Analysis of IGS Data Based on Military Action Prediction

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Abstract. In order to verify that the analysis of satellite navigation signal observation data can be used as a means of predicting military operations, this paper combines the recent Iranian shooting down of UAV event, using RTKLIB software to analyze the parameter of visible satellite numbers, SNR(signal-to-noise ratio), and accuracy factor, multipath error, positioning accuracy and other indicators in order to avoid errors in the analysis results of a single type of receiver data analysis, further IGS in the vicinity of Iran and around the world according to the type of receiver, antenna type, and firmware version used. Observe the data for analysis. The analysis shows that the signal power of the GPS L2 frequency is enhanced in the United States from 15:00 on June 20, 2019 to 9:00 on June 21, 2019. The enhancement range is global. The analysis system of this paper can as an effective means of accurately predicting and judging military operations.

1. Introduction
At about 9:00 am on June 20, 2019, Iran, a US "Global Hawk" drone was shot down at the entrance to the Strait of Hormuz. According to the media "New York Times" reported on June 20, the US President on the same day, Rump approved the air strike Iran plan, which is scheduled to be launched at 7:00 pm on the 20th, and at 4 am on the 21st, Iran time. Combined with the US military attack on Syria on April 14, 2018 (the local time in Syria), the GPS L2 frequency signal was boosted[1,2] this paper, IGS uses the continuous observation data of IGS in the tracking and monitoring stations around Iran to analyze the GPS signals in five aspects: visible satellite number, accuracy factor, multipath error, SNR, and positioning accuracy, and further according to the received receiver. The global IGS monitoring stations are classified according to the model, antenna type and firmware version, and the observation data of some monitoring stations are analyzed.

2. Introduction to basic software and data sources
The analysis software used in this paper is RTKLIB, and it is also used by Matlab for auxiliary analysis. The data source is the real-time monitoring data of IGS monitoring station. The following introduces RTKLIB and IGS.
2.1. RTKLIB software introduction
RTKLIB is an open source package developed by Takashima I of Tokyo Ocean University, Japan. It consists of a portable library and multiple application tool libraries [3], its main functions include: support for standard and precision positioning algorithms for multiple GNSS systems, support for multiple GNSS standard formats and protocols, support for multiple GNSS real-time and post-processing positioning modes, support for multiple GNSS receiver-specific data protocol formats, and support a variety of external communication methods.

2.2. IGS introduction
International GNSS Service (IGS) is a permanent service organization established by the International Association of Geodesy in 1992. It consists of more than 400 observatories around the world which are composed of global network, regional network and local network [4].

The GPS data of the global network consists of a daily measurement and navigation data file generated by the receiver-independent exchange format (RENX), which is compressed by UNIX and transmitted to the corresponding data center. The naming convention for RENIX observation data files is: sssddd.yyt. ssss is 4 characters indicating the name of the monitoring station. ddd is the annual product date of the first data record and f is the serial number of the file generated during the UTC time of day. ("0" means that the file contains all the data of the day) yy is the year represented by a 2-digit integer, t represents the type of the file, O represents the original observation, N represents the ephemeris, M represents the meteorological data, and G represents the GLONASS ephemeris, H represents the navigation message of the synchronous satellite GPS payload [5].

3. Data processing and analysis of monitoring stations in and around Iran
After viewing the official website of IGS, there are 4 IGS monitoring stations in and around Iran, namely hamd, tehn, isba, bhr4. Since the hamd monitoring station does not have data on GPS L2 frequencies, it is not analyzed. This paper first downloads the data of four monitoring stations from the CDDIS server. These monitoring stations are the tehn monitoring station in Iran and the isba and bhr4 monitoring stations around Iran. The UTC time of the downloaded data is June 20, 2019 and June 21, 2019 (Day of Year (DOY) is 171, 172).

3.1. Visible satellite number and dilution of precision
The satellite can be seen as the most fundamental condition for GPS receivers. When the number of visible satellites received by the receiver is reduced, less than 4, it will not meet the minimum requirements for positioning [6]. In satellite navigation, the concept of dilution of precision (DOP) is generally used to represent the amplification factor of the error, which is independent of the strength of the signal, the positioning algorithm used by the receiver, and the positioning performance.

Processing data of three monitoring stations, tehn, isba and bhr4, for two days (DOY 171, 172), the number of satellites and the value of DOP are shown in Figure 1 to 3.

