The impact of warming on tropical lowland rainforests

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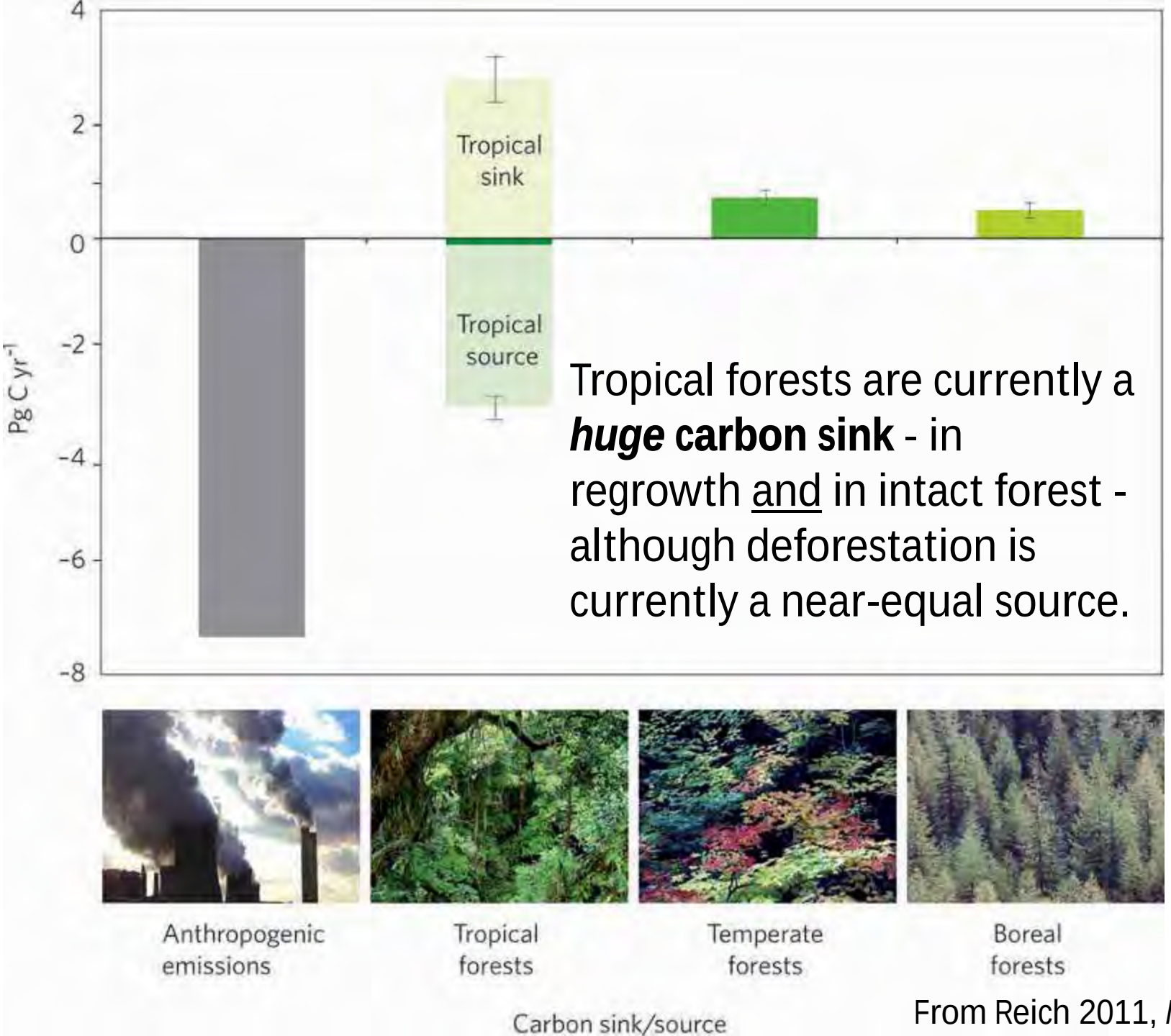


SINKS

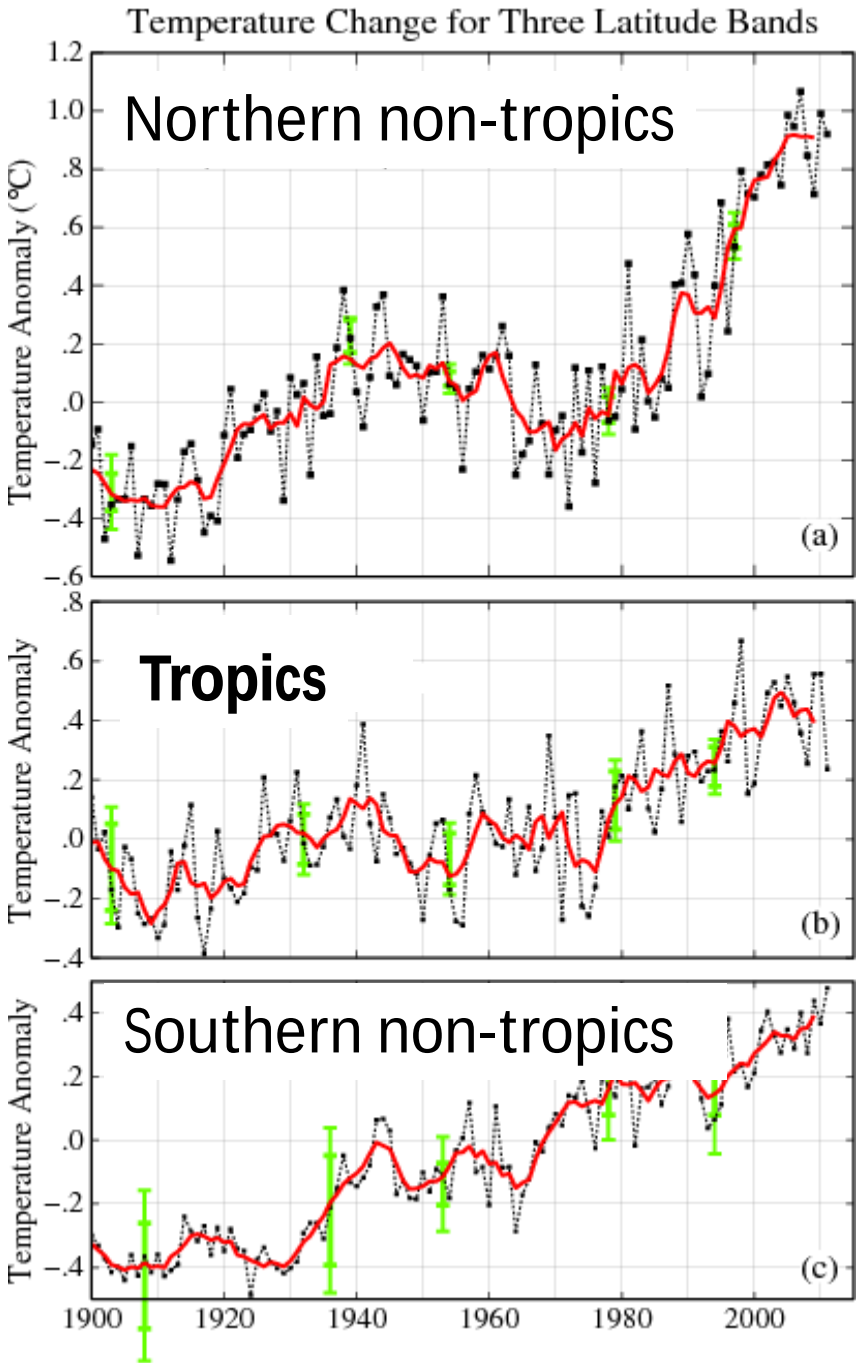
SOURCES

Tropical forests are currently a ***huge*** **carbon sink** - in regrowth and in intact forest - although deforestation is currently a near-equal source.

From Reich 2011, *Nature CC*

“Tropical forests are likely to be more affected by changes in land use than by climate change as long as deforestation continues at its current high rate.” IPCC 2nd Assessment, 1995

i.e., we have more immediate problems to worry about in the tropics.



Warming, by latitude, 1900-2012

(base period 1951-1980)

From: http://data.giss.nasa.gov/gistemp/

The tropics has warmed ***less*** than the northern non-tropics so far, and is expected to (mostly) warm ***less*** in future.

Furthermore, changes in **rainfall** may be more significant in much of the tropics:

1. Dry season length is the strongest climatic predictor of species richness.

2. Dry years have a strong influence on plant growth and mortality.

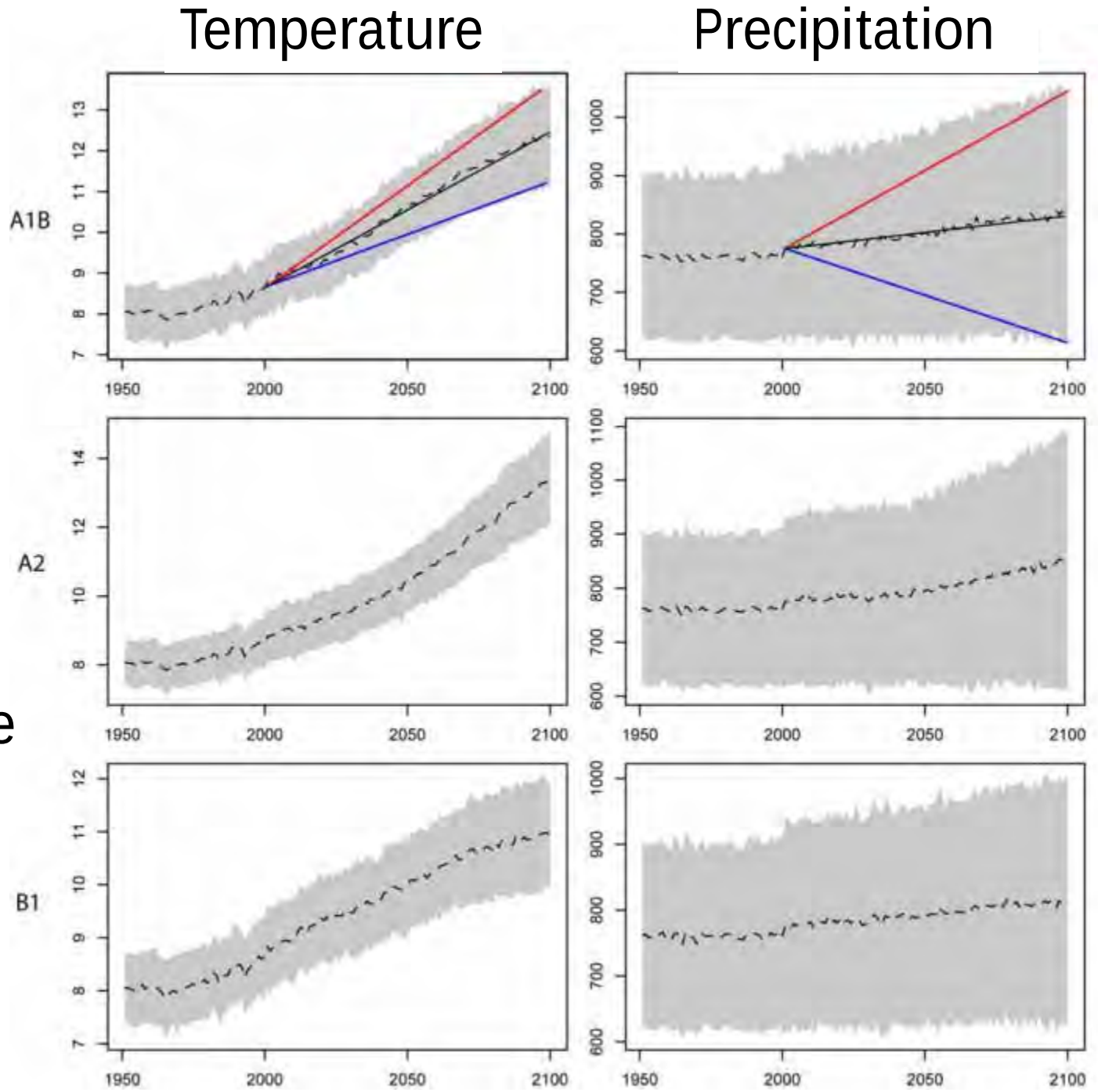
3. Dry weather strongly influences fire frequency.

NASA/IPCC 2007

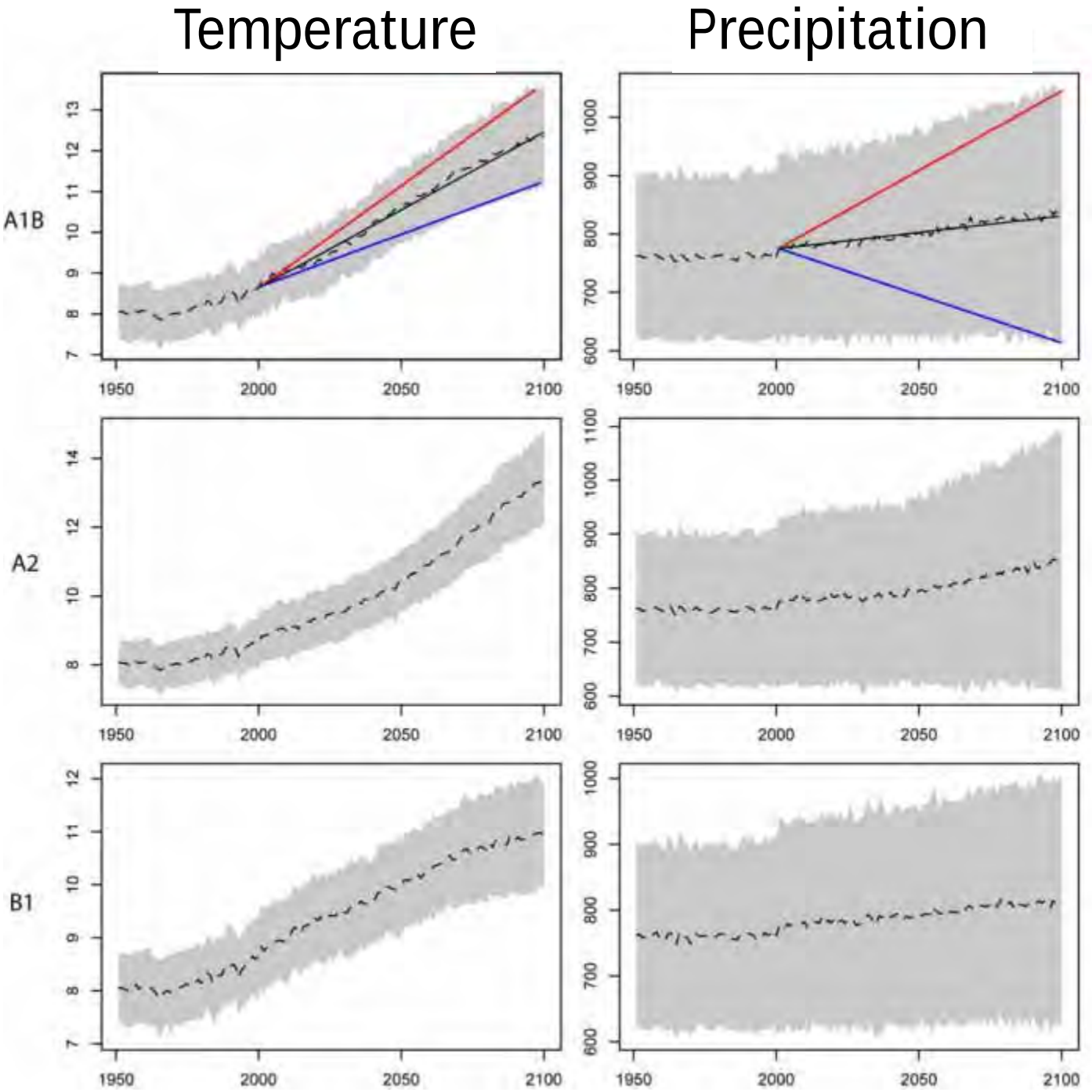
Temperature and rainfall projections from 16 GCMs (mean, global, land surface).

