

“28. Analysis of COVID-2019 Data on 2/28/2020” by Michael Levitt, Stanford University, USA

Contrary to the prevailing world concern, the COVID-19 epidemic is almost all over in China. Today's analysis uses WHO data for the past 37 days to confirm trends we have shown in reports going back to 1-Feb. We separate Hubei from non-Hubei as most cases and deaths have occurred in Hubei (**Fig. 2**). We estimate there will be 3,200 total Hubei deaths and less than 120 non-Hubei deaths in China. There will be 66,000 Hubei cases with a Hubei death rate of 4.7% (1% on Day 0 after being classified as a case; 2.4% on Days 8 & 9, the remaining 1% after day 14, **Fig. 5**). There will be 13,000 non-Hubei cases in China with a death rate of 0.85%. China Non-Hubei deaths seem to occur after 10 days, very similar to the 9 day delay most common for Hubei deaths.

As soon as it seemed possible that the epidemic was close to being over in China (Hubei and non-Hubei), which was by far hit hardest with 94% of the deaths, concern was focused on the Diamond Princess cruise ship. In many ways, this ship provides a worse-case test scenario. There were 705 cases and 4 deaths for the 2,600 passengers and 1,100 crew, who were kept on a ship 290m x 37m in size, a population density of 250,000 per square km (37 times that of Hong Kong). These passengers are older than the general population (200 were over 80 years). The passengers were tested for COVID-19 daily using PCR (polymerase chain reaction), a sensitive DNA amplification method that detects minuscule levels of virus. This led to the 19% infection rate (705/3,700), which shows that if we want to test the world's population each day, we may eventually reach this level of infection. A super-sensitive molecular-detection method like PCR find signs of the virus on people who are neither sick nor able to infect others. Four deaths, some of people older than 80, gives a death rate of 0.1% (4/3,700) in a month. By comparison, in the USA, for people 80 and over, the death rate is 11% per year or 0.9% per month. This would mean 2 deaths a month amongst 200 passengers over 80. If there are no further COVID-19 deaths amongst the Diamond Princess passengers, it seems we need not worry about this disease causing widespread death worse than influenza.

As data accumulates on Non-China cases, we turn our attention to their analysis. This data is very noisy as expected for the early phase and comes from different countries. Preliminary analysis (**Fig. 7**) shows no signs of slowing exponential growth of cases or deaths. More work is needed and we hope that detailed analysis of the epidemic in China will help the rest of the world.

For now, I raise questions for experts who may read this analysis.

- (1) Why do most deaths in China tend to occur after 9 or 10 days from infection (**Figs. 3,4 & 5**)
- (2) Why do Hubei cases have a 1% death rate on the day case in confirmed whereas Non-Hubei cases do not (**Fig. 5**)
- (3) Why do China Non-Hubei cases and deaths both peak three days before those in Hubei? Is the explanation in **Fig. 6** crazy?
- (4) Why do death rates in different countries differ so much (**Fig. 7**). Do the high rates in Iran mean only the very ill are examined?
- (5) Did the epidemic in China slow due to stringent quarantine or rise of immunity in many of those infected but never detected as a case? Can an epidemic be stopped if we use social distancing to contact with fewer people without strict quarantine?
- (6) Could certain individuals be naturally immune due to their individual antibody repertoires?
- (7) Is what happened on the Diamond Princess a good model for what a world pandemic would be (20% infection rate, 0.1% death rate in over 65-year olds). A big unknown is the role of social distancing on the ship?

