PRESENTATION GIVEN AT LTC SPRING FORUM ENTITLED:

“"INTEGRATING GEOSPATIAL AND FIELD-BASED SCIENCE TO ASSESS BIODIVERSITY CONSERVATION: A SPECIAL FORUM OF WOMEN RESEARCH LEADERS"

APRIL 2-3 & 15, 2009

UNIVERSITY OF WISCONSIN, MADISON, WI, USA

HOSTED BY

LAND TENURE SOCIETY

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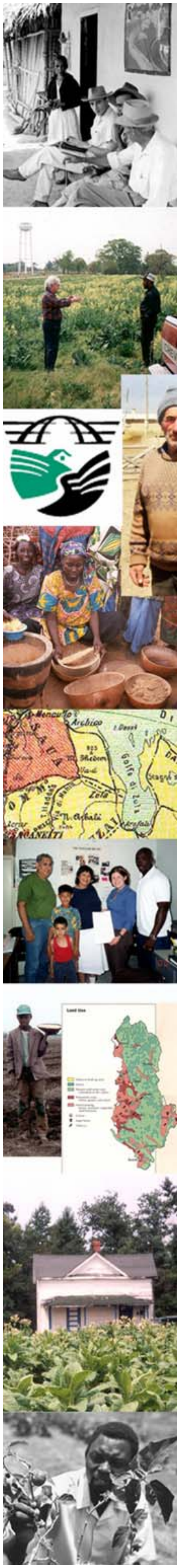
This workshop was generously supported by the American people through the United States Agency for International Development (USAID) under the terms of the TransLinks Cooperative Agreement No.EPP-A-00-06-00014-00 to the Wildlife Conservation Society (WCS). TransLinks is a partnership of WCS, The Earth Institute, Enterprise Works/VITA, Forest Trends and the Land Tenure Center. The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States government.



This work was funded with the generous support of the American people through the Leader with Associates Cooperative Agreement No.EPP-A-00-06-00014-00 for implementation of the TransLinks project. The contents of this report are the responsibility of the author and do not necessarily reflect the views of the United States government.

Land Tenure Center

PREDICTING CLIMATE CHANGE IMPACTS ON BIODIVERSITY IN THE TROPICAL ANDES

Jack Williams

LTC Spring Forum, Integrating geospatial and field-based science to assess biodiversity conservation.

♦♦♦♦♦♦♦♦

Provided by the **Land Tenure Center.** Comments encouraged:
Land Tenure Center, Nelson Institute of Environmental Studies,
University of Wisconsin, Madison, WI 53706 USA
kdbrown@wisc.edu; tel: +608-262-8029; fax: +608-262-0014
http://www.ies.wisc.edu/ltc

Predicting climate change impacts on biodiversity in Tropical Andes

Jack Williams
Department of Geography
Center for Climatic Research
University of Wisconsin

LTC & WISE Spring Forum
April 3, 2009

Thanks to: Lisa Naughton, Karyn Tabor, Steve Jackson, & John Kutzbach

DEPARTMENT OF GEOGRAPHY University of Wisconsin-Madison
CONSERVATION INTERNATIONAL
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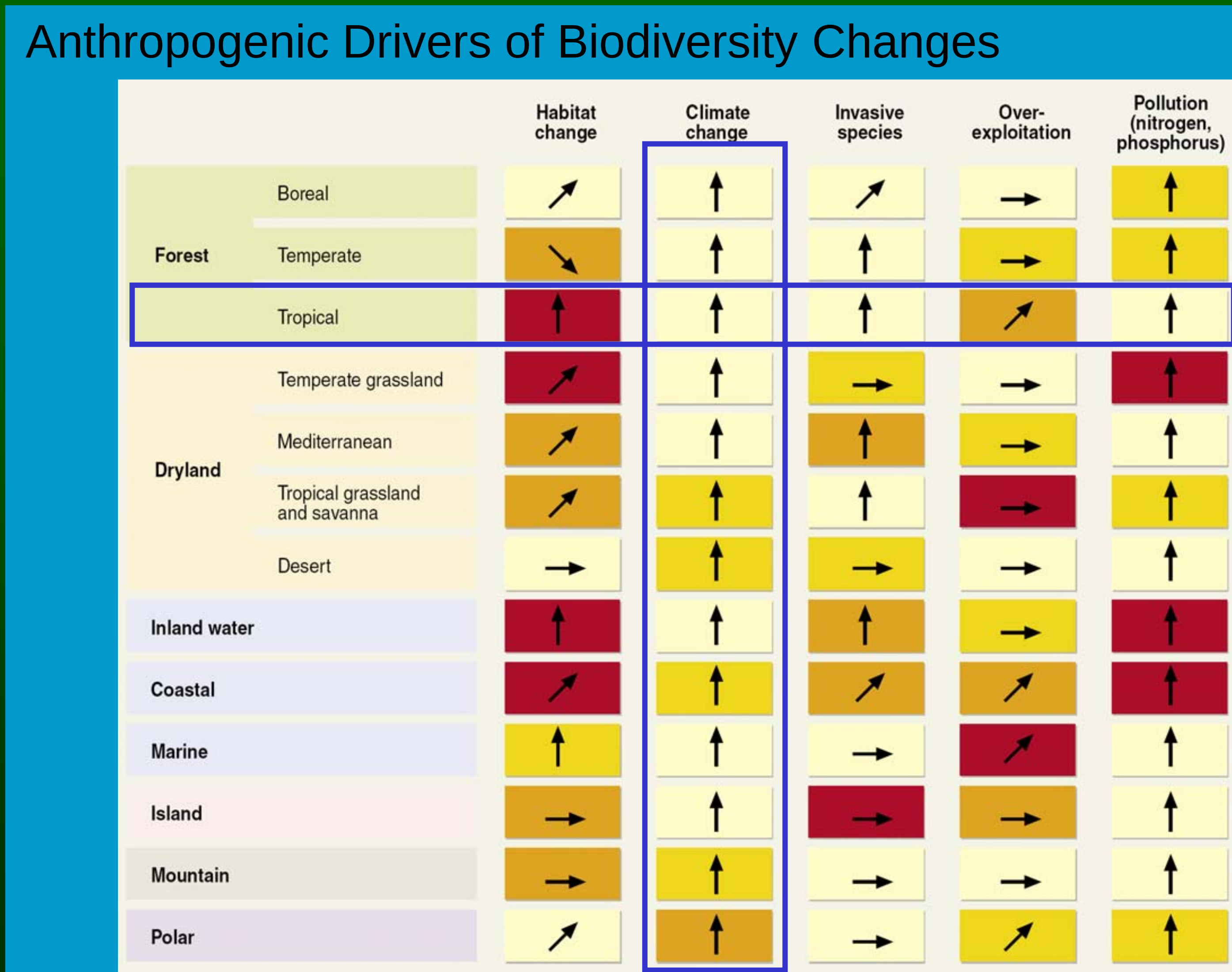
Land Tenure Center

Putting climate change into context for the tropics



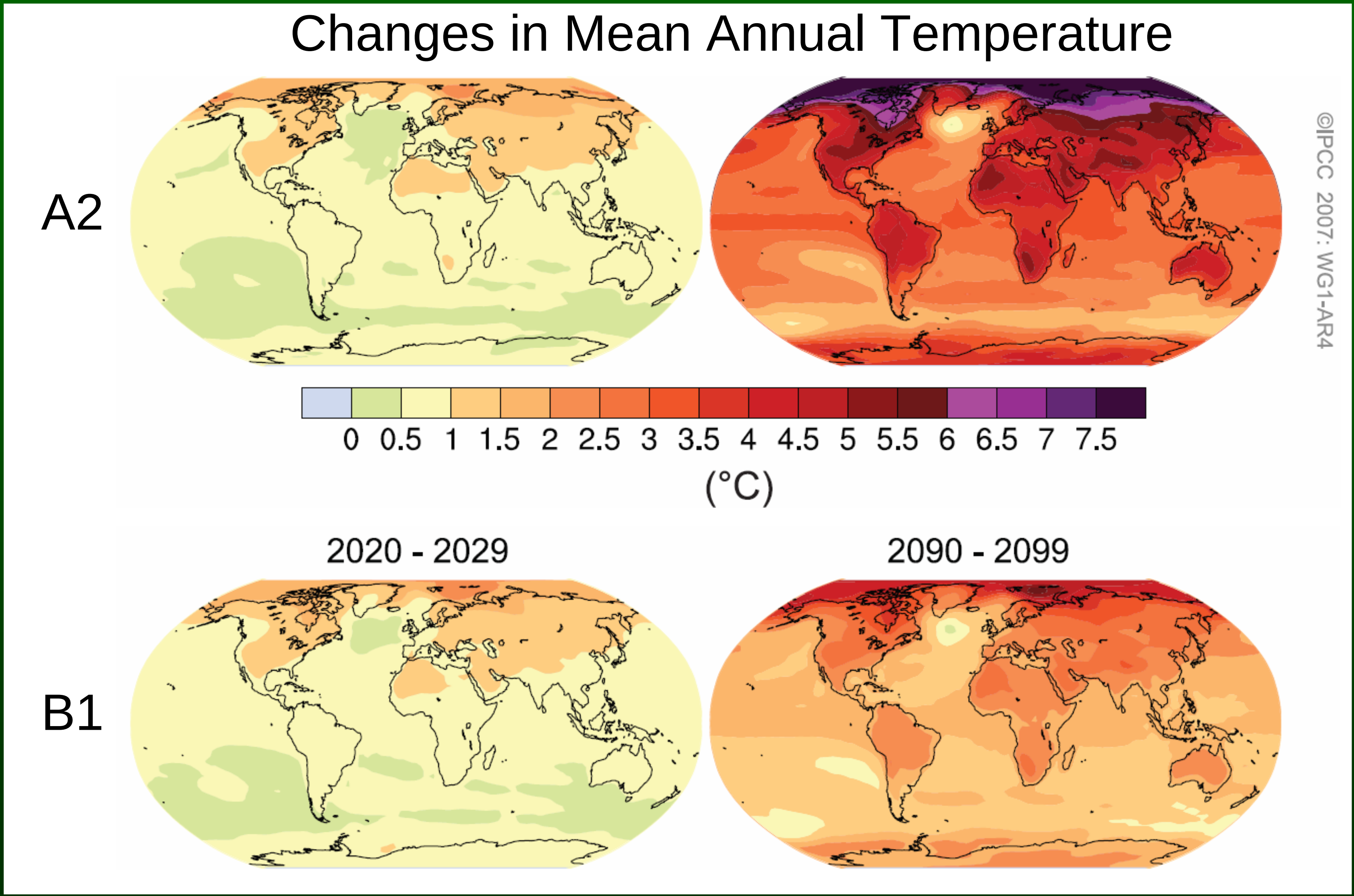
Source: Millennium Ecosystem Assessment, Synthesis Report, 2005

1. Which global ecosystems will be the most sensitive to climate change?

2. What level of intervention is justified by anticipated climate change?

i.e. where and how should we target our limited resources for conservation efforts?

Standard Metrics of Climate Change Focus Attention Away From Tropics



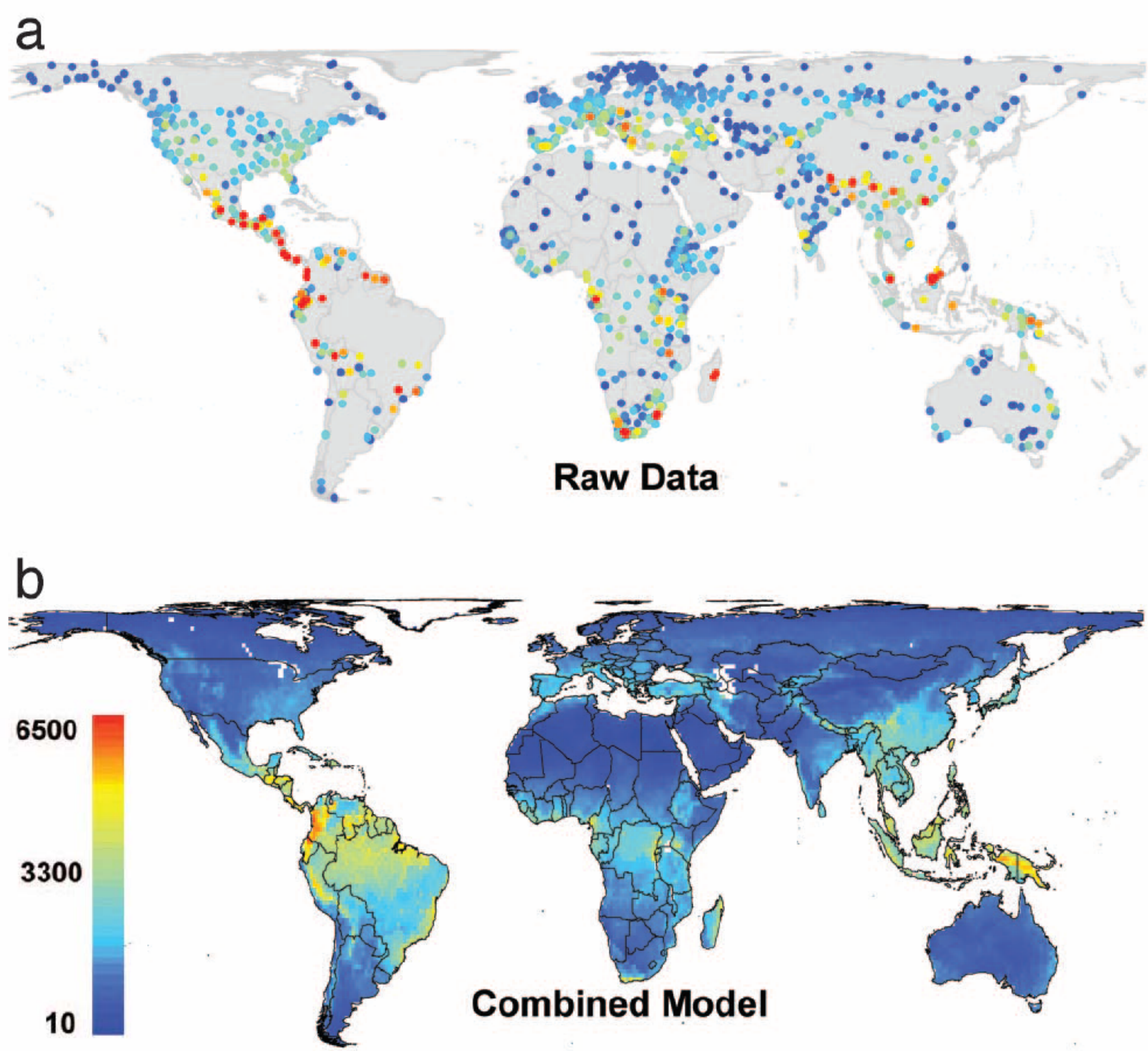
IPCC AR4 2007 Working Group I: Summary for Policymakers

