Including new equatorial African data in global Holocene magnetic field models

Poster-
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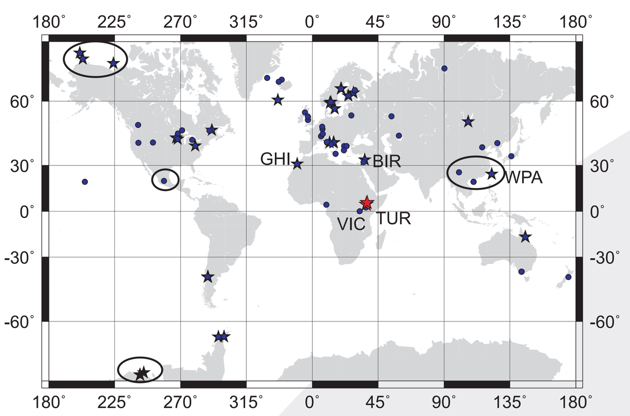
Introduction

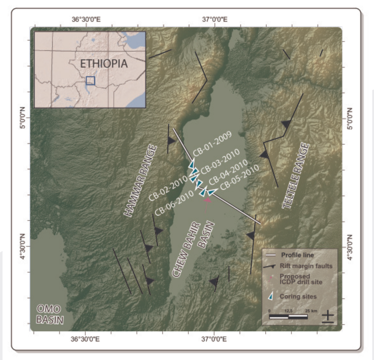
Global paleomagnetic field reconstructions of the Holocene are a useful tool to study the past evolution of the geomagnetic field at the Earth's surface and the core-mantle boundary, or to estimate shielding against galactic cosmic rays. This protection is currently weak over the South Atlantic anomaly, a feature stretching between South America and Africa. Knowledge of the long-term evolution of this anomaly and whether there are preferred longitudinal ranges of weak fields is required for a better understanding of the geodynamo process and to estimate past magnetic shielding, e.g., for any studies involving the production of cosmogenic isotopes.
The distribution of archeo- and paleomagnetic data available for global field reconstructions is highly inhomogeneous. It is strongly biased towards Europe and particularly sparse for Africa and South America. New data from these regions are necessary to confirm or improve field descriptions in Holocene spherical harmonic magnetic field models particularly for the evolution of this presently anomalous region.
Here we present new sedimentary records of inclination and relative intensity from equatorial Africa and show preliminary results regarding their implications for global field reconstructions.

Location

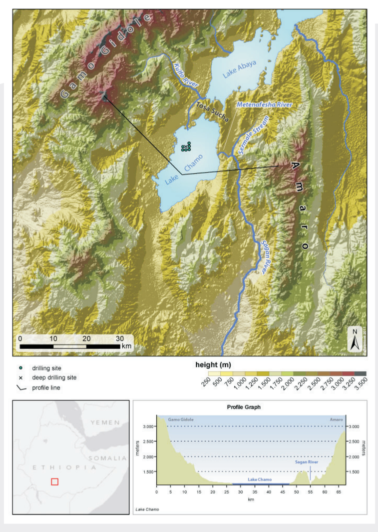
The new data come from two locations in Ethiopia, from the Chew Bahir Basin and Lake Chamo. Both of them lie in the East African rift system. They are approximately 150 km apart (see also poster EGU2012-7700).



The new data (red stars) fill a gap particularly for intensity in the previous global compilation of sediment directional (dots) and relative intensity (stars) paleomagnetic records for global modelling. The circles mark regions of data differences between CALS3k.3 andCALS3k.4. See list of references for labeled records.



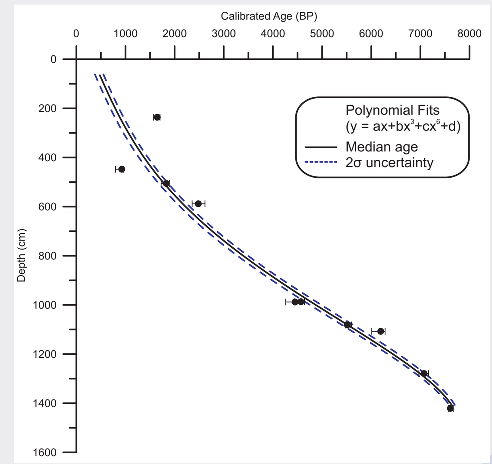
Chew Bahir is a dry lake today. Six cores were taken, three of which were used for paleomagnetic investigation. The cores span ~60 ka. Here we are only interested in the Holocene, which is 4 meters or less. The sedimentation rates vary notably across the cores. Six radiocarbon ages were transferred to a master core using rock magnetic and geochemical data sets for correlation.



