

A novel bidirectional LSTM deep learning approach for COVID-19 forecasting

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Supplementary Material 1 - All 190 countries and their respective performance with Models 1 and 2

Supplementary Material 2 - Countries which did better under Model 1/Model 2

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Supplementary Material 1: All 190 countries and their respective performance with Models 1 and 2

		Model 1					Model 2			
S/N	country	Ground Truth	Prediction	MAE	RMSE	Percentage Error	Prediction	MAE	RMSE	Percentage Error
1	Afghanistan	1,691	2,389	47	53	41%	2,521	50	55	49%
2	Albania	15,749	13,294	175	206	16%	13,522	161	201	14%
3	Algeria	5,682	5,074	66	81	11%	4,877	38	44	14%
4	Andorra	1,448	926	33	42	36%	950	33	42	34%
5	Angola	1,730	1,807	39	49	4%	1,479	28	39	15%
6	AntiguaandBarbuda	67	5	3	5	107%	6	3	5	109%
7	Argentina	223,887	186,544	2,477	2,937	17%	179,534	2,402	3,031	20%
8	Armenia	5,611	4,430	91	115	21%	10,425	213	245	86%
9	Australia	236	684	24	28	190%	362	15	18	53%
10	Austria	37,605	51,397	802	994	37%	30,227	725	848	20%
11	Azerbaijan	6,802	4,679	453	631	31%	24,850	785	825	265%
12	Bahamas	205	325	10	11	59%	139	8	12	32%
13	Bahrain	8,027	9,617	119	169	20%	7,248	70	93	10%
14	Bangladesh	14,449	20,589	270	316	42%	26,616	529	567	84%

15	Barbados	765	191	30	48	75%	145	32	49	81%
16	Belarus	39,735	42,034	200	305	6%	36,784	277	318	7%
17	Belgium	49,450	48,658	681	792	2%	46,489	610	760	6%
18	Belize	706	1,598	39	43	126%	1,729	44	48	145%
19	Benin	589	5	26	52	99%	3	26	52	99%
20	Bhutan	88	135	6	9	53%	86	4	8	2%
21	Bolivia	45,681	23,842	978	1,170	48%	22,848	995	1,146	50%
22	BosniaandHerzegovina	6,577	3,342	272	385	49%	9,879	245	303	50%
23	Botswana	5,243	855	245	446	84%	373	236	455	93%
24	Brazil	1,191,023	924,402	18,811	19,659	22%	927,888	18,078	18,908	22%
25	Brunei	7	1	0	1	82%	2	0	1	126%
26	Bulgaria	10,736	19,015	452	634	77%	19,466	410	516	81%
27	BurkinaFaso	2,816	3,231	57	73	15%	3,247	80	99	15%
28	Burma	10,662	13,404	150	202	26%	13,641	133	168	28%
29	Burundi	747	69	30	38	91%	64	30	39	91%
30	CaboVerde	1,833	1,011	36	41	45%	756	48	53	59%

31	Cambodia	79	26	3	5	68%	23	3	5	71%
32	Cameroon	2,769	15	123	377	101%	606	140	370	78%
33	Canada	133,537	170,835	1,756	2,055	28%	183,175	2,168	2,538	37%
34	Central African Republic	12	120	5	5	897%	4	2	3	63%
35	Chad	957	386	25	31	60%	299	29	34	69%
36	Chile	93,728	60,041	1,465	1,526	36%	70,391	1,015	1,120	25%
37	China	3,501	1,700	78	91	51%	1,704	79	92	51%
38	Colombia	339,316	272,388	3,587	4,016	20%	277,990	3,249	3,907	18%
39	Comoros	1,676	12	72	98	99%	61	71	96	96%
40	Congo Brazzaville	760	165	38	116	78%	98	36	117	87%
41	Congo Kinshasa	3,802	3,882	67	97	2%	2,653	68	102	30%
42	Costa Rica	15,662	26,983	669	808	72%	28,728	719	851	83%
43	Cote d'Ivoire	5,145	1,497	164	192	71%	1,160	177	204	77%
44	Croatia	14,480	5,260	426	528	64%	33,766	839	920	133%
45	Cuba	12,863	7,126	261	304	45%	6,495	283	360	50%
46	Cyprus	4,202	13,191	391	421	214%	10,881	291	315	159%

47	Czechia	175,173	274,800	4,782	5,854	57%	153,931	2,441	2,753	12%
48	Denmark	19,986	40,165	905	990	101%	46,316	1,156	1,233	132%
49	Djibouti	67	-	2	3	103%	-	1	3	102%
50	Dominica	11	-	1	1	109%	-	1	1	108%
51	DominicanRepublic	35,522	19,335	704	777	46%	18,615	735	812	48%
52	Ecuador	31,680	19,851	730	1,068	37%	21,343	709	1,051	33%
53	Egypt	18,141	28,787	463	494	59%	26,395	359	397	45%
54	ElSalvador	6,711	2,106	290	382	69%	3,739	277	342	44%
55	EquatorialGuinea	227	-	79	13	135%	-	143	16	163%
56	Eritrea	579	142	26	52	75%	42	25	54	93%
57	Estonia	11,671	11,941	147	163	2%	11,411	152	175	2%
58	Eswatini	4,736	5,104	77	89	8%	3,602	93	109	24%
59	Ethiopia	10,078	8,203	118	152	19%	9,177	113	153	9%
60	Fiji	2	0	0	0	92%	-	1	0	139%
61	Finland	7,170	4,780	113	144	33%	6,144	97	114	14%
62	France	451,177	312,163	11,397	14,419	31%	276,680	12,842	14,312	39%

