FORCintense: A graphical implementation of the Preisach method of paleointensity estimation within FORCinel

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Abstract

A non-heating method of paleointensity determination based on Preisach theory has recently been developed [1, 2]. The method uses a first-order reversal curve (FORC) diagram to generate a Preisach distribution of coercivities and interaction fields within the sample and then physically models the acquisition of TRM as a function of magnetic field, temperature and time using thermal relaxation theory. By comparing observed and simulated remanence values, an estimate of paleointensity is obtained that is typically more accurate than other non-heating methods (e.g. REM) and often comparable to Thellier-Thellier estimates. Here we present a modified implementation of the Preisach method within the FORCinel processing package [3], which allows interactive graphical comparison of the observed and simulated remanence behaviour. The method is tested using a variety of samples incuding historical lavas and synthetic samples of dusty olivine carrying a laboratory TRM.

[1] AR Muxworthy and D Heslop (2011) A Preisach method for estimating absolute paleofield intensity under the constraint of using only isothermal measurements: 1. Theoretical framework. Journal of Geophysical Research, 116, B04102, doi: 10.1029/2010JB007843.

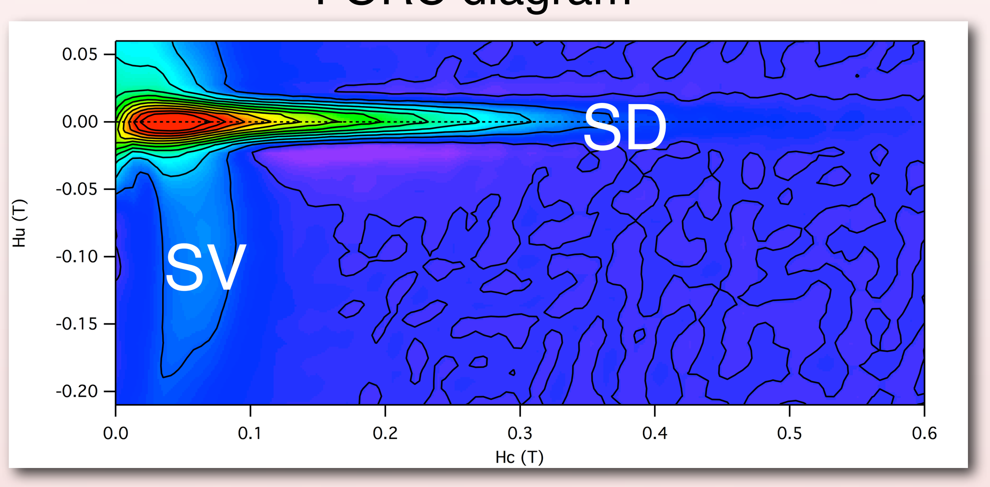
[2] AR Muxworthy, D Heslop, GA Paterson, and D Michalk. A Preisach method for estimating absolute paleofield intensity under the constraint of using only isothermal measurements: 2. Experimental testing. Journal of Geophysical Research, 116, B04103, doi: 10.1029/2010JB007844.

[3] Harrison, R.J., and J. M. Feinberg (2008), FORCinel: An improved algorithm for calculating first-order reversal curve (FORC) distributions using locally-weighted regression smoothing, Geochemistry Geophysics Geosystems, doi:10.1029/2008GC001987.

