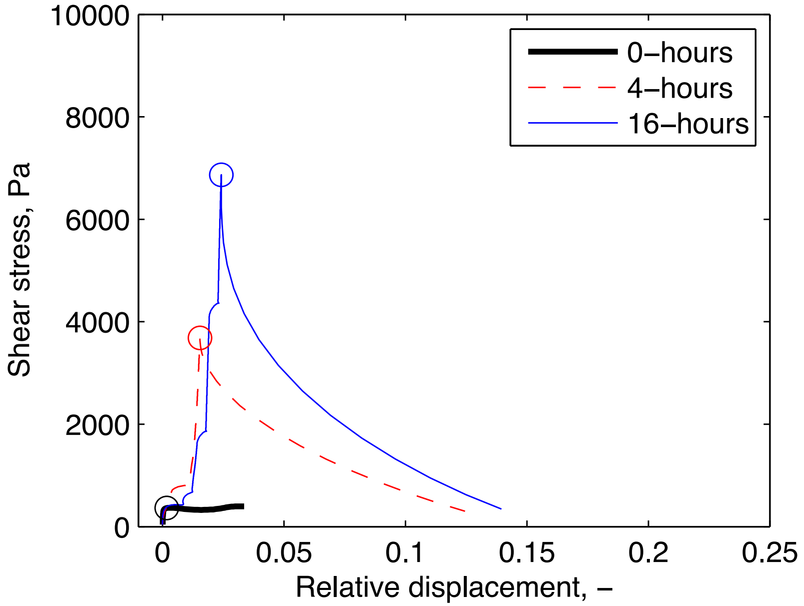


Results





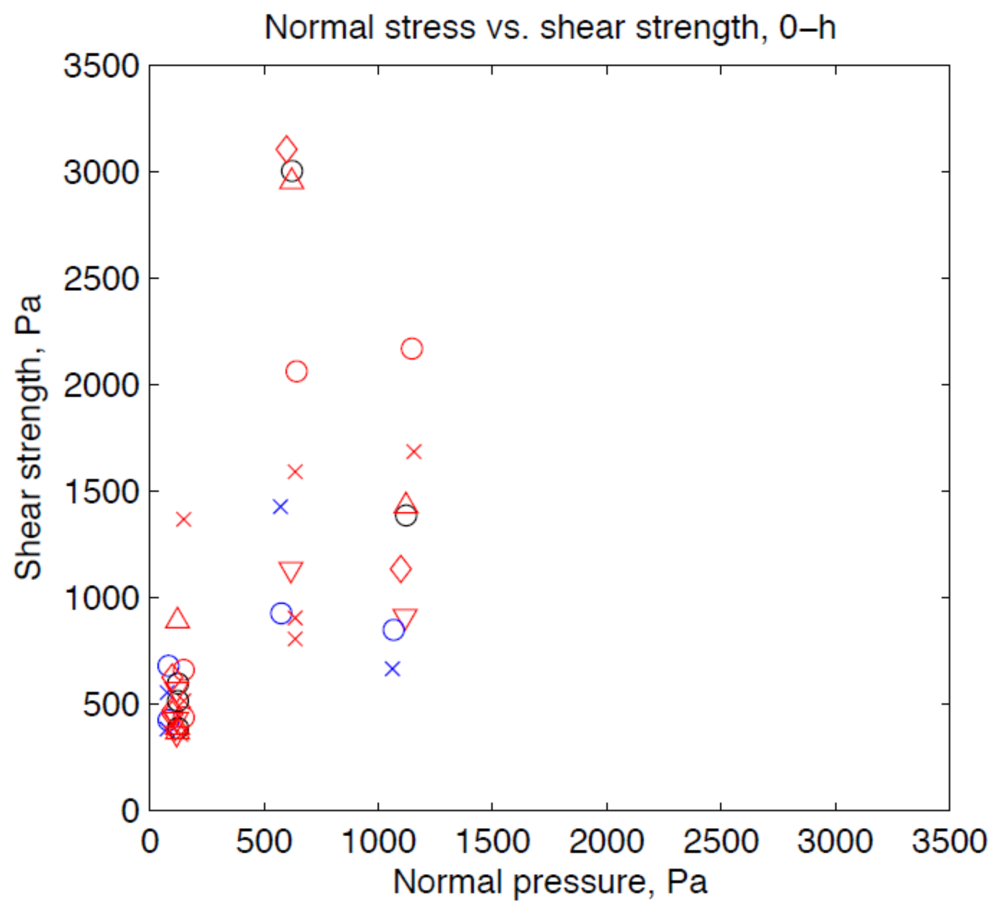
Examples of records



Sintering time: **0 h**

External normal pressure:
σ_n = 0.0, 0.5, 1.0 kPa

