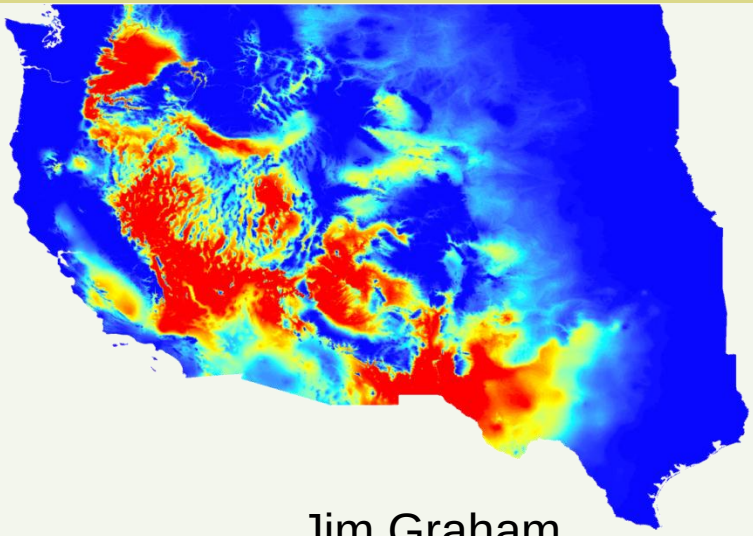
IBIS
International Biological Information System

The Hyper-Envelope Modeling Interface (HEMI): A novel approach to habitat suitability modeling



Jim Graham

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Oregon State University / Colorado State University

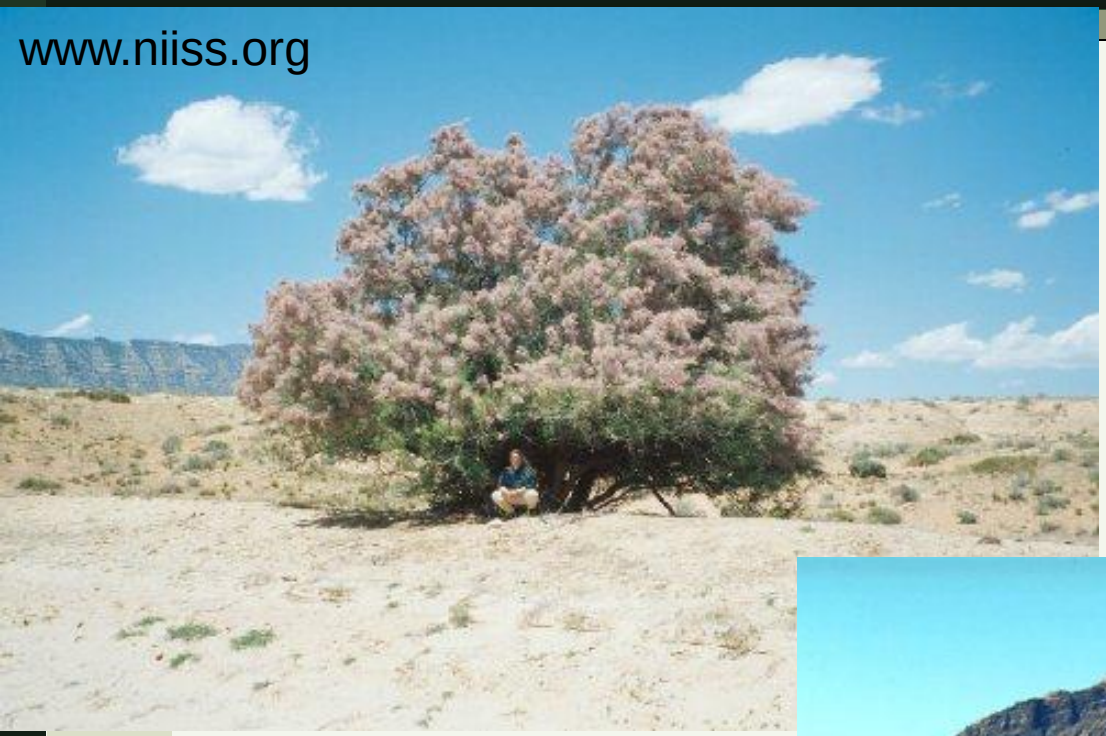
Colorado State University
Knowledge to Go Places

Natural Resource Ecology Laboratory

HEMI

- New approach to Habitat Suitability Modeling, Species Distribution Modeling (SDM)
- Challenge:
  - Predicting potential habitat for a species
  - Over large spatial scales
  - Large datasets with large or undefined uncertainties