![Figure 1. Two-day GPS visible satellite number and DOP value at tehn monitoring station.](image1)

![Figure 2. Two-day GPS visible satellite number and DOP value at isba monitoring station.](image2)
As can be seen from Figure 1 to 3, the number of satellites observed at the tehn monitoring station in Iran is about 8 or so, the average values of GDOP, PDOP, HDOP, and VDOP are 2.6, 2.3, 1.1, and 2.0 respectively. The number of satellites observed by the isba and bhr4 monitoring stations is about 10, and the respective DOP values are below 2.0. There is no obvious abnormality in the observed data.

3.2. Multipath error
Since the GPS signal passes through various reflectors, such as the ionosphere, mountains, trees, buildings, etc. From the satellite transmitting end to the receiving end of the GPS receiver antenna, the direct wave and the reflected wave exist simultaneously, which causes multipath effect. Multipath effect is an important source of error in GPS measurement and an important factor affecting positioning accuracy [7].

Processing data of three monitoring stations, tehn, isba and bhr4, for two days (DOY 171, 172), The pseudo-code multipath effect error of the GPS L2 frequency signal is shown in Figure 4 to 6.

It can be seen from Figure 4 to 6 that the multipath errors of the three monitoring stations did not change significantly during the two days, and the overall root mean square was around 0.3.

3.3. SNR
The SNR is the ratio of the carrier signal strength to the noise intensity. The larger the value, the stronger the received signal power [8]. Processing data of three monitoring stations, tehn, isba and bhr4, for two days (DOY 171, 172), The SNR variation of GPS L2 signal is shown in Figure 7 to 9.
Figure 7. Change of SNR of GPS L2 frequency point signal in tehn monitoring station in two days.

Figure 8. Change of SNR of GPS L2 frequency point signal in isba monitoring station in two days.

Figure 9. Change of SNR of GPS L2 frequency point signal in bhr4 monitoring station in two days.

It can be seen from Figure 7 to 9 that the signal power of the GPS L2 frequency of the tehn monitoring station and the bhr4 monitoring station is significantly enhanced from 15:00 pm DOY 171 to 9:00 am DOY 172, while that at isba monitoring station did not.

3.4. Positioning accuracy
Positioning accuracy is an important indicator in satellite navigation and positioning systems. The results of single-point positioning of the observed data of three monitoring stations, tehn, isba and bhr4, on DOY 171 and 172 days are shown in Figure 10 to 12.

Figure 10. The result of single point positioning of the tehn monitoring station.

Figure 11. The result of single point positioning of the isba monitoring station.

Figure 12. The result of single point positioning of the bhr4 monitoring station.

It can be seen from Figure 10 to 12 that the standard deviation and root mean square of the three monitoring stations in the east and north directions are below 1 m, the standard deviation and root
mean square of the vertical direction of the tehn station and the station site are below 2m, the standard
deviation and root mean square of the vertical direction of the bhr4 station are 2.2126m and 2.2124m,
respectively. Overall, the positioning errors of the three stations are in line with the accuracy
requirements of single point positioning. From the local details, there is no significant improvement in
the positioning accuracy of the three stations from 15:00 pm DOY 171 to 9:00 am DOY 172.

4. SNR analysis of other monitoring stations in the world
There are many factors affecting the SNR of the receiver. For example, receivers produced by
different manufacturers, different firmware versions in the same model receiver, different antenna
types, etc., will affect the SNR measured by the receiver. In order to further analyze whether GPS has
enhanced the power of L2 signal, and whether the enhancement is regional or global, in this paper,
more than 400 monitoring stations on the CDDIS server are classified according to the receiver model,
receiver firmware version and antenna type. The monitoring data of some receivers in DOY 171 and
172 are further analyzed.

First, classify the receiver using the model TRIMBLE NETR9 in the same way as the tehn
monitoring station. Then randomly select the tbl monitoring station in Letwood, USA, which uses
different firmware versions from the tehn monitoring station but the antenna type is the same, for data
analysis, the SNR results obtained by the analysis are shown in Figure. 13. Since there is no
monitoring station with the same firmware version as the tehn monitoring station after classification,
the str2 monitoring station in Canberra, Australia, which is different from the tehn monitoring station
firmware version and antenna type, is randomly selected for analysis, the SNR results obtained by the
analysis are shown in Figure 13.

