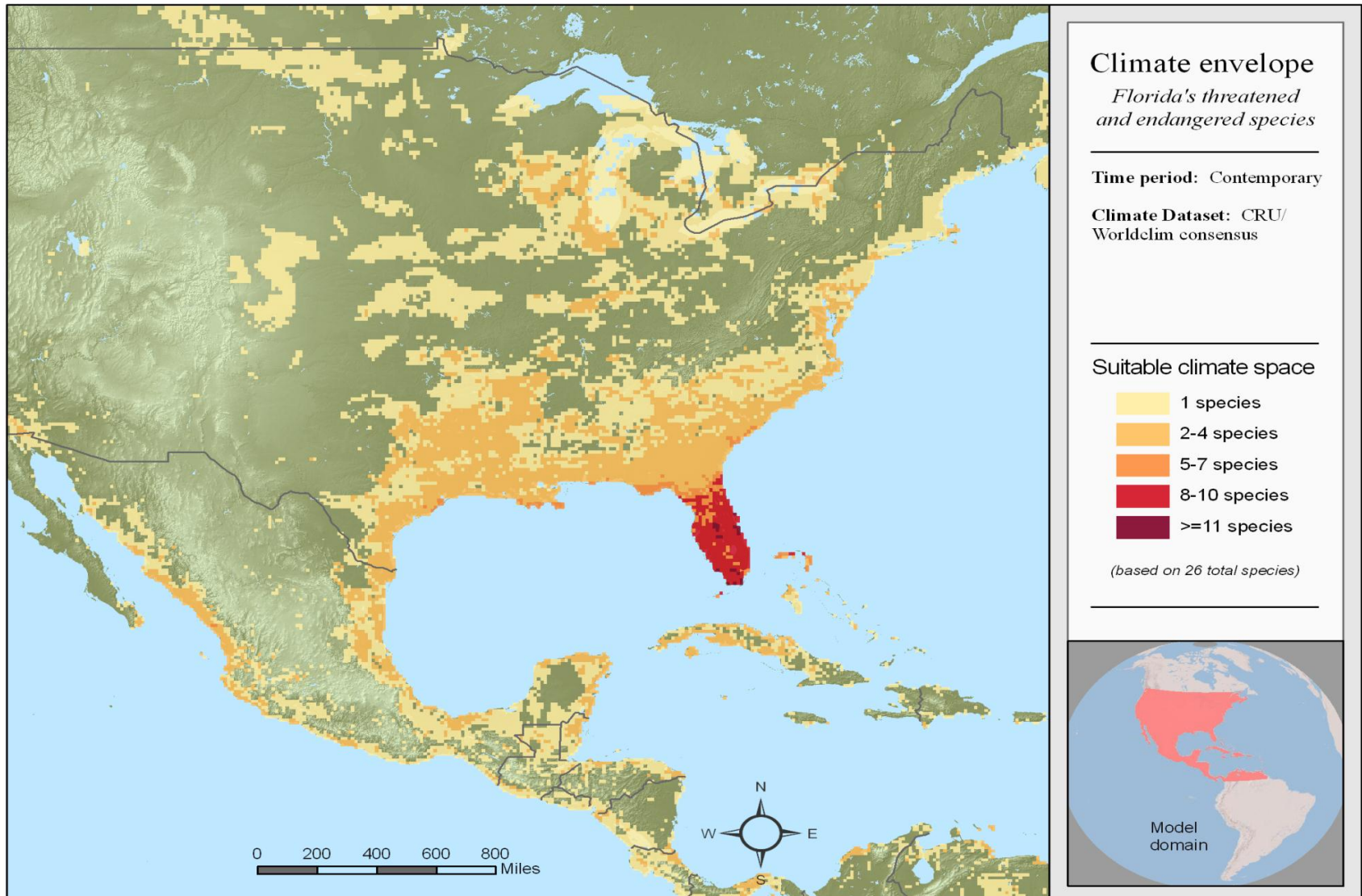
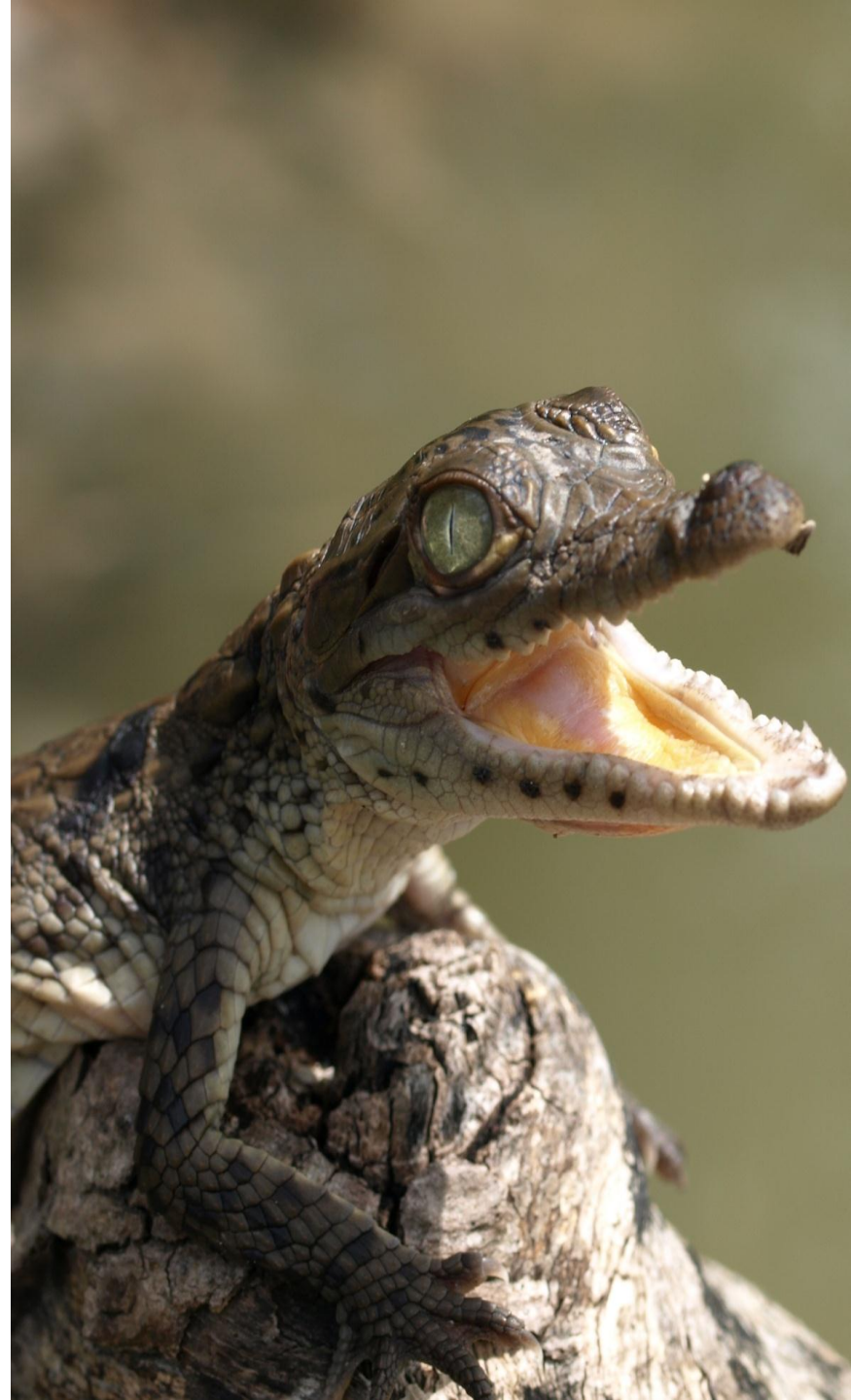


# Forecasting Climate Change Effects on Threatened and Endangered Species in the Greater Everglades Ecosystem

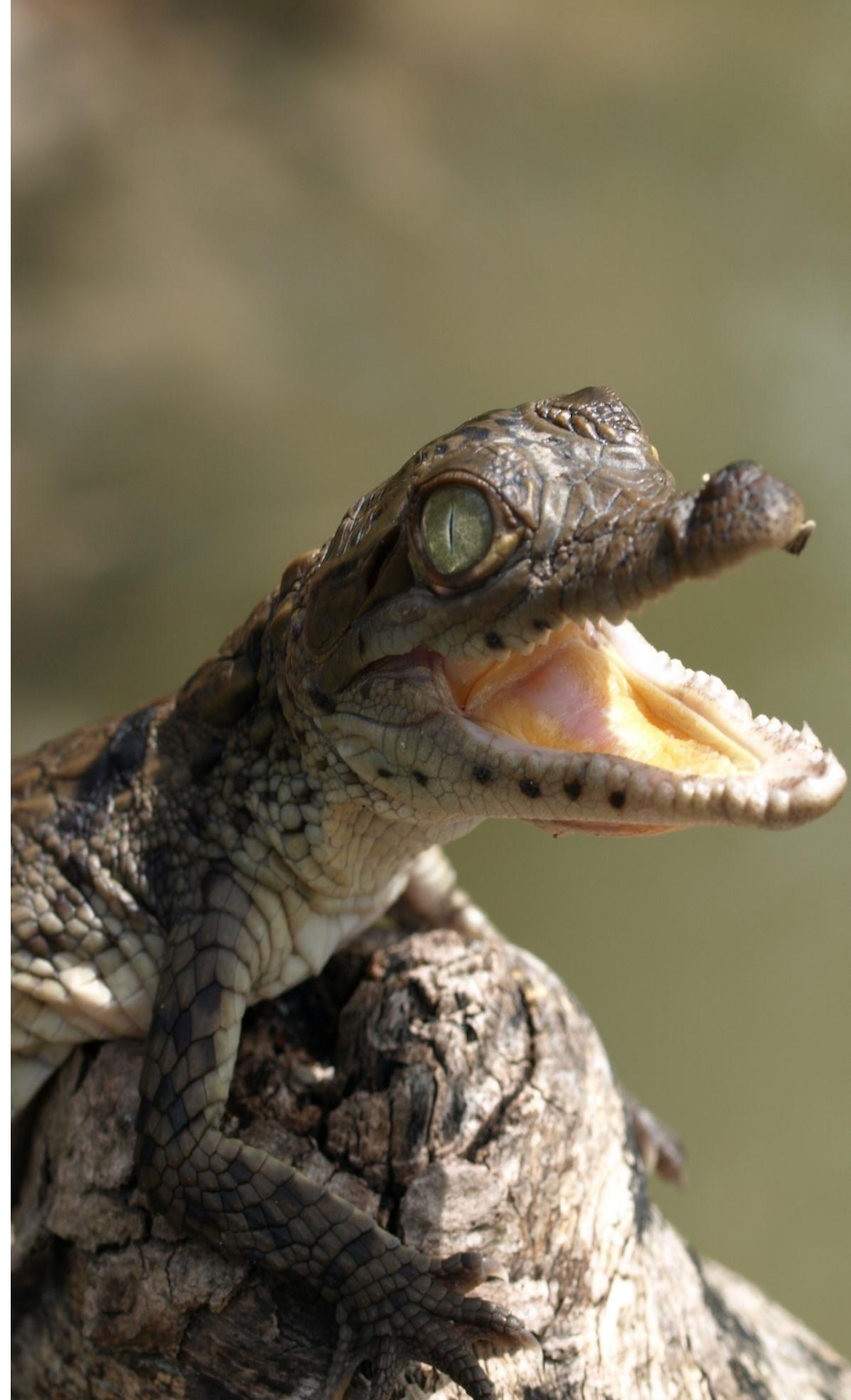
James Watling, Stephanie S. Romañach, Laura Brandt, Allison Benschoter, David Bucklin, Carolina Speroterra, and Frank Mazzotti



- I Our climate envelope models**
- II Spatial predictions and protected areas**
- III Mapping uncertainty in climate envelope models**



- I**      **Our climate envelope models**
  
- II**     **Spatial predictions and protected areas**
  
- III**    **Mapping uncertainty in climate envelope models**





# Project objectives

**Climate envelope models for 26 T & E species**

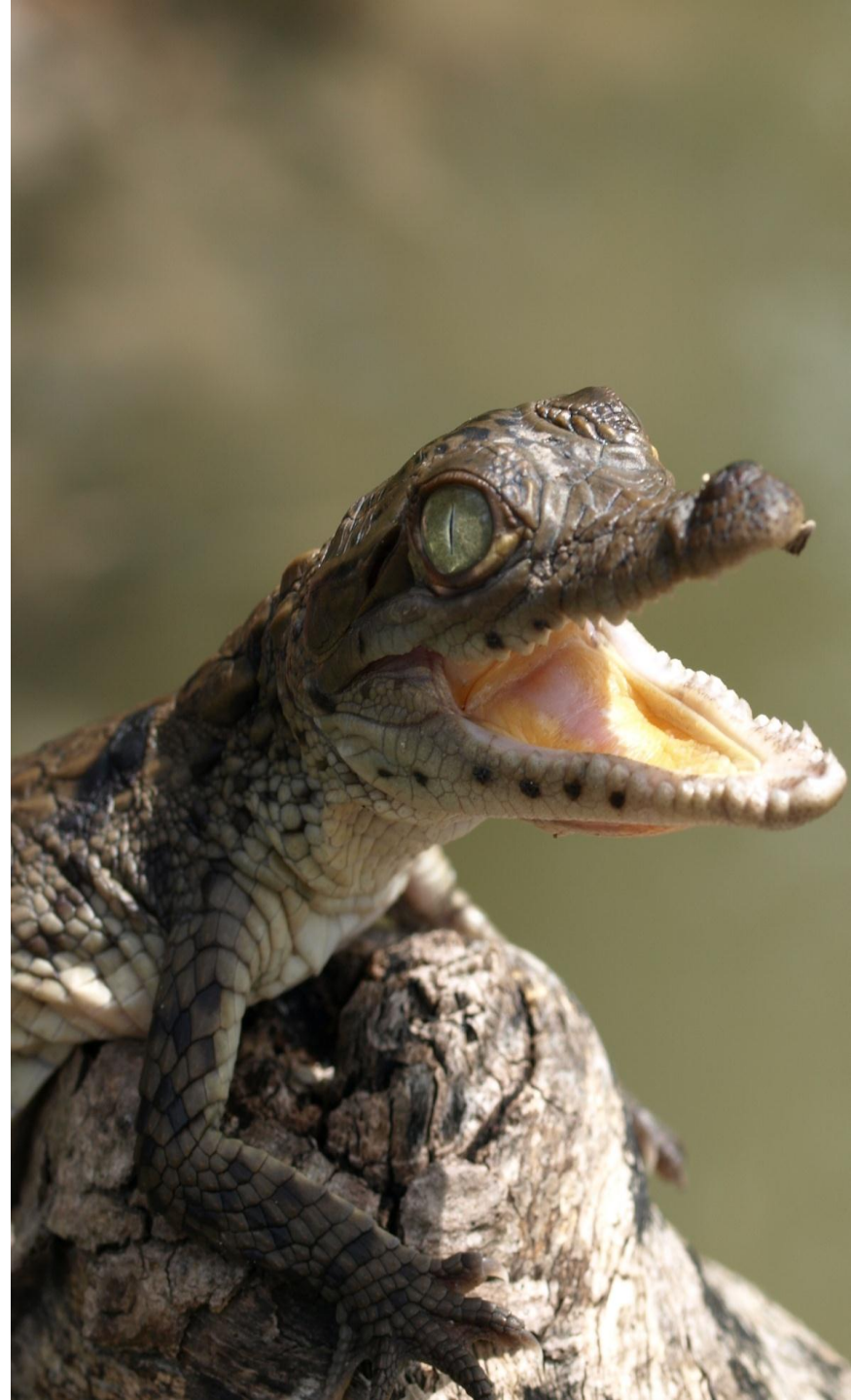
**Develop a flexible protocol for creation and use of models that can be applied to other species and locations**

**Technical guidebook for climate envelope modeling**

**Database of T&E species traits describing vulnerability to climate change**

**Model visualization tools**

**Make information available to others**





**JEM** joint ecosystem modeling

A collaborative approach to modeling and standards

home modeling standards data partners contact

**modeling**

## Tools

### EverVIEW Data Viewer

- EverVIEW Extensions
- Slice and Dice
- Data Converter
- NetCDF Grid Co

### EverVIEW Data Viewer

As EverVIEW matures, it will offer the end user a desktop environment where models can be parameterized and run, with their output immediately displayed geographically. Through a series of toolboxes,

## Models

- Alligator
- Amphibian



## Data Applications

### T&E Vertebrates

### Threatened and Endangered (T&E) Vertebrates in Florida

This database was compiled as a part of a species distribution modeling project, and contains species traits obtained from targeted literature searches for 26 threatened and endangered species located in Florida. All of the traits are searchable through the query tool below, and a list of species with data that match your criteria will be generated. All data can be exported to Excel. For more information, please refer to the [project information and metadata document](#).

