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# The Italian lightning activity: an analysis of the LAMPINET network data

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***Abstract*— Like other atmospheric phenomena, lightning is studied mainly to mitigate the risk it represents for life and human infrastructures. Despite a consolidated scientific literature, the lightning features are still not completely known today and the typical investigation approach is to resort to statistical analyses trying to identify correlation factors among all the physical quantities involved in such complex geophysical event. Following this framework, this contribution reports an analysis of the lightning activity in Italy through data from the LAMPINET network concerning the time period 2013-2014. In particular, attention is focused on the monthly behavior of the Ground Stroke Density (GSD) and its seasonal daytime distribution. Then, a deeper analysis is carried out on the grouping of strokes within a flash: the distributions of the flash multiplicity and of the distance among striking points of different strokes within a flash are derived. Finally, the Cumulative Distribution Functions (CDFs) of the peak current are obtained for negative first and subsequent strokes and positive first strokes.**

***Keywords*— *Lightning, Lightning measurements, Ground Flash Density, Channel-base current.***

## I. Introduction

Lightning is a very impressive phenomenon that can determine serious hazards on human beings and on many kinds of infrastructures (electric, ICT, civil and so on). Moreover, it is well-known that there is a strong interplay between the lightning and extreme weather events [1, 2]. For this reason, lightning has caught the attention of researchers belonging to different fields of expertise (physicists, meteorologists and engineers among others).

From a physical point of view, understanding details of such a complex phenomenon is a very hard task especially because of the difficulty in getting intracloud measurements and due to the randomic nature of the lightning processes. Consequently, the great majority of studies is conducted on a statistical basis. This allows to determine normal values of lightning parameters such as the Ground Stroke Density (GSD), the ratio between positive and negative events, the current peak and so on as a function of latitude, season, climatology, orography and others factors of influence. There are two ways of inferring such parameters: the first one consists of directly measuring lightning currents and electromagnetic fields from instrumented towers.

The main advantage of this approach is that measurements are precise (especially the ones relevant to the lightning current properties). On the other hand, such towers are very few in the world and located in specific places [3-5] which does not allow to draw sufficiently general conclusions on the variability of the phenomenon on latitude, orography and climatology. The other source of lightning data are the Lightning Location Systems (LLS), which use the field measurements to get information on the lightning polarity, point of impact and current peak. LLS are much more widespread in the world than instrumented towers, but the error on the current (i.e. the Detection Efficiency (DE)) and on the point of impact (the Location Accuracy (LA)) often prevents LLS from drawing reliable conclusions at least at individual level [6]. For this reason, in literature, the majority of studies from LLS data were concentrated on general properties rather than specific issues. Some papers focused their attention on the lightning variability over the whole Europe [7, 8] or the Mediterranean basin [9, 10]. Kotroni and Lagouvardos in [9, 11] studied the correlation between lightning (essentially GSD) and elevation, slope and vegetation using the data obtained with the Zeus LLS. In [10], Nastos et al. studied the spatial and temporal variations of lightning activity in Greece, highlighting the number of Cloud to Ground (CG) and Intra-Cloud (IC) events for each season. Finally, in [8] Anderson and Klugmann discussed about the monthly GSD and seasonal variability at different European latitudes.

On the other hand, there are other studies mainly concentrated on the lightning current properties in the Mediterranean regions. Among others, in [12] the LAMPINET network, namely the LLS owned and managed by the Italian Air Force, is used to obtain the peak current Probability Density Functions (PDFs) for positive and negative events and their seasonal variations. However, no distinction is made between first and subsequent strokes which becomes fundamental for a correct design of the protection system of electric transmission and distribution infrastructures [13, 14].

However, a comprehensive study on the lightning activity over the Italian territory with attention on all the quantities of interest both for meteorologists and engineers is still missing. So, the present paper aims at filling this gap and analyzes the lightning activity in the Italian territory for two years (2013-2014) using the data acquired from the LAMPINET network.

Results are compared with other studies conducted with other LLS in similar regions and, when possible, with the findings of direct current measurements, highlighting possible causes of eventual differences. The paper is organized as follows: in section II the main features of the LAMPINET network are briefly recalled and the domain of analysis is presented, section III reports the results while section IV draws some conclusions.

## II. LAMPINET: LIGHTNING DETECTION IN ITALY

### *A. The LAMPINET network*

At the beginning of 2000s, the Italian Air Force Meteorological Service has set up a modern lightning detection network, LAMPINET, in order to monitor comprehensively atmospheric discharges. LAMPINET consists of 15 sensors uniformly distributed over the national territory (Fig 1) and started operation during 2004 [15].