![Figure 13](image1.png)
**Figure 13.** Change of SNR of GPS L2 frequency
point signal in tbl monitoring station in two days.

![Figure 14](image2.png)
**Figure 14.** Change of SNR of GPS L2 frequency
point signal in str2 monitoring station in two days.

It can be seen from Figure 13 and 14 that there are obvious power boost periods for both
monitoring stations. The power enhancement time is from DOY 171 15:00 pm to DOY 172 9:00 am.

Then, according to the same as the isba monitoring station, the model is TRIMBLE NETR5. Since
all the stations use different firmware versions and antenna types than the isba monitoring station,
therefore, the data of the aspa monitoring station in Pago Pago, USA and the bjco monitoring station
in Cotonou, Benin, were randomly selected for analysis, the SNR of the two monitoring stations are
shown in Figure 15 and 16, respectively.

![Figure 15](image3.png)
**Figure 15.** Change of SNR of GPS L2 frequency
point signal in aspa monitoring station in two days.

![Figure 16](image4.png)
**Figure 16.** Change of SNR of GPS L2 frequency
point signal in bjco monitoring station in two days.
It can be seen from Figure 15 and Figure 16 that neither of the two monitoring stations has a period of significant power enhancement.

Next, according to the same type of receiver as the ITT 3750300, the same as the bt4 monitoring station. Since all the stations after the classification use the same firmware version and the same antenna type, so randomly select the data from the ok1 monitoring station in Sachem, England for analysis.

![Image](image1)

**Figure 17.** Change of SNR of GPS L2 frequency point signal in ok1 monitoring station in two days.

It can be seen from Figure 17 that significant power enhancement occurs between 15:00 PM at DOY 171 and around 10:00 AM at DOY 172.

Finally, the receiver models used in the above monitoring stations are selected differently, and the data of the monitoring stations using JAVAD receivers are used for further analysis. Firstly, the data of two monitoring stations with firmware versions of 3.7.6 but different antenna types were selected for analysis, the types of antennas used by the two stations are JAVRINGANT_DM and TRM29659.00, respectively, bgt monitoring station in Goboda, Colombia, and RABT monitoring station in Rabat, Morocco, the SNR of the two monitoring stations are shown in Figure 18, 19, respectively. Then select the data analysis of the met3 monitoring station in Kilconum, Finland, whose antenna type is also JAVRINGANT_DM but firmware version 3.7.5. the SNR results obtained by the analysis are shown in Figure 20.

![Image](image2)

**Figure 18.** Change of SNR of GPS L2 frequency point signal in bgt monitoring station in two days.  

**Figure 19.** Change of SNR of GPS L2 frequency point signal in RABT monitoring station in two days.

![Image](image3)

**Figure 20.** Change of SNR of GPS L2 frequency point signal in met3 monitoring station in two days.

As can be seen from Figure 18 to 20, power boosting occurs in receivers that also use JAVAD receivers but have different firmware versions and different antenna types, the power boost period is from DOY 171 15:00 pm to DOY 172 10:00 am. 

As can be seen from the analysis in Figure 13 to 20, in addition to the fact that several monitoring stations using the TRIMBLE NETR5 receiver have not monitored the power boost, the remaining stations around the world have monitored the power boost, since the stations with no power boost...
monitoring are all using the TRIMBLE NETR5 receiver, the reason may be that the TRIMBLE NETR5 receiver uses automatic gain control. Therefore, the above analysis shows that the power enhancement range of GPS L2 frequency signal is global.

5. Conclusion
This article uses RTKLIB software to analyze two days of data from some IGS stations around the world, these two days are June 20, 2019 and June 21, 2019 (DOY 171, 172). From the above analysis, it can be seen that the power of the signal of the GPS L2 frequency has increased from 15:00 on the 20th to 9:00 on the morning of the 21st, the visible satellite number, multipath effect, DOP value, and positioning error are all within the normal range, and there is no obvious abnormality. According to the analysis of this real case, it can be seen from the media report that the time when President Trump approved the military strike against Iran is located within the power enhancement period, combined with the US military attack on Syria on April 14, 2018 (Syrian local time), the signal of the GPS L2 frequency is also enhanced, it shows that the evaluation and analysis of real-time data of IGS can be used as an important and effective means to predict and judge military operations.

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