COVID-19 **ForecastHub**

The COVID-19 Forecast Hub: a collaborative effort to produce short-term forecasts of COVID-19 severity

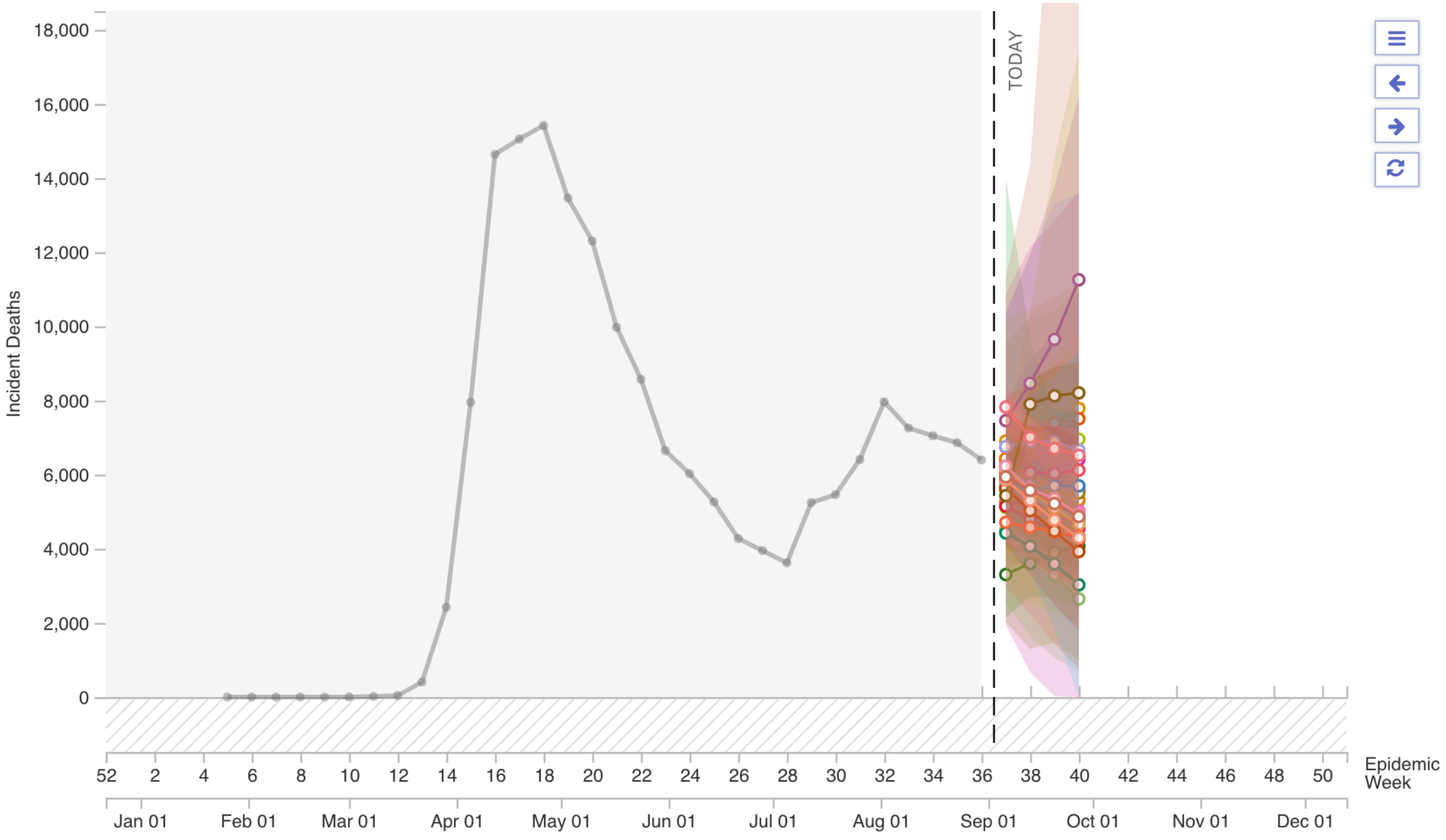
Evan L. Ray

6 April 2021

https://covid19forecasthub.org/

Demo Visualization

https://viz.covid19forecasthub.org/



Central goals of the Hub

1. Provide decision-makers and general public with reliable information about where the pandemic is headed in the next month.

2. Assess reliability of forecasts and gain insight into which modeling approaches do well.

3. Create a community of infectious disease modelers underpinned by an open-science ethos.

Individual models vary

roughly ordered by date of first submission

- IHME-CurveFit: "**hybrid modeling approach** to generate our forecasts, which incorporates elements of statistical and disease transmission models."

