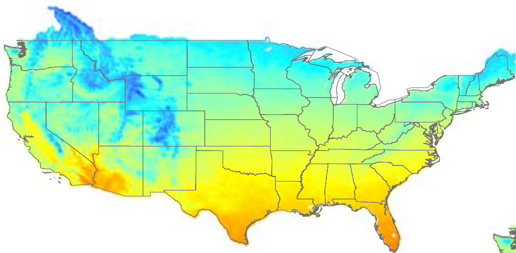
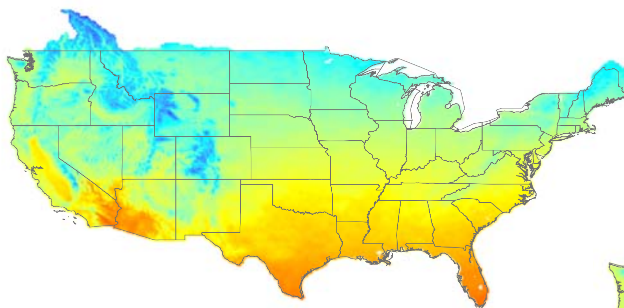
Climate Change and the Biogeography of Troublesome Weed Species

A.J. McDonald (ajm9@cornell.edu)

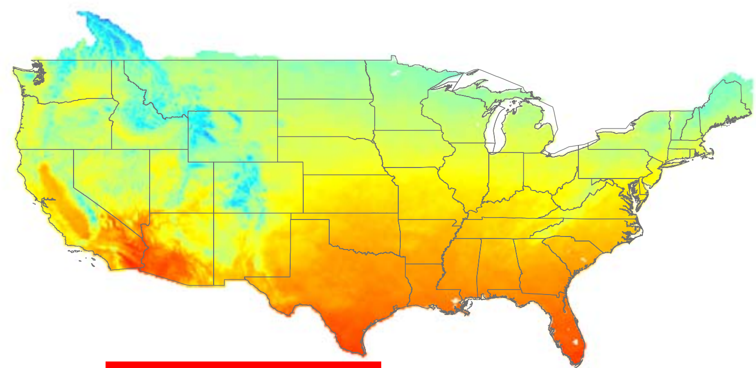
with **S.J. Riha, A. DiTommaso, & A. DeGaetano**



1961 - 1990



2016- 2045



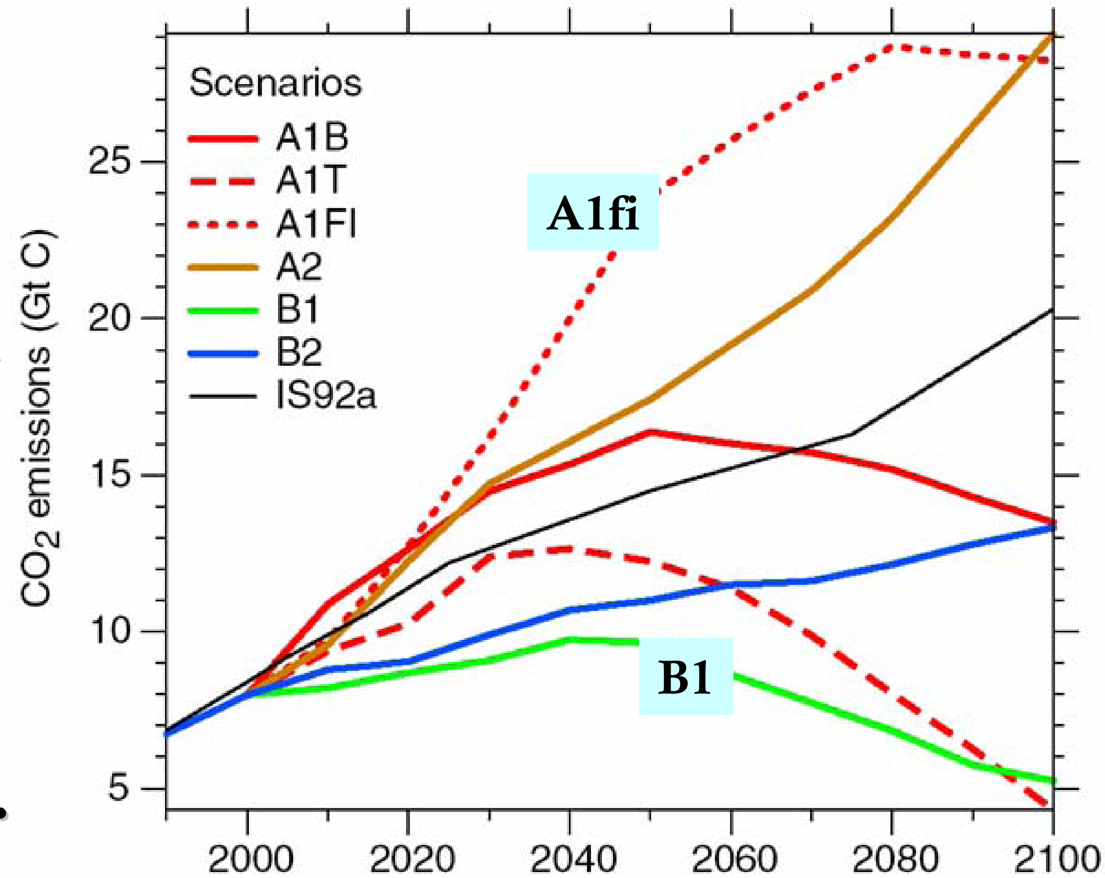
2070- 2099

Cornell University

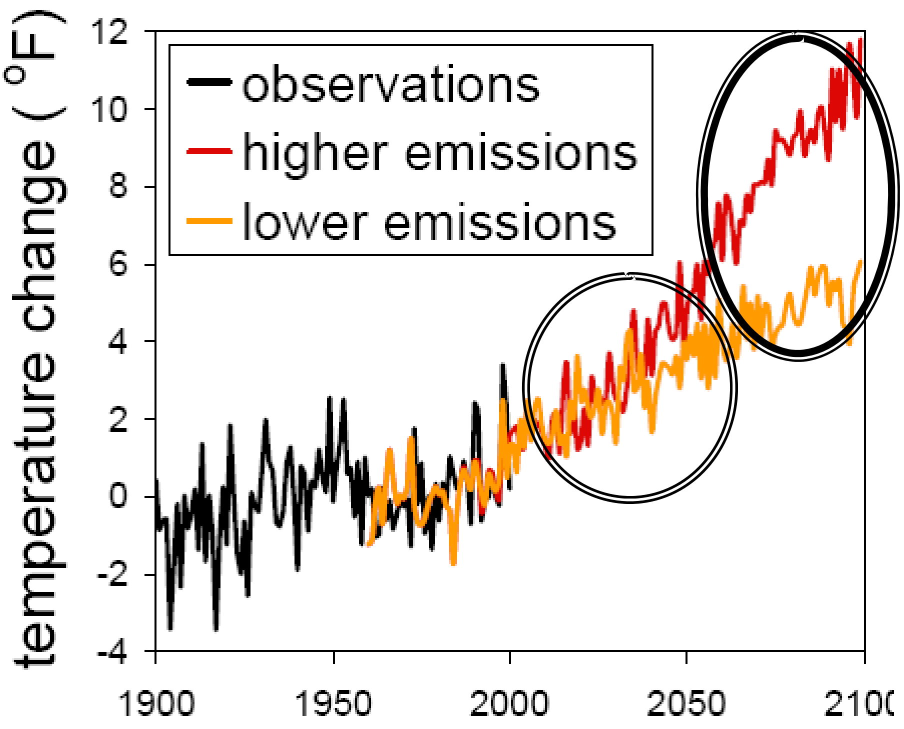
IPCC Emission Scenarios (IPCC, 2000)
range of plausible futures

- **A1fi**: Dependence on fossil fuels and rapid economic growth throughout the next century. **[CO_2] 940 ppm by 2100**
- **B1**: Global solutions to sustainability. Rapid transitions to efficient energy technologies. **[CO_2] 550 ppm by 2100.**

Present-day [CO_2] 380 ppm



Temperature projections for the NE

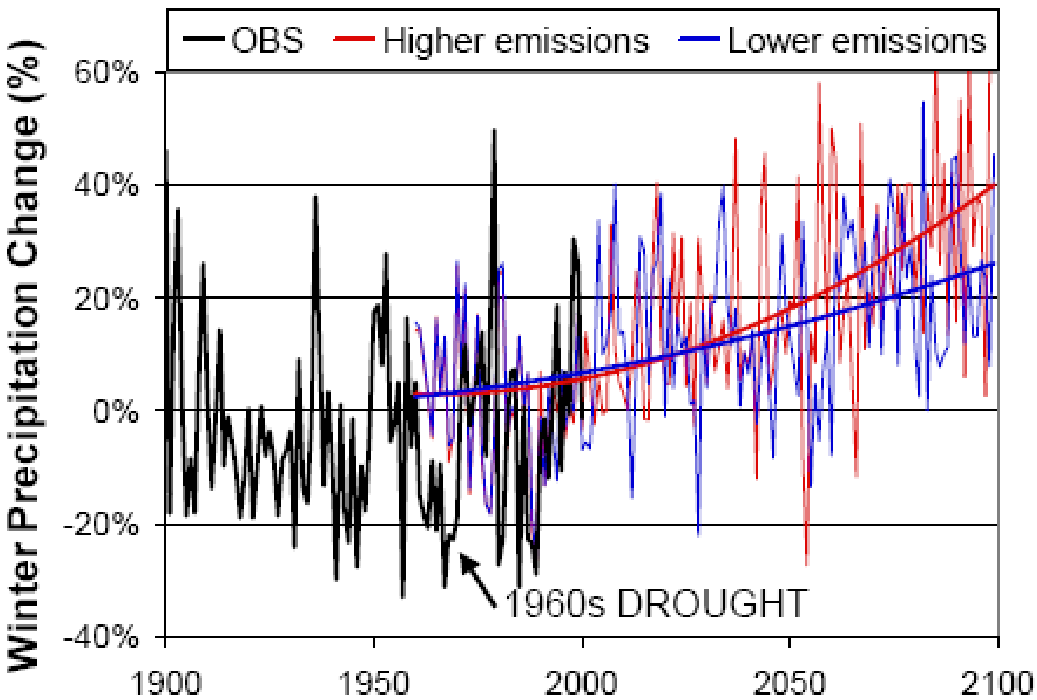


Ensemble AOGCM forecasts of annual temperature, downscaled to 1/8 ° for the Northeast (NECIA, 2006)

Until mid-century, "commitment" to a certain amount of warming, independent of GHG emissions.

At the end of the century, the B1 scenario will stabilize temperatures around 4 – 6 ° F higher than historical levels, whereas A1fi may result in a <u>10 to 12.5 ° F increase</u>.

