Technical report
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Centre of mass corrections updates for geodetic spherical satellites

Changes in the latest releases in preparation for the computation of ITRF2020 products

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How to cite

In case of citing this report, please do so together with [1].

Changelog

v0.1	2022-09-18	First draft version
v1.0	2022-11-22	Final version

Contents

Acronyms

AAC	Associate Analysis Centre
AC	Analysis Centre
ASC	Analysis Standing Committee
CoM	Centre of mass correction
IGN	Instituto Geográfico Nacional
ILRS	International Laser Ranging Service
ITRF	International Terrestrial Reference Frame
QCB	Quality Control Board
SLR	Satellite Laser Ranging

Abstract

The accurate exploitation of Satellite Laser Ranging (SLR) observations for geodetic purposes requires the application of so-called centre of mass corrections for the targets of analysis. These are the vectors that link the average optical reflection points on the laser retroreflector arrays to the centre of mass of the satellites. These corrections enable the computation of the equations of motion from measurements made to points that are not coincident with their centres of mass. The current set of corrections employed by the Analysis Standing Committee (ASC) of the International Laser Ranging Service (ILRS) for the analysis of geodetic spherical satellites is based on the work of Rodríguez, Appleby and Otsubo [1], and the satellite- and system-specific corrections are currently provided by the ILRS Associate Analysis Centre IGN-Yebes. The latest two updates of this product, v210511 and v220915, prepared for the computation of the ILRS contribution to ITRF2020 and in preparation for the adoption of ITRF2020 standards by the ASC in their routine products, are detailed here.

1 Introduction

The evolution of the hardware and engineering aspects of the SLR technique, as well as of the treatment of the observations for geodetic applications, has resulted in ever increasing levels of accuracy and precision in both the observations and their products. In order to realise the full potential of the technique, and to deliver products that meet the most stringent requirements imposed by their scientific applications, a continuous reevaluation and improvement of the models employed in the data analysis is necessary.

Efforts in this direction are in part carried out at the ILRS Quality Control Board[1], coordinated by Mike Pearlman (Harvard Smithsonian Center for Astrophysics), whose purview includes the examination of different aspects of the SLR data production chain that may affect the final quality of the products. Examples of the QCB activity to date include the scrutiny of the time series of station data and products, the investigation of artefacts connected with engineering changes, possible improvements in the data reduction routines, and seemingly inconsistent changes in the centre of mass corrections applied [2].

[1] `https://ilrs.gsfc.nasa.gov/science/qcb`

Thanks to the careful examination of this last issue[2], some potential problems that merited attention were discovered. Besides the discovery of problematic values, the continuous update of the ground network of ILRS stations demands the periodic revision of the corrections applied for each system. Here I detail the latest updates to the centre of mass corrections for the satellites employed by the ILRS ASC in their analyses, which respond to the need to keep up with the evolution of the network and the discovery of some missing or inconsistent values in the tables of corrections.

[2] In particular, thanks in no small measure to the work of Van Husson (Peraton).

1.1 Computation of corrections

A detailed description of the methods and strategy employed for the computation of the centre of mass corrections for spherical geodetic satellites is outside the scope of this report. These issues are covered in various publications cited here for reference: Otsubo and Appleby [3], Otsubo et al. [4] and Rodríguez, Appleby and Otsubo [1]. A very brief account of what the computation involves follows.

Figure 1: LARES, a typical "cannonball" geodetic satellite (Italian Space Agency).

Spherical geodetic satellites (e.g. Fig. 1), owing to the placement of cube corner retroreflectors extending over their curved surfaces, cause a spreading of the laser pulses reflected towards the stations. This unavoidable optical effect, known as *target signature effect*, must be taken into account in order to accurately relate the observations to the centre of mass of the satellites. The optical behaviour of the retroreflector array is determined from the physical characteristics of the individual cube corner retroreflectors (construction materials, dimensions, orientation and position), and from empirical data obtained by SLR observations obtained in the single-photon regime[3]. This enables the computation of the average optical response of the satellites, which in turn is used to simulate the signals as detected by different hardware equipment working according to specific operational policies (e.g. single-photon vs multi-photon). Lastly, the simulated detected signals are treated in the same way that the stations follow in their actual operational data reduction schemes (e.g. $N \times \sigma$ rejection filter).

[3] In single-photon operations the return rate is controlled and limited so that, on average, no more than a unique photo-electron is generated per each laser pulse. The distribution of returns thus obtained is easily related to the optical response of the satellite.

It can be appreciated from the above explanation that the maintenance of a suitable set of corrections with practical use depends both on the use of adequate methods for their computation as well as on the availability of the required metadata of the observations. These metadata are not always available, especially for old stations that are no longer active, limiting the accuracy with which the corrections can be computed.

1.2 Availability of this product

The centre of mass corrections provided by IGN-Yebes consist in tables of corrections for most stations of the ILRS, taking into account the different hardware configurations used in their history, as well as their operational policies and data reduction strategies. The satellites for which corrections are available are Starlette (and its twin Stella), LAGEOS-1/2 , Ajisai, Etalon-1/2, and LARES. This covers the totality of the satellites employed so far by the ILRS ASC for their geodetic products and contributions to the International Terrestrial Reference Frame (ITRF). The adoption of these new satellite- and station-specific corrections over the previously available ones, computed by Graham M. Appleby (NSGF, UK), took place after careful testing was conducted and the advantages of the new values demonstrated. The newer set of centre of mass corrections adopted by the ILRS ASC were first released in June 2019, provided by the NERC Space Geodesy Facility in the UK[4].

[4] `http://sgf.rgo.ac.uk`

In order to aid the implementation of the corrections in the different software packages employed by analysts of SLR data (not limited to the official Analysis Centres of the ILRS), example Fortran code is available with this product. The code shows how to interrogate the correction tables to obtain the expected values for a given satellite, station, wavelength, and epoch. Although the usage of the tables is documented to some extent, the implementation example is the best source to clarify any possible questions, and the recommended way to test that alternative implementations retrieve the expected values. The example code can be readily incorporated in software packages also written in Fortran, although if strict Fortran standard requirements are to be observed this point should of course be checked.

Due to a major planned update of the analysis section of the ILRS website, long-delayed owing to a number of reasons, the new centre of mass corrections were never uploaded there. The first releases of the corrections were thus distributed directly by email to interested parties, which has caused difficulties and delays in the early adoption of the corrections by different groups. With release v200610, Erricos Pavlis from JCET[5] (University of Maryland) kindly made available on a JCET server that release, which was to be employed by ILRS ACs for the ITRF2020 reanalyses[6].

