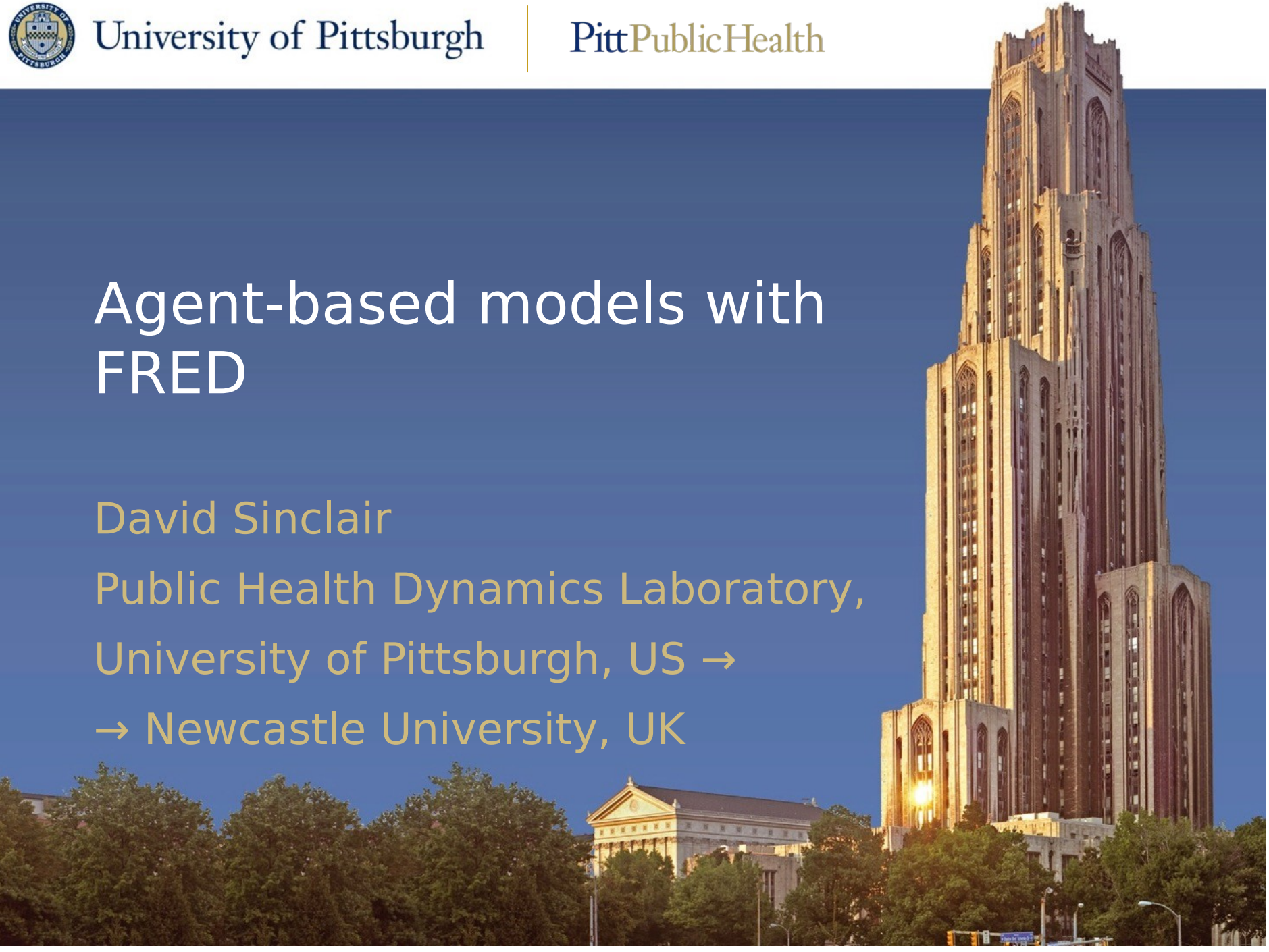

University of Pittsburgh | PittPublicHealth

Agent-based models with FRED

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FRED team

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Mary Krauland

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Robert Frankeny

Michael Lann

Donald Burke

Mark Robertfs

Workshop outline

Background: Agent-Based Models & FRED

Tutorial: FRED Web

Make your own Agent-Based Model with FRED Web

Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

FRED: Model components

FRED Web: Example

Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

FRED: Model components

FRED Web: Example

Agent-based / Individual-based models

COMPRISES A COLLECTION OF AGENTS

AGENTS FOLLOW RULES

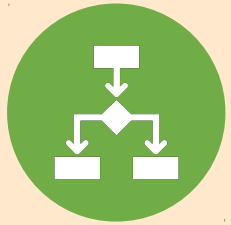
AGENT BEHAVIOR CAN ADAPT

BEHAVIOR AND INTERACTIONS OF AGENTS GENERATE POPULATION-LEVEL PHENOMENA

Agent-based Models

Study the effects of **heterogeneous** populations on **spatiotemporal dynamics**

Include **individual people/animals/ cells/etc** in the model, their **contacts** with each other and **interactions** with the environment



Include **individual** responses and **behaviors** in the model

Investigate interactions between agents and **spatially distributed resources** such as school and hospitals

Agent-based Models: Public Health Purposes

Study how interactions among *individuals and their environment* can result in patterns of *population behavior*

Study the *impact of policy and programs* on public health

Agent-Based Model Software

- NetLogo [1] - Simpler
- RePast [2]
- AnyLogic [3]
- FRED – Synthetic population.

More powerful, More complex

•[1] Netlogo, a multi-agent simulation environment. Artificial Life, 13(3):303–311, Jul 2007.

•[2] Complex adaptive systems modeling with repast simphony. Complex Adaptive Systems Modeling, 1(1):3, March 2013.

•[3] Collaborative management of complex major construction projects: AnyLogic-based simulation modelling.

• Discrete Dynamics in Nature and Society, vol. 2016, 2016.

Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

FRED: Model components

FRED Web: Example

- **FRED** is a Framework for Reconstructing Epidemiological Dynamics
- **Framework:** FRED is not a model. FRED is a tool for building epidemiological models
- **Epidemiology:** distribution and determinants of health-related states or events (WHO)
- **Dynamics:** How patterns in defined populations *vary over time*

Foundational Concepts in FRED

Space

Three-dimensional geography based on actual locations

Time

Time step = 1 hour (agents have multiple serial activities per day)

Duration = 1 day to 100 years

Agent

Individual person

Places (mixing groups for agents)

Households, neighborhoods, workplaces, schools

Flexibly create additional places

Population

Based on census data and other sources

Agents are associated with specific places

GROUP QUARTERS

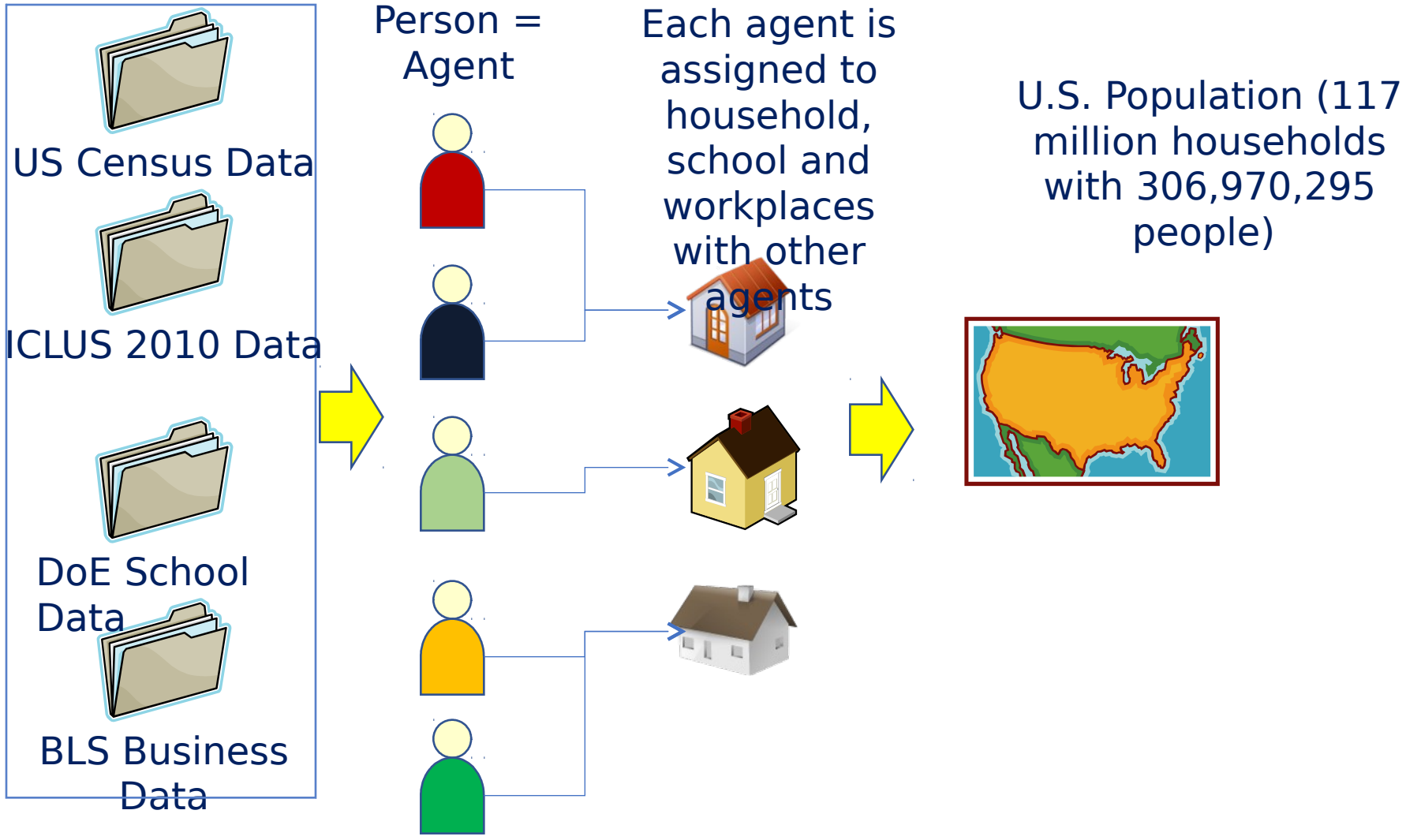
INFECTIOUS DISEASES: TRANSMISSION MODELS, DAILY TRACKING

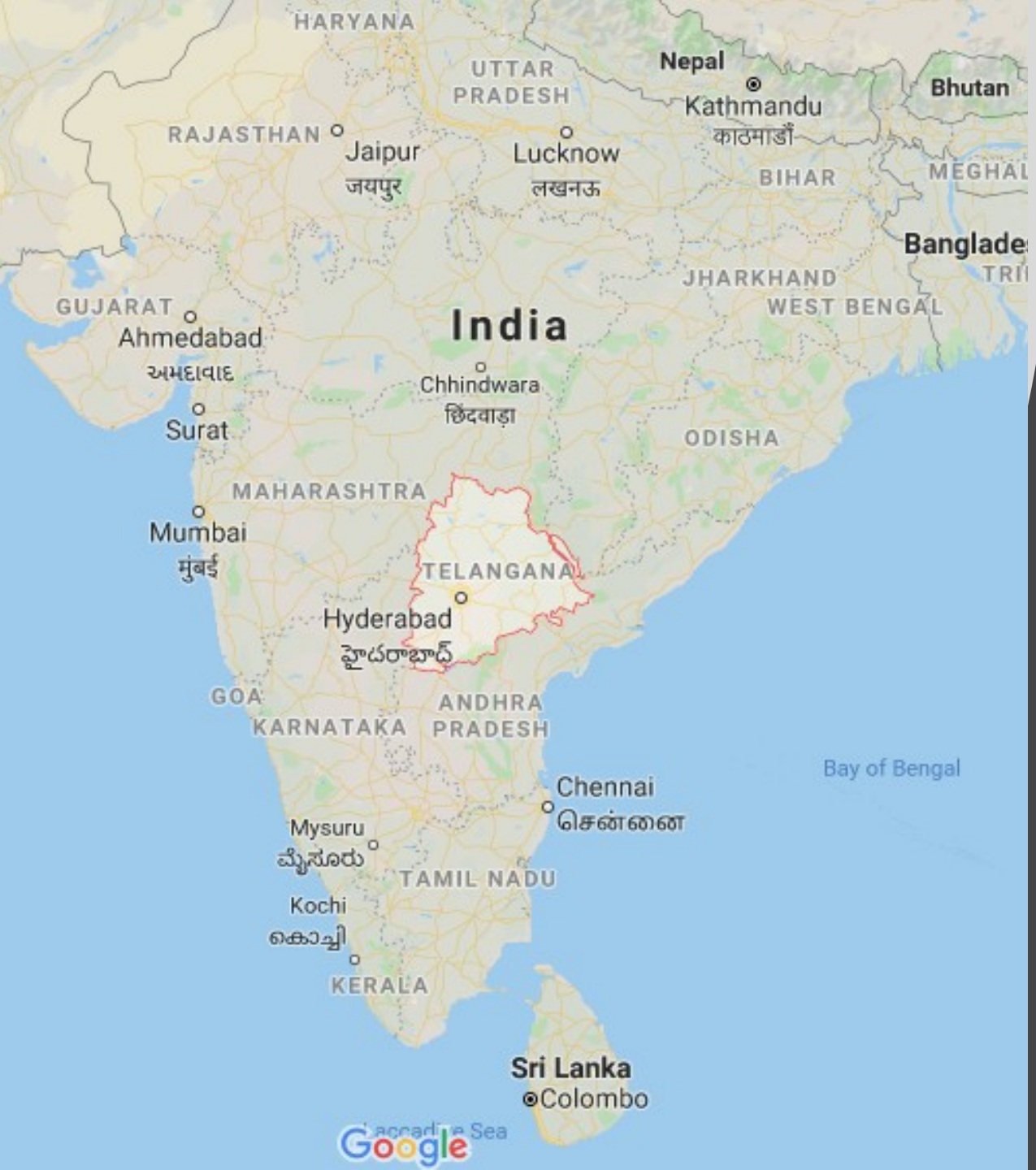
CHRONIC DISEASES: AGENT CHARACTERISTICS, TIME & VARIABLES

INTERVENTION MODELS

Further features

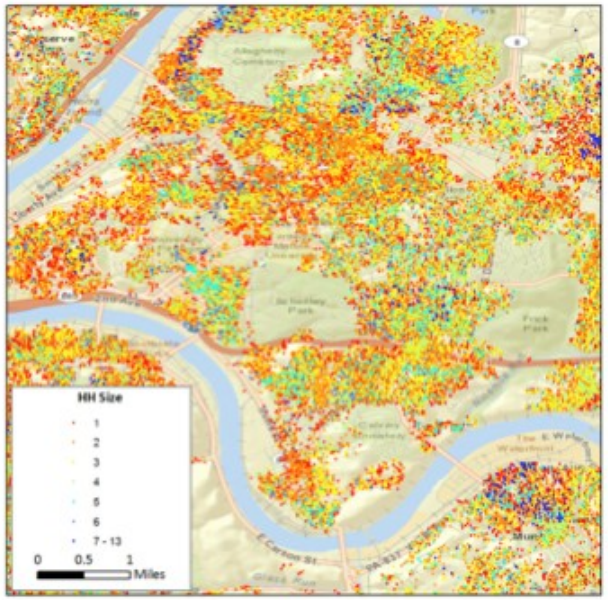
U.S. Census-matched Synthetic Population



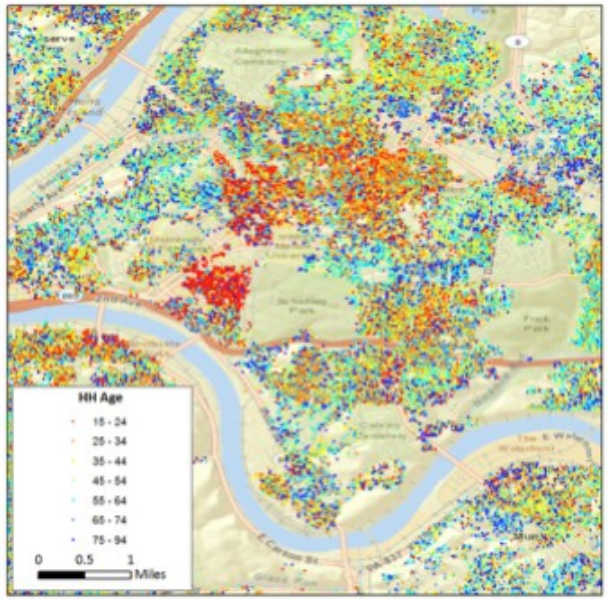


Telangana

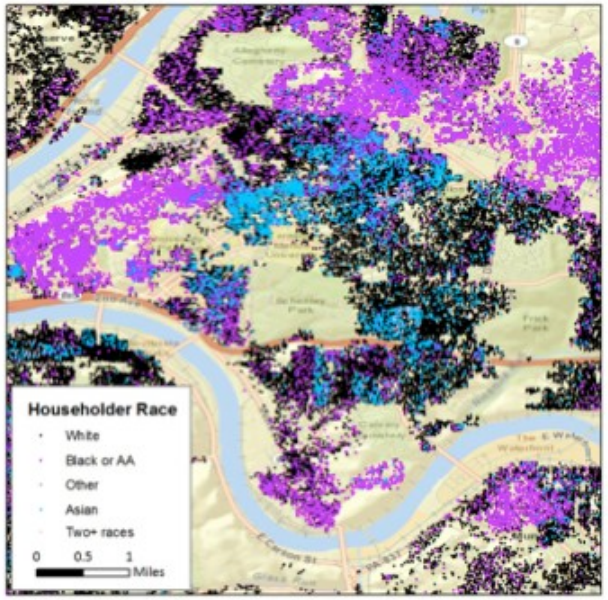
Synthetic Population Matches Real Demographics



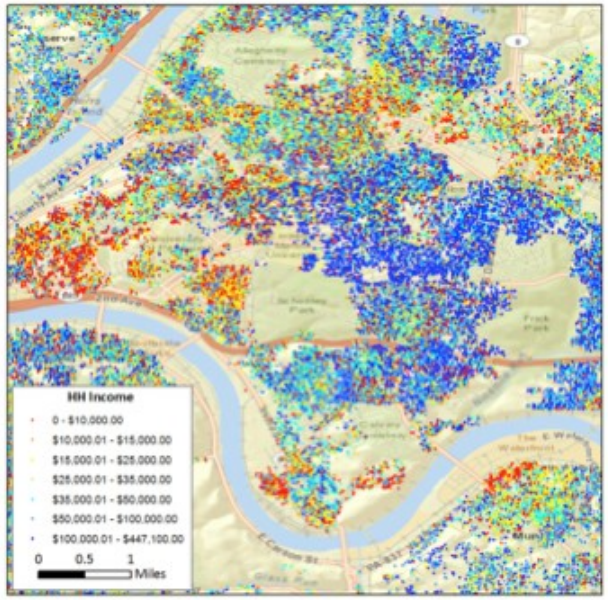
Household Size



Age

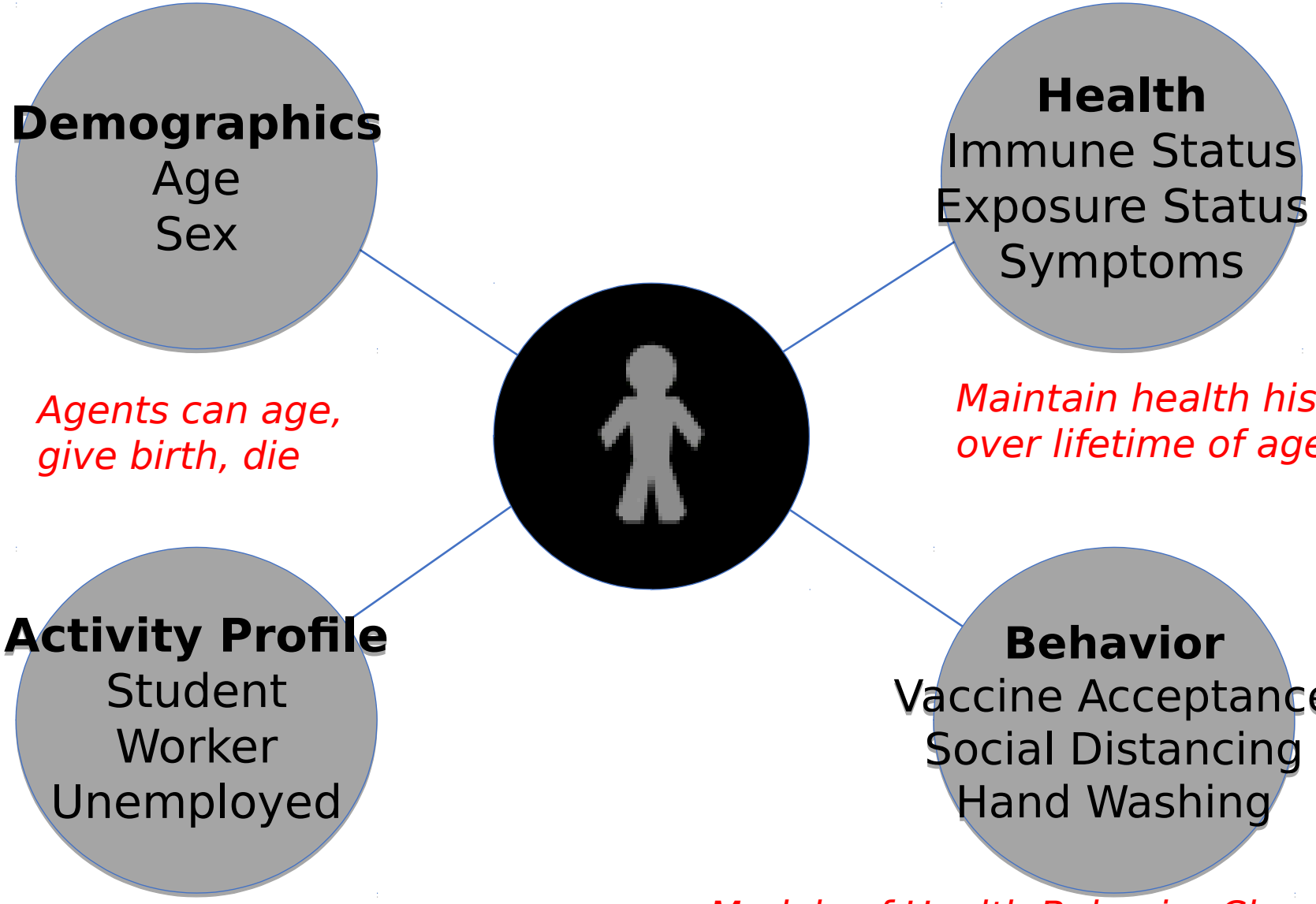


Race



Income

Agent Model



Agents can age, give birth, die

Maintain health history over lifetime of agents

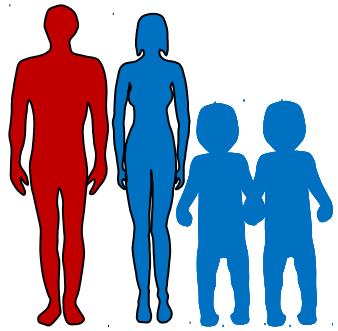
Activity Profiles can change over lifetime of agents

