

20.5: Time series

Introduction

Time series refer to any measure recorded over time. **Stationary time series** do not have trends or seasonality, just random (white) noise; **differencing time series** do have trends and or seasonality. Stationary time series will not have predictable patterns over the long term.

This page is under construction. Examples and questions are in place, but not much else; here's a resource on time series:

<http://www.itl.nist.gov/div898/handbook/pmc/section4/pmc4.htm>

R code

To conduct time series analysis use built in functions like `ts()` and `decompose()`. `HoltWinters()` also useful, now part of stats. Lots of specialized time series packages with advanced features, including `forecast`, `timeSeries` (Financial time series), `season` (Seasonal analysis of health data), and many others.

Note:

Note 1: Caution — newer versions of R have `HoltWinters()` and related functions included with base package `stats`.

Note 2: Rcmdr package for time series was [RcmdrPlugin.epack](#), no longer available as of 2018.

For up-to-date listing of time series packages, see <https://cran.r-project.org/web/views/TimeSeries.html>

Time series data sets included in R and Rcmdr

R Code:

```
data(co2, package="datasets")
co2 <- as.data.frame(co2)
```

```
#convert to time series data type with ts()
tc02 <- ts(co2,frequency=12,start=c(1959),end=c(1997))
plot.ts(tc02)
```

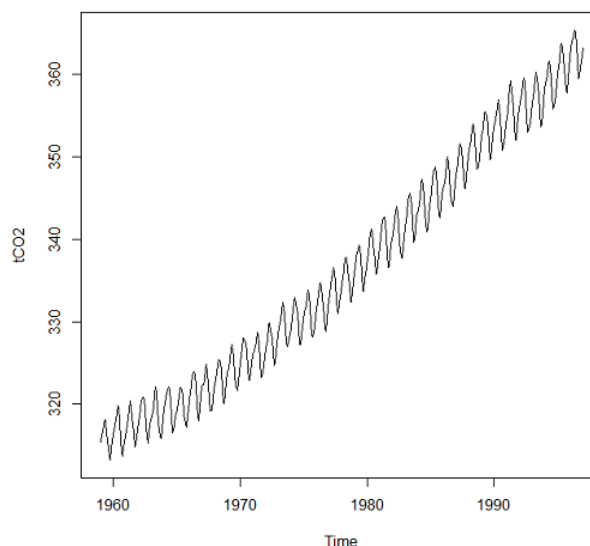


Figure 20.5.1: CO₂ data set from package datasets, comes with Rcmdr installation.

Other datasets included with R

carData::Arrests

carData::Bfox

carData::CanPop

Note: Dr D needs to complete this list

Example

Get up-to-date CO₂ data from [NOAA as text file](#). Download to your computer, load and clean in your favorite spreadsheet app. Months came as numbers 1,2,3, etc., I changed to text, Jan, Feb, Mar, etc. I grabbed three columns: year, month, ppm for import to R.

```
head(maunaLoa)
```

R output:

```
> head(maunaLoa)
  year month  ppm
1 1958  Mar 315.70
2 1958  Apr 317.45
3 1958  May 317.51
4 1958  Jun 317.24
5 1958  Jul 315.86
6 1958  Aug 314.93
```

However, it turns out the time series functions are easiest to work if only the ppm data are included.

```
tC02 <- ts(maunaLoa[, "ppm"], frequency=12, start=c(1958, 3), end=c(2020, 10))
head(tC02)
```

R output:

```
> head(tC02)
      Mar    Apr    May    Jun    Jul    Aug
1958 315.70 317.45 317.51 317.24 315.86 314.93
```

