COVID-19 ScenarioModelingHub

Flu ScenarioModelingHub

RSV ScenarioModelingHub

Scenario Modeling Hub: Update and future work

Justin Lessler and Cecile Viboud

IDM Annual Symposium 2024

PennState Huck Institutes of the Life Sciences

Infectious Disease DYNAMICS

University of Massachusetts Amherst

NIH Fogarty

INTERNATIONAL VACCINE ACCESS CENTER

MIDAS

University of Pittsburgh

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

UNIVERSITY of VIRGINIA BIOCOMPLEXITY INSTITUTE

USC University of Southern California

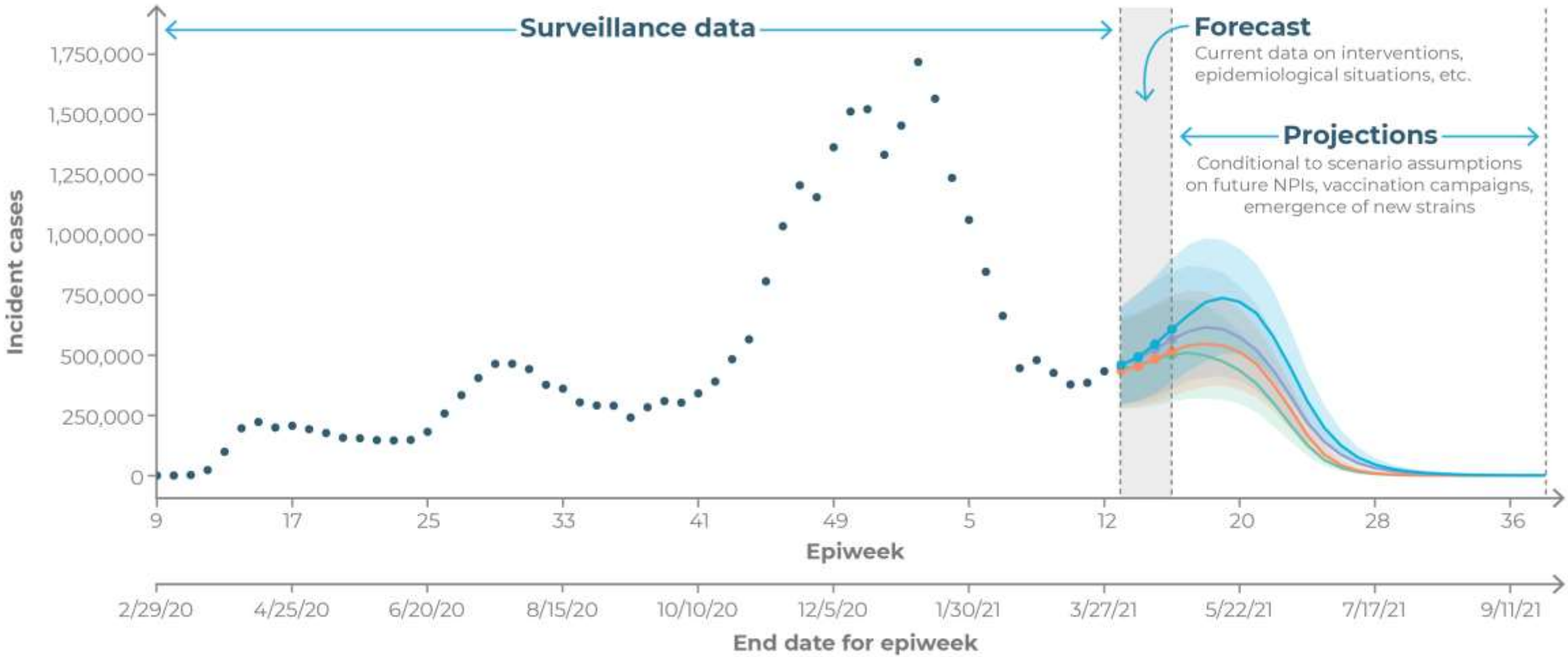
MOBS LAB

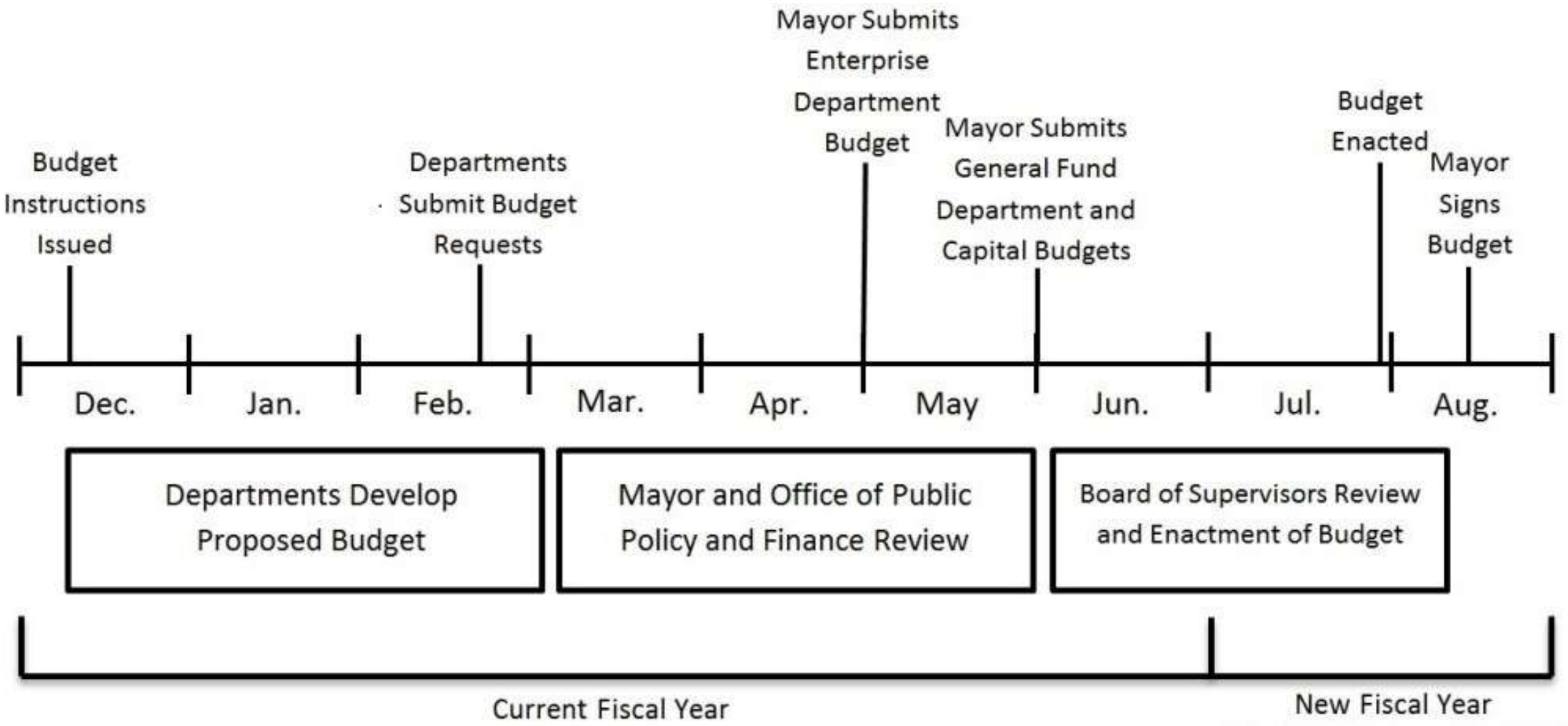
Northeastern University

University of Victoria

Why scenario modeling?

