Fall in Earth's Dipole Moment is Intermittent

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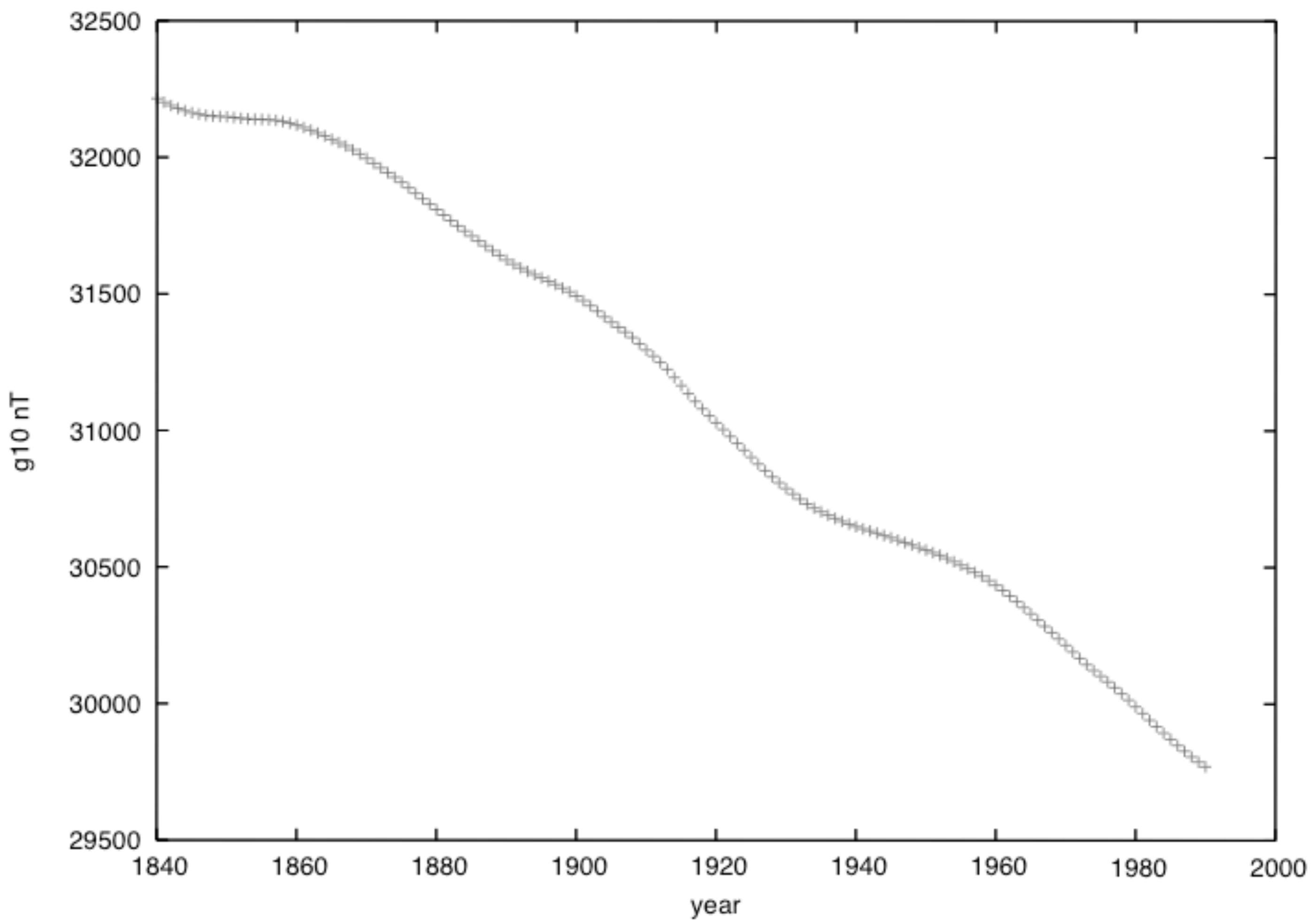
Carl Friedrich Gauss devised the first method to measure magnetic intensity in 1837, replacing Humboldt's measurements of relative intensity, made by timing the oscillation period of a suspended magnet. In the context of a global field model, relative intensity contains no more information than direction.

