

Visualizing Omicron: COVID-19 Deaths vs. Cases Over Time

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Abstract

For most of the COVID-19 pandemic, the daily focus has been on the number of cases, and secondarily, deaths. The most recent wave is caused by the omicron variant, first identified at the end of 2021 and the dominant variant through the first part of 2022. South Africa, one of the first countries to experience and report data regarding omicron, reported far fewer deaths, even as the number of reported cases rapidly eclipsed previous peaks. However, as more countries report on omicron, there remains uncertainty as to how it compares to prior waves. To more readily visualize the dynamics of cases and deaths, it is natural to plot deaths per million against cases per million. Unlike the time-series plots of cases or deaths that have become daily features of news outlets during the pandemic, which have time as the x-axis, in a plot of deaths vs. cases, time is implicit, and is indicated in relation to the starting point. Here we present and briefly examine such plots from a number of countries and from the world as a whole, illustrating how they summarize features of the pandemic in ways that are harder to extract from time series. These plots suggest that in most places, the omicron wave is very different from those that came before. Code for generating these plots for any country is provided on GitHub (<https://github.com/rarnaout/Covidcycles>).

Introduction

Visualization is an essential tool for summarizing and making sense of data. During the COVID-19 pandemic, time-series plots of cases and deaths have become fixtures of news reports, social media posts, and dashboards¹⁻³. In time-series plots, the x-axis is time and the y-axis is the variable of interest, for example daily new cases per million population. Information about a second variable of interest can be presented as a second line plotted against the same x-axis, with or without a secondary y-axis, but this is not the only way to present two variables. For example, if the desire is to draw the viewer's attention to the ratio of the two variables, the ratio can be plotted over time; however, the absolute magnitudes are lost if only the ratio is plotted.

An alternative visualization approach is to plot the two variables against each other as a scatterplot, one on the x-axis, the other on the y-. In such a plot, time has no axis of its own, but can be represented visually as a gradient of weight, width, or color along the line, and/or can be conveyed using arrows or arrowheads along the line (similar to how vector fields are often displayed). Such plots are standard in the study of dynamical systems, leading for example to the phase diagrams of differential equations^{4,5}. They are useful for drawing attention to commonalities and differences in the relationship between a pair of variables over time. In this spirit, we plotted day-by-day deaths vs. cases for the COVID-19 pandemic to date, to see what such plots might illustrate about the pandemic, and possibly its near-term tendencies.

Methods

Search

Image searches for "COVID-19 cases vs. deaths scatterplot" and simple variants thereof were performed on the Google, DuckDuckGo, and Brave search engines on January 10, 2022. For each search engine, the number of the first 20 results that (1) were plots of both cases and deaths (2) as a function of each other (as opposed to over time) (3) at multiple time points was recorded.

Data

Biweekly cases per million and biweekly deaths per million were taken from the Our World in Data GitHub repository⁶ via the following URLs:

<https://github.com/owid/covid-19-data/raw/master/public/data/jhu/biweeklycasespermillion.csv> and

<https://github.com/owid/covid-19-data/raw/master/public/data/jhu/biweeklydeathspermillion.csv>.

These biweekly moving averages are updated daily. (Our World In Data in turn credits the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, which itself lists numerous additional sources.) Vaccination rates as of January 9, 2022 were also via Our World in Data (<https://ourworldindata.org/covid-vaccinations>). Variants over time were via CoVariants (<https://covariants.org/per-country>)⁷, which in turn comes from the GISAID Initiative (<https://www.gisaid.org/>). All data were accessed on January 10, 2022.

Code

Plots were made using Python (see Availability below) and OmniGraffle 7.19.2 on an Apple M1 MacBook Air (2021).

Availability

Data and code are freely available via the rarnaout/Covidcycles repository (<https://github.com/rarnaout/Covidcycles>).

Results

Few plots of deaths vs. cases over time during the COVID-19 pandemic

Although plotting two variables against each other over time is a well established practice (as mentioned in the Introduction), plotting deaths vs. cases over time appears to be uncommon during the COVID-19 pandemic ([Table 1](#)). Web searches revealed occasional plots of total deaths vs. total deaths, but only two plot of deaths vs. cases over time: one for a one-month window from April 2020 posted by the user prograft to the COVID-19 Data Visualizations subreddit⁸, and a second from an RStudio blog (titled "Not Useful")^{9,10}.