Polar Bear as Poster Child for Climate Change & Biodiversity Impacts

Source: all over the internet

Of course, biodiversity is higher in tropics…

Vascular Plant Diversity



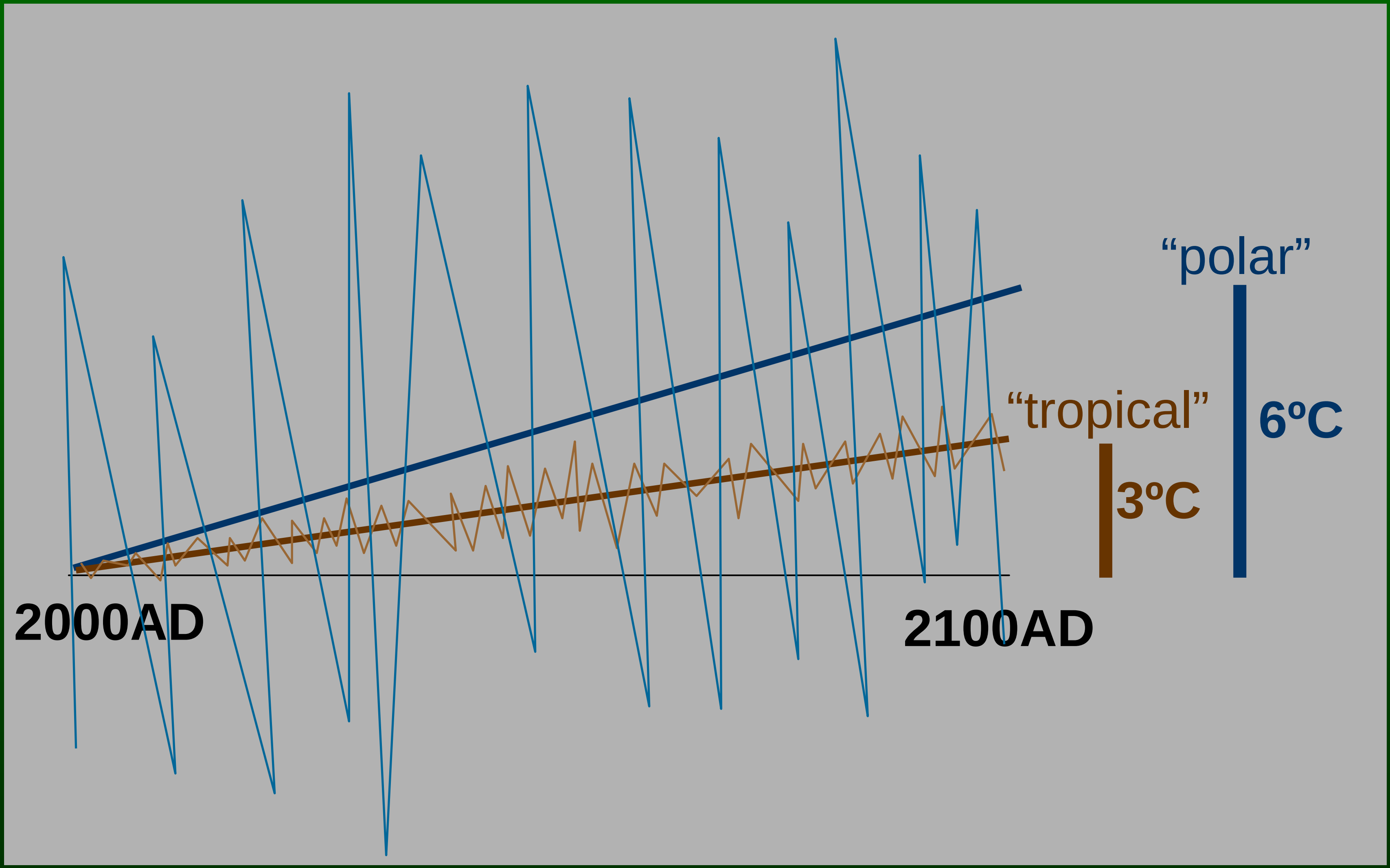
Kreft & Jetz, 2007 PNAS

But tropical species also may be more sensitive to climate change than extratropical species

Three Lines of Evidence:

- Climate/Statistical
- Biogeographical
- Physiological

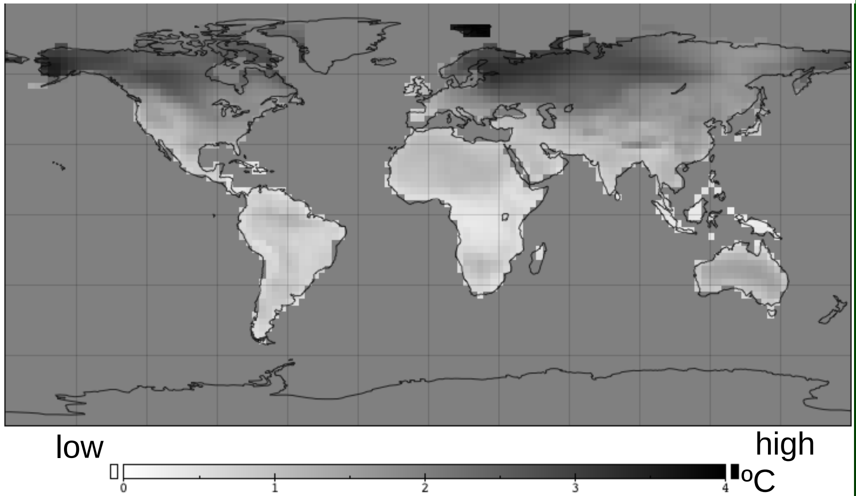
Q: Which temperature trend is more significant?



A: It depends… on the signal-to-noise ratio
(signal: 21st-century trend, noise: background var.)

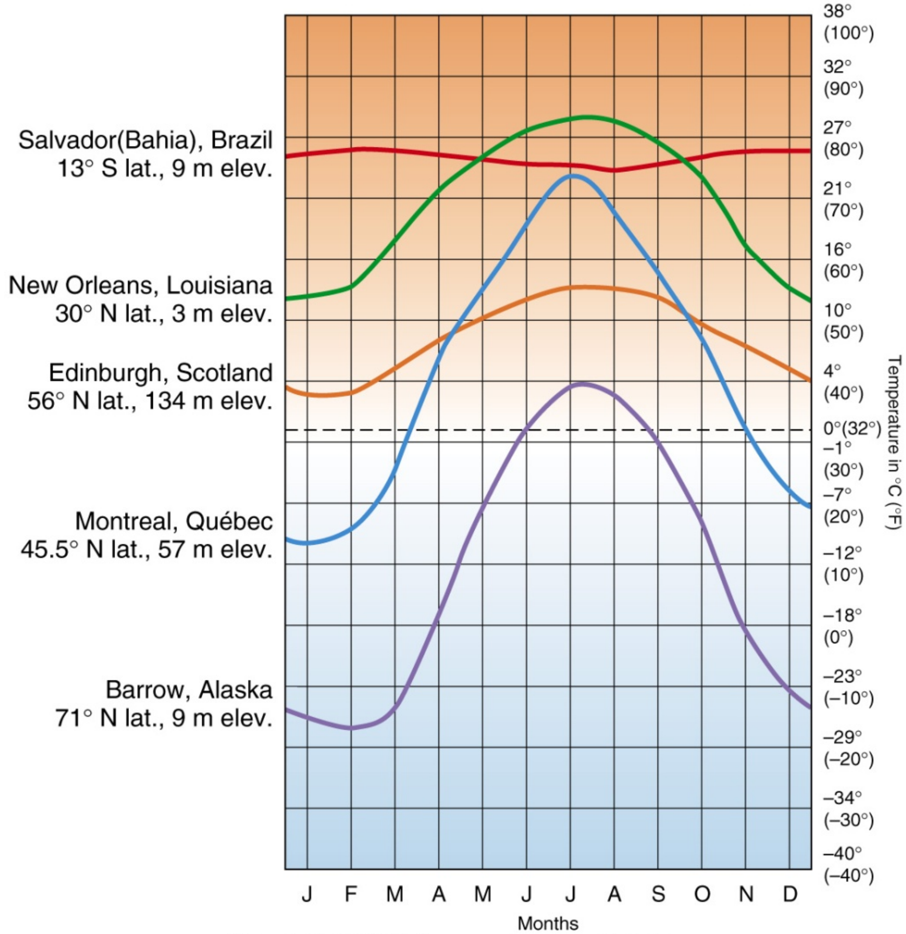
Temperature variability at all timescales is lower in tropics than in extratropics

Interannual variability (s_{DJFT})



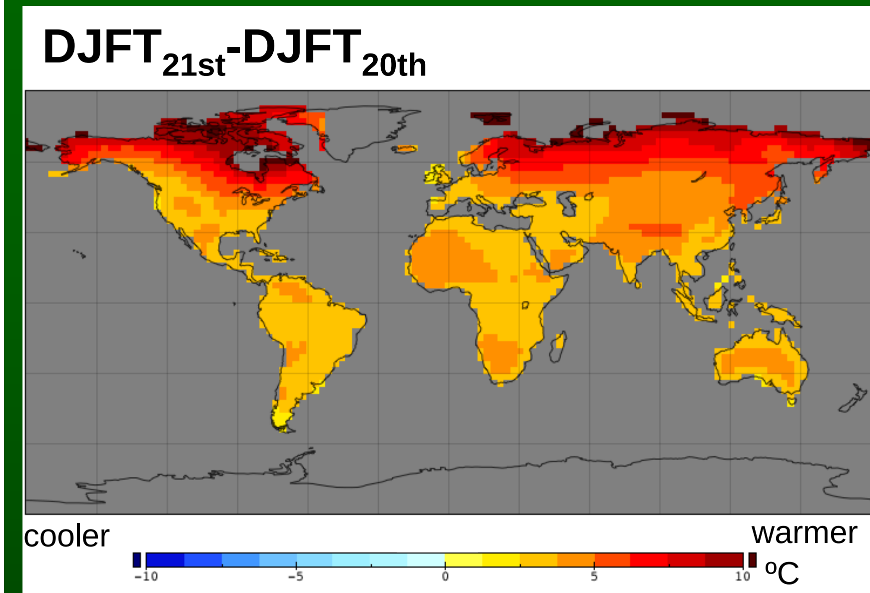
Williams, unpub.

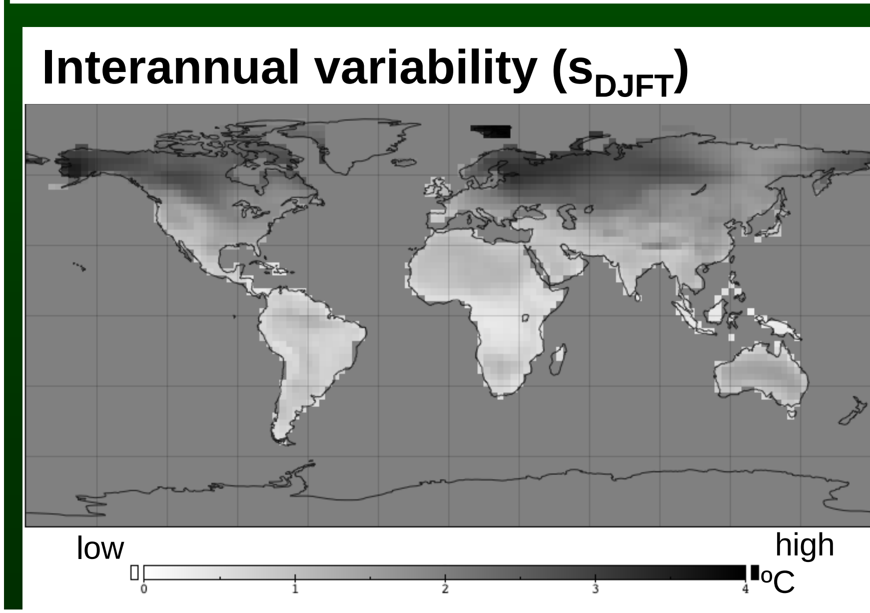
Temperature seasonality vs. latitude



Christensen, 2005, Geosystems

Temperature trends in tropics are large relative to interannual variability





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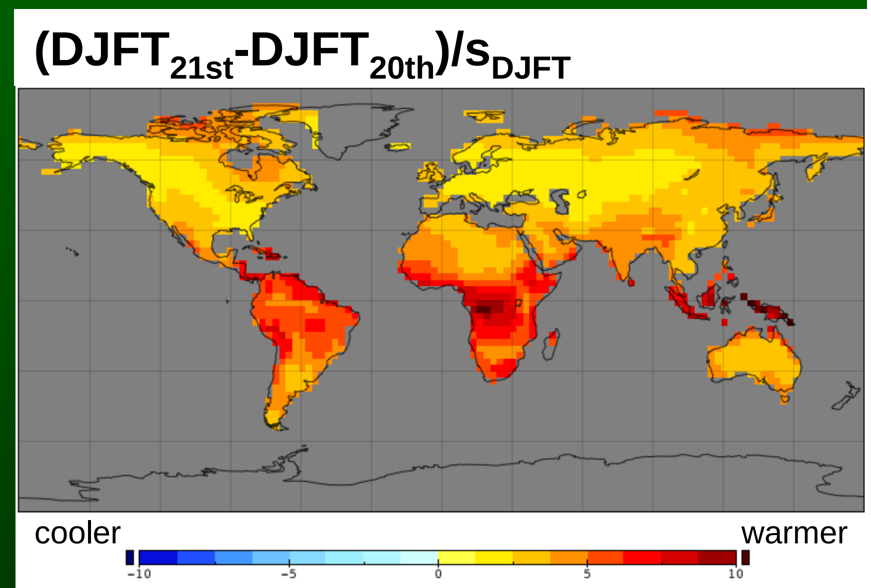
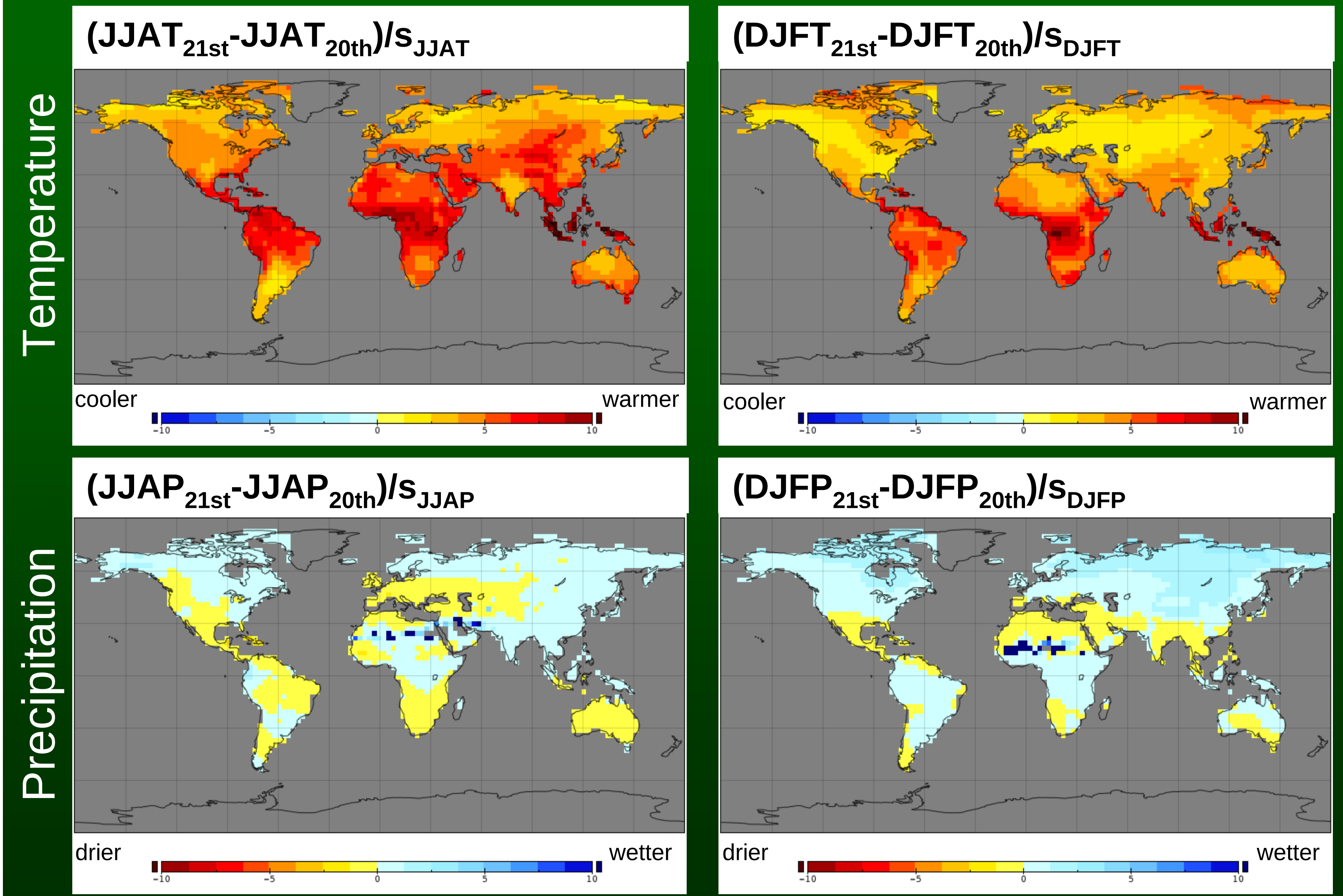


A2 Scenario

In standardized indices, warming signal dominates



(All variables on same scale)

Williams, unpub.

