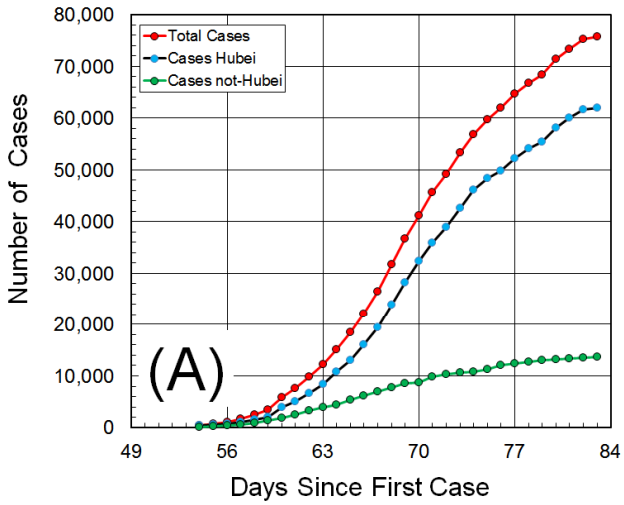
“21.Analysis of nCov-2019 Data on 2/21/2020” by Michael Levitt, Stanford University, USA

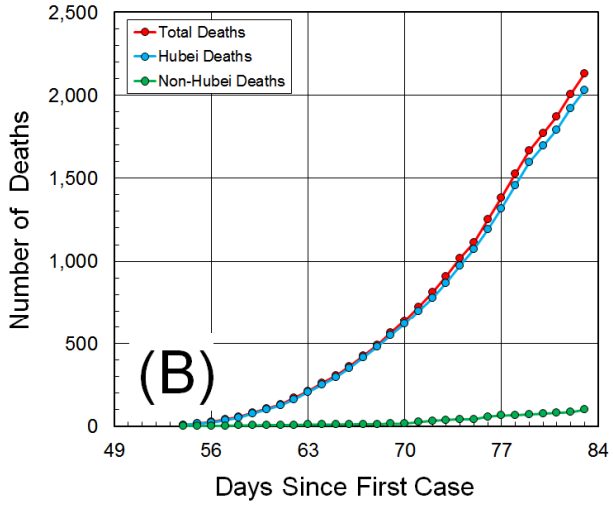
Today’s report confirms the promising trend first seen two days ago: Total Number of Hubei Deaths will reach 3,000 and the estimated for the total number of Hubei cases (Clinical and Laboratory Diagnosed) will reach 64,000. The Overall Death Rate is 4.5% with most deaths occurring on Day 0 an Day 9. Non-Hubei Cases and Deaths are estimated to reach 16,000 and 160, respectively.

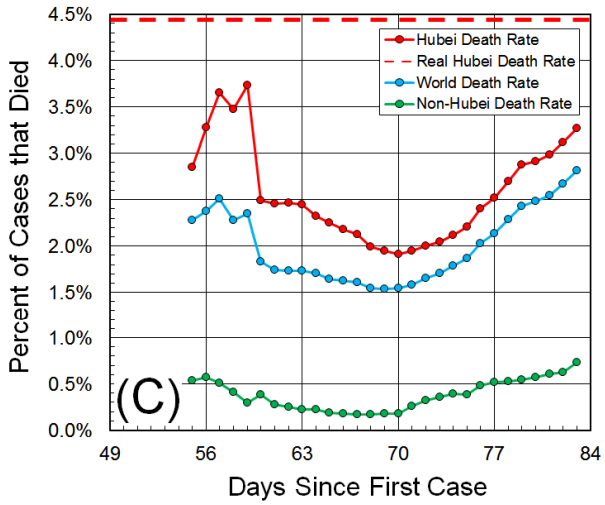
Date	Day	Total Number Cases					Total Number Deaths			Death Rate (%)			Ratio Hubei/ Others	Fraction Change Cases			Fraction Change Deaths			New/Day in Hubei	
		Total-LC	Total-L	Hubei-LC	Hubei-L	Others	Total	Hubei	Others	Total	Hubei	Others		Total	Hubei	Others	Total	Hubei	Others	Cases	Deaths
1/22/2020	54	421	314	358	251	63	6	6	0	1.42%	1.67%	0.00%	-								
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
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
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
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
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
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
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
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
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
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
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
2/3/2020	66	22201	17391	16074	11264	6127	361	350	11	1.63%	2.18%	0.18%	12.1	1.202	1.230	1.135	1.188	1.190	1.100	3007	56
2/4/2020	67	26434	20630	19398	13593	7037	425	413	12	1.61%	2.13%	0.17%	12.5	1.191	1.207	1.148	1.177	1.180	1.091	3324	63
2/5/2020	68	31731	24554	23986	16809	7745	491	478	13	1.55%	1.99%	0.17%	11.9	1.200	1.237	1.101	1.155	1.157	1.083	4589	65
2/6/2020	69	36717	28276	28208	19767	8509	564	549	15	1.54%	1.95%	0.18%	11.0	1.157	1.176	1.099	1.149	1.148	1.154	4222	71
2/7/2020	70	41191	31481	32450	22740	8741	637	621	16	1.55%	1.91%	0.18%	10.5	1.122	1.150	1.027	1.129	1.131	1.067	4242	72
2/8/2020	71	45610	34886	35838	25114	9772	723	698	25	1.59%	1.95%	0.26%	7.6	1.107	1.104	1.118	1.135	1.124	1.563	3389	77
2/9/2020	72	49217	37558	38962	27304	10254	812	779	33	1.65%	2.00%	0.32%	6.2	1.079	1.087	1.049	1.123	1.116	1.320	3124	81
2/10/2020	73	53296	40554	42583	29841	10713	909	871	38	1.71%	2.05%	0.35%	5.8	1.083	1.093	1.045	1.119	1.118	1.152	3621	92
2/11/2020	74	56886	43103	46060	32278	10825	1017	974	43	1.79%	2.11%	0.40%	5.3	1.067	1.082	1.010	1.119	1.118	1.132	3478	103
2/12/2020	75	59670	45171	48453	33955	11216	1114	1071	43	1.87%	2.21%	0.38%	5.8	1.049	1.052	1.036	1.095	1.099	1.000	2393	97
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	1.124	1.115	1.349	1312	124
2/14/2020	77	64682	49053	52231	36602	12451	1382	1318	64	2.14%	2.52%	0.51%	4.9	1.045	1.050	1.027	1.103	1.103	1.103	2466	124
2/15/2020	78	66757	50580	54061	37884	12696	1524	1457	67	2.28%	2.70%	0.53%	5.1	1.032	1.035	1.020	1.103	1.105	1.047	1829	139
2/16/2020	79	68442	51857	55424	38839	13018	1666	1595	71	2.43%	2.88%	0.55%	5.3	1.025	1.025	1.025	1.093	1.095	1.060	1363	138
2/17/2020	80	71429	54019	58182	40772	13247	1772	1696	76	2.48%	2.91%	0.57%	5.1	1.044	1.050	1.018	1.064	1.063	1.070	2758	101
2/18/2020	81	73332	NA	59989	NA	13343	1870	1789	81	2.55%	2.98%	0.61%	4.9	1.027	1.031	1.007	1.055	1.055	1.066	1807	93
2/19/2020	82	75204	NA	61682	NA	13522	2006	1921	85	2.67%	3.11%	0.63%	5.0	1.026	1.028	1.013	1.073	1.074	1.049	1693	132
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	1.061	1.056	1.176	349	108