Plots of death vs. cases illustrate country-specific COVID-19 waves

We plotted deaths per million vs. cases per million from the start of the pandemic until the time of writing, for 16 countries, colored by wave. We comment on several examples.

South Africa ([Fig. 1a](#)). The plot for South Africa clearly illustrates the main pattern of counterclockwise loops ([Fig. 1a](#)). Each loop describes a wave of the pandemic. In each loop, cases rise, then deaths rise, then cases fall, and finally deaths fall. The peak number of cases is always to the right (the date label indicates the peak for each wave). The wave ends with the population back

near the origin of the plot, with few cases and few deaths. The waves occurred roughly every six months, with two mid-summer and two mid-winter peaks.

South Africa's first wave (purple) reached its peak number of cases on July 14, 2020 (labeled). The start of the second wave (blue) coincided with the appearance of the SARS-CoV-2 beta variant, and indeed beta dominated this wave, with its frequency in the population reaching its peak frequency (0.97) nearly coincident with the peak in cases. The third wave (green) was similarly dominated by the delta variant, and the fourth (red) dominated by omicron. For the beta, delta, and now omicron waves, reported cases peaked around 4,000-5,000 cases per million.

It is interesting to note that the blue (beta), green (delta), and red (omicron) loops get progressively flatter: this indicates falling case mortality, from 125 cases per million for beta to only around 20 cases per million for omicron (although the omicron wave has not yet subsided as of this writing). Thus in South Africa, the beta wave was deadlier per capita than the delta wave, even though the delta variant is known to be quite virulent and led to substantial mortality around the world. Also, note that each wave reaches further to the right. Thus, over the last three waves, the virus has been *de facto* less virulent but more infectious.

It is tempting to attribute this pattern at least in part to herd immunity from natural infection and not vaccination, since only roughly a quarter of the South African population was fully vaccinated as of early January 2022. Otherwise, it is reasonable to expect to have seen higher mortality for the delta wave. Note that herd immunity is unlikely to be the entire explanation, since laboratory investigation has shown that omicron is inherently both less pathogenic and more transmissible than delta, regardless of a person's prior vaccination or infection status^{10–13}. In general for any country, the explanation for the dynamics observed in these plots is almost certainly similarly multifactorial, with reporting, vaccination status, prior covid infection, policy (e.g. lockdowns), demographics, and health status all contributing.

Israel (Fig. 1b). Israel, a more vaccinated country (64% fully vaccinated as of January 10, 2022, meaning they have received a single-dose vaccine or both doses of a two-dose vaccine), provides an interesting comparison to South Africa (Fig. 1b). It also had four main waves, with the second (blue) outpacing the first (purple) in both cases and deaths. (Israel's second wave was caused by the alpha variant.) As in South Africa, Israel's delta wave (green) also had more daily cases per million but fewer deaths per million, and its fourth main wave (red), the omicron wave, set a new record for daily cases per million but without a notable rise in deaths per million so far. The case peaks for

Israel's previous main waves all came a week to a few months after South Africa's. It remains to be seen whether Israel's fourth wave will follow the South African pattern, as it has so far.

Italy, Denmark, Sweden, and the United Kingdom (Fig. 2). These European countries show variations on a different pattern from that seen in South Africa and Israel: a highly deadly wave in the end of 2020 and the start of 2021, with a prominent double peak visible as a loop within a loop in Italy, the United Kingdom, and Sweden (Fig. 2a, 2c, 2d). In all cases, this coincided with the alpha variant displacing the previously predominant 20E/EU1 strain and rising to near fixation. The similarity of the pattern is notable given the policy differences among these countries in how to address the pandemic, especially in Sweden. The unusual spikiness in the plot for Sweden is likely a reporting artifact.

In Denmark (Fig. 2b), the abrupt inflection point as the curve turns from orange to red coincided with the rapid shift from the delta variant, a highly virulent strain, to omicron, which biomedical research suggests is less pathogenic^{14,15} despite antibody escape^{16,17}, especially in previously exposed/highly vaccinated populations^{18,19} (Denmark is 80% fully vaccinated), consistent with the South African experience. The plot for Denmark is thus interpreted as a "loop-pulled-taut" around the inflection point, with a somewhat similar (though less pronounced) effect in Italy. If so, deaths per million may well fall temporarily as cases rise, before they rise again to close the omicron loop.