COVID-19 ScenarioModelingHub

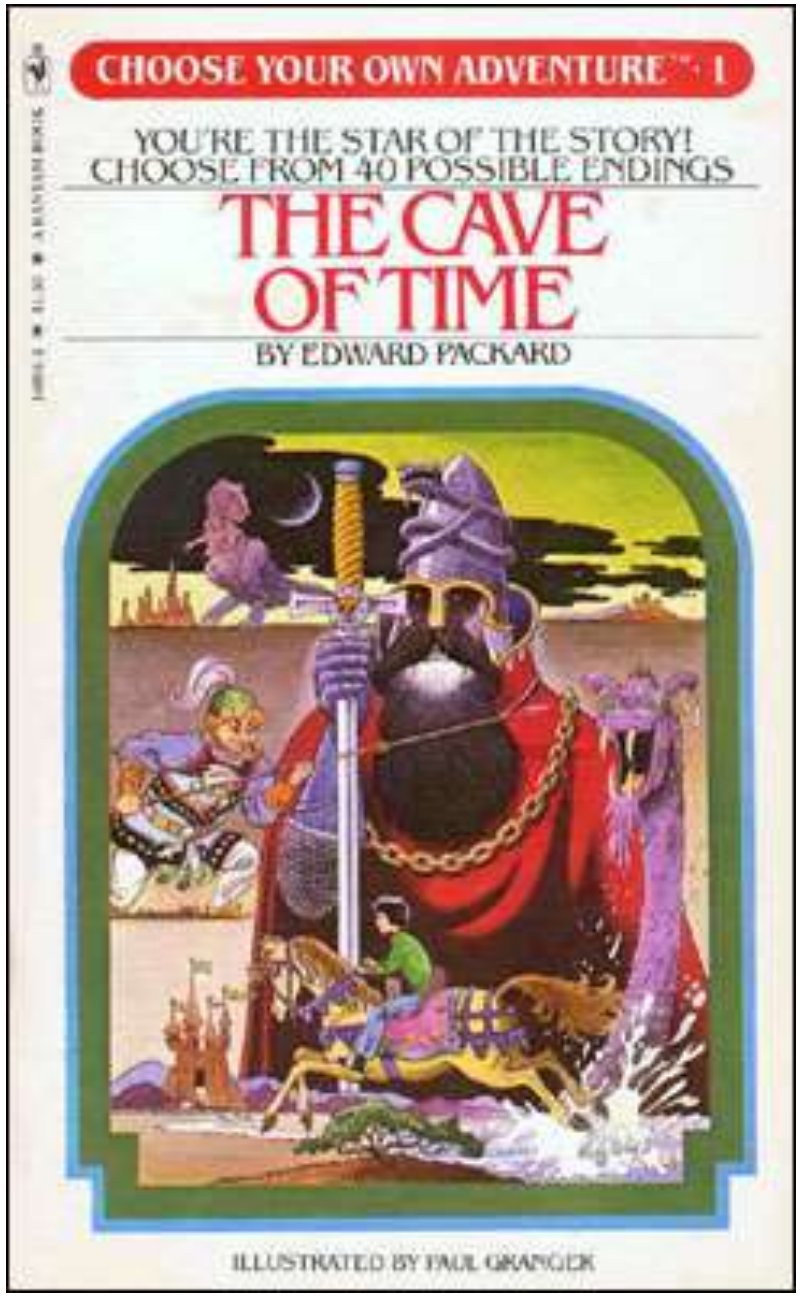


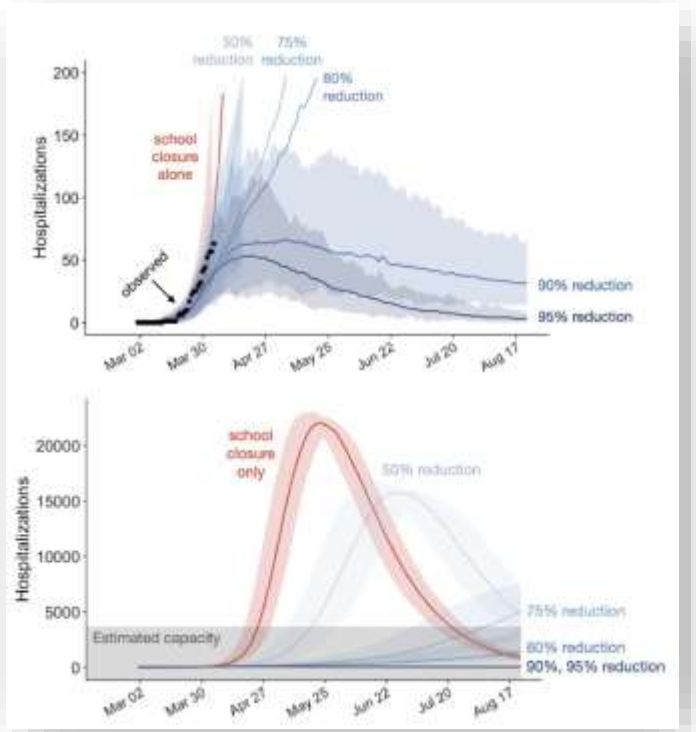


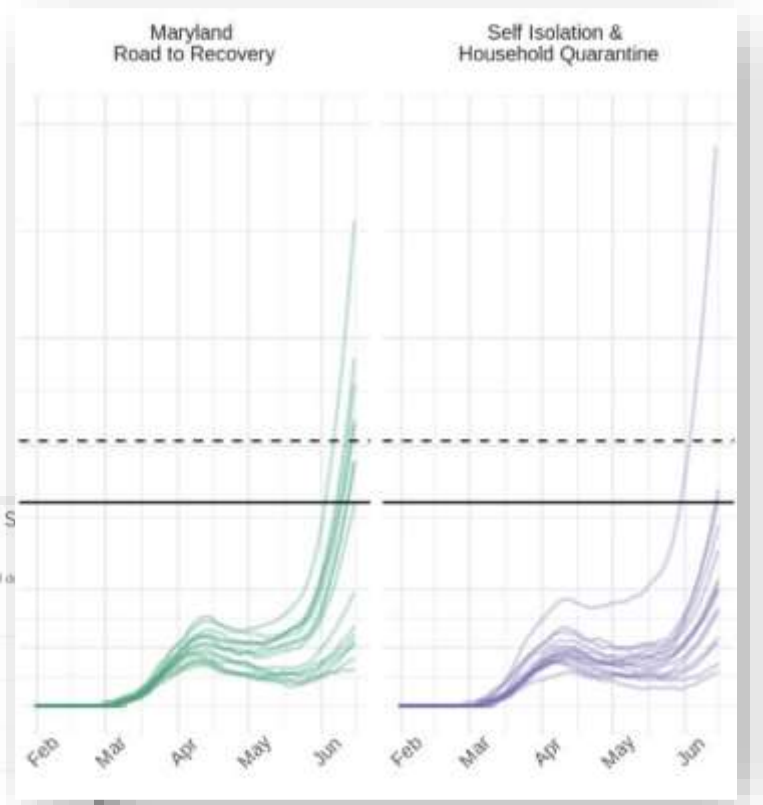
From: https://sfmayor.org/budget-cycle

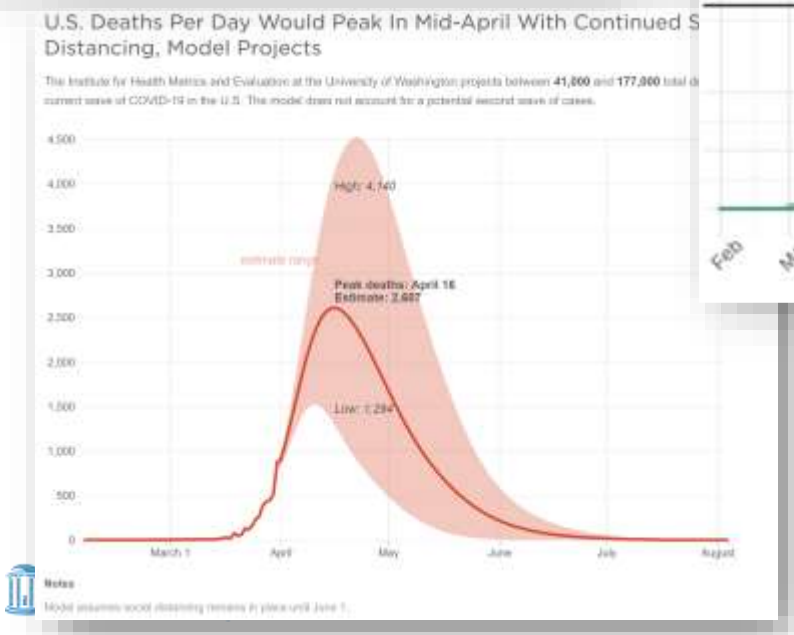
Why a Scenario Modeling **Hub?**

Reason 1: Comparing apples to apples.


CHOOSE YOUR OWN ADVENTURE™ 1
YOU'RE THE STAR OF THE STORY!
CHOOSE FROM 40 POSSIBLE ENDINGS
THE CAVE OF TIME
BY EDWARD PACKARD
ILLUSTRATED BY PAUL GRANGER


50% reduction
75% reduction
80% reduction
school closure alone
observed
90% reduction
95% reduction
Hospitalizations
school closure only
50% reduction
75% reduction
80% reduction
90%, 95% reduction
Estimated capacity
Mar 02
Mar 30
Apr 27
May 25
Jun 22
Jul 20
Aug 17


Maryland
Road to Recovery
Self Isolation &
Household Quarantine
Feb
Mar
Apr
May
Jun


U.S. Deaths Per Day Would Peak In Mid-April With Continued S
Distancing, Model Projects
High: 4,140
Peak deaths: April 16
Low: 1,294
March 1
April
May
June
July
August
Notes

Reason 2: Harnessing the power of the ensemble

“ridiculously overconfident and wildly unreliable”

Tilmann Gneiting

In: All together now: the most trustworthy covid-19 model is an ensemble | MIT Technology Review

- b

Tropical Storm Helene
Tuesday September 24, 2024
11 AM EDT Advisory 5
NWS National Hurricane Center

Current information: ×
Center location 19.5 N 84.3 W
Maximum sustained wind 45 mph
Movement NW at 12 mph

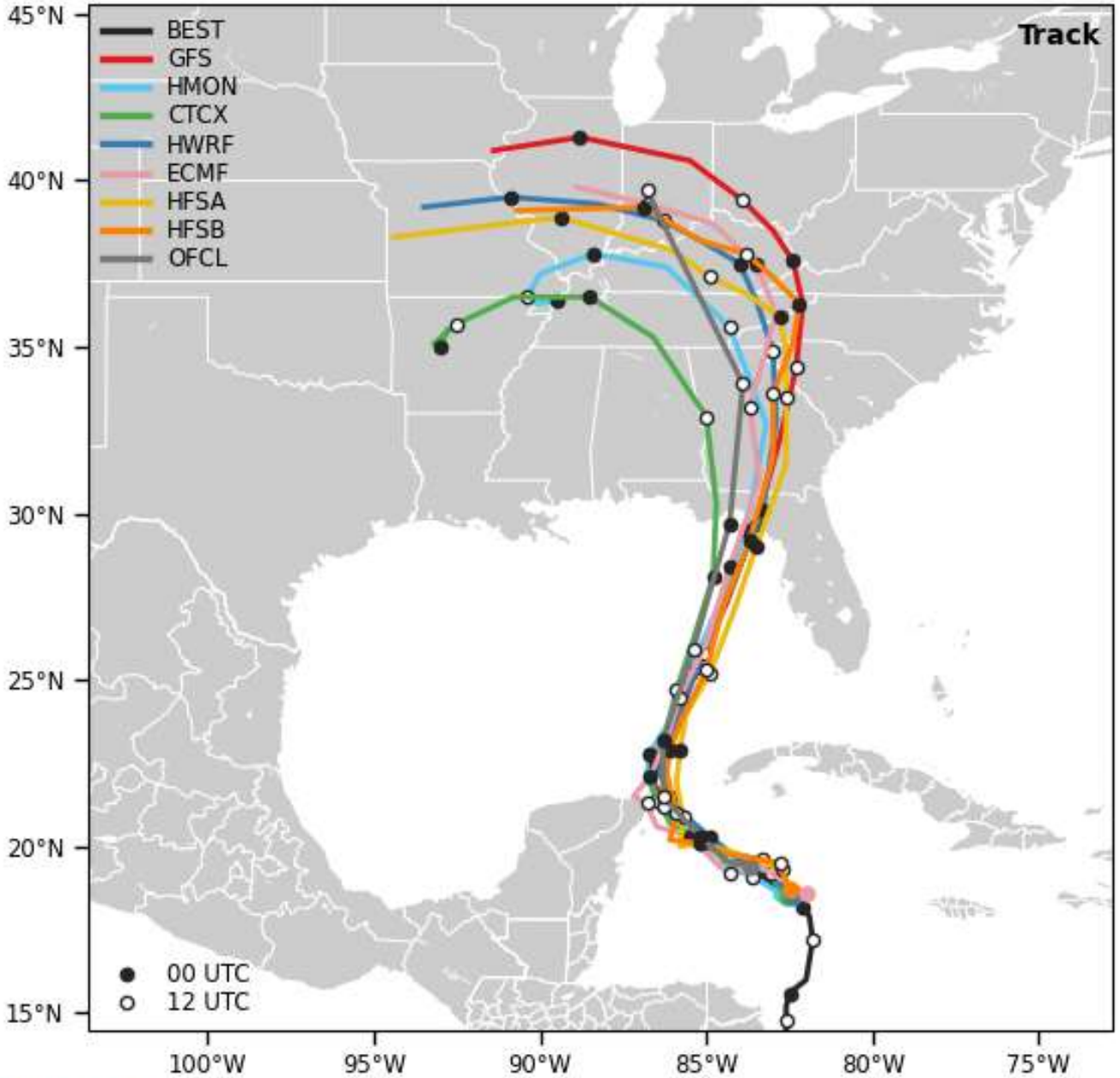
Forecast positions:
● Tropical Cyclone ○ Post/Potential TC
Sustained winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110 mph

