Variability of gas-trapping characteristics on the central Antarctic Plateau

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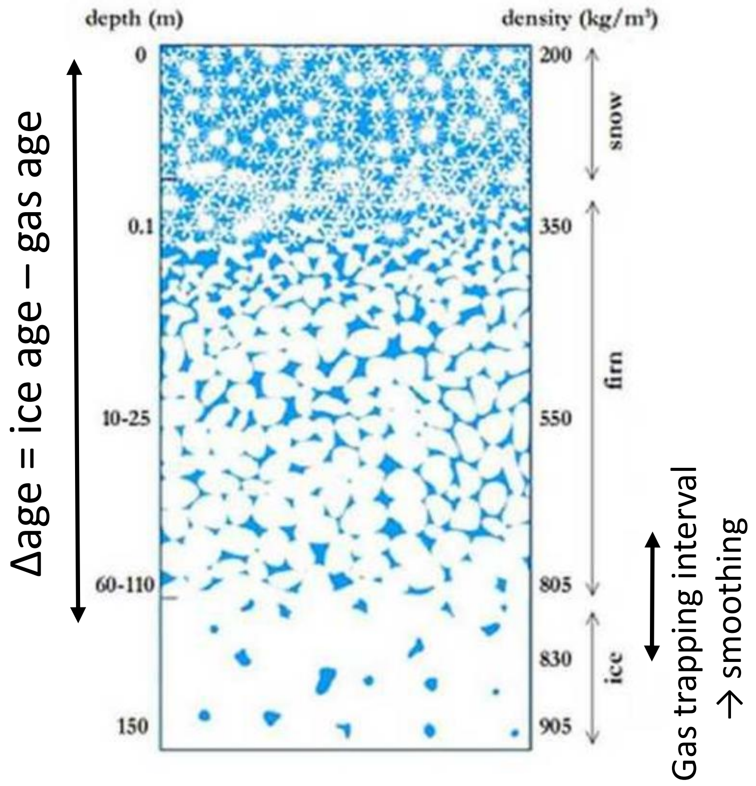
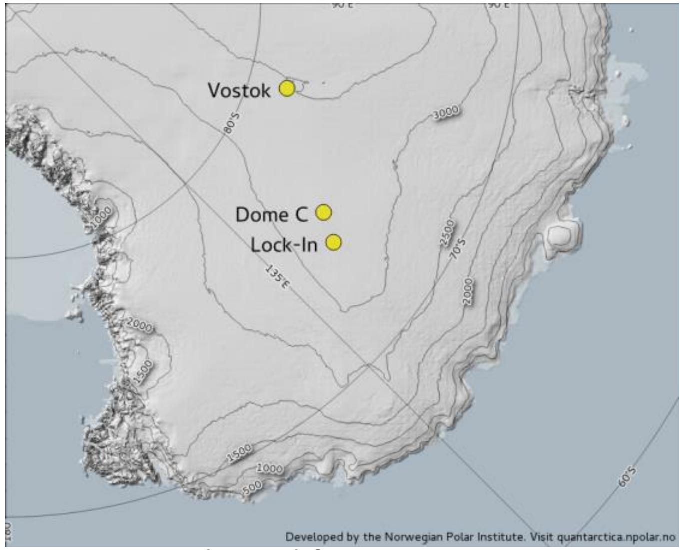


