Uncertainty: Land Management in a Time of Rapid Change

Virginia Matzek
Santa Clara University

Snowpack:
30-90% decrease this century, earlier melt by 6-21 days

Precipitation:
<10% decrease overall

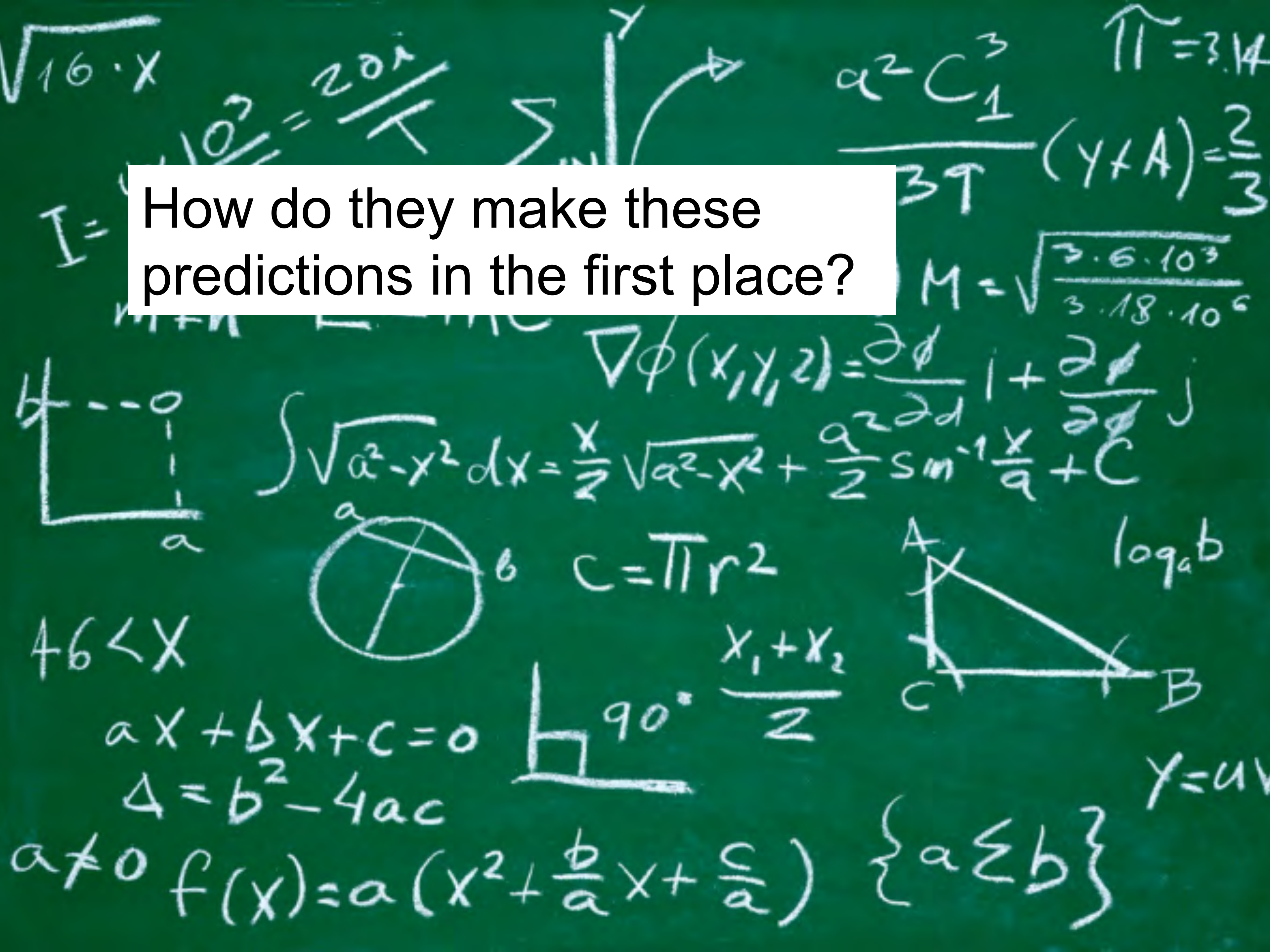
Droughts:
~5-10% more drought months in the next 30 years

Joshua Trees out of Joshua Tree NP?

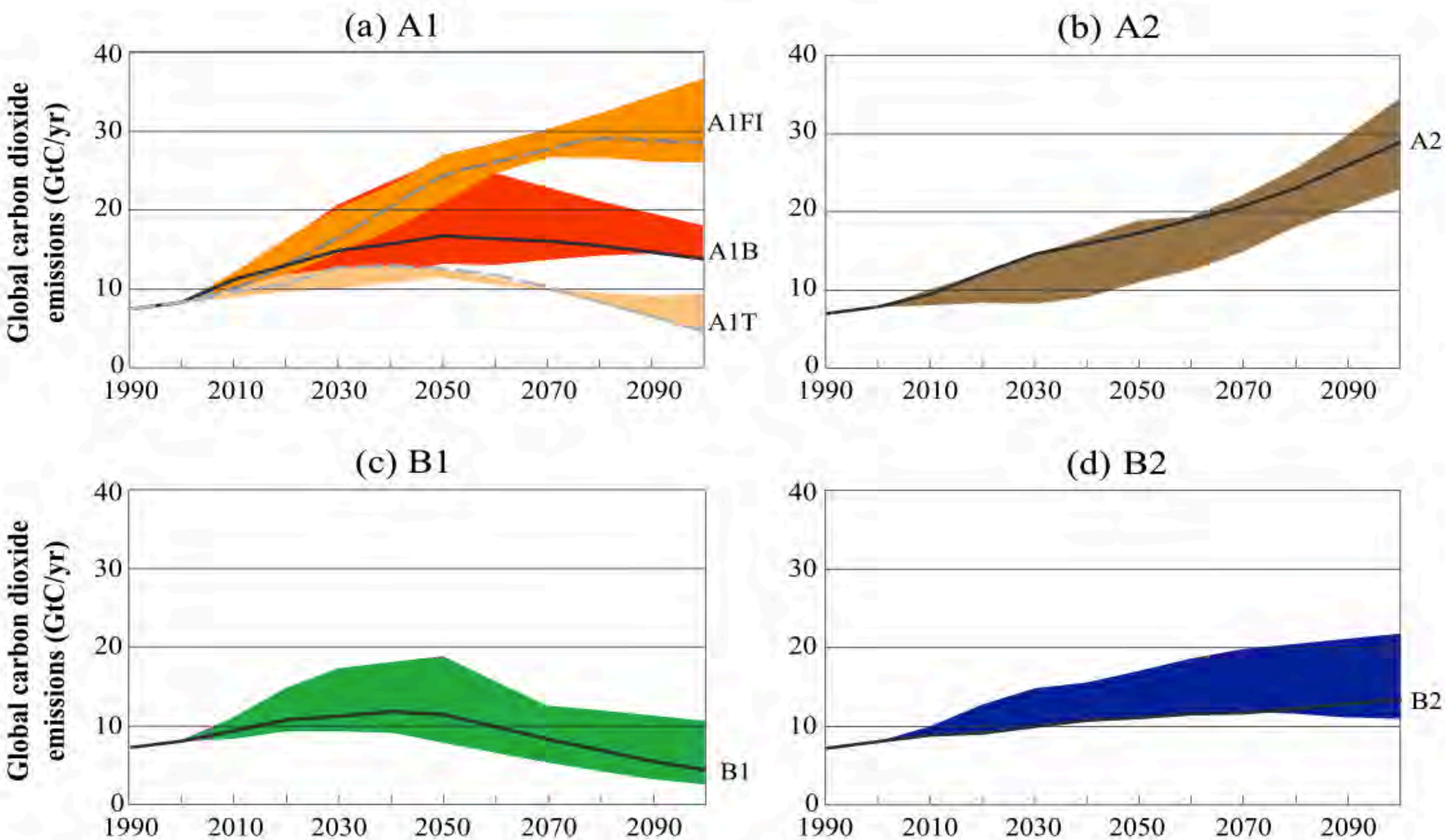
Valley Oaks out of the Central Valley?

Wider spread of tamarisk?

How do they make these predictions in the first place?

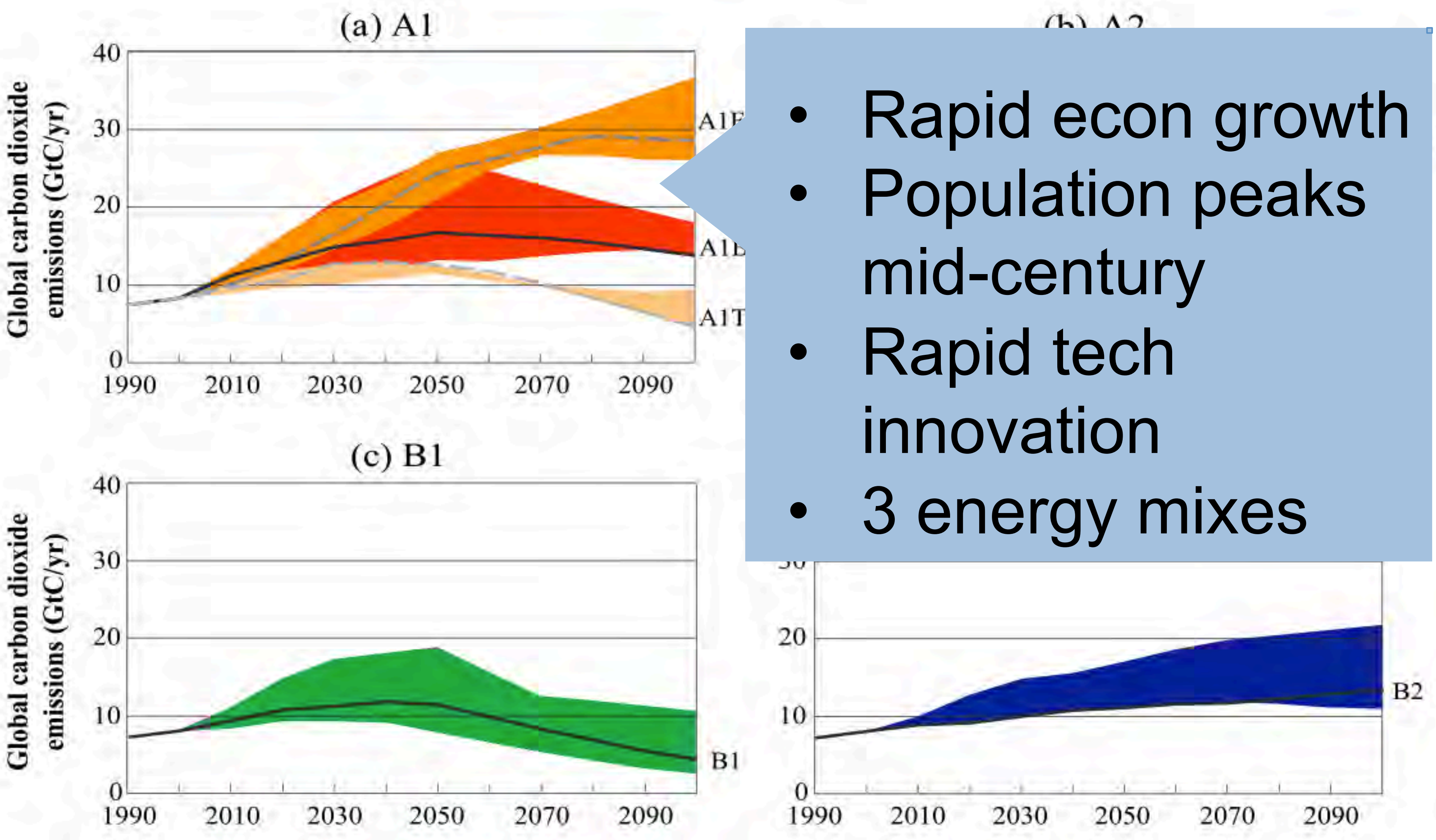


A first step: guessing at emissions scenarios



Credit:IPCC

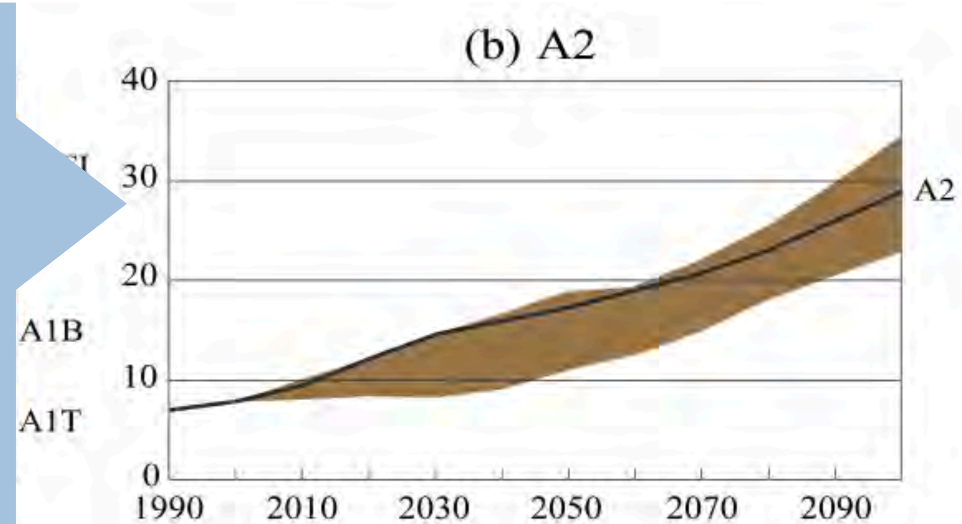
A1 "storyline" – covering a family of scenarios

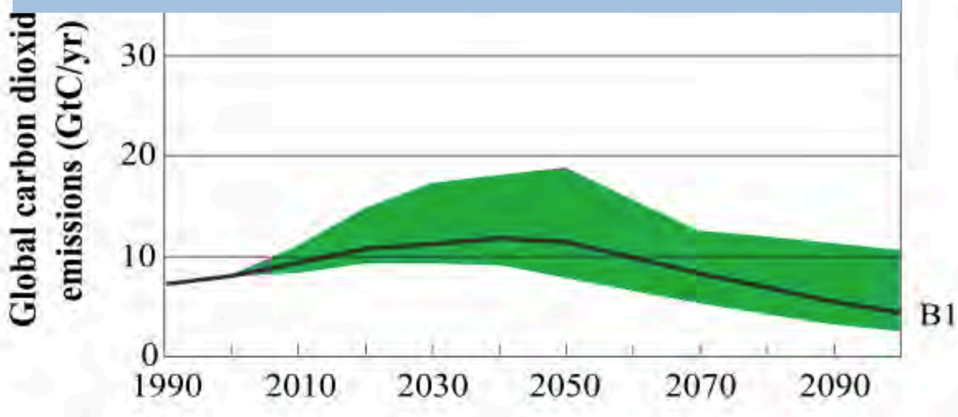


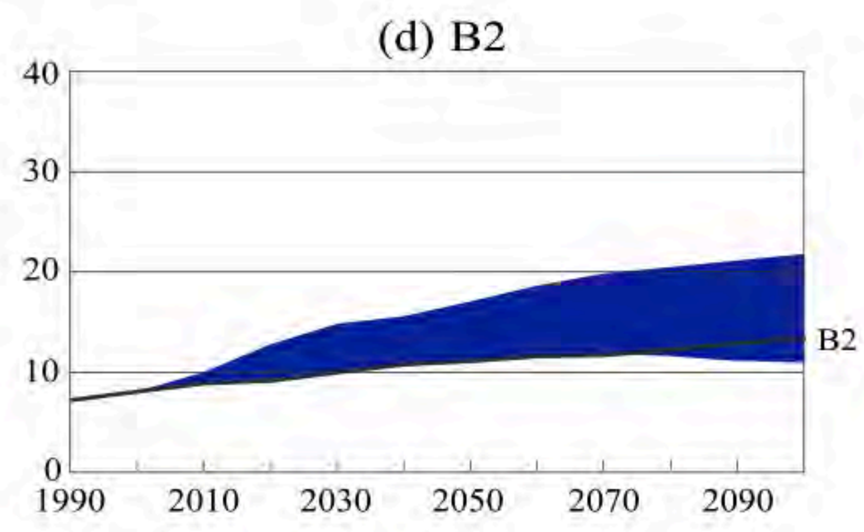
- Rapid econ growth
- Population peaks mid-century
- Rapid tech innovation
- 3 energy mixes