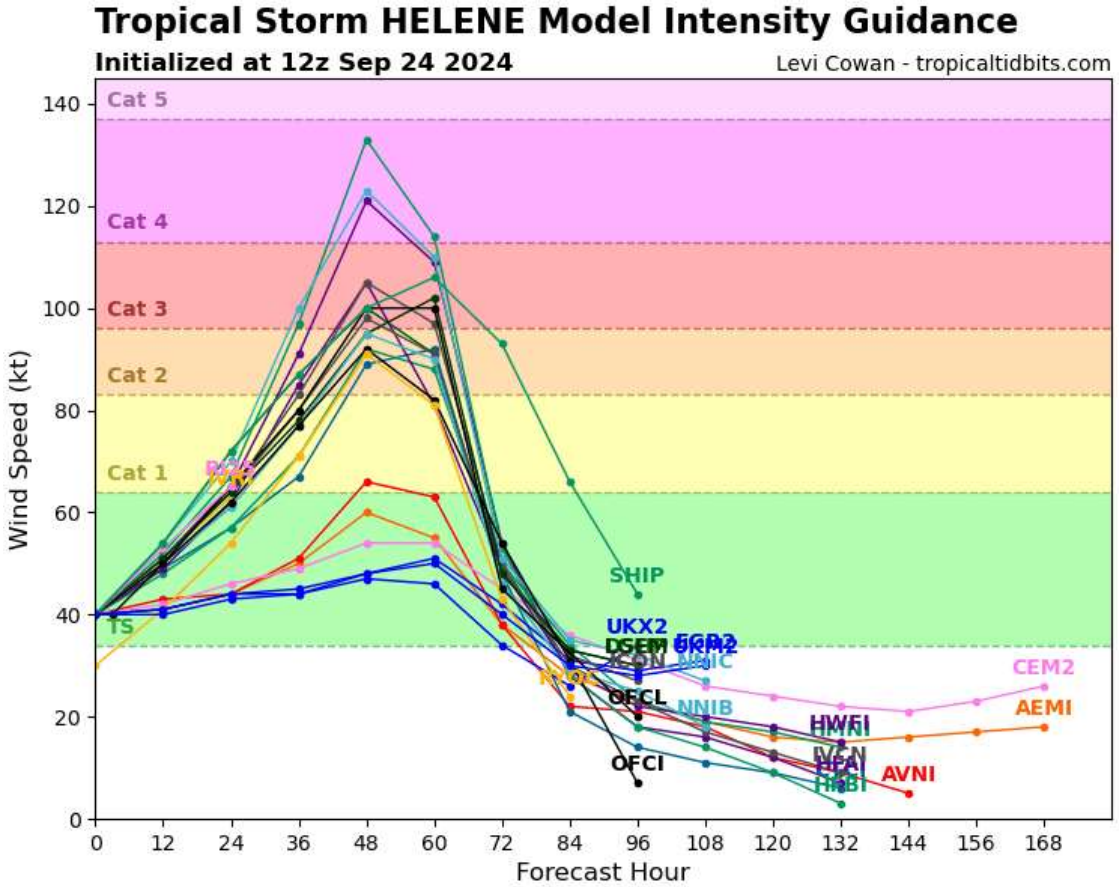
Potential track area: Day 1-3

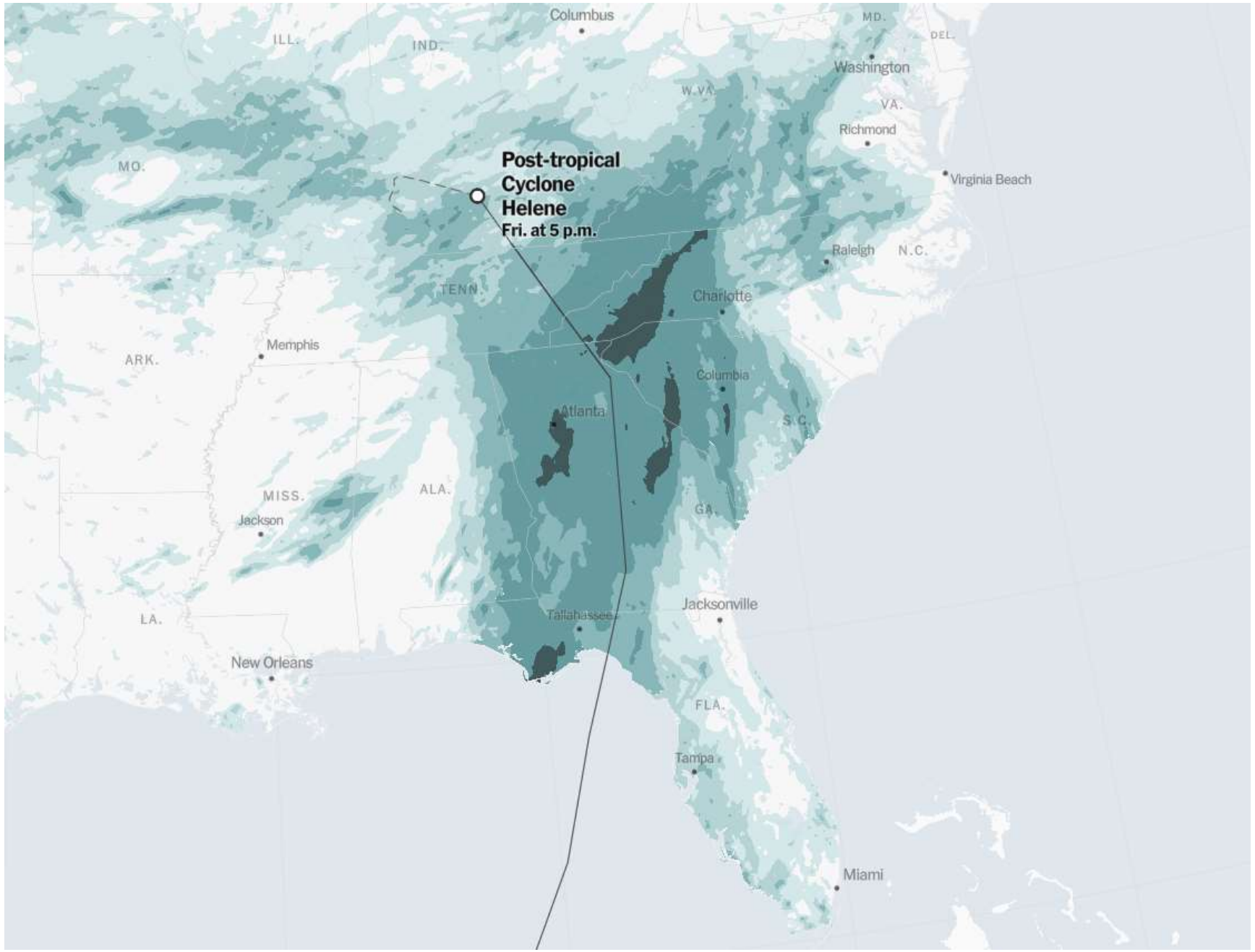
Watches: Hurricane, Trop Stm

Warnings: Hurricane, Trop Stm

Current wind field estimate: Hurricane, Trop Stm

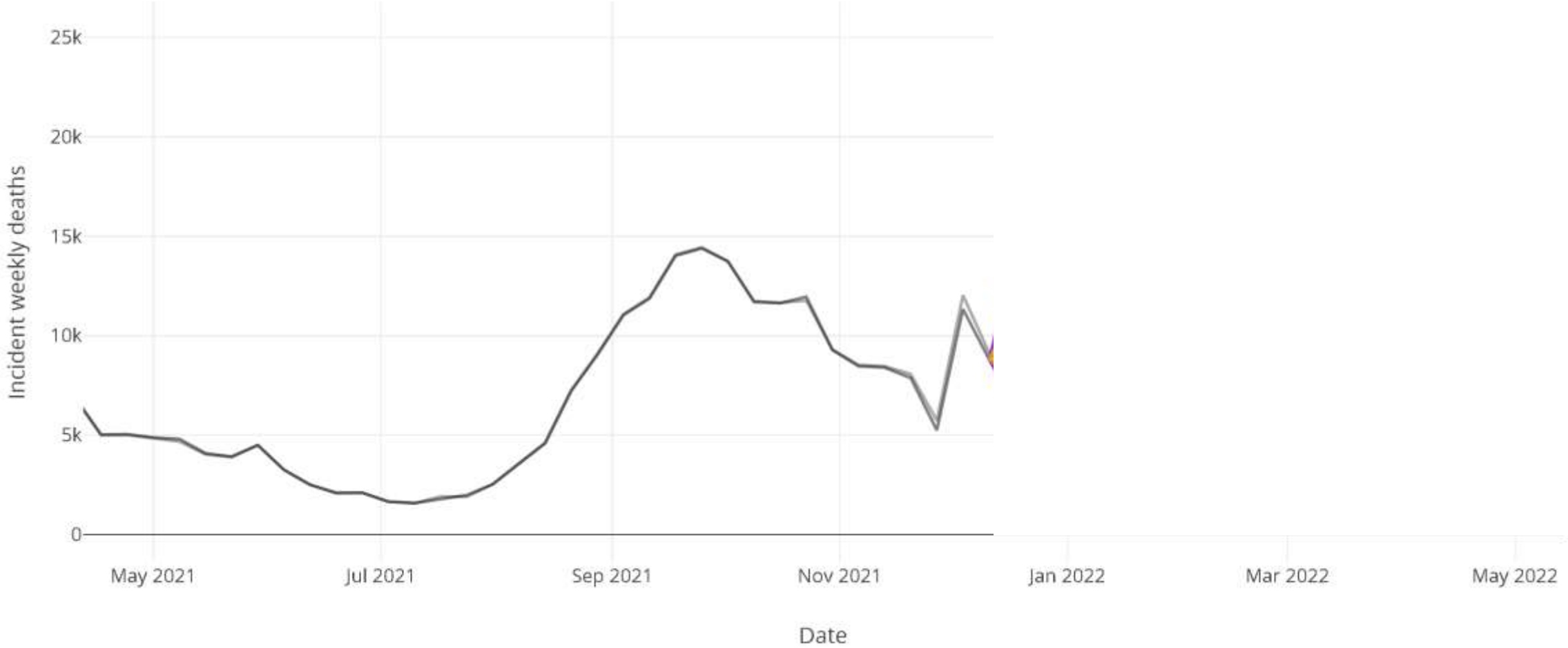

Track
BEST
GFS
HMON
CTCX
HWRF
ECMF
HFSA
HFSB
OFCL
00 UTC
12 UTC
45°N
40°N
35°N
30°N
25°N
20°N
15°N
100°W
95°W
90°W
85°W
80°W
75°W


Tropical Storm HELENE Model Intensity Guidance
Initialized at 12z Sep 24 2024
Levi Cowan - tropicaltidbits.com
Wind Speed (kt)
Forecast Hour
Cat 5
Cat 4
Cat 3
Cat 2
Cat 1
SHIP
UKX2
OFCL
NNIB
HWFI
AVNI
OFCI
CEM2
AEMI
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
20
40
60
80
100
120
140

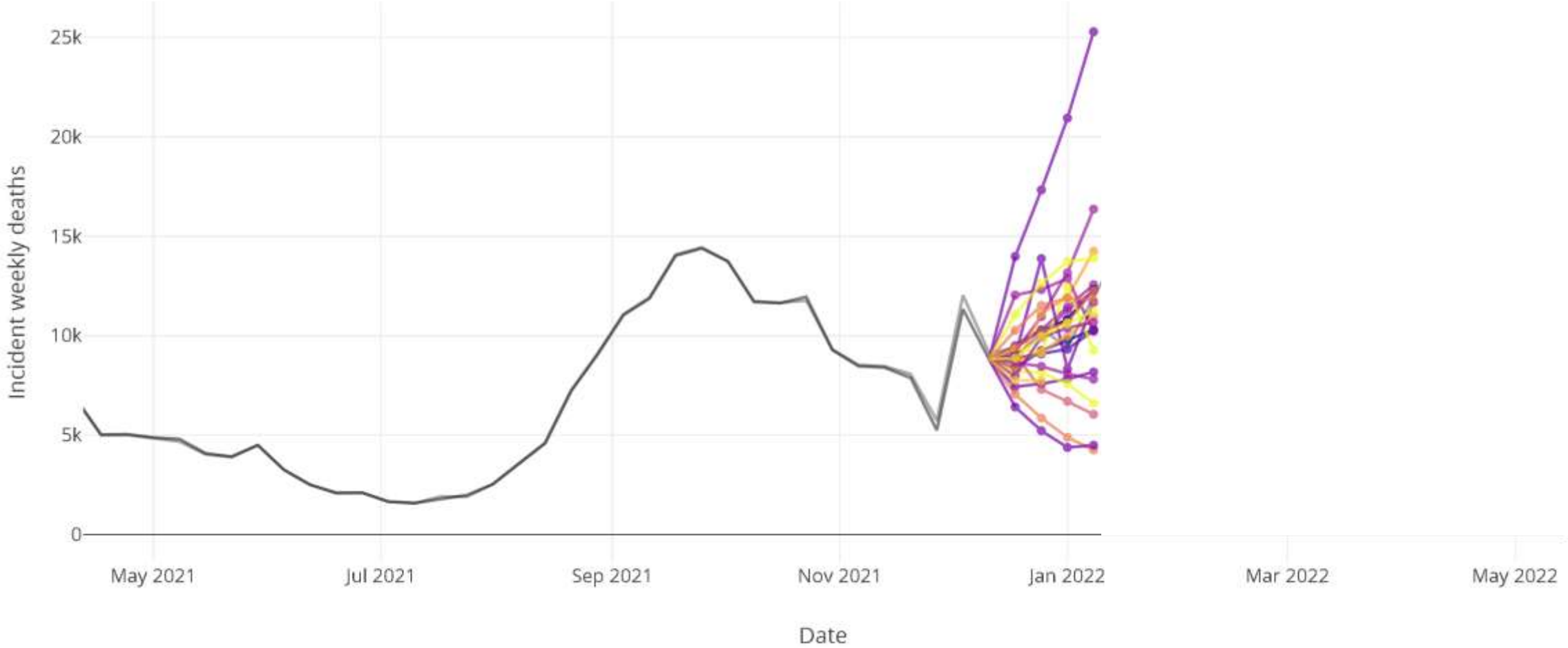


Source: [Maps: Tracking Post-Tropical Cyclone Helene - The New York Times (nytimes.com)]

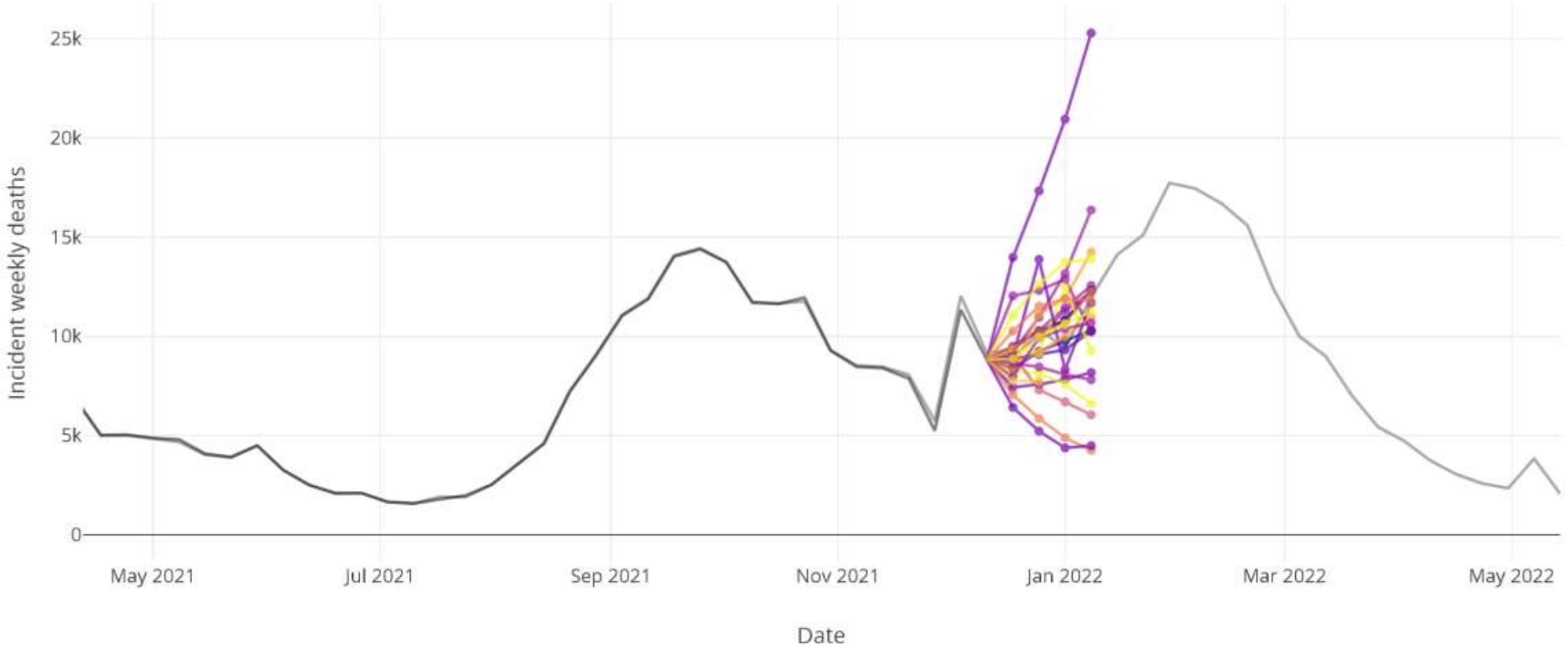
COVID-19 ForecastHub



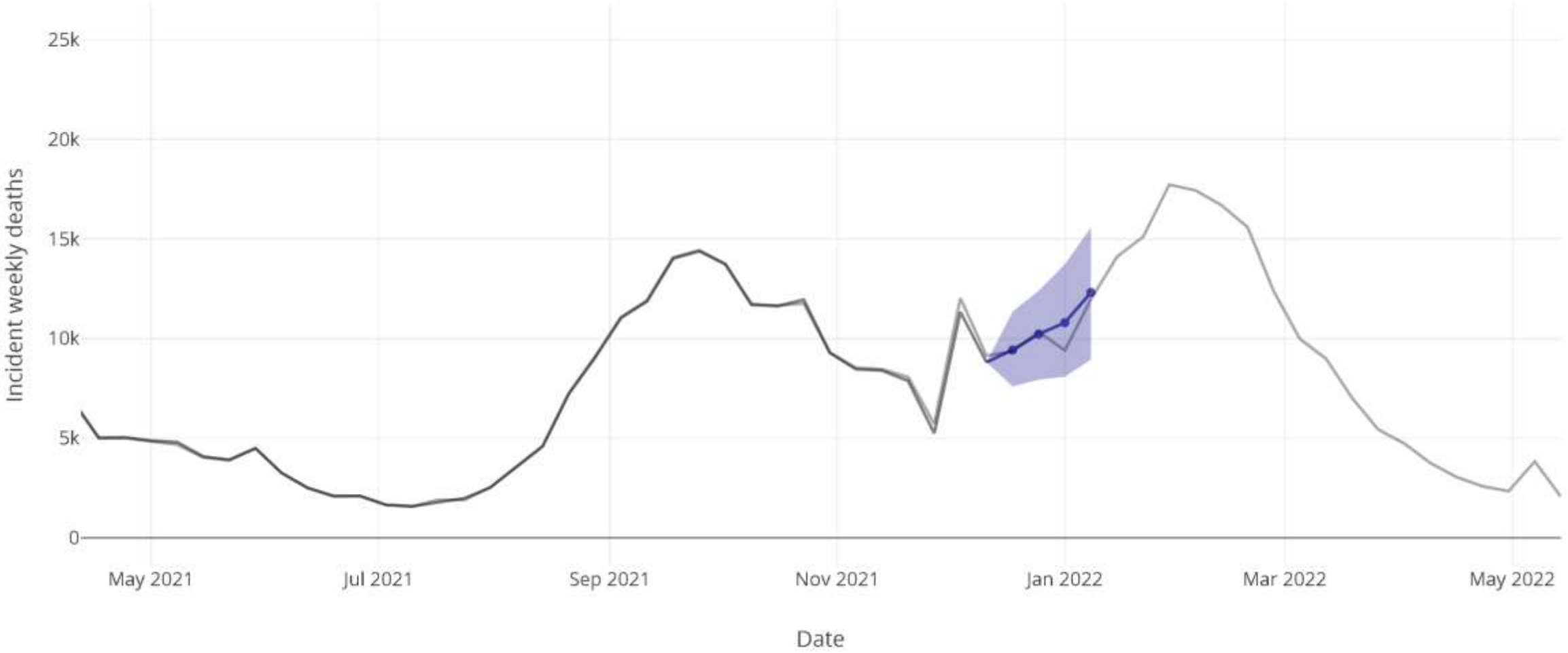
COVID-19
ForecastHub



COVID-19 ForecastHub



COVID-19 ForecastHub



The US Scenario Modeling Hub

- **Established Dec 2020 to deliver multi-model scenario projections of COVID-19 at national and state levels; close concertation with CDC & ACIP**

