# Magnetic Field and Sun Position Reference Models

AcubeSAT-ADC-EW-007

Savvidis Georgios

November 29, 2019
Version: 1.1

Aristotle University of Thessaloniki

Aristotle Space and Aeronautics Team
CubeSat Project

2019

# Contents



# Changelog

| Date | Version | Document Status | Comments |
|---|---|---|---|
| 27/11/2019 | 1.1 | INTERNALLY RELEASED | Fixed synatax and grammar (Nikolaos Saoulidis) |
| 26/11/2019 | 1.0 | INTERNALLY RELEASED | Initial Revision |

This is the latest version of this document (1.1) as of November 29, 2019. Newer versions might be available at https://helit.org/mm/docList/AcubeSAT-ADC-EW-007.

# Introduction

This report's purpose is to explain IGRF, sun position and eclipse calculator use in the ADCS of AcubeSAT, their simulation logic and figures. The simulation script is written in MATLAB environment.

# 1 Magnetic field models

The magnetic field of Earth can be described either as a dipole model, a tilted-dipole model, or the International Geomagnetic Reference Field Model (IGRF).

## 1.1 IGRF explanation and use

The IGRF is a mathematical description of the structure of Earth's main magnetic field and its secular variation near and above Earth's surface. IGRF is considered as the international standard model for space missions and satellites. Other geomagnetic field models have been developed referencing IGRF to serve specific problems, unrelated with our mission. It is updated every 5 years, with the current edition published in 2015 and will be valid until 2019 having a precision of 0.01 nT. External currents in the ionized upper atmosphere and magnetosphere cause variations in the intensity of the Earth's magnetic field, but are not considered because the ionosphere stretches out to about 400km. Therefore for the Low and High Earth Orbits, this phenomenon does not have considerable effects on our calculations.

## 1.2 Other useful models

The magnetic dipole model of Earth's magnetic field was widely used for older studies, but has hence been replaced by IGRF. This model can still find use in determining the controller gains, with less precision, in comparison to IGRF, but through less computationally demaning calculations calculations.

## 1.3 IGRF

### 1.3.1 Input

Generally, IGRF is a function that requires five inputs:

- **Time**: Insert the full date to measure the Earth's magnetic field. The keyword **"now"** can be used, to insert automatically the full date at the time you run the function.
- **Latitude**: Insert the **Geocentric** or **Geodetic** latitude of the satellite in degrees.
- **Longitude**: Insert the **Geocentric** or **Geodetic** longitude of the satellite in degrees.
- **Altitude**: Insert the altitude of the satellite.
  *Altitude = 6371.2 (Earth's Radius) + 400 (orbit altitude of AcubeSAT).*

- **Coordinates**: Specify what coordinate system is used, **Geocentric** or **Geodetic**.

#### 1.3.2 Output

IGRF computes magnetic field using the NED reference frame:

- **BX**: Northward component
- **BY**: Eastward component
- **BZ**: Vertical component (Positive Downwards)
- **D**: Declination, the difference between true north and magnetic north. *Positive if magnetic north is east of true north*
- **H**: Horizontal intensity of the magnetic field
- **I**: Inclination or dip, the angle the field vector makes with the horizontal. *Positive below the horizontal*
- **F**: The total intensity of the field.

#### 1.3.3 Matlab Function

The function we used was implemented with regards to the current 12th IGRF Model.

```
igrf(now,lat,long,6771,'geocentric');
```

Our tests have shown that this function calculates IGRF with integer precision, in nanoTeslas, which is considered sufficient for our simulations.

## 2 Sun Position Models

Sun position modeling for satellite application is quite straight-forward. David Vallado in his book [Fundamentals of Astrodynamics and Applications] has modeled it with 0.01 degrees accuracy, which is deemed sufficient for our mission.

### 2.1 Sun Position

#### 2.1.1 Input & Output

Generally, sun position modeling requires one input and computes sun position in ECI frame.

- **Input**: Insert the time, current Vallado's implementation uses JD format.
- **Output**: Vallado's function computes and returns the sun position in the ECI frame.

