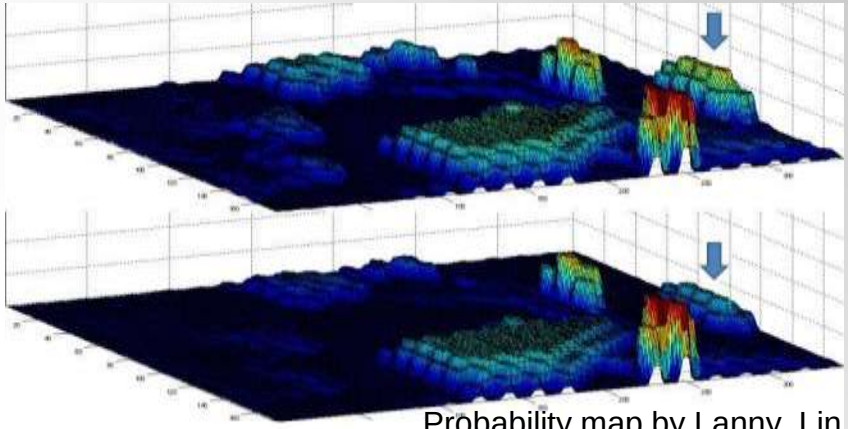
MapScore:
Probability Map Evaluation for Search & Rescue



Probability map by Lanny Lin

Eric Cawi, Nathan Jones, Dr. Charles Twardy

Funded by an NSF “Research Experience for Undergraduates” grant to colleagues at Brigham Young University. Many thanks to NSF and BYU

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Agenda

- Introduction / Context
- Website Walkthrough
- ESRI models using Koester's stats
- Tabletop Exercise

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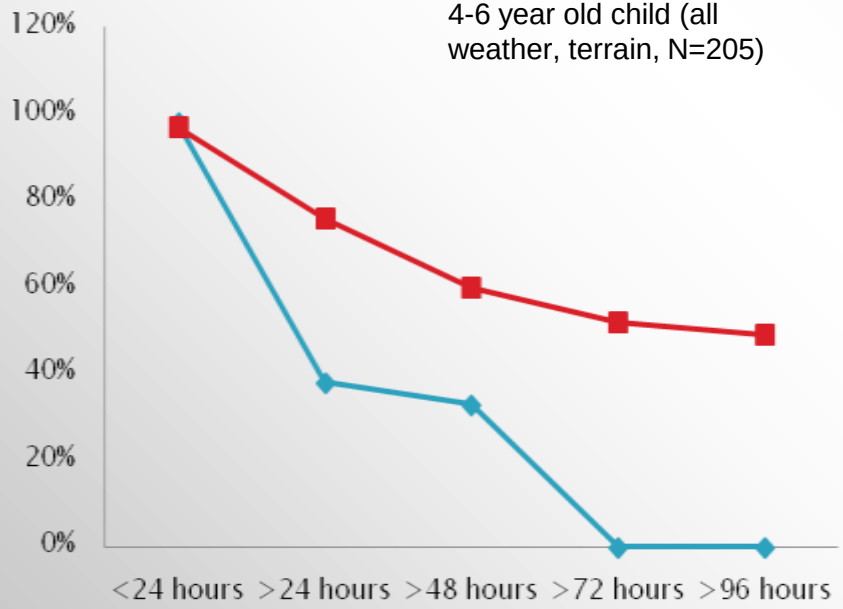
Motivation: Survivability & Cost

NPS spent $4.8 million on SAR in 2008[1].



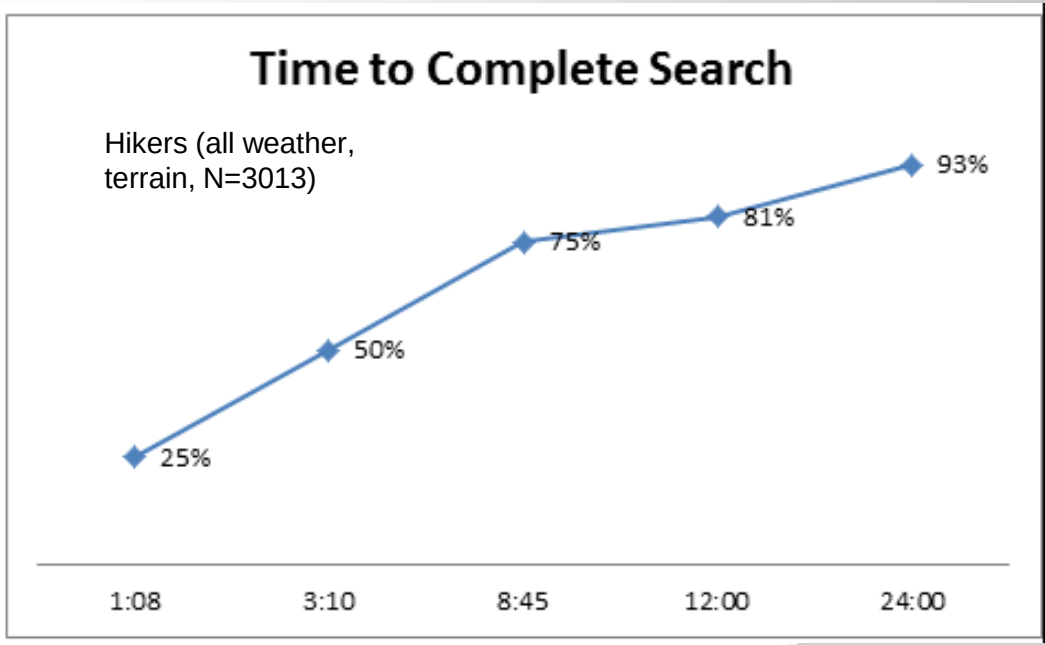


Figure from Loren Pfau 2011 Spatial Technology and Data for Volunteer-based Wilderness Search and Rescue, Capstone Peer Review. Data from Koester 2008 (ISRID).