Date	Day	Total Number Cases					Total Number Deaths			Death Rate (%)			Ratio Hubei/Others	Fraction Change Cases			Fraction Change Deaths			New/Day in Hubei		Non-China	
		Total-LC	Total-L	Hubei-LC	Hubei-L	Others	Total	Hubei	Others	Total	Hubei	Others		Total	Hubei	Others	Total	Hubei	Others	Cases	Deaths	Cases	Deaths
1/22/2020	54	421	314	358	251	63	6	6	0	1.42%	1.67%	0.00%	-	1.780	1.573	2.961	2.843	2.676	-	205	10	5	0
1/23/2020	55	750	581	564	395	186	17	16	1	2.28%	2.85%	0.54%	5.3	1.780	1.573	2.961	2.843	2.676	-	205	10	10	0
1/24/2020	56	1057	846	704	494	352	25	23	2	2.37%	3.28%	0.57%	5.8	1.410	1.249	1.895	1.470	1.437	2.000	141	7	16	0
1/25/2020	57	1631	1320	1040	729	591	41	38	3	2.51%	3.65%	0.51%	7.2	1.544	1.477	1.677	1.633	1.645	1.500	336	15	23	0
1/26/2020	58	2462	2014	1497	1049	965	56	52	4	2.27%	3.47%	0.41%	8.4	1.509	1.440	1.632	1.367	1.370	1.333	457	14	29	0
1/27/2020	59	3407	2798	2034	1425	1373	80	76	4	2.35%	3.74%	0.29%	12.8	1.384	1.358	1.423	1.429	1.462	1.000	536	24	37	0
1/28/2020	60	5786	4595	3979	2788	1807	106	99	7	1.83%	2.49%	0.39%	6.4	1.698	1.956	1.316	1.326	1.303	1.750	1945	23	56	0
1/29/2020	61	7587	6065	5087	3565	2500	132	125	7	1.74%	2.46%	0.28%	8.8	1.311	1.279	1.384	1.245	1.262	1.000	1108	26	68	0
1/30/2020	62	9785	7818	6574	4607	3211	170	162	8	1.74%	2.46%	0.25%	9.9	1.290	1.292	1.284	1.288	1.296	1.143	1487	37	82	0
1/31/2020	63	12318	9826	8328	5836	3990	213	204	9	1.73%	2.45%	0.23%	10.9	1.259	1.267	1.243	1.253	1.259	1.125	1754	42	106	0
2/1/2020	64	15163	11953	10727	7517	4436	259	249	10	1.71%	2.32%	0.23%	10.3	1.231	1.288	1.112	1.216	1.221	1.111	2399	45	132	0
2/2/2020	65	18467	14557	13066	9156	5401	304	294	10	1.65%	2.25%	0.19%	12.2	1.218	1.218	1.217	1.174	1.181	1.000	2339	45	146	0
2/3/2020	66	22201	17391	16074	11264	6127	362	350	12	1.63%	2.18%	0.20%	11.1	1.202	1.230	1.135	1.191	1.190	1.200	3007	56	153	1
2/4/2020	67	26434	20630	19398	13593	7037	426	413	13	1.61%	2.13%	0.18%	11.6	1.191	1.207	1.148	1.177	1.180	1.081	3324	63	159	1
2/5/2020	68	31731	24554	23986	16809	7745	492	478	14	1.55%	1.99%	0.18%	11.0	1.200	1.237	1.101	1.155	1.157	1.077	4589	65	191	1
2/6/2020	69	36717	28276	28208	19767	8509	565	549	16	1.54%	1.95%	0.19%	10.4	1.157	1.176	1.099	1.148	1.148	1.145	4222	71	216	1
2/7/2020	70	41191	31481	32450	22740	8741	638	621	17	1.55%	1.91%	0.20%	9.8	1.122	1.150	1.027	1.129	1.131	1.067	4242	72	270	1
2/8/2020	71	45610	34886	35838	25114	9772	724	698	26	1.59%	1.95%	0.27%	7.3	1.107	1.104	1.118	1.135	1.124	1.521	3389	77	288	1
2/9/2020	72	49217	37558	38962	27304	10254	813	779	34	1.65%	2.00%	0.33%	6.0	1.079	1.087	1.049	1.123	1.116	1.308	3124	81	307	1
2/10/2020	73	53296	40554	42583	29841	10713	910	871	39	1.71%	2.05%	0.36%	5.6	1.083	1.093	1.045	1.119	1.118	1.148	3621	92	319	1
2/11/2020	74	56886	43103	46060	32278	10825	1018	974	44	1.79%	2.11%	0.41%	5.2	1.067	1.082	1.010	1.119	1.118	1.128	3478	103	395	1
2/12/2020	75	59670	45171	48453	33955	11216	1115	1071	44	1.87%	2.21%	0.39%	5.6	1.049	1.052	1.036	1.095	1.099	1.003	2393	97	441	1
2/13/2020	76	61889	46997	49766	34874	12123	1252	1194	58	2.02%	2.40%	0.48%	5.0	1.037	1.027	1.081	1.123	1.115	1.315	1312	124	447	1
2/14/2020	77	64682	49053	52231	36602	12451	1383	1318	65	2.14%	2.52%	0.52%	4.8	1.045	1.050	1.027	1.104	1.103	1.121	2466	124	505	2
2/15/2020	78	66757	50580	54061	37884	12696	1526	1457	69	2.29%	2.70%	0.54%	5.0	1.032	1.035	1.020	1.103	1.105	1.062	1829	139	526	2
2/16/2020	79	68442	51857	55424	38839	13018	1669	1595	74	2.44%	2.88%	0.57%	5.1	1.025	1.025	1.025	1.094	1.095	1.072	1363	138	683	3
2/17/2020	80	71429	54019	58182	40772	13247	1775	1696	79	2.48%	2.91%	0.60%	4.9	1.044	1.050	1.018	1.064	1.063	1.068	2758	101	794	3
2/18/2020	81	73332	NA	59989	NA	13343	1873	1789	84	2.55%	2.98%	0.63%	4.7	1.027	1.031	1.007	1.055	1.055	1.063	1807	93	804	3
2/19/2020	82	75204	NA	61682	NA	13522	2009	1921	88	2.67%	3.11%	0.65%	4.8	1.026	1.028	1.013	1.073	1.074	1.048	1693	132	924	3
2/20/2020	83	75748	NA	62031	NA	13717	2129	2029	100	2.81%	3.27%	0.73%	4.5	1.007	1.006	1.014	1.060	1.056	1.136	349	108	1073	8
2/21/2020	84	76769	NA	62662	NA	14107	2247	2144	103	2.93%	3.42%	0.73%	4.7	1.013	1.010	1.028	1.055	1.057	1.030	631	115	1200	8
2/22/2020	85	77794	NA	63454	NA	14340	2359	2250	109	3.03%	3.55%	0.76%	4.7	1.013	1.013	1.017	1.050	1.049	1.058	792	106	1402	11
2/23/2020	86	78811	NA	64084	NA	14727	2462	2346	116	3.12%	3.66%	0.79%	4.6	1.013	1.010	1.027	1.044	1.043	1.064	630	96	1769	17
2/24/2020	87	79331	NA	64287	NA	15044	2618	2495	123	3.30%	3.88%	0.82%	4.7	1.007	1.003	1.022	1.063	1.064	1.060	203	149	2069	23
2/25/2020	88	80239	NA	64786	NA	15453	2700	2563	137	3.36%	3.96%	0.89%	4.5	1.011	1.008	1.027	1.031	1.027	1.114	499	68	2459	34
2/26/2020	89	81109	NA	65187	NA	15922	2762	2615	147	3.41%	4.01%	0.92%	4.3	1.011	1.006	1.030	1.023	1.020	1.073	401	52	2918	44
2/27/2020	90	82294	NA	65596	NA	16698	2804	2641	163	3.41%	4.03%	0.98%	4.1	1.015	1.006	1.049	1.015	1.010	1.109	409	26	3664	57

Table 1. Showing data for New Coronavirus 2019 or COVID-19) from 22 January to 27 February 2020. Total number of cases and deaths is from the World Health Organization website <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/>. Before 13-Feb., the WHO did not give cases and deaths in Hubei so we use data from <https://jobtube.cn/wv/?from=groupmessage&isappinstalled=0>. Starting on 17-Feb., the WHO includes cases clinically diagnosed in addition to those laboratory diagnosed. As no date is given for these cases, we assume that the clinical cases are a fixed percentage of the laboratory cases (46.2%) to get the revised total Hubei cases reported by the WHO on 17-Feb.(58,182). For continuity between old and new data we list Hubei cases as 'Hubei-L' for laboratory diagnosed and 'Hubei-LC' for laboratory and clinically diagnosed. We divide data into Hubei and non-Hubei as most deaths are in an area centered on Wuhan in Hubei (**Fig. 2**). The death rate is the number of deaths divided by the number of cases confirmed, and Ratio Hubei/Others is the ratio of the death rate for Hubei to the death rate for non-Hubei. The fraction change is Value_Today divided by Value_Yesterday. We give the number of new cases and new deaths in Hubei each day (subtracting yesterday from today). We replace the seemingly incorrect WHO value for Hubei deaths on 13-Feb. (1,316) with the average of 12 and 14 Feb. values (1,194) to avoid having 245 new deaths on 13-Feb. but just 2 new deaths on 14-Feb (pink shading). As cases outside China have grown, we add the number of Non-China deaths and cases from the WHO data.