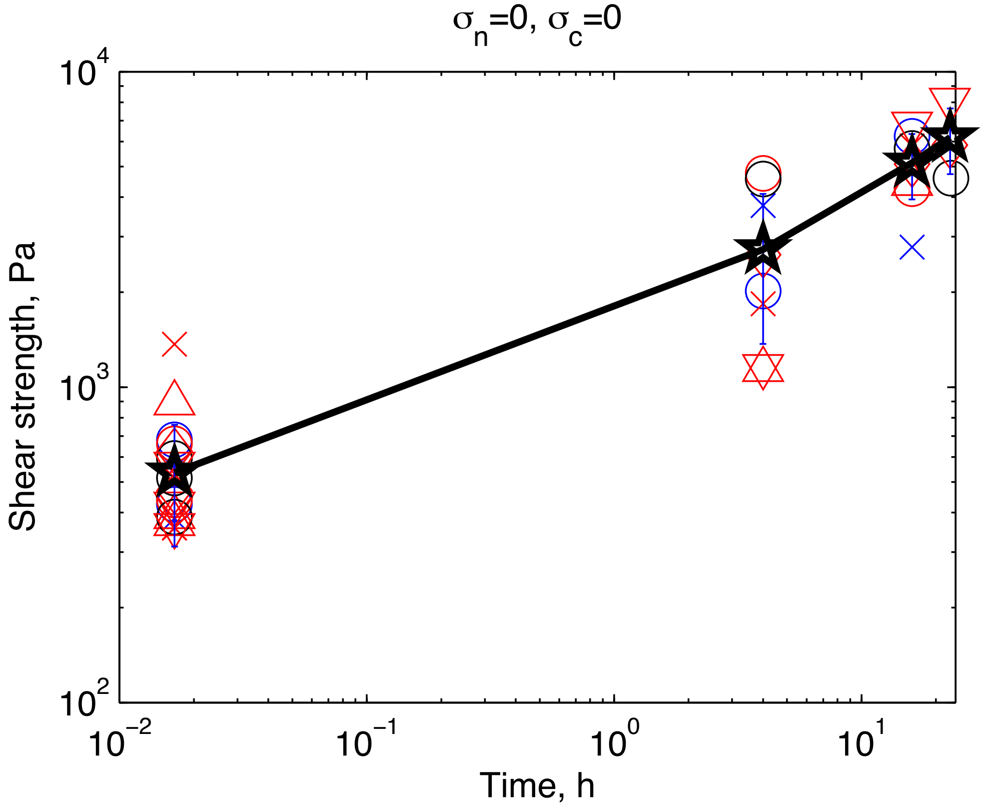
only self-weight
(≈ 0.1 kPa)



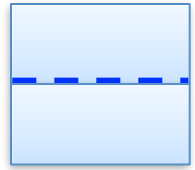
*marker shape corresponds to different specimens (blue – lower density; red – higher density)

