Macroscopic Analysis of the COVID-19 spread by Novel Indicator κ

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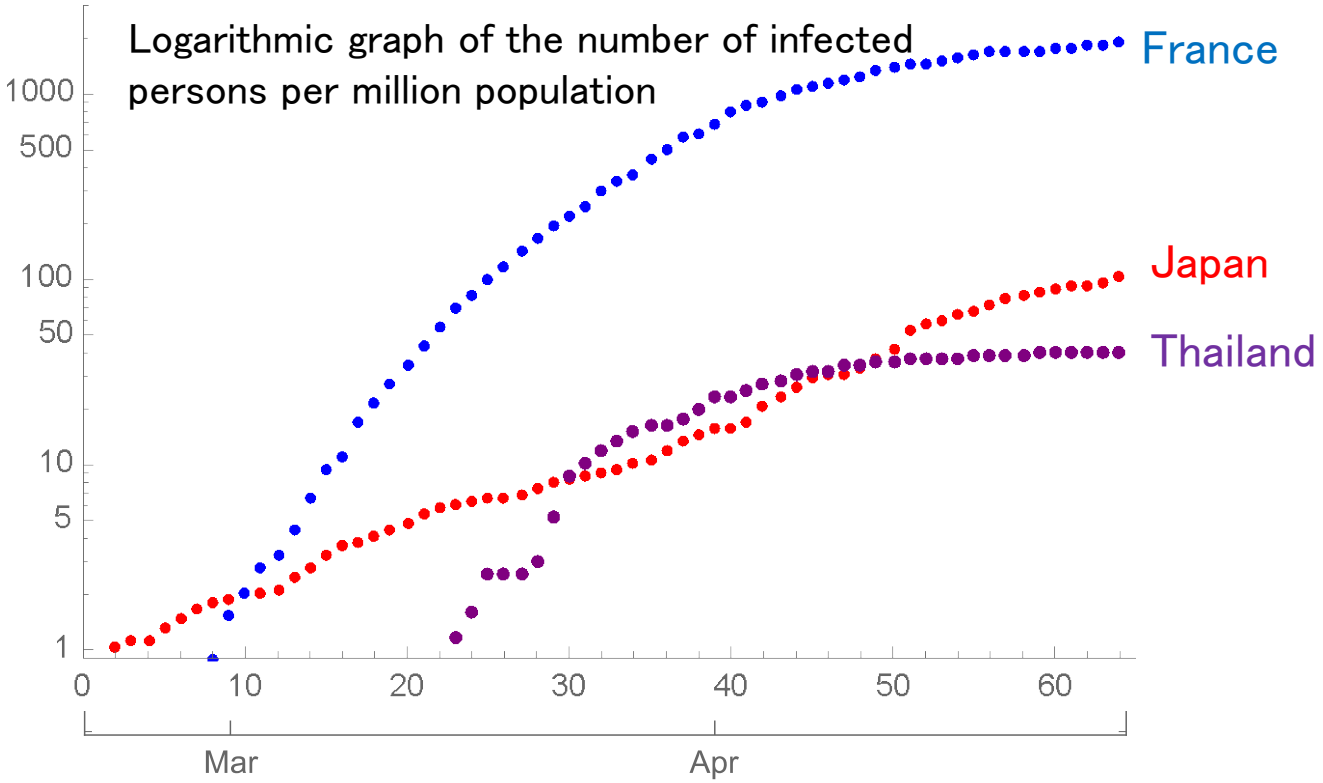
Is the change in the number of infected people in Japan unique?



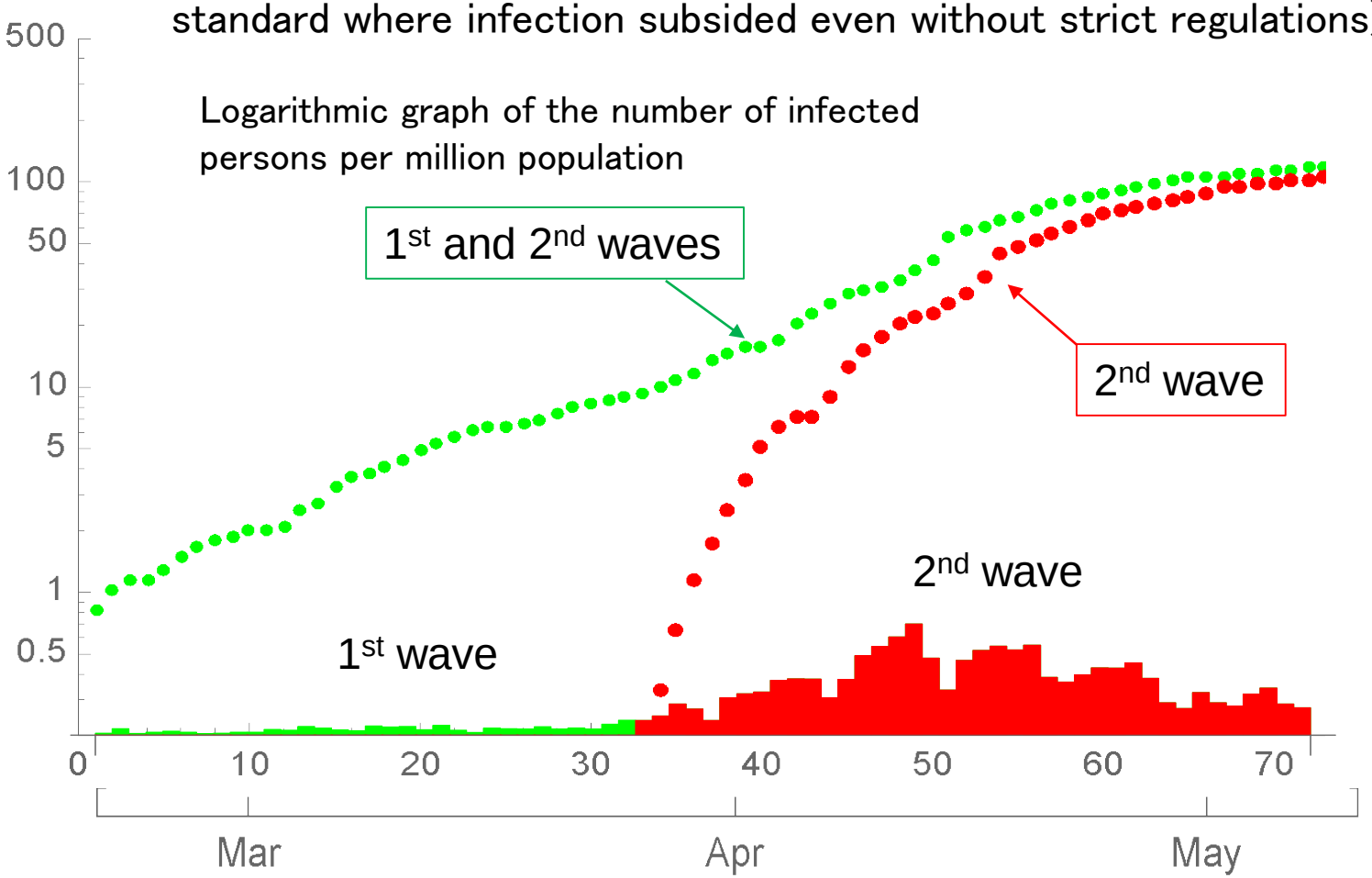
The epidemic curve in Japan appears to have a linear trend in the logarithmic graph.

"Over the next two weeks, the number of infected people doubles per week until the declared emergency begins to take effect!"

