#CovidComplete

An Inside Look at Covid-19 Forecasting

By Steve McConnell

Copyright


WORLD
THE WORLD IS
TEMPORARILY CLOSED

Goals for this Talk

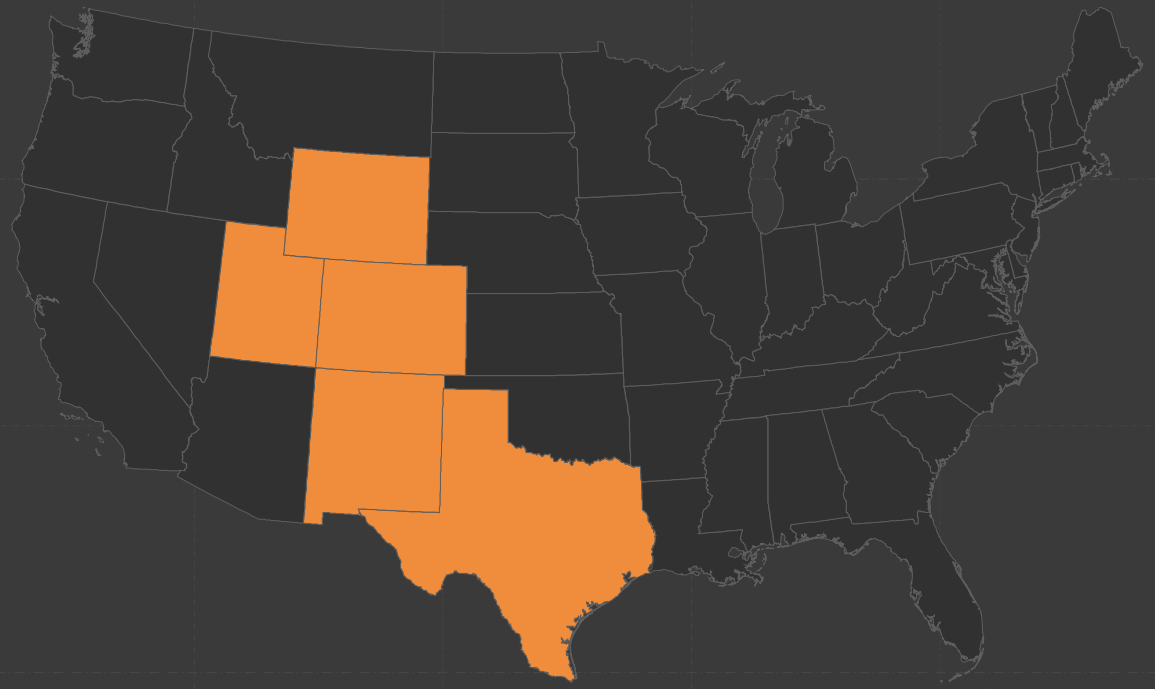
- Diffuse emotion and politics; show why you should ignore IHME's forecasts
- Demystify forecasting (vs. speculation)
- Explore Covid-19 data issues; correct common data misreporting issues
- Provide background on the CDC's forecasting process
- Explain what's possible and what is not possible in Covid-19 forecasting
- Demonstrate state of the art of current Covid-19 forecasts

#CovidComplete

Why Create State Forecasts?

- Guides near-term activity planning and event planning (1-4 weeks)
- Anticipates regional surges
- Identify areas that will need additional supplies, equipment, staff
- Identify areas that can spare supplies, equipment, staff
- Provides data-based feedback on policy decisions (as long as the forecast is based on data rather than the assumptions being tested)

Why create National Forecasts?



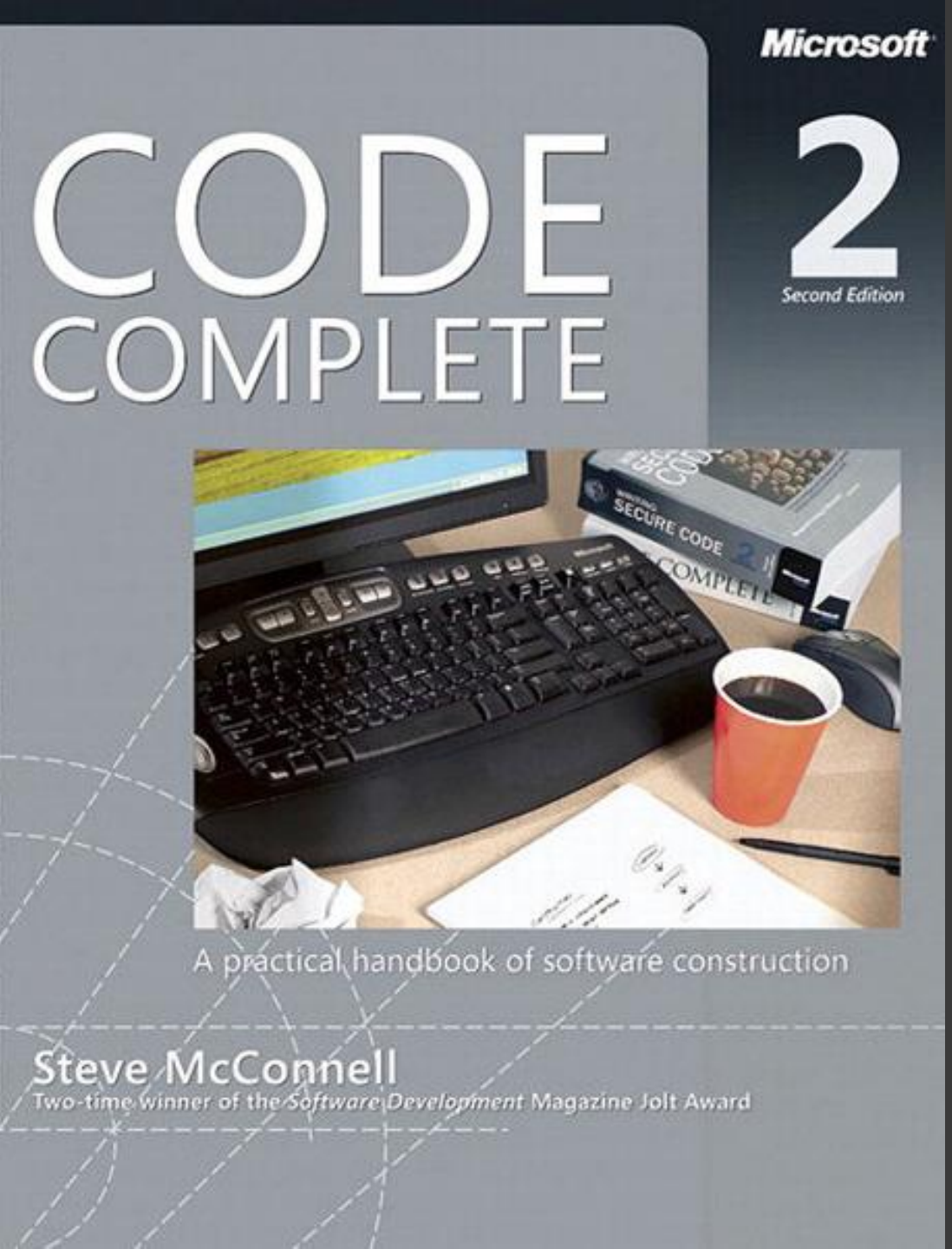
Guides near-term activity and event planning (1-4 weeks)

Provides data-based feedback on policy decisions

Provides important context for state-level decisions (how much capacity is expected to be available nationally?)

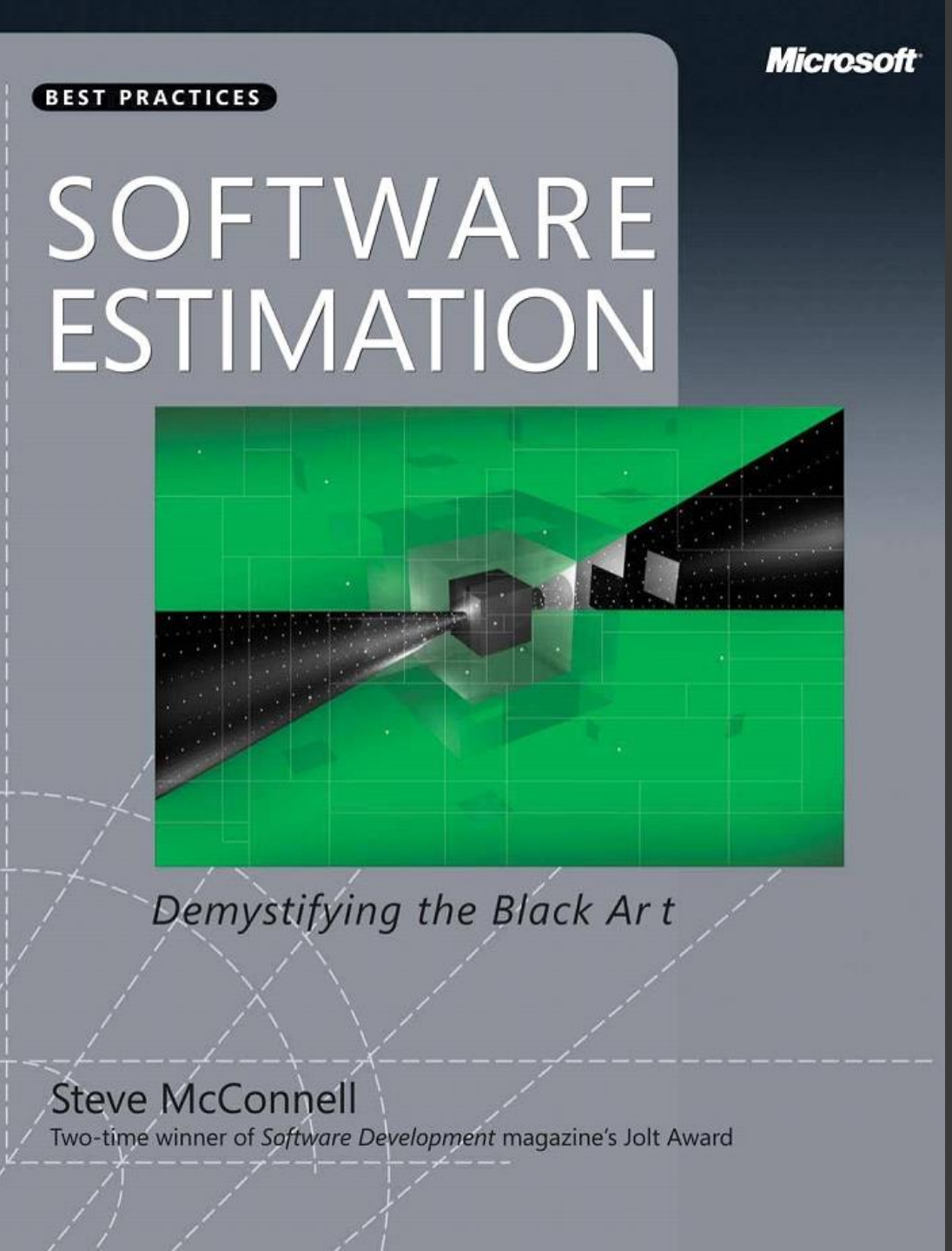
Avoid panic (or create it)

My personal role in Covid-19 Forecasting



“

For most of my career I have focused on understanding the data analytics of software development, including quality, productivity, and estimation. The techniques I’ve learned from working with noisy data, bad data, uncertainty, and forecasting all apply to COVID-19.



> Experts tend to use simple estimation strategies, even when their level of expertise in the subject being estimated in high

— *Steve McConnell, Software Estimation*

COVID-19 Forecasts: Deaths | CD

National-Forecast-Incident-Cum

cdc.gov/coronavirus/2019-ncov/covid-data/forecasting-us.html

Personal Home Page | JHU Data | Covid-19 | State Data | US Data | CDC Dropbox | Construx OnDemand | Cisco | Offsite | Other bookmarks

Coronavirus Disease 2019 (COVID-19)

CASES, DATA & SURVEILLANCE

COVID-19 Forecasts: Deaths

Updated Sept. 30, 2020 Print

Observed and forecasted new and total reported COVID-19 deaths as of September 28, 2020.

COVID-19 Forecasts: Deaths | CD

National-Forecast-Incident-Cum

cdc.gov/coronavirus/2019-ncov/covid-data/forecasting-us.html

Personal Home Page | JHU Data | Covid-19 | State Data | US Data | CDC Dropbox | Construx OnDemand | Cisco | Offsite | Other bookmarks

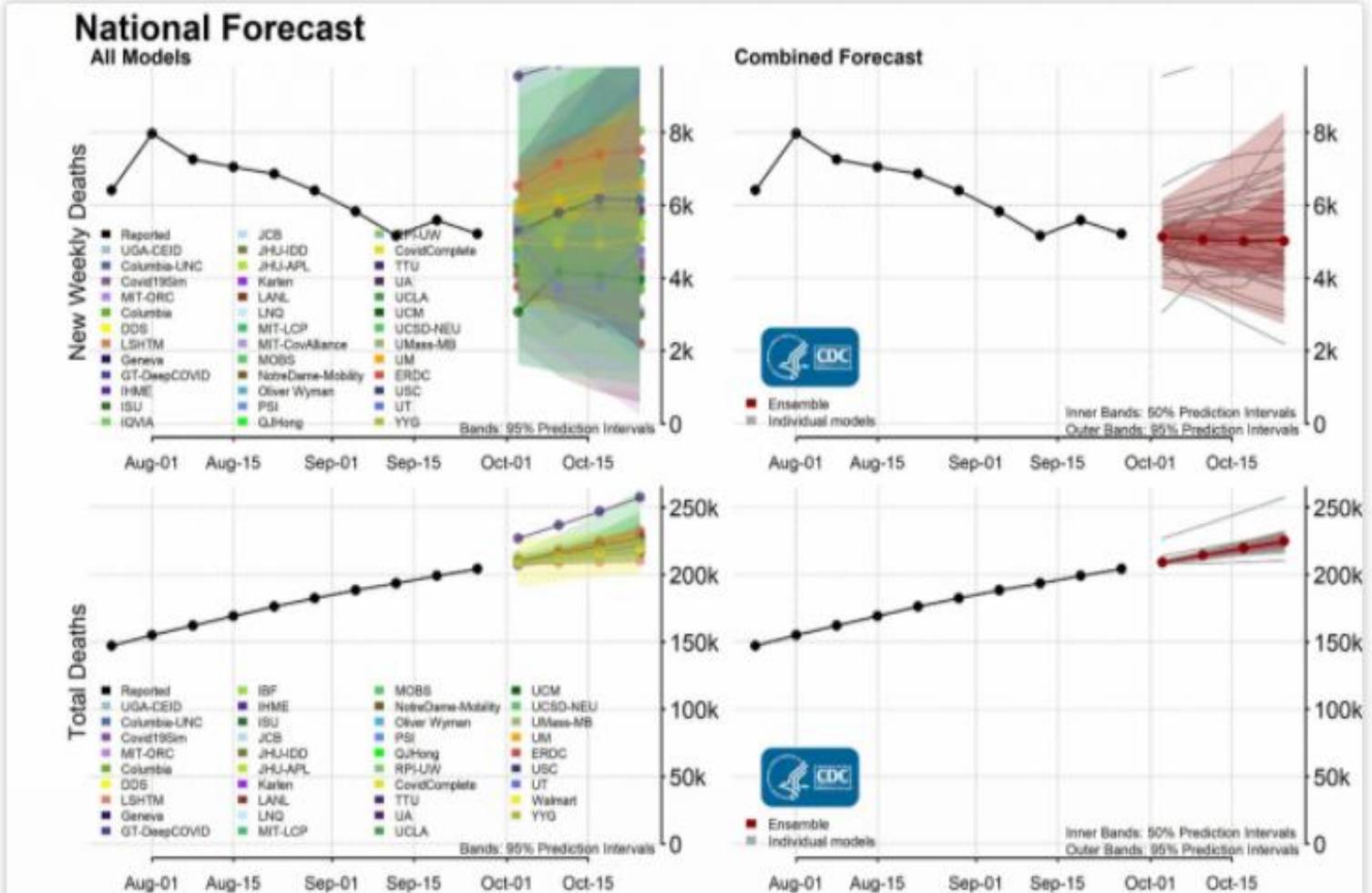
Special Populations Data +

COVIDView Weekly Summary +

Sequencing for SARS-CoV-2 (SPHERES)

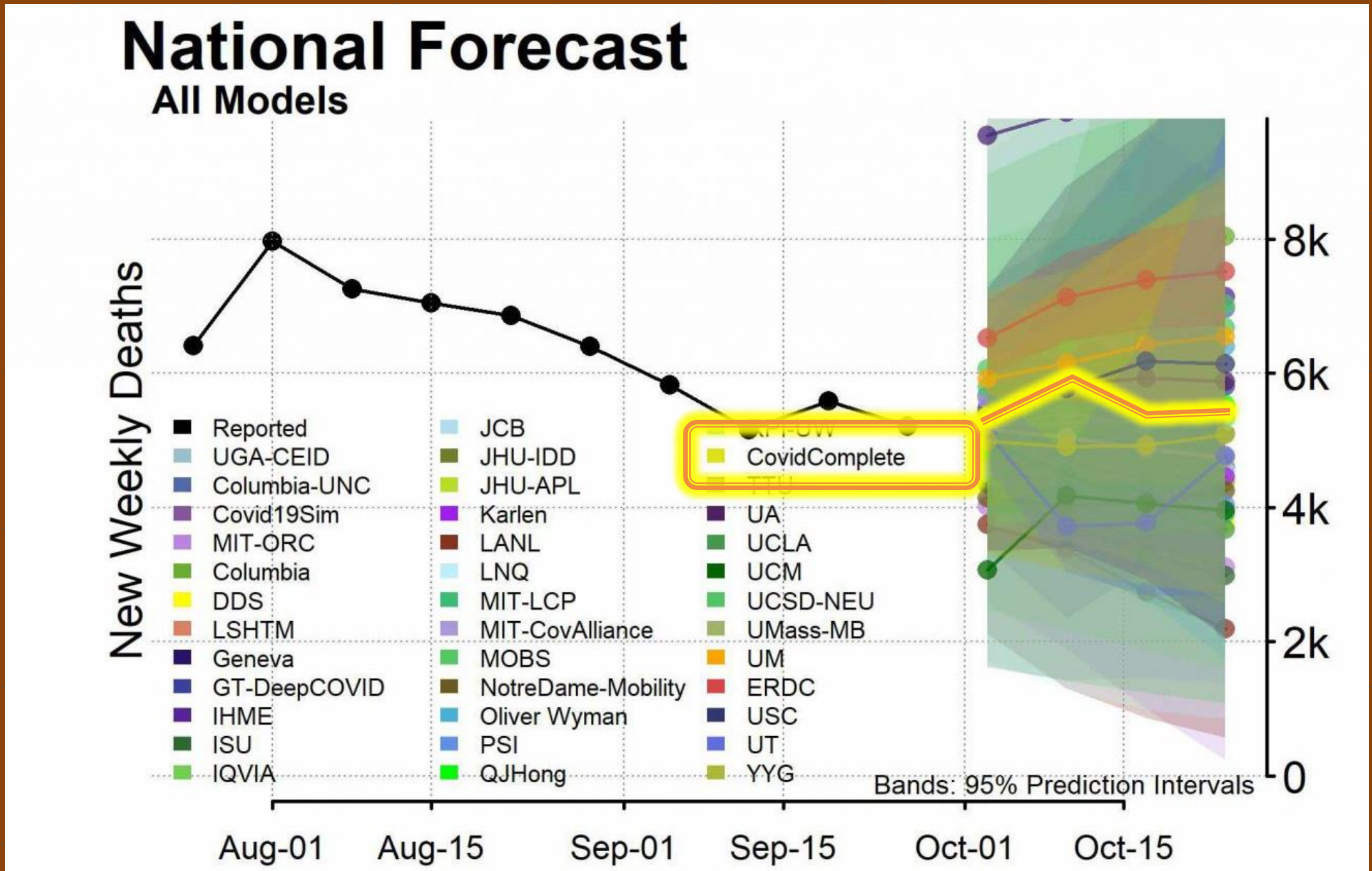
Epidemiology for COVID-19 +

National Forecast



Get Email Updates

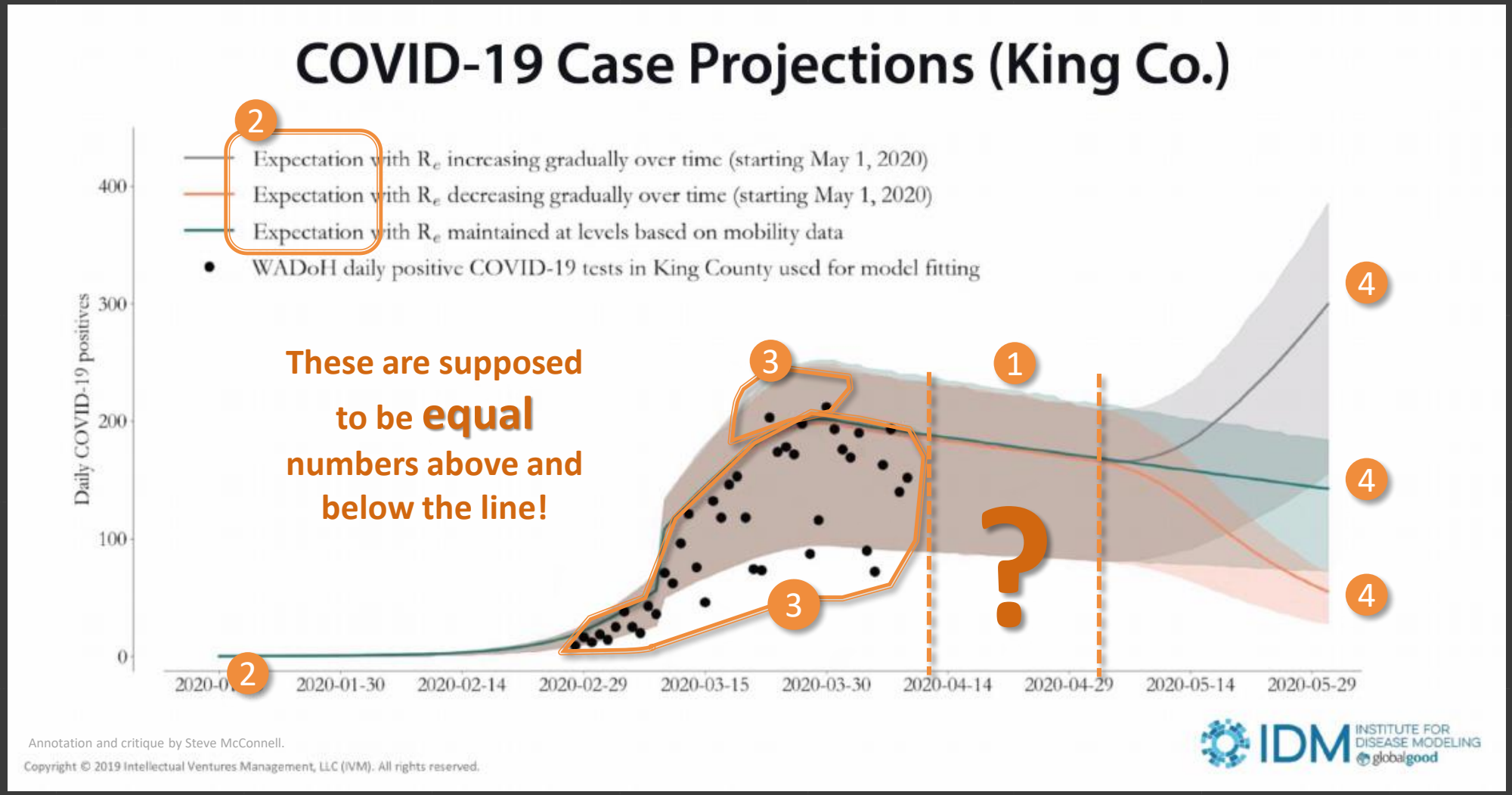
To receive email updates about COVID-19, enter your email address:


National Forecast
All Models
New Weekly Deaths
8k
6k
4k
2k
0
Reported
UGA-CEID
Columbia-UNC
Covid19Sim
MIT-ORC
Columbia
DDS
LSHTM
Geneva
GT-DeepCOVID
IHME
ISU
IQVIA
JCB
JHU-IDD
JHU-APL
Karlen
LANL
LNQ
MIT-LCP
MIT-CovAlliance
MOBS
NotreDame-Mobility
Oliver Wyman
PSI
QJHong
CovidComplete
UA
UCLA
UCM
UCSD-NEU
UMass-MB
UM
ERDC
USC
UT
YYG
Bands: 95% Prediction Intervals
Aug-01
Aug-15
Sep-01
Sep-15
Oct-01
Oct-15

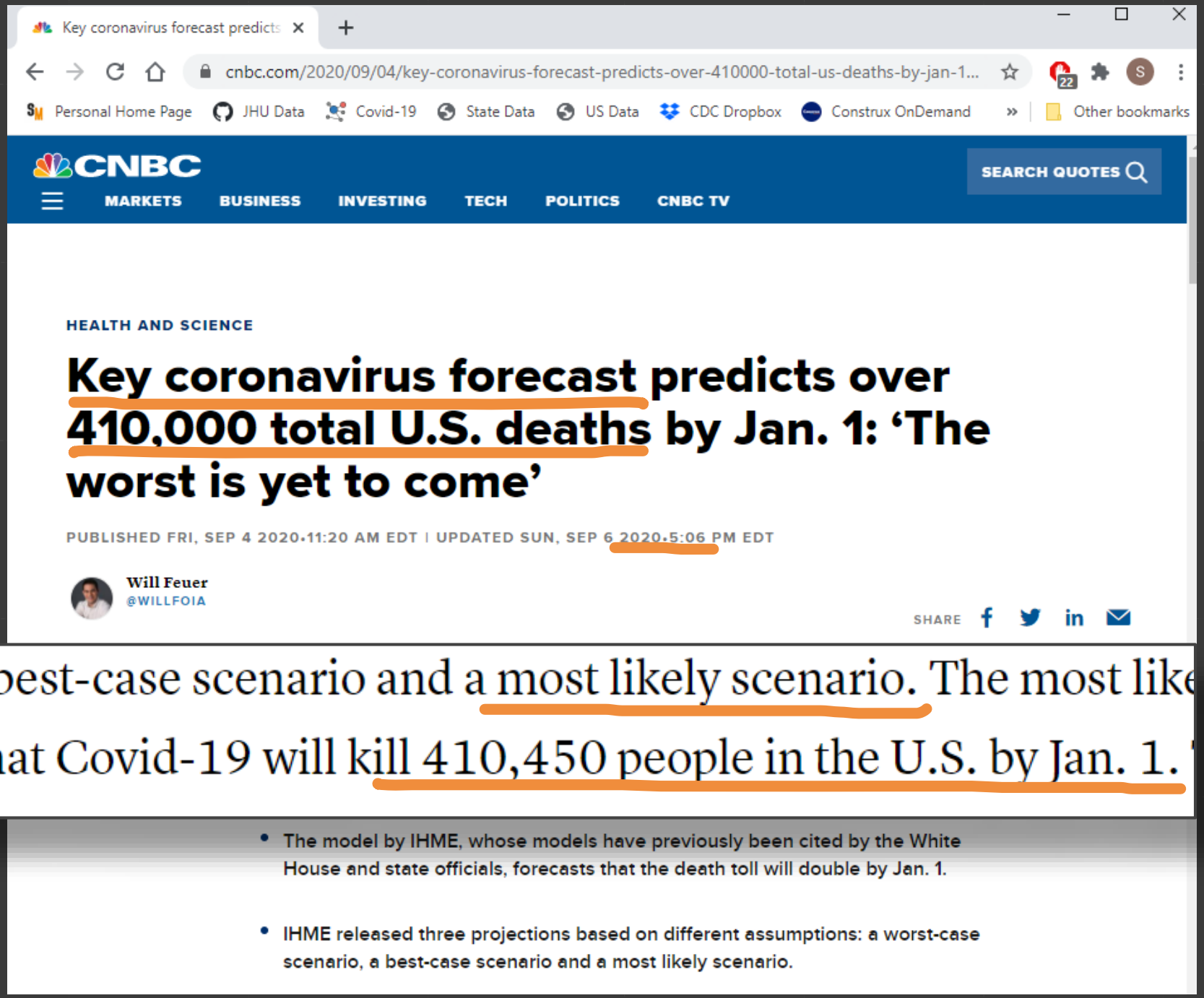
Why I got Involved

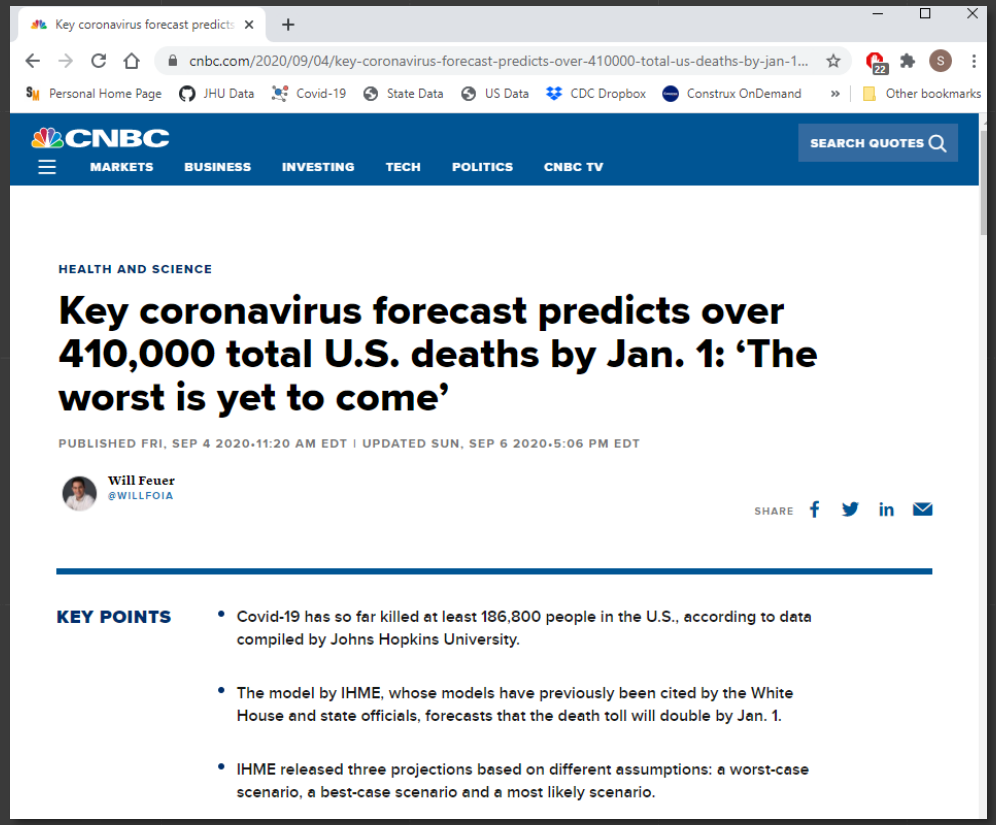
I don’t like playing games with forecasts during a global pandemic

Playing games with data – earlier



Playing games with Data, Recently





Key coronavirus forecast predicts

cnbc.com/2020/09/04/key-coronavirus-forecast-predicts-over-410000-total-us-deaths-by-jan-1...