- **25 operational rounds of respiratory virus projections**
  - COVID19 (variants, waning immunity, NPI, vaccination strategies)
  - Influenza (subtype dominance, population immunity, vaccine coverage)
  - RSV (new interventions in 2023-24)
  - Combined pathogen projections since 2022-23 season

- **Research rounds in progress (disparities, cryptic phase of a pandemic)**

COVID-19 ScenarioModelingHub

COVID-19 ScenarioModelingHub

- A multi-team effort aimed at creating and modeling planning scenarios of the mid- to long-term COVID-19 situation.
- The first, and longest running member of the Scenario Modeling Hub family
- Project ~~cases~~, hospitalizations and deaths.
- Scenarios developed in close collaboration with the government agencies and other stakeholders
- To date 18 (15 public) rounds have been completed
- 5-10 submissions per round at the national level.

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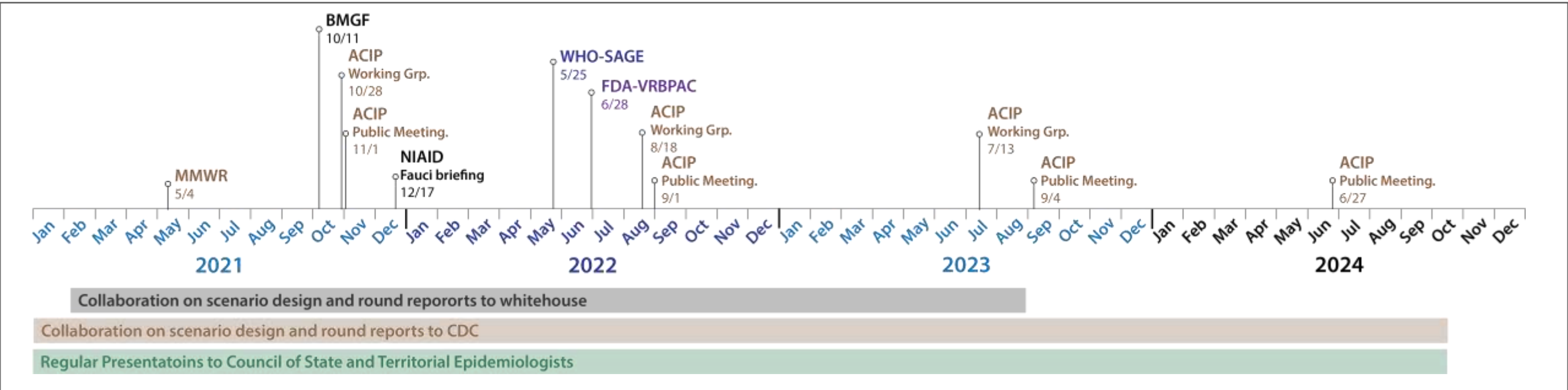
USC University of Southern California
MOBS LAB
Northeastern University
University of Victoria
THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL
IHME
UF UNIVERSITY of FLORIDA
NC STATE UNIVERSITY
UNC GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH
The University of Texas at Austin COVID-19 Modeling Consortium
CDC
COVID-19 ForecastHub

COVID-19 ScenarioModelingHub

1. Vaccine supply and non-pharmaceutical interventions [Dec 2020]
2. More transmissible variant (B.1.1.7) and NPIs [Jan 2021]
3. Vaccine supply and NPIs [March 2021]
4. Vaccine supply and NPIs [March 2021]
5. Vaccine hesitancy and NPIs [May 2021]
6. More transmissible variant and vaccine hesitancy [May 2021]
7. Delta and vaccine uptake [July 2021]
8. Immunologic waning [non-public practice round]
9. Childhood vaccination and hypothetical variant [Sept 2021]
10. Boosters and waning [unreleased due to Omicron]
11. Omicron 1, severity and transmission characteristics [Dec 2021]
12. Omicron 2, severity and transmission characteristics [Jan 2022]
13. Long term waning and variant [March 2022]
14. Boosters and hypothetical variants [July 2022]
15. Boosters and variants redux [August 2022]
16. Boosters and Emerging Variants [November 2022]
17. Reformulated vaccines and evolution [April 2023]
18. Reformulated vaccines and evolution [May 2024]

Impact and Use



Evaluating the

COVID-19 ScenarioModelingHub

Evaluation of the US COVID-19 Scenario Modeling Hub for informing pandemic response under uncertainty

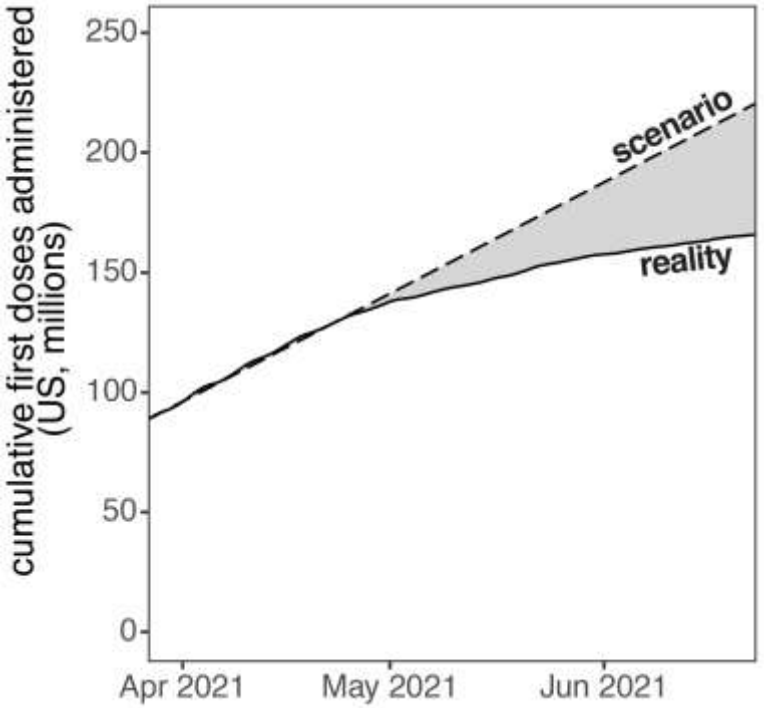
Emily Howerton, Lucie Contamin, Luke C. Mullany, Michelle Qin, Nicholas G. Reich, Samantha Bents, Rebecca K. Borchering, Sung-mok Jung, Sara L. Loo, Claire P. Smith, John Levander, Jessica Kerr, J. Espino, Willem G. van Panhuis, Harry Hochheiser, Marta Galanti, Teresa Yamana, Sen Pei, Jeffrey Shaman, Kaitlin Rainwater-Lovett, Matt Kinsey, Kate Tallaksen, Shelby Wilson, Lauren Shin, ... Justin Lessler

+ Show authors

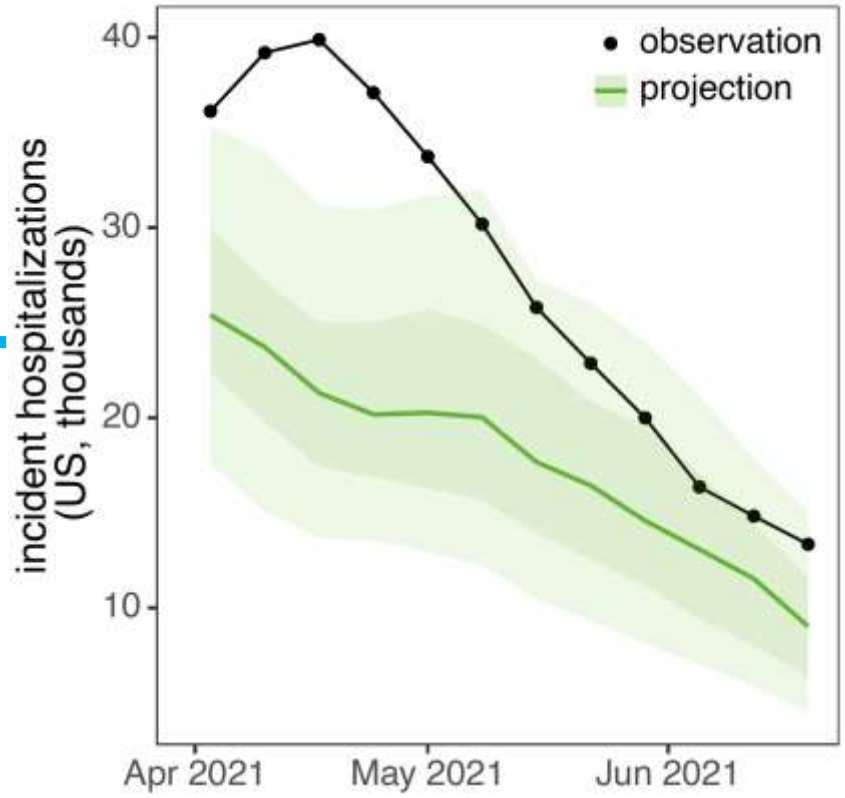
Nature Communications **14**, Article number: 7260 (2023) | Cite this article

COVID-19 ScenarioModelingHub

Model calibration given



$$\Pr(x_i \mid z_1)$$
$$\Pr(x_i \mid z_2)$$
$$\Pr(x_i \mid z_3)$$
$$\ldots$$
$$\Pr(x_i \mid z_n)$$

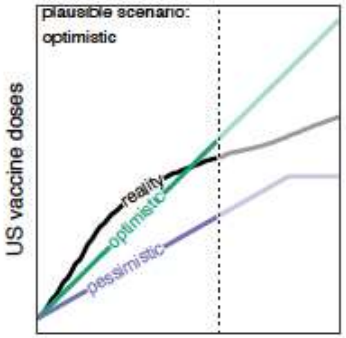


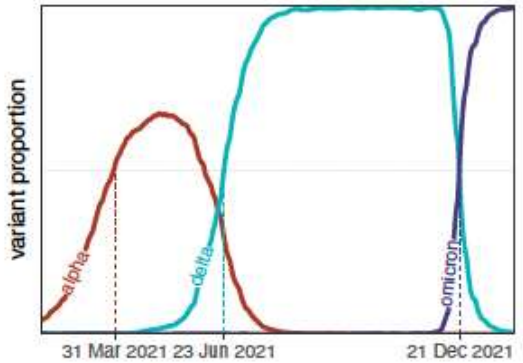
EVALUATING THE COVID-19 SCENARIO MODELING HUB

COVID-19 ScenarioModelingHub

Retrospective evaluation

Comparing SMH scenarios to reality

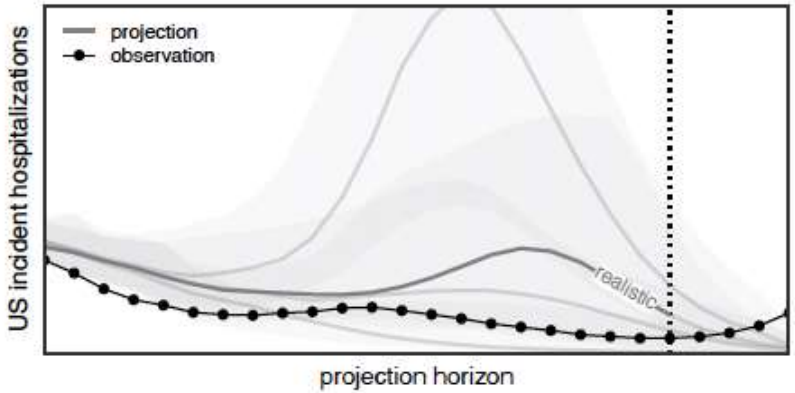




(i) identify "plausible" scenarios: compare scenario specifications to realized values

(ii) identify "divergent" time periods: truncate weeks when an unanticipated viral variant emerged

