

# #CovidComplete

Six Lessons Software Estimation Can Learn  
from Covid-19 Forecasting

By Steve McConnell

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Additional information is available at [stevemcconnell.com/covidcomplete](http://stevemcconnell.com/covidcomplete).*

#CovidComplete

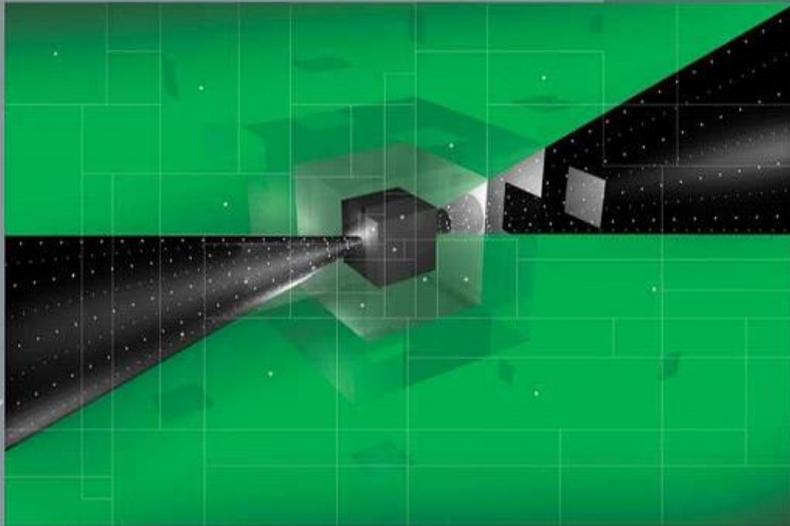
Welcome





# My personal role in Covid-19 Forecasting

# SOFTWARE ESTIMATION



*Demystifying the Black Art*

Steve McConnell

Two-time winner of *Software Development* magazine's Jolt Award



Experts tend to use simple estimation strategies, even when their level of expertise in the subject being estimated is high — *Steve McConnell, Software Estimation*

# Coronavirus Disease 2019 (COVID-19)



- Your Health
- Community, Work & School
- Healthcare Workers & Labs
- Health Depts
- Cases & Data
- More

## Cases, Data & Surveillance

US Cases & Deaths

Cases & Deaths by County

Testing Data in the US

Hospitalizations &

### 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.

On This Page

## Interpretation of Forecasts of

Special Populations Data +

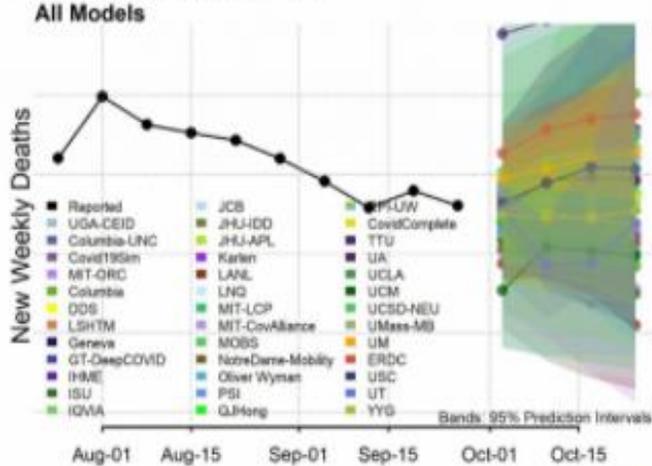
COVIDView Weekly Summary +

Sequencing for SARS-CoV-2 (SPHERES)

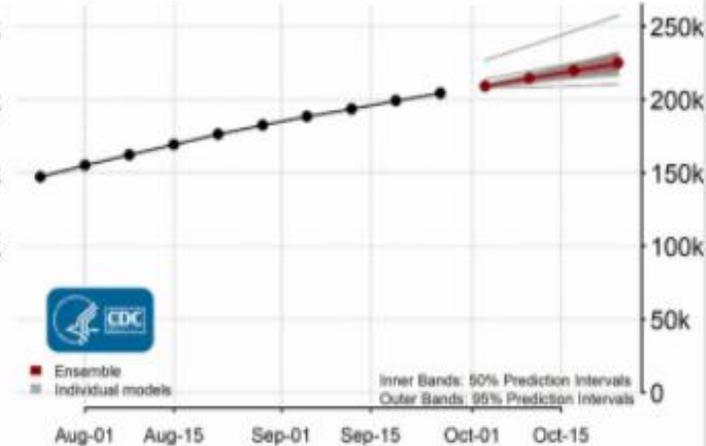
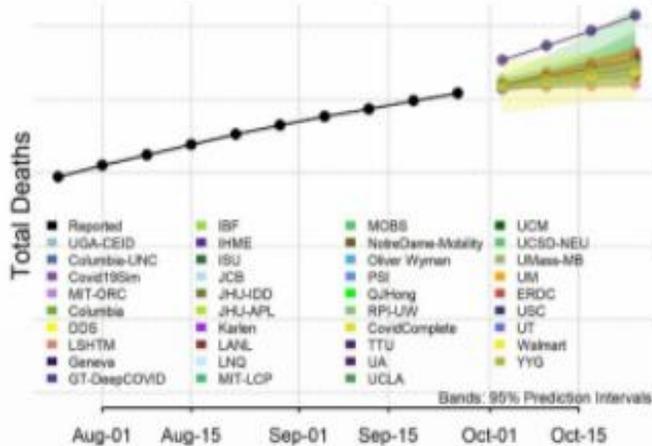
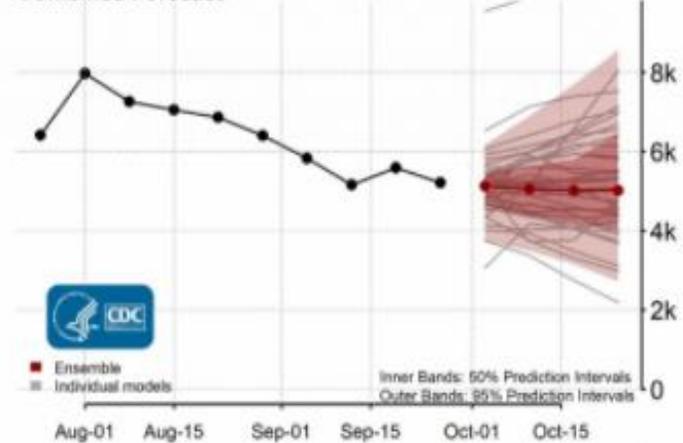
Epidemiology for COVID-19 +

# National Forecast

## National Forecast



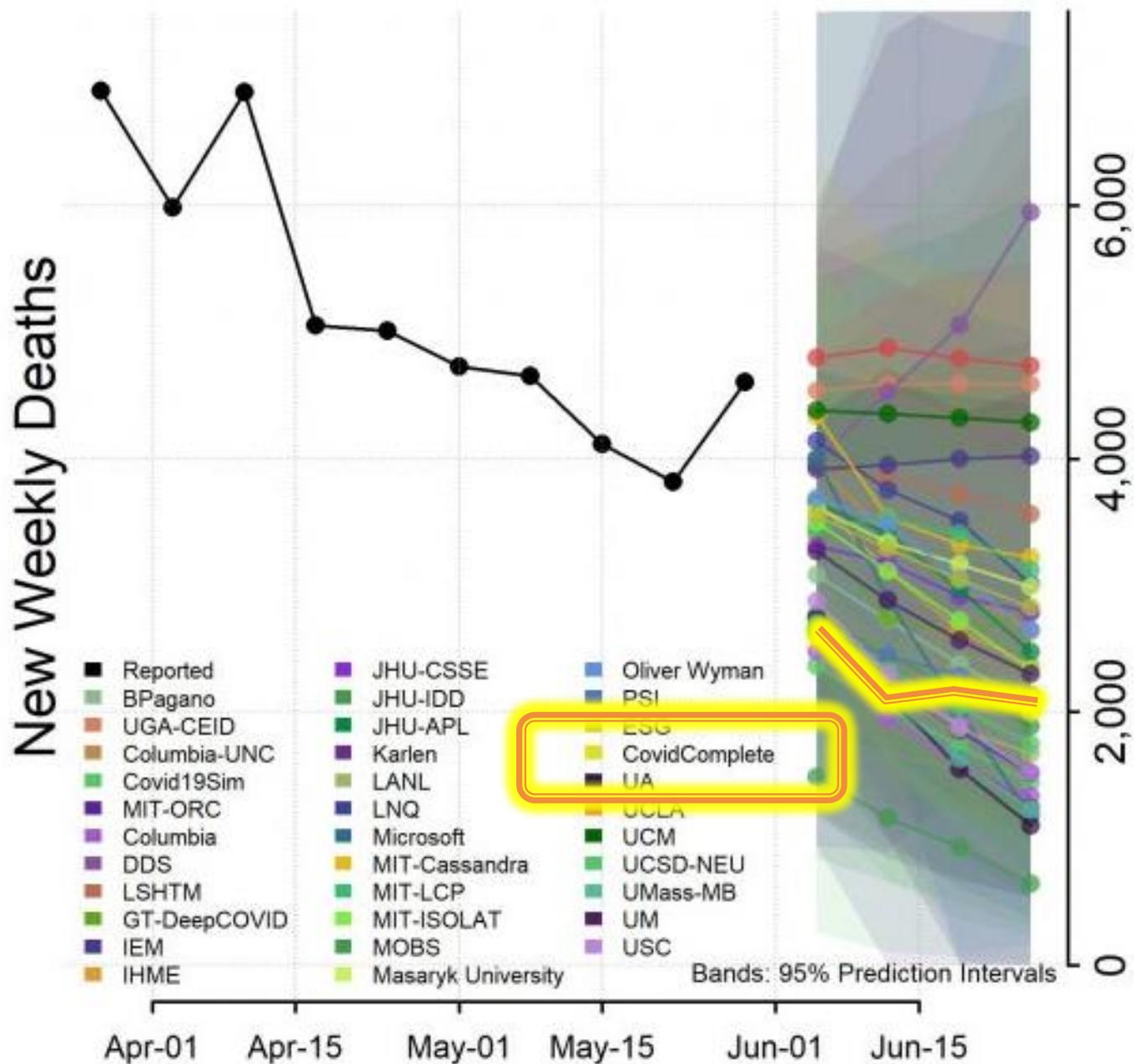
## Combined Forecast



Get Email Updates

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

# National Forecast



# — The Basics:

- Estimate
- Forecast
- Speculation

A forecast is a future-based estimate

- I can “estimate” the number of fish in a pond
- I can either “forecast” or “estimate” how many iterations my next release will require



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



The Basis of  
Forecasting/Estimation  
*“What We Know”*



# — CDC Covid Forecasting

# — CDC Covid-19 Forecast Process

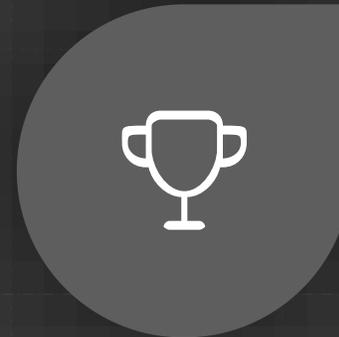
CDC work is overseen by a team at University of Massachusetts Amherst



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

# CDC Forecasting

## What Each Team Contributes Weekly

- ~30 modeling teams per week since July 2020
- Forecasts for US National, 50 US states + DC (at least)
- 1, 2, 3, and 4 week forecast horizons
  - Incremental forecasts (1 week at a time)
  - Cumulative forecasts (total for pandemic to date)
- Forecasts for these quantiles:
  - 0.01, 0.025, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.975, 0.99
- Total of about 10,000 forecasts per week, per team

# CDC Forecasting

## What I Analyze

- ▣ Forecasts for US National, 50 US states + DC
- ▣ 1, 2, 3, and 4 week forecast horizons
  - Incremental forecasts, cumulative from forecast date
- ▣ Forecast types:
  - Point forecast (0.50 quantile)
  - 50% Prediction Interval (PI) forecast (0.25 to 0.75 quantile range)
  - 95% Prediction Interval (PI) forecast (0.025 to 0.975 quantile range)
- ▣ Subset = ~625 forecasts per week, per team

# CDC Forecasting

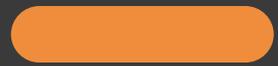
## Total Data Set of Forecasts vs. Actuals

- ▣ ~6,500 forecast sets
- ▣ ~625 forecasts per set
- ▣ Total of ~4 million forecasts vs. actuals to date
- ▣ Overall, an incredibly rich data set in which to explore topics like different estimation methods, accuracy at different time horizons (i.e., cone of uncertainty), how well models deal with uncertainty, etc.

