NVBL: Pandemic Monitoring and Modeling

Budhu Bhaduri
Project Lead

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Monitoring and modeling can answer key questions

- What are the historical and current spatiotemporal trends of disease spread?
- How effective are the implemented interventions and mitigations strategies?
- When and where will the infection curves peak?
- What is the estimate of hospital beds needed, ICU units, ventilators, etc.?
- Can we estimate the CFE (case fatality rate) for each of the age stratifications?
- How much testing capacity is needed and where is it needed?
- What is the impact of vaccine distribution strategies on the spread?

- Collective capabilities across DOE National Laboratories position us to answer these questions
  - Spatial demography and human dynamics
  - Epidemiological modeling
  - Infrastructure, economic, and risk modeling
  - Scalable data and high-performance computing
- Experience of operational support during epidemics
  - H1N1
  - Ebola

Joint DOE Pandemic Modeling and Analysis Capability

Situational awareness

- Retrospective analysis with publicly available data
- COVID-19 trends from country to county scales
  - Case
  - Death
  - Testing
  - R_0
- Mobility data analysis
- DOE-curated COVID-19 data cube at county scale

Predictive analytics

- Short-term (7–14 days) disease forecasts
- Long-term (weeks to months) disease forecasts
- Multiscale modeling
  - Statistical
  - Mechanistic
  - Agent based
- NIP scenario-based analysis
- Healthcare resource and economic impacts analysis
- **Transportation modeling**

COVID-19 platform

- Central repository for curated data and model output
- Interactive dashboards
  - Situational awareness
  - Predictive analytics
- Ensemble visualizations
- Role-based access via userid/password authentication
  - DOE only (full access to content)
  - DOE partners (limited access to content)

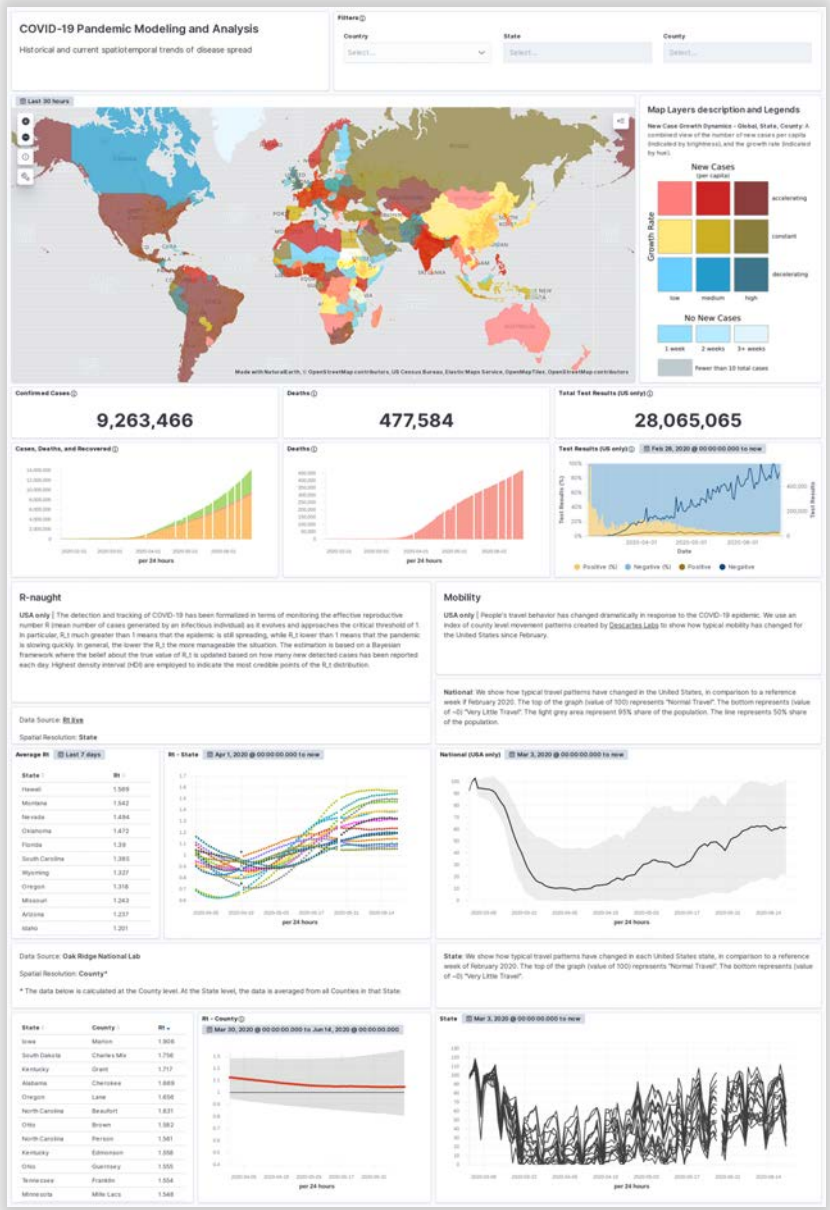
Results have helped officials in New York, Illinois, New Mexico, and Tennessee, among others, to understand the spread of COVID-19 and the effects of intervention policy measures

