As of 10 June 2016

This GOES-R Level 2+ space weather Algorithm Theoretical Basis Document (ATBD) is preliminary and subject to change as the GOES-R Program prepares for a launch in late 2016.

The NOAA National Centers for Environmental Information (NCEI) is currently developing a demonstration version of the Satellite Product Analysis and Distribution Enterprise System (SPADES) which will host the L2+ algorithms. The operational SPADES will be instantiated by the National Weather Service in FY2017 to serve the needs of the Space Weather Prediction Center (SWPC).

Updated versions of the L2+ ATBDs will periodically be made available and posted to the SPADES website.

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NCEI

http://www.ngdc.noaa.gov/stp/space-weather/online-publications/stp_sii/spades/

NOAA NESDIS CENTER for SATELLITE APPLICATIONS and RESEARCH

MAGNETOMETER COMPARISON TO QUIET FIELDS ALGORITHM THEORETICAL BASIS DOCUMENT
Version 1.3

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TITLE: MAGNETOMETER COMPARISON TO QUIET FIELDS ALGORITHM THEORETICAL BASIS DOCUMENT VERSION
1.3

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MAG COMPARISION TO QUIET FIELDS ALGORITHM THEORETICAL BASIS DOCUMENT VERSION HISTORY SUMMARY

Version	**Description**	**Revised Sections**	**Date**
1.0	Created by Dr. Paul TM Lotoaniu CU/CIRES/SWPC	New Document	Mar 10, 2008
1.2	Revised by Paul Loto'aniu	All	Mar, 2009
1.3	Revised by Paul Loto'aniu	All	Dec, 2009

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LIST OF ACRONYMS

ATBD	Algorithm Theoretical Basis Document
CIRES	Cooperative Institute for Research in Environmental Sciences
CU	University of Colorado, Boulder
MAG	Magnetomer
STAR	Center for Satellite Applications and Research
SWPC	Space Weather Prediction Center
IGRF	International Geomagnetic Reference Field
IAGA	International Association of Geomagnetism and Aeronomy

ABSTRACT

The algorithm calculates quiet field model in earth centered and local spacecraft coordinate systems. The model is composed of an external component and an internal component. For the internal component we use the 10th generation International Geomagnetic Reference Field generation standard main field model and for the external component we use the Olson-Pfitzer 1977 (OP-77) model. Mathematical and pseudo code descriptions are given of the algorithm. Described are assumptions made regarding input spacecraft attitude data and ephemerides. Example test runs using proxy data are shown and compared to results from currently implemented algorithms. Current algorithm limitations and possible future improvements are also discussed.

1.0 INTRODUCTION

1.1 Purpose of This Document

The purpose of this document is to describe the product algorithm and its theoretical basis. This document can be used as a reference for implementing the algorithm into software and as a guide to the IGRF10 and OP-77 field models. The IGRF10 and OP-77 models were chosen for the quiet field model implementation because they require no inputs external to GOES data for implementation. Furthermore, removing a geomagnetically quiet-time baseline reveals variations that have useful and physically significant. The ability to routinely compare measured magnetic field data to a field model provides valuable information for operations and the research community. Presented are the model mathematical and pseudo code descriptions, assumptions made regarding input spacecraft attitude data and ephemerides, test results using proxy data, and a discussion on the models limitations and possible future improvements.

1.2 Who Should Use This Document

The STAR AIT group shall use this document to integrate the algorithm into their collaborative framework environment. It shall also be used by the prime development and implementation contractor to design, develop, test, validate and implement the algorithm into the final operational processing system. In addition, the GOES-R AWG space weather application team shall use this ATBD to verify their operational requirements are being met by the proposed algorithm. They should also use it to understand the strengths and weaknesses of the algorithm as well as its accuracy and applicability.

1.3 Inside Each Section

Section 2.0, OBSERVING SYSTEM OVERVIEW, describes the product objectives and requirements, and assumptions made regarding magnetometer characteristics.

Section 3.0 ALGORITHM DESCRIPTION, describes the theoretical basis of the algorithm, assumptions made for sensory data, input data and ancillary data, algorithm input/output, error estimates and programming, procedural and computational considerations.

Section 4.0 TEST DATA SETS AND OUTPUTS, describes the test data sets used to characterize the performance of the algorithm and the data product

quality. Also are described are the results from the algorithm processing on simulated input data.

