# “30. Analysis of COVID-2019 Data on 3/2/2020” by Michael Levitt, Stanford University, USA

Contrary to the prevailing world concern, the COVID-19 epidemic is almost over in China. Today’s analysis uses WHO data for the past 41 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 is 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% | - | | | | | | | | | 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 |
| 2/28/2020 | 91 | 83652 | NA | 65914 | NA | 17738 | 2858 | 2682 | 176 | 3.42% | 4.07% | 0.99% | 4.1 | 1.017 | 1.005 | 1.062 | 1.019 | 1.016 | 1.080 | 318 | 41 | 4691 | 67 |
| 2/29/2020 | 92 | 85403 | NA | 66337 | NA | 19066 | 2924 | 2727 | 197 | 3.42% | 4.11% | 1.03% | 4.0 | 1.021 | 1.006 | 1.075 | 1.023 | 1.017 | 1.119 | 423 | 45 | 6009 | 86 |
| 3/1/2020 | 93 | 87137 | NA | 66907 | NA | 20230 | 2977 | 2761 | 216 | 3.42% | 4.13% | 1.07% | 3.9 | 1.020 | 1.009 | 1.061 | 1.018 | 1.012 | 1.096 | 570 | 34 | 7169 | 104 |

**Table 1**. Showing data for New Coronavirus 2019 or COVID-19) from 22 January to 1 March 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 form the WHO data.