Personal Home Page | JHU Data | Covid-19 | State Data | US Data | CDC Dropbox | Construx OnDemand | Other bookmarks

CNBC

SEARCH QUOTES

MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV

HEALTH AND SCIENCE

Key coronavirus forecast predicts over 410,000 total U.S. deaths by Jan. 1: 'The worst is yet to come'

PUBLISHED FRI, SEP 4 2020•11:20 AM EDT | UPDATED SUN, SEP 6 2020•5:06 PM EDT

Will Feuer
@WILLFOIA

SHARE

KEY POINTS

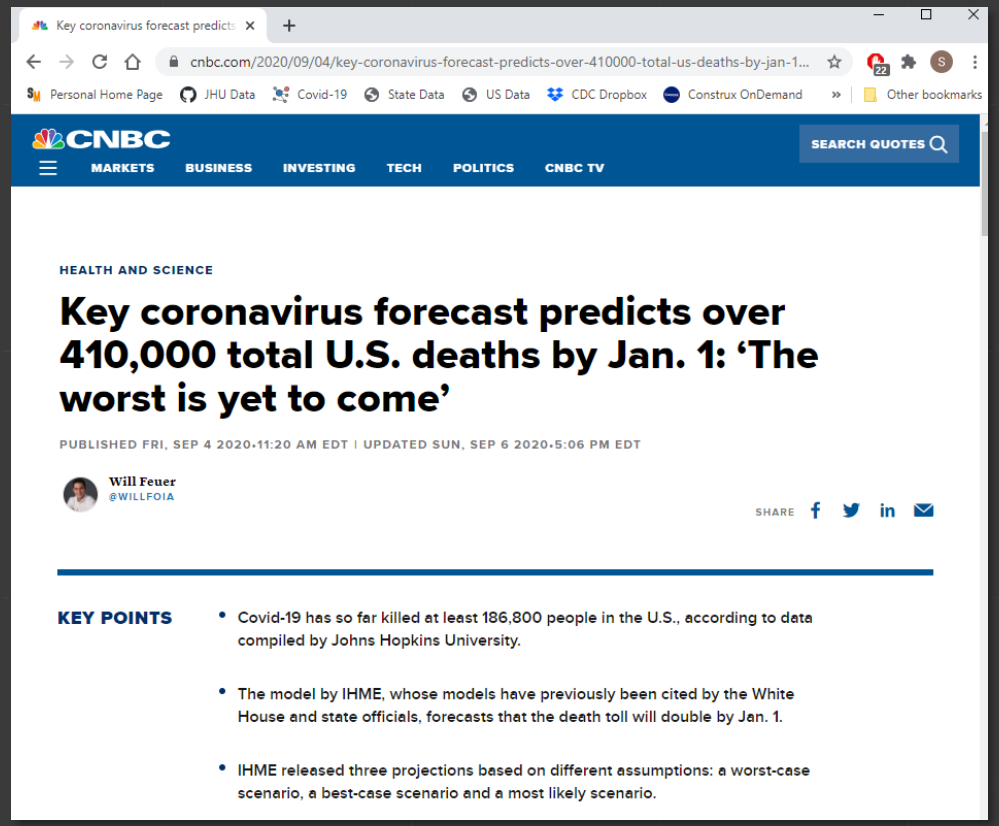
- Covid-19 has so far killed at least 186,800 people in the U.S., according to data compiled by Johns Hopkins University.
- The model by IHME, whose models have previously been cited by the White House and state officials, forecasts that the death toll will double by Jan. 1.
- IHME released three projections based on different assumptions: a worst-case scenario, a best-case scenario and a most likely scenario.

What would need to happen for this to be true?

- The death trend would need to more than double, immediately, despite trending down 10%/week for the past few weeks, along with leading indicators also trending down
- Need to incur more deaths in four months than we've had since the beginning of the pandemic

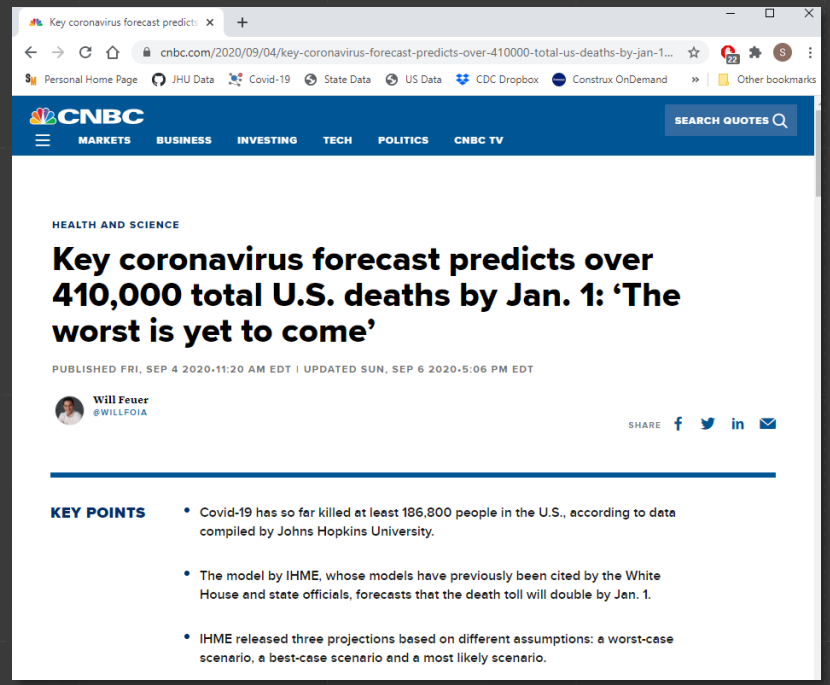
What would need to happen for this to be true?

- Need to average 1800 deaths per day for 115 days straight, which was 100 more days than we'd had that many deaths so far
- No one can take any corrective action to reduce deaths even after deaths skyrocket, and they must continue not to take any action for **4 months**

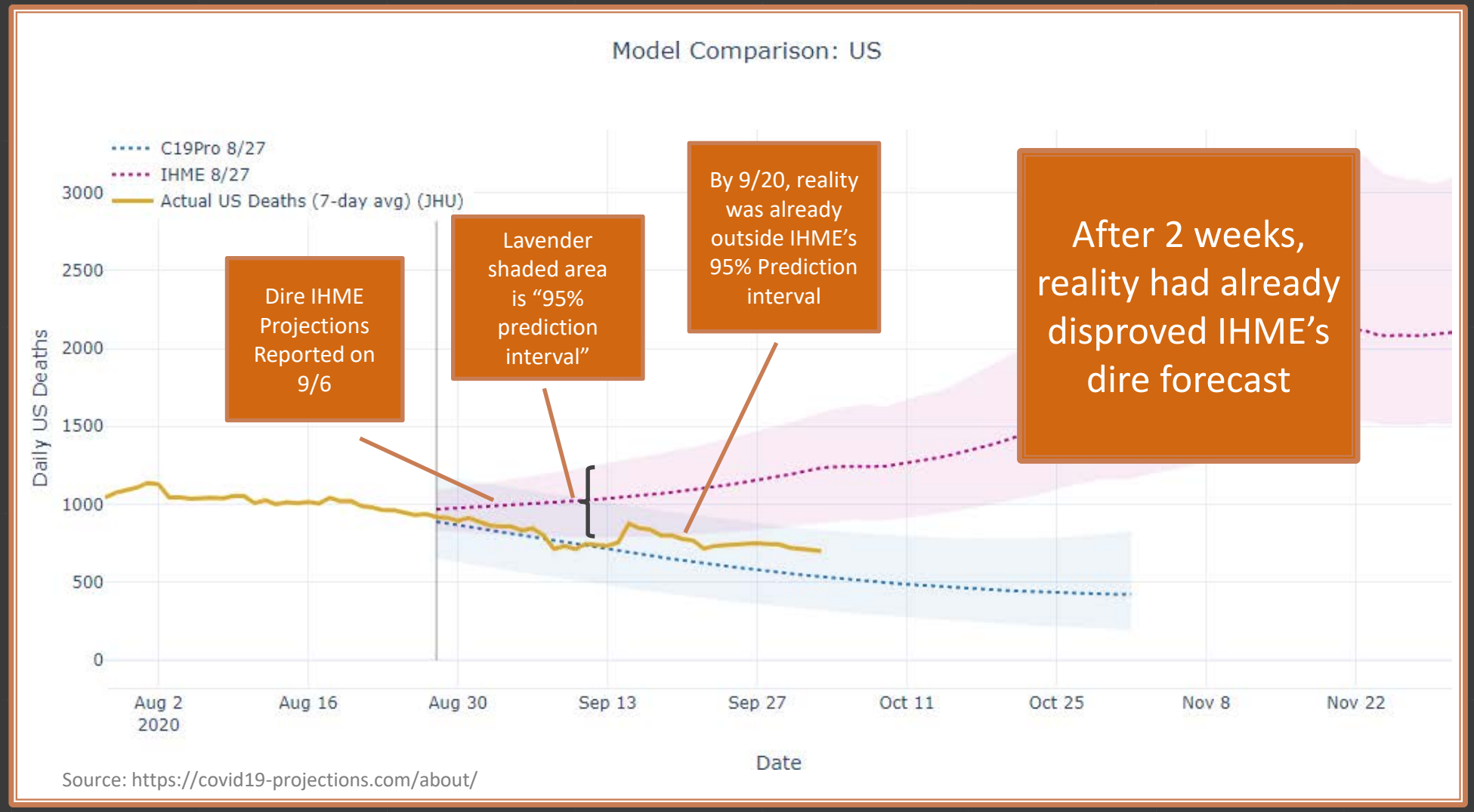


My Observations

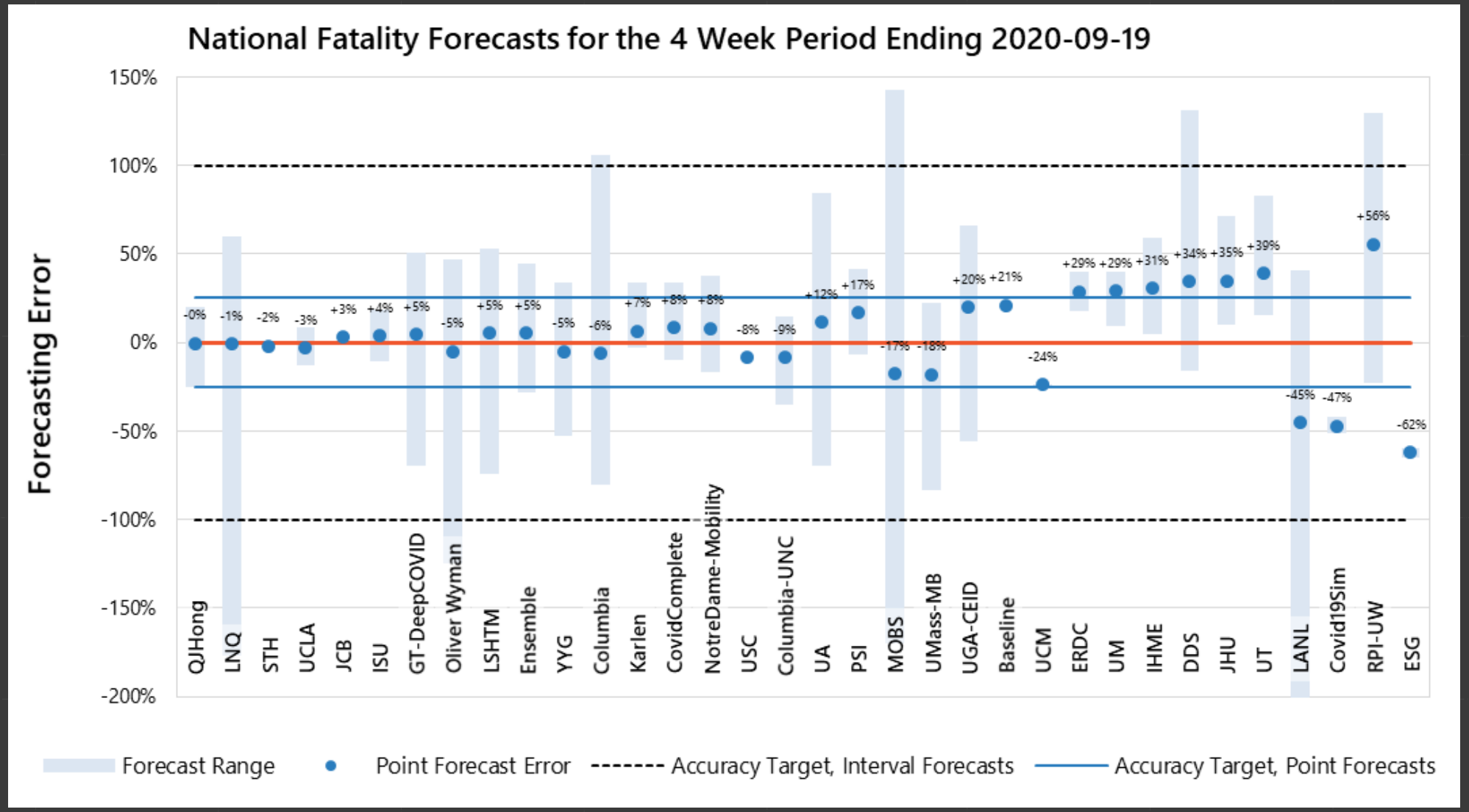
- This forecast is not going to happen
- This forecast is completely unfounded
- This forecast is in no way “most likely”



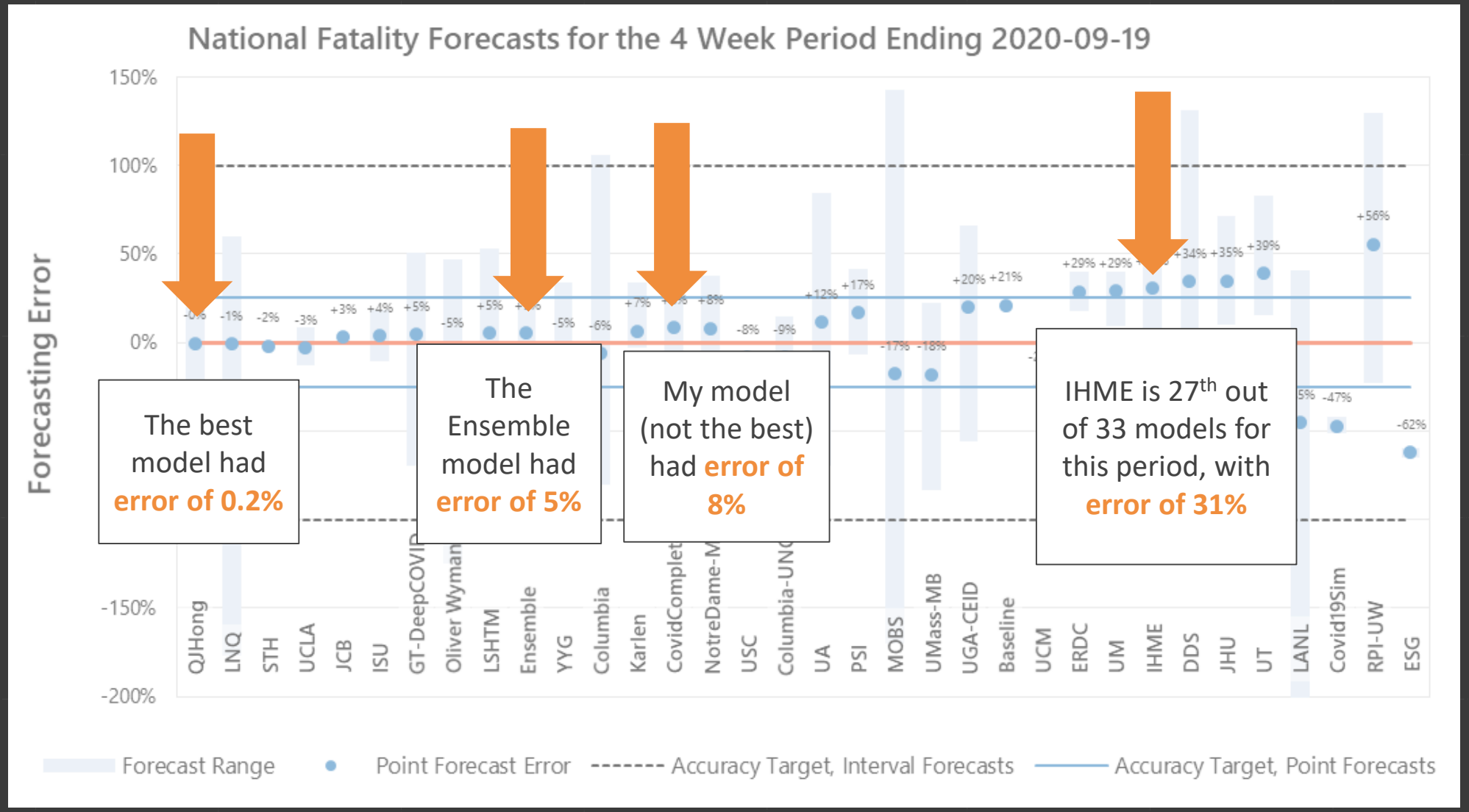
This “Forecast” is completely unfounded



How Accurate were Other Forecast for the same period?



How Accurate were Other Forecast for the same period?



Why I got Involved

I just wanted to know what is going on with the pandemic, without all the spin

The Basics: What is Forecasting?

Forecasting is
not the same as
speculation, but we are
seeing them treated
interchangeably

PostEverything • Perspective

Scientists want to predict covid-19's long-term trajectory. Here's why they can't.

Our research suggests that forecasts are unreliable further than a few weeks out

Dining outdoors in Manhattan on Monday. (Jeenah Moon/Reuters)

By **Nicholas Reich** and **Caitlin Rivers**

September 15, 2020 at 11:22 a.m. PDT

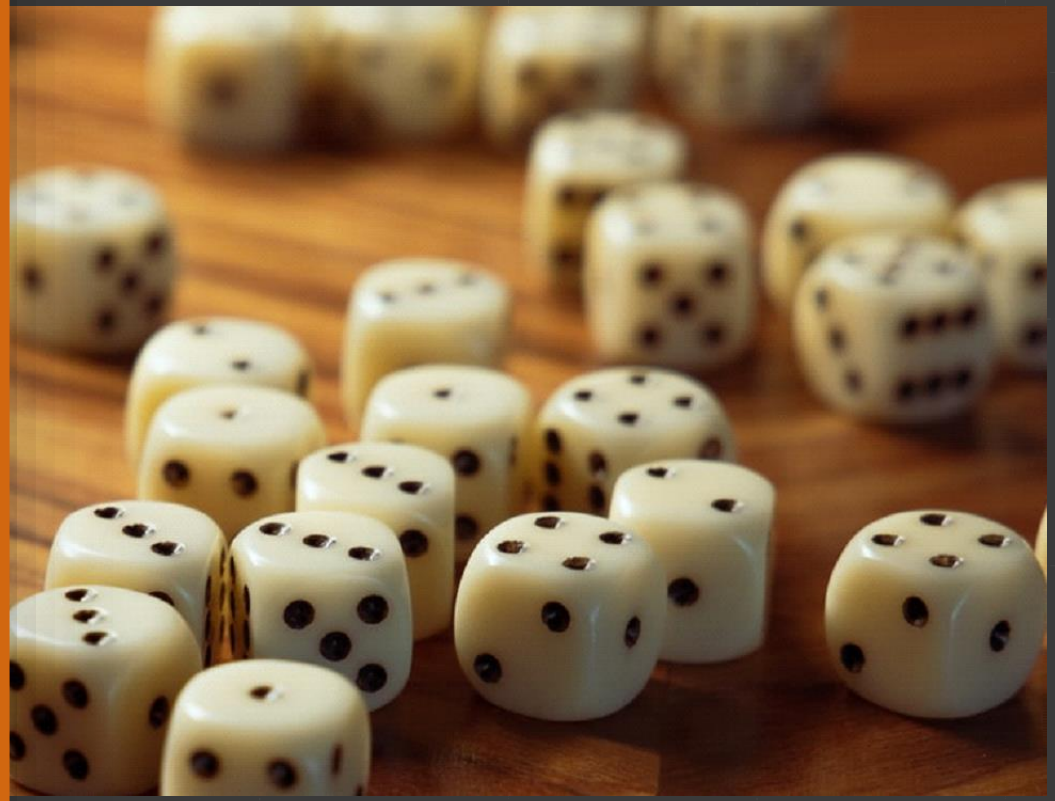
What is possible with forecasting

- ✓ 1-4 week time horizons
- ✓ Accurate national forecasts
- ✓ Pretty accurate state forecasts, especially for more active states

- Anything further out than that is speculation (even if it's dressed up with graphs and numbers, which most of it is)

Forecasting vs. Speculation

- **Forecasting**
  - Inputs are known
  - Outputs (forecasts) are calculated based on known relationships
- **Speculation**
  - Inputs are guesses
  - Outputs are guesses piled on top of other guesses



Knowns

- Number of people who have already tested positive
- Approximate relation between positive tests and cases
- Approximate fatality rates by age and comorbidity status
- Progression of the virus in individuals

Unknowns

- Specific policies that specific states will implement (or relax) in the future
- Dates those policies will be implemented or relaxed
- Effectiveness of the policies, with good compliance
- Effectiveness of the policies, with whatever compliance we actually get
- Availability of vaccines
- Effectiveness of vaccines, when and if available

The Basis of Forecasting

“What We Know”

We Know Much More About Covid-19 Now Than We Did on 1/22/20

Fatality is highly age-related (~50% of deaths are age 80+)

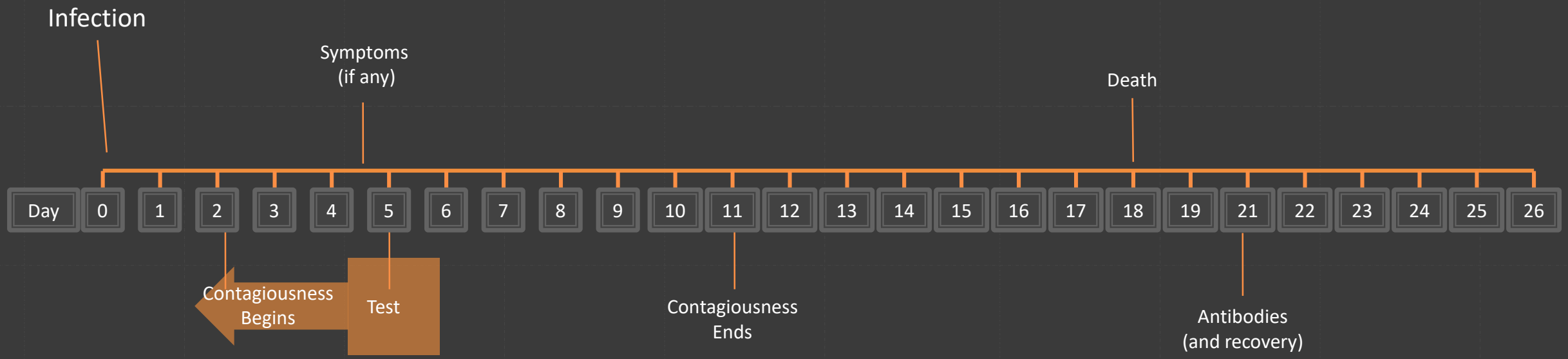
Fatality is highly co-morbidity related (~90% of fatalities involve at least one co-morbidity

A lot more people are infected than have tested positive

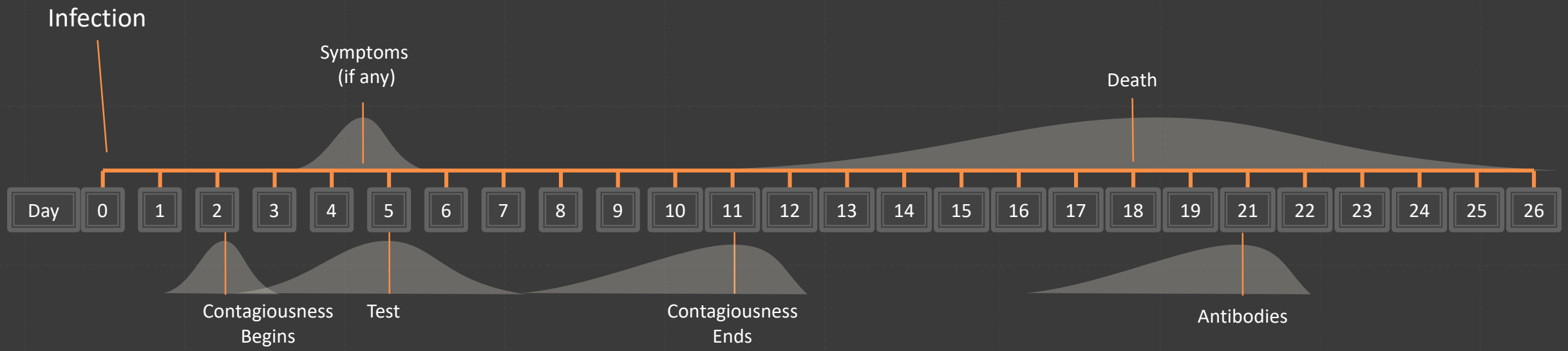
- Early in the pandemic: 10-20x cases per positive test
- Now—3-5x cases per positive test

We know the timing of the course of the disease

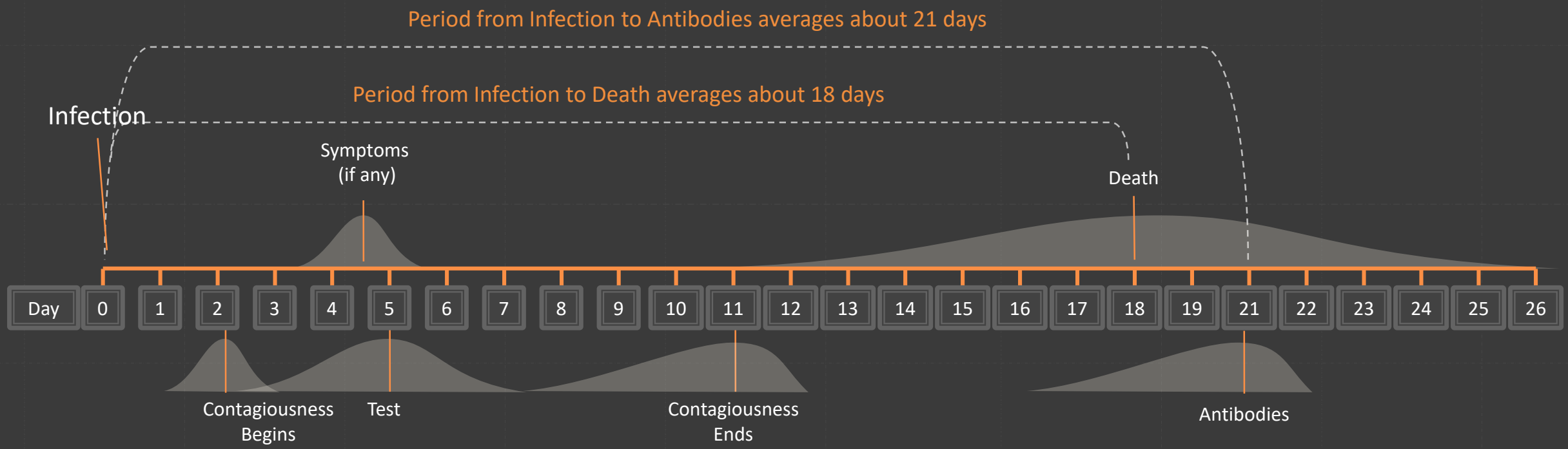
We have a pretty good view of the timing of the disease