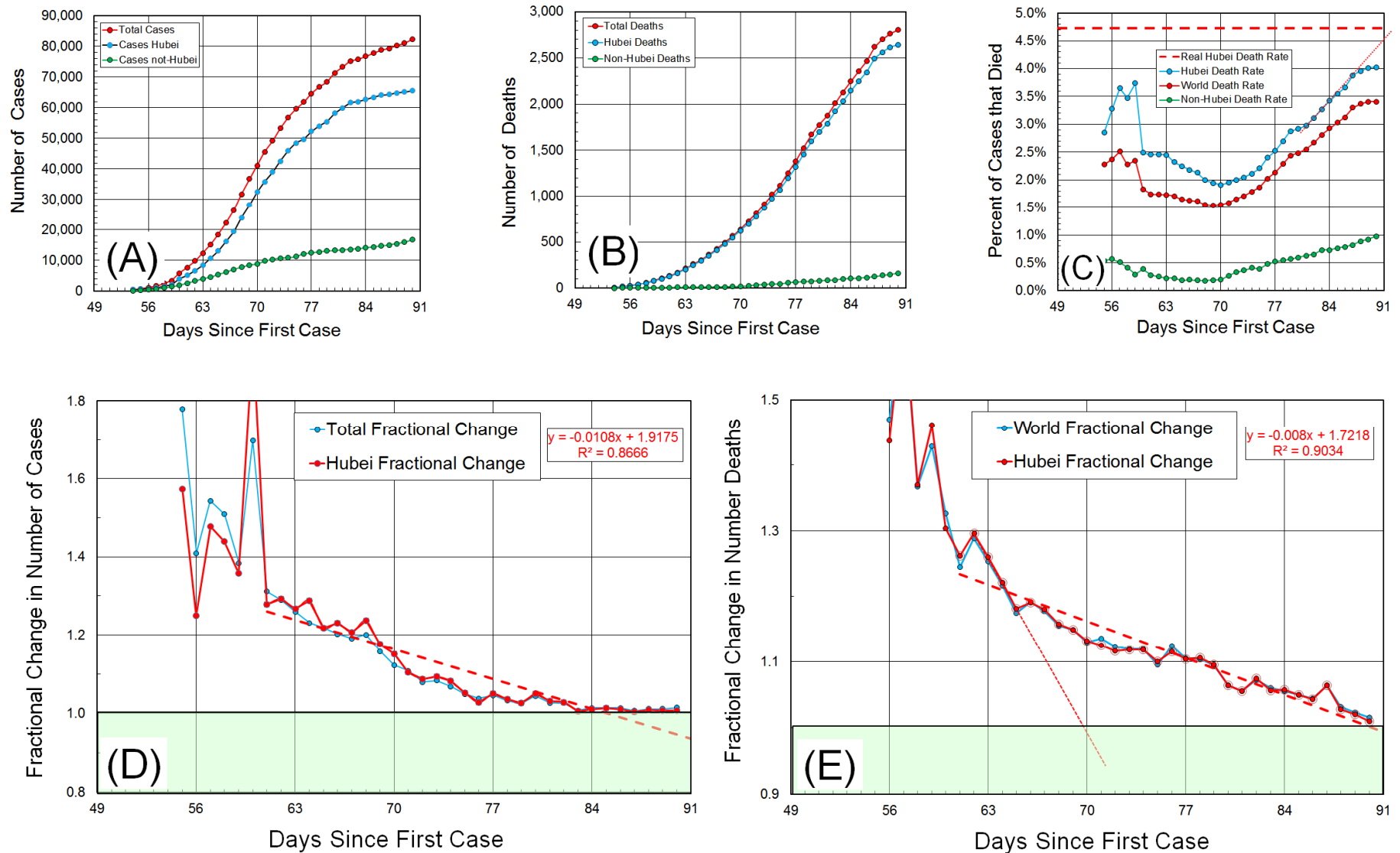


Figure 1. Variation of COVID-19 data against days since 29 Nov 2019 (guessed date of the first case). Data is taken from **Table 1**.

(A) shows a slowing increase in number of cases everywhere. (B) confirms that almost all the deaths are in Hubei. (C) shows that the Hubei death rate initially decreased from 2.5% on 27-Jan. to 1.9% on 7-Feb. only to rise to 4.0% today. Such a rise of the Hubei death rate in (C) makes no sense as the virus is not becoming more virulent. This discrepancy arises because all deaths do not occur on the same day a case is diagnosed. A proper death rate distribution gives a real Hubei death rate of 4.7% (**Fig. 5**). (D) and (E) show that the fractional change in total cases or deaths (Value_Today / Value_Yesterday) is decreasing steadily. In (D) & (E) we add linear trend-lines using data from 1/29/2020. The fractional change for cases and deaths is an excellent fit to a straight line. In (E) we also show a red short-dashed line of the linear fit to the four data points for 31-Dec to 02-Feb; this trend was seen in the first draft of this analysis dated 2/2/20, giving rise to the hope I expressed that the growth of deaths would slow soon.

