CHIME Model v1.1.5

Version 4 - Updated 5/11/2020

Summary

An implementation of Penn Medicine's COVID-19 Hospital Impact Model for Epidemics (CHIME) for use in ArcGIS Pro 2.3 or later. This tool leverages SIR (Susceptible, Infected, Recovered) modeling to assist hospitals, cities, and regions with capacity planning around COVID-19 by providing estimates of daily new admissions and current inpatient hospitalizations (census), ICU admissions, and patients requiring ventilation.

Version 4 of this tool is based on CHIME v1.1.5 (2020-05-07). Learn more about how CHIME works

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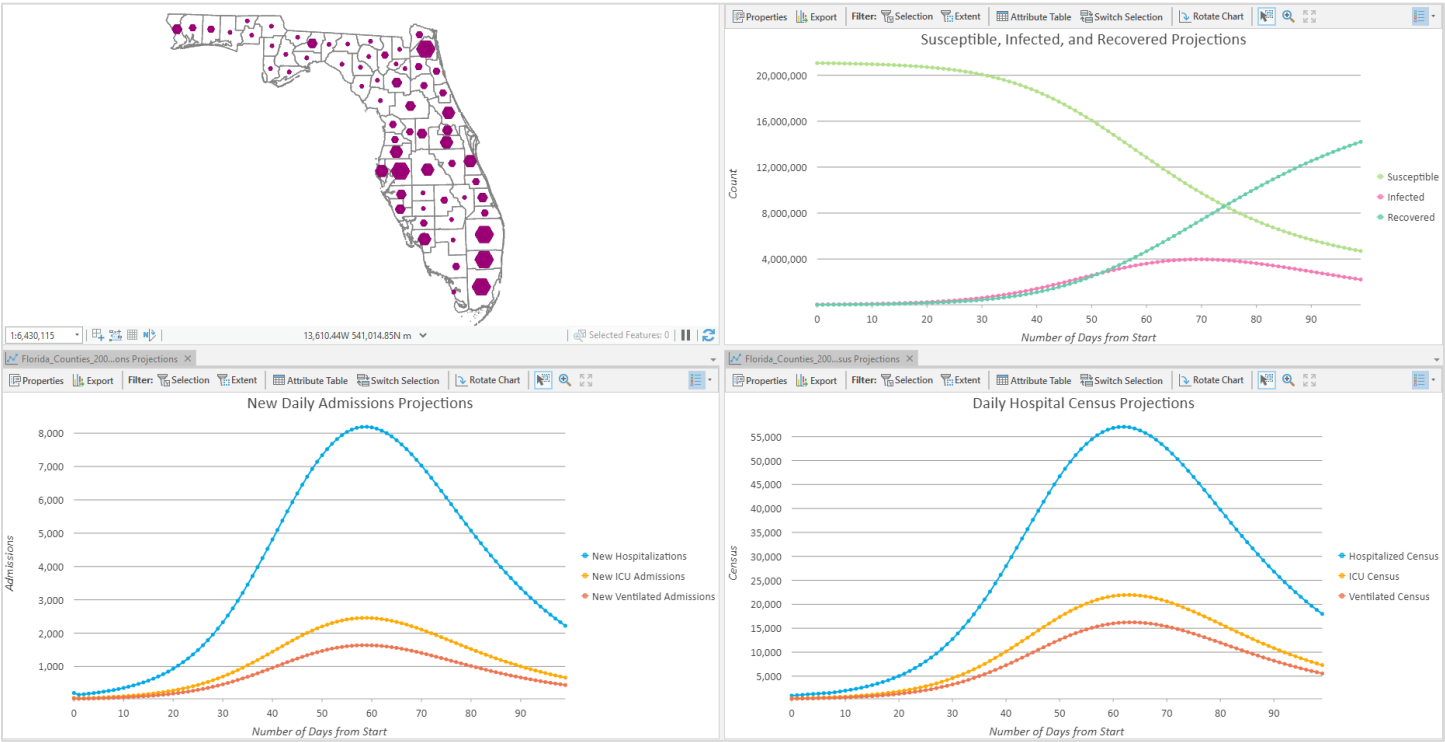
This tool requires ArcGIS Pro 2.3 (or later) to run.
Steps for upgrading ArcGIS Pro can be found here.

Watch a video about how this tool can help model COVID-19.

For questions, comments and support, visit our COVID-19 GeoNet community.

Illustration



Potential applications

- A hospital systems administrator needs a simple model to project the number of patients the hospitals in the network will need to accommodate in the next 90 days due to COVID-19. You know the population served by each hospital, the date and level of current social distancing, the number of people who have recovered, and the number of patients that are currently hospitalized with COVID-19 in each facility. Using your hospital point layer, you run the tool using the **Constant Model Parameters**, making the assumption that all hospital populations have similar social distancing and hospitalization patterns.

- A hospital systems administrator needs to model how differences in the behaviors and population will impact the hospitalization patterns across the hospital network for the next 30 days. For each hospital catchment area, you use the total population for the hospital network catchment area and the market share of the hospital to calculate a new field representing the patient population for each catchment area. Using this polygon layer, you run the tool using the **Field-Based Model Parameters** and the patient population to model the different hospitalizations expected at each hospital in the network.
- An aid agency wants to predict where and when resources will be required in the counties you serve. You know the population, the date and level of current social distancing, and the number of people currently hospitalized in each county. You run the tool using your county polygon data with a combination of the **Field-Based Model Parameters** in which you have the data for how these vary between counties, and you use the **Constant Model Parameters** when you want to use a fixed model parameter for all counties.

- A county wants to understand how interventions may impact hospital availability within the county. You create a county polygon layer with fields that reflect possible scenarios regarding COVID-19 doubling time and social distancing. You run the tool with this data and use the **Additional Outputs for Visualization** parameters to add fields indicating bed capacity and web app fields to the output. You display the published results in the Capacity Analysis configurable app so intervention scenarios can be compared.

Best practices and usage information

- This tool accepts either points or polygons. These features may correspond to specific hospital locations, hospital catchment areas, counties or regions.

- For each feature in the **Input Feature Class,** and for each of the **Number of Days to Project,** the tool provides an estimate of daily new hospitalization admissions, new ICU admissions, new ventilated hospitalizations, as well as the daily hospital census, daily ICU census, and the ventilated hospitalization census.

- The tool contains model parameters that can either be designated as fields (spatially-varying) or constants. If a field input is set for a variable, the corresponding constant value input for that parameter will display **Set as Field.** Field input always overrides constant input during execution and UI population.

Note: To change the input value for a model parameter from a specified field back to a constant, you must first delete the value provided for the input field before you can define the new constant input value.

- The **Population** field should reflect the population assigned to each record in the **Input Feature Class** whether that represents a hospital, catchment area, or an administrative boundary.
- If you do not have population data for your catchment or hospital area, you can use the Enrich tool to get Esri population data or use the Summarize Within tool or the Tabulate Intersection tool with the **Sum Fields** parameter to apportion the county data you do have to your catchment or hospital areas.
- To get the most accurate predictions, it is not recommended to subset your data for input to the **Population** field (such as only including the population from ages 6 to 8 or 65+) as COVID-19 can be spread from all subsets.
- While a parameter to include market share is provided in UPenn's CHIME model to calculate a population served for a hospital, it is not included in this tool as this tool calculates models for multiple locations and areal units such as counties or hospital networks. For hospital data, the **Population** field should represent the patient population for the hospital, considering that some of the population within the catchment of a hospital may be served by other hospitals. If the **Population** field does not represent the patient population for each hospital, use the **Calculate Field** tool to multiply the total population in the region by the proportion of patients that are served by the hospital. This calculation is needed because under-the-hood, this tool defaults to 100% market share.
- You may predict a minimum of 30 days and a maximum of 365 days. However, it is recommended not to use more than 30 days for accurate projections.
- The tool contains a **Social Distancing** parameter to estimate how much social contact is reduced in each catchment area compared to no social distancing at all. Penn Medicine Predictive Healthcare provide further guidance on how the parameter can be estimated in the context of common policies such as school closures and case isolation.
- The **Date of Social Distancing Measures Effect (May be Delayed From Implementation)** parameter allows social distancing measures to be incorporated on a date earlier or later than the **Start Date**. This should not be the date of the implementation of the measures, but the date that their impact started to be seen on new cases of COVID -19. This parameter can be specified as a field (spatially-varying) or a constant. If it is specified as a constant and the date is before the **Start Date**, the **Daily Forecast Output Feature Class** and charts will contain projections starting from this date instead of the **Start Date**.
- The output of this tool includes a feature class symbolized by the daily hospitalization census which can be time-enabled following the steps below. Informational messages and interactive charts are also provided.
- When bed capacity is not reached, the capacity date fields for hospitalizations, ICU, and ventilators are populated with the date 1/1/1900 as a placeholder.
- Features missing data for any of the input variables are dropped from the analysis and do appear in the output. It is recommended to inspect your data for null values before running the tool. The Fill Missing Values tool can be used to replace missing values with estimated values.

Installation

The tool is available as a Python Toolbox (.pyt), which can be opened and used in the same manner as geoprocessing tools in ArcGIS Pro.

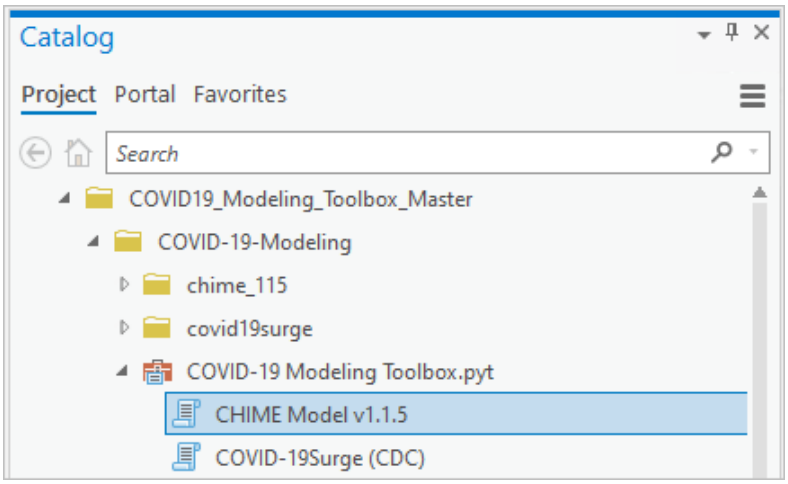
To install complete the following steps:

1. Download the geoprocessing tool .zip file.

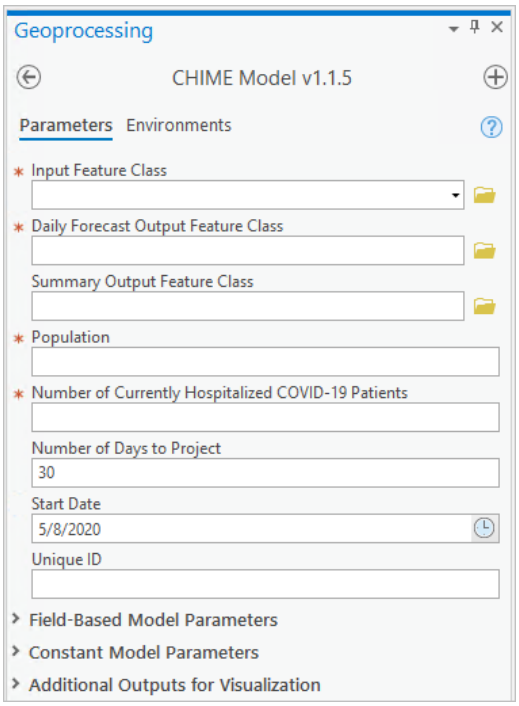
2. Unzip the file to a location in your local system.
   Note: The location must be accessible as a folder connection for ArcGIS Pro.