- YYG-ParamSearch: "**machine learning** techniques on top of a **classic infectious disease model** to make projections for infections and deaths."

- MOBS-GLEAM_COVID: "The GLEAM framework is based on **a metapopulation approach** in which the world is divided into geographical subpopulations. Human **mobility between subpopulations is represented on a network**."

- UMass-MechBayes: "**classical compartmental models from epidemiology**, prior distributions on parameters, models for time-varying dynamics, models for partial/noisy observations of confirmed cases and deaths."

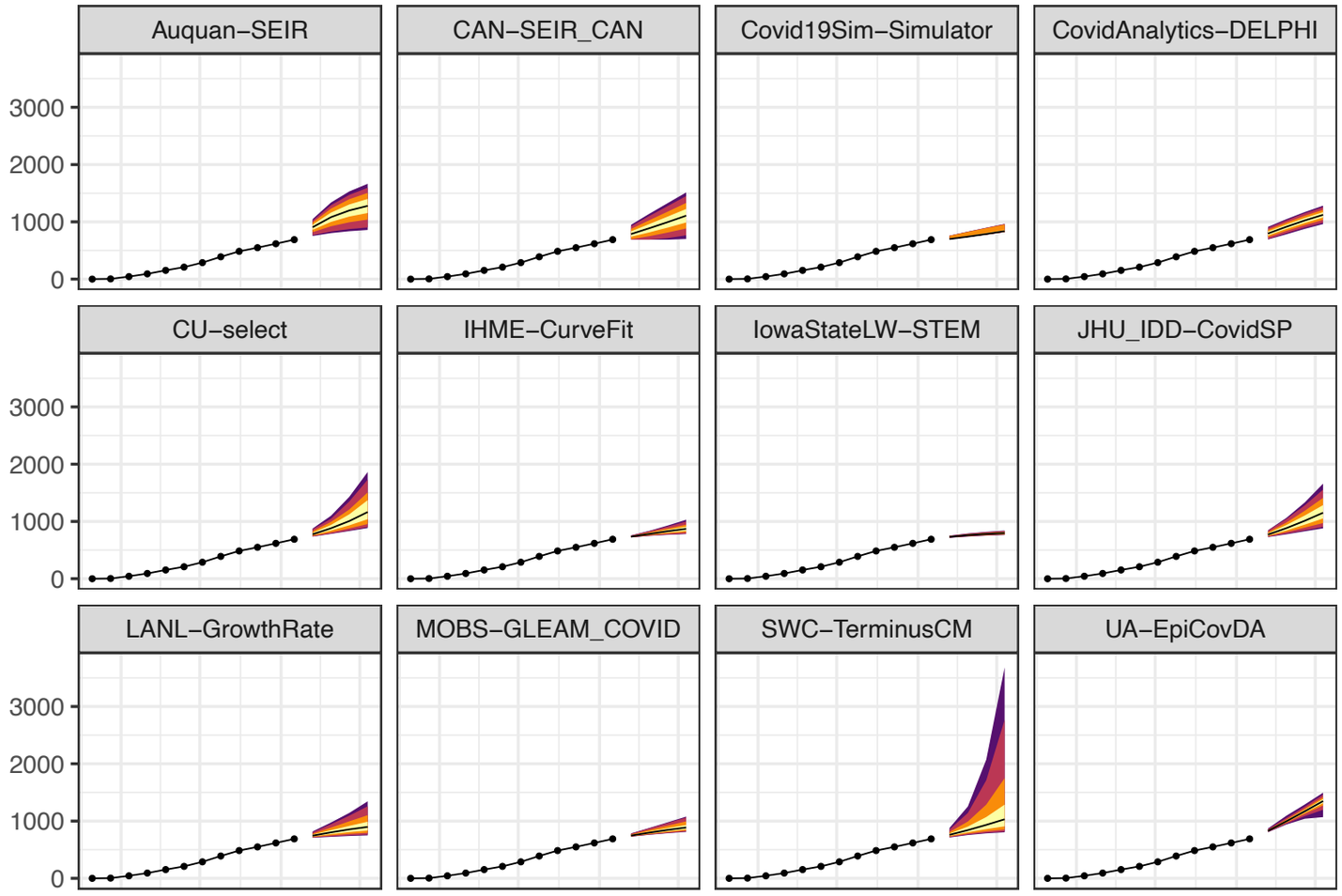
- UT-Mobility: "For each US state, **we use local data from mobile-phone GPS traces** made available by [SafeGraph] to quantify the changing impact of social-distancing measures on 'flattening the curve.' "

