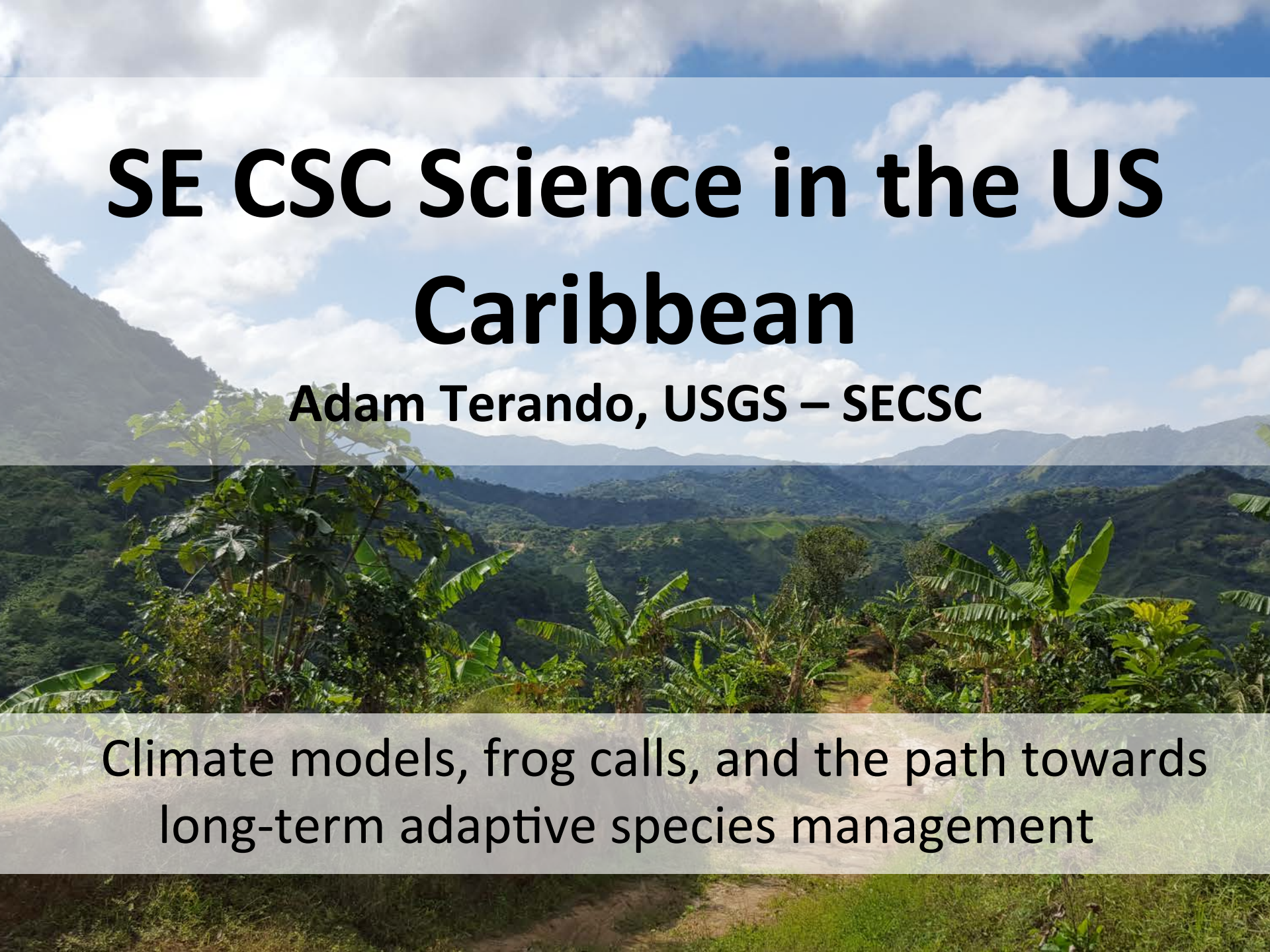
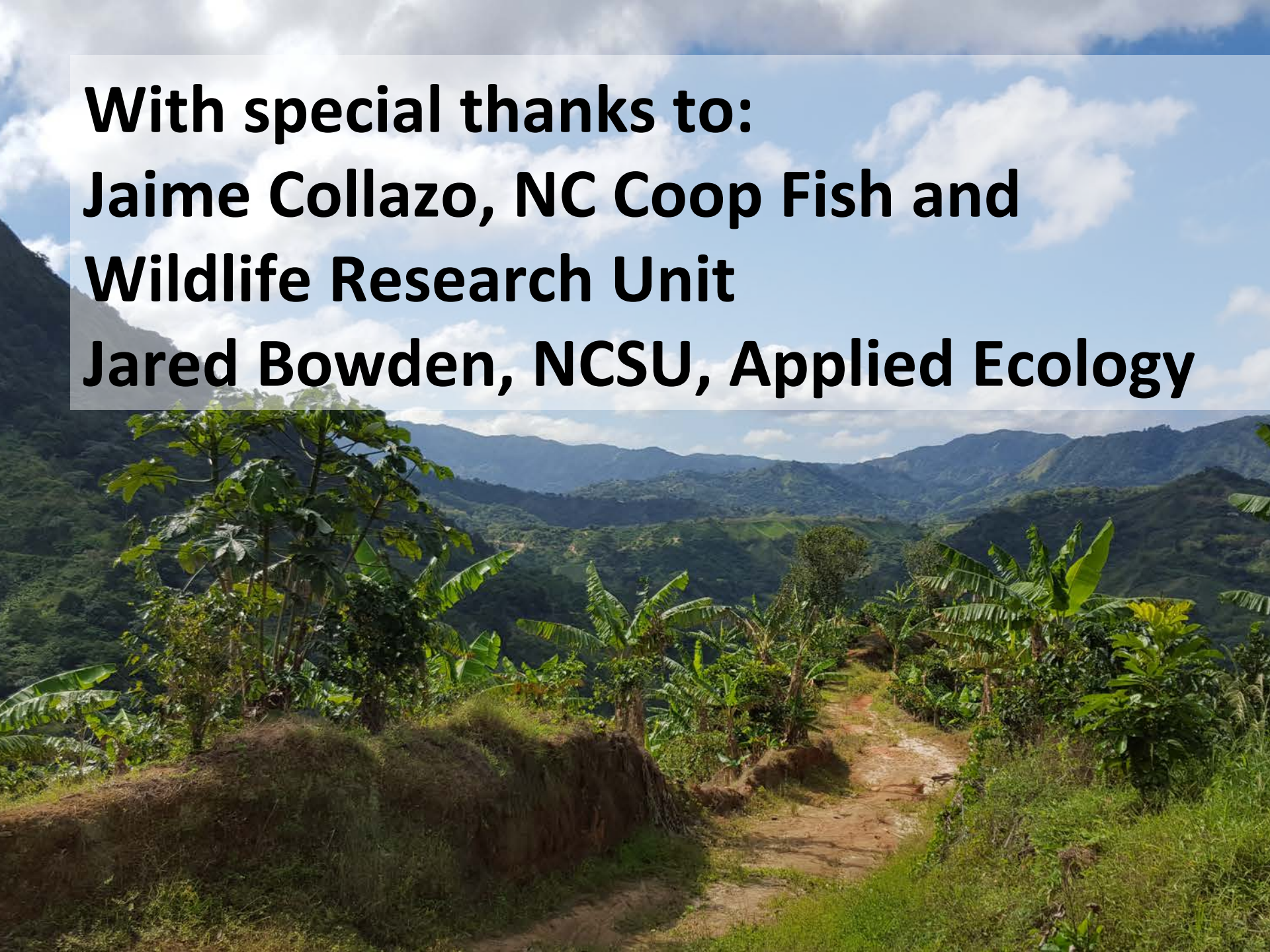


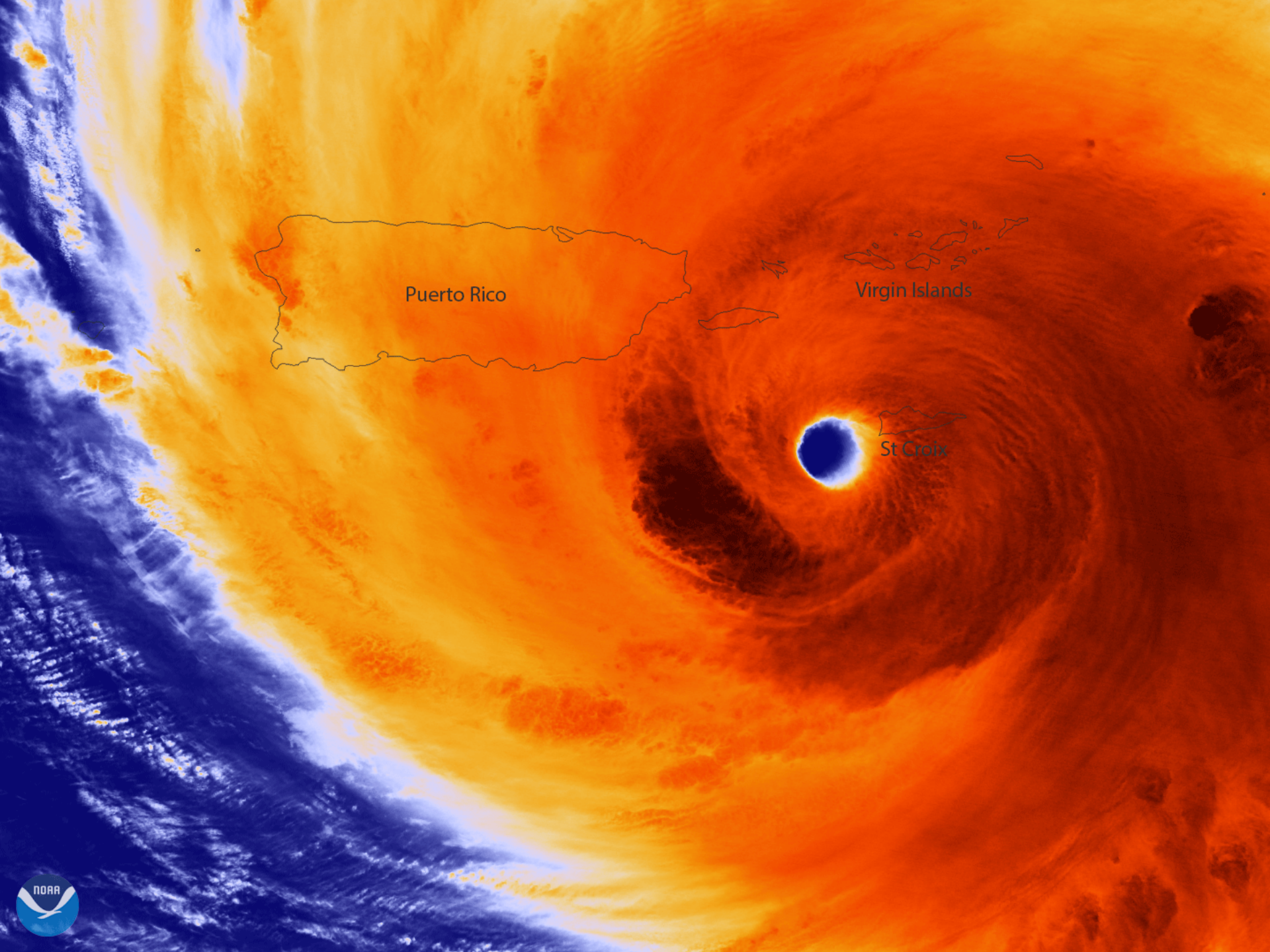
SE CSC Science in the US Caribbean

Adam Terando, USGS – SECSC

Climate models, frog calls, and the path towards long-term adaptive species management



With special thanks to:
Jaime Collazo, NC Coop Fish and Wildlife Research Unit
Jared Bowden, NCSU, Applied Ecology


Puerto Rico
Virgin Islands
St Croix
NOAA

Guajataca Dam, Quebradillas, PR. Source: The Atlantic

Utuado, PR. Source: NY Times

Corozal, PR. Source: The Atlantic

Yabucoa, PR. Source: The Atlantic

San Juan, PR. Source: The Atlantic

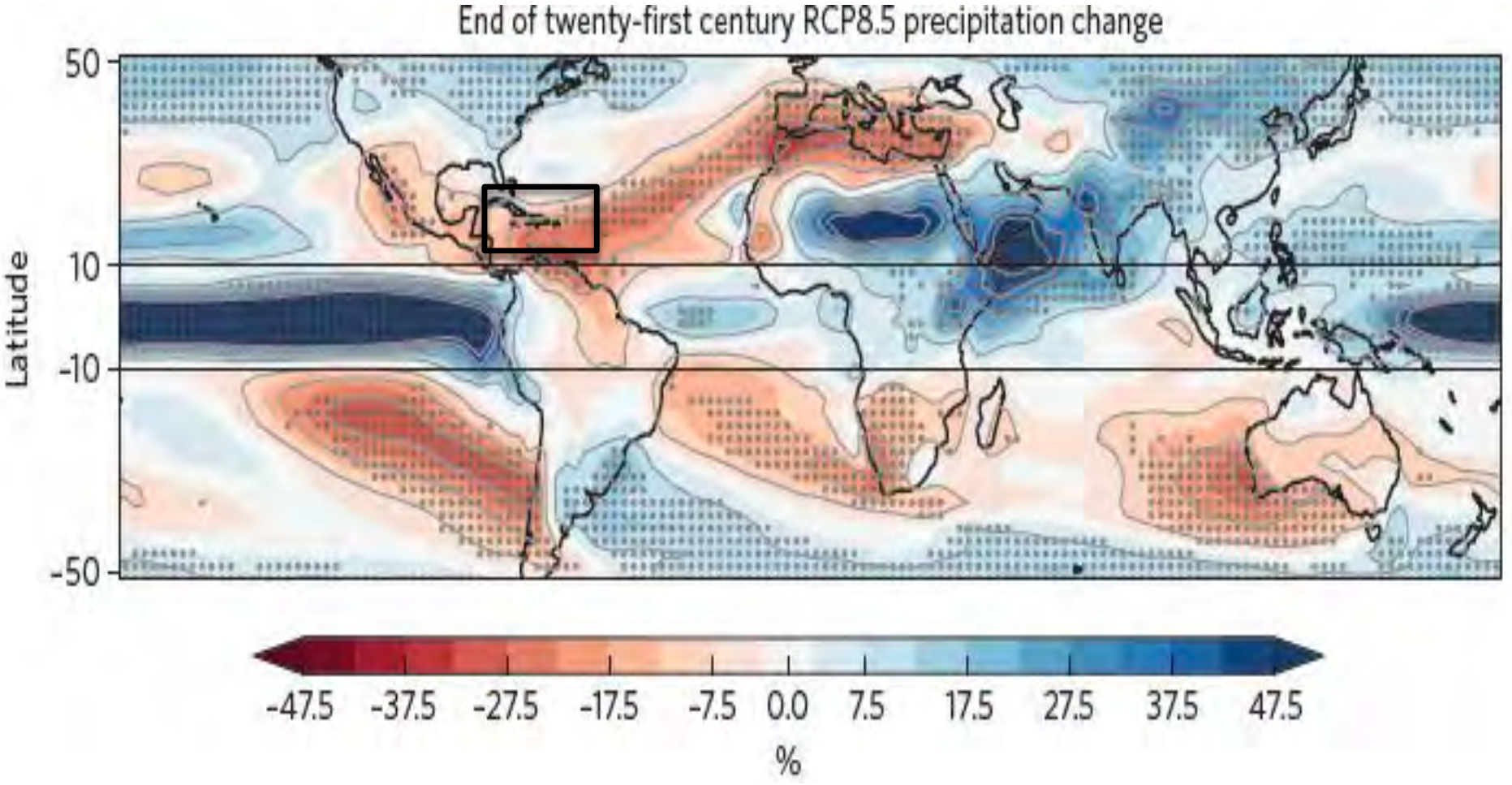
Toa Alta, PR. Source: The Atlantic

Toa Baja, PR. Source: The Atlantic

Naranjito, PR. Source: The Atlantic


Puerto Rican Parrot (*Amazona vittata*)
P Torres, FWS

MOTIVATION



Chadwick, R. 2016. Sub-tropical drying explained. *Nat. Clim. Change*.

25 species

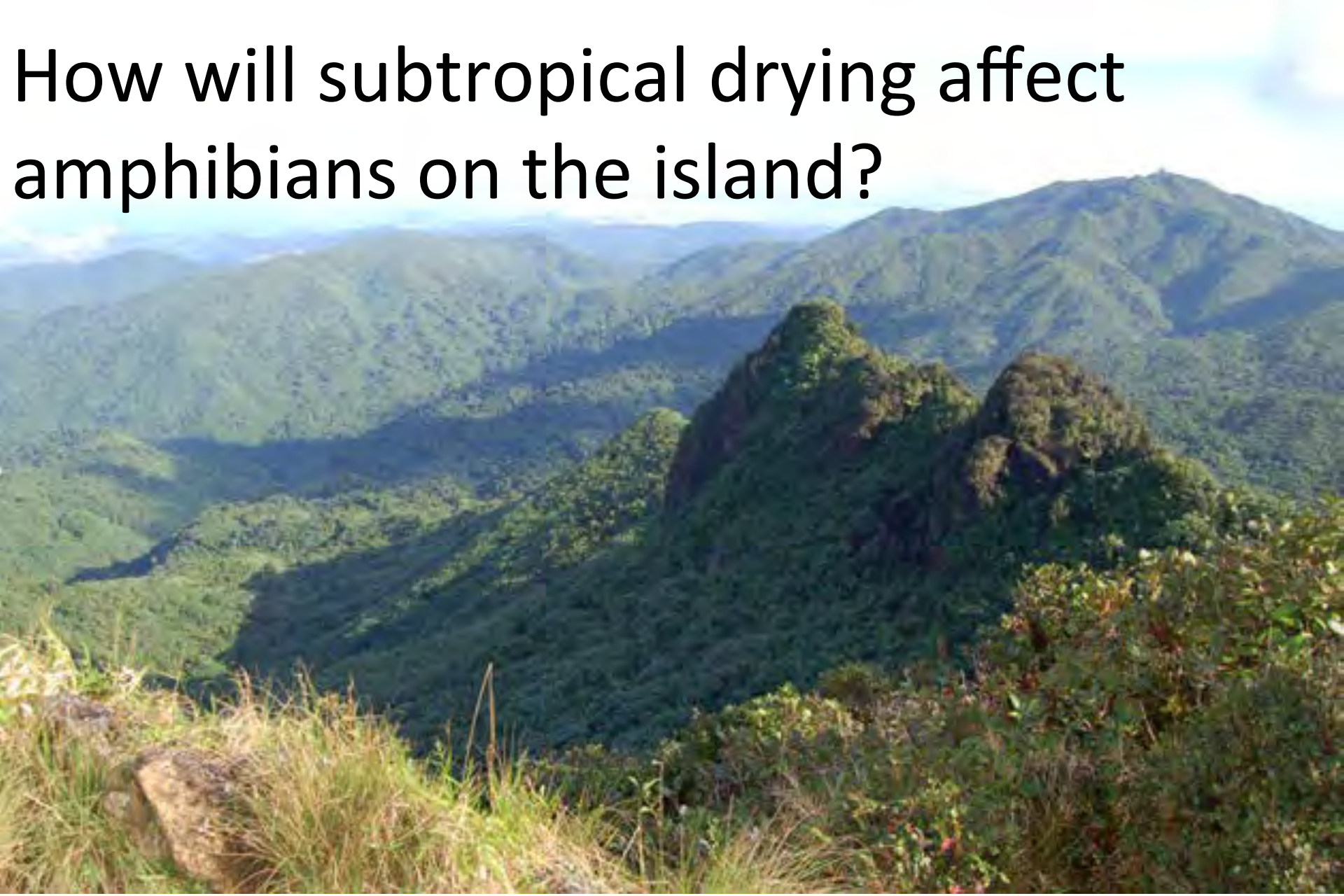
Endangered PR Crested Toad

17 *Eleutherodactylus*

- 2 endangered
- 14 at risk

Amphibians in Puerto Rico

How will subtropical drying affect amphibians on the island?