3. Open ArcGIS Pro, create a project, and create a folder connection to your unzipped folder location.
   Note: You can drag and drop the unzipped folder in the **Catalog** pane in ArcGIS Pro

4. In the **Catalog** pane, open the folder and expand the **COVID-19 Modeling Toolbox.pyt** python toolbox.



5. Open the **CHIME Model v1.1.5** tool.



Parameters

The tool uses parameters that describe the healthcare system or region being analyzed as well as the spread and contact input information for the disease. Spread and contact input information can be specified either as fields in the **Input Feature Class** or as constant values.

	Parameter	Explanation	Data type
0	Input Feature Class (in_fc) (Required)	The feature class containing information for each hospital, hospital catchment area, or county to be analyzed.	Feature Layer
1	Daily Forecast Output Feature Class (out_fc) (Required)	The output feature class to receive the results for each day's estimated hospital demand.	Feature Class
2	Population (pop_field) (Required)	The field representing the total population size of the catchment region of your hospital(s) or the total population size in each county. This is the initial S (Susceptible) input in the SIR model. This affects projections for the number of infected people as well as the numbers requiring hospitalization, intensive care (ICU), and ventilation. If the field contains decimals, the value is rounded to the nearest whole number.	Field

4	Number of Currently Hospitalized COVID-19 Patients Field (hosp_field) (Required)	The field representing the number of patients currently hospitalized with COVID-19 at the input hospital locations or catchment areas. This number is used along with population and Hospitalization % to estimate the total number of infected individuals.	Field
5	Doubling Time in Days (Up to Today) (doubling_time_field) (Optional)	The field representing the number of days required for the number of infected individuals to double. Doubling rate is meant to apply as an infection growth rate without interventions.	Field
6	Social Distancing % (Reduction in Social Contact) (social_dist_perc_field) (Optional)	The field representing the estimate of how much social contact is reduced in each catchment area compared to no social distancing at all. This parameter allows users to explore how reduction in transmission via social distancing, reduced interpersonal contact, and other methods (for example, hand washing, increased disinfection of surfaces, and so on) might slow the rate of new infections. While it is currently unclear how much any given policy may affect social contact (for example, school closures or remote work), this parameter allows you to see how projections change with percentage reductions in social contact.	Field
7	Hospitalization % (Total Infections) (hosp_rate_perc_field) (Optional)	The field representing the percentage of all infected cases that will need hospitalization. This percentage, along with the number of hospitalized COVID-19 patients and the total population are used to calculate the estimated number of currently infected Individuals. See Verity et al., which suggests that around 5% of infected people need hospitalization, while also supplying an age adjustment methodology should you want to calibrate it to your own population. Note: There is a large amount of uncertainty surrounding this figure as hospitalization requirements may vary between regions.	Field

8	ICU % (Total Infections) (icu_perc_field) (Optional)	The field representing the percentage of all infected cases that need to be treated in an ICU.	Field
9	Ventilated % (Total Infections) (vent_perc_field) (Optional)	The field representing the percentage of all infected cases that need mechanical ventilation.	Field
10	Average Hospital Length of Stay (Days) (hosp_stay_len_field) (Optional)	The field representing the average number of days spent in the hospital for ICU COVID-19 patients. This is inclusive of all hospitalized COVID-19 patients, regardless of the highest level of care they receive. If the field contains decimals, the value is rounded to the nearest whole number.	Field
11	Average Days in ICU (icu_stay_len_field) (Optional)	The field representing the average number of days of ICU treatment needed for ICU COVID-19 patients. This includes both vented and non-vented patients. If the field contains decimals, the value is rounded to the nearest whole number.	Field
12	Average Days on Ventilator (vent_stay_len_field) (Optional)	The field representing the average number of days with ventilation needed for COVID-19 patients. If the field contains decimals, the value is rounded to the nearest whole number.	Field
14	Infectious Days (inf_days_field) (Optional)	The field representing the number of days a person can infect another person (regardless of whether the infected person is symptomatic or asymptomatic). This represents gamma (γ) in the SIR model.	Field
15	Number of Days to Project (num_days) (Required)	The number of days to include in the output analysis. Using a number greater than 30 is not recommended.	Long
16	Start Date (start_date) (Required)	The date used to represent a start point for calculating projections for number of hospitalizations, ICU admissions, and patients requiring ventilation.	Date

17	Doubling Time in Days (Up to Today) (doubling_time) (Required)	The number of days required for the number of infected individuals to double before the current date. Doubling rate is meant to apply as an infection growth rate without interventions.	String
18	Social Distancing % (Reduction in Social Contact Going Forward) (social_distancing_perc) (Required)	The estimate of how much social contact is reduced in each catchment area compared to no social distancing at all. This parameter allows users to explore how reduction in transmission via social distancing or reduced interpersonal contact and other methods such as hand-washing, increased disinfection of surfaces, and so on may slow the rate of new infections. While it is currently unclear how much any given policy may affect social contact such as school closures or remote work, this parameter allows you to see how projections change with percentage reductions in social contact.	String
19	Hospitalization % (Total Infections) (hosp_rate_perc) (Required)	The percentage of all infected cases that need hospitalization. This percentage, along with the number of hospitalized COVID-19 patients, and the population inform the estimated number of currently infected individuals in the output. See Verity et al. which suggests that around 5% of infected people need hospitalization, while also supplying an age adjustment methodology should you want to calibrate it to your own population. Note: There is a large amount of uncertainty surrounding this figure as hospitalization requirements may vary between regions.	String
20	ICU % (Total Infections) (icu_perc) (Required)	The percentage of all infected cases which will need to be treated in an ICU.	String
21	Ventilated % (Total Infections) (vent_perc) (Required)	The percentage of all infected cases that need mechanical ventilation.	String
22	Average Hospital Length of Stay (Days) (hosp_stay_len)	The average number of days COVID-19 patients have needed to stay in a hospital.	String

	(Required)	If the value provided contains decimals, the value is rounded to the nearest whole number.	
23	Average Days in ICU (icu_stay_len) (Required)	The average number of days COVID-19 patients have needed ICU care. If the value provided contains decimals, the value is rounded to the nearest whole number.	String
24	Average Days on Ventilator (vent_stay_len) (Required)	The average number of days with ventilation needed for COVID-19 patients. If the value provided contains decimals, the value is rounded to the nearest whole number.	String
26	Infectious Days (inf_days) (Optional)	The field representing the number of days a person can infect another person (regardless of whether the infected person is symptomatic or asymptomatic). This represents gamma (γ) in the SIR model.	String
27	Total Bed Capacity (lic_bed_field) (Optional)	The total number of regular hospital beds available. If the field contains decimals, the value is rounded to the nearest whole number.	Field
28	Total Ventilator Capacity (staffed_vent_field) (Optional)	The total number of ventilators available. If the field contains decimals, the value will be rounded to the nearest whole number.	Field
29	Total ICU Bed Capacity (icu_beds_field) (Optional)	The total number of beds in the ICU. If the field contains decimals, the value is rounded to the nearest whole number.	Field
30	Additional Output Variable(s) (additional_fields) (Optional)	Additional fields can be appended to the **Summary Output Feature Class**.	[Field]
31	Unique ID (unique_id) (Optional)	The field from the **Input Feature Class** representing unique IDs for each feature.	Field

32	Summary Output Feature Class (out_fc2d) (Optional)	This optional summary feature class includes information about input model parameters as well as peak dates and over capacity dates for hospitalized, ICU and ventilated census	Feature Class
33	Add Additional Web App Fields in Summary (add_webapp_fields) (Optional)	This parameter is used to add necessary fields for the Capacity Analysis configurable app to the **Summary Output Feature Class**. • CREATE_WEB_FIELDS –The web app fields will be created. • NO_CREATE_WEB_FIELDS –The web app fields will not be created. If you choose CREATE_WEB_FIELDS the **Summary Output Feature Class, Unique ID,Total Bed Capacity**, **Total Ventilator Capacity** and **Total ICU Bed Capacity** fields will be required.	Boolean
34	Date of Social Distancing Measures Effect (May be Delayed From Implementation) (mitigation_date) (Optional)	A field from the **Input Feature Class** that represents the date when social distancing measures started showing their effects on new cases of COVID-19. If a field-based **Date of Social Distancing Measure Effect** is provided, the **Daily Forecast Output Feature Class** and charts will contain projections starting from the model's **Start Date.**	Field
35	Recovered (recovered) (Field)	A field from the **Input Feature Class** to specify the number of recovered cases at the **Start Date** of the model.	Field
36	Date of Social Distancing Measures Effect (May be Delayed From Implementation) (mitigation_date_const) (Optional)	The date when social distancing measures started showing their effects on new cases of COVID-19. By default, this parameter is populated with current date. If you delete this value, the model's **Start Date** will be used as the default and a warning will be displayed. If a constant **Date of Social Distancing Measure Effect** is provided, the **Daily Forecast Output Feature Class** and charts will contain projections starting from the model's **Date of Social Distancing**	Date

		Measure Effect if this date is before the model's **Start Date.**	
37	Recovered (recovered_const) (Optional)	The number of recovered cases at the initial **Start Date** of the model. The same number will apply for each feature. If the number of recovered is different for each feature, the field-based version of this parameter should be used.	String

Running the tool from Python

As with other geoprocessing tools, you may execute this tool via Python using ArcPy. Since this tool is imported separately from other geoprocessing in ArcGIS Pro, an additional step is required to first import the toolbox. To do this, first run:

```
arcpy.ImportToolbox(r"YOUR PATH\COVID-19-Modeling\COVID-19 Modeling Toolbox.pyt")
```

Then execute the tool via ArcPy using the following syntax:

```
arcpy.covid19.CHIME(in_fc, out_fc, pop_field, {known_infections}, hosp_field, {doubling_time_field},
{hosp_rate_perc_field}, {icu_perc_field}, {vent_perc_field}, {hosp_stay_len_field},
{icu_stay_len_field}, {vent_stay_len_field}, {hosp_market_share_field}, {inf_days_field}, num_days,
start_date, doubling_time, social_distancing_perc, hosp_rate_perc, icu_perc, vent_perc,
hosp_stay_len, icu_stay_len, vent_stay_len, {hosp_market_share}, {inf_days}, {lic_bed_field},
{staffed_vent_field}, {icu_beds_field}, {additional_fields}, {unique_id}, {out_fc2d},
{add_webapp_fields}, {mitigation_date}, {recovered}, {mitigation_date_const}, {recovered_const})
```