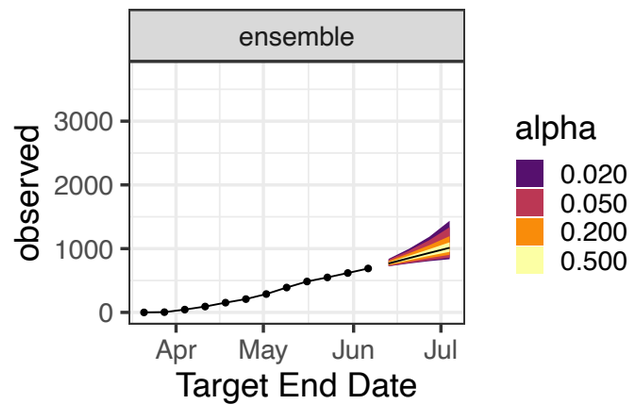
- GT-DeepCOVID: "This **data-driven deep learning model** learns the dependence of hospitalization and mortality rate on various detailed syndromic, demographic, mobility and clinical data."

- Google Cloud AI: "a novel approach that integrates **machine learning** into **compartmental disease modeling** to predict the progression of COVID-19"

- Facebook AI: "**recurrent neural networks** with a vector autoregressive model and train the joint model with a specific regularization scheme that increases the **coupling between regions**"

A "Hub" enables model synthesis





- Consistent finding across numerous settings:

  Combining models into an "ensemble" provides more consistent forecasts than any single model.

  Flu: Reich et al. 2019, *PLOS Comp Bio*.
  Flu: McGowan et al. 2019, *Sci Rep*.
  Dengue: Johansson et al. 2019, *PNAS*.
  Ebola: Viboud et al. 2018, *Epidemics*.

Evaluation (Top 5 models by MAE)

- **Mean Absolute Error (MAE)**: On average, how far was the prediction from the eventually observed data?
  - For context, we display relative to a baseline that predicts constant incidence equal to the most recent reported value
- **95% Coverage Rate**: What proportion of the time do 95% prediction intervals include the eventually observed data?

Cases

model	rel. MAE	95% cov.
LNQ-ens1	0.85	0.96
COVIDhub-ensemble	0.93	0.77
COVIDhub-baseline	1.00	0.68
CEID-Walk	1.03	0.68
LANL-GrowthRate	1.04	0.85

