Modelling pluvial flooding in Portland using Malstroem Bluespots

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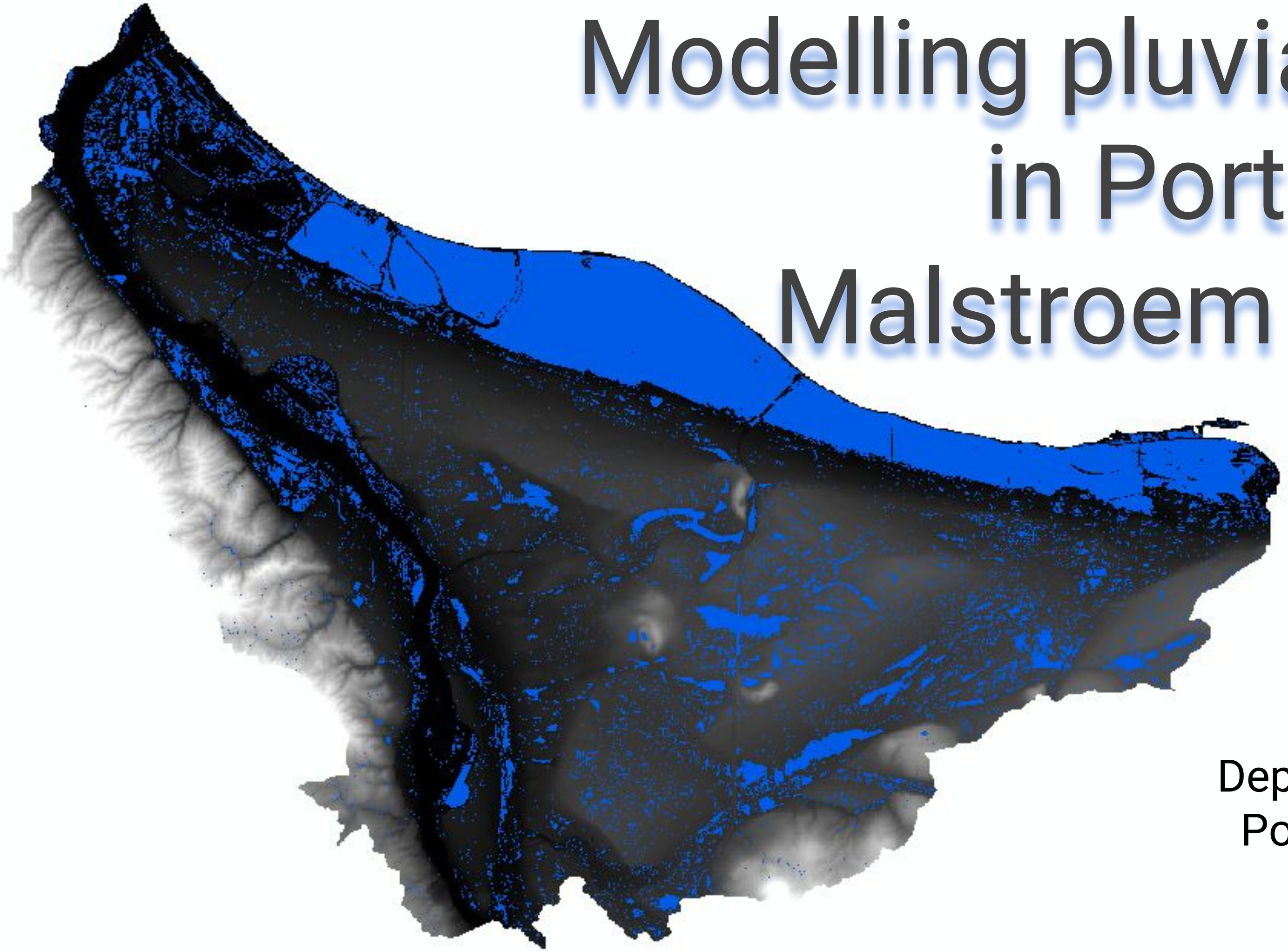
12/3/2018

