

Monitoring COVID-19 Community Outbreaks using SaTScan

CSTE Spatial Analysis Workgroup
January 19, 2021

Presenters: Sharon K. Greene, Martin Kulldorff

Outline

- Introducing SaTScan to leadership
- Template for cluster reporting
- Newly available SaTScan features
- Aligning the analysis with the public health purpose

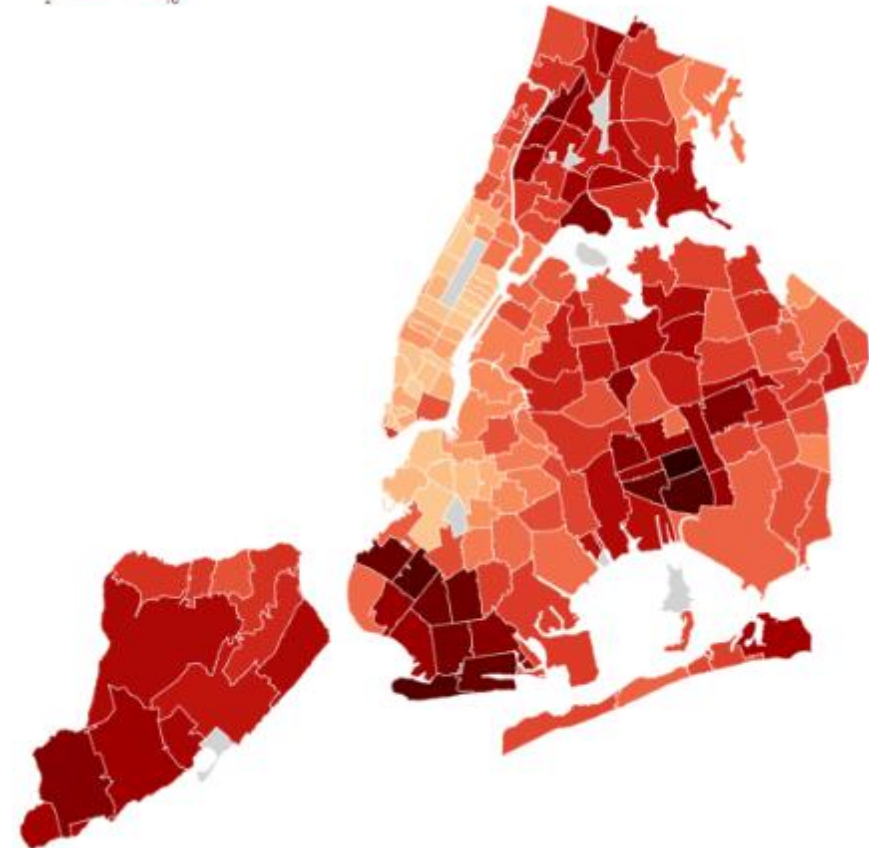
Introducing SaTScan to leadership

How do we support geographic resource allocation for COVID-19?

Percent Positive and Test Rate of Molecular Testing by ZIP Code

These data show the percent of people given a molecular test who tested positive, by ZIP code, for the most recent seven days of available data.

7-day percent positive
2 16



- Static maps show data at one geographic resolution and one temporal resolution
- SaTScan can quickly find areas emerging with the most unusually high % positivity, by scanning:
 - All different areas of the City
 - Across areas of many different sizes
 - Over varying time periods

MEDICAL DISPATCH

THE PANDEMIC'S WINTER SURGE IS
HERE*The numbers are rising. Our leaders must react quickly to prevent unnecessary deaths.***By Dhruv Khullar**
November 12, 2020

SaTScan, on the other hand, has been vital to New York City's efforts. "It's one of the jewels of our response," Dave Chokshi, the city's health commissioner, said.

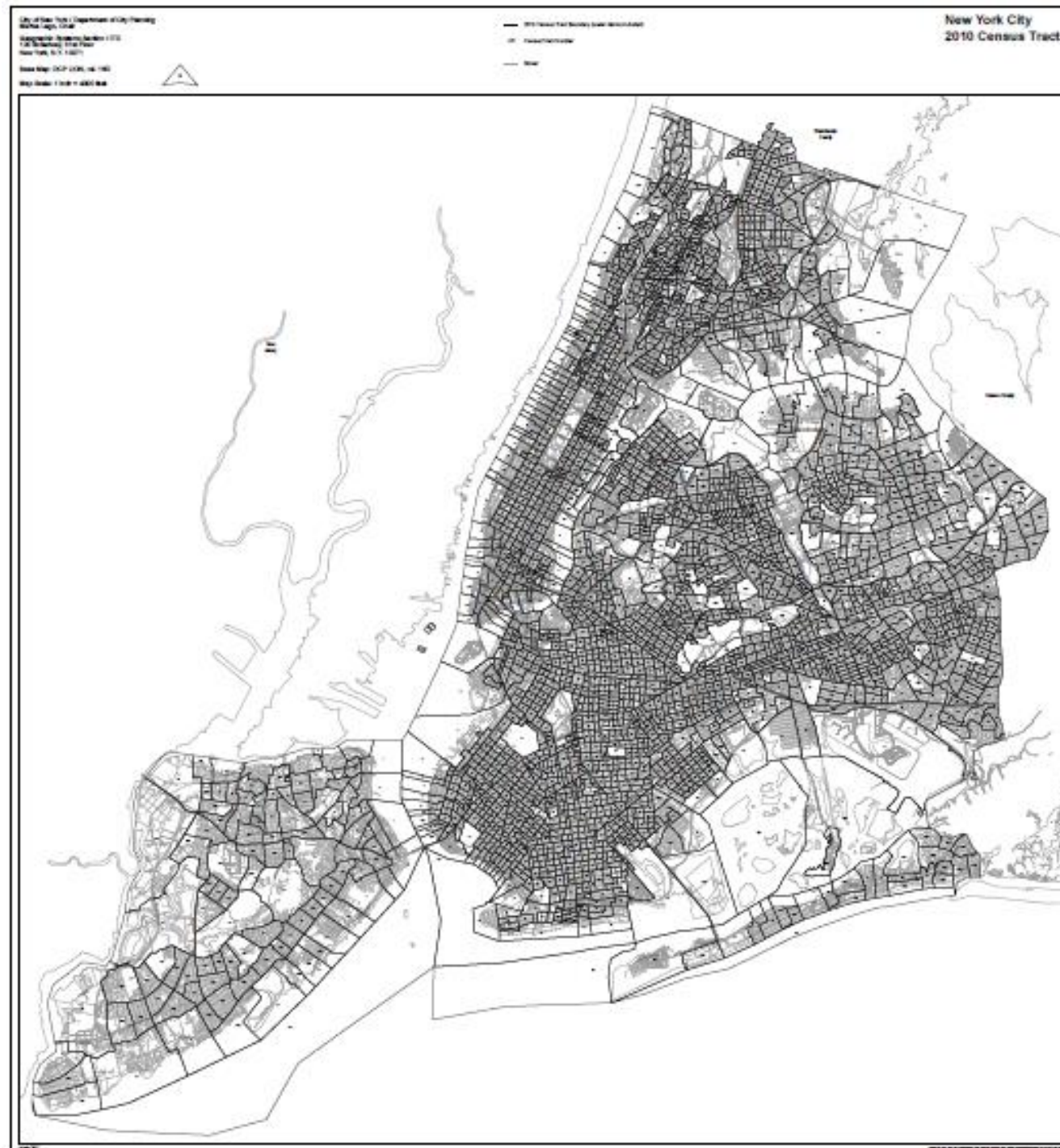
"Think of it as a very, very early warning system for disease activity," Demetre Daskalakis, the city's deputy health commissioner, told me. "The parcels of land we create for administrative purposes don't capture how diseases actually transmit," he went on.