			16-Feb				12-Feb				6-Feb				4-Feb				2-Feb				31-Jan		
Province or City in Hubei	Population	Deaths / million pop	Cases	Deaths	Death Rate	Death Ratio	Cases	Deaths	Death Rate	Death Ratio	Cases	Deaths	Death Rate	Death Ratio	Cases	Deaths	Death Rate	Death Ratio	Cases	Deaths	Death Rate	Death Ratio	Cases	Deaths	Death Rate
Hubei	58,500,000	29.0	58,182	1696	2.91%	1.44	34,874	1176	3.37%	1.90	22,112	618	2.79%	1.29	16,678	479	2.87%	1.37	11,177	350	3.13%	1.41	7,153	249	3.48%
Wuhan	11,080,000	118.1	41,152	1309	3.18%	1.45	19,558	902	4.61%	1.89	11,618	478	4.11%	1.32	8,351	362	4.33%	1.37	5,142	265	5.15%	1.38	3,215	192	5.97%
Huanggang	7,403,000	10.5	2,831	78	2.76%	1.34	2,441	58	2.38%	1.81	1,897	32	1.69%	1.28	1,645	25	1.52%	1.47	1,246	17	1.36%	1.21	726	14	1.93%
Xiaogan	4,900,000	14.3	3,279	70	2.13%	1.43	2,839	49	1.73%	1.96	2,141	25	1.17%	1.39	1,462	18	1.23%	1.29	918	14	1.53%	1.17	628	12	1.91%
Jingzhou	3,692,000	10.0	1,501	37	2.47%	1.61	1,114	23	2.06%	2.30	885	10	1.13%	1.11	713	9	1.26%	1.50	499	6	1.20%	1.50	287	4	1.39%
Ezhou	1,050,000	33.3	1,274	35	2.75%	1.17	1,010	30	2.97%	1.67	471	18	3.82%	1.00	382	18	4.71%	1.20	306	15	4.90%	1.67	227	9	3.96%
Jingmen	3,023,000	10.9	915	33	3.61%	1.38	725	24	3.31%	1.41	553	17	3.07%	1.06	422	16	3.79%	1.45	345	11	3.19%	2.20	251	5	1.99%
Suizhou	2,500,000	9.6	1,267	24	1.89%	1.71	1,160	14	1.21%	1.56	915	9	0.98%	1.13	706	8	1.13%	1.60	458	5	1.09%	5.00	304	1	0.33%
Yichang	4,060,000	5.9	895	24	2.68%	2.18	810	11	1.36%	1.57	610	7	1.15%	1.75	496	4	0.81%	4.00	392	1	0.26%	1.00	276	1	0.36%
Xiangyang	900,000	22.2	1,155	20	1.73%	1.54	1,101	13	1.18%	4.33	838	3	0.36%		735	2	0.27%		548	0	0.00%		347	0	0.00%
Xiantao	1,175,000	16.2	531	19	3.58%	1.19	478	16	3.35%	3.20	307	5	1.63%	1.25	225	4	1.78%	1.33	169	3	1.78%	3.00	97	1	1.03%
Huangshi	2,450,000	6.1	983	15	1.53%	1.67	899	9	1.00%	4.50	635	2	0.31%	1.00	509	2	0.39%	1.00	334	2	0.60%	1.00	209	2	0.96%
Tianmen	1,731,000	5.8	485	10	2.06%	1.00	336	10	2.98%	1.00	163	10	6.13%	1.00	128	10	7.81%	1.00	115	10	8.70%	1.43	82	7	8.54%
Xianning	2,800,000	3.6	861	10	1.16%	1.43	528	7	1.33%		443	0	0.00%		384	0	0.00%		296	0	0.00%		206	0	0.00%
Qianjiang	1,000,000	6.0	182	6	3.30%	1.20	94	5	5.32%	5.00	74	1	1.35%	1.00	54	1	1.85%	1.00	35	1	2.86%	1.00	27	1	3.70%
Enshi	750,000	5.3	249	4	1.61%	1.33	210	3	1.43%		157	0	0.00%		138	0	0.00%		111	0	0.00%		87	0	0.00%
Shiyan	3,340,000	0.6	612	2	0.33%	2.00	559	1	0.18%		395	0	0.00%		318	0	0.00%		256	0	0.00%		177	0	0.00%
Shennongjia	76,000	0.0	10	0	0.00%		10	0	0.00%		10	0	0.00%		10	0	0.00%		7	0	0.00%		7	0	0.00%

Table 2. Number of cases, number of deaths, death rates and fractional changes in death numbers (death ratio) shown for 17 Hubei cities from 31 Jan to 16 Feb. City data is sorted by decreasing number of deaths. We distinguish death rates $\geq 3\%$ (scarlet), $\geq 1\%$ (rose) & $< 1\%$ (green). The deaths per million population is much higher in Wuhan than any other city at almost 120 per million (0.012%). The number of cases (clinically plus laboratory diagnosed) is 0.37% of the Wuhan population of 11 million. On 31-Jan. there were 8 of 17 cities with death rates less than 1%; by 16-Feb., there were only 2 of 17.

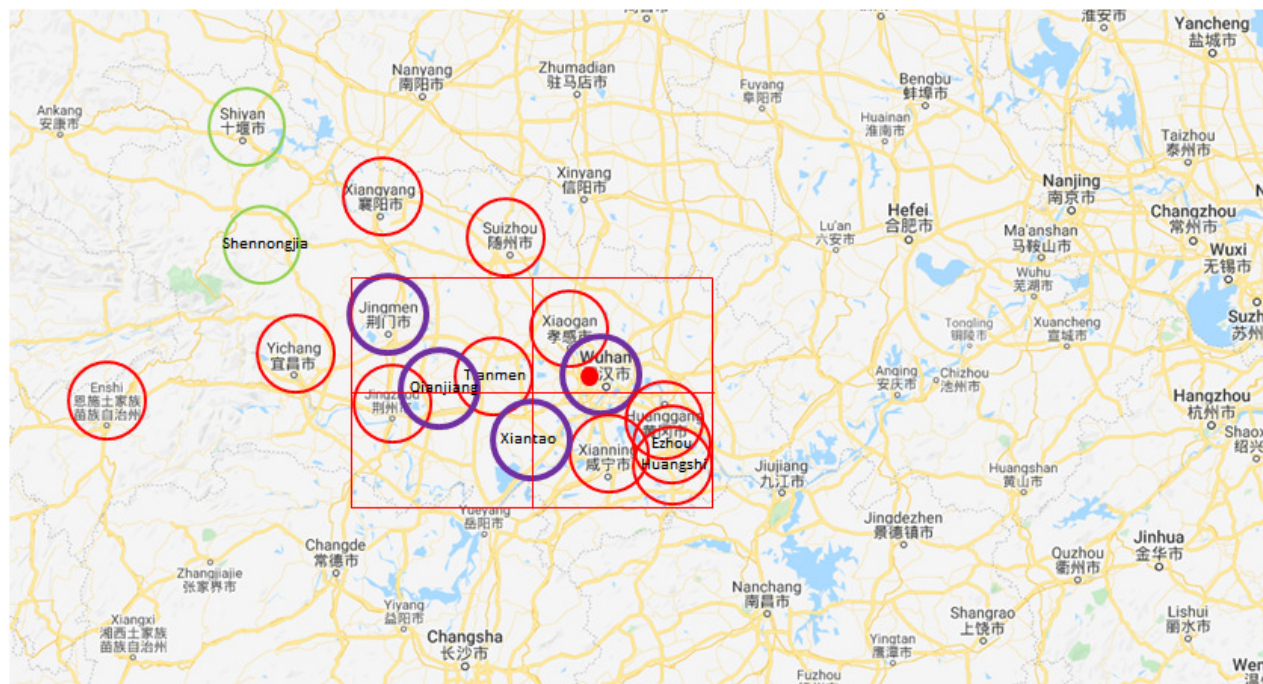


Figure 2. Map of Hubei circling in purple cities with a death rate of $\geq 3\%$, in red cities with a death rate of $\geq 1\%$ and in green other cities for which there is data in Table 2. Most deaths are localized to a 90 km x 35 km area centered near Tianmen and high death rates occur in four cities: Wuhan, Jingmen, Qianjiang and Xiantao (See Table 2). Two cities, in the same area have low death rates, comparable to those elsewhere in China and the rest of the world (data from jobtube.cn from 31-Jan. to 16-Feb.). The red dot marks the Wuhan South China Seafood Market thought to be the source of this coronavirus.