Comparing SMH projections to observations



(i) use metrics for evaluating probabilistic predictions, such as coverage and weighted interval score

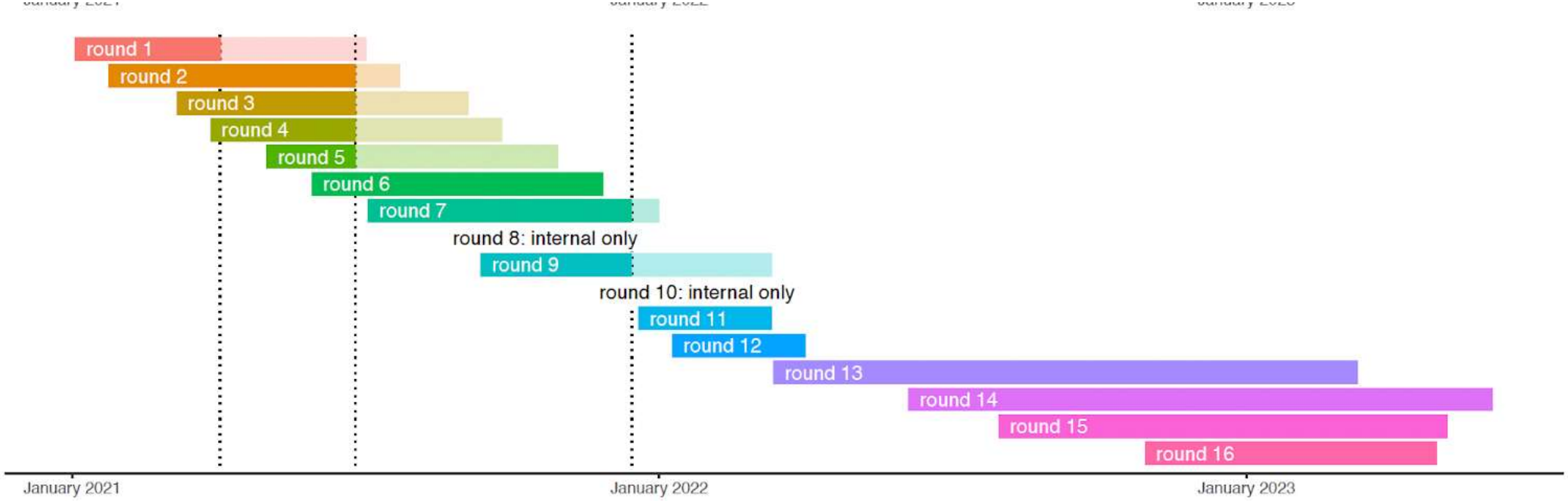
(ii) assess utility for public health planning, such as ability to predict epidemic trends

for a meaningful assessment of model calibration, compare projections from realistic scenarios and non-divergent weeks

PLAUSIBE WEEKS AND BRACKETING PERFORMANCE

COVID-19 ScenarioModelingHub

B



C

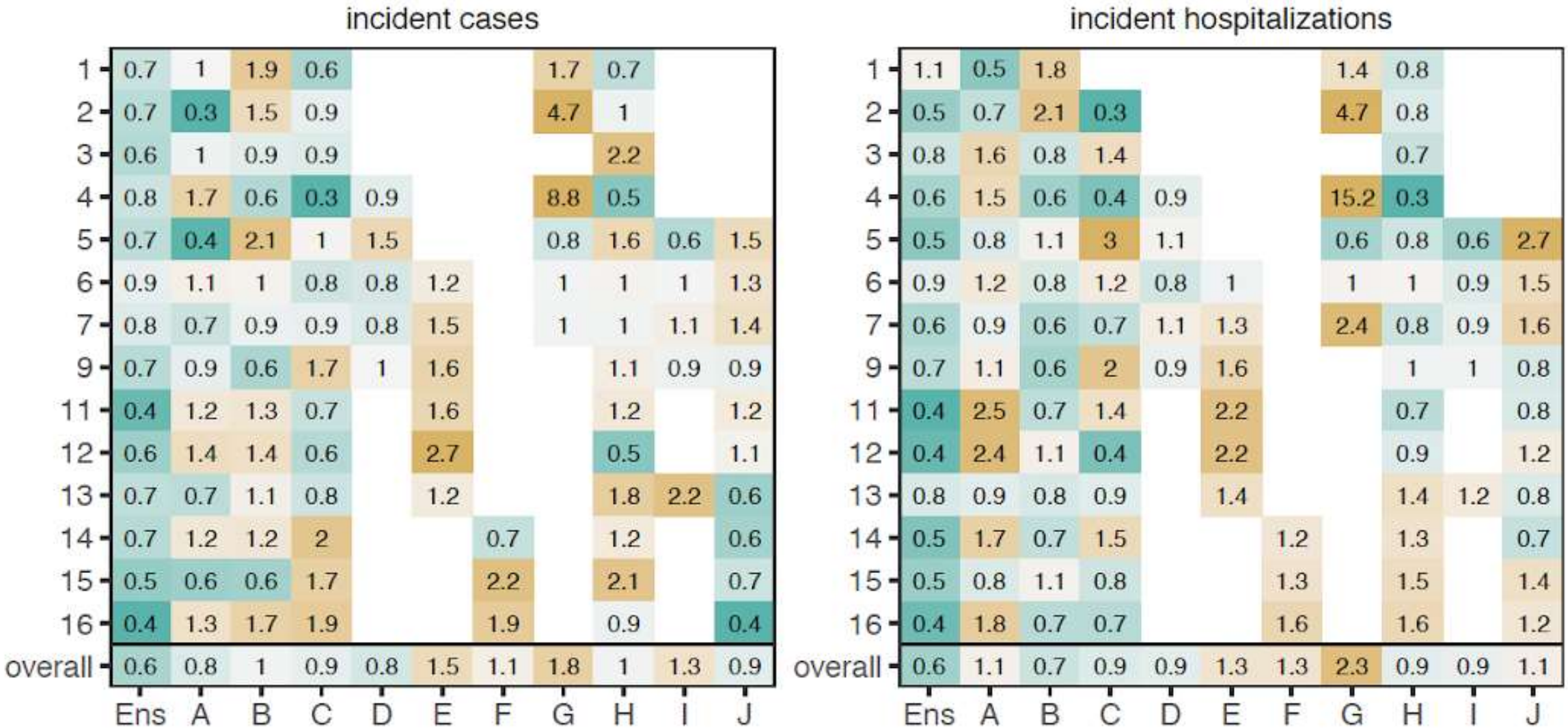
	round 1	round 2	round 3	round 4	round 5	round 6	round 7	round 9	round 11	round 12	round 13	round 14	round 15	round 16
number of models	5	5	4	6	8	9	9	9	8	8	8	6	5	6
turnaround time	58 days	27 days	31 days	34 days	29 days	23 days	16 days	23 days	21 days	11 days	51 days	65 days	25 days	39 days
NPI assumptions	NPI compliance	NPI compliance	NPI compliance	NPI compliance	NPI compliance									
vaccination assumptions	vaccine supply	**vaccine supply**	vaccine supply	vaccine supply	**vaccine uptake**	**vaccine uptake**	vaccine uptake	**childhood vaccination**				**booster uptake**	booster uptake	booster uptake
variant assumptions		emergence (alpha)				**transmissibility (hypothetical)**	**transmissibility (delta)**	emergence (hypothetical)	**severity/ immune escape (omicron)**	**severity/ immune escape (omicron)**	immune escape (hypothetical)	immune escape (hypothetical)	immune escape (hypothetical)	immune escape (mix of variants)

THE

THE SUPERIORITY OF THE ENSEMBLE

COVID-19 ScenarioModelingHub

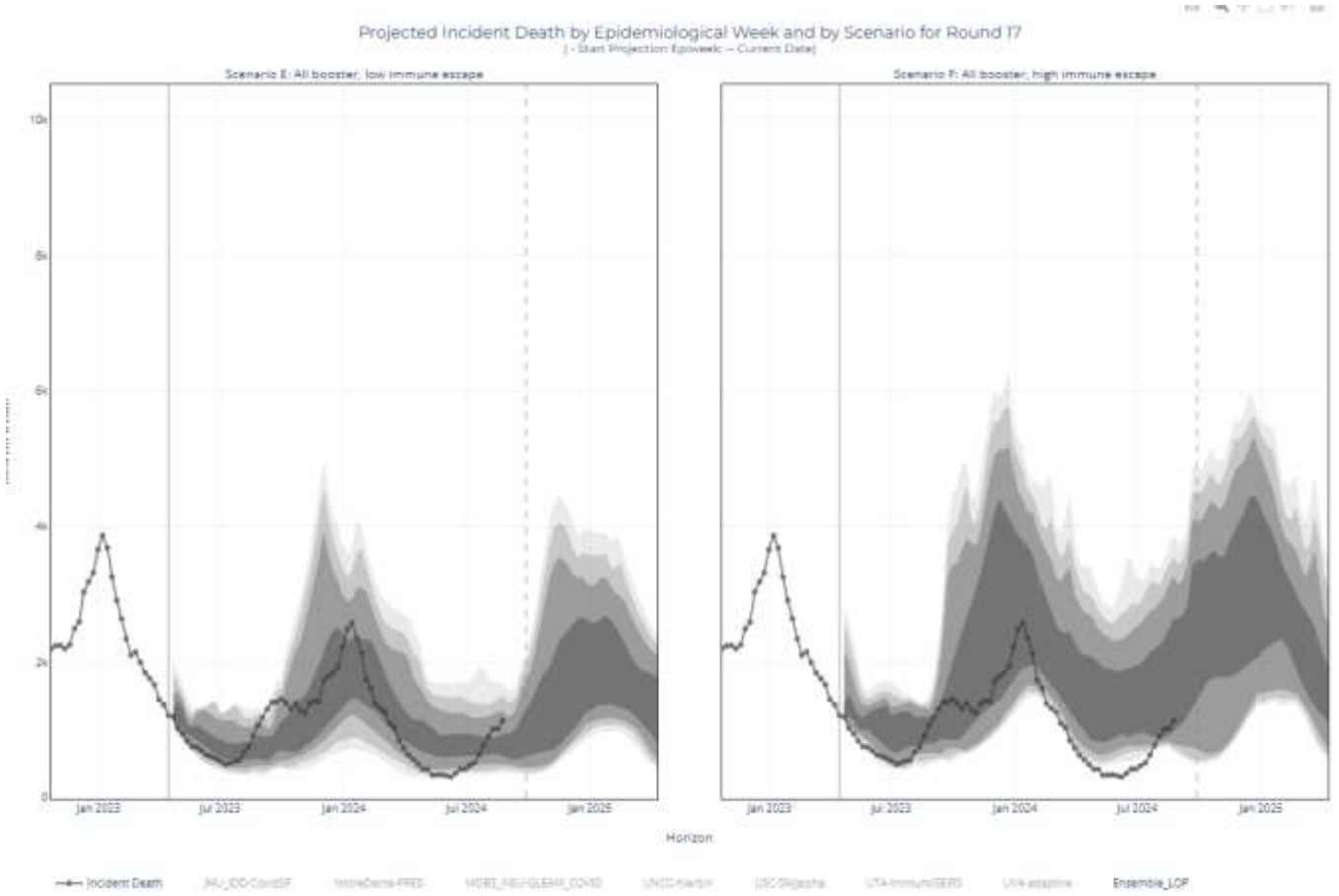
C



Recent Rounds

Round 17: The first “mega-round”

	Low immune escape	High immune escape
No vaccine recommendation	**Scenario A** **Low immune escape** - Immune escape occurs at a constant rate of **20% per year** **No vaccine recommendation** - Continued uptake of existing vaccines is left to discretion of teams	**Scenario B** **High immune escape** - Immune escape occurs at a constant rate of **50% per year** **No vaccine recommendation** - Continued uptake of existing vaccines is left to discretion of teams
Reformulated annual vaccination recommended for 65+ and immunocompromised	**Scenario C** **Low immune escape** - Immune escape occurs at a constant rate of **20% per year** **Reformulated annual vaccination recommended for 65+ and immunocompromised** - Reformulated vaccine has **X% VE against variants circulating in June** - Vaccine becomes **available September 1st** - Update same as first booster dose	**Scenario D** **High immune escape** - Immune escape occurs at a constant rate of **50% per year** **Reformulated annual vaccination recommended for 65+ and immunocompromised** - Reformulated vaccine has **X% VE against variants circulating in June** - Vaccine becomes **available September 1st** - Update same as first booster dose
Reformulated annual vaccination recommended for all currently eligible groups	**Scenario E** **Low immune escape** - Immune escape occurs at a constant rate of **20% per year** **Reformulated annual vaccination recommended for all currently eligible groups** - Reformulated vaccine has **X% VE against variants circulating in June** - Vaccine becomes **available September 1st** - 65+ uptake same as first booster dose, coverage in other groups saturates at 30%	**Scenario F** **High immune escape** - Immune escape occurs at a constant rate of **50% per year** **Reformulated annual vaccination recommended for all currently eligible groups** - Reformulated vaccine has **X% VE against variants circulating in June** - Vaccine becomes **available September 1st** - 65+ uptake same as first booster dose, coverage in other groups saturates at 30%



Potential impact of annual vaccination with reformulated COVID-19 vaccines: Lessons from the US COVID-19 scenario modeling hub