[Launch the T&E Vertebrates Query Tool](#)



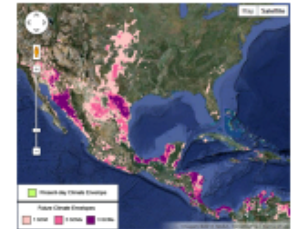
HOME CURRENT PROJECTS PAST PROJECTS OUTREACH PUBLICATIONS STAFF JOBS LINKS

Home » Current Projects » Climate Envelope Modeling for Threatened and Endangered Species

## Climate Envelope Modeling for Threatened and Endangered Species

Climate change is creating new challenges for biodiversity conservation. As temperatures, rainfall patterns, and sea levels change, distributions of plants and animals may shift geographically, altering their relationships with the environment and other species. As part of the response to climate change, the conservation community is starting to make decisions on longer time frames and with a focus on "adaptation" strategies to help species and habitats adjust. One of the first steps in adaptation planning is to conduct vulnerability assessments to identify which species or systems are likely to be most affected by climate change and why.

Climate envelope models are an important tool used in vulnerability assessments to help resource managers understand how plants and animals may respond to a changing climate. Climate envelope models describe the climate where a species currently lives (its climate "envelope"), and then map the geographic shift of that



### Interactive Map

This map shows climate envelopes for two endangered and three threatened animal species. Choose a species from the drop-down menu on the left, and click on the radio buttons to view its climate envelope for today, 2060, and 2100. The present-day climate envelope is defined based on the specific temperatures and rainfall patterns where the species currently exists. The future climate envelopes are estimated using data from three different general circulation models (GCMs), which are the models scientists use to make projections of future climate conditions. Future climate envelopes are shown on the map as predicted by one, two, or all three of the GCMs. The more the GCMs overlap, the more certain the prediction.

**Remember:** The future climate envelope represents where a species may occur based on climate factors alone. That is, these maps do not consider the types of habitats, topography, or food sources each species needs to survive. For example, we would not expect American crocodiles, a coastal species, to turn up in the Midwest. Thus, these models serve best as initial screening tools to identify priority areas for further study.

American Crocodile  Present-day climate envelope  2060 climate envelope  2100 climate envelope

**American Crocodile**  
*Crocodylus acutus*

Photo credit: Jameana Carrigan

Federal Status: Threatened

Florida Status: Threatened

Distribution: Coastal areas of Florida

## **Mammals**

Key deer

Key Largo cotton mouse

Southeastern beach mouse

Anastasia Island beach mouse

Florida panther

Lower keys marsh rabbit

Silver rice rat

Key Largo woodrat

Florida salt marsh vole

Florida bonneted bat

## **Birds**

Audubon crested caracara

Florida scrub jay

Everglades snail kite

Piping plover

Cape Sable seaside sparrow

Florida grasshopper sparrow

Wood stork

Red-cockaded woodpecker

Roseate tern

Whooping crane

## **Amphibians and Reptiles**

American crocodile

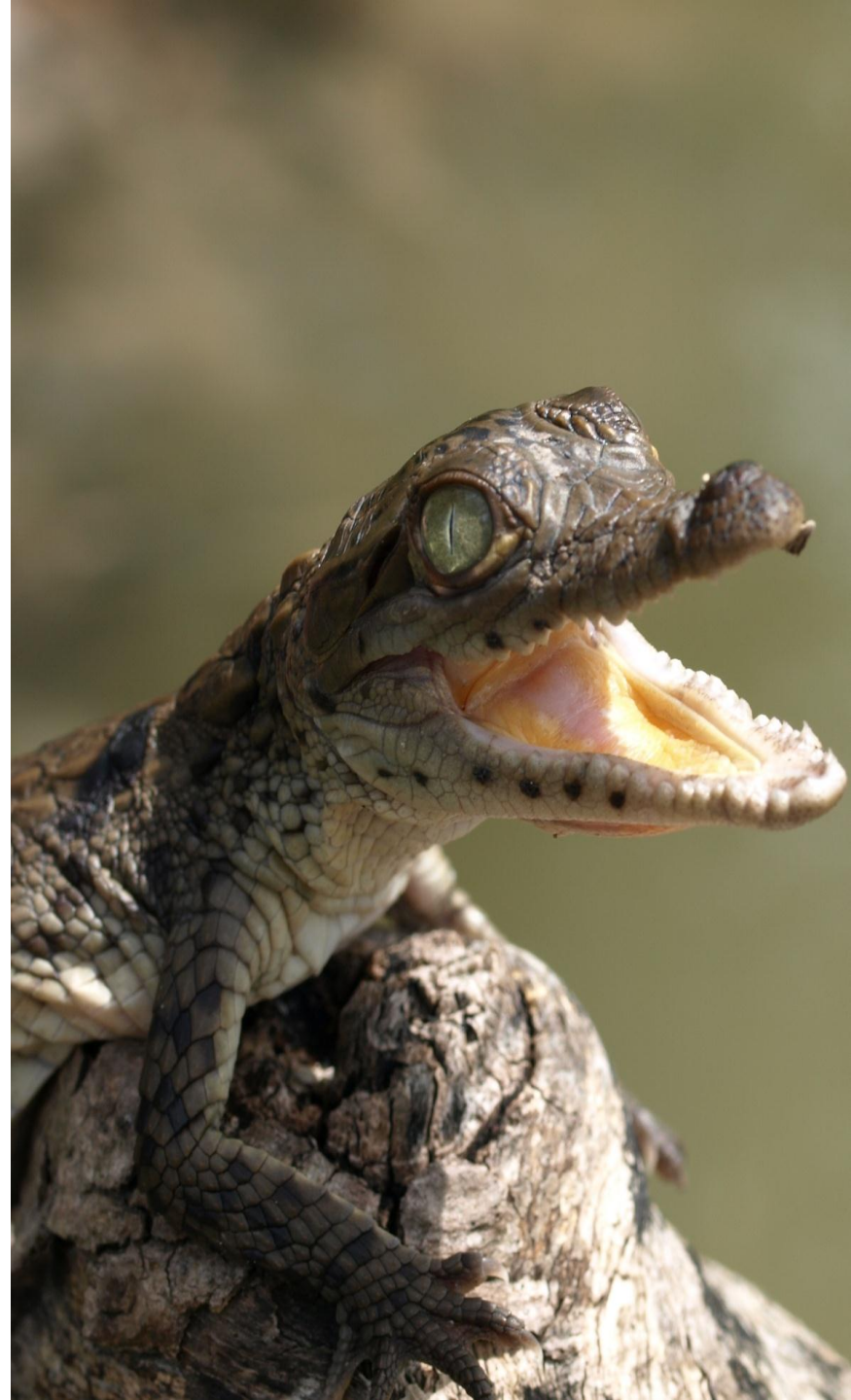
Bluetail mole skink

Sand skink

Atlantic salt marsh snake

Eastern indigo snake

Flatwoods salamander





# Climate envelope model (CEM)

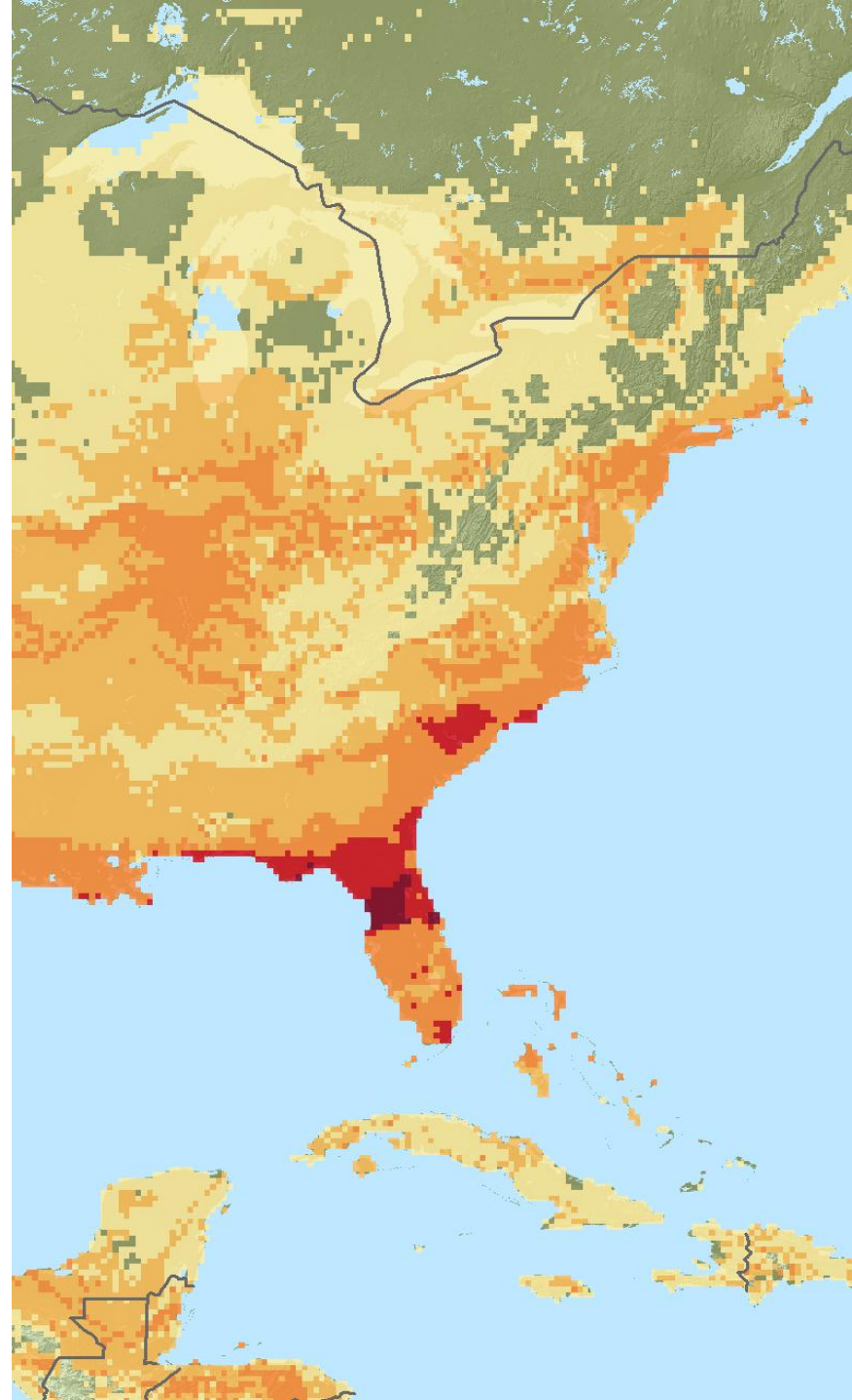
**Uses a statistical model to extrapolate species distribution data in space and time**

**Make a spatial prediction of environmental suitability**

**Species-climate relationship**

## Our models

- **Monthly mean temperature**
  - **Monthly precipitation**
- **Calibrated on contemporary conditions (~ 1950 – 2000)**
- **Extrapolated using climate projections (2040 – 2059)**





# Climate projections

**Three General Circulation Models (GCMs)... the models of atmospheric and ocean dynamics to make climate change projections:**

- **GFDL CM2**
- **NCAR CCSM3**
- **UKMO HADCM3**

**Two emissions scenarios:**

- **A1B (high emissions, balanced among many sources)**
- **A2 (high emissions, fossil-intensive)**