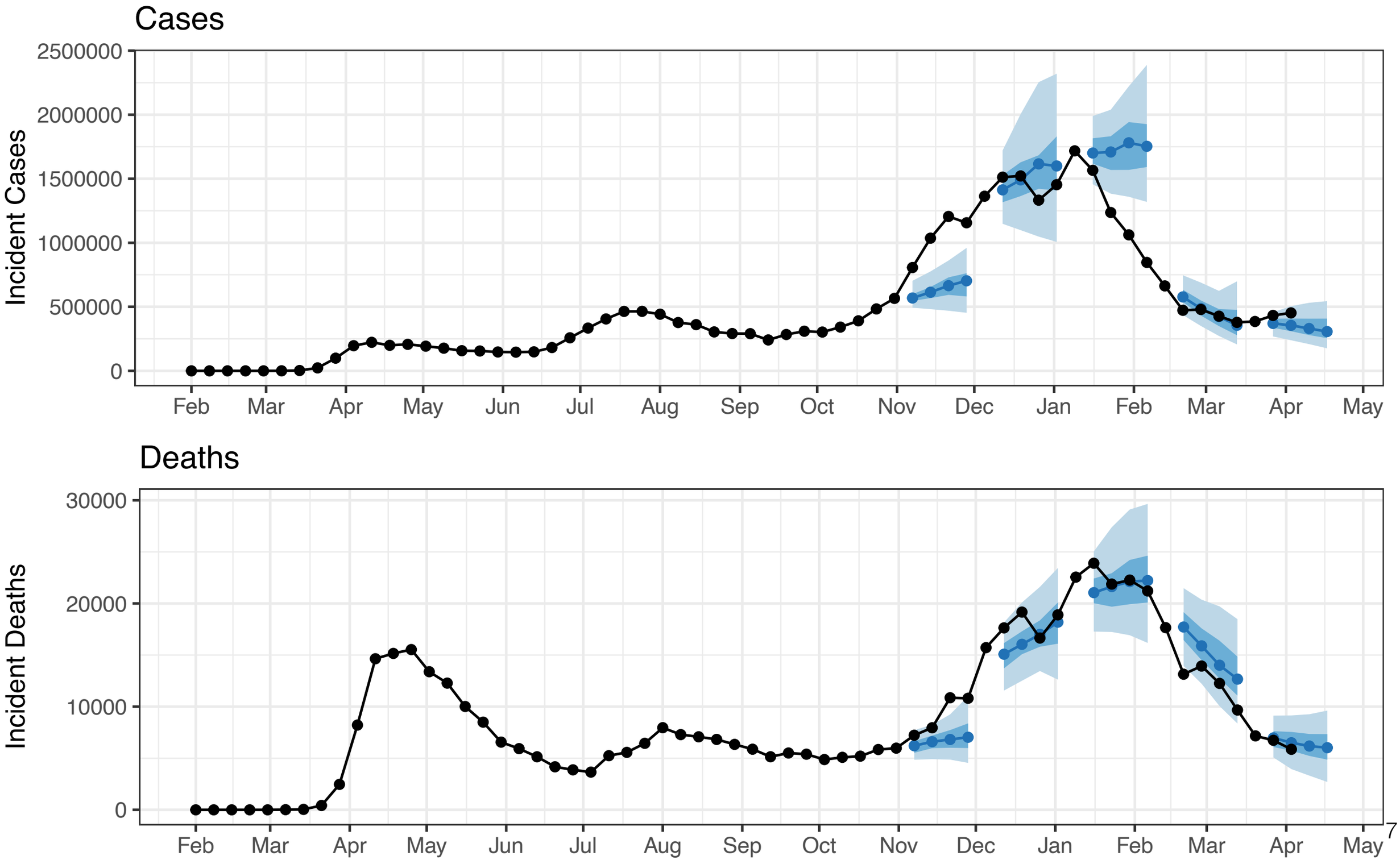
Deaths

model	rel. MAE	95% cov.
COVIDhub-ensemble	0.68	0.87
UMass-MechBayes	0.77	0.95
LNQ-ens1	0.77	0.99
OliverWyman-Navigator	0.78	0.85
Karlen-pypm	0.85	0.83

- Overall, performance is better for deaths than for cases
- Ensemble is among the best models for both targets
- Interval coverage rates are a little lower than we'd like

Ensemble Forecasts Over Time

US national level forecasts generated on
2020-11-02, 2020-12-07, 2021-01-11, 2021-02-15, and 2021-03-22



Weekly reports from the Hub

Summary

COVID-19 ForecastHub

Home Data Community About GitHub

Weekly Forecast Summaries

Browse the archive

State: US Date: 2021-02-16 Submit

- Background
- COVID-19 Mortality Forecasts
  - National level
  - State level

COVID-19 US Weekly Forecast Summary

The COVID-19 Forecast Hub Team

https://covid19forecasthub.org/

report generated 2021-02-17

Background

This report provides a brief summary of the weekly ensemble forecast from the COVID-19 Forecast Hub based on forecasts submitted on February 15, 2021. In collaboration with the US CDC, our team aggregates COVID-19 forecasts from dozens of teams around the globe. Typically on Wednesday of each week, a summary of the week's forecasts from the COVID-19 Forecast Hub appear on the official CDC COVID-19 forecasting page.

Every week, teams submit their forecasts to the COVID-19 Forecast Hub. This past week, 59 models were submitted.

Each Monday evening or Tuesday morning, we combine the most recent forecasts from each team into a single "ensemble" forecast of reported COVID-19 cases at the county, state, and national level and deaths at the state and national level. At the moment, we only generate ensemble forecasts for four weeks into the future, as the available evidence suggests that models are less accurate at longer forecast horizons.

An archive of weekly reports from the COVID-19 Forecast Hub can be found at this page.

COVID-19 Mortality Forecasts

National level

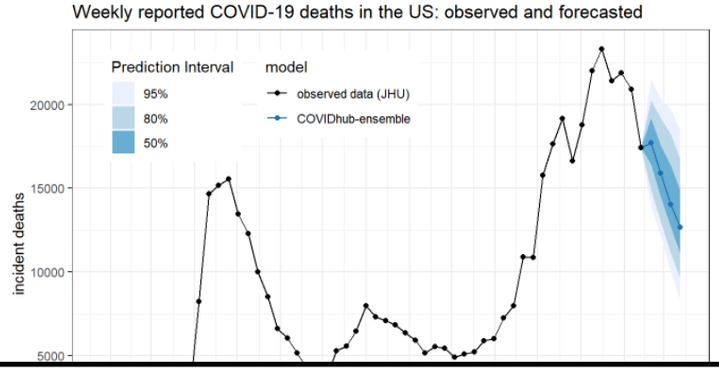
This week, our ensemble combined forecasts from 45 different models.