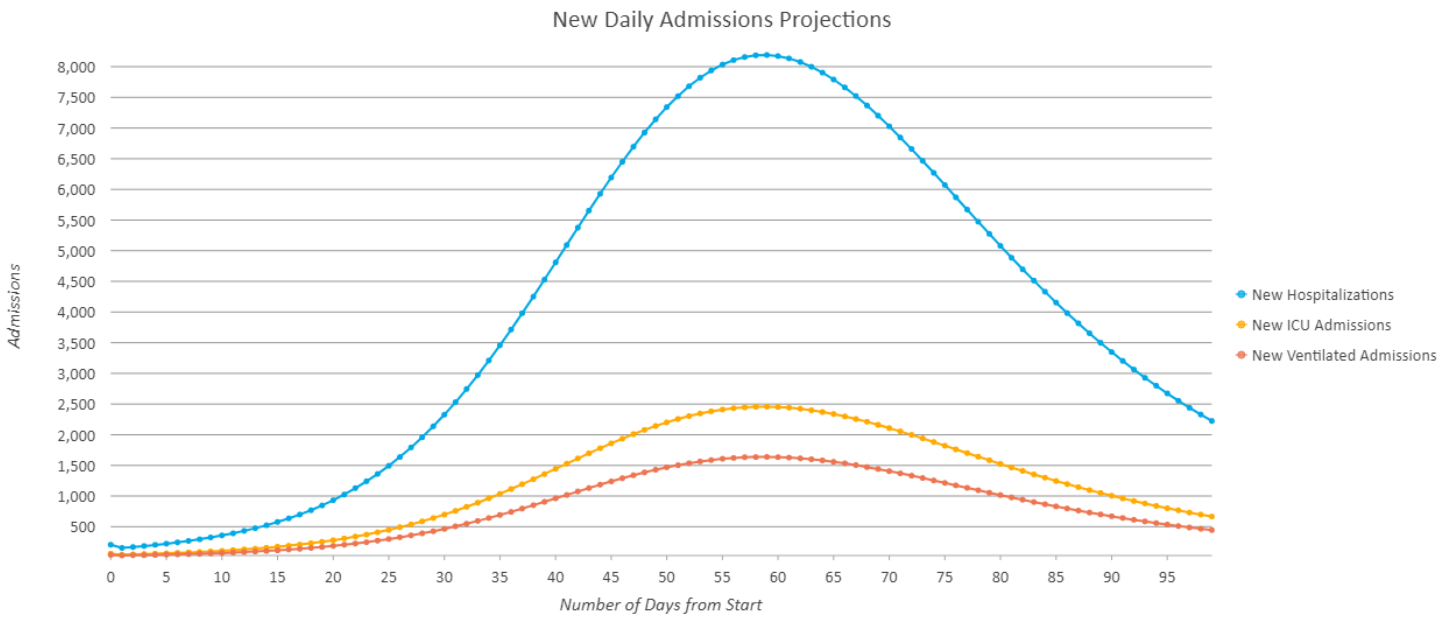
Interpreting the outputs

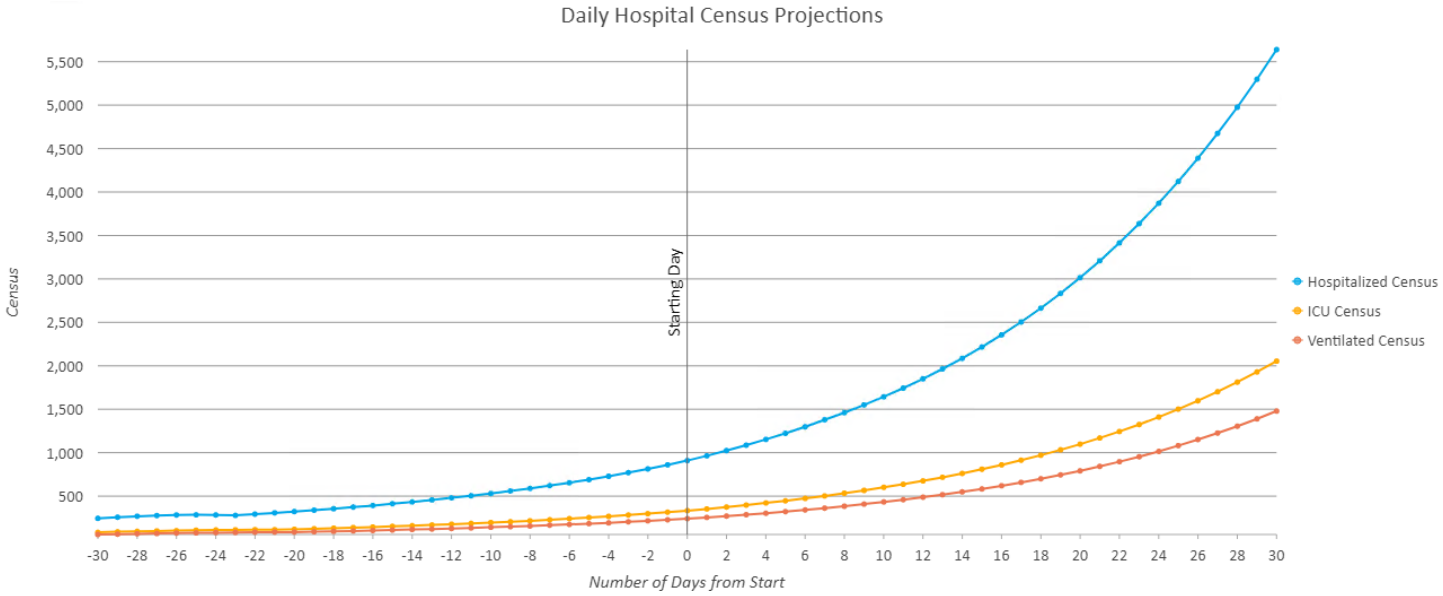
The tool provides a **Daily Forecast Output Feature Class** with fields and accompanying charts pertaining to each day's estimates for new daily admissions, and a census of inpatient hospitalizations, ICU admissions, and patients requiring ventilation, as well as each day's projected total susceptible, infected, and recovered in the provided population. The default symbology of this layer is the projected hospitalization census by day.

The geometry of the output features matches the geometry of its inputs; for example, if you are using a feature class of hospital points, the output is points, and if you are using a feature class of county polygons, the output is county boundaries.

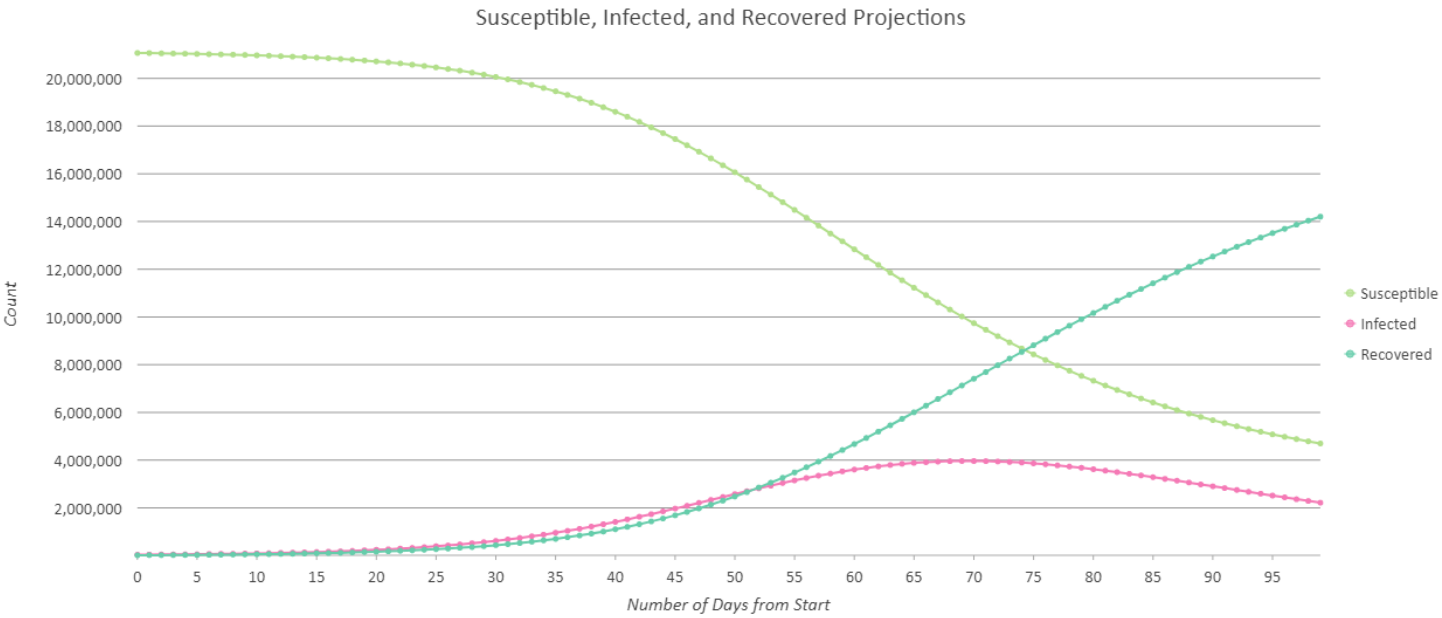
Chart outputs

Three charts are created to visualize the outputs of the CHIME model: **New Daily Admissions Projections**, **Daily Hospital Census Projections**, and **Susceptible, Infected, and Recovered Projections**

