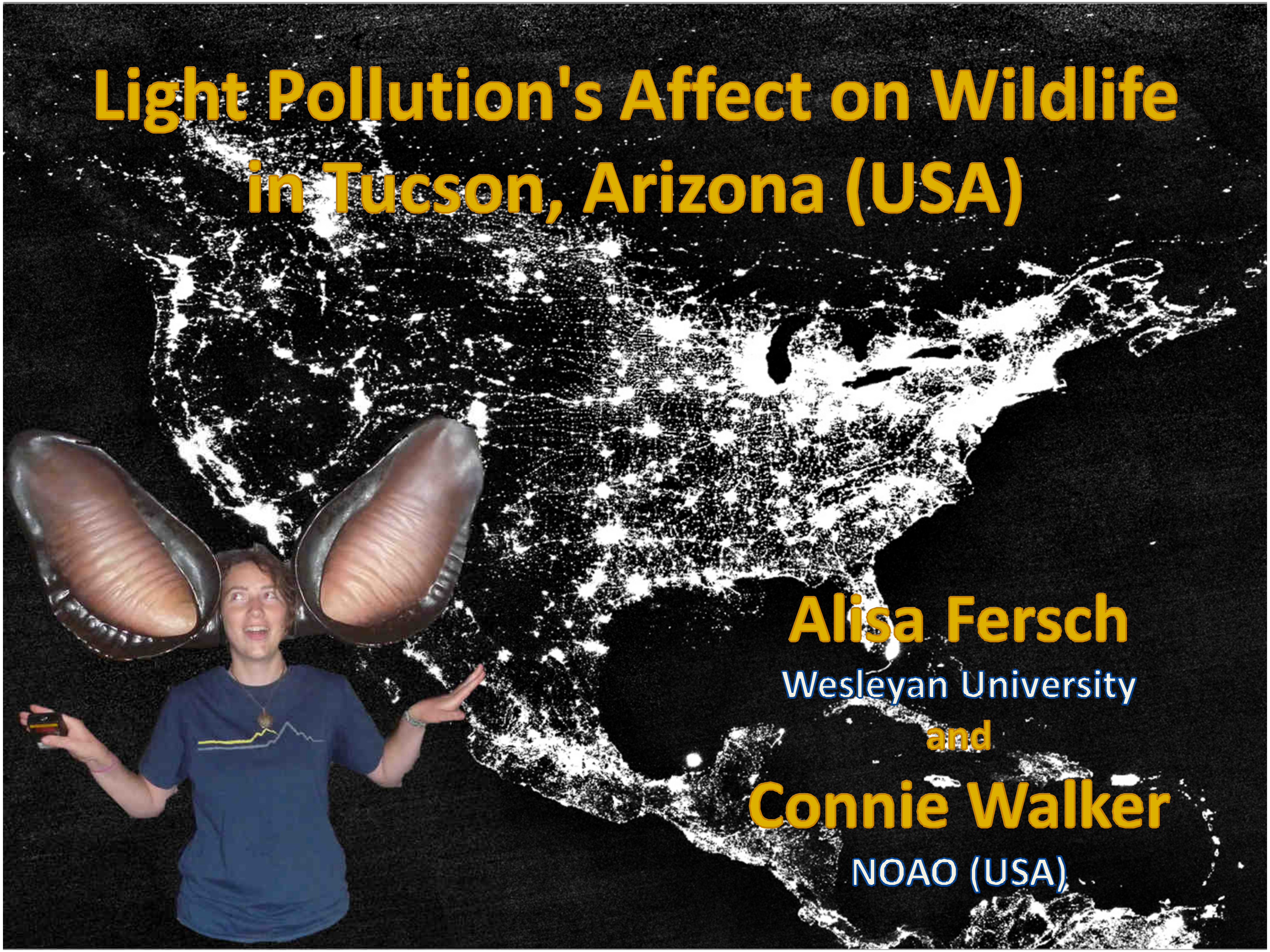


Light Pollution's Affect on Wildlife in Tucson, Arizona (USA)

Alisa Fersch
Wesleyan University
and
Connie Walker
NOAO (USA)

Goals

- Collect more light pollution data around Tucson, using the Sky Quality Meter (SQM)
- Create a contour map of the sky quality
- Run an analysis to see if light is affecting the distribution of lesser long-nosed bats

Introduction: Light Pollution

- “Any adverse effect of manmade light” (IDA)
- But it’s not just a problem for astronomers.
- → Ecological Light Pollution

- **Can affect animals’ foraging, reproduction, migration and communication**

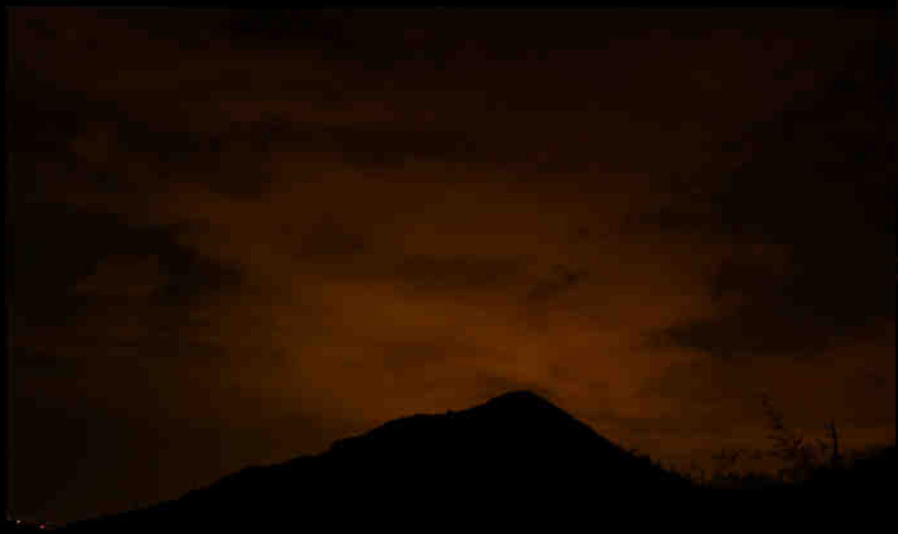
Introduction:
General effects of light pollution on bats