Section 5.0 PRACTICAL CONSIDERATIONS, discusses issues involving numerical computation, programming and procedures, quality assessment and diagnostics and exception handling.

Section 6.0 ASSUMPTIONS AND LIMITATIONS, discusses algorithm performance with regard to accuracy and the limitations of the algorithm and possible improvements.

Section 7.0 REFERENCES, provides all references mentioned in the ATBD.

1.4 Related Documents

1. GOES-R MAGNETOMETER PORD (417-R-MAGPORD).

2. GOES-R Mission Requirements Document 2B Prime (MRD-2B').

3. Magnetometer convert data to alternative geophysical coordinate systems, ATBD Version 1.0, 2008.

1.5 Revision History

Revision Number	Date	Author	Revision Description	Reason for Revision
1.0	Mar, 2008	Paul Loto'aniu	Create document	Create document
1.2	Mar, 2009	Paul Loto'aniu	Revised all sections	Revised all sections
1.3	Dec, 2009	Paul Loto'aniu	Revised all sections	Revised all sections

2.0 OBSERVING SYSTEM OVERVIEW

2.1 Product Generated

The MAG comparison to quiet-field model algorithm generates field model data that simulates the GOES-R MAG Level 1B output in local spacecraft and earth centered coordinate systems. Output includes times tags. The quiet-time field model product will be routinely compare to the MAG measured magnetic field data. Significant difference between the modeled and observed values will suggest enhanced space weather activity. Note: measured sensor data will not be part of the output from the product but instead will be part of the overall data stream from all MAG product outputs.

2.2 Instrument Characteristics

The MAG instrument operational requirements and characteristics are detailed in section 3.4.2.7 of the GOES-R Series Mission Requirements Document (MRD) Version 3.0 dated February 2007 and the MAG instrument Performance and Operational Requirements Document (PORD) draft dated November 2004. The accuracy of the algorithm relies on precise knowledge of spacecraft attitude and location. *The accuracy of the modeled data is independent of the MAG instrument*. However, during comparison to MAG sensor data the accurate knowledge of instrument orientation, calibration and data timing will affect the validity of the comparisons. Algorithm development by the SWx AT will assume the instrument meets the performance requirements outlined in the GOES-R MRD and MAG PORD.

3.0 ALGORITHM DESCRIPTION

3.1 Algorithm Overview

The MAG comparison to quiet-field model algorithm generates modeled MAG data in earth centered and local spacecraft coordinate systems, based on knowledge of spacecraft location and time. The quiet-time field model product will be routinely compared to the MAG measured magnetic field data post-product. Significant difference between the modeled and observed values will suggest enhanced space weather activity.

The quiet-field model is actually composed of an external component and an internal component. For the internal component we use the 10th generation IGRF standard main field model adopted by the IAGA. The external component is the OP-77 model, which is valid for quite times and all tilt angles of the Earth's dipole field. In this section we describe the IGRF10 and OP-77 field model algorithms along with associated coordinate transformations.

3.2 Processing Outline

The processing outline of the comparison to quiet field algorithms is summarized in the figure 3.1 below. The current algorithms are implemented as C++ routines with an object oriented emphasis. However, current maturity does not meet ISO 2003 standard.