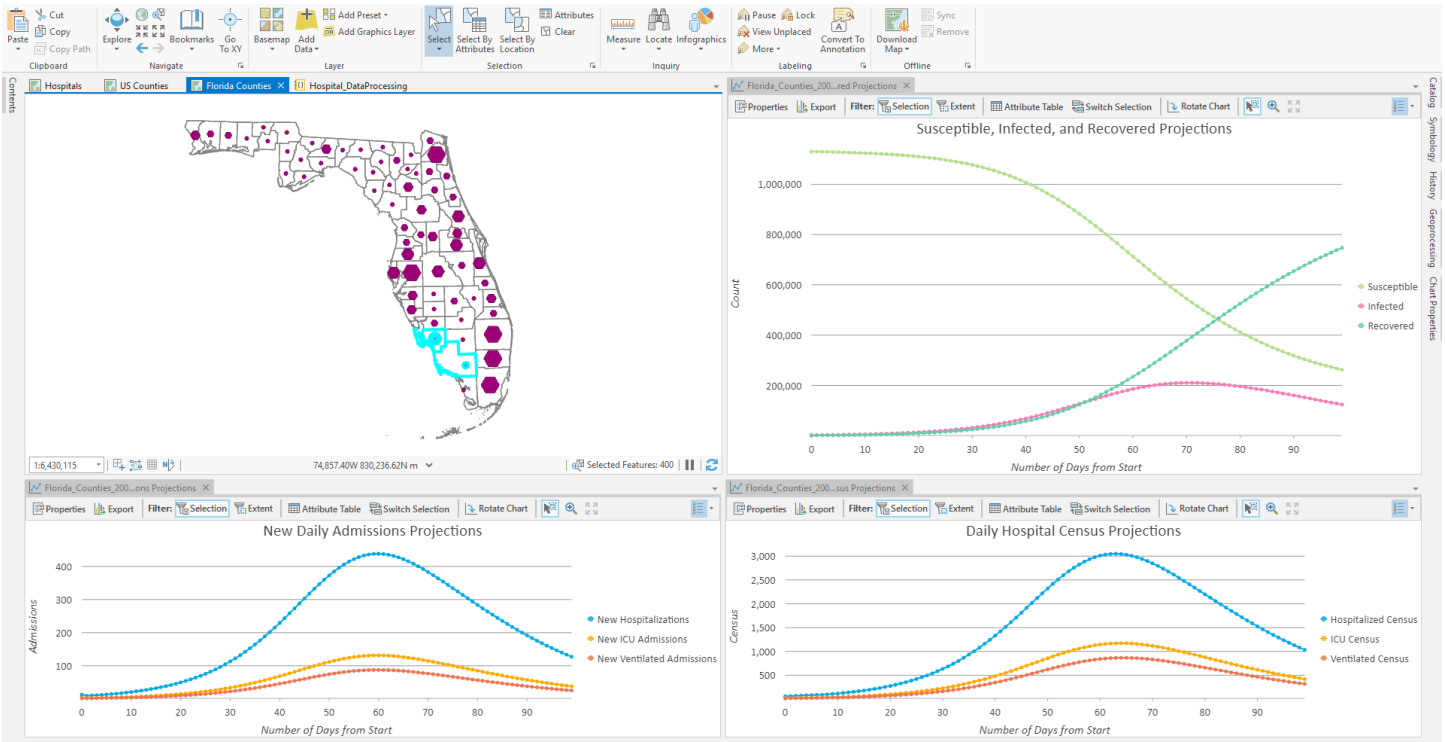




Note: Results from earlier than the starting day will only be shown in the **Daily Forecast Output Feature** Class and charts if the **Date of Social Distancing Measures Effect (May be Delayed From Implementation)** is defined as a constant, and the date is earlier than the **Start Date**.



A useful approach to explore and visualize CHIME model projections for individual features in your data is to enable **Filter by Selection** in your chart. Once enabled, you can select features and the corresponding charts will reflect projections for each selected hospital, catchment area, or administrative boundary.



Note: If comparing chart outputs across different models, it is recommended to lock the Y-axis of the charts.

Setting the Daily Forecast Output Feature Class as a time enabled layer

The **Daily Forecast Output Feature Class** can be configured as a time-enabled layer by performing the following steps:

1. Double-click the output layer in the **Contents** pane to open the **Layer Properties** dialog box.
2. Click the **Time** tab.
3. For **Layer Time**, select **Each feature has a single time field** from the dropdown menu.
4. Make sure the **Time Field** is pointing to the **date** field.
5. Click **Calculate**.
6. Click **OK**.

Once this is set, the **Map** pane displays a time slider.

Daily Forecast Output Feature Class Fields

Field alias (field name)	Explanation
Day (day)	The incremental day of the forecast.
Date (date)	The date of the forecast.
New Hospitalizations (new_hosp)	Projected new hospitalizations for the forecast day.
New ICU Admissions (new_icu)	Projected new ICU admissions for the forecast day.
New Ventilated Admissions (new_vent)	Projected new patients requiring ventilation for the forecast day.
Hospitalized Census (cen_hosp)	Census of hospitalizations for the forecast day.
ICU Census (cen_icu)	Census of ICU admissions for the forecast day.
Ventilated Census (cen_vent)	Census of patients requiring ventilation for the forecast day.
Susceptible (susceptible)	Projection of total susceptible in the population for the forecast day.
Infected (infected)	Projection of total infected in the population for the forecast day.
Recovered (recovered)	Projection of total recovered in the population for the forecast day.

Summary Output Feature Class Fields

In addition to the **Daily Forecast Output Feature Class**, the tool can also provide a **Summary Output Feature Class** containing a summary of each feature's peak values for the census of inpatient hospitalizations, ICU admissions, and patients requiring ventilation. The first 12 fields of this feature class (from **Doubling Time** to **Number of Hospitalized**) summarize the inputs to the model from the **Population**, **Number of Currently Hospitalized COVID-19 Patients**, **Field-Based Model Parameters** and **Constant Model Parameters** parameters.

Note: From CHIME v1.1.5, the field **R0** is reported in the **Summary Output Feature Class**. This can be used in the **New Infections Per Case (R0)** parameter of the COVID-19Surge tool in the COVID-19 Modeling Toolbox.

If fields for the **Additional Outputs for Visualization** parameters for **Total Bed Capacity**, **Total Ventilator Capacity**, or **Total ICU Bed Capacity** were provided, the tool also calculates metrics for the maximum difference between projected needs and available resources, including the maximum difference as a total and as a percent, the day and date in which the highest difference occurred, and the amount of days in which total projected needs exceeded available resources.

Note: If bed, ventilator, or ICU capacity is not surpassed by projected needs, a value of 1/1/1900 is populated as a placeholder for the date fields.

If the **Add Additional Web App Fields in Summary** parameter is checked, the tool will add the fields required for the **Summary Output Feature Class** to be used in the Capacity Analysis configurable app.

The symbology of this output feature class reflects the peak census of inpatient hospitalizations and the geometry of the output features matches the geometry of its inputs (in a similar fashion to the **Daily Forecast Output Feature Class**.

Summary Output Feature Class Field Names

Field alias (field name)	Explanation
Peak Hospitalized Census (pk_hsp)	The highest number in the census of hospitalizations during the forecast.
Peak Day for Hospitalized Census (pk_day_hsp)	The incremental day containing the highest number in the census of hospitalizations during the forecast.
Peak Date for Hospitalized Census (pk_date_hsp)	The date containing the highest number in the census of hospitalizations during the forecast.
Peak ICU Census (pk_icu)	The highest number in the census of ICU admissions during the forecast.
Peak Day for ICU Census (pk_day_icu)	The incremental day containing the highest number in the census of ICU admissions during the forecast.
Peak Date for ICU Census (pk_date_icu)	The date containing the highest number in the census of ICU admissions during the forecast.
Peak Ventilated Census (pk_icu)	The highest number in the census of patients requiring ventilation during the forecast.
Peak Day for Ventilated Census (pk_day_icu)	The day containing the highest number in the census of patients requiring ventilation admissions during the forecast.
Peak Date for Ventilated Census (pk_date_icu)	The date containing the highest number in the census of patients requiring ventilation during the forecast.

Over Capacity Hospitalized Maximum Number (oc_hos_num)	The maximum difference between projected hospitalizations and available hospital beds during the forecast.
Over Capacity Hospitalized Day (oc_hos_day)	The incremental day containing the maximum difference between projected hospitalizations and available hospital beds during the forecast.
Over Capacity Hospitalized Date (oc_hos_dte)	The date containing the maximum difference between projected hospitalizations and available hospital beds during the forecast.
Over Capacity Hospitalized Maximum Percent (oc_hos_pct)	The maximum difference as a percent between projected hospitalizations and available hospital beds during the forecast.
Over Capacity Hospitalized Number of Days (oc_hos_day)	The number of days in which the feature was projected to have more hospitalizations than available beds.
Over Capacity ICU Maximum Number (oc_hos_num)	The maximum difference between projected ICU admissions and available ICU beds during the forecast.
Over Capacity ICU Day (oc_hos_day)	The incremental day containing the maximum difference between projected ICU admissions and available ICUs during the forecast.
Over Capacity ICU Date (oc_hos_dte)	The date containing the maximum difference between projected ICU admissions and available ICUs during the forecast.
Over Capacity ICU Maximum Percent (oc_hos_pct)	The maximum difference as a percent between projected ICU admissions and available ICUs during the forecast.
Over Capacity ICU Number of Days (oc_hos_day)	The number of days in which the feature was projected to have more ICU admissions than available ICUs.
Over Capacity Ventilated Maximum Number (oc_hos_num)	The maximum difference between projected patients requiring ventilation and available ventilators during the forecast.
Over Capacity Ventilated Day (oc_hos_day)	The incremental day containing the maximum difference between projected patients requiring ventilation and available ventilators during the forecast.
Over Capacity Ventilated Date (oc_hos_dte)	The date containing the maximum difference between projected patients requiring ventilation and available ventilators during the forecast.
Over Capacity Ventilated Maximum Percent (oc_hos_pct)	The maximum difference as a percent between projected patients requiring ventilation and available ventilators during the forecast.
Over Capacity Ventilated Number of Days (oc_hos_day)	The number of days in which the feature was projected to have more patients requiring ventilation than available ventilators.

Web New Hospitalizations (web_nhosp)	Projected new hospitalizations for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **Hospitalized Census** field of the **Daily Forecast Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.
Web New ICU Admissions (web_nicu)	Projected new ICU admissions for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **ICU Census** field of the **Daily Forecast Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.
Web New Ventilated Admissions (web_nvent)	Projected new ventilated admissions for all days in ascending order, separated by a pipe (|) delimiter. This is the same data as shown output in the **Ventilated Census** field of the **Daily Forecast Output Feature Class**, and is created specifically for use in the Capacity Analysis configurable app.
Web Number of Days (web_days)	The value set in the **Number of Days to Project** parameter. This field is created specifically for use in the Capacity Analysis configurable app.
Web Start Date (web_date)	The value set in the **Start Date** parameter. This field is created specifically for use in the Capacity Analysis configurable app.
Web Name (web_name)	This feature name for use in the Capacity Analysis configurable app. The name is derived from the value set in the **Unique ID** parameter.

Example workflow

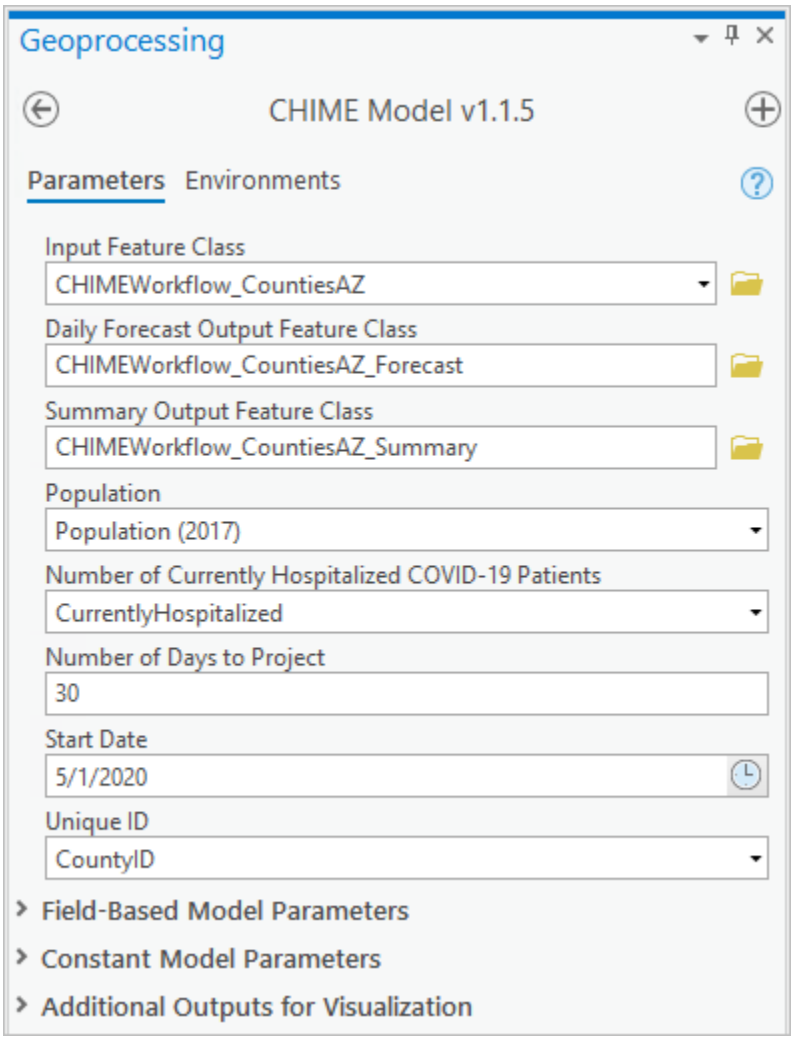
The following workflow is an example of how to use the tool with county polygon data. You can reference the sample data in the ExampleWorkflows.gdb file geodatabase.