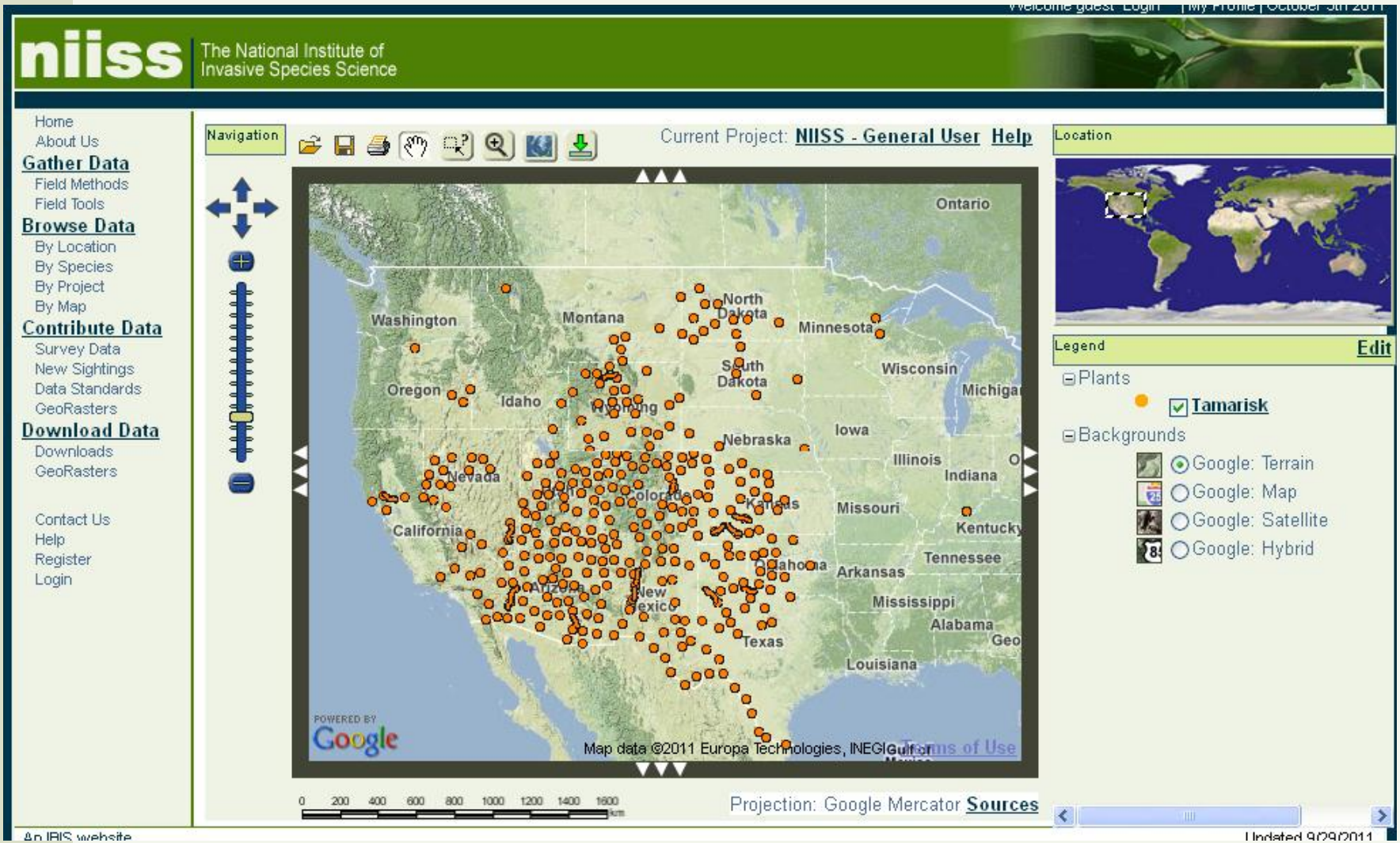
Invasive Tamarisk / *Tamarix*

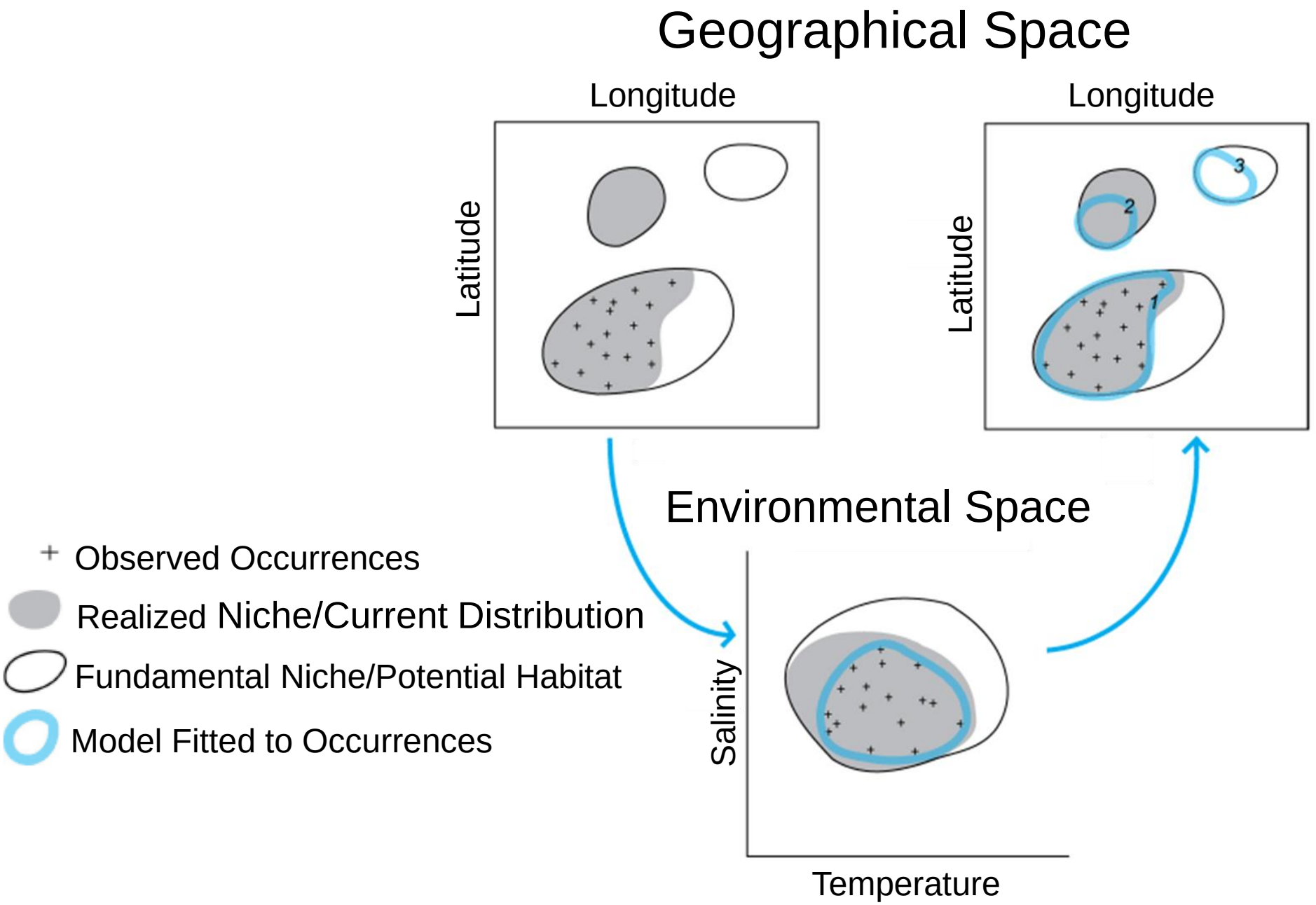


Species:

- *T. chinensis*
- *T. ramosissima*
- *And hybrids*

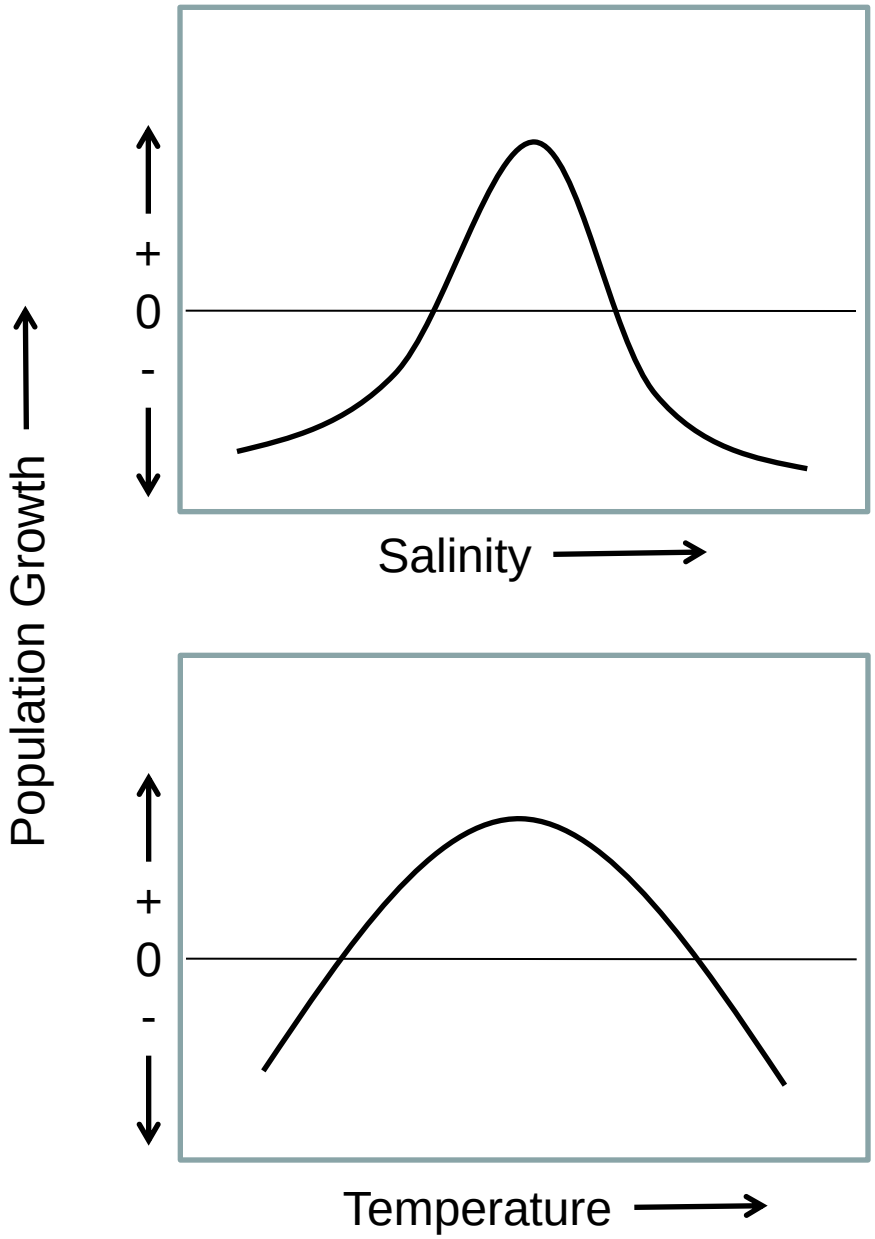
NIISS.org: Tamarisk Data

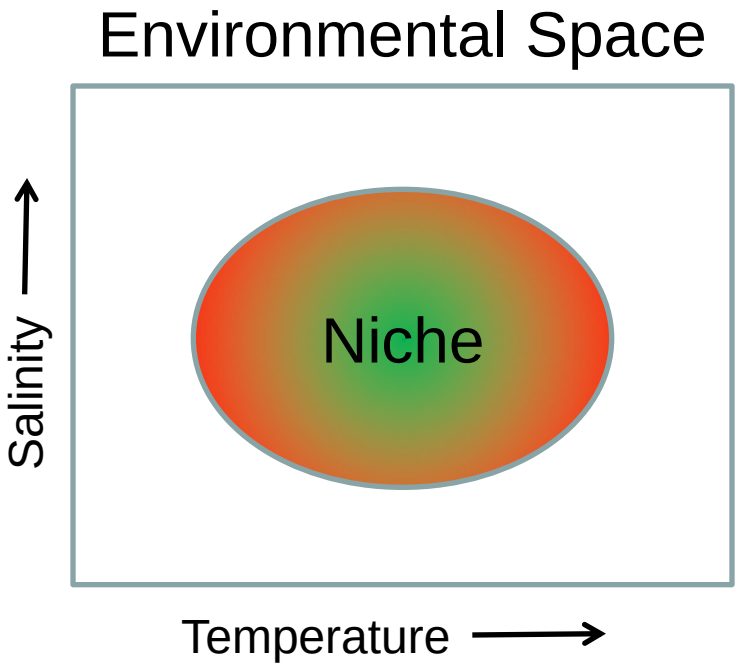




Adapted from Richard Pearson, Center for Biodiversity and Conservation at the American Museum of Natural History