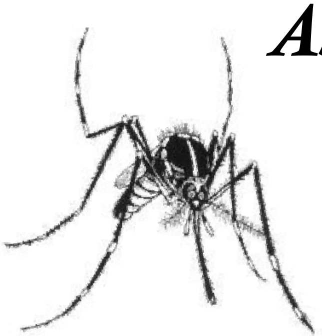
NE precipitation projections



Ensemble AOGCM forecasts of annual temperature, downscaled to 1/8 ° for the Northeast (NECIA, 2006)

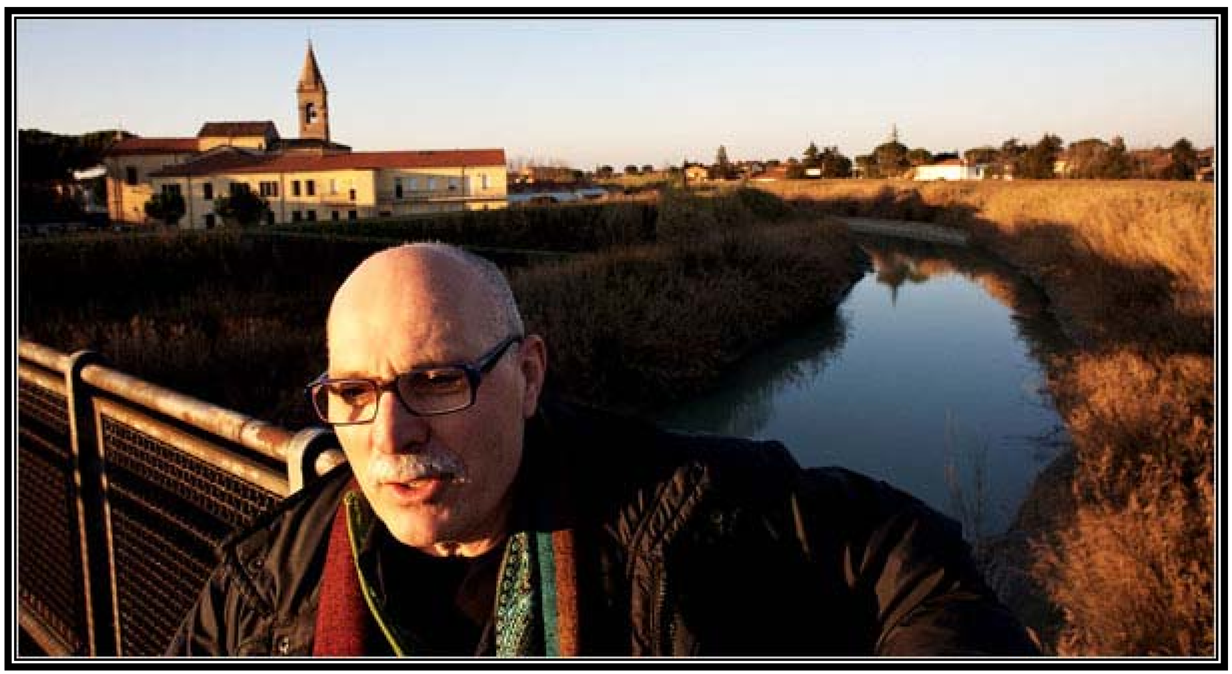
- **Little change in <u>summer precipitation</u>** in any emission scenario.
- **Significant increases in <u>winter precipitation</u>,** especially under higher emissions.
- **<u>Total precipitation</u> will increase by ~ 15%** by end of century under higher emissions scenario.

The Predictable
Chikungunya in Southern Europe



As Earth Warms Up, Tropical Virus Moves to Italy

NY Times, 12/23/07



The Unexpected

Global change and the price of *beer*?

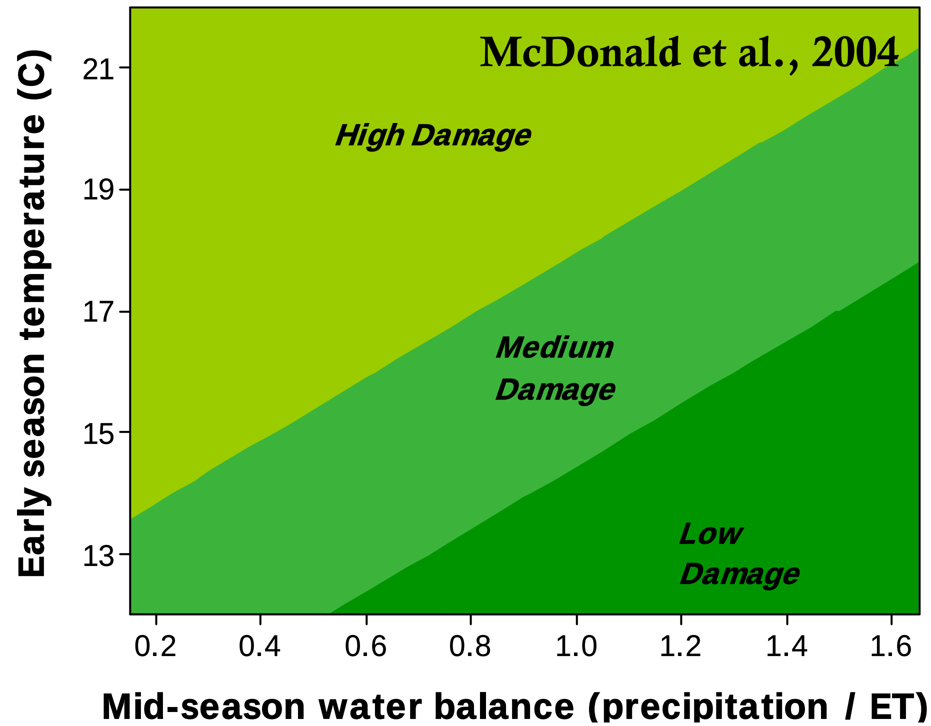
CLIMATE CONSENSUS

BIOFUEL EXPANSION

SHORTAGE OF HOPS & BARLEY

Direct effects of climate change on weeds (I)

In-season competition: growing-season weather has a strong influence on the dynamics crop-weed interference

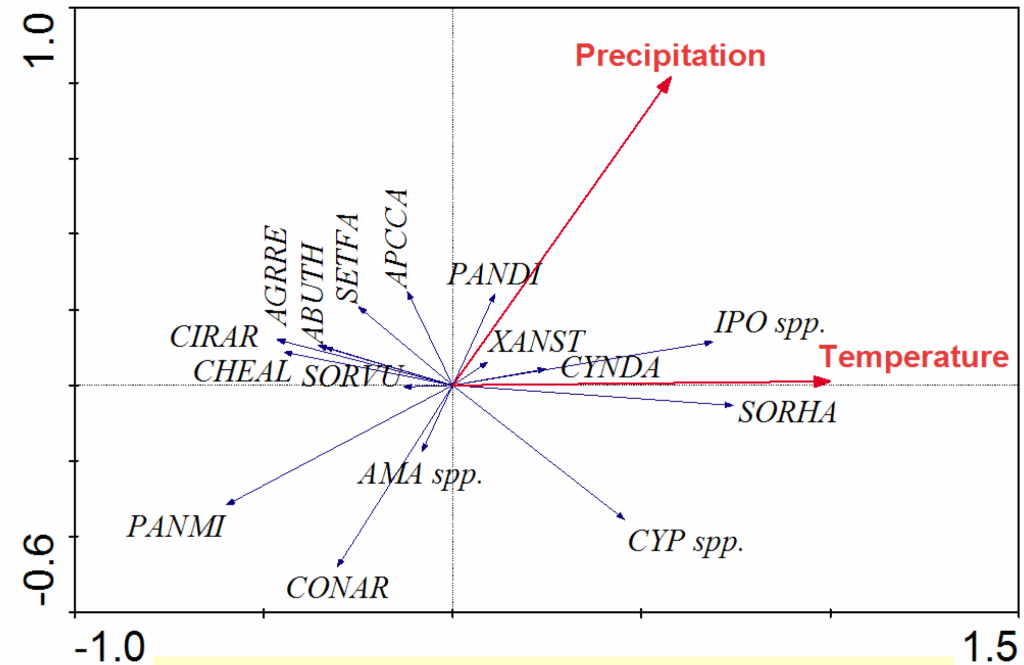


Climate change and increased weather variability: more difficult to anticipate competitive outcomes?

Adaptive management strategies to cope with uncertainty

Direct effects of climate change on weeds (II)

<u>Weed populations</u>:
climate (i.e. long-term weather) has a strong influence on weed community composition



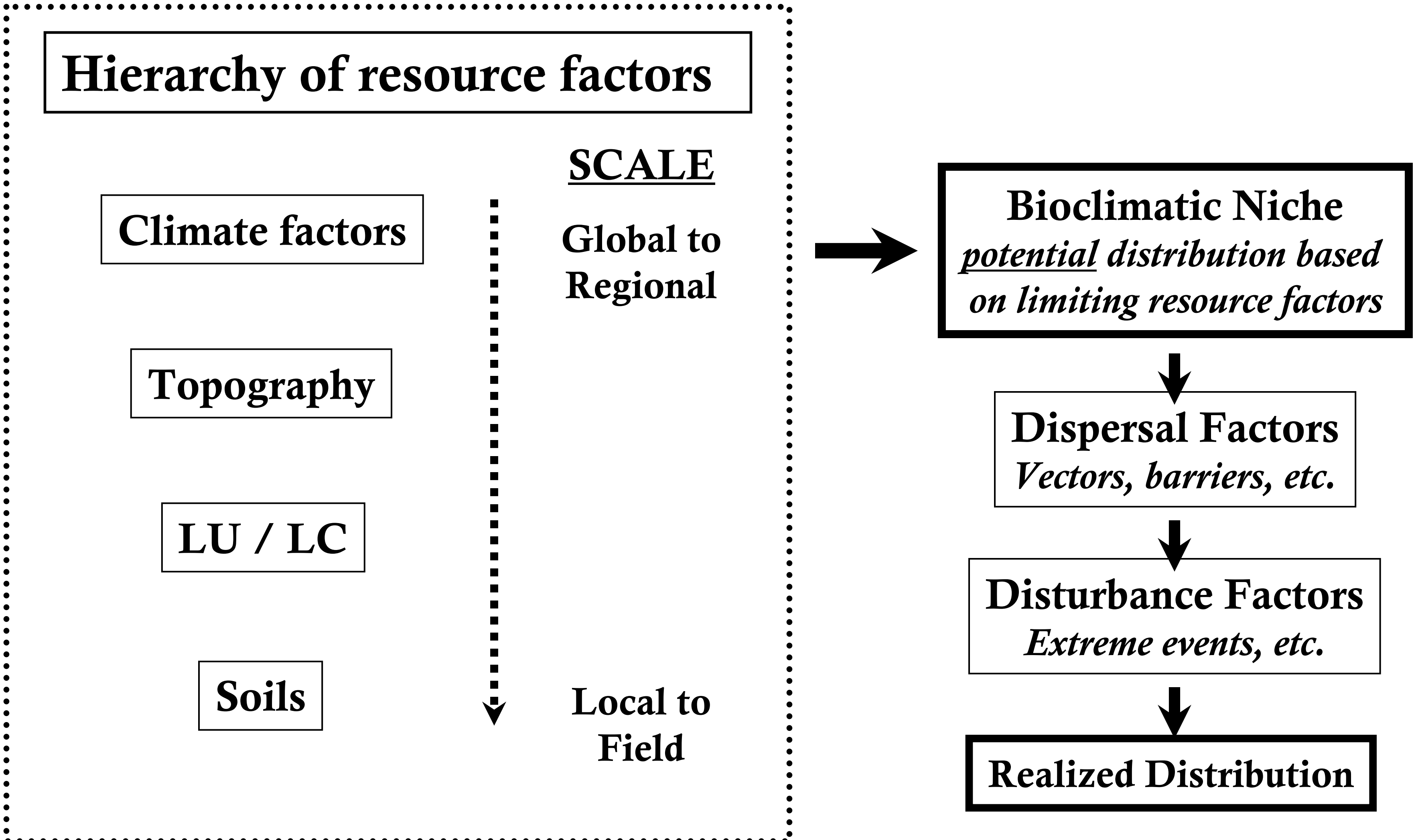
Ordination of weed species in maize

<u>Biogeography</u>: study of where organisms live, at what abundance, and *why*

As the climate warms, geographic range for species will shift

Bioclimatic Niche

resource "rules" that govern potential geographic distribution

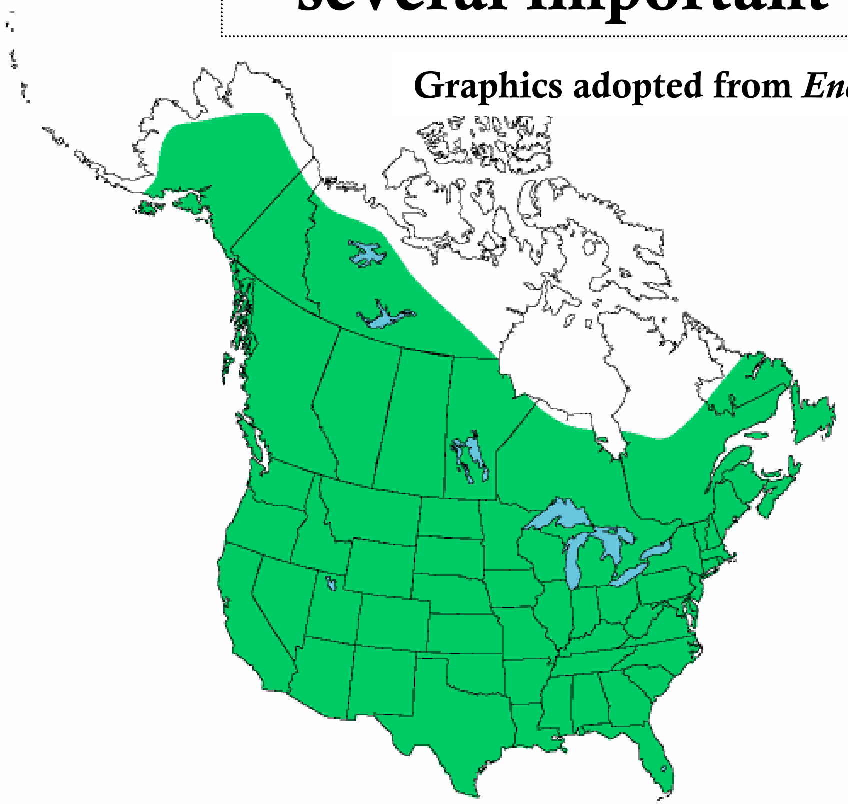


(adopted from Pearson & Dawson, 2003)