Get our plot (Figure 20.5.2).

```
plot(tC02)
```

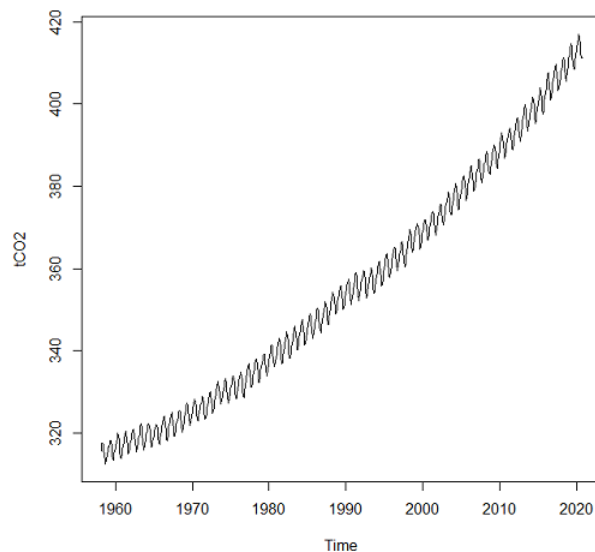


Figure 20.5.2: CO₂ ppm monthly average data from NOAA, last data October 2020.

Seasonal time series come with a trend component, a seasonal component, and a random component.

R code:

```
dectC02 <- decompose(tC02)
head(dectC02)
plot(dectC02)
```

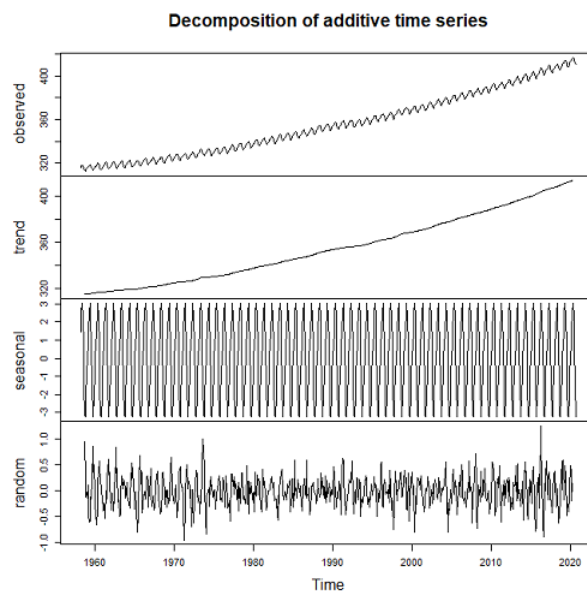


Figure 20.5.3: Observed (panel, top), trends over time (panel, second from top), seasonal changes (panel, second from bottom), and random error (panel, bottom).

Forecasting

Excellent resource at <https://otexts.com/fpp2/>

Exponential smoothing, weighted averages of past observations, weighted so that more recent observations are more influential.

Holt-Winters method extracts seasonal component (additive or multiplicative).

```
#set start value to value of first observation
tCO2cast <- HoltWinters(tCO2, l.start=315.42)
```

```
#Predict for next ten years. Because frequency in ts() was monthly, ten years is h=120
forecastCO2 <- forecast(tCO2cast, h=120)
plot(forecastCO2, fcol="red")
```

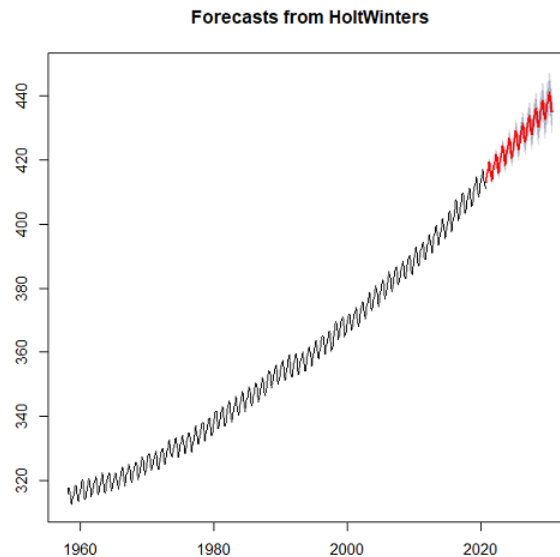


Figure 20.5.4: Data in black, predicted values in red (additive) shaded by confidence interval.

