MODELO SIRC – VALORES ABSOLUTOS

El resultado de implementar el modelo SIRC en Matlab para la población de Colombia y en un periodo de tiempo de 360 días con los siguientes parámetros:

$\alpha = 0.0714$ (Hay que buscar el valor correcto para el Covid en la literatura médica)

$\delta = 0.0027$ (Hay que buscar el valor correcto para el Covid en la literatura médica)

$\Upsilon = 0.0056$ (Hay que buscar el valor correcto para el Covid en la literatura médica)

$\mu = 0.0116$ (Obtenido del Dane)

$\sigma = 14.1700$ (Calculado dentro del modelo)

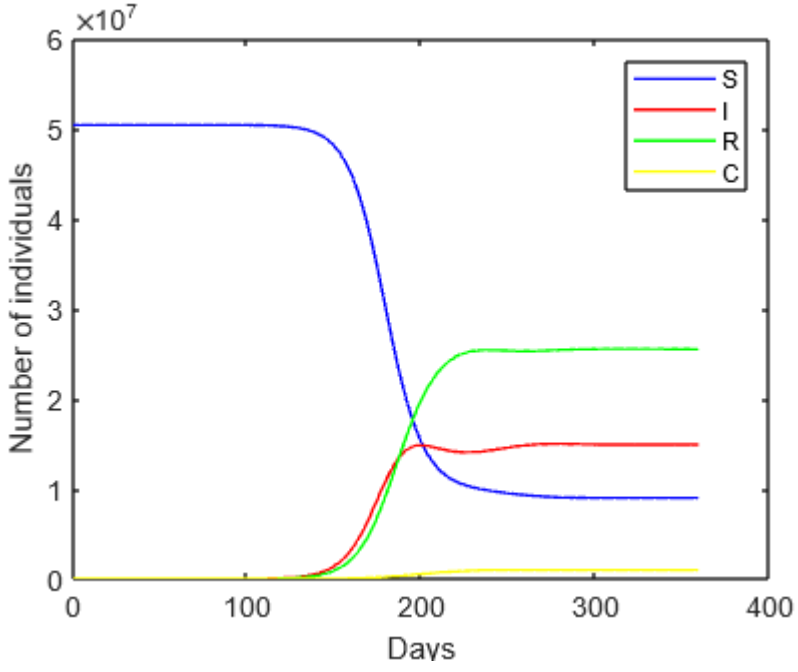
$\beta = 0.1826$ (Calculado dentro del modelo)

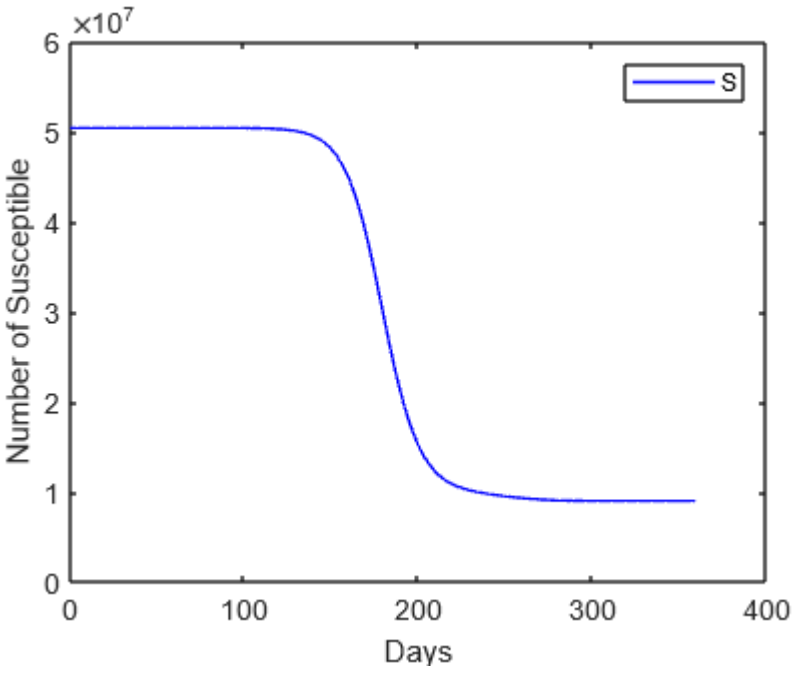
$r = 0.0260$ (Hay que buscar el valor correcto para el Covid en la literatura médica)