**Precipitation, Years 2040-2059**  
**GCM: GFDL CM2, Scenario: A1B**



**Climate suitability  
for up to 12 T & E  
species**





## Climate envelope

*Florida's threatened  
and endangered species*

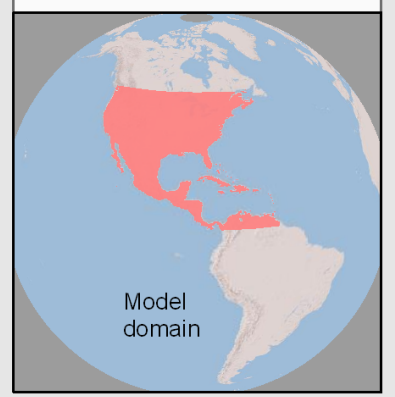
**Time period:** Contemporary

**Climate Dataset:** CRU/  
Worldclim consensus

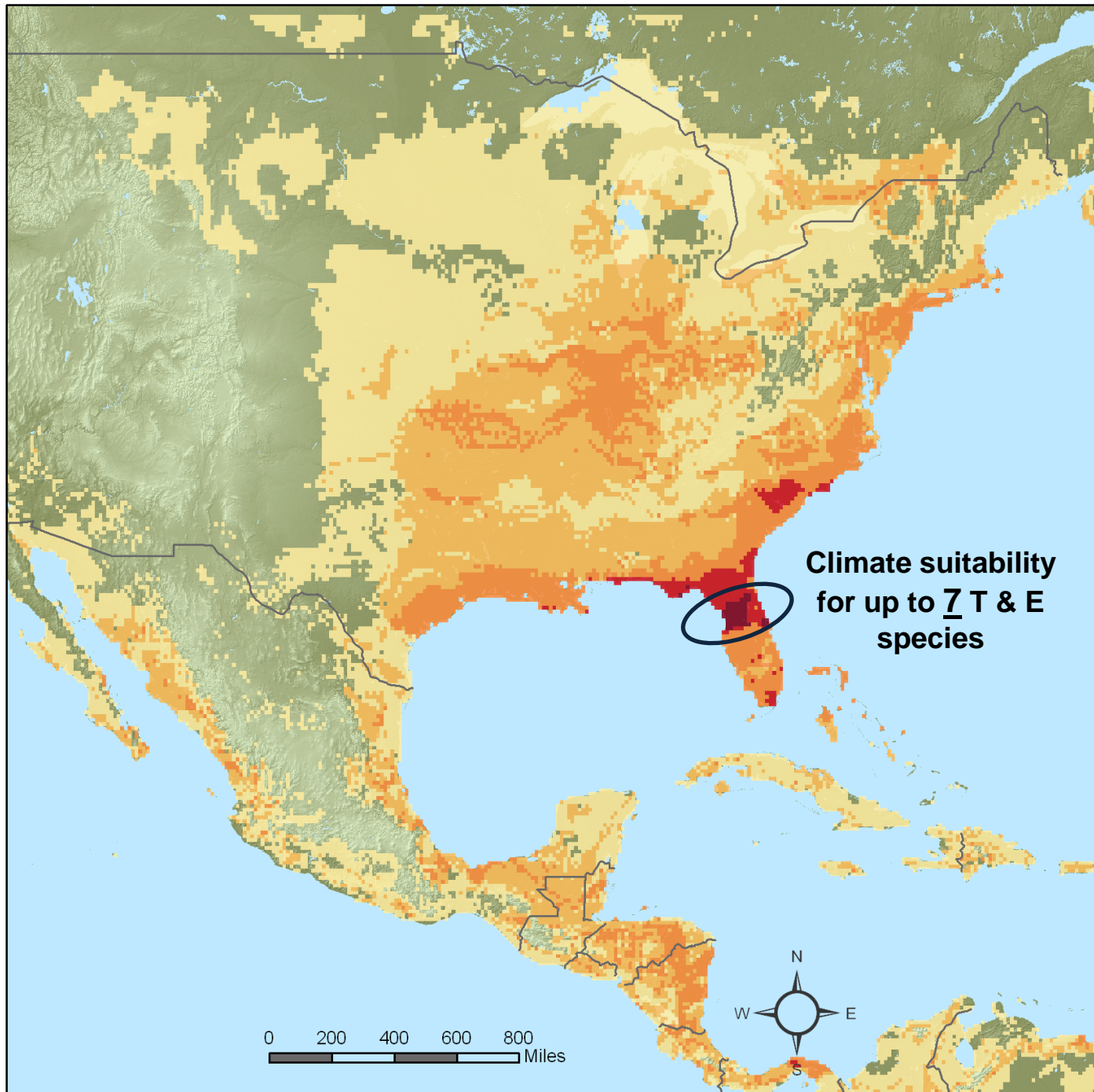
## Suitable climate space

-  1 species
-  2-4 species
-  5-7 species
-  8-10 species
-  >=11 species

*(based on 26 total species)*



Model  
domain



## Climate envelope

*Florida's threatened and endangered species*

**Time period:** 2040-2059

**IPCC Scenario:** A1B

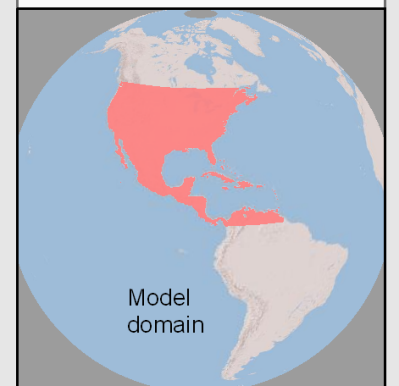
**GCMs:** GFDL CM2.0,  
NCAR CCSM3,  
UKMO HADCM3 (consensus)

### Suitable climate space

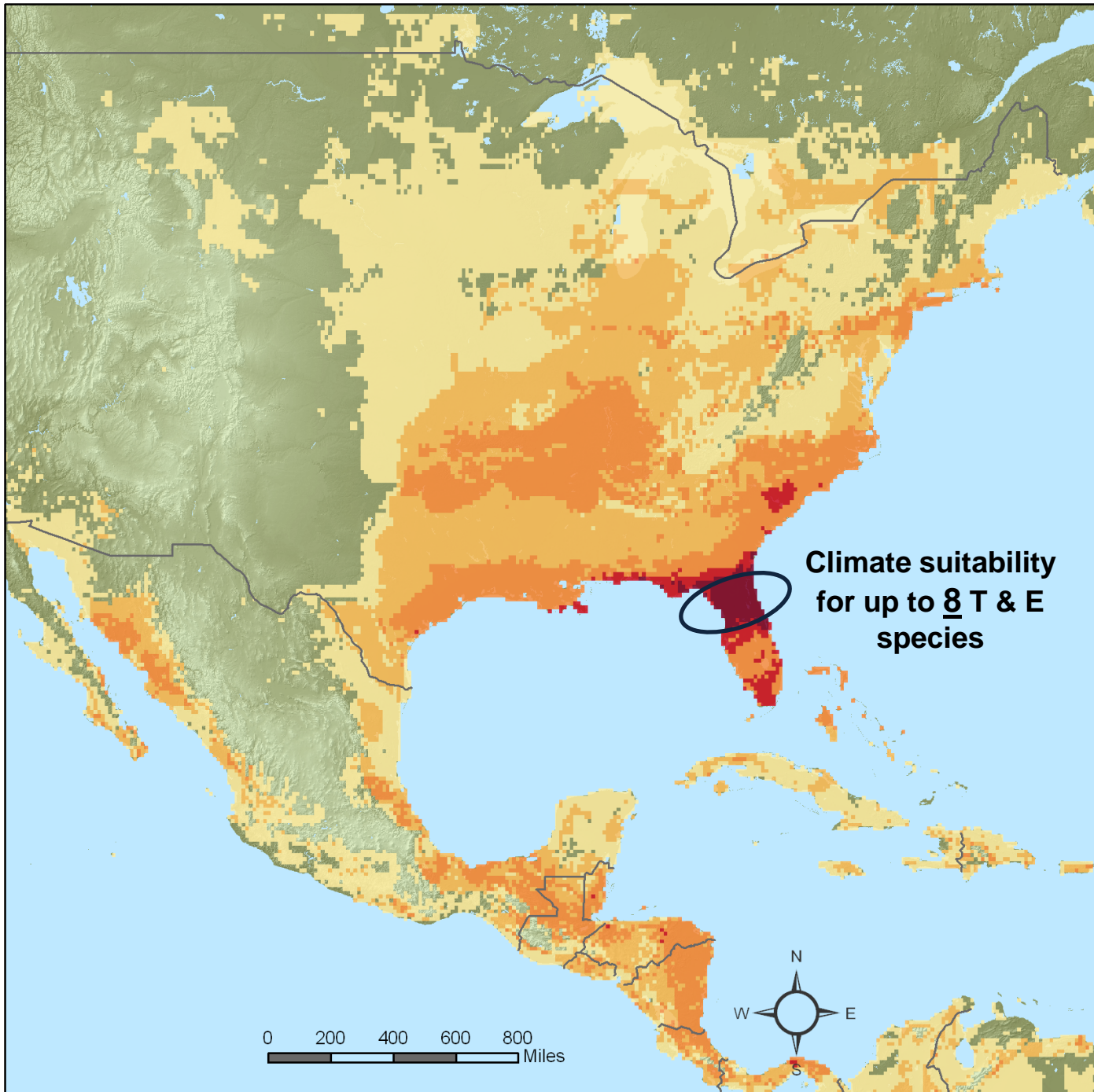


*(based on 26 total species)*

**Climate suitability  
for up to 7 T & E  
species**







## Climate envelope

*Florida's threatened and endangered species*

**Time period:** 2040-2059

**IPCC Scenario:** A2

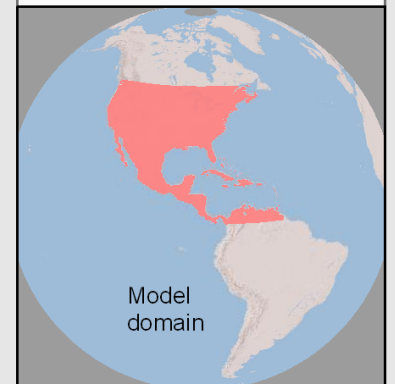
**GCMs:** GFDL CM2.0,  
NCAR CCSM3,  
UKMO HADCM3 (consensus)

### Suitable climate space



*(based on 26 total species)*

**Climate suitability  
for up to 8 T & E  
species**



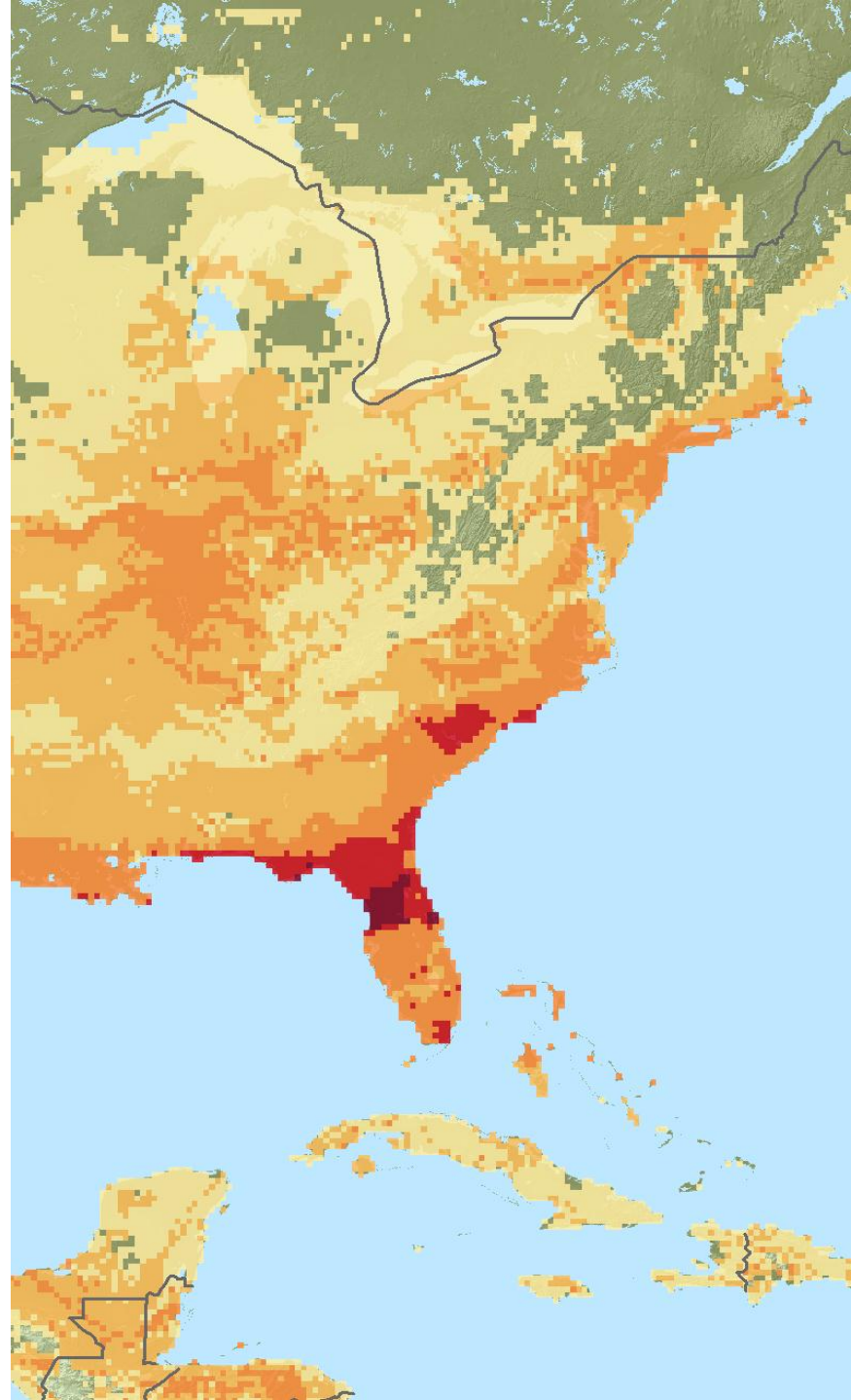
**Take home points:**

**Models suggest a reduction in the maximum number of T & E species experiencing climate suitability in any one place:**

**12 species today**

**vs.**

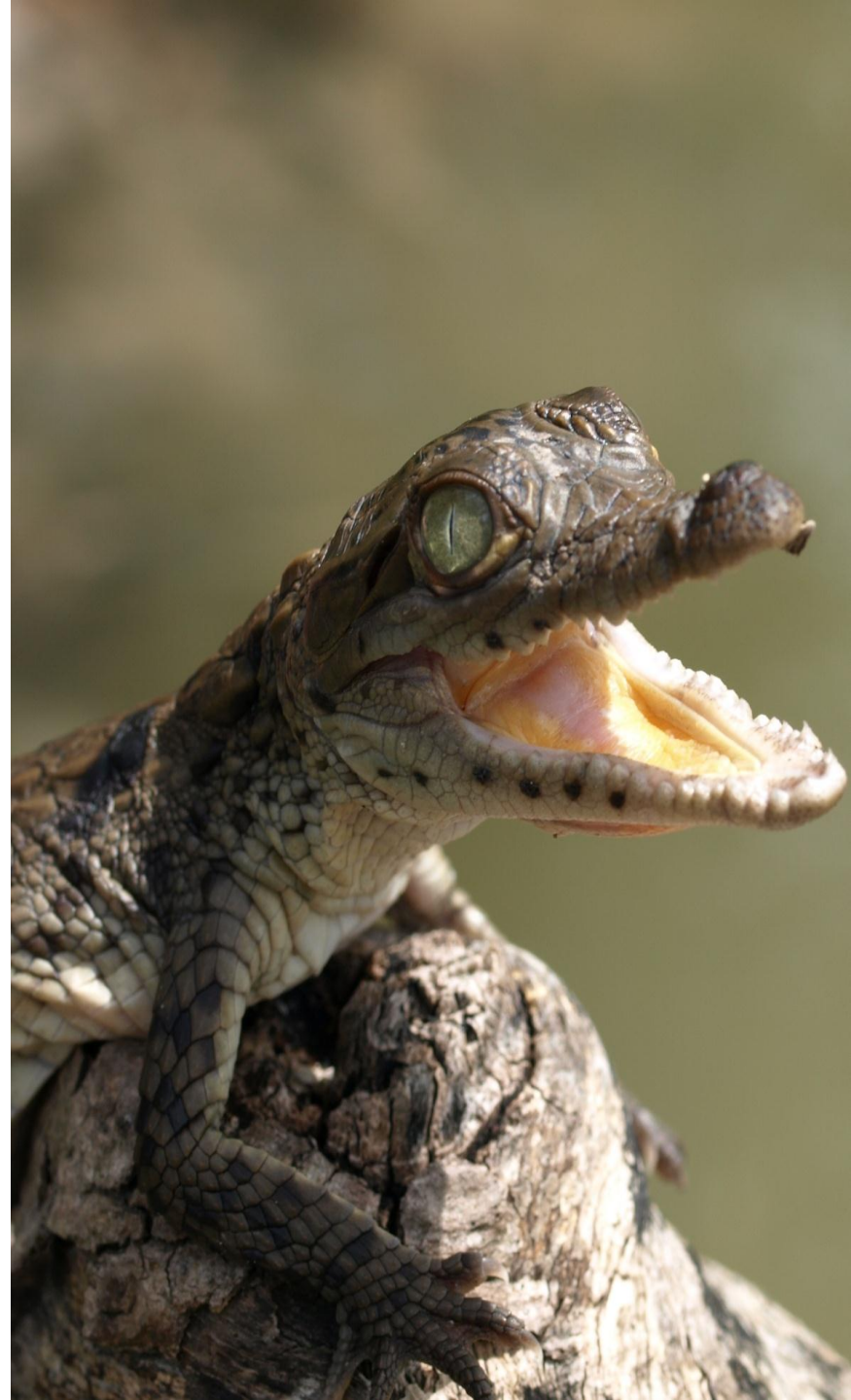
**7 (A1B) or 8 (A2) species at mid-century**