# — CDC Forecasting Context

Forecasts and actuals are all public information

- Detailed Forecasts: <https://github.com/reichlab/covid19-forecast-hub>
- Summary Forecasts: <https://www.cdc.gov/coronavirus/2019-ncov/covid-data/forecasting-us-previous.html>
- Actuals: [https://github.com/CSSEGISandData/COVID-19/tree/master/csse covid 19 data/csse covid 19 time series](https://github.com/CSSEGISandData/COVID-19/tree/master/csse%20covid%2019%20data/csse%20covid%2019%20time%20series)
- Evaluation data: <https://github.com/stevemccconnell/covid19-forecast-evaluations>
- Evaluation graphs: <https://stevemccconnell.com/covidcomplete>

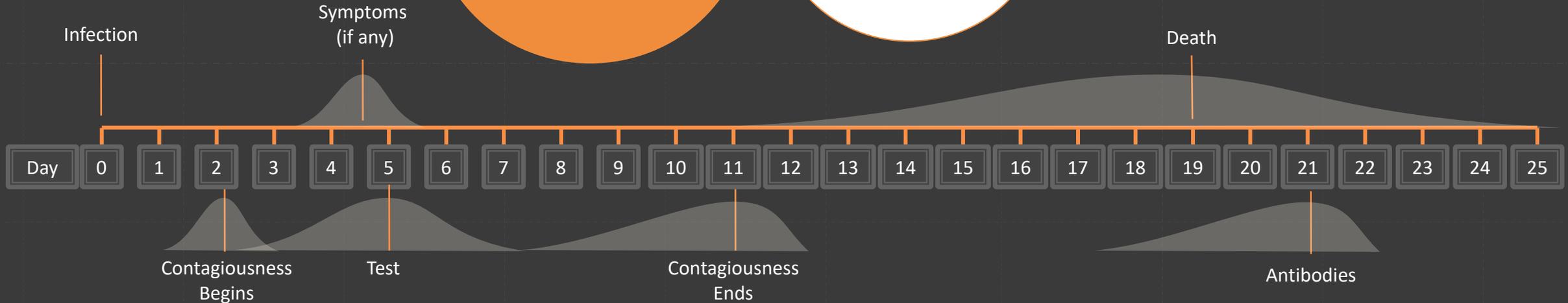


# Covid Complete's Forecasting Approach

# 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 for another 7-14 days



We can take the **test** number, which we know on date X

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

We can forecast the **deaths** number, 14-21 days ahead

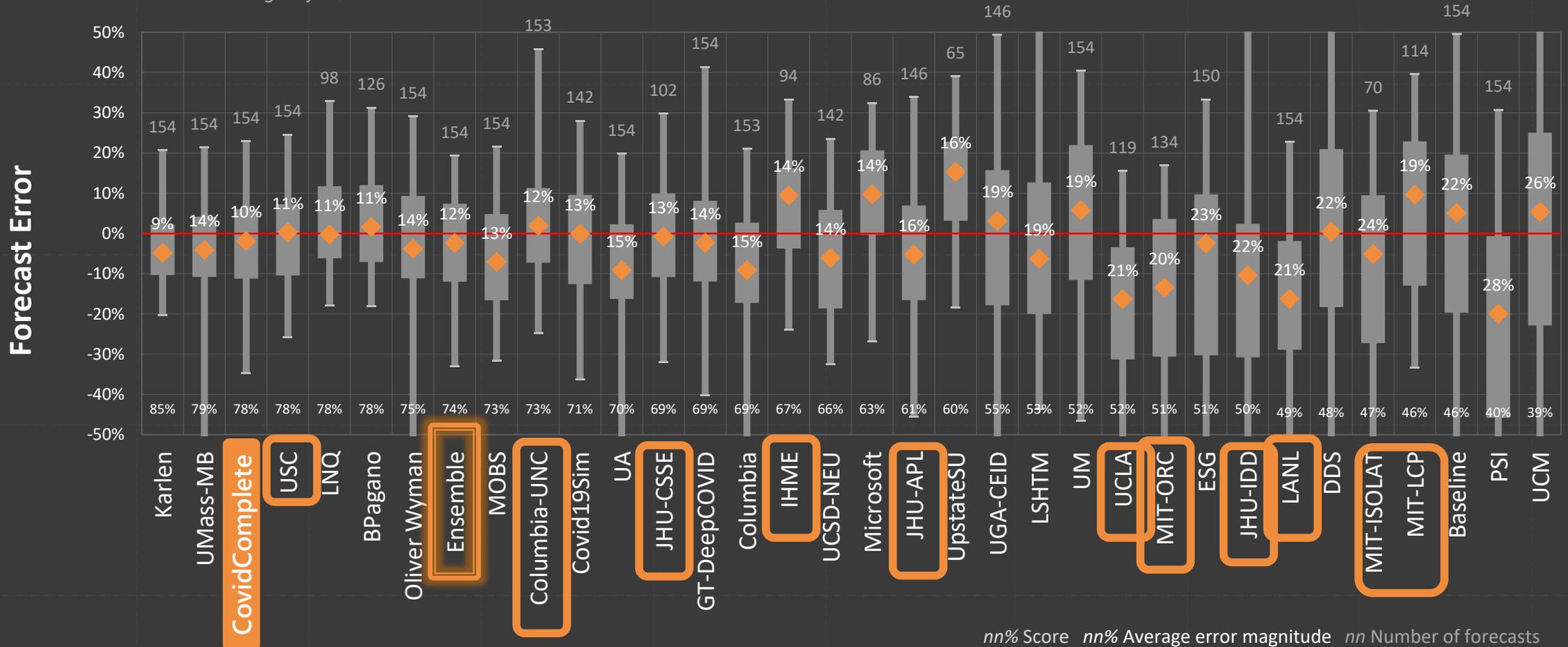
# — The Theory Sounds Good, Right?

- ❑ But is it working in practice? I.e.,
- ❑ How is CovidComplete performing?

# How is CovidComplete Performing?

## US National Point Fatality Forecasts from Aug 24 to May 24, 2021

Forecasts ending May 29, 2021



For national forecasts, CovidComplete has been among the top 5 models over the long term

■ Middle 50%

◆ Median Forecast Bias

– Worst High and Low Forecasts

[stevemccconnell.com/covidcomplete](http://stevemccconnell.com/covidcomplete)

# Use Historical Data



# — Most Common Forecast Method: SEIR

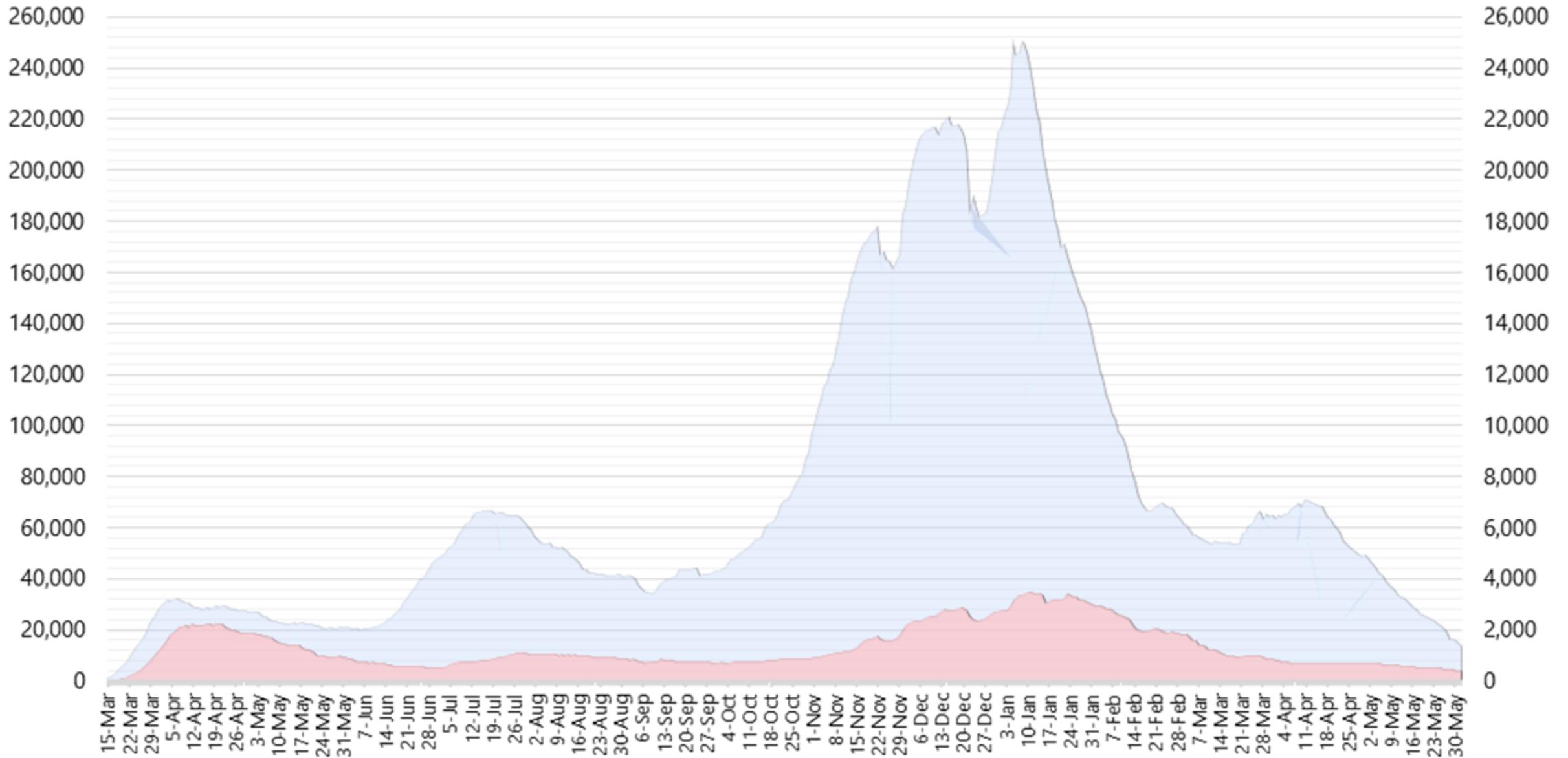
- ▣ SEIR = Susceptible, Exposed, Infected, Recovered
- ▣ This is the established epidemiological model
- ▣ Forecast results from these models were mediocre for many months but have improved recently
  - Mistaken old assumptions must be removed from the models, e.g., from flu forecast models
  - Mistaken new assumptions take time to invalidate and then remove

## — Other Methods

- ❑ Massive data sets, e.g., 500 million records
- ❑ Esoteric data, e.g., use of mobility data from cell phone records
- ❑ Machine learning
- ❑ Artificial intelligence
- ❑ Bayesian analysis, Monte Carlo simulations, etc.

