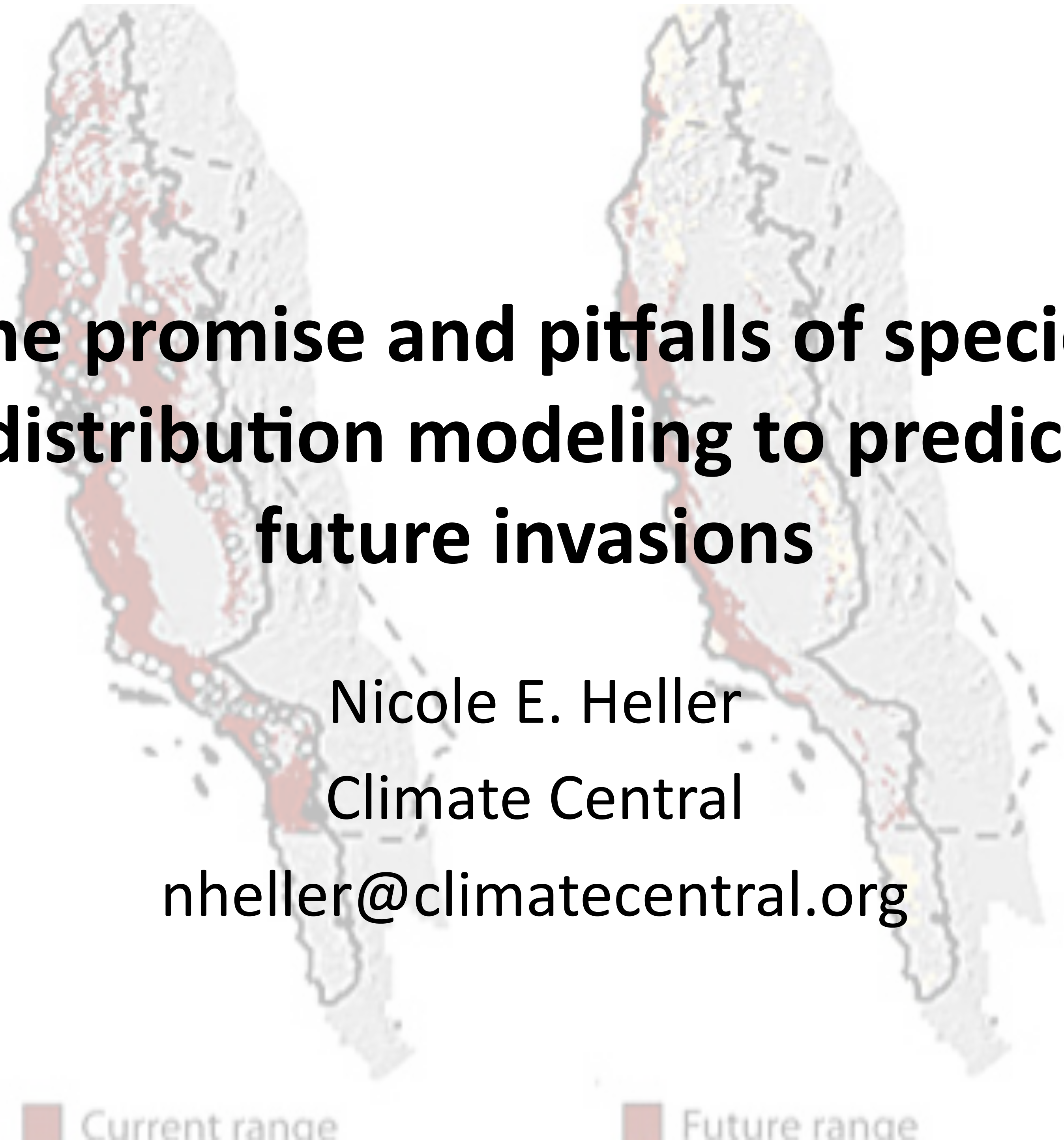
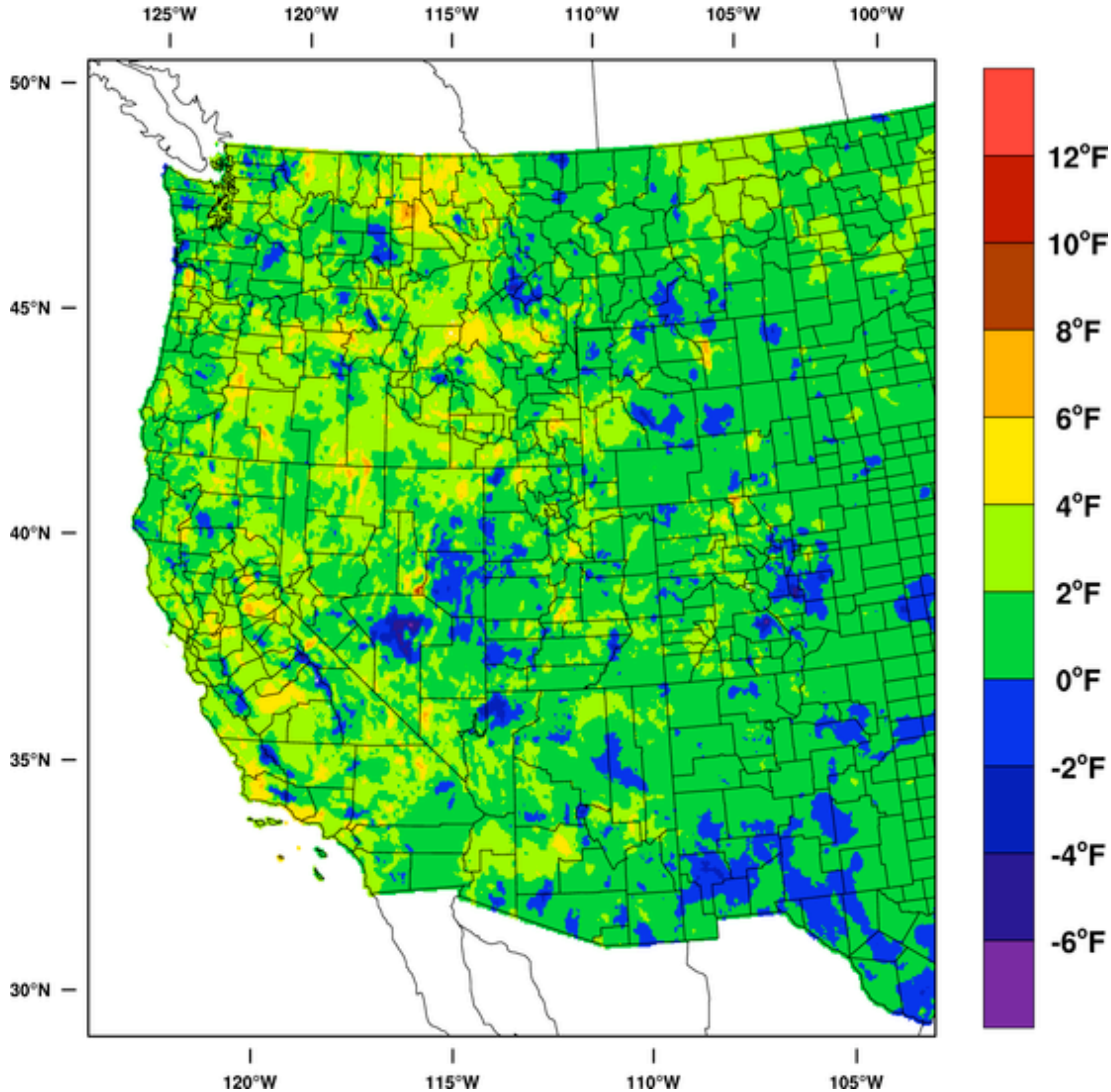


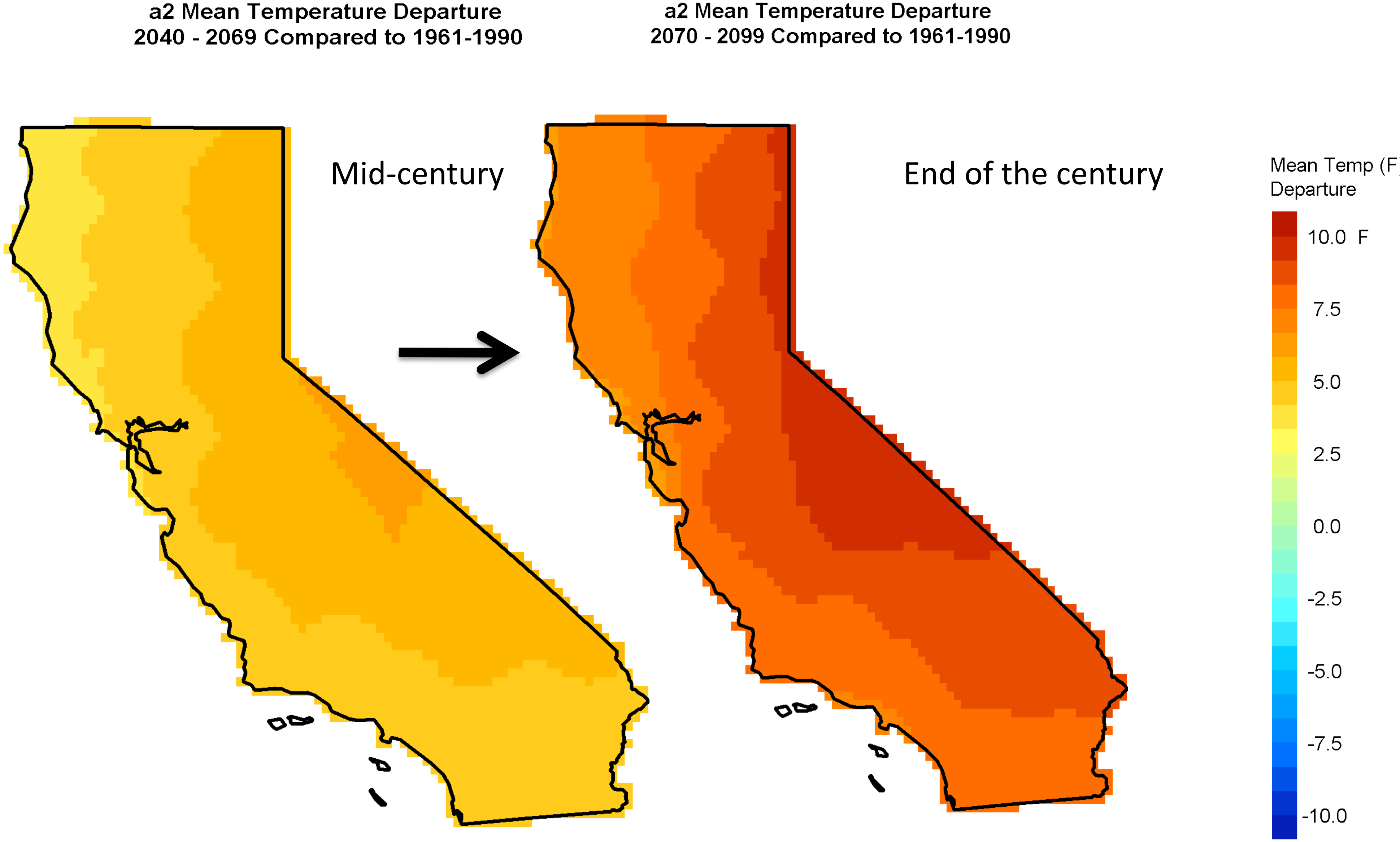
The promise and pitfalls of species distribution modeling to predict future invasions