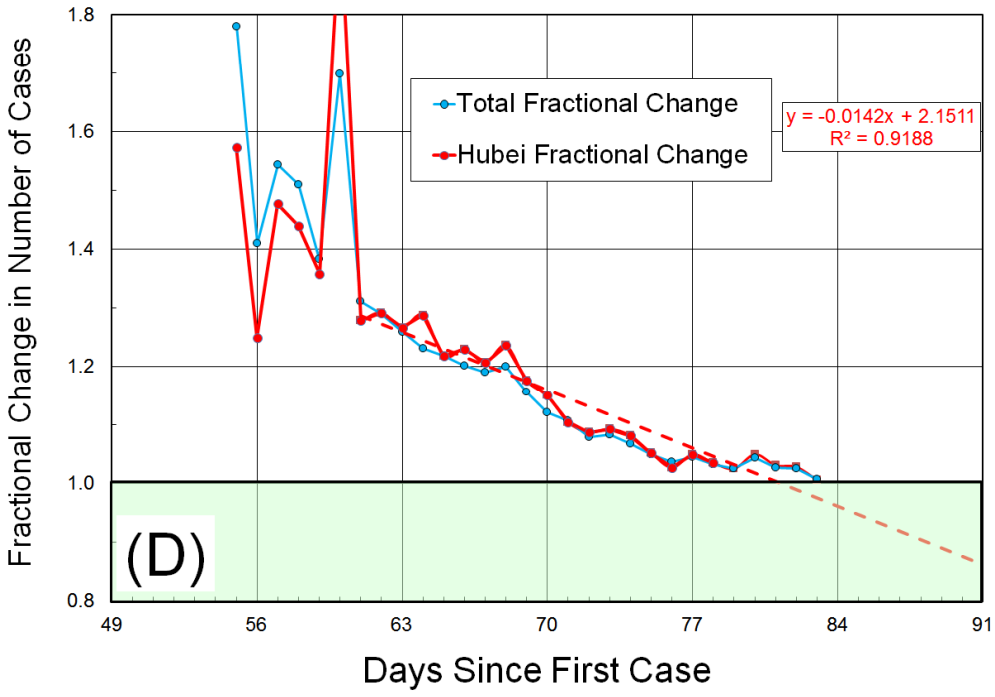
Health Organization website https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/. Before 13-Feb., the WHO did not give Cases and Deaths in Hubei so we use https://jobtube.cn/wv/?from=groupmessage&isappinstalled=0. Starting on 17-Feb., the WHO includes cases Clinically diagnosed in addition to 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 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 Deaths divided by the Number 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 he 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 on 14-Feb (pink shading).

Plots of this data against date are shown in **Fig. 1**. Panel (A) shows a slowing increase in Number of Cases everywhere. Panel (B) confirms that almost all the deaths are in Hubei. Panel (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 3.3% today, which it is wrongly estimated. Panels (D) and (E) shows that the Fractional Change in Total Cases (Cases_Today / Cases_Yesterday) is decreasing steadily. **Fig. 3** shows the number of New Cases and New Deaths in Hubei. While New Cases peaked on Day 69 (6-Feb.), New Deaths peaked on Day 78 (15-Feb.). This difference shows that on-average death occurs at 9 days after diagnosis. This is confirmed by the correct distribution of Death Rate calculated in **Fig. 5**, which also gives a fixed Hubei Death Rate of 4.5%, much larger than currently accepted.









