IHME
Measuring what matters

# Global Case Studies for Pandemic Predictions: The Case of COVID-19

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# History of the Model

- Original model developed to provide estimates of COVID-19 patient hospital utilization and help hospital systems plan for the upcoming surge
    - Initially in response to a request from UW Medicine, but demand prompted expansion to all US States and additional countries
- Second generation model developed to better fit the observed declines, as many locations began to see longer, flatter peaks & slower declines
- Third generation model now released: Random knot combination spline (RKCS)-SEIR Model


# Model Introduction

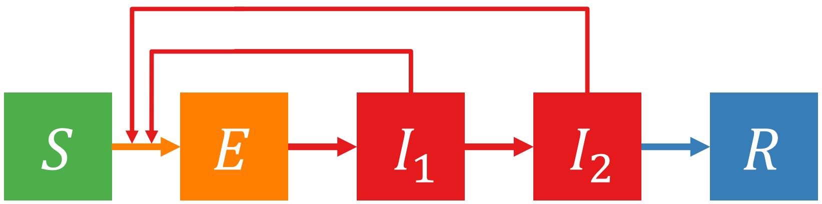
The IHME modeling process forecasts the following through Dec 1, 2020:

- Daily deaths
- Total deaths
- Hospital resource use for COVID-19 patients (beds, ICU bed, ventilators)
- Mobility
- Testing
- Confirmed and estimated infections

# COVID Model Development Over the Past 3 Months

| CurveFit<br>Mar 26 – May 3 | CurveFit-SEIR Hybrid<br>May 4 – June 10 | RKCS-SEIR Hybrid<br>June 11- |
|---|---|---|
| • Statistical, deaths-based model<br>• Performed well initially for locations with >50 deaths<br>• Focused on predicting initial peak of hospital resource use as a function of social distancing<br>• Did not predict decline after the peak well | • Mixture of CurveFit and SEIR<br>• Fitted a statistical model to the past and next 8 days; and an SEIR model to predict after 8 days<br>• Future transmission a function of covariates: mobility, testing, temperature, pop density<br>• Better fit to observed declines after peak | • Analysis of cases, hospitalizations, and deaths to estimate past & next 8 days<br>• Fit an SEIR model to these trends<br>• Future transmission a function of covariates: mask use, mobility, pneumonia seasonality, testing per capita, population density, PM2.5, smoking, altitude, pneumonia death rate |