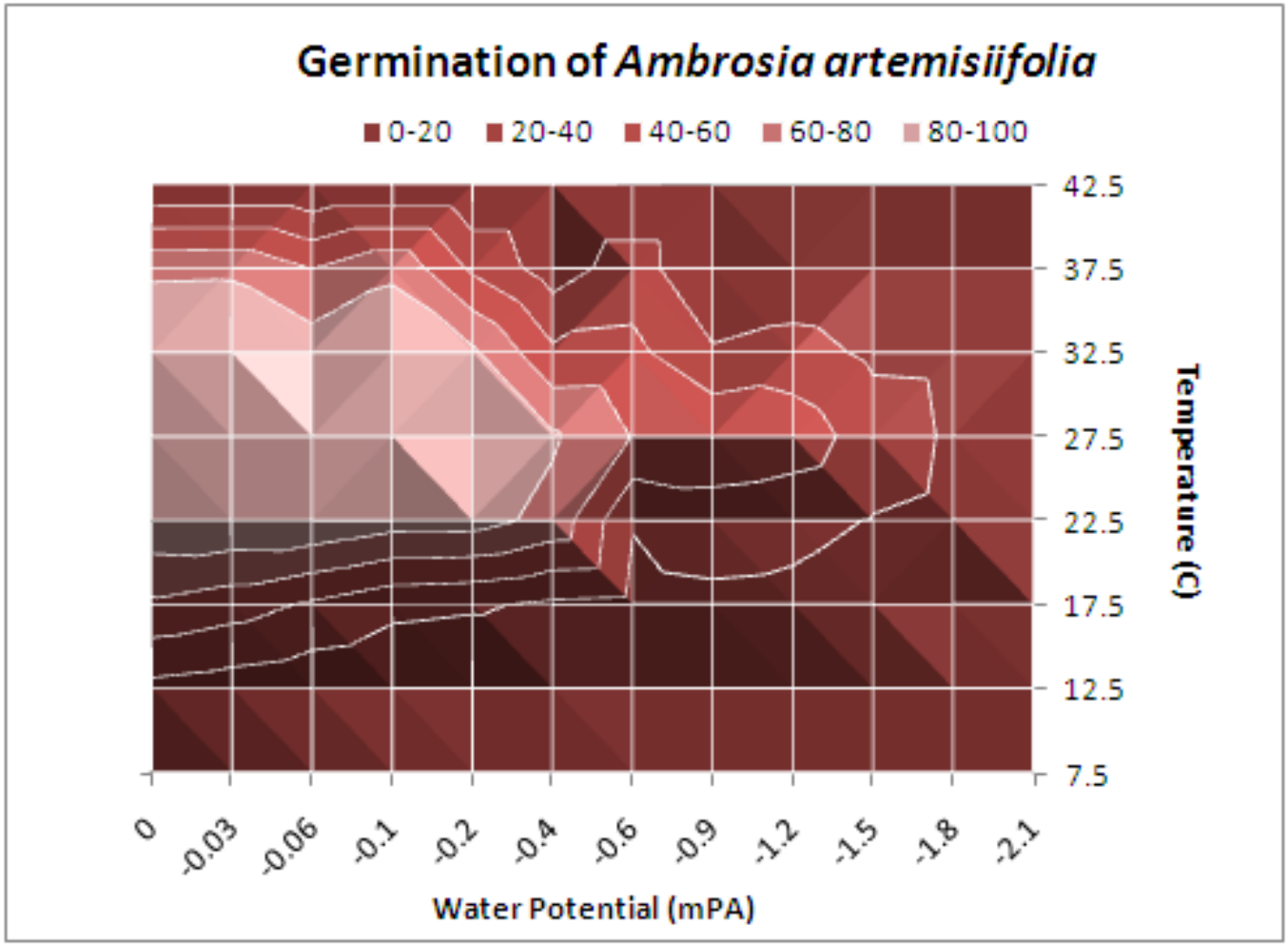
From the Theory of Biogeography





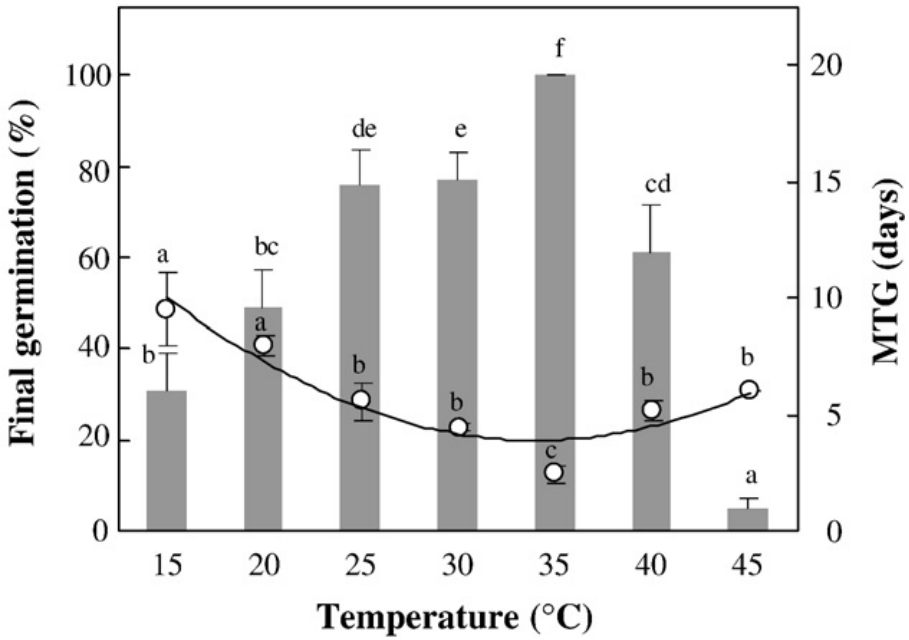
Brown, J.H., Lomolino, M.V. 1998, Biogeography: Second Edition. Sinauer Associates, Sinauer Massachusetts

Germination Percentage

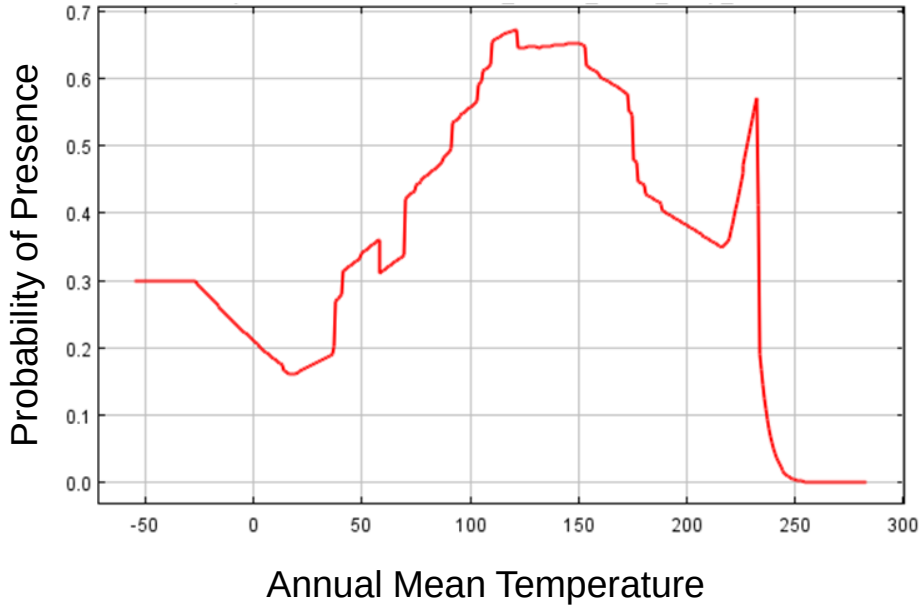


Shrestha, A., E. S. Roman, A. G. Thomas, and C. J. Swanton. 1999. Modeling germination and shoot-radicle elongation of Ambrosia artemisiifolia. Weed Science 47:557-562.

Measured germination of *Ziziphus lotus* (a buckthorn)



Maxent model for *Tamarix* in the US with temperature and precipitation



What should the model look like?

Are we over-fitting the data?

Maraghni, M., M. Gorai, and M. Neffati. 2010. Seed germination at different temperatures and water stress levels, and seedling emergence from different depths of Ziziphus lotus. South African Journal of Botany 76:453-459.