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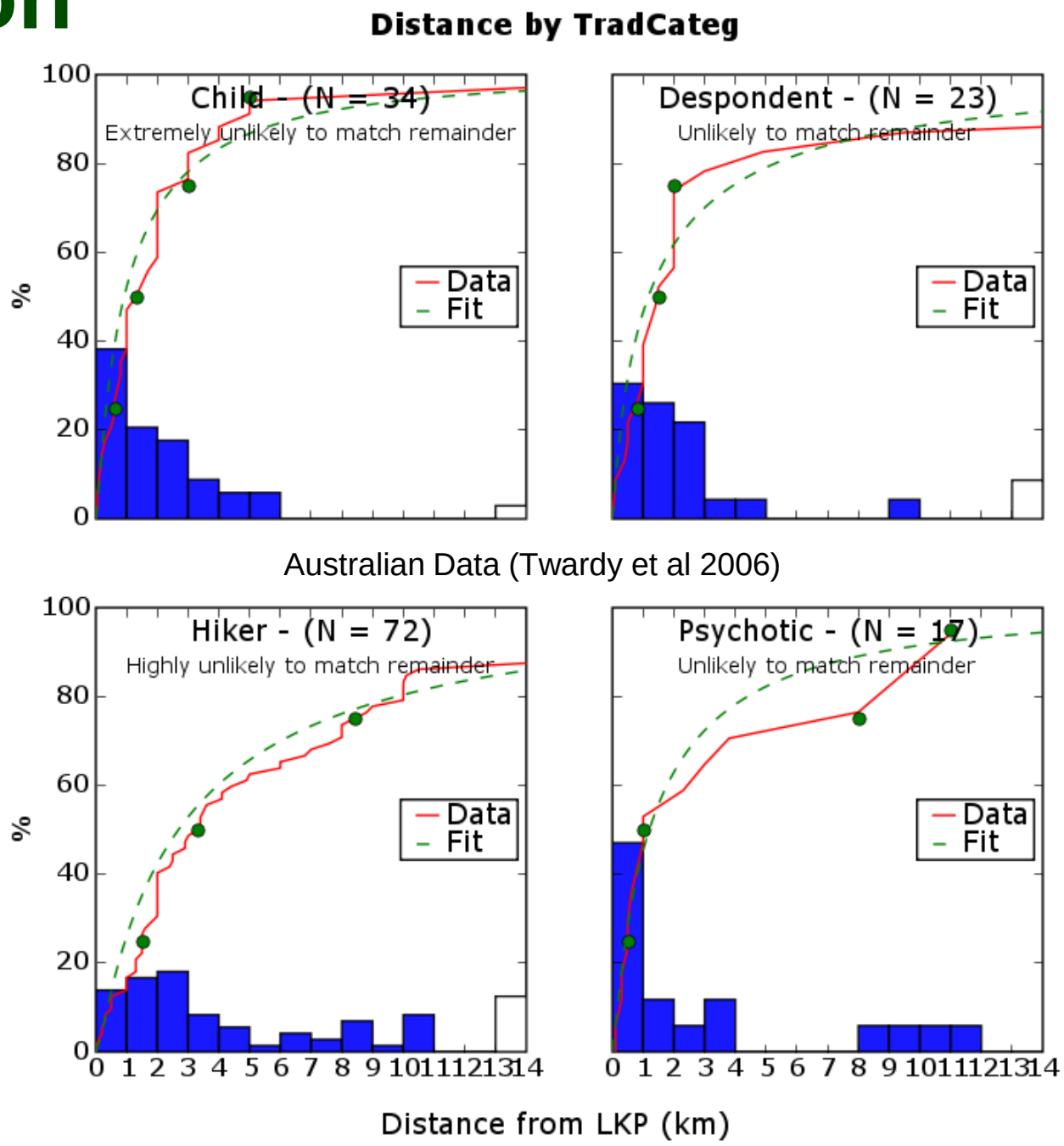
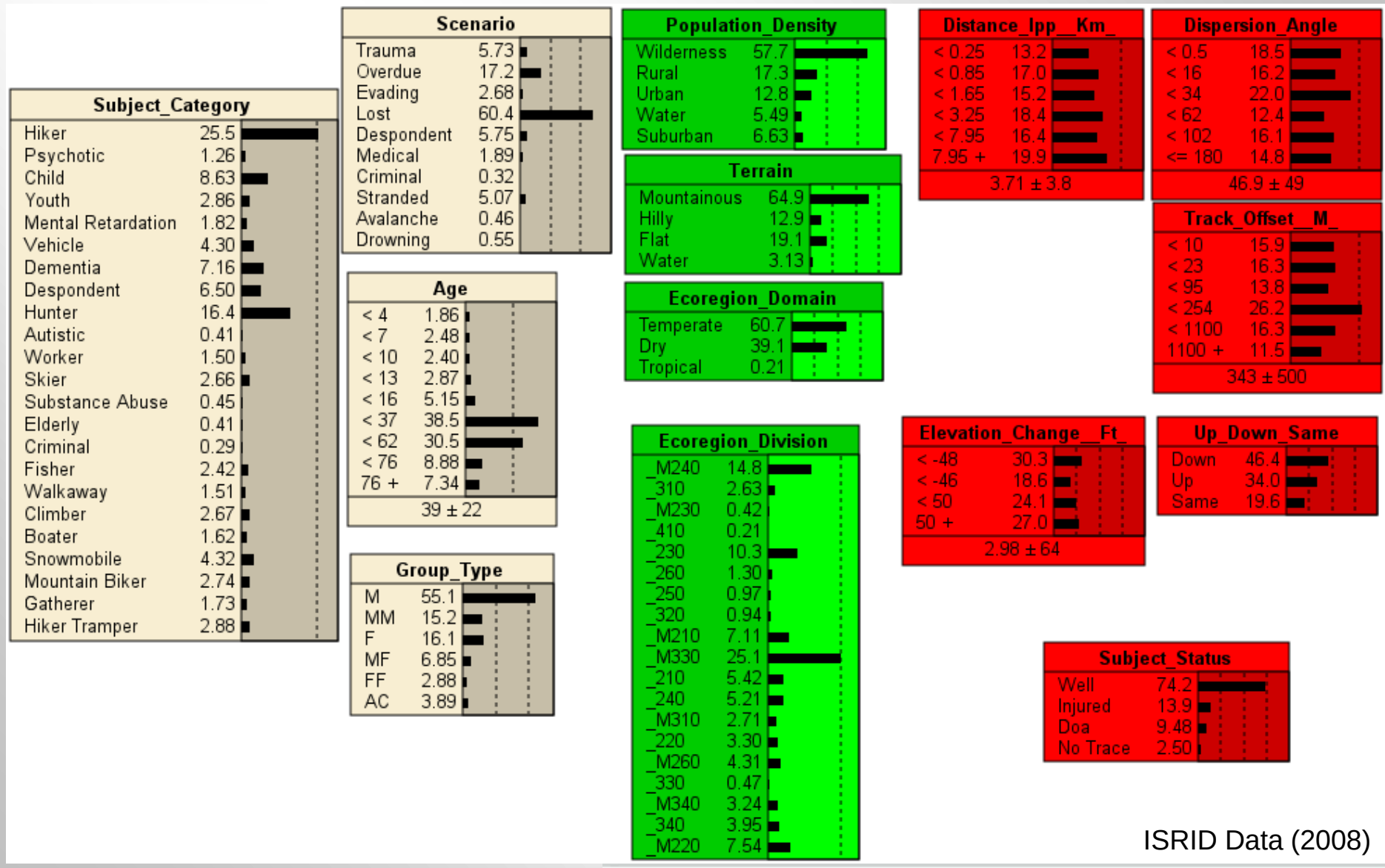
Lost Person Behavior



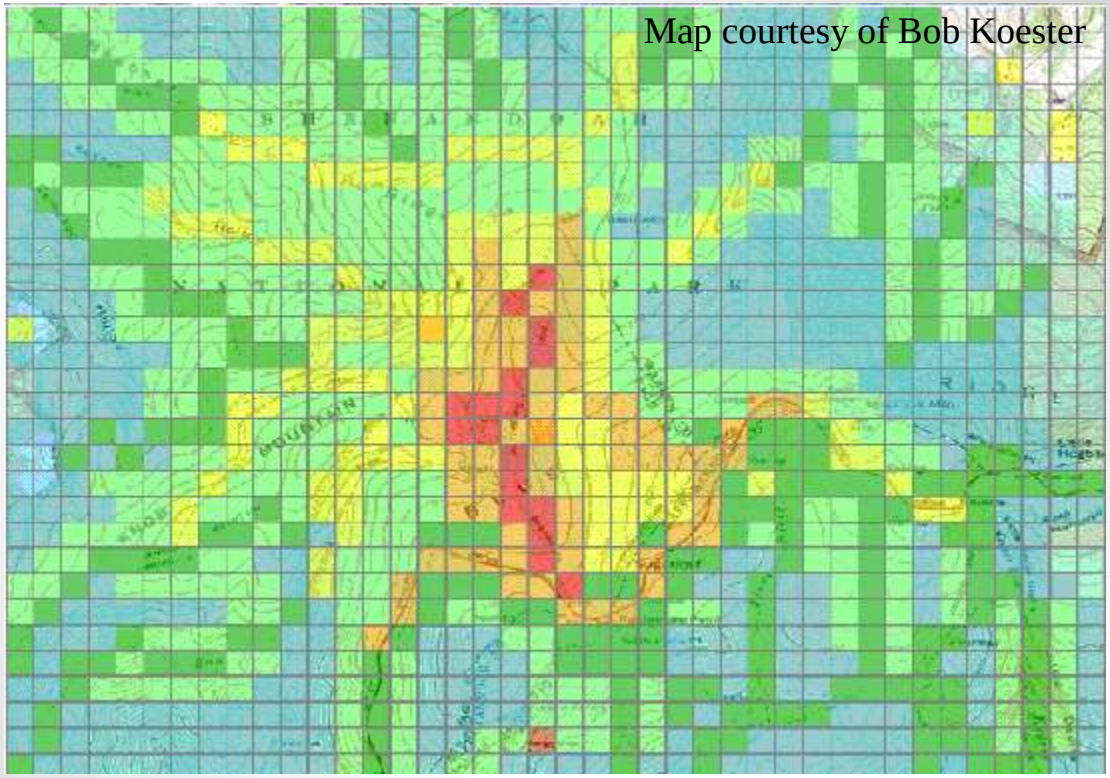
Australian Data (Twardy et al 2006)

Lost Person Behavior: Many Vars



ISRID Data (2008)

SAR Probability Mapping



But how good is it?

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NSF REU with BYU

The BYU team (above) & UAV bait (below)

- **BYU** had a different approach to making probability maps.
- How can we compare?
- BYU offered us REU funding on their WiSAR project for MapScore.
- We hired two *great* students
  - Nathan Jones (website)
  - Eric Cawi (GIS models)

Many thanks to the WiSAR team at BYU and to the NSF!

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MapScore Functional Goals

- Provide researchers with an environment to test probability maps based on actual lost person scenarios.

- Establish competition among research groups to create the most accurate models.

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Main Menu

George Mason University:
Lost Person Model Rating System

Main Menu

Welcome to the lost person model rating system. This system is intended to provide academic and research affiliated organizations with an opportunity to compare their lost person models with other models being developed in the field.

