Magnetic Compensation of Magnetic Noises Related to Aircraft's Maneuvers in Airborne Survey

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SAGEEP 2004

- **Effects of aircraft motion on data**
  - *a) What are the effects?*
  - *b) Traditional approaches*
  - *c) Why Study Compensation? – methodology , direction*
- **Investigation of some fundamentals**
  - a) *Solvers, Filters*
  - b) *The use of synthetic data*
- **Compensation with multiple GPS antennae**
  - *a) Methodology*
  - *b) Results*
- **Where to from here?**

Compensation of AeroMagnetic Noises

OVERVIEW

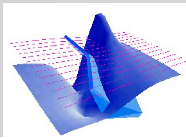
BASICS

- **New generations of optically pumped sensors have their sensitivity quoted in pT**
- **New instrumentation is also attempting to measure high accuracy vector data.**

- **Aircraft/helicopter itself emanates magnetic signals**
- **Compensation a limiting factor in obtaining highly accurate data**

TOPICS

1) **problems and techniques related to removing the effects of the moving platform**
2) **attempts to study the subject with the use of simulated data.**
3) **Attempts to use GPS data as orientation**



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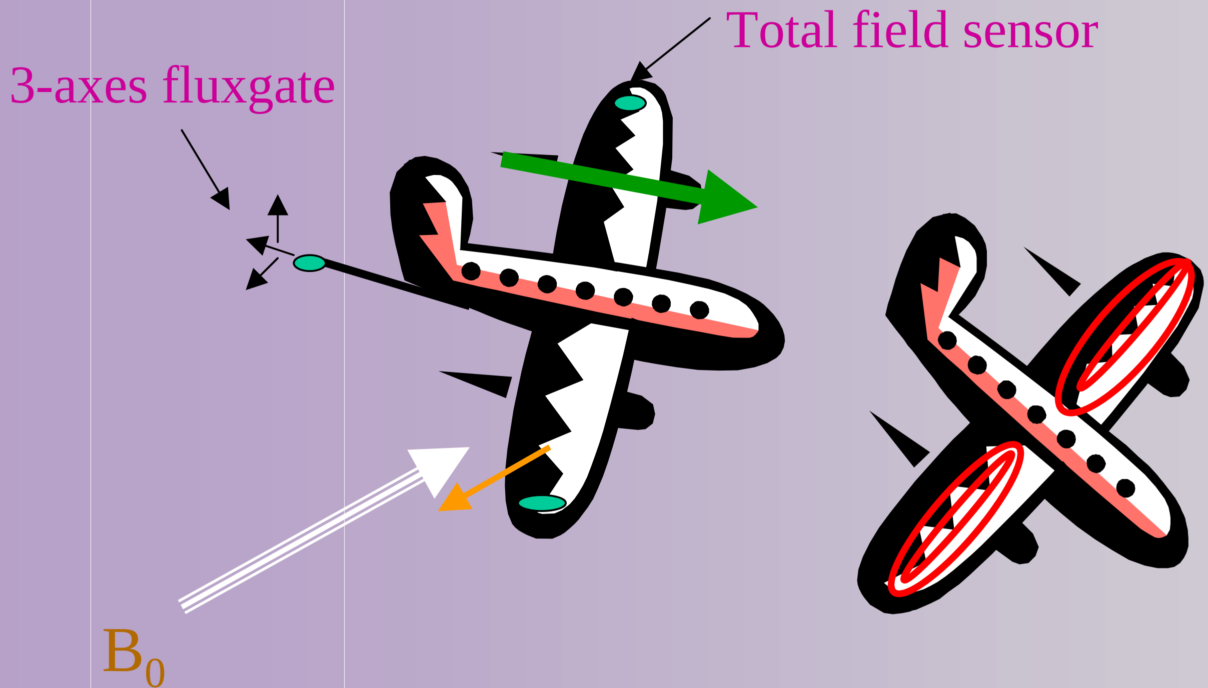
BASICS



- Permanent
- Induced
- EM ?