63	Gabon	1,054	264	47	72	75%	264	48	72	75%
64	Gambia	252	17	11	18	93%	33	10	18	87%
65	Georgia	22,083	38,530	759	952	74%	44,744	1,021	1,205	103%
66	Germany	320,021	227,119	6,779	8,649	29%	315,722	6,583	8,395	1%
67	Ghana	11,549	1,106	493	684	90%	1,918	470	648	83%
68	Greece	13,463	16,378	221	291	22%	17,724	224	297	32%
69	Grenada	21	7	1	2	67%	- 3	1	3	114%
70	Guatemala	17,440	13,261	398	458	24%	13,634	382	441	22%
71	Guinea	642	551	17	22	14%	597	18	21	7%
72	GuineaBissau	179	- 36	9	24	120%	- 24	9	24	113%
73	Guyana	1,172	425	33	39	64%	464	32	37	60%
74	Haiti	1,330	157	56	75	88%	59	56	76	96%
75	Honduras	22,286	7,874	627	660	65%	7,281	652	688	67%
76	Hungary	29,843	35,489	558	746	19%	43,916	694	871	47%
77	Iceland	135	307	9	11	127%	391	12	15	190%
78	India	344,193	334,051	3,728	5,324	3%	295,560	3,453	5,578	14%

79	Indonesia	269,974	187,557	3,583	3,921	31%	182,837	3,789	4,146	32%
80	Iran	143,485	138,544	533	650	3%	155,993	606	737	9%
81	Iraq	18,212	15,272	193	225	16%	11,969	289	346	34%
82	Ireland	60,663	15,082	2,018	2,524	75%	6,378	2,360	2,716	89%
83	Israel	166,078	194,961	2,544	3,117	17%	120,102	2,618	3,428	28%
84	Italy	315,142	347,217	3,566	4,100	10%	349,663	2,893	3,616	11%
85	Jamaica	2,242	1,400	42	53	38%	1,631	36	46	27%
86	Japan	115,219	88,893	1,538	1,877	23%	101,728	1,591	1,812	12%
87	Jordan	21,692	31,580	455	501	46%	43,742	959	997	102%
88	Kazakhstan	28,161	19,038	415	505	32%	23,290	301	369	17%
89	Kenya	2,819	8,046	227	261	185%	7,186	190	204	155%
90	KoreaSouth	10,509	11,353	160	200	8%	14,003	218	260	33%
91	Kosovo	6,954	3,305	280	368	52%	5,416	221	286	22%
92	Kuwait	11,784	7,411	195	212	37%	9,782	97	121	17%
93	Kyrgyzstan	2,597	658	108	134	75%	658	144	163	125%
94	Laos	3	2	0	1	24%	2	0	1	46%

95	Latvia	18,459	20,573	285	368	11%	17,689	230	280	4%
96	Lebanon	90,913	72,354	1,231	1,639	20%	87,730	896	1,136	4%
97	Lesotho	3,494	102	150	262	97%	195	149	260	94%
98	Liberia	160	12	7	21	108%	49	7	20	69%
99	Libya	14,629	11,640	314	373	20%	11,859	299	351	19%
100	Liechtenstein	182	467	13	14	157%	443	11	12	143%
101	Lithuania	26,000	46,601	1,022	1,097	79%	47,529	1,082	1,160	83%
102	Luxembourg	2,644	4,276	126	147	62%	4,865	119	145	84%
103	Madagascar	1,298	35	61	136	103%	267	68	145	121%
104	Malawi	16,038	598	674	744	96%	751	667	738	95%
105	Malaysia	83,851	49,767	1,566	1,890	41%	48,730	1,527	1,817	42%
106	Maldives	1,801	792	45	55	56%	730	47	58	59%
107	Mali	579	1,319	33	37	128%	915	20	22	58%
108	Malta	3,936	3,152	42	49	20%	2,942	46	57	25%
109	MarshallIslands	-	0	0	0	NA	0	0	0	NA
110	Mauritania	1,283	1,542	42	48	20%	2,458	52	59	92%

111	Mauritius	30	11	2	3	65%	8	1	3	75%
112	Mexico	356,329	240,925	5,884	6,907	32%	240,771	5,657	6,637	32%
113	Micronesia	1	0	0	0	106%	0	0	0	113%
114	Moldova	11,135	13,038	223	266	17%	18,292	311	369	64%
115	Monaco	448	429	12	15	4%	308	10	13	31%
116	Mongolia	406	324	7	10	20%	272	8	10	33%
117	Montenegro	10,063	10,039	56	68	0%	10,692	66	78	6%
118	Morocco	20,936	37,287	711	857	78%	34,807	603	677	66%
119	Mozambique	18,172	2,243	693	729	88%	2,570	678	715	86%
120	MSZaandam	-	1	0	0	NA	1	0	0	NA
121	Namibia	6,689	8,107	111	136	21%	5,846	85	110	13%
122	Nepal	6,800	812	351	398	112%	4,430	172	223	35%
123	Netherlands	121,012	161,613	1,773	2,067	34%	176,486	2,596	2,884	46%
124	NewZealand	116	16	5	8	86%	42	5	8	64%
125	Nicaragua	156	5	7	19	103%	37	8	19	124%
126	Niger	770	1,116	23	27	45%	1,212	24	32	57%