[5] `https://jcet.umbc.edu`

[6] `http://geodesy.jcet.umbc.edu/ILRS_ASC_RESOURCES/CoG_2020.06.10`

Starting with the latest update described in this report, v220918, the tables of corrections, associated code, and documentation will be distributed through the Yebes Observatory website to ensure their public availability. Ideally, these products will also be available from the ILRS website, pending the update of its relevant sections.

The location in the Yebes Observatory website where these products will be published from now on, along with other supporting information considered relevant, is:

`https://icts-yebes.oan.es/slr`

2 Changes in the v210511 release

This release added several stations that were missing in the tables of corrections. The rationale for including these stations, and the details concerning the specific values adopted for them, are explained in a presentation given to the ILRS Analysis Standing Committee in May 2021. This is available from the Yebes Observatory website referenced in the previous section, and summarised in the following.

For the ITRF2020 reanalysis the ILRS ASC was requested to compute solutions for the 1983–1993 period, as it is considered valuable to the long-term definition of the reference frame. For this period there are only observations to the LAGEOS satellite, and the data quality is poorer than that from later years. It was realised that there were several productive stations that had been active during this period for which centre of mass corrections were missing. These were pre-ILRS stations whose site logs are unavailable from the ILRS website or data centres. The need to include these stations prompted the computation of corrections for LAGEOS from the little information available for those systems. In total, 8 stations out of the top 24 most performing sites in the 1983–1993 period were missing, as detailed in Table 1.

Most of the missing stations are known NASA systems for which centre of mass corrections had been computed already. With this in mind, and considering the absence of detailed information for these stations, it was decided to assign centre of mass values as the

Table 1: Historic stations missing from previous CoM releases

station	system	period	# arcs
7109 Quincy	MOB-8	1993.10–1997.06	220
7907 Arequipa	SAO-2	1983.10–1992.08	194
7122 Mazatlan	MOB-6	1983.03–1991.04	175
7834 Wetzell		1983.02–1991.02	144
7086 McDonald	MLRS	1982.10–1988.02	101
7121 Huahine	MOB-1	1983–1986	53
7097 Easter Island	TLRS-2	1987.11–1995.03	49
7123 Huahine	TLRS-2	1987.08–1992.08	44

arithmetic averages of the values already computed for systems that, in principle, were equivalent. The justification for such a bold approach hinges upon three facts:

- These stations were standard systems part of the same network (save for 7834 Wettzell[7])
- There is no information available to take signal return rate into account in the modelling
- The data quality for those systems was of inherently worse precision compared to that of current systems

[7] Information for 7834 was produced by station engineers, and its CoM value had already been computed but wrongly assigned to 8834 in previous releases.

Therefore, the conclusion was that it would neither be worthwhile nor in fact possible to model these systems with the same level of scrutiny devoted to modern stations [5].

The stations that were identified as being similar or equivalent to those missing from the tables were 7090 MOB-5, 7105 MOB-7, 7110 MOB-4, 7403 TRLR-3, 7110 TLRS-4, 7080 MLRS, 7939 SAO Matera, and 8834 Wettzell (1989). The mean values available from the different time entries of these stations were the proposed ones for the missing stations. These were all within 1.6 mm of the default centre of mass value for LAGEOS (245.4 mm), and fall close to the middle of the range of the historically adopted LAGEOS values (240 and 251 mm). Thus, despite the likely limited accuracy of the proposed corrections for the missing stations, these appear to be *safe* values to adopt.

Figure 2 shows the worsening of the agreement between empirical data and simulated results, regarding the RMS of the distributions of detection [1]. This illustrates how the combination of lack of information and intrinsically worse data quality means that the modelling of the historic stations can not be expected to match the results for modern systems. It must be noted that the differences between the RMS of the simulated and empirical observations do not map 1:1 to errors in the computed centre of mass corrections. The latter are much more forgiving than the former, which is to be understood as

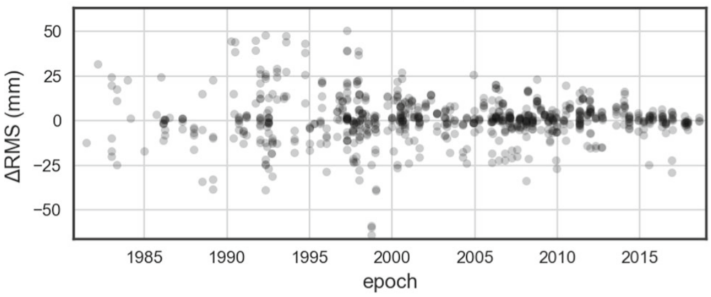

Figure 2: Differences between the modelled and empirical NP RMS for the satellites and stations included in the first release of the CoM tables [1].

an indirect measure of the quality of the simulations.

3 Changes in the v220915 release

The latest update to the tables of corrections is motivated by the upcoming transition by the ILRS ASC to ITRF2020 standards for the computation of their routine products (daily and weekly solutions estimating station coordinates, Earth orientation parameters, and orbits of the satellites employed). The ILRS ASC includes in its solutions all available stations, regardless of the length of their time series. This is in contrast with the strategy followed for global reference frame reanalyses, where stations with less than a minimum time period are not worth including due to their weak contribution to the estimation of the secular frame. For this reason, past releases of the centre of mass corrections missed the latest hardware updates for a few stations, whose data were not included in the ITRF2020 reanalysis. Since the routine ILRS ASC products were not using ITRF2020 standards, there was no urge for the computation of corrections for the few latest station changes.

The review of site log changes that could potentially affect the computed centre of mass corrections was done examining all the changes flagged by Christian Schwatke's (DGFI, Eurolas Data Center[8]) automatic site log processing service. Many site log updates are completely unrelated to relevant parameters for this work (e.g. contact persons) and can be discarded immediately. Other changes need reviewing to assess whether they should elicit a recomputation of the correction values. For this update, ten stations did require a new computation: 7110, 7124, 7249, 7396, 7701 (new site), 7821, 7824, 7838, 7941, and 8834.

[8] https://edc.dgfi.tum.de/en

The personnel responsible for some of these stations were contacted to request clarifications on some aspect of the site log updates found. In general, the set of changes that prompted this update are very minor, such as slight changes in laser pulse widths or detector jitter.

During the revision of the changes, a few inconsistencies in the epochs and hardware details for some stations were also found, which have now been fixed. Additionally, the normal point database employed to estimate return rates for the different satellites and stations was updated in order to include the latest system configurations.

