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Calibration of flux-gate magnetometers

I. Calibration check

How can we tell that data are badly calibrated?

a) comparing with measurement of another instrument (scalar or vector) – **Ex. A1**
b) on a spinning spacecraft – spin tones and harmonics are visible in the magnitude – **Ex. B1**
c) comparing with model magnetic field (close to Earth)

Gives model field magnitude for S/C position
http://sscweb.gsfc.nasa.gov/cgi-bin/sscweb/Locator.cgi
IGRF model:
http://www.ngdc.noaa.gov/IAGA/vmod/igrf.html
Tsyganenko models:
http://modelweb.gsfc.nasa.gov/magnetos/data-based/modeling.html

d) intercomparison between spacecraft if the distance is small enough, see **Basic Analysis Techniques and Multi-Spacecraft Data Computer Session** by Joachim Vogt

II. Effects of different errors on the magnetic field magnitude on a spinning spacecraft – Ex. B2

III. Determination of calibration errors

a) on ground
b) in space (in-flight)

Calibration method:
Fit to a constant or known magnitude – **Ex. A2 & A3**
Minimising the correlation between direction and magnitude

Ex. A1
Use “ground_bvalues.txt” data
Contains 5 columns:
0:2 are the FGM measured vector magnetic field,
3: Bext (scalar reference field), 4 Bmagn error

;Read file
fnam='../input/ground_bvalues.txt'
read_input,t,b,nli,fnam
help,b

;compute magnitude of FGM and Bmagn
bb=magn(b(0:2,*))
bmagn=transpose(b(3,*))

;PLOT magnitude of FGM and Bmagn and their differences
window,2 & !p.multi=[0,1,2]
yr=[min([bb,bmagn]),max([bb,bmagn])]

;panel 1 - magnitudes over plot
plot,bb,line=2,/xsty,ytitle='B [nT]',title=fnam,yrange=yr
oplot,bmagn

;panel 2 - differences of magnitudes
plot,bb-bmagn,/xsty,ytitle='delta_B [nT]'
oplot,bmagn-bmagn,line=3

Alternatively: Download FGM and EDI data from CAA (Cluster Active Archive)
Compare FGM magnitude with EDI time-of-flight data by over plotting.
Make the distribution (histogram) of the differences and ratios – requires synchronization of time series by interpolation or averaging.

Ex. A2
Input ground measurement data: “ground_bvalues.txt”
Fit the calibration parameters using IDl Powell routine
Plot initial and fitted data

Ex. A3
Input ground measurement data: “ground_bvalues.txt”.
Compute the variance of the magnitude to the known constant value in dependency on the 3 offset parameters (**Z**x, **Z**y, **Z**z)
Represent the in 3D the result versus each pair of parameters.

Ex. B1
Input uncalibrated Cluster data in spinning S/C system “b_uncal.txt”
FFT on one component to see where the spin tone is
FFT on magnitude
;; READ uncal
inpf='b_uncal.txt'
fnam='ex_b1'
read_input,t,b,nli,inpf
b0=b(0:2,*)
bmag0=magn(b0) & nr=n_elements(bmag0)

;; PLOT magnitude
window,2 & !p.multi=[0,1,3] &chars=2
plot,t,bmag0,/xsty,/ysty,ytitle='B/nT',xtitle='hours',charsize=chars

;; compute FFT of magnitude
fft0=fft(bmag0-mean(bmag0),-1,/double)
fftc=fft(b(1,*)-mean(b(1,*)),-1,/double)

;; PLOT power of FFT of magnitude and one component
yr=[1.0e-10,1.0e5]
plot,abs(fftc(0:nr/2-1))^2,/ylog,/xsty,yrange=yr,$
xtitle='freq[Hz]',ytitle='power sp of By [nT^2/Hz]',charsize=chars
plot,abs(fft0(0:nr/2-1))^2,/ylog,/xsty,yrange=yr,$
xtitle='freq[Hz]',ytitle='power sp of B_uncal [nT^2/Hz]',charsize=chars

Ex. B2
First like **Ex. B1**.
USAGE: b1,Zz,Sy,Oxy,Oyz
Read Calibration parameters, apply calibration correction and FFT magnitude again.
Effect of the **wrong offset**:
Change the z-offset Zz (add 0.2 nT), calibrate, plot magnitude and FFT
Effect of **wrong scaling factor**:
Add 0.02 to Sy (scaling of y-axis), calibrate, plot magnitude and FFT
Effect of **wrong orthogonality**:
Add 0.02 to the Oxz (angle between spin axis and z) element of the matrix, calibrate, plot magnitude and FFT
Add 0.02 to the Oyz (angle in the spin plane) element of the matrix, calibrate, plot magnitude and FFT

To facilitate the programming task, some read-input and other functions and subroutines are included in the “userlib.pro” file that has to be included in every program: @userlib.pro

magn returns the magnitude of an array of vectors (usage: bb=magn(b(0:2,*))

bcal returns the calibrated magnetic field (usage: b_cal=bcal(calm)
calm=calibration coefficients

chisqu returns the variance of the magnitude of b_cal relative to a known or constant magnitude (used by the powell minimization routine)

read_input***,time,b,number_b*** returns an array of **B**-vectors, their number and time if available in the data

init_powell,***nr_parameters,calm,xi,Ftol*** initializes Powell-fit for
input = nr_parameters: 3 (offsets), 4 (offsets+magnitude), 12 (all calibration parameters)