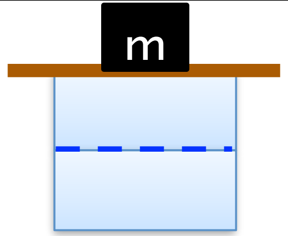
Sintering time: **0, 4, 16, 23 h**

σ_n = 0.0 kPa



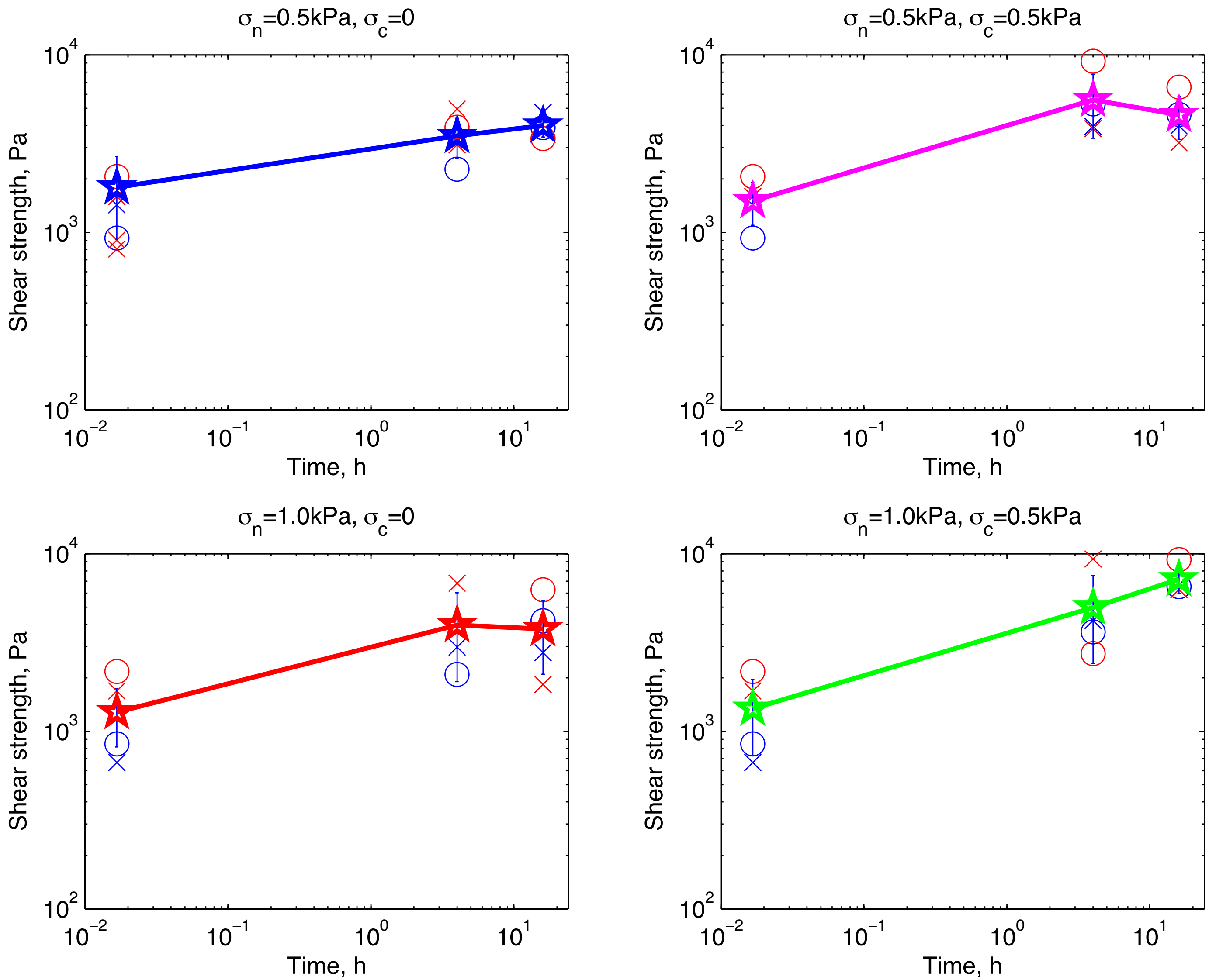
Sintering without or
with **constant**
norm. pressure
σ_c= **0.5 kPa**



