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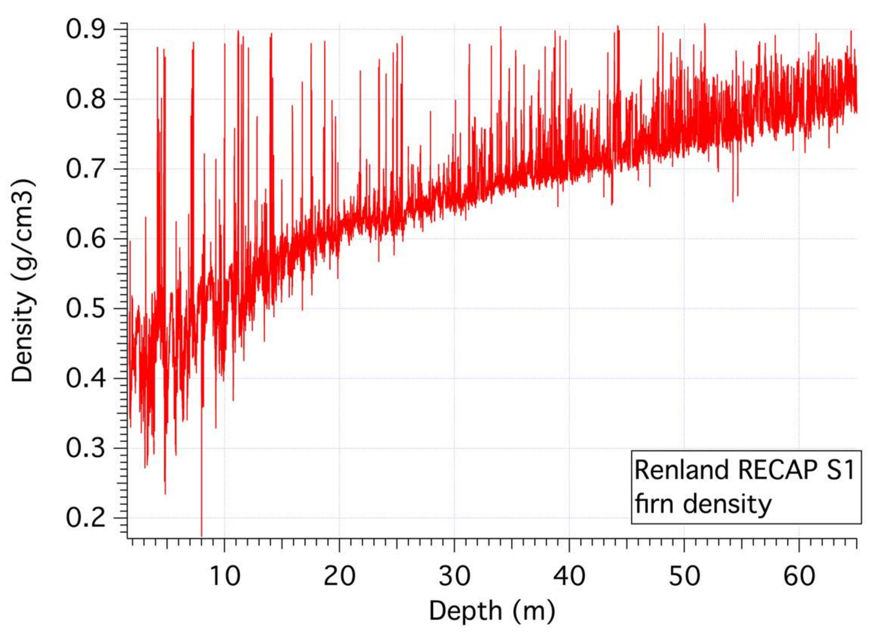
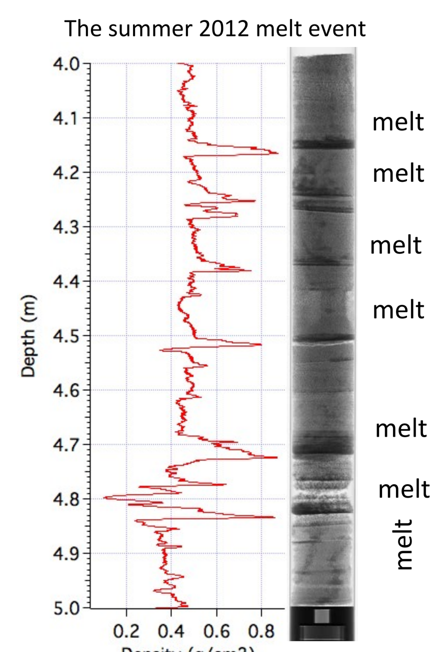
Bubble observations and analysis of the Renland ice core

Bubble studies on the Renland ice core are from particular interest: the Renland ice core includes the oldest bubbly ice retrieved so far in ice core drilling projects and it contains bubbly ice that has been exposed to tremendous deformation and thinning. What can we learn about climate conditions during densification, pore close-off, melting, strain and deformation?