Maxent Model Parameters

- bio12_annual_percip_CONUS, -4.946359908378759, 52.0, 3269.0
- bio1_annual_mean_temp_CONUS, 0.0, -27.0, 255.0
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- densityNormalizer, 1311.2581836276431
- numBackgroundPoints, 10000
- entropy, 8.358957722359722

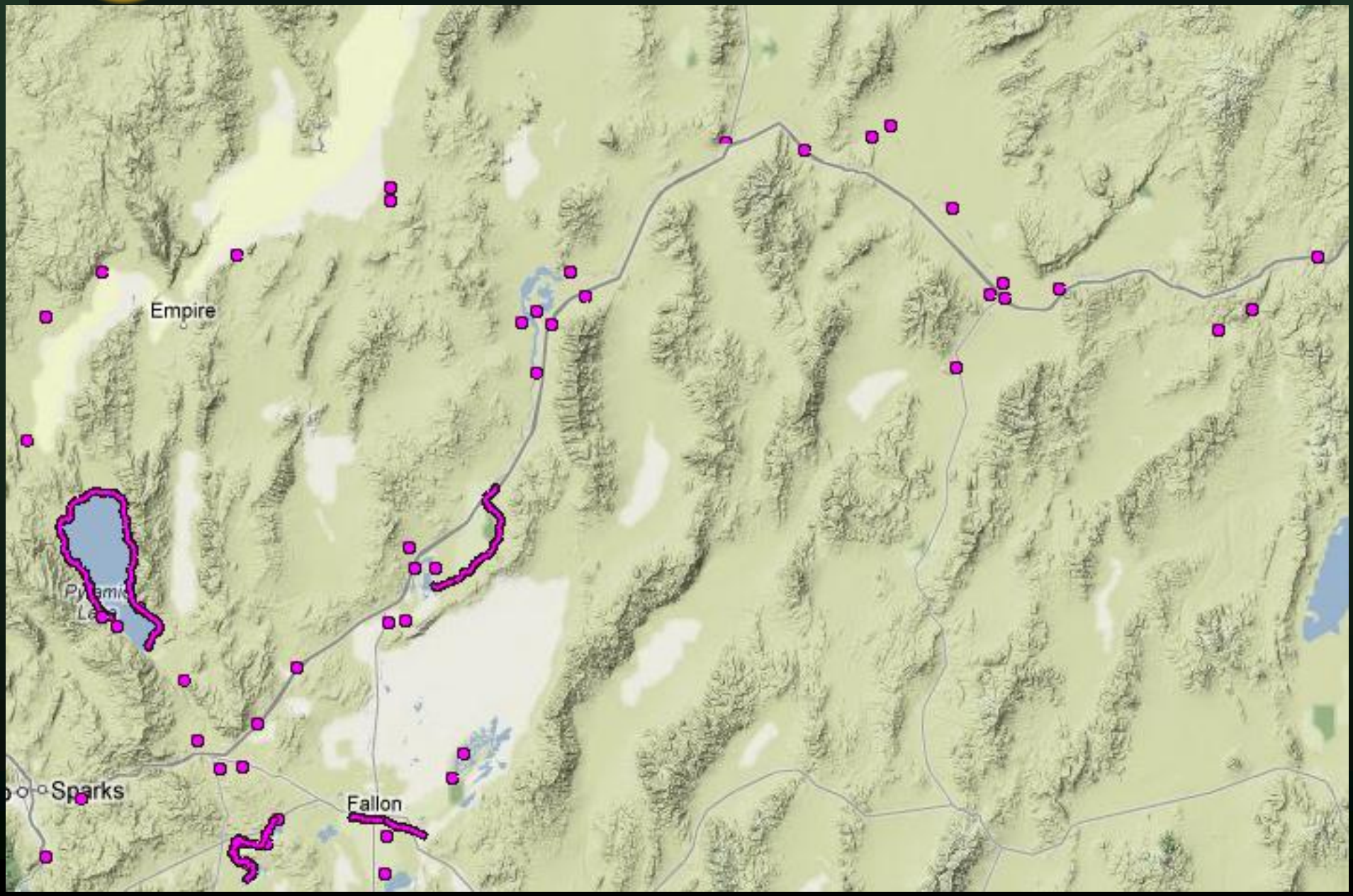
162 Parameters

Maxent model from Tamarix model of western US using precipitation and temperature.

Some Caveats

- We are using “observations”
  A. Modeling occurrences with some uncertainty
  B. Modeling the realized niche if the data is a complete sample for the environmental space the species currently occupies
  C. Modeling the fundamental niche if B is true and the species is covering it’s full possible range of habitats
- To model suitable habitat
  - With some uncertainty

Bias from Roads

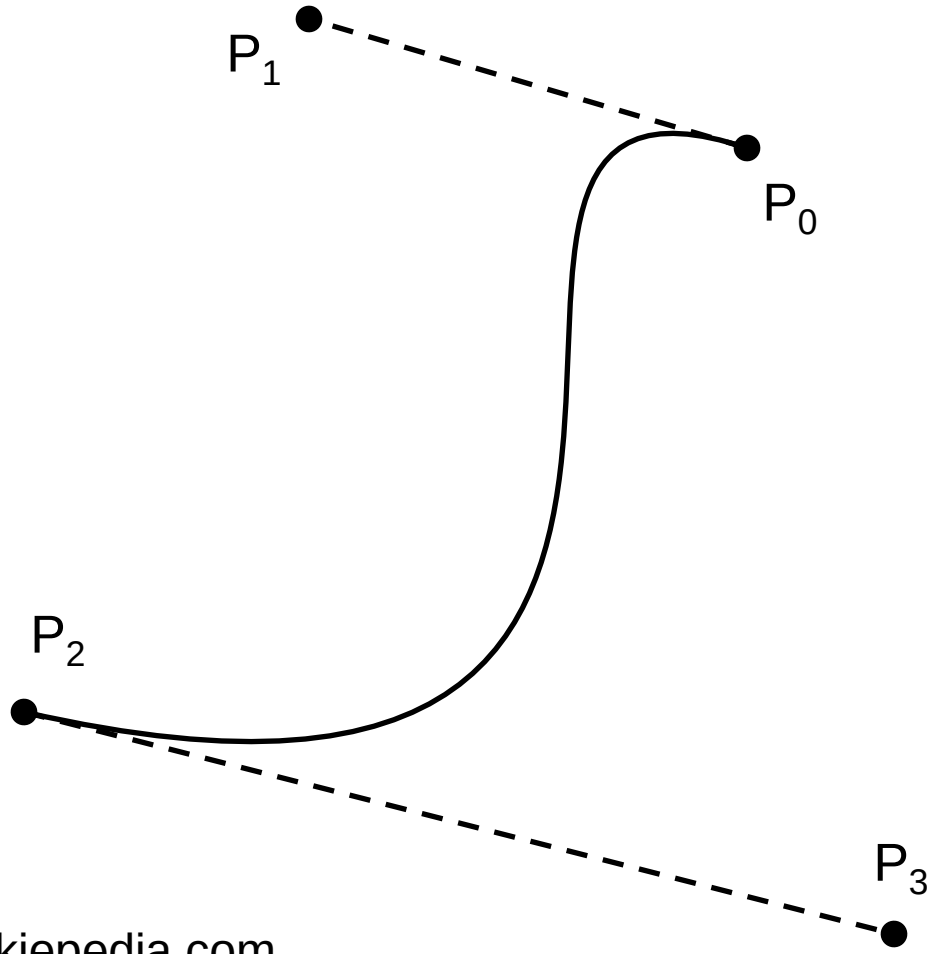


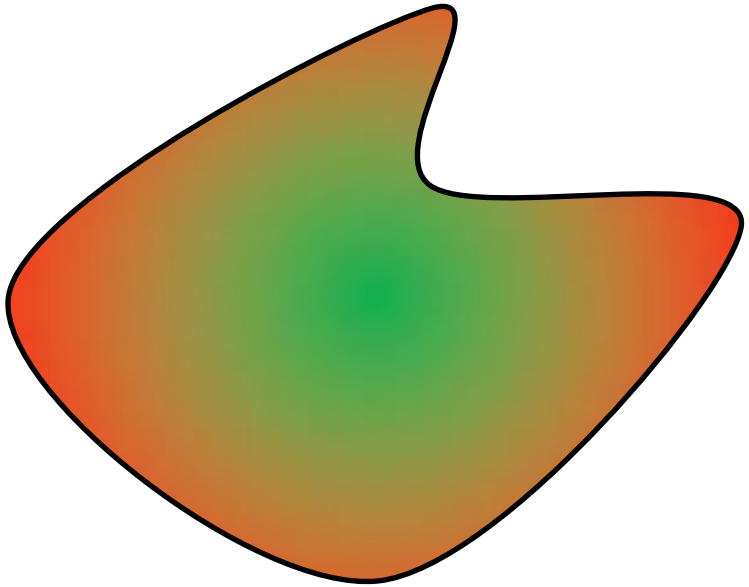
Can we?

- Create a habitat suitability modeling method that:
  - Uses a smaller number of parameters?
  - Minimize over-fitting the data?
  - Allows visualization of the model in environmental space?
  - Does not use absence points?
  - Allows editing the model to try scenarios?