- aircraft (helicopters, moving platforms) are magnetic
- magnetic effects VARY with the aircraft's attitude – (wrt B_0)
- Motion within B_0, Gradients in B_0, heading effects
- Determine the effects as a function of attitude and rotation rates

METHOD

$$B_T = \sum C_i a^i, \ i=1,N$$ Leliak, 1961

C_i, $i=1,3$ - permanent

C_i, $i=4,9$ - induced

C_i, $i=10,18$ - induced EM

C_i, $i=19,?$ - gradients, heading effects, em noise

$a_i = f^i$ (cosX,cosY,cosZ) or **B_0 g^i (cosX,cosY,cosZ)**

B_0 h^i [d/dt (cosX,cosY,cosZ)]

where cos(..) are direction cosines

of the aircraft's axes wrt to B_0 traditionally from fluxgate data

➢➢➢ - find c_i at altitude in a *uniform field*

and apply corrections to survey data

Compensation of AeroMagnetic Noises

Issues and Objectives

- **History clouded**

  military,exploration
- **Adequacy of assumed mathematical system**

  number of terms, synthetic models
- **Solution techniques**
- **Sensor, Gradient effects**

  box data
- **Effects of non-uniform fields – gradients, anomalies**
- **GPS attitude**

  fluxgate data not actually used to determine orientation

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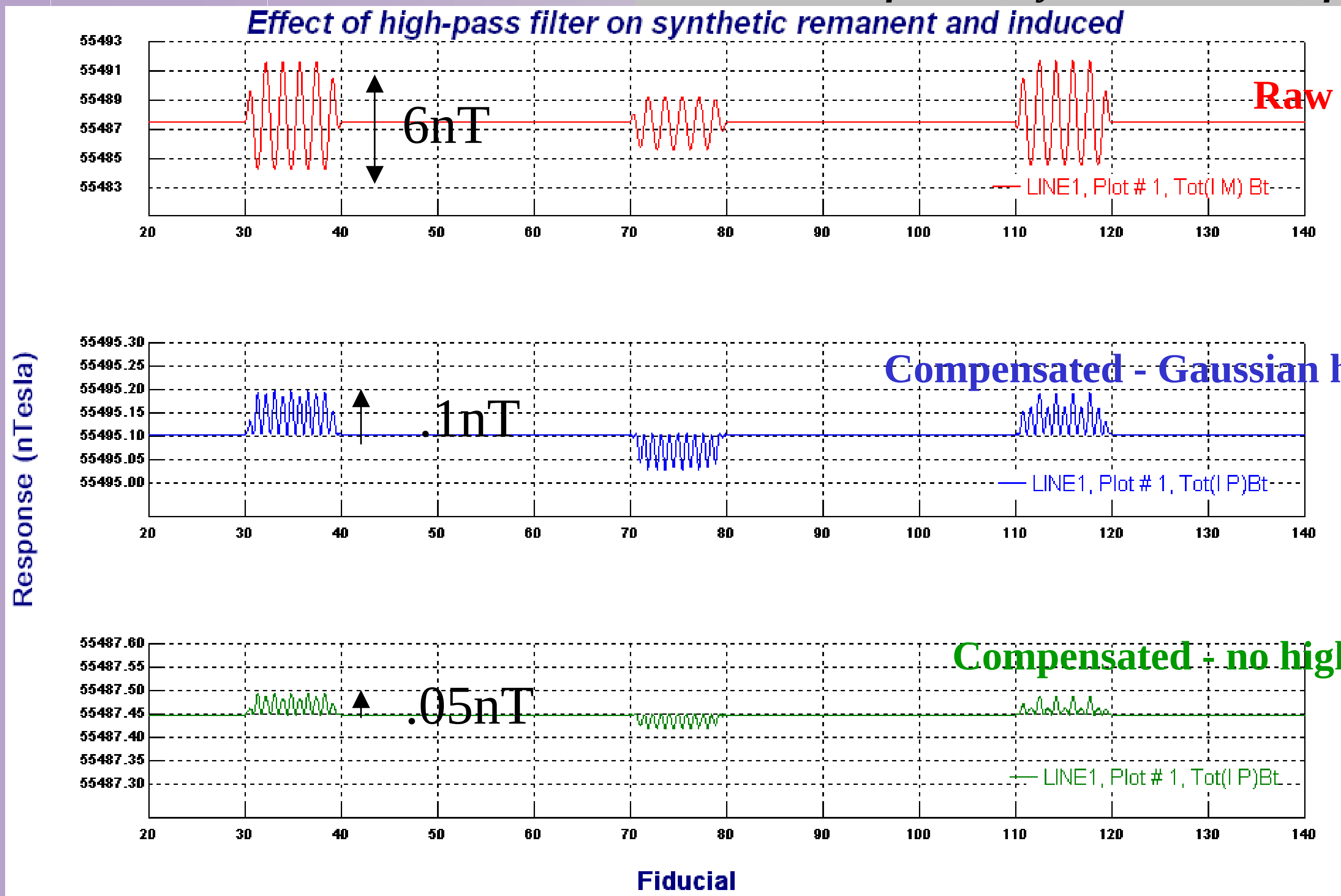
Issues and Objectives - 1