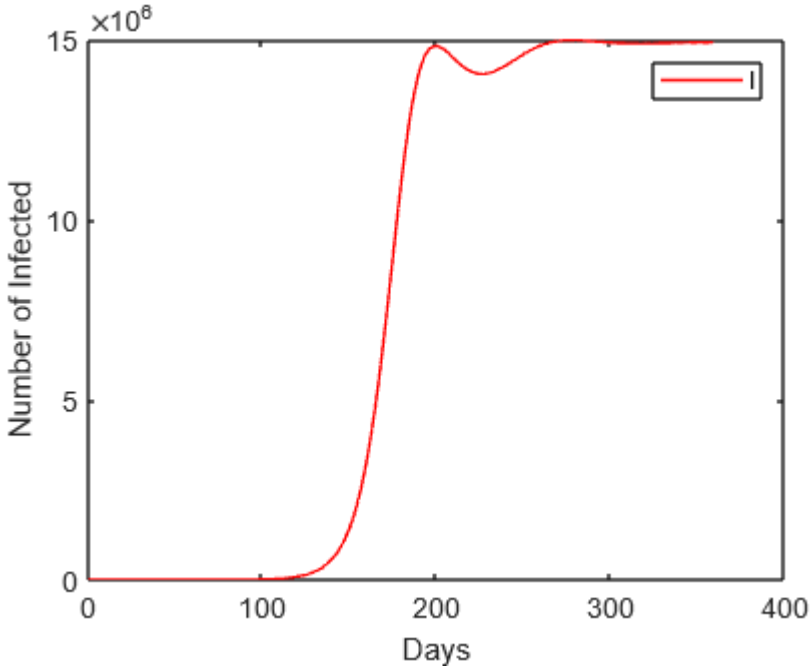
$R_o = 2.20$ (Obtenido de la literatura médica)

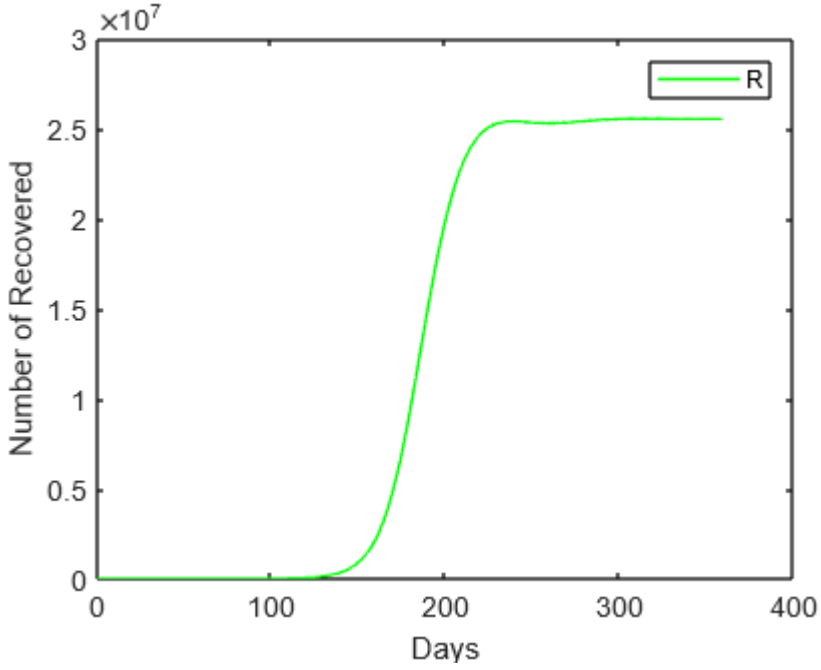
$I_o = 1$ (La pandemia se inicia con un primer contagado)