Gas trapping characteristics control Δage and the smoothing of gas signals



Adapted from Fourteau, CP, 2020

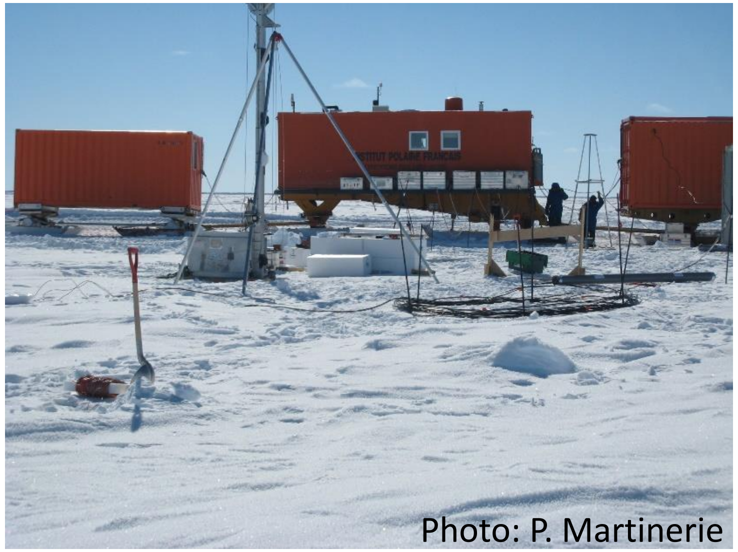
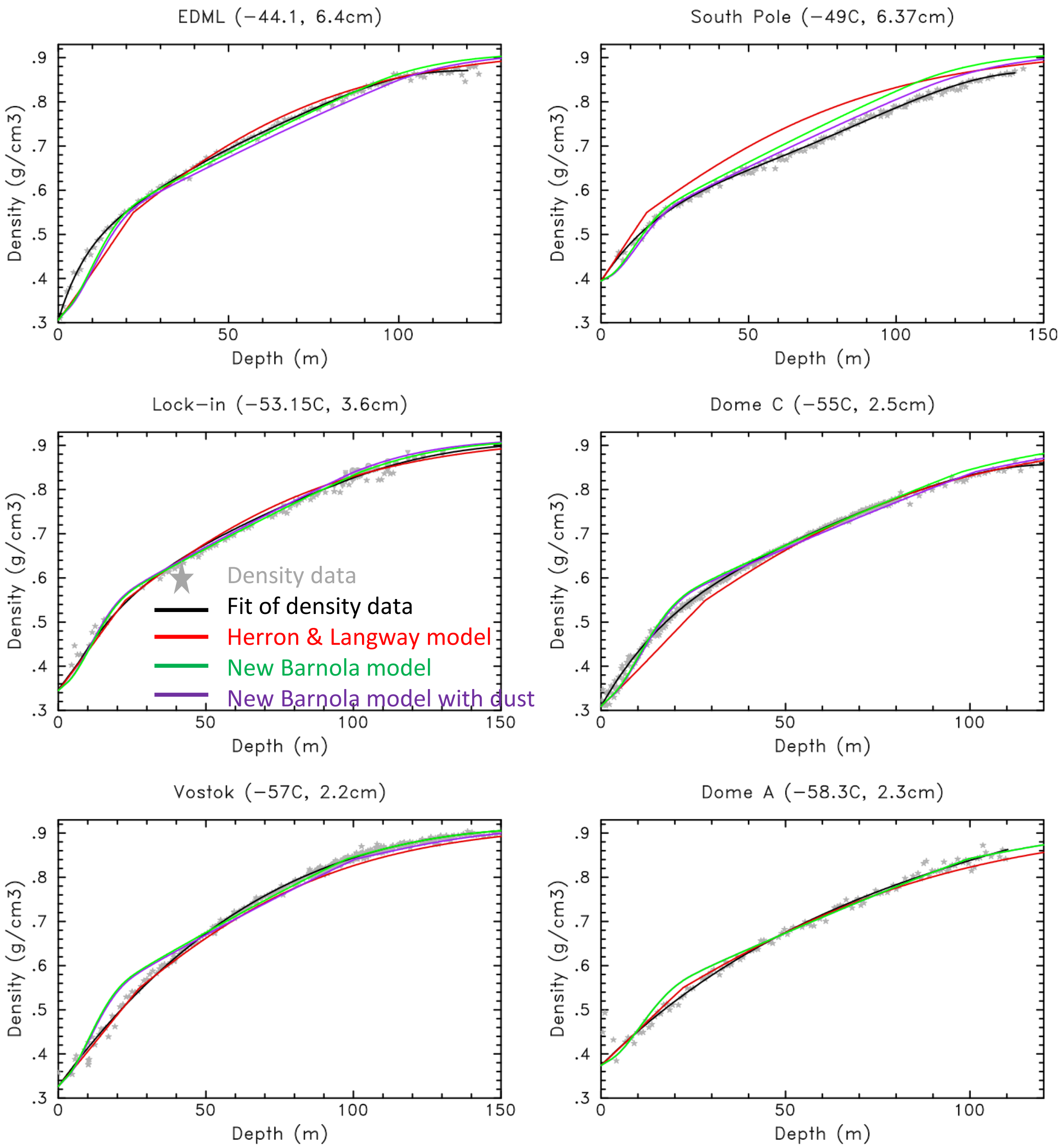