- **Adequacy of assumed mathematical system**

  number of terms, synthetic models, filters



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Issues and Objectives - 1

- **Adequacy of assumed mathematical system**

  number of terms, synthetic models, filters

✓***Even for induced and permanent system not complete***

✓***High-pass introduces noise and DC shift***

✓***For synthetic data solvers equivalent***

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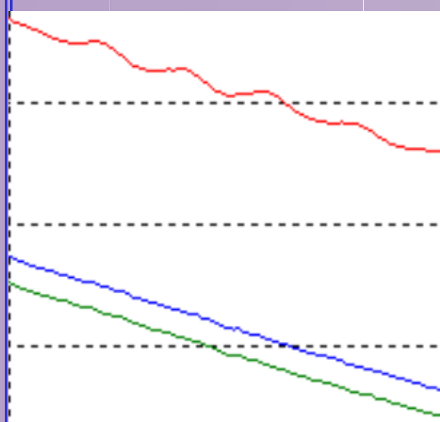
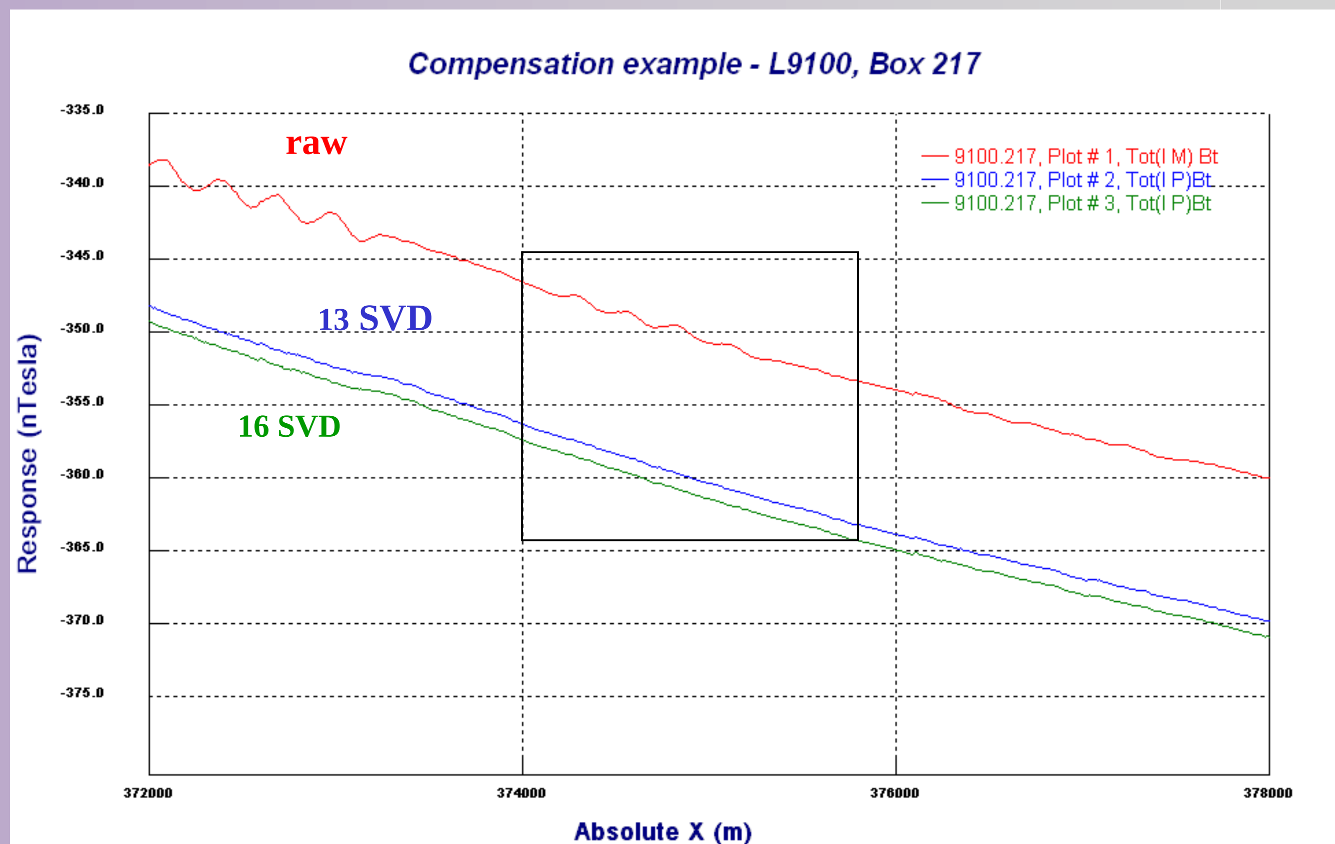
Issues and Objectives -2