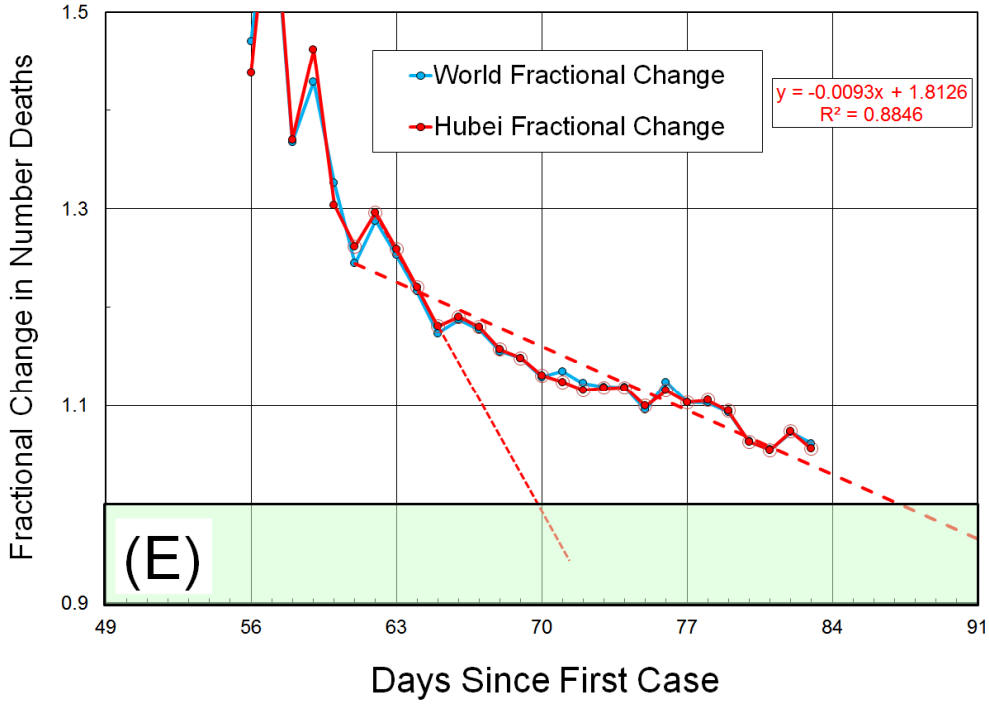


Figure. 1. Variation of COVID-19 data against Days since 29 Nov 2019 (guessed date of the first case). **Table 1** data is plotted from 22 Jan. to 20 Feb. 2020. The rise of Hubei Death Rate in Panel (C) makes no sense as the virus is not becoming more virulent. This discrepancy arises because all Deaths do not occur on the same day a case is diagnosed. A proper Death Rate Distribution gives a real Hubei Death Rate of 4.4% (Fig. 6). In Panels (D) & (E) linear trend-lines are added using data from 1/29/2020. The Fraction Change for Cases and Deaths is an excellent fit to a straight line. In panel (E) we also show a red short-dashed of the straight-line the fit to the four data points for 31-Dec to 02-Feb; this trend was used in the first draft of this analysis dated 2/2/20, giving the expectation 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 ≥ 3% (scarlet), ≥ 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 3.7% of the Wuhan population of 11 million. On 31-Jan. there were 8 of 17 cities with death rates < 1%; by 16-Feb., there were only 2 of 17.

