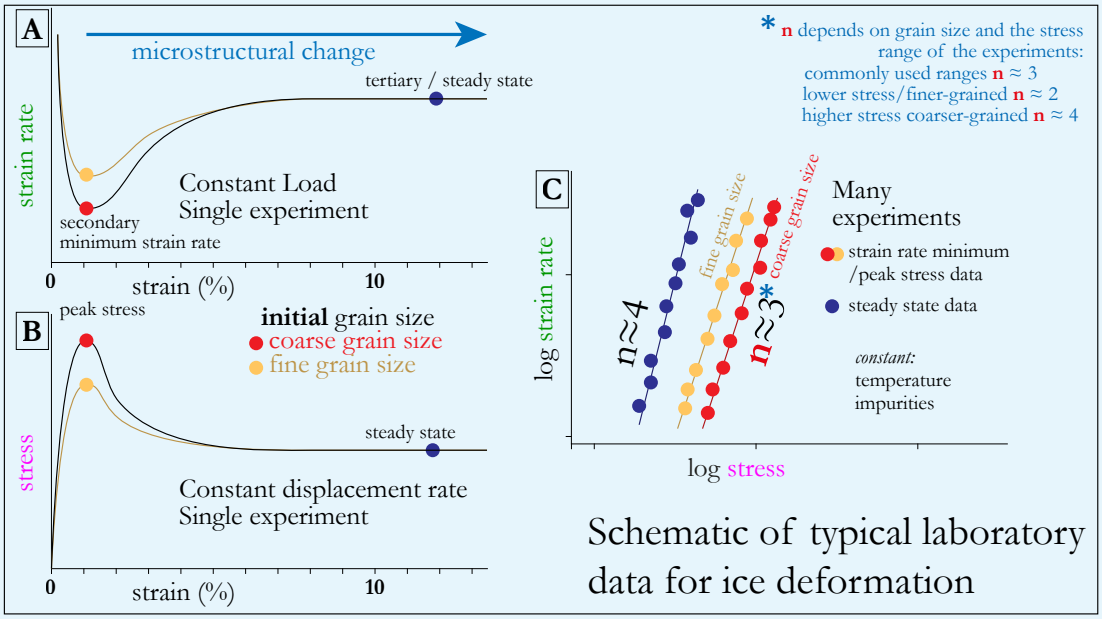
Flow laws for ice sheet modelling: what do experiments tell us?

Ice deformation is commonly described by a power law relationship in which:

$$\text{strain rate} \propto (\text{stress})^{n}$$

This presentation focuses on just one aspect of flow laws: the stress exponent (n).

In many ice-sheet models the stress exponent (n) is assigned the value 3 and this is often named the Glen Law (Paterson, 1994). John Glen was very clear in all of his papers concerning ice creep (Glen, 1952; 1953, 1955), that the values of n of 3.2 or 3.3 (his experimental values) applied only to minimum strain rate (secondary creep) in experiments. In all his papers he argues that at the steady state (tertiary creep) achieved at higher strains, n should be about 4. He was right.



There is a microphysical explanation, that comes from De Bresser et al., (2001), that explains why (for ice) n will be ~ 4 at steady state. The explanation relates to the microstructural changes that occur between minimum strain rate/ peak stress and steady state and will be outlined in the additional document.

n values for minimum strain rate (secondary creep) data, that do not also include a "microstructural" parameter (for example grain size) are of limited value. The n value will change depending on the grain size and stress range of the experiments. They should not be applied to deformation of ice at high strain (steady state).

What should we do in models? For now:

For ice at high strain: including basal ice, shear margins, general "flow":

use $n = 4$ ~~$n = 3$~~

For ice in other states (e.g borehole closure, sudden changes in kinematics)

use a composite flow law with grain size sensitivity

(Goldsby & Kohlstedt., 2001; Goldsby, 2006; Kuiper et al 2020a; 2020b). Note the composite flow law can also be applied to steady state, it will give the same result as an n=4 flow law with no built in grain size sensitivity.

Hopefully: there will be an additional document with more info uploaded for the conference (time!). References in this doc. Dave Prior will be available at the "Meeting Hub" during the scheduled poster times - but as a back up (and for a many person chat), he will also be on ZOOM, drop by and say hello: ZOOM room 2028787054 Password: ICEISCOOL

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