A New, Simple Projection Model for COVID-19 Pandemic

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Abstract: With the worldwide outbreak of COVID-19, an accurate model to predict how the coronavirus pandemic will evolve becomes important and urgent to help policy makers in different countries address the epidemic outbreak and determine policies to control spread more efficiently and effectively. Unlike the classic public health and virus propagation models, this new projection model takes government intervention and public response into account to make reliable projections of the outbreak 10 days to 2 weeks in advance.

1. Introduction

The classic epidemic models are mainly based on the virus capacities to propagate in an environment without protection. Their variables include disease incubation period, speed and strength of virus propagation while introducing some assumptions related to the slowdown barriers. However, reality could be a lot more complicated. For instance, COVID-19's incubation period varies from 1 to 14 days. What's more, to stop epidemic spread and reduce infections to low levels is a concerted effort of both the government and the people. The strategies of dealing with the outbreak, the strength of government execution, how people react and respond to the measures are critical to the number of infections.

In addition, facing such a great uncertainty, it is impossible to think of the future in terms of a single result but rather a range of possibilities. To project the possibility of a variety of outcomes, a model derived from real propagation data that can summarize the possibilities and describe their relative likelihood will say a lot – but not everything - about the likely future. Otherwise, the results are likely to generate a huge scatter of errors.

Making use of primary data at the initial stage of the outbreak, right after the drastic containment measure imposed in different countries and regions, this new projection model is an integrative multi parameters model that evaluates the effectiveness of the government interventions while forecasting the spread of virus. As mentioned above, such effectiveness is affected by two other major factors: public response (including how much awareness they have, the level of their cooperation) as well as efficiency of healthcare system (including the capacity, advancement, and effectiveness).

2. Model and Method

In any given country, the outbreak usually starts slow, followed by a rapid-growing unstable period. The length of this unstable period depends on the performance of initial defence and control measures in each country and how swift government intervention is. For COVID-19, we found the rate of increase in the number of infections was around 1.3 during the unstable period in China.

China declared a level 1 health emergency on January 29 evening. On January 30, transport suspension in Hubei and Beijing began. This new model was first built with the data of infected cases in Mainland China starting from February 1.

While charting the number of infected cases since February 1, we project different reduction coefficient of daily cases increase rate (R_c) which is a combined indicator of the effectiveness of government intervention, public response, and healthcare system. Five $R_c(s)$ give out five scenarios and five projectionn curves based on the formula below:

$$N(D_n)_{total} = N(D_{n-1})_{total} \times (R_{n-1} - R_c \times D_n)$$

where D_n is the number of days starting from the first simulation day to day n;

$N(D_n)_{total}$ is the total number of infected cases till day n;

R_{n-1} is the case increase rate prior to day n;

R_c is the reduction coefficient of daily cases increase rate.

The value of R_c varies according to the effectiveness of government intervention, the awareness and response of the public as well as the efficiency of healthcare system. Therefore, it is different among countries. For China, we used R_c as 0.03, 0.02, 0.015, 0.0125, 0.01.

When $R_{n-1} - R_c \times D_n < 1\%$, the increase percentage will be fixed at 1% per day for the coming 5 days and 0.5% for another 5 days to predict the total number of infected cases.

3. Prediction Results and Analysis

3.1 Greater China

The figure 1 shows the prediction figure and the real confirmed cases every day in China. The spread of COVID-19 was stable with the number of infections increase along with the R_c curve of 1.5% before February 12. The leapt on February 12 was due to a change of China's methodology of calculation by including people diagnosed via CT scans as well as via testing kits in Hubei.

Afterwards, the projection of R_c 1.25% curve gave out the total number of 82764 on March 27, which was close to the actual infections of 80100.

3.2 South Korea

The figure 2 shows the prediction figure and the real confirmed cases every day. The number of infected cases went along with the R_c 2% curve.

3.3 Iran

The figure 3 shows the prediction figure and the real confirmed cases every day in Iran. Iran has a R_c around 1.5%.

3.4 Italy

The figure 4 shows the prediction figure and the real confirmed cases every day in Italy. Italy's R_c is close to 1.25%, indicating a total number of cases could reach 56971 on 5th April 2020. Italy's R_c moved from 1.25% to 1%, showing an important deterioration of the disease control which may generate more than 100000 cases.

3.5 France

The figure 5 shows the prediction figure and the real confirmed cases every day. France's R_c is also around 1.25%.

3.6 Germany

The figure 6 shows the prediction figure and the real confirmed cases every day. Germany's R_c moved from 3% to 2%, showing a deterioration of the disease control.

