Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 6 Issue 6, June - 2022

Statistical Analysis Of Nigcosat 1R Satellite Orbital Altitude Prediction Datasets

Uchegbu, C. E[1]

Dept. of Electrical and Electronic Engineering,
Abia State University, Uturu

Young, Emem Godwin
Department of Computer Engineering
Akwa Ibom State Polytechnic , Ikot Osurua Ikot Ekpene

Okon, Abasiama Colman
Department of Computer Engineering
Akwa Ibom State Polytechnic , Ikot Osurua Ikot Ekpene

***Abstract*—In this paper, statistical analysis of NIGCOSAT 1R satellite orbital altitude prediction datasets is presented. The study is based on five different datasets of 170 hour NIGCOSAT 1R satellite orbital altitude predictions extracted (from 2020 to 2022) using CELESTRAK online tool accessed via https://www.satellite-calculations.com/. The statistical analysis is performed using the t-test approach with NIGCOSAT 1R geo-satellite mean altitude of 35786.0 km, along with a significance level, α of 0.05, which is equivalent to confidence level of 95% . The results of the statistical analysis of the first dataset extracted from 1st of April 2022 to 8th of April 2022 (2022-04-01 9:23:19 to 2022-04-08 11:23:19) show that the sample mean, is 35783.94944 km, the sample standard deviation is 10.95183505 km, the test statistics is -2.448 and the critical value is 1.962. Also, for the given dataset, the upper value of the mean that meets the critical value is 35787.64319 km while the lower value is 35784.35681 km. accordingly, the first dataset does not support the accepted population mean altitude of 35786.0 km and hence, the first dataset need to be discarded. In all, based on the t-test results for the five datasets, the first and fifth dataset need to be discarded while the second, third and fourth datasets are accepted, as their sample mean altitudes are within the acceptable range that support the population mean altitude of 35786.0 km.**

Keywords: Statistical Analysis, NIGCOSAT 1R, Satellite, Orbital Altitude, Satellite Tracking, T-Test

1. Introduction

Today, satellite communication has become the backbone of global communication framework [1,2,3,4,5,6,7] which provides support for diverse categories of wireless and wired communication systems at the local area and wide area network levels [8,9,10,11,12,13,14,15,16,17,18]. In order to benefit immensely from satellite communication technologies, Nigerian government has partnered with Chinese company to build and launch some satellites for different purposes [19,20,21,22,23]. Among the Nigerian owned satellites is the NigComSat-1R which was launched into geosynchronous equatorial orbit (GEO) in 2011 with orbital slut of 42.5° E [24,25,26,27,28]. The satellite has 15 years lifespan and it is equipped with facilities that can support communication in four different microwave bands, namely; Ku, C, Ka and L Band.

Importantly, satellite communication is a line of sight wireless communication in the microwave frequencies [29,30,31,32,33,34,35,36]. Similar to other wireless communication systems, the satellites signals are subjected to various environmental and climatic factors [37, 38,39, 40,41,42,43, 44,45, 46,47, 48,49, 50,51, 52]. Also, the communication path length impact on the communication system component selection and link performance [53,54,55,56]. Hence, effective application of the satellite communication link requires careful computation of essential communication equipment and communication link parameters [57,58,59]. In the various computations required, the satellite altitude data is very essential. Generally, the geo-satellite mean orbital altitude is known to be 35786.0 km [60,61,62,63,64,65]. However, the instantaneous value of the orbital altitude is not constant, but varies with time. Notably, the variation in the orbital altitude affect the instantaneous values of communication range, propagation loss, communication delay time, among other parameters. These parameters are always utilised in determination of the received signal strength, the operating system margin, the required transmission power and other performance parameters of the satellite communication link. As such, researchers and satellite communication link designers seek for ways to assess the variation in attitude and other satellite orbital parameters. Some online satellite tracking tools provide satellite track prediction datasets for a given time range. However, before such datasets are utilised in further analysis of the satellite operations, the acquired prediction dataset need to be assessed to see whether it conforms to the known mean values for the give orbit. Accordingly, in this paper, the orbital altitude is used to assess the applicability of satellite track prediction dataset. Specifically, the t-distribution statistical approach is used in a two-tailed analysis [66'67'68'69'70'71'72]. In this paper, a number of orbital altitude datasets were examined and the results are discussed in view of the t-test analysis outcome.

2. Methodology

In this paper, the variation in the orbital altitude of NIGCOSAT 1R satellite which is supposed to maintain a constant geo-satellite orbital altitude of 35,786 km is analysed. The essence of the study is to ascertain if the prediction dataset accurately characterises the orbital motion of the satellite. The working dataset is obtained from orbital track prediction data for the case study satellite extracted from two different online satellite tracking tools. The analysis is essential to know which dataset is good enough to be used for characterization of the orbital motion of the satellite and further application of such dataset in the computation of satellite communication with the earth station and with other satellites.

Specifically, in this paper, only the orbital altitude is considered in the analysis. Also, the analysis used the t-test approach whereby the mean and standard deviation of the predicted NIGCOSAT 1R satellite orbital altitude dataset are computed and then the known geo-satellite NIGCOSAT 1R orbital altitude of 35,786 km is used to assess if the dataset conforms to the known orbital altitude of 35,786 km. Where the predicted satellite orbital altitude dataset fails to satisfy the t-test within the chosen significance level, the dataset will be discarded, otherwise the dataset will be accepted as good enough for characterizing the orbital motion of the selected satellite.

2.1 Determination of the Mean and Standard Deviation of the satellite altitude

For the data set consisting of satellite latitudes, h_k for k = 1,2,3,…, K_{max} , the mean altitude ($\bar{h}$) and the standard deviation are given as;

$$\bar{h} = \frac{\left[\sum_{k=1}^{K_{max}}(h_k)\right]}{K_{max}} \quad (1)$$

$$s^2 = \frac{\left[\sum_{k=1}^{K_{max}}(h_k-\bar{h})^2\right]}{(K_{max}-1)} \quad (2)$$

Also, s^2 can be computed as follows;

$$s^2 = \frac{\left(\left(\sum_{k=1}^{K_{max}}(h_k)^2\right)-\left[\frac{\left(\sum_{k=1}^{K_{max}}(h_k)\right)}{K_{max}}\right]^2\right)}{(K_{max}-1)} \quad (3)$$

Hence,

$$s = \sqrt[2]{s^2} \quad (4)$$

2.2 Analysis of the sample satellite altitude dataset with respect to the known population mean of geo-satellite altitude of 35,786 km

The t-test is the statistical analysis approach that can be used to ascertain if there exit significant difference between the means of two datasets that have certain features in common. In this case, the paper seeks to ascertain if there is a significant difference between the sample mean of geo-satellite orbital altitude and the known geo-satellite orbital altitude value of 35,786 km. In this case, when the difference is significant based on the chosen significance level, the dataset if deemed unfit and need to be discarded otherwise the data is acceptable and need to be retained. In the t-test, the significance level (α) indicates the probability that a hull hypothesis can be rejected when it is true. Conversely, the value of (1- α) % if the confidence level that the null hypothesis is rejected correctly or accepted correctly.

The t-test analysis is performed according the following analytical expressions and procedure;

The null hypothesis, H_o:

$$H_o = \mu = 35{,}786 \quad (5)$$

The alternate hypothesis, H_a :

$$H_a \neq 35{,}786 \quad (6)$$

Sample mean, $\bar{h}$ as stated in Eq 1.

Sample standard deviation, s as stated in Eq 2 to Eq 4.