- Increased light may impair vision; may be more sensitive to UV

- Delayed emergence from day roosts

- Lights can act as barriers, causing bats to change flight routes

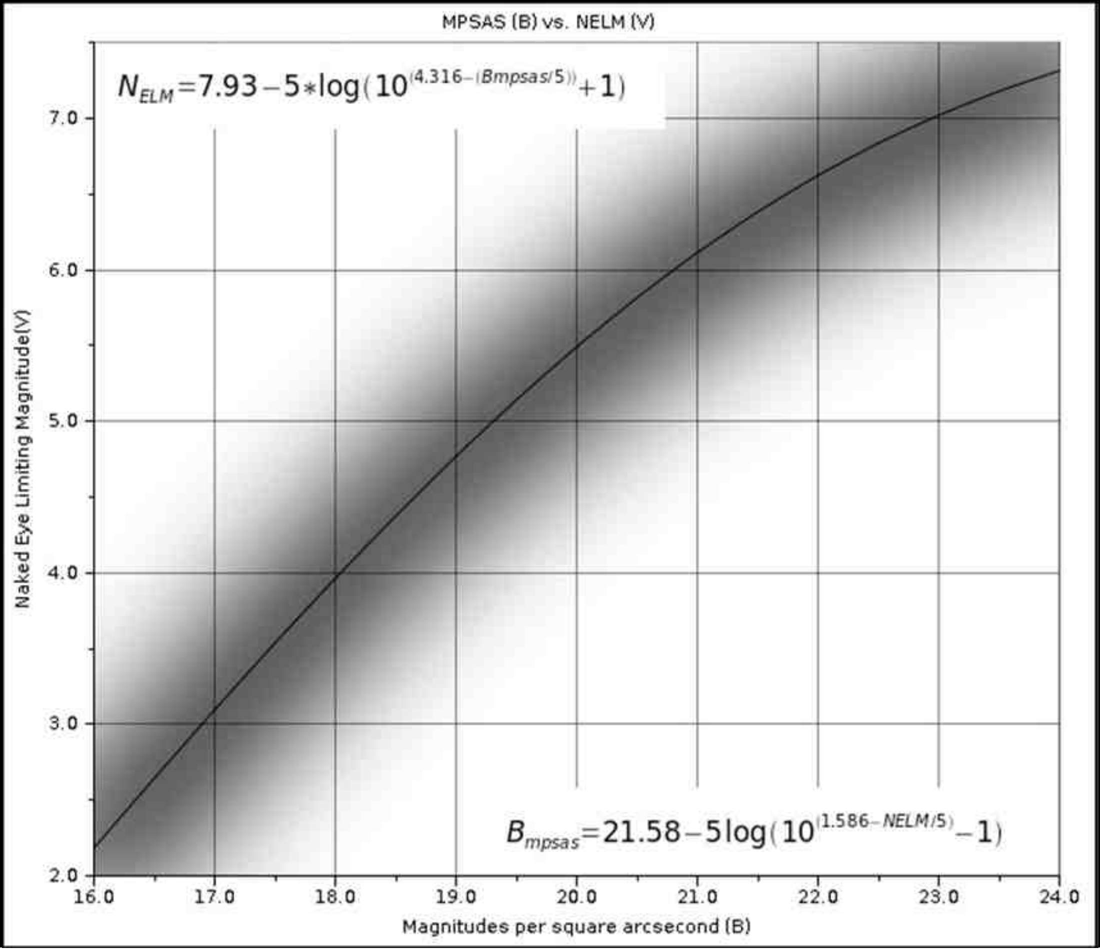
Step 1: Data Collection



Data Collection: The Gadget

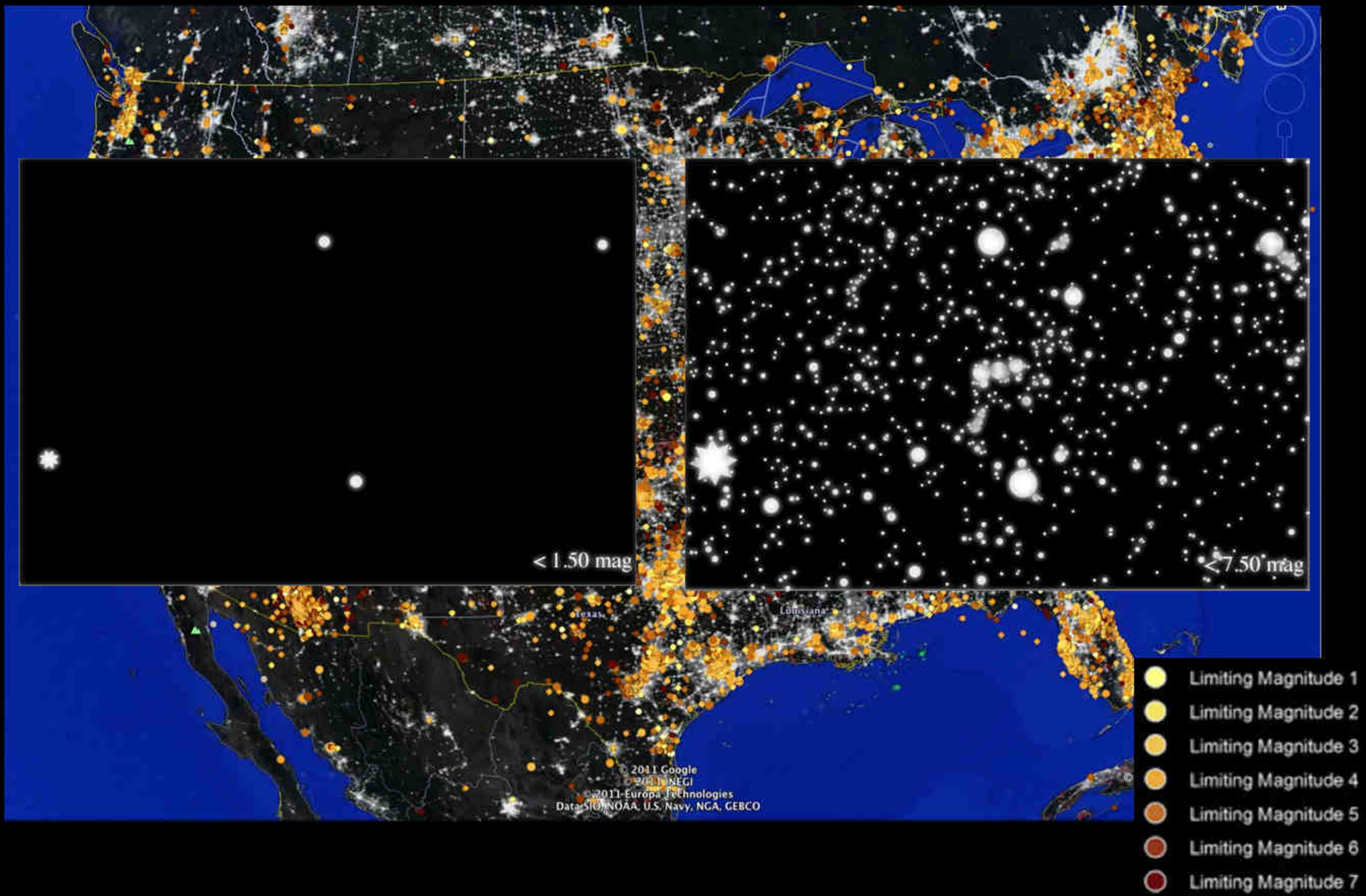
The "Sky Quality Meter"
...or SQM

- Measures brightness of the sky in units of magnitudes/arcsec²



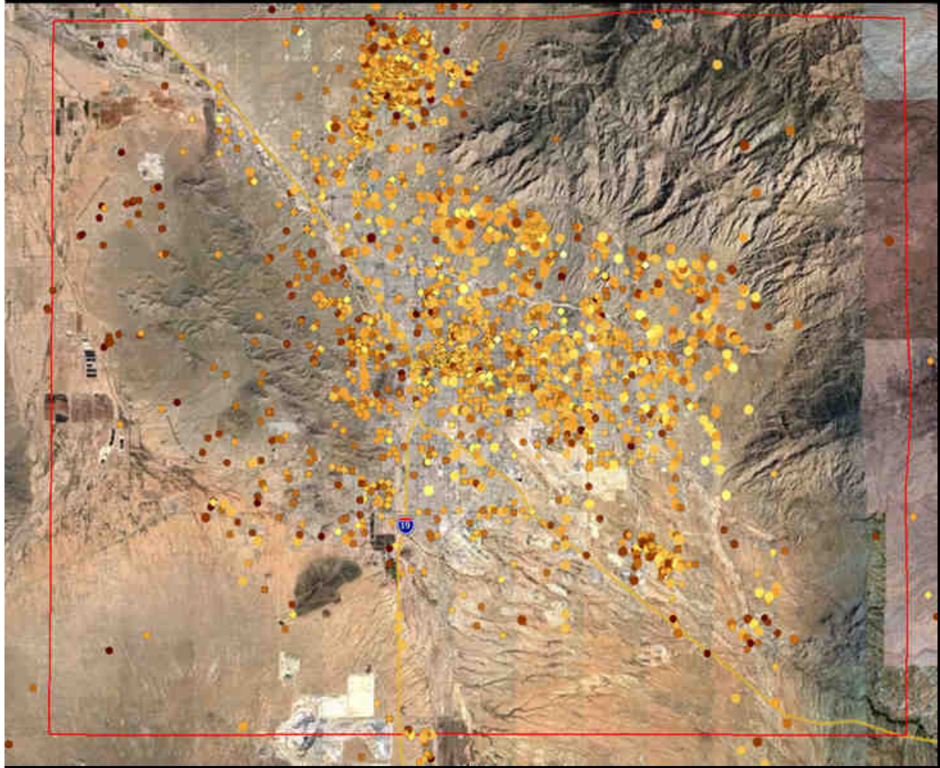
Conversion Calculator and Chart
by K. Fisher

GLOBE at Night data in the US

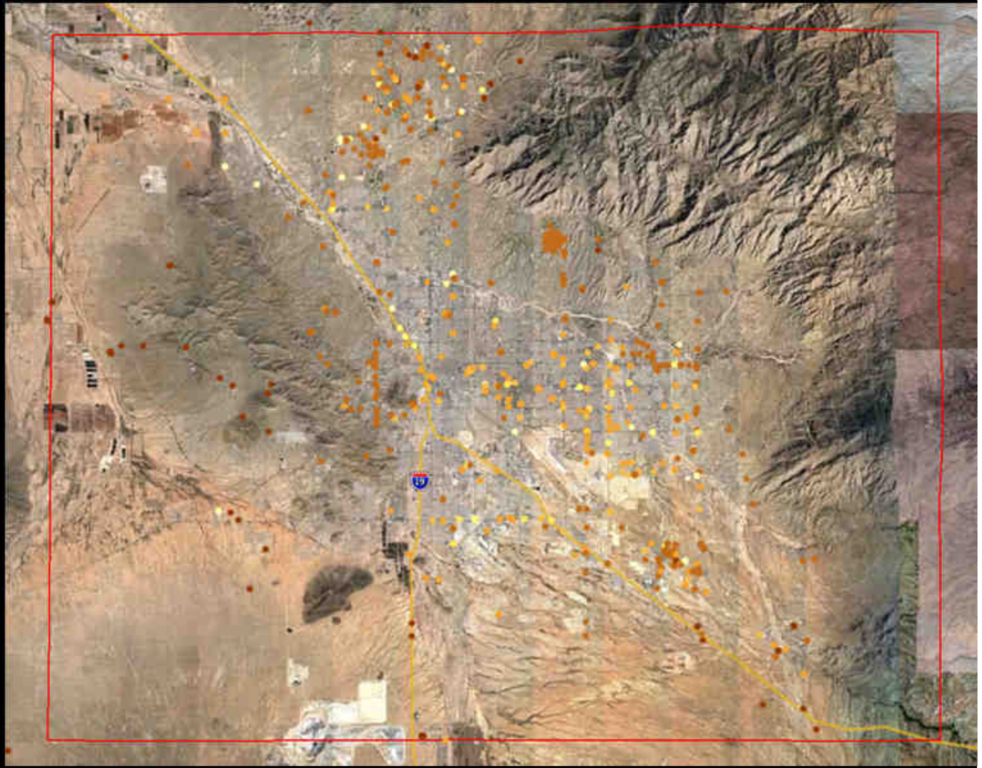


GLOBE at Night observations

All (visual + SQM) GLOBE at Night observations
2006-2011



SQM only GLOBE at Night observations
2007-2011

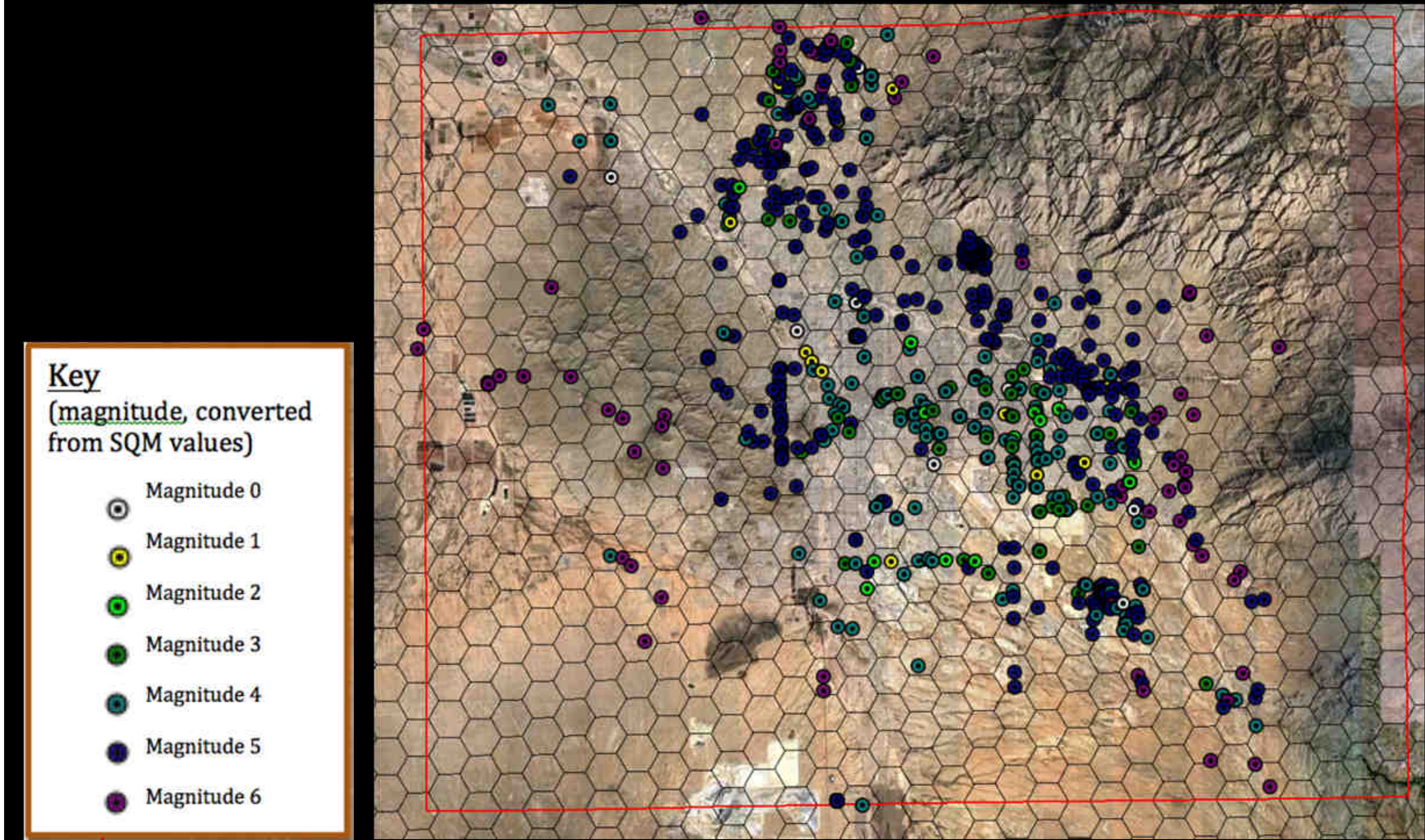


Study area:
NW corner= 32.4517842777369 N, 111.272317916375 W
SE corner = 31.9894847605149 N, 110.58604366931 W

Northern border: 64.39 km; southern border: 64.72km
Eastern and Western border: 51.41 km

The study area was broken up into 5 km^2 hexagons… **742 of them!**

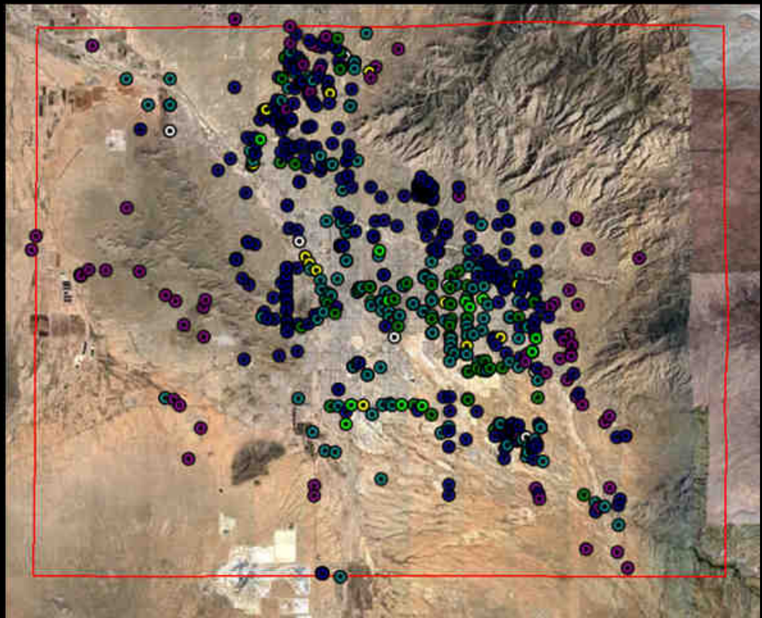
For the lesser long-nosed bat study, our goal is **3** SQM data points per hexagon