#### 2.1.2 Sun

The function we used:

```
sun_position(time_jd);
```

### 2.2 Eclipse Calculation

The fine sun sensor that will be deployed in AcubeSAT has a specific field of view and the satellite will frequently be in eclipse. Thus, sun sensor measurements cannot be taken into account. To make our simulations more realistic we need to calculate when we are in eclipse and then sun sensor measurements are excluded.
Eclipse is modeled as if earth has a conical shadow, based on David Vallado's book [Fundamentals of Astrodynamics and Applications]. This means that there are three regions where AcubeSAT may be:

1. **Umbral**: None of sun's rays hit the AcubeSAT. [total eclipse]
2. **Penumbral**: Some of sun's rays hit the AcubeSAT. [partial eclipse]
3. **No Eclipse**: All of sun's rays hit AcubeSAT.

We have decided to consider both umbral and penumbral scenarios are being in eclipse, thus not taking into account sun sensor measurements.

## 3 Simulation

### 3.1 Simulation Logic

To fully demonstrate model computation and results we decided on combining it with the orbit propagator explained in [AcubeSAT-ADC-EW-006 Orbit Determination]. The Simulation Logic sequence was explained in [2.2 Logic]. All of the needed parameters are provided to the model functions using the orbit propagator.

### 3.2 Simulation Figures

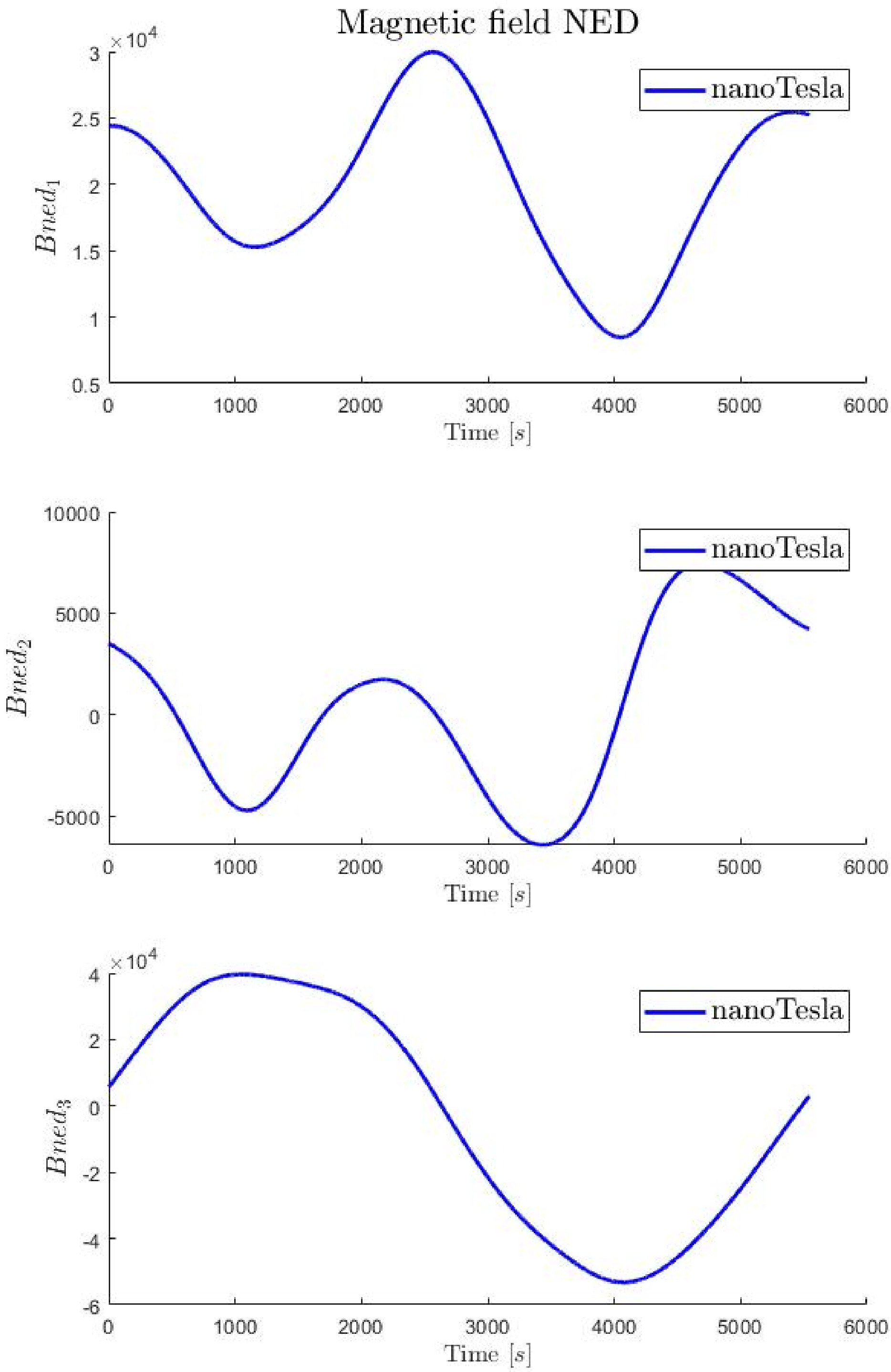


***Figure 1**: Magnetic field in NED for 1 orbit*

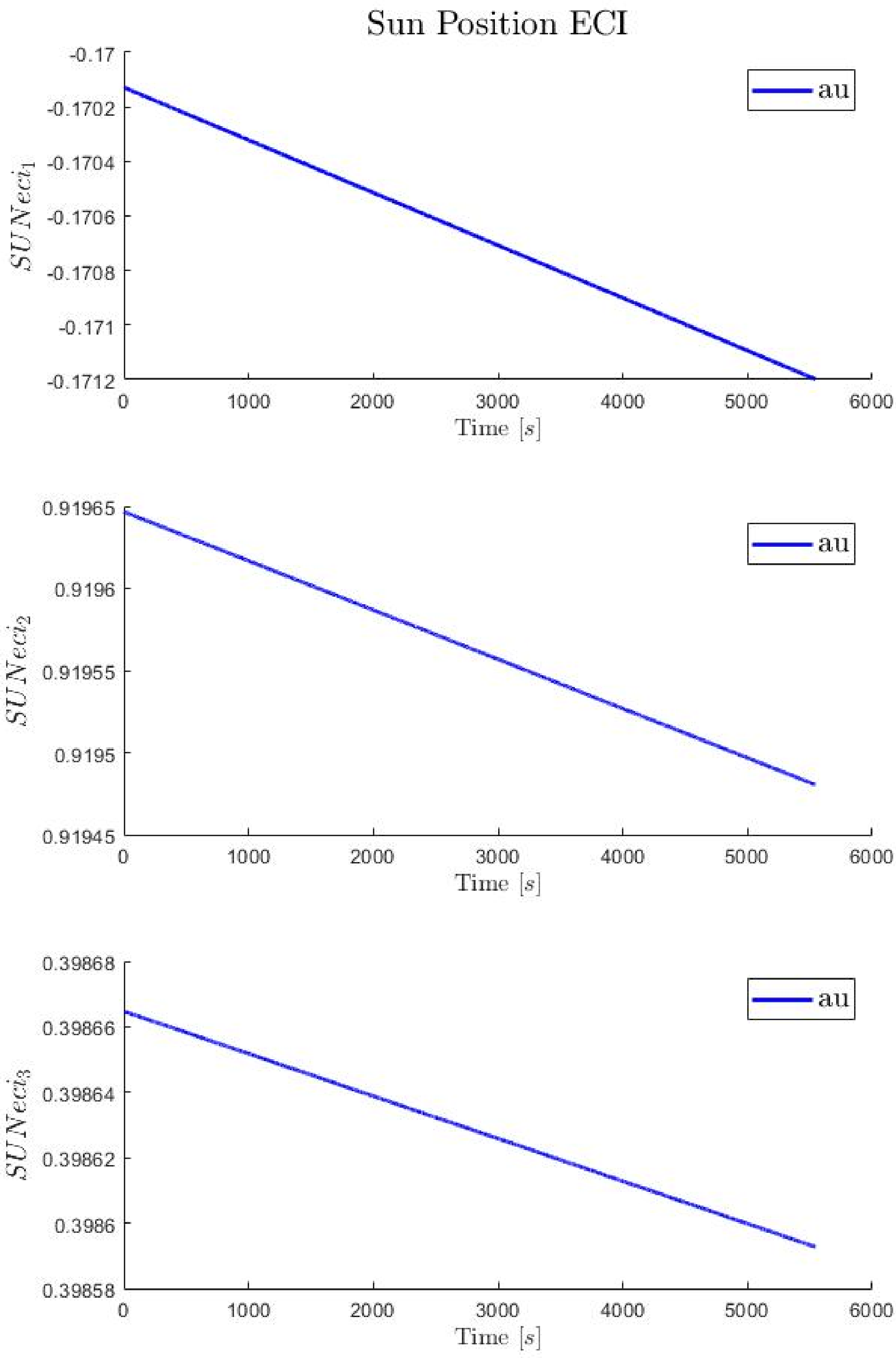


