DATA YIELD OF THE ILRS GLOBAL NETWORK OVER THE PAST DECADE

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Abstract

We present an analysis of the data yield history of the ILRS Global Network. Variations due to seasonal, weekly and anthropogenic effects will be evaluated and quantified. The data from only the two LAGEOS satellites are used in this study. This ensures that the results are independent of other reasons for which an increase or decrease in data yield could be observed (e.g. targeted campaigns, loss of scientific interest in a particular target, ranging restrictions due to mission constraints, etc.). We will attempt to quantify the effect of the recent NASA-network reduction in the overall yield of the GLTN.

Introduction

The Global Laser Tracking Network (GLTN) is now managed by the International Laser Ranging Service (ILRS) and its coordinating bodies. It is no secret that Satellite Laser Ranging (SLR) never managed to achieve a uniform global distribution of tracking sites, not even close to those of other space techniques like GPS and DORIS. The non-uniform landmass distribution on the globe is the primary reason, with the high cost of equipment and operations being a close second. In recent years the lack of southern hemisphere sites had been slowly addressed with the strategic transfer of older and new systems in targeted locations. Unfortunately this process not only came to a screeching halt, it was entirely reversed, with NASA's decision to resolve funding shortcomings with the closing of the Haleakala, Hawaii and the Arequipa, Peru sites in 2003, and curtailment of operations at the rest of the NASA-supported GLTN sites. With autonomously operating systems soon to become available, the fortunes of the GLTN may soon be reversed, however, it was felt that a closer look be taken of the data yield from GLTN over the past decade, in order to assess the trends in data collection and identify any systematic shortcomings due to the current schedule of routine operations. We decided to do this by looking at the data yield of the network when tracking the two geodetic satellite targets LAGEOS and LAGEOS 2. The reasons behind this are the fact that according to ILRS rules, an operational site must meet minimum tracking requirements for these two targets, which are the primary targets when it comes to the definition of the Terrestrial Reference Frame (TRF) and monitoring Earth Orientation Parameters (EOP) on a daily basis. Additionally, focusing on these two satellites, avoids confusing temporary data yield variations due to targeted campaigns, special target tracking requirements and changes in the scientific interest on some SLR targets over time. We will examine in detail the data yield for the first quarter of 2004, and then we will look at the statistics of the 1993-2003 data set collected by the GLTN. The analysis is done on the basis of the total daily data yield on both LAGEOS and LAGEOS 2 satellites for each of the active tracking sites.

First quarter 2004 results

The GLTN sites are shown in Figure 1. The highly non-uniform distribution of sites over the northern and southern hemispheres is obvious. It is also very clear that there is a very high density of stations over central Europe.

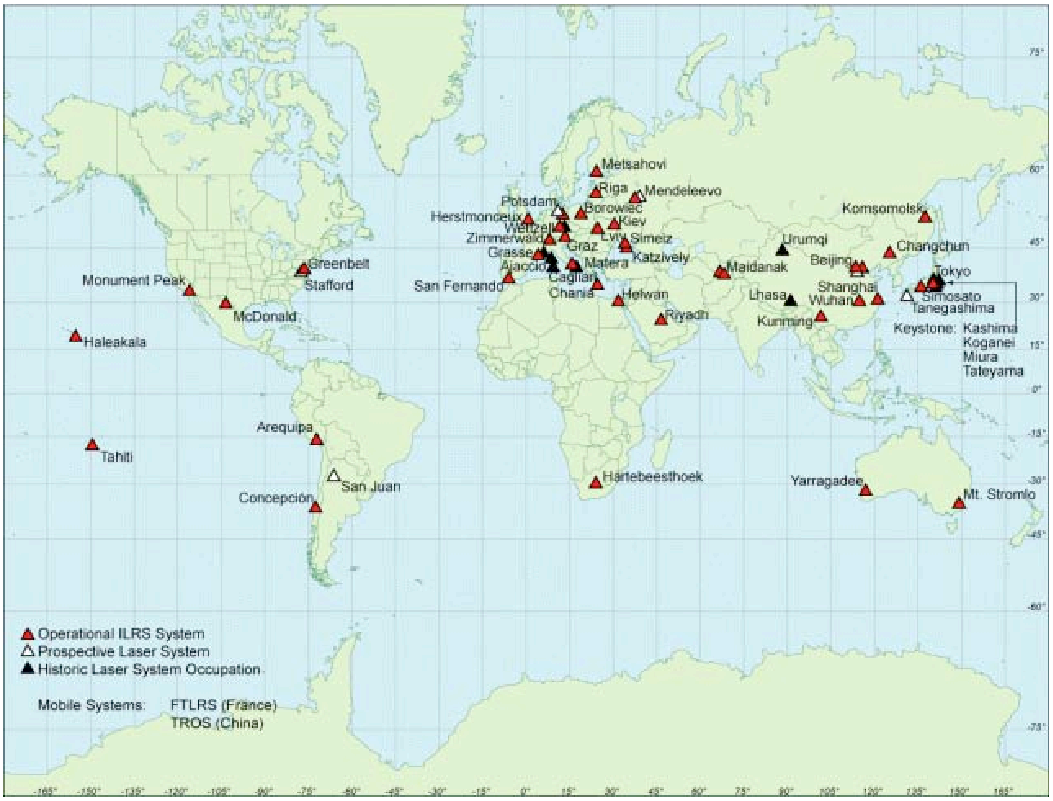

Figure 1. The ILRS Global Laser Tracking Network at present (ca. mid-2003).