# SEIR Model Fit to Death Data



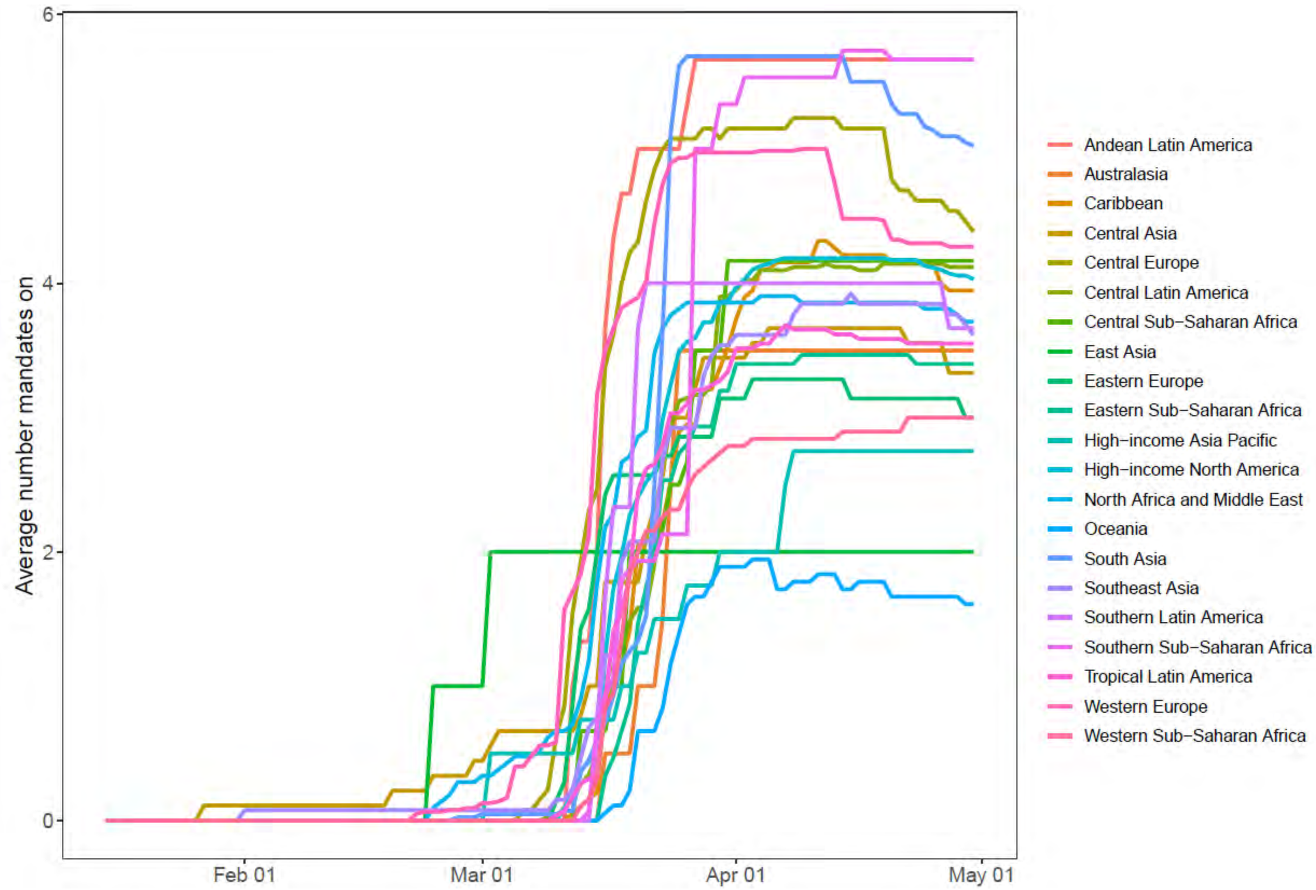

$$\frac{dS}{dt} = -\frac{\beta(t)S\,(I_1 + I_2)^{\alpha}}{N}$$
$$\frac{dE}{dt} = \frac{\beta(t)S\,(I_1 + I_2)^{\alpha}}{N} - \sigma E$$
$$\frac{dI_1}{dt} = \sigma E - \gamma_1 I_1$$
$$\frac{dI_2}{dt} = \gamma_1 I_1 - \gamma_2 I_2$$
$$\frac{dR}{dt} = \gamma_2 I_2$$

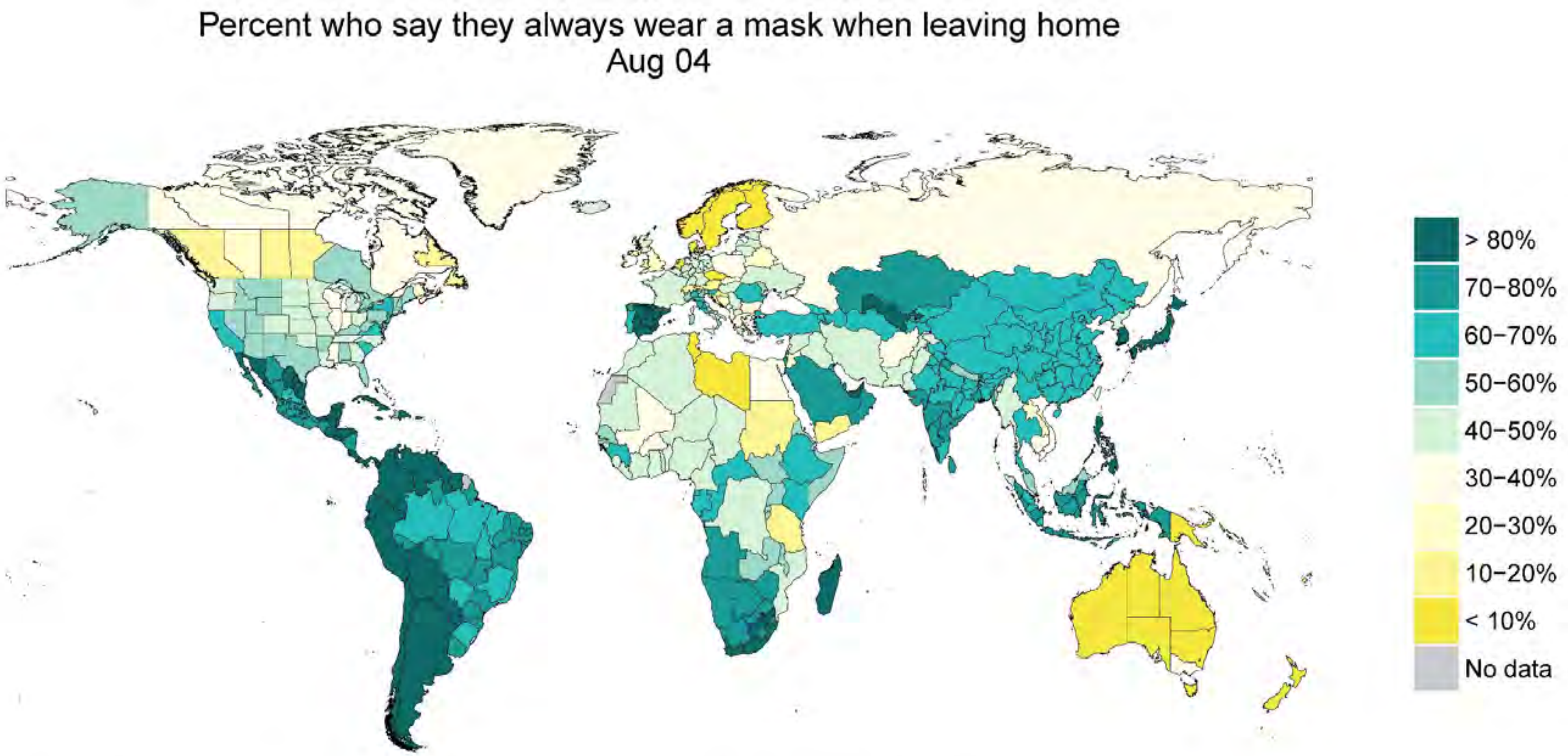
**SEIR model steps:**

- Fit SEIR model (e.g., fit $\beta(t)$)* to past and recent death model output for all locations.
- Regress $\beta(t)$ on available covariates*
- Forecast time-varying covariates into the future
- Combine regression with forecasts to forecast $\beta(t)$*
- Run forecasted $\beta(t)$ through SEIR model to forecast infections*
- Calculate deaths from infections and IFR*