Models of Health Behavior Change:

- *Stochastic*
- *Social norms / influence*
- *Health Belief Model*

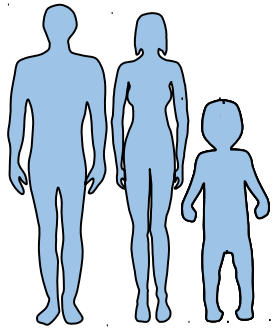
FRED Daily Dynamics

Location and size
of each school

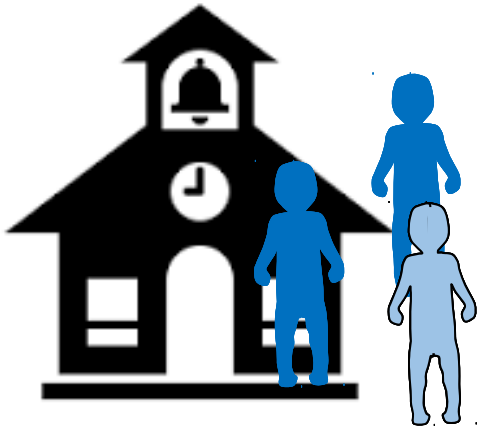


Household size,
ethnicity, ages,
income

Location and size
of each workplace

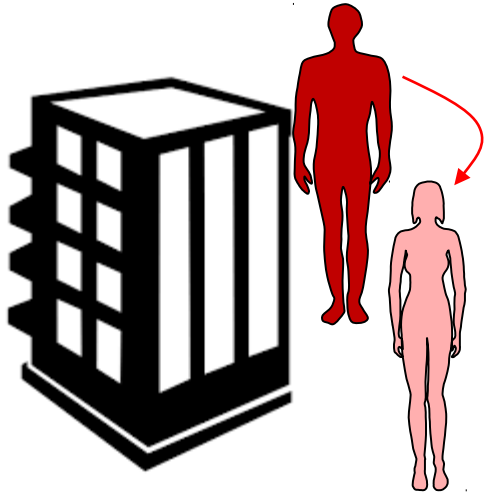


FRED Daily Dynamics



Location and size
of each school

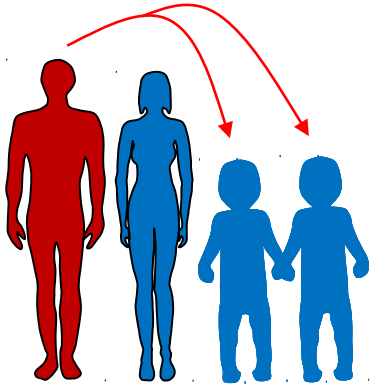
Household size,
ethnicity, ages,
income



Location and size
of each workplace

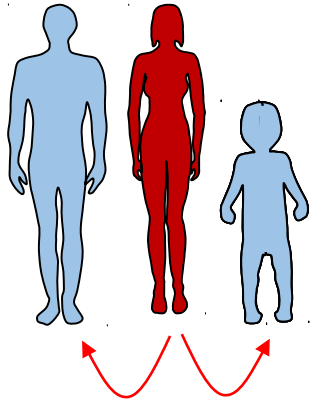
FRED Daily Dynamics

Location and size
of each school



Household size,
ethnicity, ages,
income

Location and size
of each workplace



FRED Outputs

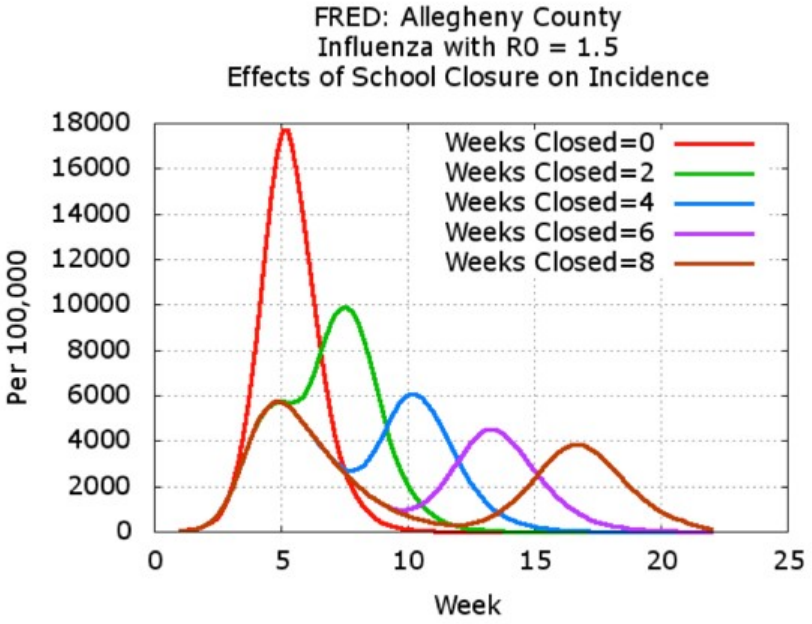
Daily Summary Statistics of Population Health Status

- Incidence
- Prevalance, etc

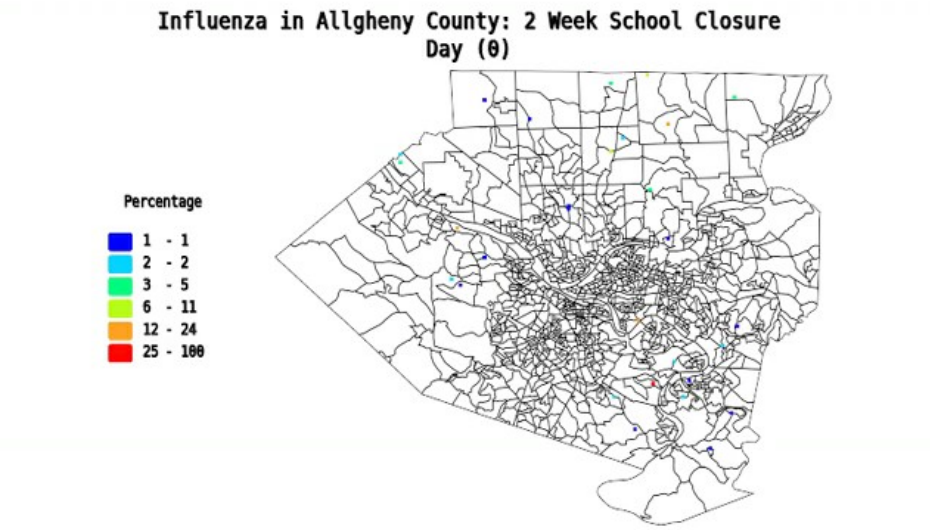
Individual transmission events

- Who infects whom, and where infection occurs

Plots of user-selectable variables



Data for producing maps and movies



Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

FRED: Model components

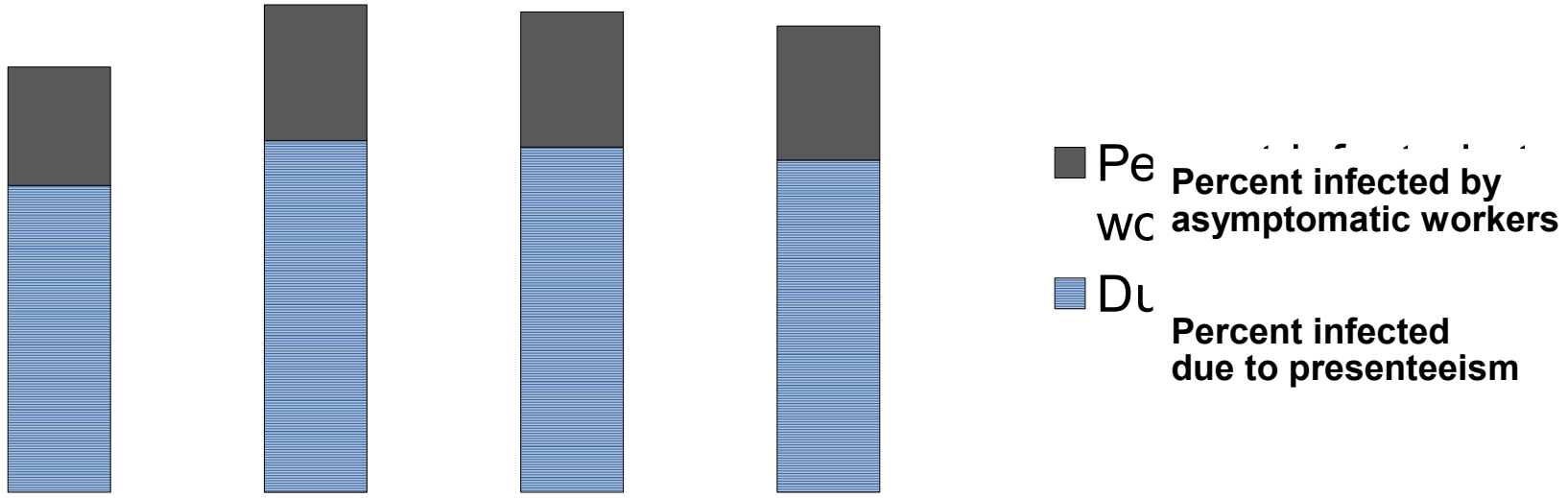
FRED Web: Example

Paid sick leave

- US does not have universal access to paid sick leave (Heymann et al. 2009)
- Employees sometimes turn up at work when sick and infect others
- Would paid sick leave help?

Case study: Paid sick leave

Simulated epidemic: R_0=1.4



Conclusion: ~71% of infections at work occur due to presenteeism

Policies to reduce influenza in the workplace: Impact assessments using an agent-based model. Ku

Lessons Learned

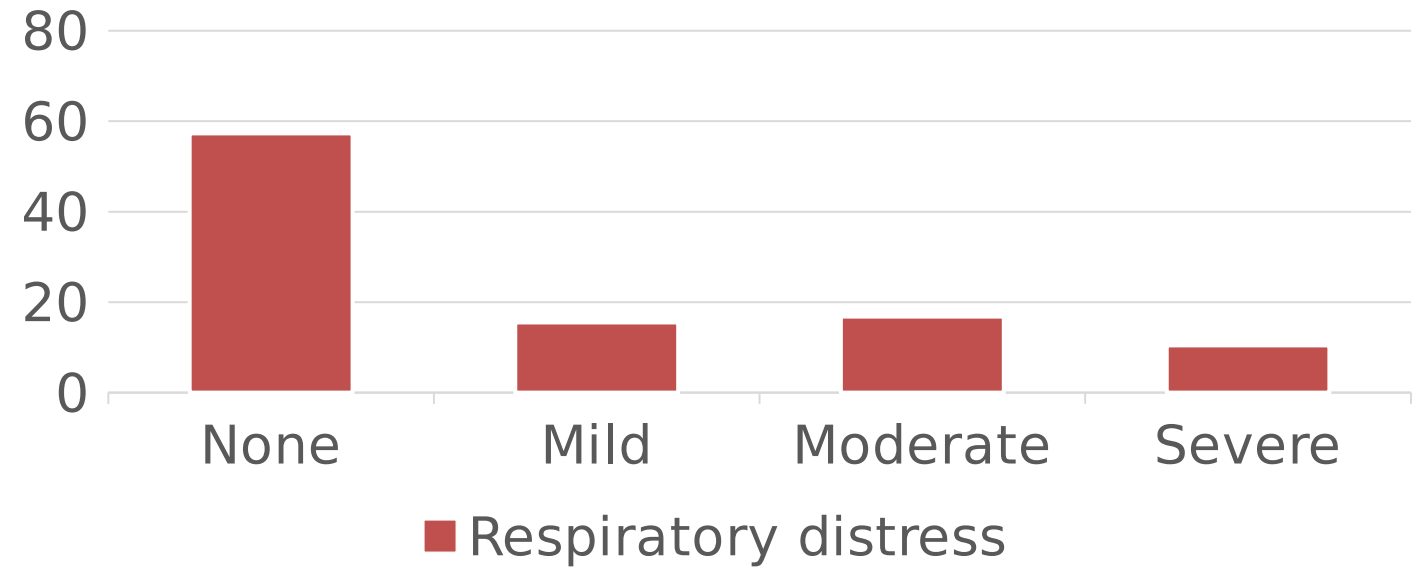
- Universal access to paid sick days reduces influenza infections due to workplace transmission by about 6%
- Flu Days have a larger impact on infection reduction:
  - 25% (1 Flu day)
  - 39% (2 Flu days)
- Combination of universal paid sick days and interventions to increase the number of days spent at home may have a large as well as an equitable impact

Case study: Smog emergency

Background: Donora PA, 27-31 Oct 1948

- Heavy air pollution
- Temperature inversion
- 70 excess deaths within 1 month
- Elevated mortality for 10 years

Population fraction with respiratory distress



Case study: Smog emergency

Scenario

- Pittsburgh experiences a severe heat wave
- At the same time, an air pollution event occurs
- An air temperature inversion occurs, trapping dense smog at lower elevations

Focus

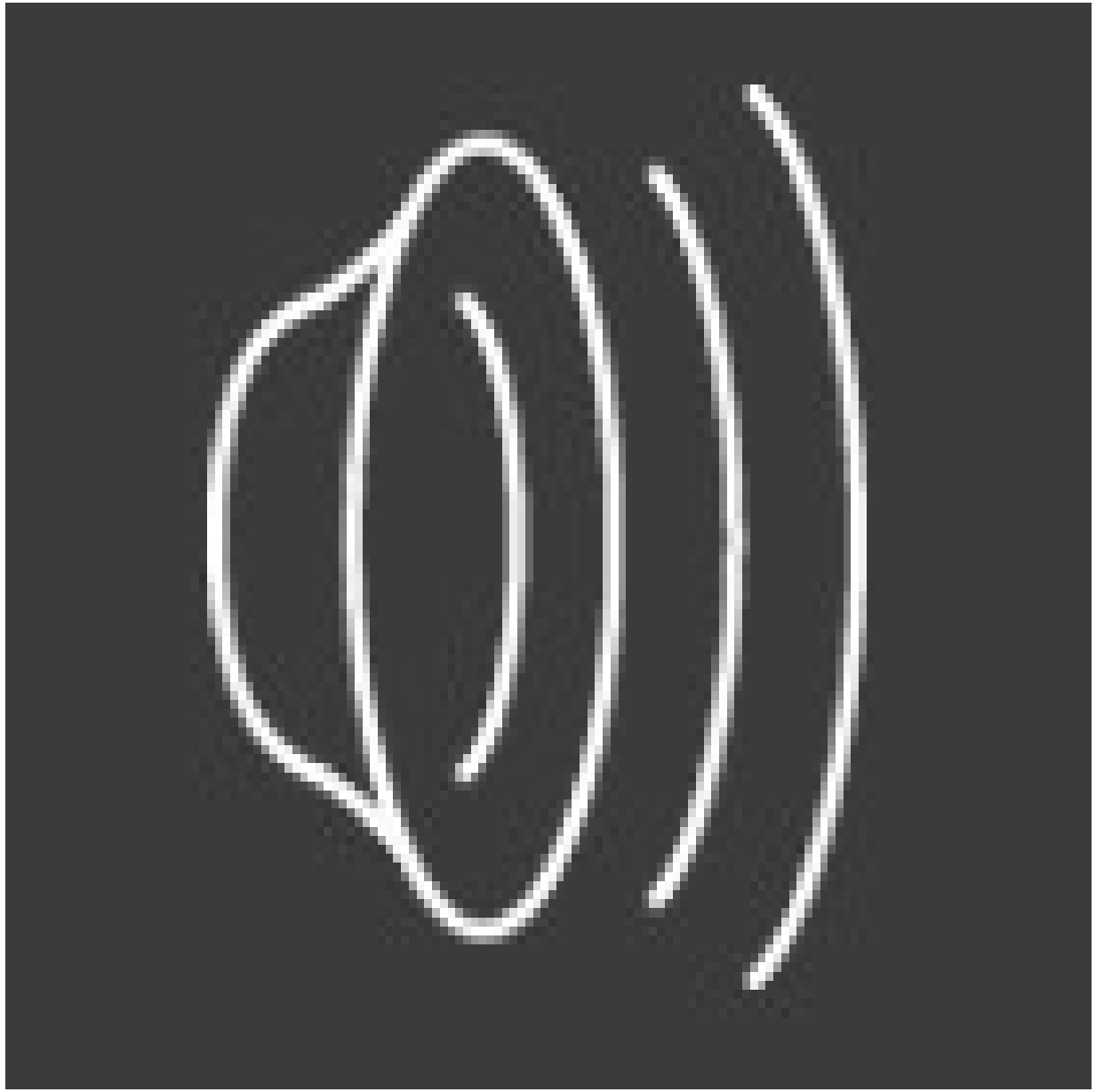
- How well does the City's emergency response system deal with the crisis?