3.7 USA

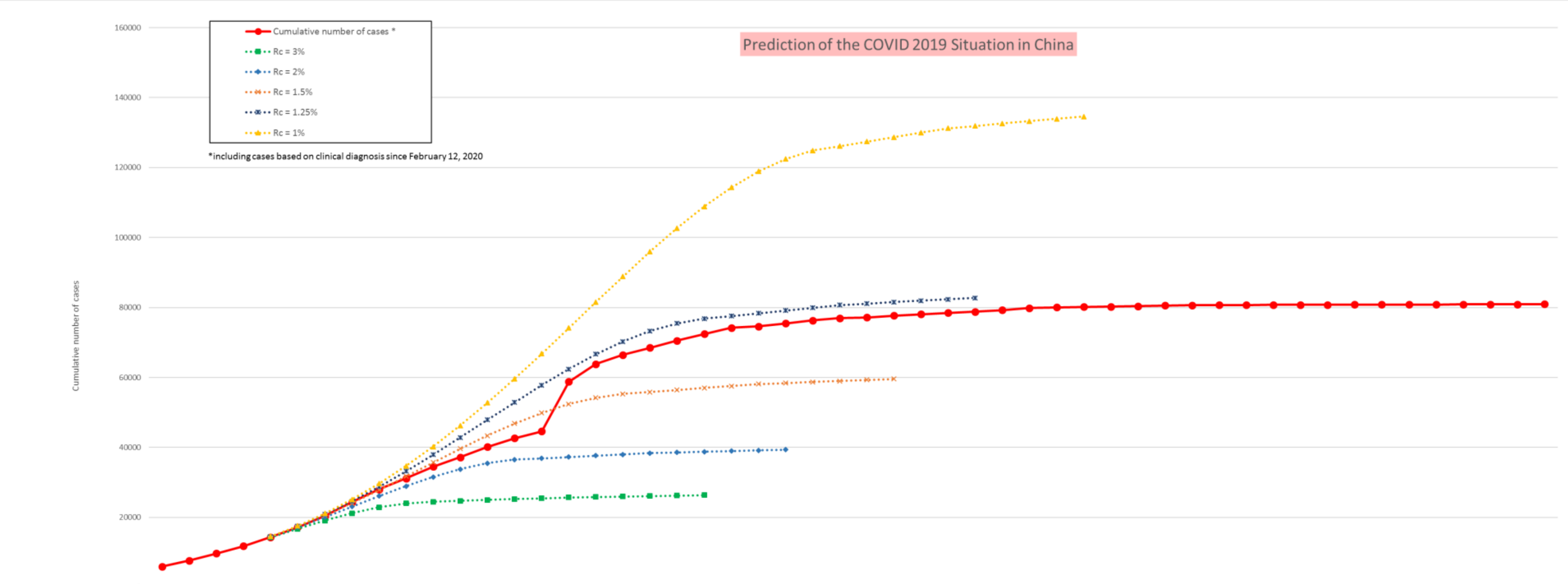
The figure 7 shows the prediction figure and the real confirmed cases every day in USA. USA's R_c is less than 0.5 % by mid-March, indicating that there could be at least a million infections if the situation does not improve.

Conclusion

The new, simple projection model had successfully applied to the epidemic situation in Mainland China and offered a decent, reliable prediction of the number of infected people for the coming two to four weeks. The model outlines which outcome is most likely and what other outcomes also have a good chance of occurring, how braod the range of possible outcomes. It offers an idea of the tendency of the infection situation and the projection model is applicable to other countries like South Korea, Iran, Italy, France, USA, and Germany.

This projection model aims to achieve two major tasks of epidemic control: one is to assess the effectiveness of government intervention, the level of cooperation from the public and the efficiency of healthcare system; second is to track and give a decent prediction of the growth and number of infections. To eradicate a pandemic, both information is critical for policy makers to outline strategies and make adjustment to measures to curb the spread of infection, minimizing the social and economic impact to one's country and to the world.