*** By draw**

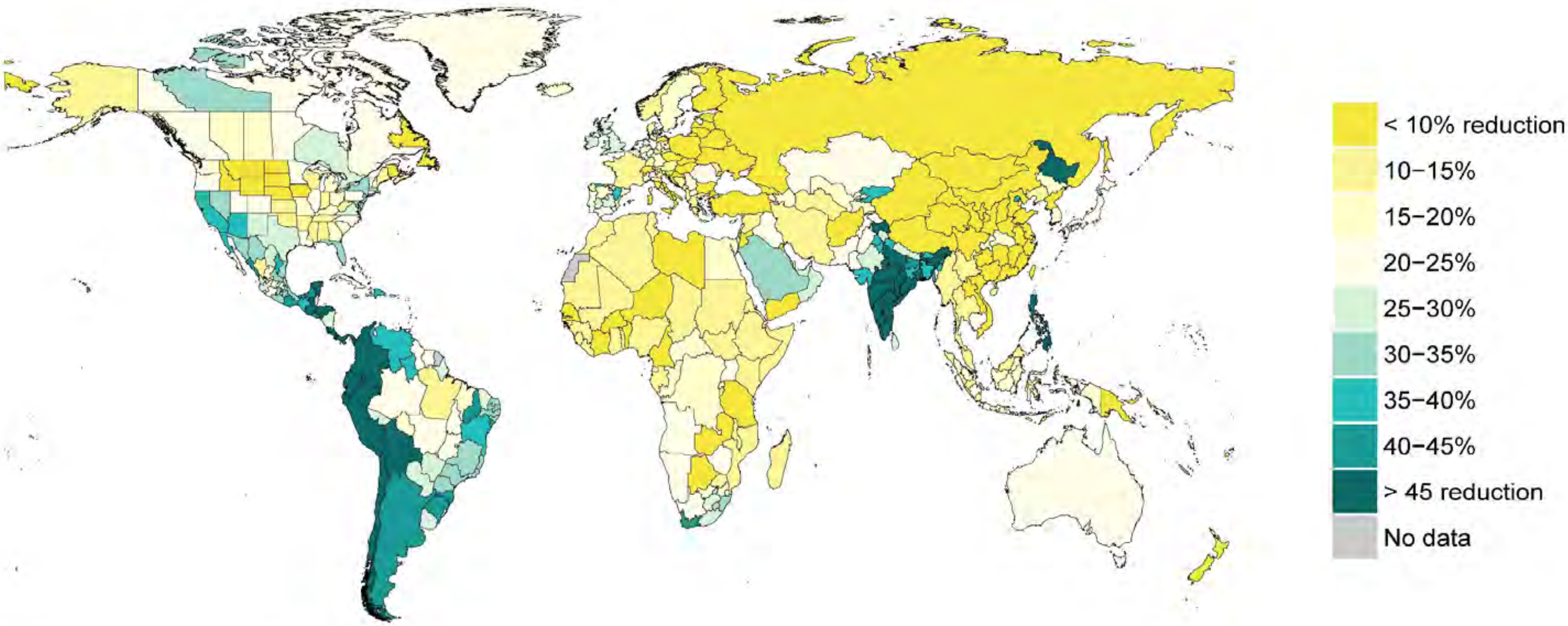
# Key Drivers of Cases and Deaths: Mandates