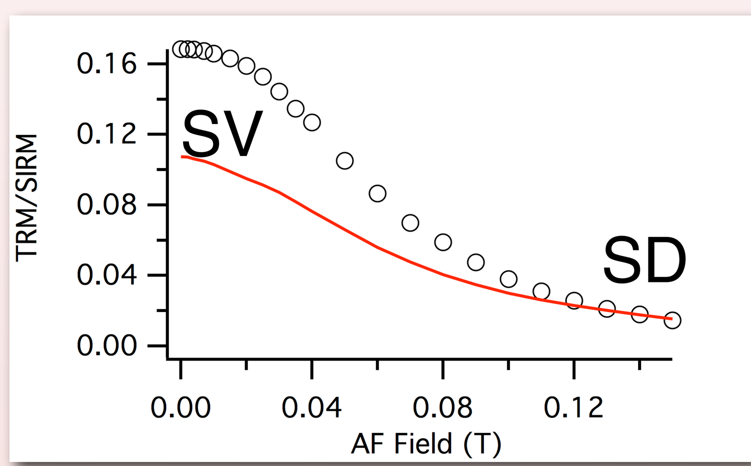
Application to Synthetic Dusty Olivine

We tested the method on a suite of synthetic dusty olivine samples: reduced olivine containing submicron particles of metallic Fe in a mixture of SD and single vortex (SV) states (see EGU2012-11211 and EGU2012-11395). There is poor agreement between observed and calculated NRM demag curves for Hc < 100 mT, which corresponds to the part of the FORC diagram where SV states dominate. At high AF demag fields, where SD states are more dominant, there is much better agreement. No baseline shift was necessary because FORCs were measured to Hc >> max AF demag. If the observed SIRM demag data is supplied, FORCintense will also simulate the REM' values. This was found to be an effective method of isolating the high coercivity portion of the signal, yielding excellent agreement with experiments (especially for samples made with natural olivine precursor).

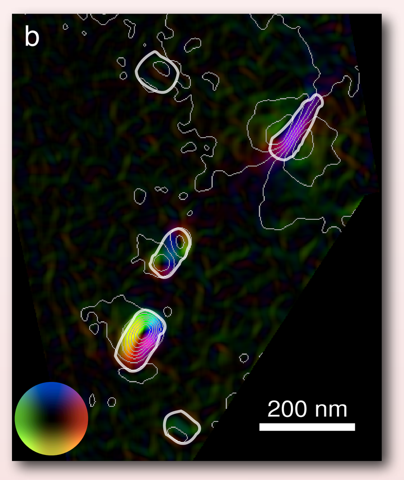
FORC diagram



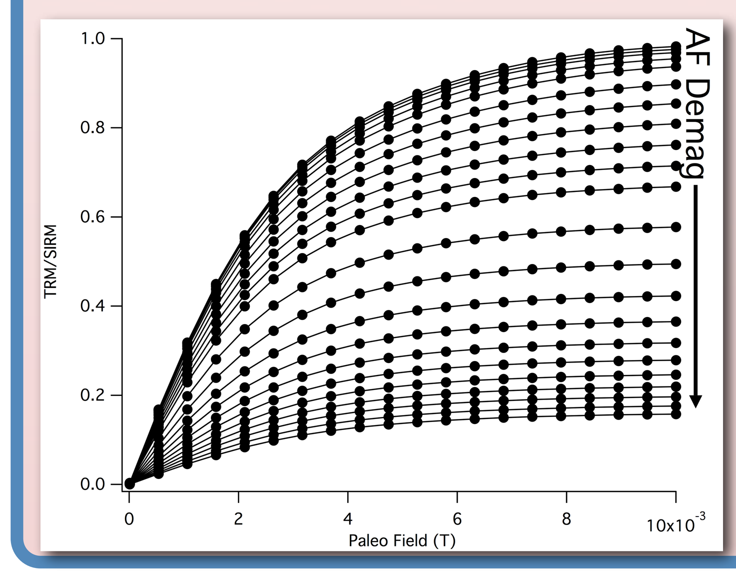
Simulated AF demag at 340 μT (equal to lab field)