Situational awareness products

Retrospective analysis of publicly available data

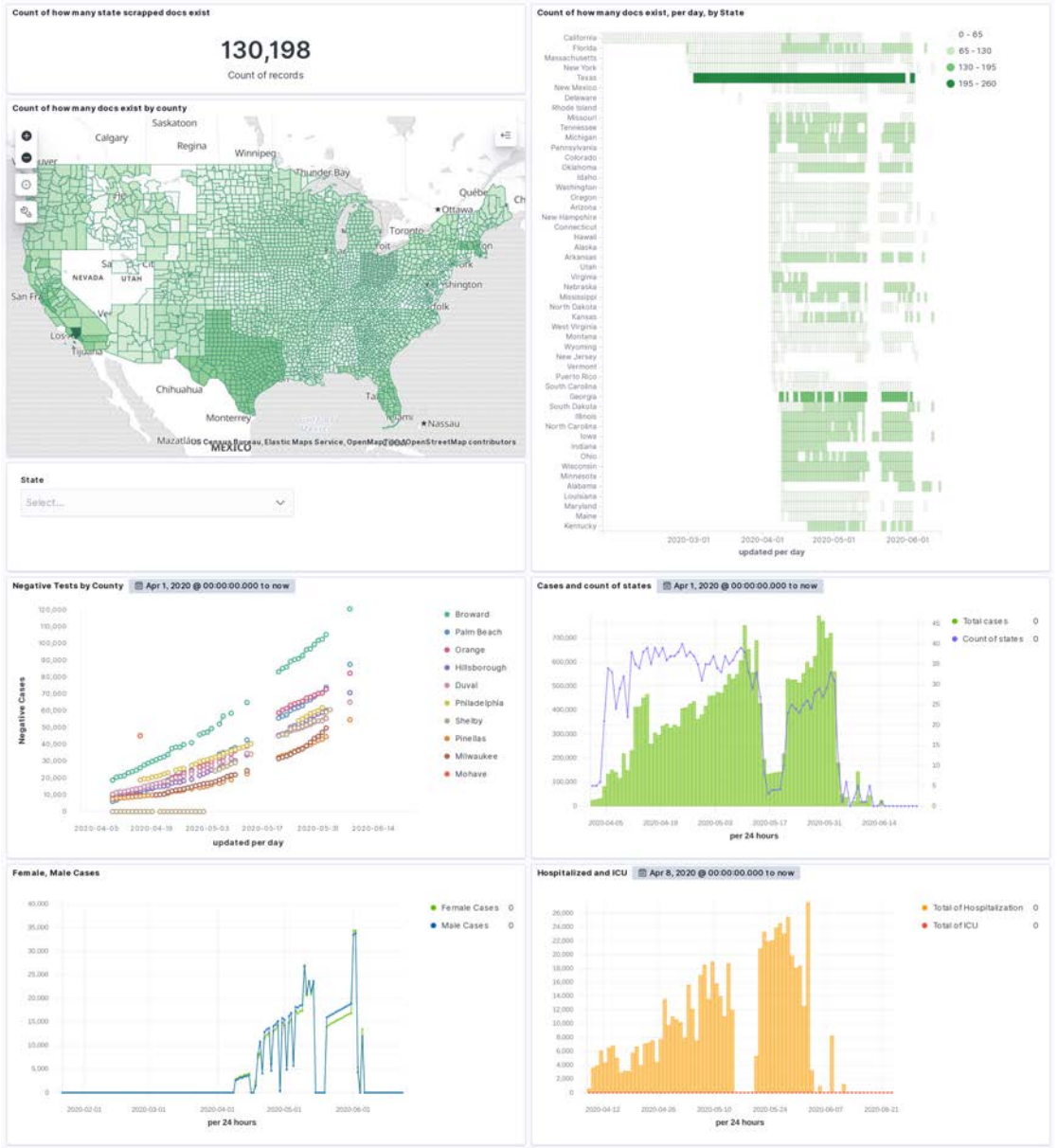
21 data layers, including:

- **Disease dynamic maps** (country, state, and county resolution)
- **COVID cases and deaths:** Maps and temporal trend charts (country, state and county resolution)
- COVID **testing** data
- **Mobility** reduction maps and trend charts
- **R_0** trend charts
- Infrastructure layers
  - LandScan **population**
  - **Hospitals**
  - **Stadium (temporary triage centers)**



DOE-curated COVID-19 data cube

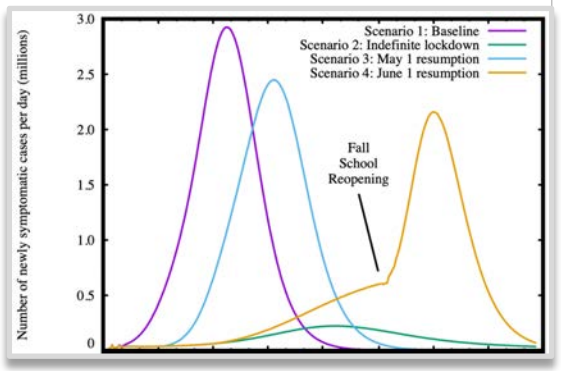
- Geographic coverage
  - All 50 states, DC, Puerto Rico, associated US territories
  - FIPS-equivalent coverage in most states
  - Other common geographies: Health district, zip codes, some individual cities
  - Some facility data: LTC facilities, hospitals
- Temporal coverage: 50 states since March 18
- Attribute extent: Varies by state
  - **Cases:** Common to all geographies
  - Many attributes with large-scale coverage at state and county level: **Tested, hospitalized, deaths, cases by sex/gender,** etc.
  - Many states have high-resolution detail in one area (e.g., New York: comorbidities; Ohio: extensive county coverage; North Dakota: case exposure)



Multiscale modeling of COVID-19 dynamics

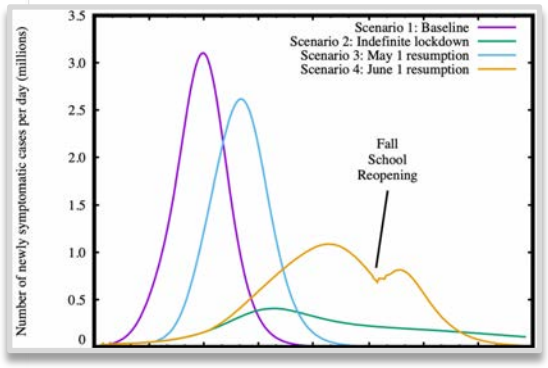
Statistical

- Short-term (~7 day) forecasts of epidemic trends
- Region, state, and county scale daily output
- Bayesian inference based



