# Texture evolution measurement and modelling along the Talos Dome ice core

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Fabrics have been measured along the Talos Dome ice core using the Automatic Ice Texture Analyser of D. Russel-Head (Russel-Head and Wilson, 2001 J. Glaciol. 24). Fabric data are available high in the firn, from 18m depth. The fabric evolution is compared with climatic signals and analysed regarding the thinning function extracted from the TALDICE-1 chronology (Buiron et al. 2011 Clim. Past 7).

Using the second order VPSC scheme (Lebensohn et al. 2007 Phil. Mag. 87), we modelled the fabric evolution under compression, with a constant strain rate consistent with the one expected along the Talos Dome ice core. The Talos Dome chronology TALDICE 1 is used to obtained the cumulated compressive strain as a function of depth along the core, from the thinning function.

- A reasonably good fit is obtained over the global trend. From area of mismatch between data and model results, hypotheses can be given about the influence on flow conditions of shear stress and changes of ice viscosity due to climatic conditions.

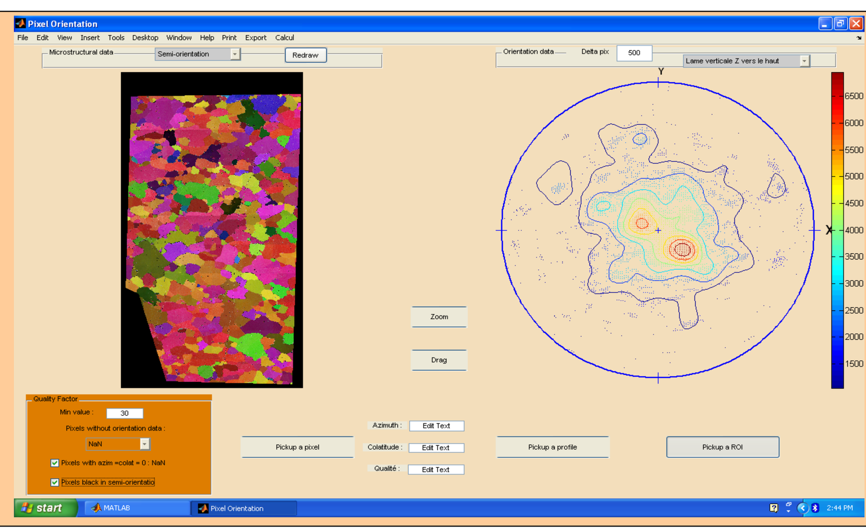
The best fit is obtained using a non isotropic initial fabric confirming the influence of the initial conditions on the fabric evolution all along the core.

From the modelling tool, data were inversed to predict a thinning function in the case of an ideal dome. Comparison will be helpful in the future to better constraint the dating scenario of the inverse method used to obtain the chronology (Lemieux-Dudon et al. 2010 Quater. Sc. Rev. 29).

## Experimental procedure :

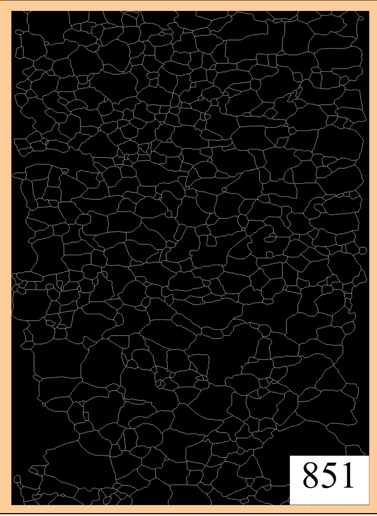
**The Automatic Ice Texture Analyser**

**Spatial resolution** :
232×232 pixels for 10×10 mm² section (43µm)
320×240 pixels for 2×1.5mm² sections (6.25µm)
**Angular resolution** :
+/- 1.1° for local analyses (on one section)
+/- 3° for full sample measurements (several 10×10 mm² sections)



Matlab® toolbox for data treatment :
- pole figure
- colatitude or azimuth along a section
- area selection
- removing of invalid data
- calculation of texture parameters
- contours extraction for grain size measurement

