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Sponsor : International Indian Statistical Association (IISA)
Co- sponsor : Indian Association for Statistics in Clinical Trials (IASCT)

# Tools for Modeling Disease Dynamics

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*VIT UNIVERSITY, VELLORE*

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# Disease Modeling

- Disease models can project how infectious diseases progress to show the likely outcome of an epidemic and help inform public health interventions.
- Models use some basic assumptions and mathematics to find parameters for various infectious diseases and use those parameters to calculate the effects of possible interventions, like mass vaccination programmes.

# Tools for Modeling Disease Dynamics

- FRED (A Framework for Reconstructing Epidemiological Dynamics)
- ArcGIS (Aeronautical Reconnaissance Coverage Geographic Information System)
- MATLAB (Matrix Laboratory)

# About FRED

- FRED (A Framework for Reconstructing Epidemiological Dynamics) is a modeling system that supports research on the dynamics of infectious disease epidemics and the interacting effects of mitigation strategies, viral evolution, and personal health behavior.
- FRED was designed as a flexible, modular, open source framework for epidemic modeling, rather than a model of a particular infectious disease.

# Key features of FRED

- Highly modular, object-oriented software design
- Realistic synthetic populations
- Scalable and efficient simulation of large epidemics
- Flexible ways to specify agent health behavior and decision rules

# Synthetic Population

- FRED explicitly represents every individual in a specific geographic region. Each agent has a set of socio-demographic characteristics and daily behaviors that include age, sex, employment status, occupation, and household location and membership in a set of social contact networks.

# FRED: Framework for Reconstructing Epidemic Dynamics

Population

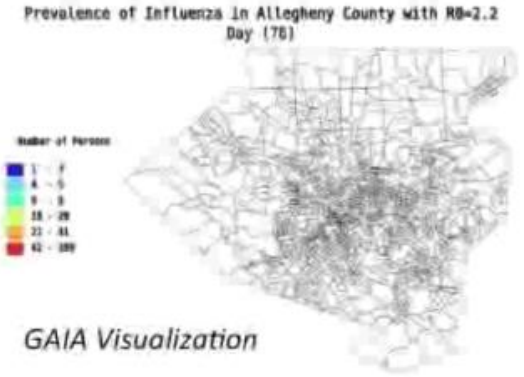
Behavior

Simulation Engine

Disease

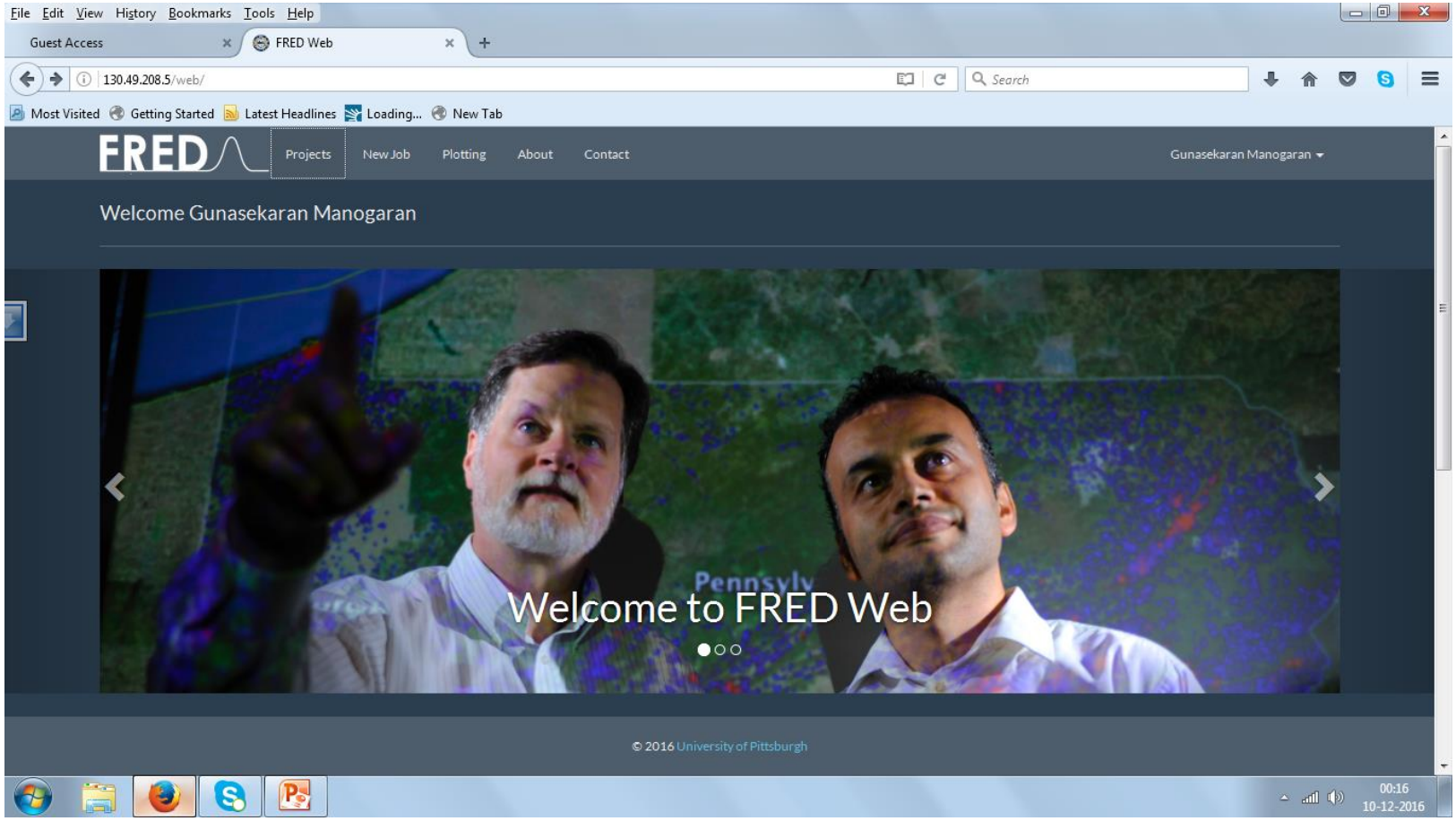
Interventions

- Agent-based epidemic modeling system using census-based population models
- User settable parameters specify infectiousness of epidemic, control measures and human behaviors
- Simulation available for every county in the U.S.




*GAIA Visualization*

# FRED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Welcome Gunasekaran Manogaran
Welcome to FRED Web
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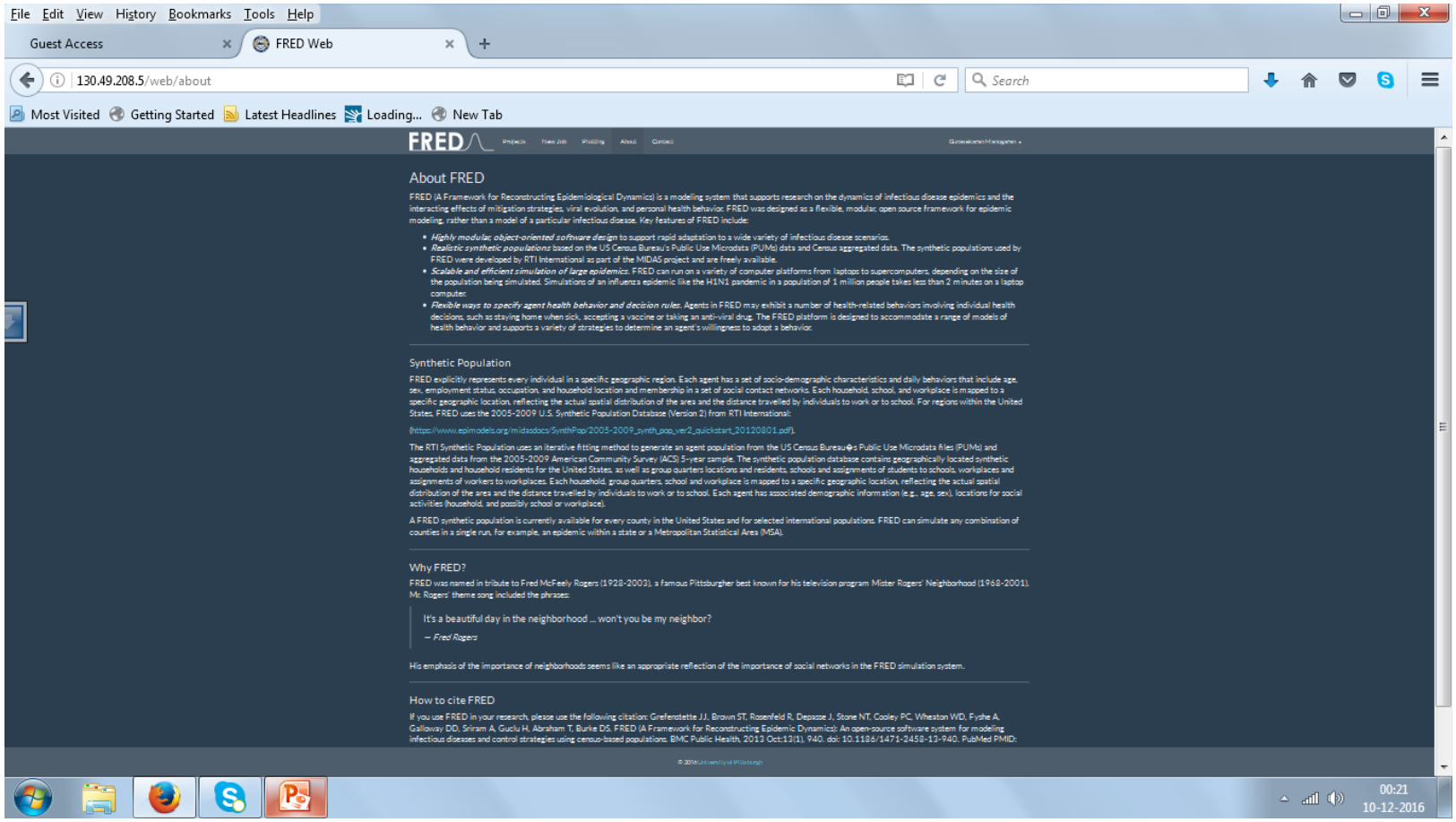
# FRED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FRED
About FRED
FRED (A Framework for Reconstructing Epidemiological Dynamics) is a modeling system that supports research on the dynamics of infectious disease epidemics and the interacting effects of mitigation strategies, viral evolution, and personal health behavior. FRED was designed as a flexible, modular, open source framework for epidemic modeling, rather than a model of a particular infectious disease. Key features of FRED include:
Highly modular, object-oriented software design to support rapid adaptation to a wide variety of infectious disease scenarios.
Realistic synthetic populations based on the US Census Bureau's Public Use Microdata (PUMs) data and Census aggregated data. The synthetic populations used by FRED were developed by RTI International as part of the MIDAS project and are freely available.
Scalable and efficient simulation of large epidemics. FRED can run on a variety of computer platforms from laptops to supercomputers, depending on the size of the population being simulated. Simulations of an influenza epidemic like the H1N1 pandemic in a population of 1 million people takes less than 2 minutes on a laptop computer.
Flexible ways to specify agent health behavior and decision rules. Agents in FRED may exhibit a number of health-related behaviors involving individual health decisions, such as staying home when sick, accepting a vaccine or taking an anti-viral drug. The FRED platform is designed to accommodate a range of models of health behavior and supports a variety of strategies to determine an agent's willingness to adopt a behavior.
Synthetic Population
FRED explicitly represents every individual in a specific geographic region. Each agent has a set of socio-demographic characteristics and daily behaviors that include age, sex, employment status, occupation, and household location and membership in a set of social contact networks. Each household, school, and workplace is mapped to a specific geographic location, reflecting the actual spatial distribution of the area and the distance travelled by individuals to work or to school. For regions within the United States, FRED uses the 2005-2009 U.S. Synthetic Population Database (Version 2) from RTI International:
(https://www.epimodels.org/midsdocs/SynthPop/2005-2009_synth_pop_ver2_quickstart_20120801.pdf).
The RTI Synthetic Population uses an iterative fitting method to generate an agent population from the US Census Bureau's Public Use Microdata files (PUMs) and aggregated data from the 2005-2009 American Community Survey (ACS) 5-year sample. The synthetic population database contains geographically located synthetic households and household residents for the United States, as well as group quarters locations and residents, schools and assignments of students to schools, workplaces and assignments of workers to workplaces. Each household, group quarters, school and workplace is mapped to a specific geographic location, reflecting the actual spatial distribution of the area and the distance travelled by individuals to work or to school. Each agent has associated demographic information (e.g., age, sex), locations for social activities (household, and possibly school or workplace).
A FRED synthetic population is currently available for every county in the United States and for selected international populations. FRED can simulate any combination of counties in a single run, for example, an epidemic within a state or a Metropolitan Statistical Area (MSA).
Why FRED?
FRED was named in tribute to Fred McFeely Rogers (1928-2003), a famous Pittsburgher best known for his television program 'Mister Rogers' Neighborhood (1968-2001). Mr. Rogers' theme song included the phrases:
It's a beautiful day in the neighborhood ... won't you be my neighbor?
— Fred Rogers
His emphasis of the importance of neighborhoods seems like an appropriate reflection of the importance of social networks in the FRED simulation system.
How to cite FRED
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:
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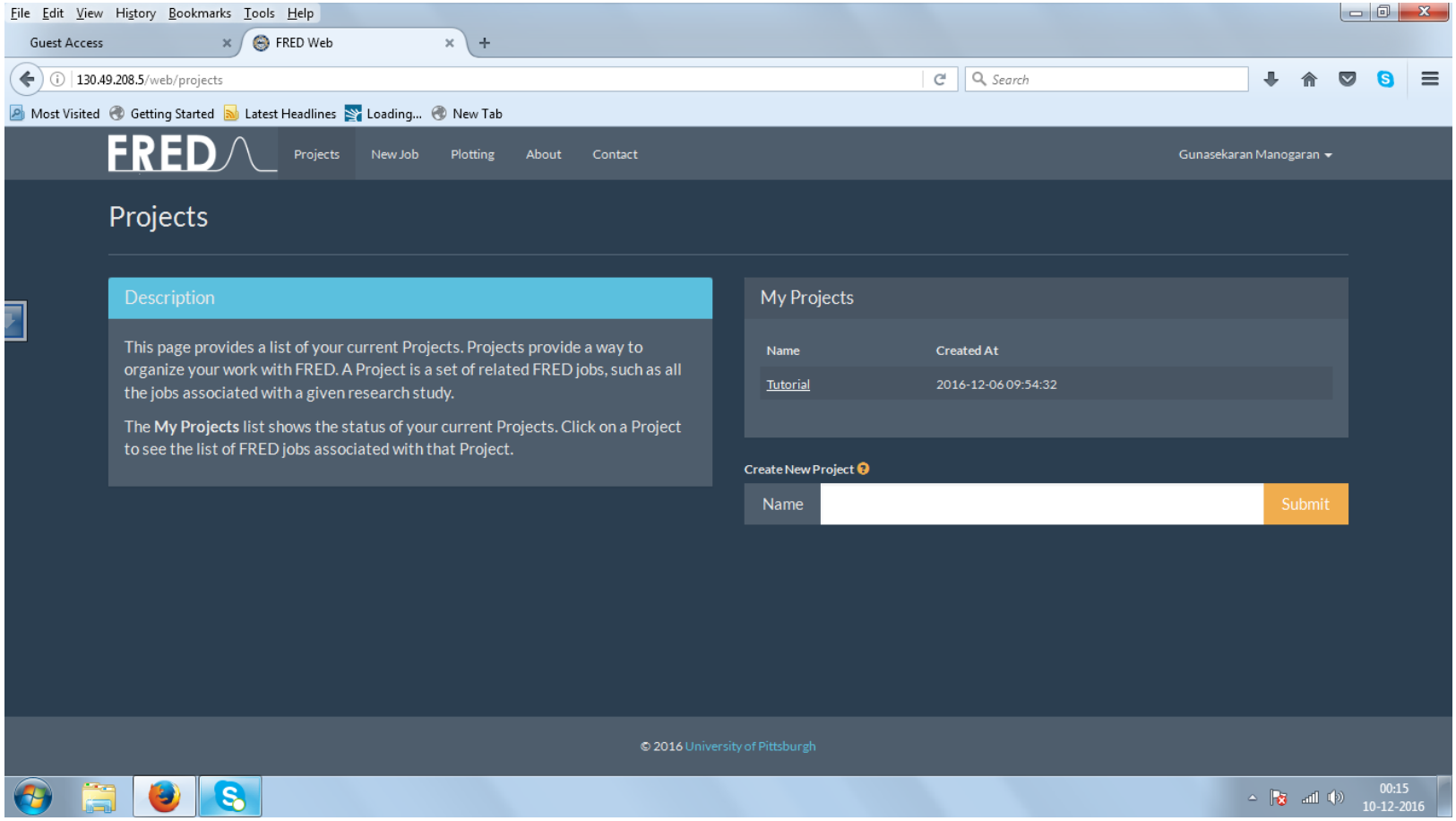
10-12-2016