Top Rated Models

Institution Name	Model Name	Average Rating	Tests Completed
Virginia Tech	Hokie	0.99758	1
TestA	Alpha	0.99758	1
University of Virginia	Cavalier	0.0	1
William and Mary	Arrow	-0.24642	1
Columbia University	Manhattan	-0.98046	1

Account Menu

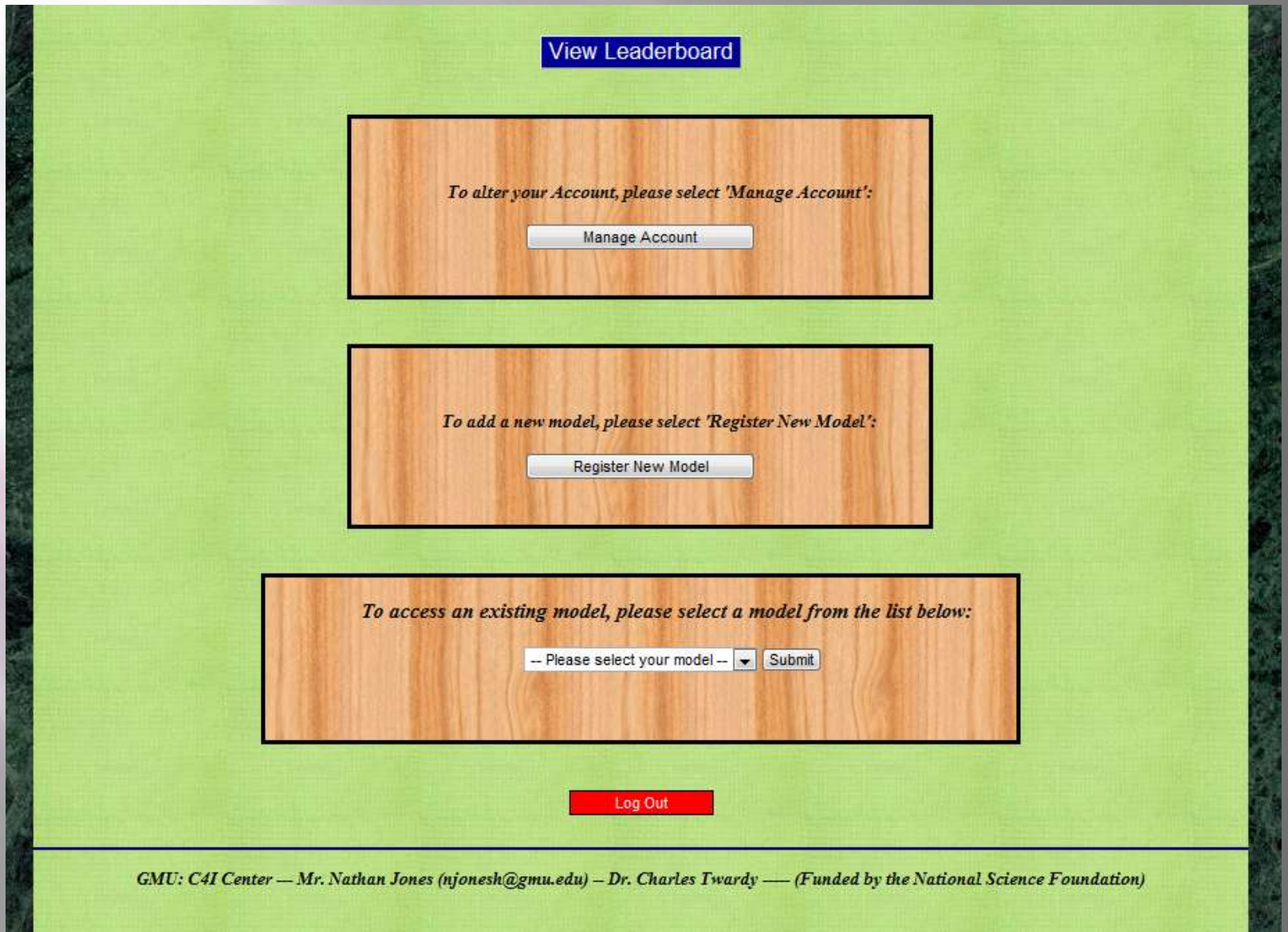
George Mason University:
Lost Person Model Rating System

[Log Out | Leaderboard] *Account Menu* [Issue Tracker | Help]

Account Name: TestA

Nathan Jones, MapScore Webslinger

Account Menu



Accept New Test Case

George Mason University:
Lost Person Model Rating System

[Log Out | Leaderboard] *Test Selection* [Issue Tracker | Help]

Initial Planning Point (IPP)

Account Name: TestA
Model Name: Alpha

A new testing scenario has been randomly chosen for you to complete. Once completed this scenario will be rated by our system and your model's standings will be updated. Once this scenario is accepted, you will go through a set of standard procedures to complete the test.

Provided below are the known lost person scenario parameters:

Test Case Name: *Hiker01*

Required Coordinate System: *WGS_84*

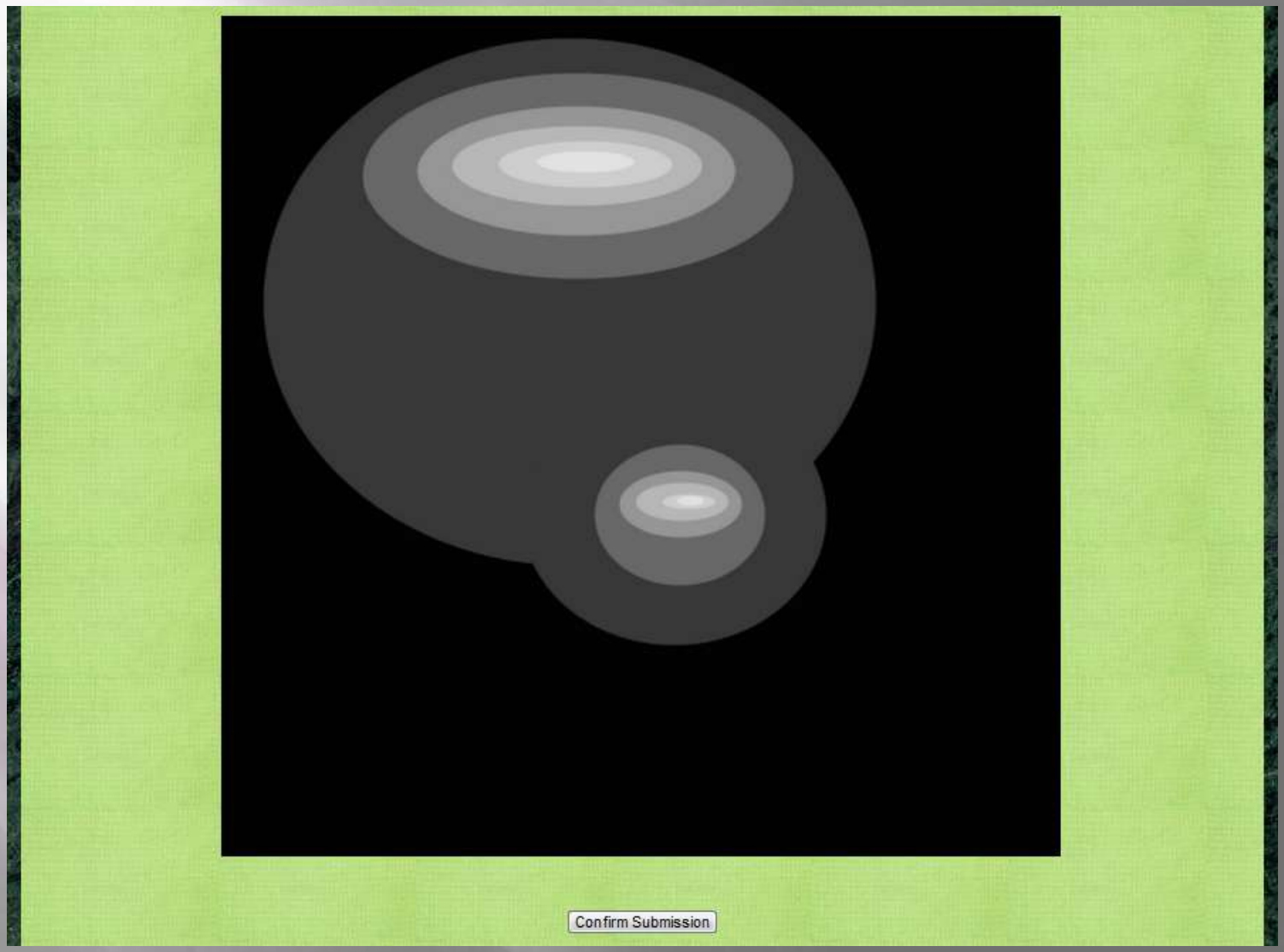
Subject(s) Information:

Subject age: *34*
Subject sex: *F*
Subject Category: *Hiker*
Scenario: *Medical*
Subject Sub-Category: *UNDOCUMENTED ALIEN*
Subject Activity: *Hiking*
Group Type: *F*
Number Lost: *1*