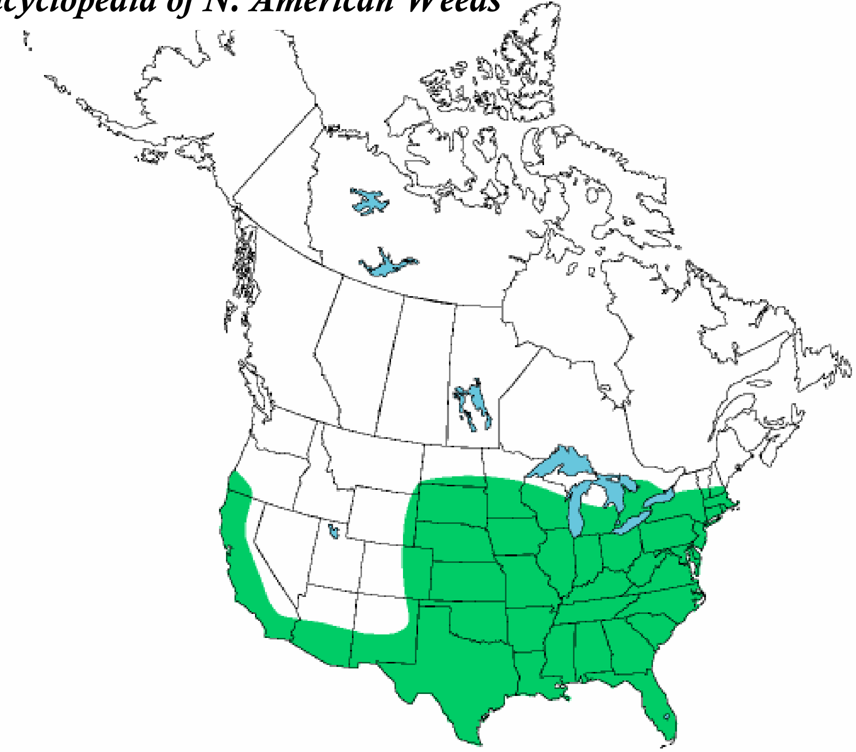
Will climate change matter to the geographic range of US agronomic weeds?

Extensive bioclimatic niche for several important agronomic weeds

Graphics adopted from *Encyclopedia of N. American Weeds*

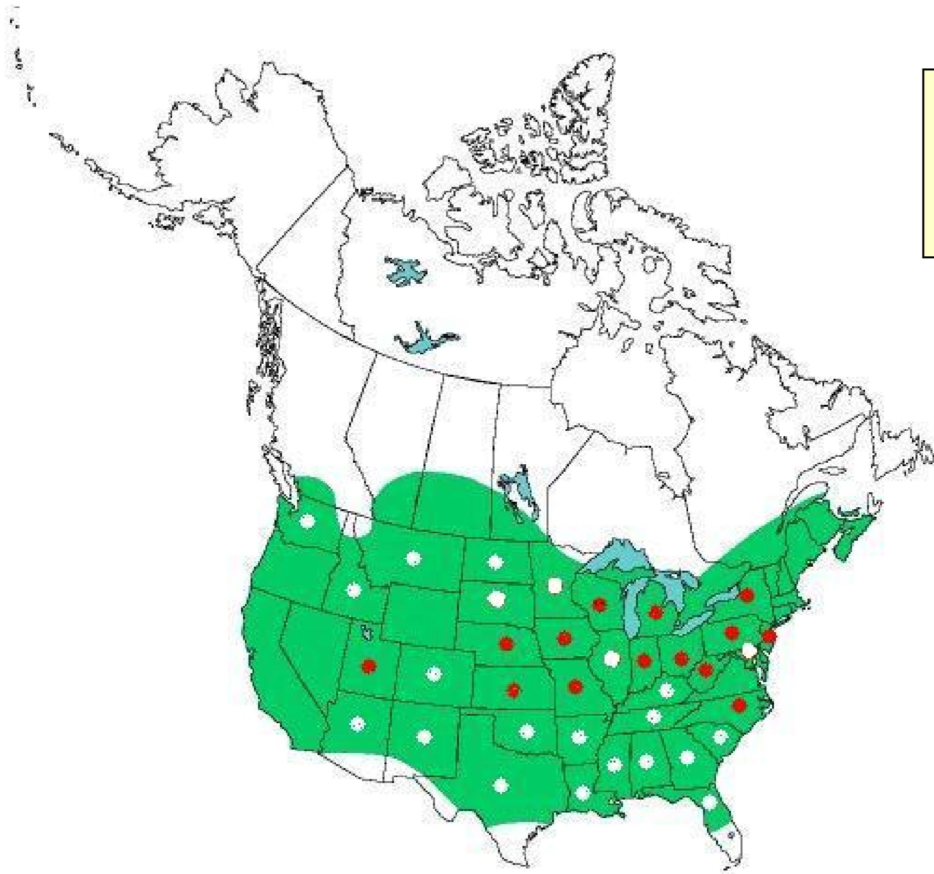


***C. album* distribution**



***S. halepense* distribution**

<u>Damage Niche</u>: *environmental conditions where species are abundant & damaging to specific crops, not simply present*

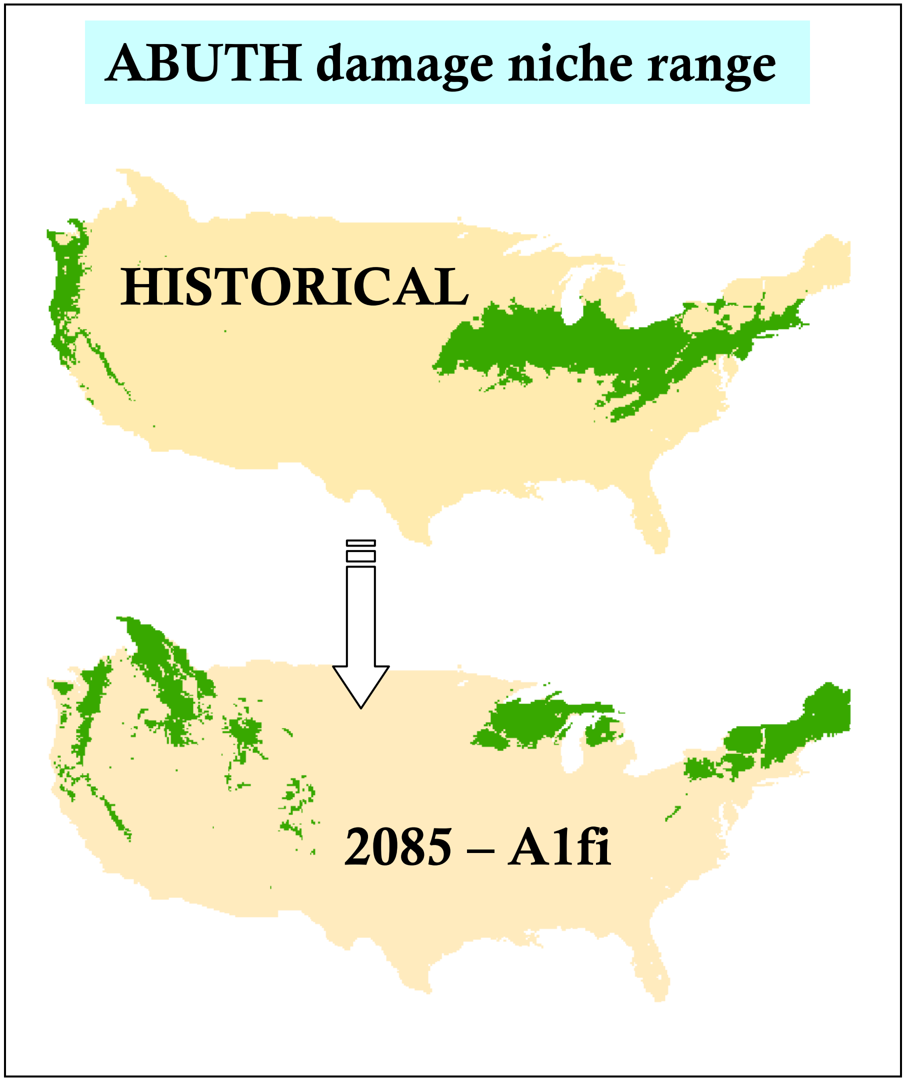


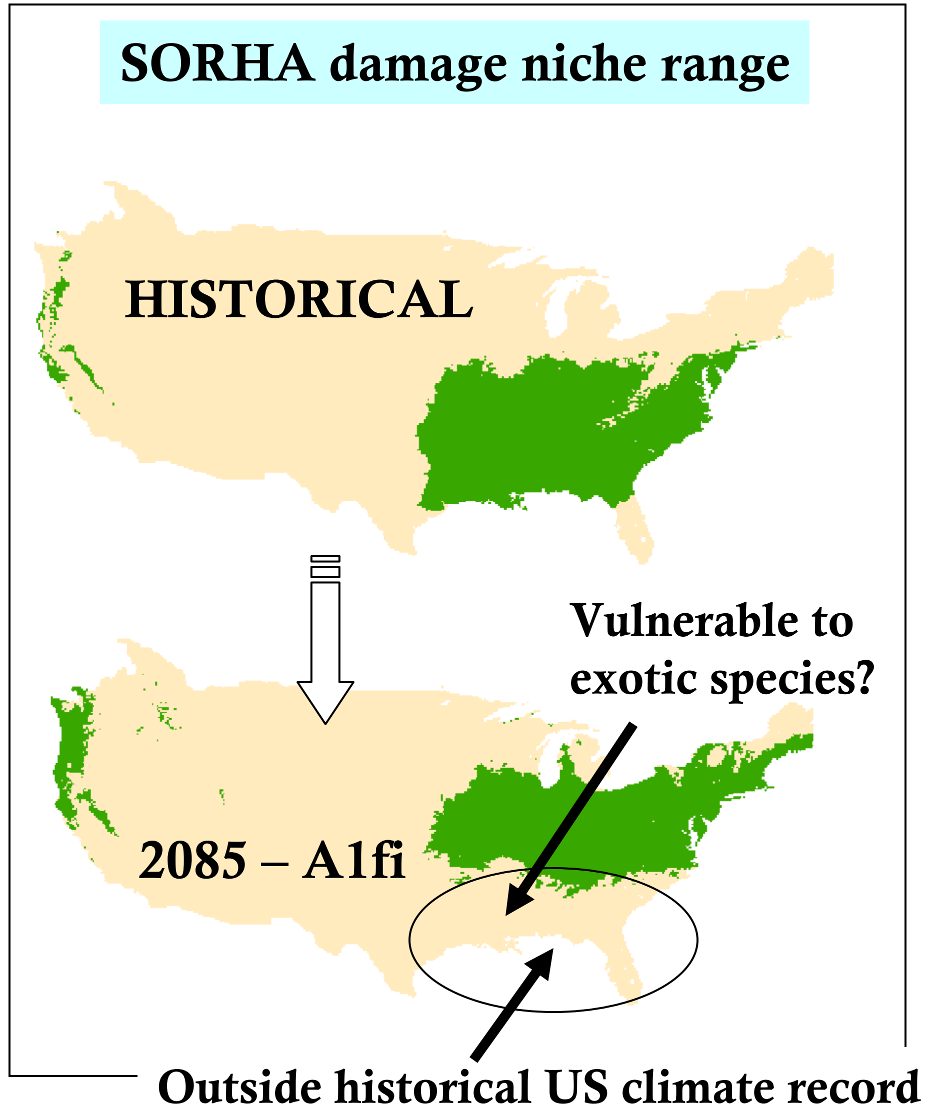
A. theophrasti is considered troublesome to maize in only 14 of 38 States where maize is cultivated (Bridges, 1992).