ARIMA models

DrD needs to complete

Questions

1. If a time series data set obtains observations collected at yearly intervals, what value should you enter in `ts()` function for frequency?
2. For the CO₂ dataset included in Rcmdr (co2, datasets), obtain forecast for year 2020 and compare against actual 2020 data (see Figure 20.5.2).
3. Positive clinical samples between September 2015 and November 2020 for flu virus in the USA are provided in the data set below (scroll or [click here](#)). The frequency of observations was weekly. Apply `decompose()` and obtain the seasonal and trend components of the data set. Which month does the peak positive sample occur?
4. Total pounds of fish (variable = Pounds) and pounds of Akule and Opelu (variable = Akule.Opelu) caught by commercial industry in Hawaii, from 2000 to 2018 are provided in the data set below (scroll or [click here](#)). Apply `decompose()` and obtain the seasonal and trend components of the data set for Total pounds and again for Akule (*Selar crumenophthalmus*) and Opelu (*Decapterus macarellus*). Is there evidence for trends, and if so, describe the trend. Is there evidence of seasonality? If so, which month did peak fishing occur?

Flu data set this page

Flu, extracted 28 Nov 2020 from <https://gis.cdc.gov/grasp/fluview/fluportaldashboard.html>

Year	Date	Week	Positive
2015	09/28/15	40	1.05578
2015	10/05/15	41	1.29662

2015	10/12/15	42	1.10855
2015	10/19/15	43	1.10807
2015	10/26/15	44	1.12344
2015	11/02/15	45	1.38224
2015	11/09/15	46	1.19344
2015	11/16/15	47	1.38506
2015	11/23/15	48	1.39498
2015	11/30/15	49	1.47544
2015	12/07/15	50	2.51181
2015	12/14/15	51	2.287
2015	12/21/15	52	2.45958
2016	01/04/16	1	2.93137
2016	01/11/16	2	4.25384
2016	01/18/16	3	5.48463
2016	01/25/16	4	6.95974
2016	02/01/16	5	9.69858
2016	02/08/16	6	12.5491
2016	02/15/16	7	15.5359
2016	02/22/16	8	18.3621
2016	02/29/16	9	21.1098
2016	03/07/16	10	23.6454
2016	03/14/16	11	19.972
2016	03/21/16	12	18.4709
2016	03/28/16	13	16.2265
2016	04/04/16	14	14.0164
2016	04/11/16	15	13.2362
2016	04/18/16	16	12.3464
2016	04/25/16	17	10.2615
2016	05/02/16	18	8.12094
2016	05/09/16	19	6.68559
2016	05/16/16	20	5.81108
2016	05/23/16	21	4.71918
2016	05/30/16	22	3.0595
2016	06/06/16	23	3.02006
2016	06/13/16	24	1.82927

2016	06/20/16	25	1.71228
2016	06/27/16	26	1.22261
2016	07/04/16	27	0.903312
2016	07/11/16	28	0.869153
2016	07/18/16	29	0.849185
2016	07/25/16	30	0.781793
2016	08/01/16	31	0.933921
2016	08/08/16	32	0.900745
2016	08/15/16	33	0.803482
2016	08/22/16	34	1.40485
2016	08/29/16	35	1.67771
2016	09/05/16	36	1.46146
2016	09/12/16	37	1.51255
2016	09/19/16	38	1.74135
2016	09/26/16	39	1.78369
2016	10/03/16	40	1.56951
2016	10/10/16	41	1.35914
2016	10/17/16	42	1.40304
2016	10/24/16	43	1.50862
2016	10/31/16	44	1.91569
2016	11/07/16	45	2.20089
2016	11/14/16	46	2.57608
2016	11/21/16	47	3.34773
2016	11/28/16	48	3.3191
2016	12/05/16	49	4.25987
2016	12/12/16	50	6.68342
2016	12/19/16	51	10.7819
2016	12/26/16	52	13.9993
2017	01/02/17	1	13.3436
2017	01/09/17	2	15.373
2017	01/16/17	3	18.2865
2017	01/23/17	4	18.5299
2017	01/30/17	5	21.4215
2017	02/06/17	6	24.1525
2017	02/13/17	7	24.5117