Note that even with the compression of the x scale in these plots, relative to the plots for South Africa and Israel above, the dynamics—i.e. the loop patterns—of these European countries have been different. The reason for the compression is of course the great number of omicron cases (red), which for each of these countries dwarfs the daily cases per million seen previously. Note also that the y scales are fairly comparable. In no case is there evidence of the omicron wave peaking. However, in every case it has begun according to a very different trajectory from the previous waves.

Germany and the Netherlands (Fig. 3). These neighboring countries share the double loop of their European counterparts in Fig. 2 but are notable for an additional loop in the final months of 2021 and the start of 2022 (red). In both cases, the delta variant still accounted for between half and 90% of cases through the period shown. The wave seen subsiding in these plots appears to be merging into the omicron wave, creating the beginning of what will likely be another loop within a loop as the omicron wave hits these countries. Compare to the plot for Denmark (Fig. 2b).

Japan and South Korea (Fig. 4). Japan (Fig. 4a) barely completed a wave dominated by the alpha variant (blue) before entering its delta-variant wave (green). Japan had not yet begun its omicron

wave as of January 10, 2022. Nearby South Korea ([Fig. 4b](#)) is notable for still being in the midst of its delta wave, transitioning from delta 21I to delta 21J, and the trajectory of its latest wave (orange-red) is consistent with that of delta waves in other countries. Note the small absolute numbers in both these countries.

India and China ([Fig. 5](#)). The plots for the two most populous countries look very different from each other. By the time of this writing, India's prominent delta wave resolved (green) and its omicron wave had begun (red), not unlike many other countries ([Fig. 5a](#)). China, where the SARS-CoV-2 virus was first reported, has reported almost no cases or deaths per million since early in the pandemic (note the axis scales), a notable outlier among the countries presented here ([Fig. 5b](#)).

Australia and New Zealand ([Fig. 6](#)). Australia ([Fig. 6a](#)) is notable for low case and death rates but high mortality per reported case, visible in the steepness of the yellow loop, which was dominated by the delta variant (even on an uncompressed x-scale). In December 2021-January 2022, Australia decided omicron (red) would be uncontrollable and changed from a strategy featuring lockdowns to one geared toward blunting the effect on mortality. New Zealand ([Fig. 6b](#)), the country with the smallest population in the countries discussed here (5.1 million people, vs. 5.8 million for second-lowest Denmark), has reported very few cases and deaths per million throughout the pandemic, including a very small delta wave (red). The choppiness of the line may be due to these small absolute numbers.

North America ([Fig. 7](#)). The plot for the United States ([Fig. 7a](#)) illustrates a substantial blunting of the alpha wave (blue) relative to the previous wave (purple), but its delta wave (green) was deadlier per case, without the flattening seen for South Africa ([Fig. 1a](#)). The loop for the delta wave was blunter but otherwise similarly shaped to the January, 2021 wave nine months earlier, indicating a similar per-case fatality rate. Like Denmark, Germany, and the Netherlands, the death rate remained high into the start of the omicron wave. Canada ([Fig. 7b](#)) is similar except that its delta wave (green) is shallower than its alpha wave (blue), with the omicron wave beginning shallower still, reminiscent of South Africa. The blunting of successive waves in Mexico ([Fig. 7c](#)) bear an even stronger resemblance to that seen for South Africa and Israel. Mexico reported being 56% fully vaccinated as of January 2022, with Cuba ([Fig. 7d](#)) at 86%, Canada at 78%, and the United States at 62%.

The World ([Fig. 8](#)). Worldwide the picture is of a devastating first wave (purple), a slightly shallower second wave (blue), and blunted third wave (green), and very high cases at the start of the fourth wave, dominated by omicron in almost all countries visualized. New waves have hit every three to five months. Again, the distinctiveness of the omicron wave is clear: very high cases per million

without a substantial rise in death rate per million, at least as of this writing.

Discussion

The x-y scatterplot with time as an implicit variable is not a new invention. However, it has been little used in relation to cases and deaths in the COVID-19 pandemic. This communication may be considered a humble re-introduction, with brief mention of some of the observations that such visualization can facilitate. The most striking observation is the difference of the nascent omicron wave to those that have come before. Also evident is a flattening of subsequent waves, following the initial outbreak in 2020, most evident in South Africa and Israel and to a lesser extent in Canada and Japan. Finally, regional differences and other patterns are clearly visible.