Challenge to biogeography in agricultural systems:

Determining the damage niche, rather than the broader bioclimatic niche, for important weed species

Bridges Data *rough guide to damage niche geography for widely-distributed species*





Biogeography Methods: *What weed species will be damaging to crops in a changing climate and where?*

1. **Ecophysiological studies and mechanistic modeling** (*difficult to test multiple resource factors and interactions, results not readily extrapolated to field conditions*)

2. **Bioclimatic niche modeling** With high-resolution survey data of troublesome species (e.g. finer than state-level), use quantitative statistical techniques to correlate environment factors with geographic distribution of damage (*survey data does not yet exist*).

3. **Space-for-time substitution** With existing low-resolution survey data for troublesome weeds (i.e. Bridges, 1992), identify historical analogues for projected climates.

Space-for-Time Substitution *based on annual state climatology and Bridges survey data*

WEED SURVEY

- **Bridges (1992) "top-ten" survey of troublesome weeds in corn** for different US states (corn has the widest geographic range of any agronomic crop, hence was used in this analysis).

CLIMATE DATA

- **A1fi emissions scenario**
- **Historical data and ensemble AOGCM projections for mean annual precipitation and temperature** (aggregated to state-level from downscaled projections, Hayhoe et al., 2006)
- **Three time periods for state climatology**: historical (1961 – 1990), coming decades (2016 – 2045), end of century (2070 – 2099)

Analysis Caveats (selected!)

- Suggests **<u>potential</u> weed community changes** based on climate factors. Actual changes will be influence by other factors such as dispersal processes.

- Does not account for the role of **<u>climate variability</u>** or increasing **<u>atmospheric CO_2</u>**

- Cannot be use for **<u>emergent climate conditions</u>** (e.g. in southern US) and other states with no historical analogue

Results

Nine States

<u>Appalachia</u> – Kentucky

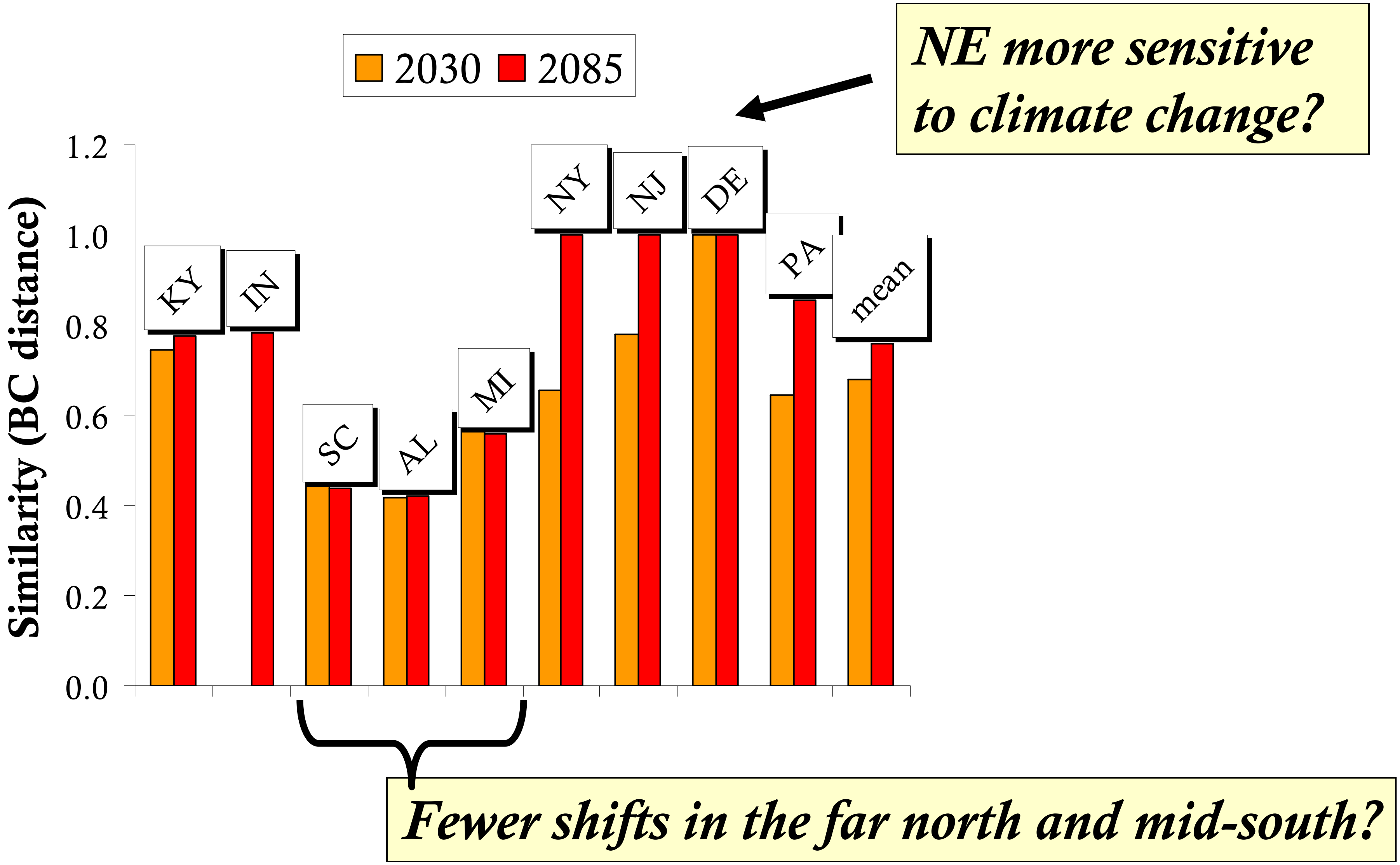
<u>Southeast</u> – Alabama, South Carolina

<u>Lake States</u> – Michigan

<u>Northeast</u> – Delaware, New York, New Jersey, Pennsylvania

Troublesome weed community changes

(Bray – Curtis Similarity, weighted by damage rank)

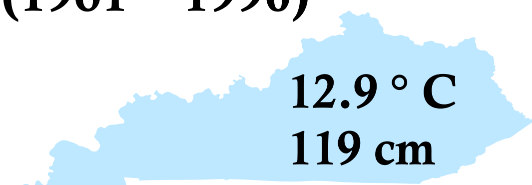


Appalachia

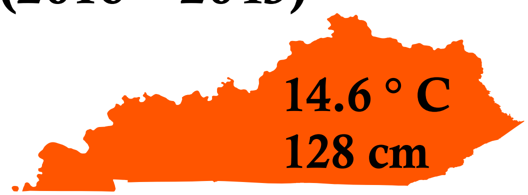
Kentucky: A1F1 Emissions Scenario

Annual Mean Climatology: Precipitation & Temperature

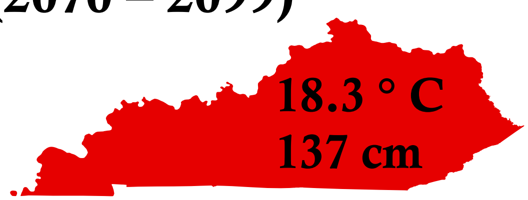
Historical
(1961 – 1990)



Coming Decades
(2016 – 2045)

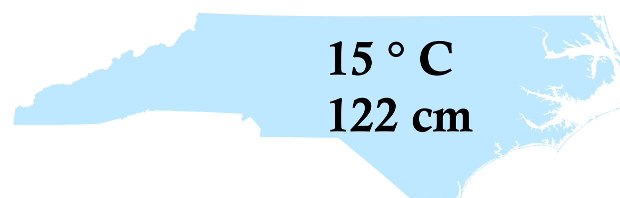


End of Century
(2070 – 2099)

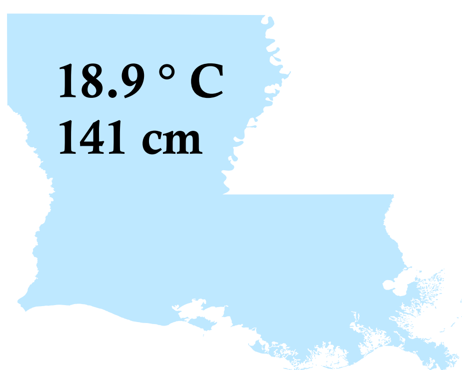


RESEMBLING HISTORICAL

NC



LA



Kentucky (A1fi scenario)
Potential troublesome weed species in maize

KENTUCKY

1. ***S. halepense***
2. *S. vulgare*
3. *A. trifida*
4. *C. laeve*
5. *P. dichotomiflorum*
6. ***S. angulatus***
7. *C. radicans*
8. *C. arvensis*
9. *I. hederacea*
10. *X. strumarium*

N. CAROLINA

1. ***S. halepense***
2. *U. texana*
3. *U. platyphylla*
4. *S. obtusifolia*
5. *Ipomoea spp.*
6. *Cyperus spp.*
7. ***S. angulatus***
8. *S. carolinense*
9. *A. theophrasti*
10. *C. dactylon*

Retained: 2 / 10

LOUISIANA

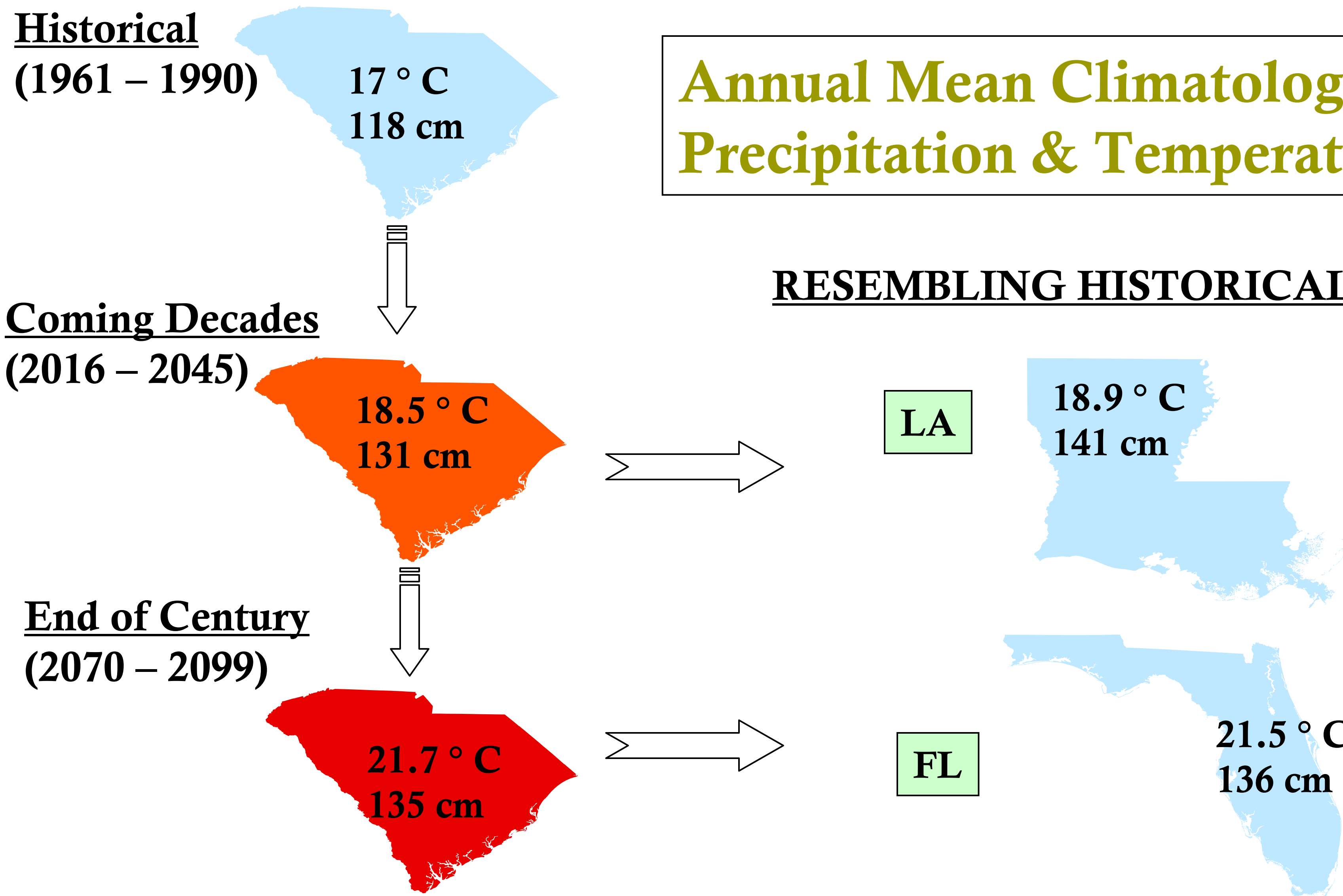
1. ***S. halepense***
2. *R. cochinchinensis*
3. *U. platyphylla*
4. *Ipomoea spp*

