Supplementary online material

Ice core evidence for decoupling between mid-latitude atmospheric water cycle and Greenland temperature during the last deglaciation

A. Landais[1,*], E. Capron[2, 3], V. Masson-Delmotte[1], S. Toucanne[4], R. H. Rhodes[5], T. Popp[2], B. Vinther[2], B. Minster[1], F. Prié[1]

[1] Laboratoire des Sciences du Climat et de l'Environnement, IPSL, UMR 8212, CEA-CNRS-UVSQ-UPS, Gif sur Yvette, France

[2] Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK-2900, Copenhagen, Denmark

[3] British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK

[4] IFREMER, Laboratoire Géophysique et enregistrement Sédimentaire, CS 10070, 29280 Plouzané, France

[5] Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ UK

[*] Corresponding author: phone : +33 (0)169084672, email : amaelle.landais@lsce.ipsl.fr, ORCID : 0000-0002-5620-5465

Keywords: Deglaciation, Water isotopes, ^{17}O-excess, d-excess, Heinrich event, Mystery interval

1- Statistical analyses

To infer objectively the timing of the changes observed in the d-excess (from NGRIP and GRIP) and ^{17}O excess (from NGRIP) records within Heinrich Stadial 1, we use the ramp-fitting method computed in the Fortran 77 program RAMPFIT (Mudelsee, 2000), which follows the simple approach that the shifts observed in the tracers can be characterized as a ramp, i.e. a linear change from one stable state to the other. This method is based on weighted least-squares regression to determine within a prescribed search time interval the ramp location and a bootstrap simulation to estimate the uncertainty of the results. For each record, we run RAMPFIT on three different time windows to test the sensitivity of the ramp-fitting method to the prescribed search time interval. The results for the onset, the end and associated standard deviation associated with the NGRIP and GRIP d-excess and NGRIP ^{17}O-excess records are displayed on Table S1. No robust ramp can be obtained from the $\delta^{18}O$ signals at GRIP, NGRIP and GISP2. Note that the timings for the onset and the end of the d-excess and ^{17}O-excess changes within HS1 inferred with RAMPFIT are in good agreement with those determined using an alternative ramp-fitting method (A. Grinsted and S. O. Rasmussen, comm. pers.) based on probabilistic inference using an ensemble Markov Chain Monte Carlo (MCMC) sampler (Goodman and Weare, 2000). Indeed, timing differences for the onset and the end of the GRIP and NGRIP d-excess and NGRIP ^{17}O-excess changes between the two ramp-fitting methods are of ~40 years on average.

	t_end rampfit (ka)	t_onset rampfit (ka)
NGRIP d-excess		
15.1 - 17.1 ka	16.016 ± 0.267	16.114 ± 0.267
15.6 - 16.6 ka	15.991 ± 0.052	16.114 ± 0.045
15.85 -16.35 ka	15.991 ± 0.057	16.114 ± 0.042

GRIP d-excess		
15.1 -17.1 ka	15.895 ± 0.176	16.479 ± 0.157
15.6-16.6 ka	15.895 ± 0.149	16.479 ± 0.123
15.85-16.35 ka	16.178 ± 0.084	16.204 ± 0.068
NGRIP ^{17}O-excess		
15.1 -17.1 ka	16.078 ± 0.236	16.519 ± 0.211
15.6 - 16.6 ka	16.078 ± 0.189	16.519 ± 0.155
15.85 - 16.35 ka	16.153 ± 0.088	16.179 ± 0.075

Table 1: Statistical determination of the timing of onset and end of the ramp for changes in NGRIP d-excess, GRIP d-excess and NGRIP ^{17}O-excess over three different temporal windows (15.1-17.1 ka, 15.6-16.6 ka and 15.85-16.35 ka)

2- Correlations

Figures S1, S2 and S3 display the relationships between d-excess and δ^{18}O as well as ^{17}O-excess vs δ^{18}O at NGRIP and GRIP over HS1 (14700 – 17000 yrs BP, red) and over a period of same length encompassing the onset of the Bølling-Allerød (12900 – 15200 yrs BP, blue). While there is a clear anticorrelation between δ^{18}O and d-excess over the sequence encompassing the onset of the Bølling-Allerød, no clear relationship can be observed between δ^{18}O and d-excess at NGRIP and GRIP over HS1 (Figures S1 and S3). Similarly, while the correlation between ^{17}O-excess and δ^{18}O is significant over the sequence encompassing the onset of the Bølling-Allerød and Younger Dryas, it is much less visible over HS1 at NGRIP (Figure S2).