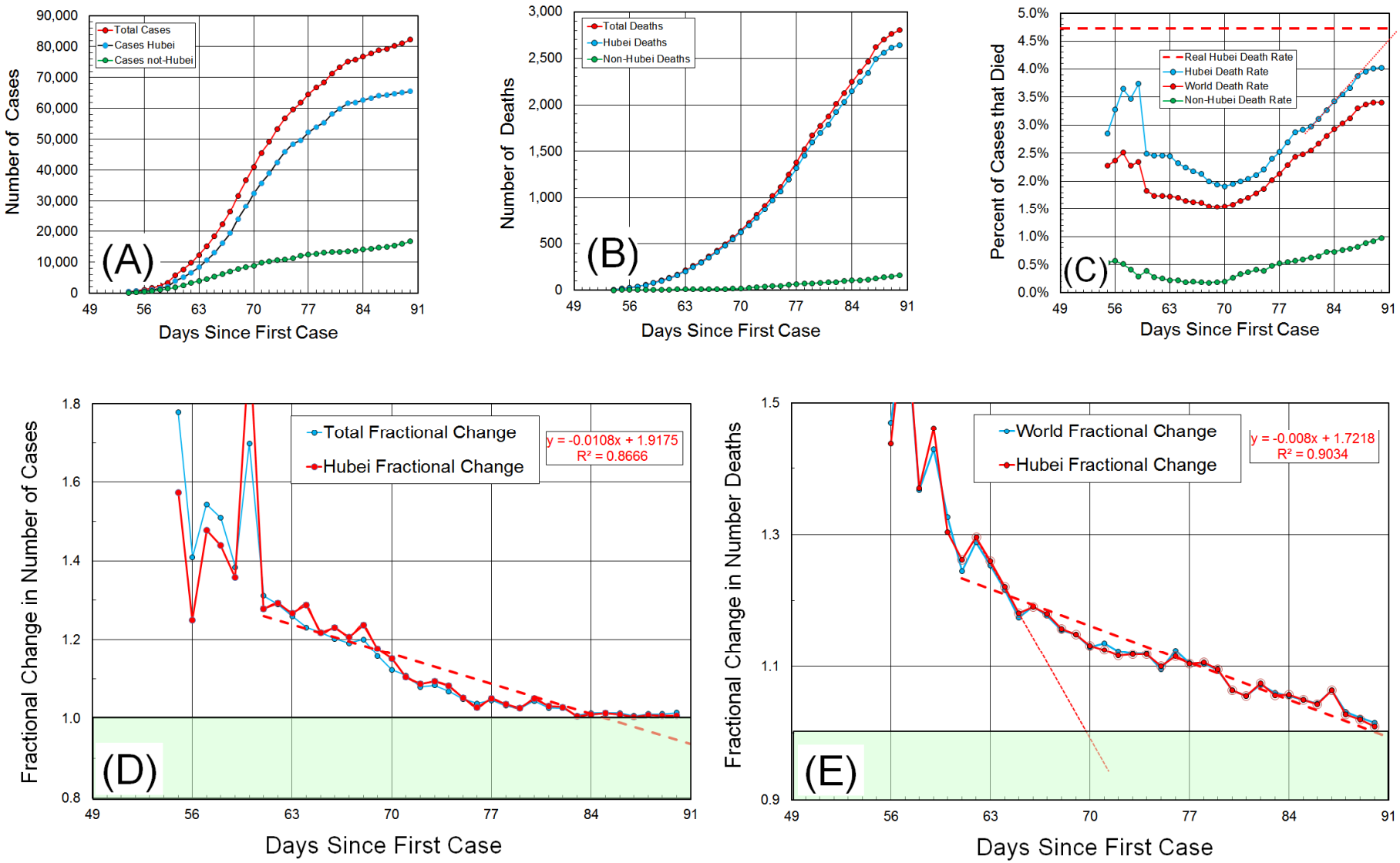



**Figure 1**. **Variation of COVID-19 data against days since 29 Nov 2019 (guessed date of the first case)**. Data is taken from **Table 1.**

**(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 ≥ 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 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.