Alexander von Humboldt

Carl Friedrich Gauss

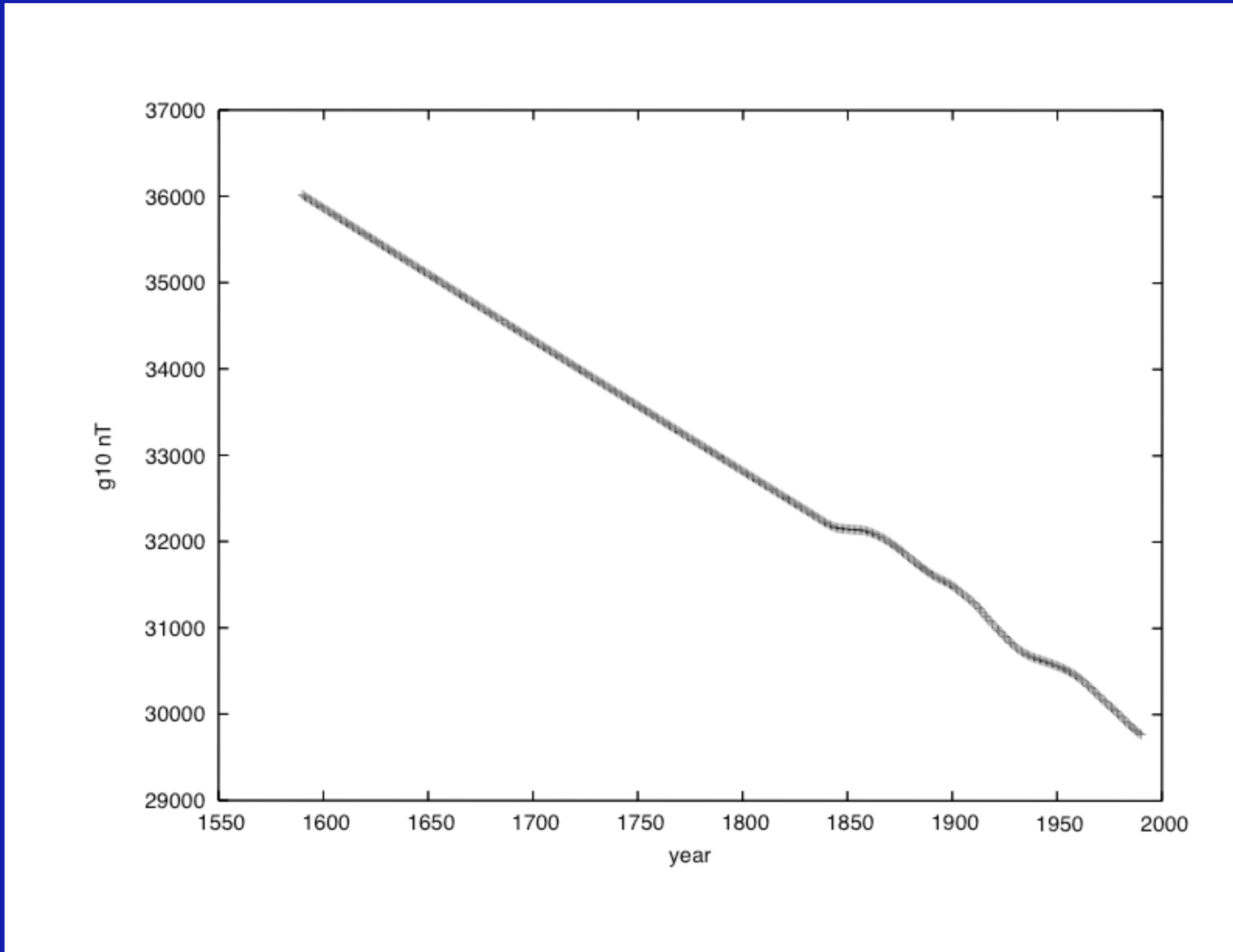
The *Göttinger Magnetische Verein* was set up to make global measurements in 1836. This was continued and driven for the next 40 years by Edward Sabine and Humphrey Lloyd in what is now called the *Magnetic Crusade.* This has left us with good global coverage of intensity from 1840 onwards, with no direct measurements earlier than 1837.