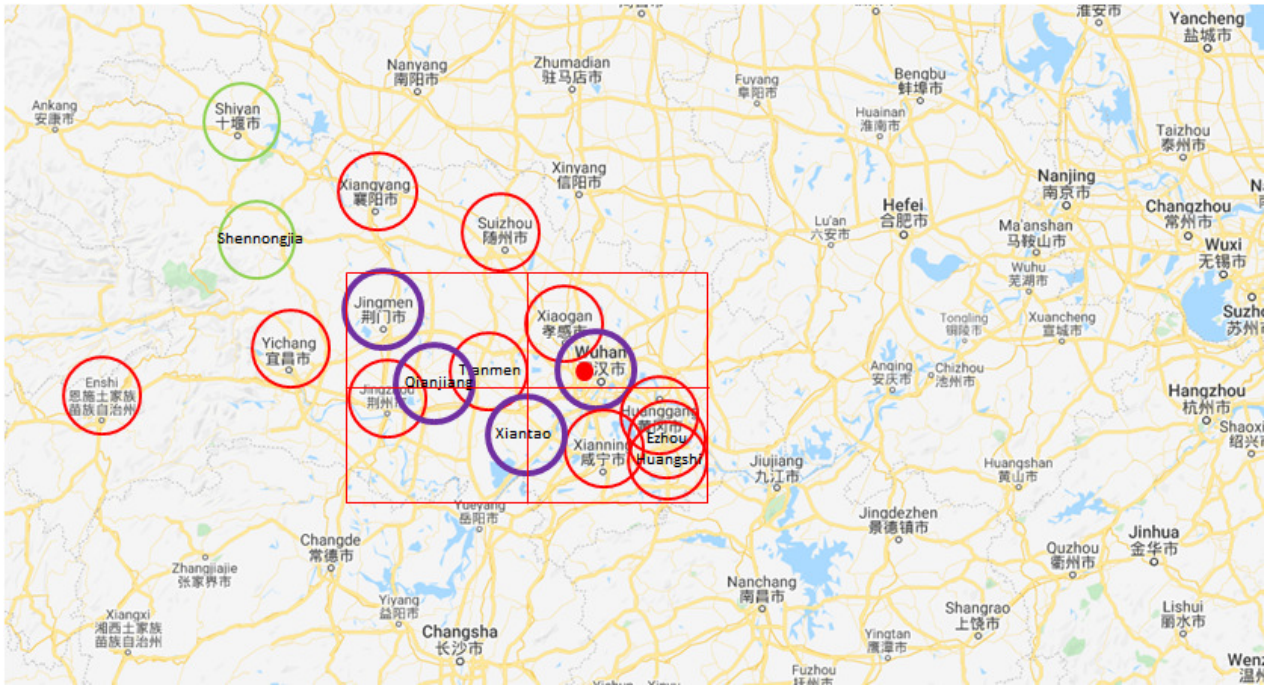
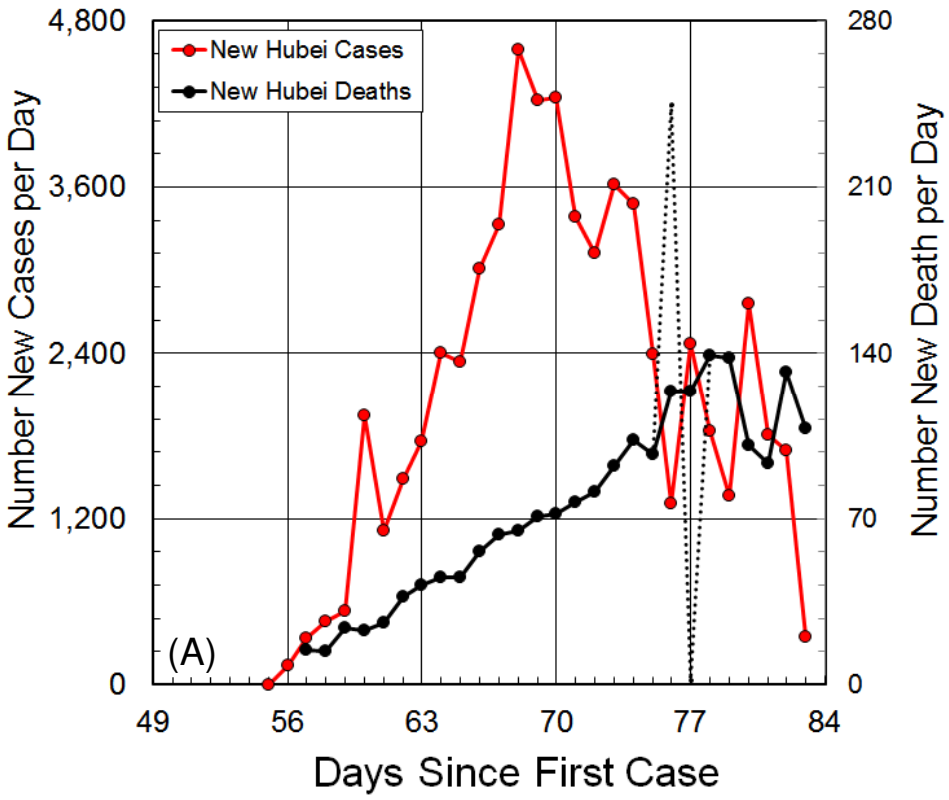


Figure. 2. Map of Hubei circling in purple cities with a death rate of ≥ 3%, in red cities with a death rate of ≥ 1% and in green other cities for which there is data. Most deaths are localized to a 90km x 35km area centered near Tianmen and high death rates occur in four cities: Wuhan, Jingmen Qianjian 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 (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.