Reference: https://www.worldometers.info/coronavirus/

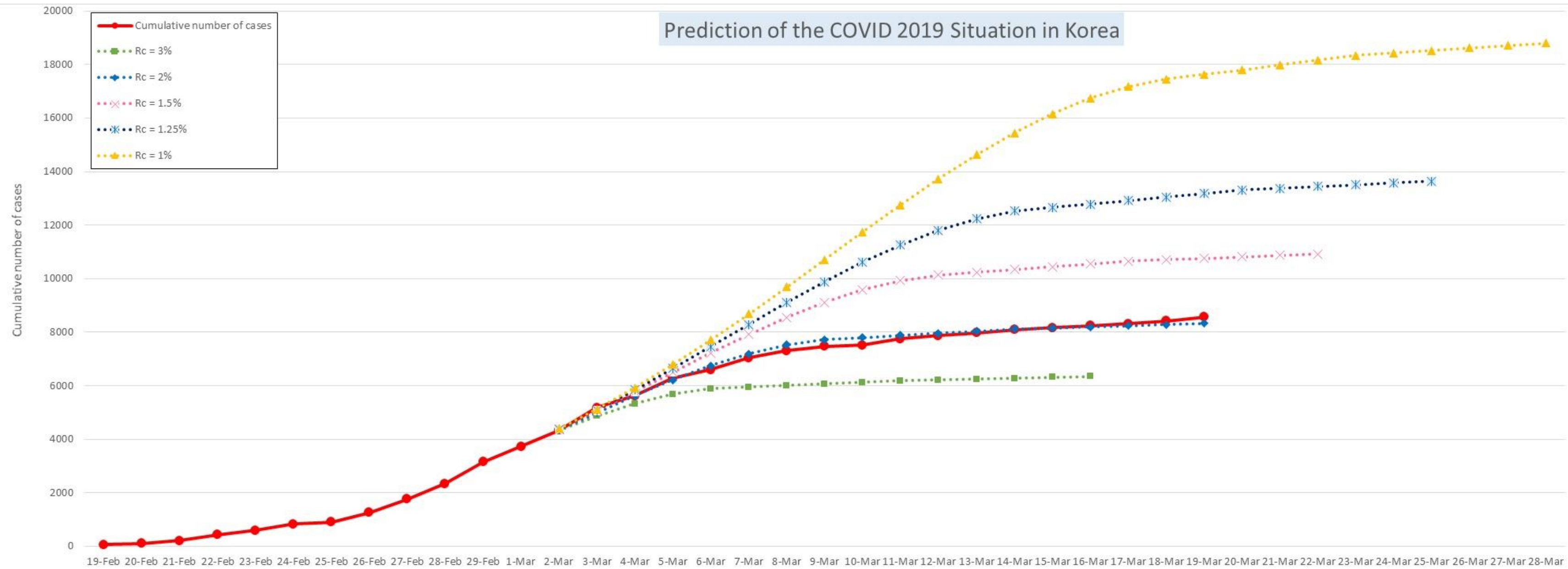


	28 Jan	29	30	31	1 Feb	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cumulative number of cases *	5974	7711	9692	11791	14380	17205	20440	24324	28018	31161	34546	37198	40171	42638	44653	58761	63851	66492	68500	70548	72436
Rc = 3%					14305	16737	19080	21179	22873	24017	24497	24742	24990	25240	25492	25747	25876	26005	26135	26266	26397
Rc = 2%					14424	17165	20083	23096	26098	28969	31576	33786	35476	36540	36905	37274	37647	38024	38404	38596	38789
Rc = 1.5%					14484	17381	20596	24098	27833	31729	35696	39622	43386	46857	49903	52398	54232	55316	55870	56428	56993
Rc = 1.25%					14514	17489	20856	24610	28732	33185	37914	42843	47877	52904	57798	62422	66635	70300	73288	75487	76808
Rc = 1%					14544	17598	21117	25130	29653	34694	40245	46282	52761	59620	66775	74120	81532	88870	95979	102698	108860

	18	19	20	21	22	23	24	25	26	27	28	29	1 Mar	2	3	4	5	6	7	8	9
Cumulative number of cases *	74185	74576	75465	76288	76936	77150	77658	78064	78497	78824	79251	79824	80026	80151	80270	80409	80552	80651	80695	80735	80754
Rc = 3%																					
Rc = 2%	38983	39178	39374																		
Rc = 1.5%	57562	58138	58429	58721	59015	59310	59606														
Rc = 1.25%	77576	78352	79135	79927	80726	81129	81535	81943	82353	82764											
Rc = 1%	114303	118875	122441	124890	126139	127400	128674	129961	131260	131917	132576	133239	133905	134575							

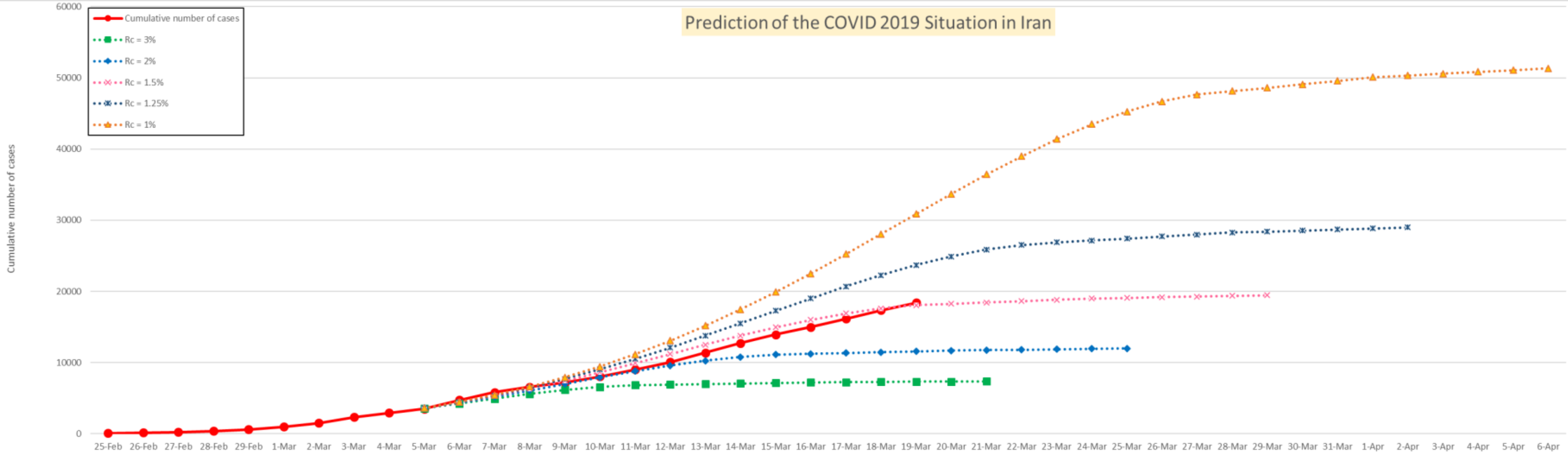
	10	11	12	13	14	15	16	17	18	19
Cumulative number of cases *	80778	80793	80813	80824	80844	80860	80881	80894	80928	80967
Rc = 3%										
Rc = 2%										
Rc = 1.5%										
Rc = 1.25%										
Rc = 1%										