Gray shade is "one standard deviation of the 16 models used."

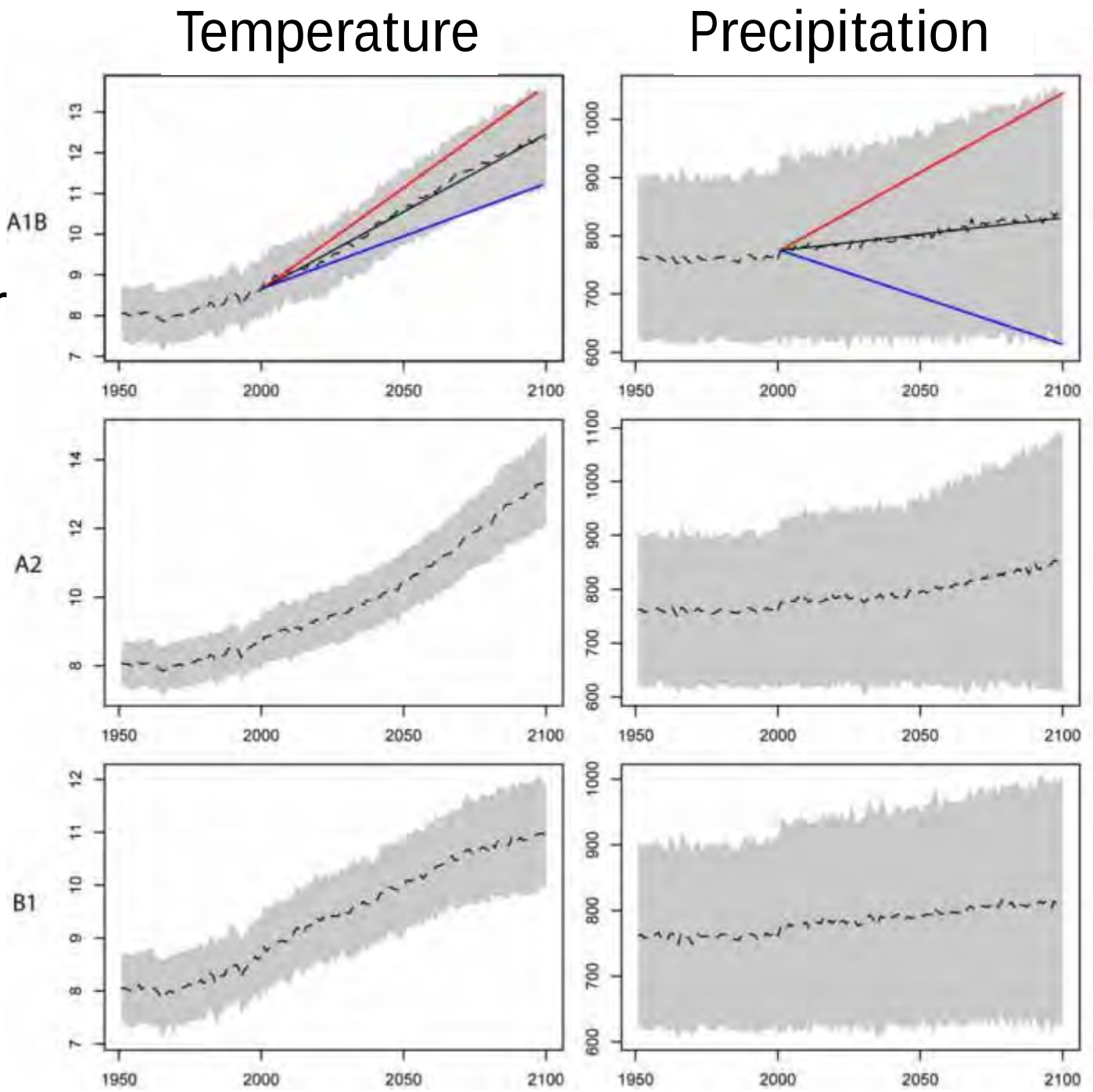
Loarie et al. 2009. *Nature*



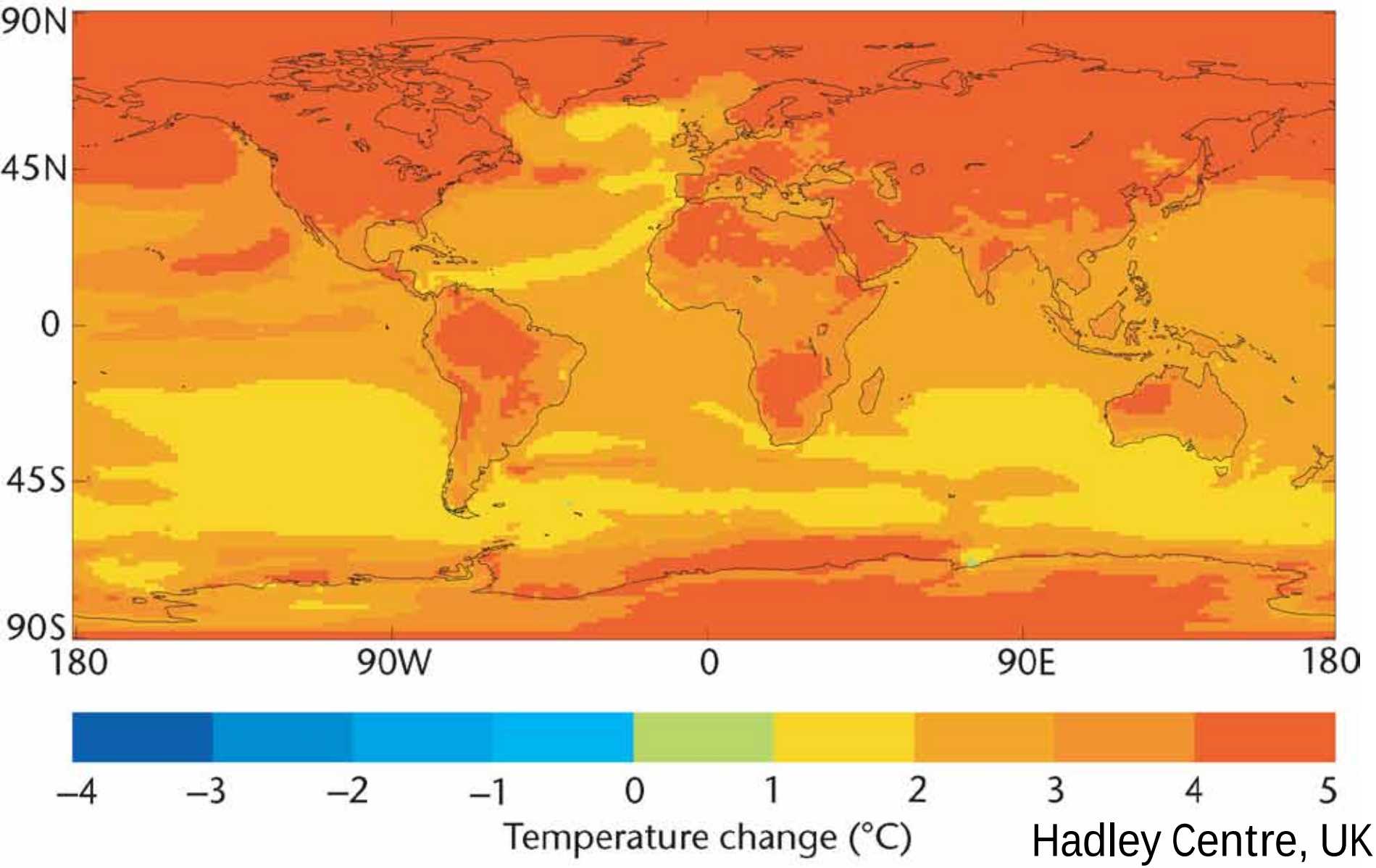
All tropical forests will be **at least 2-4ºC warmer** by 2100, while rainfall may increase, stay the same, or decrease, and projections are still highly model-dependent.



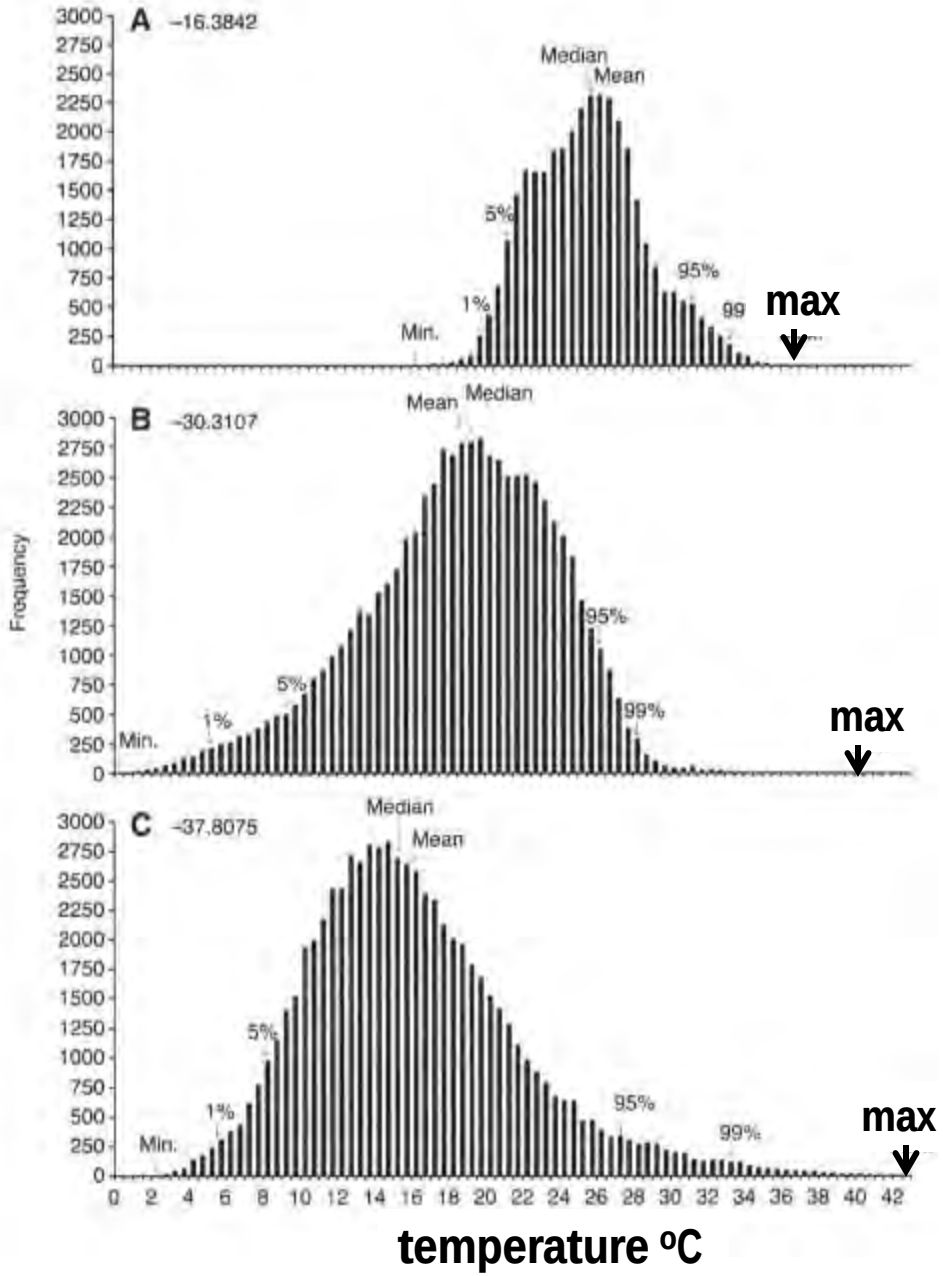
But you cannot separate them, since warming increases water stress even when rainfall is unchanged.



Warming is expected to be less in most of the tropics…
but the biological impacts may be more.