Bezier Curves

$$\mathbf{B}(t) = (1-t)^3\mathbf{P}_0 + 3(1-t)^2 t\mathbf{P}_1 + 3(1-t)t^2\mathbf{P}_2 + t^3\mathbf{P}_3 \ , \ t \in [0,1].$$





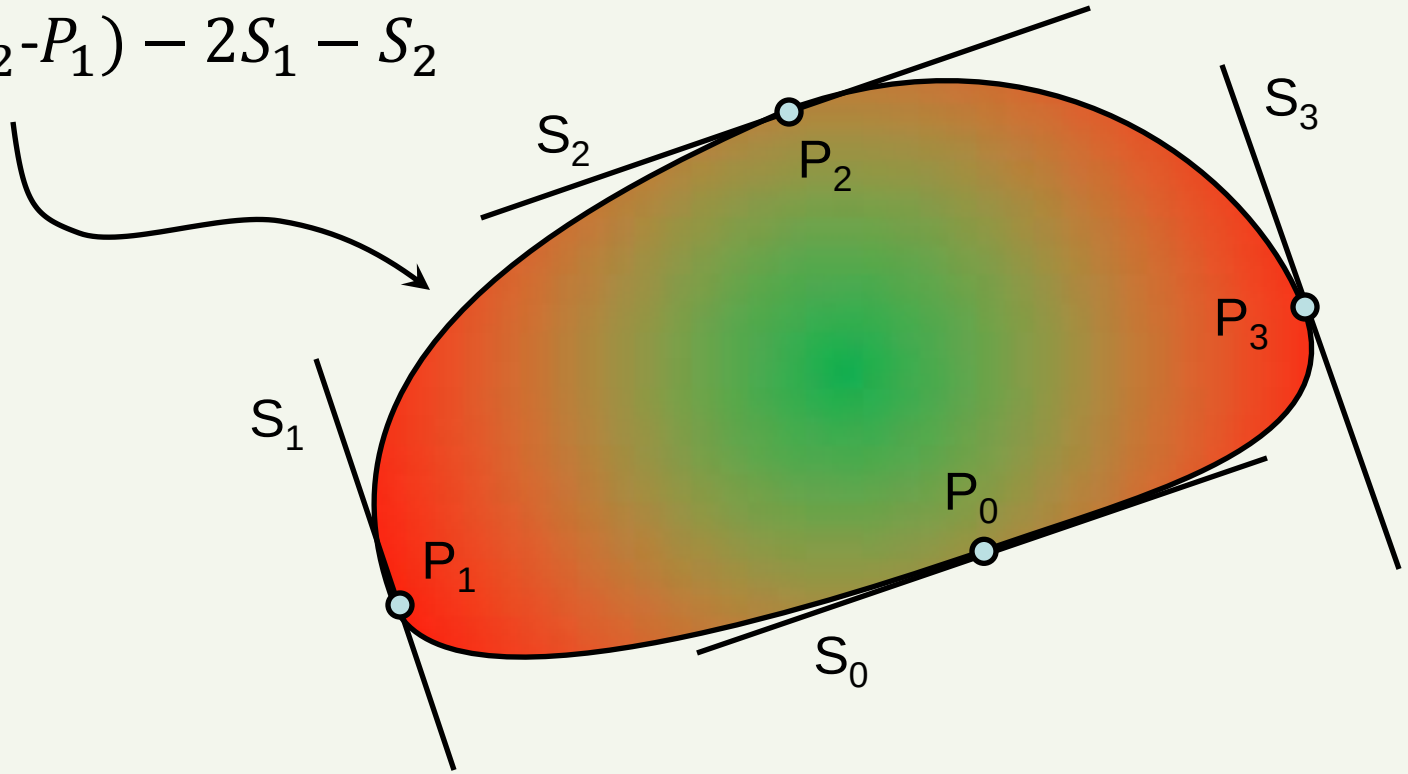
Wikiepedia.com

Modified Bezier Curves

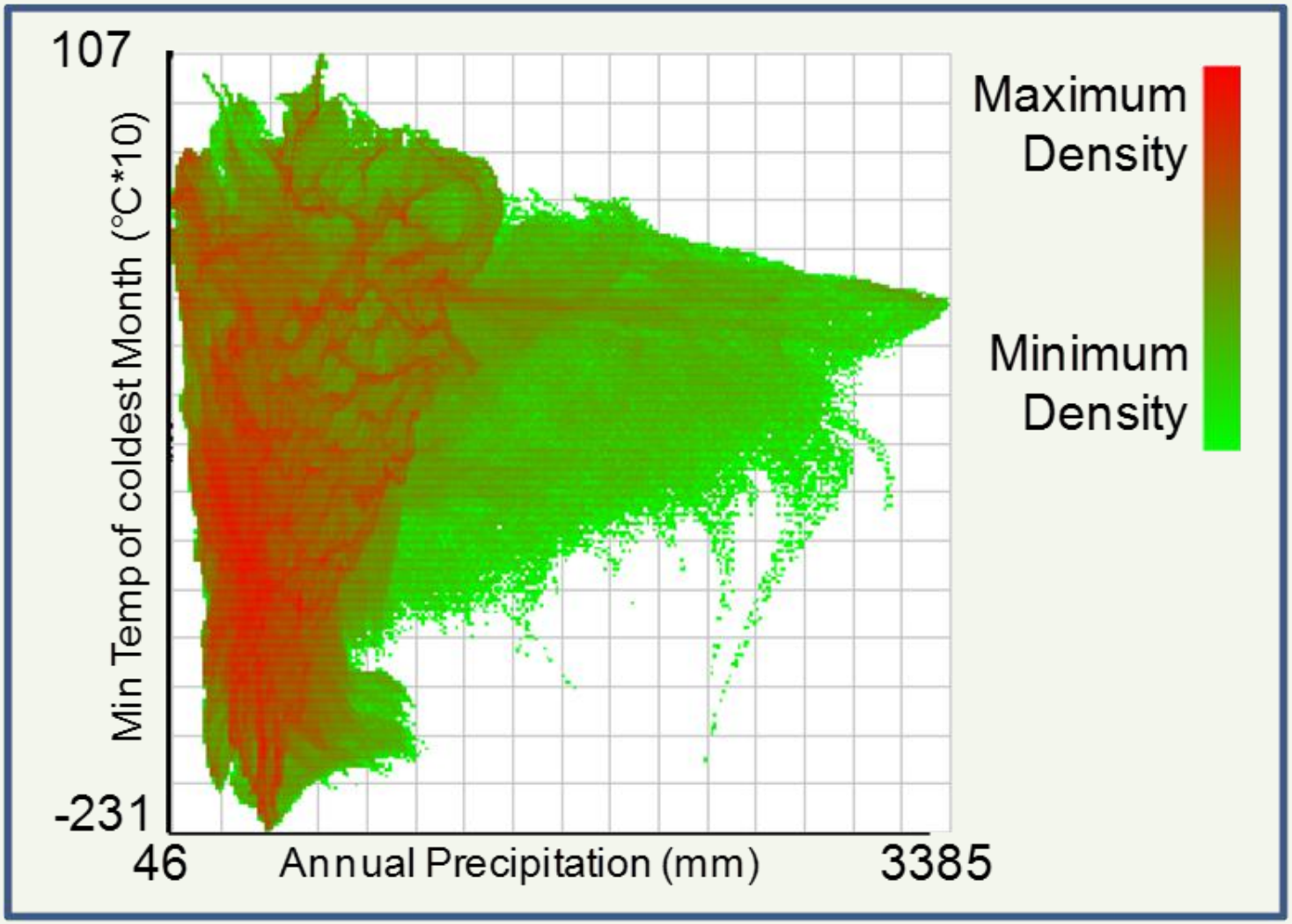
$$B(t) = at^3 + at^2 + S_1 t + P_1$$

$$a = 2(P_1\text{-}P_2) + S_1 + S_2$$

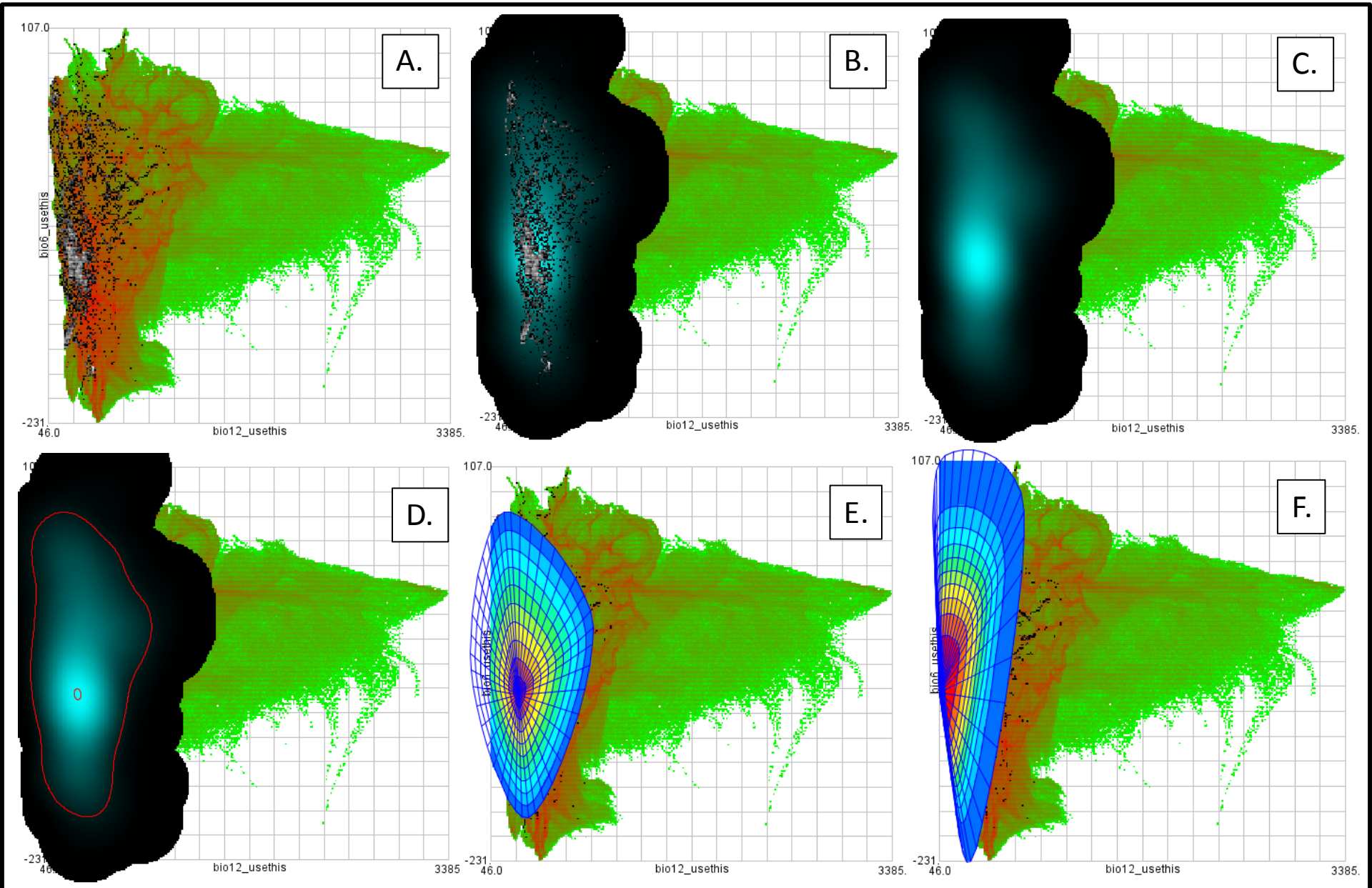