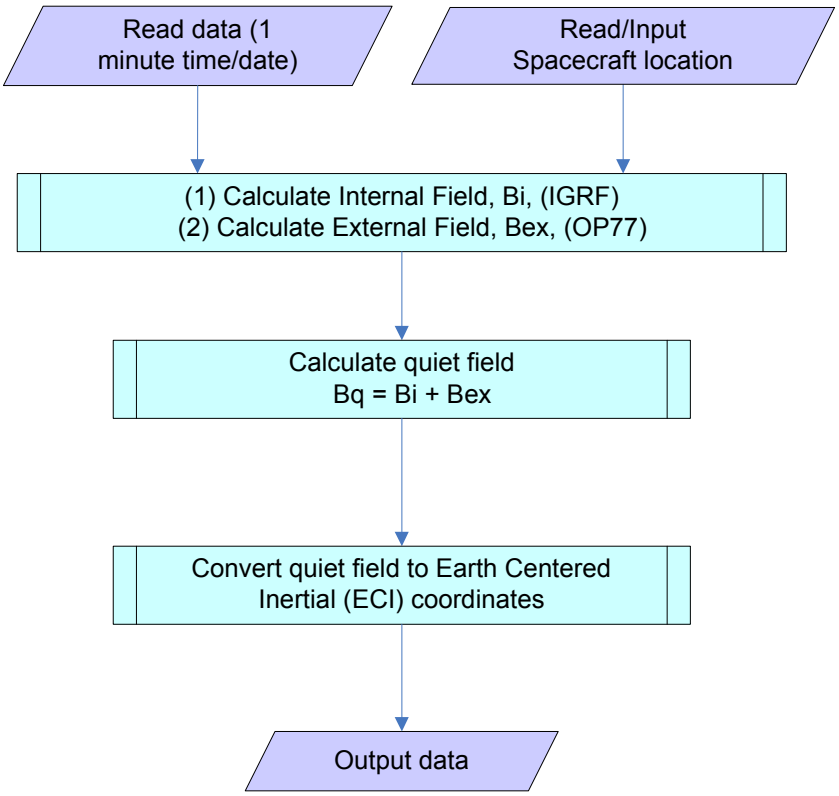

Figure 3.1: High-level flowchart of the MAG quiet field algorithm.

3.3 Algorithm Input

The algorithm requires only spacecraft location and time. Direct comparison with sensor data would be done post-algorithm output.

3.3.1 Quiet field model input

- Data date and time tags.
  - Hour and minutes are 1 or 2 digit integers.
  - Seconds is double with are least 100 millisecond accuracy.
  - Day and month are 1 or 2 digit integer.
  - Year is 4 digit integer
- Spacecraft location in geographic longitude and latitude.
- Spacecraft altitude in kilometers assuming spherical earth.
- Spacecraft 3-D vector location in kilometer units and in Solar magnetic (SM) coordinates.
- Earth dipole tilt angle relative to the Sun-Earth line.
- Additional model input options:
  - Which model to calculate
    - 1 = calculates only IGRF10 model
    - 2 = calculate OP=77 + IGRF10 model
  - Ouput coordinate system
    - "eci" = return modeled magnetic field values in earth centered interial (or gei) coordinates.
  - Calculation of coordinate transformation matrices and dipole tilt angle are accomplished internally to the transformation routines. See, related document *magnetometer convert data to alternative geophysical coordinate systems*, ATBD Version 1.0, 2008.

3.4 Theoretical Description

3.4.1 Physics of the Problem

3.4.1.1 The Olson-Pfitzer 1977 external field model

The OP-77 field model is based on the work of Olson and Pfitzer (1977) and Olson and Pfitzer (1974). The model includes contributions from the magnetopause currents, and current distributed throughout the magnetosphere (the tail and ring currents). It is valid for all tilt angles of the Earth's dipole axis and is valid during quiet magnetic conditions.

The model is semi-empirical based on both physical principles and several data sets that describe quantitatively the structure of the magnetospheric magnetic field. A generalized least squares method was employed to fit coefficients of a power series (including exponential terms) through fourth order in space and

third order in tilt angle. This expansion was optimized for the near earth region and is valid to 15 earth radii. Outside of this region the field diverges rapidly and a template sets the field to zero. For the inner magnetosphere the earth's internal field dominates below about two earth radii and these variations are not sufficiently expressed by the OP-77 model. Hence, the field is set to zero below two earth radii.

In order to calculate the OP-77 model input requirement to the model includes time/date, satellite location (longitude and latitude geographic) and dipole tilt angle with respect to the solar magnetic coordinate system. Hence, coordinate transformation is required for addition to the IGRF10 model.

3.4.1.2 The 10th IGRF main field model

The IGRF10 is the tenth generation standard main field model adopted by the International Association of Geomagnetism and Aeronomy (IAGA). This is a degree and order 13 model for years 2005-2010 with models for 1900 forward enabling estimation of the main field for dates between January 1, 1900 and January 1, 2010. For more information on the IGRF and IAGA, visit the IAGA Working Group V-MOD Web site at: http://www.ngdc.noaa.gov/IAGA/vmod/

The model only considers internal (core) contributions and is also semi-empirical employing coefficients in spherical harmonics that represents the internal field at the earths surface and above. The model algorithm generates magnetic field values in ECI coordinates and therefore requires coordinate transformation for addition to the OP-77 model.

