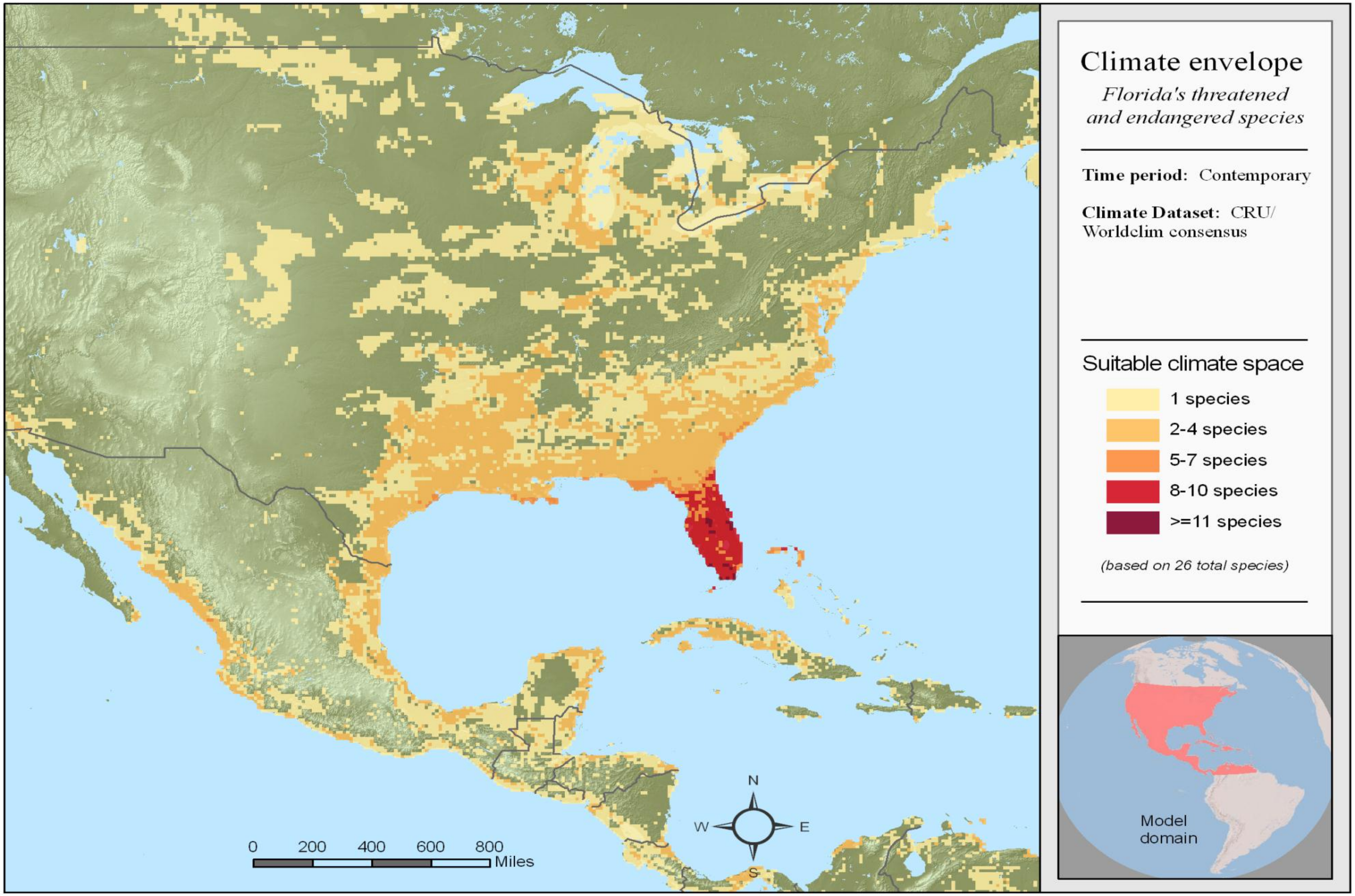
Forecasting Climate Change Effects on Threatened and Endangered Species in the Greater Everglades Ecosystem

James Watling, Stephanie S. Romañach, Laura Brandt, Allison Benscoter, 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

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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

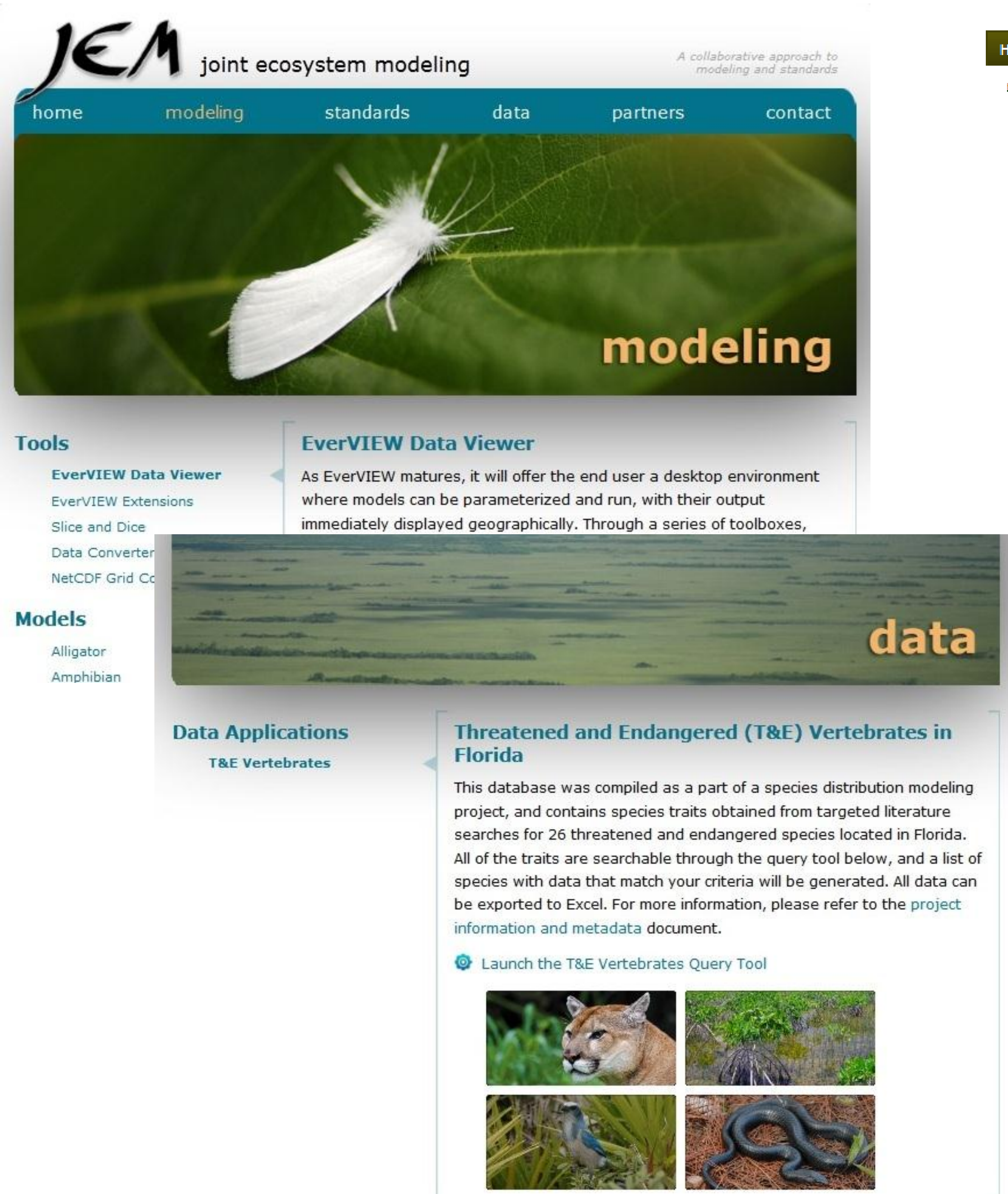
Database of T&E species traits describing vulnerability to climate change

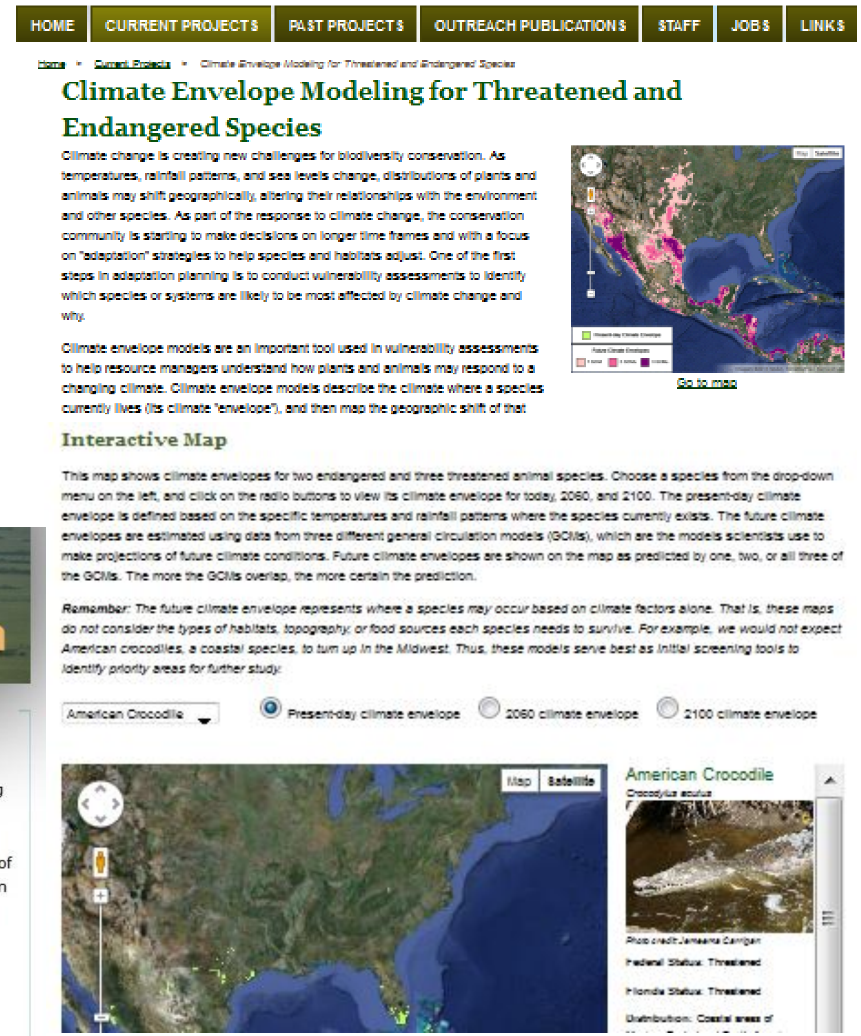
Model visualization tools

Make information available to others

www.jem.gov

crocdocs.ifas.ufl.edu





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)