My forecasting  
method

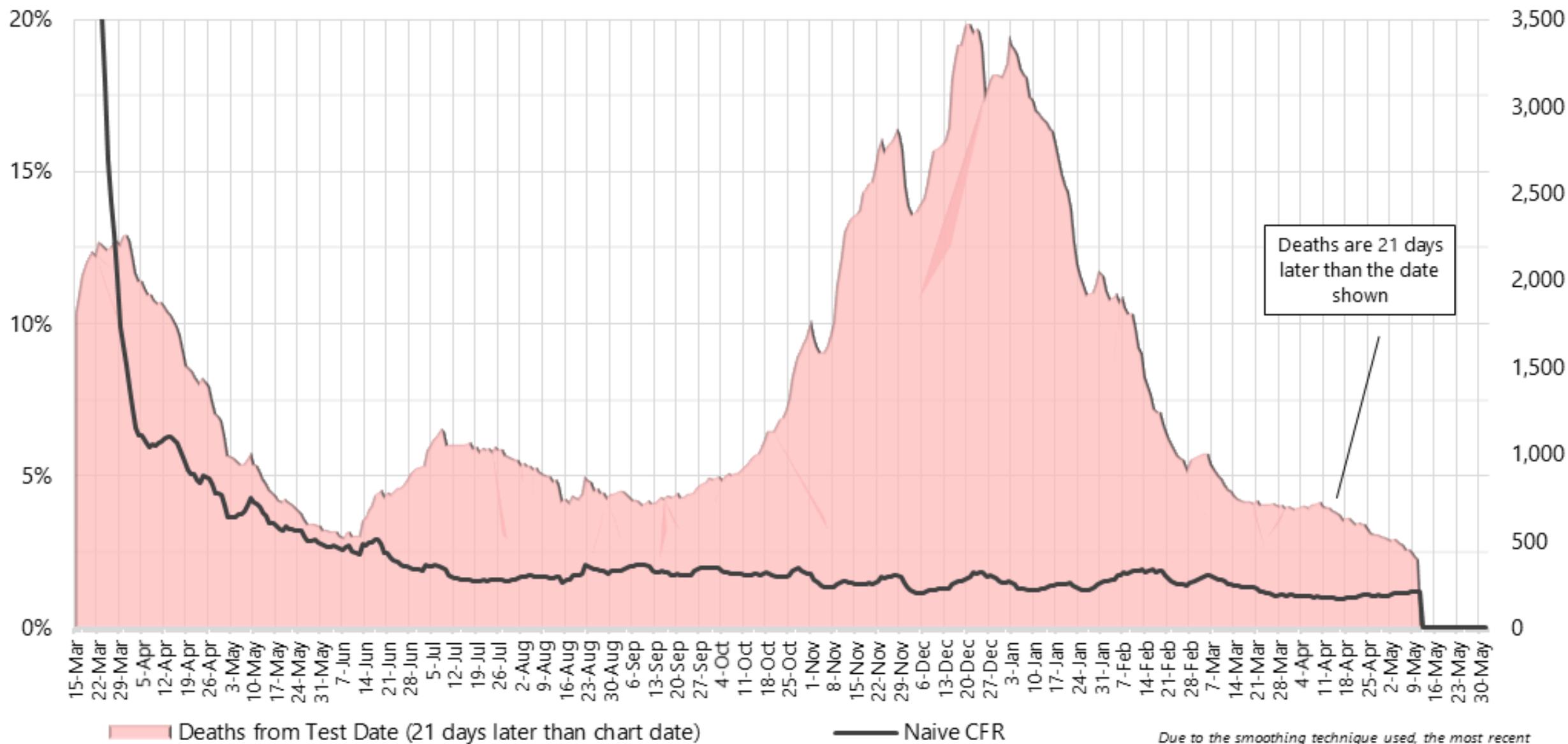
# US Smoothed Daily Positive Tests and Deaths as of 6/1/21



Source: [stevemcconnell.com/covidcomplete](http://stevemcconnell.com/covidcomplete)

Positive Tests Deaths

# US Smoothed Naive CFR, Positive Test %, and Deaths 21 Days Later as of 6/1/21



Source: [stevemccconnell.com/covidcomplete](http://stevemccconnell.com/covidcomplete)

*Due to the smoothing technique used, the most recent 3 days are likely to change over the next 3 days.*

# — My forecasting method

The essence of my forecasting method:

- Count positive tests
- Calculate current CFR (death rate)
- Multiply tests by current CFR

# — The Best Approach So Far

- ❑ Simple models based on positive tests and the lag from positive tests to deaths
- ❑ A few of the more accurate models use this simple approach, including CovidComplete

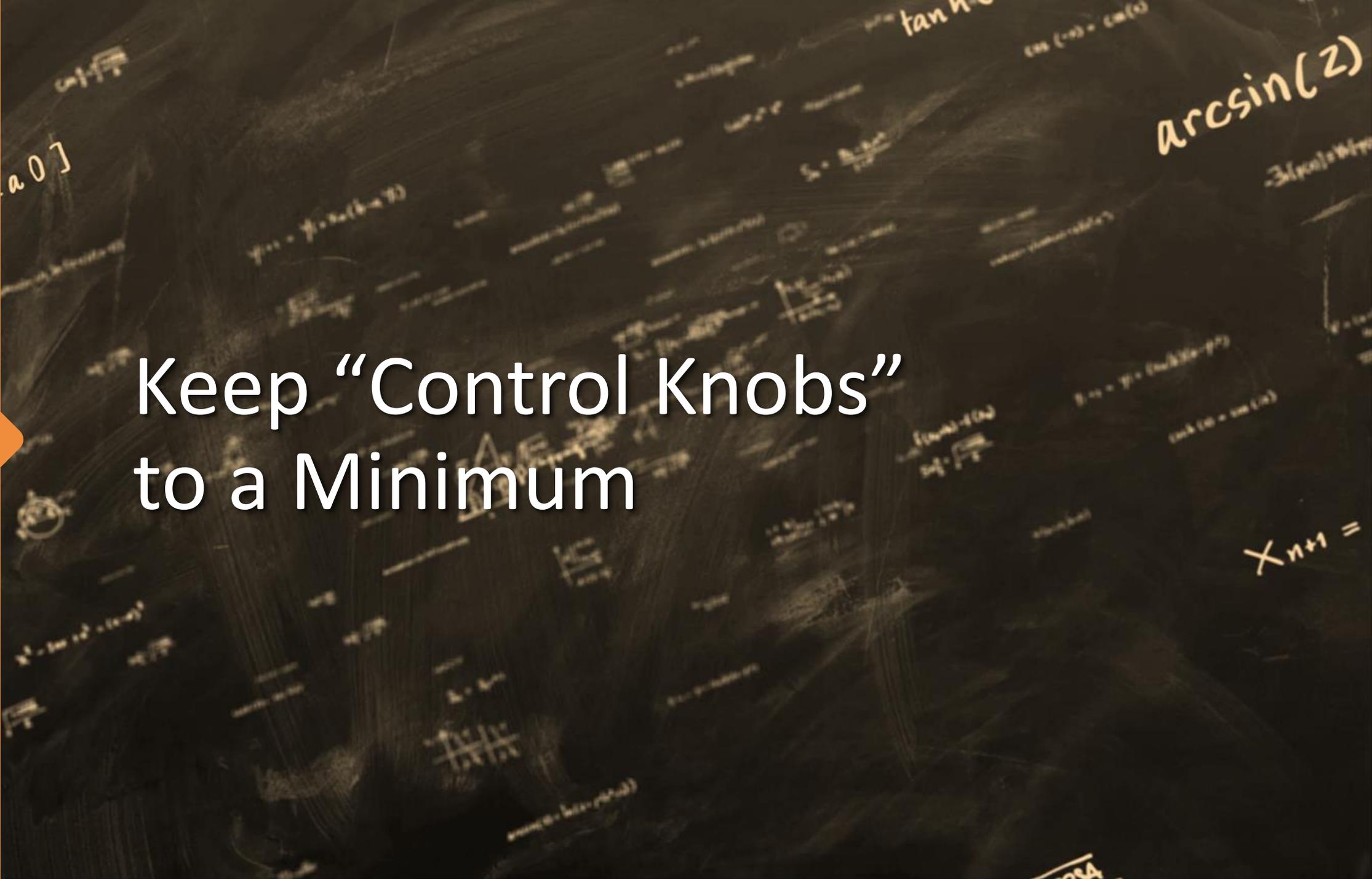


# Software Lesson Learned

## Use Historical Data

- ▣ Your historical data accounts for most or all factors that affect your productivity, and it is not subject to estimation bias
  - E.g., velocity
- ▣ Put your effort into being sure your historical data is accurate and means what you think it means

Keep “Control Knobs”  
to a Minimum



# 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*





# Software Lesson Learned

## Keep “Control Knobs” to a Minimum

- ❑ Favor simple models where you understand the data you’re using
- ❑ In general, this means proxy-based estimation
- ❑ Examples include story points, stories, features per week/month/sprint, etc.

# Accuracy First, Precision Second

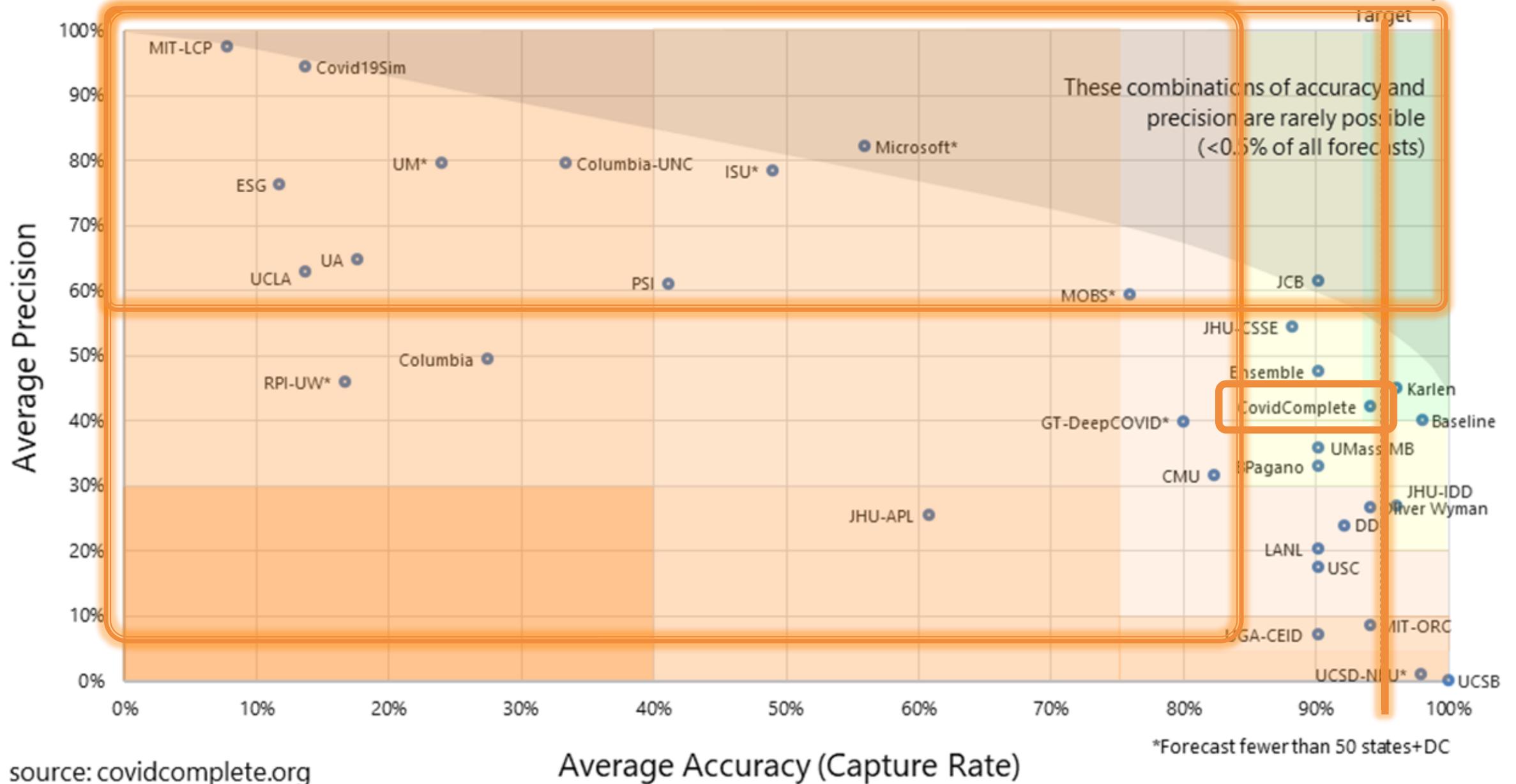


# — Accuracy vs. Precision

- ▣ Accuracy = Did you hit the mark?
  - For prediction intervals, this refers to whether the PI captured the intended percentage of actuals, e.g., a 95% PI should capture about 95% of actuals
- ▣ Precision = How exact was your forecast?
  - In engineering, precision is normally the number of significant digits used to represent a quantity
  - In forecasting, precision is the width of the forecast range
  - The Ensemble team refers to this as “sharpness”