127	Nigeria	33,764	24,291	561	728	28%	13,225	893	984	61%
128	NorthMacedonia	7,099	10,355	158	211	46%	10,632	169	210	50%
129	Norway	8,490	12,295	199	235	45%	12,205	185	210	44%
130	Oman	4,256	4,053	155	212	5%	4,601	144	184	8%
131	Pakistan	46,911	54,106	501	582	15%	46,709	437	539	0%
132	Panama	47,342	76,302	1,421	1,683	61%	67,771	1,048	1,150	43%
133	PapuaNewGuinea	40	- 8	2	4	120%	- 5	2	4	111%
134	Paraguay	19,233	19,666	221	267	2%	20,481	161	187	6%
135	Peru	112,059	39,658	4,718	6,245	65%	1,815	5,026	7,118	98%
136	Philippines	41,766	27,844	605	686	33%	21,242	892	953	49%
137	Poland	147,740	221,857	3,531	4,644	50%	245,252	4,240	4,807	66%
138	Portugal	253,807	103,978	6,514	7,041	59%	127,786	5,479	6,288	50%
139	Qatar	5,869	12,359	286	312	111%	5,501	51	63	6%
140	Romania	64,944	99,682	1,512	1,670	53%	101,520	1,602	1,769	56%
141	Russia	487,185	512,598	2,285	2,749	5%	528,872	2,483	2,967	9%
142	Rwanda	5,936	2,995	130	161	50%	2,630	147	172	56%

143	SaintKittsandNevis	3	- 1	0	0	133%	1	0	0	60%
144	SaintLucia	800	44	33	47	94%	67	34	46	92%
145	SaintVincentandtheGrenadines	752	3	33	49	100%	- 2	33	49	100%
146	SanMarino	397	805	19	22	103%	890	24	34	124%
147	SaoTomeandPrincipe	203	2	9	11	99%	14	8	11	93%
148	SaudiArabia	4,492	584	170	189	87%	1,625	128	142	64%
149	Senegal	5,851	3,150	118	135	46%	3,715	99	112	37%
150	Serbia	39,138	58,724	1,063	1,442	50%	68,412	1,346	1,482	75%
151	Seychelles	754	28	32	52	96%	18	32	53	98%
152	SierraLeone	811	220	27	41	73%	158	29	43	81%
153	Singapore	700	699	17	22	0%	996	17	21	42%
154	Slovakia	48,749	49,781	709	897	2%	47,859	709	867	2%
155	Slovenia	29,844	40,091	571	748	34%	45,153	752	927	51%
156	SolomonIslands	-	- 0	0	0	NA	1	0	0	NA
157	Somalia	58	- 3	3	8	106%	- 17	4	8	129%
158	SouthAfrica	261,191	300,036	4,753	5,618	15%	247,097	3,904	5,098	5%

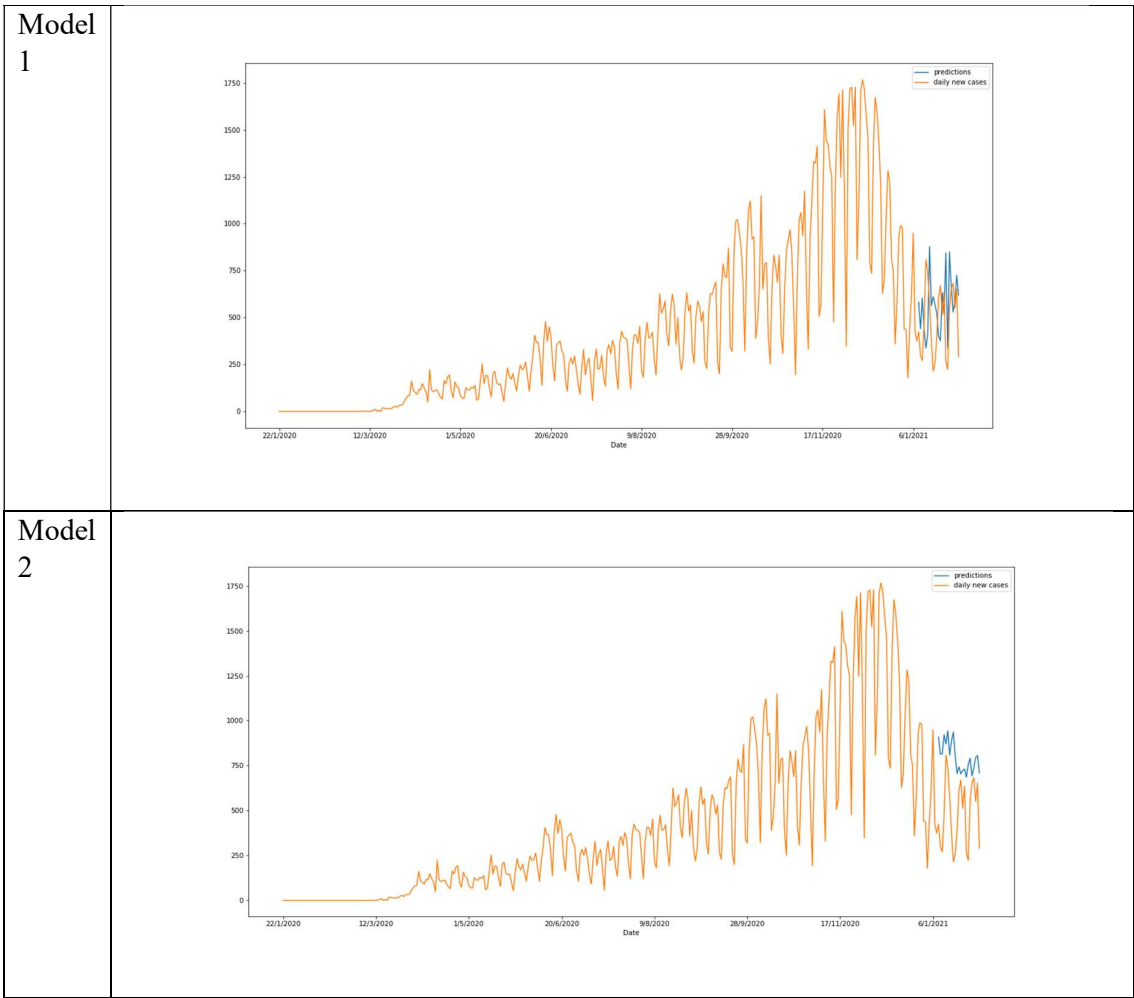
159	SouthSudan	340	50	15	34	85%	1	15	35	100%
160	Spain	692,759	256,826	26,974	33,565	63%	205,444	28,834	35,293	70%
161	SriLanka	16,852	12,418	199	227	26%	13,400	157	197	20%
162	Sudan	3,101	3,742	157	256	21%	3,566	153	264	15%
163	Suriname	1,584	1,010	26	32	36%	888	30	36	44%
164	Sweden	77,486	40,482	3,216	4,361	48%	23,315	3,278	4,853	70%
165	Switzerland	43,337	79,678	1,894	2,196	84%	125,957	3,740	4,148	191%
166	Syria	1,869	2,224	18	23	19%	2,438	25	31	30%
167	Taiwan	86	70	2	3	19%	66	2	3	24%
168	Tajikistan	3	511	22	22	16928%	502	22	22	16633%
169	Tanzania	-	23	1	1	NA	29	1	1	NA
170	Thailand	9,565	1,216	376	550	87%	1,241	376	550	87%
171	TimorLeste	21	- 1	1	2	103%	0	1	2	99%
172	Togo	1,180	574	32	47	51%	770	30	45	35%
173	TrinidadandTobago	345	375	6	7	9%	- 562	39	42	263%
174	Tunisia	53,982	50,503	657	865	6%	44,824	656	870	17%