# FRED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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
Tutorial
2016-12-06 09:54:32
Create New Project
Name
Submit
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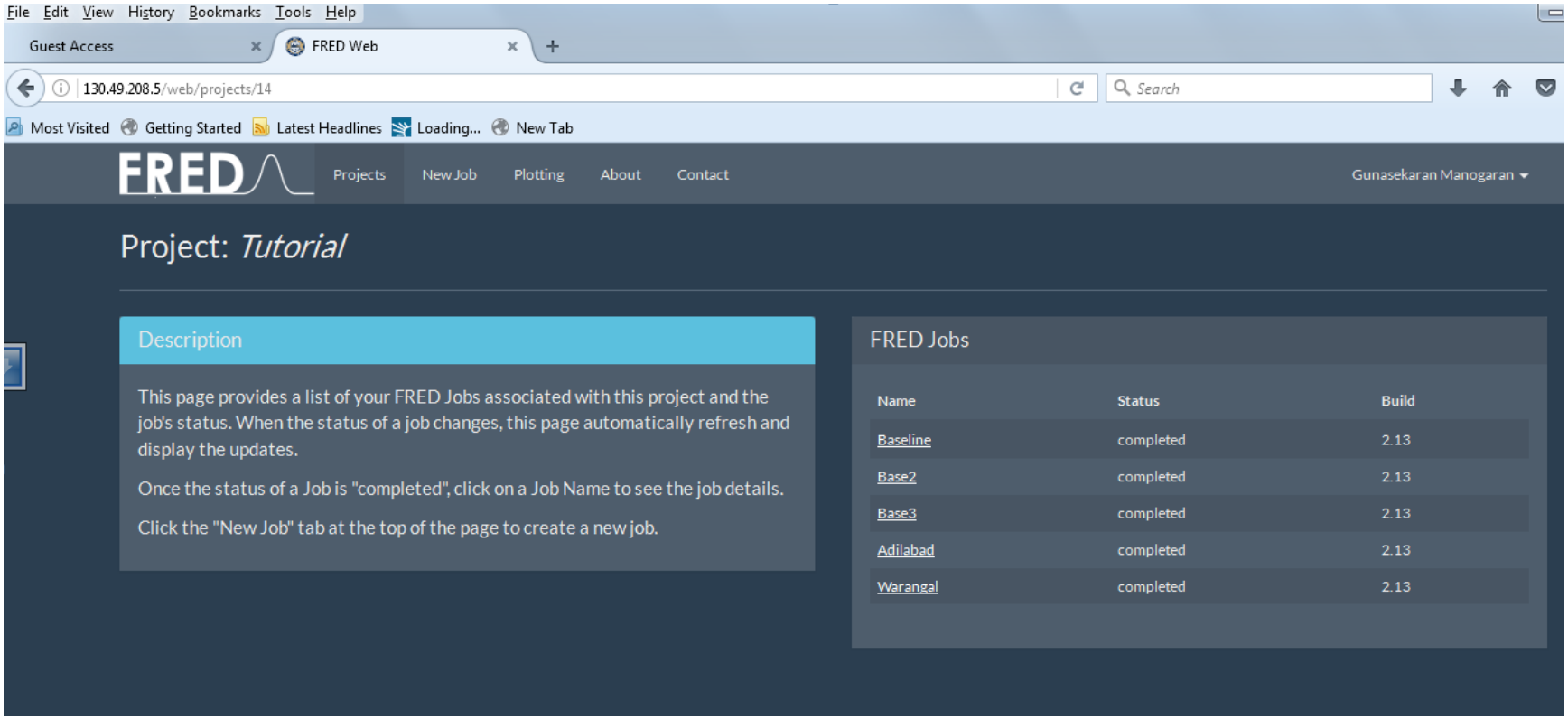
10-12-2016

# FRED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Search
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Project: Tutorial
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 "New Job" tab at the top of the page to create a new job.
FRED Jobs
Name
Status
Build
Baseline
completed
2.13
Base2
completed
2.13
Base3
completed
2.13
Adilabad
completed
2.13
Warangal
completed
2.13

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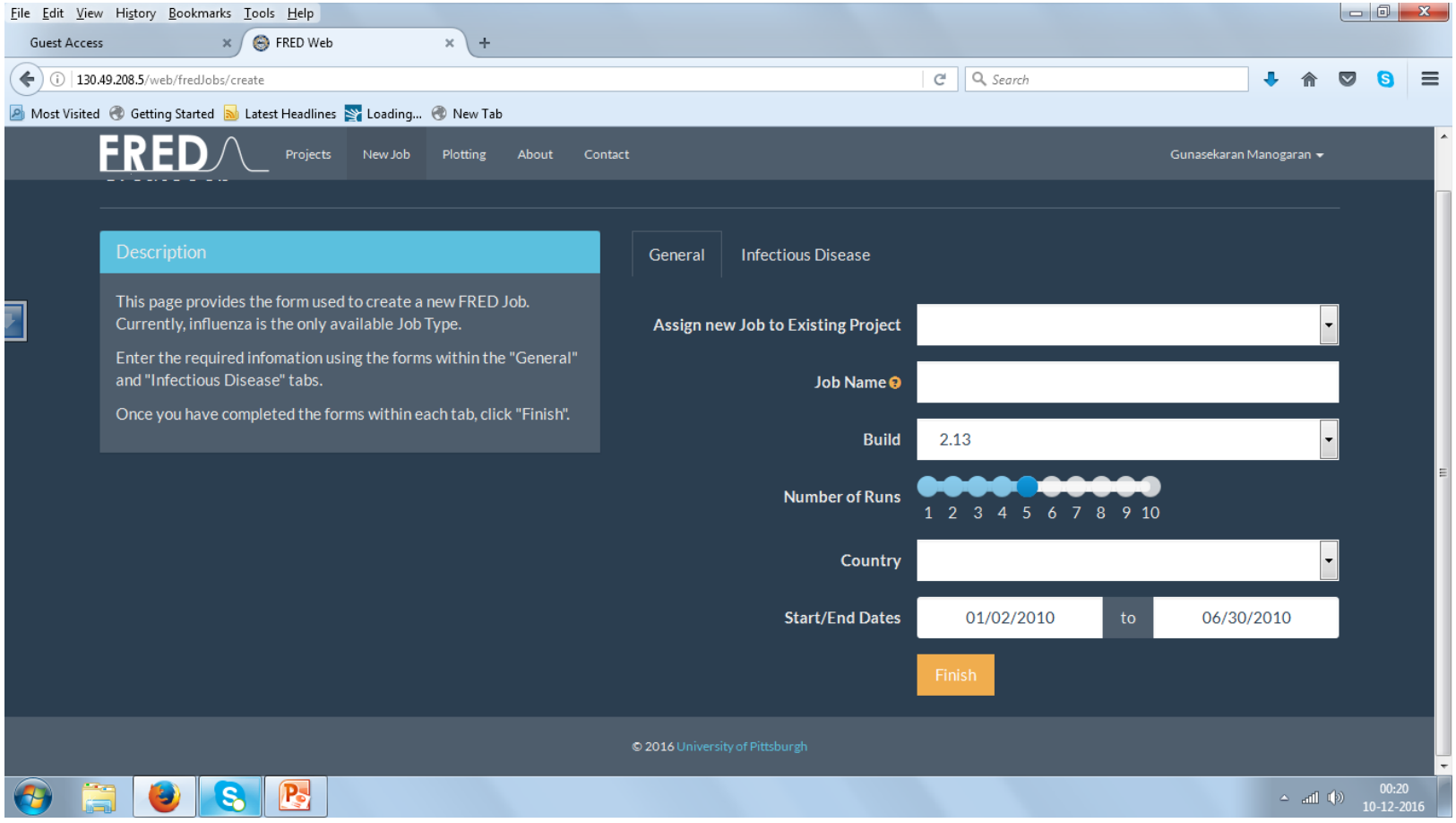
File Edit View History Bookmarks Tools Help
Guest Access
FRED Web
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Search
Most Visited
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Latest Headlines
Loading...
New Tab
FRED
Projects
New Job
Plotting
About
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Description
This page provides the form used to create a new FRED Job. Currently, influenza is the only available Job Type.
Enter the required infomation using the forms within the "General" and "Infectious Disease" tabs.
Once you have completed the forms within each tab, click "Finish".
General
Infectious Disease
Assign new Job to Existing Project
Job Name
Build
2.13
Number of Runs
1 2 3 4 5 6 7 8 9 10
Country
Start/End Dates
01/02/2010
to
06/30/2010
Finish
© 2016 University of Pittsburgh
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10-12-2016