A2 storyline and associated scenarios

- Regional diversity
- Population grows continuously
- Economic development uneven

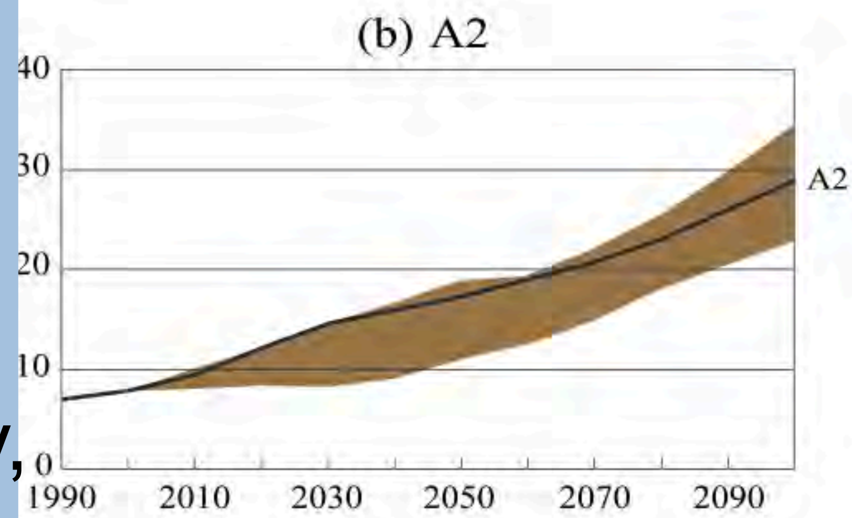


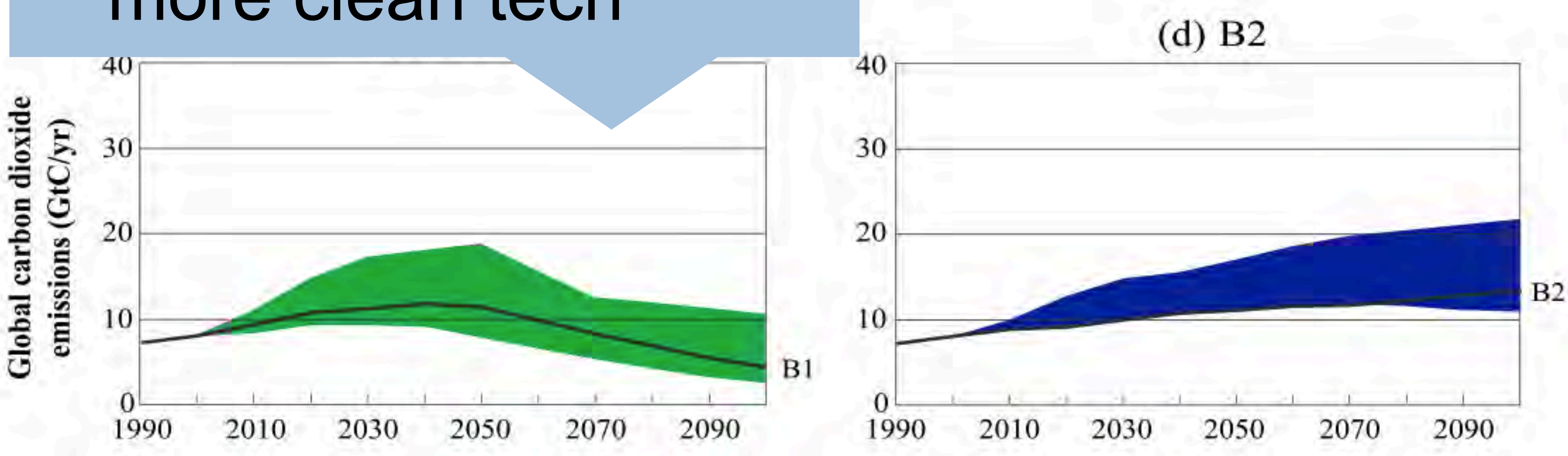




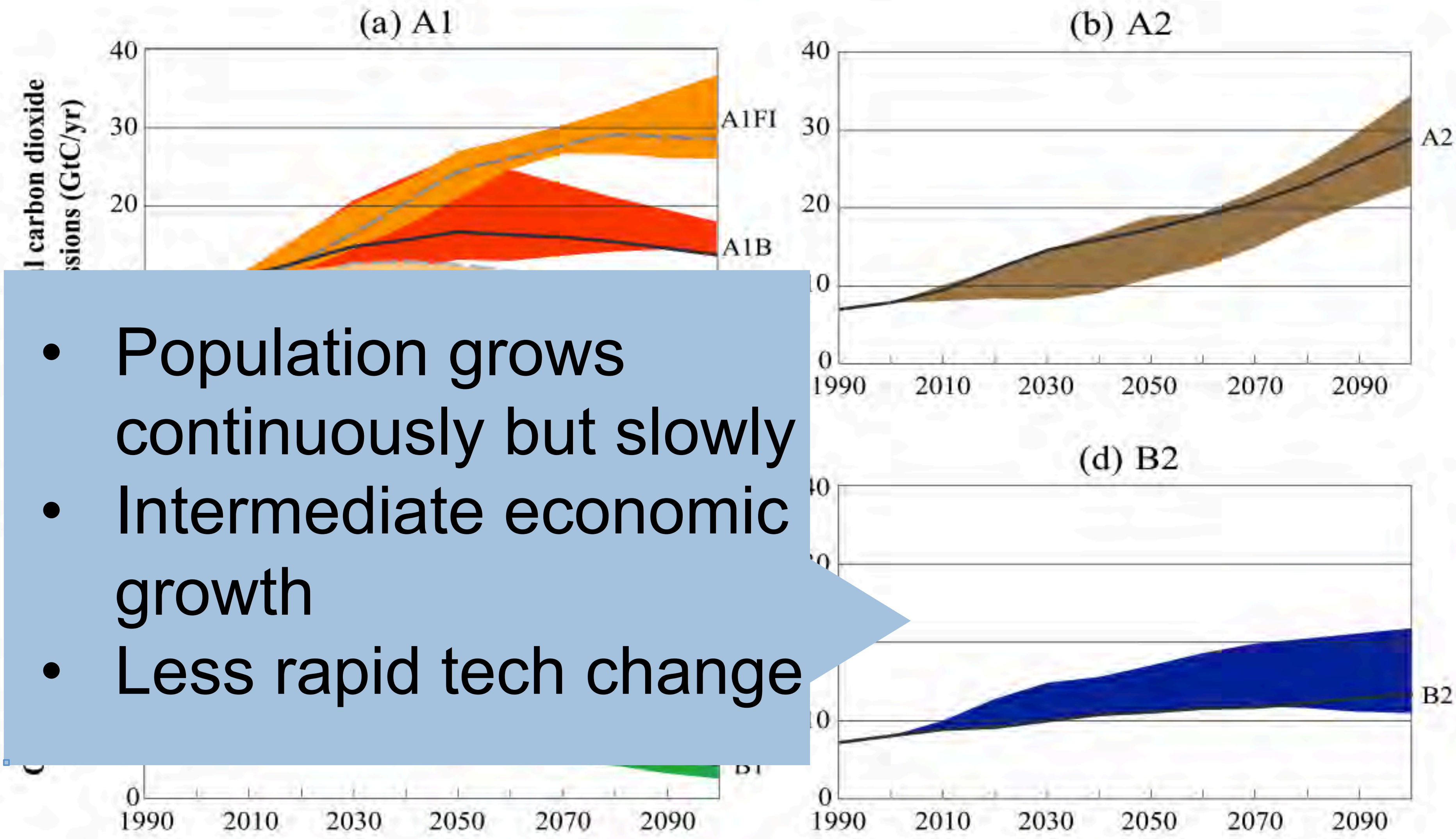
B1 storyline and associated scenarios

- Population peaks mid-century
- Economy based on service/info
- Less resource-intensity, more clean tech



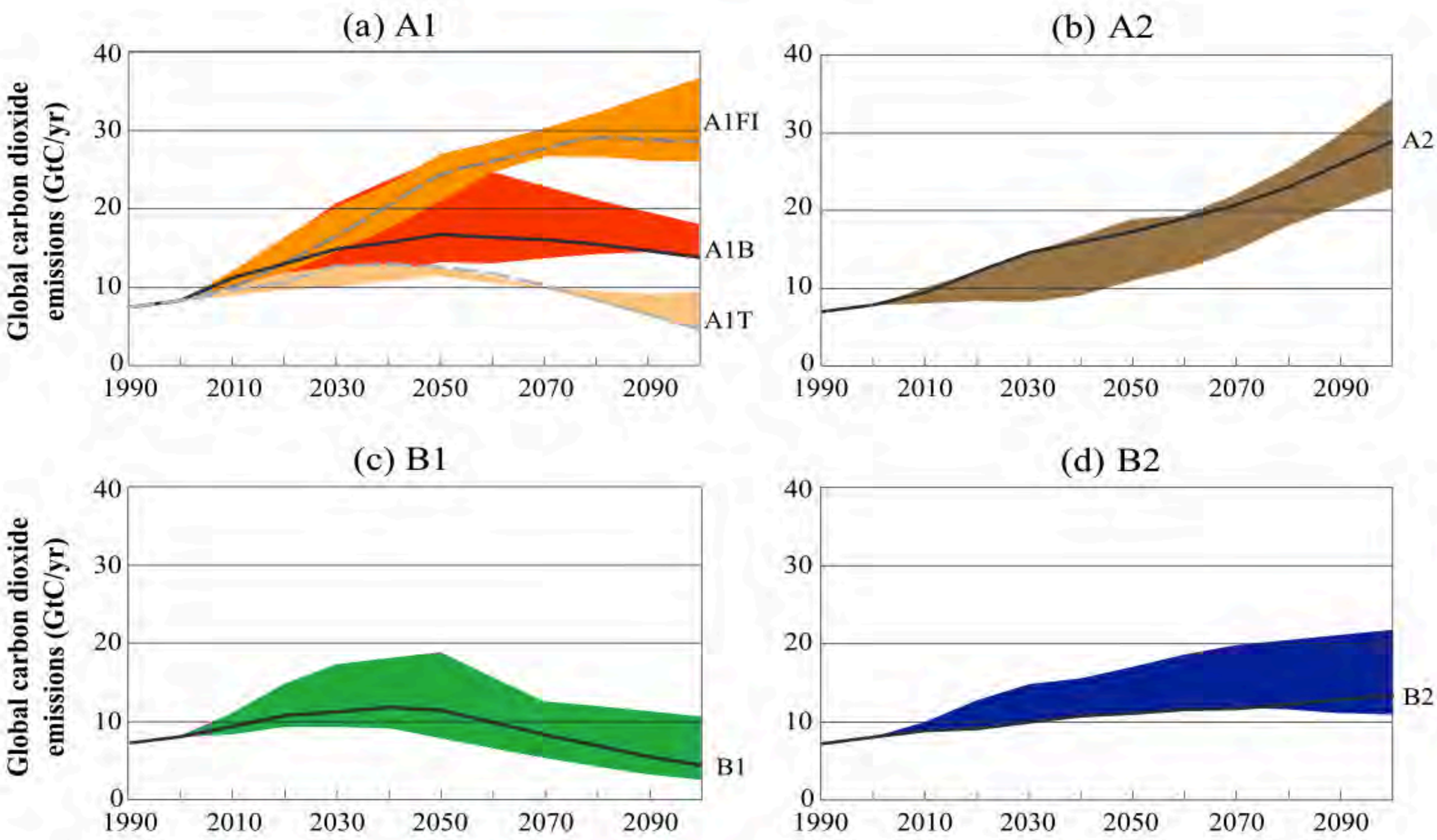


B2 storyline and associated scenarios



- Population grows continuously but slowly
- Intermediate economic growth
- Less rapid tech change

All told, the 4 storylines yield 40 scenarios…



…assuming different energy choices, etc.