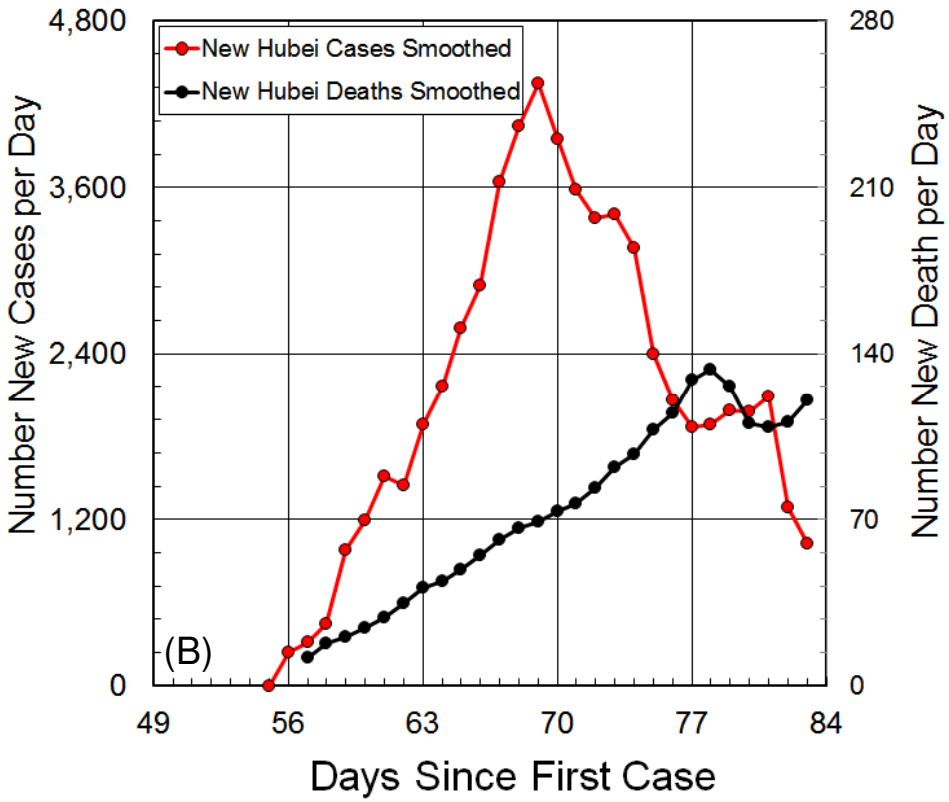


Figure. 3A. Showing the variation with time of Number of New Hubei Cases per Day (red line) and the Number of New Hubei Deaths per Day (black line). For New deaths, the WHO data values fluctuated wildly on 13 and 14 Feb. as shown by black dotted line. For this reason, the Numbers of New Deaths of 245 on 13-Feb. and 2 on 14-Feb. (Table 1) are averaged to give 124 New Deaths on each day, correcting what may have a been a typo in the value for 13-Feb. (black dashed line).

Figure 3B. 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 may have peaked on Day 78 (15-Feb.), which is 9 days later. Note that we need a few more days of data to see if the drop in number of deaths on 17-Feb. is real or a random fluctuation. For sigmoid growth like that shown in **Fig. 4**, the number of new cases or deaths reaches a maximum midway through the curve. If this holds here, then the total Number of Hubei Cases will reach 60,000 (laboratory plus clinically diagnosed cases), which is approximately twice 28,208, the number of such cases on 6-Feb.. Were the Number of New Hubei Deaths to peak today, the number of Total Hubei Deaths will reach 3,000, which is approx. twice 1,457, the number of Hubei Deaths on 15-Feb. Better analysis in Fig. 4 gives asymptotic values of 64,000 and 3,000 for Number of Cases and Deaths, respectively.

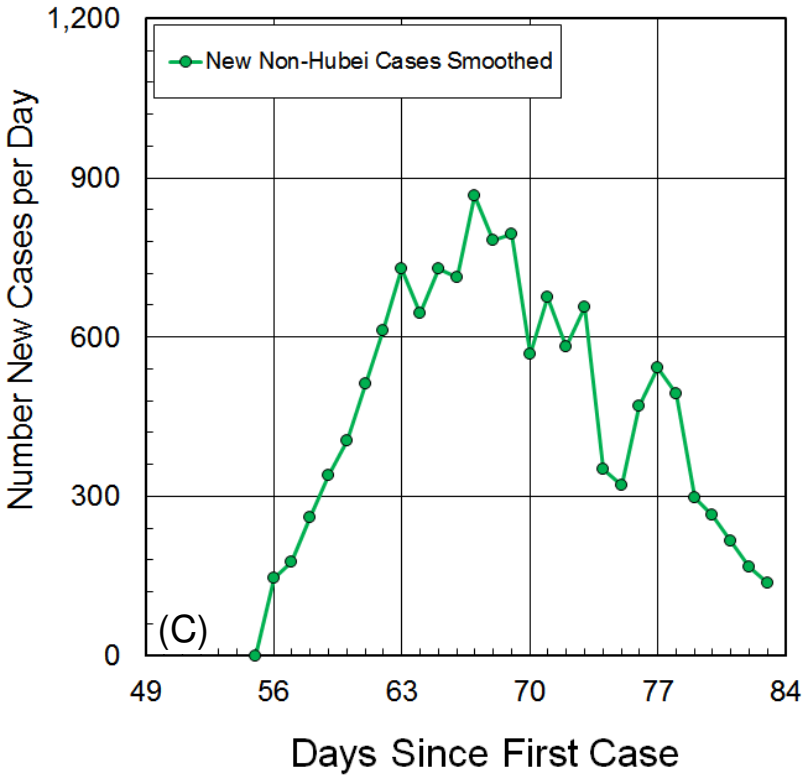
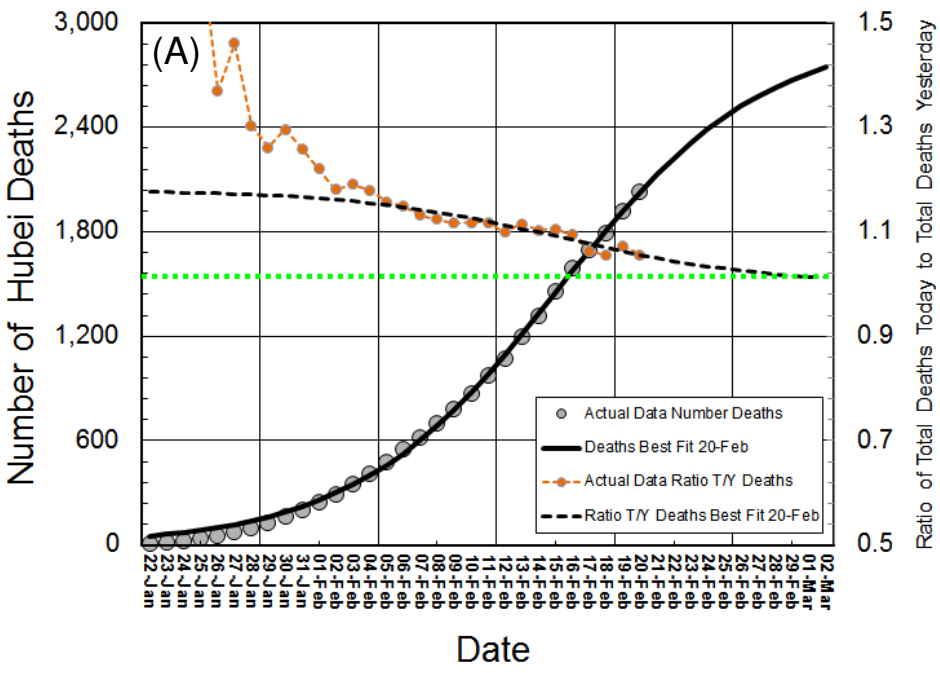