Because changes will be larger relative to current variation



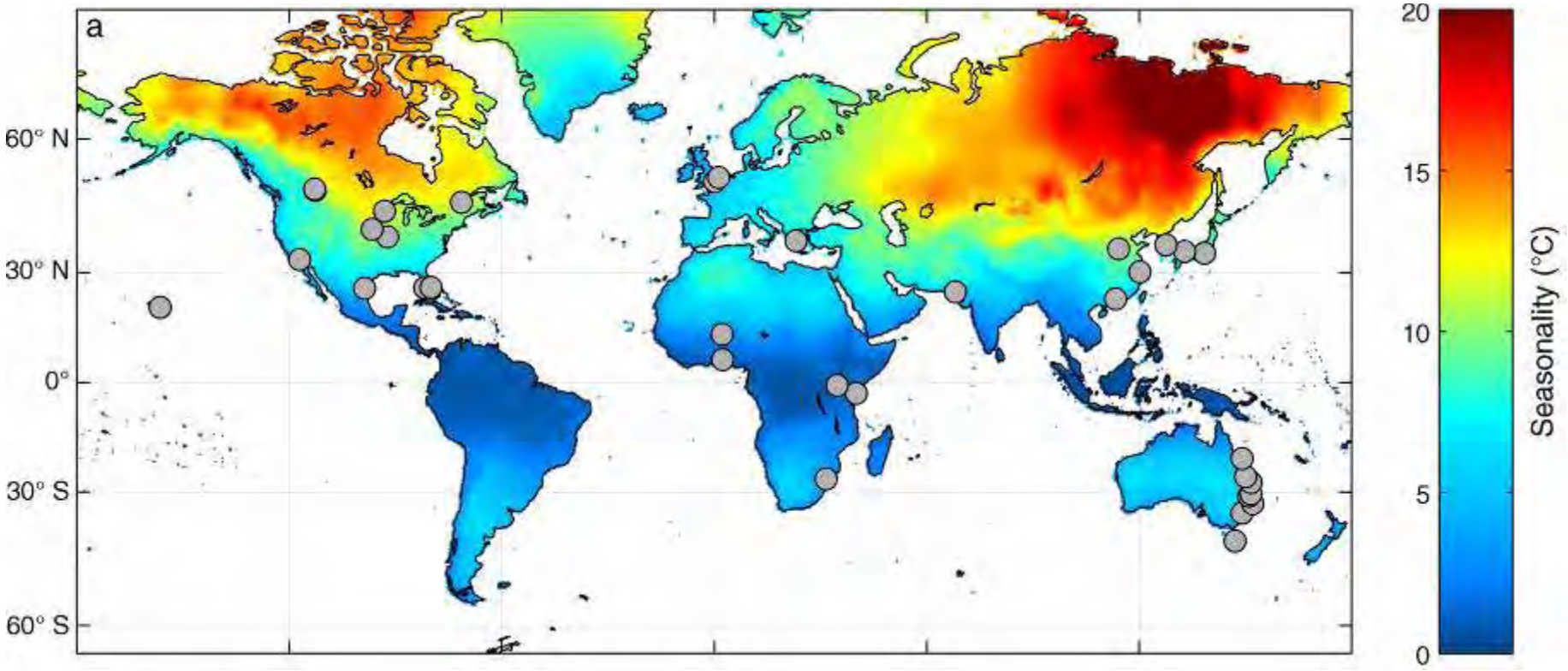
Tropical
(but not equatorial)

Subtropical

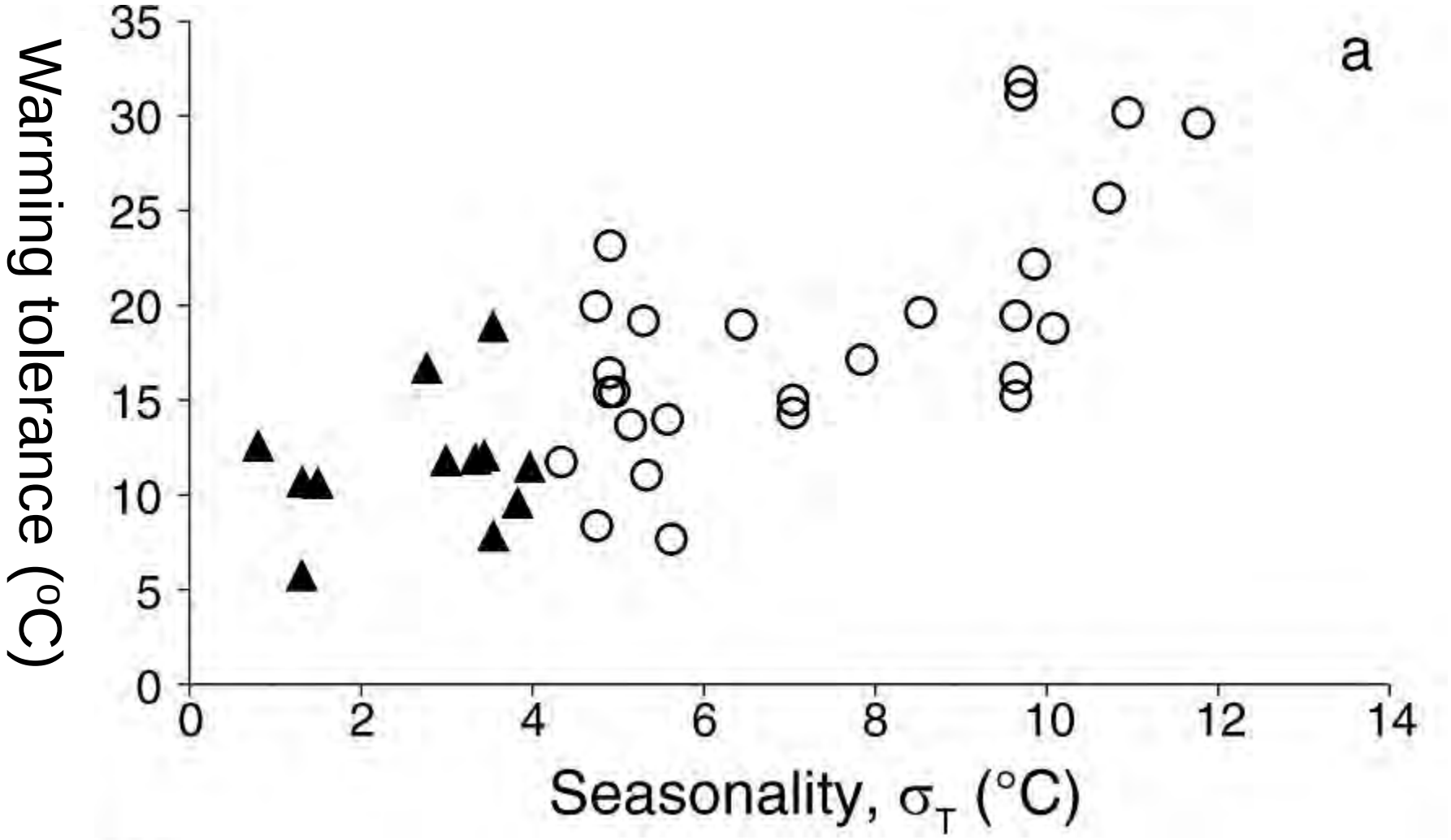
Temperate

Eastern Australia

[3-hourly records from low altitude locations: Hoffman 2010. *J. Exp. Biol*.]

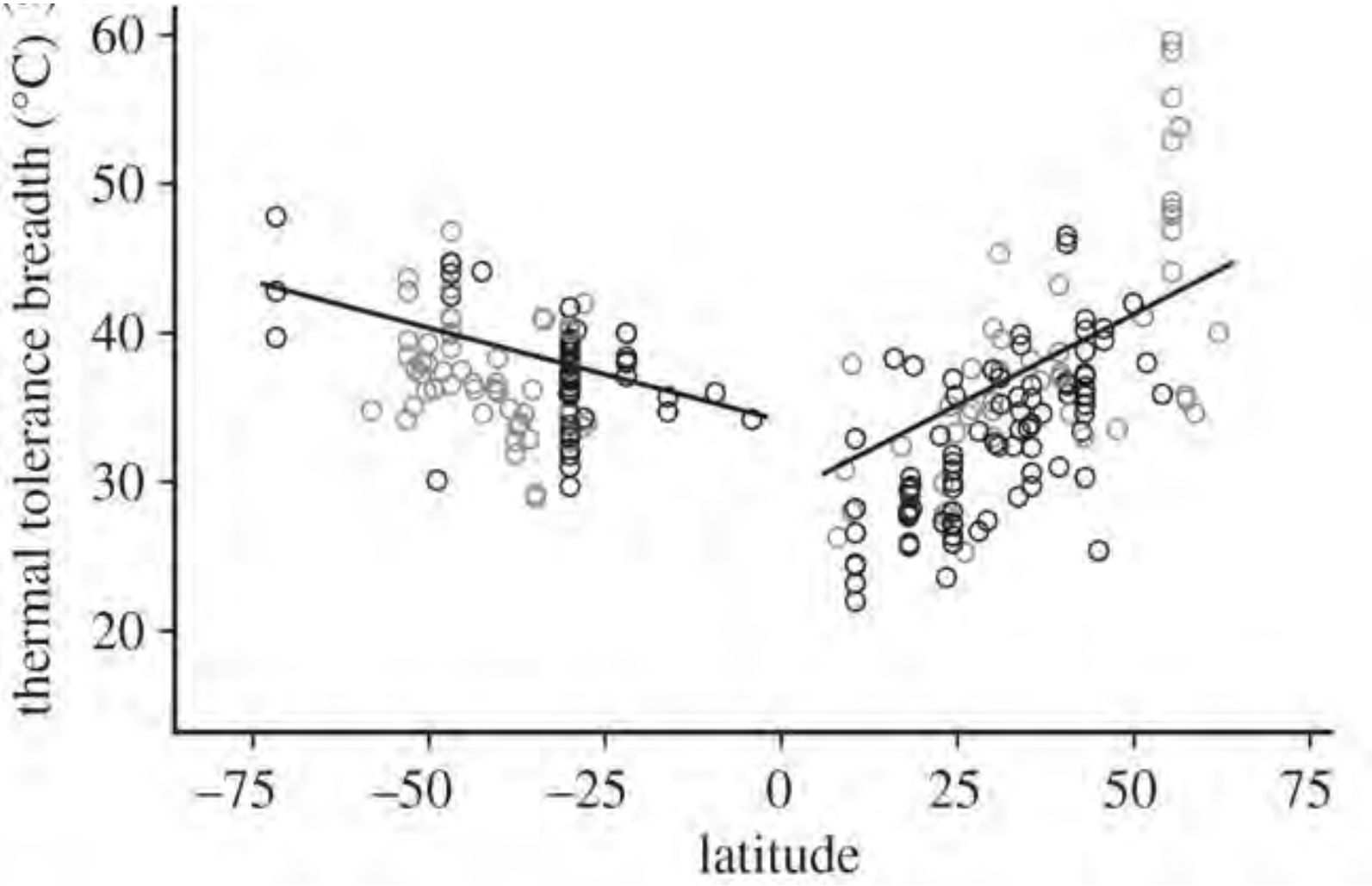


Seasonality (intra-annual standard deviation of temp.):
blue low, red high
(Bonebrake & Deutsch, 2012, *Ecology*)



Warming tolerance of insects *vs* seasonality

(Bonebrake & Deutsch, 2012, *Ecology*)

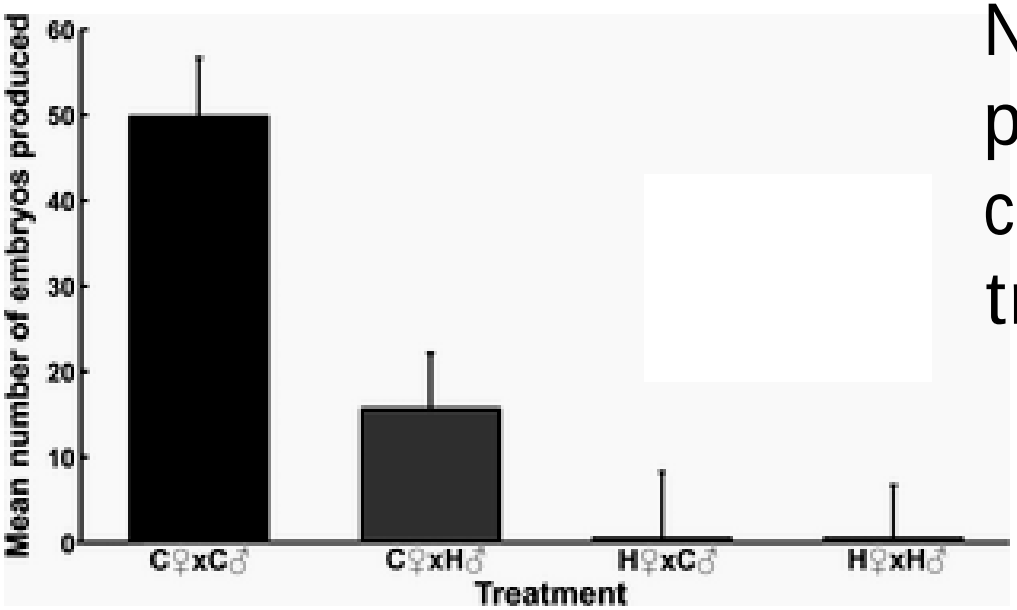


Thermal tolerance breadth of ectotherms *vs.* latitude

Sunday et al. 2011, *Proc. Roy. Soc. B*

And at least some tropical ectotherms are already near their upper thermal limits, e.g.

Reproductive success in a Neotropical rainforest pseudoscorpion under control and +3.5ºC treatments.

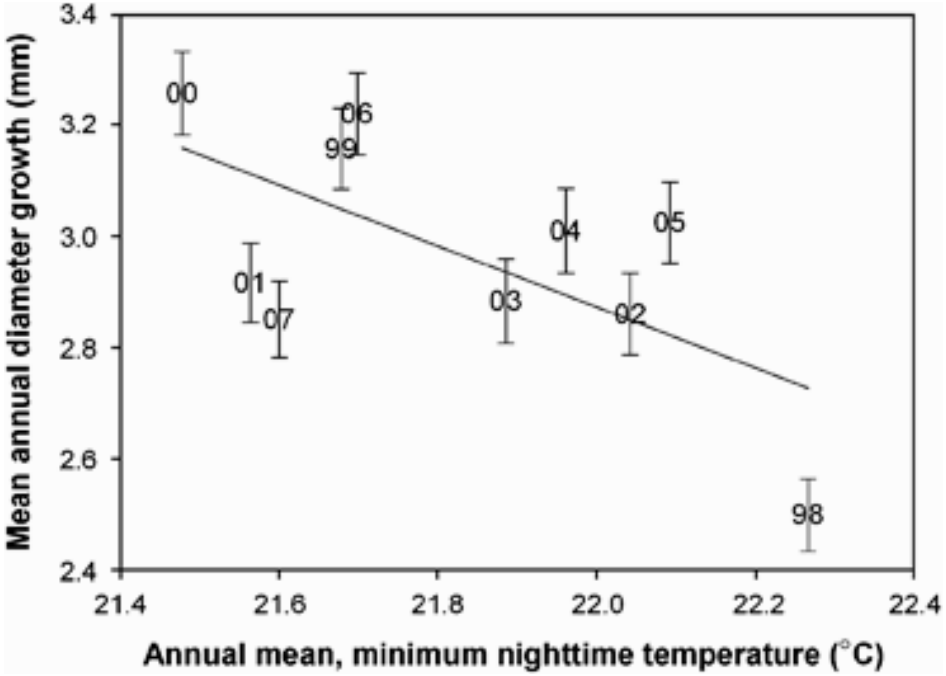


control m & f **control f warm m** **control m warm f** **warm m & f**

Zeh et al. 2012, *Global Change Biology*

Tree growth and mortality in a lowland rainforest in Costa Rica were strongly linked to night-time temperature over 10 years, despite a <1ºC range.