3.4.1.3 The quiet-field model

The quiet field model is a summation of the IGRF10 internal model and the OP-77 external model. The OP-77 model includes contribution from both magnetopause current and distributed currents (tail current). The IGRF10 gives the main field due to internal contributions.

At GOES-R altitudes and during quiet times the main field can still dominate. During active times external contributions can be significant. The OP-77 model also takes into account the dipole tilt angle. However, other external contributions to the magnetic field strength at the GOES-R location during active periods, e.g.

negative solar wind Bz and solar wind velocity, should result in sometimes large differences between the quiet model values and observation.

3.4.1.4 Coordinate Systems

There a several coordinate systems of importance to the quiet-field model implementation. The IGRF10 model output is a local coordinate system while for the OP-77 model input Solar magnetic (SM) coordinates are important. Furthermore, the model output is earth centered interial (ECI or GEI). In this section we describe these three coordinate systems.

Coordinate transformations are accomplished by calling the coordinate transformation routines. See related document *magnetometer convert data to alternative geophysical coordinate systems, ATBD Version 1.0, 2008*, for detailed discussions of coordinate transformation algorithms and other important coordinates to the GOES-R MAG products.

Geocentric Equatorial Inertial System (GEI) or Earth-Centered Inertial (ECI) System

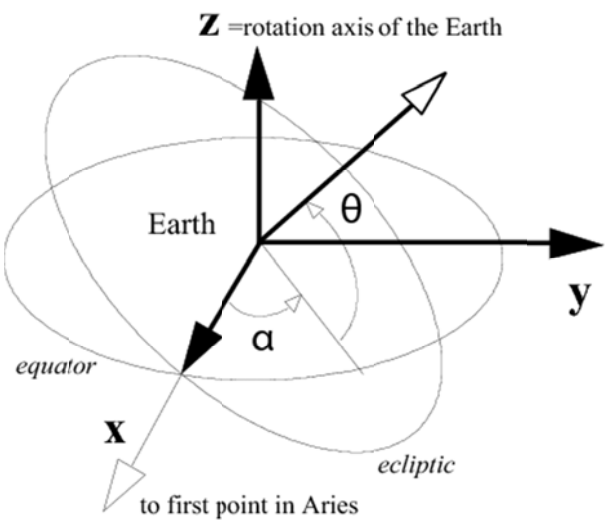

Figure 3.2 GEI or ECI System

The Z-axis is parallel to the rotation axis of the Earth. The X-axis is defined by the intersection of the equator plane and the ecliptic plane, and is pointing

towards the first point of Aries (Sun position at the vernal equinox). The angles are *right ascension,* α, and the *declination* θ.

Solar Magnetic (SM) system

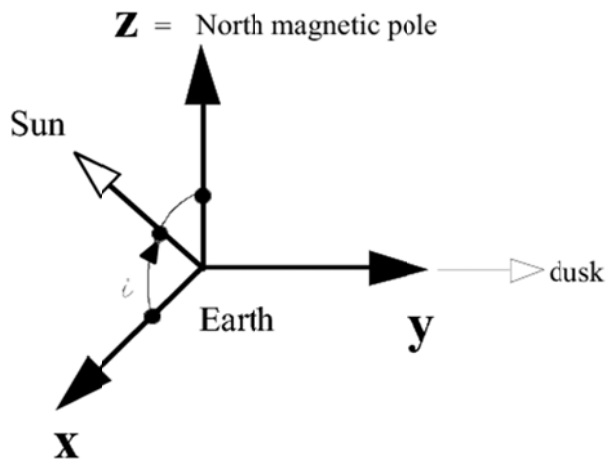

Figure 3.3: The Z-axis is parallel to the North magnetic pole, the X-Z plane contains the direction of the Sun and Y-axis is perpendicular to the Earth-Sun line toward dusk. The SM system rotates with both a yearly and daily period with respect the inertial system.