Nicole E. Heller
Climate Central
nheller@climatecentral.org

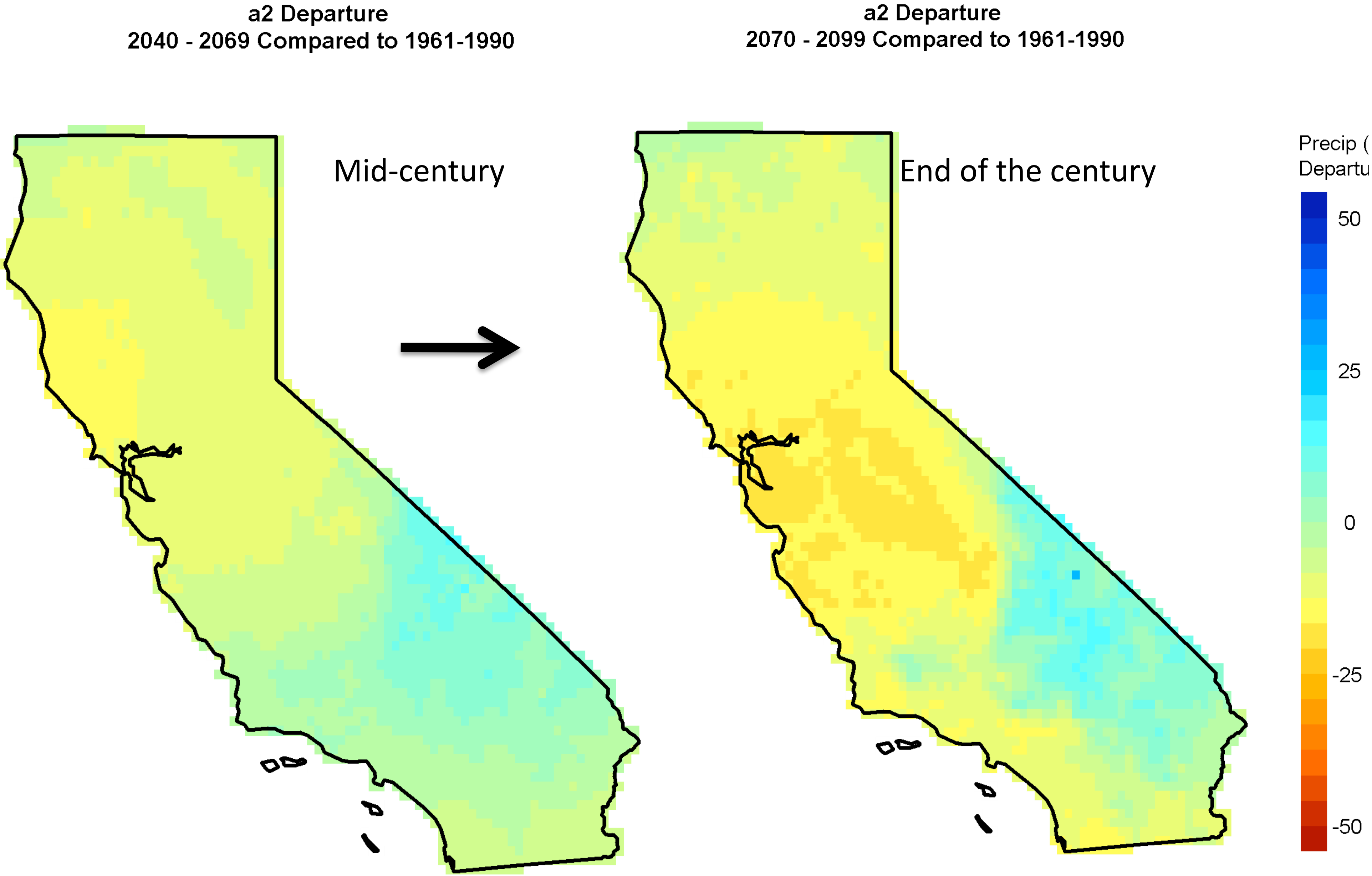
Change in average minimum temperatures, 1900 – 1950 relative to 1970 - 2009



Data from Westmap

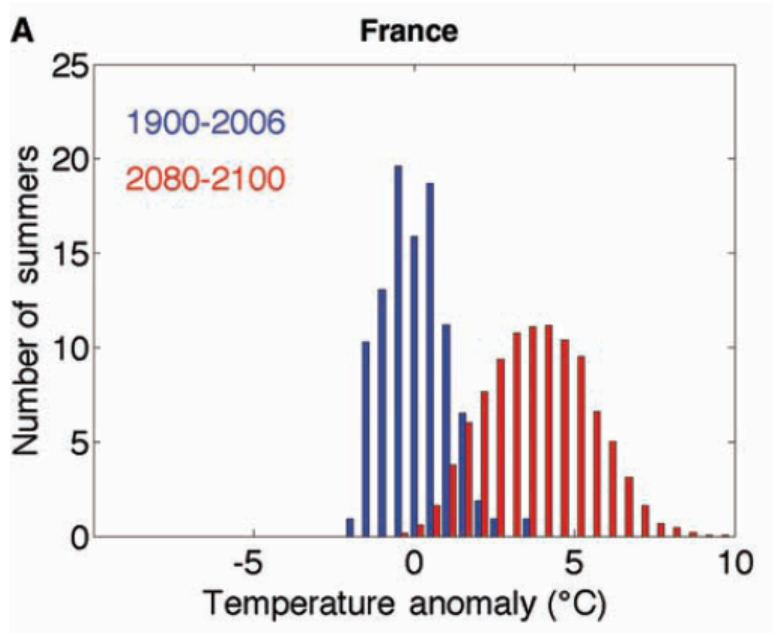


From ClimateWizard
Ensemble of 3 GCMs

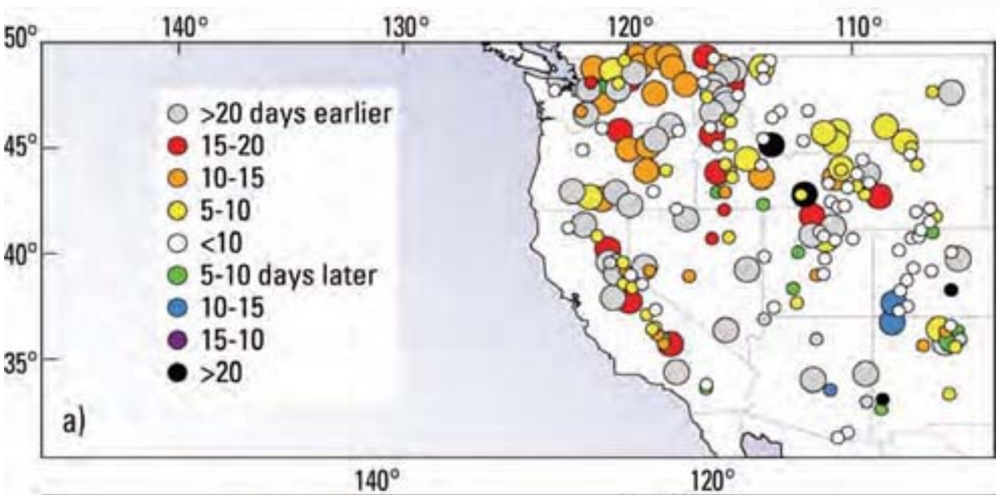


From ClimateWizard, Ensemble of 3 GCMs

Changes beyond means



Battisti et al 2009



Dettinger et al. 2004

Motivations for trying to predict *future* invasions

1) Risk assessment of invaders

2) Prioritize areas for eradication

3) Project impacts of climate change on invasive species

4) Testing the accuracy of species distribution models

Can we predict invasions in the future?

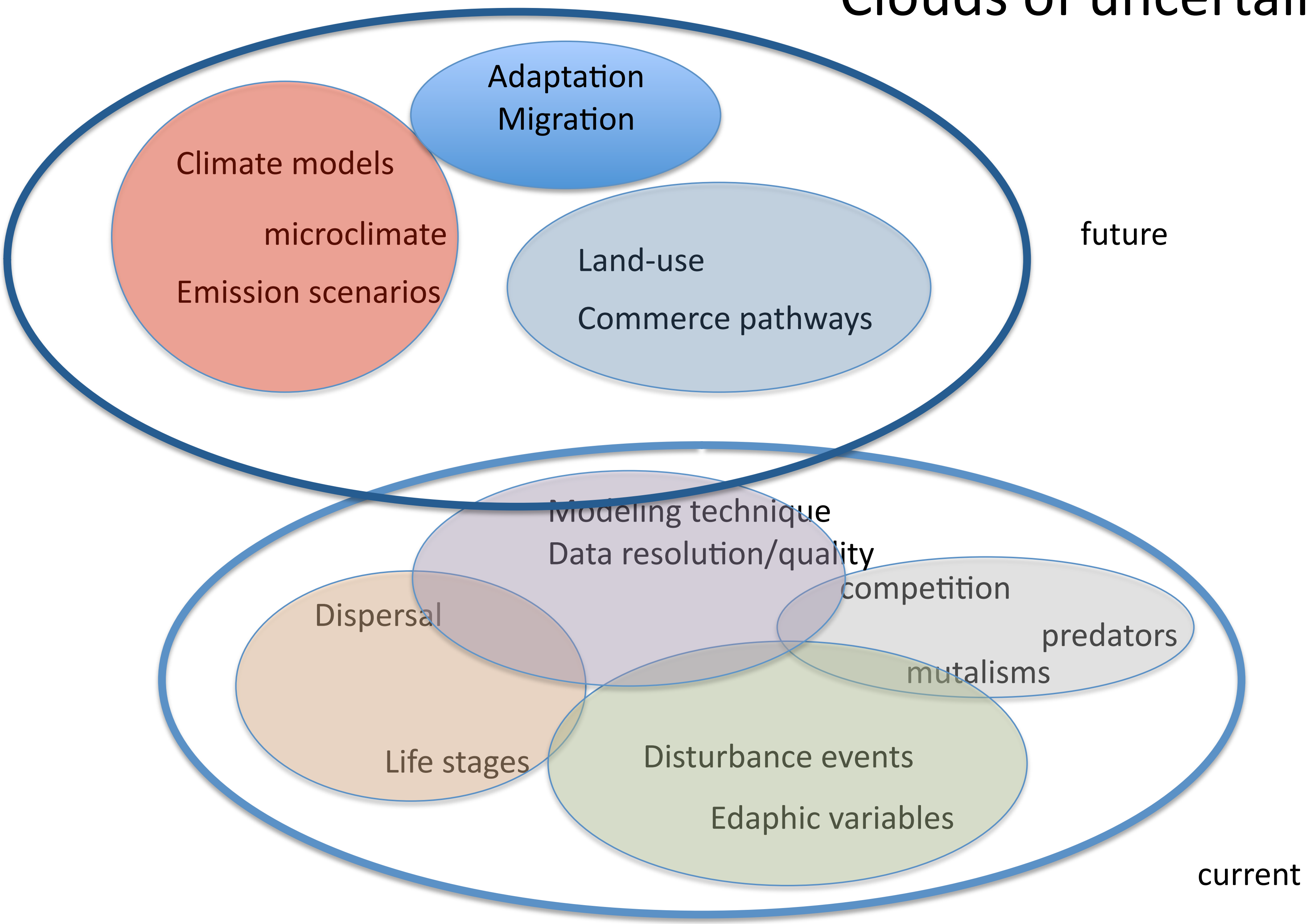
1) Introduction to Species Distribution modeling