# State 95% Prediction Range Fatality Forecasts for the 4 Week Period Ending 2021-1-23

Forecast date: 2020-12-28



source: covidcomplete.org

\*Forecast fewer than 50 states+DC

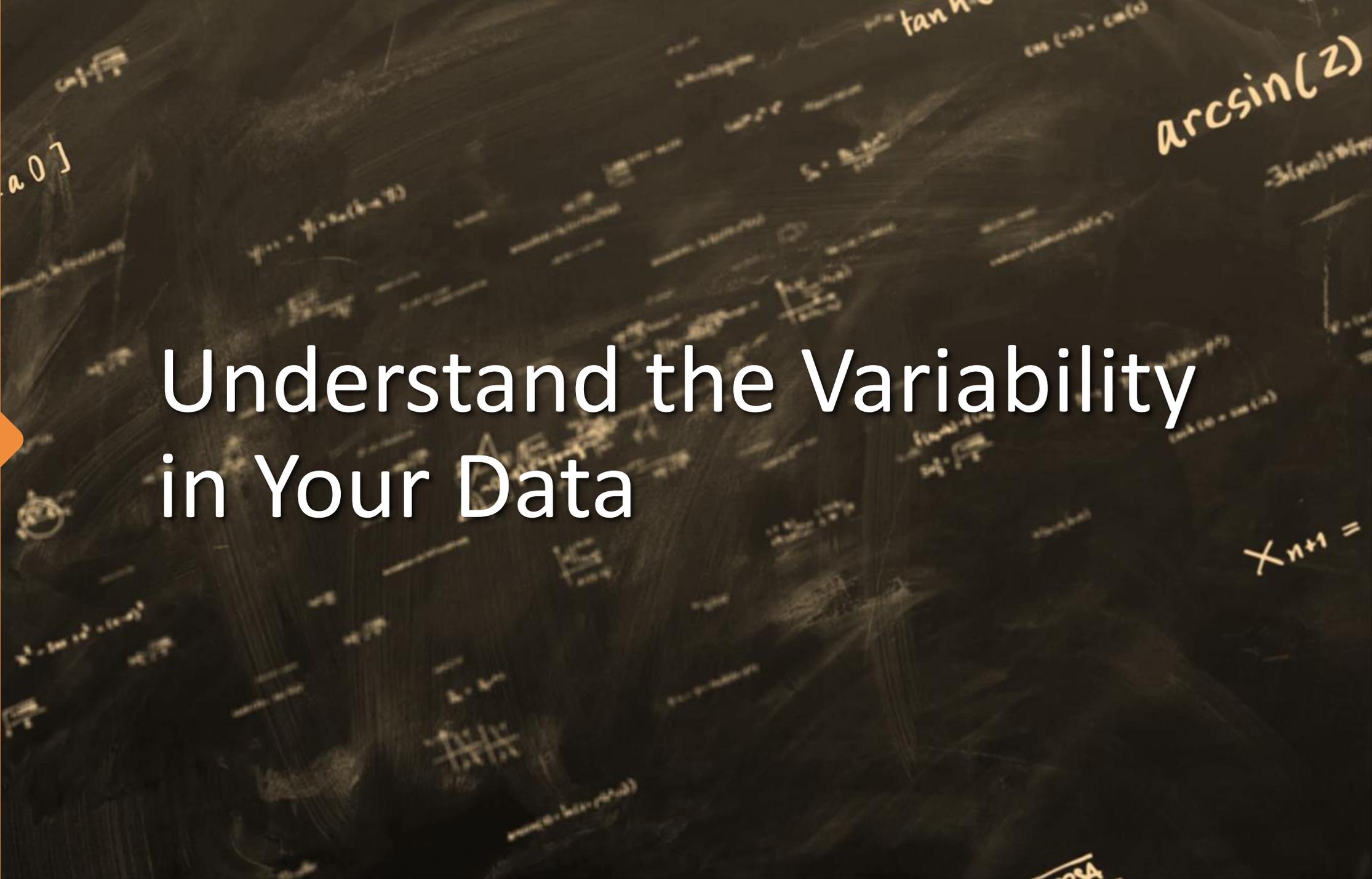


# Software Lesson Learned

## Accuracy First, Precision Second

- ❑ Avoid presenting estimates that mismatch accuracy and precision, e.g., avoid “This release will take 4 sprints, plus or minus 3 sprints”

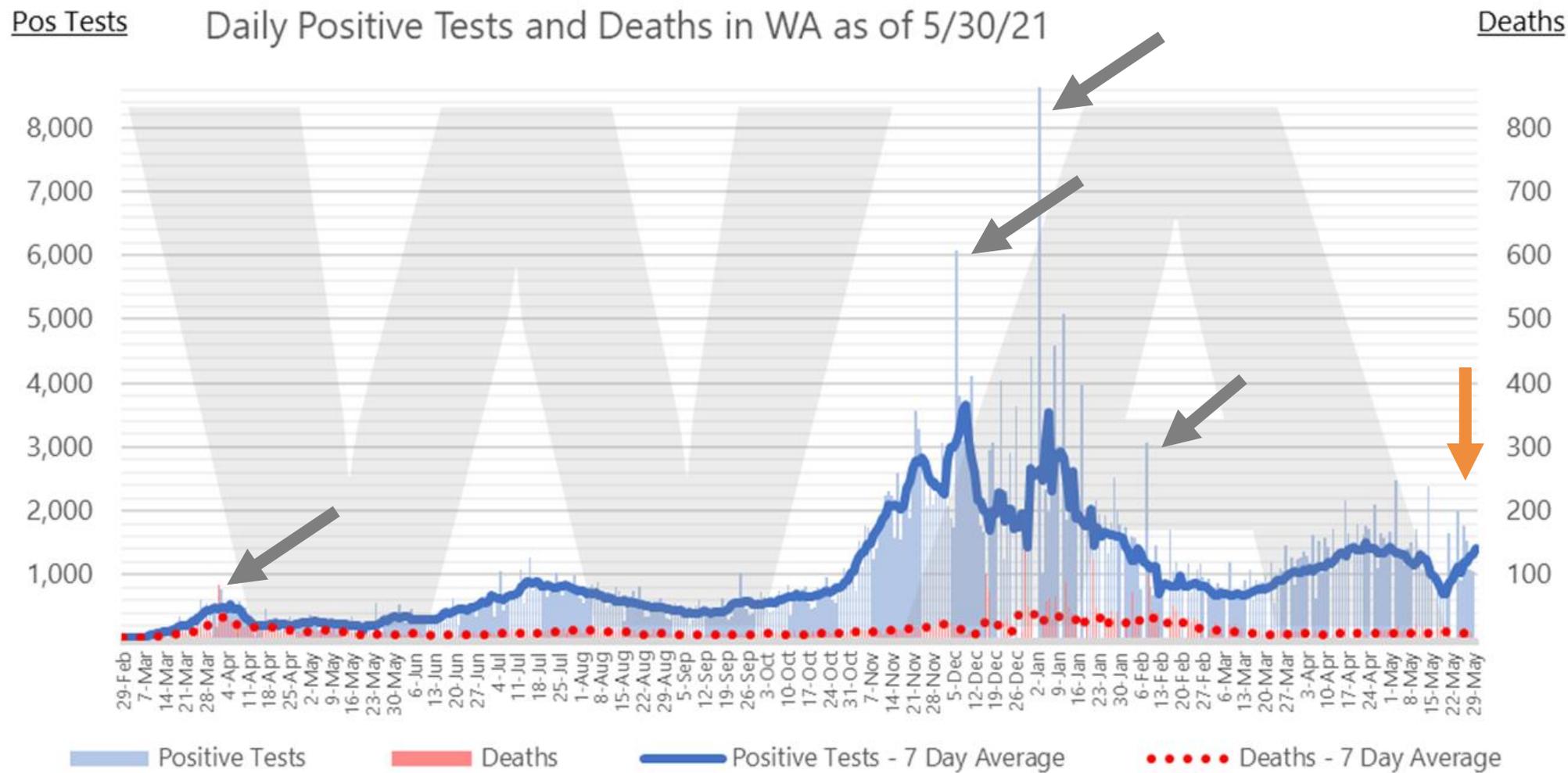
# Understand the Variability in Your Data



# Data Issue #1: Corrections



# — Spikes (Corrections) in State Level Data



Source: [stevemccconnell.com/covidcomplete](http://stevemccconnell.com/covidcomplete)

# — Corrections in the Past 7 Days

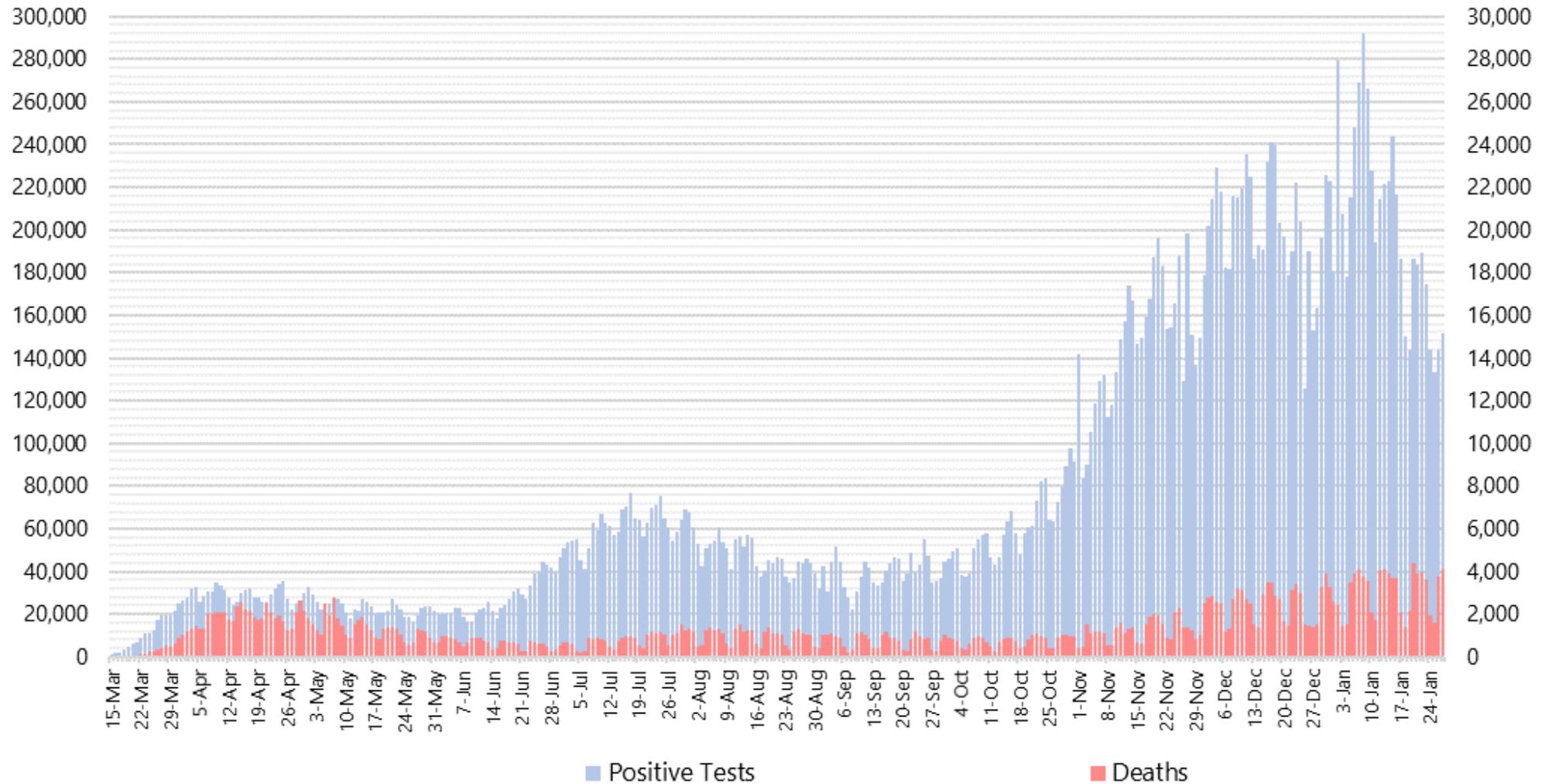
- Large numbers of states did not update on Memorial Day
- WA added ~3000 backlogged cases from May 26-29
- WI added 41 backlog deaths May 27
- NM added 100 backlog deaths May 24
- TX added 628 backlogged cases May 24
- OK added ~350 deaths May 26
- MD added 583 backlogged deaths May 27
- LA added 3857 backlogged cases May 27
- WY added 100+ cases May 20