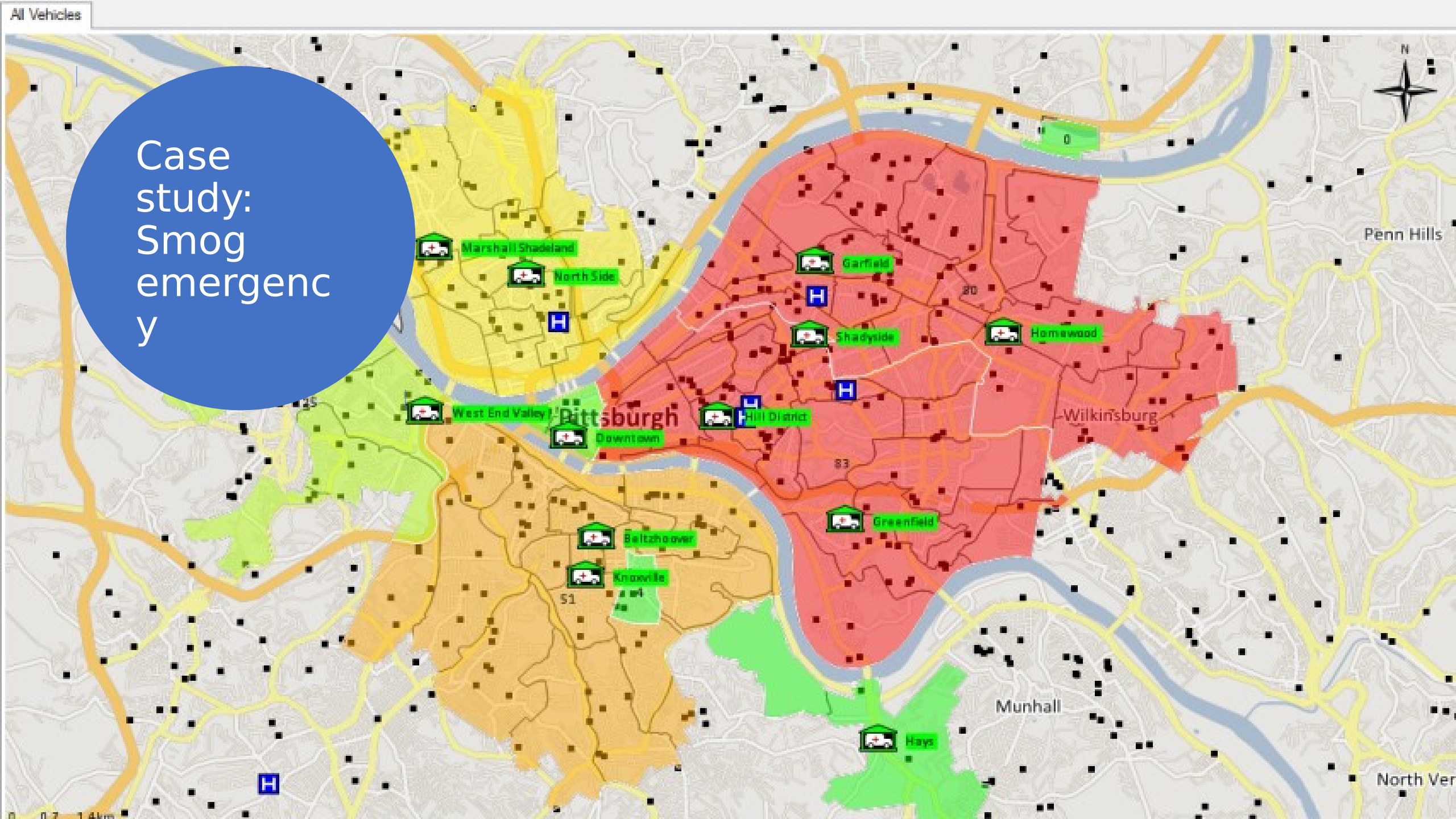
Case study: Smog emergency

Simulation of Ambulance requests

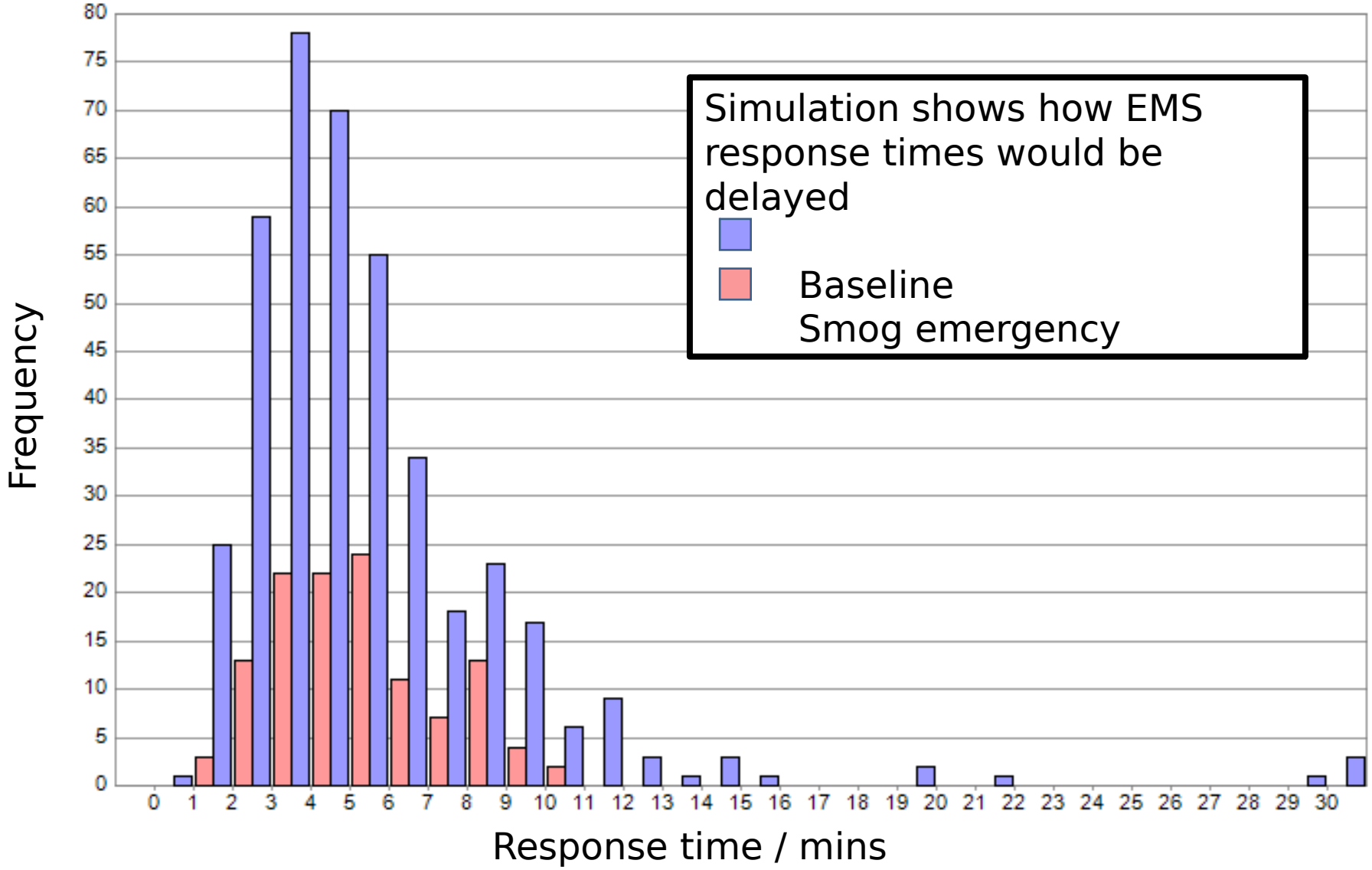
- Assign asthma and heat stroke risks to individuals
- Based on age, gender and race

- Air pollution at lower elevations
- Heat wave throughout area




All Vehicles
Case study: Smog emergency
Marshall Shadeland
North Side
West End Valley
Downtown
Pittsburgh
Hill District
Garfield
Shadyside
Homewood
Greenfield
Beltzhoover
Knoxville
Hays
Penn Hills
Wilkinsburg
Munhall
North Ver
N

Case study: Smog emergency



Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

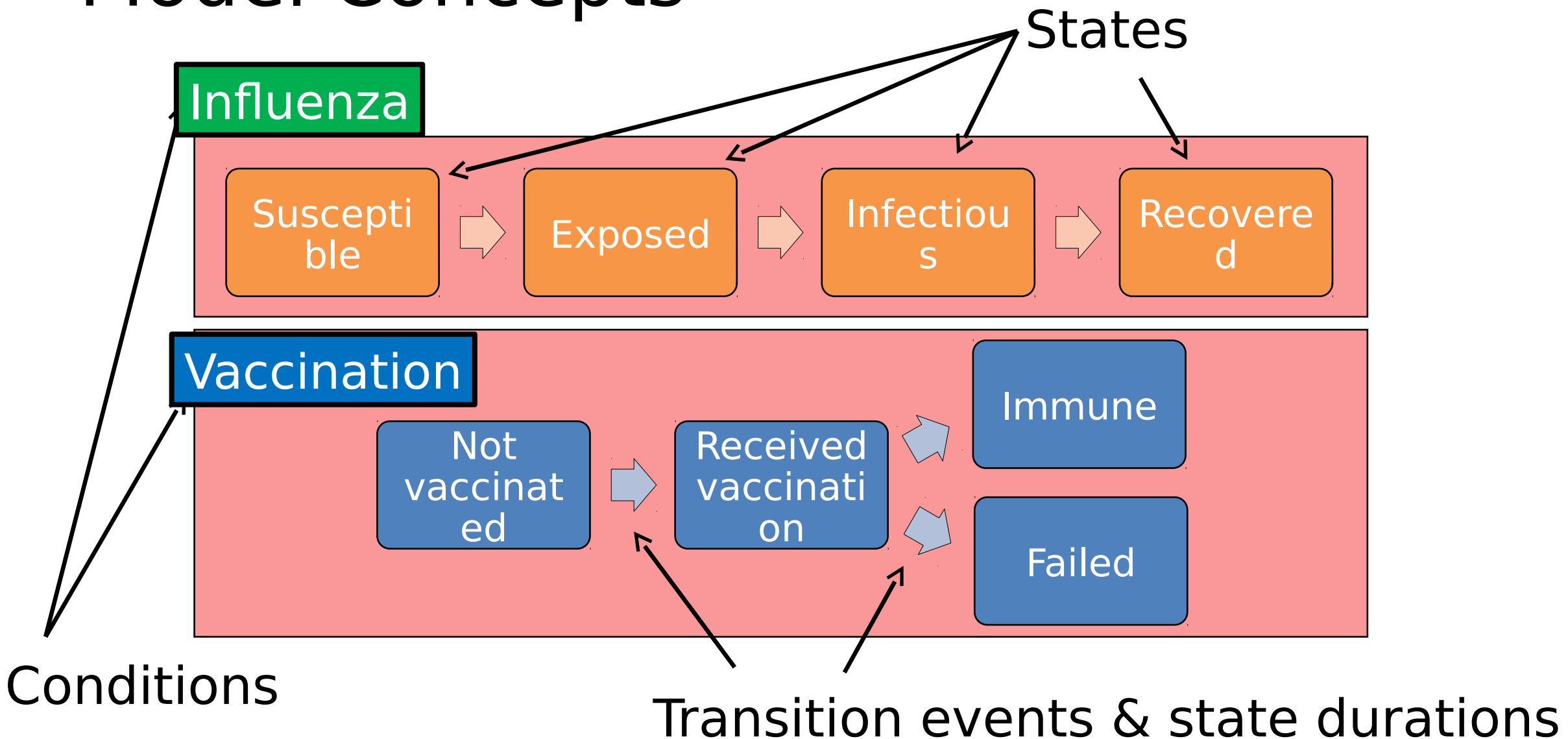
FRED: Model components

FRED Web: Example

FRED: Model Components

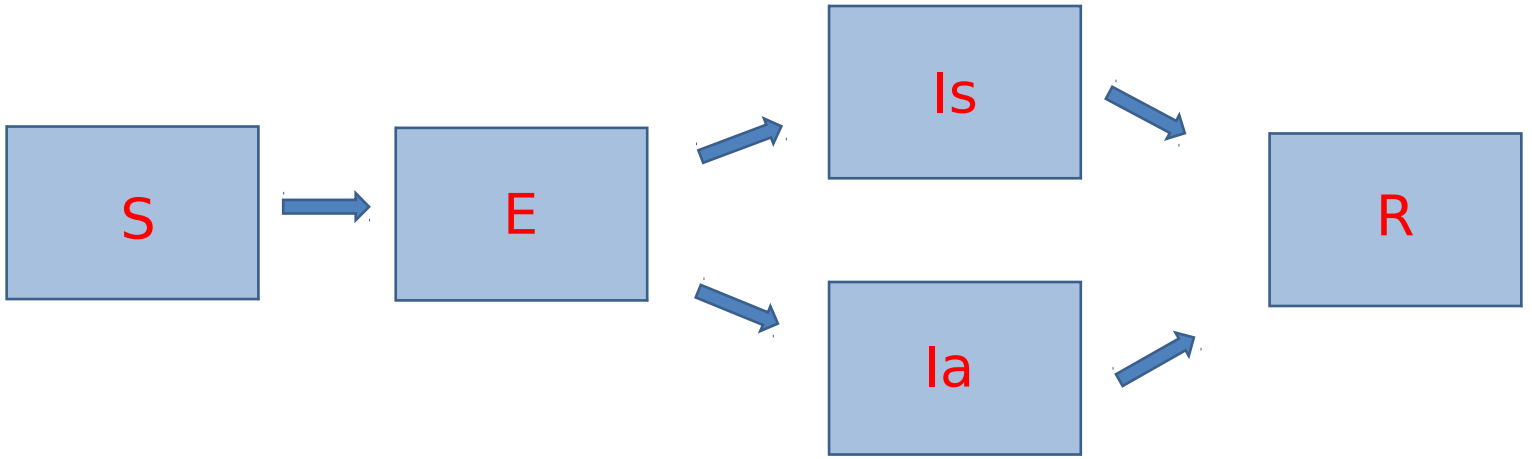
Condition	Process to model
States	Parts of condition
Durations	Time in a state before evaluating whether to move to another state
Transitions	How agents move from one state to another

Model Concepts



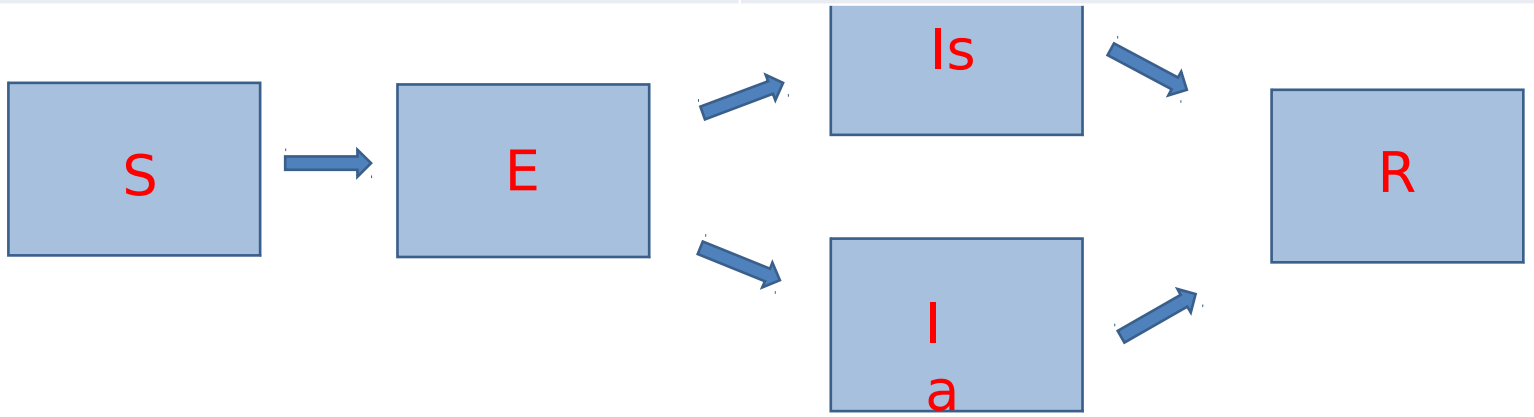
Example—Infectious Disease Model

- Simple infectious disease model -- influenza
- Susceptible
- Exposed
- Infectious symptomatic
- Infectious asymptomatic
- Recovered



Conditions and States

Reality	FRED
Disease - Influenza	Conditions = INF
Stages - Susceptible, Exposed, Infectious (symptomatic), Infectious (asymptomatic), Recovered	INF.states = S E Is Ia R

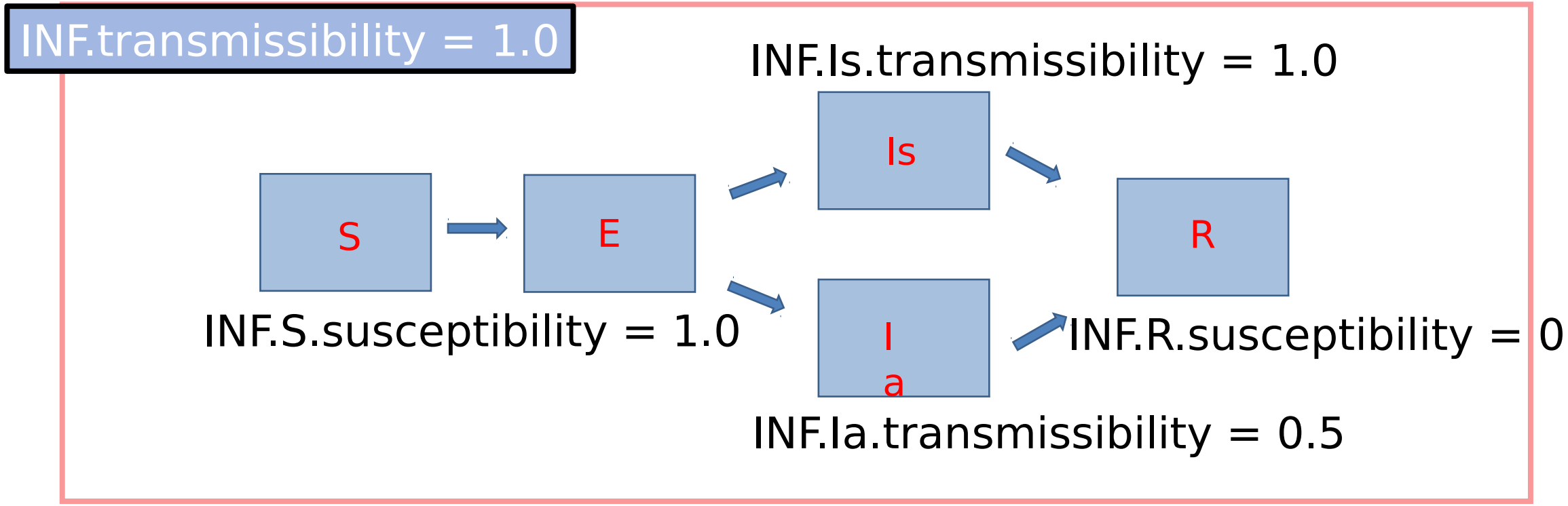


Transmissibility

- FRED conditions have transmission mode
- May be `None’ if not transmissible
- Transmissibility & susceptibility modifies infection probability

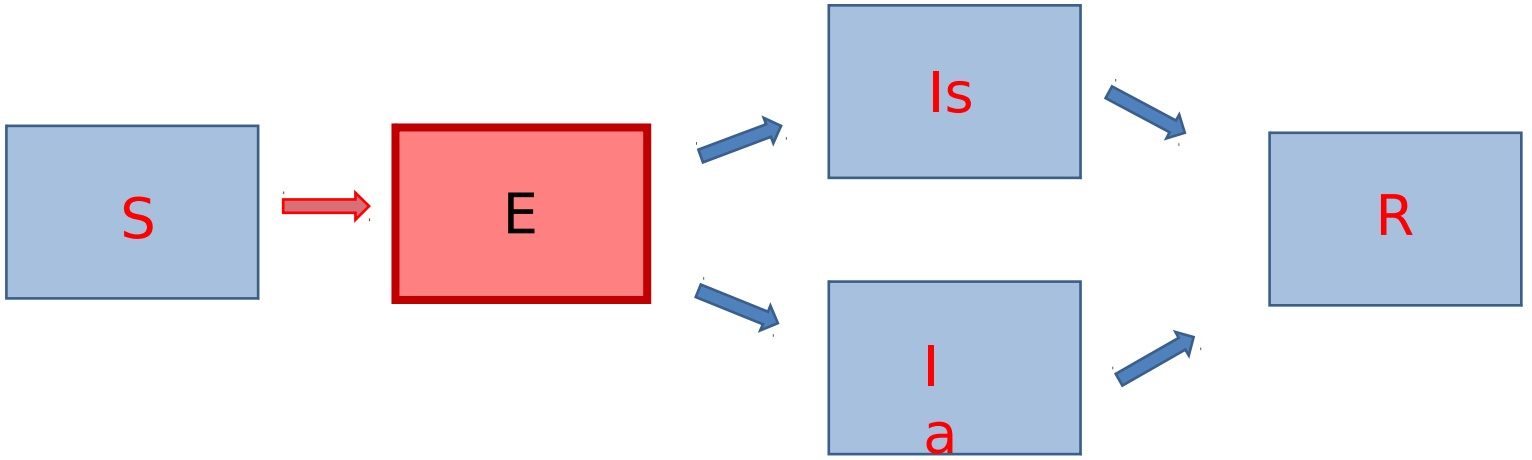
When agents are co-located in a Place, chance of infection event occurring multiplied by:

$$\text{Transmissbility}_{\text{Condition}} * \text{Transmissibility}_{\text{State}} * \text{Susceptibility}_{\text{State}}$$



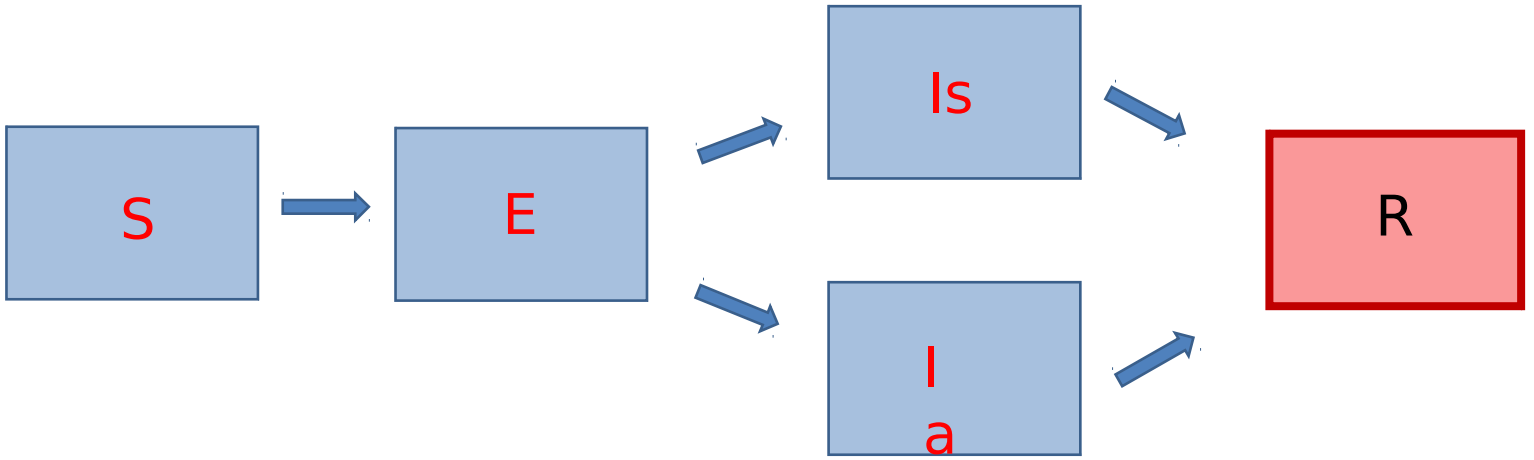
Exposed state

- Exposed means being infected
- In FRED, the *exposed_state* is state to enter after an exposure event
- Infection event is required to trigger state change S to E