Solution techniques

$$\underline{A}C = Y, \quad nxm, \quad n=18, \quad m>>18$$

1. Ridge Regression
2. Singular Value Decomposition
3. Conjugate Gradient
4. Symmetric Inverse





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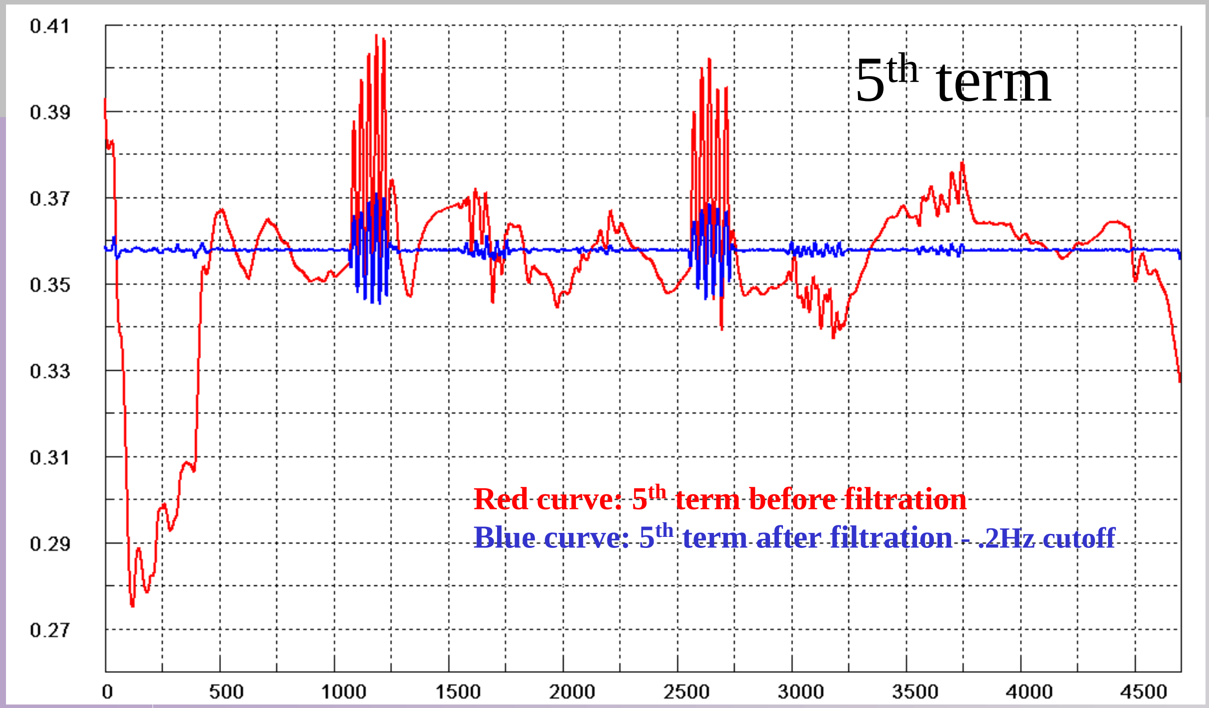
Issues and Objectives - 3

- **Aircraft attitude and Filtering**
  or *Filter the Data* or *Filter the Operator*