**I** Project introduction &  
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climate envelope models





# Climate envelope

*Florida's threatened and endangered species*

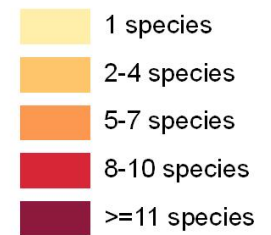
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Time period: Contemporary

Climate Dataset: CRU/  
Worldclim consensus

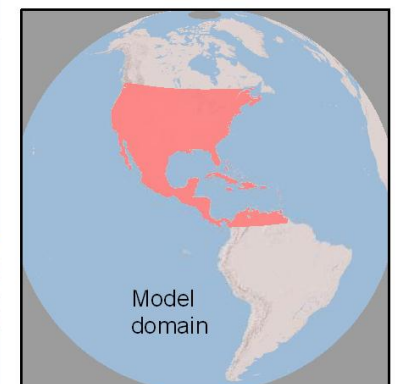
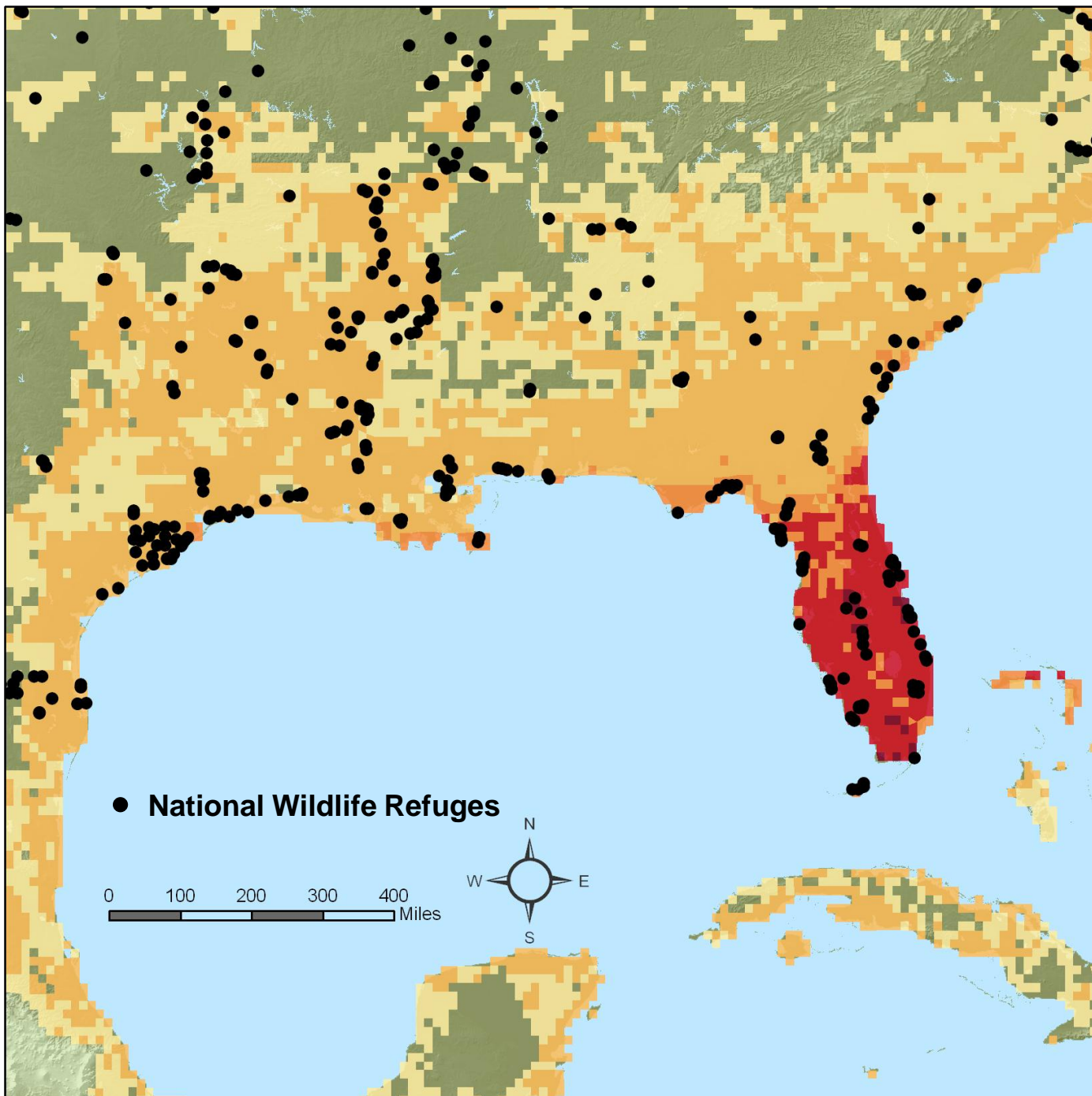
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## Suitable climate space



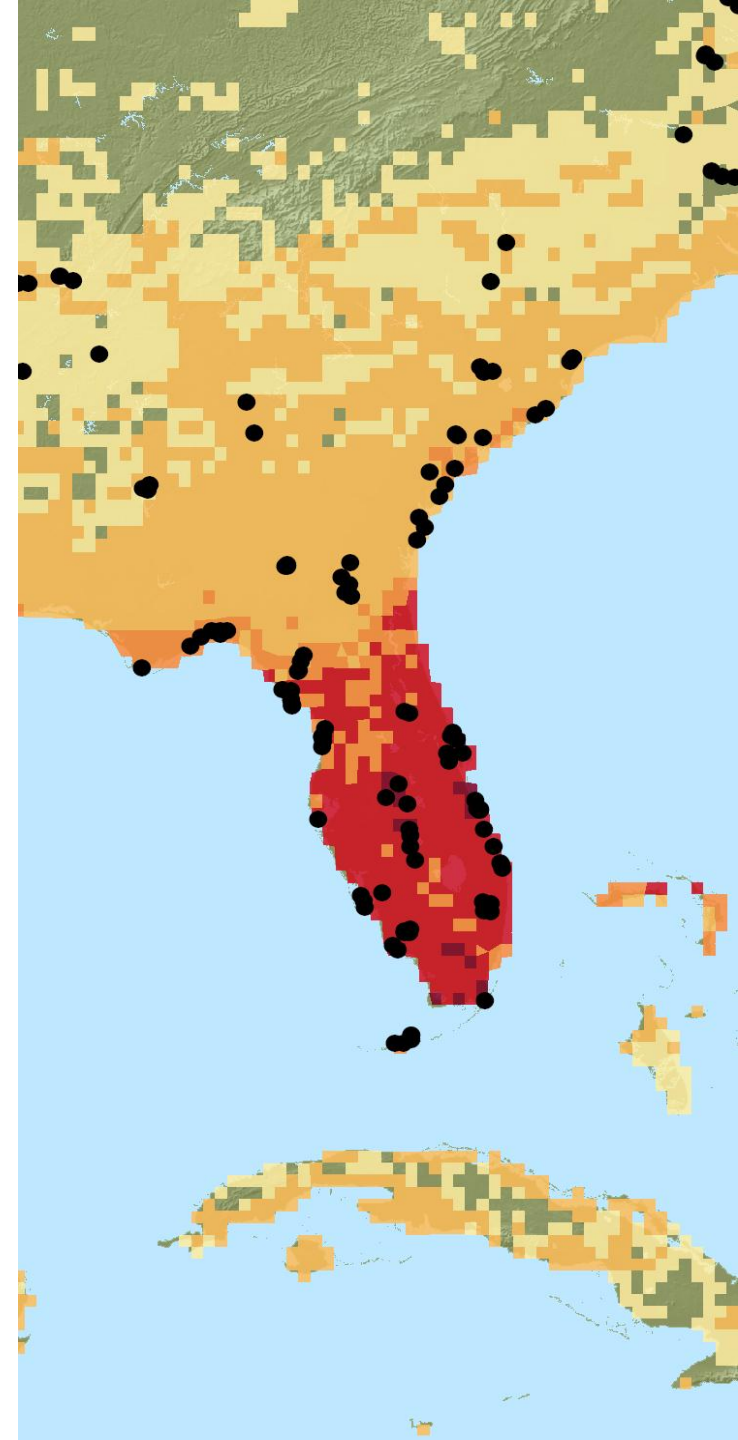
(based on 26 total species)

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## Spatial overlap of CEMs with USFWS refuges

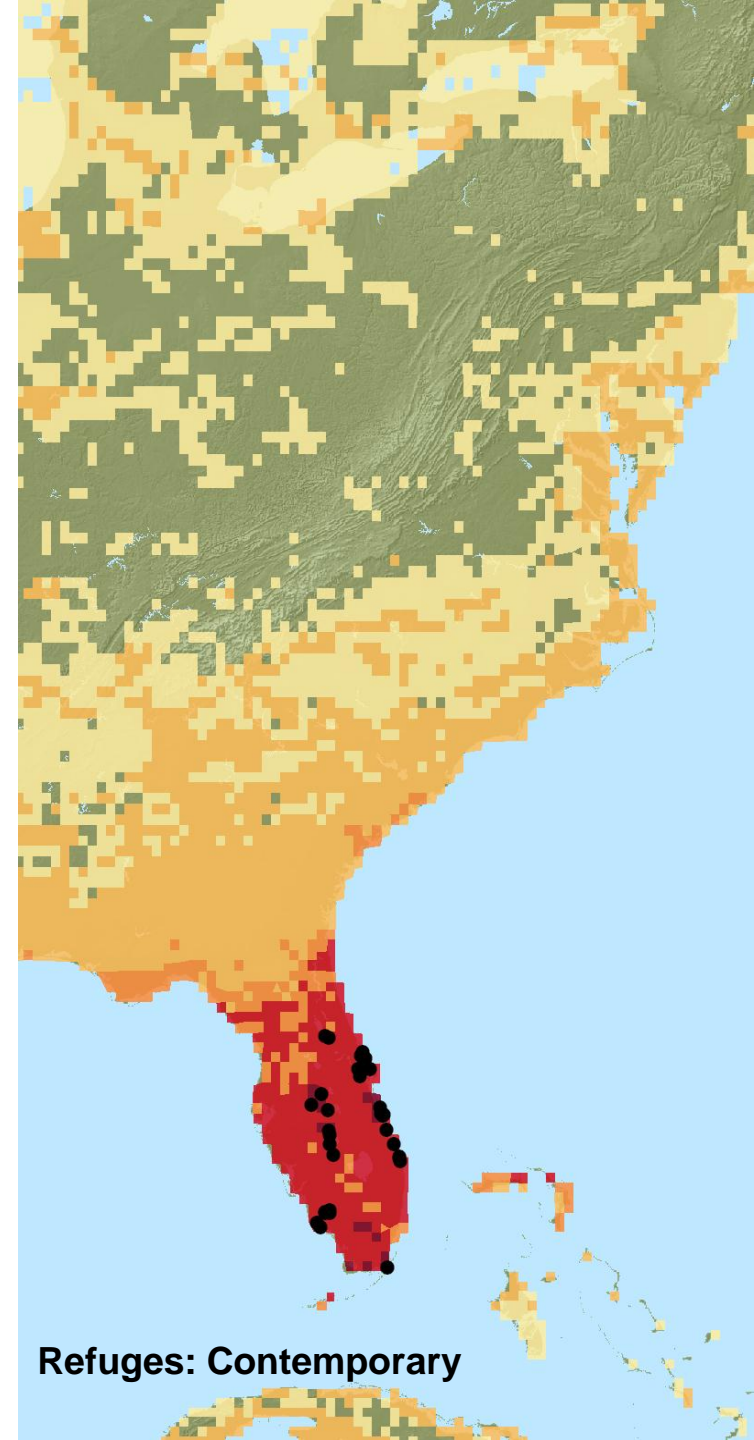
	10-12 T & E species	7-9 T & E species	4-6 T & E species	1-3 T & E species
Contemporary	10 refuges	22 refuges	28 refuges	100+ refuges
Mid-century: A1B				
Mid-century: A2				



## Spatial overlap of CEMs with USFWS refuges

Refuges with maximal CEM  
overlap (*contemporary*)

Archie Carr NWR  
Crocodile Lake NWR  
Florida Panther NWR  
Hobe Sound NWR  
Lake Wales Ridge NWR  
Lake Woodruff NWR  
Merritt Island NWR  
Pelican Island NWR  
St Johns NWR  
Ten Thousand Islands NWR