The repercussions of this lopsided distribution are exacerbated by the fact that not all stations perform or operate in a similar way, and others despite their high quality equipment, are situated in areas affected by weather that prevents SLR operations over long time periods at a time. Examining the data yield from the recent first quarter period of 2004 (Figure 2), we notice that in its present configuration, the network fails to ensure a geometrically strong daily network, with a median number of tracking sites at eleven, but with a wide variation (a standard deviation of three sites), with a minimum of as little as five stations, and a maximum of nineteen sites, a number that can not even be considered acceptable for TRF maintenance and EOP monitoring purposes. In contrast for instance, the IGS GPS network uses a network of “core” sites in the order of sixty around the globe, with a similar situation for the other satellite technique, the DORIS network. In terms of data points, the daily median of about 350 normal points, with a large standard deviation of some 135 points, indicate that there is severe lack of robustness in the network yield, with wild variations which are only worse due to the further burden of the unequal quality of data from various sub-groups of stations.

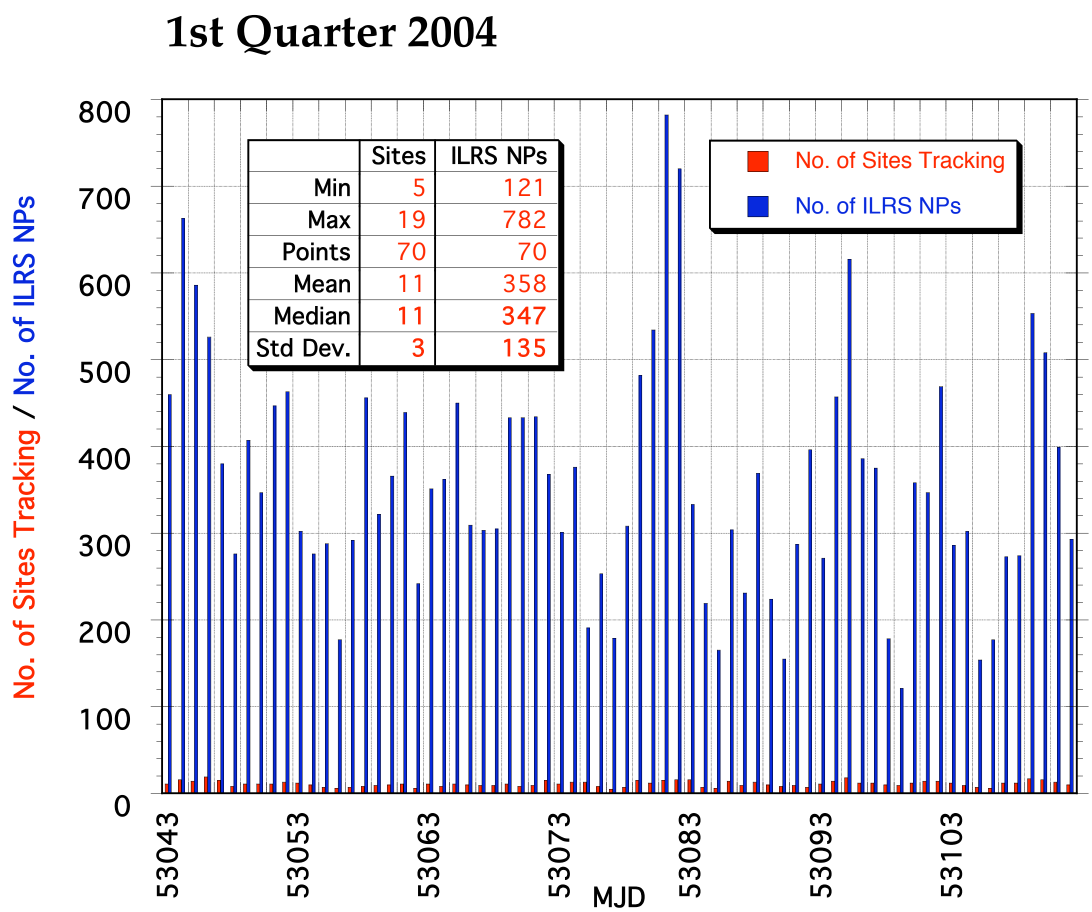

Figure 2. Daily normal point and tracking station distribution for the 1st quarter of 2004.

The latter has significant geographic correlation, and that generates even more problems in our contributions for the stable (in time) definition of the TRF, its origin (geocenter), scale, orientation, and other attributes [Pavlis, 2002; and in these proceedings].

The histogram of Figure 2 indicates some obvious periodicities in the data. In the past, it was observed that SLR data yield dropped significantly during the weekends, and the effect was termed naturally, the “weekend effect”. We therefore decided to fit a model that included a bias, a slope and a 7-day periodic component. Given all other factors that affect data yield as we outlined above, it is really amazing how well this model fits the data during this time period. The results are displayed in Figure 3, along with the parameters and statistics of the fitted model. The –1.2±0.7 NP/d drop in data is much too insignificant to worry, but the fact that the weekend effect has an amplitude of some 81 NPs and it is significant at the 4-σ level, is something we need to address. The model explains about half of the variance in the data set (47%), considering though the previously estimated standard deviation of some 135 NPs in the data yield, we conclude that the weekend effect is largely responsible for most of this variability. The fact that this drop is concentrated over the weekend, a more appropriate model would be to look at the data variability over the weekdays separately from the weekends.