-for synthetic data results are equivalent
- Gaussian high-pass best we found



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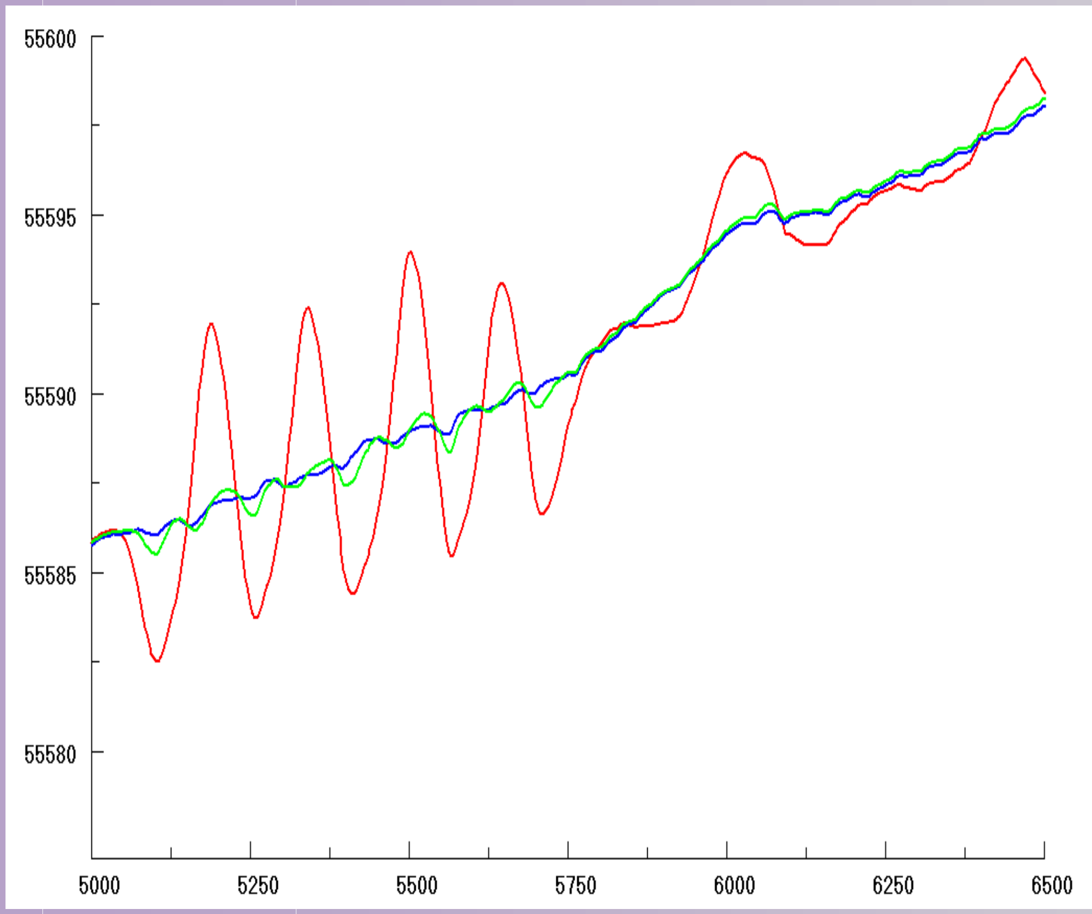
Issues and Objectives - 3

- **Aircraft attitude and Filtering**

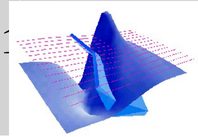
  or ***Filter the Data*** **or** ***Filter the Operator***

Real Data

- Highpass of data easier to understand but not always the best



Red curve: measured total field (nT)
Green curve: results by filtering data
Blue curve: results by filtering operator



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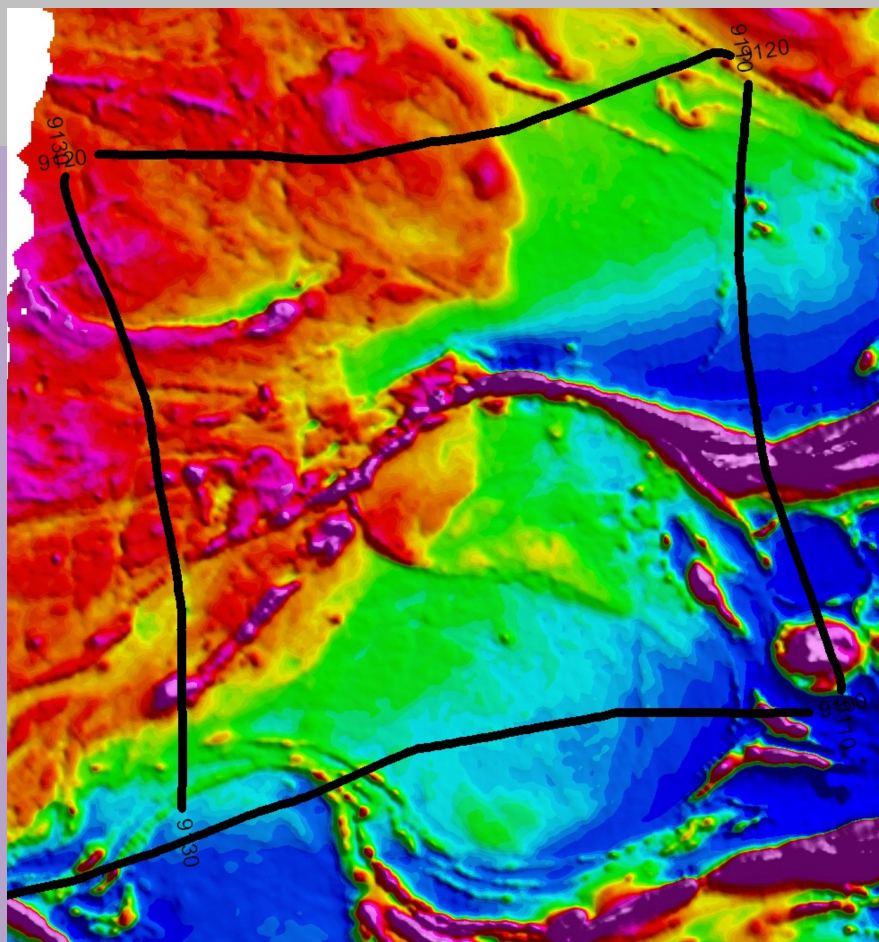
Issues and Objectives -4