EpiGrid

- Compartmental SEIR based; deterministic
- Global (5 km resolution
- Explicitly models real-world mitigations
- Flexible and interactive



EpiCast

- Mechanistic, agent-based model; stochastic
- ~300M US population in ~65k census tracts
  - Community behavior
  - 99 workforce sectors (NAICS code)
- Distributed memory and scalable

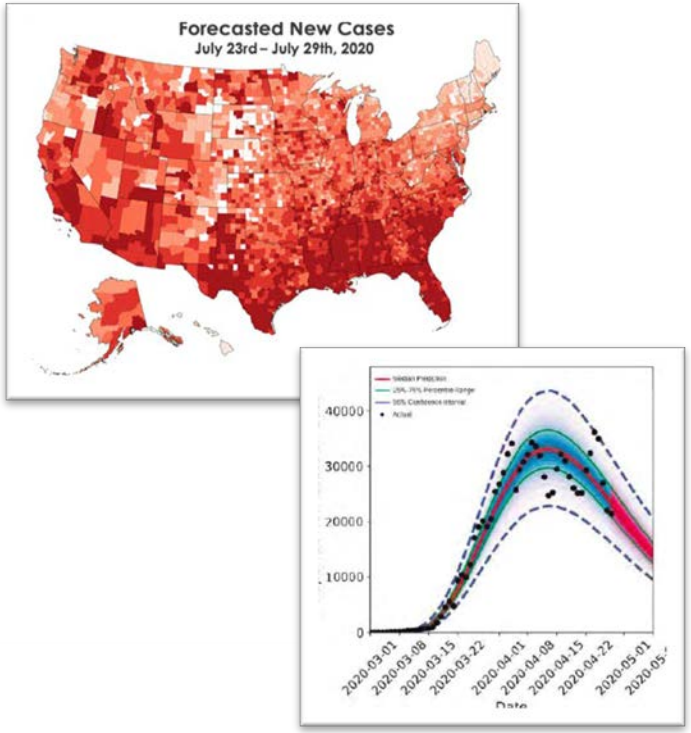
CityCovid

- Mechanistic, agent-based model; stochastic
- ~3M Chicago population
  - Individual behavior
  - 1.2M places
- HPC (Theta) required

Epidemiological modeling highlights

Short-term assessments

- Estimation of R_{eff} values
- 7-day forecasting of disease prevalence by county