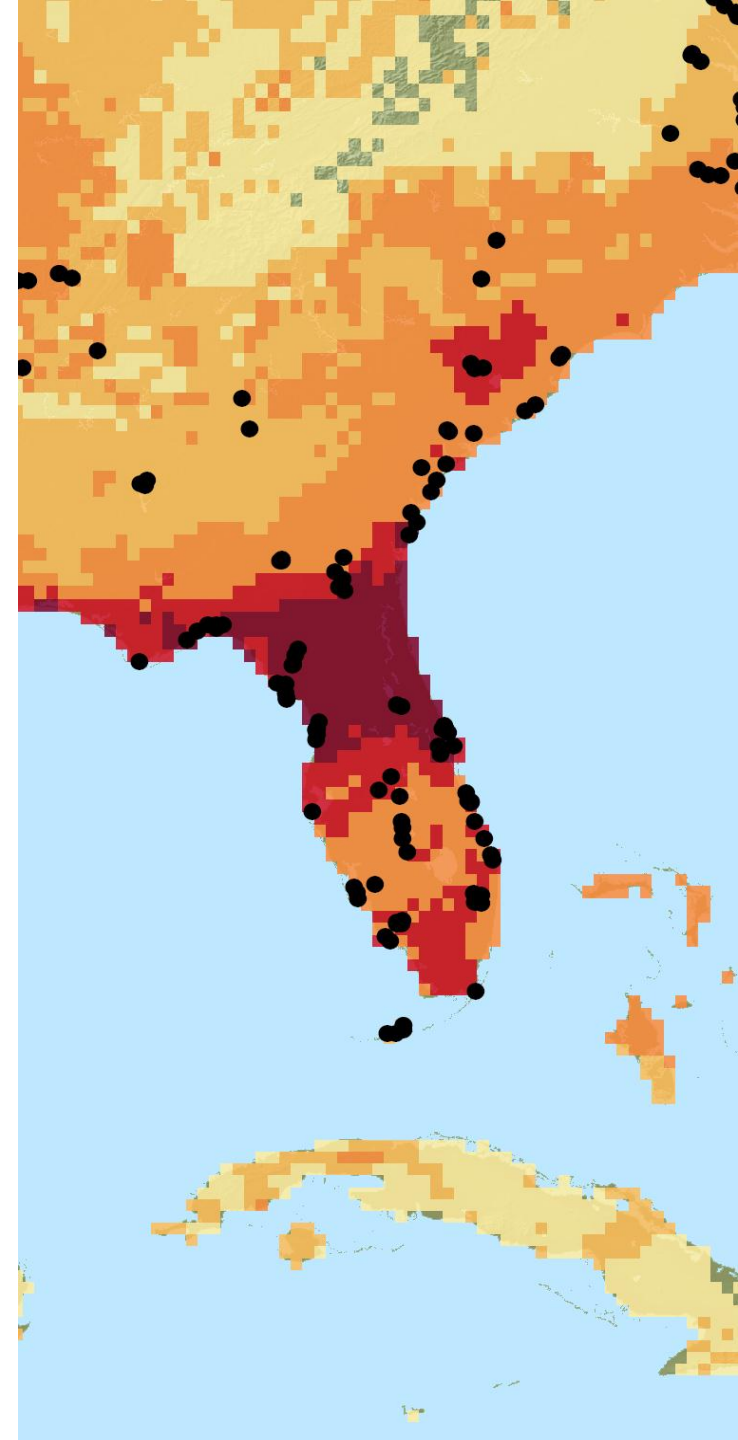


Refuges: Contemporary



## Spatial overlap of CEMs with USFWS refuges

	10-12 T & E species	7-9 T & E species	4-6 T & E species	1-3 T & E species
Contemporary	10 refuges	22 refuges	28 refuges	100+ refuges
Mid-century: A1B		5 refuges	52 refuges	100+ refuges
Mid-century: A2		11 refuges	52 refuges	100+ refuges



# Spatial overlap of CEMs with USFWS refuges

Refuges with maximal CEM  
overlap (*future*)

Blackbeard Island NWR

Cedar Keys NWR

Chassahowitza NWR

Crystal River NWR

Lake Woodruff NWR

Lower Suwannee NWR

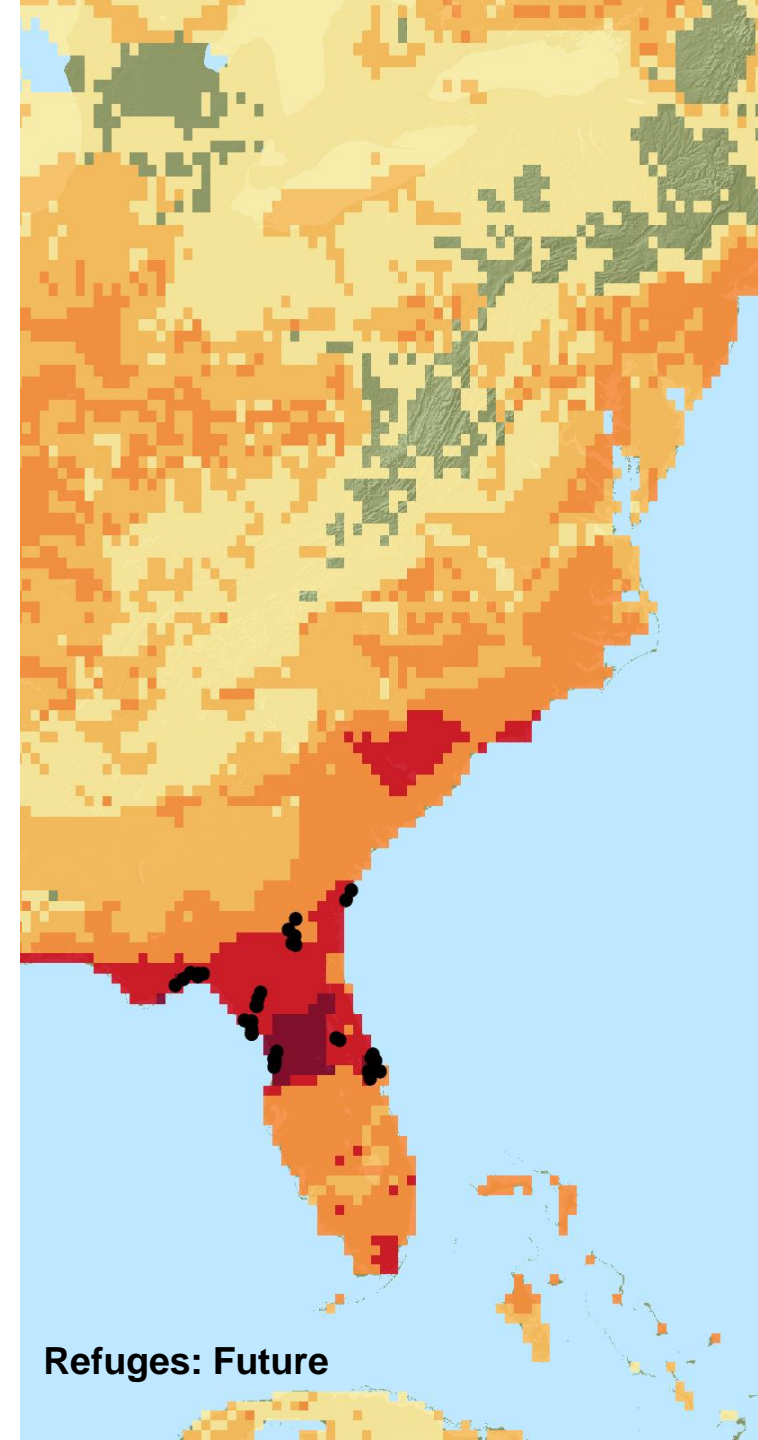
Merritt Island NWR

Okefenokee NWR

St Johns NWR

St Marks NWR

Wolf Island NWR



Refuges: Future

# Spatial shift of CEMs with USFWS refuges

## Refuges with maximal CEM overlap (*contemporary*)

Archie Carr NWR  
Crocodile Lake NWR  
Florida Panther NWR  
Hobe Sound NWR  
Lake Wales Ridge NWR  
Lake Woodruff NWR  
Merritt Island NWR  
Pelican Island NWR  
St Johns NWR  
Ten Thousand Islands NWR

## Refuges with maximal CEM overlap (*future*)

Blackbeard Island NWR  
Cedar Keys NWR  
Chassahowitza NWR  
Crystal River NWR  
Lake Woodruff NWR  
Lower Suwannee NWR  
Merritt Island NWR  
Okefenokee NWR  
St Johns NWR  
St Marks NWR  
Wolf Island NWR

mean latitude = 27.4 N

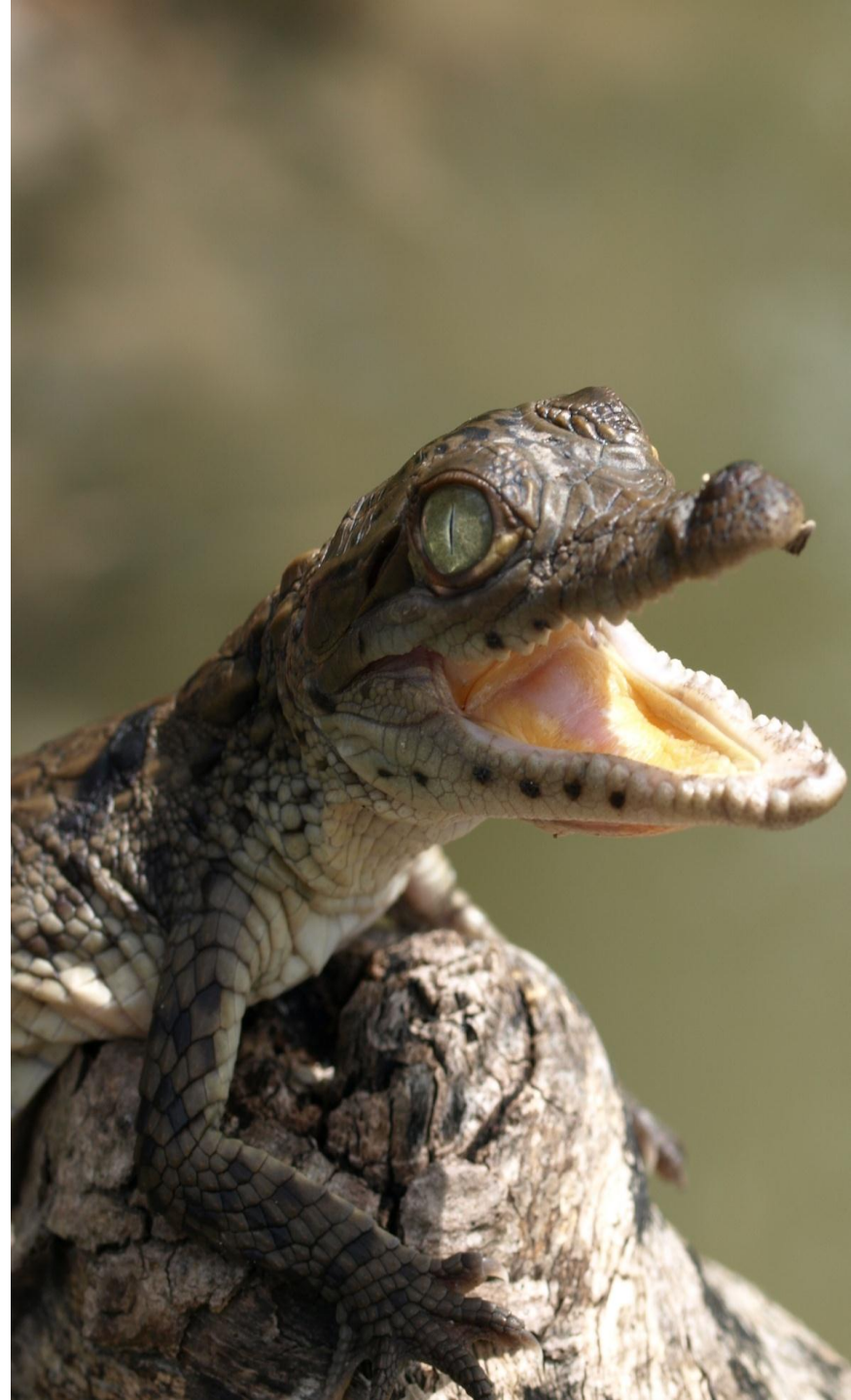
mean latitude = 29.6 N

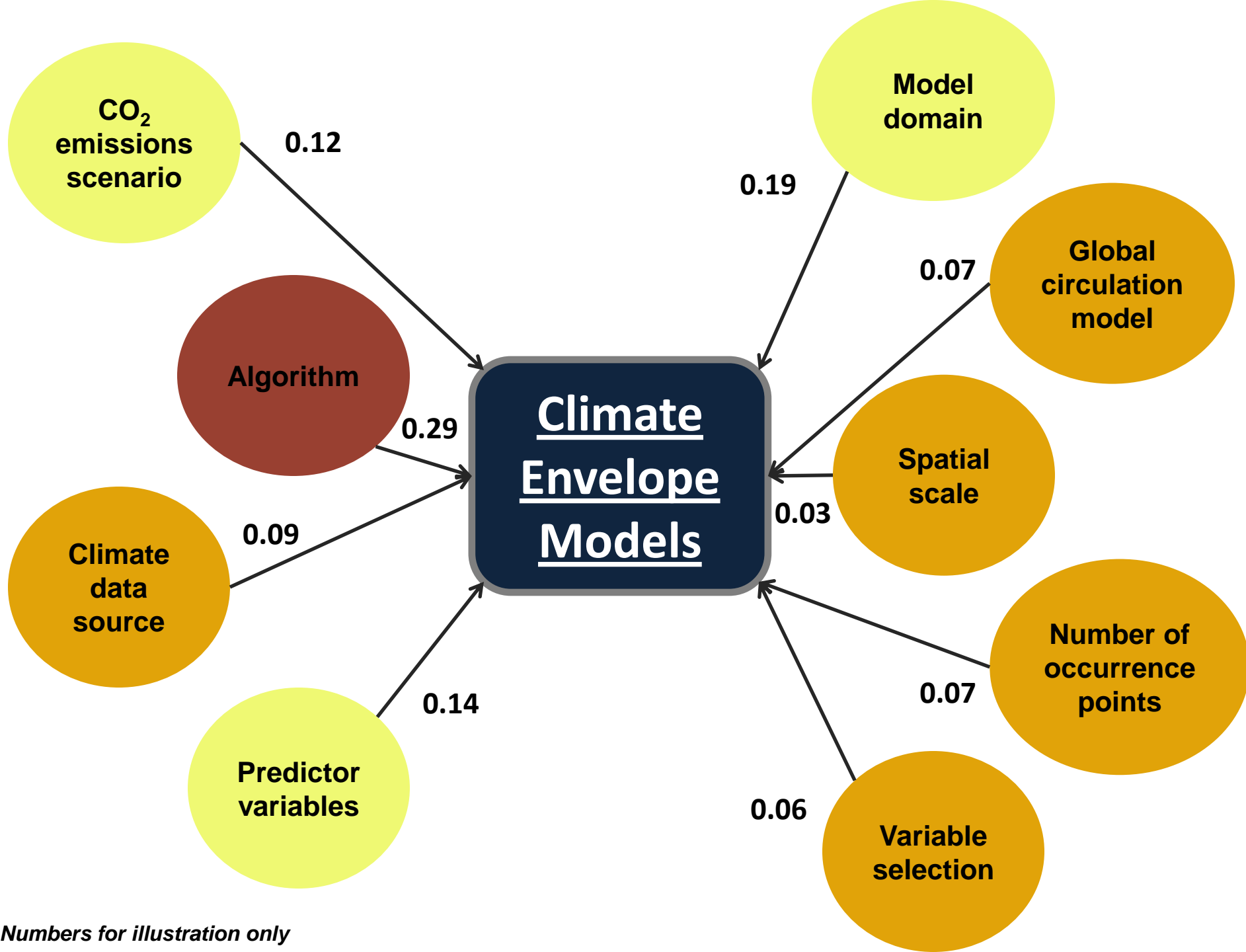


**I** Project introduction &  
climate envelope  
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climate envelope models