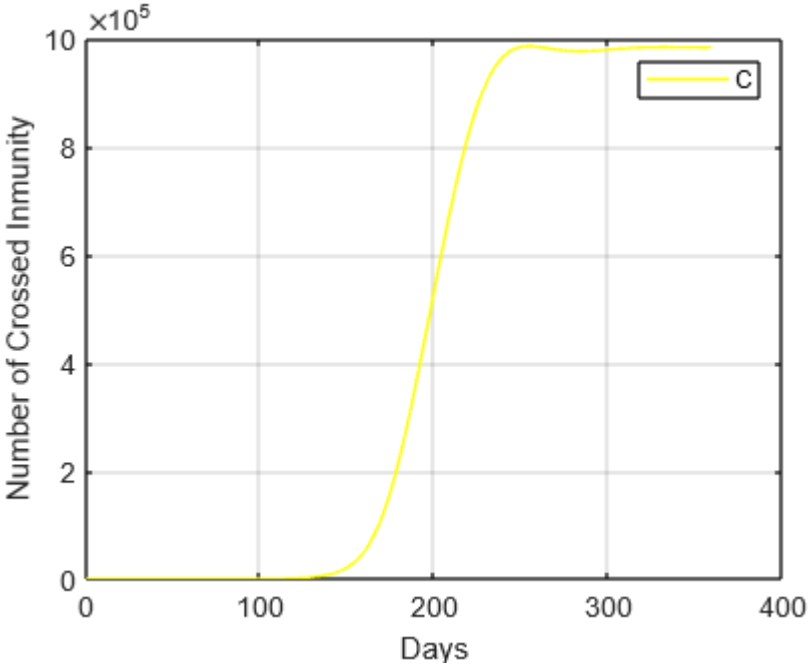
RESULTADOS:




×10^7
6
5
4
3
2
1
0
Number of Susceptible
S
0
100
200
300
400
Days


×10^6
15
10
5
0
Number of Infected
I
0
100
200
300
400
Days


×10^7
3
2.5
2
1.5
1
0.5
0
Number of Recovered
R
0
100
200
300
400
Days


×10^5
10
8
6
4
2
0
Number of Crossed Inmunity
C
0
100
200
300
400
Days

RESULTADOS NUMÉRICOS

Los resultados numéricos se muestran en la siguiente tabla:

Day	S	I	R	C
1	50,372,000	1	0	0
2	50,372,000	1	0	0
3	50,372,000	1	0	0
4	50,371,999	1	0	0
5	50,371,999	1	0	0
6	50,371,999	2	0	0
7	50,371,999	2	1	0
8	50,371,998	2	1	0
9	50,371,998	2	1	0
10	50,371,998	2	1	0
11	50,371,997	3	1	0
12	50,371,997	3	1	0
13	50,371,996	3	1	0
14	50,371,996	3	2	0
15	50,371,995	4	2	0
16	50,371,995	4	2	0
17	50,371,994	5	2	0
18	50,371,993	5	3	0
19	50,371,992	6	3	0
20	50,371,991	6	3	0
21	50,371,990	7	4	0
22	50,371,989	7	4	0
23	50,371,988	8	5	0
24	50,371,987	9	5	0
25	50,371,985	10	6	0
26	50,371,984	11	6	0
27	50,371,982	12	7	0
28	50,371,980	13	8	0
29	50,371,978	14	9	0
30	50,371,975	16	9	0
31	50,371,973	17	10	0
32	50,371,970	19	12	0
33	50,371,967	21	13	0
34	50,371,963	23	14	0
35	50,371,960	25	15	0
36	50,371,956	28	17	0
37	50,371,951	31	19	0
38	50,371,946	34	21	0
39	50,371,940	37	23	0

40	50,371,934	41	25	1
41	50,371,928	45	28	1
42	50,371,920	49	30	1
43	50,371,912	54	33	1
44	50,371,904	59	37	1
45	50,371,894	65	41	1
46	50,371,883	72	45	1
47	50,371,871	79	49	1
48	50,371,859	87	54	1
49	50,371,844	95	59	1
50	50,371,829	105	65	1
51	50,371,812	115	72	2
52	50,371,793	127	79	2
53	50,371,772	139	87	2
54	50,371,749	153	96	2
55	50,371,724	169	105	2
56	50,371,697	185	116	3
57	50,371,666	204	128	3
58	50,371,633	224	140	3
59	50,371,596	246	154	4
60	50,371,556	271	170	4
61	50,371,512	298	187	4
62	50,371,463	328	205	5
63	50,371,409	360	226	5
64	50,371,350	396	248	6
65	50,371,285	436	273	6
66	50,371,214	479	300	7
67	50,371,136	527	330	8
68	50,371,050	579	363	8
69	50,370,955	637	399	9
70	50,370,851	700	439	10
71	50,370,736	770	483	11
72	50,370,610	847	531	12
73	50,370,472	931	584	14
74	50,370,320	1,024	642	15
75	50,370,152	1,126	706	17
76	50,369,968	1,238	776	18
77	50,369,766	1,361	853	20
78	50,369,543	1,497	938	22
79	50,369,298	1,646	1,032	24
80	50,369,029	1,810	1,135	27
81	50,368,733	1,990	1,248	29
82	50,368,407	2,189	1,372	32