Figure 1 Prediction and real evolution in China



	19-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	25-Feb	26-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	
Cumulative number of cases	58	111	209	436	602	833	911	1261	1766	2337	3150	3736	4335	5186	5621	6284	6593	7041	7313	7478	7513	7755	7869	7979	8086	8162	8236	8320	8413	8565									
Rc = 3%													4319	4863	5330	5682	5886	5945	6004	6064	6125	6186	6217	6248	6280	6311	6343												
Rc = 2%													4356	4992	5621	6217	6752	7197	7528	7724	7801	7879	7958	8038	8118	8159	8200	8241	8282	8323									
Rc = 1.5%													4375	5057	5770	6497	7219	7912	8553	9117	9582	9927	10135	10237	10339	10443	10547	10652	10706	10759	10813	10867	10921						
Rc = 1.25%													4384	5090	5846	6641	7461	8289	9106	9889	10616	11263	11810	12235	12522	12660	12787	12914	13044	13174	13306	13372	13439	13506	13574	13642			
Rc = 1%													4394	5123	5922	6787	7710	8681	9688	10715	11744	12754	13723	14629	15448	16158	16740	17175	17450	17625	17801	17979	18159	18340	18432	18524	18617	18710	18803

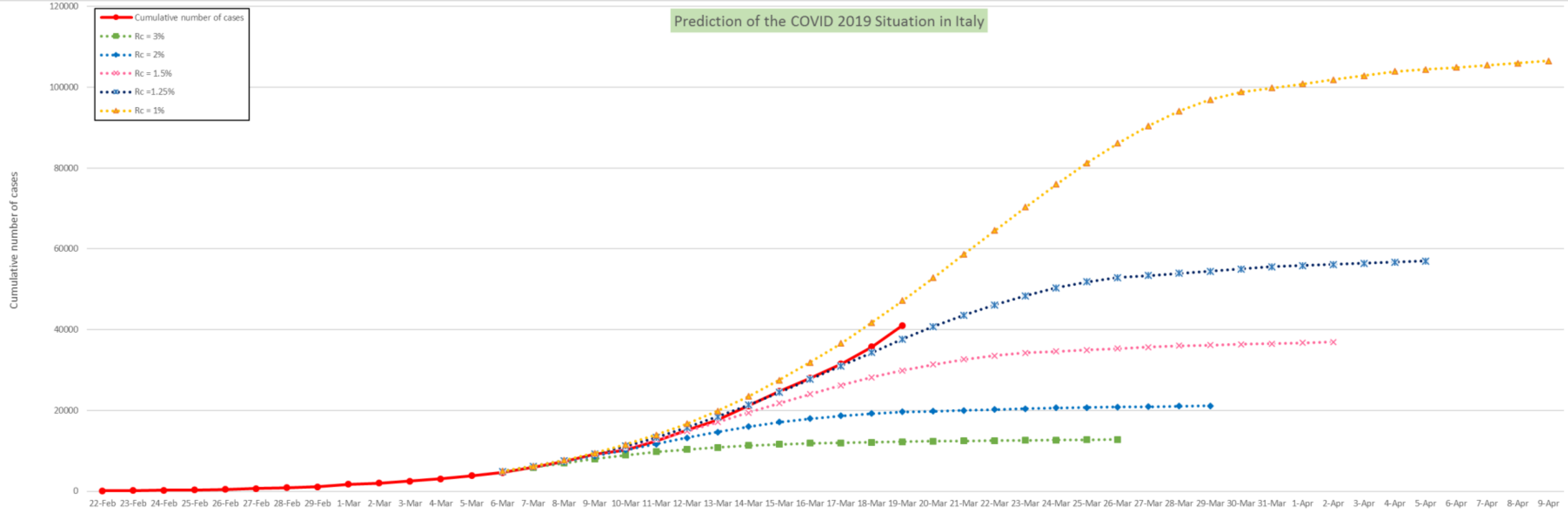
Figure 2 Prediction and real evolution in South Korea



