1   **Outbreak analysis with a logistic growth model shows COVID-19 suppression dynamics**

2   **in China**

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19

20 **Abstract**

21 China reported a major outbreak of a novel coronavirus, SARS-CoV2, from mid-January till

22 mid-March 2020. The number of cases outside China is now growing fast, while in mainland

23 China the virus outbreak is largely under control. We review the epidemic virus growth and

24 decline curves in China using a phenomenological logistic growth model to summarize the

25 outbreak dynamics using three parameters that characterize the epidemic's timing, rate and

26 peak. During the initial phase, the number of virus cases doubled every 2.7 (range 2.2 - 4.4)

27 days. The rate of increase in the number of reported cases peaked approximately 10 days after

28 suppression measures were started on 23-25 January 2020. The peak in the number of

29 reported sick cases occurred on average 18 days after the start of measures. From the time of

30 starting measures till the peak, the number of cases increased by a factor 39 in the province

31 Hubei, and by a factor 9.5 for all of China (range: 6.2-20.4 in the other provinces). Complete

32 suppression took up to 2 months (range: 23-57d.), during which period severe restrictions,

33 social distancing measures, testing and isolation of cases were in place. The suppression of

34 the disease in China has been successful, demonstrating that suppression is a viable strategy to

35 contain SARS-CoV2.

36

38 **Introduction**

39 The coronavirus SARS-CoV2 emerged in Wuhan, Hubei province, China, in late 2019. From

40 there it spread, first in Hubei, then across China during the spring holiday, and finally across

41 the world. Currently (as of 8 April 2020), the virus has been reported from 212 countries areas

42 or territories and the cumulative number of cases outside China has exceeded 1.2 million[1].

43 In mainland China, few new cases have been reported since 18 March, and most new cases

44 have originated from outside China[2]. Thus, the SARS-CoV-2 outbreak in China appears to

45 be, for now, under control.

46

47 Virtually the entire global population is susceptible to SARS-CoV2 infection and no vaccine

48 is available yet. Unless a successful NPI (Non-Pharmaceutical Intervention) strategy is

49 implemented in the early stages of transmission, an exponential global proliferation threatens

50 to overwhelm the health care systems of many countries. Three NPI strategies are being

51 discussed for managing the current COVID-19 epidemic: (1) suppression, (2) mitigation, and

52 (3) containment[3]. In **suppression**, strict measures are taken to reverse the epidemic spread,

53 essentially by bringing the effective reproduction number R_e (the number of new cases per

54 existing case) below one[4, 5]. Social distancing is a key factor in suppression[6]. In

55 **mitigation** the aim is not to necessarily stop all transmission, but rather to reduce the rate of

56 transmission and in effect lower the number of infected people at any given time[3, 7]. It has

57 been suggested that mitigation strategies might prevent inundation of the health care system

58 by "flattening" the peak of sick people"[3]. However, even in the most optimistic scenarios

59 for mitigation, healthcare capacity is likely to be still seriously overwhelmed, as it was in

60 Wuhan in February 2020 and in Italy in March 2020. Herd immunity has been suggested as a

61 component of mitigation, but is only a viable option once a vaccine is available because up to

62 20% of people with confirmed infection develops serious symptoms and needs hospitalization

63   or intensive care [8]. The proportion of unreported cases is uncertain (86% before measures

64   but 16-21% after measures in the whole of China according to Li, Pei (9); 59% or more in

65   Wuhan according to Wang, Liu (10)). If underreporting is accounted for, the proportion of

66   infected people requiring hospitalization is still in the order of 3% or more. Containment is

67   based on intensive surveillance of possible cases, testing, followed by isolation of infected

68   people and their contacts[11]. Containment is only possible if the virus is not freely

69   circulating in a population. Currently, because in many countries outside of China the virus is

70   circulating within the population, these countries are practicing suppression. Policy makers

71   may ask:

72

73   (1) How long will it take for the epidemic to peak after suppression measures have been

74   implemented?

75   (2) What will the peak number of sickness cases be?

76   (3) How long do suppression measures need to be maintained to suppress the virus to

77   sufficiently low incidence to allow containment (search and quarantine flare-ups of the

78   virus)?

79

80   Here we analyze with a phenomenological logistic model the epidemics of SARS-CoV2 in

81   China and 20 of its provinces that reported more than 150 cases. The logistic model is widely

82   used in ecology to analyze boom and bust population dynamics[12]. Logistic models are not

83   as widely used in human disease epidemiology as more mechanistic compartment-based SIR

84   and SEIR models[13-16] because the parameters lack a strict mechanistic interpretation in

85   terms of transmission rate and disease etiology (e.g. latency period, incubation period and

86   infectious period). However, this disadvantage is compensated by the usefulness of the

87   parameters for providing a simple and intuitive description of the outbreak dynamics in time.

88   We do not imply that logistic models can replace established epidemiological models, but we

89   do argue that phenomenological models, given the urgency and severe consequences of the

90   worldwide SARS-CoV2 outbreak for public health management, have a place along

91   mechanistic models to inform on disease dynamics[17] and support narratives on outbreak

92   dynamics with simple metrics like relative rate of increase, doubling time, and time to the

93   peak. Using data from China, logistic models shows the key disease dynamic parameters

94   before and after suppression policies were implemented[18].

95

96   **Methods**

97   All data were extracted from official reports from the National Health Commission of

98   China[19]. We obtained time series data of total confirmed, total recovered, and total death

99   cases for each provinces of China. We used the data starting on 21 January when reporting

100   daily infected cases started at the national level, and up to 10 March 2020 when almost no

101   new confirmed case in China[19]. We did not use data after 10 March to minimize the

102   influence of cases introduced from outside China.

103

104   We used three-parameter logistic models to fit the time series of the total confirmed and of the

105   total recovered cases. Parameters refer to the asymptotic value (*a*; number of cases),

106   the inflection point of the curve (*b*; date) and a scale parameter (*c*; days).

107
$$T_t = \frac{a}{1 + \exp\left(\frac{b - t}{c}\right)}$$

108

109
$$C_t = \frac{a_2}{1 + \exp\left(\frac{b_2 - t}{c_2}\right)}$$

110   where T_t and C_t are total infected and recovered cases at day t.