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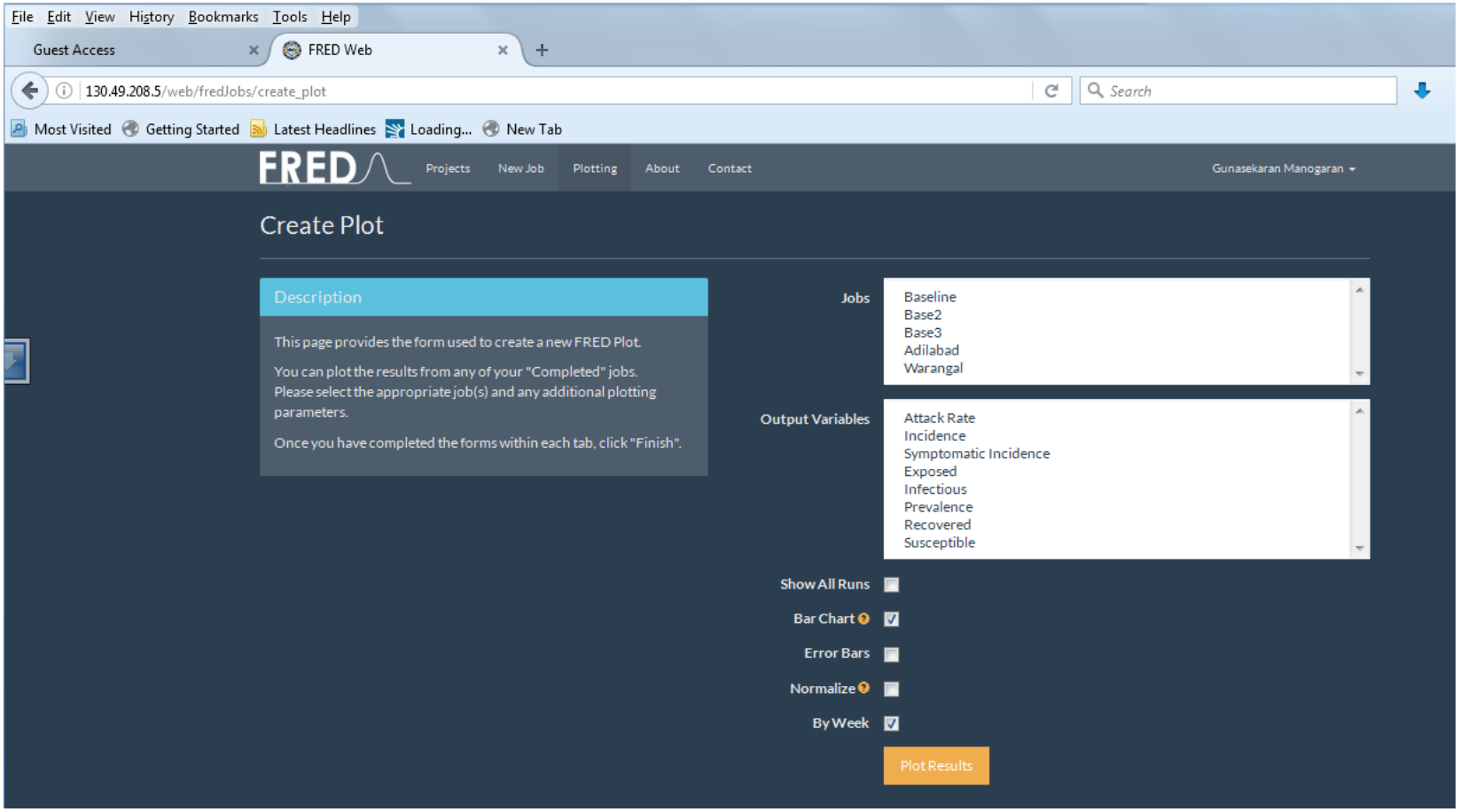
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Search
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New Tab
FRED
Projects
New Job
Plotting
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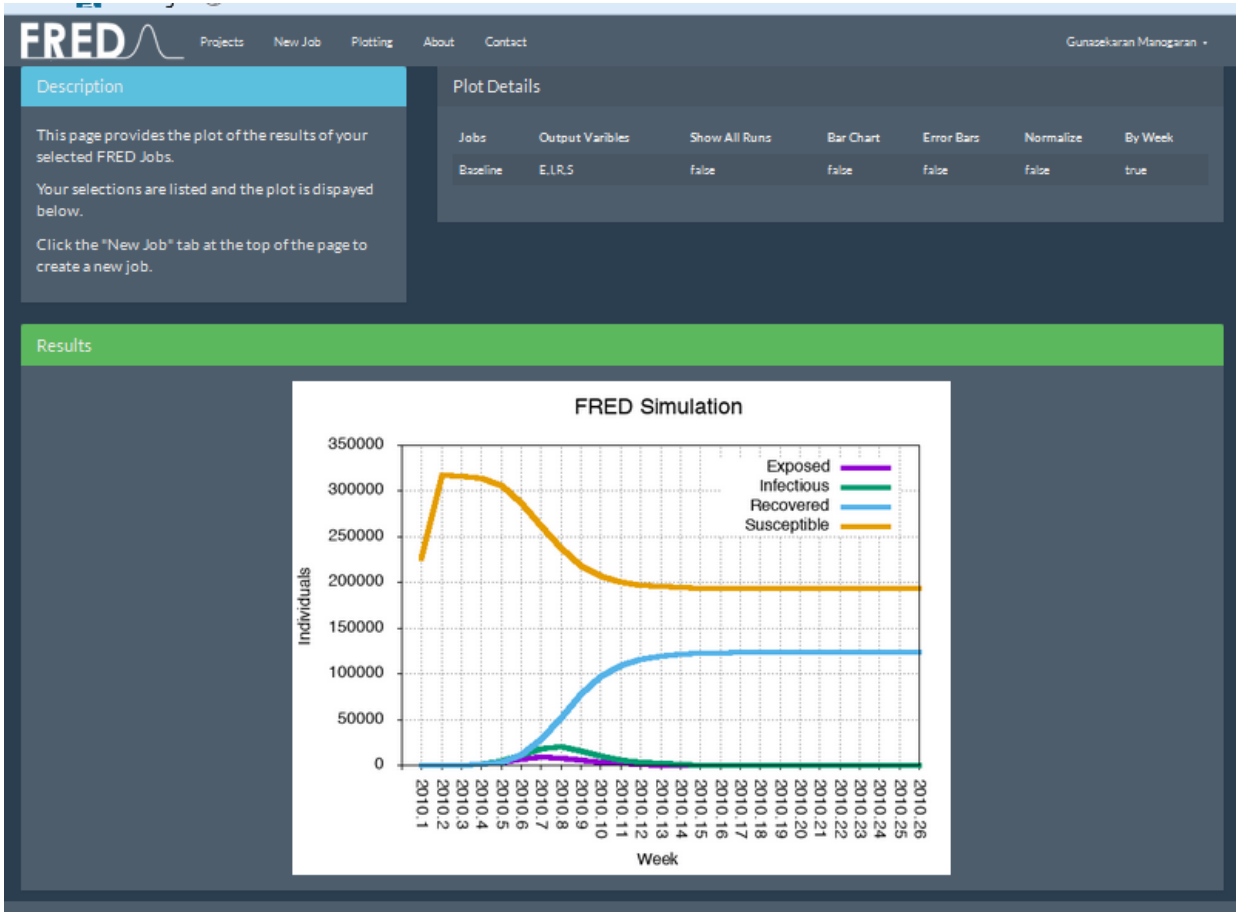
Create Plot
Description
This page provides the form used to create a new FRED Plot.
You can plot the results from any of your "Completed" jobs. Please select the appropriate job(s) and any additional plotting parameters.
Once you have completed the forms within each tab, click "Finish".
Jobs
Baseline
Base2
Base3
Adilabad
Warangal
Output Variables
Attack Rate
Incidence
Symptomatic Incidence
Exposed
Infectious
Prevalence
Recovered
Susceptible
Show All Runs
Bar Chart
Error Bars
Normalize
By Week
Plot Results

# FRED SIMULATION

# FRED SIMULATION



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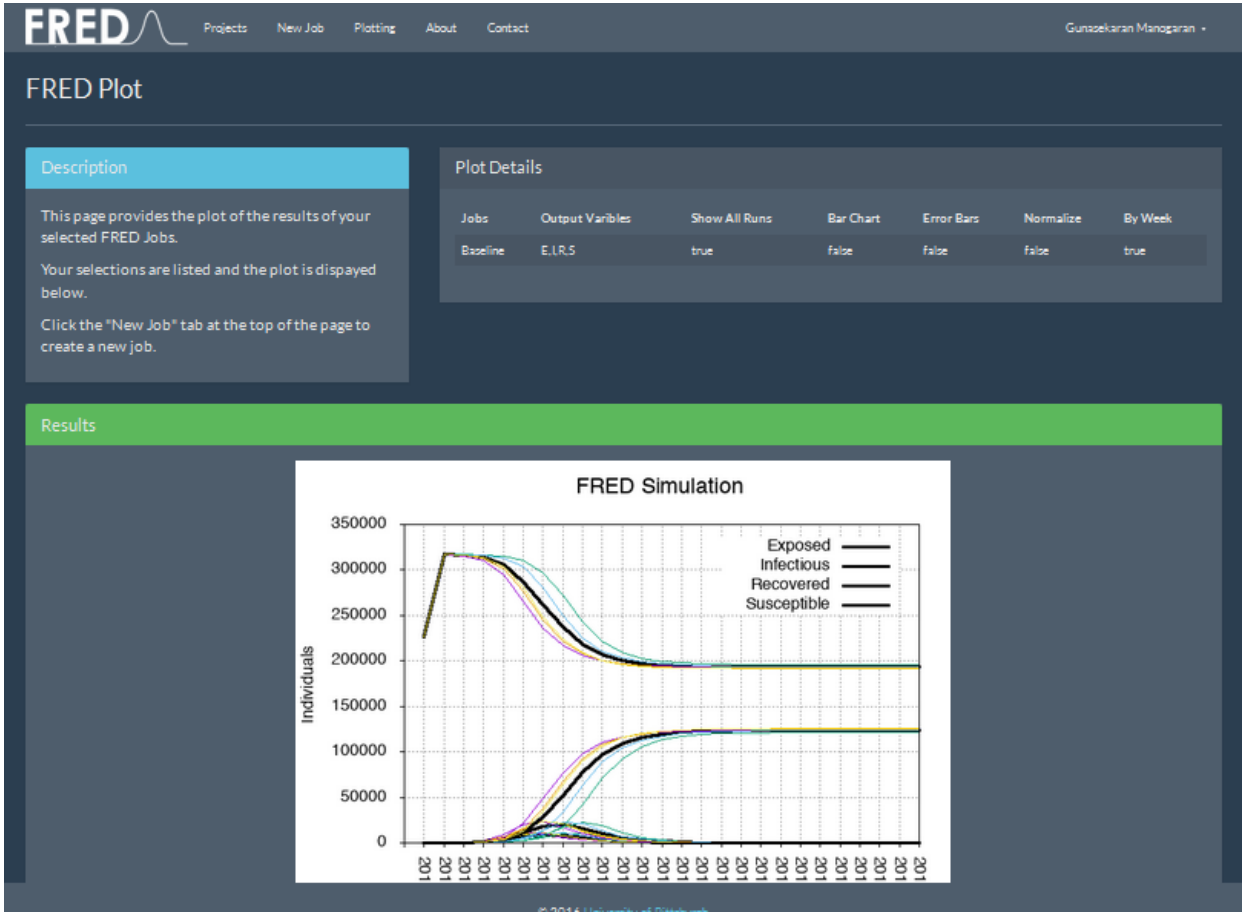

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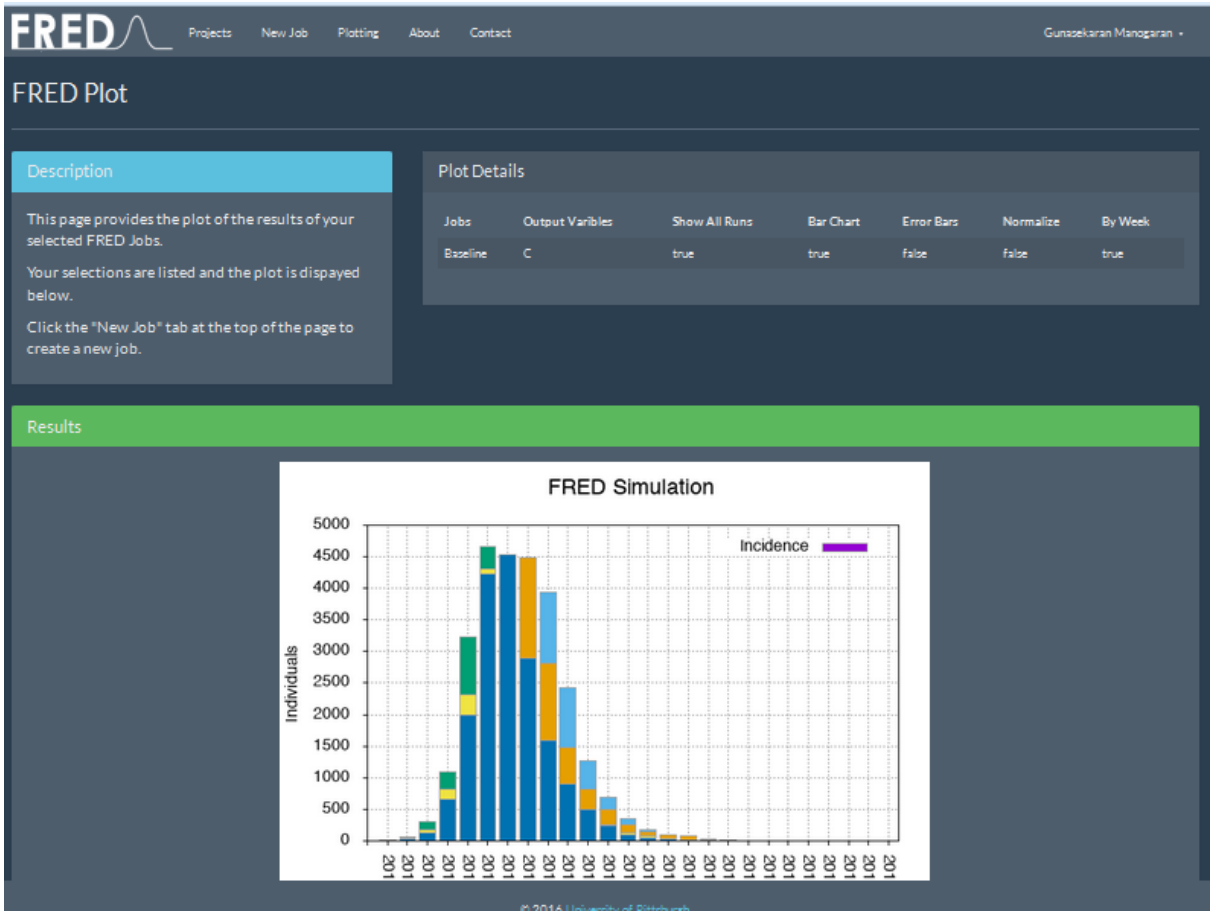

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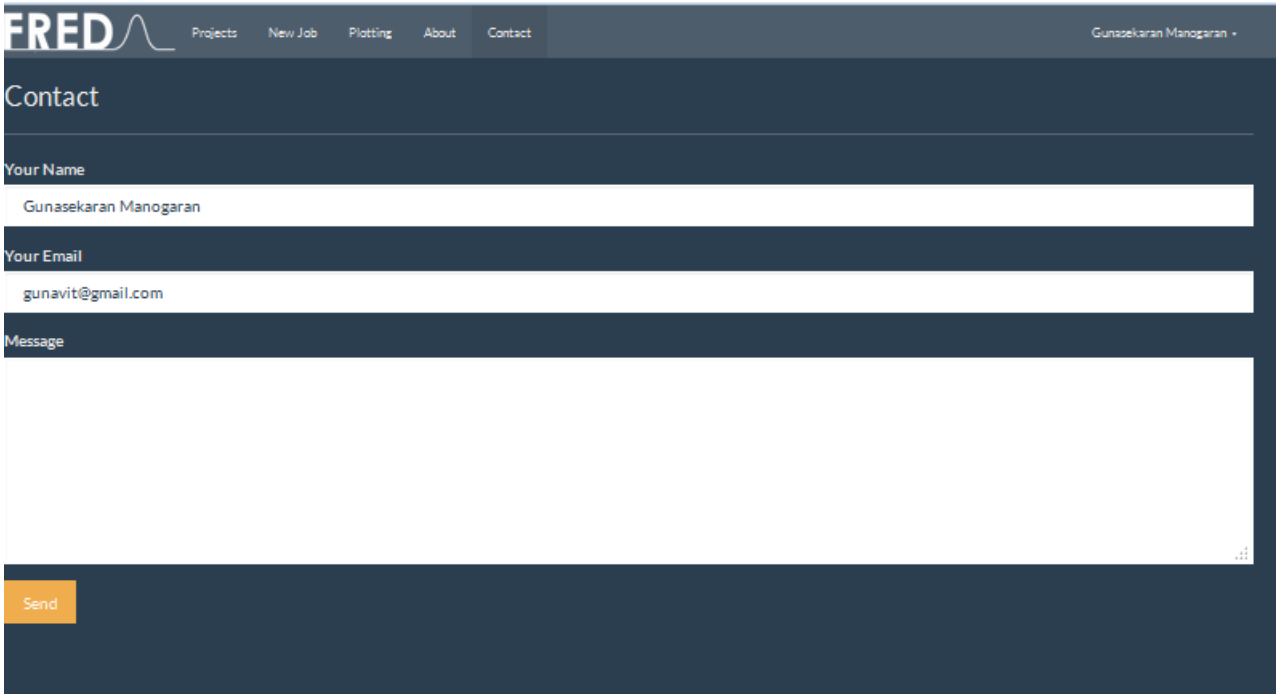