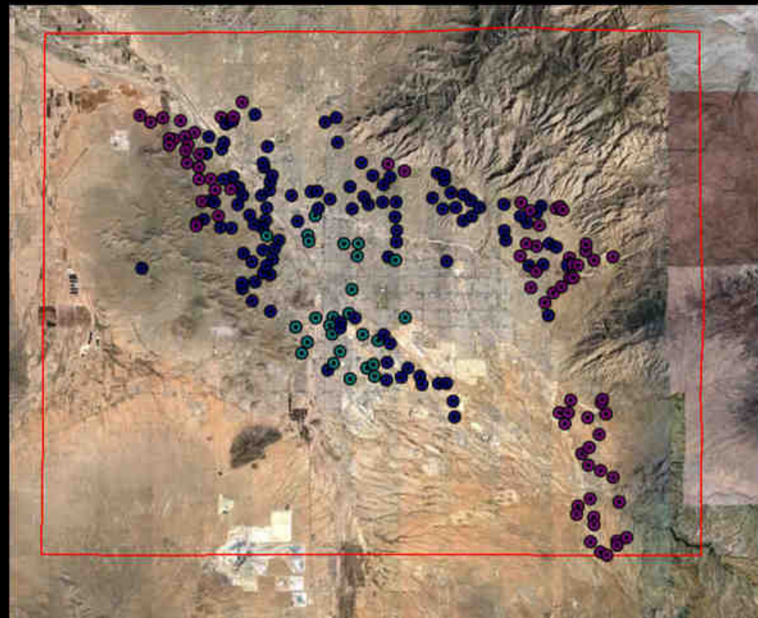
Previous GLOBE at Night data

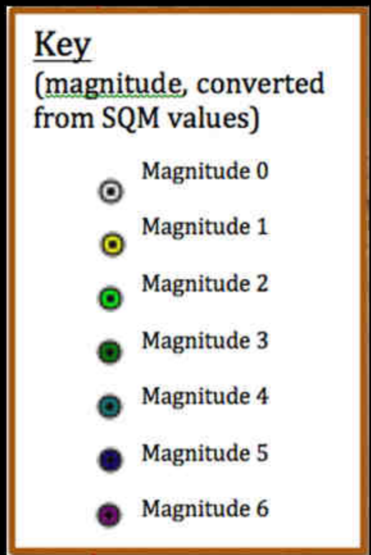
Data Collection: SQM points in the study area

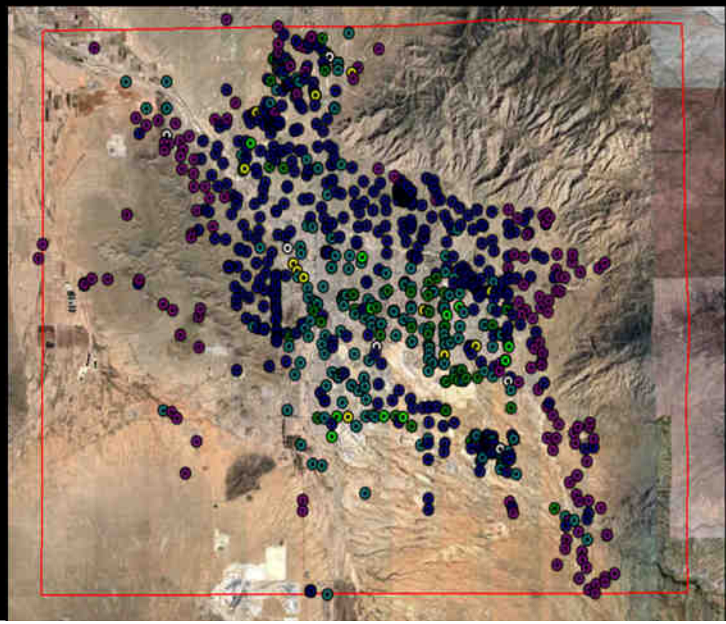
GLOBE at Night data (735)



Data points Alisa took this summer (211)



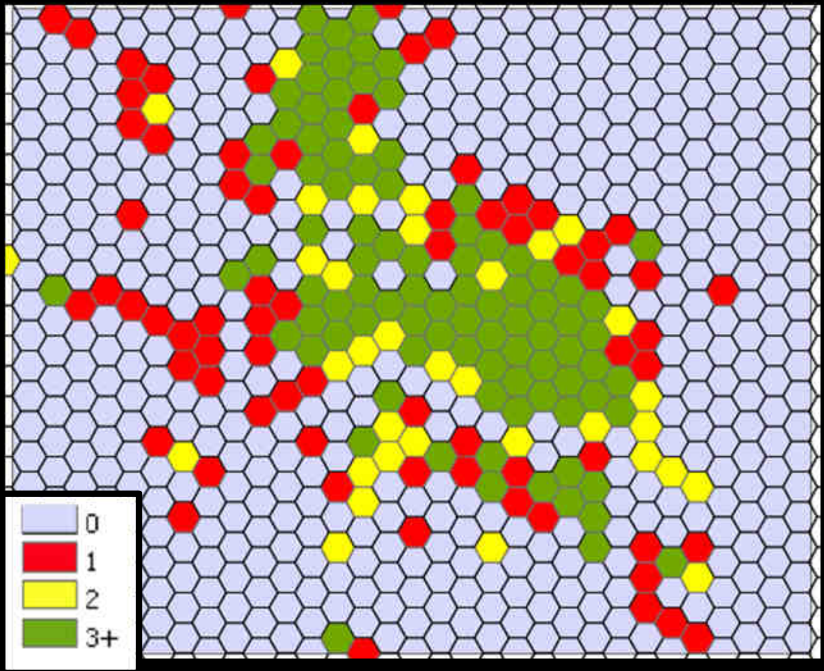




All of the SQM points we currently have within the study area (946)

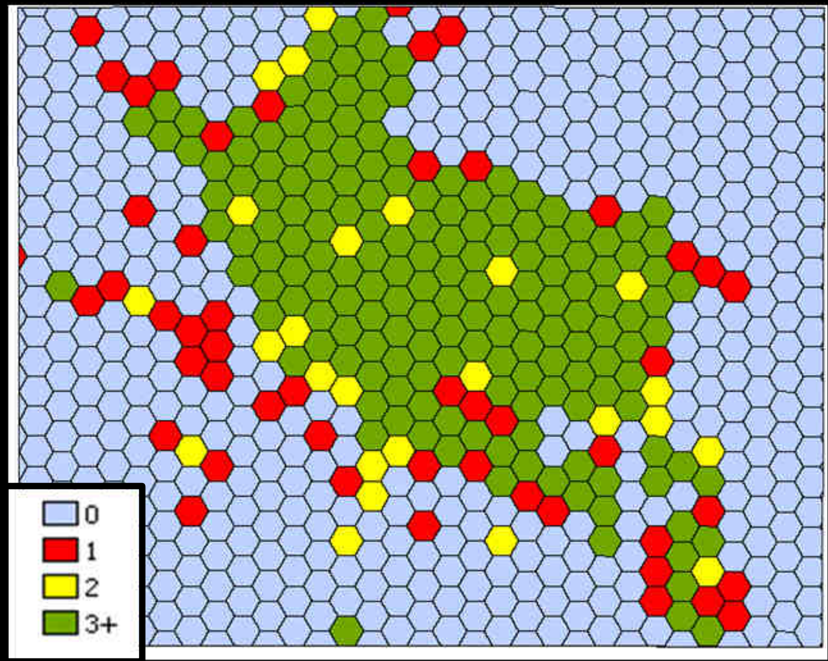
Number of points per hexagon

From previous GLOBE at Night data

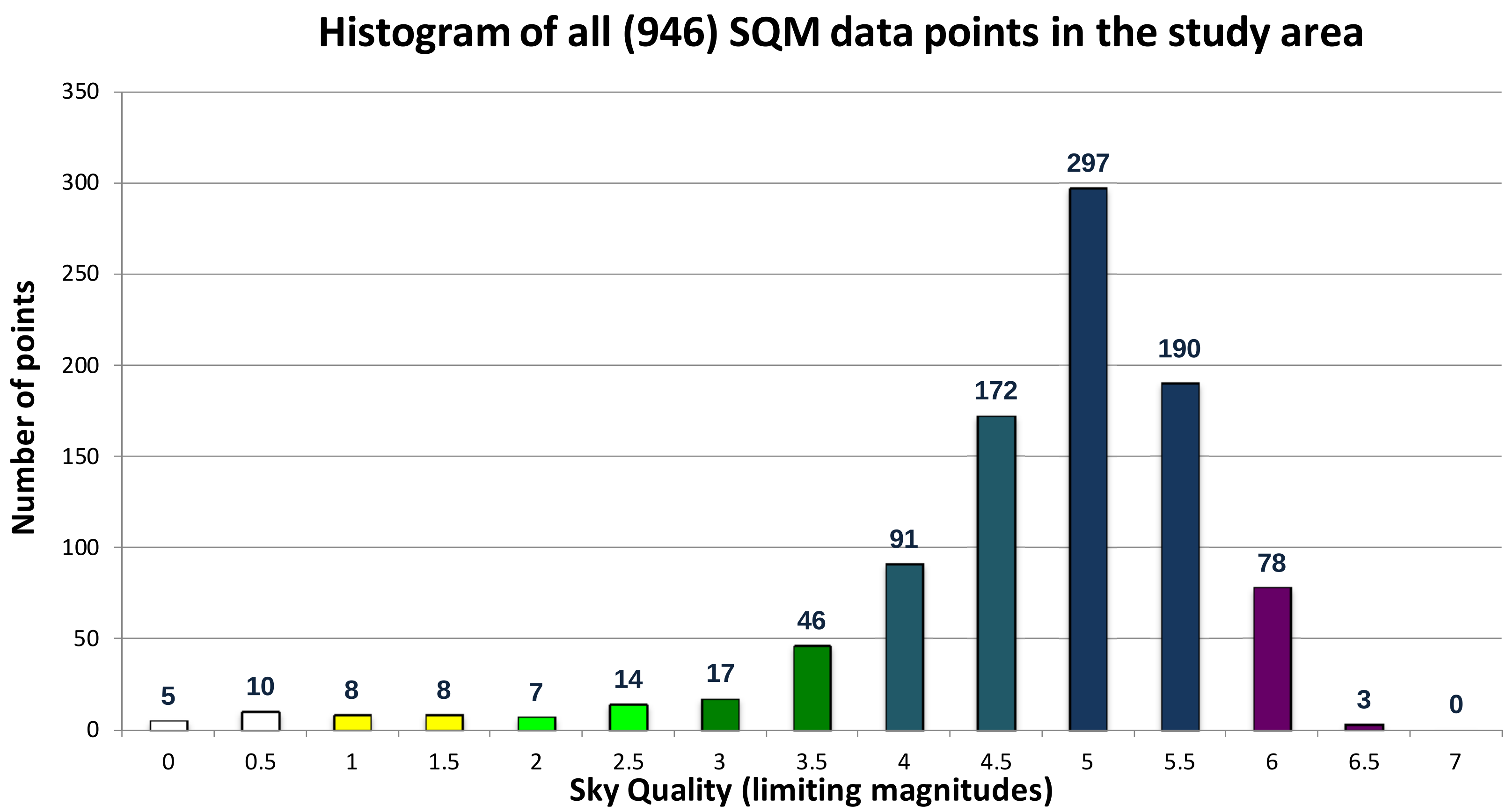


- 543 have no data
- 71 have 1 data point
- 35 have 2 data points
- 93 have 3 or more data points

With Alisa's SQM data added in



- 496 have no data
- 50 have 1 data point
- 25 have 2 data points
- 171 have 3 or more data points