175	Turkey	169,882	452,440	12,285	12,434	166%	147,561	1,687	2,007	13%
176	Uganda	2,283	8,792	289	302	285%	6,576	203	224	188%
177	Ukraine	121,746	143,264	1,580	1,851	18%	156,017	1,975	2,231	28%
178	UnitedArabEmirates	78,905	32,988	1,996	2,021	58%	36,719	1,834	1,871	53%
179	UnitedKingdom	861,939	1,373,007	27,386	32,037	59%	836,075	13,602	17,024	3%
180	UnitedStates	4,224,535	5,028,886	44,250	52,940	19%	5,011,509	47,506	55,796	19%
181	Uruguay	17,399	22,202	317	354	28%	13,521	215	308	22%
182	Uzbekistan	1,226	797	90	99	165%	179	61	70	115%
183	Vanuatu	-	0	0	0	NA	0	0	0	NA
184	Venezuela	11,260	4,645	288	301	59%	5,366	256	273	52%
185	Vietnam	305	101	13	31	67%	91	13	31	70%
186	WestBankandGaza	12,888	22,651	424	463	76%	23,776	473	490	84%
187	WesternSahara	-	0	0	0	NA	0	0	0	NA
188	Yemen	17	2	1	1	115%	13	1	2	175%
189	Zambia	28,891	6,258	984	1,030	78%	4,128	1,077	1,120	86%
190	Zimbabwe	13,728	17,814	650	754	30%	6,953	469	556	49%

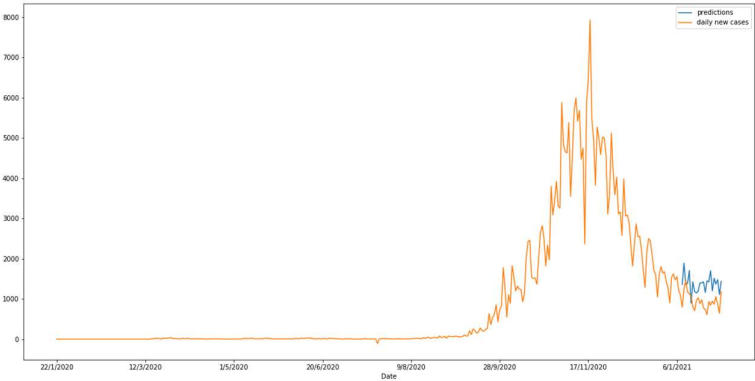
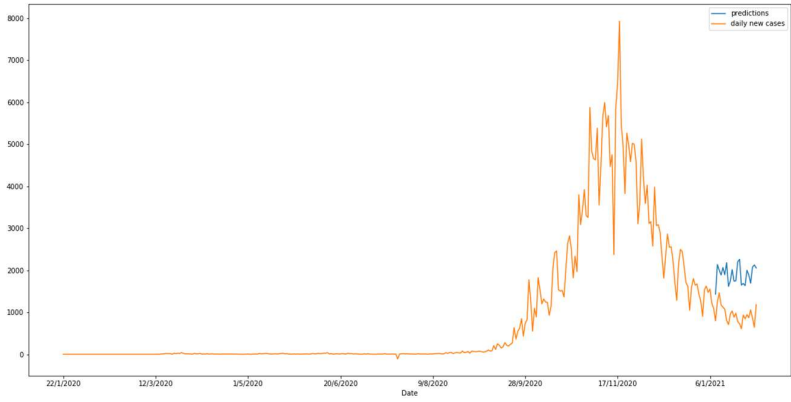
Supplementary Material 2: Countries which did better under Model 1/Model 2