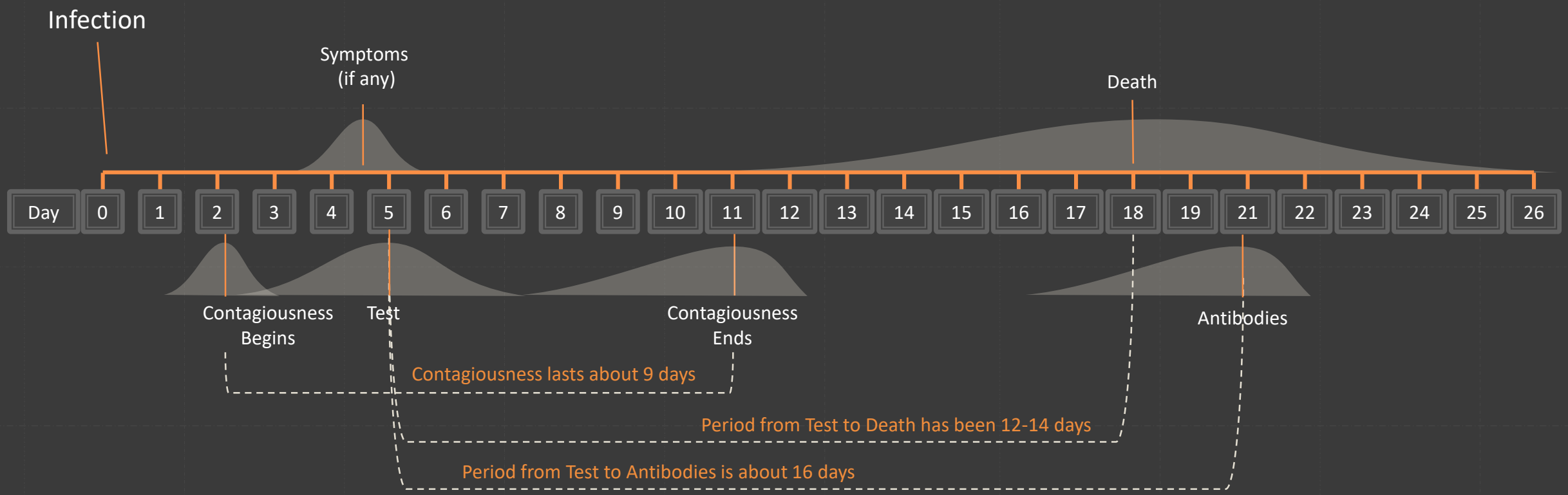
Of course there's variability in all of this



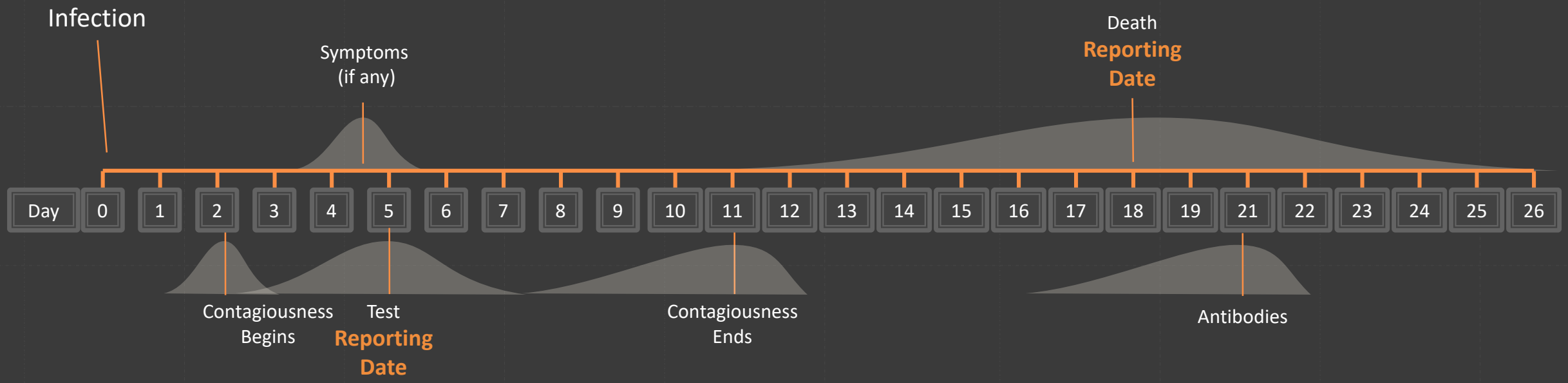
This allows us to draw some inferences



This allows us to draw some inferences



This is more about reporting dates, more than actual dates

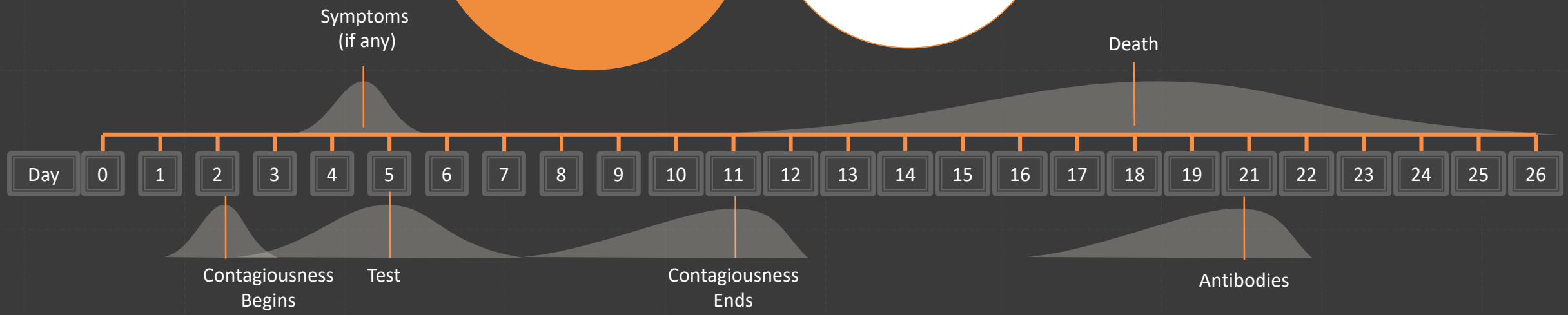


What Does This Have to do With Forecasting?

Timing forms the basis of forecasting (for my method)

We can do this with terrific accuracy at the national level, and with fair accuracy at the state level

And because trends tend to continue, we can project forward another 14 days



We can take this number, which we know on date X

We can apply what we've learned about the ratio of positive tests to deaths

We can forecast this number, **14 days ahead**

Forecasting Begins with Data

Current State of Data, Part 1

Current State of Data, Part 2

Problems with Cumulative Data

Issues with cumulative data, examples

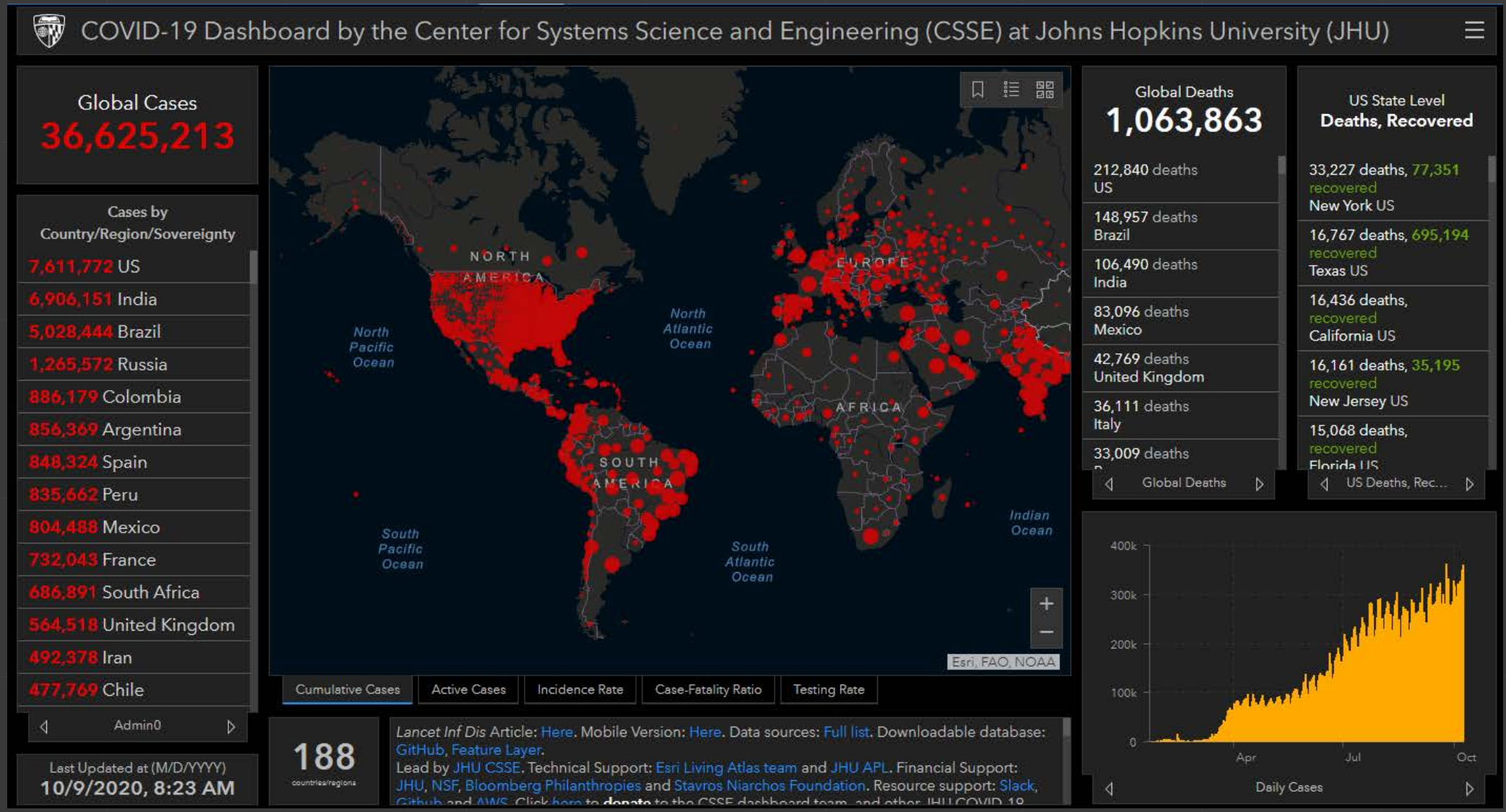
- Bing/covid graph
- JHU graphic
- What is cumulative data good for?

#CovidComplete

Typical Cumulative Graph

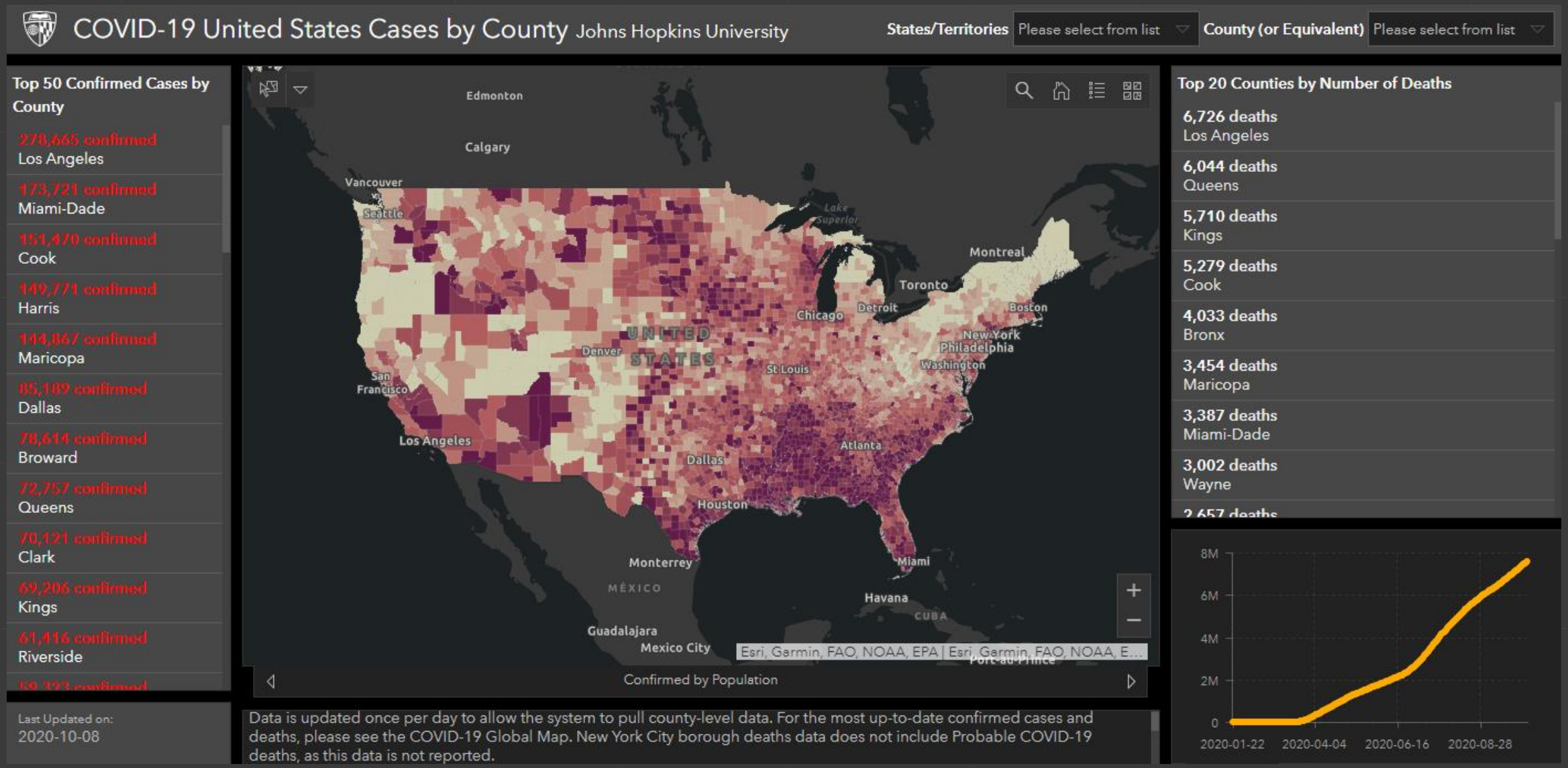
Source: https://www.bing.com/covid/local/unitedstates?vert=graph

Johns Hopkins Coronavirus Dashboard



Source: https://coronavirus.jhu.edu/map.html

Johns Hopkins Coronavirus Dashboard – Newer Graphic



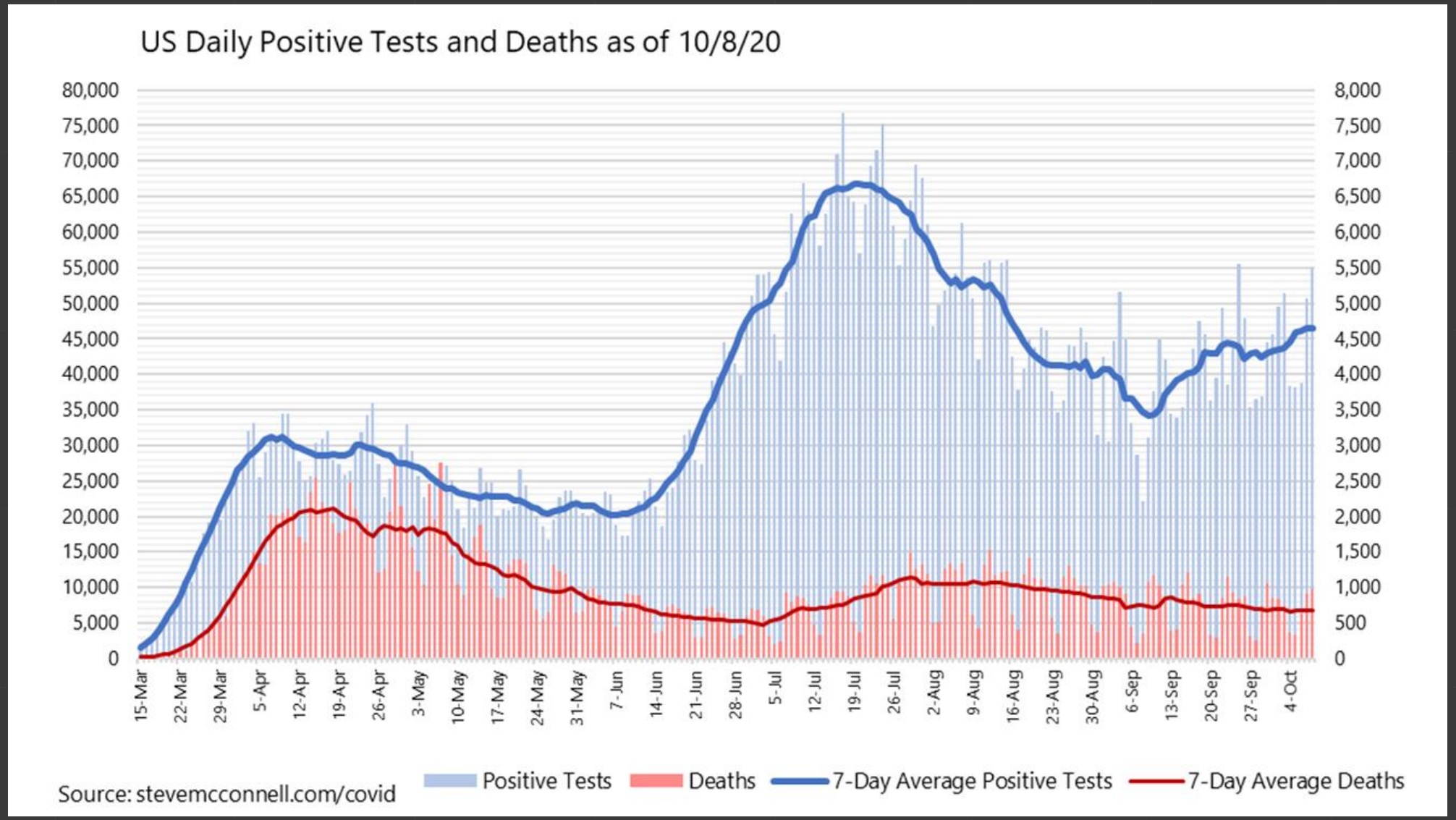
Source: https://coronavirus.jhu.edu/us-map

Incremental Data

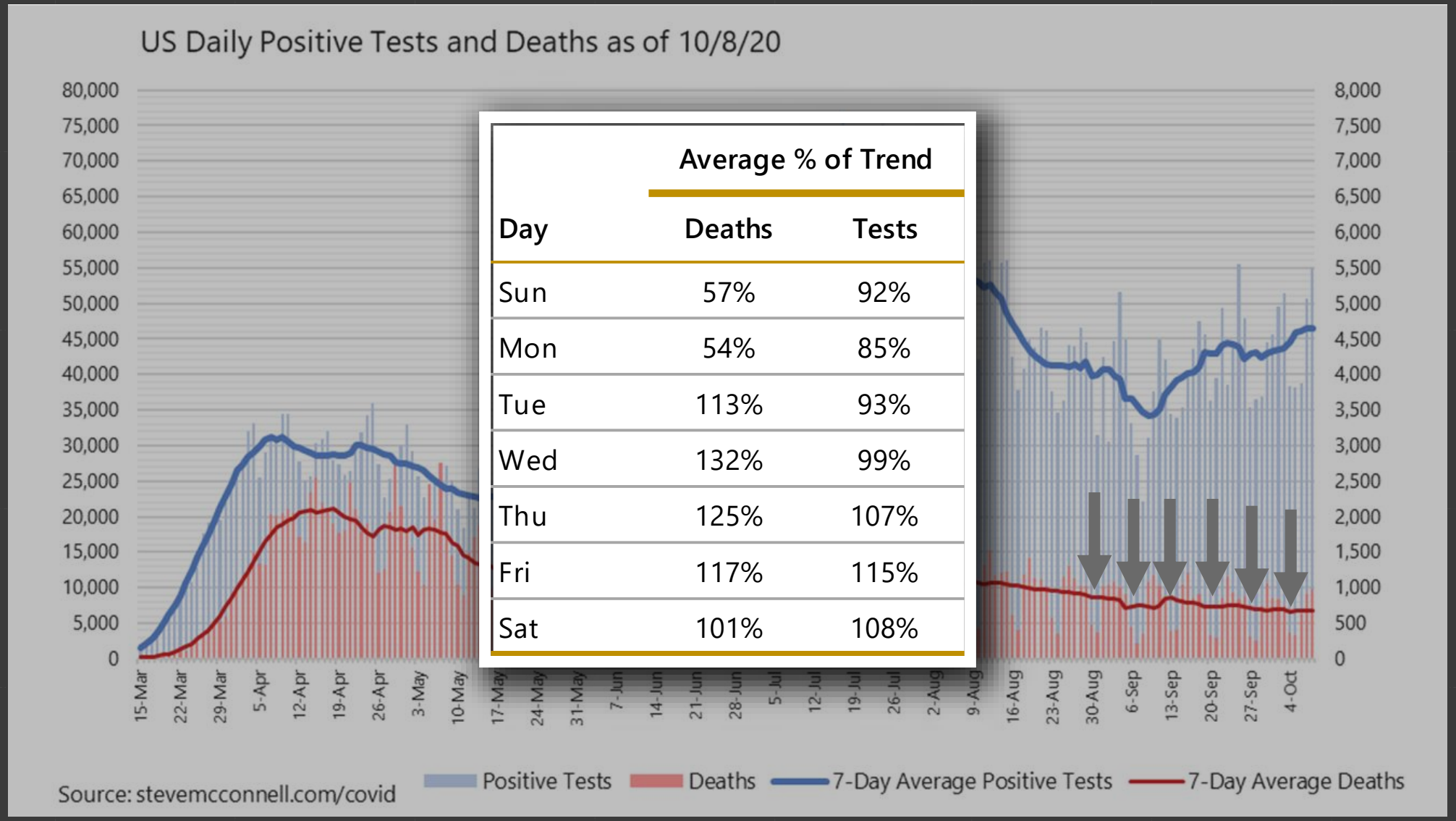
- Incremental data is more meaningful than cumulative data
- But it also opens the door to a whole new set of data quality issues

#CovidComplete

Daily Graphic

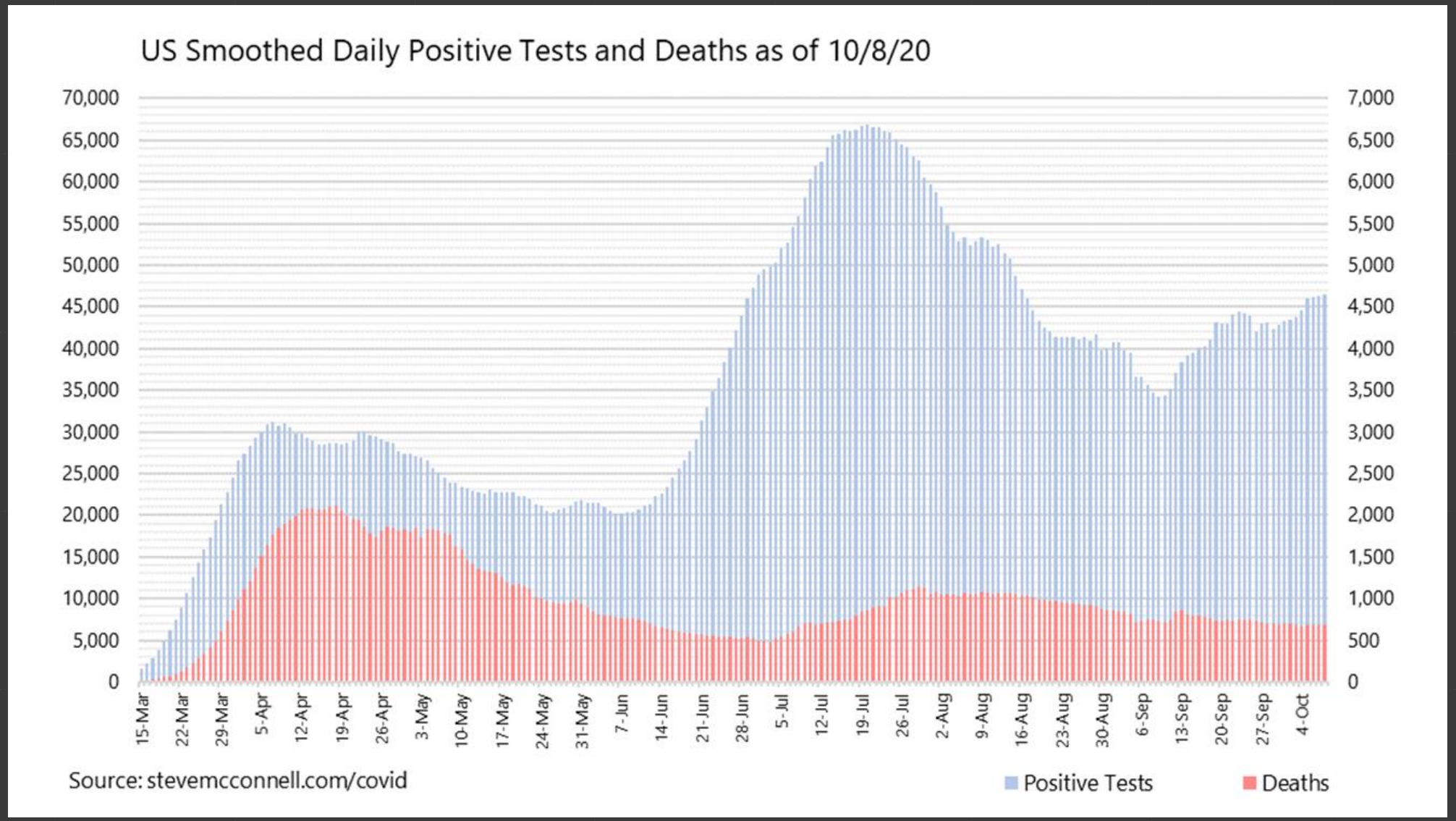


Issue #1 with Daily Data – Sundays!

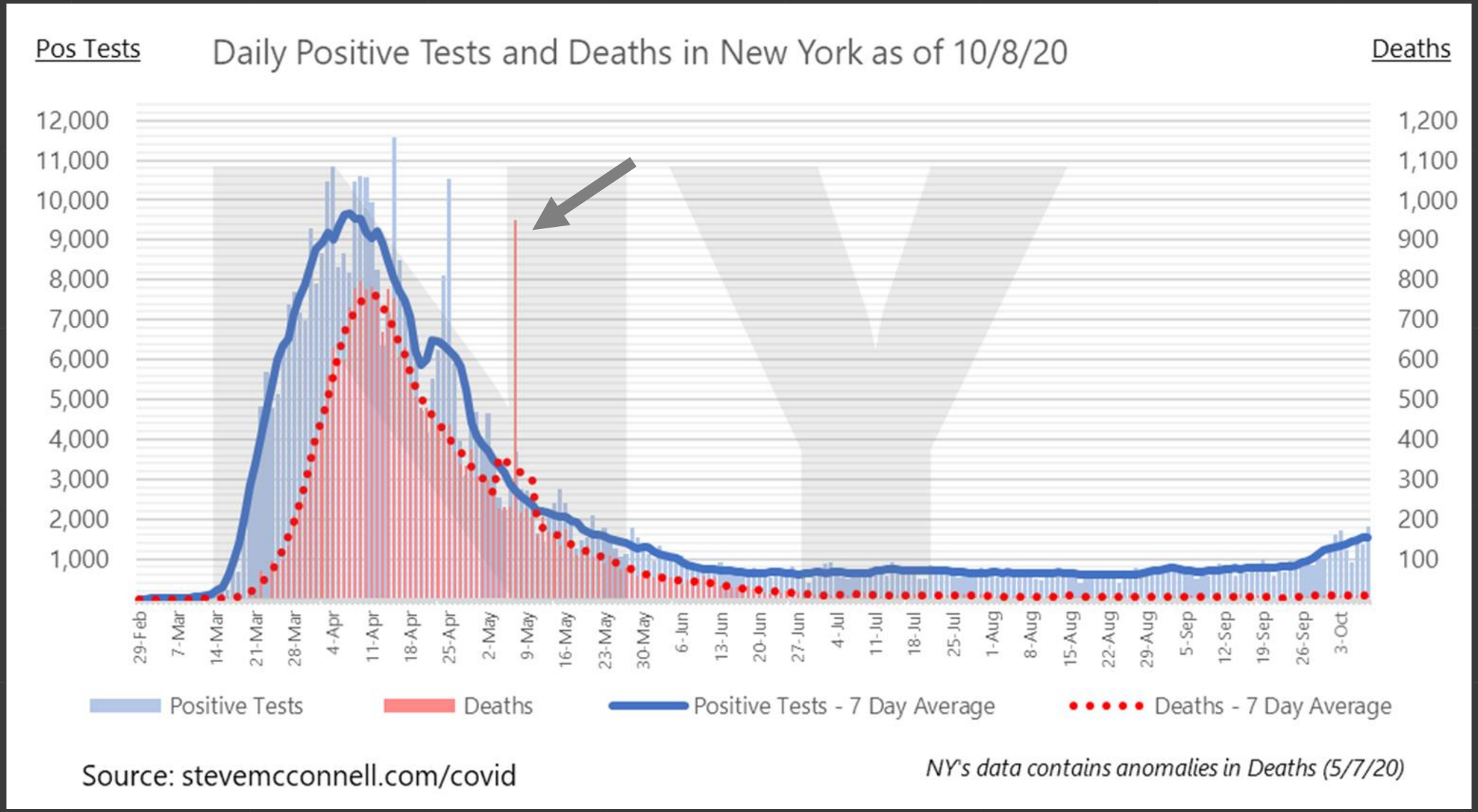


Day	Average % of Trend	
	Deaths	Tests
Sun	57%	92%
Mon	54%	85%
Tue	113%	93%
Wed	132%	99%
Thu	125%	107%
Fri	117%	115%
Sat	101%	108%

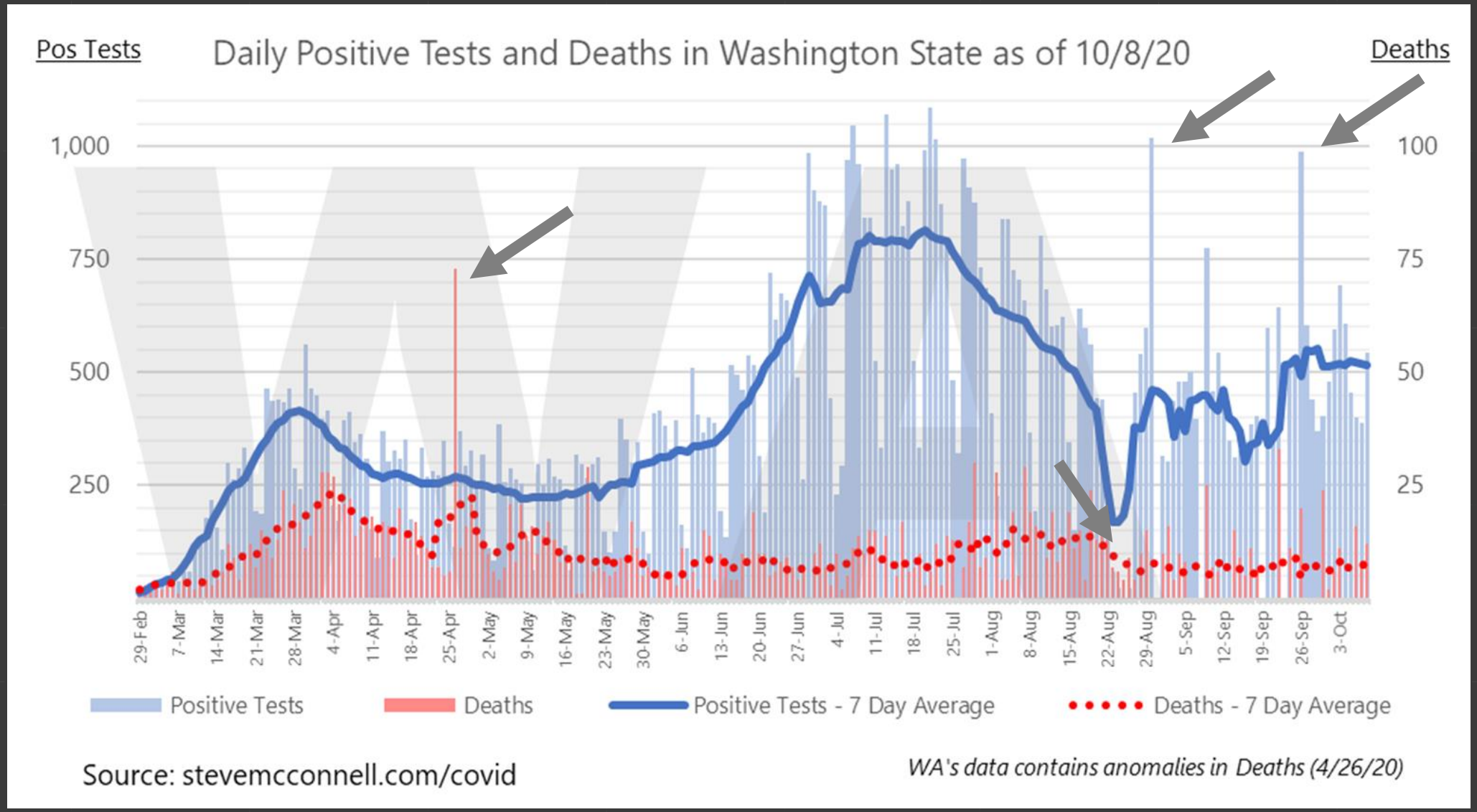
Issue #1 with Daily Data – Sundays!