Retained: 1 / 10

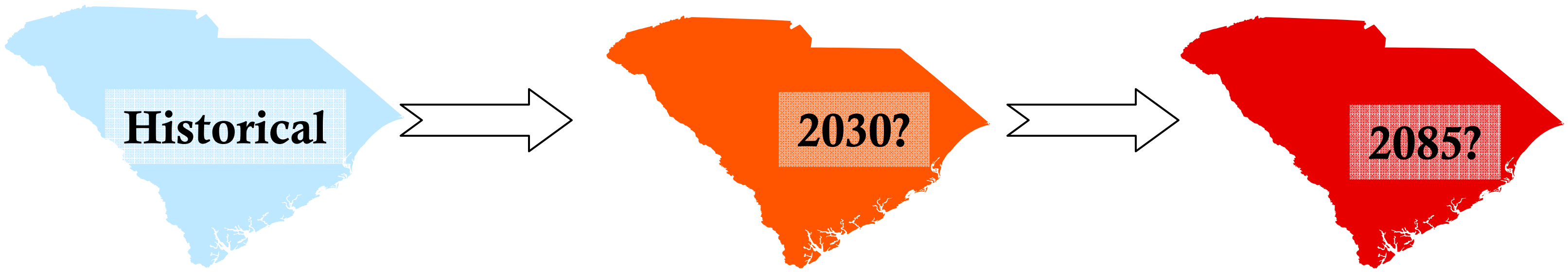
Southeast

South Carolina: A1fi Emissions Scenario

Annual Mean Climatology: Precipitation & Temperature



<u>South Carolina</u> (A1fi scenario)
Potential troublesome weed species in maize



<u>SOUTH CAROLINA</u>

1. *C. dactylon*
2. ***U. texana***
3. ***U. platyphylla***
4. ***S. halepense***
5. ***Ipomoea spp.***
6. ***Cyperus spp.***
7. ***C. obtusifolia***
8. *P. dichotomiflorum*
9. *A. palmeri*
10. ***X. strumarium***

<u>LOUISIANA</u>

1. ***S. halepense***
2. *R.cochinchinensis*
3. ***U. platyphylla***
4. ***Ipomoea spp.***

Retained: 3 / 8

<u>FLORIDA</u>

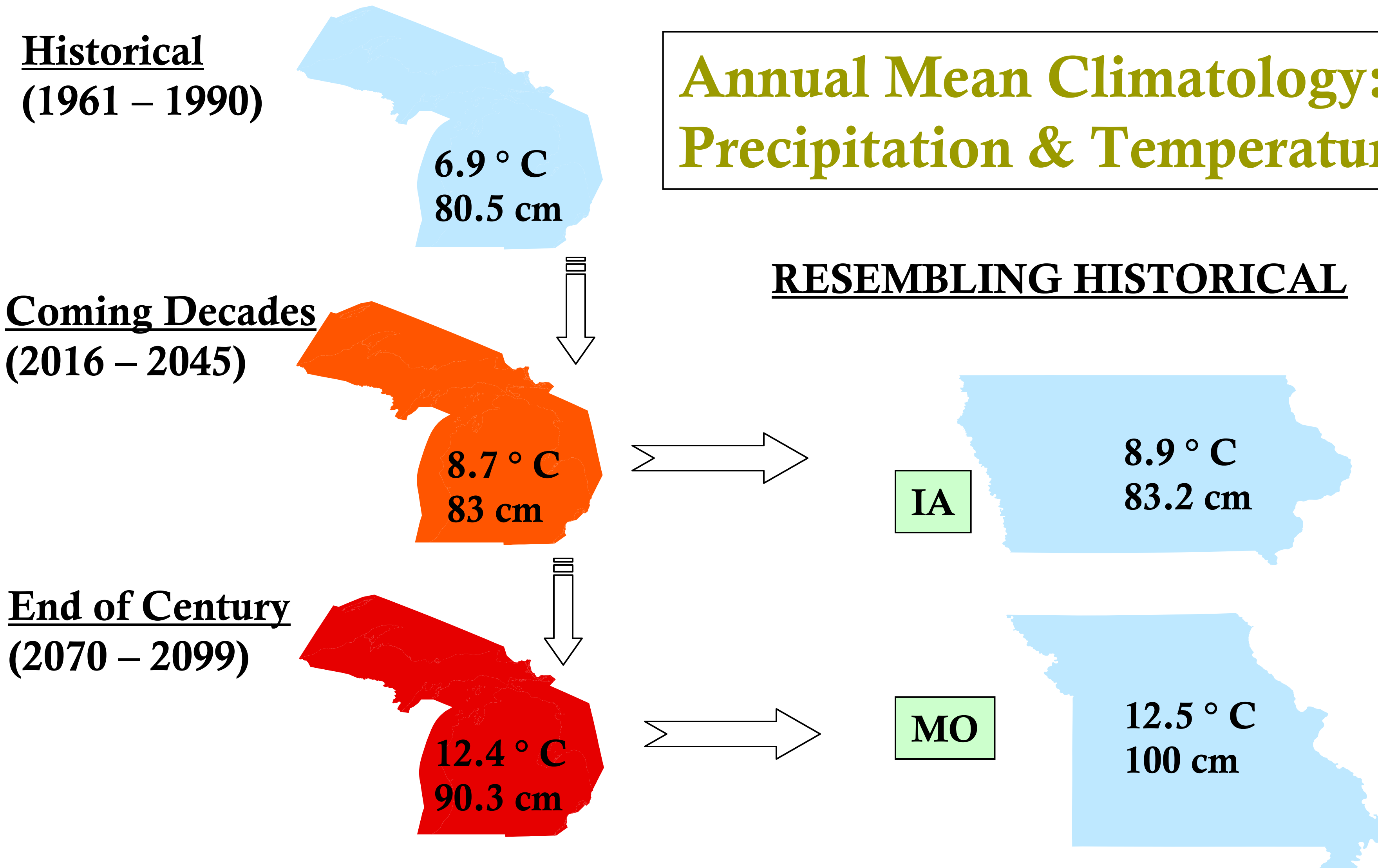
1. ***U. texana***
2. *D. tortuosum*
3. ***C. obtusifolia***
4. ***S. halepense***
5. ***X. strumarium***
6. ***Ipomoea spp.***
7. *A. hispidum*
8. ***Cyperus spp.***
9. *Amaranthus spp.*
10. *Digitaria spp.*

Retained: 6 / 8

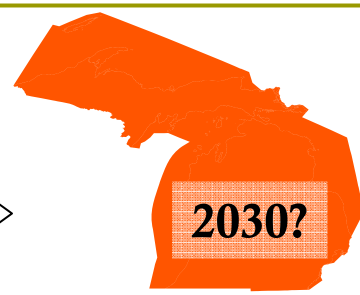
Lake States

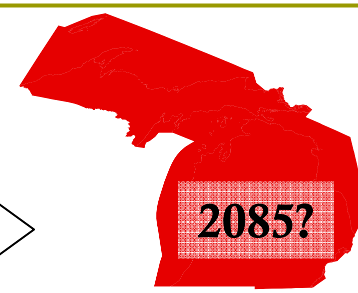
Michigan: A1fi Scenario

Annual Mean Climatology: Precipitation & Temperature



Michigan (A1fi scenario)
Potential troublesome weed species in maize





MICHIGAN

1. ***A. theophrasti***
2. ***P. dichotomiflorum***
3. ***E. repens***
4. ***C. album***
5. *C. arvense*
6. ***A. cannabinum***
7. *C. arvensis*
8. *D. sanguinalis*
9. ***S. faberi***

IOWA

1. ***S. faberi***
2. ***A. theophrasti***
3. *Amaranthus spp.*
4. ***C. album***
5. *X. strumarium*
6. *P. pensylvanicum*
7. *H. annuus*
8. *S. bicolor*
9. *E. villosa*
10. ***E. repens***

Retained: 4 / 9

MISSOURI

1. ***A. theophrasti***
2. *S. bicolor*
3. ***S. faberi***
4. *A. rudis*
5. ***P. dichotomiflorum***
6. *A. syriaca*
7. ***A. cannabinum***
8. *S. halepense*
9. ***C. album***
10. *X. strumarium*

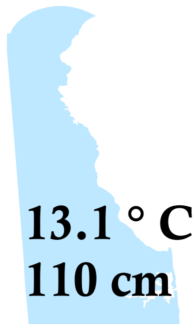
Retained: 5 / 9

Northeast

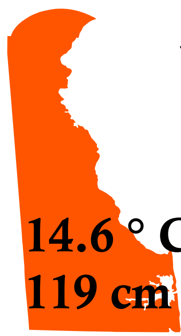
Delaware: A1fi Scenario

Annual Mean Climatology: Precipitation & Temperature

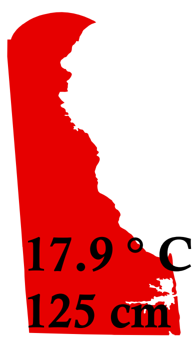
Historical
(1961 – 1990)



Coming Decades
(2016 – 2045)

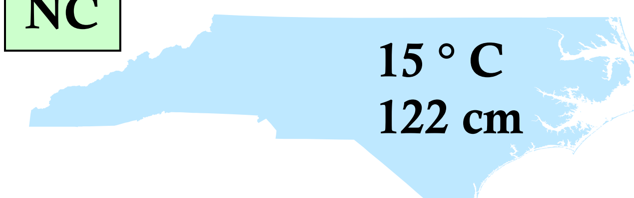


End of Century
(2070 – 2099)

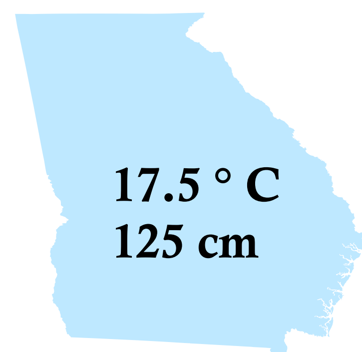


RESEMBLING HISTORICAL

NC

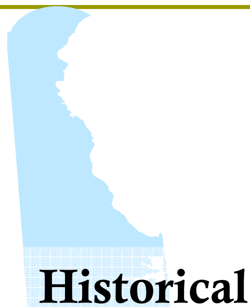


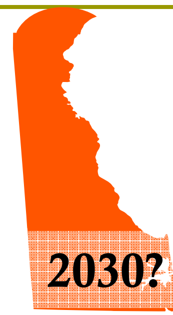
GA



Delaware (A1fi scenario)

Potential troublesome weed species in maize





DELAWARE

1. *C. arvense*
2. *P. dichotomiflorum*
3. *A. cannabinum*
4. *S. faberi*
5. *Amaranthus spp.*

N. CAROLINA

1. *S. halepense*
2. *U. texana*
3. *U. platyphylla*
4. *C. obtusifolia*
5. *Ipomoea spp.*
6. *Cyperus spp.*
7. *S. angulatus*
8. *S. carolinense*
9. *A. theophrasti*
10. *C. dactylon*

Retained: 0 / 10

GEORGIA

1. *U. texana*
2. *Ipomoea spp.*
3. *X. strumarium*
4. *C. obtusifolia*
5. *C. occidentalis*
6. *S. halepense*