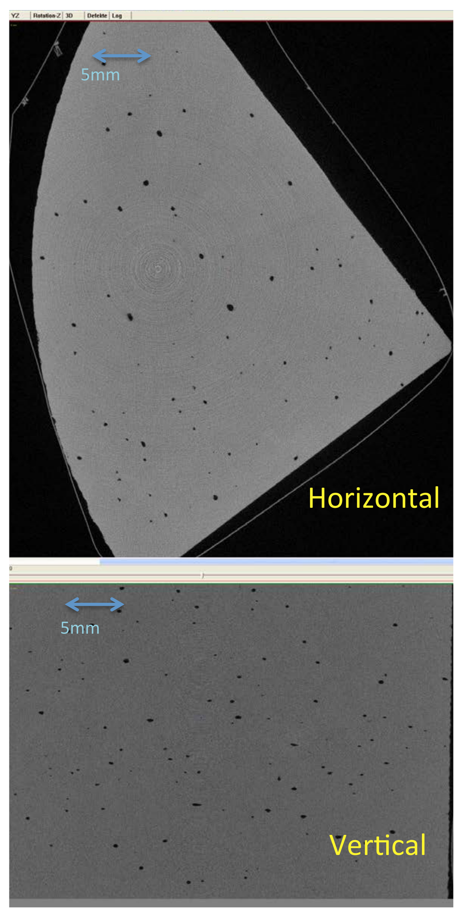
In this preliminary work we present first 3D-microfocus-X-ray CT measurements and estimates for bubble shape, size, porosity and number densities. The most surprising finding are distinct layers of elongated bubbles which appear in many depths. They might be probably linked to layers that have been formerly affected by melt and are maybe not a result of deformation. Are they useful as seasonal marker for dating issues?

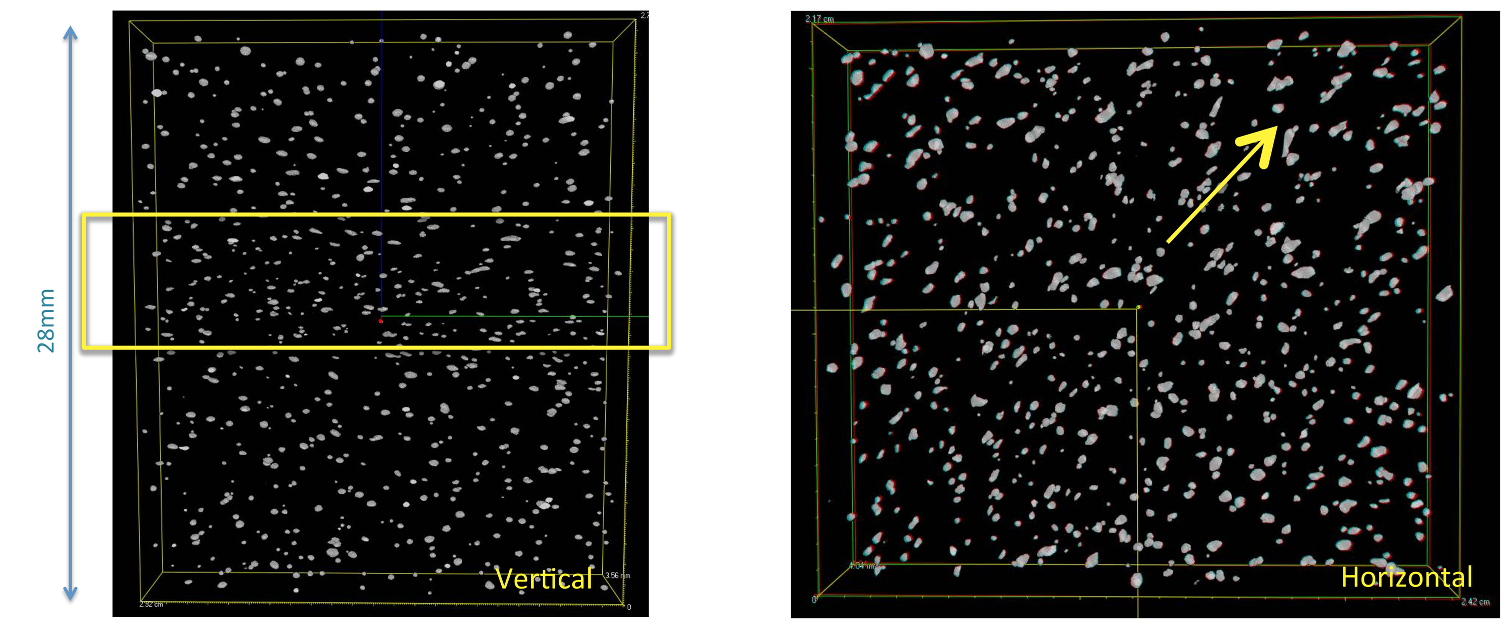
Location of the Renland drilling project RECAP (May-June 2015): 71N18'14'', 26W 42'48'', 2340m a.s.l., Tmean=-18°C, 460mm w.eq./a. Total length: 584m. Prelimary considerations suggest Holocene and Glacial ice with Eemian ice close to bedrock.