2017	02/20/17	8	24.7251
2017	02/27/17	9	19.772
2017	03/06/17	10	19.2714
2017	03/13/17	11	19.0338
2017	03/20/17	12	19.7113
2017	03/27/17	13	18.4816
2017	04/03/17	14	15.4251
2017	04/10/17	15	12.7395
2017	04/17/17	16	9.69626
2017	04/24/17	17	6.76776
2017	05/01/17	18	5.91752
2017	05/08/17	19	5.33264
2017	05/15/17	20	4.86286
2017	05/22/17	21	4.35223
2017	05/29/17	22	4.16524
2017	06/05/17	23	3.38586
2017	06/12/17	24	3.06229
2017	06/19/17	25	2.64932
2017	06/26/17	26	2.53401
2017	07/03/17	27	2.17791
2017	07/10/17	28	2.16392
2017	07/17/17	29	1.83895
2017	07/24/17	30	1.80607
2017	07/31/17	31	1.94796
2017	08/07/17	32	1.90048
2017	08/14/17	33	1.34281
2017	08/21/17	34	1.43382
2017	08/28/17	35	1.93535
2017	09/04/17	36	1.88806
2017	09/11/17	37	1.89622
2017	09/18/17	38	1.66942
2017	09/25/17	39	1.70313
2017	10/02/17	40	2.20191
2017	10/09/17	41	2.08975
2017	10/16/17	42	2.17647

2017	10/23/17	43	2.58279
2017	10/30/17	44	3.60729
2017	11/06/17	45	4.24472
2017	11/13/17	46	5.29966
2017	11/20/17	47	7.0877
2017	11/27/17	48	7.30533
2017	12/04/17	49	10.7453
2017	12/11/17	50	15.3549
2017	12/18/17	51	22.777
2017	12/25/17	52	25.3864
2018	01/01/18	1	25.3653
2018	01/08/18	2	26.9421
2018	01/15/18	3	27.034
2018	01/22/18	4	27.3698
2018	01/29/18	5	27.0643
2018	02/05/18	6	26.9981
2018	02/12/18	7	26.1174
2018	02/19/18	8	22.6155
2018	02/26/18	9	18.4867
2018	03/05/18	10	15.6938
2018	03/12/18	11	15.5813
2018	03/19/18	12	15.328
2018	03/26/18	13	15.1135
2018	04/02/18	14	12.6888
2018	04/09/18	15	11.2486
2018	04/16/18	16	9.39813
2018	04/23/18	17	7.99876
2018	04/30/18	18	6.25914
2018	05/07/18	19	4.39311
2018	05/14/18	20	3.16606
2018	05/21/18	21	2.39003
2018	05/28/18	22	1.52934
2018	06/04/18	23	1.57683
2018	06/11/18	24	1.29914
2018	06/18/18	25	1.02329

2018	06/25/18	26	1.11356
2018	07/02/18	27	1.00305
2018	07/09/18	28	0.916118
2018	07/16/18	29	1.0534
2018	07/23/18	30	0.995099
2018	07/30/18	31	0.953592
2018	08/06/18	32	0.95729
2018	08/13/18	33	0.764331
2018	08/20/18	34	1.33625
2018	08/27/18	35	1.50367
2018	09/03/18	36	1.74739
2018	09/10/18	37	1.68745
2018	09/17/18	38	1.69929
2018	09/24/18	39	1.49699
2018	10/01/18	40	1.74855
2018	10/08/18	41	1.6967
2018	10/15/18	42	1.99298
2018	10/22/18	43	2.05527
2018	10/29/18	44	2.17372
2018	11/05/18	45	2.7331
2018	11/12/18	46	3.15674
2018	11/19/18	47	3.92782
2018	11/26/18	48	3.91485
2018	12/03/18	49	6.23152
2018	12/10/18	50	10.3644
2018	12/17/18	51	14.2649
2018	12/24/18	52	16.352
2019	12/31/18	1	12.1387
2019	01/07/19	2	12.7217
2019	01/14/19	3	16.3174
2019	01/21/19	4	19.3918
2019	01/28/19	5	22.5493
2019	02/04/19	6	25.1342
2019	02/11/19	7	26.026
2019	02/18/19	8	26.2407