Number of data items in the sample, n as stated for Eq 1.

$$n = K_{max} \quad (7)$$

Degree of freedom, df

$$df = n - 1 = K_{max} - 1 \quad (8)$$

The level of significance to test, α

The test statistics, t_{test} value

$$t_{test} = \frac{(\bar{h}-\mu)}{\left(\frac{s}{\sqrt{n}}\right)} \quad (9)$$

The critical value, $t_{critical}$ at $\alpha/2$ =0.05/2 =0.025

$$t_{critical} = t_{\alpha/2} = t_{0.025} \text{ at df} \quad (10)$$

The hull hypotheses is rejected if the t_{test} is in the rejection region, that is if

$$\left.\begin{array}{ll} |t_{test}| > |t_{critical}| & \textit{reject the null hypothesis} \\ |t_{test}| \le |t_{critical}| & \textit{accept the null hypothesis} \end{array}\right\} \quad (11)$$

Now, from the $t_{critical}$ value, the acceptable range of values for the mean based on the level of significance, α is computed from Eq 9 as follows;

$$\mu_{lower} = \min\left(\left[\mu + \left((t_{critical})\left(\frac{s}{\sqrt{n}}\right)\right)\right], \left[\mu - \left((t_{critical})\left(\frac{s}{\sqrt{n}}\right)\right)\right]\right) \quad (12)$$

$$\mu_{upper} = \max\left(\left[\mu + \left((t_{critical})\left(\frac{s}{\sqrt{n}}\right)\right)\right], \left[\mu - \left((t_{critical})\left(\frac{s}{\sqrt{n}}\right)\right)\right]\right) \quad (13)$$

So

$$\left.\begin{array}{ll} \bar{h} < \mu_{lower} \text{ or } \bar{h} > \mu_{upper} & \textit{reject the null hypothesis} \\ \mu_{lower} \le \bar{h} \le \mu_{upper} & \textit{accept the null hypothesis} \end{array}\right\} \quad (14)$$

2.3 The Case Study Datasets

The study used NIGCOSAT 1R satellite orbital altitude prediction datasets extracted using CELESTRAK online tool accessed via https://www.satellite-calculations.com/. Specifically, five datasets of the orbital altitude are used and these datasets are extracted in a space of three years (from 2020 to 2022) listed as follows;

1) Satellite altitude data extracted from 1st of April 2022 to 8th of April 2022 (2022-04-01 9:23:19 to 2022-04-08 11:23:19)
2) Satellite altitude data extracted from 20th of June 2021 to 28th of June 2021 (2021-06-20 22:45:21 to 2021-06-28 0:45:21)
3) Satellite altitude data extracted from 7th of August 2021 to 14th of August 2021 (2021-08-07 10:45:28 UTC to 2021-08-14 11:45:28 UTC)

4) Satellite altitude data extracted from 18th of December 2021 to 1st of April 2022 (2021-12-18 T18:59:42 to 2022-04-01 T03:49:22)
5) Satellite altitude data extracted from 23rd of April 2020 to 8th of April 2020 (4/23/2020 6:27 to 4/30/2020 8:27)

The fifth dataset on the orbital altitude extracted from 23rd of April 2020 to 25th of April 2020 (4/23/2020 6:27 to 4/30/2020 8:27) using CELESTRAK online tool accessed at https://www.satellite-calculations.com/ is shown in Table 1. The graph of the 170 hour orbital altitude distance from GEO altitude (35786 km) of the case study satellite is shown in Figure 1.

Table 1 The fifth dataset on the orbital altitude extracted from 23rd of April 2020 to 25th of April 2020 (4/23/2020 6:27 to 4/30/2020 8:27) using **CELESTRAK** online tool accessed at https://www.satellite-calculations.com/

S/N	Date Time [UTC]	Altitude [km]	S/N	Date Time [UTC]	Altitude [km]	S/N	Date Time [UTC]	Altitude [km]
1	4/23/2020 6:27	35783.8	58	4/25/2020 15:27	35782.9	115	4/28/2020 0:27	35789.0
2	4/23/2020 7:27	35782.7	59	4/25/2020 16:27	35784.0	116	4/28/2020 1:27	35788.4
3	4/23/2020 8:27	35781.8	60	4/25/2020 17:27	35785.3	117	4/28/2020 2:27	35787.5
4	4/23/2020 9:27	35781.0	61	4/25/2020 18:27	35786.5	118	4/28/2020 3:27	35786.4
5	4/23/2020 10:27	35780.6	62	4/25/2020 19:27	35787.6	119	4/28/2020 4:27	35785.2
6	4/23/2020 11:27	35780.5	63	4/25/2020 20:27	35788.5	120	4/28/2020 5:27	35784.0
7	4/23/2020 12:27	35780.7	64	4/25/2020 21:27	35789.1	121	4/28/2020 6:27	35782.8
8	4/23/2020 13:27	35781.2	65	4/25/2020 22:27	35789.5	122	4/28/2020 7:27	35781.7
9	4/23/2020 14:27	35782.0	66	4/25/2020 23:27	35789.6	123	4/28/2020 8:27	35780.8
10	4/23/2020 15:27	35783.0	67	4/26/2020 0:27	35789.3	124	4/28/2020 9:27	35780.2
11	4/23/2020 16:27	35784.1	68	4/26/2020 1:27	35788.7	125	4/28/2020 10:27	35779.9
12	4/23/2020 17:27	35785.4	69	4/26/2020 2:27	35787.9	126	4/28/2020 11:27	35779.9
13	4/23/2020 18:27	35786.6	70	4/26/2020 3:27	35786.8	127	4/28/2020 12:27	35780.2
14	4/23/2020 19:27	35787.7	71	4/26/2020 4:27	35785.7	128	4/28/2020 13:27	35780.8
15	4/23/2020 20:27	35788.6	72	4/26/2020 5:27	35784.4	129	4/28/2020 14:27	35781.6
16	4/23/2020 21:27	35789.3	73	4/26/2020 6:27	35783.2	130	4/28/2020 15:27	35782.7
17	4/23/2020 22:27	35789.7	74	4/26/2020 7:27	35782.1	131	4/28/2020 16:27	35783.9
18	4/23/2020 23:27	35789.8	75	4/26/2020 8:27	35781.2	132	4/28/2020 17:27	35785.1
19	4/24/2020 0:27	35789.6	76	4/26/2020 9:27	35780.5	133	4/28/2020 18:27	35786.3
20	4/24/2020 1:27	35789.1	77	4/26/2020 10:27	35780.2	134	4/28/2020 19:27	35787.4
21	4/24/2020 2:27	35788.3	78	4/26/2020 11:27	35780.1	135	4/28/2020 20:27	35788.2
22	4/24/2020 3:27	35787.2	79	4/26/2020 12:27	35780.4	136	4/28/2020 21:27	35788.8
23	4/24/2020 4:27	35786.1	80	4/26/2020 13:27	35780.9	137	4/28/2020 22:27	35789.1
24	4/24/2020 5:27	35784.8	81	4/26/2020 14:27	35781.8	138	4/28/2020 23:27	35789.1
25	4/24/2020 6:27	35783.6	82	4/26/2020 15:27	35782.8	139	4/29/2020 0:27	35788.8
26	4/24/2020 7:27	35782.5	83	4/26/2020 16:27	35784.0	140	4/29/2020 1:27	35788.2
27	4/24/2020 8:27	35781.6	84	4/26/2020 17:27	35785.2	141	4/29/2020 2:27	35787.3
28	4/24/2020 9:27	35780.9	85	4/26/2020 18:27	35786.4	142	4/29/2020 3:27	35786.2

29	4/24/2020 10:27	35780.5	86	4/26/2020 19:27	35787.5	143	4/29/2020 4:27	35785.0
30	4/24/2020 11:27	35780.4	87	4/26/2020 20:27	35788.4	144	4/29/2020 5:27	35783.8
31	4/24/2020 12:27	35780.6	88	4/26/2020 21:27	35789.0	145	4/29/2020 6:27	35782.6
32	4/24/2020 13:27	35781.1	89	4/26/2020 22:27	35789.4	146	4/29/2020 7:27	35781.5
33	4/24/2020 14:27	35781.9	90	4/26/2020 23:27	35789.4	147	4/29/2020 8:27	35780.7
34	4/24/2020 15:27	35782.9	91	4/27/2020 0:27	35789.1	148	4/29/2020 9:27	35780.1
35	4/24/2020 16:27	35784.1	92	4/27/2020 1:27	35788.5	149	4/29/2020 10:27	35779.7
36	4/24/2020 17:27	35785.3	93	4/27/2020 2:27	35787.7	150	4/29/2020 11:27	35779.7
37	4/24/2020 18:27	35786.5	94	4/27/2020 3:27	35786.6	151	4/29/2020 12:27	35780.1
38	4/24/2020 19:27	35787.6	95	4/27/2020 4:27	35785.5	152	4/29/2020 13:27	35780.7
39	4/24/2020 20:27	35788.5	96	4/27/2020 5:27	35784.2	153	4/29/2020 14:27	35781.6
40	4/24/2020 21:27	35789.2	97	4/27/2020 6:27	35783.0	154	4/29/2020 15:27	35782.6
41	4/24/2020 22:27	35789.6	98	4/27/2020 7:27	35781.9	155	4/29/2020 16:27	35783.8
42	4/24/2020 23:27	35789.7	99	4/27/2020 8:27	35781.0	156	4/29/2020 17:27	35785.0
43	4/25/2020 0:27	35789.4	100	4/27/2020 9:27	35780.4	157	4/29/2020 18:27	35786.2
44	4/25/2020 1:27	35788.9	101	4/27/2020 10:27	35780.0	158	4/29/2020 19:27	35787.3
45	4/25/2020 2:27	35788.1	102	4/27/2020 11:27	35780.0	159	4/29/2020 20:27	35788.1
46	4/25/2020 3:27	35787.0	103	4/27/2020 12:27	35780.3	160	4/29/2020 21:27	35788.7
47	4/25/2020 4:27	35785.9	104	4/27/2020 13:27	35780.9	161	4/29/2020 22:27	35789.0
48	4/25/2020 5:27	35784.6	105	4/27/2020 14:27	35781.7	162	4/29/2020 23:27	35789.0
49	4/25/2020 6:27	35783.4	106	4/27/2020 15:27	35782.8	163	4/30/2020 0:27	35788.6
50	4/25/2020 7:27	35782.3	107	4/27/2020 16:27	35783.9	164	4/30/2020 1:27	35788.0
51	4/25/2020 8:27	35781.4	108	4/27/2020 17:27	35785.2	165	4/30/2020 2:27	35787.1
52	4/25/2020 9:27	35780.7	109	4/27/2020 18:27	35786.3	166	4/30/2020 3:27	35786.0
53	4/25/2020 10:27	35780.3	110	4/27/2020 19:27	35787.4	167	4/30/2020 4:27	35784.8
54	4/25/2020 11:27	35780.2	111	4/27/2020 20:27	35788.3	168	4/30/2020 5:27	35783.6
55	4/25/2020 12:27	35780.5	112	4/27/2020 21:27	35788.9	169	4/30/2020 6:27	35782.4
56	4/25/2020 13:27	35781.0	113	4/27/2020 22:27	35789.3	170	4/30/2020 7:27	35781.3
57	4/25/2020 14:27	35781.8	114	4/27/2020 23:27	35789.3	171	4/30/2020 8:27	35784.3