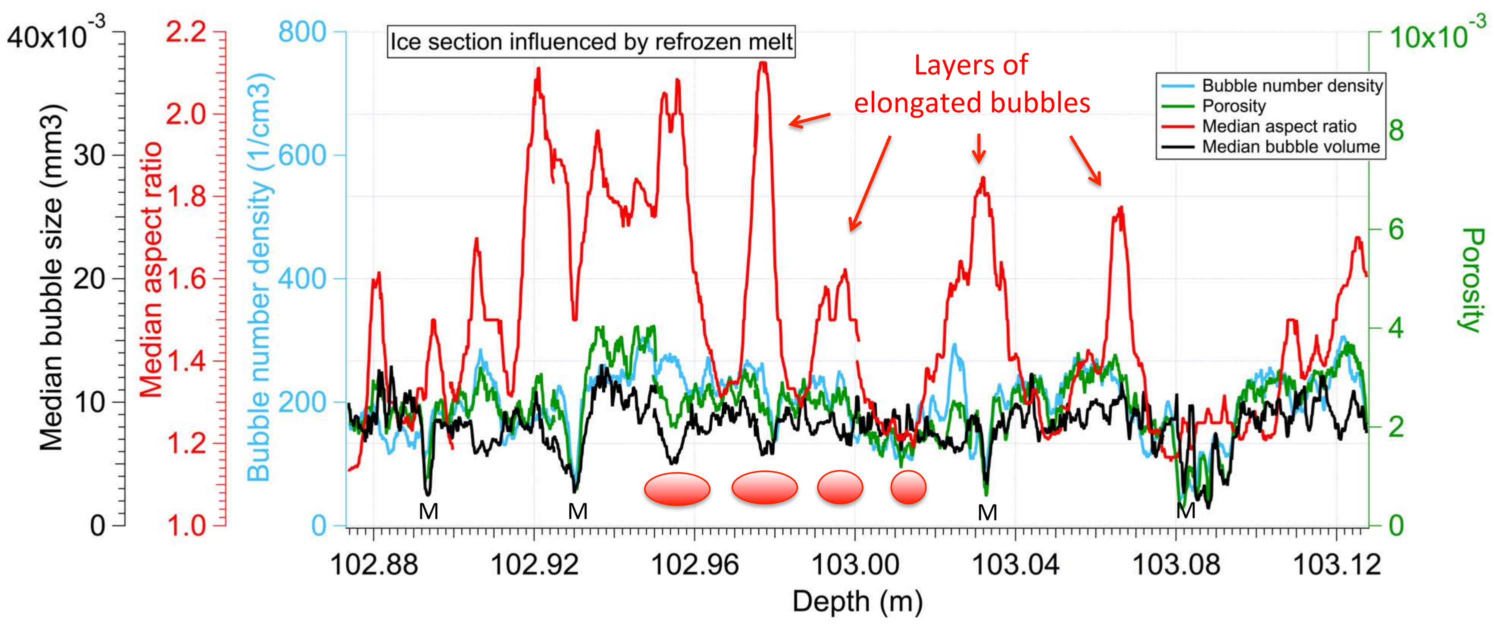
BEFORE BUBBLE FORMATION: The modern firn at RECAP is characterized by the periodic occurence of melt layers and infiltrated firn indicated by high density peaks in the profile (left) or as dark patches in the x-ray scans of the core bags (right).