Sensor, Heading and Gradients Effects



-removal of 1st order gradient does not improve results

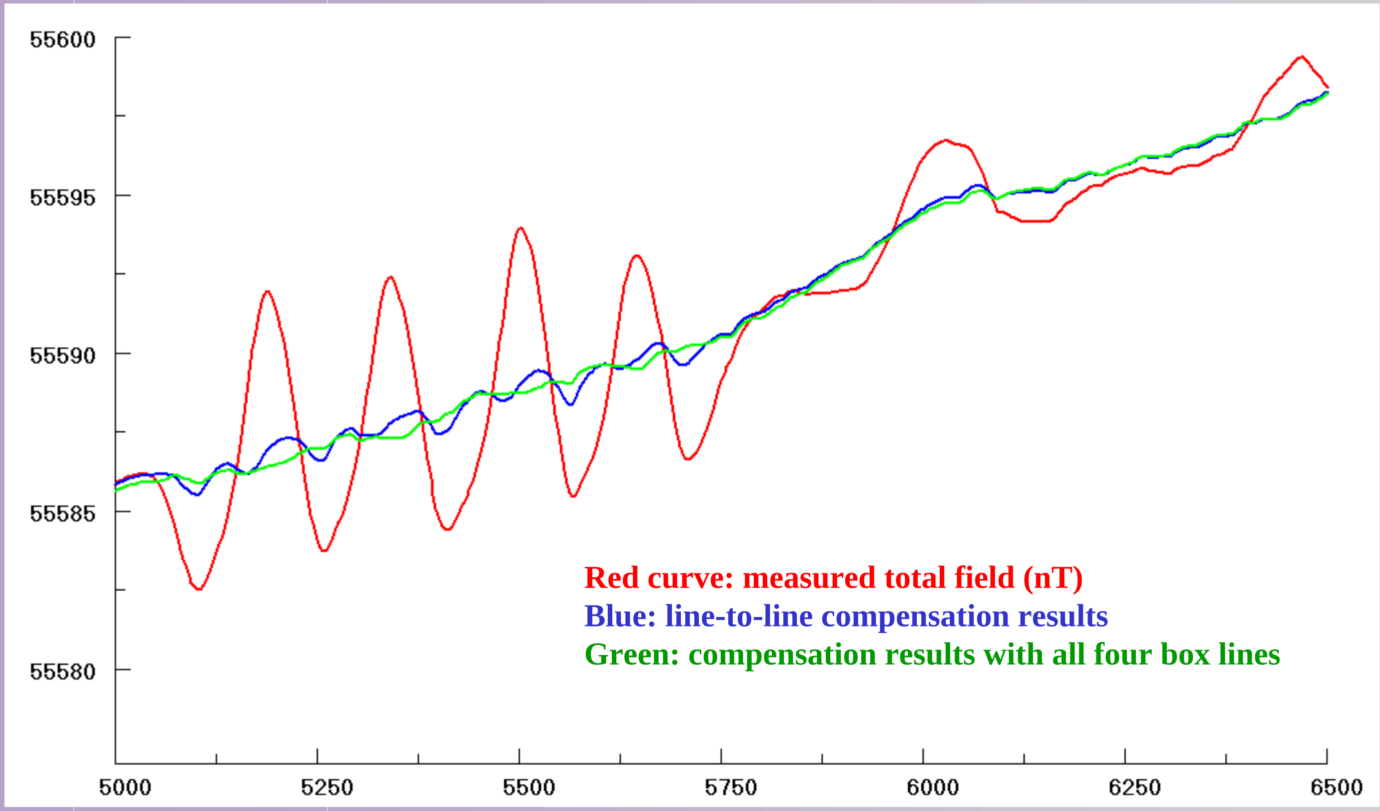
-for best results each sensor treated differently – *coefficients, solver, filters*