111

112   In addition, we assume a constant daily death rate k, which was calculated as the average of

113   number of deceased each day, divided by the infected cases on that day:

114
$$k = \frac{1}{n} \sum_{i=1}^{n} \frac{D_i}{I_i}$$

115   Where D_t and I_t are the number of daily death cases and active infected cases at day t. We

116   excluded data before 25 January and data where $I_t < 50$ in this calculation, as values are

117   poorly estimated at an early stage of the outbreak (under-estimated denominator) and at low I_t

118   (high variability in the outcome).

119

120   We then calculated the active infected cases, which can be expressed as

121
$$I_t = T_t - TD_t - C_t$$

122   Of which TD_t is the number of total death at day t, which equals

123
$$TD_t = \sum_{i=1}^{t} k \, I_i$$

124   And therefore (see Appendix 1 for inference)

125
$$I_t = \frac{(T_t - T_{t-1}) - (C_t - C_{t-1}) + I_{t-1}}{1 + k}$$

126   where $T_t - T_{t-1}$ is the daily change in the number of infected cases, and $C_t - C_{t-1}$ is the daily

127   change in the number of recovered cases.

128

129   Based on the fitted model, we then calculated the peak date of 1) active sick people, which is

130   also the date of peak number of daily death, 2) number of sick cases during the peak, 3) the

131   date of maximum increase in the number of infected cases and 4) the daily rate of increase on

132   this date, 5) total infected cases on this date, 6) the relative rate on this date, 7) the end date of

133   daily increase (<1) case (operationally the end of the epidemic), and 8) time from maximum

134   increase till sick peak. Taking the date of level 1 public health emergency action as the

135   implementation of suppression measures[20], which varied between 23 January to 25 January

136   across provinces[21] (we set the median date, 24 January as the date for entire China), we

137   then calculated 9) the delay from the action date until the sick peak, 10) the delay from the

138   action date until the date at which the rate of increase peaked, 11) the time from suppression

139   measure till the end date of daily increase in number of reported infections, 12) the ratio

140   between sick cases at peak and total infected case at the action date, as well as 13) the same

141   ratio considering a reporting delay of 6 days[9], i.e. by taking the ratio of

142    $\text{sick}(t_{peak})/\text{sick}(t_{action}+6)$.

143

144   Calculations were made for 20 Chinese provinces with more than 150 reported cases, and also

145   for China excluding Hubei, by far the worst affected province. The built-in function "SSlogis"

146   in R[22] was used to fit logistic growth curves. Data were obtained using package

147   "nCov2019" [23, 24].

148

149   **Results**

150   The cumulative number of cases (confirmed by testing or based on clinical symptoms) was

151   described very well by a logistic growth pattern with R^2 greater than 0.99 for all provinces,

152   except Shandong (R^2>0.98, Table A1). Three provinces enacted suppression measures on 23

153   January, five implemented measures on 24 January, and the remaining 12 provinces started

154   measures on 25 January. The time scale for the increase was $c = 3.91$ d. for China

155   (excluding Hubei, range 3.13 - 6.39) and 4.13 d. for Hubei (Table A1), indicating doubling

156   times of $c * \ln(2) = 2.7$ d. (range $2.2 – 4.4$ d) and 2.9 d. for China (excluding Hubei) and for

157   Hubei, respectively, during the early epidemic. Some lack of fit during the early phase of the

158   epidemic (before measures) suggests the actual doubling times may be even shorter than these

159   estimates (Table A1).

160

161   The number of reported active sick cases (total infected minus recovered minus deceased) in

162   Hubei peaked 25 days after suppression measures were implemented, which in the model also

163   indicates the peak of number of deaths on the same day. Outside Hubei, the peak number of

164   reported sick cases (and peak of daily number dying) was on average reached 18 days after

165   the start of suppression (Table 1). The rate of daily increase in reported cases peaked 17 days

166   after the start of suppression measures in Hubei, and on average 10 days after the start of

167   measures in the other provinces (range: 8 to 15 days). When assuming a reporting delay of 6

168   days[9], the actual peak in the rate of increase occurred at 11 days after the implementation of

169   measures in Hubei and at 4 days after the implementation of measures in the other provinces.

170   The actual peak in the number of sick cases peaked at 19 days after the start of measures in

171   Hubei and at 12 days after the start of measures in the other provinces.

172

173   The relative rate of increase in the number of cases at the time of the peak rate was rather

174   consistent among provinces, with an average of 0.11 cases/case/day for Hubei and 0.12

175   cases/case/day for the rest of China (range: 0.08 to 0.15). Between suppression

176   implementation and the peak number of reported cases, the number of active cases in Hubei

177   increased by a factor 39, while in other provinces it increased by a factor of 9.5 with

178   considerable variation between provinces (range: 6.2 in Hainan and Chongqing to 20.4 in

179   Heilongjiang). If a 6-day reporting delay is accounted for in the estimate of the factor increase

180   from the start of measures to the peak, then this multiplication factor is diminished to a value

181   of 9.5 for Hubei and an average of 2.6 for the other provinces. The daily death rate of the

182   active sick people was 0.34 percent per day for Hubei, much higher than in other provinces

183   (on average 0.05 percent per day, ranging between 0 in Jiangsu Province (see also Sun, Qiu

184   (25)) and 0.18 percent per day in Hainan Province, Appendix 3), which indicates that on the

185   day of peak sick in Hubei (about 50,000 reported cases), 170 individuals died. Cumulative to

186   10 March, the modelled logistic curve showed that for China (excluding Hubei) 0.85% of the

187   reported cases died which is close to the actual value of 0.86%. The death rate was

188   overestimated in Hubei as 6.7%, compared to the actual 4.5%, due to the actual daily death

189   rate declining during the later stages of the epidemic.

190

191   Modelled logistic curves show that the total number of infected cases had plateaued by 21

192   March for Hubei and by 6 March for the rest of mainland China, i.e. 57 and 42 days (range:

193   23 to 46 days) after the start of suppression measures (Fig. 1, Table 1).