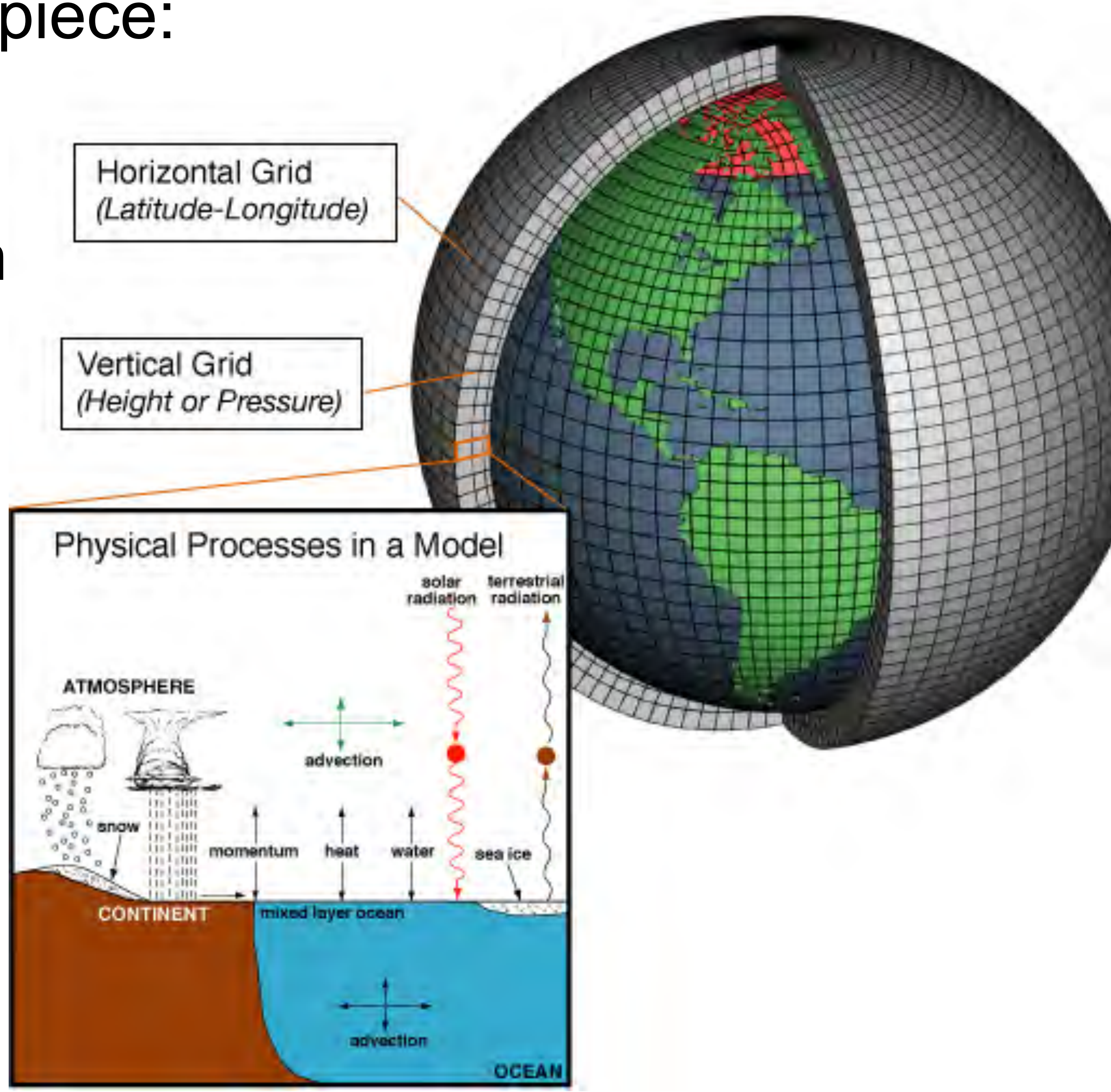
The other piece:

General Circulation Models

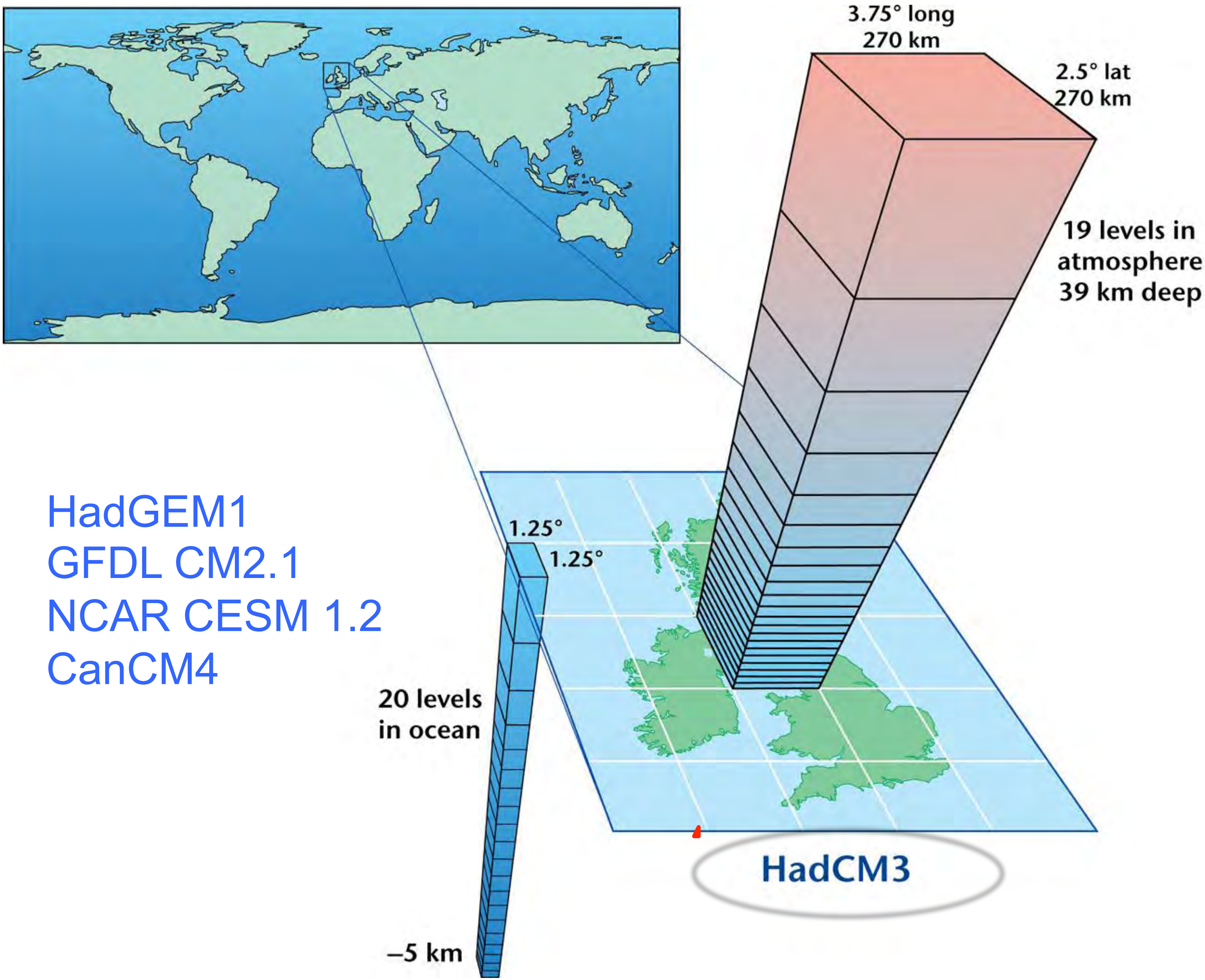
or

Global Climate Models

(GCMs)



Credit: NOAA

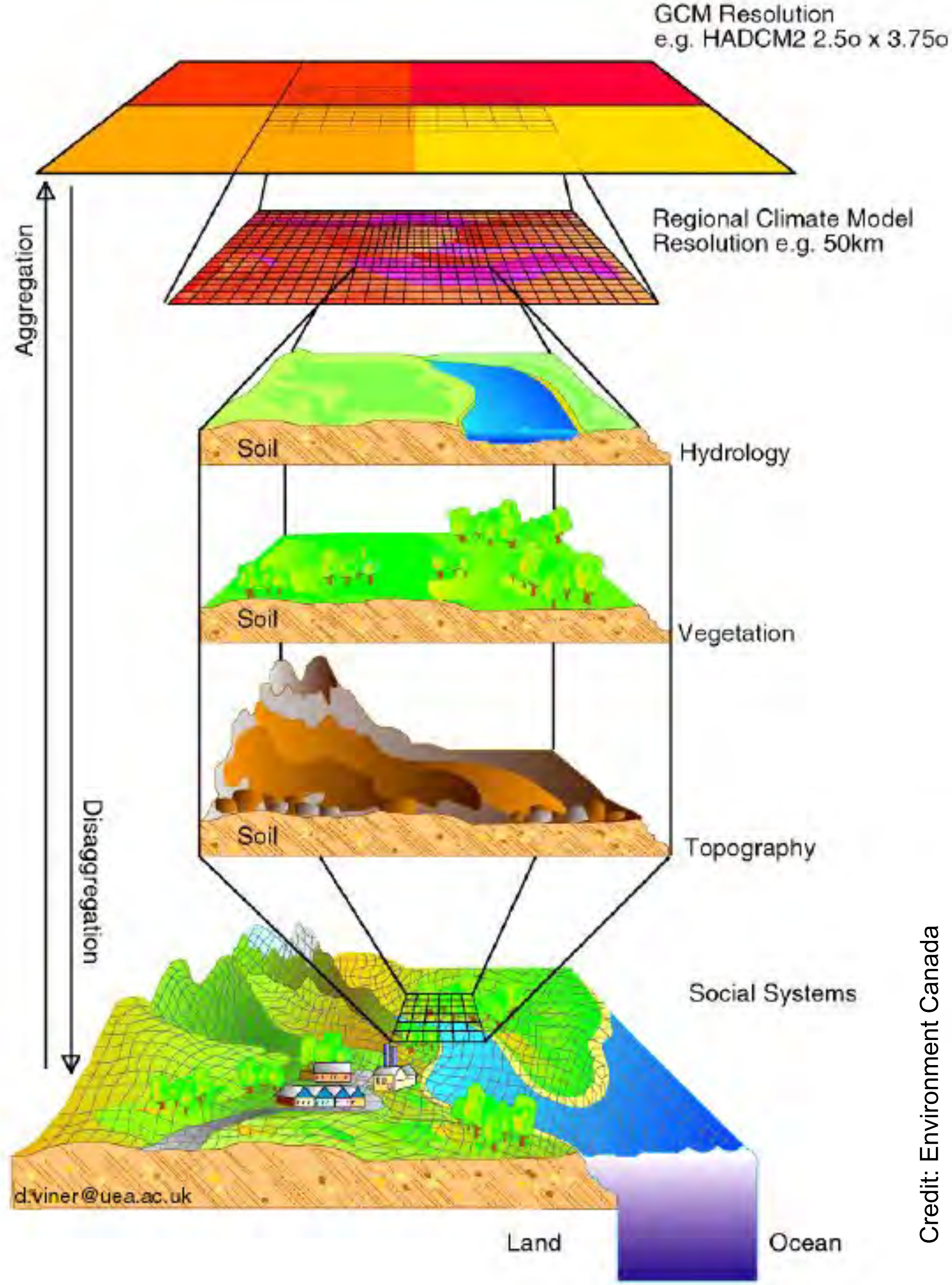


HadGEM1
GFDL CM2.1
NCAR CESM 1.2
CanCM4

Credit: Uk Climate Projections

GCM grid cells are too big to estimate local impact

- *Regional climate models* to incorporate local topography and land cover, e.g. RegCM2.5
- *Statistical downscaling* to relate large-scale climate variables to small-scale variables



Credit: Environment Canada

OK, that gets us to climate predictions.

Snowpack:
30-90% decrease this century, earlier melt by 6-21 days

Precipitation:
<10% decrease overall

NP00433936 [RM] © www.visualphotos.com

Droughts:
~5-10% more drought months in the next 30 years

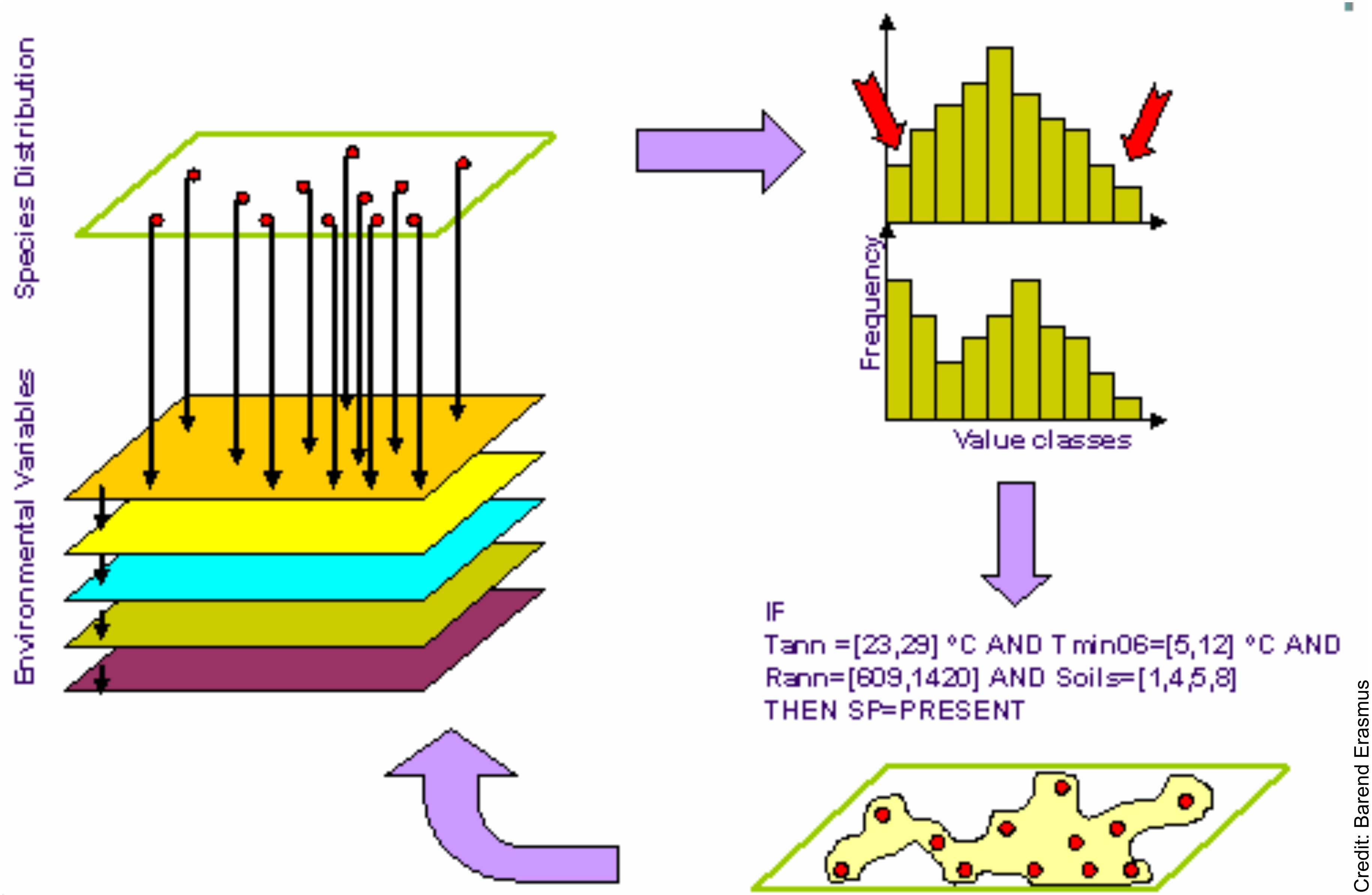
How do we model the biotic responses?

Joshua Trees out of Joshua Tree NP?

Valley Oaks out of the Central Valley?