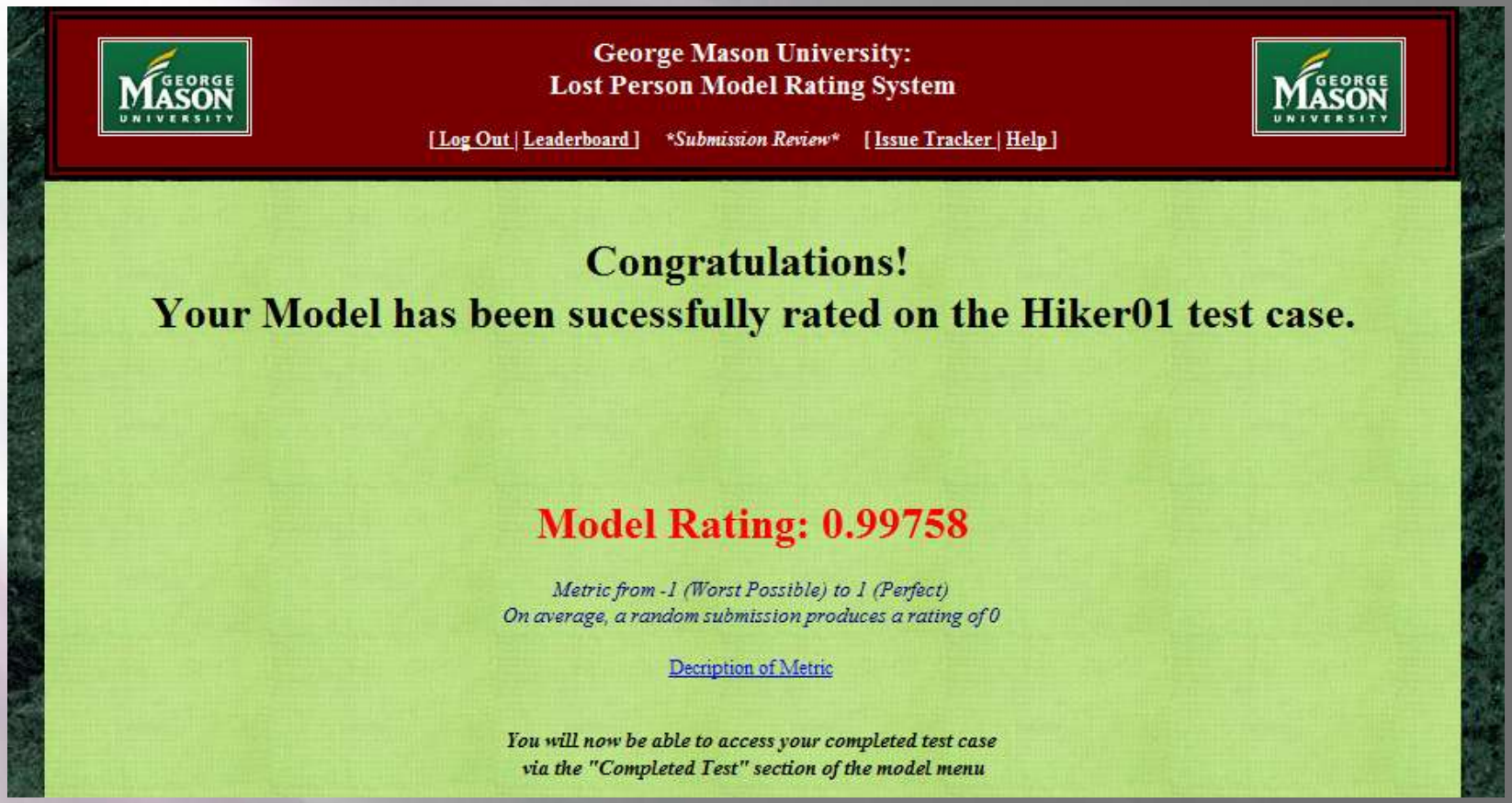
Search Region Information:

Terrain: *Mountainous*
Ecoregion Domain: *Dry*

Probability Map Upload



Probability Map Rating



Rossmo Metric [7]

- ***P* = prob(the find location)**
- ***r* = proportion of pixels > *P***
  - Roughly.
  - Add half the pixels with prob = *P*. (Koester)
- **Scaled to be more intuitive**
  - ***R* = (.5 – *r*)/(.5)**
  - **Range = - 1 (bad) to 1 (good)**

Operationally: average time-to-find depends on *r*.

Simplest case:

- All searchers travel the same speed everywhere.
- There is no transit time.
- It takes *T* hours to search the whole map.
- Resources are allocated by *P.*
- All searchers have perfect detection everywhere.

Then: average time to find is rT.

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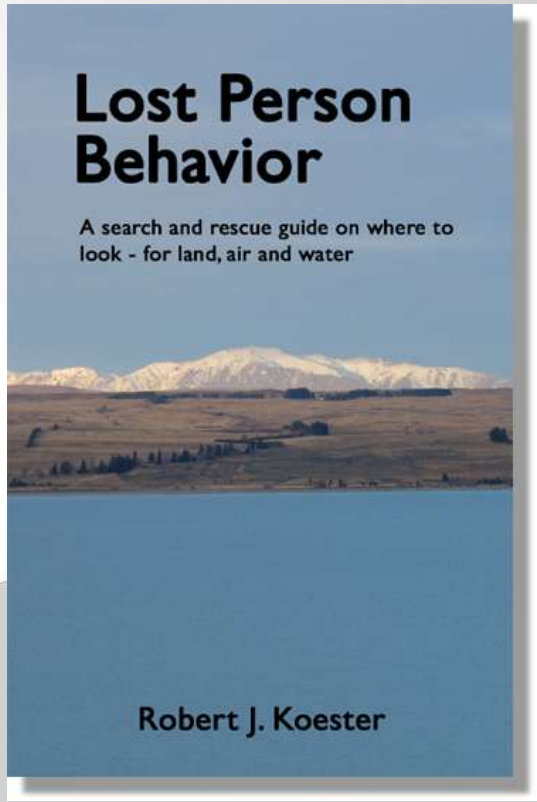
Modified E**SRI** Models

- Distance from IPP
- Elevation Change from IPP
- Linear Features/Track offset
- Find Location

Base models created for Yosemite by Liz Sarow, ESRI.
Based on statistics from
***Lost Person Behavior* by Robert Koester.**
Generalized & modified for MapScore by Eric Cawi.



Distance

- Creates a 4 level buffer ring with 25, 50, 75, and 95 percent rings

- Calculates probability per cell based on the area of each ring.

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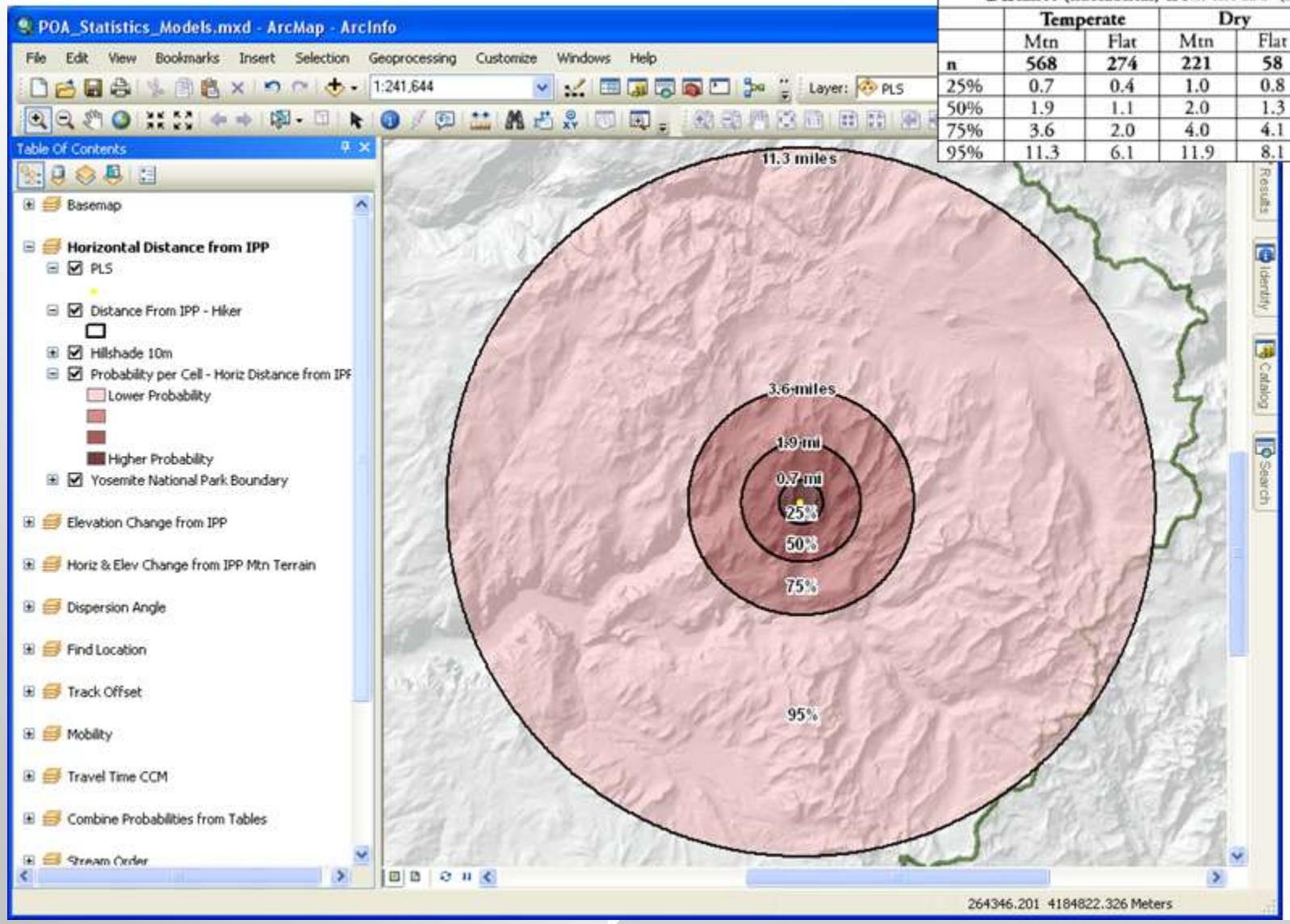
Example Distance Model (ESRI slide)