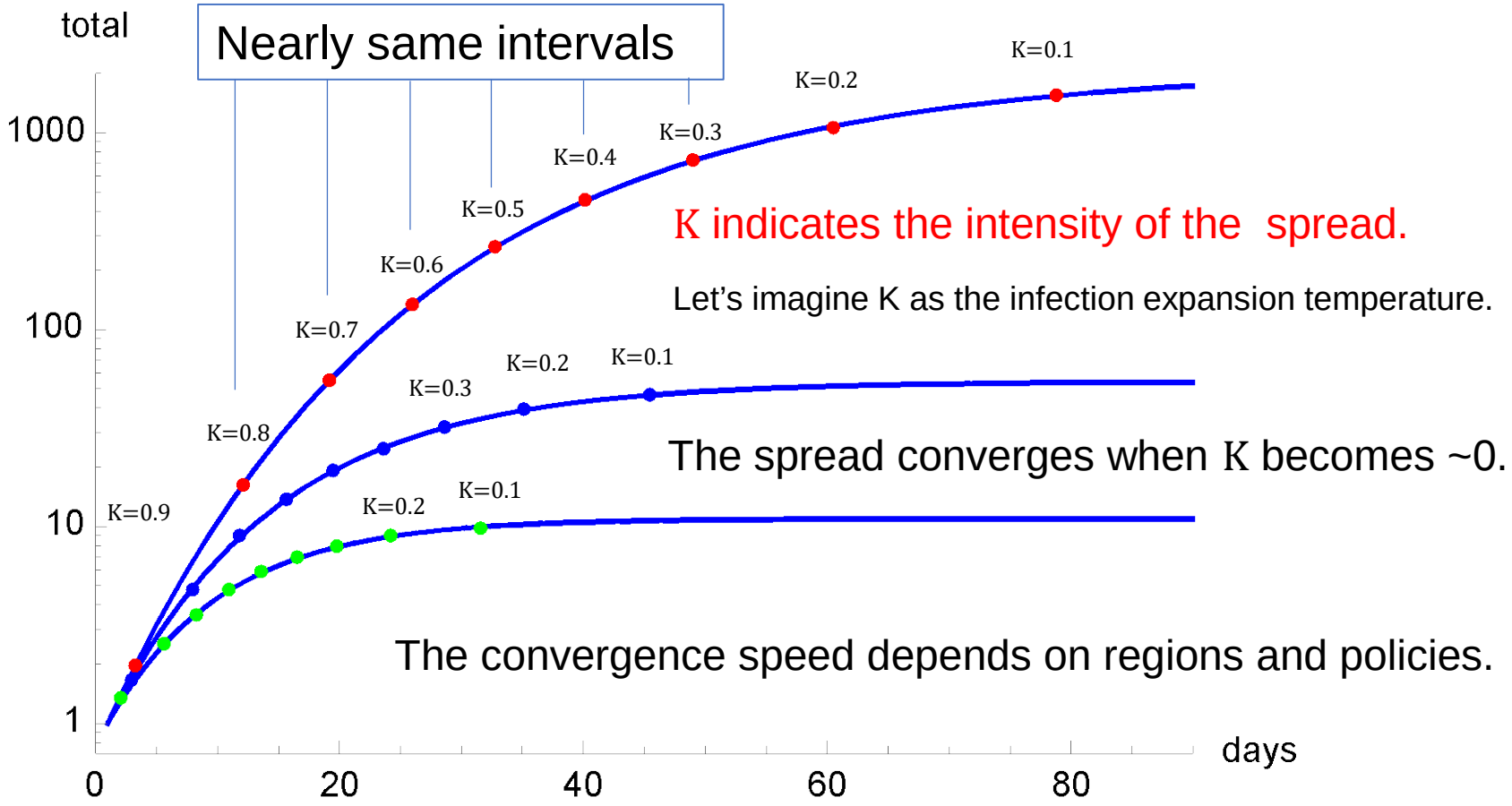
Really?

Correct trends in the number of infected people in Japan

After the cumulative total counter was reset on March 25, the trend in Japan appeared to be an international standard (especially the Asian standard where infection subsided even without strict regulations).



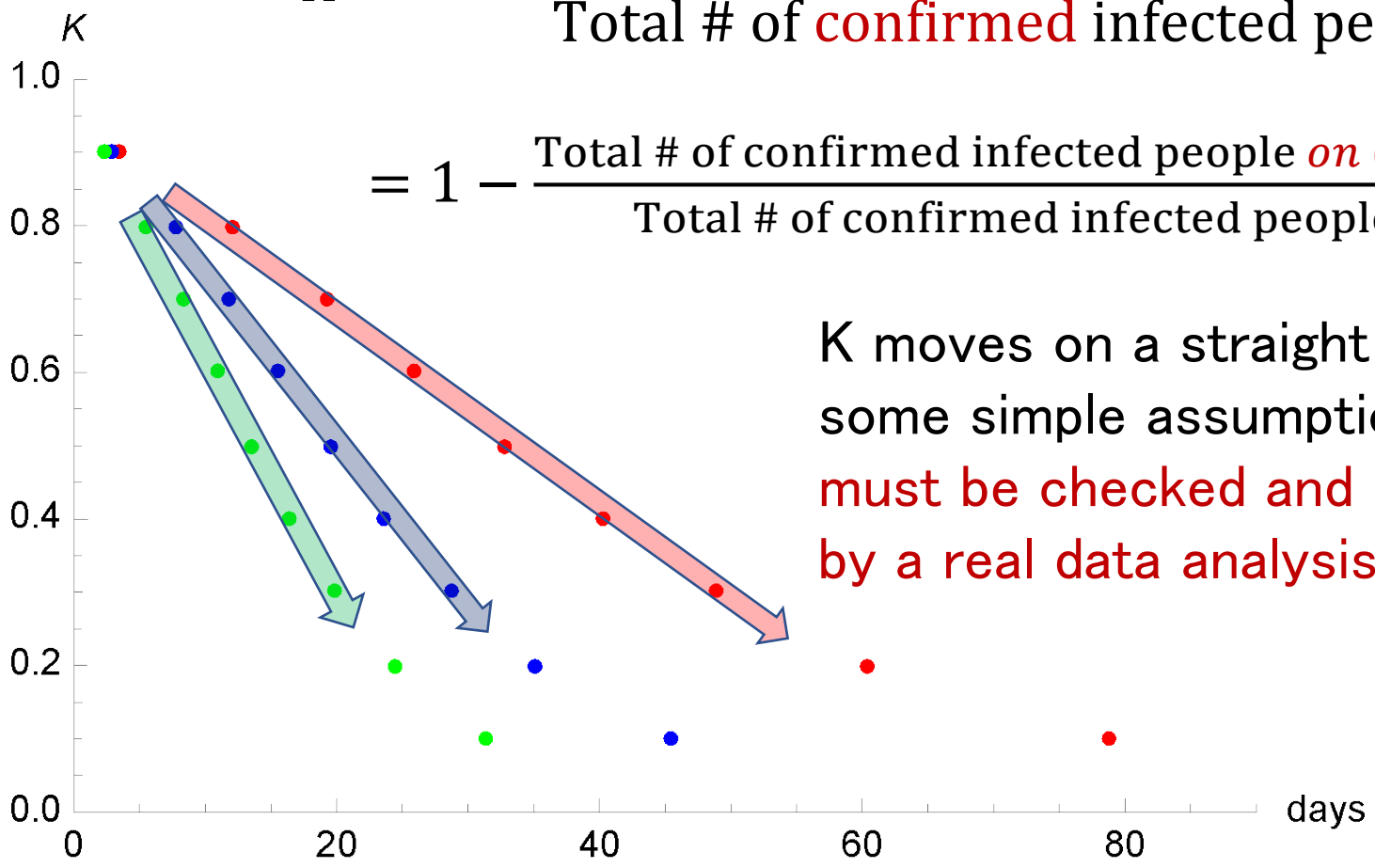
Novel indicator K of change in COVID-19 spread status



Linearity of K as a function of the elapsed days

$$K = \frac{\text{Total \# of confirmed infected people } in\ 7\ days}{\text{Total \# of confirmed infected people}}$$

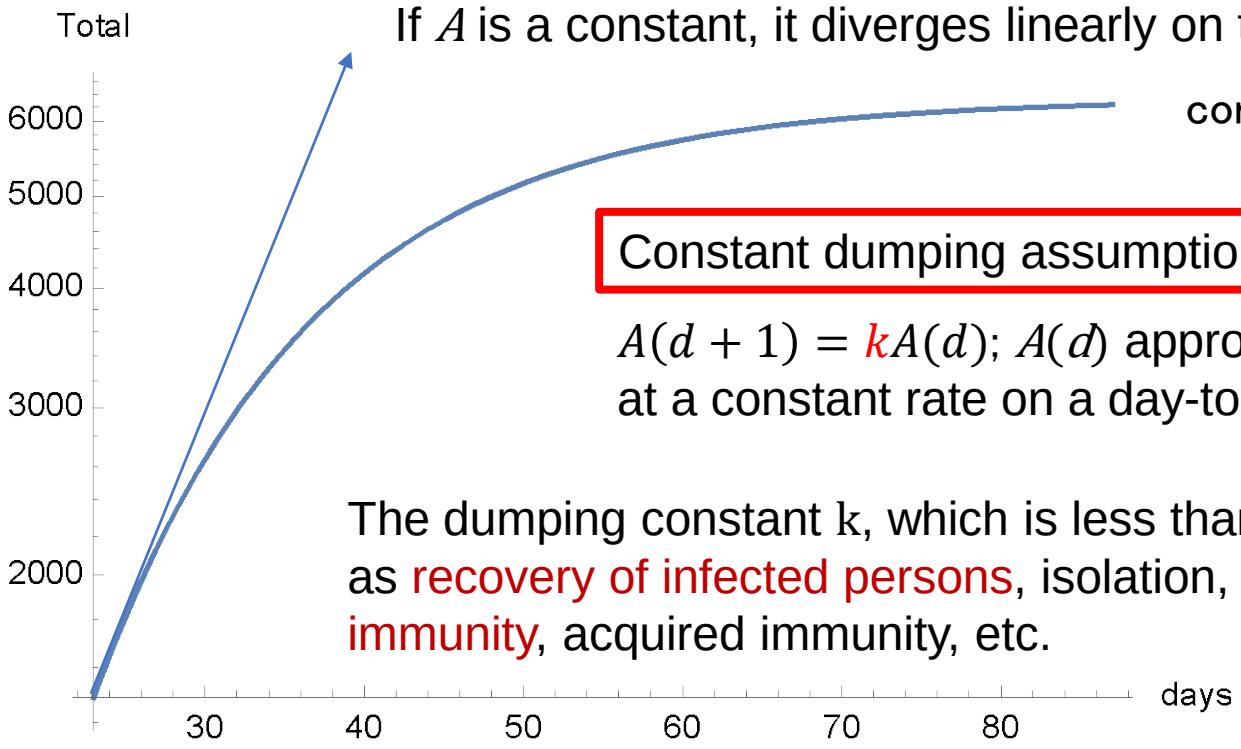
$$= 1 - \frac{\text{Total \# of confirmed infected people } on\ (d-7)}{\text{Total \# of confirmed infected people}}$$



K moves on a straight line under some simple assumption that must be checked and confirmed by a real data analysis.