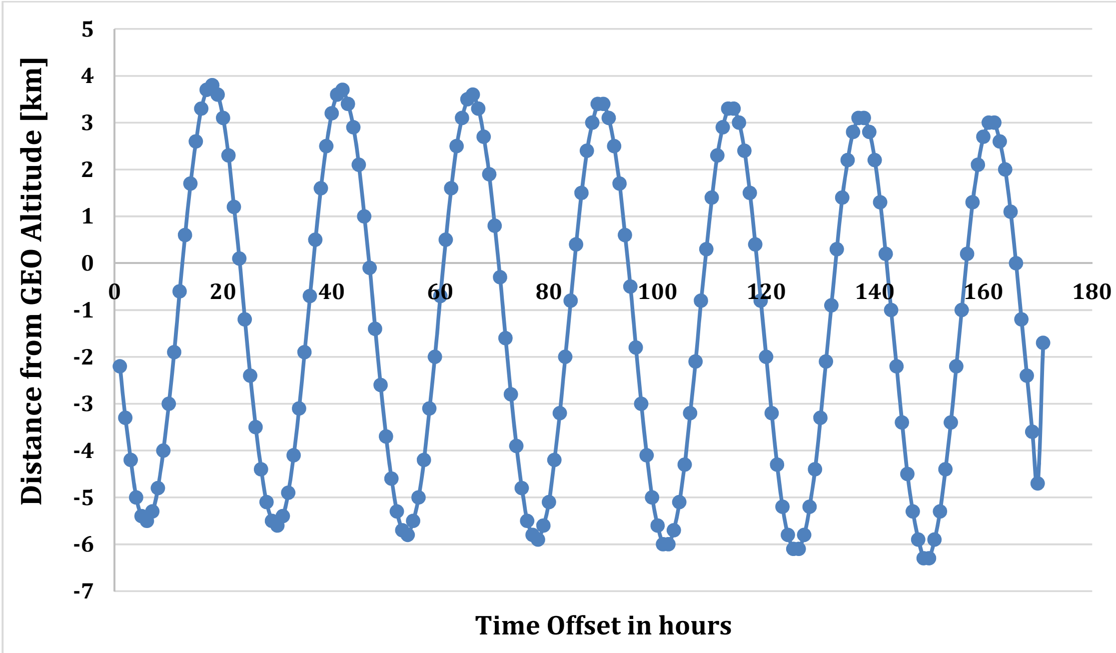

Figure 1 The graph of the 170 hour orbital altitude distance from GEO altitude (35786 km) of the case study satellite

3. Results and discussion

The analysis is conducted on the five datasets of NIGCOSAT 1R satellite orbital altitude prediction obtained from online satellite track prediction tools, as presented in section 2.3. The datasets are collected in 2020, 2021 and 2022. Also, in this paper, for the t-test data analysis a significance level of (α = 0.05, which is equivalent to confidence level of 95%) is adopted. Also, for the NIGCOSAT 1R geo-satellite, the accepted mean altitude is 35786.0 km. This mean altitude is used in the t-distribution analysis to assess whether the dataset is acceptable or whether the dataset should be discarded.

The scatter plot diagram for the first dataset is shown in Figure 2, for the second dataset is shown in Figure 3, for the third dataset is shown in Figure 4, for the fourth dataset is shown in Figure 5 and for the fifth dataset is shown in Figure 6. It can be seen that the scatter plot for the first, second, third and fifth datasets are periodic with sinusoidal outlines whereas that of the fourth dataset is not periodic and has no definite outline. The reason is that the first, second, third and fifth datasets are extracted on hourly basis over a period of 170 consecutive hours; hence the dataset is a diurnal data of the orbital altitude versus time in hours. On the other hand, the fourth dataset is taken once data items per day for about 256 days. As such, the value of the altitude depends on the hour in the day the data was extracted.