$$b = 3(P_2\text{-}P_1) - 2S_1 - S_2$$

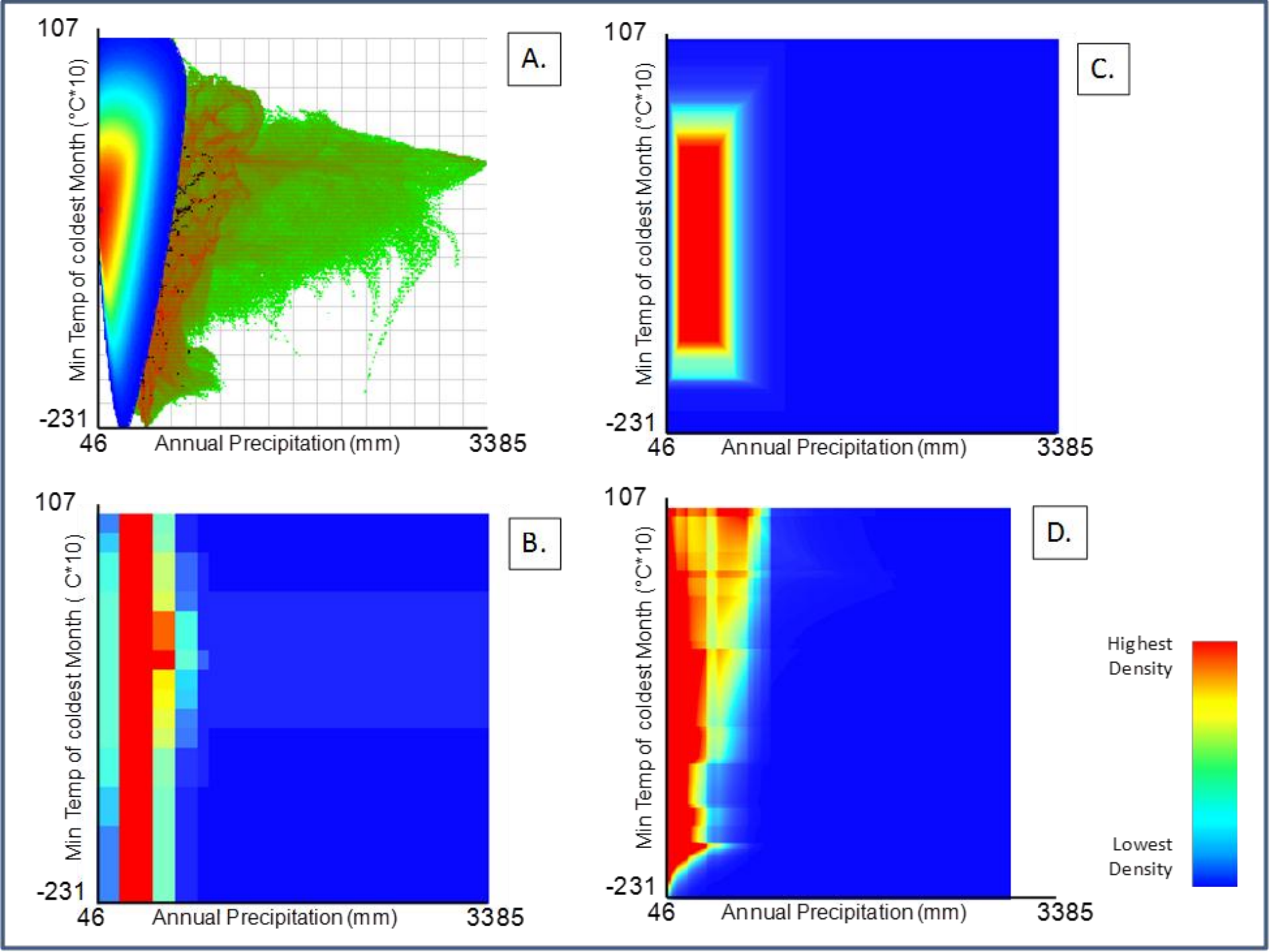


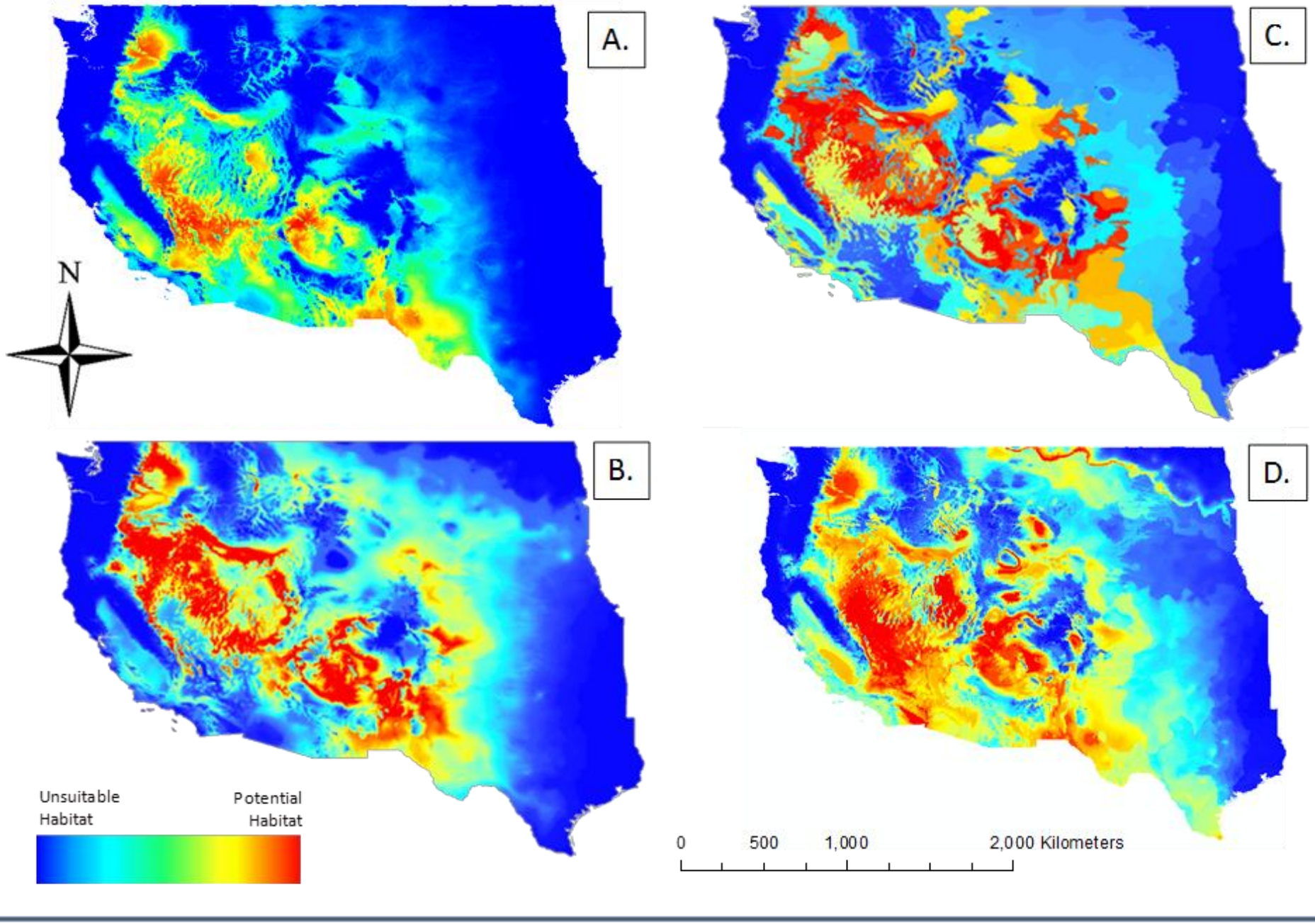
Available Environment



HEMI Modeling Process




A.
107
Min Temp of coldest Month (°C*10)
-231
46
Annual Precipitation (mm)
3385
C.
107
Min Temp of coldest Month (°C*10)
-231
46
Annual Precipitation (mm)
3385
B.
107
Min Temp of coldest Month (C*10)
-231
46