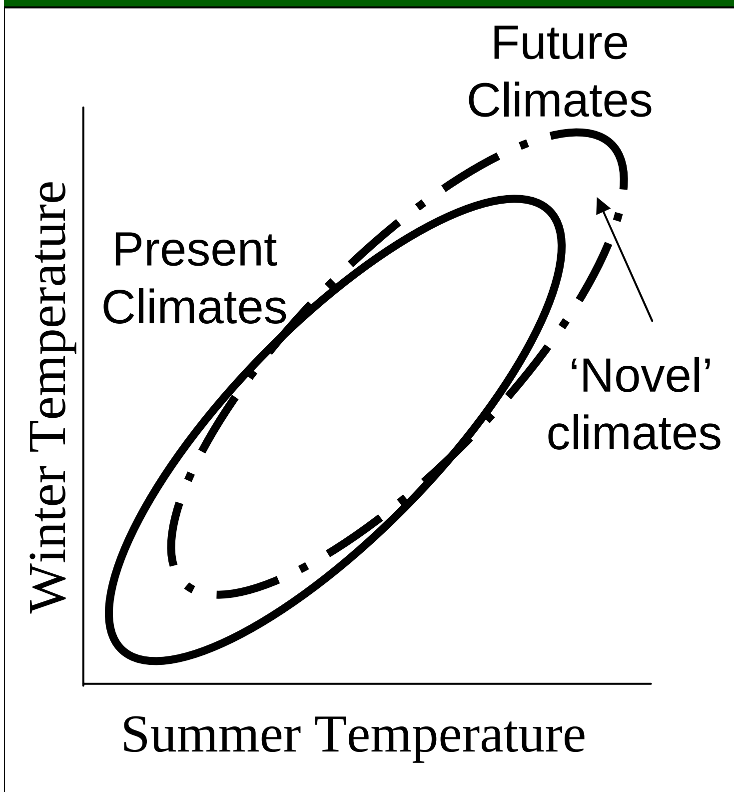
Climate-Change Index: Standardized Euclidean Distance (SED)

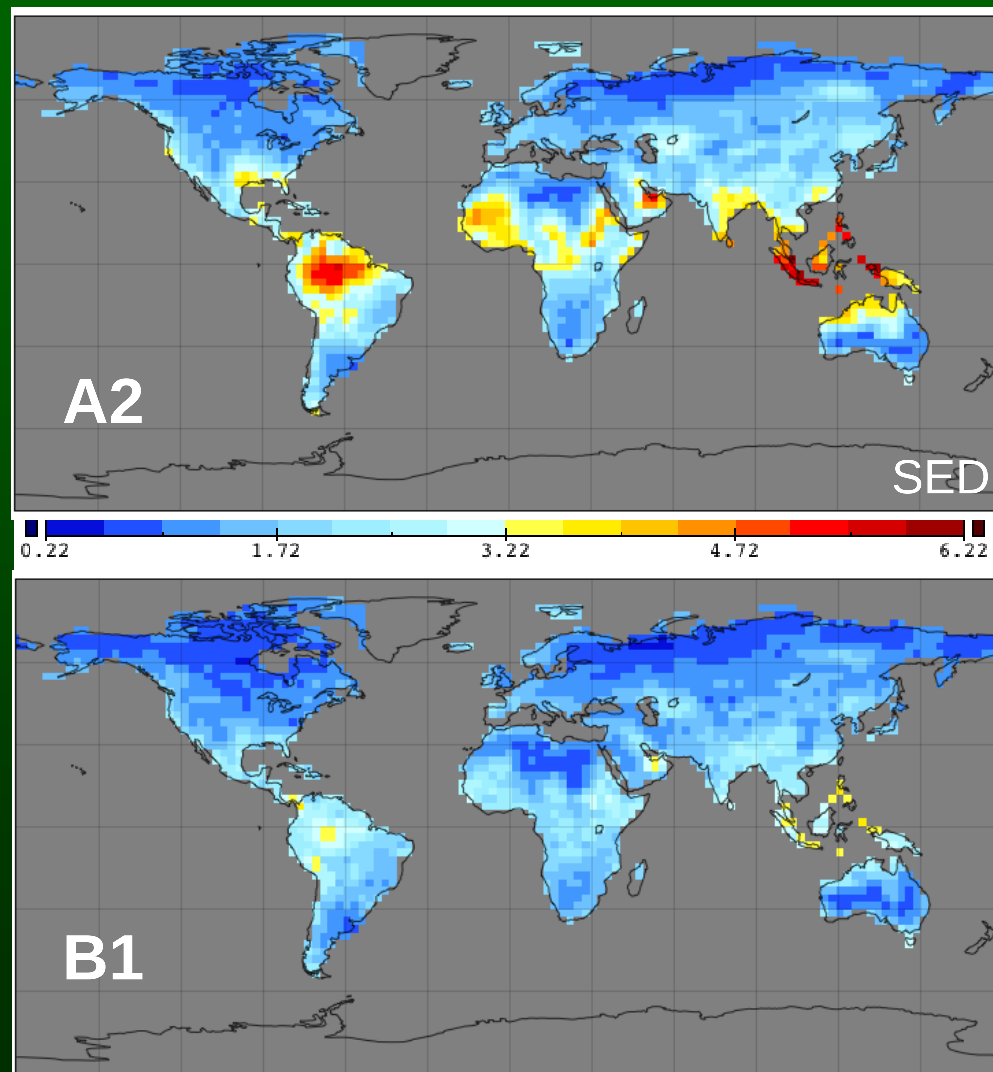
Euclidean Distance: $c = \sqrt{a^2 + b^2}$

$$SED_{ij} = \sqrt{\left(\frac{\left(JJAT_{21st} - JJAT_{20th}\right)}{s_{JJAT}}\right)^2 + \left(\frac{\left(JJAP_{21st} - JJAP_{20th}\right)}{s_{JJAP}}\right)^2 + \left(\frac{\left(DJFT_{21st} - DJFT_{20th}\right)}{s_{DJFT}}\right)^2 + \left(\frac{\left(DJFP_{21st} - DJFP_{20th}\right)}{s_{DJFP}}\right)^2}$$

- Integrates 4 variables: JJA Temp., JJA Precip., DJF Temp., DJF Precip
- Time Periods: 1980-1999 vs. 2080-2099 climate means
- 9 GCM's from IPCC Fourth Assessment Report (IPCC AR4)
- 2 scenarios: A2 (850ppm) and B1 (540ppm)
- **Climate differences are standardized by 1980-1999 interannual variance for each variable**

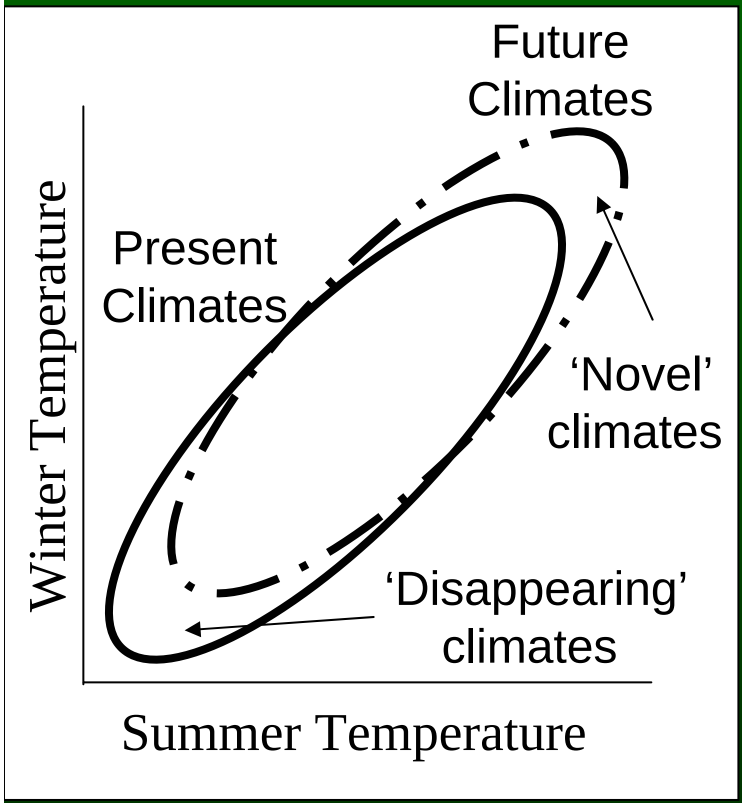
In a warming world, the *lowland tropics* will first move outside the current set of observed climates

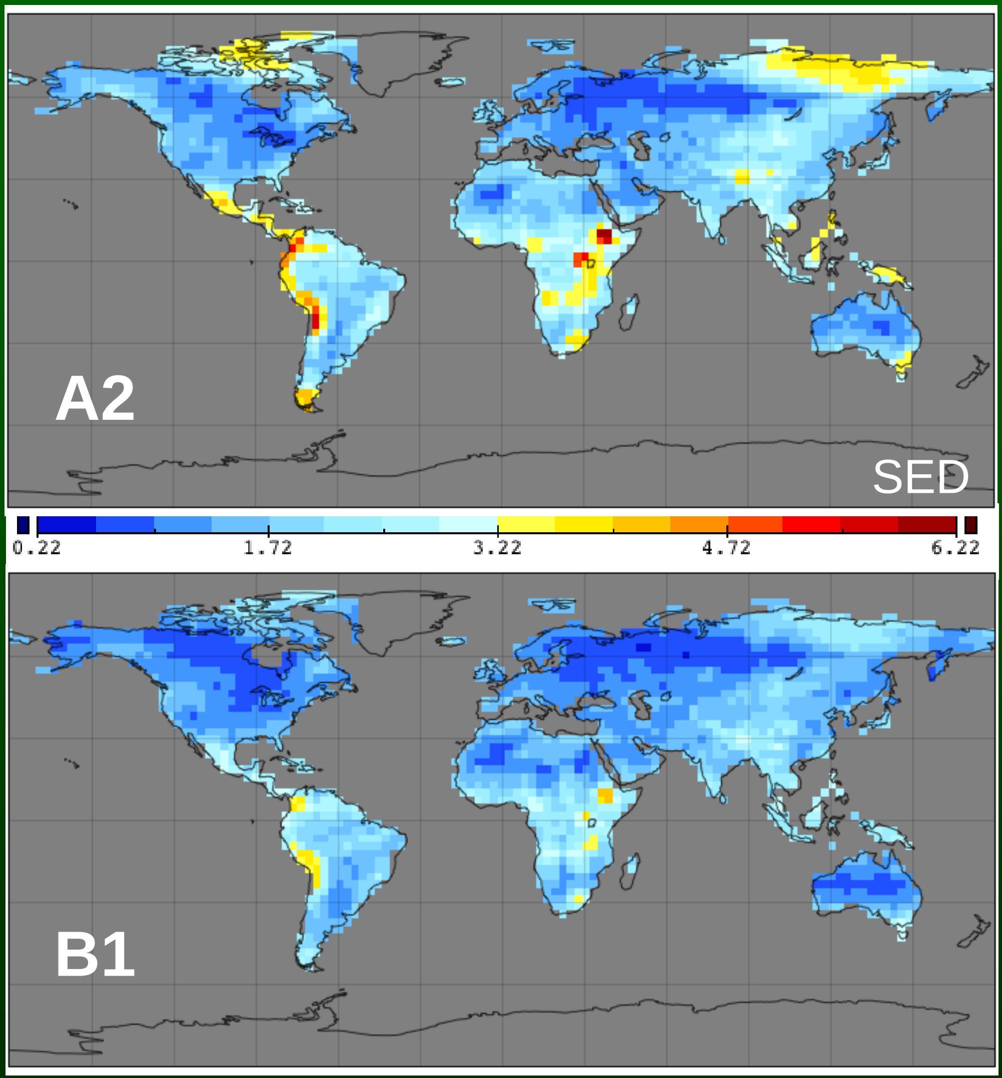




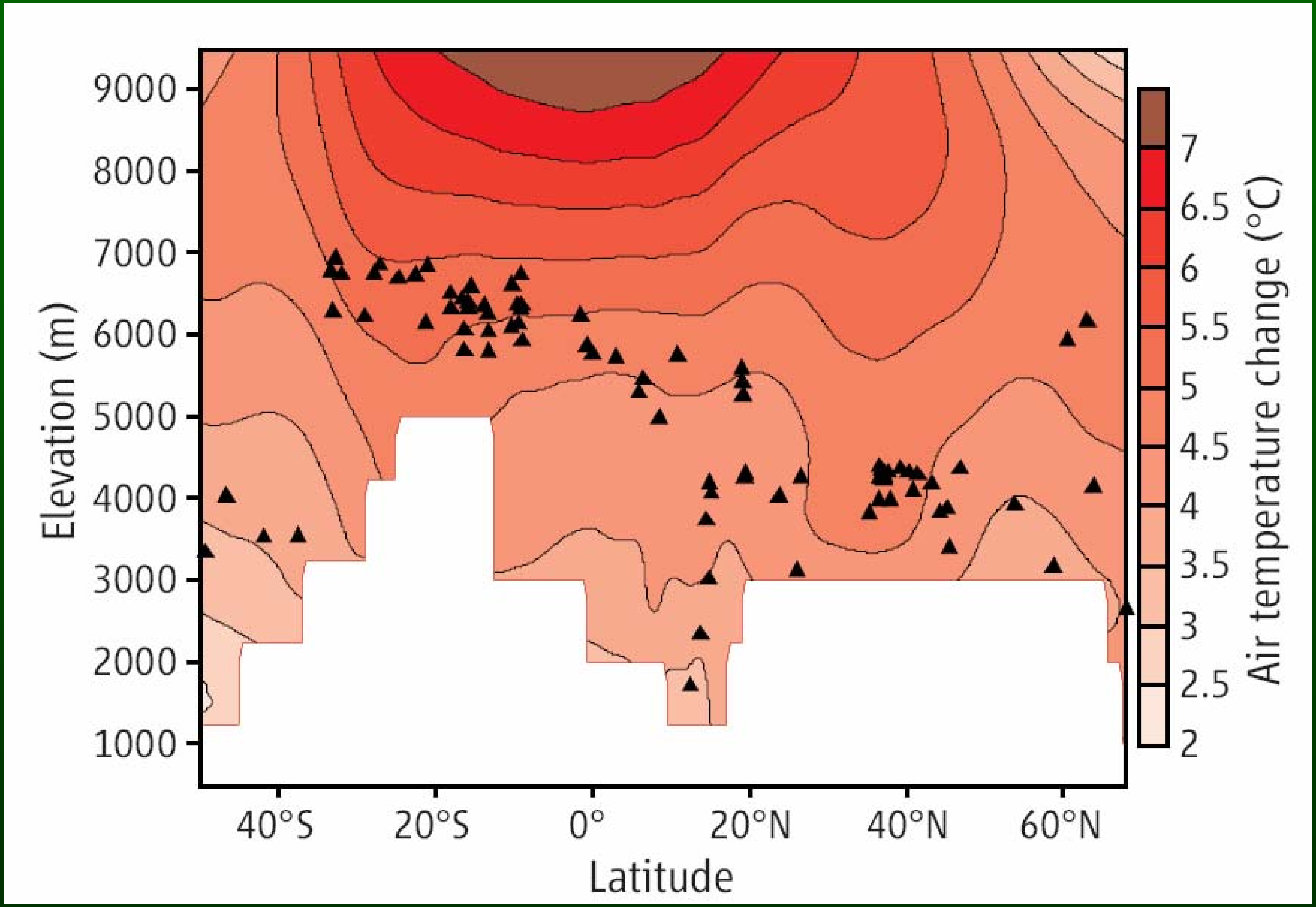
Williams et al. (2007) PNAS

In a warming world, *tropical montane* and *poleward* climates most at risk of disappearing entirely