*Numbers for illustration only*

Scientific Name	Algorithm	Variable selection	Climate data source	Number of occurrence points	Model domain	AUC	Kappa
Ambystoma cingulatum	GLM	Biomapper	CRU	All	Target	0.96	0.002
Ambystoma cingulatum	GLM	Biomapper	CRU	Subset	Target	0.91	0.003
Ambystoma cingulatum	GLM	Random	CRU	All	Target	0.97	0.007
Ambystoma cingulatum	GLM	Random	CRU	Subset	Target	0.96	0.005
Ambystoma cingulatum	GLM	Biomapper	CRU	All	Mod_Range	0.99	0.017
Ambystoma cingulatum	GLM	Biomapper	CRU	Subset	Mod_Range	0.98	0.002
Ambystoma cingulatum	GLM	Random	CRU	All	Mod_Range	0.99	0.057
Ambystoma cingulatum	GLM	Random	CRU	Subset	Mod_Range	0.98	0.029
Ambystoma cingulatum	Maxent	Biomapper	CRU	All	Target	0.96	0.008
Ambystoma cingulatum	Maxent	Biomapper	CRU	Subset	Target	0.98	0.008
Ambystoma cingulatum	Maxent	Random	CRU	All	Target	0.95	0.027
Ambystoma cingulatum	Maxent	Random	CRU	Subset	Target	0.97	0.008



**Uncertainty arising  
from climate data**



**Uncertainty arising  
from differences  
between algorithms**



## Climate envelope

*Florida's threatened  
and endangered species*

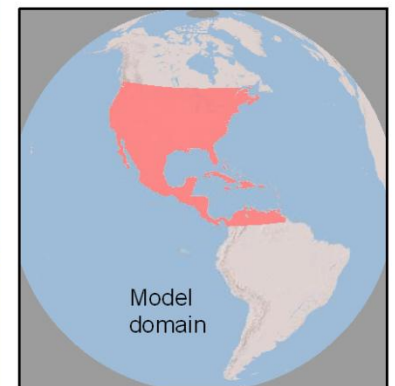
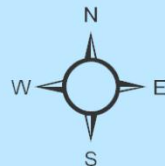
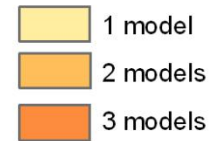
---

**Time period:** Contemporary

**Climate Dataset:** CRU/  
Worldclim consensus

---

### Model Overlap



## Algorithm

GLM vs Maxent vs RF

## Climate dataset

CRU vs WorldClim

## Variable selection

Uncorrelated vs random

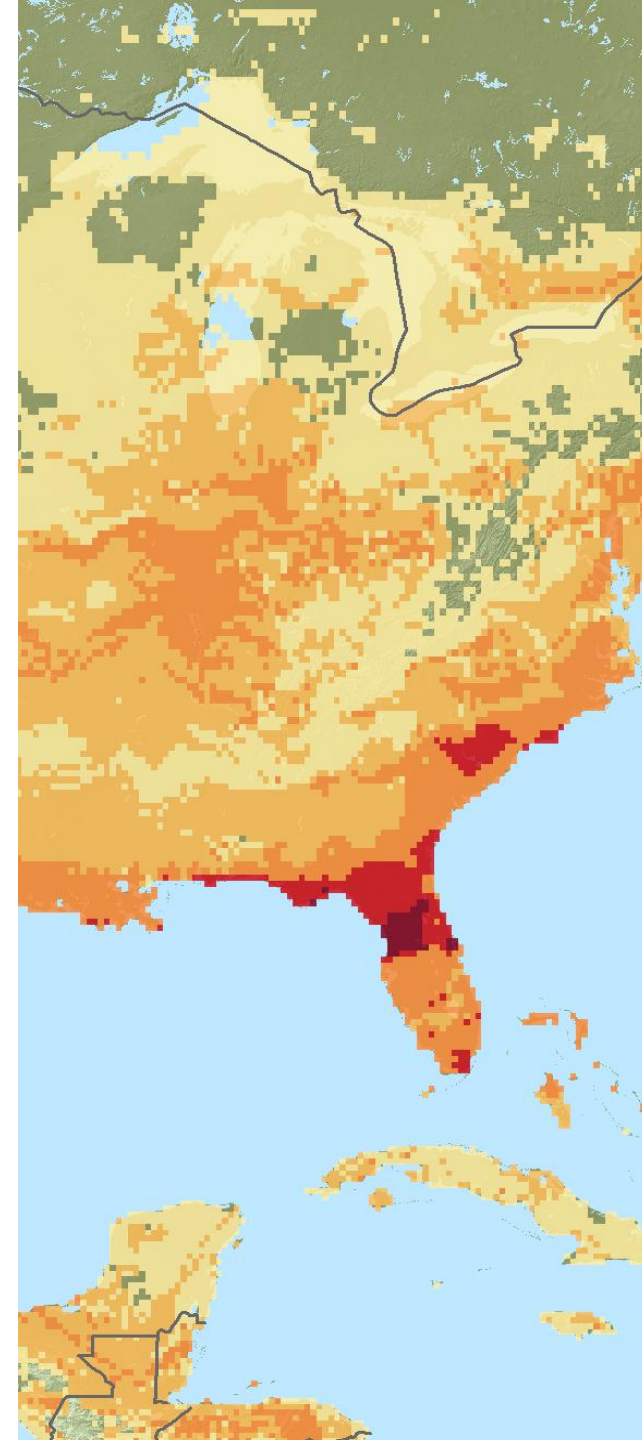
## Model domain

Varied vs fixed

## Number of occurrence points

All available vs subset

$3 \times 2 \times 2 \times 2 \times 2 = 48$  prediction  
maps per species





Algorithm: A  
Climate data: B  
Variable selection: B  
Number of occurrences: B  
Model domain: A

Algorithm: B  
Climate data: B  
Variable selection: B  
Number of occurrences: B  
Model domain: B

Algorithm: A  
Climate data: A  
Variable selection: A  
Number of occurrences: A  
Model domain: B

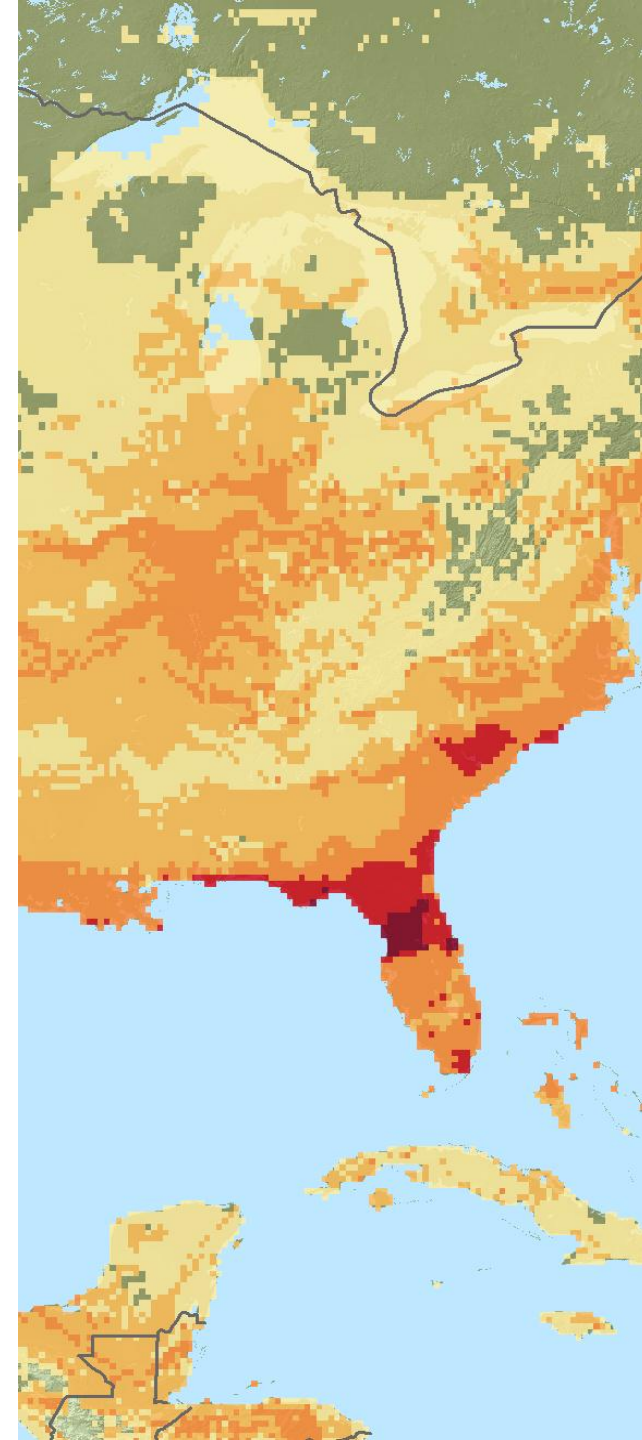
Algorithm: B  
Climate data: B  
Variable selection: A  
Number of occurrences: A  
Model domain: A



# ANOVA-based approach to quantifying spatial uncertainty in CEMs

Suitability ~ Algorithm + Climate data + Number of occurrence points + Model domain...

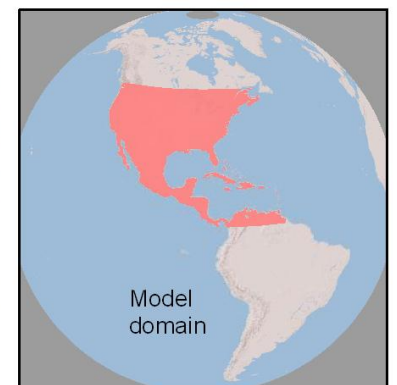
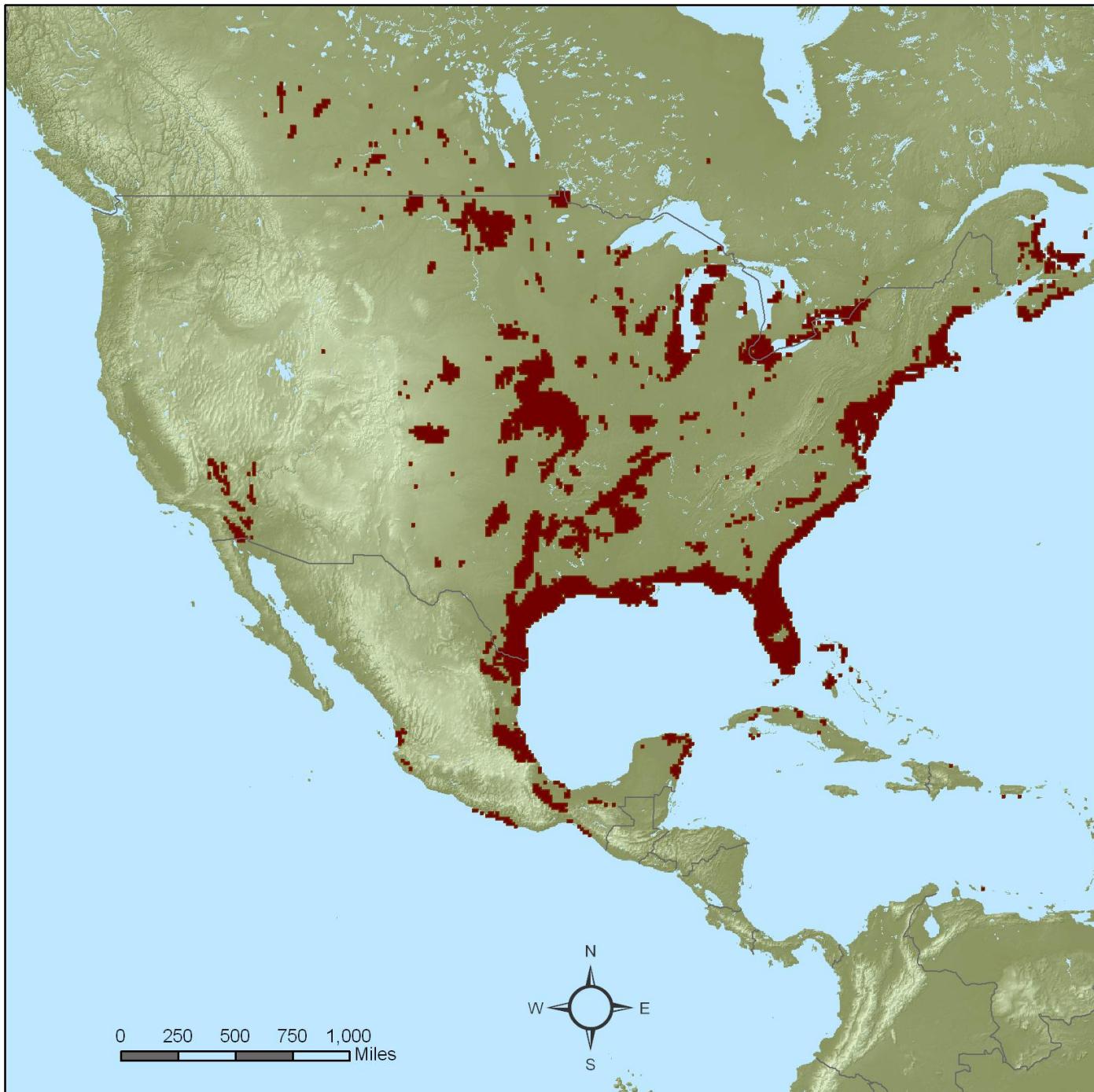
	<u>DF</u>	<u>Sum Squares</u>	<u>F-value</u>	<u>P</u>
Algorithm	1	0.016	8.149	0.046
Climate	1	0.007	3.631	0.129
Occurrence	1	0.004	0.224	0.660
Residuals	4	<u>0.008</u>		
		0.035		