Figure. 3C. Showing the variation with time of the smoothed Number of New Non-Hubei Cases per Day. Although smoothed by averaging over a window of three values, this data remains noisy. Nevertheless, it does indicate that a peak in the Number New Non-Hubei Deaths occurred on day 67 or 68 (4-Feb. or 5-Feb.) 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. Non-Hubei deaths are two few to plot in this way but if we assume that they peaked 9 days later day 79 or 80 (see **Fig 3B**.), the Total Number of non-Hubei Deaths can be expected to reach a total Number of Non-Hubei Deaths of 160. This will mean an overall Non-Hubei Death Rate of 1% (160/16,000).



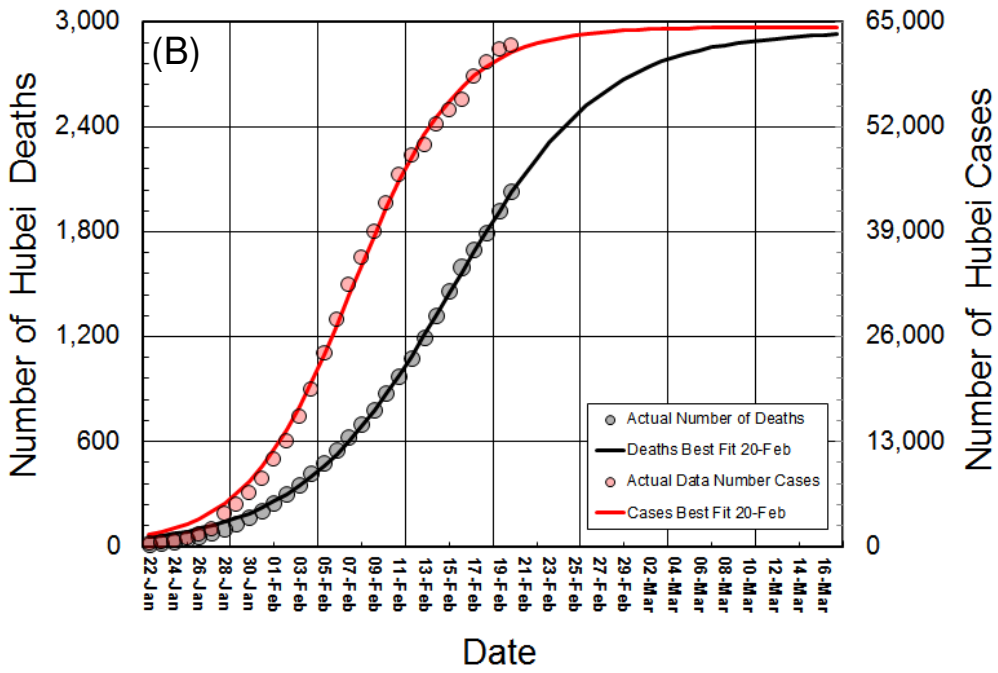


Figure. 4A. Fit of the sigmoid function f(x) = 1/(1-exp(-x)) to the actual Total Number of Hubei Deaths from the coronavirus COVID-19 since 22 Jan 2020. The best fit to actual values (black line) is obtained using Excel to optimize the parameters A, B & C in f(x) = A/(1-exp(-x+B)/C) until the weighted (weight=sqrt(Number Deaths)) difference between the calculated and actual Number of Deaths is a minimum. Particularly impressive is that the Ratio of Deaths Today to Yesterday (T/Y) from the actual data (orange dashed line and circles on secondary axis) is well fit by the calculated Ratio (black dashed line on secondary axis), which decreases in the linear fashion assumed in **Fig. 2 (E)** towards the value of 1.0 when there is no further growth in number of deaths.

Figure. 4B. Showing the sigmoid fit to the Number of Cases and Number of Deaths in Hubei predicted by the data since 22-Jan 2020. As suggested by **Fig. 3B**, the total Number of Hubei Cases will be close to 64,000, while the current estimate for Total Number of Deaths will be close to 3,000. This will mean an overall Hubei Death Rate of almost 5% (3,000/64,000), which is 5 times higher than the estimated Non-Hubei Death Rate of 1%. This estimate is now confirmed by the Death Rate Distribution derived in **Fig. 5.**