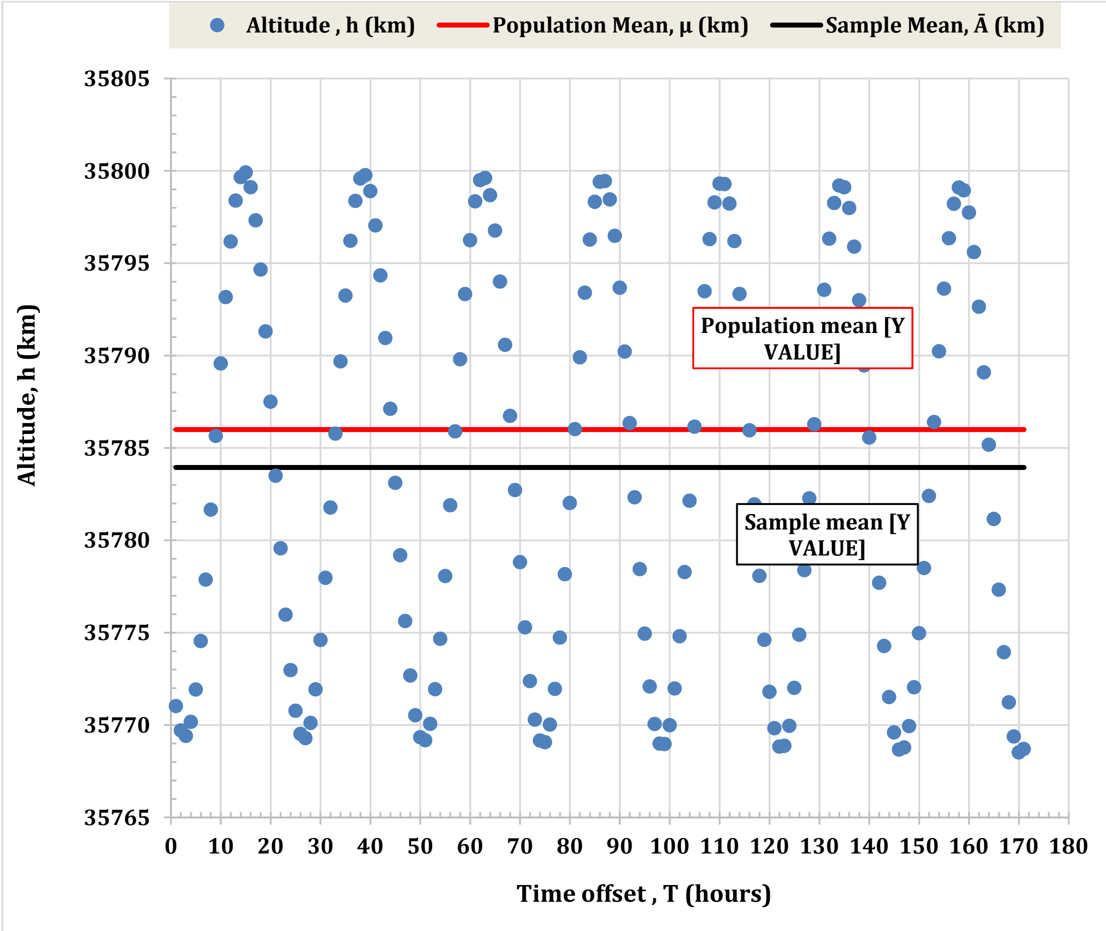

Figure 2 The scatter plot diagram of the first dataset

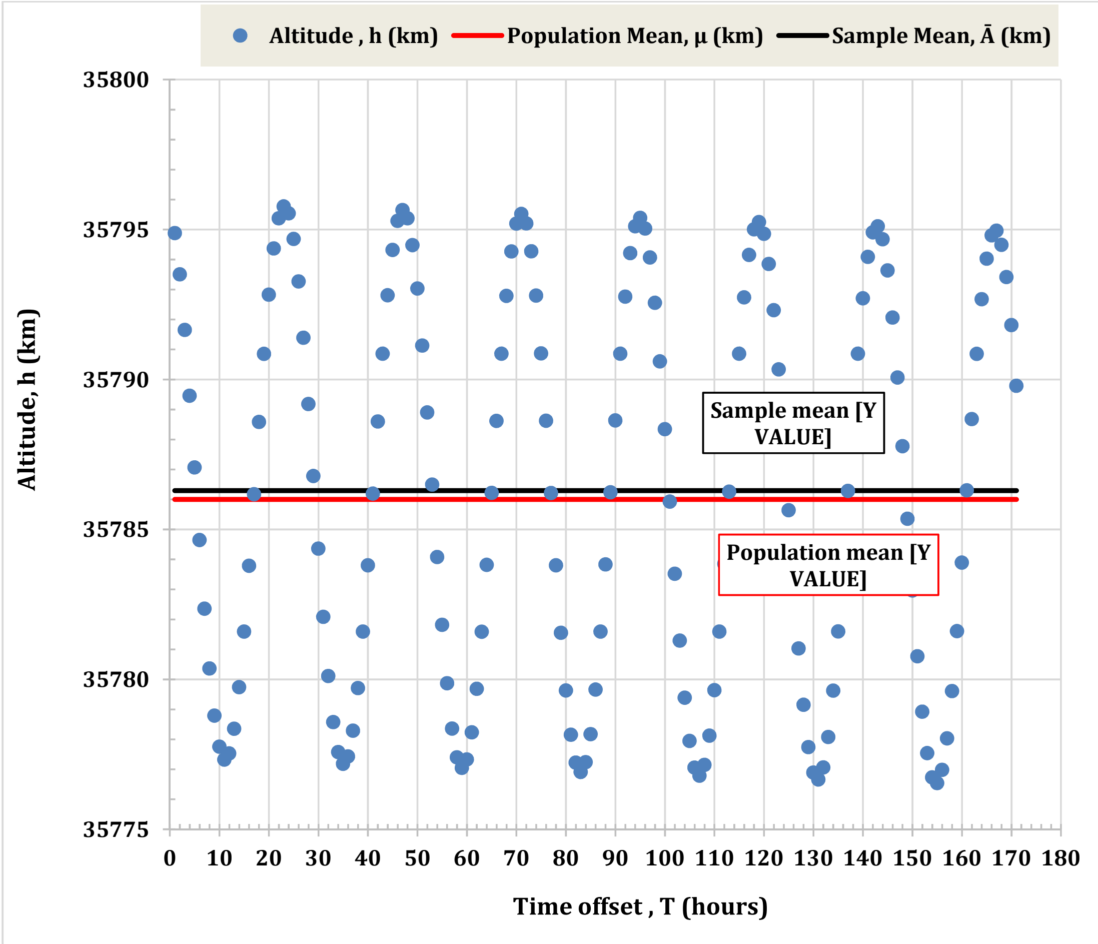

Figure 3 The scatter plot diagram of the second dataset

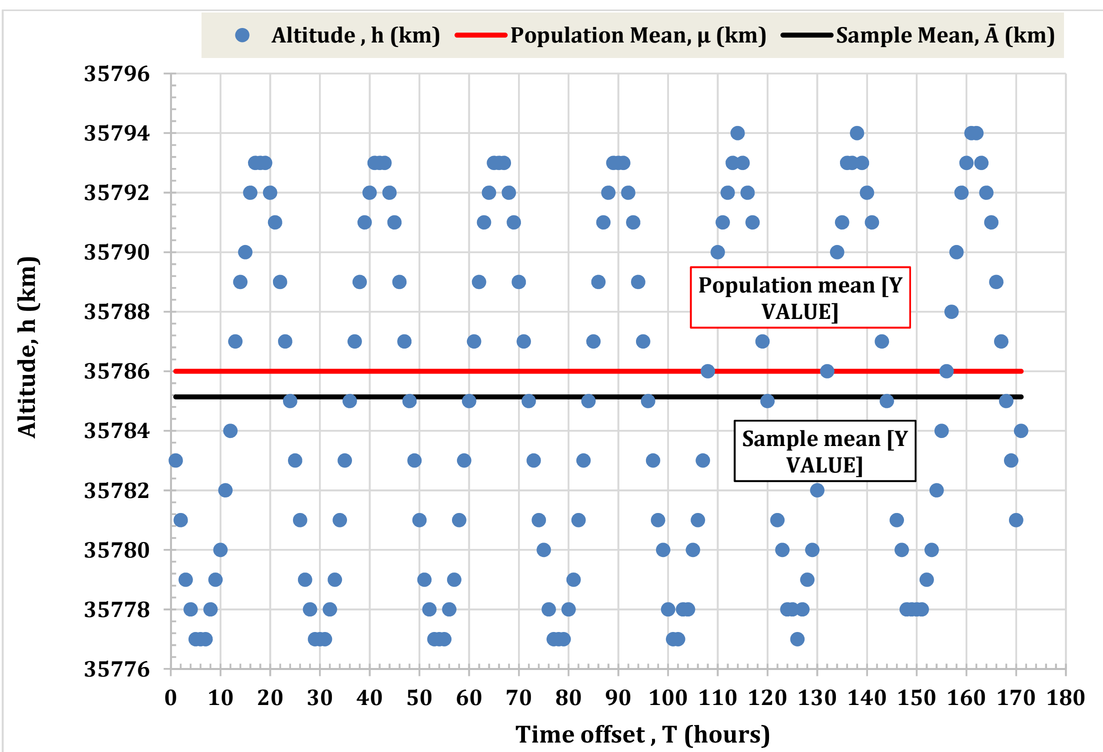

Figure 4 The scatter plot diagram of the third dataset

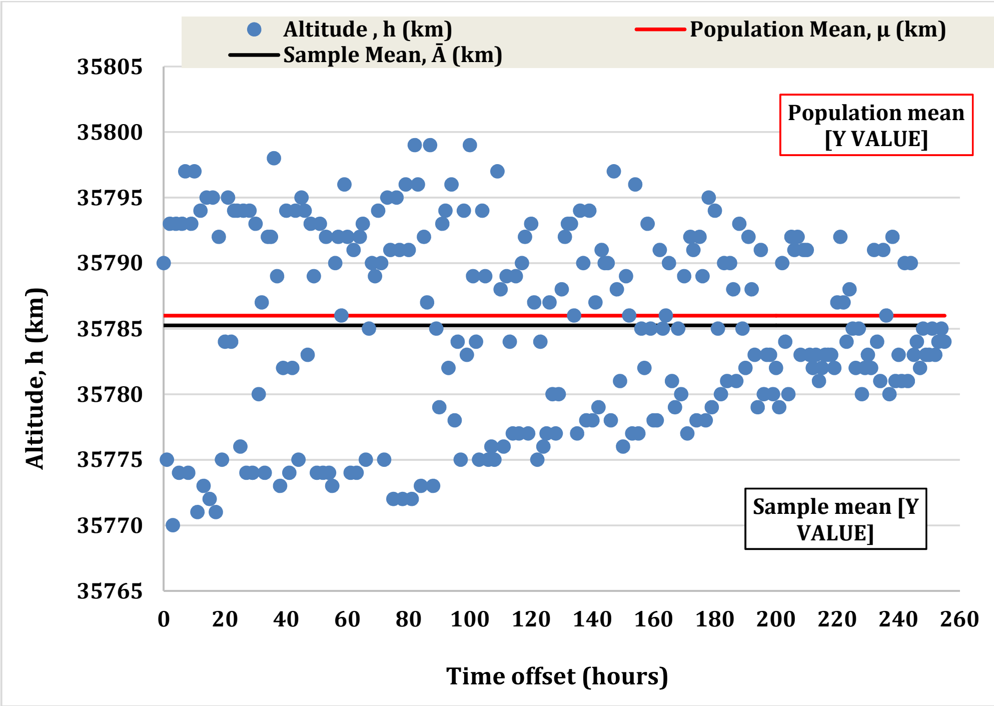

Figure 5 The scatter plot diagram of the fourth dataset

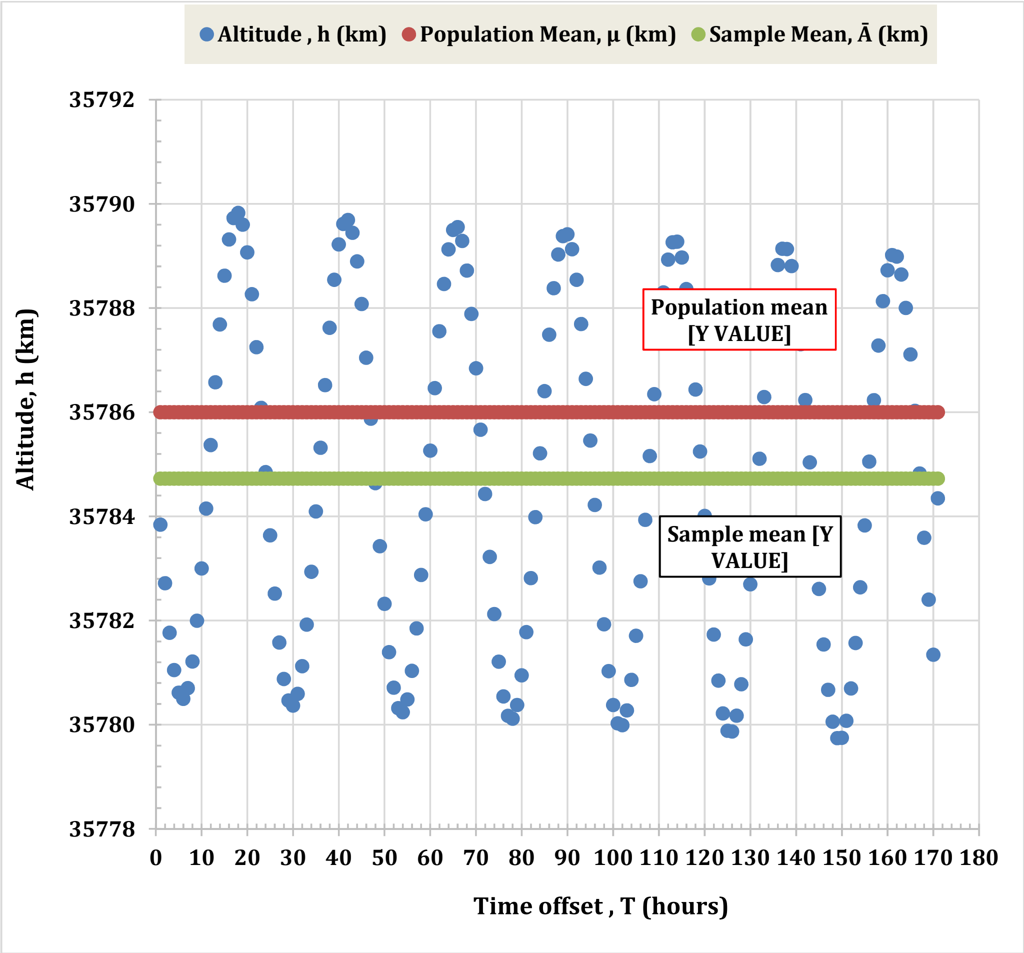

Figure 6 The scatter plot diagram of the fifth dataset

The results of statistical analysis for the first dataset extracted from 1st of April 2022 to 8th of April 2022 (2022-04-01 9:23:19 to 2022-04-08 11:23:19) show that the sample mean, is 35783.94944, the sample standard deviation is 10.95183505, the test statistics is -2.448 and the critical value is 1.962. Also, for the given dataset, the upper value of the mean that meets the critical value is 35787.64319 while the lower value of the mean that meets the critical value is 35784.35681. The visualisation of the t-distribution showing the location of the sample mean of 35783.94944 relative to the acceptable range of mean values, is shown in Figure 7. According to the graph in Figure 7, the sample mean of 35783.94944 is lower than the lower value of the mean that meets the critical value. Hence, the null hypotheses is rejected. This means that the given dataset does not support the accepted mean altitude of 35786.0. Essentially, this dataset need to be discarded.

The results of the statistical analysis of the five satellite altitude datasets are shown in Table 2 while the visualisation of the t-distribution showing the location of the sample mean relative to the acceptable range of mean values are shown for the five satellite altitude datasets in Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11. According to the results in Table 2 and the Figure 7 to Figure 11, the null hypothesis is rejected for the first and the fifth datasets while for the second, third and fourth datasets, the null hypothesis is accepted. In all, the first and fifth dataset need to be discarded while the second, third and fourth datasets should be accepted.