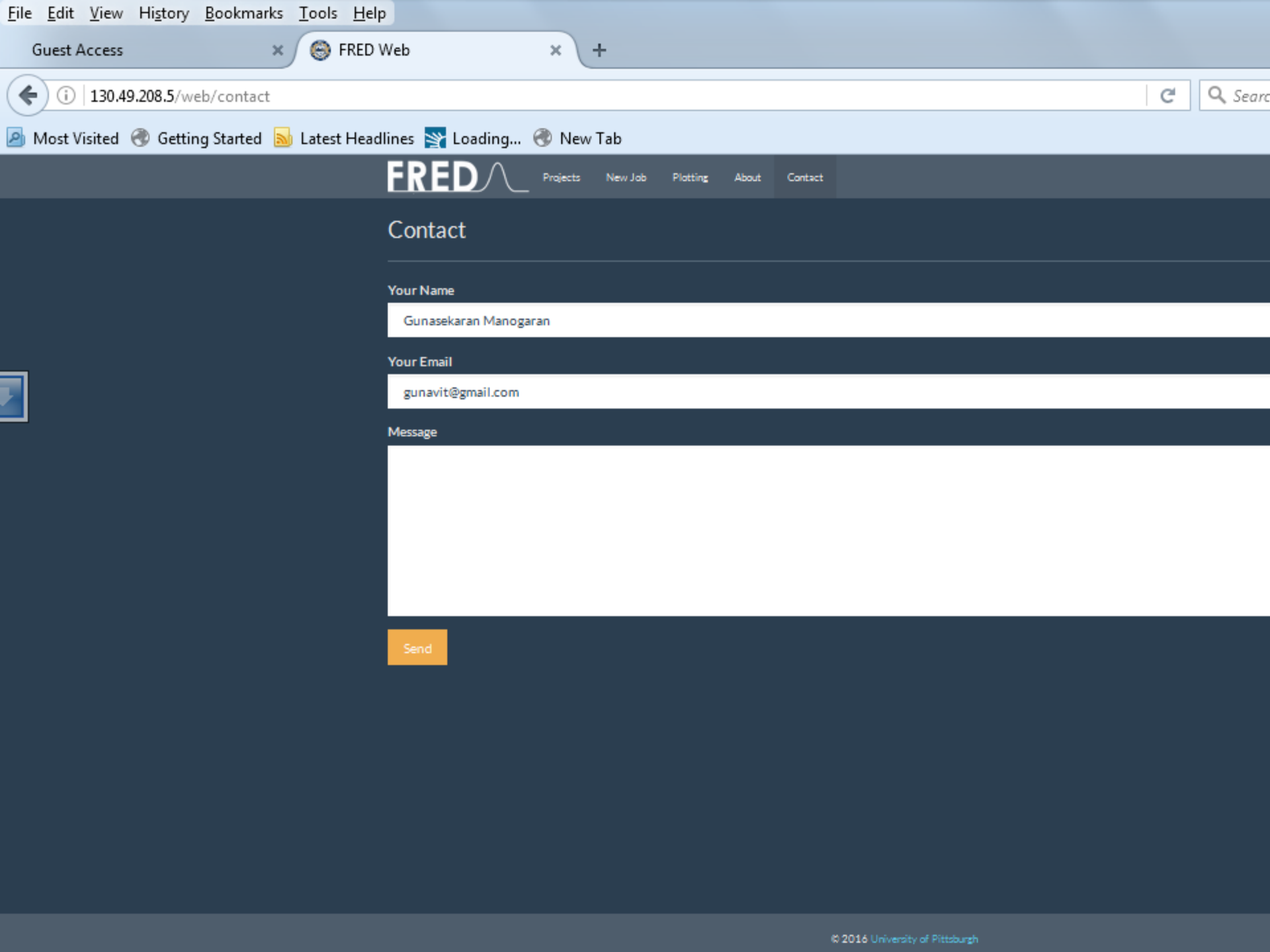
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130.49.208.5/web/contact
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FRED
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Contact
Contact
Your Name
Gunasekaran Manogaran
Your Email
gunavit@gmail.com
Message
Send
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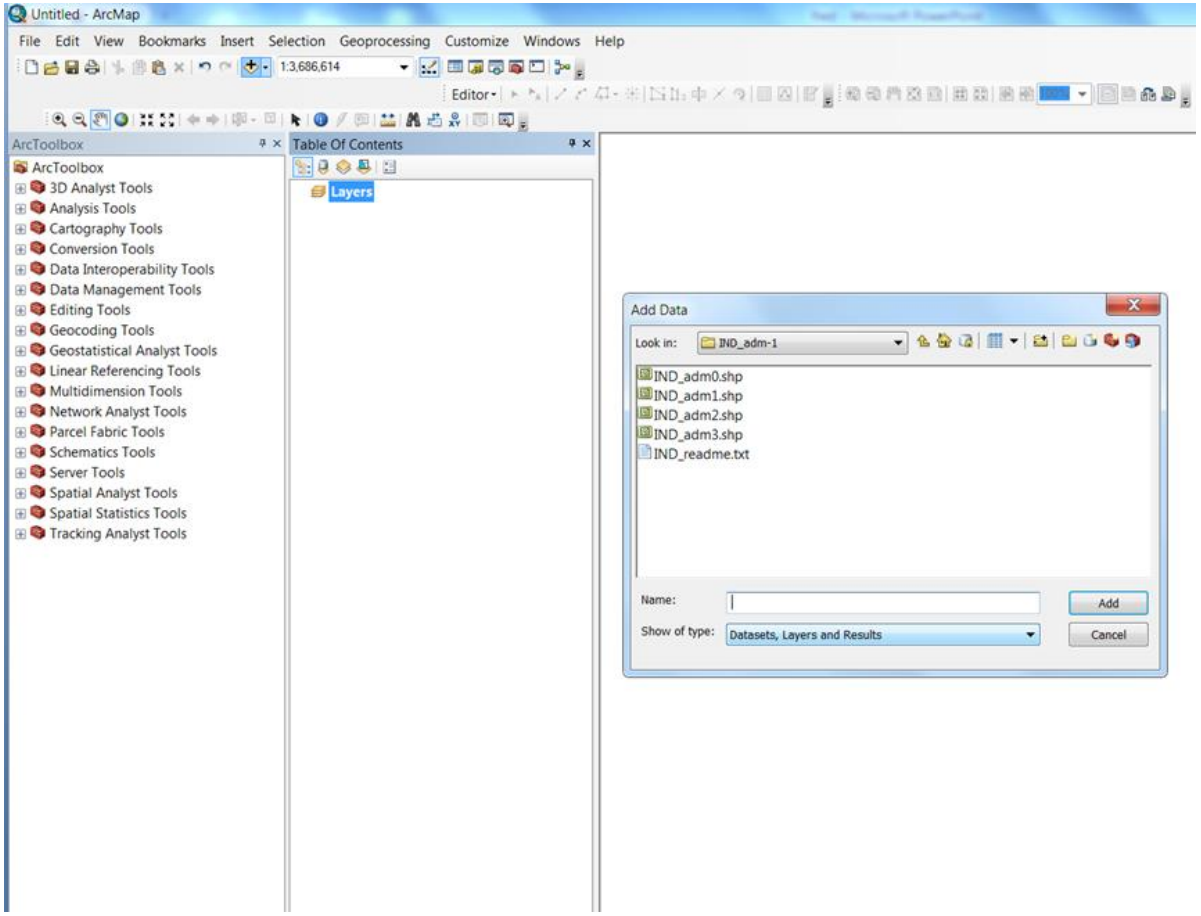
# Spatial Epidemic Modeling in ArcGIS

# Spatial Modeling of Diseases in ArcGIS Software

ArcGIS for Desktop allows you to analyze your data and author geographic knowledge to examine relationships, test predictions, and ultimately make better decisions.

# ArcGIS Simulation



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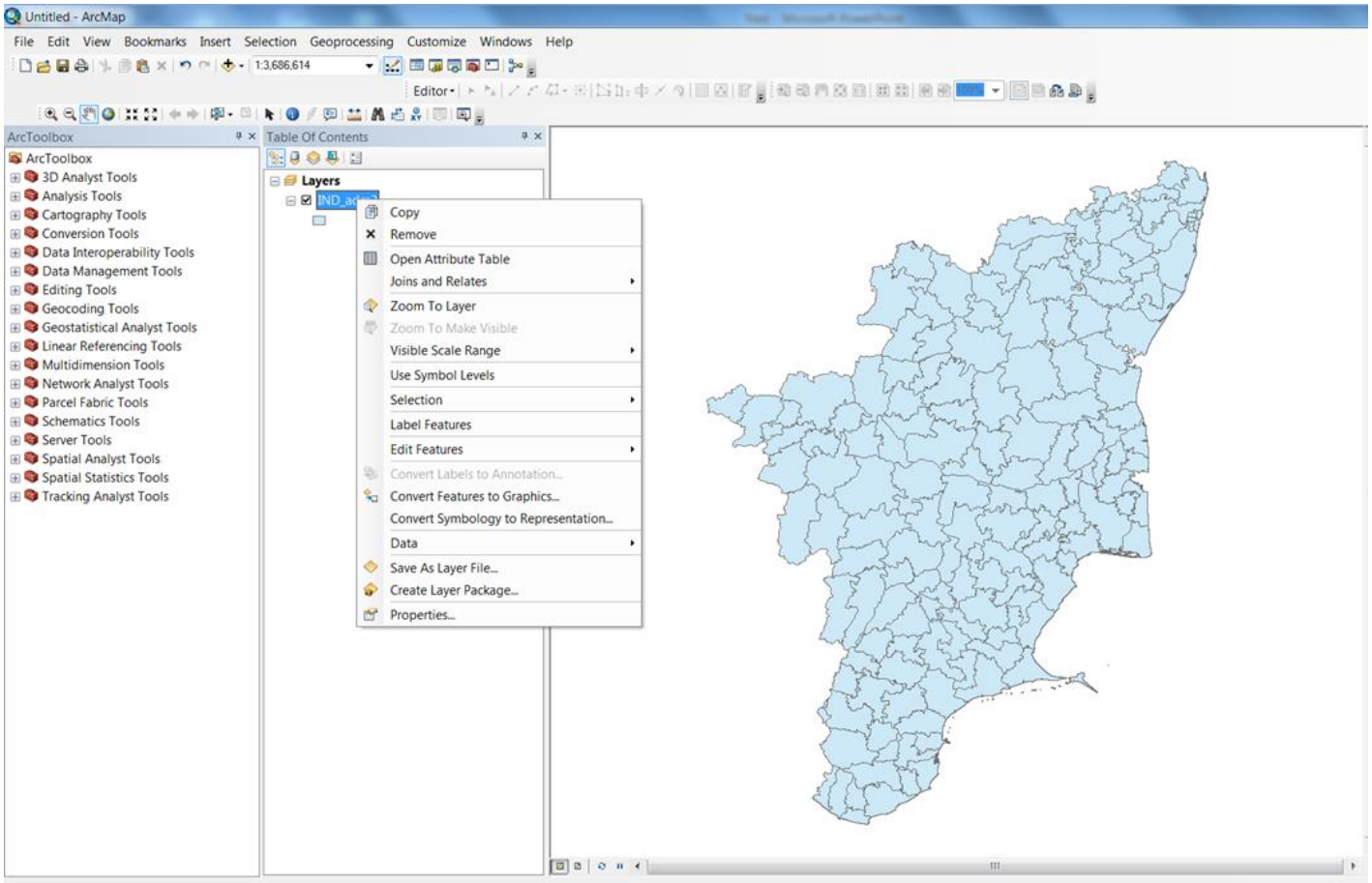