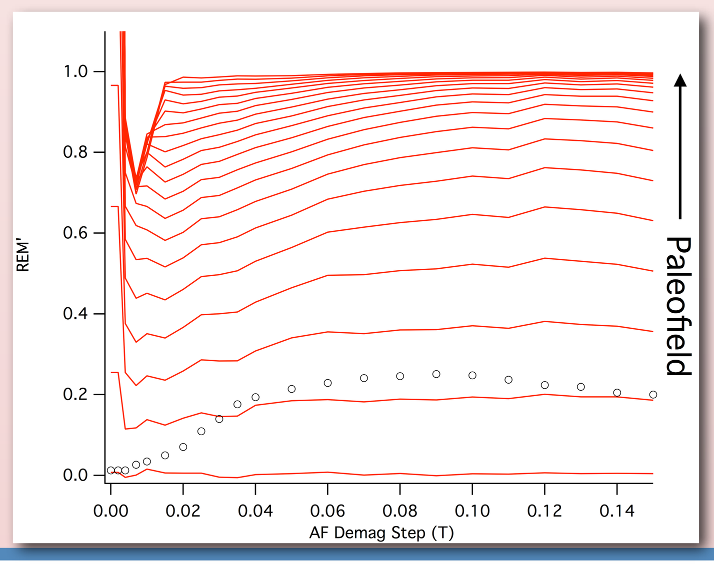
Electron holography



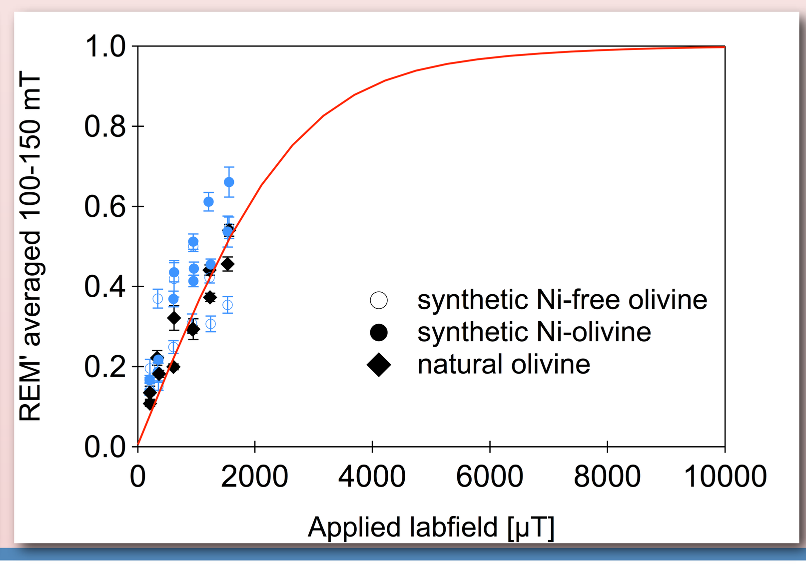
Non-linear TRM acquisition



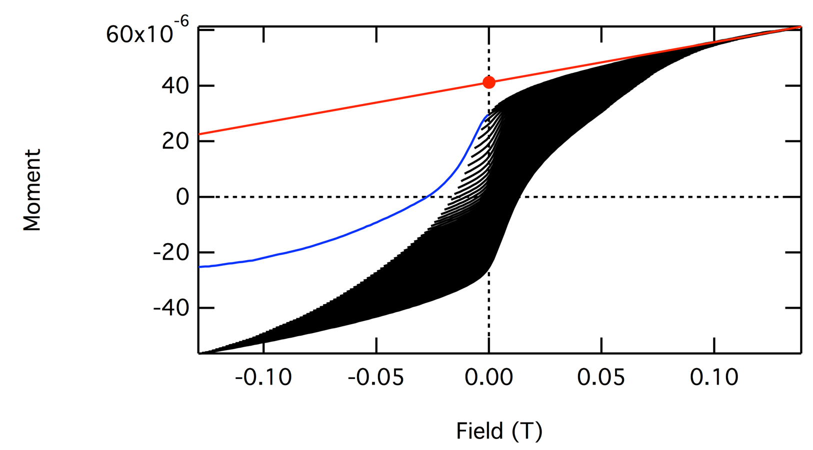
Calculated vs observed REM'



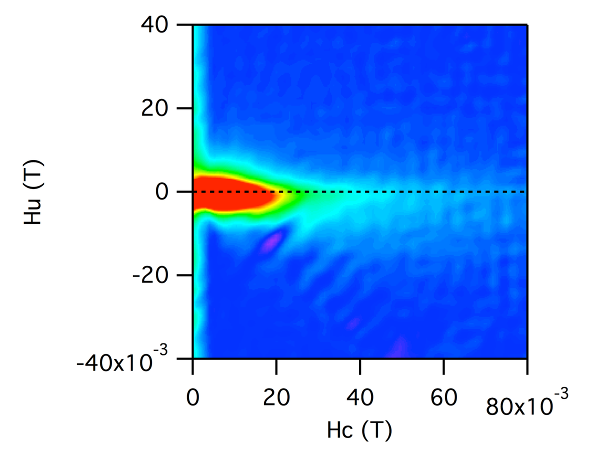
REM' acquisition curve compared to experimental data