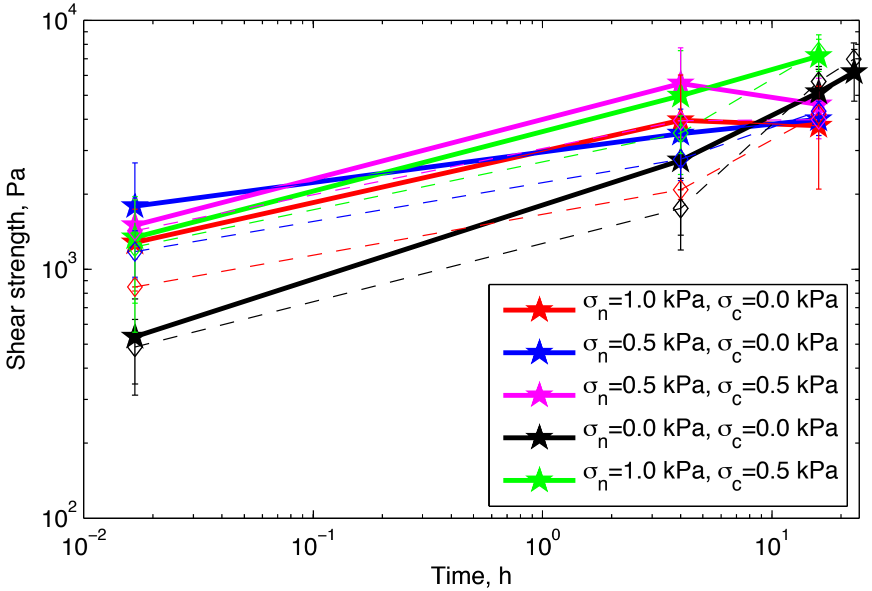


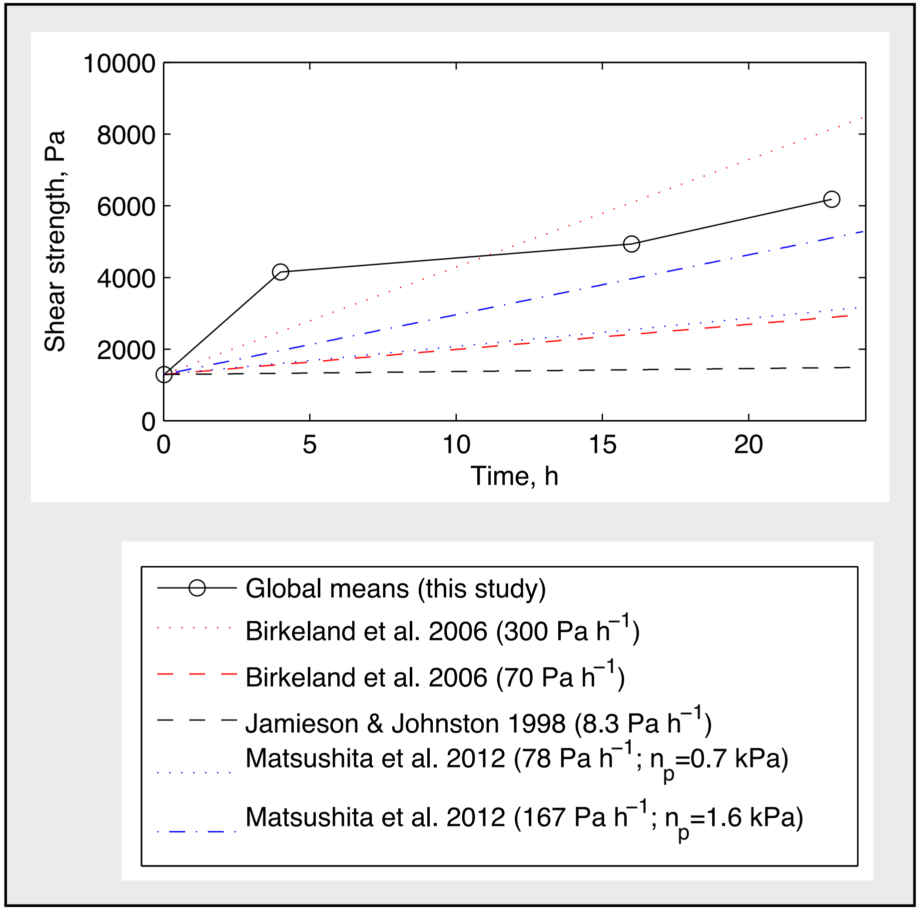
σ_n=0.5 kPa

σ_n=1.0 kPa



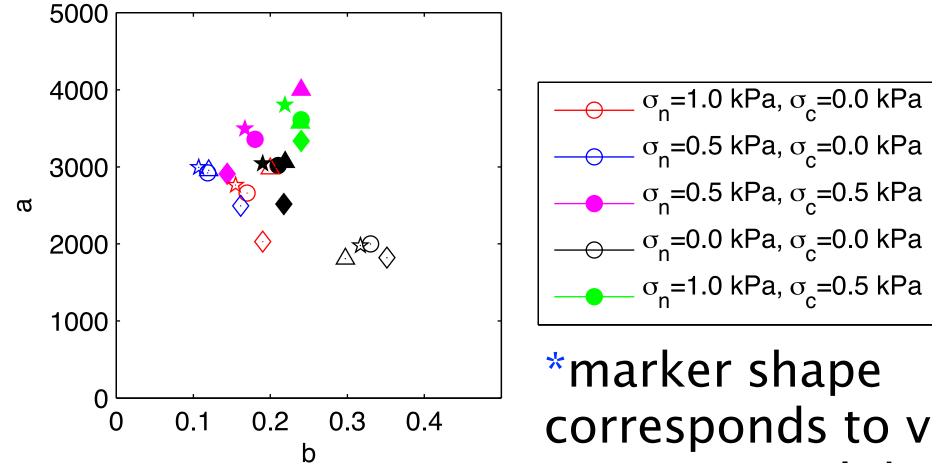
Comparing with other studies – **linear?**