	25-Feb	26-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar
Cumulative number of cases	95	139	245	388	593	978	1501	2336	2922	3513	4747	5823	6566	7161	8042	9000	10075	11364	12729	13938
Rc = 3%										3568	4249	4933	5580	6143	6579	6849	6918	6987	7057	7127
Rc = 2%										3597	4356	5188	6075	6992	7908	8786	9586	10266	10790	11124
Rc = 1.5%										3612	4410	5318	6334	7449	8648	9911	11209	12509	13772	14957
Rc = 1.25%										3619	4437	5384	6466	7685	9038	10515	12103	13779	15516	17277
Rc = 1%										3626	4464	5450	6600	7927	9441	11150	13057	15159	17448	19908

	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar						
Cumulative number of cases	14991	16169	17361	18407																		
Rc = 3%	7198	7234	7271	7307	7343	7380																
Rc = 2%	11236	11348	11462	11576	11692	11750	11809	11868	11928	11987												
Rc = 1.5%	16019	16916	17609	18067	18248	18430	18615	18801	18989	19084	19179	19275	19372	19468								
Rc = 1.25%	19022	20705	22279	23693	24902	25860	26533	26891	27160	27431	27706	27983	28263	28404	28546	28689	28832	28976				
Rc = 1%	22516	25240	28042	30874	33684	36412	38997	41376	43486	45269	46673	47653	48129	48611	49097	49588	50083	50334	50586	50838	51093	51348

Figure 3 Prediction and real evolution in Iran

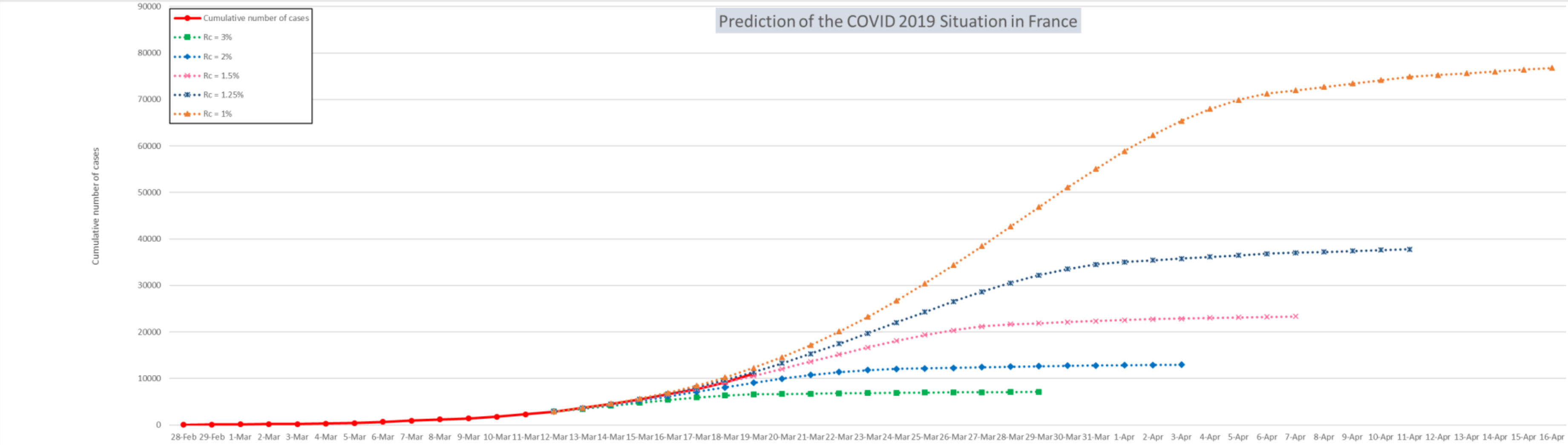


	22-Feb	23-Feb	24-Feb	25-Feb	26-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar
Cumulative number of cases	79	157	229	323	470	655	889	1128	1701	2036	2502	3089	3858
Rc = 3%													
Rc = 2%													
Rc = 1.5%													
Rc =1.25%													
Rc = 1%													

	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar
Cumulative number of cases	4636	5883	7375	9172	10149	12462	15113	17660	21157	24747	27980	31506	35713	41035
Rc = 3%	4869	5892	6953	7996	8955	9761	10347	10864	11299	11637	11870	11989	12109	12230
Rc = 2%	4909	6038	7306	8694	10172	11697	13218	14672	15993	17112	17968	18686	19247	19632
Rc = 1.5%	4928	6111	7486	9058	10825	12773	14881	17113	19423	21754	24038	26201	28166	29856
Rc =1.25%	4938	6148	7577	9245	11163	13340	15774	18456	21362	24460	27701	31025	34360	37624
Rc = 1%	4948	6185	7669	9433	11509	13926	16711	19886	23465	27454	31847	36624	41751	47179