194

195   **Discussion**

196   Our results show compelling evidence for suppression of SARS-CoV-2 transmission in

197   China, both in Hubei and the other provinces. No new cases were reported within mainland

198   China on 18, 19 and 20 March, 2020, with all new cases on those days from returning

199   overseas travelers, signaling the beginning of the end of the outbreak. However isolated cases

200   still occur, e.g. there was one new case on 24 March in Hubei. Thus, successful suppression

201   need to be followed by measures that will prevent a new outbreak[11].

202

203   Here we used logistic models to study the disease dynamic parameters. The analysis shown in

204   our results was continually updated from 1 February to 3 March while the epidemic was

205   progressing[26]. Based on the data up till 16 February 2020, a peak in sick incidence was

206   identified for 12 February, which was proven correct[27]. Thus, logistic models may be used

207   to determine early when suppression measures are expected to result in decreased rate of

208   epidemic growth and a decline in number of sick cases. However, any model shows lack of

209   fit[18]. The logistic model did not capture that the rate of increase in the early epidemic is

- 9 -

210   faster than the rate of decline during the tapering out of the epidemic (Appendix A1). Thus,

211   the logistic underestimates both the early relative growth rate and the increase of the number

212   of sick people from the start of measures till the peak for the Chinese data (Appendix A1).

213   Uncertainties in predictions also result from unknown reporting delay[9]. Improvements may

214   be possible by defining better tailored models, and especially, by collecting better data, e.g.

215   more (random) testing.

216

217   The results show that suppression can lead to (almost) complete removal of active virus

218   infected cases from the population, although given that not all active cases have recovered,

219   the outbreak is not completely over. The virus could still be present in asymptomatic

220   individuals or it could be re-introduced from unknown reservoirs. Re-entry of the virus from

221   countries outside China now needs to be prevented. Because the vast majority of the

222   population is not immune to SARS-SoV2, the virus can rapidly re-establish. Therefore,

223   suppression needs to be followed up by containment, a strategy based on strict surveillance,

224   testing of all individuals with symptoms, and followed by isolation of all infected individuals

225   and their recent contacts[11]. Currently, quarantine restrictions are gradually being lifted in

226   China, including Hubei Province, after no new cases have been detected for several weeks,

227   allowing people to return to work and businesses to start up again. Moreover, in China,

228   schools are preparing to reopen in April and normal social activities are slowly resuming[28].

229   These findings indicate that the implemented measures have been effective for controlling

230   SARS-CoV2 transmission in China[21, 29-31].

231

232   Many individuals infected with SARS-CoV2 show minimal or no symptoms. Due in part to

233   asymptomatic carriers, many infected individuals remain untested and unreported. Before 31

234   March, asymptomatic cases were not included in in the outbreak's daily report in China [32].

235 It is estimated that unreported cases were responsible for 77% of the reproduction number of

236 the disease before the start of measures in China and 16-21% thereafter[9, 10]. Moreover,

237 about half of infected individuals that develop symptoms do not show symptoms until 5 days

238 after infection, and some not up to 14 days, and maybe even up to 30 days[10, 33]. Cases with

239 a long incubation period, if they exist, could contribute to re-emergence of COVID-19 after

240 restrictions are lifted. Nonetheless, as the experience in China and several other

241 countries/regions (e.g. South Korea, Taiwan, Hongkong, Japan and Singapore) has shown, a

242 containment strategy can prevent the virus from uncontrolled spread if it re-emerges. Given

243 the worldwide pandemic spread of SARS-CoV2, it seems increasingly unavoidable that

244 worldwide containment will depend on a vaccine. Until a vaccine is ready and accessible, the

245 world population must confront the pandemic by combining suppression and containment in a

246 practical way that minimizes the human and economic costs. As noted by Wu and McGoogan

247 (8), "It is not only individual rights that need to be considered. The rights of those who are not

248 infected, but at risk of infection, must be considered as well."

249

250 Important lessons from the outbreak and its control in China are in our opinion:

251 1. Suppression of SARS-CoV-2 is possible even after widespread community transmission.

252 2. Suppression can be achieved in one to two months if stringent measures are implemented

253   and maintained.

254 3. If implementation of stringent suppression measures is delayed, as was the case in Hubei,

255   the peak outbreak time is later, the increase in the number of sick people is greater, the

256   mortality rate is higher, and the necessary period of suppression is longer.

257 4. China provides compelling evidence that suppression of SARS-CoV-2 transmission can be

258   achieved within 60 days, even following widespread community transmission. It is the

259   opinion of the authors that addressing the widespread SARS-CoV-2 transmission in other

260   countries with unproven mitigation strategies may subject a large part of their populations

261   unnecessarily to the adverse health risks associated with COVID-19[7, 34].

262

263   **Contributors**

264   YZ and WW conceived the study. YZ performed the analysis. YZ, SP, JK and WW wrote the

265   manuscript with significant contributions from all authors. All authors approved the final

266   version for submission.