12 overlapping core sections were taken from Lake Chamo, making one composite profile. This 14 m profile spans the last 7.5 ka, giving a much higher resolution than Chew Bahir.

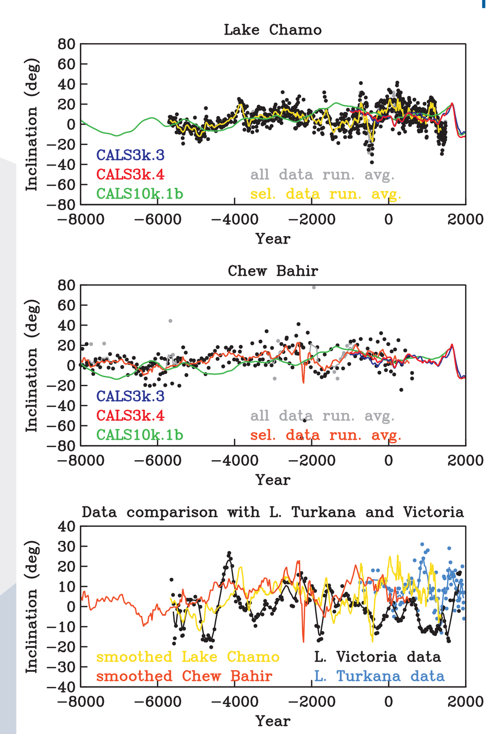
Age models

Preliminary age models for the composite Lake Chamo and the Chew Bahir records were obtained by fitting third degree polynomials to the calibrated tie-point ages. We are working on improving the age models by Bayesian methods.



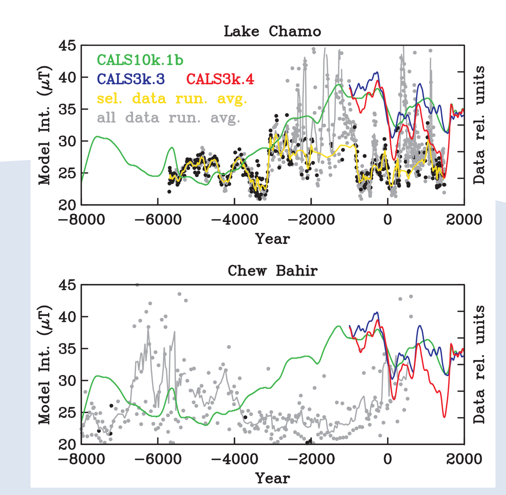
Lake Chamo age model

Comparison to previous models and data



Comparison of inclinations

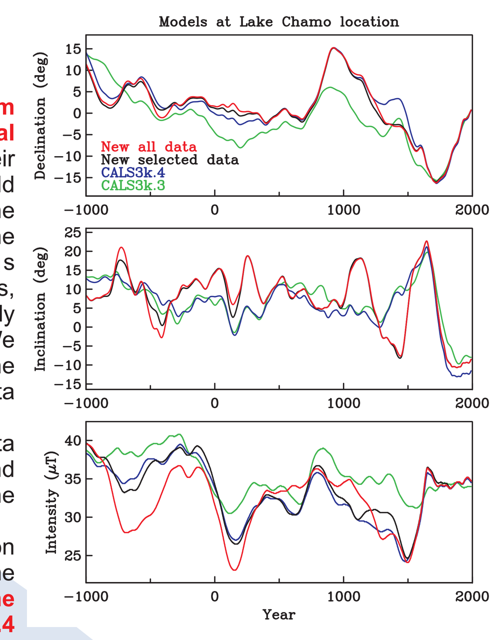
The new records, both complete (gray dots) and selected according to the described paleomagnetic quality criteria (black dots), are compared to existing global models and to nearby inclination data. Both new records show a general agreement of inclination with previous global models, but details vary. **The comparison of the two new smoothed inclination records suggests a possible age offset, which might indicate that the Chew Bahir radiocarbon ages are too old by ~200 years.** The comparison to data from Lake Victoria shows several consistent features with some temporal offsets. The Lake Turkana data might be of rather low quality.
The RPI records differ clearly from previous global models, particularly in long-term trend. The selection by paleomagnetic criteria rejects nearly all of the Holocene Chew Bahir results. It rejects many unlikely strongly varying data from Lake Chamo, but also several apparently reasonable results.



Comparison of intensities with absolute model scale on the left and relative scales for the data on the right. Nearby previous RPI records do not exist.