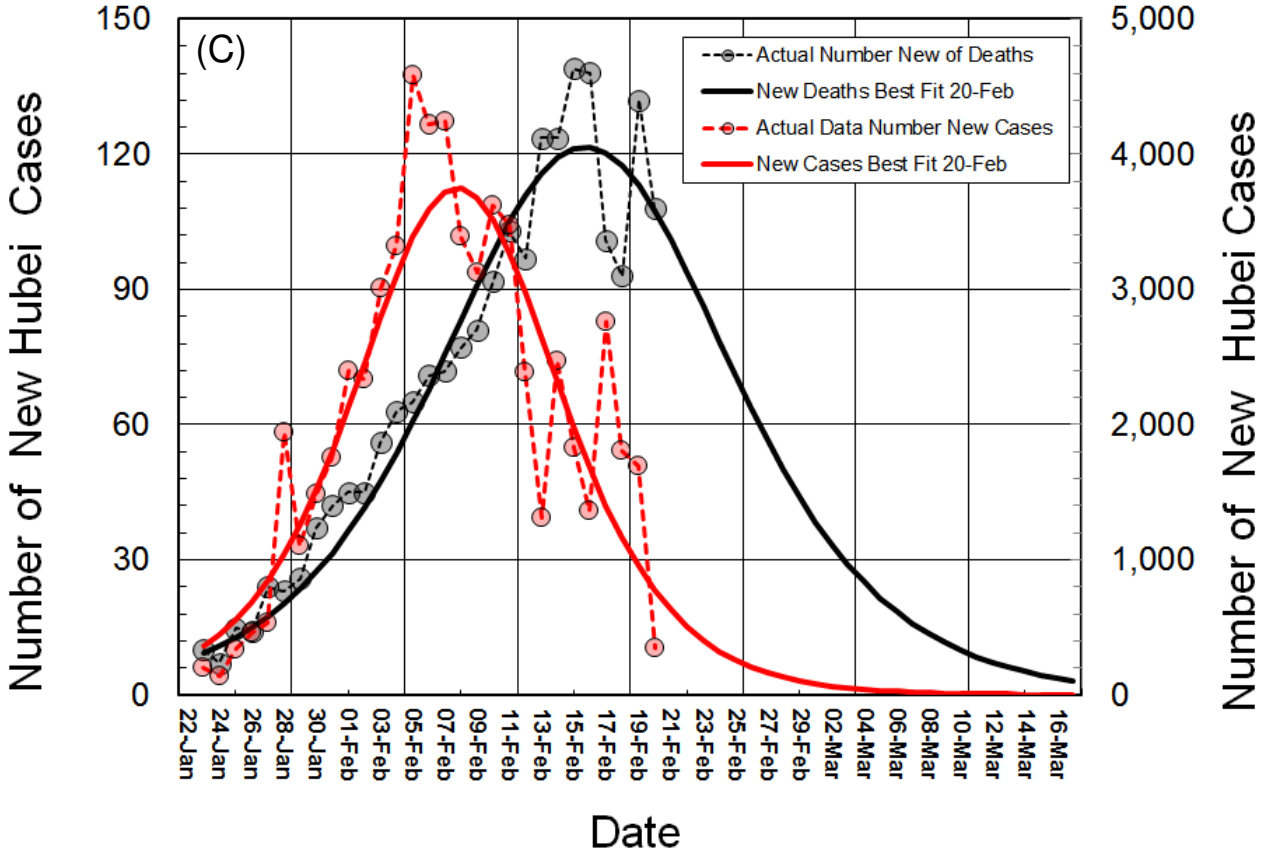
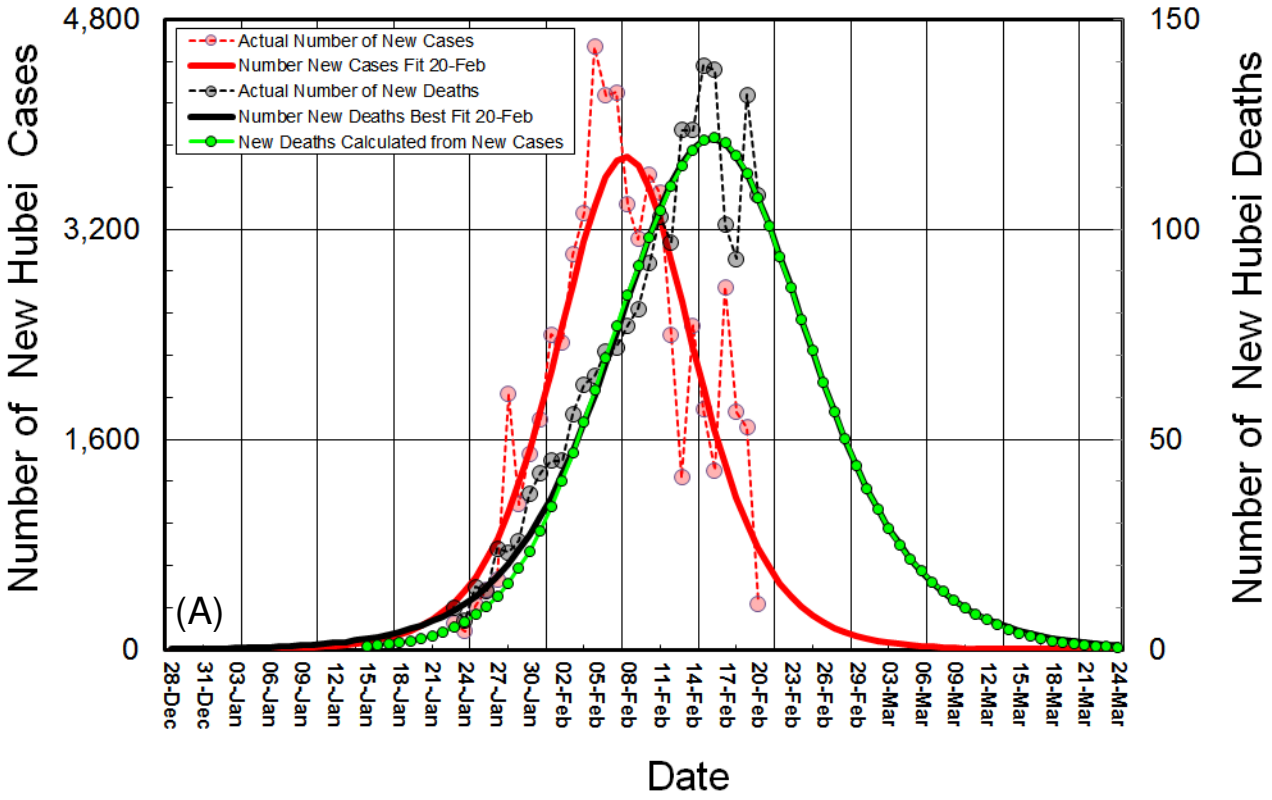