1. Add the data CHIMEWorkflow_CountiesAZ feature class from the ExampleWorkflows.gdb file geodatabase to a map in ArcGIS Pro. The Shape, County Name, State Name, and Population fields were derived from the USA counties layer in Living Atlas. All other fields in this dataset are artificial data created to demonstrate the functionality of this tool.

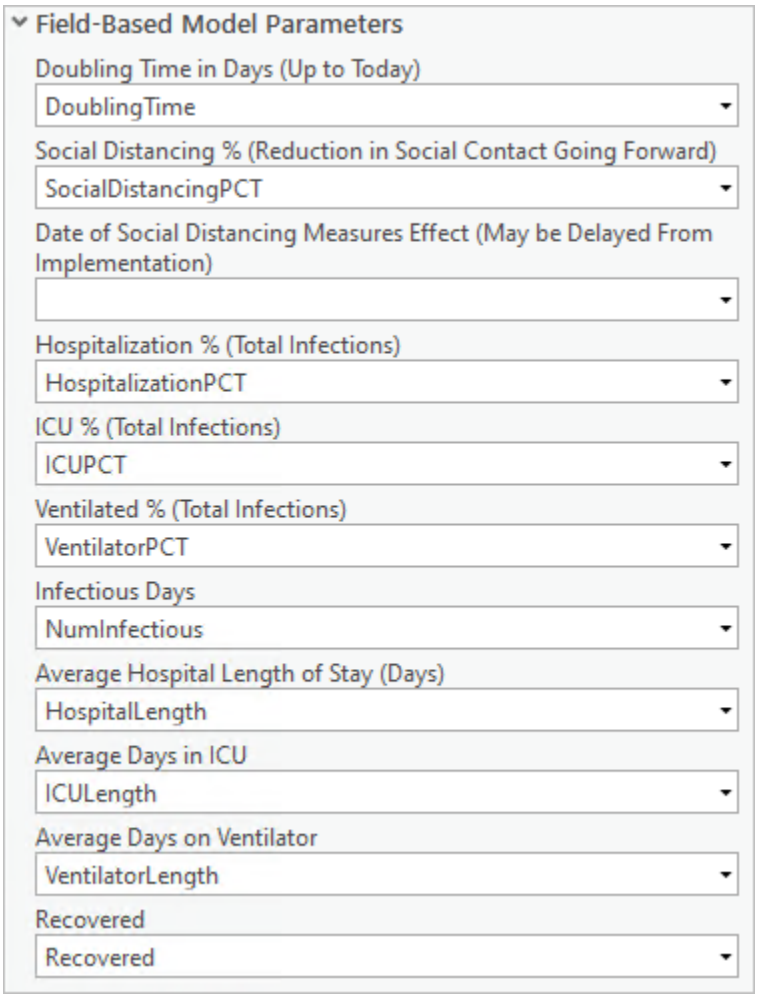
   Running CHIME using this tool in ArcGIS Pro allows you to run the model for many locations at once, and to apply different model parameters to each point or polygon (in this case counties), based on different characteristics of each area or location. Look at the attribute table of the Arizona Counties data-you'll notice there are 15 records, one for each county, and that the fields such as DoublingTime and VentilatorLength vary by county.

2. Open the **CHIME Model v.1.1.5** tool. The Installation section of this document above explains the steps to install and open the tool.

3. Populate parameters of the tool as follows:

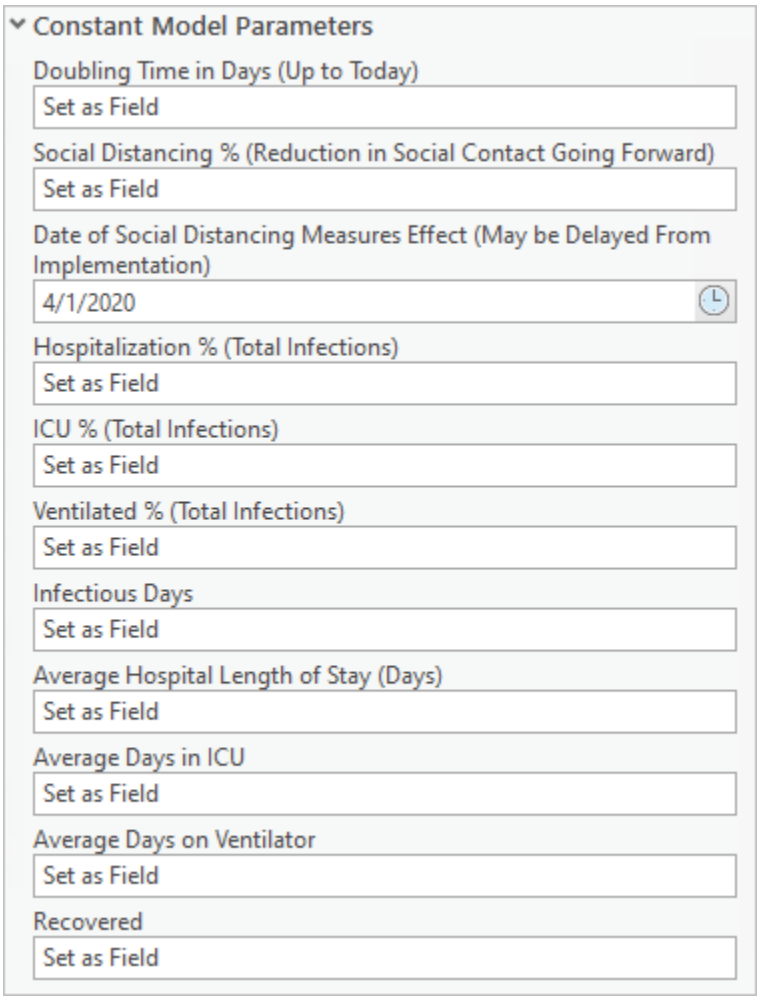


4. Expand the **Field-Based Model Parameters** section of the tool to populate the parameters as follows:



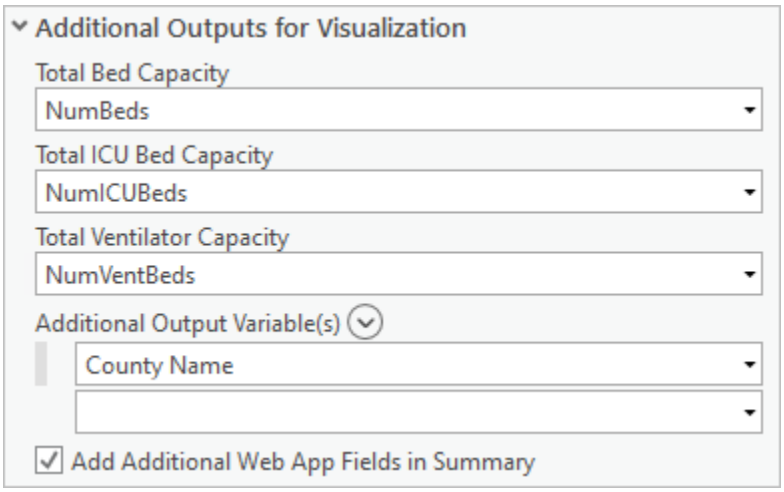
Note: When applying this tool to your study area, consult [the CHIME comparison with Imperial College COVID-19 Publication article]() published by Penn Medicine Predictive Healthcare for help estimating the reduction in social contact.

5. Expand the **Constant Model Parameters** section and set the **Date of Social Distancing Measures Effect (May be Delayed From Implementation)** parameter as shown below. Note that all of the other parameters are filled with **Set as Field**. This means that the parameter is being set using the **Field-Based Model Parameters** section. Each parameter is repeated in both sections and can only be defined in one place-the **Field-Based Model Parameters** section takes precedence.



6. Expand the **Additional Outputs for Visualization** section and populate the parameters as follows.

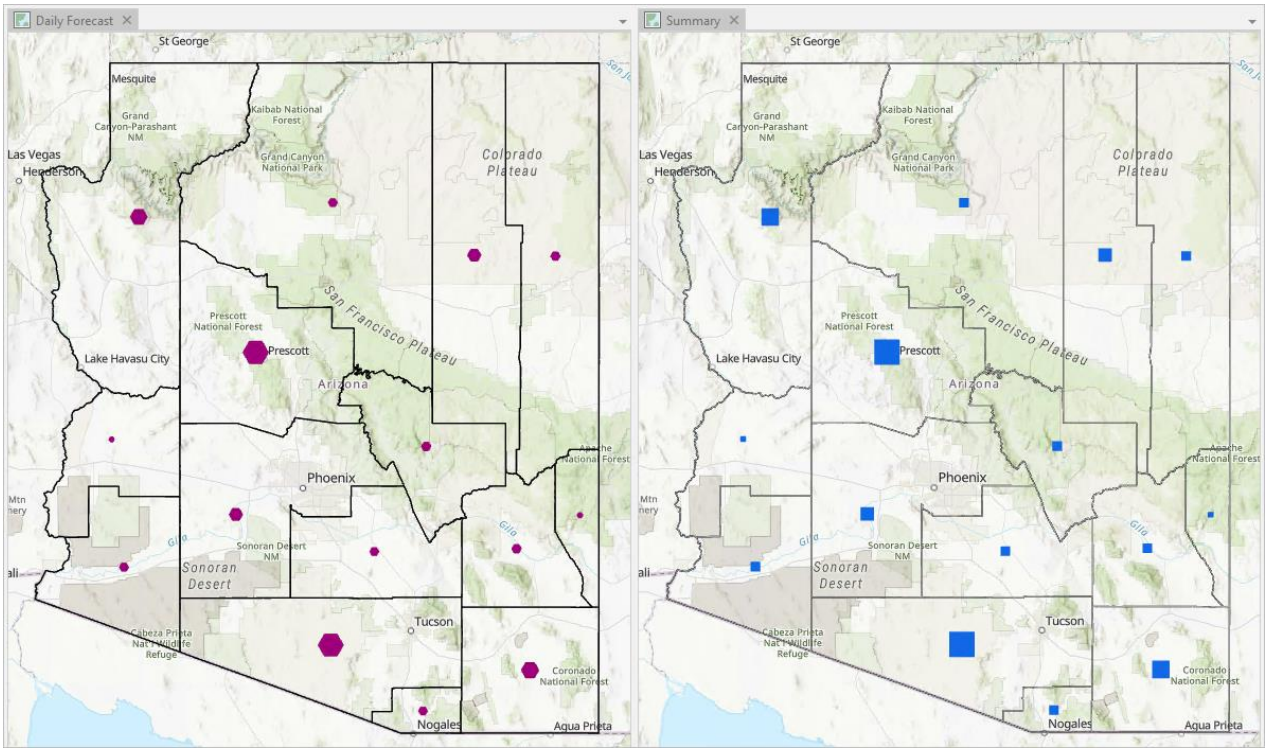
   The **Total Bed Capacity**, **Total Ventilator Capacity** and **Total ICU Bed Capacity** parameters are used to calculate over capacity fields in the **Summary Output Feature Class**. The **Additional Output Variable(s)** are appended to the **Summary Output Feature Class**. Useful fields to append may include state or hospital names. The **Add Additional Web App Fields in Summary** parameter is used to add necessary fields for the Capacity Analysis configurable app to the **Summary Output Feature Class**.