Also: raw temperature increases larger for upper elevations of tropical Andes



Bradley et al. 2006 Science

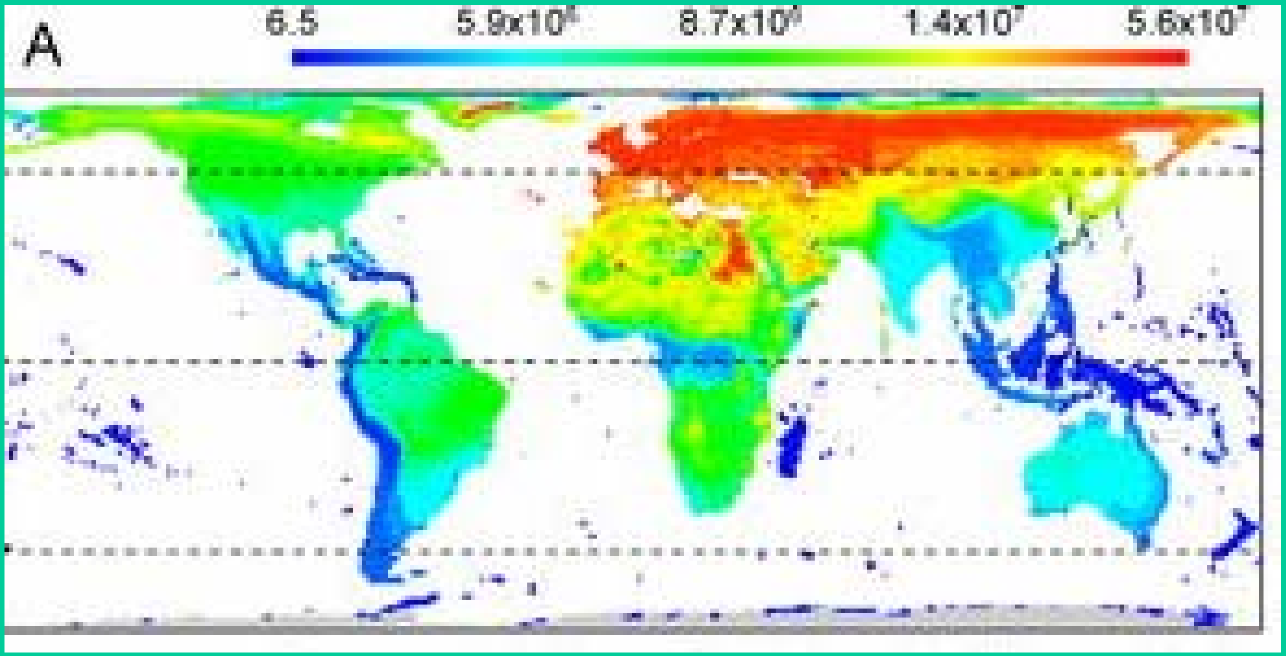
But tropical species also may be more *sensitive* than extratropical species

Three Lines of Evidence:

- Climate/Statistical
- Biogeographical
- Physiological

Rapaport's Rule: Species' (geographic) range areas tend to decrease towards the equator

Median range area (km^2) for the global avifauna



Orme et al. (2006) PLoS Biology

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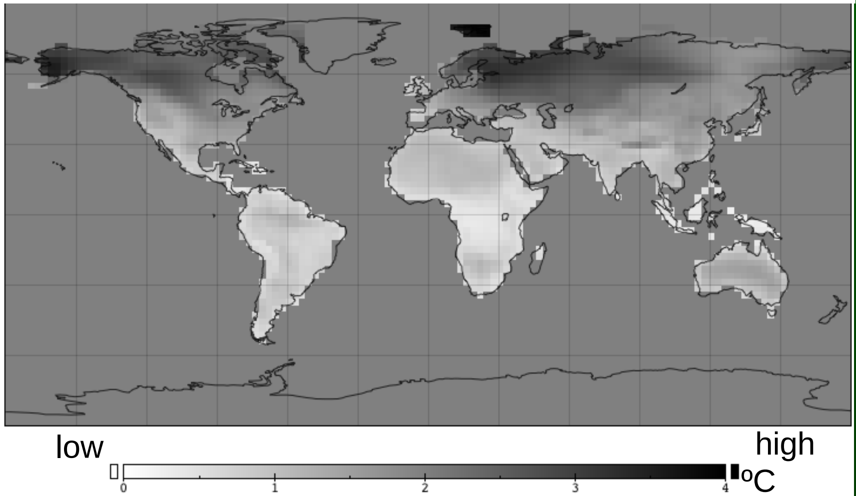
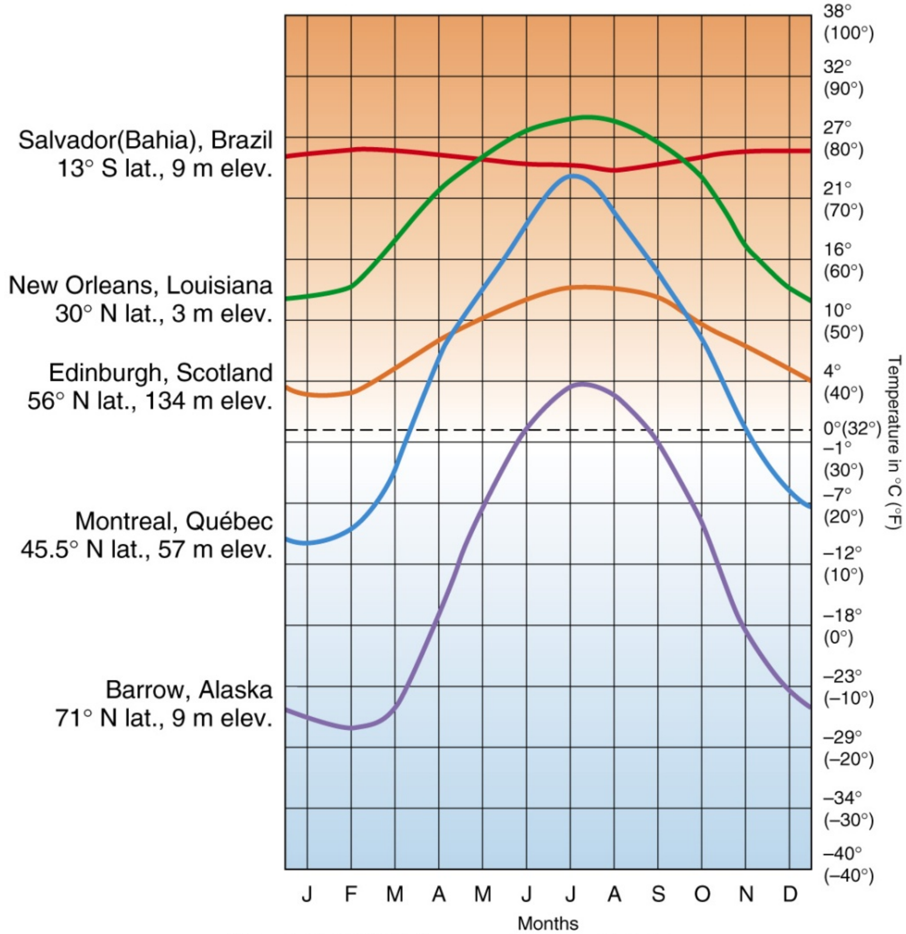


Williams, unpub.

Temperature seasonality vs. latitude



Christensen, 2005, Geosystems

Therefore, the areas of species thermal ranges (niches) should also decline towards the equator

Vol. 101, No. 919 The American Naturalist May–June, 1967

WHY MOUNTAIN PASSES ARE HIGHER IN THE TROPICS*

DANIEL H. JANZEN

Department of Entomology, The University of Kansas, Lawrence

"The larger the usual variation around the mean environmental values, the higher the probability that an organism will survive a given deviation from that mean." – Janzen 1967

Biogeographic theory thus predicts that tropical species will have a higher climatic endemism than temperate species.

Therefore, tropical species should be more sensitive/vulnerable to changes in temperature.

But tropical species also may be more sensitive than extratropical species

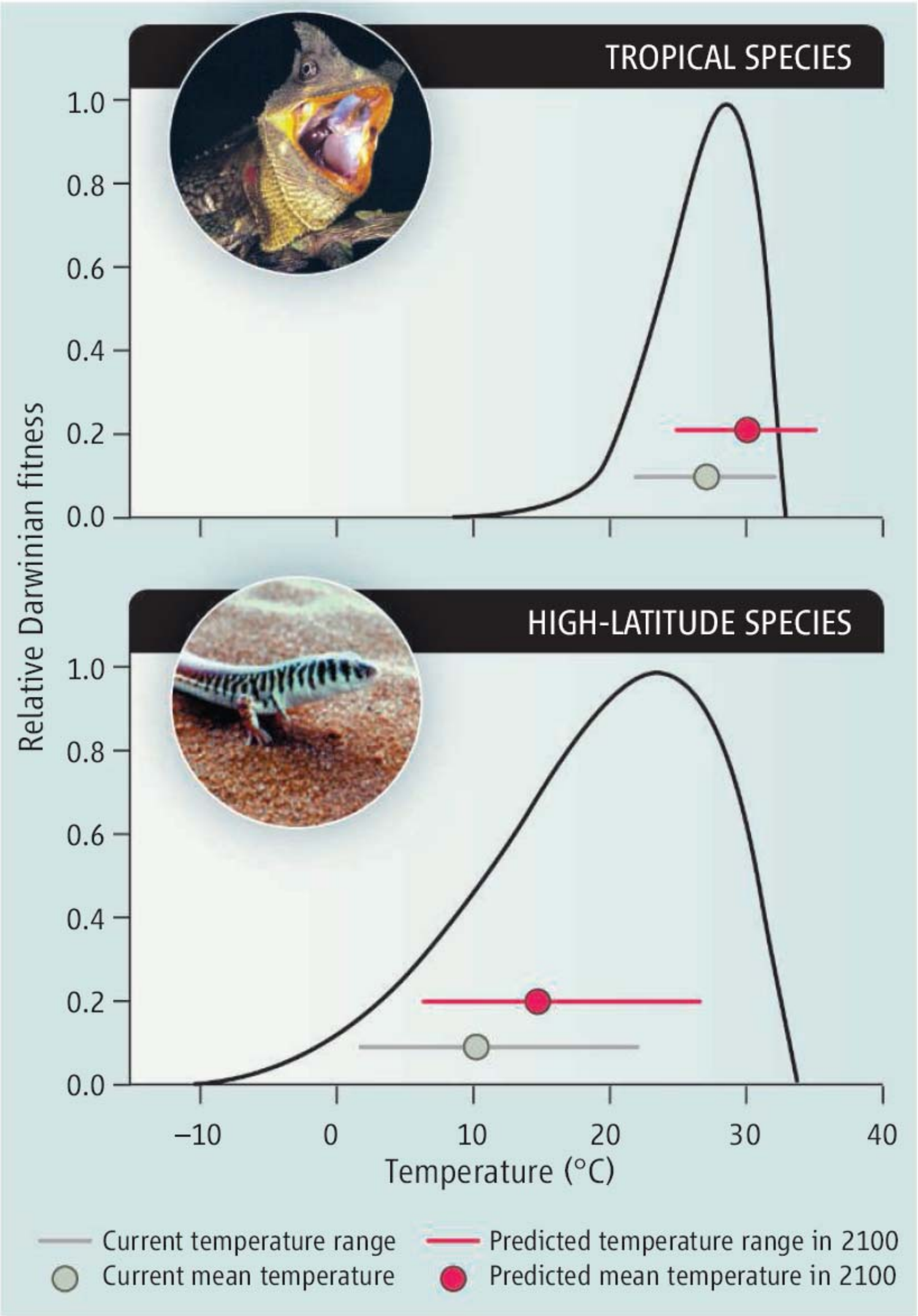
Three Lines of Evidence:

- Climate/Statistical
- Biogeographical
- Physiological

Janzen hypothesis supported by physiological data for ectotherms

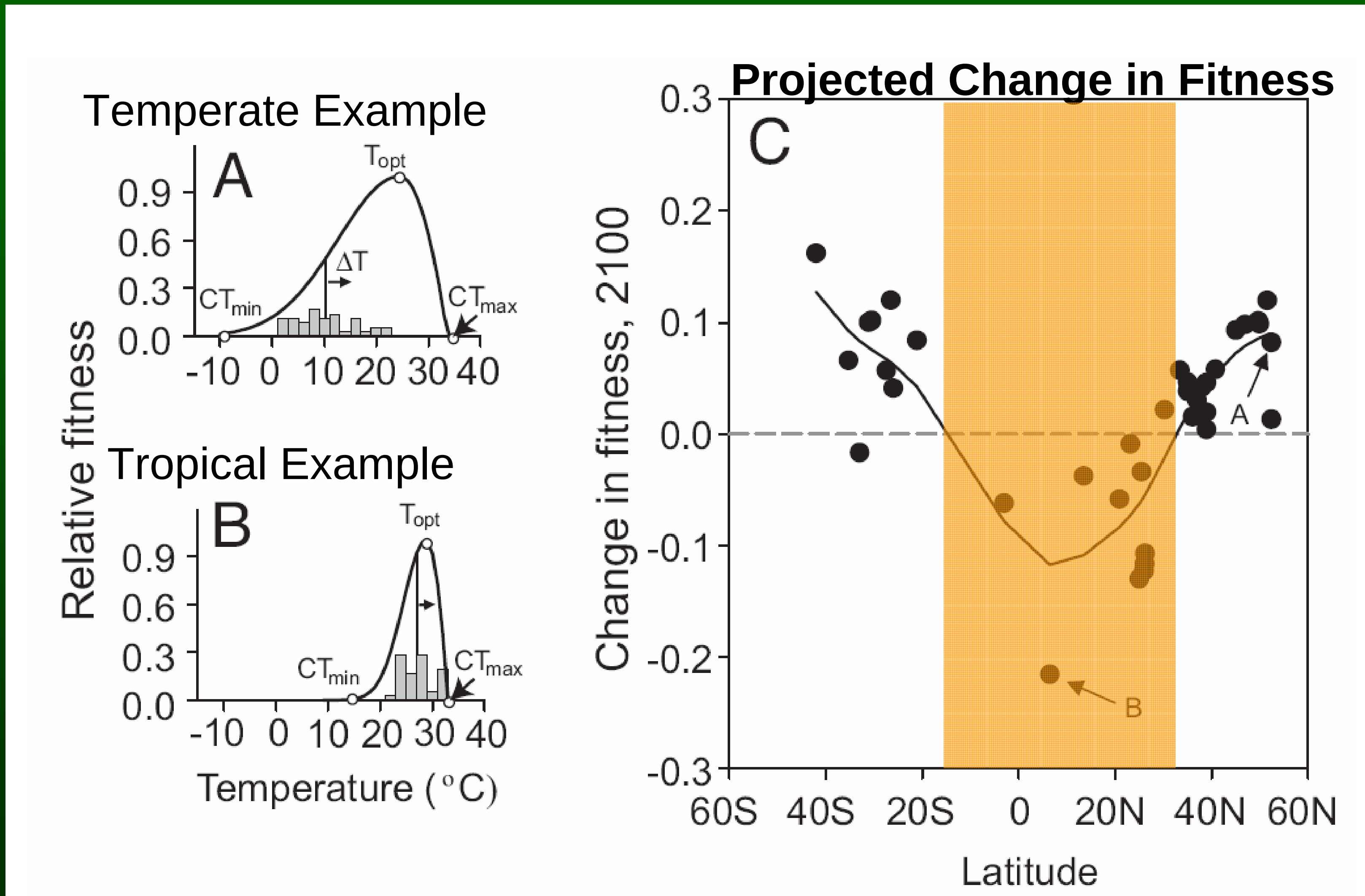
Temperate species have wider fitness range (black line)