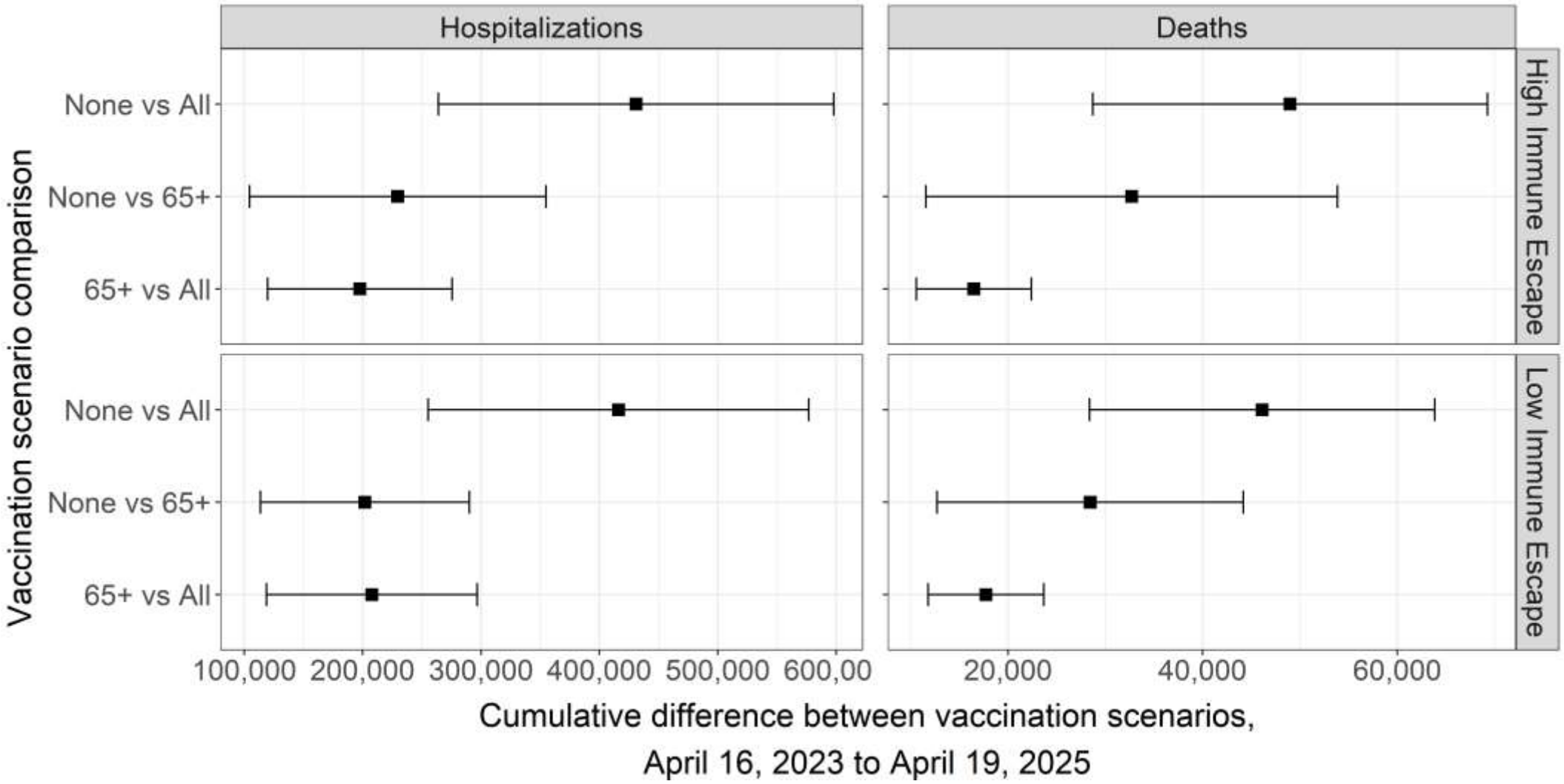
Sung-mok Jung, Sara L. Loo, Emily Howerton, Lucie Contamin, Claire P. Smith, Erica C. Carcelén, Katie Yan, Samantha J. Bents, John Levander, Jessi Espino, Joseph C. Lemaitre, Koji Sato, Clifton D. McKee, [...] Justin Lessler

[view all]

Version 2 Published: April 17, 2024 • https://doi.org/10.1371/journal.pmed.1004387

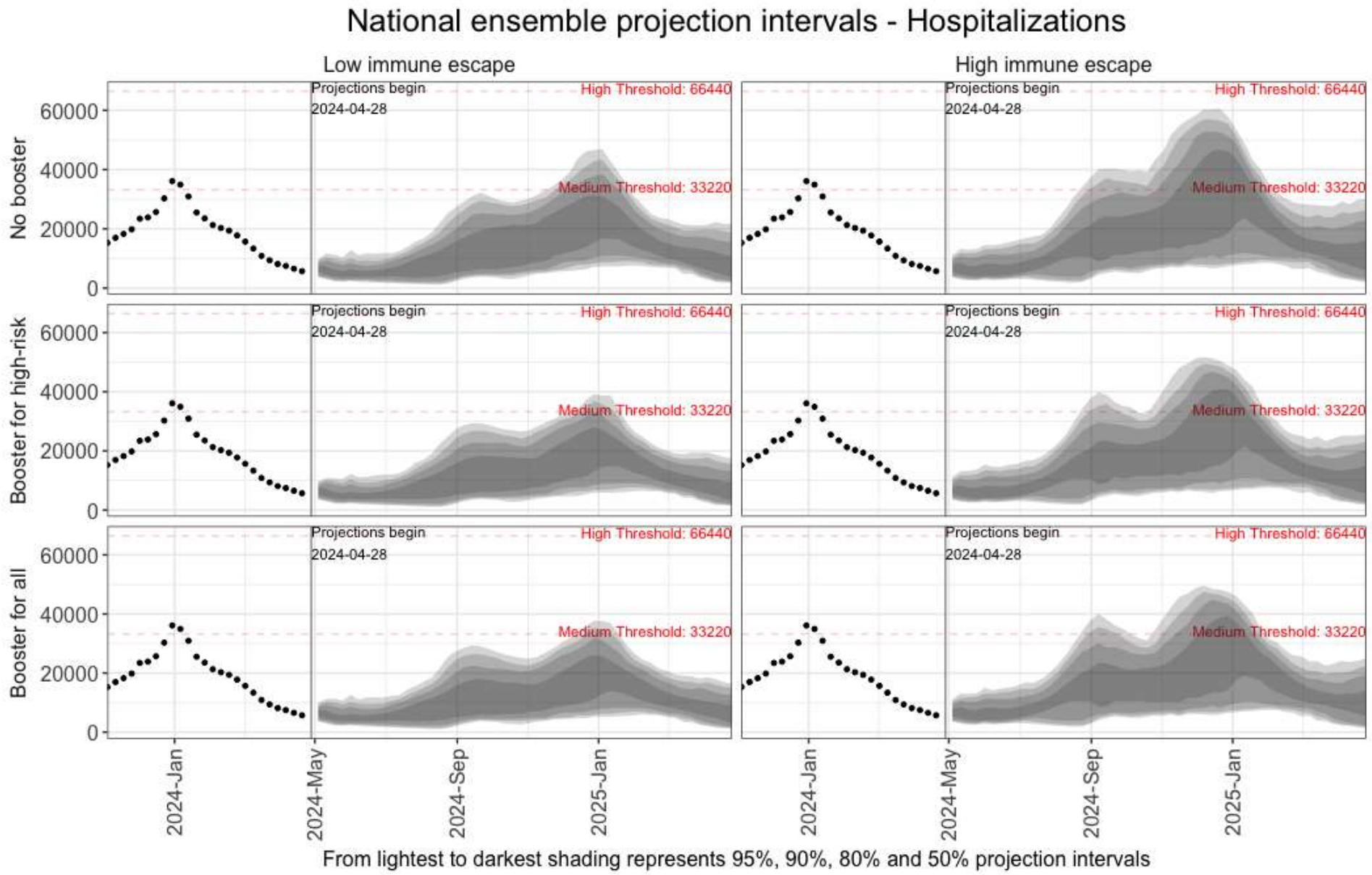
UNC GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH

Round 17: The first “mega-round”