Abstract - Malstroem bluespot modelling can be a useful tool to model pluvial flooding in an urban environment, especially in cities with limited monetary and digital resources. Pluvial flooding is small scale flooding that can be caused by many factors, such as impervious surface depressions in the landscape where water naturally tends to pool or the incapacity of a stormwater system to manage increased precipitation inputs in an environment. The need to model pluvial flooding as will grow in importance with climate change, land use change, and aging infrastructure. Malstroem bluespot methodology was applied to three HUC 6 watersheds covering the spatial extent of Portland, Oregon for a 100 year, 1 hour rainfall event using a high resolution Lidar DEM. After accounting for the ability of the sewer system to convey stormwater, analysis shows modelled flooding covering most of Portland, though the percent of which the bluespots are filled with water varies. When bluespot volume values are aggregated to a census block group scale, clustering of high flooding volume are apparent in north, northeast and east Portland. Bluespot volume does not correlate with citizen based flood reports. A spatial lag model shows that 39% of the variance of bluespot volume is associated with a decrease in AB soil type, green infrastructure, population density, % of population in poverty, % of population with a higher education, and an increase in impervious surface.

Keywords: Pluvial flooding, bluespots, DEM, Malstroem, Portland OR, flood reports



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What is pluvial flooding?

When precipitation intensity exceeds the capacity of natural and engineered drainage systems (Rosenzweig et al 2018).

In Portland: flooded intersections, basements, sidewalks, parking lots

Expected to increase with climate change, urbanization, aging infrastructure
(Hossain et al 2015, Rosenzweig et al 2018)

Portland pluvial flooding *is not:*

Why doesn’t pluvial flooding get attention?

1. Pluvial flooding is a “solved” technical problem- sewer systems, culverts, pumps
    a. Conventional engineering is based on static land cover and climate, past climate
2. Pluvial flooding is often assumed to be a “nuisance” with minimal impacts
3. Pluvial flooding is excluded in flood frequency analyses

(Rosenzweig et al 2018)

Research questions:

1. How much pluvial flooding could be expected from an 100 year, 1 hour rain event?

2. Is there a correlation between flood reports and bluespots?

3. What explains the spatial distribution of bluespot volume?

So how do we model pluvial flooding?

Malstroem bluespots: Methodology

The malstroem model uses command line tools and a python api to calculate:

- Depressionless (filled, hydrologically conditioned) terrain models
- Surface flow directions
- Accumulated flow
- Blue spots
- Local watershed for each bluespot
- Pour points (point where water leaves blue spot when it is filled to its maximum capacity)
- Flow paths between blue spots
- Fill volume at specified rain incidents
- Spill over between blue spots at specified rain incidents

(Balstrom and Crawford 2018)

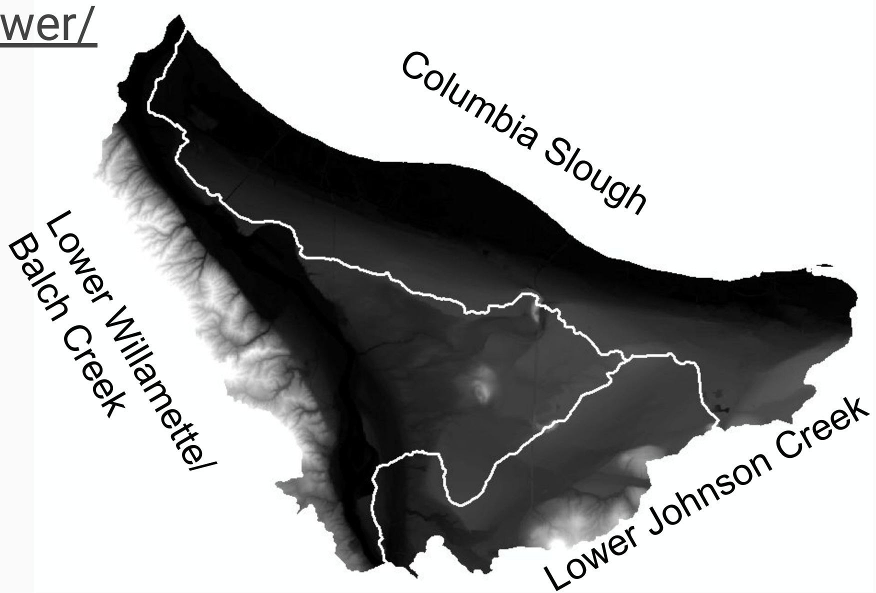
Malstroem: Data

High resolution DEM of Portland, Oregon (2014) from
https://gis.dogami.oregon.gov/maps/lidarviewer/