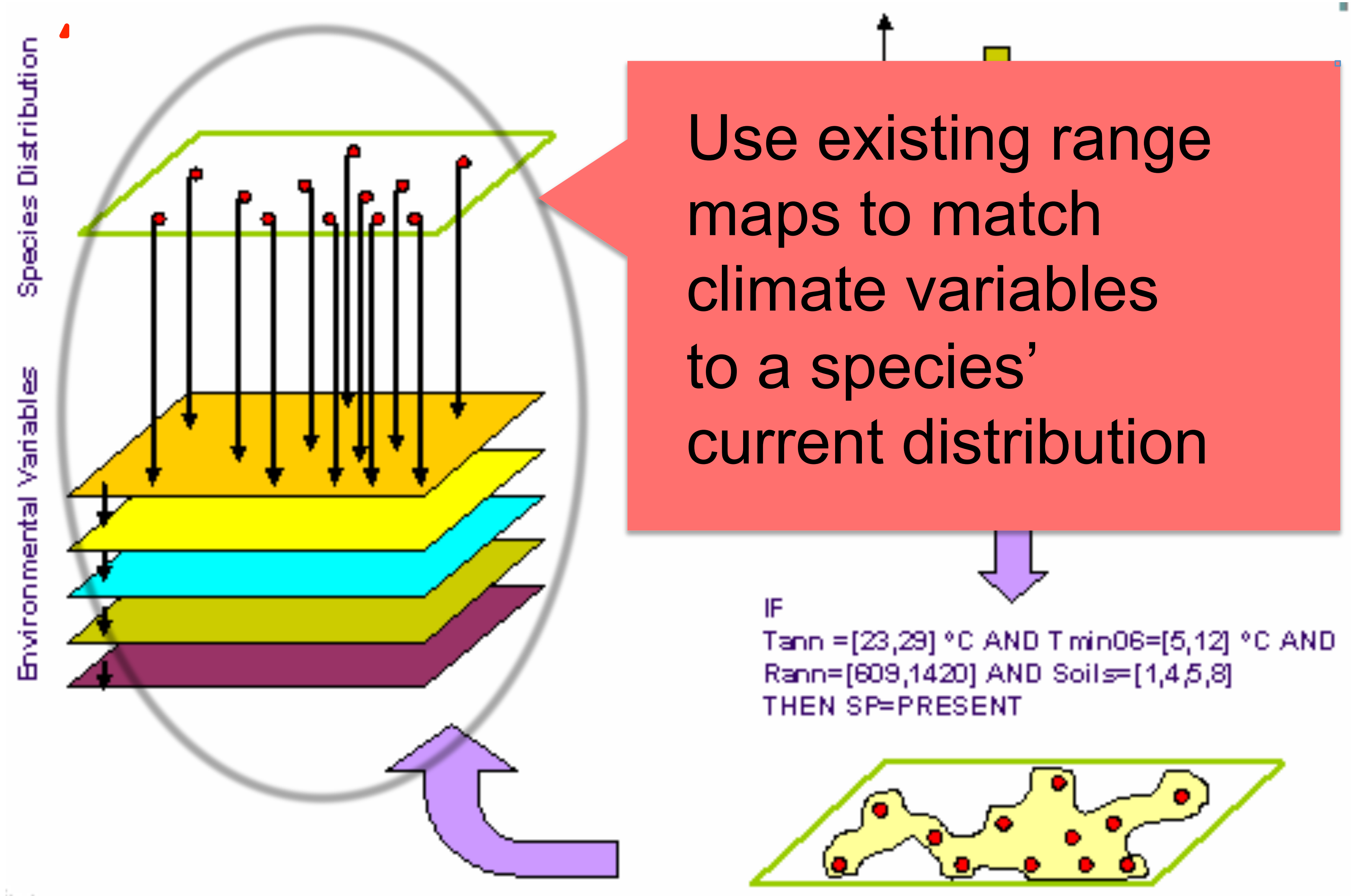
More tamarisk in Southern Cal?

Bioclimatic envelope models, aka “niche” models



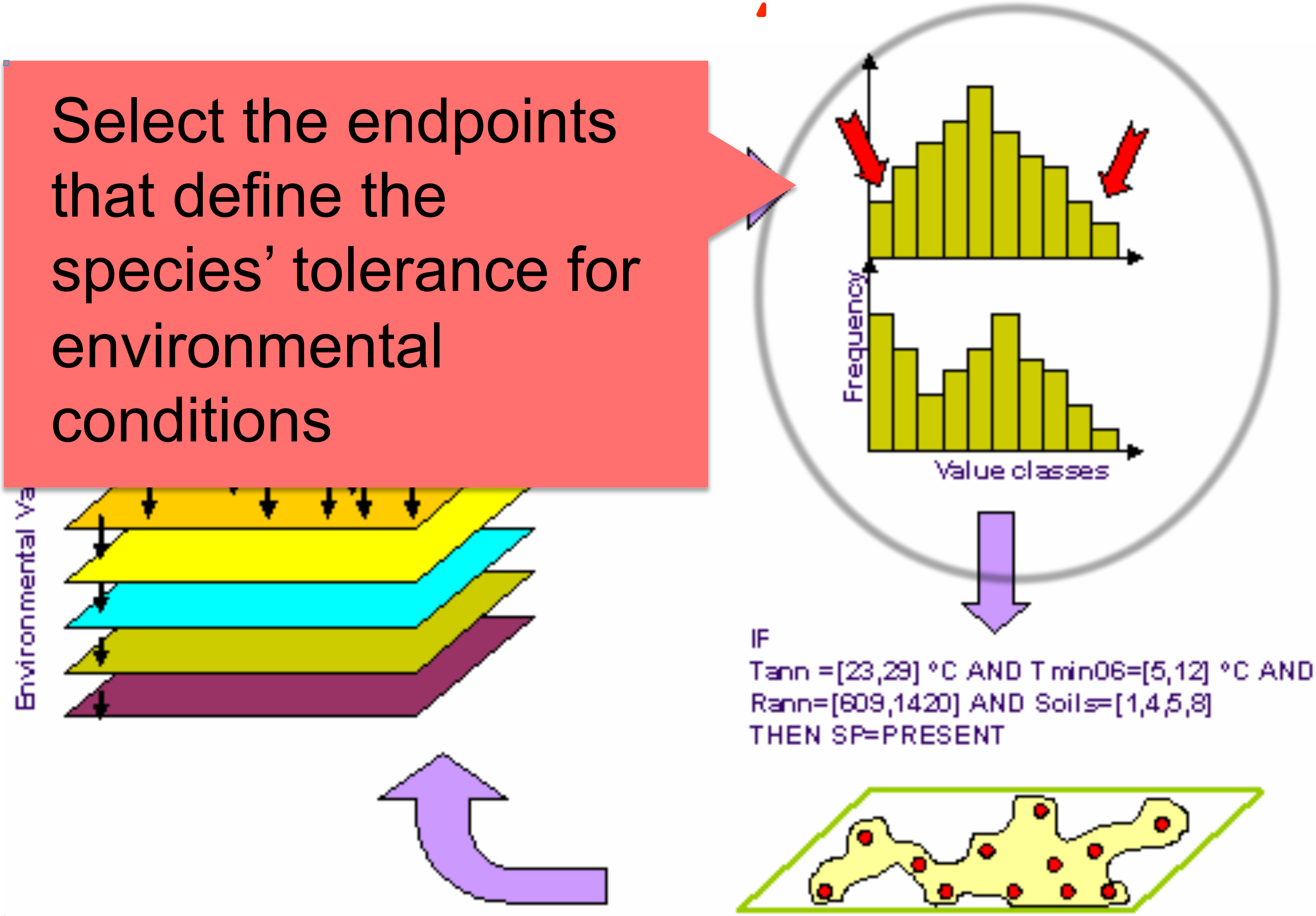
Credit: Barend Erasmus

Bioclimatic envelope models, aka "niche" models



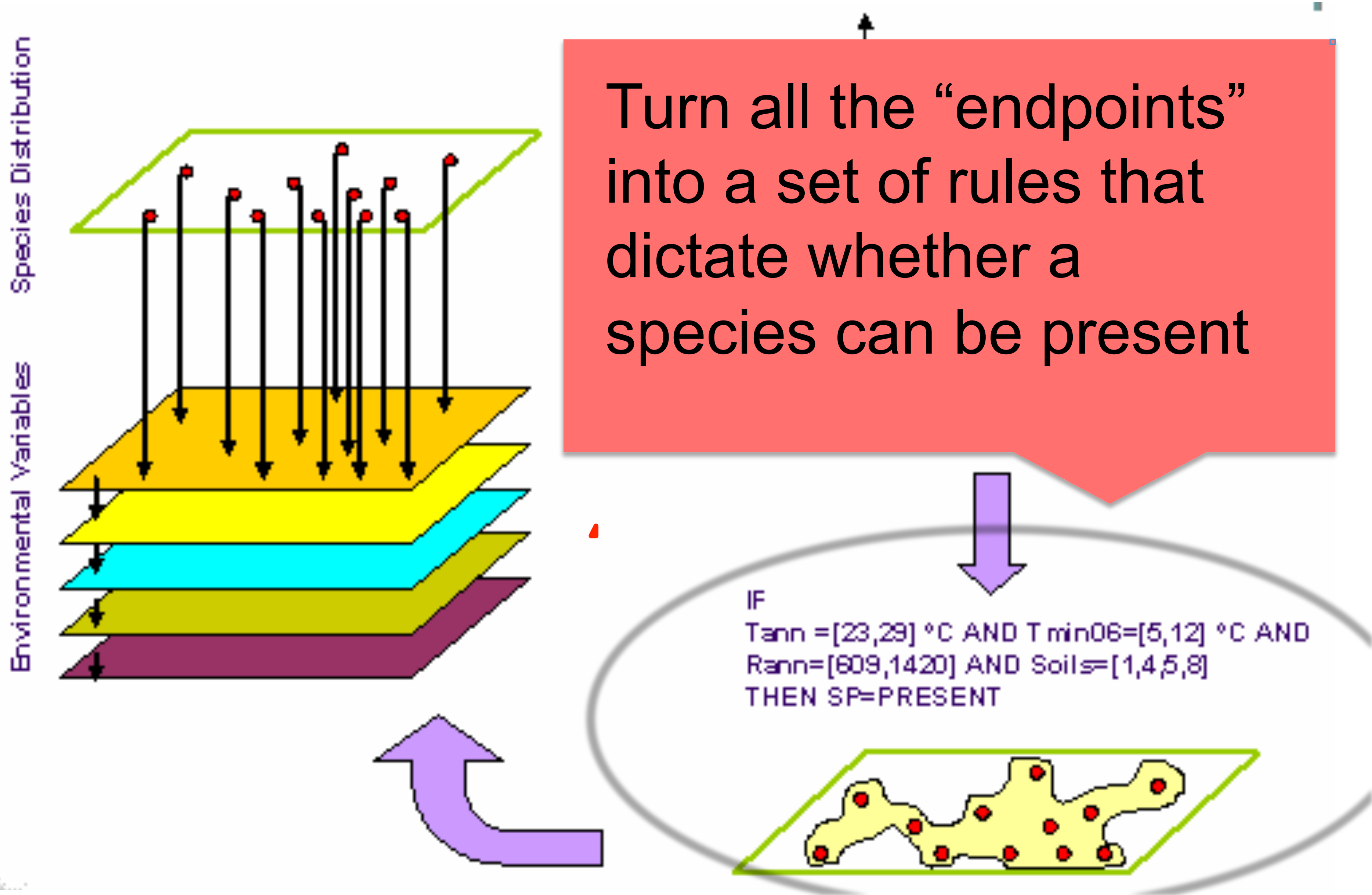
Bioclimatic envelope models, aka “niche” models

Select the endpoints that define the species’ tolerance for environmental conditions

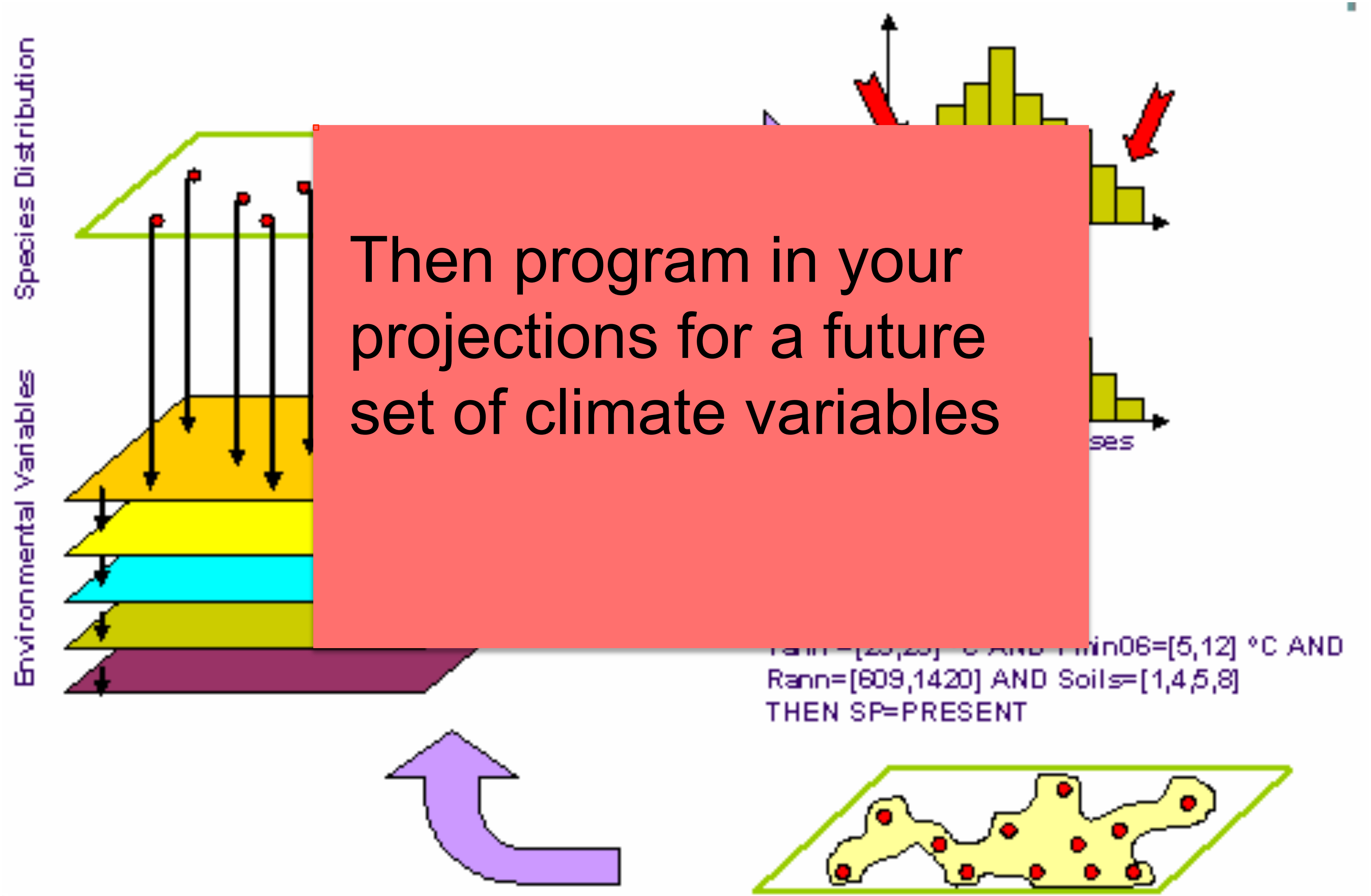


Bioclimatic envelope models, aka "niche" models

Turn all the "endpoints" into a set of rules that dictate whether a species can be present