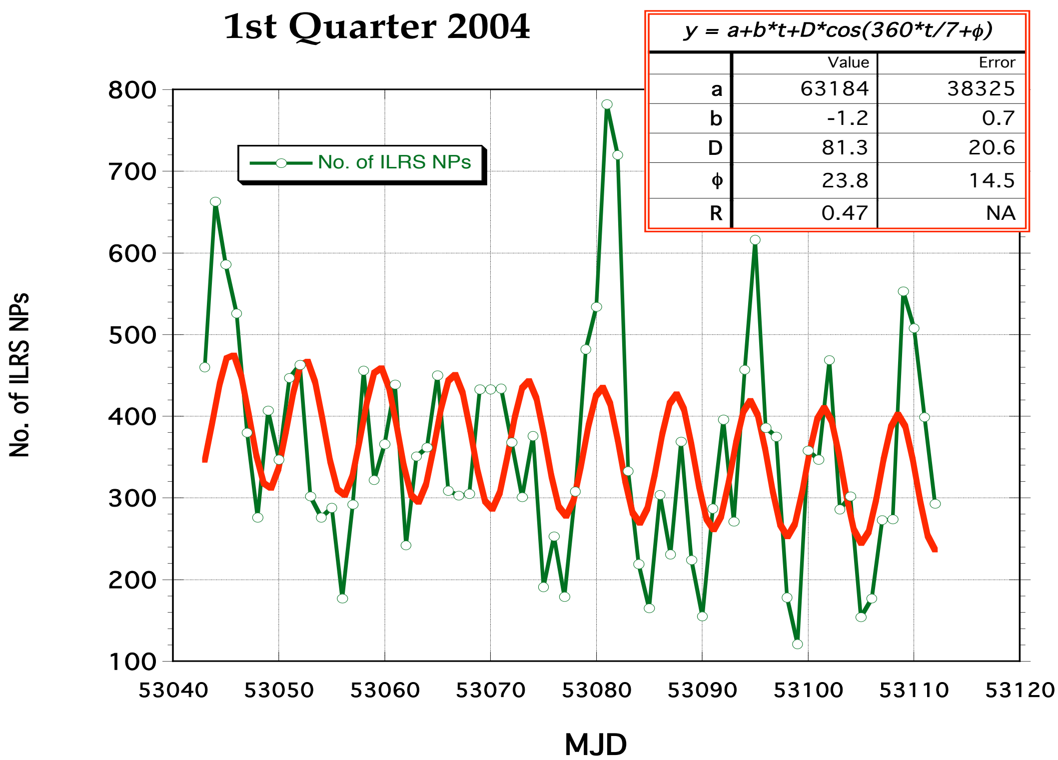

Figure 3. Model fit with a 7-day periodic component for the 1st quarter of 2004 data.

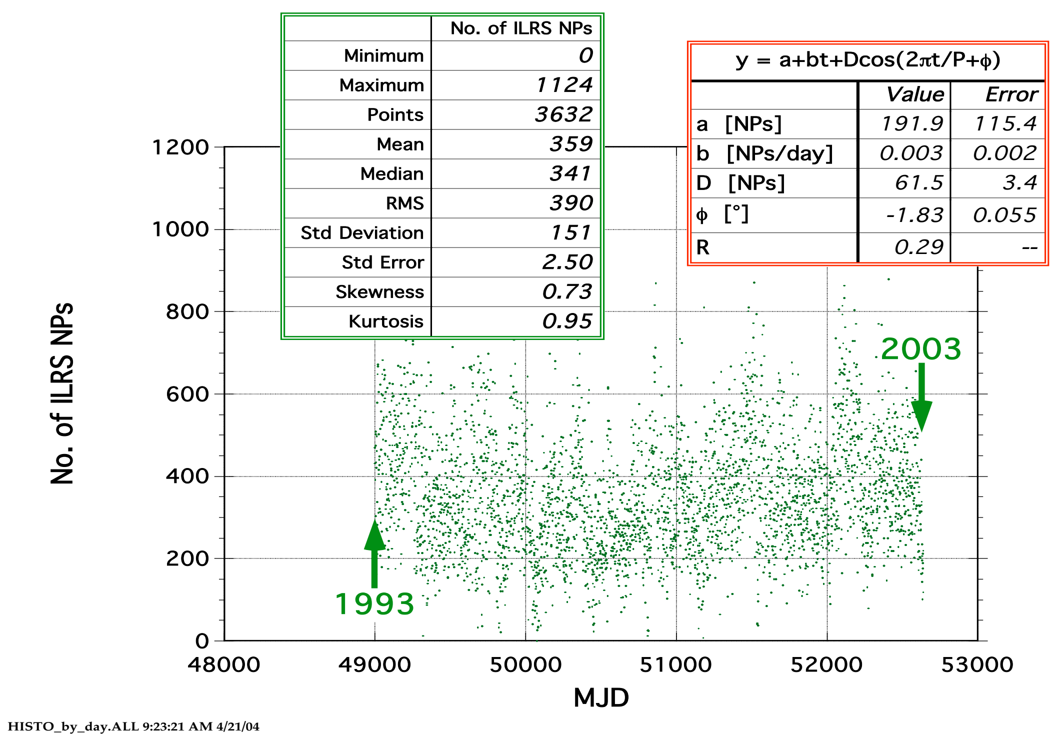

Figure 4. Model fit as in Figure 3 but on the entire 1993 – 2003 SLR LAGEOS data set.