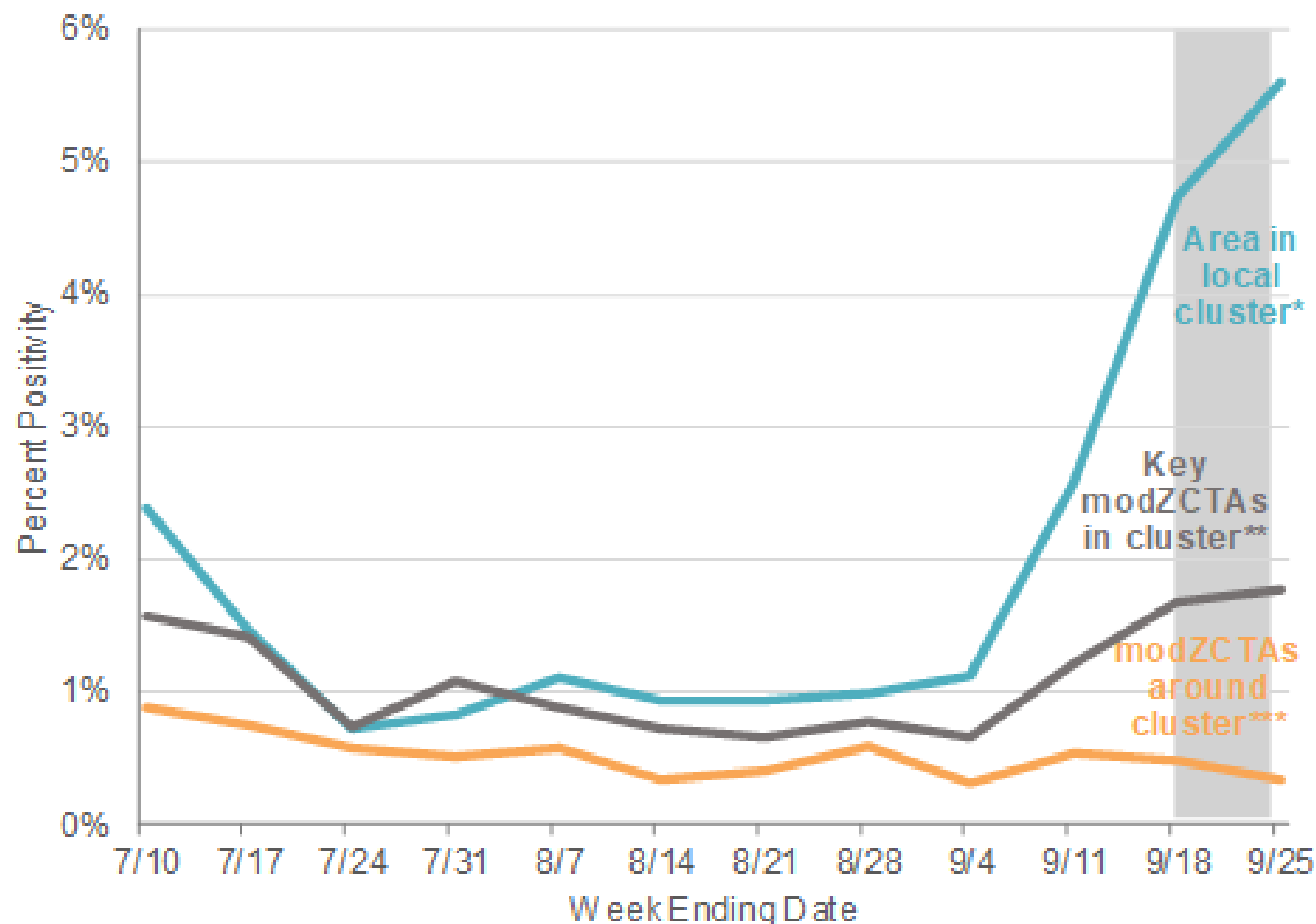
If a cluster is identified, the health department shifts advertisements and robocalls to the area, distributes masks, and encourages residents to get tested, either at existing centers or mobile and pop-up testing sites, which can be set up as soon as the next day. To get the word out, the health department works with faith leaders from churches and synagogues.

No artificial spatial boundaries

- Detects clusters that:
 - Cross ZIP Code Tabulation Area (ZCTA) boundaries
 - Are smaller than one ZCTA
 - Encompass some or all of >1 ZCTA
- More robust than maps of census tract-level % positivity
 - Census tract-level data are sparse/unstable
 - Need to group and regroup adjacent census tracts together in many combinations to precisely detect clusters
- Precisely support targeted, hyperlocal response

Data
aggregated to
census tract
resolution,
for spatial
precision





Rapidly detected increased transmission in [area].

This increase is missed/delayed when aggregating to ZCTA-level.

Data for most recent week are incomplete

Source: Surveillance and Epidemiology Branch, NYC DOHMH, September 28, 2020.

Data exclude: residents of long-term care and correctional facilities; persons with addresses at long-term care or correctional facilities but who are not residents. Data are preliminary and subject to change.

*Area in local cluster are census tracts where the percent positivity within the signal area was considerably higher than the rest of the city.

No artificial temporal boundaries

- Detects clusters that are emerging:
 - Rapidly, taking as few as 7 days to emerge
 - More slowly, taking as long as 21 days to emerge
 - Any other length of time in between
- More robust than displaying static 1-week or 2-week periods
- Precisely identify date when an area began increasing

No bias from testing uptake

- Outcome is % positivity
 - Adjusting the expected case count based on the number of persons tested
- Detects emerging clusters regardless of whether testing uptake in that area or citywide is high, low, increasing, or decreasing
- More robust than analyzing case counts or case rates, which cannot distinguish increases in testing from increases in transmission

Identifies areas
of highest
concern without
arbitrary %
positivity
thresholds

- More robust than mapping % positivity at breakpoints (e.g., >2%, >5%, >10%, etc.)
- Detects the most concerning emerging clusters regardless of whether citywide transmission is:
 - Increasing
 - Steady
 - Decreasing
- Adjusts for citywide temporal trends

Can identify areas newly emerging, even if not yet higher than citywide % positivity

- Detects areas with relative increases from baseline, regardless of whether % positivity in the past in that area was:
 - Low
 - Medium
 - High
- More robust than mapping % positivity for a single time period, because SaTScan considers change in % positivity over time
- Option to adjust for purely spatial variation

Template for cluster reporting

**Surveillance and Epidemiology Branch
New York City Department of Health and Mental Hygiene**

**SaTScan cluster of increasing COVID-19 percent positivity,
centered in [neighborhood name]**

[Date prepared]

Cluster summary: [Neighborhood name of cluster center | Borough]

Cluster details

- Specimen collection date range of cluster:
- Number of cases in cluster:

PCR percent positivity

- In cluster:
- Citywide for week ending [date]:

Testing rate per 100,000 for week ending [date]

- In cluster:
- In key ZCTAs in cluster:
- In ZCTAs around cluster:
- Citywide:

Primary language(s) spoken at home in cluster area:

[Map inset of census tracts in cluster area highlighted in yellow, overlaid on ZCTA boundaries]