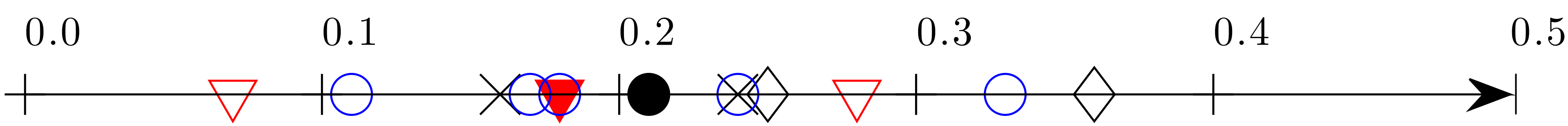


Comparing with other studies – **power?**

$f(t) = a\, t^{b}$



*marker shape corresponds to various sensitivity validations



o – all our loading conditions

• – our global mean

▽ – van Herwijnen and Miller [2013] – from SMP – homogeneous snow

x – Hobbs and Mason [1964] – from sintering between ice spheres

◇ – Blackford [2007] – from sintering between multiple small ice particles

Concluding remarks

- Large variability between tests / no clear difference between snow types.
- Rapid non-linear healing of interfaces (0.71 kPa h^{-1} within 4 hours, 0.14 kPa h^{-1} within the next 12 hours; global mean to 16 hours = 0.26 kPa h^{-1})
- Power law strengthening, *f(t)* (exponent = 0.21±0.08)
- Higher strength under normal pressure / need further tests for clarifications.

Follow-up work

- Instrument modifications (side wall, gap, strain-control, preparations for field version, new sensors)

- Particle Image Velocimetry (PIV) of deformations – cold room, CEN

- In situ field campaigns (winter 2013/2014)

- Tests with wet-snow – cold room, Japan (?)

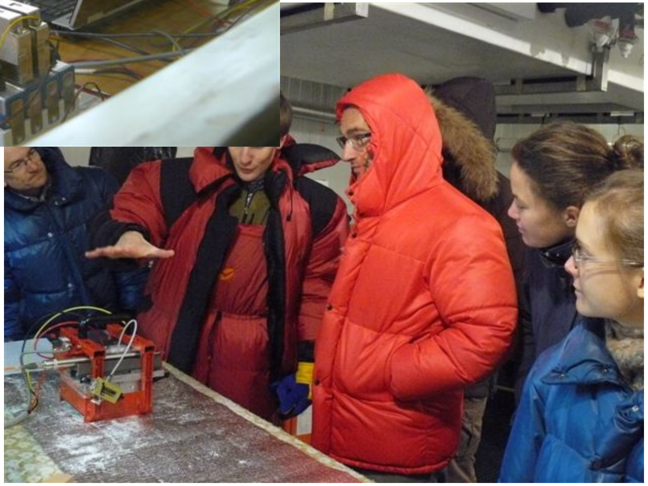
- CT-scans for some tested samples (?)

Merci!