# Data Issue #2: Sundays



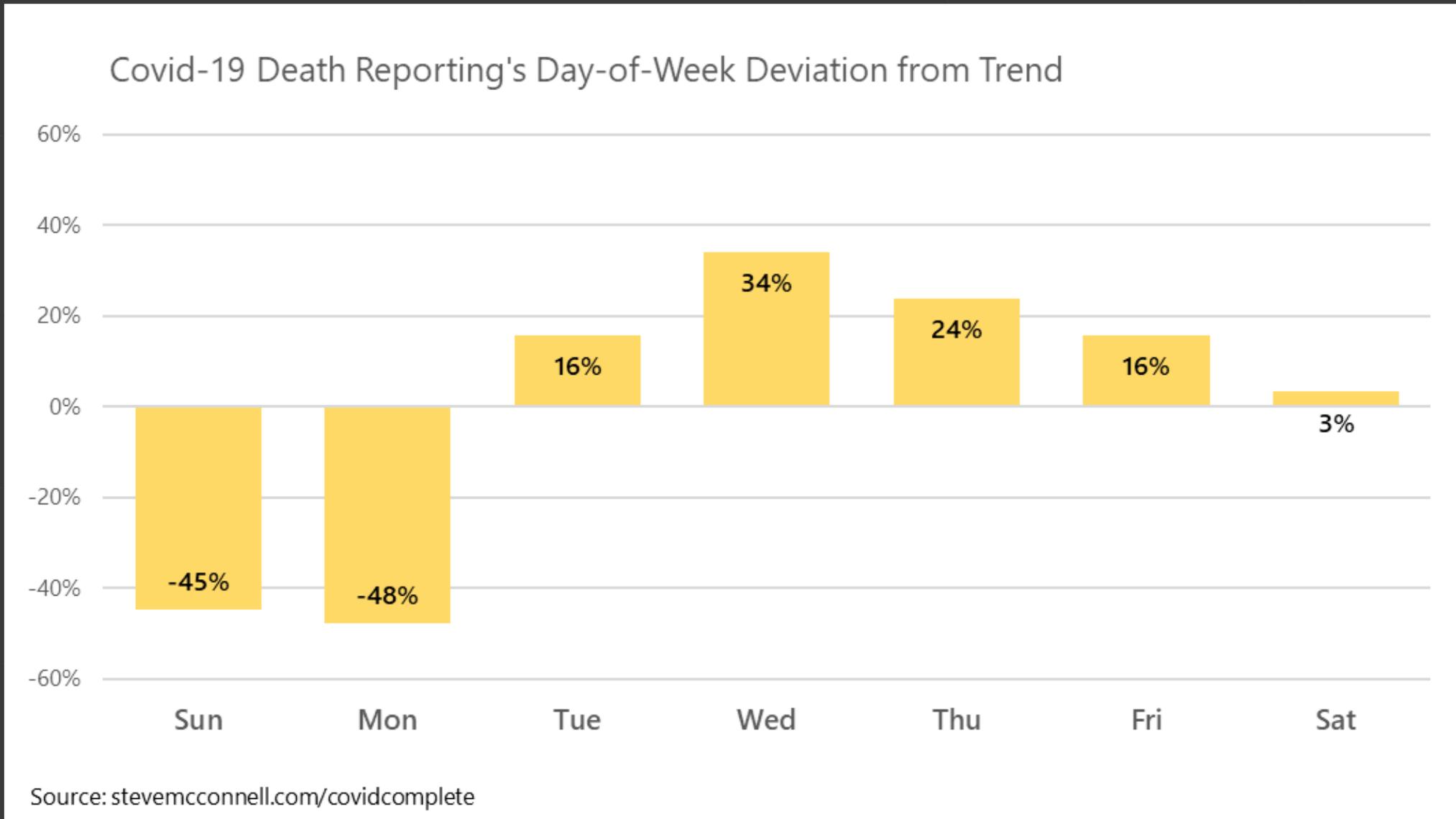
# Issue with Daily Data – Sundays!

US Daily Positive Tests and Deaths as of 1/27/21



Source: [stevemccconnell.com/covidcomplete](http://stevemccconnell.com/covidcomplete)

# — Variation in Data Reporting by Day-of-Week

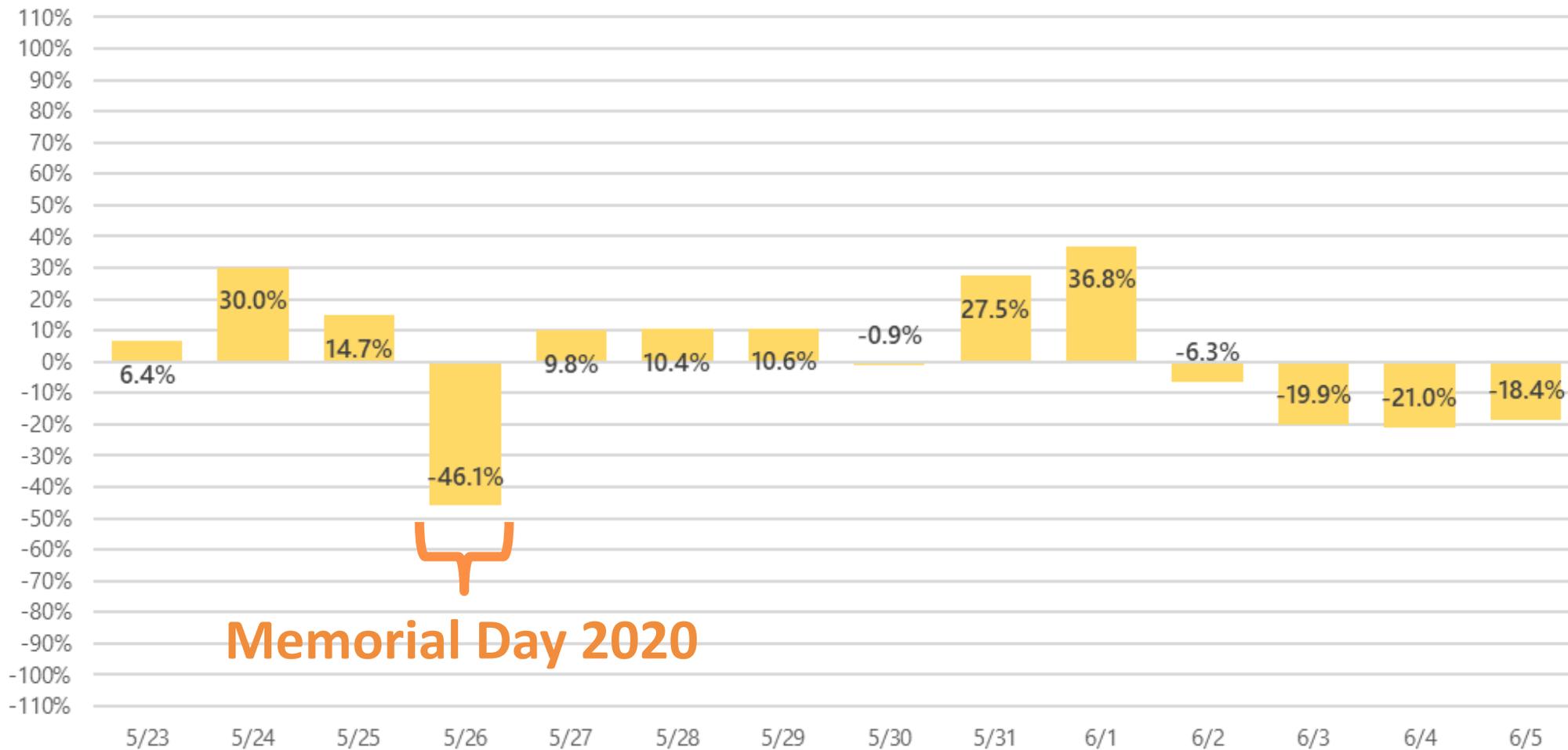


# Data Issue #3: Holidays



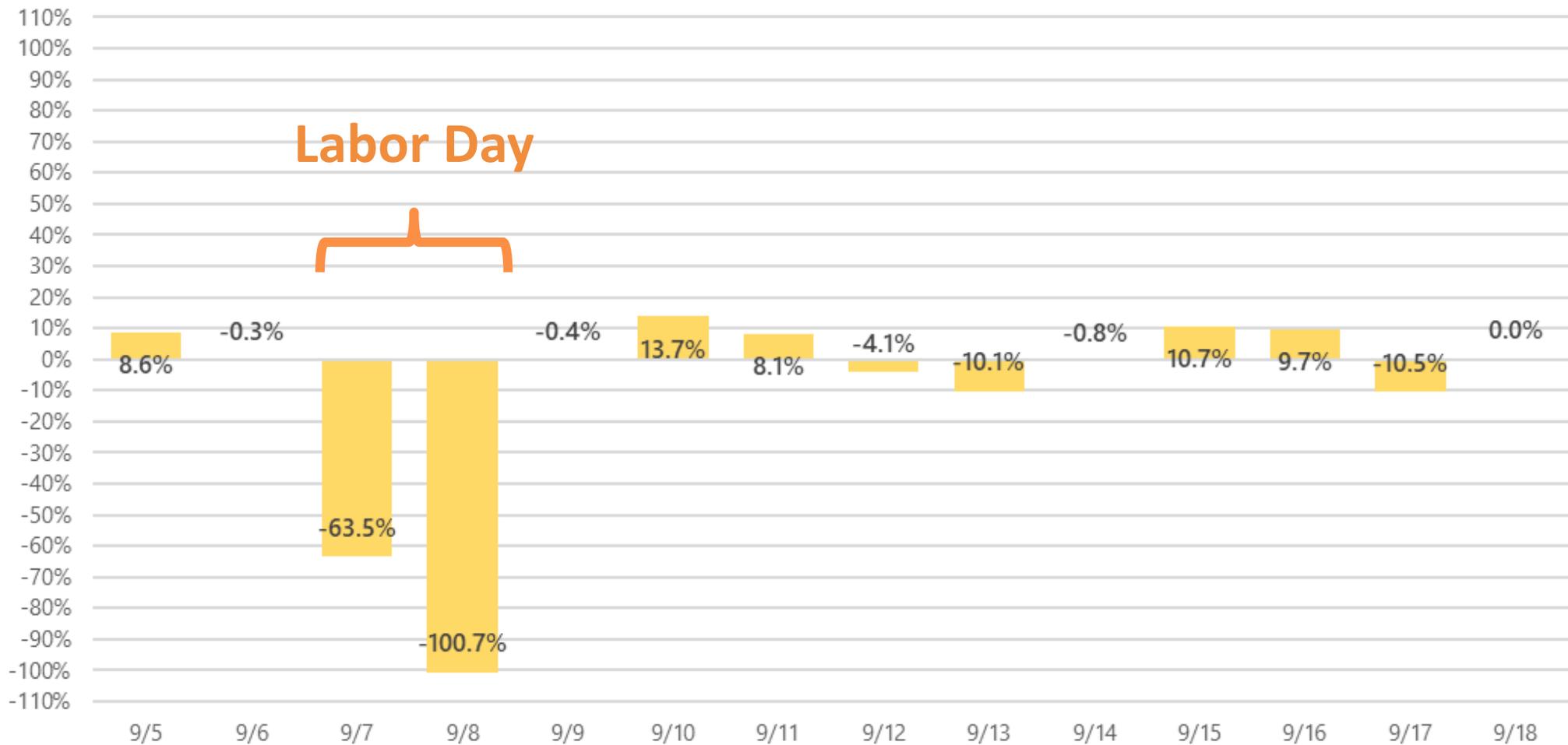
# Holidays

Covid-19 Death Reporting's Deviation from Trend  
Adjusted for normal day-of-week variation