A summary of the relevant station changes follows:

- **7110, Monument Peak**. Fixed modelling issue found for this station (see below).
- **7124, Tahiti**. Updated an interval counter HP5370B to a Cybioms event timer.
- **7249, Beijing**. New laser in 2022, plus a few updates and aggregation of previous entries where hardware changes are not significant. Station out of quarantine on 2022/05/26. The new data is biased (JCET evaluation report) but it looks clean and stable. The NP RMS appears lower than expected, but the station personnel reported no changes regarding the data reduction procedures.
- **7396, JiuFeng** (new Wuhan station). New laser. There is a mismatch between the simulated RMS and the observations. No response from the station
- **7701, Izaña-1** (Canary Islands, Spain). New engineering station currently producing data for testing purposes.
- **7821, Shanghai**. Fixed inconsistencies in the dates and specifications of the application of a leading edge filter for data reduction. Details and clarification kindly provided by Zhang Zhoping (SHAO).
- **7824, San Fernando**. Minor updates to laser characteristics of no consequence, plus an upgrade to event timer from 2022/08/22.
- **7838, Shimosato**. Previously held information about the station from the site logs available ended in 2009. There have been several updates that were taken into account for this release.
- **7941, Matera**. New site log entry detailing new micro-channel plate detector. Minor updates to the information previously used for the station (differences in the detector jitter, 167 ps vs 120 ps).

As mentioned above, the changes found in the site logs are minor, affecting the computed CoM values only slightly for the most part. I discuss below two cases of particular interest due to the magnitude of the changes involved and their origin.

7110 Monument Peak. Of special mention are the new results obtained for station 7110, which fix a genuine error present in previous releases of the corrections. Van Husson reported to the ILRS QCB

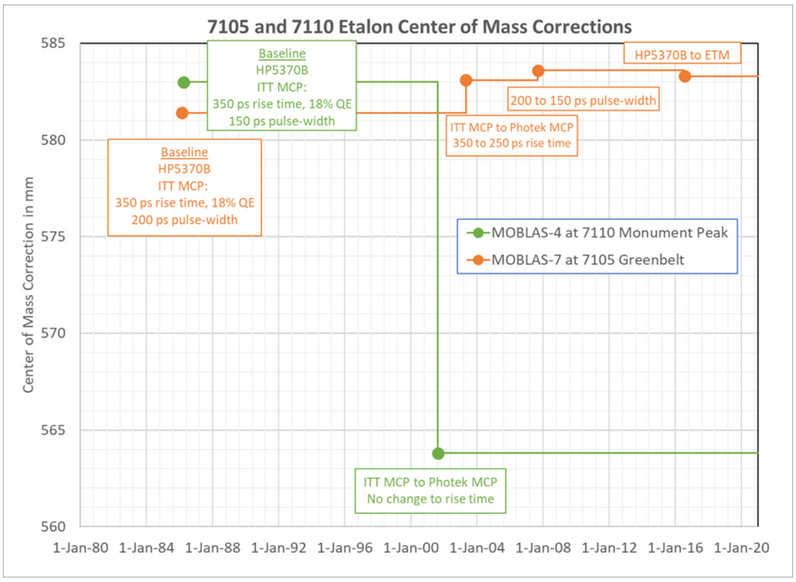

Figure 3: Etalon corrections for MOBLAS stations Goddard and Monument Peak (NASA). The ~2 cm drop for 7110 points to a modelling error. Credit: Van Husson (Peraton).

that the centre of mass values for Etalon and Ajisai appear to have a behaviour inconsistent with that of other MOBLAS systems (see Fig. 3). The ~20 mm step change had no obvious origin that could be related to the hardware changes detailed in the site log. Investigating this issue it surfaced that the chosen value for the parameter that defines the discriminator threshold in multi-photon stations was incoherent with the station data. The discriminator threshold is the energy level beyond which a detection is obtained. In an actual station it is set as a voltage of the discriminator, which in microscopic terms is equivalent to set the detection threshold to certain number of photoelectrons[9]. Lowering the discriminator threshold leads to a more sensitive system, but the variance of the signal detected is also greater, as well as the background noise present. In the simulated systems used for the computation of the centre of mass corrections, this parameter is set as an integer number of photoelectrons, and it is simply chosen on the basis of the best agreement with the RMS of the normal point observations. The value that best fits this observable is most often one photoelectron, but for 7110 it was changed to two photoelectrons for unclear reasons. The effect of the simulated discriminator setting in the computed centre of mass corrections is moderate for small to medium targets such as Starlette or LAGEOS, but it can be very big for large targets. The centre of mass values for Etalon and Ajisai for 7110 Monument Peak have changed by ~20 and ~14 mm in this release. The corresponding changes for the LAGEOS satellites are just over 1 mm, at the threshold of what should be considered significant.

[9] An additional complication arises from the fact that some stations use different detection setups for different satellites, which is not taken into account here.

7821 Shanghai. The changes in the corrections computed for LAGEOS and LAGEOS-2 are sub-mm in all cases, save for the aforementioned

~1 mm for 7110, and for 7821. Since 2014 this station has been employing a leading edge filter in the reduction of LAGEOS data in order to reduce the NP variability [6]. It appears that the station engineers have tweaked the parameters of the leading edge filter to optimise the results obtained. An examination of the time series of NP RMS for 7821, shown in Fig. 4, reveals several step changes in the single-shot precision of the observations. While most of these were caused by changes and upgrades in station hardware, the last one (2021) has its origin in a tightening of the leading edge algorithm to select a narrower range of full rate observations. The computed change in the centre of mass corrections for LAGEOS and LAGEOS-2 is -3.7 mm, which is very significant for the estimation of the long-term behaviour of its coordinates. Given that reaching this level of accuracy requires the accumulation of data for ideally a number of years, it is still too early to assess whether the magnitude of this change and its sign leads to a lower estimated range bias for this station.

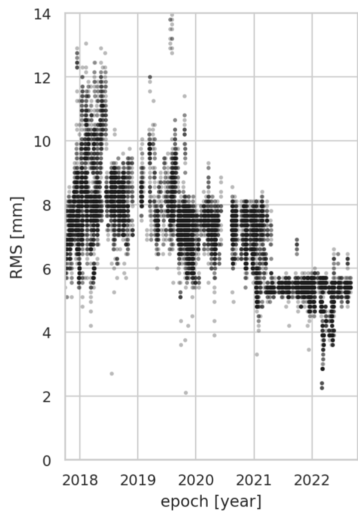

Figure 4: RMS of normal points from 7821.

Full list of changes. All the changes in the latest release of the CoM corrections can be found in Appendix A [10], showing the values from the previous release, the updated ones in v20220915, and their differences broken down by station and satellite. Considering the small magnitude of the differences between the old and updated values—except in the cases discussed above—the adoption of this release by the analysis centres of the ILRS should not present major difficulties in terms of significant step changes that would need to be taken into account.