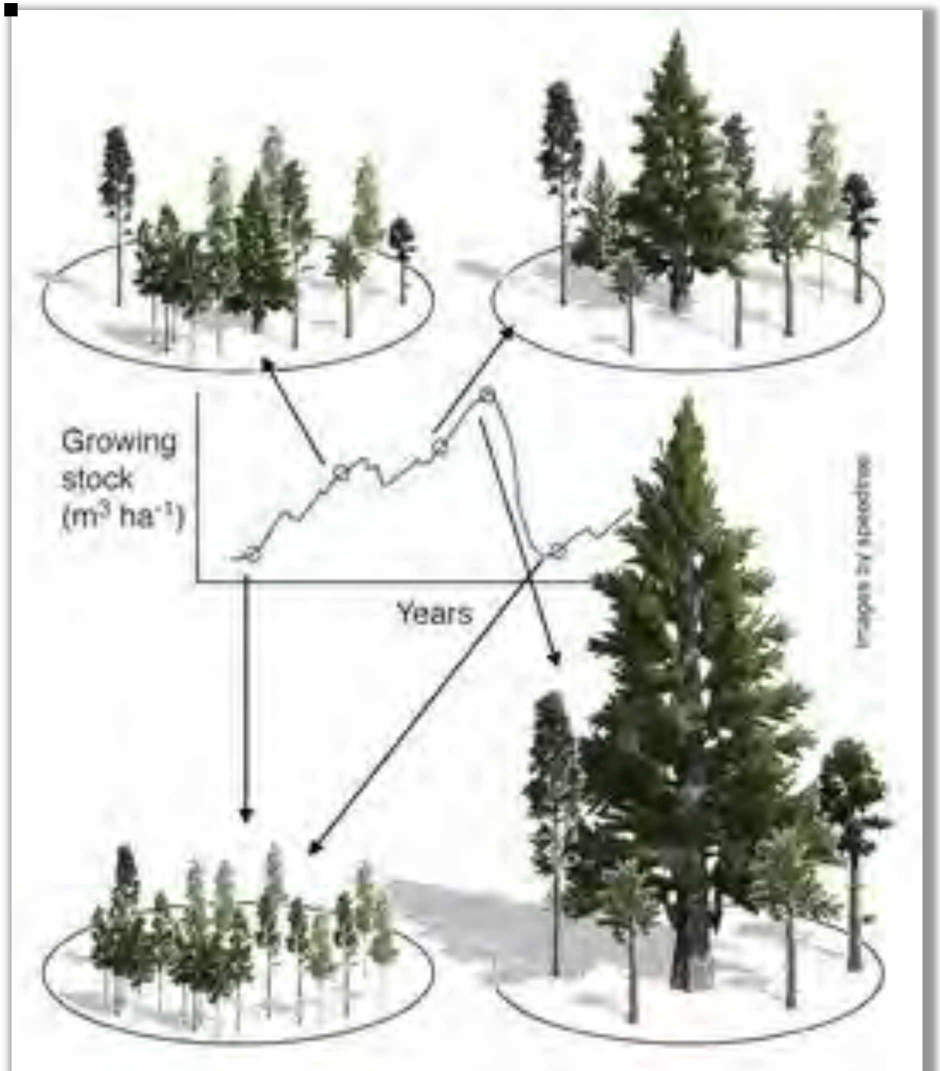


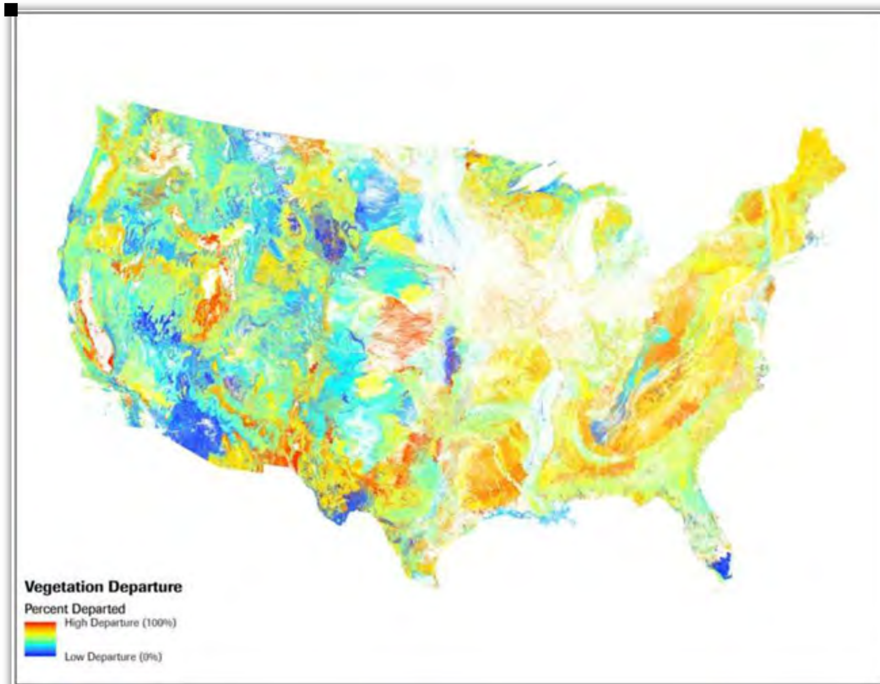
Bioclimatic envelope models, aka “niche” models



Then program in your projections for a future set of climate variables

There are other biotic response models:





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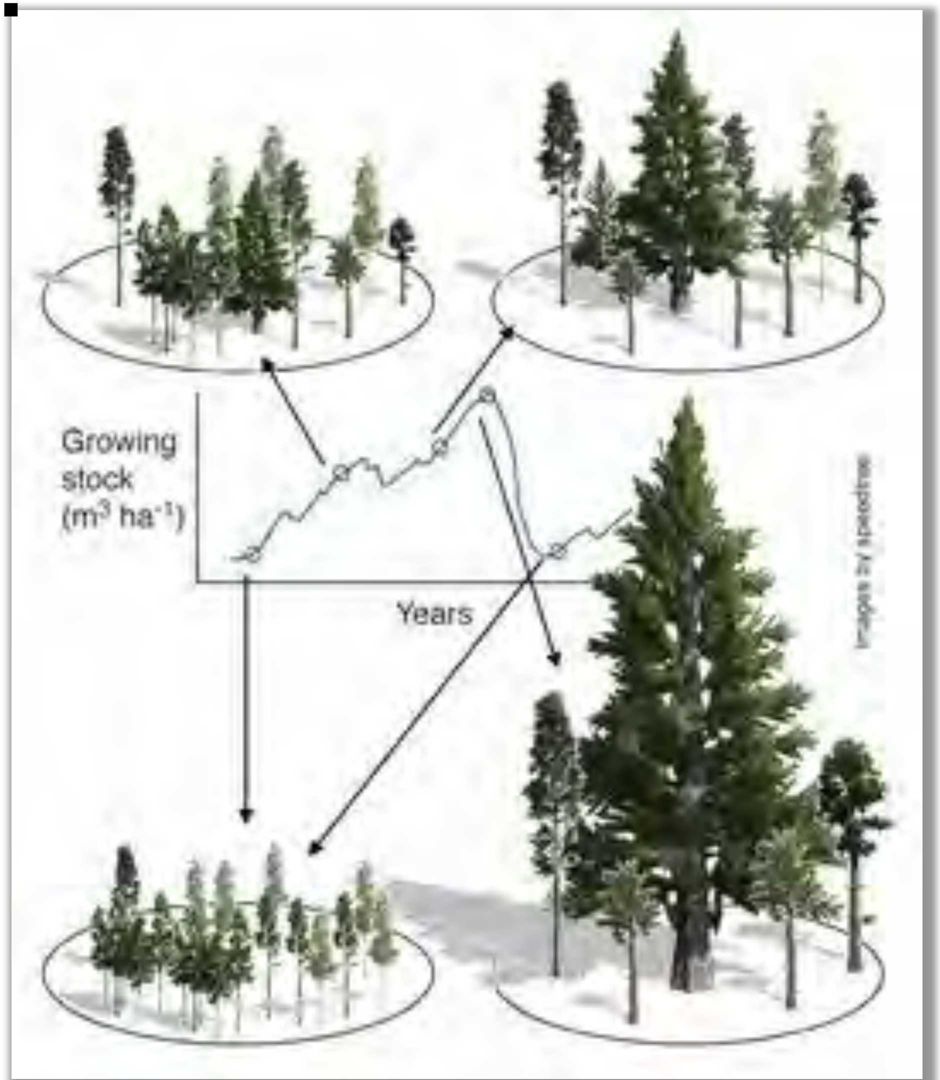


Forest gap models

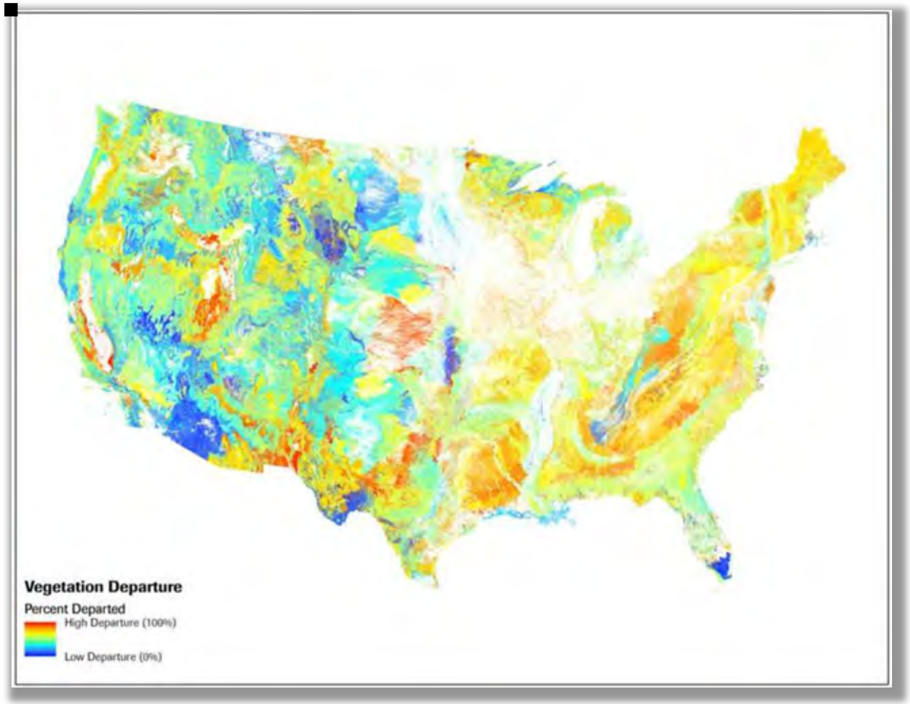
Model individual tree growth for multiple species in long-lived forests

Credit: Speedtree

There are other biotic response models:

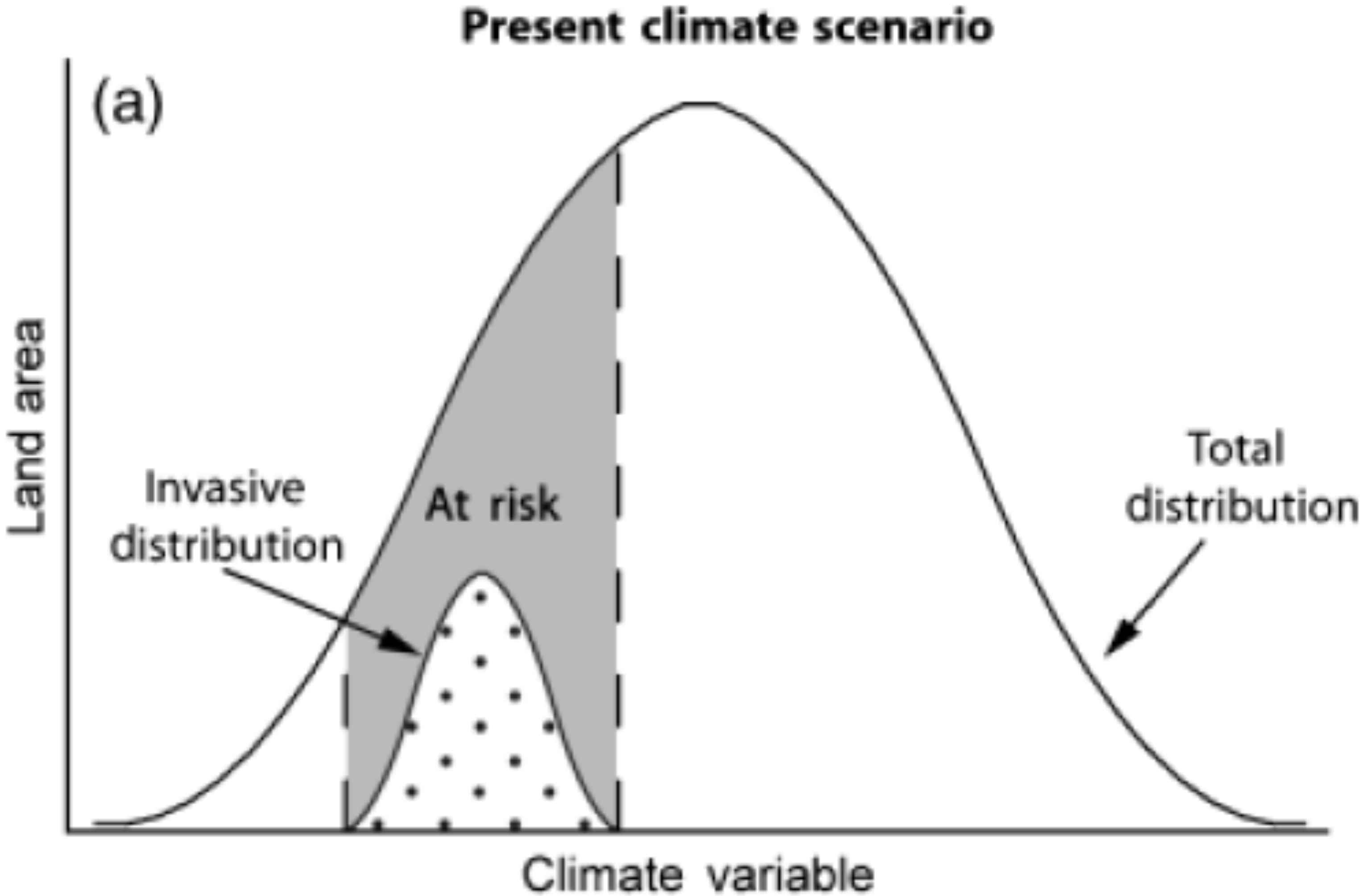
Credit:US Forest Service

Dynamic vegetation models

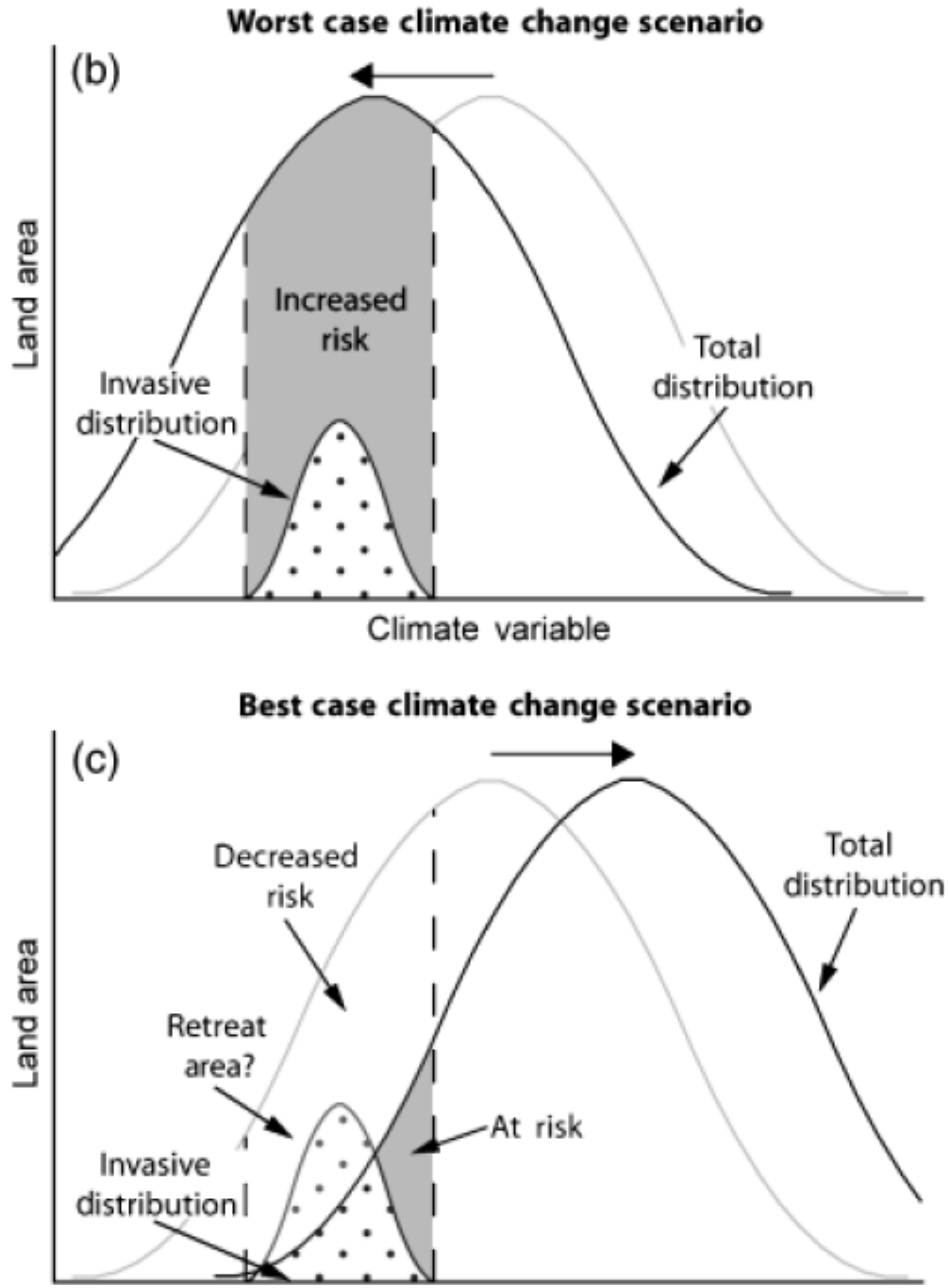


Include feedbacks with ecosystem processes like nutrient fluxes, water use, fire

But we'll focus on bioclimatic envelope models, most commonly used to predict invasive species

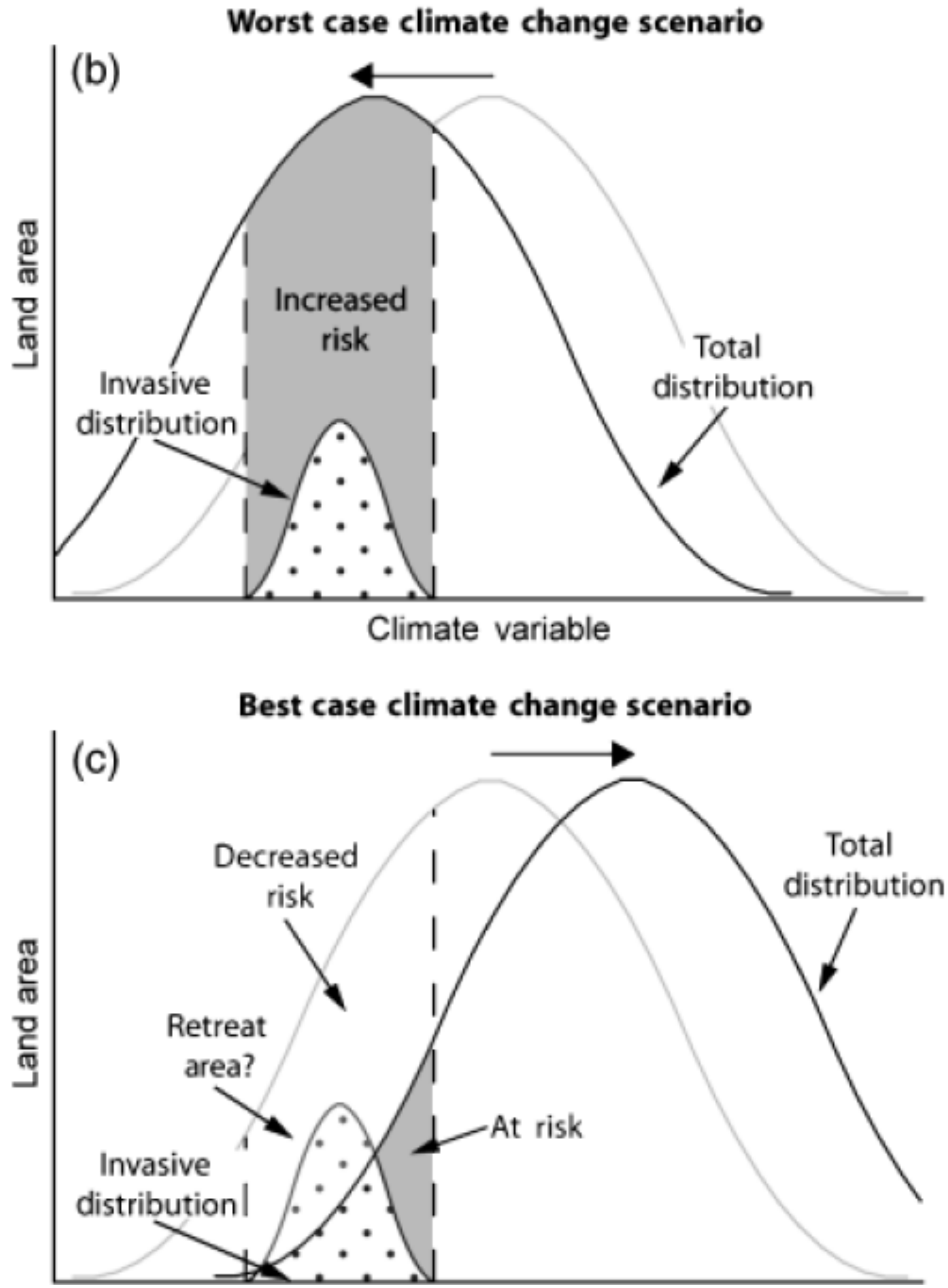


Credit: Bradley et al. 2009, Global Change Biology

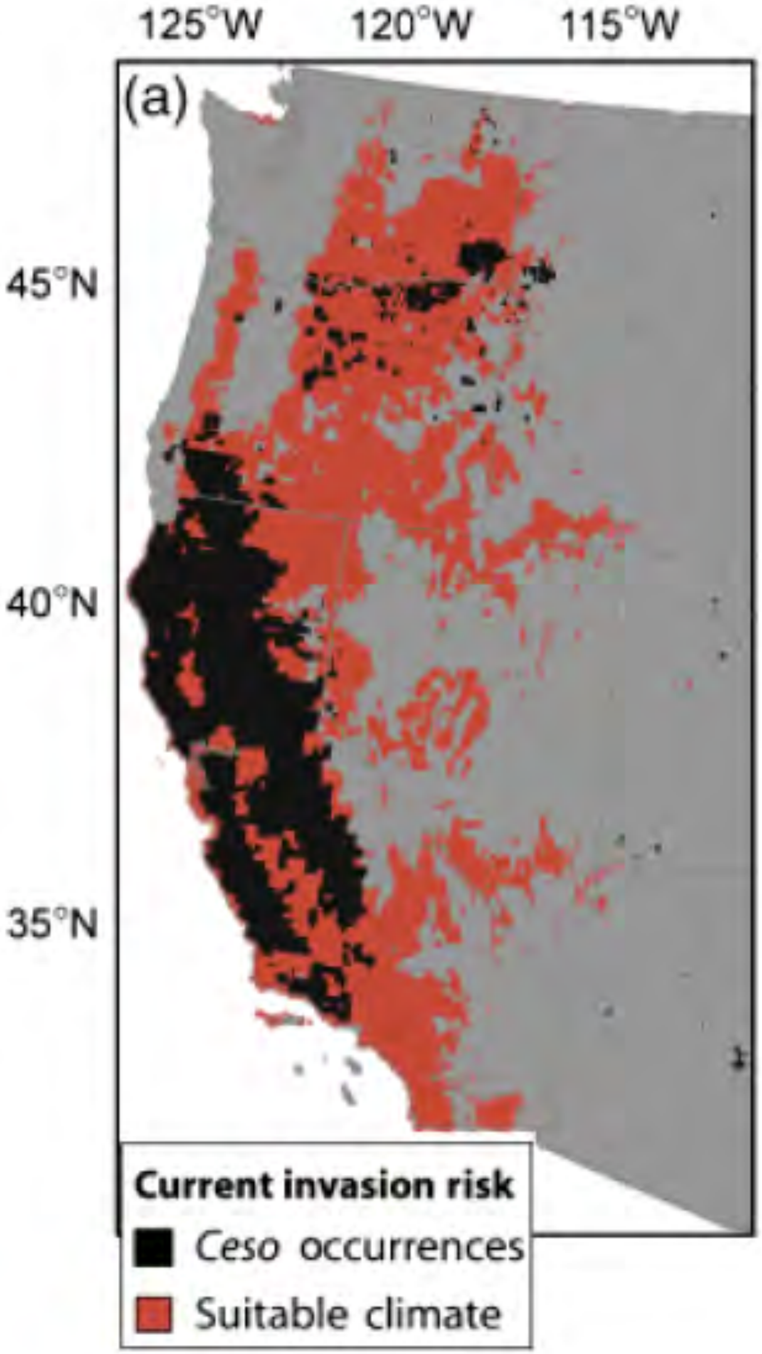


Worst case climate change scenario
(b)
Land area
Increased risk
Invasive distribution
Total distribution
Climate variable
Best case climate change scenario
(c)
Land area
Decreased risk
Total distribution
Retreat area?
At risk
Invasive distribution

So, climate might move in a direction that *increases OR decreases* the land area at risk from invaders



An example using my “favorite” invader, yellow starthistle (*Centaurea solstitialis*)