Given the history of this type of plot (for example, its utility in modeling pressure-volume or flow-volume dynamics for cardiopulmonary systems), it is interesting that it has been little used so far in the pandemic. We speculate that the main reason is that because the waves have taken place on the relatively slow timescale of months, and there have been relatively few of them to against which to see patterns (“small n ”), their potential utility did not emerge until long after time series had become fixtures of COVID-19 reporting. However, going forward there are a number of variations that may prove interesting. These including subsetting by age, race, gender, and vaccination status. Substituting excess deaths per million in place of deaths per million is another example. It may also be fruitful to explore how the rich dynamics illustrated by these plots correlate with, or can be predicted by, reporting, vaccination status, public policy (e.g. lockdowns, worker compensation), and health status. The code that produced these plots has been made public, and the data are also all publicly available.

It should be noted that this work would not have been possible without expert data collection and curation at all levels, together with the selfless commitment to openness and sharing that resulted in this data being publicly available, and easily so (nonetheless, the usual reporting caveats apply; for example in the second week of January 2022 several jurisdictions have begun pulling back from testing in light of the overwhelming wave of omicron). We used biweekly cases and deaths, i.e. running averages, to better visualize trends without the noisiness and sampling granularity of daily reporting (e.g. weekend dips). The reader's attention has been called to the differences in scale between the plots, which is sometimes worthy of note. The plots could also have been presented on the same scale, although differences in rates of testing and reporting, known to differ across countries, would have to be taken into account for fair conclusions to be drawn.

In conclusion, plotting deaths per million vs. cases per million over time, with appropriate annotation, is a potentially useful way to visualize waves of infection in the COVID-19 pandemic.

Competing interests

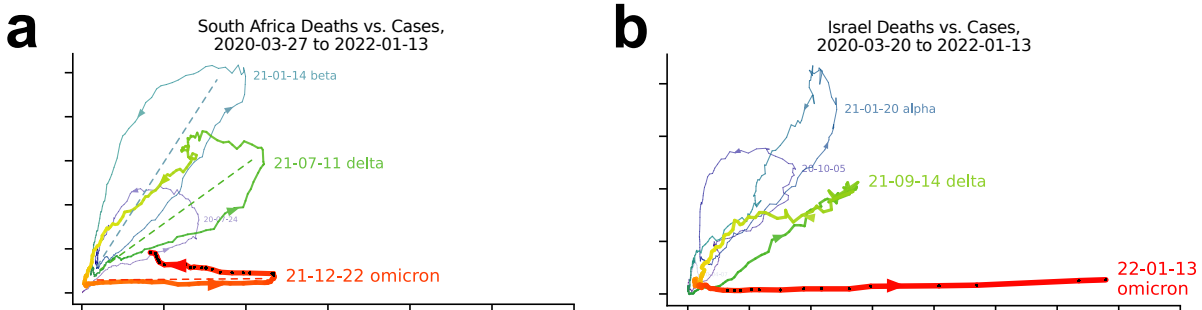
The authors declare no competing interests.

Tables and Figures

Table 1. Images of COVID-19 Deaths vs. Cases Over Time, Various Search Engines

Source	Plot both cases and deaths...	...as a function of each other...	...at multiple timepoints
Google	7	7	1
DuckDuckGo	16	2	1
Brave	15	1	0

Figure 1. South Africa and Israel.



All plots are colored by wave. Black dots indicate days for the most recent 2-3 weeks. Spacing therefore indicates rate of change. Waves are labeled by variant if a single known variant predominated. Date labels appear at the peak cases-per-million for each wave. Arrowheads indicate the flow of time. Dotted lines in (a) are guides to the eye regarding the orientation of the loops, indicating the progressive flattening of the last three waves.

Figure 2. Select European countries.