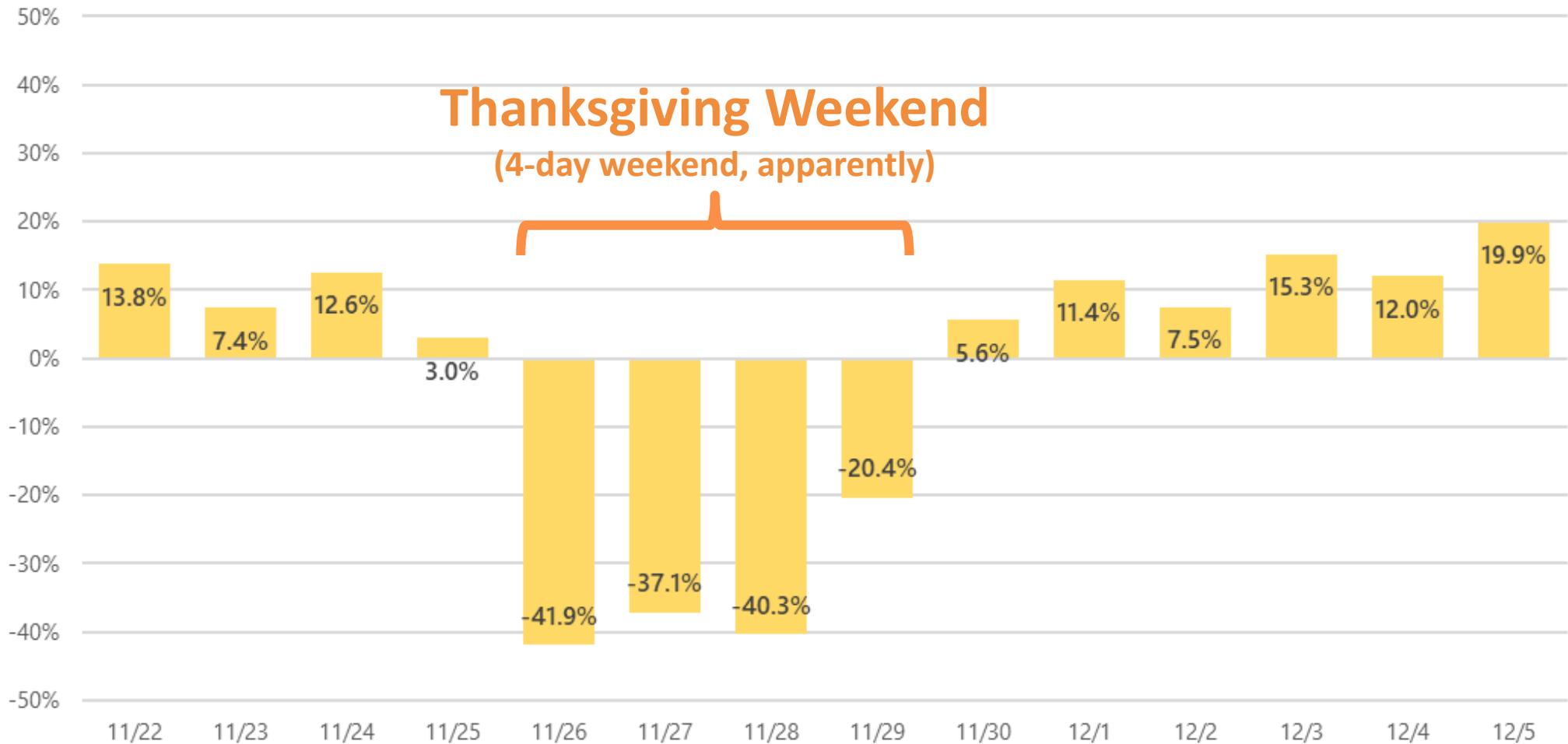
# Holidays

Covid-19 Death Reporting's Deviation from Trend  
Adjusted for normal day-of-week variation



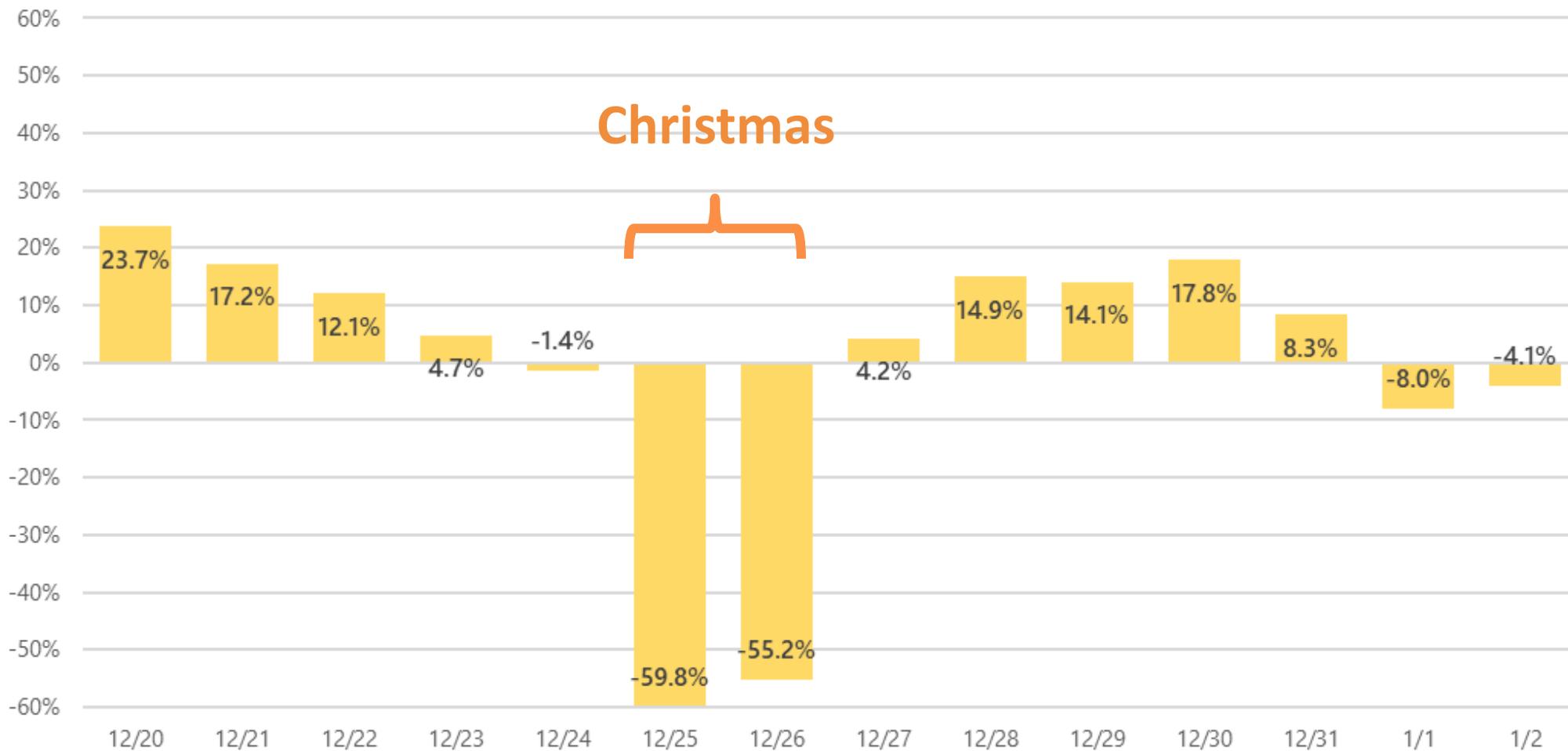
# Holidays

Covid-19 Death Reporting's Deviation from Trend  
Adjusted for normal day-of-week variation



# Holidays

Covid-19 Death Reporting's Deviation from Trend  
Adjusted for normal day-of-week variation



# — Data Issues: “Special Cause” Variations

- ❑ Wrongly classified deaths and subsequent corrections
  - Adding deaths “attributed to” CV
  - Subtracting deaths classified as “with CV” that were not “from CV”
- ❑ Wrongly classified tests (PCR vs. antibody) and subsequent corrections
- ❑ Data initially reported on wrong date, and later corrected
- ❑ Deaths initially reported in one state and later changed to another

# — Data Issues: “Common Cause” Variations

- ▣ Weekly reporting cycle
- ▣ Holiday under- and over-reporting (which is a mix of common cause and special cause)



# Software Lesson Learned

## Understand the Variability in Your Data

- ▣ Variations in velocity
- ▣ People's personal schedules
- ▣ People's allocation to your project
- ▣ Holidays, sick days, training days, etc.

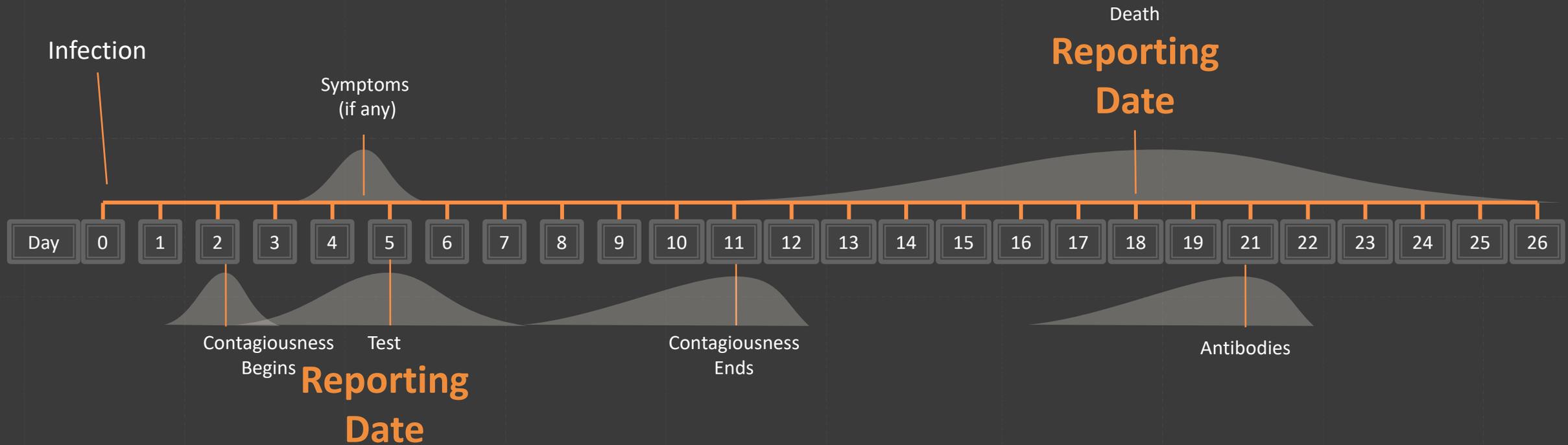
# Minimize Differences Between Reporting and Ground Truth

We're really working with 3 entities, not 2:

- Forecast
- Ground Truth



# — This is more about reporting dates, more than actual dates



We're really working with 3 entities, not 2:

- Forecast
- Ground Truth
- **Reporting** of the Ground Truth





# Software Lesson Learned

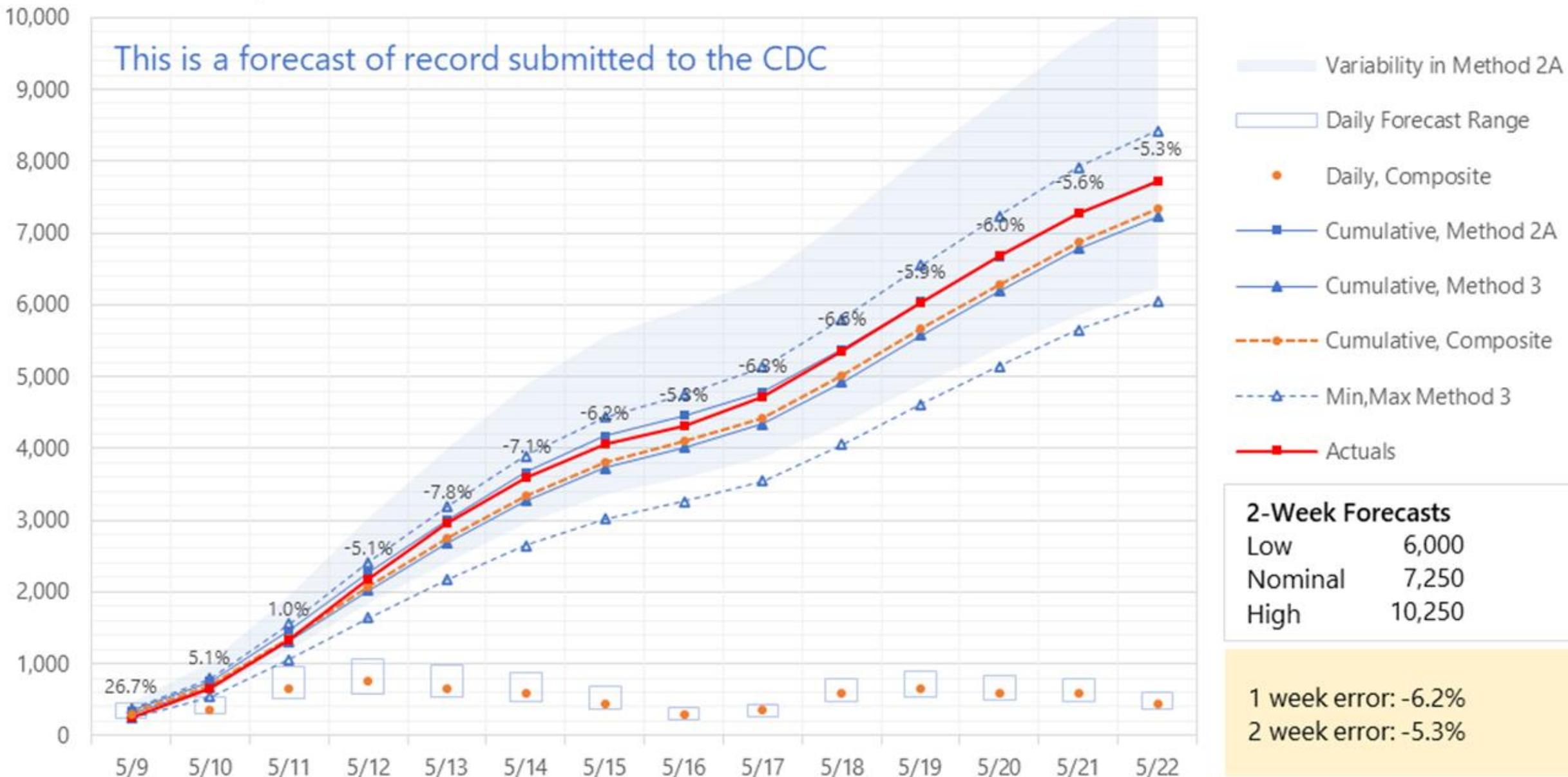
## Minimize differences between reporting and ground truth

- ❑ Do you actually finish stories each sprint. If not, is your velocity really “ground truth” or is it really an estimate of ground truth?
- ❑ Do you change point values of stories after completing them (“This was more like a ‘5’ than a ‘3’”)?
- ❑ Did you really meet the sprint goal, or was the sprint goal redefined so that you could meet it?
- ❑ Are you accounting for weekends and holidays in your estimates and plans?