Issue #2 with Daily Data – Spikes in State Level Data



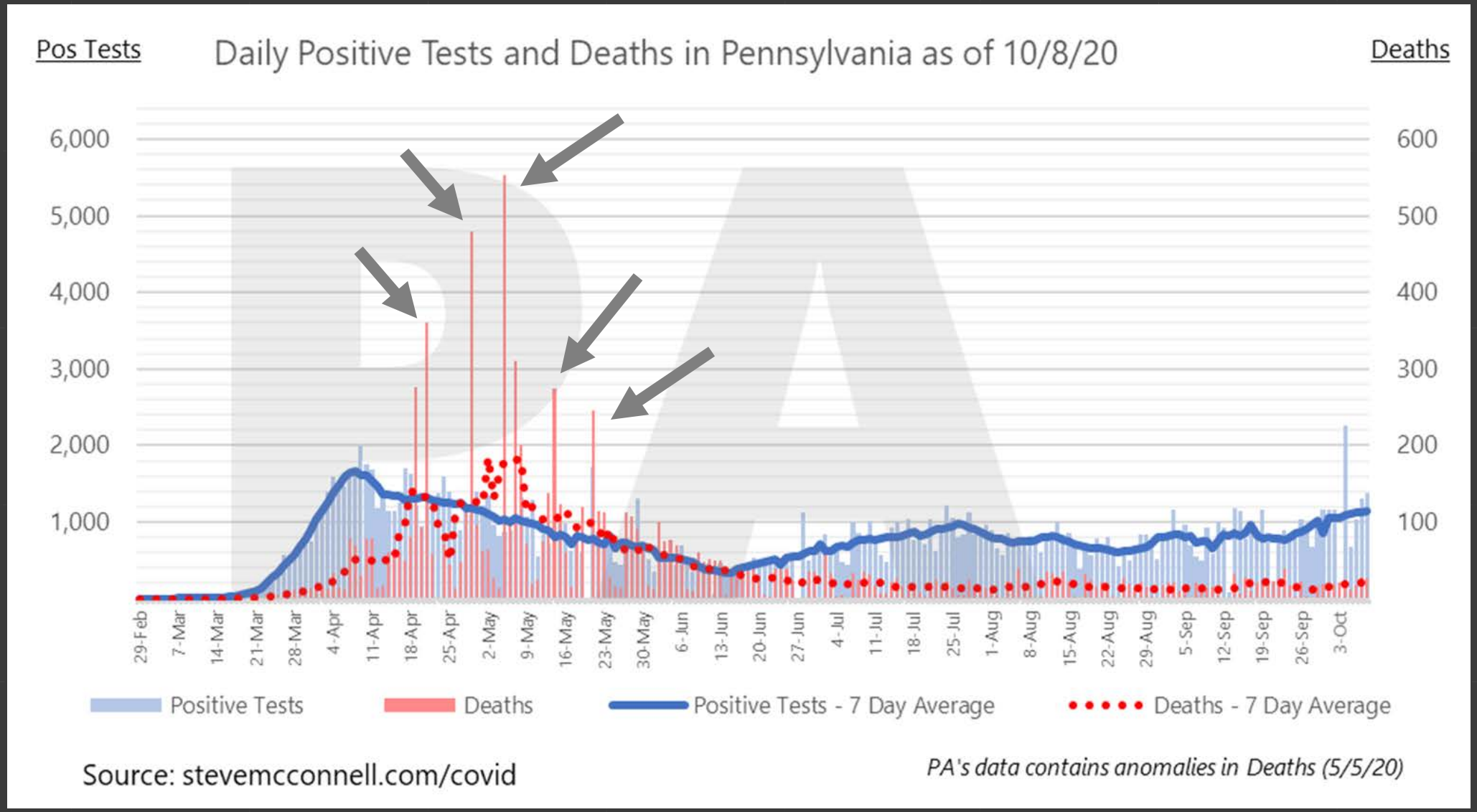
Issue #2 with Daily Data – State Level Data



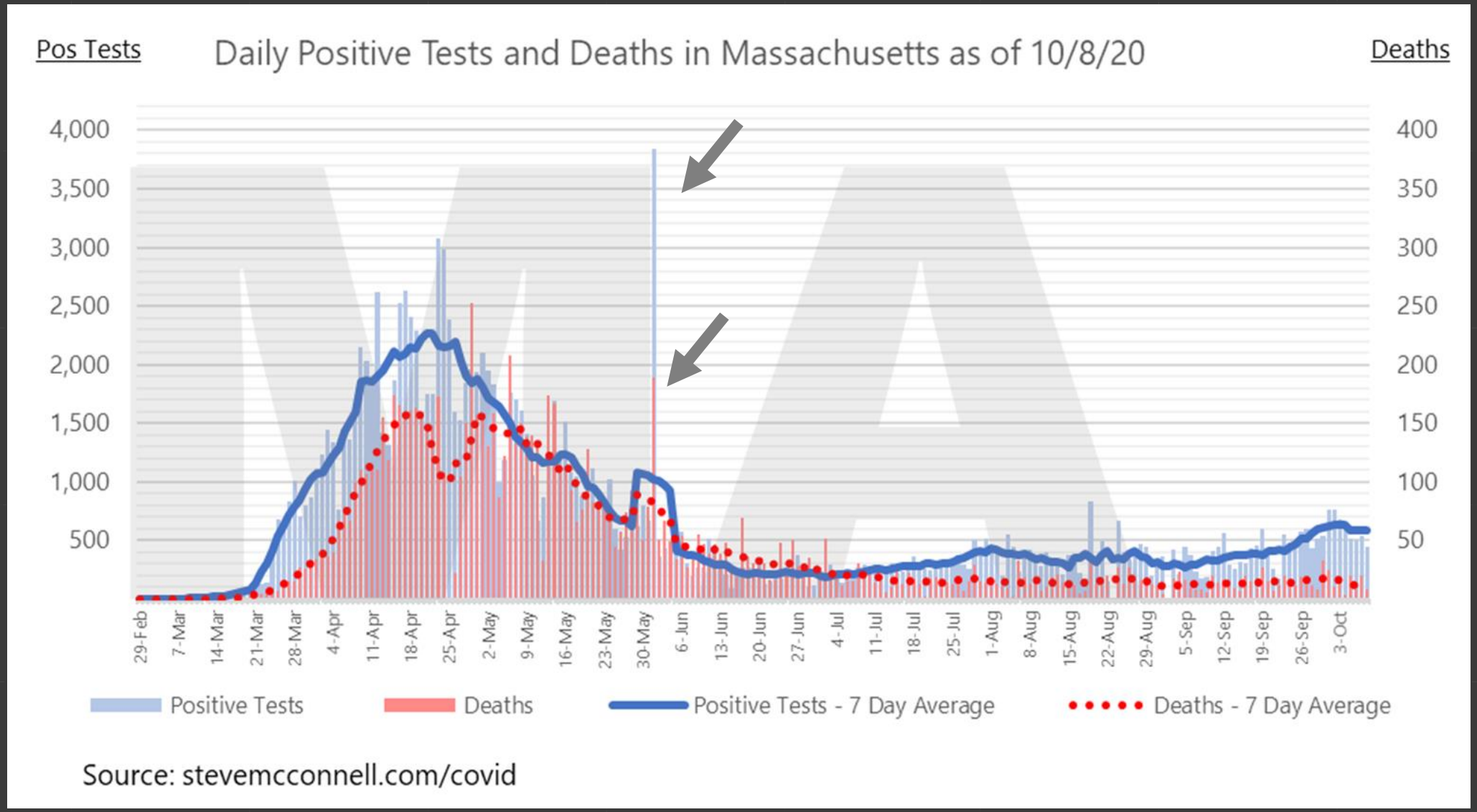
Source: stevemcconnell.com/covid

WA's data contains anomalies in Deaths (4/26/20)

Issue #2 with Daily Data – State Level Data

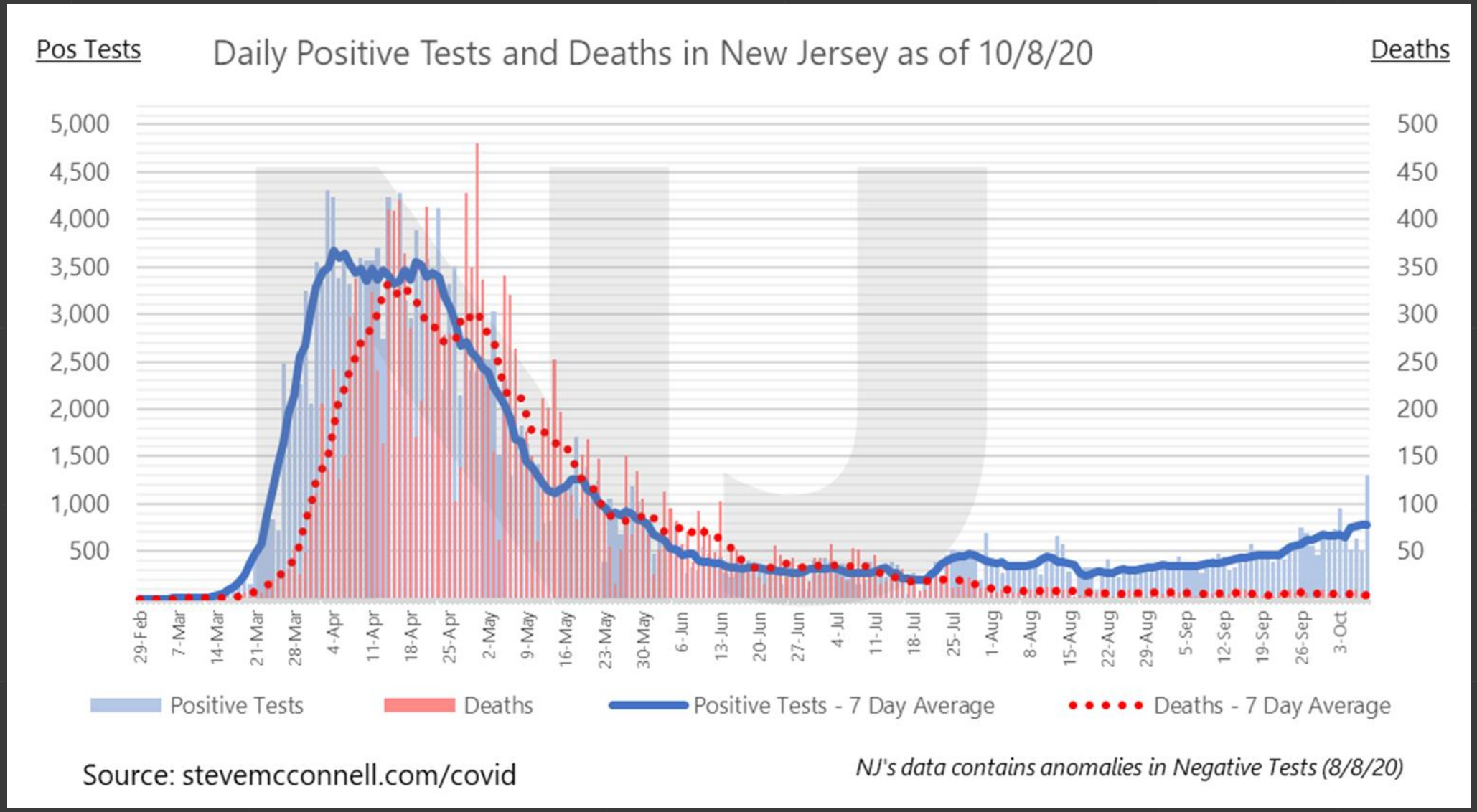


Issue #2 with Daily Data – State Level Data

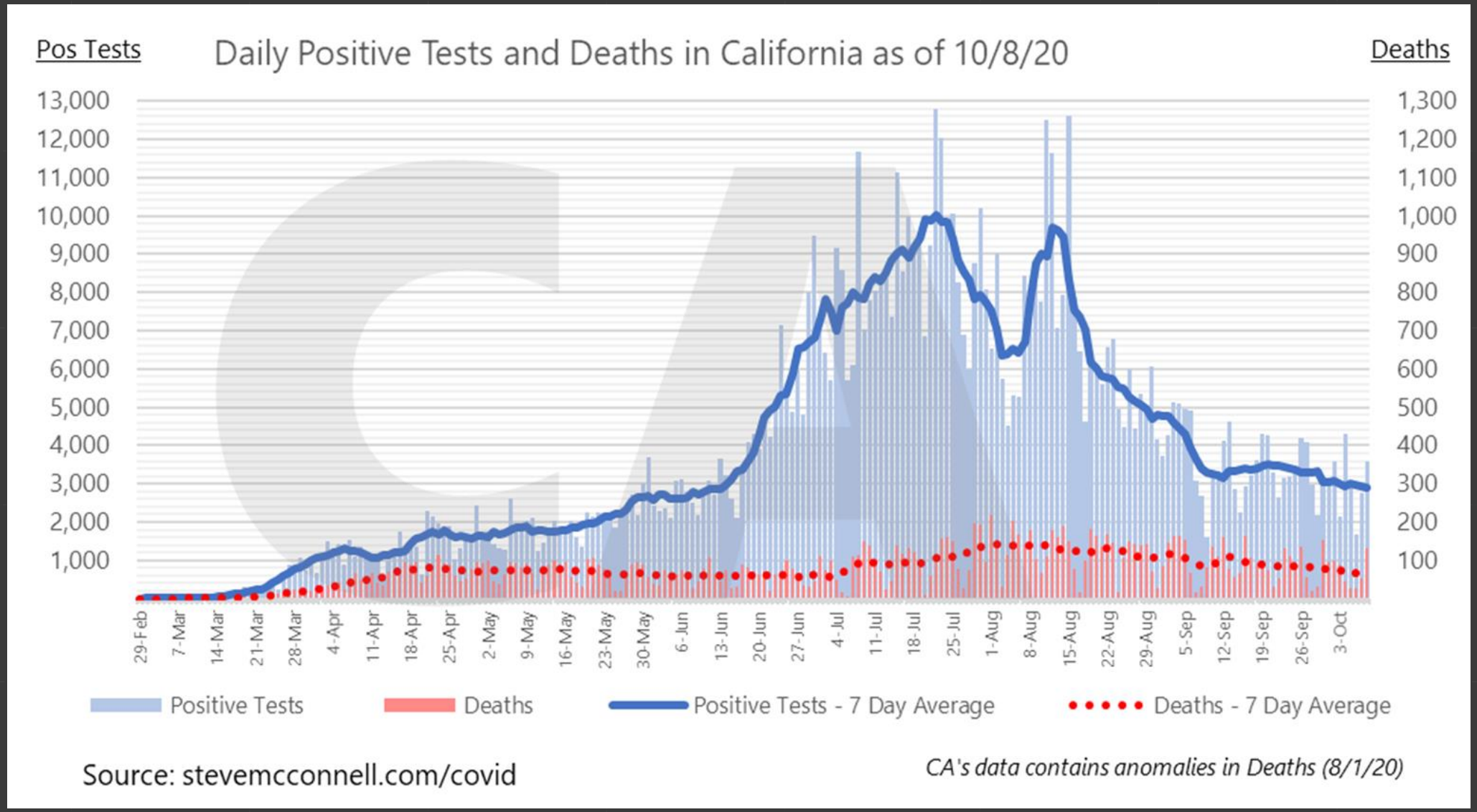


Source: stevemcconnell.com/covid

Issue #2 with Daily Data – State Level Data



Issue #2 with Daily Data – State Level Data



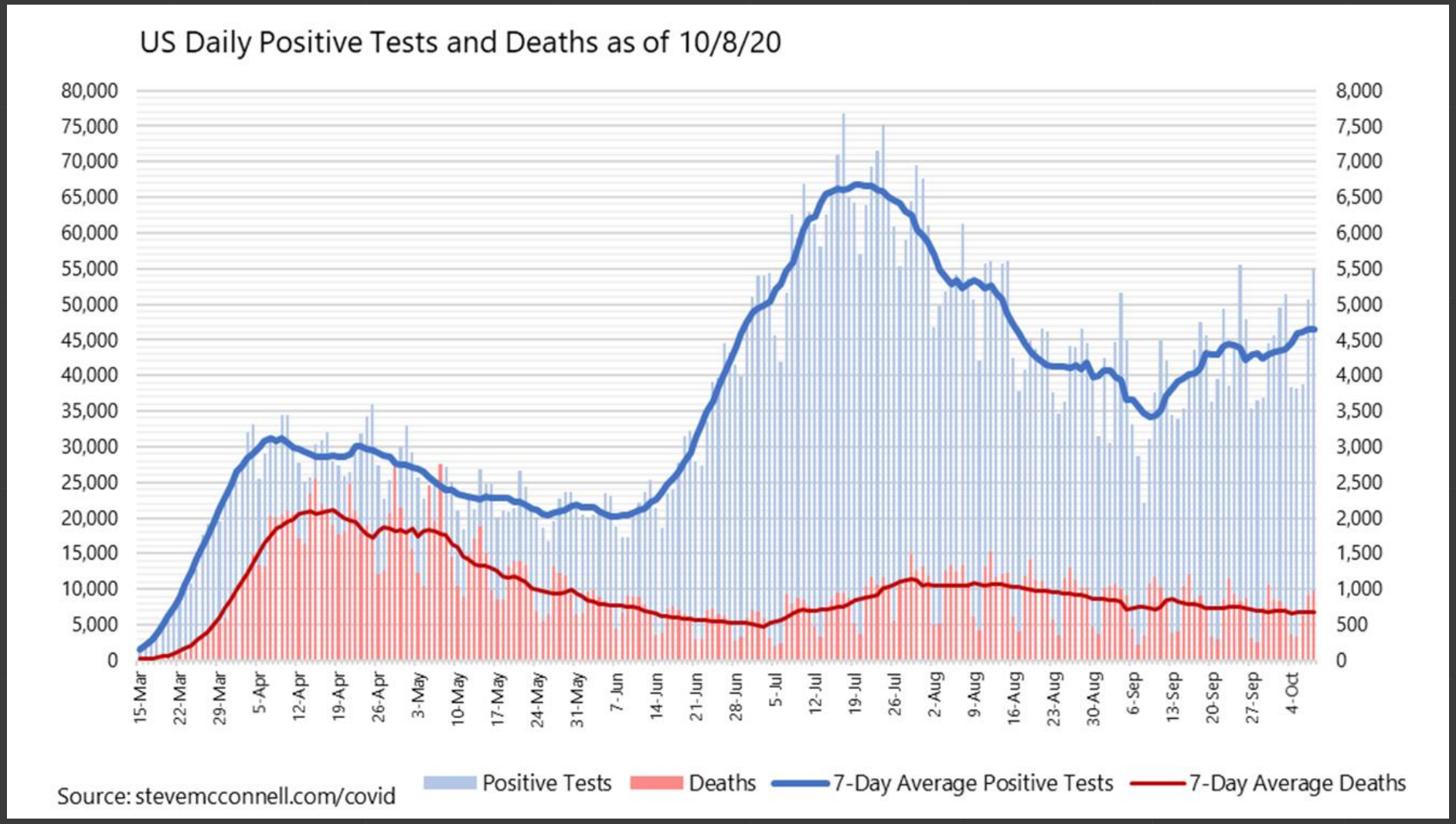
State Level Data Smoothing

- Due to non-regular reporting frequencies, smoothed data is actually more accurate than non-smoothed data
- The smoothing period must be a multiple of 7 days
- By the same reasoning, weekly data is more accurate than daily data
- Smoothing helps, but it doesn't change the fact that there are still weird spikes in the data

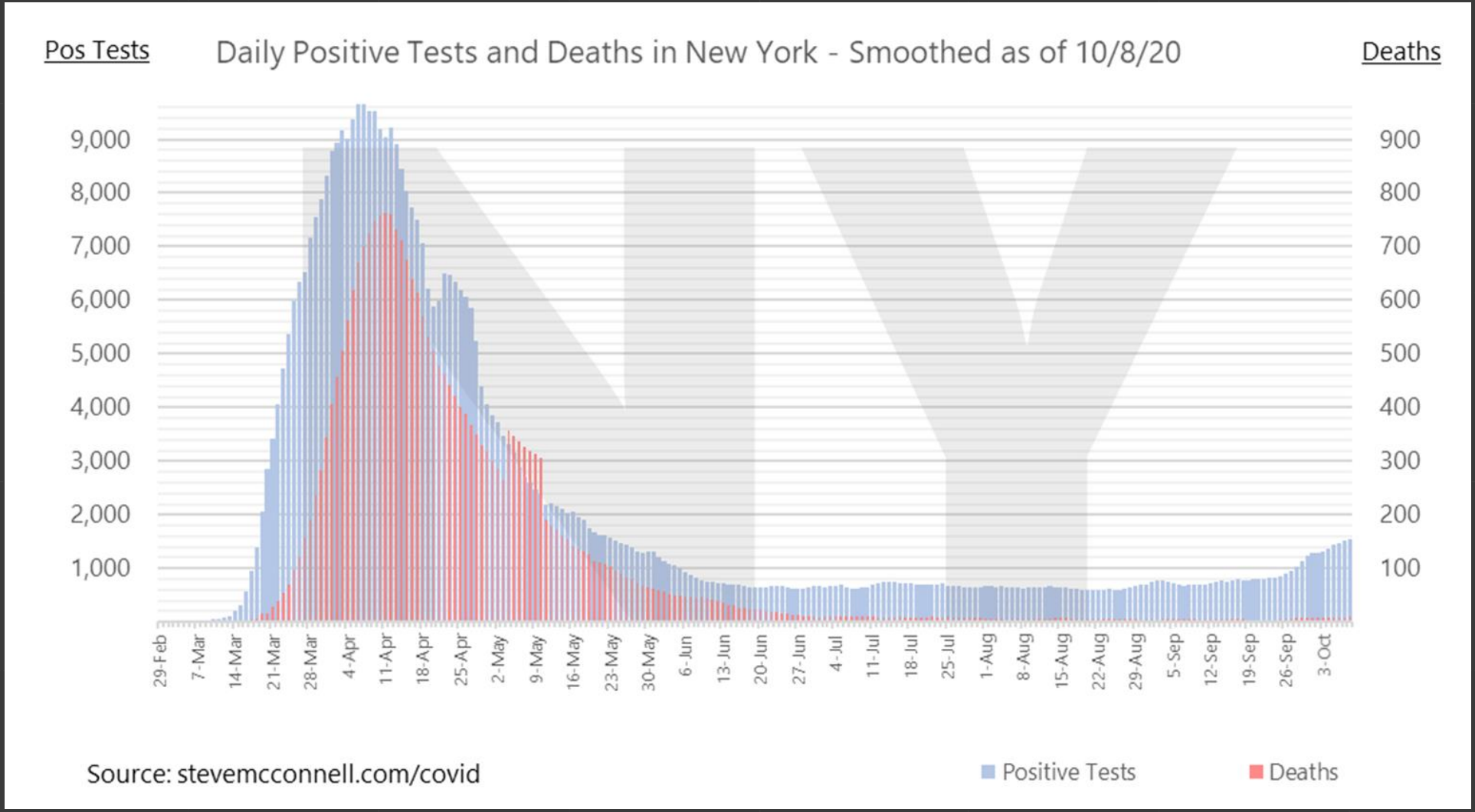
Covid-19 Data Issues

- Issues with daily data
  - Part 1: Sundays (the weekly cycle)
  - Part 2: State-level data spikes and corrections
- Alternatives
  - Running averages
  - Deltas