Annual Precipitation (mm)
3385
D.
107
Min Temp of coldest Month (°C*10)
-231
46
Annual Precipitation (mm)
3385
Highest Density
Lowest Density


A.
C.
B.
D.
N
Unsuitable Habitat
Potential Habitat
0
500
1,000
2,000 Kilometers

Area Under the Curve Metric

- Area Under the Curve (AUC)
  - 1=Perfect
  - 0.5=Random

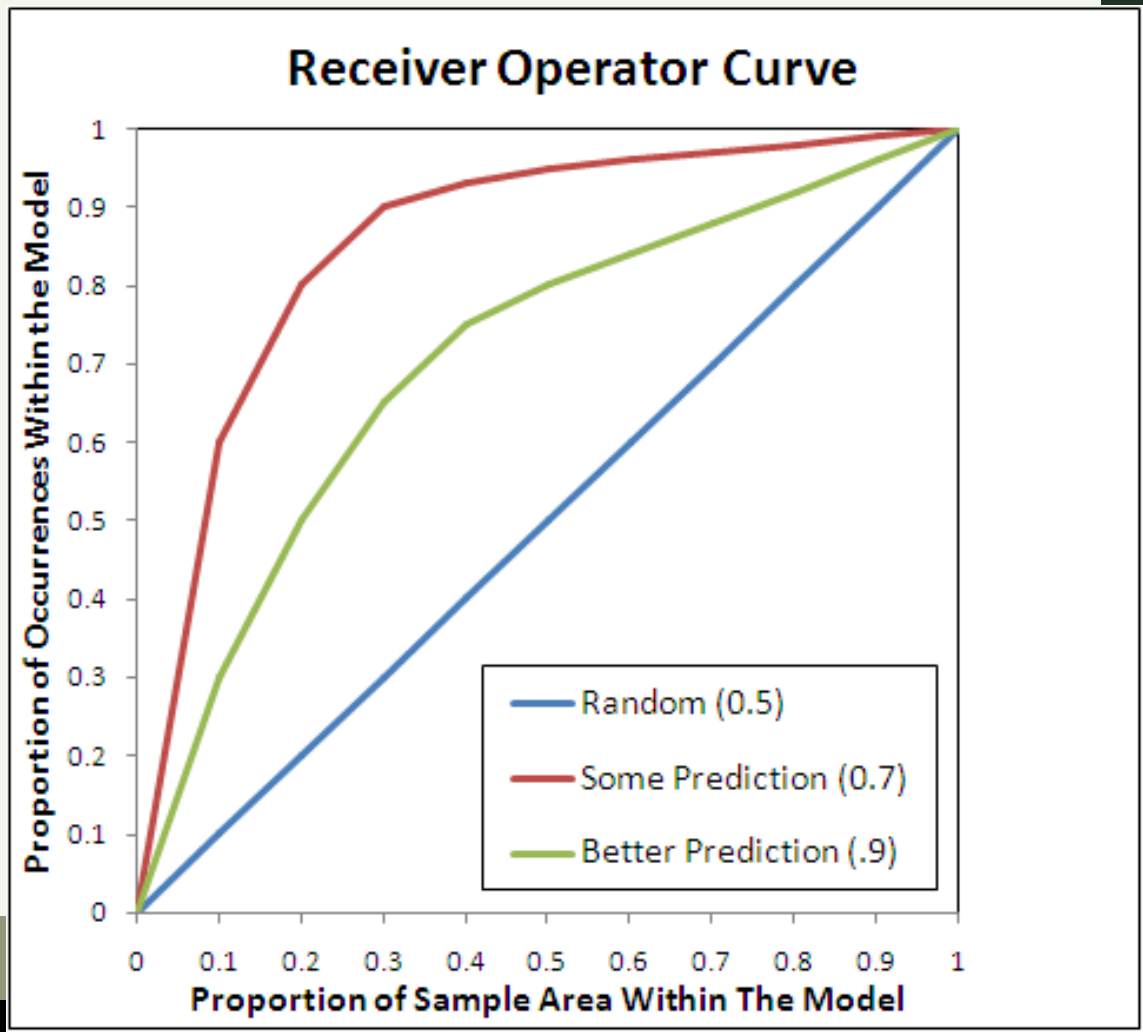
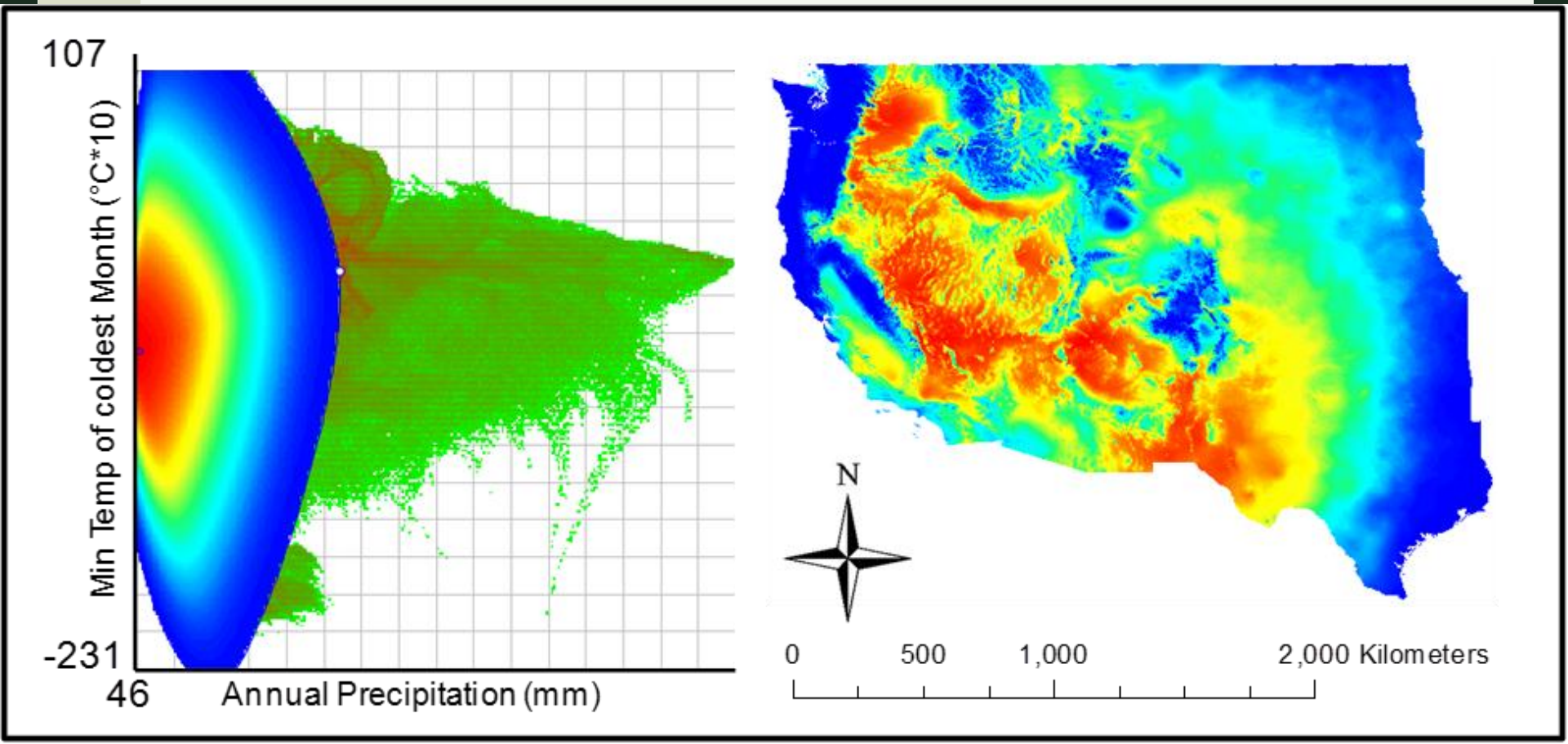