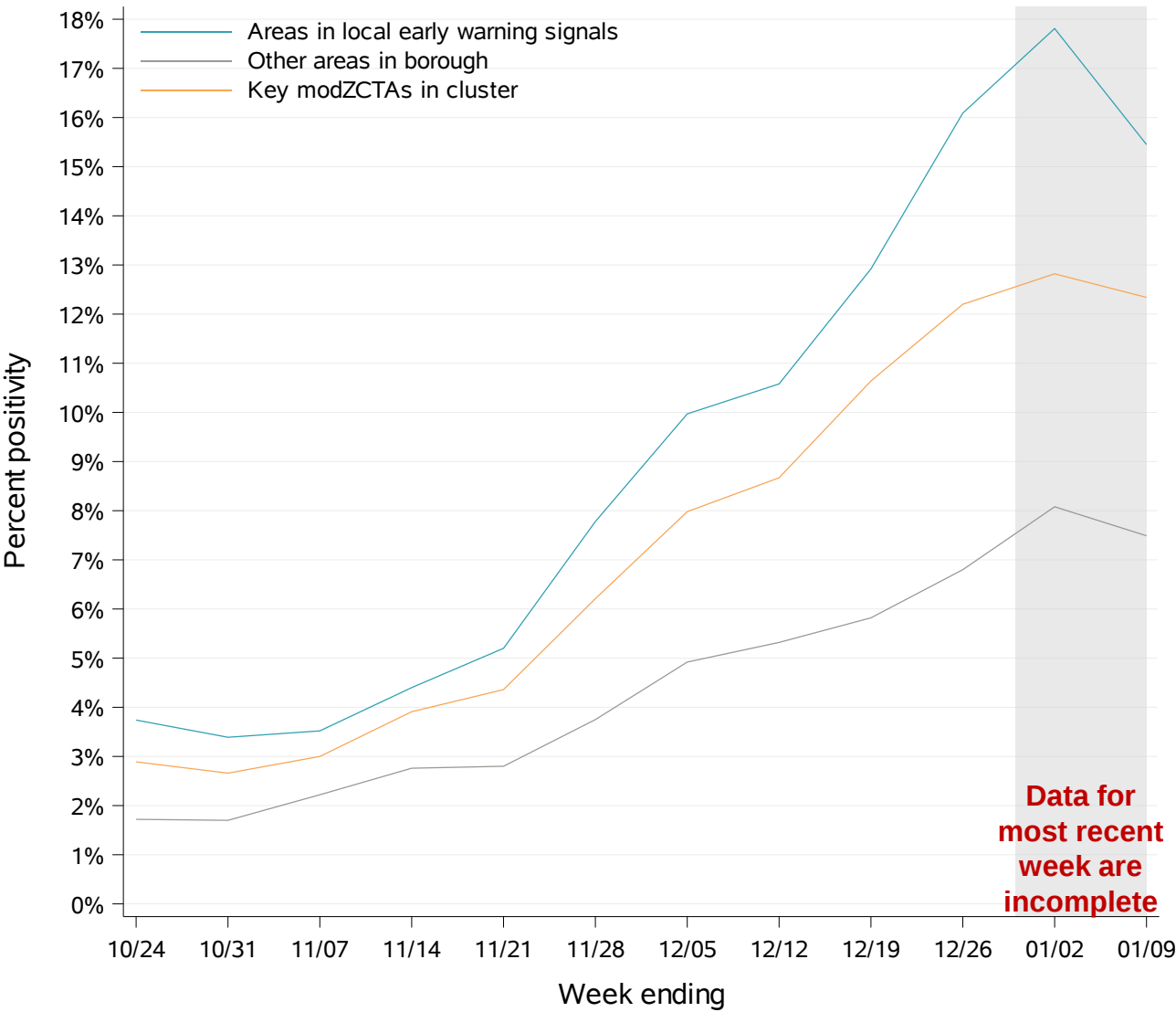
Summary characteristics of patients in clusters

- Age (median, range):
- Sex distribution:
- Race/ethnicity distribution:
- Symptomatic: % (vs. % citywide for week ending [date])

Key ZCTAs in clusters: [list]

Notes:
 Both ZCTA and SaTScan signal borders are artificial lines used to delineate areas of higher risk, but not meant to be interpreted that persons who live just outside the border are not at similar risk.
 The cluster area only accounts for persons who seek testing at labs that report to DOHMH. Persons tested by point of care testing where providers are not reporting would not be reflected.

PCR Percent Positivity



Week ending	Areas in local early warning signal	Other areas in borough	Key ZCTAs in cluster
-------------	-------------------------------------	------------------------	----------------------

[insert percent positivities]

Key ZCTAs in clusters: [list]

Data exclude: residents of long-term care and correctional facilities; persons with addresses at long-term care or correctional facilities but who not residents.

Data are preliminary and subject to change

Newly available SaTScan features

SaTScan Enhancement Project

- Funded by CDC Foundation, CDC ELC CARES (grant NU50CK000517-01-09), Alfred P. Sloan Foundation, and Open Society Foundations. Managed by the Fund for Public Health in New York City
- Enhancements already available:
 - v.9.7: new spatial and temporal trend adjustment options
 - v.10.0 beta:
 - detect clusters along a distance matrix/network (accommodate irregular geographies)
 - cluster drilldown



Enhancement 1

New spatial and temporal
trend adjustment options

Adjust for
purely
temporal
trends



- If test % positivity is increasing in NYC overall, detect areas where the increase is more than citywide average increase



- If test % positivity is decreasing in NYC overall, detect areas where the decrease is less than citywide average decrease

- Temporal adjustments:
 - Log-linear
 - Log-quadratic
 - Nonparametric

Temporal Trend Adjustment Options

SaTScan - Software for the Spatial and Space-Time Scan Statistic

File Session Windows Help

R:\EmergencyEvents\2019_nCoV\SurvEpi\EpiData Unit Doc Ops\Mapping\SaTScan\Results\20210111\casefil...

Input **Analysis** Output

Type of Analysis

Retrospective Analyses:

- ☐ Purely Spatial
- ☐ Purely Temporal
- ☐ Space-Time
- ☐ Seasonal
- ☐ Spatial Variation in Temporal Trends

Prospective Analyses:

- ☐ Purely Temporal
- ☒ Space-Time

Probability Model

Discrete Scan Statistics:

- ☒ Poisson
- ☐ Bernoulli
- ☐ Space-Time Permutation
- ☐ Multinomial
- ☐ Ordinal
- ☐ Exponential
- ☐ Normal
- ☐ Uniform Time

Continuous Scan Statistics:

- ☐ Poisson

Scan For Areas With:

- ☒ High Rates
- ☐ Low Rates
- ☐ High or Low Rates

Time Aggregation

Units: ☐ Year ☐ Month ☒ Day

Length: Days

Advanced >>

Advanced Analysis Features

Spatial Window Temporal Window Cluster Restrictions

Space and Time Adjustments Inference Border Analysis Power Evaluation Drilldown

Temporal Trend Adjustments

- ☐ None
- ☐ Nonparametric
- ☐ Log linear trend with % per year
- ☒ Log linear with automatically calculated trend
- ☐ Log quadratic with automatically calculated trend

☐ Adjust for day-of-week

Spatial Adjustments

- ☐ None
- ☒ Nonparametric

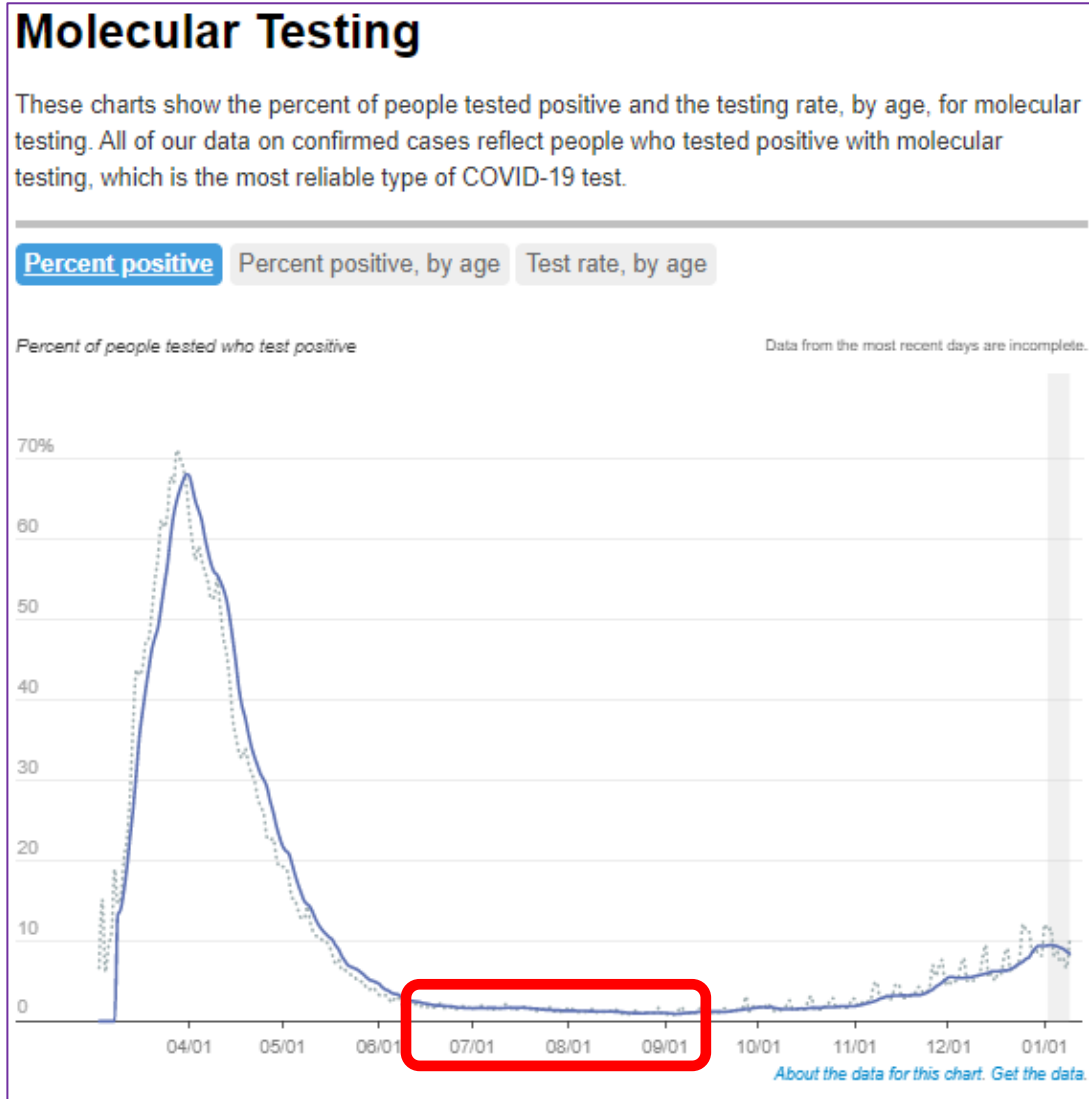
Temporal, Spatial and/or Space-Time Adjustments