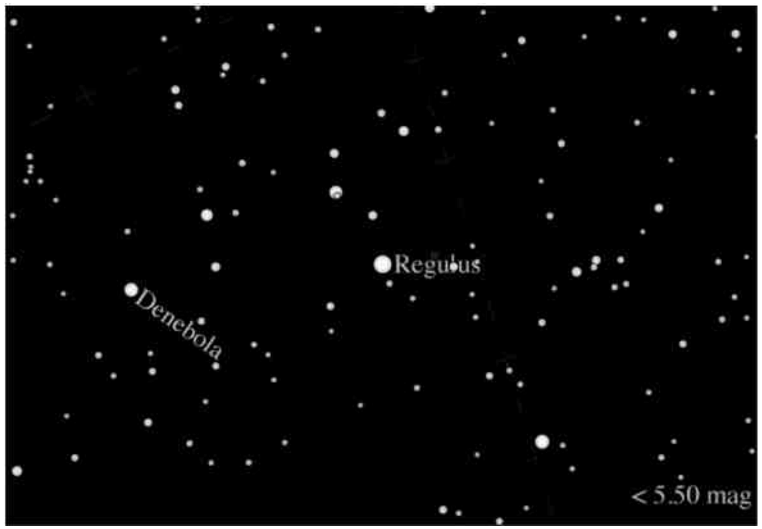
Median = 19.258667 mag/arcsec^2

Mean = 18.9756533 mag/arcsec^2

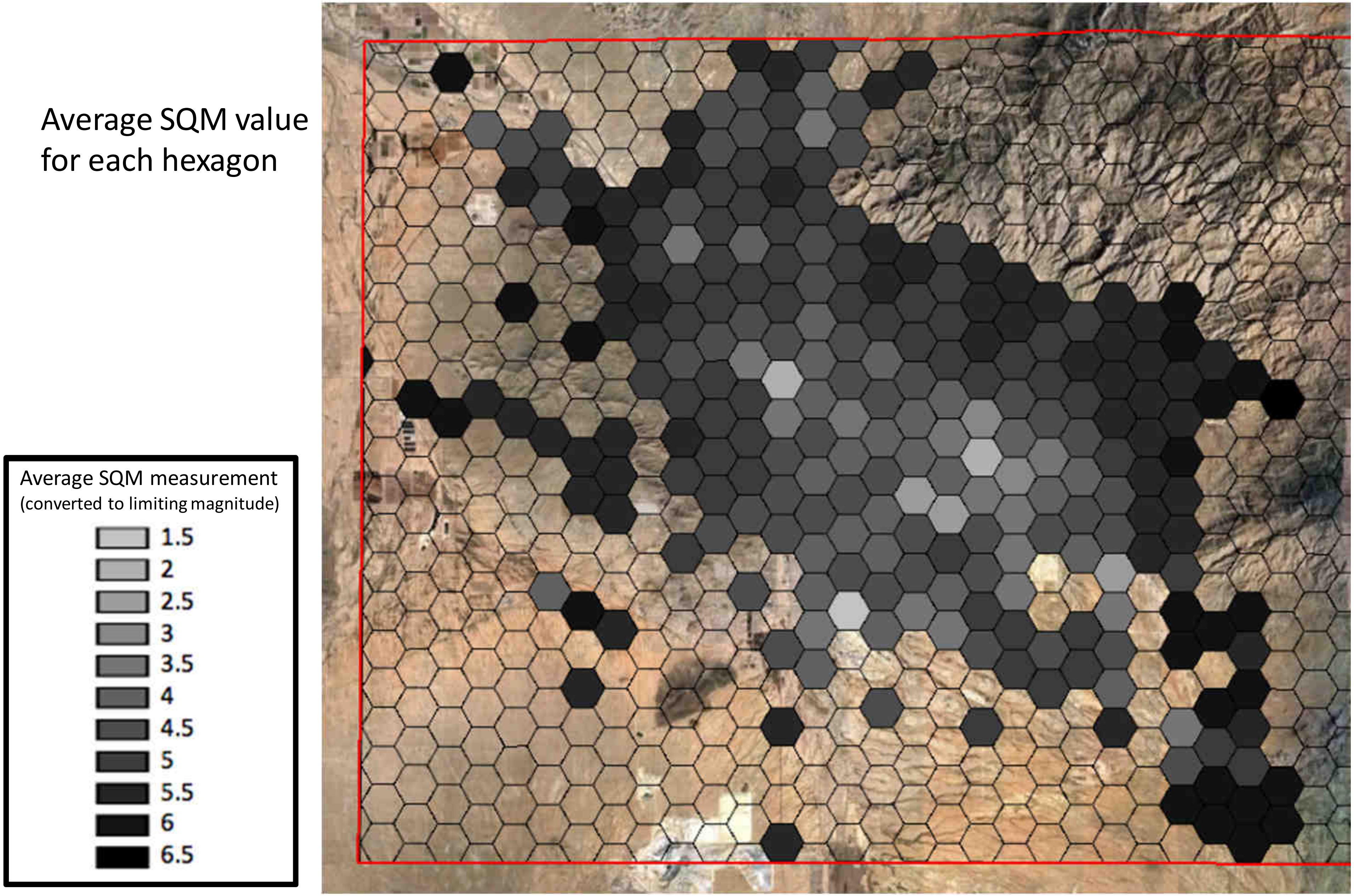
Standard Deviation = 1.28041413 mag/arcsec^2

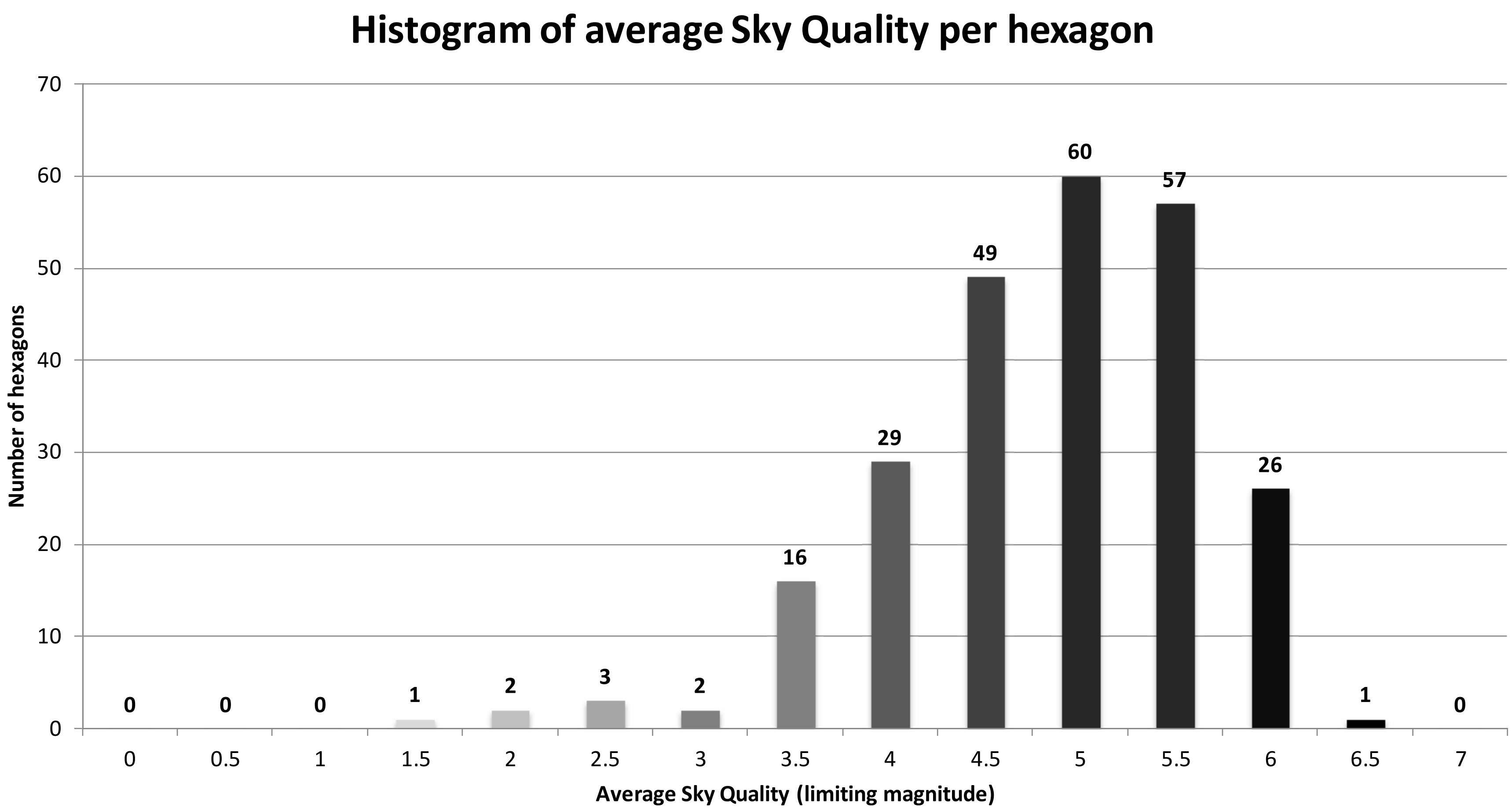
Minimum: 13.14 mag/arcsec^2

Maximum: 21.3 mag/arcsec^2



Average SQM value
for each hexagon





Median = 19.24875 mag/arcsec^2

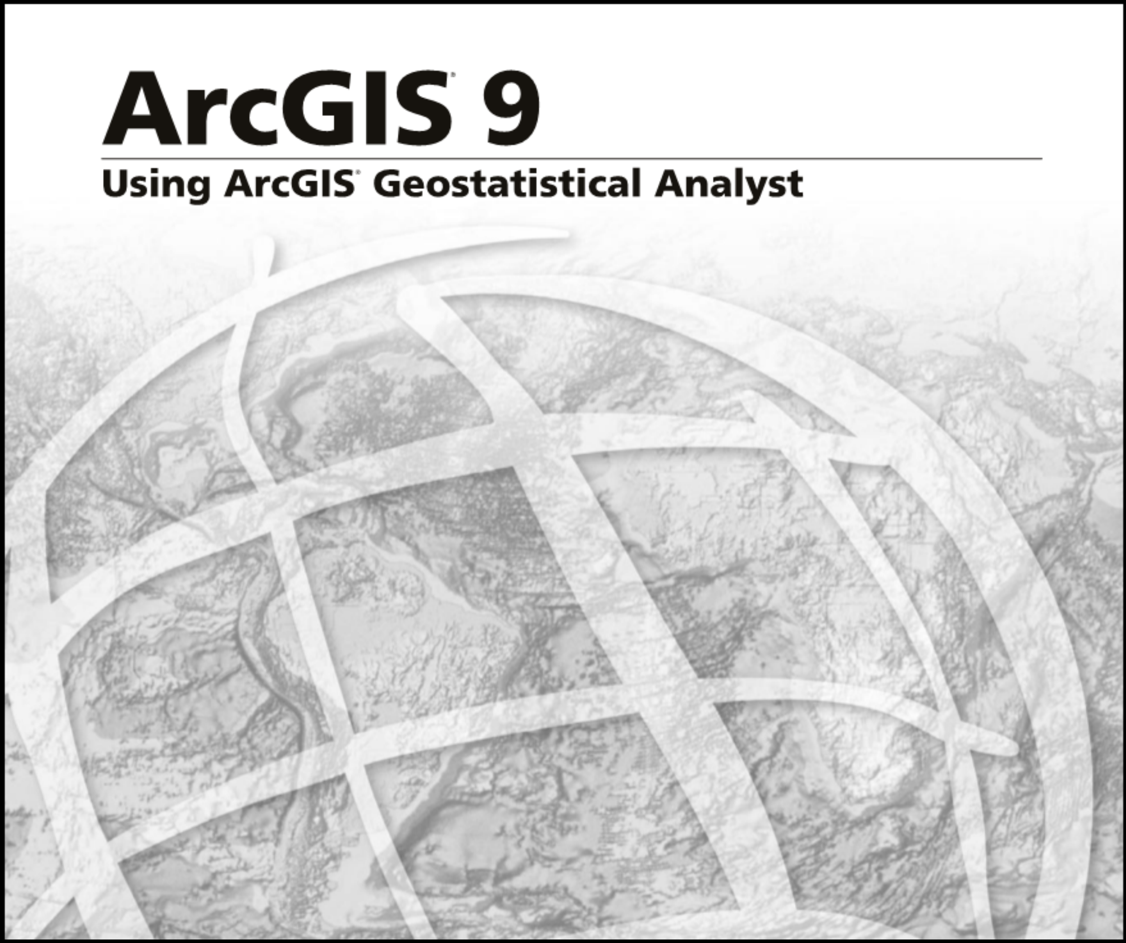
Min: 15.515 mag/arcsec^2

Mean = 19.13481487974 mag/arcsec^2

Max: 21.3 mag/arcsec^2

Standard Deviation = 1.07763931 mag/arcsec^2

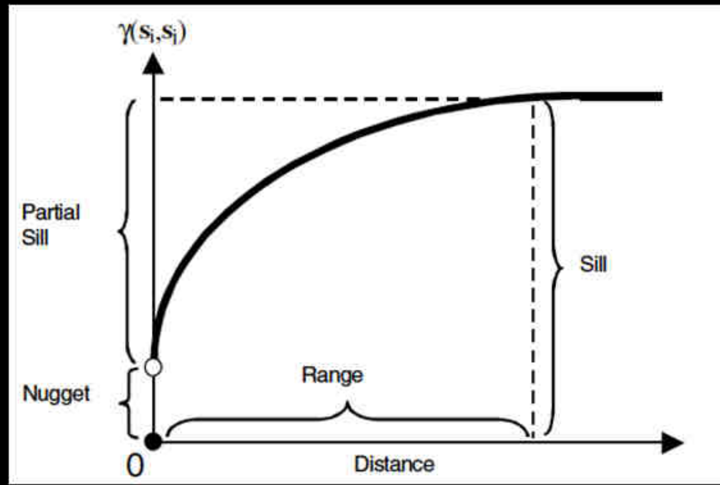
Step 2: Contour mapping with ArcGIS



ArcGIS: creating contour maps using “Kriging”