Tropical species closer to their thermal limit



Tewksbury et al. 2008 Science

Fitness declines projected for tropical insects



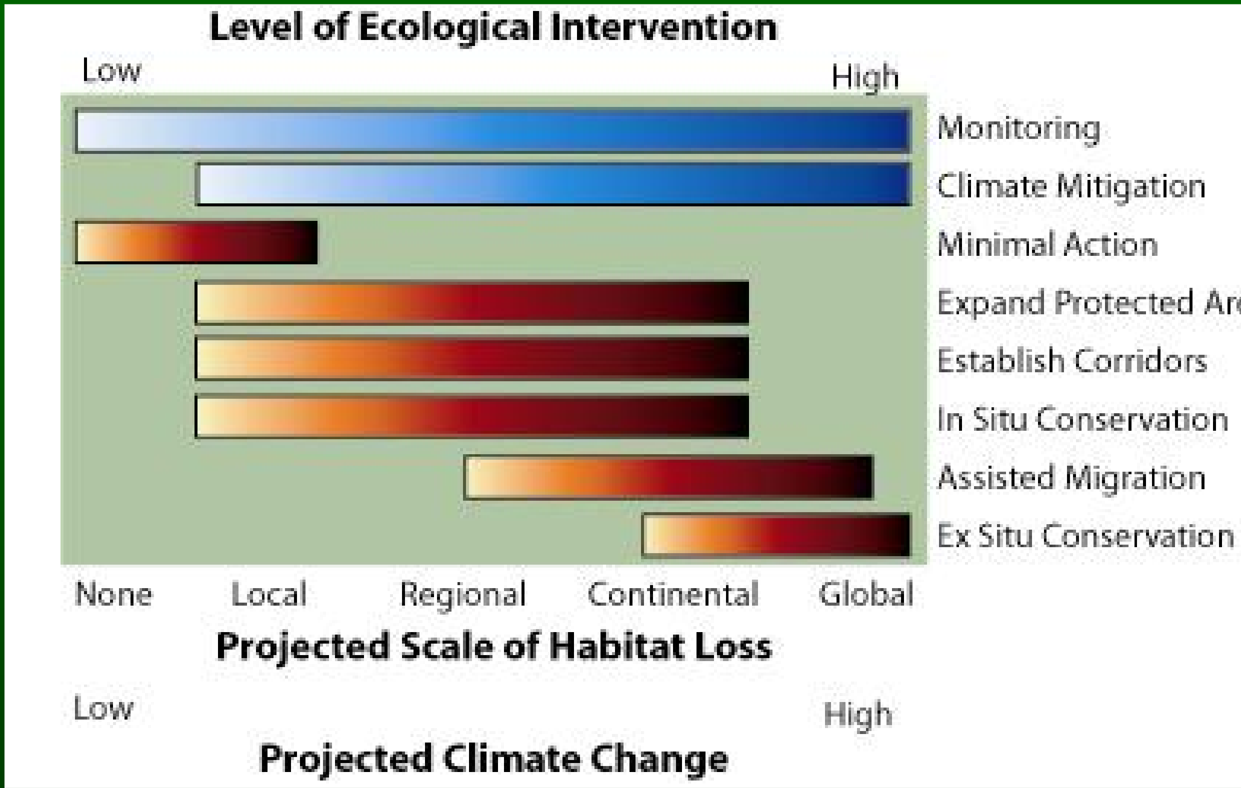
Deutsch et al. 2008 PNAS

1. Which global ecosystems will be the most sensitive to climate change?

2. What level of intervention is justified by anticipated climate change?

i.e. where and how should we target our limited resources for conservation efforts?

What level of intervention is justified by anticipated climate change?



Williams, unpub.

Given high uncertainty of future regional climate projections and ecological sensitivity, a portfolio approach is needed

Climate-Change Index: Standardized Euclidean Distance (SED)

Euclidean Distance: $c = \sqrt{a^2 + b^2}$

$$SED_{ij} = \sqrt{\left(\frac{(JJAT_{21st} - JJAT_{20th})}{s_{JJAT}}\right)^2 + \left(\frac{(JJAP_{21st} - JJAP_{20th})}{s_{JJAP}}\right)^2 + \left(\frac{(DJFT_{21st} - DJFT_{20th})}{s_{DJFT}}\right)^2 + \left(\frac{(DJFP_{21st} - DJFP_{20th})}{s_{DJFP}}\right)^2}$$

- Integrates 4 variables: JJA Temp., JJA Precip., DJF Temp., DJF Precip
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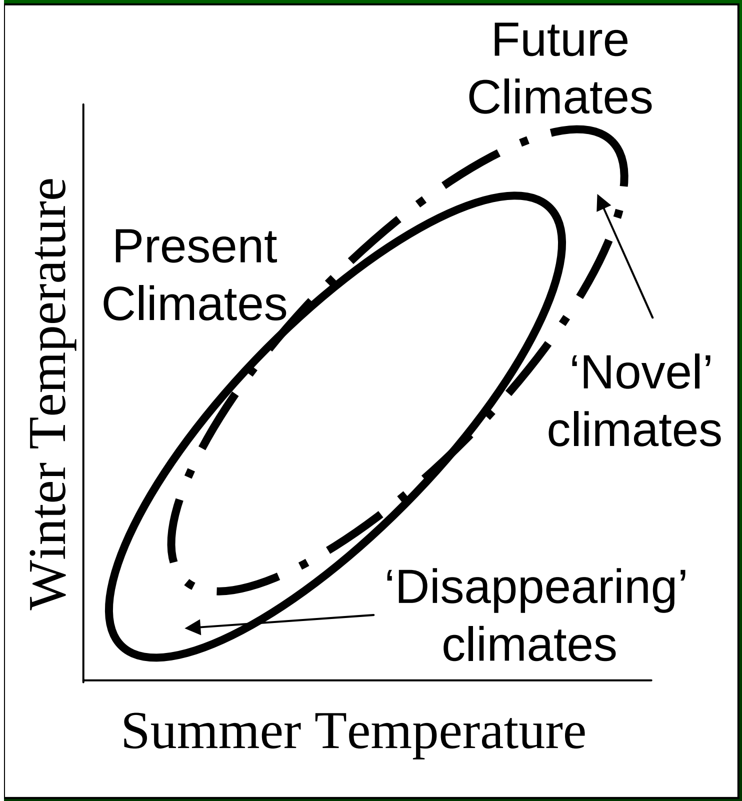
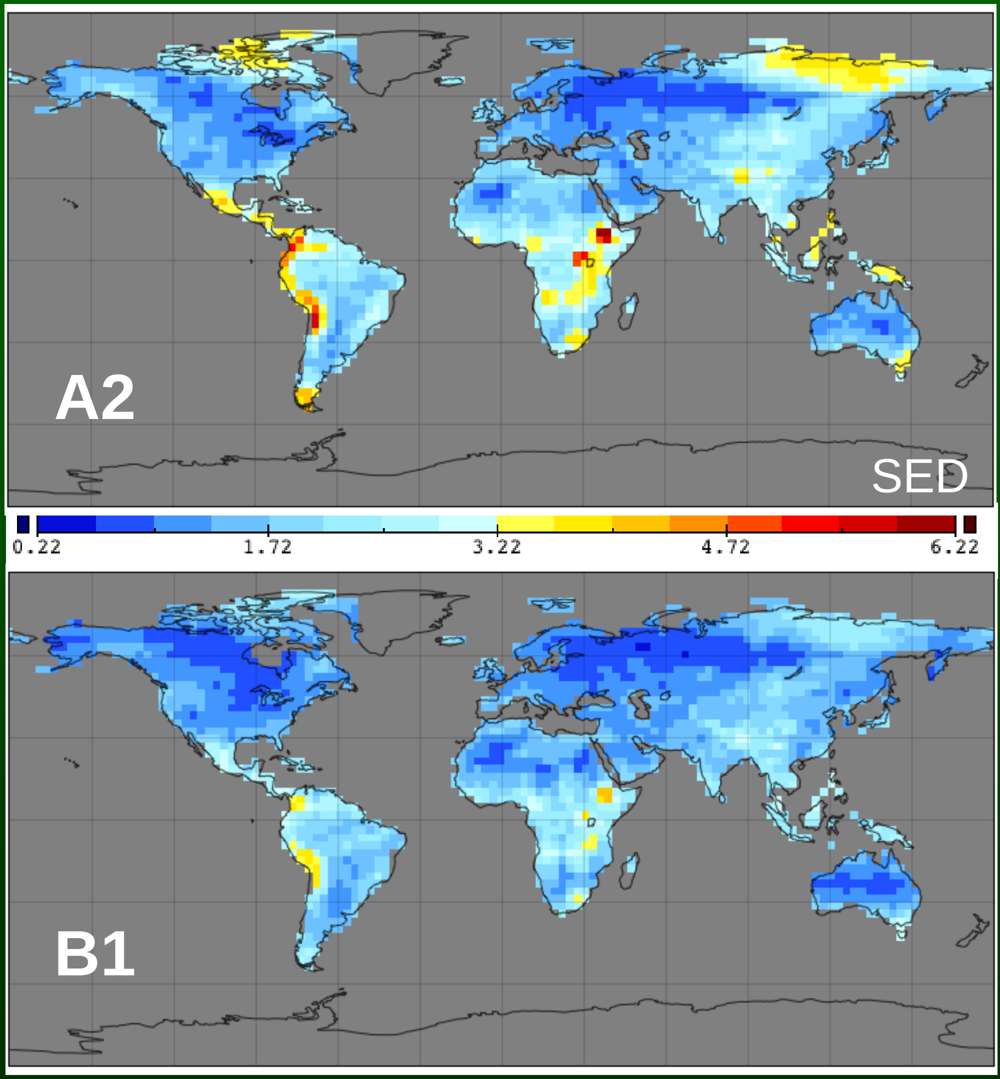
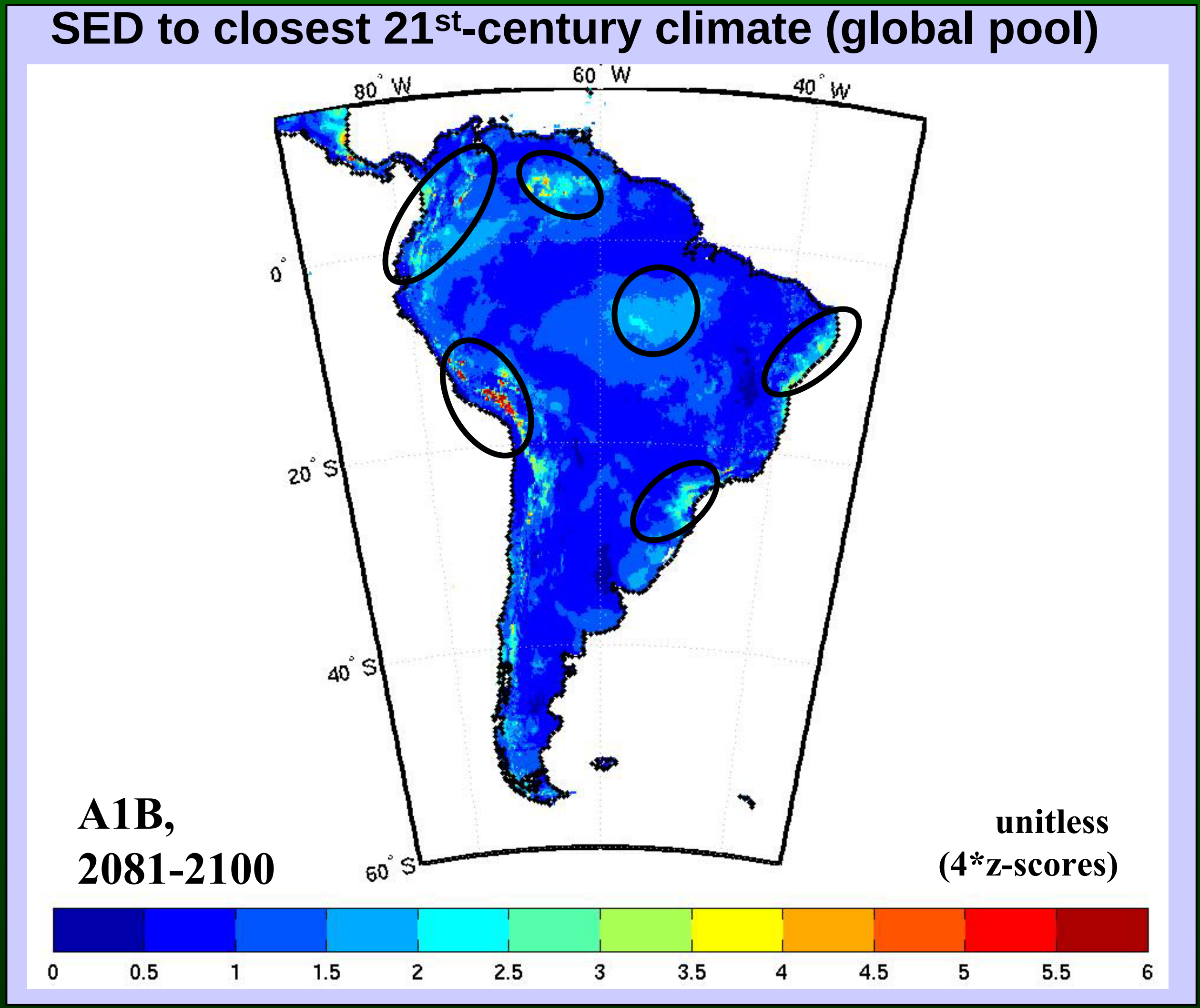


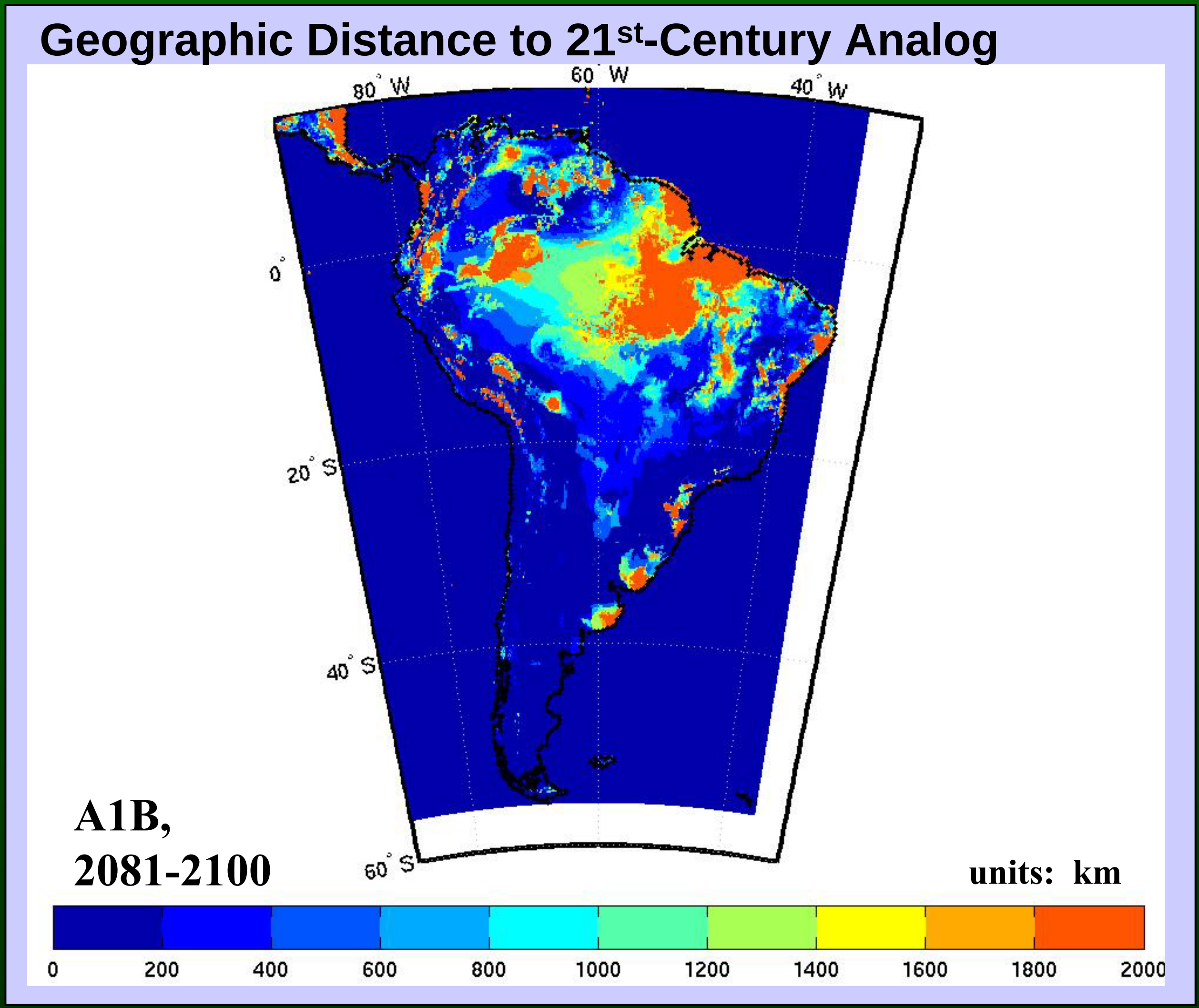


Priorities for ex situ conservation: sites with no good future analogs.