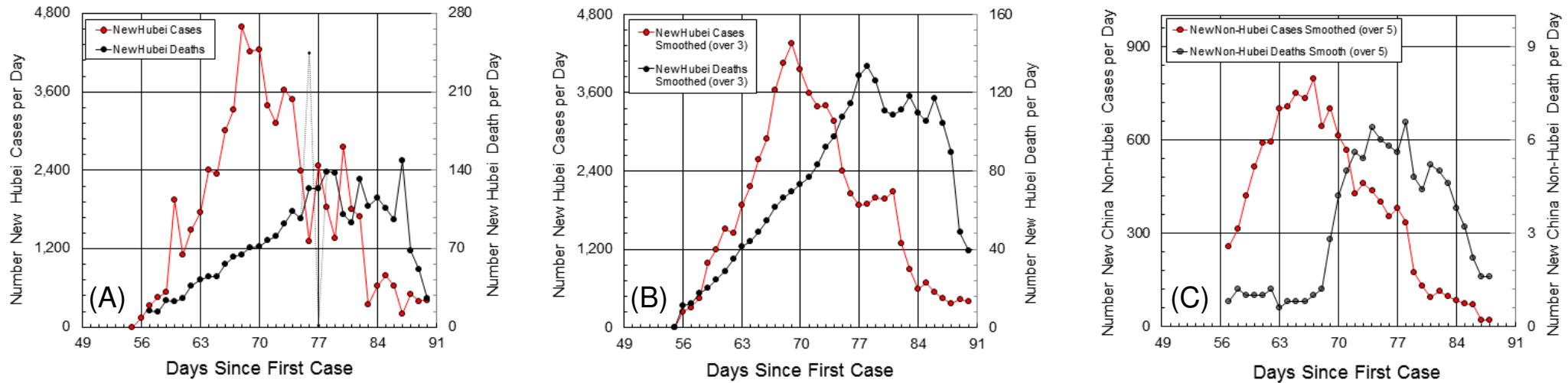


Figure 3. Time variation of number of new cases and new deaths in China, separated into Hubei and elsewhere in mainland China (Non-Hubei).

(A). Showing the number of new Hubei cases per day (red line) and the number of new Hubei deaths per day (black line). For new deaths, the WHO data values fluctuated wildly on 13 and 14 Feb. as shown by the black dotted line. For this reason, the numbers of new deaths of 245 on 13-Feb. and 2 on 14-Feb. (Table 1) are averaged to give 124 new deaths on each day, correcting what may have been a typo in the value for 13-Feb. (black dashed line).

(B) The same data is smoothed by averaging over a three-day window so that, for example, the value plotted on day 69 is the average of the values on days 68, 69 & 70. These smoothed curves clearly show that the number of new Hubei cases per day peaked on Day 69 (6-Feb) and that the number of new Hubei deaths per day peaked on Day 78 (15-Feb.), which is 9 days later. For sigmoid growth like that shown in **Fig. 4**, the number of new cases or deaths reaches a maximum midway through the curve. This predicts the total number of Hubei cases will reach 60,000 (laboratory plus clinically diagnosed cases), approximately twice 28,208, the number of such cases on 6-Feb. This also predicts total number of Hubei deaths will reach 2,914, twice 1,457, the number of Hubei deaths on 15-Feb. Better analysis in **Fig. 4** gives asymptotic values of 65,834 and 3,150 for number of Hubei cases and deaths, respectively.

(C) Showing the variation with time of the smoothed number of new Non-Hubei cases in China per day (red line). Although smoothed by averaging over a window of five values, this data remains noisy. Nevertheless, it does indicate that a peak in the number of new Non-Hubei cases in China occurred on day 67 or 68 (4-Feb. or 5-Feb.) allowing the maximum total number of Non-Hubei cases to be estimated as twice 7,037 or 7,745, the values on 4-Feb. or 5-Feb, for a value of between 14,000 and 16,000. The same argument estimates the total number of non-Hubei deaths to reach a 160. Again, **Fig. 4** gives better asymptotic values of 13,075 and 109 for the total number of Non-Hubei cases and deaths, respectively.