Photo: P. Martinerie

New drilling & firn air pumping site : Lock-in 136 km from Dome C
74°8.31'S, 126°9.51'E; 3209 m asl
Tmean=-53.13°C accu=3.6 cm w.eq/yr
Compared with other Antarctic Plateau sites

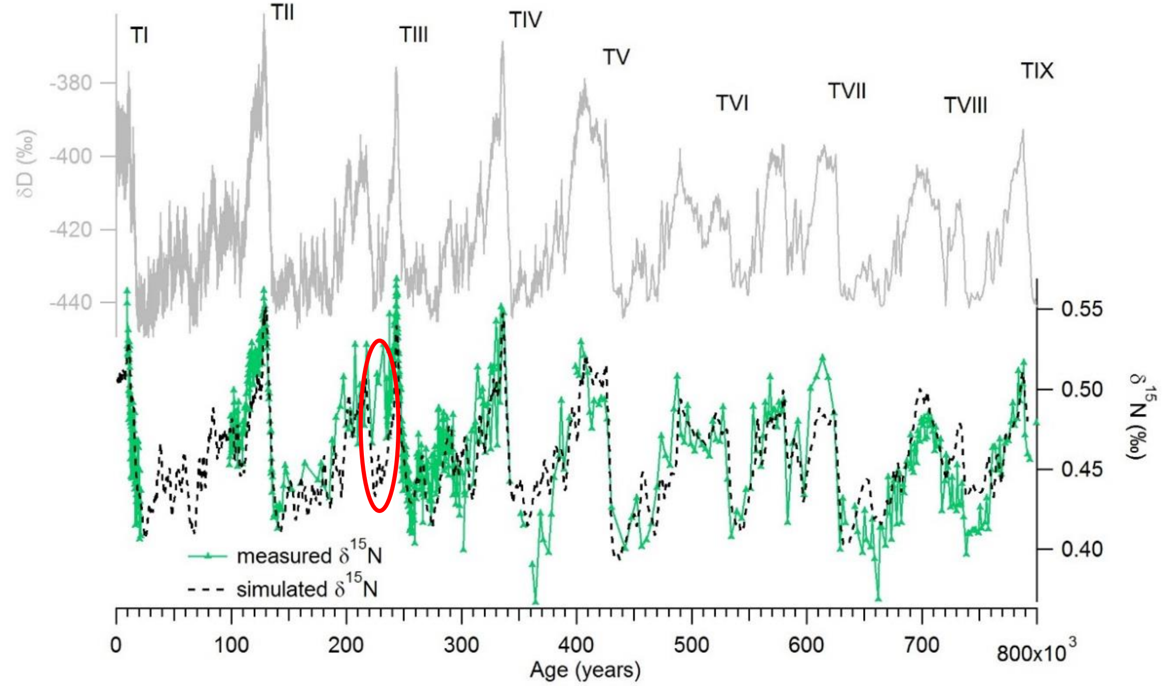
Density profile and densification modelling