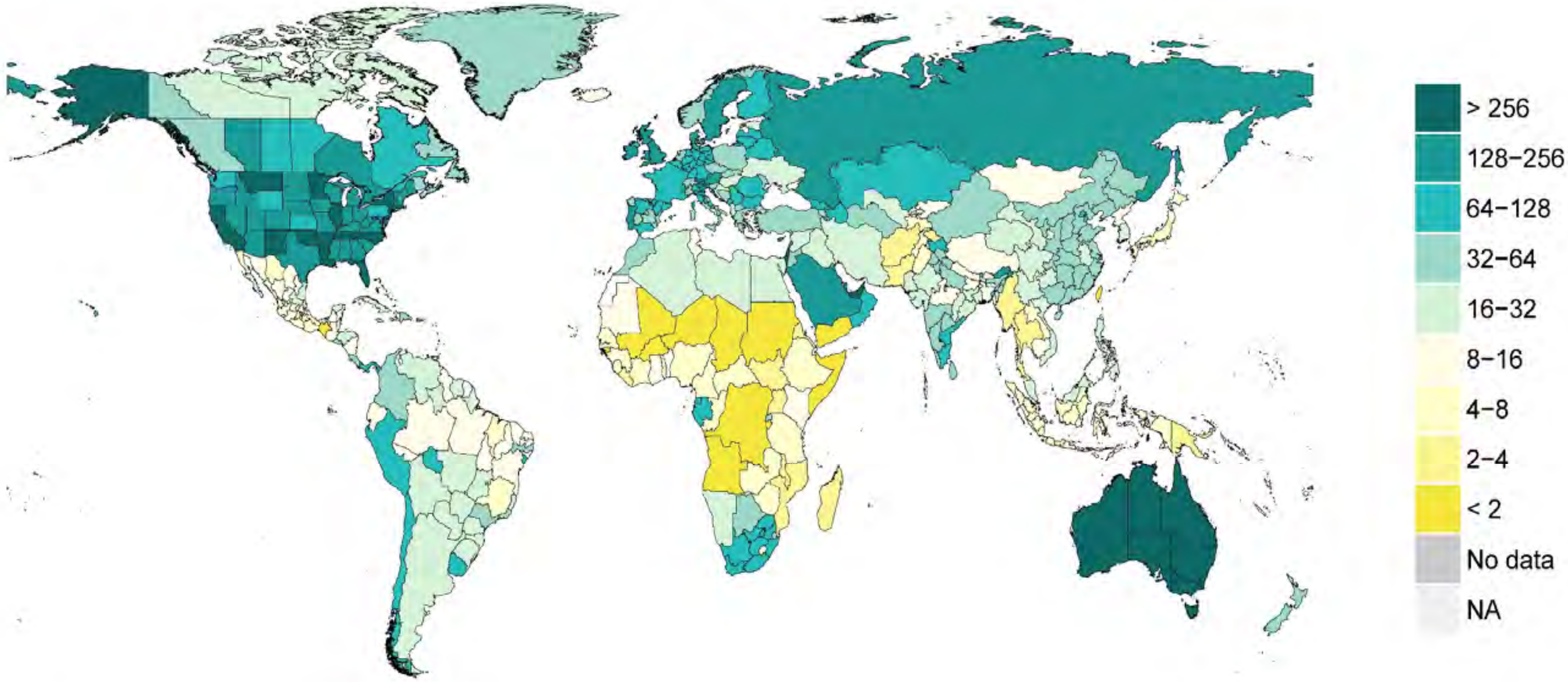

Data source: Facebook Global symptom survey (This research is basedon survey results from University of Maryland Social Data Science Center.)