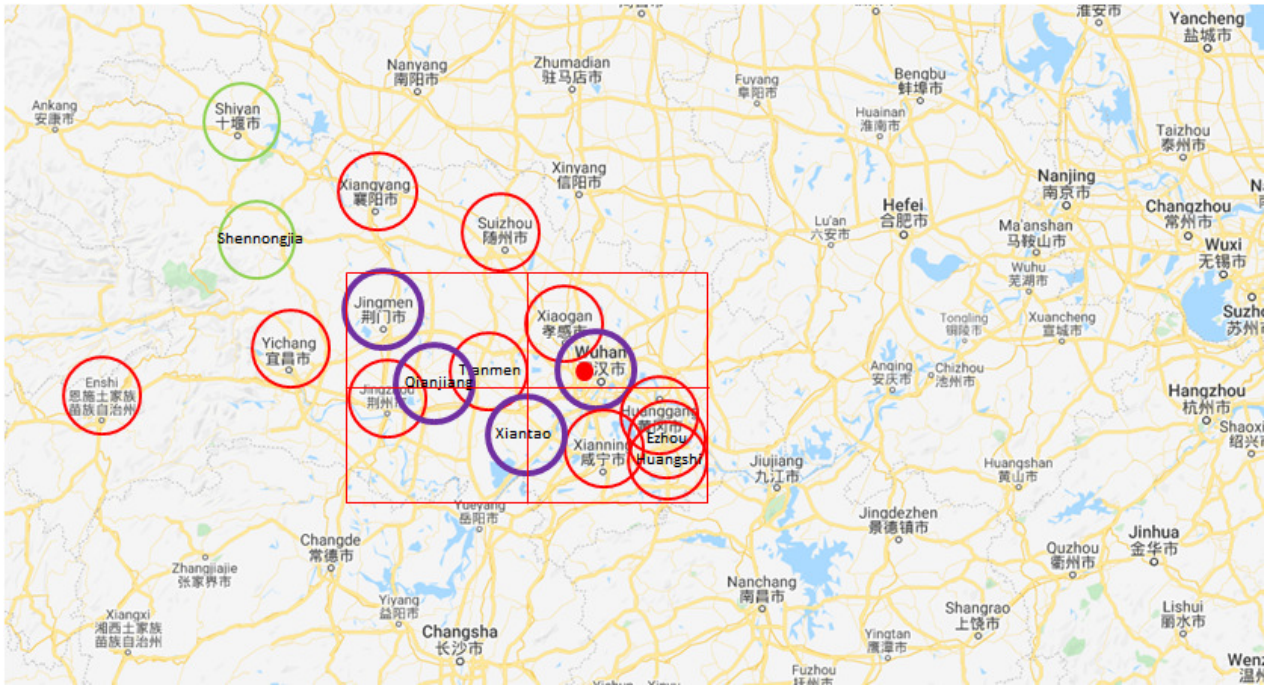



**Figure 2**. Map of Hubei circling in purple cities with a death rate of ≥ 3%, in red cities with a death rate of ≥ 1% and in green other cities for which there is data in Table 2. Most deaths are localized to a 90 km x 35 km area centered near Tianmen and high death rates occur in four cities: Wuhan,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

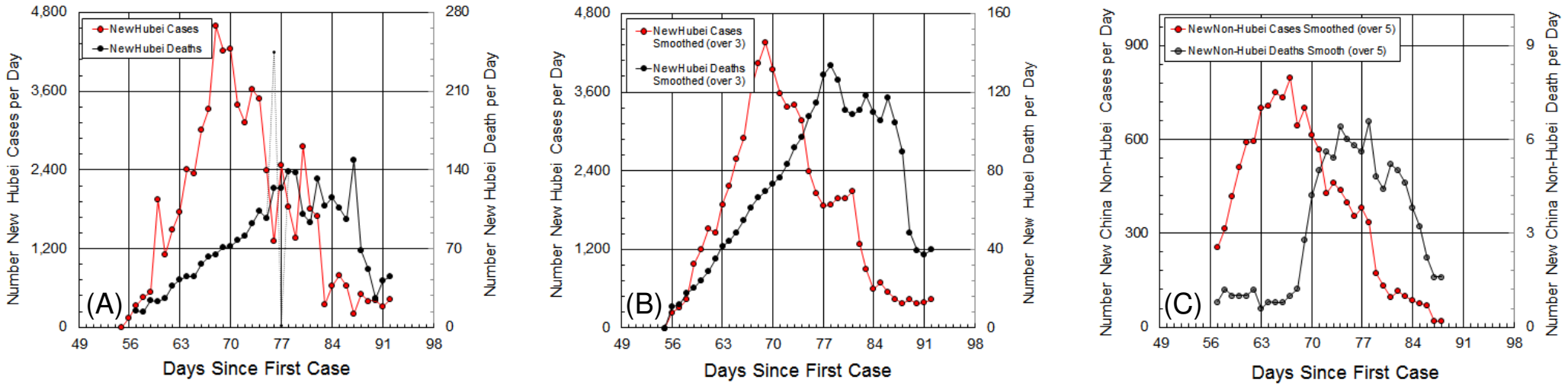



**Figure 3. Time variation of number of new cases and new deaths in China, separated into Hubei and elsewhere in mainland China (Non-Hubei).**