Breant et al., CP, 2017 modified, with Lock-in

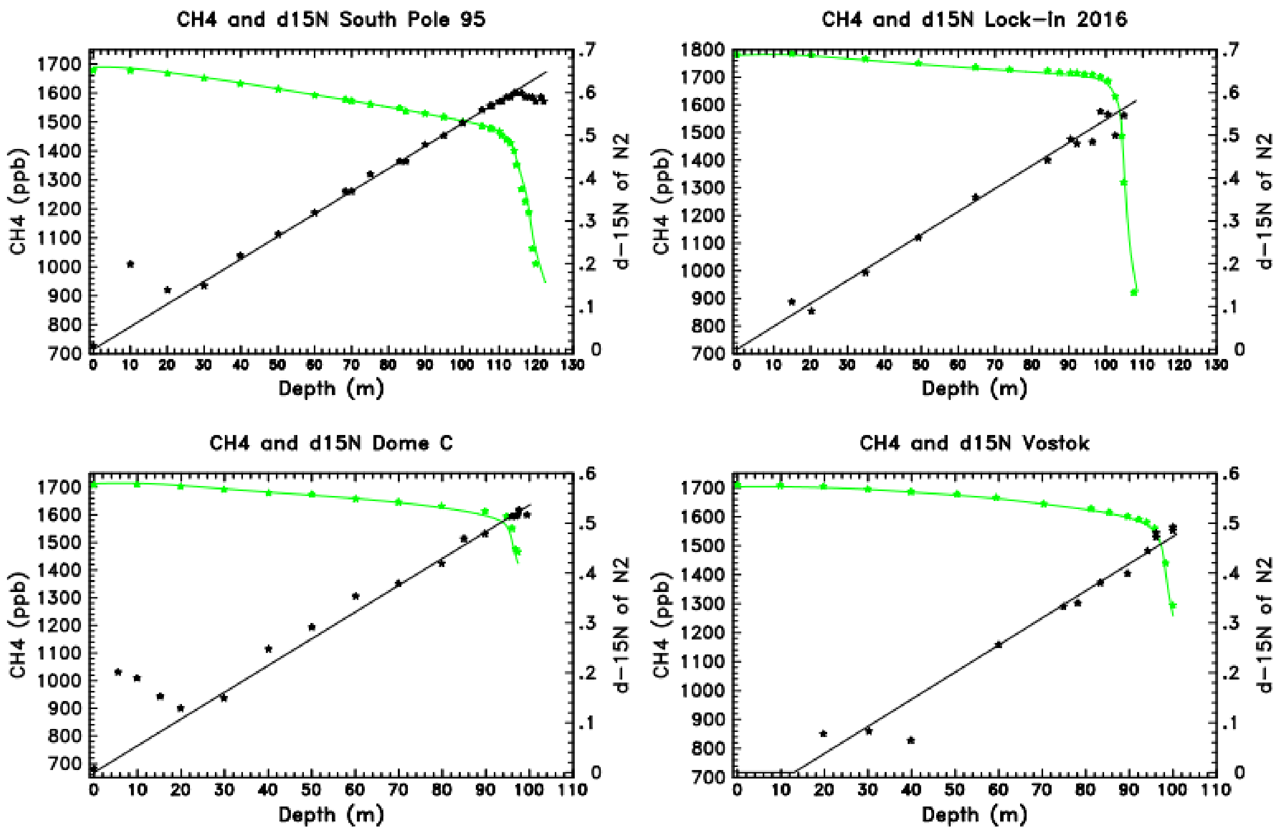
Lock-in appears as an "easy to simulate" site with densification models (Herron and Langway, J Glaciol., 1989 ; Bréant et al., CP, 2017)
But Antarctic plateau sites show a large variability in the shape of their measured density profiles

The new version of Barnola densification model (Bréant et al., CP, 2017) now simulates correctly the general shape of EDC $\delta^{15}N$ profile
But localised anti-phase behaviour remain (example shown in red)

