Uncertainties on the ^{10}Be-peak empirical constraints

Here, we give more detail on the uncertainties related to the empirical estimates of Δage and Δdepth during the Laschamp event. The principle is to use a linear relationship on an interval to define the tie points. The uncertainties are calculated on the length of the interval.

1 Δage method

1.1 Application at EDC

We estimate the uncertainty of the Δage value as the square root of the sum of the following uncertainties:

1) The uncertainty in the ^{10}Be NGRIP-EDC synchronisation
This inaccuracy is due to the structure of the signal of the ^{10}Be peak. The estimated measurement uncertainty is about 1,1 m for each of the two sub-peaks (Raisbeck et al., 2007) at both cores (annual layer thickness is roughly the same), corresponding to an uncertainty in ages of 70 years and 90 years for the first and second sub-peak respectively.

2) The uncertainty in the isotope NGRIP – methane EDC synchronisation
Due to the different shapes of the records, this is the largest source of uncertainty. At EDC, the depths DC-d_1 for both ^{10}Be sub-peaks coincide with DO #8 in methane. The synchronisation cannot be done at their exact location because the methane and isotope variations are not abrupt enough. So we synchronise the transitions at the onset of DO #8 and DO #7. We then use a linear interpolation, in ages at NorthGRIP and in depths at EDC, to determine NG-d_2. The uncertainty of this synchronisation is estimated as the square root of the sum of the squares of : the uncertainties of the synchronisations at onsets of DO #8 and DO#9 (estimated at 150 yr) plus the uncertainty in the linear interpolation process.
We estimated the latter uncertainty as 10% of the time interval from the ^{10}Be sub-peak to the closest DO onset (DO #7 for the first sub-peak and DO #8 for the second sub-peak). This gives respective uncertainties of 120 and 60 yr.

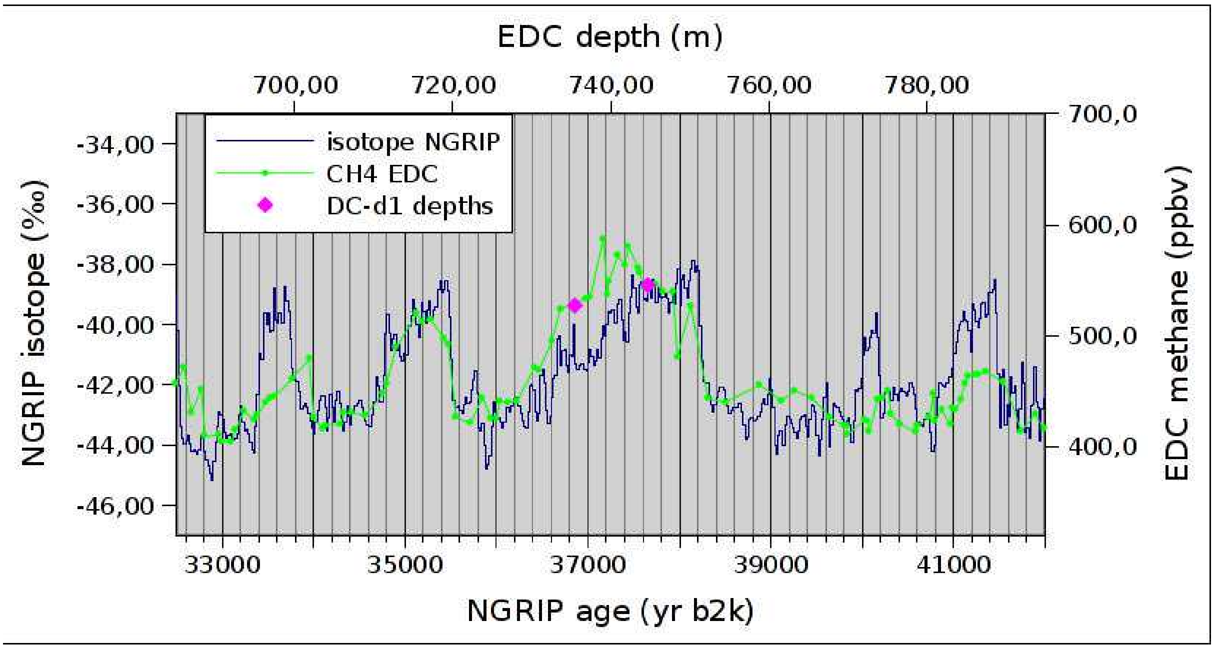

Figure 1: Illustration of the isotope NorthGRIP - methane EDC synchronisation.