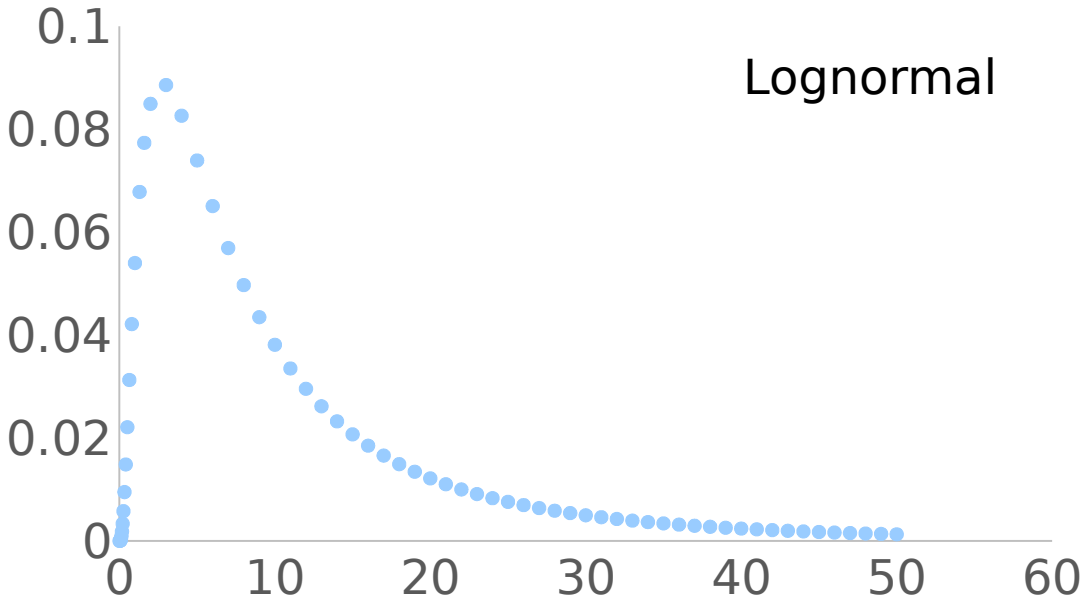
Dormant states

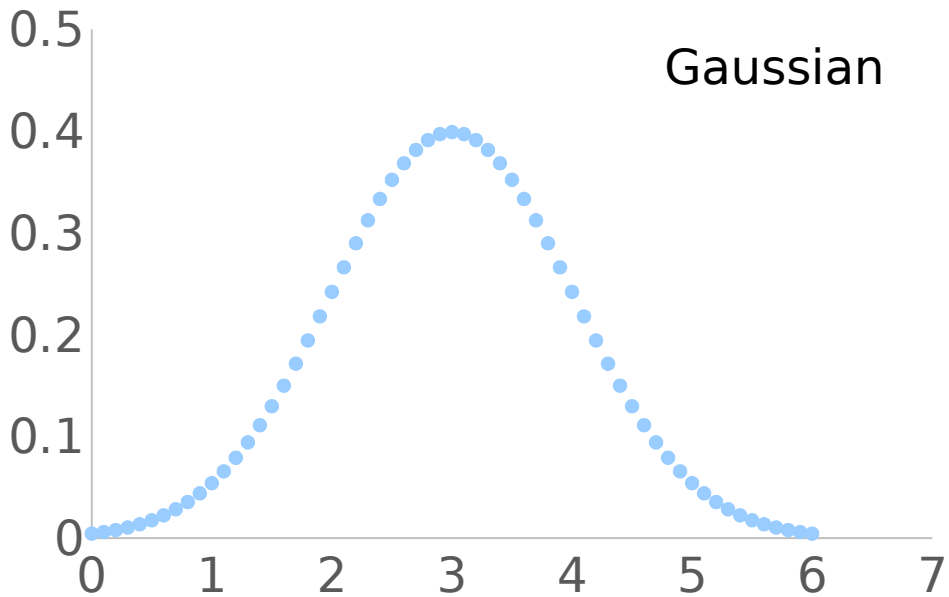
- In FRED, state is dormant when state does not change
- Speeds up simulation times



Duration

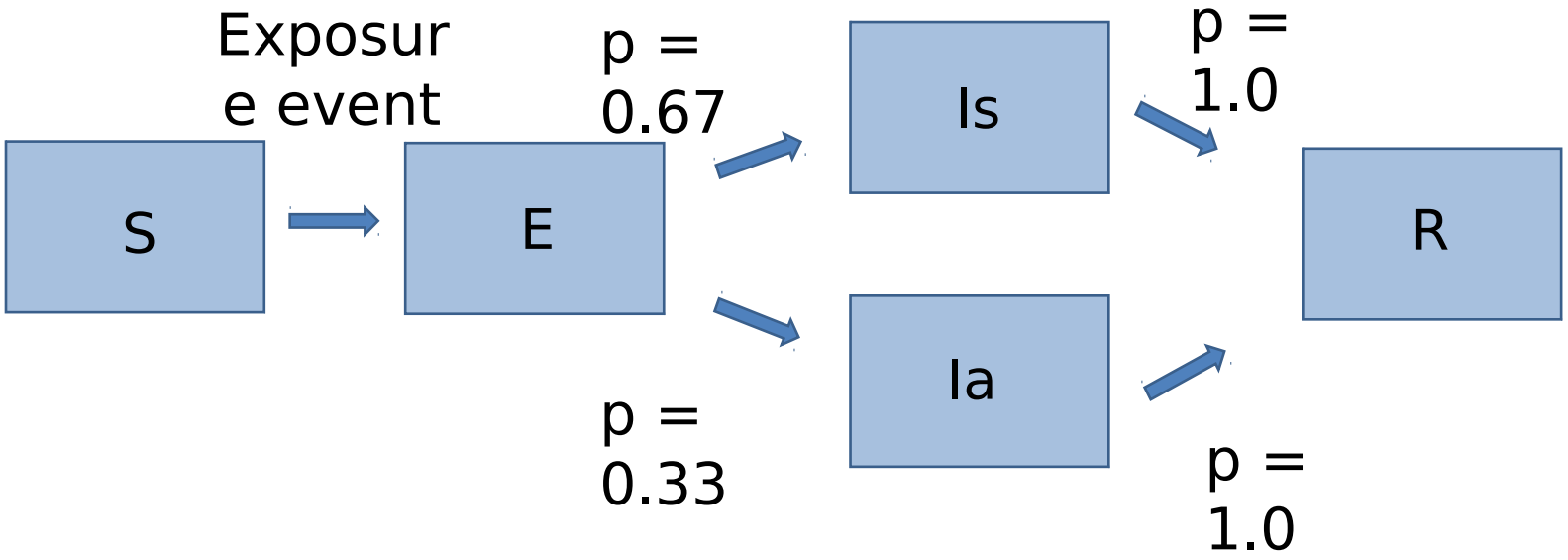
- Duration—When to check for new state
- Specify in simulation days and distribution
- Different distributions available





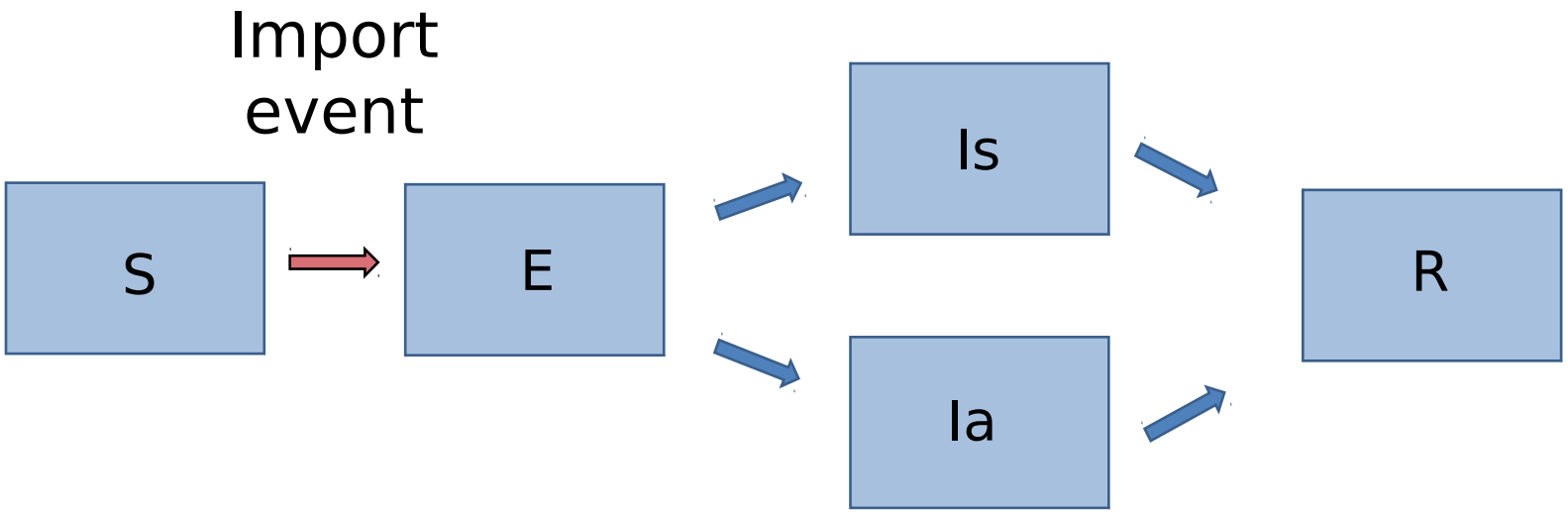
Transitions

- Specifies probabilities of each state-to-state transition
- Logistic regression for combining multiple factors to determine probability

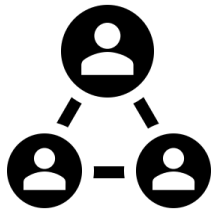


Transitions: Imports

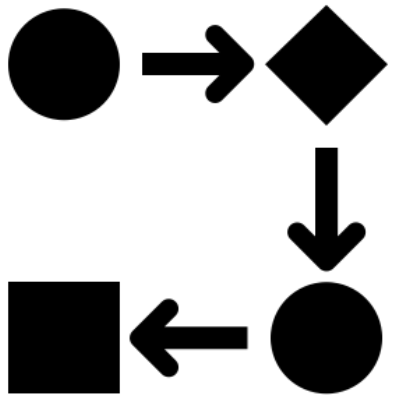
- Imports
- Seed outbreaks



Model Concepts - Summary



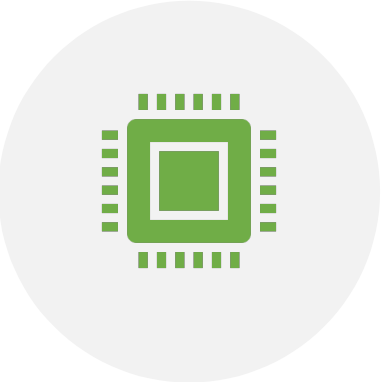
- Model is made of Conditions
- Conditions have states and transitions
- States
  - Have durations
  - May receive an event (like infection)
  - May be the result of an event
- Conditions may be transmissible
  - Level of transmissibility at Condition and state level, which interact



FRED

BARRIERS TO USE

LEARNING CURVE



COMPUTING RESOURCES

FRED Web

Online platform for creating, running & analyzing agent-based models in FRED

Simulations run on dedicated server

Graphical User Interface

Plotting and mapping tools for data analysis

Theory outline

Agent-based models

FRED: Key features

FRED: Case studies

FRED: Model components

FRED Web: Example

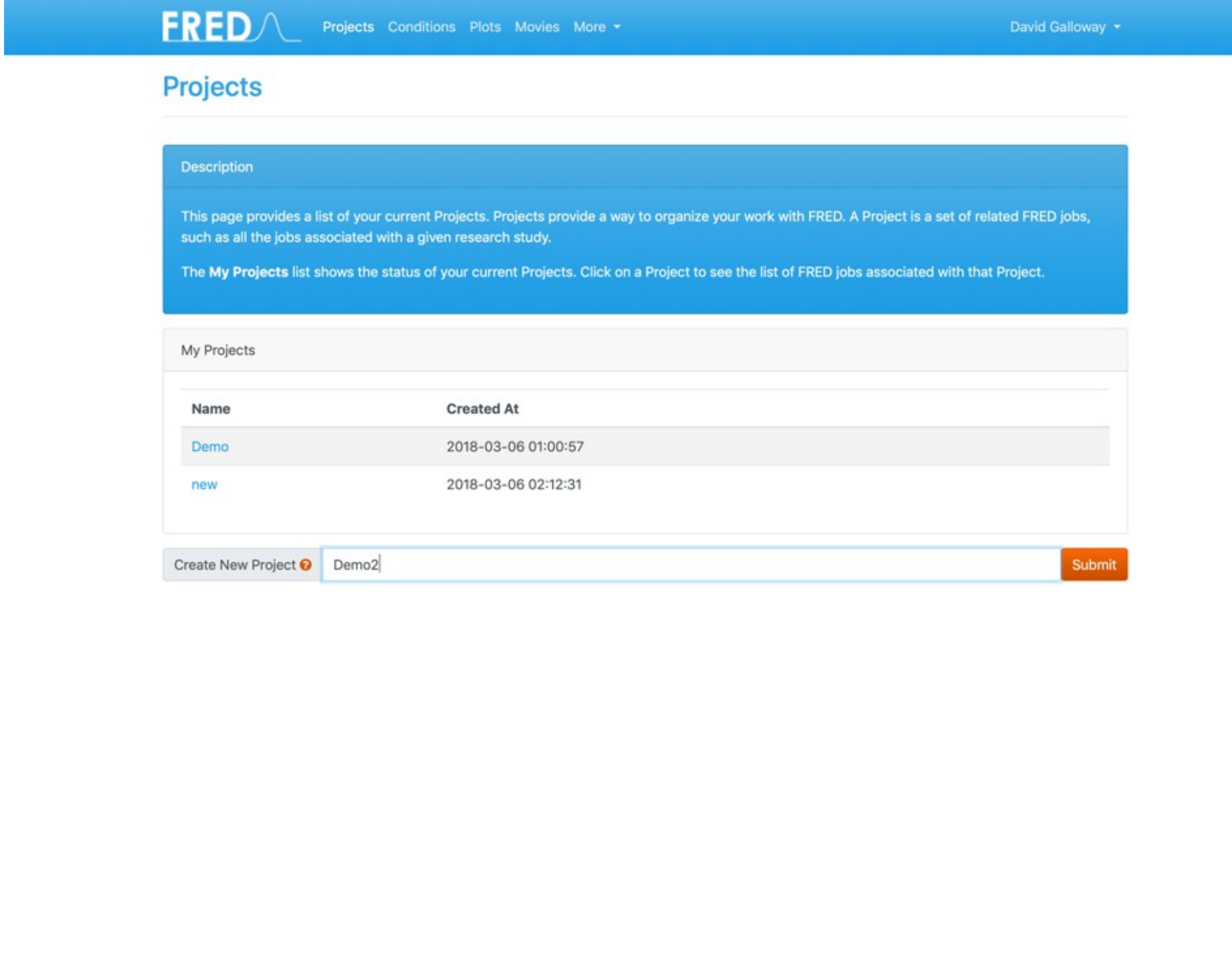
FRED Web: Example

- Simple example
- Measles outbreak
- **SHARED** condition

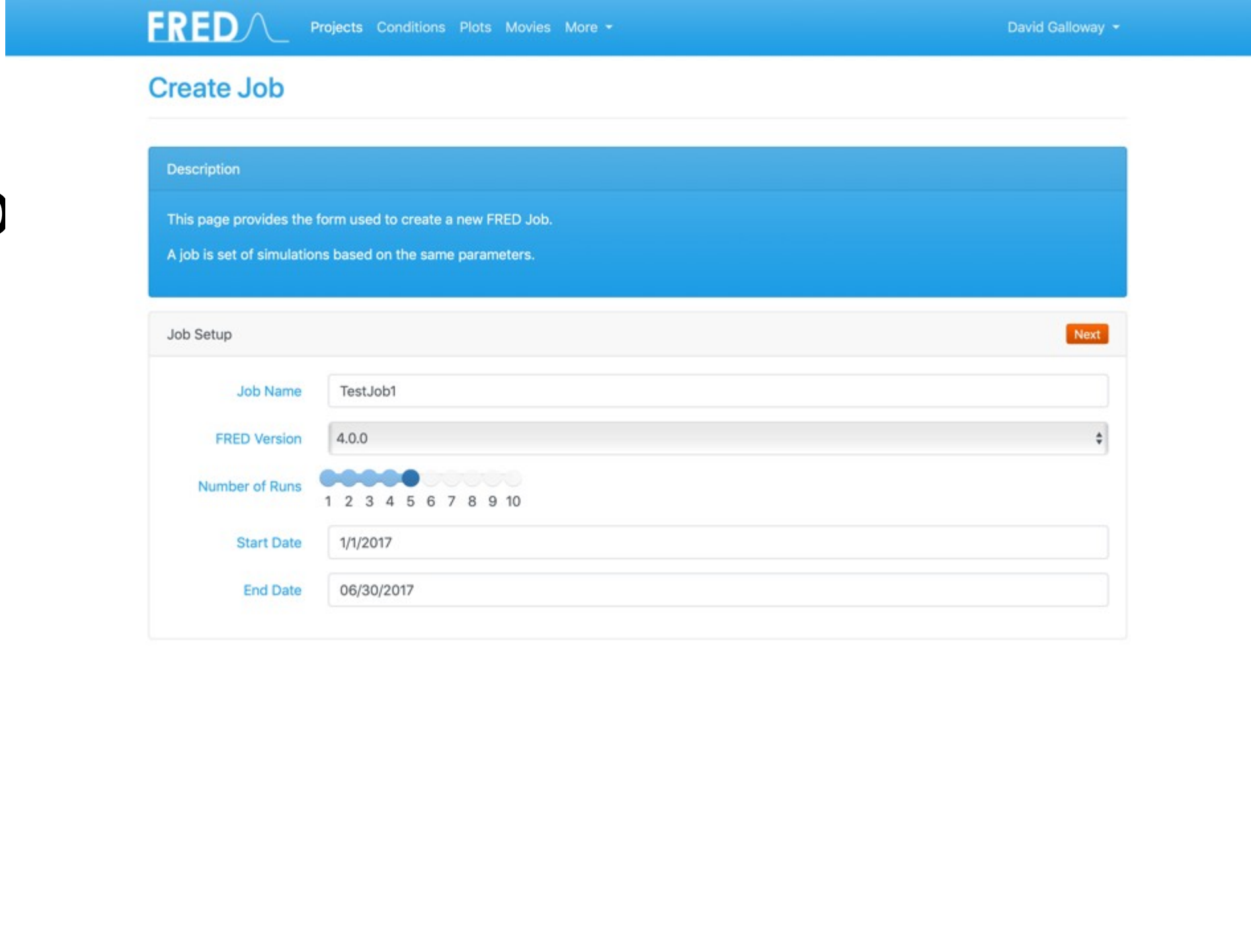
Home page


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
FRED Modeling System
A flexible, modular, open source framework for epidemic modeling.
Try the new FRED Measles page!
FRED (A Framework for Reconstructing Epidemiological Dynamics) is an agent-based modeling system developed by the Pitt Public Health Dynamics Laboratory.
FRED represents every person in a real geographic region as a separate individual each with her/his own unique social, familial, demographic, behavioral, and health characteristics. Individuals interact within realistic household, school, and workplace social networks.
FRED was originally developed to simulate infectious disease epidemics, but has been extended to enable users to model a wide range of health conditions and to study how patterns of those conditions vary over time in a specific region.
FRED is available through this web interface in the hopes of making large-scale agent-based models more useful to the policy-making community, the research community, and as a teaching tool for students in public health.
Citation
If you use FRED in your research, please use the following citation:
Grefenstette JJ, Brown ST, Rosenfeld R, Depasse J, Stone NT, Cooley PC, Wheaton WD, Fyshe A, Galloway DD, Sriram A, Guclu H, Abraham T, Burke DS. FRED (A Framework for Reconstructing Epidemic Dynamics): An open-source software system for modeling infectious diseases and control strategies using census-based populations. BMC Public Health, 2013 Oct;13(1), 940. doi: 10.1186/1471-2458-13-940. PubMed PMID: 24103508
Funding
Support for this work is provided by the National Institute of General Medical Sciences under MIDAS grant 1U54GM088491-01, by the Vaccine Modeling Initiative funded by the Bill and Melinda Gates Foundation, and by the Robert Wood Johnson Foundation.
FRED Web v2.2.0, © 2018 Public Health Dynamics Laboratory, University of Pittsburgh

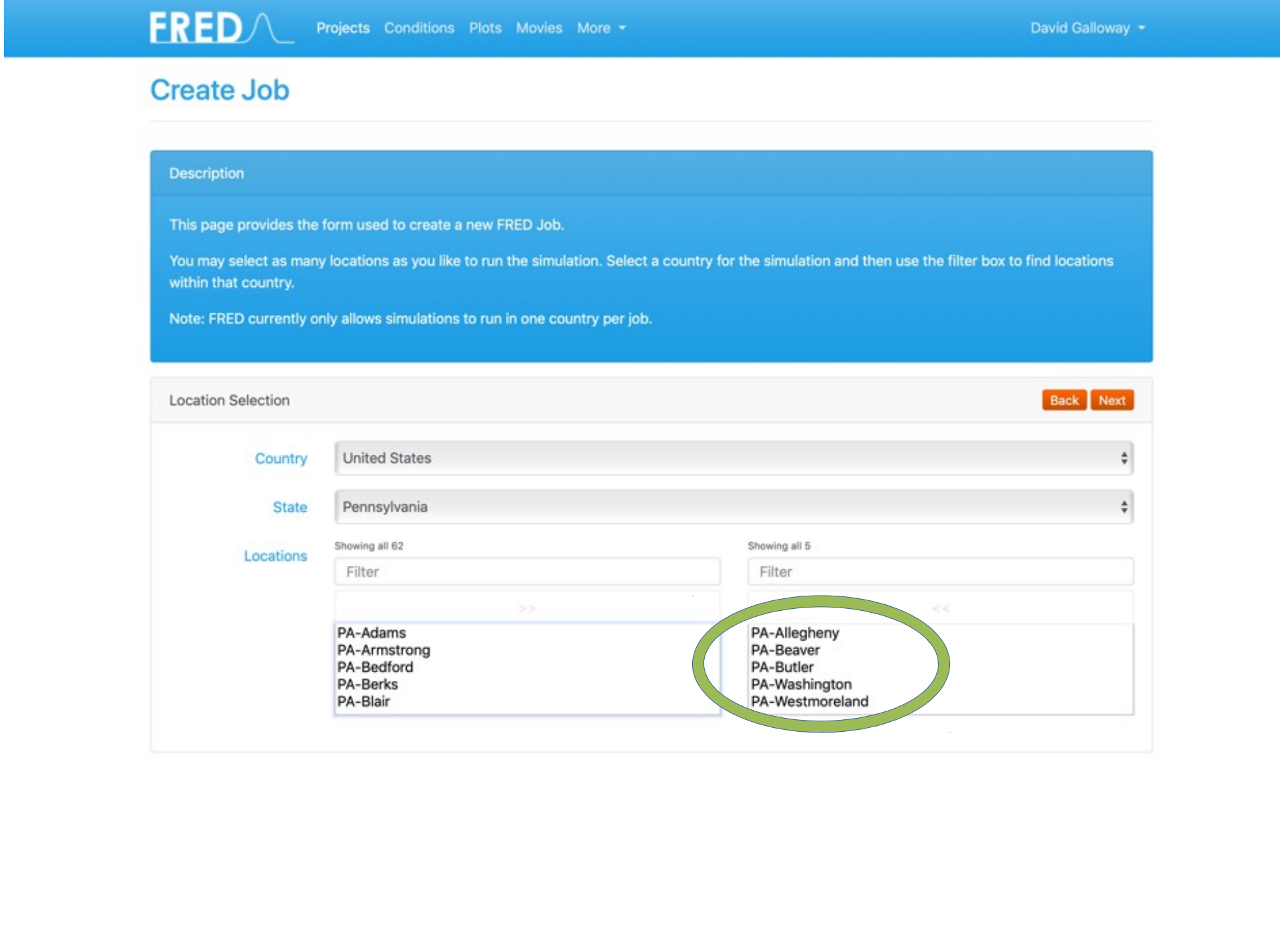
Projects


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Projects
Description
This page provides a list of your current Projects. Projects provide a way to organize your work with FRED. A Project is a set of related FRED jobs, such as all the jobs associated with a given research study.
The My Projects list shows the status of your current Projects. Click on a Project to see the list of FRED jobs associated with that Project.
My Projects
Name
Created At
Demo
2018-03-06 01:00:57
new
2018-03-06 02:12:31
Create New Project
Demo2
Submit