Fitting the same model to the entire data set 1993 to 2003, we find similar if not identical results (Figure 4). It now explains only about 30% of the variance, but that is not surprising given the so many changes that the GLTN undergoes over periods of time due to operations changes, change of tracking priorities, targeted campaigns, long-term weather patterns, addition or deletion of stations, etc. One parameter that seems to be even better determined from the longer record is the amplitude of the weekend effect. Although over the longer time the magnitude undergoes variations and the value drops to just over 61 NPs from 81 that we found during the 1st quarter of 2004, the standard deviation is now down to 3.4 NPs, indicating this is a real effect, and if want a GLTN that will deliver products with a uniform quality, it has to be addressed and resolved.

Despite significant changes and additions to the GLTN over the examined period, it is disappointing to see that the median daily yield and associated standard deviation over the longer period is practically the same with what we observed over the recent 1st quarter of 2004 analysis. Since it is impossible to see any details in a figure that covers a whole decade, we have generated individual plots corresponding to approximately one-year slices of Figure 4. These are illustrated in Figure 5 (a) through (j). The model that was fit to the entire data set is overlaid on each figure, centered at the median daily value. We did not consider any slope, since its value is statistically insignificant. A close examination of the actual data yield during each year, in comparison to the average indicated by the model, reveals some very interesting facts.

First of all, it seems that 1993 was our best year in data yield and it has been downhill ever since. Year 1996 had a low yield, while 1997 had an exceptionally low yield. For the rest of the years, except for an above average performance in 2001, they are all at about average. Looking at each year even more closely, we find that in 1994, the second half of the year shows enhanced yield, and a similar performance in 1999. In 1995 and 2000, we have a strong annual signal, and although not as pronounced due to the severe drop in yield, years 1996 and 1997 also show similar signals. In 1998 we notice a drop in the second half of the year, while in 2001, there is a very significant enhancement in the middle of the year. Finally, the end of 2002 shows a very strong decrease in yield over about the period of a month.

Summary

The analysis of the ten-year record of tracking data from the ILRS GLTN for LAGEOS and LAGEOS 2 indicates that there is a strong weekend effect present throughout the years. The large variability of station participation in the daily network, compounded by the non-uniform quality of the network sites, results in a degraded contribution for such research areas requiring high quality and stability, as the definition of the TRF and its origin, scale and orientation, and monitoring their changes over time. Planning of any system improvements or network expansions, one should consider these issues first, if the goals outlined in national and international programs under consideration are to be served by the SLR technique properly.

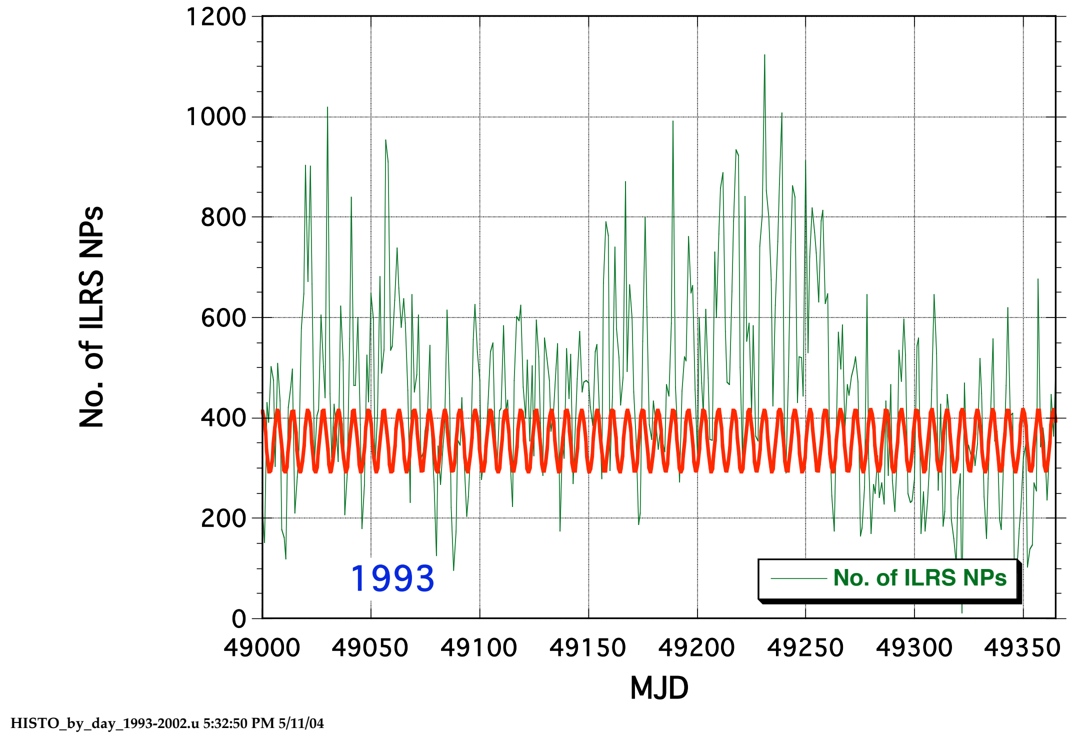

Figure 5. (a) Daily data distribution for 1993.