3.4.2 Mathematical Description

3.4.2.1 IGRF10 model magnetic field representation

The IGRF10 model uses spherical harmonic expansions of the scalar potential V to describe the internal field and its secular variations. The main field is given by

$$\vec{B} = -\vec{\nabla} V$$

where,

$$V(\phi,\lambda,r,t) = a\sum_{n=1}^{N}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^{n+1}\left[g_n^m(t)\cos(m\lambda) + h_n^m(t)\sin(m\lambda)\right]\overline{P}_n^m(\sin\phi)$$

where, a corresponds to the mean earth radius (6371.2 km), (ϕ,λ,r) are the geographic latitude, longitude and the geocentric radius, respectively, and $g_n^m(t)$

and $h_n^m(t)$ are the time-dependent model Gaussian coefficients of degree n and order m. $\overline{P}_n^m$ are the Schmidt normalized associated Legendre functions defined as

$$\overline{P}_n^m(\sin\phi) = \sqrt{2\frac{(n-m)!}{(n+m)!}}\overline{P}_n^m(\sin\phi) \quad \text{if } m>0,$$

$$\overline{P}_n^m(\sin\phi) = \overline{P}_n^m(\sin\phi) \qquad \text{if } m=0.$$

By differentiating the vector potential the equations for the main field are

$$X(\phi,\lambda,r) = -\sum_{n=1}^{N}\left(\frac{a}{r}\right)^{n+2}\sum_{m=0}^{n}(g_n^m(t)\cos m\lambda + h_n^m(t)\sin m\lambda)\frac{d\overline{P}_n^m(\sin\phi)}{d\phi}$$

$$Y(\phi,\lambda,r) = \frac{1}{\cos\phi}\sum_{n=1}^{N}\left(\frac{a}{r}\right)^{n+2}\sum_{m=0}^{n}m(g_n^m(t)\cos m\lambda - h_n^m(t)\sin m\lambda)\overline{P}_n^m(\sin\phi)$$

$$Z(\phi,\lambda,r) = -\sum_{n=1}^{N}(n+1)\left(\frac{a}{r}\right)^{n+2}\sum_{m=0}^{n}(g_n^m(t)\cos m\lambda - h_n^m(t)\sin m\lambda)\overline{P}_n^m(\sin\phi).$$

The IGRF coefficients, degree and order are referenced to an epoch, and values are different for each epoch. Hence, the IGRF10 can be regarded as a collection of models for each epoch. At any one epoch, the IGRF specifies the numerical coefficients of a truncated spherical harmonic series: for dates until 2000 the truncation is at n=10, with 120 coefficients, but from 2000 the truncation is at n=13, with 195 coefficients. Each model is specified every 5 years, for epochs 1900.0, 1905.0 etc. For dates between the model epochs, coefficient values are given by linear interpolation. Model coefficients are inputted into the algorithm from an ASCII file (IGRF10.unx) along with epoch degree and order. The coefficients of the 10th generation IGRF are also available from the IAGA website http://www.iugg.org/IAGA. The current limit of the IGRF is 2010. Hence, for GOES-R future IGRF epoch models must be incorporated.

FORTRAN and C implementations of the IGRF10 model can be found at http://www.ngdc.noaa.gov/IAGA/vmod/igrf.html. Note: in order to be compatiable with previous implementations, the C++ encoding for GOES-R uses indexing starting with *m=1* rather than *m=0*.

3.4.2.2 OP-77 model magnetic field representation

In Cartesian form the three components of the magnetic field at the observation (satellite location) point is represented by

$$B_x = \sum_{i=0}^{4}\sum_{j=0}^{2}\sum_{k=0}^{4}\left[a_{ijk} + b_{ijk}\exp(-0.06\cdot r^2)\right]\cdot x^i \cdot y^{2j} \cdot z^k$$

$$B_y = \sum_{i=0}^{4}\sum_{j=0}^{2}\sum_{k=0}^{4}\left[c_{ijk} + d_{ijk}\exp(-0.06\cdot r^2)\right]\cdot x^i \cdot y^{2j+1} \cdot z^k$$

$$B_z = \sum_{i=0}^{4}\sum_{j=0}^{2}\sum_{k=0}^{4}\left[e_{ijk} + f_{ijk}\exp(-0.06\cdot r^2)\right]\cdot x^i \cdot y^{2j} \cdot z^k$$

where, x,y and z are the spacecraft location in units of earth radii in SM coordinates, r is earth radii and