Jack Williams, University of Wisconsin
Karyn Tabor, Conservation International

Priorities for assisted migration: sites where similar future climates exist, but are far away



Jack Williams, University of Wisconsin
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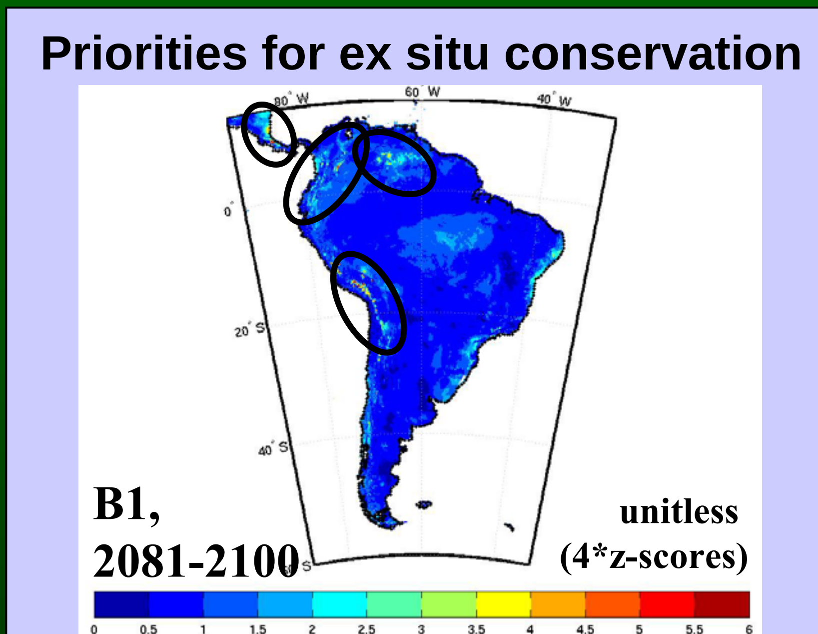
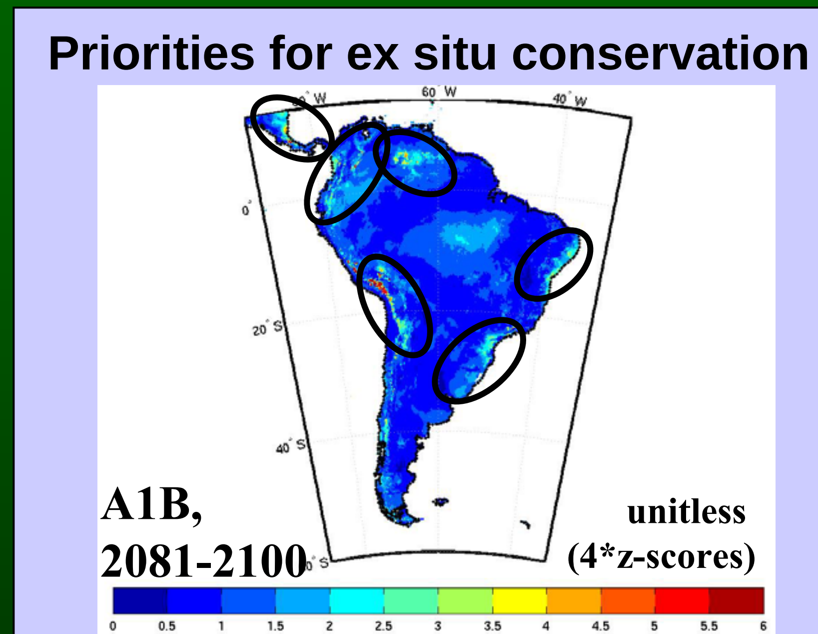
Alternate Emission Scenarios Provide Rationale for Mitigation Efforts

B1



A1B



1. Which global ecosystems will be the most sensitive to climate change?

Well, all, but tropics certainly a contender…

2. What level of intervention is justified by anticipated climate change?

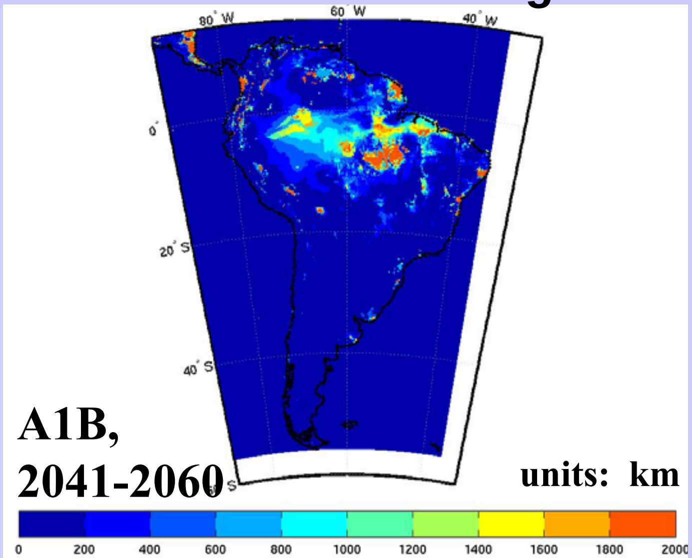
All options should be on the table; more work needed to determine the appropriate mix for each region.

SCRAP

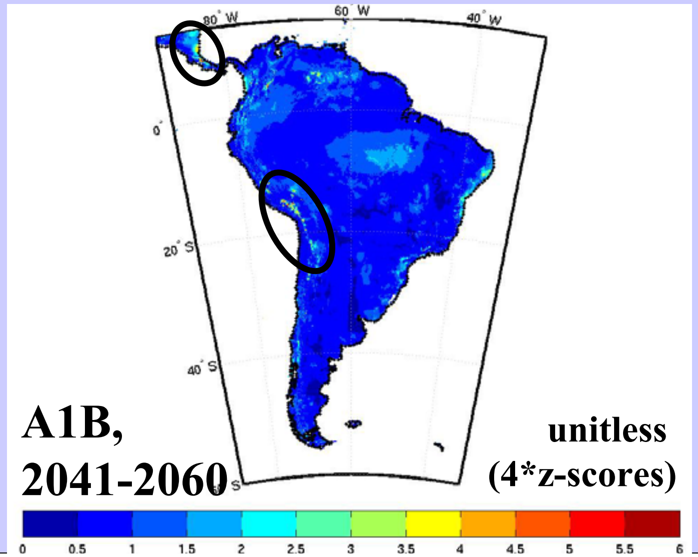
Alternate time horizons

2050

Priorities for Assisted Migration

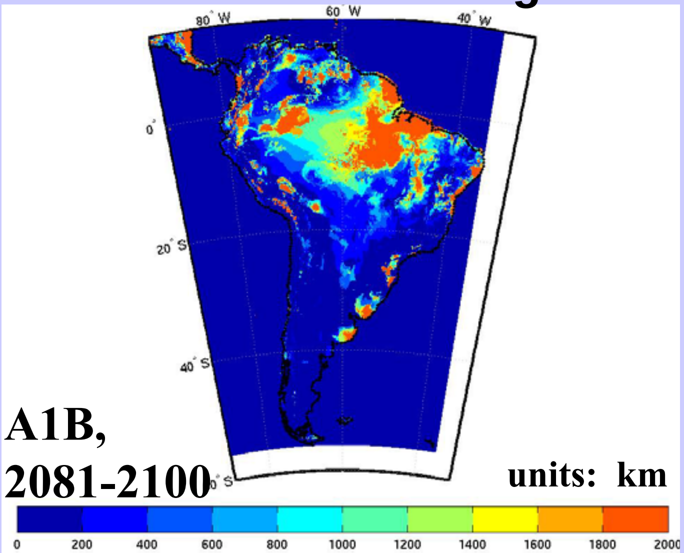


Priorities for ex situ conservation

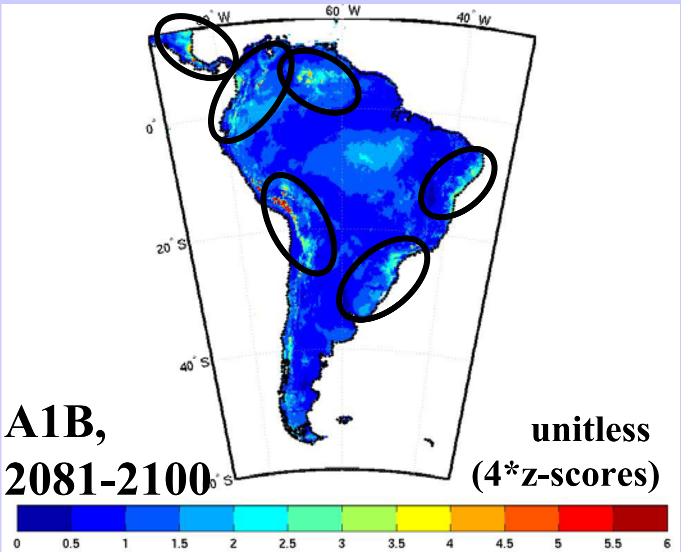


2090

Priorities for Assisted Migration

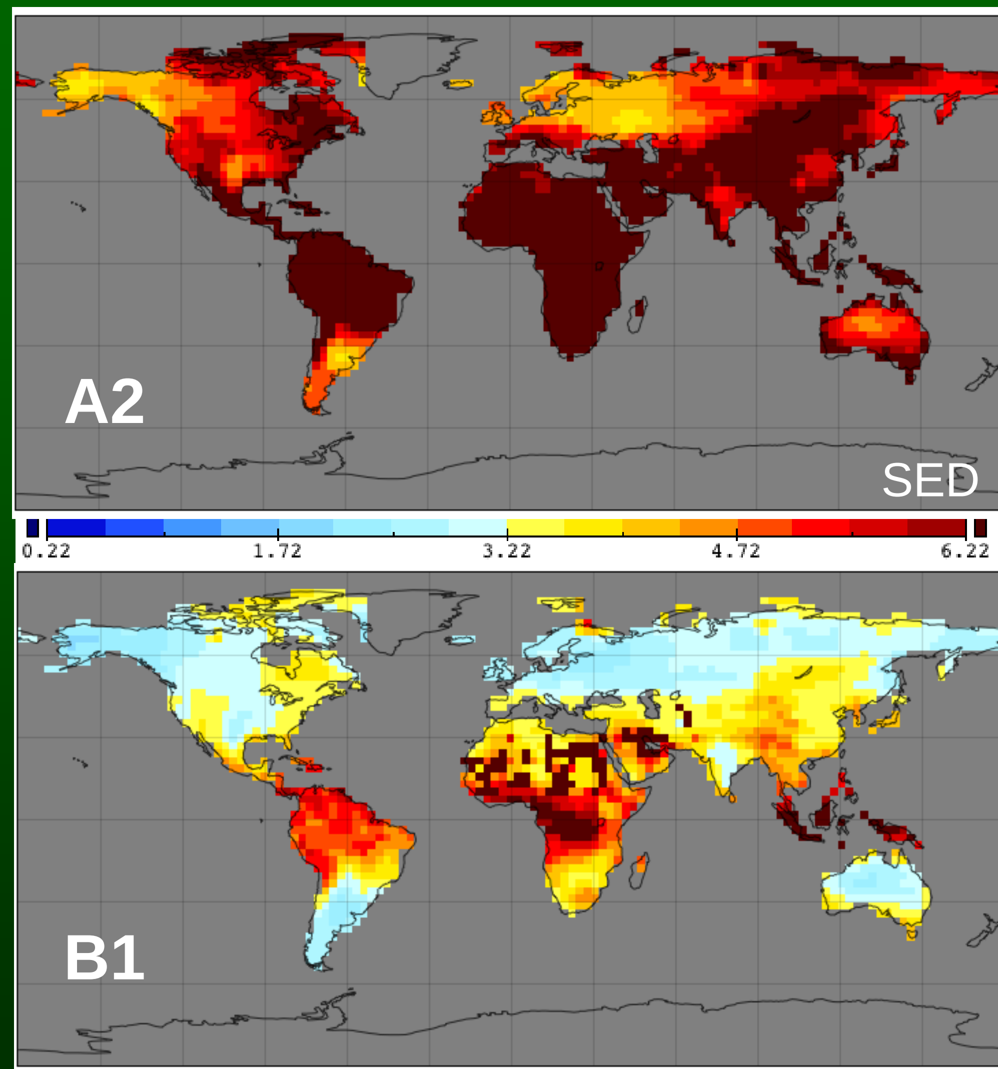


Priorities for ex situ conservation

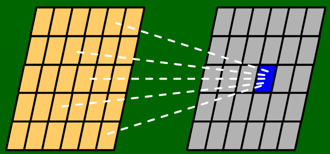


Which areas will experience large climate changes in the 21st century?