Compensation of AeroMagnetic Noises

Issues and Objectives -4

Sensor, Heading and Gradients Effects

multiple line coefficients vs single line coefficients



Issues and Objectives -5

Use of GPS attitude

to improve compensation over anomalies
improve coefficient calculation due to regional effects
compensate fluxgate data
fluxgate data not actually used to determine orientation

- Field tests were done with 3 Novatel Millenium geodetic grade, dual frequency GPS's on Terraquest's Navajo
- GPS's were sampled at 10 Hz
- base station was 40 to 70 kms away
- base station a Novatel Millenium sampled at 10 Hz
- differential corrections done with WayPoint software

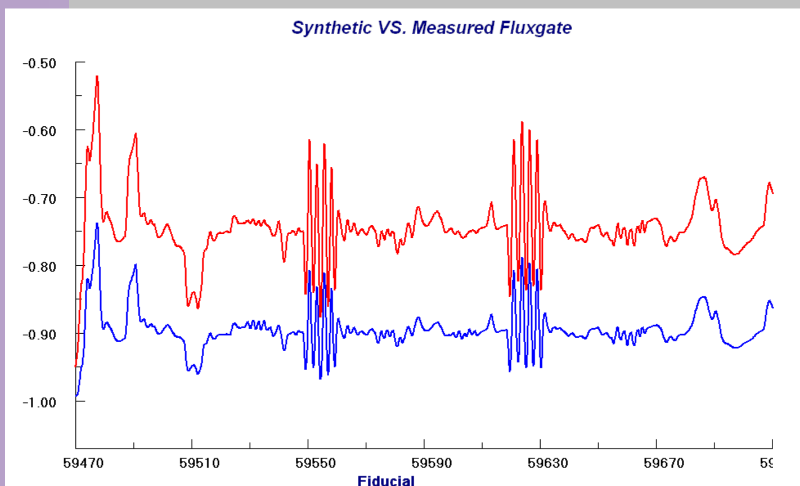
➢GPS data has what appears to be a long period drift

➢ Utilized on-board as basestation – 3 local difference vectors

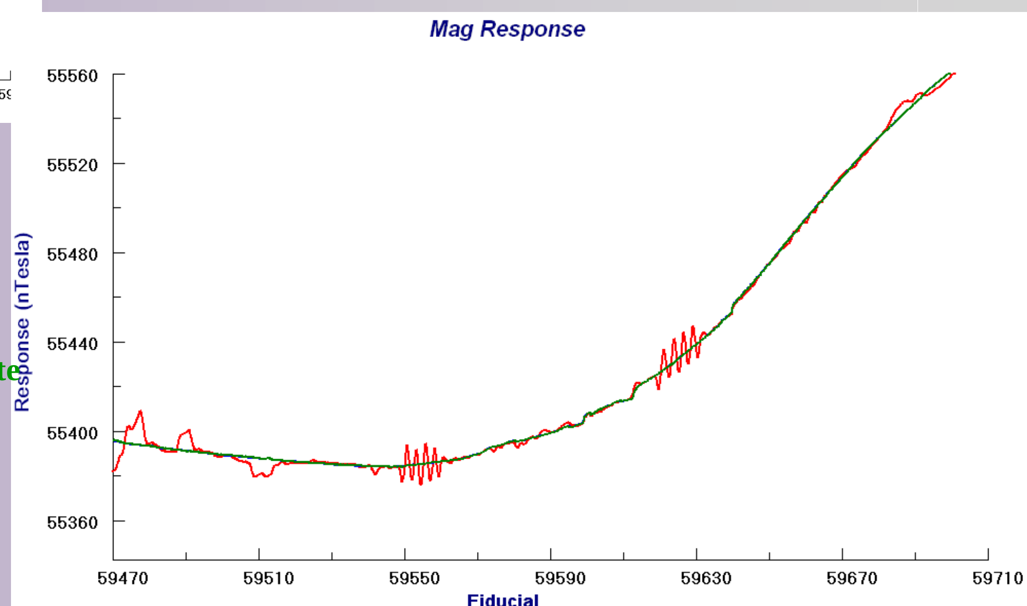
Compensation of AeroMagnetic Noises
Issues and Objectives -5