Global test models

The new data are the first RPI records from the African continent and from equatorial latitudes in general. In order to investigate their influence on global spherical harmonic field reconstructions, we added the records to the data set used for CALS3k.4. We kept all the methodology and parameter settings unchanged and produced two new test models, one using all the new data, and one using only the selected data fulfilling our quality criteria. We include predecessor model CALS3k.3 in the comparison, which also mainly differs by data distribution.
With 2% (selected) to 4% (all data) more data the new models have slightly higher spatial and temporal variability than CALS3k.4 with the fixed parameters.
The new data cause clear changes in inclination between 1000 and 1500 AD and amplifies some features of earlier times. **In intensity, some features already suggested by CALS3k.4 compared to CALS3k.3 (although the differences in data lie in far away regions) are confirmed and even amplified by the new data.** Note that additional data in intensity amounts to 13% for all, but only 2% for the selected data.

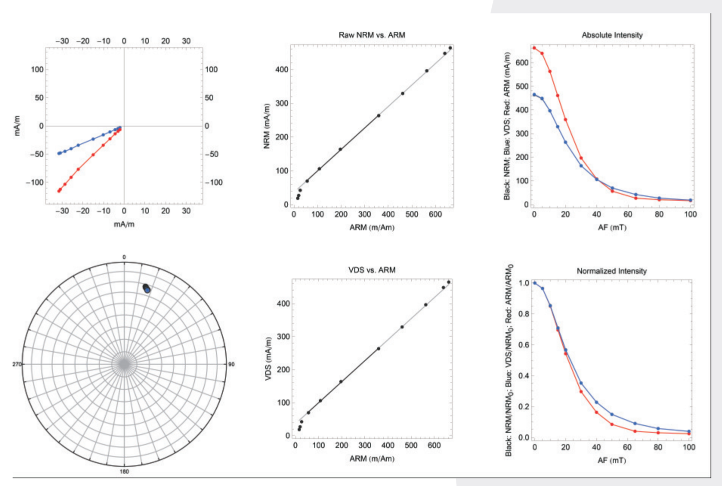


Comparison of different global model predictions for the Lake Chamo location. Changes to CALS3k.4 in declination, where no new data were added, are small. Changes in inclination and intensity are most pronounced if all data are used.

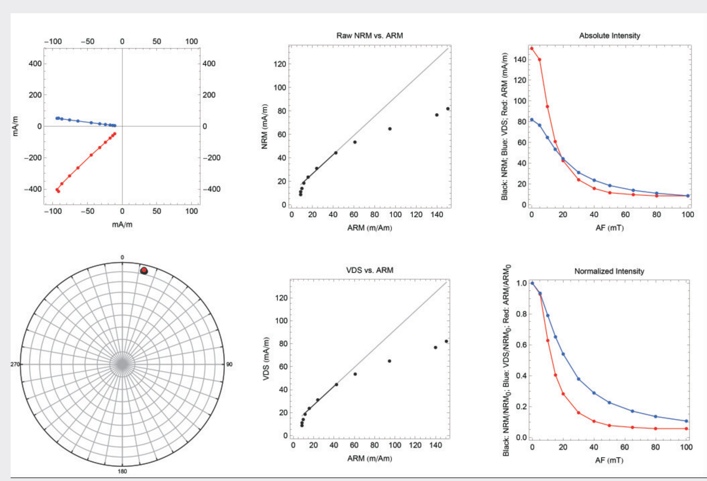
Paleomagnetic results

Paleomagnetic and rock magnetic measurements were carried out in the GFZ paleomagnetic laboratory on 2 cm standard cube samples, including progressive alternating field (AF)-demagnetisation of an anhysteretic remanent magnetization (ARM) and imprinting of a saturation isothermal magnetization (SIRM). The directions of the characteristic remanent magnetization (ChRM) were determined by vector analysis of the results of progressive AF-demagnetisation of the natural remanent magnetization (NRM). Declination results could not be used due to twisting of the cores during the core recovery. In addition to the standard procedure of relative paleointensity (RPI) determination, using either the SIRM or the ARM for normalization of the NRM, a series of tests and criteria was applied to judge on the reliability of the data. Characteristic plots thus provide information about the quality of the ChRM-inclinations and relative paleointensity (RPI) results.

Two examples from Lake Chamo at different depths are shown below in the form Zijderveld diagrams (red: y-x plane, blue y-z plane), inclination-declination plots, NRM (natural remanent magnetization) or VDS (the vector difference sum, which unravels overprints in the NRM) versus ARM (anhysterertic remanent magnetization) and demagnetization plots of absolute and normalized intensity. Both give good inclination results, but the second one is unsatisfactory for RPI determination.