3 HUC 6 watersheds for Portland (RLIS):

1. Lower Willamette
2. Columbia Slough
3. Lower Johnson Creek

→ *Great for cities with limited resources!*



Malstroem: Assumptions

1. The model assumes that the terrain is an impermeable surface.
2. The model does not know the concept of time.
   a. This means that the capacity of surface streams is infinite no matter the width or depth. Streams won't flow over. The end result is the situation after infinite time, when all water has reached its final destination.
3. Water flows from one cell to another (the D8 method)

(Balstrom and Crawford 2018)

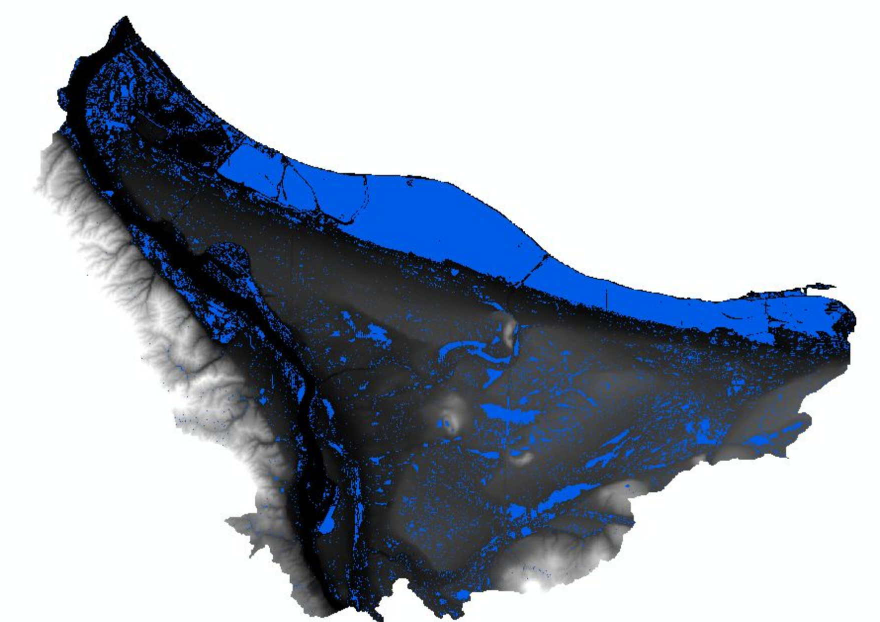
For example...

c:\Python27\Scripts>malstroem complete ***-r8*** *-filter "****area > 18.58 and volume > 5.66****"*
-dem F:\Malstroem\Portland_DEMs\Pdx_wtrsh_M.tif -outdir E:\PDX_8mm