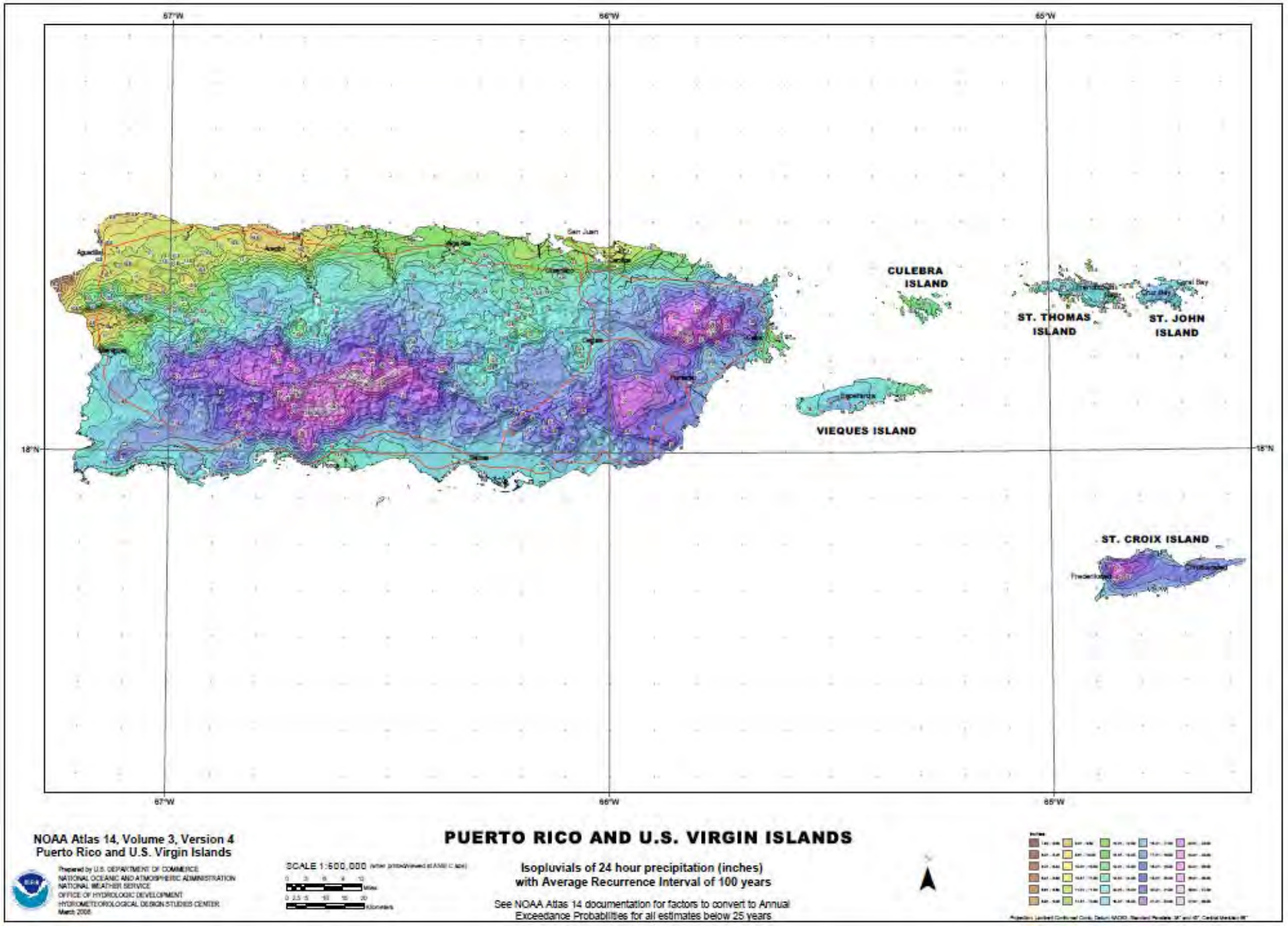


El Yunque Rainforest

How will subtropical drying affect amphibians on the island?

Guánica Dry Forest

How will subtropical drying affect amphibians on the island?



PUERTO RICO AND U.S. VIRGIN ISLANDS

Isopluvials of 24 hour precipitation (inches)
with Average Recurrence Interval of 100 years

See NOAA Atlas 14 documentation for factors to convert to Annual Exceedance Probabilities for all estimates below 25 years

NOAA Atlas 14, Volume 3, Version 4
Puerto Rico and U.S. Virgin Islands

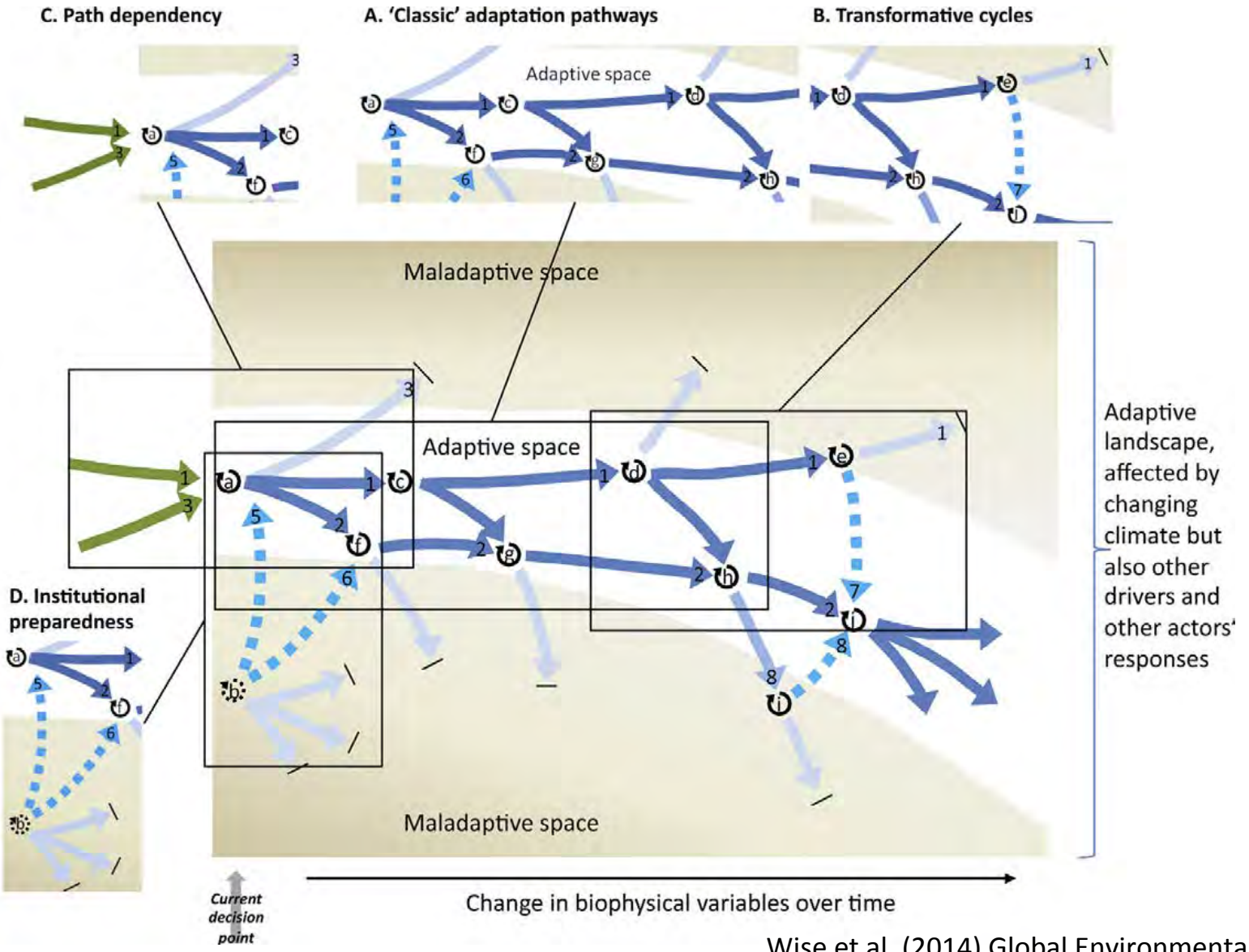
Prepared by U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
OFFICE OF HYDROLOGIC DEVELOPMENT
HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
March 2006

SCALE 1:600,000 (when printed/viewed at ANSI C size)

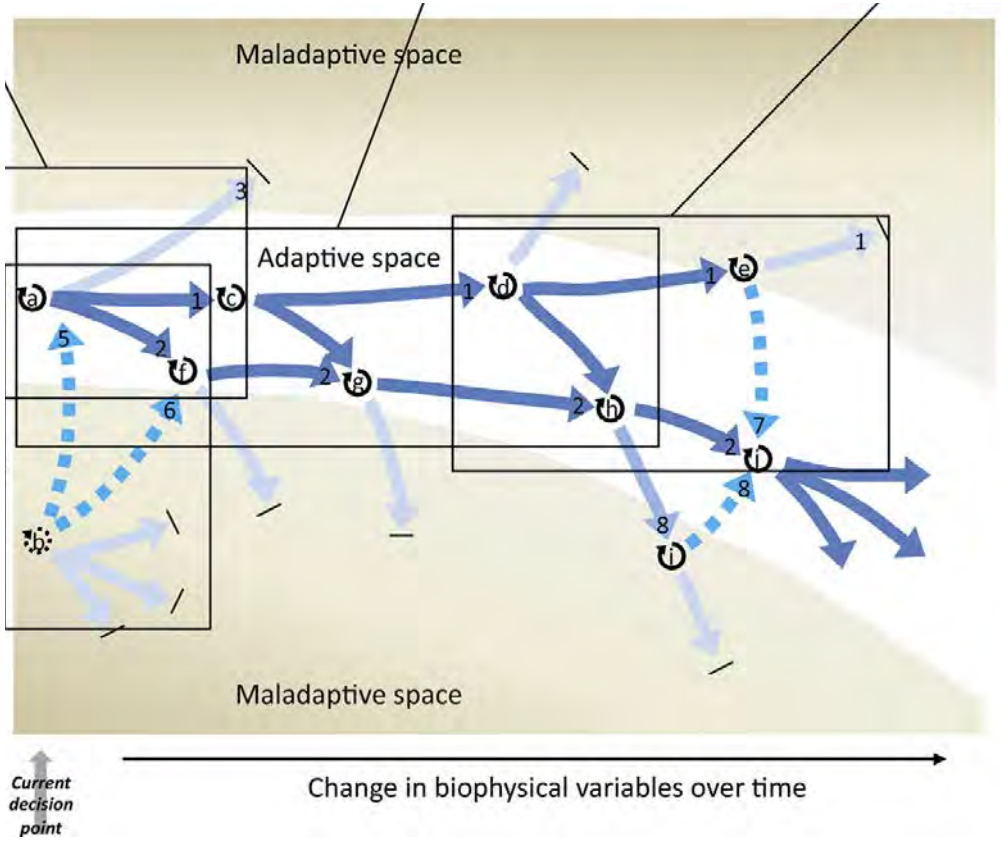
Miles

Kilometers

BROADER CONCEPTUALIZATION



Wise et al. (2014) Global Environmental Change.

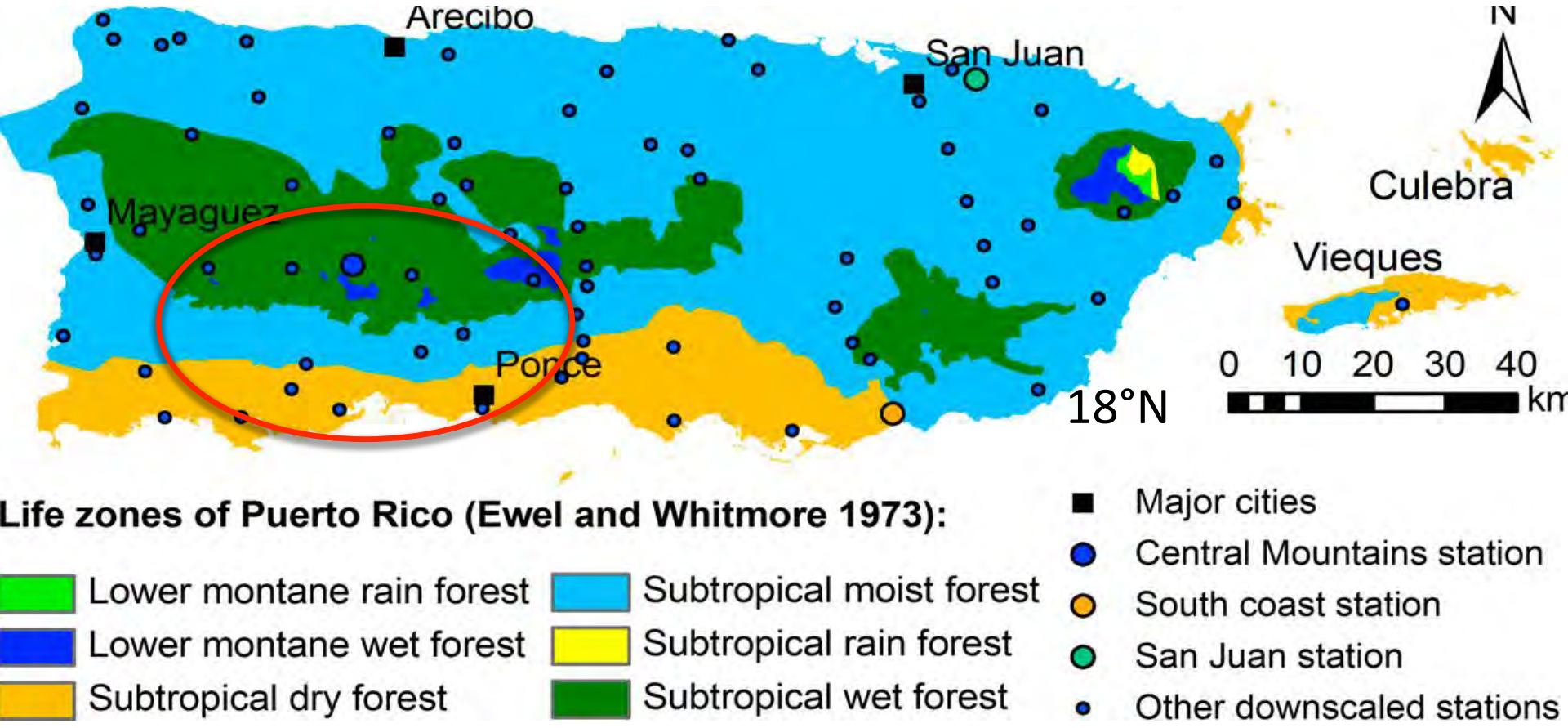


How wide is this space? VULNERABILITY

What is it's trajectory? FORCING

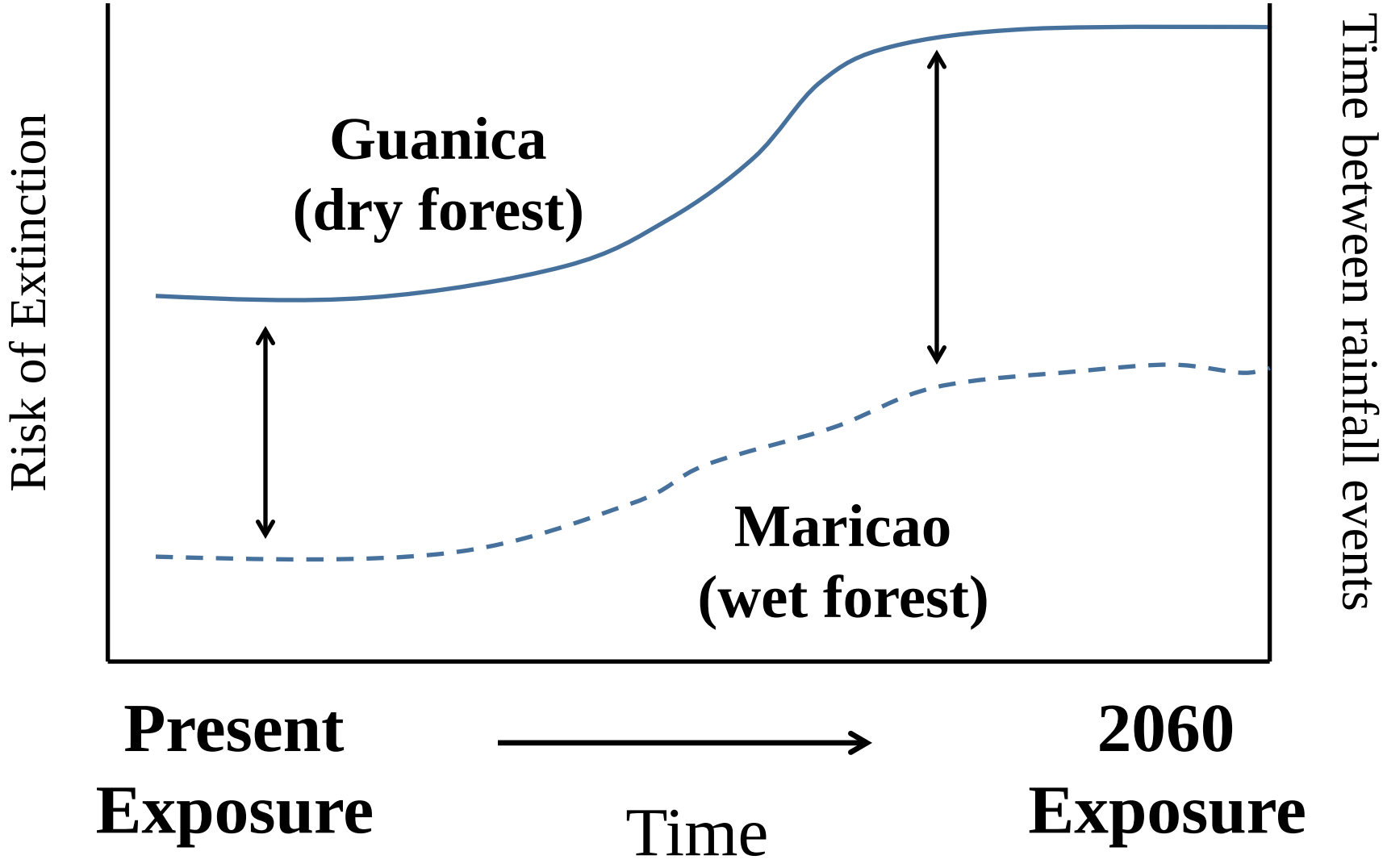
Ultimately, trying to evaluate candidate strategies for adaptive management

- Passive management in marginal habitats
- Translocate Populations
- Habitat acquisition

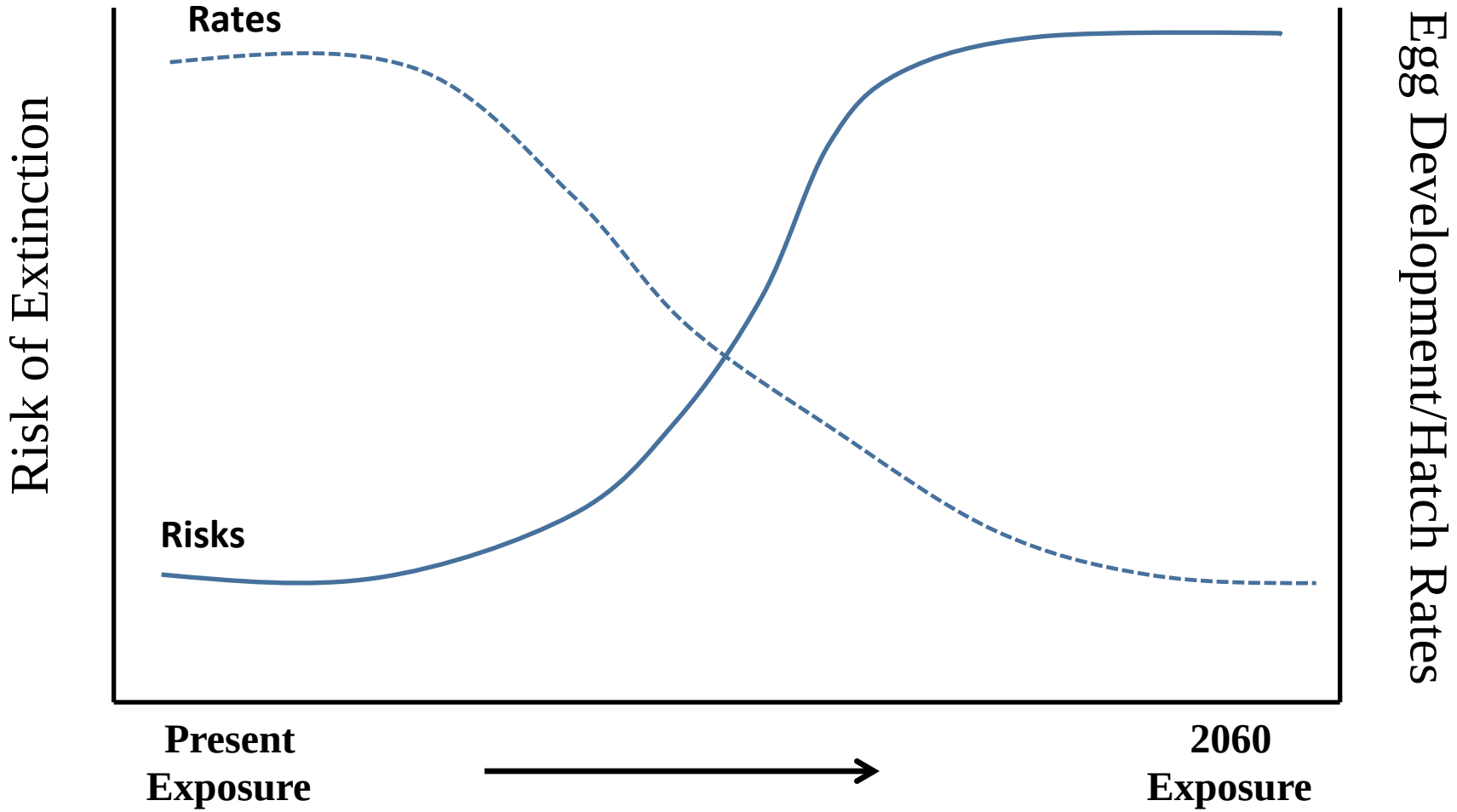


Khalyani et al. (2016)

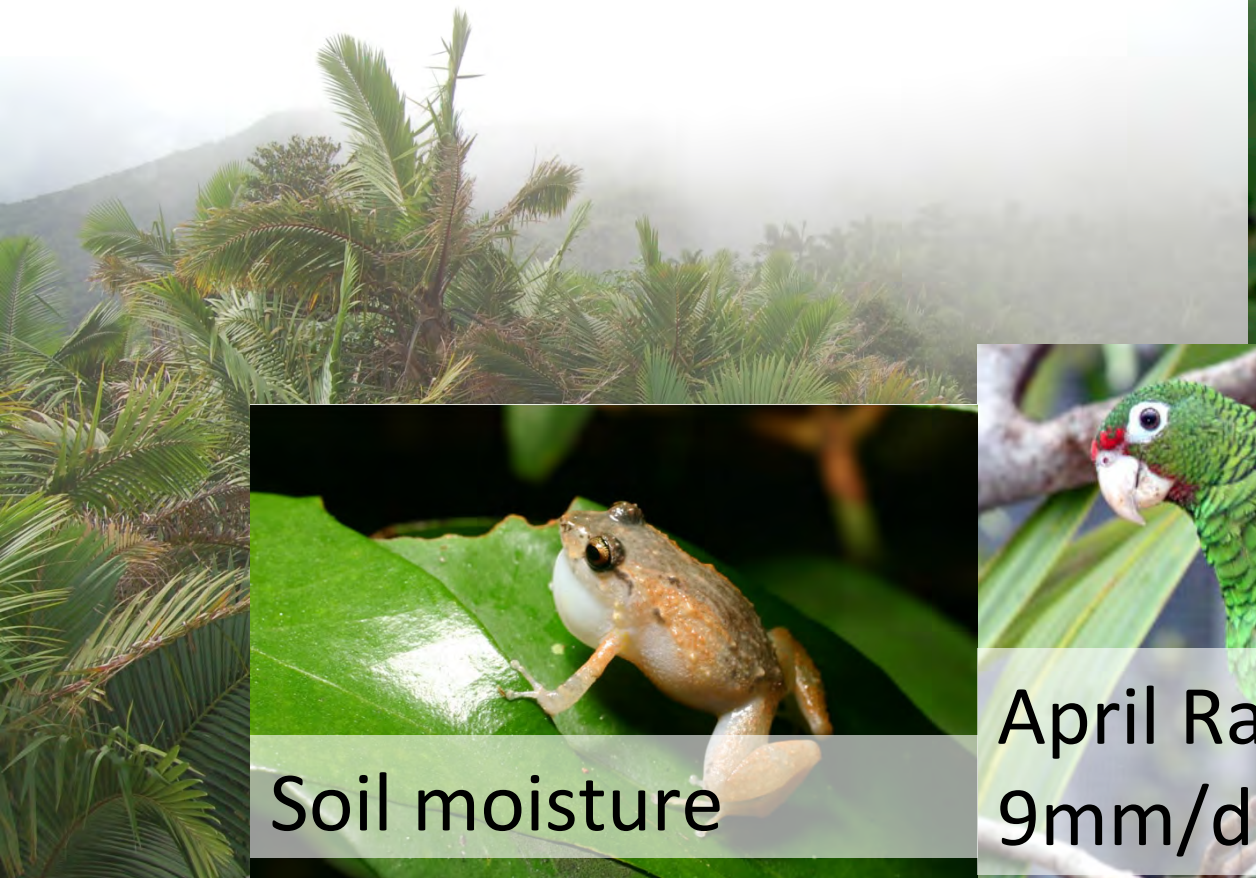
Exposure/Response Functions



Exposure/Response Functions



Cloud-based height



Ground heat flux

Soil moisture

April Rainfall > 9mm/day

Need information about the *climate-response function* of species and systems of interest.