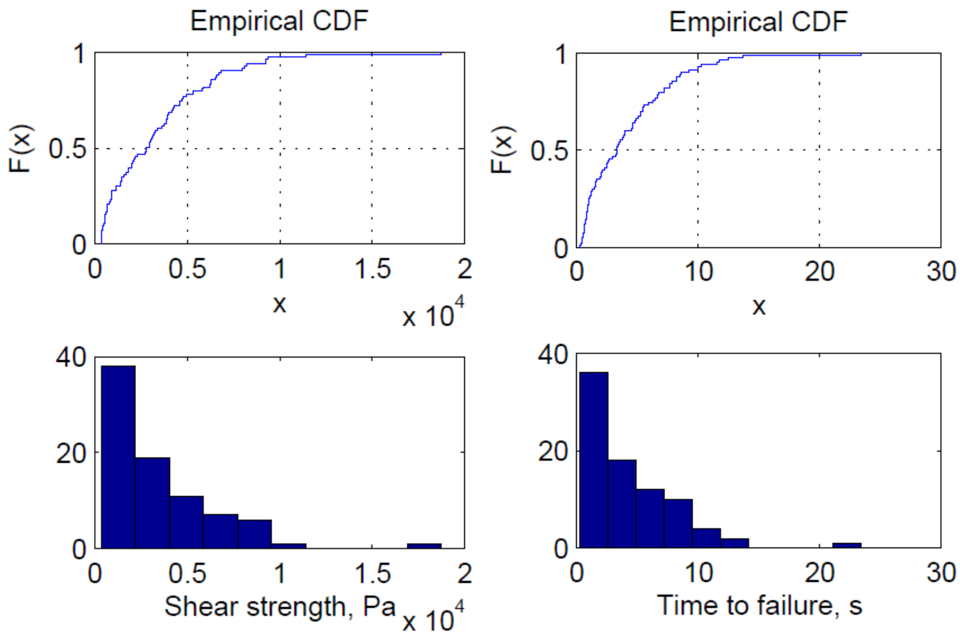




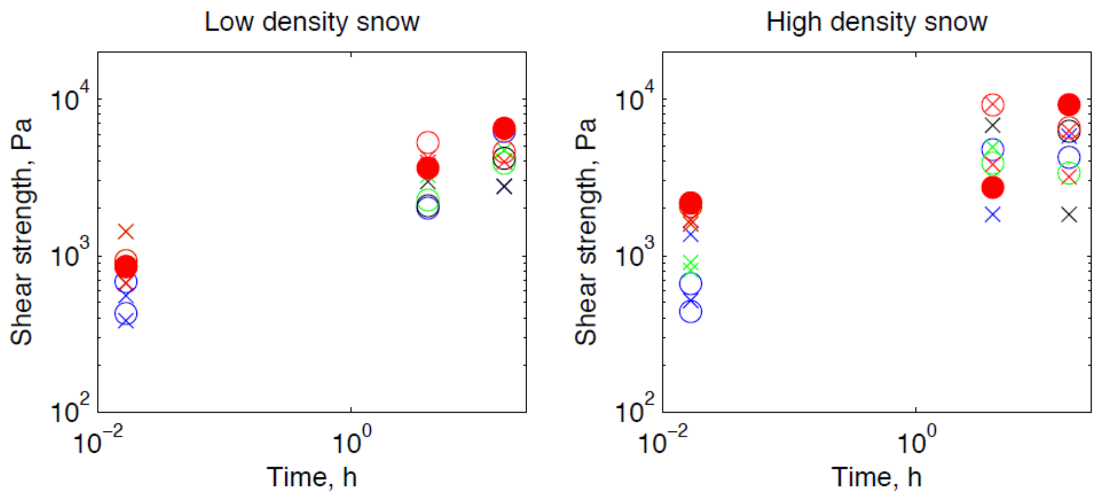




Back up slides

Overview of all tests

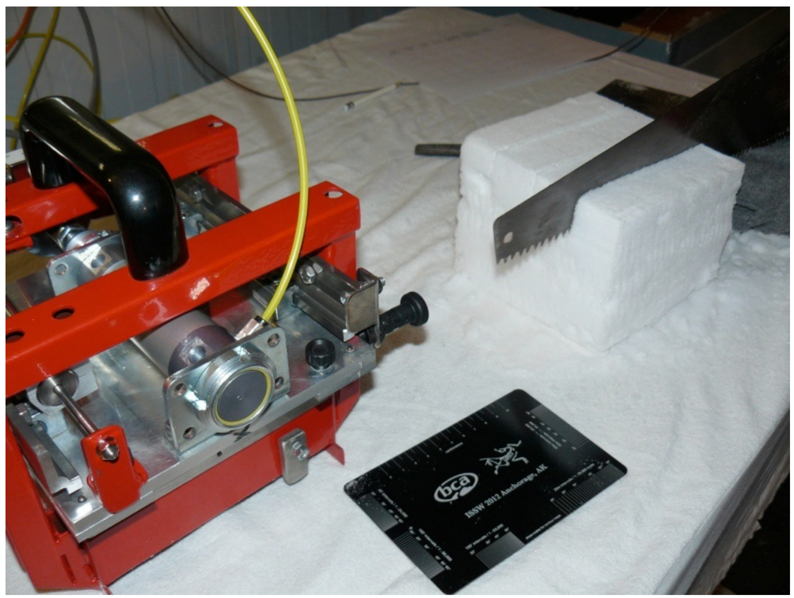


Median = 2.8 kPa 3 s



*marker shape corresponds to different specimens; color – to different loading conditions