## Climate envelope

*Florida's threatened  
and endangered species*

---



# Climate envelope

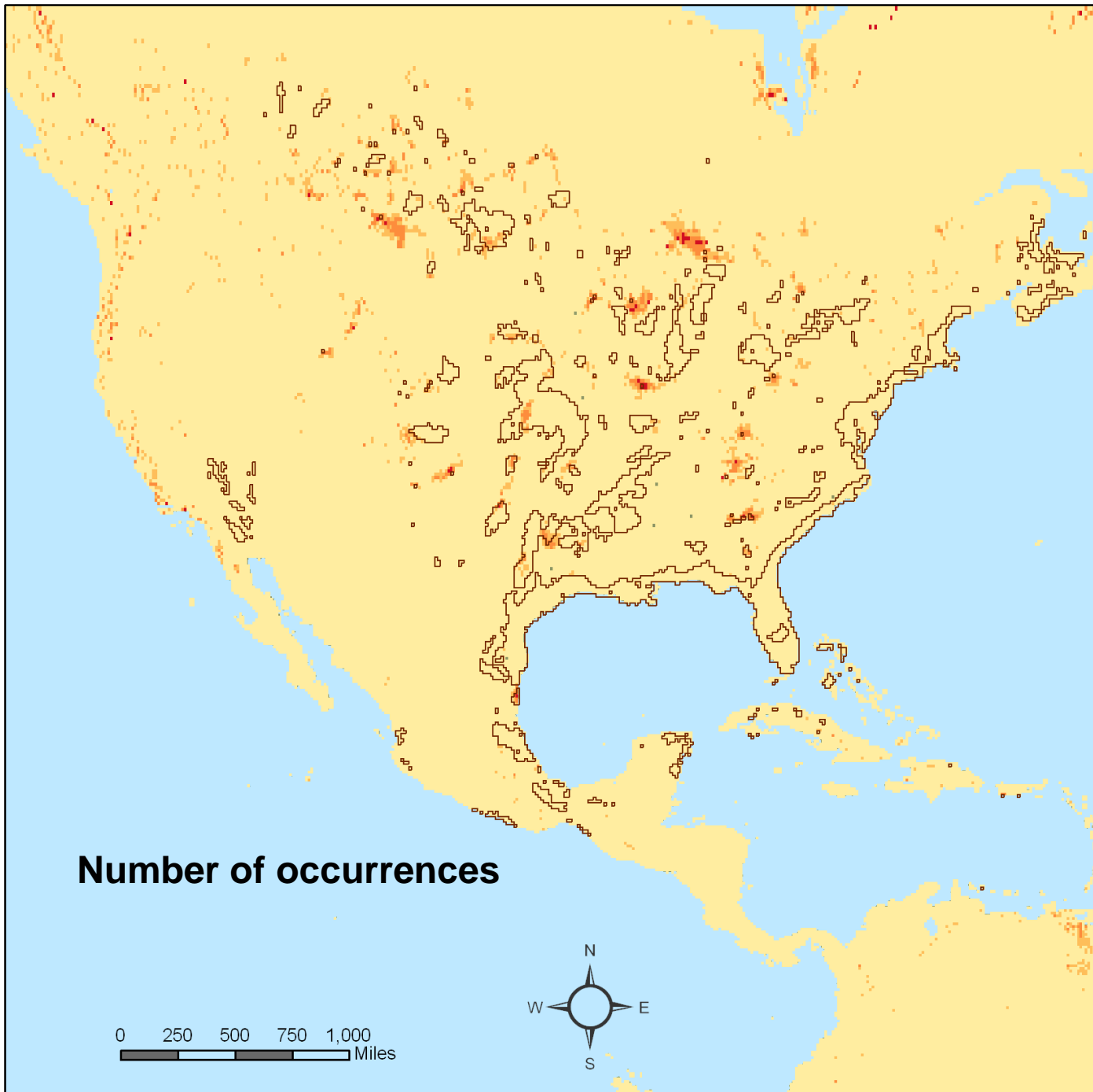
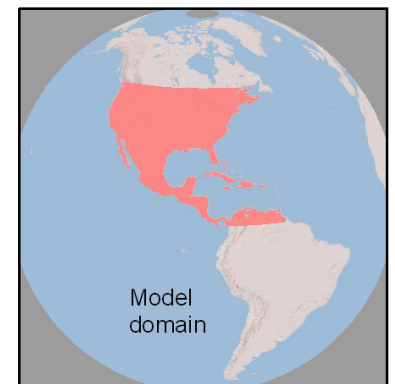
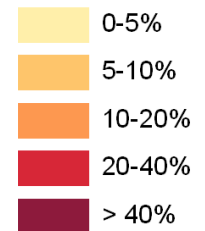
*Florida's threatened and endangered species*

**Time period:** 2040-2059

**IPCC Scenario:** A1B

**GCMs:** GFDL CM2.0,  
NCAR CCSM3,  
UKMO HadCM3 (consensus)

## variance explained





## Climate envelope

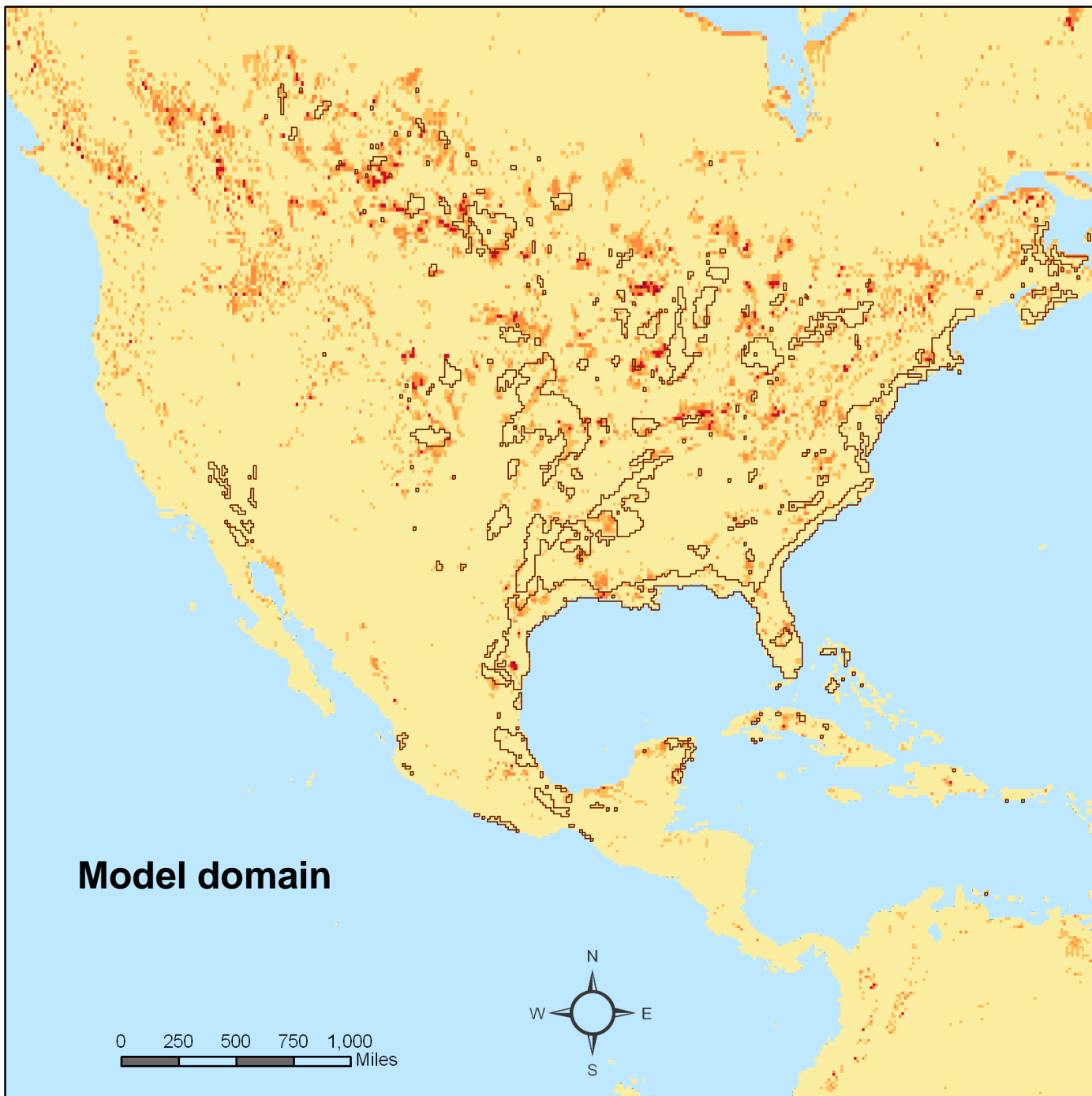
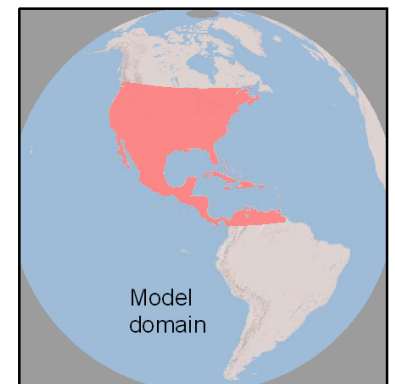
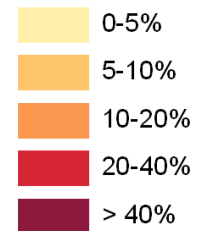
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### variance explained



# Climate envelope

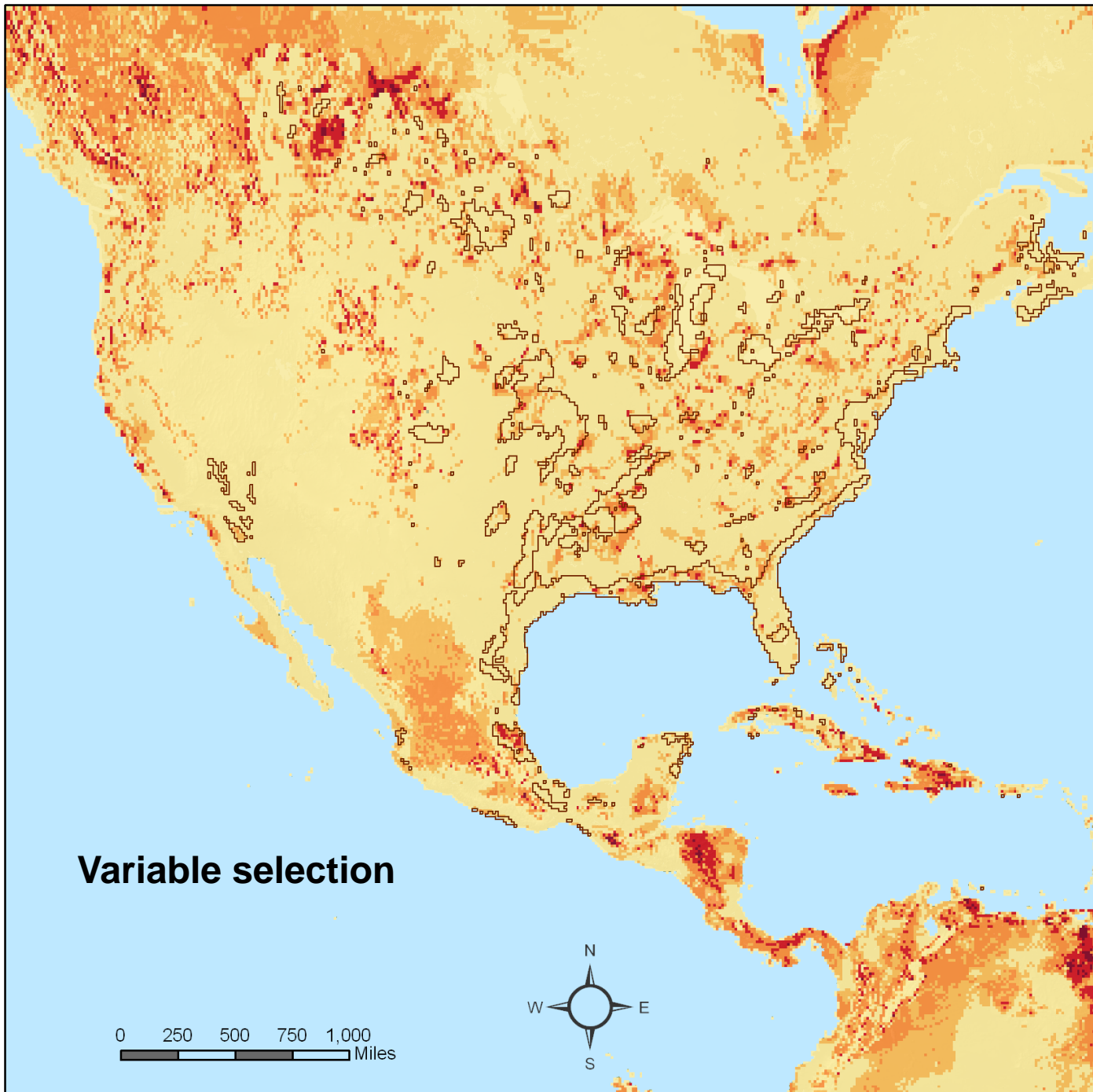
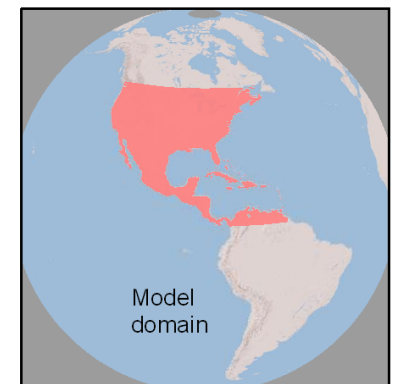
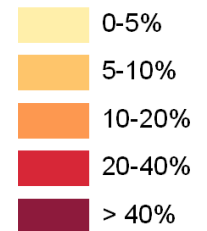
*Florida's threatened and endangered species*