**(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.

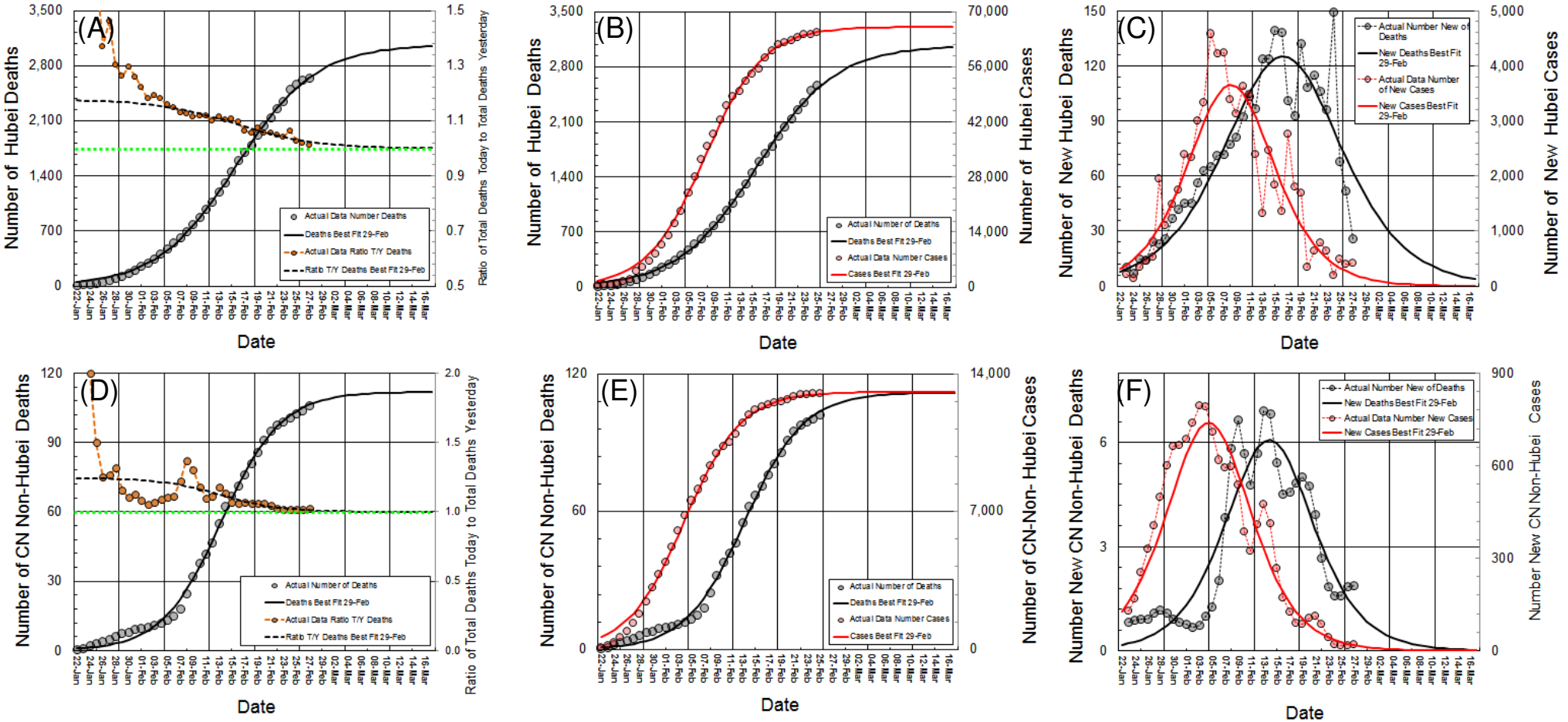



**Figure 4. Fit of a sigmoid function to the total number of COVID-19 cases and deaths in Hubei. (A)** The best fit (black line) to the actual deaths (black dots). The fit is obtained using Excel Solver to find parameters *A, B & C in f(x) = A/(1+exp(-(x-B)/C))* that minimize the weighted RMS difference 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)**. =A/(1+EXP(-(x-B)/C))

**(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 66128, 70.6 & 4.52 for Hubei cases; 3069, 78.7 & 6.13 for Hubei deaths; 13081, 67.0 & 4.42 for Non-Hubei cases; and 112, 76.14 & 4.6 for Non-Hubei deaths.