83	50,368,050	2,407	1,509	35
84	50,367,656	2,646	1,659	39
85	50,367,223	2,910	1,824	43
86	50,366,748	3,200	2,006	47
87	50,366,224	3,518	2,206	52
88	50,365,649	3,869	2,426	57
89	50,365,017	4,254	2,667	63
90	50,364,321	4,678	2,933	69
91	50,363,556	5,143	3,225	76
92	50,362,715	5,656	3,546	83
93	50,361,791	6,219	3,899	91
94	50,360,774	6,838	4,288	101
95	50,359,656	7,519	4,715	111
96	50,358,427	8,268	5,184	122
97	50,357,075	9,091	5,701	134
98	50,355,589	9,996	6,268	147
99	50,353,955	10,991	6,892	162
100	50,352,159	12,085	7,579	178
101	50,350,184	13,288	8,333	196
102	50,348,012	14,611	9,163	215
103	50,345,624	16,065	10,075	236
104	50,342,998	17,664	11,078	260
105	50,340,112	19,421	12,181	286
106	50,336,938	21,354	13,394	314
107	50,333,449	23,479	14,727	346
108	50,329,613	25,814	16,193	380
109	50,325,396	28,382	17,804	418
110	50,320,760	31,205	19,576	459
111	50,315,663	34,308	21,524	505
112	50,310,060	37,719	23,666	555
113	50,303,900	41,469	26,020	611
114	50,297,129	45,591	28,609	671
115	50,289,687	50,121	31,454	738
116	50,281,506	55,101	34,582	811
117	50,272,514	60,573	38,021	892
118	50,262,632	66,588	41,800	981
119	50,251,770	73,197	45,955	1,078
120	50,239,833	80,460	50,522	1,185
121	50,226,715	88,441	55,541	1,303
122	50,212,301	97,209	61,058	1,433
123	50,196,462	106,843	67,120	1,575
124	50,179,060	117,426	73,783	1,731
125	50,159,942	129,051	81,105	1,903

126	50,138,941	141,818	89,150	2,092
127	50,115,873	155,840	97,989	2,299
128	50,090,537	171,236	107,700	2,527
129	50,062,714	188,140	118,369	2,777
130	50,032,165	206,696	130,088	3,052
131	49,998,625	227,062	142,959	3,354
132	49,961,810	249,410	157,095	3,685
133	49,921,404	273,930	172,617	4,049
134	49,877,068	300,824	189,659	4,449
135	49,828,428	330,317	208,368	4,887
136	49,775,079	362,651	228,901	5,368
137	49,716,580	398,089	251,435	5,896
138	49,652,450	436,916	276,158	6,476
139	49,582,170	479,441	303,278	7,111
140	49,505,174	525,999	333,019	7,808
141	49,420,852	576,950	365,626	8,572
142	49,328,543	632,683	401,366	9,409
143	49,227,533	693,614	440,528	10,325
144	49,117,055	760,193	483,423	11,329
145	48,996,284	832,897	530,390	12,429
146	48,864,337	912,237	581,795	13,631
147	48,720,267	998,755	638,032	14,947
148	48,563,068	1,093,024	699,524	16,384
149	48,391,669	1,195,648	766,727	17,955
150	48,204,939	1,307,261	840,129	19,671
151	48,001,685	1,428,524	920,249	21,542
152	47,780,655	1,560,120	1,007,642	23,583
153	47,540,545	1,702,752	1,102,897	25,806
154	47,280,004	1,857,136	1,206,634	28,226
155	46,997,638	2,023,995	1,319,509	30,858
156	46,692,028	2,204,047	1,442,207	33,718
157	46,361,736	2,397,998	1,575,443	36,822
158	46,005,327	2,606,528	1,719,958	40,188
159	45,621,381	2,830,274	1,876,513	43,832
160	45,208,524	3,069,816	2,045,887	47,772
161	44,765,445	3,325,660	2,228,868	52,027
162	44,290,930	3,598,211	2,426,244	56,615
163	43,783,892	3,887,757	2,638,797	61,554
164	43,243,407	4,194,442	2,867,290	66,861
165	42,668,747	4,518,246	3,112,453	72,555
166	42,059,422	4,858,955	3,374,973	78,651
167	41,415,215	5,216,144	3,655,477	85,164
168	40,736,222	5,589,154	3,954,515	92,110