☐ Adjust for known relative risks

Adjustments File: ...

Set Defaults Close

Appropriate temporal trend adjustment depends on observed trend during study period

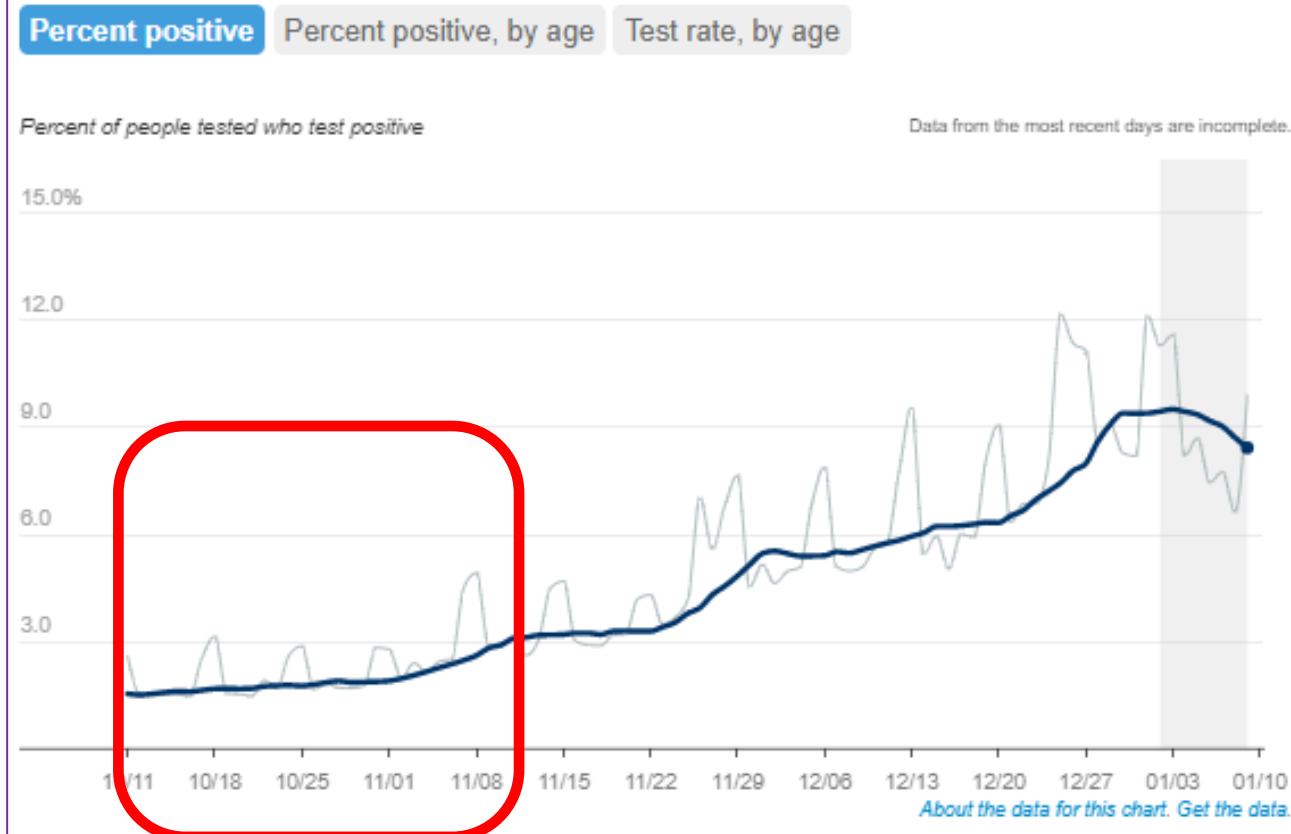


Log-linear trend adjustment was appropriate in NYC during summer 2020

Appropriate temporal trend adjustment depends on observed trend during study period

Molecular Testing Citywide and by Age

These charts show percent positivity and test rate for molecular tests.

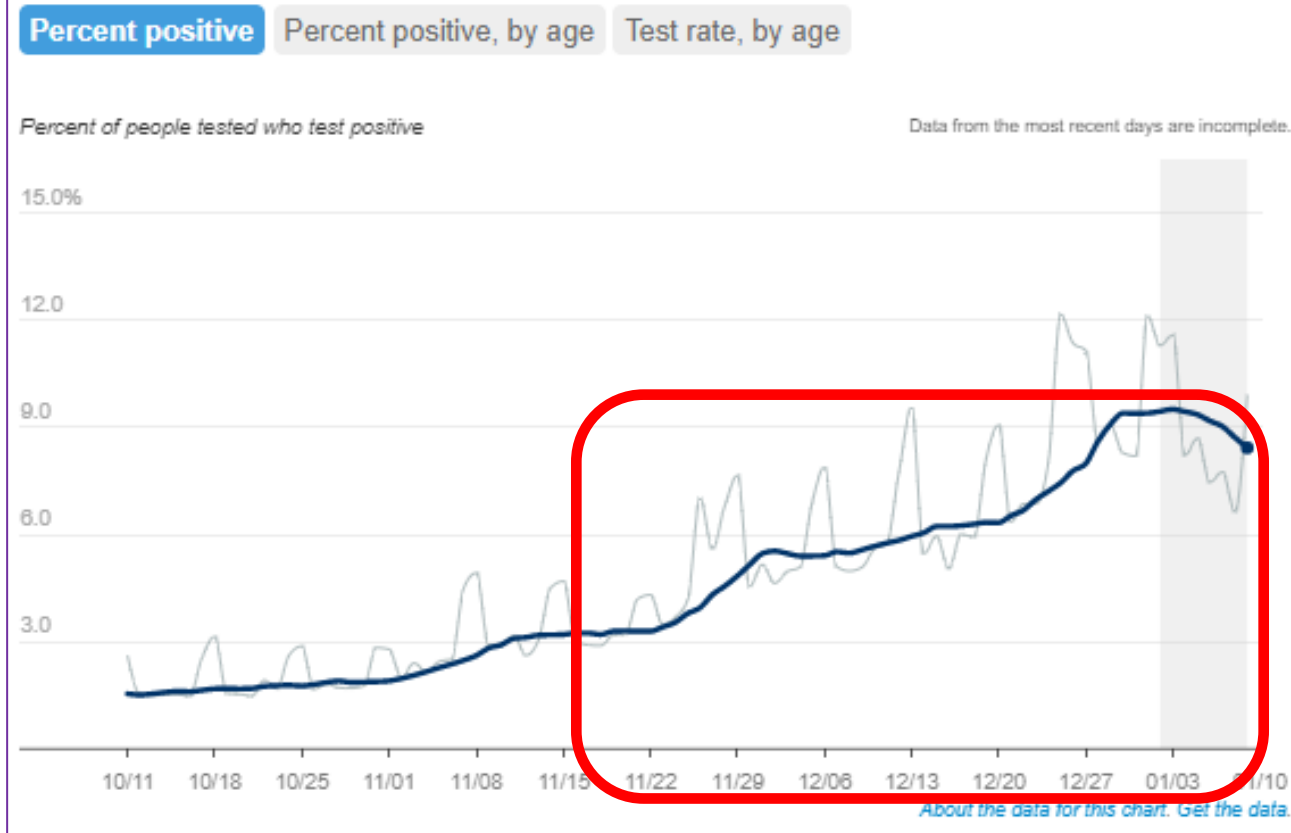


Log-quadratic trend adjustment was appropriate during fall

Appropriate temporal trend adjustment depends on observed trend during study period