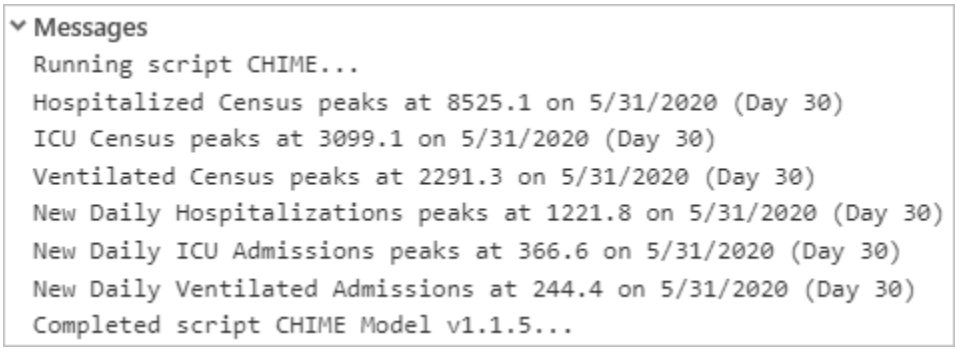
Note: When applying this tool to your own study area, consider using the Living Atlas USA Hospital Bed data to help understand hospital bed capacity as a resource.

7. Click **Run** in the **Geoprocessing** pane. The tool creates two output feature classes, called CHIMEWorkflow_CountiesAZ_Forecast and CHIMEWorkflow_CountiesAZ_Summary. The layer CHIMEWorkflow_CountiesAZ_Forecast has three charts: **New Daily Admissions Projections**, **Daily Hospital Census Projections**, and **Susceptible, Infected and Recovered Projections**. The layers should resemble the screenshot below.

   The CHIMEWorkflow_CountiesAZ data is shown in this map as black lines, but yours may differ based on your chosen symbology.

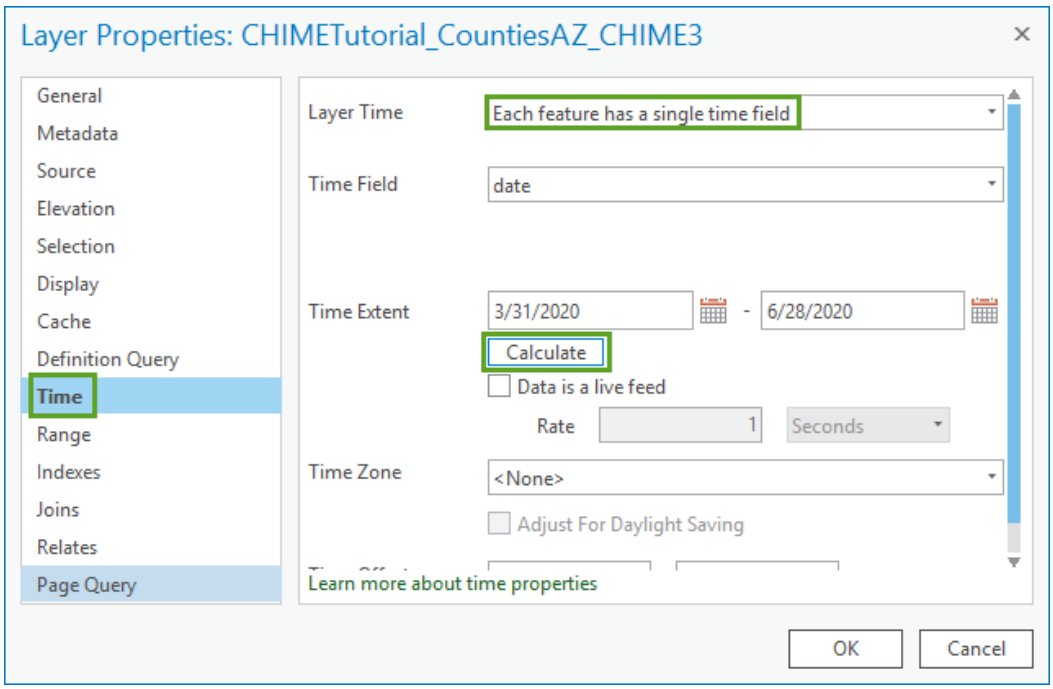


8. Click View Details at the bottom of the Geoprocessing pane. This opens the Geoprocessing Messages. Scroll down to the Messages section, where you can see a summary of the census and daily hospitalization peaks for all the counties combined.



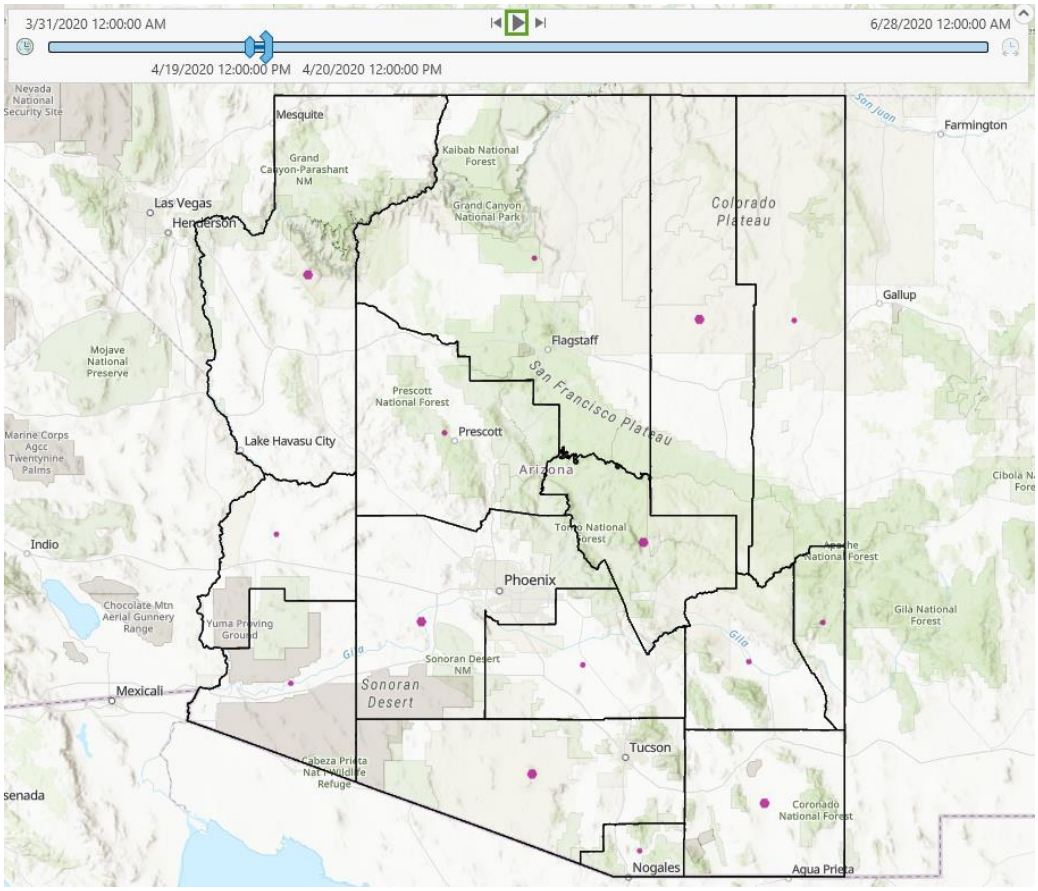
9. Open the attribute table for the layer CHIMEWorkflow_CountiesAZ_Forecast. You'll notice there are 915 rows. Since you used the **Date of Social Distancing Measures Effect (May be Delayed From Implementation)** in the **Constant Model Parameters** section, the **Daily Forecast Output Feature Class** will contain the results from the date of social distancing until the end date. In this case, this is 61 days, so for each location on the map there are 61 coincident polygons - one for each projected day. The total number of rows is the table is 61 days multiplied by the number of records in the **Input Feature Class** (15).

10. Right-click the output layer in the **Contents** pane, click **Properties**, and click **Time**. For **Layer Time**, choose **Each feature has a single time field**. Then in the **Time Extent**, click **Calculate**. Click **OK** to close the window.



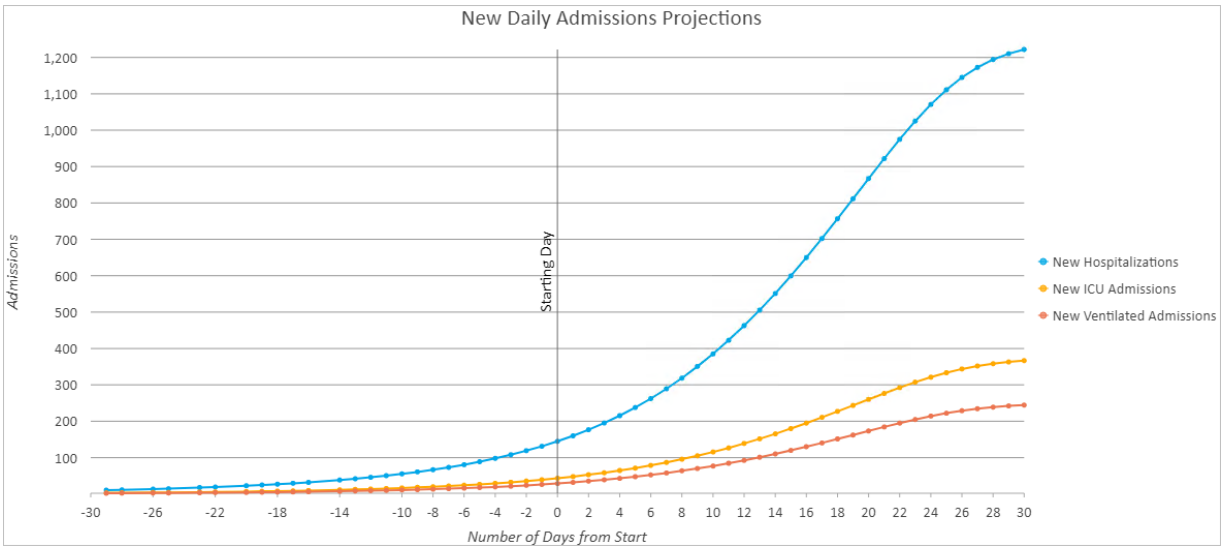
11. The output layer is now time enabled. The time slider appears on your map. Click play, and the layer sequences through each day on the map. While this happens, your attribute table is filtered to only show the records of the current time range.