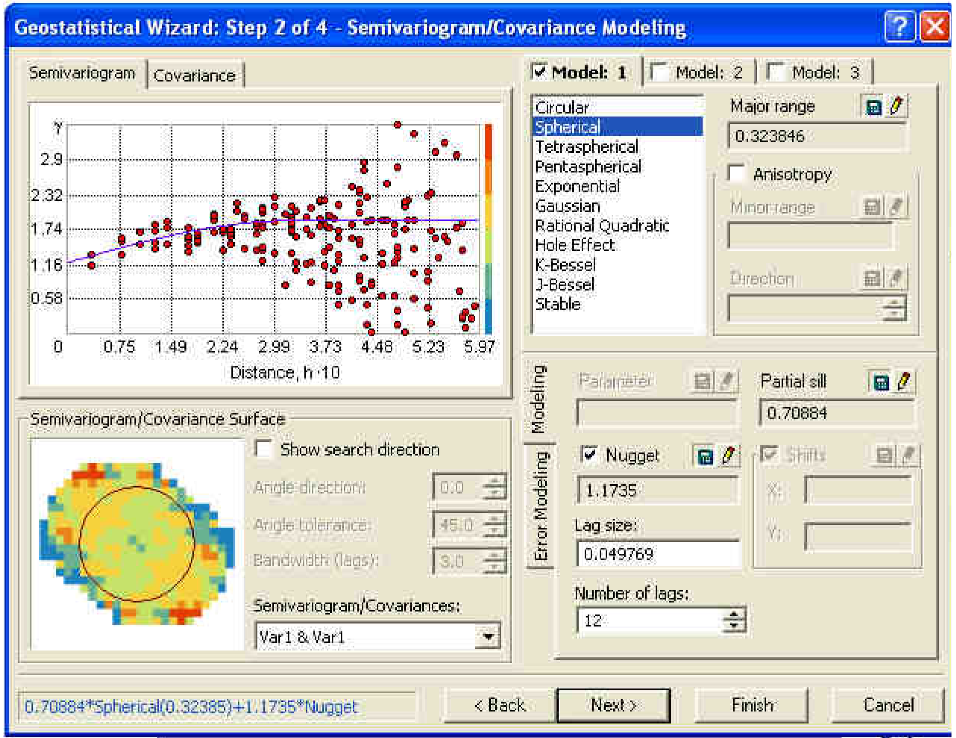
-Constructs a variogram

$$\gamma(\mathbf{s}_i,\mathbf{s}_j) = \tfrac{1}{2}\,\mathrm{var}(Z(\mathbf{s}_i) - Z(\mathbf{s}_j)),$$

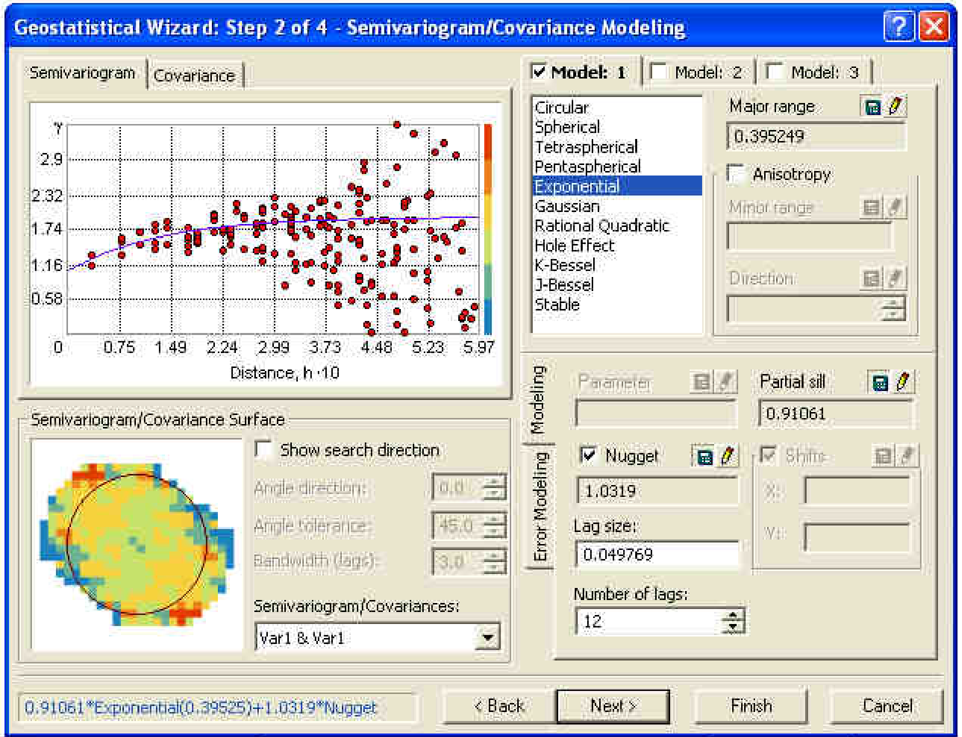


Variograms

Spherical



Exponential



Spherical

The semivariogram model is

$$\gamma(\mathbf{h};\boldsymbol{\theta}) = \begin{cases} \theta_s\left[\dfrac{3}{2}\dfrac{\|\mathbf{h}\|}{\theta_r} - \dfrac{1}{2}\left(\dfrac{\|\mathbf{h}\|}{\theta_r}\right)^3\right] & \text{for } 0 \le \|\mathbf{h}\| \le \theta_r \\ \theta_s & \text{for } \theta_r < \|\mathbf{h}\| \end{cases}$$

where $\theta_s \ge 0$ is the partial sill parameter and $\theta_r \ge 0$ is the range parameter.

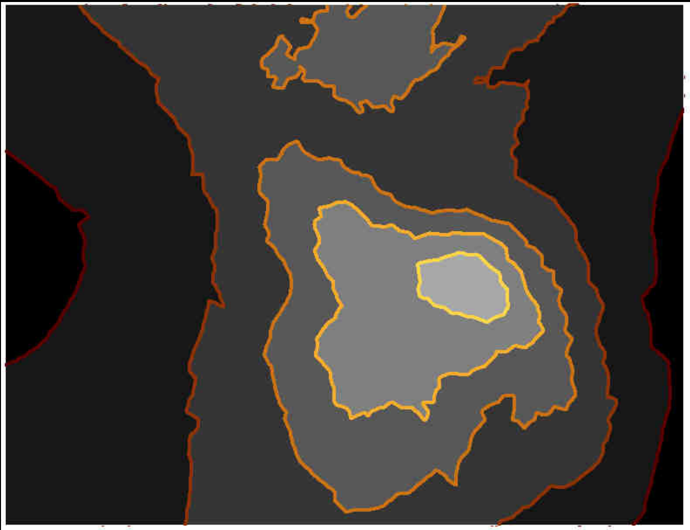
Exponential

The semivariogram model is

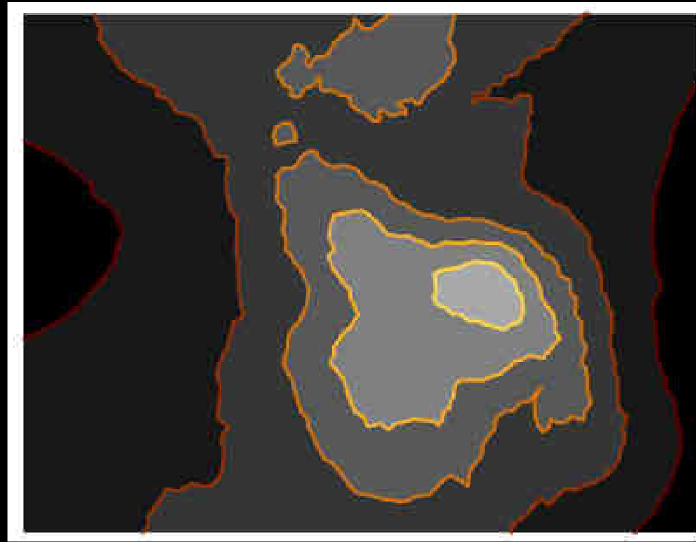
$$\gamma(\mathbf{h};\boldsymbol{\theta}) = \theta_s\left[1 - \exp\left(-\frac{3\|\mathbf{h}\|}{\theta_r}\right)\right] \text{ for all } \mathbf{h},$$

where $\theta_s \ge 0$ is the partial sill parameter and $\theta_r \ge 0$ is the range parameter.

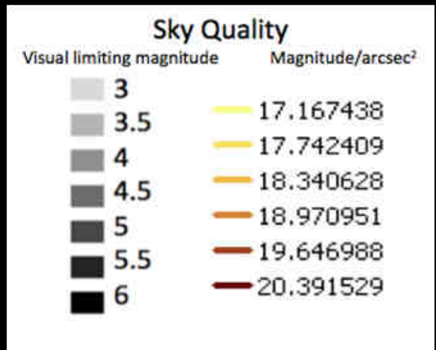
Maps using different variogram models

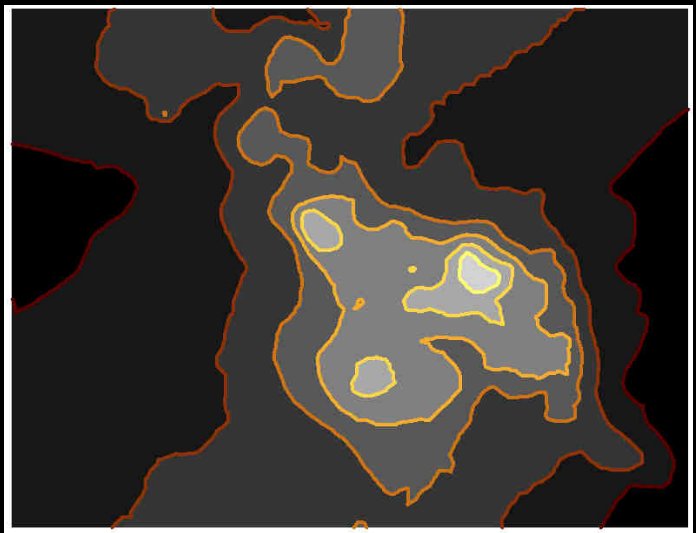


Hole Effect

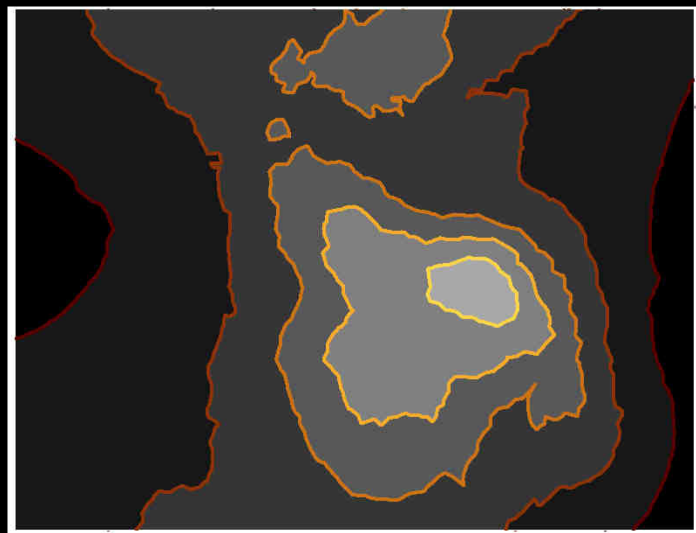


K-bessel





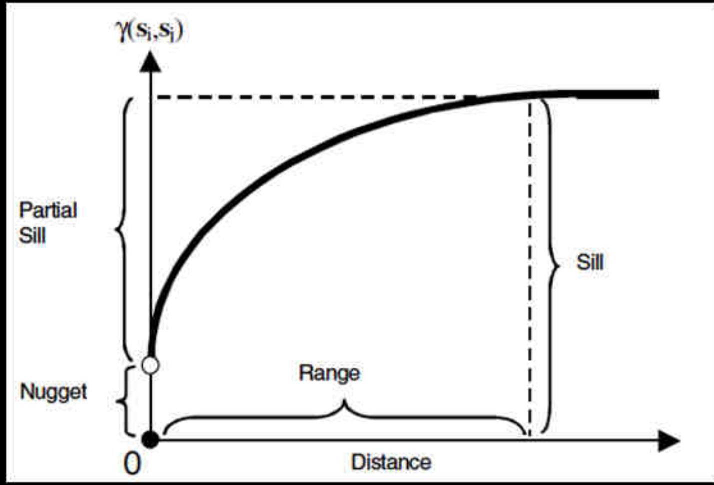
Stable



Gaussian

ArcGIS: creating contour maps using "Kriging"

-Constructs a variogram



$$\gamma(\mathbf{s}_i,\mathbf{s}_j) = \tfrac{1}{2}\,\mathrm{var}(Z(\mathbf{s}_i) - Z(\mathbf{s}_j)),$$