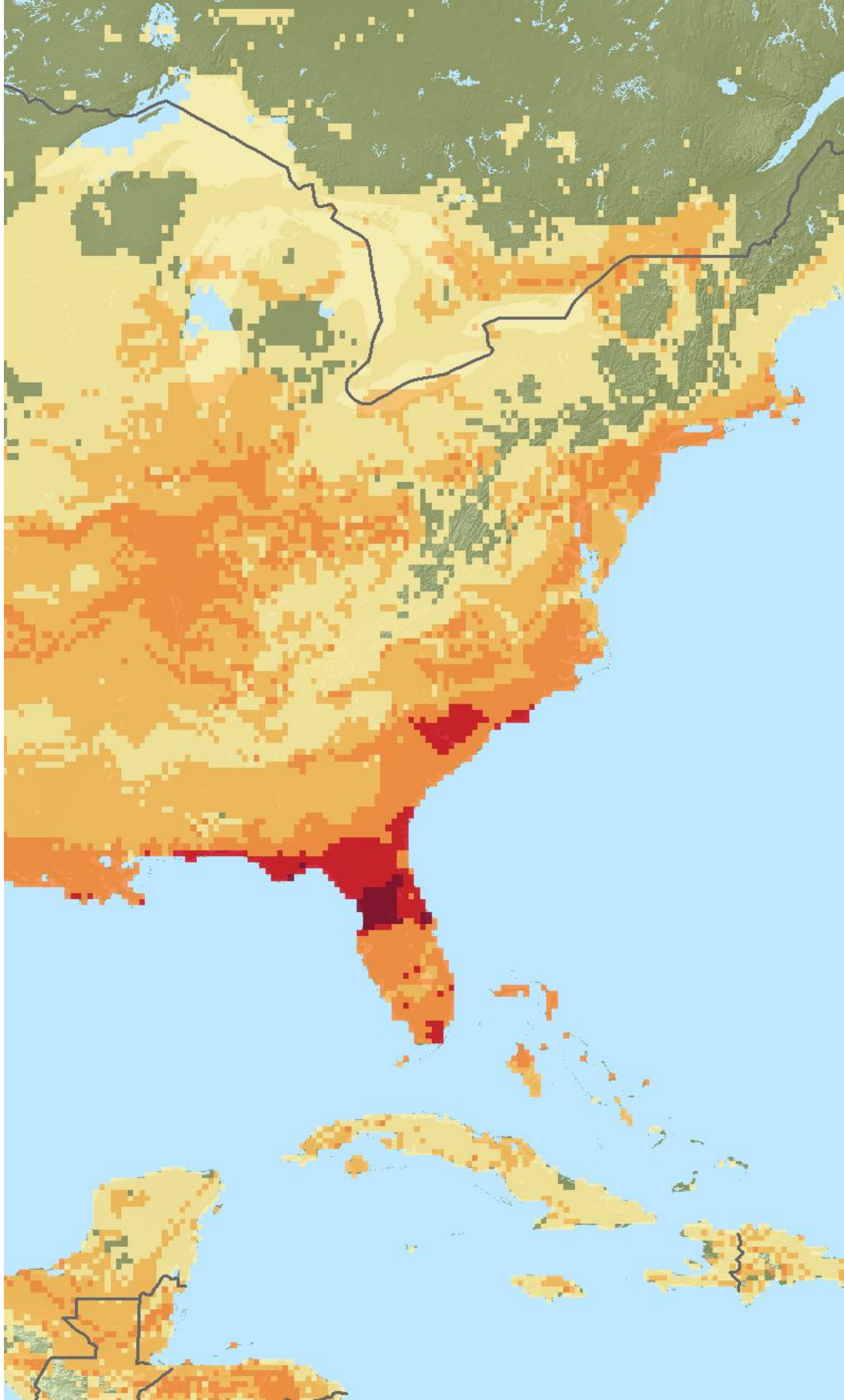
Uses a statistical model to extrapolate species distribution data in space and time

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)**



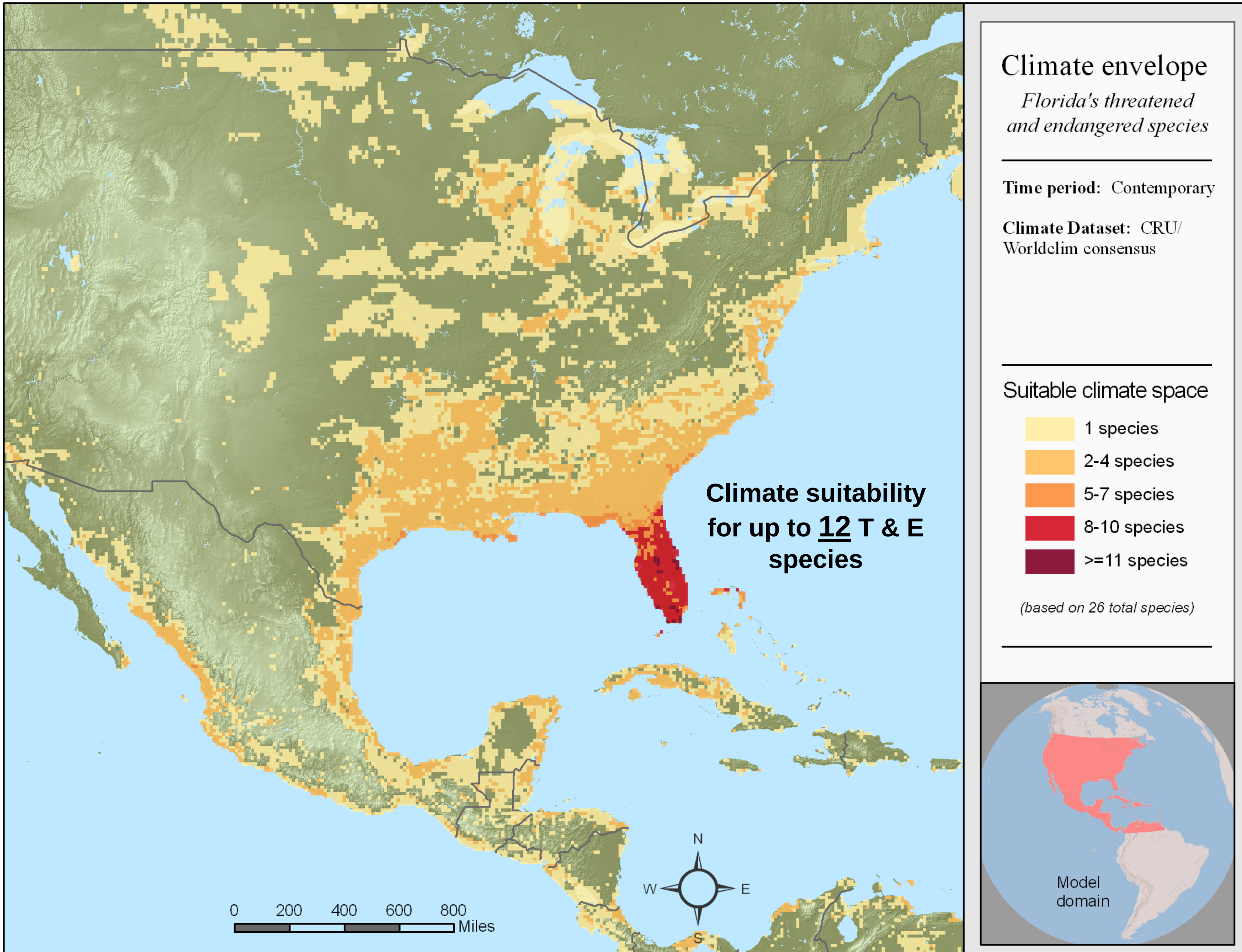
Climate projections

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

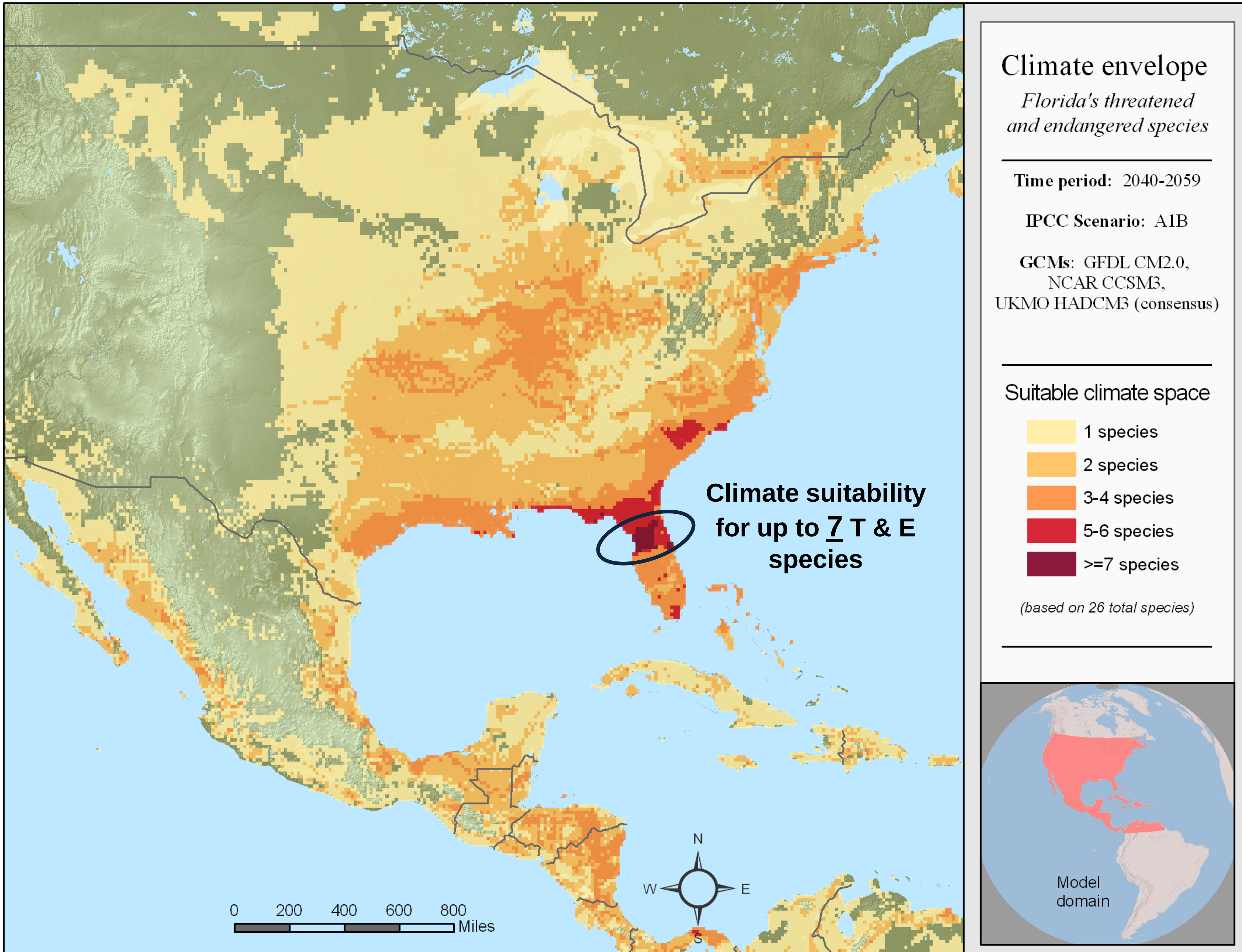
- **GFDL CM2**
- **NCAR CCSM3**
- **UKMO HADCM3**

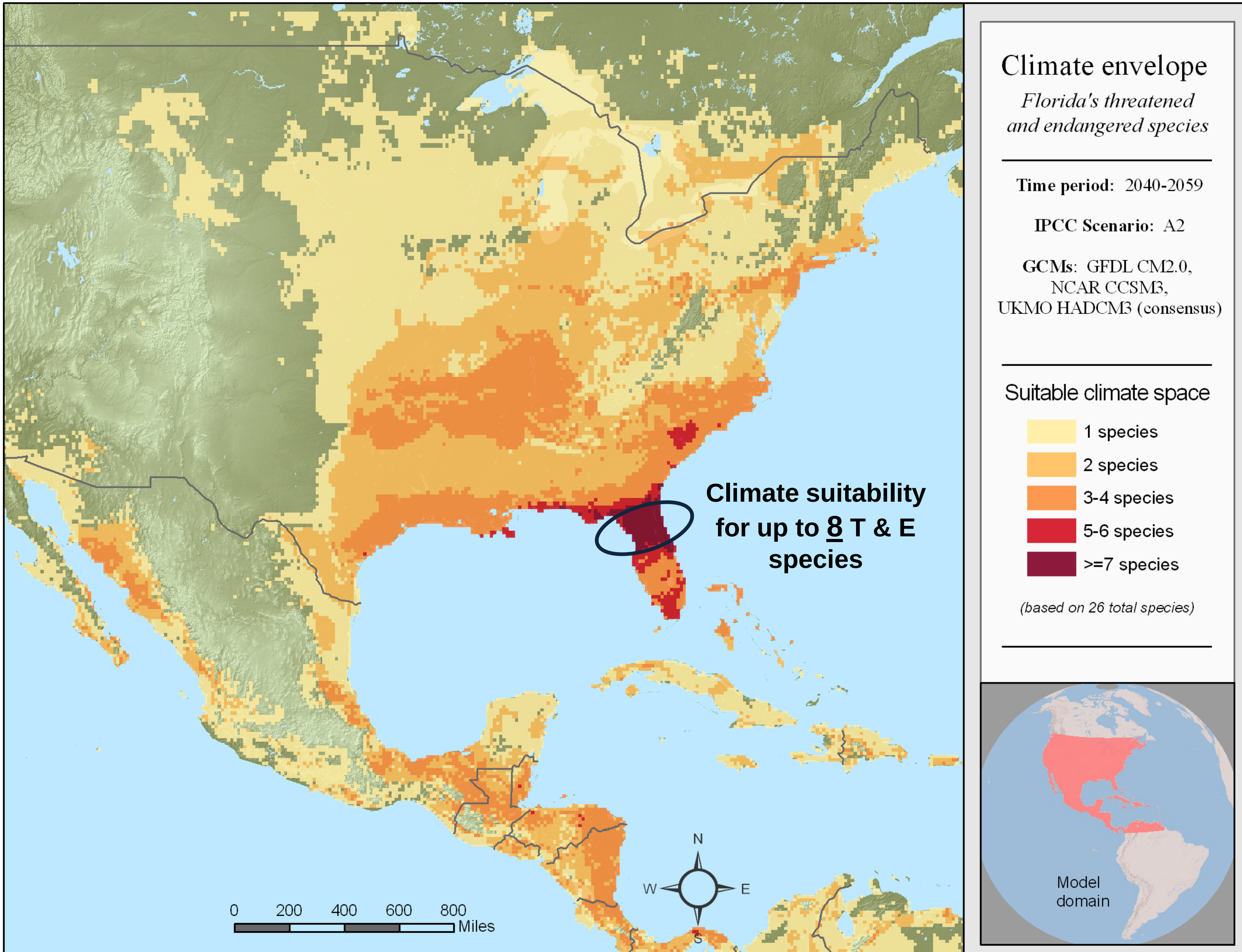
Two emissions scenarios:

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



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)
Climate suitability for up to 12 T & E species
0 200 400 600 800
Miles
N
W
E
S
Model domain

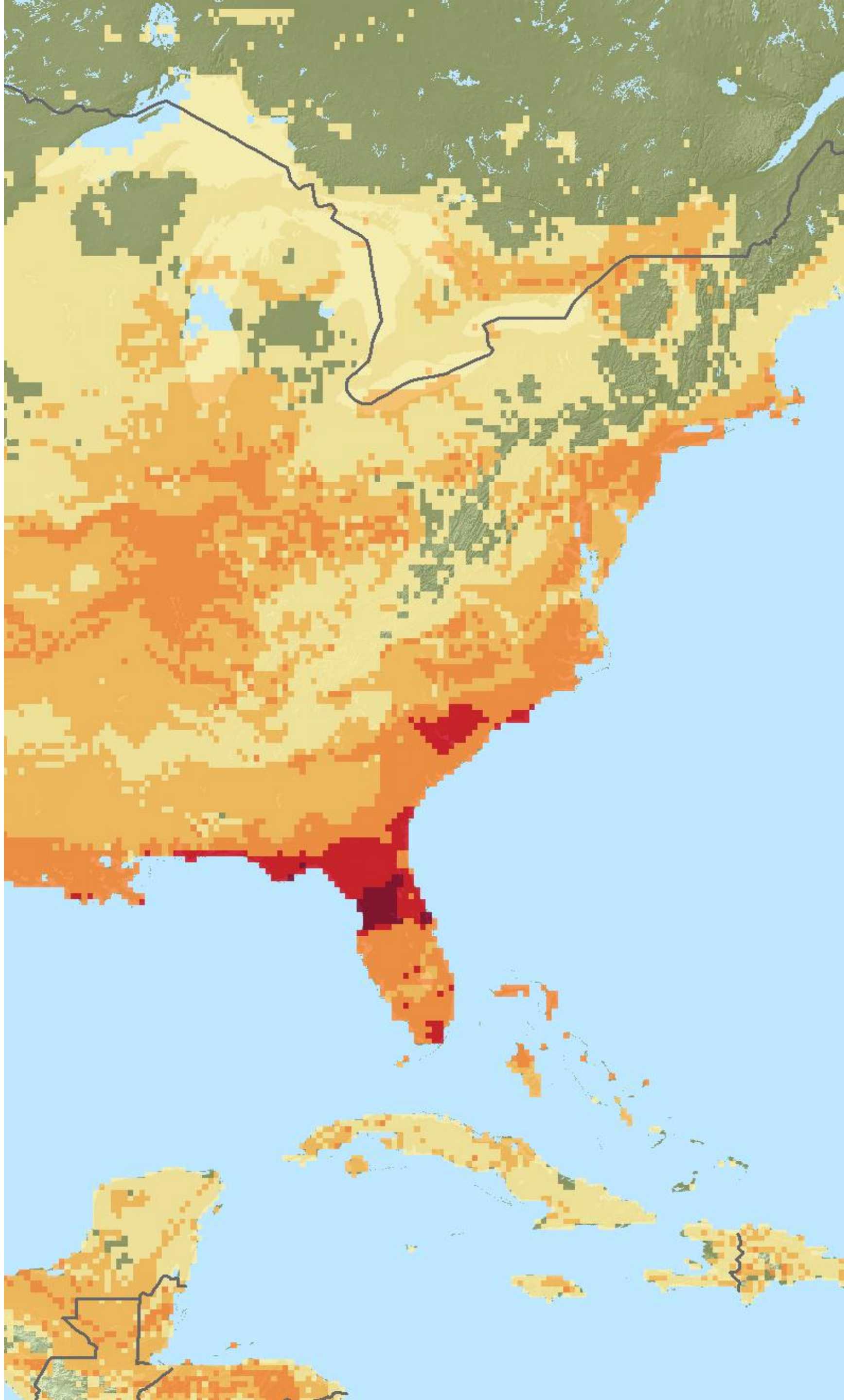

Climate envelope
Florida's threatened and endangered species
Time period: 2040-2059
IPCC Scenario: A1B
GCMs: GFDL CM2.0, NCAR CCSM3, UKMO HADCM3 (consensus)
Suitable climate space
1 species
2 species
3-4 species
5-6 species
>=7 species
(based on 26 total species)
Model domain
Climate suitability for up to 7 T & E species
N
W
E
S
0
200
400
600
800
Miles


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
1 species
2 species
3-4 species
5-6 species
>=7 species
(based on 26 total species)
Model domain
Climate suitability for up to 8 T & E species
N
S
W
E
0
200
400
600
800
Miles

<u>Take home points:</u>

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



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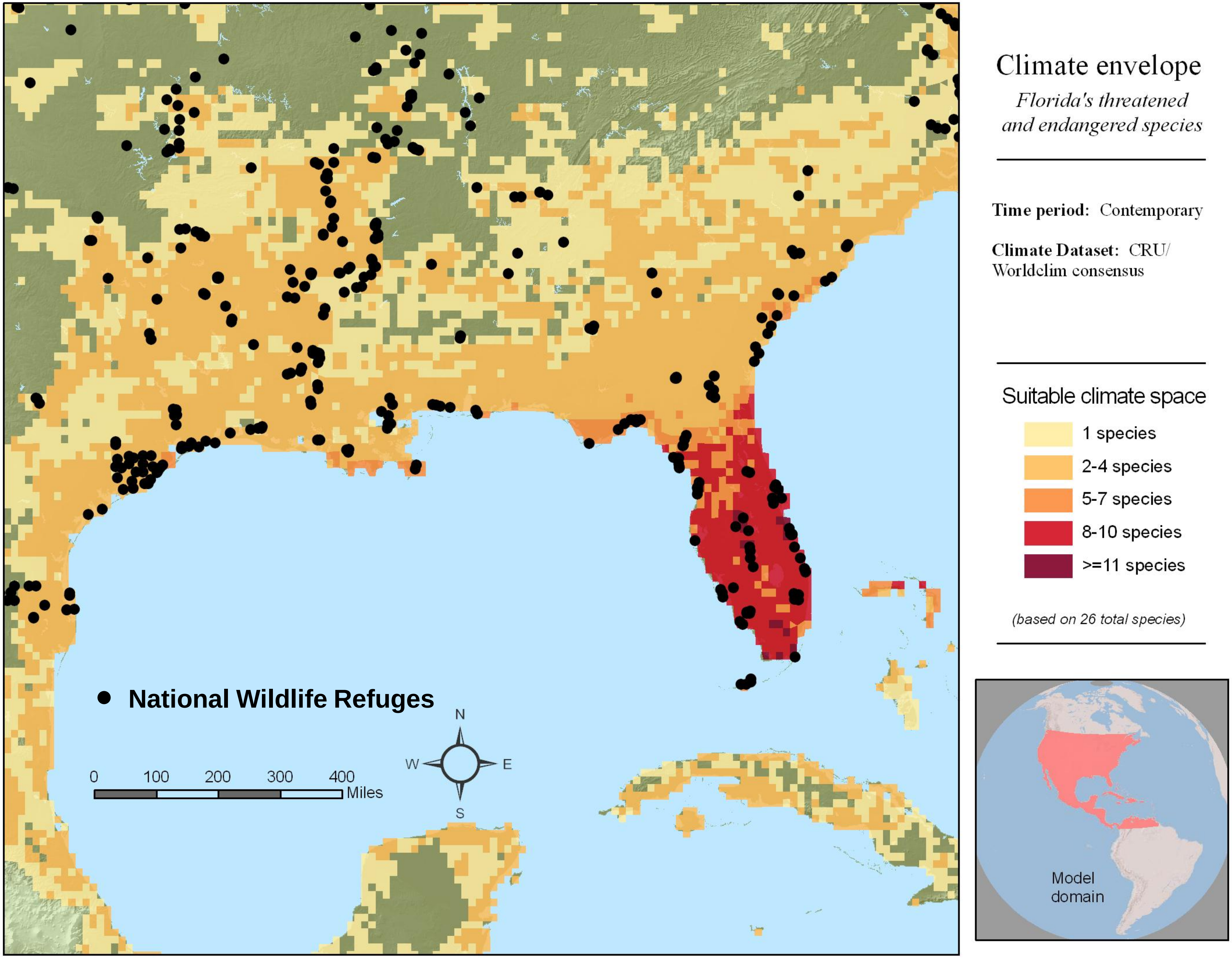
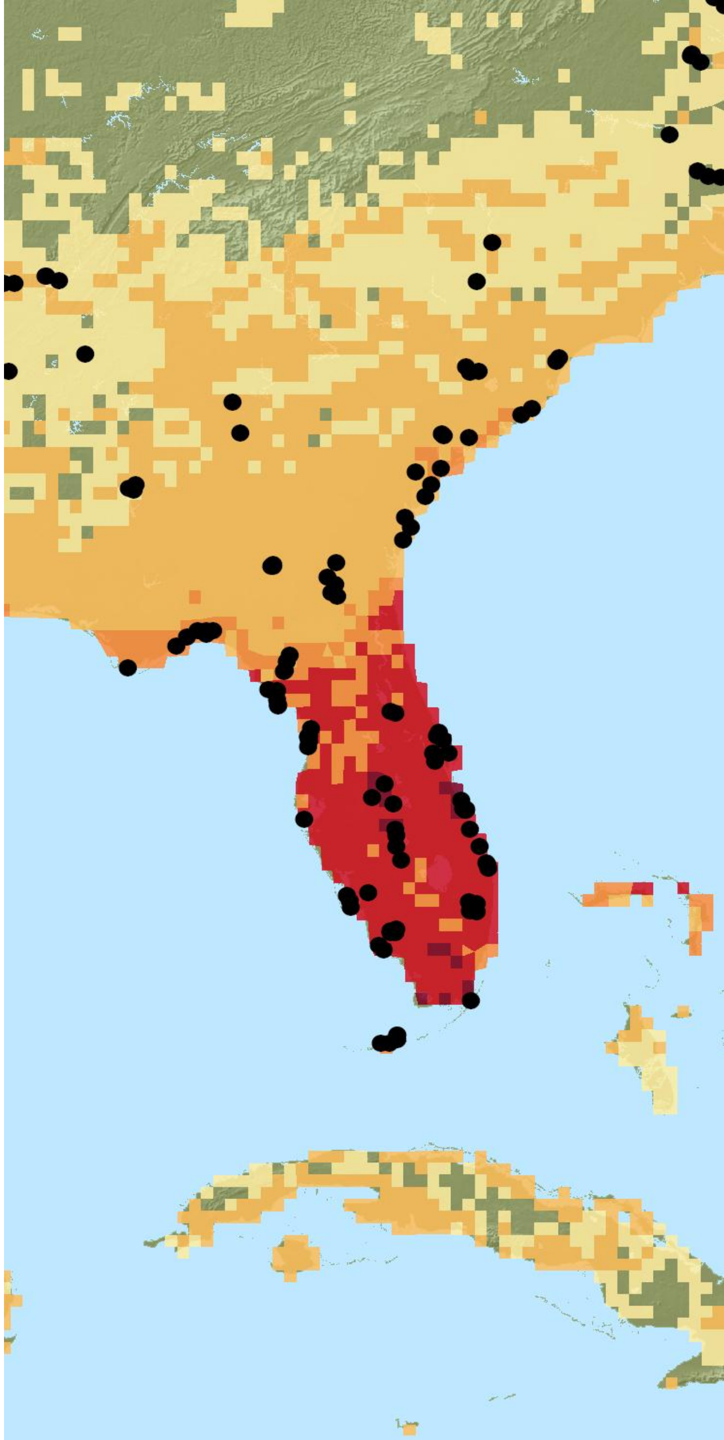
III Mapping uncertainty in climate envelope models


