Applying Satellite Geomagnetism To Probe Ocean Flow

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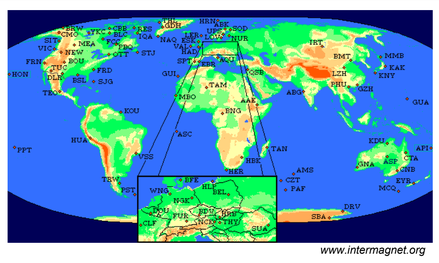
1. Motivation:

While many sources which contribute to the geomagnetic field have been extensively studied one source to receive little attention is the magnetic field generated via motional induction in the oceans. As part of the GEOSPACE consortium, we are attempting to gain a better understanding of the fields generated by this source and the flows that generate them. While recent work has highlighted the potential to extract a global tidal signal from satellite magnetic data, here we attempt to isolate a far more localised signal. Focusing on the Argentine Basin we aim to identify a circulation within the basin, to date only identified in TOPEX altimetry data. Using simple data analysis, it has been possible to isolate this signal in both CHAMP & SAC-C satellite datasets as well as in ground-based observatory data from Port Stanley.

2. Background Information:

- Motional Induction;
  - Due to high salt concentration, oceans act as an ionised fluid.
  - Movement of ocean through main core field induces electric currents in the oceans.
  - Movement of electric currents subsequently generates ever evolving secondary magnetic fields.
- Data Sources;
  - CHAMP
    - Launched in 2001, high precision scalar and vector magnetic data.
    - Provides excellent spatial coverage, but poor temporal coverage.
    - Orbits at approx. 400km, with 1Hz sampling rate.
  - SAC-C
    - Launched in 2001, orbits at approx. 700km with 1Hz sampling rate.
    - In permanent repeat track orbits, periodicity ~ 17 days.
    - Orbit configuration ensures slow change in local time, useful for repeat track analysis. Is an advantage over Oersted.
  - Observatories
    - Ground based magnetic measurements.
    - Dataset:- 1880s – present.
    - Poor spatial coverage, excellent temporal coverage.



www.intermagnet.org

Map of geographic distribution of ground based magnetic observatories across the globe.

3. Model Configuration:

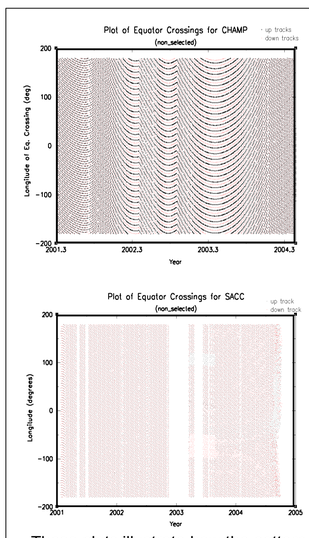
- CO2003 field model:
  - Validity period; 2001 - 2004
  - Derived using satellite data.
  - V. accurate main field estimation.
  - Main field estimated up to degree 32.
- CM4 (*Sabaka et al., 2004)*:
  - Validity period 1962 - 2004
  - Individual source estimation.
  - Parameter co-estimation.
  - Parameterised external field.
  - Derived using satellite and observatory data.

4. Data Selection Criteria:

- Datasets of both selected & non selected data compiled.
- Latitude dependant data selection employed.
- Data accepted on a point by point basis according to following criteria:
  - Night time (1800-0600)
  - Dst/dt < ±3nT/hr
  - Kp < 2+
  - Pcn < ±0.2

5. Repeat track Isolation:

- Use simple model residuals and repeat track data.
- A repeat track simply a pair of rapidly repeating overlying tracks
- Small temporal difference between tracks allows us to remove static residuals via differencing.
- Identification criteria change due to satellite orbit setup.