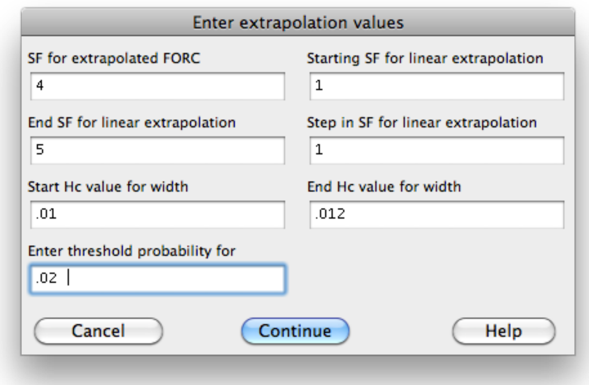
Load FORC data



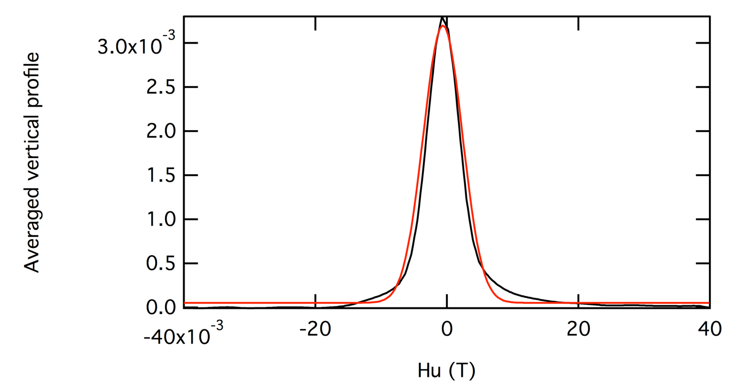
Process FORC data



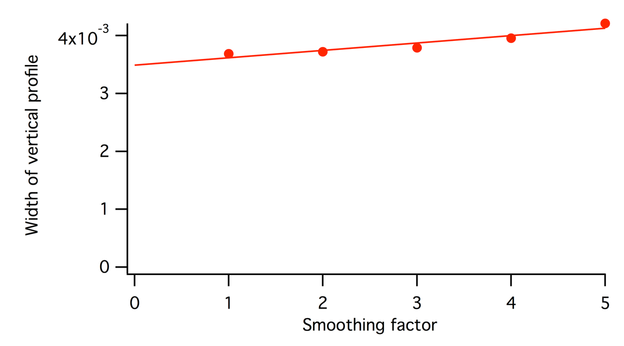
Make Preisach Distribution



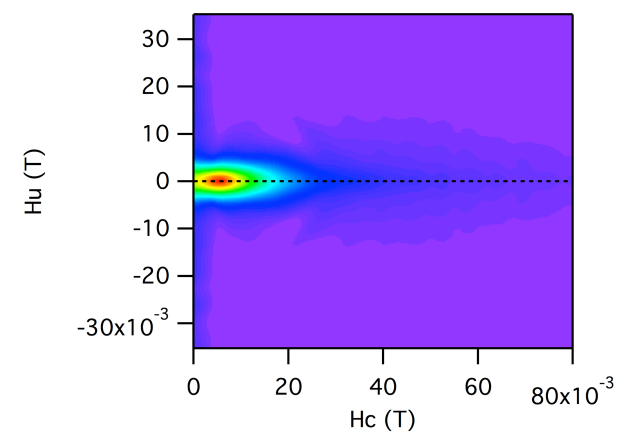
Width of vertical profile over specified Hc range is calculated as a function of SF