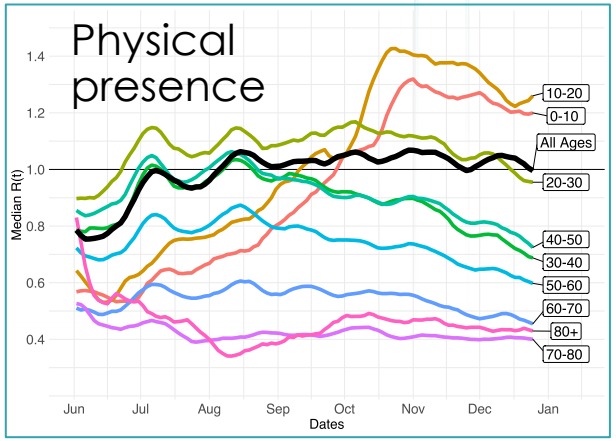
Scenario-based analysis

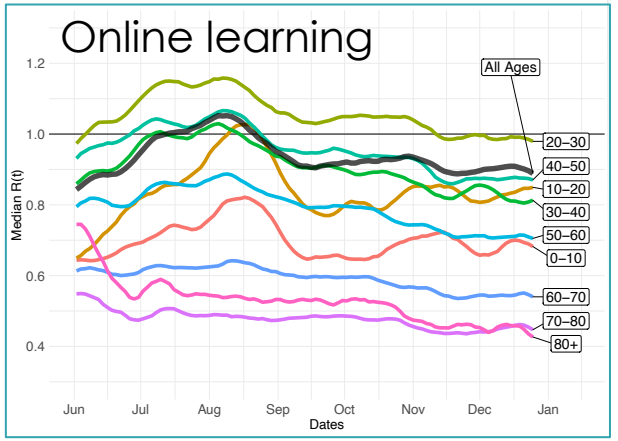
- Consequences of various non-pharmaceutical interventions
- Estimated transmission reduction of 85% and activity reduction of 50% for Chicago, while the stay-at-home order in effect in IL
- Detailed comparison of impact of bars and school re-opening on COVID spread

Mitigation planning

- Developed systems-engineering model (Median) relating testing turnaround time, sensitivity and specificity, contact tracing and isolation to consequence

Back to school scenarios



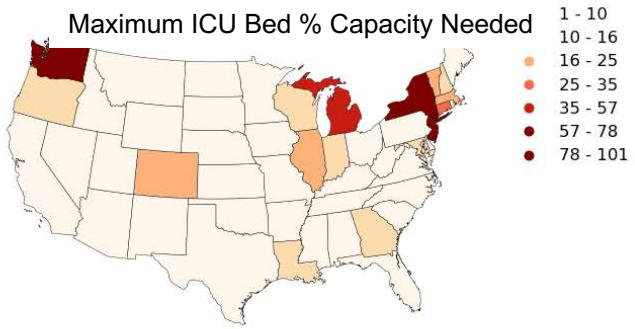


Resource, economic, and vaccine modeling highlights

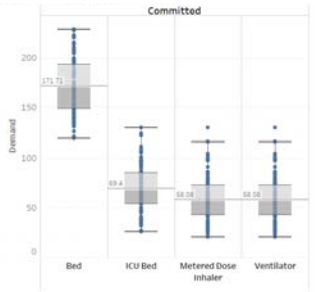
Medical resource demand

Using EpiGrid as an input, calculated demand for practitioner types, committed, and consumable resources for each county in multiple scenarios

State and county risk indicators

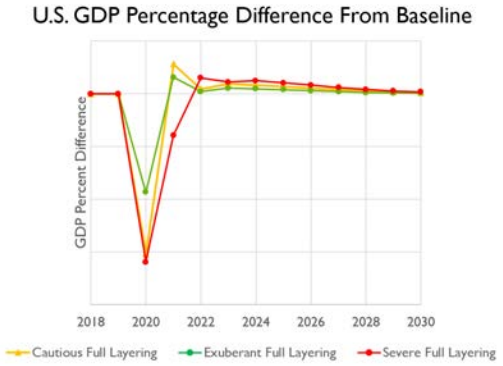


Maximum number of resource needs with a range of uncertainty

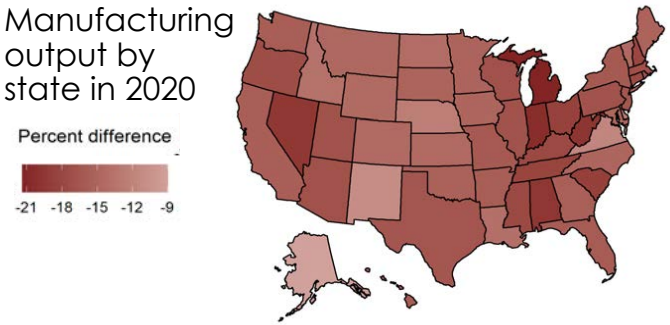


Economic impacts

May 2020: Estimated cumulative economic impacts of shutdowns and potential recovery strategies