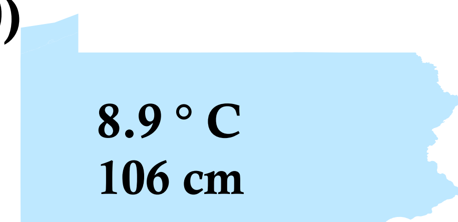
Retained: 0 / 10

Northeast

Pennsylvania: A1fi Scenario

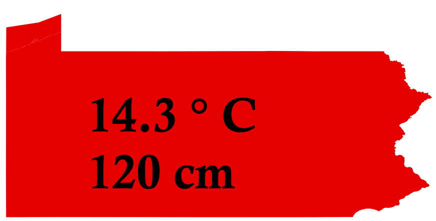
Annual Mean Climatology: Precipitation & Temperature

Historical
(1961 – 1990)



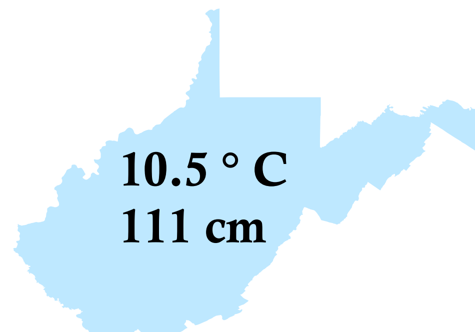
Coming Decades
(2016 – 2045)

End of Century
(2070 – 2099)

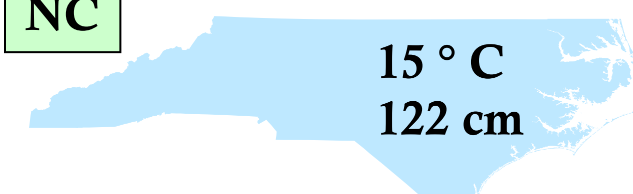


RESEMBLING HISTORICAL

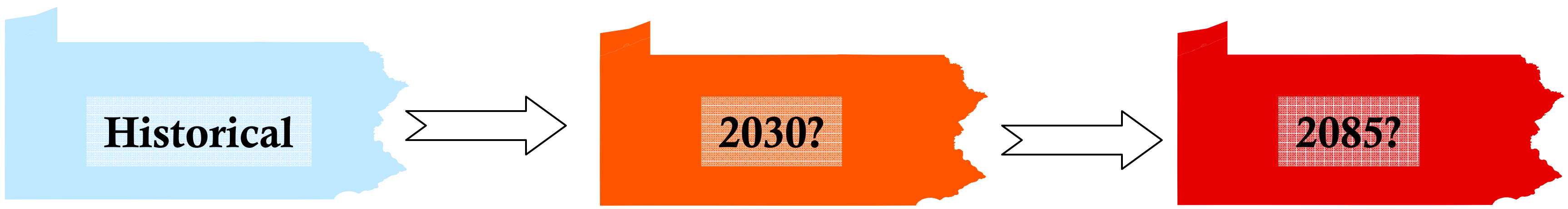
WV



NC



Pennsylvania (A1fi scenario)
Potential troublesome weed species in maize



PENNSYLVANIA

1. *A. artemisiifolia*
2. ***A. cannabinum***
3. ***S. carolinense***
4. ***M. frondosa***
5. *R. fruticosus*
6. ***E. repens***
7. ***A. theophrasti***
8. ***S. angulatus***
9. *C. arvensis*
10. ***C. album***

W. VIRGINIA

1. *S. halepense*
2. *A. retroflexus*
3. ***C. album***
4. ***A. theophrasti***
5. ***M. frondosa***
6. ***E. repens***
7. *Cyperus spp.*
8. *A. syriaca*
9. ***A. cannabinum***
10. ***S. angulatus***

Retained: 6 / 10

N. CAROLINA

1. *S. halepense*
2. *U. texana*
3. *U. platyphylla*
4. *C. obtusifolia*
5. *Ipomoea spp.*
6. *Cyperus spp.*
7. ***S. angulatus***
8. ***S. carolinense***
9. ***A. theophrasti***
10. *C. dactylon*

Retained: 3 / 10

Conclusions

Climate change and the geography of damage

- **Geographic distribution** of troublesome species is likely to be significantly transformed
- In some states, potential **nearer-term changes** are commensurate to those possible by the end of the century
- Weed communities in the **NE** may experience more significant changes than other US regions
- Emerging climate niches in the South suggests new vulnerabilities to **exotics**
- Projections could be useful for targeting climatically-favored species for **control**

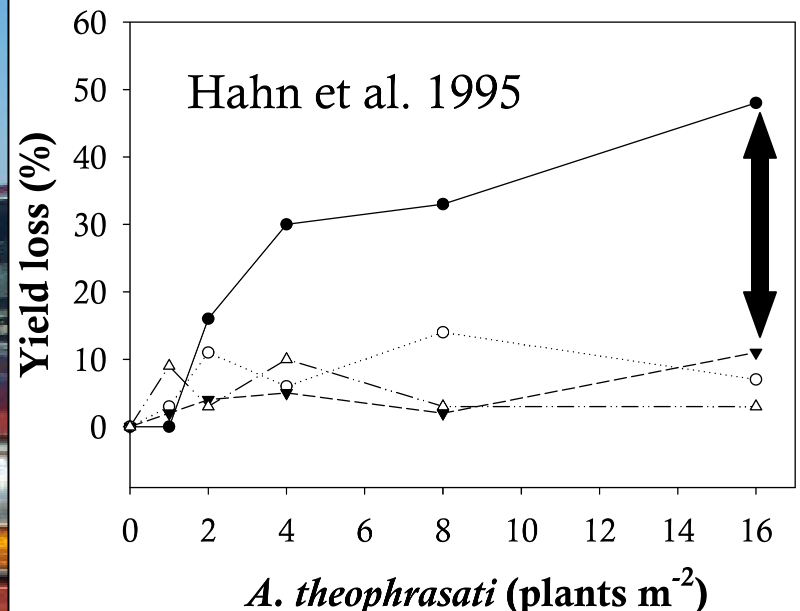
Refining results

improved survey data of troublesome weed species

- Finer **geographic scale** (e.g. NOAA climate divisions, or physiographic regions of a state)
- Account for major **management factors** like tillage systems and irrigation
- Consistent definition of **'troublesome'**
- **Multiple respondents** for each survey area (reduce influence of observer bias)

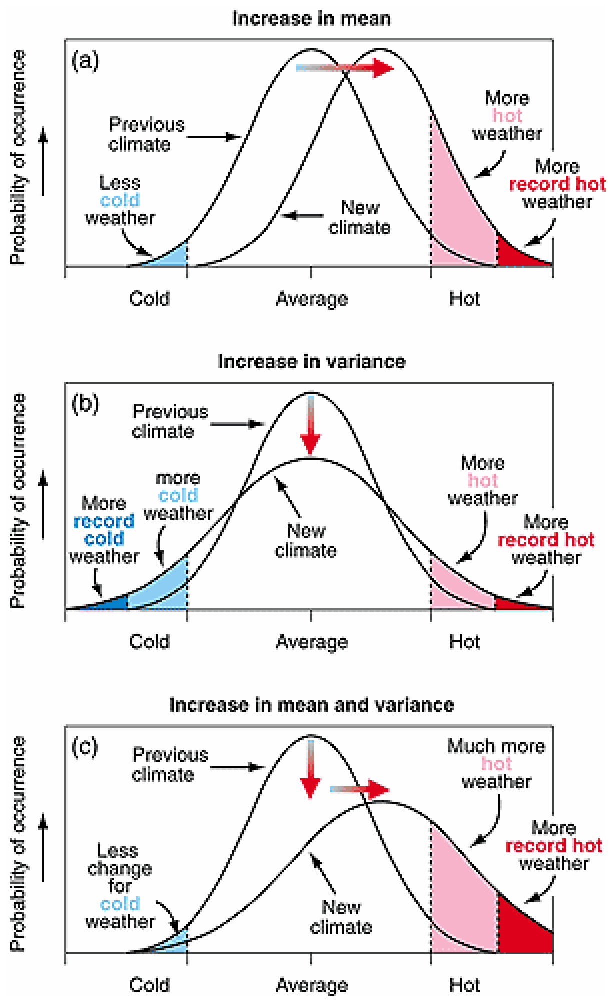
Competition is a dynamic process….

Chenopodium album *Abutilon theophrasti*



and weather is an important driver

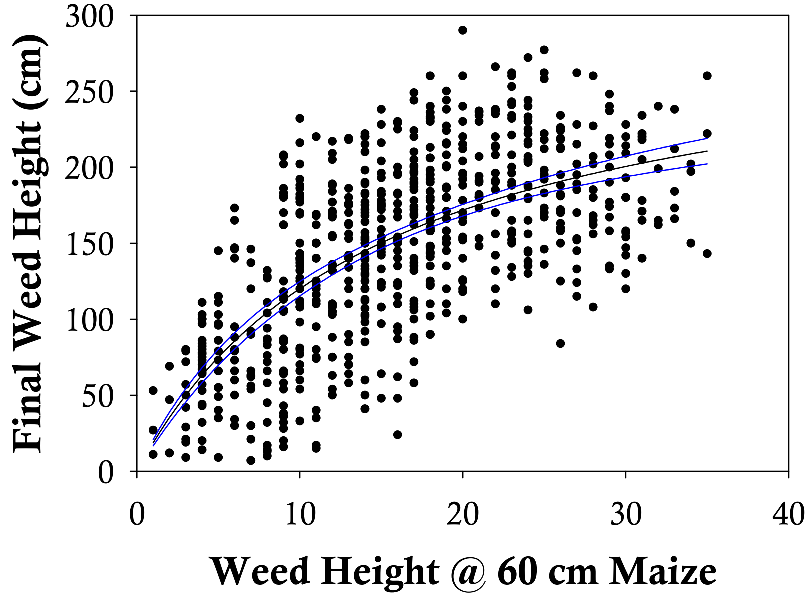
With climate change, historical outcomes may be an increasingly poor guide to management



IPCC, 2001

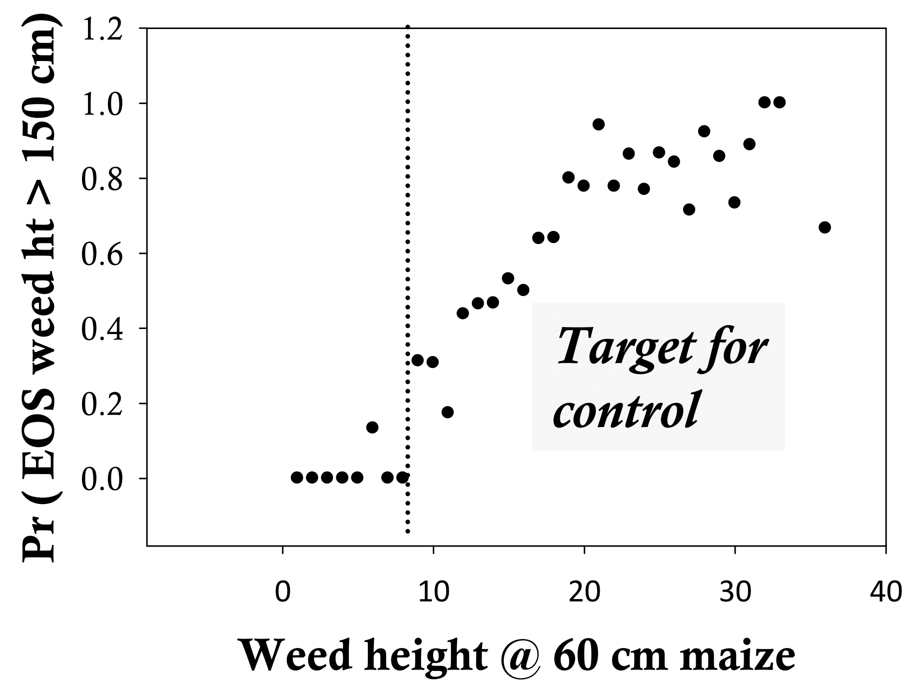
<u>Challenge for adaptation</u>: devise simple, reliable methods for predicting weed interference that integrate weather & other important drivers of competition

Early weed height as a robust indicator of damage potential in maize?