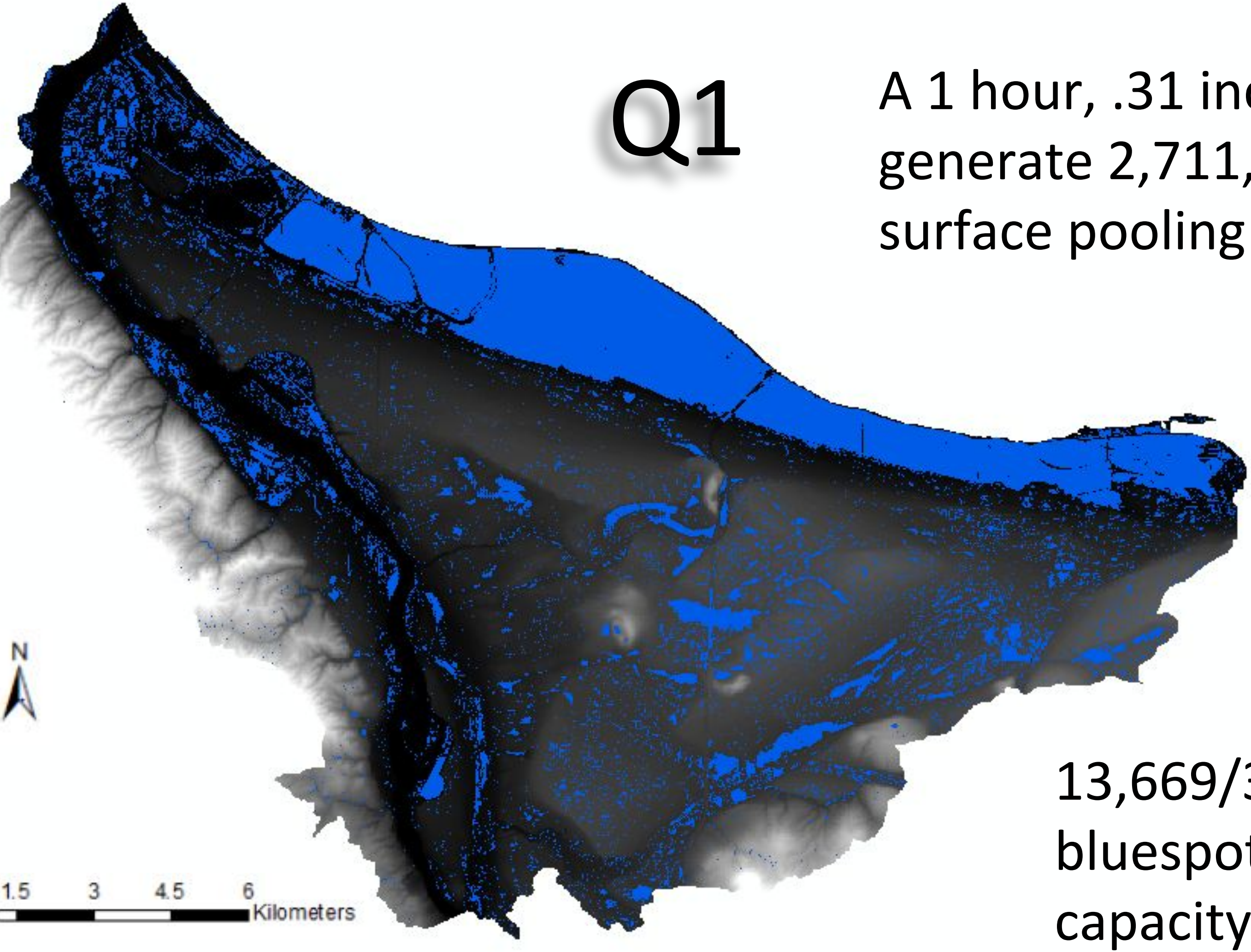
Table

8mm_bluespot_project

FID	Shape *	bspot_id	percent	FID_1	pctv_8	nodetype	cell_row	dstrnodeid	wshed_area	rainv_8	v_8	nodeid	spillv_8	cell_col	bspot_area	bspot_id_1	bspot_vol
0	Polygon	1	0	1	100	pourpoint	73	0	860.375053	6.883	6.210799	1	0.672201	4106	160.536453	1	6.210799
1	Polygon	2	0	2	100	pourpoint	138	0	6836.177295	54.689418	30.758171	2	23.931247	4061	514.218326	2	30.758171
2	Polygon	3	0	3	97.184062	pourpoint	131	2	941.479407	7.531835	7.531835	3	0	4096	182.275764	3	7.750073
3	Polygon	4	0	4	100	pourpoint	163	0	1584.461347	12.675691	10.125182	4	2.550508	4035	282.611048	4	10.125182
4	Polygon	5	0	5	26.545721	pourpoint	250	8	5020.944797	40.167558	40.167558	5	0	4014	2112.893839	5	151.314626
5	Polygon	6	0	6	47.662568	pourpoint	224	0	1671.418593	13.371349	13.371349	6	0	3968	552.680185	6	28.054193
6	Polygon	7	0	7	100	pourpoint	242	0	6274.299709	50.194398	18.408138	7	31.786259	3916	444.819756	7	18.408138
7	Polygon	8	0	8	77.636271	pourpoint	231	6	798.501629	6.388013	6.669787	8	0	3996	209.03184	8	8.591071
8	Polygon	9	0	9	100	pourpoint	263	8	2072.759725	16.582078	16.300304	9	0.281774	4001	320.236779	9	16.300304
9	Polygon	10	0	10	7.743373	pourpoint	536	20	12444.919626	99.559357	99.559357	10	0	3892	6219.115304	10	1285.736273
10	Polygon	11	0	11	100	pourpoint	368	0	6527.6463	52.22117	25.184619	11	32.771464	3814	411.374661	11	25.184619
11	Polygon	12	0	12	100	pourpoint	431	0	5514.259939	44.11408	28.686039	12	15.428041	3966	323.581288	12	28.686039
12	Polygon	13	0	13	96.084469	pourpoint	413	0	1467.403517	11.739228	11.739228	13	0	4011	199.834439	13	12.217613