METHOD: The core-scale AWI-ICE-CT is used for the 3D-reconstruction of air inclusions in ice of the SC-stripes (3cmx3cm quarter pieces, 55cm length) with a spatial resolution of 18µm. Horizontal and vertical sections of raw images (air bubbles in black) and binarized volumes (air bubbles in white) are shown. The selected volume includes a distinct layer of elongated bubbles highlighted in the vertical cross section by the yellow rectangle. Many bubbles are aligned in the horizontal as well (yellow arrow). Sample: Bag580 ≈ 319m depth.

Fig. A



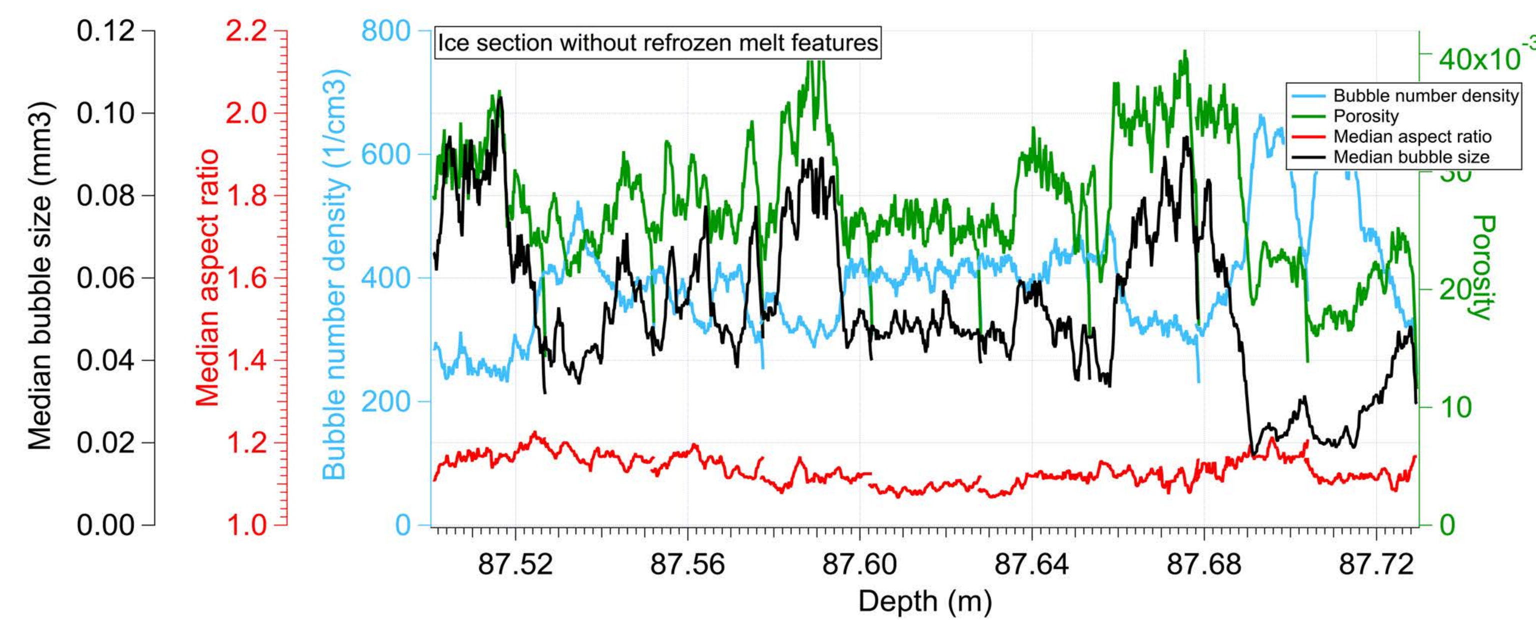
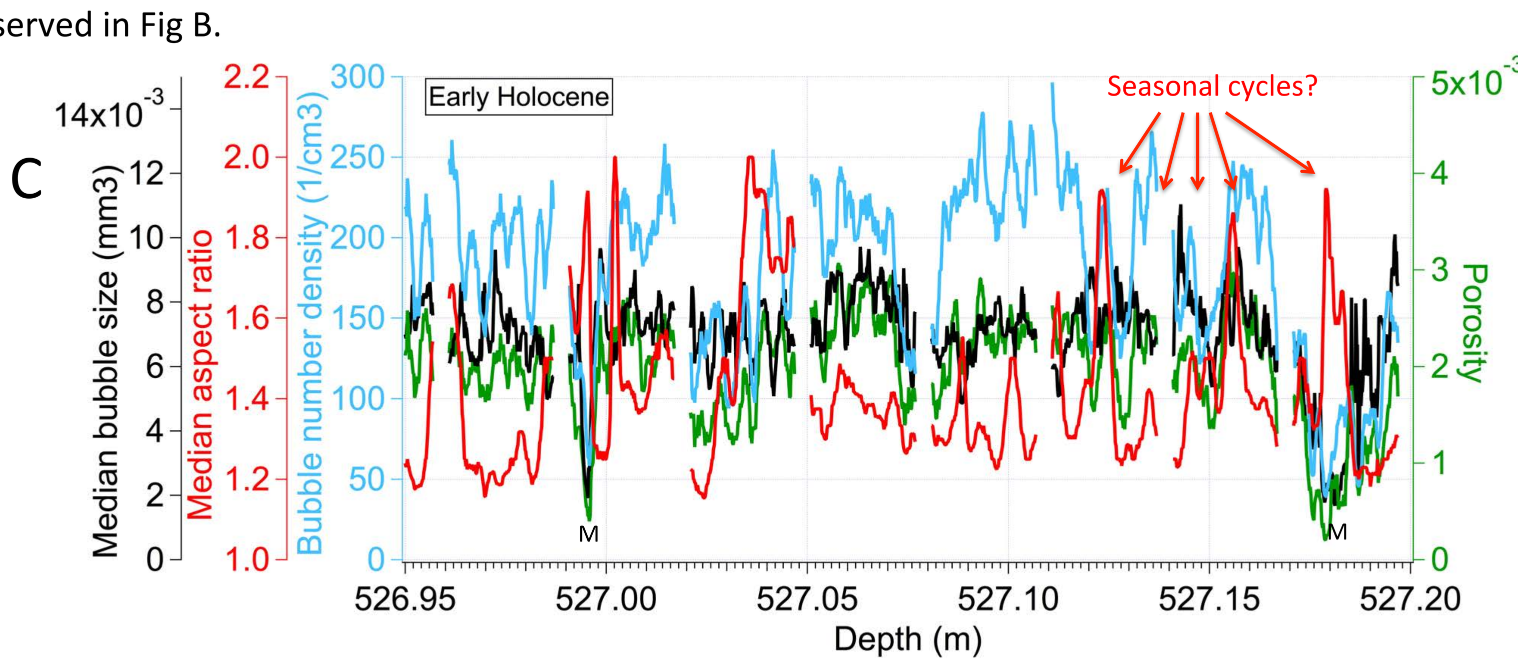