2) The limitations of SDMs for this problem

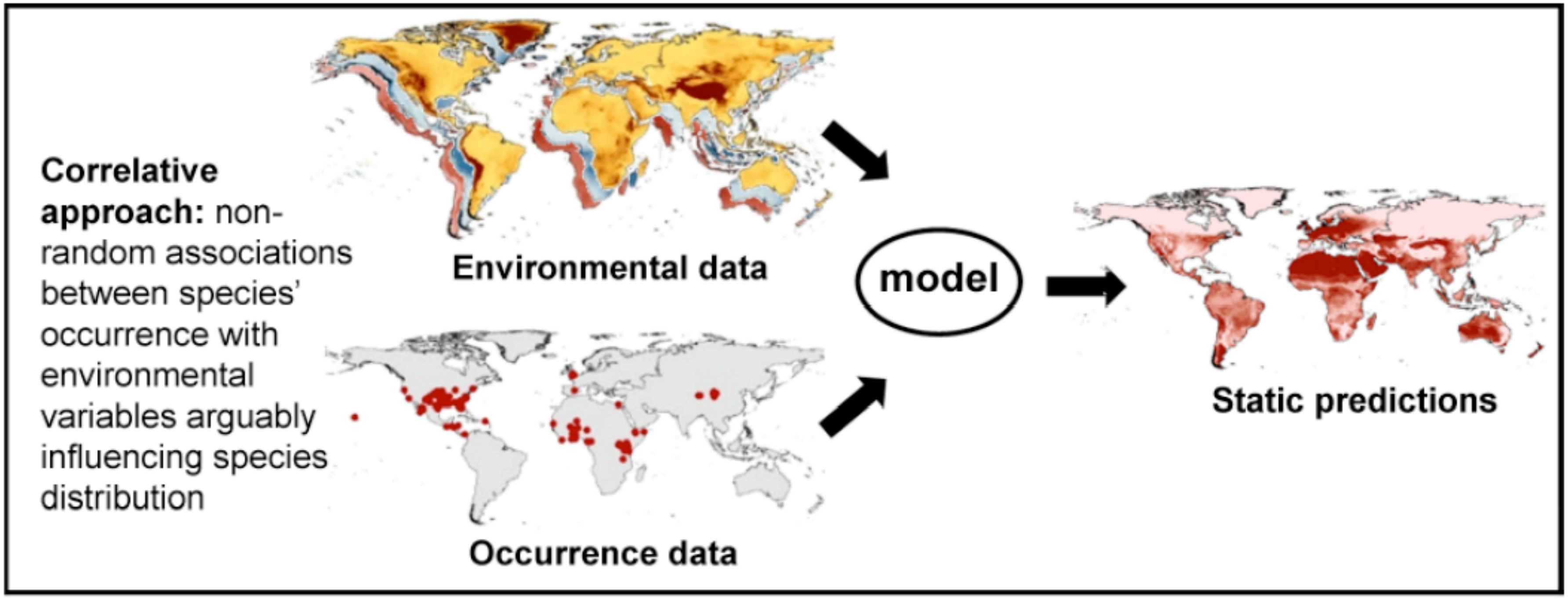
3) What is to be done?

4) Survey of where we are to date

Clouds of uncertainty



Species distribution modeling



Based in niche concept = multidimensional environmental space in which a species can survive and grow.

Roura-pascule & Suarez 2008

Key assumptions of correlative SDM modeling approaches

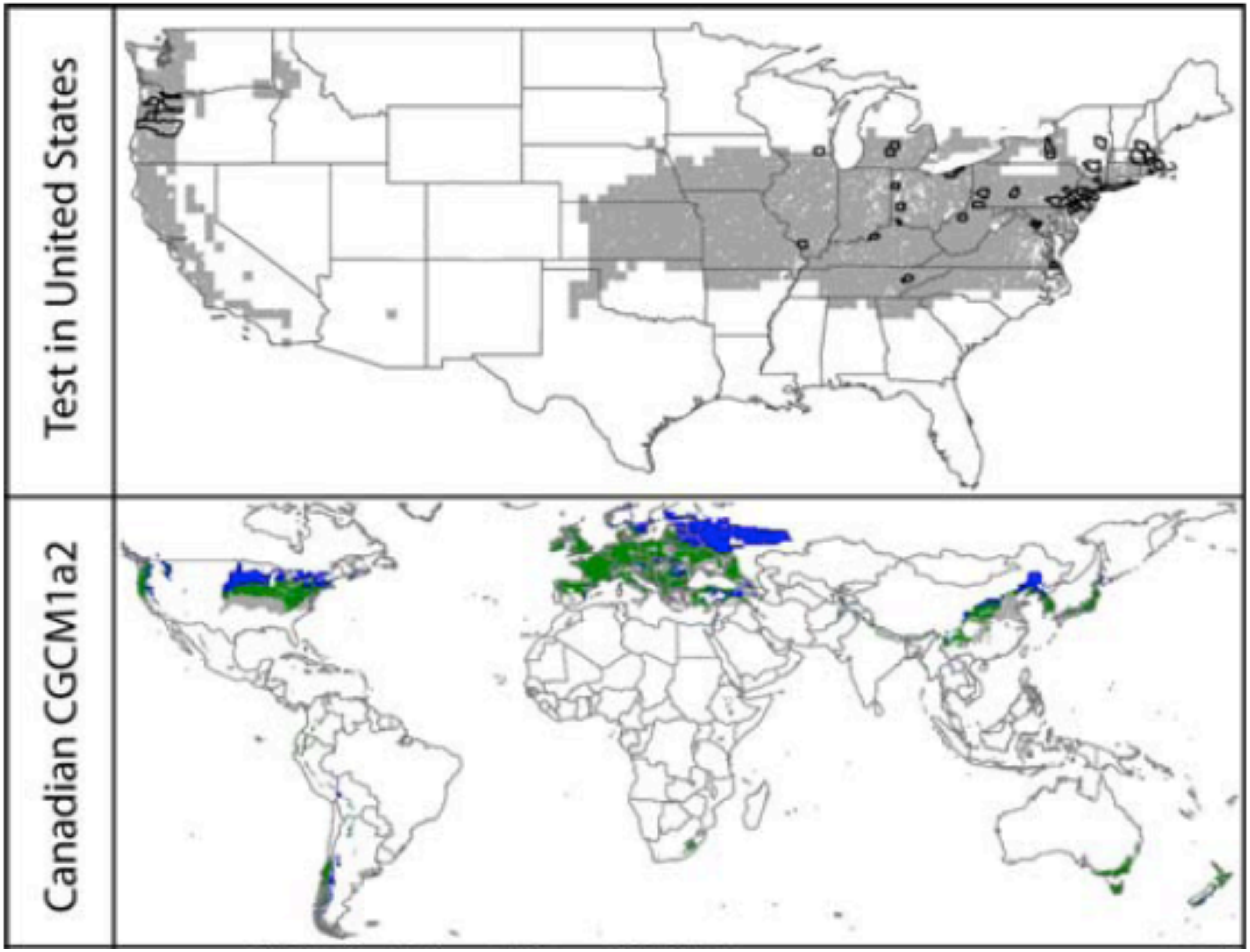
- Species are not evolving.
- Species interactions are not important or constant across space and time.
- Sampled distribution is at equilibrium (species have dispersed everywhere they are able to live)
- Occurrence data is non-biased

Many different modeling techniques

- Statistical
  - General linear models, General additive models
- Climate envelope
  - BIOCLIM, DOMAIN, HABITAT, Mahalanobis distance
- Classification, Regression Tree
  - Classification and regression tree analysis (CART)
- Machine learning, neural networks, genetic algorithms
  - MaxEnt, Artificial Neural Network (ANN), Genetic Algorithm for-Rule-set Production (GARP)

*For more information and review see
http://biodiversityinformatics.amnh.org/
Jeschke and Strayer 2008, Ann. N.Y. Acad. Sci