169	40,022,881	5,977,074	4,272,545	99,499
170	39,276,009	6,378,731	4,609,916	107,344
171	38,496,820	6,792,678	4,966,850	115,653
172	37,686,945	7,217,200	5,343,424	124,431
173	36,848,438	7,650,318	5,739,562	133,683
174	35,983,770	8,089,808	6,155,012	143,410
175	35,095,815	8,533,229	6,589,345	153,610
176	34,187,822	8,977,958	7,041,940	164,280
177	33,263,369	9,421,233	7,511,988	175,411
178	32,326,314	9,860,206	7,998,484	186,996
179	31,380,733	10,292,005	8,500,240	199,021
180	30,430,843	10,713,791	9,015,892	211,474
181	29,480,930	11,122,822	9,543,910	224,339
182	28,535,264	11,516,515	10,082,624	237,597
183	27,598,025	11,892,505	10,630,240	251,230
184	26,673,225	12,248,691	11,184,866	265,218
185	25,764,638	12,583,282	11,744,540	279,541
186	24,875,742	12,894,822	12,307,259	294,177
187	24,009,673	13,182,218	12,871,006	309,103
188	23,169,184	13,444,737	13,433,780	324,299
189	22,356,626	13,682,014	13,993,619	339,741
190	21,573,934	13,894,028	14,548,630	355,408
191	20,822,631	14,081,085	15,097,008	371,276
192	20,103,836	14,243,787	15,637,053	387,324
193	19,418,287	14,382,995	16,167,190	403,529
194	18,766,364	14,499,789	16,685,978	419,868
195	18,148,126	14,595,435	17,192,120	436,319
196	17,563,343	14,671,332	17,684,466	452,859
197	17,011,530	14,728,987	18,162,018	469,465
198	16,491,993	14,769,968	18,623,926	486,113
199	16,003,854	14,795,876	19,069,491	502,780
200	15,546,092	14,808,314	19,498,151	519,443
201	15,117,576	14,808,863	19,909,484	536,077
202	14,717,088	14,799,061	20,303,192	552,659
203	14,343,351	14,780,386	20,679,097	569,166
204	13,995,056	14,754,241	21,037,132	585,572
205	13,670,873	14,721,947	21,377,326	601,855
206	13,369,473	14,684,736	21,699,801	617,990
207	13,089,543	14,643,746	22,004,758	633,954
208	12,829,789	14,600,018	22,292,468	649,725
209	12,588,953	14,554,501	22,563,267	665,279
210	12,365,817	14,508,047	22,817,540	680,596
211	12,159,205	14,461,421	23,055,721	695,653