CHAMP Criteria:
- Eq cross <0.2° apart.
- Time Interval <3days

SAC-C Criteria:
- Eq cross <0.2° separation.
- Time Interval <16.5days

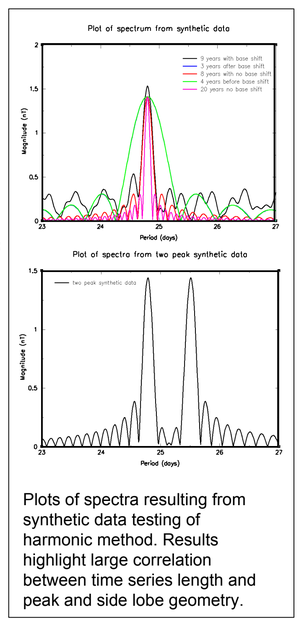
These plots illustrate how the pattern of equator crossings change through time depending on the orbit setup of each satellite. They also allow us to identify periods of time which satisfy the repeat track criteria for the satellite.

6. Methodology & Testing:

- Initial data selection of satellite data.
- Calculation and removal of main field on a point by point basis, using CO2003 and CM4 field models.
- Isolate data from desired region.
- Use least squares fit of 3 parameter harmonic function to predict contribution to total signal at given period/frequency.

$$M(t) = M_o + A\cos\omega t + B\sin\omega t$$

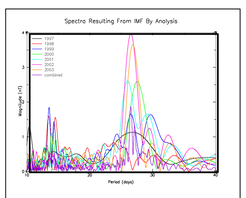
- Run harmonic least squares fit over range of periods to give period/frequency spectra of data.
- A peak in spectrum indicates presence of signal at this frequency in data.
- Testing carried out using synthetic datasets of varying length with set 24.8 day period.



Plots of spectra resulting from synthetic data testing of harmonic method. Results highlight large correlation between time series length and peak and side lobe geometry.

7. IMF By:

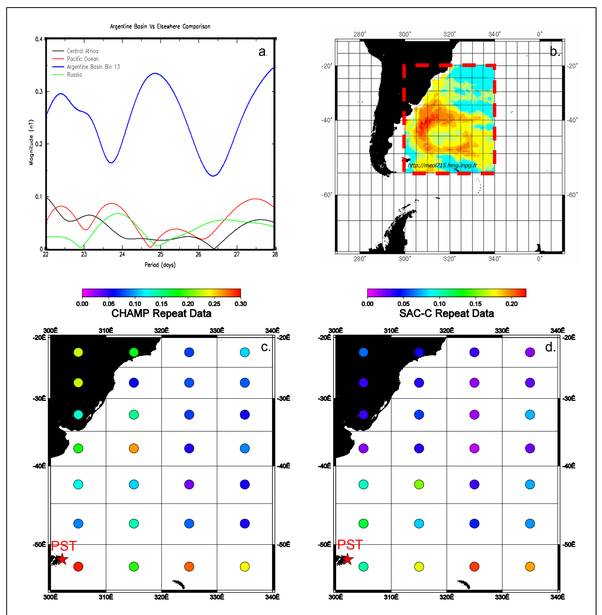
- It has been suggested that the signals being found in the magnetic results were contamination from IMF By.
- To test this hypothesis we have used IMF By data as input in harmonic routine, as before.
- No peak in resulting spectra suggests little or no influence from IMF By at this frequency, for this time period.



This plot highlights that IMF By does not appear to have any significant content at a period of 24.8 days. Thus suggesting our magnetic results are not of IMF By origin.

8. Satellite Results:

- Argentine Basin situated east of Argentina.
- Using both CHAMP & SAC-C datasets as input for harmonic analysis.
- Study area covers 40° x 35°, subsequently split into 28 individual bins, each having dimensions of 10° x 5°.
- Both standard residuals and repeat track data are analysed.
- By plotting amplitude of spectra at desired period we gain an insight into the spatial relationship of bins across the basin.
- Both CHAMP & SAC-C based spectra exhibit the expected spatial signatures one would expect from the circulation we have identified from TOPEX data.
- It is important to note that we see small signals away from the circulation interior as is expected.
- Plots highlight that, as expected amplitudes over the circulation interior are increased.
- Due to large gradients across east and southern edges of circulation, we expect large amplitudes in magnetic data. It is possible to identify this feature in the CHAMP & SAC-C repeat track spectra.
- In general we can identify no significant signal at the desired frequency when considering data from other areas of globe.