3) The error in the GICC05 age difference *a1-a2*, that is to say the number of uncertain layers between the *NG-d2 and NG-d1* depths (which is much smaller than the uncertainty on the absolute age at these depths).
We obtain 210 and 220 years for the first and second ^{10}Be sub-peak respectively.

We obtain a total uncertainty of 290 for both ^{10}Be sub-peak.

1.2 Applications at EDML

The method is the same as for EDC. The total uncertainty for the Δage value is thus the square root of the sum of:

1) The inaccuracy in the ^{10}Be NGRIP-EDML synchronisation
In addition to the 1.1 m uncertainty in the EDC-NorthGRIP synchronisation described above, which corresponds to a value of 1.94 m at EDML, we have to take into account the uncertainty in the EDML-EDC volcanic synchronisation: 0.23 and 0.35 m respectively (Ruth et al., 2007). We obtain uncertainties in depth of 2.17 and 2.29 m, corresponding to uncertainties in time of 120 and 130 yr, respectively.

2) The inaccuracy in the isotope NGRIP – methane EDML synchronisation
As for EDC, the synchronisation cannot be performed at the exact DML-d_1 depth in methane. So we synchronise the closest DO transitions, which are the onset of DO #10 and DO #8. The uncertainty is estimated to 150 yr for the two sub-peaks.
We then linearly interpolate between those two synchronisation markers, in age for NorthGRIP and in depth for EDML. The uncertainty, estimated as 10% of the time interval to the closest synchronisation marker, is estimated at 140 and 100 yr, respectively.

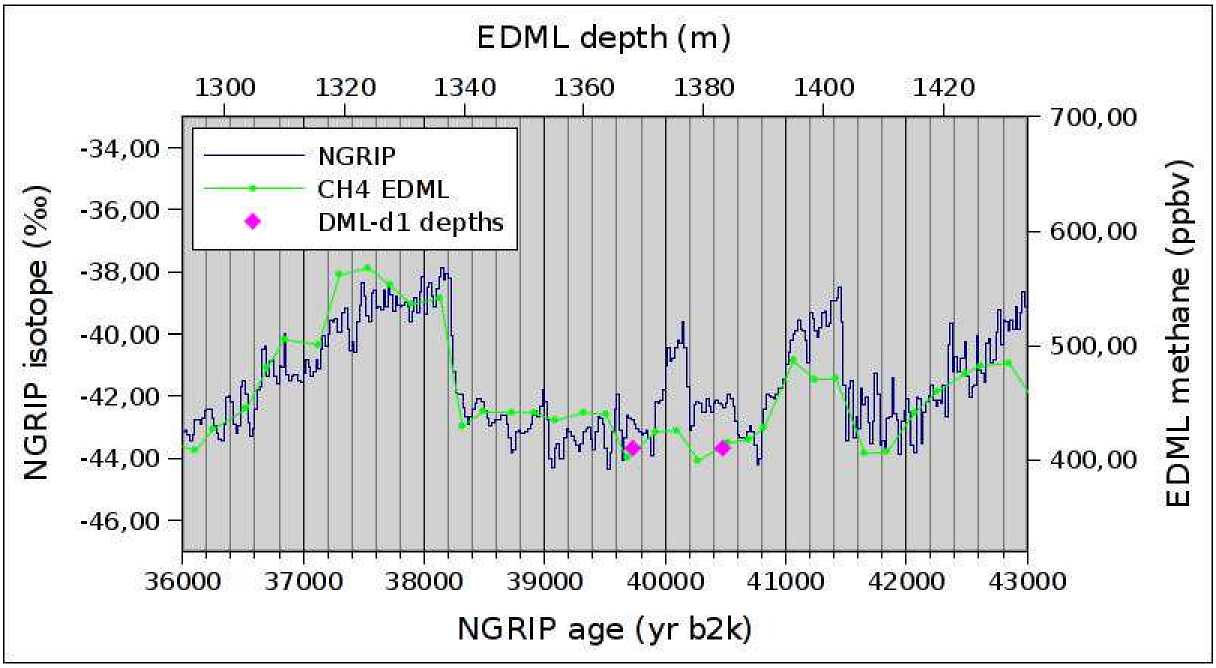

Figure 2: Illustration of the isotope NorthGRIP - methane EDML synchronisation.