[Clark et al. 2010, *Global Change Biology*]



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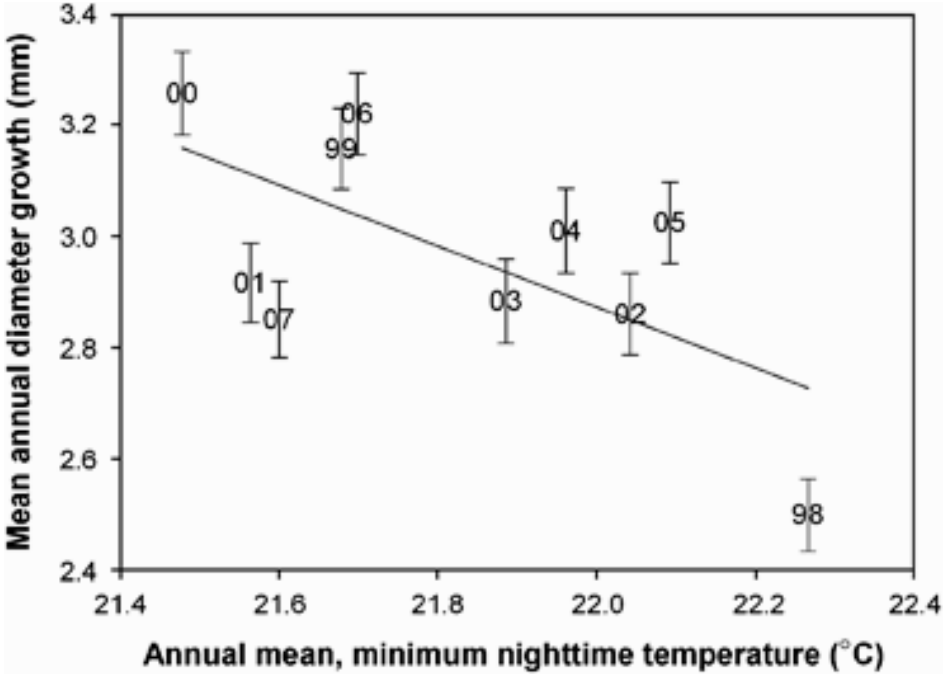
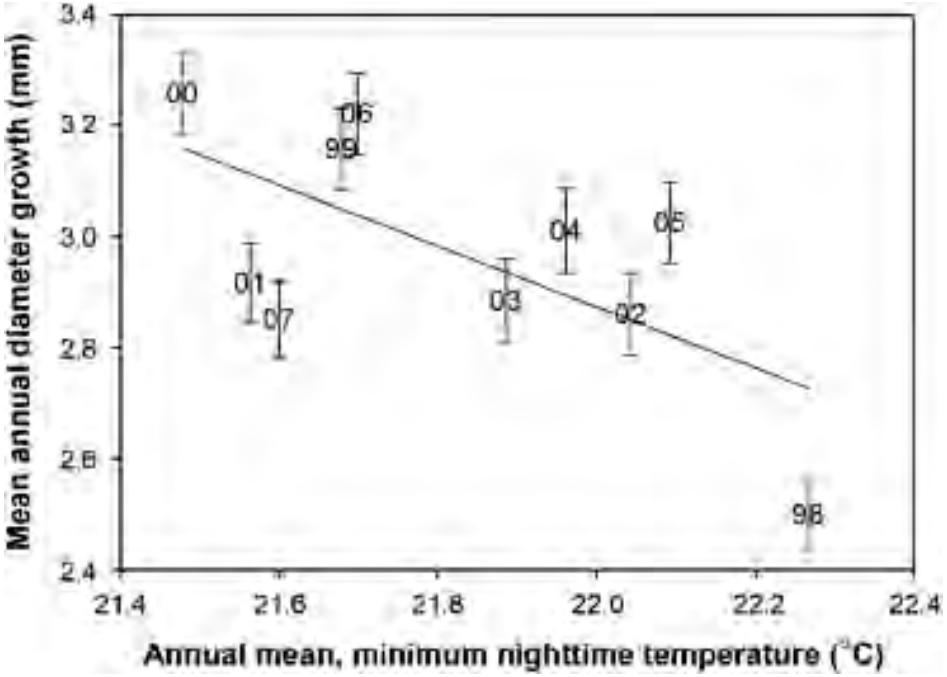
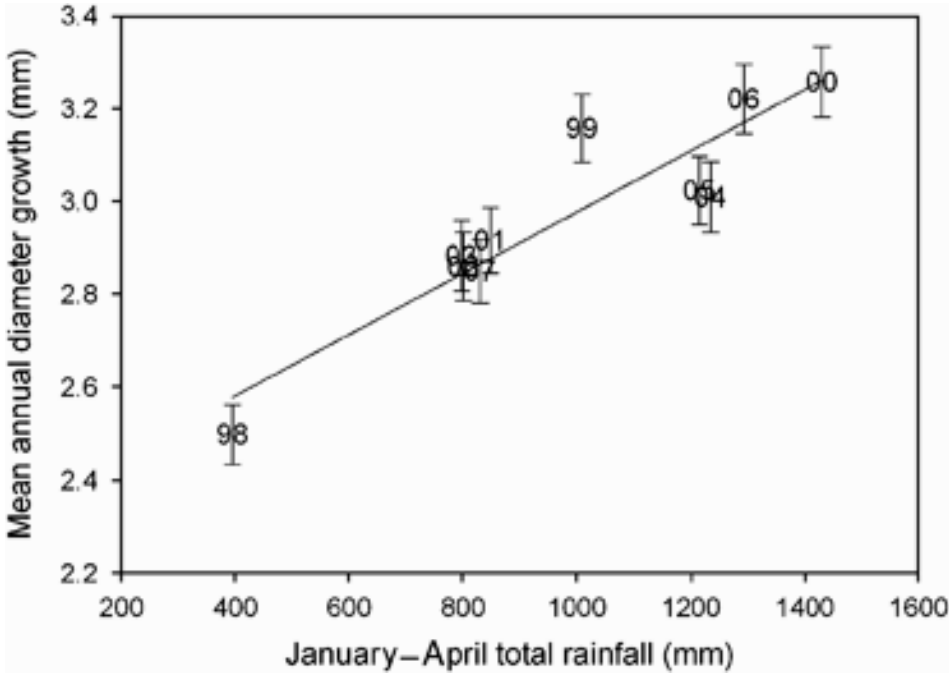


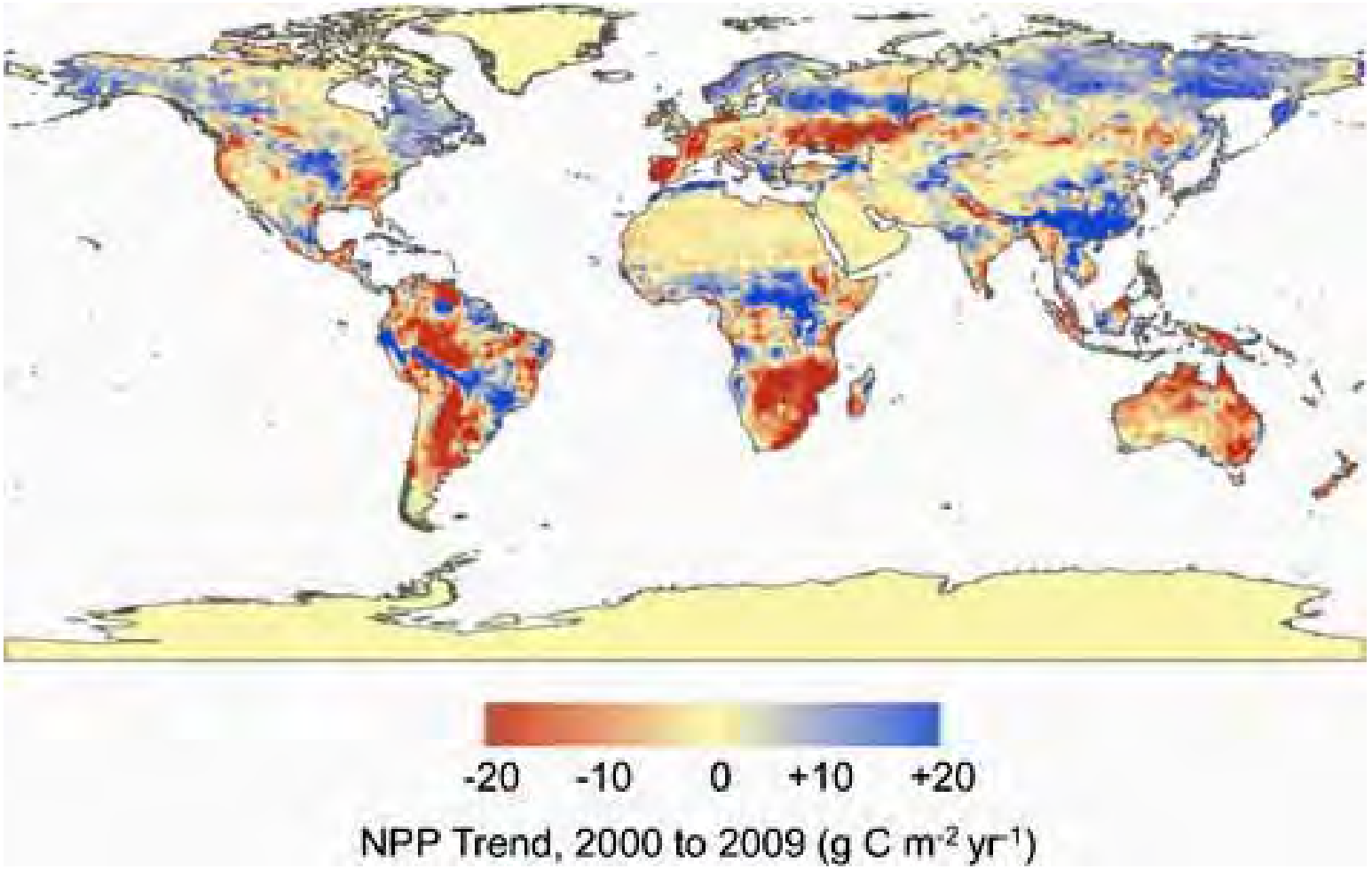
The relationship with nighttime temperatures suggests an impact on nocturnal respiration, while a variety of other evidence suggests that the brightly-lit leaves that contribute most to photosynthesis are already warmed to the point where daytime gas exchange is reduced.

Tree growth and mortality in a lowland rainforest in Costa Rica were strongly linked to night-time temperature over 10 years, despite a <1^{o}C range.

Dry season rainfall had an independent effect on tree growth, despite the driest dry season having >100 mm per month.

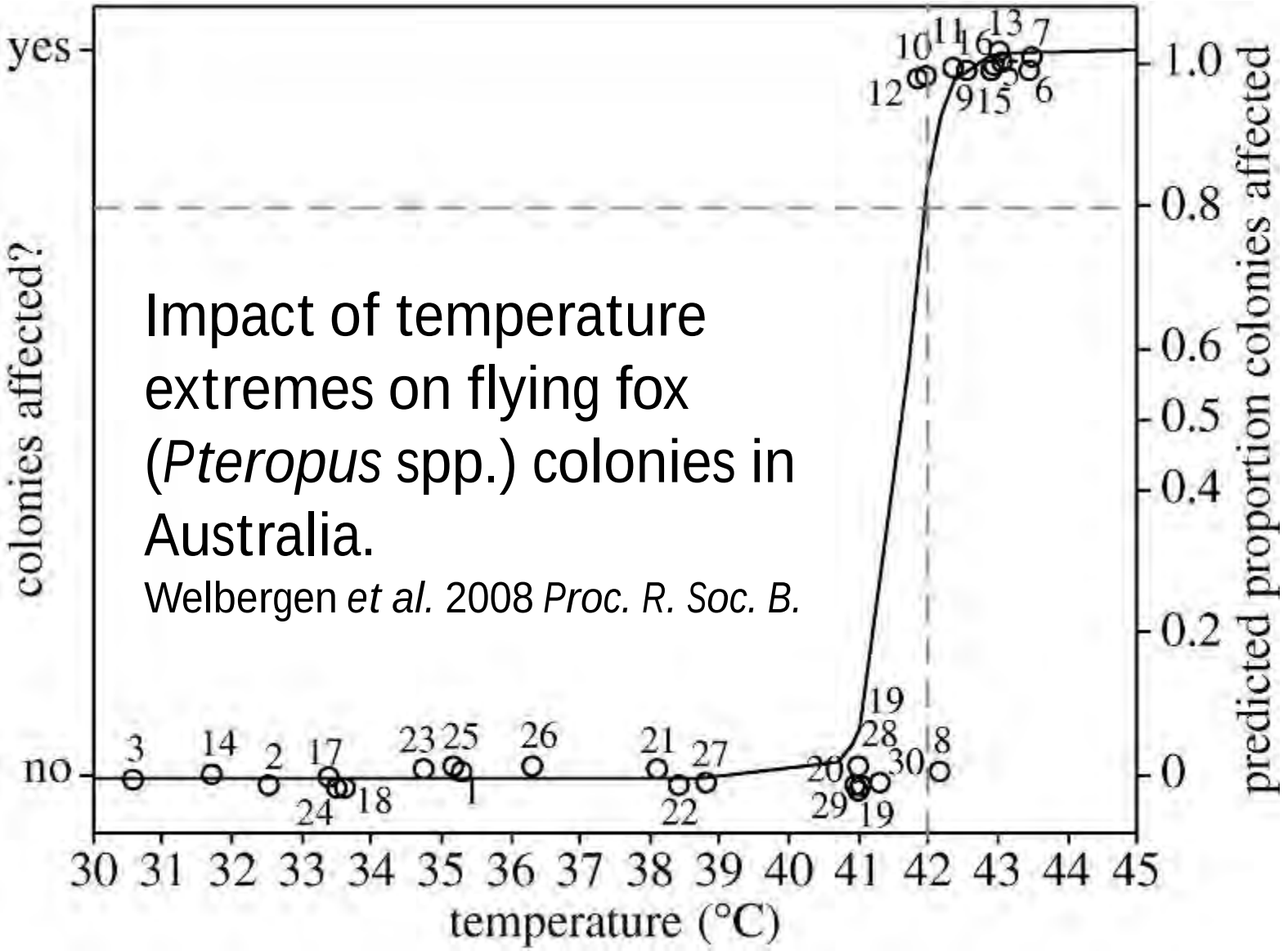






NPP trends 2000-2009 (from MODIS and modeling). A small global increase was almost entirely from forests > 50^{o}N. [Potter et al., 2012. *Climatic Change*]