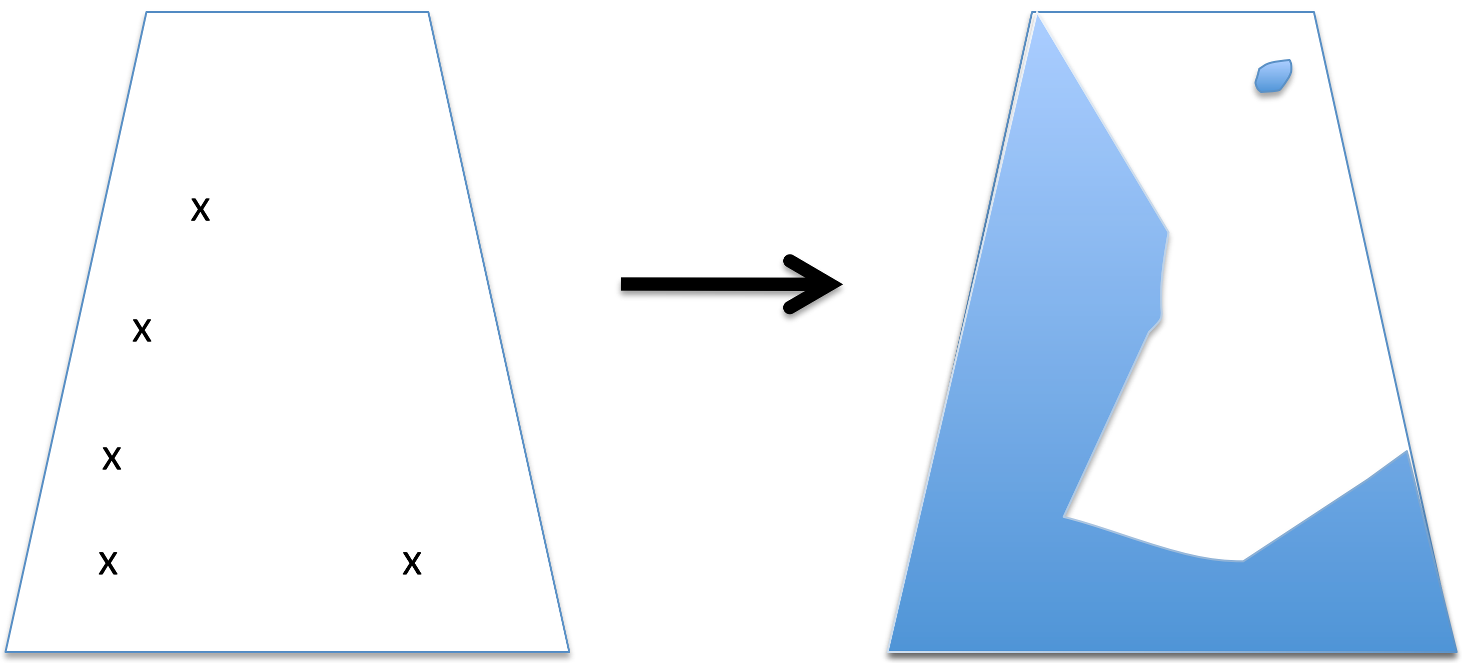
Example with *Ranunculus ficaria*



Peterson et al 2008

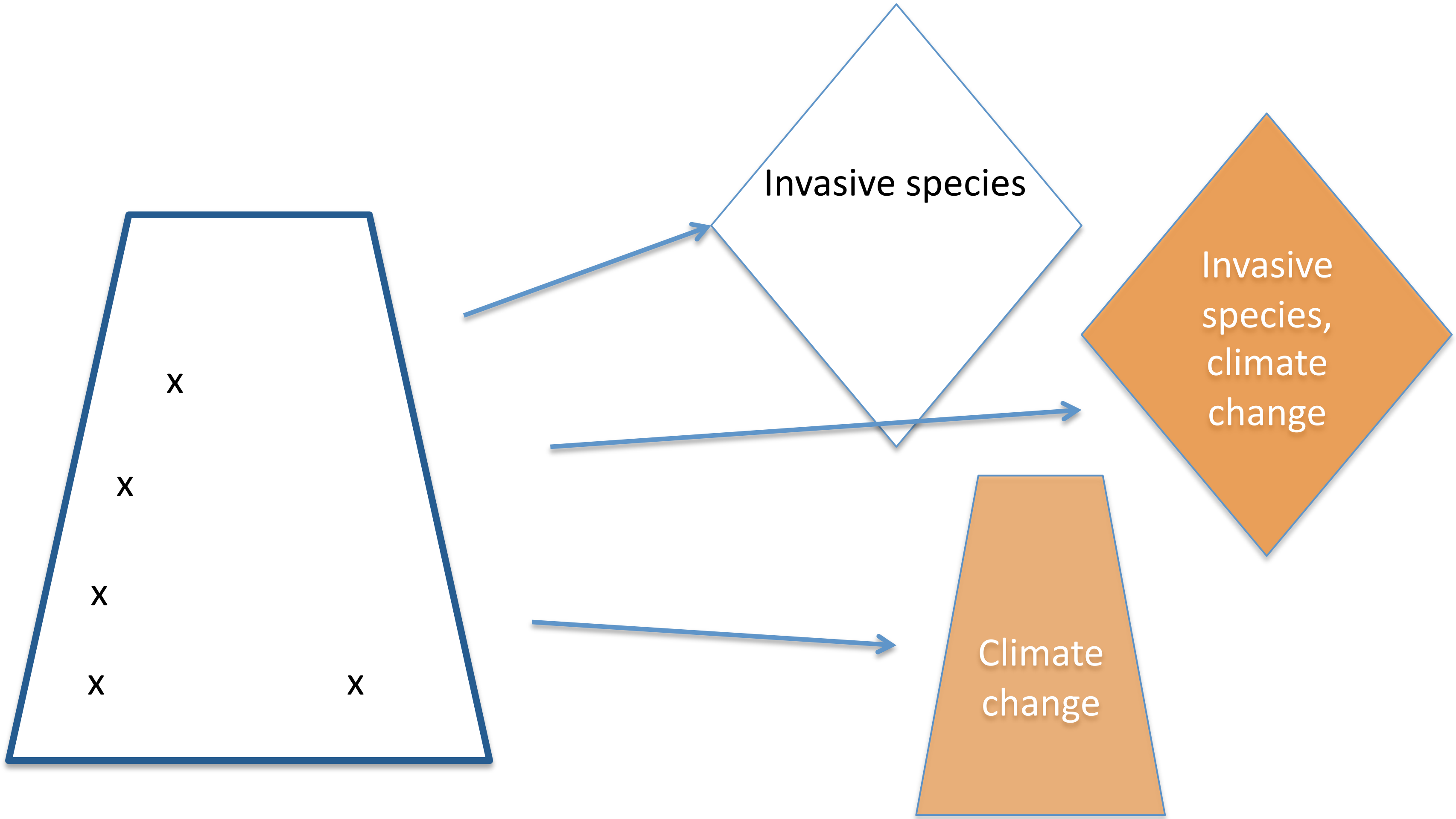
Interpolation

- Filling in the range from partially sampled data



Transferability

extrapolating a model calibrated in one location to novel situations

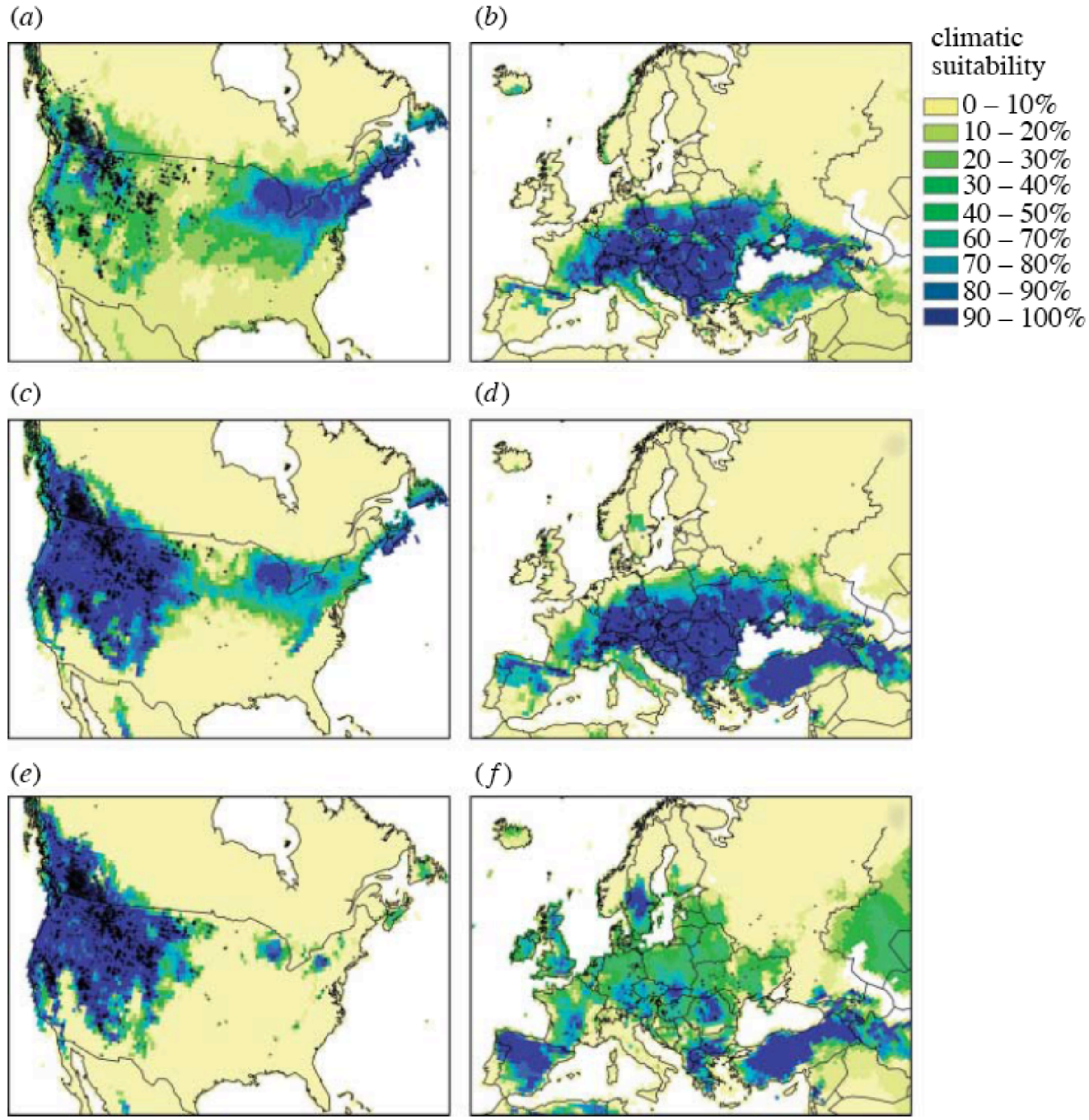


Spotted Knapweed example; data used to calibrate the model matters

Calibrated in Europe
and projected
to North America

Calibrated in both
and projected to
both

Calibrated in NA
And projected to
Europe



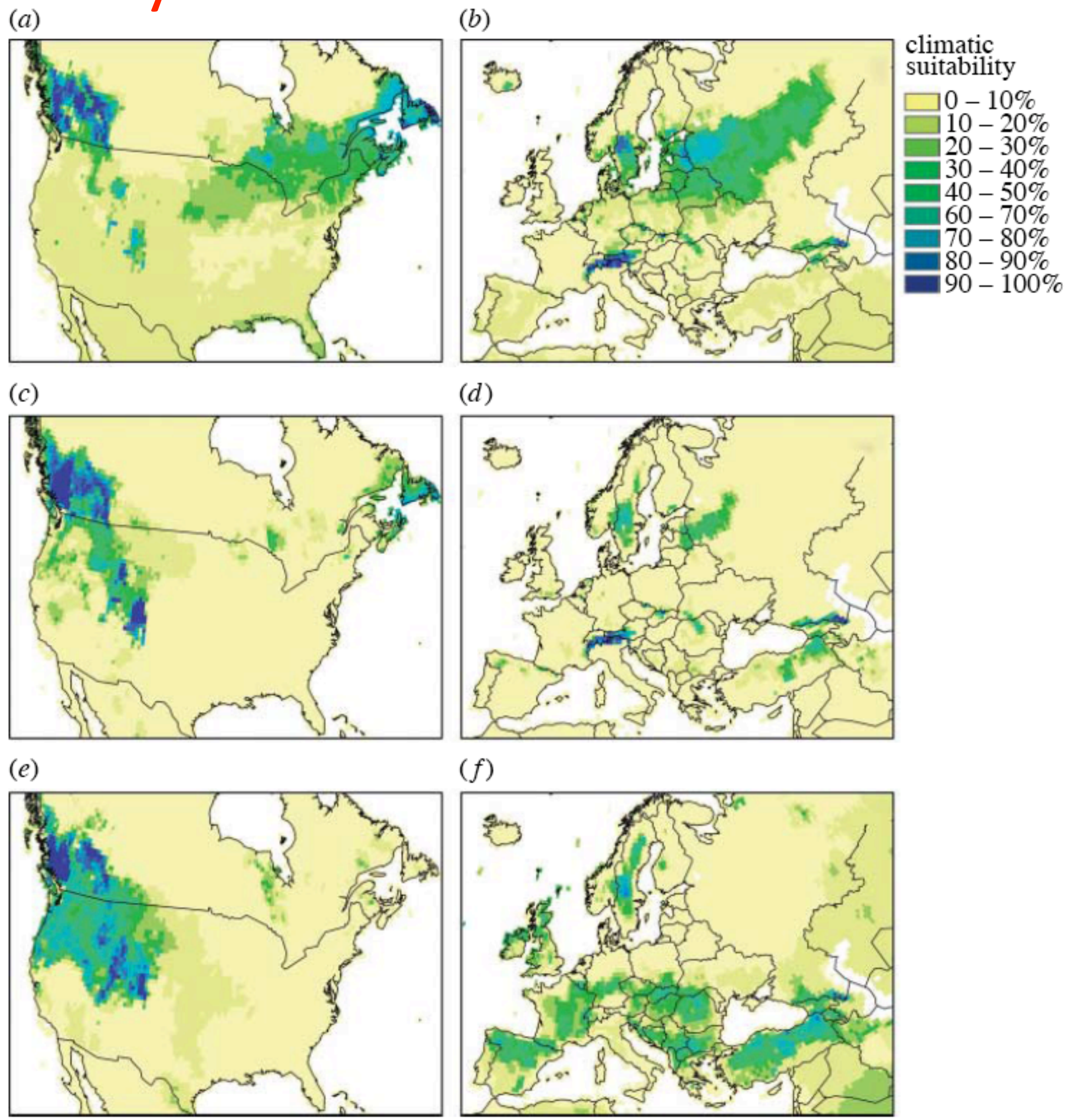
Broennimann and Guisan 2008

In 2080 under Hadley model

Europe
→NA