Constant dumping assumption

$$N(d) = N_0 e^{Ad}$$



If A is a constant, it diverges linearly on the logarithmic axis.

converges at A = 0.

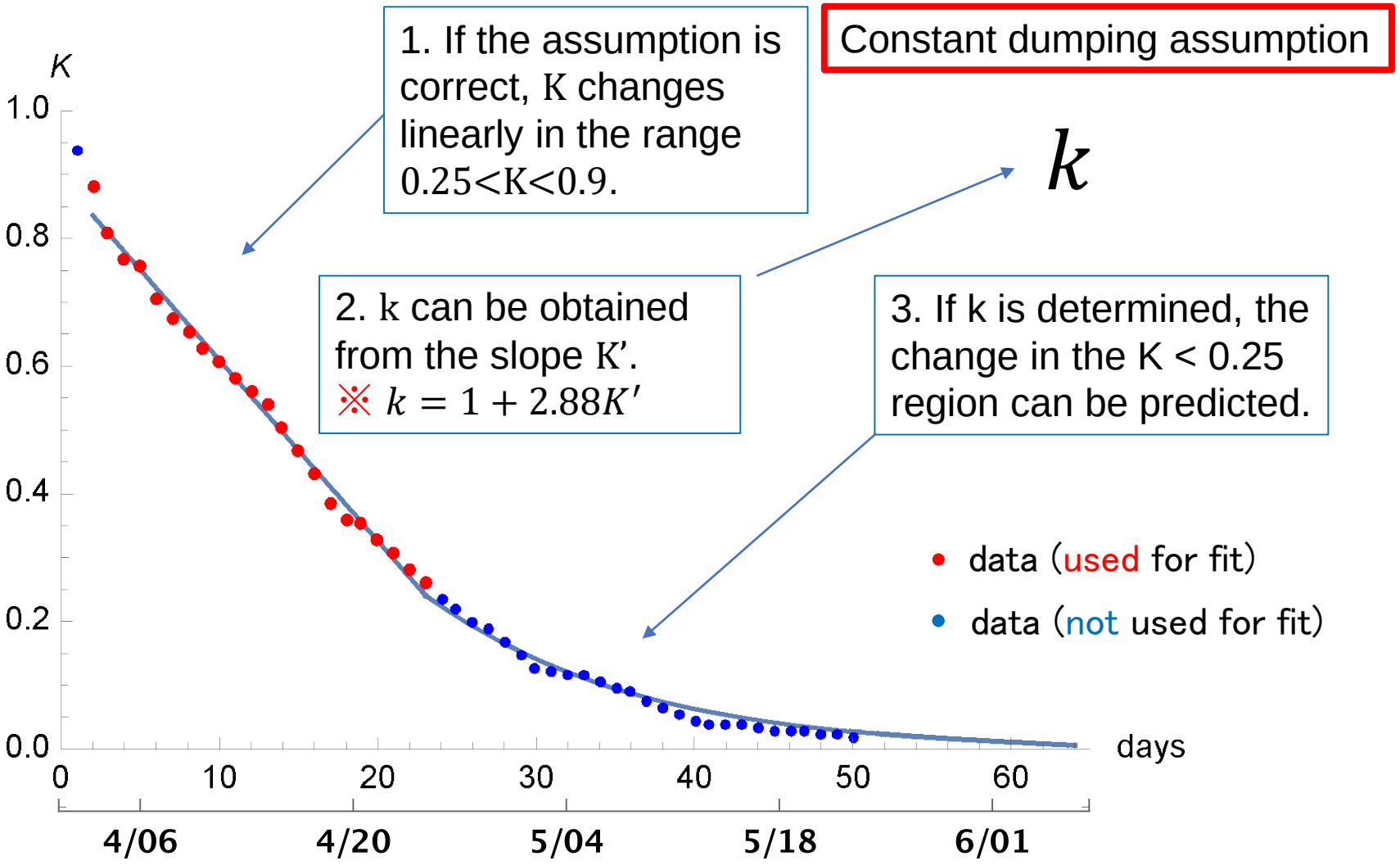
Constant dumping assumption

$A(d+1) = kA(d)$; $A(d)$ approaches zero at a constant rate on a day-to-day basis. ※

The dumping constant k, which is less than 1, reflects all effects such as recovery of infected persons, isolation, death, social distance, innate immunity, acquired immunity, etc.

※ Prof. Y. Akiyama of Tokyo Inst. Tech. proved that the constant dumping assumption is mathematically equivalent to the assumption that the time evolution of K is given by a double exponential function $K(t) = 1 - e^{-L(0)e^{-(1-k)t}}$.

Constant dumping assumption and transition of K in Japan



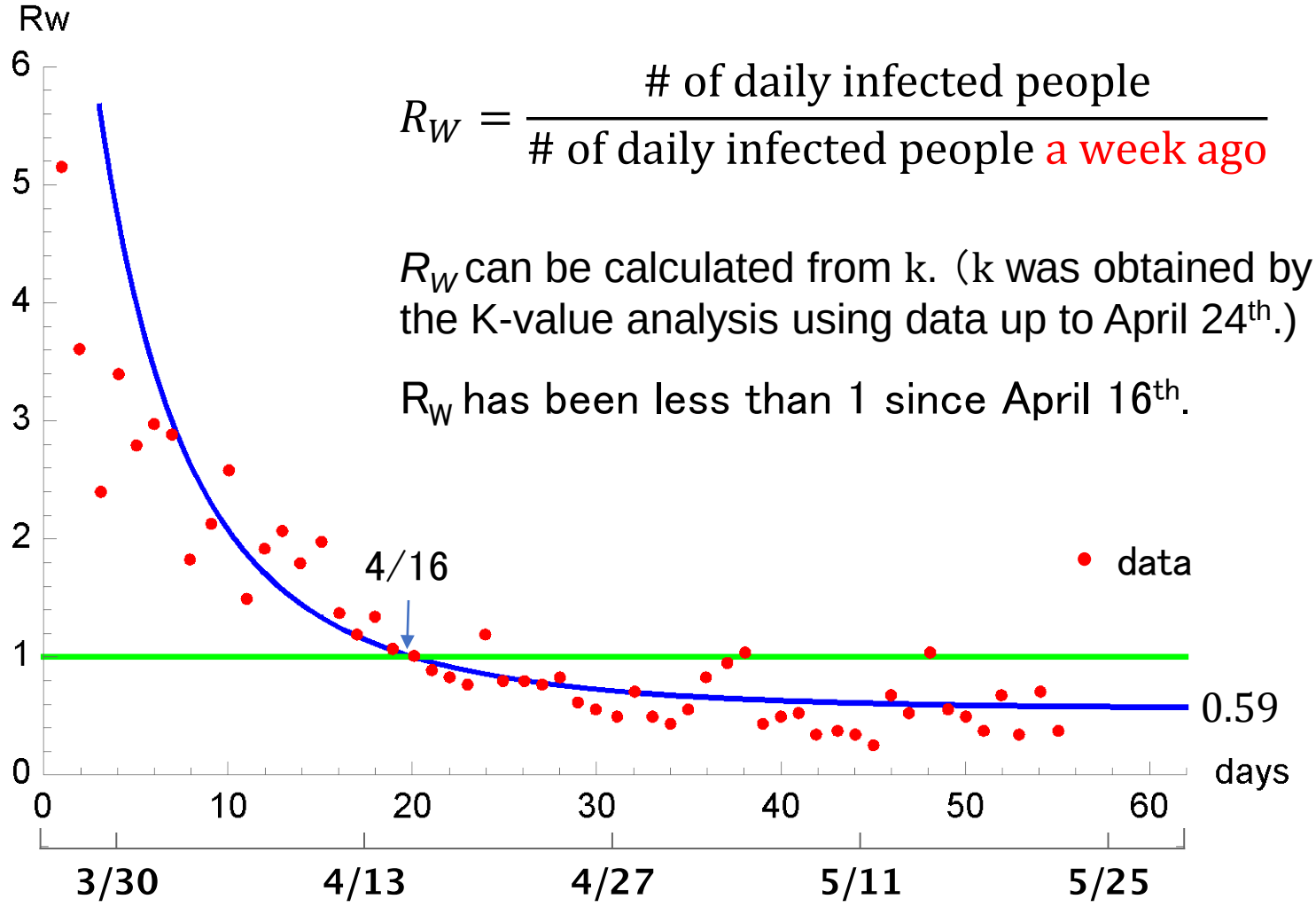
※The relationship between K' and k was proved by Prof. Y. Akiyama.