[10] Tables produced by Erricos Pavlis (JCET, UMBC) for the assessment of the requirements by the ILRS ASC to introduce the new corrections in the operational products. Reproduced here with permission.

References

[1] J. Rodríguez, G. Appleby and T. Otsubo. 'Upgraded modelling for the determination of centre of mass corrections of geodetic SLR satellites: impact on key parameters of the terrestrial reference frame'. In: *Journal of Geodesy* 93 (2019), pp. 2553–2568.

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[5] José C. Rodríguez et al. 'Geodetic Analyses at the National Geographic Institute of Spain'. In: *International Association of Geodesy Symposia*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2022.

[6] G. Kirchner, D. Kucharski and F. Koidl. 'Millimeter ranging to centimeter targets'. In: *Proceedings of the 16th International Workshop on Laser Ranging*. Poznan, Poland, 2008.

Appendices

A List of CoM changes

Site ID#	Sat. ID	PREVIOUS MODEL RELEASE								OLD CoG mm	REVISED MODEL RELEASE								NEW CoG mm	ΔCoG OLD-NEW mm
			Start Date			Stop Date						Start Date			Stop Date					
7110	LG1	Site ID#	dd	mm	yyyy	dd	mm	yyyy	Wavelength		Site ID#	dd	mm	yyyy	dd	mm	yyyy	Wavelength		
		7110	15	8	1983	31	3	1986	532	243.6	7110	15	8	1983	31	3	1986	532	244.7	-1.1
		7110	31	3	1986	19	8	2001	532	245.6	7110	31	3	1986	19	8	2001	532	245.8	-0.2
		7110	19	8	2001	1	1	2050	532	244.6	7110	19	8	2001	1	1	2050	532	245.7	-1.1
7110	LG2																			0
		7110	31	3	1986	19	8	2001	532	245.4	7110	31	3	1986	19	8	2001	532	245.3	0.1
		7110	19	8	2001	1	1	2050	532	243.9	7110	19	8	2001	1	1	2050	532	245.2	-1.3
7110	ET1																			0
		7110	31	3	1986	19	8	2001	532	583.0	7110	31	3	1986	19	8	2001	532	583.3	-0.3
		7110	19	8	2001	1	1	2050	532	563.8	7110	19	8	2001	1	1	2050	532	583.4	-19.6
7110	LAS																			0
		7110	19	8	2001	1	1	2050	532	130.0	7110	19	8	2001	1	1	2050	532	130.1	-0.1
7110	STR																			0
		7110	15	8	1983	31	3	1986	532	75.5	7110	15	8	1983	31	3	1986	532	75.8	-0.3
		7110	31	3	1986	19	8	2001	532	76.1	7110	31	3	1986	19	8	2001	532	76.1	0
		7110	19	8	2001	1	1	2050	532	75.6	7110	19	8	2001	1	1	2050	532	76.2	-0.6
7110	AJI																			0
		7110	15	8	1983	31	3	1986	532	981.1	7110	15	8	1983	31	3	1986	532	992.9	-11.8
		7110	31	3	1986	19	8	2001	532	994.5	7110	31	3	1986	19	8	2001	532	995.0	-0.5
		7110	19	8	2001	1	1	2050	532	983.1	7110	19	8	2001	1	1	2050	532	996.9	-13.8
7124	LG1																			0
		7124	1	8	1997	27	6	2008	532	245.6	7124	1	8	1997	27	6	2008	532	245.7	-0.1
		7124	27	6	2008	21	10	2019	532	246.1	7124	27	6	2008	21	10	2019	532	246.3	-0.2
		7124	22	10	2019	1	1	2050	532	246.1	7124	22	10	2019	1	1	2050	532	246.4	-0.3
7124	LG2																			0
		7124	1	8	1997	27	6	2008	532	245.0	7124	1	8	1997	27	6	2008	532	245.2	-0.2
		7124	27	6	2008	21	10	2019	532	245.8	7124	27	6	2008	21	10	2019	532	245.9	-0.1
		7124	22	10	2019	1	1	2050	532	245.8	7124	22	10	2019	1	1	2050	532	245.7	0.1
7124	ET1																			0
		7124	1	8	1997	27	6	2008	532	585.6	7124	1	8	1997	27	6	2008	532	584.8	0.8
		7124	27	6	2008	21	10	2019	532	587.7	7124	27	6	2008	21	10	2019	532	586.4	1.3
		7124	22	10	2019	1	1	2050	532	587.7	7124	22	10	2019	1	1	2050	532	586.6	1.1
7124	LAS																			0
		7124	27	6	2008	21	10	2019	532	130.3	7124	27	6	2008	21	10	2019	532	130.6	-0.3
		7124	22	10	2019	1	1	2050	532	130.3	7124	22	10	2019	1	1	2050	532	130.6	-0.3
7124	STR																			0
		7124	1	8	1997	27	6	2008	532	76.0	7124	1	8	1997	27	6	2008	532	76.2	-0.2
		7124	27	6	2008	21	10	2019	532	76.4	7124	27	6	2008	21	10	2019	532	76.6	-0.2
		7124	22	10	2019	1	1	2050	532	76.4	7124	22	10	2019	1	1	2050	532	76.5	-0.1
7124	AJI																			0
		7124	1	8	1997	27	6	2008	532	996.9	7124	1	8	1997	27	6	2008	532	996.8	0.1
		7124	27	6	2008	21	10	2019	532	999.1	7124	27	6	2008	21	10	2019	532	999.6	-0.5
		7124	22	10	2019	1	1	2050	532	999.1	7124	22	10	2019	1	1	2050	532	999.0	0.1
7249	LG1																			0
		7249	20	5	1990	26	12	1998	532	243.1	7249	20	5	1990	26	12	1998	532	242.9	0.2
		7249	26	12	1998	27	7	2009	532	243.5	7249	26	12	1998	27	7	2009	532	243.3	0.2
		7249	12	7	2010	3	1	2012	532	244.8	7249	12	7	2010	3	1	2012	532	244.8	0
		7249	4	1	2012	20	12	2021	532	244.9	7249	4	1	2012	20	12	2021	532	244.8	0.1
		7249	20	12	2021	1	1	2050	532	244.9	7249	20	12	2021	1	1	2050	532	244.8	0.1
7249	LG2																			0
		7249	20	5	1990	26	12	1998	532	242.0	7249	20	5	1990	26	12	1998	532	242.3	-0.3
		7249	26	12	1998	27	7	2009	532	242.6	7249	26	12	1998	27	7	2009	532	242.4	0.2
		7249	12	7	2010	3	1	2012	532	244.1	7249	12	7	2010	3	1	2012	532	244.0	0.1
		7249	4	1	2012	20	12	2021	532	244.1	7249	4	1	2012	20	12	2021	532	244.0	0.1
		7249	20	12	2021	1	1	2050	532	244.1	7249	20	12	2021	1	1	2050	532	244.0	0.1
7249	ET1																			0
		7249	20	5	1990	26	12	1998	532	559.1	7249	20	5	1990	26	12	1998	532	559.8	-0.7
		7249	26	12	1998	27	7	2009	532	558.9	7249	26	12	1998	27	7	2009	532	558.7	0.2
		7249	12	7	2010	3	1	2012	532	558.3	7249	12	7	2010	3	1	2012	532	557.9	0.4
		7249	4	1	2012	20	12	2021	532	558.2	7249	4	1	2012	20	12	2021	532	557.9	0.3