Climate Science Centers & National Climate Change and Wildlife Science Center

Home About - CSCs - Science - Get Involved - News

Modeling Future Temperature and Precipitation for Puerto Rico and the U.S. Caribbean

Project Summary

While 21st century temperatures are projected to increase in Puerto Rico and the broader U.S. Caribbean (whose geography is contained within the Caribbean Landscape Conservation Cooperative, or CLCC), the low variability and already high annual average temperatures suggest that the largest climate-related impact on ecosystems and water resources is more likely to be through changes in the timing, pattern, and availability of moisture. The development of adaptation strategies that respond to anthropogenic climate change for the CLCC, and particularly for Puerto Rico, is currently hindered by the lack of local-scale climate scenarios that resolve the complex topographical and meso-scale

...dynamically downscaled, nonhydrostatic climate model ...lobal tropics with a highly dynamic climate regime. The ...ranges of species' thermal/moisture optima. This ...bbean LCC.

CLIMATE MODELING

Adam Terando (U.S. Geological Survey)

Start Date: 2013
End Date: 2016
Status: In Progress
Science Topics(s): Education, Modeling and Tools
Science Subtopics(s): Climate and Ecosystem Modeling
Fiscal Year: 2013

Publications and Other

Final Project Memorandu
PRDownscalingFinalMemo

Climate Change Implicati
Khalyani et al. 2016; Journ

ScienceBase Link: https://

USGS science for a changing world

Climate Science Centers & National Climate Change and Wildlife Science Center

Home About - CSCs - Science - Get Involved - News

Climate Change Implications for the Conservation of Amphibians in Tropical Environments

Project Summary

FIELD ECOLOGY

...y birds and threatened and endangered species). The ...regions of the world because of the limited size of their ...opical environments will experience greater changes in ...that could impact the health of important natural ...ts. To help address this problem, the SE CSC project ...ironmental Resources (PRDNER), University of Puerto ...ctions to help advance the recovery and conservation of amphibians in Puerto Rico. The USFWS and PRDNER seek to implement an adaptive conservation strategy to achieve recovery of three endangered frog species (of the genus Eleutherodactylus) and prevent federal listing of 14 other amphibians considered at risk. Implementation of the strategy requires identifying suitable habitat for the species at present and in the future, and ensuring the availability of field-tested protocols for locally supplementing, introducing, and translocating species as necessary. The main objectives of this project are: (1) to develop an understanding of the eco-physiological limits of these species and the influence of those limits on extinction rates in local patches (i.e., heterogeneous micro-habitats within an ecosystem), and (2) to assess their adaptive capacity (i.e. the ability of the amphibians to adapt to changing environmental conditions). This will inform implementation of the conservation strategy, which is partly constrained by the availability of conservation areas that meet required eco-physiological conditions. This research will contribute to a decision framework developed by NCSU scientists that can assist decision makers in determining when and where to implement conservation actions to maximize species persistence. The framework

DEPARTMENT *of the* INTERIOR
SE CLIMATE SCIENCE CENTER

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Modeling Future Temperature and Precipitation for Puerto Rico and the U.S. Caribbean

Ryan Boyles and Adam Terando, USGS DOI Southeast Climate Science Center
Jaime Collazo, USGS NC Cooperative Fish and Wildlife Research Unit
Jared Bowden, UNC Institute for the Environment
William Gould, USDA Forest Service International Institute of Tropical Forestry
Vasu Misra, Florida State University

DEPARTMENT *of the* INTERIOR
SE CLIMATE SCIENCE CENTER

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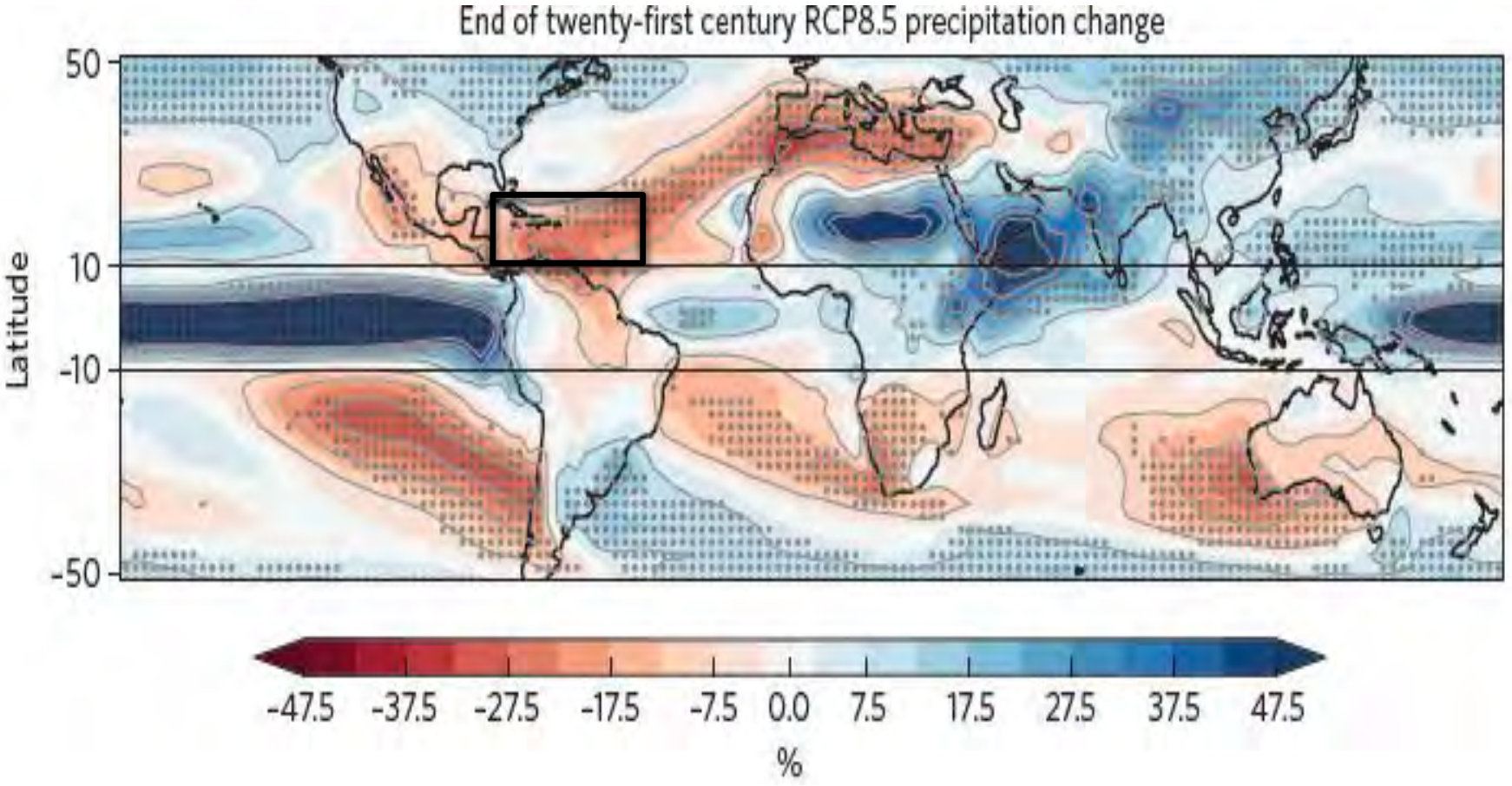
Climate Change Implications for the Conservation of Amphibians in Tropical Environments

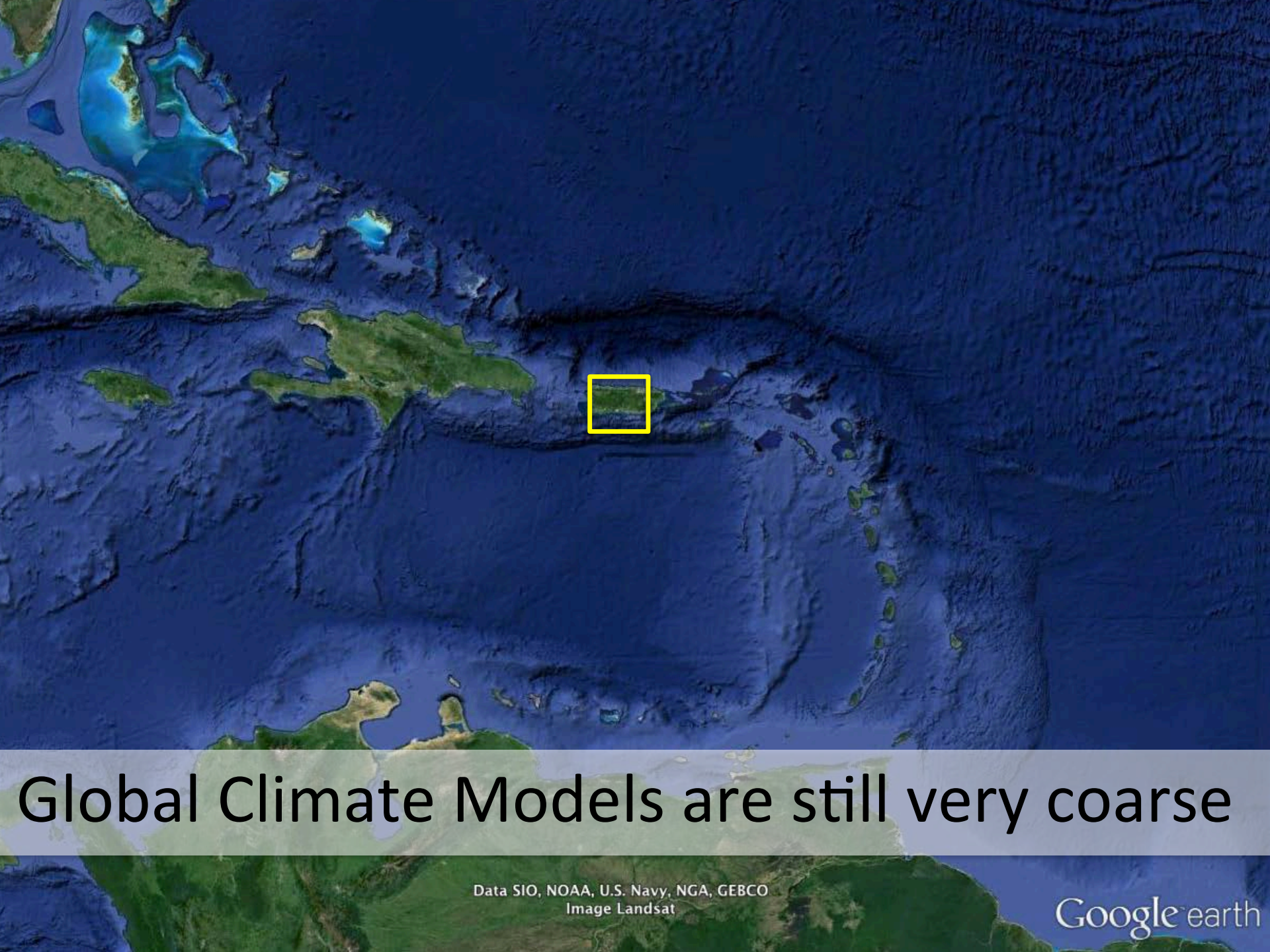
Jaime Collazo, Department of Applied Ecology and USGS Coop Unit, NC State University

Total Planned Funding: $140,000
Project Completion: August 2019
Implements Science Theme: 4
Co-PIs: Adam Terando, USGS Southeast Climate Science Center
Krishna Pacifici, Department of Forestry and Environmental Resources, NC State University
Jared Bowden, Institute of the Environment, UNC-Chapel Hill

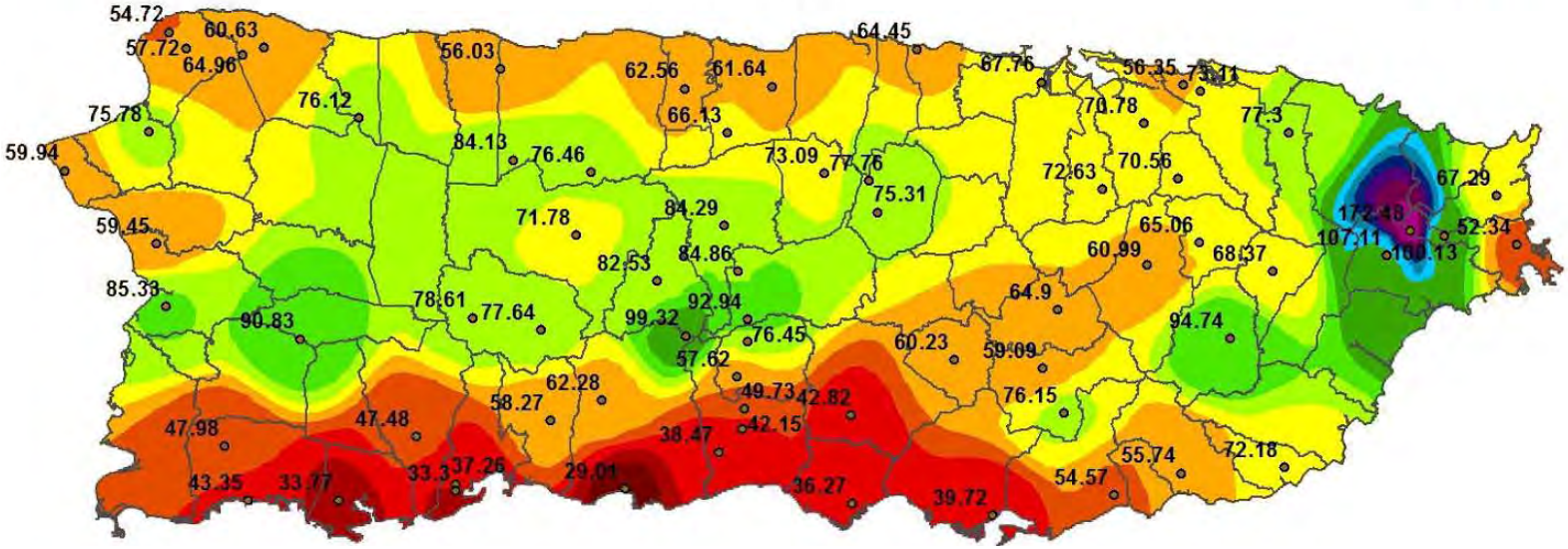
Expect Sub-tropical Drying in This Region



Chadwick, R. 2016. Sub-tropical drying explained. *Nat. Clim. Change*.