$a_{ijk} = b_{ijk} = 0$ if $i + 2j + k > 6$

$c_{ijk} = d_{ijk} = 0$ if $i + 2j + 1 + k > 6$

$e_{ijk} = f_{ijk} = 0$ if $i + 2j + k > 6$

The coefficients, a-f, depend only on position and are recalculated each time the tilt angle of the dipole is changed. The coefficients, a-f, are determined from the tilt dependent constants, aa-ff, by the following expressions

$$a_{ijk} = aa_{ijk1}\cdot\mu^p + aa_{ijk2}\cdot\mu^q$$

$$b_{ijk} = bb_{ijk1}\cdot\mu^p + bb_{ijk2}\cdot\mu^q$$

$$c_{ijk} = cc_{ijk1}\cdot\mu^m + cc_{ijk2}\cdot\mu^n$$

$$d_{ijk} = dd_{ijk1}\cdot\mu^m + dd_{ijk2}\cdot\mu^n$$

$$e_{ijk} = ee_{ijk1}\cdot\mu^s + ee_{ijk2}\cdot\mu^t$$

$$f_{ijk} = ff_{ijk1}\cdot\mu^s + ff_{ijk2}\cdot\mu^t$$

where, μ is the tilt angle and the subscript numbers, represented by l=0 or 1, varies most rapidly followed by, in descending order k, j and i. (p,q,m,n,s,t) are given by

$$p = 1 - (k \bmod 2),$$
$$q = 3 - (k \bmod 2),$$
$$m = 1 - (k \bmod 2),$$
$$n = 3 - (k \bmod 2),$$
$$s = k \bmod 2,$$
$$t = (k \bmod 2) + 2.$$

The OP-77 model is described in related documents *Olson, W. P., and K. A. Pfitzer, Magnetospheric magnetic field modeling, Annual Scientific Report, AFOSR Contract No. F44620-75-C-0033, 1977*. Included in the reference is a FORTRAN-77 implementation of the OP-77 model.

3.4.2.3 The quiet-filed model description

The quiet-field model of the magnetospheric magnetic field can be written in terms of contributions as

$$\vec{B} = \vec{B}_G + \vec{B}_{MP} + \vec{B}_D$$

where, $\vec{B}_G$ is the main field, $\vec{B}_{MP}$ is the field due to magnetopause currents and $\vec{B}_D$ is the distributed currents contribution. The main component is calculated using the IGRF10 model and contributions from external currents calculated using the OP-77 model. Hence,

$$\vec{B} = \vec{B}_{IGRF} + \vec{B}_{OP77}$$

where,

$$\vec{B}_{IGRF} = \vec{B}_G$$
$$\vec{B}_{OP77} = \vec{B}_{MP} + \vec{B}_D .$$

The OP-77 calculates field values in solar magnetic coordinates while default output coordinates is ECI. Hence, coordinate transformation is included in the algorithm to allow the addition of the two field models giving the quiet-field model.

3.4.2.4 Earth dipole tilt angle

The dipole tilt angle relative to the SM coordinate system is defined and discussed in related document *magnetometer convert data to alternative geophysical coordinate systems, ATBD Version 1.0, 2008*.

3.4.2.5 Time and date

For the calculation of the external OP-77 model no time and date input is required. However, the dipole tilt angle is time dependent and is described and discussed in related document *magnetometer convert data to alternative geophysical coordinate systems, ATBD Version 1.0, 2008*.

For the internal IGRF10 field model input date and time is converted into decimal year. We used the following algorithm to calculate decimal year, sdate:

Integer F1 = ((275.0 * month) / 9.0)
Integer F2 = ((month + 9.0) / 12.0)

N = F1 - (2 * F2) + day – 30
If leap year, N = F1 - F2 + day – 30.

dblDay = N + (hour + (min + (sec / 60.0)) / 60.0) / 24.0;

if leap year, sdate year+dblDay/367 (1-366.999999... day range)
else, sdate = year + dblDay/366 (1-365.999999... day range).

Note: The decimal should be 100 msecs accuracy in order to account for high resolution MAG data comparisons.

3.4.2.6 Coordinate Transformations

The OP-77 algorithm calculates model field values in SM coordinates. The IGRF10 algorithm calculates model main field values in a local coordinate system. In order to sum the two models to give the quiet field model values we convert one or both model outputs. The output for the quiet field model GEI (ECI) coordinates. The coordinate transformations are accomplished by calling transformation routines described in related document *magnetometer convert data to alternative geophysical coordinate systems, ATBD Version 1.0, 2008*.