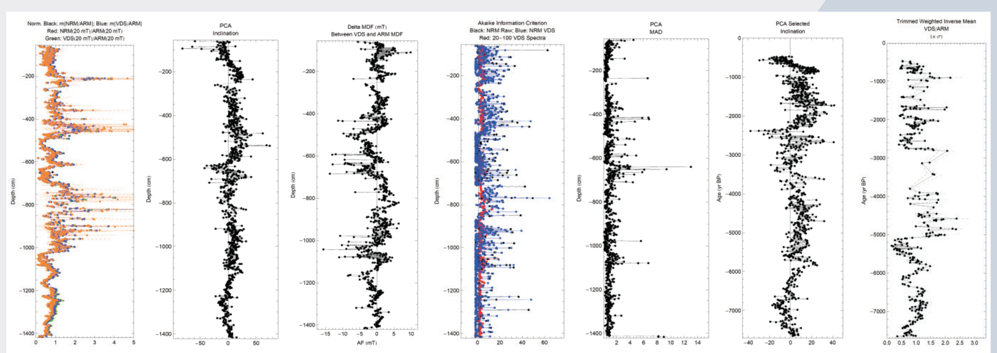


Example of good results from Lake Chamo sample at 465 cm depth.

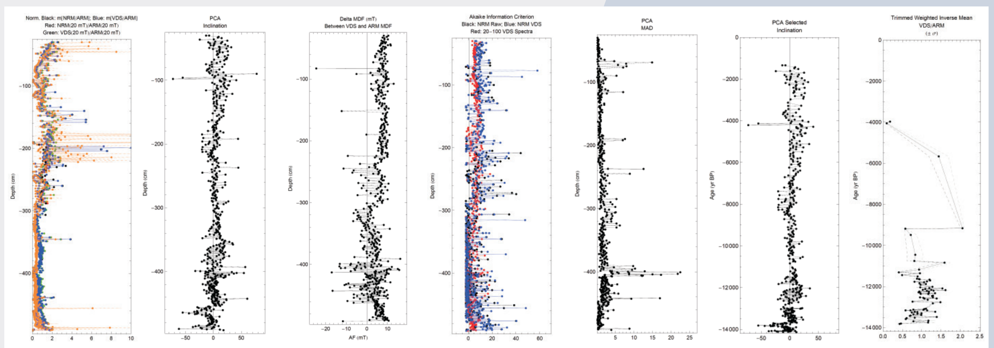


Example of unsatisfying RPI results from Chew Bahir sample at 186 cm depth .