Table 2 The results of the statistical analysis of the five satellite altitude datasets

	First Dataset	Second Dataset	Third Dataset	Fourth Dataset	Fifth Dataset
Parameter	Satellite altitude data extracted from 1st of April 2022 to 8th of April 2022 (2022-04-01 9:23:19 to 2022-04-08 11:23:19)	Satellite altitude data extracted from 20th of June 2021 to 28th of June 2021 (2021-06-20 22:45:21 to 2021-06-28 0:45:21)	Satellite altitude data extracted from 7th of August 2021 to 14th of August 2021 (2021-08-07 10:45:28 UTC to 2021-08-14 11:45:28 UTC)	Satellite altitude data extracted Satellite altitude data extracted from 18th of December 2021 to 1st of April 2022 (2021-12-18 T18:59:42 to 2022-04-01 T03:49:22)	Satellite altitude data extracted from 23rd of April 2020 to 8th of April 2020 (4/23/2020 6:27 to 4/30/2020 8:27)
Number of data items in the sample, n	**171**	**171**	**171**	**256**	**171**
Degree of freedom, df	**170**	**170**	**170**	**255**	**170**
Level of significance, α	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Sample mean, $\bar{h}$	**35783.94944**	**35786.29574**	**35785.14035**	**35785.24609**	**35784.724522**
Sample standard deviation, s	**10.95183505**	**6.556370209**	**5.735663241**	**7.18263049**	**3.299132138**
Population mean, μ	**35786.00000**	**35786.000000**	**35786.0000**	**35786.00000**	**35786.00000**
The test statistics, t_{test}	**-2.448**	**0.590**	**-1.960**	**-1.6793987**	**-5.056**
The critical value, $t_{critical}$	**1.962**	**1.962**	**1.962**	**1.962**	**1.962**
μ_{upper}	**35787.643190**	**35786.983704**	**35786.860567**	**35786.880770**	**35786.494995**
μ_{lower}	**35784.356810**	**35785.016296**	**35785.139433**	**35785.119230**	**35785.505006**
Decision	**Reject because $\bar{h} < \mu_{lower}$**	**Accept because $\mu_{lower} \le \bar{h} \le \mu_{upper}$**	**Accept because $\mu_{lower} \le \bar{h} \le \mu_{upper}$**	**Accept because $\mu_{lower} \le \bar{h} \le \mu_{upper}$**	**Reject because $\bar{h} < \mu_{lower}$**

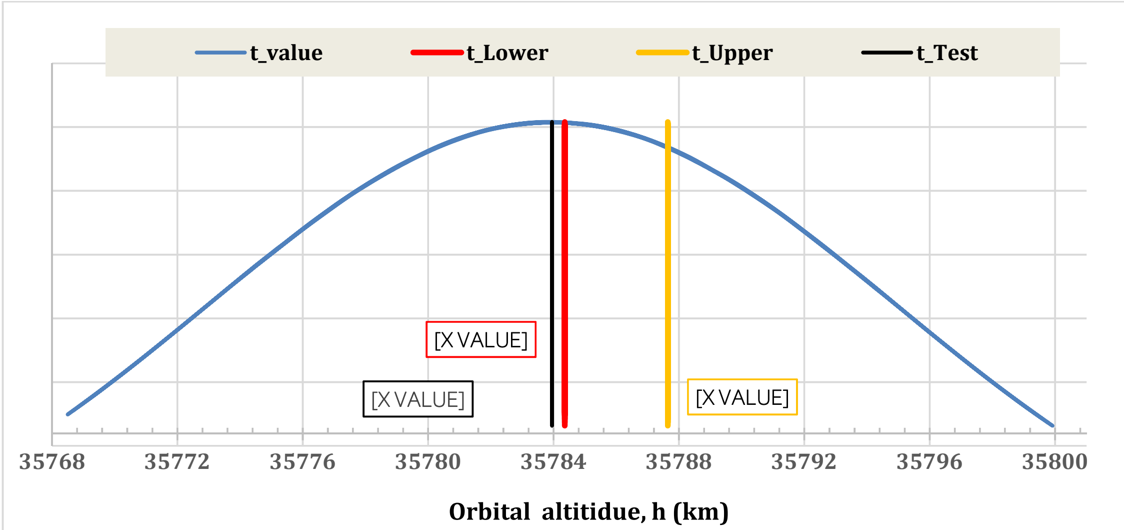

Figure 7 Visualisation of the t-distribution for the first dataset showing the location of the sample mean of 35783.94944 relative to the acceptable range of mean values