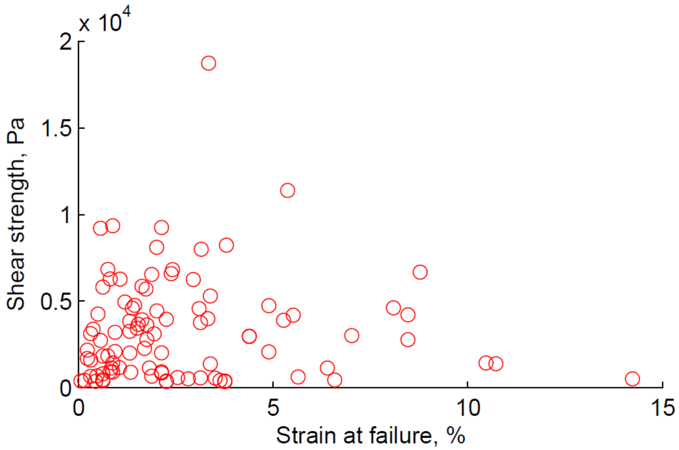
First attempts to use fins

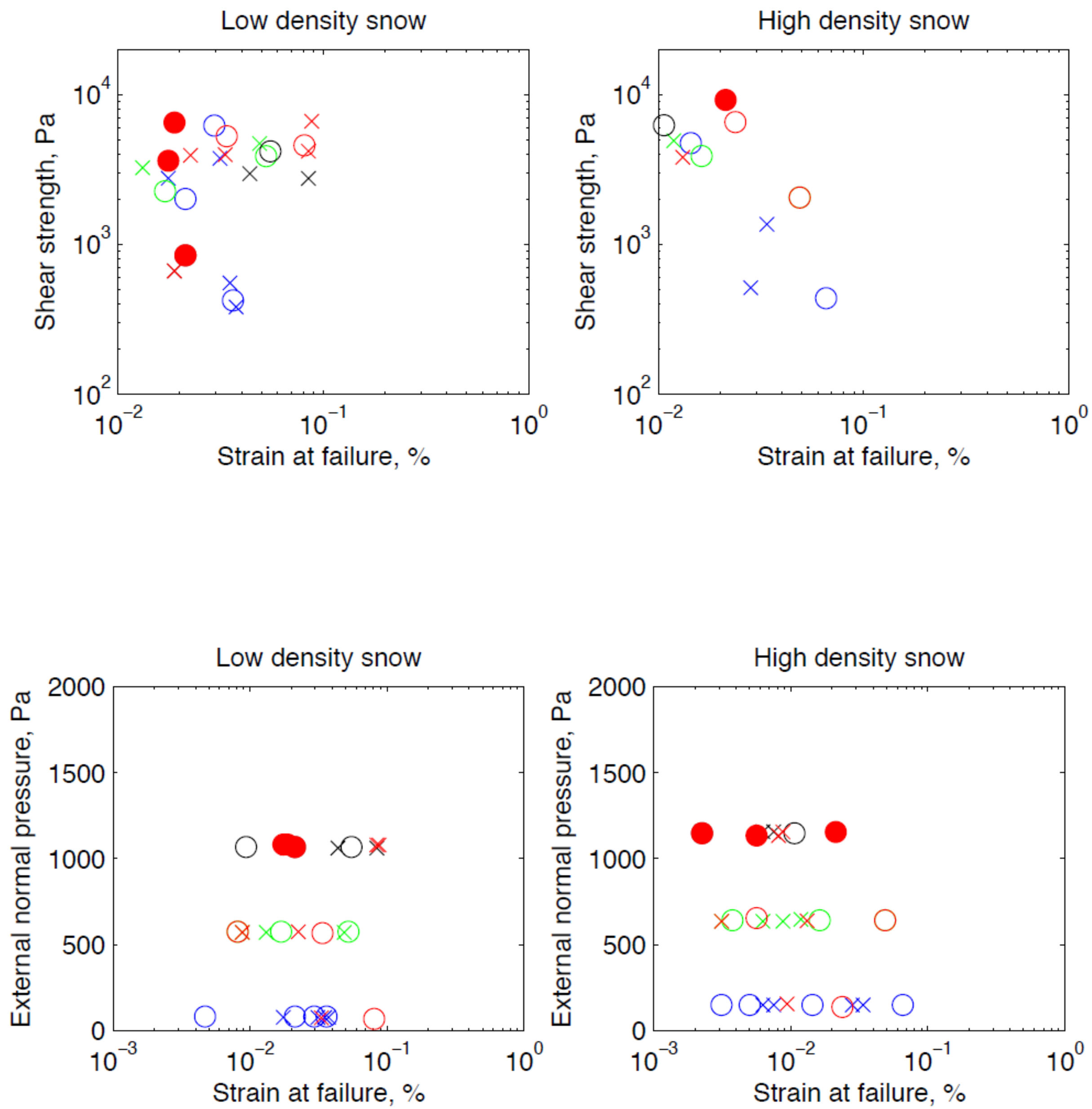


with 1 fin→

with 3 fins→

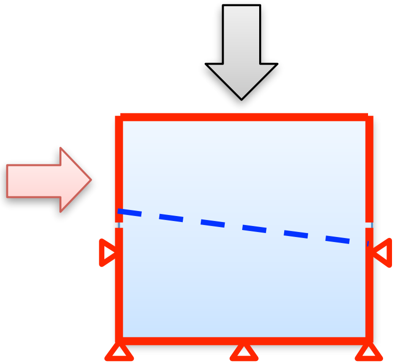
Strains / strength / normal pressure

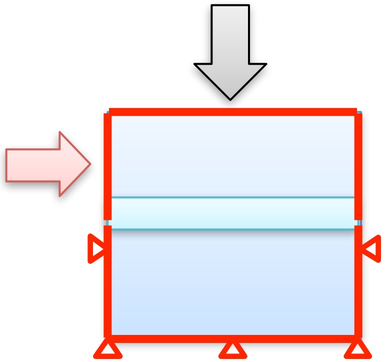




*marker shape corresponds to different specimens; color – to different loading conditions