***Figure 2***: *Sun position in ECI for 1 orbit*

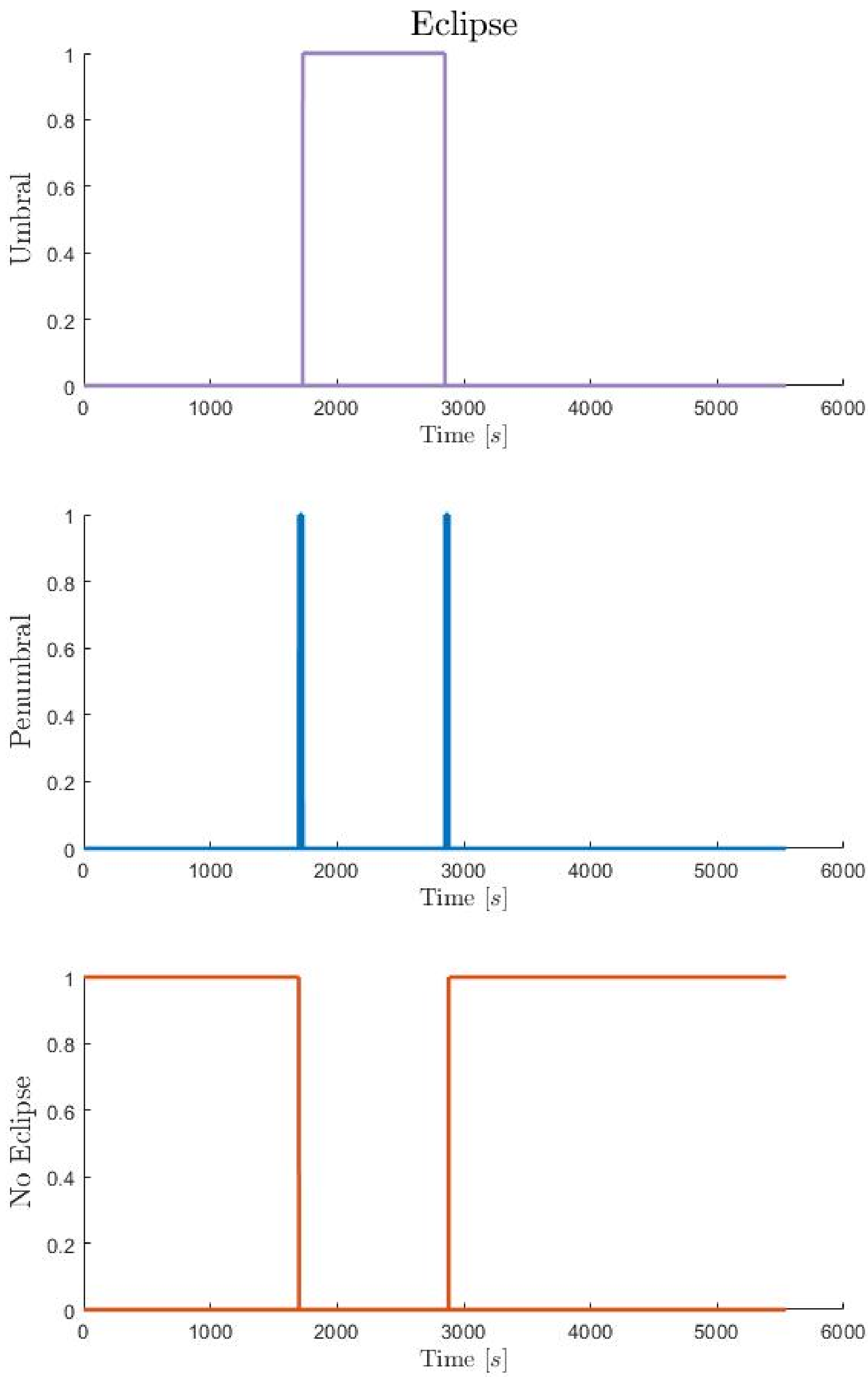


***Figure 3**: Eclipse calculations for 1 orbit. 1 is true 0 is false*

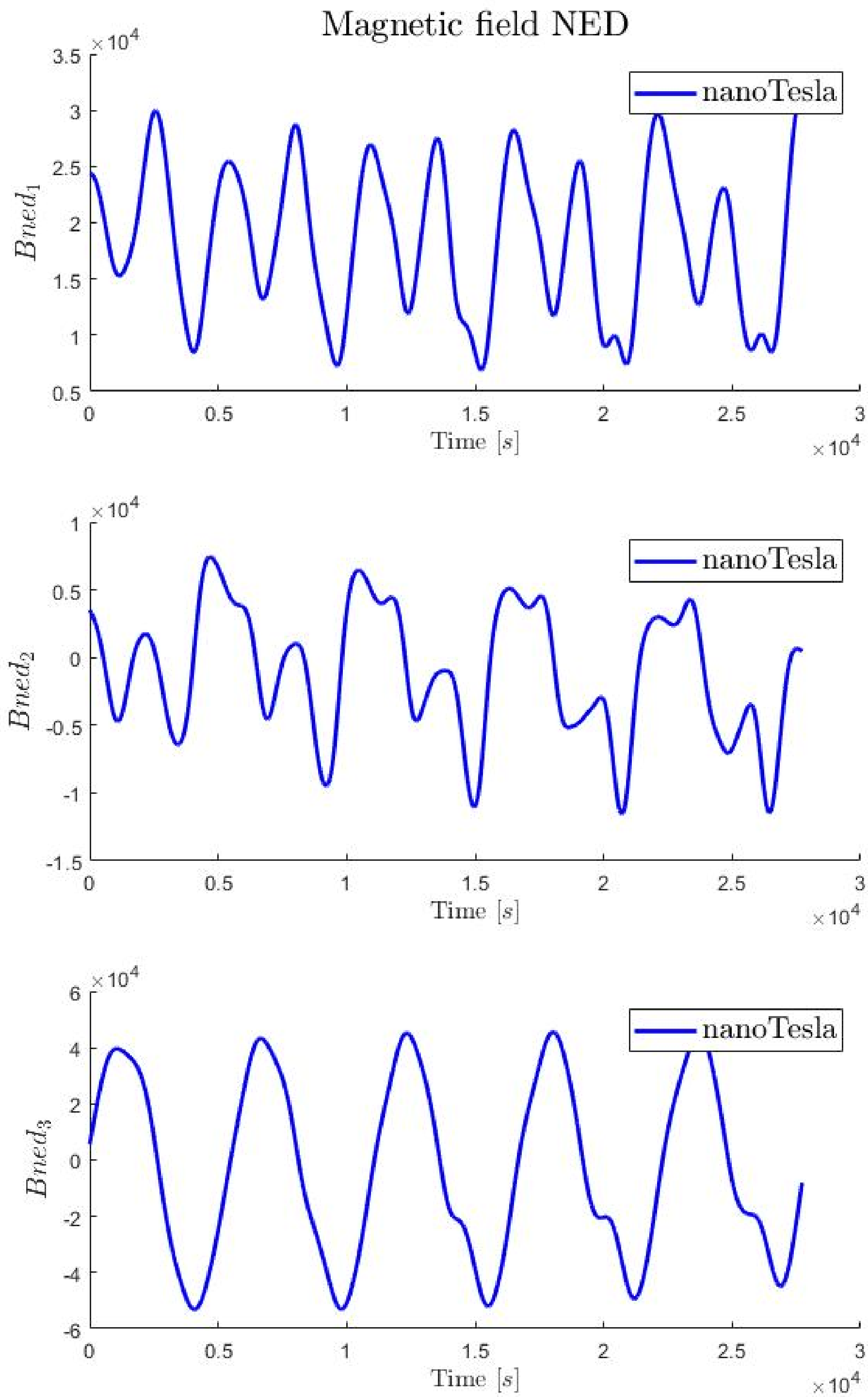


***Figure 4**: Magnetic field in NED for 5 orbits*

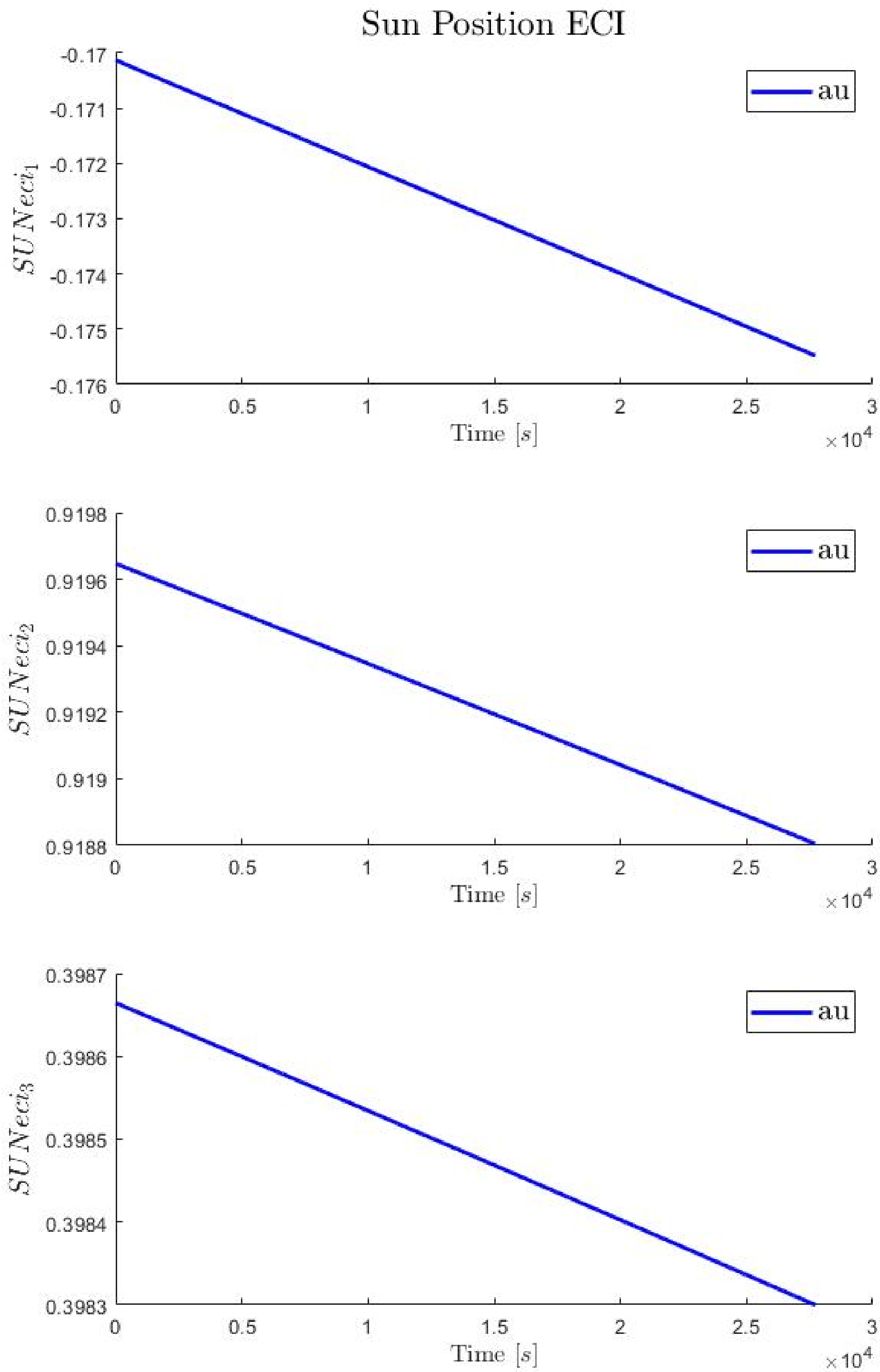


***Figure 5**: Sun position in ECI for 5 orbits*