## Percent reduction from average mobility
## Jul 28

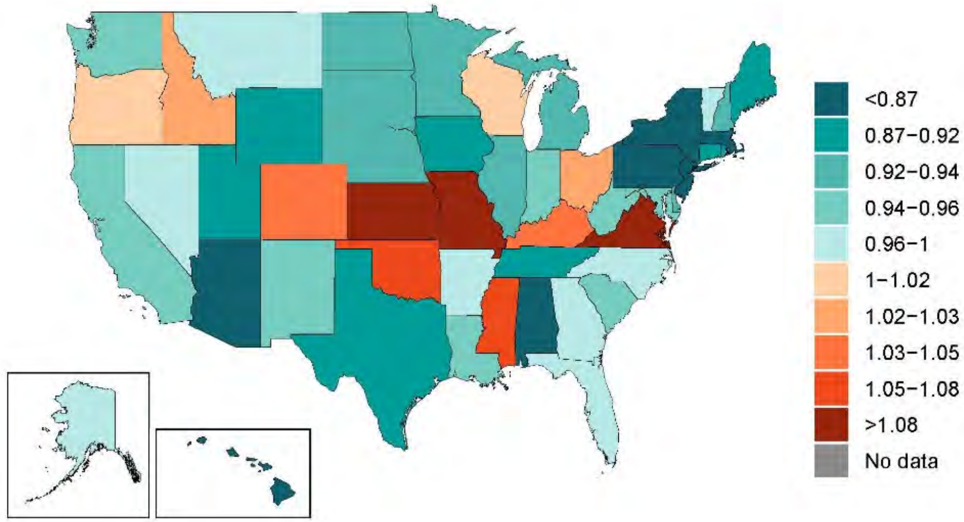



Source: IHME

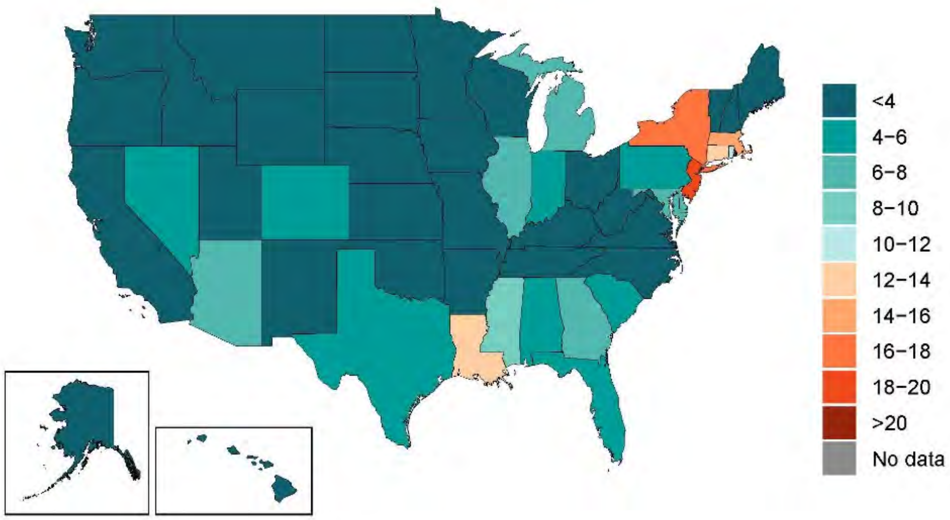
# Tests per 100,000 population
Jul 30




Source: IHME

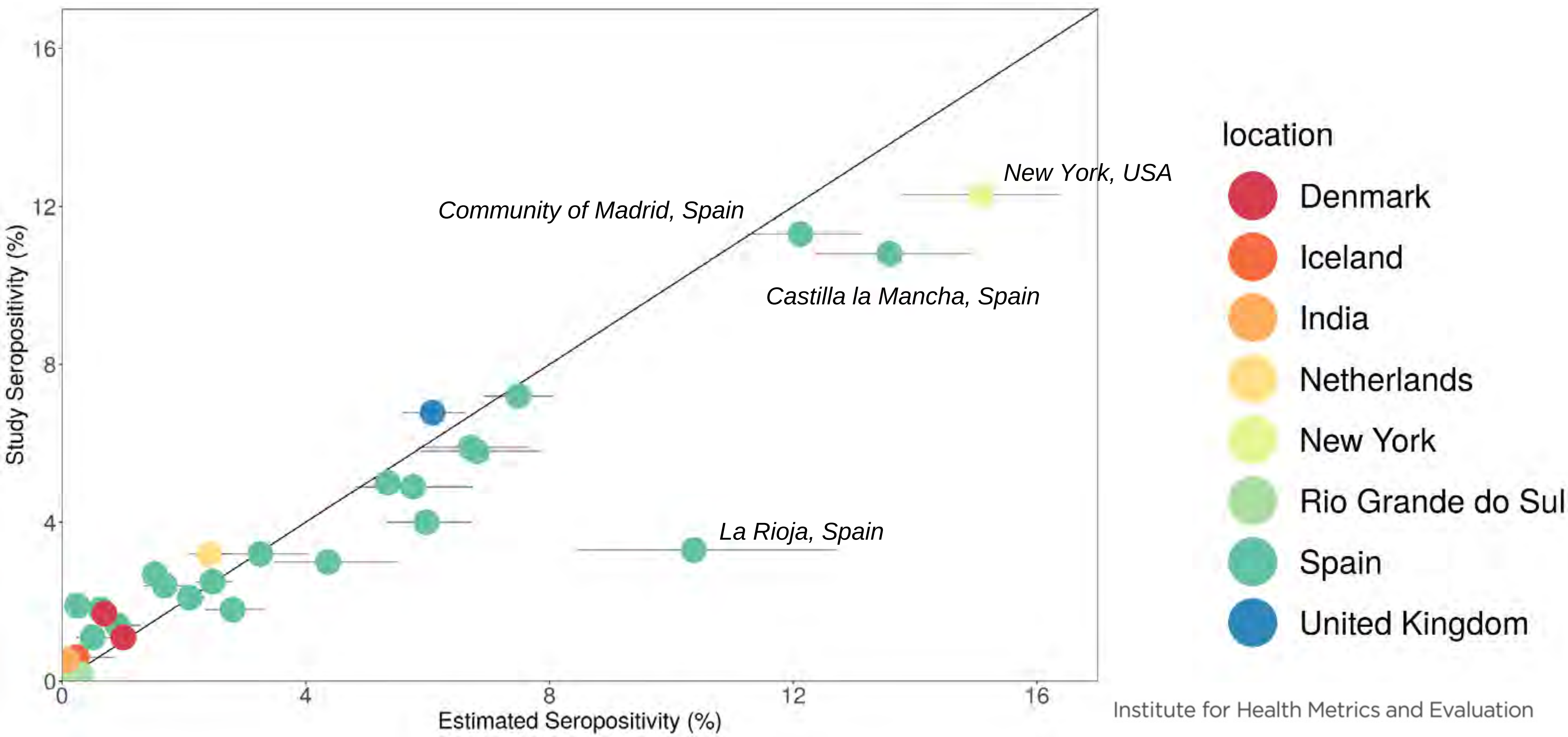



Mean $R_e$ on (July 23)




Percent infected (August 03)