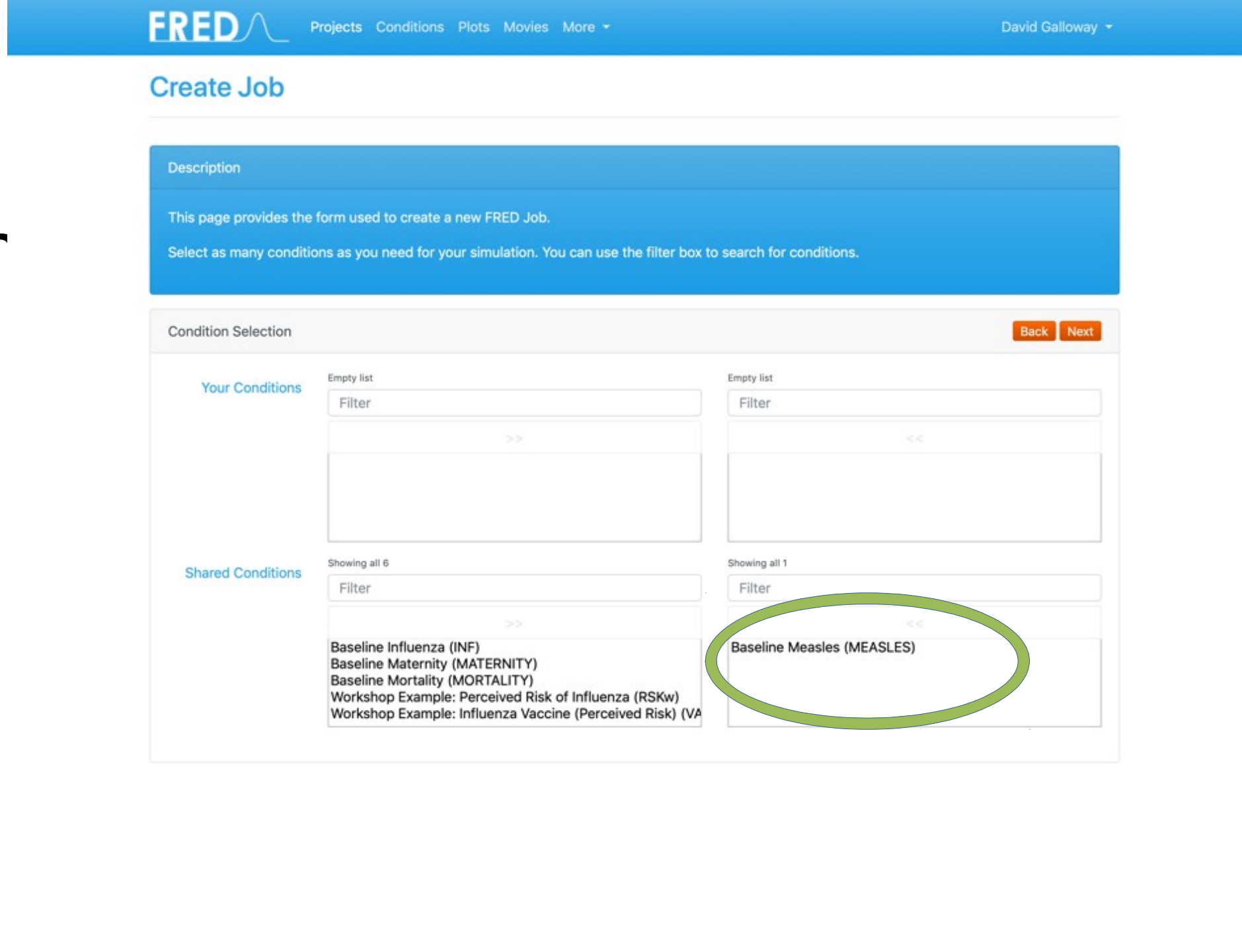
Create Jo


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Create Job
Description
This page provides the form used to create a new FRED Job.
A job is set of simulations based on the same parameters.
Job Setup
Next
Job Name
TestJob1
FRED Version
4.0.0
Number of Runs
1 2 3 4 5 6 7 8 9 10
Start Date
1/1/2017
End Date
06/30/2017

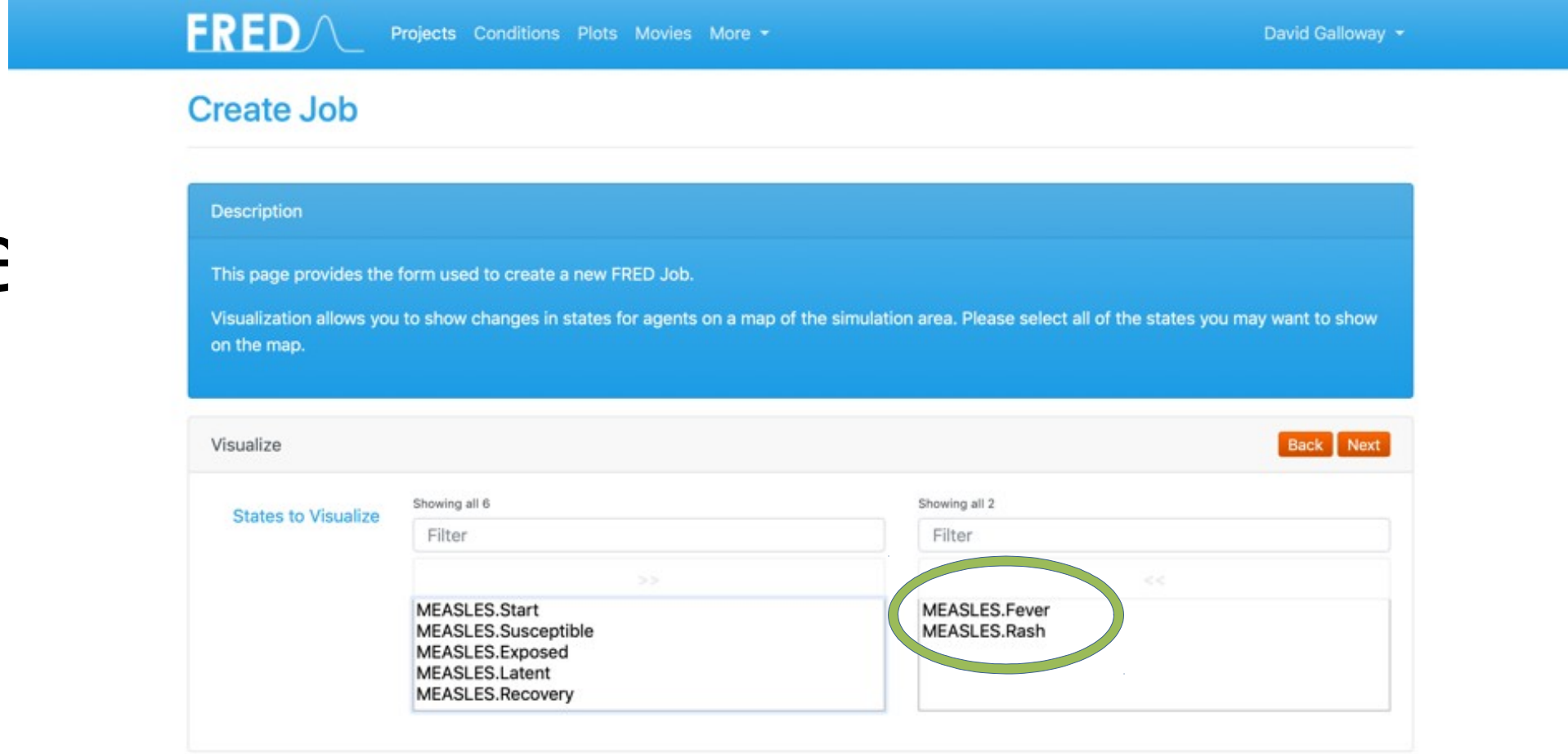
Select location



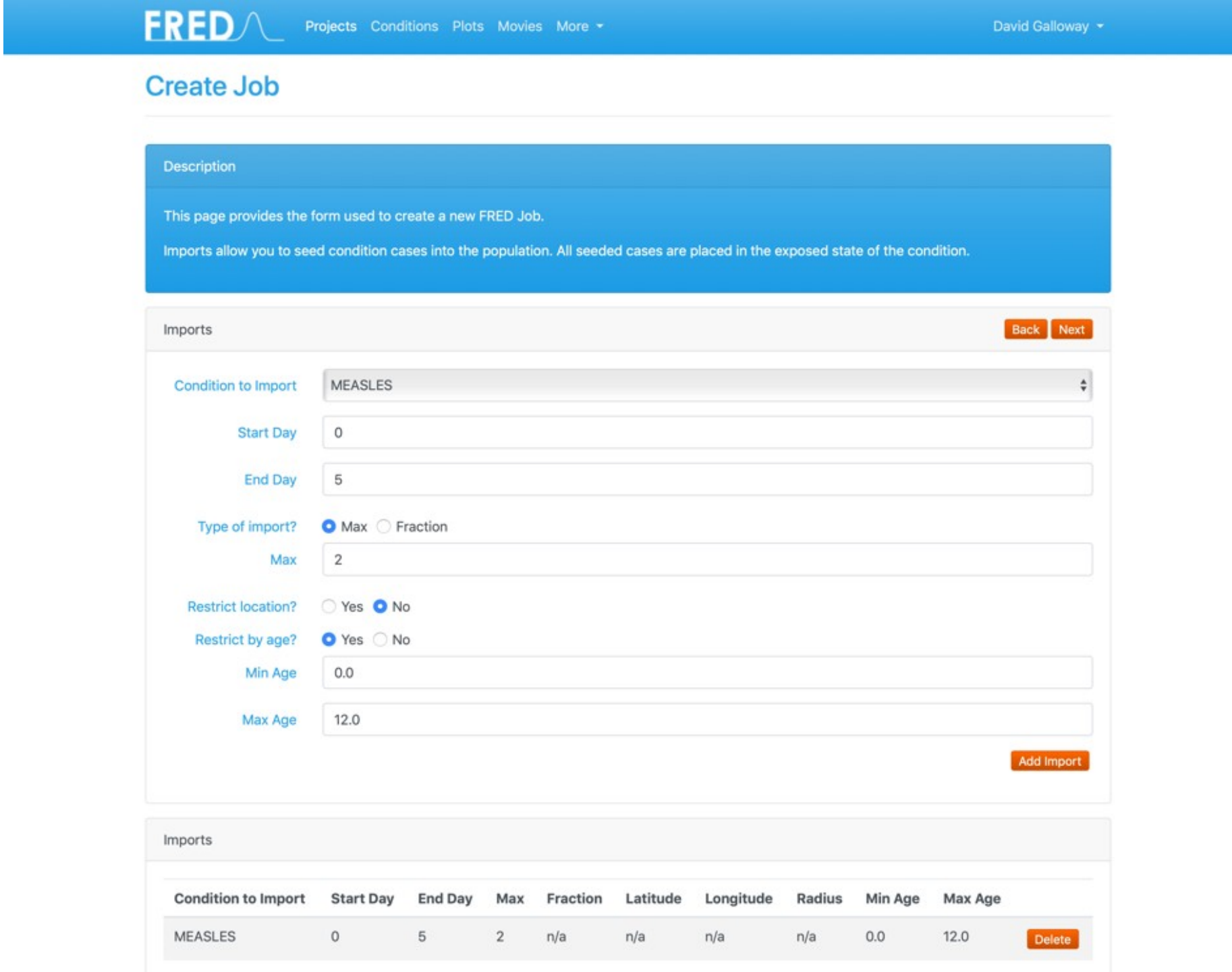
Select Conditior



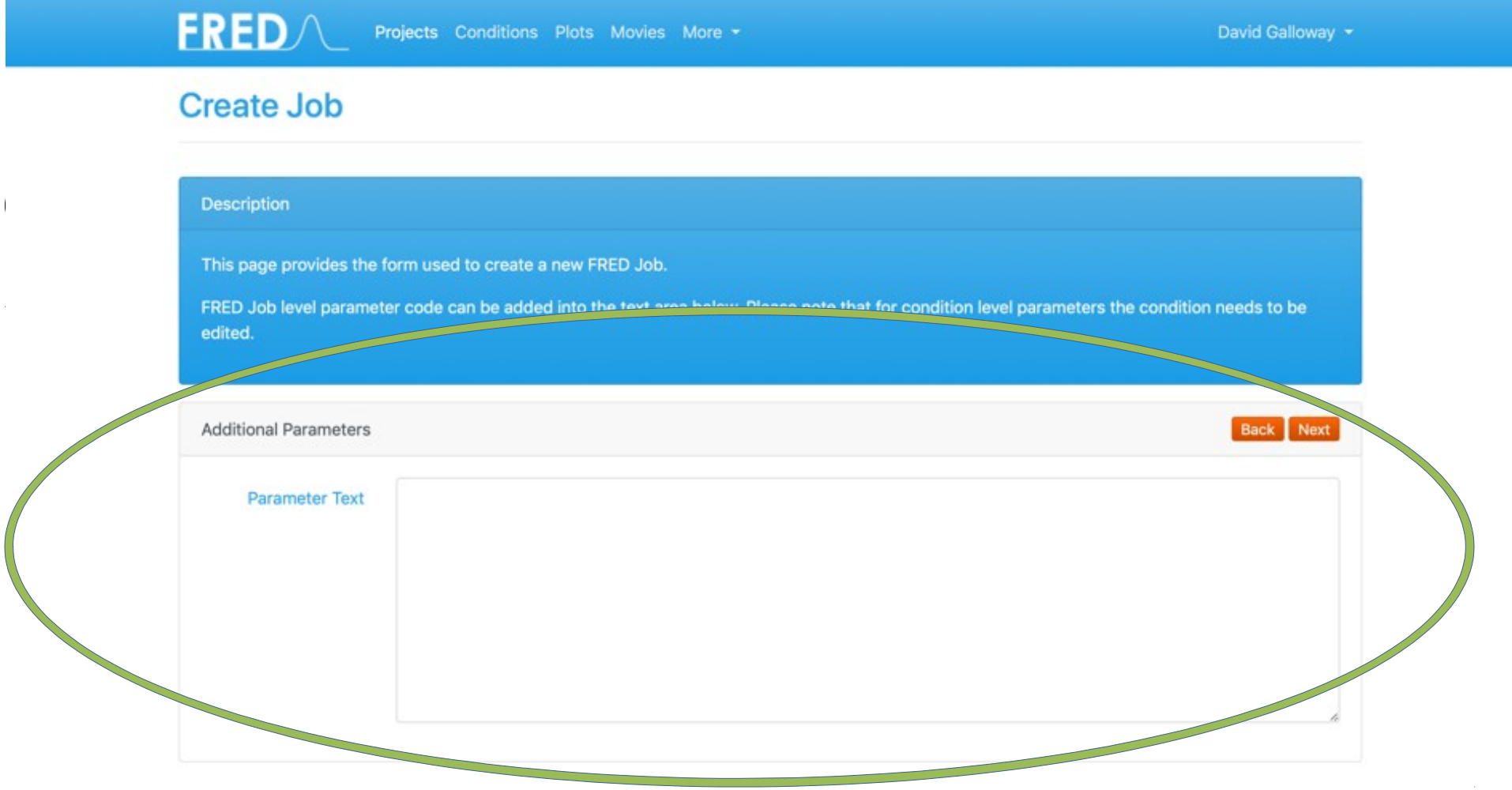
Visualize


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Create Job
Description
This page provides the form used to create a new FRED Job.
Visualization allows you to show changes in states for agents on a map of the simulation area. Please select all of the states you may want to show on the map.
Visualize
Back
Next
States to Visualize
Showing all 6
Filter
MEASLES.Start
MEASLES.Susceptible
MEASLES.Exposed
MEASLES.Latent
MEASLES.Recovery
Showing all 2
Filter
MEASLES.Fever
MEASLES.Rash

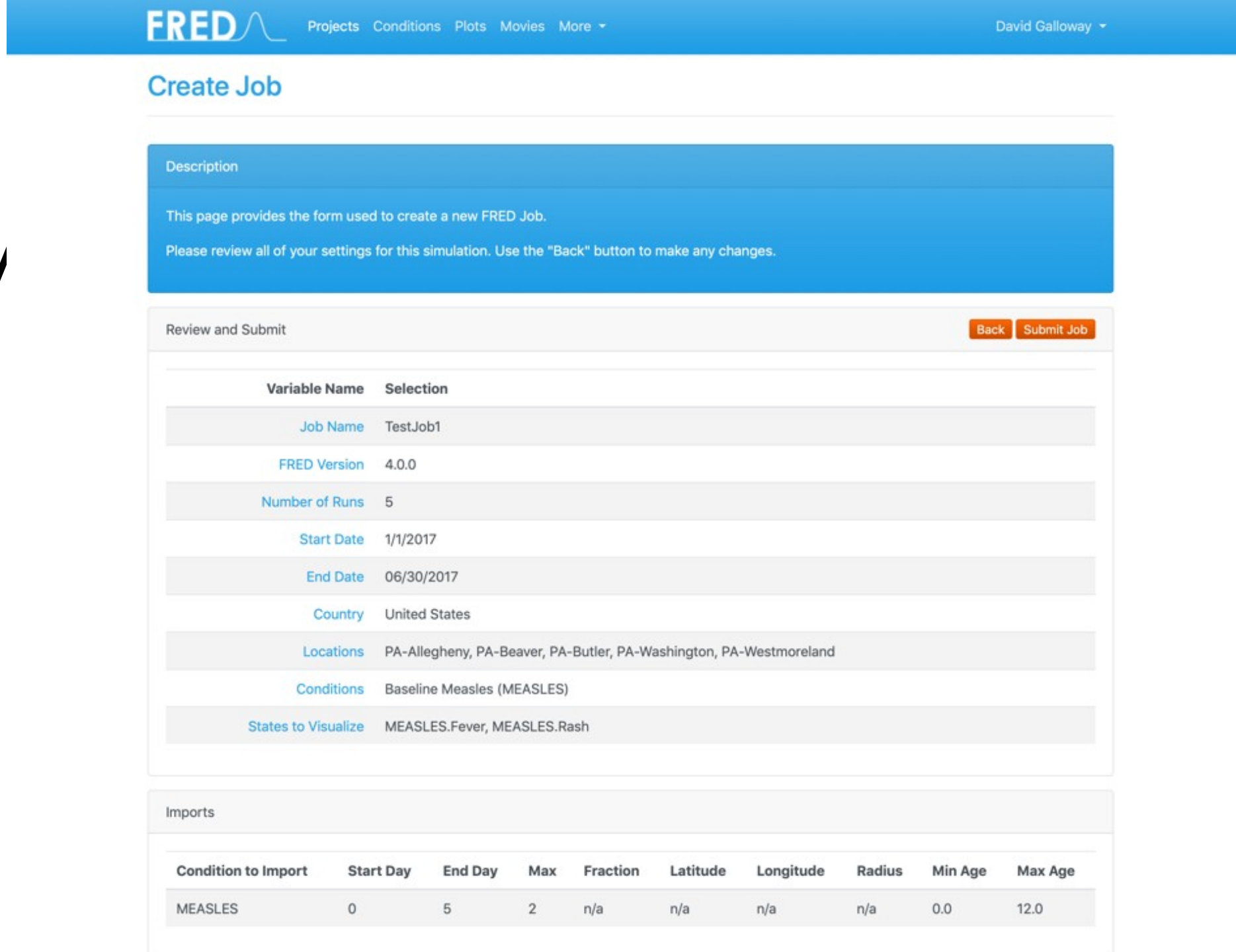
Import


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Create Job
Description
This page provides the form used to create a new FRED Job.
Imports allow you to seed condition cases into the population. All seeded cases are placed in the exposed state of the condition.
Imports
Back
Next
Condition to Import
MEASLES
Start Day
0
End Day
5
Type of import?
Max
Fraction
Max
2
Restrict location?
Yes
No
Restrict by age?
Yes
No
Min Age
0.0
Max Age
12.0
Add Import
Imports
Condition to Import
Start Day
End Day
Max
Fraction
Latitude
Longitude
Radius
Min Age
Max Age
MEASLES
0
5
2
n/a
n/a
n/a
n/a
0.0
12.0
Delete