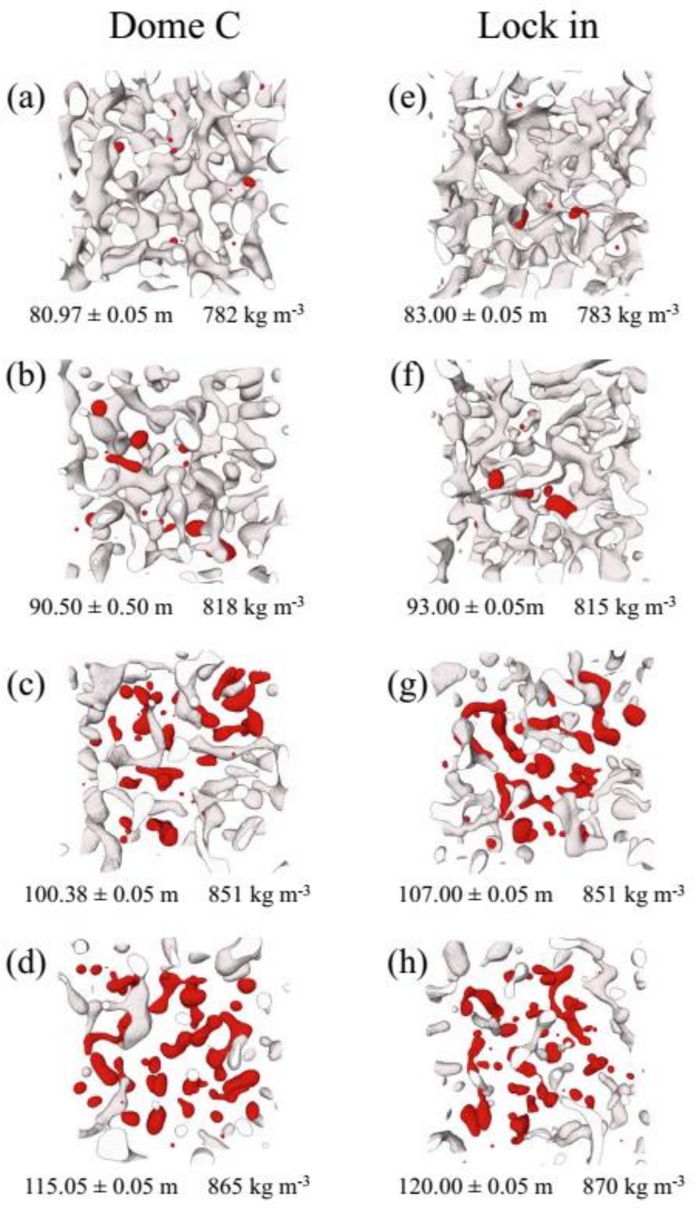


Bréant et al., QSR, 2019, supplement

Contrasted gas transport in deep firn



Witrant et al., ACP, 2012 ; Yeung et al., Nature, 2019



Burr et al., TC, 2018

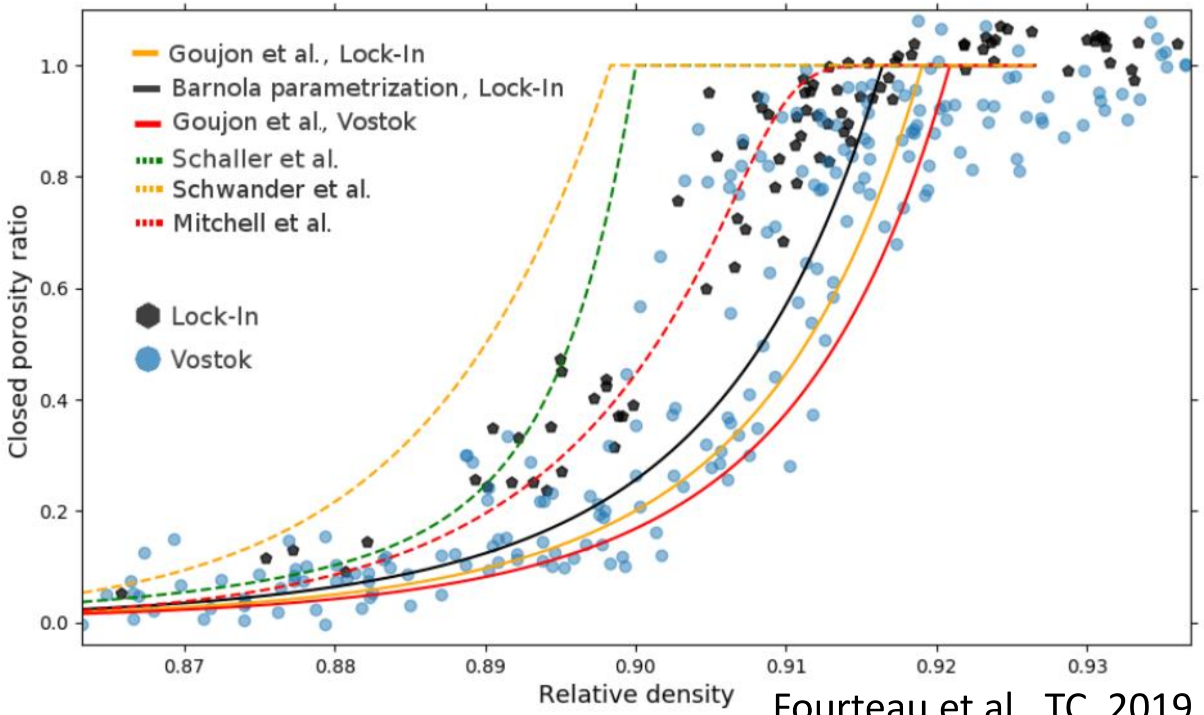
CH_4: low concentrations (old air) at South Pole and Lock-in
much higher concentrations in deep firn at Dome C and Vostok