		7249	20	12	2021	1	1	2050	532	558.2	7249	20	12	2021	1	1	2050	532	557.9	0.3
7249	LAS																			0
		7249	12	7	2010	3	1	2012	532	131.0	7249	12	7	2010	20	12	2021	532	130.4	0.6
		7249	3	1	2012	1	1	2050	532	130.6	7249	20	12	2021	1	1	2050	532	130.4	0.2
7249	STR																			0
		7249	20	5	1990	26	12	1998	532	75.2	7249	20	5	1990	26	12	1998	532	74.9	0.3
		7249	26	12	1998	27	7	2009	532	76.5	7249	26	12	1998	27	7	2009	532	76.2	0.3
		7249	12	7	2010	3	1	2012	532	76.0	7249	12	7	2010	3	1	2012	532	75.7	0.3
		7249	4	1	2012	20	12	2021	532	76.0	7249	4	1	2012	20	12	2021	532	75.7	0.3
		7249	20	12	2021	1	1	2050	532	76.2	7249	20	12	2021	1	1	2050	532	75.7	0.5
7249	AJI																			0
		7249	20	5	1990	26	12	1998	532	976.4	7249	20	5	1990	26	12	1998	532	977.4	-1
		7249	26	12	1998	27	7	2009	532	980.7	7249	26	12	1998	27	7	2009	532	980.4	0.3
		7249	12	7	2010	3	1	2012	532	980.9	7249	12	7	2010	3	1	2012	532	980.0	0.9
		7249	4	1	2012	20	12	2021	532	980.9	7249	4	1	2012	20	12	2021	532	980.0	0.9
		7249	20	12	2021	1	1	2050	532	982.2	7249	20	12	2021	1	1	2050	532	979.2	3
7396	LG1																			0
		7396	1	6	2019	1	9	2020	532	244.5	7396	1	6	2019	1	9	2020	532	244.5	0
		7396	1	9	2020	1	1	2050	532	244.5	7396	1	9	2020	1	1	2050	532	244.6	-0.1
7396	LG2																			0
		7396	1	6	2019	1	9	2020	532	243.8	7396	1	6	2019	1	9	2020	532	243.7	0.1
		7396	1	9	2020	1	1	2050	532	243.8	7396	1	9	2020	1	1	2050	532	243.8	0
7396	ET1																			0
		7396	1	6	2019	1	9	2020	532	557.7	7396	1	6	2019	1	9	2020	532	557.7	0
		7396	1	9	2020	1	1	2050	532	557.7	7396	1	9	2020	1	1	2050	532	558.0	-0.3
7396	LAS																			0
		7396	1	6	2019	1	9	2020	532	130.2	7396	1	6	2019	1	9	2020	532	130.2	0
		7396	1	9	2020	1	1	2050	532	130.2	7396	1	9	2020	1	1	2050	532	130.2	0
7396	STR																			0
		7396	1	6	2019	1	9	2020	532	75.6	7396	1	6	2019	1	9	2020	532	75.4	0.2
		7396	1	9	2020	1	1	2050	532	75.6	7396	1	9	2020	1	1	2050	532	75.5	0.1
7396	AJI																			0
		7396	1	6	2019	1	9	2020	532	981.0	7396	1	6	2019	1	9	2020	532	979.5	1.5
		7396	1	9	2020	1	1	2050	532	981.0	7396	1	9	2020	1	1	2050	532	978.9	2.1
7701	LG1																			0
		7701	21	6	2021	1	1	2050	532	246.7	7701	21	6	2021	1	1	2050	1064	247.5	-0.8
7701	LG2																			0
		7701	21	6	2021	1	1	2050	532	246.3	7701	21	6	2021	1	1	2050	1064	247.0	-0.7
7701	ET1																			0
		7701	21	6	2021	1	1	2050	532	570.7	7701	21	6	2021	1	1	2050	1064	571.6	-0.9
7701	LAS																			0
		7701	21	6	2021	1	1	2050	532	131.1	7701	21	6	2021	1	1	2050	1064	131.7	-0.6
7701	STR																			0
		7701	21	6	2021	1	1	2050	532	76.5	7701	21	6	2021	1	1	2050	1064	76.8	-0.3
7701	AJI																			0
		7701	21	6	2021	1	1	2050	532	988.4	7701	21	6	2021	1	1	2050	1064	991.4	-3
7821	LG1																			0
		7821	10	7	2005	1	9	2009	532	244.7	7821	10	7	2005	1	9	2009	532	244.1	0.6
		7821	1	9	2009	26	11	2014	532	244.9	7821	1	9	2009	26	11	2014	532	244.5	0.4
		7821	27	11	2014	10	8	2019	532	247.5	7821	27	11	2014	10	8	2019	532	247.7	-0.2
		7821	10	8	2019	1	5	2021	532	247.5	7821	10	8	2019	1	5	2021	532	247.8	-0.3
		7821	1	5	2021	1	1	2050	532	247.5	7821	1	5	2021	1	1	2050	532	251.2	-3.7
7821	LG2																			0
		7821	10	7	2005	1	9	2009	532	243.9	7821	10	7	2005	1	9	2009	532	243.2	0.7
		7821	1	9	2009	26	11	2014	532	244.2	7821	1	9	2009	26	11	2014	532	243.8	0.4
		7821	27	11	2014	10	8	2019	532	247.3	7821	27	11	2014	10	8	2019	532	247.5	-0.2
		7821	10	8	2019	1	5	2021	532	247.3	7821	10	8	2019	1	5	2021	532	247.6	-0.3
		7821	1	5	2021	1	1	2050	532	247.3	7821	1	5	2021	1	1	2050	532	251.0	-3.7
7821	ET1																			0
		7821	10	7	2005	1	9	2009	532	558.9	7821	10	7	2005	1	9	2009	532	558.7	0.2
		7821	1	9	2009	26	11	2014	532	558.3	7821	1	9	2009	26	11	2014	532	558.0	0.3
		7821	27	11	2014	10	8	2019	532	570.1	7821	27	11	2014	10	8	2019	532	569.9	0.2
		7821	10	8	2019	1	5	2021	532	570.1	7821	10	8	2019	1	5	2021	532	570.0	0.1