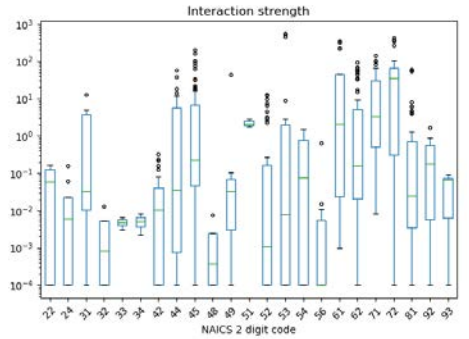


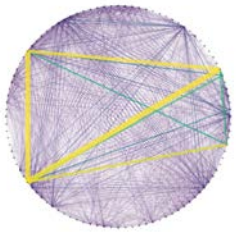
Manufacturing output by state in 2020

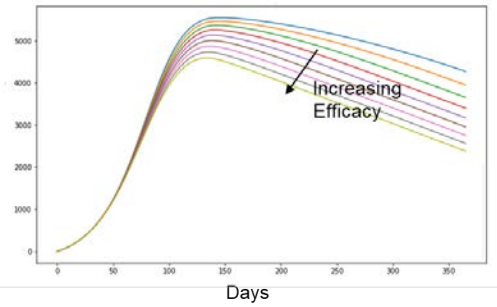


Vaccine distribution strategy

Use SNL's Adaptive Recovery Model to test vaccine strategy impact on cases, hospitalizations, testing, and contact tracing needs, reflecting current population behaviors using mobility patterns





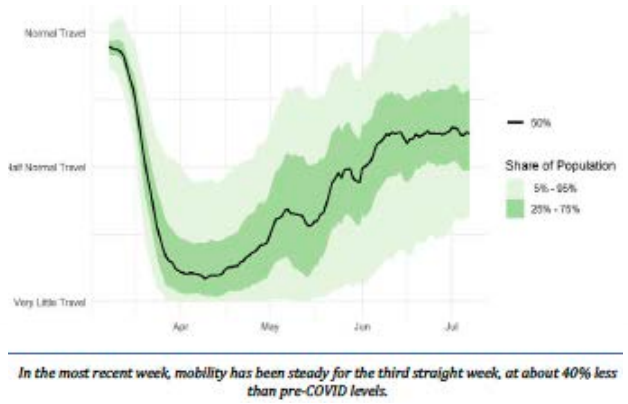


Contact tracing queue with changes in vaccine efficacy

Transportation modeling highlights

Personal mobility

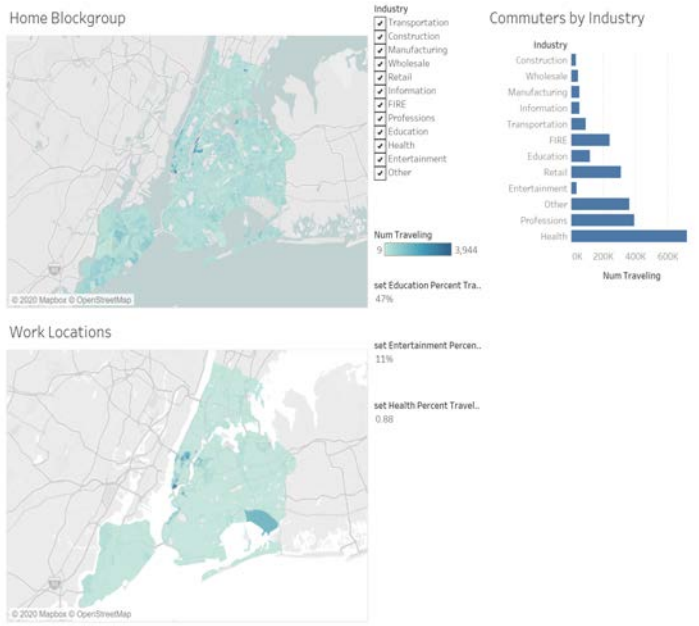
- At the national level, mobility drastically decreased across all modes at the onset of the pandemic, with personal vehicle travel rebounding over time
- Yet transit, air, and shared modes remain severely lagging due to fear of disease transmission



In the most recent week, mobility has been steady for the third straight week, at about 40% less than pre-COVID levels.