Molecular Testing Citywide and by Age

These charts show percent positivity and test rate for molecular tests.



Recent trends more complex → switched to nonparametric trend adjustment

Option to adjust for purely spatial variation

- To detect areas with relative increases from baseline, even if still lower than the citywide average
- Will not detect areas with consistently high percent positivity
- Spatial adjustment: nonparametric, with spatial stratified randomization

New: Simultaneous Nonparametric Temporal and Spatial Adjustments

SaTScan - Software for the Spatial and Space-Time Scan Statistic

FileSessionWindowsHelp

R:\EmergencyEvents\2019_nCoV\SurvEpi\EpiData Unit Doc Ops\Mapping\SaTScan\Results\20210111\casefil...

InputAnalysisOutput

Type of Analysis

Retrospective Analyses:

☐ Purely Spatial

☐ Purely Temporal

☐ Space-Time

☐ Seasonal

☐ Spatial Variation in Temporal Trends

Prospective Analyses:

☐ Purely Temporal

☒ Space-Time

Probability Model

Discrete Scan Statistics:

☒ Poisson

☐ Bernoulli

☐ Space-Time Permutation

☐ Multinomial

☐ Ordinal

☐ Exponential

☐ Normal

☐ Uniform Time

Continuous Scan Statistics:

☐ Poisson

...

Scan For Areas With:

☒ High Rates

☐ Low Rates

☐ High or Low Rates

Time Aggregation

Units:

☐ Year

☐ Month

☒ Day

Length: 1 Days

Advanced >>

Advanced Analysis Features

Spatial Window

Temporal Window

Cluster Restrictions

Space and Time Adjustments

Inference

Border Analysis

Power Evaluation

Drilldown

Temporal Trend Adjustments

☐ None

☒ Nonparametric

☐ Log linear trend with 0.0 % per year

☐ Log linear with automatically calculated trend

☐ Log quadratic with automatically calculated trend

☐ Adjust for day-of-week

Spatial Adjustments

☐ None

☒ Nonparametric

Temporal, Spatial and/or Space-Time Adjustments

☐ Adjust for known relative risks

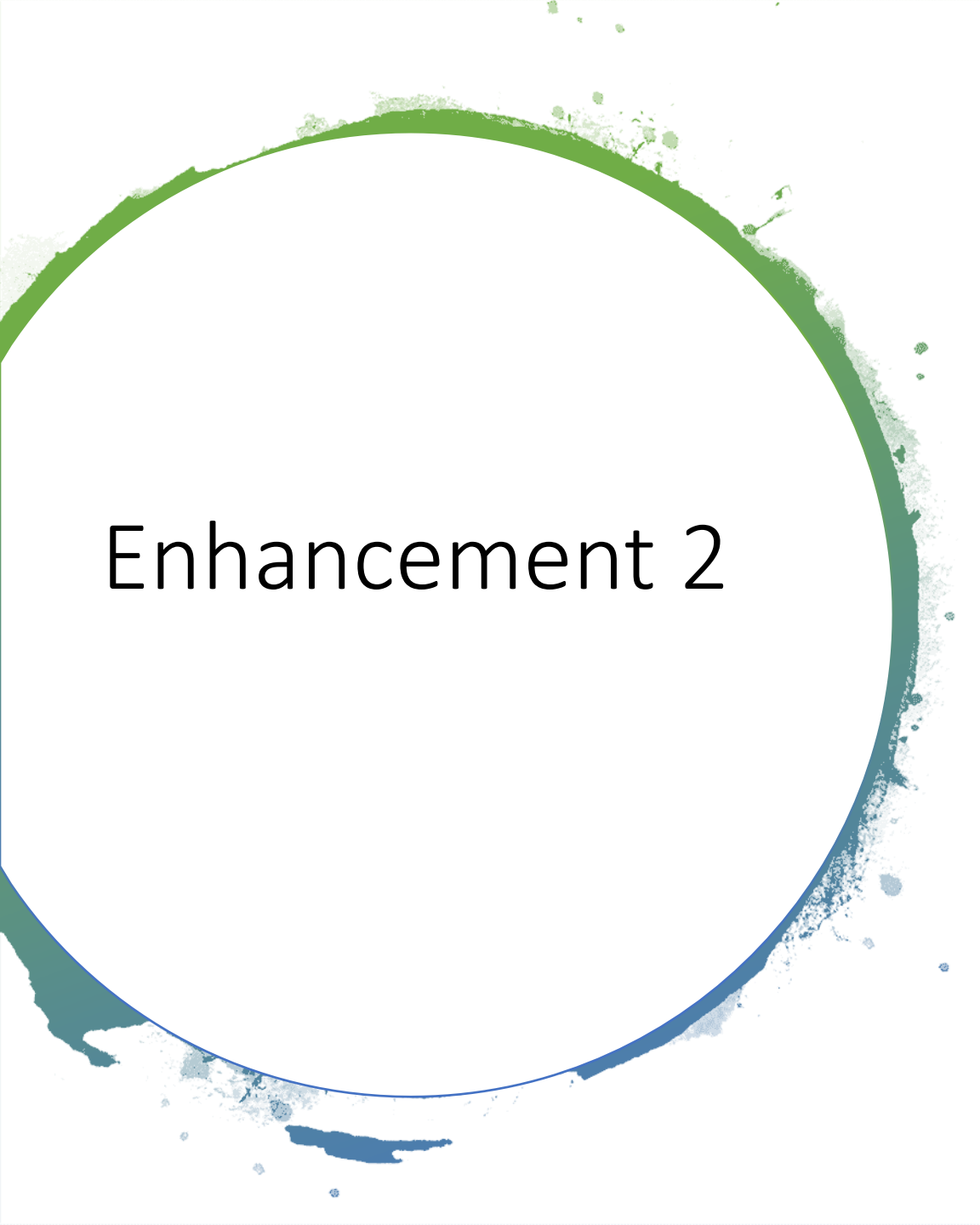
Adjustments File:

...