Global Climate Models are still very coarse


54.72
60.63
57.72
64.96
56.03
64.45
62.56
61.64
87.76
56.35
75.78
76.12
66.13
70.78
77.3
59.94
84.13
76.46
73.09
77.76
72.63
70.56
67.29
75.31
59.45
71.78
84.29
65.06
172.48
52.34
107.11
82.53
84.86
60.99
68.37
85.33
78.61
77.64
92.94
64.9
90.83
99.32
76.45
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57.62
59.09
62.28
49.73
42.82
58.27
76.15
47.98
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72.18
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29.01
36.27
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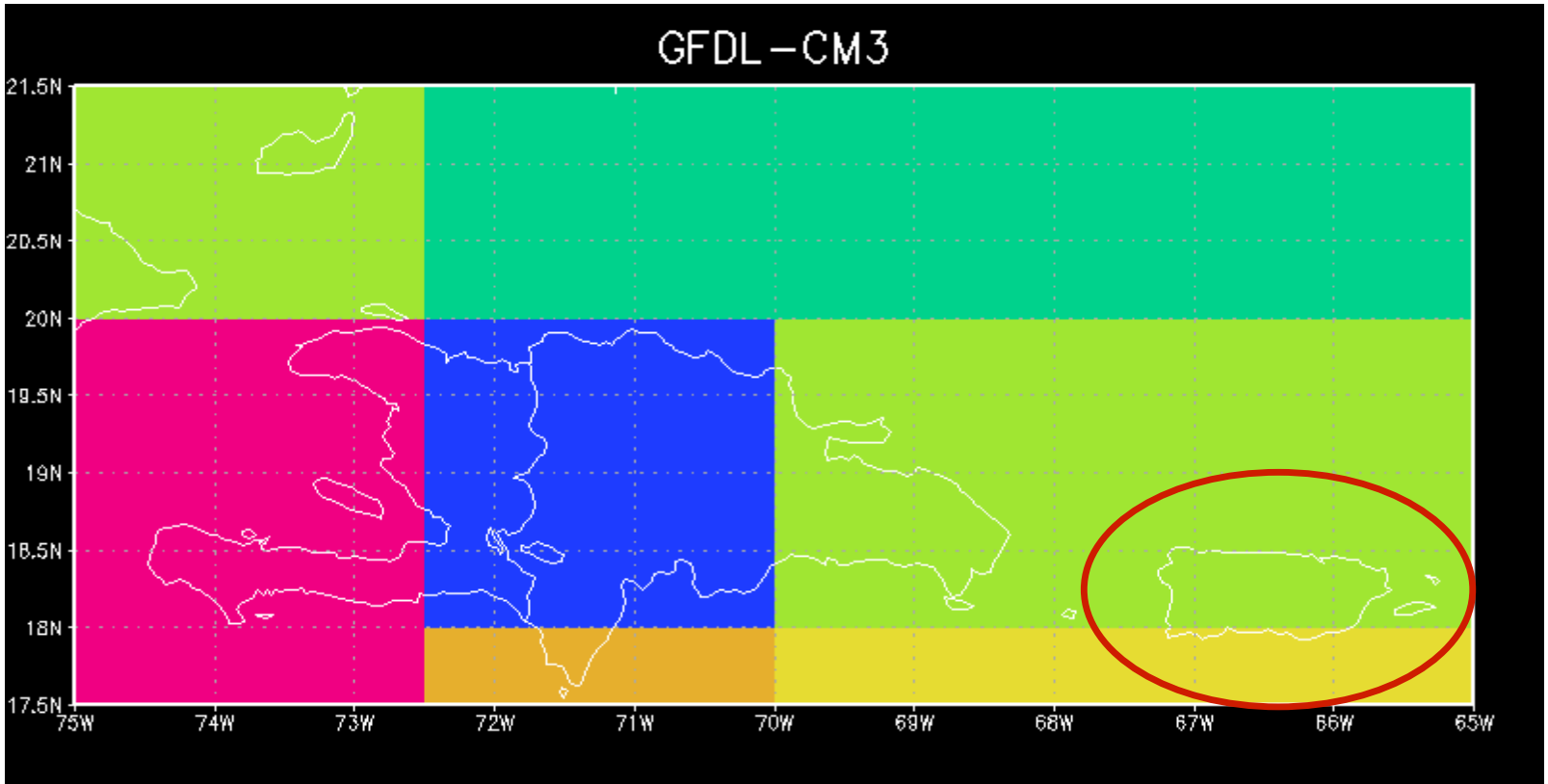
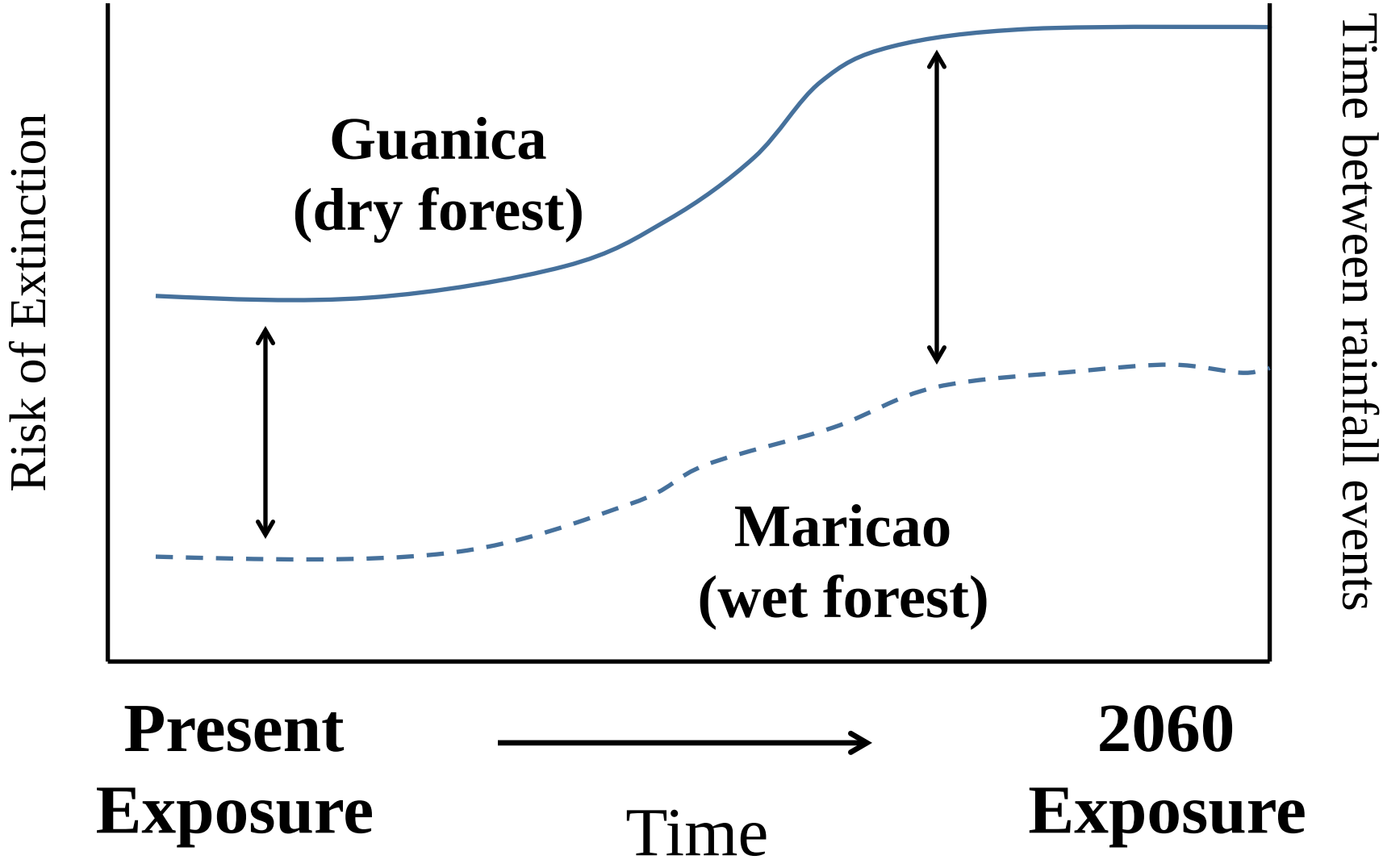
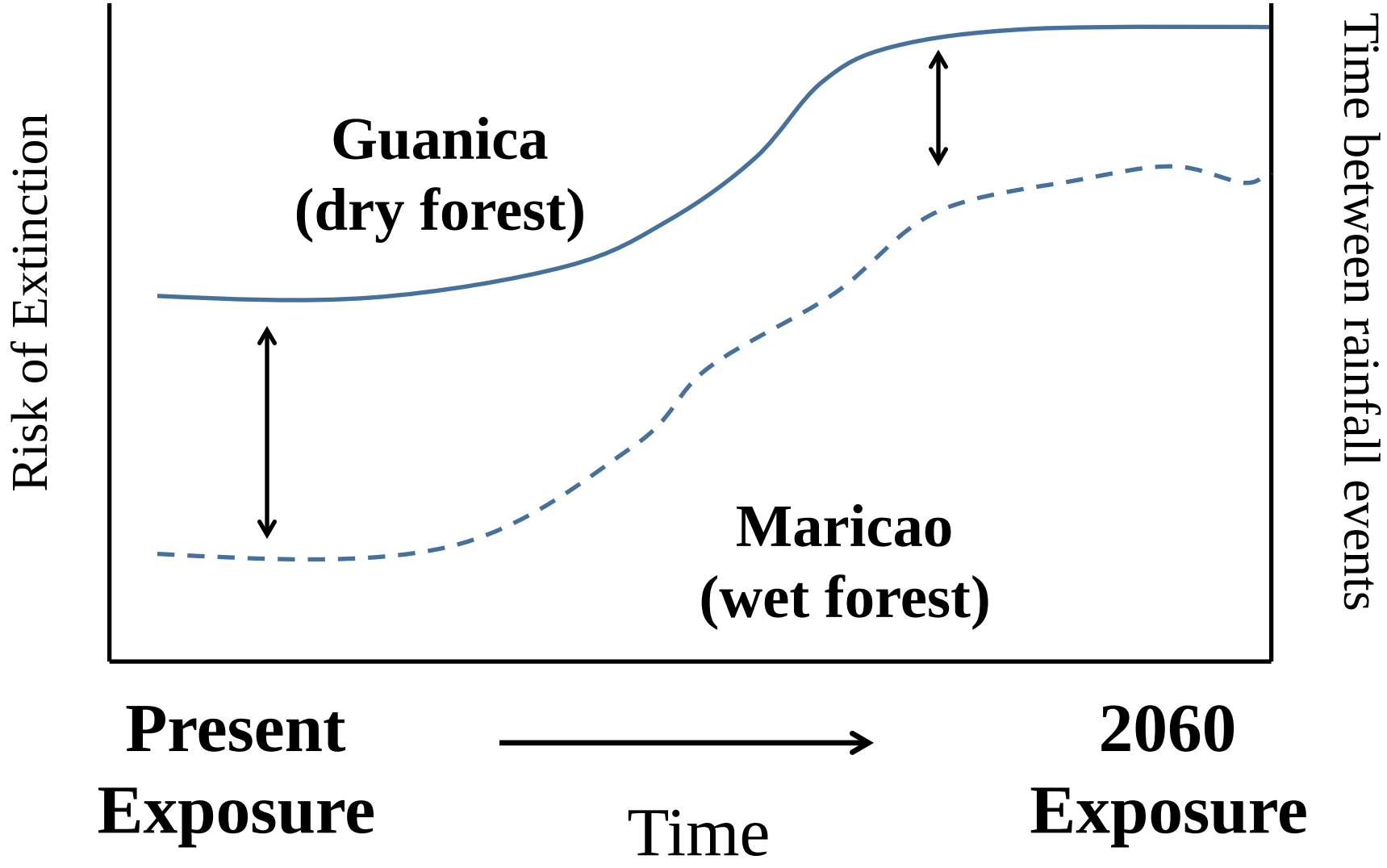
39.72

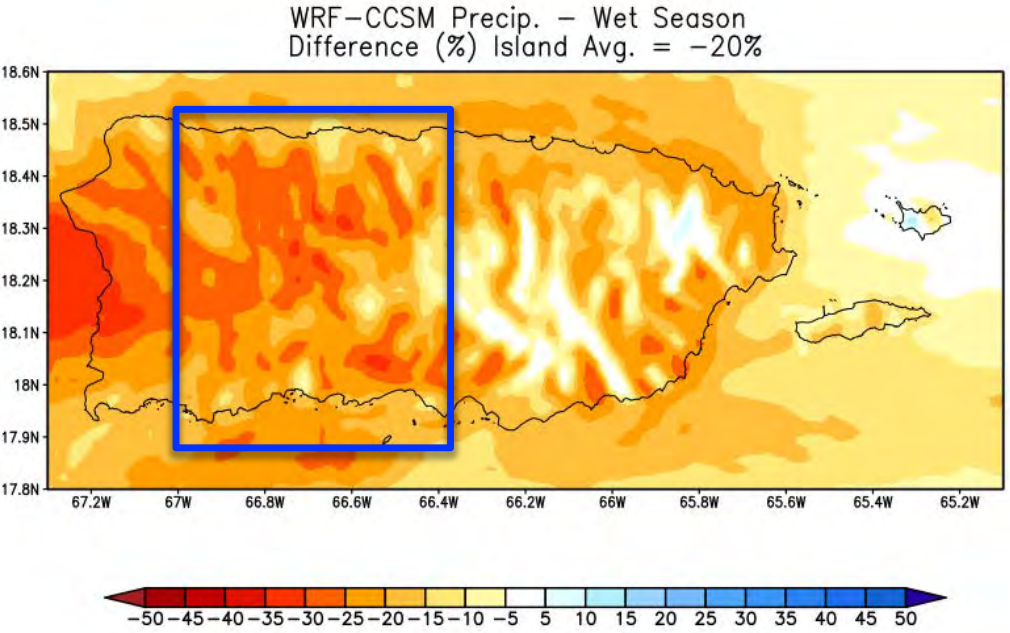

GFDL-CM3
21.5N
21N
20.5N
20N
19.5N
19N
18.5N
18N
17.5N
75W
74W
73W
72W
71W
70W
69W
68W
67W
66W
65W

Exposure/Response Functions



Insights from Downscaling

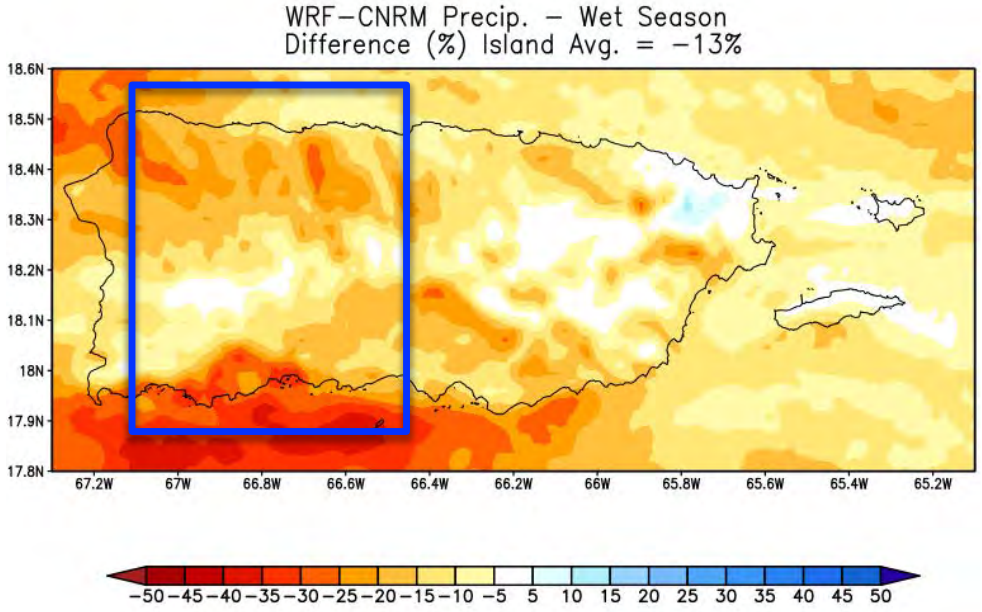




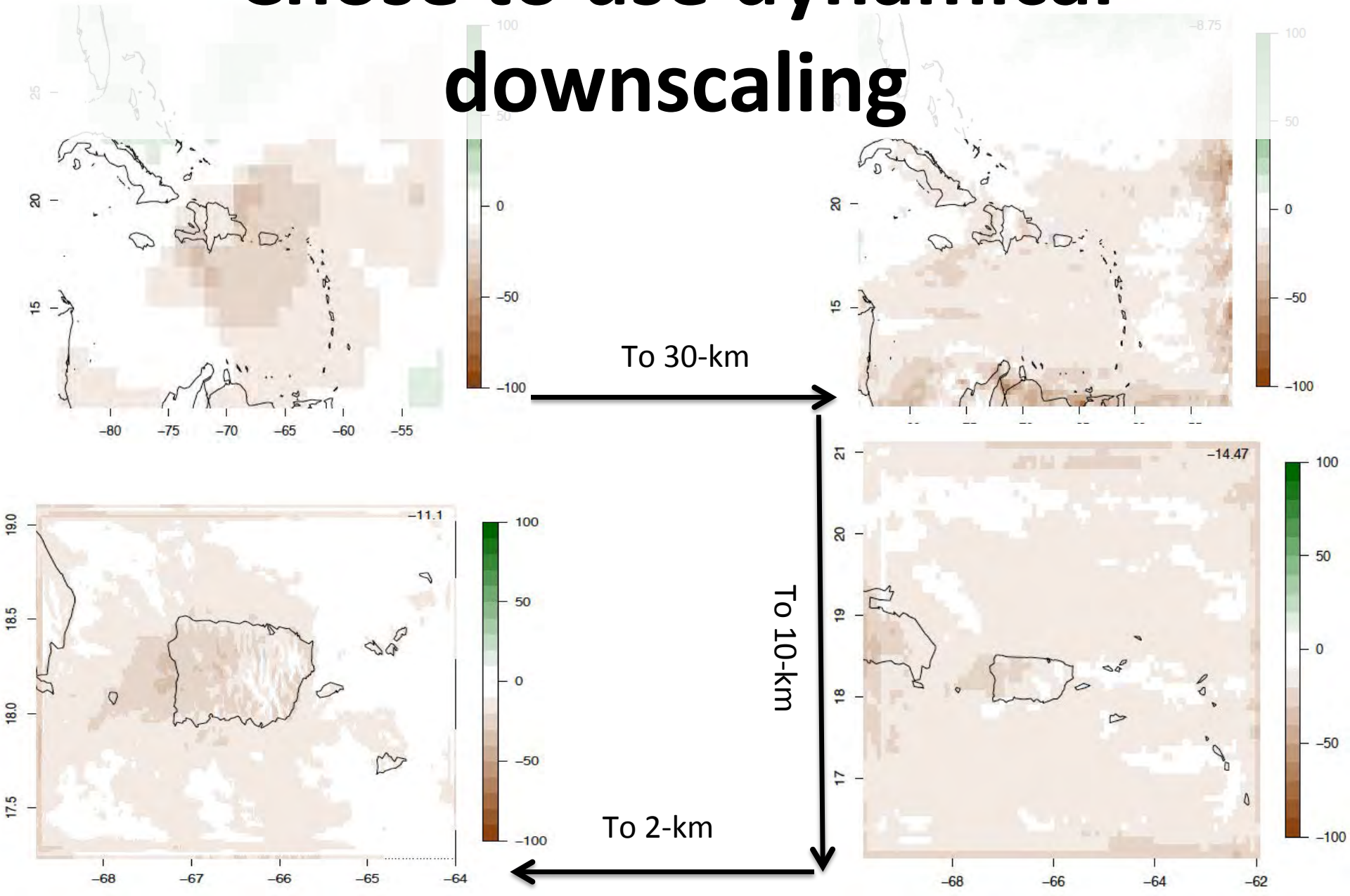
1) Projections that reflect reality given constraints of GCMs and oceanic context.

2) Simulate precipitation and other covariates response to the anthropogenic forcings across Puerto Rico.

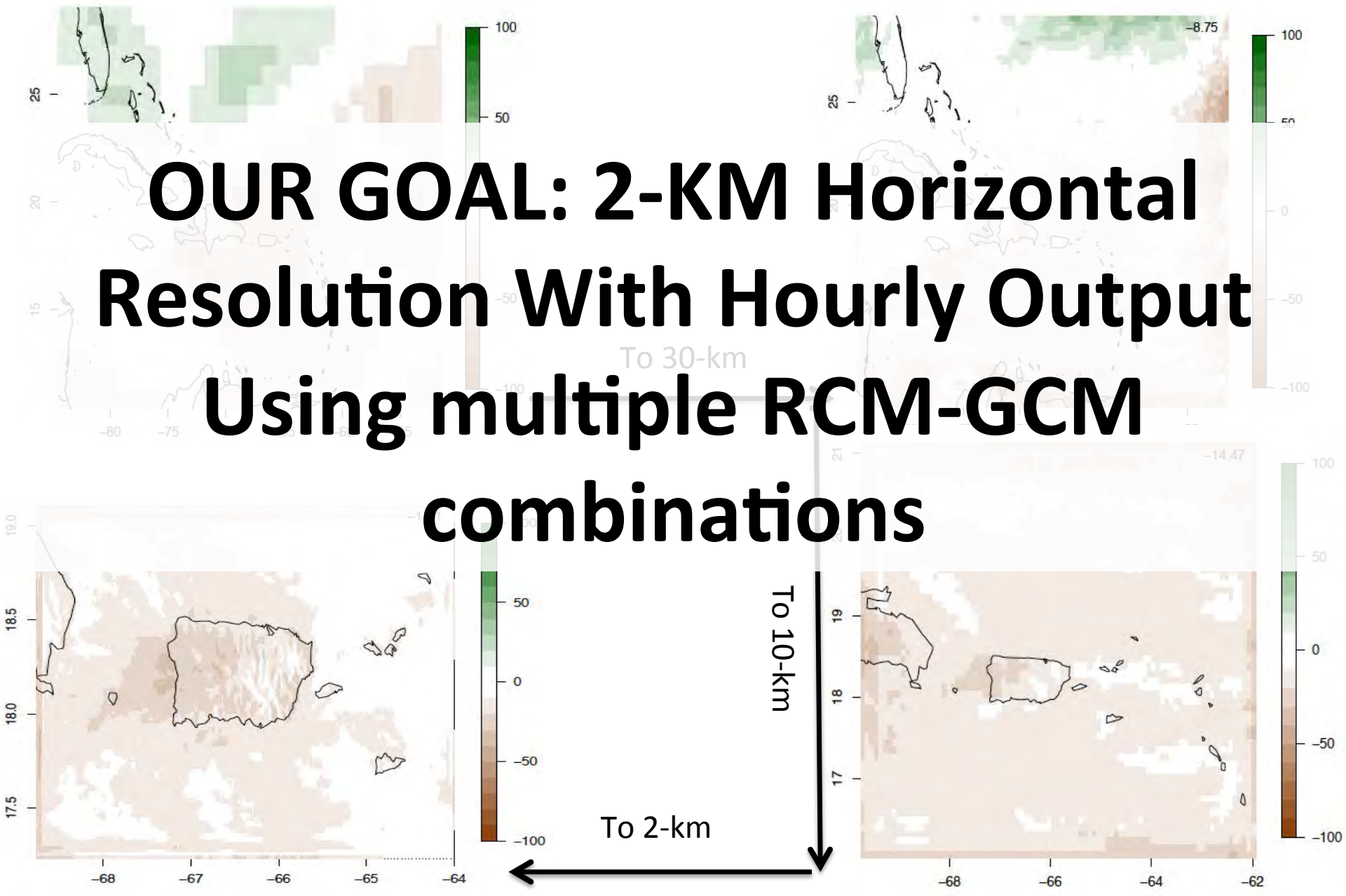
**Elicit expert knowledge to select relevant climate variables.