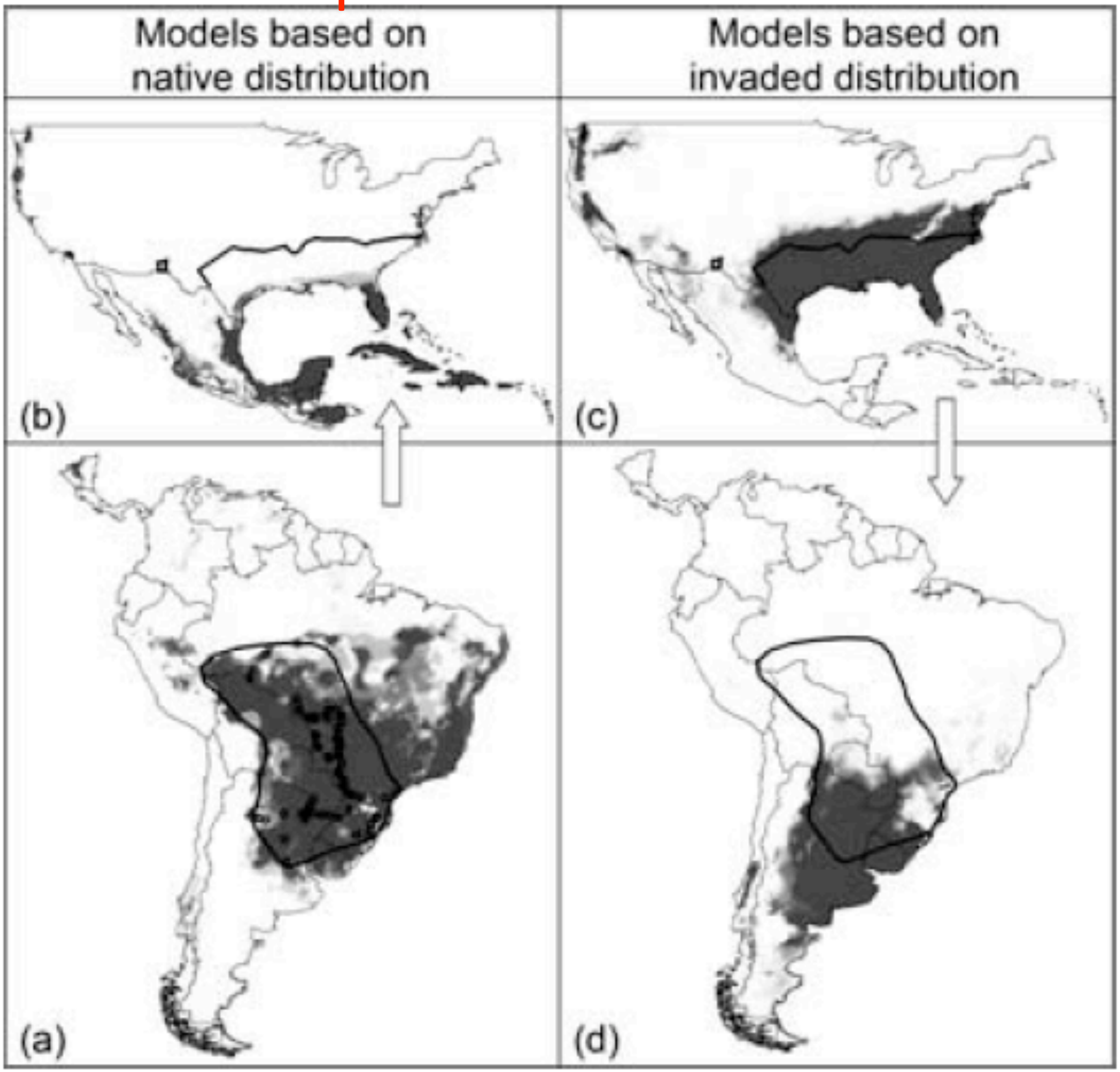
Europe and
NA → both

NA → Europe



Broennimann and Guisan 2008

Example with red imported fire ant



Fitzpatrick et al 2007

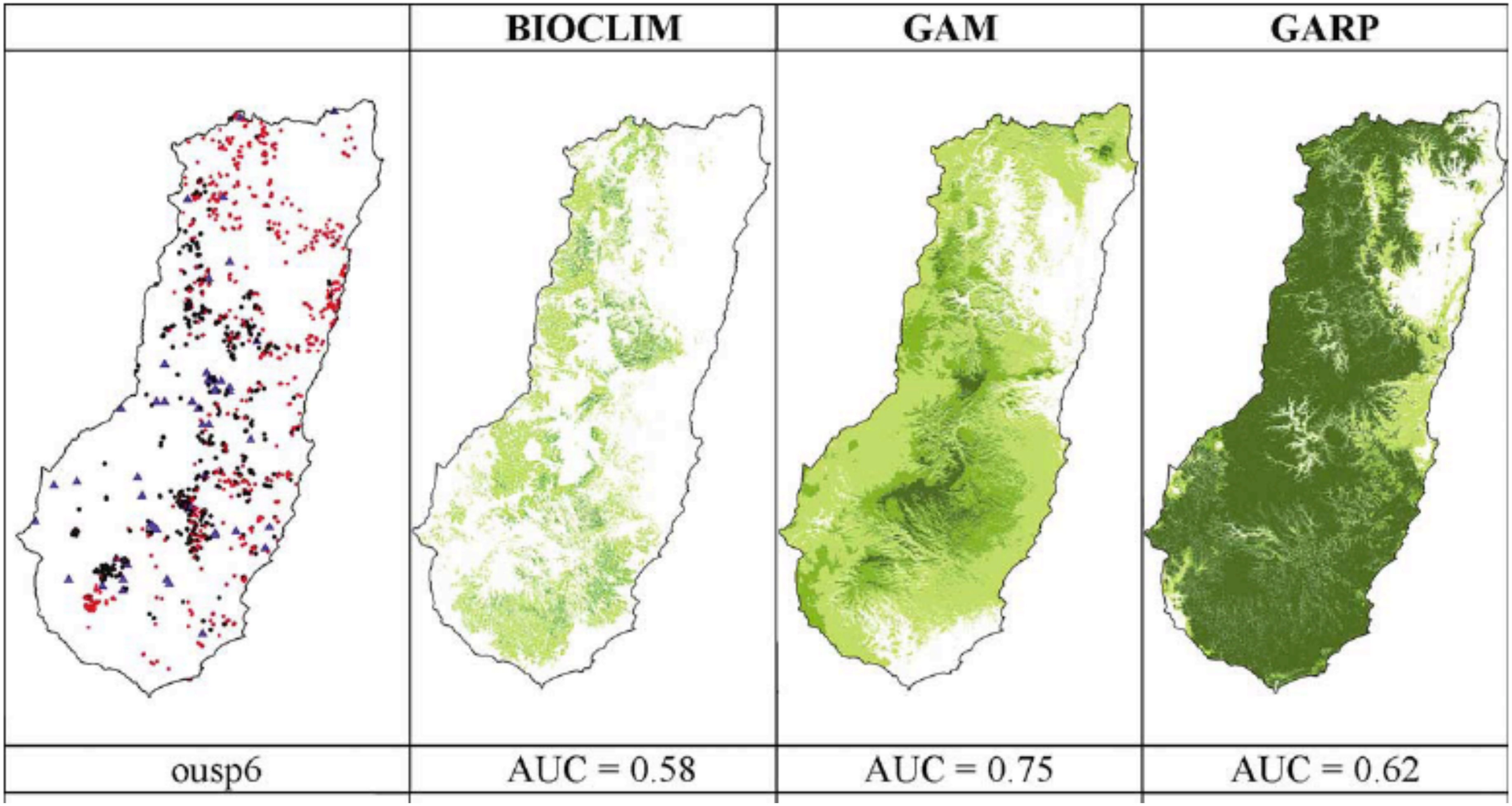
Why aren't these models transfering?

- Species are evolving (niche is not conserved).
- Species interactions are important and vary across space and time.
- Species are not at equilibrium (species have not dispersed everywhere they are able to live).
- Distributions are not well-sampled

AND

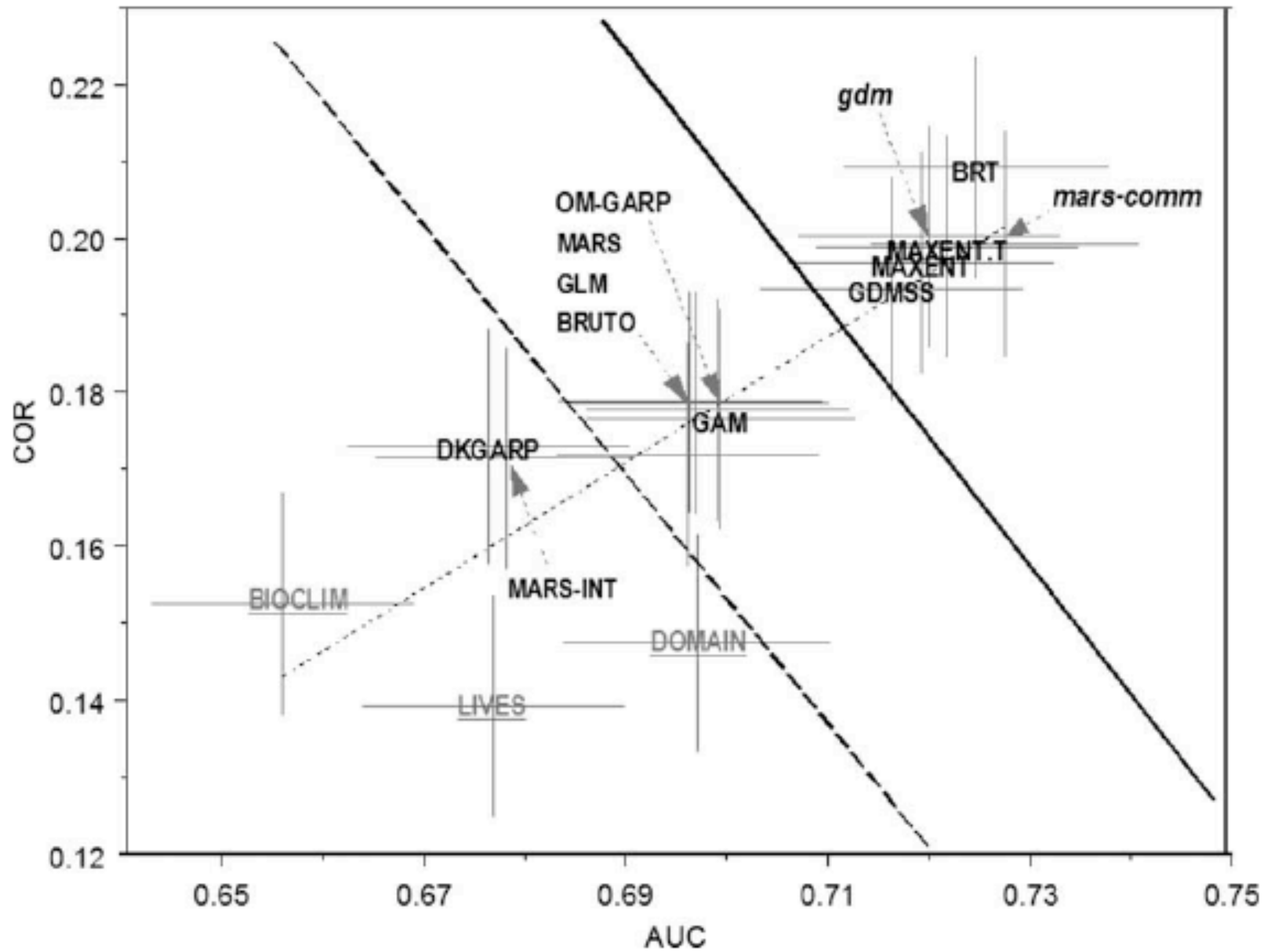
- Models are projecting into space that is outside of the range of calibrated model (no-analog conditions) ~ modeling error