Distance (horizontal) from the IPP (miles)					
	Temperate		Dry		Urban
	Mtn	Flat	Mtn	Flat	
n	568	274	221	58	8
25%	0.7	0.4	1.0	0.8	
50%	1.9	1.1	2.0	1.3	1.6
75%	3.6	2.0	4.0	4.1	
95%	11.3	6.1	11.9	8.1	

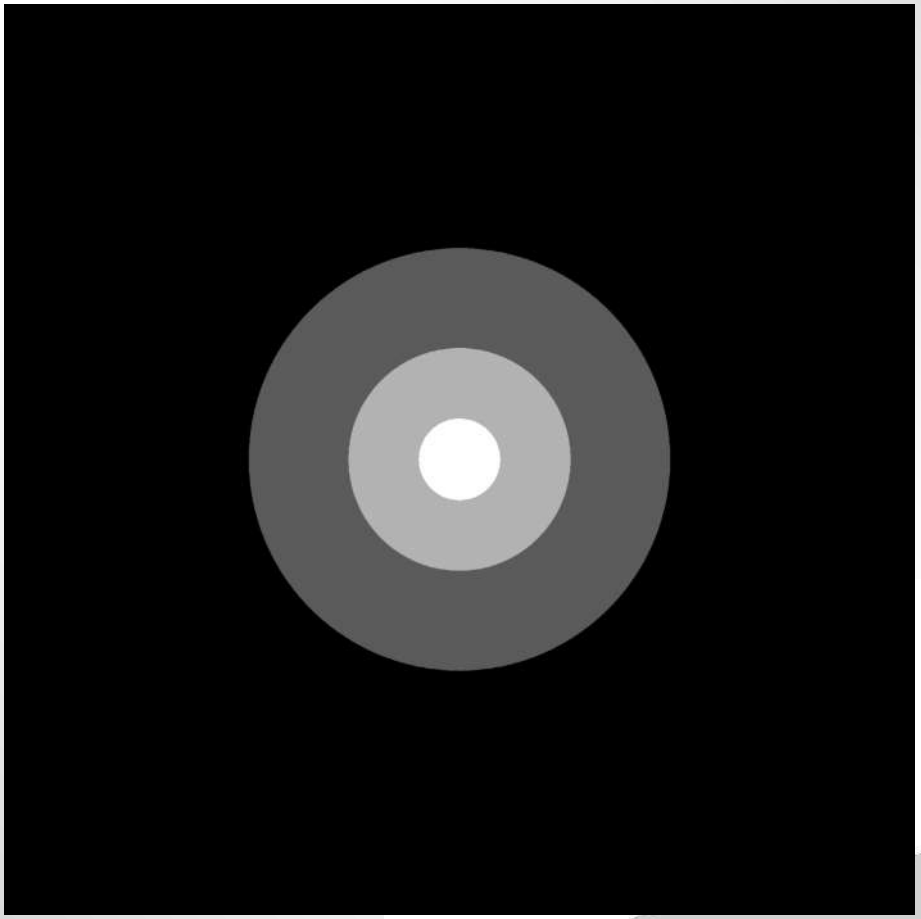


Example Distance Map for Scoring

I've adjusted the brightness and contrast of all the greyscale maps so they look better on my monitor. ☺

The actual values given to the computer are sometimes hard for the eye to distinguish.

But the scoring metric cares only about relative value anyway.



From the New York 108 Case

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Elevation

- Calculates the elevation change from the last known point for every cell
- The “downhill”, “uphill”, and the “same” elevation cells are assigned different probabilities
- The hiker model calculates probability per cell based on both distance from LKP and elevation change.

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Example elevation Probability map (Dementia Model)

From the Arizona 02 Case

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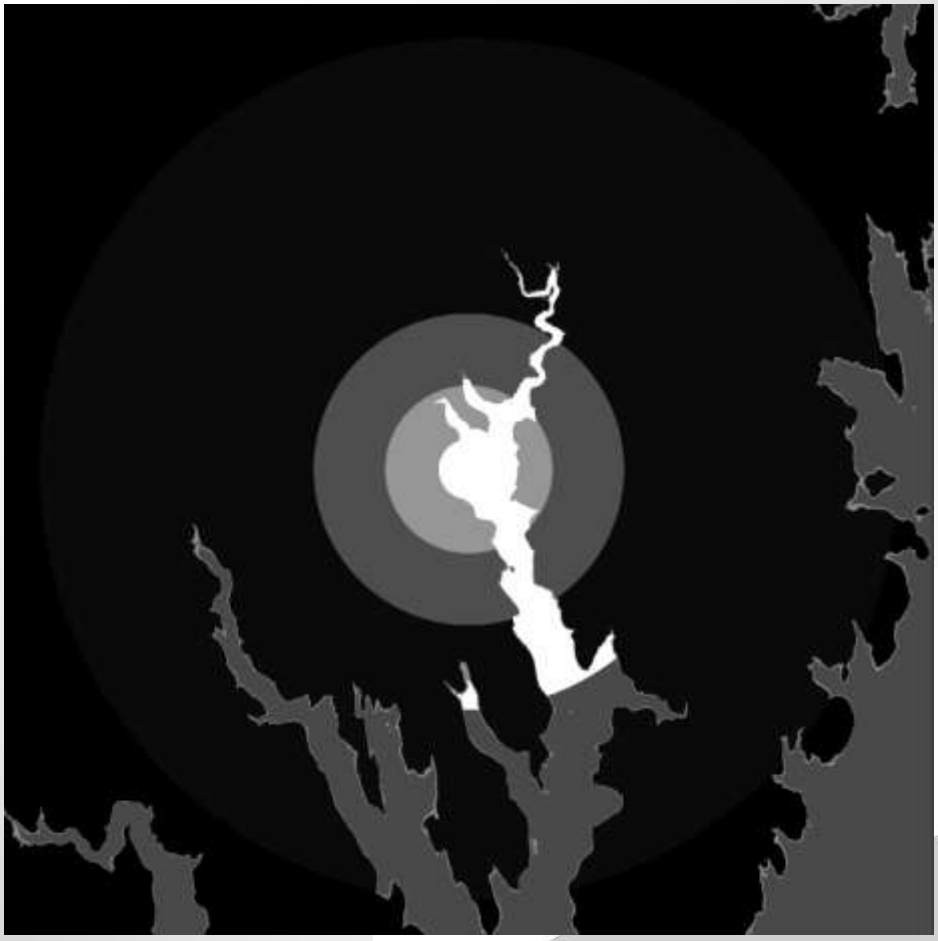
Example Elevation Probability Map (Hiker Model)



From the New York 108 Case

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Linear Features/Track Offset

- Linear features used: roads and rivers, trails (when available)
- Calculates distance from linear features and classifies based on probability areas

- Calculates probability per cell based on area of each ring

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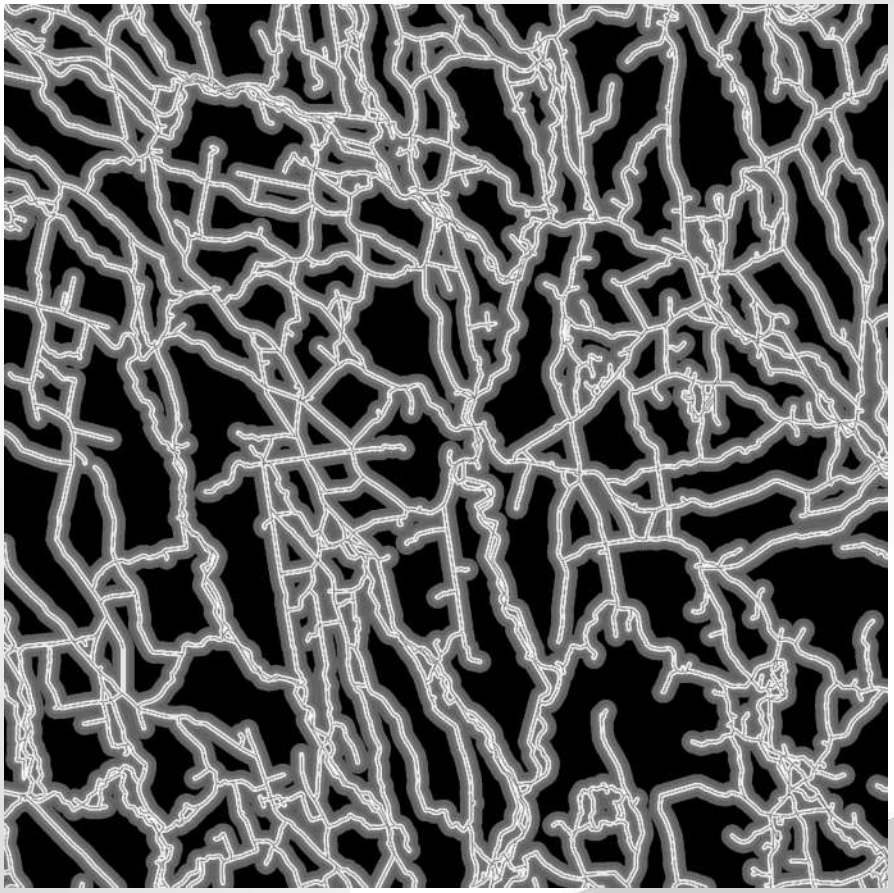
Example Linear Features Probability Map