At the national level, the ensemble model predicts that weekly totals of observed deaths in each of the next four weeks will be between 12,700 and 17,700 deaths (Figure 1) with around 543,900 deaths by March 13 (95% prediction interval: 530,439 - 559,454).

For the week ending March 13, the ensemble forecasts that reported COVID-19 deaths in the US will be between 8,400 and 18,500 (95% prediction interval: 8,358 - 18,474).

You can explore the full set of models, including their forecasts for past weeks online at our interactive forecast visualization.

Weekly reported COVID-19 deaths in the US: observed and forecasted



Evaluation

COVID-19 ForecastHub

- Overview
- Incident Case Forecasts
- Incident Death Forecasts

COVID-19 US Forecast Evaluation Report

US COVID-19 Forecast Hub and Delphi Group Forecast Evaluation Working Group

(alphabetical order) Jacob Bien, Johannes Bracher, Logan C Brooks, Estee Y Cramer, Jed Grabman, Kate Harwood, Evan L Ray, Nicholas G Reich, Chris Scott

February 15, 2021

Overview

This report provides an evaluation of the accuracy and precision of probabilistic forecasts of COVID-19 cases and deaths submitted to the US COVID-19 Forecast Hub. Some analyses include forecasts submitted starting in April 2020. Others focus on evaluating "recent" forecasts, submitted only in the last 10 weeks.

In collaboration with the US Centers for Disease Control and Prevention (CDC), the COVID-19 Forecast hub collects short-term COVID-19 forecasts from dozens of research groups around the globe. Every Tuesday morning we combine the most recent forecasts from each team into a single "ensemble" forecast for each of the target submissions. This forecast is used as the official ensemble forecast of the CDC, typically appearing on their forecasting website on Wednesday.

Incident Case Forecasts

Summary Tables | WIS components | Evaluation by Week | Evaluation by location | Observed data

The first table evaluates models based on their adjusted relative weighted interval scores (WIS, a measure of distributional accuracy), and adjusted relative mean absolute error (MAE). Scores are aggregated separately for the most recent 10 weeks and for all historical weeks. To account for the variation in difficult of forecasting different weeks and locations, a pairwise approach was used to calculated the relative adjusted WIS and MAE. Models with relative scores lower than 1 have been more accurate than the baseline on average, whereas relative scores greater than 1 indicate less accuracy than baseline on average.

The second table evaluates models based on their prediction interval coverage at the 50% and 95% levels. Scores are aggregated seperately for the most recent 10 weeks and for all historical weeks.

Inclusion criteria for each column are detailed below the table.

Accuracy Table | Coverage Table

Show 5 entries Search:

Model	n recent forecasts	Recent rel WIS	Recent rel MAE	n historical forecasts	Historical rel WIS	Historical rel MAE
All	All	All	All	All	All	All
LNQ-ens1	2280	0.7	0.87	6722	0.68	0.85
COVIDhub-ensemble	2280	0.72	0.9	6494	0.81	0.93
LANL-GrowthRate	2160	0.76	0.96	6588	0.85	1.04
CEID-Walk	2109	0.89	1.02	5643	0.97	1.03
JHU_IDD-CovidSP	2280	0.81	1.04	6678	0.99	1.2

Showing 1 to 5 of 27 entries Previous 1 2 3 4 5 6 Next

https://covid19forecasthub.org/doc/reports/

COVID-19 **ForecastHub**

- Forecast data from the COVID-19 Forecast Hub is shared directly with the CDC, and published on the CDC website weekly.