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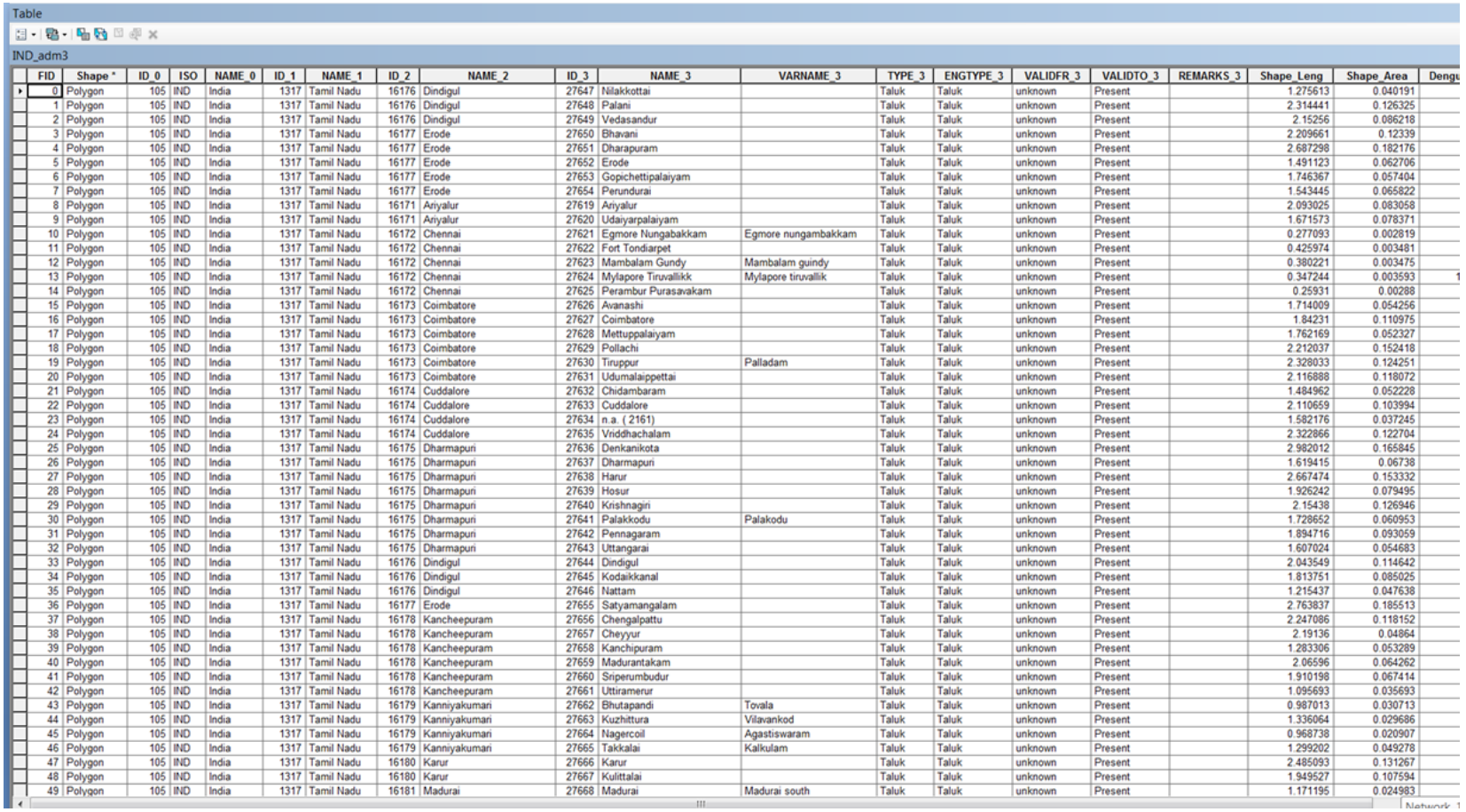

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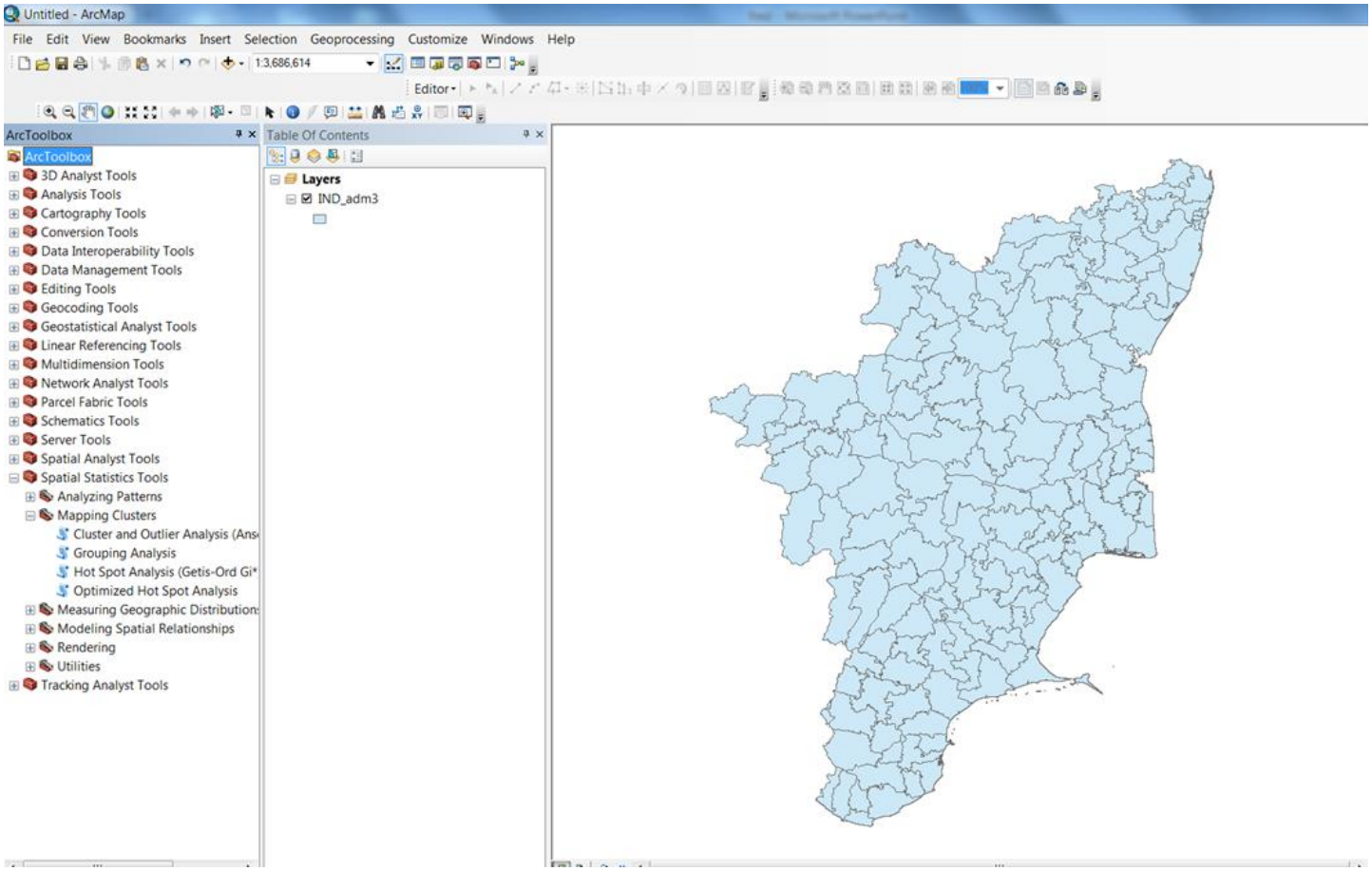
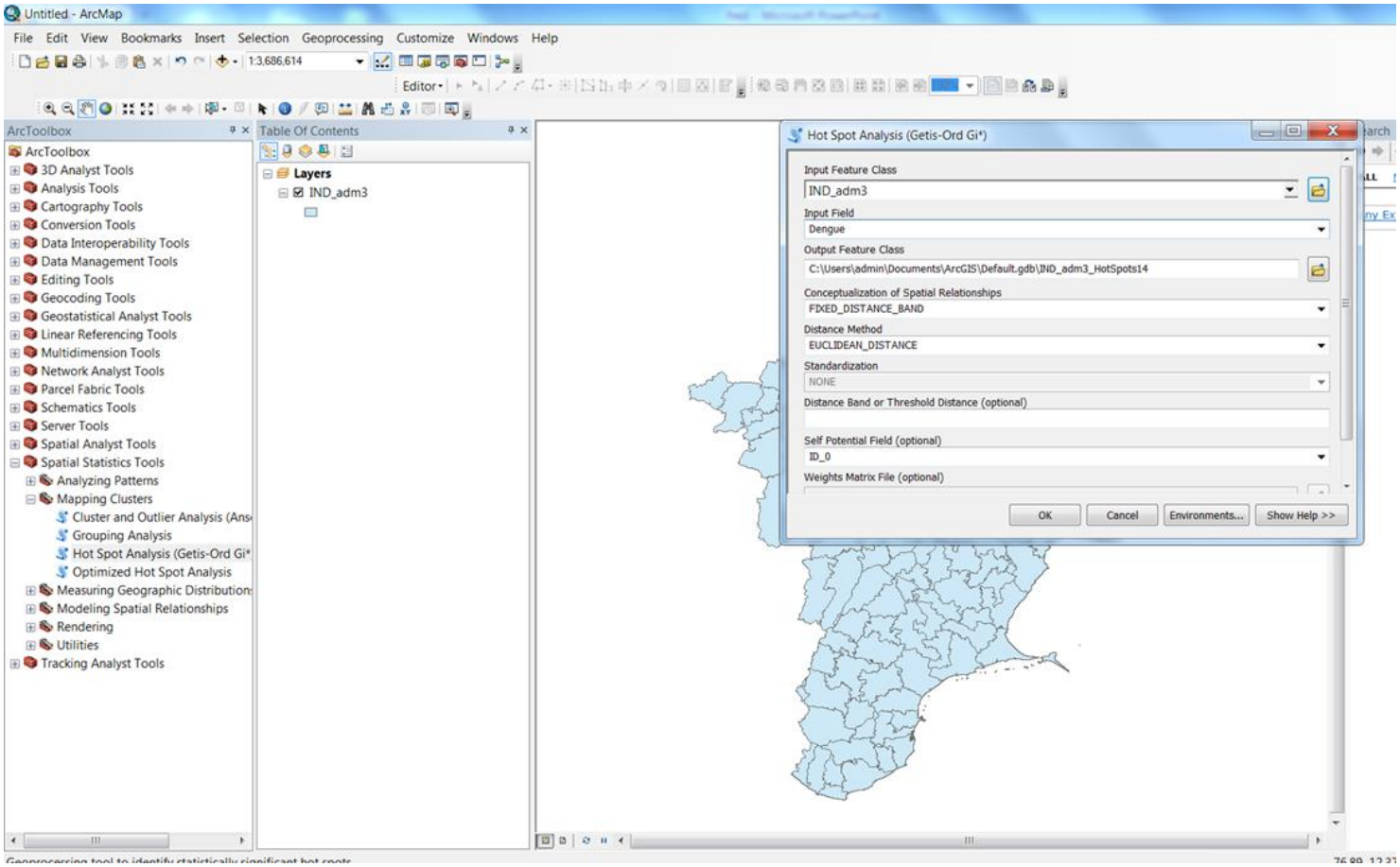
| 43 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16179 | Kanniyakumari | 27662 | Bhutapandi | Tovala | Taluk | Taluk | unknown | Present | | 0.987013 | 0.030713 | |
| 44 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16179 | Kanniyakumari | 27663 | Kuzhittura | Vilavankod | Taluk | Taluk | unknown | Present | | 1.336064 | 0.029686 | |
| 45 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16179 | Kanniyakumari | 27664 | Nagercoil | Agastiswaram | Taluk | Taluk | unknown | Present | | 0.968738 | 0.020907 | |
| 46 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16179 | Kanniyakumari | 27665 | Takkalai | Kalkulam | Taluk | Taluk | unknown | Present | | 1.299202 | 0.049278 | |
| 47 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16180 | Karur | 27666 | Karur | | Taluk | Taluk | unknown | Present | | 2.485093 | 0.131267 | |
| 48 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16180 | Karur | 27667 | Kulittalai | | Taluk | Taluk | unknown | Present | | 1.949527 | 0.107594 | |
| 49 | Polygon | 105 | IND | India | 1317 | Tamil Nadu | 16181 | Madurai | 27668 | Madurai | Madurai south | Taluk | Taluk | unknown | Present | | 1.171195 | 0.024983 | |