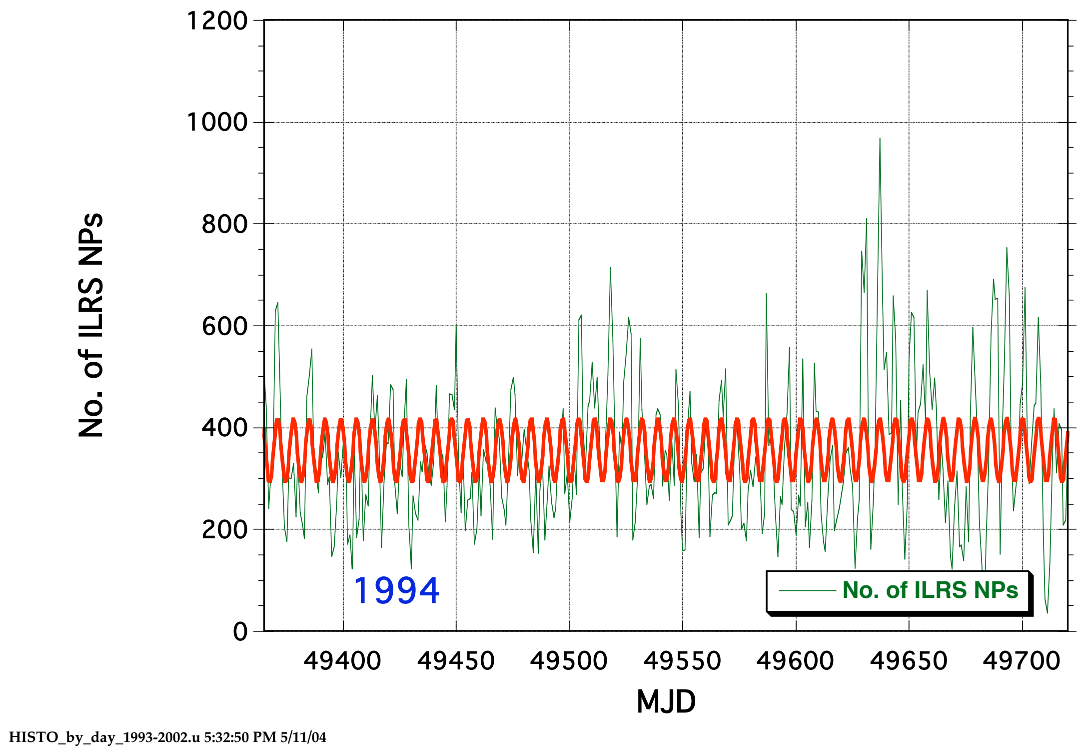

Figure 5. (b) Daily data distribution for 1994.

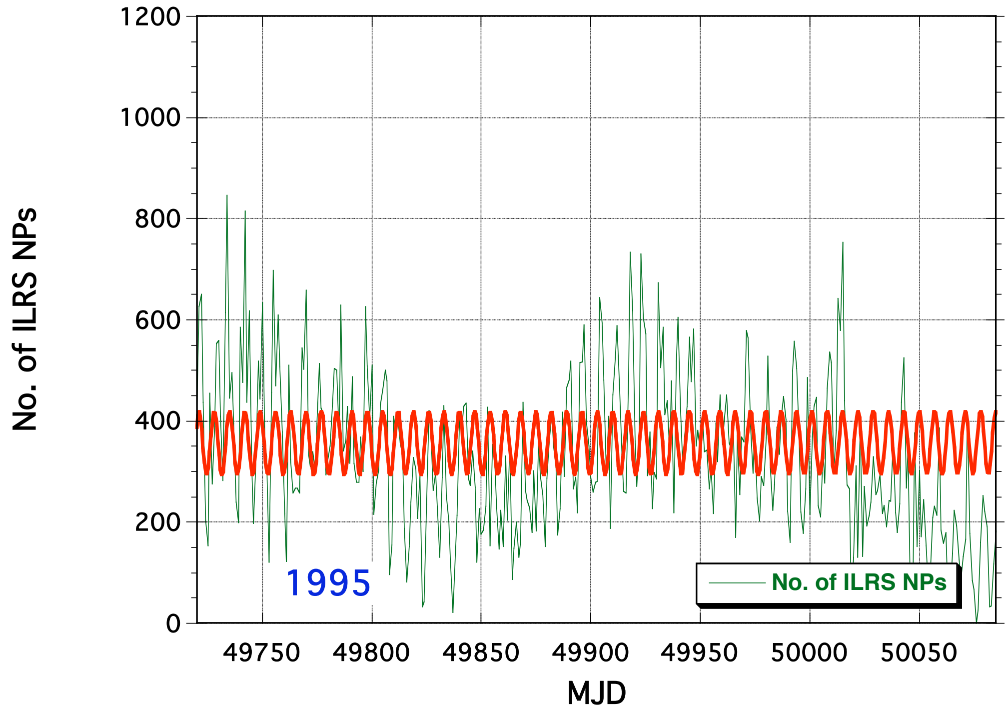

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Figure 5. (c) Daily data distribution for 1995.