# Close the Loop



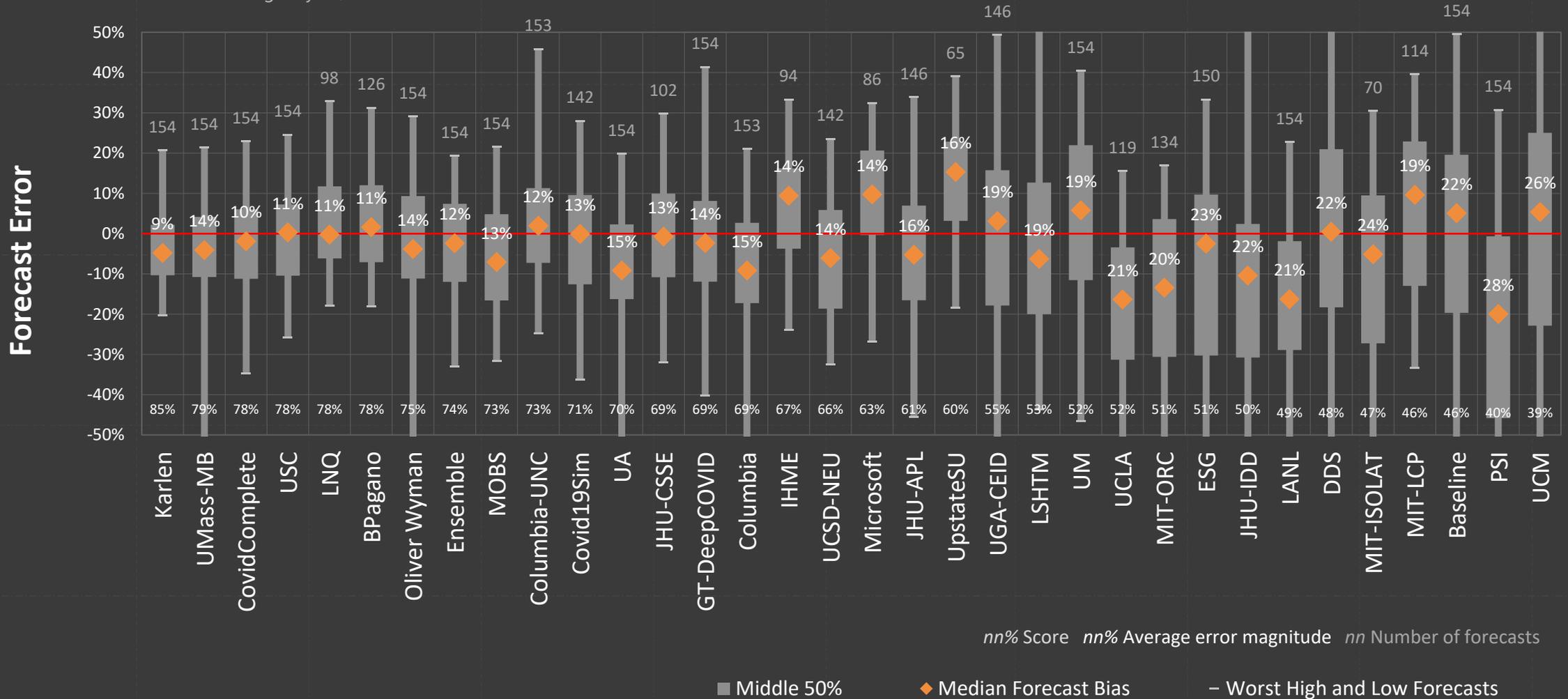
# CovidComplete Forecasts for Covid-19 Deaths in the US, forecast date of 5/8/21



# Remember this chart?

## US National Point Fatality Forecasts from Aug 24 to May 24, 2021

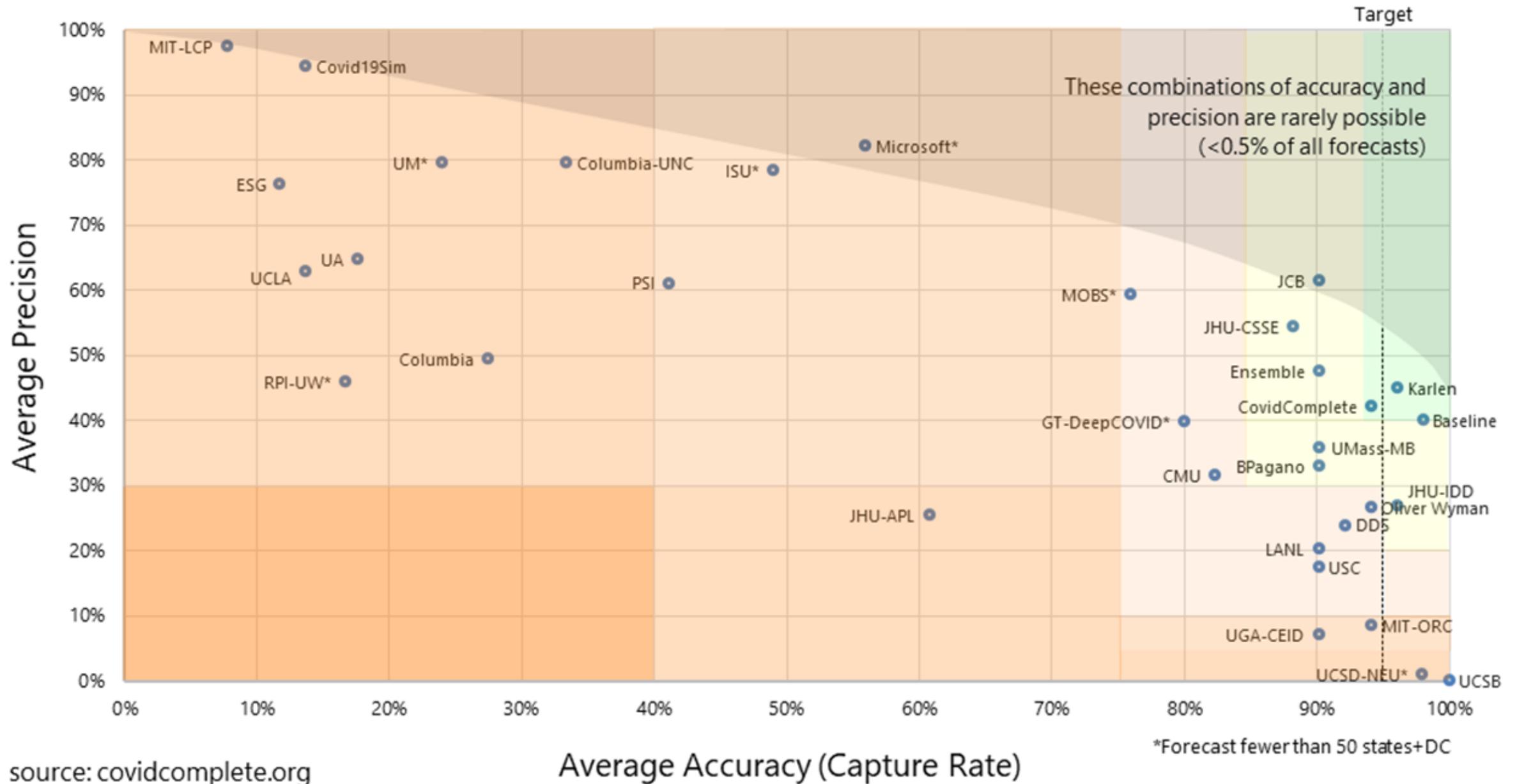
Forecasts ending May 29, 2021



www.stevemcconnell.com

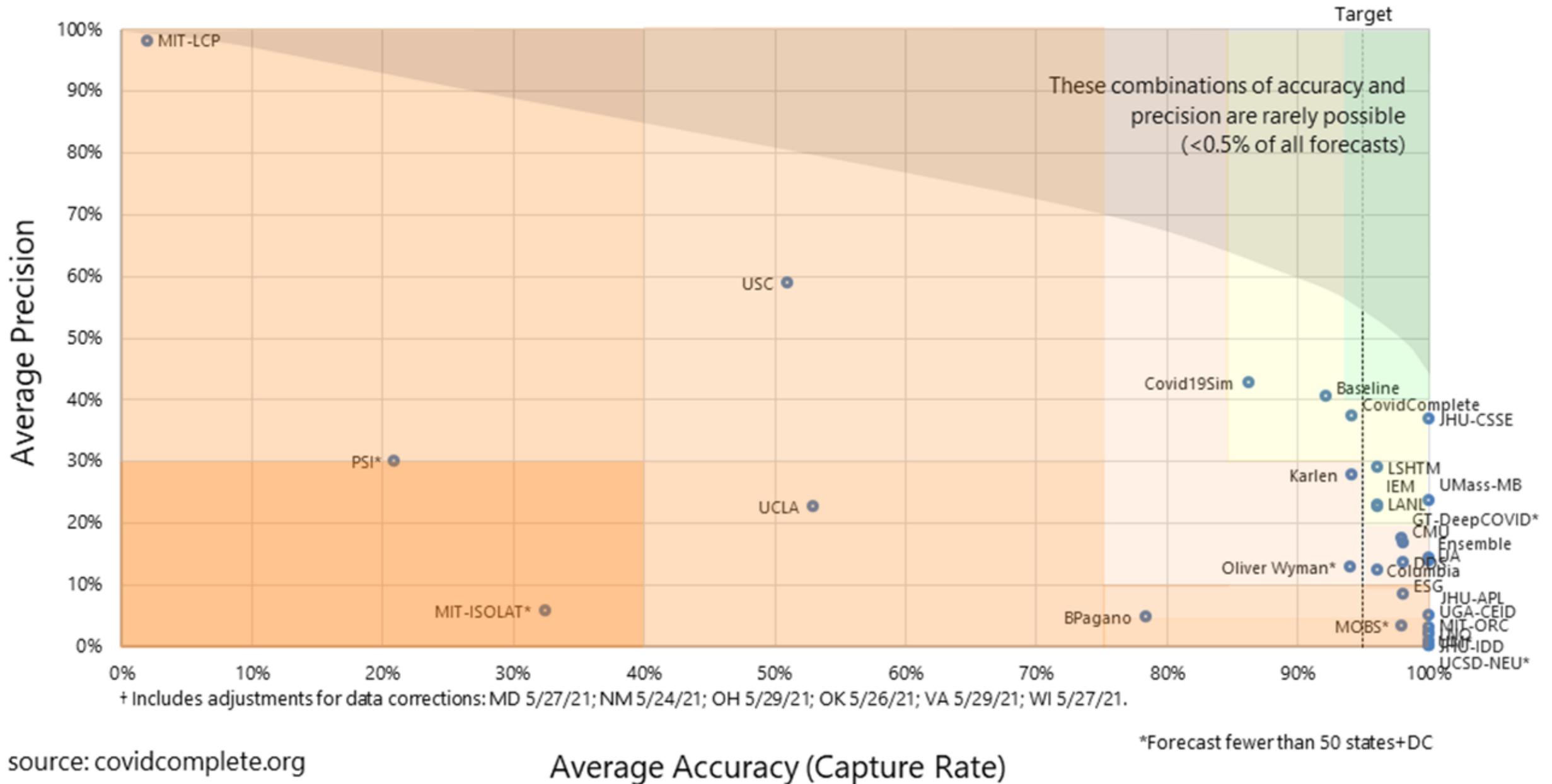
*nn%* Score *nn%* Average error magnitude *nn* Number of forecasts