From the New York 108 Case

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Land Classification/Find Location

- Assigns different probabilities to different types of land cover
- e.g. forests, rivers, meadows, etc.
- Calculates probability per cell based on area of each classification

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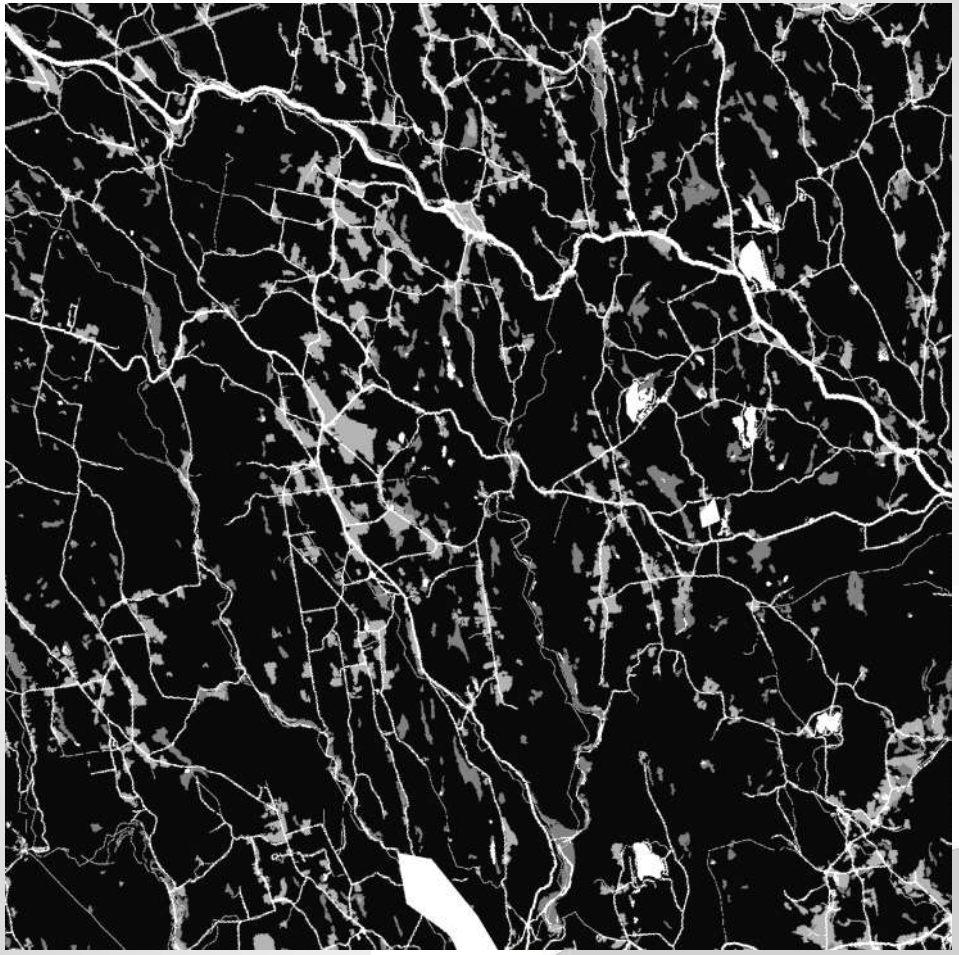
Example Land Classification Probability Map



From the New York 108 Case

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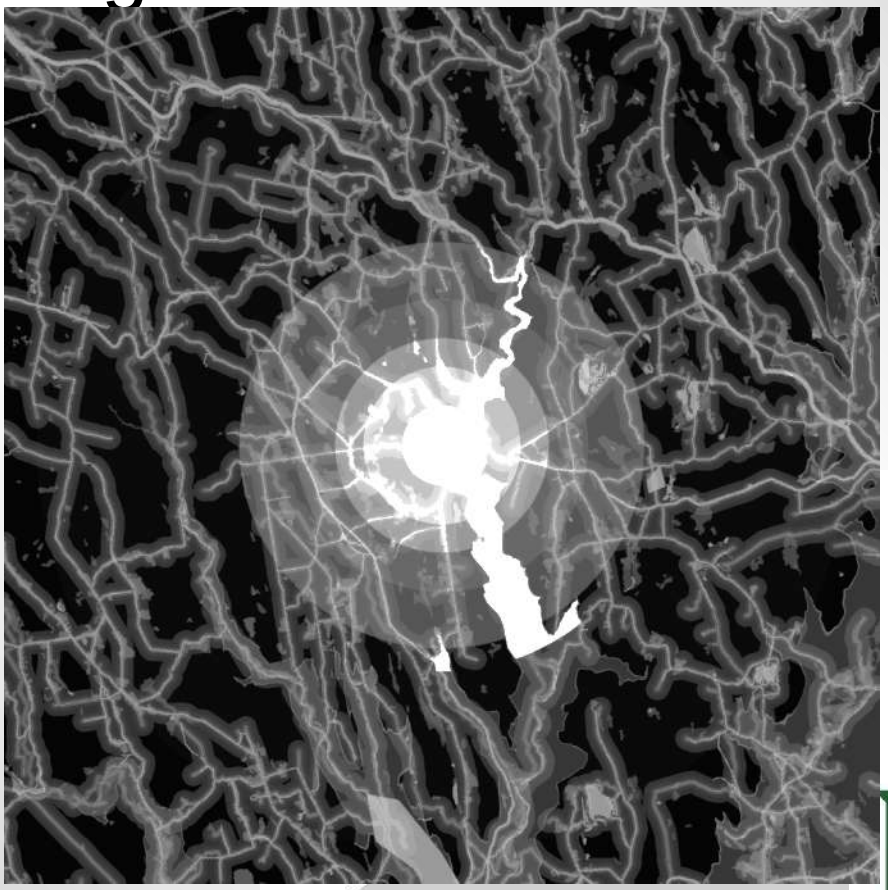
Combined Probability

- Average of all the probability maps, equally weighted.



From the New York 108 case

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Average Scores

Model	Average Score	Tests Completed
DELL	0.81…	6
Distance	0.73…	6
Elevation	0.29…	6
Linear Features	0.28…	6
Land Classification	0.084…	6

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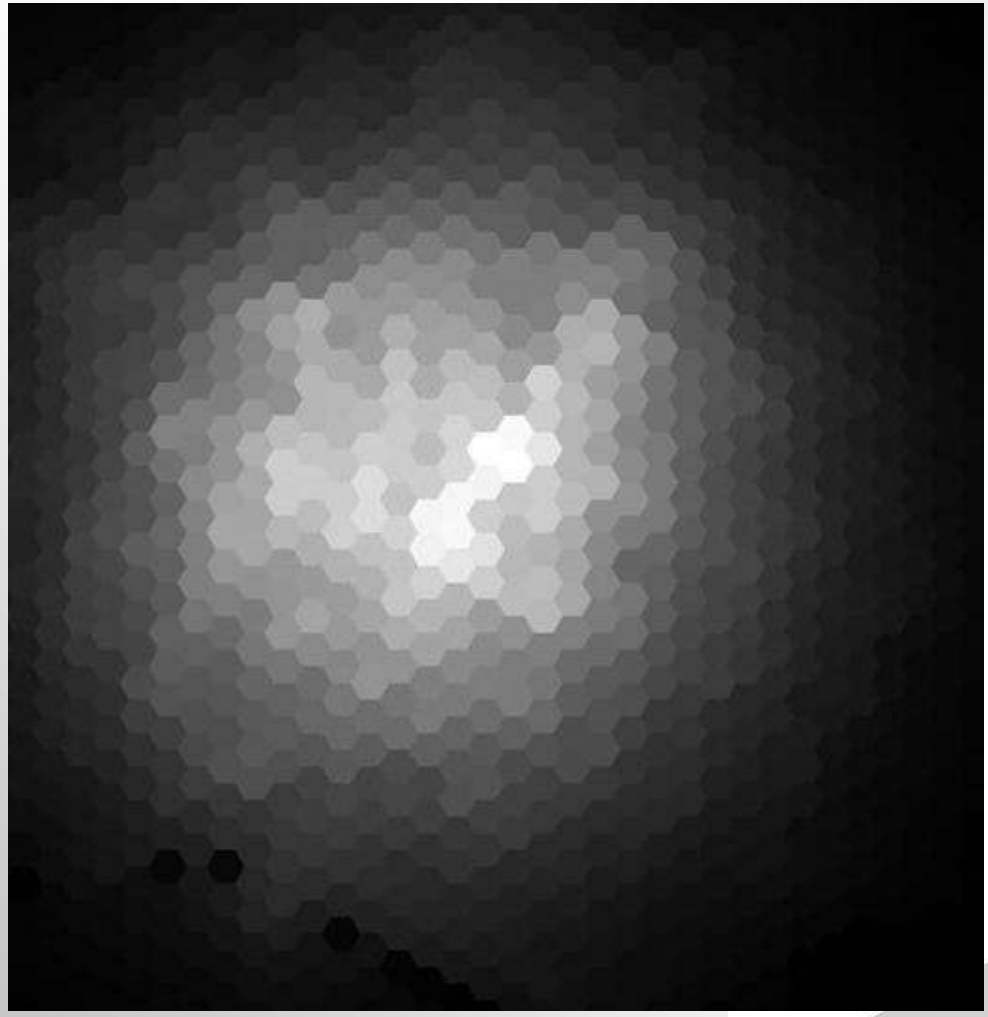
Case by Case Scores