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

COVID-19 Forecasts: Deaths

Updated Nov. 19, 2020 Print

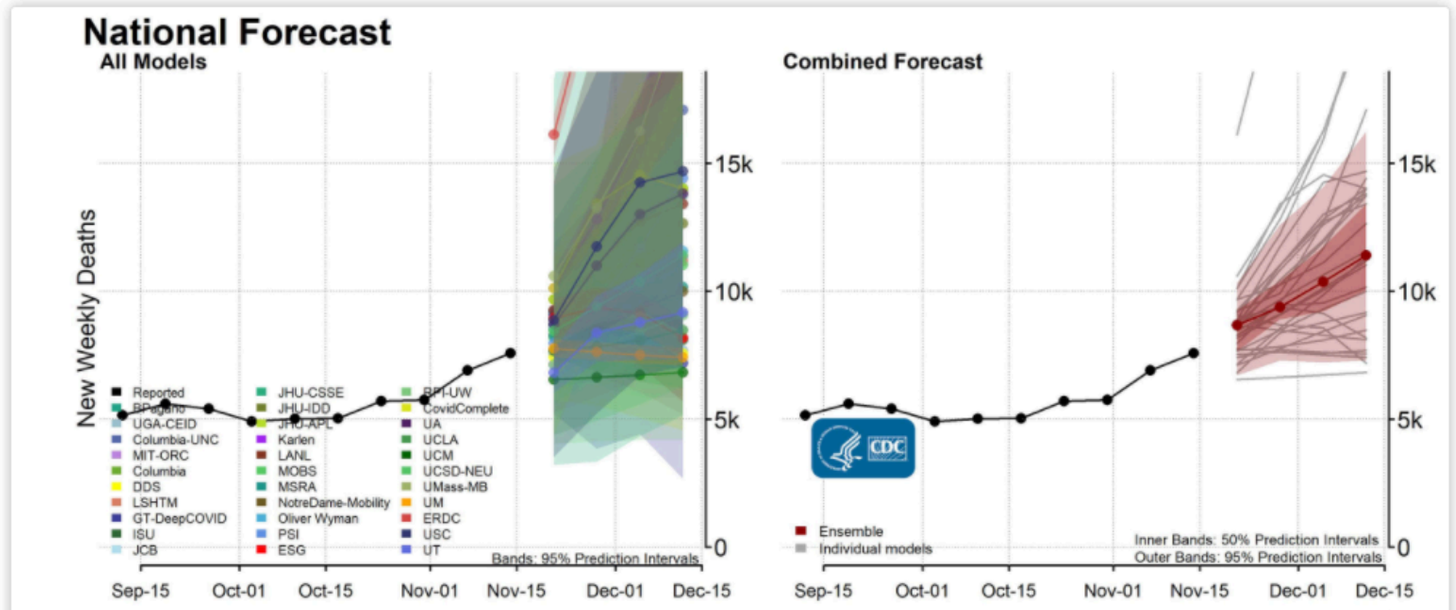
Observed and forecasted new and total reported COVID-19 deaths as of November 16, 2020.

Interpretation of Forecasts of New and Total Deaths

On This Page
- National Forecast
- State Forecasts
- Ensemble Forecast
- Forecast Assumptions

- This week CDC received forecasts of COVID-19 deaths over the next 4 weeks from 36 modeling groups that were included in the ensemble forecast. Of the 36 groups, 33 provided forecasts for both new and total deaths, two groups forecasted total deaths only, and one forecasted new death only.
- This week's national ensemble forecast predicts that the number of newly reported COVID-19 deaths will likely increase over the next four weeks, with 7,300 to 16,000 new deaths likely to be reported in the week ending December 12, 2020. The national ensemble predicts that a total of 276,000 to 298,000 COVID-19 deaths will be reported by this date.
- The state- and territory-level ensemble forecasts predict that over the next 4 weeks, the number of newly reported deaths per week will likely increase in 36 jurisdictions, which are indicated in the forecast plots below. Trends in numbers of future reported deaths are uncertain or predicted to remain stable in the other states and territories.

National Forecast



https://www.cdc.gov/coronavirus/2019-ncov/covid-data/mathematical-modeling.html

COVID-19
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https://covid19forecasthub.org/

Hub Citations (https://covid19forecasthub.org/doc/research/)

- Cramer EY, Ray EL, Lopez VK, et al. “Evaluation of individual and ensemble probabilistic forecasts of COVID-19 mortality in the US.” 2021. *medRxiv*. (preprint). https://www.medrxiv.org/content/10.1101/2021.02.03.21250974v1

- Bracher J, Ray EL, Gneiting T, Reich NG. “Evaluating epidemic forecasts in an interval format.” 2021. *PLOS Comp Bio:* 17 (2), e1008618. https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1008618

- NG Reich, M Cornell, EL Ray, K House, K Le. The Zoltar forecast archive, a tool to standardize and store interdisciplinary prediction research. 2021. *Scientific Data:* 8 (1), 1-11. https://www.nature.com/articles/s41597-021-00839-5

- Logan C. Brooks, Evan L. Ray, Jacob Bien, Johannes Bracher, Aaron Rumack, Ryan J. Tibshirani, Nicholas G. Reich. “Comparing ensemble approaches for short-term probabilistic COVID-19 forecasts in the U.S.” 2020. International Institute of Forecasters Blog. https://forecasters.org/blog/2020/10/28/comparing-ensemble-approaches-for-short-term-probabilistic-covid-19-forecasts-in-the-u-s/

- Evan L Ray, Nutcha Wattanachit, et al. “Ensemble Forecasts of Coronavirus Disease 2019 (COVID-19) in the U.S.” 2020. *medRxiv*. (preprint) https://www.medrxiv.org/content/10.1101/2020.08.19.20177493v1

Thanks!