- Largest climate changes in tropics
- Caused by:
  1) moderate temperature changes
  2) low interannual temperature variability
  3) precipitation changes

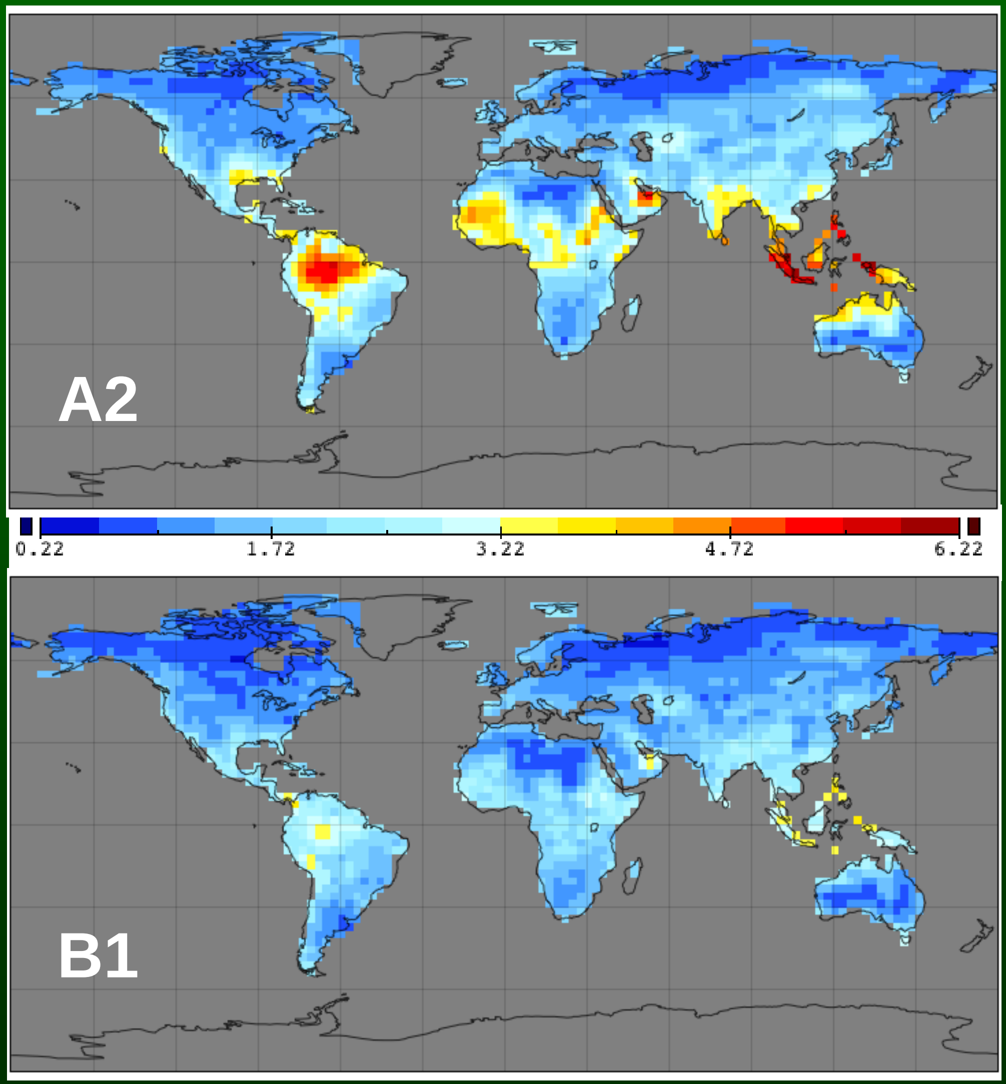


Williams et al. (2007) PNAS



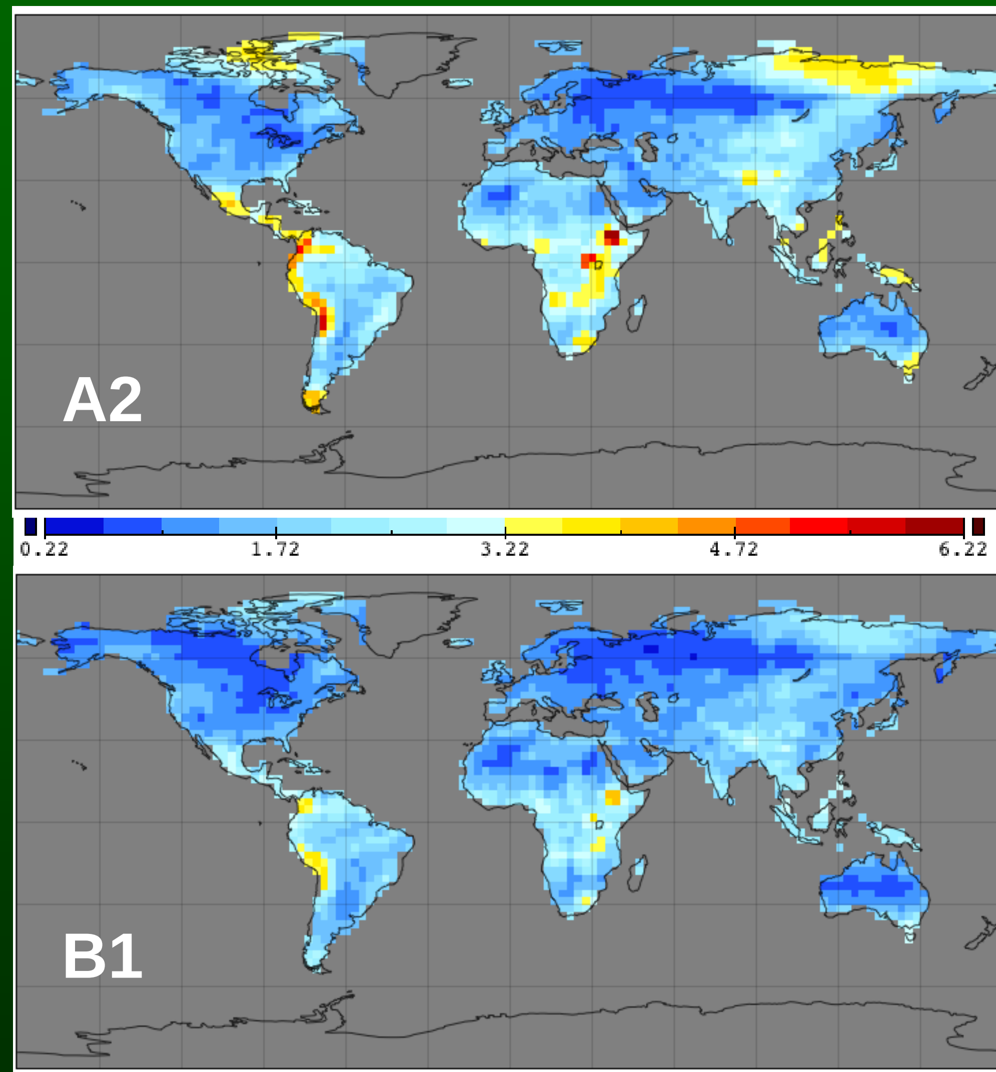
Which end-21st-century climates will lack current analogs?

- Novel climates most common in humid tropical ecosystems
- %Area with novel climates:
  A2: 5-35%
  B1: 0-16%

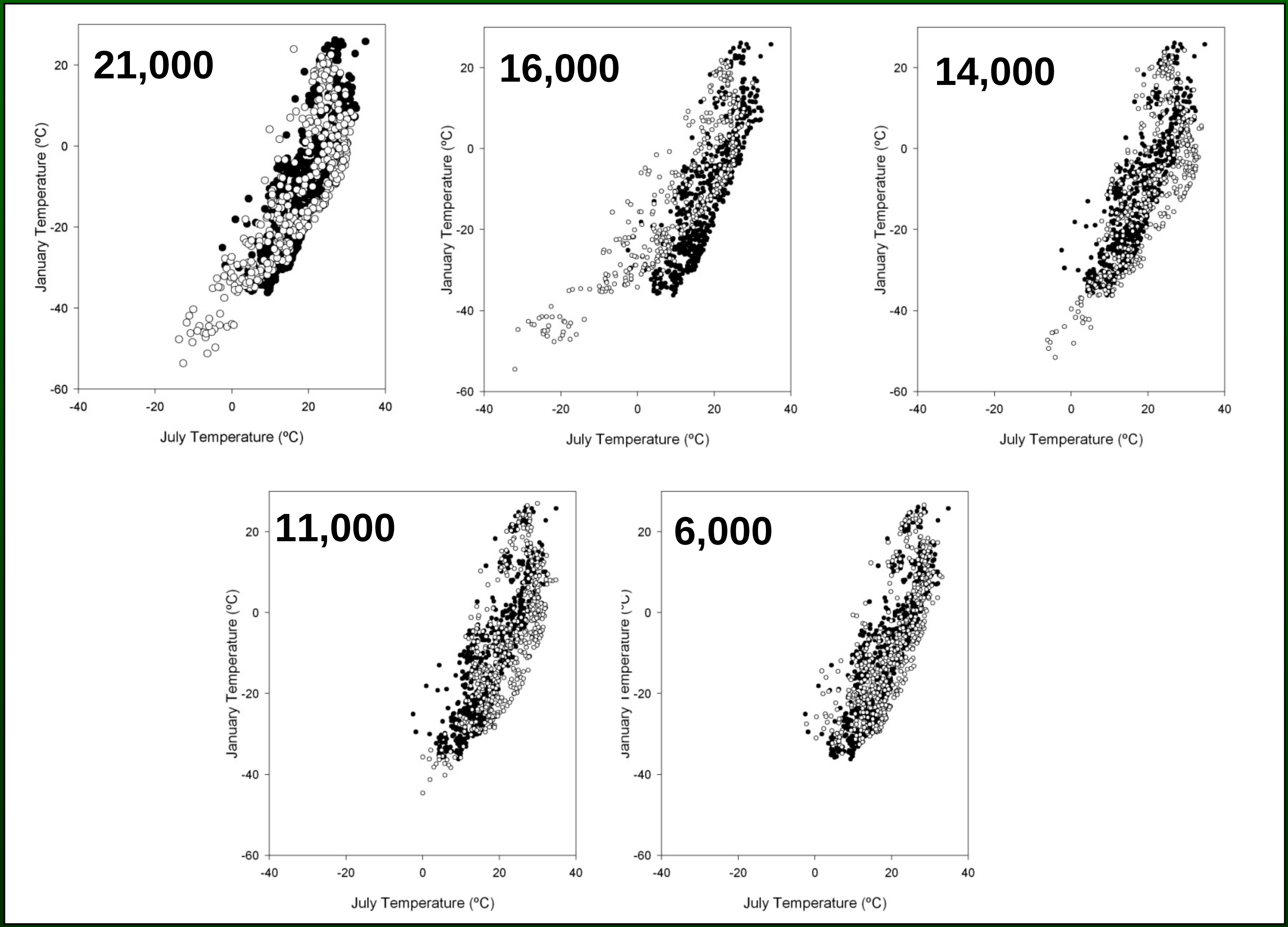


Which current climates will disappear?

- Disappearing climates common in tropical montane and poleward regions
- %Area with disappearing climates:
  A2: 4-34%
  B1: 0-10%



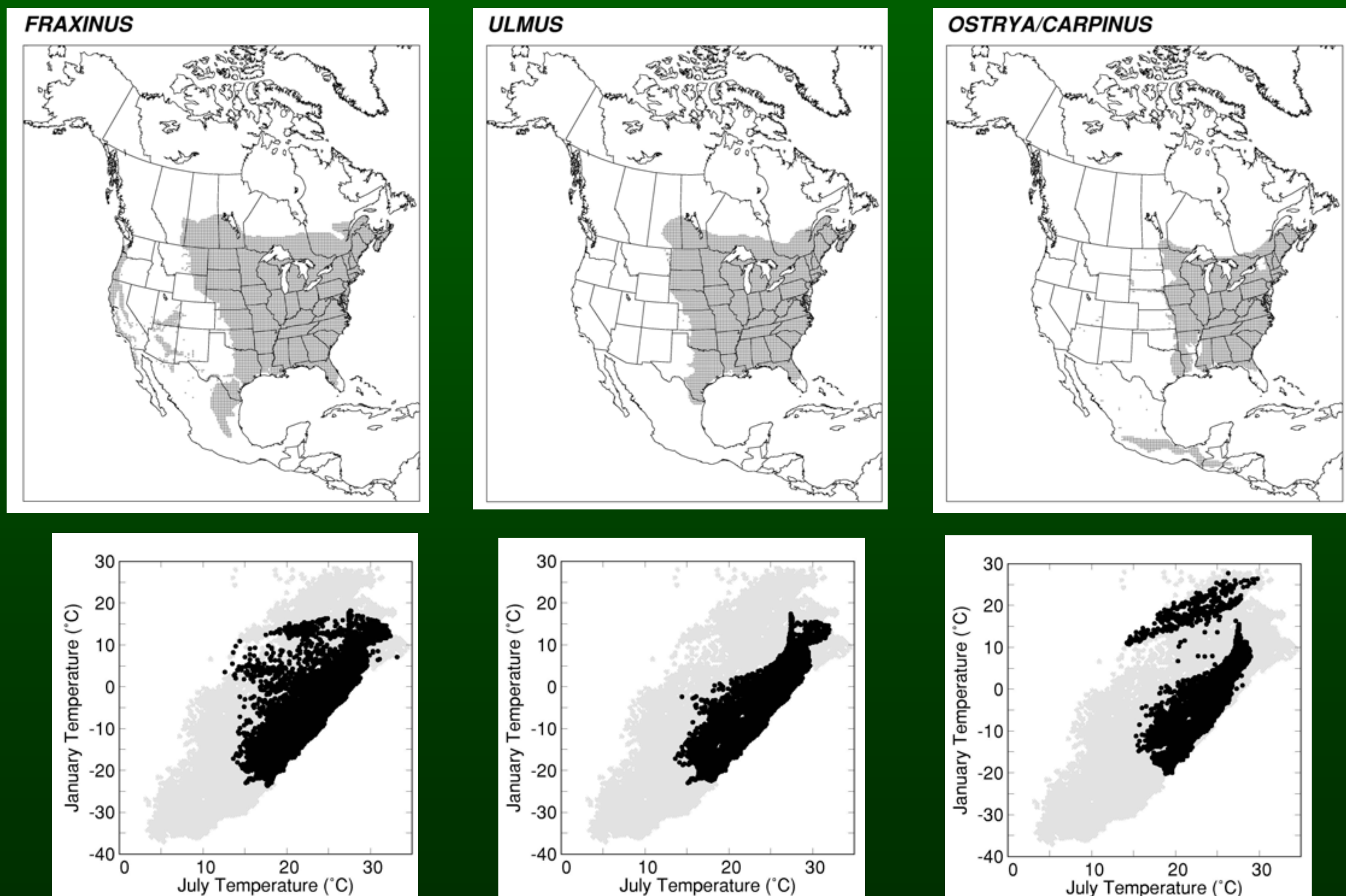
CCM1: 'no-analog' climates in direction of increased seasonality



(Jackson and Williams 2004 AREPS)

Increased seasonality is consistent with modern climate distributions of key plant taxa

Tree Ranges in Modern Climate Space



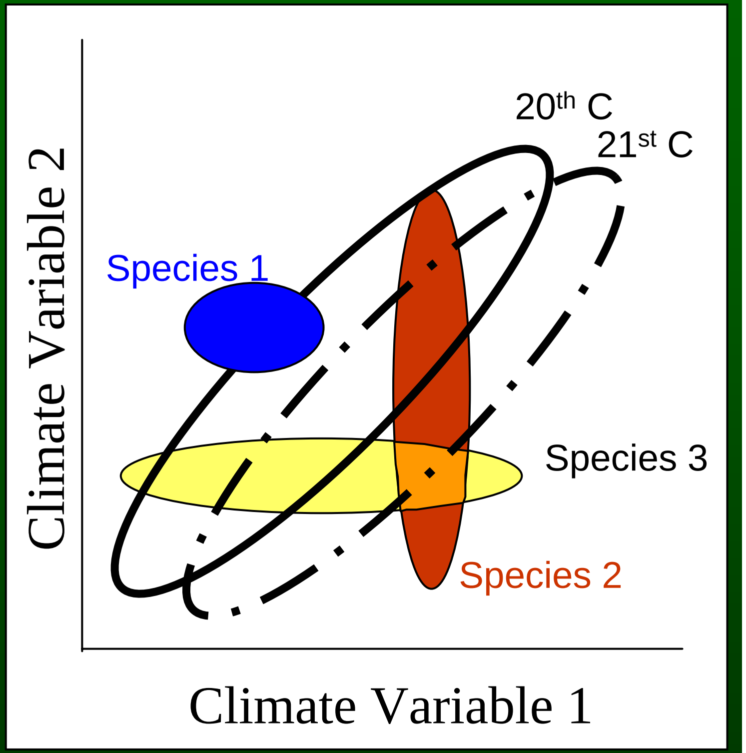
(Thompson et al. 1999a,b)

Summary of Late-Quaternary Analyses

- ‘No-analog’ pollen assemblages widespread in upper Midwest 17-12ka
- Characterized by mixture of boreal conifers and temperate deciduous taxa able to accommodate highly seasonal conditions
- Local vegetation responses lag climate by <100yr
- Multiple lines of evidence support niche theory and connection between no-analog climates and vegetation