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)
National Wildlife Refuges
0 100 200 300 400 Miles
N
W
E
S
Model domain

Spatial overlap of CEMs with USFWS refuges

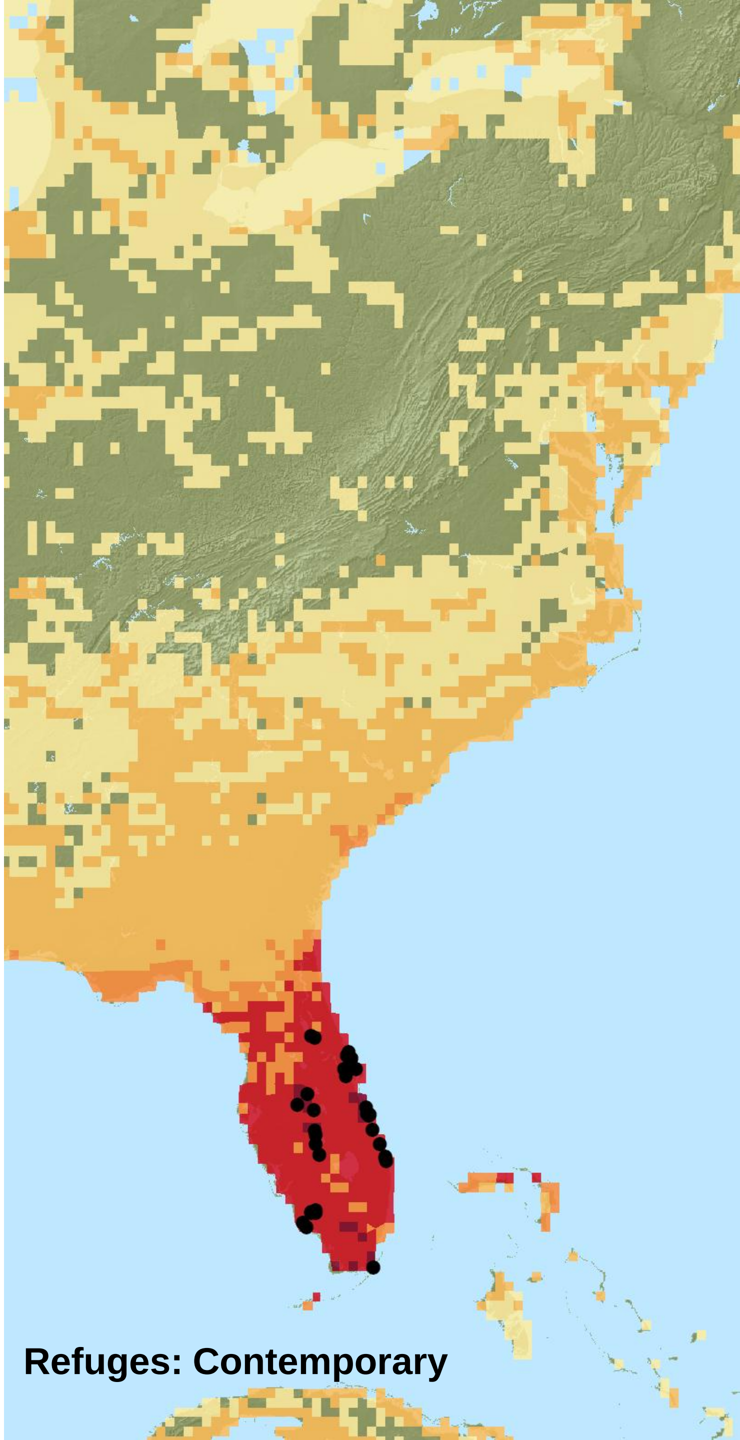
	10-12 T & E species	7-9 T & E species	4-6 T & E species	1-3 T & E species
Contemporary	10 refuges	22 refuges	28 refuges	100+ refuges
Mid-century: A1B				
Mid-century: A2				



Spatial overlap of CEMs with USFWS refuges

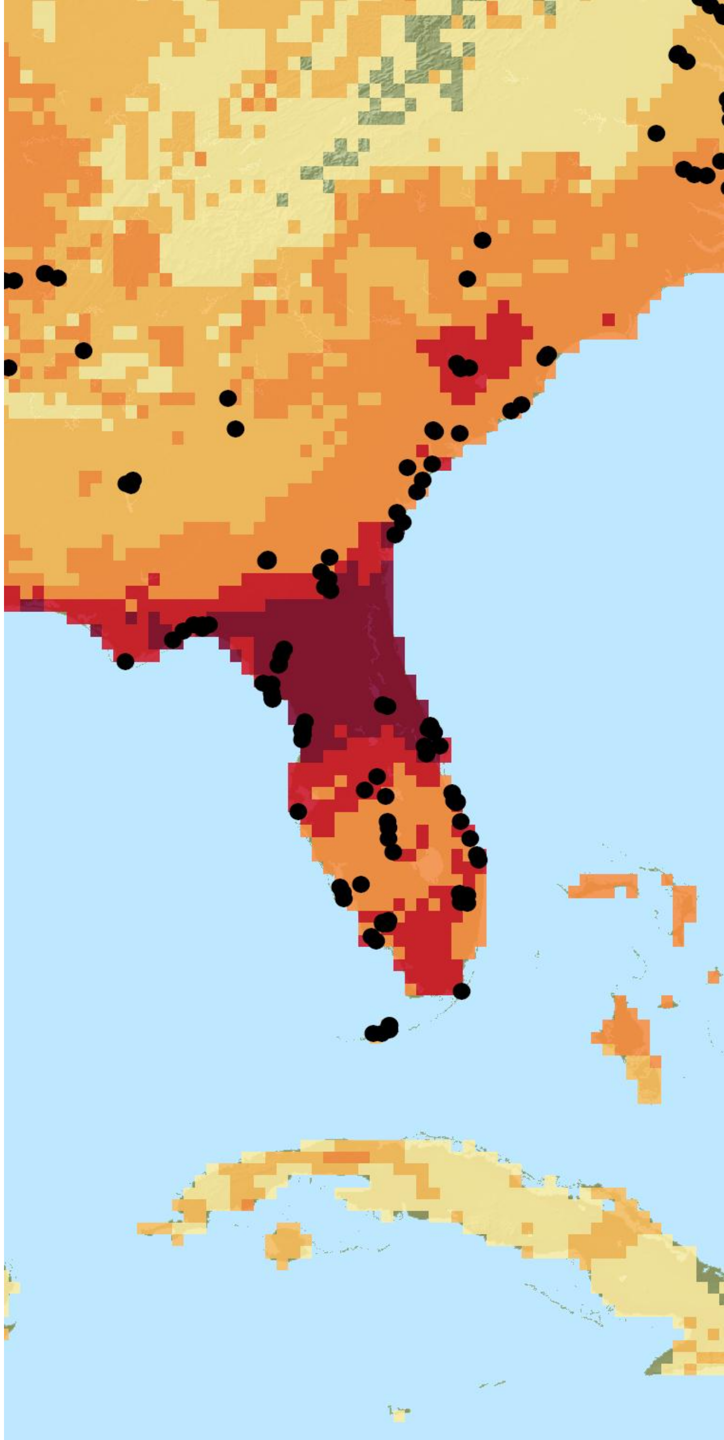
Refuges with maximal CEM overlap (*contemporary*)

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



Spatial overlap of CEMs with USFWS refuges

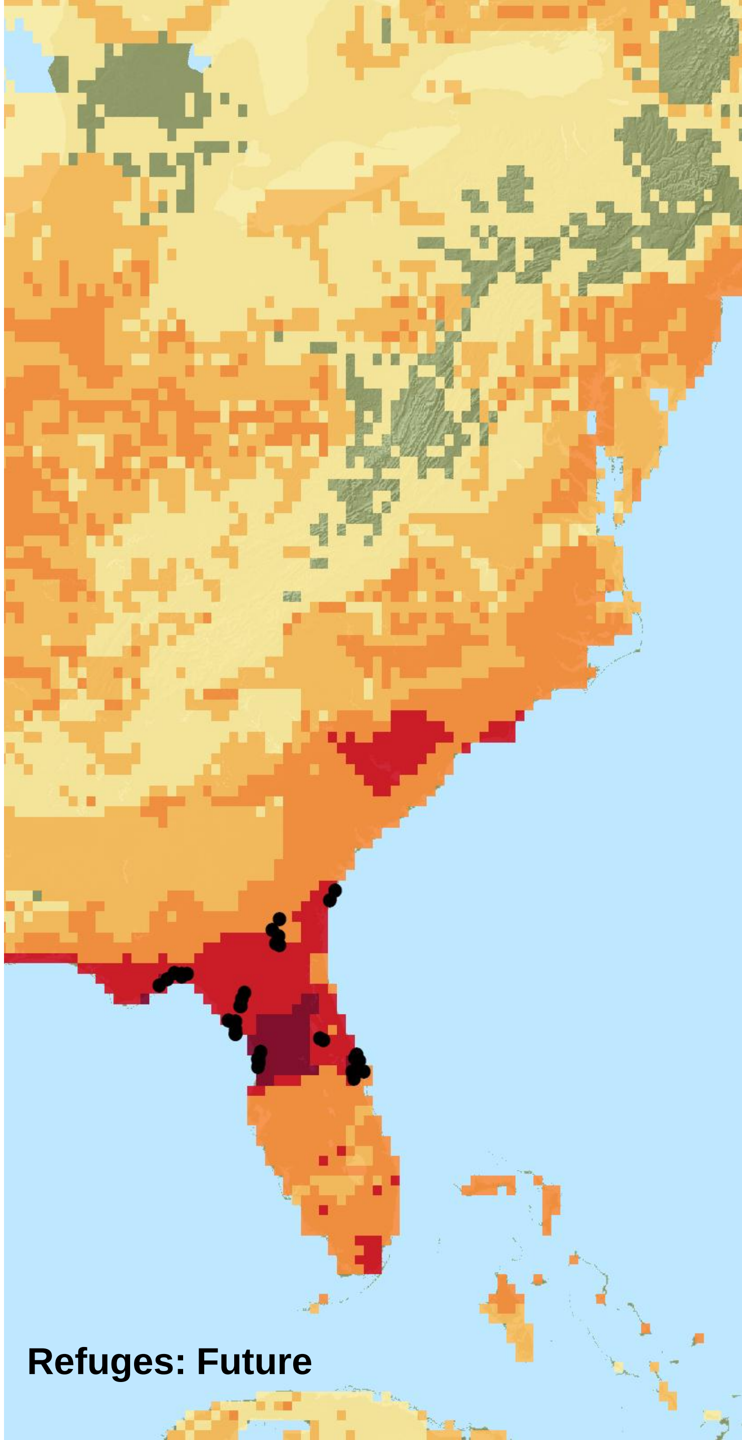
	10-12 T & E species	7-9 T & E species	4-6 T & E species	1-3 T & E species
Contemporary	10 refuges	22 refuges	28 refuges	100+ refuges
Mid-century: A1B		5 refuges	52 refuges	100+ refuges
Mid-century: A2		11 refuges	52 refuges	100+ refuges



<u>Spatial overlap of CEMs with USFWS refuges</u>

Refuges with maximal CEM overlap (*future*)