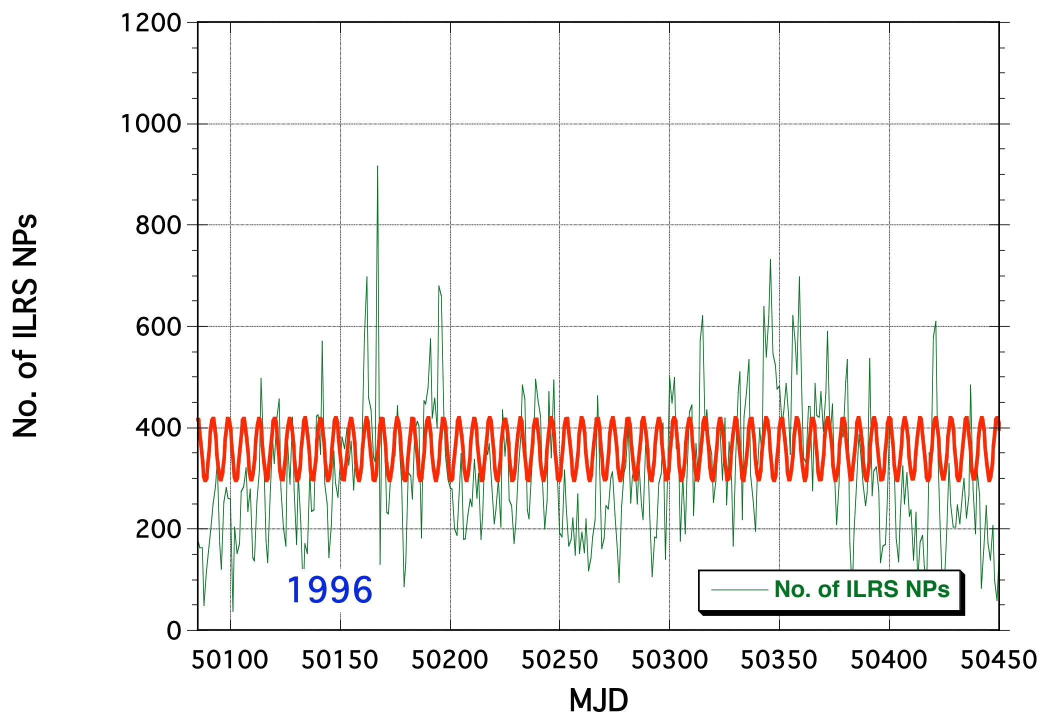

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Figure 5. (d) Daily data distribution for 1996.

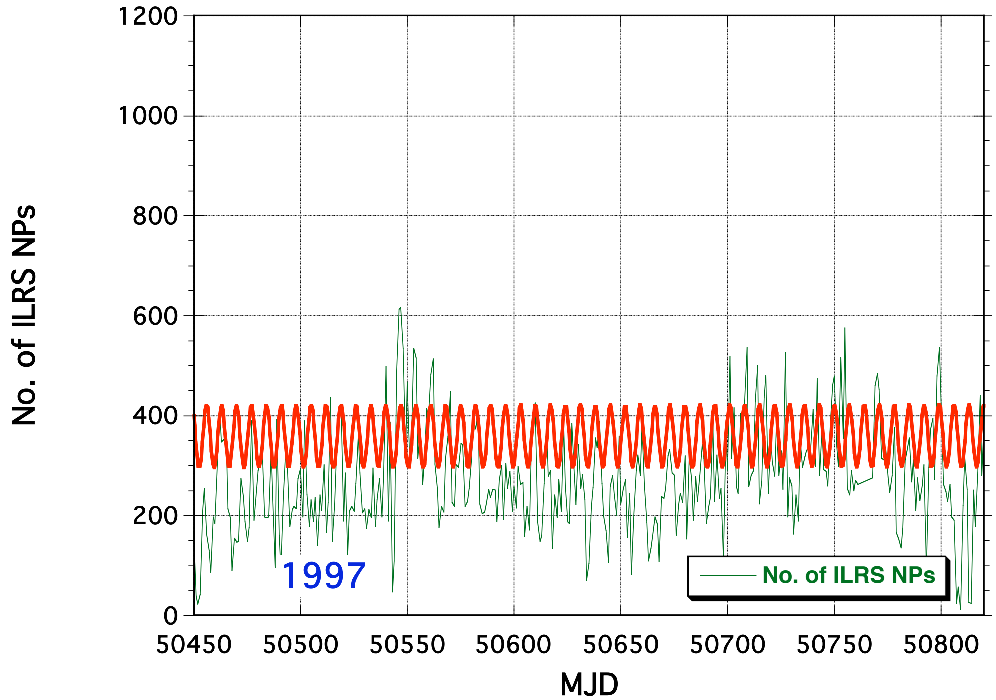

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Figure 5. (e) Daily data distribution for 1997.