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## variance explained



## Climate envelope

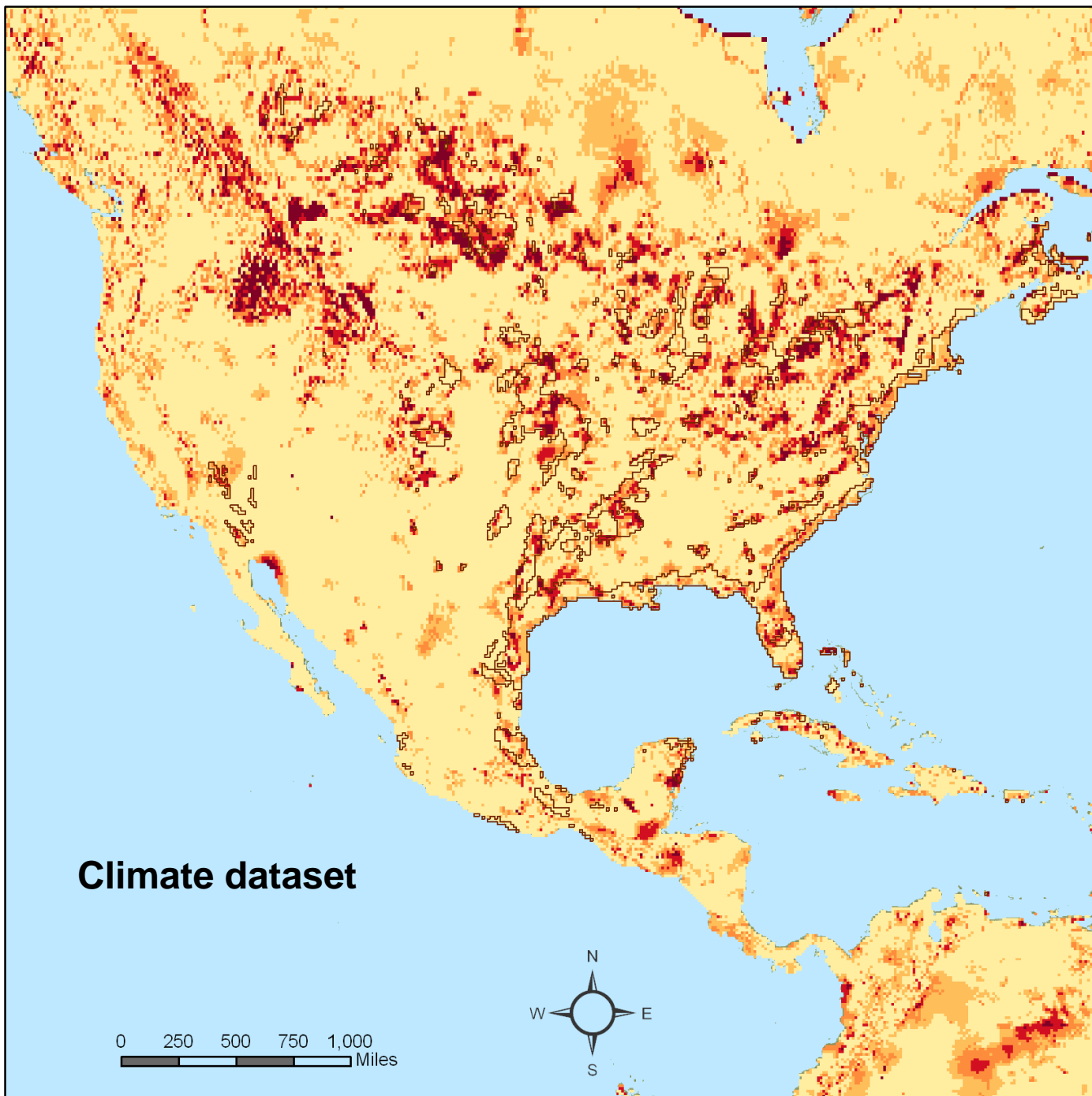
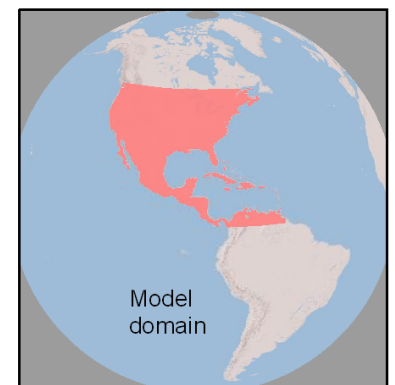
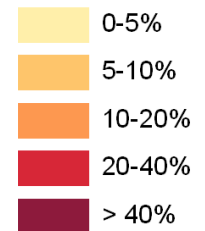
*Florida's threatened and endangered species*

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### variance explained





# Climate envelope

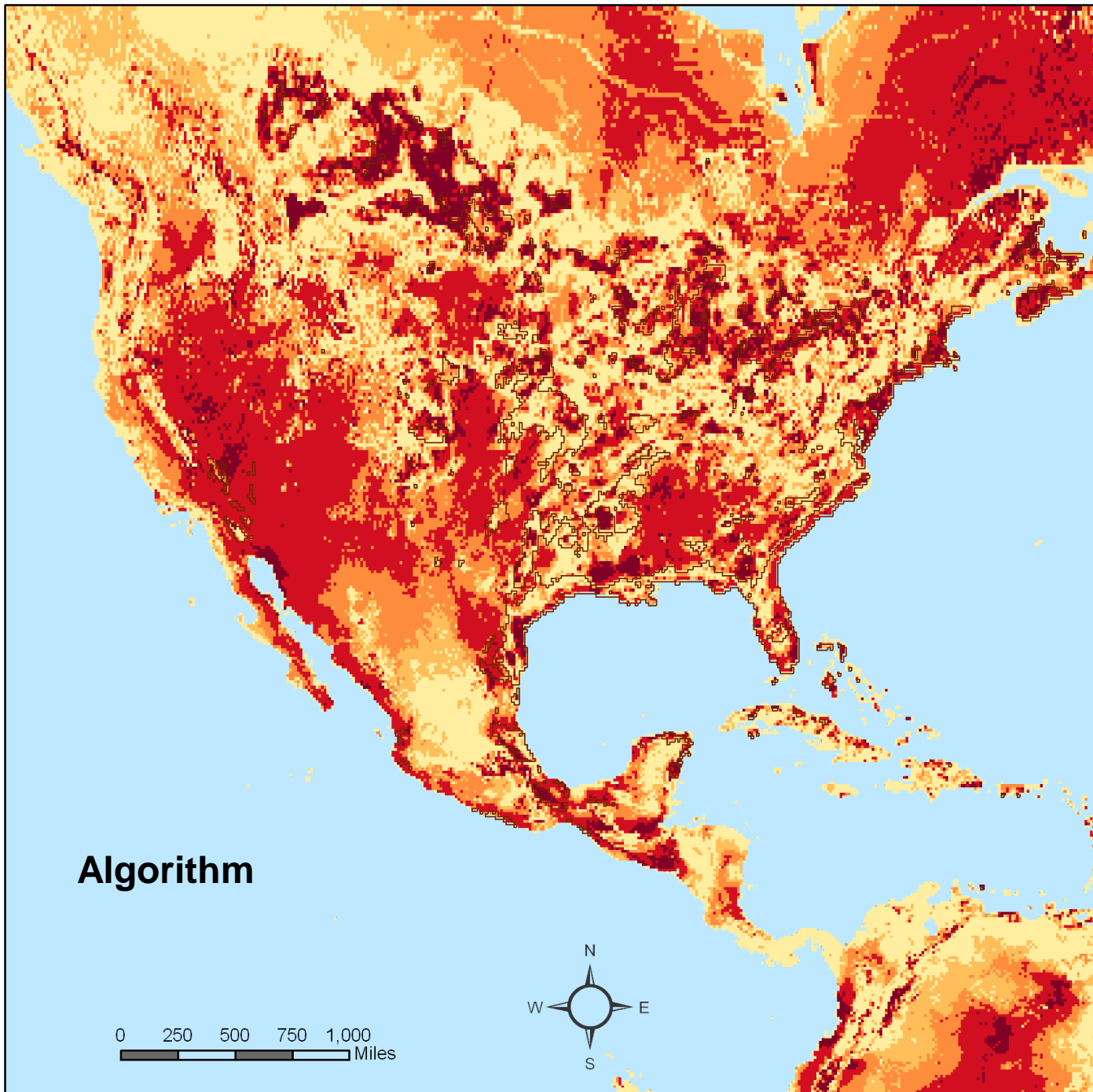
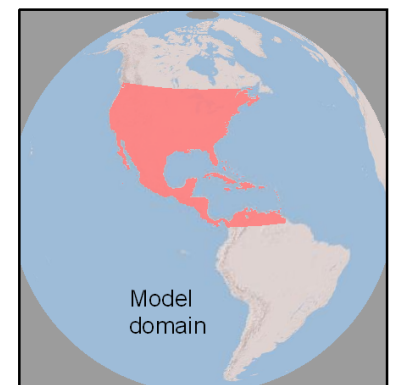
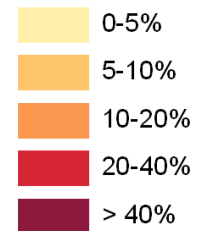
*Florida's threatened and endangered species*

**Time period:** 2040-2059

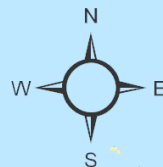
**IPCC Scenario:** A1B

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NCAR CCSM3,  
UKMO HADCM3 (consensus)

## variance explained

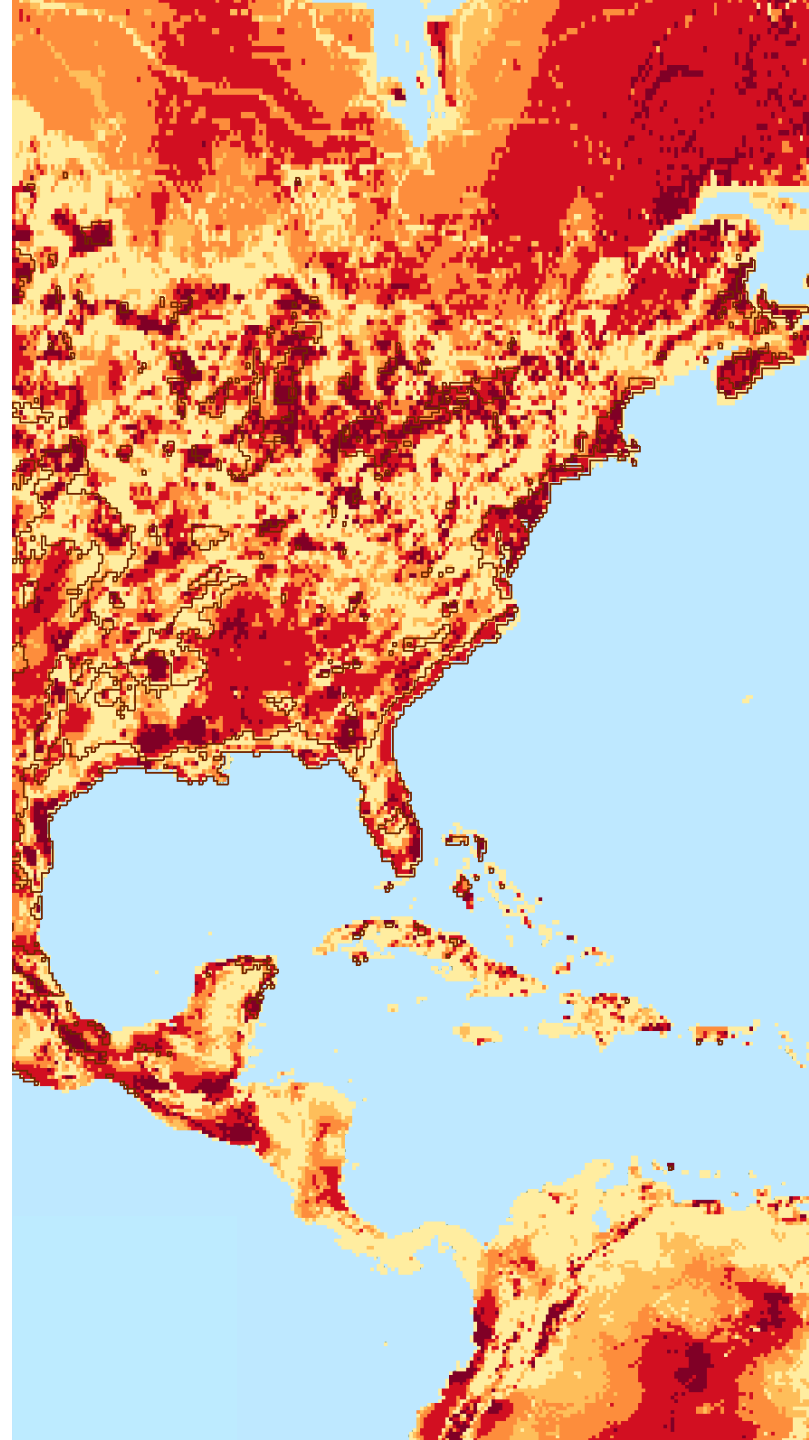


## Algorithm



## Sources of variation in spatial predictions in CEMs

1. Algorithm
2. Climate dataset
3. Variable selection
4. Model domain
5. Number of occurrence points

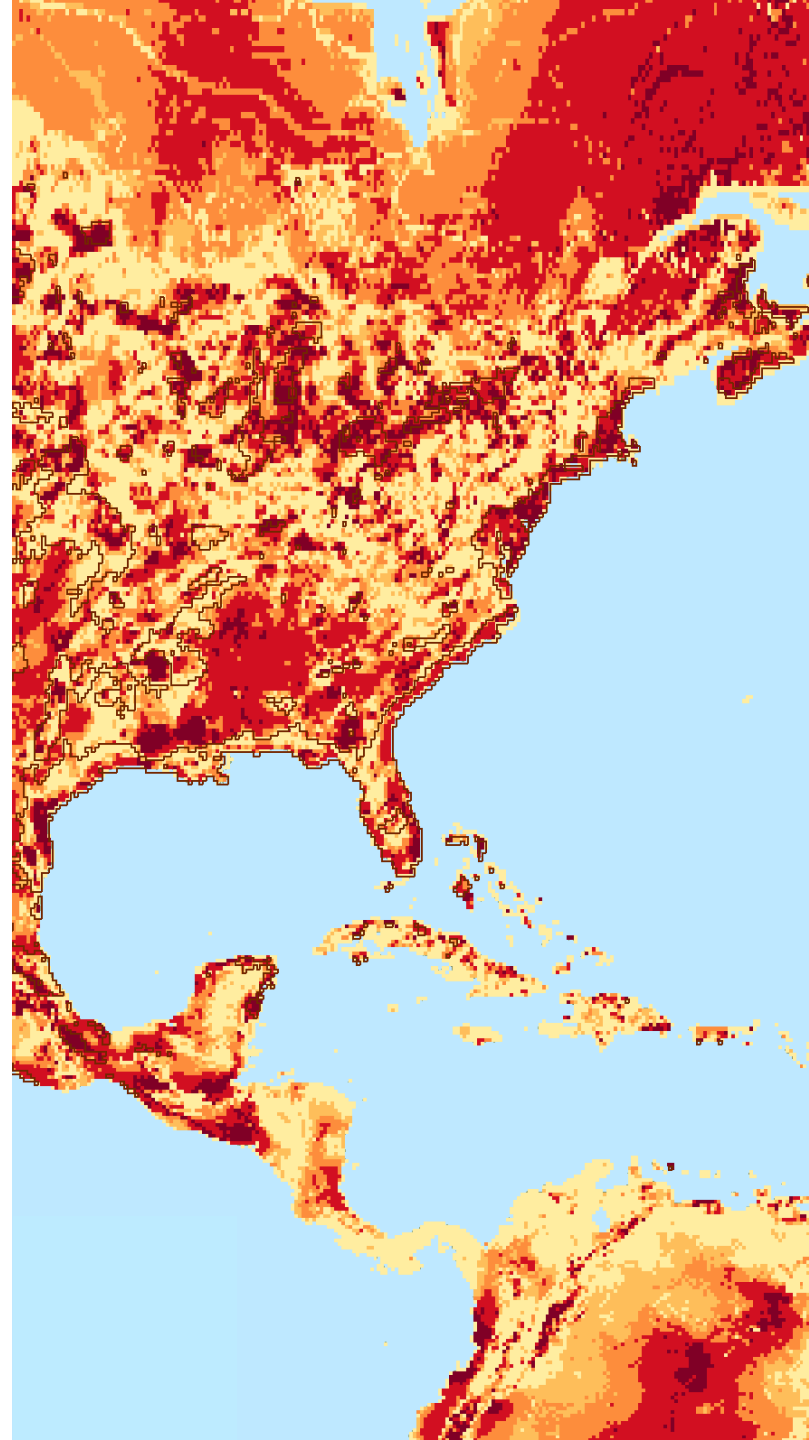


## Take home points:

**Models suggest the number of species for which climate will be suitable in any one place may decrease over time**

**We see spatial shifts in NWRs where climate is suitable for the greatest number of species *included in our analysis***

**Using an approach to describe the spatial signature of uncertainty in CEMs to assist in comprehensive climate planning**





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