Fall of the dipole moment since AD1840



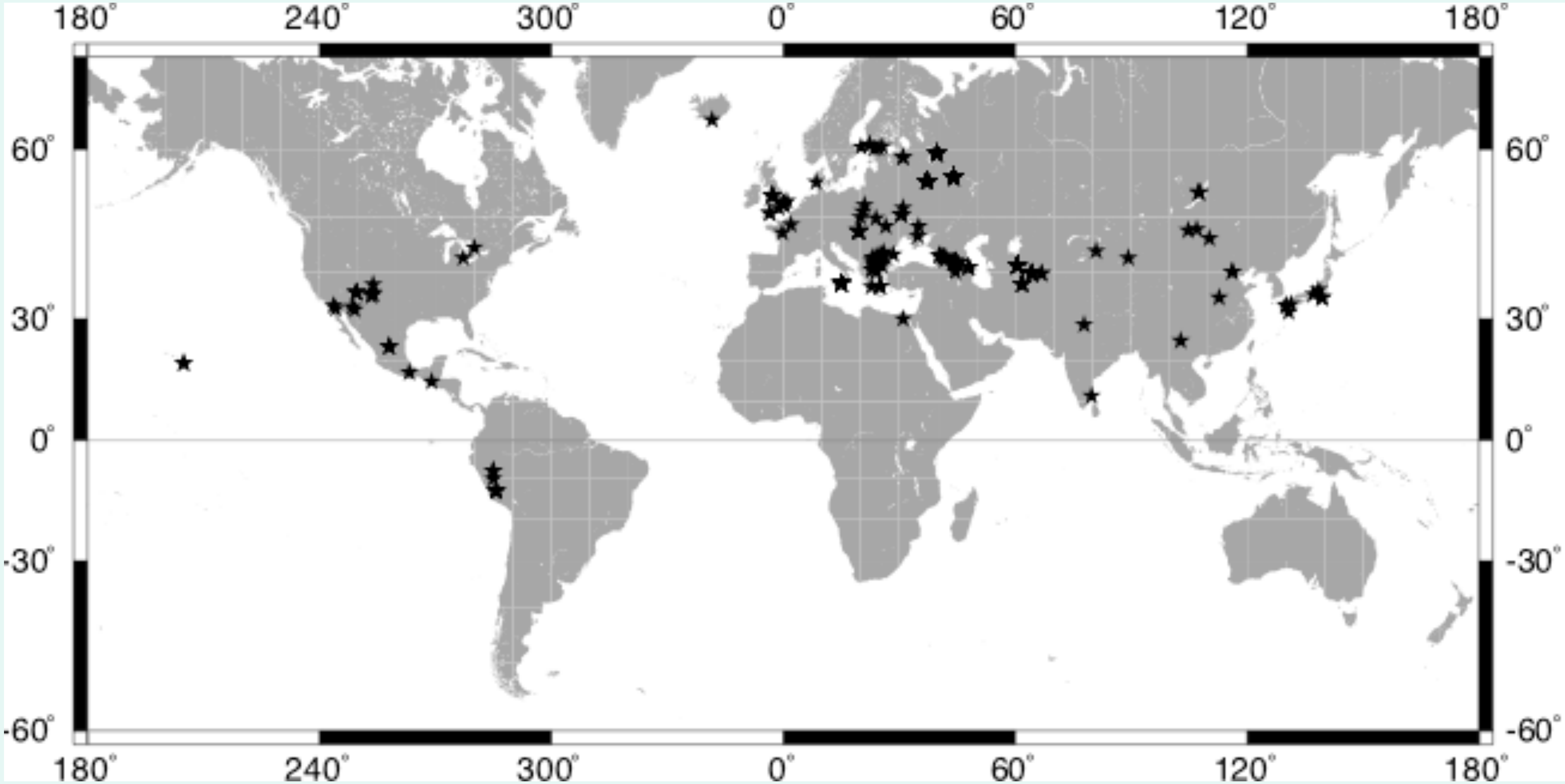
Fall of the dipole moment since AD1595

15 nT/year assumed before 1840



Paleo- and archeo-intensity data 1595-1840