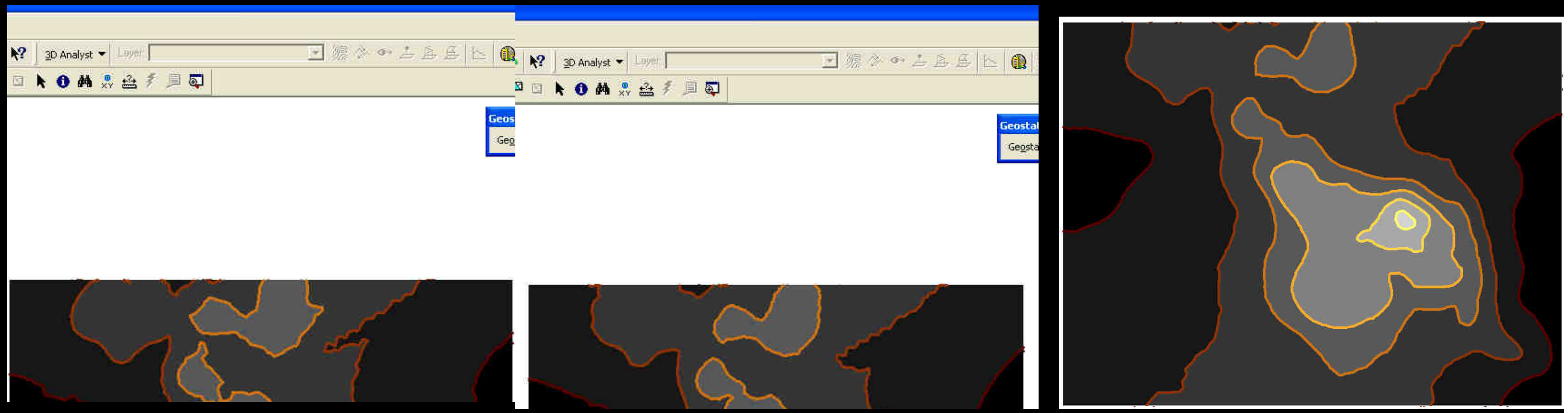
-The variogram is used to compute weights

-The predicted value for each unknown location is then calculated:

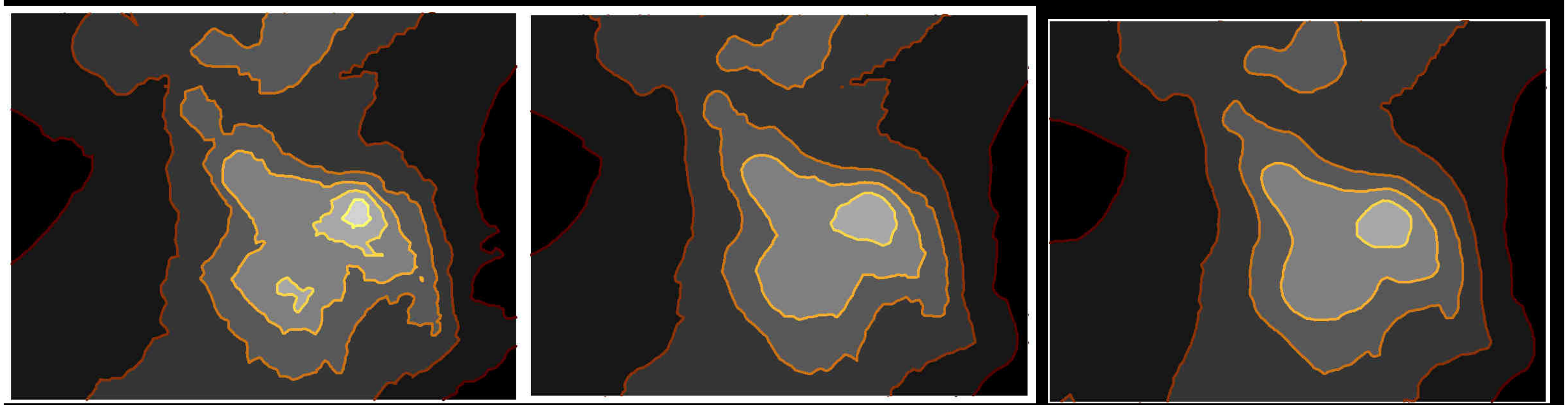
$$F(x,y) = \sum_{i=1}^{n} w_i f_i$$

where f_i is the value of each surrounding known point and w_i is the weight assigned to each

Exponential



25 Neighbors | 50 Neighbors | 100 Neighbors

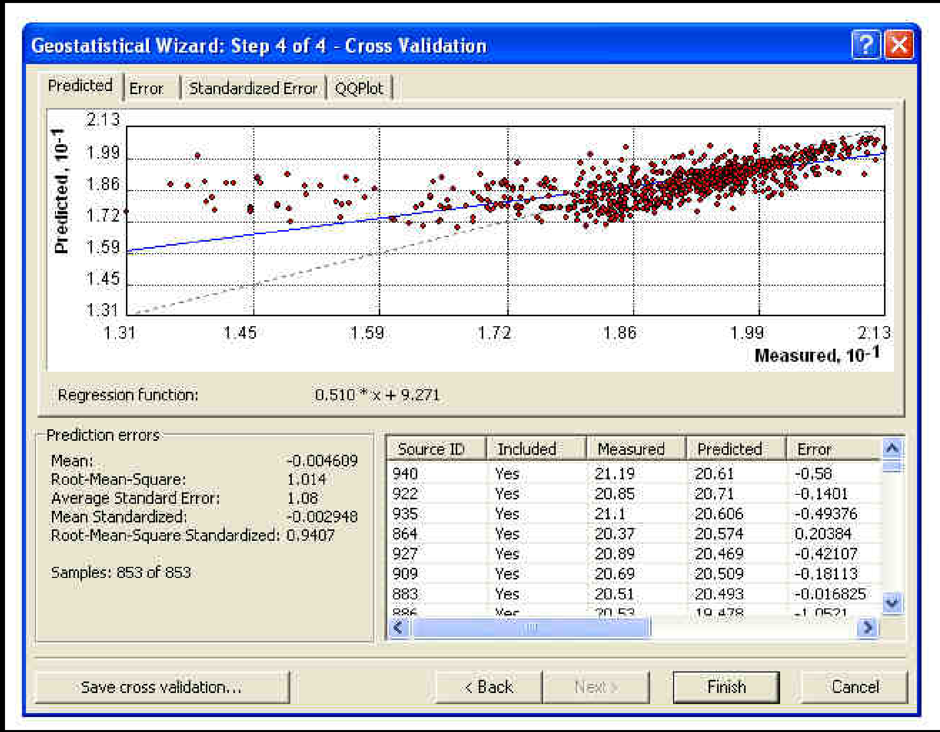


Spherical

Which map is best?!?

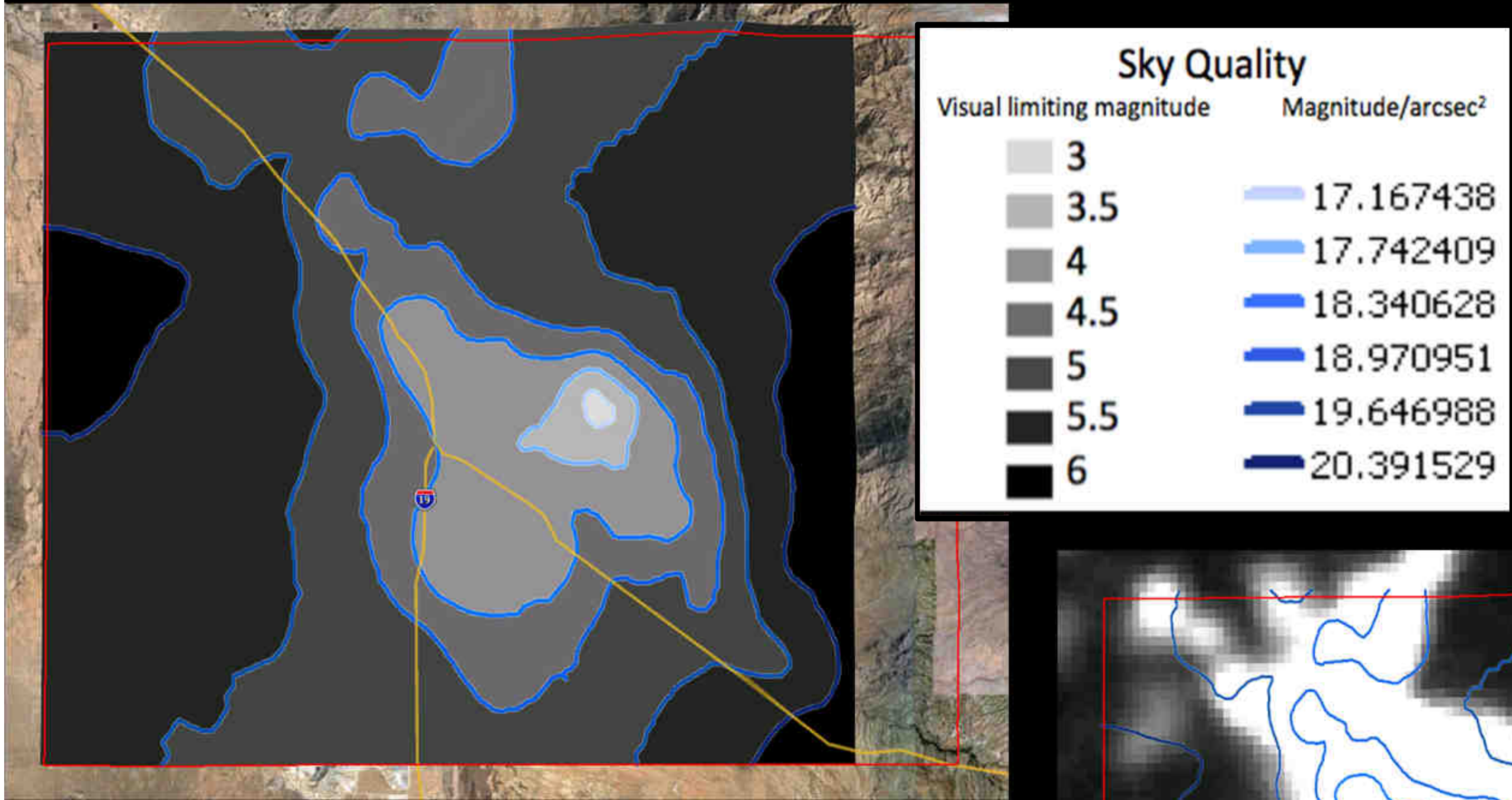
- By using Kriging, prediction errors can be calculated.
  - A measured value is taken out and the 'predicted' value for that location is calculated and then compared to what was actually measured