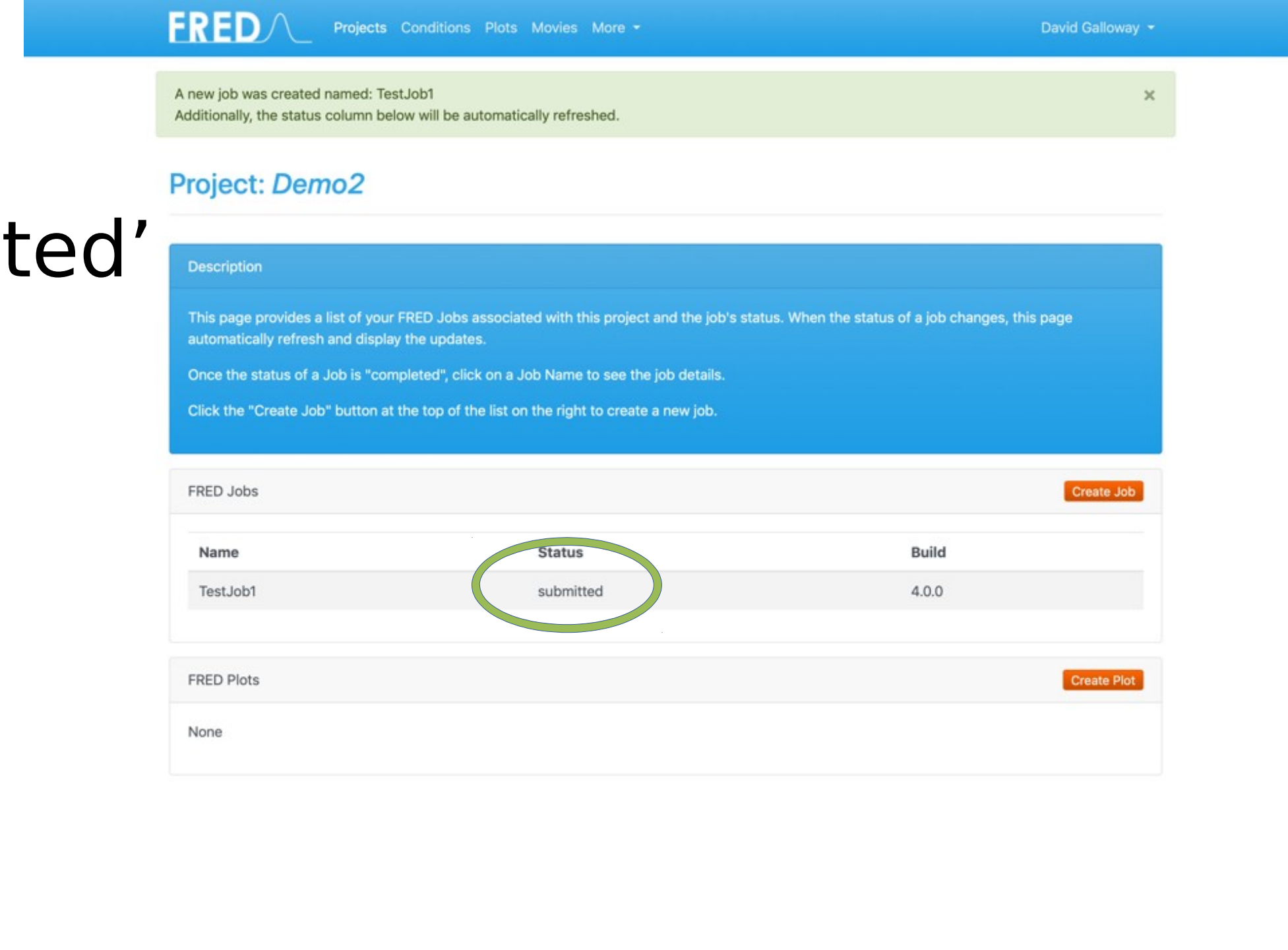
Paramet
Text



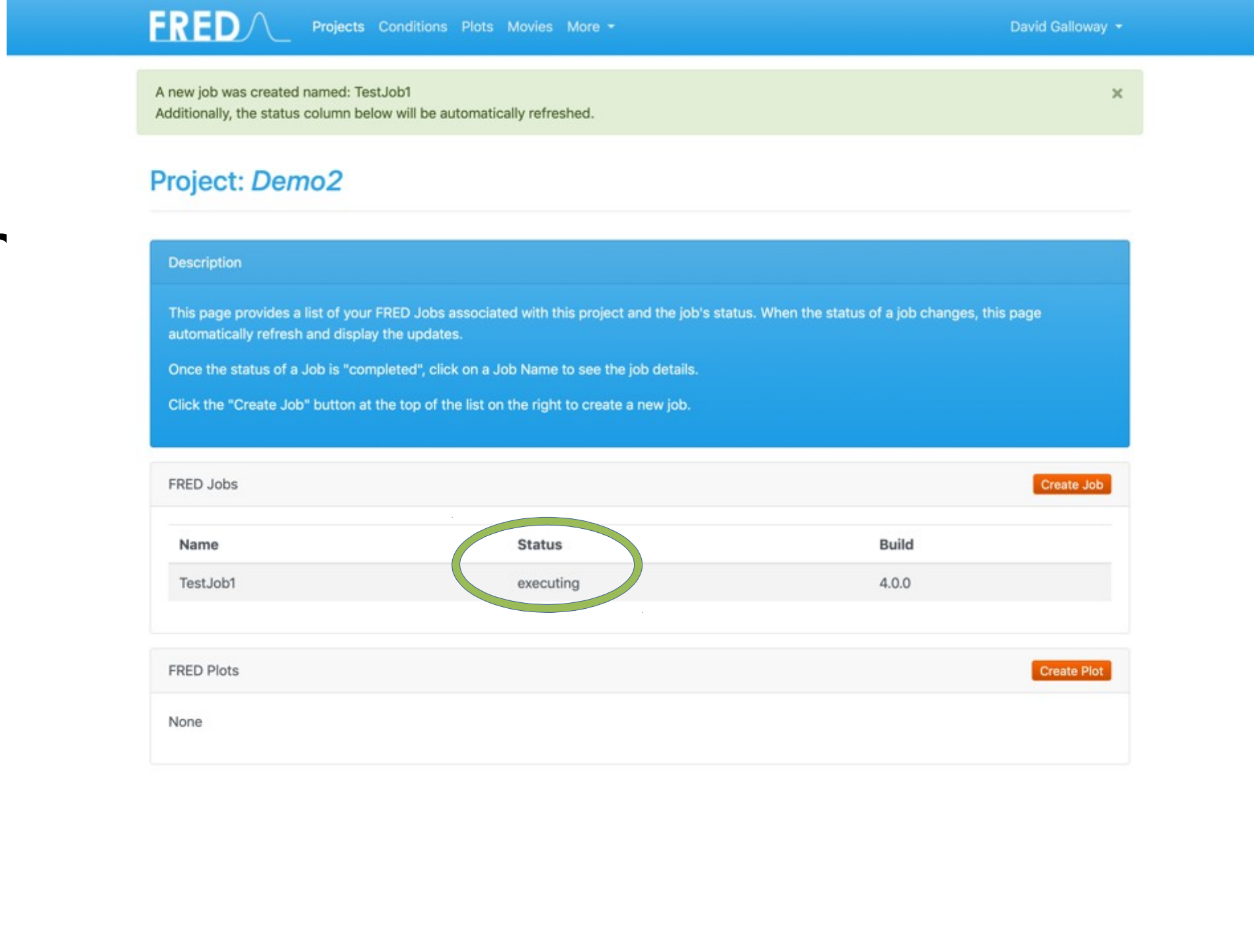
Job Summary


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Create Job
Description
This page provides the form used to create a new FRED Job.
Please review all of your settings for this simulation. Use the "Back" button to make any changes.
Review and Submit
Back
Submit Job
Variable Name
Selection
Job Name
TestJob1
FRED Version
4.0.0
Number of Runs
5
Start Date
1/1/2017
End Date
06/30/2017
Country
United States
Locations
PA-Allegheny, PA-Beaver, PA-Butler, PA-Washington, PA-Westmoreland
Conditions
Baseline Measles (MEASLES)
States to Visualize
MEASLES.Fever, MEASLES.Rash
Imports
Condition to Import
Start Day
End Day
Max
Fraction
Latitude
Longitude
Radius
Min Age
Max Age
MEASLES
0
5
2
n/a
n/a
n/a
n/a
0.0
12.0

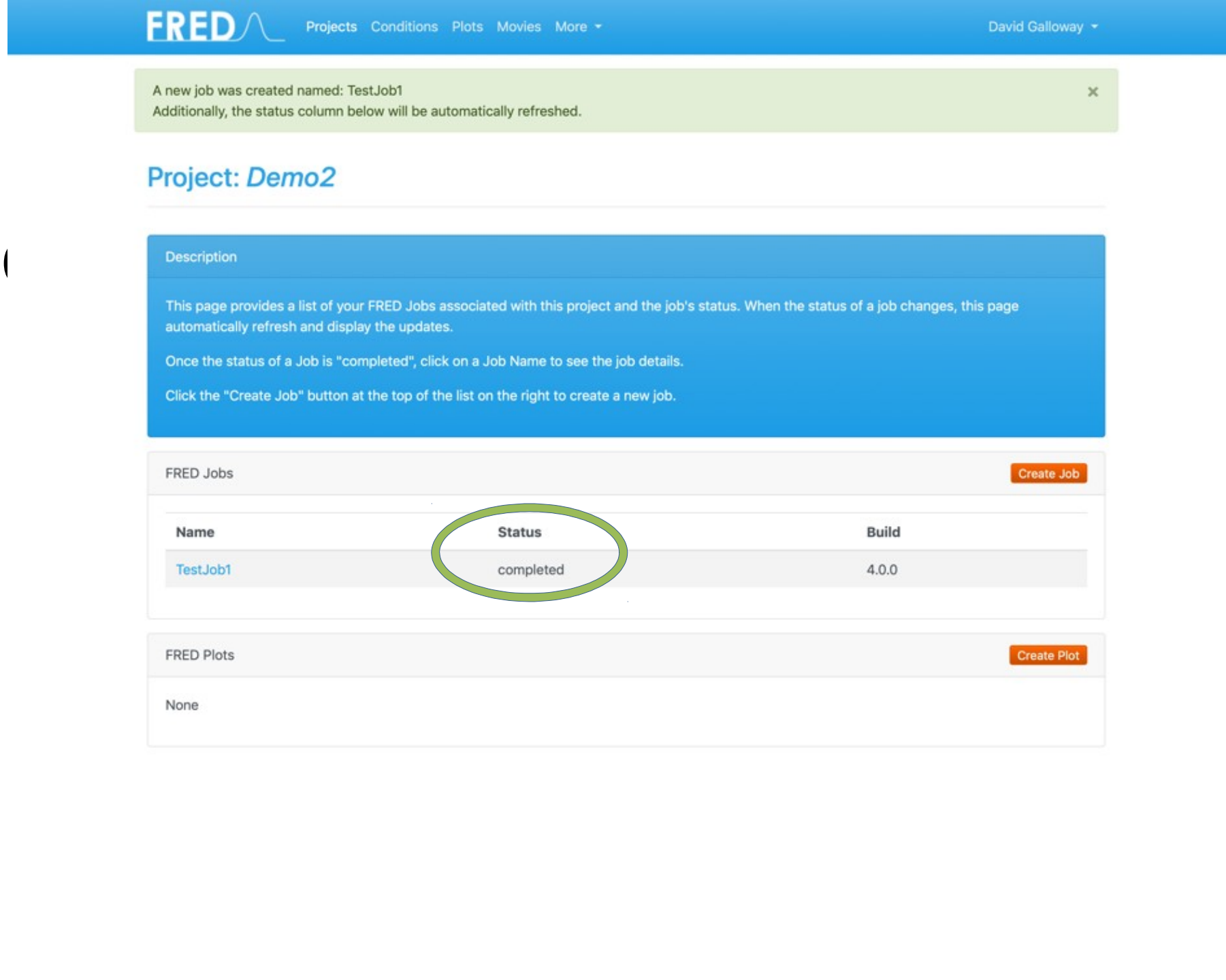
Job ‘Submitted’



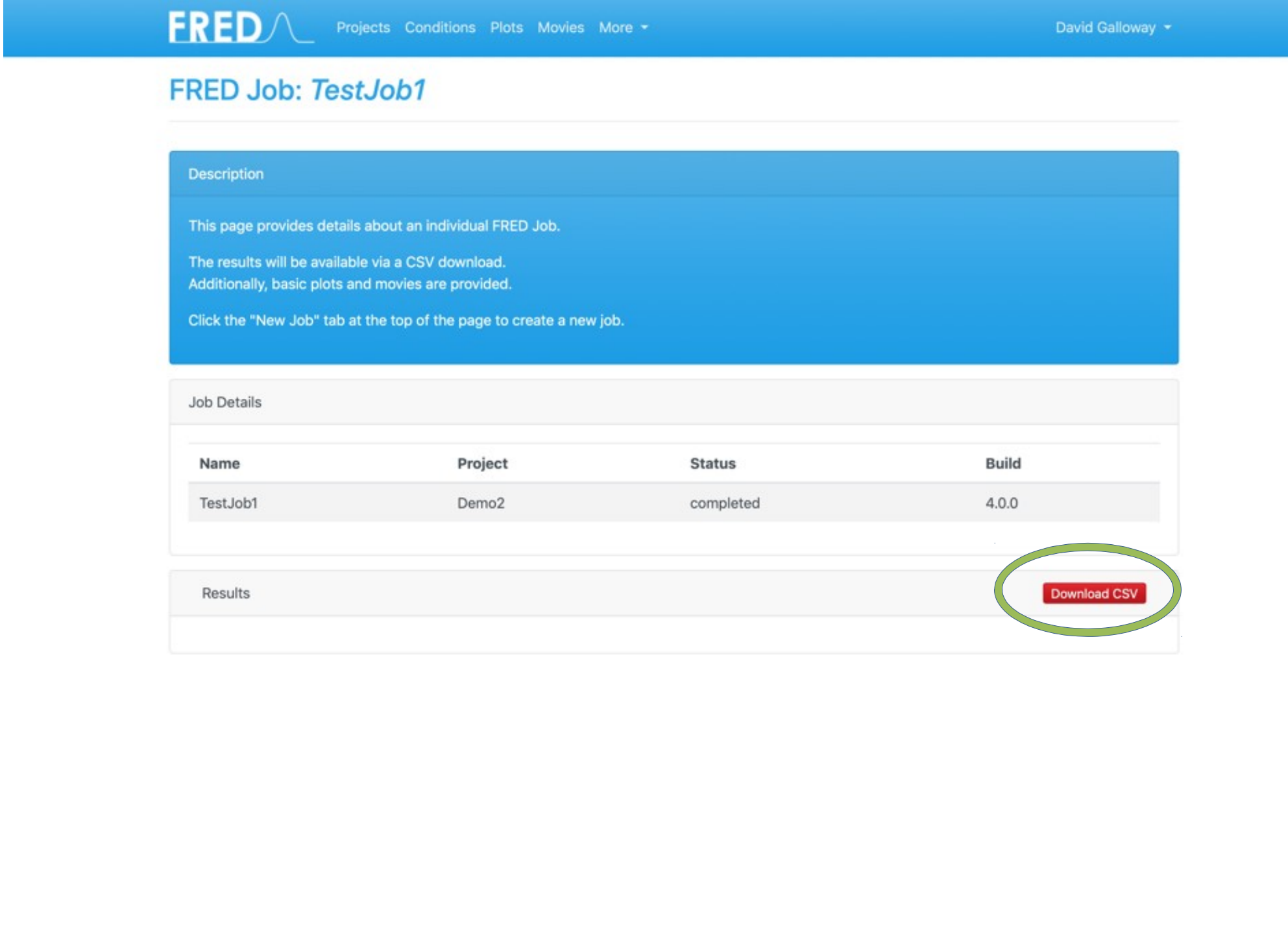
Job ‘Executir



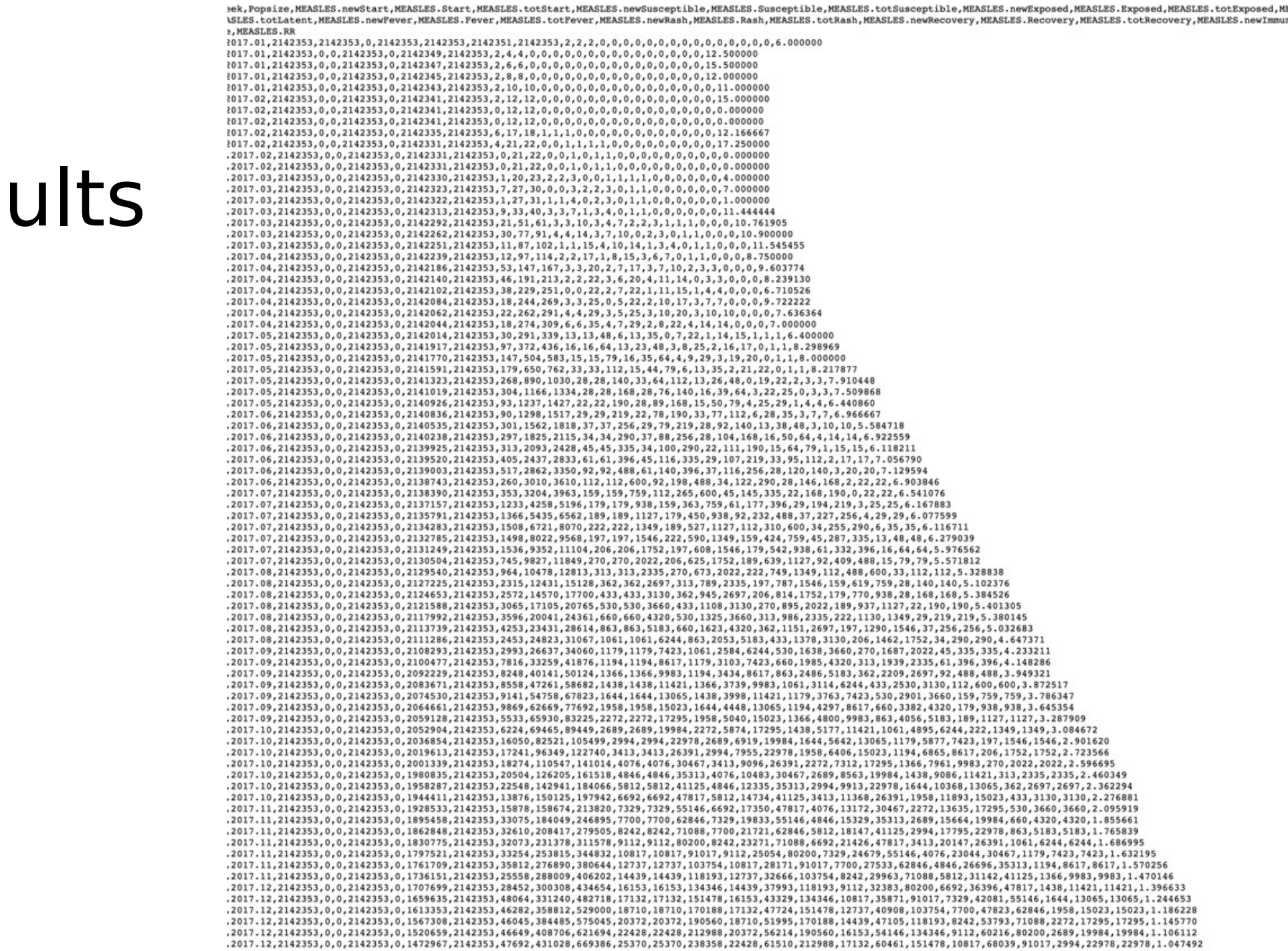
Job ‘Complete



Job Results


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
FRED Job: TestJob1
Description
This page provides details about an individual FRED Job.
The results will be available via a CSV download.
Additionally, basic plots and movies are provided.
Click the "New Job" tab at the top of the page to create a new job.
Job Details
Name
Project
Status
Build
TestJob1
Demo2
completed
4.0.0
Results
Download CSV