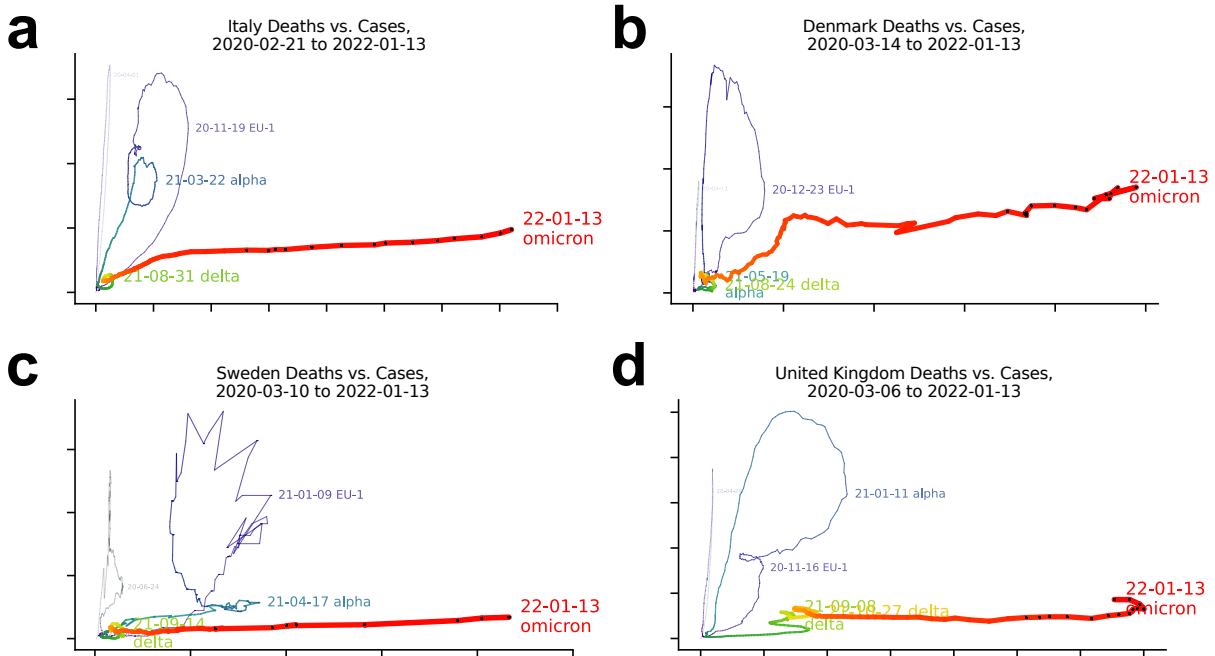


Figure 3. More European countries: Germany and the Netherlands.

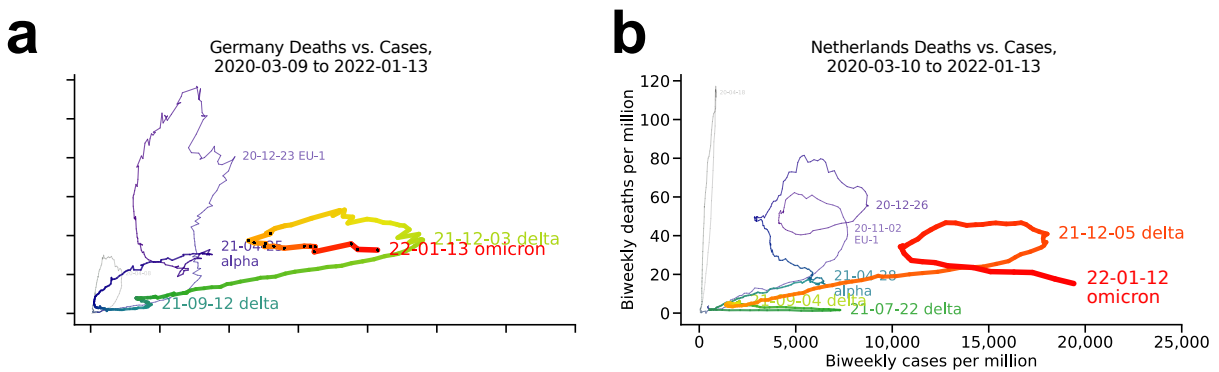


Figure 4. Japan and South Korea.