= Cross-Validation

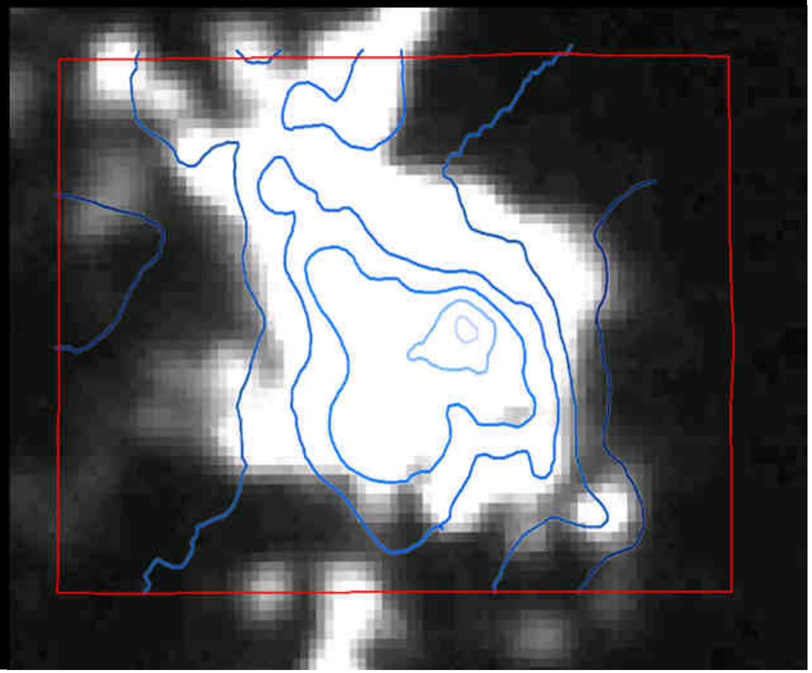


-Summary statistics are used to compare different models

"Optimal" model =
Exponential Kriging, 75 neighbors



2009 DMSP data



Step 3: The Bat Research

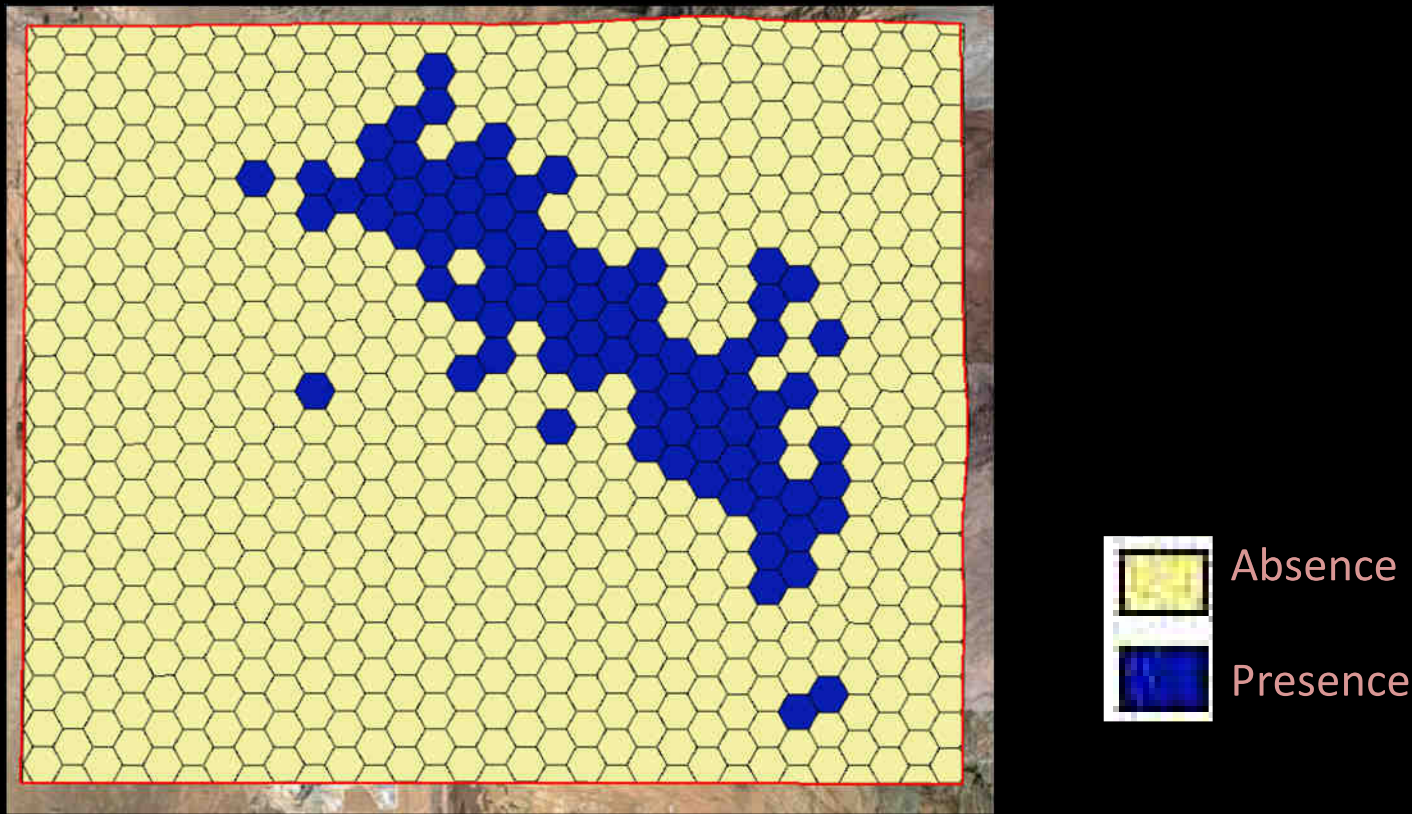
- Compare light and other variables to the distribution of lesser long-nosed bats and use linear regression analysis to determine which variables best explains the bats' presence/absence.

Lesser Long-nosed Bat (Leptonycteris curasoae)

- Federally endangered
- Feeds on nectar and pollen
- Here in Arizona for the summer
- Foraging typically begins half an hour to an hour after sunset