Modeling techniques used affects the outcome

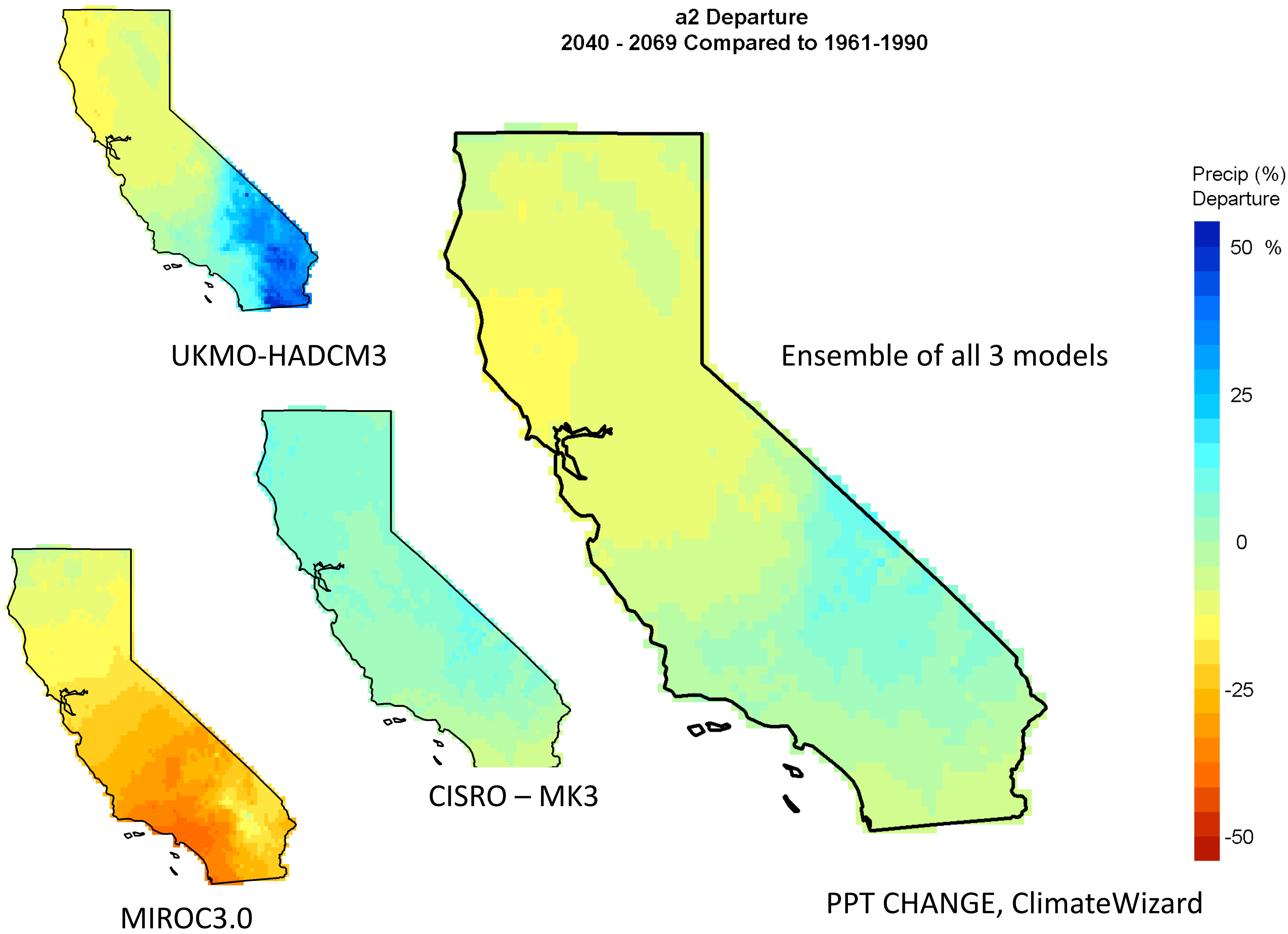


Elith et al 2006

Some models are better than others, but hierarchies are not stable



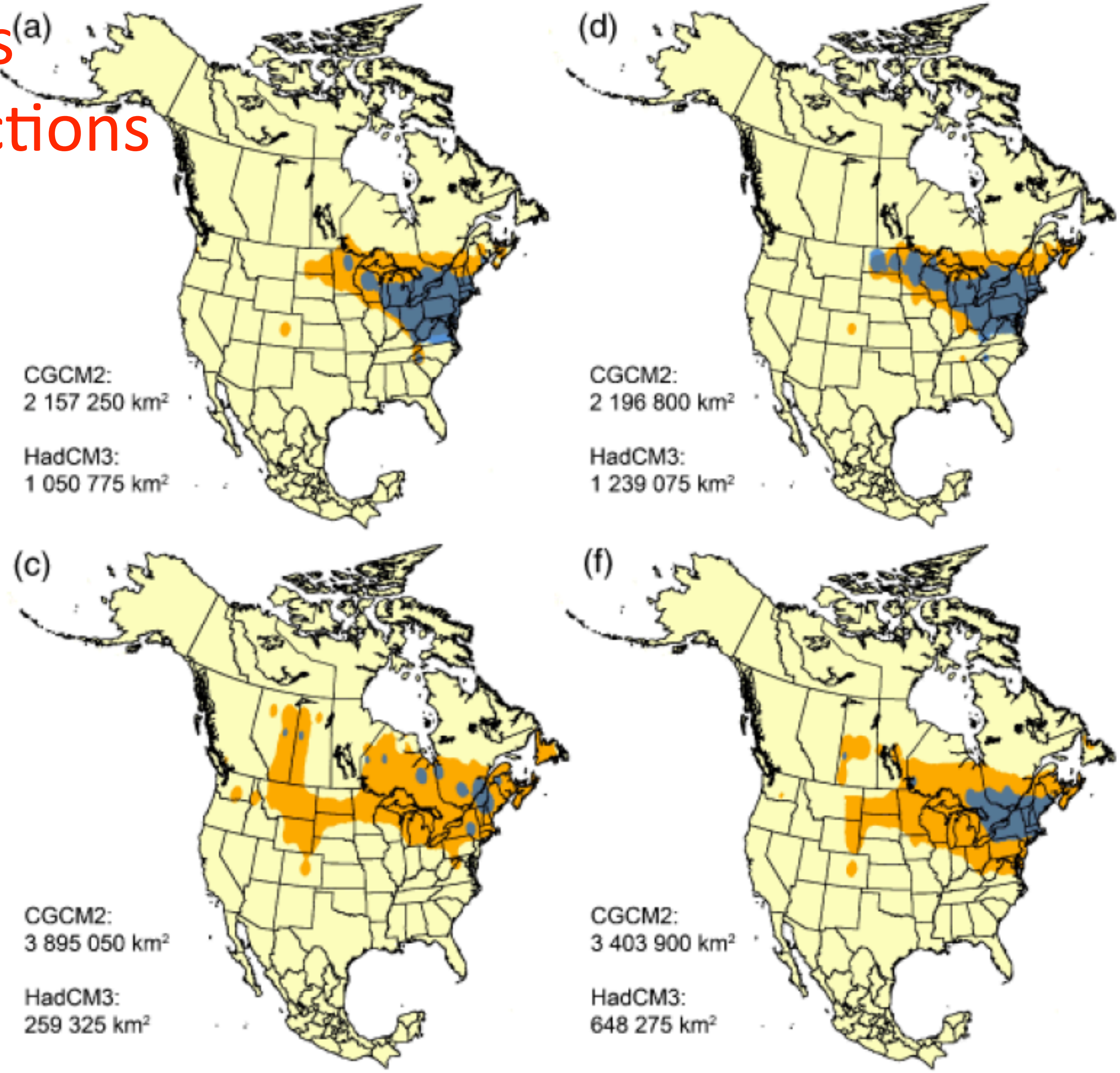
Elith et al 2006


a2 Departure
2040 - 2069 Compared to 1961-1990
Precip (%)
Departure
50 %
25
0
-25
-50
UKMO-HADCM3
Ensemble of all 3 models
CISRO – MK3
MIROC3.0
PPT CHANGE, ClimateWizard