267

268   **Declaration of interests**

269   We declare no competing interests.

270

271   **Data sharing**

272   Data used in this study are publicly accessible.

273

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278

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1
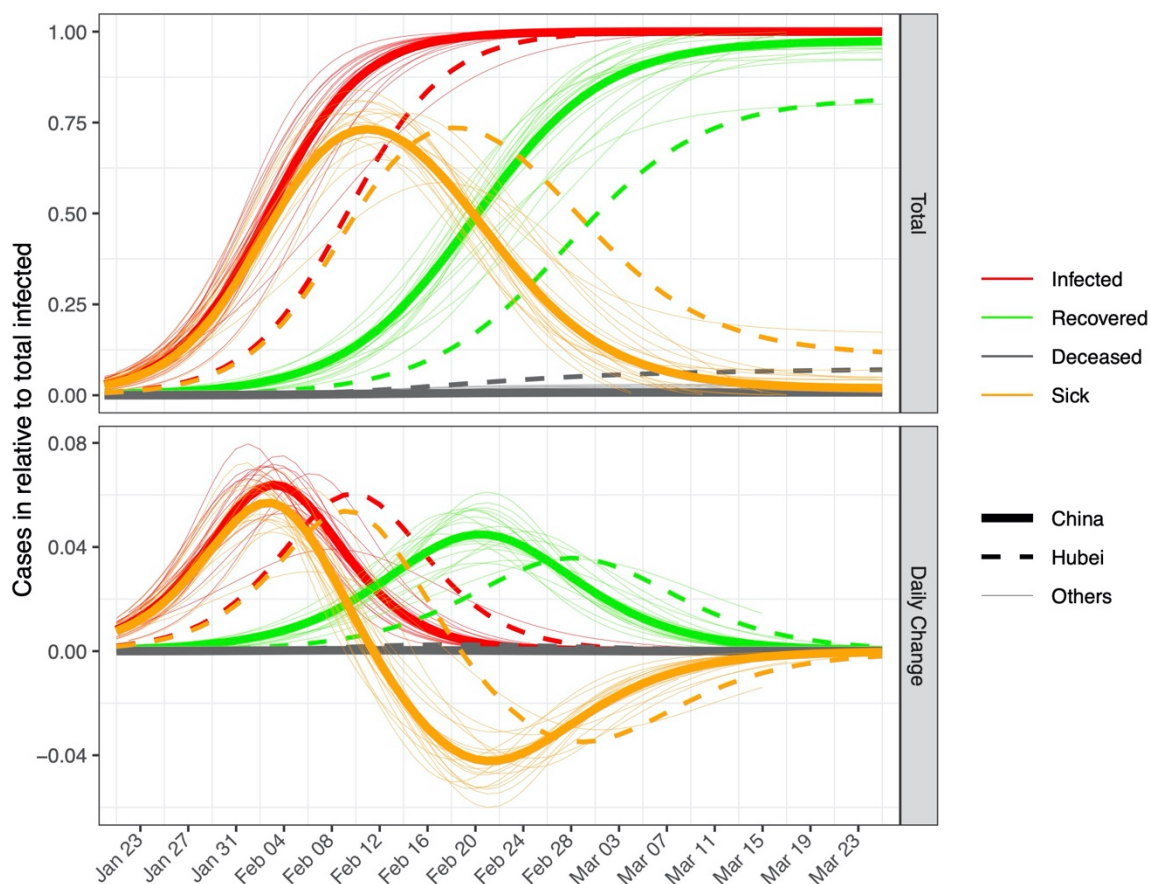
2
3   Fig. 1. Fitted epidemic curves based on the observed data of SARS-CoV2 in China excluding

4   Hubei (thick solid lines), Hubei (dashed lines), and 19 other provinces (thin solid lines). The

5   y-axis of the top panel shows the number of cases relative to the maximum cumulative

6   infected for each region (the value a, see methods). The bottom panel shows the daily change

7   on the same relative scale. Red, green and grey colors indicate confirmed, recovered and

8   deceased cases. Orange color indicates the number of "active" sick cases (relative to total

9   infected, top panel), i.e. infected and not yet recovered or deceased, and the daily changes

10   (bottom panel), with negative values in the lower panel indicating that the number of active

11   cases is decreasing. Fitted and observed values for the true number can be found in Fig. A1

12   and Fig. A2.

Table 1: Total confirmed infected cases (up to 10th March), emergency action start date and characteristics of logistic growth curves of epidemic progress in mainland China (excluding Hubei) and other 20 provinces with at least 150 cases of SARS-CoV2. Ratio refers to the sick cases at peak to the total number of infected cases at action date.

Region	Total confirmed infected cases	Emergency action start date	Peak date of active sick cases (or peak daily death)	Daily increase peak date	Daily increase end date	Delay from action until sick peak	Delay from action until maximum rate	Time from action to the outbreak end	Time from maximum rate till sick peak	Max Sick cases	Cases at time of maximum daily increase	Total infected cases at maximum daily increase date	Relative rate At peak increase rate (cases/case/d)	Ratio no reporting delay	Ratio 6 days reporting delay
China excluding Hubei	13004	24–Jan	11–Feb	3–Feb	6–Mar	18	10	42	8	9423	823	6692	0.12	9.5	2.6
Hubei	67773	24–Jan	18–Feb	10–Feb	21–Mar	25	17	57	8	49719	4086	36796	0.11	39	9.6
Guangdong	1353	23–Jan	10–Feb	3–Feb	24–Feb	18	11	32	7	1009	95	765	0.12	13.7	3.1
Henan	1272	25–Jan	10–Feb	3–Feb	24–Feb	16	9	30	7	947	91	659	0.14	10.0	2.4
Zhejiang	1215	23–Jan	9–Feb	1–Feb	20–Feb	17	9	28	8	926	95	648	0.15	12.4	2.5
Hunan	1018	23–Jan	9–Feb	2–Feb	23–Feb	17	10	31	7	718	72	516	0.14	12.7	2.9
Anhui	990	24–Jan	11–Feb	4–Feb	24–Feb	18	11	31	7	781	70	542	0.13	15.4	3.5
Jiangxi	935	24–Jan	11–Feb	4–Feb	23–Feb	18	11	30	7	731	70	529	0.13	17.3	3.5
Shandong	758	24–Jan	17–Feb	8–Feb	10–Mar	24	15	46	9	451	30	399	0.08	6.3	2.8
Jiangsu	631	25–Jan	11–Feb	4–Feb	24–Feb	17	10	30	7	451	41	337	0.12	8.9	2.5
Chongqing	576	24–Jan	11–Feb	2–Feb	24–Feb	18	9	31	9	416	33	291	0.11	6.2	2.1
Sichuan	539	24–Jan	13–Feb	4–Feb	26–Feb	20	11	33	9	373	28	291	0.10	6.7	2.4
Heilongjiang	482	25–Jan	14–Feb	6–Feb	25–Feb	20	12	31	8	374	33	247	0.13	20.4	4.6
Beijing	435	24–Jan	11–Feb	3–Feb	23–Feb	18	10	30	8	299	24	223	0.11	6.8	2.3
Shanghai	344	24–Jan	9–Feb	2–Feb	19–Feb	16	9	26	7	261	23	190	0.12	7.7	2.1
Hebei	318	24–Jan	12–Feb	5–Feb	25–Feb	19	12	32	7	207	18	161	0.11	10.3	3.1
Fujian	296	24–Jan	10–Feb	1–Feb	18–Feb	17	8	25	9	238	21	149	0.14	8.2	2.2
Guangxi	252	24–Jan	12–Feb	3–Feb	21–Feb	19	10	28	9	195	14	137	0.10	7.1	2.4
Shaanxi	245	25–Jan	11–Feb	2–Feb	19–Feb	17	8	25	9	197	16	126	0.12	6.8	2.1
Yunnan	174	24–Jan	10–Feb	1–Feb	16–Feb	17	8	23	9	145	11	91	0.13	7.1	2.1
Hainan	168	25–Jan	11–Feb	4–Feb	20–Feb	17	10	26	7	120	10	94	0.10	6.2	2.1