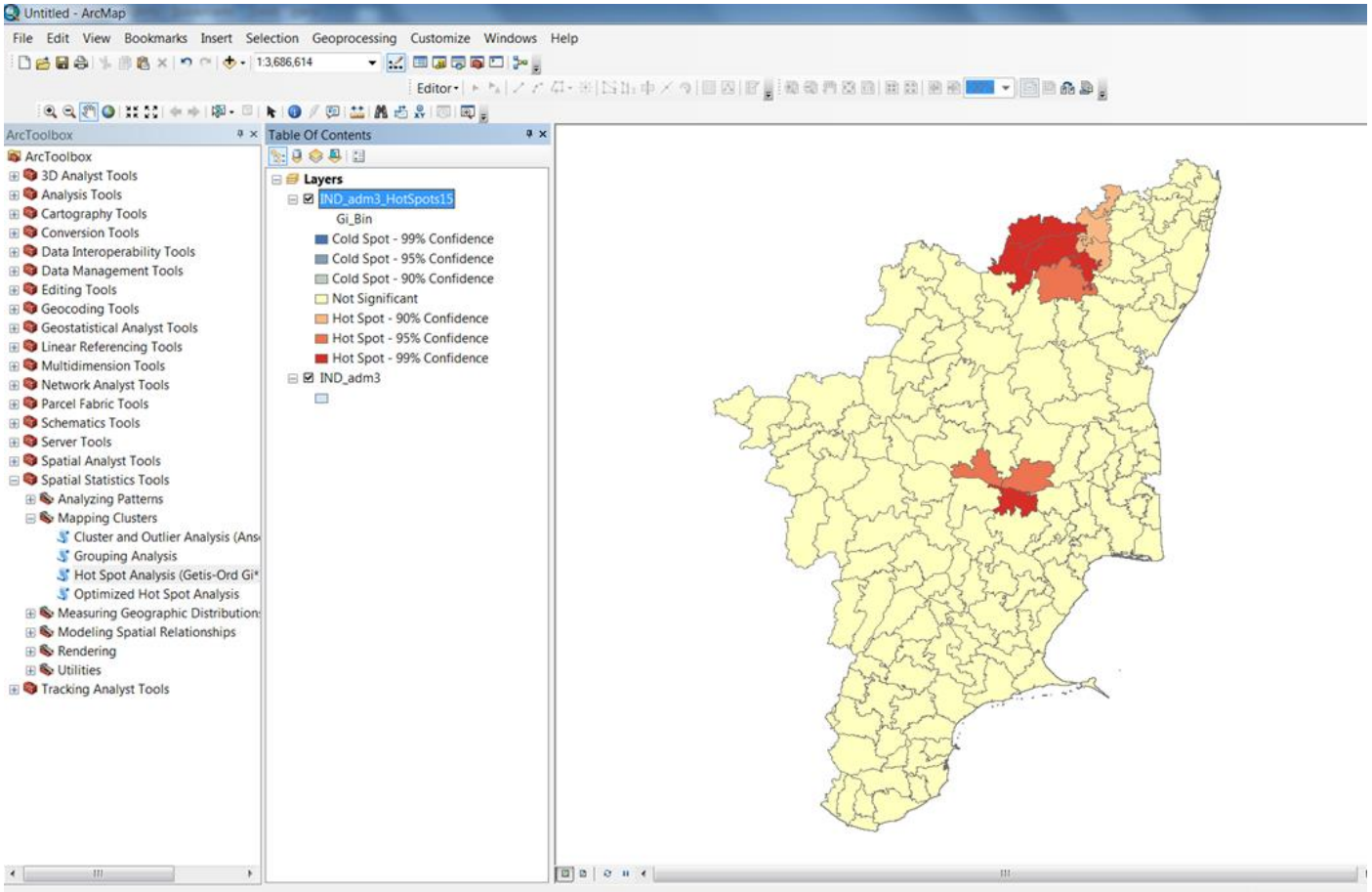
# ArcGIS Simulation



# ArcGIS Simulation



# ArcGIS Simulation



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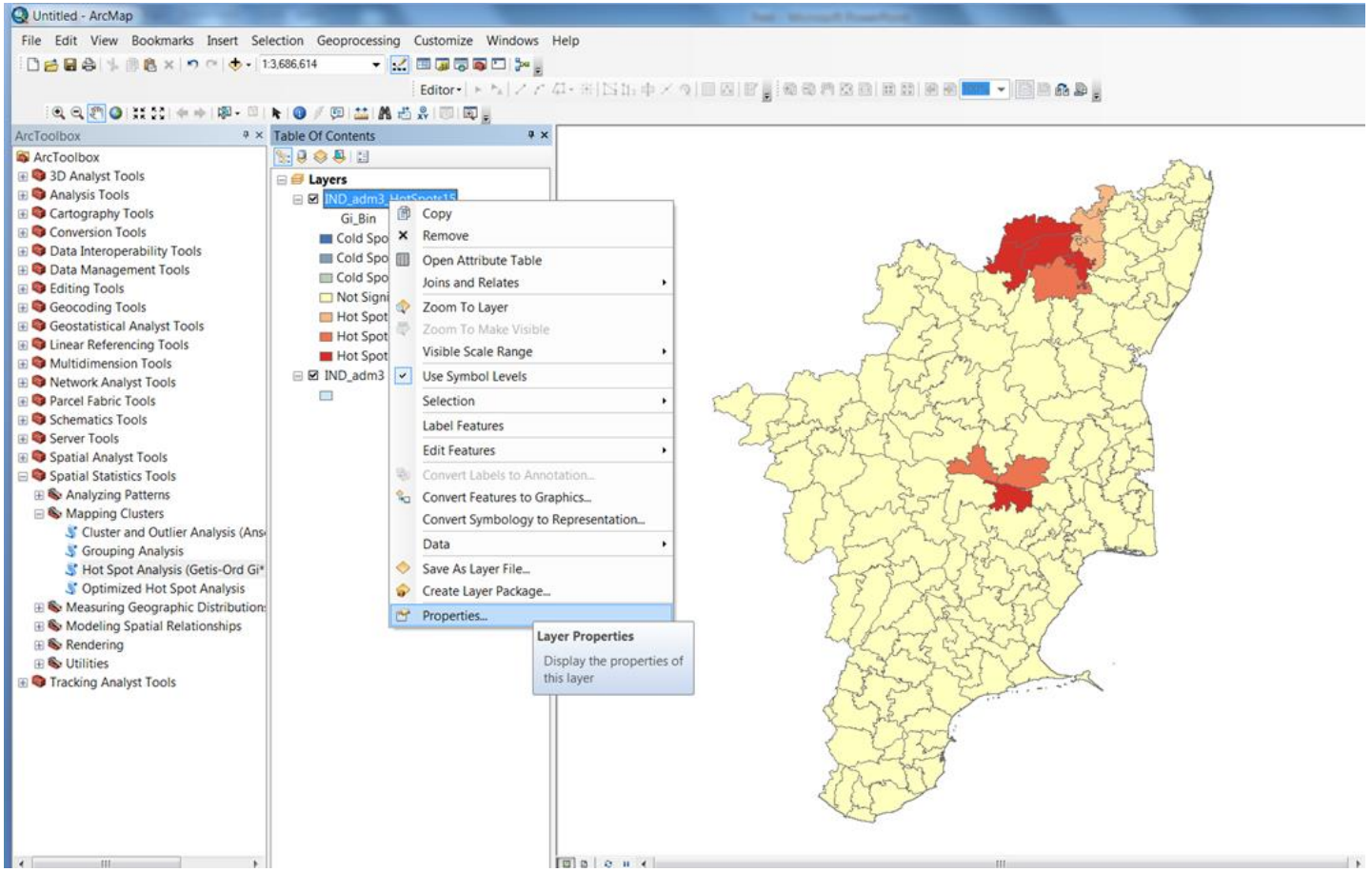
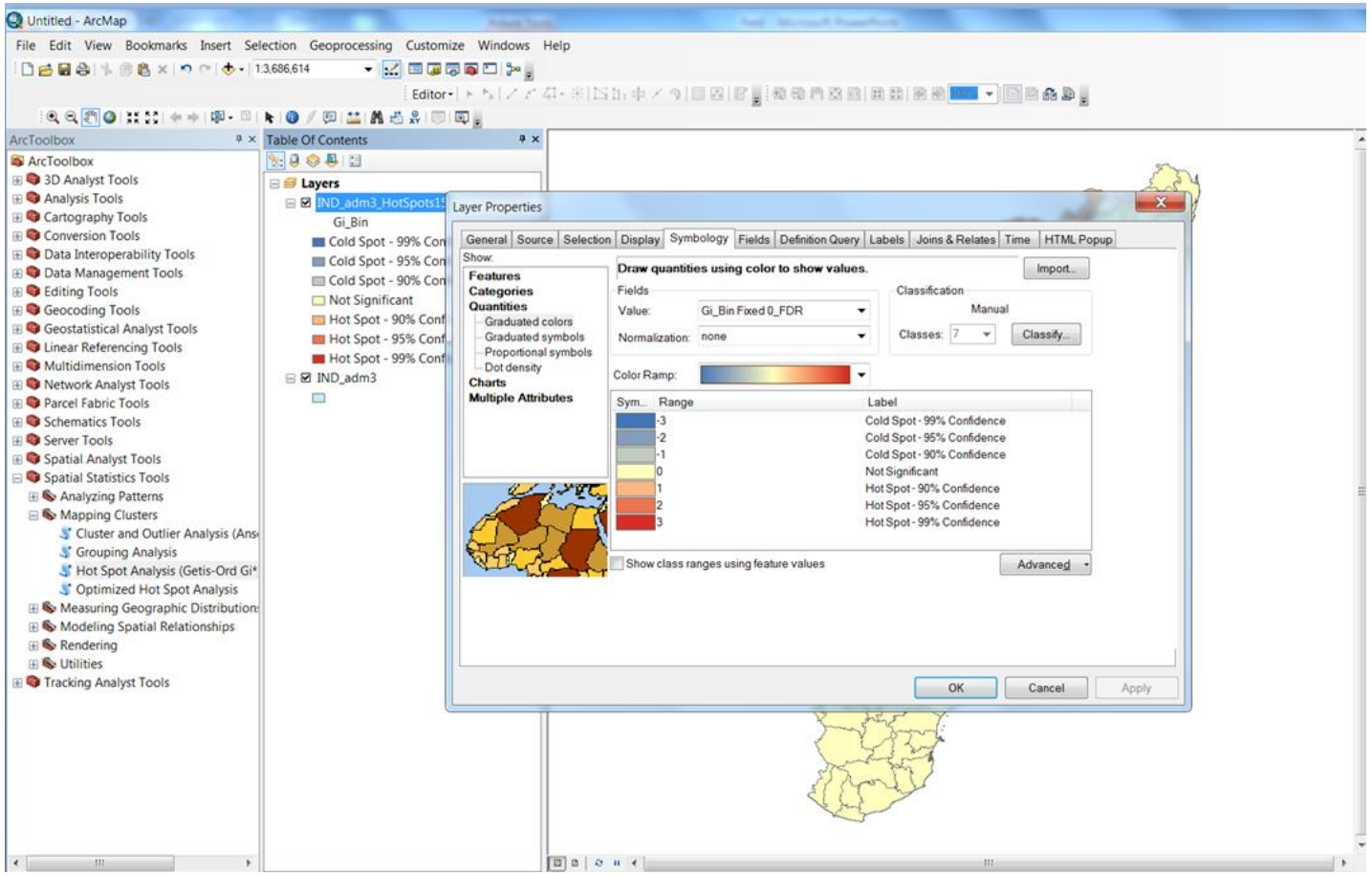
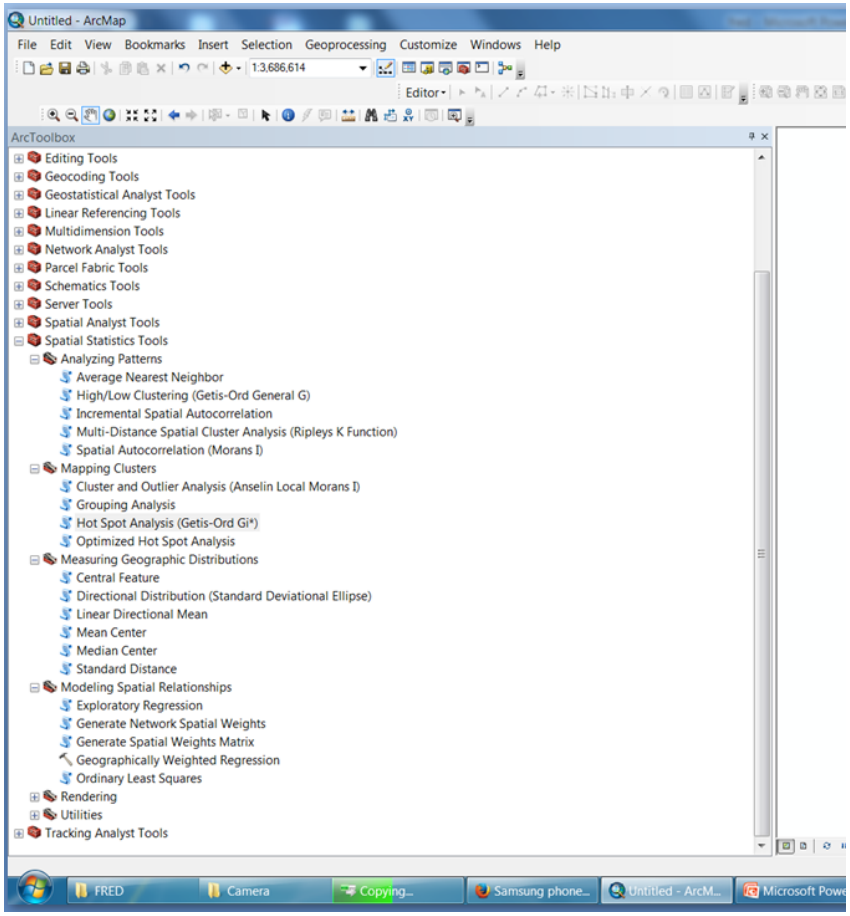