Freight movement

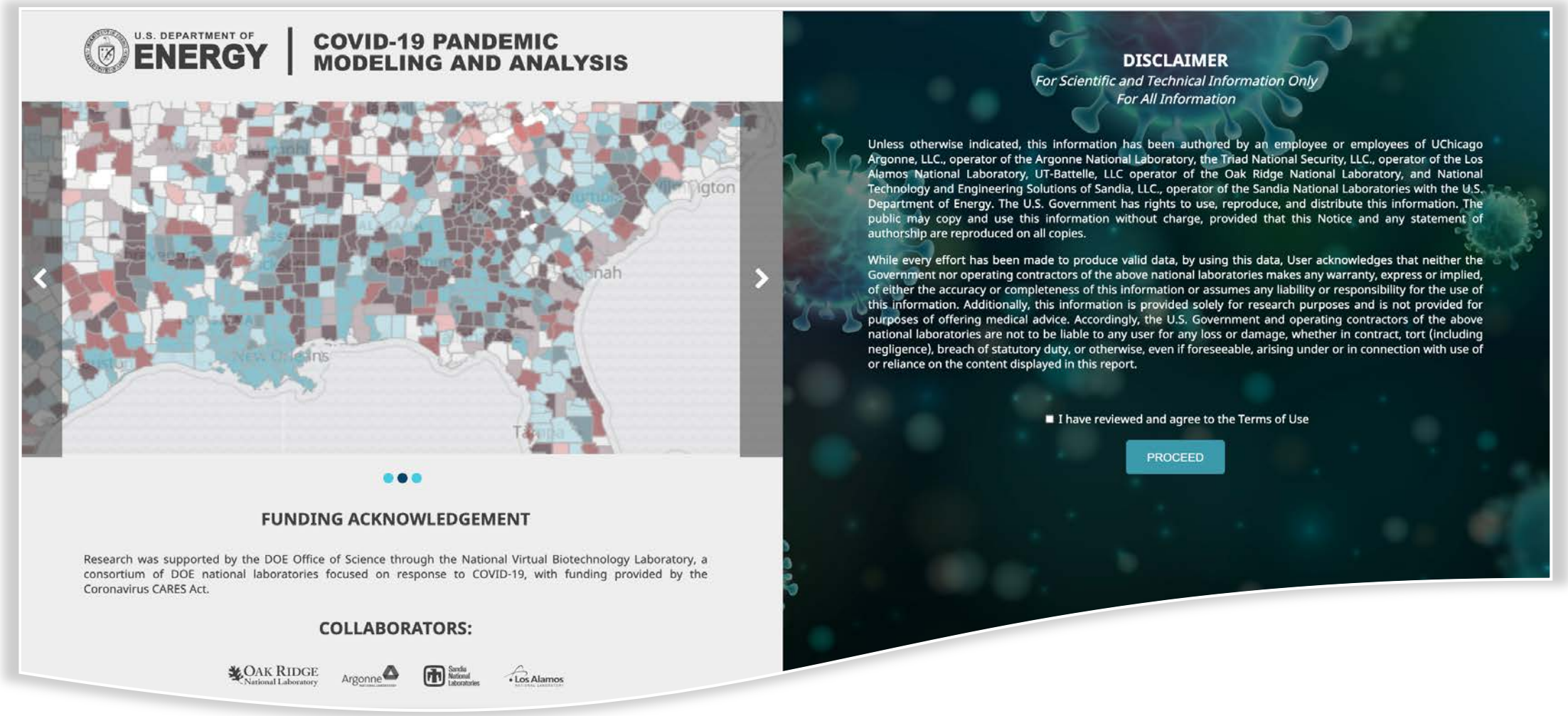
- Freight mobility was not impacted to the same degree, with roughly 20% impact at most, and has rebounded to pre-pandemic levels