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



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

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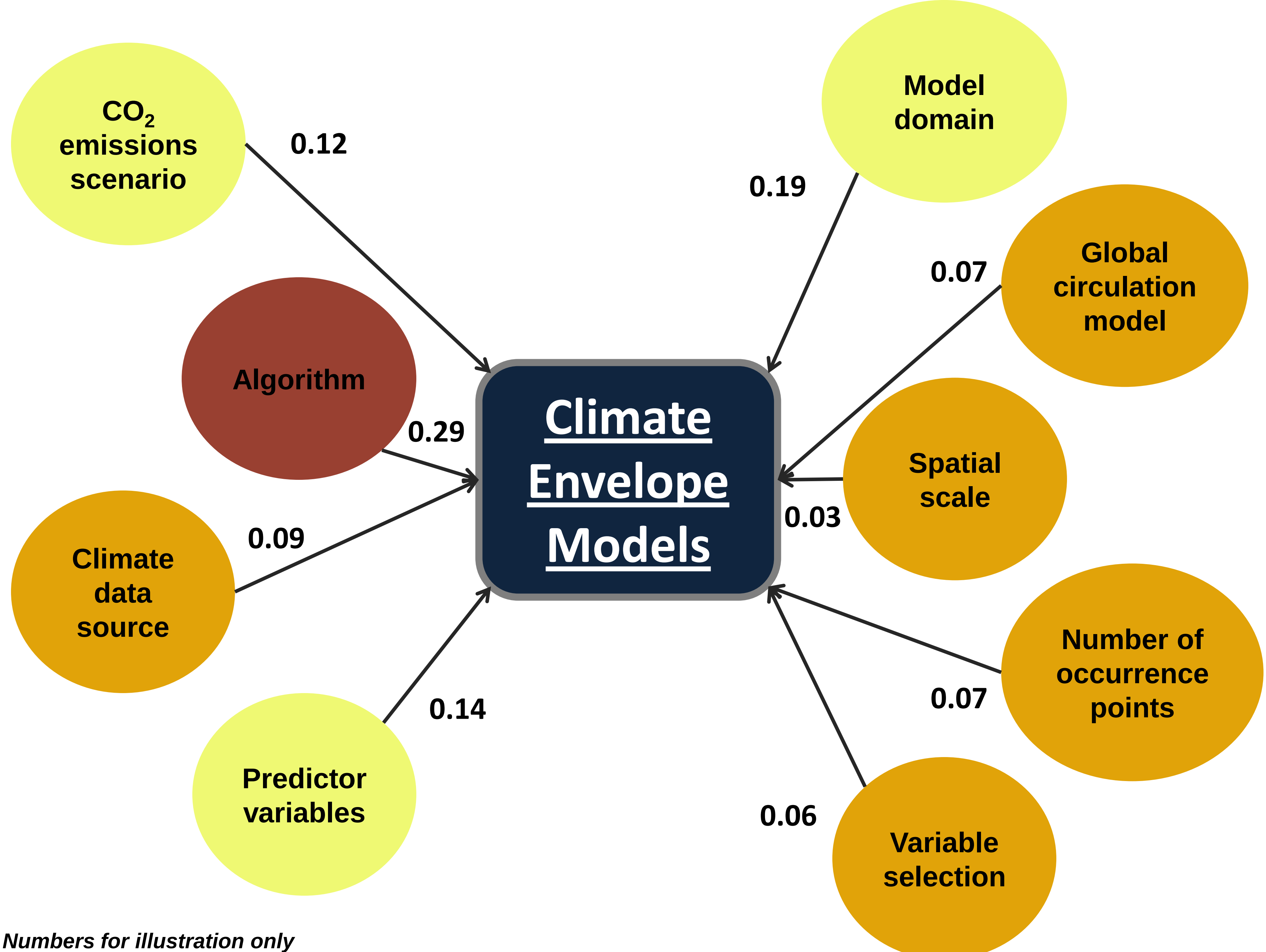
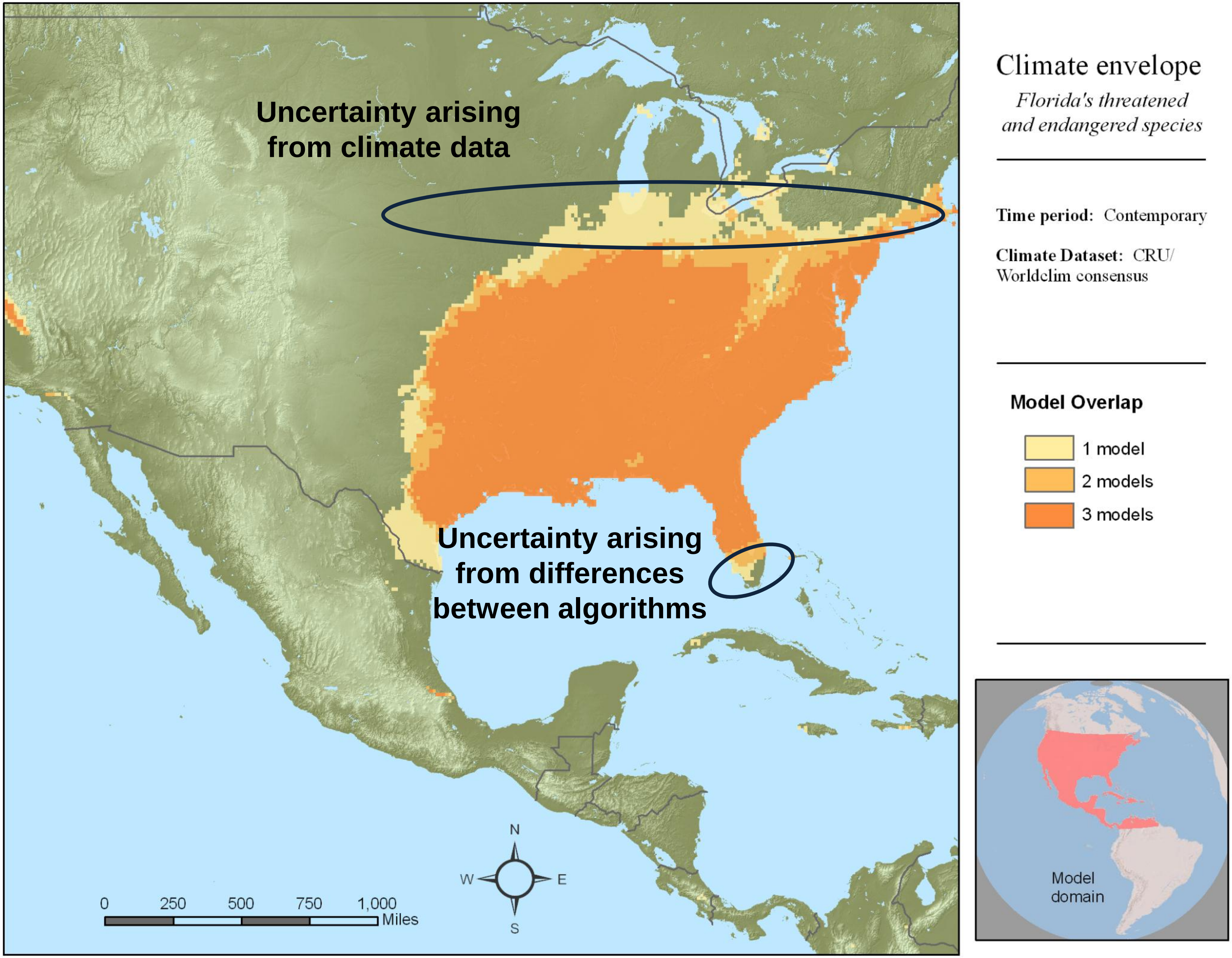


Numbers for illustration only

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


Climate envelope
Florida's threatened and endangered species
Time period: Contemporary
Climate Dataset: CRU/ Worldclim consensus
Model Overlap
1 model
2 models
3 models
Uncertainty arising from climate data
Uncertainty arising from differences between algorithms
N
W
E
S
0
250
500
750
1,000
Miles
Model domain