    You can read more about using time in the ArcGIS Pro [documentation on using Temporal data](#).



12. Click the **Disable Time** button on the time slider to revert to the full temporal range of the data.

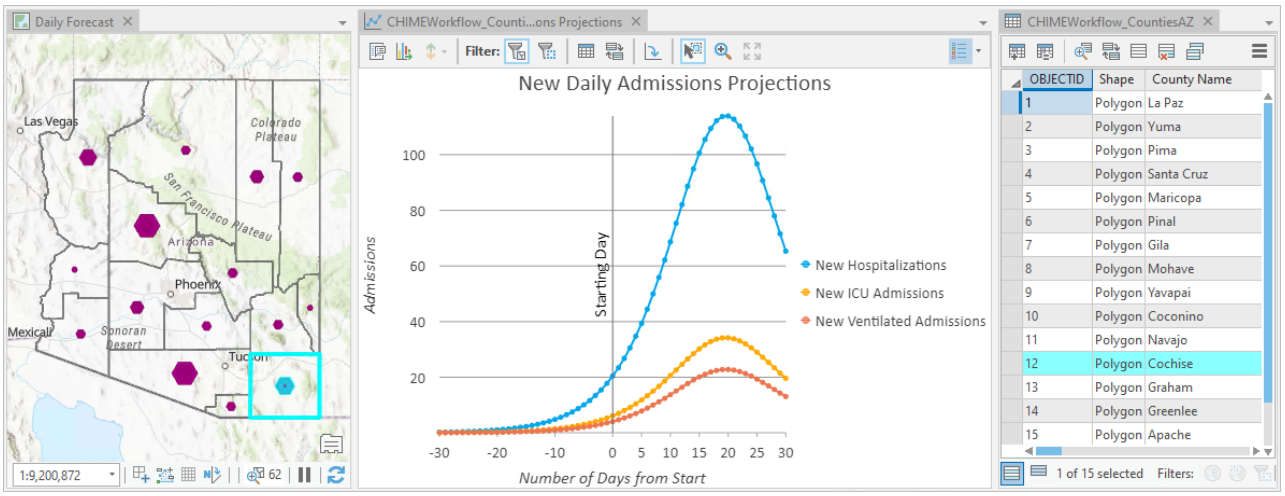
13. Open the chart **New Daily Admissions Projections** created by the tool. This chart shows three series: the number of new patients hospitalized, new patients hospitalized in the ICU, and new patients hospitalized with ventilation on each modeled day. The chart begins at the **Date of Social Distancing Measures Effect (May be Delayed From Implementation)** and the grey line shows the day of the **Start Date**.

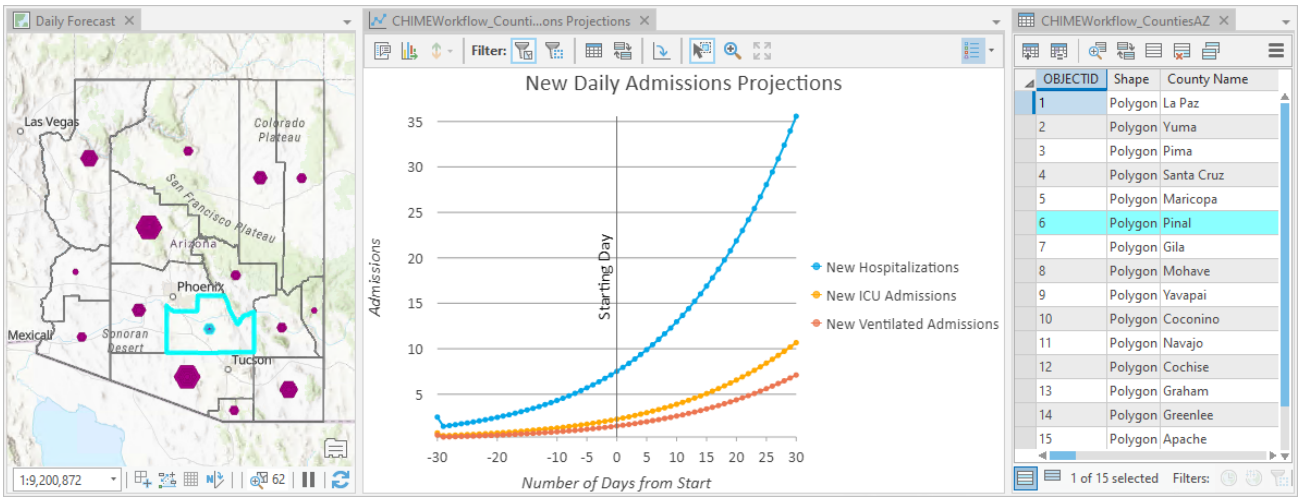


14. The **New Daily Admissions Projections** chart is aggregating the data for all the counties in Arizona. You can view how the chart varies by county by selecting each county on the map.

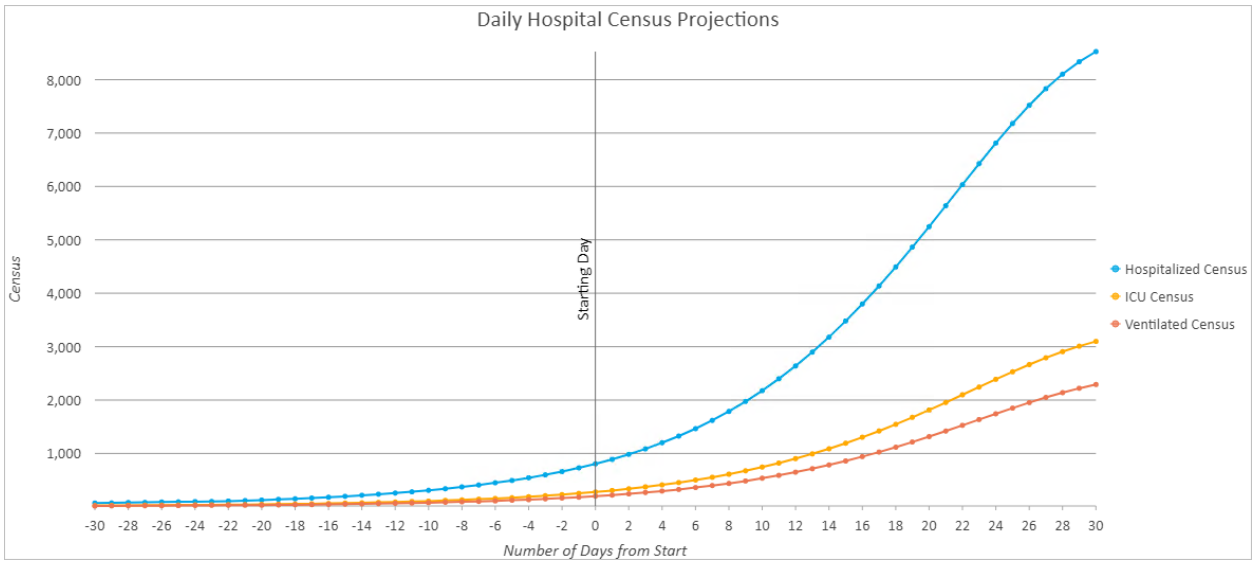
    Click the **Filter by Selection** button at the top of the chart window. The chart temporarily appears blank. Then use the selection tool to select the coincident polygons in the output feature class for one of the counties on the map. The chart displays only the selected county's values.

    You can use this method to compare the time series for each county. These charts are shown below for Cochise and Pinal counties. Notice how the shape of the admissions results differ dramatically between these counties.

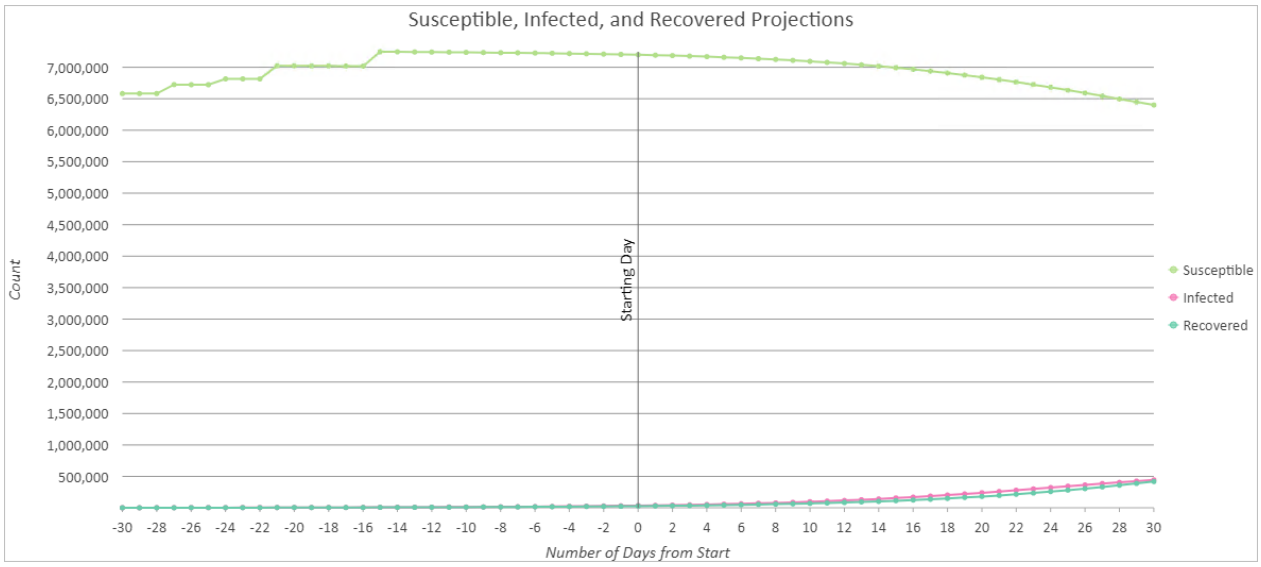




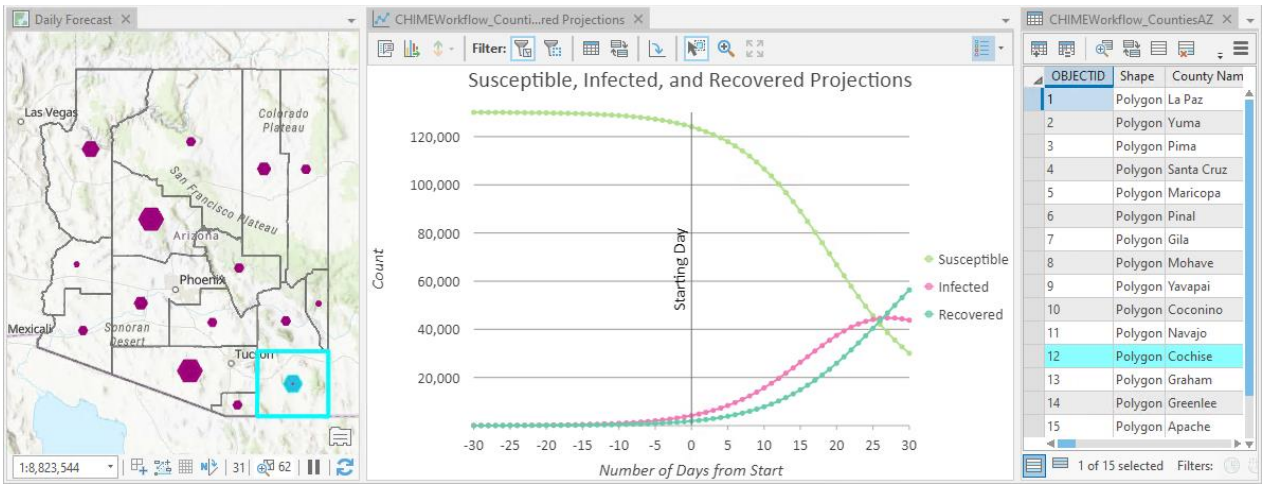
15. Open the chart **Daily Hospital Census Projections**. This chart shows three series of a similar shape to the **New Daily Admissions Projections** chart, but for this chart these pertain to the total number of people hospitalized, in ICU, and on ventilation for each day-otherwise known as the hospital census.