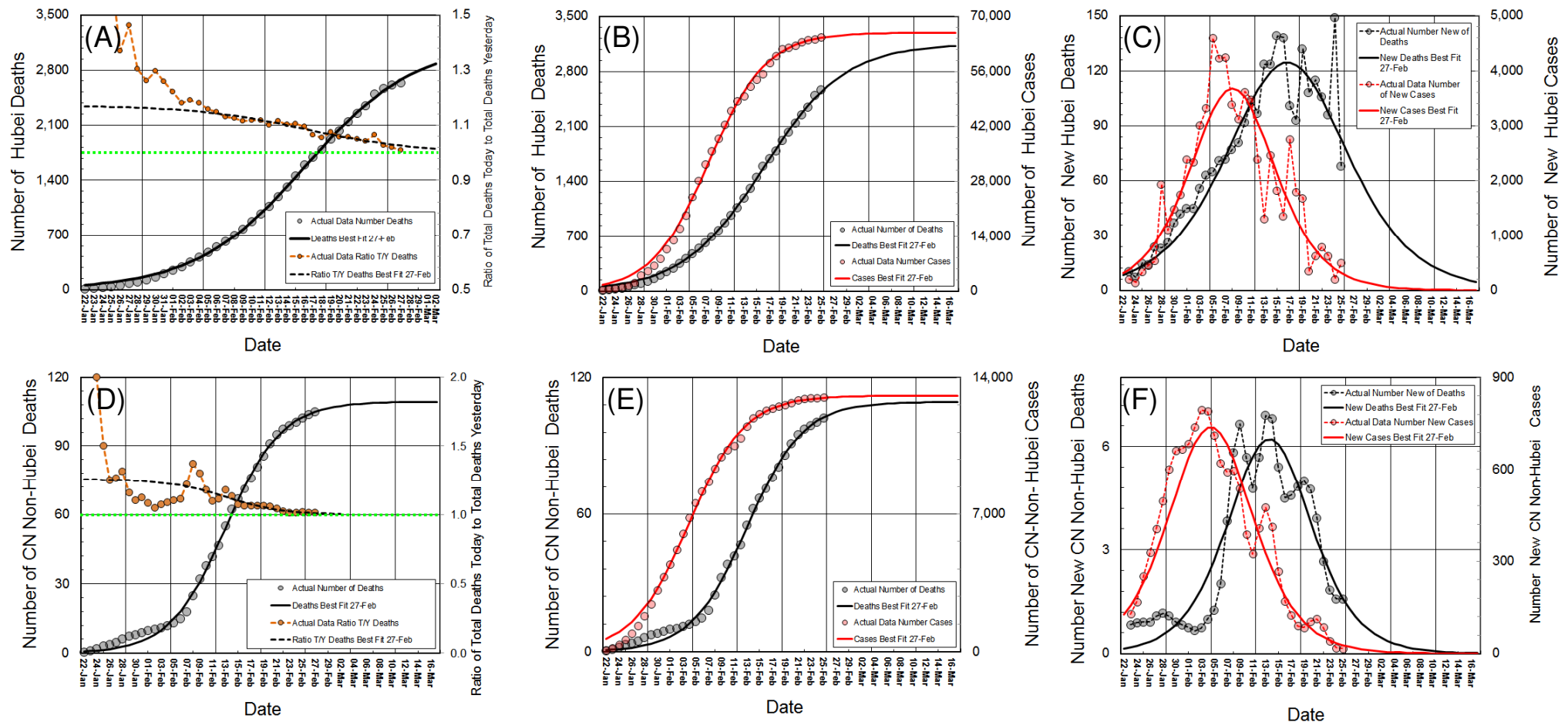


Figure 4. Fit of a sigmoid function to the total number of COVID-19 cases and deaths in Hubei. (A) The best fit (black line) to the actual deaths (black dots). The fit is obtained using Excel Solver to find parameters A , B & C in $f(x) = A/(1-\exp(-(x+B)/C))$ that minimize the weighted RMS difference of calculated and actual number (weight=sqrt(number deaths)). We calculate ratio of value today to those yesterday (T/Y, black dashed line) and compare with the actual data (orange dashed line and circles on secondary axis). The fit is excellent and the calculated ratio decreases approximately linearly towards a value of 1.0 as assumed in **Fig. 2 (E)**.

(B) Sigmoid fits to both the number of cases and number of deaths in Hubei. The final total number of Hubei cases will be close to 66,000, while the current estimate for total number of deaths will be close to 3,200. This will mean an overall Hubei death rate of almost 5% ($3,200/66,000=4.8\%$).

(C) By subtracting values for yesterday from today, the sigmoid function fitted to the actual number of new Hubei cases or deaths shown in **Fig. 4B**, gives the number of new Hubei cases or new Hubei deaths (solid red and black lines, respectively). These curves are a good fit to the actual number of new Hubei cases or deaths (red and black transparent circles joined by dashed read and black lines, respectively), although the real data is noisy with large fluctuations. The smooth new cases curve (solid red line) peaks at Day 70.4 and the smooth new deaths curve (solid black line) peaks at Day 78.6).

Corresponding plots for cases and deaths in China but Non-Hubei is plotted in panels (D), (E) & (F). The Non-Hubei death rate is almost 1% ($109/13075=0.83\%$), which is about 5 times lower than that in Hubei.

The A , B & C parameters for sigmoid curves are 65834, 70.6 & 4.47 for Hubei cases; 3150, 79.1 & 6.32 for Hubei deaths; 13075, 67.0 & 4.41 for Non-Hubei cases; and 109, 76.1 & 4.39 for Non-Hubei deaths.

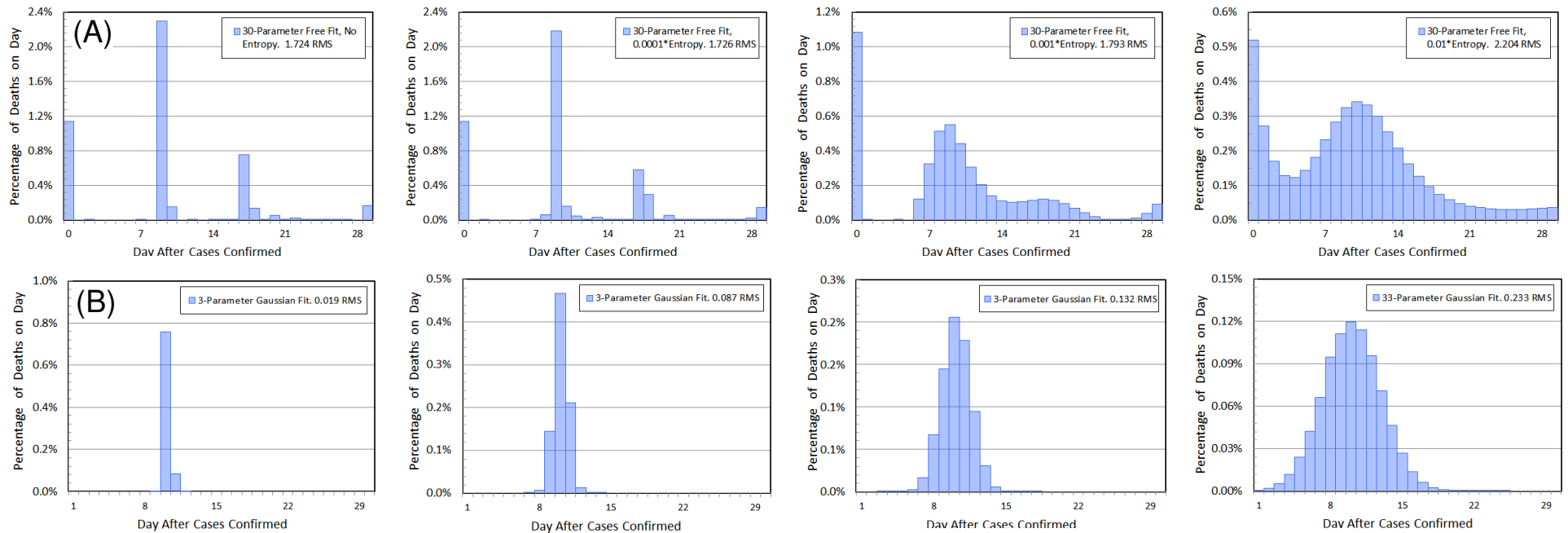


Figure 5. Relating new cases to new deaths via a death rate distribution, which gives the fraction of cases that die i days after a case is confirmed.