		7821	1	5	2021	1	1	2050	532	570.1	7821	1	5	2021	1	1	2050	532	570.0	0.1
7821	**LAS**																			0
		7821	1	9	2009	26	11	2014	532	130.8	7821	1	9	2009	26	11	2014	532	130.3	0.5
		7821	27	11	2014	10	8	2019	532	131.8	7821	27	11	2014	10	8	2019	532	131.3	0.5
		7821	10	8	2019	1	5	2021	532	131.8	7821	10	8	2019	1	5	2021	532	131.3	0.5
		7821	1	5	2021	1	1	2050	532	131.8	7821	1	5	2021	1	1	2050	532	131.3	0.5
7821	**STR**																			0
		7821	10	7	2005	1	9	2009	532	76.1	7821	10	7	2005	1	9	2009	532	76.1	0
		7821	1	9	2009	26	11	2014	532	76.4	7821	1	9	2009	26	11	2014	532	75.7	0.7
		7821	27	11	2014	10	8	2019	532	77.7	7821	27	11	2014	10	8	2019	532	76.9	0.8
		7821	10	8	2019	1	5	2021	532	77.7	7821	10	8	2019	1	5	2021	532	76.8	0.9
		7821	1	5	2021	1	1	2050	532	77.7	7821	1	5	2021	1	1	2050	532	76.8	0.9
7821	**AJI**																			0
		7821	10	7	2005	1	9	2009	532	983.5	7821	10	7	2005	1	9	2009	532	982.6	0.9
		7821	1	9	2009	26	11	2014	532	984.3	7821	1	9	2009	26	11	2014	532	980.4	3.9
		7821	27	11	2014	10	8	2019	532	991.7	7821	27	11	2014	10	8	2019	532	989.8	1.9
		7821	10	8	2019	1	5	2021	532	991.7	7821	10	8	2019	1	5	2021	532	989.5	2.2
		7821	1	5	2021	1	1	2050	532	991.7	7821	1	5	2021	1	1	2050	532	989.7	2
7824	**LG1**																			0
		7824	15	12	1997	10	8	2001	532	245.8	7824	15	12	1997	10	8	2001	532	245.7	0.1
		7824	10	8	2001	22	1	2004	532	245.6	7824	10	8	2001	22	1	2004	532	244.9	0.7
		7824	22	1	2004	1	1	2014	532	245.6	7824	22	1	2004	1	1	2014	532	244.7	0.9
		7824	1	1	2014	31	7	2017	532	244.6	7824	1	1	2014	31	7	2017	532	244.7	-0.1
		7824	31	7	2017	30	8	2022	532	244.6	7824	31	7	2017	30	8	2022	532	244.9	-0.3
		7824	30	8	2022	1	1	2050	532	244.6	7824	30	8	2022	1	1	2050	532	244.7	-0.1
7824	**LG2**																			0
		7824	15	12	1997	10	8	2001	532	245.2	7824	15	12	1997	10	8	2001	532	245.2	0
		7824	10	8	2001	22	1	2004	532	245.0	7824	10	8	2001	22	1	2004	532	244.1	0.9
		7824	22	1	2004	1	1	2014	532	245.0	7824	22	1	2004	1	1	2014	532	244.0	1
		7824	1	1	2014	31	7	2017	532	243.8	7824	1	1	2014	31	7	2017	532	244.0	-0.2
		7824	31	7	2017	30	8	2022	532	243.8	7824	31	7	2017	30	8	2022	532	243.9	-0.1
		7824	30	8	2022	1	1	2050	532	243.8	7824	30	8	2022	1	1	2050	532	244.0	-0.2
7824	**ET1**																			0
		7824	15	12	1997	10	8	2001	532	567.9	7824	15	12	1997	10	8	2001	532	568.5	-0.6
		7824	10	8	2001	22	1	2004	532	558.6	7824	10	8	2001	22	1	2004	532	558.3	0.3
		7824	22	1	2004	1	1	2014	532	558.6	7824	22	1	2004	1	1	2014	532	558.3	0.3
		7824	1	1	2014	31	7	2017	532	558.5	7824	1	1	2014	31	7	2017	532	558.3	0.2
		7824	31	7	2017	30	8	2022	532	558.5	7824	31	7	2017	30	8	2022	532	558.4	0.1
		7824	30	8	2022	1	1	2050	532	558.5	7824	30	8	2022	1	1	2050	532	558.3	0.2
7824	**LAS**																			0
		7824	10	8	2001	1	1	2014	532	130.7	7824	22	1	2004	1	1	2014	532	130.0	0.7
		7824	1	1	2014	31	7	2017	532	130.3	7824	1	1	2014	31	7	2017	532	130.0	0.3
		7824	31	7	2017	30	8	2022	532	130.3	7824	31	7	2017	30	8	2022	532	130.6	-0.3
		7824	30	8	2022	1	1	2050	532	130.3	7824	30	8	2022	1	1	2050	532	130.3	0
7824	**STR**																			0
		7824	15	12	1997	10	8	2001	532	76.2	7824	15	12	1997	10	8	2001	532	75.8	0.4
		7824	10	8	2001	22	1	2004	532	77.5	7824	10	8	2001	22	1	2004	532	76.5	1
		7824	22	1	2004	1	1	2014	532	77.5	7824	22	1	2004	1	1	2014	532	76.2	1.3
		7824	1	1	2014	31	7	2017	532	75.9	7824	1	1	2014	31	7	2017	532	76.2	-0.3
		7824	31	7	2017	30	8	2022	532	75.9	7824	31	7	2017	30	8	2022	532	75.8	0.1
		7824	30	8	2022	1	1	2050	532	75.9	7824	30	8	2022	1	1	2050	532	75.8	0.1
7824	**AJI**																			0
		7824	15	12	1997	10	8	2001	532	980.7	7824	15	12	1997	10	8	2001	532	981.4	-0.7
		7824	10	8	2001	22	1	2004	532	993.6	7824	10	8	2001	22	1	2004	532	989.9	3.7
		7824	22	1	2004	1	1	2014	532	993.6	7824	22	1	2004	1	1	2014	532	988.3	5.3
		7824	1	1	2014	31	7	2017	532	986.6	7824	1	1	2014	31	7	2017	532	988.3	-1.7
		7824	31	7	2017	30	8	2022	532	986.6	7824	31	7	2017	30	8	2022	532	986.6	0
		7824	30	8	2022	1	1	2050	532	986.6	7824	30	8	2022	1	1	2050	532	981.8	4.8
7838	**LG1**																			0
		7838	1	3	1982	1	7	1990	532	242.6	7838	1	3	1982	1	7	1990	532	243.0	-0.4
		7838	1	7	1990	1	1	1998	532	244.5	7838	1	7	1990	1	1	1998	532	244.0	0.5
		7838	1	1	1998	30	6	2004	532	244.6	7838	1	1	1998	30	6	2004	532	244.4	0.2
		7838	30	6	2004	1	4	2008	532	244.3	7838	30	6	2004	1	4	2008	532	243.9	0.4