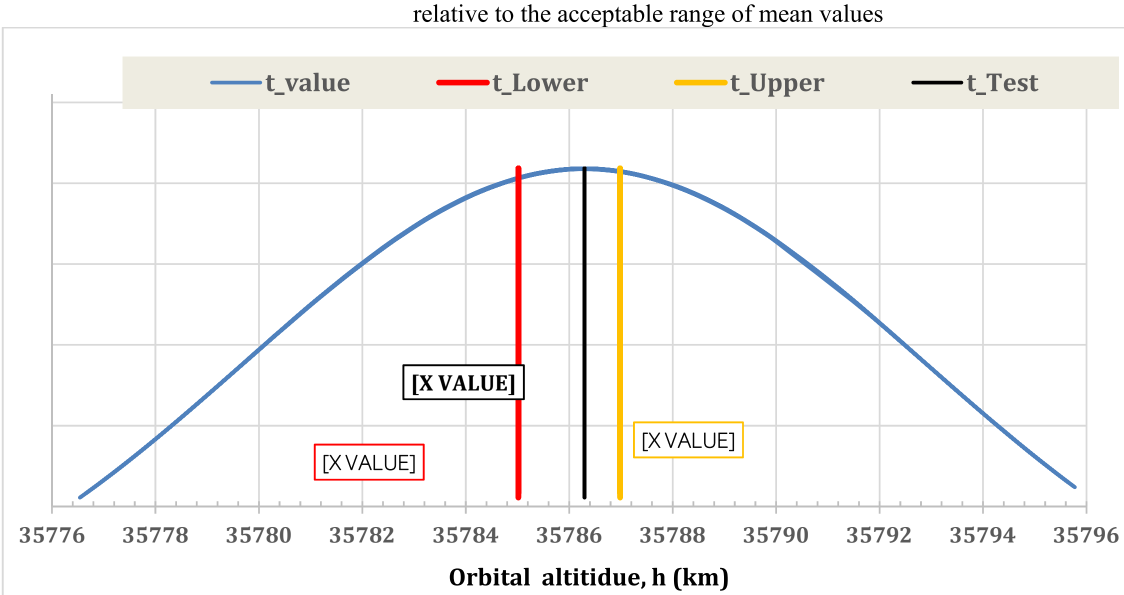

Figure 8 Visualisation of the t-distribution for the second dataset showing the location of the sample mean of **35786.29574** relative to the acceptable range of mean values

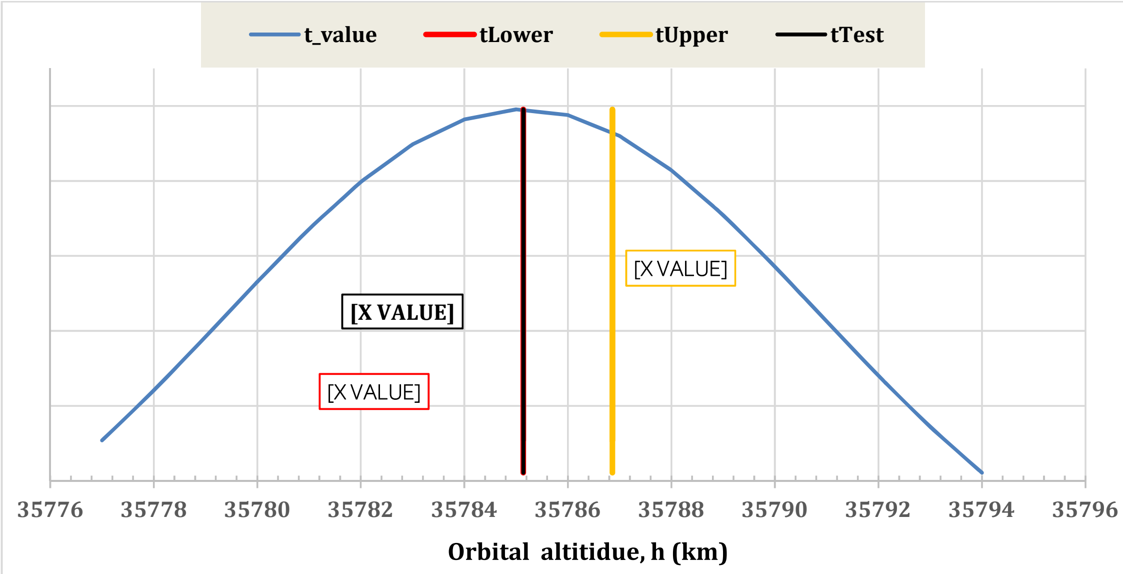

Figure 9 Visualisation of the t-distribution for the third dataset showing the location of the sample mean of **35785.14035** relative to the acceptable range of mean values

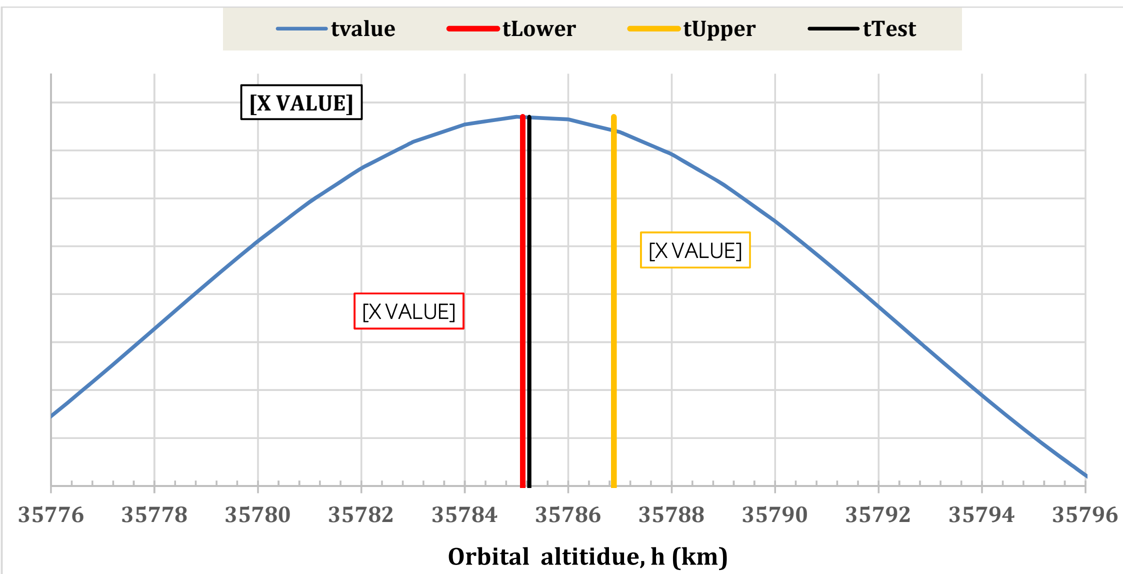

Figure 10 Visualisation of the t-distribution for the fourth dataset showing the location of the sample mean of 35785.24609 relative to the acceptable range of mean values

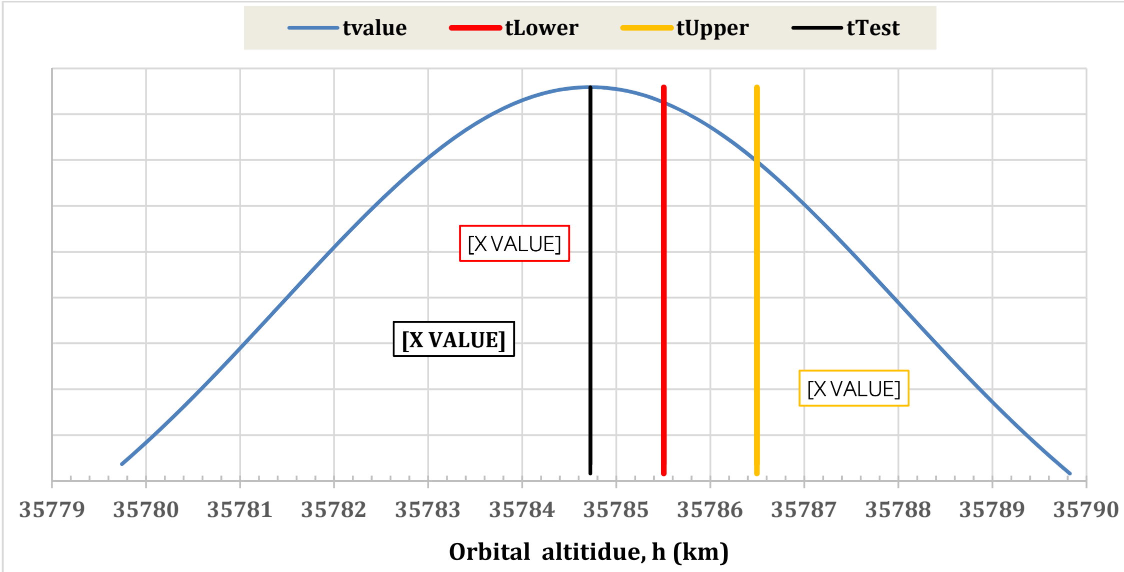

Figure 11 Visualisation of the t-distribution for the fifth dataset showing the location of the sample mean of **35784.72452** relative to the acceptable range of mean values

4. Conclusion

Statistical analysis of the orbital altitude of a geostationary satellite is presented. The case study satellite is NIGCOSAT 1R which is known to have mean geo-satellite altitude of 35786 km . The 170 hour tracking data of the case study satellite were obtained using online satellite orbital motion tracking tool which provided the dataset with 171 altitude data items. Five different datasets were examined and two of the dataset were discarded based on the t-distribution analysis results which showed that at 95 % confidence level, the mean altitude of the two dataset do not fall within the lower and upper range of acceptable mean altitude for geo-satellites. However, three of the datasets satisfied the t-test at 95 % confidence interval and were then recommended for application in the satellite parameter computations.