Fig. B

COMPARISON OF BUBBLE PROPERTIES between ice sections close (Fig. A) and apart (Fig. B) from meltlayers. Bands of deformed, horizontally elongated bubbles occur in the vicinity of meltlayers (M). The red curve in Fig. A displays the aspect ratio defined by the mean lateral dimension divided by the vertical dimension and reaches values of more than 2. A positive correlation between bubble size, bubble number density and porosity is developed (Fig A, black, blue and green lines). This correlation in melt-affected ice is partly opposed to bubbly ice from dry snow zones where bubble number density is anticorrelated to porosity and bubble size as it is observed in Fig B.

Fig. C



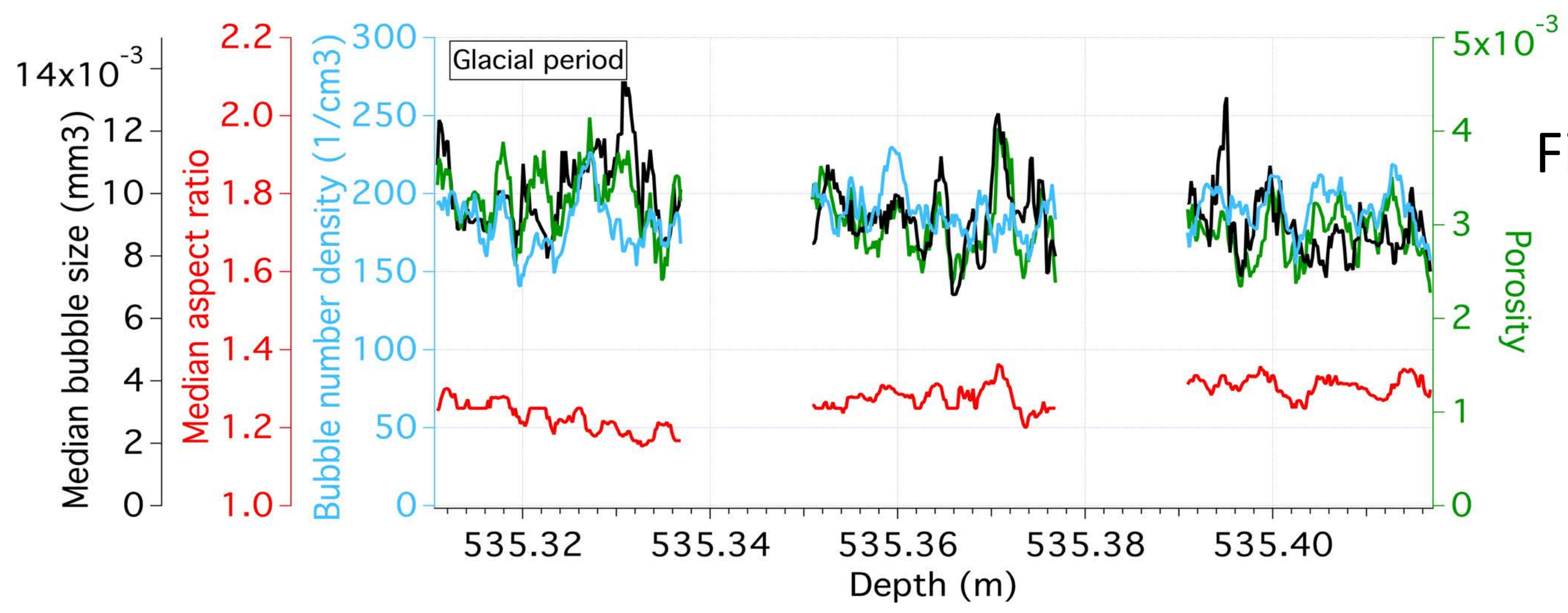
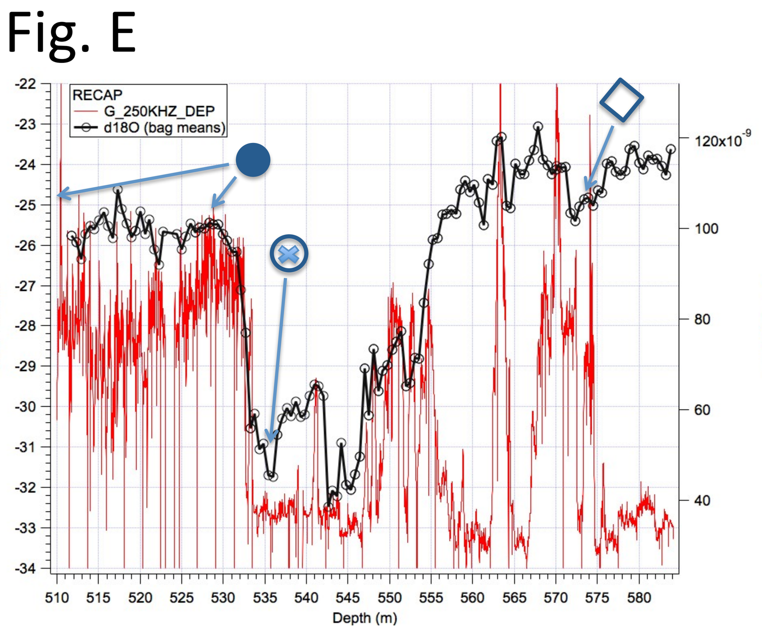