Climate models differ in projections

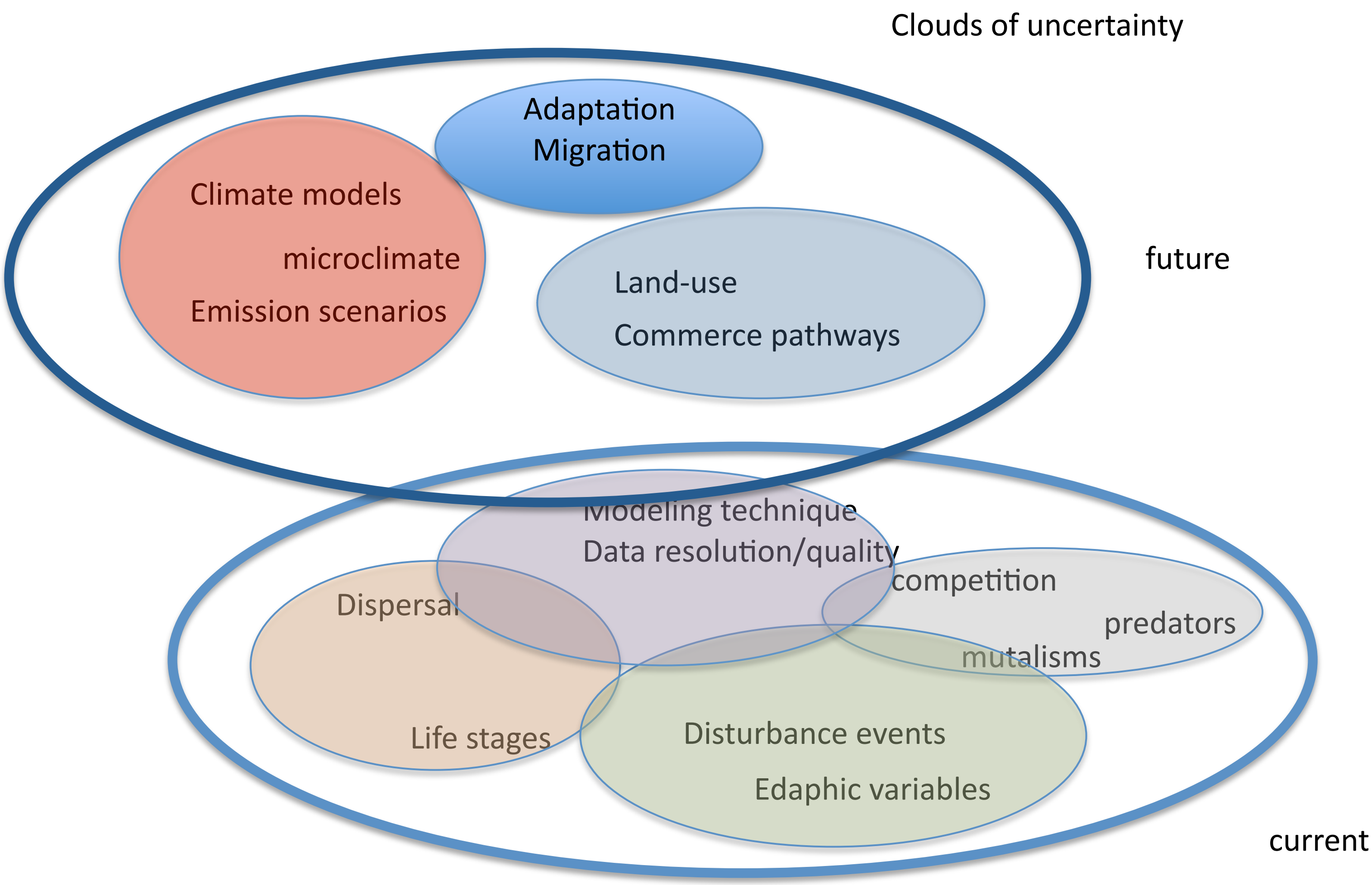
mid-century

End of century



Mika et al 2008

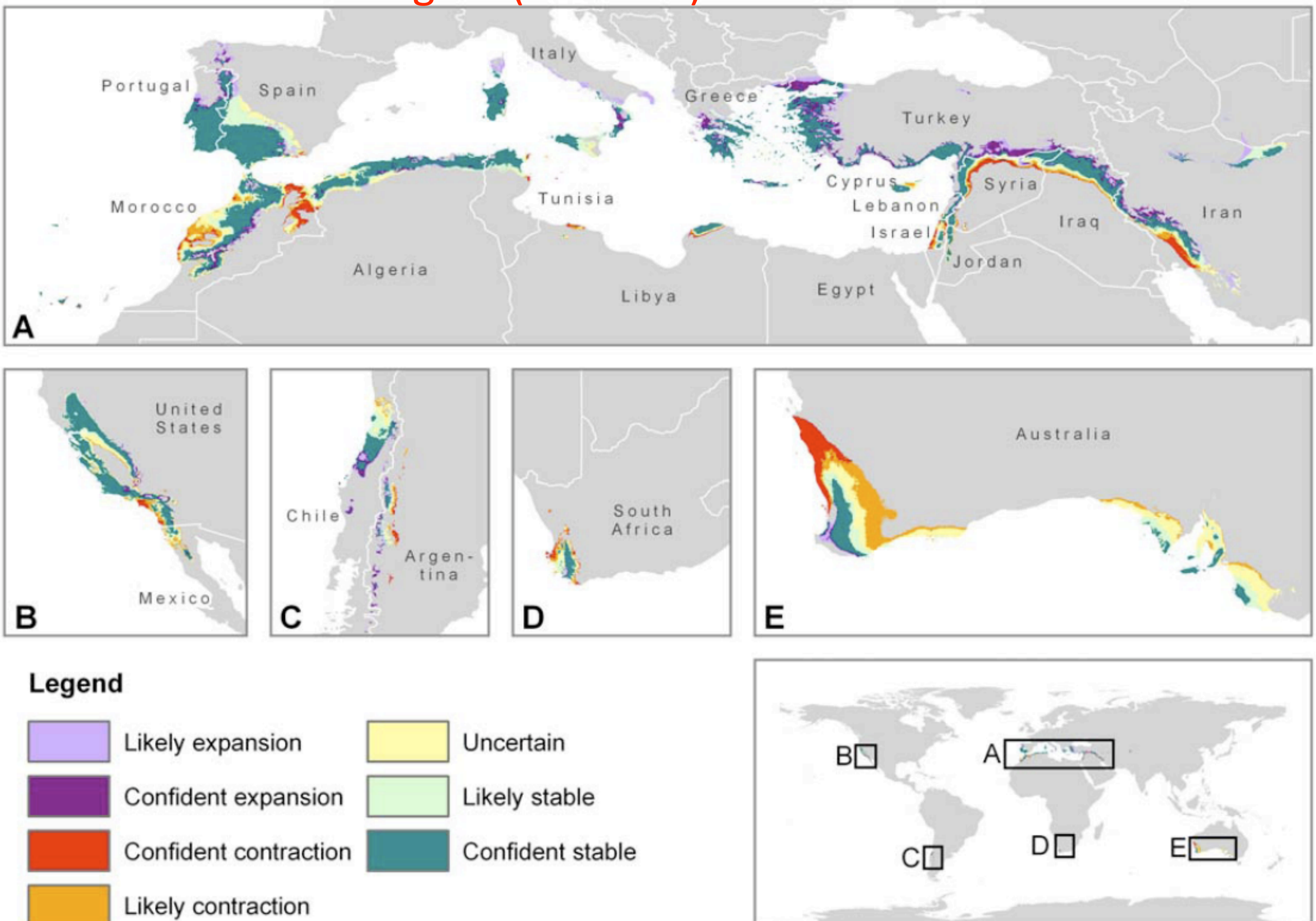
WHAT IS TO BE DONE??



Explore sensitivity & quantify uncertainty

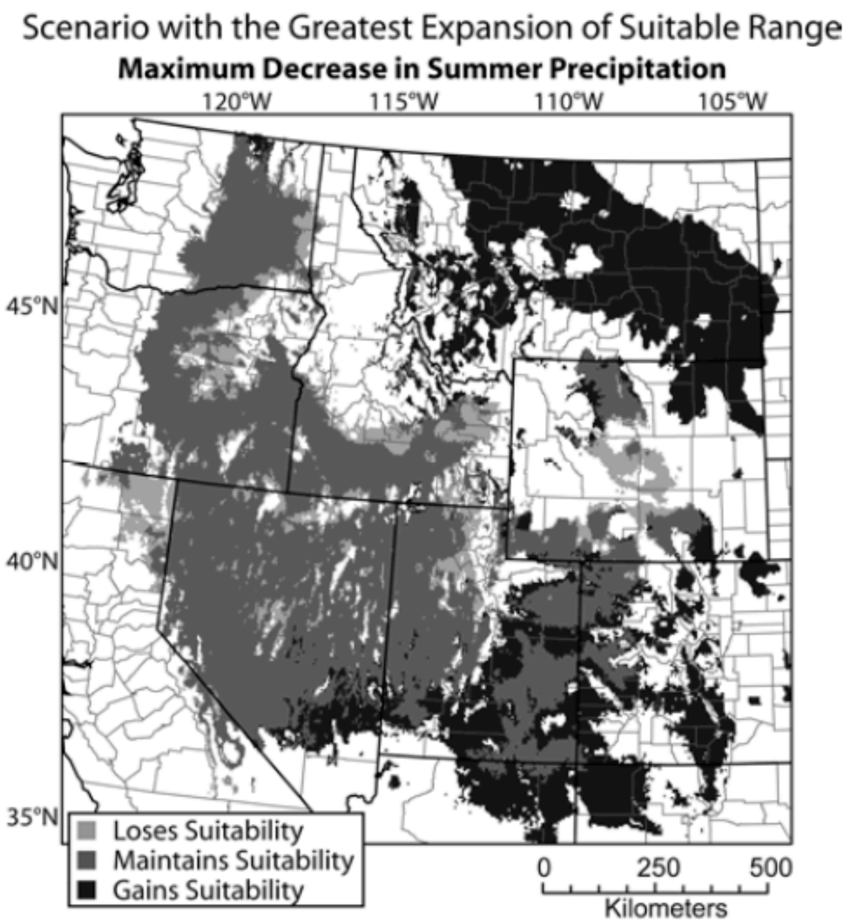
- **Use MANY climate models**
  - There are outputs of multiple GCMs (for example WCRP CMIP3 Multi-Model Dataset)
- **Use MANY modeling techniques**
  - There are packages to help do this (i.e. Biomod in R, Openmodeller)
- **Experiment with extent of range data used to calibrate the model**
- **Experiment with the spatial resolution of the data you input.**
- **Use mechanistic models**

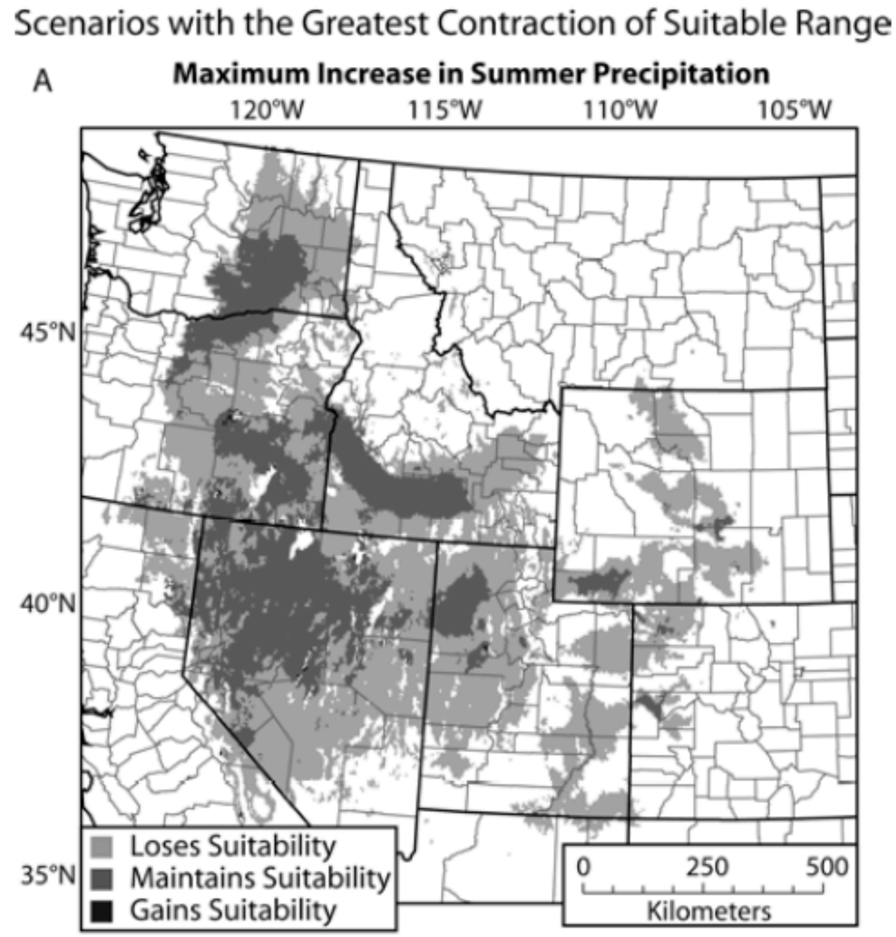
Confidence is a function of the number of climate models that agree (10 used)