Set Defaults

Close

26



Enhancement 2

Detect clusters along a
locations network

Relationship Type

— shared edge

— shared point

— bridge connection

— manual



- R code to generate a census tract relationship file based on shared vertices using FIPS codes as inputs, with options:
 - To add connectivity via bridges
 - To exclude unpopulated areas

github.com/gmculp/satscan R functions

Locations Network

SaTScan - Software for the Spatial and Space-Time Scan Statistic

File Session Windows Help

Input Analysis Output

Case File: \\NASLOCSHARE240\AgencyShare\EmergencyEvents\2019_nCoV\SurvEpi\EpiData Unit Doc Ops\Mapping\SaTScan\Results\20210111\casefil...
Control File: (Bernoulli Model)
Study Period: Start Date: 2020 11 07 End Date: 2021 01 08
Population File: (Poisson Model)
Coordinates File: \\nasprgshare220\share\DIS\BCD\COMDISshared\Analyst_of_the_week\Maven\SaTScan\S
Grid File: (optional)
Time Precision: ☐ None ☐ Year ☐ Month ☒ Day ☐ Generic
Coordinates: ☒ Cartesian ☐ Lat/Long

Advanced >>

Advanced Input Features

Multiple Data Sets Data Checking Spatial Neighbors **Network**

Locations Network

☒ Specify locations through a network file
Network File: S:\BCD\COMDISshared\Analyst_of_the_week\Maven\SaTScan\SupportingFiles\CT2010_relationships.txt

CT2010_relationships - Notepad

File	Edit	Format	View	Help
36061000900			36085000300	
36005000100			36081012301	
36005000100			36081031700	
36005001900			36061019200	
36005001900			36061024000	
36005001900			36061024200	
36005001900			36081009900	
36005002300			36061019200	
36005002300			36061024200	
36005002500			36061019200	
36005002500			36061024200	
36005005100			36061021000	
36005005100			36061024200	

- Defines a network connection between 2 locations
- Euclidean distance is obtained from coordinates file

Set Defaults Close

Poll Question

Type answer in chat

Which spatial resolution(s) might you use for SaTScan analyses:

- Census tract
- ZIP Code
- ZIP Code Tabulation Area
- County
- Other

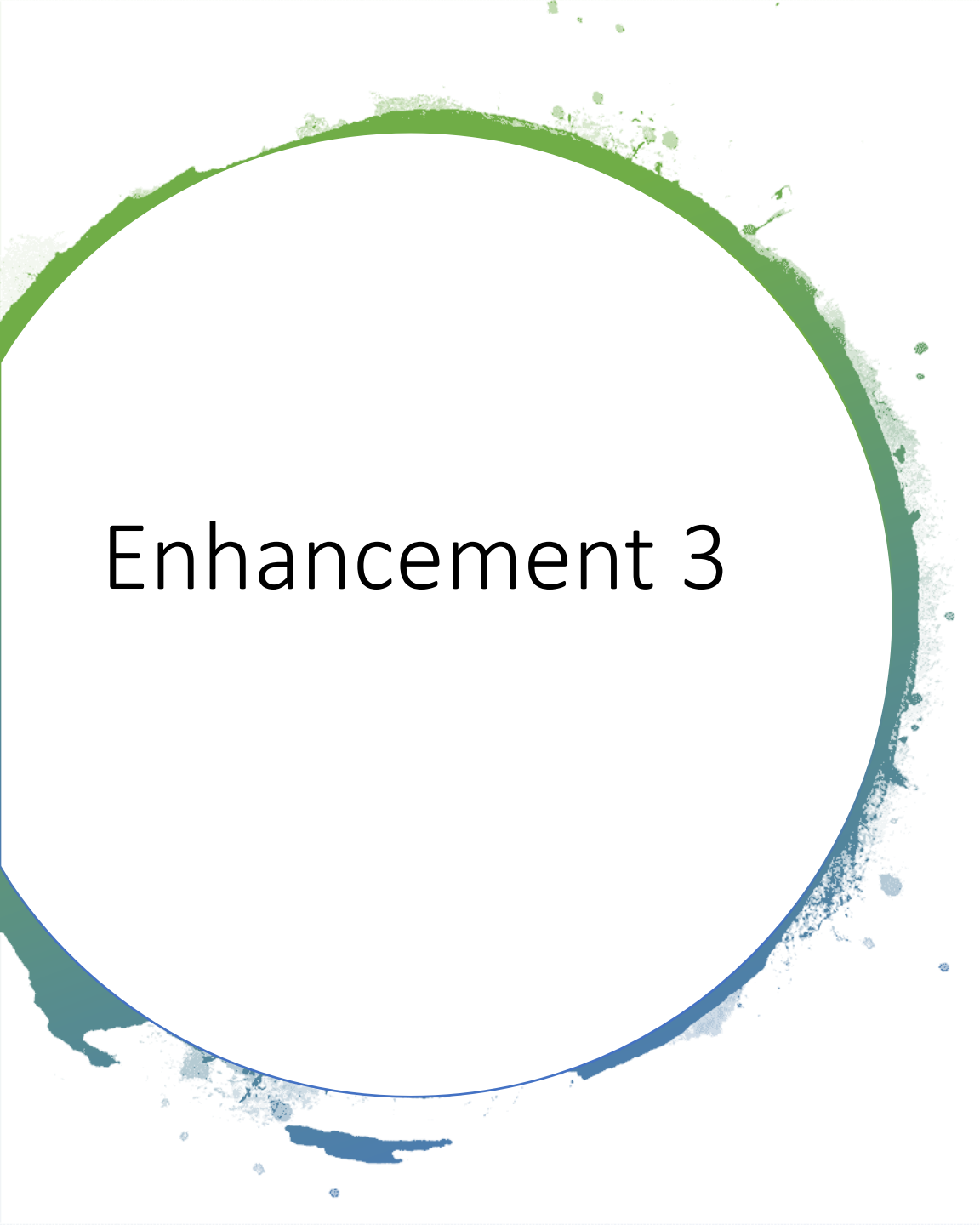
?

For illustration only – not real cluster!

- Without specifying a locations network, clusters can be unsatisfying for public health action:
 - Geographically large
 - Span unpopulated areas and bodies of water
 - Extend outside jurisdiction
- It is possible (but not necessary) to fine-tune using locations network

For illustration only – not real clusters!

- By instead searching along a network and using Euclidean distance from coordinates file, clusters can be more precise
- Detectable without specifying locations network, but cluster extent less precise — makes a difference mainly when clusters involve irregular geographies



Enhancement 3

Cluster drilldown

Drilldown: Setup

SaTScan - Software for the Spatial and Space-Time Scan Statistic

File Session Windows Help

R:\EmergencyEvents\2019_nCoV\SurvEpi\EpiData Unit Doc Ops\Mapping\SaTScan\Results\20210111\casefil...

Input **Analysis** Output

Type of Analysis

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Probability Model

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Continuous Scan Statistics:

- ☐ Poisson

Scan For Areas With:

- ☒ High Rates
- ☐ Low Rates
- ☐ High or Low Rates

Time Aggregation

Units: ☐ Year ☐ Month ☒ Day

Length: Days

Advanced >>

Advanced Analysis Features

Spatial Window	Temporal Window	Cluster Restrictions	
Space and Time Adjustments	Inference	Border Analysis	Power Evaluation

Drilldown

Cluster Drilldown

- ☒ Same Design as Main Analysis
- ☐ Purely Spatial Bernoulli
- ☐ With Day of Week Adjustment

Drilldown for Clusters with:

P-Value Less Than Or Equal:

Minimum Locations:

Minimum Cases:

Set Defaults Close

Drilldown: Output

SaTScan - Software for the Spatial and Space-Time Scan Statistic

File Session Windows Help



SaTScan v10.0 Beta 2 Build 1

Program run on: Wed Jan 13 10:31:16 2021

Prospective Space-Time analysis
scanning for clusters with high rates
using the Discrete Poisson model.
Adjusted for time trend with an annual decrease of 1.68306%.
Adjusted for purely spatial clusters with stratified randomization.