COVID-19 ForecastHub

Acknowledgments to:

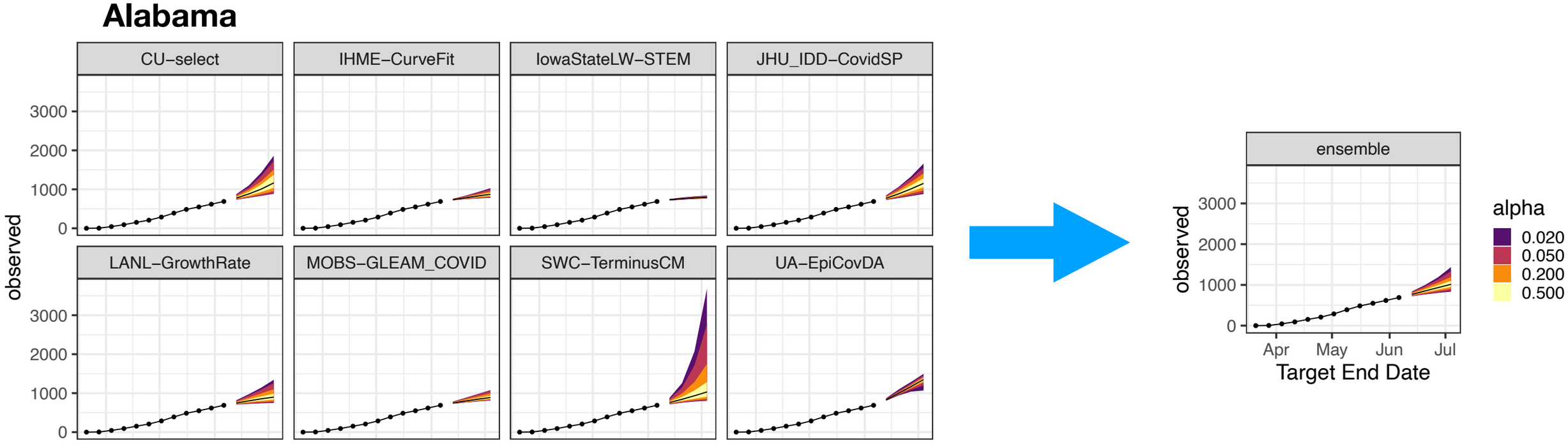
Team: Martha Zorn, Nutcha Wattanachit, Serena Wang, Ariane Stark, Apurv Shah, **Nicholas Reich**, Evan Ray, Jarad Niemi, Khoa Le, Abdul Kanji, Dasuni Jayawardena, Yuxin Huang, Katie House, Aaron Gerding, Estee Cramer, Matt Cornell, Alvaro J. Castro Rivadeneira, Andrea Brennen, Johannes Bracher
* underline denotes ensemble contributor

US CDC Collaborators: Matthew Biggerstaff, Michael Johansson, Velma Lopez, Rachel Slayton, Jo Walker

Ensemble “advisors": Jacob Bien, Logan Brooks, Sebastian Funk, Tilmann Gneiting, Anja Muhlemann, Aaron Rumack, Ryan Tibshirani

Modeling groups: Over 80 (!!) groups at various institutions have contributed forecasts to the hub

Building the Ensemble: View 1



- For each combination of spatial unit s, time point t, and forecast horizon h, teams are required to submit K=23 quantiles of a predictive distribution:

$$\widehat{P}(Y \le q^m_{s,t,h,1}) = 0.01,\ \widehat{P}(Y \le q^m_{s,t,h,2}) = 0.025,\ \ldots,\ \widehat{P}(Y \le q^m_{s,t,h,12}) = 0.5,\ \ldots,\ \widehat{P}(Y \le q^m_{s,t,h,23}) = 0.99$$