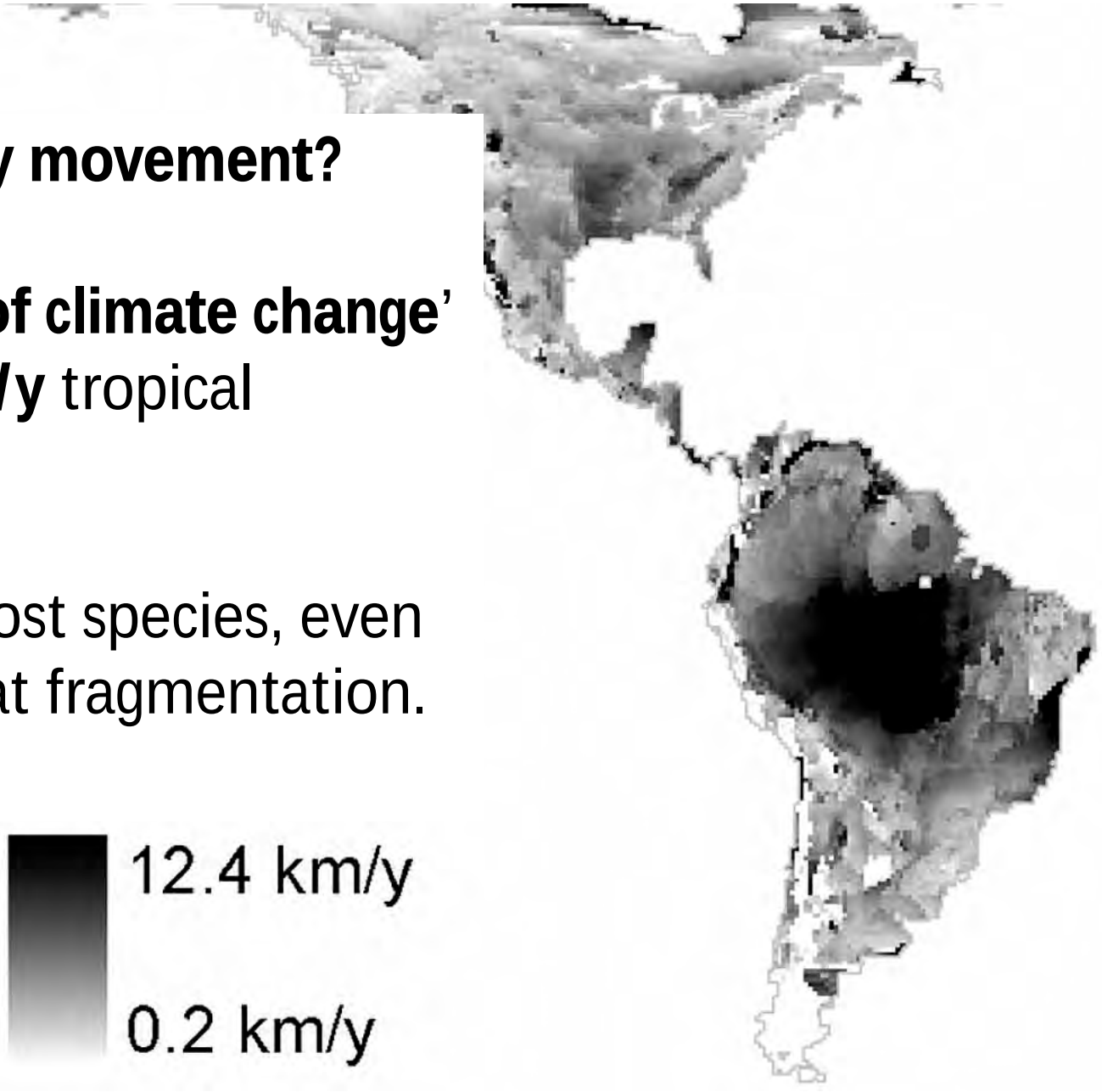
Energy and water costs of maintaining stable core temperature mean **endotherms** also vulnerable:



Compensatory movement?

The '**velocity of climate change**' will be **> 1 km/y** tropical lowlands.

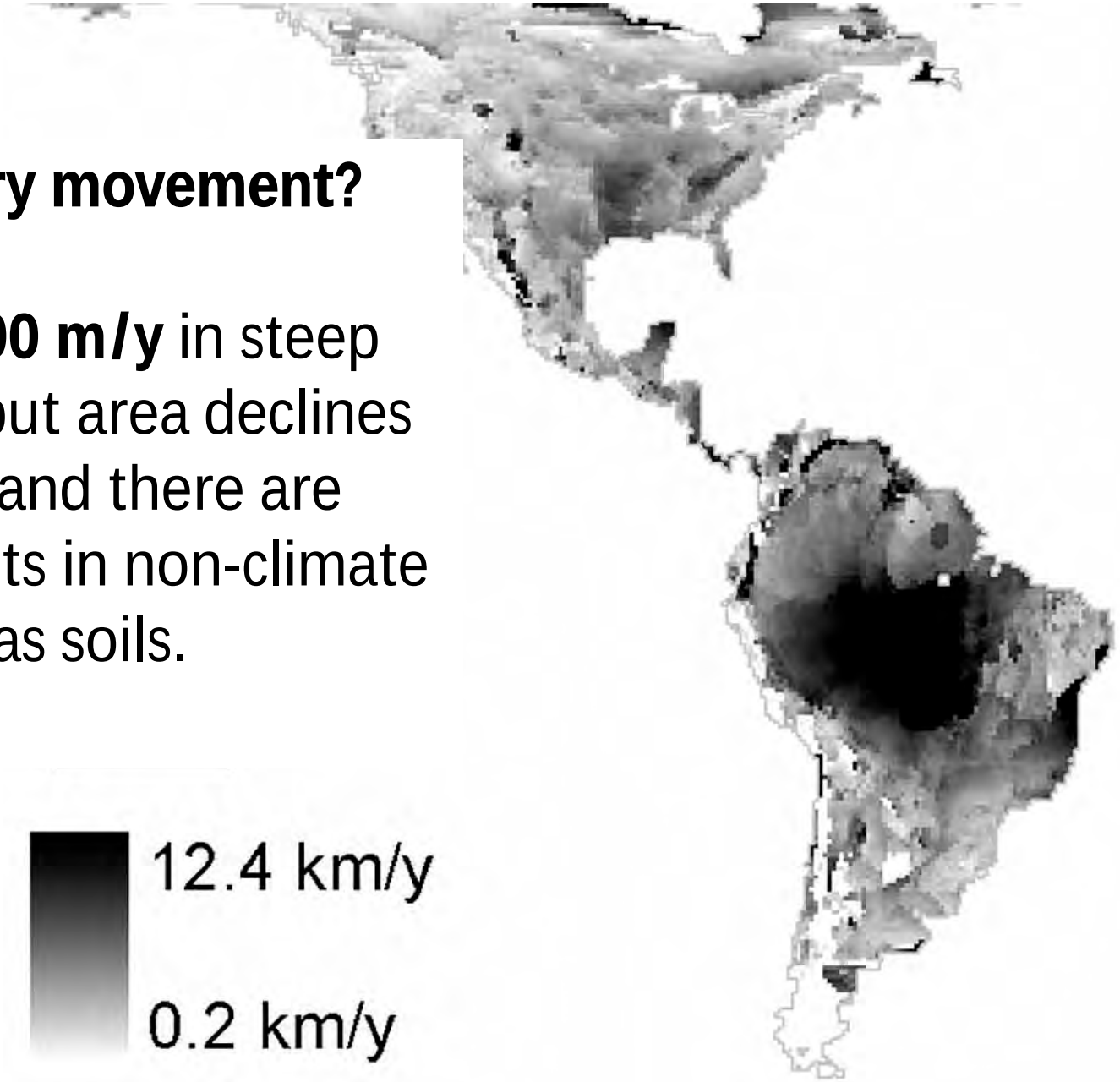
Too fast for most species, even without habitat fragmentation.



Schloss et al. 2012 *PNAS*

Compensatory movement?

vs. only **10-100 m/y** in steep topography, but area declines with altitude and there are steep gradients in non-climate factors, such as soils.



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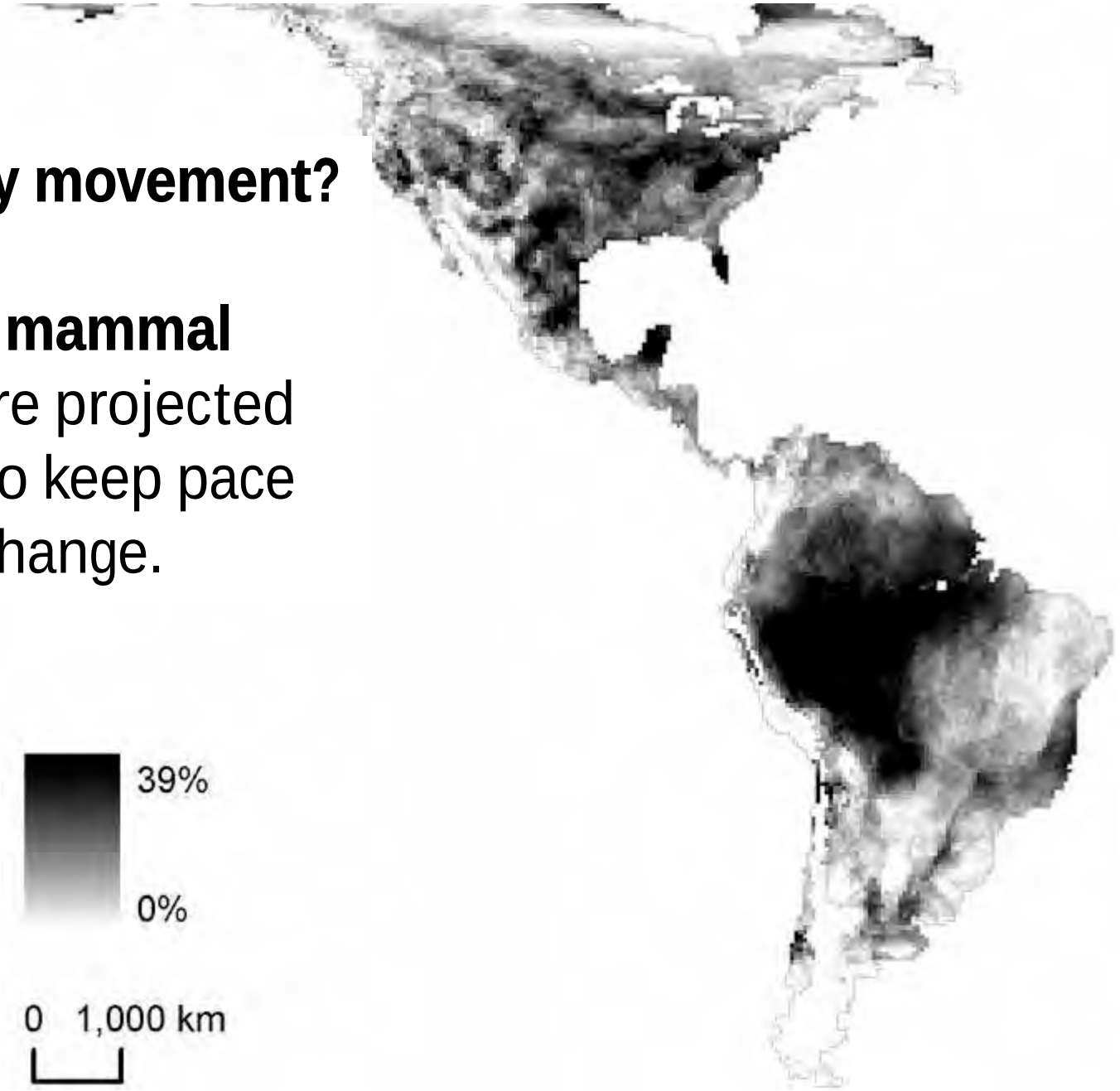
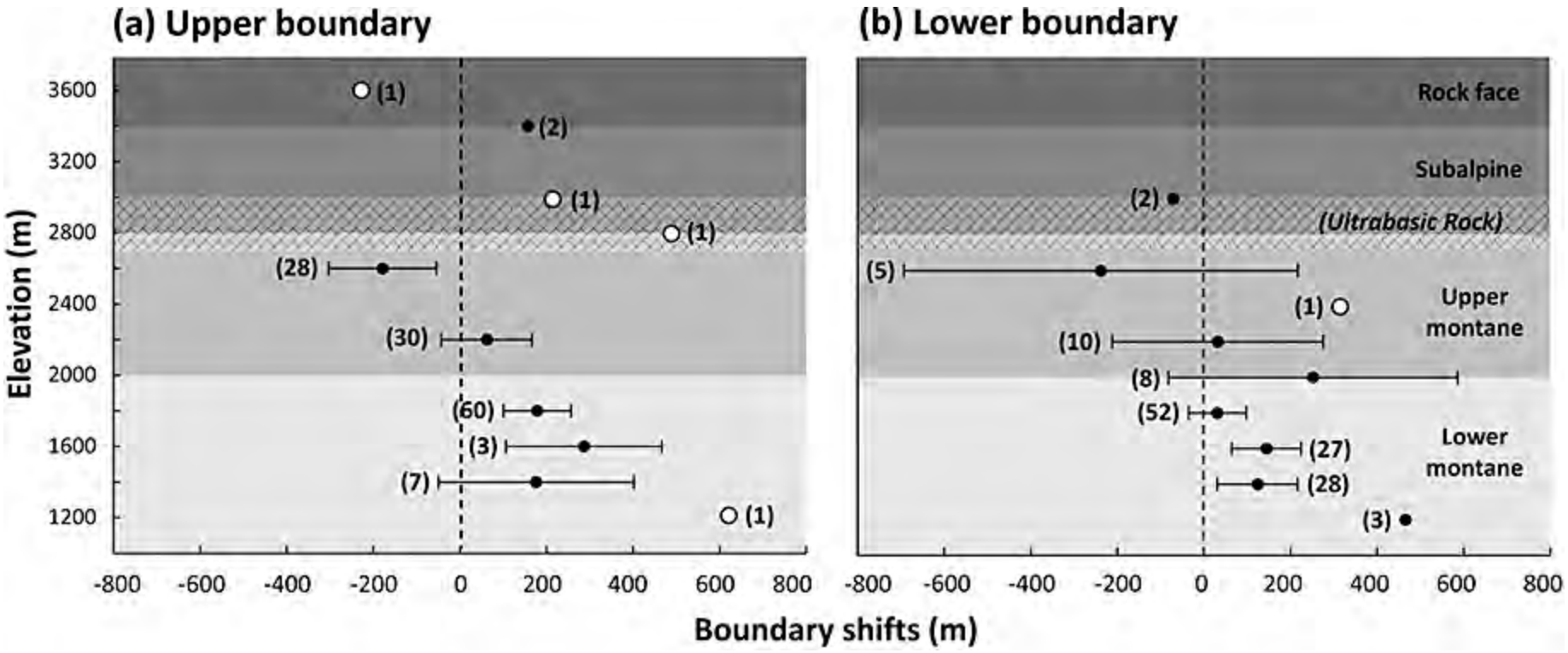
Compensatory movement?