$\delta^{15}N$: Plateau in South Pole deep firn, (variability at Lock-in), no
plateau at Dome C and Vostok → diffusive firn deep down

Tomography: may be due to larger pore diameter at Dome C than Lock-in

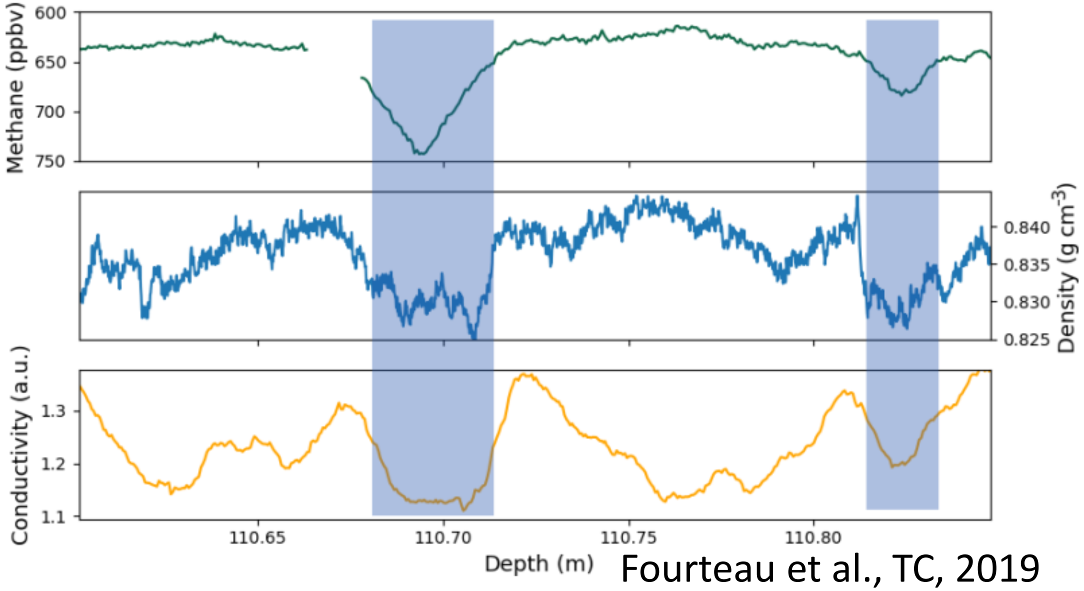
Pore closure in the firn

Closed porosity data



Fourteau et al., TC, 2019

Layered gas trapping at Lock-in



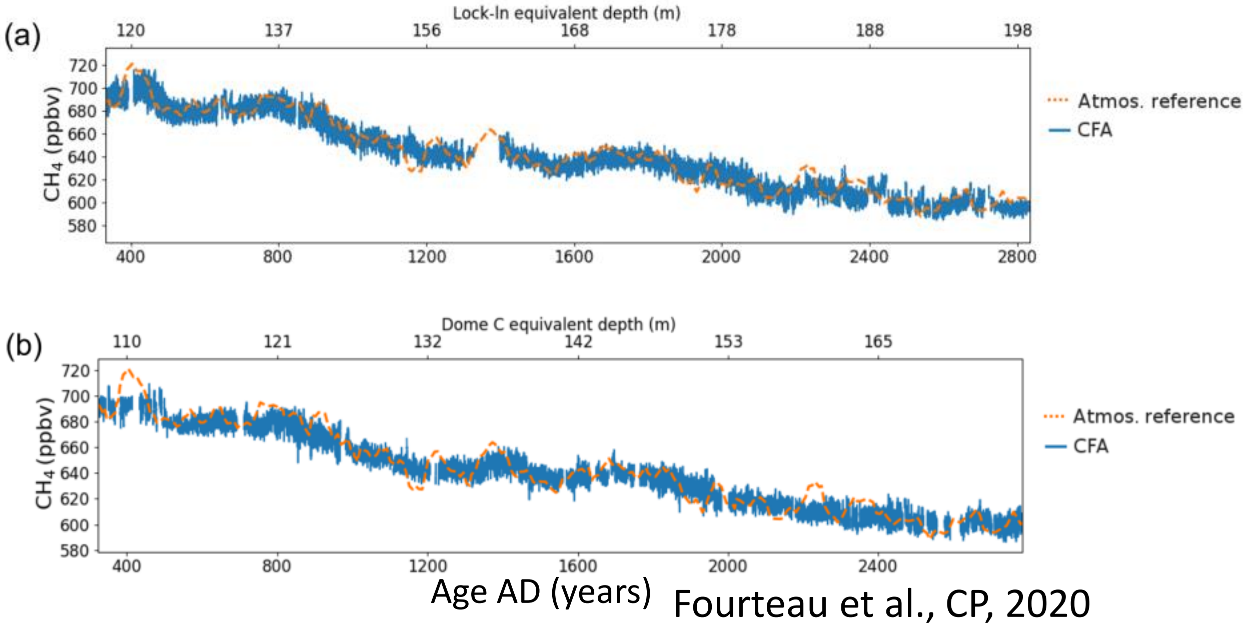
Fourteau et al., TC, 2019

Consistent results with pycnometry and tomography
New parameterizations with pore closure at lower densities