Klausmeyer and Shaw 2009

Explore the <u>sensitivity</u> of the invader to the range of projected climate changes

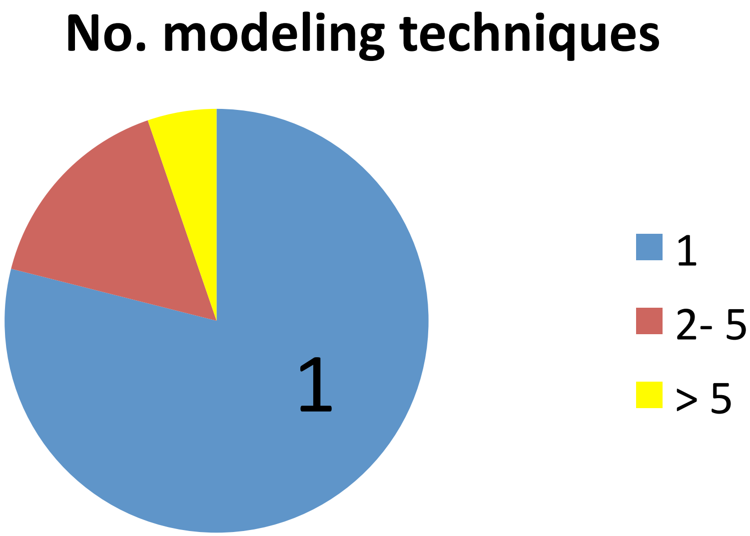


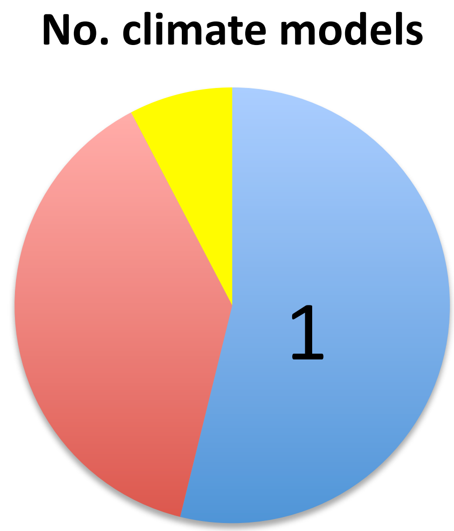


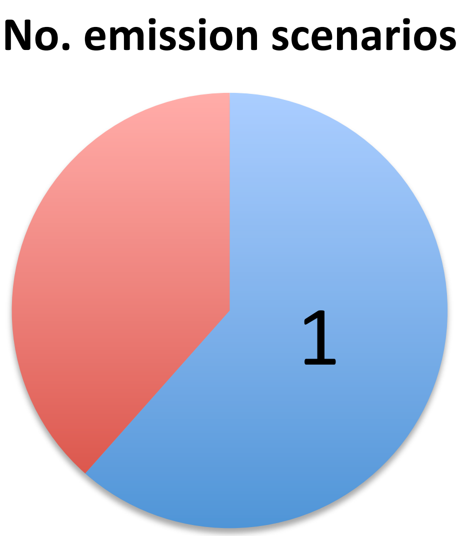
Range may increase 45% or decrease 70%...Cheatgrass

Bradley in press, Global Change Biology

Currently few studies do this

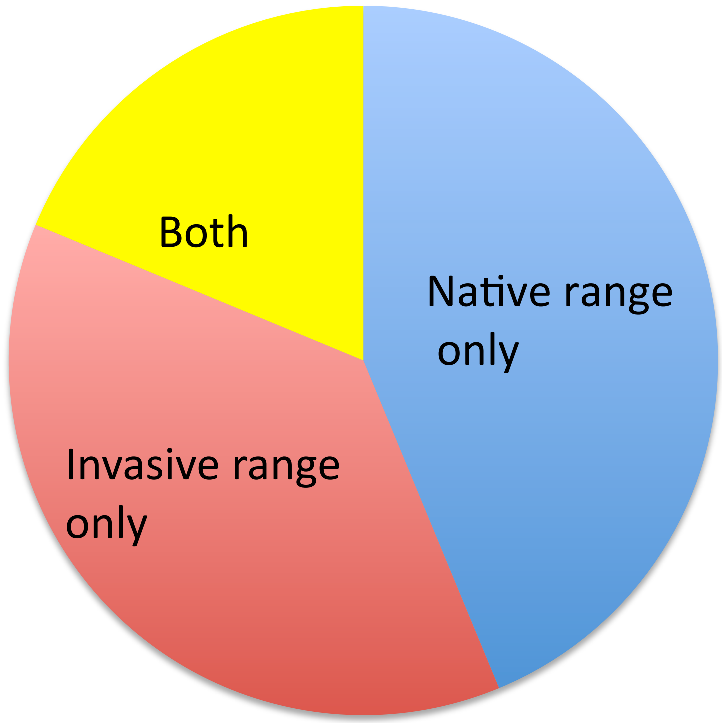






Survey of 20 studies

What data should you use to calibrate your model?



The answer might differ depending on the stage of invasion. Areas first vulnerable to invasion may be best modeled by native range, while areas at the leading edge of already invasive populations might be best modeled by the global range.

Survey of 20 studies

We shouldn't get myopic about climate!!!

- Currently, 80% of studies using only climate variables as environmental predictors of range.
- Other variables that control species distributions
- Why not include these in models?
- These variables will be important to hone in for local risk assessment.

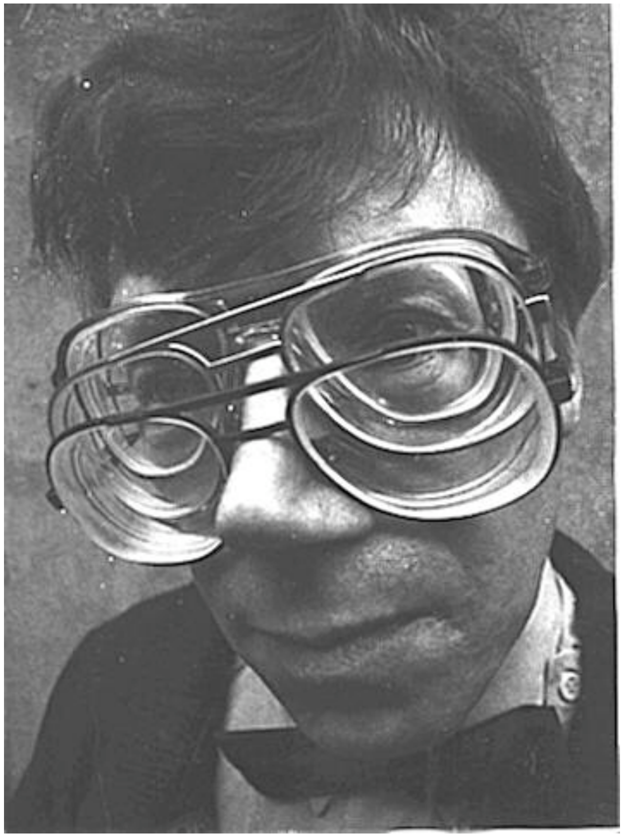


Photo credit: http://www.eye-care-inc.com/myopia.html

Conservative conclusion: Models just are not up to the task for deterministic predictions at local scales

"Bioclimatic models, especially for projecting range shifts due to climate change or the spread of invaders, need further improvements before they can reliably lead to to excellent or even good predictions"

Jeschke and Strayer 2008

"We suggest that the SDM literature has not yet matured to the point that it provides clear guidance for selecting relevant methods."

Elith and Graham 2009

"It may be conceptually inadequate to use these projections as face value for making predictions of future events."

Arajuro et al. 2005

"Garbage in, garbage out."

Phil Duffy, personal communication

But things are improving rapidly…

- Higher quality data inputs, biological and environmental data
- Greater exploration of climate data projections, more regional climate models available
- Better systems for data reporting and data integration (i.e. Global Organism Detection and Monitoring System on the NIISS website)
- Better methods to detect invasive species
- More testing and refinement of modeling techniques

Climate Change Adaptation

Table 1 – List of recommendations for climate change adaptation strategies for biodiversity management assembled from 112 scholarly articles. 524 records were condensed into 113 recommendation categories and are ranked by frequency of times cited in different articles.

Rank	Recommendation	No. articles	References
1	Increase connectivity (design corridors, remove barriers for dispersal, locate reserves close to each other, reforestation	24	Beatley (1991), Chambers et al. (2005), Collingham and Huntley (2000), Da Fonseca et al. (2005), de Dios et al. (2007), Dixon et al. (1999), Eeley et al. (1999), Franklin et al. (1992), Guo (2000), Halpin (1997), Hulme (2005), Lovejoy (2005), Millar et al. (2007), Morecroft et al. (2002), Noss (2001), Opdam and Wascher (2004), Rogers and McCarty (2000), Schwartz et al. (2001), Scott et al. (2002), Shafer (1999), Welch (2005), Wilby and Perry (2006) and Williams (2000)
2	Integrate climate change into planning exercises (reserve, pest outbreaks, harvest schedules, grazing limits, incentive programs	19	Araujo et al. (2004), Chambers et al. (2005), Christensen et al. (2004), Dale and Rauscher (1994), Donald and Evans (2006), Dyer (1994), Erasmus et al. (2002), Hulme (2005), LeHouerou (1999), McCarty (2001), Millar and Brubaker (2006), Peters and Darling (1985), Rounsevell et al. (2006), Scott and Lemieux (2005), Scott et al. (2002), Soto (2001), Staple and Wall (1999), Suffling and Scott (2002) and Welch (2005)
3	Mitigate other threats, i.e. invasive species, fragmentation, pollution	17	Bush (1999), Chambers et al. (2005), Chomesky et al. (2005), Da Fonseca et al. (2005), de Dios et al. (2007), Dixon et al. (1999), Halpin (1997), Hulme (2005), McCarty (2001), Noss (2001), Opdam and Wascher (2004), Peters and Darling (1985), Rogers and McCarty (2000), Shafer (1999), Soto (2001), Welch (2005) and Williams (2000)

Heller and Zavaleta 2009, Biological Conservation

Invasive species management is more important than ever!!!

Thanks!!!

- Thanks to Phil Duffy, David Ackerly, and Scott Loarie for useful discussions on climate change and species distribution modeling

- Climate Central for supporting this work
  www.climatecentral.org