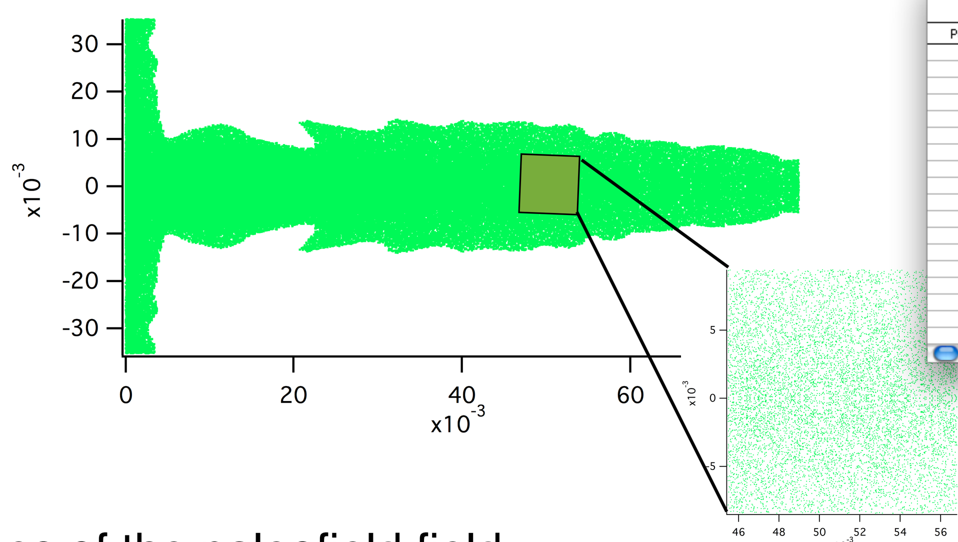
Width at SF = 0 calculated from linear extrapolation



Preisach distribution formed from symmetricised FORC and extrapolated to 0 SF



200,000 hysterons used to sample the Preisach distribution. A threshold of 0.02 sets noise limit.



Enter NRM AF demag data and SIRM

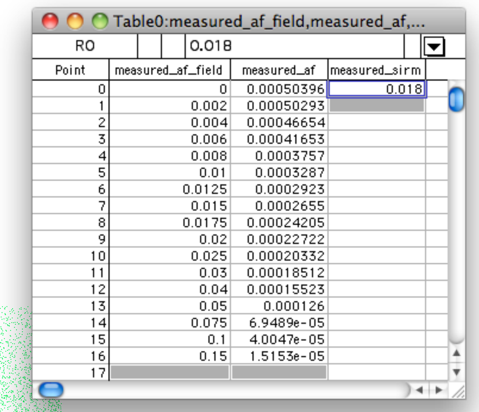
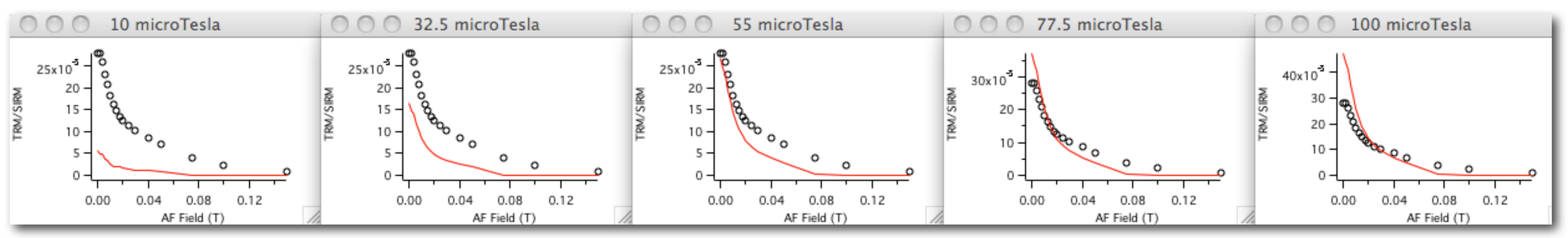


Table0:measured_af_field,measured_af,...