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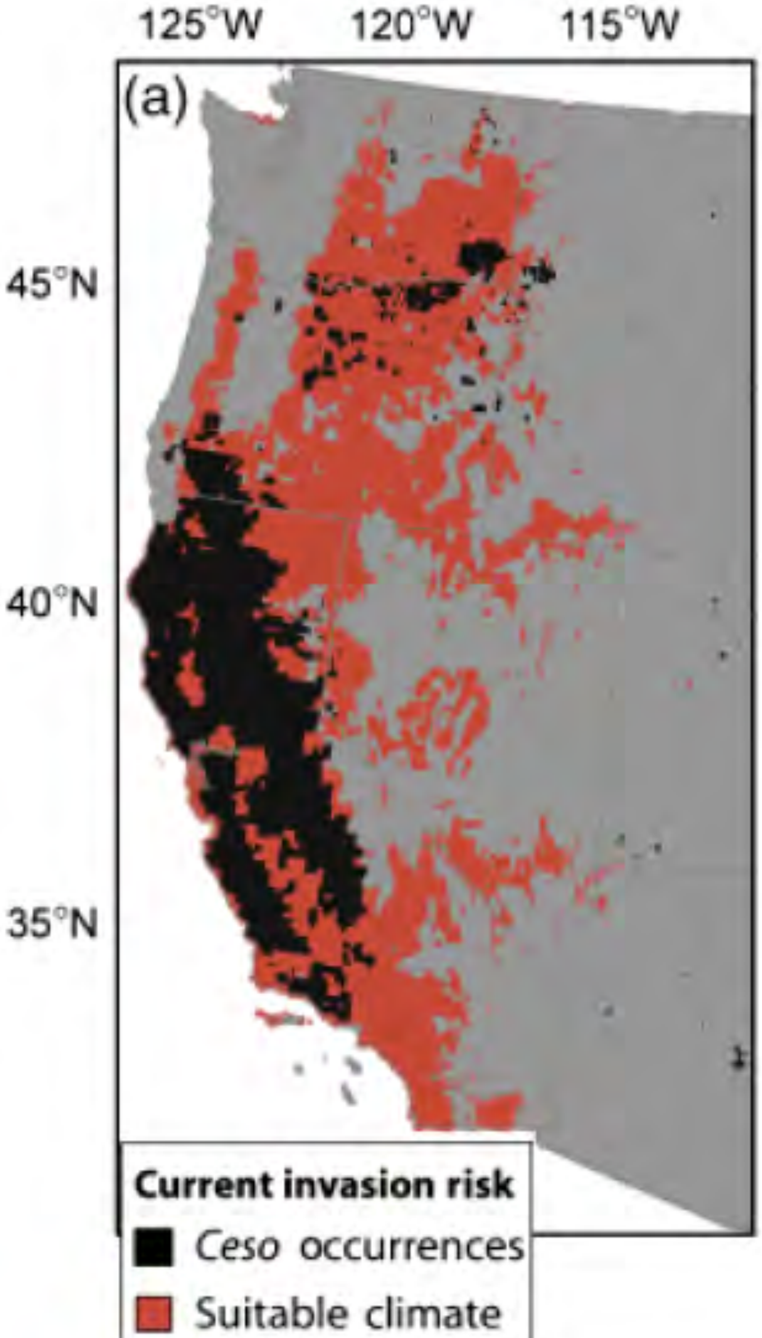
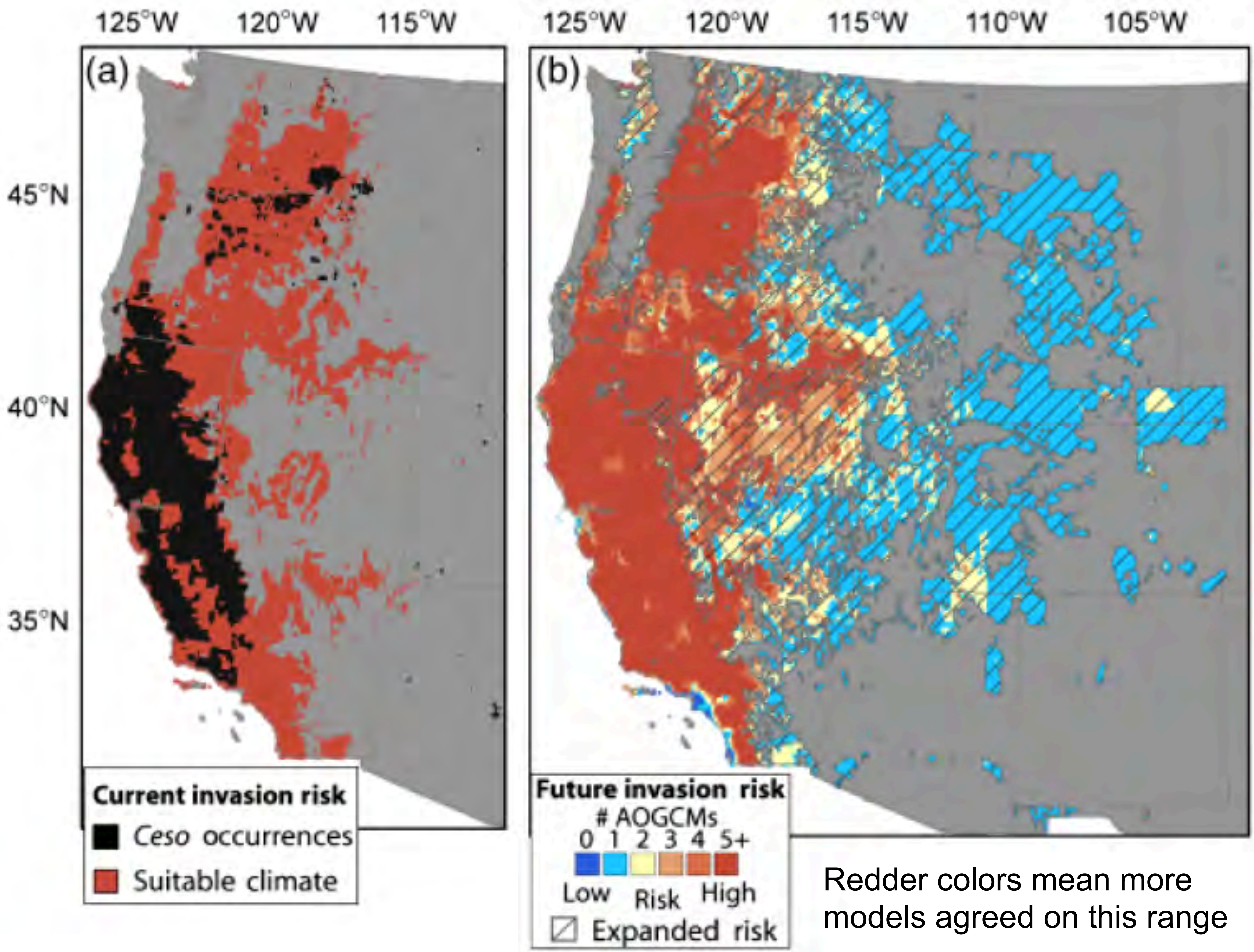
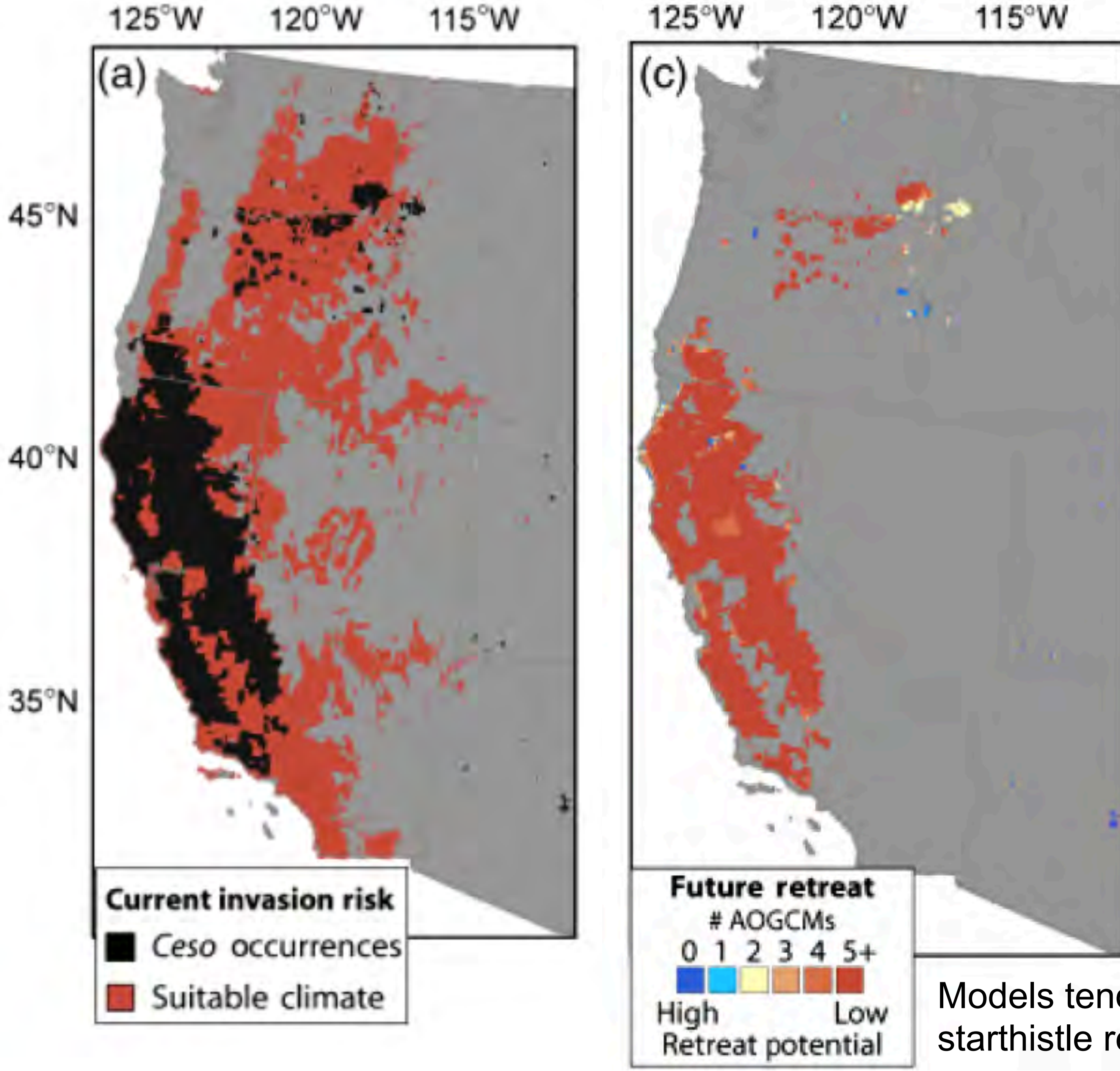


An example using my "favorite" invader, yellow starthistle (*Centaurea solstitialis*)

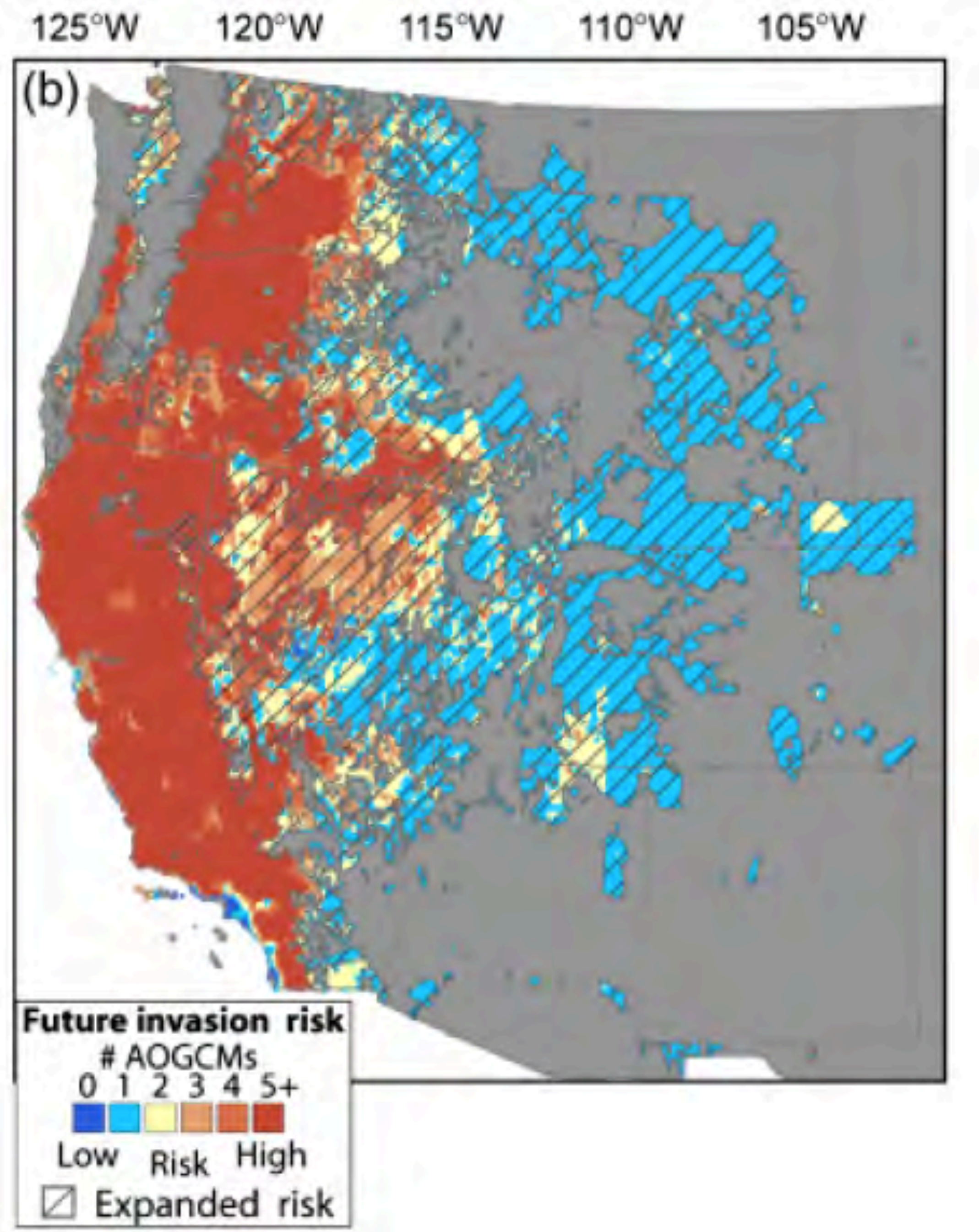
- Ensemble approach with 10 different GCMs included
- A1-b emissions scenario
- Mapping based on ~6 km resolution of actual distribution as assessed by expert opinion
- 4 climate variables (monthly precip, annual precip, min temp, max temp)



Redder colors mean more models agreed on this range



Models tended to agree that starthistle retreat was unlikely



There's obviously some uncertainty in this model…

…but actually, there's more than meets the eye.

Source of Uncertainty #1:
The emissions scenarios are just educated guesses about what the future will be like.

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Source of Uncertainty #3:
Downscaling and RCMs are just educated guesses about how local impacts will play out.

Source of Uncertainty #1:
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x

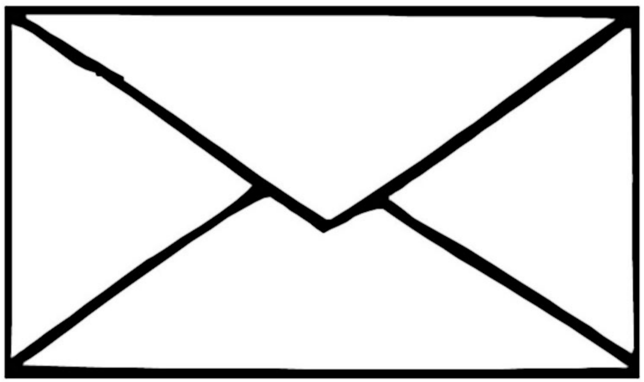
Source of Uncertainty #2:
The GCMs are just educated guesses about what's driving the climate system.

x

Source of Uncertainty #3:
Downscaling and RCMs are just educated guesses about how local impacts will play out.

Propagation of error from 24 GCMs x 40 scenarios means the outcome of a prediction must be a range, which may include zero.

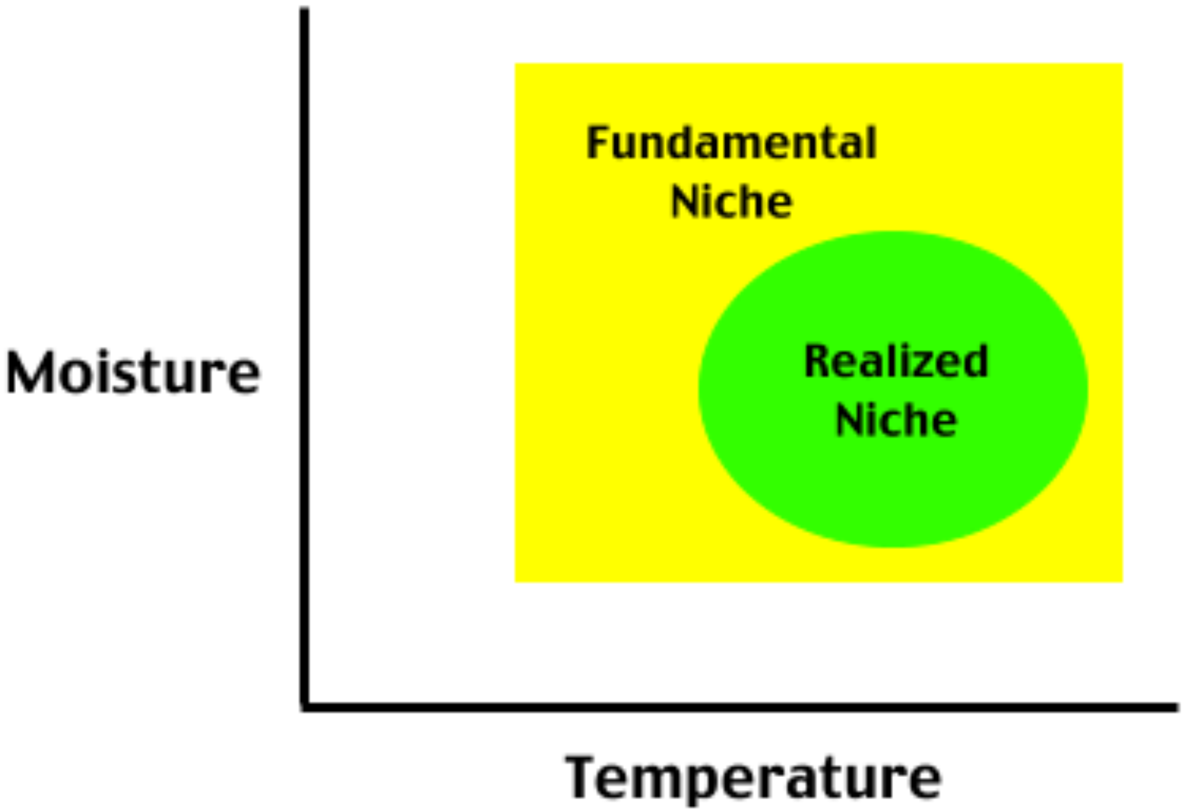
And now, some additional uncertainties due to assumptions built into BE models.