# Remember this Chart?

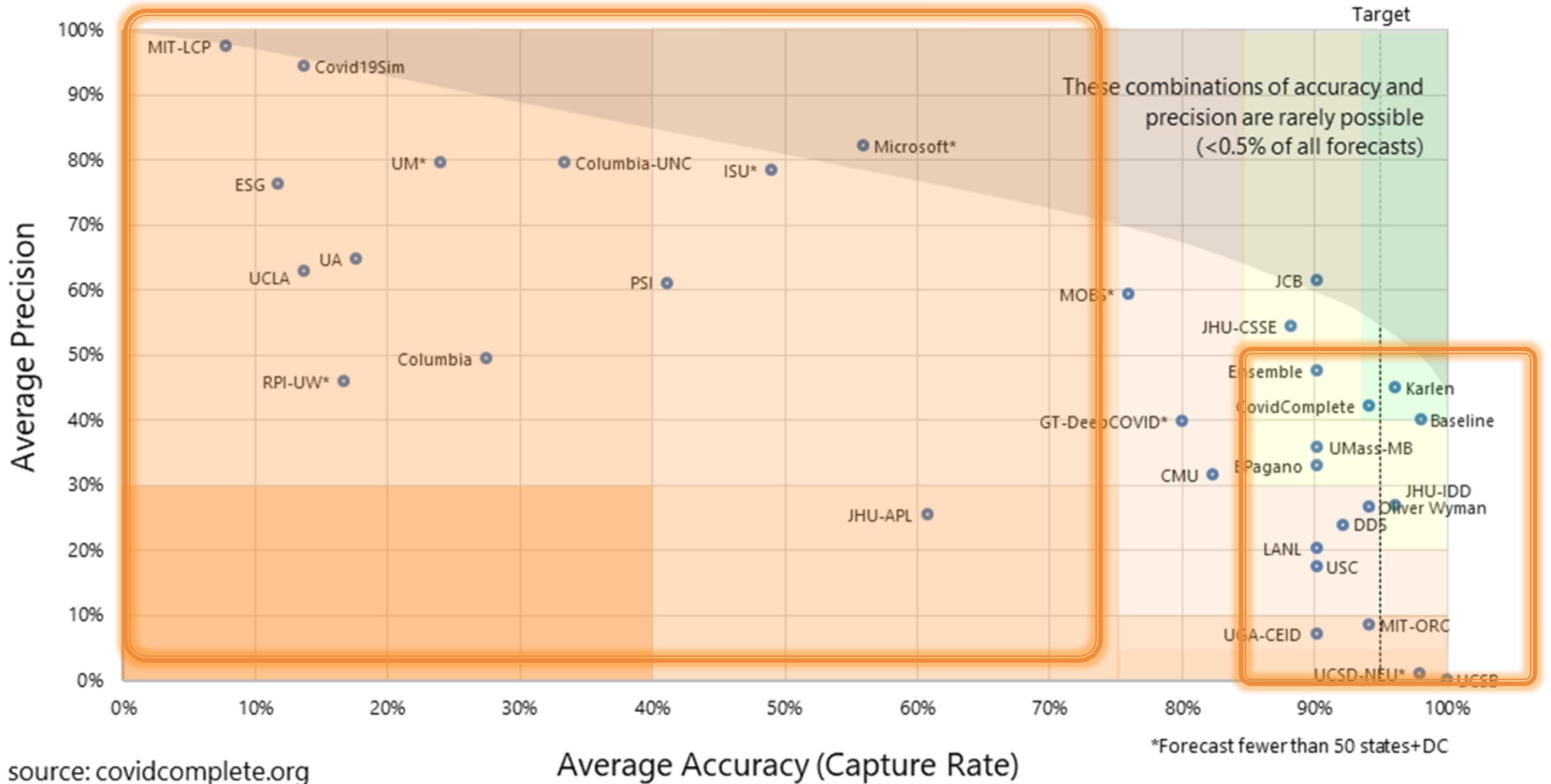


source: covidcomplete.org

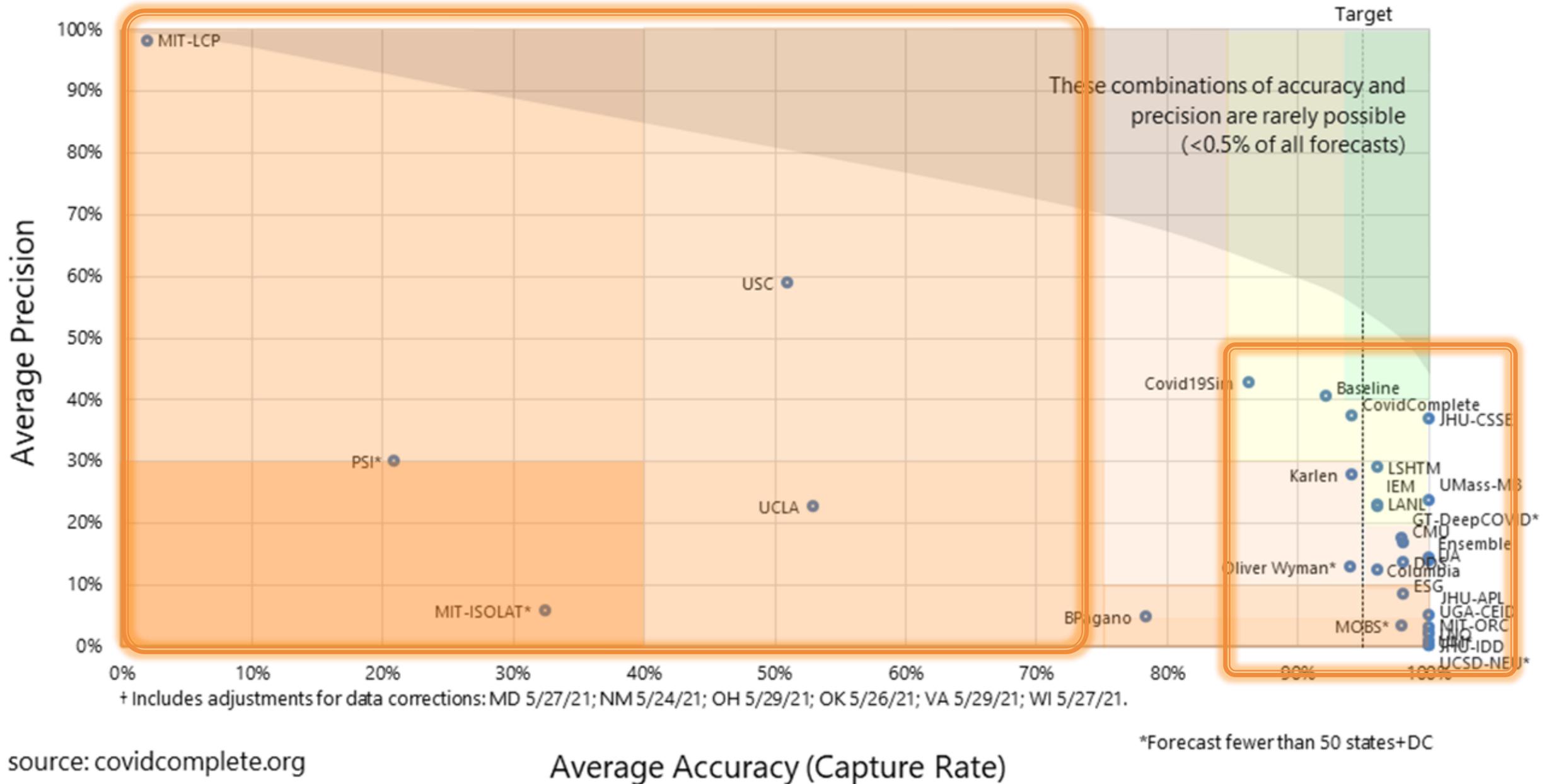
# This is what it looks like now



# Look at the improvement! (Past)



# Look at the improvement! (Present)





# Software Lesson Learned

## Close the Loop

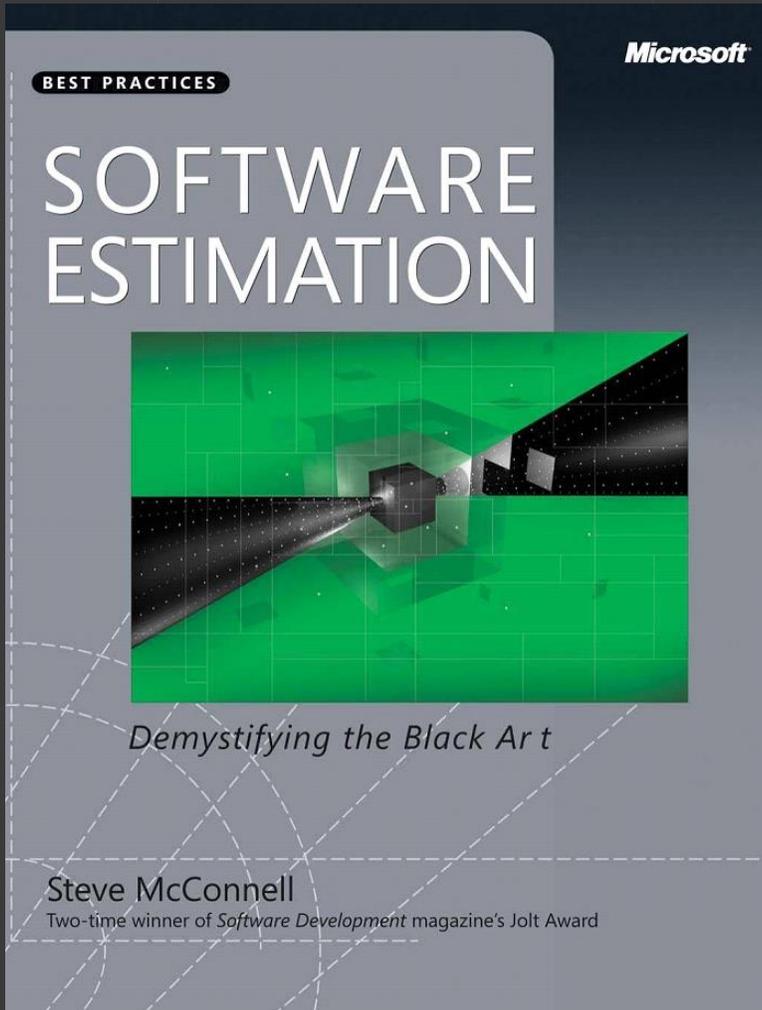
- Compare estimates to actuals—see how you did!
- When there are gaps, be sure you understand the reasons
- Iterate your estimation process based on this error feedback
- Inspect and adapt: this is arguably **the most important point** in this talk





# Summary

- ▣ Use historical data
- ▣ Keep “control knobs” to a minimum
- ▣ Accuracy first, precision second
- ▣ Understand the variability in your data
- ▣ Minimize differences between reporting and ground truth
- ▣ Close the loop



# Background on Much of This is in My Estimation Book



# Useful Links

## Covid-19 Resources

- SteveM's Covid-19 Data Center  
<https://www.stevemcconnell.com/covid>
- SteveM's Covid-19 Forecast Model Evaluations  
<https://github.com/stevemcconnell/covid19-forecast-evaluations>
- SteveM's detailed articles on Medium  
<https://stevemcc.medium.com/>
- CDC forecast hub  
<https://viz.covid19forecasthub.org/>

## Software Estimation Resources

- SteveM's website (link to SteveM's estimation book)  
<https://www.stevemcconnell.com/>
- Construx's website—resources, online virtual classes, elearning classes  
<https://www.construx.com/>

# — Discussion