Figure. 4C. By subtracting values for yesterday from today, the sigmoid function f(x) = 1/(1-exp(-x)) fit to the actual Total Number of Hubei Cases or Deaths shown in **Fig. 4B** can be used to get a calculated Number of New Hubei Cases or New Hubei Deaths (solid red and black lines, respectively). These 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.



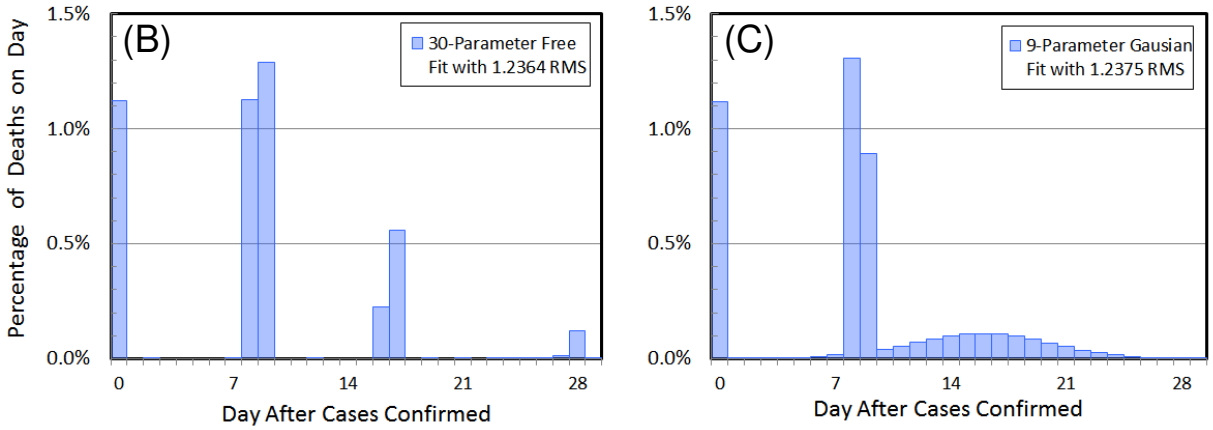


Figure. 5A. The data on Number of New Cases and New Deaths each day in **Fig. 4C**. is shown again (solid red and black lines) in our attempt to relate New Cases to New Deaths by deriving a Death Rate Distribution. This distribution gives the Death Rate *i* days (where *i* is 0, 1, 2, etc.) after confirmation as a new case. It shows the progression of the disease fitting the data we have.

We assume that for each case diagnosed on day 0, there will be Death Rate P_i for death after i = 0, 1, 2, .. 29 days (we tried i up to 44 but there was no signal for Days 30 to 44). The Number of New Deaths, D_n, on day n is the sum of deaths from C_{n-i}, the Number of New Cases on previous days:

$$D_n = C_n*P_0 + C_{n-1}*P_1 + C_{n-2}*P_2 + \ldots + C_{n-29}*P_{29}$$

The corresponding total Death Rate is the sum of all P_i values and will be the same for each day.

Again we use Excel Solver to determine the values for the P_n values. This is done in two ways:

(1) With all 30 parameters, one for each P_n values.

(2) With just 9 parameters obtained by calculating the P_n values as a sum of three Gaussian functions $g(n) = A_i*exp(-((n-B_i)/C_i)^2)$, where there are 3 parameters (A_i ,B_i, C_i) for each Gaussian.

We run Solver repeatedly for the 30-parameter model always reaching the same best fit with a weighted error of 1.236 (weight is taken a sqrt(D) where D is Number of New Deaths in **Fig. 4C**). A similar best fit is also obtained with the 9-parameter model. The Number of New Deaths from the best 30-parameter solution is shown as the green line in **Fig. 5A**. The fit is almost perfect (hiding the black line)except for 15-Jan. to 31-Jan. when it is low. This could mean that the number of Confirmed Cases was low then due to the difficult conditions in Hubei.

Figure. 5 B. Showing the Death Rate Distributions for 30-Parameter and 9-Parameter fits are very similar. Both have unexpected features as follows: there is a Death Rate of 1.1% on day 0, the day a case is confirmed; there is a death rate of about 2.4% summed over days 8 & 9; there is a death rate of 1.2% summed over later days. The total Death Rate is 4.46%, which is higher than that calculated in **Fig. 1C**.