ImageJ® plugin for manual correction of grain size contours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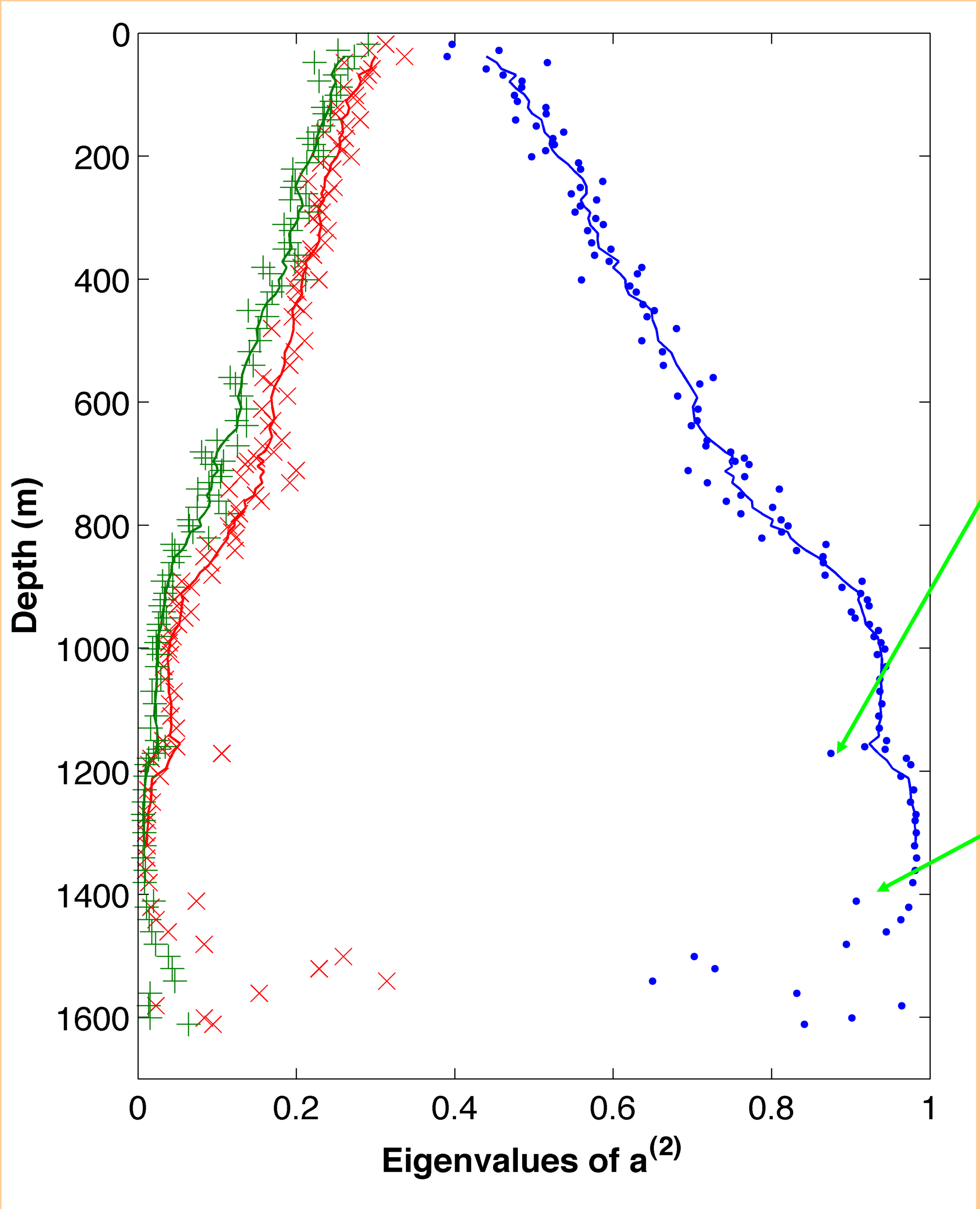
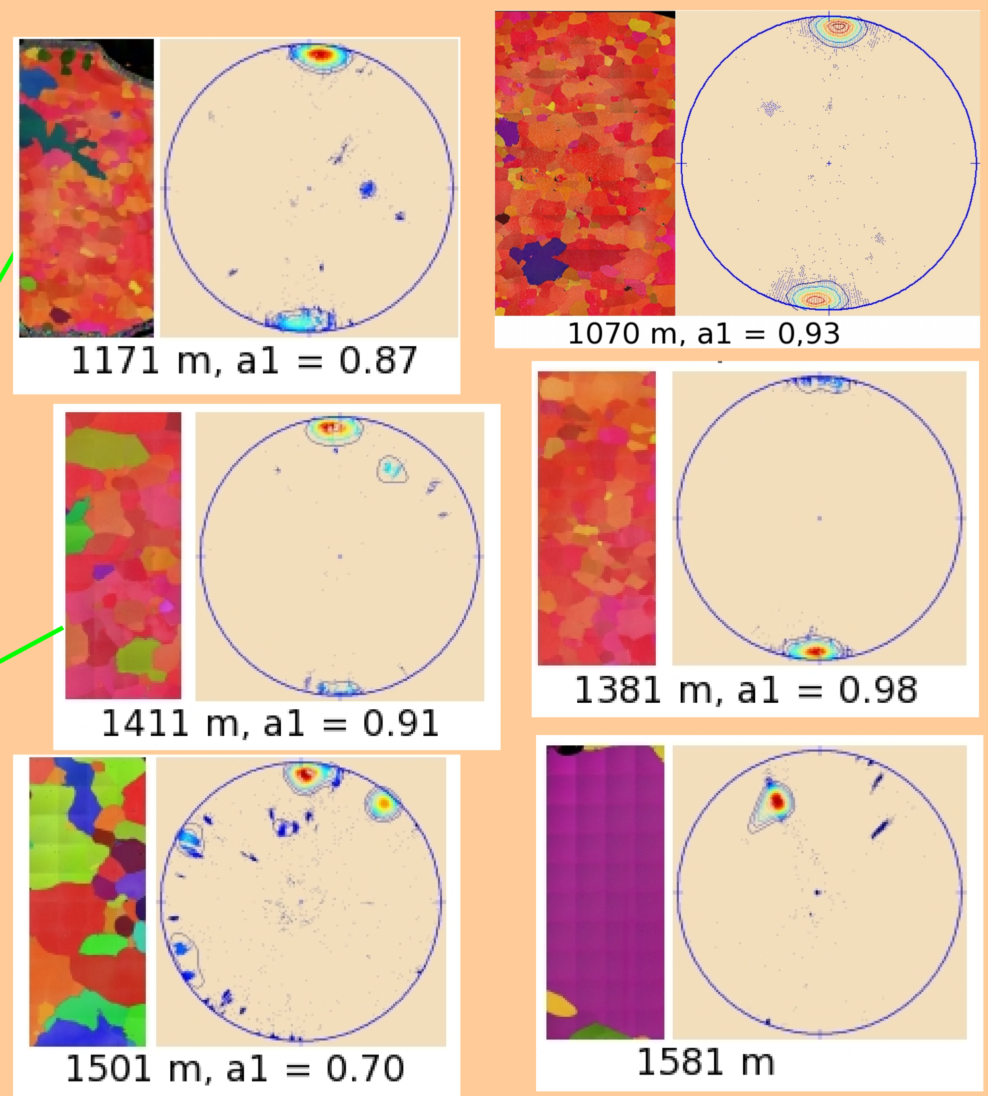