Fig. D

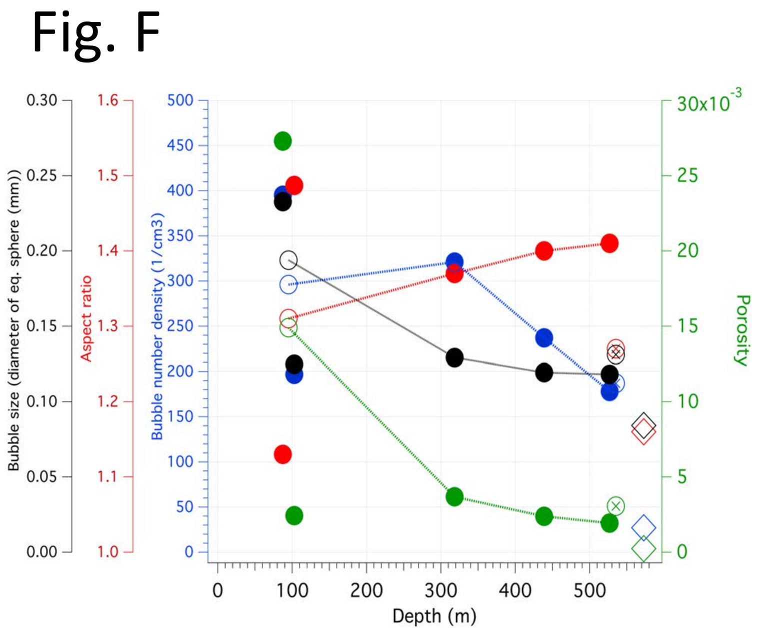
COMPARISON OF BUBBLE PROPERTIES between ice sections from EARLY HOLOCENE (Fig. C) and LAST GLACIAL (Fig. D). The early Holocene ice shows a continuous sequence of distinct layers of elongated bubbles in a centimetre distance (red curve, Fig C). In the Glacial ice only small variations in the aspect ratio are visible (Fig D). Bubble numbers differ not significantly between the two climate phases, porosity and bubble sizes are slighty higher in the Glacial ice than in the early Holocene.

Fig. E



Bag-mean isotope and DEP profiles of the lowest 75m part of the Renland ice core (Fig E) and the EVOLUTION OF MEAN BUBBLE PROPERTIES WITH DEPTH (Fig. F) Solid circles represent the Holocene period, the open circles with a cross are values from the Glacial period. The open diamonds are probably from the EEM-period close to bedrock (Fig. E)

Fig. F



Conclusions

Process: Bubble record is dominated by melt infiltration processes
-> occurrence of distinct layers of elongated, non-spherical bubbles
-> large variations (>>50%) in bubble size, shape, number and porosity
-> imposed correlation between bubble numbers and porosity/size

Proxy: Bubble aspect ratio as seasonal marker?
(elongated bubbles as indication for summer)

Climate: Less and more deformed bubbles point to a warm early Holocene

Outlook: Searching for not-melt-affected layers to investigate the inprint of deformation on bubble distribution functions and bubble shape

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