Use of GPS attitude

Note: Operator terms in Leliak's system are projections of B_i on $|B|$



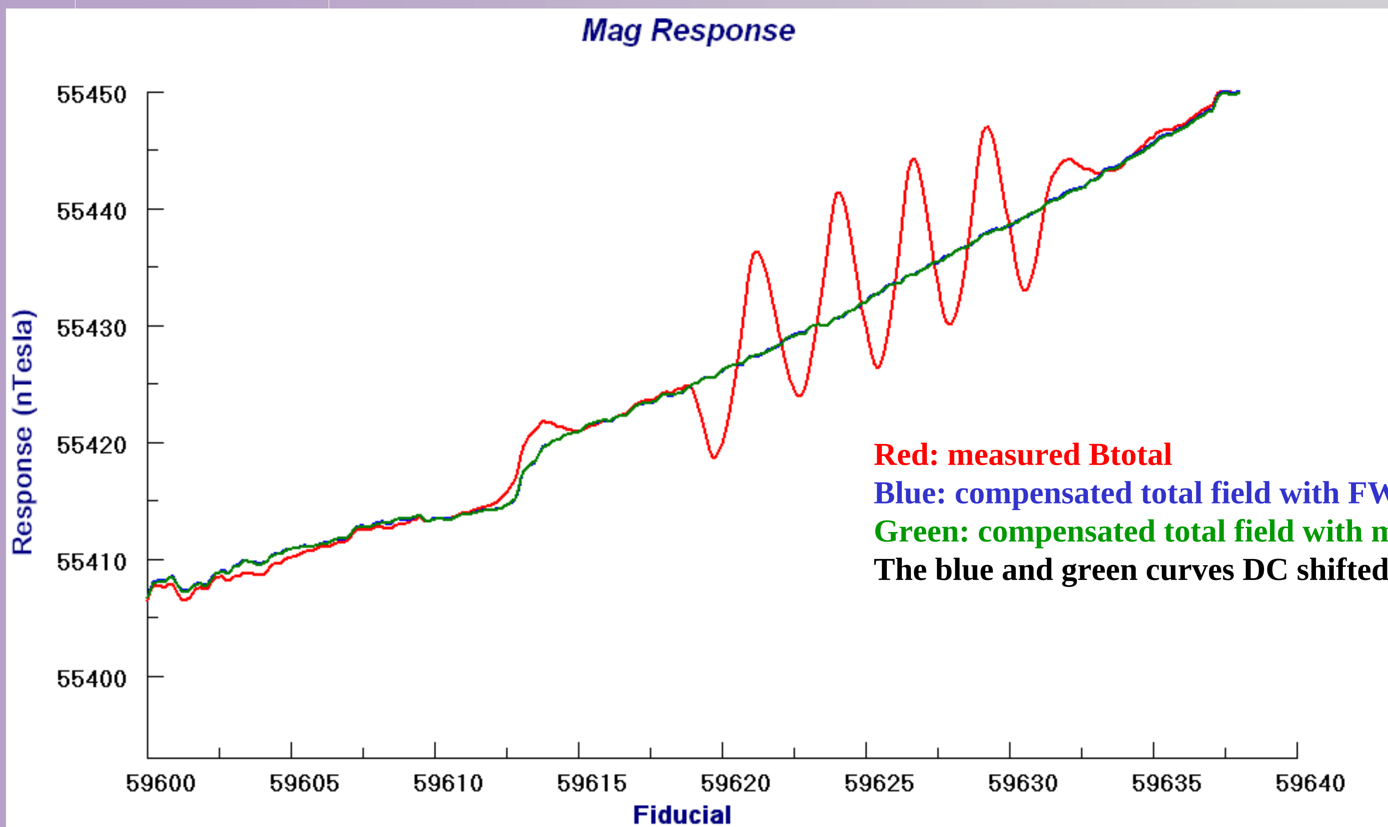
Red: simulated Bz
Blue: measured Bz



Red: measured Btotal
Blue: compensated total field with FW and FS vectors
Green: compensated total field with measured Fluxgate
The blue and green curves DC shifted.

Compensation of AeroMagnetic Noises
Issues and Objectives -5

Use of GPS attitude



Red: measured Btotal
Blue: compensated total field with FW and FS vectors
Green: compensated total field with measured Fluxgate
The blue and green curves DC shifted.

Conclusions

- Synthetic models reveal useful information
- Compensation can be improved under most conditions via the judicious use of different solvers and parameters,
- there are other assumptions within Leliak's formulation which are only approximations as "perfect" synthetic data cannot be totally compensated.
- some assumptions, such as accurate orientation information from fluxgate magnetometers, are not valid under all circumstances,
- other methods of obtaining orientation data such as using multiple GPS's are possible
- Ridge regression analysis and truncated singular value decomposition are effective techniques to improve the predicative power of the 16-term and 18-term interference models, particularly when multicolinearities exist in the interference models.

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