	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	
Cumulative number of cases																					
Rc = 3%	12352	12476	12538	12601	12664	12727	12791														
Rc = 2%	19828	20027	20227	20429	20633	20737	20840	20944	21049	21154											
Rc = 1.5%	31349	32603	33581	34253	34596	34941	35291	35644	36000	36180	36361	36543	36726	36909							
Rc =1.25%	40728	43579	46085	48389	50325	51835	52871	53400	53934	54473	55018	55568	55846	56125	56406	56688	56971				
Rc = 1%	52840	58653	64518	70325	75951	81267	86143	90451	94069	96891	98829	99817	100815	101823	102841	103870	104389	104911	105436	105963	106493

Figure 4 Prediction and real evolution in Italy

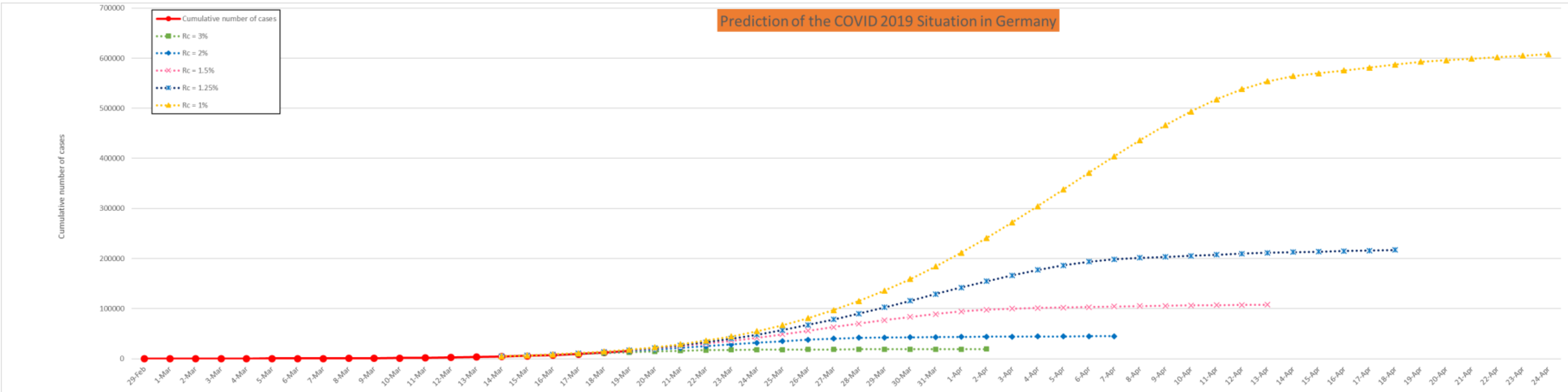


	28-Feb	29-Feb	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar
Cumulative number of cases	57	100	130	191	212	285	423	653	949	1209	1412	1784	2281	2876	3661	4499	5423	6633	7730	9134	10995
Rc = 3%														2849	3473	4129	4786	5403	5938	6348	6595
Rc = 2%														2872	3558	4337	5201	6131	7106	8094	9057
Rc = 1.5%														2883	3601	4444	5417	6522	7755	9104	10551
Rc = 1.25%														2889	3623	4498	5527	6724	8096	9646	11373
Rc = 1%														2895	3644	4552	5640	6931	8449	10215	12248

	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr
Cumulative number of cases																				
Rc = 3%	6661	6728	6795	6863	6932	6966	7001	7036	7072	7107										
Rc = 2%	9954	10740	11374	11818	12042	12162	12284	12407	12531	12656	12720	12783	12847	12911	12976					
Rc = 1.5%	12071	13628	15182	16685	18086	19334	20378	21173	21681	21898	22117	22338	22561	22787	22901	23015	23130	23246	23362	
Rc = 1.25%	13267	15310	17476	19730	22029	24320	26545	28642	30547	32196	33533	34505	35074	35425	35779	36137	36499	36864	37048	37233
Rc = 1%	14562	17169	20070	23262	26728	30443	34370	38460	42652	46875	51046	55079	58880	62354	65409	67960	69931	71259	71972	72692

	9-Apr	10-Apr	11-Apr	12-Apr				
Cumulative number of cases								
Rc = 3%								
Rc = 2%								
Rc = 1.5%								
Rc = 1.25%	37419	37606	37794					
Rc = 1%	73419	74153	74894	75269	75645	76023	76403	76785