# Measured Antibody Sero-prevalence vs Model Predictions

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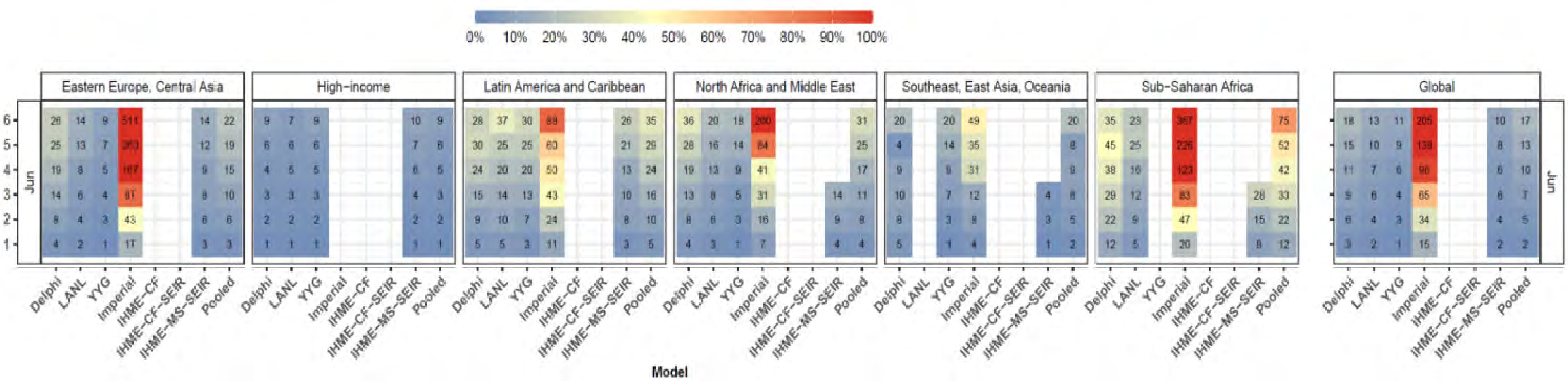
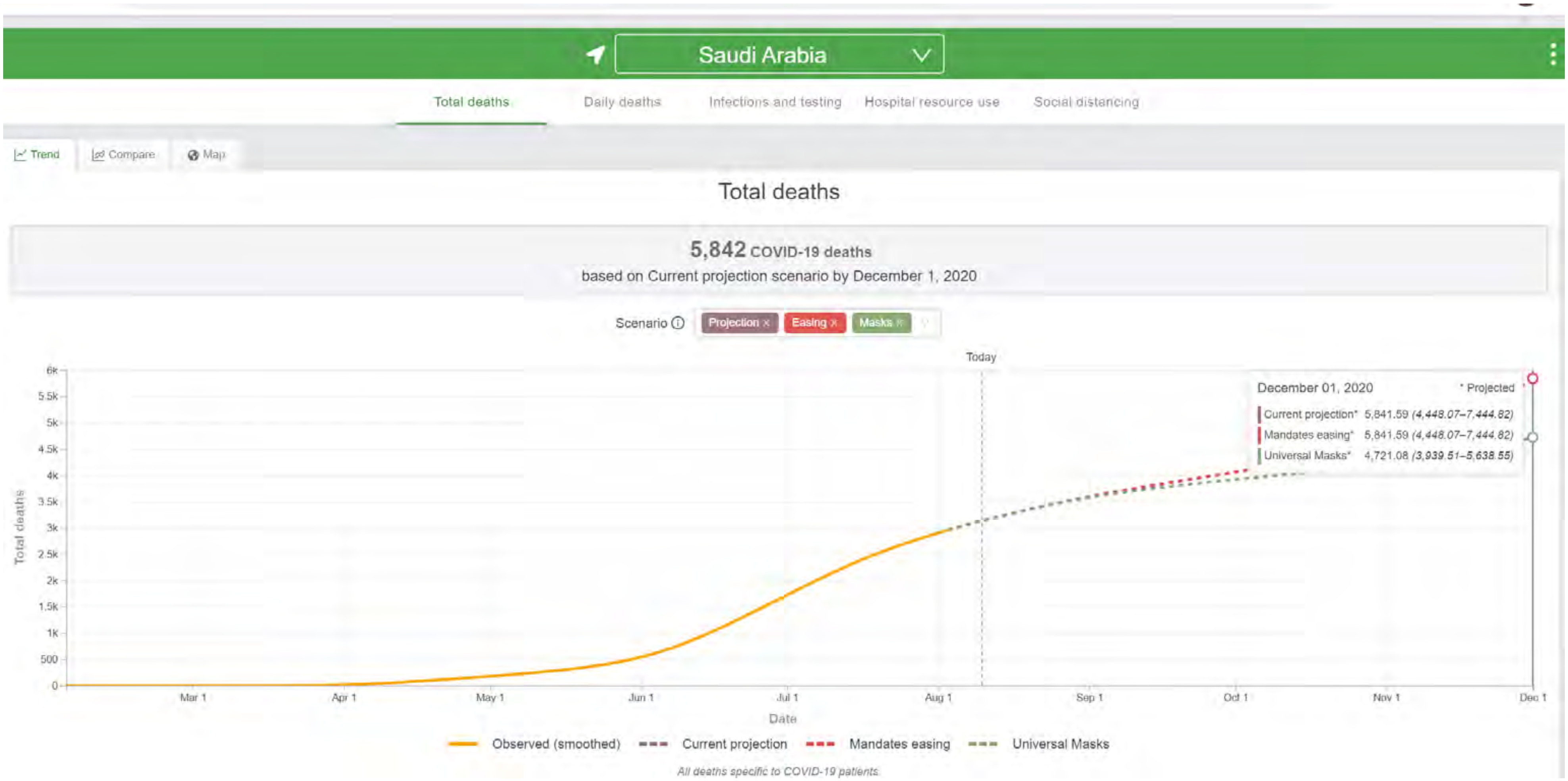
# Median Absolute Percent Error by Week for 6 Publicly Released Models