Fig 1. Sensor positions in LAMPINET [15]

LAMPINET can reach a DE of 90% for currents greater than 50 kA, and a LA of 500 m in the central areas of Italy; larger errors are expected in the border areas and beyond the network [12]. For each lightning event, LAMPINET reports the following attributes: date and time; current intensity in kA (with specified polarity); type (CG and IC); point of impact latitude and longitude.

The data acquired from LAMPINET network have been elaborated through the QGIS software [16], a free and open-source platform for geographic information that supports viewing, editing, and analysis of geospatial data. The data extracted from the LAMPINET database were divided into months and limited to the CG flashes. The area under investigation is depicted in Fig 2, which extents for 4.487.345 km$^2$, including part of the Mediterranean Sea, the Corsica island and a non-Italian side of the Alps.

Fig 2. Studied domain.

The main reasons for this choice are the following: lightning is associated to atmospherical phenomena coming mainly from West, which approach the peninsula passing over the sea; the land surface includes, in addition to Italy, also Corsica (whose presence from an orographic point of view could influence lightning activity) and the non-Italian side of the Alps, that includes a high concentration of events.

## III. RESULTS

The set of data used for the present study is reported in the Appendix: analyzing it, the first conclusion that can be drawn is that the higher activity occurs during June, July and August, when the diurnal cycle maximizes afternoon and evening convection, frequently accompanied by heavy rain, hail, and severe thunderstorms generated on a daily basis, with formation of high towering cumulus and cumulonimbus. During the period September-November the lightning activity is concentrated over the sea in the central and southern parts of Italy. In winter months (December, January and February), lightning activity is lower. In the period March-May, lightning occurs more concentrated over the peninsula, the Adriatic area and the south-west Tyrrhenian sea.

More in details, the following analysis concentrates on the monthly behavior of the GSD and of the ratio between positive and negative strokes (subsection A) as well as their seasonal daytime distributions (subsection B). Then, attention is paid to grouping strokes into flashes and extracting the corresponding distributions of i) distance among the points of impact of different strokes within a flash and flash multiplicity (i.e. number of strokes within a flash) (subsection C) and iii) current for first and subsequent strokes (subsection D)

### *A. Monthly behaviour of the Ground Stroke Density*

The Ground Stroke Density (GSD) is given by the ratio between the number of lightning strokes occurring in an area and the corresponding surface area [6]. The GSD is introduced in the analysis since the considered land and sea surfaces are different (sea surface 448.734 km$^2$, land surface 381.399 km$^2$). In Fig 3 and Fig 4, the different seasonal locations of discharges reflect the typical climatology of a central Mediterranean country. Both for positive and negative strokes the highest values of the two-years monthly GSDs occur between June and August over the land and between August and October over the sea. Hence, it seems that the favorable season for lightning activity over the sea is autumn and over the land is summer. During the summer, in the Italian mountainous regions the moist air is lifted by the action of strong convection producing severe winds, heavy rainfall and lightning. Conversely, during autumn, lightning activity is concentrated over the sea as the high summer temperatures have warmed up the sea; the water vapor released in the cool autumn air produces instability that in turns determines convective clouds and lightning activity along the peninsula. The monthly values of the ratio between negative CG and positive CG are always between 2÷6 both over the sea and over the land with a two-years mean ratio about ≈ 3.6. Such value is a noteworthy underestimation of the typical value of 9 [17]; according to [6] this difference can be mainly ascribed to the LLS misclassification of some IC events as positive strokes.