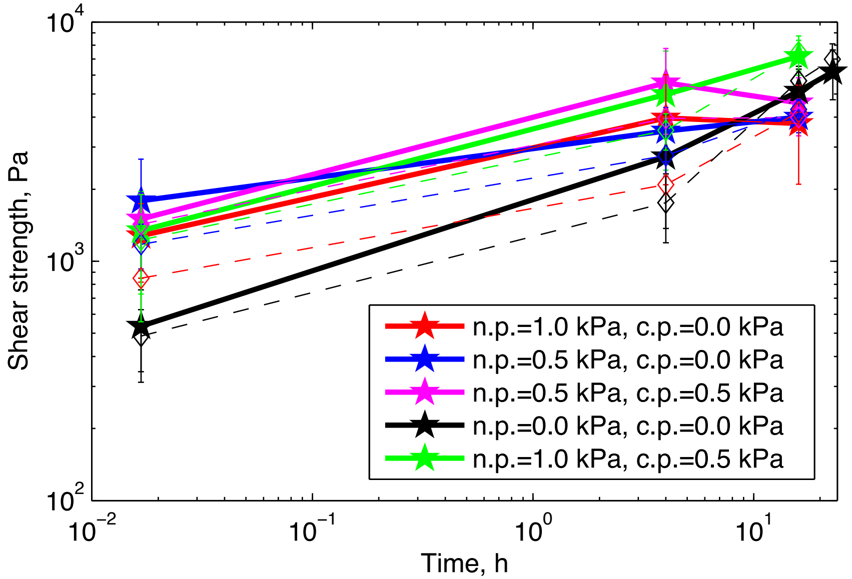
In situ?



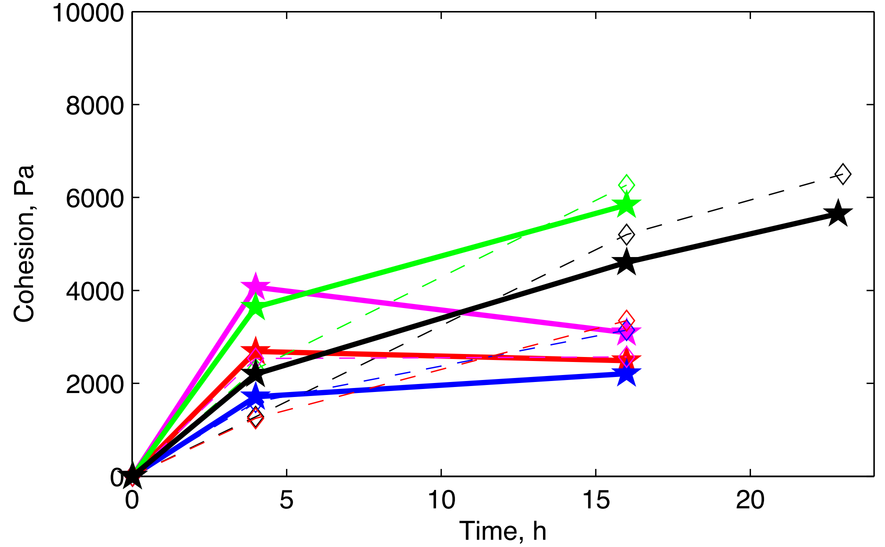


Why focus on snow sintering?

1. **A way to provide valuable data while testing / calibrating the instrument.**
2. Key process of snowpack evolution [Blackford, 2006]
3. Very poorly studied [McClung and Schaerer, 2006]
4. Has the fastest rates in geology [Szabo and Schneebeli, 2007]
5. Sub-critical weak layer fractures & slab avalanche release [McClung, 1979, 2011; Fyffe and Zaiser, 2004; Birkeland et al., 2006]
6. Post-fracture healing of snow weak layers [Birkeland et al., 2006; Reiweger, 2011]
7. Snow engineering (igloo, snow shelters, etc.) [USAP Field Manual, 2001]
8. Astrophysics & planetary science [Sirono, 2011]



10^4
10^3
10^2
Shear strength, Pa
10^{-2}
10^{-1}
10^0
10^1
Time, h
n.p.=1.0 kPa, c.p.=0.0 kPa
n.p.=0.5 kPa, c.p.=0.0 kPa
n.p.=0.5 kPa, c.p.=0.5 kPa
n.p.=0.0 kPa, c.p.=0.0 kPa
n.p.=1.0 kPa, c.p.=0.5 kPa



10000
8000
6000
4000
2000
0
Cohesion, Pa
0
5
10
15
20
Time, h