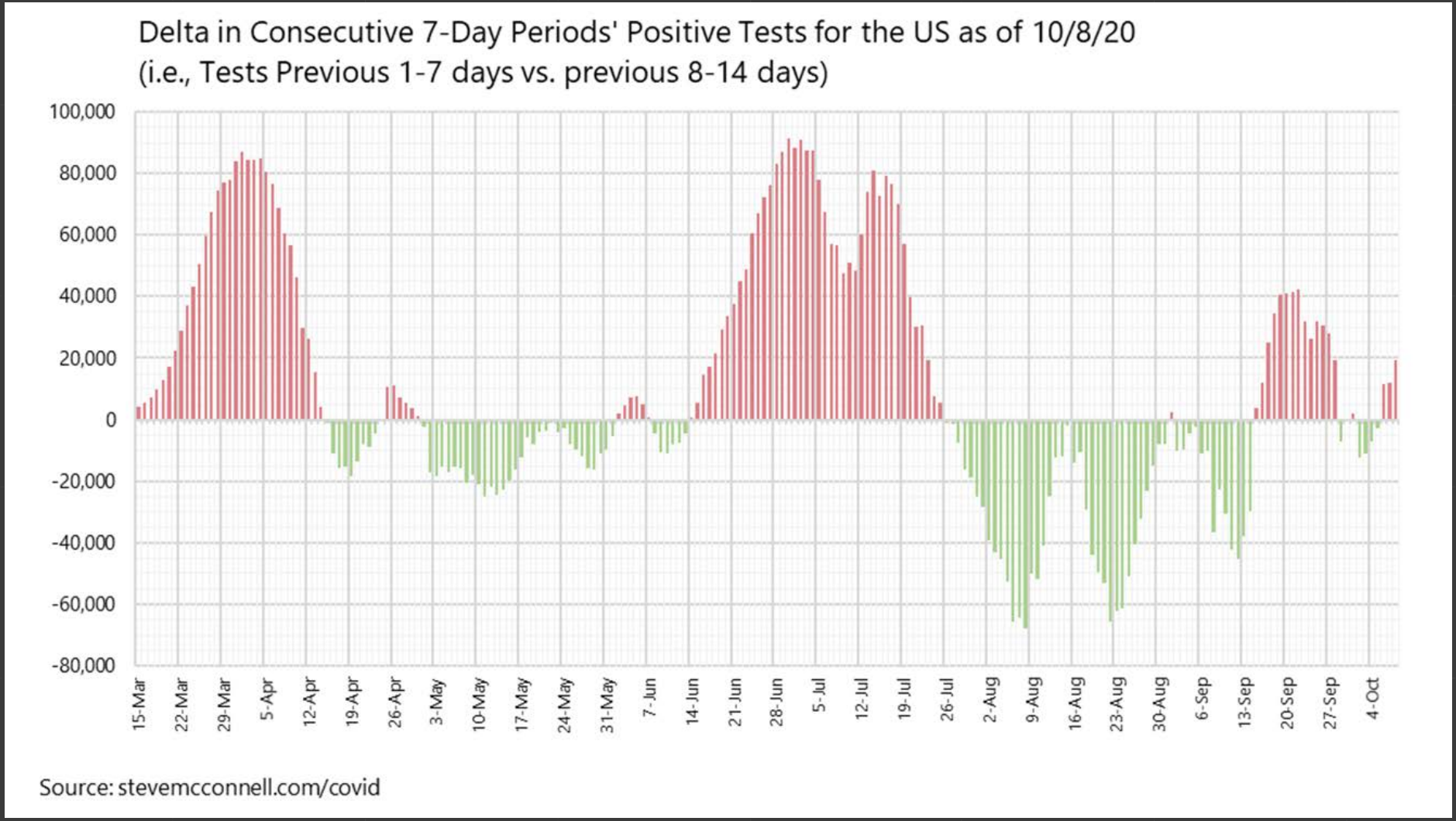
Data Smoothing – Running Averages



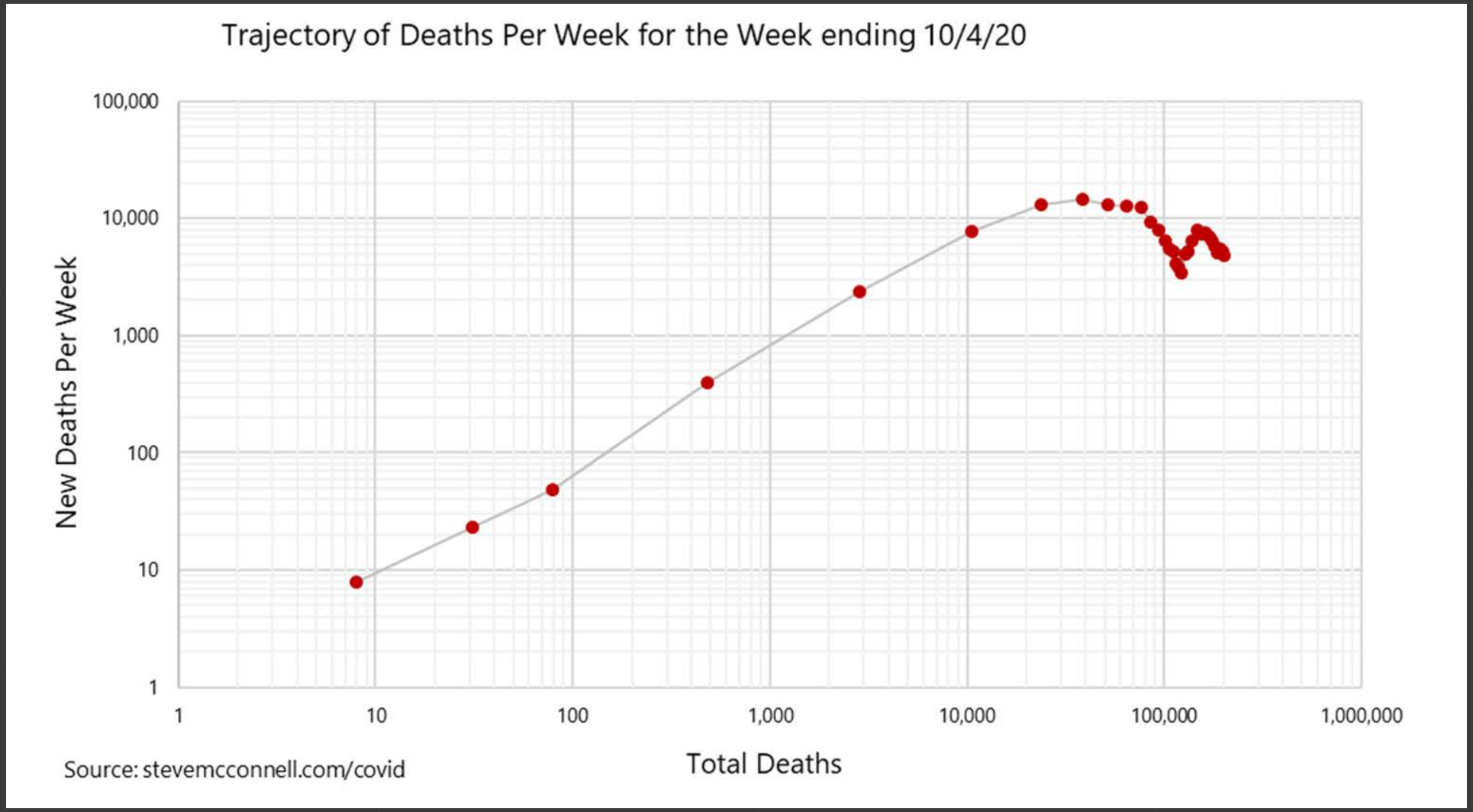
Data Smoothing – Running Averages



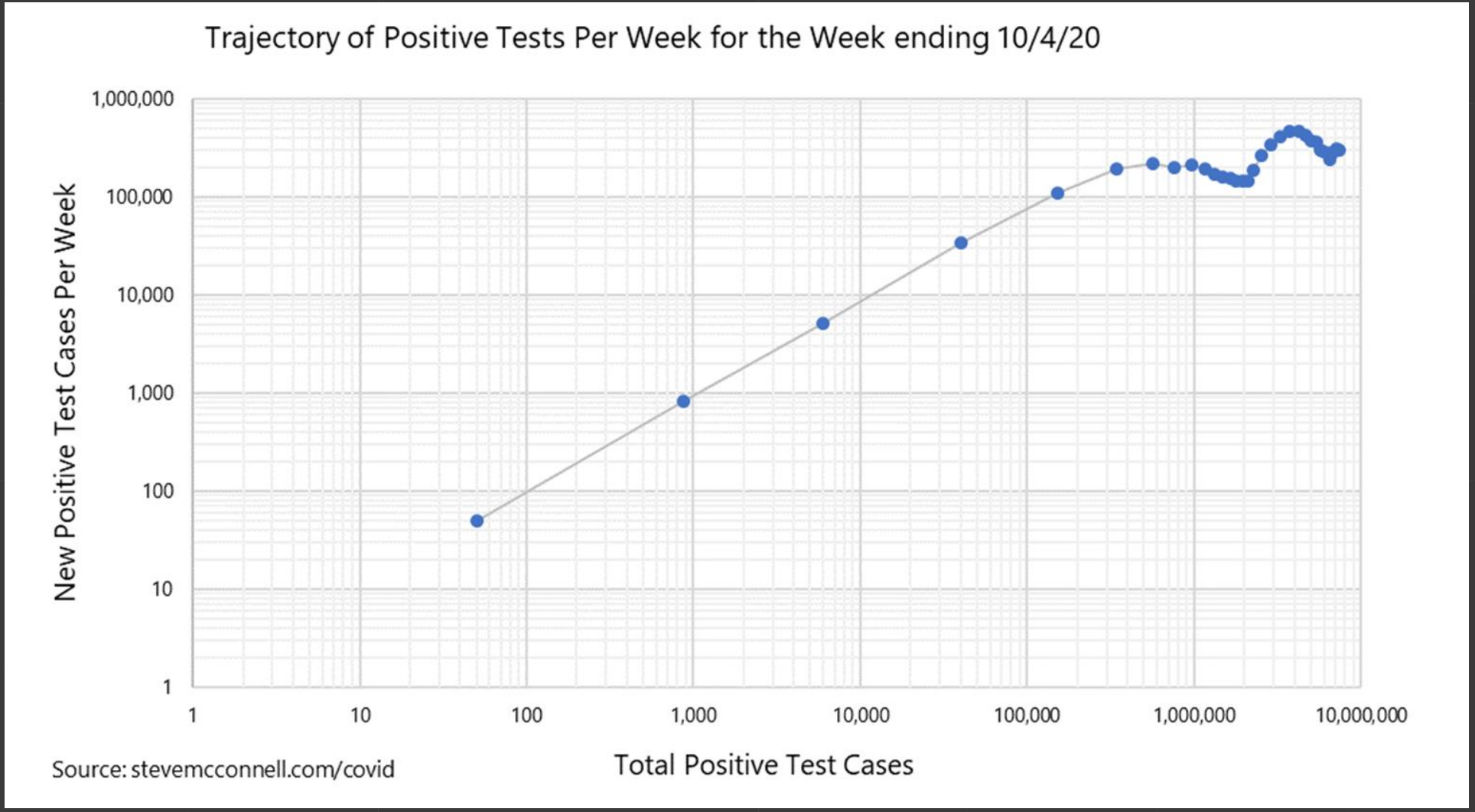
Data Smoothing – Deltas (linear)



Data Smoothing – Deltas (log)



Data Smoothing – Deltas (log)



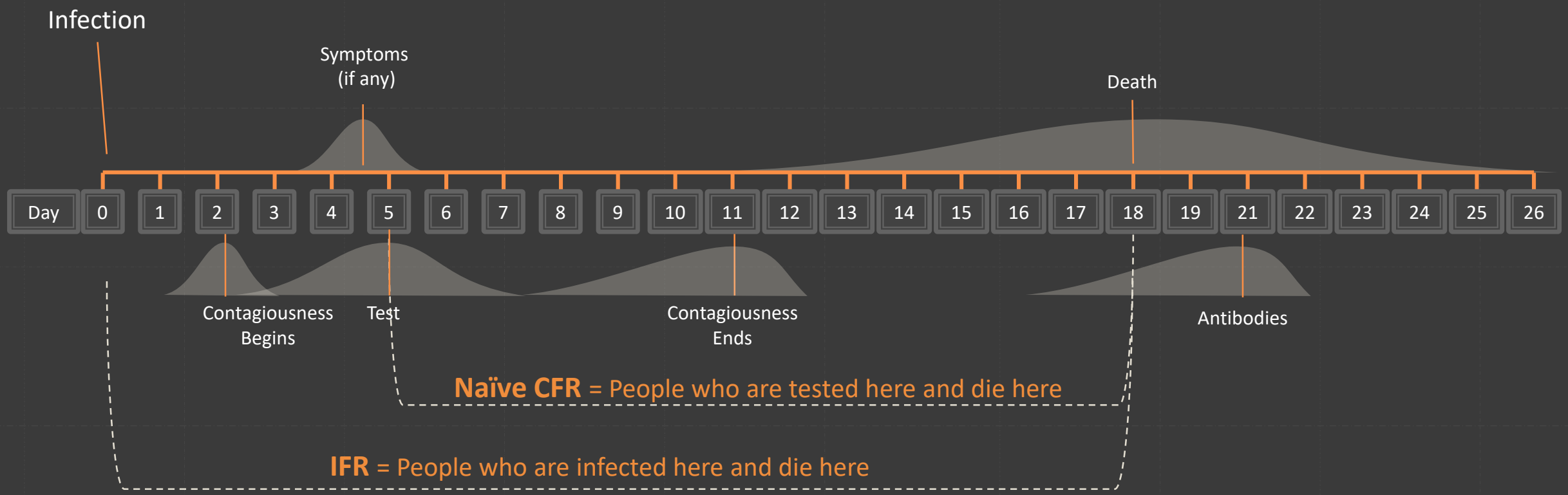
Specific Data Relationships

Calculating CFR/IFR

CFR vs. IFR - Terminology

- "Case" – people who are diagnosed/tested as positive
- "Infected" – people who get the virus whether they're tested or not
- "CFR" = Case Fatality Rate
  - This is number of fatalities divided by number of "cases" (positive tests)
- "Junk CFR" = Today's fatalities divided by today's positive tests
- "Naïve CFR" = Today's fatalities divided by the number of positive tests at some sensible point in the past (e.g., 14 days)
- "IFR" = Infection Fatality Rate – percentage of people infected who die, whether they've been tested or not
- BOTH Naïve CFR and IFR are useful for certain purposes

IFR vs. CFR



Usefulness of IFR

Useful for assessing risk

- To an overall population
- To specific groups within the population

Usefulness of CFR

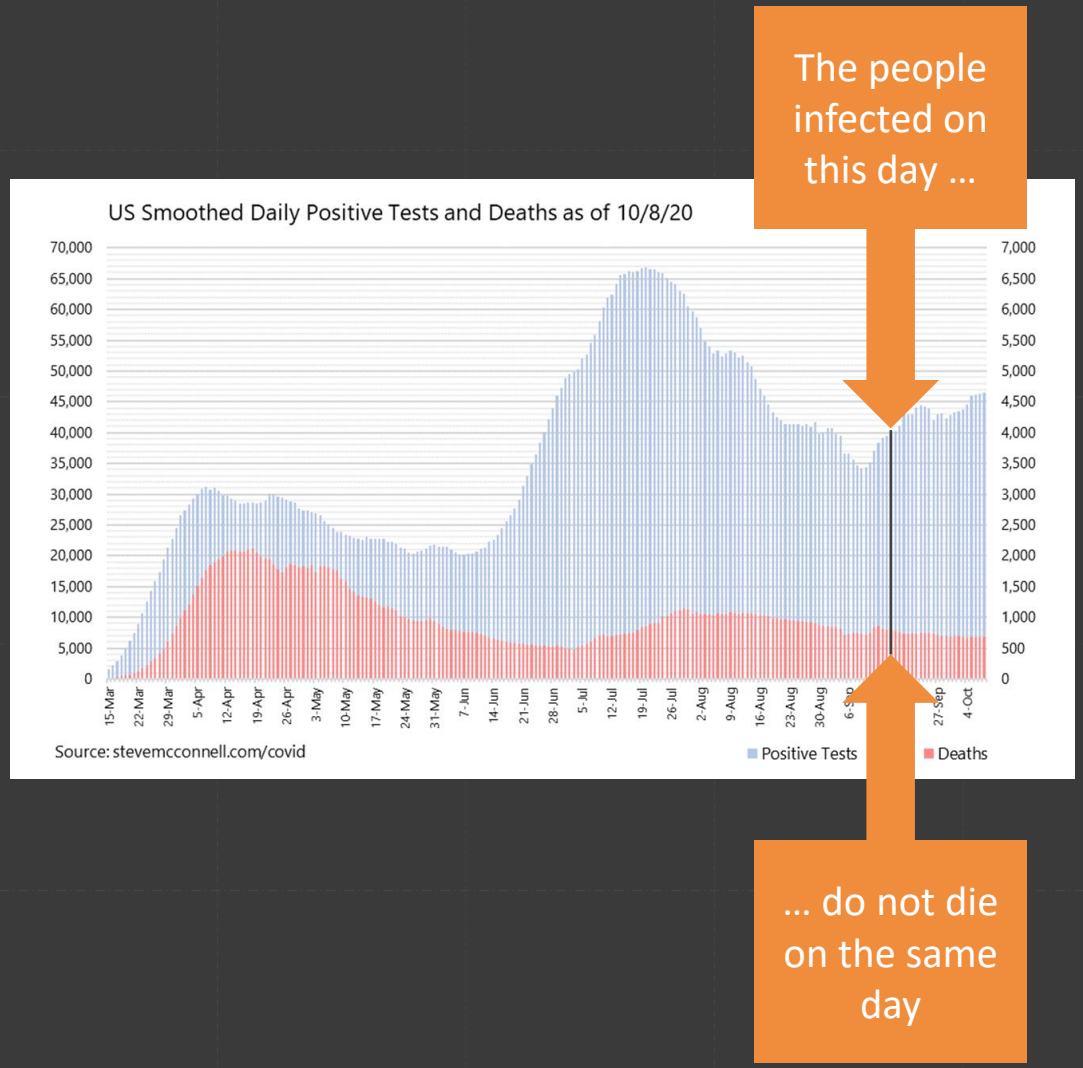
Useful for estimation purposes

- IF you get all your facts straight (data assumptions)
- Calculations are usually presented incorrectly in ways that undermine clear understanding of the data

Data Correction #1

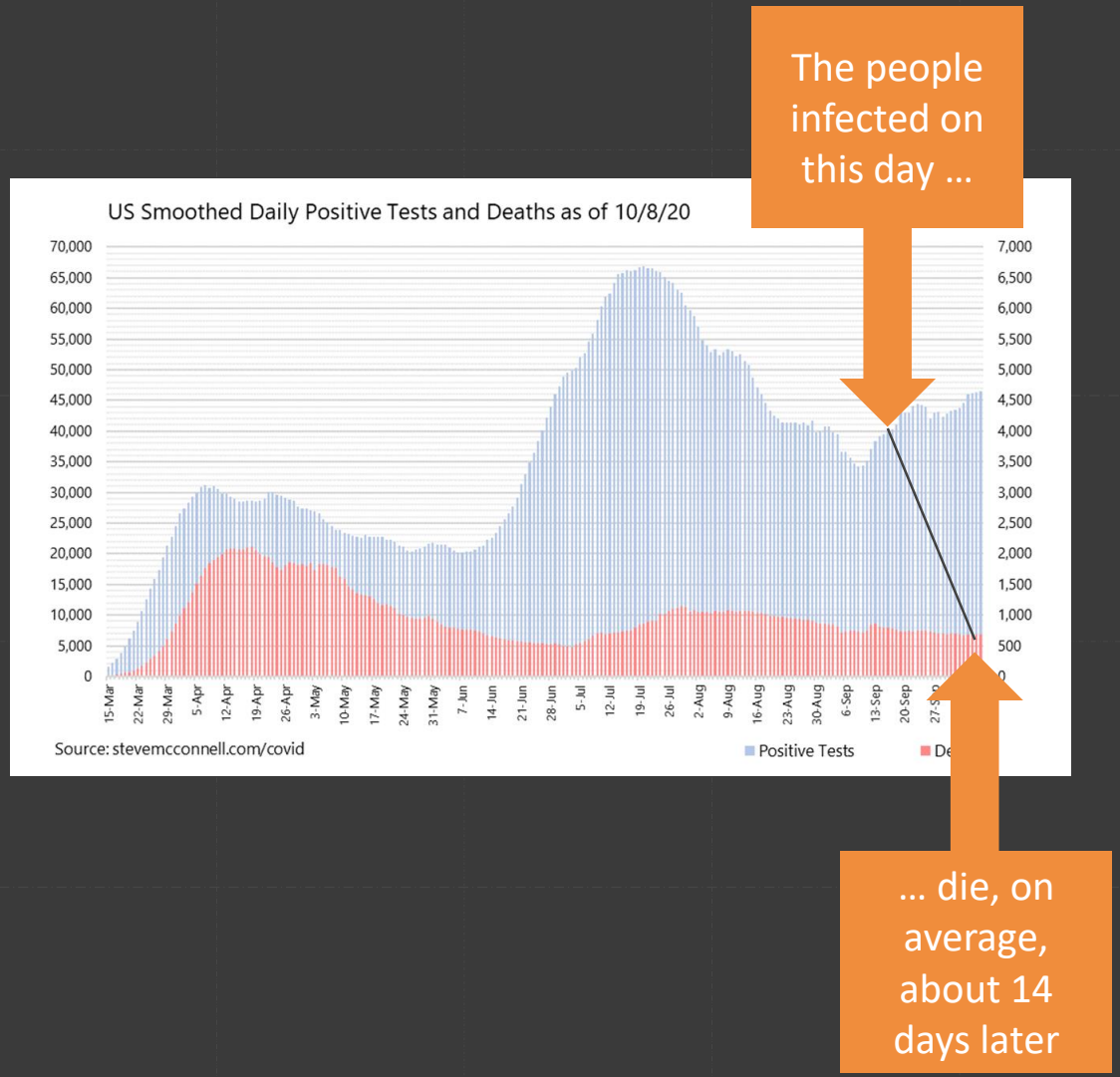
Lining up time periods correctly for Naïve CFR

Correcting “Junk CFR” (line up time periods correctly)



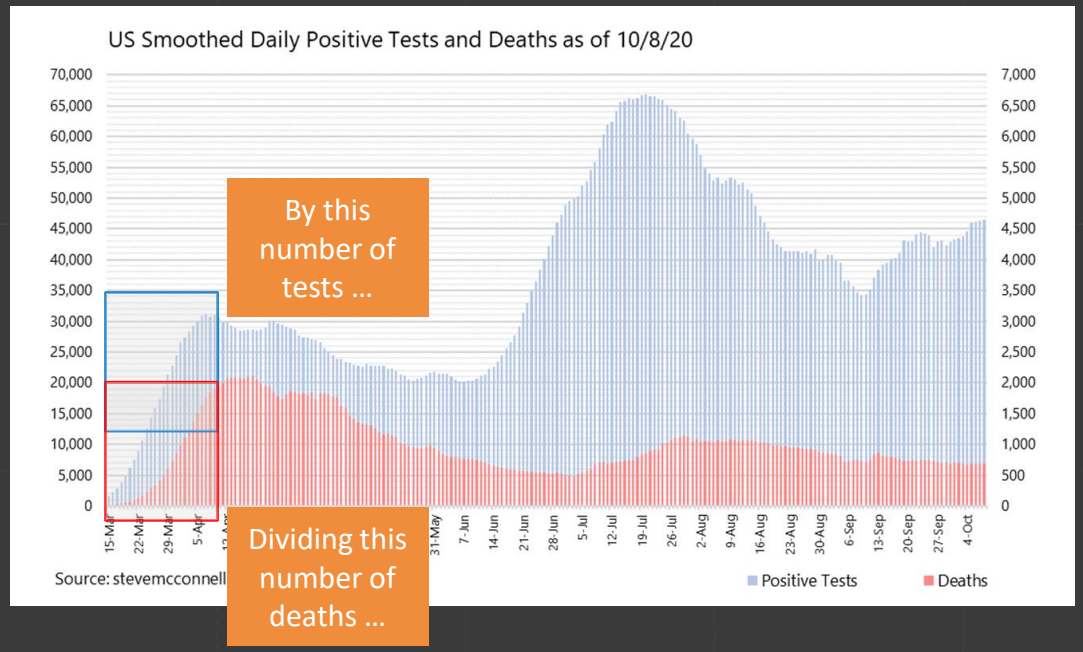
- People do not get infected, test positive, and die on the same day
- But commonly reported CFRs effectively assume that’s the way it happens

Correcting “Junk CFR” (line up time periods correctly)



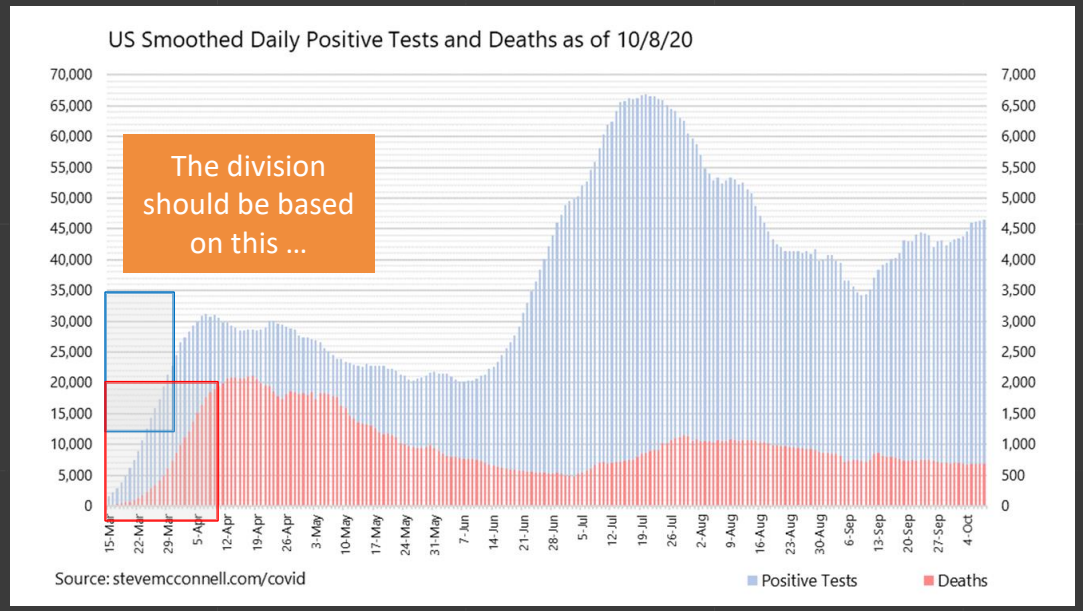
- People do not get infected, test positive, and die on the same day
- But commonly reported CFRs effectively assume that’s the way it happens

Correcting “Junk CFR” (line up time periods correctly)



- This mistake gives rise to dramatically inaccurate calculations of fatality rates, especially in the early days of the pandemic

Correcting “Junk CFR” (line up time periods correctly)



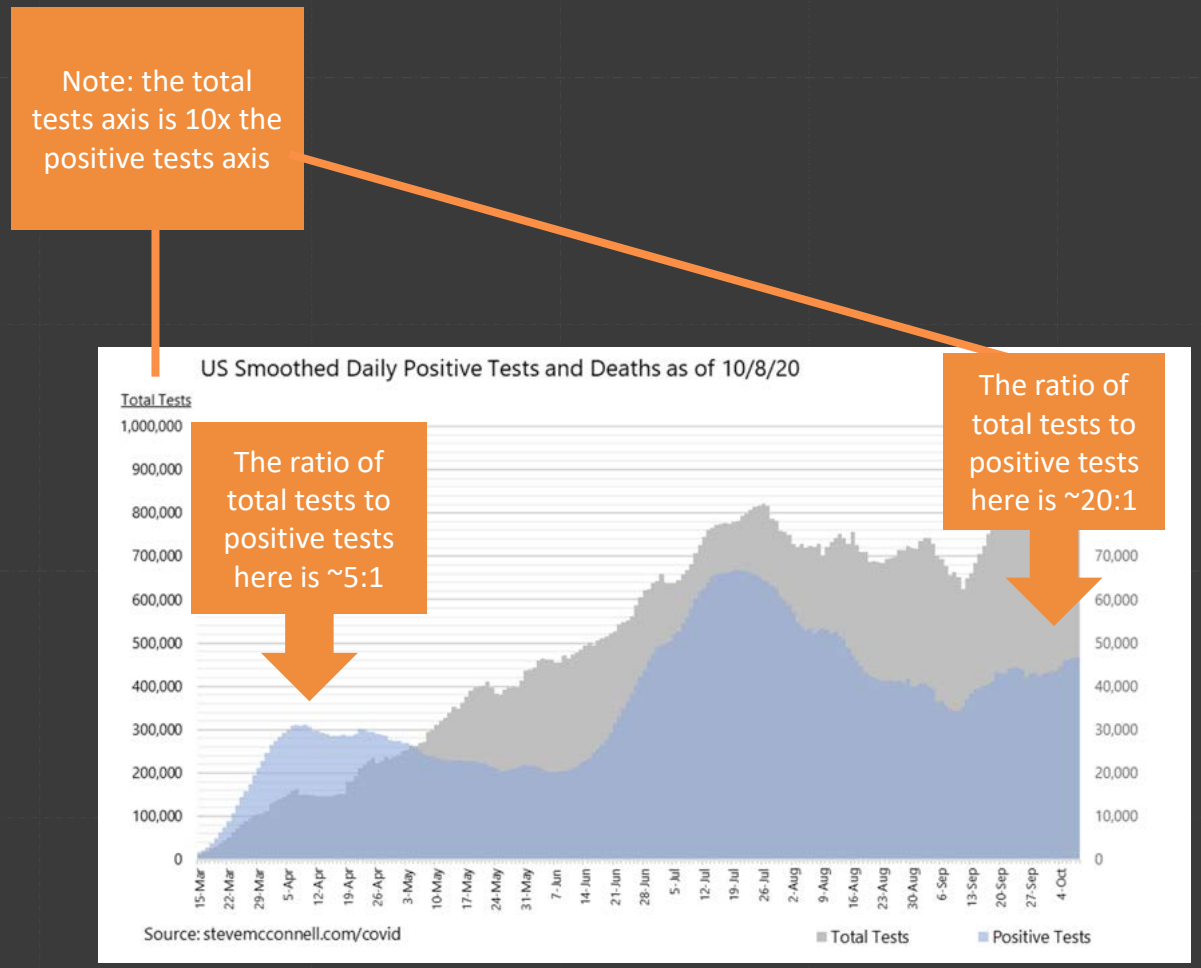
- This mistake gives rise to dramatically inaccurate calculations of fatality rates, especially in the early days of the pandemic
- This correction results in a **higher** CFR than was reported by the media at the time (but that doesn’t imply the IFR was higher)