- PDX_11mm
  - vector
    - events.shp
    - nodes.shp
    - pourpoints.shp
    - streams.shp
  - bluespots.tif
  - bs_depths.tif
  - filled.tif
  - flowdir.tif
  - watersheds.tif



Q1

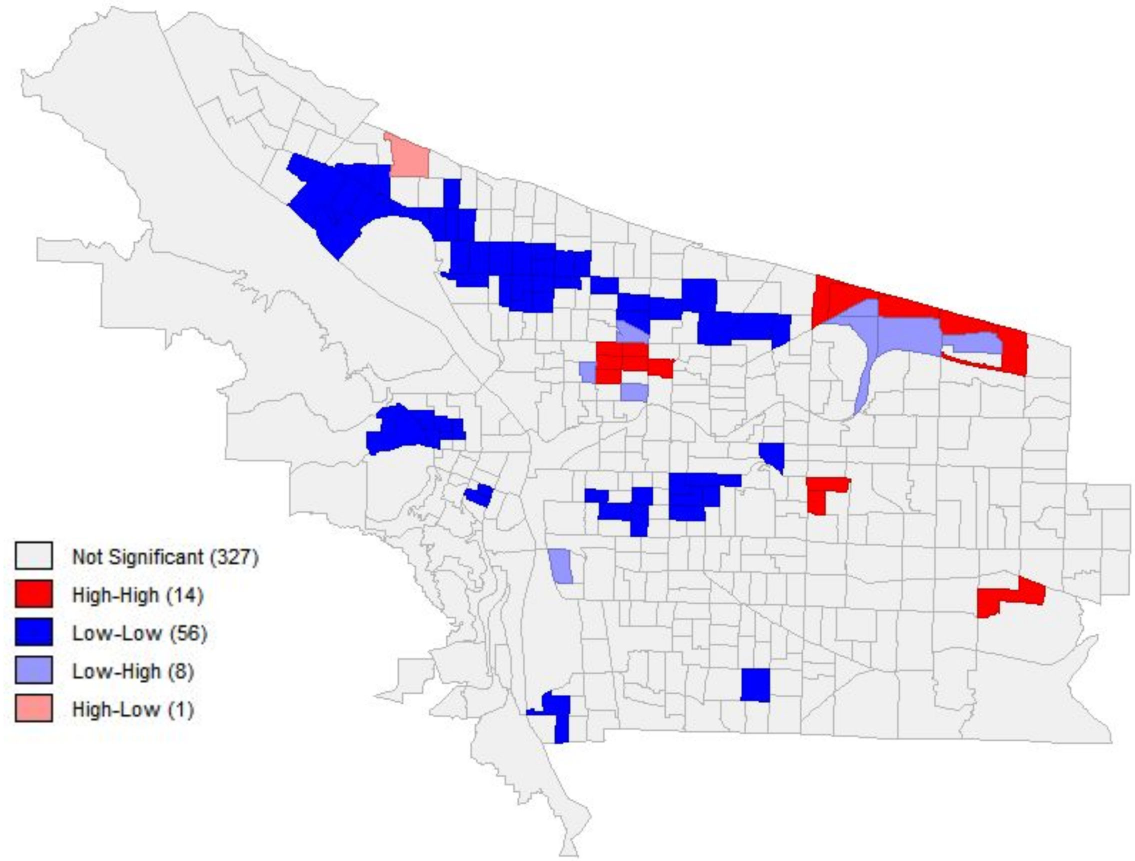
A 1 hour, .31 inch/8mm event can generate 2,711,041.59 m^3 of surface pooling