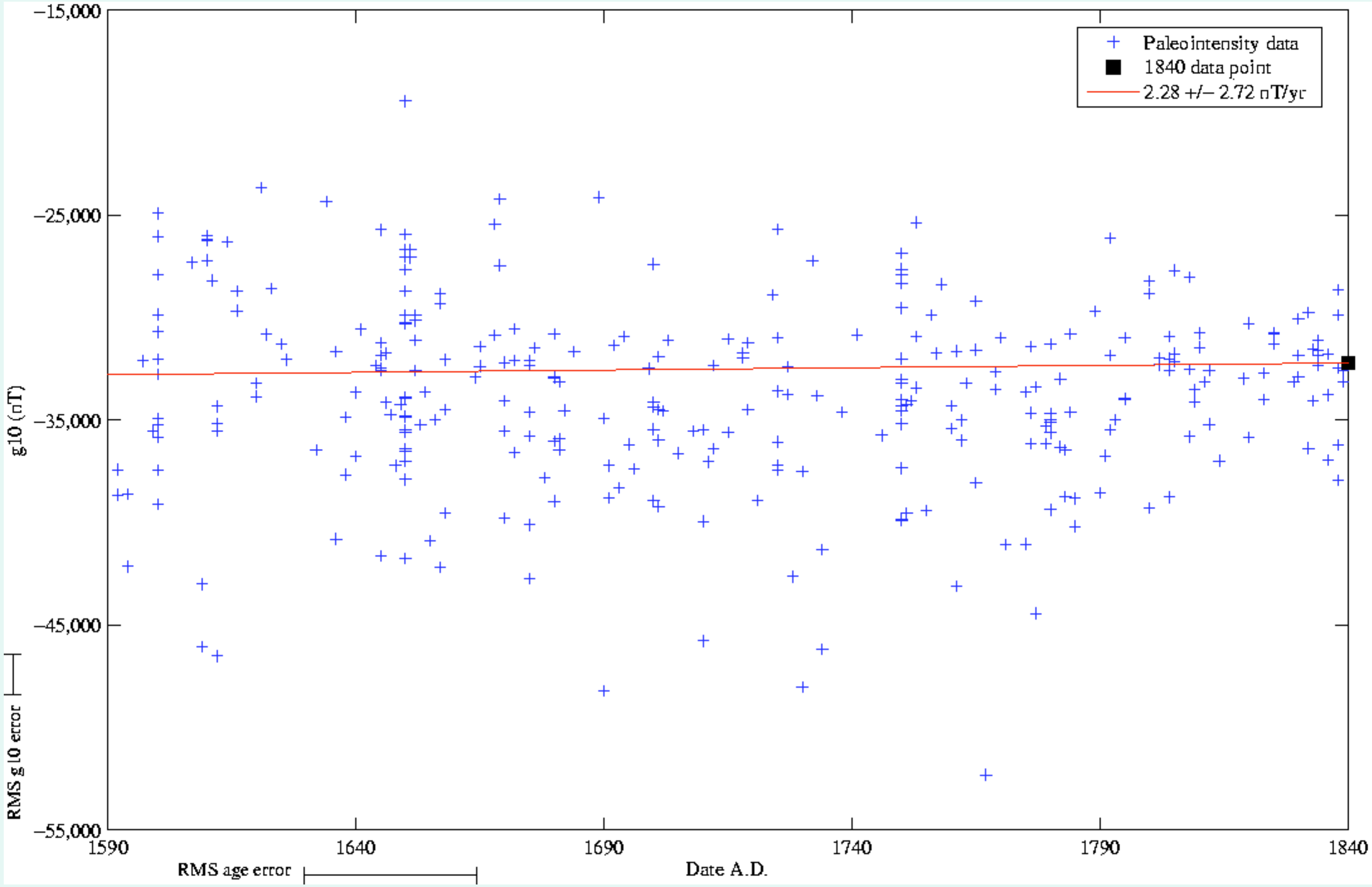
- There are 315 measurements of intensity in the database
- Typical errors 10% or 3000 nT, equivalent to 200 years @ 15 nT/yr
- Single measurements therefore do not constrain historical SV at all