Bat Data

- Radio telemetry from AZ Game & Fish
- Hummingbird feeder monitoring study

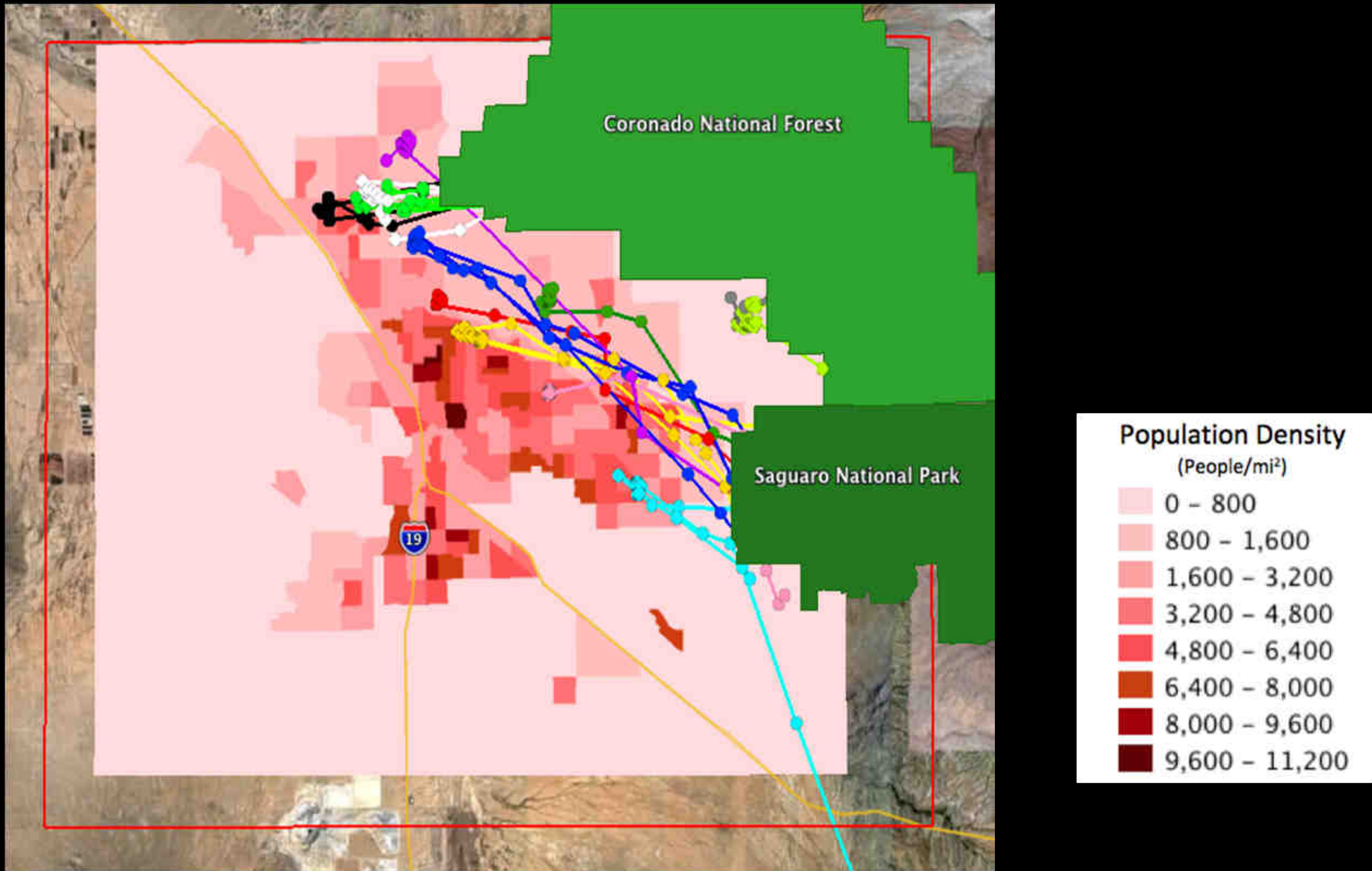


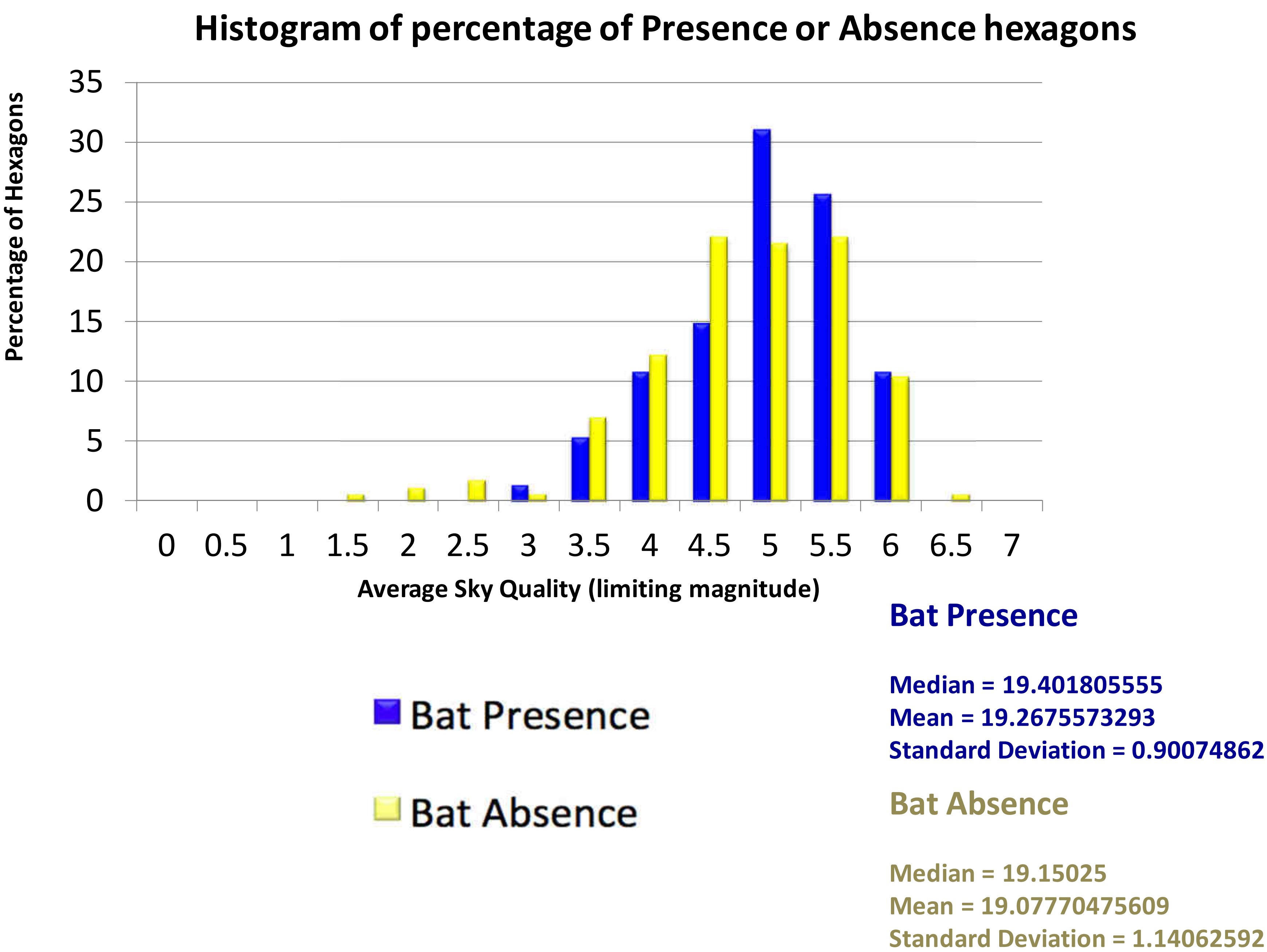
How to get telemetry

1. Capture bats

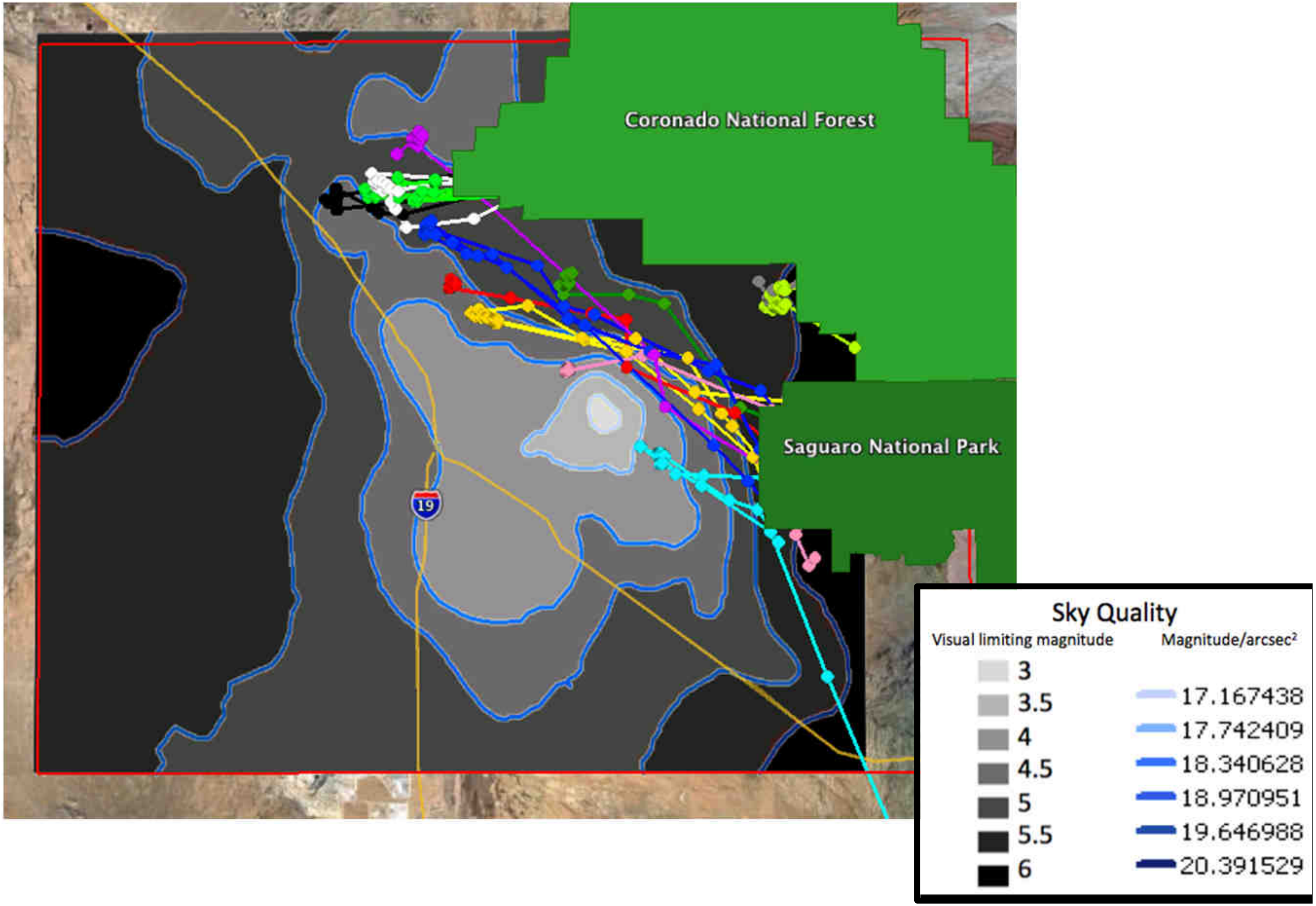
2. Put small radio transmitters on the bats
3. Follow the bats

Bat Telemetry and 2010 Census Population Density




Histogram of percentage of Presence or Absence hexagons
Percentage of Hexagons
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
Average Sky Quality (limiting magnitude)
Bat Presence
Bat Absence
Bat Presence
Median = 19.401805555
Mean = 19.2675573293
Standard Deviation = 0.90074862
Bat Absence
Median = 19.15025
Mean = 19.07770475609
Standard Deviation = 1.14062592

Kriging (Exponential, 75 neighbors) and Bat Telemetry



Logistic Regression Analysis

- Goal: determine which variables accurately describe the distribution of the bats
- Run by AZ Game & Fish using different combinations of predictor variables

    -Ecoregion

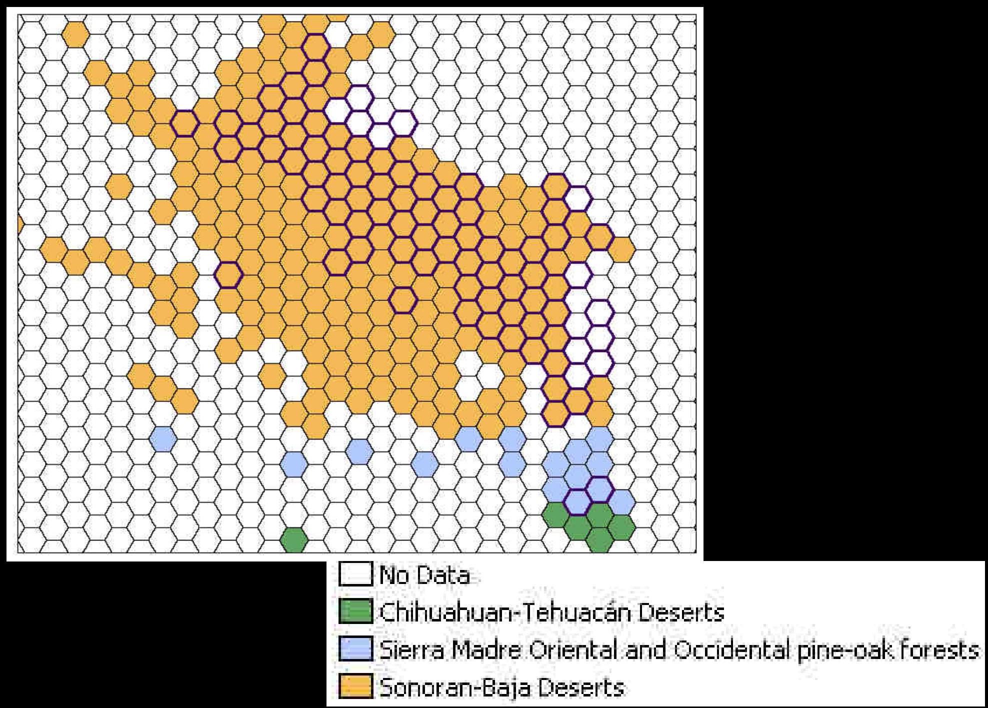
    -Vegetation Cover

    -Landform

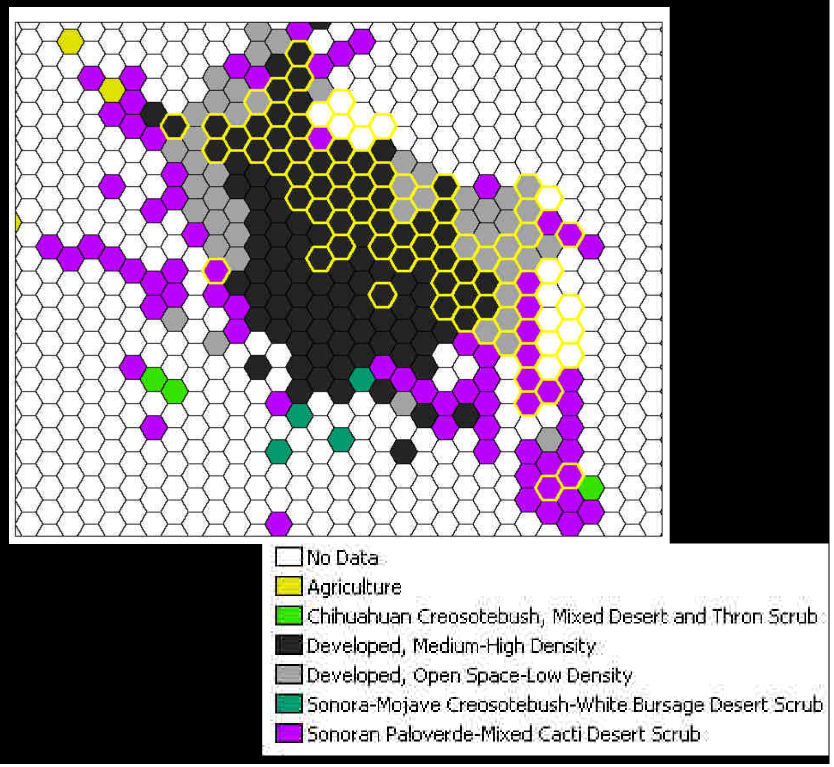
    -Light

- Ecoregion =
  - -Chihuahuan-Tehuacan Deserts
  - -Sierra Madre Oriental and Occidental pine-oak forests
  - -Sonoran-Baja Deserts
- Vegetation cover = 18 ‘classes’
- Landform = the shape of the land
- Light = SQM data from Globe at Night and this summer

Ecoregion



Vegetation



So…which variables influence bat presence/absence?

- To compare models, used Akaike Information Criterion (AIC)

-method which rewards goodness of fit and penalizes for having too many parameters

- The best model is the one with the lowest AIC value.

- Only shows how good it is *compared to the other models you are testing*.

- Anything with a higher AIC than the “intercept” does not explain the outcome.

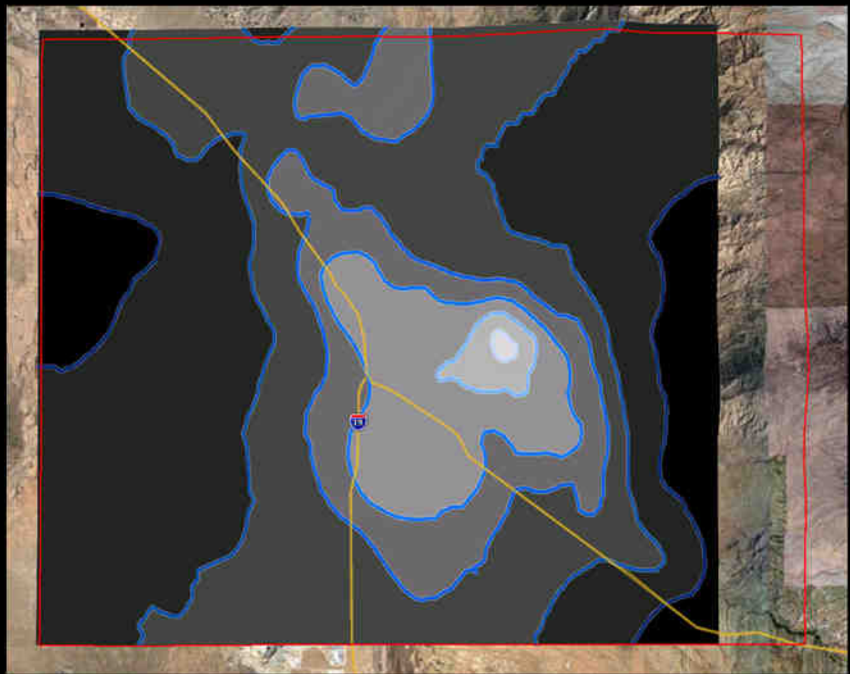
Logistic Regression Analysis Results

Model	AIC
Ecoregion + Vegetation cover + Light	292.307
Ecoregion + Vegetation cover	295.201
Vegetation cover	296.219
Ecoregion	298.558
Intercept	**303.597**
Light	304.520
Landform	304.780

- Light alone has a larger AIC value than the intercept, indicating that it is a poor model for the distribution of the lesser long-nosed bats
- Vegetation cover and ecoregion are both (separately and together) good models

Conclusions

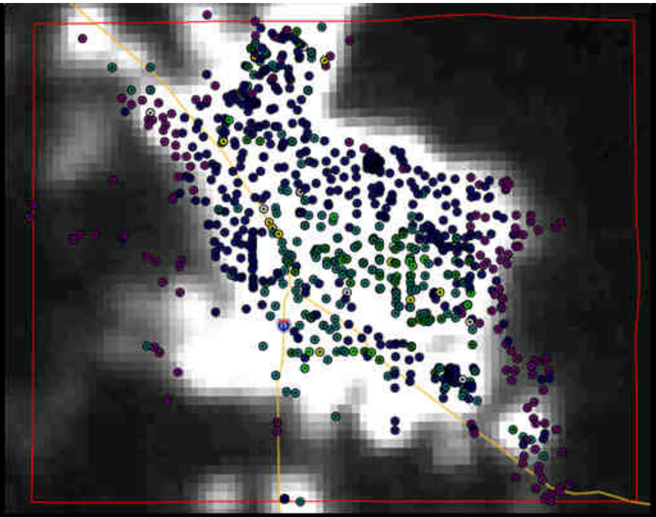
The exponential, 75 neighbors kriging is the best contour map of light pollution around Tucson that was made.



The logistic regression analysis showed that light alone does not explain the observed presence/absence of lesser long-nosed bats, but light *is* part of the current 'best' model.

Model	**AIC**	**Δ AIC**
Ecoregion + Vegetation cover + Light	292.307	0.000

Looking to the future



- The entire study area was not covered; there is not much data in the west, the southern third or the National Parks and Forests. One of our main objectives is to continue to get more SQM data points.

- Once there is better spatial coverage, the parameters in the contour models can be experimented with more to find the optimal kriging model.

- The study of lesser long-nosed bats by AZ Game & Fish is ongoing; their logistic regression analysis can be run with other parameters (i.e. population density, climate variables, elevation) and with continued trapping and tagging, the bat presence/absence will get more accurate.


Thank-you for your attention