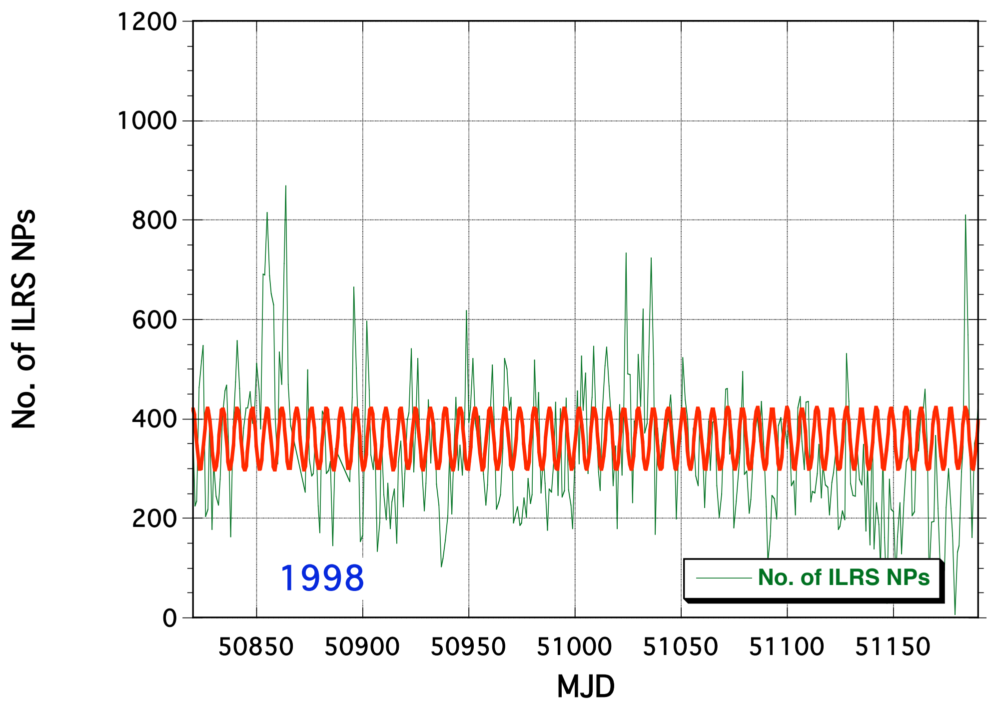

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Figure 5. (f) Daily data distribution for 1998.

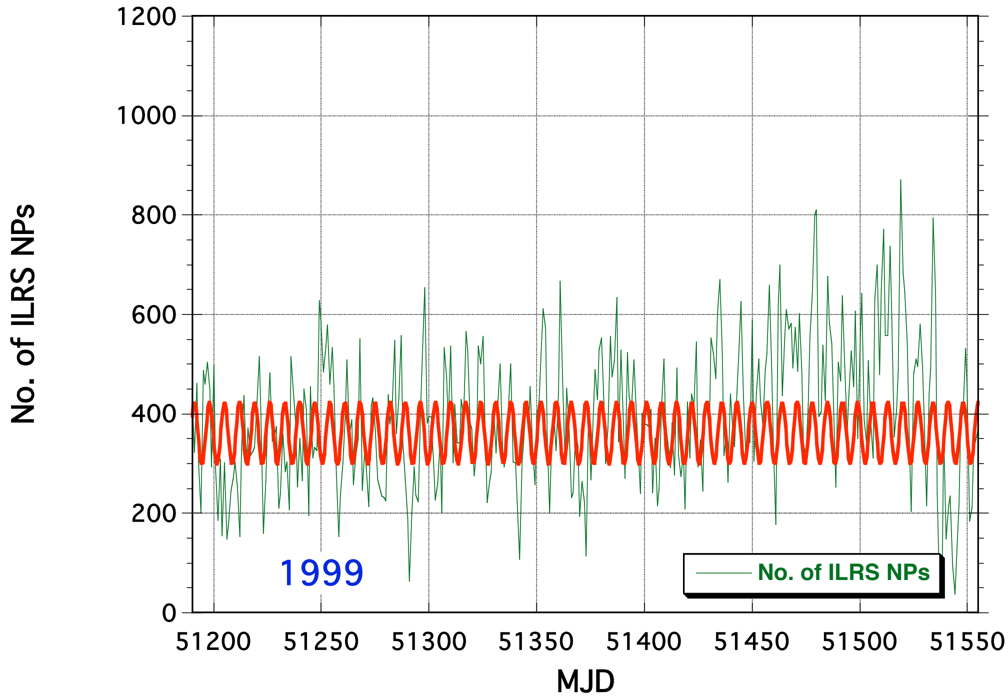

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Figure 5. (g) Daily data distribution for 1999.

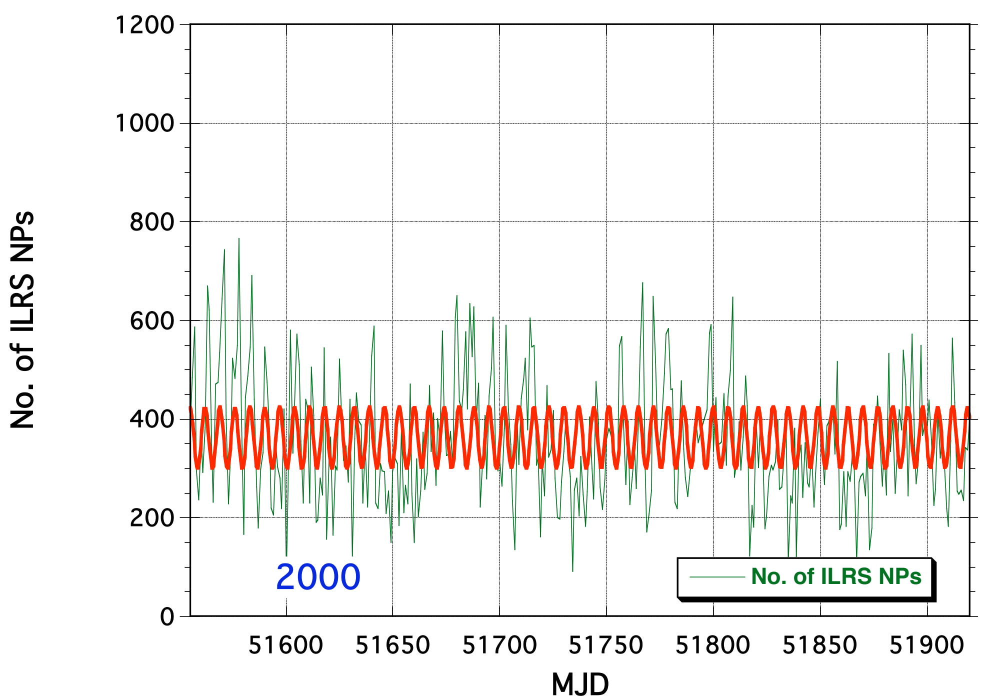

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Figure 5. (h) Daily data distribution for 2000.