1 **Supplementary information**

2

3 Appendix 1. Formula inference

4

5 $I_t = T_t - \sum_{i=1}^{t} k\, I_i - C_t$ (1)

6

7 $I_{t-1} = T_{t-1} - \sum_{i=1}^{t-1} k\, I_i - C_{t-1}$ (2)

8 Equation (1) - Equation (2)

9 $I_t - I_{t-1} = (T_t - T_{t-1}) - (C_t - C_{t-1}) - k\, I_t$

10 $I_t - I_{t-1} + k\, I_t = (T_t - T_{t-1}) - (C_t - C_{t-1})$

11 $I_t + k\, I_t = (T_t - T_{t-1}) - (C_t - C_{t-1}) + I_{t-1}$

12 $I_t\,(1 + k) = (T_t - T_{t-1}) - (C_t - C_{t-1}) + I_{t-1}$

13 Therefore,

14 $I_t = \dfrac{(T_t - T_{t-1}) - (C_{t-1} - C_{t-1}) + I_{t-1}}{1 + k}$

15

16

- 17 -

Table A1. Estimated model parameters per province and for China (excluding Hubei) and other 20 provinces with at least 150 cases of SARS-CoV2

| Region	Daily fatality rate (%)	a	b	c	R-squared	a2	b2	c2	R-squared2
China (excluding Hubei)	0.05 ± 0.01	12882 ± 42	14.7 ± 0.1	3.91 ± 0.07	0.999	12558 ± 83	31.9 ± 0.1	5.43 ± 0.09	0.999
Hubei	0.34 ± 0.05	67622 ± 463	21.3 ± 0.2	4.13 ± 0.13	0.996	55387 ± 556	39.6 ± 0.2	5.73 ± 0.08	0.999
Guangdong	0.05 ± 0.03	1344 ± 3	14 ± 0.1	3.52 ± 0.05	0.999	1304 ± 24	32.4 ± 0.4	6.19 ± 0.24	0.995
Henan	0.17 ± 0.06	1270 ± 4	13.7 ± 0.1	3.47 ± 0.06	0.999	1288 ± 8	29.8 ± 0.1	4.62 ± 0.09	0.999
Zhejiang	0.00 ± 0.00	1196 ± 5	12.5 ± 0.1	3.13 ± 0.09	0.997	1245 ± 16	31.6 ± 0.3	6.30 ± 0.18	0.997
Hunan	0.02 ± 0.01	1018 ± 3	12.9 ± 0.1	3.50 ± 0.07	0.999	972 ± 11	27.8 ± 0.2	5.30 ± 0.17	0.997
Anhui	0.02 ± 0.01	993 ± 2	15.3 ± 0.1	3.54 ± 0.04	0.999	1003 ± 5	32.4 ± 0.1	4.43 ± 0.06	0.999
Jiangxi	0.00 ± 0.00	936 ± 3	15.1 ± 0.1	3.32 ± 0.06	0.999	938 ± 5	31.6 ± 0.1	4.61 ± 0.07	0.999
Shandong	0.04 ± 0.02	774 ± 13	19.6 ± 0.5	6.39 ± 0.40	0.979	854 ± 39	39.6 ± 0.9	7.81 ± 0.37	0.993
Jiangsu	0.00 ± 0.00	635 ± 2	13.5 ± 0.1	3.89 ± 0.09	0.998	616 ± 5	28.9 ± 0.1	4.89 ± 0.12	0.998
Chongqing	0.05 ± 0.02	575 ± 2	12.9 ± 0.1	4.40 ± 0.09	0.998	543 ± 9	30.8 ± 0.3	5.57 ± 0.22	0.995
Sichuan	0.03 ± 0.02	536 ± 3	15.2 ± 0.2	4.72 ± 0.14	0.996	515 ± 9	34.7 ± 0.3	6.89 ± 0.19	0.997
Beijing	0.11 ± 0.05	411 ± 2	14.2 ± 0.1	4.35 ± 0.12	0.996	330 ± 3	31.9 ± 0.2	5.92 ± 0.11	0.999
Heilongjiang	0.15 ± 0.05	482 ± 2	16.8 ± 0.1	3.66 ± 0.06	0.999	445 ± 6	34.7 ± 0.2	5.03 ± 0.15	0.997
Shanghai	0.04 ± 0.03	337 ± 1	13 ± 0.1	3.67 ± 0.06	0.999	311 ± 2	29.4 ± 0.1	4.35 ± 0.11	0.998
Hebei	0.11 ± 0.05	319 ± 2	14.9 ± 0.1	4.42 ± 0.12	0.997	315 ± 2	29 ± 0.1	4.56 ± 0.07	0.999
Fujian	0.02 ± 0.02	294 ± 2	10.9 ± 0.1	3.57 ± 0.12	0.995	307 ± 3	31.4 ± 0.2	5.45 ± 0.13	0.998
Guangxi	0.03 ± 0.02	251 ± 1	14.2 ± 0.1	4.38 ± 0.10	0.998	255 ± 3	35.7 ± 0.2	5.96 ± 0.14	0.998
Shaanxi	0.03 ± 0.03	244 ± 1	11.8 ± 0.1	3.89 ± 0.09	0.997	233 ± 2	30.1 ± 0.1	4.32 ± 0.11	0.998
Yunnan	0.07 ± 0.05	172 ± 1	12.6 ± 0.2	3.77 ± 0.19	0.988	177 ± 2	32.5 ± 0.2	4.20 ± 0.13	0.997
Hainan	0.18 ± 0.09	170 ± 1	15 ± 0.1	4.41 ± 0.12	0.996	163 ± 1	31.4 ± 0.1	4.64 ± 0.11	0.998