Case	Distance	Elevation	Linear Features	Land Classification	DELL
Arizona95	0.99354	-0.49825	0.915229	-0.047413	0.942662
Arizona01	-0.19774	-0.16843	-0.03983	0.95349	0.79786
Arizona03	0.94675	0.88205	0.97485	-0.07843	0.98671
NewYork108	0.99364	0.98085	-0.07907	-0.15934	0.98287
Avg Hiker	**0.68408**	**0.29906**	**0.44279**	**0.16708**	**0.92753**
Arizona02	0.64351	-0.42168	-0.0288	0.2041	0.35105
Arizona24	0.99676	0.98127	-0.09049	-0.37102	0.81521
Avg Dem	**0.82014**	**0.27980**	**-0.05965**	**-0.08346**	**0.58313**
Avg	**0.73429**	**0.28775**	**0.27531**	**0.08356**	**0.81273**

BYU Motion Model



New York 53 (46yo male camper)

Probability Map by Lanny Lin
Brigham Young University

Score: 0.98558 (**98+%**)

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So far

- On average, combining the models does better than any of **our** individual models
- Distance is the most accurate of **our** individual models.
- **The BYU motion model did well so far. :-)**

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Mt. Rogers Tabletop Exercise

- The search area has been divided into segments
- Estimate the probability for each segment. Two rounds:
  - "Anonymous" estimates recorded, averaged, and displayed.
  - Discussion.
  - 2nd round of anonymous estimates.

Mount Rogers Test Case

- Two elderly couples one local and one visiting from Florida decide to go a day hike. They drive to Grayson Highland State Park and park at the Massie Gap Parking lot. They hike on National Forest Trail for a short distance which then connect with the Appalachian Trail, along Wilburn Ridge and then to Mt Rogers, where they reach the summit via a summit spur trail. The plan is to return along the same route. They all reach the AT. Along the AT the local couple is hiking faster. The location they last saw Paul and June is 36.655944 -81.522989 heading NE along the AT.

- June was found (alive) at 36.638874 -81.510373. She last saw Paul at 17:30 (same day) heading east along the trail which at point was difficult to see due to fog.

- The following day a sighting occurs at 36.683935, -81.475615. The reporting partying (berry pickers) said they ran into an elderly gentleman who reported his wife was lost, he had spent the night trying to get help for her, and where was the closest phone. They directed him to stay on the gravel road until he would reach a paved road at the bottom, and then to turn right where is was just a few mile walk into town. They described his small fanny pack and the clothing description matched.

- A pencil from his golf course in Florida was found in an area where is looked liked someone had spent the night 36.675969 -81.520200

- Paul was found alive at 36.691434, -81.504536

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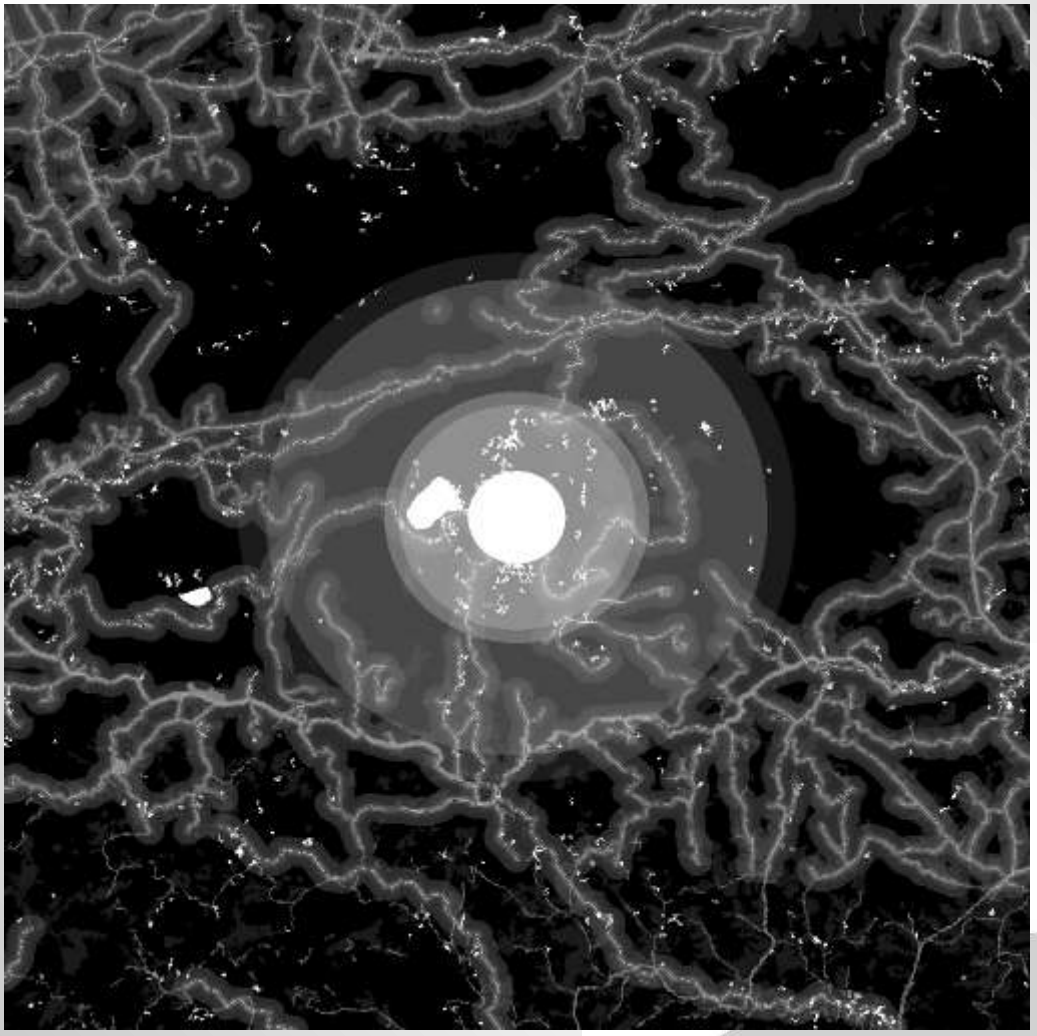
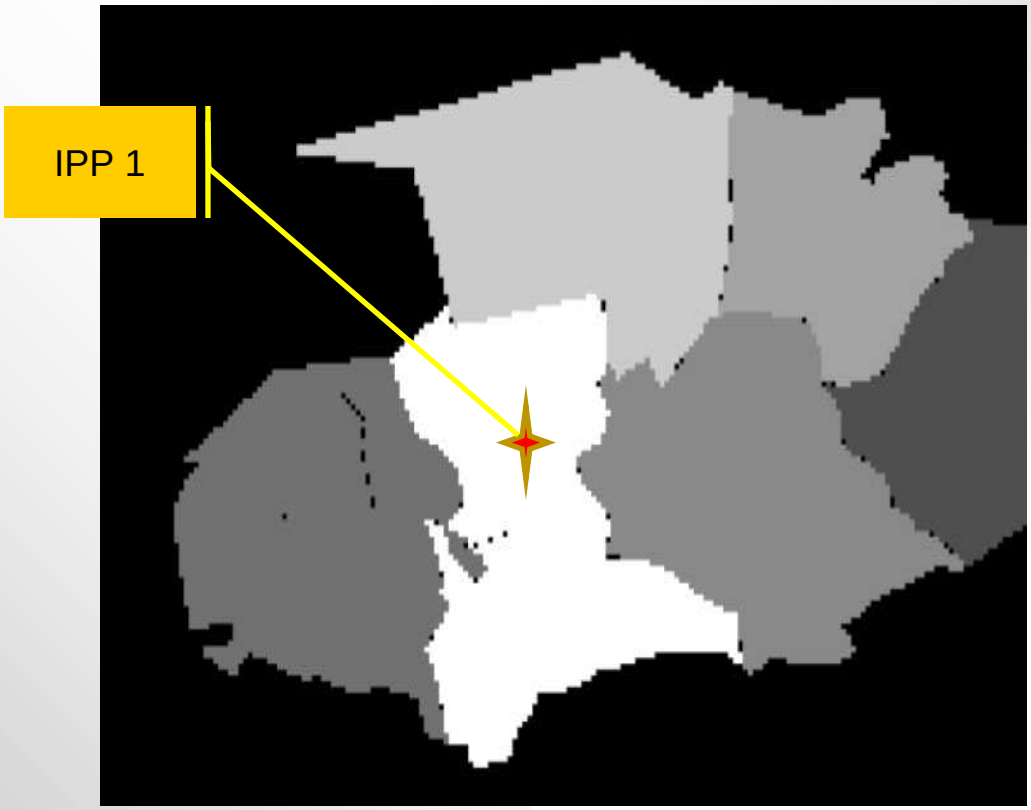
DELL probability Map (1st IPP)