Questions for the 21st Century

- *Which areas will experience large climate changes in the 21st century?*
- *Which end-21st-century climates will lack current analogs?*
- *Which current climates will disappear?*



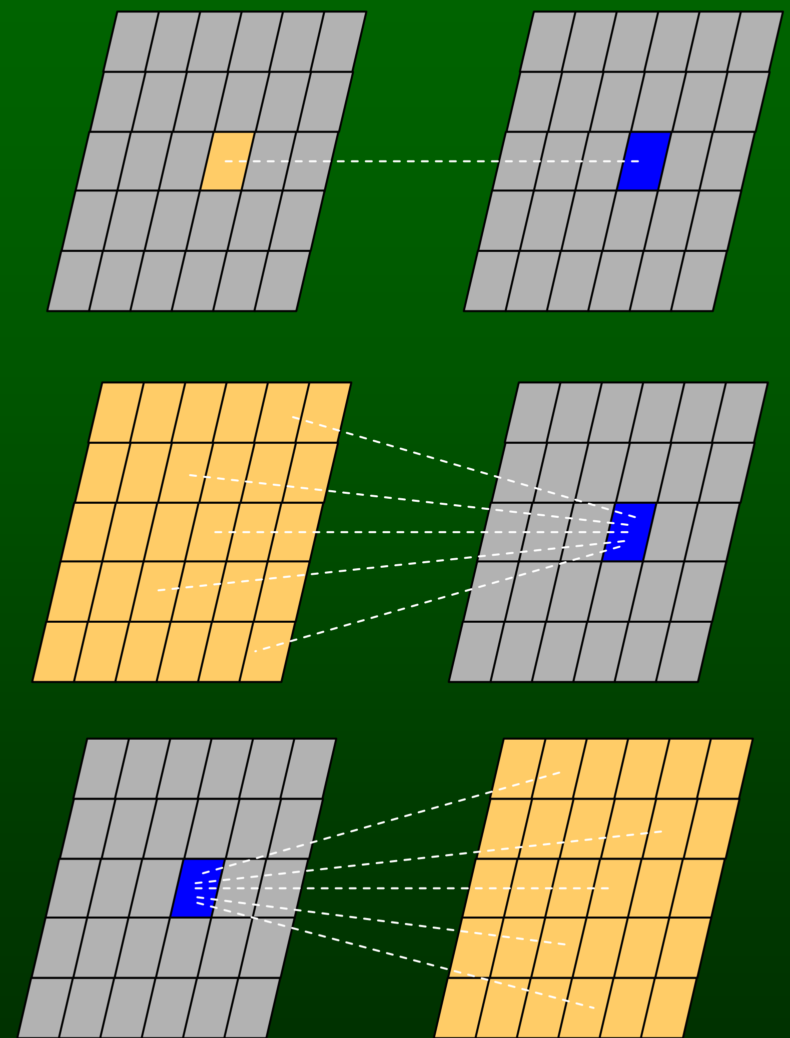
Jackson and Williams 2004 AREPS (redrawn)

Methods and Data

- Calculate dissimilarities between simulated 1980-1999 and 2080-2099 climate means
- Climate simulations from IPCC Fourth Assessment Report (IPCC AR4)
- 9 GCM's
- 2 scenarios: A2 (850ppm) and B1 (540ppm)

Three Questions, Revisited

20th Century 21st Century



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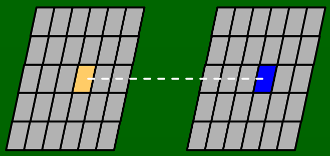

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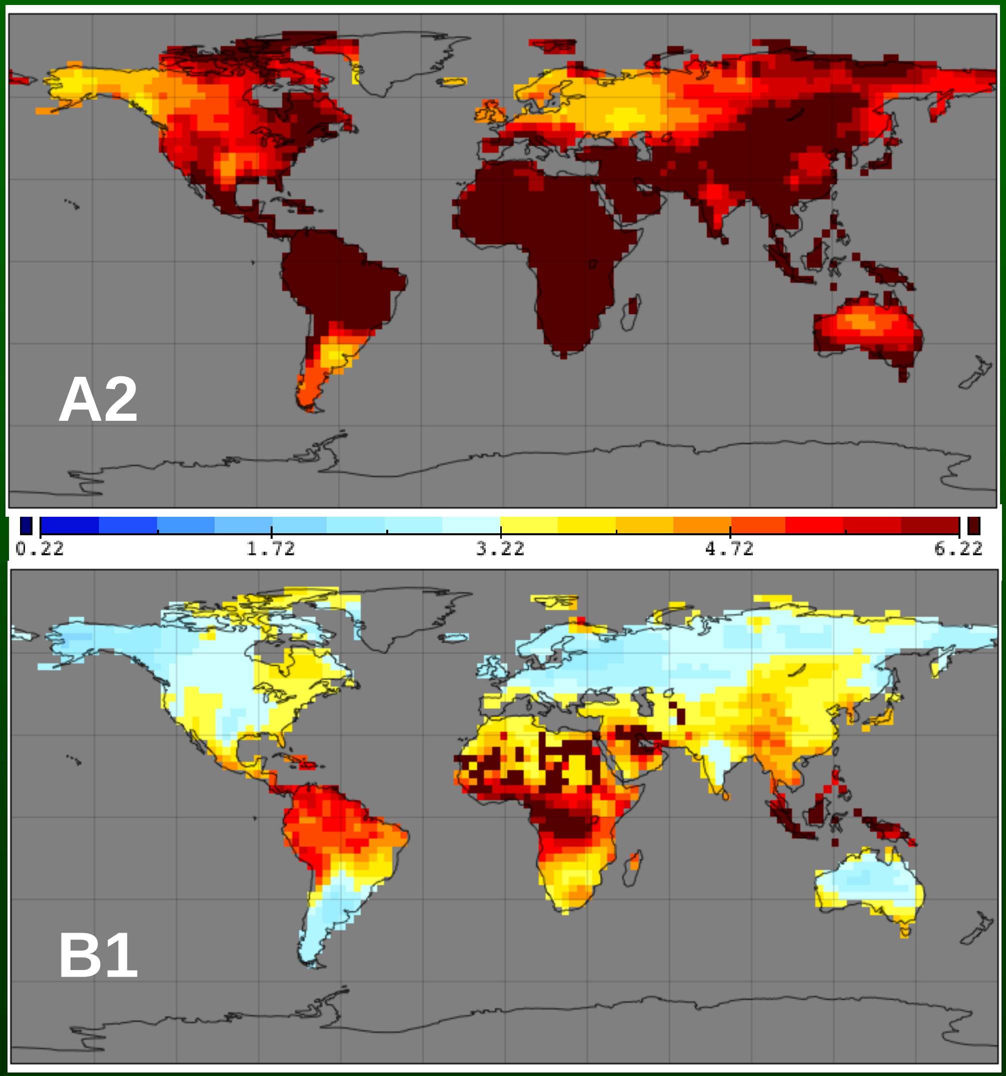

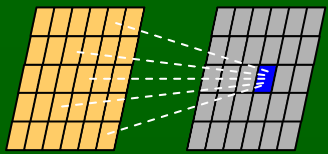

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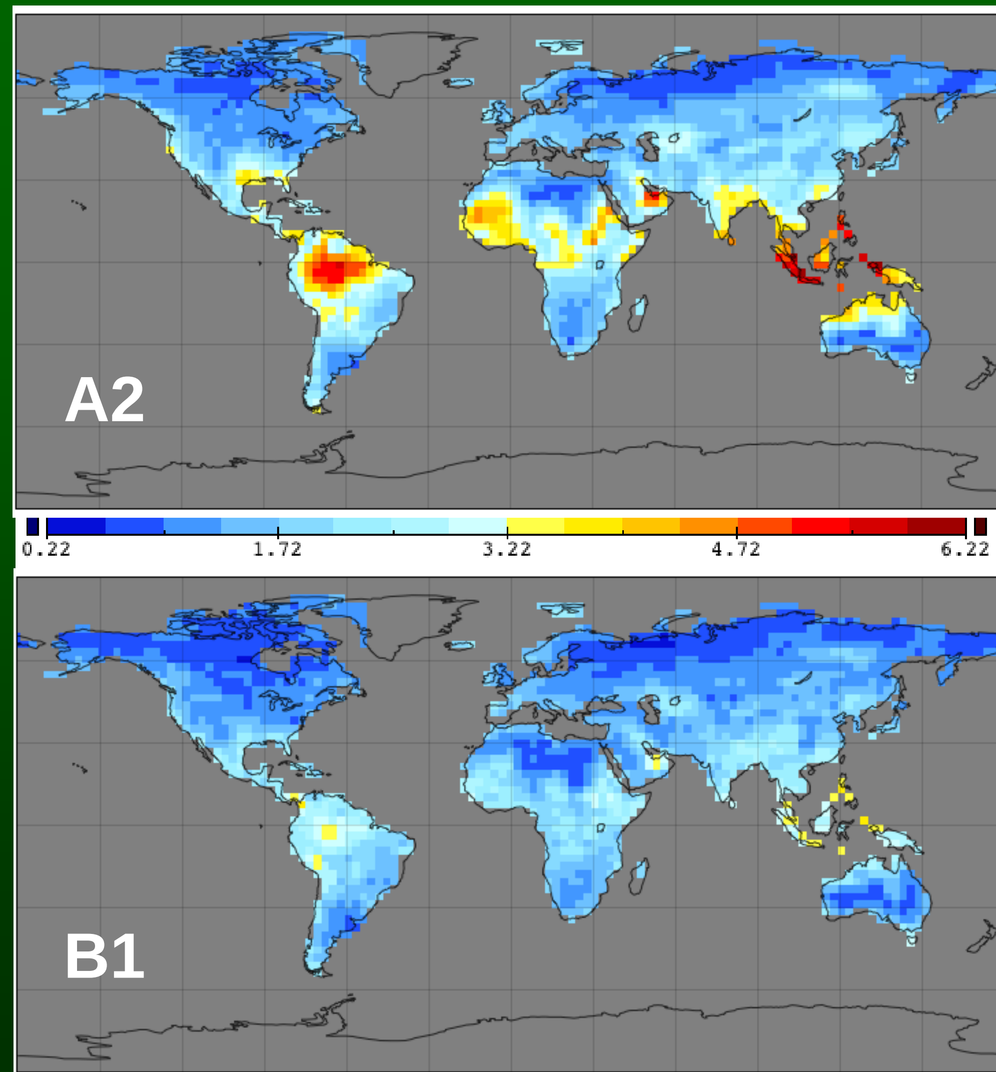
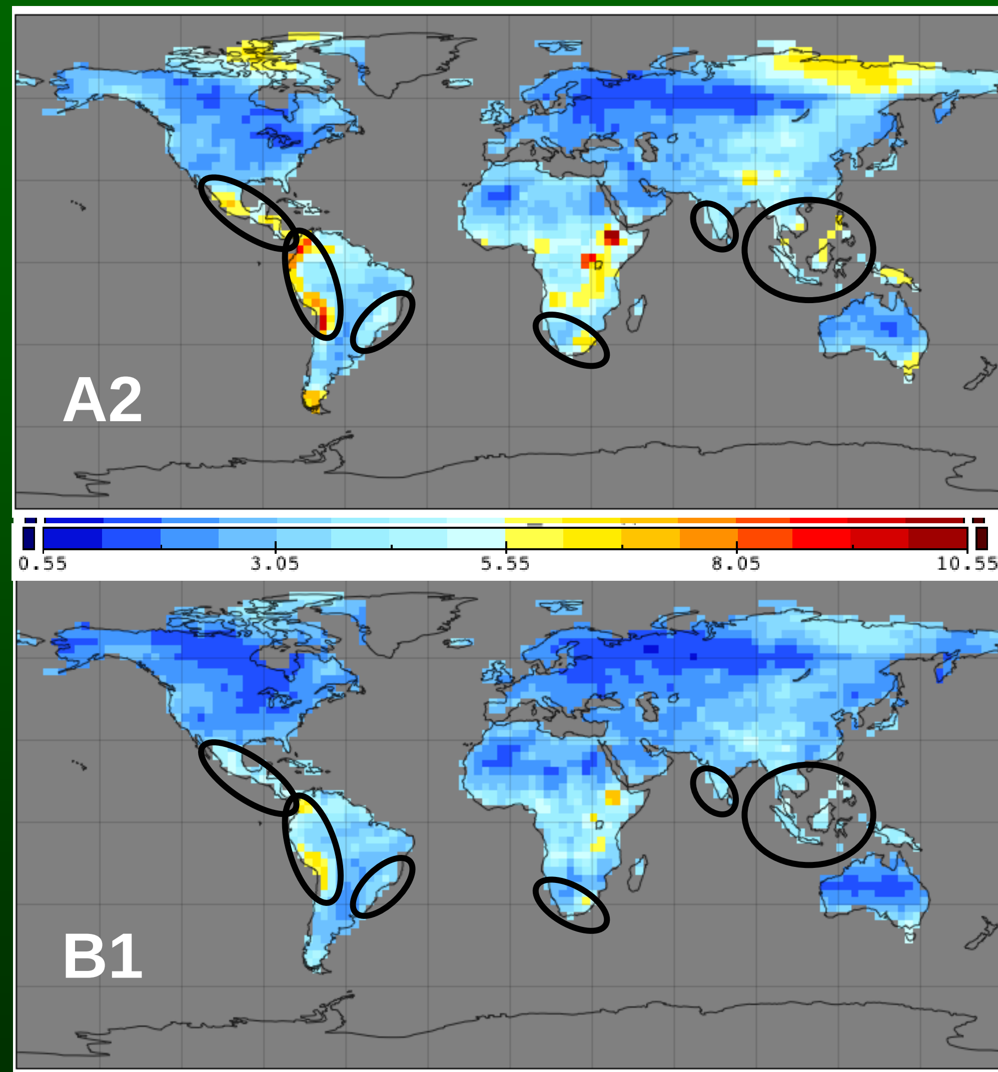


Which current climates will disappear?

- Strong overlap with biodiversity/endemics hotspots



Summary of 21st-Century Analyses

- Novel climates prevail in humid tropics
  - Ecological surprises likely
  - Challenge to bioclimatic models
- Disappearing climates prevail in tropical montane and poleward regions
  - Enhanced extinction risks
  - Strong overlap with endemics hotspots
- Emissions scenarios matter: A2>>B1

Some Final Thoughts…

- Disappearing climates may be major challenge for conservation biologists & reserve design
- Prospect of novel 21st-century climates poses severe challenge for niche models; likelihood of ecological surprises heightened by interaction between climate change and other global change factors
- Late-glacial environments *not* a direct analog for end-21st century climates but are excellent case study for testing and developing robust ecological models
- Also, many classic ENA lake records are inadequately dated and lack independent climate proxies – a critical need for recoring and reanalysis

Thanks to:

Colleagues and Collaborators: Bryan Shuman, Tom Webb, Steve Jackson, Pat Bartlein, John Kutzbach, Phil Leduc

Data: Eric Grimm and the North American Pollen Database

Support: NSF-Earth System History Program, NCEAS

Unanswered Questions

- What is the spatial scale of ‘no-analog’ represented by late-glacial pollen assemblages?
- Do other no-analog assemblages correlate with higher-than-present seasonality?
- Do other factors contribute?
  - CO_2
  - Megafaunal extinction
- Can we model and predict past (and future!) species distributions and associations?

Research Questions

Climate → Plant Species

- What mechanisms link plant taxon distributions to climate?
- How rapidly can plant communities respond to abrupt climate change?

Species → Vegetation

- What higher-order vegetation properties emerge from species-level behavior?

Vegetation → Atmosphere

- Are vegetation feedbacks important modifiers of atmosphere dynamics at Is vegetation change an important modWhat are the key feedbacks between vegetation change and atmospheric