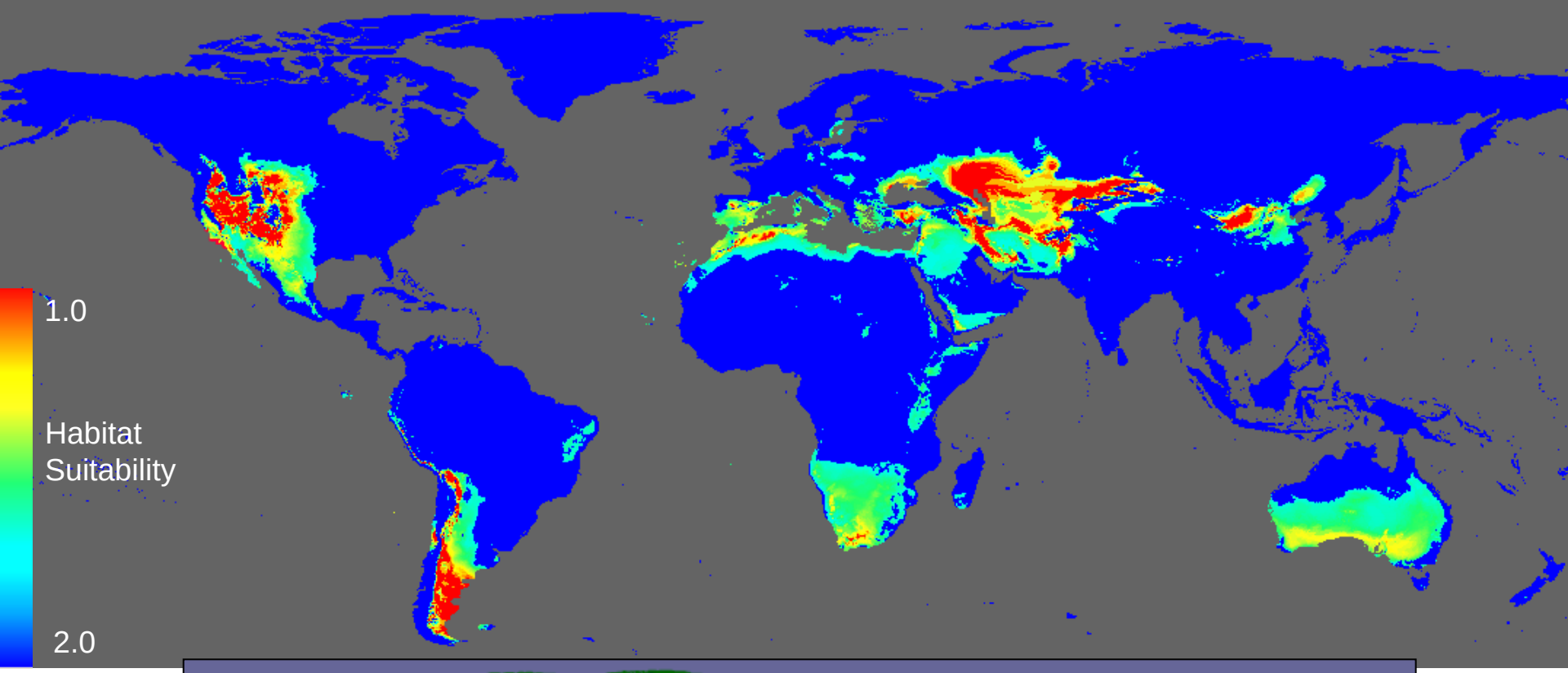
Table of AUC Values

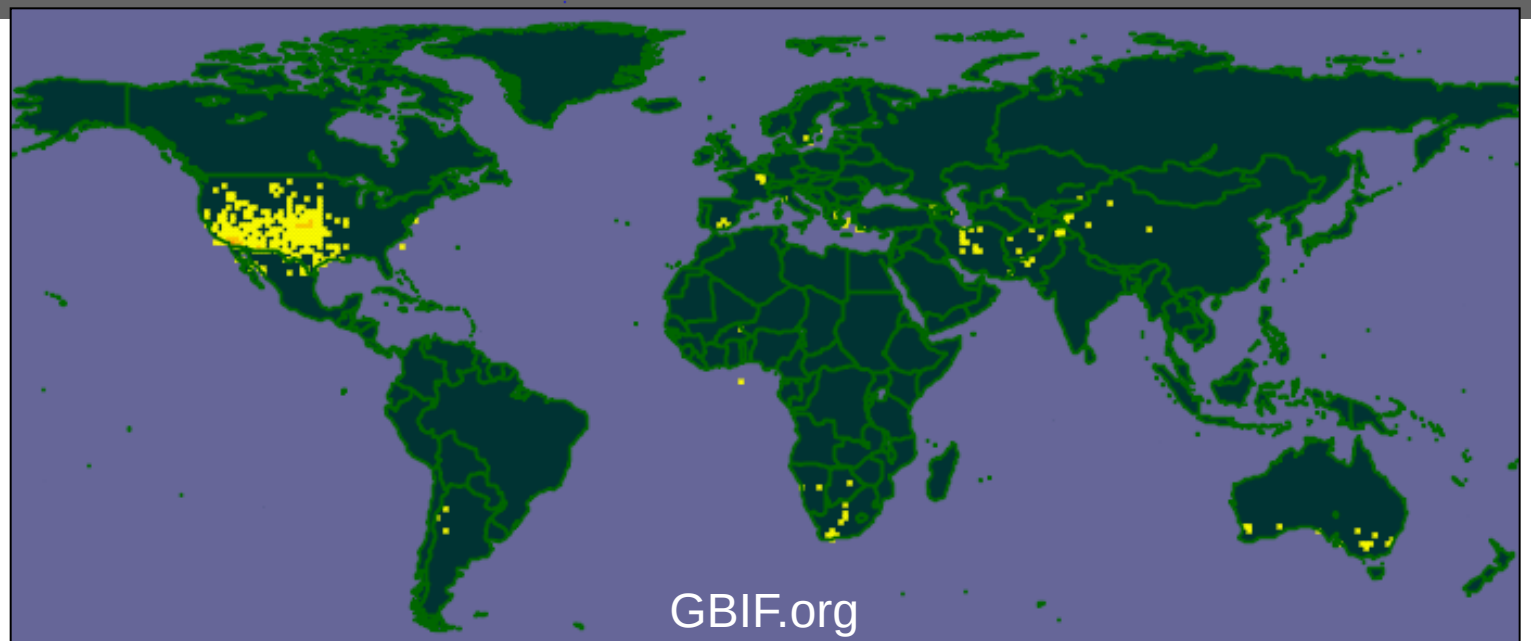
Method	Train AUC	Parameters	Test AUC
HEMI Automatic	0.75	10	0.76
HEMI Edited	0.73	10	0.73
BioClim	0.67	8	0.68
BioMapper Median	0.74	625	0.72
Maxent	0.77	162	0.78

Editable Control Points

- Expanded habitat




1.0
Habitat
Suitability
2.0


GBIF.org

Conclusions

- Number of parameters can be reduced while minimizing over-fit with a small loss of model accuracy to the data
- We can visualize models in environmental space
  - At least in 2 dimensions
- Absence points are not required
- We can edit the models for scenarios

Next Steps

- Expand to N dimensions
- Faster parameter optimization
- Evaluate with additional species
- Include uncertainty analysis and error surfaces
- Improved data!

Develop Guidelines

- “Over-fitting”
  - Conservative estimate of suitable habitat
  - Appropriate for threatened and endangered species where we want to ensure we are preserving suitable habitat
- “Under-fitting”
  - Expanded estimate of suitable habitat
  - Appropriate for invasive species where we want to check anywhere the species may be becoming established

Acknowledgements

- Tom Stohlgren, Lane Carter, Abby Flory, Paul Evangelista, Sunil Kumar, Alycia Crall, Kirstin Holfelder, Sara Simonson, Lee Casuto, Annie Simpson, Jeff Morisette, and many more…
- Funding: USGS, NASA, NSF, GBIF, NBII
  - NSF Grant #OCI-0636210
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