Better performance using Model 1 – Moldova, Jordan, Croatia, Switzerland

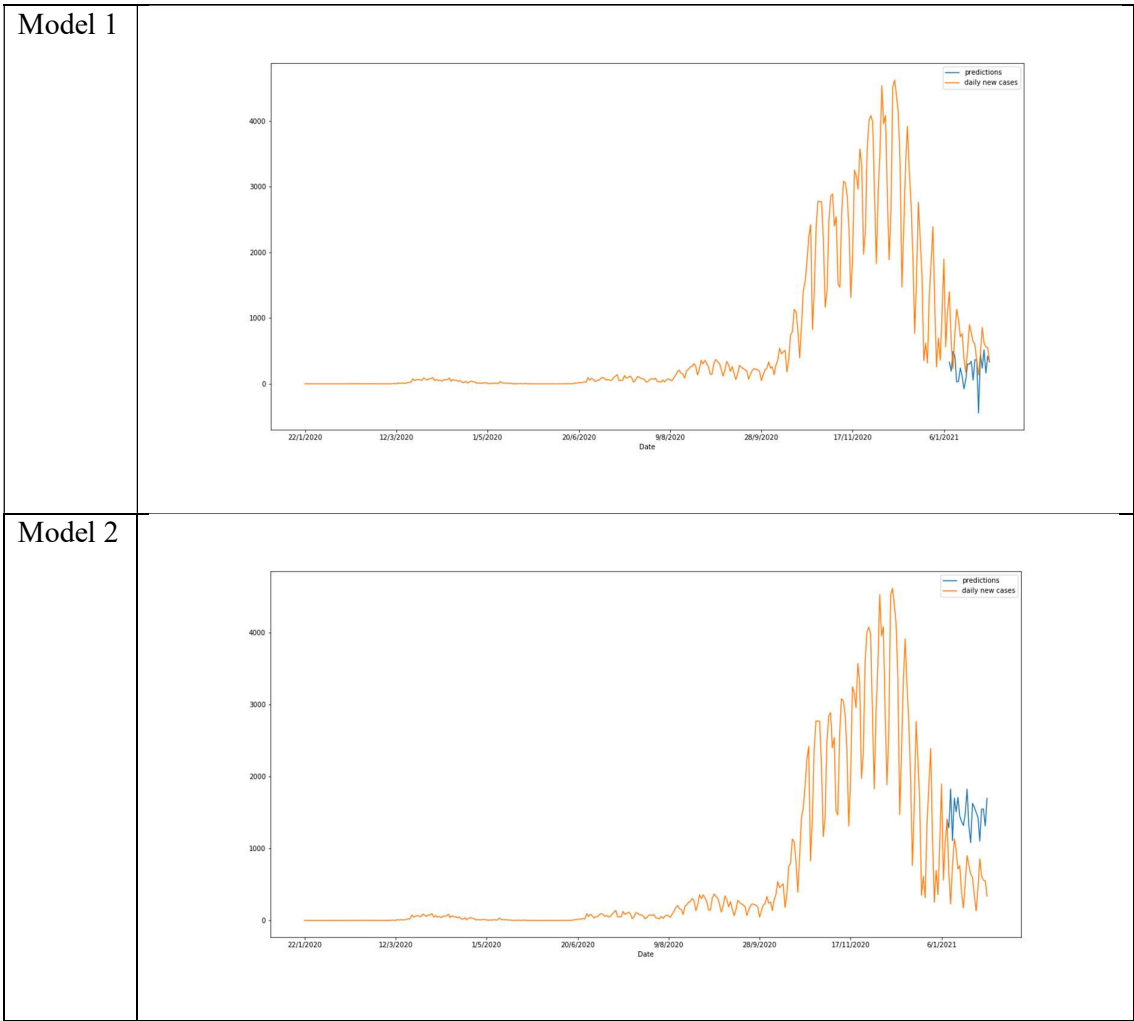
Moldova



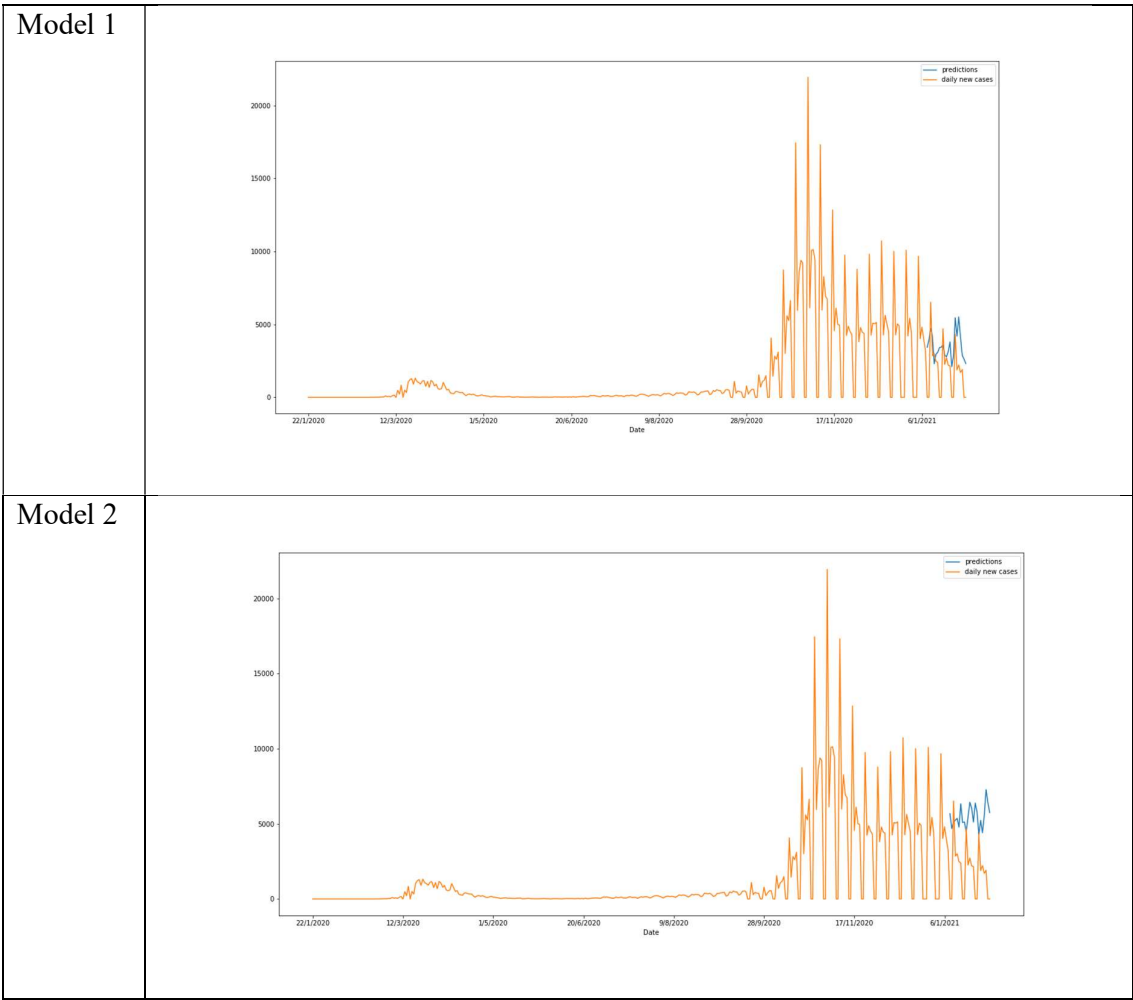
Jordan

Model 1	 The graph for Model 1 displays daily new cases (orange line) and predictions (blue line) from January 2020 to June 2021. The y-axis represents the number of cases, ranging from 0 to 8000. The x-axis shows dates from 22/1/2020 to 6/1/2021. The data shows a significant peak in daily new cases around November 2020, reaching nearly 8000. The predictions closely follow the actual data, showing a similar peak and subsequent decline.
Model 2	 The graph for Model 2 displays daily new cases (orange line) and predictions (blue line) from January 2020 to June 2021. The y-axis represents the number of cases, ranging from 0 to 8000. The x-axis shows dates from 22/1/2020 to 6/1/2021. The data shows a significant peak in daily new cases around November 2020, reaching nearly 8000. The predictions closely follow the actual data, showing a similar peak and subsequent decline.