Fig. A1
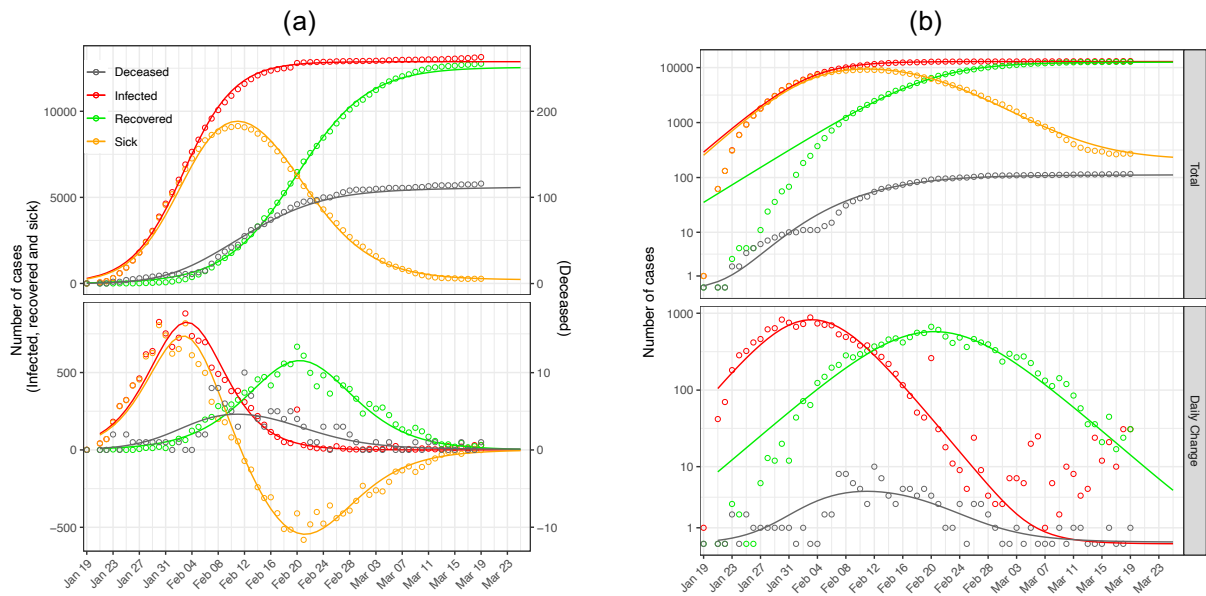
Fig. A1 Observed and fitted epidemics of SARS-CoV2 in mainland China excluding Hubei province for normal- (a) and log-scale (b) y-axis. Dots are observed cases and lines are model fits. Top panel refers total cases and bottom panel refers to daily changes. For the normal scale (A), the left y-axis is for infected, recovered and sick cases and the right y-axis for deceased cases. Red colour indicates the total number of infected cases (confirmed and suspected) (top panel) or the daily rate of increase in the number of cases (bottom