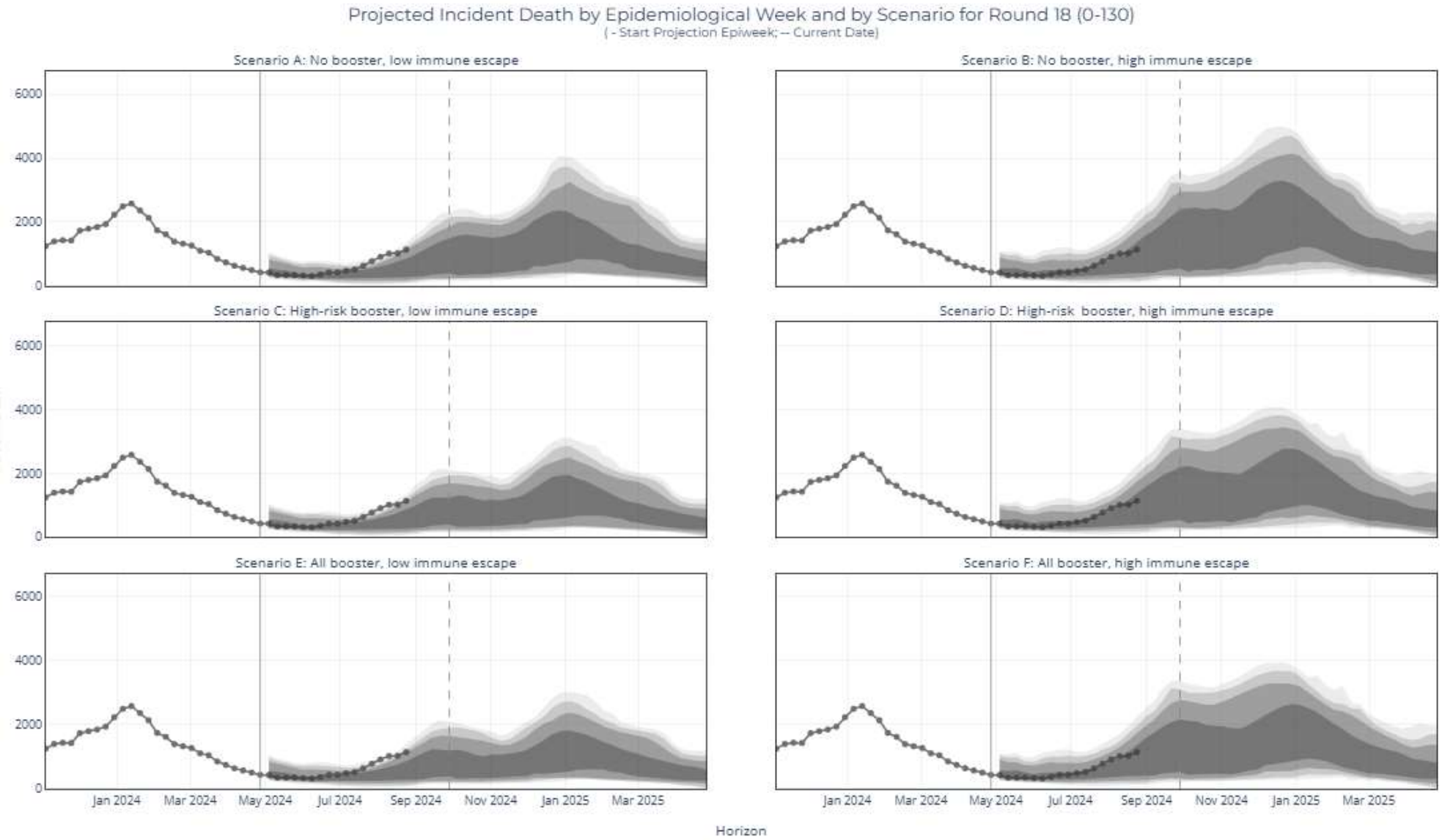


UNC GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH

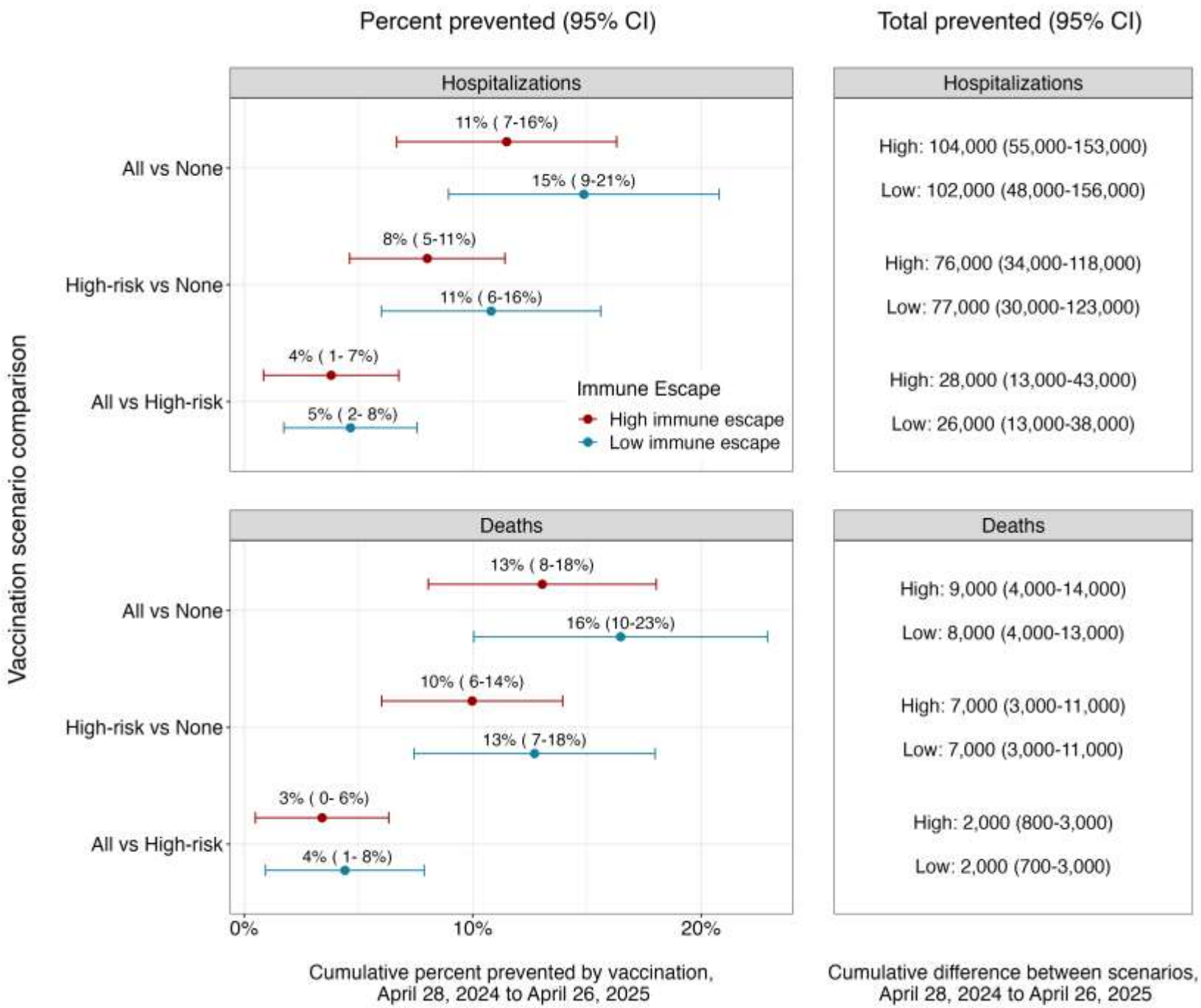
Round 18


National ensemble projection intervals - Hospitalizations
Low immune escape
High immune escape
No booster
Booster for high-risk
Booster for all
Projections begin
2024-04-28
High Threshold: 66440
Medium Threshold: 33220
60000
40000
20000
0
2024-Jan
2024-May
2024-Sep
2025-Jan
From lightest to darkest shading represents 95%, 90%, 80% and 50% projection intervals

Round 18


Projected Incident Death by Epidemiological Week and by Scenario for Round 18 (0-130)
(- Start Projection Epiweek; -- Current Date)
Scenario A: No booster, low immune escape
Scenario B: No booster, high immune escape
Scenario C: High-risk booster, low immune escape
Scenario D: High-risk booster, high immune escape
Scenario E: All booster, low immune escape
Scenario F: All booster, high immune escape
0
2000
4000
6000
Jan 2024
Mar 2024
May 2024
Jul 2024
Sep 2024
Nov 2024
Jan 2025
Mar 2025
Horizon

Round 18


Percent prevented (95% CI)
Total prevented (95% CI)
Hospitalizations
Deaths
Vaccination scenario comparison
All vs None
High-risk vs None
All vs High-risk
11% (7-16%)
15% (9-21%)
8% (5-11%)
11% (6-16%)
4% (1- 7%)
5% (2- 8%)
Immune Escape
High immune escape
Low immune escape
13% (8-18%)
16% (10-23%)
10% (6-14%)
13% (7-18%)
3% (0- 6%)
4% (1- 8%)
0%
10%
20%
High: 104,000 (55,000-153,000)
Low: 102,000 (48,000-156,000)
High: 76,000 (34,000-118,000)
Low: 77,000 (30,000-123,000)
High: 28,000 (13,000-43,000)
Low: 26,000 (13,000-38,000)
High: 9,000 (4,000-14,000)
Low: 8,000 (4,000-13,000)
High: 7,000 (3,000-11,000)
Low: 7,000 (3,000-11,000)
High: 2,000 (800-3,000)
Low: 2,000 (700-3,000)
Cumulative percent prevented by vaccination, April 28, 2024 to April 26, 2025
Cumulative difference between scenarios, April 28, 2024 to April 26, 2025

Flu ScenarioModelingHub

Scenario projections for influenza since 2022

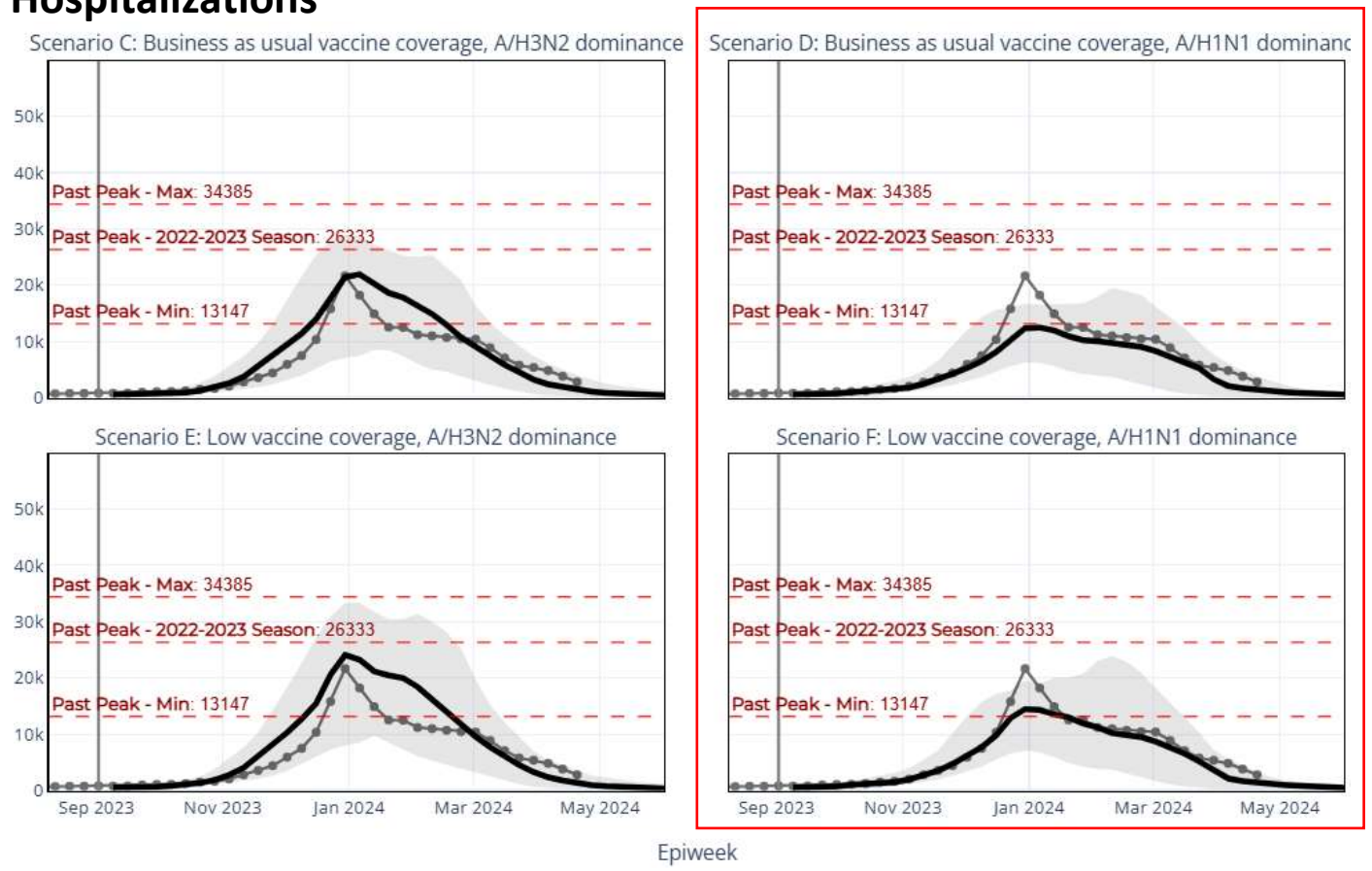
- In 2022-23, addressed the impact of immunity debt on post-pandemic rebound (3 rounds, pre-season, early- and mid-season)

- In 2023-24 and 2024-25, focused on subtype dominance and vaccine coverage

Flu ScenarioModelingHub 2023-24 round

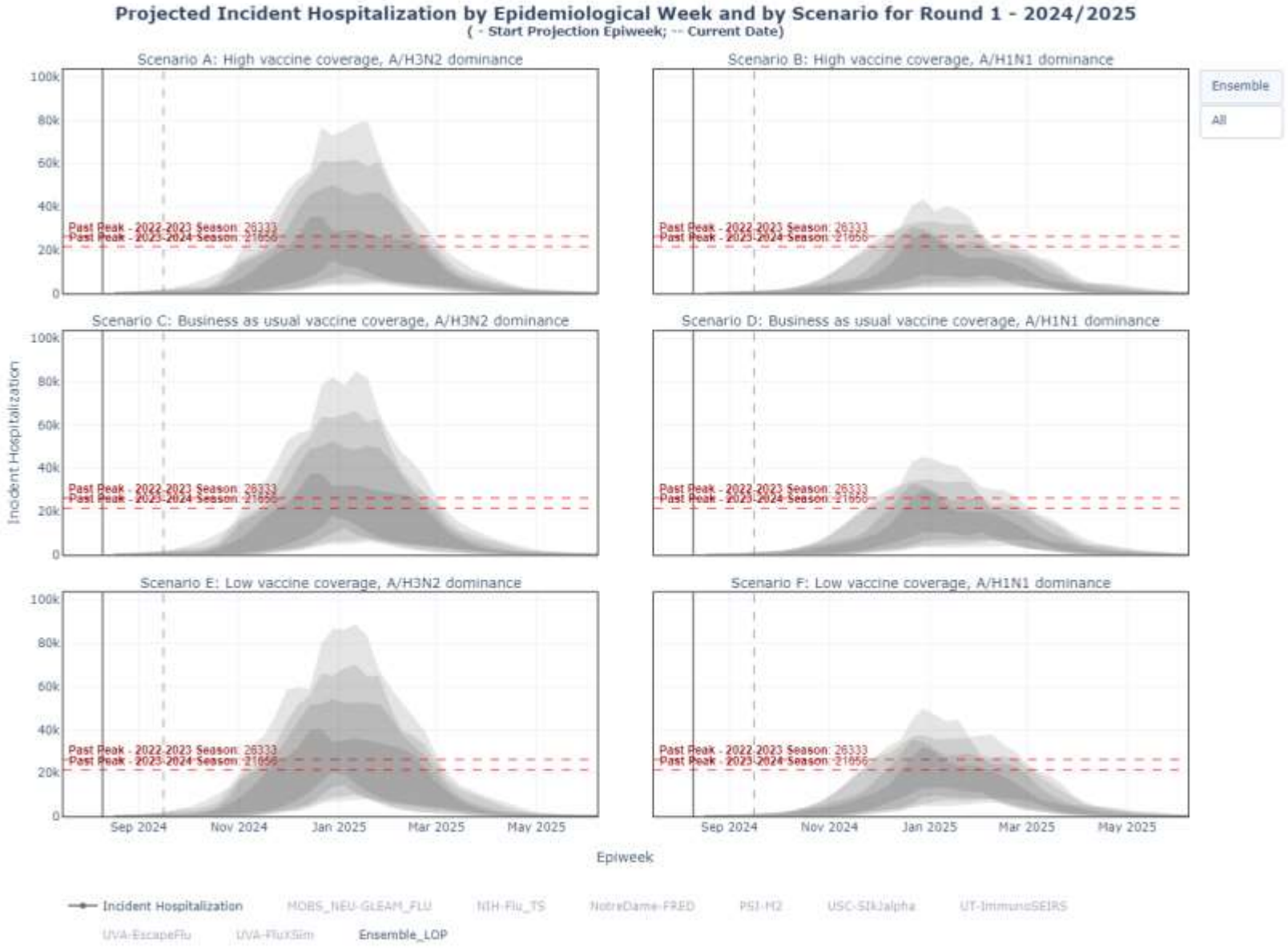
- Pre-season projections
- 10 teams contributed (9 national)
- A/H1N1 was dominant, ~10% lower than usual vaccine coverage
- Performance evaluation in progress