Croatia

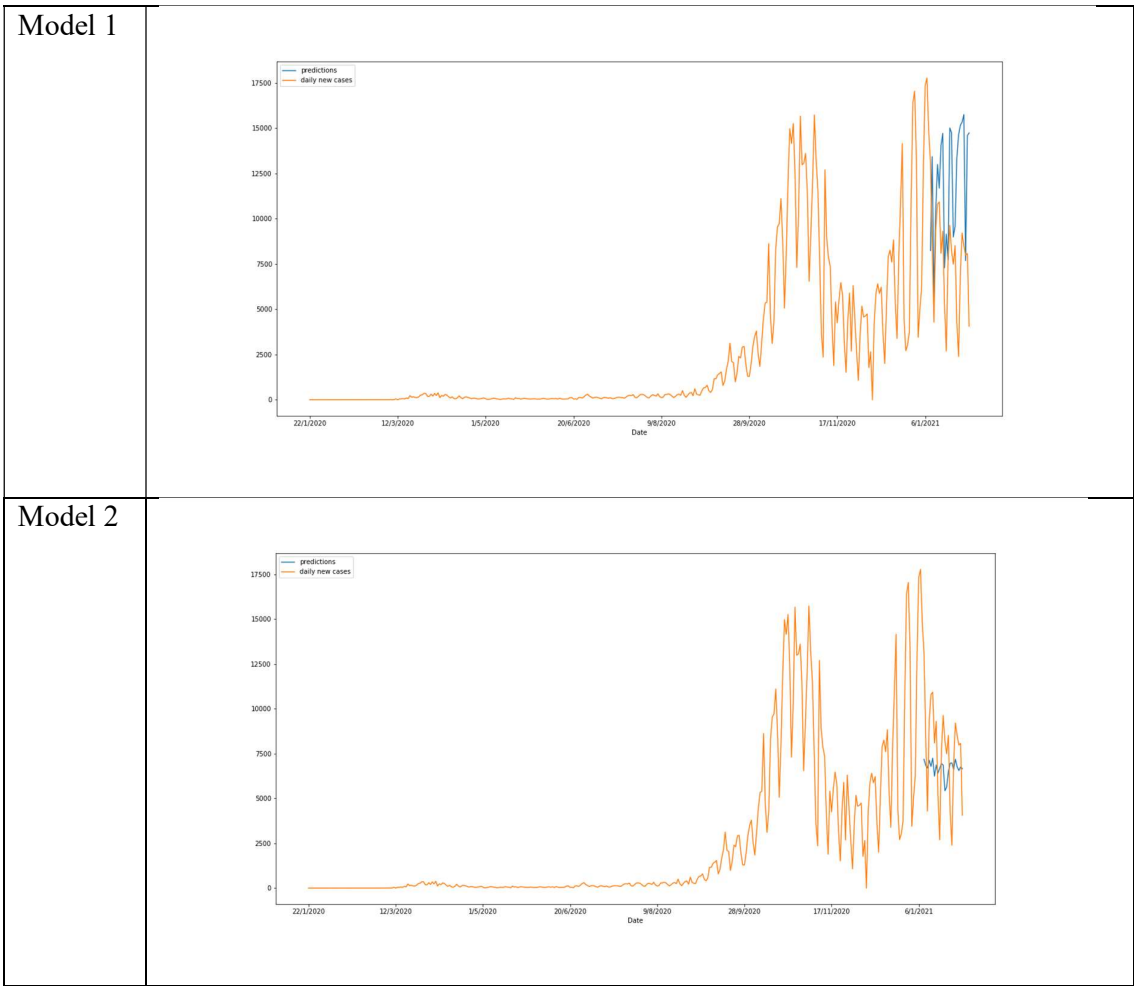


Switzerland

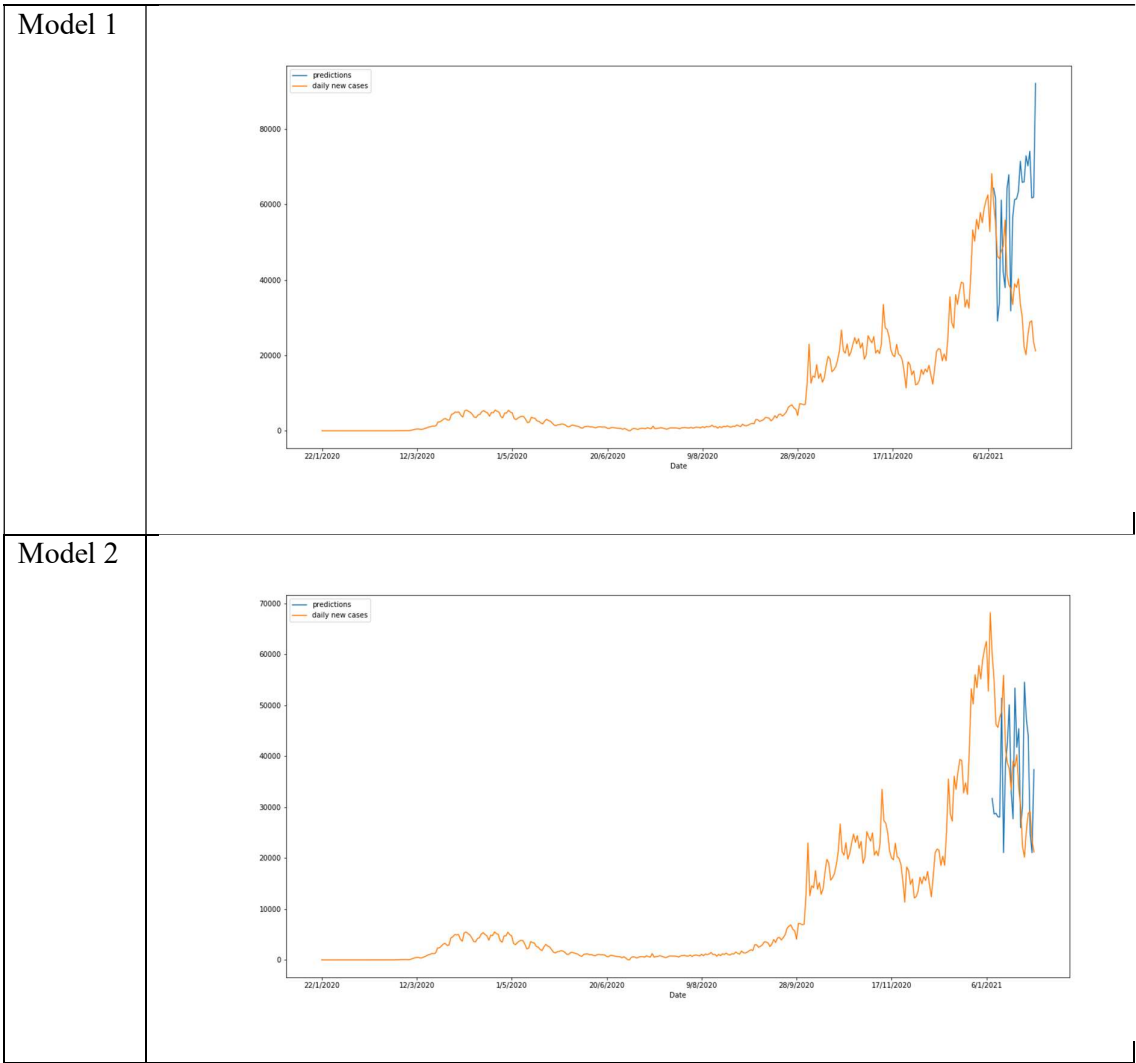


Better performance using Model 2 – Czechia, UK, Turkey, Germany

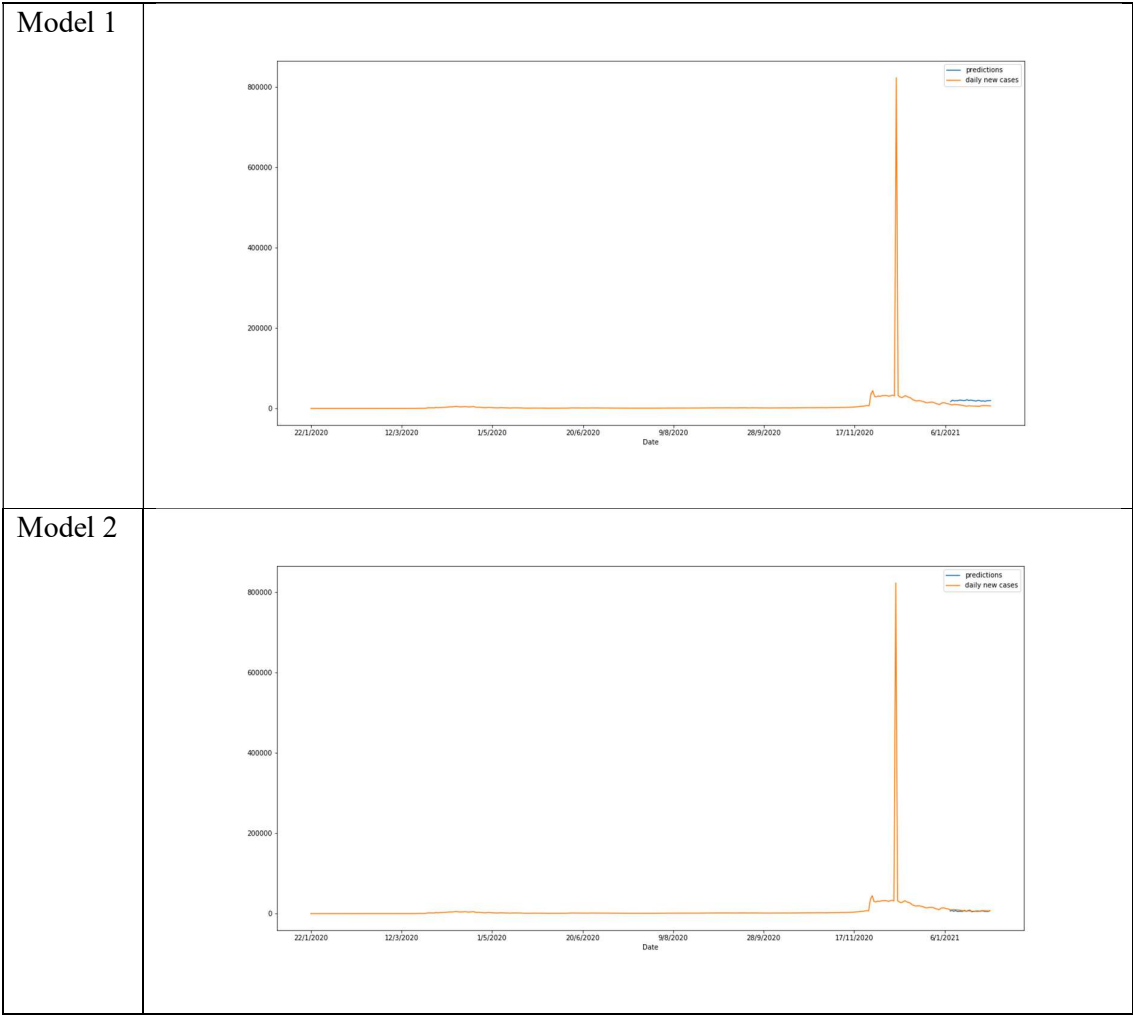
Czechia



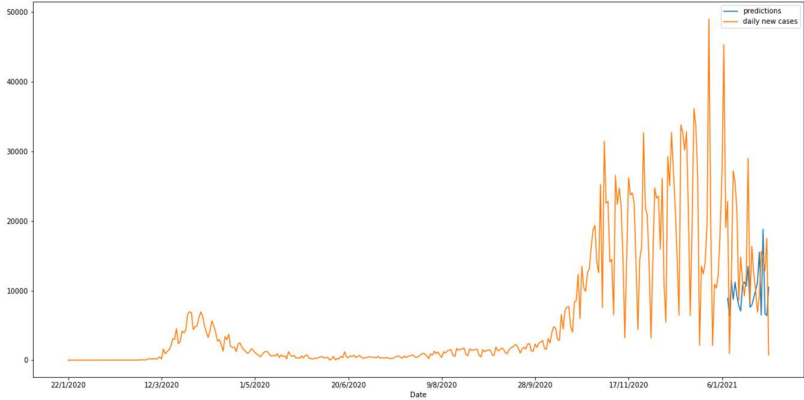
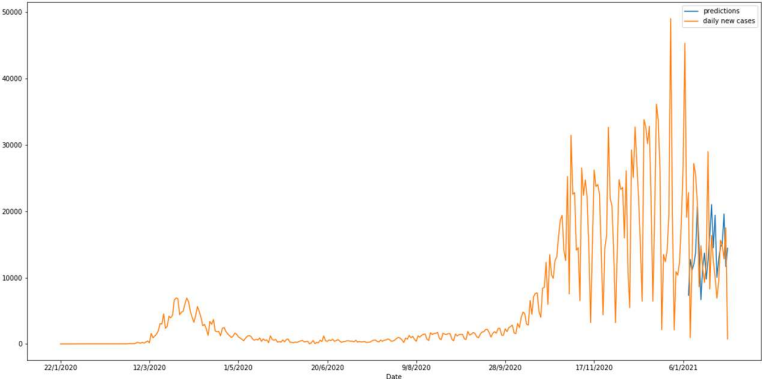
UK



Turkey



Germany

Model 1	 This line chart for Model 1 displays daily new cases (orange line) and predictions (blue line) in Germany. The x-axis represents the date from 22/1/2020 to 6/1/2021, with major ticks every 5 days. The y-axis represents the number of cases, ranging from 0 to 50,000 in increments of 10,000. The orange line shows a small peak of approximately 8,000 cases in mid-March 2020, followed by a period of low activity until late September. A significant surge begins in late September, reaching a peak of nearly 50,000 cases in early December 2020, followed by high-frequency, high-amplitude oscillations between 10,000 and 40,000 cases through January 2021. The blue prediction line follows the general trend of the orange line but is only visible for the most recent data points, showing a sharp decline from the peak in December.
Model 2	 This line chart for Model 2 displays daily new cases (orange line) and predictions (blue line) in Germany. The x-axis represents the date from 22/1/2020 to 6/1/2021, with major ticks every 5 days. The y-axis represents the number of cases, ranging from 0 to 50,000 in increments of 10,000. The orange line shows a small peak of approximately 8,000 cases in mid-March 2020, followed by a period of low activity until late September. A significant surge begins in late September, reaching a peak of nearly 50,000 cases in early December 2020, followed by high-frequency, high-amplitude oscillations between 10,000 and 40,000 cases through January 2021. The blue prediction line follows the general trend of the orange line but is only visible for the most recent data points, showing a sharp decline from the peak in December.