The predictive median

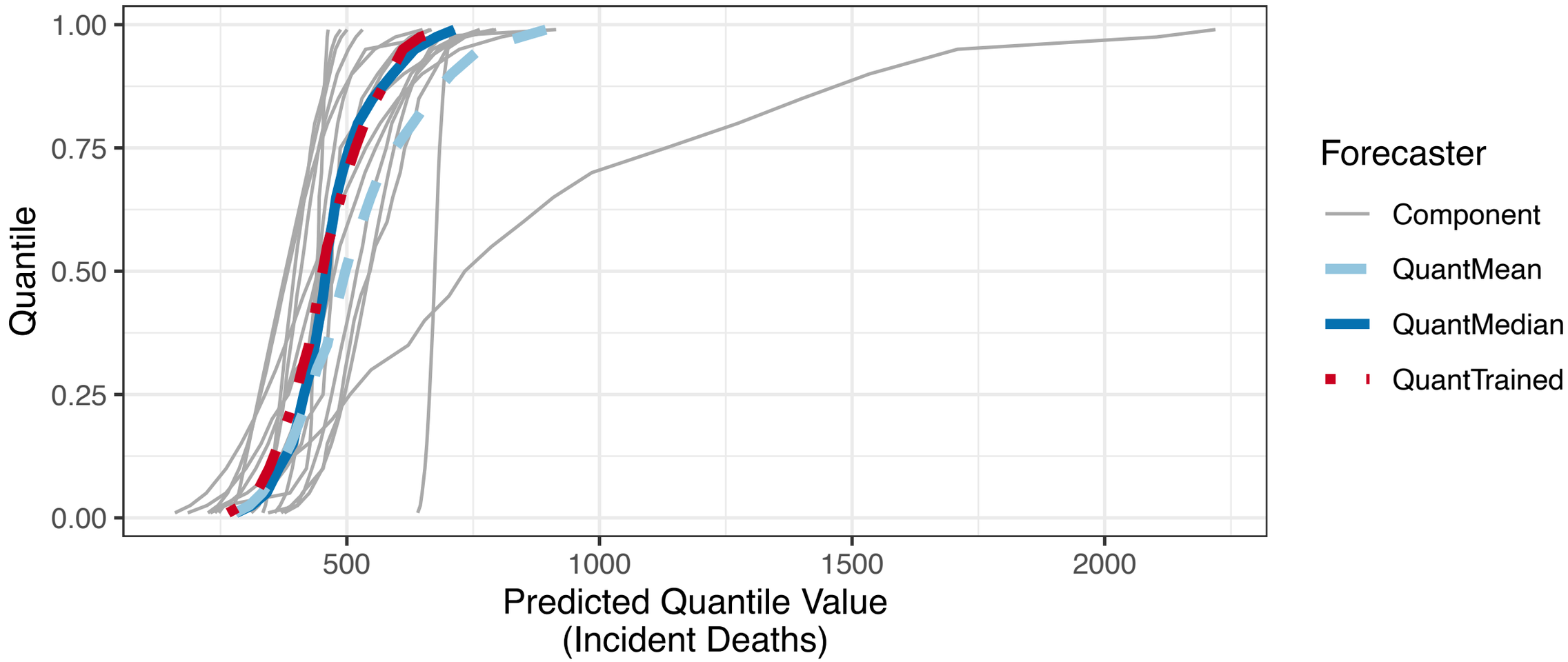
Limits of a 98% prediction interval

- The predictive quantiles for the ensemble are a combination of component predictions at each quantile level:

$$q_{s,t,h,k} = f(q^1_{s,t,h,k}, \ldots, q^M_{s,t,h,k}) \textbf{ for each } k = 1,\ldots,23$$

Building an Ensemble: View 2

- The pairs $\left(q^m_{s,t,h,k},\ \widehat{P}\left(Y^m_{s,t,h} \leq q^m_{s,t,h,k}\right)\right)$ fall along the predictive CDF for model m



- Three options for the combination function f:
  - QuantMean: $q_{s,t,h,k} = \frac{1}{M}\sum_{m=1}^{M} q^m_{s,t,h,k}$ **Used through July 21, 2020**
  - QuantMedian: $q_{s,t,h,k} = \textbf{median}(q^1_{s,t,h,k}, \ldots, q^M_{s,t,h,k})$ **Used starting July 28, 2020**
  - QuantTrained: $q_{s,t,h,k} = \beta^0_{t,h,k} + \sum_{m=1}^{M} \beta^m_{t,h,k} \cdot q^m_{s,t,h,k}$ **Evaluated, not released each week**

Hub ensemble is most consistent

Across 5,296 predictions it made, the ensemble is ranked in the top half of all forecasts for incident deaths over 75% of the time. No other model achieves this level of consistency.