Plots of results from satellite study:

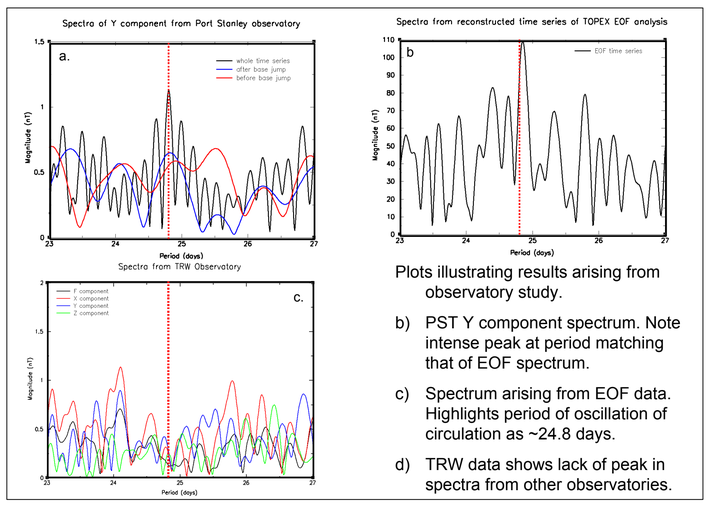
b) Spectra from other locations around the globe compared to a spectrum from inside the circulation. These plots highlight the lack of signal at the period we require, suggesting Argentine Basin results are localised.

c) Map of 24.8 day eddy identified from TOPEX data.

d) Plot showing spatial extent and structure of circulation across Argentine Basin using CHAMP repeat data as input.

e) Plot showing very similar features to (c), however on this occasion using SAC-C repeat data as input.

9. Observatory /EOF Results:



Plots illustrating results arising from observatory study.

b) PST Y component spectrum. Note intense peak at period matching that of EOF spectrum.

c) Spectrum arising from EOF data. Highlights period of oscillation of circulation as ~24.8 days.

d) TRW data shows lack of peak in spectra from other observatories.

EOF Analysis:

- Initial evidence of circulation found in TOPEX altimetry data.
- To verify period of oscillation a TOPEX time series has been constructed from an EOF study of the original TOPEX data from C. Hughes (POL).
- New time series used as input in harmonic method.
- Resulting spectrum highlights a clear peak at 24.8 days, thus replicating result from literature.

Observatory:

- Post main field removal, residuals are used as input in harmonic method.
- Results highlight a strong peak in Y component at very similar period to that of EOF analysis.
- Results from nearby Trelew observatory highlight no peak at desired period in any component.
- Lack of peak in other time series suggests result from PST is localised to the Argentine Basin.

10. Summary/Conclusions:

- Motional induction allows us to study the possibility of ocean flow patterns being present in magnetic field data.
- Most effective method of signal isolation at present is field model removal and repeat track analysis (in some circumstances).
- Using simple data analysis it is possible to predict periodic signals in magnetic data.
- We can, to some extent isolate localised signals in magnetic data from oceanic sources.
- We can render the suggestion of IMF contamination unlikely.

11. Future Work:

- Parameterize tidal signals and other periodic signals with a view to predict and remove from main datasets.
- Analyse wider reaching extent of Argentine Basin signal.
- Use similar technique to identify other localised signals globally.
- Use PCA/EOF analysis to identify and isolate localised signals in magnetic records.
- Re-implement method using the new CHAOS field model .

12. References:

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