Subjective Consensus (Round 1)



VASARCON, April 2012

Regions drawn by Bob Koester

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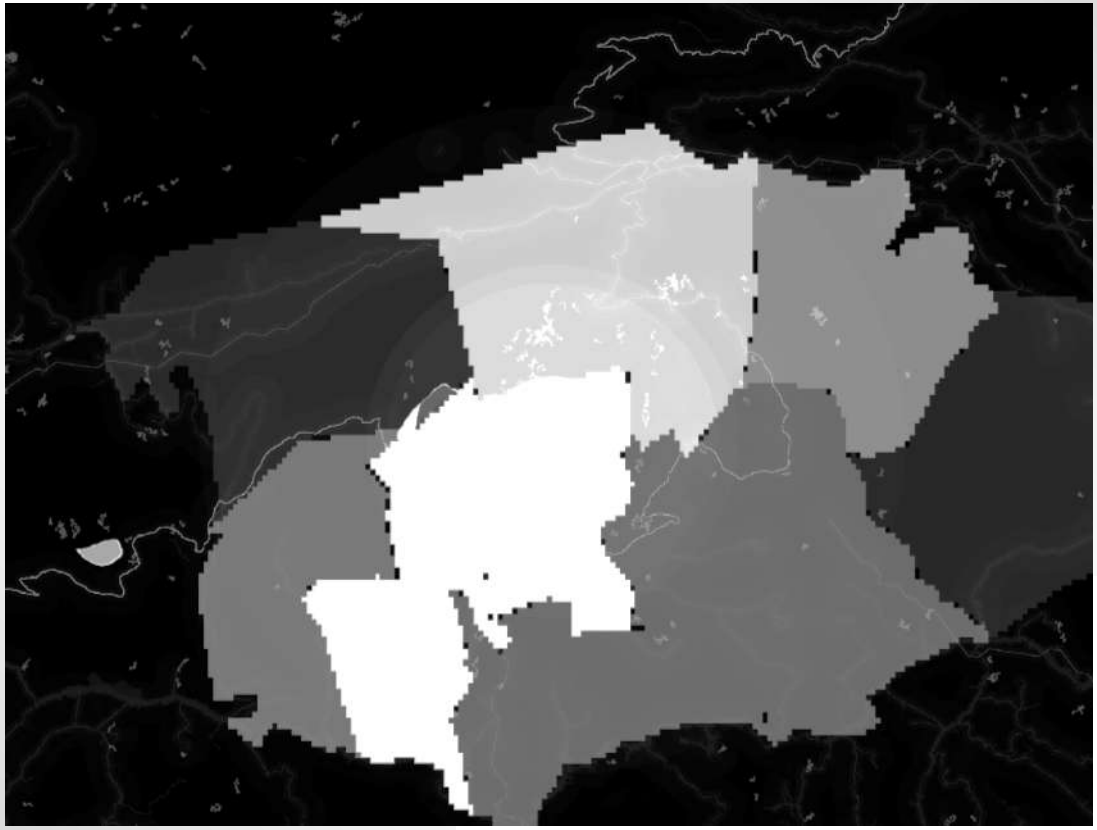
Hybrid Subjective & DELL

Note trail lines and gradations.

If you have a good monitor, you can even see the Appalachian Trail extending off into the black region West and NorthEast.



- **VASARCON, May 2012**
- **Improved over the straight DELL model**

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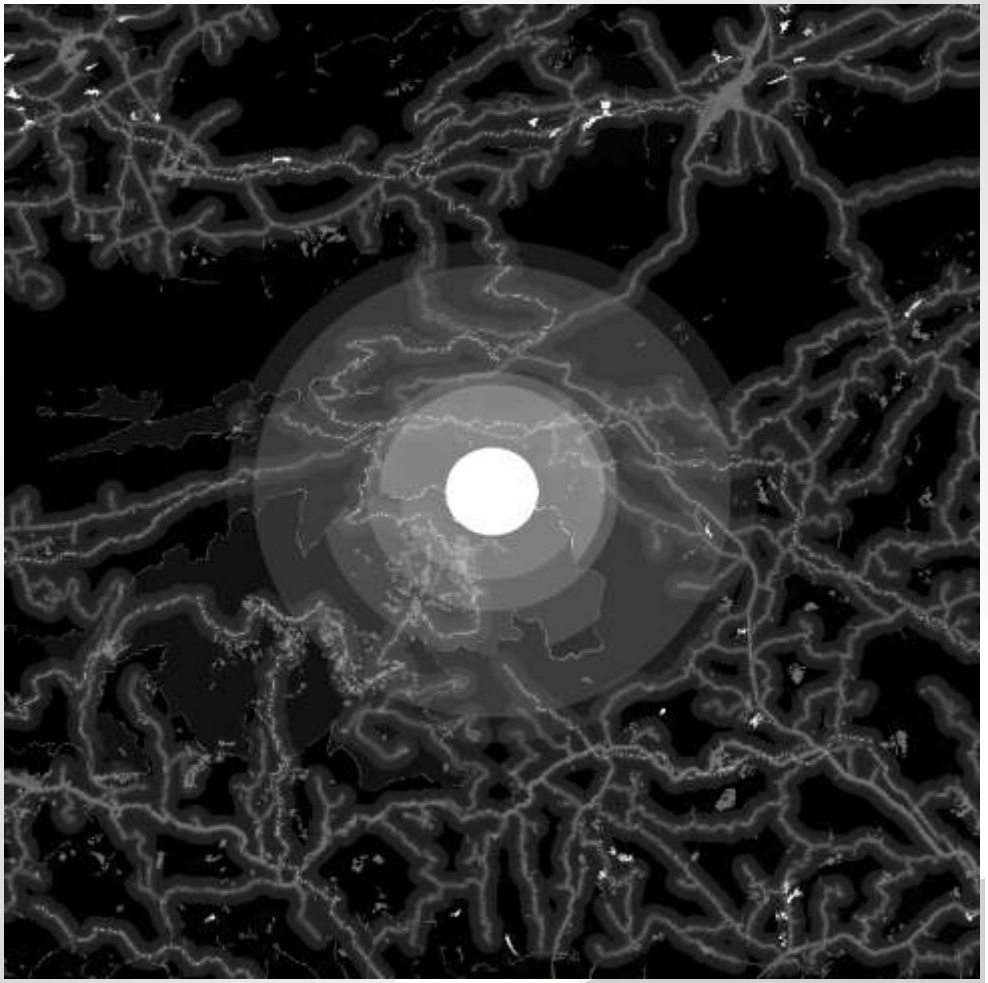
Probability Map for 2nd IPP



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Future Work

- ~~Providing GIS Layers for test cases.~~
- Run more test cases.
- Automated baseline models.
- Scripting support.

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Citations

[1] http://www.nationalparkstraveler.com/2010/08/search-and-rescue-ops-cost-national-park-service-48-million-20086495

[2] http://www.odt.co.nz/news/national/38500/search-and-rescue-operations-cost-400000?page=0%2C1

[3] http://faculty.cs.byu.edu/~mike/mikeg/papers/LinGoodrichIROS2009.pdf

[4] Robert J. Koester 2008. *Lost Person Behavior*

[5] Elizabeth Sarow 2011. Determining Probability of Area for Search and Rescue using Spatial Analysis in ArcGIS 10. ESRI slides.

[6] Proportional Consensus spreadsheet. http://www.sarblog.info/proportional-consensus-method/.

[7] Rossmo, D. K. (1999). *Geographic Profiling* (1st ed.). CRC Press.

SAR*Bayes*: http://sarbayes.org

MapScore: http://mapscore.sarbayes.org

BYU WiSAR: https://facwiki.cs.byu.edu/WiSAR/index.php/Main_Page

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Further Reading

- Some cool BYU articles
  - L. Lin and M. A. Goodrich. A Bayesian Approach to Modeling Lost Person Behaviors Based on Terrain Features in Wilderness Search and Rescue. To appear in *Computational and Mathematical Organization Theory.*
  - M. A. Goodrich, B. S. Morse, C. Engh, J. L. Cooper, and J. A. Adams. Towards using Unmanned Aerial Vehicles (UAVs) in Wilderness Search and Rescue: Lessons from field trials. *Interaction Studies* , 10(3), pp455-481, 2009. Copy available on request.
  - M. A. Goodrich, B. S. Morse, Damon Gerhardt, J. L. Cooper, M. Quigley, J. A. Adams, and C. Humphrey. Supporting Wilderness Search and Rescue using a Camera-Equipped Mini UAV. *Journal of Field Robotics*, 25 (1-2), pp89-110, 2008. The paper is available for free from Wiley InterScience.
  - L. Lin and M. A. Goodrich. A Bayesian Approach to Modeling Lost Person Behaviors Based on Terrain Features in Wilderness Search and Rescue. *Proceedings of the 18th Conference on Behavior Representation in Modeling and Simulation.* Sundance, UT, USA. March 31-April 2, 2009. pp. 49-56.

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