#1: It’s not really an “envelope.”

Some variables, such as temperature and sea-level rise, can alter *independently*—increasing the potential for “no-analog” climates

#2: BE models typically ignore the role of other variables besides climate on species' ranges



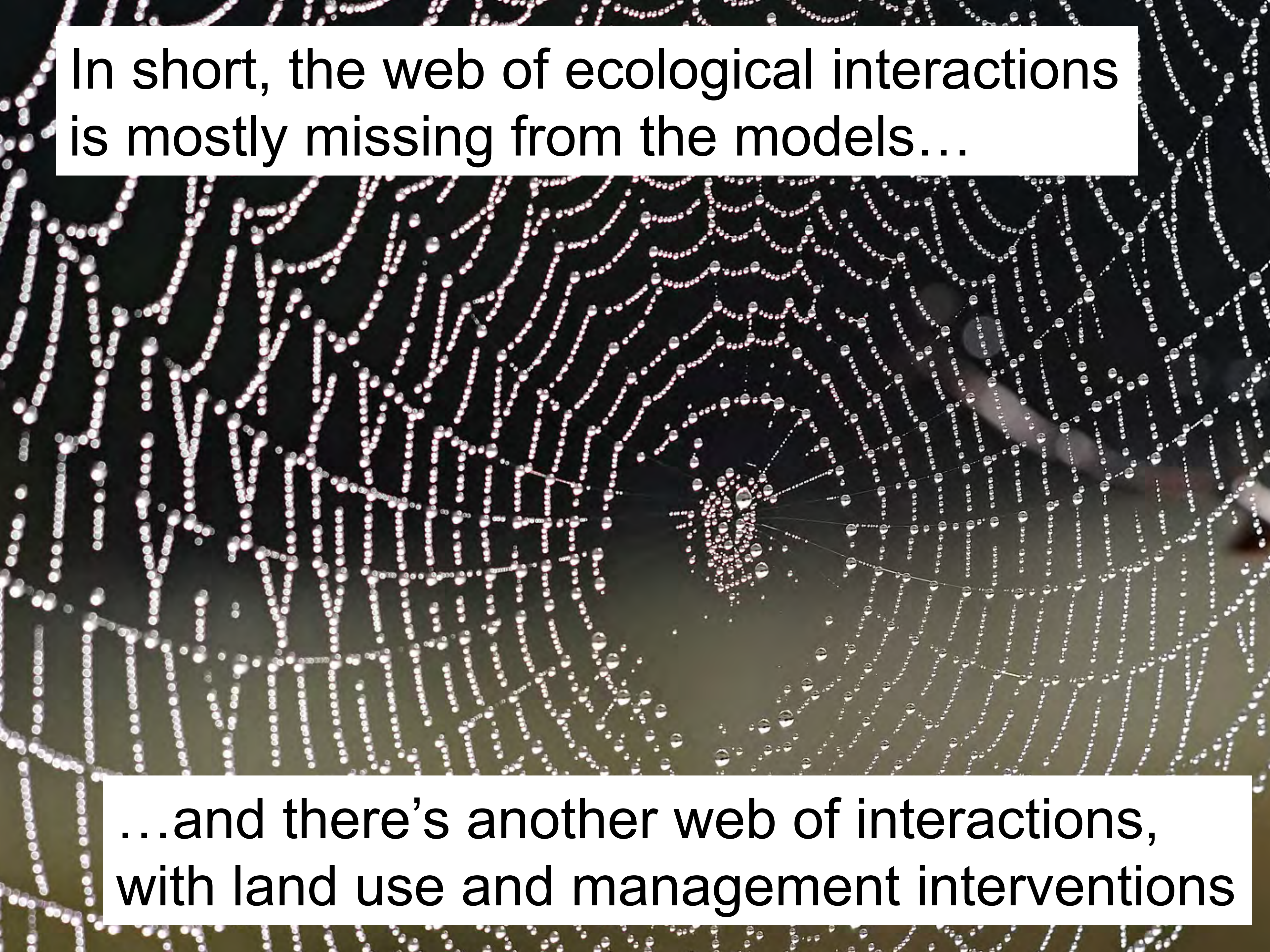
- Soil factors
- Competition
- Predation
- Dispersal limitation

#3: BE models assume no plasticity or evolutionary change

- Selection for climate tolerance?
- “Sleeper” weed populations?
- CO_2 fertilization effect?
- Drought effect on flammability?

#4: BE models assume that ecological communities will stay together, and competitive interactions will remain stable.

…but dispersal rates and tolerances will differ, so “no-analog communities” will form



In short, the web of ecological interactions is mostly missing from the models…

…and there's another web of interactions, with land use and management interventions

Like what?

Biocontrol agents.

Credit: agri.state.id.us

- High temperatures may increase insect population growth
- Higher C:N of plant tissue may decrease impact of insect feeders

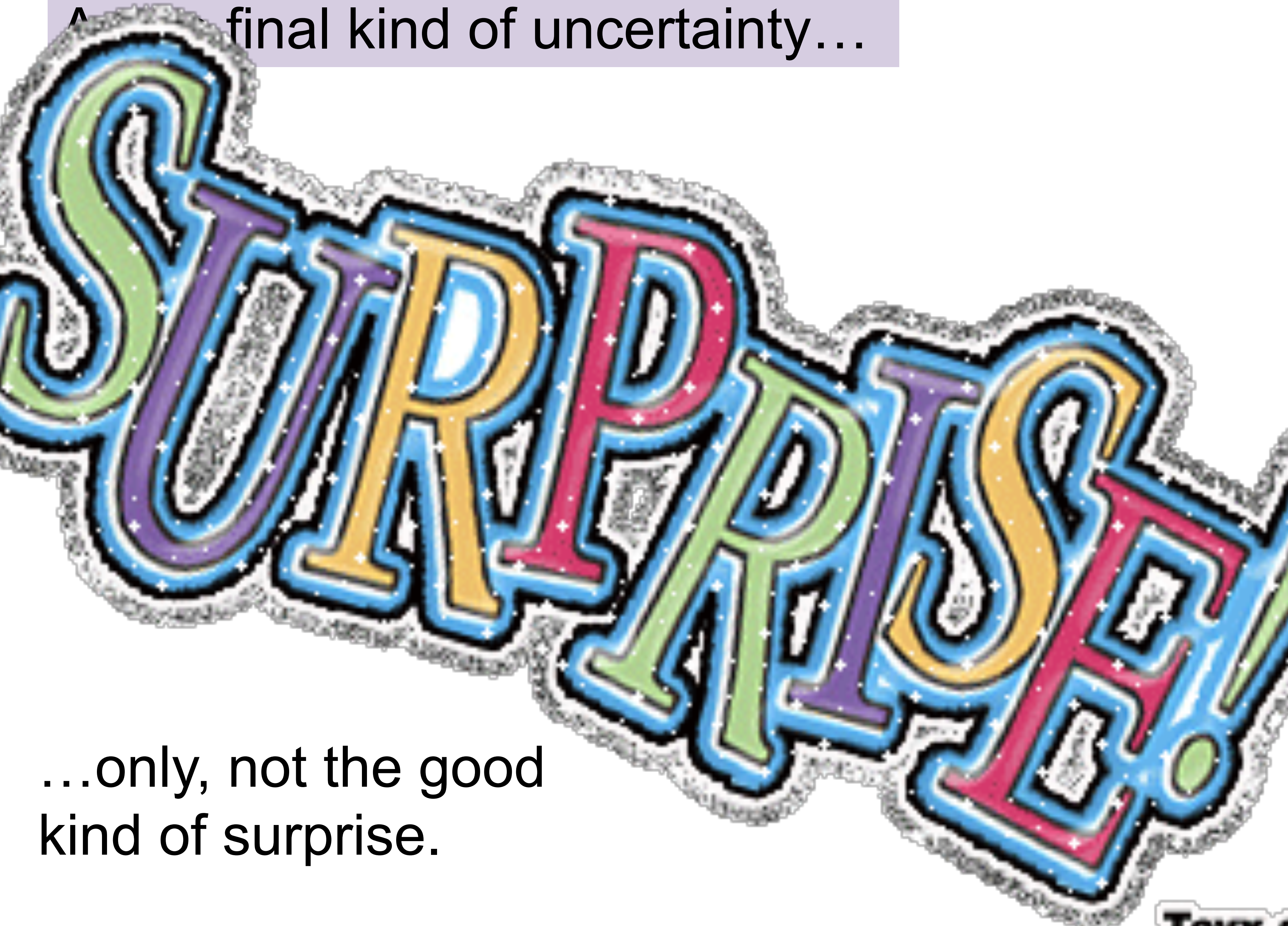
Like what?

Spraying herbicides.

- Shorter spray window when plants grow faster
- Higher shoot:root dilutes glyphosate
- Herbicides less effective with increased heat, dry wind

Credit: cfr.msstate.edu/nbci

A [illegible] final kind of uncertainty…



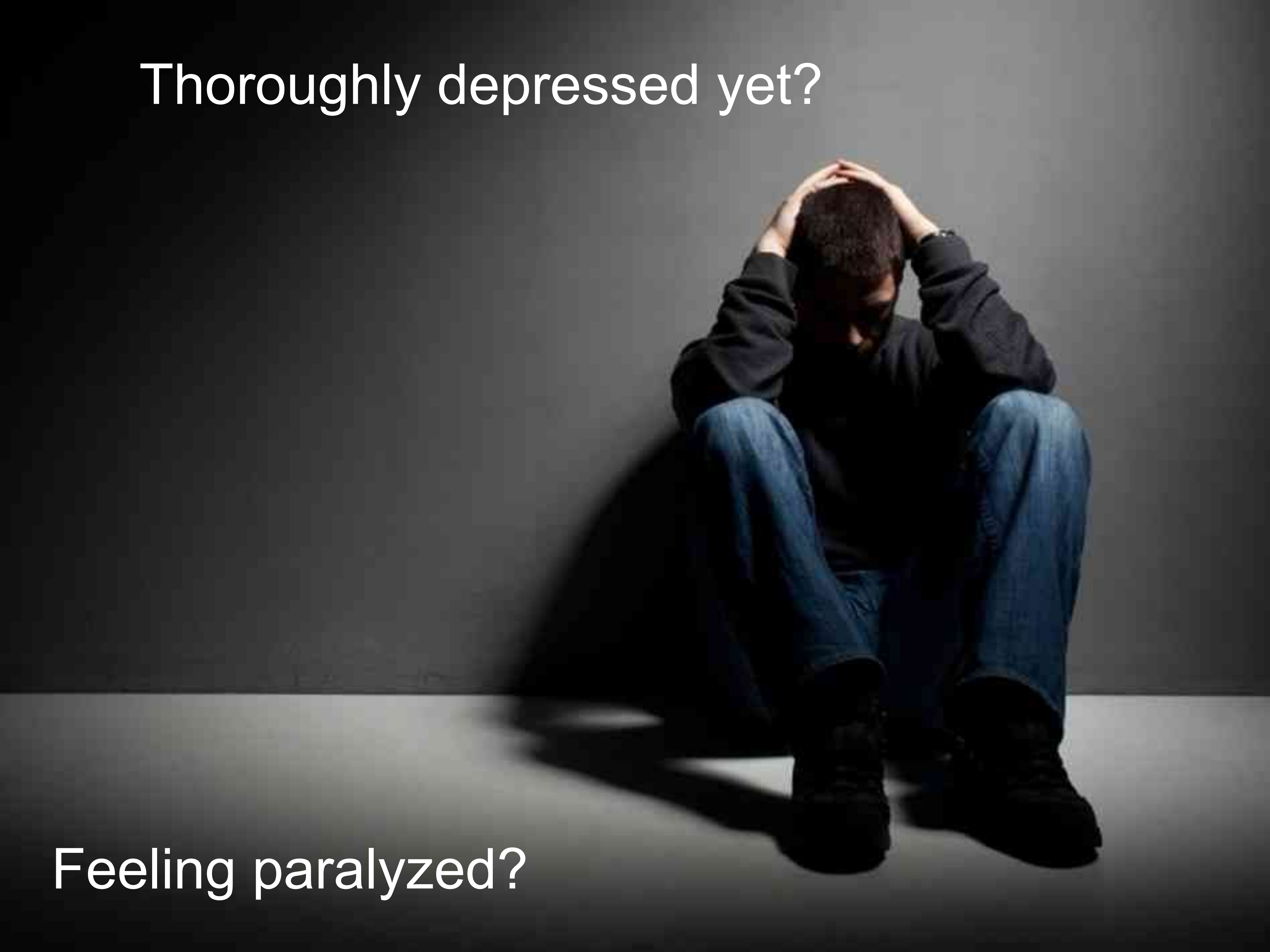
…only, not the good kind of surprise.

Source of Uncertainty #10:

The climate models mostly neglect positive feedbacks like melting sea ice and methane emissions from permafrost…

Source of Uncertainty #10:

…resulting in a higher potential for non-linearities, rapid changes, and climate “surprises” than we’re planning for


Thoroughly depressed yet?
Feeling paralyzed?

To work past paralysis, our approach must not be to DENY or IGNORE uncertainty.

It must be to EMBRACE uncertainty.

We should be thinking about RESILIENCE to change, not RESISTANCE to change.

1. Elicit (temporary) consensus among models *that suits your purposes.*

- How important is it to constrain the range of possibilities?
- Is there a threshold that matters to you? How likely is that to occur?
- Prioritize “ensemble” models that include as much variability as possible

2. Remember that decision sets are finite—there's only so many choices you can make.

- Some decisions are independent of climate change (e.g. adding reserve area) and will probably do no harm, but may be inadequate
- Others are direct responses to climate change (e.g. translocations) and have a higher potential for success/backfiring
- Remember that model time points are fixed (e.g. 2050) but change is gradual…

3. Formulate management plans more like risk analyses.

From a report on climate change and weed management in South Australia:

The results of using this scenario are in no way intended to be prescriptive or predictive in the sense of indicating the likely state of the system in 2080. Rather, the maps and analyses in this report are intended to indicate the likely direction and magnitude of change in the weed threats…By knowing the likely direction of change in weed threats, steps can be taken to identify vulnerable assets, and to monitor for these expected changes.

4. Pursue monitoring and experimentation with the same zeal as eradication/treatment

- Extended variable set (not just vegetation and weather data)
- Extended time scale to capture phenology changes

5. Accept no-analog systems as the new norm…we are not going back to the past. This may require *triage*; it may require more of a paleo-perspective.

Wise words from Heller & Zavaleta (2009):

To build resilience to climate change into systems, however, may require radical shifts in perspective for many conservation stakeholders and re-evaluation of conservation goals. Land managers might need to view a broader range of ecosystem states as desirable, such as novel or dynamic local assemblages that maintain functioning and trophic complexity but not necessarily species.

Perhaps we can draw a lesson from Monterey Pine…

Now Then