Identify convergence phase by K-value analysis

$$R_W = \frac{\#\text{ of daily infected people}}{\#\text{ of daily infected people a week ago}}$$

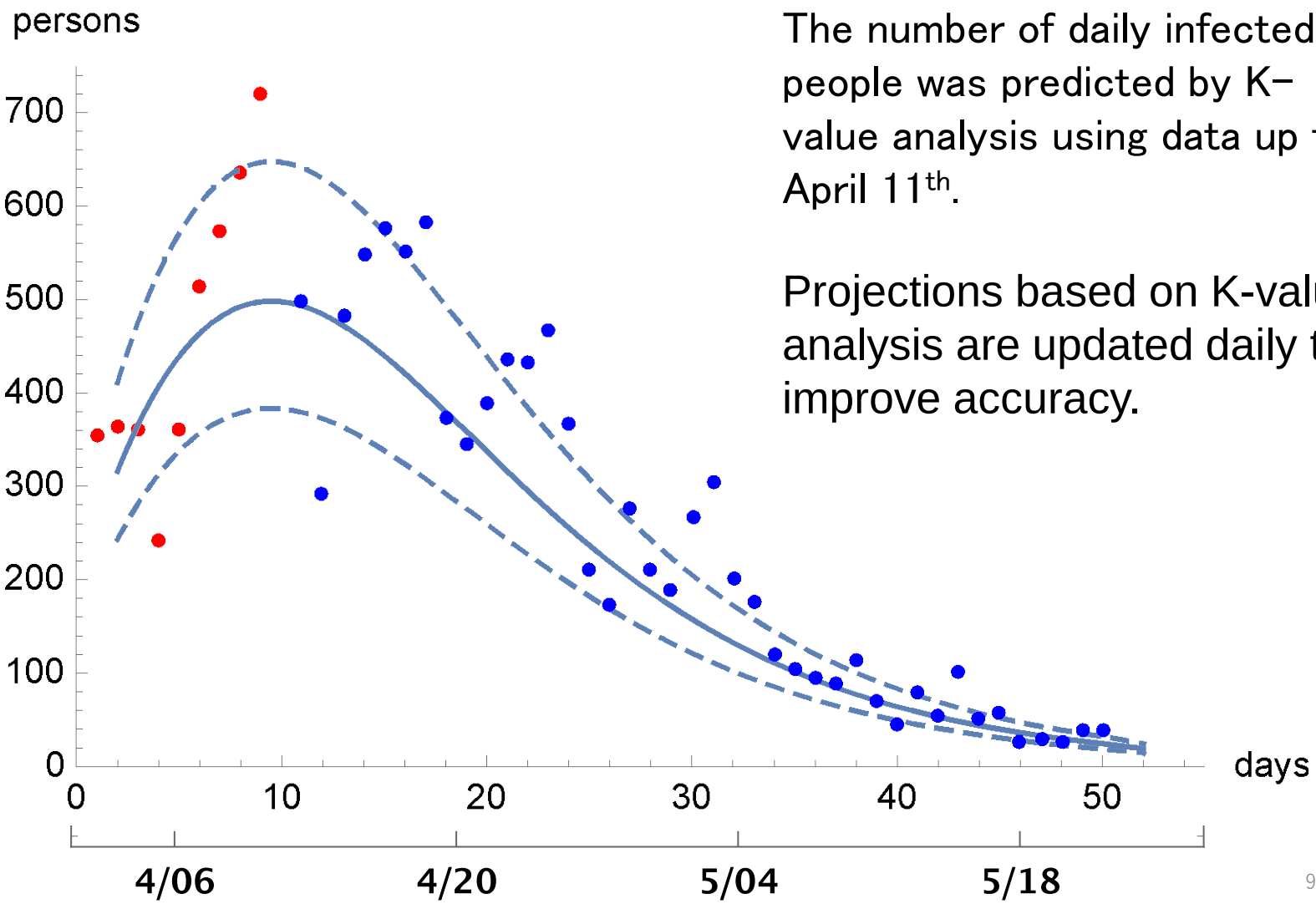
R_W can be calculated from k. (k was obtained by the K-value analysis using data up to April 24th.)

R_W has been less than 1 since April 16th.



The mathematical relation between R_W and k was clarified by Associate Prof. Y. Yasuda of Osaka University.

Early forecast based on K-value analysis



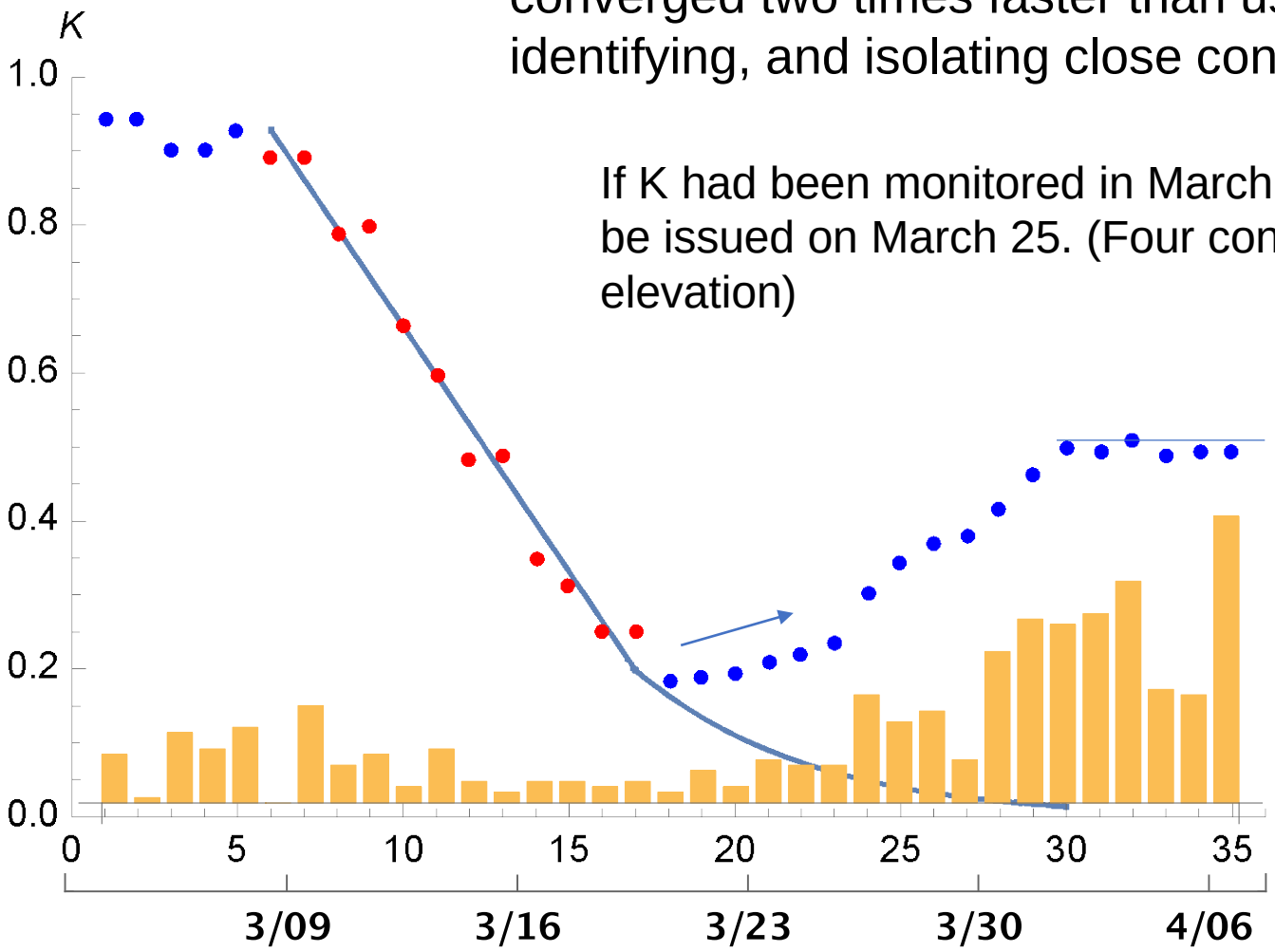
The number of daily infected people was predicted by K-value analysis using data up to April 11th.

Projections based on K-value analysis are updated daily to improve accuracy.

Early detection of outbreak

Osaka

Cluster infections originating from live houses converged two times faster than usual by following, identifying, and isolating close contacts.



If K had been monitored in March, an alarm could be issued on March 25. (Four consecutive days of elevation)