References

1) Jin, X., Zhang, P., & Yao, H. (2016, September). A communication framework between backbone satellites and ground stations. In *2016 16th International Symposium on Communications and Information Technologies (ISCIT)* (pp. 479-482). IEEE.

2) Simeon, Ozuomba. (2017). “Determination Of The Clear Sky Composite Carrier To Noise Ratio For Ku-Band Digital Video Satellite Link” *Science and Technology Publishing (SCI & TECH) Vol. 1 Issue 7, July – 2017*

3) Su, W., Lin, J., & Ha, T. (2017, January). Global communication coverage using Cubesats. In *2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC)* (pp. 1-7). IEEE.

4) Jia, M., Gu, X., Guo, Q., Xiang, W., & Zhang, N. (2016). Broadband hybrid satellite-terrestrial communication systems based on cognitive radio toward 5G. *IEEE Wireless Communications*, *23*(6), 96-106.

5) Simeon, Ozuomba. (2016) "Comparative Analysis Of Rain Attenuation In Satellite Communication Link For Different Polarization Options." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 3 Issue 6, June – 2016*

6) Li, T., Zhou, H., Luo, H., & Yu, S. (2017). SERvICE: A software defined framework for integrated space-terrestrial satellite communication. *IEEE Transactions on Mobile Computing*, *17*(3), 703-716.

7) Simeon, Ozuomba. (2016) "Comparative Analysis Of Rain Attenuation In Satellite Communication Link For Different Polarization Options." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 3 Issue 6, June – 2016*

8) Bembe, M., Abu-Mahfouz, A., Masonta, M., & Ngqondi, T. (2019). A survey on low-power wide area networks for IoT applications. *Telecommunication Systems*, *71*(2), 249-274.

9) Kalu, C., Ozuomba, Simeon. & Udofia, K. (2015). Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. *European Journal of Engineering and Technology, 3 (8)*, 30-43.

10) Phemius, K., Bouet, M., & Leguay, J. (2014, May). DISCO: Distributed SDN controllers in a multi-domain environment. In *2014 IEEE Network Operations and Management Symposium (NOMS)* (pp. 1-2). IEEE.

11) Buurman, B., Kamruzzaman, J., Karmakar, G., & Islam, S. (2020). Low-power wide-area networks: Design goals, architecture, suitability to use cases and research challenges. *IEEE Access*, *8*, 17179-17220.

12) Samuel, Wali, Simeon Ozuomba, and Philip M. Asuquo (2019). EVALUATION OF WIRELESS

SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 11, November - 2019*

13) De Sanctis, M., Cianca, E., Araniti, G., Bisio, I., & Prasad, R. (2015). Satellite communications supporting internet of remote things. *IEEE Internet of Things Journal*, *3*(1), 113-123.

14) Simeon, Ozuomba. (2020). "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June – 2020*

15) Wixted, A. J., Kinnaird, P., Larijani, H., Tait, A., Ahmadinia, A., & Strachan, N. (2016, October). Evaluation of LoRa and LoRaWAN for wireless sensor networks. In *2016 IEEE SENSORS* (pp. 1-3). IEEE.

16) Samuel, W., Ozuomba, Simeon, & Constance, K. (2019). SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 6 Issue 12, December – 2019*

17) Wu, H., Li, J., Lu, H., & Hong, P. (2016, December). A two-layer caching model for content delivery services in satellite-terrestrial networks. In *2016 IEEE global communications conference (GLOBECOM)* (pp. 1-6). IEEE.

18) Njoku, Felix A., Ozuomba Simeon, and Fina Otosi Faithpraise (2019). Development Of Fuzzy Inference System (FIS) For Detection Of Outliers In Data Streams Of Wireless Sensor Networks. *International Multilingual Journal of Science and Technology (IMJST) Vol. 4 Issue 10, October – 2019*

19) Klinger, J. (2020). China, Africa, and the Rest: Recent Trends in Space Science, Technology, and Satellite Development.

20) Jackman, N. (2018). Chinese Satellite Diplomacy: China's Strategic Weapon for Soft and Hard Power Gains.

21) Okon, E. O. (2018). Africa’s Space Technology Investment and Socio-Economic Returns: The Case of Nigeria. *International Journal of Business and Management Future*, *2*(1), 1-12.

22) Agbim, P. (2018, May). The Nigerian Space Legislation. In *Innovation in Outer Space: International and African Legal Perspective* (pp. 313-326). Nomos Verlagsgesellschaft mbH & Co. KG.

23) Belward, A. S., & Skøien, J. O. (2015). Who launched what, when and why; trends in global land-cover observation capacity from civilian earth observation satellites. *ISPRS Journal of Photogrammetry and Remote Sensing*, *103*, 115-128.

24) Ikpaya, I., Onuh, S., Achem, C., & Madalla, F. (2016). Quest of Nigeria into Space for Sustainable Development. In *14th International Conference on Space Operations* (p. 2345).

25) Ajiboye, A. T., Yusuf, A. O., & Ajayi, A. R. (2019). Characterization and analysis of propagation time delay range within NigComSat-1R footprints. *Nigerian Journal of Technological Development*, *16*(3), 105-110.

26) SALAMI, L. L., & CHATWIN, C. R. (2015). Enhancing public safety and security of critical national infrastructure utilizing the Nigerian satellite augmentation system (NSAS).

27) Dairo, O. F., & Kolawole, L. B. (2017, November). Statistical analysis of tropospheric scintillation of satellite communication signals using Karasawa and ITU-R models. In *2017 IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON)* (pp. 347-352). IEEE.

28) SALAMI, E. L. L. (2014). Emergency Communication Preparedness in Africa Exploiting Communication Satellites.

29) Simeon, Ozuomba. (2020). "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 12, December - 2020*

30) Dinc, E., & Akan, O. B. (2014). Beyond-line-of-sight communications with ducting layer. *IEEE communications magazine*, *52*(10), 37-43.

31) Ayo, A. O., Owolawi, P. A., Ojo, J. S., & Mpoporo, L. J. (2020, November). Rain impairment model for satellite communication link design in South Africa using neural network. In *2020 2nd International Multidisciplinary Information Technology and Engineering Conference (IMITEC)* (pp. 1-8). IEEE.

32) Ozuomba Simeon (2019) Evaluation Of Optimal Transmission Range Of Wireless Signal On Different Terrains Based On Ericsson Path Loss Model Vol. 3 Issue 12, December – 2019 Available at : http://www.scitechpub.org/wp-content/uploads/2021/03/SCITECHP420157.pdf