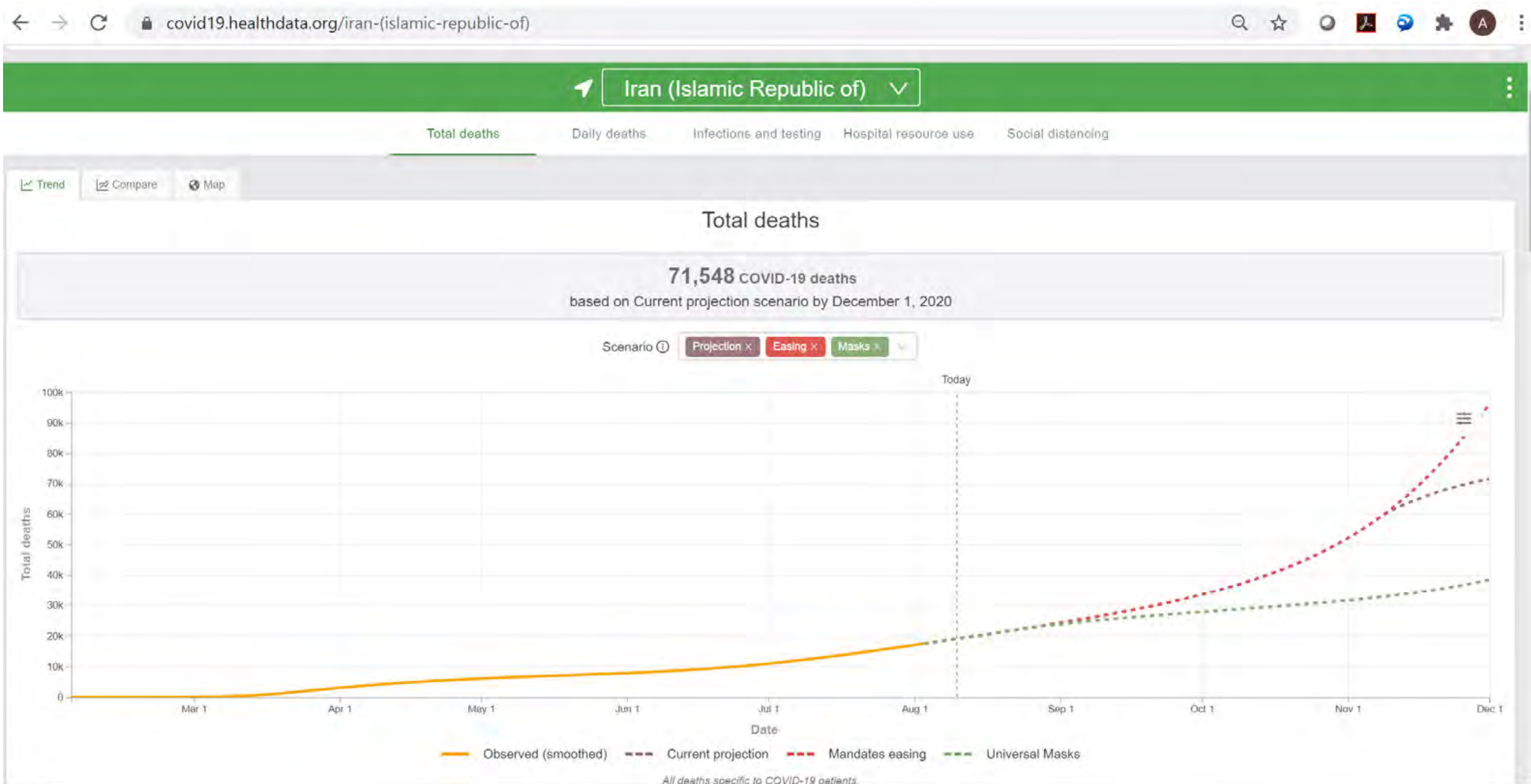

IHME hybrid SEIR model has lowest MAPE of 13% at 6 weeks

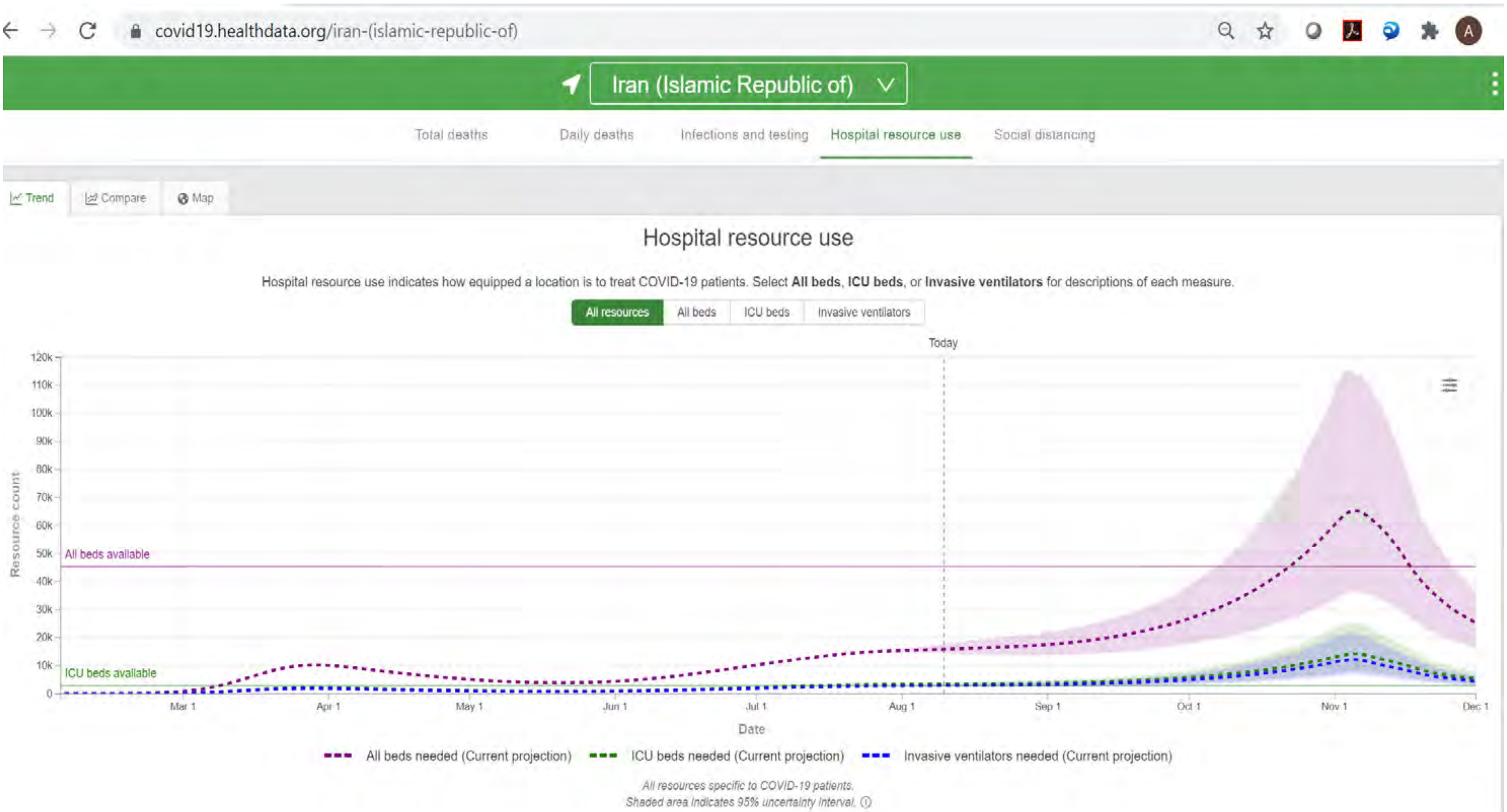

United States of America
To see results within this country, select a subnational location
Total deaths
Daily deaths
Infections and testing
Hospital resource use
Social distancing
Trend
Compare
Map
Total deaths
295,011 COVID-19 deaths
based on Current projection scenario by December 1, 2020
Scenario
Projection
Easing
Masks
Today
December 01, 2020
* Projected
Mandates easing* 391,723.27 (303,088.6–523,982.03)
Current projection* 295,010.52 (242,022.4–370,109.04)
Universal Masks* 228,271.24 (205,463.57–255,133.13)
Total deaths
400k
350k
300k
250k
200k
150k
100k
50k
0
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Date
Observed (smoothed)
Current projection
Mandates easing
Universal Masks
All deaths specific to COVID-19 patients.



Saudi Arabia
Total deaths
Daily deaths
Infections and testing
Hospital resource use
Social distancing
Trend
Compare
Map
Total deaths
5,842 COVID-19 deaths
based on Current projection scenario by December 1, 2020
Scenario
Projection
Easing
Masks
Today
December 01, 2020
* Projected
Current projection* 5,841.59 (4,448.07–7,444.82)
Mandates easing* 5,841.59 (4,448.07–7,444.82)
Universal Masks* 4,721.08 (3,939.51–5,638.55)
Total deaths
Date
Observed (smoothed)
Current projection
Mandates easing
Universal Masks
All deaths specific to COVID-19 patients.


covid19.healthdata.org/saudi-arabia
Saudi Arabia
Total deaths
Daily deaths
Infections and testing
Hospital resource use
Social distancing
Trend
Compare
Map
Hospital resource use
Hospital resource use indicates how equipped a location is to treat COVID-19 patients. Select All beds, ICU beds, or Invasive ventilators for descriptions of each measure.
All resources
All beds
ICU beds
Invasive ventilators
Today
All beds available
ICU beds available
Resource count
28k
26k
24k
22k
20k
18k
16k
14k
12k
10k
8k
6k
4k
2k
0
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Date
All beds needed (Current projection)
ICU beds needed (Current projection)
Invasive ventilators needed (Current projection)
All resources specific to COVID-19 patients.
Shaded area indicates 95% uncertainty interval.


covid19.healthdata.org/iran-(islamic-republic-of)
Iran (Islamic Republic of)
Total deaths
Daily deaths
Infections and testing
Hospital resource use
Social distancing
Trend
Compare
Map
Total deaths
71,548 COVID-19 deaths
based on Current projection scenario by December 1, 2020
Scenario
Projection
Easing
Masks
Today
100k
90k
80k
70k
60k
50k
40k
30k
20k
10k
0
Total deaths
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Date
Observed (smoothed)
Current projection
Mandates easing
Universal Masks
All deaths specific to COVID-19 patients.