CSV Results



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.2017.12,2142353,0,0,2142353,0,1472967,2142353,47692,431028,669386,25370,25370,238358,22428,61510,212988,17132,60461,151478,10817,68039,91017,2994,22978,22978,1.047492
```

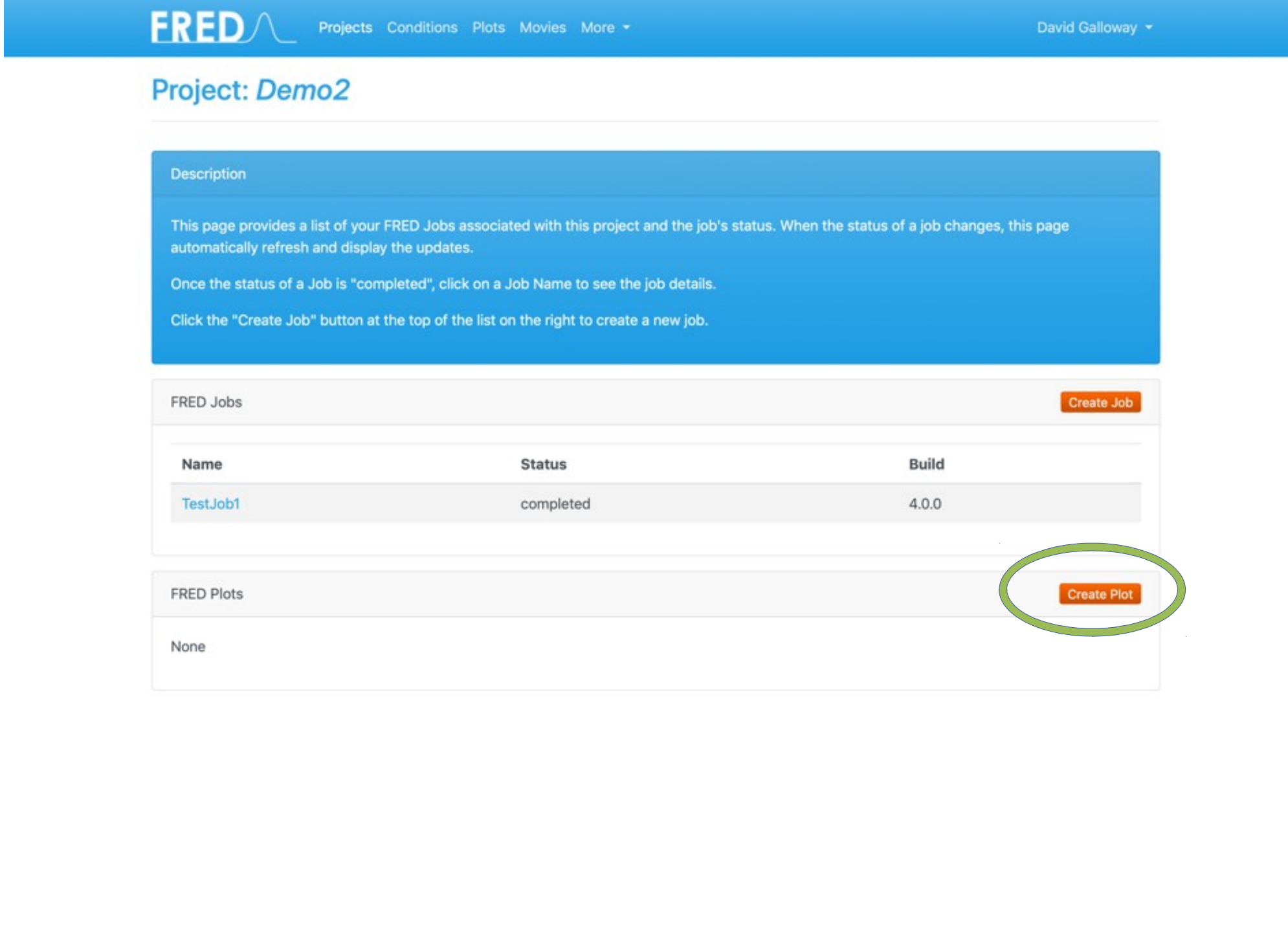
Example

Now we can create a plot

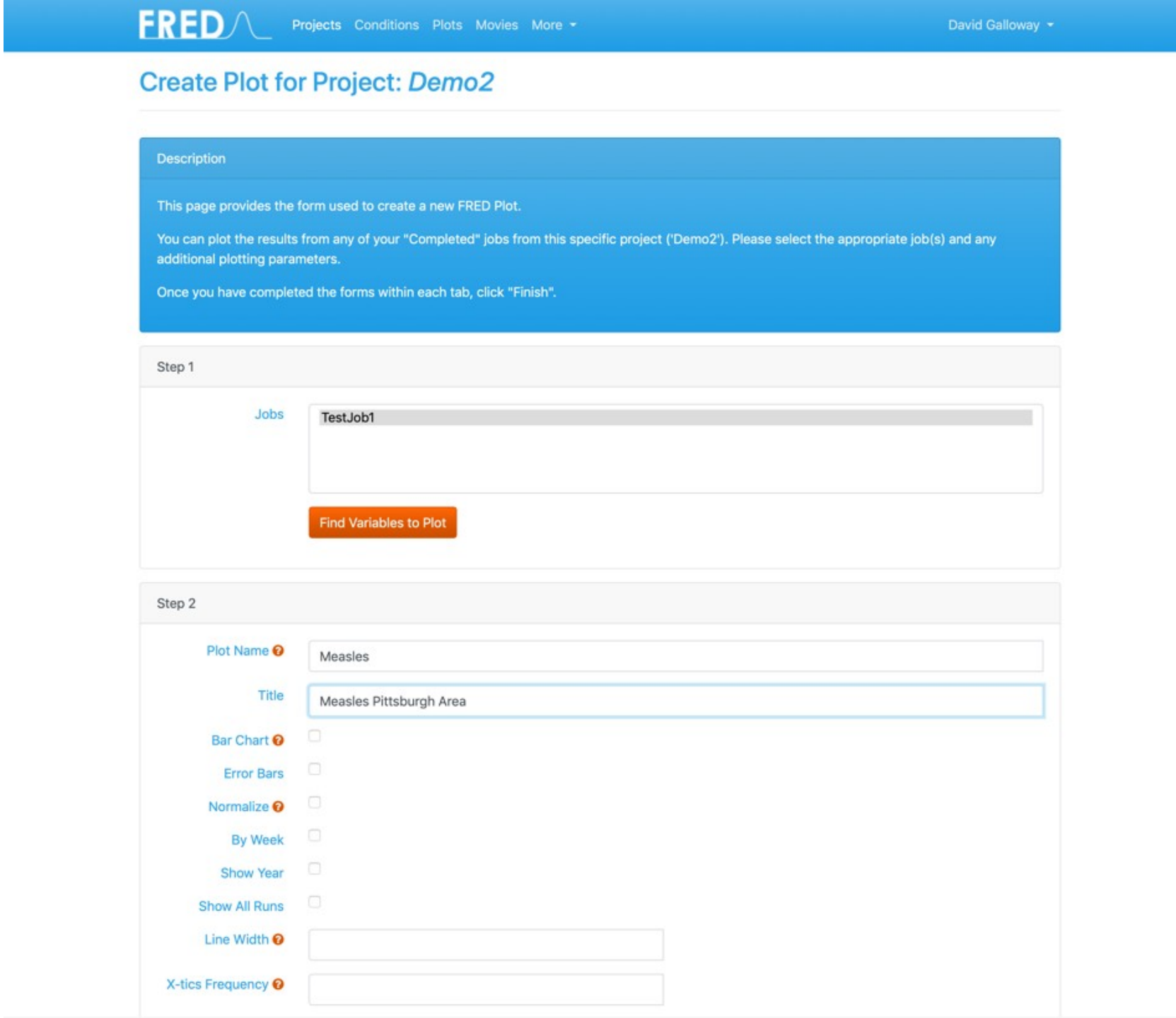
Let’s look at the following states

Susceptible	Exposed	Fever	Rash	Recovery

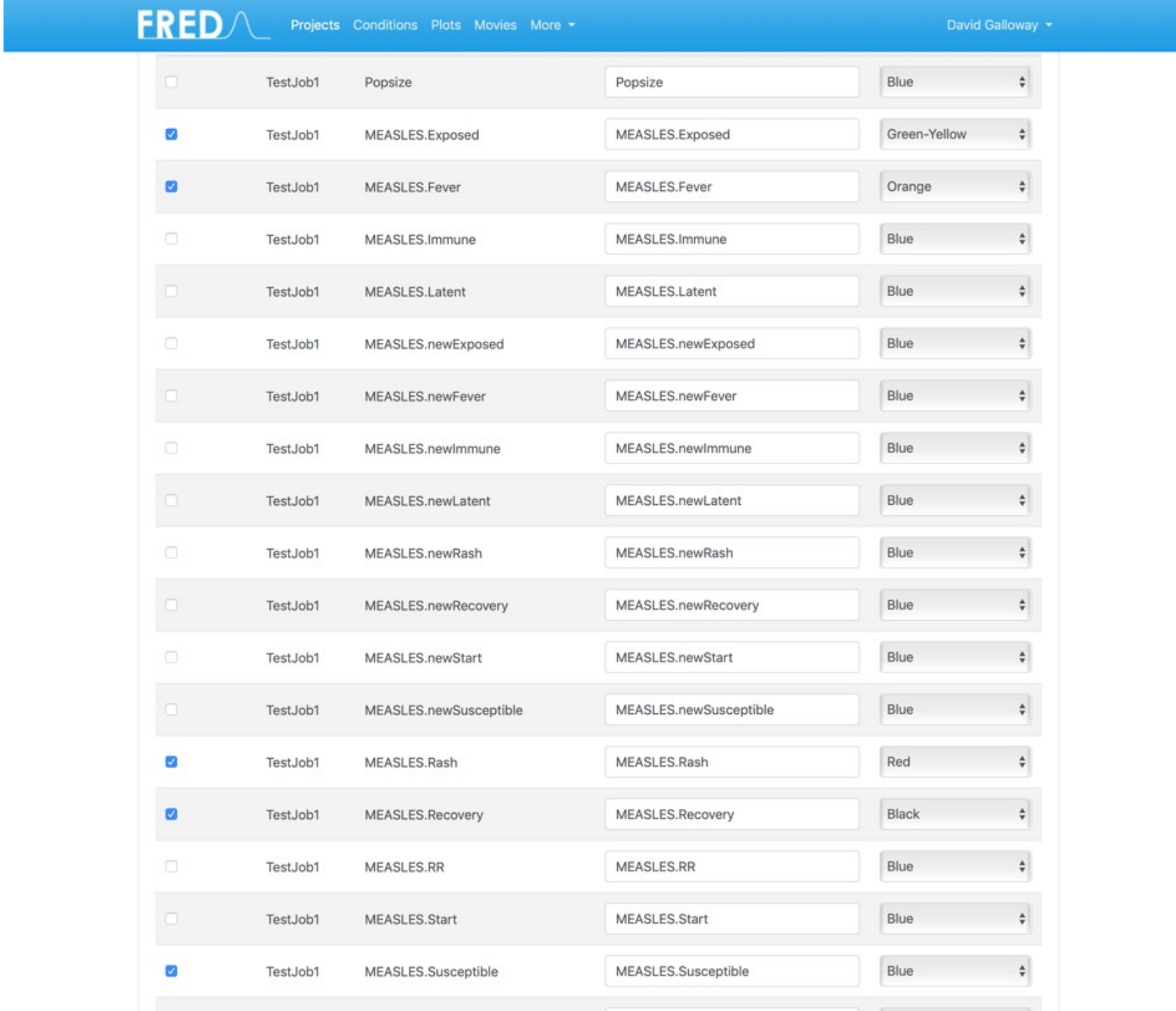
Create Plot


FRED
Projects
Conditions
Plots
Movies
More
David Galloway
Project: Demo2
Description
This page provides a list of your FRED Jobs associated with this project and the job's status. When the status of a job changes, this page automatically refresh and display the updates.
Once the status of a Job is "completed", click on a Job Name to see the job details.
Click the "Create Job" button at the top of the list on the right to create a new job.
FRED Jobs
Create Job
Name
Status
Build
TestJob1
completed
4.0.0
FRED Plots
Create Plot
None

Plot Options



States to plot



Example Plot

FRED Projects Conditions Plots Movies More David Galloway

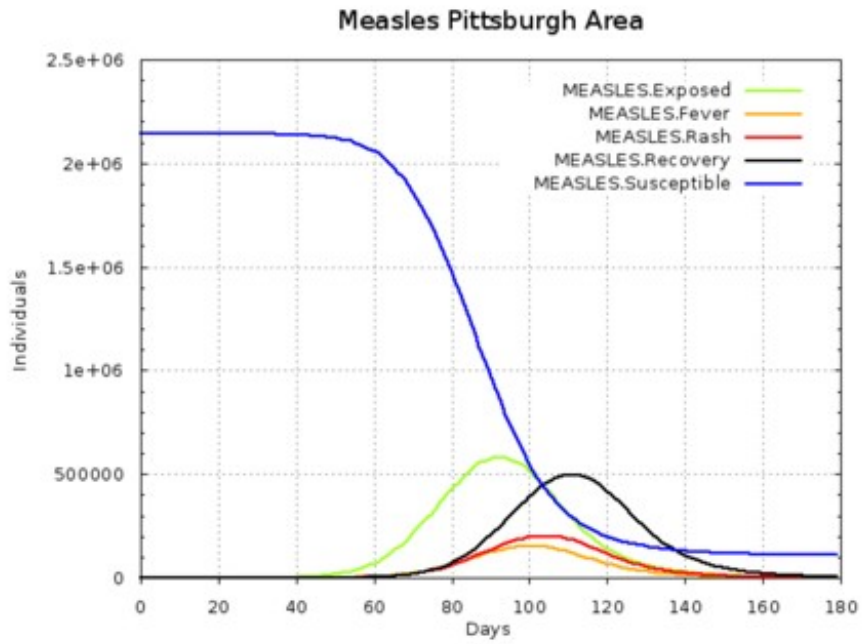
FRED Plot for Project: *Demo2*

Description

This page provides the plot of the results of your previously selected FRED Jobs.

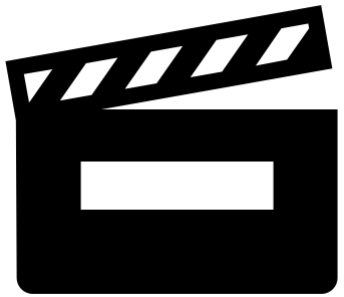