Algorithm

GLM vs Maxent vs RF

Climate dataset

CRU vs WorldClim

Variable selection

Uncorrelated vs random

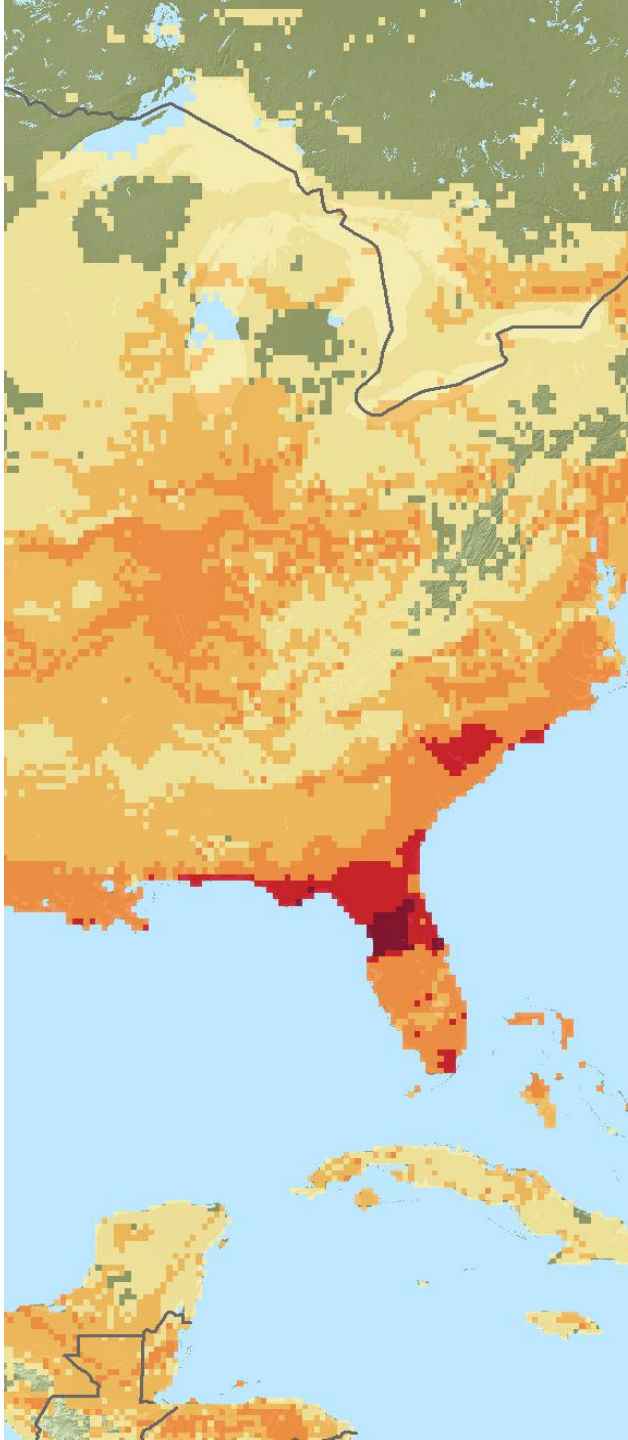
Model domain

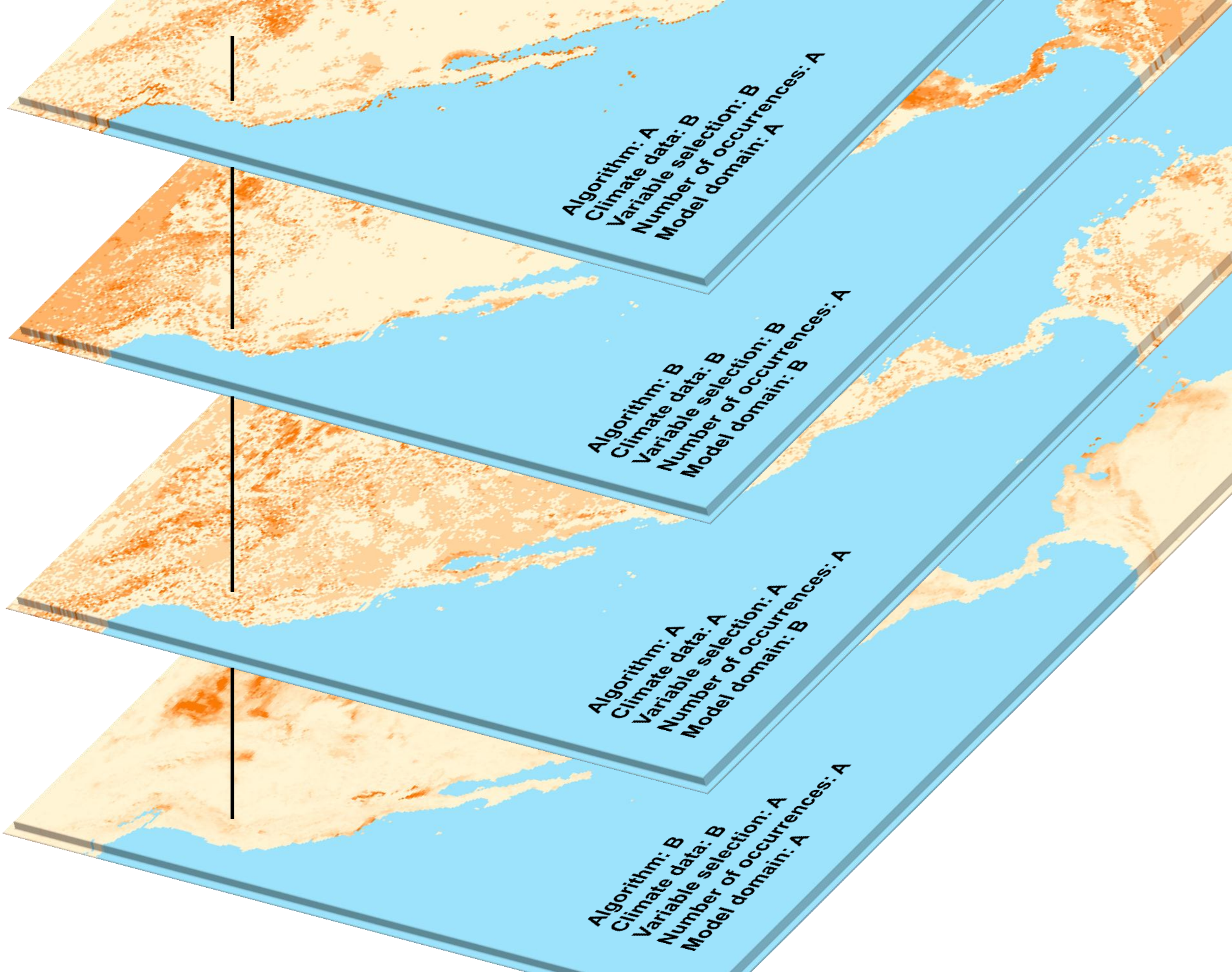
Varied vs fixed

Number of occurrence points

All available vs subset

3 x 2 x 2 x 2 x 2 = 48 prediction maps per species



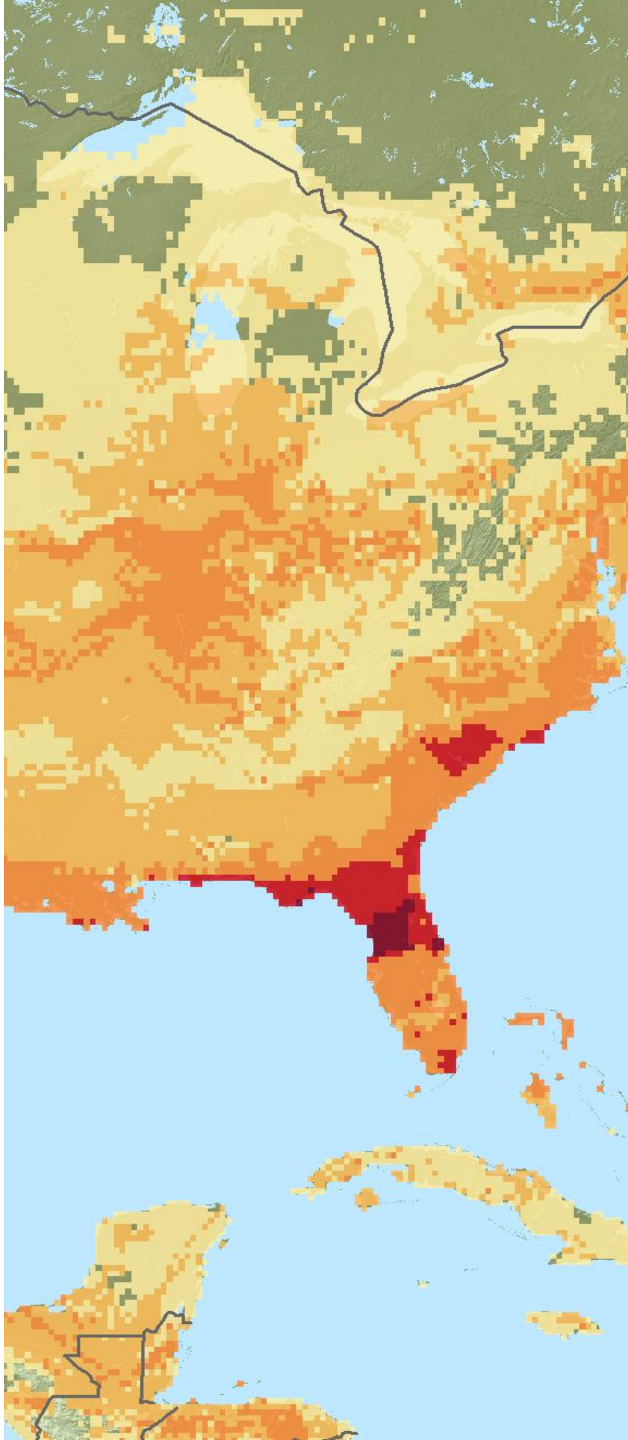


Algorithm: A
Climate data: B
Variable selection: B
Number of occurrences: A
Model domain: A
Algorithm: B
Climate data: B
Variable selection: B
Number of occurrences: A
Model domain: B
Algorithm: A
Climate data: A
Variable selection: A
Number of occurrences: A
Model domain: B
Algorithm: B
Climate data: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

ANOVA-based approach to quantifying spatial uncertainty in CEMs

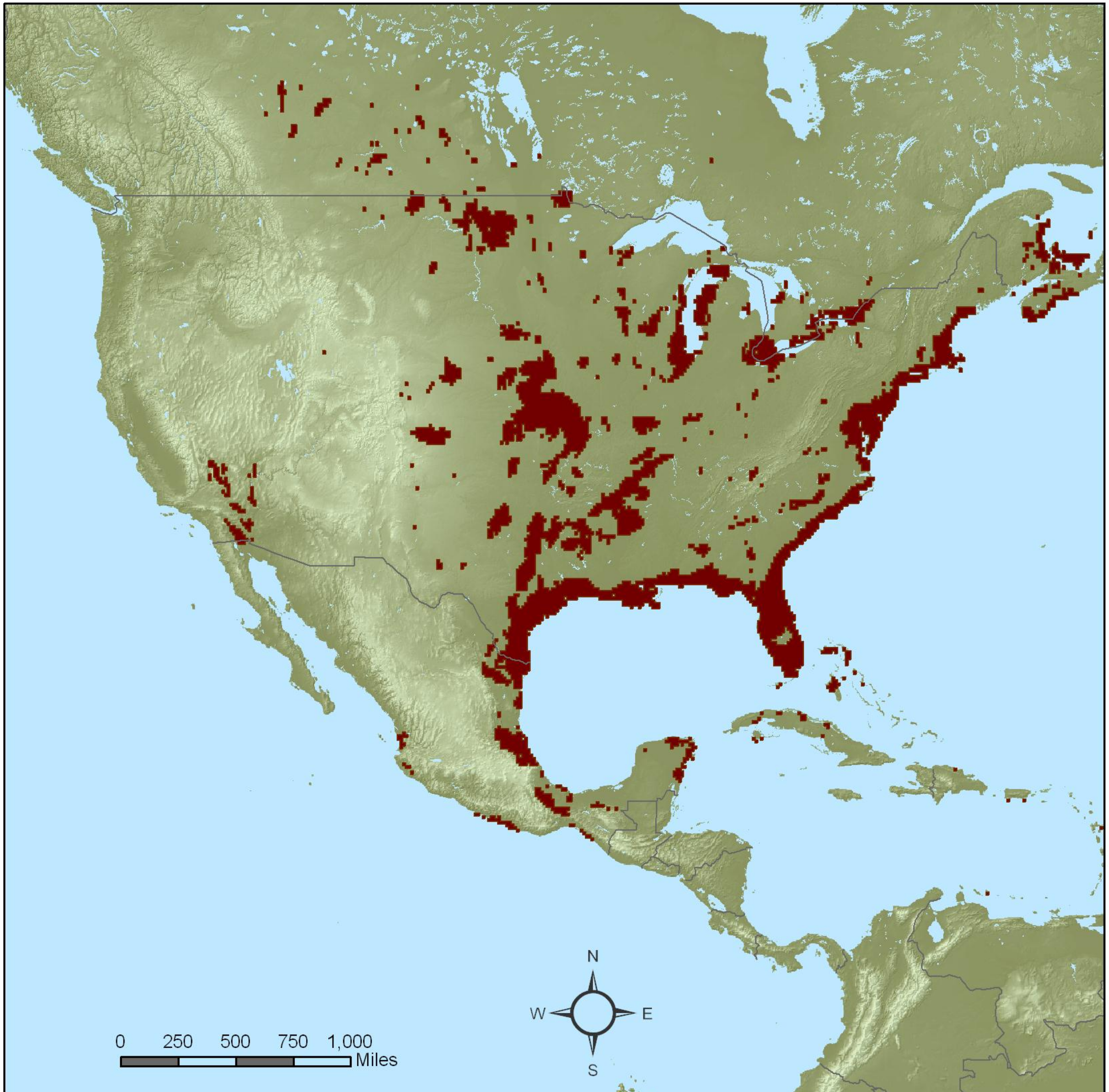
Suitability ~ Algorithm + Climate data + Number of occurrence points + Model domain…

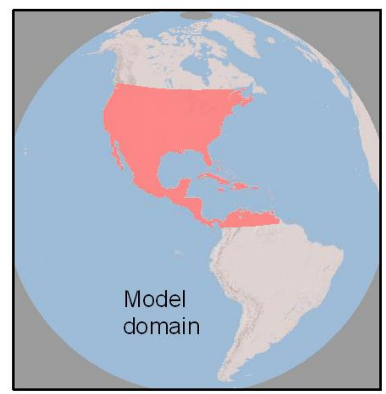
	DF	Sum Squares	F-value	P
Algorithm	1	0.016	8.149	0.046
Climate	1	0.007	3.631	0.129
Occurrence	1	0.004	0.224	0.660
Residuals	4	0.008		
		0.035		