212	11,967,991	14,415,299	23,278,280	710,431
213	11,791,098	14,370,273	23,485,720	724,909
214	11,627,502	14,326,861	23,678,568	739,069
215	11,476,232	14,285,505	23,857,370	752,893
216	11,336,367	14,246,578	24,022,689	766,365
217	11,207,040	14,210,394	24,175,096	779,470
218	11,087,432	14,177,206	24,315,169	792,194
219	10,976,775	14,147,213	24,443,489	804,523
220	10,874,349	14,120,569	24,560,637	816,446
221	10,779,478	14,097,381	24,667,189	827,953
222	10,691,532	14,077,715	24,763,718	839,035
223	10,609,923	14,061,603	24,850,789	849,686
224	10,534,102	14,049,043	24,928,957	859,898
225	10,463,561	14,040,002	24,998,769	869,669
226	10,397,826	14,034,424	25,060,757	878,994
227	10,336,460	14,032,226	25,115,442	887,872
228	10,279,058	14,033,307	25,163,331	896,304
229	10,225,248	14,037,546	25,204,917	904,289
230	10,174,686	14,044,806	25,240,677	911,832
231	10,127,056	14,054,937	25,271,072	918,936
232	10,082,070	14,067,778	25,296,547	925,605
233	10,039,464	14,083,156	25,317,532	931,848
234	9,999,000	14,100,891	25,334,438	937,670
235	9,960,460	14,120,799	25,347,660	943,082
236	9,923,647	14,142,686	25,357,575	948,092
237	9,888,385	14,166,361	25,364,542	952,712
238	9,854,517	14,191,626	25,368,904	956,953
239	9,821,901	14,218,286	25,370,985	960,828
240	9,790,412	14,246,145	25,371,093	964,351
241	9,759,942	14,275,009	25,369,514	967,534
242	9,730,395	14,304,690	25,366,522	970,393
243	9,701,688	14,335,001	25,362,369	972,942
244	9,673,750	14,365,761	25,357,292	975,197
245	9,646,521	14,396,797	25,351,508	977,173
246	9,619,952	14,427,940	25,345,221	978,887
247	9,593,999	14,459,031	25,338,615	980,354
248	9,568,632	14,489,919	25,331,858	981,591
249	9,543,823	14,520,461	25,325,102	982,614
250	9,519,554	14,550,524	25,318,485	983,438
251	9,495,810	14,579,984	25,312,127	984,079
252	9,472,583	14,608,730	25,306,135	984,553
253	9,449,868	14,636,658	25,300,600	984,874
254	9,427,664	14,663,675	25,295,603	985,058

255	9,405,973	14,689,701	25,291,207	985,119
256	9,384,799	14,714,664	25,287,466	985,071
257	9,364,148	14,738,503	25,284,422	984,927
258	9,344,028	14,761,169	25,282,104	984,699
259	9,324,447	14,782,620	25,280,533	984,401
260	9,305,413	14,802,826	25,279,719	984,042
261	9,286,936	14,821,765	25,279,664	983,635
262	9,269,025	14,839,426	25,280,360	983,189
263	9,251,688	14,855,804	25,281,795	982,713
264	9,234,932	14,870,904	25,283,948	982,217
265	9,218,764	14,884,736	25,286,793	981,708
266	9,203,190	14,897,319	25,290,298	981,193
267	9,188,213	14,908,679	25,294,427	980,680
268	9,173,838	14,918,845	25,299,142	980,175
269	9,160,066	14,927,853	25,304,399	979,682
270	9,146,895	14,935,743	25,310,155	979,207
271	9,134,326	14,942,560	25,316,361	978,753
272	9,122,355	14,948,351	25,322,970	978,325
273	9,110,976	14,953,166	25,329,933	977,925
274	9,100,185	14,957,058	25,337,202	977,555
275	9,089,973	14,960,083	25,344,726	977,218
276	9,080,332	14,962,295	25,352,459	976,914
277	9,071,251	14,963,751	25,360,352	976,646
278	9,062,718	14,964,508	25,368,361	976,413
279	9,054,720	14,964,624	25,376,439	976,217
280	9,047,244	14,964,155	25,384,546	976,056
281	9,040,275	14,963,156	25,392,639	975,930
282	9,033,796	14,961,683	25,400,682	975,839
283	9,027,792	14,959,788	25,408,638	975,782
284	9,022,244	14,957,524	25,416,474	975,757
285	9,017,136	14,954,941	25,424,160	975,764
286	9,012,448	14,952,086	25,431,666	975,800
287	9,008,162	14,949,005	25,438,968	975,864
288	9,004,259	14,945,743	25,446,043	975,955
289	9,000,720	14,942,339	25,452,871	976,070
290	8,997,525	14,938,833	25,459,435	976,208
291	8,994,655	14,935,260	25,465,719	976,366
292	8,992,092	14,931,654	25,471,712	976,543
293	8,989,815	14,928,045	25,477,403	976,736
294	8,987,807	14,924,463	25,482,786	976,944
295	8,986,048	14,920,932	25,487,855	977,165
296	8,984,521	14,917,477	25,492,606	977,396
297	8,983,208	14,914,116	25,497,039	977,636