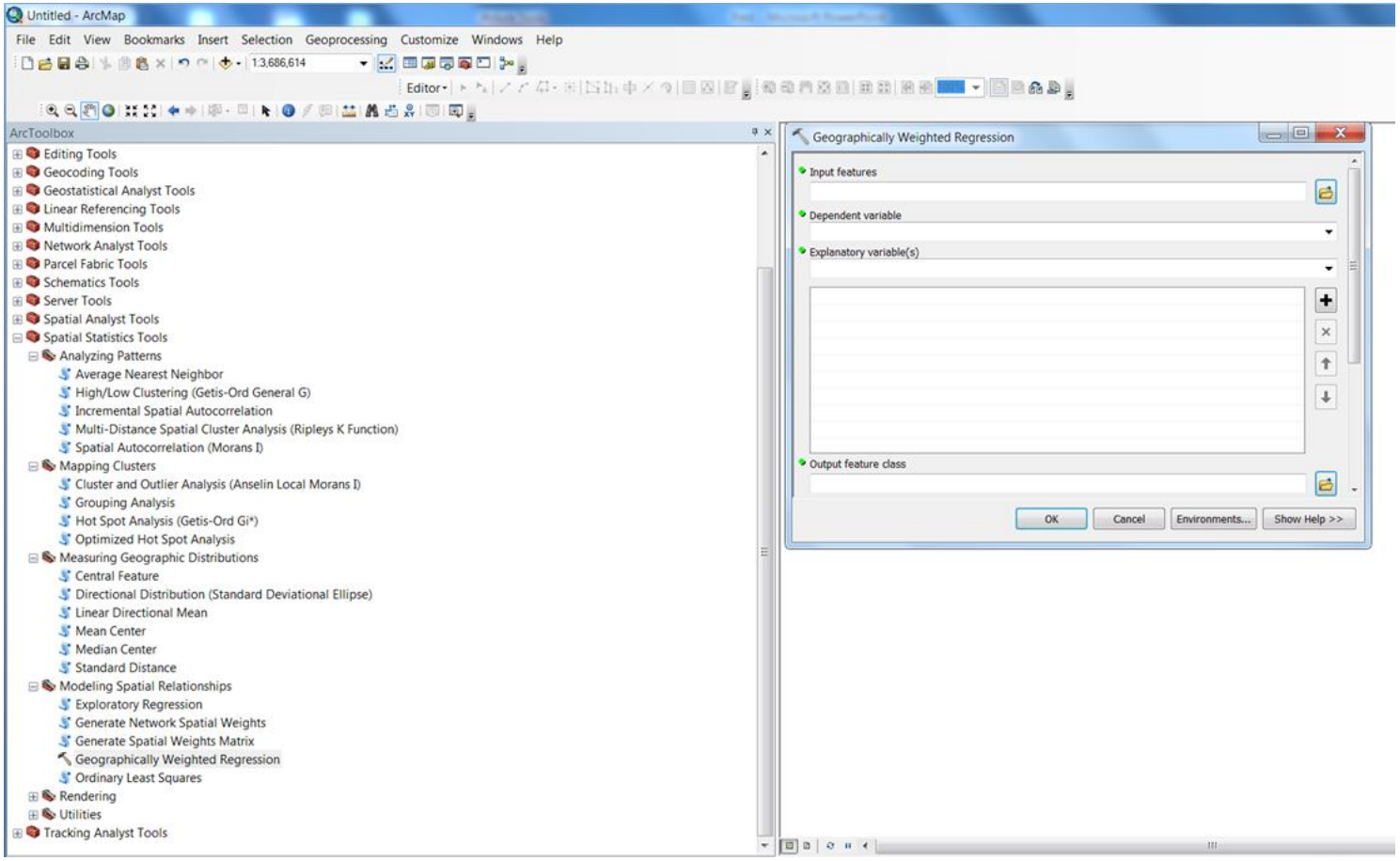
# ArcGIS Simulation



# ArcGIS Simulation



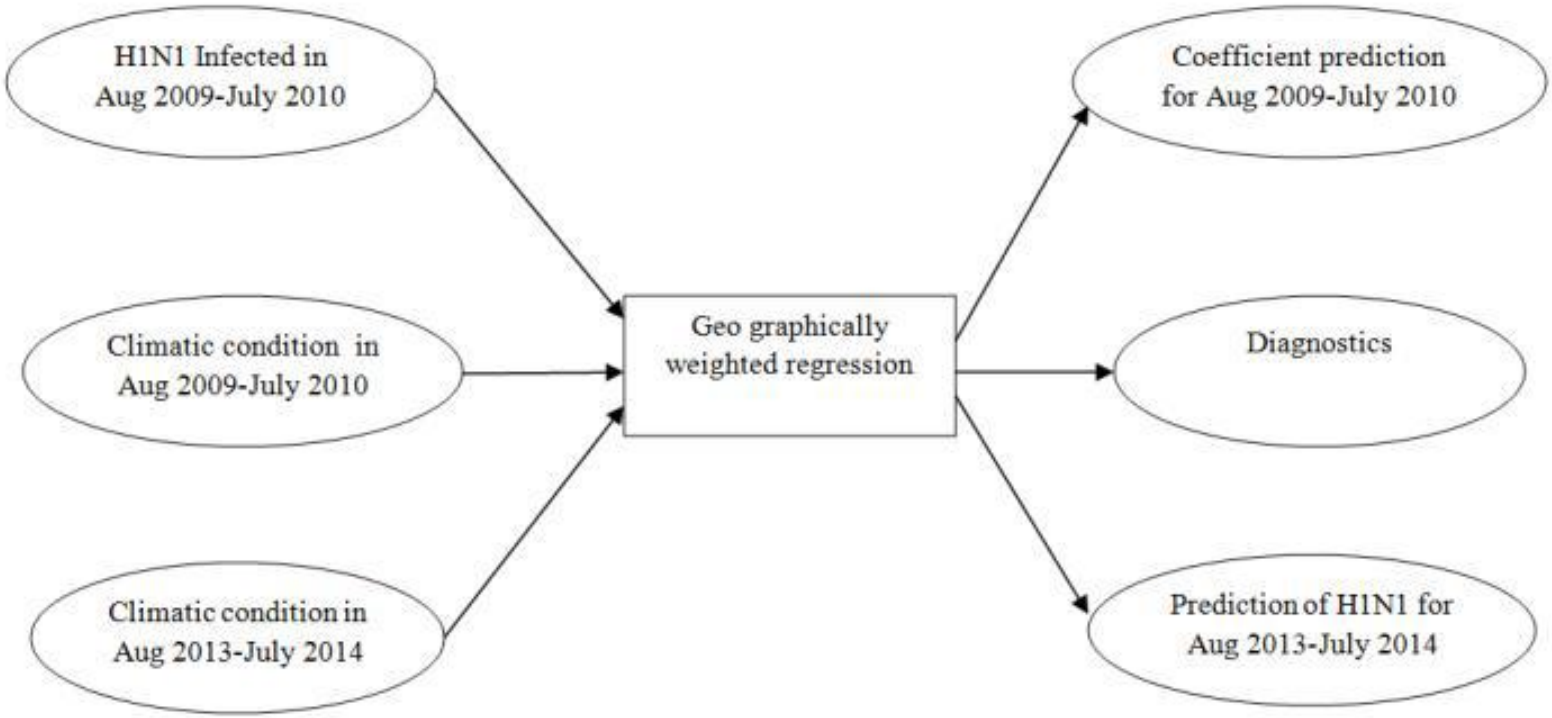
# ArcGIS Simulation



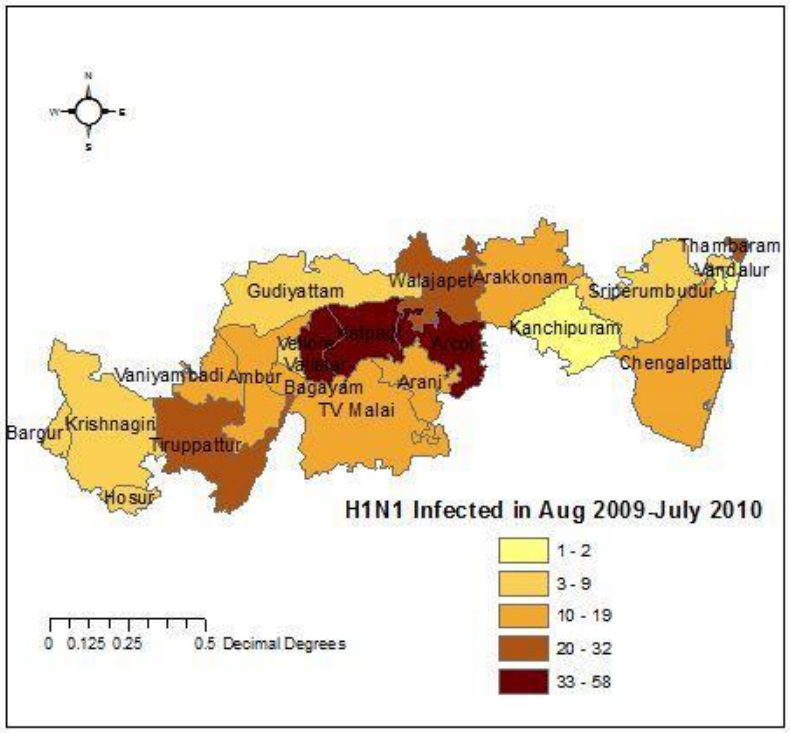
# Case Study

The study objective is to develop a spatial data model to predict the epidemiological impact of influenza in Vellore, India.

# Geographically Weighted Regression Model of H1N1 Influenza Epidemic



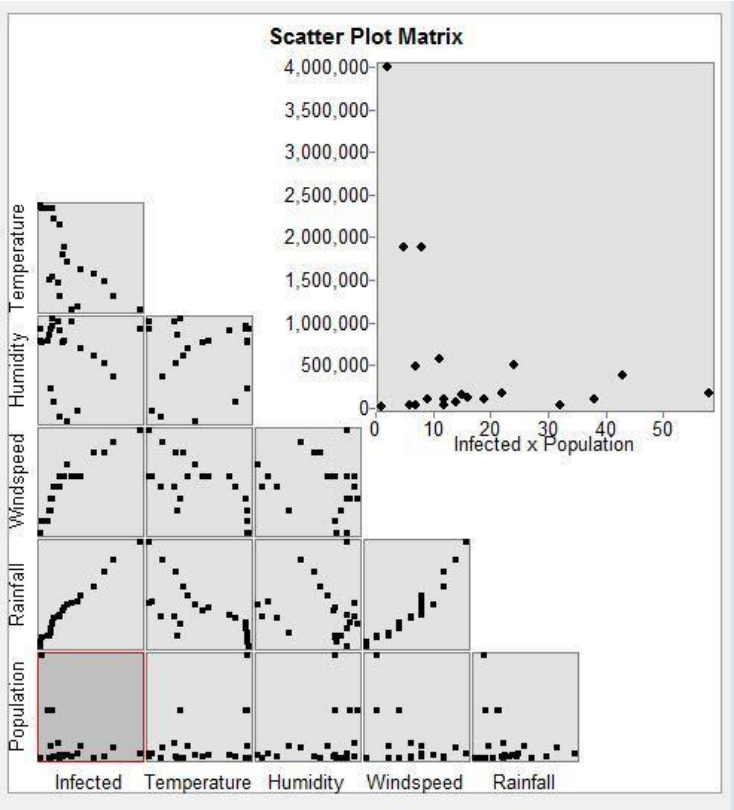
# H1N1 influenza prevalence during August 2009-July 2010

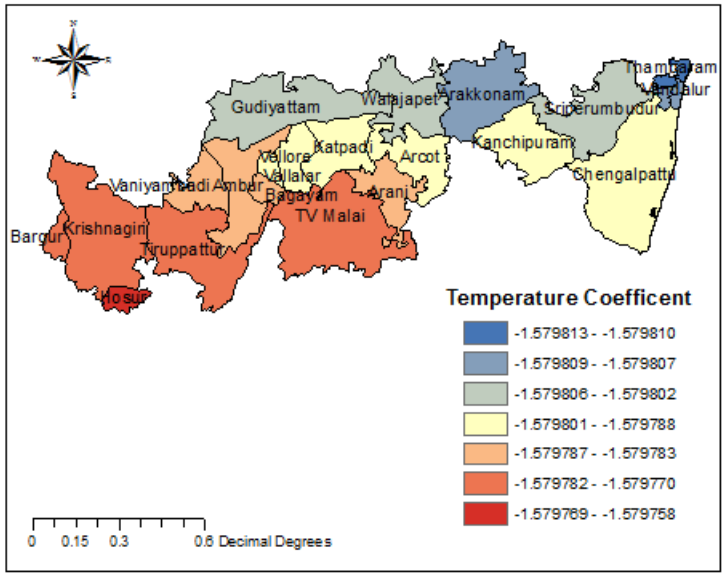


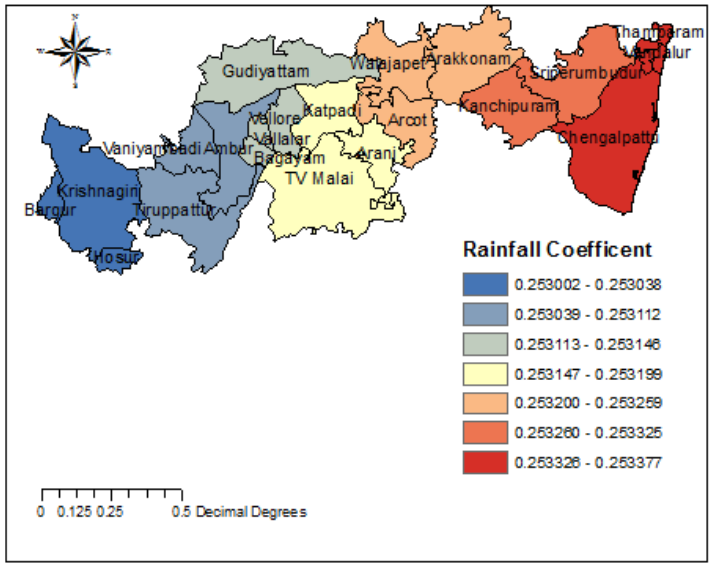
# Climate conditions in Vellore.

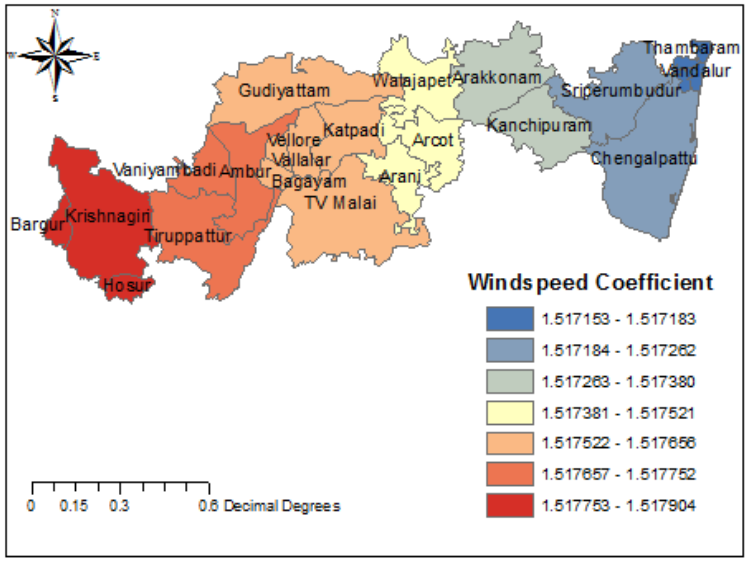
| FID | NAME_3 | Infected | Temperature | Humidity | Windspeed | Rainfall | Population |
|---|---|---|---|---|---|---|---|
| 0 | Kelambakkam | 6 | 24.56 | 64.21 | 6 | 63 | 23453 |
| 1 | Thambaram | 22 | 20.76 | 54.23 | 9 | 85 | 174787 |
| 2 | Koyambedu | 1 | 35.56 | 64.98 | 4 | 56 | 12323 |
| 3 | Vandalur | 1 | 35.24 | 63.45 | 4 | 59 | 13311 |
| 4 | Krishnagiri | 8 | 25.02 | 66.34 | 7 | 71 | 1879809 |
| 5 | Chengalpattu | 11 | 24.12 | 65.96 | 8 | 75 | 571254 |
| 6 | Kanchipuram | 2 | 35.23 | 63.23 | 5 | 62 | 3998252 |
| 7 | Sriperumbudur | 7 | 35.23 | 57.04 | 6 | 65 | 486063 |
| 8 | Arani | 14 | 28.43 | 63.12 | 9 | 79 | 63671 |
| 9 | TV Malai | 15 | 29.45 | 63.34 | 9 | 81 | 144278 |
| 10 | Arakkonam | 12 | 32.65 | 64.85 | 9 | 76 | 101626 |
| 11 | Arcot | 38 | 24.3 | 60.4 | 11 | 105 | 95955 |
| 12 | Gudiyattam | 9 | 33.56 | 55.34 | 8 | 74 | 91558 |
| 13 | Tiruppattur | 24 | 26.2 | 62.34 | 9 | 89 | 500455 |
| 14 | Ambur | 16 | 27.3 | 52.76 | 10 | 83 | 114608 |
| 15 | Katpadi | 43 | 22.3 | 58.57 | 12 | 112 | 387922 |
| 16 | Walajapet | 32 | 25.4 | 61.34 | 11 | 95 | 32397 |
| 17 | Vaniyambadi | 19 | 20.23 | 65.87 | 9 | 84 | 95061 |
| 18 | Bagayam | 12 | 22.12 | 53.32 | 8 | 75 | 23145 |
| 19 | Vellore | 58 | 20.3 | 65.01 | 13 | 124 | 177230 |
| 20 | Vallalar | 7 | 35.1 | 64.98 | 7 | 68 | 25092 |
| 21 | Hosur | 8 | 35.023 | 65.34 | 7 | 72 | 1879809 |
| 22 | Bargur | 5 | 35.22 | 63.3 | 5 | 63 | 1879809 |