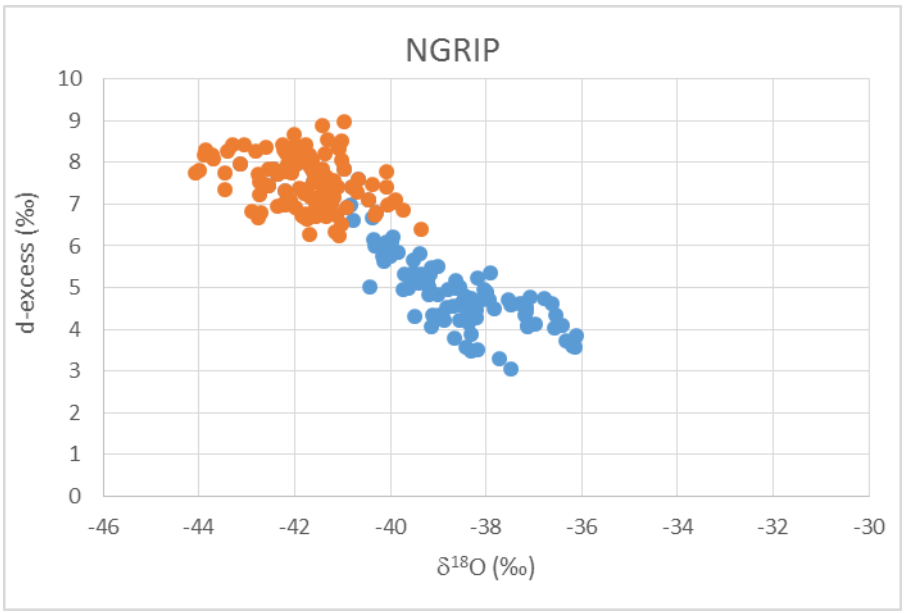

Figure S1: Relationship between d-excess and $\delta^{18}O$ at NGRIP over the periods 14700-17000 yrs BP (red) and 12900-15200 yrs BP (blue).

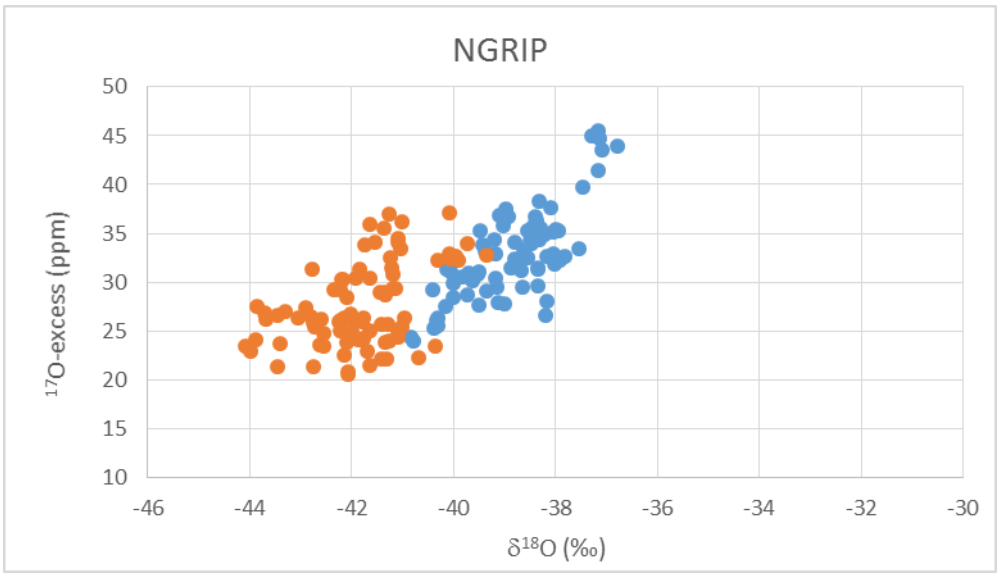

Figure S2: Relationship between ^{17}O-excess (5 points average) and $\delta^{18}O$ at NGRIP over the periods 14700-17000 yrs BP (red) and 12900-15200 yrs BP (blue).

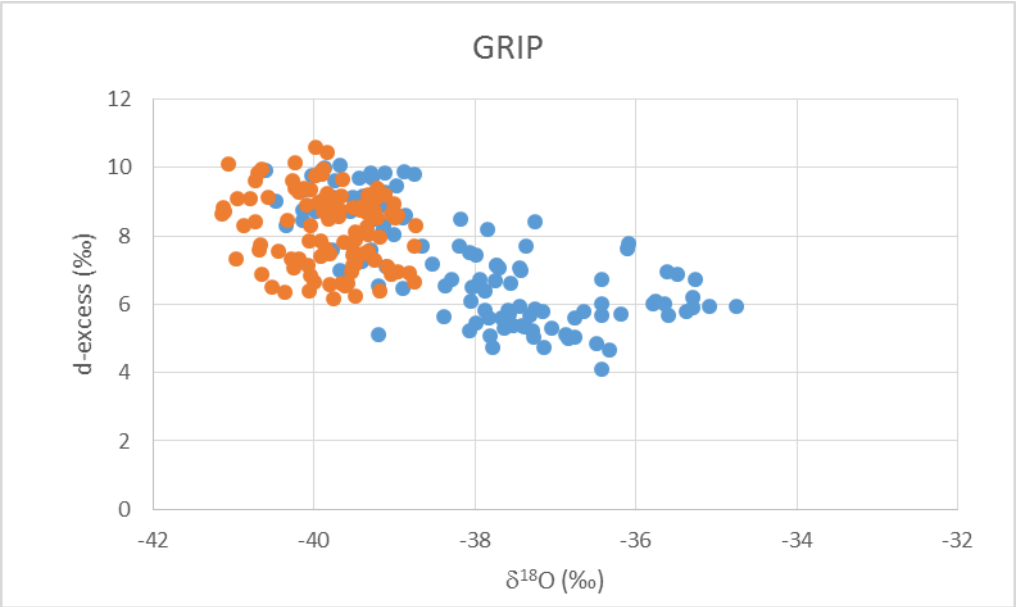

Figure S3: Relationship between d-excess and $\delta^{18}O$ at GRIP over the periods 14700-17000 yrs BP (red) and 12900-15200 yrs BP (blue).

References:

Goodman, J. and Weare, J.: Ensemble samplers with affine invariance, Communications in Applied Mathematics and Computational Science, 5(1), 65-80, 2010

Mudelsee, M.: Ramp function regression: A tool for quantifying climate transitions, Comput. Geosci., 26(3), 293–307, 2000