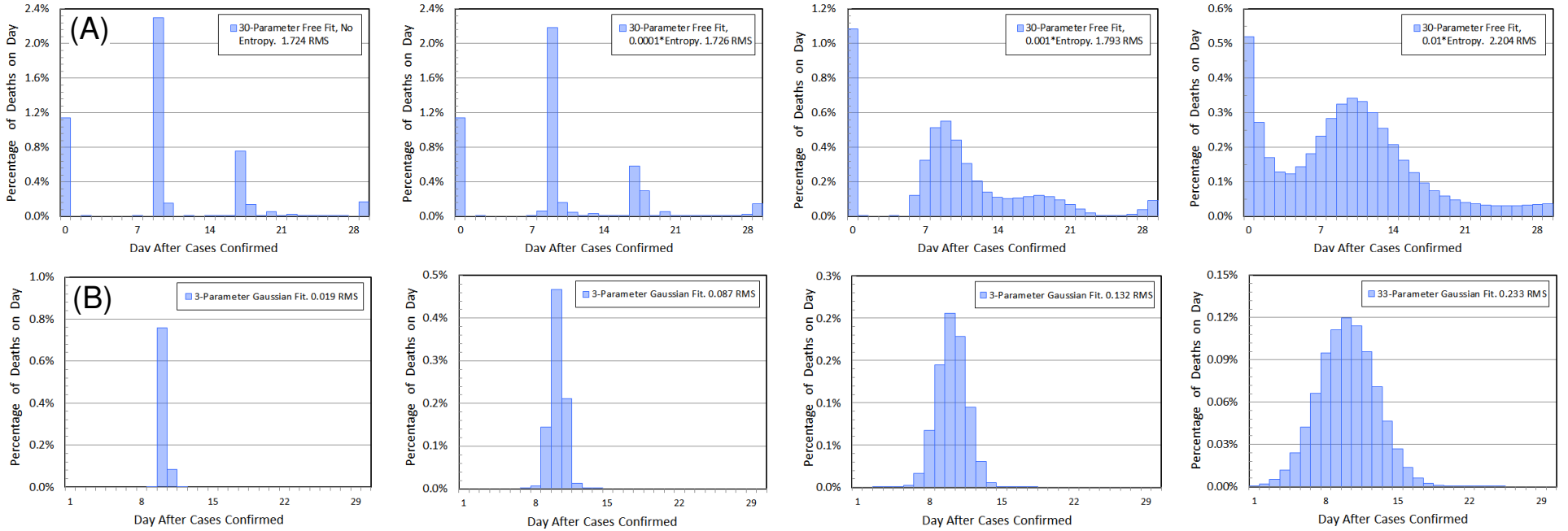


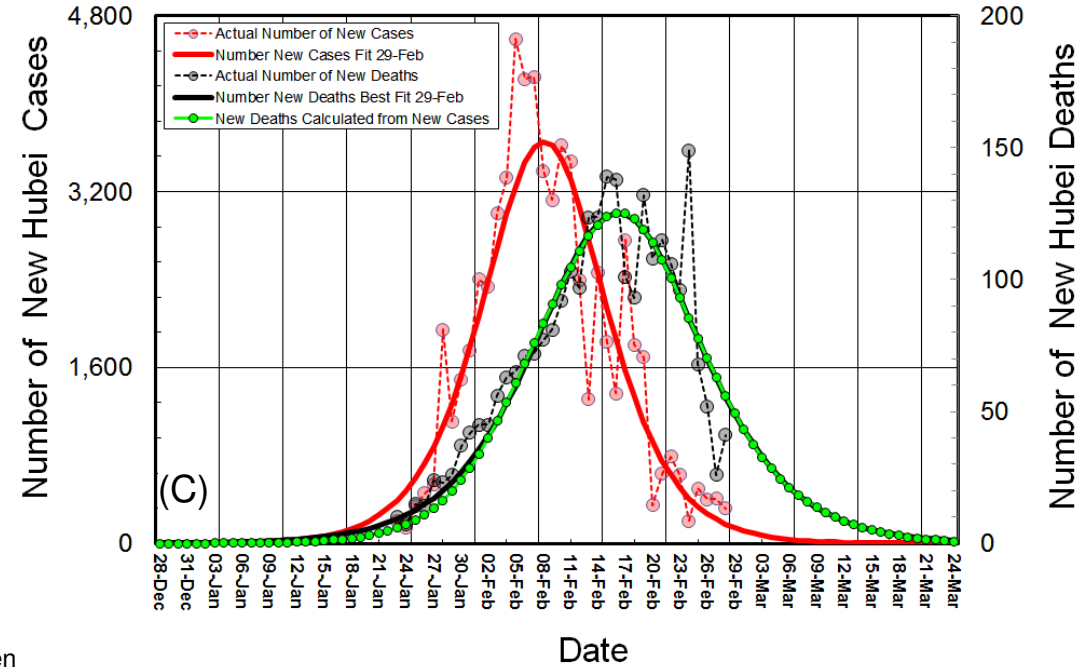

**Figure 5.** Relating new cases to new deaths via a death rate distribution, which gives the fraction of cases that die *i* days after a case is confirmed.