Data Correction #2

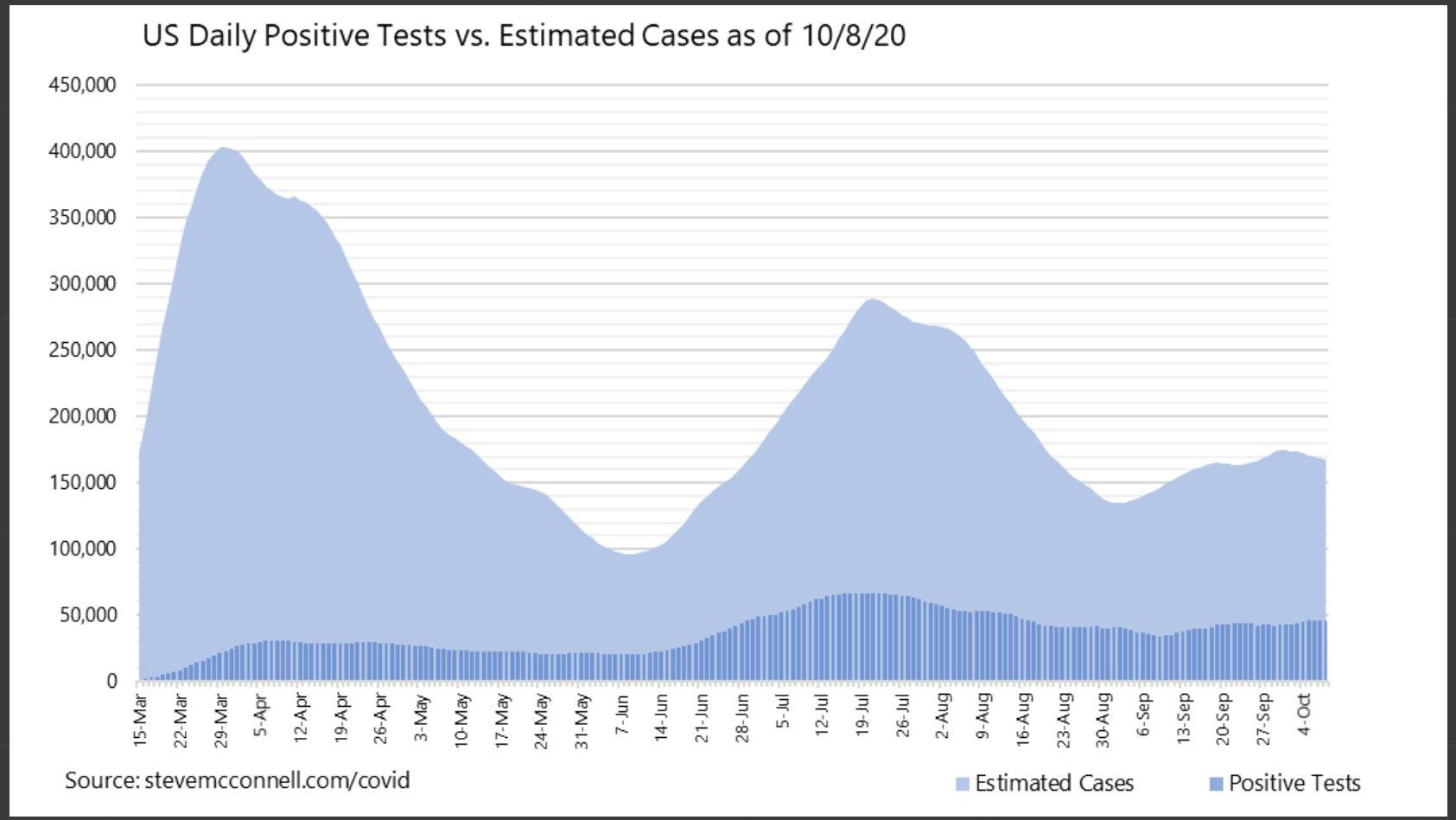
Tests <> Cases

Relationship between positive tests and cases has changed

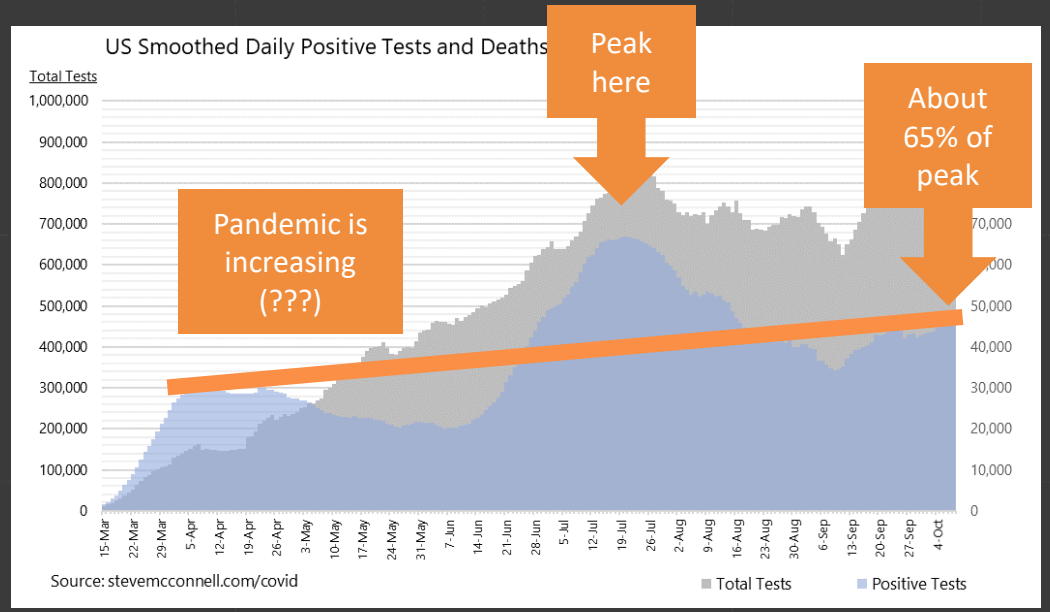
- The level of testing has steadily increased over the course of the pandemic
- Early in the pandemic, there were **10-20** cases per positive test
- More recently, there are **3-5** cases per positive test

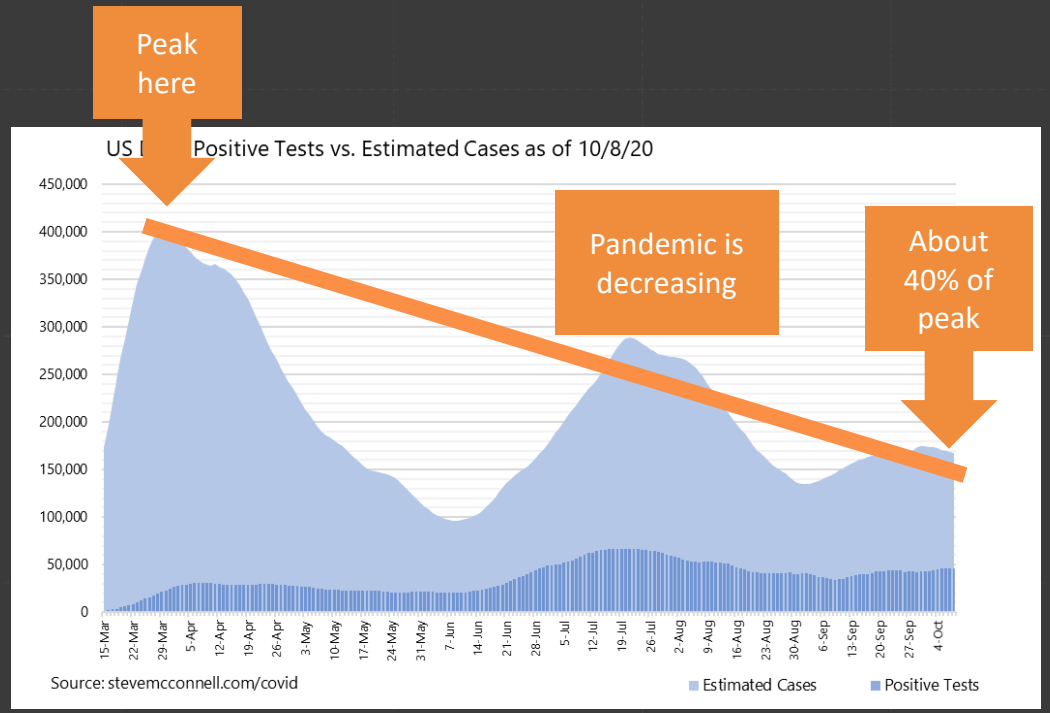


Positive Tests vs. Estimated Cases Over Time

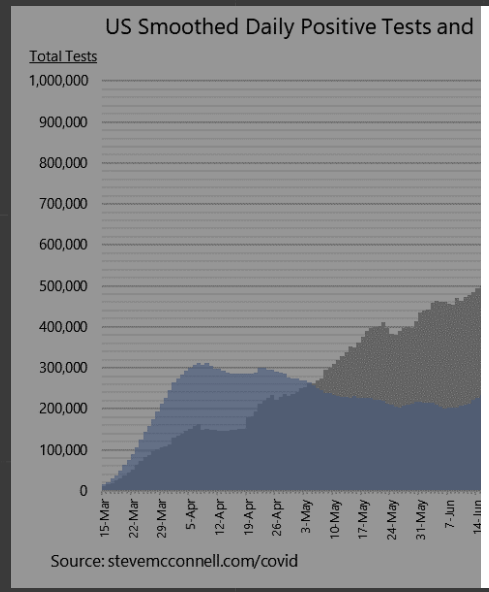


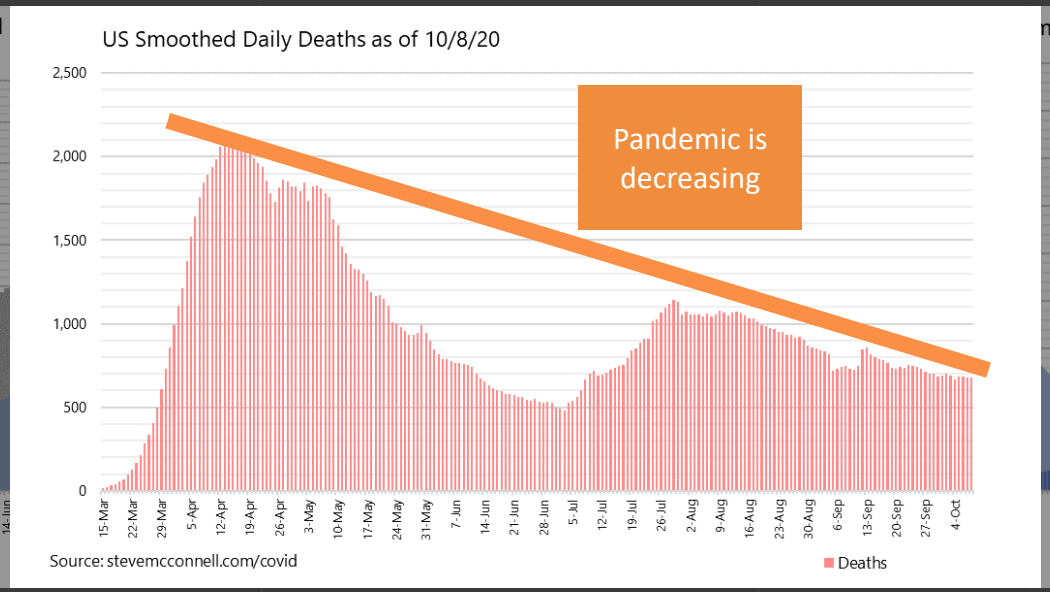
More on Positive Tests vs. Cases

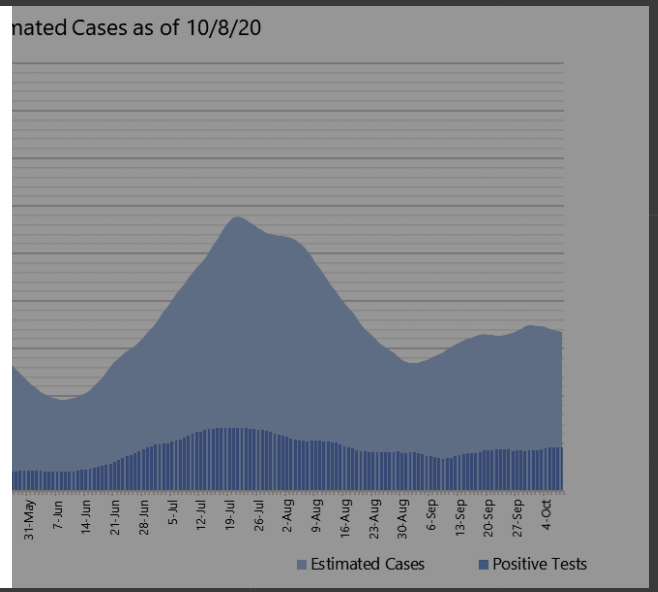




The Estimated Cases Trend Aligns with Death Trend (The Positive Tests Trend Does not)







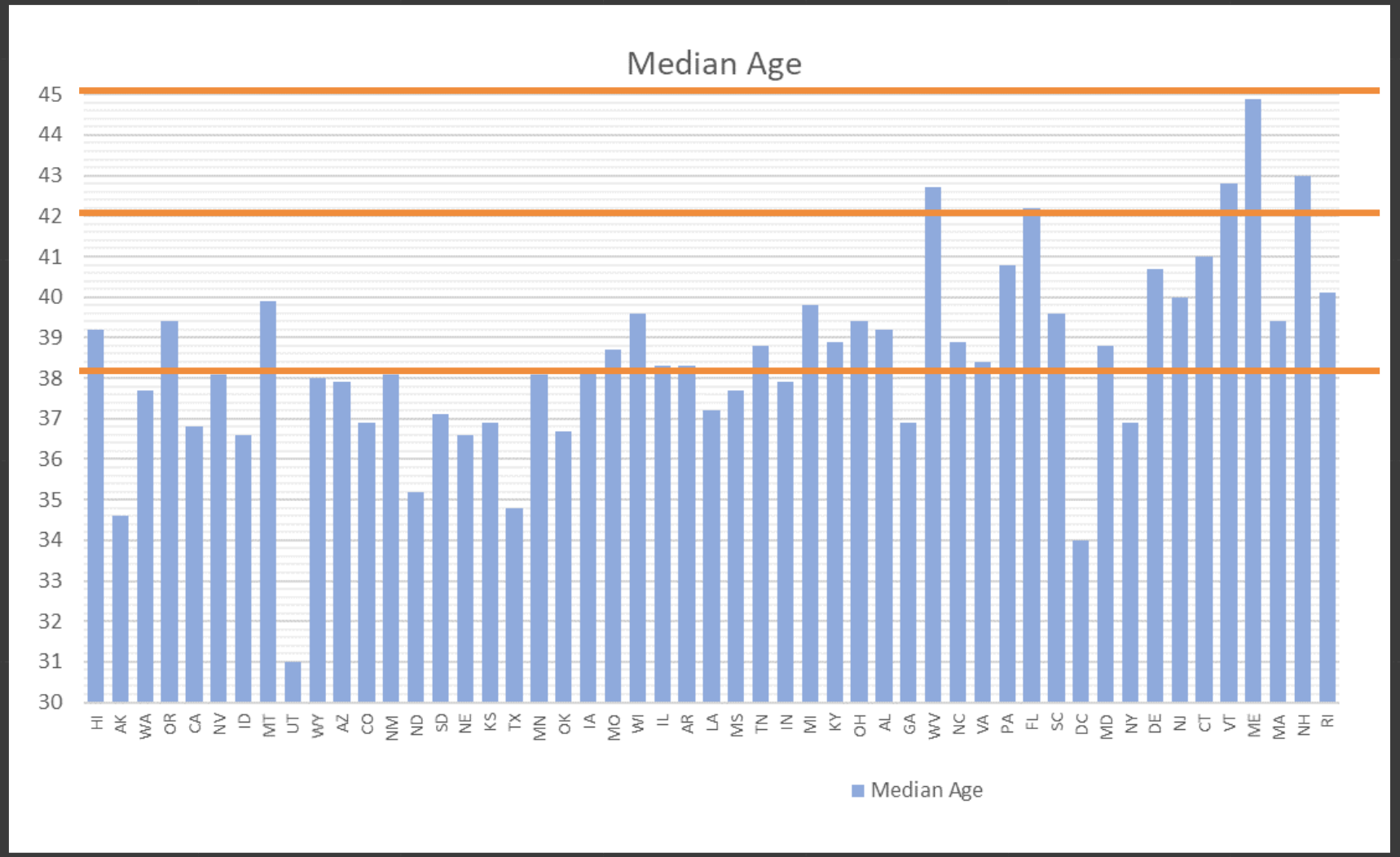
Calculating Meaningful CFR

- Get our time periods for tests and deaths lined up correctly
- Get clear about the idea that tests <> infections
- Calculate a correct number for infections

Data Correction #3

Account for Age

Remaining CFR Issue: CFR is Age-Based



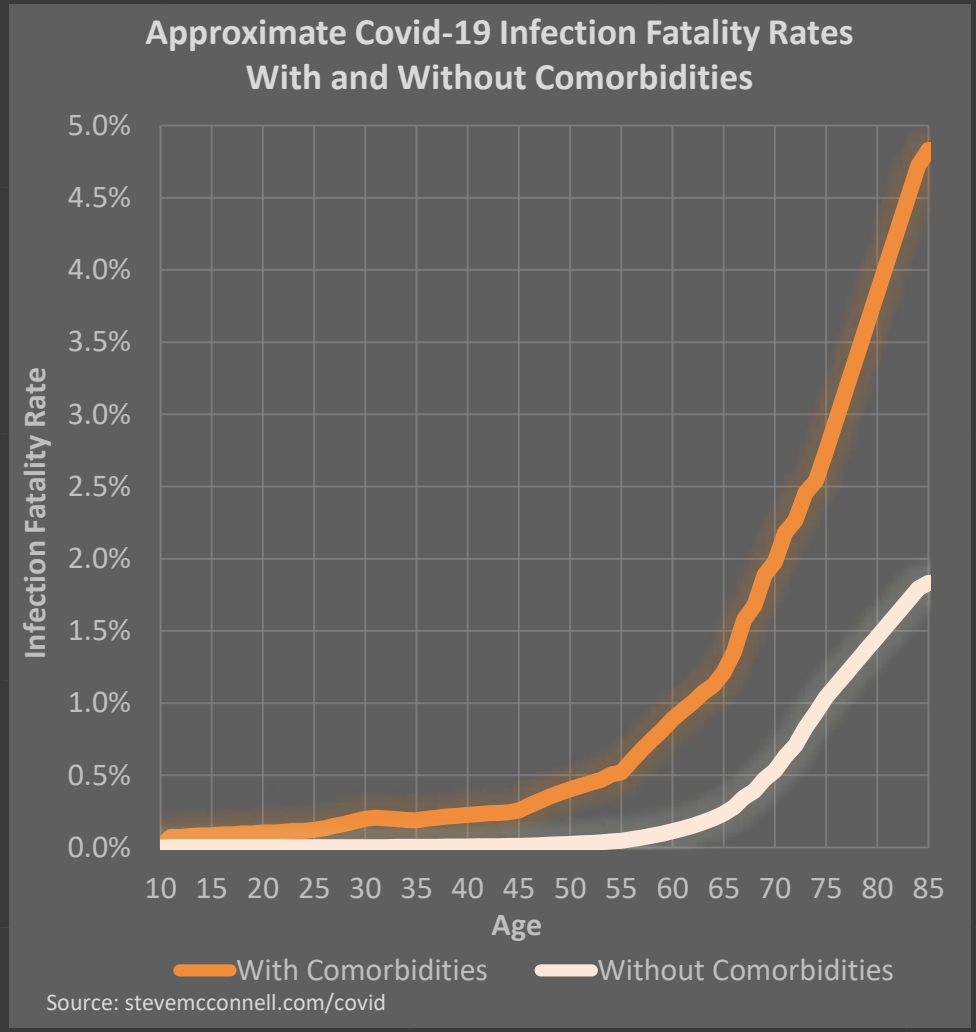
Italy's average is 45.1

Spain's average is 42.3

Average age in the US is 38.2

IFRs and Co-Morbidity

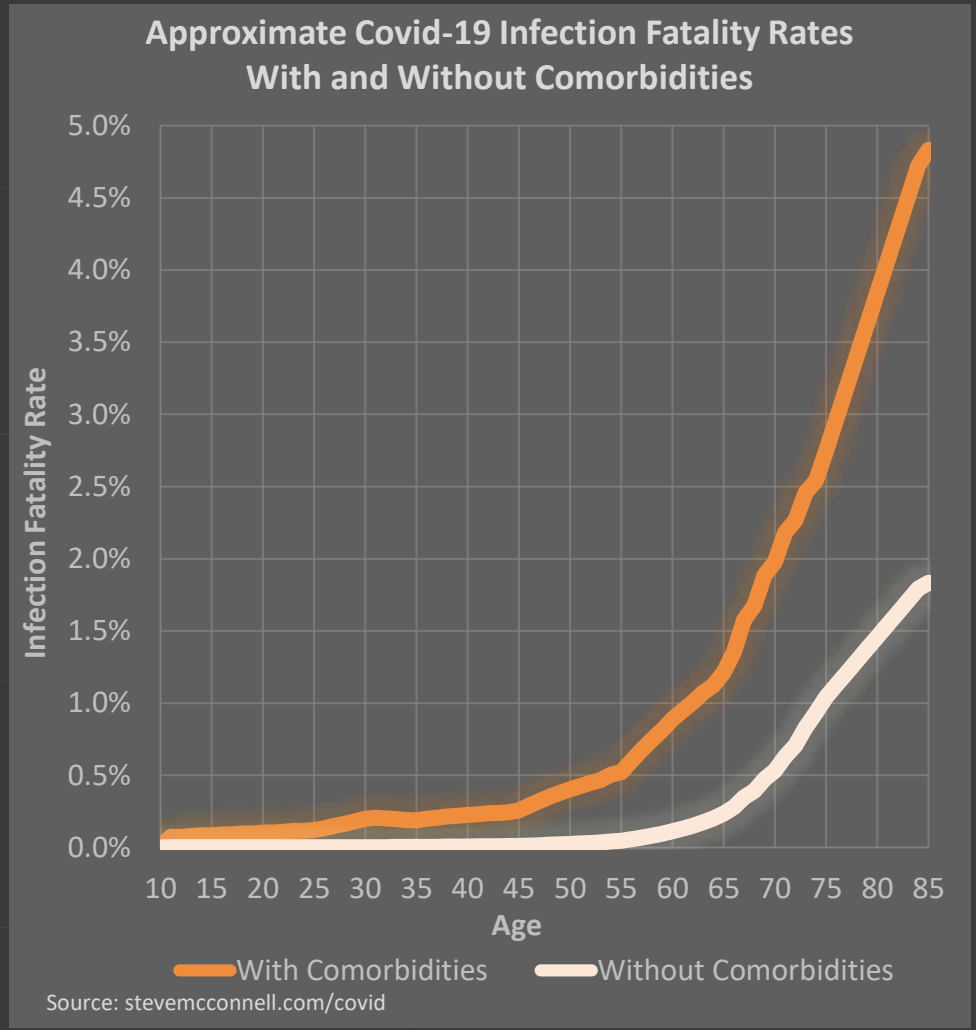
- 90% of deaths have involved at least 1 co-morbidity
- Risk of death with a co-morbidity is HIGHER than published; risk without is LOWER
- At younger ages this makes a HUGE difference in risk



Most serious comorbidities, according to CDC

- Serious heart conditions, such as heart failure, coronary artery disease, or cardiomyopathies
- Cancer
- Chronic kidney disease
- COPD
- Obesity (BMI> 30)
- Sickle cell disease
- Solid organ transplantation
- Type 2 diabetes mellitus

CDC list of risk levels of specific comorbidities and level of evidence for each: https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/evidence-table.html



Summary of “Tools” we can use for Forecasting

- Corrections to raw data reporting (weekly cycle issues)
- Corrections to timeline (lag from positive tests to deaths)
- Understanding of what is needed to estimate infections (not tests)
- Potential to adjust for the key factor of age

CDC

Covid-19 Forecasting

CDC Forecasting Website

CDC Covid-19 Forecast Process

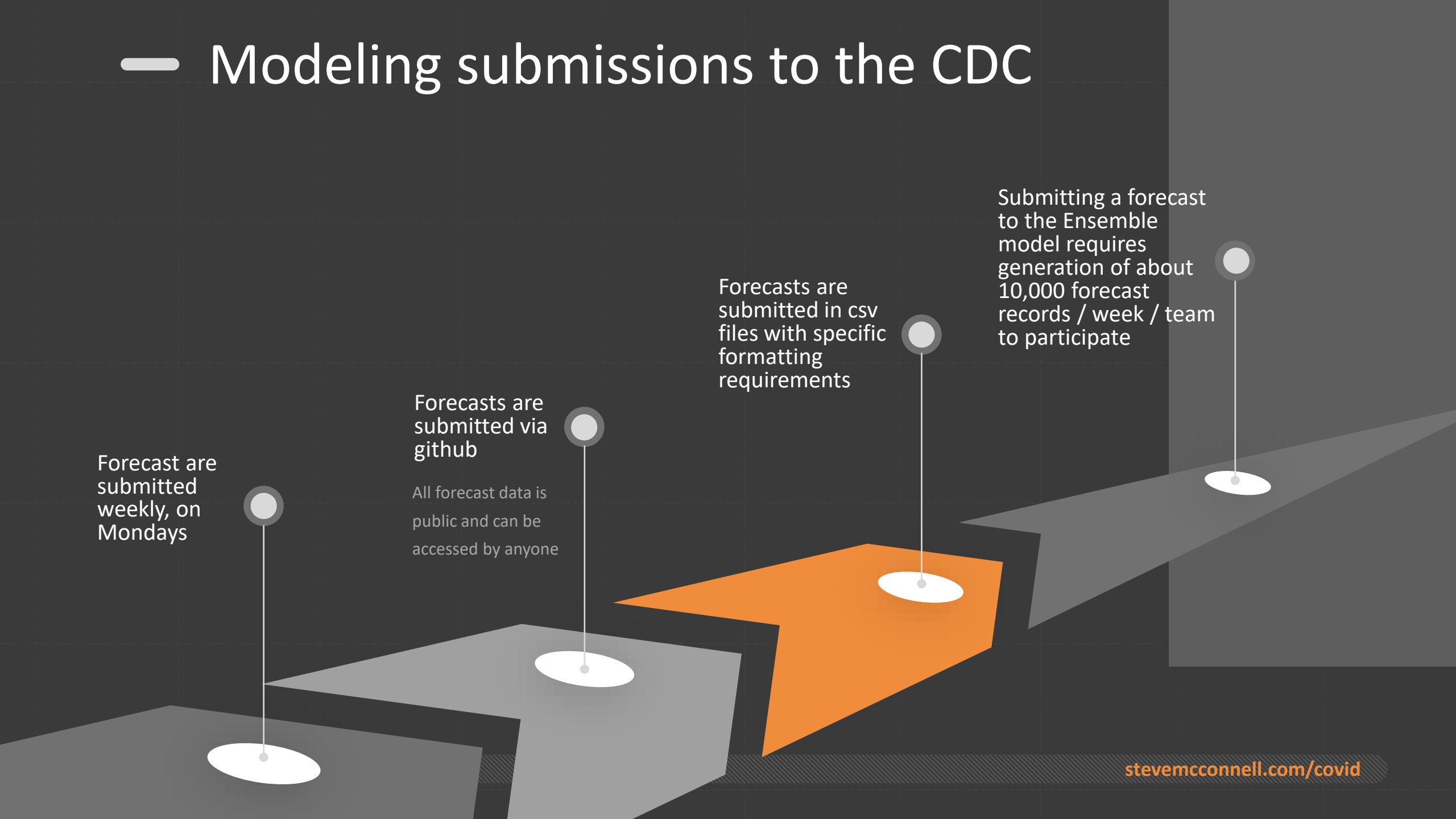
CDC work is overseen by a team at University of Massachusetts Amherst

Modeling groups submit forecasts to the CDC

Specific organization is Reich Lab based in the Department of Biostatistics and Epidemiology

Forecasts that meet certain criteria are combined into the “Ensemble” model, which is the forecast model of record for the CDC

Modeling submissions to the CDC



CDC Covid-19 Forecasts

Types

"Point" forecast

"Prediction interval" (commonly known as 95% confidence ranges)

Quantities

"Cases" (positive tests)

Deaths

Regions

51+ states and territories

US National

Time Period

Week 1

Week 2

Week 3

Week 4

Forecast Teams

Universities

Carnegie Mellon
Columbia
Columbia/UNC
Georgia Tech
Harvard
Iowa State
Johns Hopkins
London School of Hygiene and Tropical Medicine
MIT
Northeastern
Notre Dame

Universities

RPI
Texas Tech
UCLA
USC
UW/IHME
University of AZ
U Cal Merced
UCSD
University of Geneva
University of Georgia
U Mass Amherst
U Michigan
U Texas Austin

Research Labs

Los Alamos National Lab
US Army Research and Development Center
Walmart Labs Data Science Team
Covid19 Simulator Consortium (MassGen, Harvard, Georgia Tech, Boston Medical Center)

Individuals and Firms

Discrete Dynamical Systems
Institute for Business Forecasting
IQVIA
John Burant
Karlen Working Group
LockNQuay
Oliver Wyman
Predictive Science Inc
Qi-Jun Hong
Robert Walraven
Steve McConnell
Youyang Gu

Forecast Teams and Coordination

- The better forecast teams and the worst are not what you'd expect them to be, considering some of the institutions involved
- There's a weekly forecast call Tuesdays at noon Pacific time to review the week's forecasts
- The university teams can be quite academic ("once you know how the sausage is made, you'll never eat sausage again")
- Some well-known, highly respected institutions are submitting **terrible** forecasts

Groups use Various Methods

- Massive data sets, e.g., 500 million records
- Esoteric data, e.g., use of mobility data from cell phone records
- Machine learning
- AI
- Bayesian analysis, Monte Carlo simulations, etc.
- Pre-existing infectious diseases models

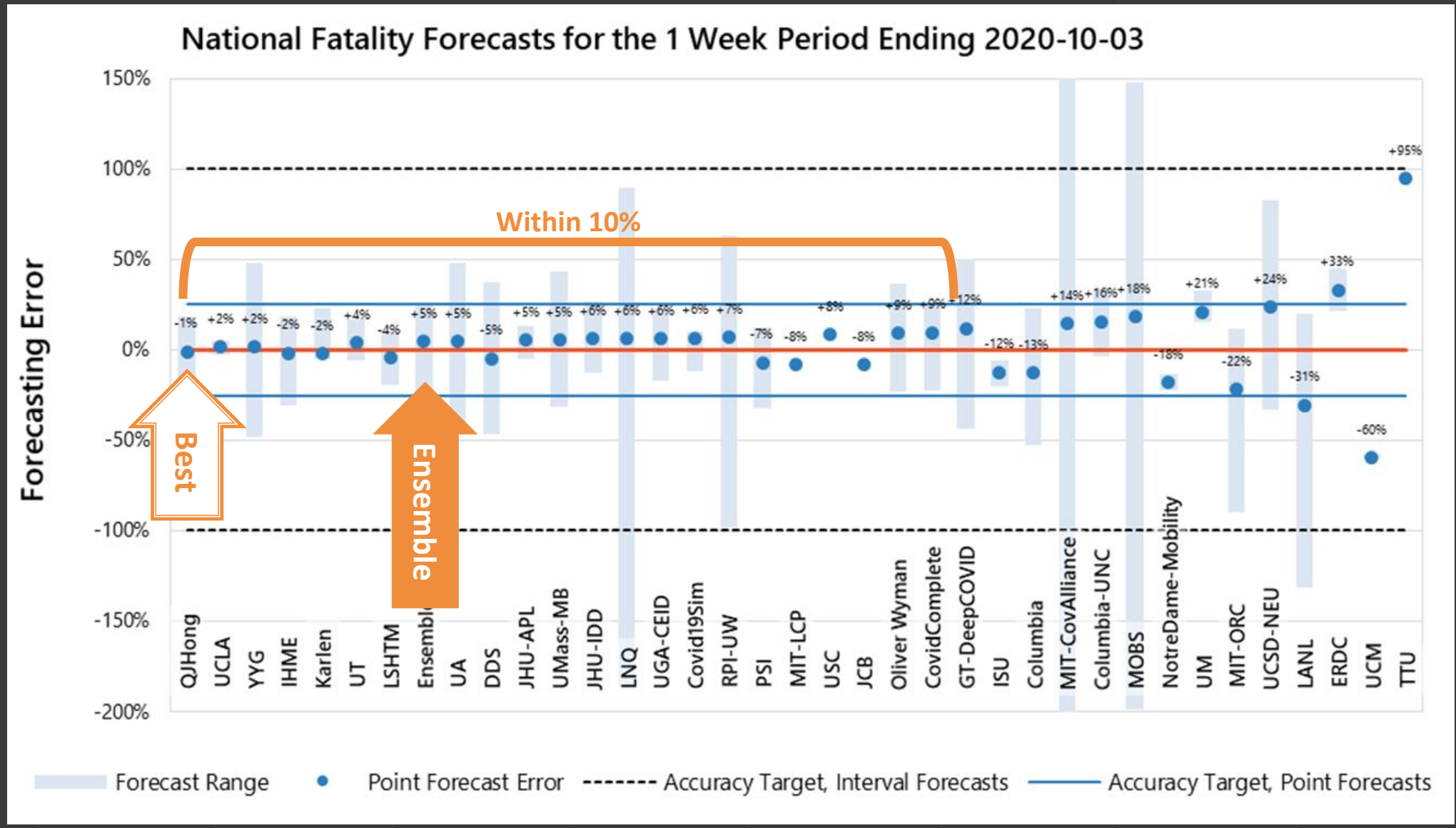
Model descriptions are available from the CDC website (many just link to github)

One of the most enduring and useful conclusions from research on forecasting is that simple methods are generally as accurate as complex methods.