inconsistent with air content data
This can’t be due to different compression rates in open and
closed pores (Fourteau et al., Frontiers Earth Sci, 2020)
Reversible pore closure?

High resolution measurements:
Correlated anomalies in gas trapping (CH_4),
density and liquid conductivity

Chemical impurities responsible for the
liquid conductivity variations need further investigation

Smoothing and layering



Fourteau et al., CP, 2020

Recent past:

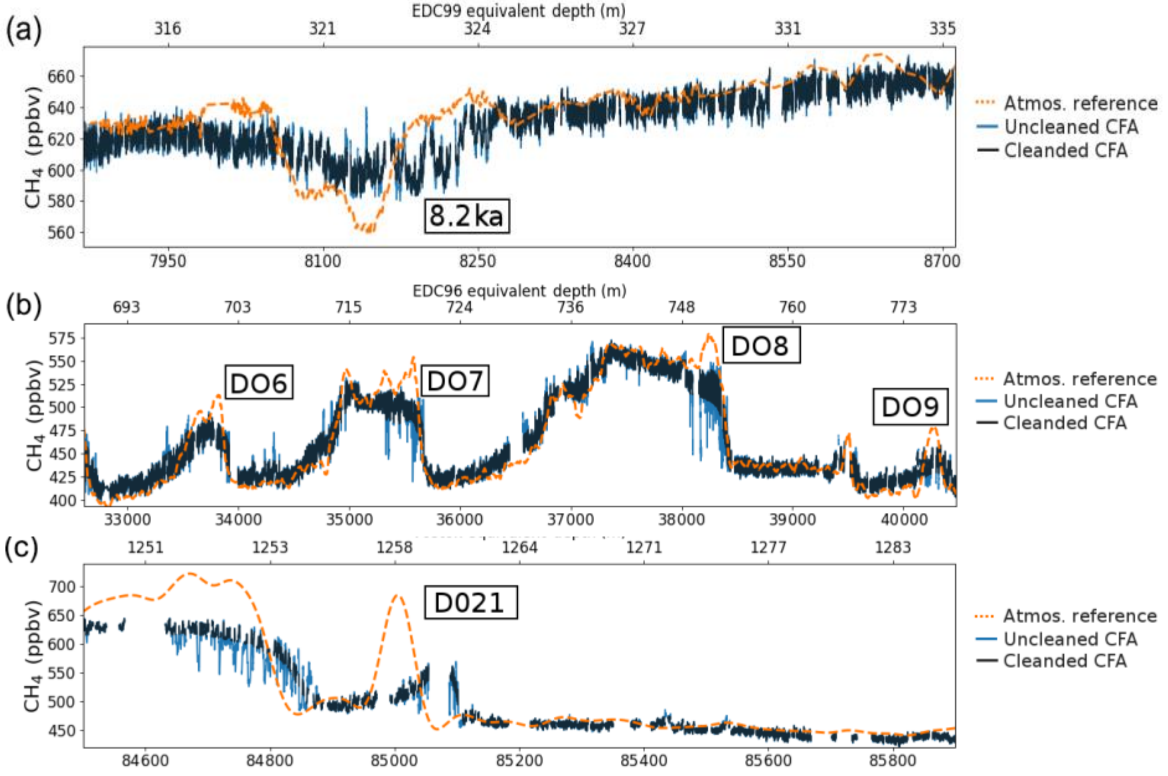
Smoothed signals at Lock-in and Dome C with respect to WAISD