## Fabric data

--- Fabric measurements in the firn, from 18 m depth
Anisotropy: 18m $a_1$=0.39, 28m a1=0.45, 38m $a_1$=0.39.

--- Evidence of **dynamic recrystallization** from 1171 m depth.
Strong impact on texture below 1400 m depth

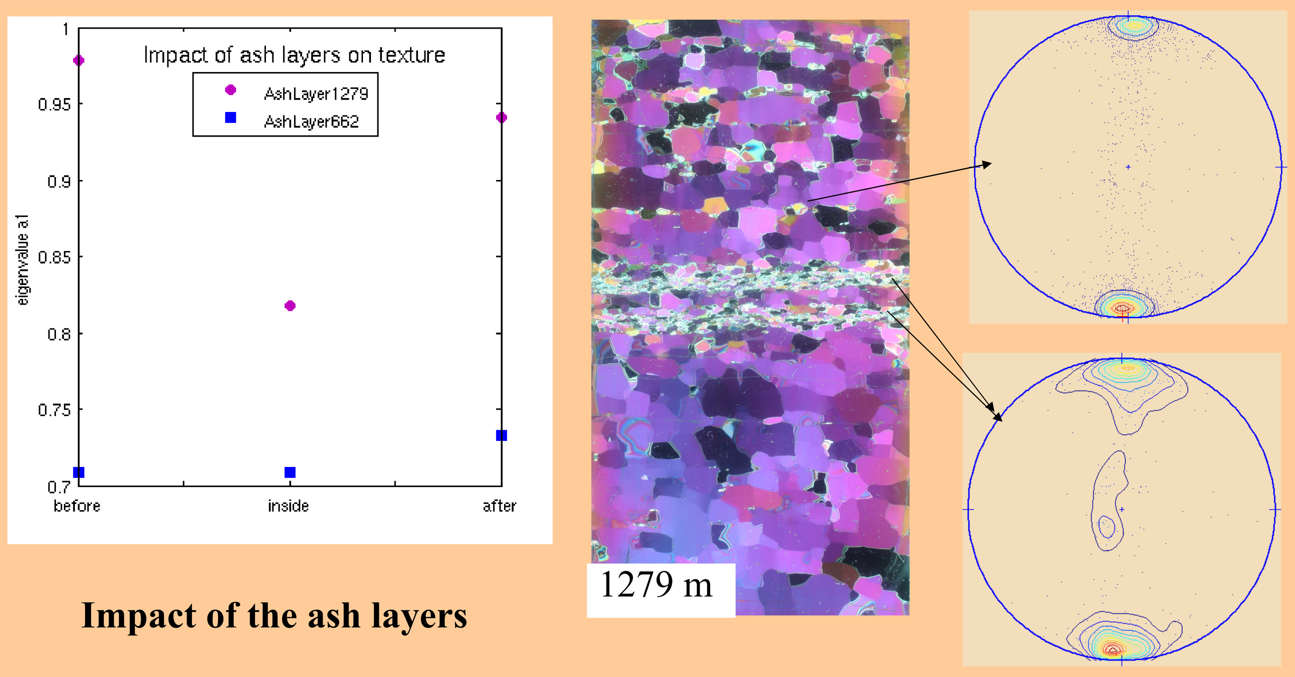



## Fabric measurements

**Second order orientation tensor $a^{(2)}$** $a^{(2)} = \sum f_k c^k \otimes c^k$

where $c^k$ is the orientation of the c-axis of the crystal k.
The data are represented via the **3 eigenvalues of the tensor a1, a2 and a3** which can be seen as the lengths of the axis of the ellipsoid that best fit the density distribution of the grain orientations.
For an isotropic fabric a1 = a2 = a3 = 1/3
For a single maximum fabric a2 ≈ a3 < 1/3
For a girdle type fabric a1 ≈ a2 > 1/3

The parameters are calculated on each valuable pixel, **the grain area is then taken into account as a statistical weight**