If P_i is fraction of cases that die after $i = \text{days}$, the number of new deaths on day n , D_n , is the sum of deaths from the new cases, C_{n-i} on previous days, where $D_n = C_n * P_0 + C_{n-1} * P_1 + C_{n-2} * P_2 + \dots + C_{n-29} * P_{29}$. The total death rate is $\sum P_i$.

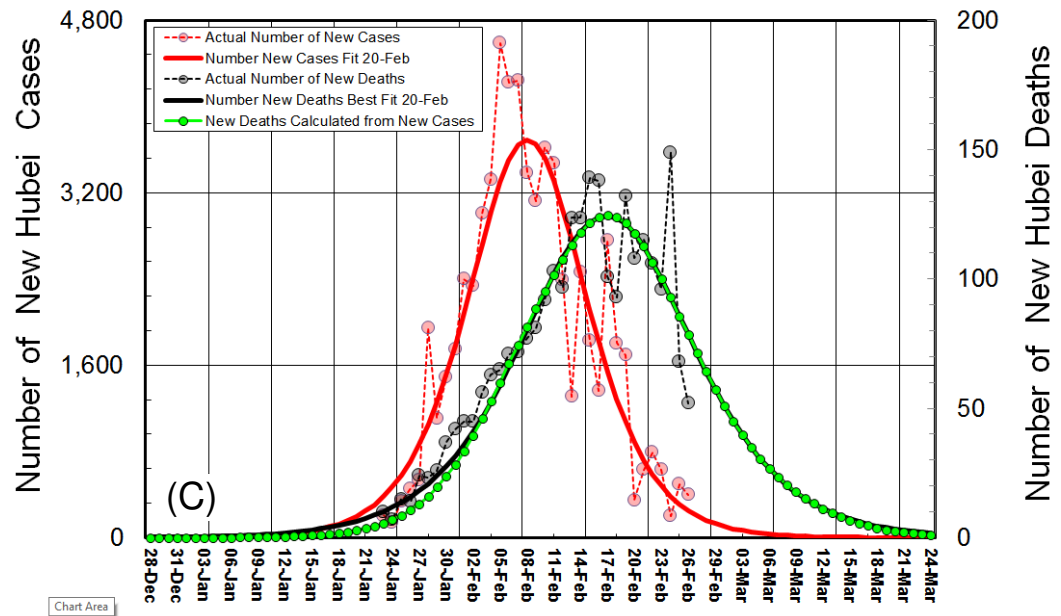
Excel Solver is used to determine values for the P_n unknowns in two ways:

- (1) 30 parameters, one for each P_n value.
- (2) 3 parameter Gaussian $P_n = P * \exp(-(n-Q)/R)^2)$, a with parameters P , Q & R . The distributions are smoothed with an entropy penalty of $-W \sum P_n \ln(P_n)$ added to the weighted least squares fit of predicted and actual number of new deaths.

(A). The death rate distribution that best fits predicted deaths to actual deaths in Hubei has 4 peaks with a death rate of 1.1% on day 0, the day a case is confirmed, of 2.4% summed over days 9 & 10 and about 1% over later days. Smoother fits found by increasing the entropy weight W are more realistic but fit slightly less well. The total death rate in all cases is 4.7%.

(B) A death rate distributions allows China Non-Hubei new deaths to be predicted from China Non-Hubei new cases. Single Gaussian fits broadened by added entropy all peak on Day 10. The total death rate in all cases is 0.85%. For both Hubei and Non-Hubei, the death rate is higher than in **Fig. 1C**.

(C) The new deaths predicted from actual new cases (red line) is shown as a green dotted line. The fit between the predicted new deaths and the actual new deaths (black line) is excellent (hiding black line) except for 15-Jan. to 29-Jan. when it is low. In that period, the number of new cases confirmed could have been underestimated due to difficult conditions in Hubei.