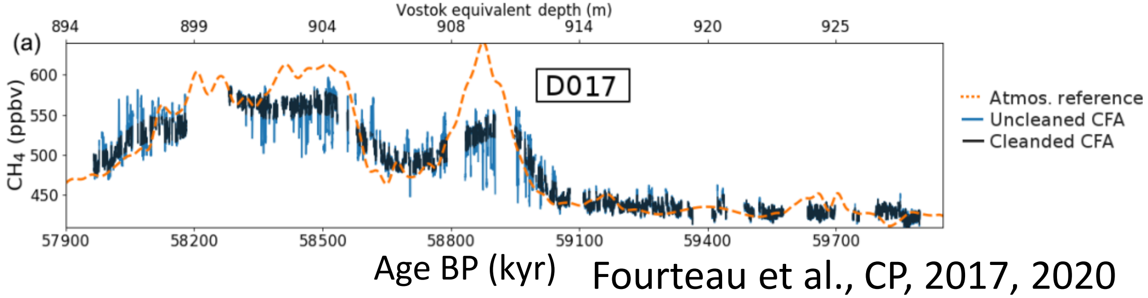
Insufficient atmospheric variability to detect layering

Conclusions:

Important smoothing at low accumulation sites due to long trapping duration

Consistent but limited data to evaluate gas signals smoothing of Antarctic Plateau sites





Fourteau et al., CP, 2017, 2020

Fast events of last glacial cycle:

Multiple evidences of layered gas trapping

Important smoothing compared to WAISD

Constrains gas age distributions in past conditions

Conclusions and references

Conclusions/perspectives:

- Unexplained contrasted shapes of density profiles
- Contrasted behaviour of gas transport with very old / very young air in deep firn
- Inconsistency between closed porosity and air content data needs investigation
- Impurity-related gas age anomalies should be explored
- Important smoothing of gas signals at low accumulation sites to be further constrained

  → Need to further investigate gas trapping processes

  → A slight increase in temperature and accumulation in Dome C like sites could induce a large change in firn behaviour

References:

Bréant et al., CP, 2017, https://www.clim-past.net/13/833/2017/
Bréant et al., QSR, 2019, https://www.sciencedirect.com/science/article/abs/pii/S0277379118310059
Burr et al., TC, 2018, https://www.the-cryosphere.net/12/2481/2018/
Fourteau et al., CP, 2017, https://www.clim-past.net/13/1815/2017/
Fourteau et al., TC, 2019, https://www.the-cryosphere.net/13/3383/2019/
Fourteau et al., CP, 2020, https://www.clim-past.net/16/503/2020/
Fourteau et al., Frontiers Earth Sci, 2020, https://www.frontiersin.org/articles/10.3389/feart.2020.00101/full
Herron and Langway, J. Glaciol., 1980, https://doi.org/10.3189/S0022143000015239
Witrant et al., ACP, 2012, https://www.atmos-chem-phys.net/12/11465/2012/
Yeung et al., Nature, 2019, https://www.nature.com/articles/s41586-019-1277-1