13,669/32,596 (~42%) bluespots filled to 100% capacity

Moran's I: Bluespot volume

Moran's I: 0.29

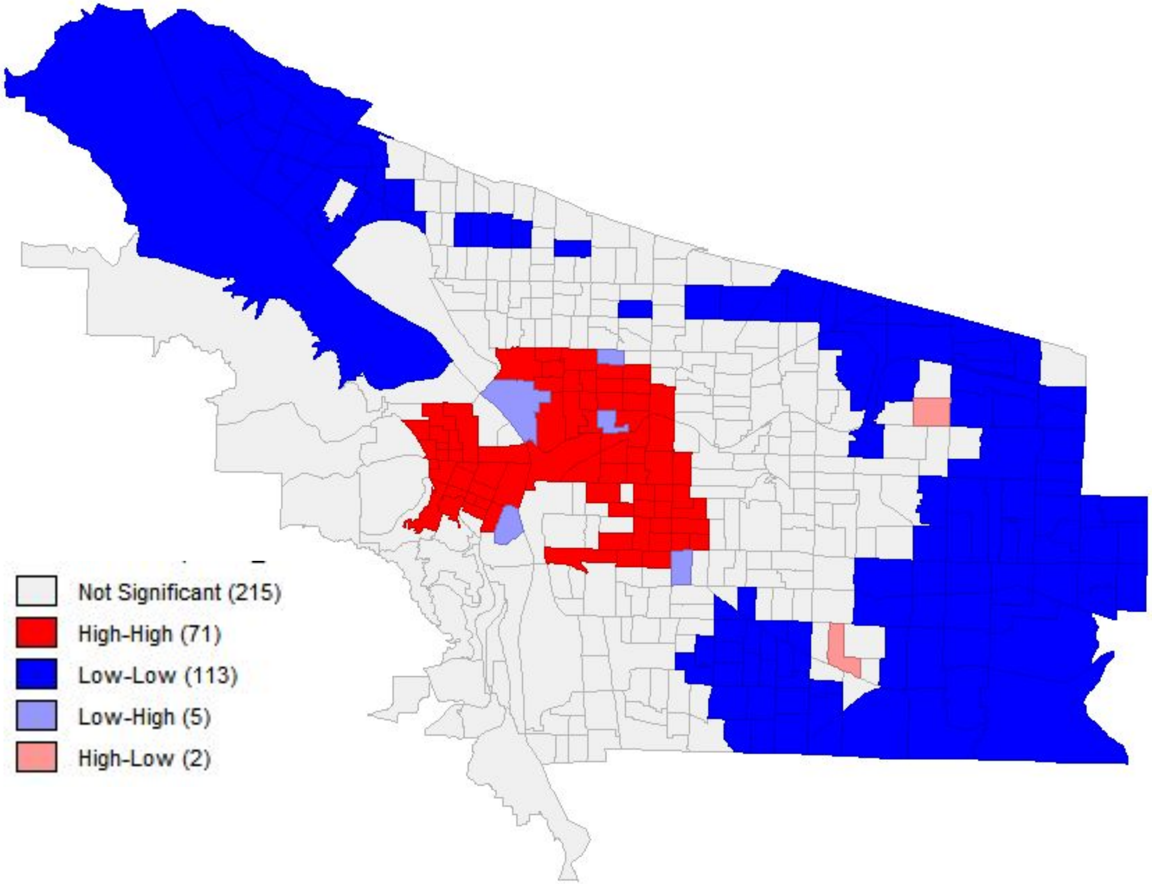
P-value: 0.000



Moran's I: Citizen-based Flood reports

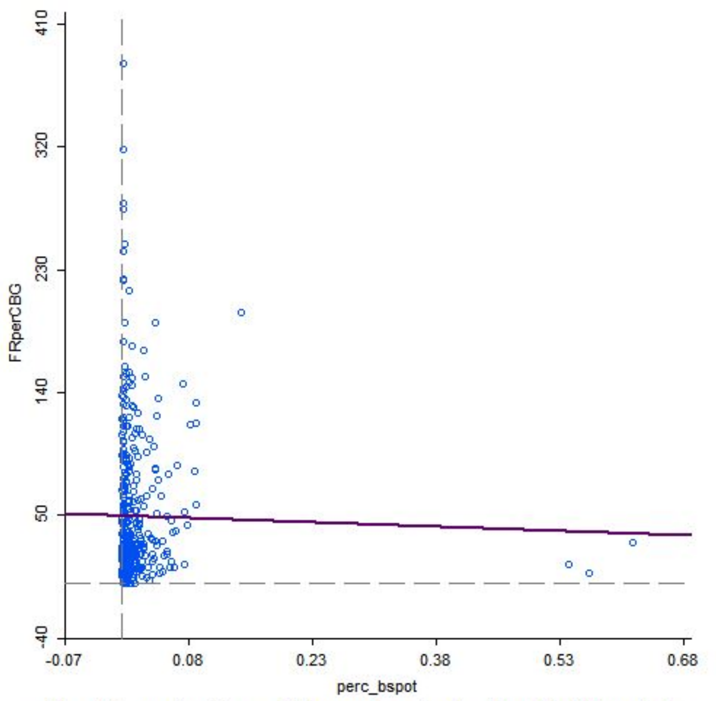
Moran's I: 0.63

P-value: 0.000



Is there a correlation between flood reports and bluespots?