		7838	1	4	2008	26	11	2009	532	245.4	7838	1	4	2008	26	11	2009	532	245.4	0
		7838	26	11	2009	23	10	2018	532	245.6	7838	26	11	2009	23	10	2018	532	245.6	0
		7838	23	10	2018	1	1	2050	532	245.6	7838	23	10	2018	1	1	2050	532	245.3	0.3
7838	**LG2**																			0
		7838	1	7	1990	1	1	1998	532	243.8	7838	1	7	1990	1	1	1998	532	243.2	0.6
		7838	1	1	1998	30	6	2004	532	243.9	7838	1	1	1998	30	6	2004	532	243.5	0.4
		7838	30	6	2004	1	4	2008	532	243.5	7838	30	6	2004	1	4	2008	532	243.1	0.4
		7838	1	4	2008	26	11	2009	532	244.6	7838	1	4	2008	26	11	2009	532	244.6	0
		7838	26	11	2009	23	10	2018	532	245.0	7838	26	11	2009	23	10	2018	532	244.7	0.3
		7838	23	10	2018	1	1	2050	532	245.0	7838	23	10	2018	1	1	2050	532	244.6	0.4
7838	**ET1**																			0
		7838	1	3	1982	1	7	1990	532	559.3	7838	1	3	1982	1	7	1990	532	558.5	0.8
		7838	1	7	1990	1	1	1998	532	560.2	7838	1	7	1990	1	1	1998	532	560.2	0
		7838	1	1	1998	30	6	2004	532	560.7	7838	1	1	1998	30	6	2004	532	560.5	0.2
		7838	30	6	2004	1	4	2008	532	562.1	7838	30	6	2004	1	4	2008	532	563.2	-1.1
		7838	1	4	2008	26	11	2009	532	560.0	7838	1	4	2008	26	11	2009	532	561.2	-1.2
		7838	26	11	2009	23	10	2018	532	560.7	7838	26	11	2009	23	10	2018	532	560.5	0.2
		7838	23	10	2018	1	1	2050	532	560.7	7838	23	10	2018	1	1	2050	532	561.0	-0.3
7838	**LAS**																			0
		7838	26	11	2009	23	10	2018	532	131.2	7838	26	11	2009	23	10	2018	532	131.0	0.2
		7838	23	10	2018	1	1	2050	532	131.2	7838	23	10	2018	1	1	2050	532	130.8	0.4
7838	**STR**																			0
		7838	1	3	1982	1	7	1990	532	75.1	7838	1	3	1982	1	7	1990	532	75.0	0.1
		7838	1	7	1990	1	1	1998	532	75.3	7838	1	7	1990	1	1	1998	532	75.5	-0.2
		7838	1	1	1998	30	6	2004	532	75.6	7838	1	1	1998	30	6	2004	532	75.5	0.1
		7838	30	6	2004	1	4	2008	532	75.2	7838	30	6	2004	1	4	2008	532	75.4	-0.2
		7838	1	4	2008	26	11	2009	532	76.2	7838	1	4	2008	26	11	2009	532	76.2	0
		7838	26	11	2009	23	10	2018	532	76.2	7838	26	11	2009	23	10	2018	532	76.4	-0.2
		7838	23	10	2018	1	1	2050	532	76.2	7838	23	10	2018	1	1	2050	532	75.7	0.5
7838	**AJI**																			0
		7838	1	3	1982	1	7	1990	532	979.9	7838	1	3	1982	1	7	1990	532	980.7	-0.8
		7838	1	7	1990	1	1	1998	532	978.7	7838	1	7	1990	1	1	1998	532	980.1	-1.4
		7838	1	1	1998	30	6	2004	532	981.6	7838	1	1	1998	30	6	2004	532	981.5	0.1
		7838	30	6	2004	1	4	2008	532	977.2	7838	30	6	2004	1	4	2008	532	979.4	-2.2
		7838	1	4	2008	26	11	2009	532	982.0	7838	1	4	2008	26	11	2009	532	982.3	-0.3
		7838	26	11	2009	23	10	2018	532	981.8	7838	26	11	2009	23	10	2018	532	982.8	-1
		7838	23	10	2018	1	1	2050	532	981.8	7838	23	10	2018	1	1	2050	532	975.6	6.2
7941	**LG1**																			0
		7941	1	1	2000	19	2	2007	532	249.4	7941	1	1	2000	19	2	2007	532	249.5	-0.1
		7941	19	2	2007	20	6	2008	532	249.7	7941	19	2	2007	20	6	2008	532	249.8	-0.1
		7941	20	6	2008	16	9	2009	532	249.0	7941	20	6	2008	16	9	2009	532	249.0	0
		7941	16	9	2009	24	5	2010	532	249.9	7941	16	9	2009	24	5	2010	532	250.0	-0.1
		7941	24	5	2010	4	12	2017	532	249.5	7941	24	5	2010	4	12	2017	532	249.6	-0.1
		7941	4	12	2017	1	1	2050	532	249.5	7941	4	12	2017	1	1	2050	532	248.7	0.8
7941	**LG2**																			0
		7941	1	1	2000	19	2	2007	532	249.2	7941	1	1	2000	19	2	2007	532	249.2	0
		7941	19	2	2007	20	6	2008	532	249.4	7941	19	2	2007	20	6	2008	532	249.5	-0.1
		7941	20	6	2008	16	9	2009	532	248.6	7941	20	6	2008	16	9	2009	532	248.7	-0.1
		7941	16	9	2009	24	5	2010	532	249.6	7941	16	9	2009	24	5	2010	532	249.7	-0.1
		7941	24	5	2010	4	12	2017	532	249.2	7941	24	5	2010	4	12	2017	532	249.3	-0.1
		7941	4	12	2017	1	1	2050	532	249.2	7941	4	12	2017	1	1	2050	532	248.4	0.8
7941	**ET1**																			0
		7941	1	1	2000	19	2	2007	532	595.3	7941	1	1	2000	19	2	2007	532	595.4	-0.1
		7941	19	2	2007	20	6	2008	532	595.8	7941	19	2	2007	20	6	2008	532	595.5	0.3
		7941	20	6	2008	16	9	2009	532	595.0	7941	20	6	2008	16	9	2009	532	594.7	0.3
		7941	16	9	2009	24	5	2010	532	596.2	7941	16	9	2009	24	5	2010	532	595.8	0.4
		7941	24	5	2010	4	12	2017	532	595.6	7941	24	5	2010	4	12	2017	532	595.6	0
		7941	4	12	2017	1	1	2050	532	595.6	7941	4	12	2017	1	1	2050	532	594.0	1.6
7941	**LAS**																			0
		7941	24	5	2010	4	12	2017	532	132.1	7941	24	5	2010	4	12	2017	532	132.1	0
		7941	4	12	2017	1	1	2050	532	132.1	7941	4	12	2017	1	1	2050	532	131.7	0.4
7941	**STR**																			0
		7941	1	1	2000	19	2	2007	532	78.2	7941	1	1	2000	19	2	2007	532	78.4	-0.2