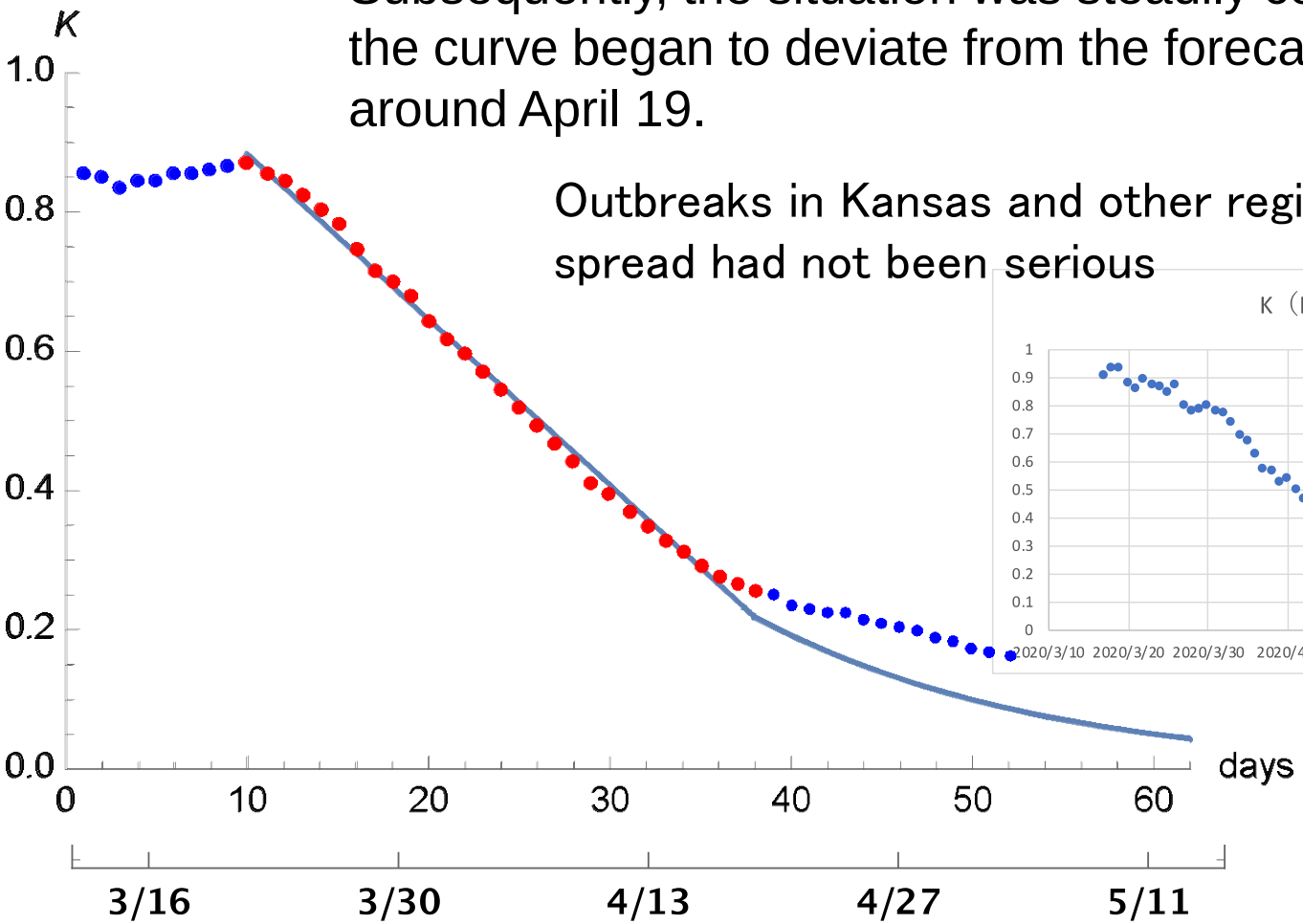
K = 0.5 corresponds to "weekly doubled"

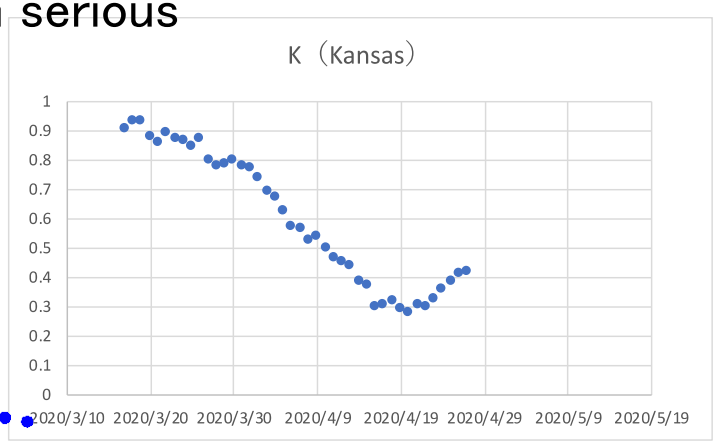
Spread of COVID-19 in the United States

Initially, a period with K > 0.8 (five times over a week) lasted more than 10 days, which caused a serious problem.

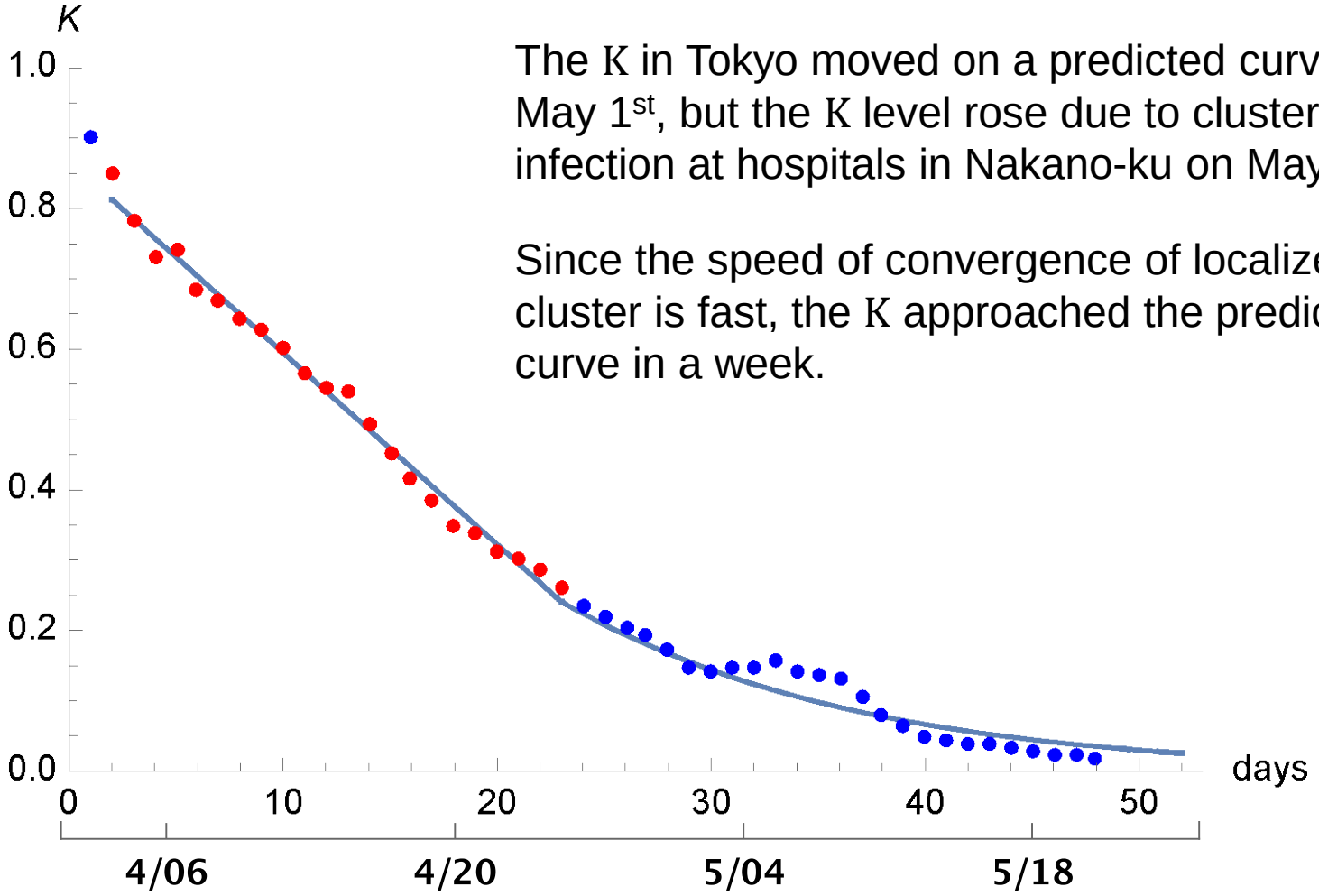
Subsequently, the situation was steadily converged, but the curve began to deviate from the forecast curve around April 19.

Outbreaks in Kansas and other regions where the spread had not been serious





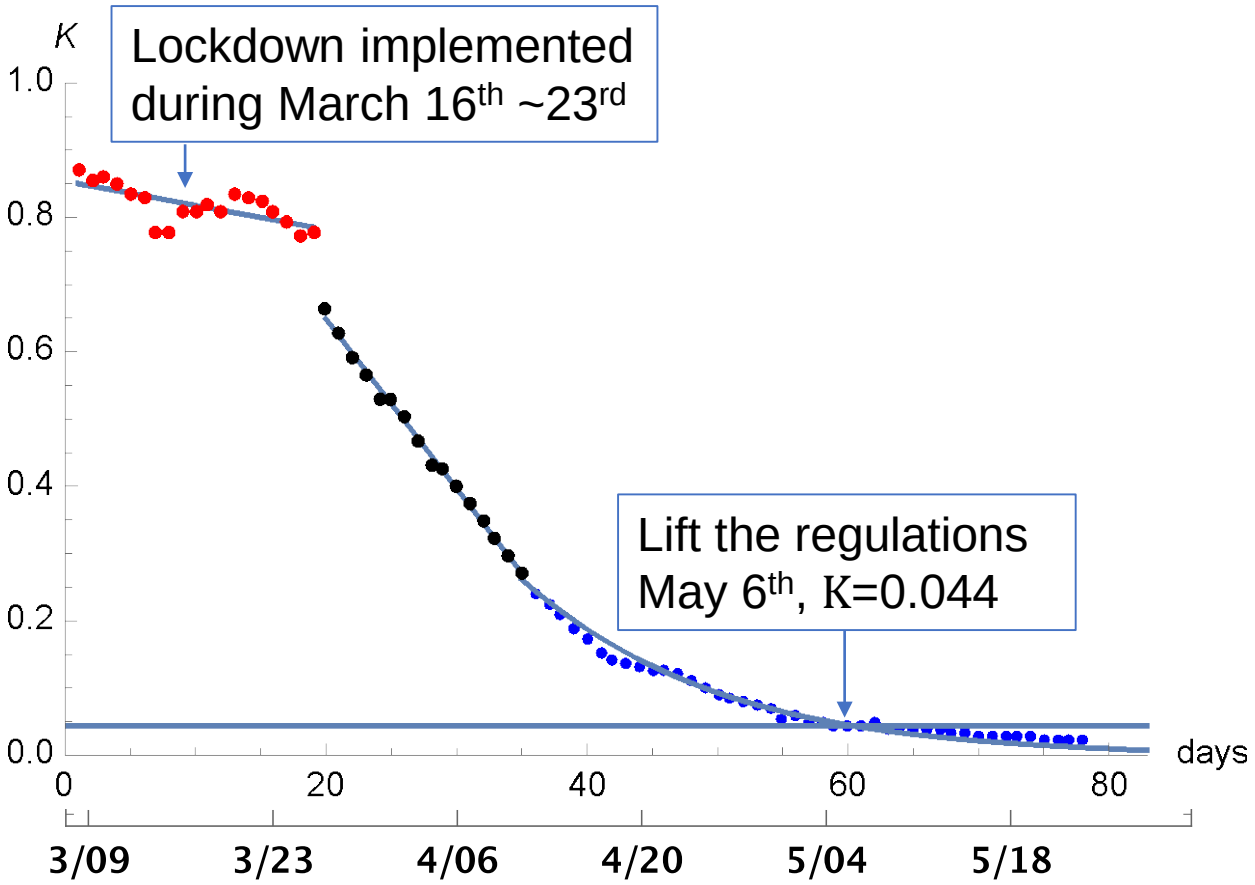
Detection of relatively large cluster infections