Q2



#obs	R^2	const a	std-err a	t-stat a	p-value a	slope b	std-err b	t-stat b	p-value b
406	0.000	50.128	2.801	17.898	0	-21.443	51.549	-0.416	0.678
0	0	0	0	0	0	0	0	0	0
406	0.000	50.128	2.801	17.898	0	-21.443	51.549	-0.416	0.678

no….

So what explains bluespot volume?

Q3

→ Spatial lag model

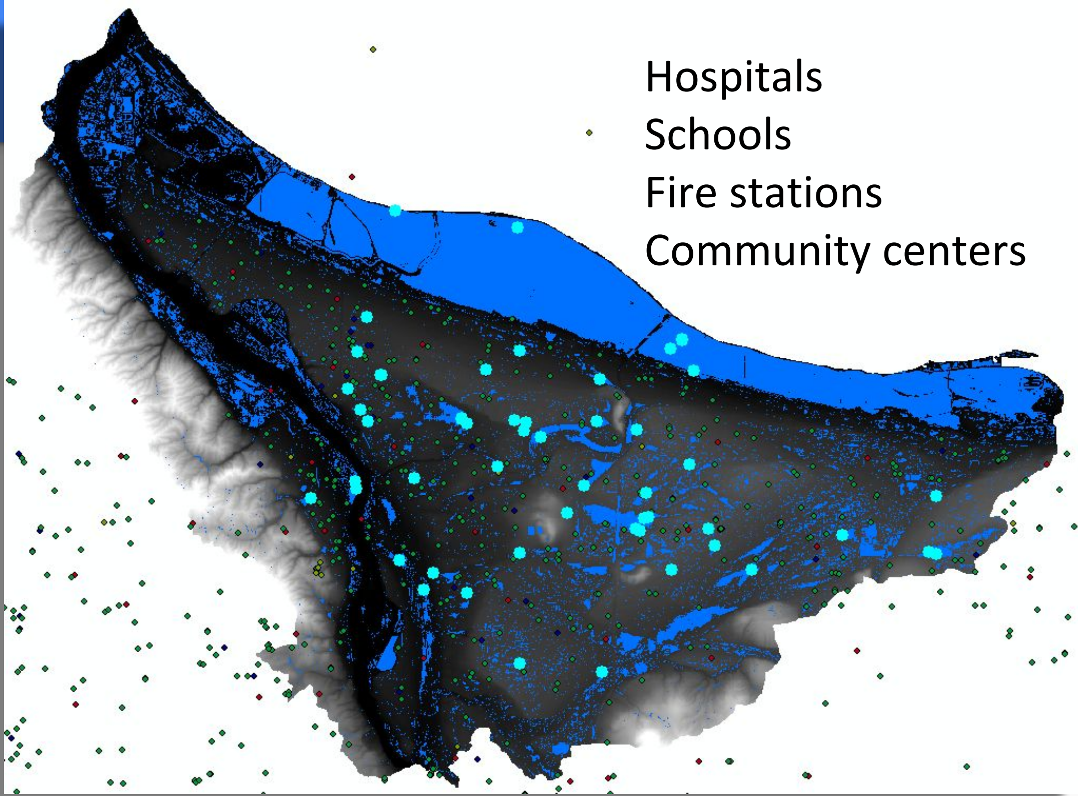
Independent Variables		Log (Bluespot area)	
		Coefficient	p-value
Biophysical	% A/B Soil	-0.629	0.011
	% Green infrastructure	-0.004	0.002
	% Impervious	2.236	0.000
Sociodemographic	% Poverty	-0.810	0.086
	% Higher Education	-1.598	0.000
	Population Density (per 10,000)	-0.911	0.003
	Lag coefficient (rho)	0.600	0.000
R^2		**0.39**	
SE of regression		**1.14**	

Further questions

What type of critical facilities are located within bluespots?

How can we better model climate change? Land use change?

How does the bluespot model compare across other cities in the US?



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