SUMMARY OF DATA

Study period.....: 1900/01/01 to 1942/12/31
Number of locations.....: 2171
Population, averaged over time.....: 13982
Total number of cases.....: 8455
Annual cases / 100000.....: 1406.4

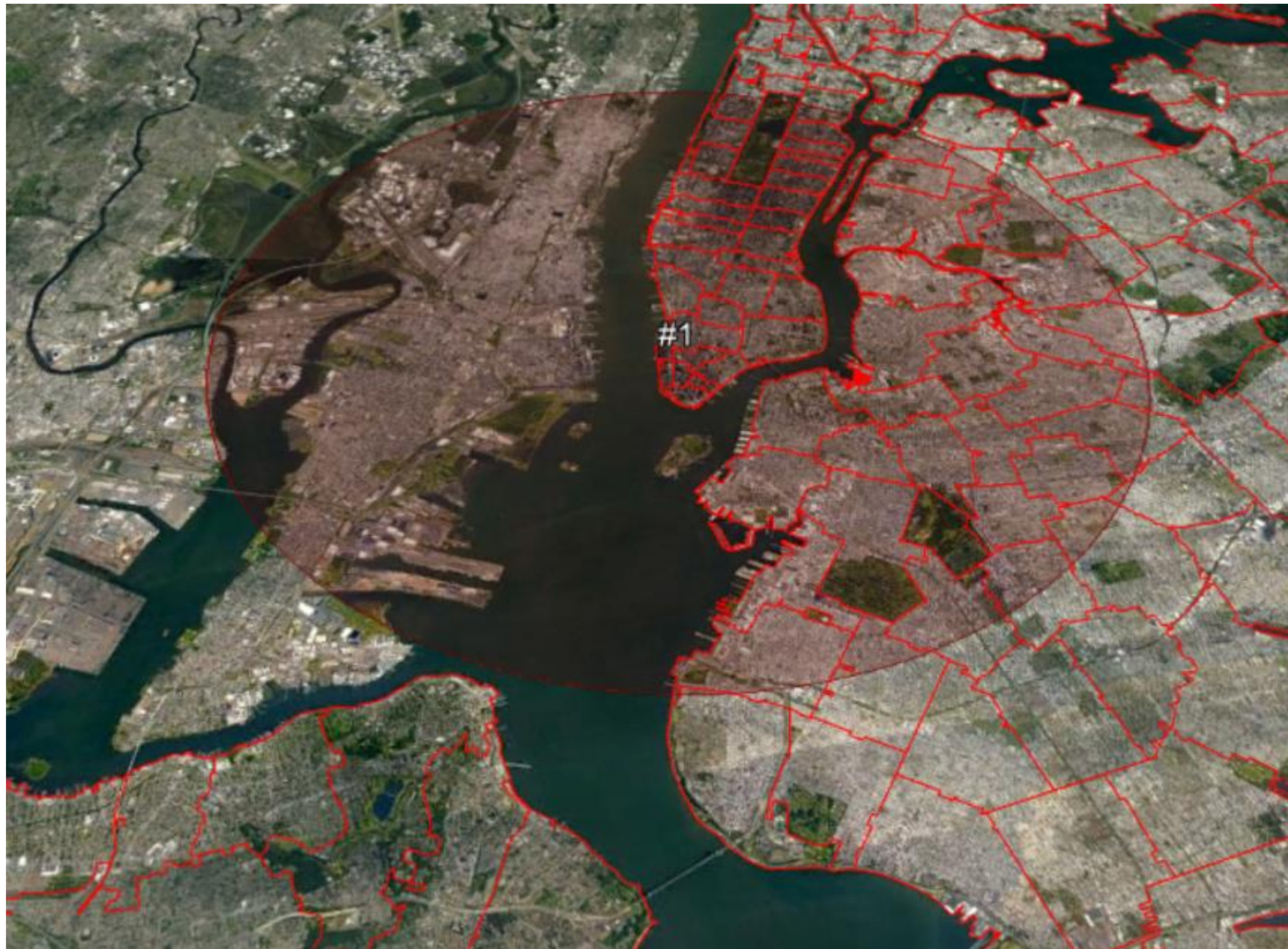
CLUSTERS DETECTED

Warnings/Errors Drilldown

- output.txt
 - C1-bin
 - C1-std
 - C2-std
 - C2C2-std

View Google Earth

For illustration only – not real cluster!



- Clusters can be unsatisfying for public health action:
 - Geographically large
 - Span unpopulated areas and bodies of water
 - Extend outside jurisdiction
- Risk could be uniformly high across cluster, but is it?

For illustration only – not real clusters!



First-level drilldown focuses to areas of highest concern within larger cluster

For illustration only – not real clusters!



Second-level
drilldown further
focuses areas of
concern

Pending SaTScan software enhancements for COVID-19

- Temporal and spatial adjustments for Bernoulli (0/1) model
- Software interface for prospective surveillance
- Automated outbreak alert notices
- Descriptive outbreak investigation tools (e.g., patient linelists)
- Support weekly prospective analysis using data with daily resolution
- Etc.
- Suggestions welcome for new enhancements

Aligning the analysis with the public health purpose

How do I detect newly emerging hotspots?

- Methods in [preprint](#), apply purely temporal and purely spatial adjustments
- Use longer minimum and maximum temporal cluster sizes (e.g., 7–21 days) to identify sustained increases

The New York Times

<https://nyti.ms/3iFIIFO>

How a Virus Surge Among Orthodox Jews Became a Crisis for New York

New York City had been holding off a second wave, but an uptick in cases in Brooklyn and Queens now threatens to bring one on.



By [Liam Stack](#) and [Joseph Goldstein](#)

Oct. 8, 2020, 3:00 a.m. ET

All summer, life had been returning to normal in the Orthodox Jewish neighborhoods of Brooklyn. On Eastern Parkway and along 13th Avenue, throngs of men in black hats and coats once again visited synagogues three times a day. Children went off to camp. Weddings filled large banquet halls.

Hardly anyone wore a mask.

Then in mid-August, the city's disease data detection program — called SaTScan — began to blare a warning about a rise of coronavirus cases in Borough Park. In response, the city's new health commissioner, Dr. Dave Chokshi, held an urgent conference call with Orthodox Jewish news outlets to warn of rising transmission and to express concern that public health advice was not being diligently followed in these communities.

Mayor de Blasio Expands Hyper-Local Testing Response in Sunset Park, Brooklyn

Effort will combine testing and comprehensive outreach to reach all 38,000 residents of Sunset Park through Friday, August 21st

Aug 12, 2020

[See all News →](#)

New York, NY

Mayor de Blasio today announced that the City will activate the next stage of its hyper-local COVID-19 response in Sunset Park, Brooklyn. As the area continues to see low testing rates and higher rates of positivity, the City will deploy additional testing and outreach resources to ensure residents can immediately safely separate and receive assistance through supportive services, such as food and financial counseling

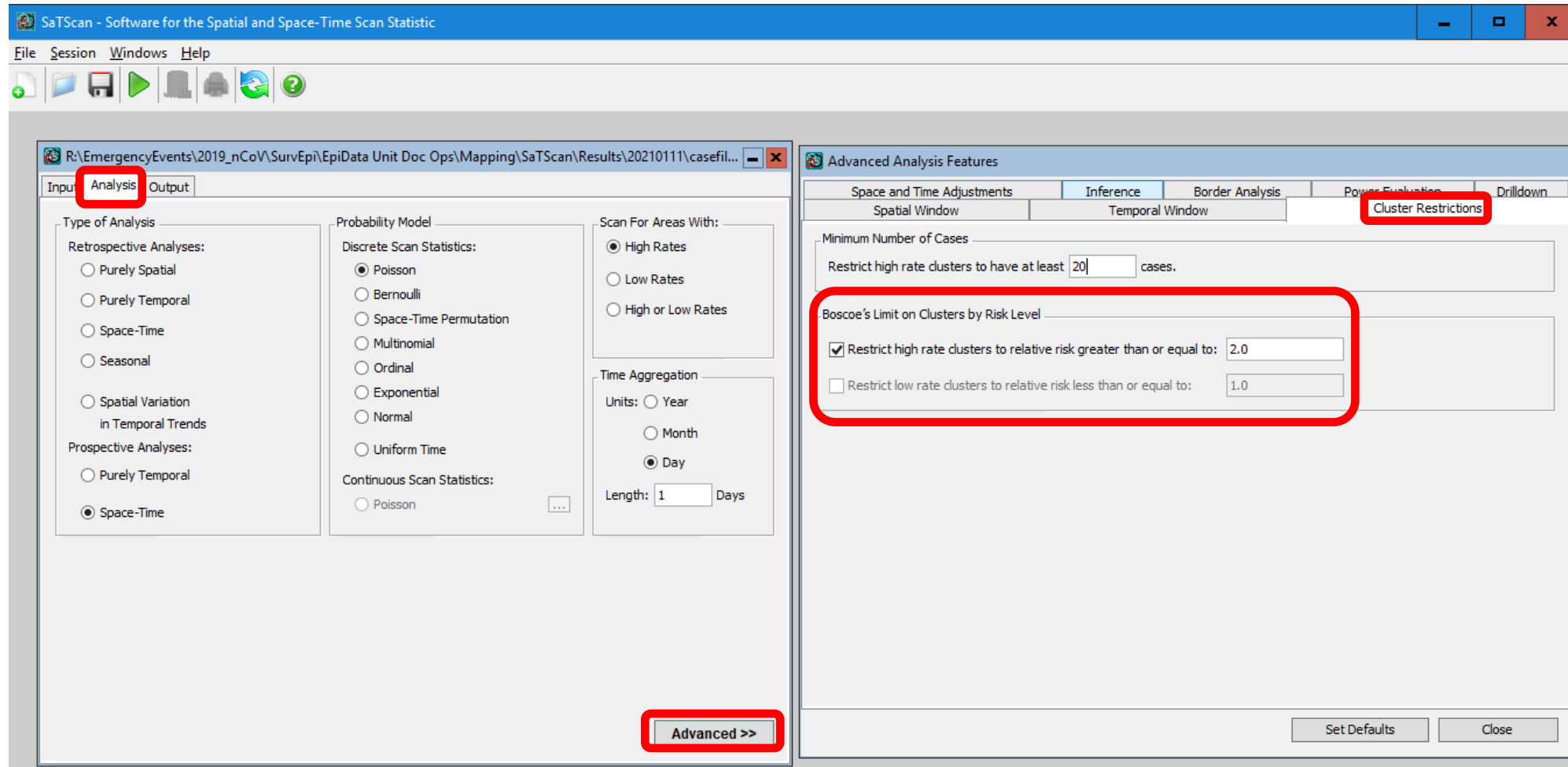
"A warning sign is blinking, and we are flooding the zone in Sunset Park to reach as many people as we can," said **Mayor Bill de Blasio**. "We know that testing and tracing is the key to reopening our city safely, which is why we are doing everything we can to connect people with the resources they need to protect themselves and their loved ones."