Percentage of **mammal** species that are projected to be unable to keep pace with climate change.

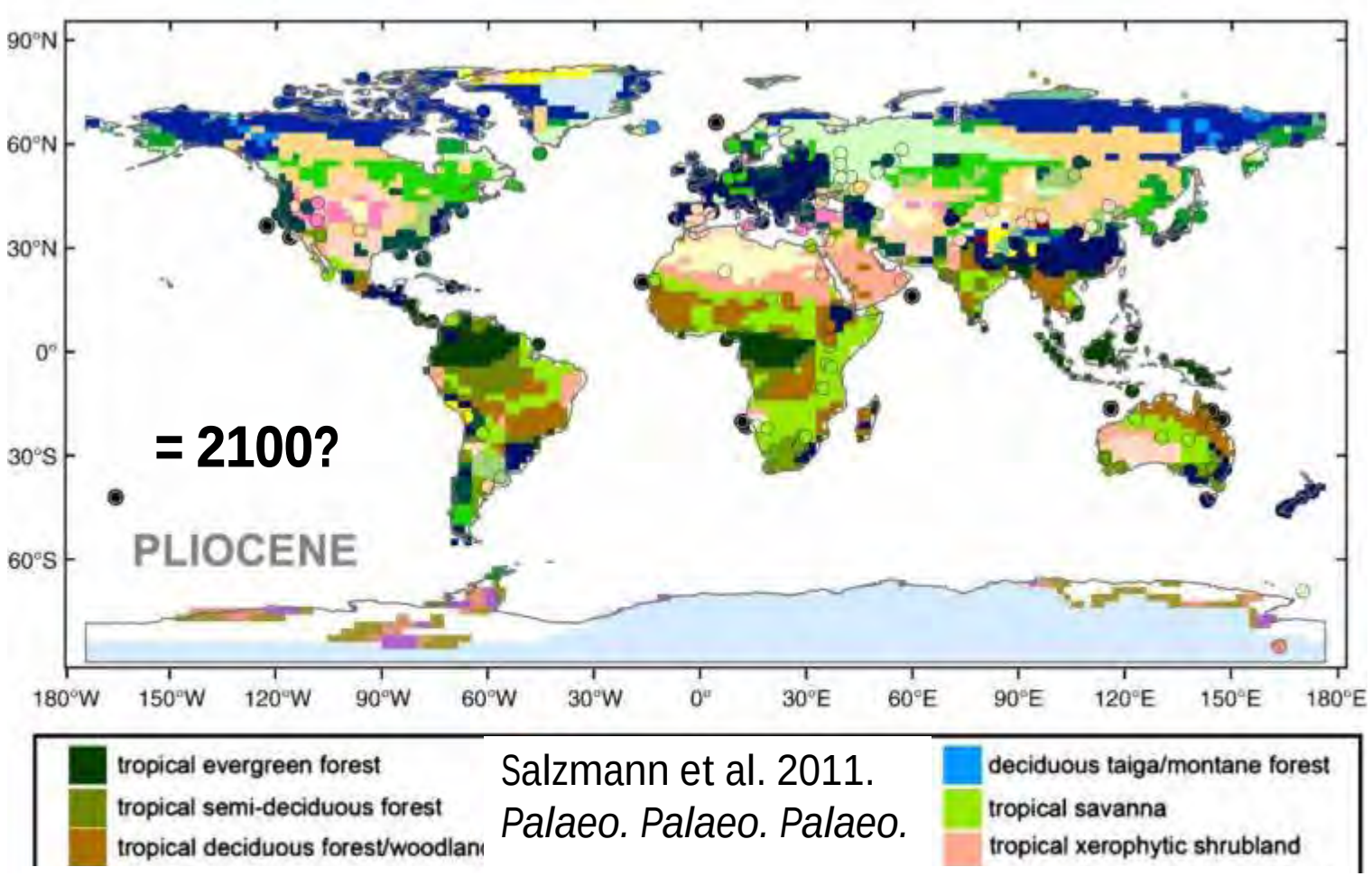


Schloss et al. 2012 *PNAS*

Over 42 years on Mt Kinabalu, moth species range changes were more complex than predicted by warming alone:

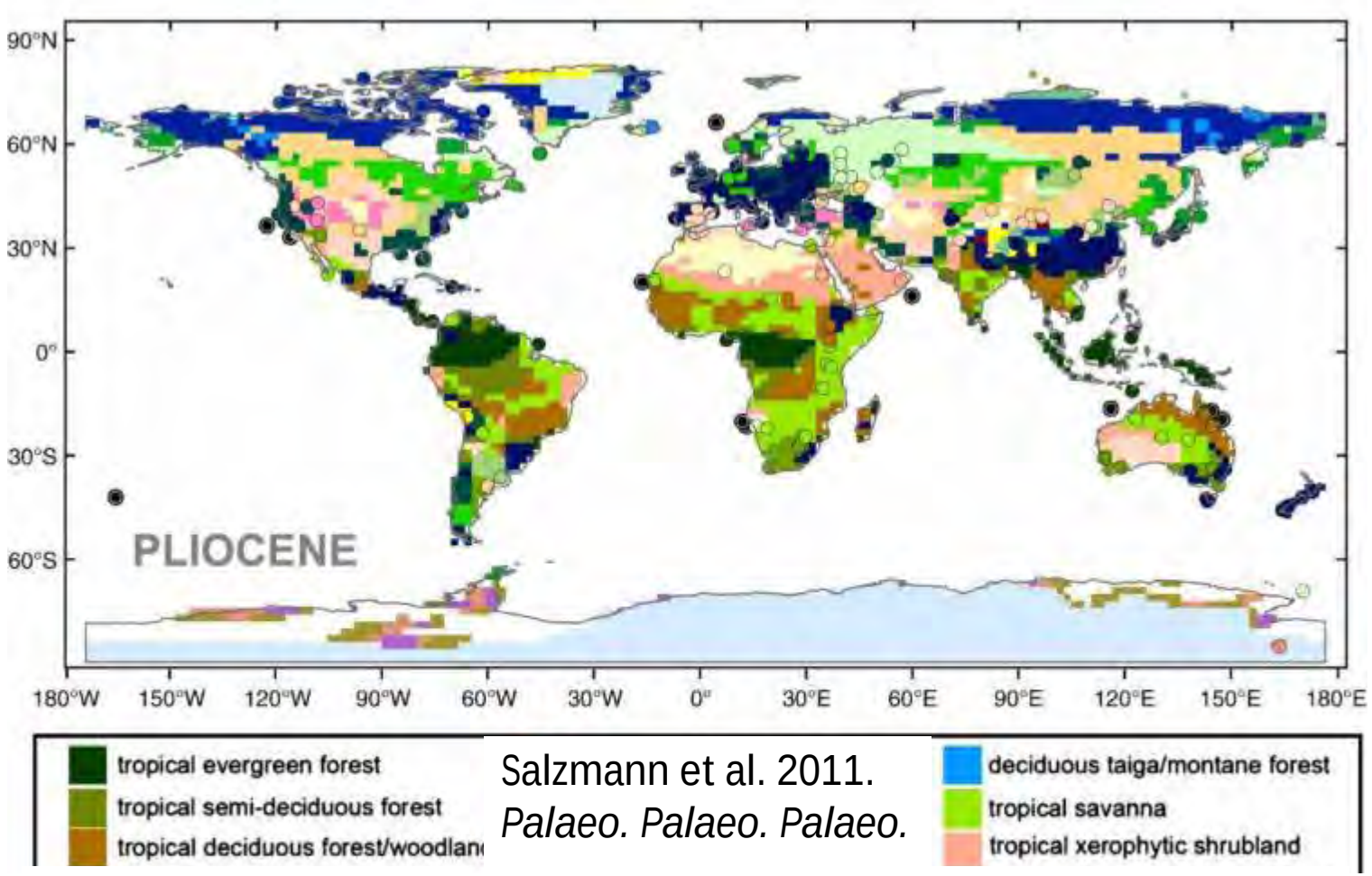


Chen et al. 2011. *Global Ecology & Biogegraphy*



Salzmann et al. 2011.
Palaeo. Palaeo. Palaeo.

Nearest past analogue for similar warmth: **Pliocene**, **3.0-3.3 m years ago**: similar biota, geography, climate and CO_2 to 2100, but less polar ice and higher sea-levels.



Salzmann et al. 2011.
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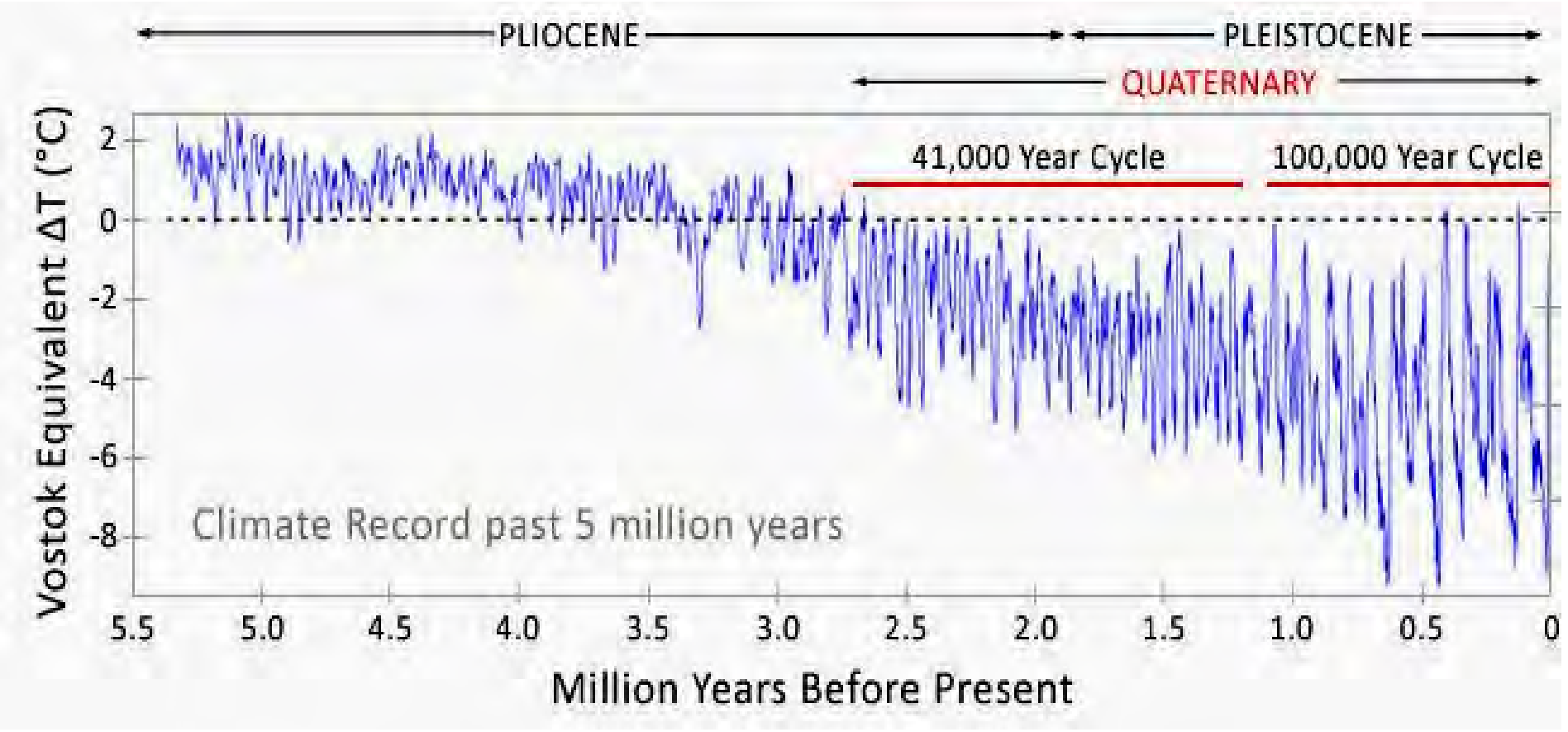
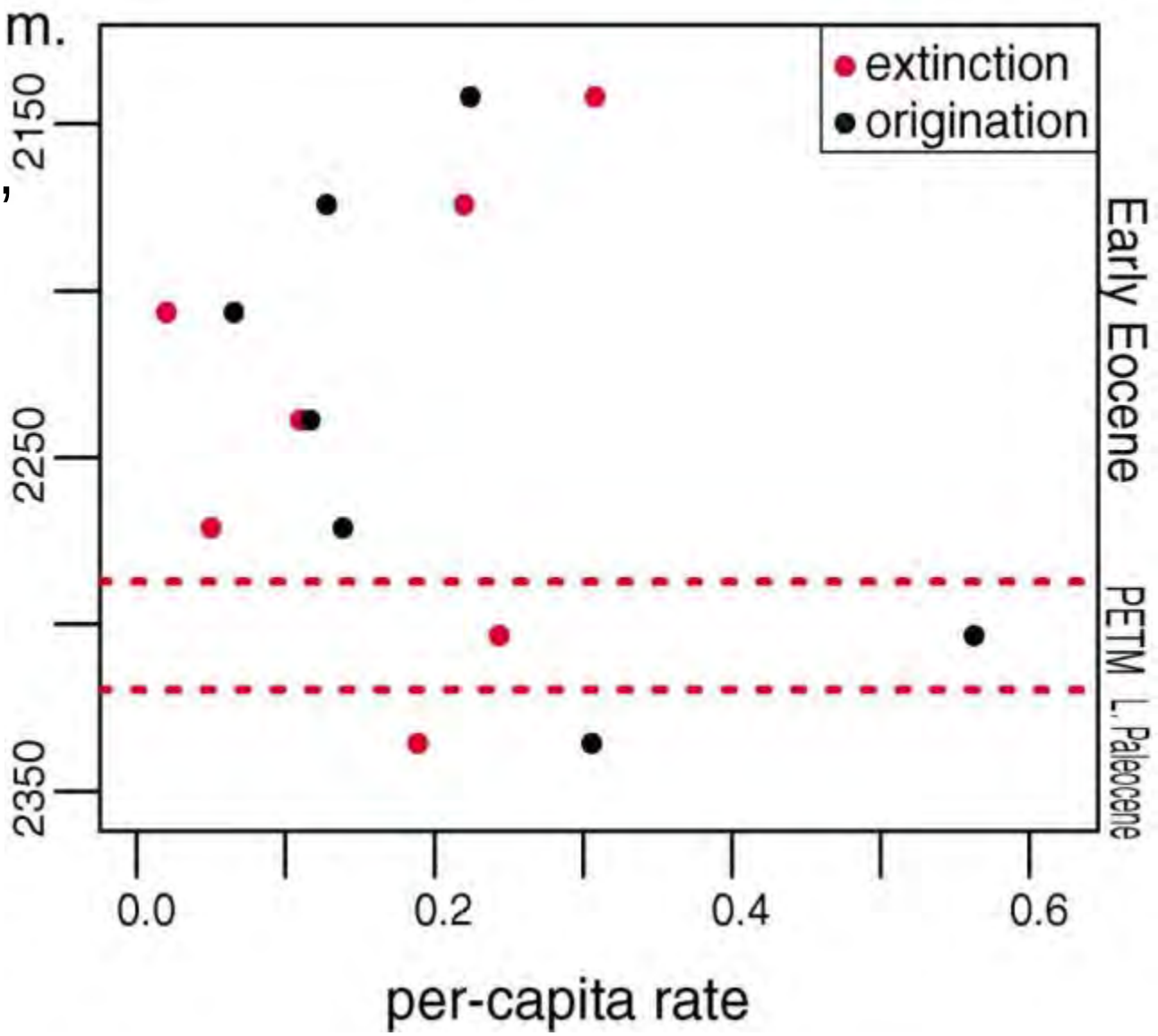
Modeling and paleo-environment records show similar extent of **tropical moist forests** and large expansion of **dry forests and savannas** at the expense of desert.