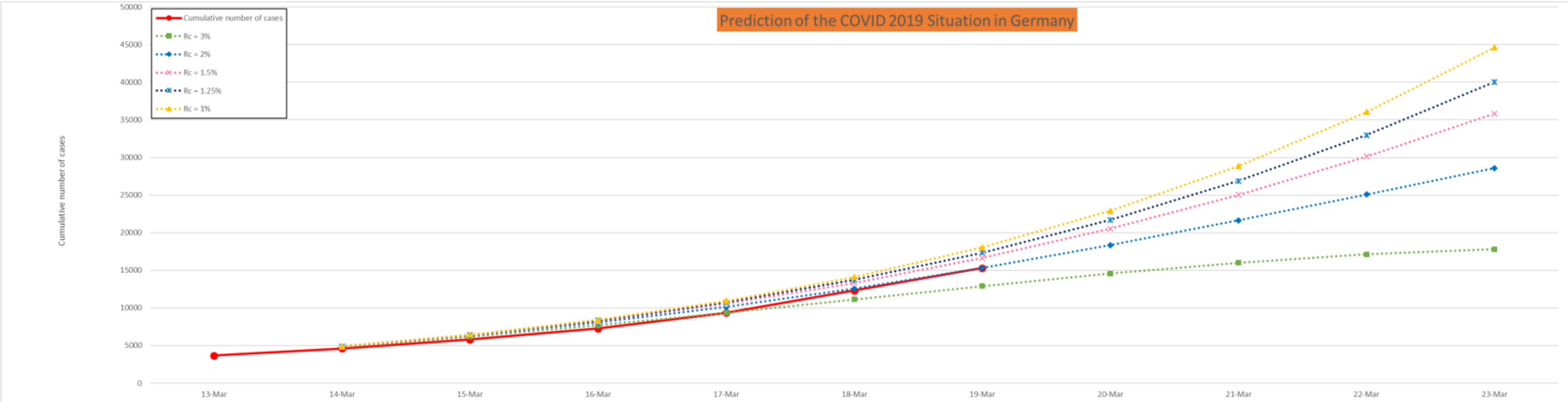
Figure 5 Prediction and real evolution in France



	29-Feb	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar
Cumulative number of cases	79	130	165	203	262	545	670	800	1040	1224	1565	1966	2745	3675
Rc = 3%														
Rc = 2%														
Rc = 1.5%														
Rc = 1.25%														
Rc = 1%														

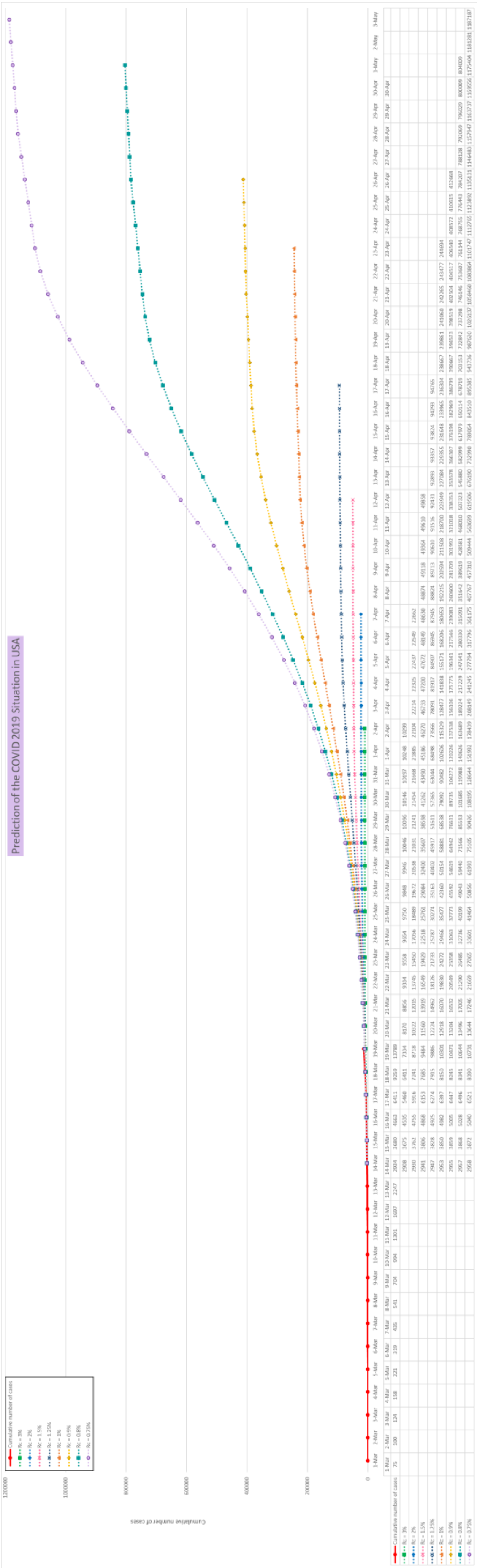
	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar
Cumulative number of cases	4599	5813	7272	9367	12327	15320												
Rc = 3%	4811	6153	7685	9368	11138	12909	14574	16017	17123	17790	17968	18148	18329	18513	18698	18791	18885	18980
Rc = 2%	4847	6297	8053	10139	12563	15314	18361	21648	25090	28577	31978	35144	37920	40158	41724	42141	42562	42988
Rc = 1.5%	4866	6369	8242	10541	13324	16642	20536	25033	30140	35837	42072	48762	55783	62979	70159	77105	83582	89349
Rc = 1.25%	4875	6406	8337	10746	13718	17339	21700	26886	32976	40033	48099	57190	67284	78318	90184	102719	115713	128904
Rc = 1%	4884	6442	8433	10954	14120	18059	22917	28853	36037	44650	54875	66892	80873	96966	115293	135931	158903	184168