The K in Tokyo moved on a predicted curve until May 1st, but the K level rose due to cluster infection at hospitals in Nakano-ku on May 2nd.

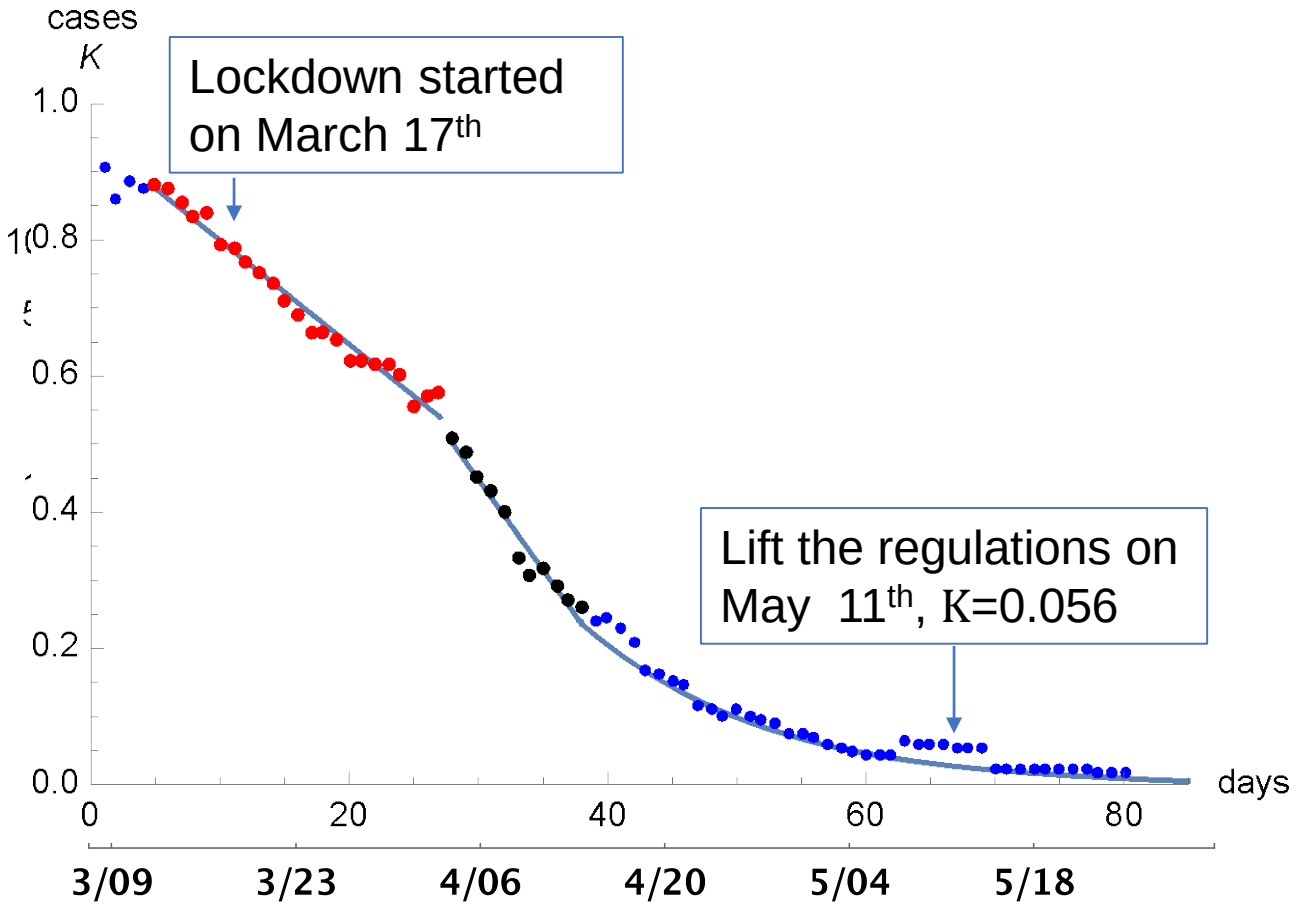
Since the speed of convergence of localized cluster is fast, the K approached the predicted curve in a week.

Evaluation of effects of measures in Germany

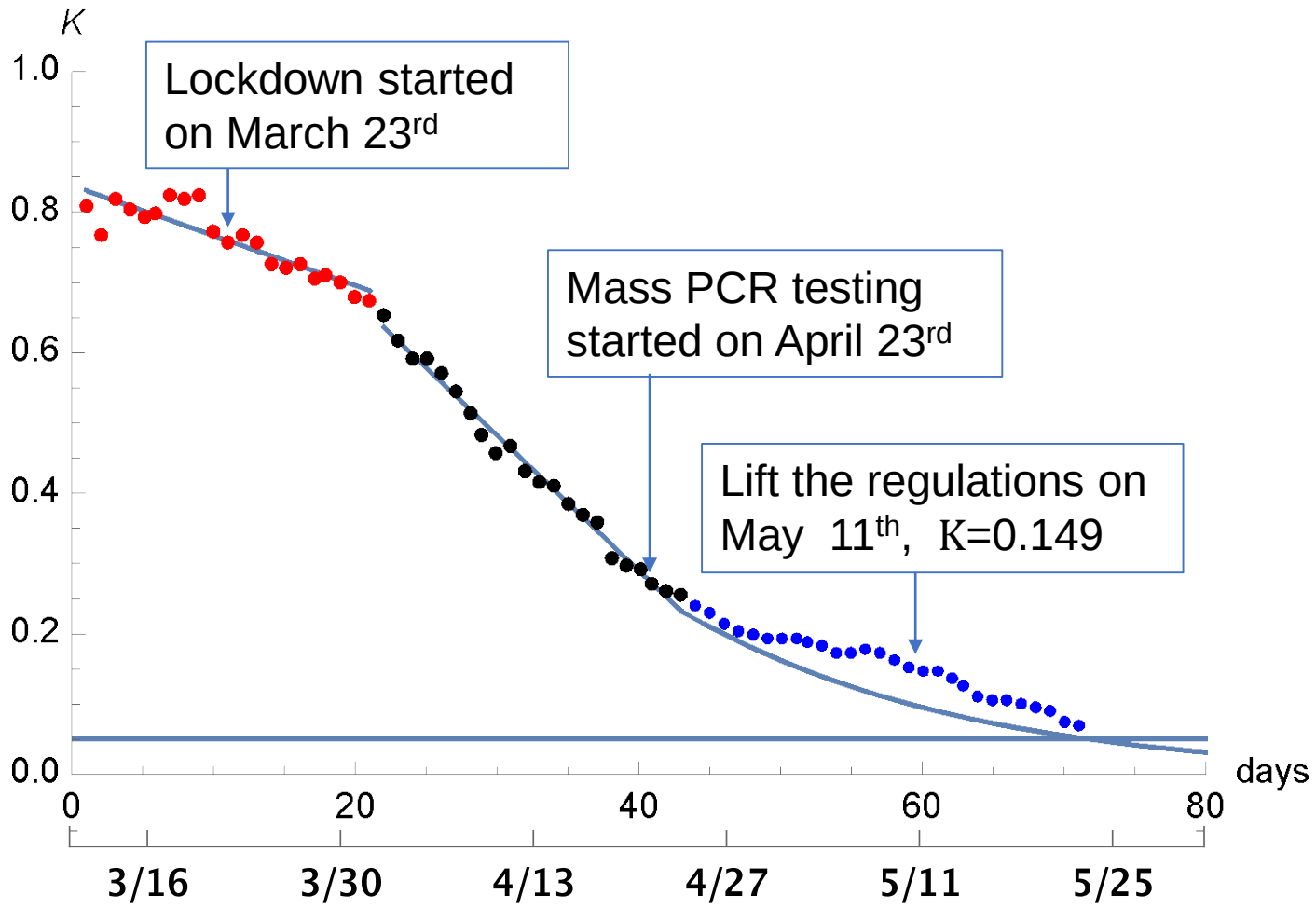


In European countries, there are changes in the slope of K before and after strict measures such as the blockage of cities.