METHOD

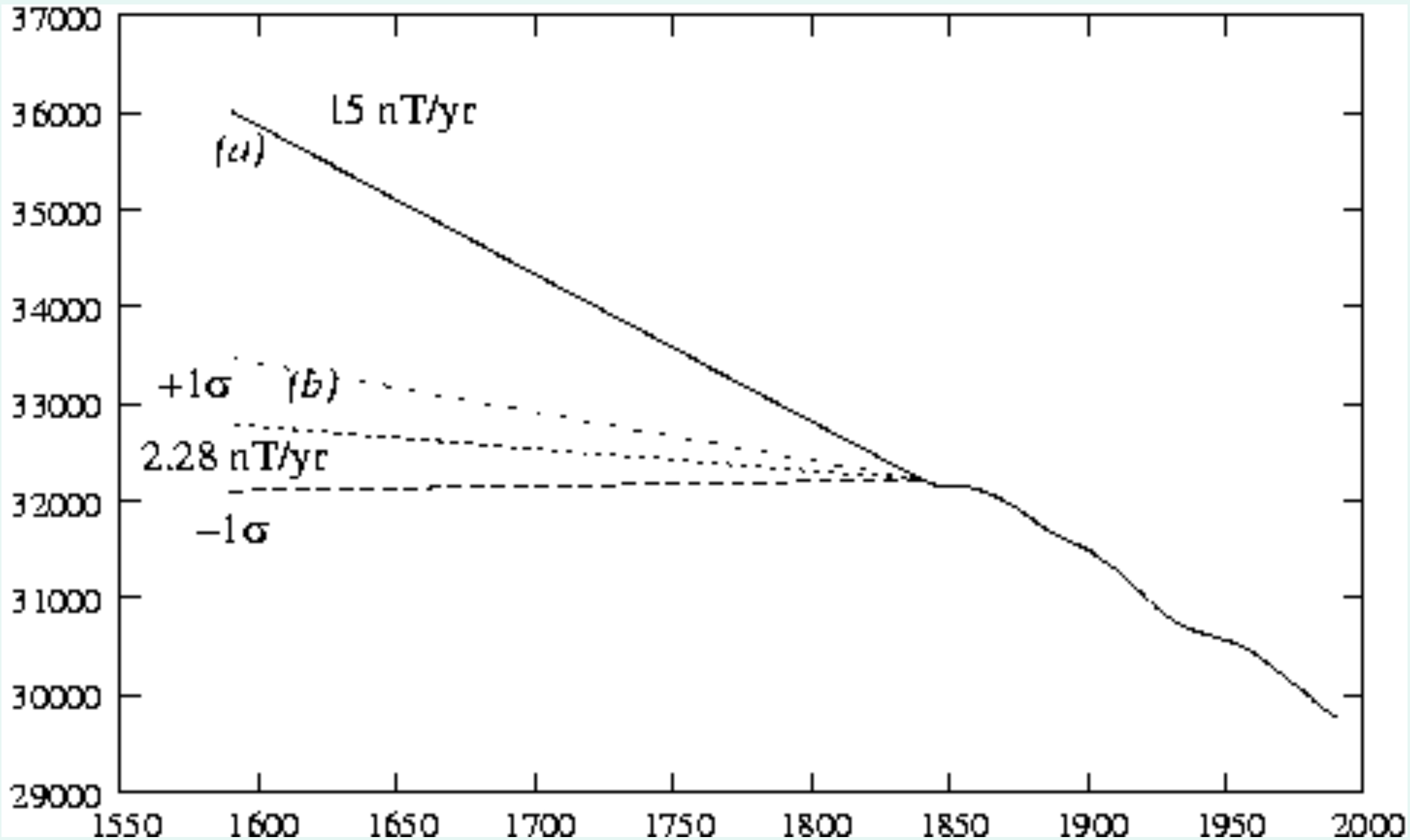
- Given a good directional model, only one intensity measurement is needed to normalise the intensity everywhere provided there are only 2 dip-poles *[Hulot et al. 1997].*
- We therefore map each intensity determination into an estimate of g_1^0 and map its error into an error on g_1^0.
- We assume a constant fall in g_1^0 from AD 1595 to 1840 and fix its 1840 value to be that of the global model *gufm*.
- This leaves one parameter, the slope of the line, to be determined from 315 paleointensity measurements.
- We determine the slope of the best-fitting straight line taking into account errors in **both** *F* and time.
- χ^2 gives the goodness-of-fit, how well the data can be fitted to a straight line
- σ^2 gives the standard error on the determined slope, and a Student t-test gives the confidence the slope is different from some other value - notably the assumed 15 nT/yr of the later epoch 1840-1990.

BEST-FITTING STRAIGHT LINE



RESULTS

- The rate of fall in *g10* before 1840 was 2.28±2.72 nT/yr
- χ2=258 with 314 degrees of freedom - a straight line is a good fit
- The derived slope differs of 2.28 differs from the later 16.1 nT/yr with more than 99.9% confidence



SO WHAT HAPPENED IN 1840?

The fall in dipole moment is actually caused by redistribution of magnetic flux on the core surface:

$$\frac{dg_1^0}{dt} = \frac{3c^2}{8\pi a^2} \oiint \frac{\partial B_r}{\partial t} \cos\theta dS$$

either by flux weakening or reversing or by flux drifting in latitude.

