Dating of terrestrial ice cores:

- Identify and count annual layers
- Synchronize with reference horizons
- Orbital matching/tuning
- Modelling

Z2 – 54.5 ± 2 kyr BP (NorthAtlantic Ash Zone II)
NorthGRIP time scale model ‘ss09sea’

Two fix points:
- End of Younger Dryas at 11,500 BP
- End of Marine Isotope Stage 5d at 110 kyr BP

Accumulation rates obtained from $\delta^{18}O$, assuming a relation: $\text{Acc} = \text{Acc}_0 \cdot \exp(b \cdot \Delta \delta^{18}O)$

Thinning of annual layers with depth calculated by ice-flow model

Correction for past shifts in sea water $\delta^{18}O$

Reconstructions of past accumulation rate

An example from the EPICA Dome C core, the East Antarctic plateau (Cauquoin et al 2015)

1) Assuming a physical link between moisture content and temperature of air masses:
   $Acc = Acc_0 \cdot \exp(b \cdot \Delta \delta^{18}O)$

2) Using $^{10}$Be and assuming a constant deposition flux. $^{10}$Be is produced by cosmic rays interacting with the atmosphere. Variations in $^{10}$Be flux are linked to variations in
   1) the geomagnetic field, 2) solar activity
The Greenland Ice Core Chronology 2005 (GICC05)

0 – 2 kyr: Three cores δ¹⁸O

2 – 4 kyr: DYE-3, GRIP δ¹⁸O

4 – 8 kyr: DYE-3 δ¹⁸O, δD (New!)

8 – 10 kyr: GRIP CFA, ECM

10 – 60 kyr: NGRIP CFA, ECM, VS

CFA = Continuous Flow Analysis
ECM = Electrical Conductivity Measurement
VS = Visual Stratigraphy
Datasets and acknowledgements

DYE-3, GRIP, and NorthGRIP stable isotopes and Electrical Conductivity Measurements (ECM)

Dansgaard et al., Nature, 364 (6434), 218-220, 1993
Johnsen et al., JQS, 16 (4), 299-307, 2001
NorthGRIP Members, Nature, 431, 147-151, 2004

Claus U. Hammer
Dorthe Dahl-Jensen
Annual layer counting in a mild glacial period
Greenland Interstadial 7 (GI-7), 35 kyr BP
Saksunarvatn tephra
9.0 ± 0.1 ¹⁴C kyr BP (Björck et al., 2001)
Tephra at 1528.6 m in GRIP (Grönvold et al., 1995)

Vedde tephra (Z1)
10,330 ± 65 ¹⁴C kyr BP (Wastegård et al., 1998)
Tephra at 1639.5 m in GRIP (Grönvold et al., 1995)

Fugloyarbanki tephra
23.2 ± 0.3 ¹⁴C kyr BP (Rasmussen et al., 2003)
Tephra at 1848.0 m in NGRIP (Davies et al., in prep.)

'33ka tephra'
33 ¹⁴C kyr BP (Rasmussen et al., 2003)
Tephra at 2067.0 m in NGRIP (Davies et al., in prep.)

Laschamp geomagnetic excursion
40.4 ± 2.0 kyr cal BP (Guillou et al., 2004)
Located around GI-10

North Atlantic Ash Zone II (Z2)
54.5 ± 2 kyr cal BP (Southon/McIntosh, 2004)
Tephra at 2359.5 m in NGRIP
GICC05 – Radiometric ages

![Radiometric Ages Graph]

Legend:
- IntCal04 (Reimer et al., 2004)
- Fairbanks0805 (Fairbanks et al., 2005)
- C-14 ages
- Ar-Ar ages

Key Events:
- North Atlantic ash layer II (Z2) (Southon/McIntosh, 2004)
- Laschamp event (Guillou et al., 2004)
- “33ka tephra” (Davies) (Rasmussen et al., 2003)
- Mono Lake event (Benson et al., 2003)
- Fugloyarbanki tephra (Davies et al., 2005) (Wastegård et al., 2006)
- Vedde tephra (Z1)