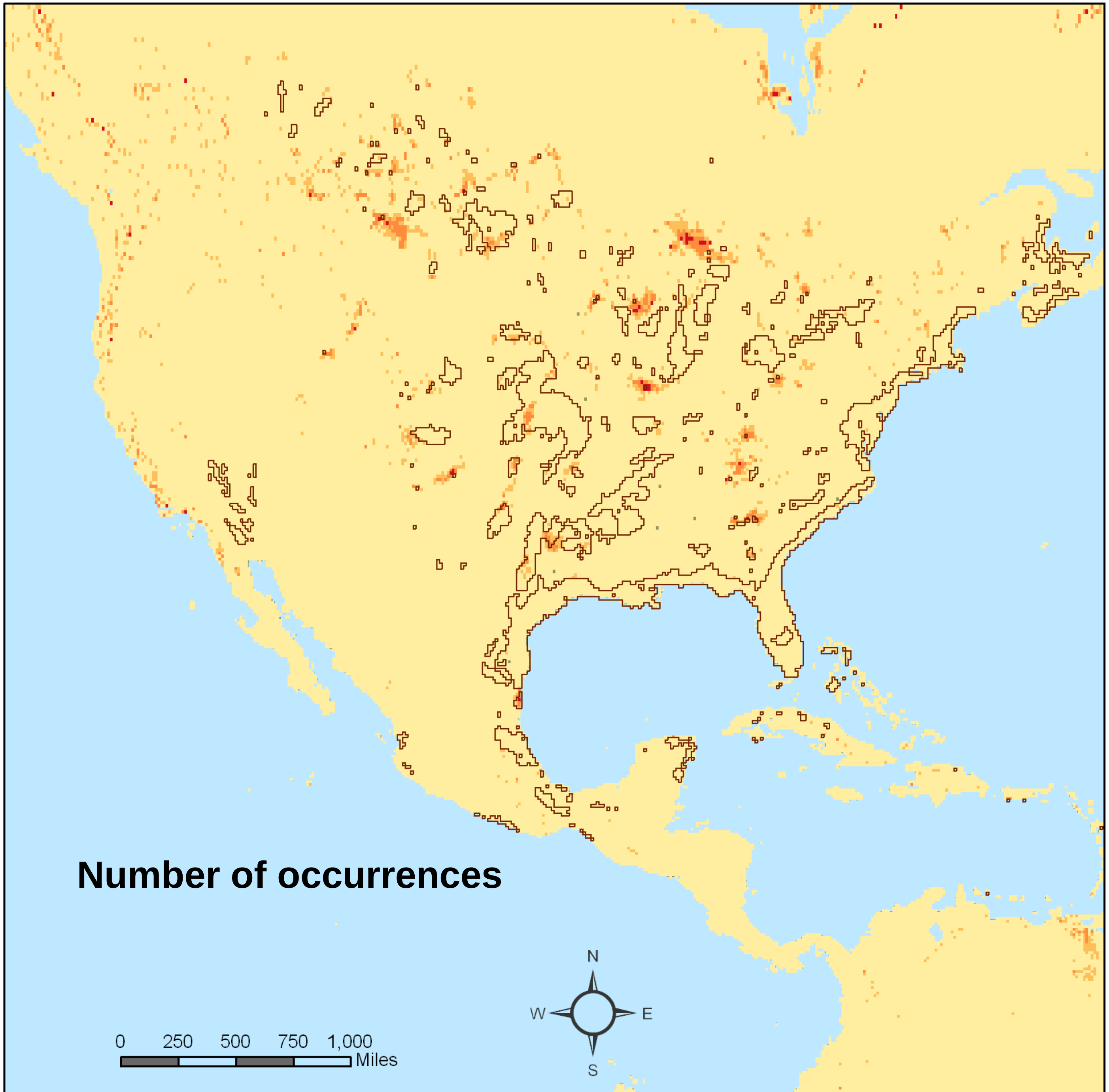


Climate envelope

Florida's threatened and endangered species







Climate envelope

Florida's threatened and endangered species

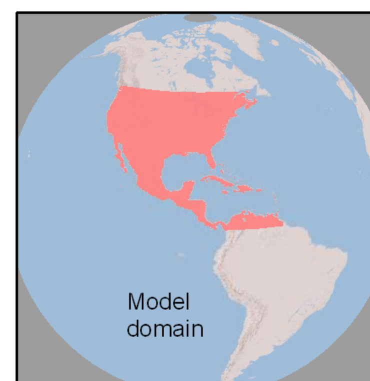
Time period: 2040-2059

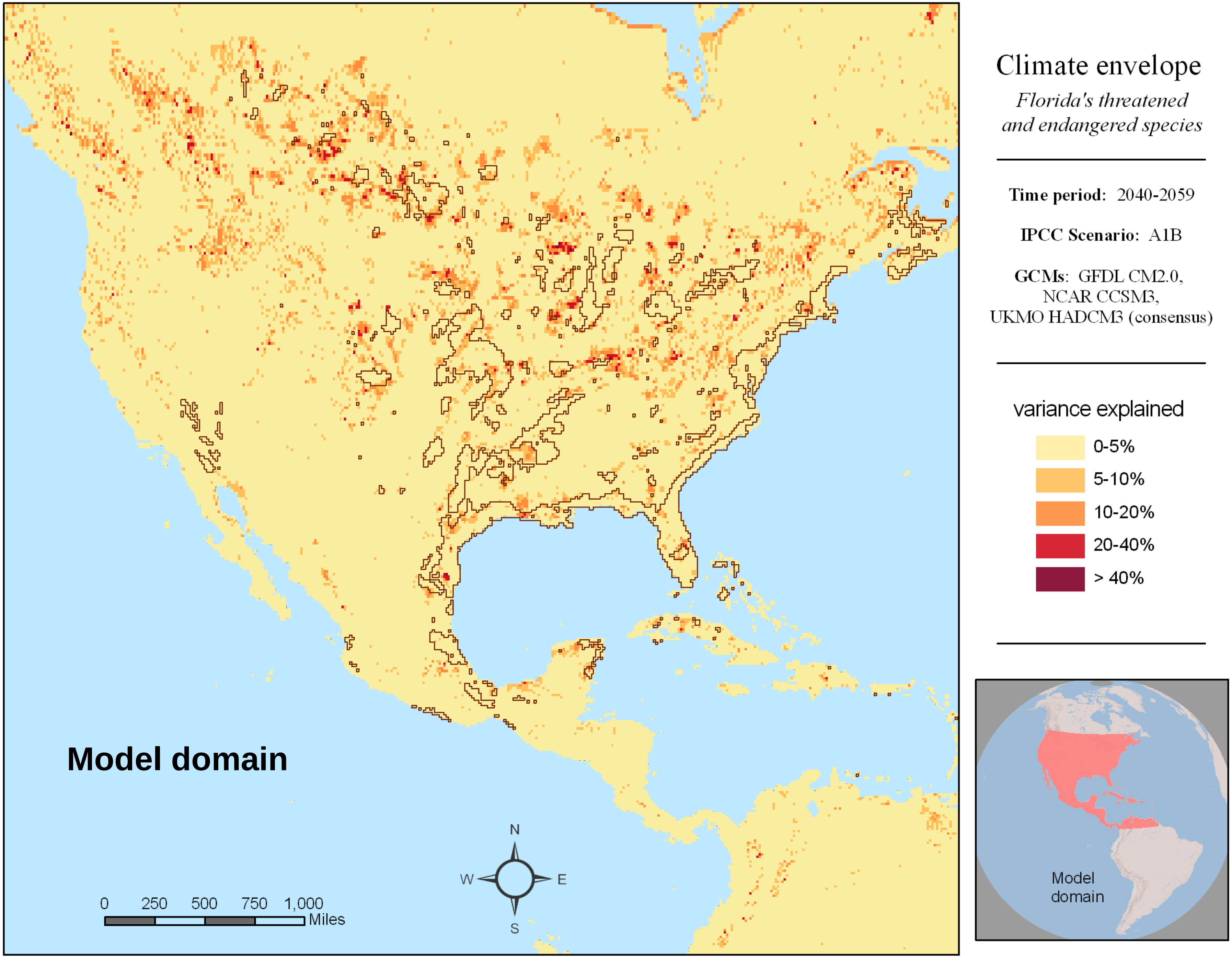
IPCC Scenario: A1B

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

variance explained

- 0-5%
- 5-10%
- 10-20%
- 20-40%
- > 40%

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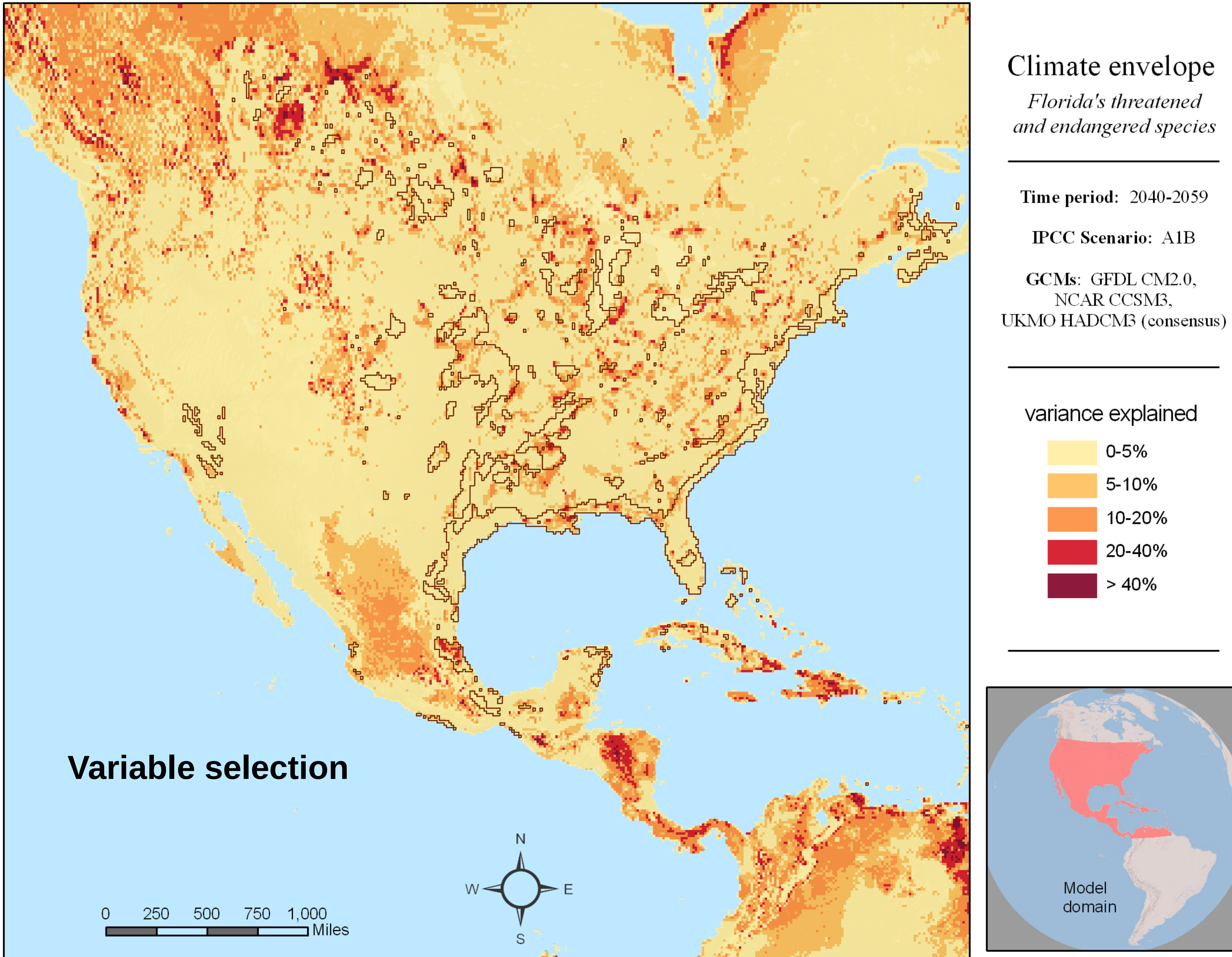
variance explained
0-5%
5-10%
10-20%
20-40%
> 40%
Model domain
N
W
E
S
0
250
500
750
1,000
Miles
Model domain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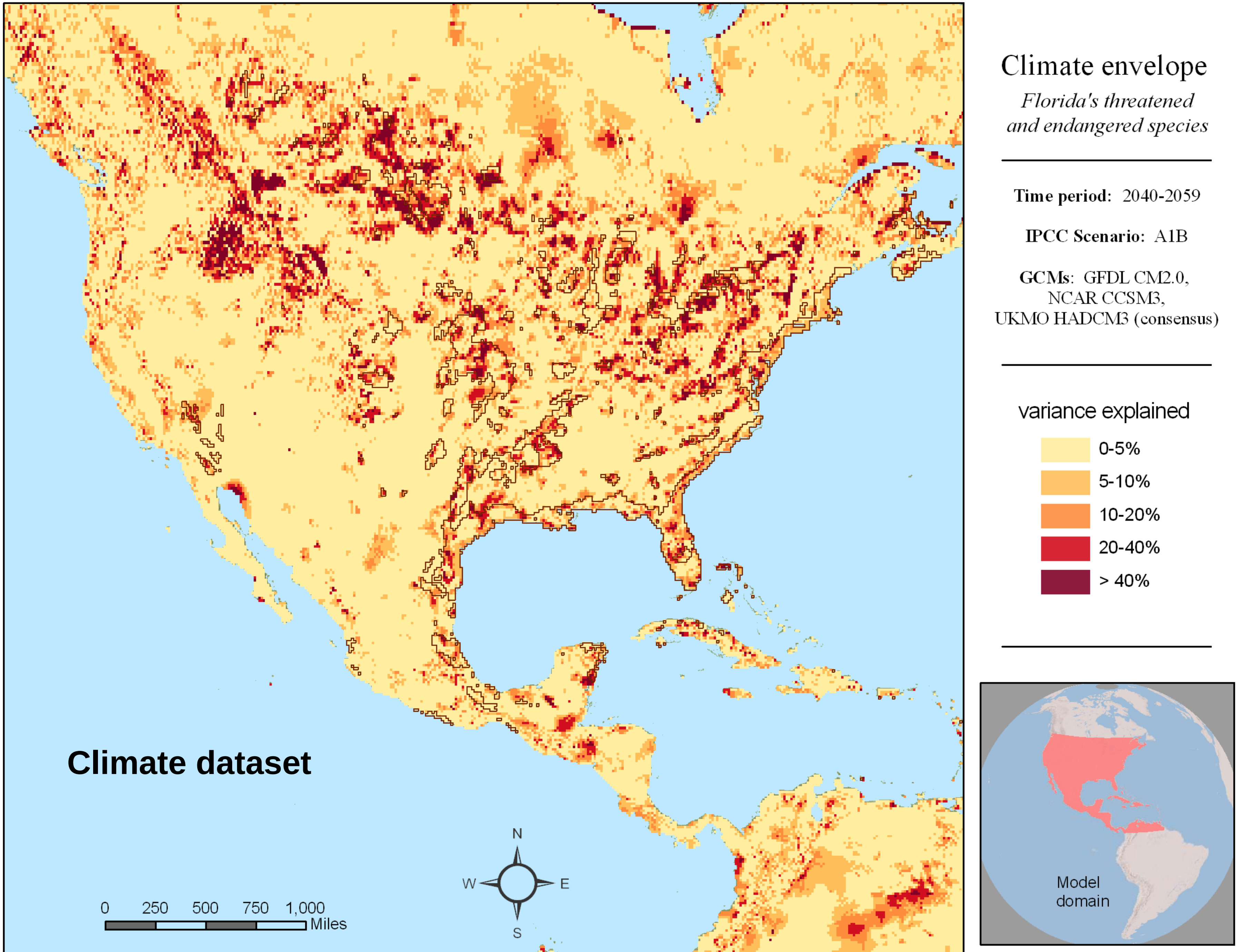
variance explained
0-5%
5-10%
10-20%
20-40%
> 40%
Model domain
Variable selection
N
W
E
S
0 250 500 750 1,000
Miles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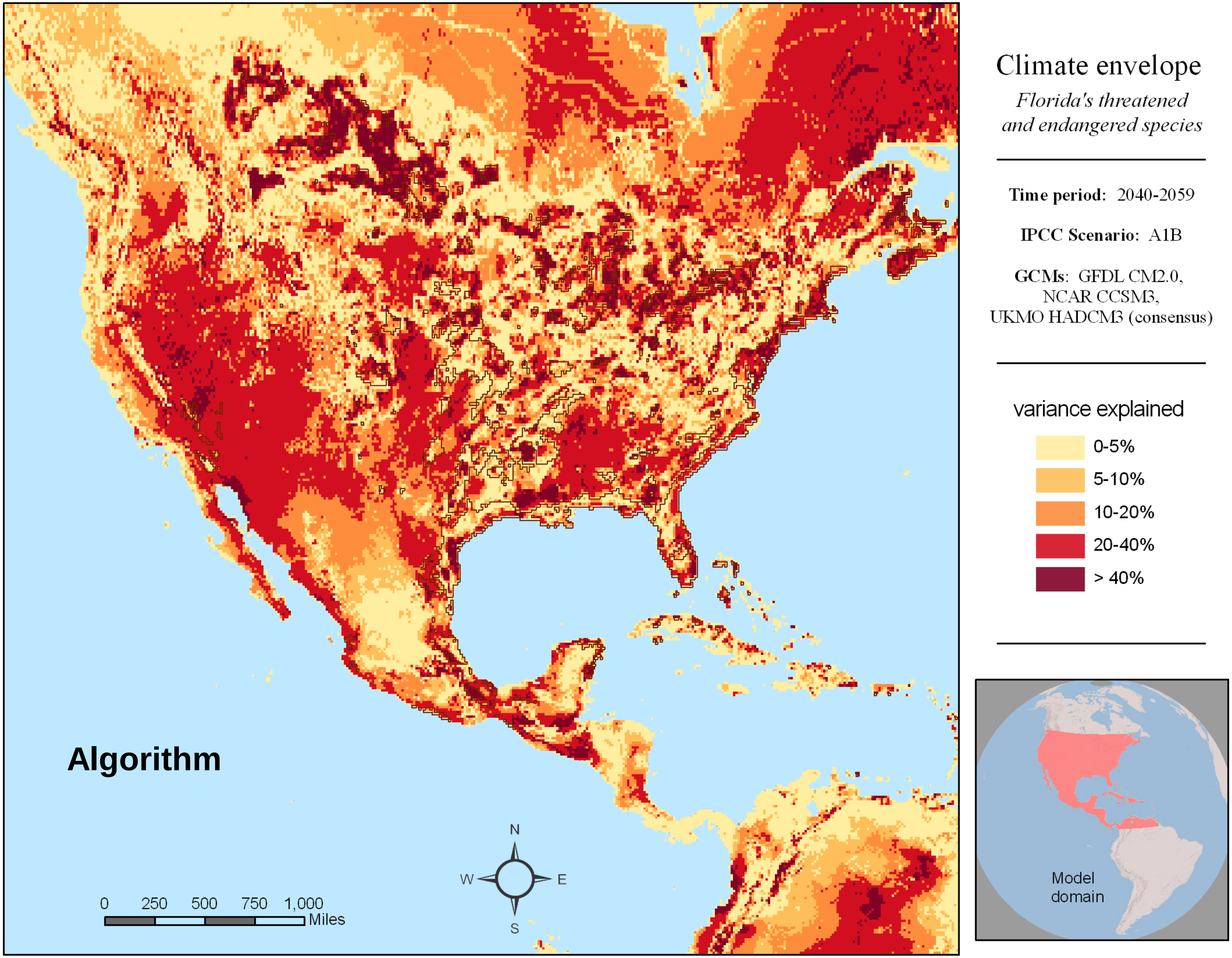
variance explained
0-5%
5-10%
10-20%
20-40%
> 40%
Model domain
Climate dataset
N
W
E
S
0 250 500 750 1,000
Miles