33) Soe, L. N., Zaw, K. T., & Aung, W. P. (2019). System Consideration, Design and Implementation of Point-To-Point Microwave Link for Internet Access. *System*, *3*(5).
34) Balal, Y., & Pinhasi, Y. (2019). Atmospheric effects on millimeter and sub-millimeter (THz) satellite communication paths. *Journal of Infrared, Millimeter, and Terahertz Waves*, *40*(2), 219-230.
35) Johnson, Enyenihi Henry, Simeon Ozuomba, and Ifiok Okon Asuquo. (2019). Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm. *Universal Journal of Communications and Network, 7(1), 9-20.*
36) Zimbelman, E. G., & Keefe, R. F. (2018). Real-time positioning in logging: Effects of forest stand characteristics, topography, and line-of-sight obstructions on GNSS-RF transponder accuracy and radio signal propagation. *PLoS One*, *13*(1), e0191017.
37) Akaninyene B. Obot , Ozuomba Simeon and Afolanya J. Jimoh (2011); "*Comparative Analysis Of Pathloss Prediction Models For Urban Macrocellular" Nigerian Journal of Technology (NIJOTECH)* Vol. 30, No. 3 , October 2011 , PP 50 – 59
38) Helman, D. (2018). Land surface phenology: What do we really 'see' from space?. *Science of the Total Environment*, *618*, 665-673.
39) Njoku Chukwudi Aloziem, Ozuomba Simeon, Afolayan J. Jimoh (2017) Tuning and Cross Validation of Blomquist-Ladell Model for Pathloss Prediction in the GSM 900 Mhz Frequency Band , *International Journal of Theoretical and Applied Mathematics*
40) Zhang, L., Zhang, Z., Luo, Y., Cao, J., & Tao, F. (2019). Combining optical, fluorescence, thermal satellite, and environmental data to predict county-level maize yield in China using machine learning approaches. *Remote Sensing*, *12*(1), 21.
41) Kalu Constance, Ozuomba Simeon, Umana, Sylvester Isreal (2018). Evaluation of Walficsh-Bertoni Path Loss Model Tuning Methods for a Cellular Network in a Timber Market in Uyo. *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 12, December - 2018*
42) Measho, S., Chen, B., Trisurat, Y., Pellikka, P., Guo, L., Arunyawat, S., ... & Yemane, T. (2019). Spatio-temporal analysis of vegetation dynamics as a response to climate variability and drought patterns in the semiarid region, Eritrea. *Remote Sensing*, *11*(6), 724.
43) Ozuomba, Simeon, Johnson, E. H., & Udoiwod, E. N. (2018). Application of Weissberger Model for Characterizing the Propagation Loss in a Gliricidia sepium Arboretum. *Universal Journal of Communications and Network, 6(2), 18-23.*
44) Benveniste, J., Cazenave, A., Vignudelli, S., Fenoglio-Marc, L., Shah, R., Almar, R., ... & Wöppelmann, G. (2019). Requirements for a coastal hazards observing system. *Frontiers in Marine Science*, *6*, 348.
45) Li, J., Carlson, B. E., & Lacis, A. A. (2015). How well do satellite AOD observations represent the spatial and temporal variability of PM2. 5 concentration for the United States?. *Atmospheric Environment*, *102*, 260-273.
46) Constance, Kalu, Ozuomba Simeon, and Ezuruike Okafor SF. (2018). Evaluation of the Effect of Atmospheric Parameters on Radio Pathloss in Cellular Mobile Communication System. Evaluation, 5(11). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 5 Issue 11, November - 2018*
47) Demattê, J. A. M., Fongaro, C. T., Rizzo, R., & Safanelli, J. L. (2018). Geospatial Soil Sensing System (GEOS3): A powerful data mining procedure to retrieve soil spectral reflectance from satellite images. *Remote Sensing of Environment*, *212*, 161-175.
48) Imoh-Etefia, Ubon Etefia, Ozuomba Simeon, and Stephen Bliss Utibe-Abasi. (2020). "Analysis Of Obstruction Shadowing In Bullington Double Knife Edge Diffraction Loss Computation." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 1, January – 2020*
49) Akaninyene B. Obot , Ozuomba Simeon and Kingsley M. Udofia (2011); "Determination Of Mobile Radio Link Parameters Using The Path Loss Models*" NSE Technical Transactions , A Technical Journal of The Nigerian Society Of Engineers,* Vol. 46, No. 2 , April - June 2011 , PP 56 – 66.
50) Simeon, Ozuomba, Ezuruike Okafor SF, and Bankole Morakinyo Olumide (2018). Development of Mathematical Models and Algorithms for Exact Radius of Curvature Used in Rounded Edge Diffraction Loss Computation. Development, 5(12). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 5 Issue 12, December – 2018*
51) O'Reilly, C. M., Sharma, S., Gray, D. K., Hampton, S. E., Read, J. S., Rowley, R. J., ... & Zhang, G. (2015). Rapid and highly variable warming of lake surface waters around the globe. *Geophysical Research Letters*, *42*(24), 10-773.
52) Dialoke, Ikenna Calistus, Ozuomba Simeon, and Henry Akpan Jacob. (2020) "ANALYSIS OF SINGLE KNIFE EDGE DIFFRACTION LOSS FOR A FIXED TERRESTRIAL LINE-OF-SIGHT MICROWAVE COMMUNICATION LINK." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 2, February – 2020*
53) Ippolito Jr, L. J. (2017). *Satellite communications systems engineering: atmospheric effects, satellite link design and system performance*. John Wiley & Sons.

54) Rajbhandari, S., Chun, H., Faulkner, G., Cameron, K., Jalajakumari, A. V., Henderson, R., ... & O'Brien, D. (2015). High-speed integrated visible light communication system: Device constraints and design considerations. *IEEE Journal on Selected Areas in Communications*, *33*(9), 1750-1757.
55) Maral, G., Bousquet, M., & Sun, Z. (2020). *Satellite communications systems: systems, techniques and technology*. John Wiley & Sons.
56) Kaushal, H., Jain, V. K., & Kar, S. (2017). *Free space optical communication* (p. 60). New Delhi: Springer india.
57) Li, M., Hong, Y., Zeng, C., Song, Y., & Zhang, X. (2018). Investigation on the UAV-to-satellite optical communication systems. *IEEE Journal on Selected Areas in Communications*, *36*(9), 2128-2138.
58) Appasani, B., & Mohanta, D. K. (2018). A review on synchrophasor communication system: communication technologies, standards and applications. *Protection and control of modern power systems*, *3*(1), 1-17.
59) Maattanen, H. L., Hofstrom, B., Euler, S., Sedin, J., Lin, X., Liberg, O., ... & Israelsson, M. (2019, December). 5G NR communication over GEO or LEO satellite systems: 3GPP RAN higher layer standardization aspects. In *2019 IEEE Global Communications Conference (GLOBECOM)* (pp. 1-6). IEEE.
60) Li, F. (2019, May). Design of GEO/LEO Double-Layered Satellite Network Based on Rateless Code for Global Information Distribution. In *Wireless and Satellite Systems: 10th EAI International Conference, WiSATS 2019, Harbin, China, January 12–13, 2019, Proceedings, Part I* (Vol. 280, p. 13). Springer.
61) Wang, C., Bian, D., Xu, X., Cheng, J., & Li, F. (2019, January). Design of GEO/LEO Double-Layered Satellite Network Based on Rateless Code for Global Information Distribution. In *International Conference on Wireless and Satellite Systems* (pp. 13-24). Springer, Cham.
62) Dongfang, W., Baojun, P., & Weike, X. (2017). GEO space debris flux determination based on earth-fixed coordinate system. *Acta Astronautica*, *130*, 60-66.
63) Dongfang, W., Baojun, P., & Weike, X. (2017). GEO space debris environment determination in the earth fixed coordinate system. In *7th European Conference on Space Debris. ESA Space Debris Office, Darmstadt, ESOC*.
64) Li, X., Zhang, K., Ma, F., Zhang, W., Zhang, Q., Qin, Y., ... & Bian, L. (2019). Integrated precise orbit determination of multi-GNSS and large LEO constellations. *Remote Sensing*, *11*(21), 2514.
65) İbrahim, O. Z., & cezmi YILMAZ, Ü. (2019). Design Tradeoffs in Full Electric, Hybrid and Full Chemical Propulsion Communication Satellite. *Sakarya University Journal of Computer and Information Sciences*, *2*(3), 124-133.
66) Wahiduzzaman, M., Yeasmin, A., Luo, J. J., Ali, M., Bilal, M., & Qiu, Z. (2020). Statistical approach to observe the atmospheric density variations using swarm satellite data. *Atmosphere*, *11*(9), 897.
67) Pesevski, A., Franczak, B. C., & McNicholas, P. D. (2018). Subspace clustering with the multivariate-t distribution. *Pattern Recognition Letters*, *112*, 297-302.
68) Lv, Z., & Zhang, W. (2018). Contextual analysis based approach for detecting change from high resolution satellite imagery. *Journal of the Indian Society of Remote Sensing*, *46*(1), 43-50.
69) Jang, H. S., Bae, K. Y., Park, H. S., & Sung, D. K. (2016). Solar power prediction based on satellite images and support vector machine. *IEEE Transactions on Sustainable Energy*, *7*(3), 1255-1263.
70) Cilden-Guler, D., Raitoharju, M., Piche, R., & Hajiyev, C. (2019). Nanosatellite attitude estimation using Kalman-type filters with non-Gaussian noise. *Aerospace Science and Technology*, *92*, 66-76.
71) Ho, W. K., Ling, K. V., Vu, H. D., & Wang, X. (2014). Filtering of the ARMAX process with generalized t-distribution noise: The influence function approach. *Industrial & Engineering Chemistry Research*, *53*(17), 7019-7028.
72) Fang, L., Chen, B., Yu, H., & Qian, Y. (2018). Identifying systemic important markets from a global perspective: Using the ADCC ΔCoVaR approach with skewed-t distribution. *Finance Research Letters*, *24*, 137-144.