# Correlation analysis using scatter plots

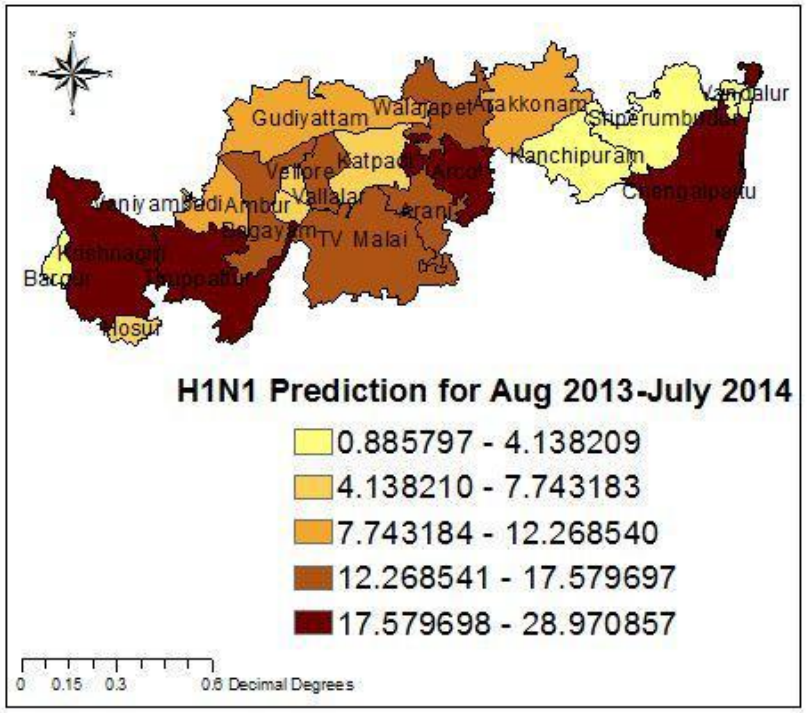



Gudiyattam
Walajapet
Arakkonam
Sriperumbudur
Thambaram
Vandalur
Kanchipuram
Chengalpattu
Katpadi
Vellore
Vallalar
Arcot
Vaniyambadi Ambur
Bagayam
Aranj
TV Malai
Bargur
Krishnagiri
Tiruppattur
Hosur
Temperature Coefficent
-1.579813 - -1.579810
-1.579809 - -1.579807
-1.579806 - -1.579802
-1.579801 - -1.579788
-1.579787 - -1.579783
-1.579782 - -1.579770
-1.579769 - -1.579758
0 0.15 0.3 0.6 Decimal Degrees


Gudiyattam
Walajapet
Arakkonam
Sriperumbudur
Thambaram
Vandalur
Kanchipuram
Chengalpattu
Katpadi
Vellore
Vallalar
Arcot
Vaniyambadi Ambur
Bagayam
Aranj
TV Malai
Bargur
Krishnagiri
Tiruppattur
Hosur
Rainfall Coefficent
0.253002 - 0.253038
0.253039 - 0.253112
0.253113 - 0.253146
0.253147 - 0.253199
0.253200 - 0.253259
0.253260 - 0.253325
0.253326 - 0.253377
0 0.125 0.25 0.5 Decimal Degrees


Gudiyattam
Walajapet
Arakkonam
Sriperumbudur
Thambaram
Vandalur
Kanchipuram
Chengalpattu
Katpadi
Vellore
Vallalar
Arcot
Vaniyambadi Ambur
Bagayam
Aranj
TV Malai
Bargur
Krishnagiri
Tiruppattur
Hosur
Windspeed Coefficient
1.517153 - 1.517183
1.517184 - 1.517262
1.517263 - 1.517380
1.517381 - 1.517521
1.517522 - 1.517656
1.517657 - 1.517752
1.517753 - 1.517904
0 0.15 0.3 0.6 Decimal Degrees

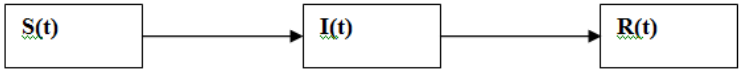
# Prediction of H1N1 influenza



# Epidemic Modeling in MATLAB

# SIR Epidemic Model in MATLAB

**SIR Model**




**Model Equation**

$$\frac{di}{dt} = \lambda si - \mu i, \qquad I(0) = i_0$$

$$\frac{ds}{dt} = -\lambda si, \qquad S(0) = s_0$$

$$\frac{dr}{dt} = \mu i, \qquad r_0 = 0$$

$$S(t) + I(t) + R(t) = N$$

Where,

s → susceptible

i → infected

r → recovered

λ → Contact rate

μ → Recovered rate

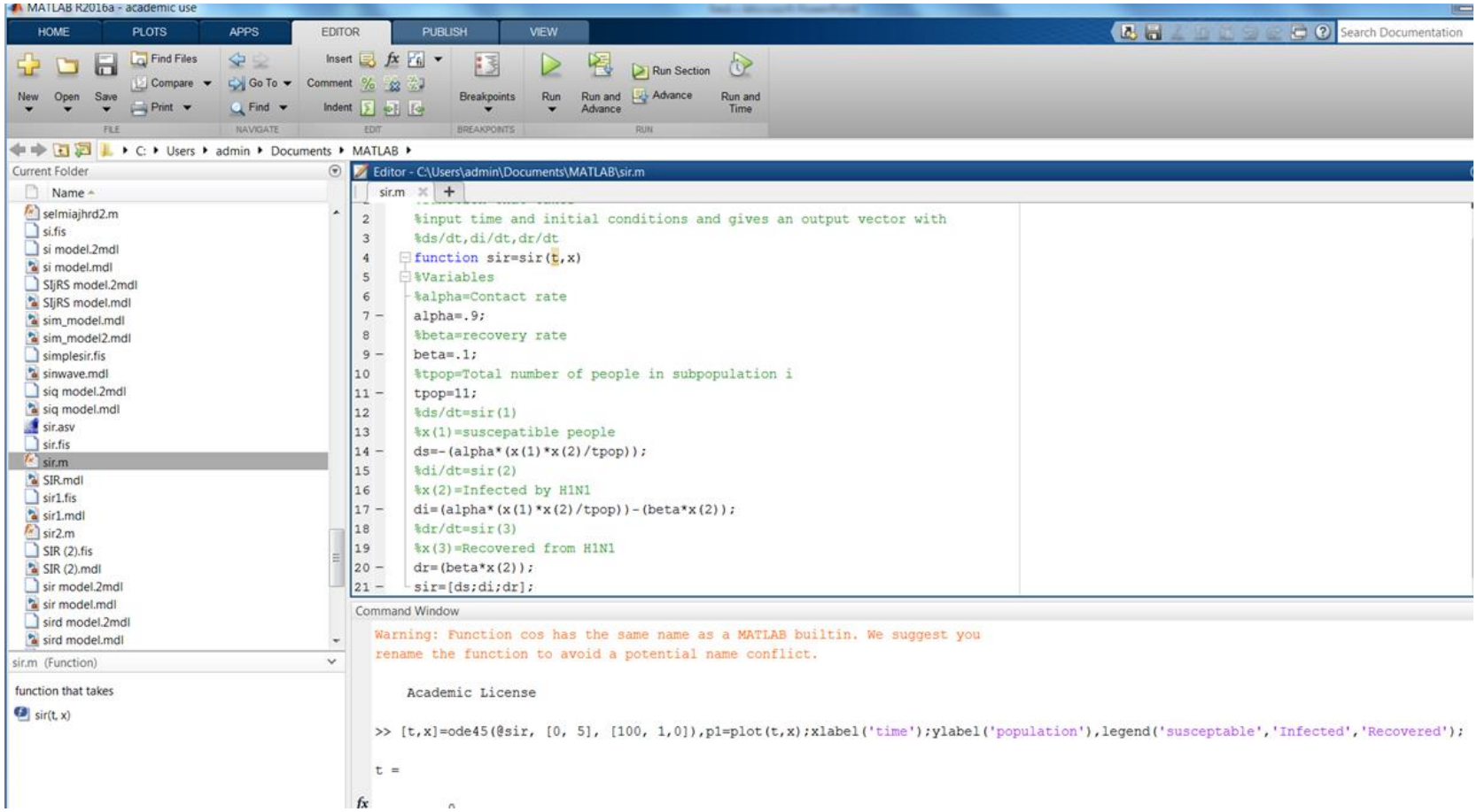
# MATLAB Code for SIR Epidemic Model

```
%function that takes
%input time and initial conditions and gives an output vector with
%ds/dt,di/dt,dr/dt
function sir=sir(t,x)
%Variables
%alpha=the global transmission rate
alpha=.3;
%beta=contact rate per day by people in subpopulation i
beta=.9;
%gamma=Infectious mortality of subpopulation i, from infected class
%gamma=.01;
%tow=Rate of progression from exposed to infected (? ?1 is latent period )
tow=1;
%row=Recovery rate
row=.5;
%tpop=Total number of people in subpopulation i
tpop=10;
%ds/dt=sir(1)
```

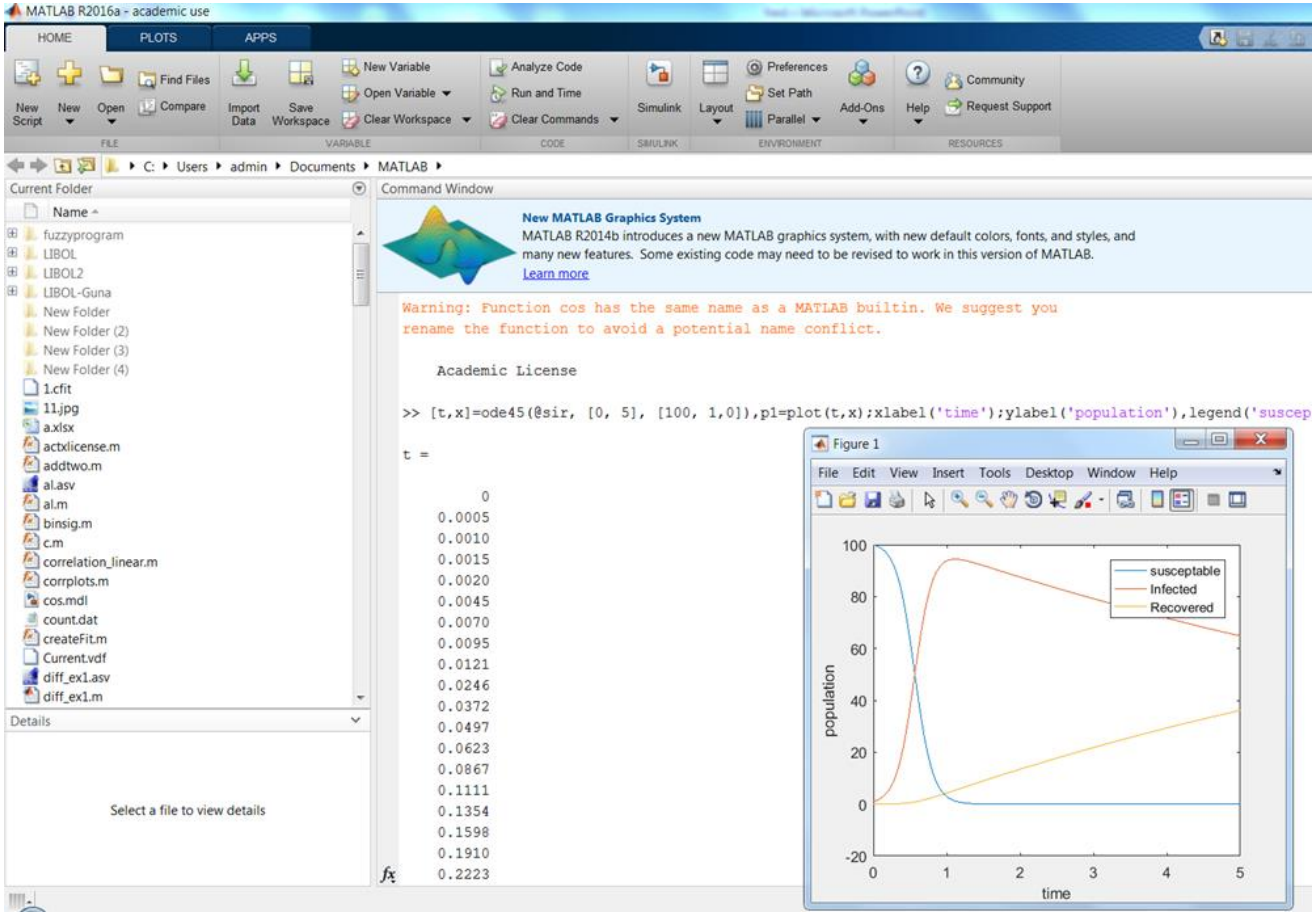
```
%x(1)=suscepatible people
ds=-(beta*alpha*(((x(2)+x(3))*x(1))/tpop));
%de/dt=sir(2)
%x(2)=exposed by H1N1
%di=(beta*alpha*(((x(2)+x(3))*x(1))/tpop))-(tow*x(2));
%di/dt=sir(3)
%x(3)=Infected by H1N1
di=(alpha*(((x(2)+x(3))*x(1))/tpop))-(tow*x(2));
%dr/dt=sir(4)
%x(4)=Recovered from H1N1
dr=(row*x(2));
%dr/dt=sir(5)
%x(4)=Death people

sir=[ds;di;dr];
```

# MATLAB Simulation



# MATLAB Simulation



# Thank You!