298	8,982,093	14,910,870	25,501,154	977,883
299	8,981,157	14,907,753	25,504,954	978,136
300	8,980,386	14,904,779	25,508,443	978,391
301	8,979,764	14,901,960	25,511,627	978,649
302	8,979,276	14,899,305	25,514,512	978,907
303	8,978,907	14,896,822	25,517,107	979,164
304	8,978,645	14,894,516	25,519,420	979,419
305	8,978,477	14,892,391	25,521,462	979,670
306	8,978,390	14,890,449	25,523,245	979,916
307	8,978,374	14,888,691	25,524,778	980,157
308	8,978,417	14,887,117	25,526,075	980,391
309	8,978,510	14,885,724	25,527,149	980,617
310	8,978,643	14,884,509	25,528,012	980,835
311	8,978,809	14,883,469	25,528,678	981,045
312	8,978,998	14,882,597	25,529,159	981,245
313	8,979,205	14,881,889	25,529,471	981,435
314	8,979,422	14,881,338	25,529,625	981,615
315	8,979,644	14,880,935	25,529,636	981,785
316	8,979,866	14,880,675	25,529,515	981,944
317	8,980,082	14,880,548	25,529,278	982,092
318	8,980,289	14,880,546	25,528,935	982,230
319	8,980,483	14,880,661	25,528,499	982,357
320	8,980,662	14,880,883	25,527,982	982,473
321	8,980,822	14,881,203	25,527,395	982,579
322	8,980,962	14,881,614	25,526,750	982,674
323	8,981,080	14,882,104	25,526,056	982,760
324	8,981,175	14,882,667	25,525,323	982,836
325	8,981,245	14,883,292	25,524,560	982,902
326	8,981,291	14,883,973	25,523,777	982,960
327	8,981,312	14,884,699	25,522,980	983,008
328	8,981,309	14,885,464	25,522,178	983,049
329	8,981,281	14,886,260	25,521,378	983,081
330	8,981,229	14,887,079	25,520,586	983,107
331	8,981,154	14,887,915	25,519,806	983,125
332	8,981,056	14,888,761	25,519,046	983,137
333	8,980,938	14,889,611	25,518,308	983,143
334	8,980,800	14,890,459	25,517,598	983,144
335	8,980,643	14,891,300	25,516,918	983,139
336	8,980,469	14,892,130	25,516,271	983,130
337	8,980,280	14,892,943	25,515,660	983,117
338	8,980,076	14,893,736	25,515,088	983,101
339	8,979,860	14,894,505	25,514,555	983,081
340	8,979,632	14,895,247	25,514,062	983,058

341	8,979,396	14,895,960	25,513,611	983,033
342	8,979,151	14,896,641	25,513,202	983,006
343	8,978,901	14,897,288	25,512,834	982,977
344	8,978,645	14,897,899	25,512,508	982,947
345	8,978,386	14,898,474	25,512,223	982,916
346	8,978,125	14,899,011	25,511,978	982,885
347	8,977,864	14,899,510	25,511,773	982,853
348	8,977,604	14,899,971	25,511,605	982,821
349	8,977,345	14,900,393	25,511,473	982,789
350	8,977,089	14,900,776	25,511,377	982,758
351	8,976,838	14,901,122	25,511,313	982,727
352	8,976,592	14,901,431	25,511,281	982,697
353	8,976,351	14,901,703	25,511,278	982,668
354	8,976,117	14,901,941	25,511,302	982,640
355	8,975,891	14,902,144	25,511,352	982,613
356	8,975,673	14,902,314	25,511,425	982,588
357	8,975,463	14,902,453	25,511,520	982,564
358	8,975,263	14,902,563	25,511,633	982,541
359	8,975,072	14,902,644	25,511,764	982,520
360	8,974,891	14,902,699	25,511,909	982,501