	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr
Cumulative number of cases																								
Rc = 3%	19075	19170																						
Rc = 2%	43418	43852	44071	44292	44513	44736	44959																	
Rc = 1.5%	94173	97846	100195	101196	102208	103231	104263	105305	105832	106361	106893	107427	107965											
Rc = 1.25%	141988	154625	166454	177107	186228	193491	198619	201399	203413	205447	207502	209577	211673	212731	213795	214864	215938	217018						
Rc = 1%	211610	241023	272115	304497	337687	371118	404148	436075	466165	493668	517858	538054	553658	564177	569819	575517	581273	587085	592956	595921	598901	601895	604905	607929



	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar
Cumulative number of cases	3675	4599	5813	7272	9367	12327	15320				
Rc = 3%		4811	6153	7685	9368	11138	12909	14574	16017	17123	17790
Rc = 2%		4847	6297	8053	10139	12563	15314	18361	21648	25090	28577
Rc = 1.5%		4866	6369	8242	10541	13324	16642	20536	25033	30140	35837
Rc = 1.25%		4875	6406	8337	10746	13718	17339	21700	26886	32976	40033
Rc = 1%		4884	6442	8433	10954	14120	18059	22917	28853	36037	44650

Figure 6 Prediction and real evolution in Germany



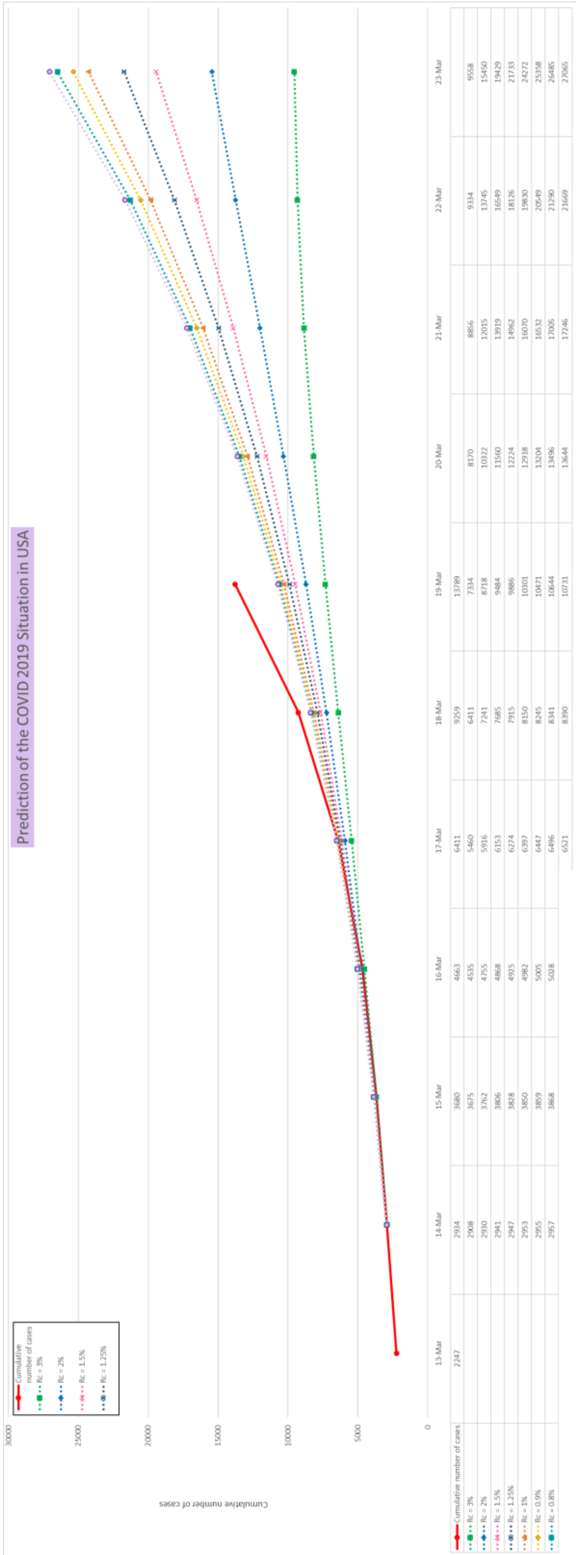


Figure 7 Prediction and real evolution in USA