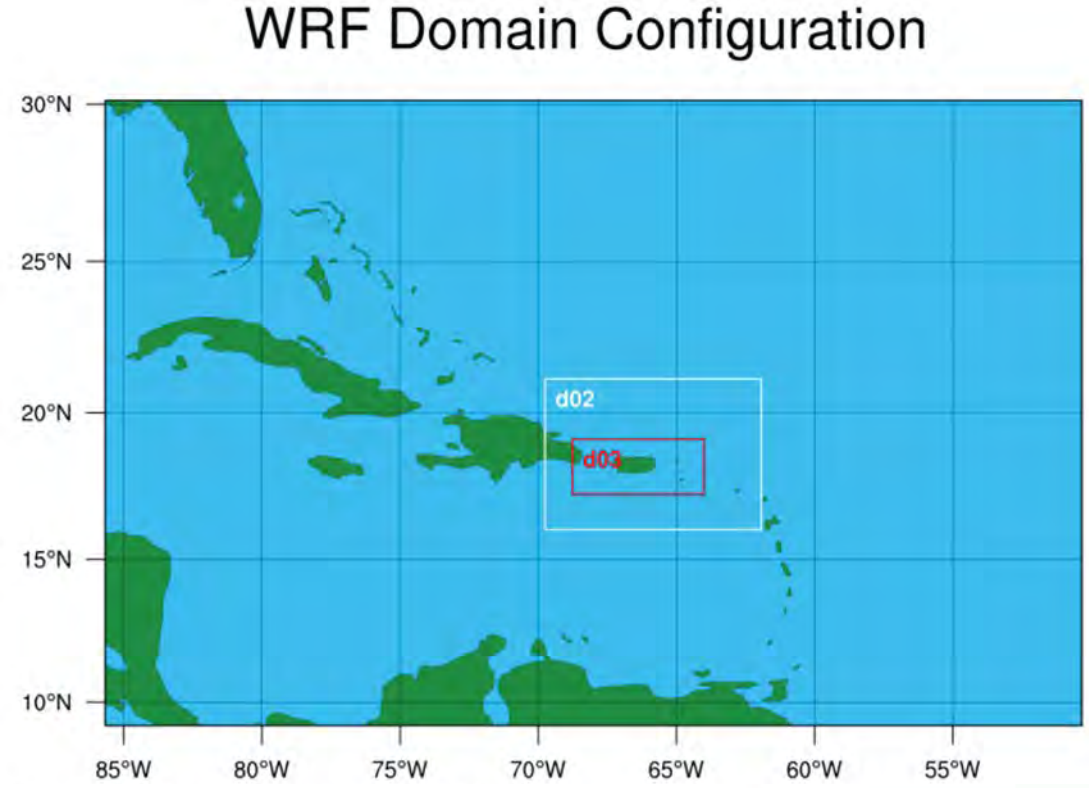


Chose to use dynamical downscaling



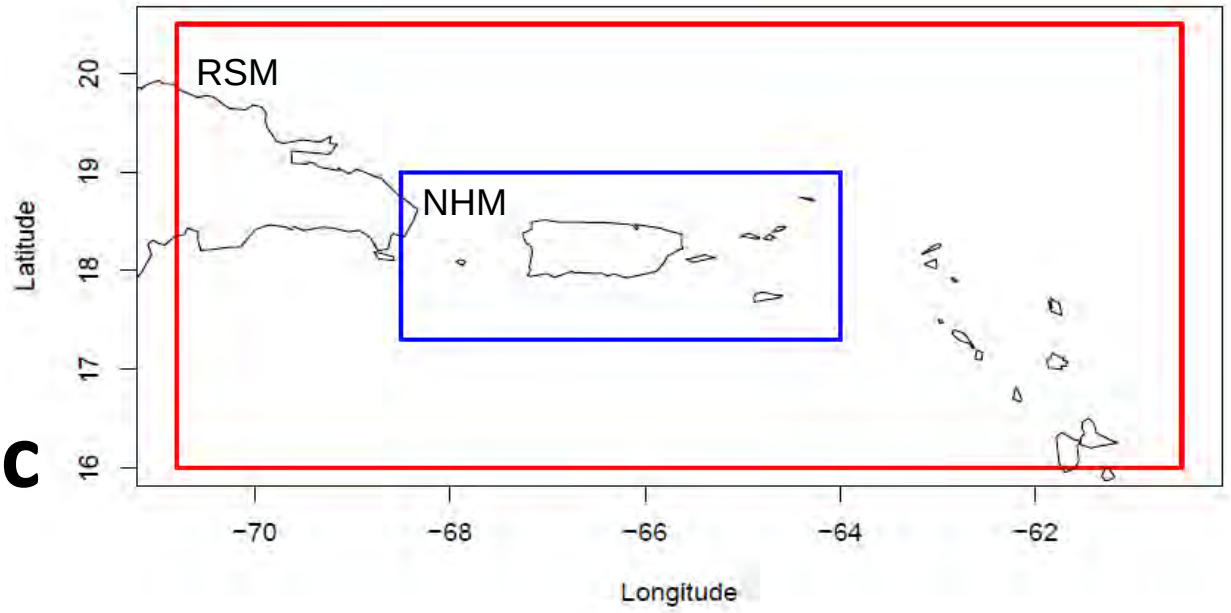
OUR GOAL: 2-KM Horizontal Resolution With Hourly Output Using multiple RCM-GCM combinations





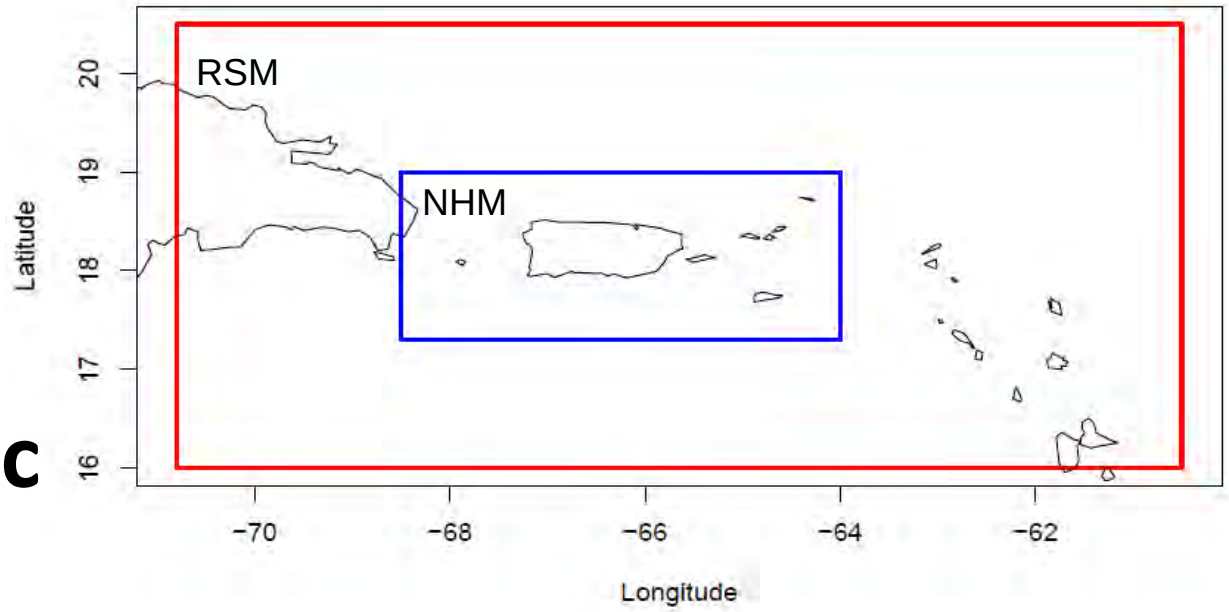
Weather Research and Forecasting Model (WRF)

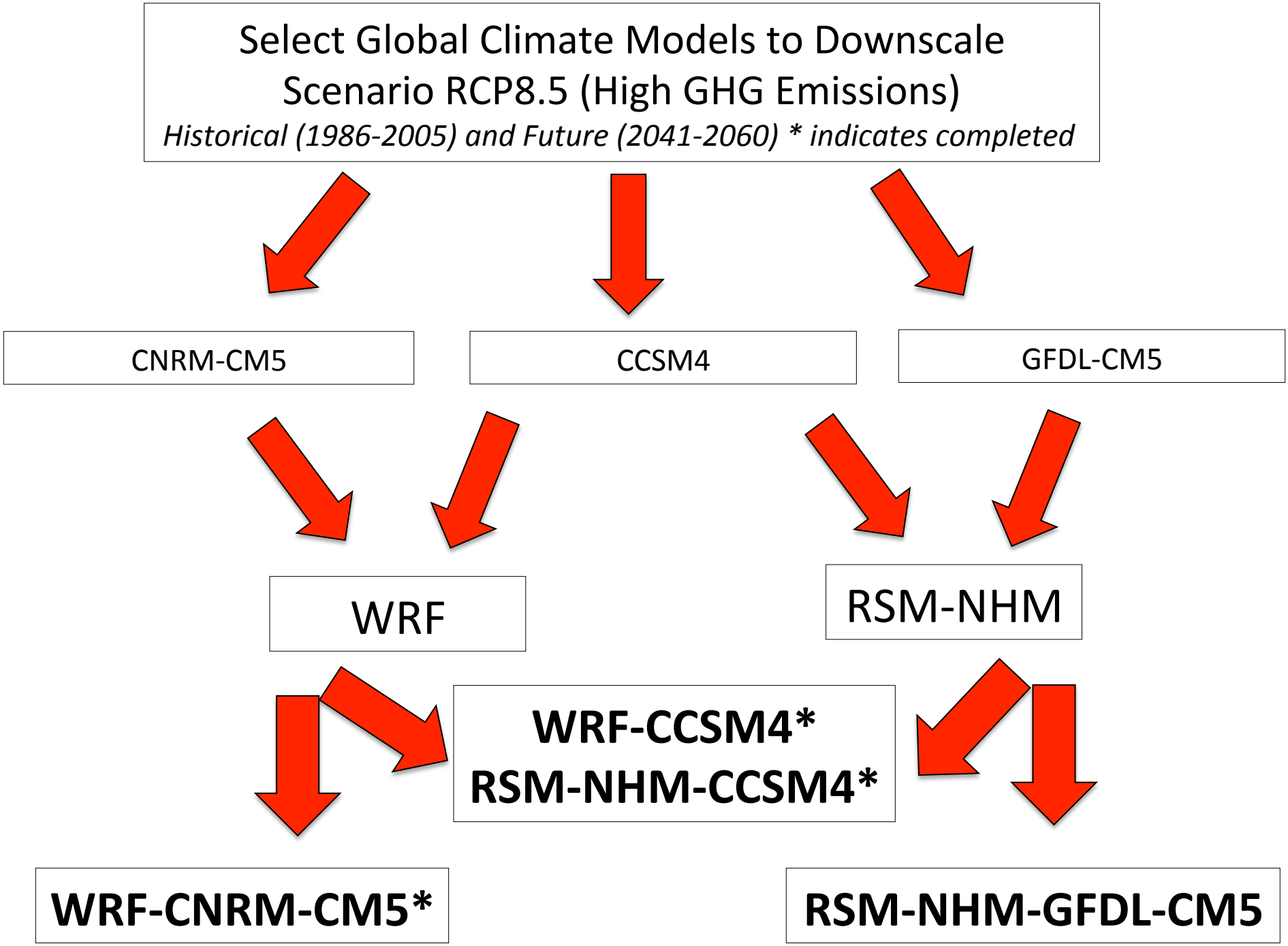
Regional Spectral Model (RSM) and the Non-Hydrostatic Model (NHM)



Collaboration with Vasu Misra at FSU

Regional Spectral Model (RSM) and the Non-Hydrostatic Model (NHM)




Select Global Climate Models to Downscale
Scenario RCP8.5 (High GHG Emissions)
*Historical (1986-2005) and Future (2041-2060) * indicates completed*
CNRM-CM5
CCSM4
GFDL-CM5
WRF
RSM-NHM
WRF-CCSM4*
RSM-NHM-CCSM4*
WRF-CNRM-CM5*
RSM-NHM-GFDL-CM5

Experimental Design for Regional Climate Modeling

- ***THREE GCMs***
  - CCSM4, CNRM5, GFDL-CM3
- ***TWO RCMs***
  - WRF, NHM-RSM
- ***TWO 20 year periods***
  - 1986-2005 (past)
  - **2040-2060 (future)**
  - RCP 8.5 – high fossil fuel emissions scenario

Many More Physical Variables Available
(and relationships between variables are maintained)

- Surface
  - Rainfall, Temperature, Humidity, winds, soil moisture/ temperature, runoff, evapotranspiration, pressure
- Above canopy
  - As above, plus others
  - Mixing height, vertical winds
- Radiation
  - Incoming, outgoing, diffuse, net, cloud fraction
- Diagnostic Variables
  - Height of cloud base,
  - Statistical : Heat Wave duration, extremes, percentiles, etc.

Many More Physical Variables Available

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  - Statistical : Heat Wave duration, extremes, percentiles, etc.

Time, Storage, and Processing Constraints => Cannot Retain All Variables at All Time Steps


2-Day Stakeholder workshop hosted by CLCC in San Juan to refine climate model output

IDEA IS TO HAVE CLIMATE PROJECTIONS THAT ARE SPECIFIC TO THE DECISION, BUT ALSO RELEVANT TO OTHER SCIENTIFIC/ ECOLOGICAL QUESTIONS

How could climate change affect shade coffee production?

Providing public goods

Follow-up workshop in August 2016 to discuss available modeling outputs

Providing public goods

Rank climate variables based on ***ecological significance***

	Variable	Keep	Why	Temporal Scale	Notes
Temperature					
	Air temperature at pressure levels	yes	It might have effects on the canopy and sensitive species	Daily	if hourly, need more info on which levels
	Air temperature at 2m	yes	Rate of ecosystem processes, decomposition rates, tolerance of species, animal physiology, ET	Hourly	
	Ground temperature	yes	amphibians and reptiles, ground surfaces processes	Daily/hourly	
Moisture					
	Relative humidity at pressure levels	yes	important for gas exchange for leaves	daily/hourly	
	Specific humidity at 2m	yes	for amphibians and reptiles	daily	
	Dewpoint Temperature	yes	use for calculation of RH	daily	
	Canopy wetness	yes	live fuel moisture, plant disease, soil chemistry, thrufall, flooding modeling	hourly	same time step as precipitation
Precipitation					
	Convective precipitation	no			
	Total precipitation	yes	many reasons	hourly	rainfall recommended at 15 minutes for exploration
Winds					
	Speed, direction at 10m	yes	ET, traffic patterns, fire risk, wind mills	hourly	needed at 2m, discussion regarding the air quality modeling if there really is a need for hourly winds

Used this dialogue to help retain necessary climate model data

Downscaled Climate Variables

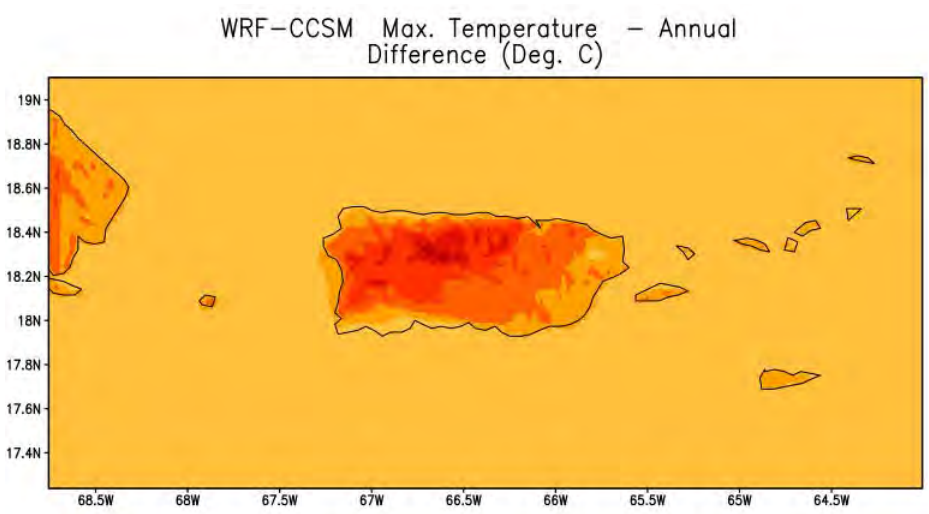
	Variable
Temperature	
	Air temperature at pressure levels
	Air temperature at 2m
	Ground temperature
	Soil Temperature
Moisture	
	Relative humidity at pressure levels
	Specific humidity at 2m
	Dewpoint Temperature
	Canopy wetness
Precipitation	
	Convective precipitation
	Total precipitation
	Soil Moisture
Winds	
	Speed, direction at 10m
	Speed, direction at pressure levels
	Vertical velocity at pressure levels

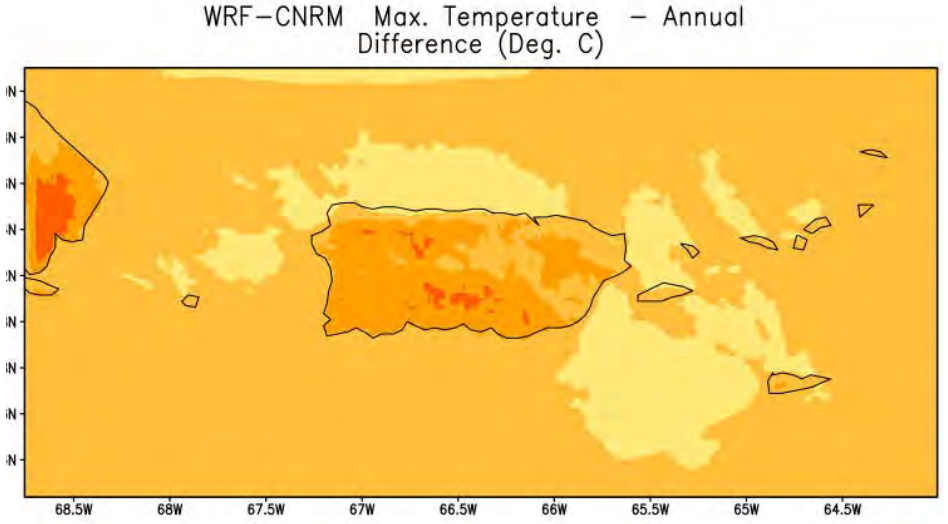
	Variable
Radiation	
	Solar radiation down
	Solar radiation up
	Terrestrial radiation down
	Terrestrial radiation up
Clouds	
	Bottom height (for low, medium, high clouds)
	Top height (for low, medium, high clouds)
	Cloud cover % (low, medium, high, total)
Pressure	
	Surface pressure
	Pressure tendency (i.e., time-derivative of pressure, indicates pressure rising or falling)
	Geopotential height (i.e., height of pressure levels)
Energy Fluxes	
	Sensible
	Latent
	Ground
	Potential evapotransporation

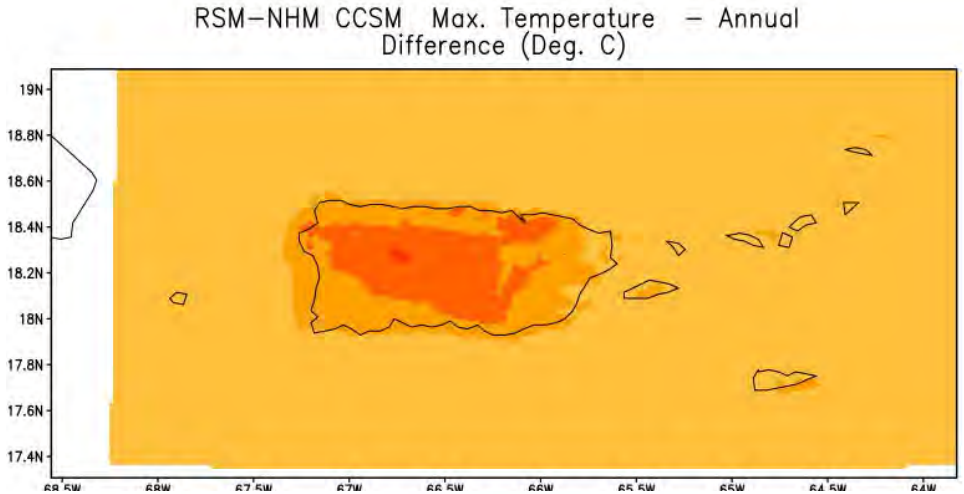
Exceeded ***1 million*** CPU hours to accomplish the downscaling for just one of the regional climate models.

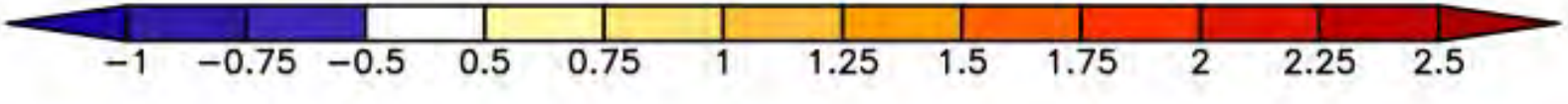
We reduced ~1 Petabyte of model output to < 20TB with the knowledge of climate variables to retain from prior workshop