		7941	19	2	2007	20	6	2008	532	78.4	7941	19	2	2007	20	6	2008	532	78.5	-0.1
		7941	20	6	2008	16	9	2009	532	77.8	7941	20	6	2008	16	9	2009	532	78.0	-0.2
		7941	16	9	2009	24	5	2010	532	78.6	7941	16	9	2009	24	5	2010	532	78.7	-0.1
		7941	24	5	2010	4	12	2017	532	78.2	7941	24	5	2010	4	12	2017	532	78.4	-0.2
		7941	4	12	2017	1	1	2050	532	78.2	7941	4	12	2017	1	1	2050	532	77.8	0.4
7941	**AJI**																			0
		7941	1	1	2000	19	2	2007	532	1007.6	7941	1	1	2000	19	2	2007	532	1007.8	-0.2
		7941	19	2	2007	20	6	2008	532	1008.8	7941	19	2	2007	20	6	2008	532	1009.2	-0.4
		7941	20	6	2008	16	9	2009	532	1007.0	7941	20	6	2008	16	9	2009	532	1007.2	-0.2
		7941	16	9	2009	24	5	2010	532	1008.1	7941	16	9	2009	24	5	2010	532	1008.5	-0.4
		7941	24	5	2010	4	12	2017	532	1007.5	7941	24	5	2010	4	12	2017	532	1007.8	-0.3
		7941	4	12	2017	1	1	2050	532	1007.5	7941	4	12	2017	1	1	2050	532	1006.4	1.1
8834	**LG1**																			0
		8834	1	1	1991	1	1	1998	532	244.7	8834	1	1	1991	1	1	1998	532	244.7	0
		8834	1	1	1998	12	10	2000	532	246.2	8834	1	1	1998	12	10	2000	532	246.5	-0.3
		8834	12	10	2000	24	3	2009	532	247.4	8834	12	10	2000	24	3	2009	532	247.7	-0.3
		8834	24	3	2009	4	7	2019	532	244.9	8834	24	3	2009	4	6	2019	532	244.7	0.2
		8834	5	6	2019	1	1	2050	1064	248.6	8834	5	6	2019	1	1	2050	1064	248.5	0.1
8834	**LG2**																			0
		8834	1	1	1991	1	1	1998	532	244.1	8834	1	1	1991	1	1	1998	532	243.8	0.3
		8834	1	1	1998	12	10	2000	532	246.0	8834	1	1	1998	12	10	2000	532	245.8	0.2
		8834	12	10	2000	24	3	2009	532	247.0	8834	12	10	2000	24	3	2009	532	247.0	0
		8834	24	3	2009	4	7	2019	532	244.2	8834	24	3	2009	4	6	2019	532	244.0	0.2
		8834	5	6	2019	1	1	2050	1064	248.2	8834	5	6	2019	1	1	2050	1064	248.1	0.1
8834	**ET1**																			0
		8834	1	1	1991	1	1	1998	532	565.0	8834	1	1	1991	1	1	1998	532	564.1	0.9
		8834	1	1	1998	12	10	2000	532	571.6	8834	1	1	1998	12	10	2000	532	571.4	0.2
		8834	12	10	2000	24	3	2009	532	568.4	8834	12	10	2000	24	3	2009	532	569.1	-0.7
		8834	24	3	2009	4	7	2019	532	563.9	8834	24	3	2009	4	6	2019	532	562.6	1.3
		8834	5	6	2019	1	1	2050	1064	578.3	8834	5	6	2019	1	1	2050	1064	578.1	0.2
8834	**LAS**																			0
		8834	24	3	2009	4	6	2019	532	130.3	8834	24	3	2009	4	6	2019	532	130.1	0.2
		8834	5	6	2019	4	7	2019	532	130.3	8834	5	6	2019	4	7	2019	1064	132.3	-2
		8834	5	7	2019	1	1	2050	1064	132.5	8834	5	7	2019	1	1	2050	1064	132.3	0.2
8834	**STR**																			0
		8834	1	1	1991	1	1	1998	532	75.7	8834	1	1	1991	1	1	1998	532	75.7	0
		8834	1	1	1998	12	10	2000	532	76.5	8834	1	1	1998	12	10	2000	532	76.4	0.1
		8834	12	10	2000	24	3	2009	532	77.3	8834	12	10	2000	24	3	2009	532	77.3	0
		8834	24	3	2009	4	7	2019	532	76.2	8834	24	3	2009	4	6	2019	532	75.9	0.3
		8834	5	6	2019	1	1	2050	1064	77.7	8834	5	6	2019	1	1	2050	1064	77.4	0.3
8834	**AJI**																			0
		8834	1	1	1991	1	1	1998	532	981.5	8834	1	1	1991	1	1	1998	532	981.5	0
		8834	1	1	1998	12	10	2000	532	994.3	8834	1	1	1998	12	10	2000	532	993.5	0.8
		8834	12	10	2000	24	3	2009	532	990.6	8834	12	10	2000	24	3	2009	532	990.8	-0.2
		8834	24	3	2009	4	7	2019	532	988.9	8834	24	3	2009	4	6	2019	532	989.0	-0.1
		8834	5	6	2019	1	1	2050	1064	995.5	8834	5	6	2019	1	1	2050	1064	994.7	0.8