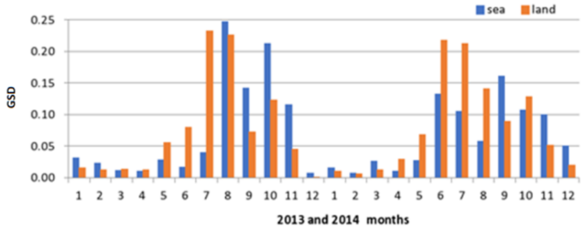


Fig 3. Monthly GSD for positive CG strokes

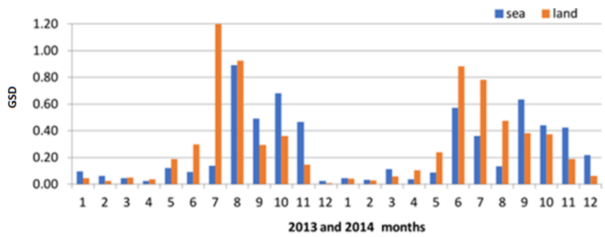


Fig 4. Monthly GSD for negative CG strokes

## *B. Seasonal daytime distribution*

Seasonal daytime distributions are obtained by evaluating the percentage of CG strokes per hour for each season. In each season the highest concentration of both positive (Fig 5A) and negative (Fig 5B) strokes on the land occurs between 10 UTC and 17 UTC, while the lightning activity is almost constant along the day over the sea (Fig 6A and Fig 6B). Moreover, the peak of concentration around midday hours over the land is more relevant for spring and summer. The reason is due to the excessive heating from sunlight on land during the warmest hours of the day that increases the convective activity. The obtained results are consistent with the observations reported in [9] for the Mediterranean region.

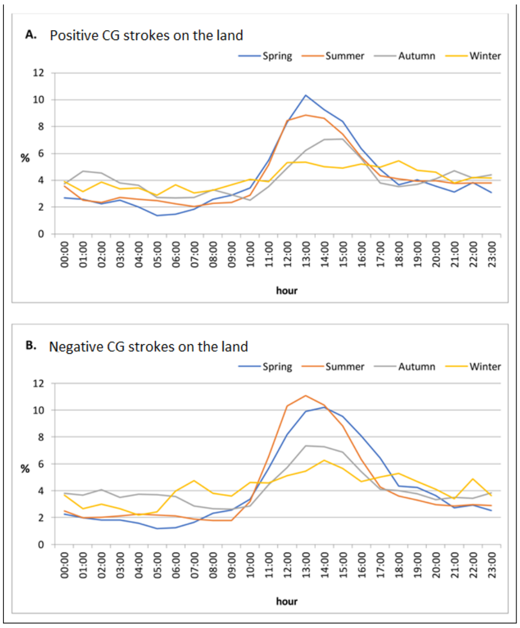


Fig 5. Percentage frequency with respect to the total samples of occurrences per hour of positive (A) and negative (B) CG strokes over the land.

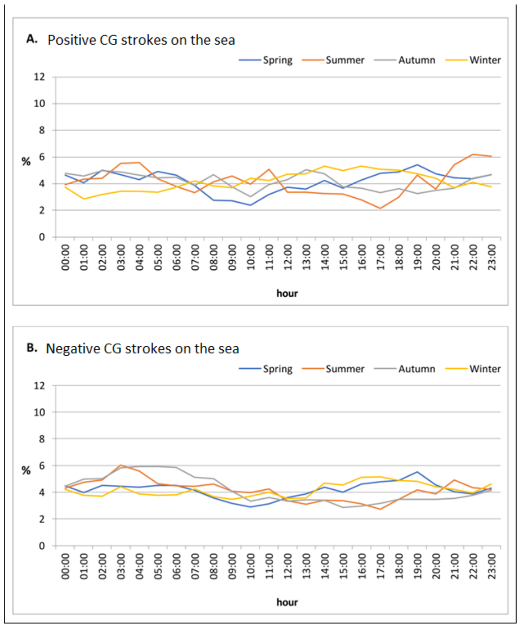


Fig 6. Percentage frequency with respect to the total samples of occurrences per hour of positive (A) and negative (B) CG strokes over the sea.

## *C. Distance among points of impact and flash multiplicity*

All the LLS detect single strokes. So, some grouping algorithms are necessary to infer properties of the flashes. According to [6] two strokes belong to the same flash if the distance between the points of impact is below a space-threshold D and the difference in the occurrence time is smaller than a time threshold T. Typically one has that T=500 ms and D=10 km. However, here D=2 km is assumed because this is the value that produced a flash multiplicity distribution consistent with the well-known fact that positive flashes do not present subsequent strokes [17] (Fig 7). Moreover, the obtained distribution of the distance among the points of impact of different strokes within a flash is consistent with the findings of [18], according to which the majority of samples had a distance ranging between 1 and 2 km. (Fig 8).