Maximum 2-m Temperature Change
annual average



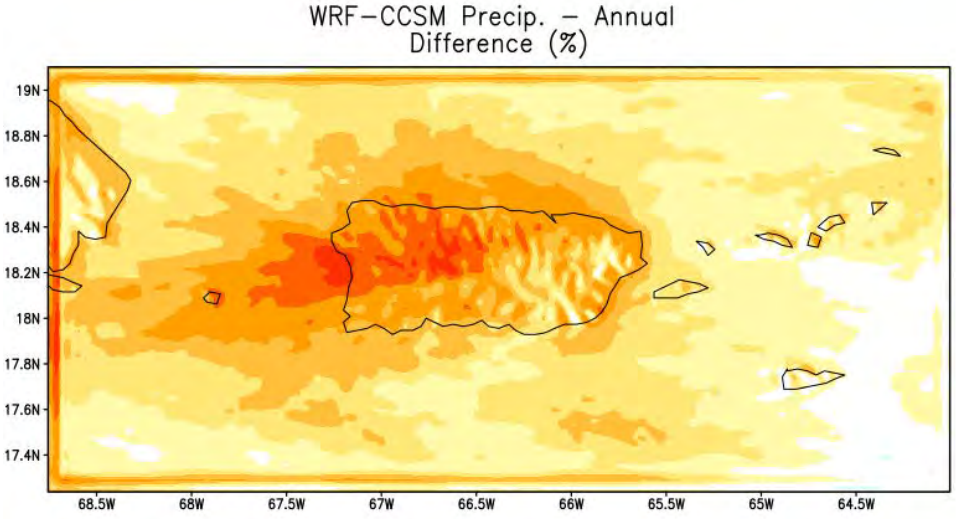


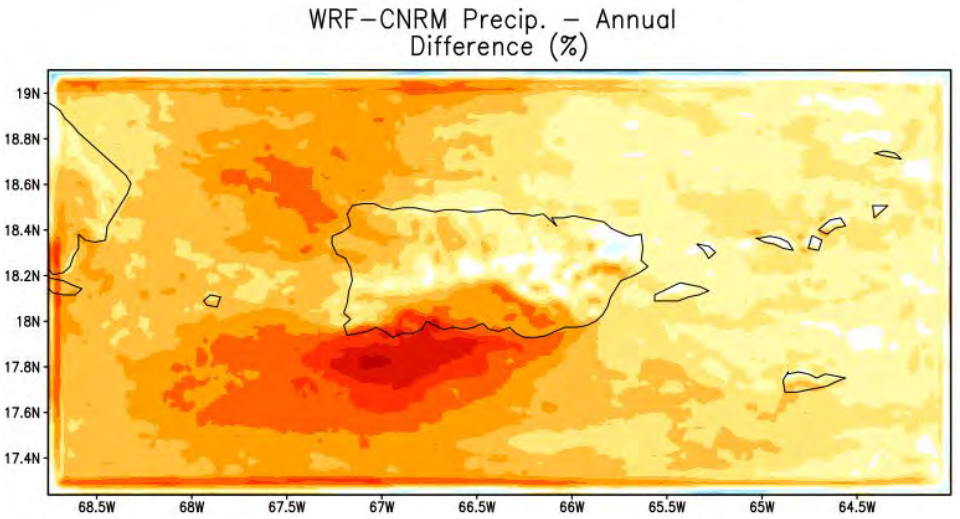


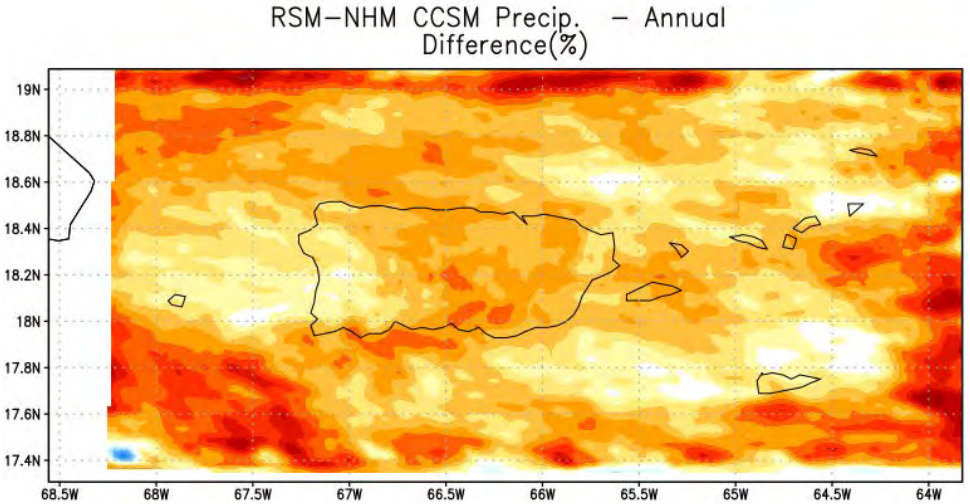


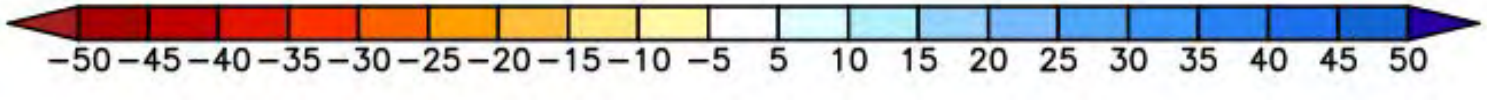
Precipitation Change

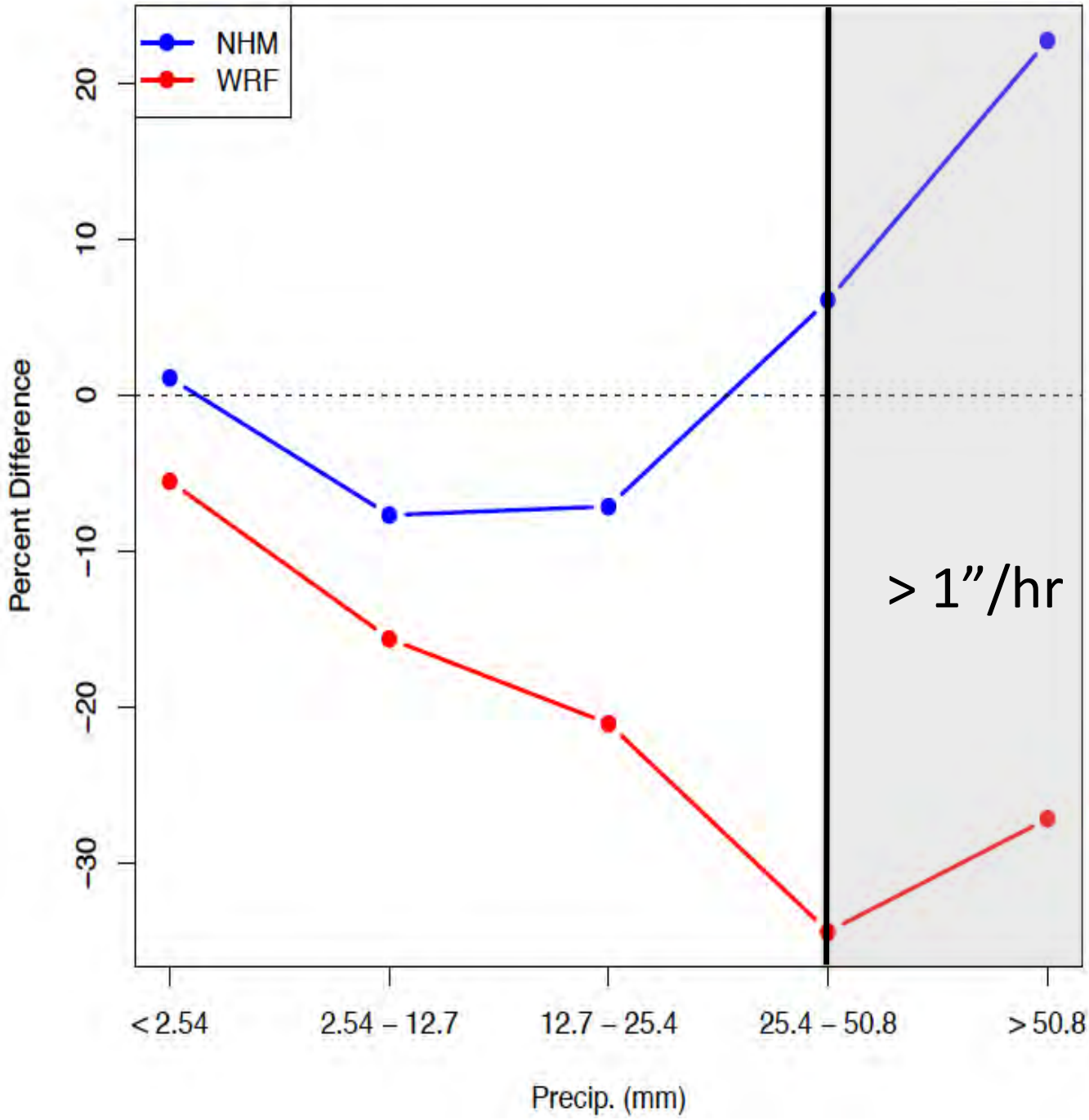
percent change for the annual total





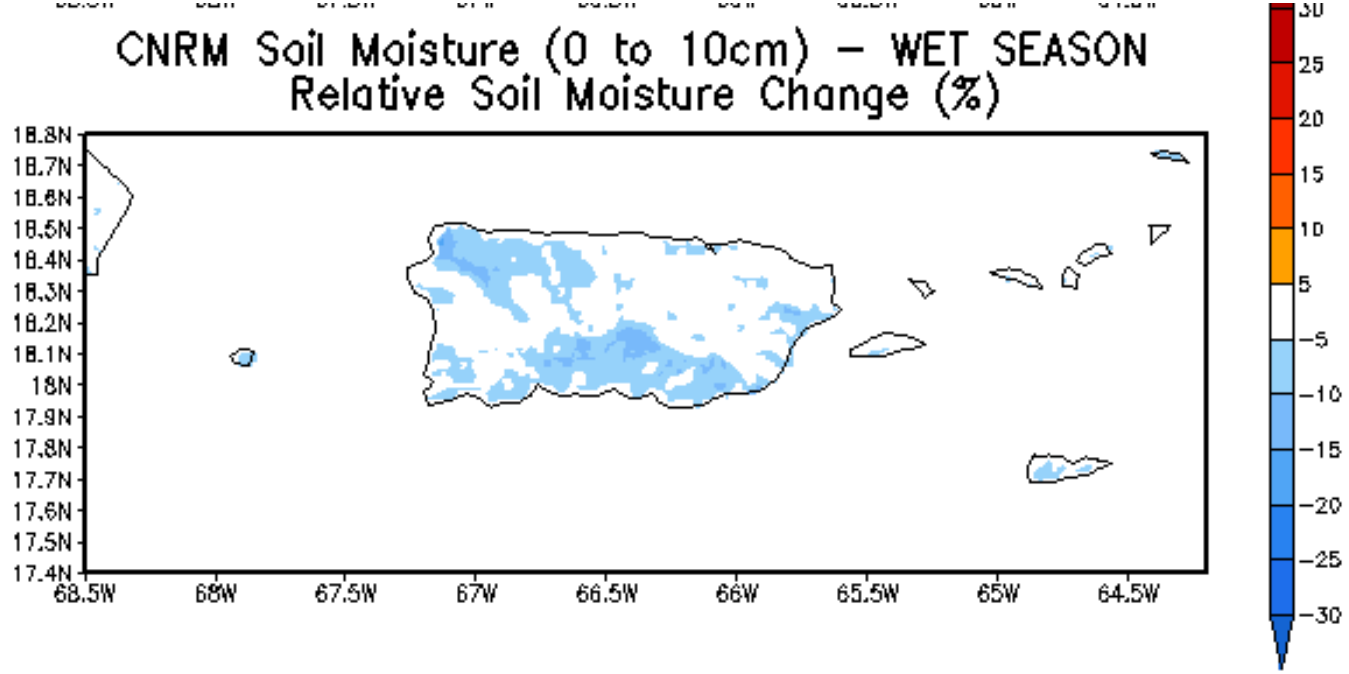




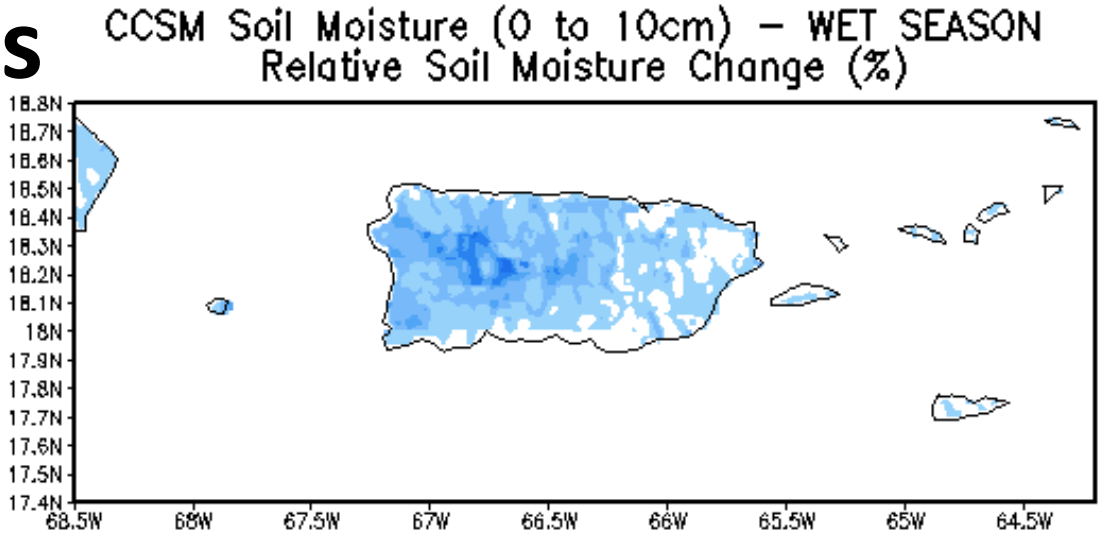


Hourly rainfall bin % difference

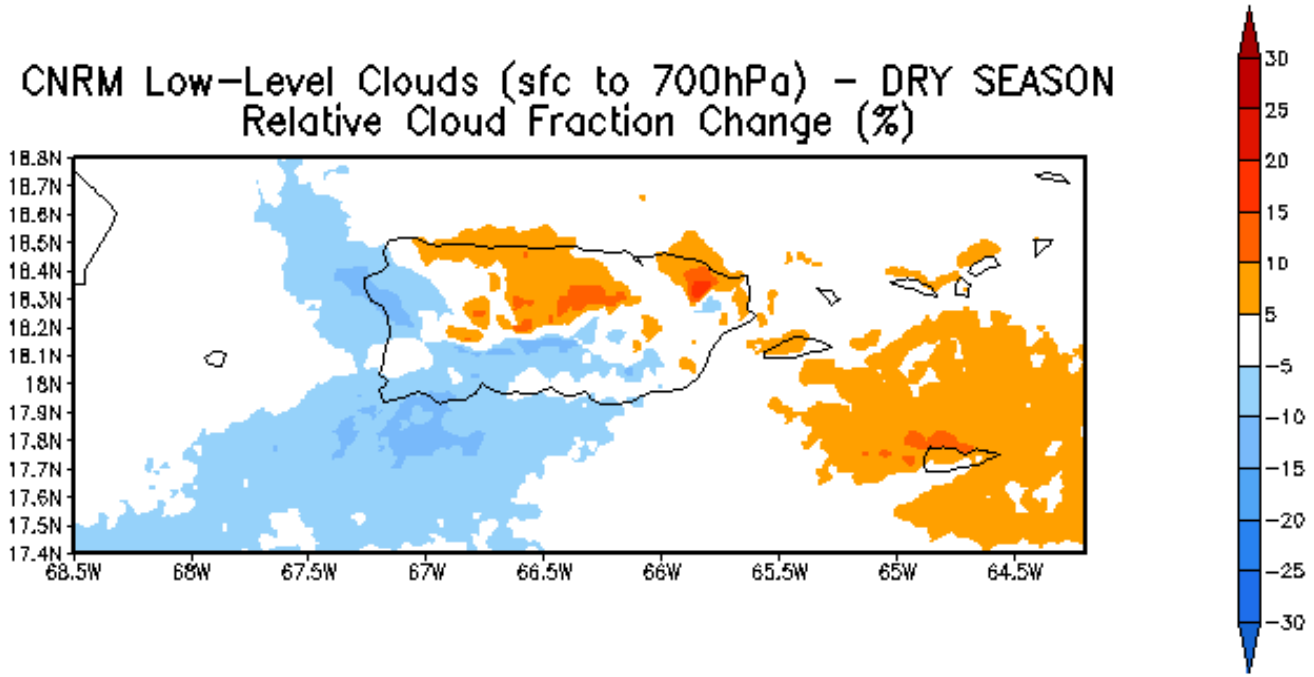
ECOREGION ANALYSIS (Subtropical wet forest - wet season)

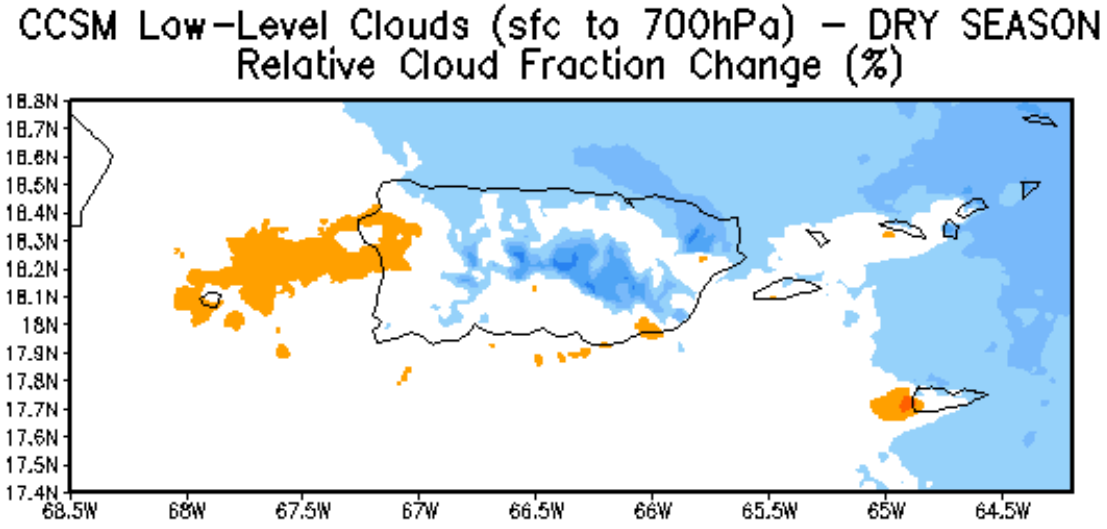


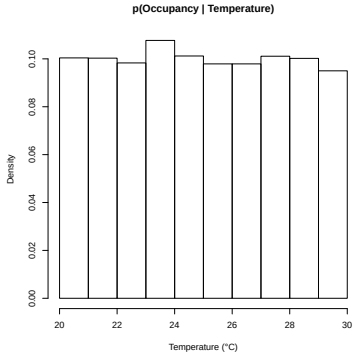
Projected Changes Soil Moisture



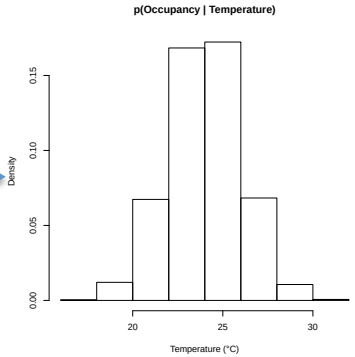
Low-level Cloud Fraction

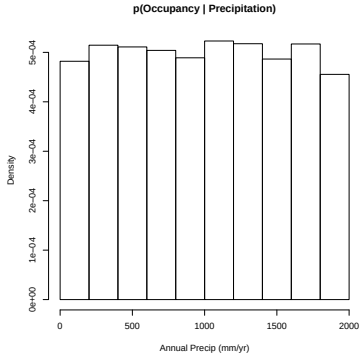




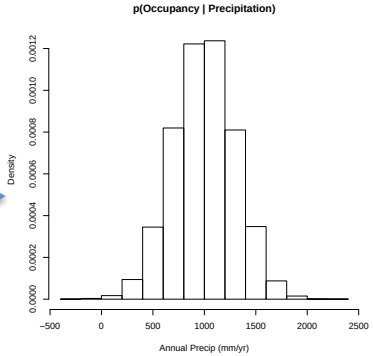


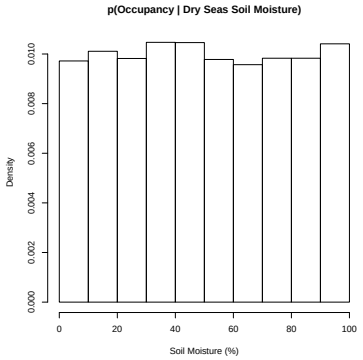
Temperature



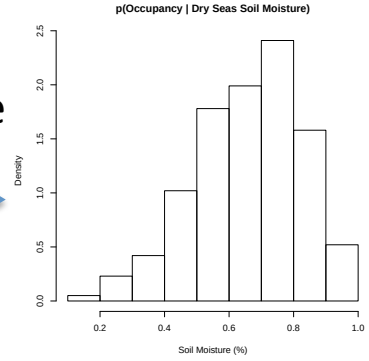


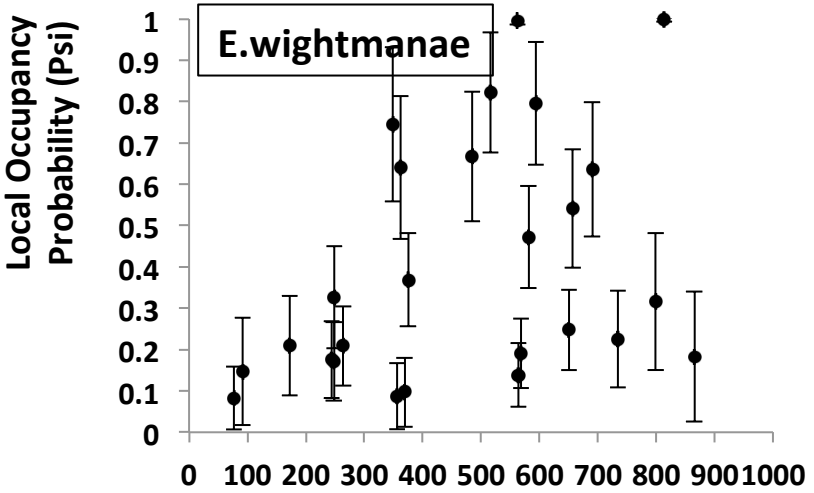
Precipitation

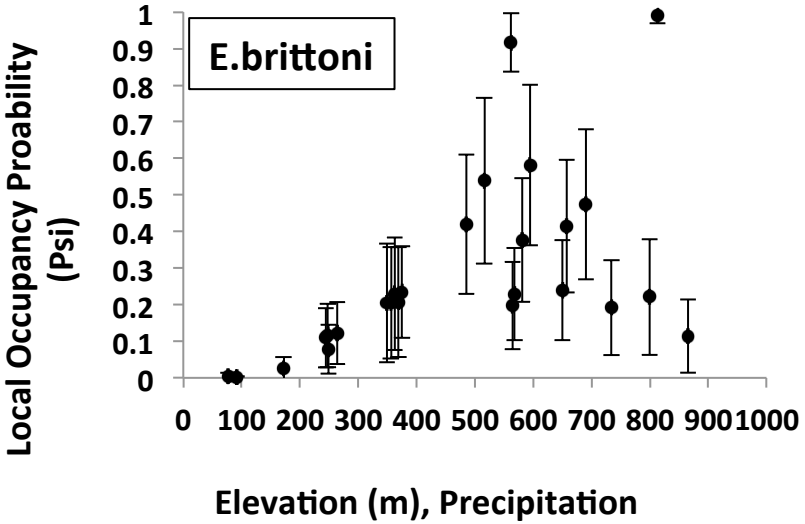




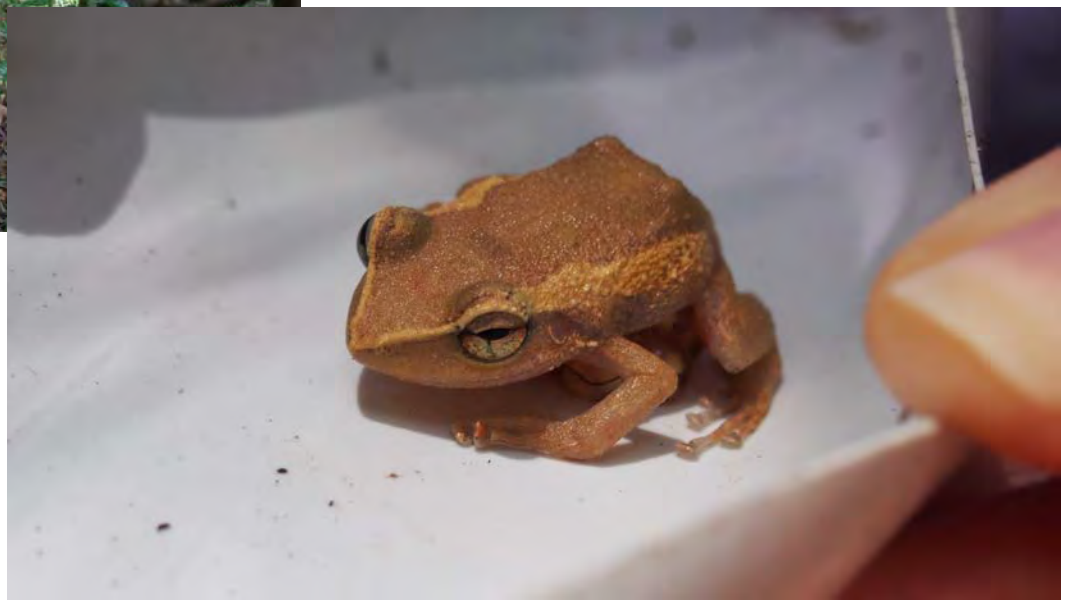
Soil Moisture







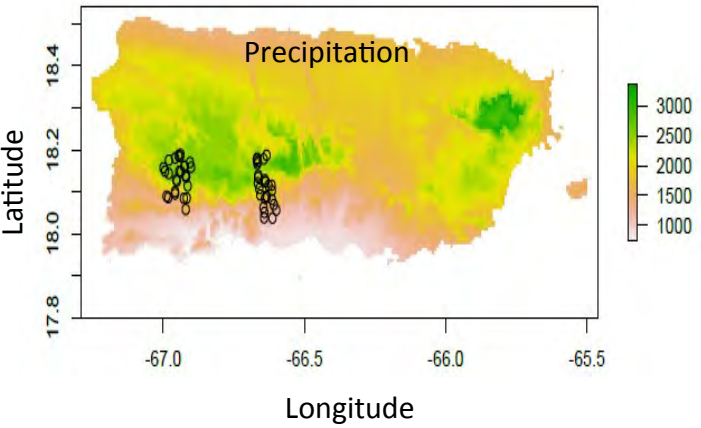
What are the environmental limits of these species?