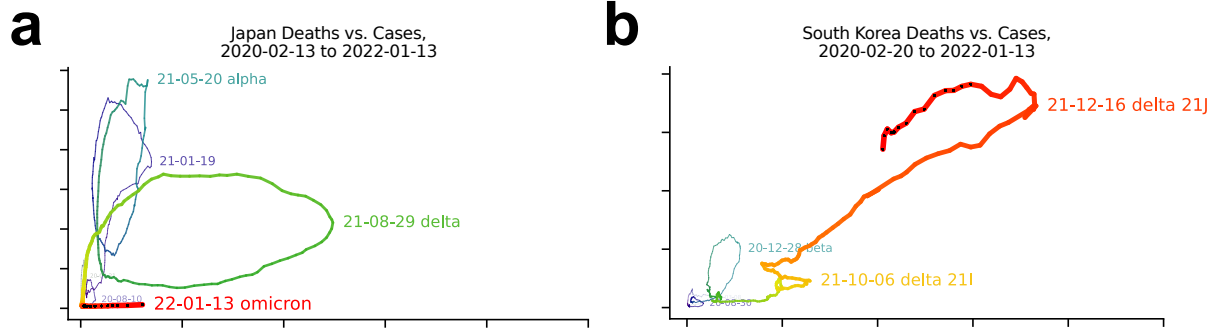
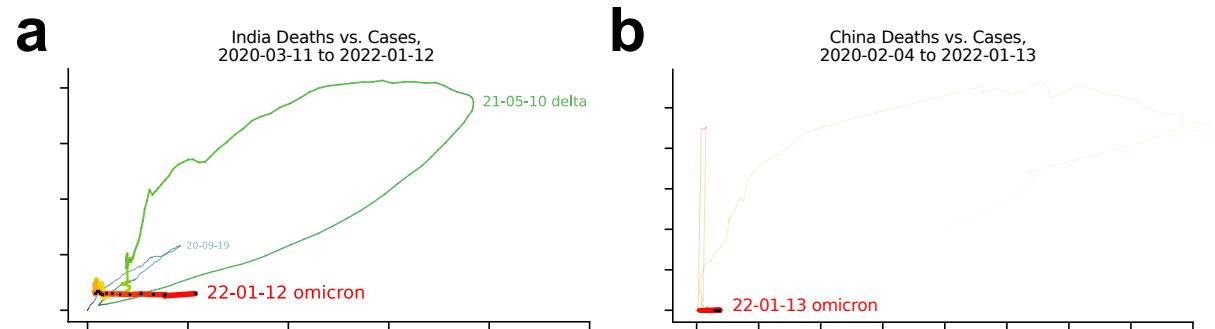


Figure 5. India and China.



The two most populous countries.

Figure 6. Australia and New Zealand.