Many tropical species and most genera are at least this old. Have they retained their thermal tolerance through the last 2.5 million years when climates have generally been cooler than the present?

The **Paleocene-Eocene Thermal Maximum (PETM)**, 56 m years ago. Plant diversity rose at two Neotropical sites, with a slight increase in extinctions, despite rapid **3-5ºC warming** (to 31-34ºC).



[Jaramillo et al. 2010, *Science*]

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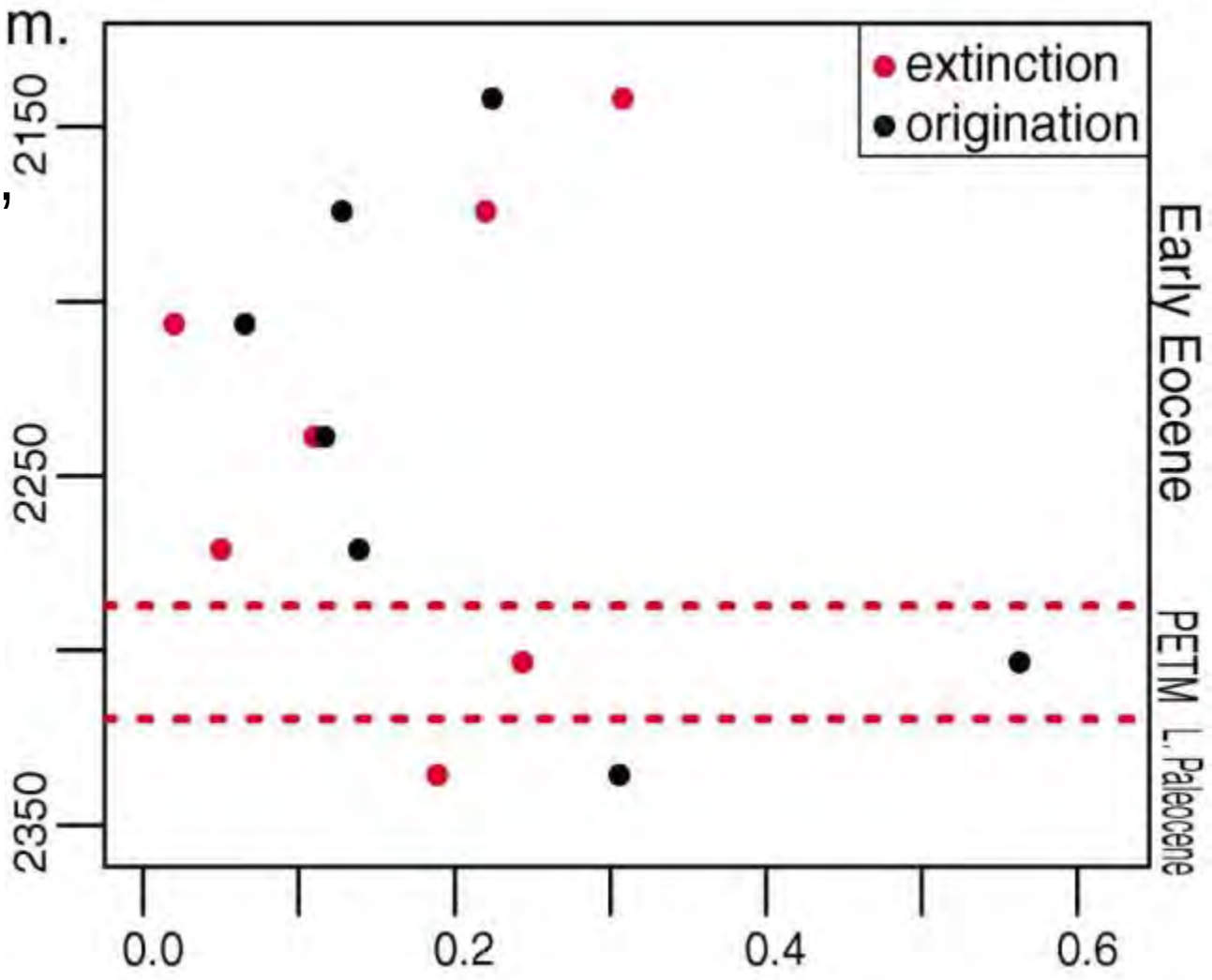

Note: The points are 200,000 years apart – a very different timescale

Possible reasons for cautious (relative) optimism:

1.We observe only *currently realized* climatic niches, while paleo-ecological data suggests ***fundamental* niches** can be much larger.

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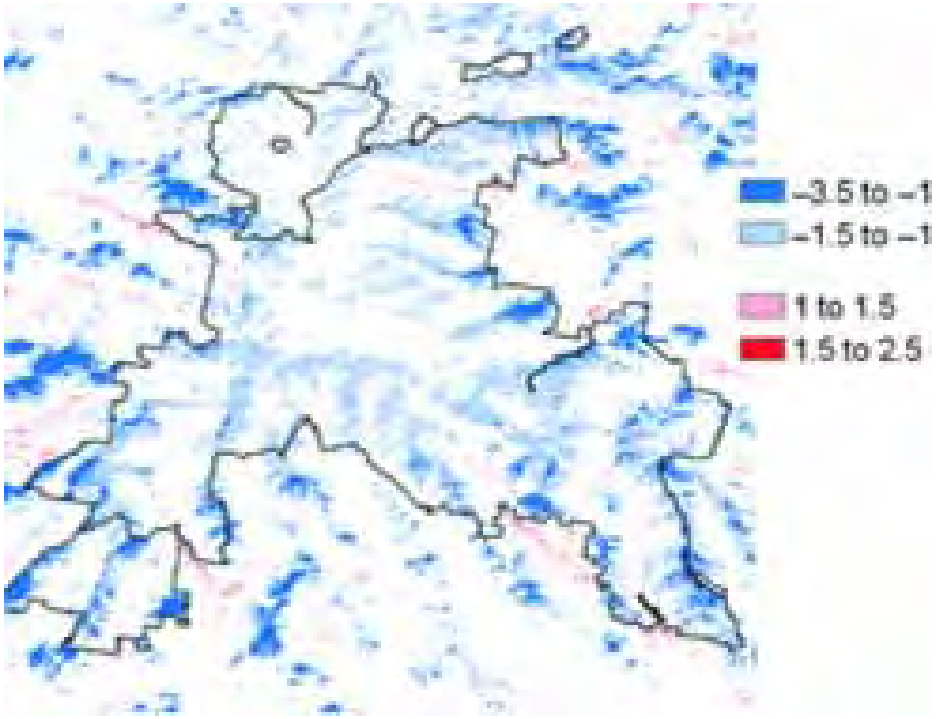
3.Spatial heterogeneity can provide refugia within dispersal range.



Ashcroft et al. 2012, *Global Change Biology*

Cool microrefugia (blue) in the Barrington Tops region of eastern Australia (32ºS).

Based on the 95% percentile of maximum temperatures

Cool microrefugia were distinguished by:

- ü high canopy cover
- ü high elevation
- ü nearness to the coast.

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6.Rising CO_2 could offset at least part of the effects of warming (and drying) on plants.

Research needs:

1. Rigorous, quantitative, multi-decadal **monitoring** of tree growth, survival and fecundity on at least an annual basis.

2. Establish baseline data for the detection of **range shifts** along steep climatic gradients.

3. More information on **thermal tolerances** of tropical organisms, including **acclimation** capacity and **heritable genetic variation**.

Conclusions:

1. The most pervasive impact on tropical rainforests will be rising temperature.
2. These rises will be large compared to current variability.
3. A variety of evidence suggests that many tropical animals and plants may already be near to their upper thermal limits.
4. *But*... this pessimistic appraisal largely neglects acclimation, evolution and spatial heterogeneity.
5. We urgently need more research, with an emphasis on setting up long-term monitoring projects.

Thank you!