2019	02/25/19	9	26.0743
2019	03/04/19	10	25.6065
2019	03/11/19	11	26.1318
2019	03/18/19	12	22.4805
2019	03/25/19	13	19.3035
2019	04/01/19	14	14.9422
2019	04/08/19	15	11.9093
2019	04/15/19	16	8.61102
2019	04/22/19	17	5.84355
2019	04/29/19	18	4.81976
2019	05/06/19	19	3.83986
2019	05/13/19	20	3.54159
2019	05/20/19	21	3.41968
2019	05/27/19	22	3.0826
2019	06/03/19	23	2.78989
2019	06/10/19	24	2.31579
2019	06/17/19	25	1.90194
2019	06/24/19	26	2.0806
2019	07/01/19	27	2.42883
2019	07/08/19	28	2.01653
2019	07/15/19	29	2.21849
2019	07/22/19	30	2.37706
2019	07/29/19	31	2.39817
2019	08/05/19	32	2.05446
2019	08/12/19	33	2.08183
2019	08/19/19	34	2.36167
2019	08/26/19	35	3.45517
2019	09/02/19	36	3.09749
2019	09/09/19	37	2.48391
2019	09/16/19	38	2.75656
2019	09/23/19	39	2.74367
2019	09/30/19	40	1.30976
2019	10/07/19	41	1.47877
2019	10/14/19	42	1.55203
2019	10/21/19	43	2.25335

2019	10/28/19	44	3.05701
2019	11/04/19	45	5.16261
2019	11/11/19	46	6.75594
2019	11/18/19	47	9.54599
2019	11/25/19	48	10.9385
2019	12/02/19	49	11.6554
2019	12/09/19	50	16.1542
2019	12/16/19	51	22.533
2019	12/23/19	52	26.9336
2020	12/30/19	1	23.4883
2020	01/06/20	2	23.1187
2020	01/13/20	3	26.0826
2020	01/20/20	4	28.2813
2020	01/27/20	5	30.1465
2020	02/03/20	6	30.2596
2020	02/10/20	7	29.675
2020	02/17/20	8	28.3215
2020	02/24/20	9	25.7517
2020	03/02/20	10	22.4914
2020	03/09/20	11	15.8125
2020	03/16/20	12	7.50171
2020	03/23/20	13	2.32158
2020	03/30/20	14	1.0312
2020	04/06/20	15	0.61823
2020	04/13/20	16	0.623139
2020	04/20/20	17	0.218375
2020	04/27/20	18	0.262953
2020	05/04/20	19	0.326173
2020	05/11/20	20	0.305966
2020	05/18/20	21	0.212681
2020	05/25/20	22	0.16518
2020	06/01/20	23	0.339751
2020	06/08/20	24	0.279818
2020	06/15/20	25	0.38117
2020	06/22/20	26	0.282336

2020	06/29/20	27	0.210322
2020	07/06/20	28	0.176197
2020	07/13/20	29	0.37594
2020	07/20/20	30	0.150451
2020	07/27/20	31	0.132626
2020	08/03/20	32	0.176141
2020	08/10/20	33	0.132385
2020	08/17/20	34	0.226904
2020	08/24/20	35	0.314861
2020	08/31/20	36	0.201675
2020	09/07/20	37	0.186246
2020	09/14/20	38	0.39985
2020	09/21/20	39	0.224669
2020	09/28/20	40	0.330089
2020	10/05/20	41	0.400802
2020	10/12/20	42	0.350483
2020	10/19/20	43	0.25138
2020	10/26/20	44	0.201148
2020	11/02/20	45	0.176706
2020	11/09/20	46	0.221837

Fish data set in this page

Fish, Hawaii state DLNR, Pounds refers to total catch, Akule.Opelu refers to pounds for the two kinds of fish

Year	Month	Pounds	Akule.Opelu
1999	Jan	2064023	85331
1999	Feb	2286785	89537
1999	Mar	2083789	112897
1999	Apr	2446840	136301
1999	May	2300842	103692
1999	Jun	2340116	134432
1999	Jul	2646429	138814
1999	Aug	2254408	96569
1999	Sep	1926381	56598
1999	Oct	2233789	76834
1999	Nov	1730672	134706