How do I use clusters to search for epidemiologic linkages?

- Methods in [preprint](#), apply purely temporal and purely spatial adjustments
- Use shorter minimum and maximum temporal cluster sizes (e.g., 3–7 days) to identify quickly emerging clusters
- Interview patients in clusters to collect and compare potential common exposures
 - Proof-of-concept: a surveillance investigator determined two patients in a cluster had attended the same gathering
 - Ultimately low-yield: NYC DOHMH discontinued reactively interviewing cluster patients for linkages and instead used clusters to proactively target resources and communications
- Similar methods could be used to prioritize areas to collect specimens for whole-genome sequencing, to search for variants with increased transmissibility

How do I force clusters to be geographically smaller?

- Arbitrary/not generally recommended: impose a maximum spatial cluster size
- Use new v.10.0 beta features: specify a locations network; drilldown
- Impose a minimum relative risk



How do I support geographic resource allocation when transmission is widespread?

- Apply purely temporal but not purely spatial adjustments to include areas with sustained increases
- Use longer minimum and maximum temporal cluster sizes (e.g., 14–21 days)
 - Require percent positivity in most recent week to be 1.5X citywide
- Generate “microclusters” by imposing minimum relative risk (e.g., 2.0)
- Impose minimum number of cases (e.g., 20) to avoid directing resources to areas with few detected cases
- Switch from cluster-level to borough-level summaries
- Given inequitable COVID-19 burden, there are always clusters; helps to focus resources where currently most needed

How do I detect clusters using both PCR and antigen tests?

- Prepare separate case and population files for each test type
- Analyze multiple data sets, adjusting for test type

The screenshot displays the SaTScan software interface, which is used for spatial and space-time scan statistics. The interface is divided into two main panels: 'Input' and 'Advanced Input Features'.

Input Panel:

- Case File:** A text box containing the path \\NASLOCSHARE240\AgencyShare\EmergencyEvents\2019_nCoV\SurvEpi\EpiData Unit Doc Ops\Mapping\SaTScan\Results\20210111\casefil... with a browse button (...).
- Control File:** A text box with the label (Bernoulli Model) and a browse button (...).
- Study Period:** A section with 'Start Date' (Year: 2020, Month: 11, Day: 07) and 'End Date' (Year: 2021, Month: 01, Day: 08).
- Population File:** A text box with the label (Poisson Model) and a browse button (...).
- Coordinates File:** A text box with the path \\nasprgshare220\share\DIS\BCD\COMDISshared\Analyst_of_the_week\Maven\SaTScan\S... and a browse button (...).
- Grid File:** A text box with the label (optional) and a browse button (...).
- Time Precision:** Radio buttons for None, Year, Month, Day (selected), and Generic.
- Coordinates:** Radio buttons for Cartesian (selected) and Lat/Long.
- Advanced >>** A button at the bottom right of the Input panel.

Advanced Input Features Panel:

- Multiple Data Sets:** A tab selected at the top of the panel.
- Additional Input Data Sets:** A section with a list box containing 'Data Set 2' and buttons 'Add' and 'Remove'.
- Purpose of Multiple Data Sets:** A section with two radio buttons:
 - Multivariate Analysis (clusters in one or more data sets)
 - Adjustment (clusters in all data sets simultaneously)** (selected)
- Set Defaults** and **Close** buttons at the bottom right.

How do I prioritize clusters?

- Percent positivity
- Relative risk
- Case count
- Epidemic curve trajectory
- Radius
- Demographics
- Persistence: how quickly can resources be reallocated?
- Less important: statistical significance

How do I notice when a lab stops sending SARS-CoV-2 reports, overall or for one test type?



Journal of Public Health Management and Practice
November/December 2020, Volume 26 (6), p 570–580
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doi: 10.1097/PHH.0000000000000969
ISSN: 1078-4659

RESEARCH REPORTS: PRACTICE FULL REPORT [Full-featured View ↗](#)

Detecting Drop-offs in Electronic Laboratory Reporting for Communicable Diseases in New York City

Greene, Sharon K. PhD, MPH; Andrews, Erin M. DrPH; Evans Lloyd, Pamela MPA; Baumgartner, Jennifer MSPH; Peterson, Eric R. MPH [Author Information](#) ▾

Email

Cite

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Article

Complete Reference

doi: [10.1097/PHH.0000000000000969](https://doi.org/10.1097/PHH.0000000000000969)

SaTScan Resources for COVID-19 (and other Diseases)

- [Preprint](#): Detecting Emerging COVID-19 Community Outbreaks at High Spatiotemporal Resolution — New York City, June–July 2020
 - Corresponding author: Sharon Greene (sgreene4@health.nyc.gov)
- Code for automating prospective SaTScan analyses for COVID-19 in batch mode and outputting cluster summaries and visualizations
 - In SAS, NYC DOHMH: github.com/CityOfNewYork/communicable-disease-surveillance-nycdohmh
 - For questions: Eric Peterson (epeterson@health.nyc.gov) and Alison Levin-Rector (alevinrector@health.nyc.gov)
 - In R, Cook County DPH: github.com/kb230557/rsatscan-cluster-detection-covid
- Updating [rsatscan](#)
 - For suggestions and testing, contact Gretchen Culp (gculp@health.nyc.gov)
- Evaluate SaTScan version 10 beta release
 - Instructions for download on [Basecamp](#)
 - For [Basecamp](#) access: Maria Patselikos (mpatselikos@cste.org), Scott Troppy (scott.troppy@state.ma.us), or Ricardo Contreras (riccontreras@ph.lacounty.gov)
 - Code to generate network locations file: github.com/gmculp/satscan_R_functions

Extra Slide

When should I apply purely spatial adjustments?

		Current period: % positivity in cluster area		
		Low	Medium	High
Baseline period: % positivity in cluster area	Low	not of interest	to detect: must apply purely spatial adjustment	generally detectable regardless of purely spatial adjustment
	Medium		not of interest, stable	
	High		not of interest, declining	to detect: must <u>not</u> apply purely spatial adjustment

- Want to detect areas newly emerging with relative increases from baseline, even if still lower than average citywide? *Apply spatial adjustment.*

vs.

- Want to detect areas currently with highest transmission, even if stable (not necessarily newly emerging)? *Do not apply spatial adjustment.*