If $P_i$ is fraction of cases that die after $i$ = 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 $D_n = C_n*P_0 + C_{n-1}*P_1 + C_{n-2}*P_2 + \ldots + C_{n-29}*P_2$. The total death rate is $\Sigma P_i$.

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 $-W\Sigma P_n ln(P_n n)$ 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 (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.

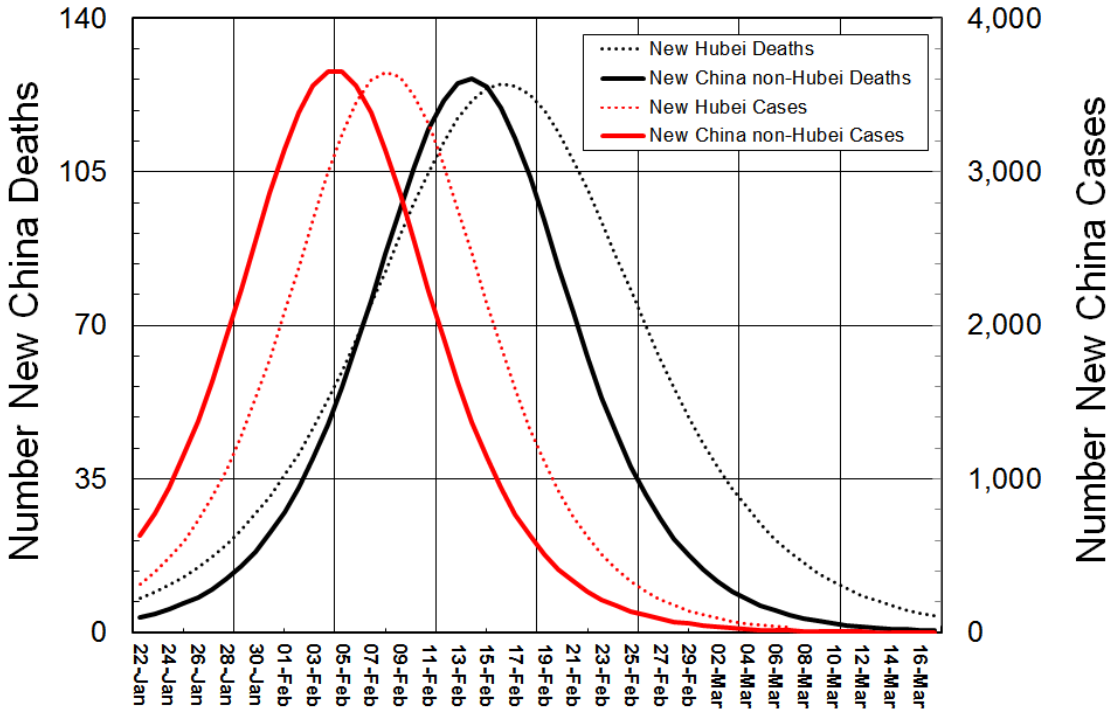
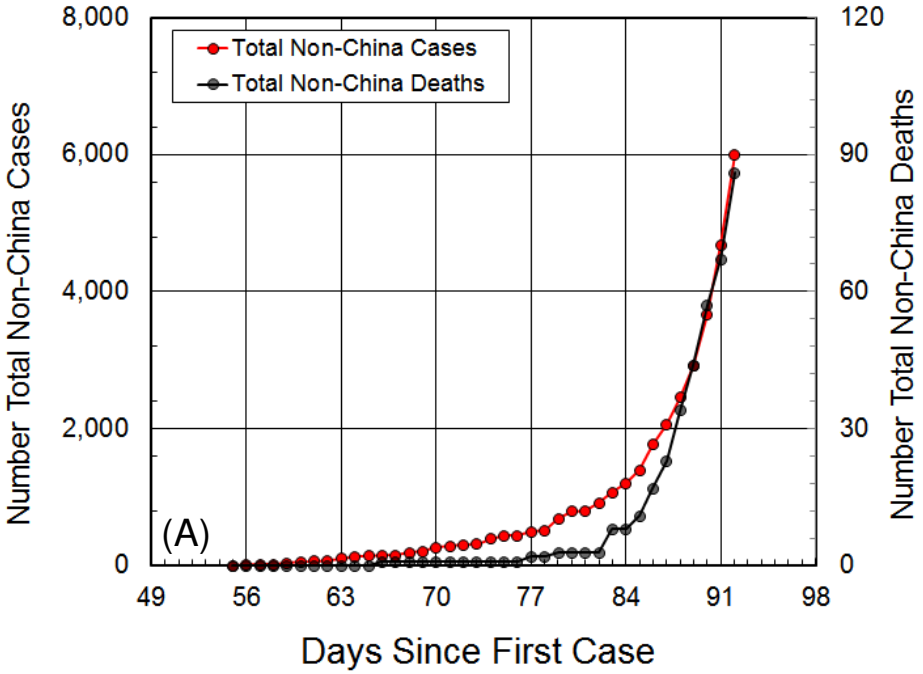