Lake Chamo

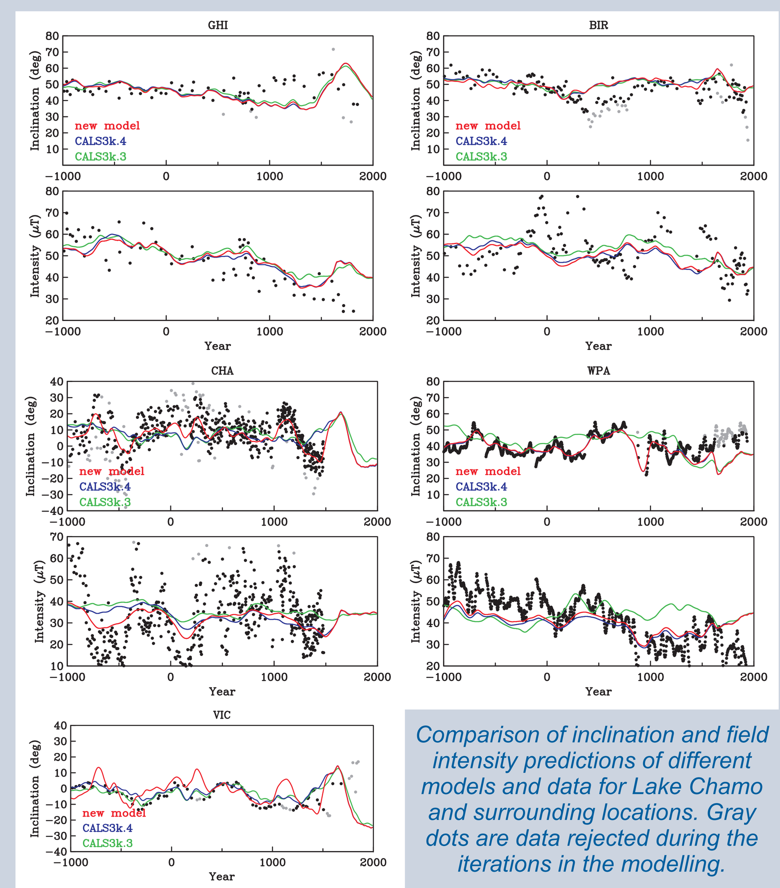


Chew Bahir



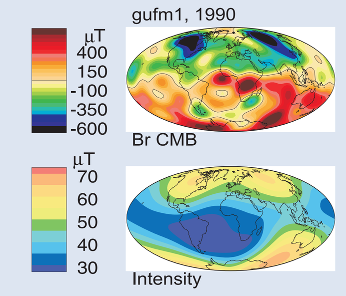
From left to right: RPI normalised in different ways and inclination. Mean destructive field difference (delta MDF) of absolute value > 5 mT, Akaiki information criterion on curvature of the VDS against ARM plot of > 1, or maximum angular deviation > 2.5 were taken as criteria to reject data from the selected data sets of inclination and RPI, shown against calibrated age BP on the right..

Preliminary modelling results

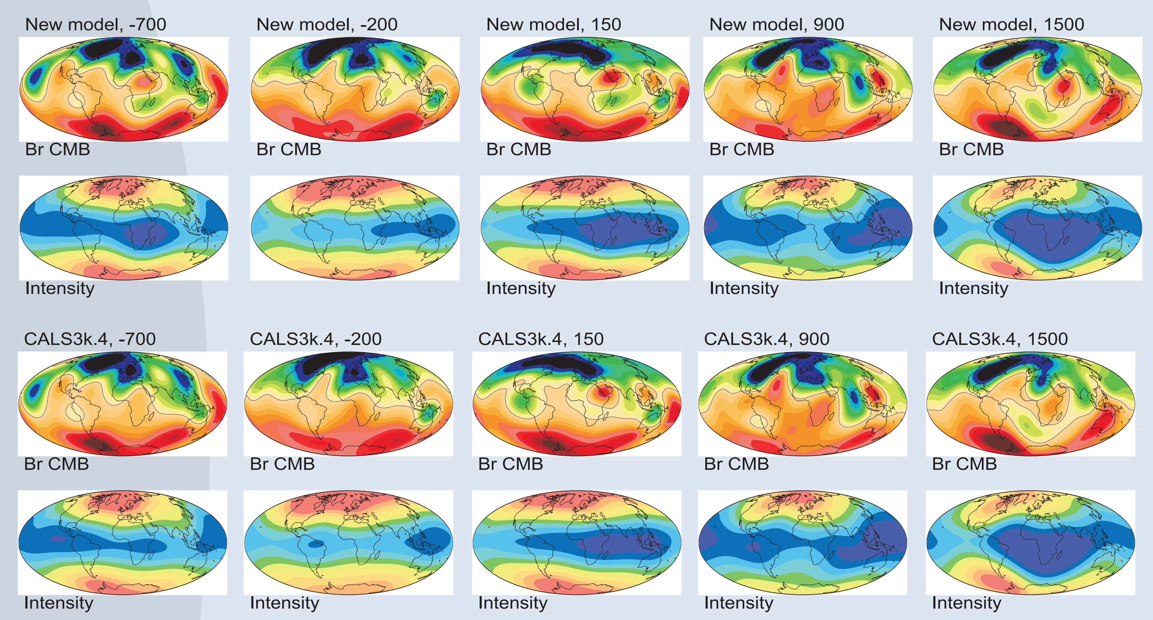


Comparison of inclination and field intensity predictions of different models and data for Lake Chamo and surrounding locations. Gray dots are data rejected during the iterations in the modelling.

Addition of the new equatorial African data to the global data set modify the spherical harmonic model mainly in the immediate vicinity of the new location. The new inclination data are largely compatible with the previous Lake Victoria data, but the new data suggest three moderate inclination maxima (~1100 AD, ~200 AD and ~750 BC) which are not supported by the Lake Victoria data.
Global plots of field intensity at Earth's surface and radial field at the core-mantle boundary (CMB) show that **the new data indicate a recurrence of a weak field structure resembling the present day South Atlantic anomaly at similar longitudes (~1500 AD, ~150 AD and ~700 BC).** More RPI data from equatorial and southern hemisphere locations are needed to confirm these results and better constrain the longitudinal behaviour of this structure.



South Atlantic Anomaly



CALS3.4 and the new model's radial field at the CMB and intensity at Earth's surface for different epochs.

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Acknowledgements

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