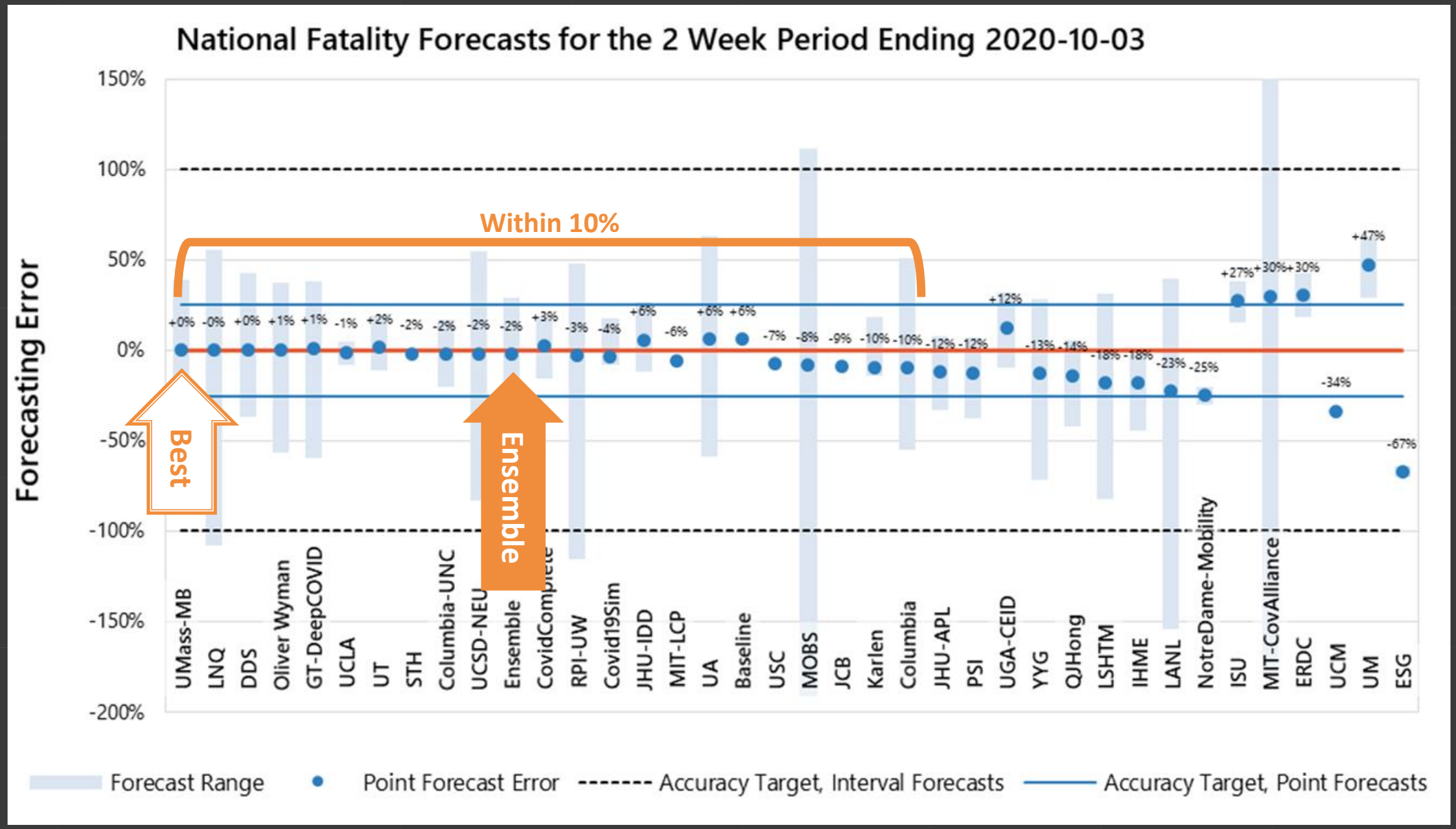
— *J. Scott Armstrong,*
Principles of Forecasting

What’s Possible with Forecasting Nationally?

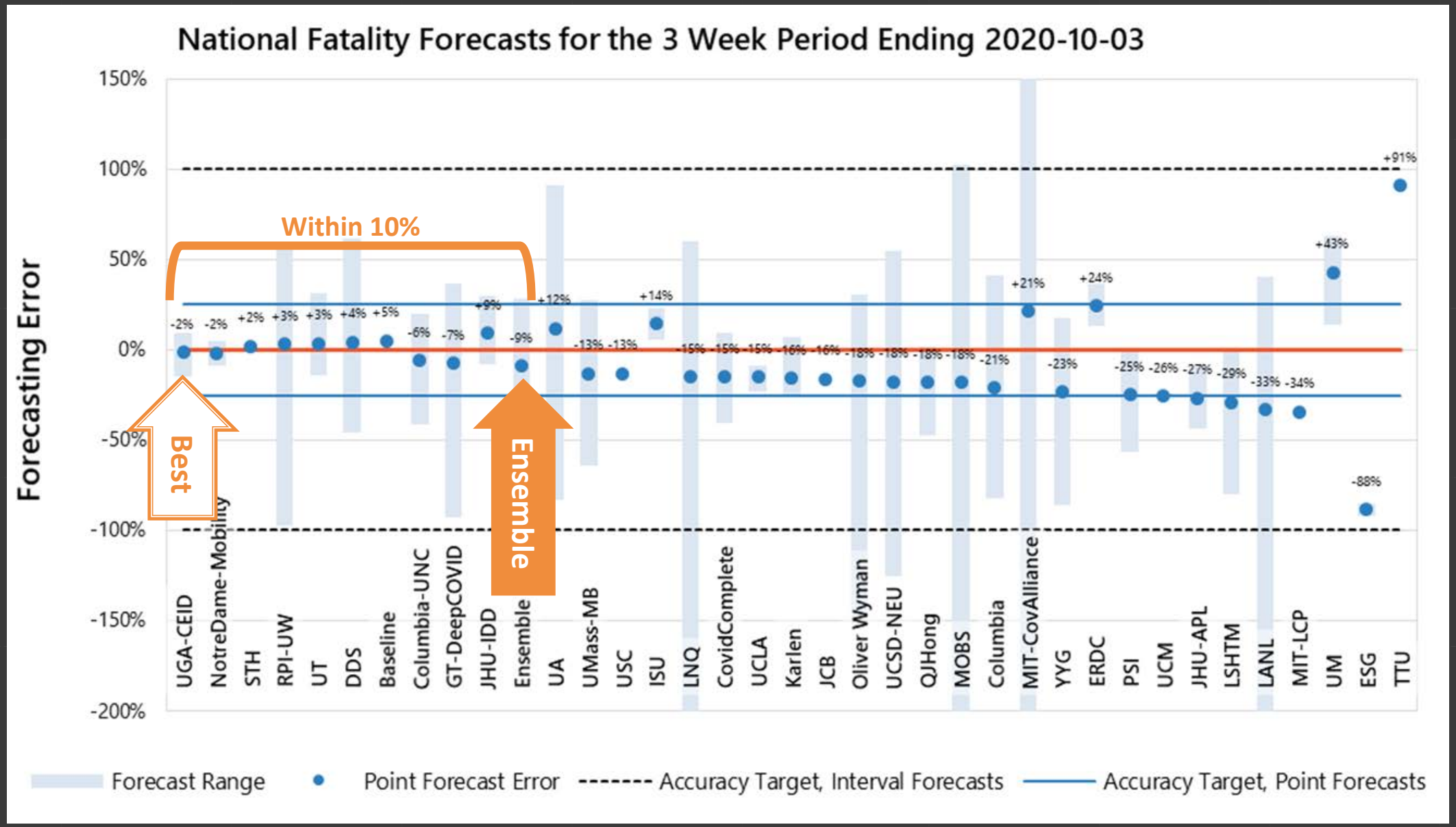
Recent National Forecasts



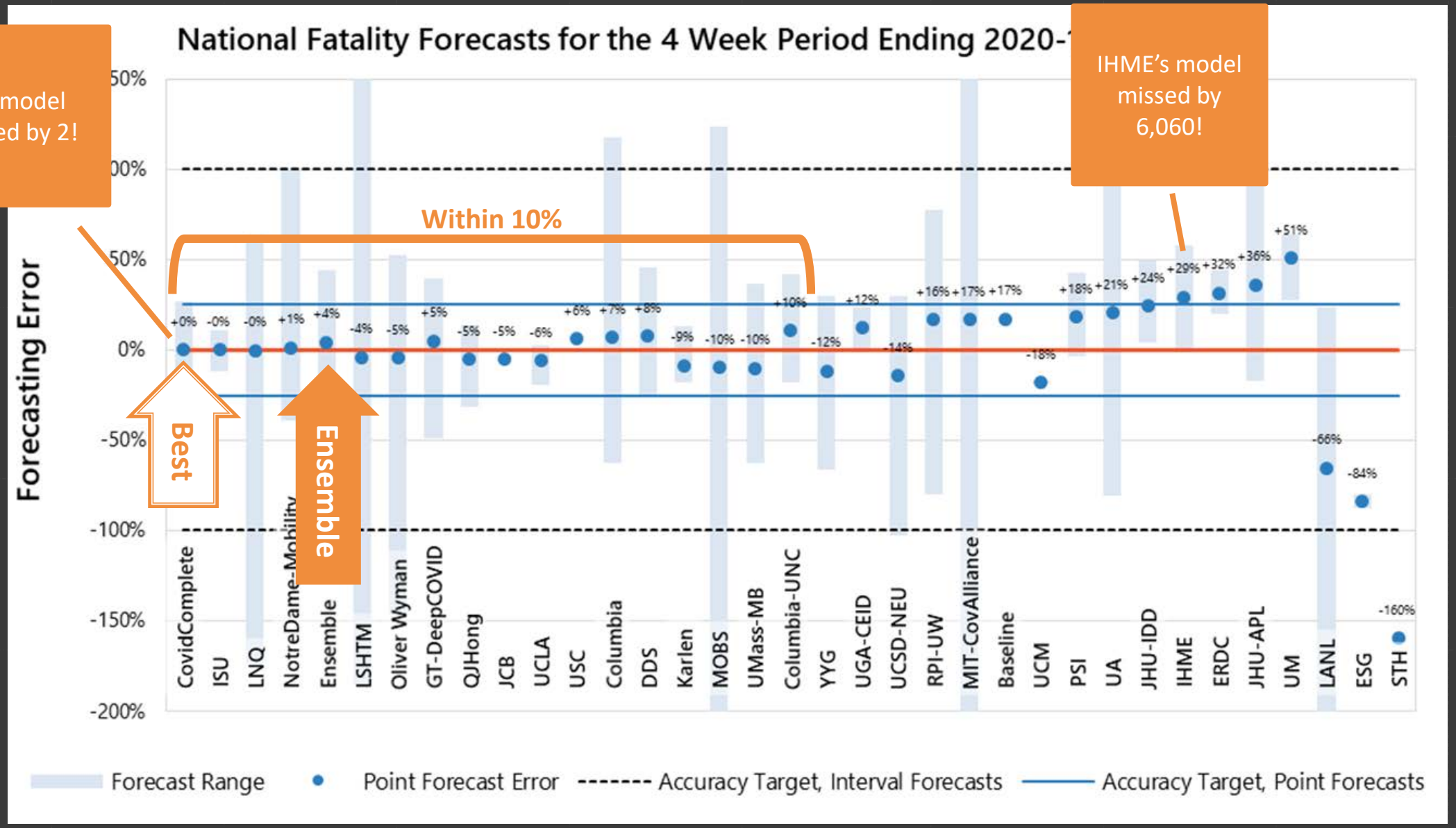
Recent National Forecasts



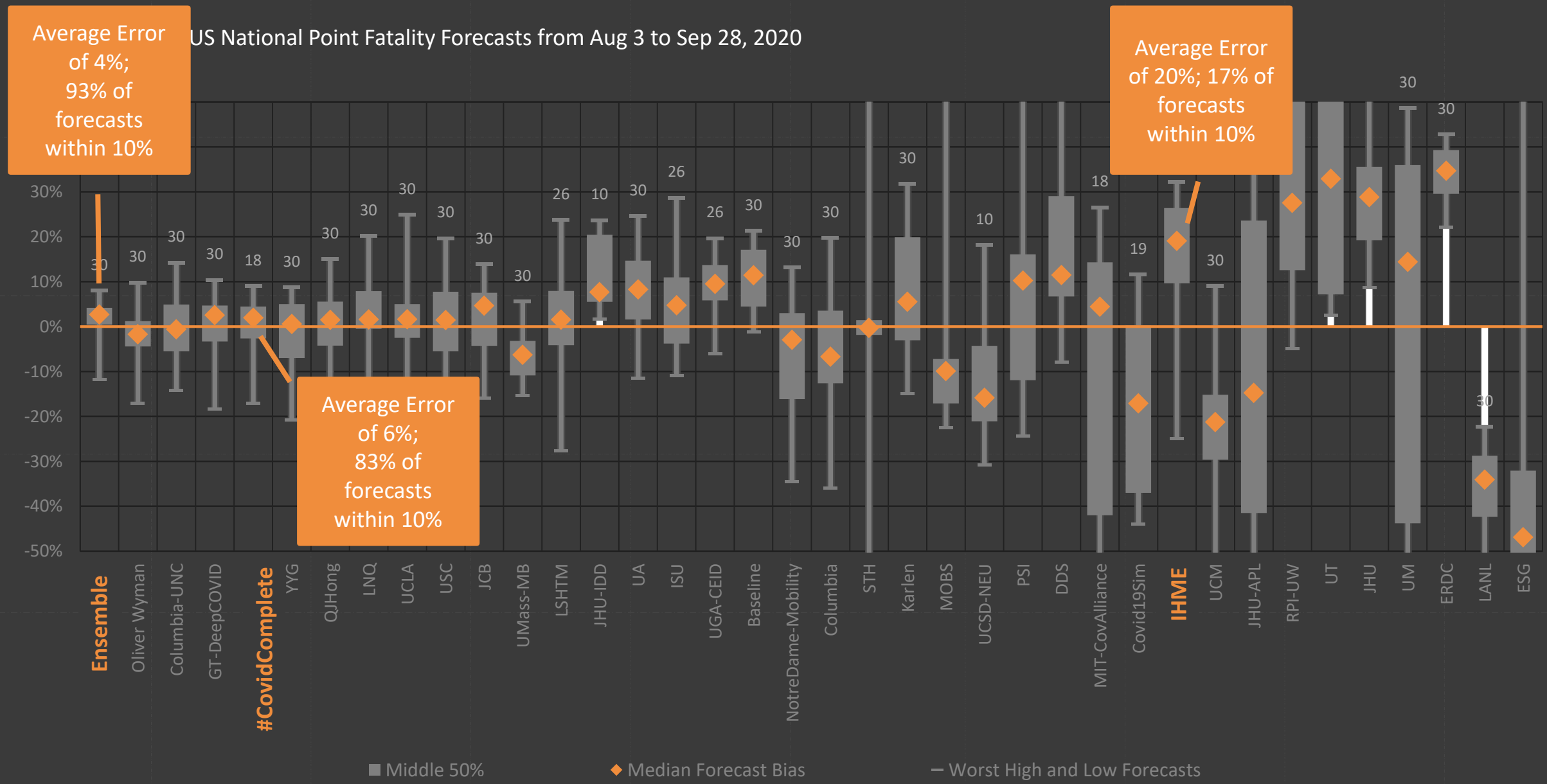
Recent National Forecasts



Recent National Forecasts



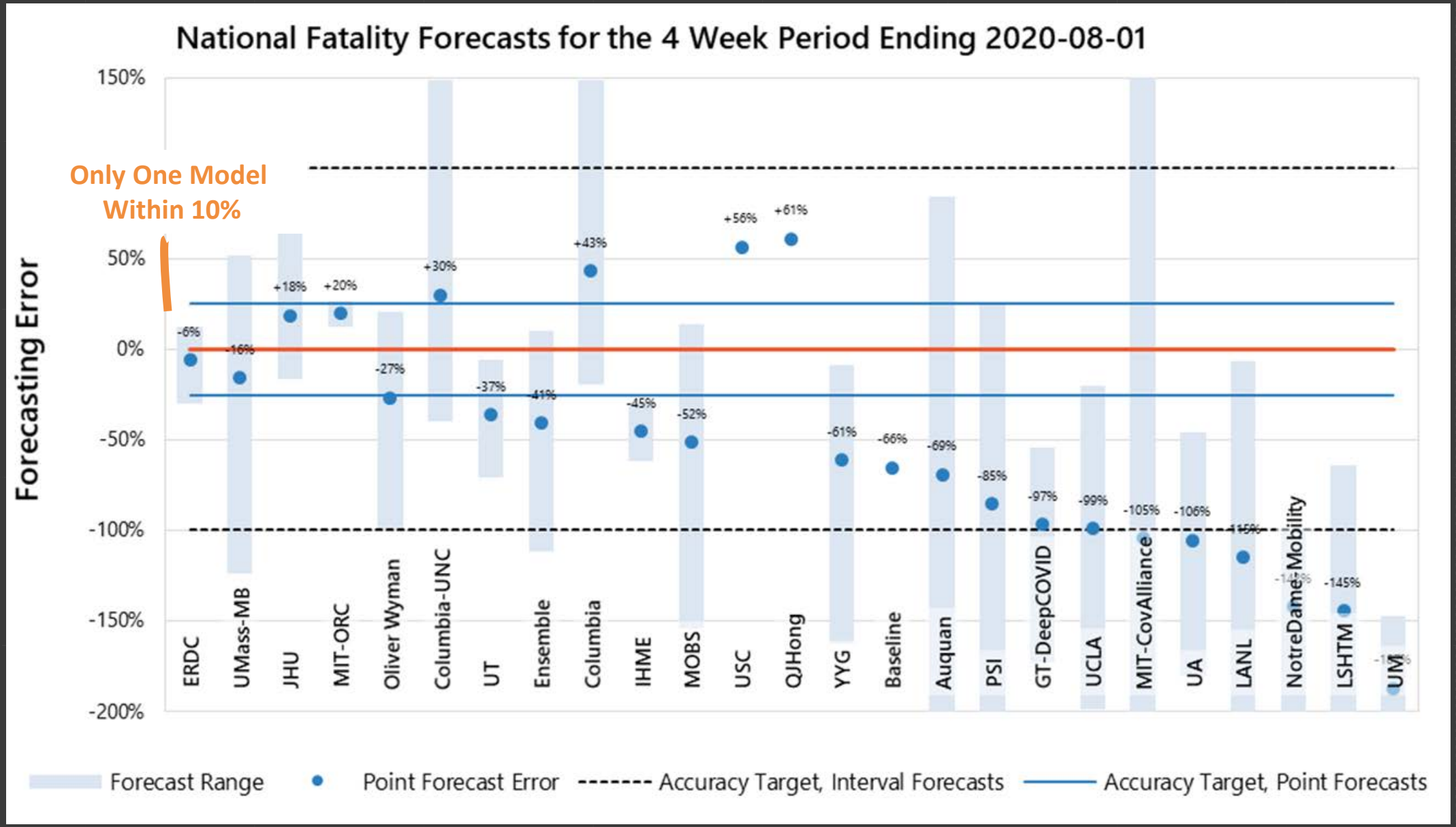
Accuracy over time for 1, 2, 3, and 4-week forecasts



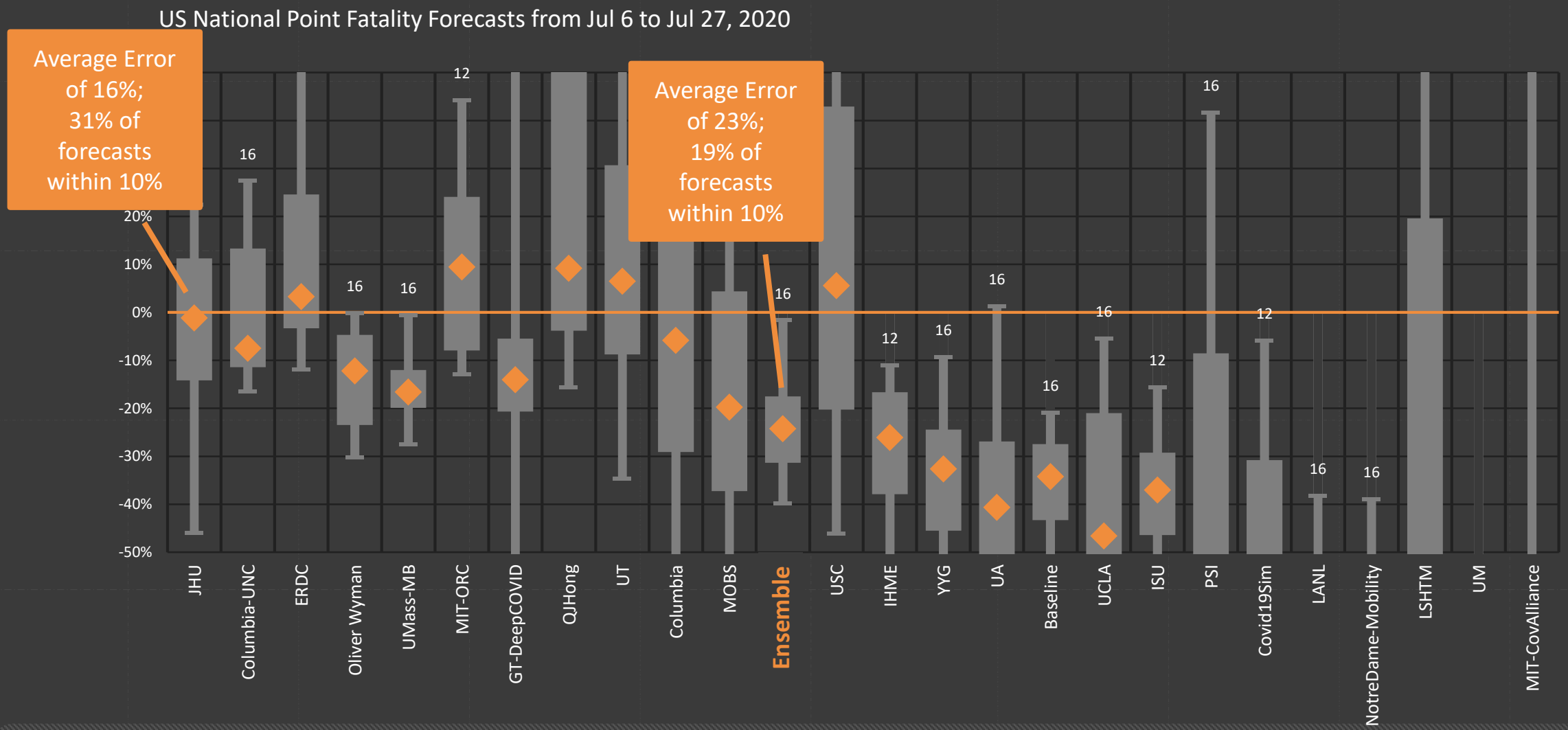
Covid-19

National Forecasts Have Improved Markedly Since July

Earlier National Forecasts



Longer-term history of earlier national forecasts



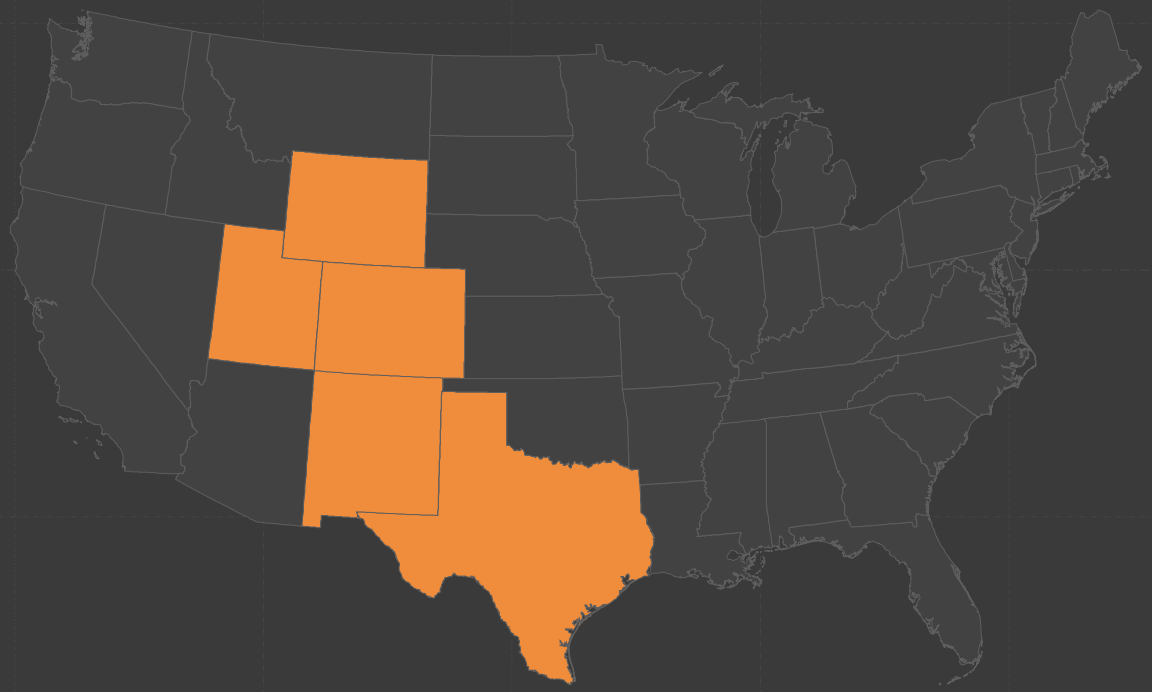
#CovidComplete by Steve McConnell ■ Middle 50% ◆ Median Forecast Bias – Worst High and Low Forecasts stevemcconnell.com/covid

www.stevemcconnell.com

More National Forecast Evaluations

www.stevemcconnell.com/covid

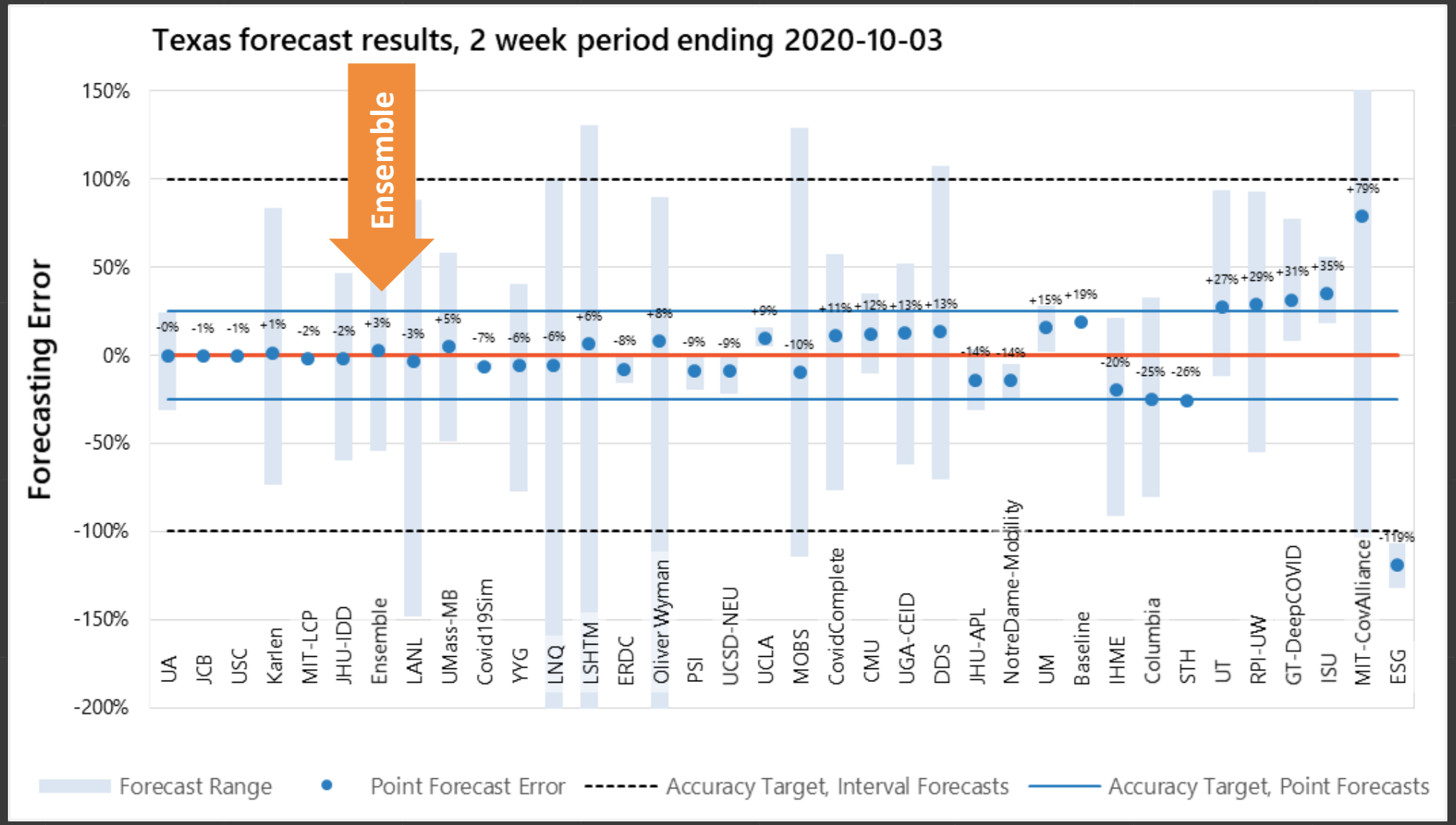
What’s Possible with Forecasting at the State Level?