**Figure 6** compares the sigmoid curves for cases and deaths in Hubei and China Non-Hubei (see **Fig. 4**) . The smaller number of Non-Hubei cases are scaled by a factor of 4.99 so they are the same height as Hubei cases. The same is done to the much smaller number of Non-Hubei deaths, which are scaled 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.



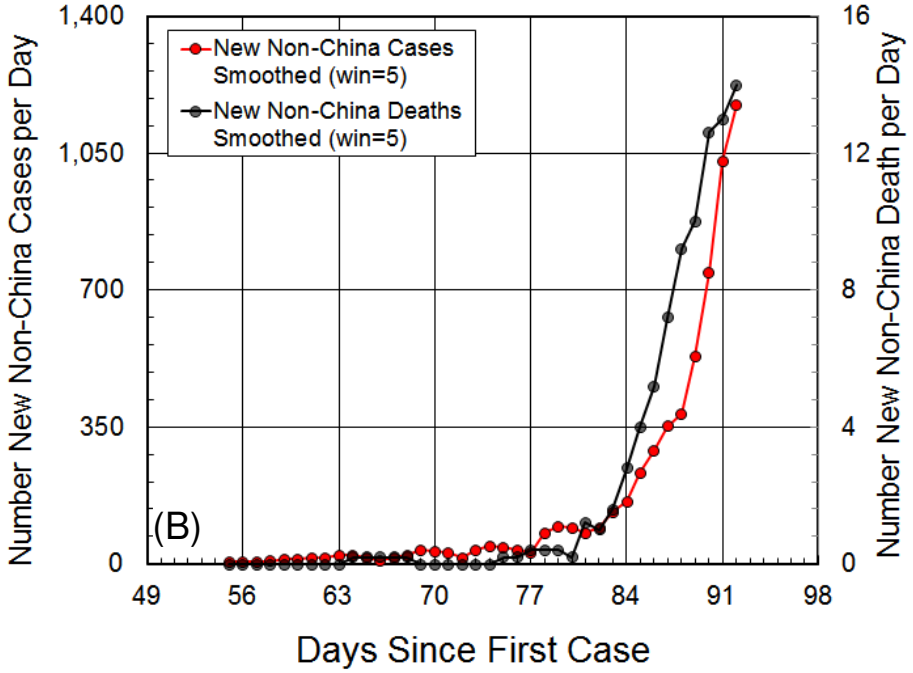




**Figure 7** shows the number of cases and deaths outside China. These plots involve small numbers and are beset by high levels of noise. Still, now is the time when prediction is important.

(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 patience 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: 0.99% in for the 705 cases on the Diamond Princes, 0.52% for the 3736 cases in South Korea, 2.34% for the 239 cases in Japan, 1.73% for the 1128 cases in Italy and 5.52% for the 593 cases in Iran. Unfortunately, the number of cases outside China is still too small to allow any prediction.