1999	Dec	1762375	92255
2000	Jan	1501164	147104
2000	Feb	1993373	104165
2000	Mar	2220831	132028
2000	Apr	2398180	119224
2000	May	2557229	121268
2000	Jun	2510298	145200
2000	Jul	2270954	93883
2000	Aug	1912654	69107
2000	Sep	1365264	65007
2000	Oct	1615117	51208
2000	Nov	1388453	117493
2000	Dec	1802926	121486
2001	Jan	1481810	170702
2001	Feb	1496356	44575
2001	Mar	1579528	101764
2001	Apr	1184591	89388
2001	May	2091424	124193
2001	Jun	1966886	61122
2001	Jul	2113931	73266
2001	Aug	1926661	29386
2001	Sep	1353429	30268
2001	Oct	1338289	29577
2001	Nov	1747198	80350
2001	Dec	1458336	22817
2002	Jan	1517609	107406
2002	Feb	1729084	31030
2002	Mar	1747985	67691
2002	Apr	2109451	101043
2002	May	2069921	57251
2002	Jun	1640151	100501
2002	Jul	1979382	87584
2002	Aug	1831678	65566
2002	Sep	1734201	53162
2002	Oct	1779207	93867

2002	Nov	2191825	106167
2002	Dec	2576191	67881
2003	Jan	1910500	49420
2003	Feb	2075168	55006
2003	Mar	2245753	71616
2003	Apr	1562751	102993
2003	May	2440228	106600
2003	Jun	1842907	101715
2003	Jul	1957279	48453
2003	Aug	2143823	69130
2003	Sep	1503212	74525
2003	Oct	1611779	70949
2003	Nov	1668167	54004
2003	Dec	2312537	43054
2004	Jan	1605595	75751
2004	Feb	1705533	94864
2004	Mar	2079402	120305
2004	Apr	1883704	90950
2004	May	1830168	111599
2004	Jun	1918622	76392
2004	Jul	2029787	98937
2004	Aug	1928009	72577
2004	Sep	1620224	82650
2004	Oct	1854643	74587
2004	Nov	1981567	59753
2004	Dec	2022272	44353
2005	Jan	2088821	60972
2005	Feb	2106948	59469
2005	Mar	2386327	84551
2005	Apr	2122171	101099
2005	May	2369953	79042
2005	Jun	2342117	104814
2005	Jul	2281871	71065
2005	Aug	2124303	53383
2005	Sep	1734986	37195

2005	Oct	1920131	48632
2005	Nov	1969506	88235
2005	Dec	2323933	98768
2006	Jan	1702766	50553
2006	Feb	2060204	89037
2006	Mar	2244570	33916
2006	Apr	2068922	74430
2006	May	2164076	108689
2006	Jun	1935951	89503
2006	Jul	1968513	93758
2006	Aug	1741802	111080
2006	Sep	1508897	44537
2006	Oct	1892535	46747
2006	Nov	2208173	82938
2006	Dec	1381412	42260
2007	Jan	2211384	114496
2007	Feb	2391437	60618
2007	Mar	2724021	94251
2007	Apr	2639245	90078
2007	May	3168913	129258
2007	Jun	2706972	116628
2007	Jul	2523392	129345
2007	Aug	2272502	88997
2007	Sep	2121837	71560
2007	Oct	2472996	52915
2007	Nov	3040118	107555
2007	Dec	2934174	39239
2008	Jan	2656539	44672
2008	Feb	3101819	35213
2008	Mar	2816846	74421
2008	Apr	3064837	63355
2008	May	3560993	52287
2008	Jun	2920219	33685
2008	Jul	2516561	31288
2008	Aug	2338205	62171