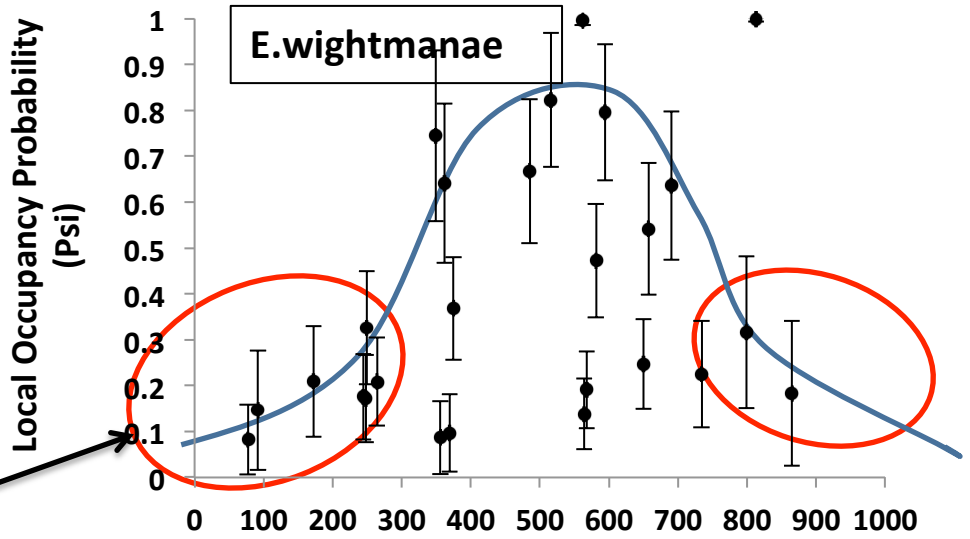
Use acoustic recorders to estimate occupancy of three species across environmental gradients

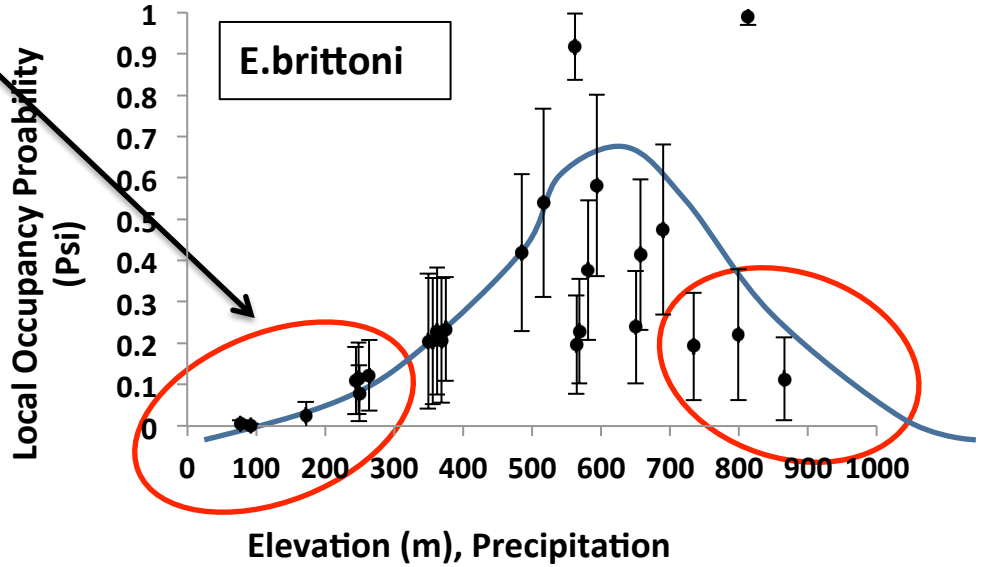
Estimate occupancy based on recorded calls


Arbimon
Dashboard
Data
Visualizer
Analysis
Jobs 3
Settings
Forum
NCSU coqui monster
kelen
Help
a87
Apr 28, 2014
a87, Apr 28, 2014 1:56 AM
a87, Apr 28, 2014 1:57 AM
1.81 s
24.06 s, 6.9 kHz
a87-2014-04-28_01-56.flac
No tags associated to this recording.
Species Presence Validation
2 / 4
Training Sets
Click to set current play time to 24.06s
Frequency (kHz)
Time (s)

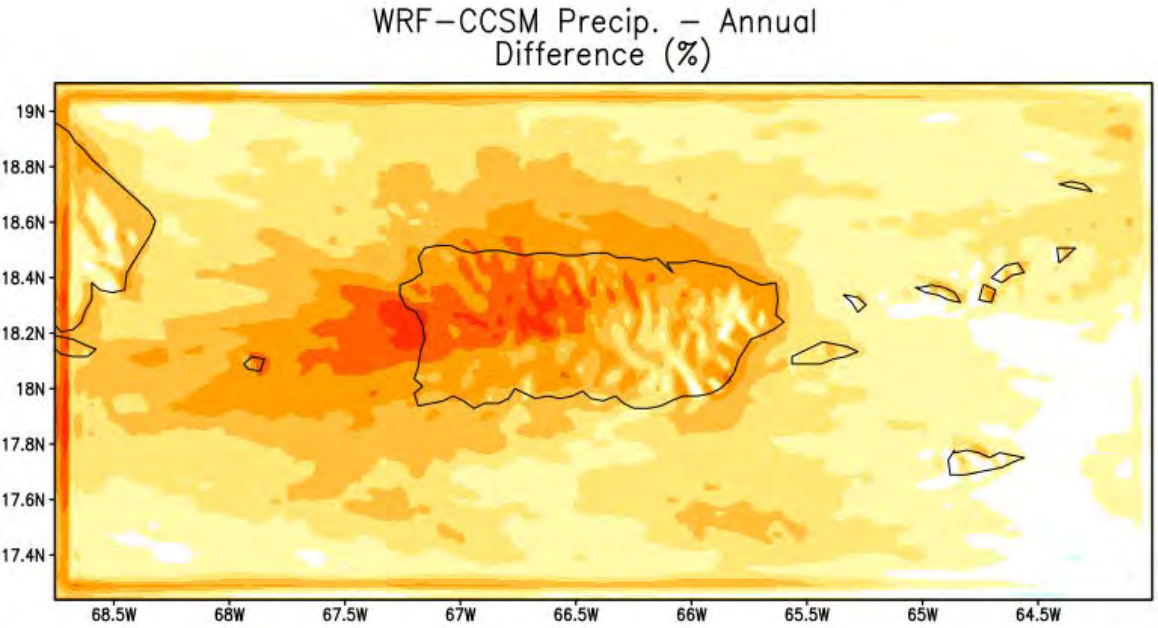


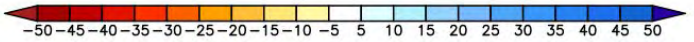
How could these gradients change with climate change?