**Impact of the ash layers**

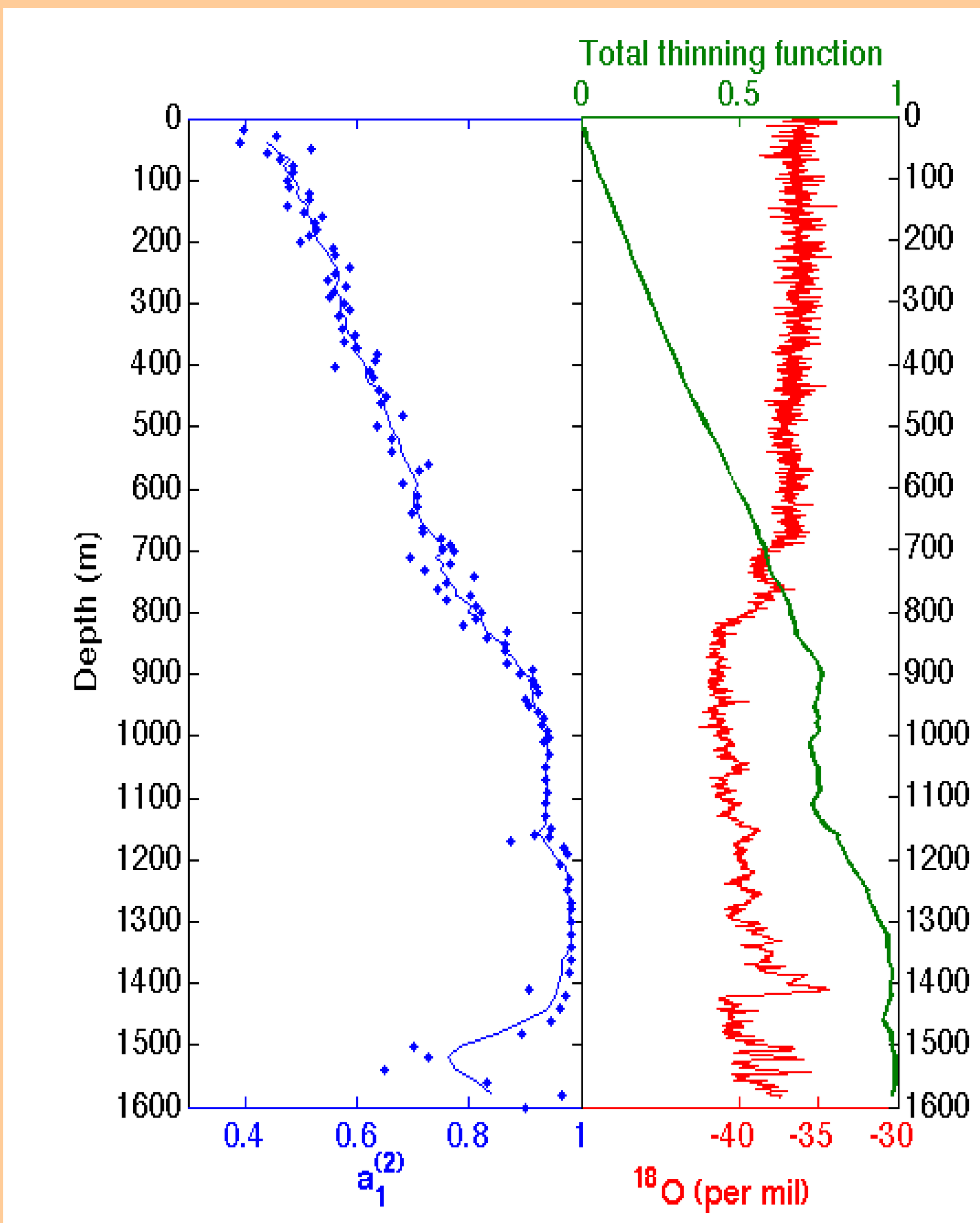
----- Between 750-950 m (11.5-30.3 kyr BP, from TALDICE1) -----
Deglaciation period (MIS 2 to early Holocene, encompassing LGM).
**Change of slope in the fabric evolution**, increase in the rate of fabric clustering.
SHEARING + CHANGE in VISCOSITY : positive feedback in fabric strengthening

----- Between 950-1150 m (40.3-46.6 kyr) -----
**No fabric evolution**: successive layers must have followed different deformation history / trajectories in the ice sheet.
Displacement of the dome + increase of shear stress + impact of variable dust content.
Reduced compressive strain rate, reduction in the thinning.

----- Between 1150-1200 m (46.6-51.2 kyr) -----
Abrupt cooling at about 46kyr (AIM 12)
**Abrupt fabric concentration change**. Synchronous with the resumption of the thinning rate evolution toward a gradual decrease.

----- Between 1200-1400 m (51.2-124.8 kyr) -----
**Maximum level of fabric concentration.** Higher that what can be reached by uniaxial compression.

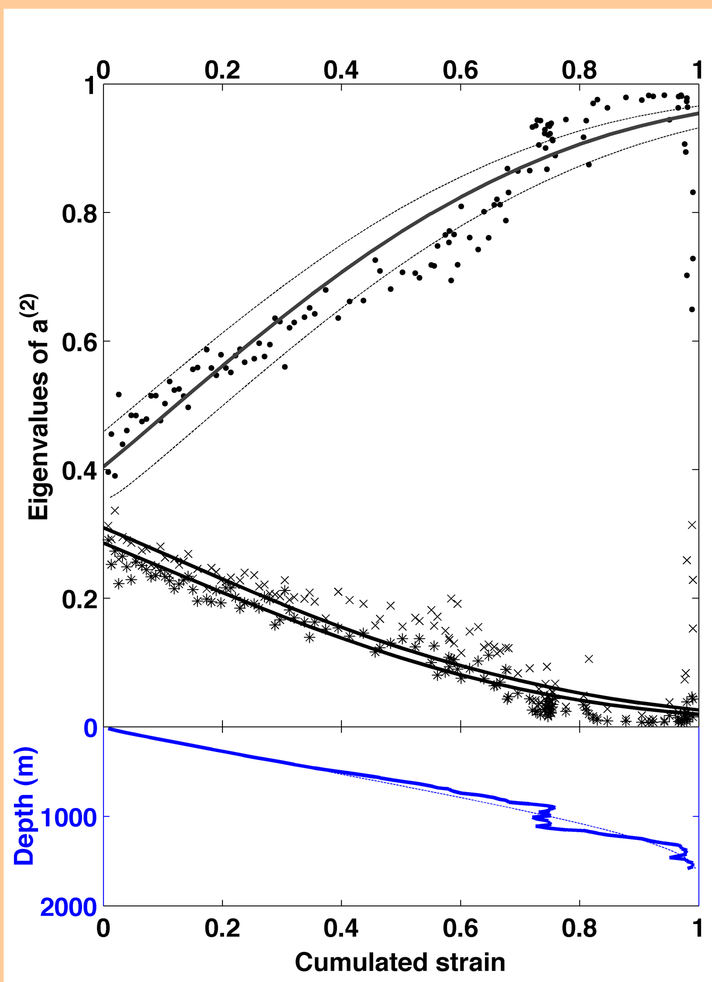
----- From about 1400 m (124.8 kyr) -----
Abrupt changes toward dynamic recrystallization textures.
End of the last interglacial signal recorded.