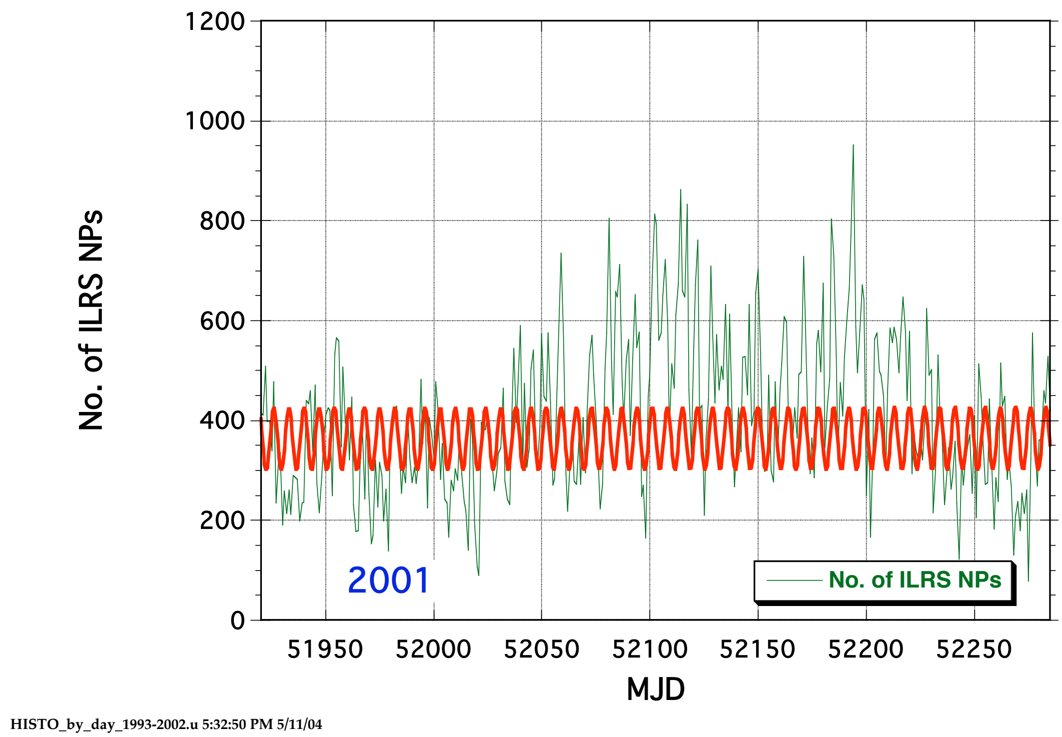

Figure 5. (i) Daily data distribution for 2001.

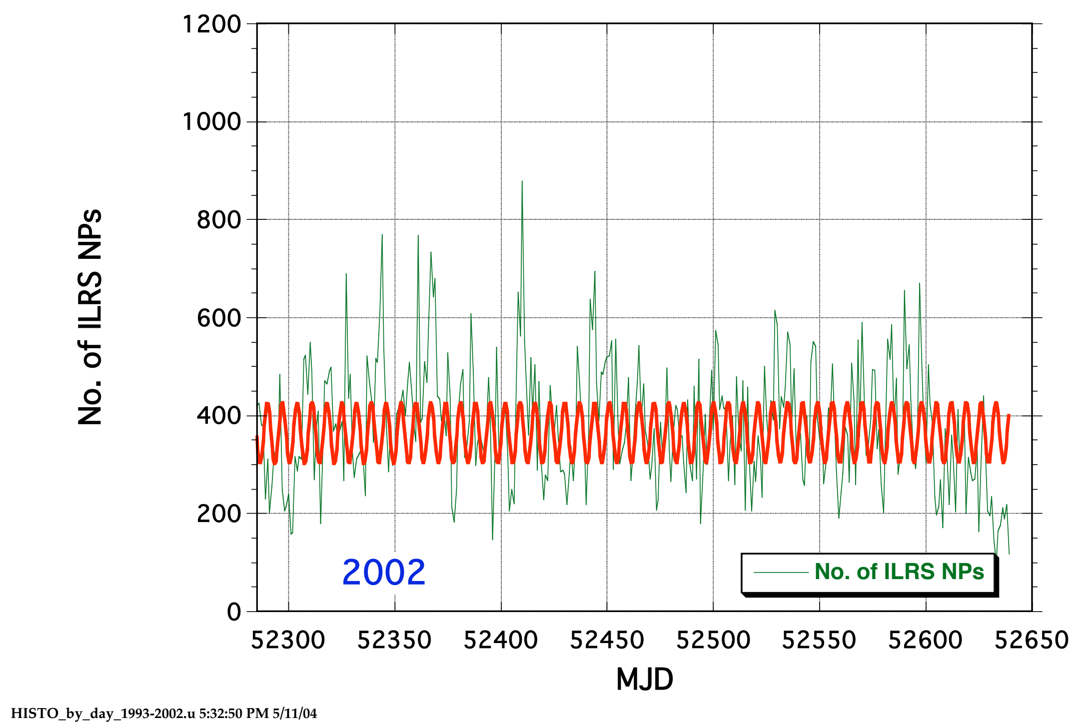

Figure 5. (j) Daily data distribution for 2002.

References

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