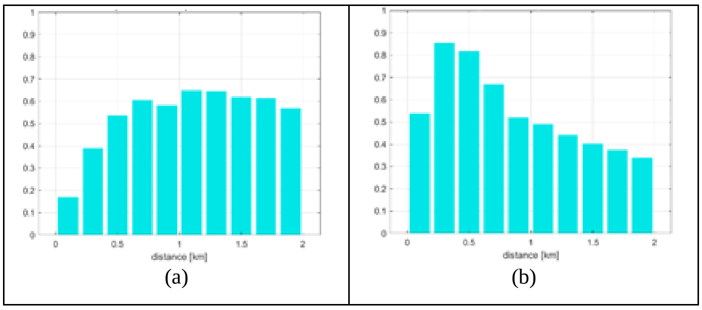


Fig 7. Distribution of the distance among the striking points of different strokes within a positive flash (A) and within a negative flash (B).

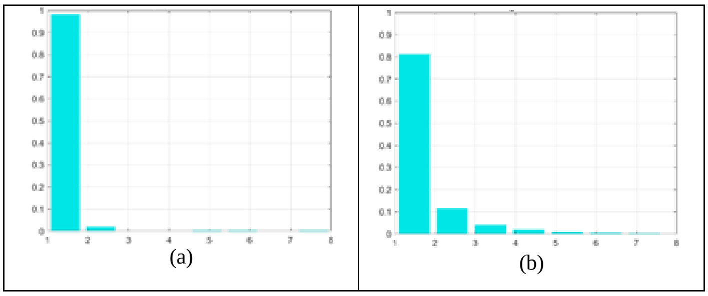


Fig 8. Distribution of the number of strokes within a positive flash (A) and within a negative flash (B).

### D. Peak current distribution

As specified before, the knowledge of the current distribution is of fundamental importance when designing the protection system against lightning for power transmission and distribution lines. In doing this, typically, reference is made to the work of Berger et al. [19] in 1975 who analyzed more than 100 events occurred on the summit of Monte San Salvatore (Switzerland). However, as the lightning activity strongly depends on the region of interest, having at disposal local data is of crucial importance. This is the reason why, in the present subsection, the peak current Cumulative Distribution Functions (CDFs) are reported for negative first and subsequent strokes and positive first strokes (Fig 9, where the red lines represent the $5^{th}$, $50^{th}$ and $95^{th}$ percentiles). However, it is important to underline that the use of current data coming out from LLS has been validated at statistical level only for negative subsequent strokes [20]. The observation of Fig 9 suggests that median values negative first strokes (11.5 kA) are highly underestimated with respect to measurements obtained by Berger (30 kA). Moreover, median values for negative subsequent strokes (19 kA) are overestimated with respect to Berger's results (12 kA). The reasons for such differences are basically due to errors in the grouping algorithm that misclassifies some high current first strokes as subsequent ones. Indeed same differences have been found with the Euclid network [6] (median values of the first stroke current in Austria was found to be10 kA).

Positive strokes (median value equal to 11.5 kA) are strongly underestimated with respect to Berger's results (35 kA). The reasons for these differences are essentially two: LLS often label as positive strokes some IC events with small current [6]; moreover, restricting the analysis to latitudes greater than $45.5^{\circ}$ (above Milan) one gets about 21 kA, which suggests that true regional differences can influence the result.

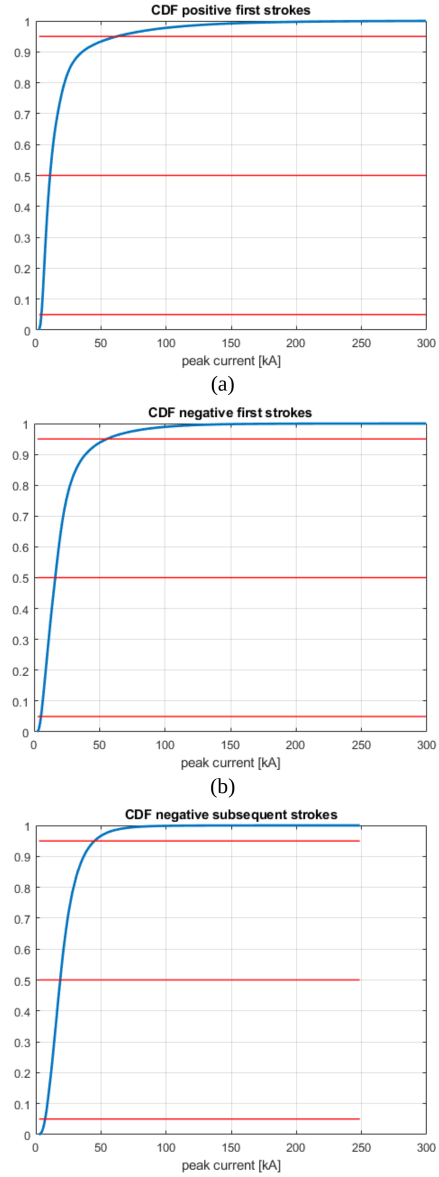


Fig 9. Cumulative Disrtribution Functions of peak current for positive first strokes (a), negative first strokes (b) and negative subsequent strokes (c)