panel). Green colour indicate the recovered cases in both panels. Grey colour indicates cumulative deaths in the upper graph and daily death cases in the lower panel. Orange colour indicates the number of "active" cases (top panel), i.e. infected and not yet recovered or deceased, and the daily change in the number of active cases (bottom panel). Negative values (in normal scale) in the lower panel mean that the number of active cases is decreasing.
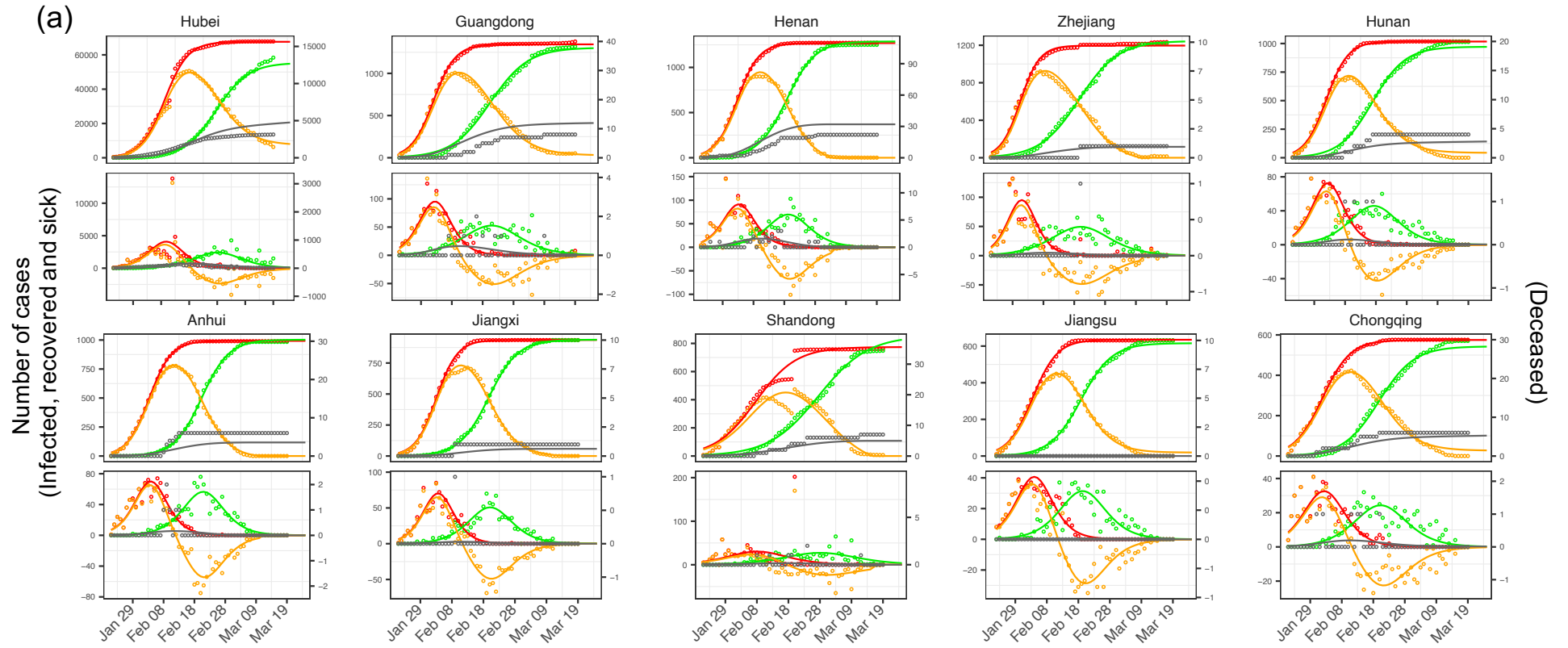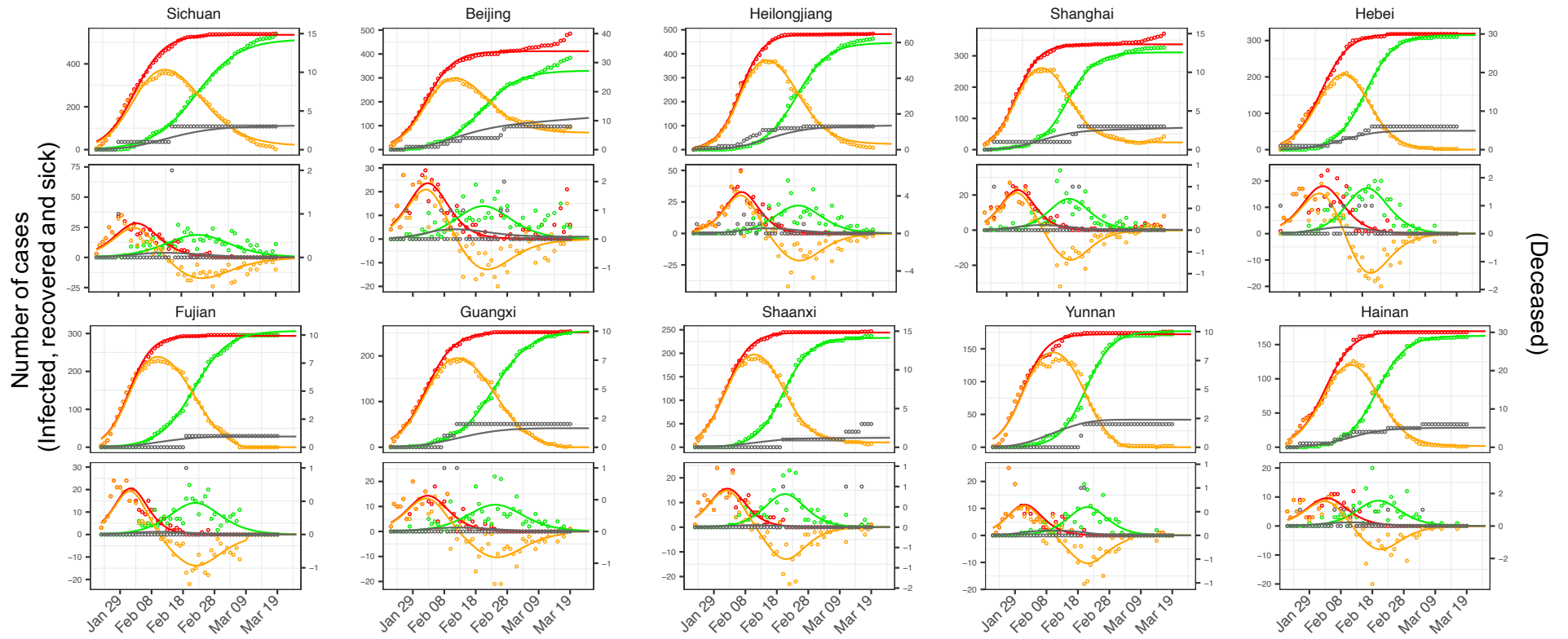
Fig. A2-a
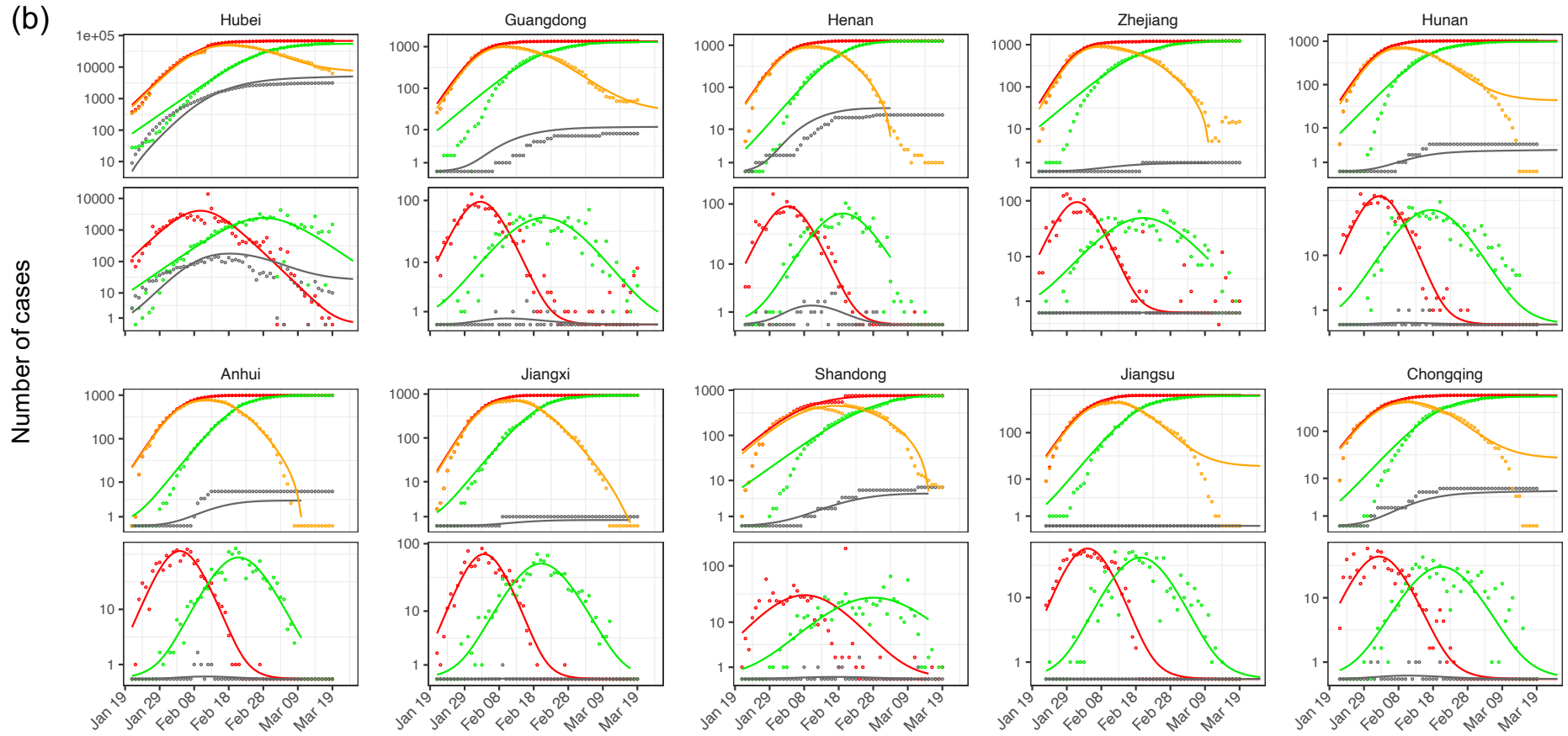