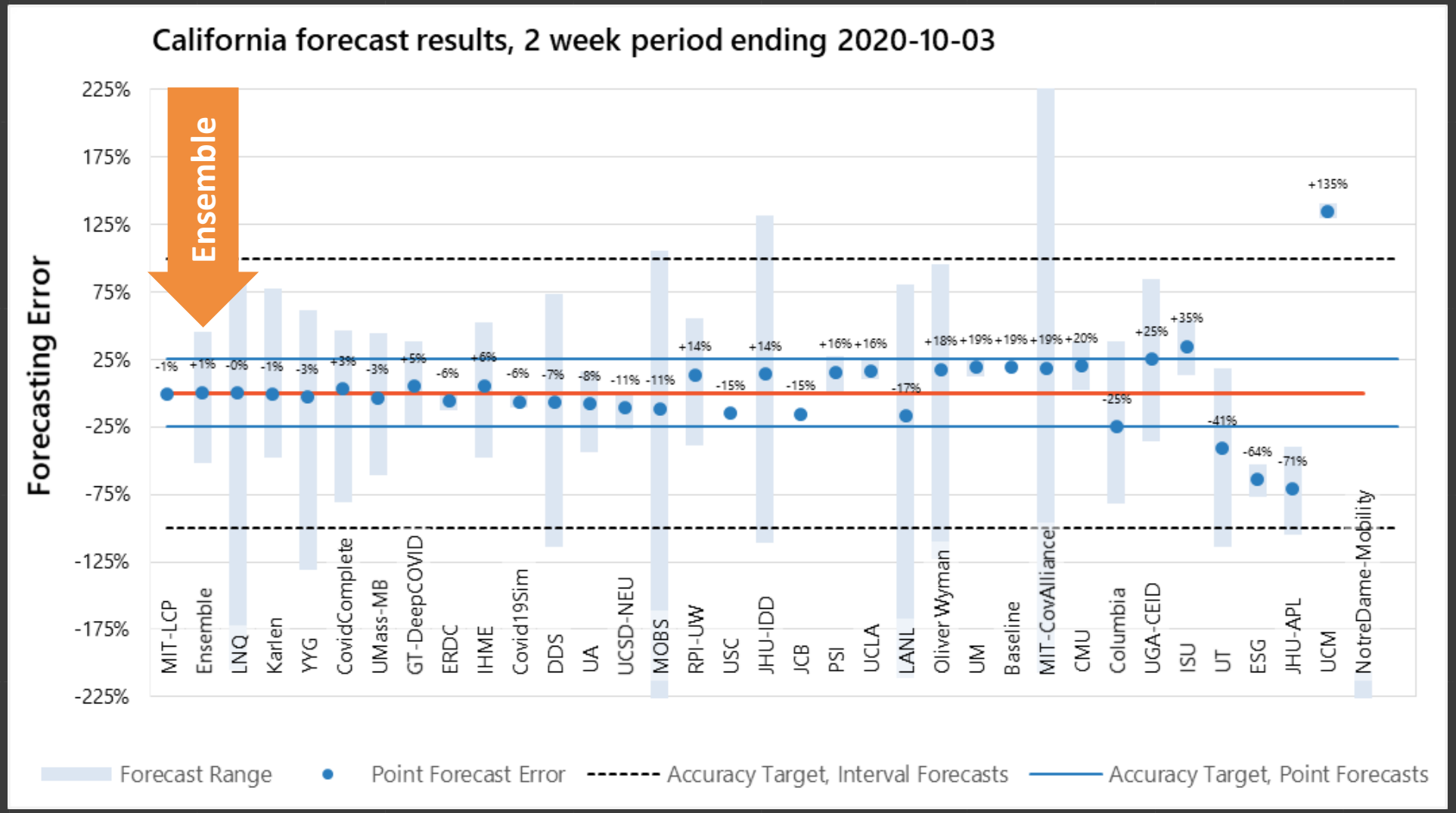
State Level Forecasts

- Numbers of total tests, positive tests, cases, and deaths are smaller
- Data is rougher
- Models tend to do better on states with bigger numbers
- Accurate forecasting is arguably more important than national forecasts

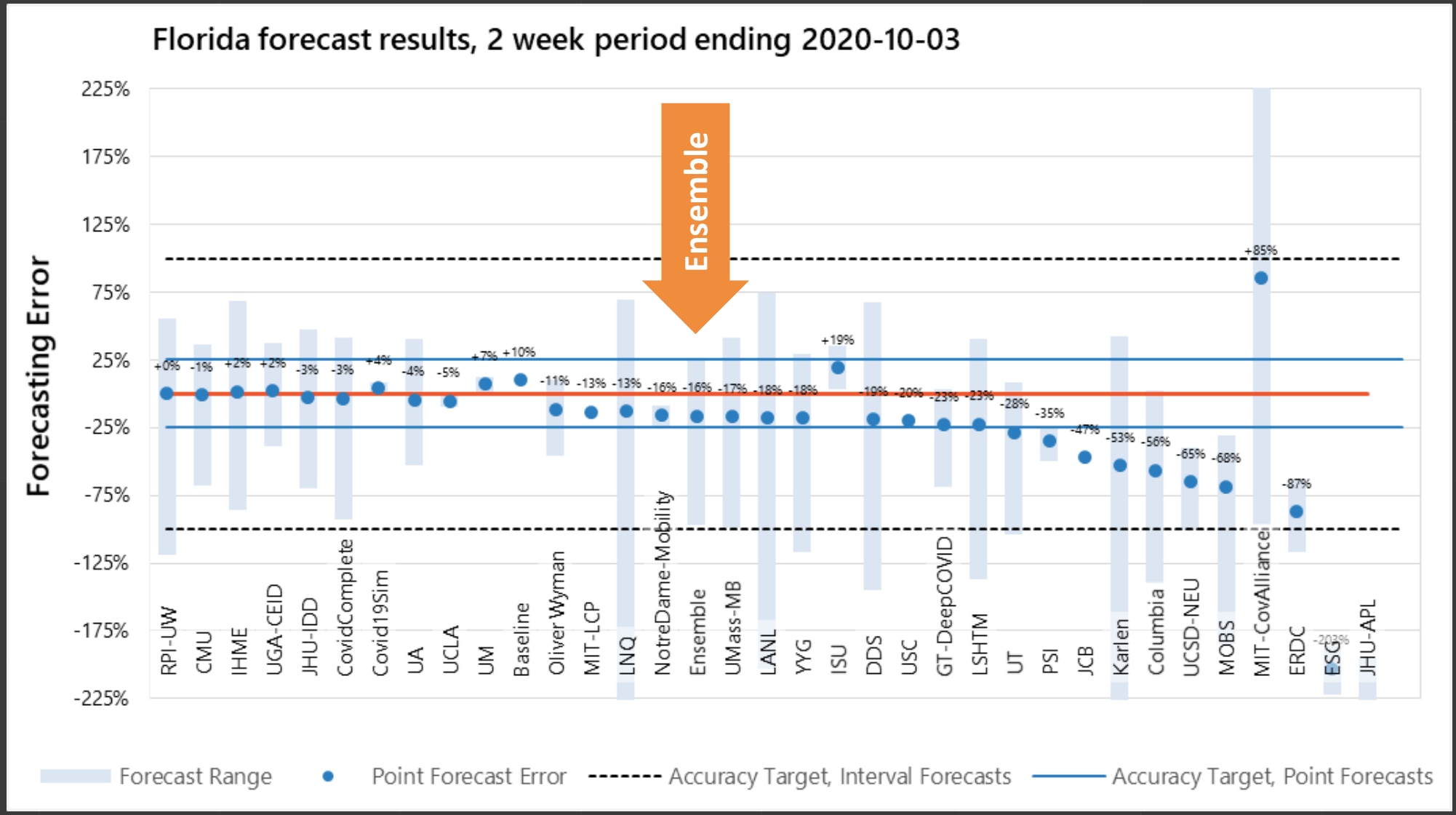
State Forecast Examples



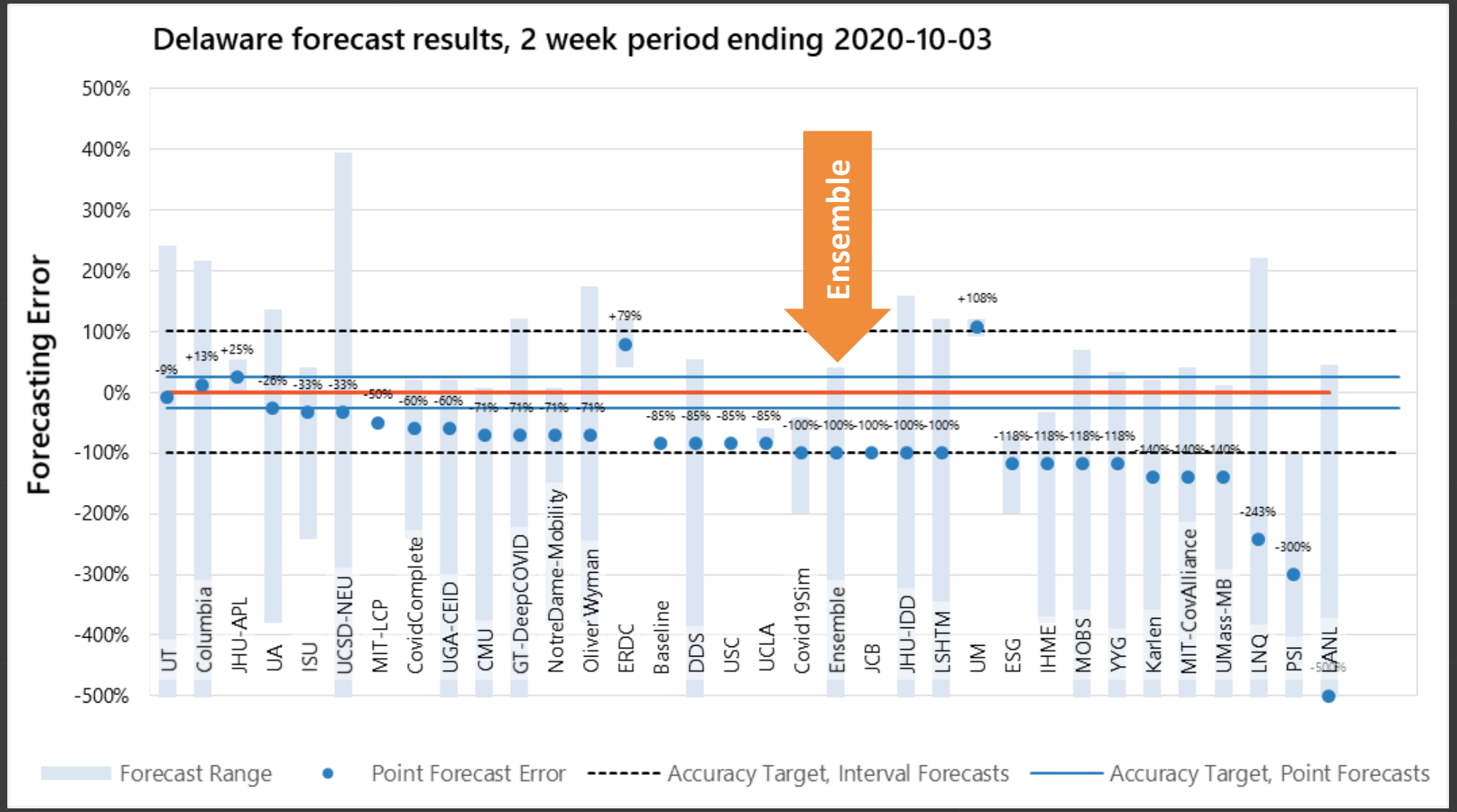
State Forecast Examples



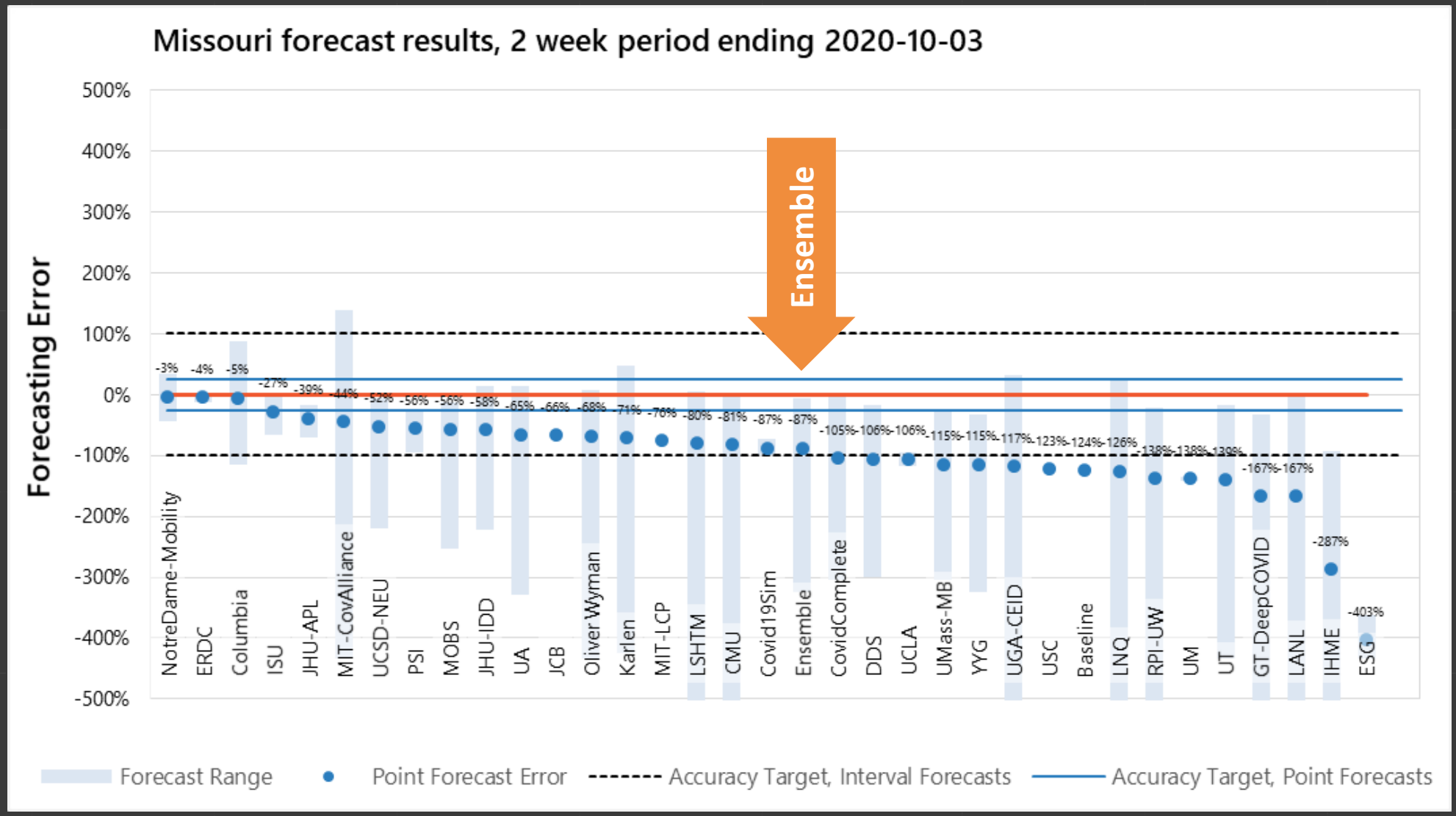
State Forecast Examples



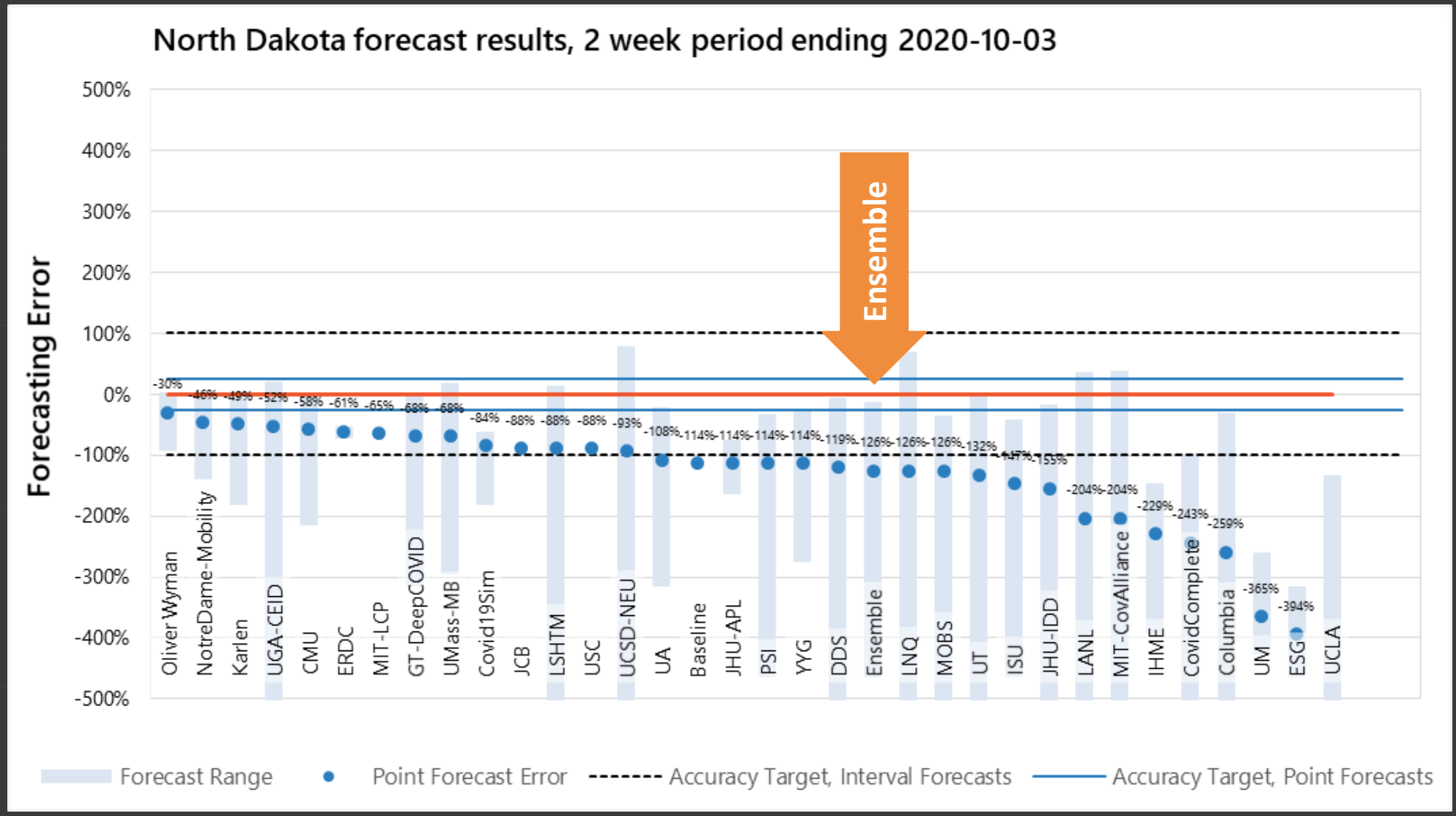
State Forecast Examples



State Forecast Examples

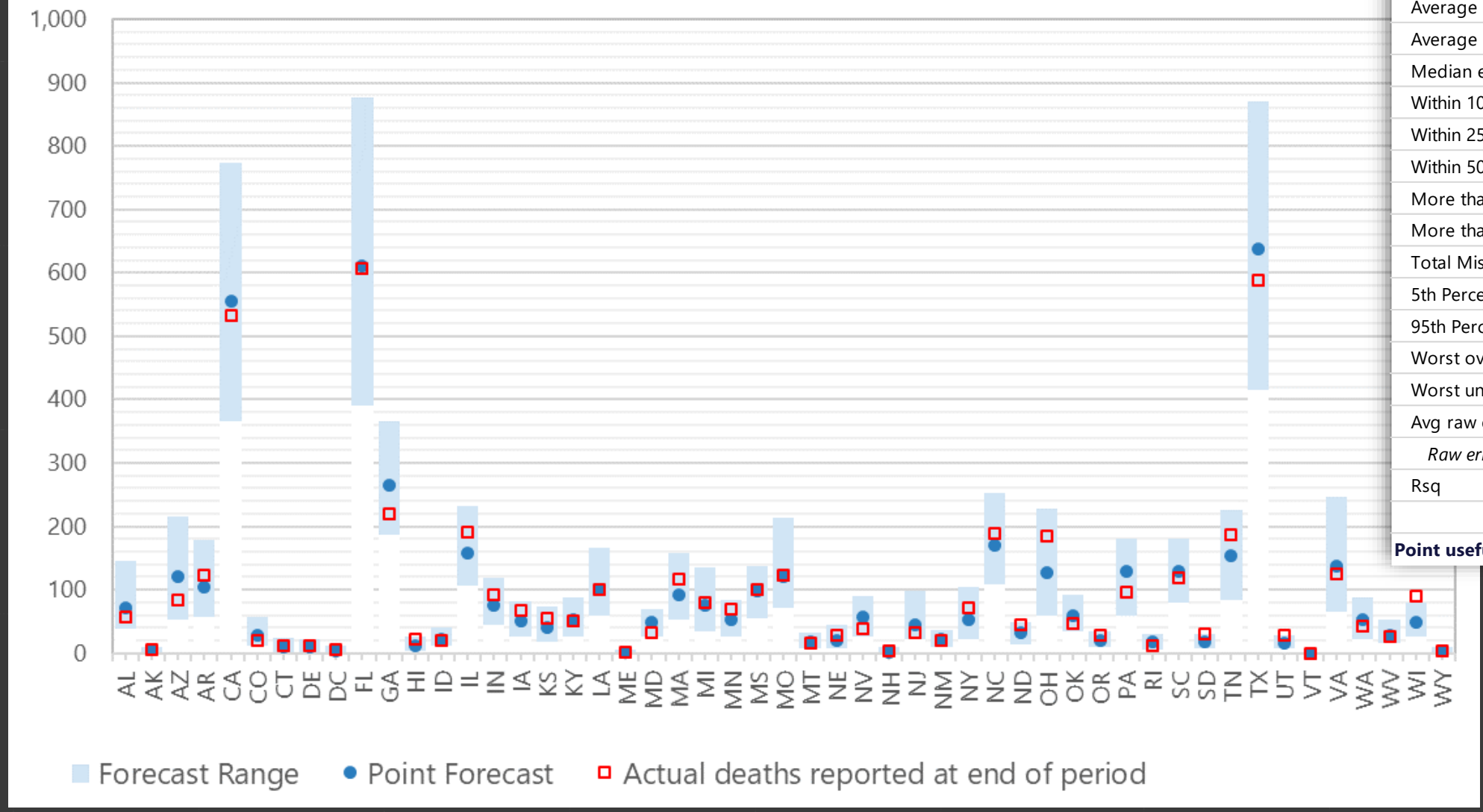


State Forecast Examples



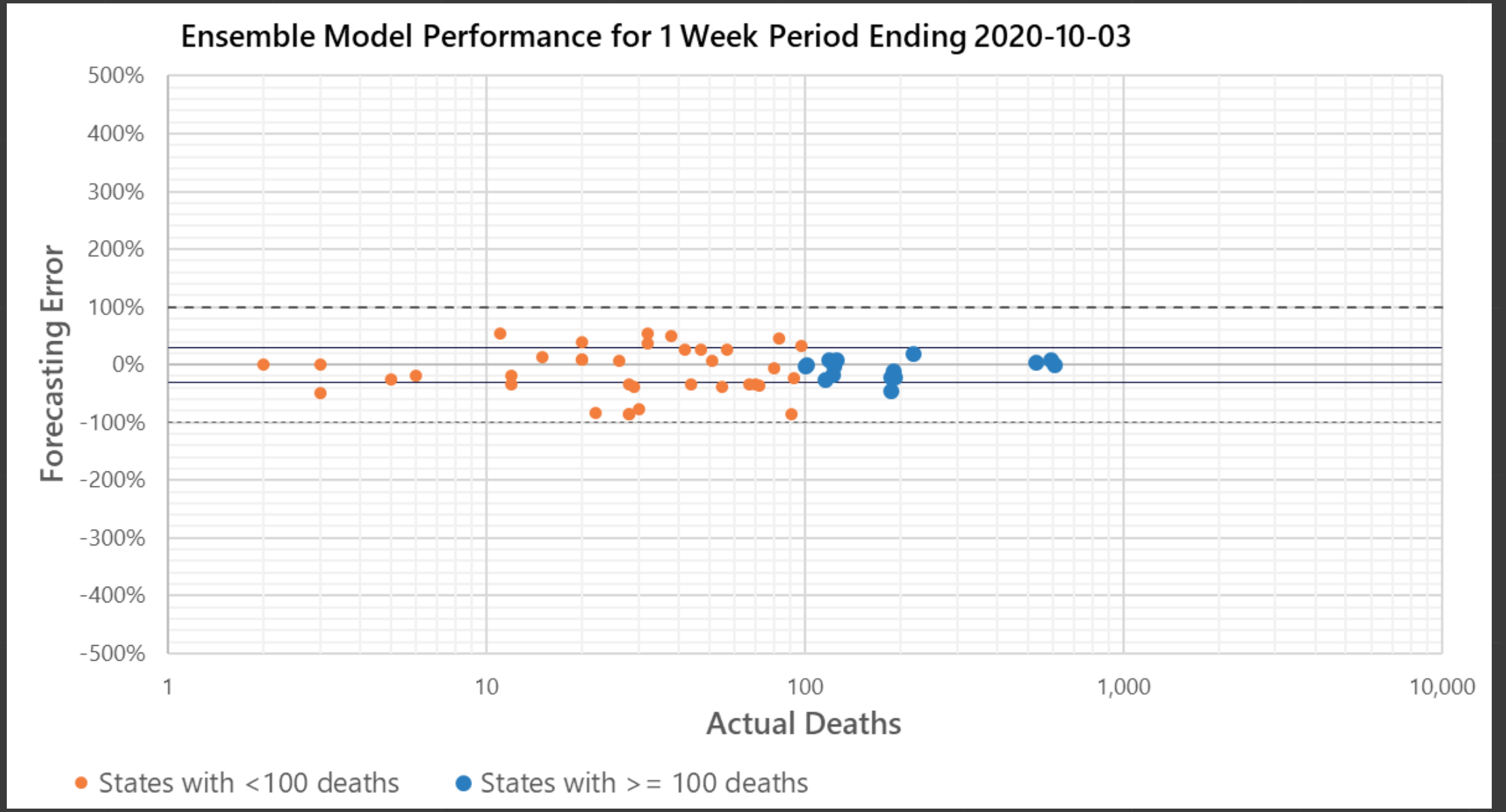
State Forecasting at its Best: 1 Week Horizon

Ensemble Model Performance for 1 Week Period Ending 2020-10-03



Point Forecasts	
Median error magnitude:	**25%**
Average error magnitude	27%
Average bias:	-8%
Median error bias:	**-1%**
Within 10%:	31%
Within 25% of actual:	**53%**
Within 50% of actual:	88%
More than 100% high	0%
More than 100% low	0%
Total Missed by more than 100%	**0%**
5th Percentile:	-80%
95th Percentile:	+47%
Worst overestimate:	+55%
Worst underestimate:	-87%
Avg raw error	14
Raw error as %	15%
Rsq	0.98
Point usefulness	**71%**

State Forecasting at its Best: 1 Week Horizon



More State Forecast Evaluations

www.stevemcconnell.com/covid

More Overall Forecast Evaluations

www.stevemcconnell.com/covid

Summary

Summary

- Accurate forecasts are possible on 1-4 week horizons
- National forecasts were not accurate into early summer, but have become quite accurate in late summer and fall
- State forecasts are not as accurate as national forecasts; forecasts for bigger states tend to be more accurate, but not always
- The most accurate forecasts come from private individuals as often as they come from universities; the most prestigious universities are not producing accurate forecasts
- The CDC's Ensemble model is consistently among the most accurate forecast models for nearly all periods and types of forecasts

#CovidComplete

Covid-19 Spin-Free Data Center

stevemcconnell.com/covid

Useful Links

- SteveM's Covid-19 Data Center
  https://www.stevemcconnell.com/covid
- SteveM's article on detailed age and comorbidity risk
  https://medium.com/@stevemcc/the-one-graph-you-need-to-understand-covid-19-comorbidities-5c7c8b64254f
- CDC list of specific comorbidity risks
  https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/evidence-table.html
- CDC forecast hub
  https://viz.covid19forecasthub.org/
- Washington state data dashboard
  https://coronavirus.wa.gov/what-you-need-know/covid-19-risk-assessment-dashboard
- Tableau international comparison data
  https://public.tableau.com/profile/jonas.nart#!/vizhome/COVID19_15844962693420/COVID19-TrendTracker

Discussion