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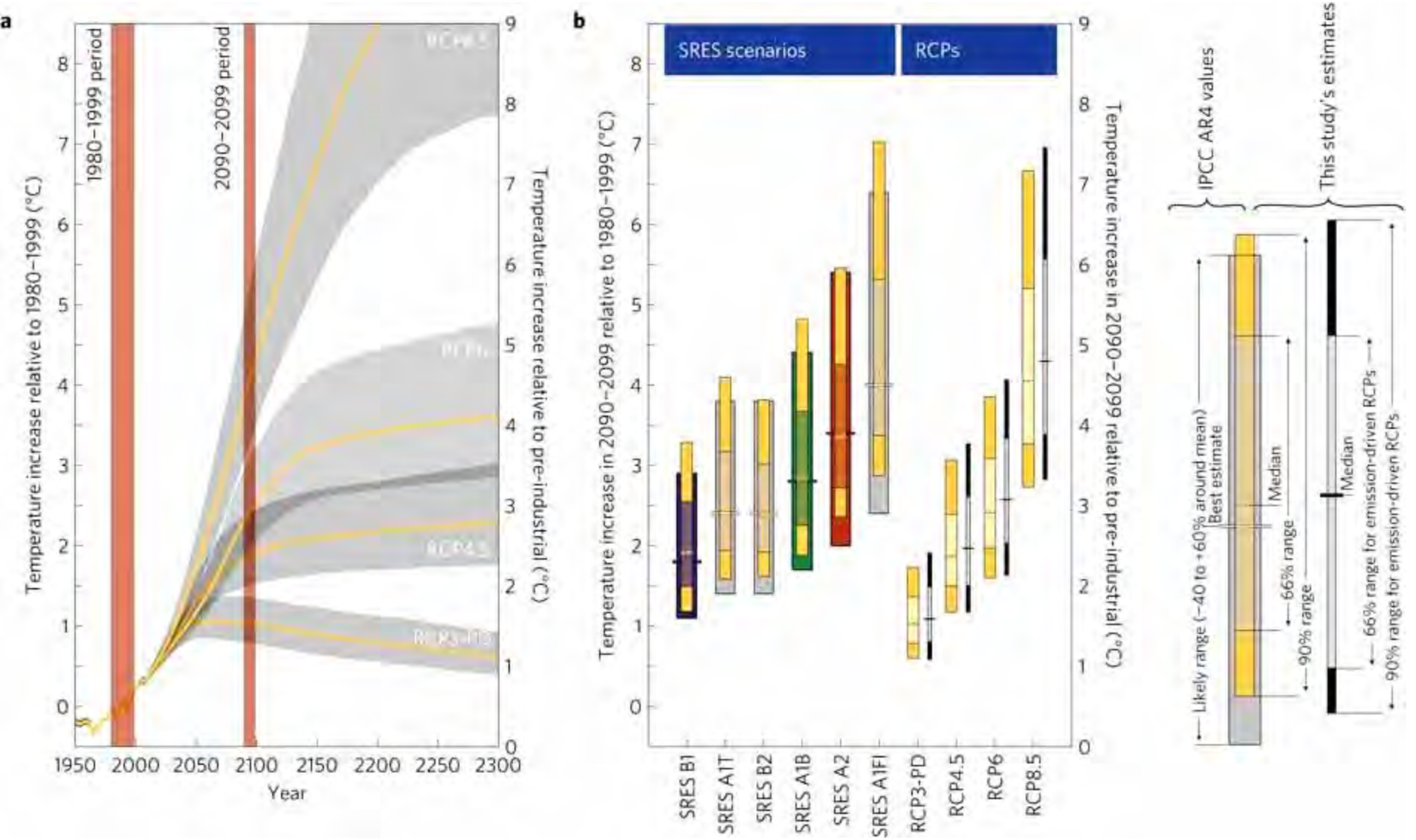
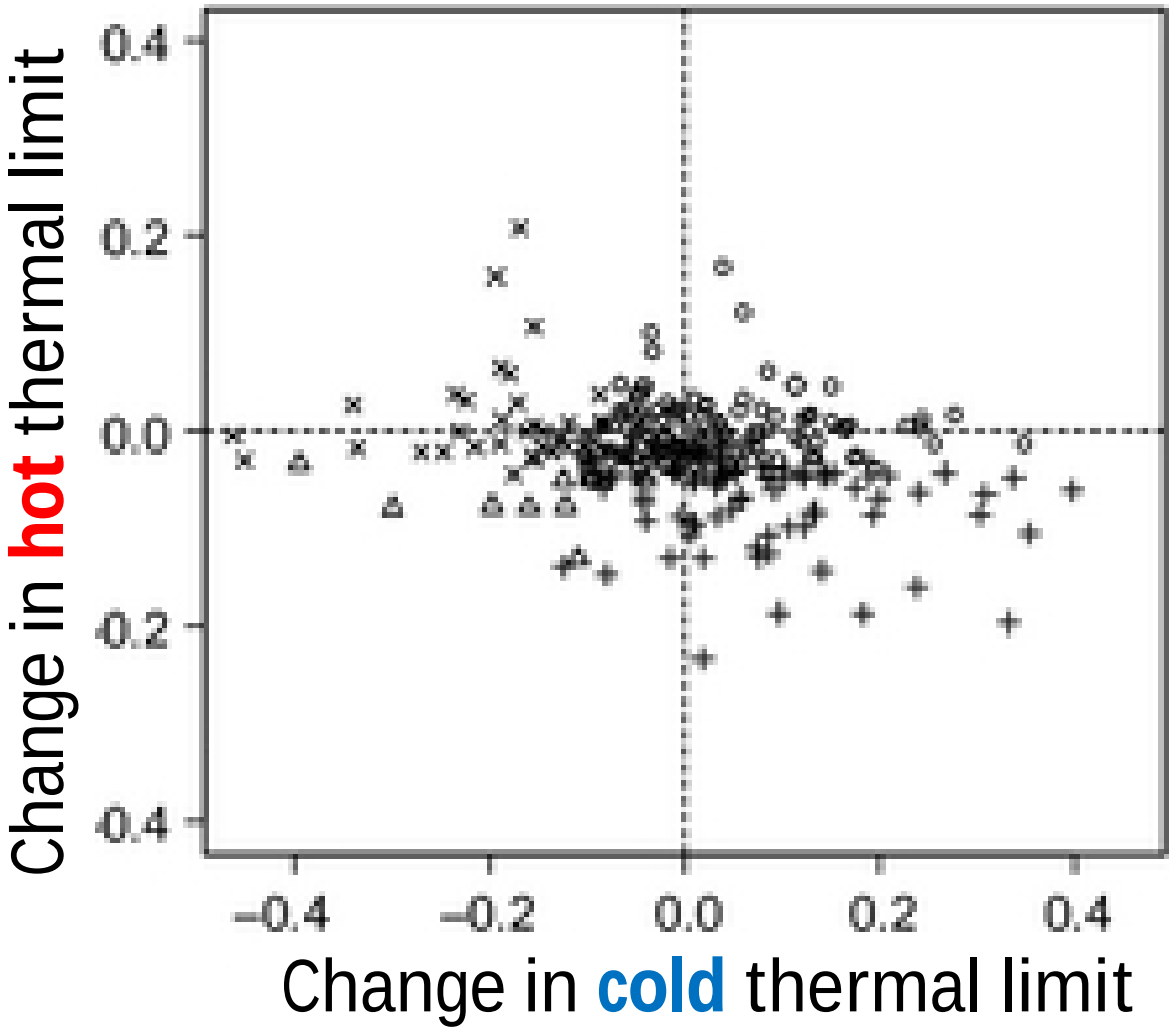
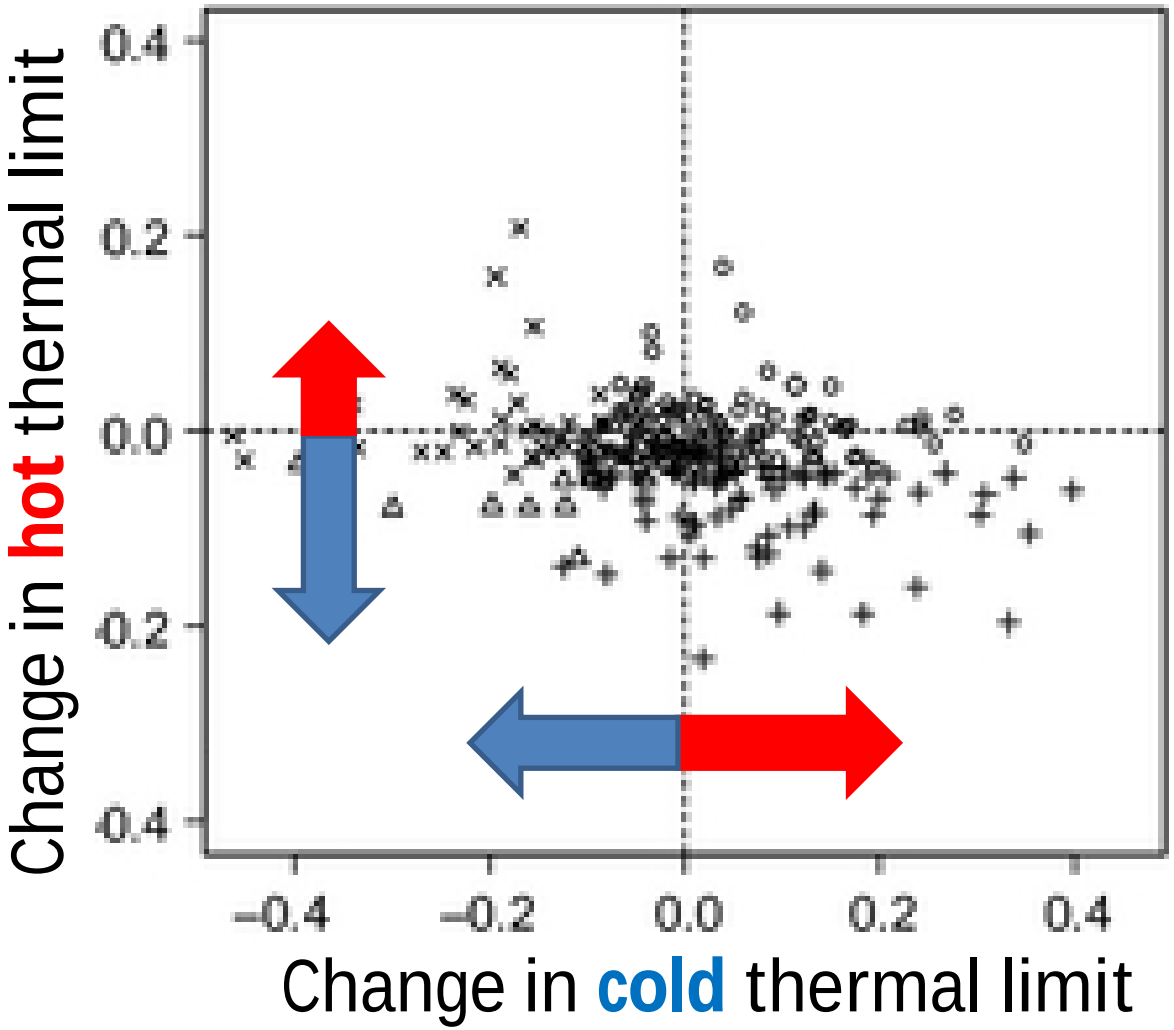


Rogelj et al. 2012. *Nature Climate Change*



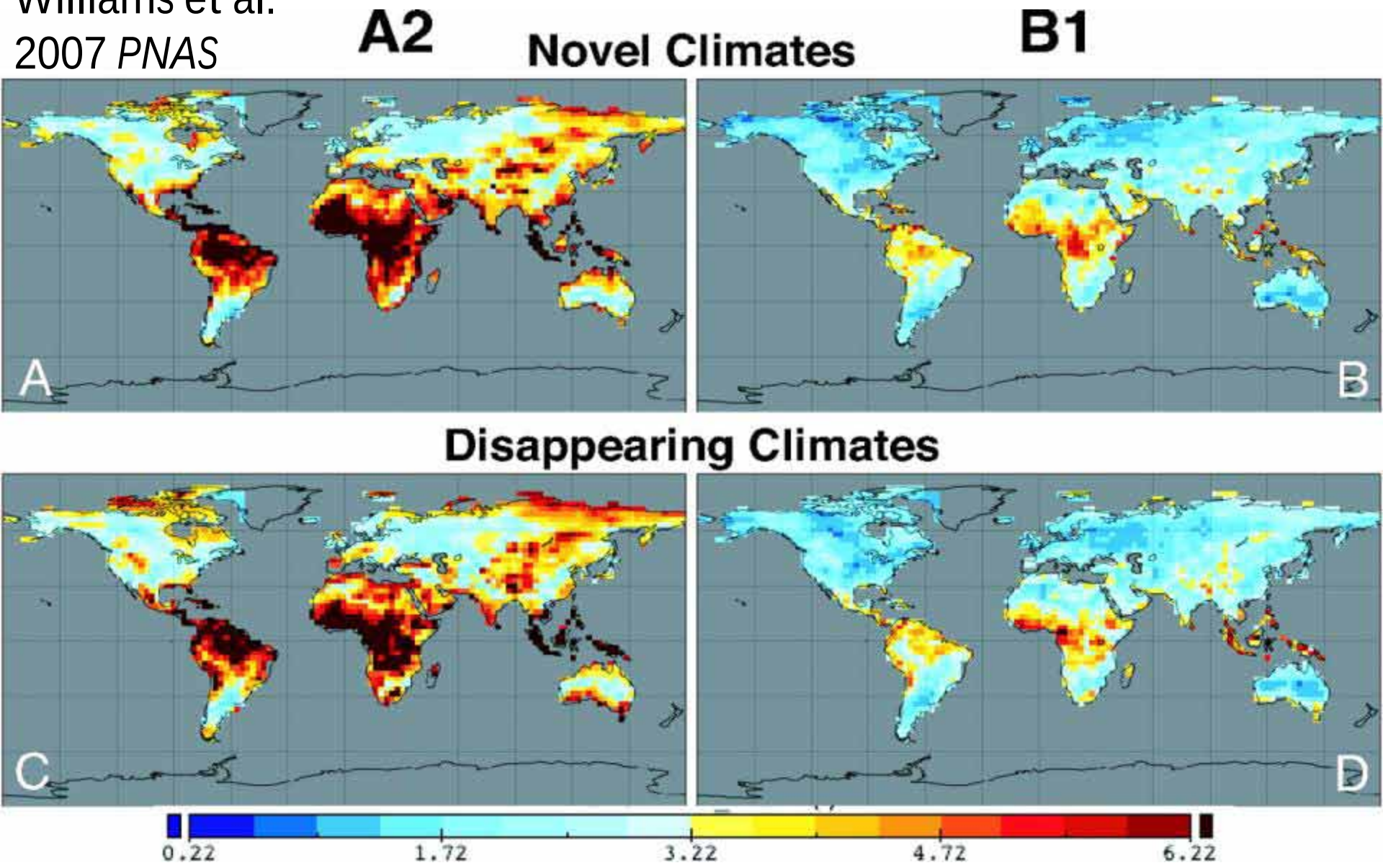
Changes in the thermal distributions of 239 South American plant species, 1970-2009, from dated herbarium records.
[Feeley 2012. *Global Change Biology*]



Many species show an apparent retreat from their hot thermal limits but no expansion of their cold thermal limits.

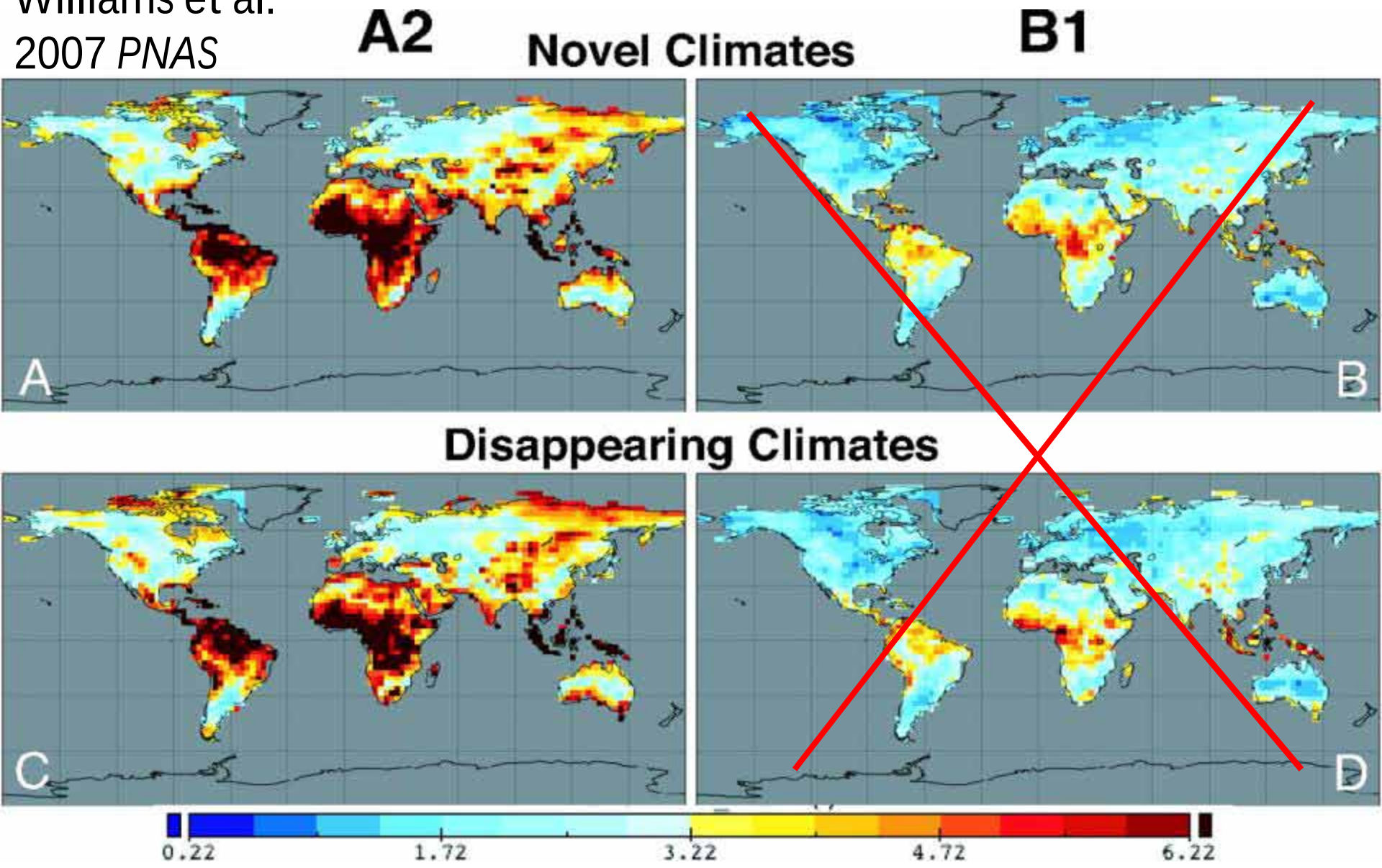
[Feeley 2012. *Global Change Biology*]

Williams et al.
2007 *PNAS*



Changes in climate standardized against interannual variability.
(Note: ‘novel’ and ‘disappearing’ within 500 km radius.

Williams et al.
2007 *PNAS*



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