CÓDIGO MATLAB

El código Matlab es es siguiente:

```
% https://www.mathworks.com/matlabcentral/fileexchange/75100-sir-epidemic-spread-model
clc;
clear;
close all;

% Model parameters
N=50372000; % Total population N = S + E + I + R - https://datosmacro.expansion.com/paises/colombia

alfa = 1/14; %Average time spent by subjects in the compartment I - Search for the accurate value of Covid in medical lierature
delta = 1/365;%Average time spent by subjects in the compartment R - Search for the accurate value of Covid in medical lierature
gamma = 1/180; %Average time spent by subjects in the compartment C - Search for the accurate value of Covid in medical lierature

mu = 145788*4/N; %Mortality rate in every compartment, equal to rate of newborn in population - %https://www.dane.gov.co/index.php/estadisticas-por-tema/salud/nacimientos-y-defunciones/nacimientos/nacimientos-2021
r = 0.026; % rate of infection - Search for the accurate value of Covid in medical literacy
Ro = 2.2; %Average reproduction number - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0248731

beta= Ro *(mu + alfa); %Contact rate
sigma = r * (1/delta + 1/gamma); %Average reinfection probability of a cross-inmune subject

I0 = 1/N; % Proportion initial number of infected
T = 360; % period of 30 days
dt = 1; % time interval of 6 hours (1/4 of a day)

fprintf('Paramaters and their values: \n')
fprintf('Value of alfa is %.4f \n',alfa)
fprintf('Value of delta is %.4f \n',delta)
fprintf('Value of gamma is %.4f \n',gamma)
fprintf('Value of mu is %.4f \n',mu)
fprintf('Value of sigma is %.4f \n',sigma)
fprintf('Value of beta is %.4f \n',beta)
fprintf('Value of r is %.4f \n',r)

fprintf('Value of parameter R0 calculated is %.2f \n',beta/gamma)
fprintf('Value of parameter R0 is %.2f \n',Ro)
fprintf('Value of parameter I0 is %.2f \n',I0)

% Calculate the model
[S,I,R,C] = sirc_model(alfa, delta, gamma, beta, mu, sigma,1,I0,T,dt);

% Converts to absolute values
[S,I,R,C] = sirc_absolute(T,dt,N,S,I,R,C);
```

```
% Plots that display the epidemic outbreak
tt = 0:dt:T-dt;
% Curve
plot(tt,S,'b',tt,I,'r',tt,R,'g',tt,C,'y','LineWidth',1); %grid on;
xlabel('Days'); ylabel('Number of individuals');
legend('S','I','R','C');

figure
% Plots that display the epidemic outbreak
tt = 0:dt:T-dt;
% Curve
plot(tt,S,'b','LineWidth',1); %grid on;
xlabel('Days'); ylabel('Number of Susceptible');
legend('S');

figure
% Plots that display the epidemic outbreak
tt = 0:dt:T-dt;
% Curve
plot(tt,I,'r','LineWidth',1); %grid on;
xlabel('Days'); ylabel('Number of Infected');
legend('I');

figure
% Plots that display the epidemic outbreak
tt = 0:dt:T-dt;
% Curve
plot(tt,R,'g','LineWidth',1); %grid on;
xlabel('Days'); ylabel('Number of Recovered');
legend('R');

figure
% Plots that display the epidemic outbreak
tt = 0:dt:T-dt;
% Curve
plot(tt,C,'y','LineWidth',1); grid on;
xlabel('Days'); ylabel('Number of Crossed Inmunity');
legend('C');

function [S,I,R,C] = sirc_absolute(T,dt,N,S,I,R,C)
  fprintf('tt | S | I | R | C \n')
  for i = 1:(T/dt)
      S(i)=S(i)*N;
      I(i)=I(i)*N;
      R(i)=R(i)*N;
      C(i)=C(i)*N;
      fprintf('%d | %.0f | %.0f | %.0f | %.0f \n',i,S(i),I(i),R(i),C(i));
  end
end

function [S,I,R,C] = sirc_model(alfa, delta, gamma, beta, mu, sigma,N,I0,T,dt)
    % if delta = 0 we assume a model without immunity loss
    S = zeros(1,T/dt);
    S(1) = N;
```

```
    I = zeros(1,T/dt);
    I(1) = I0;
    R = zeros(1,T/dt);
    R(1)=0.0;
    C = zeros(1,T/dt);
    C(1)=0.0;

    for tt = 1:(T/dt)-1
        % Equations of the model
        dS = (mu * (1 - S(tt)) - beta * S(tt) * I(tt) + gamma * C(tt)) * dt;

        dI = (beta * S(tt) * I(tt) + sigma * beta * C(tt) * I(tt) - (mu + alfa)
*  I(tt)) * dt;

        dR = ((1 - sigma) * beta * C(tt) * I(tt)  + alfa * I(tt) - (mu + delta)
* R(tt)) * dt;

        dC = (delta * R(tt) - beta * C(tt) * I(tt) - (mu + gamma) * C(tt)) * dt;

        S(tt+1) = S(tt) + dS;
        I(tt+1) = I(tt) + dI;
        R(tt+1) = R(tt) + dR;
        C(tt+1) = C(tt) + dC;
    end
end
```