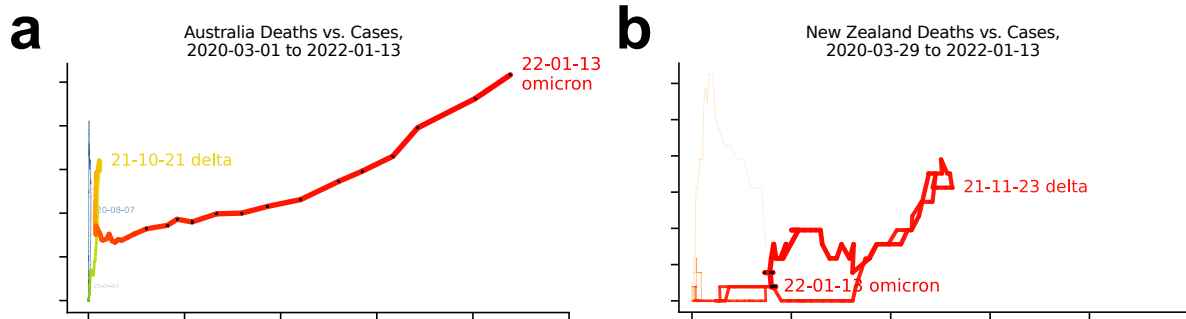
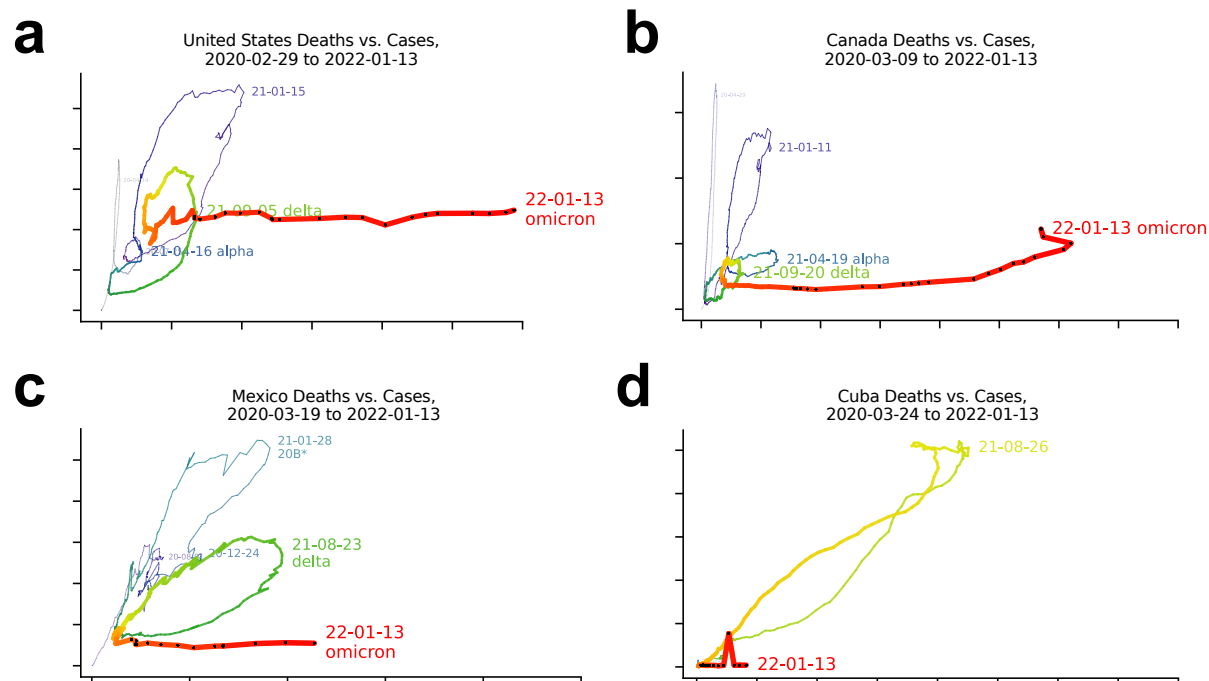
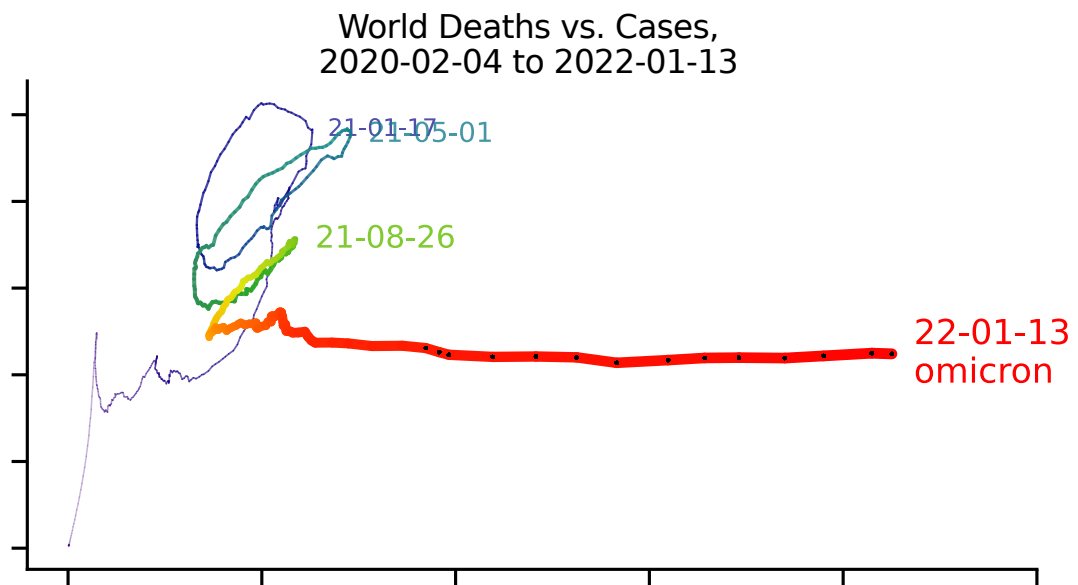


Figure 7. North America.



*20B accounted for 47% of reported strains in the January 2021 case peak in Mexico.

Figure 8. The World.



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