Field experiments

- 4 weed species
- 4 planting dates
- 3 relative emergence times
- 2 growing seasons
- 700+ weed individuals



When weeds were ≤ 8 cm at 60 cm maize, **Pr weed would be competitive was less than 2%** (2 out of 108 cases)

Hierarchy-based, selective management *targeting individuals for POST control based on early height*

- Retard the evolution of **herbicide resistance** (e.g. glyphosate stewardship)
- Promote in-field **biodiversity & ecosystem services**
- Reduce the economic and environmental **costs** of weed control, while maintaining high yields and limiting seedbank additions
- Help producers adapt to increased **weather uncertainty** in a changing climate

QUESTIONS?

ADDITIONAL MATERIAL

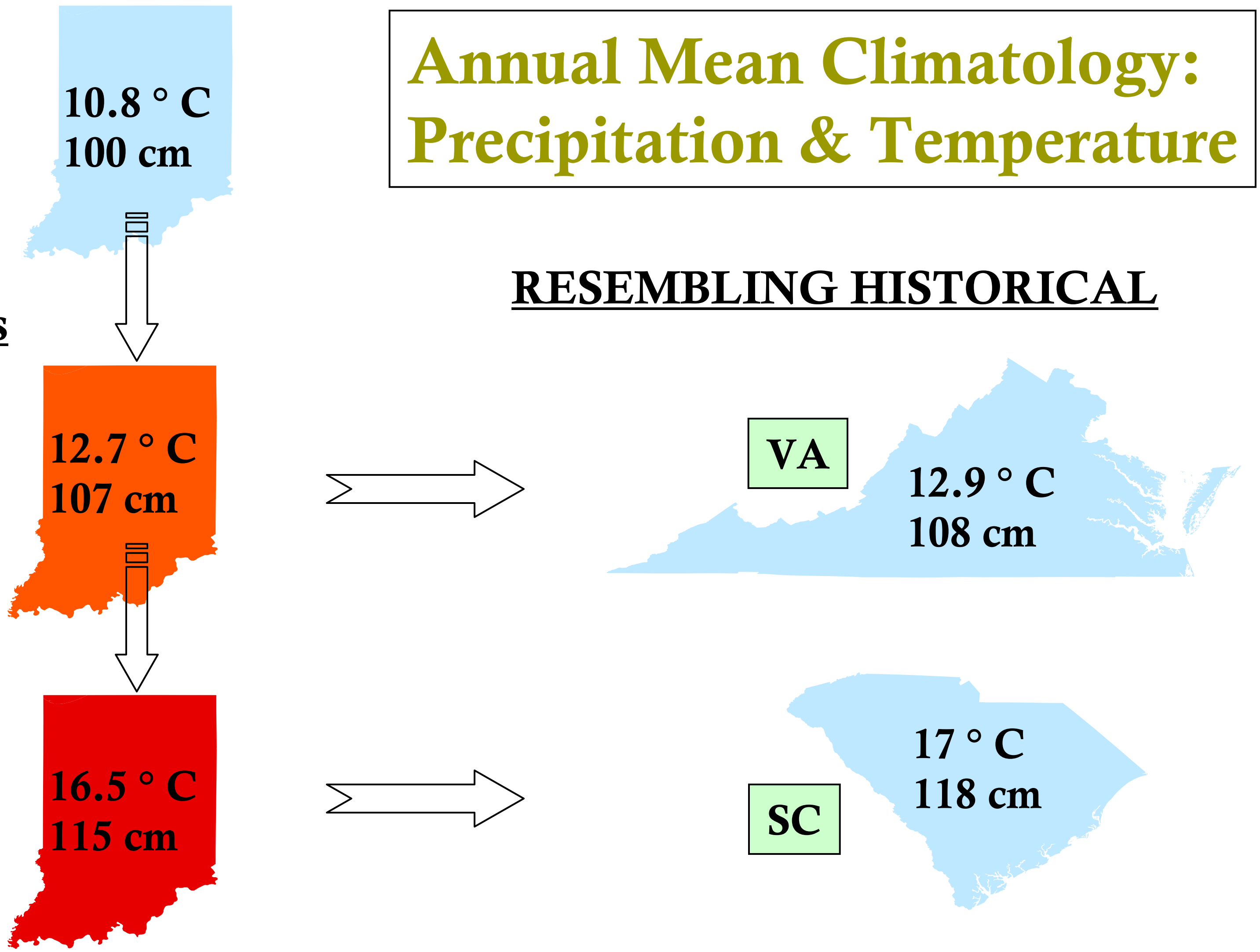
Corn Belt

Indiana: A1fi Emissions Scenario

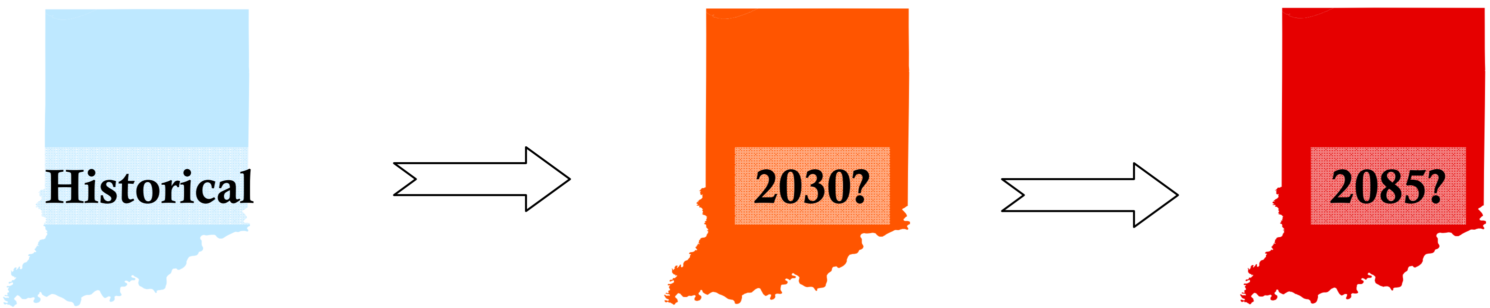
Historical
(1961 – 1990)

Coming Decades
(2016 – 2045)

End of Century
(2070 – 2099)



<u>Indiana</u> (A1fi scenario)
Potential troublesome weed species in maize



<u>INDIANA</u>

1. *A. theophrasti*
2. *A. trifida*
3. ***S. halepense***
4. *C. arvense*
5. ***X. strumarium***
6. *S. faberi*
7. ***Ipomoea spp.***
8. *S. angulatus*
9. *A. cannabinum*
10. *D. stramonium*

<u>VIRGINIA</u>

???

<u>SOUTH CAROLINA</u>

1. *C. dactylon*
2. *U. texana*
3. *U. platyphylla*
4. ***S. halepense***
5. ***Ipomoea spp.***
6. *Cyperus spp.*
7. *C. obtusifolia*
8. *P. dichotomiflorum*
9. *A. palmeri*
10. ***X. strumarium***

Retained: 3 / 10

Southeast

Alabama: A1fi Emissions Scenario

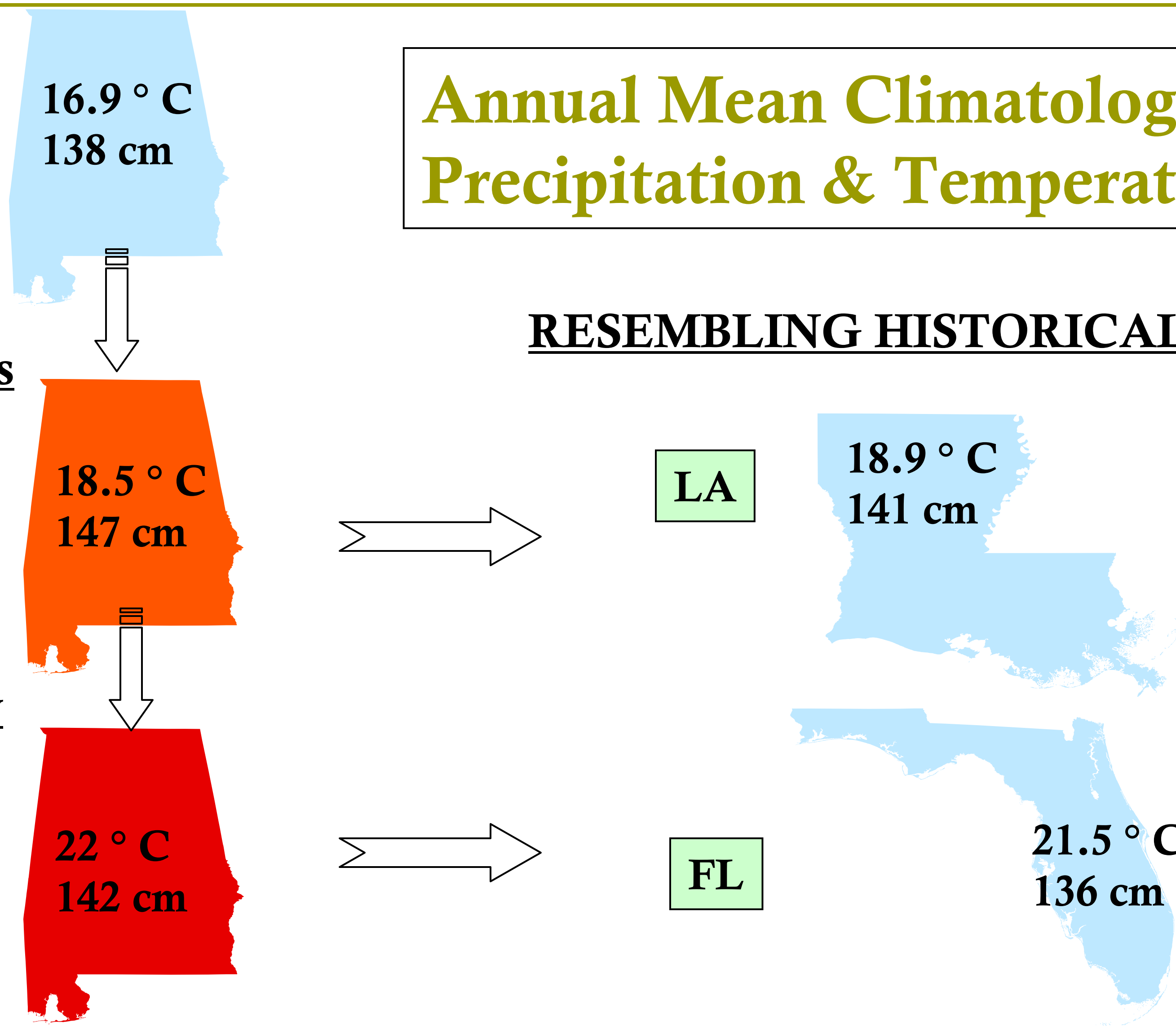
Annual Mean Climatology: Precipitation & Temperature

Historical
(1961 – 1990)

Coming Decades
(2016 – 2045)

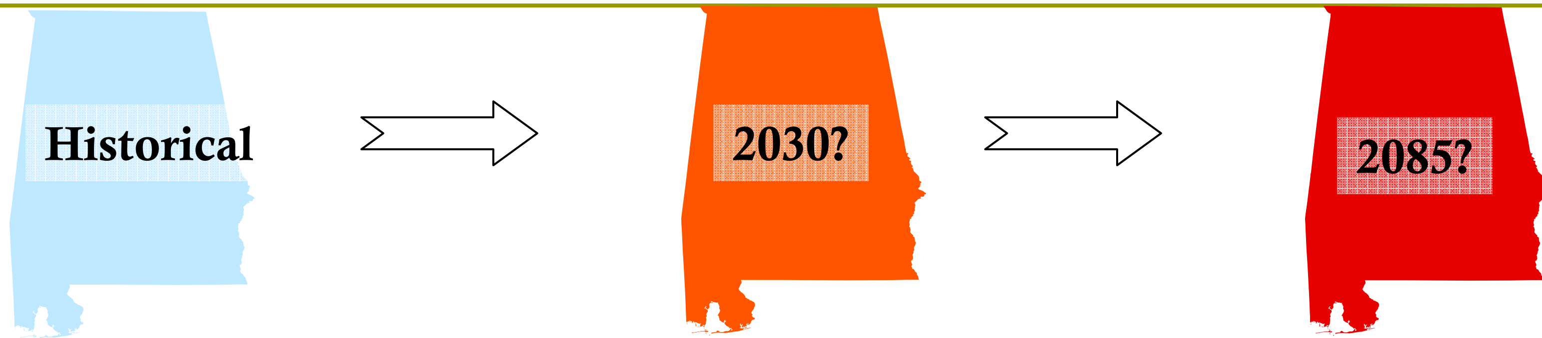
End of Century
(2070 – 2099)