## IV. Conclusions

This contribution investigated the variability of the CG lightning characteristics in Italy as a function of different geographical and/or temporal parameters. Lightning data were acquired from the LAMPINET network for the time period 2013-2014. The analysis showed that the GSD presents the highest values in the summer period for land lightning events, and in autumn months for phenomena over the sea. To this concern, strokes over the sea are almost constant in each season, while on the land the highest concentration has been registered between 10 am and 5 pm. Moreover, grouping strokes into flashes allowed to obtain the distribution of the flash multiplicity and of the distance among striking points of different strokes within a flash as well as peak current CDFs. Comparison with the well-known data from Berger et al. suggested that some noteworthy differences appear, which are consistent with findings obtained with other LLS and which highlight that the complex Italian territory climatology exhibits unique peculiarities.

## ACKNOWLEDGMENT

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## APPENDIX

TABLE I. COUNT OF POSITIVE AND NEGATIVE STROKES OCCURRED ON THE SEA DURING 2013 AND 2014

| **Year** | **Month** | **N° CG** | **N° CG +** | **N° CG -** | **GSD** | **GSD +** | **GSD -** | **N° CG+ / N° CG-** |
|---|---|---|---|---|---|---|---|---|
| 2013 | 1 | 57746 | 14048 | 43698 | 0.129 | 0.031 | 0.097 | 3.111 |
| 2013 | 2 | 51776 | 10341 | 41435 | 0.115 | 0.023 | 0.092 | 4.007 |
| 2013 | 3 | 25125 | 5305 | 19820 | 0.056 | 0.012 | 0.044 | 3.736 |
| 2013 | 4 | 15728 | 4785 | 10943 | 0.035 | 0.011 | 0.024 | 2.287 |
| 2013 | 5 | 66368 | 12718 | 53650 | 0.148 | 0.028 | 0.120 | 4.218 |
| 2013 | 6 | 48838 | 7684 | 41154 | 0.109 | 0.017 | 0.092 | 5.356 |
| 2013 | 7 | 79997 | 18130 | 61867 | 0.178 | 0.040 | 0.138 | 3.412 |
| 2013 | 8 | 510959 | 110942 | 400017 | 1.139 | 0.247 | 0.891 | 3.606 |
| 2013 | 9 | 284165 | 64242 | 219923 | 0.633 | 0.143 | 0.490 | 3.423 |
| 2013 | 10 | 401895 | 95738 | 306157 | 0.896 | 0.213 | 0.682 | 3.198 |
| 2013 | 11 | 260566 | 51669 | 208897 | 0.581 | 0.115 | 0.466 | 4.043 |
| 2013 | 12 | 13429 | 3382 | 10047 | 0.030 | 0.008 | 0.022 | 2.971 |
| 2014 | 1 | 27834 | 6877 | 20957 | 0.062 | 0.015 | 0.047 | 3.047 |
| 2014 | 2 | 17356 | 3448 | 13908 | 0.039 | 0.008 | 0.031 | 4.034 |
| 2014 | 3 | 61220 | 11632 | 49588 | 0.136 | 0.026 | 0.111 | 4.263 |
| 2014 | 4 | 21935 | 5001 | 16934 | 0.049 | 0.011 | 0.038 | 3.386 |
| 2014 | 5 | 51378 | 12448 | 38930 | 0.114 | 0.028 | 0.087 | 3.127 |
| 2014 | 6 | 315509 | 59567 | 255942 | 0.703 | 0.133 | 0.570 | 4.297 |
| 2014 | 7 | 210025 | 47403 | 162622 | 0.468 | 0.106 | 0.362 | 3.431 |
| 2014 | 8 | 85769 | 26423 | 59346 | 0.191 | 0.059 | 0.132 | 2.246 |
| 2014 | 9 | 356784 | 72303 | 284481 | 0.795 | 0.161 | 0.634 | 3.935 |
| 2014 | 10 | 246839 | 48296 | 198543 | 0.550 | 0.108 | 0.442 | 4.111 |
| 2014 | 11 | 235469 | 45324 | 190145 | 0.525 | 0.101 | 0.424 | 4.195 |
| 2014 | 12 | 120098 | 22737 | 97361 | 0.268 | 0.051 | 0.217 | 4.282 |
| Tot 2013 | | 1816592 | 398984 | 1417608 | 4.048 | 0.889 | 3.159 | 3.553 |
| Tot 2014 | | 1750216 | 361459 | 1388757 | 3.982 | 0.806 | 3.095 | 3.842 |
| Tot 2013+2014 | | 3566808 | 760443 | 2806365 | 7.949 | 1.695 | 6.254 | 3.690 |