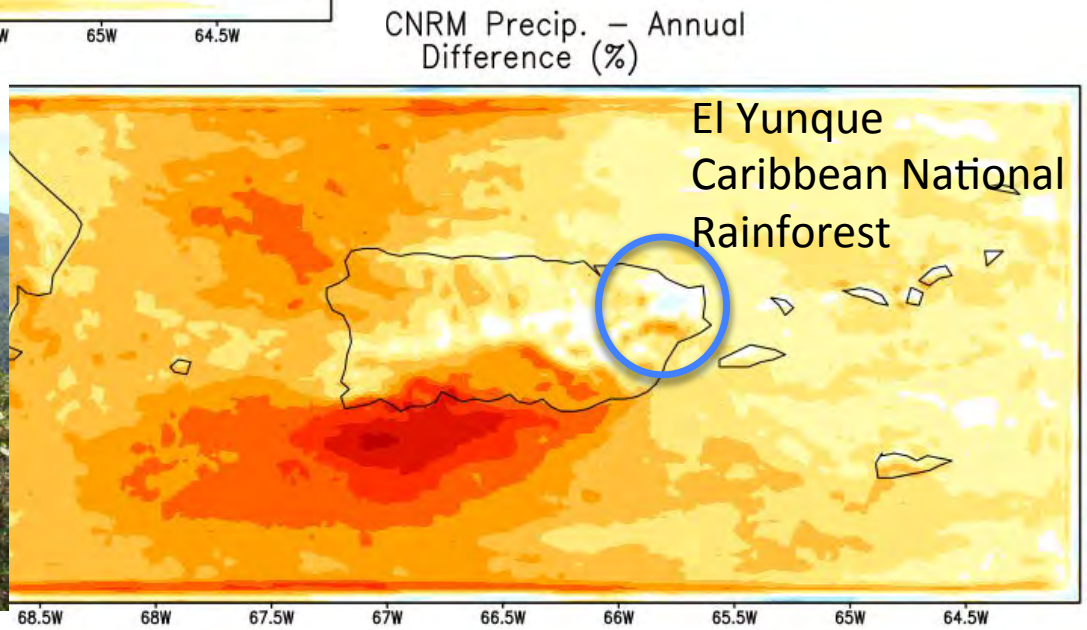




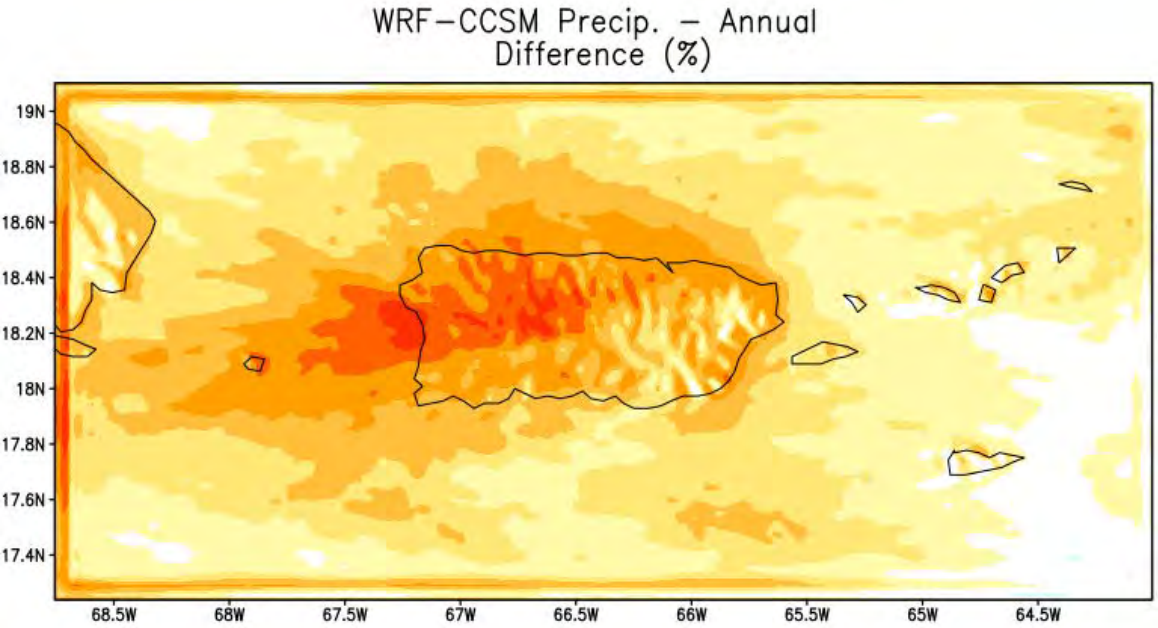
NEXT STEPS

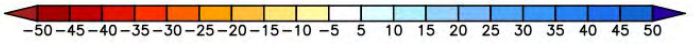


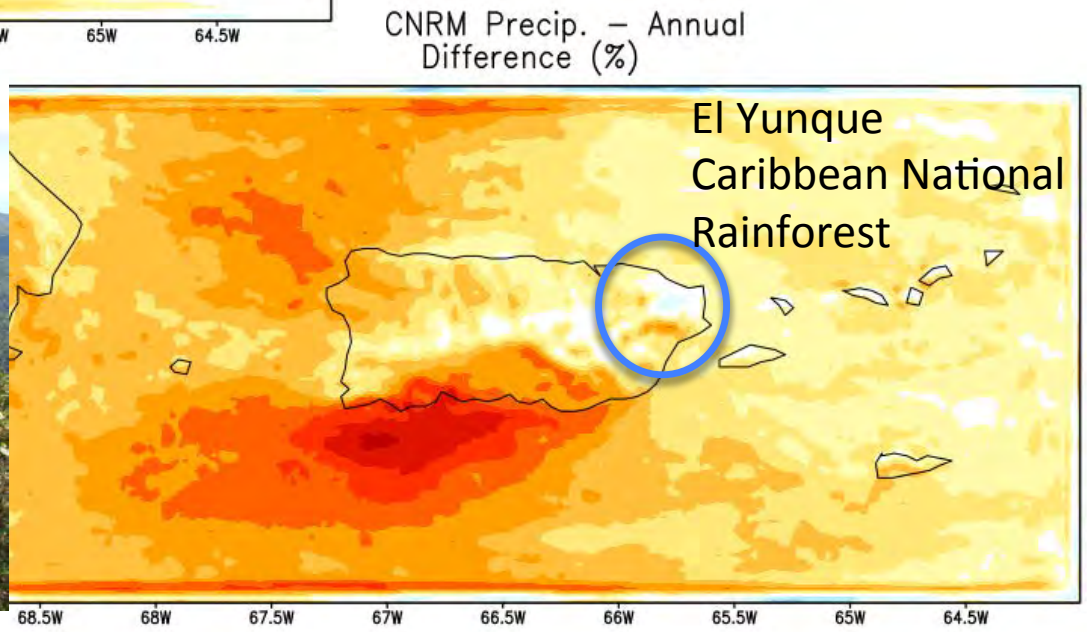




Next steps: Explore resilience of windward slopes

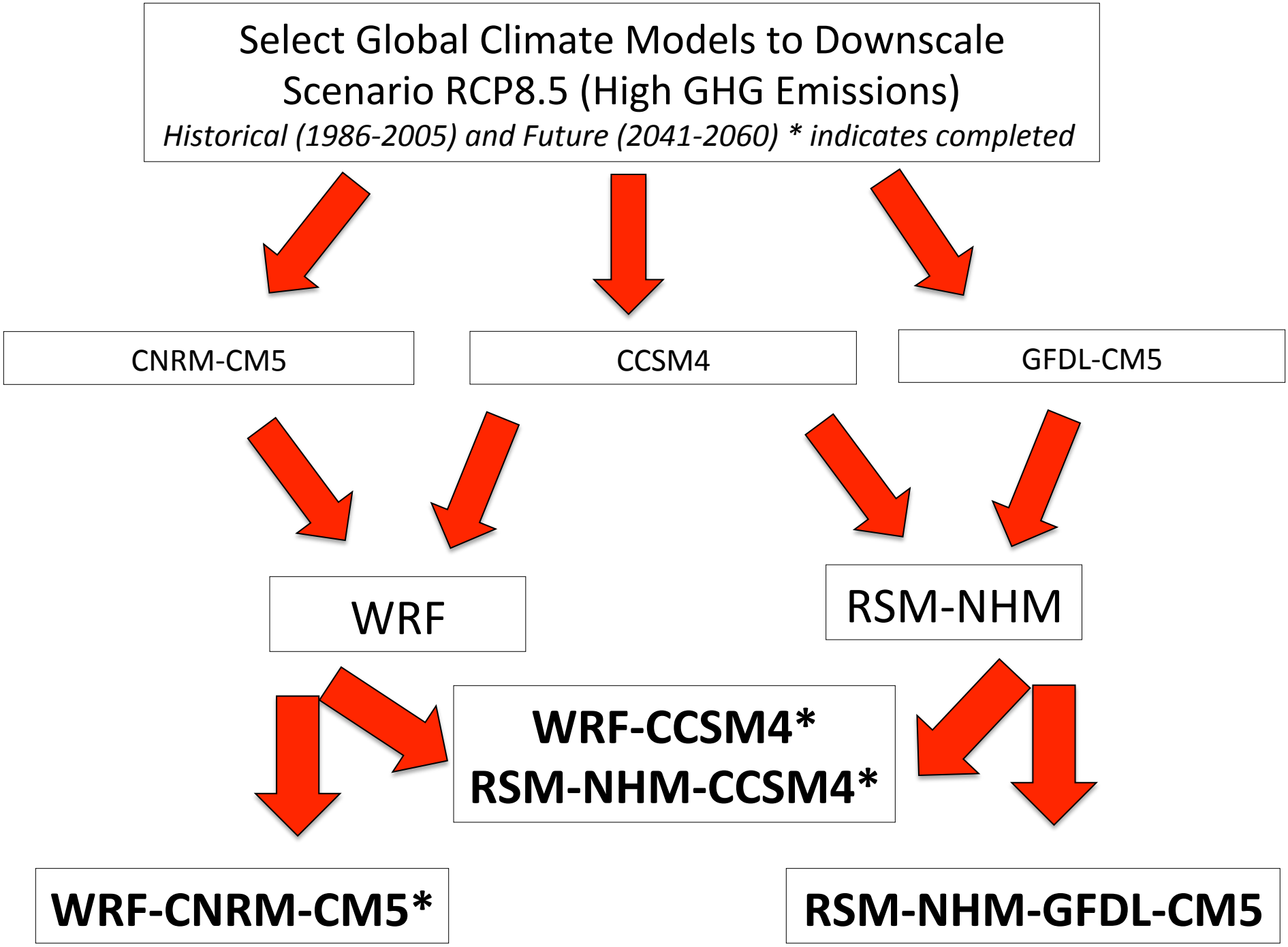


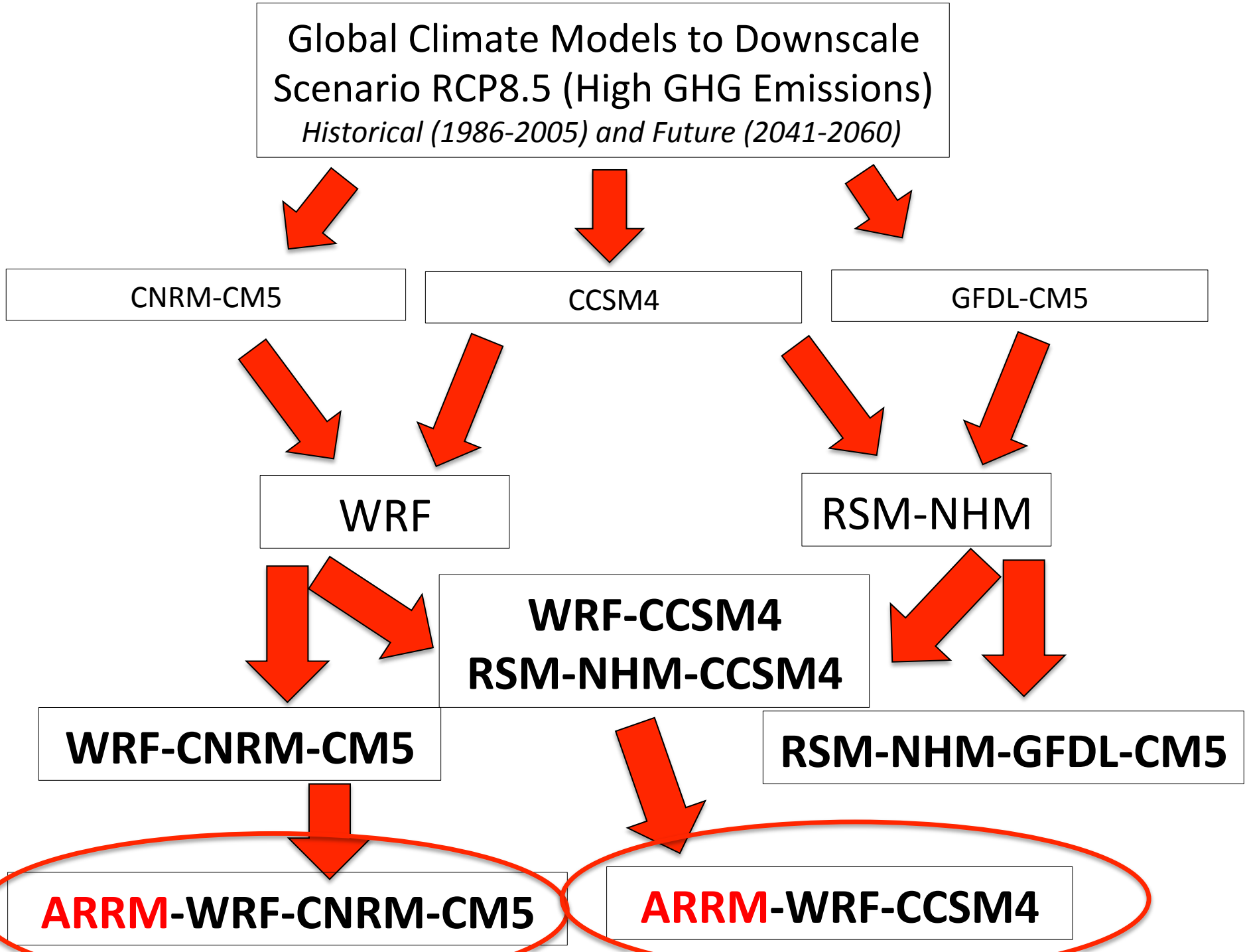


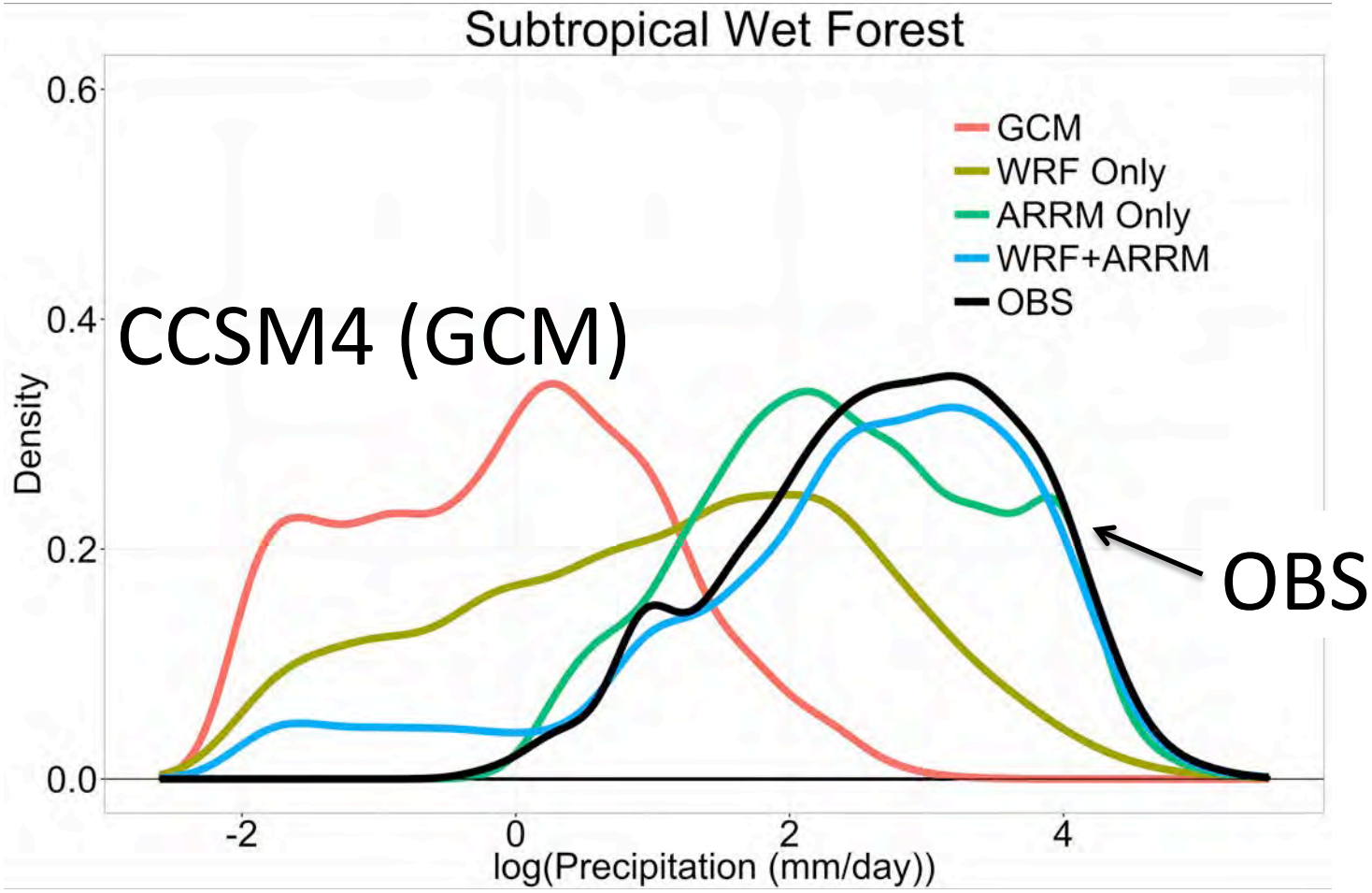


Potential to couple to WRF-Hydro Model

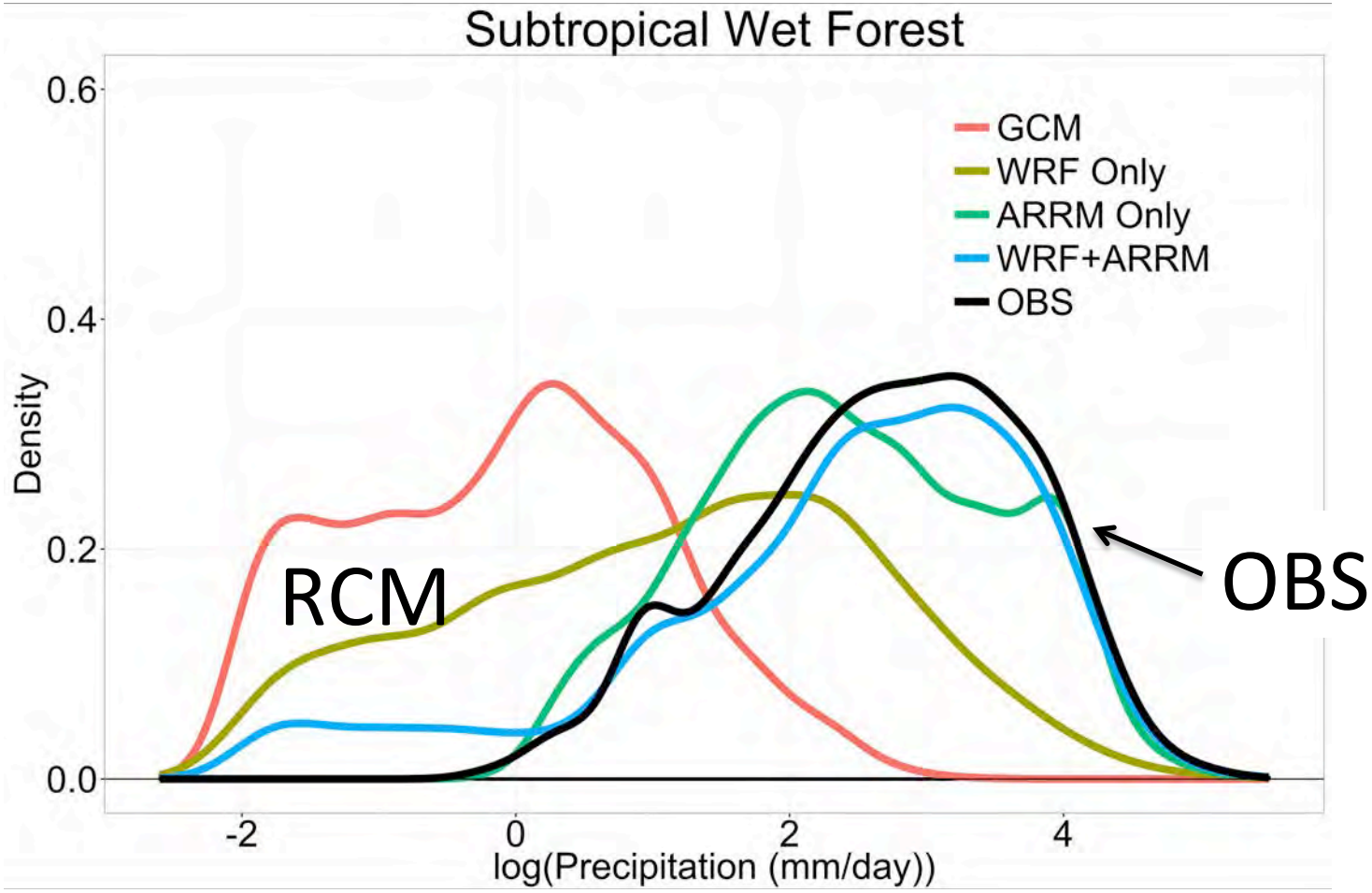
Hybrid downscaling


Select Global Climate Models to Downscale
Scenario RCP8.5 (High GHG Emissions)
*Historical (1986-2005) and Future (2041-2060) * indicates completed*
CNRM-CM5
CCSM4
GFDL-CM5
WRF
RSM-NHM
WRF-CCSM4*
RSM-NHM-CCSM4*
WRF-CNRM-CM5*
RSM-NHM-GFDL-CM5

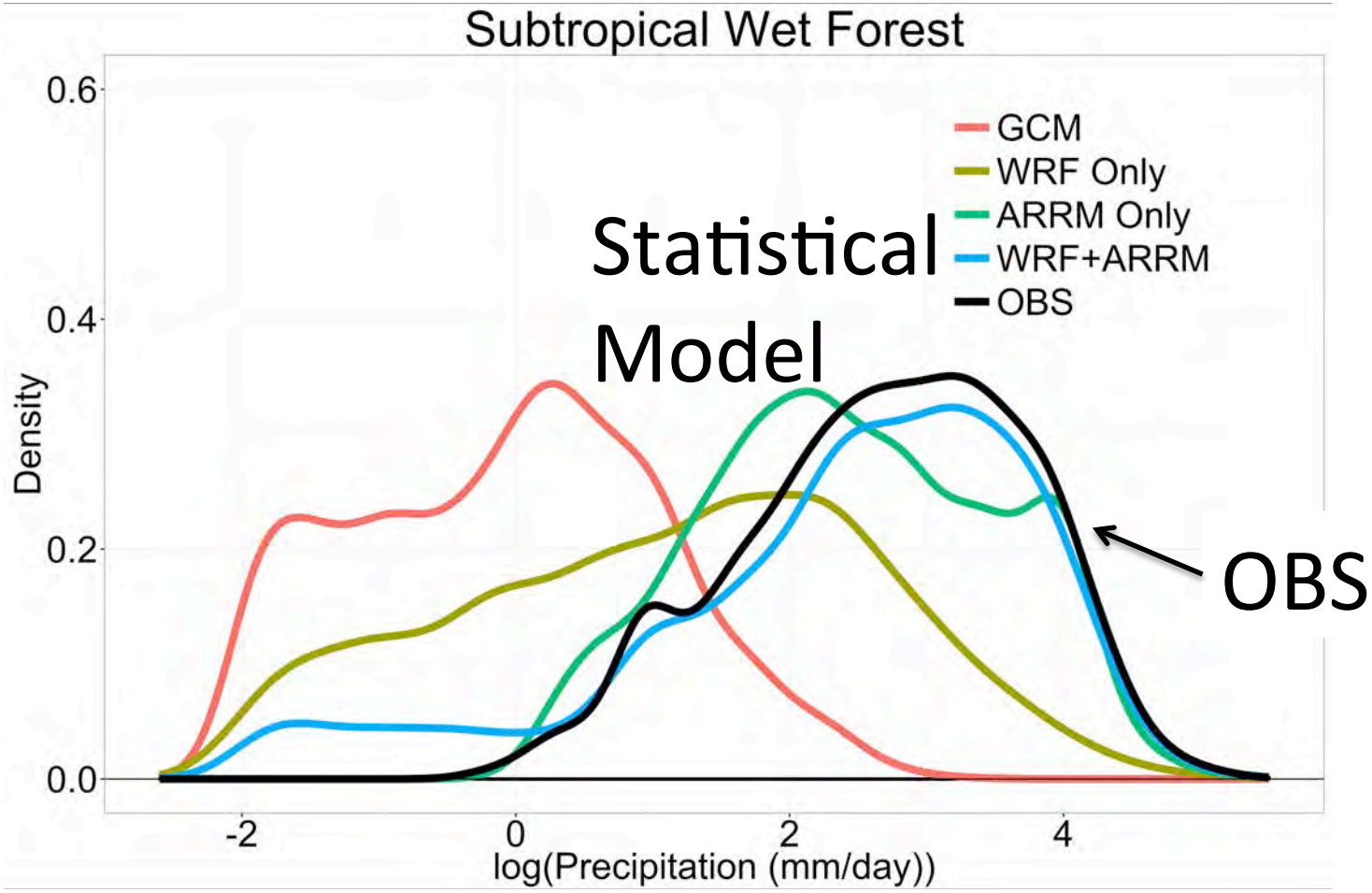

Global Climate Models to Downscale Scenario RCP8.5 (High GHG Emissions)
Historical (1986-2005) and Future (2041-2060)
CNRM-CM5
CCSM4
GFDL-CM5
WRF
RSM-NHM
WRF-CCSM4
RSM-NHM-CCSM4
WRF-CNRM-CM5
RSM-NHM-GFDL-CM5
ARRM-WRF-CNRM-CM5
ARRM-WRF-CCSM4



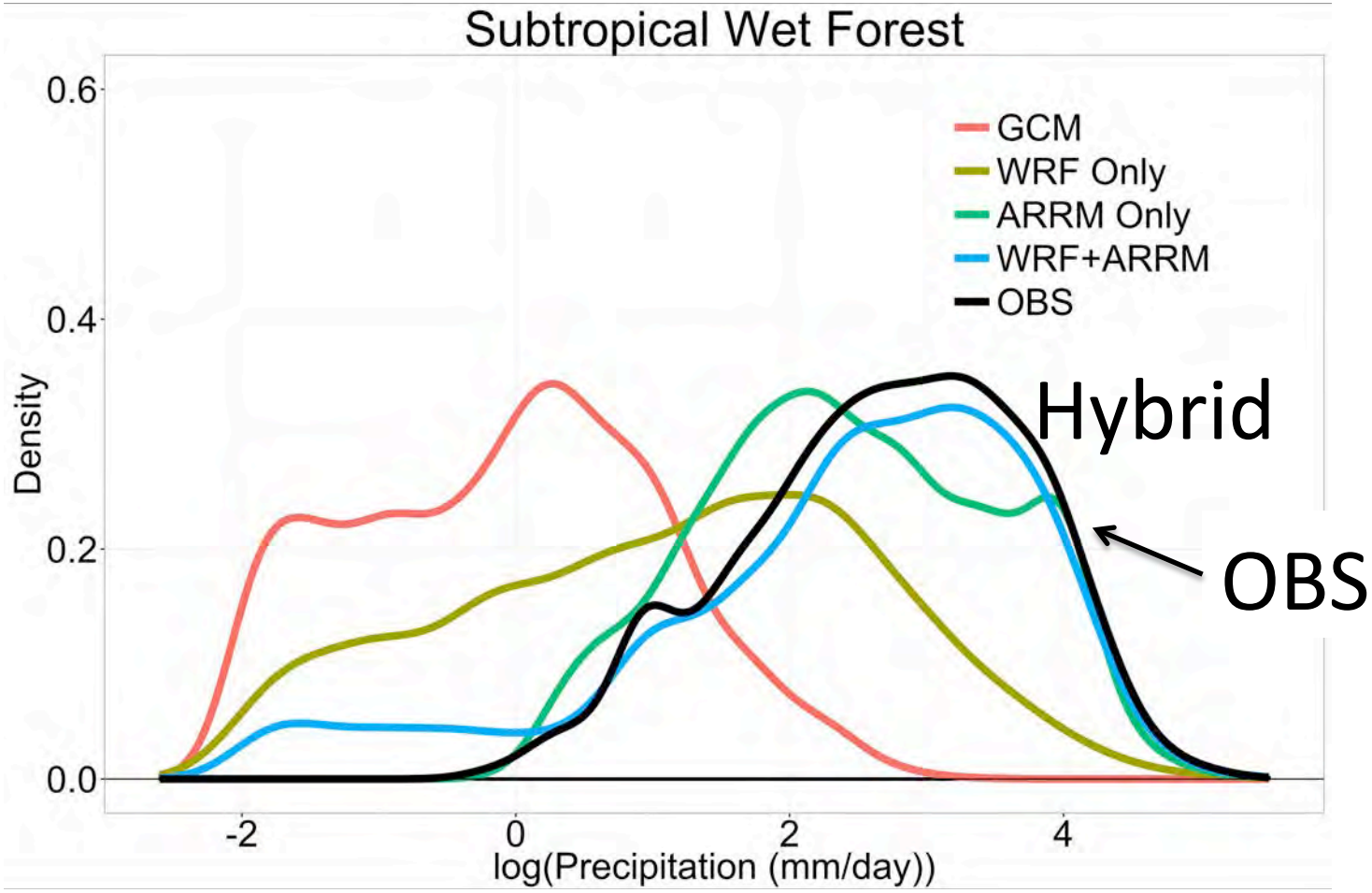
Combining statistical and dynamical downscaling approaches



Combining statistical and dynamical downscaling approaches



Combining statistical and dynamical downscaling approaches



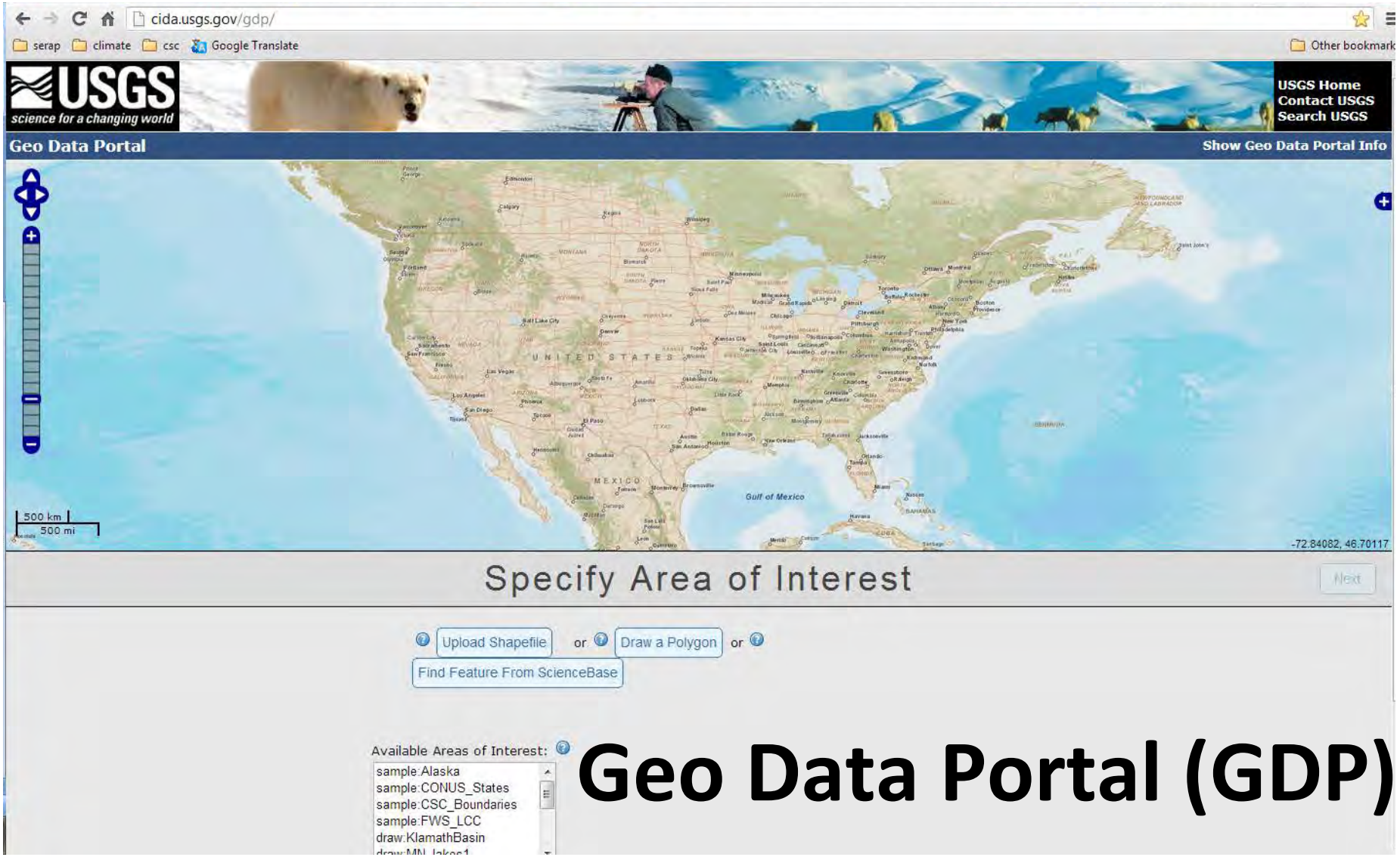
Combining statistical and dynamical downscaling approaches

Taking occupancy modeling a step further.

Is reproduction occurring at occupied sites? Are sites being occupied by a few individuals or by “many”?

Plus genetic work to establish population structure.

Augment field work with terraria experiments to test eco-physiological limits (w/colleagues at Univ. Puerto Rico)



Web-based access to and processing of global change data to address climate and landscape change


THANKS!
QUESTIONS?