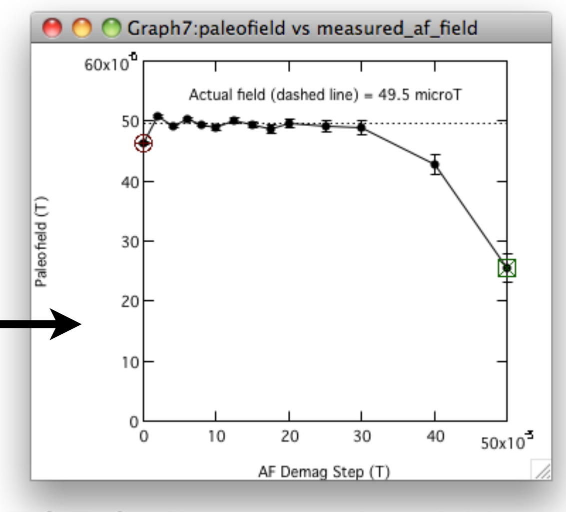
RO 0.018

Point	measured_af_field	measured_af	measured_sirm
0	0	0.00050396	0.018
1	0.002	0.00050293	
2	0.004	0.00046654	
3	0.006	0.00041653	
4	0.008	0.0003757	
5	0.01	0.0003287	
6	0.0125	0.0002923	
7	0.015	0.0002655	
8	0.0175	0.00024205	
9	0.02	0.00022722	
10	0.025	0.00020332	
11	0.03	0.00018512	
12	0.04	0.00015523	
13	0.05	0.000126	
14	0.075	6.9489e-05	
15	0.1	4.0047e-05	
16	0.15	1.5153e-05	
17			

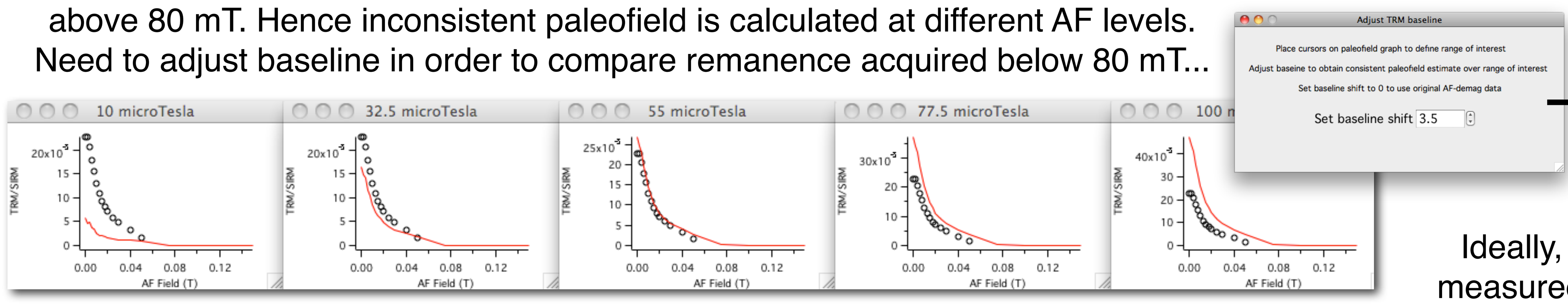
Simulate TRM acquisition and AF demag spectra at different values of the paleofield. Compare observed (circles) and calculated (curves) AF spectra.



Compute paleofield needed to match demag spectrum at each AF field step. Ideally this graph should be horizontal line - your mileage may vary. Cursor positions define range for averaging.



Note that FORC diagram only measured to 80 mT but sample has remanence above 80 mT. Hence inconsistent paleofield is calculated at different AF levels. Need to adjust baseline in order to compare remanence acquired below 80 mT...



Ideally, the FORC diagram should be measured to high enough Hc so that the baseline shift is not necessary.

Beta testing

When the method has worked well, you should obtain a constant value of the paleofield over a wide range of AF steps, a good agreement between the calcualted and observed AF demag spectra, and an average paleofield over the desired range of AF steps that is close to the actual paleofield. FORCinel version 1.21 is now available for beta testing (http://www.esc.cam.ac.uk/research/research-groups/forcinel). We would like to hear from the community about how well the method works in the real world, and specifically:

What types of FORC diagram work well/poorly?

How sensitive are the results to the threshold value?

What criteria can we use to assess the confidence in the results?

Is the baseline shift method appropriate, and how can we determine the best shift value?

How well does the Barbier relationship [1] hold for different types of sample?

Do we get better results by comparing observed and calculated REM' values?