Climate envelope
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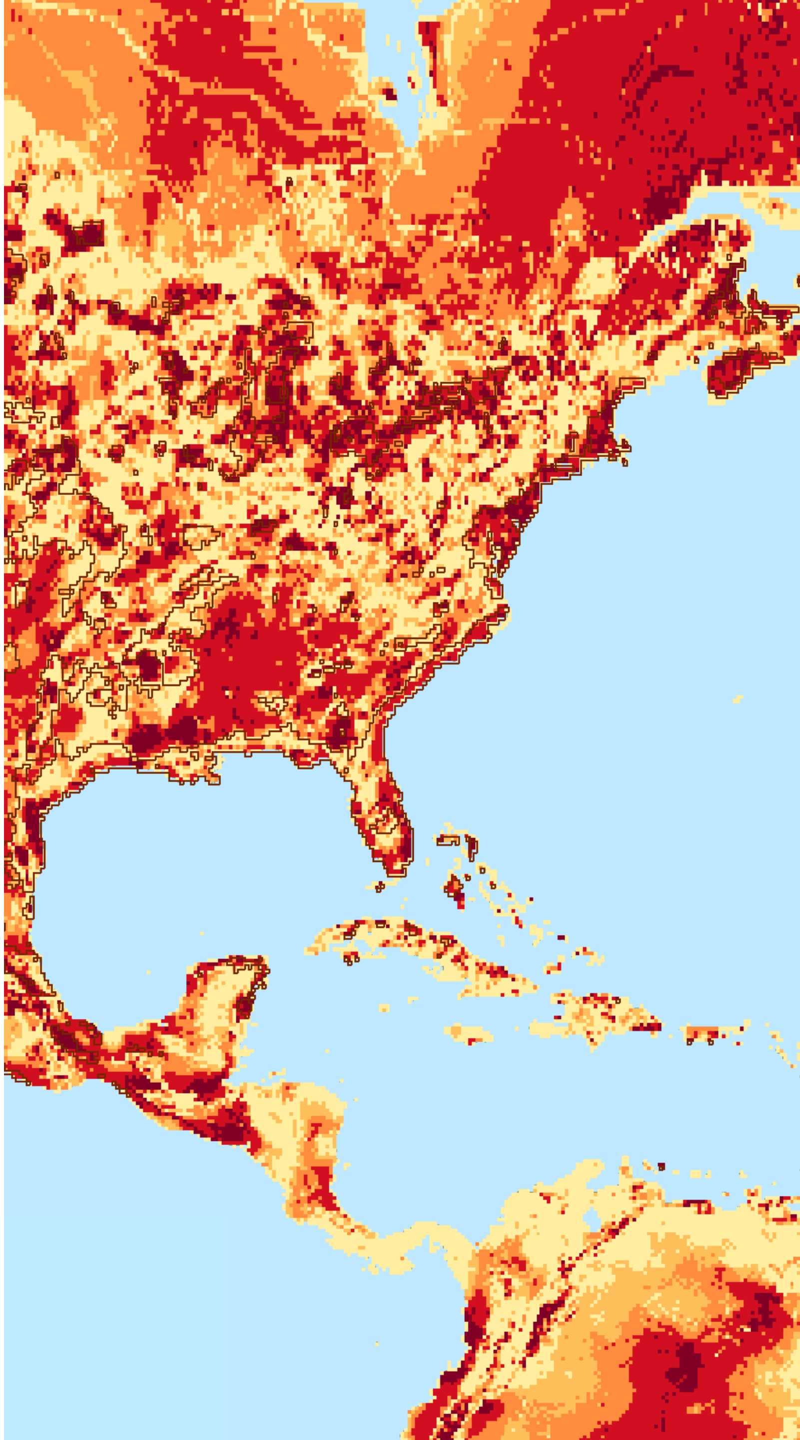
IPCC Scenario: A1B
GCMs: GFDL CM2.0, NCAR CCSM3, UKMO HADCM3 (consensus)
variance explained
0-5%
5-10%
10-20%
20-40%
> 40%
Model domain
Algorithm
N
W
E
S
0
250
500
750
1,000
Miles

Sources of variation in spatial predictions in CEMs

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

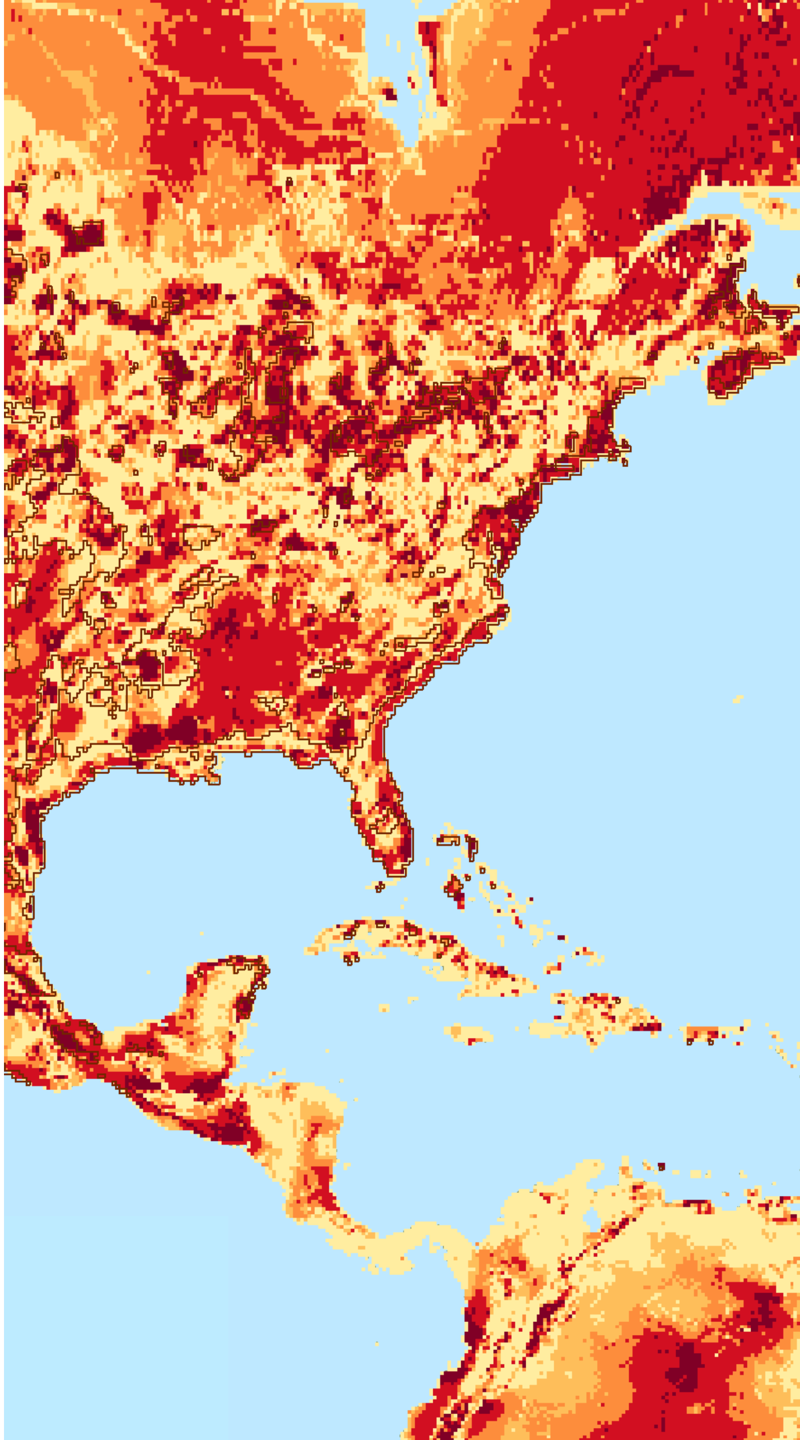


<u>Take home points:</u>

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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NPS (Critical Ecosystem Studies Initiative)

USGS (Greater Everglades Priority Ecosystem Science)