3) The error in the GICC05 age difference *a1-a2*, that is to say the number of uncertain layers between the *NG-d2 and NG-d1* depths (which is much smaller than the uncertainty on the absolute age at this depth).

We obtain respectively 70 and 50 years for the first and second ^{10}Be sub-peak respectively.

We obtain a total uncertainty of 240 and 220 yr for each ^{10}Be sub-peak.

2 Δdepth method

2.1 Applications at EDC

The total uncertainty is estimated as the square root of the sum of:

1) The uncertainty in the ^{10}Be NGRIP-EDC synchronisation
As explained above, it is estimated at 1.1 m for both ^{10}Be sub-peaks.

2) The uncertainty in the isotope NorthGRIP – methane EDC synchronisation
The method is the same as for the Δage method, except that we now synchronise the NorthGRIP isotope at NG-d_1 with the EDC methane record. Fortunately, these two NorthGRIP depths fall very close to the onset and end of DO #10, making the synchronisation more precise (the uncertainty on the linear interpolation can be neglected). We estimate this uncertainty at 2 m at EDC for both ^{10}Be sub-peaks.

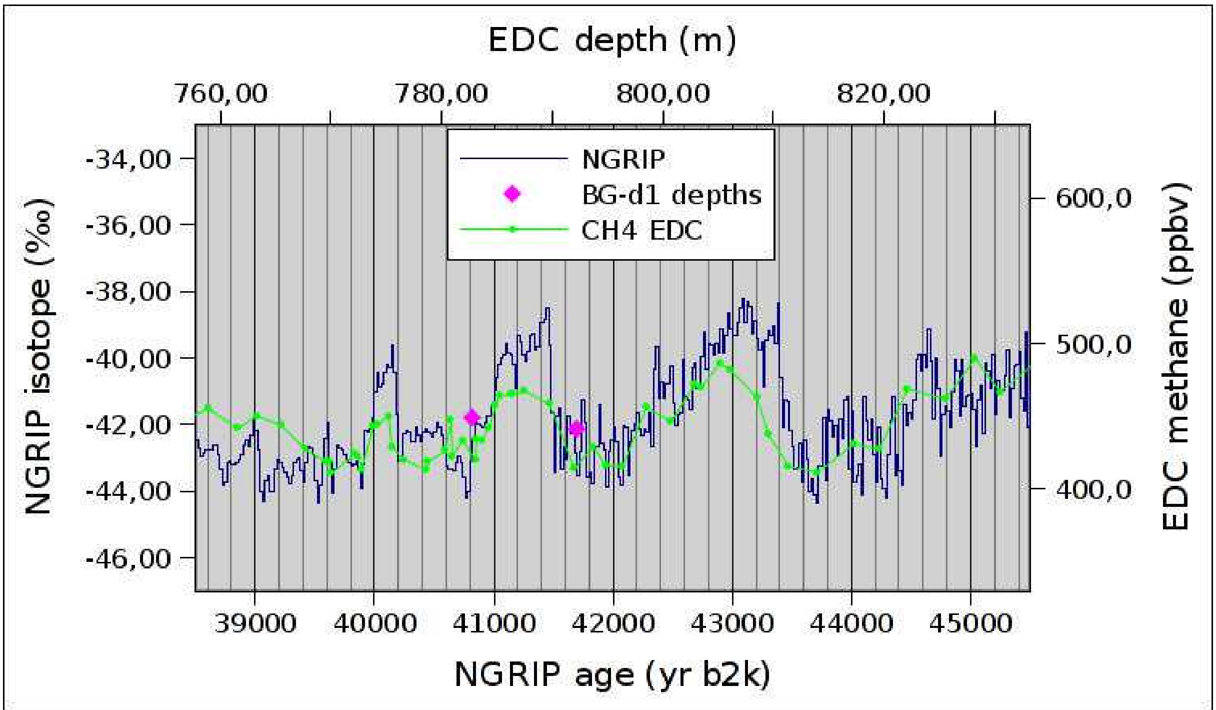

Figure 3: Illustration of the isotope NorthGRIP - methane EDC synchronisation.