16. Open the chart **Susceptible, Infected and Recovered Projections**. This chart shows the number of susceptible, infected, and recovered individuals in the **Population** for each day.

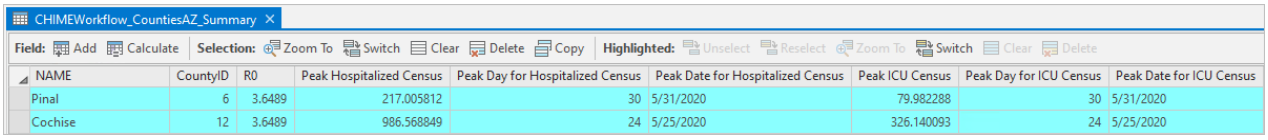


17. Using the same methodology shown in step 14, filter the **Susceptible, Infected, and Recovered Projections** chart by selection to show only Cochise county. You'll see that for this county, the number of susceptible and the number of recovered begin to invert around day 26.



18. Open the attribute table for the layer CHIMEWorkflow_CountiesAZ_Summary. This table helps you understand when the peaks in hospitalization will occur, and when and by how many the hospital beds will be over capacity.

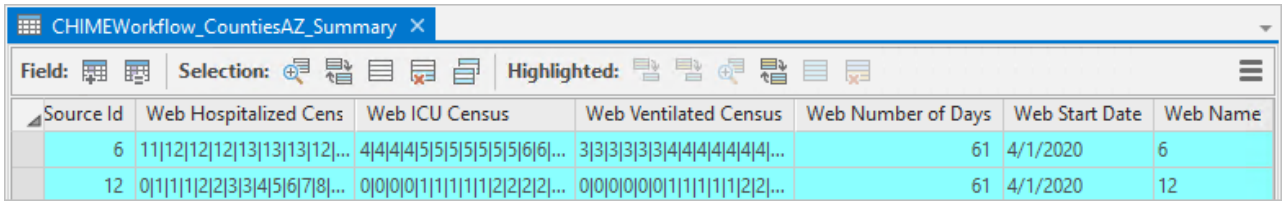
    The screenshot below shows Pinal county and Cochise county (the same counties from step 14). You can see that with this fictional data, the peak hospitalization would occur on 5/31/2020 and 5/25/2020, respectively. As 5/31/2020 is the last day projected, it is likely that the peak would occur later than this date.



CHIMEWorkflow_CountiesAZ_Summary

NAME	CountyID	R0	Peak Hospitalized Census	Peak Day for Hospitalized Census	Peak Date for Hospitalized Census	Peak ICU Census	Peak Day for ICU Census	Peak Date for ICU Census
Pinal	6	3.6489	217.005812	30	5/31/2020	79.982288	30	5/31/2020
Cochise	12	3.6489	986.568849	24	5/25/2020	326.140093	24	5/25/2020

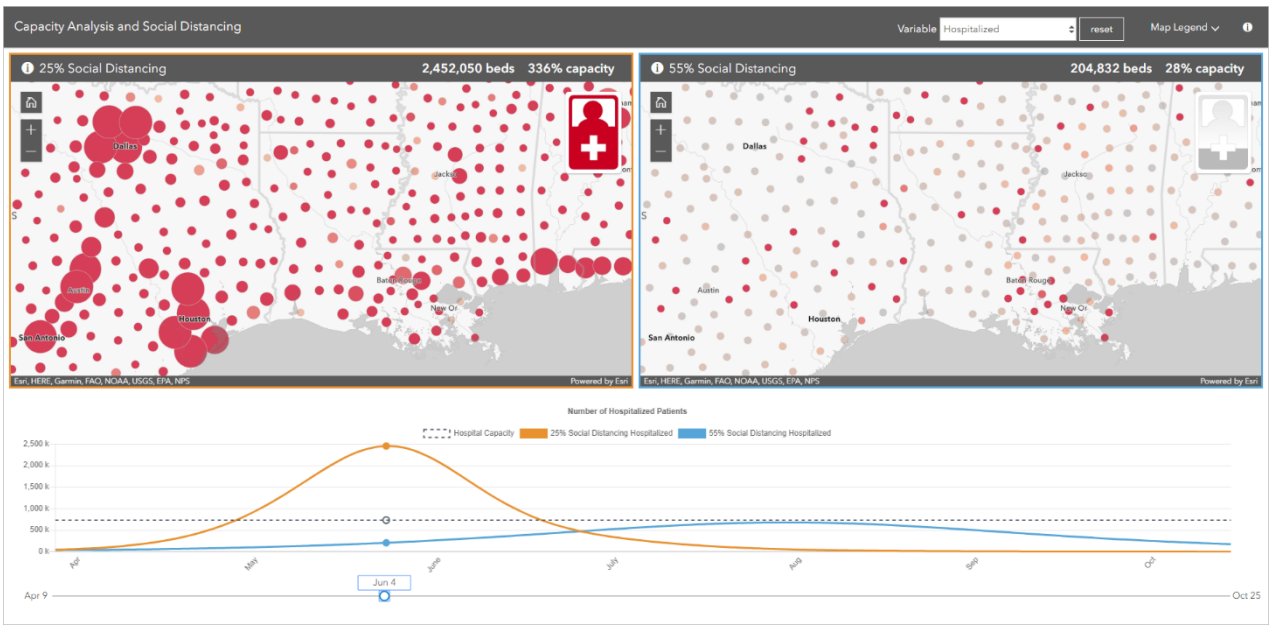
19. Scroll to the right of the attribute table. You will see six fields with names beginning with the word Web. These fields are configured specifically for use in the optional Capacity Analysis configurable app which can be published in ArcGIS Online and ArcGIS Enterprise to allow easy comparison of CHIME models in a web application.



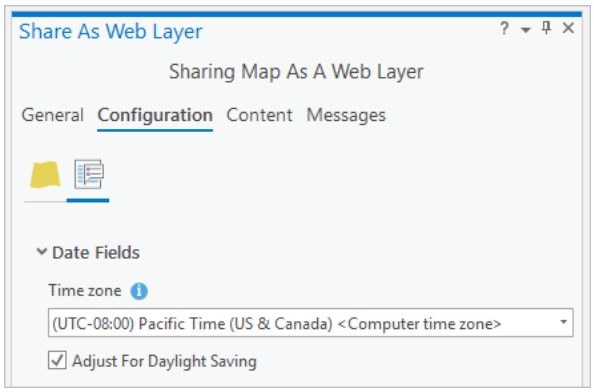
CHIMEWorkflow_CountiesAZ_Summary

Source Id	Web Hospitalized Cens	Web ICU Census	Web Ventilated Census	Web Number of Days	Web Start Date	Web Name
6	11|12|12|12|13|13|13|12|...	4|4|4|4|5|5|5|5|5|5|5|6|6|...	3|3|3|3|3|3|4|4|4|4|4|4|4|...	61	4/1/2020	6
12	0|1|1|1|2|2|3|3|4|5|6|7|8|...	0|0|0|0|1|1|1|1|1|2|2|2|2|...	0|0|0|0|0|0|1|1|1|1|1|2|2|...	61	4/1/2020	12

The Capacity Analysis configurable app requires two layers – one for the left pane and one for the right pane – and is designed to compare two models with different parameters but the same geography. So, to use the Arizona results in the app, you could edit the Arizona data to simulate a different scenario (for example, 20% less social distancing in each county) then run the tool again. Then, you'd publish the two results as different layers, and use these layers in each pane in the app.



Note: When publishing the layers for the Capacity Analysis configurable app, the service will assume the date fields are in UTC format. For the correct dates to appear in the chart in the app, you should specify the time zone that the data was created in within the Configuration tab of the Sharing pane.



Change log

Changes in version 4

- Updated the CHIME tool to Penn Medicine's CHIME v1.1.5 (2020-05-08) model.
    - Added a new parameter called **Date of Social Distancing Measures Effect** to specify the date when social distancing measures started showing their effects on new cases.
    - Added a new parameter called **Recovery** to specify the number of recovered cases at the start of the model.
    - Updated the default model parameters.
- The New Infections Per Case (R0) is now reported in the Summary Output Feature Class for use with the COVID-19Surge tool in the same toolbox.
- Bug fixes.

Changes in version 3

- Added the **Add Additional Web App Fields in Summary** parameter to provide compatibility with the Capacity Analysis configurable app. The **Summary Output Feature Class** is required to use this parameter.
- Bug fixes.

Changes in version 2

- Updated the tool to Penn Medicine's CHIME v1.1.2 (2020-04-01) model.
    - Between CHIME v1.1.1 (2020-04-01) and CHIME v1.1.2 (2020-04-01), small differences were made to the model solver. The impacts are minimal when doubling times are close to the default doubling time of 4 days. However, there will be minor changes to new admission, census and susceptible, infected and recovered results. If doubling times are very large (such as multiple weeks), the results may differ significantly in the ArcGIS Pro tool compared to CHIME Model v1.1.1.
    - In CHIME v1.1.1, the census results were reported as integers. In CHIME v1.1.2 these are reported as doubles. This means there may be slight variations in the peak day and date for the census in the ArcGIS Pro tool in cases in which several sequential days reached the same peak when expressed as integers.
- The tool can now accept a variety of date formats and decimal delimiters.
- The tool is now compatible with ArcGIS Pro 2.3 and 2.4. In earlier versions of ArcGIS Pro the tool fails with an error message explaining this.
- The tool can now be run using ArcPy outside the ArcGIS Pro environment.
- Bug fixes and improved UI validation.
- Enhancements to the geoprocessing messages and popups for the **Summary Output Feature Class**.

Known issues

- If you are seeing odd results, check your input tool parameters and ensure that they are not equal to or exceeding the **Population** value.
- This tool requires ArcGIS Pro 2.3 or more recent to run. ArcGIS Pro 2.5 is recommended for optimal tool performance.

References

- This tool is an implementation of the CHIME (COVID-19 Hospital Impact Model for Epidemics) app developed by the Penn Medicine Predictive Healthcare Team along with Code for Philly and other partners.
- For questions, comments and support, please visit the Esri COVID-19 GeoNet community.