TABLE II. COUNT OF POSITIVE AND NEGATIVE STROKES OCCURRED ON THE LAND DURING 2013 AND 2014

| **Year** | **Month** | **N° CG** | **N° CG +** | **N° CG -** | **GSD** | **GSD +** | **GSD -** | **N° CG+ / N° CG-** |
|---|---|---|---|---|---|---|---|---|
| 2013 | 1 | 22894 | 5891 | 17003 | 0.060 | 0.015 | 0.045 | 2.89 |
| 2013 | 2 | 14073 | 4756 | 9317 | 0.037 | 0.012 | 0.024 | 1.959 |
| 2013 | 3 | 24529 | 5404 | 19125 | 0.064 | 0.014 | 0.050 | 3.539 |
| 2013 | 4 | 18641 | 4908 | 13733 | 0.049 | 0.013 | 0.036 | 2.798 |
| 2013 | 5 | 92478 | 21390 | 71088 | 0.242 | 0.056 | 0.186 | 3.323 |
| 2013 | 6 | 143944 | 30715 | 113229 | 0.377 | 0.081 | 0.297 | 3.686 |
| 2013 | 7 | 546015 | 88967 | 457048 | 1.432 | 0.233 | 1.198 | 5.137 |
| 2013 | 8 | 439873 | 86737 | 353136 | 1.153 | 0.227 | 0.926 | 4.071 |
| 2013 | 9 | 139448 | 27711 | 111737 | 0.366 | 0.073 | 0.293 | 4.032 |
| 2013 | 10 | 185026 | 47126 | 137900 | 0.485 | 0.124 | 0.362 | 2.926 |
| 2013 | 11 | 73554 | 17175 | 56379 | 0.193 | 0.045 | 0.148 | 3.283 |
| 2013 | 12 | 2902 | 669 | 2233 | 0.008 | 0.002 | 0.006 | 3.338 |
| 2014 | 1 | 19288 | 4135 | 15153 | 0.051 | 0.011 | 0.040 | 3.665 |
| 2014 | 2 | 13801 | 2694 | 11107 | 0.036 | 0.007 | 0.029 | 4.123 |
| 2014 | 3 | 26887 | 4768 | 22119 | 0.070 | 0.013 | 0.058 | 4.639 |
| 2014 | 4 | 51034 | 11321 | 39713 | 0.134 | 0.030 | 0.104 | 3.508 |
| 2014 | 5 | 117123 | 25914 | 91209 | 0.307 | 0.068 | 0.239 | 3.520 |
| 2014 | 6 | 420641 | 83130 | 337511 | 1.103 | 0.218 | 0.885 | 4.060 |
| 2014 | 7 | 379890 | 81183 | 298707 | 0.996 | 0.213 | 0.783 | 3.679 |
| 2014 | 8 | 234564 | 53781 | 180783 | 0.615 | 0.141 | 0.474 | 3.361 |
| 2014 | 9 | 180451 | 33983 | 146468 | 0.473 | 0.089 | 0.384 | 4.310 |
| 2014 | 10 | 191007 | 48982 | 142025 | 0.501 | 0.128 | 0.372 | 2.900 |
| 2014 | 11 | 91234 | 19643 | 71591 | 0.239 | 0.052 | 0.188 | 3.645 |
| 2014 | 12 | 31328 | 7433 | 23895 | 0.082 | 0.019 | 0.063 | 3.215 |
| Tot 2013 | | 1703377 | 341449 | 1361928 | 4.466 | 0.895 | 3.571 | 3.989 |
| Tot 2014 | | 1757248 | 376967 | 1380281 | 4.607 | 0.988 | 3.619 | 3.662 |
| Tot 2013+2014 | | 3460625 | 718416 | 2742209 | 9.074 | 1.884 | 7.190 | 3.817 |

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