RESEMBLING HISTORICAL



Alabama (A1fi scenario)

Potential troublesome weed species in maize



ALABAMA

1. ***S. halepense***
2. ***U. texana***
3. ***U. platyphylla***
4. ***Ipomoea spp.***
5. ***P. dichotomiflorum***
6. ***C. obtusifolia***
7. ***Amaranthus spp.***
8. ***Cyperus spp.***

LOUISIANA

1. ***S. halepense***
2. *R.cochinchinensis*
3. ***U. platyphylla***
4. ***Ipomoea spp.***

Retained: 3 / 8

FLORIDA

1. ***U. texana***
2. *D. tortuosum*
3. ***C. obtusifolia***
4. ***S. halepense***
5. *X. strumarium*
6. ***Ipomoea spp.***
7. *A. hispidum*
8. ***Cyperus spp.***
9. ***Amaranthus spp.***
10. *Digitaria spp.*

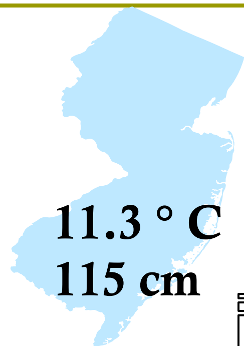
Retained: 6 / 8

Northeast

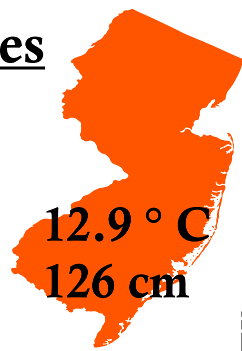
New Jersey: A1fi Scenario

Annual Mean Climatology: Precipitation & Temperature

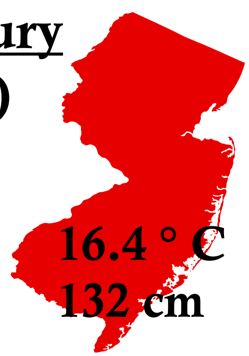
Historical
(1961 – 1990)



Coming Decades
(2016 – 2045)

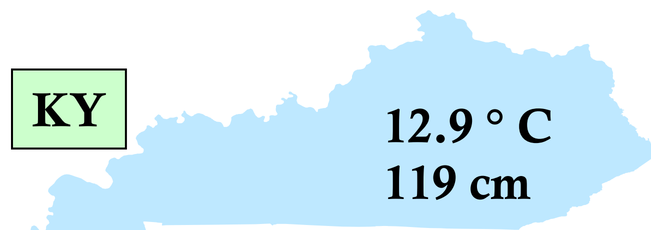


End of Century
(2070 – 2099)



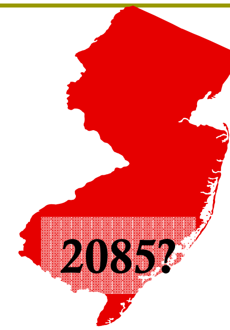
RESEMBLING HISTORICAL

KY



AL

New Jersey (A1fi scenario)
Potential troublesome weed species in maize



NEW JERSEY

1. *A. cannabinum*
2. *S. bicolor*
3. *A. theophrasti*

KENTUCKY

1. *S. halepense*
2. *S. vulgare*
3. *A. trifida*
4. *A. albidus*
5. *P. dichotomiflorum*
6. *S. angulatus*
7. *C. radicans*
8. *C. arvensis*
9. *I. hederacea*
10. *X. strumarium*

Retained: 0 / 3

ALABAMA

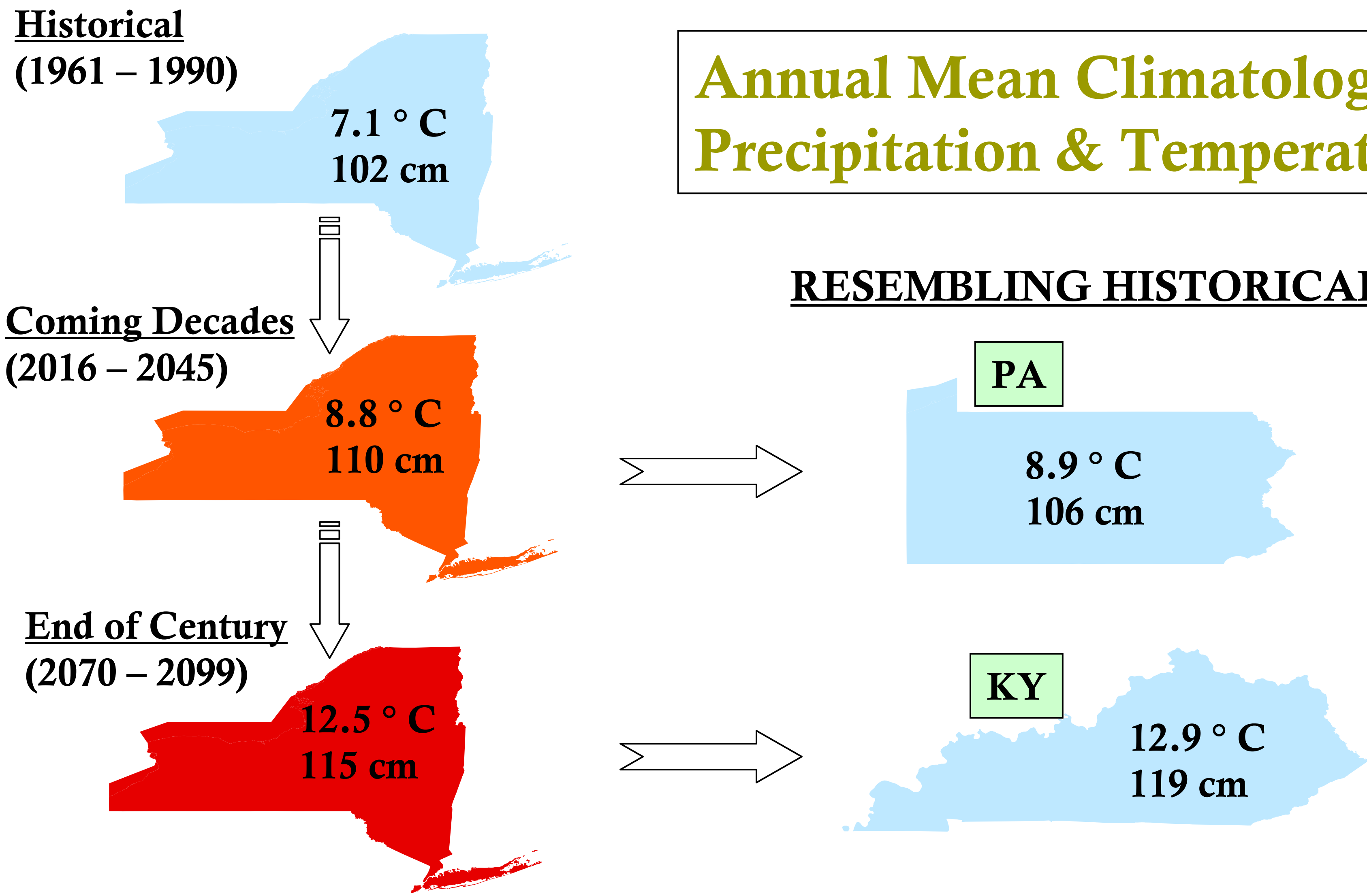
1. *S. halepense*
2. *U. texana*
3. *U. platyphylla*
4. *Ipomoea spp.*
5. *P. dichotomiflorum*
6. *C. obtusifolia*
7. *Amaranthus spp.*
8. *Cyperus spp.*

Retained: 0 / 3

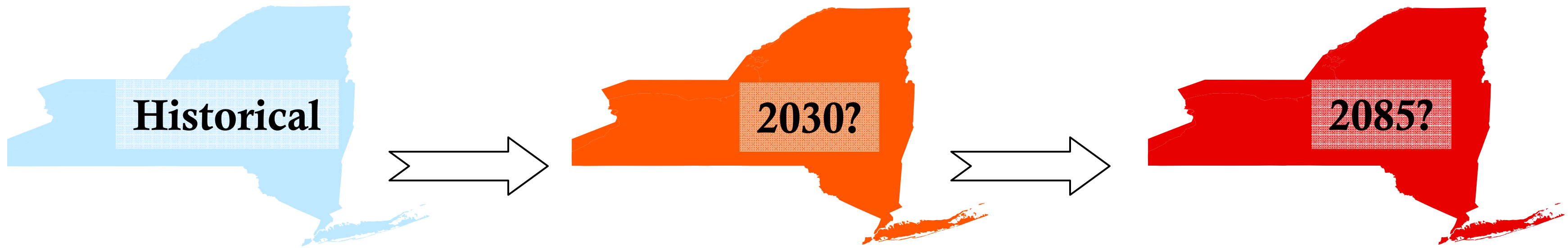
Northeast

New York: A1fi Emissions Scenario

Annual Mean Climatology: Precipitation & Temperature



<u>New York</u> (A1fi scenario)
Potential troublesome weed species in maize



<u>NEW YORK</u>

1. ***A. theophrasti***
2. ***C. album***
3. ***M. frondosa***
4. *A. syriaca*
5. ***S. carolinense***
6. *C. sepium*
7. *S. faberi*

<u>PENNSYLVANIA</u>

1. *A. artemisiifolia*
2. *A. cannabinum*
3. ***S. carolinense***
4. ***M. frondosa***
5. *R. fruticosus*
6. *E. repens*
7. ***A. theophrasti***
8. *S. angulatus*
9. *C. arvensis*
10. ***C. album***

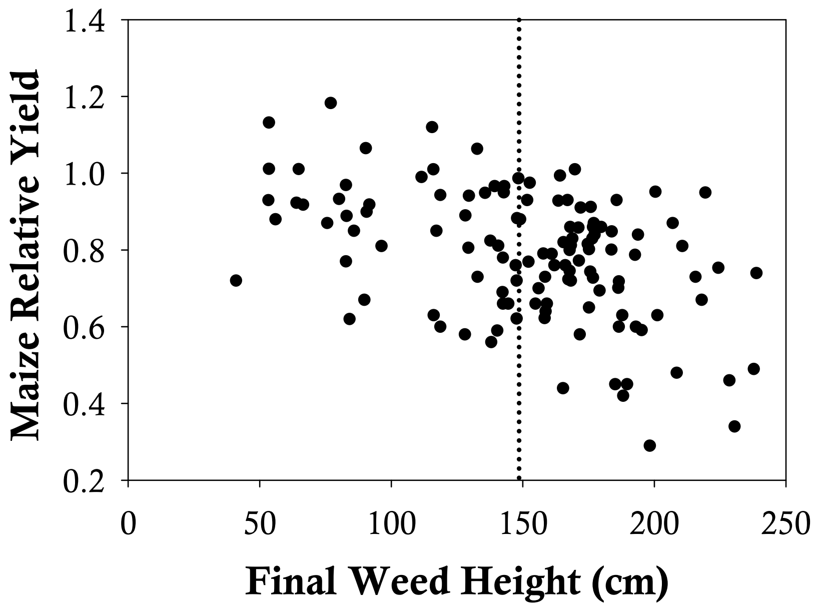
Retained: 4 / 7

<u>KENTUCKY</u>

1. *S. halepense*
2. *S. vulgare*
3. *A. trifida*
4. *C. laeve*
5. *P. dichotomiflorum*
6. *S. angulatus*
7. *C. radicans*
8. *C. arvensis*
9. *I. hederacea*
10. *X. strumarium*

Retained: 0 / 7

When do weeds become troublesome?



Yield loss in maize intensifies when weed canopy height exceeds 150 cm

Fecundity (ABUTH) increases rapidly when individual plants grow larger than 150 cm