## Modelling the fabric evolution using the VPSC second order scheme

- Accumulated compressive strain = 1 – thinning.
Thinning extracted from the TALDICE1 chronology (Buiron et al. 2011, Clim. Past, 7, 1-16)

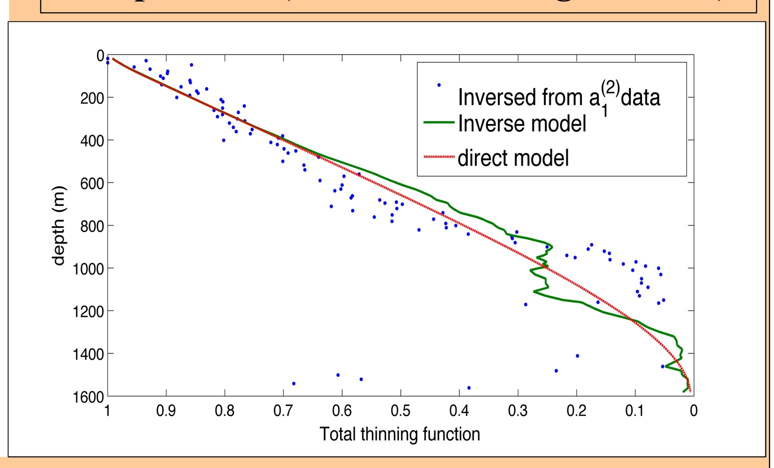
- the model provides the fabric evolution of a polycrystal of 500 grains under uniaxial vertical compression with constant strain rate of $10^{-12}$ $s^{-1}$




**Full lines** : model result with an initially anisotropic fabric ($a_{1(0)}$ = 0,4 ≈ $a_{1(0\ exp)}$)
**Dash lines** : lower bound from an isotropic initial fabric, upper bound from a fabric more anisotropic ($a_{1(0)}$ = 0,42)

**To consider a non isotropic initial fabric similar to the one measured is essential to provide the best fit with data.**

**Comparison enlighten areas where flow conditions depart from uniform compression (inversed thinning function)**




## TO SUMMARIZE:

----- Global trend of fabric evolution comparable with the GRIP or EPICA Dome C core: uniaxial compression as the main deformation mode. Clear departure from this trend in relation with climatic transitions.
--- Non isotropic fabrics in the firn, with a clear impact on the fabric evolution along the core. Must be associated with firn densification processes (strain concentration at junction between ice aggregates).
----- Strong evidence of dynamic recrystallization processes from 1400 m depth, and higher on isolated samples (1171 m for instance): signature of a highly heterogeneous state of strain.
--- Comparison with simulation of an ideal uniaxial compression: departure from the ideal case associated with climatic transitions. Impact of shear associated with changes of viscosity. Role of such changes on the thinning function irregularities.
----- Possible signature of dome movement in the past and / or changes in firn anisotropy associated with abrupt changes in dust content (Delmonte et al. 2010 J. Quater. Sci.).

PERSPECTIVES:
--- Model simulation can be use to inverse the fabric data to provide adjustement parameters to constrain the error matrix of the dating inverse modelling (Lemieux-Dudon et al. 2010 Quater. Sc. Rev. 29)
----- Quantify the role of tephra layers on changes in ice viscosity (Narcisi et al. 2010 J. Quater. Sc. 25)
--- Grain size measurements in progress.

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