Scenario-based modeling

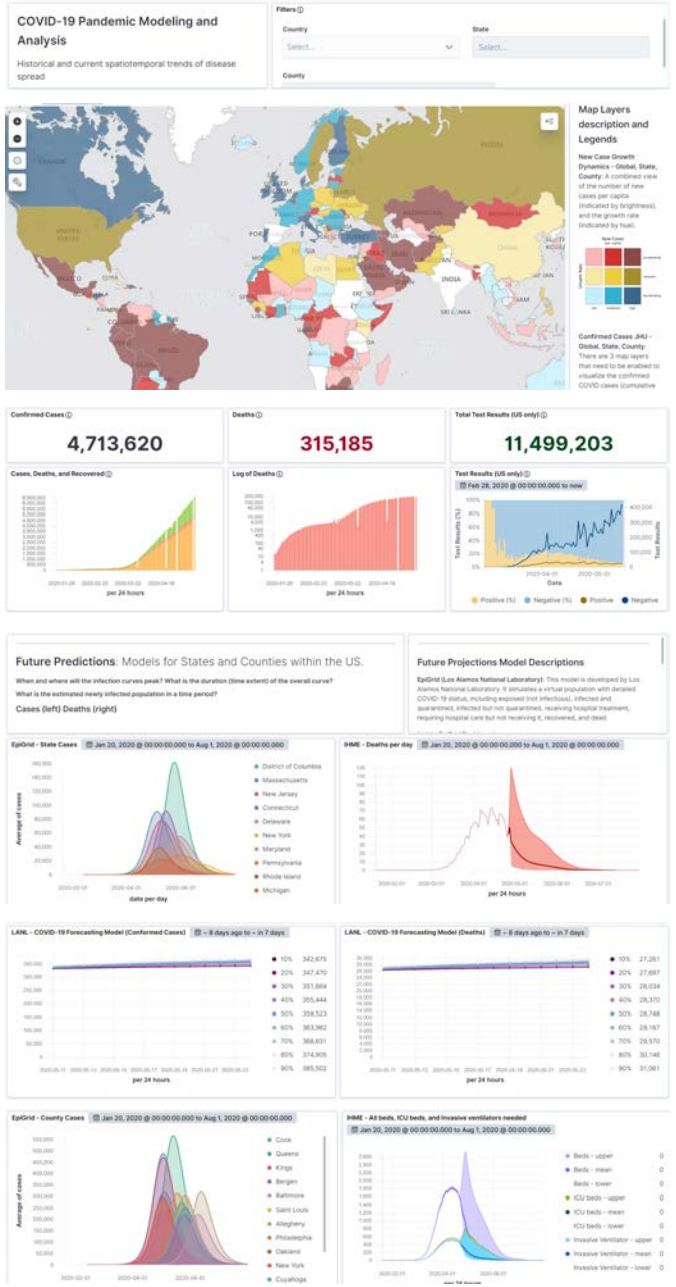
- Lab partnership with Chicago and New York on Agent Based Mobility models identified in likely scenarios
  - AM travel peaks subside, PM travel peaks broaden
  - Roadway systems do not have adequate capacity without transit recovery

COVID-19 project portal



COVID-19 platform

- **Centralized repository** of curated datasets from all the national labs pursuing policy guidance
- Serve as a **situational awareness and analytics** platform
  - The **dynamic nature** of the **curve** (cases and deaths, trends, growth rates at global, state and county level)
  - **Measure mitigation** policies against the curve
  - Anticipate future curve states
  - Assess **impacts** against healthcare infrastructure
  - Perform **space and time analytics** to assess impact
  - Monitor potential **recovery** efforts
  - **Ensemble visualization** of model results

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