2008	Sep	2314458	31311
2008	Oct	2407240	42766
2008	Nov	2060666	75102
2008	Dec	2329268	74508
2009	Jan	2198569	44459
2009	Feb	2314764	33206
2009	Mar	1846459	64879
2009	Apr	2659230	36638
2009	May	2692440	77011
2009	Jun	2387175	49217
2009	Jul	2672895	55033
2009	Aug	2174027	40398
2009	Sep	2259153	51386
2009	Oct	2386749	58095
2009	Nov	2081706	51798
2009	Dec	2702871	55148
2010	Jan	2059964	40855
2010	Feb	2632985	100598
2010	Mar	2430562	39887
2010	Apr	2652013	40528
2010	May	2460228	71483
2010	Jun	2743053	120553
2010	Jul	2278847	96315
2010	Aug	2618427	62854
2010	Sep	2483861	66613
2010	Oct	2503321	53353
2010	Nov	2370032	104360
2010	Dec	2431047	57919
2011	Jan	2527241	37755
2011	Feb	2786453	51863
2011	Mar	3789076	40188
2011	Apr	3148826	60494
2011	May	3015187	49037
2011	Jun	2718583	58380
2011	Jul	2284521	43096

2011	Aug	2475519	33612
2011	Sep	2461640	48697
2011	Oct	2420554	49929
2011	Nov	2059769	63045
2011	Dec	2882776	64430
2012	Jan	2825116	42894
2012	Feb	2653892	23528
2012	Mar	2544758	39839
2012	Apr	3050109	47250
2012	May	3264666	41357
2012	Jun	2798204	56808
2012	Jul	3331174	46853
2012	Aug	2864088	62682
2012	Sep	2219536	33641
2012	Oct	2482162	47478
2012	Nov	2545142	49232
2012	Dec	3129507	35924
2013	Jan	2902748	32373
2013	Feb	2388197	21922
2013	Mar	2831279	41718
2013	Apr	2467444	54619
2013	May	3131153	57183
2013	Jun	2819983	33484
2013	Jul	3473180	44240
2013	Aug	2586863	52288
2013	Sep	2459258	38145
2013	Oct	3228317	48533
2013	Nov	2998732	53187
2013	Dec	3023918	33381
2014	Jan	2503733	31233
2014	Feb	2615184	33134
2014	Mar	2808639	38876
2014	Apr	2857514	45819
2014	May	3363746	58283
2014	Jun	2778689	54266

2014	Jul	2828847	41221
2014	Aug	3074061	39744
2014	Sep	2703440	40668
2014	Oct	2744813	37263
2014	Nov	2541143	72020
2014	Dec	3325799	44128
2015	Jan	3130822	54942
2015	Feb	2806020	45098
2015	Mar	3560866	53378
2015	Apr	3341695	43642
2015	May	3717487	70583
2015	Jun	3678283	56578
2015	Jul	3954460	53615
2015	Aug	3016100	42015
2015	Sep	2209724	38904
2015	Oct	2795409	55583
2015	Nov	3426753	70399
2015	Dec	3357454	51095
2016	Jan	3087231	54089
2016	Feb	3374485	48683
2016	Mar	3260054	45472
2016	Apr	2930106	63926
2016	May	3383331	76757
2016	Jun	3209613	45557
2016	Jul	2765143	37198
2016	Aug	2732867	40213
2016	Sep	2180347	41660
2016	Oct	2298348	34699
2016	Nov	2545574	71924
2016	Dec	3691485	37448
2017	Jan	3383297	48974
2017	Feb	2856584	35716
2017	Mar	3413039	39789
2017	Apr	3361156	30625
2017	May	3576410	31092

2017	Jun	3348469	27734
2017	Jul	2741187	27041
2017	Aug	2675625	32476
2017	Sep	2700675	33394
2017	Oct	2779159	31373
2017	Nov	2817012	40681
2017	Dec	3726216	33955
2018	Jan	3361591	46166
2018	Feb	2625263	29890
2018	Mar	3219102	31454
2018	Apr	3593287	25954
2018	May	3798285	35908
2018	Jun	3362829	31899
2018	Jul	2735326	30968
2018	Aug	2397549	19849
2018	Sep	2323735	29324
2018	Oct	2472451	28927
2018	Nov	2687466	40497
2018	Dec	3236293	36603

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