covid19.healthdata.org/iran-(islamic-republic-of)
Iran (Islamic Republic of)
Total deaths
Daily deaths
Infections and testing
Hospital resource use
Social distancing
Trend
Compare
Map
Hospital resource use
Hospital resource use indicates how equipped a location is to treat COVID-19 patients. Select All beds, ICU beds, or Invasive ventilators for descriptions of each measure.
All resources
All beds
ICU beds
Invasive ventilators
Today
Resource count
All beds available
ICU beds available
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Date
All beds needed (Current projection)
ICU beds needed (Current projection)
Invasive ventilators needed (Current projection)
All resources specific to COVID-19 patients.
Shaded area indicates 95% uncertainty interval.

# Excess Mortality and Antibody Testing

- In many countries, evaluation of daily all-cause mortality suggests profound under-registration of deaths and cases.
- Random sample survey of antibody prevalence using a high specificity assay can also be used to evaluate completeness of death and case detection.
- Relationship between deaths and infections, the infection-fatality rate by age, has so far been very stable. Higher than expected antibody prevalence would provide an indication of under-registration.
- Individuals respond to the epidemic by modifying their behavior avoiding contact, wearing a mask, decreasing travel, increased personal hygiene.
- Governments respond by imposing mandates

# Current Recommendations

- Include daily Covid-19 hospitalizations in the analysis. Trend in hospitalizations is a leading indicator that is not as sensitive to the expansion of testing as daily cases.
- Evaluate excess mortality in DHSSs in an ongoing basis.
- Undertake an antibody survey every month.
- Early phases of the epidemic – transmission may take off but a clear trend has not emerged. Model forecasts should be revised weekly to reflect the state of transmission and models should be developed by province.
- Implement a universal mask mandate – can reduce transmission by one third which can at the population level have a huge effect on the course of the epidemic.

# IHME Predictions and Scenarios

- Balancing economic activity with public health goals in some countries leading to the idea of planned intermittent mandates.
- In hotspots consider Planned Intermittent Mandates – 2 or 3 weeks of strict social distancing mandates followed by 4-6 weeks of no mandates on a regular schedule may be useful if the epidemic enters a widespread phase.
- Model certain businesses closure and impact on pandemic.
- Model phased vaccination approach and impact on pandemic (certain groups first, etc…).

# Thank you!

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