Evaluation of effects of measures in France



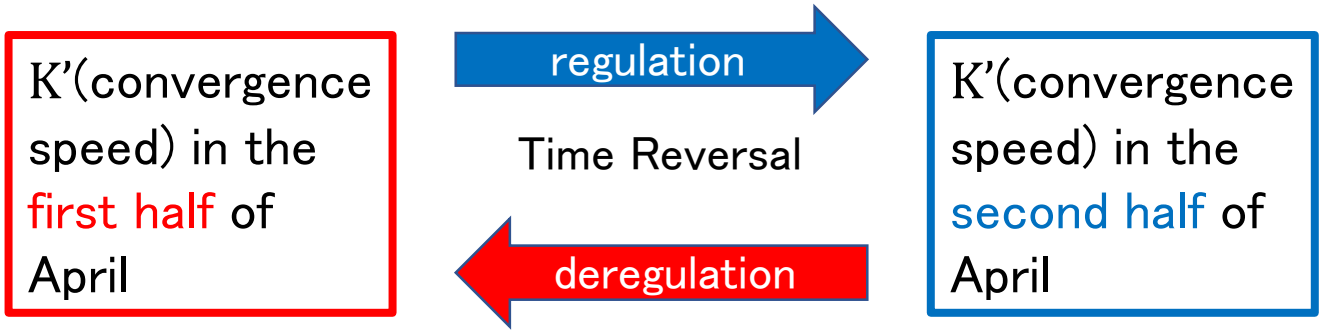
Evaluation of effects of measures in UK



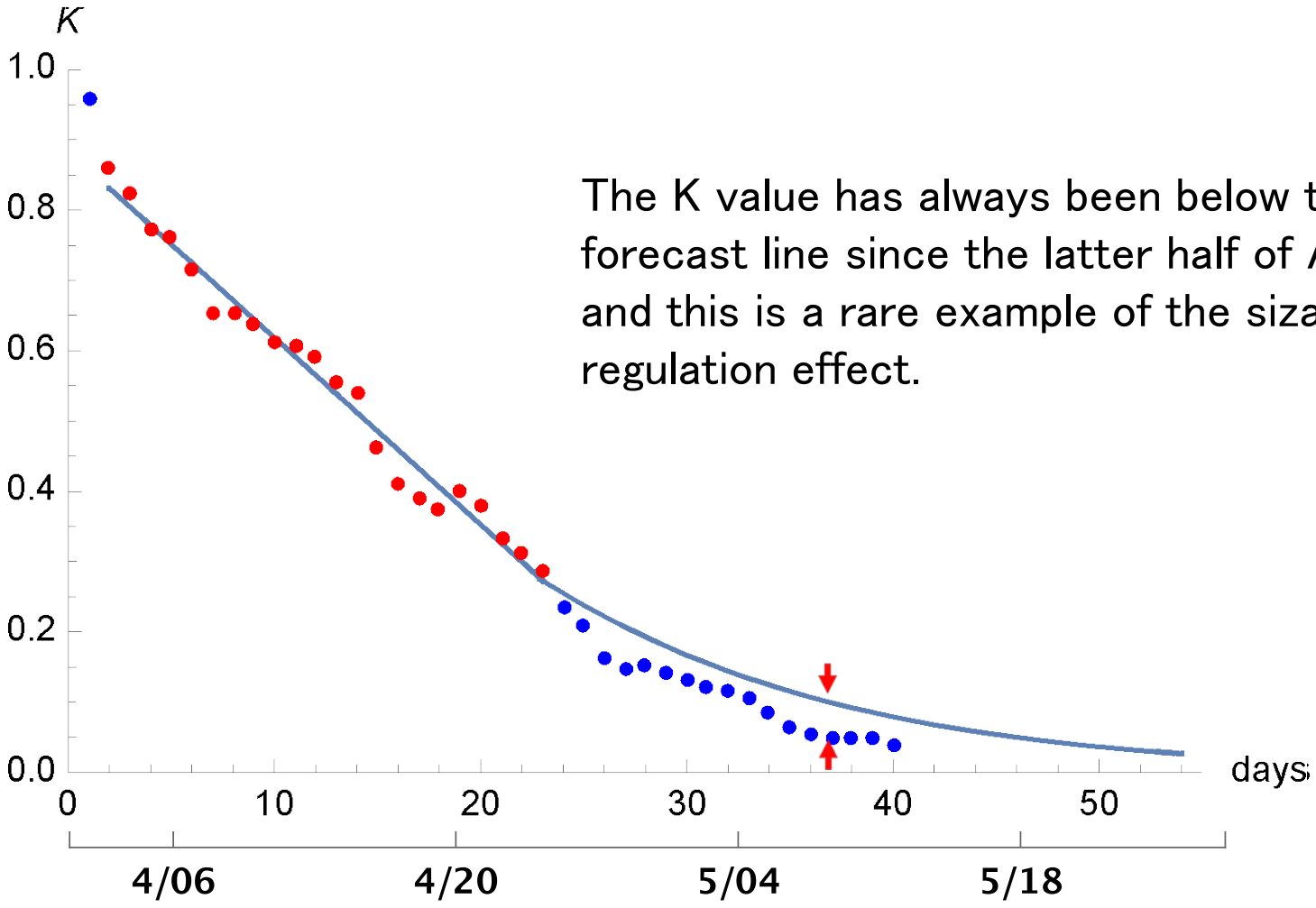
Minimizing the period with a small slope is a key to prevent a catastrophic situation.

Estimation of effects of regulation/deregulation in Japan

- There must be some effects.
- However, data show little difference in the slope of K (K') between the first half and the second half of April.
- The K has been below the forecast line in Osaka due to possible regulation effect since the latter half of April.
- Detailed re-analysis of Osaka data may reveal the (maximum) impact of deregulation from the change in K'.



Transition of K in Osaka



The K value has always been below the forecast line since the latter half of April, and this is a rare example of the sizable regulation effect.

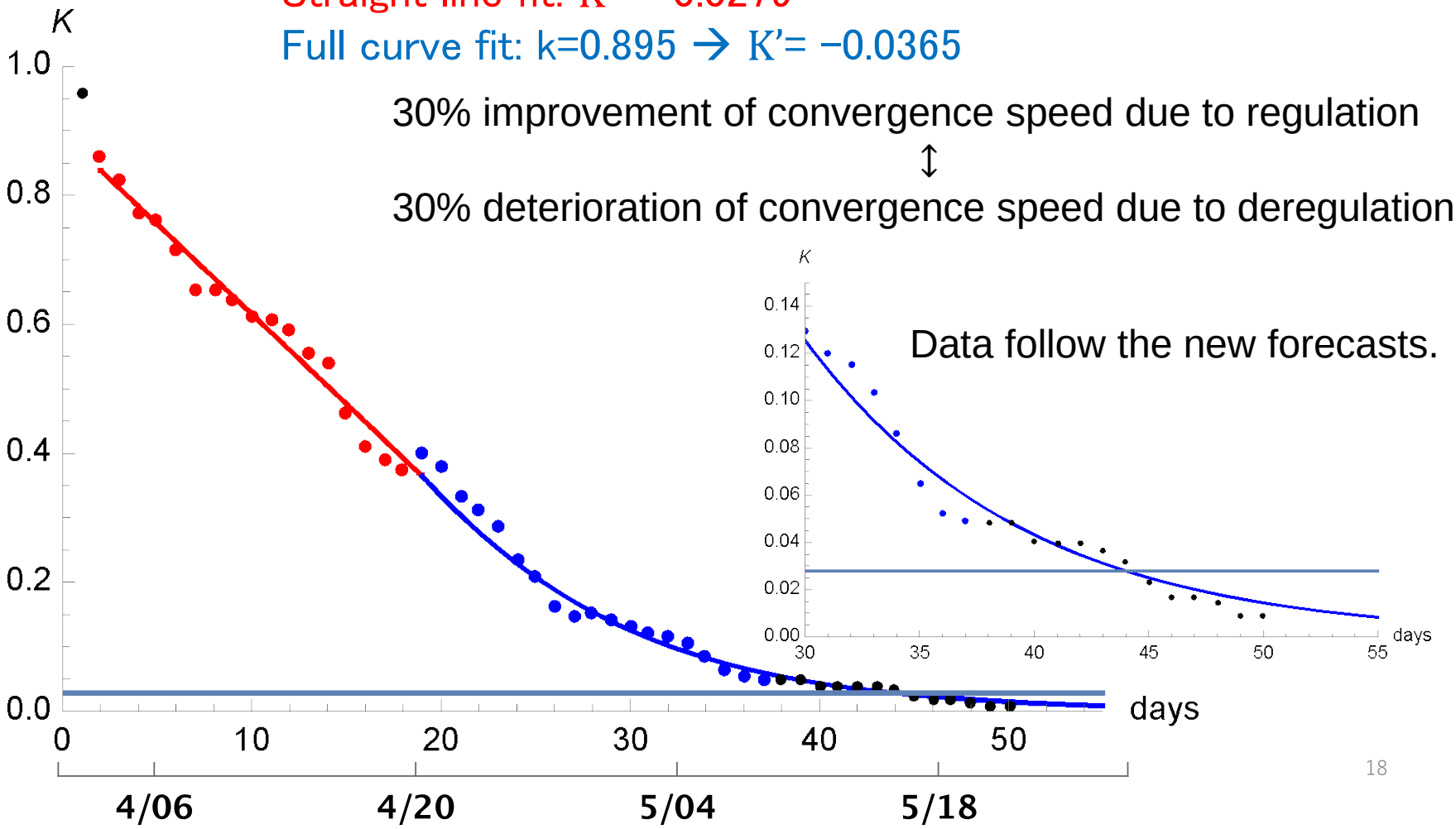
Detailed Analysis of the K in Osaka

Fit the first half data (before April 20) with a straight line
Fit the second half data (after April 20) with k as a fitting parameter
Straight line fit: K'= −0.0279
Full curve fit: k=0.895 → K'= −0.0365