3.4.3 Algorithm Output

The algorithm produces model magnetic field data with nanoTesla units and in GEI (ECI) coordinates.

4.0 TEST DATA SETS AND OUTPUTS

4.1 Simulated/Proxy Input Data Sets

The proxy data consists of magnetometer data from previous GOES (10-13) observations that represent both quiet and active geomagnetic conditions. In addition, model values were computed using previous legacy FORTRAN for comparisons.

4.2 Output from Simulated/Proxy Inputs Data Sets

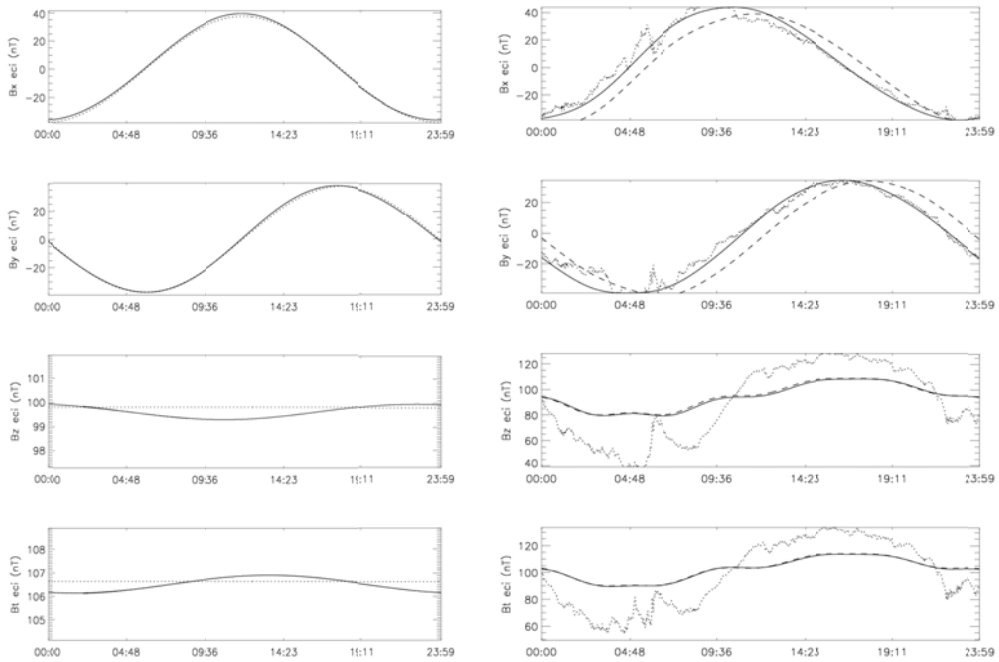

Figure 4.1 Comparisons of legacy FORTRAN code to GOES-R C++ algorithm. Left panel shows IGRF field only with solid line indicating GOES-R algorithm and dotted line legacy code results (legacy code assumes zero degree inclination); Right panel shows quiet field (IGRF + OP-77) with

solid indicating GOES-R code results, dashed line are legacy code results and dotted line represent actual measurments.

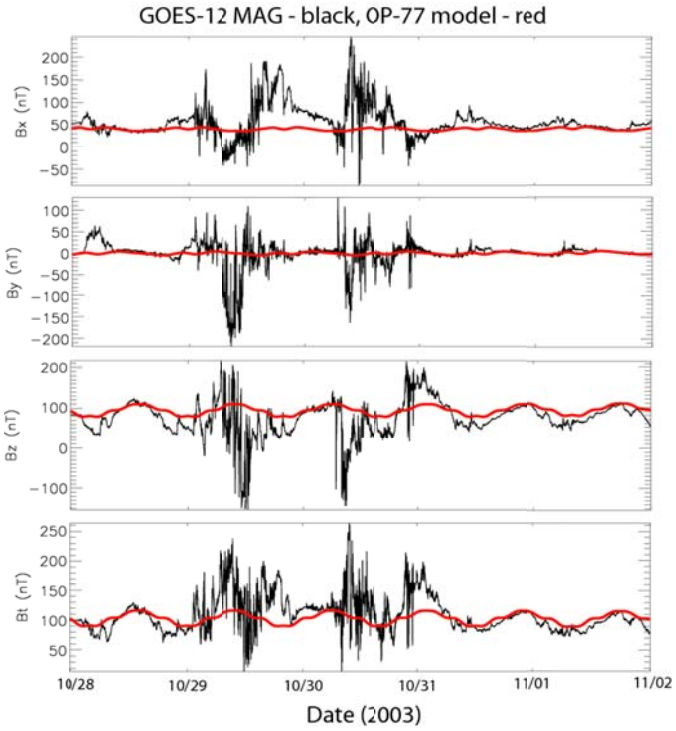

Figure 4.2 Comparison between GOES-12 measured data (black line) and the GOES-R quiet field model algorithm (red line).