Since about 1860 this effect has been most prominent in the Southern Hemisphere, with particularly strong expulsion of flux in the early 20th century creating a reversed flux patch at the core surface off SE Africa.

Prior to 1860 these reverse flux patches were absent or much less active.

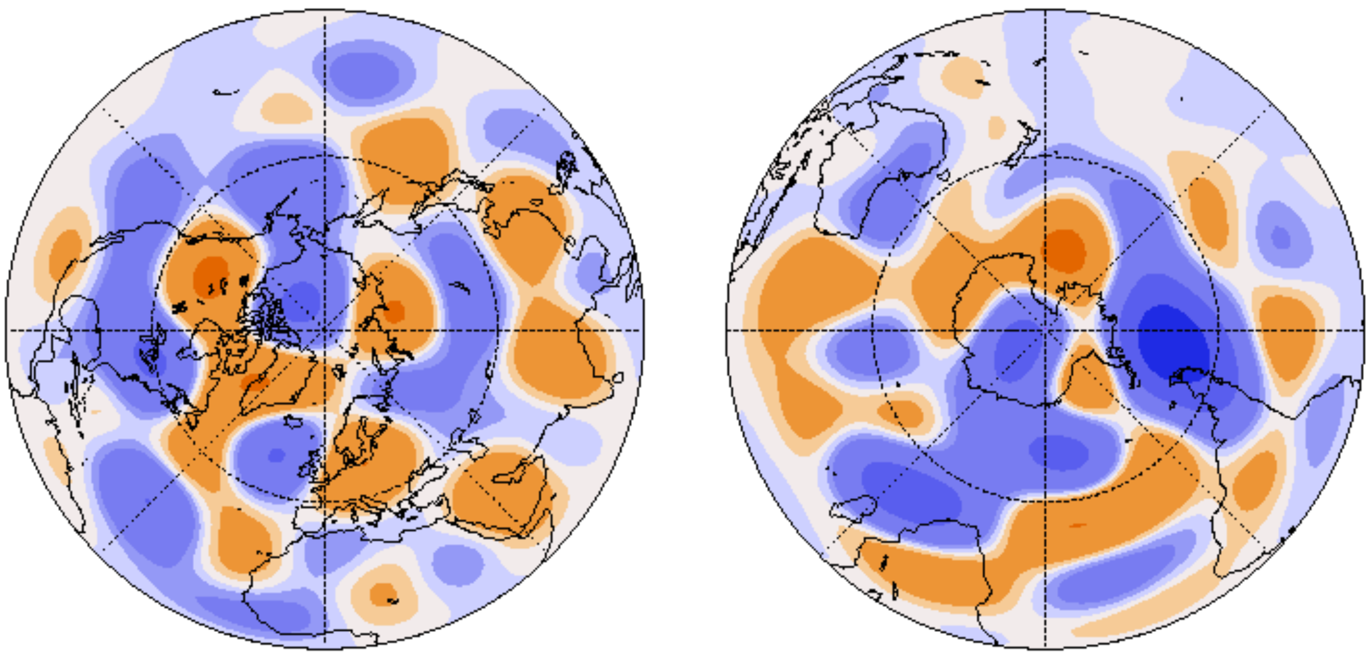
Intensities are not needed to follow the location or relative sizes of the reverse flux patches

CONTRIBUTIONS FROM NORTHERN AND SOUTHERN HEMISPHERES

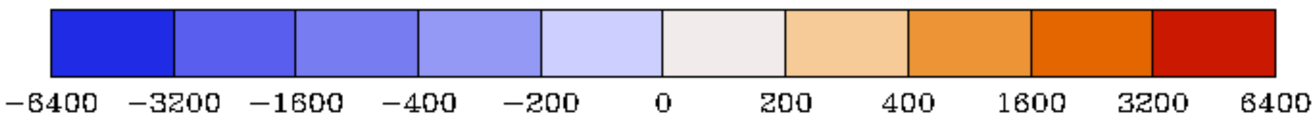
$$\frac{dg_1^0}{dt} = \frac{3c^2}{8\pi a^2} \oiint \frac{\partial B_r}{\partial t} \cos\theta dS = \dot{g}_N + \dot{g}_S$$

	north	south	ratio
1595-1840	-0.8nT.yr	3.2nT/yr	4
1840-1990	-0.1nt/yr	16.2nT/yr	161