30% improvement of convergence speed due to regulation

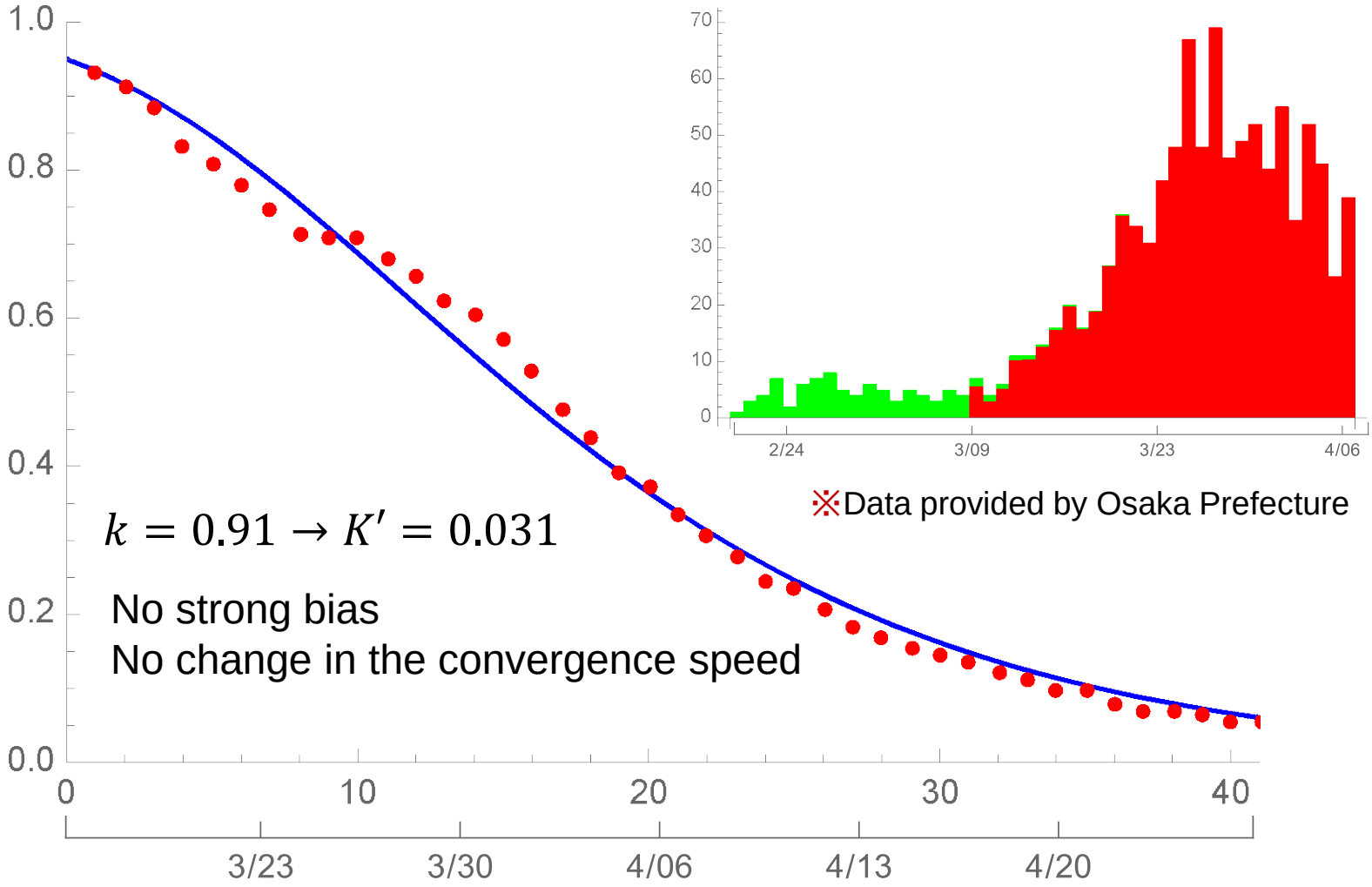
↕

30% deterioration of convergence speed due to deregulation



Data follow the new forecasts.

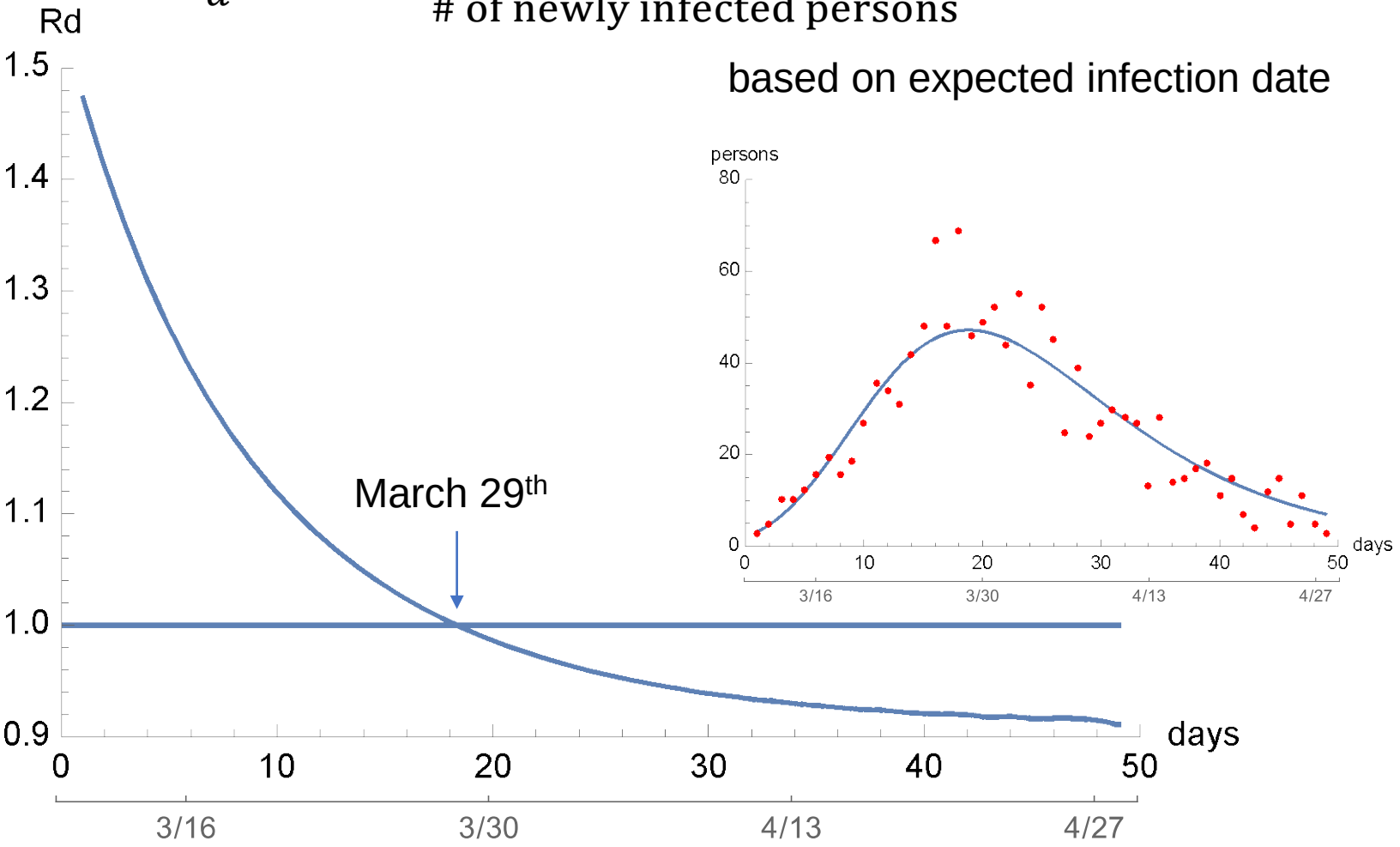
K analysis based on expected infection date※



The real situation of COVID-19 spread

$$R_d = \frac{\#\text{ of newly infected persons one day later}}{\#\text{ of newly infected persons}}$$

based on expected infection date



Conclusion

- The indicator K for COVID-19 spread is attenuated according to the double exponential, regardless of the region or policy.
- The dumping constant k, which is the only parameter of the double exponential function, is obtained from K'.
- Therefore, macroscopic analysis of K enables us to
  - Forecast the changes in the number of infected people.
  - Detect the sign of new outbreak.
  - Evaluate the effects of measures to prevent the spread.
- Characteristics of the COVID-19 spread in Japan are
  - Strong tendency to diminish spontaneously.
  - Constant converging speed and no sizable effect of measures introduced after the declaration of an emergency.
  - Target strategy by cluster response team was effective.
  - The spread from the end of March should be considered as the second wave. The cause of the outbreak is probably the influx of infected people from Europe and the United States.