The total uncertainty is estimated at 2.3 m for each ^{10}Be sub-peak.

2.2 Applications at EDML

The method is the same as for EDC. The total uncertainty for the Δage value is thus the square root of the sum of:

1) The uncertainty in the ^{10}Be NGRIP-EDML synchronisation

As described for the Δage method, this uncertainty is estimated at 2.2 and 2.39 m respectively.

2) The uncertainty in the isotope NGRIP – methane EDML synchronisation

Due to the different shapes of the records, especially on the DO 9 event, we have to take into account the important inaccuracy due to this method. The errors are estimated on the maximum uncertainties giving an error of 4m for the two sub-peaks.

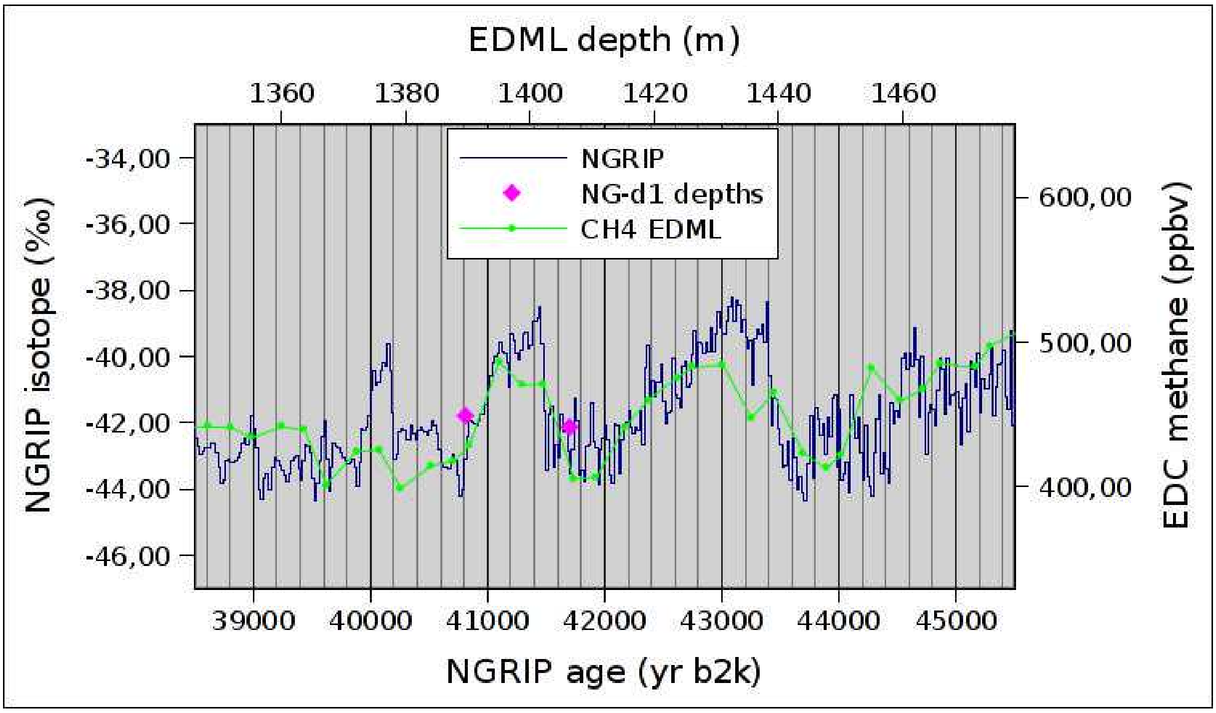

Figure 4: Illustration of the isotope NorthGRIP - methane EDML synchronisation.

The total uncertainty is estimated at 4.6 m for each ^{10}Be sub-peak.