Mean rate of change of *g10* since 1840

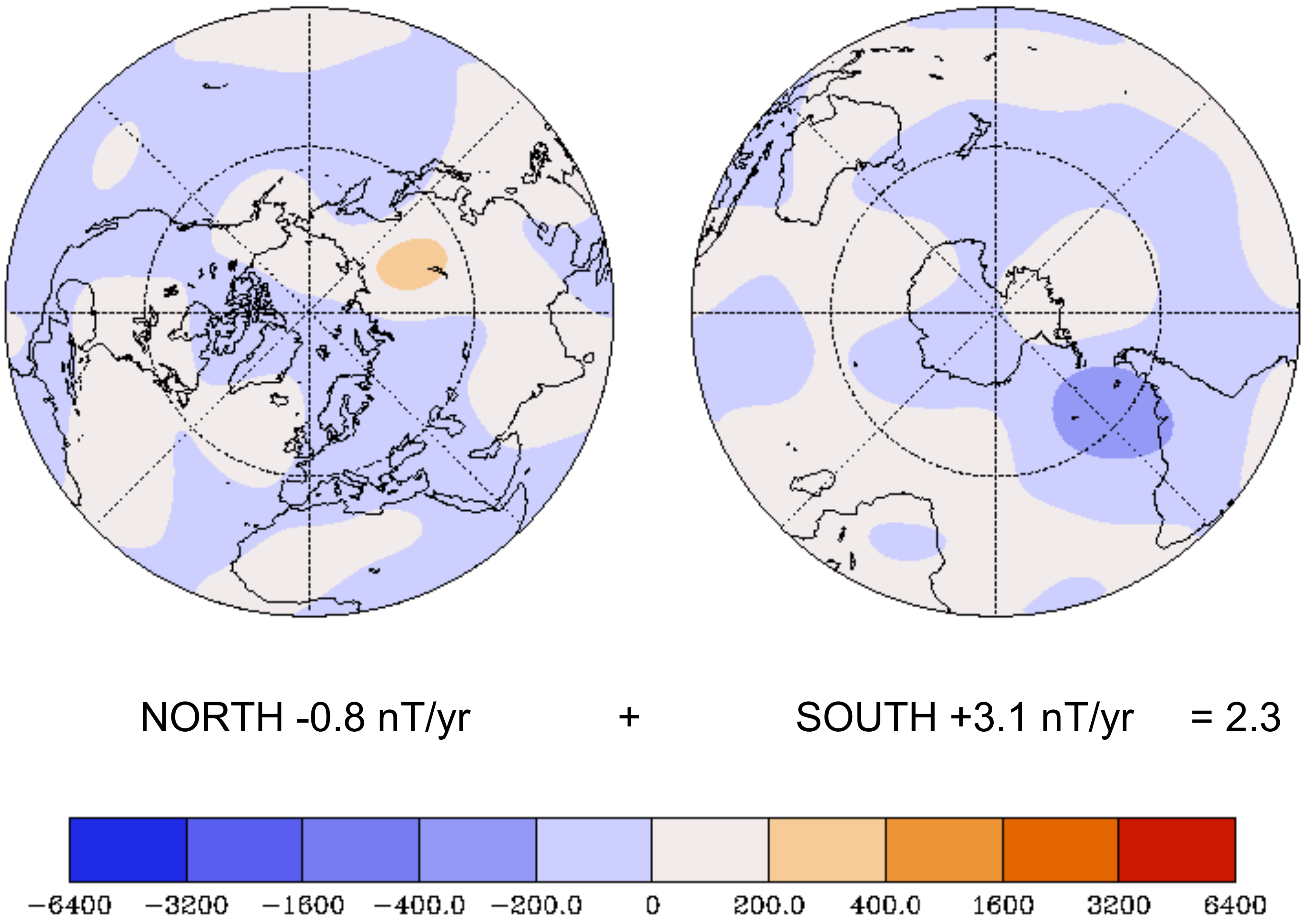


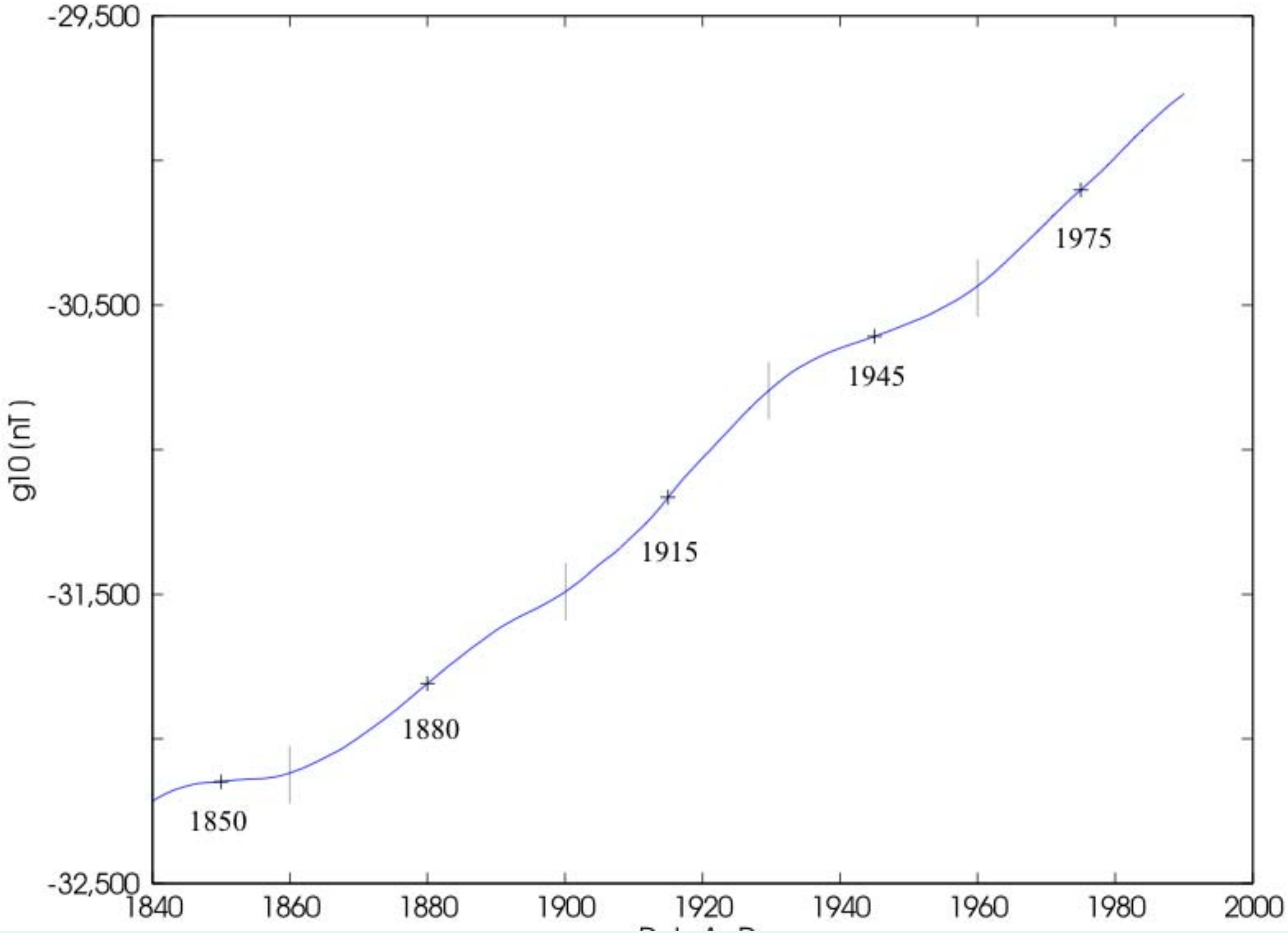
NORTH -0.1 nT/yr + SOUTH +16.2 nT/yr = 16.1



Mean rate of change of *g10* before 1840

(2.28 nT/yr)





g10 (nT)
-29,500
-30,500
-31,500
-32,500
1840
1860
1880
1900
1920
1940
1960
1980
2000
1850
1880
1915
1945
1975

CONCLUSIONS

- The present rapid fall in dipole moment started in the mid-19th century
- Paleointensities show that the fall has been underway at least since Roman times, about 20000 nT in 2000 years or 10 nT/yr
- Both are consistent with intervals of rapid fall separated by intervals of quiescence
- A plausible cause is periods of expulsion of toroidal flux through the core surface followed by periods of regeneration of toroidal flux inside the core.
- Can SWARM identify the changes in the core field responsible for current changes in fall in the dipole moment? - this requires mapping secular acceleration on the core surface.