Hospitalizations



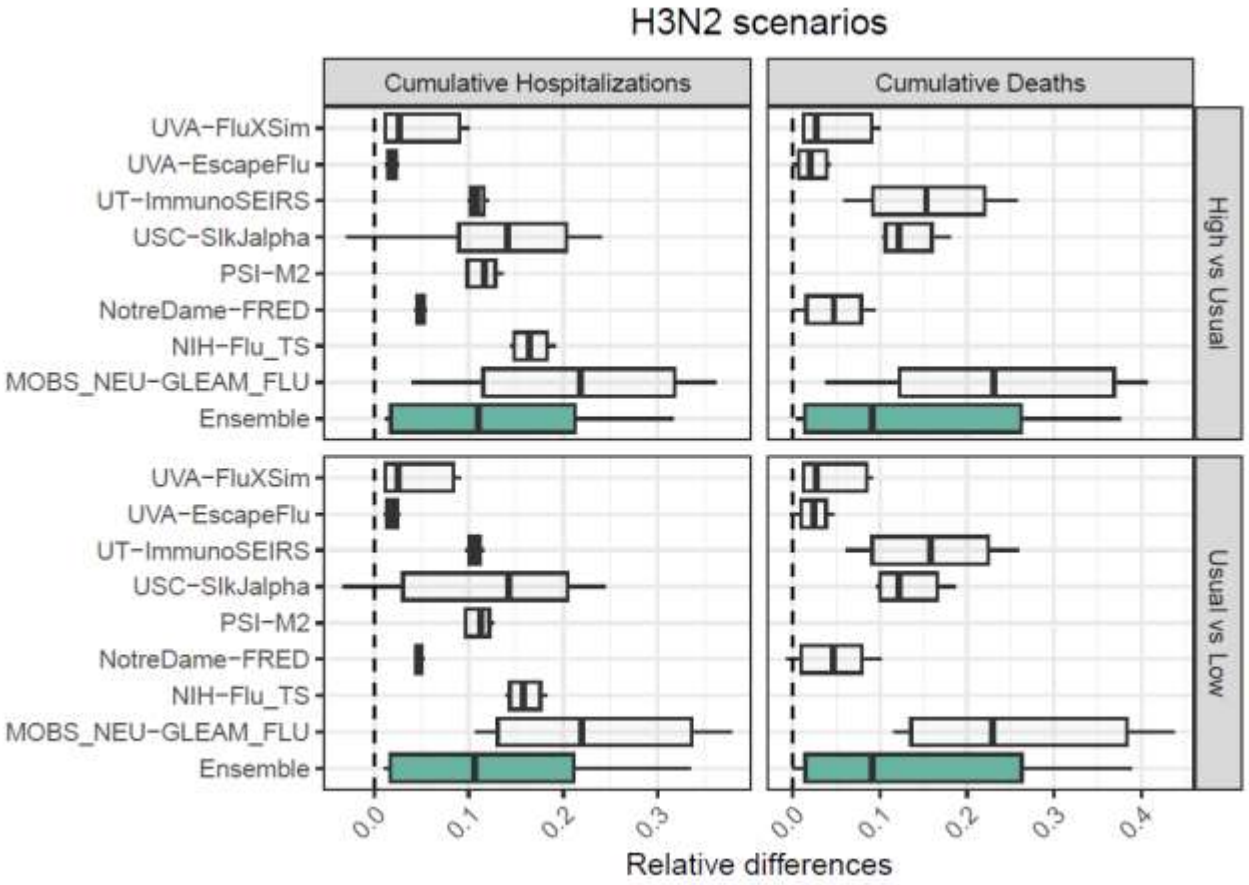
Flu ScenarioModelingHub 2024-25 round

- Just completed!
- 9 teams (8 national)
- Hospitalization projections stable compared to last year
- Median death projections more than doubled, more in line with historic median of ~27,000 flu deaths



Projected impact of changes in influenza vaccination coverage this season

- A 20% relative vaccine increase would reduce influenza-related hospitalizations by 11% (95% CI 1%, 29%) in the H3N2 scenario
- This represents a differences in the order of 24,000 to 32,000 hospitalizations (range of medians across scenarios).
- Projected percent changes in deaths range between 8-12% for a 20% change in vaccine coverage, depending on the scenario, corresponding to differences of 1,300-1,900 influenza-related deaths.



RSV ScenarioModelingHub

Scenario projections for the impact of RSV interventions in 2023-24

- New interventions rolled out in 2023-24
- Limited data availability and modeling capabilities for RSV
- Combined respiratory virus projections

RSV Scenarios

(released October 2023, https://github.com/midas-network/rsv-scenario-modeling-hub)

Scenarios		RSV vaccination among seniors over 60 years		
		Optimistic • VE against RSV hospitalization =90% • Coverage saturates at 29% nationally**	**Pessimistic** • VE against RSV hospitalization =70% • Coverage saturates at 14% nationally**	**No intervention**
Long-acting RSV monoclonals among infants 0-6 months	**Optimistic** • VE against RSV hospitalization =80% • Coverage saturates at 36% nationally*	**A**	**B**	
	Pessimistic • VE against RSV hospitalization =60% • Coverage saturates at 12% nationally*	**C**	**D**	
	No intervention			**E** counterfactual

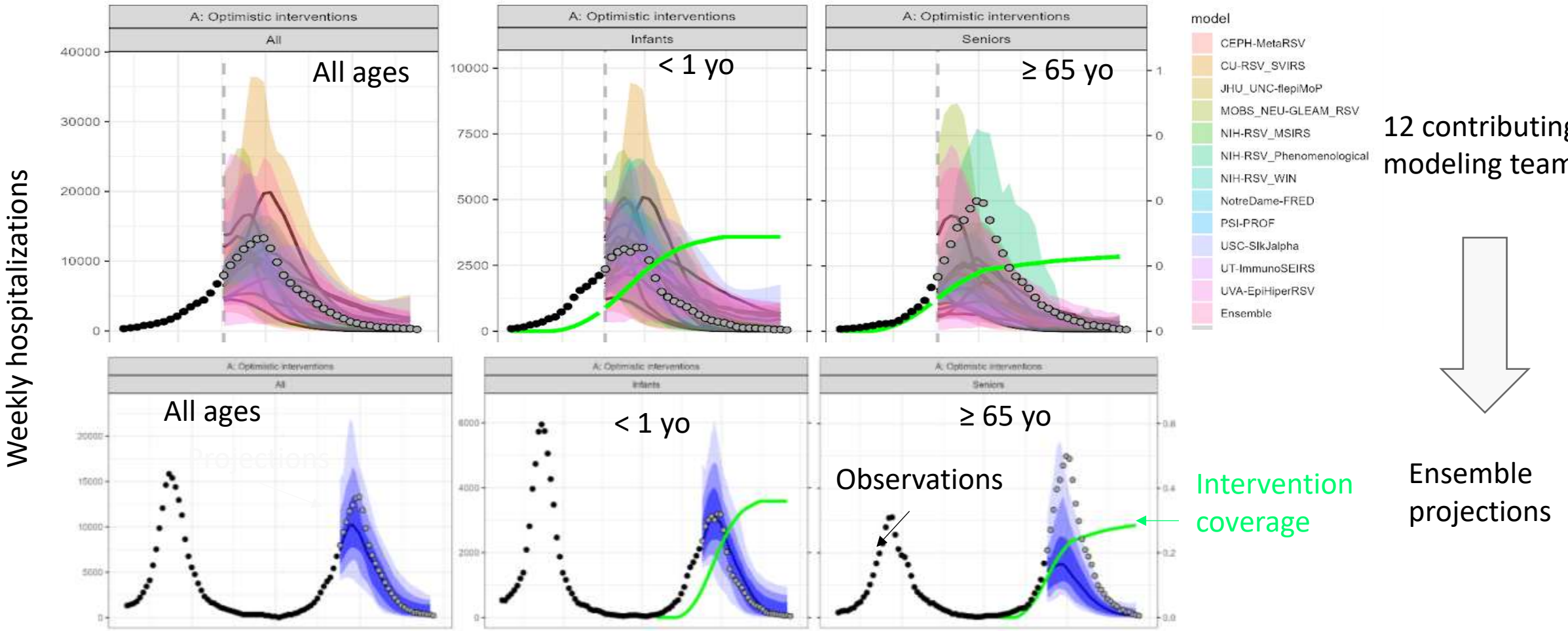
Scenario assumptions:

- indexed on flu vaccine uptake and RSV RCT data

Projections targets:

- Weekly projections of no RSV hospitalizations in 12 states and nationally
- 5 age groups (<1, 1-4, 5-64, 65+, all ages)
- Nov 12, 2023 to June 1, 2024 (29 weeks)
- Calibration to RSV-NET

Weekly ensemble projections of RSV hospitalizations, Nov 2023-June 2024



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Projections for scenario A, closest to reality (optimistic interventions in seniors and infants)

Sizable benefits of RSV interventions despite modest coverage, 2023-24

Age group	Baseline RSV hospitalizations per 100,000 (RSV-NET, 2018-20)	No hospitalizations averted	Percent hospitalizations averted	No doses needed to avert 1 hospitalization
Infants <1 yo	1,304	5,400 (2,400 – 9,200)	12% (7% - 19%)	120 (70 - 300)
Seniors ≥ 65 yo	85	6,300 (4,600 – 9,300)	20% (16% - 20%)	2,600 (1,800 – 3,600)

Reductions estimated by subtracting total projected hospitalizations at the end of the season for intervention scenario A from counterfactual scenario E (paired analysis, median and IQR of projected distributions)

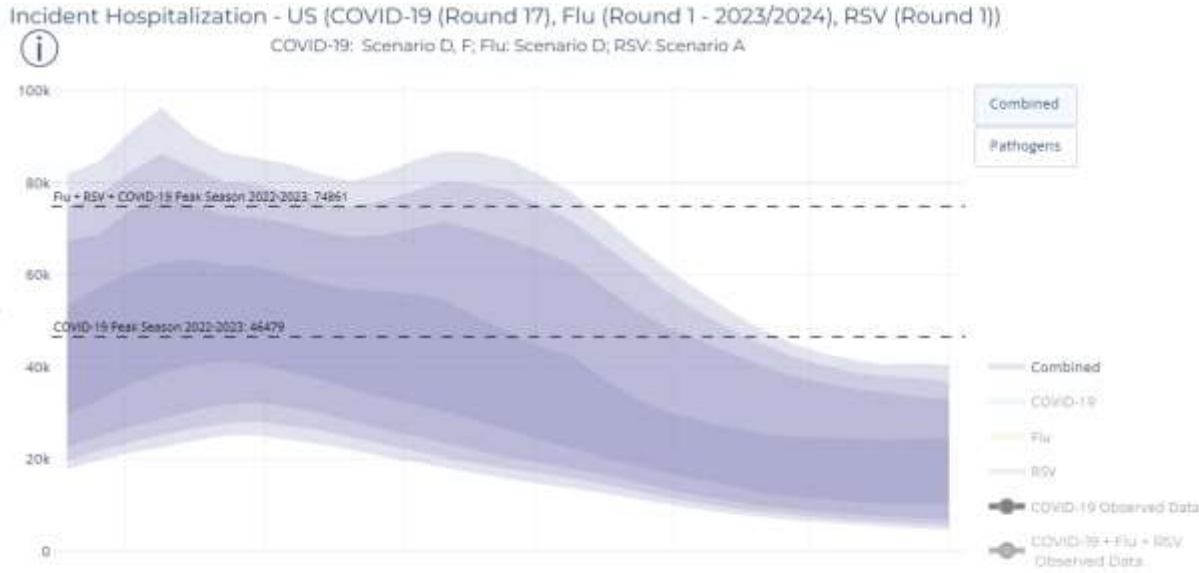
RSV projections for the 2024-25 season, in concertation with CDC

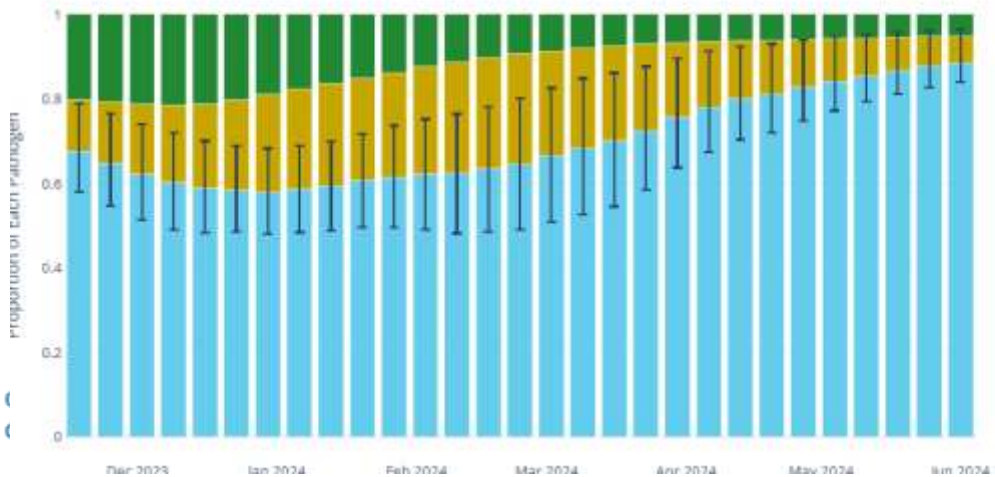
- **2024-25 scenarios will address:**
- Timing of infant interventions (Aug-Mar vs Oct-Mar)
- Impact of waning immunity among seniors vaccinated last year

  Change in recommendations for seniors
  - Age-restrictions (60-74 yo with chronic conditions, all 75+ yo)
  - Revaccination not recommended
  - Uncertainty in VE in the second year after vaccination
- Results expect in late fall 2024
- Potential use for ACIP discussions in spring 2025

Projections of the combined impact of influenza, RSV and COVID-19 on hospitalizations

- A tab on all SMH sites for 2023-24 projections
- Opportunity to guide hospital capacity planning in future years





ScenarioModelingHub

Improving the Science and Future of Scenario Projections

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The Cryptic Round

Projections addressing the cryptic phase of a pandemic

- Aim: build capacity in scenario projections and inference in early stages of a pandemic

- Epidemiological process
  Synthetic epidemiological data generated from global (GLEAM) and local (UVA-EpiHiper) models
  - Control over epidemiological and behavioral conditions (natural history, testing propensity, noise, etc)
  - Full ground truth known (major advantage for evaluation)
  - Simulate invasion of new respiratory pathogen from Asia/Africa into two US states and a European country (TBC)

Process and timeline

- Two phases
  - Phase I: very early cryptic phase (some importations, local transmission unclear)
  - Phase II: late cryptic phase (on-going transmission– how large will it be? Social distancing measures?)

- Model targets:
  - 3-month ahead scenario projections of infections, cases, deaths
  - Estimates of natural history parameters (Ro, CFR, serial interval)
  - Scenario defined in collaboration with public health partners

- Open call to interested teams; likely to involve RespiCompass (EU hub)
- **Scheduled for early 2025**

COVID-19 & Flu & RSV Scenario Modeling Hubs

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Questions?

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