4.2.1 Precisions and Accuracy Estimates

The algorithm is a field model and accuracy is defined by the model intentions and boundaries. The model expansion was optimized for the near earth region and is valid to 15 earth radii. Outside of this region the field diverges rapidly and a template sets the field to zero. For the inner magnetosphere the earth's internal field dominates below about two earth radii and these variations are not sufficiently expressed by the OP-77 model. Hence, the field is set to zero below two earth radii. The quiet field is valid for Kp=0 and 1 and represents only an average state of the quiet magnetosphere.

In terms of the algorithm implementation a comparisons between legacy FORTRAN codes to the GOES-R C++ algorithm shows excellent agreement (see Fig 4.1). The difference between the legacy and new algorithm results seen in the panels are due to the legacy code assuming zero inclination while the new algorithm inputs actual spacecraft location. In Fig 4.2 the comparison between model and measurments diverge considerably when the magnetic field is highly

active, emphazising the model not being accurate during geomagnetically active periods.

4.2.2 Error Budget

Since this algorithm is a field model the only errors to consider are the limit of the model itself. This is dicussed in sections 3.4.1 and 4.2.1

5.0 PRACTICAL CONSIDERATIONS

5.1 Numerical Computation Considerations

The computation time of the algorithm is slow. For example, calculating 2 hours of 2 Hz 3-component model field data at the GOES-12 location took 197 seconds (13 msec per data point). However, given the algorithm will be implemented on streaming real-time data 13 msec per data point is still well within the data latency of 5 secs.

Still, pre-planned improvements will include optimization of the code. This may include setting a limit on the order of the IGRF summation, since at geosyschronous orbit the higher order terms should have less than 0.01 nT influence on the total field values.

5.2 Programming and Procedural Considerations

The model optional inputs are:

- Which model to calculate:-
    - 1 = calculates only IGRF10 model
    - 2 = calculate OP=77 + IGRF10 model
- The ouput coordinate system
    - "eci" = return modeled magnetic field values in earth centered interial (or gei) coordinates.
    - The input coordinate system for the OP-77 model calculations is solar magnetic. Hence, to ouput values in ECI/GEI the transformation object is called within the model object.

5.3 Quality Assessment and Diagnostics

The following procedures are recommended for diagnosing the performance of the GOES-R MAG quiet field model.

- Compare model results to research community publications.

- Compare model results to GOES MAG data during quiet geomagnetic conditions.

5.4 Exception Handling

Model member functions return 0 or 1. 0 means no error and 1 means error. However, no exception action is taken given an error. Exception handling will have to be included in future updates. The algorithm does not consider invalid input data, hence, invalid values must be removed/filled in after function return.

5.5 Algorithm Validation

Pre-Launch Validation:

The algorithm will be/has been validated as described in section 4 using previous GOES magnetometer data as proxy and comparisons legacy code and to research community results.

Post-Launch Validation:

The algorithm will be validated by comparing model output to GOES-R MAG observations during quiet geomagnetic conditions and by comparing results to research community results and previously implemented legacy codes.

6.0 ASSUMPTIONS AND LIMITATIONS

6.1 Performance

Since GOES-R will be at geosychnronous orbit the algorithm is within the models normal paramters. However, computation time is slow and pre-planned improvement includes optimization of the code.

6.2 Assumed Sensor Performance

The algorithm only assumes that time tags are accurate. It does not require the sensor data itself to work. However, time tag issues could arise if the sensor is not working within normal parameters. Hence, the algorithm assumes the sensor

will meet its specifications and performance is within normal operational parameters.

6.3 Pre-Planned Product Improvements

An improvement to the algorithm will be exception handling. Also, planned improvements include updating IGRF model as updates become available. Imprivements also include optmisation to minimize computation time.

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