(a)

Number of cases
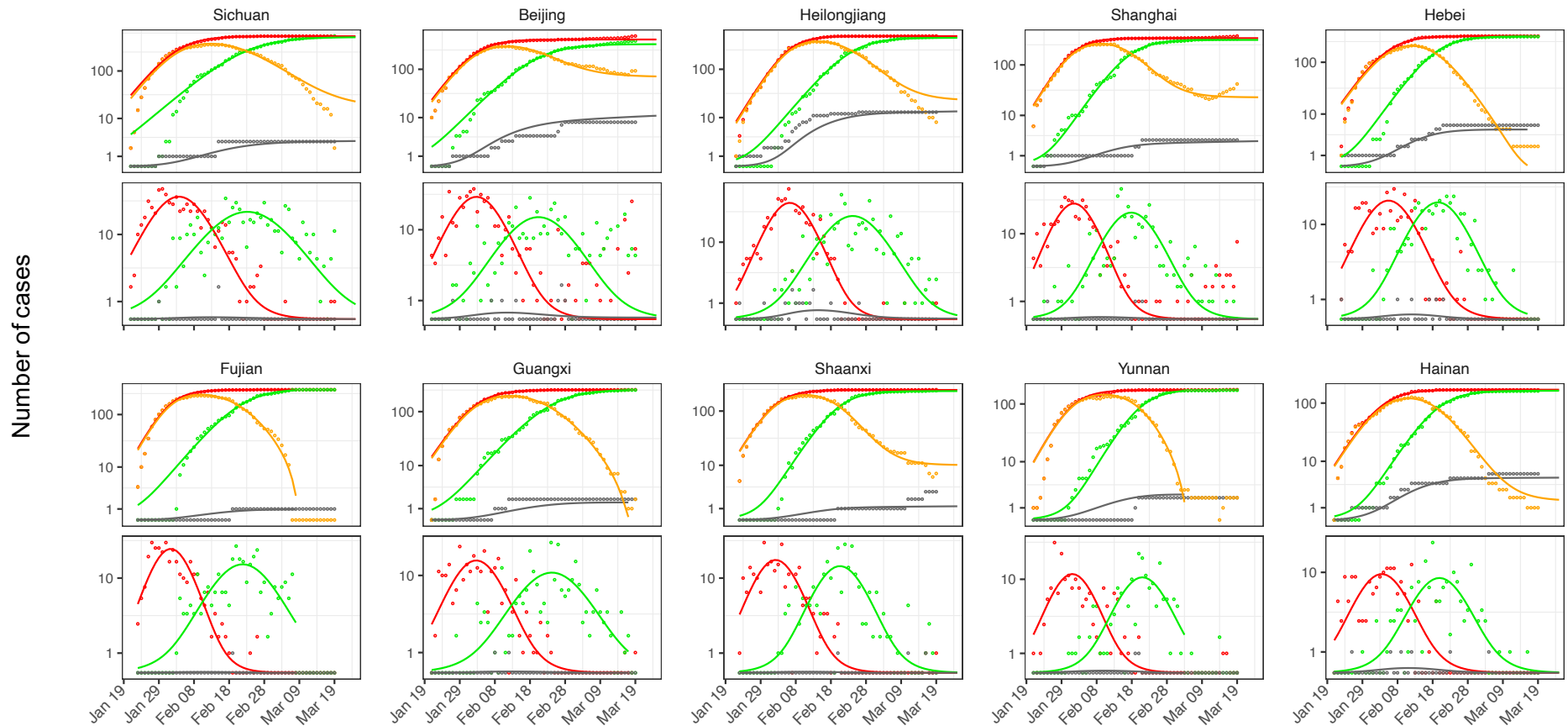(Infected, recovered and sick)

(Deceased)

Fig. A2-b

Fig. A2. Epidemics of SARS-CoV2 in 20 Chinese provinces with a minimum of 150 cases for normal- (a) and log-scale (b) y-axis. Dots are observed cases and lines are model fits. Red, green and grey colors indicate confirmed, recovered and deceased cases. For the normal scale (a), the left y-axis is for infected, recovered and sick cases and the right y-axis for deceased cases. Orange color indicates the number of "active" sick cases (relative to total infected, top panel), i.e. infected and not yet recovered or deceased, and the daily changes (bottom panel), with negative values (in normal scale) in the lower panel indicating that the number of active cases is decreasing. The upper panel for each province refers to the total number of cases while the lower panel refers to the daily change in the number of cases.