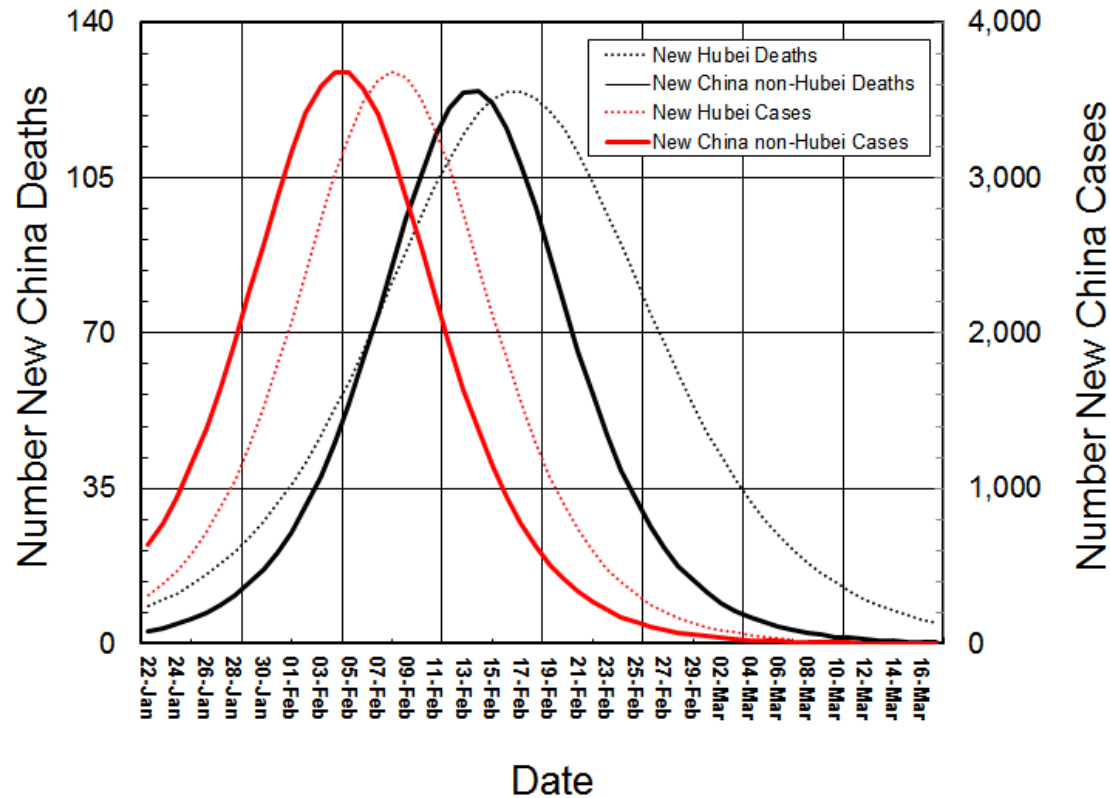


Figure 6 compares the sigmoid curves for cases and deaths in Hubei and China Non-Hubei (see **Fig. 4**) . The smaller number of Non-Hubei cases are scaled by a factor of 4.99 so they are the same height as Hubei cases. The same is done to the much smaller number of Non-Hubei deaths, which are scaled by a factor of 20.06. This shows that Non-Hubei cases peaked three days before those in Hubei, while Non-Hubei deaths peaked two days before those in Hubei. This seems impossible but I believe it may be explained if the Non-Hubei cases were all infected in Hubei three days before the majority of those infected in Hubei. This means that these Non-Hubei cases are from infected people who left Wuhan for the Spring Festival (Chinese New Year) and before the city was locked down on 23 Jan. The lack of further infection suggests that the quarantine of those coming from Hubei to other parts of China prevented any further spread of infection. This conjecture is still uncertain but illustrates just how much analysis of the data may reveal.

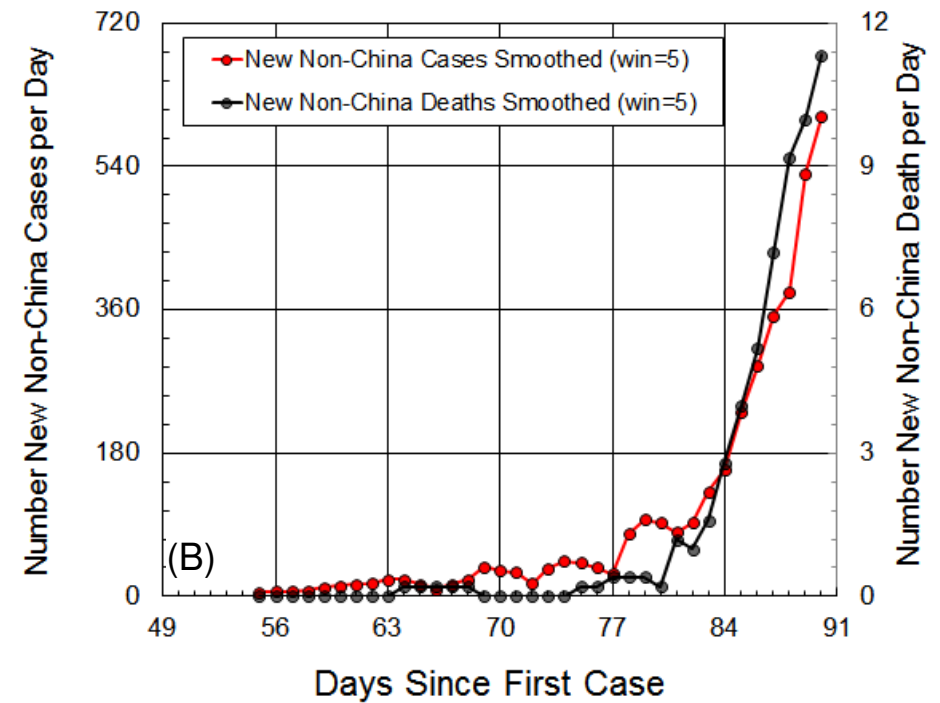
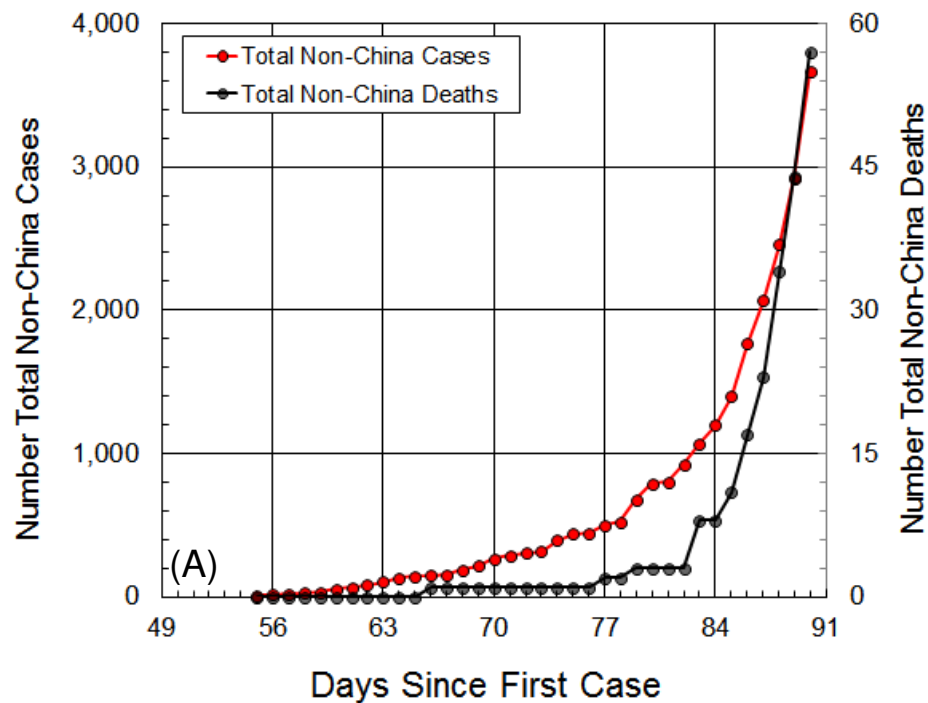


Figure 7 shows the number of cases and deaths outside China. These plots involve small numbers and are beset by high levels of noise. Still, now is the time when prediction is important.

(A) Shows both cases and deaths are increasing rapidly.

(B) Shows that the number of new cases and new deaths per day are increasing together and without the lag seen in **Fig. 4B & E**. This suggests that many cases are not detected until symptoms are severe and patients die on the same day.

(C) Shows the fractional changes in number of cases and deaths is fluctuating widely and does NOT SHOW any slowing of exponential growth. It was this slowing shown in **Fig. 1D & E**, that suggested hope for situation in Hubei as early on 1-Feb.

We note that the data outside of China comes from very different countries with very different health systems and facilities to test for cases. This is shown by the wide range of death rates: 0.57% in for the 705 cases on the Diamond Princess, 0.74% for the 1766 cases in South Korea, 1.61% for the 186 cases in Japan, 3.0% for the 400 cases in Italy and 15.6% for the 141 cases in Iran. We are investigating this now.