Measles

Back to Project



Example

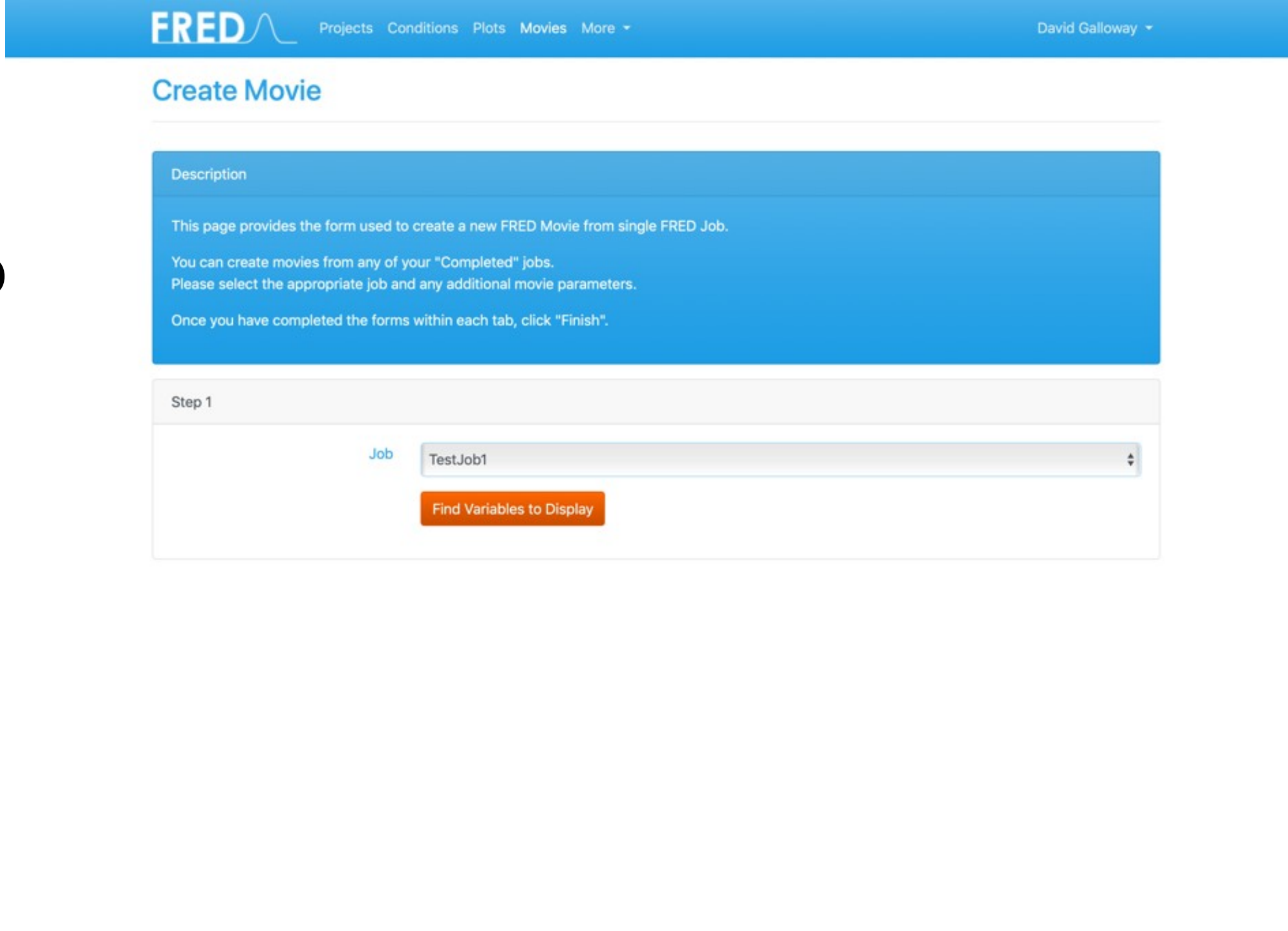
We can also make a movie



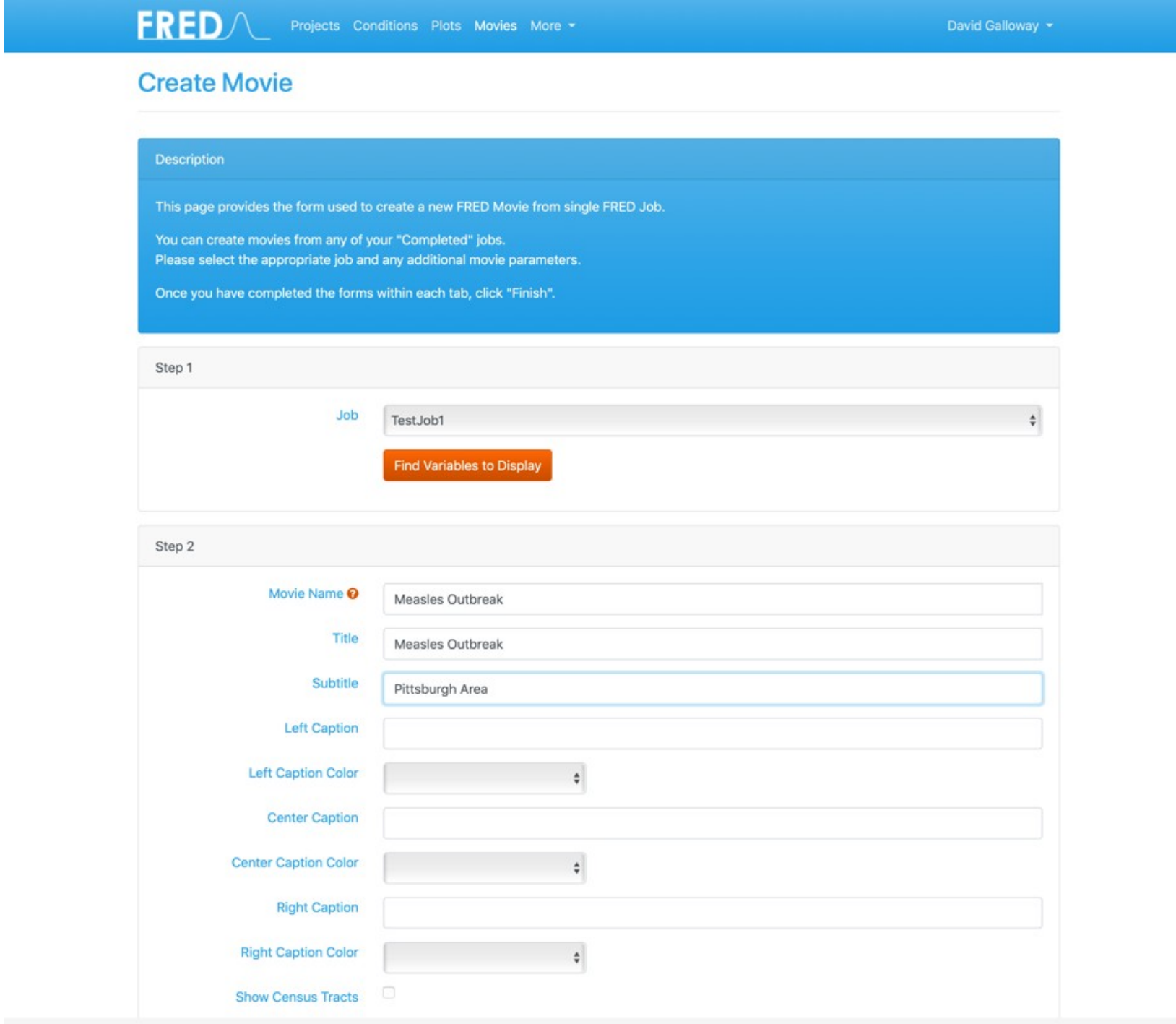
Let’s show the new agents who are in the following states on a given day

Fever	Rash

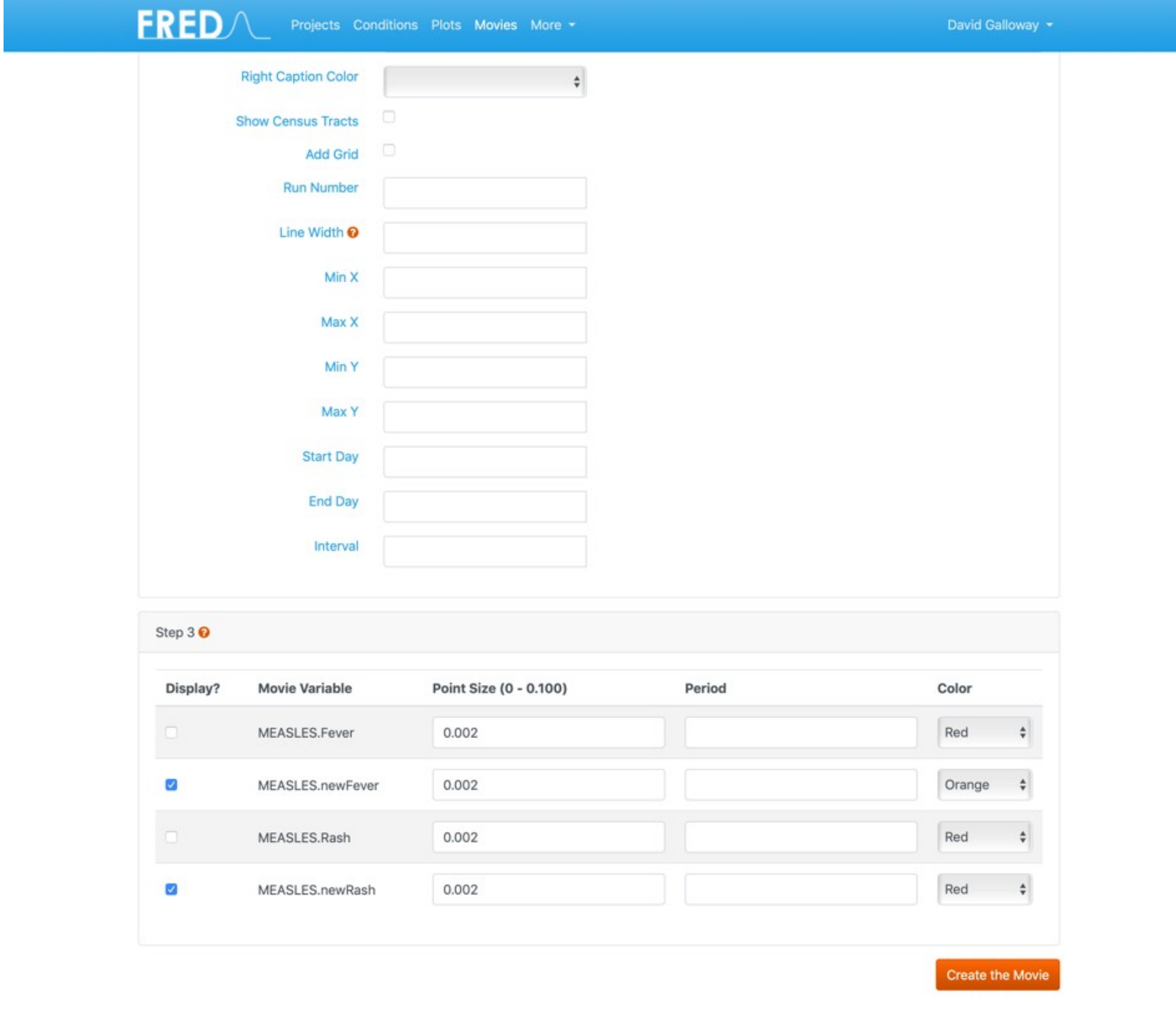
Create Movie: Select Jo



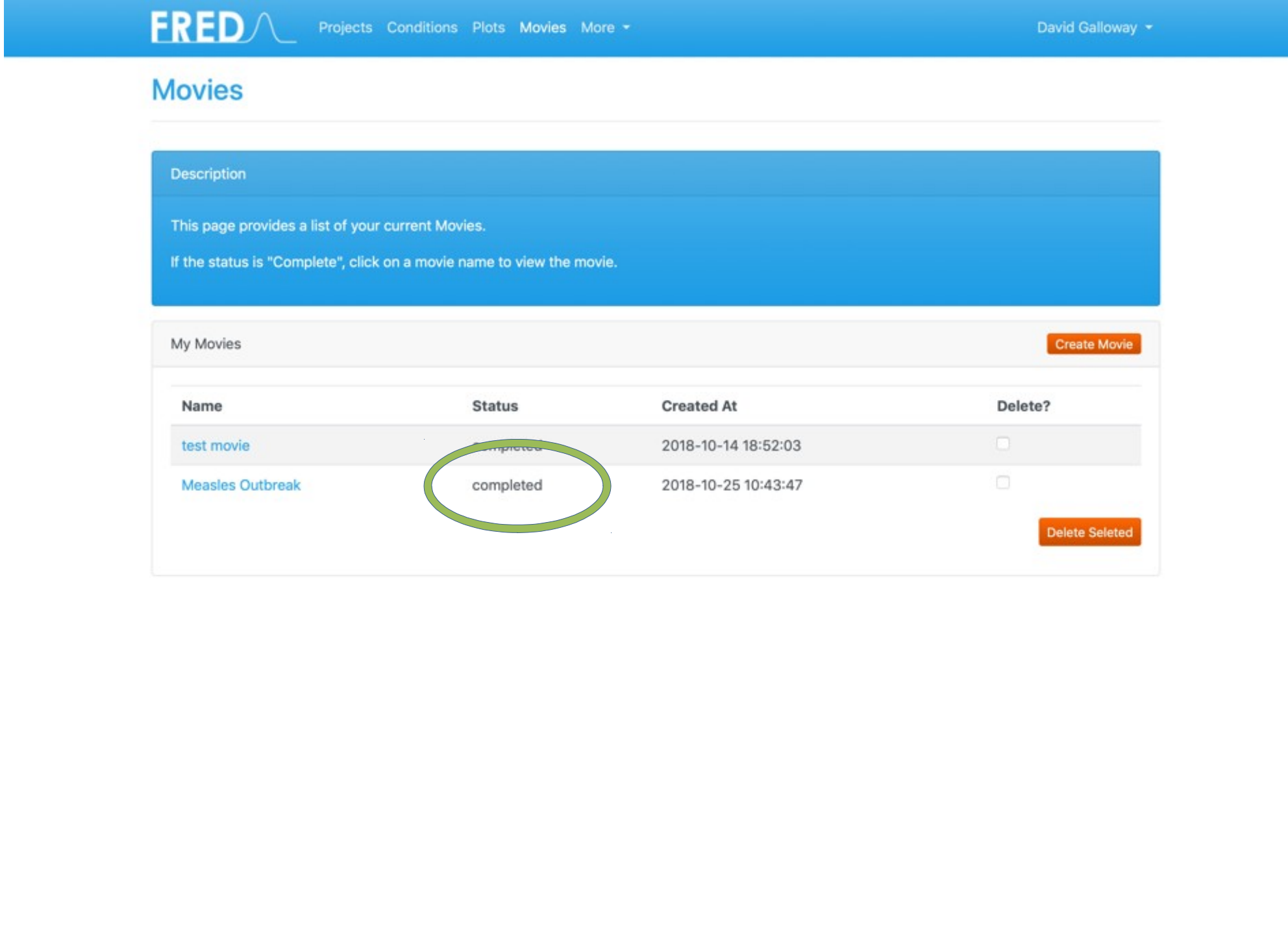
Create Movie: Customise



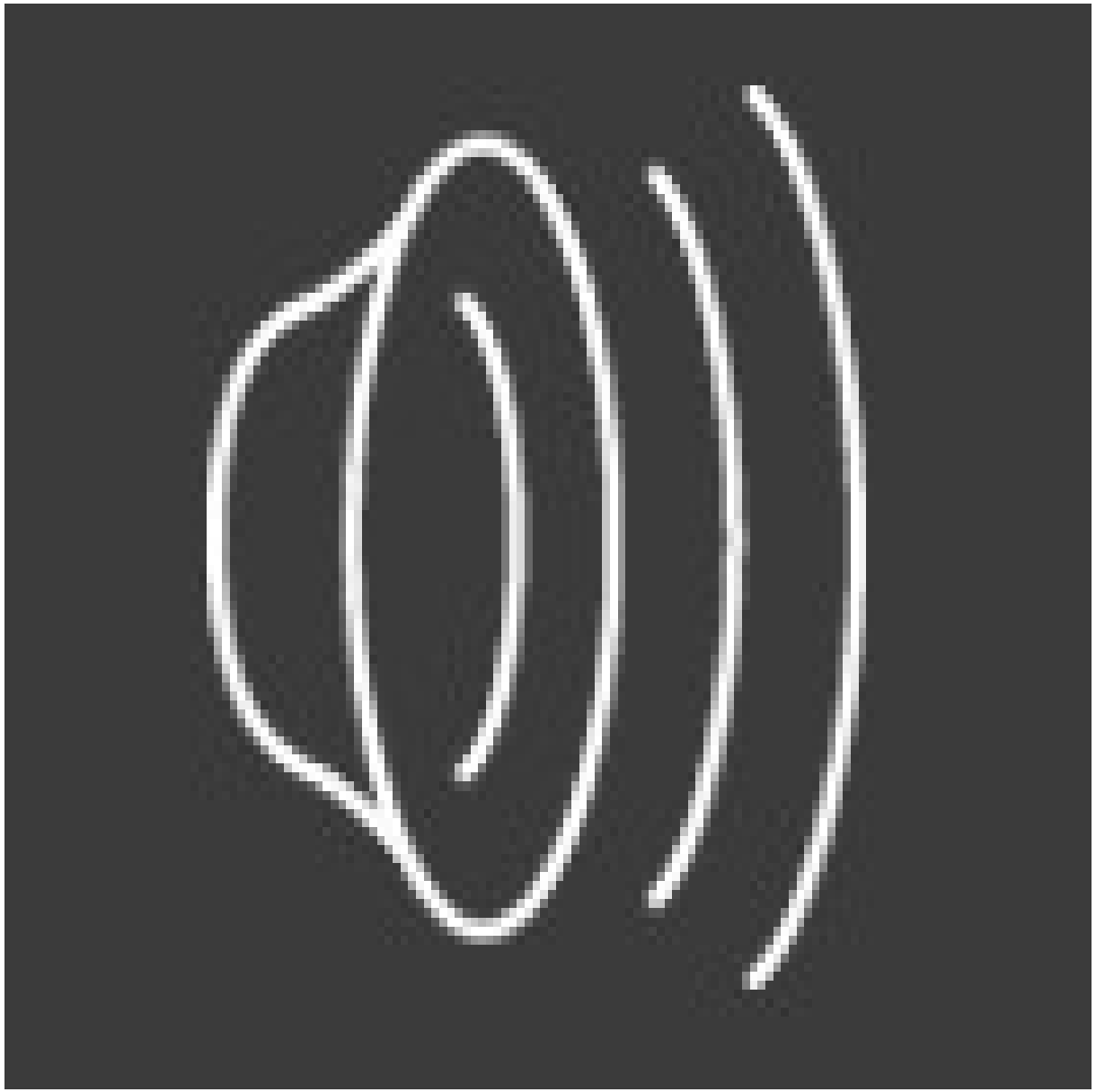
Create Movie: Select State



Create Movie: Wait

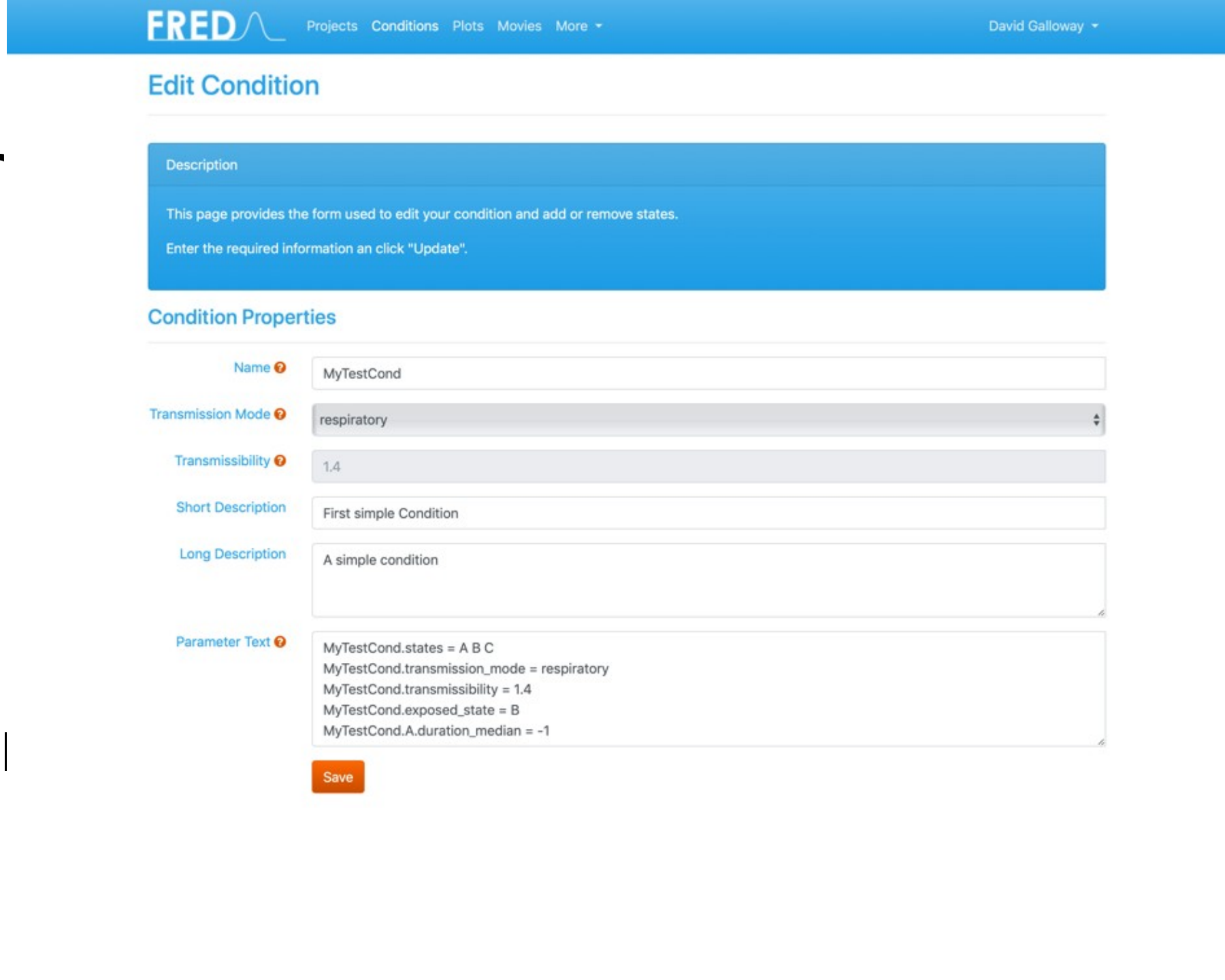


View Movie



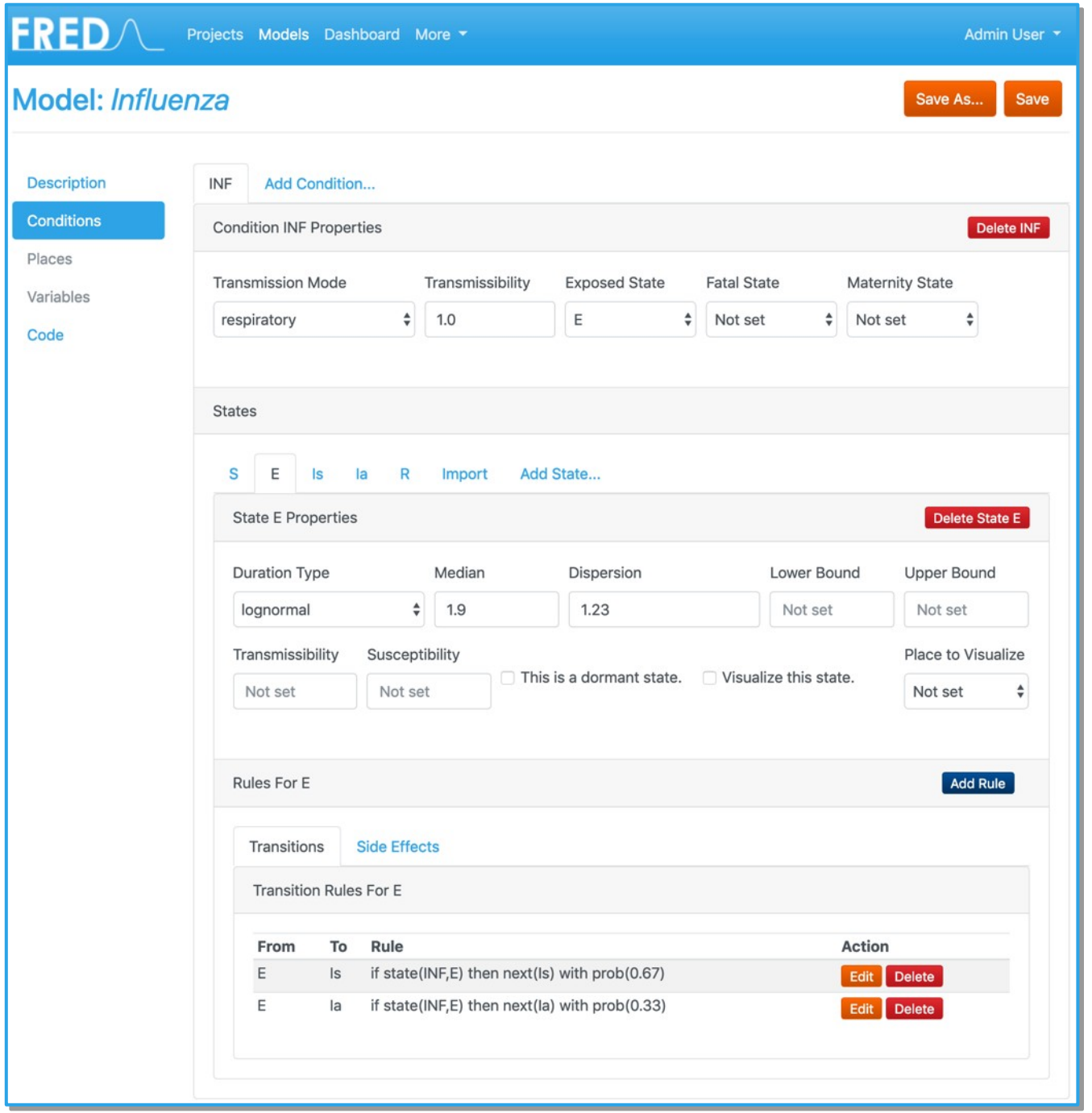
Parameter text box

- Uses FRED programming language
- Allows more flexibility than GUI
- Slightly unstabl



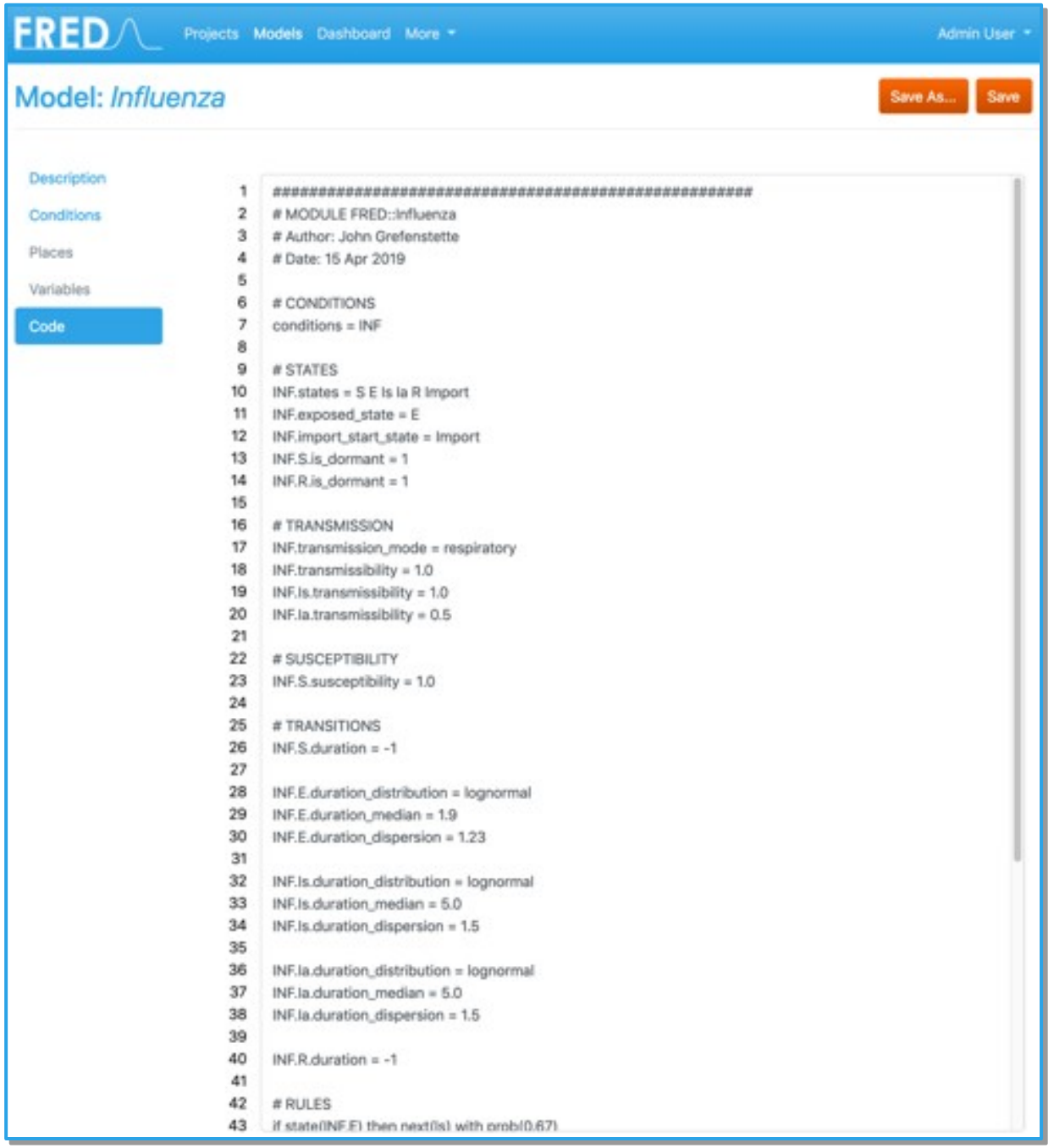
Coming soon:

New interface



Coming soon:

New interface



Summary

FRED IS A PLATFORM FOR DEVELOPING AGENT-BASED MODELS

FRED WEB IS AN ONLINE INTERFACE TO FRED

SIMPLE INTERFACE DESIGNED TO FACILITATE EASY MODEL DEVELOPMENT

INCLUDE ANALYSIS TOOLS: PLOTTING AND ANIMATION

Computer practical

- Website: https://fred.publichealth.pitt.edu
- Open tutorial document: Help → Tutorial
- Please run simulations with small ($\leq 10^6$ people). Telangana will takes hours per simulation.
- Not all options currently functional in movies/plotting customization.
- Ask me for help.
- Work through Tutorial, then make your own model